EUROGAM

and Beyond

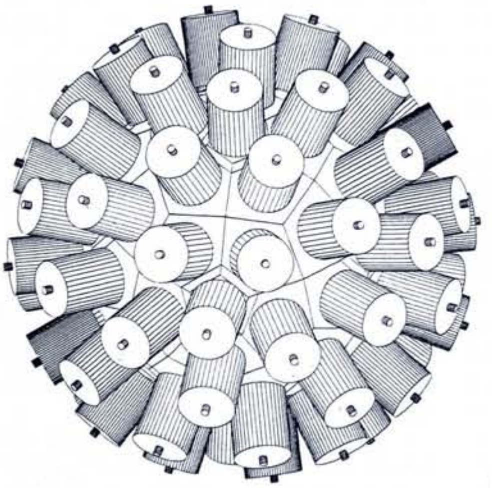
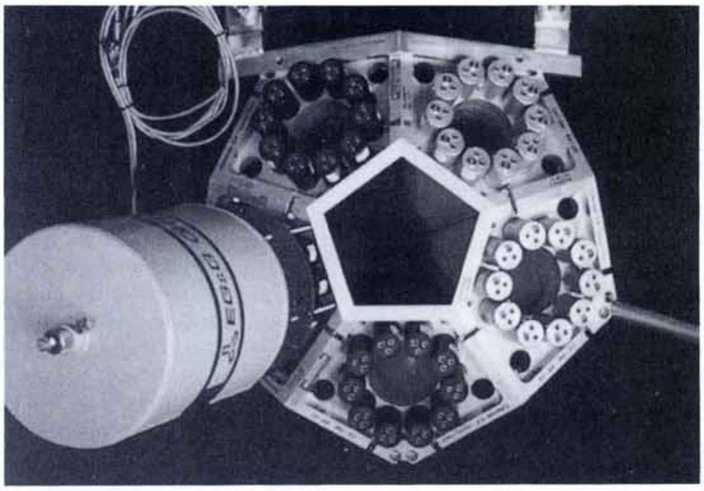


Fig. 1 — A schematic of the EUROGAM detector array for the γ-ray spectroscopy of highly deformed nuclei.



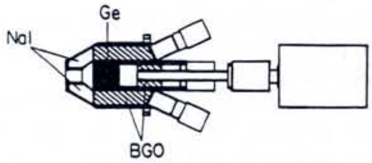


Fig. 2 — A prototype of one of the 12 pentagons (1 m large) that make up the EUROGAM array. Shown is the outer surface with five irregular pentagons and one regular pentagon at the centre. A ring of 10 photomultiplier tubes is mounted on a bismuth germinate (BGO) shield in each of five of the pentagons. The pentagon on the bottom left is hidden by the dewar of a Ge detector, a cross-section of which (to the left) illustrates the coaxial detector with its large Ge crystal and a shield of very dense BGO scintillator. Escape suppression of Compton scattering is achieved by using only those signals from the Ge detector which are not in coincidence with any escaping radiation picked up by the BGO shield, thus enabling the selection of those events where a γ-ray from the target looses all its energy in the Ge.

The European Gamma Ray Microscope (EUROGAM) is not only intended to lead the way in a new generation of spectrometers for nuclear structure studies but also represents the first major ambulatory device of its type. The detector has its roots in the GAMIC spectrometer designed by Daresbury Laboratory which, with the signature of the French-UK (CNRS-SERC) agreement on 28 February 1991, officially became the EUROGAM project with a budget 50 MFF. The agreement is for four years and envisages two phases: the first effectively began in late 1989 and involves the commissioning in the UK of a 45 element detector array with a high efficiency for suppressing Compton background radiation. It is planned to start experiments in early 1992 using Daresbury's 20 MV Tandem Van de Graff so proposals for experiments will be called for in September 1991 and evaluated by a recently constituted international committee.

The geometry of EUROGAM (Fig. 1) is based on a dodecahedron shape consisting of 12 pentagons surrounding the target or source of γ-rays. The pentagons are split into five irregular pentagons and one regular pentagon, each with a Ge detector and a surrounding BGO shield with 10 photomultiplier tubes for suppressing Compton background radiation (Fig. 2). Regular pentagons are left out to provide passages for the incoming and outgoing heavy ion beam so there will be a total of 70 detectors in the final assembly.

