NEUTRINO CONFERENCE TURNS 50

$$\nu + p \rightarrow p + \mu + \pi$$

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In February 1972, in the break of a regional meeting of particle physicists held in Budapest *Herbert Pietschmann* (Vienna), *Jan Nilsson* (Göteborg) and *George Marx* (Budapest) discussed the subdued position of weak interactions at international conferences. *H. Pietschmann*: "For George Marx it was quite obvious that the neglect of neutrino physics at the big international conferences had to be neutralised by a dedicated international conference on neutrino physics. Instead of pushing some international committee, he took the idea in his own hands and organised a Europhysics neutrino conference in Hungary by himself."

The first Neutrino conference took place in Balatonfüred, Hungary June 11-17, 1972. One might just wonder how the organisers were able to invite successfully so many first class speakers and a bunch of enthusiastic young physicists on such short notice from both sides of the iron curtain. *L. M. Sehgal* (Aachen): "The Neutrino'72 Conference was the very first conference I attended and turned out to be an important event in my scientific life. There was a whole galaxy of famous people there - R. Feynman (Nobel Prize [NP] 1965), T. D. Lee (NP 1957), R. Marshak, V. Weisskopf, B. Pontecorvo, V. Telegdi, F. Reines (NP 1995), C. Cowan, R. Davis (NP 2002), J. Bahcall, B. Barish (NP 2017), D. Cline, C. Baltay and many others."

The solar neutrino problem fully recognised

Kenneth Lande (U. Pennsylvania) recalls: "The main focus at the first part of the meeting was the initial result from Ray Davis's chlorine based solar neutrino detector." Davis's initial result in 1968, based on two runs was ≤ 3 Solar Neutrino Unit (SNU). His new results based on six runs, presented at this conference, were a ^{37}Ar production rate of 0.18 ±0.10 per day. After subtraction of the estimated cosmic ray induced background, Davis gave an upper limit on the solar neutrino induced signal of 1 SNU[1].

John Bahcall then provided a clear and very detailed description of how the solar neutrino emission is determined including the dependence on the various parameters. His conclusion was that the lowest possible signal in the Davis detector was 5 – 9 SNUs. The "decrease factor" between Bahcall's predicted signal and Davis's observed signal was known as the "solar neutrino problem."

In his summary talk *Bruno Pontecorvo* took a rather conservative attitude: "the conclusion by Davis is that the Sun emits much less ^{8}B neutrinos than expected." Then he asked: "Is the discrepancy serious enough to force us to draw revolutionary conclusions about the Sun or about the neutrino properties? My opinion is: no." Since the ^{8}B neutrinos to which the reaction was dominantly sensitive represent a tiny part of the whole emission "the • • •

[1] As a reminder, a SNU is the integrated product of neutrino flux x cross section for the neutrino induced ^{37}Cl →^{37}Ar in units of 10^{-36} per second per ^{37}Cl target atom.

◂ First observation of a neutrino in a hydrogen bubble chamber, on 13 ovember 1970, at Argonne National Laboratory. Here a neutrino hits a proton in a hydrogen atom; the collision occurs at the point where three tracks emanate. The invisible neutrino comes from 'below' on the picture. In the collision a muon is created (the long track) and a pi-meson (the shorter track). The third short track is the proton.

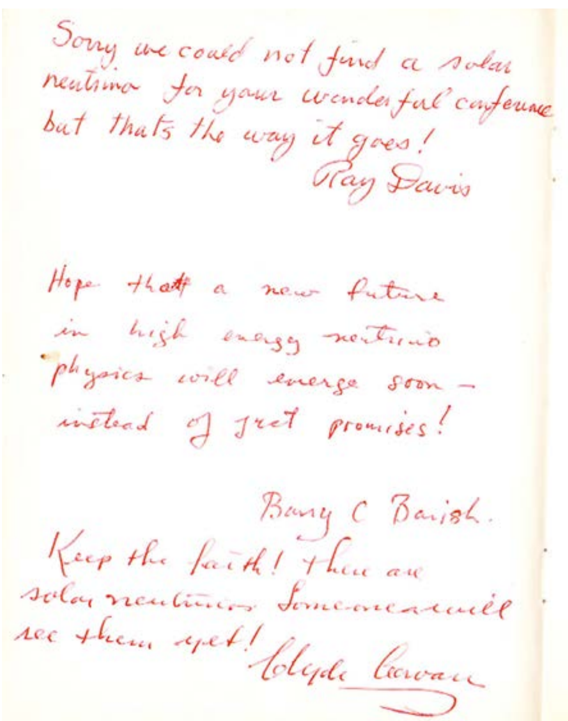
▾ **FIG. 1:** Seated, from left: T.D. Lee, L. Radicati, R.P. Feynman, B. Pontecorvo, G. Marx, V.F. Weisskopf, F. Reines, C. Cowan, P. Budini reactions leading to this emission are quite unimportant from the point of view of the structure of the Sun." Related to this reaction new parameters might be needed but irrespective to this "the Sun will nevertheless shine as before". His advice sounded: New detectors capable to observe pep neutrinos [generated in the reaction p + e + p → deuteron + neutrino] should be developed in the first place.

