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EPS Council report

Neutrino oscillations - the Double Chooz experiment

Revisiting Farm Hall

Measurement of neutrino mass in double beta decay

Not seeing the light

38/4
2007

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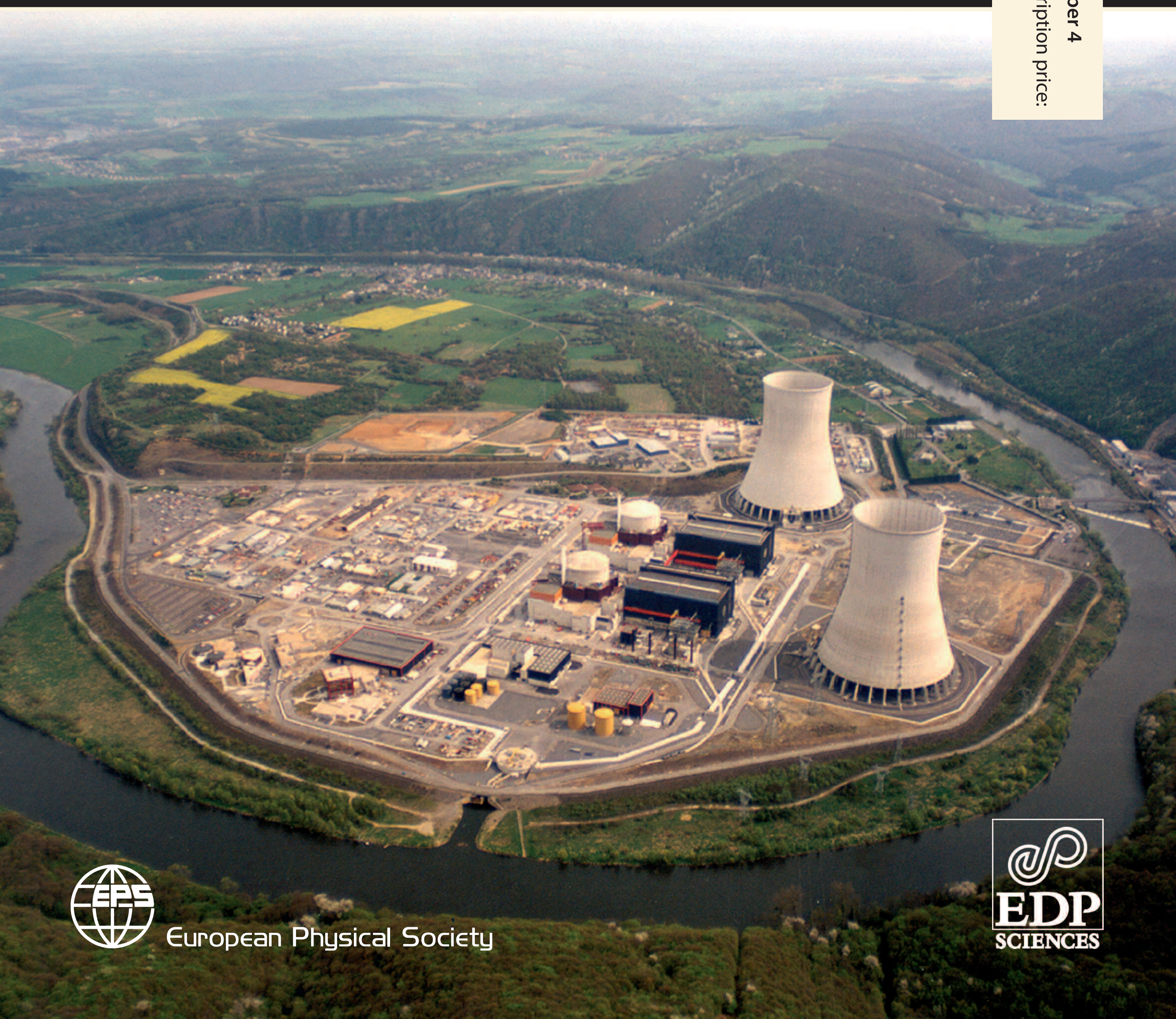

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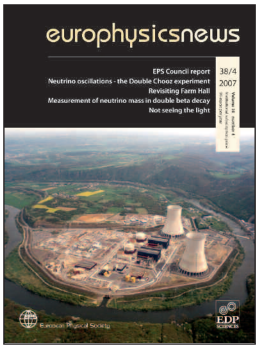

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Cover picture: An aerial view of the site in the Ardennes of the Double Chooz neutrino oscillation experiment.
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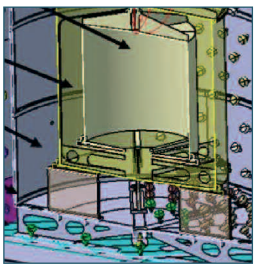

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Neutrino oscillations - the Double Chooz experiment

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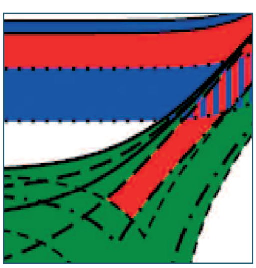
Revisiting Farm Hall



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On the impact of experts [EDITORIAL]

Already before the G-8 summit in Heiligendamm, there were remarkable and positive moves in the climate protection issue by USA and China - the two largest producers of CO_2. At the summit, all representatives acknowledged that the temperature rise the earth is exposed to is mostly anthropogenic and a consequence of the undisputed rise in CO_2 concentration and that it represents a severe threat for the present form of life on earth. They seriously considered reducing the CO_2 concentration by 50% by 2050. This unanimity is thanks to the overwhelming evidence collected by the climate scientists and analysed for and presented in the frame of the IPCC (International Panel on Climate Change) activity. One can be relieved about this final acceptance but still distressed how long it took and how large the efforts had to be to finally have an impact. This has also to do with the loss of respect and credibility of the experts both in the eyes of the public and the so-called decision makers. This loss does not apply to the climate sciences alone but is also the case in many other fields, particularly in the field of energy, which is flooded by opinions – those with a sound technical and scientific backing on one side and those which represent a programmatic element of a political party on the other. The experience is that the less the scientific background is, the more immovable is the standpoint.

Though the majority of scientists are of the opinion that indeed global warming is man-made there are still schools that have reservations. This often leads to the misunderstanding in the public that scientists never agree and therefore the expert is not useful when it comes to decisions. Outsiders are not familiar with one of the fundamental rules of science which is to challenge the evidence. Verification and falsification occur in the scientific debate and the most valuable contribution by every participant in this debate is well founded scepticism. Therefore, those who have good reasons to remain sceptical in the overall climate debate have to be encouraged. The reservation has often to do with ones own scientific work and the insight one has gained. One controversial issue seems to be the variability of the climate in the past and the question whether the present temperature is unique for the Holocene or whether periods with similar or even higher temperatures have already existed since the last ice-age. The scientific aspect seems to be the agreement or the missing agreement, respectively between dendrochronological studies and *e.g.* the conclusions taken from the isotopic composition of stalactides. It is conjectured that the analysis of tree rings might be hampered by a systematic error because the winter climate is not well reproduced during the inactive period of the flora.

Another topic under discussion is the question whether a higher sea-surface temperature gives rise to more frequent and more intense hurricanes. As the warm water is the energy source for the hurricanes, this conjecture is plausible. In addition, it is reproduced in the climate modelling. However, sediment studies seem to contradict this hypothesis. The inner circle of archipelagos is normally sheltered by a ridge. In some cases, the topology does not provide shelter from large hurricanes. In these cases the sediments of the core are enriched by the material transported over the ridges. The sediments from the core region carry the code of the number of hurricanes and their intensity. The analysis seems to indicate that there is no firm correlation between frequency and strengths of hurricanes and surface water temperature.

Open books are better than closed ones; the same is correct for scientific issues. The differences of opinions should be maintained for a better understanding of the climate data and the methods to gain them. Our fundamental understanding of the climate change can only benefit from it.

Let me change topics now. One external aspect of the G-8 summit was the accompanying entertainment programme for all those who met there to protest against the meeting or against globalisation in general. Many participants went there with the best motives to express their sincere concerns and to exercise their constitutional rights. I write about this side of the meeting because I happen to live 80 km east of Heiligendamm close enough to pick up some of the actions and activities.

The largest crowds with 100,000 participants or even more were attracted •••

… by singers who used the summit to transport their political messages – Grönemeyer and Bono. I am not astonished that they use the gathering of so many people to spread their thinking but I am surprised that so many people obviously adopt their views and agree with them. I am not aware that someone who can write a song and who can perform it well (at least in the judgment of their fans) has a deeper political insight than those who do not have this talent but may have another one.

I want to come back to the situation of the experts. We scientists – and I only talk about them for the moment – work in a specialised field (or in several fields) and we have contributed to deepen and to expand the knowledge and understanding of our field. We are aware about all the facts in our field and we can give competent answers if asked. Some research areas enjoy high public attention and climate research indeed is deservedly one of them.

I have problems however, when an expert uses the fully acknowledged reputation he has gained by his work in and contributions to one field to comment another field, which has its own experts who are more knowledgeable. It is often the case that scientists are dragged into discussions with the public which go beyond their field of direct expertise. I wish and would expect that an expert clearly states in such a case that he now talks as a layman without the backing of his own research and that he properly references the experts in the field under discussion. The examples in our histories are numerous, which show that also experts, well trained in scientific methodology, can fail outside their scientific terrain. With the readiness to use ones scientific prestige to impact the conditions and circumstances in another field, one also sends wrong signals to those who are interested in the leverage by the backing of a scientist but who are not necessarily interested in the scientific truth. I am afraid that this aspect of scientific conduct – if ignored - does more harm to the appreciation of experts in general than the scientific scepticism we are committed to. ■

Friedrich Wagner,
President of the EPS

Physics EuroOlympiad (PhEO) - A Proposal [LETTER]

Waldemar Gorzkowski [1],
Institute of Physics, Polish Academy of Sciences al. Lotników 32/36 • 02-668 Warszawa • Poland

Some time ago I was pleased to inspire the creation of the Asian Physics Olympiads (APhOs) - see: www.apho.org/en/olympiad/medalist.php. These first continental Olympiads were organized in Indonesia in 2000. Since that time, six more APhOs have been organized, one each year. Some statistical data on the APhOs may be interesting not only for the Asian countries but also for other people active in the Olympic movement.

Look at the Table. It consists of two parts. The upper part refers to the Asian countries participating in the International Physics Olympiads and in the Asian Physics Olympiads, while the lower part refers to the European countries participating in the International Physics Olympiads. The Table contains two columns with "%" in the header. These columns refer to the "efficiency of participation" (The notations in the Table are explained at the end):

1. for the last ten years (*i.e.* from the 28th until the 37th IPhOs) and
2. for all the Olympiads organized until now (*i.e.* from the 1st until the 37th IPhOs).

The Table contains only those countries for which the efficiency was calculated. The ones that did not participate in the IPhOs before the 28th Olympiad are not included.

The Asian countries have made a huge progress (see the last column in the Table). Efficiency of participation increased for all of them! It is obvious that it comes from the existence of the APhOs. This has been confirmed by numerous private talks with many delegation leaders. The Asian countries treat the Asian Physics Olympiad as a very important element of work with gifted and talented pupils. Moreover, some of them seem to treat the Asian Olympiad as a kind of training of the national team to the IPhOs. This is favoured by the organization of the APhO about two months before the IPhO, with 8 students per APhO team against 5 at IPhO, allowing an improved selection.

On the other hand, the lower part of the Table (referring to European countries) shows a relatively constant efficiency of participation over the last 10 years and, with a few exceptions only, as well for all the 37 Olympiads.

For these reasons, I propose the creation of the European Physics Olympiad, the structure of which would be similar to the International Physics Olympiads (see: www.jyu.fi/ipho) and to the Asian Physics Olympiads. I am sure that such an Olympiad should improve the results of the European countries at the IPhOs and affect physics teaching in Europe. I have contacted a number of people in Poland and have found that the proposal is favorably considered. However, **no decisions have been taken yet**, but one may hope that the 1st PhEO might be organized in Poland in the second half of May 2009 or 2010.

Organizing the first EurOlympiad should not be too difficult. The difficult problem is ensuring continuation of the competition. In this respect, we would like to find possible organizers of the 2nd and the 3rd PhEO and to collect data that could allow us to estimate the likely number of participants in the 1st PhEO. If you have any information with respect to the above, please contact the author of this letter. We are waiting also for any comments and remarks, hoping that by our common effort we will be able to defeat apathy. ■

[1] President of the International Physics Olympiads; Honorary President of the Asian Physics Olympiads; you may contact the Author by e-mail: gorzk@ifpan.edu.pl

No.	Country	Last ten years (28th - 37th IPhOs)									From very beginning (1st - 37th IPhOs)									Progress in efficiency
		A	1	2	3	H	S	T	V	%	A	1	2	3	H	S	T	V	%	
Asian countries (and Australia)																				
01	Australia	0	6	16	18	9	2	49	50	58,5	0	6	19	33	30	5	88	100	44,3	14,3
02	China	2	38	7	0	0	15	45	45	96,1	7	67	20	9	2	39	98	100	87,0	9,1
03	Indonesia	1	12	8	19	7	4	46	50	58,5	1	12	9	22	15	5	58	70	47,9	10,6
04	Israel	0	1	6	16	16	0	39	45	38,9	0	1	8	20	22	5	51	60	37,5	1,4
06	Singapore	0	9	8	16	13	3	46	50	52,5	0	10	10	23	25	6	68	90	39,2	13,3
07	Taiwan	1	21	12	13	4	4	50	50	75,0	1	23	15	16	8	5	62	65	68,1	6,9
08	Thailand	0	6	10	7	14	2	37	50	41,0	0	6	10	9	17	3	42	85	26,2	14,8
09	Vietnam	1	3	15	25	4	2	47	50	55,5	1	5	21	37	17	8	80	115	37,8	17,7
European countries																				
01	Austria	0	2	3	4	11	0	20	45	20,0	0	2	5	12	33	6	52	120	16,7	3,3
02	Belarus	1	4	10	18	14	1	46	50	48,0	1	4	11	20	17	1	52	60	44,2	3,8
03	Belgium	0	0	0	1	9	0	10	50	5,5	0	0	0	3	15	1	18	95	5,5	0,0
04	Bosnia & Herc.	0	0	0	1	5	0	6	50	3,5	0	0	0	1	5	0	6	55	3,2	0,3
05	Bulgaria	0	1	8	12	12	0	33	50	32,0	1	11	20	39	53	9	123	182	32,3	-0,3
06	Croatia	0	0	1	6	12	0	19	50	13,5	0	0	1	7	19	4	27	75	12,0	1,5
07	Cyprus	0	0	1	0	4	0	5	45	3,9	0	0	1	1	8	2	10	90	3,6	0,3
08	Czechlands	0	3	9	17	17	1	46	50	45,0	0	5	12	23	24	5	64	70	45,0	0,0
09	Denmark	0	0	0	2	19	0	21	50	11,5	0	0	0	2	19	0	21	55	10,5	1,0
10	Estonia	0	1	3	12	21	0	37	50	29,0	0	1	3	16	24	2	44	75	23,0	6,0
11	Finland	0	0	1	8	20	0	29	50	19,5	0	1	2	19	51	2	73	140	17,7	1,8
12	Georgia	0	2	6	5	8	1	21	50	22,0	0	2	6	6	8	2	22	55	20,9	1,1
13	Germany	0	7	13	19	10	2	49	50	57,5	2	21	40	56	24	24	141	155	54,8	2,7
14	Great Britain	0	1	9	21	7	2	38	45	44,4	2	9	23	40	19	17	91	110	46,4	-1,9
15	Hungary	1	12	15	19	4	4	50	50	67,5	3	33	37	68	33	17	171	182	56,6	10,9
16	Iceland	0	0	0	1	9	0	10	50	5,5	0	0	0	2	15	4	17	115	4,1	1,4
17	Italy	0	0	4	11	20	2	35	50	27,0	0	1	6	18	32	4	57	110	20,5	6,5
18	Latvia	0	1	1	7	14	0	23	50	17,5	0	1	1	8	14	0	24	55	16,8	0,7
19	Lithuania	0	0	1	13	14	1	28	45	23,9	0	0	1	18	21	3	40	75	20,0	3,9
20	Macedonia	0	0	0	1	3	0	4	45	2,8	0	0	0	1	4	0	5	50	3,0	-0,2
21	Moldova	0	0	3	7	12	0	22	50	17,5	0	0	3	7	15	0	25	60	15,8	1,7
22	Netherlands	0	0	3	15	19	0	37	50	29,0	1	4	11	31	43	6	89	125	30,8	-1,8
23	Norway	0	0	0	1	4	0	5	50	3,0	0	1	0	4	16	2	21	115	6,1	-3,1
24	Poland	0	4	8	17	15	0	44	50	44,5	4	18	31	51	52	16	152	182	43,8	0,7
25	Portugal	0	0	1	3	3	0	7	50	6,0	0	0	1	3	3	0	7	65	4,6	1,4
26	Romania	0	7	18	10	10	1	45	50	56,0	2	28	51	49	29	18	157	182	53,8	2,2
27	Russia	2	26	20	3	1	11	50	50	85,5	2	35	28	7	3	17	73	75	80,3	5,2
28	Slovakia	0	2	6	11	21	0	40	50	34,5	0	2	9	15	29	4	55	70	33,6	0,9
29	Slovenia	0	1	1	7	22	1	31	45	23,9	0	1	2	11	27	4	41	70	21,1	2,8
30	Spain	0	0	1	2	14	1	17	50	10,5	0	0	1	2	17	3	20	85	7,1	3,4
31	Sweden	0	0	1	1	9	1	11	45	7,8	0	1	9	13	41	13	64	140	17,5	-9,7
32	Switzerland	0	2	2	7	14	2	25	50	21,0	0	2	2	9	17	2	30	60	20,4	0,6
33	Ukraine	0	10	14	17	7	0	48	50	61,5	0	13	21	25	11	6	70	75	58,7	2,8
34	Serbia & Mont.	0	1	7	11	20	1	39	45	37,2	0	1	7	13	26	1	47	55	35,0	12,2

Explanation:

A - number of Absolute winners
1 - number of 1st prizes
2 - number of 2nd prizes
3 - number of 3rd prizes
H - number of Honourable mentions

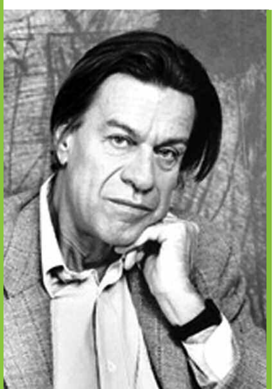
S - number od Special prizes
T - Total number of regular prizes and honourable mentions
V - possible number of participants ("participation Volume")
% - "Efficiency of participation" expressed in a percentage as: (1+0,75*2+0,5*3+0,25*H)/V

To reduce the role of fluctuations, the "efficiency of participation" is not counted for countries that have participated less than 5 times in the competition in the periods considered. Such countries are not included. Also the countries that did not participate before the 28th IPhO are not included.

