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The first CERN Neutrino Experiment (1961)
A personal recollection by P. G. Innocenti

In spring 1959 I joined the team working on the project of the CERN Heavy Liquid Bubble Chamber (HLBC) also known as Ramm chamber. Early in 1960 the chamber was under construction and was designated as one of the detectors for the CERN neutrino experiment, in a PS beam obtained from an internal target. In the bubble chamber team we were busy with day to day tasks and had little time for looking at the physics of neutrinos. At that time I remember taking a quick reading of the paper by Schwartz [1]; the neutrino we were supposed to detect was Puppi's neutretto [2] [3].

In summer 1960 discussions took place on the beam layout. A beam from internal target 1 had the advantage of a long straight section before the next magnet; a beam from internal target 5 would permit leaving the HLBC in the place where it was being assembled and tested, at the far end of the PS South Hall [4] [5]. The layout from target 5 was chosen [6]. Data taking by the HLBC was planned for May 1961 [7].

In December 1960 the HLBC was ready for the "final" engineering run. The chamber operated satisfactorily: it took pictures of tracks of particles from a source placed near the beam window and of cosmic rays. Some disturbing boiling was present on the rubber expansion membrane (which did not match the axial symmetry of the chamber because of hydrostatic pressure of the heavy freon); moreover, the fine adjustment of the expansion and re-compression cycle was tricky, with a risk to stress the membrane. In the evening of 18th December there was a major freon leak causing the collapse of the glass window [8].

During the end of the year holidays we cleared the window's debris and assessed the damage. I designed a throttle to ease the fine tuning of the expansion and re-compression cycle, making it less aggressive to the rubber membrane. In the new year we mended and polished the chamber body, we installed a new glass window (luckily a spare was available) and replaced many damaged components. We also installed the throttle, a massive and complicated piece of equipment which had been built in record time by the CERN Central Workshop.

At the end of May 1961 the chamber was ready to take data in the neutrino beam.

As a thunderbolt in a clear sky, the calculations[1] by von Dardel [9] reduced the expected rate of neutrino induced events by one order of magnitude! Von Dardel's logic was straightforward: the pions absorbed in the coils of the next magnet after target 5 do not decay to muons and neutrinos (see fig. 1 in [9]).

The consequences were devastating; the emotions are well described in the letters quoted in The History of CERN Vol. 2, reference 237 [10].

The neutrino experiment was stopped!

Bernardini reported the accident at a conference at CERN early in June [12] and at a meeting of the Scientific Policy Committee [13].

1 In the History of CERN, vol. 2, p. 220 [10] , one reads: " The first setback: von Dardel's measurements …": reference is made to [9], in which the reduction of the estimated event rate by one order of magnitude is the result of an analytical calculation. Von Dardel and collaborators had measured the pion flux from internal target 1 [11] to check the prediction by von Behr and Hagedorn on particle production, but the layout of their measurements was different from the one of the neutrino experiment.

The CERN Management needed a confirmation of von Dardel's findings and started two actions: a measurement of the pion flux with emulsions, in a geometry reproducing the layout around target 5, and a numerical calculation.
The emulsion measurements by Bingham et al. [14] and the numerical calculations [15] confirmed the findings reported in von Dardel's note [9]. Von Dardel produced an addendum to his note [16] and a generalization of his method of calculation [17].

Although the race with Brookhaven for the discovery of the muon neutrino was lost, the CERN Management decided "*… that what was in question was not a single experiment but a new field of physics, and that the various measures aimed at improving the experimental conditions should be continued*" [18]
The enhanced neutrino beam, with proton fast extraction and magnetic horn, which had been proposed in February 1961 [19] [20] was given high priority; the construction of a massive spark chamber downstream of the HLBC [21] was started.

