Neutrino oscillations: personal memories

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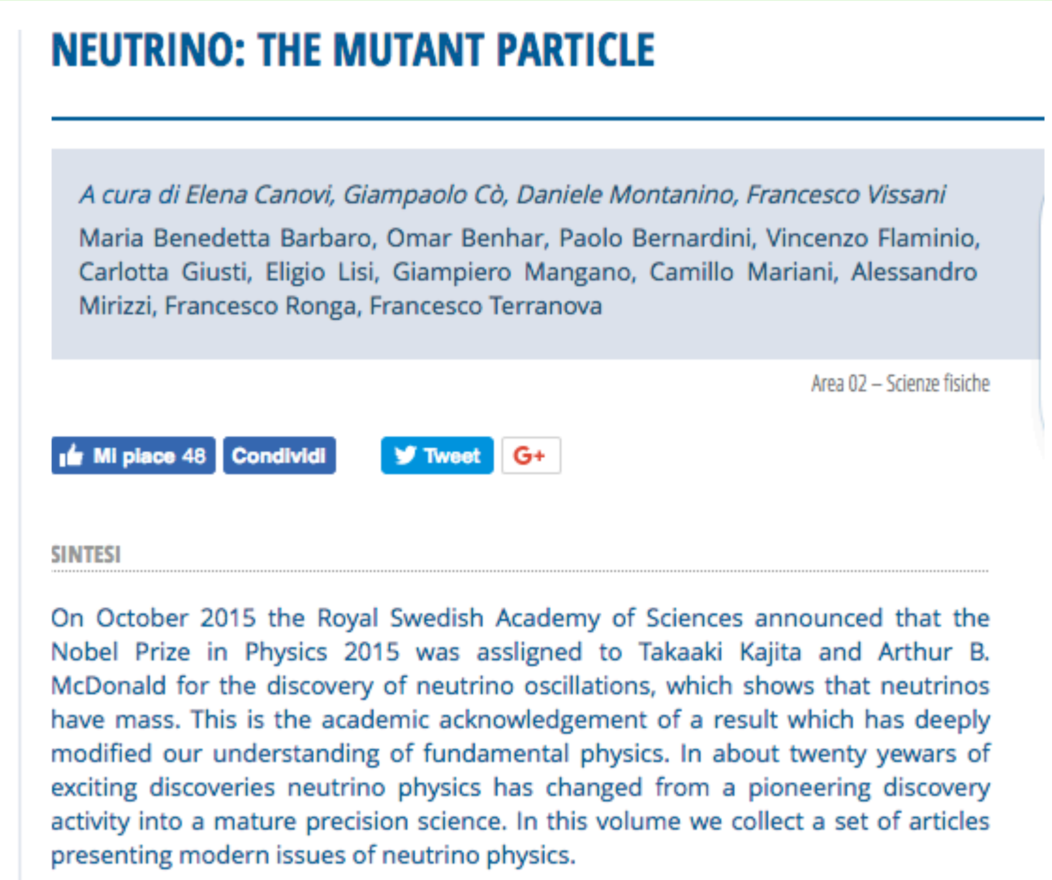
This short neutrino oscillations history is focused to the period up to June 1998, from the point of view of a researcher working in the past MACRO experiment at the Gran Sasso Laboratory, scheduled to talk at the Takayama conference just before the historical Tataaki Kajita's talk.

References:
F. Ronga: "A story of neutrino oscillations in the book" Neutrino the mutant particle" Aracne editions
http://www.aracneeditrice.it/index.php/pubblicazione.html?item=9788854895805
also in
http://www.dmf.unisalento.it/~gpco/Ithaca_VI_2015.pd (english version)

In the spring of 2015 (before the neutrino Nobel prizes) Giampaolo Co' planned a special number of the online magazine Ithaca dedicated to neutrino. G. Co' and Paolo Bernardini asked me to write an article on the neutrino history.
Later in 2016 a book was published by Aracne editions



1968 beginning of the solar neutrino anomaly. Why more than 30 years to establish neutrino oscillations?