Pierre-Gilles de Gennes (1932-2007) [OBITUARY]

Etienne Guyon,
Ecole Supérieure de Physique et Chimie Industrielles de Paris • France

Four years ago, Europhysics News published (*EPN* **34/4**, p.157, 2003) a lively conversation with Pierre Gilles de Gennes, illustrated with pictures of him taken during the interview by G. Morrison and myself. Today, after the death of PGG, as his colleagues called him, many scientists around the world feel as orphans. The influence of de Gennes, as stressed in the EPS article, not only came from his major achievements in various fields of condensed matter, initiated by his work on magnetism, superconductors and on soft condensed matter which led to his award of the Nobel prize in 1991, but also from his unmistakable style which he applied to all the subjects he approached.



◄ Pierre-Gilles de Gennes in 1991at the Nobel Prize awarded "for discovering that methods developed for studying order phenomena in simple systems can be generalized to more complex forms of matter, in particular to liquid crystals and polymers".

The interview was focused on problems of pedagogy which were of concern to him, from his students in Ecole de Physique et Chimie de Paris (ESPCI) down to elementary school pupils. He stressed the need for a broad training, including physics and chemistry as basic components, and leading towards biology. But, at the same time, he emphasized the need for a different approach, much more pragmatic than what is usually the case (in particular in France!). He emphasized the role of experiment and observation leading to simple inductive reasoning rather than a pure theoretical approach (he suggested that no more than "half" a theorist should be in an experimental group of ten, despite he himself being a famous theorist!). He also always expressed his favour of small science and even showed some distrust in the development of some large scale projects.

A few days after his death, the new French President Nicolas Sarkozy gave the name "*Espace Pierre Gilles de Gennes*" to the "*Espace des sciences*" of ESPCI, which PGG had intended to create as a direct interface between the results of the local laboratories and the public. The style of de Gennes was unique both in his research activity and in his attitude toward sharing science and he could not conceive of one independently of the other.

Let us say a few words on his activities. De Gennes was a student at Ecole Normale Supérieure in Paris from 1951, where he studied with Alfred Kastler, Yves Rocard and where he particularly enjoyed the inspiration of Pierre Aigrain, a leading figure in semiconductors. But he also stressed the major role of the school of les Houches, created by Cécile de Witt, where he and colleagues of his generation, such as his classmate Philippe Nozières, learned modern physics in the post-war period when teaching in France was utterly classical. His thesis in Saclay on spin fluctuations in magnetic materials next to the Curie point was verified shortly after and made him known to the solid state community. He pursued his career in Orsay next to Jacques Friedel, André Guinier and Raimond Castaing by creating and leading a superconductivity group with a strong emphasis on experiments connected with his work, and favouring a team spirit in what he called "the Orsay group on superconductivity". He introduced the subject of proximity between superconductors and normal metals, discovered surface superconductivity in high parallel fields and, more generally, studied high magnetic field effects, extending the work of Abrikosov and Gorkov which dealt with magnetic impurities. His book "*Superconductivity of Metals and Alloys*" remains a classic reference work today. He performed a similar group operation by being the pilot of a successful activity on liquid crystals in the mid-'70s years and, again, "*Physics of Liquid Crystals*" became a classic reference. He illuminated in particular the subject of the transitions between liquid-crystal phases by introducing rigorous correspondence with other fields of condensed matter such as that between the smectic-nematic transition and the lambda transition of helium. He later regretted that the French leadership in the subject at this time did not lead to more practical industrial results, a subject which concerned him in his further work in soft condensed matter.

In the Collège de France where he held a prestigious Condensed Matter Chair, he developed a very important activity in polymer science (see "*Scaling concepts in polymer physics*"), benefiting from a tradition of the subject in Strasbourg. In his work on polymers, as previously with liquid crystals, he was very concerned with a proper treatment of the chemical aspect of the problem and not just with the fundamental approach (although his $n = 0$ renormalisation group solution of the problem of polymers is by itself a major result). He was also concerned with other subjects in soft matter, included wetting and interfacial physico-chemical effects, colloids, friction… (Pierre Gilles was always most interested in what happens at boundaries both in a physical and in a symbolic sense!).

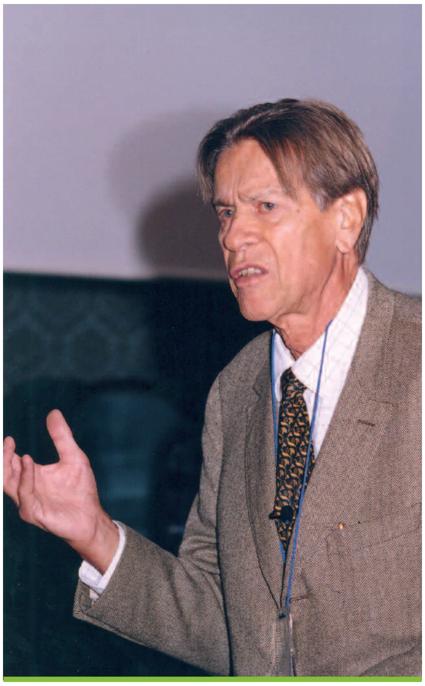
We also shared a strong interest in applied problems of the physics of disordered materials. A first example is multiple-phase flows in porous media, of interest for oil recovery, where a rigorous connection with percolation models could be established (it should be noted that he had been the inventor of percolation independently of Hammersley). A second subject, which he particularly enjoyed was granular flows and avalanches, a domain which has known important developments later. For two years, his advanced classes in Collège de France had a title "*In the footsteps of Bagnold*" (a British officer in Libya who, in the forties, produced an extensive description on such problems as dune formation and sand motions).

After he retired from Ecole de Physique et Chimie, of which he had been the Director for 25 years, and of the Collège de France, he joined the physico-chemical laboratory of the medical campus of Institut Curie with Jean François Joanny and Françoise Brochard, where he started working on biology-oriented problems such as olfaction, cellular transport and neurones. But he also maintained an interest in many other problems, such as the mystery of superfluid solid helium or the quantum motion of dislocations, with Jacques Friedel. An article in progress at the time of his death dealt with superconductors, another with the shape of a honey filament… He continued his research activities up to the end with a remarkable courage and discretion, another factor in our admiration of our master and friend.

I have had the opportunity to work closely with Pierre Gilles in many instances for nearly half a century and on very different fields. Despite the variety of the subjects, I always found a great unity of style in his approach to science: a broad culture, the important role of images both mental and real, the place of analogies, a well organised approach to problems, an immense curiosity (he liked to be surprised when a student would present him with a new and unexpected result rather than just confirming his professor's expectations), and a scientific generosity in sharing his findings.

I would like to let his friend Philippe Nozières conclude "*Pierre Gilles était un explorateur, presque un aventurier, plus enclin à se tailler une voie à coups de serpe qu'à cultiver un jardin de curé. Il aurait eu sa place à la grande époque du 18ème siècle où l'Académie envoyait une équipe de savants en Amérique du Sud, en principe pour mesurer le méridien, mais en fait pour tout découvrir sur ce continent inexploré. Les savants étaient alors physiciens, astronomes, géologues ou botanistes aux curiosités multiples !*"[1] ■

[1] Pierre Gilles was an explorer, a near-adventurer, more inclined to chop his way through than to cultivate his home garden. He would have found his place during the great period of the 18th century, when the Academy was sending a team of scientists to South-America, supposedly to measure the Meridian, but in fact to discover all about this unexplored continent. The scientists were then physicists, astronomers, geologists or botanists, curious of everything!



▲ Pierre-Gilles de Gennes in 2006 during the conference "The nature of memory objects: the example of olfaction".

EPS Council: Highlights 23-24 March 2007, London [REPORT]

The Institute of Physics hosted the 2007 EPS Council meeting in London at the Rutherford Conference Centre in downtown London. With more than 80 participants, this was one of the best attended meetings in recent history.

Changes in Council Structure

In 2005, under O. Poulsen and M. Huber, the EPS began experimenting with new formats for its Council meetings, in order to focus on issues of particular importance to the Society. Physics education, increasing the membership of national societies, gender equality and mainstreaming and the development of tools for the efficient management of EPS members were topics addressed in 2005 and 2006.

Further innovations were introduced in 2007 by F. Wagner, designed to increase the exchange among the various stakeholders in EPS. The overall organisation consisted of 2 plenary sessions for all EPS Council delegates, plus 4 parallel sessions. The plenary sessions were devoted to ordinary Council business, such as reports by the President, Secretary and Treasurer, approval of the accounts, elections, new members, etc. The parallel sessions allowed more in depth discussions on EPS organisation, strategy and activities. Moreover, Council members heard interesting and informative presentations on the Bologna Process (U. Teichler), Physics and energy (T. Hammacher), Physics publications in Europe (JM Raimond) and on the European Research Area (J. Rostop Nielsen).

Highlights 2006

O. Poulsen provided an overview of the main activities of the EPS in 2006. Publication in science is one of EPS's main concerns not only because as physicists all EPS members publish their research, but also because many EPS Member Societies are also physics publishers. The EPS is leading a new initiative to bring together learned society publishers, academic publishers and physicists to address issues that are of importance to the European physics community. Among the proposal that will be followed up in 2007 is the creation of a physics publishing portal (P3) that is designed to provide tools for more effective physics research, and to increase the visibility of physics publications in Europe.

In 2006, the EPS received the first prize from the European Economic and Social Council for its contributions to the organised civil society in Europe. Using the cash prize received, the EPS has created a Forum Physics and Society which will bring together scientists and policy makers to discuss issues at the interface of science and society. These include education, technology, energy etc. The forum will meet yearly, and will draft recommendations which will be submitted to European institutions on appropriate science policy measures to be enacted.

The EPS has also been active in discussions regarding the establishment of the European Institute of Technology. O. Poulsen, and representatives of other learned societies met with the President of the European Commission, JM Barroso to discuss the basic configuration of the EIT. The viewpoints expressed by O. Poulsen and approved by Council are:

- The EIT should not be a funding body for research. Funds should be used to create networks and clusters and for administrative purposes;
- The EIT should not be a degree-granting body. Students successfully completing the course work in the EIT cluster should receive their degree from their home institution, with an EIT label;
- The EIT should define domains important for innovation in the EU, but the clusters should be built from the bottom up with interested and qualified participating institutions;
- The EIT should be decentralised, leaving the researchers and students in their respective universities.

Regular Business

In the regular business sessions, Council approved the creation of a new Grants Committee. EPS devotes around 30% of its activities budget to grants, mainly for travel, study and conference grants. The creation of a Grants Committee will allow the EPS to distribute grants as a complement to its other policy activities, such as the promotion of young physicists or increased membership.

Council also approved as new Member Societies:
Liechtenstein Science Society, Physics Section; The Serbian Physical Society; The Physical Society of Montenegro. This brings the number of physical societies represented by EPS to 40.

Council also elected the following individuals as Fellows of the EPS:

- Gerardo Delgado-Barrio
- John Enderby
- Gillian Gehring
- Luigi Lugiato
- Steve Meyers
- Denes Nagy
- Zenonas Rudzikas
- Ann Thorne

Last but not least

Finally, Council confirmed F. Wagner as the President of the Society. O. Poulsen, the outgoing President, would remain on the Executive Committee for another year as Vice-president. We are all grateful to Ove and his hard work and dedication and welcome Fritz and look forward to (another) exciting 2 years. ■

Goodbye Maria and Magdi

After more than 15 years of loyal and efficient service, Maria Lazar and Magdi Balla at the EPS Secretariat in Budapest have decided to take their well-earned retirement and to close the EPS offices on Vaci utca. The EPS opened its Secretariat there more than 20 years ago during W Buckel's presidency (1986-1988) as both a cost-cutting measure and as a way to improve relations with countries in Eastern and Central Europe. We would like to take this opportunity to say good bye and thank you to Maria and Magdi and to wish them all the best for the future. ■

NANOMETA 2007 [CONFERENCE REPORT]

The first European Topical Meeting on Nanophotonics and Metamaterials (NANOMETA 2007) was held in Seefeld, Austria, 8-11 January 2007. It was a truly international high-profile gathering of key players with representatives from 34 countries. The conference was chaired by Professor Nikolay Zheludev, Deputy Director (Physics), Optoelectronics Research Centre, University of Southampton, UK and Professor Ekmel Ozbay, Director, Nanotechnology Research Centre, Bilkent University, Bilkent, Ankara, Turkey.

NANOMETA 2007 brought together the research communities in the burgeoning fields of Nanophotonics and Metamaterials. The topics covered at the conference included negative index materials, plasmon optics, nano-structured metallic and dielectric surfaces, light in confined geometries, chiral structures, random structures, fractals and quasi-crystals, single molecule and single nanoparticle photonics and many others. Two plenary talks were given by Sir John Pendry, Imperial College London, UK (Controlling light with metamaterials) and by Eli Yablonovitch, University of California, Los Angeles, CA, USA (What is the smallest volume into which light can be focused, efficiently?)

The conference featured about 60 invited and 90 contributed talks together with 130 poster presentations. The conference was well attended by professional press and was reviewed in *Nature* (**445**, 346, 2007) and *Nature Photonics* (**1**, 141, 2007).

For further details, see conference web site at www.nanometa.org

The next NANOMETA meeting is planned for 5-8 January 2009. ■

Nikolay Zheludev

◄ NANOMETA Plenary Speakers, **Sir John Pendry**, Imperial College, London, UK (on the left) and **Professor Eli Yablonovitch**, University of California, Los Angeles, USA

Conference Announcements

One dimensional Nanostructures

The second International Conference on One-dimensional Nanostructures - ICON 2007 – will be held in Malmö (Sweden), 26-29 September 2007. ■

> **Website:** www.pronano.se/~icon

Soft Matter Conference

The International Soft Matter Conference will take place in Aachen (Germany), 1-4 October 2007. It will be an interdisciplinary conference covering topics in physics, physical chemistry and biology. ■

> **Website:** www.fz-juelich.de/iff/ismc2007

Water Interfaces

The "Water Interfaces in Physics, Chemistry and Biology: A Multi-Disciplinary Approach" is a ESF-FWF Conference in Partnership with LFUI. It will be held in Universitätszentrum Obergurgl (Ötz Valley, near Innsbruck, Austria), 8-13 December 2007. ■

> **Website:** www.esf.org/conferences/07225

"Physics in our times" Symposium: what is coming next in physics? [REPORT]

The "Physics In Our Times" symposium was held at the 'Fondation Del Duca' de l'Institut de France, Paris, on Thursday 10 May 2007, to celebrate the ongoing success of EPL (*Europhysics Letters*), the letters journal exploring the frontiers of physics.

Predicting future developments in science is great fun for experts and non-experts alike. But forecasting the evolution of physics is no easy task, even for leaders in the field, and for a full day, members of the international physics community met in Paris to celebrate current achievements in physics, to identify emerging trends within physics and to try to imagine what physics will look like in twenty years' time.

The journal EPL brought together some of the leading figures in physics at the symposium entitled "Physics in our times: how will it evolve and what are the major remaining challenges?" to look at these issues from the perspective of a number of different fields within physics, from quantum physics to new materials, biological physics and nanotechnology.

Having been treated to lively presentations from Daniel Esteve (European Research Council Vice-President), Denis Jérome (Editor-in-Chief of EPL 2004-2007) and Volker Dose (Editor-in-Chief of EPL from 2007), delegates heard from Professor Serge Haroche (Ecole Normale Supérieure and Collège de France), Professor Dieter Vollhardt (Universität Augsburg), Professor Jacques Prost (Ecole Supérieure de Physique et de Chimie Industrielles de Paris) and Professor Alvaro de Rújula (CERN); each talking on the progress of research in their field and putting forward ideas for future developments in their disciplines.

We are pleased to let you know that the presentations of Professors Haroche, Vollhardt, Prost and de Rújula are now available online, along with an interview with each researcher at www.iop.org/EJ/journal/-page=extra.4/0295-5075.

For all enquiries, please contact **Caroline King** • e-mail caroline.king@iop.org. ■

Maurice Jacob (1933 - 2007) [OBITUARY]

Martin C.E. Huber,
Former President of the EPS

Maurice Jacob, who was EPS President from 1991 to 1993, died suddenly on May 2nd, 2007, following a heart attack. A large gathering of friends and colleagues, among them Ministers and Nobel Laureates, have joined Maurice's family in a moving, yet serene funeral service in the Temple Protestant of Petit-Saconnex near Geneva.

Maurice was a leader in the theory of high-energy hadron physics. He had made many key contributions to the development of the helicity formalism that is being used increasingly in modern theoretical calculations. His theoretical insight led him to predict phenomena, such as the existence of high-transverse-momentum processes in proton-proton collisions or the production of jets which were subsequently observed, respectively, at the CERN Intersecting Storage Rings (ISR) and the CERN Proton-Antiproton Collider.

He was a great convenor and discussion leader: he brought together theorists and experimentalists and promoted and led their debates on the meaning of new results and on proposals for new measurements with great enthusiasm. As the leader of the CERN Theoretical Physics Division between 1982 and 1988, Maurice was greatly involved in the management of CERN. This also meant for him the responsibility to preserve a working environment for his colleagues in the Division, which was free from administrative interference.

Maurice was a strong, yet fair advocate in the discussions on future CERN machines. He also was highly influential in preparing and advertising their physics: he had organised in 1978 the Les Houches workshop that brought the Large Electron-Positron Collider (LEP) project to the attention of the wider European community of particle physicists, and he was the organiser of the workshop of the European Committee for Future Accelerators (ECFA), held in Lausanne in 1984, that explored the possible physics of the Large Hadron Collider (LHC).

Later, in the 1990s, during the difficult period when approval and funding for the LHC were being secured, Maurice served as advisor to the CERN Director General for relations with the Member States. In this capacity he served the particle-physics community tirelessly through intense consultations between CERN and its many stakeholders. It is sad, indeed, that Maurice, who did so much for this project, did not live to see the LHC put into operation — and to enjoy its findings.

Collaboration between European physicists and European physics journals were close to Maurice's heart: he was founding editor of Physics Reports and acted for many years as editor of Physics Letters B. He led the French Physical Society as their President in 1985, and from 1991 until 1993 he was President of the European Physical Society.

At that time, following the fall of the Berlin wall, Maurice brought much relief to colleagues in Central and Eastern Europe by providing free EPS journals and by strongly collaborating with INTAS, the International Association for the Promotion of Co-operation with Scientists from the New Independent States of the Former Soviet Union. The conference on large facilities that was organised by both the American and the European Physical Societies (APS and EPS) in Budapest in May 1992 was another example of his collaborative spirit.