The best response is obtained by making each Ge detector as large as possible and surrounding it with a BGO suppression shield. The design thus aims to accommodate large Ge detectors and to make efficient use of the BGO by sharing it between neighbouring Ge detectors. The first phase of EUROGAM will use the largest coaxial Ge detectors that are available (75 mm in diameter and 85 mm in length) so, with their BGO shields, they will have a photopeak efficiency twice as high as the Ge detectors used in the first generation of 4π γ-ray spectrometers (OSIRIS, Château de Cristal, TESSA-3, NORDBALL).

EUROGAM Phase 2

Phase 2 starts in January 1993 when EUROGAM is transferred to CERN Strasbourg in France, where experiments will continue using the new 35 MV Vivatron accelerator. An improved energy resolution and a two-fold increase in γ coincidence measurement will be achieved by keeping 30 of the Phase 1 detectors, and by installing 30 to 48 detector modules of a new type (a clover leaf shaped cluster of four Ge detectors being developed in France) in a configuration with a high granulometry (see below) at scattering angles of around 90°. Phase 2 will thus allow the measurement of very low intensity γ-ray transitions where a high coincidence level *n* is needed (the aim is 6-fold events, up from 4-fold in Phase 1 and 2-fold today).

The optimization of EUROGAM is thus being accompanied by developments in several technical fields (highly efficient Ge detectors, integrated electronics based on hybrid, SMD and VLSI circuits, and the new VXI standard, data analysis using, for example, workstations). Increasing the number of detectors will provide a very significant increase in the array efficiency in order to measure the multipolarity of γ-ray transitions with very low intensity levels.

The construction of EUROGAM, along with the scientific preparation for the first experiments, are greatly enhanced by the complementary strengths of the cooperation without loosing the potential for an even larger European collaboration in some future project such as EUROBALL (see below). Some 80 scientists split between six French centres and three British laboratories participate, with lively interchange between the two countries. Several Greek scientists have been closely associated with Phase 1 and a number of other European groups have indicated their intention to participate in Phase 2.

EUROBALL

The EUROBALL collaboration was formed with the aim of ensuring that the next generation of multi-detector γ-ray spectrometers can be constructed in Europe and become available to the whole γ-ray spectroscopy community. The EUROBALL Steering Committee recommends that to achieve this goal the EUROBALL array will be modular in design and use the EUROGAM frame to ensure that both currently available and advanced detectors can be incorporated. Mobility is an essential feature as the concept is to continue developing more efficient detector modules at several centres, and to have EUROBALL

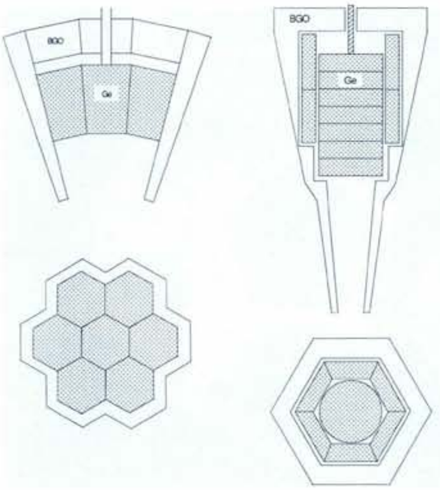


Fig. 3 — Cross-sections through advanced composite detectors. a, left) CLUSTER with seven tapered, vacuum canned Ge detector crystals and a common BGO suppression shield. b, right) Stacked configuration.

move between sites offering complementary beams and facilities so that different experiments could be set up.

Composite Detectors

The most important parameter of a γ-ray detection system is the total photopeak detection efficiency P_T which must be maximized at the same time as the energy resolution and detector response. The inherent energy resolution of a Ge detector can only be approached if the Doppler shift is minimized by having a small solid angle for each detector (*i.e.* a high granularity), a quality which is also needed to reduce multiple hits in events of large multiplicity M arising in studies of superdeformed nuclei. To maximize P_T, the total solid angle ω of the Ge detectors should approach 4π and each Ge detector must have the largest possible photopeak efficiency P_1. To avoid pile-up effects due to high γ multiplicity, a rule of thumb is that the optimum number of detector modules made from large Ge crystals should be about $2M$.

The ideal Ge detector has been calculated to have a 10 times larger volume than is currently available. A way to approach this is to pack several detectors to form a composite (Fig. 3), the basic idea being to increase P_1 by summing signals from neighbouring Ge crystals. Instead of the classical coaxial Ge detector module for nuclear structure studies comprising a large Ge crystal surrounded by a BGO scintillator shield (Fig. 2), the Phase 2 upgrade of EUROGAM as well as an eventual EUROBALL project will therefore exploit composite detector modules.

