

Preparing the Gargamelle bubble chamber at CERN in 1969. In 1973 the chamber took the first historic photographs of neutral current interactions.

(Photo CERN 409.9.69)

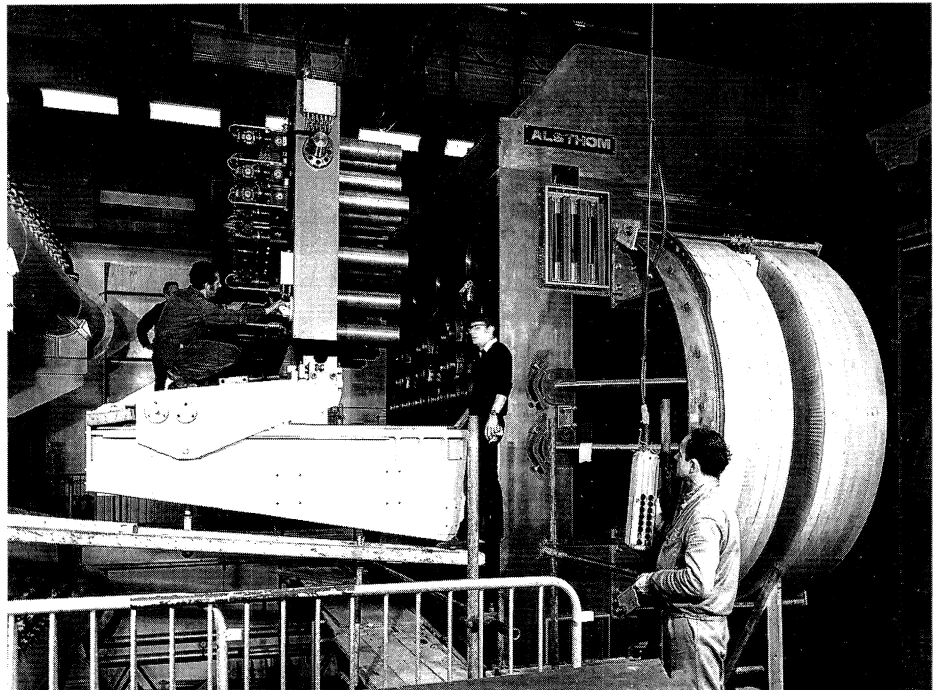
Neutrino book

Gargamelle and Neutral Currents - The Story of a Vital Discovery
by André Rousset

André Rousset's book (in French - *Gargamelle et les Courants Neutres* - Ecole des Mines de Paris) tells the story of Gargamelle and the discovery at CERN in 1973 of neutral currents, the cornerstone of the electroweak theory. This vital discovery helped to give credence to the Standard Model of particle physics.

Rousset is both an observer and one of the key figures in the story. His book is lively and well documented; in it he uses archive material to ensure the accuracy of his information on dates, choices and decisions.

After an introduction to particle physics which puts into perspective the electroweak theory unifying weak and electromagnetic interactions, Rousset comes straight to the point. From the late 1950s onwards he was involved in the construction of the first heavy liquid bubble chambers by the BP1, BP2 and BP3 teams at the Ecole Polytechnique in Paris. For Gargamelle a bigger laboratory was needed, and it was at the CEA (French Atomic Energy Commission) in Saclay that the chamber was designed by teams from the Saturne accelerator and the Ecole Polytechnique. However, the decision to build Gargamelle was taken in 1965 through the impetus of André Lagarrigue, in defiance of the normal CERN procedures. Gargamelle was then in competition with the other big bubble chamber project, BEBC; was it really necessary to build two big chambers? The decision by Francis Perrin and the CEA to contribute "gener-



ously" to the project was probably what swung the decision.

Construction took five years, during which many problems were encountered, right up to the fault in the main part of the chamber which caused delays and, a few years later, was to prove fatal to the detector. As Rousset correctly states, Gargamelle was probably the first big detector designed to be built on industrial lines, in direct cooperation with industry. The reward: the first neutrino interaction was photographed on 28 January 1971.

While it was clear that neutrino physics was Gargamelle's main goal from the start, it was not obvious to all the physicists in the collaboration once the detector had been built that the primary objective was research into neutral currents. Rousset points out that the key role played by neutral currents in electroweak unification did not come to the fore until 1971, when Gargamelle went into operation. Here, he emphasises

in an interesting manner the theorists' "green light", giving the go-ahead to the experimentalists. In fact, the European collaboration (Aachen, Brussels, CERN, Ecole Polytechnique, Milan, Orsay, UC London) was divided between a study of the quark-parton model, research into the intermediate boson... and research into neutral currents.