As EPS President, Maurice took measures to reduce the notorious deficit that had plagued the Society for years. This involved a reorganisation of the Budapest Secretariat, including a two-year residency of the then Secretary General Gero Thomas in Budapest. Maurice initiated a revision of the EPS Constitution that provided for a wider distribution of Europhysics News particularly in the large countries, where EPN is not widely distributed. He was also keen on providing a bridge between EPS and the then newly-founded European Astronomical Society (EAS). With the founding of EAS, the Astrophysics Division of EPS had lost much of its *raison d'être*. But it had a very active Solar Physics Section. Through the Joint Astrophysics Division (JAD) of EPS and EAS, Maurice Jacob enabled European solar astronomers to continue working in the well-functioning framework of EPS, yet provided them with a direct link to the night-sky astronomers, who made up the membership of the EAS.

Several years after his EPS Presidency, Maurice Jacob agreed to chair the Joint Astrophysics Division, and organised a joint ESA-CERN workshop in April 2000, where space-research applications of high-energy physics developments were examined as part of a general discussion of future fundamental-physics research in space. Then, in 2001, a Gravitational Physics Section was established, so that EPS can now cater to the renewed interest of European physicists in gravitation and, particularly, in the rapidly progressing field of gravitational waves. His chairmanship of JAD followed a related one in the European Space Agency (ESA) Maurice Jacob served as a supremely qualified adviser within ESA's Scientific Programme, by taking on the chair of the Fundamental Physics Advisory Group (FPAG). This Group, established in 1994 to complement the already existing Solar System Working Group and the Astronomy Working Group, was charged with advising on the merit of proposals for future science missions in the field of Fundamental Physics. In fact, by that time, about a third of all the proposals for ESA science missions fell into the category of 'Fundamental Physics in Space'. The most prominent mission of this kind is the joint ESA-NASA Laser

Interferometer Space Antenna (LISA), which is now a component of ESA's current 'Cosmic Vision' long-term science programme. LISA will complement the existing ground-based detectors, which — owing to the gravitational noise of their environment — are blind to anything below about 10 Hz, and, therefore, are forced to focus on gravitational waves at high frequencies, where only transient sources occur. LISA, on the other hand, will be able to detect — with a large signal-to-noise ratio — gravitational waves of low frequencies (10^{-1} Hz to 10^{-4} Hz), where a wealth of continuous sources, including merging massive black holes, are predicted to exist.

Maurice Jacob was a generous, resourceful, always considerate person with vast knowledge reaching far beyond science into history, literature and the arts. Unfortunately, as he approached retirement, he was struck by a chronic, debilitating ailment that made it difficult for him to enjoy to the full his retirement. His colleague John Ellis perfectly described our loss in the CERN Bulletin with the words: "*Maurice's many friends around the world have always valued immensely his selfless kindness, his modesty, his lucidity, his energy and his inexhaustible willingness to help, advise and assist them. We will miss him sorely.*" ■

EPS Prize for "Science on Stage" [AWARDS]

Martin C.E. Huber, Former President of the EPS

Per Kornhall, a Swedish science teacher, was awarded the EPS Prize for an outstanding contribution at the 'Science on Stage' festival that was held in Grenoble from 2 to 6 April 2007. The prize, consisting of € 1000 in cash, was given for the high-school teaching project "*Teach Science in a Different Way*".

Per Kornhall was faced with a class of pupils, who were not going to study science later in their life, who didn't like science and were generally very tired of being at school. Indeed, there were even problems with attendance in the class, and thus the idea of teaching them the foundations of chemistry and physics was not a very promising one.

The teacher therefore decided that his first aim must be to give his pupils some knowledge of science that they could need in their future working lives, where they might actually become decision makers in Government or Industry. Secondly, he wanted to convey to his pupils some science that they would not forget and that would stimulate in them some interest. So, instead of starting with elementary chemistry and physics, the teacher started at the other end. In his lessons he spoke about string-theory, relativity, the making of the atomic bomb, modern organic chemistry, and so on.

The result: attendance in class rose quickly. The pupils had been told that they only had to attend the lessons in order to pass, but to obtain a higher grade, they had to take a final test. Even the most bored pupils started to listen and even to ask questions — and all but four took the test!

Asked to evaluate the project, the pupils said that they had gained a new insight into science, that they now better understood how complex it could be but also how fascinating, and that they had gained respect for natural science.

For the teacher, preparing the course was, of course, a challenge, but it opened a new way of thinking about science education. The teacher also commented that he had had a really good time himself! ■

▼ **Per Kornhall** receives the EPS Prize for his outstanding project "Teach Science in a Different Way" from **Martin C.E. Huber**, former EPS President, during the Closing Ceremony of 'Science on Stage 2'.

From ASDEX to the HL-2A Tokamak [REPORT]

Xuru Duan,
Southwestern Institute of Physics, Center for Fusion Science • Chengdu, Sichuan • China

In China there are two major research institutes dedicated to scientific and technological development of fusion energy for peaceful use. In addition, there are few smaller research groups and education and training units for nuclear fusion and plasma physics at universities. One of the institutes, the Southwestern Institute of Physics (SWIP), was officially founded in 1965. It is the oldest and largest institute focused on nuclear fusion and plasma physics studies in China. The mission of SWIP is dedicated to the R&D necessary for the realization of fusion energy. Since its foundation, various experimental facilities for magnetically confined controlled fusion research have been built and operated at SWIP, including a Stellarator (1971), the MM-2 device (super-conducting magnetic mirror, 1972), a RFP (reversed-field pinch, 1990), and finally the HL-1 tokamak (1984) and HL-1M tokamak (1994).

After the construction and scientific exploitation of HL-1M, SWIP planned to build a new tokamak - the HL-2 project. The size and scope of the planned HL-2 was similar to that of ASDEX - in the '80s the largest divertor tokamak of the European fusion programme, operated in the Max-Planck Institute for Plasma Physics in Garching (IPP). The HL-2 concept foresaw, however, a larger plasma shaping with larger triangularity d and elongation e. According to the estimation of the SWIP engineers, a construction time of 8 years for HL-2 was expected at a budget of about 200 Millions CNY. At that time it was difficult to see how such a project could be fully supported by the government.

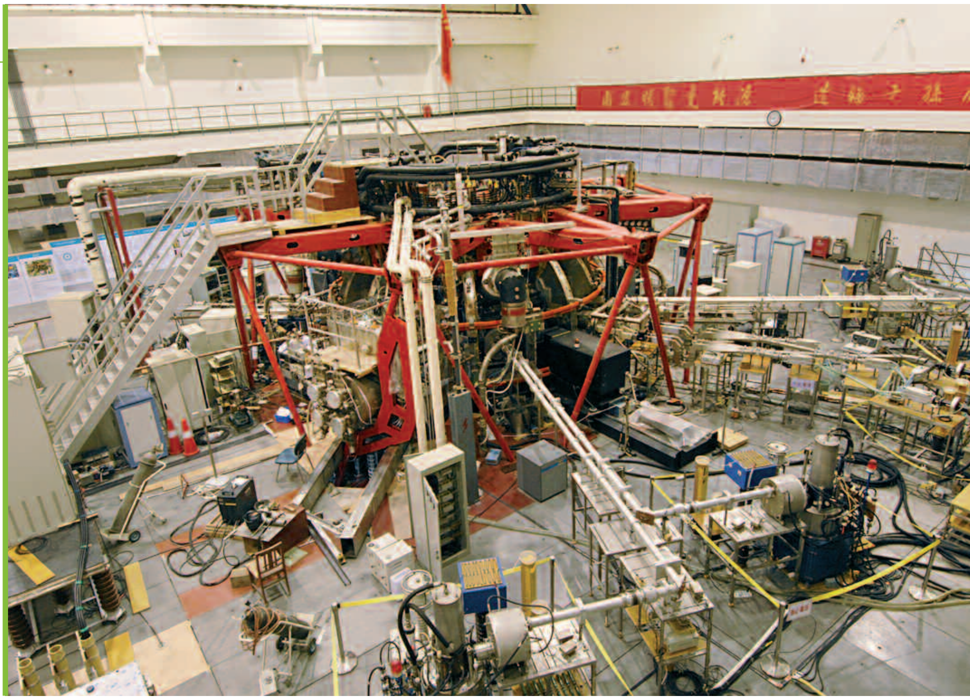
In 1994, IPP expressed its willingness to transfer the ASDEX machine to SWIP. By transferring ASDEX to SWIP and making minor modifications, it could replace the planned HL-2 project. By doing so, the overall costs could be reduced, and the construction duration be shortened significantly. After the consultation of the European fusion associations and the formal approval by EURATOM an agreement between IPP and SWIP for the transfer of ASDEX was signed. In 1995 a team of 15 Chinese engineers and technicians were sent to Garching to dismantle ASDEX, document and enumerate all components by a delicate system and pack them for transport. This process took about 6 months. The dismantled components were shipped from Hamburg to SWIP in 1996.

SWIP planned to reconstruct the machine at the new site of the Institute in Chengdu, the capital of the province Sichuan. All the previous experiments were located at the other site of SWIP, in Leshan, 130 km south of Chengdu. Along with the resources to set up a new project on the basis of ASDEX, SWIP also became a brand new Institute at the new site. A photo of it is shown in Fig. 1. All the sub-systems, including pumping system, cooling system, power supply system, diagnostics system, etc. had to be designed and constructed by SWIP. The whole became formally known as the HL-2A project. After approval from the Chinese Government in 1999, SWIP started the construction of HL-2A, and it was finished in 2002. In November 2002, the first plasma discharge was achieved on the HL-2A device. Since then, the largest tokamak with divertor in China has been under operation at SWIP. The transfer of ASDEX has greatly shortened the construction period of the HL-2 project. It represented an important contribution to the development of the Institute and was an important step forward for the fusion efforts of China. In addition, the work and experience gained with HL-2A at SWIP have helped China during the negotiations to become a partner in the ITER project.

The programme on HL-2A comprises experimental plasma physics for understanding and improving plasma performance and the development of novel diagnostic techniques, fusion technology and engineering, and the investigation of fusion materials. In 2003 a lower single null divertor configuration was successfully achieved in HL-2A. This was the first tokamak discharge with non-circular plasma cross section in China. Since then new diagnostics have been developed, and a powerful electron cyclotron wave heating system (ECRH) has been installed. The overview of HL-2A tokamak and some subsystems is shown in Fig. 2. The plasma parameters have been improved and notable successes have been achieved in the last two years. Fig. 3 shows, for example, the development of the core electron temperature with ECRH. Meanwhile, HL-2A contributes to the most exciting and challenging questions in fusion research. For example, the toroidal symmetry of the geodesic acoustic mode (GAM), the oscillating branch of zonal flows has been demonstrated for the first time using a novel

◄ **Fig. 1:** Overview over the new SWIP institute in Chengdu.

▶ **Fig. 2:** Overview of the HL-2A tokamak.



3-step Langmuir probe, and the poloidal and radial structure of the low frequency (7~9 kHz) electric potential and field were simultaneously observed [the specialists may consult: Zhao *et al. Physical Review Letters* **96**, 255004 (2006)].

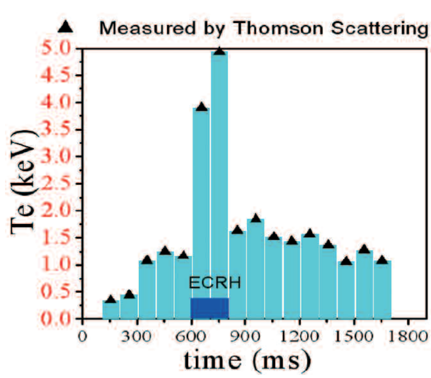
For the further development of the Institute's programme, SWIP is planning to eventually modify HL-2A into HL-2M. HL-2M will be an advanced tokamak with high beta, high confinement time as relevant parameters and the device should be flexible enough to carry out tasks and topics directly related to ITER and the basic plasma physics, which will be important for the optimization of a future fusion power plant. The plasma parameters of HL-2M will be: Plasma current I_p = 1.2 MA, major radius R = 1.8 m, minor radius a = 0.5 m, ẹ = 1.6-1.8, $\delta > 0.4$. This plasma geometry will still fit into the coils of the old ASDEX.

Another institute in China focused on nuclear fusion is the Institute of Plasma Physics of the Chinese Academy of Sciences (ASIPP). Founded in 1978 in Hefei, it had built a few smaller tokamaks in the 1980s and constructed a superconducting tokamak HT-7 in 1994, based on a re-design of the T-7 tokamak from Russia. The new, fully self-designed and completely superconducting experimental tokamak fusion device, EAST, got its first plasma at ASIPP in September 2006. The EAST tokamak has not only superconducting toroidal coils, but also superconducting poloidal coils. The scientists and engineers at ASIPP are developing auxiliary heating and diagnostic systems for the tokamak, and they will contribute to one of the most critical questions in the development of fusion, long pulse plasma operation at relevant physical parameters as well as solving the technical implications.

As mentioned above, China has been undertaking fusion research since the 1960s to explore a new energy source, because energy consumption in China will increase fast with substantial economic growth and a rise in living standards. Moreover, China's population could grow up to 1.6-2.0 billion by the middle of this century, while the annual energy consumption, which mainly comes from coal at present, could be up to 4~5 billions STCE (standard tones of coal equivalent). Considering the finite reserve of fossil fuels and the global warming of the environment, the Chinese believe that it will be crucial for the future of China to develop non-fossil energy sources on a massive scale. Of the various energy sources under consideration, fusion energy is considered to be the most attractive option.

The fusion energy project, ITER, is aimed at developing a clean, cheap and abundant energy source to replace fossil fuels. Participating in the ITER project as one of the seven partners is a major step and will push forward fusion research in China. This accelerated progress will allow China to enter the DEMO stage of the fusion development (DEMO, the demonstration reactor is the step foreseen after ITER) simultaneously with other countries. The work with HL-2A and later with HL-2M will also be a contribution to the training of a new generation of scientists and engineers in the field of nuclear fusion. Having joined the ITER project is one of the key steps China has taken to be involved in international mega-science and technology cooperation and in international efforts to develop new energy sources in the fight against global warming.

The major contribution of China to ITER construction includes 10% of the ITER budget, staff, and physics and technology support research, etc. In the next few years the technical activities will be focused on the completion of R&D and the design of superconductors and related components, the blanket and blanket shield, power supply, magnet supporters, gas injection and glow discharge cleaning system, and diagnostics, etc. China is also engaged in the preparations for the test blanket module programme to test tritium breeding from lithium. In addition, a domestic program to complement and support the ITER Project is also being undertaken involving, for example, scientific work by the two upgraded devices (HL-2M and EAST) combined with theory and numerical simulation. ■



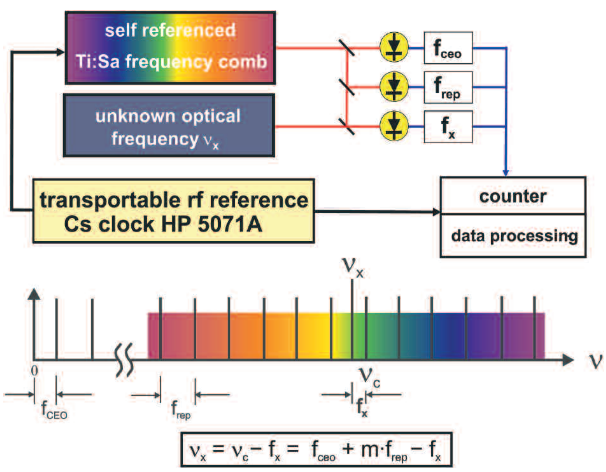
▲ **Fig. 3:** Core electron temperature measured by laser Thomson scattering during high power electron cyclotron resonant heating (ECRH).

Highlights from european journals

Optical visit into K-K_2 cold collisions

In many fundamental experimental studies such as, for example, of optical frequency standards or of time variation of fundamental constants, optical frequencies must be measured precisely. Since the invention of optical frequency combs based on a femtosecond pulsed laser, such measurements have become fairly straightforward. Frequency combs are nowadays available in many laboratories, opening new possibilities for other applications as well. In an experiment in Hannover, the transition frequencies ν_x of spectral lines of K_2 around 818 nm, in the near infrared spectral region, were recently measured using a frequency comb. The goal of the experiment is to investigate the weak interaction of potassium atoms and K_2 molecules by low energy collisions, which manifests itself in a frequency shift of the optical transitions of the collision partners. K atoms and K_2 molecules are prepared in a particle beam. Their relative velocity is small and thus the collision energy low. By deflection of the atoms out of the beam with laser light, the collision rate between K atoms and K_2 molecules can be changed. The particle beam is spatially narrowed to reduce the Doppler width geometrically to less than 1 MHz. In addition the experiment was arranged in a saturation spectroscopy-like way such that the typical observed widths of the spectral features were about 0.5 MHz. An accuracy of the optical frequencies better than 40 kHz was achieved, corresponding to a relative uncertainty $\delta\nu/\nu = 1\times10^{-10}$. The frequencies of molecular transitions at low collisional rates are compared with those for high ones and the limits for the collisional frequency shift within the beam are determined. Common mode rejection reduces the uncertainty for a comparison of different collision conditions by about a factor of three with respect to absolute frequencies. The sensitivity of the experiment will be enhanced in the future by application of a molecular Ramsey-Bordé matter wave interferometer. ■

I. Sherstov, **S. Liu**, **Ch. Lisdat**, **H. Schnatz**, **S. Jung**, **H. Knöckel**, and **E. Tiemann**, 'Frequency measurements in the b $^3\Pi(0_u^+)$ – X $^1\Sigma_g^+$ system of K_2', *Eur. Phys. J. D* **41**, 485 (2007)



◄ Principle of the measurement of an unknown frequency of a laser source with a femtosecond optical frequency comb. The upper part sketches the experimental arrangement, while the lower part gives the scheme of the determination of the unknown frequency ν_x by comparison with the known comb frequency ν_c. Symbols ν denote frequencies in the optical region, while the symbol f is used for RF-frequencies.

Electron dynamics in quantum gate operation

Just as classical computers use networks of standard gates to manipulate bits, so do quantum computers use networks of quantum gates to manipulate qubits. But quantum computing uses entanglement as a resource, the special quantum dance that correlates the behaviours of these qubits.

A Kerridge *et al.* (University College, London) have looked at the dynamics of quantum gate operation. They consider an important class of solid-state gates - those employing optically-controlled electron spin qubits. Such gates form the basis of a possible realisation of the basic component of a proposed quantum information processor that might even operate at useful temperatures.