The extracted beam and the magnetic horn as well as the spark chamber were operational in late spring 1963 when neutrino data taking resumed with spark chamber and HLBC. Neutrino induced events from the initial runs were reported at the Brookhaven Conference [22][23] in September and at the Sienna Conference [24] in October 1963 . The bubble chamber results were interesting because they provided a precise picture of the particles produced in the interaction. The idea of building large bubble chambers for neutrino physics was discussed at Sienna [25], a seed to the project of Gargamelle and to the discovery of neutral currents.
After the conference, an enlargement of the HLBC, by more than a factor three in fiducial volume, was proposed [26]. This upgrade was launched at the beginning of 1964 [27] with no neutrino data taking in the second half of that year; the enlarged chamber was operational in February 1965 [28] [29].

In summer 1961, after the experiment was stopped, I had a first look at the history of muon neutrinos.
I started by reading Pontecorvo's 1959 paper [30] and I learned, to my surprise, that he was proposing to detect muon neutrinos by stopping low-energy muons in matter and observing their decay at rest. This was the same approach Pontecorvo had outlined at the 1959 Kiev Conference [31]. Such an experiment required an intense pion beam from a "pion factory" like the one which was under discussion at that time in Dubna as a proposal for a new facility, a cyclotron of 700 MeV; for this type of experiment high energy beams, soon available at the CERN PS or the BNL AGS, were not needed.
From the Proceedings of the 1960 Rochester Conference I learned about the work of Markov [32] and his student Fakirov in 1958 and of Polubarinov in 1959: they were proposing to detect muon neutrinos produced by the decay of high-energy pions, same approach as Schwartz.
In the same Proceedings Bernardini [33}, in a note following his presentation "The Program of Neutrino Experiments at CERN", acknowledges humorously the work of Markov and Fakirov:
"*During and after the discussion which followed my report, I learned that many others had put forward the idea of experiments with high energy neutrino beams.*
Particularly M. A. Markov "Hyperonen and K-mesonen" Verlag der Wissenschaften, Berlin (1960) ; Fakirov, D. " On Spacial Distribution of the Neutrino Beam Generated by High Energy Nucleon Collisions". Facuité des Sciences de Sofia ***53****, livre 2 (1958/59), and others.*
At this point the only thing that I may say with certainty is that l did not have this idea."

Over the years, the history of the hypothesis that electron neutrino and muon neutrino are different particles and of the proposals to detect muon neutrinos at accelerators have been reported by different authors with variations.

Are electron neutrino and muon neutrino different particles?

When I started working for the neutrino experiment I took for granted that Puppi's neutretto was different from the electron neutrino.

- Pontecorvo in his 1982 recollections "The Infancy and Youth of Neutrino Physics" [34] says "*...for people working on muons in the old times, the question about different types of neutrinos has always been present. True, later on many theoreticians forgot all about it and some of them "invented" again the two neutrinos…*"

- Reines in his 1982 recollections "Neutrinos to 1960" [35] quotes from his article in Nature [36]: "*The question arises as to the identity of these neutrino-like particles* (from π - μ decay) *with the neutrino of nucleon decay…*" but says that theoreticians thought "*that there was no good reason to assume them to be different*".
In the discussion following Reines presentation, Puppi pointed out that "*at the time when the universal Fermi interaction was proposed, the belief was … that the neutral counterpart of the muon (the μ_0) and the neutral counterpart of the electron (the ν) were two different particles. One of the reasons was that at that time the mass of the neutretto (μ_0) was believed to be different from zero.*"

- Markov in his 1963 monograph "The Neutrino" [37] states: "*The possible existence of two different kinds of neutrinos has been considered theoretically by several authors. The earliest papers date from 1957.*" [38] [39]. He refers explicitly to [38] when speaking of neutrinic charges (нейтринные заряды)[2] in his book Hyperons and K-mesons [41]. In 1985, in his paper "Early Development of Weak Interactions in the USSR" [42], Markov gives credit to Sakata for proposing in 1942 "*the idea of two neutrinos*"[3] but points out the need of "*specifying something new which characterizes the difference between two neutrinos even in case of equal masses and spins*" as in Schwinger [38] and Nishijima [39].