Question to McDonald (raised by Cabibbo) during a meeting at the Accademia dei Lincei organized by Milla Baldo Ceolin in 2003
Several reasons

- **sociological:** difficult to admit that particle physics could be done with astrophysical sources
- **theoretical** prejudice : **small oscillation amplitude** predicted (similar to quarks), **large neutrino mass** preferred (dark matter)
- **experimental:** discrepancy between atmospheric neutrino experiments

Consequences :

- second generation solar neutrino experiments were **delayed**, Gallium solar neutrino experiment not approved in USA and moved to Europe (GallEx Italy, SAGE Russia)
- CERN-Gran Sasso neutrino beam (planned from the beginning of the Gran Sasso laboratory), **approved only in Dec 1999.** Some CERN countries voted against the beam (even if most of the money was INFN)

1986 Start of the atmospheric neutrino anomalies

IMB and later Kamiokande
In 1992 a result on the IMB stopping muons excluded oscillations

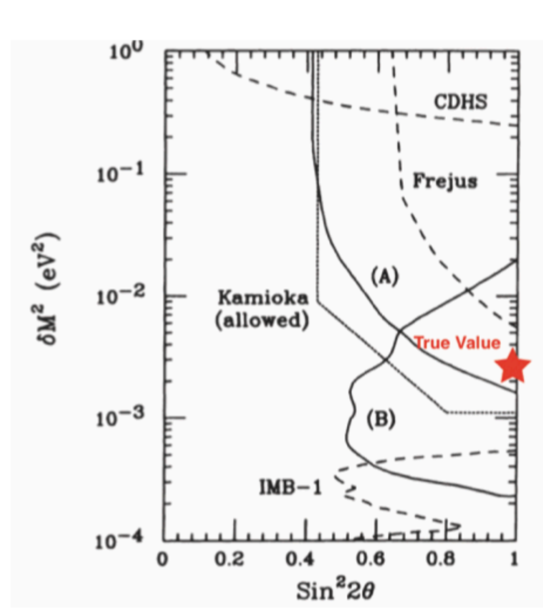
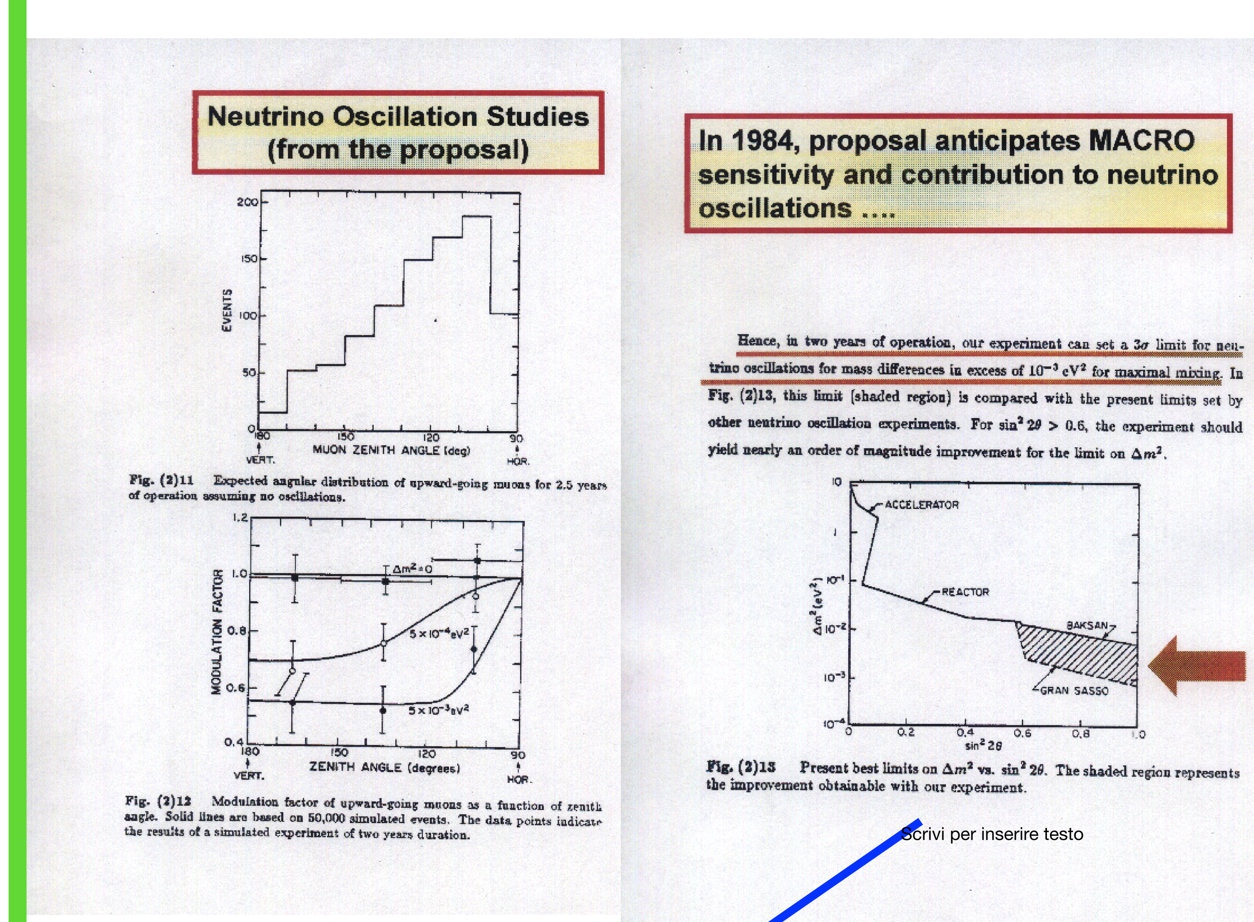