Their approach took a time-dependent configuration interaction method to study how the electronic structure of two electron spin qubits evolved when they interacted with a third, optically-excited, control spin in an applied magnetic field. They could identify unitary operations, which approximately disentangle the control spin, and use these operations to construct high-accuracy two-electron operations that were locally equivalent to the standard CNOT, SWAP, and root-SWAP operations. They could then estimate the accuracy of a set of candidate quantum gates, evaluating the residual entanglement of the control electron and overall gate operation times. Their results attest to the feasibility of the silicon-based quantum gates proposed by Stoneham *et al.* [*J. Phys.: Condens. Mat.* **15**, L447 (2003)].

Whilst it is important to show that high accuracy gates are possible, what is particularly novel is their demonstration that state-of-the-art electronic structure methods can be used to model the dynamics of two-qubit gates, a significant advance over previous analytical studies. Their approach can be generalised to multi-qubit systems, and is the basis of a powerful tool to optimise a number of solid-state routes to quantum information processing. ■

A. Kerridge, **A. H. Harker** and **A. M. Stoneham**, 'Electron dynamics in quantum gate operation', *J. Phys.: Condens. Mat.* **19**, 282201 (2007)

Counterion distribution near a monolayer of variable charge density

Although the distribution of counterions (ions of opposite charge accompanying an ionic species in order to maintain electric neutrality) near charged surfaces was predicted almost a hundred years ago, experimental verification with high resolution has been missing. Classical Poisson-Boltzmann (P-B) theory describing interplay between entropy and electrostatic attraction by the surface has become a cornerstone of modern colloid and biomolecular science research. However, a large gap persists between theoretical predictions of the counterion density profile at molecular scales and the experimental capability to observe the distribution. Recent theoretical studies predicted fundamental deviations from classical theory.

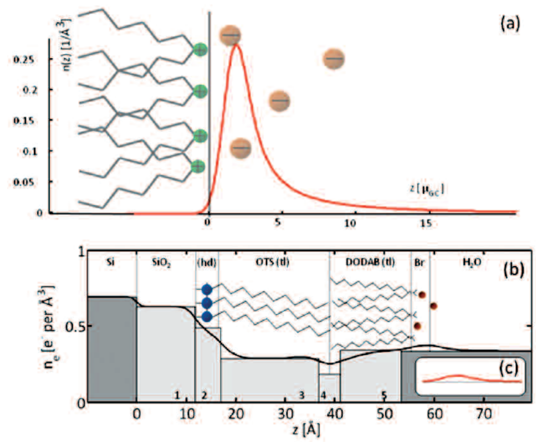
This study concentrates on an electrolyte concentration of counterions only, using surface charge density as an external control parameter. This idealized case of a flat, positively-charged solid-liquid interface, gives rise to an algebraic decay of the counterion distribution according to the classical P-B theory. The interface was a deposition of a charged surfactant with bromide counterions onto a hydrophobized silicon support. Surface charge density was varied by integrating a neutral lipid into the surface monolayer.

The charged interface was examined by resonant X-ray reflectivity (ESRF, ID1). Photon energy was varied around the bromide K-edge to change the scattering contrast of the counterions, leaving contributions from all other components constant.

The electron density perpendicular to the surface was modeled using a sum of error functions with an added counterion contribution according to classical theory, convoluted with a Gaussian to account for interface roughness, thermal fluctuations and finite experimental resolution.

The change in the reflectivity curves due to variation of the surface charge density could be consistently modelled. No deviation from the classical mean-field theory was observed within experimental accuracy.

Klaus Giewekemeyer and **Tim Salditt**, 'Counterion distribution near a monolayer of variable charge density', *Europhys. Lett.* **79**, 18003 (2007)



▲ **(a)** Counterion distribution according to classical P-B theory. **(b)** Fitted electron density perpendicular to the charged interface on the silicon support. **(c)** Magnified region of the counterions, modelled with P-B theory

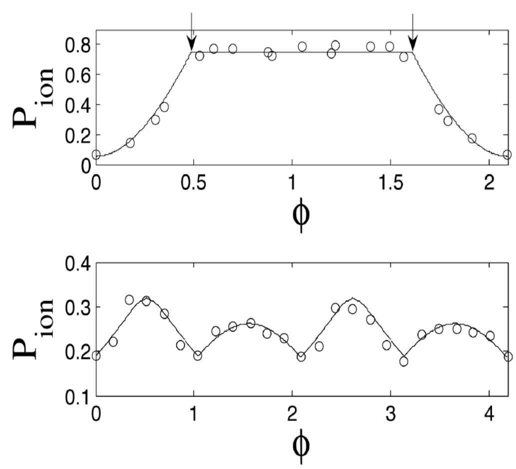
Inside multi-photon ionization of hydrogen

Simple systems can display extraordinarily complex behaviour: This lesson from three decades of chaos theory has altered the direction of many areas of physics. A case in point is the multi-photon ionization of hydrogen by a strong bichromatic microwave field, a system prototypical for atomic control research. In the present communication, we show how periodic orbit analysis captures this system's complexity: Through the stability of a few periodic orbits we can reproduce the variation of experimental ionization rates with a control parameter (the phase lag between the two modes of the field). More broadly, our results constitute rules by which this quantum system can be controlled. Such systematic and practical coherent rules remain very rare and sought after. Clearly, the hope is that experience gained from this prototypical system will help to control more complex systems ranging from atoms to plasmas.

Here control denotes tailoring the physical behaviour of nonlinear dynamical systems (which generically exhibit chaotic dynamics) using "knobs" (*i.e.*, suitable external parameters). Success depends on identifying simple knobs and understanding why and how they alter the system.

The present communication identifies precisely such a knob for a complex quantum system, and shows how ionization behaviour can be predicted with high accuracy using periodic orbits.

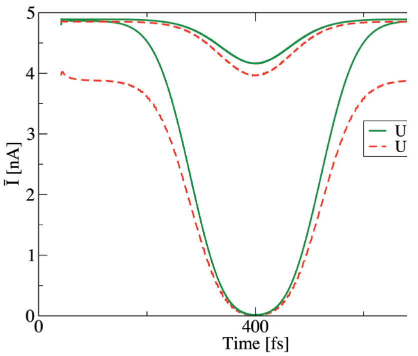
S. Huang, **C. Chandre** and **T. Uzer**, 'How periodic orbit bifurcations drive multi-photon ionization', *J. Phys. B: At. Mol. Opt. Phys.* **40**, F181 (2007)



▲ Solid curves represent the normalized ionization probability versus the phase lag based on the stability analysis of a few periodic orbits for two different mode-locked microwave fields. Circles represent the data obtained by one-dimensional quantum calculations, taken from [Koch *et al.*, *J. Phys. B* **36**, 4755 (2003)]. Arrows indicate the locations of the periodic orbit bifurcations.

Laser-controlled current in molecular junctions

Electronic transport through molecular wires and junctions has recently attracted much attention experimentally as well as theoretically because atomic-scale wires might have many technological applications. When in a simulation an external time-dependent field, such as a laser field or an additional ac voltage, is applied to the molecular junction, several interesting effects arise, which might be used to switch the current.



▲ Current induced by a laser with Gaussian shape of the envelope and a maximum amplitude which fulfils the criterion for coherent destruction of tunnelling. Shown is an average current obtained by averaging over several periods of the carrier frequency of the external field. The two lower lines are for a small bias voltage, the top lines for a larger one.

The electron tunnelling through a molecular junction can be studied using a master equation approach. In the case of small bias voltages and high carrier frequencies of the external field, we observe the phenomenon of coherent destruction of tunnelling, *i.e.* the current through the junction vanishes completely for certain parameters of the external field. In previous studies the tunnelling within isolated and open multi-site systems was suppressed by changing the effective tunnelling between the sites. In the current investigation it is shown that the tunnelling between a single site and electronic reservoirs, *i.e.* the leads, can be suppressed as well.

For larger bias voltages the current does not vanish any more since further tunnelling channels participate in the electron conduction and one can observe photon-assisted tunnelling which leads to steps in the current-voltage characteristics. Additional steps occur if electron interaction is taken into account, known also as a Coulomb staircase.

The described phenomena are demonstrated not only for monochromatic fields but also for laser pulses and therefore could be used for ultra fast optical switching of the current through molecular junctions. ■

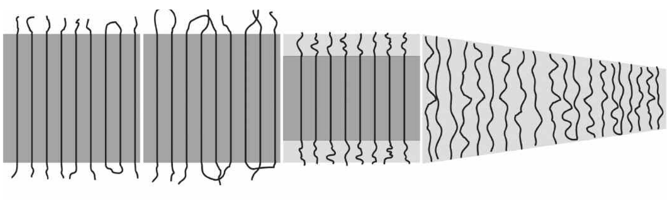
Guangqi Li, **Michael Schreiber** and **Ulrich Kleinekathöfer**, 'Coherent laser control of the current through molecular junctions', *Europhys. Lett.*, **79**, 27006 (2007)

Laws controlling crystallization and melting in bulk polymers

After the fundamental structure of semi-crystalline polymers - layer-like crystallites with thicknesses of several nanometers being embedded in a liquid matrix - had been discovered in the '50s, attention turned to the mechanism of formation. After intense controversy an approach put forward by Hoffman and Lauritzen prevailed. This approach was based on an easily visualised picture - crystalline lamella with smooth lateral faces and a surface occupied by sharp chain folds, growing laterally layer by layer with a secondary nucleation as rate determining step - and yielded simple relationships. The main control parameter is the supercooling below the equilibrium melting point T_f^∞ which determines both the thickness dc of the crystallites and their lateral growth rate G. But these simple Hoffman-Lauritzen relationships are now being challenged by experiments carried out during the last decade, and a new understanding is starting to emerge. The experimental results can be expressed by two laws, which include two further controlling temperatures, T_c^∞ and T_{zg}, with $T_c^\infty > T_f^\infty > T_{zg}$: (i) d_c is inversely proportional to the distance to T_c^∞ (ii) G vanishes already at T_{zg}.

We interpret the observations as indication that the pathway followed in the growth of polymer crystallites includes an intermediate phase of mesomorphic character (see Figure). A thin layer with mesomorphic inner structure forms between the lateral crystal face and the melt, stabilized by epitaxial forces. The first step in the growth process is an attachment of chain sequences from the melt onto the growth face of the mesomorphic layer. The high mobility of the chains in the layer permits spontaneous thickening, up to a critical thickness, at which point the layer solidifies under formation of blocks. The last step involves the removal of defects from the blocky crystallites, leading to a further stabilization. The transitions between melt, mesomorphic layers and crystallites can be described with the aid of a nanophase diagram. T_c^∞ and T_{zg} are identified with the temperatures of the (hidden) transitions mesomorphic-crystalline and liquid-mesomorphic, respectively. The rate determining step for the lateral crystal growth is the attachment of chain sequences from the melt onto the lateral face of the mesomorphic layer at the growth front. The necessary straightening of the sequence prior to an attachment is the cause of the activation barrier. Comparison of the predictions of the model theories with experimental results from small angle X-ray scattering, optical microscopy and calorimetry yields latent heats of transition, surface free energies and the activation barrier. ■

G. Strobl and **T.Y. Cho**, 'Growth kinetics of polymer crystals in bulk', *Eur. Phys. J. E* **23**, 55 (2007)



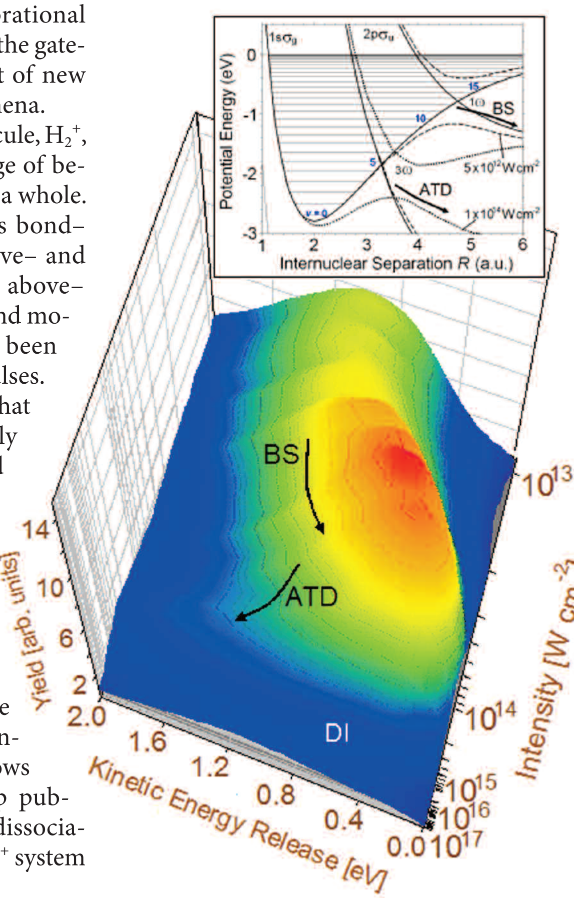
◀ Multistage-pathway followed in the growth of polymer crystallites

Severing molecular bonds with intense femtosecond laser pulses

Intense laser pulses of optical and near-infrared light are a versatile tool for probing the dynamics of both small and complex molecules. With inherent electric fields which often exceed an atomic unit of field strength, and pulse durations routinely below the vibrational timescale of the fastest systems, the gateway is open to exploring a host of new and exciting molecular phenomena.

The most fundamental molecule, H_2^+, is found to display a broad range of behaviour generic to molecules as a whole. For example, processes such as bond–softening and –hardening, above– and below–threshold dissociation, above–threshold Coulomb explosion and molecular alignment have all been observed using intense laser pulses. Its basic structure also means that H_2^+ is the most theoretically tractable of all molecules and thus an exemplar test system.

In recent years pioneering developments by the groups of Williams, Figger, and Ben-Itzhak, and co-workers have paved the way for crossed beams experiments on pre-ionized, fast H_2^+ targets. These have enabled a cleaner study of the underlying physics. The Figure shows the work of the former group published recently, demonstrating dissociation of the isolated two-level $^2H_2^+$ system (inset) over a large range of intensity. The dominant shift of the dissociation peak to lower kinetic energy release with increasing intensity illustrates the mechanism of bond-softening (BS), probing lower, more deeply bound, vibrational states which also are Stark-shifted to lower energy. The traces of flux, which can be seen to ebb to higher energy release at high intensity, is a signature of above-threshold dissociation (ATD). Indeed, the shallow grave which develops beyond this intensity reflects dissociation giving way to dissociative ionization (DI) resulting in Coulomb explosion of the molecule. Continued work of this nature will enable a broader understanding of ultrafast laser-molecule interactions, essential for extension to more complex molecules in the advance towards the goal of quantum control of chemical processes. ■



◀ Dissociation spectra of $^2H_2^+$ demonstrating the intensity dependence of bond-softening (BS), above-threshold dissociation (ATD) and dissociative ionization (DI) mechanisms as a function of energy release. Inset: Photon-dressed-states potential energy diagram of $^2H_2^+$.

D. S. Murphy, J. McKenna, C. R. Calvert, W. A. Bryan, E. M. L. English, J. Wood, I. C. E. Turcu, W. R. Newell, I. D. Williams and J. F. McCann, 'Controlling dissociation processes in the D_2^+ molecular ion using high-intensity, ultrashort laser pulses', *J. Phys. B: At. Mol. Opt. Phys.*, **40**, S359 (2007)

Secured quantum key distribution

Quantum Key Distribution is a technique to expand secret keys for use in ultra-secure communication systems. A short time ago this technique has entered the commercial market. Since the security of the devices cannot be demonstrated experimentally, it is important to have theoretical proofs of their security and to link these security proofs to the apparatus. In our work we have closed the gap between theoretical security and experimental implementation and provided the first full QKD security check for real devices.

Our security proof gives an unconditional secure key rate, which does not require any assumption about the way an adversary interacts with the signals or about the computational power that is at his disposal. As it is in the nature of any security result, we list the modelling assumptions about sending and receiving devices, which we may reasonably assume to be valid during high quality experimental implementations.

Security proofs for idealized QKD setups using ideal qubits, such as polarization states of single photons, have been known for a while. Current implementations, however, use weak laser pulses as signal sources, so that the known security proofs are not applicable. Weak laser pulses are likely to contain more than one photon, and these events leak, in the usual Bennett-Brassard protocol, their complete information to an eavesdropper. It is the chief contribution of this paper to show how to deal with these events and to demonstrate that one can obtain unconditional secure keys using standard optical communication equipment. ■

H. Inamori, N. Lütkenhaus and D. Mayers, 'Unconditional security of practical quantum key distribution', *Eur. Phys. J. D* **41**, 599 (2007)

Errata

The editors apologize for the minor errors which appeared in several parts of the previous issue, in particular in the President's Curriculum vitae and in the Laudation Ove Poulsen.

This was due to the use of uncorrected files in place of the final ones. ■

Neutrino oscillations - the Double Chooz experiment

[DOI: 10.1051/epn:2007014]

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Tremendous progress has been achieved in neutrino oscillation physics, but the smallness of the θ_{13} neutrino mixing angle still remains enigmatic. Double Chooz will use two identical detectors near the Chooz nuclear reactor cores to search for a non vanishing θ_{13}, and hopefully open the way to unveiling CP violation in the leptonic sector. The experiment may have some outcome in the field of non- proliferation.

Fact and mysteries in neutrino physics

Invented by W. Pauli in 1930 in order to reconcile the energy conservation with the β-decay experiments, the elusive neutrino was first experimentally discovered by F. Reines and C. Cowan at Savannah River nuclear Plant (South Carolina) in 1956. This opened the door to the use of neutrinos as a sensitive probe of particle physics. This pioneering experiment used the delayed coincidence technique to search for the reaction anti-$\nu_e + p \rightarrow e^+ + n$ where an electron antineutrino interacted with a free proton in a large tank filled with cadmium loaded liquid scintillator [1,2].

All neutrino flavours, ν_e, ν_μ, and ν_τ, are produced in nature, and they have been studied through various channels: atmospheric neutrinos produced in the earth's atmosphere by cosmic rays, neutrinos created in the sun, beamed accelerator neutrinos observed at a few hundred kilometres, and reactor neutrinos emitted by nuclear power stations. These sources have been observed in underground detectors, so as to prevent the contamination of the signal by cosmic ray induced background. Nowadays, the understanding of neutrinos has tremendously improved. Indeed, there is now convincing evidence for flavour conversion of atmospheric, solar, reactor and accelerator neutrinos, and 'oscillation' is the most promising mechanism to explain how neutrinos mix among themselves as they propagate.