Of the various composite detectors (*e.g.* clover, stacked, cluster, *etc.* — Fig. 3), a clover prototype is at the most advanced stage of development. Meanwhile, a German team is developing a CLUSTER module consisting of seven, vacuum canned, hexagonal, tapered Ge detectors surrounded by a common BGO suppression shield. It has the same energy and time resolution as the classical coaxial and EUROGAM Phase 1 clover modules, but the increase in ω would result in an approximately two-fold increase in P_1 for CLUSTER relative to the clover module.

Replacing the Phase 1 Ge detectors with CLUSTER detectors in the standardized EUROGAM detector configuration with its close to 70 detector modules is estimated to raise P_T, the total photopeak efficiency for the array, to $\approx$ 17% (for a γ-ray energy of 1 MeV with $M = 30$) from 0.65, 5.2 and 9.8% for the present generation, EUROGAM Phase 1 and EUROGAM Phase 2 arrays, respectively. The actual performance improvement would be even larger as it scales as P_T^n.

The EUROBALL Working Committee has proposed a first step involving a 1π solid angle using 15 CLUSTER detectors at backward scattering angles (EUROCLUSTER) for work with relativistic heavy ions. This arrangement would give $P_T \approx$ 6% for events of small multiplicity but with a much higher granularity than is needed in superdeformed nucleus studies to handle the large recoil velocities. An alternative that is being explored is to take the German-developed cluster detectors to EUROGAM at Strasbourg.

A next step could then be to fill the remaining faces with the best of Europe's available detectors, which could come from any of the present generation of spectrometers (EUROGAM; GASP — a 45 detector array with $P_T \approx$ 4% under construction at INFN, Legnaro, Italy for superdeformed nucleus studies; and DECA — a 10 detector array with $P_T \approx$ 2% under construction at GSI Darmstadt, Germany for high recoil velocity experiments). The outcome would be a 4π spectrometer with a significantly better performance ($P_T \approx$ 12% at $M = 30$ for a 1 MeV γ-ray energy) than the American GAMMASPHERE ($P_T \approx$ 10.5%), funding for which was approved last September. By allowing the measurement of high-energy γ-rays (P_T at 12 MeV would be roughly the same as today's efficiency for 1 MeV), the aim would be to extend γ-ray spectroscopy to the light nuclei where full-shell calculations are possible.

Aligning Science and Religion

Professor Sir Neville Mott, an Honourary Member of EPS, is well known as an outstanding British, European and international solid state physicist, as a Nobel Laureate and beyond this as a remarkable person with authority in the fields of education, weapons control and several other aspects of public life. He has presented the religious quintessence of "a life in science" in a book by the same title [Mott N., *A Life of Science* (Taylor & Francis, London) 1986] which is highly relevant to other scientists in this century.

"Not brought up in any religious faith" and involved in a brilliant career in science, he "had little interest in religion until the age of about 50" when he was invited in 1957 to give a lecture in the Cambridge University church on "Religion and the Scientist". He prepared it so carefully and convincingly, that he was to concern himself more and more with the topic in lectures, study groups and publications. He now plays "a considerable part in the life of the local church", accepted as a critical believer in the village to which he retired.

His latest book *"Why Scientists Believe?"* [Ed.: Mott N., (James & James, London) 1990] arose from a friend's casual request that developed into a series of invited essays by colleagues and other leading scientists. The book has generated considerable interest throughout Europe, including public debates and the possibility of a translation to German. He himself wrote on miracles, which he calls "part of the culture of the 1st century", as they represent his own personal "stumbling block". Professor Siegfried Methfessel from Bochum, Germany, a friend and himself an eminent physicist, summarizes the book's main themes.

Sir Neville Mott

Can Scientists Believe?

The western world entered the 20th century with the proud faith that science has an unlimited capability to reduce everything, even religion, to chemistry, physics and, finally, to the motions of atoms and electrons, which can, in principle, be controlled through, and predicted by, mathematical equations. At best, a few as yet unexplained areas, rapidly decreasing in number, were reserved for a "God of the Gap" [1, 8]. Now, towards the end of this century, we have learned painfully that science and rational arguments are not remedies for everything; that the