Figure 1. Figure analogous to that of the IMB paper published on Physics Review Letters in 1992 [8]. All the curves include excluded regions, except that of Kamiokande, which defines the allowed region. One should notice that the curve B of IMB completely excludes the red star that represents the presently accepted oscillation values. This wrong result generated great confusion and slowed down the claim of the discovery

Atmospheric Neutrino study in the MACRO, magnetic monopole search, proposal (1984)



Takayama neutrino 1998 conference, agenda June 5

9.10 Contained events and Soudan2 (E. Peterson) main result the muon deficit in iron in agrement with water detector and in agreement with oscillations

9.35 Upward-going muons and MACRO (F.Ronga) I was quite nervous. Our results **different from the one** of Kamiokande. Possibility to have an immediate denial by a much better experiment like Superkamiokande. Paolo Bernardini already presented our results to the Vulcano workshop.

9.55 Results from Kamiokande and SuperKamiokande (T.Kajita)

I was very happy after the Kajita talk. **Our results were in complete agreement with** SK and new Kamiokande data. Of course the statistical evidence was much lower (3 σ in 1998 ==> 5 σ with the full data set in 2000)

Takayama

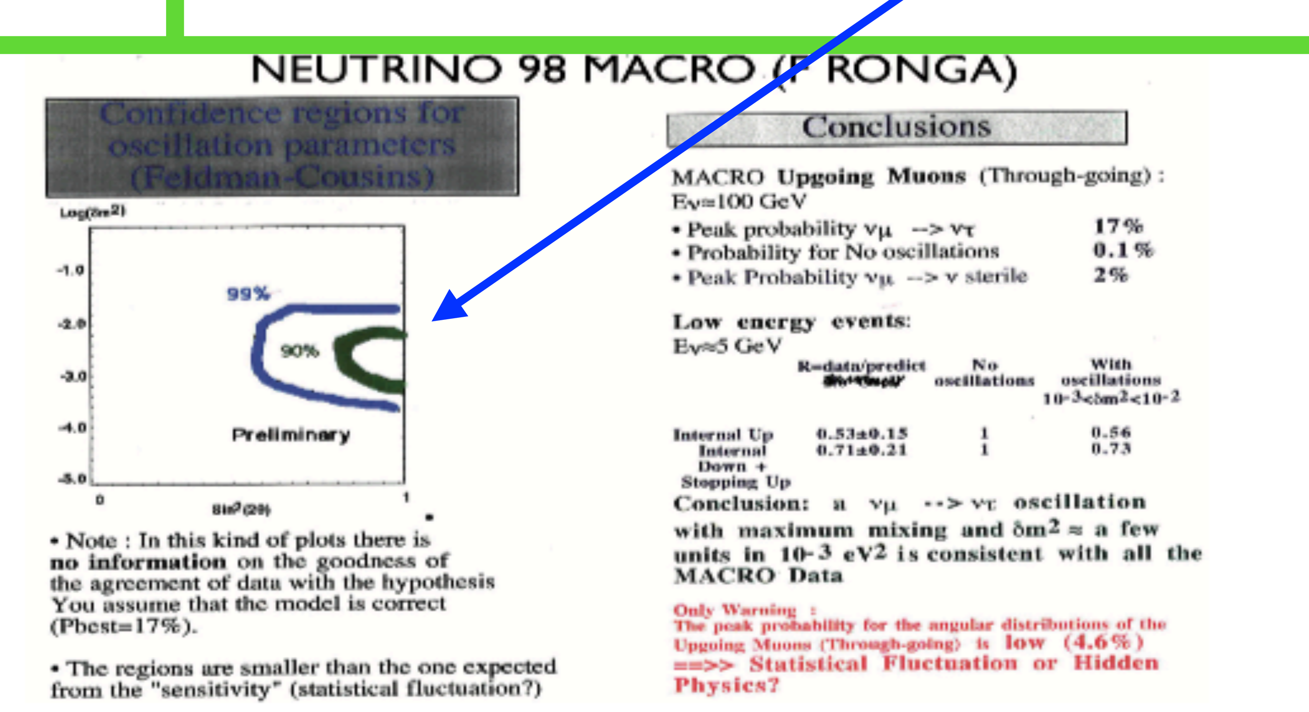


Figure 3. Slides of the MACRO presentation at "neutrino 1998". The slides are still on the conference link http://www-sk.icrr.u-tokyo.ac.jp/nu98/scan/index.html. Similar slides had already been shown by Paolo Bernardini six days earlier at the Vulcano workshop 1998

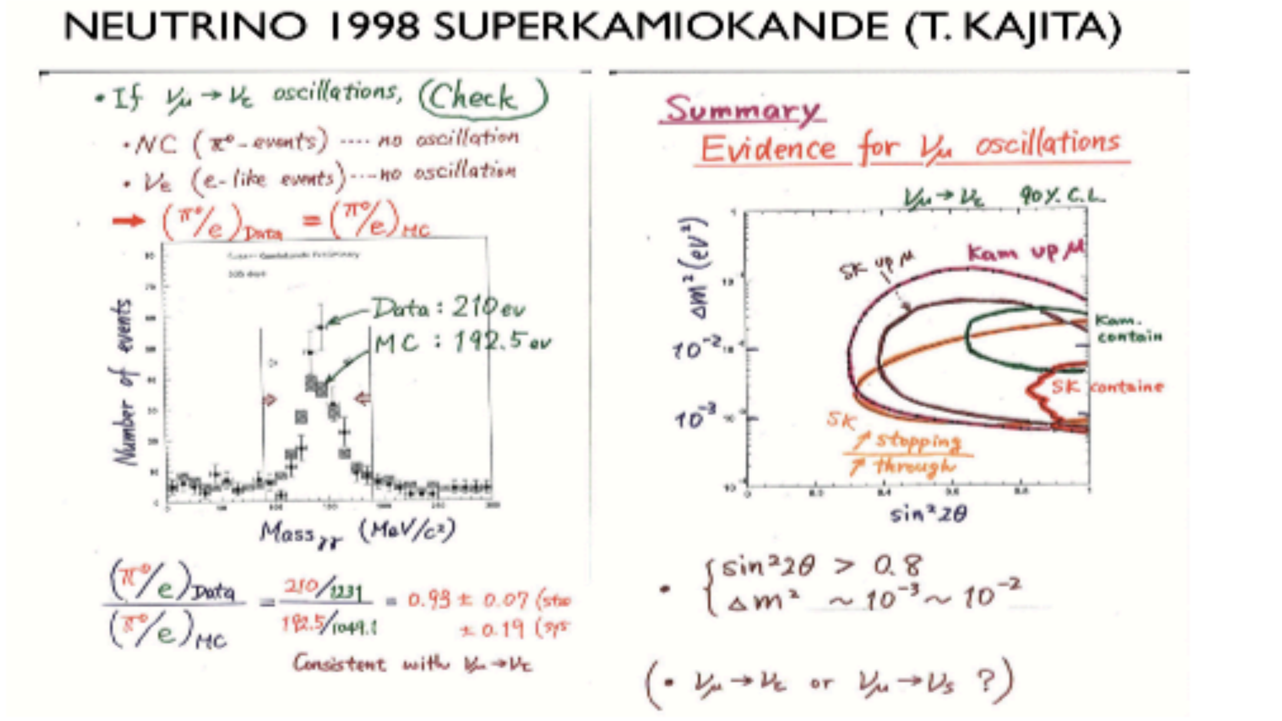


Figure 4. Slides of the Super–Kamiokande presentation at neutrino 1998.

1998 papers after Takayama

M. Ambrosio et al. [MACRO Collaboration], "Measurement of the atmospheric neutrino induced upgoing muon flux using MACRO," Phys. Lett. B 434, 451 (1998) [hep-ex/9807005]

Y. Fukuda et al. [Super-Kamiokande Collaboration], "Evidence for oscillation of atmo- spheric neutrinos," Phys. Rev. Lett. 81, 1562 (1998) [hep-ex/9807003]..

Note the preprint numbers **9807003** (Superkamiokande) **9807005** (MACRO). Our paper was **ready** before that of SK, but Giorgio Giacomelli (co-spokesman together B. Barish) waited for the green light from his colleague and friend Koshiba to submit to the arXiv the paper soon after that of SK