The oscillation phenomenon implies that neutrinos have non-vanishing masses, leading to a spectrum of three mass eigenstates, ν_1, ν_2, ν_3 that are the analogues of the charged-lepton mass eigenstates, e, μ, and τ. The neutrino data can thus be described within the framework of a 3 × 3 mixing matrix between the flavour and mass eigenstates:

$$\begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_{23} & \sin\theta_{23} \\ 0 & -\sin\theta_{23} & \cos\theta_{23} \end{pmatrix} \times \begin{pmatrix} \cos\theta_{13} & 0 & e^{-i\delta_{CP}}\sin\theta_{13} \\ 0 & 1 & 0 \\ -e^{i\delta_{CP}}\sin\theta_{13} & 0 & \cos\theta_{13} \end{pmatrix} \times \begin{pmatrix} \cos\theta_{12} & \sin\theta_{12} & 0 \\ -\sin\theta_{12} & \cos\theta_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Three mixing angles, labelled θ_{12}, θ_{23}, and θ_{13} characterise the amplitude of the oscillations; moreover a complex CP-violating term entering the formalism could entail neutrino-antineutrino asymmetry (we omitted the two Majorana phases which do not play any role in neutrino oscillations). We note here that θ_{13} is the mixing angle that couples the field of neutrino number 3 (the heaviest) to the electron field. The neutrino mass has a deep implication for the Standard Model of Particle Physics (SM) given that neutrinos are regarded as massless fermions. Consequently there is neither mixing nor CP violation in the lepton sector. The SM has thus to be modified to account for the experimental evidence. The extension of the SM depends on the nature of the physics that gives neutrino mass: either a coupling mimicking the quark masses, providing 'Dirac neutrinos', that conserve the lepton number that distinguishes neutrinos from antineutrinos, or a new mass term that does not conserve the lepton number, providing 'Majorana neutrinos', and preventing the distinction of a neutrino from its antiparticle. Unlike β and rare double-β processes, or the study of the structure formation in the universe, neutrino oscillation experiments cannot access the absolute neutrino mass scale, but only differences between the squared masses: $\Delta m_{21}^2 = m_2^2 - m_1^2 \sim 8 \times 10^{-5}$ eV^2 and $\Delta m_{32}^2 = m_3^2 - m_2^2 \sim 3 \times 10^{-3}$ eV^2 [3,4].

Massive neutrinos provide us with the first evidence of physics beyond the SM [5]. But what is the relevance of knowing θ_{13}? Over the last years, the angle θ_{12} has been measured to be large, $\sin^2(2\theta_{12})\sim0.8$, by the combination of solar and long-baseline reactor neutrino experiments. The angle θ_{23} has been measured to be close to maximum, $\sin^2(2\theta_{23})>0.9$, by atmospheric and long baseline accelerator neutrino experiments. However, we only have an upper limit for the mixing angle θ_{13}, given mainly by the CHOOZ reactor neutrino experiment, $\sin^2(2\theta_{13})<0.2$. The large value of both θ_{12} and θ_{23} indicates a strong difference between leptonic and quark mixings, whereas the smallness of θ_{13} testifies to the peculiarity of the neutrino sector. The value of θ_{13} is of fundamental interest to understand leptonic mixing and to determine the correct neutrino mass model. Knowing the smallness of θ_{13} is also essential to plan for the future experimental programme in neutrino physics, since CP-violating effects directly scale with $\sin^2(2\theta_{13})$. Several questions remain to be answered: What are the neutrino

◀ **Fig. 1:** Picture of the Double Chooz far laboratory hall constructed by EDF, located close the old Chooz-A underground power plant.

▲ **Fig. 2:** Picture of the Double Chooz collaboration at the Chooz nuclear power station, on June 2007.

masses? Are the neutrinos Majorana particles? What are the neutrino mixing angles? Does the behaviour of neutrinos violate CP? Double Chooz aims to measure the last undetermined mixing angle θ_{13} in order to pave the way for the future measurement of CP violation in the lepton sector.

Reactor neutrinos and CHOOZ

Nuclear reactors are prolific sources of anti-ν_e, with an energy E (MeV) extending out to approximately 10 MeV. Reactor neutrino experiments measure the survival probability P(anti-$\nu_e \rightarrow$ anti-ν_e) over a distance L (km). For distances less than 5 km, this specific oscillation probability can be expressed by

$$P(\text{anti-}\nu_e \rightarrow \text{anti-}\nu_e) = 1 - \sin^2(2\theta_{13})\, \sin^2(\Delta m_{32}^2\, L/4E).$$

This two-neutrino formula is a very good approximation, primarily due to the smallness of the ratio $\Delta m_{21}^2/\Delta m_{32}^2$. Furthermore, thanks to the combination of the low energies and the short baselines considered, the modification of the oscillation probability induced by the coherent forward scattering from matter electrons (the so-called matter effect) can be safely neglected. In addition, the disappearance probability does not depend on the CP complex phase. These latter points support the case that a kilometre-baseline reactor neutrino experiment can lead to a clean measurement of the parameter $\sin^2(2\theta_{13})$, a simple function of θ_{13}.

At the end of the '90s, the CHOOZ experiment was performed to test the hypothesis that the electron neutrino oscillates in the parameter region probed by the atmospheric neutrino experiments $\Delta m_{32}^2 \sim 10^{-3}$ eV^2 [4,6]. The CHOOZ experiment was located in the Ardennes region of France, 1,050 m away from the double-unit Chooz nuclear power station. The detector was located in an underground laboratory below a 100 m rock overburden, providing, for the first time at a reactor, a strong reduction of the cosmic ray induced backgrounds. A homogeneous detector was filled by a 5 ton gadolinium-doped liquid scintillator target, surrounded by a thick active scintillating buffer and a muon veto. The external tank was surrounded by an additional layer of low radioactive sand. This composition of shielding moderates the neutrons induced by muons outside the detector as well as the gamma rays produced by the rocks. Since the two Chooz reactors were commissioned after the start of the experiment, in 1997, there was a unique opportunity to perform an in-situ background measurement. CHOOZ did not observe any evidence of neutrino oscillation, except for small mixing, and excluded $\nu \rightarrow \nu_e$ as an explanation for the atmospheric deficit. But unpredictably, CHOOZ became more famous over the last few years for reason of its bound on θ_{13}, $\sin^2(2\theta_{13})<0.2$, still being the world's best mark [6].

The Double Chooz concept

In order to improve the CHOOZ sensitivity, two (or more) identical detectors close to a power station are required. The first, located at a few hundred meters from the nuclear cores, monitors the neutrino flux and spectrum before the neutrinos oscillate. The second, located between 1 and 2 km away from the cores, searches for a departure from the overall $1/L^2$ behaviour of the neutrino energy spectrum, the footprint of oscillation. Since the reactor neutrino source led to the largest systematic uncertainties in the CHOOZ experiment, this new set-up provides a great improvement in the search for a small mixing angle. Two identical detectors allow a relative comparison, within one percent precision or less using standard technologies. Of course, the statistical error has also to be decreased by a similar amount, leading to an increase of the exposure by a factor of 15 at least.

An international union in the French Ardennes

The Double Chooz initiative started in the summer 2003 after an extensive review over several months of the few possible French sites suitable to carry out a new reactor neutrino experiment dedicated to θ_{13}. The Chooz site was selected because of the availability of the underground neutrino laboratory located at 1.05 km from the nuclear cores (Fig.1), funded and constructed by Electricité de France (EDF) for the first experiment carried out at Chooz. This site selection was done in parallel with other similar efforts in Brazil, China, Japan, South-Korea, Russia, Taiwan, and the United States, where 11 sites were being investigated. This international effort led to five international workshops, from 2002 to 2005, which have outlined the challenges and benefits of a new reactor experiment to measure θ_{13} and reviewed the potential of each site [7]. Today the worldwide conditions have changed and only four projects are still being considered: Angra (Brazil), Daya Bay (China), Double Chooz (France), and RENO (Korea). These experiments may be classified into two generations. Double Chooz, and RENO will attempt to probe the value of $\sin^2(2\theta_{13})$ down to 0.02-0.03, whereas Angra and Daya Bay will endeavour to track $\sin^2(2\theta_{13})$ down to 0.01. The first phase will push every single experimental technique to the state of the art. The second generation will require a significant R&D effort since the effective fiducial target mass will be increased by one order of magnitude and moreover systematic and background uncertainties have to be further reduced.

The withdrawal of several of the site candidates led to a reorganisation in participation. Today, the Double Chooz collaboration (Fig.2) is composed of 32 institutions from Brazil, •••

··· France, Germany, Japan, Russia, Spain, United Kingdom and United States, and the experiment has been approved by most of the respective Scientific Councils, standing surety for the launching of the experiment [8].

Neutrino production and detection at Chooz

The antineutrinos used in the experiment are those produced by the pair of reactors located at the Chooz-B nuclear power station operated by the French company Electricité de France. They are located in the Ardennes region, in the northeast of France, very close to the Belgian border, in a meander of the Meuse river (Fig.3). Both nuclear cores are the most powerful type reactors, with a thermal power of 4.27 GW each. Nuclear reactors produce energy through the fissions of ^{235}U and ^{239}Pu, induced by thermal neutrons. The fission fragment nuclei, too rich in neutrons, are particularly unstable and thus decay toward stable nuclei with an average of 6 β-decays per fission, leading to the emission of 6 anti-ν_e. Several hundreds of unstable nuclei are involved in these processes, which makes it very difficult to make accurate predictions. Furthermore the fuel composition evolves with time. In the eighties and nineties, several experiments were performed at a few tens of meters from nuclear reactor cores at Goesgen (Switzerland), Rovno, Krasnoyarsk (Russia), ILL Grenoble, and Bugey (France). From this set of experiments, the absolute normalization and the spectral shape of reactor neutrinos are known to a precision of about 2%.

The Double Chooz experiment will employ two almost identical detectors of 10 cubic meter active size. The laboratory located 1.05 km from the two nuclear cores will be used again. This is the main advantage of this site compared with other locations. In order to cancel the lack of knowledge of the neutrino spectrum, as well as to reduce the set of systematic errors related to the detector, a second device will be installed at about 300 m away from the nuclear cores. Since no high natural hills or underground cavity already exist at this location, a 40 m deep shaft will have to be excavated and equipped.

Reactor antineutrinos have an energy range extending to ten MeV; they are usually detected through the inverse β-decay: anti-$\nu_e + p \rightarrow e^+ + n$ (threshold of 1.8 MeV), with a cross section in the order of 10^{-42} cm^2. Experimentally one detects the very clear signature of the coincidence signal of the prompt positron followed in space, < 1 m, and time, ~100 ms, by the delayed neutron capture, thereby allowing a strong rejection of accidental background. Quite a few gamma rays with a summed energy of about 8 MeV are emitted subsequently to the neutron capture on gadolinium, whereas the gammas from natural radioactive decays hardly deposit more than 2.6 MeV in total. Thus, the addition of gadolinium enhances the neutron tagging, increasing the signal over noise ratio. The energy of the incident antineutrino is directly related to the kinetic energy of the positron, since the neutron is created with a tiny momentum. At Double Chooz, an averaged visible neutrino rate of 55 (550) events per day is expected to be detected inside the far (near) detector, taking into account the various inefficiencies, if no oscillations. Assuming a signal half way from the Chooz bound to zero, the expected oscillation neutrino spectrum is shown in Figure 4.

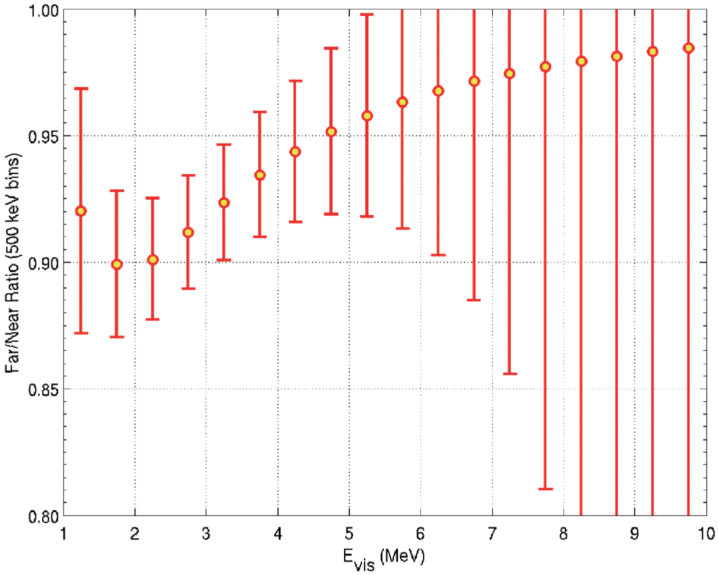
▼ **Fig. 3:** Overview of the Chooz experiment site.

Systematics errors and backgrounds

The basic principle of the multi-detector concept is the cancellation of the reactor-induced systematic error. Though an uncertainty from the neutrino contribution of spent fuel pools remains, it is negligible for Double Chooz. Technically, the two detectors should have a set of very similar parameters to guarantee their conformity for the neutrino oscillation search. For instance, the neutrino rates are proportional to the number of free protons inside the target volumes, which thus has to be experimentally determined with a precision of 0.2%. This constitutes one of the major improvements with respect to CHOOZ. In order to correct for the unavoidable differences between the two detector responses, a comprehensive calibration system is being enforced, consisting of radioactive sources deployed in the different detector regions, laser light flashers, and LED pulses. Meanwhile, the new Double Chooz design has been implemented in order to simplify the analysis and to reduce the systematic errors while keeping high statistics and high detection efficiency. Only three selection cuts will be used for the tagging of the neutrino signal instead of seven for the CHOOZ experiment.

Naturally occurring radioactivity mostly creates accidental background, defined as a random coincidence of a prompt energy deposition similar to the true prompt positron signal, followed by a delayed neutron-like event in the fiducial volume within a one hundred microsecond interval. Selection of high purity materials for detector construction and passive shielding around the active region provide an efficient protection against this type of background. Furthermore, accidentals can be accurately measured in situ.

Cosmic ray muons dominate the trigger rate at the detector sites, and they induce the main source of background. Muon-induced production of the radioactive isotopes ^{8}He, ^{9}Li and ^{11}Li cannot be correlated to the primary muon interaction since their lifetimes are much longer than the characteristic time between two subsequent muon interactions. These neutron-rich radioisotopes β-decay, mimicking the prompt signal, and later evaporate a neutron. This cascade fakes the neutrino signal, and the few events produced each day in the target volume have to be correctly subtracted to give the true neutrino events. A further source of background comes from neutrons that are produced in the surrounding rocks by radioactivity and in cosmic



▲ **Fig. 4:** Far to Near spectrum ratio for a hypothetical oscillation signal, assuming a true value $\sin^2(2\theta_{13})$=0.1 and Δm_{32}^2= 2.5×10^{-3} eV^2, for 3 years of data taking with both detectors.

ray muon induced hadronic cascades. In the latter case dominant at shallow depth, the primary cosmic ray muon may not penetrate the detector, being thus invisible. Fast neutrons may then enter the detector, create recoil protons mimicking the prompt signal and be captured by gadolinium nuclei after thermalisation. Such a sequence can be misidentified as a neutrino event. Fortunately this background can be fairly well estimated to one to two counts per day at the far site, from the measurements of the CHOOZ experiment during reactor off periods.

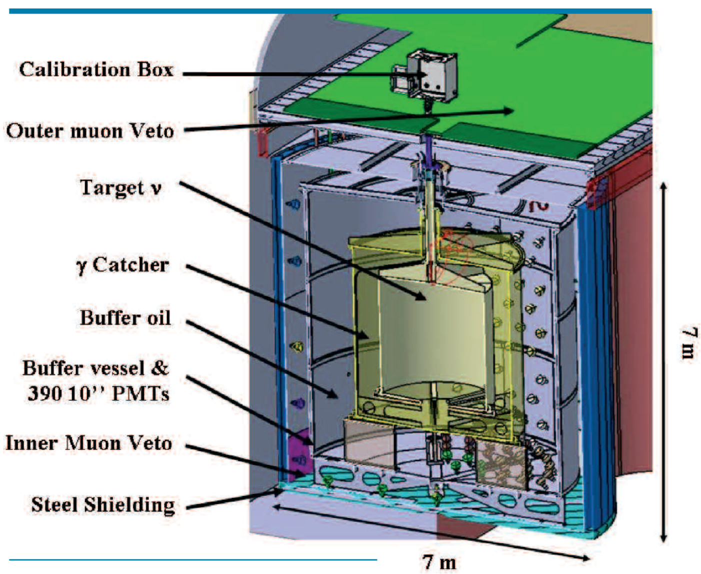
The detectors

The Double Chooz detector design is an evolution of the CHOOZ detector. The heart of the detector consists of a proton-rich liquid scintillator mixture loaded with gadolinium at a concentration of 1 g/l. The solvent is a phenyl-xylylethane/dodecane mixture at a volume ratio of 20:80, so as to improve the chemical compatibility with the acrylic and to increase the number of free protons in the target. Primary and secondary components, called "fluors" are also used to shift the photon wavelengths to the suitable range of the photocathodes, and to improve the scintillator transparency. Metal loading of liquid scintillators has been comprehensively studied within the collaboration for a few years, and a new complex has been designed for Double Chooz, based on β-diketonate chemistry. Large scale production of 16 tons of target scintillator has already started in order to provide identical neutrino targets for both Double Chooz detectors from 2008 and for several years thereafter.

Starting from the centre the detector elements are as follows (Fig.5). The fiducial volume consists of a cylindrical region of 1.15 m radius and 2.8 m height (10.3 m^3) filled with a gadolinium-doped liquid scintillator. The target vessels are built with acrylic plastic material, transparent to visible photons. A second acrylic vessel, the gamma-catcher, encloses the target, providing a 55 cm thick buffer of non-loaded liquid scintillator all around. This scintillating buffer is necessary to fully contain the energy deposition of gamma rays from the neutron capture on gadolinium, as well as the positron annihilation gamma rays in the central region. It also improves the rejection of the fast neutron background. The gamma-catcher vessel is surrounded by a 105 cm thick region of non-scintillating oil so as to reduce the level of accidental background, coming mainly from the radioactivity of the photomultiplier tubes (^{40}K, ^{238}U, ^{232}Th). The oil is contained in an opaque vessel made of thin stainless steel sheets and stiffeners, supports 390 inward facing 10-inch photomultiplier tubes (PMTs), providing 13% photocathode coverage. The inner detector is encapsulated within a muon veto shield, 50 cm thick, and filled with scintillating organic liquid and viewed by about 70 8-inch PMTs. It allows the detection of particles entering or leaving the inner detector. Because of space constraint, the 70 cm sand shielding of CHOOZ is replaced by a 15 cm iron layer so as to increase the target volume. Above the detector pit, a highly segmented muon tracker system will identify and locate the muons missed by the inner system, with the purpose of improving the background rejection. The near and far detectors will be "identical" inside the PMTs supporting structure, allowing a relative normalization error of 0.6 %, or less.