Only if these efforts would fail one could look for what Pontecorvo called "exotic" solutions. A few of them were presented in the sessions: pulsating Sun activity (Lande *et al.*), decaying neutrinos (Bahcall *et al.*), $\nu_e \leftrightarrow \nu_\mu$ oscillation (Gribov & Pontecorvo). He made two important remarks: a) with neutrino oscillations one can measure neutrino mass differences "several million times more sensitive than the ordinary ones for neutrino mass measurements"; b) "only with very sophisticated and remote experiments can the "decrease factor" become larger than 2." These remarks set out the strategic directions of neutrino physics for the last third of the 20th century. It took about 25 years until the problem of missing neutrino flux was clarified.

Constraining neutrino masses on an absolute scale was also discussed at the conference, emphasising their role in the cosmological evolution. *A. Szalay* (Johns Hopkins U.) recalls: "I was finishing my undergraduate dissertation on the cosmological effects of neutrino masses. This work was one of the first in what later became Neutrino Astrophysics. Today the best limits on the neutrino masses are still coming from astrophysics"

Neutrinos identify partons with quarks

The second half of the conference dealt with weak and electromagnetic interactions as tools in exploring the subnuclear structure of the proton and neutron. The starting point was the solidly established scaling behaviour of the form factors characterising deep inelastic electron-proton scattering. The talks by *T.D. Lee* and *R.P. Feynman* in the same morning session suggested two characteristically different approaches. Lee emphasised the importance of a Lorentz invariant quantum field theoretical approach. In his bound state model the masses of the constituents combined with the constant binding coupling necessarily break scaling for large enough energies. Feynman's strategy (in the interpretation of *Victor Weisskopf*) was: "Don't bother with field theory, we know so little about it. Let us apply simple concepts. At very high energies we can consider the hadron essentially as an assembly of free partons." This picture can be valid only in a reference system where the nucleon is moving very fast, but for Feynman apparently Lorentz invariance was not an issue.


Sorry we could not find a solar neutrino for your wonderful conference but that's the way it goes!
Ray Davis

Hope that a new future in high energy neutrino physics will emerge soon – instead of just promises!
Barry C Barish

Keep the faith! There are solar neutrinos. Someone will see them yet!
Clyde Cowan

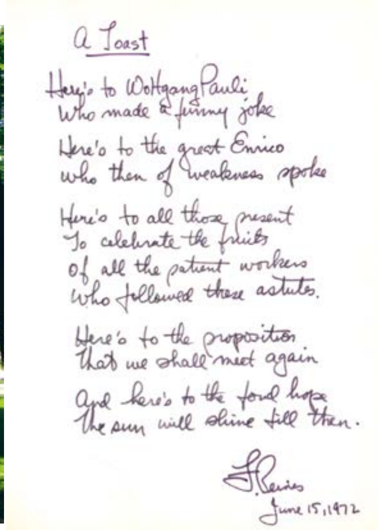
▸ **FIG. 2:** Solar neutrino puzzle as it has been told by R. Davis, B.C. Barish and C. Cowan in the guestbook of George Marx

One learns the prehistory of the talk of Feynman from a recollection of *J. Kuti* (U. of California San Diego), reviewing deep inelastic lepton-nucleon scattering at the conference: "Months before the conference, the phone was ringing at my MIT office. Dick Feynman called. He introduced the notion of partons in high-energy experiments a couple of years earlier but surprisingly did not take the last step in his famous PRL publications to identify the partons with quarks. He was very concerned that he did not have any new results. Shortly before the conference he called again. He knew now what he would talk about, identifying his partons with quarks and suggesting ways of nailing down their quantum numbers in new experiments."