Gargamelle's first data were taken at the CERN PS (the SPS not yet being in operation), and the average energy of the neutrinos was only a few GeV. In a muon-neutrino interaction, either there is a muon among the final particles and it is said that there is a W exchange interaction (charged current), or there is a muon neutrino in the final state and there is a Z exchange interaction (neutral current). Neither the W nor the Z particles were known in 1972 and one of Gargamelle's goals was precisely the identification of the W particle (an impossible task, as we now know, since the PS did not



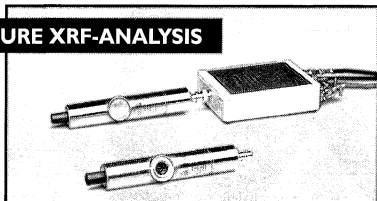
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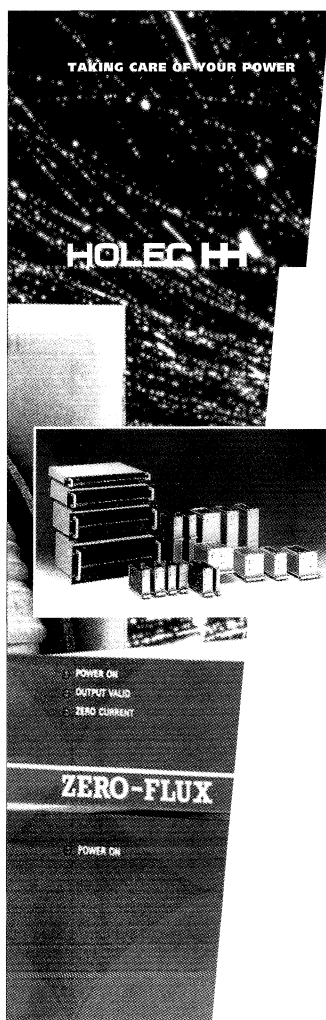
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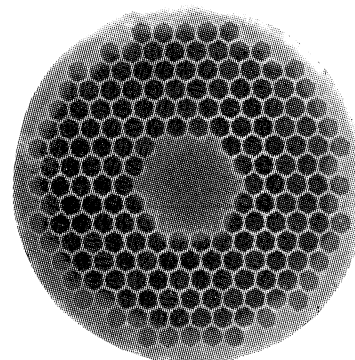
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produce the required energy).

The first neutral current event was identified in early 1973 in Aachen. This was a leptonic neutral current, where a muon neutrino scatters off an electron, which crosses the chamber in a very specific way. However, André Rousset somewhat disregards leptonic neutral currents, to which he considers history has paid too much attention. May we be allowed to disagree, since the beauty of the picture is undeniable?

With perspicuity, Rousset expands on research into hadronic neutral currents, where the final state comprises an escaping neutrino and hadrons. The difficulty is in separating such an interaction from that which could be produced by the interaction of a neutron from the immediate chamber surroundings. Rousset gives a descriptive and detailed account of this complicated and painstaking work, without losing sight of the main points.

The first half of 1973 was highly emotionally charged for the collaboration, which took time to understand the data and finalize its analyses. The sociological aspect of the collaboration was also examined. The announcement of the discovery was finally made by Paul Musset at CERN on 19 July 1973 and the two papers were published in *Physics Letters* on 3 September. Musset had been the central figure during the construction period and had played a coordinating role in the analysis work.

André Rousset does not overlook the competition: at Fermilab, in the United States, the 'HPWF' collaboration placed its 60 tonne neutrino detector alongside the new 400 GeV accelerator, which went into operation in 1972. The neutrino energy was several tens of GeV and *a priori*

it was easier to differentiate neutron interactions, the great neutral current simulators, from neutrino interactions. However, the detector was not easy to understand either. The HPWF's first results came hot on the heels of the Gargamelle announcement. There were fewer neutral currents, which disappeared altogether a few weeks later ... only to reappear at the beginning of 1974. This episode of "alternating" neutral currents worried... or kept the community entertained, for several months.

It was at the London Conference in July 1974 that the existence of neutral currents was conclusively established and accepted by the scientific community. Even today Rousset asks whether neutral currents had really been observed. This question, which is to his credit as a scrupulous physicist, may seem surprising; however, there was clearly no choice at the time: neutral currents had been predicted, even expected, by theory, and were by far the most simple interpretation of Gargamelle's results.

There are few reservations about Rousset's work. The book contains a few minor but unimportant errors (the chlorine solar neutrino detector was built in South Dakota and not Utah). A little more information on the discussion surrounding the possible existence of neutral currents in the small chambers before Gargamelle would have been welcome, and a comparison of Gargamelle's results with the present parameter values would have provided a useful perspective. Furthermore, it is perhaps regrettable that Rousset does not always adopt the necessary detachment, particularly when referring to the rival experiment in the United States at Fermilab (HPWF), but is

that really to be expected from such an enthusiastic and ardent observer/participant?

In conclusion, one may be sorry, like Rousset, that this important discovery was not rewarded by a Nobel Prize. This can probably be ascribed to the early death of André Lagarrigue, the father of Gargamelle, in 1974, followed by the death of Paul Musset in an accident in 1985.

The collective scientific venture which led to the discovery of neutral currents is a wonderful story, to which André Rousset makes a very important contribution. Supplemented by Peter Galison's article ("How the first neutral current experiments ended", *Review of Modern Physics* 55 (1983) 477), it will make a fascinating read (in French) for all those who want to know the details of this famous chapter in the history of contemporary physics.

By Michel Spiro

(Michel Spiro, Michel Cribier and Daniel Vigaud are the authors of a new book 'La lumière des neutrinos', published by Editions du Seuil, Paris. A review of this book will appear in a forthcoming issue.)