Sensitivity, competition and complementarity

Two other new reactor neutrino experiments are being prepared to search for θ_{13}: Daya Bay in China, and RENO in Korea, the Angra project still being at the conceptual stage. Daya Bay is an experiment composed of institutions from China, Taiwan, the United States, and Russia. It will be located in the Guang-Dong Province, on the site of the Daya Bay nuclear power station. This consists of two pairs of twin reactors, while an additional pair of reactors is currently under construction. Each core has a thermal power of 2.9 GW. In the full installation setup, 3.3 km of tunnel and 3 laboratories have to be excavated in order to accommodate 8 detector modules containing a fiducial volume of 20 tons of gadolinium-loaded scintillator each. With a systematic uncertainty goal of 0.4%, the Daya Bay collaboration aims to reach a sensitivity of $\sin^2(2\theta_{13})$~0.01 [9,10]. The RENO experiment will be located close to the Yonggwang nuclear power plant in Korea, about •••



▲ **Fig. 5:** The Double Chooz detector layout.

··· 400 km south of Seoul. The power plant is a complex of six reactors, equally distributed on a straight segment extending over 1.5 km, each of them producing a thermal power of 2.73 GW. Two neutrino laboratories have to be built and equipped in order to host the detectors. Both laboratories will be located at the edge of two tunnels to be excavated. With identical systematic errors as in Double Chooz, RENO could obtain a sensitivity of $\sin^2(2\theta_{13})<0.025$ after 3 years of data taking [7,10].

Beside the reactor neutrino program, new accelerator neutrino beams coupled with off-axis detectors, will search for a ν_e appearance signal leading to similar constraint on θ_{13} [11]. The observation of a ν_e excess in an almost pure nm neutrino beam would be major evidence for a non-vanishing θ_{13}. But in addition to the statistical and systematic uncertainties, correlations and degeneracies between mixing angles, the neutrino masses, and the CP phase degrade the accessible knowledge on θ_{13} [12].

The Double Chooz experiment offers the world's particle-physics community a valuable opportunity to measure the mixing angle θ_{13} within an unrivalled time scale. The data taking will be divided in two phases: a first one with the far detector only, and a second phase with both near- and far-detectors running simultaneously. Double Chooz will be sensitive to $\sin^2(2\theta_{13})>0.06$ after 1.5 year of data taking in phase I, and to $\sin^2(2\theta_{13})>0.03$ or better after 3 years of operation with two detectors (Fig.6). If θ_{13} is large, the information gained by Double Chooz could break the parameter correlations and degeneracies and long-baseline off-axis neutrino experiments will be able to search for CP violation in the lepton sector. The reactor and accelerator programs will provide complementary results to better constrain the last undetermined mixing parameters.

Non-proliferation

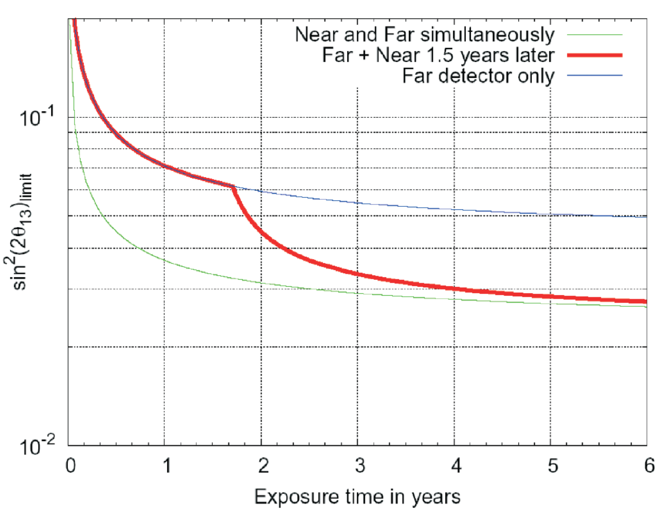
In the past, neutrino experiments have only been used for fundamental research. Today, thanks to the extraordinary progress of the field, neutrinos could be useful for Society. The International Atomic Energy Agency (IAEA) works with its member states to promote safe, secure and peaceful nuclear technologies. One of its missions is to make sure that safeguarded nuclear material and activities are not used for military purposes. In a situation of international tension, neutrino detectors could help the IAEA to verify the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), signed by 145 states around the world.

In a pressurized water reactor the initial fuel consists of enriched uranium rods, with a ^{235}U content typically of 3.5%, the rest being ^{238}U. As soon as the reactor is operating, reactions of neutron capture on ^{238}U build up ^{239}Pu and ^{241}Pu, producing around 200 kg of plutonium per year. But in these processes the number of antineutrinos per fission from ^{239}Pu is less than from ^{235}U, and the energy released larger by 5%. This sizeable difference offers a handle to monitor changes in the relative amounts of ^{235}U and ^{239}Pu in the core. Combined with the high penetration power of antineutrinos, this provides a new mean to make remote, non-intrusive measurements of plutonium content in reactors. A two cubic meter neutrino detector located at a few tens of meters from a nuclear core, coupled with the well-understood principles that govern the evolution of the nuclear core in time, could in principle monitor nuclear reactor cores non-intrusively, robustly and automatically at a level of accuracy of a few percent. Double Chooz will be a research laboratory with a very high sensitivity to study neutrino oscillations, and a million of events is expected in the near detector. These huge statistics could be exploited to help the IAEA in its Safeguards missions since the near detector will perform a measurement of the antineutrino flux and its energy spectrum with an unprecedented accuracy. This will provide the precious input to undertake a feasibility study of the detection of antineutrinos for safeguards applications by testing the potential of neutrinos to detect various diversion scenarios. In the future, Double Chooz data could serve as a benchmark of this new monitoring technique.

Conclusion

Double Chooz is now moving towards the construction phase. The first "far" detector will be installed in the existing underground laboratory at the beginning of 2008. The second, identical, "close" detector will be constructed from 2009 in a new neutrino laboratory, located down a 45 m well that will be excavated 300 m from the cores. The Double Chooz experiment promises to lead the race towards θ_{13} from the end of 2008, and to open the field of non-proliferation neutrino applied physics. ■

▼ **Fig. 6:** Sensitivity of the Double Chooz experiment after its start in 2008.



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Revisiting Farm Hall [DOI: 10.1051/epn:2007015]

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In his book *Hitler's Scientists*, writer John Cornwell [1] relates a pilgrimage style visit, in November 2002, to a mansion named Farm Hall, near Cambridge (UK), by a small party of science historians, Heisenberg scholars, and other writers. Farm Hall had served as a detention house for a group of ten nuclear academics and other scientists captured in Germany at the end of WWII by a special Anglo-American intelligence mission codenamed ALSOS and directed by Samuel Goudsmit [2] of electron spin fame. The interned group was composed of six prominent German professors, Werner Heisenberg, Otto Hahn, Carl F. von Weizsäcker, Paul Harteck, Walter Gerlach and Karl Wirtz, along with three younger nuclear assistants, Kurt Diebner, Erich Bagge and Hans Korsching, plus one prestigious outsider, Professor Max von Laue. They were kept incommunicado at Farm Hall from July to December 1945, a period covering the Hiroshima-Nagasaki bombings of August 6 and 9 and during which time their conversations were recorded without their knowledge. The recordings were translated on the spot from German into English and sent to a few top UK and US military and intelligence wartime authorities. These so-called "*Farm Hall Transcripts*" (FHT) were kept secret but were known to exist, *e.g.* through the memoirs published in 1962 by one of the recipients, the head of the American Manhattan project, General Leslie Groves [3]. Only in 1992 were they released to the public. A complete version was first published in 1993 by The Institute of Physics with a detailed technical background introduction by Sir Charles Frank, FRS [4].

The 2002 gathering at Farm Hall gave the learned visitors an opportunity to exchange privately their contrasting opinions on the German nuclear scientists on the inspiring premises of their detention. I will list the names of the debating scholars, since their books about science in the Third Reich and related issues represent a good literature sampling for further reading. In addition to Cornwell [1], there were playwright Michael Frayn of "*Copenhagen*" fame [5], science historian Mark Walker [6], nuclear physicist and science writer Jeremy Bernstein [7], Heisenberg scholar and historian Paul Lawrence Rose [8] and biochemist and author Walter Gratzer [9]. I cannot discuss the writings of these authors on the FHT nor their private deliberations at Farm Hall [1]. However I would like to single out Bernstein's book [7] which presents the complete text of the Transcripts with expert scientific and historical annotations. The book includes an extensive prologue outlining the history of fission up to Farm Hall, important technical appendices and an excellent summary on the German wartime nuclear program by David Cassidy [10], one of Heisenberg's most trusted biographers.

Before the release of the Transcripts, dozens of books, biographies, personal letters, diaries, magazine articles, etc… had appeared expressing diverging views on the moral responsibility of the German nuclear researchers working under the Nazi regime. The major controversy arose from the prevailing tone that the scientists liberated from Farm Hall used to report publicly on their wartime research activities. For example, in a detailed paper entitled "*Research in Germany on the Technical Application of Atomic Energy*" written in 1947 for Die Naturwissenschaften and translated for Nature [12], Heisenberg states in the opening paragraphs: "I*n view of the possibility that England and the United States might undertake the development of atomic weapons, the Heereswaffenamt (Army Weapons Bureau) created a special research group (the so called Uranverein or Uranium Society), under Schumann, whose task it was to examine the possibility of the technical exploitation of atomic energy*". The reader may have detected the careful choice of words: atomic **weapons** on the Allied side, atomic energy on the German side. Heisenberg's statement is moreover self contradictory since a vague exploitation of atomic **energy** (*e.g.* for ship propulsion) is not the type of project which would have appeased the anxieties of the Heereswaffenamt in the face of the threat of a terrific new bomb from the Allies. Senior readers may also have balked at the blatant inversion of the historical truth. //Namely that German scientists, who duly warned their authorities of the possibility of a super bomb already in 1939, led them (???) to firmly believe that they were the only ones capable of developing it and therefore that, even late in the war, the Reich had no nuclear surprise to fear from the Allies, contrary to Heisenberg's statement.// By contrast, it was the veritable terror of the threat of a Nazi Germany wielding nuclear weapons which prompted the refugees - the likes of Einstein, Fermi, Szilard, Wigner, Teller, Frisch, Peierls and dozens of others who had personally experienced the brutal ways of the Nazi regime - to press the governments of their host countries for nuclear action. At the end of his report, Heisenberg briefly discusses moral implications, as he sees them, along the following lines: "*Finally - and this is a most important fact – the undertaking (a German atomic bomb project) could not even be initiated against the psychological background of the men responsible for German war policy. These men expected an early decision of the war, even in 1942, and any major project which did not promise quick returns was specifically forbidden. …. From the beginning, German physicists had consciously striven to keep control of the project and had used their influence as experts to direct the work into the channels (towards a peaceful, energy-generating uranium reactor) which have been mapped in the foregoing report. In the upshot they were spared the decision as to whether or not they should aim at producing atomic bombs*". The FHT and what follows will reveal to the reader just what kind of *conscious striving* there was at the beginning of the war and even up to 1942.

Such self exonerating statements as just quoted failed to prevent the recurrent dispute over the moral responsibility of the German scientists, especially that of the most prominent among them who were in a position to choose to work on or to keep away from a project which could have been decisive for an issue of the war in favour of the Nazi ideology. The role of the FHT in resolving that dispute is compared by Bernstein to that of the Rosetta Stone in deciphering the ···

··· Egyptian Hieroglyphics [7]: the Transcripts indeed helped clarify to a great extent the true and changing intentions of the Germans under the Hitler regime.

The book-length Transcripts are far too extensive to discuss in this brief article [11]. Instead I will comment on a few fragments of conversations which took place just after the radio announcement of the Hiroshima bombing and which relate most directly to the moral stance taken by the detainees confronted with the momentous event and after the war.

During the few weeks of their rounding up in defeated Germany and detention prior to Hiroshima, the nuclear scientists expect to be revered by their guardians as proud and brilliant nuclear pioneers. At Farm Hall they receive a princely treatment in a generous enemy country gravely weakened by the war. In spite of this they manifest a great deal of impatience at being left guessing why they are interned and what is expected from them. They lament about the likely dreadful treatment inflicted by barbarous invaders on their families left behind in occupied Germany. They even threaten to escape and to sell their superior nuclear knowledge to Russia or to Argentina, etc….

Suddenly their haughty attitude is shattered by the news of the Hiroshima bombing announced by the BBC radio on the evening of August 6. Their shocked reactions to the news, which make the most gripping part of the FHT, are commensurate with their illusions of the previous days: incredulity first, then enormous stupor, devastation, sometimes scorn and anger towards each other. For hours, they wonder how the bomb was made, speculate on technical issues such as which isotope enrichment methods were used, what was the fissile mass, etc…. They scramble to understand how the Allies could have progressed so quickly in a research and technical field which they had themselves created by their discovery of fission and which they were confident to be alone developing. Then late on the evening of Hiroshima and the next day, an explanation gradually emerges as to why they have fallen so far behind in the nuclear adventure: a novel interpretation is skilfully crafted by von Weizsäcker in a declaration which after the war would cause the continuing controversy referred to above and which lingered even as late as 2002 amongst the distinguished investigators revisiting Farm Hall [1]:

von Weizsäcker: *History will record that the Americans and English made a bomb, and that at the same time the Germans, under the Hitler regime, produced a workable engine. In other words, the peaceful development of the uranium engine was made in Germany under the Hitler regime, whereas the Americans and the English developed this ghastly weapon of war.*

Upon reading this, one may remember Winston Churchill quipping "*History will be kind to me because I intend to write it*". Some time after the war von Weizsäcker's pronouncement was qualified by von Laue (who had nothing to do with the work of the Uranverein) as just a "*Lesart*", a version or a reading of history. While von Weizsäcker's statement hardly represents what factually occurred, its underlying moral message is definitely not what history will have recorded after publication of the FHT: the latter, combined with the post war reports of the liberated professors, show that the Lesart should be perceived not just as a personal interpretation of the facts by one particular individual but as a conscious attempt at a full, self-serving revision of history for future internal and external consumption. Bernstein reformulates it as follows [7]: "*The German scientists behaved morally in an immoral regime, while the allied counterparts did just the opposite*".

On carefully reading the Transcripts it appears that von Weizsäcker's conclusion did not come out of his imaginative mind all of a sudden: it was the final product of a previous period of groping by him and others of his colleagues to build up a high moral ground from which to explain, to the full satisfaction of their own conscience, why they had failed to produce an atomic weapon for Hitler. For example here are bits of conversations recorded in the FHT on the evening of Hiroshima (August 6) [7]:

von Weizsäcker: *I think it is dreadful of the Americans to have done it. I think it is madness of their part.*

Heisenberg: *One can't say that. One could equally say "That's the quickest way of ending the war".*

Hahn: *That's what consoles me.*

…

Heisenberg: *We wouldn't have had the moral courage to recommend to the government in the spring of 1942 that they should employ 120.000 men just for building the thing up* (the bomb).

von Weizsäcker: *I believe the reason we didn't do it was because all the physicists didn't want to do it, on principle. If we had all wanted Germany to win the war we would have succeeded.*

Hahn: *I don't believe that but I am thankful we didn't succeed.*

…

Wirtz: *I think it is characteristic that the German made the discovery and didn't use it, whereas the Americans have used it. I must say I didn't think the Americans would dare to use it.*

…

Hahn: *Surely you are not in favour of such an inhuman weapon as the uranium bomb ?*

Gerlach: *No. We never worked on a bomb…. You cannot prevent its development. I was afraid to think of the bomb, but I did think of it as a thing for the future, and that the man who could threaten the use of the bomb would be able to achieve anything. That is exactly what I told Geist, Sauckel and Murr* (political authorities).

Gerlach (of the Stern-Gerlach experiment) became the Uranverein top administrator late in the war. In these exchanges, Heisenberg and Hahn contradict von Weizsäcker, Gerlach contradicts himself and von Weizsäcker and Wirtz claim for all of them moral superiority over the Americans. In the Transcripts one comes across such statements until the Lesart is promulgated and implicitly endorsed by all at Farm Hall. An attenuated form of it (with the finger-pointing toward the Allies removed), namely that the Uranverein worked exclusively on a peaceful uranium engine, was incorporated in a memorandum written and signed at Farm Hall by all detainees (with reservations from von Laue), which represents their common version of the goals and achievements of the Uranverein [7],[11].

After the war, the Lesart would become, shall we say, the official ideological party line, with its ethical import explicitly or implicitly used by several of the detainees in their recollections and memoirs, and by their apologists, such as author Robert Jungk [13], Heisenberg's biographer Thomas Power [14] and Heisenberg's wife Elisabeth [15].

However, while von Laue was well placed to denounce the Lesart, several post war historians and commentators also raised strong objections to reports inspired from it. Among the most famous are Goudsmit [2], Rose [8], Arnold Kramish [16] and Aage Bohr [17]. Also crucial for gauging the credibility of the Lesart are the poignant letters (recently released [18]) written by Niels Bohr to Heisenberg concerning their fateful 1941 meeting in Copenhagen so artfully fictionalised by Frayn [5]. The controversy boils down to just one question: did the German nuclear researchers intend to build an atomic bomb for the regime or, as the Lesart implies, did they intentionally refrain from ever working on the bomb since the launch of the Uranverein in 1939? As put most directly by Walker, "*were they Nazis or anti-Nazis?*" [6].