The information on the subnuclear structure is encoded into a number of form factors, which in the framework of the parton model depend only on the momentum fraction carried by the partonic constituents. For instance one finds for the electron-deuteron case the scaling function f_2 as sum over the form factors of the proton and the neutron $f_2^{ep}+f_2^{en}$. When partons are identified with quarks this becomes a sum over the densities of the u, d, s quarks and their antiquarks weighted by the squares of the respective electric charges. Feynman has derived for the related form factor $f_2^{\nu p}+f_2^{anti\text{-}\nu p}$ measured in (anti)neutrino-proton scattering another simple expression. Assuming the density of the strange quark (s) negligible one finds for the ratio $(f_2^{\nu p}+f_2^{anti\text{-}\nu p})/(f_2^{ep}+f_2^{en})$ the prediction 18/5.

This result generated extreme excitement as *F. Ravndal* (Oslo Univ.), a postdoc working that time with Feynman has recalled: "During that term Feynman went to Hungary to take part in a neutrino conference at Balatonfüred. He came back fired up with the first quantitative experimental confirmation of the parton model and the fractional quark charges. This was the measurement of the famous factor of 5/18."

Another simple consequence of the quark-parton identification was a prediction for the ratio of the total cross section of neutrino to that of anti-neutrino nucleon scattering. The proposed value of 1/3 was close to the



A Toast

Here's to Wolfgang Pauli
Who made a funny joke
Here's to the great Enrico
who then of weakness spoke
Here's to all those present
To celebrate the fruits
of all the patient workers
who followed these astutes.
Here's to the proposition
That we shall meet again
And here's to the fond hope
The sun will shine till then.

F. Reines
June 15, 1972

FIG. 3: 13th of June 1972, R. Feynman and B. Pontecorvo planting (photo by D. Rein). June 2021: the memorial trees of the first international Neutrino Conference (photo by A. Patkós)

result communicated to the conference by the Gargamelle group. For subsequent developments Kuti refers also to spin polarised deep inelastic experiments: "A few years later Vernon Hughes's experiment succeeded by measuring the deep spin-polarization distribution of quarks inside the nucleon with the experimental confirmation of an important theoretical sum rule James Bjorken established earlier."

An East-West bridge over the Balaton

For the future of the conference the local political ambiance and collegial confidence proved important. *D. Rein* (Aachen): "Apart from the somewhat depressing entrance procedures at the Hungarian border (we were amidst the cold war) I felt free and enjoyed the warm and friendly reception of the organisers and the people around. There was a smell of political tolerance and personal independence in the air, presumably mostly due to George Marx." The atmosphere has encouraged informal contacts between Soviet and US scientists. K. Lande: "George Marx offered to arrange a lunch at which our group could discuss future possibilities with our Soviet counterparts. Thus, Ray Davis, Fred Reines, John Bahcall and I met with Aleksandr Chudakov, Vadim Kuzmin, Aleksandr Pomanski and Bruno Pontecorvo. What we learned was that they were excavating, a single-ended tunnel into the side of a steep mountain of the Caucasus range. As a result of the Neutrino '72 Conference Ray Davis and I decided to try to develop the technology for a gallium solar neutrino detector. These became the basis of the SAGE (Baksan) and GALLEX (Gran Sasso) solar neutrino detectors."

A highlight happened on the Tagore Alley near the Lake Balaton. *Z. Kunszt* (ETH Zurich): "In the Alley this was Rabindranath Tagore the famous Indian poet who has planted the first tree (NP 1913). Later the Italian poet Salvatore Quasimodo also planted a tree (NP 1953). The tradition that if a Nobel-Prize laureate visits Balatonfüred he or she ought to plant a tree follows the idea of Marx. He suggested that Feynman as Nobel-prize holder should also plant a tree. But one had to have balance between East and West, so Bruno Pontecorvo has been asked to plant a tree."

The President of the International Neutrino Committee, S. Parke (Fermilab) could proudly state: "In June of 2022, the 50th anniversary of Neutrino '72, thirty such Neutrino Conferences will have been held in locations in Europe, North America and Asia/Oceania. George Marx, as founder of this series, presided over the first twenty of these meetings. The 50th anniversary meeting, Neutrino 2022 is to be held in Seoul, South Korea. Neutrino 2030 will celebrate the 100th anniversary of Wolfgang Pauli's hypothesis that there exists a light neutral lepton, the neutrino. The International Conference on Neutrino Physics and Astrophysics Series has become the premier international neutrino conference where diversity, inclusiveness and transparency are recognised as of essential importance for great discoveries." ■

About the Author

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References

The proceedings of *Neutrino '72* have been digitized and are available at https://zenodo.org/communities/neutrino-72/?page=1&size=20

The full text of the recollections quoted in the text was published in the March special issue of Fizikai Szemle (Hungarian Physical Review), the monthly journal of the Roland Eötvös Physical Society and is also accessible at the above link.