Sakata and Inoue presented in 1942 at the 41st Semi-Annual Meeting of IPCR a communication, which was published in Japanese [43] and translated into English (with some re-arrangements) only in 1946 [44], sketching a theoretical frame[4] which assumed that electron neutrino and muon neutrino are different particles [46].
A positive[5] "Yukawa particle " Y^+ decays to a positive spin ½ "meson" m^+ and to a "neutral meson" n "*which is assumed … to have a negligible mass, and consequently may be regarded as equivalent with the neutrino*". The "meson" m^+ decays to three bodies $m^+ \rightarrow e^+ + \nu + n$.
As prime goal, that publication covered the **two meson hypothesis** [47][48], which was later to be presented by Marshak at the Shelter Island Conference in June 1947 and published by Marshak and Bethe [49].
The work of Sakata and Inoue has been ignored by most authors for many years.

2 Schwinger's *neutrinic charge* was later renamed neutrinic quantum number by S. Glashow [40].
3 The reference to the work of Sakata and Inoue given in [42] is approximate and incomplete.
4 In a later publication [45] the original paper [44] is referred to as "A prototype of two neutrino theory…"
5 A neutral Yukawa particle Y^o is called neutretto in [44].

Who proposed to use medium or high-energy accelerators to detect muon neutrinos?

- Reines [35] [50] mentions that the idea of using accelerators for neutrino experiments was discussed and discouraged at Los Alamos in 1956, where design studies for a 2 GeV synchrocyclotron and a 12 GeV proton synchrotron were under way at that time [51][6].

- Markov at the 1960 Rochester conference [32]. reports the studies made at Dubna in 1958 to observe neutrinos from the decay of energetic pions. In his monograph “The Neutrino” [37] he gives a colorful account of the early discussions in Dubna of neutrino physics with accelerators. He points out that the beam intensity at the 10 GeV synchrophasotron in operation since 1957 *“...ruled out the treatment of the experiment as real”*.

- Pontecorvo at the 1959 Kiev conference proposed to observe the interactions produced by anti-neutrinos from the decay of positive muons at rest [31]. He confirmed this approach in his 1959 seminal paper [30] , but he did not close the door to high energy experiments by pointing out that “*... A good source of muon neutrinos is the π - μ decay in which the neutrinos are produced with high energies. It would be of interest to use a high-energy antineutrino , say >>100MeV, since the cross section for neutrino-induced processes grows rapidly with energy. However, at very high energies the intensity of generation of muon neutrinos is reduced due to the relativistic increase in the lifetime of the π mesons and therefore we shall discuss an experiment for a neutrino with energy < 100 MeV.”* He confirmed the low energy approach in his paper submitted to the 1960 Rochester Conference [53].

Bernardini reporting to the CERN Scientific Policy Committee in November1960 (just after the 1960 Rochester Conference) on the progress of the CERN experiment [54] states *“It is well known that the idea of this kind of experiment was first put forward by Pontecorvo”*: this sounds surprising after what Markov had presented at the Rochester Conference and because neutrinos in the CERN experiment were not produced by the decay at rest of muons but by the decay in flight of positive pions.
Many authors (e. g. [55], [56], [57]) have repeated Bernardini’s narrative.
It should be noted that Pontecorvo, on p. 223 of his recollections [33], shares with Markov and Schwartz the idea of *“the use of high energy neutrino beams from π - μ and other decays”* for neutrino studies[7].

I have no doubt that the trigger for the first neutrino experiment at CERN came from the paper by Schwartz [1].

6 Eventually a proton beam with neutrinos produced by muon decay at rest was operational at LAMPF in the 1990’s for a neutrino oscillations experiment [52] !

7 In the History of CERN, vol. 2, p. 217 [9] , one reads: “The idea of using the new generation of accelerators at CERN and at Brookhaven as a source for high-energy neutrinos was proposed by Bruno Pontecorvo in mid-1959 [30] [29] and independently by Melvin Schwartz early 1960 [1].“ Although this may sound very plausible, neither Pontecorvo nor Schwartz mention the CERN PS or the BNL AGS in their papers.

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