In his introduction to the FHT, Sir Charles Franck [4] remarks: "*having, for whatever reason, renounced work on the bomb it would be only human to reinforce that decision with a sense of virtue*". Implicit in this judgment is that to be in a position of *deciding to renounce work on the bomb*, the Uranverein members must have had the *intention to build one in the first place*. Did they really have such a plan ? Indeed the FHT leave absolutely no doubt that the *initial goals* of the Uranverein included *both* the building of nuclear explosives *and* the construction of a not-so-peaceful Uranium engine, that is a natural-uranium reactor moderated by heavy water which, to the full knowledge of the scientists, could breed a fissile transuranic element, Pu239 (used for the Nagasaki bomb). Here are the relevant oral exchanges in the FHT of August 6, post Hiroshima:

Bagge: *We must take off our hats to these people for having the courage to risk so many millions.*

Harteck: *We might have succeeded if the highest authorities had said "We are prepared to sacrifice everything"*

von Weizsäcker: *In our case even the scientists said it* (the bomb) *couldn't be done.*

Bagge: *That is not true. You were there yourself at that conference in Berlin. I think it was on 8th September* (1939) *that everyone was asked – Geiger, Bothe and you Harteck were there too – and everyone said "it must be done at once". Someone said "Of course it is an open question whether one ought to do a thing like that". Thereupon Bothe got up and said "Gentlemen it must be done." Then Geiger got up and said "If there is the slightest chance that it is possible – it must be done."*

These explicit early commitments to making a bomb are aggravated by the fact that these persons, Bothe, Geiger, Harteck, Heisenberg, etc… were not even Nazi sympathisers, let alone party members. Lest such oral recommendations be viewed by apologists as nothing more than opportunistic, thoughtless boastings, one should note that these initial intentions were confirmed by several of the prominent scientists who did go out of their way to inform, *this time in writing*, high-ranking military or political authorities of the wonderful virtues of nuclear explosives. In a letter dated April 24, 1939, Harteck from Hamburg, with his assistant Wilhelm Groth wrote to Erich Schumann, the head of the Heereswaffenamt that [7],[19] "*We take the liberty of calling to your attention the newest developments in nuclear physics, which, in our opinion will probably make it possible to produce an explosive many orders of magnitude more powerful than the conventional ones. That country which first make use of it has an unsurpassable advantage over the others*". At conferences organized in Berlin in February and June 1942 to inform high-level Nazi dignitaries (including Himmler, Speer,…), Heisenberg lectured on the Uranverein program describing most explicitly what could be achieved with a Uranium reactor then under prototype development in Germany [7]: "*As soon as such a machine is in operation, the question of the production of a new explosive takes a new turn, according to an idea of von Weizsäcker. The transformation of uranium in the machine produces, in fact, a new substance (element 94) which* •••

▼ **Fig. 1:** The ten German nuclear scientists held at Farm Hall: upper line left to right: W. Heisenberg, O. Hahn, M. Von Laue, C. F. von Weizsäcker, P. Harteck lower line left to right: W. Gerlach, K. Wirtz; K. Diebner, E. Bagge, H. Korsching.

··· *is most probably, just like U235, an explosive of the same unimaginable effect. This substance can be obtained much more easily from uranium than is U235 because it may be separated chemically from the uranium*". The mechanism of plutonium breeding in a reactor, advertised by von Weizsäcker as the "*open road to the bomb*", was described in a *written document* sent by him to the Heereswaffenamt again, with a copy to Heisenberg, as early as July 1940 [7].

Albeit only lukewarm regime supporters, what these top scientists were doing by dangling the *unsurpassable advantage* of the nuclear explosive at the nose of power hungry military and political dignitaries can hardly be qualified as a "*conscious striving*" at directing the work towards peaceful applications ! Did they perhaps feel that their own recommendations were not realistic and would not be taken seriously? Fortunately for them and for the rest of the world, they indeed were not. The Nazi authorities never felt it urgent to take their scientists at their own word since, as mentioned earlier, they were led to believe that Germany could not be surprised by atomic weapons from their enemies any time soon. On that count they were right by only a few weeks at the end of the war in Europe.

How is it then that, if not from ethical restraint, the Uranverein failed to achieve its initial objectives in spite of a 2½ years head start over the Manhattan project? There are many concrete elements of explanation [20] one of which has to do with the *critical mass* of U235 or Pu239 required for a bomb. It appears that on this crucial question, at the very beginning of the war, *two technical mistakes* were made which have influenced the course of events decisively but in opposite directions for the German and Allied programs. On the one hand, as argued in great detail by Rose throughout his book [8], already in 1940 Heisenberg is said to have made an initial evaluation based on an erroneous use of the random walk process for calculating the scattering and multiplication of neutrons in a fast fission bomb. The conceptual error, which Heisenberg reproduces at Farm Hall in answer to Hahn's questioning on how the bomb works [11], leads to a grossly *over evaluated critical mass amounting to several tons*. Coming from the prestigious head of the Uranverein, this wrong model would have been uncritically accepted by the nuclear community and caused the German bomb project to be pushed on the back burner. On the other hand, in the UK at about the same time, Otto Frisch and Rudolf Peierls [7] solved the correct neutron diffusion equation to evaluate the critical mass but used too optimistic nuclear constants [20]. This resulted in a serious under evaluation of merely one pound, which had the immediate effect of giving to the British bomb project a status of highest priority and, some time later, helped kick start the Manhattan project [19].

The consequences of this spectacular, somewhat serendipitous technical divergence between the German and Allied sides were further amplified by the contingencies of the war. In Germany, with the great military successes of the Blitzkrieg and all its attendant self-assurance and self-delusion, no one in a position of power felt *any immediate need* for weapons more potent than the conventional ones. After the set-backs in the air war against Britain and especially after 1942-1943, with their first serious reverses in Russia, the German armies went on the defensive and *it was now too late* to think of diverting massive resources for a hypothetical nuclear weapon system (such resources as still remained available were already committed for other "wonder weapons", jet engines, cruise missiles and ballistic rockets). Then the Uranverein could retreat into a state of limbo which would suit most of its members, all good patriots holding to their own head but none fanatic Nazis. By contrast, on the Allied side, the same initial successes of the Axis Powers in the European and Pacific wars put the Manhattan authorities under great pressure to explore all possible avenues of making a nuclear bomb [19] and to maintain this effort until reaching the explicit objectives of hastening the end of the war and of gaining the coveted "*unsurpassable advantage*" for the post war era.

As for the psychological implications of the Lesart, one may wonder why von Weiszäcker and his colleagues attempted to cover up their true initial intentions. After all, if the evil nature of the Nazi regime may be disregarded for a while, their commitment to work on all applications of nuclear fission, including the military, could claim the same legitimacy as that of the allied scientists, namely that provided by the emerging concept of nuclear deterrence. Then why did they pretend to have consciously avoided work on a bomb from the very beginning, when in fact their conversations at Farm Hall prove the contrary and even reveal [7] that in 1941 the Kaiser Wilhelm Institute for Physics filed a patent for an atomic bomb on their behalf? Could it be that, upon being informed of the Hiroshima horror, some of them experienced an acute retrospective sense of guilt (repeatedly expressed in the Transcripts by Hahn about his discovery of fission) aggravated by their knowledge of the atrocities committed by the Nazi regime under which they chose to remain and work [11]. For von Weizsäcker (who belonged to a notorious family of diplomats), for Heisenberg (the adulated hero of Quantum Mechanics) and for some of the others, that guilty conscience may have been personally so embarrassing for their anticipated post-war image, that they found it necessary to repress it and go so far as to substitute for it a sense of virtue, to use Sir Charles's phrase.

The FHT make a fascinating reading and constitute a totally trustworthy set of documents [11]. What indeed can be more factually reliable and psychologically revealing than the conversations between uninhibited collegial experts who confide themselves to each other, exchanging their immediate and spontaneous thoughts in total confidence, unaware of being overheard. This cannot be said of many of the post-war writings of the protagonists and apologists which, as in the case of Heisenberg's Nature paper [12], are most likely to have been influenced by a great deal of afterthoughts and copious editing.

The delay in publishing the FHT so long after their recording, imposed by military state secrecy and humanitarian concern for the liberated professors, goes a long way in explaining why the Lesart could take root and why a big ensuing controversy was allowed to develop in the post-war literature on this dramatic episode of science history. ■

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Not seeing the light [DOI: 10.1051/epn:2007016]

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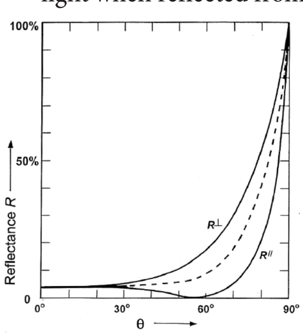
Back in 1808 the young French soldier Etienne Louis Malus noted that there is something funny about reflections. While looking through a crystal of Iceland spar calcite in his Paris apartment, he noticed variations in the sunlight reflected from windows in the *Palais du Luxembourg* across the street when he rotated the crystal. This observation, often considered as the discovery of light polarization, laid the basis for our Polaroid glasses. Indeed, the most common use of Polaroid glasses is aimed at reducing annoying reflections.

To fully appreciate the issue, let us recall the behaviour of light when reflected from glass, or from water. The reflectance as a function of incident angle θ (the angle to the normal) is given here for convenience. The graph is for the case of glass, but is only marginally different in the water case. It shows the reflectance for the two polarizations parallel and perpendicular with respect to the plane of incidence. The dashed curve is the average, or the effective reflectance for non-polarized light.

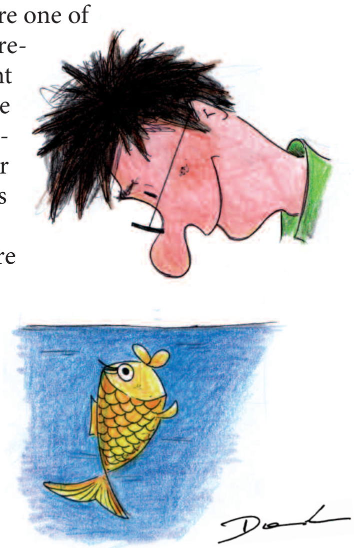


Before entering into a discussion of the two different polarizations, it is interesting to notice that for grazing incidence (θ = 90°) the reflectance becomes unity. Therefore, the image of the setting sun above a quiet lake appears just as bright as the sun itself, for example.

At the other end of the axis, for light incident along the surface normal, the reflectance is a few percent only: for glass having a refractive index n = 3/2 we find $(n-1)^2 / (n+1)^2 = (1/5)^2$ or 4%. For water with n = 4/3 we find even less: $(1/7)^2$ or 2 % only. Therefore, if we look straight into a pond, the reflection of our own face is really weak, and there is a fair chance that we can see the fish, provided that it is there and that the water is clear.

But we can do better than that by going to angles in between these two extremes and using Polaroid glasses. Obviously, our best choice is Brewster's angle, where one of the two polarizations has zero reflectance, such that the reflected light is completely polarized. It is the angle whose tangent is the index of refraction: θ = 56° for glass and 53° for water. Here our Polaroid glasses work perfectly.

So, if we want to make a picture of something behind glass, Brewster comes to our rescue, provided that we orient our Polaroid filter correctly. And, in the case of the pond: using Polaroid glasses we can completely get rid of the reflection of the sky. Use a bit of physics, and outsmart the fish.



Measurement of neutrino mass in double beta decay

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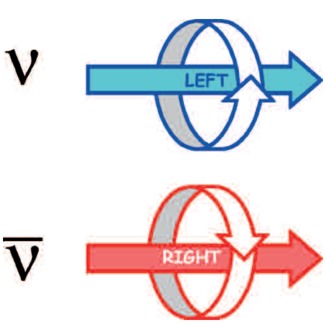
The long and exciting story of the neutrino started on December 4, 1930 with a famous letter " *Liebe Radioactive Damen un Herren*" addressed by Wolfang Pauli to a Conference on Radioactivity which took place in Tubingen (?). The reason of the absence of Pauli to this conference was an unusual one : "*Unfortunately I cannot be with you due to a ball that is going to take place in Zurich in the night between the 6 and 7 of January*".

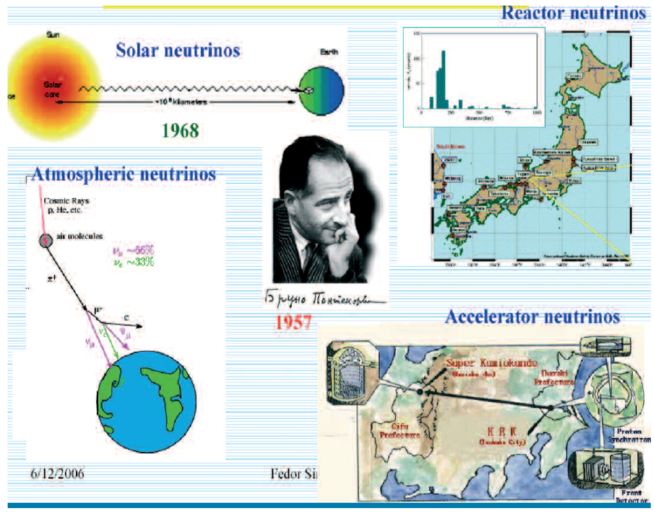
The problem in those days came from calorimetric measurements of the β decay of ^{210}Bi where the energy delivered in the process was found to be less than half that expected. Disregarding the unpalatable possibility of non-conservation of energy, Pauli postulated in this letter the emission of a neutral particle together with the electron in the decay and named it "*neutron*" (the real neutron had not yet been discovered!). Stimulated by a conference given by Pauli in Italy, Enrico Fermi investigated in depth the process, constructed the beautiful weak interaction theory and named this new particle *neutrino* (Italian for *little neutral one*).

Neutrino is therefore a "thief" of energy and as all good thieves is hard to discover: put in other way it interacts very weakly. In fact Pauli then declared: "*I did a terrible thing tonight: I invented a particle that experimental physicists will never be able to find*". Fortunately this pessimistic view was not true: in 1956 C.Cowan and F.Reines detected the interactions due to copious neutrino beams produced by the fission products in a nuclear reactor. This was the beginning of a series of exciting discoveries. It was first suggested and then proved that parity was violated in weak interactions and that the neutrino was spinning anticlockwise with respect to it sense of motion, while its antiparticle, the antineutrino, was spinning clockwise (Fig.1) . A few years later it was discovered that there were two different types of neutrino: the *electronic* one associated with beta decay and the *muonic* one associated with the *muon*, a particle similar to the electron, but with a mass about 200 times larger and unstable.

We now know that another type of neutrino exists : the *tauonic* one, associated with a third particle, the *tau*. All these particles, named *leptons*, form therefore three families made by the three charged leptons and their neutrinos. To the particles of each family correspond obviously their antiparticles (*antileptons*), whose lepton number is -1. The three families are identified by a new quantum number named *flavour* (*electronic, muonic or tauonic*). In the Standard Model of weak interactions this number is conserved. A very important event in fundamental physics has been the discovery in the last years of neutrino oscillations [1-4] which were first predicted almost fifty years ago by the great physicist Bruno Pontecorvo.



▲ **Fig. 1:** Chirality, namely the alignment of neutrino spin towards the sense of motion



▲ **Fig. 2:** The various experiments showing neutrino oscillations, as suggested by B.Pontecorvo (center)

Let us consider as an example the neutrinos produced by the fusion processes which take place in the central region of the Sun and which are the source of the great energy produced in this and in all other stars. The copious flux of these neutrinos, which are of the electronic type, is such that their interactions, even if indeed rare, can be revealed in a very massive detector placed underground to avoid the "noise" due to cosmic rays. A pioneering experiment carried out in the United States and further searches performed in Japan, Russia, in the Gran Sasso Laboratory in Italy and more recently in Canada have clearly shown the presence of these neutrinos, but with a flux definitely lower than the expected one. This is due to the fact that solar electronic neutrinos *oscillate* inside the Sun and in their long path toward the Earth transform themselves into neutrinos of muonic or tauonic flavours. As a consequence the flux of electronic neutrinos on the Earth is lower than predicted by the so called *Solar Model*.

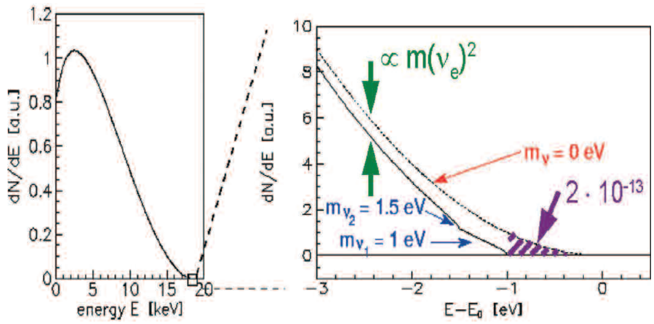
Neutrino oscillations have been confirmed with neutrinos produced by cosmic rays in the atmosphere, and artificially by particle accelerators and nuclear reactors (Fig.2). These oscillations, which obviously violate the conservation of the flavour number, can only occur if the difference of the squared masses of two neutrinos of different flavours is finite. This obviously means that at least one neutrino has a mass different from zero, but neutrino oscillations are unable to determine its absolute value.

The problem of the neutrino mass is crucial in fundamental physics: if it is finite the neutrino can propagate with a velocity lower that the velocity of light and the alignment of its spin (Fig.1) with respect to the direction of motion would be less than 100 % etc. Another consequence would be that the total lepton number is likely to be violated and that there is not an absolute distinction between a neutrino and an antineutrino. This possibility had been suggested in 1937 by the great physicist Ettore Majorana.

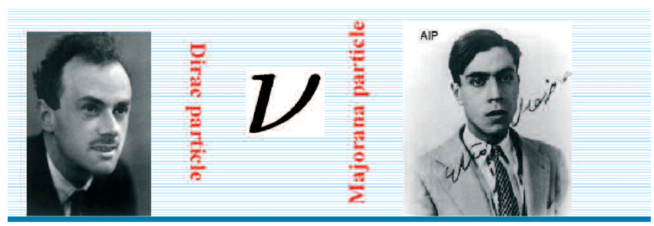
The most direct method to determine the mass of the neutrino [4,5] is the study of the deformation at the end point of the spectrum of the electron in single beta decay (Fig.3). No evidence for a finite neutrino mass has been obtained, but the present upper limits of about 2 eV are still far from what is suggested by neutrino oscillations. A new experiment carried out, as most of the previous ones, on the decay of tritium is being designed in Germany and aims to reach a sensitivity of 0.2 eV.

A more powerful, but model dependent, method to determine the mass of the neutrino comes from cosmology. Our Universe is presently embedded in a "sea" of photons decoupled from matter about 400 000 years after the Big Bang. It is the so called cosmic microwave background (CMB) . We are also embedded in a sea of relic neutrinos decoupled much before, about a second after the big bang. The mass of these neutrinos would modify the distribution in space of the CMB. Recent measurements on this CMB background have set an upper limit on the neutrino masses slightly lower that that obtained in the direct measurements mentioned before, but are still far from values predicted by oscillations.

A third method to determine the effective neutrino mass is connected to a fundamental puzzle in neutrino physics: is the neutrino a Dirac or a Majorana particle (Fig.4). In the former hypothesis the neutrino would be totally different from the antineutrino, its chirality, namely the property shown in Fig.1, would be 100% and its mass most likely null. In the latter case, based on a brilliant theory suggested in 1937 by Ettore Majorana, the neutrino would not be distinct from its antiparticle, its mass finite and the lepton number would be violated. The most powerful method to investigate lepton number conservation is double beta decay (DBD), a rare nuclear process suggested by Maria Goeppert Mayer [3] in 1935, only one year after the Fermi weak interaction theory. This process (Fig.5) consists in the direct transition from a nucleus (A,Z) to its isobar (A,Z+2) and can be investigated when the single beta decay of (A,Z) to (A,Z+1) is energetically forbidden or at least strongly hindered. The decay can occur in three channels



▲ **Fig. 3:** Deformation of the beta decay spectrum due to the neutrino mass



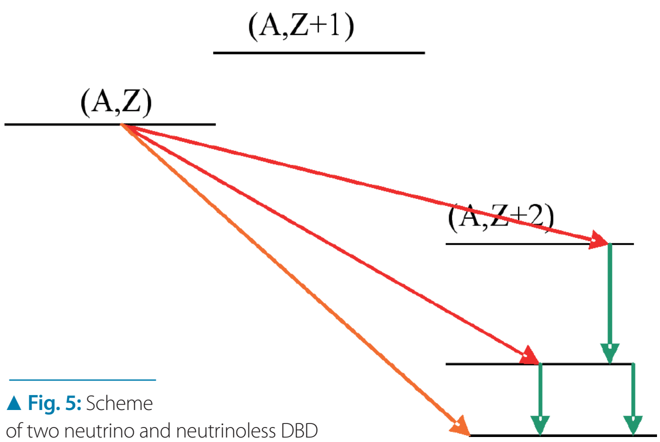
▲ **Fig. 4:** Dirac and Majorana

$$(A,Z+2) \rightarrow (A,Z+2) + 2\,e^- + 2\bar{\nu} \quad (1)$$
$$(A,Z+2) \rightarrow (A,Z+2) + 2\,e^- + (1,2\ldots\,\nu) \quad (2)$$
$$(A,Z+2) \rightarrow (A,Z+2) + 2\,e^- \quad (3)$$

In the first channel two antineutrinos are emitted. This process does not violate the lepton number, it is allowed by the Standard Model, and has been found in ten nuclei. We will not consider the second channel which violates the lepton number with the emission of one or more massless Goldstone particles named "Majoron". Our interest will be devoted to the third process which is normally called *neutrinoless* DBD, even if also no neutrino is emitted in process (2). This process would strongly dominate the two neutrino channel if lepton number •••

Nucleus	Experiment	%	$Q_{\beta\beta}$	Enrich. (%)	Technique	$T_{0\nu}$	$<m_\nu>$ (eV)
^{48}Ca	Elegant IV	0.19	4271		Scintillation	$>1.4\times10^{22}$	7-45
^{76}Ge	Heidelb-Moscow	7.8	2039	87	Ionization	$>1.9\times10^{25}$	0.12-1
^{76}Ge	IGEX	7.8	2039	87	Ionization	$>1.6\times10^{25}$	0.14-1.2
^{76}Ge	Klapdor *et al*	7.8	2039	87	Ionization	1.2×10^{25}	0.44
^{82}Se	NEMO 3	9.2	2995	97	Tracking	$>1.0\times10^{23}$	1.8-4.9
^{100}Mo	NEMO 3	9.6	3034	95-99	Tracking	$>4.6\times10^{23}$	0.7-2.8
^{116}Cd	Solotvina	7.5	3034	83	Scintillation	$>1.7\times10^{23}$	1.7- ?
^{128}Te	Bernatoviz *et al*	34	867		Geochemical	$>7.7\times10^{24}$	0.1-4.
^{130}Te	CUORICINO	33.8	2529		Bolometric	$>3.0\times10^{24}$	0.16-0.84
^{136}Xe	DAMA	8.9	2476	69	Scintillation	$>1.2\times10^{24}$	1.1-2.9
^{150}Nd	Irvine	5.6	3367	91	Tracking	$>1.2\times10^{21}$	3- ?

▶ **Table 1:** Present results on neutrinoless DBD and limits on neutrino mass (eV).



▲ **Fig. 5:** Scheme of two neutrino and neutrinoless DBD

··· is violated. From the experimental point of view, in neutrinoless DBD the two electrons would share the total transition energy since the energy of the nuclear recoil is negligible. A peak would therefore appear in the spectrum of the sum of the two electron energies in contrast with the wide bump expected, and already found, for the two neutrino DBD (Fig.6). The presence of neutrinoless DBD almost naturally implies that a term $\langle m_\nu \rangle$ called the "effective neutrino mass" is different from zero.

DBD is a very rare process both in the case of the two neutrino and of the neutrinoless mode. In the latter process its rate would be proportional to a phase space term, to the square of the nuclear matrix element and to the square of the above-mentioned term $\langle m_\nu \rangle$. While the phase space term can be easily calculated, this is not true for the nuclear matrix element whose evaluation is a source of sometimes excited debates. The calculated values could vary by factors up to two. As a consequence the discovery of neutrinoless DBD should be made on two or more different nuclei. From the experimental point of view there is an even more compelling reason to do that. In a common spectrum many peaks appear due to radioactive contaminations and many of them can hardly be attributed to a clear origin. It is not possible therefore to exclude the possibility that a peak in the region of neutrinoless DBD could be mimicked by some unknown radioactive event. Investigation of spectra obtained from different nuclear candidates where the neutrinoless DBD peak is expected in different regions would definitely prove the existence of this important phenomenon.

The value of $\langle m_\nu \rangle$ and therefore the rate of neutrinoless DBD is correlated to properties of oscillations As shown in Fig.6 values of a few tens of units or units of meV are expected in the case of the two different ordering of neutrino masses, named "inverted" and "normal" hierarchy, respectively.

Experimental approach

Two different experimental approaches are adopted in the search for DBD [6-9]: the indirect and the direct one.

Indirect experiments

The most common indirect approach is the geochemical one. It consists in the isotopic analysis of a rock containing a relevant percentage of the nucleus (A,Z) to search for an abnormal isotopic abundance of the nucleus (A,Z+2) produced by DBD. This method was very successful in the first searches for DBD and led to its discovery in various nuclei, but could not discriminate between the various DBD modes (two neutrino or neutrinoless decay, decays to excited levels, etc.). The same is true for the *radiochemical* methods that consist in storing for a long time large masses of DBD candidates (*e.g.* ^{238}U) and in searching later for the presence of a radioactive product (*e.g.* ^{238}Th) due to DBD.

Direct experiments

Direct experiments are based on two different approaches (Fig.7). In the *calorimetric* one the detector itself is made of a material containing the DBD candidate nucleus (*e.g.* ^{76}Ge in a Germanium semiconductor detector or ^{136}Xe in a Xenon TPC, scintillator or ionization detector). In the *source ≠ detector* approach, sheets of the DBD source are interleaved with suitable detectors of ionizing particles. A weak magnetic field could also be present to eliminate various sources of background. Thin sheets have to be used to optimize the resolution in the measurement of the sum of the two electron energies.

Thermal detectors

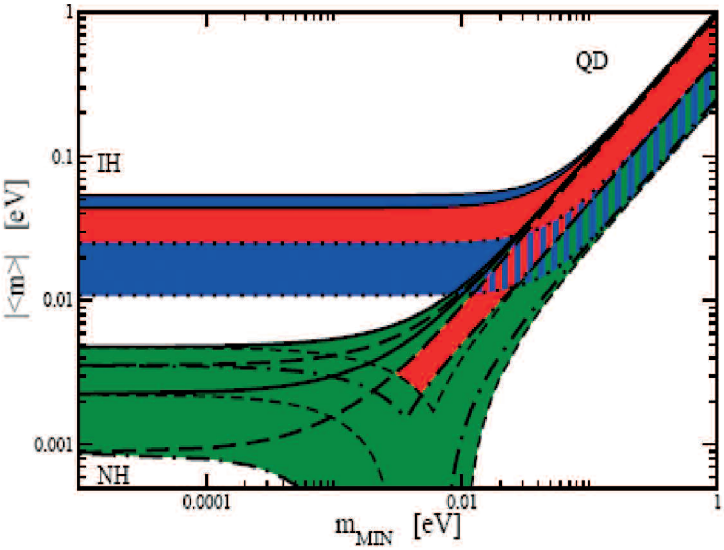
A new approach [10-13] based on the direct detection of DBD is the use of thermal or cryogenic detectors, widely adopted also in searches for Dark Matter particles and for direct measurement of the neutrino mass in single beta decay. An *absorber* is made by a crystal, possibly of diamagnetic and dielectric type, kept at low temperature where its heat capacity is proportional to the cube of the ratio between the operating and the Debye temperatures. As a consequence, in a cryogenic set-up such as a dilution refrigerator, this heat capacity could become so low that the increase of temperature due to the energy released by

Name		%	$Q_{\beta\beta}$	% E	B c/y	T (year)	Tech	<m>
CUORE	^{130}Te	34	2533	90	3.5	$1.8x10^{27}$	Bolometric	9-57
GERDA	^{76}Ge	7.8	2039	90	3.85	$2x10^{27}$	Ionisation	29-94
Majorana	^{76}Ge	7.8	2039	90	.6	$4x10^{27}$	Ionisation	21-67
GENIUS	^{76}Ge	7.8	2039	90	.4	$1x10^{28}$	Ionisation	13-42
Supernemo	^{82}Se	8.7	2995	90	1	210^{26}	Tracking	54-167
EXO	^{136}Xe	8.9	2476	65	.55	$1.3x10^{28}$	Tracking	12-31
Moon-3	^{100}Mo	9.6	3034	85	3.8	$1.7x10^{27}$	Tracking	13-48
DCBA-2	^{150}Nd	5.6	3367	80		$1x10^{26}$	Tracking	16-22
Candles	^{48}Ca	.19	4271	-	.35	$3x10^{27}$	Scintillation	29-54
CARVEL	^{48}Ca	.19	4271	-		$3x10^{27}$	Scintillation	50-94
GSO	^{160}Gd	22	1730	-	200	$1x10^{26}$	Scintillation	65-?
COBRA	^{115}Cd	7.5	2805				Ionisation	
SNOLAB+	^{150}Nd	5.6	3367				Scintillation	

◄ **Table 2:** Future experiments on Double Beta Decay

▼ **Table 3:** Possible thermal candidates for neutrinoless DBD

Compound	Isotopic abundance	Transition energy (Kev)
$^{48}CaF_2$	.0187 %	4272
^{76}Ge	7.44 %	2038,7
$^{100}CaPbO_4$	9.63 %	3034
$^{116}CdWO_4$	7.49 %	2804
$^{130}TeO_2$	34 %	2528
$^{150}NdF_3$	5.64 %	3368
$^{150}NdGaO_3$		



▲ **Fig. 6:** Effective neutrino mass expected in DBD experiments from neutrino oscillations. The upper and lower curves refer to the so called inverted and normal hierarchies.

a particle in the absorber can be detected and measured by means of a suitable thermal sensor. The resolution of these detectors, even if still in their infancy, is already excellent. In X-ray spectroscopy made with bolometers of a milligram or less the FWHM resolution can be as low as 3 eV, more than an order of magnitude better than in any other detector. In the energy region of neutrinoless DBD the resolution with absorbers of masses up to a kg is comparable with or better than that of Ge diodes.

Present results and future experiments

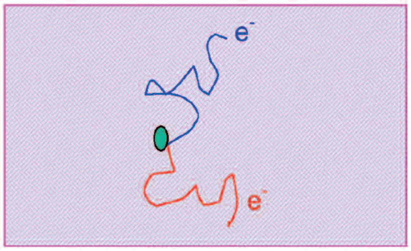
Present results

The present results [6-9] on neutrinoless DBD are reported in Table 1 with the corresponding limits on neutrino mass, where the large uncertainties on nuclear matrix elements are taken into account. It can be seen that so far no experimental group has indicated the existence of neutrinoless DBD, with the exception of a subset of the Heidelberg-Moscow collaboration led by H.Klapdor-Kleingrothaus who claim the existence of this process in ^{76}Ge. This evidence is still widely debated in the international arena.

NEMO 3 and CUORICINO

Two experiments are presently running with a sensitivity on neutrino mass comparable to the evidence reported by H.Klapdor-Klingrothaus *et al*: NEMO 3 and CUORICINO.

NEMO 3: this is a source ≠ detector experiment (Fig.8) presently running in a Laboratory situated in the Frejus tunnel between France and Italy at a depth of ~3800 meters of water equivalent (m.w.e). This experiment has yielded extremely good results on two neutrinos DBD of various nuclei. The limits on the neutrinoless channel of ^{100}Mo and ^{82}Se (Table 1) are already approaching the value of neutrino mass presented as evidence by Klapdor *et al.*



CUORICINO: this is at present the most sensitive neutrinoless DBD experiment running. It operates in the Laboratori Nazionali del Gran Sasso under a overburden of rock of ~3500 m.w.e. (Fig 9). It consists of a column of 62 crystals of natural TeO_2 to search for the neutrinoless DBD of ^{130}Te. Its mass of 40.7 kg is more than an order of magnitude larger than in any other cryogenic set-up. No evidence is found for a peak in the region of neutrinoless DBD setting a 90% lower limit of 3 x 10^{24} years on the lifetime of the neutrinoless DBD of ^{130}Te. The corresponding upper limit on $<m_\nu>$ (0.16-0.9 eV) almost entirely covers the span of evidence coming from the claim of H.Klapdor-Kleingrothaus *et al.* (0.1-0.9 eV).

Future experiments

A list of proposed future experiments [5-9] is reported in Table 2 with the techniques adopted and the expected background and sensitivity. Only two of them have been approved and partially funded: GERDA and CUORE. These and a few others will be briefly described here.

GERDA and Majorana: Both these experiments are based on the "classical" detection of neutrinoless DBD of ^{76}Ge in a calorimetric approach with Germanium diodes. They are logical continuations of the Heidelberg-Moscow and IGEX experiments, respectively. GERDA, already approved in its preliminary version, is going to be mounted in the Gran Sasso Underground Laboratory. An intense R&D activity is being carried out by the Majorana collaboration in connection with the installation of this experiment. Its underground location has not yet been decided.

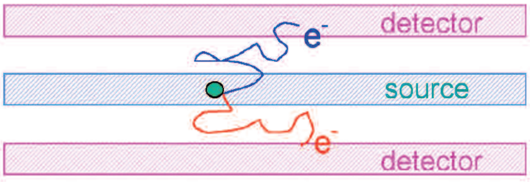
MOON, based on the source ≠ detector approach to search for neutrinoless DBD of ^{100}Mo, is to be installed in the Oto underground laboratory in Japan. The set-up will be constructed of thin sheets of enriched molybdenum interleaved with planes of scintillating fibres. The experiment is also intended to detect the low-threshold interactions of solar neutrinos on 100Mo leading to 100Rb.

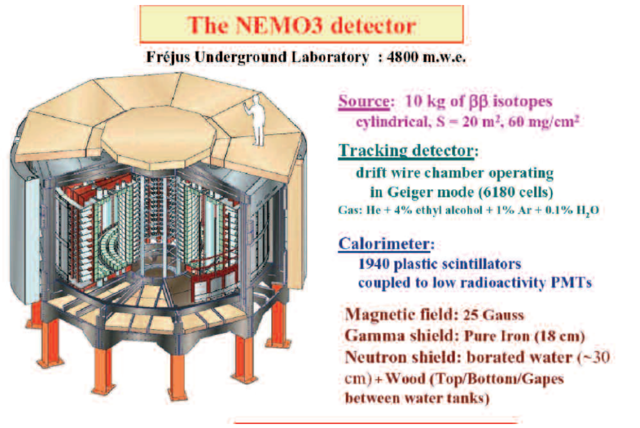
SUPERNEMO is also a source ≠ detector experiment, mainly intended to search for neutrinoless DBD of ^{82}Se, to be installed in an as yet undecided underground laboratory in Europe. The system is similar to the one adopted by NEMO 3, but with a considerably different geometry.

XENON is a scintillation-based experiment to be carried out in Japan with a large mass of enriched Xenon to search for neutrinoless DBD of ^{136}Xe. Due to the large mass it will also be used in a search for interactions of Dark Matter particles (WIMPS).

EXO is also intended to search for the neutrinoless DBD of ^{136}Xe-^{136}Ba, but with a totally new approach: to search for DBD events by detecting with the help of LASER beams single Ba++ ions produced by the process. The option of liquid or gaseous Xenon and the underground location has not yet been decided, •••

◀ **Fig. 7:** The two different approaches to direct search for DBD





▲ **Fig. 8:** NEMO 3

··· but a 100 kg litre liquid Xenon experiment without Ba tagging is going to operate soon in the WIPP underground laboratory in the USA.

CUORE (Cryogenic Underground Observatory of Rare Events) is the only second generation experiment approved so far. The set-up will consist of 988 crystals of natural TeO_2 arranged in 19 columns, practically identical to that of CUORICINO, but with a total mass of about 750 kg. The experiment has already been approved by the Scientific Committee of the Gran Sasso Laboratory, by the Italian Institute of Nuclear Physics and by DOE. The basement for its installation has been prepared in Gran Sasso (Fig.9). As shown in Table 3, ^{130}Te has been chosen for CUORE due to its high isotopic abundance, but the versatility of thermal detectors will allow many other interesting, but expensive, double-beta active materials to be studied.

Conclusions

After 70 year the brilliant hypothesis of Ettore Majorana is still valid and is strongly supported by the discovery of neutrino oscillations, which implies that the difference between the squared masses of two neutrinos of different flavours is different from zero. As a consequence at least one of the neutrinos has to be massive and the measurement of the neutrino mass becomes imperative. Double 3 is a Majorana particle.

The future second generation experiments being designed, proposed and already in the case of CUORE under construction, will allow us in a few years to reach the sensitivity in the neutrino mass predicted by the results of oscillations in the inverse hierarchy scheme. ■

About the author

Ettore Fiorini is presently professor of Nuclear Physics at the University of Milano-Bicocca. His research activity in experimental nuclear, particle and astroparticle physics has been carried out with various techniques such as cloud and bubble chambers, solid state and thermal detectors. He is presently spokesman of the CUORE experiment.

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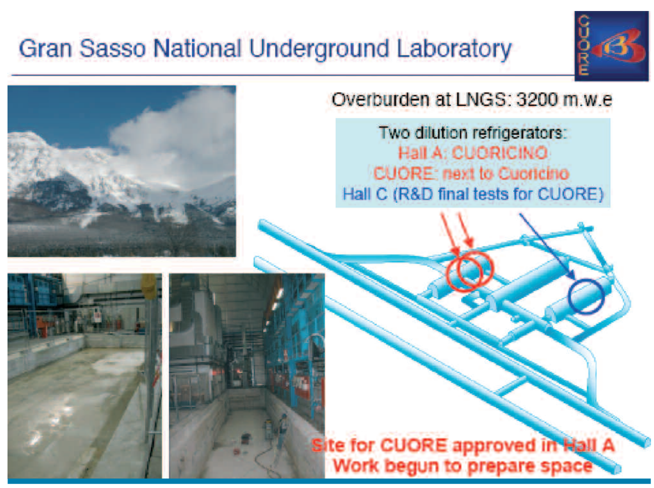

▲ **Fig. 9:** Location of CUORICINO and of R&D for CUORE in the Gran Sasso Laboratory