Поиск несохранения барионного (лептонного) числа.

Один из законов сохра-ия: ЗСЭ, ЗСЗ, ЗСВ, ЗСL.

$$n \to p + e^- + \bar{\nu}_e$$

$B = 1$, p, n, (u, d, s, c, b, t) – кварки $\quad L = 0$

$B = 0$, мезоны, π, K, e, μ ν $\quad (L = 1, -1)$

$B = -1$, $\bar{p}$, $\bar{n}$, (анти кварки) $\quad L = 0$

Не наблюдается распадов в которых не сохраняется B или L, но Вселенная состоит из вещества $\Rightarrow$ при $\nearrow^x T \Rightarrow \nearrow^x E$. B и L не сохра-ся!

$\Rightarrow \exists$ взаимодействие и его переносчики (γ - элек-ое) которые нарушают ЗСВ, ЗСL.

Теории великого объединения (SUSY)

SUSY – SU(5)

$$p \to \bar{\nu}_\mu \cdot K^+$$

если $\tau_p > 5 \cdot 10^{33}$ лет

$\Rightarrow$ должны наблюдать час-у при $E \simeq 100$ ГэВ (LEP)

NON-SUSY – SO(10)

$$p \to e^+ \pi^0, \; (\pi^0 \to 2\gamma)$$

$\tau_p = 1.4 \cdot 10^{32 \div 38}$ лет,

$$Br(p \to e^+ \pi^0) = Br(p \to \bar{\nu} \pi^+)$$

$$\boxed{\tau_{\text{вселенной}} \simeq 1.4 \cdot 10^{10} \text{ лет.}}$$

Поиск распада протона.

Оценки.

$m_p = 1.7 \cdot 10^{-24}$ г ; $N_p(1\text{ тонна}) = \dfrac{10^6 \text{ г}}{1.7 \cdot 10^{-24}} \simeq 5 \cdot 10^{29}$ шт.

За 1 год распад 1p в 1 тонне при $\tau_p = 5 \cdot 10^{29}$ лет

Для регистрации необ-мо $\simeq 10 \div 100$ расп. $\Rightarrow M_{дет} \to 10^{4\div5}$ т

Детекторы. ($\mathrm{I}^{ого}$ поколения)

- IMB-3, Kamiokanda (1993 ÷ 1994) гг

  $M \simeq 3.5$ кт.

  Опреде-ие τ_p огра-сь систематикой:

  $$\frac{N_{\nu_\mu}}{N_{\nu_e}} \simeq 0.54 \pm 0.06 \quad ???$$

  В последствии стало ясно, что это само по себе открытие ν^x-осцилляций. !!!

- Soudan - II $M \sim 10$ кт ; (Fe + ПК)

  время набора статистики 5 лет.

$p \to \nu K^+$ ($K^+ \to \mu^+ \nu$, $\mu^+ \to e^+ \nu \bar{\nu}$)

$n \to e^- K^+$ ($K^+ \to$ — " —)

$n \to \mu^- K^+$ ($K^+ \to$ — " —)

$\tau_{p,n} > (4.5 \div 7.5) \cdot 10^{30}$ лет

II – поколение.

- **Kamiokanda – II** (1994 год → ?)

$N = 326$ соб. $\int M_{det}\, dt \simeq 20$ кт-лет

$p \to e^+ \pi^0$, $\tau_p > 3.3 \cdot 10^{32}$ лет

$p \to K^+ \bar{\nu}$, $\tau_p > 1.3 \cdot 10^{32}$ лет

- **Super Kamiokanda** (1996 г → 2002 г)

$\int M dt \simeq 100$ кт-лет (к 2002 году)

$p \to e^+ \pi^0$, $\tau_p > 10^{34}$ лет

$p \to K^+ \bar{\nu}$, $\tau_p \gtrsim 10^{33}$ лет

III – поколение.

- **ICARUS – проект**

LAr ионизационная камера $M_{Ar} = 5$ кт

очень хорошая идентификация по $\frac{dE}{dx}$

$\Rightarrow$ низкий уровень фона

$p \to K^+ \bar{\nu}$, $\tau_p > 5 \cdot 10^{32}$ за 1 год работы

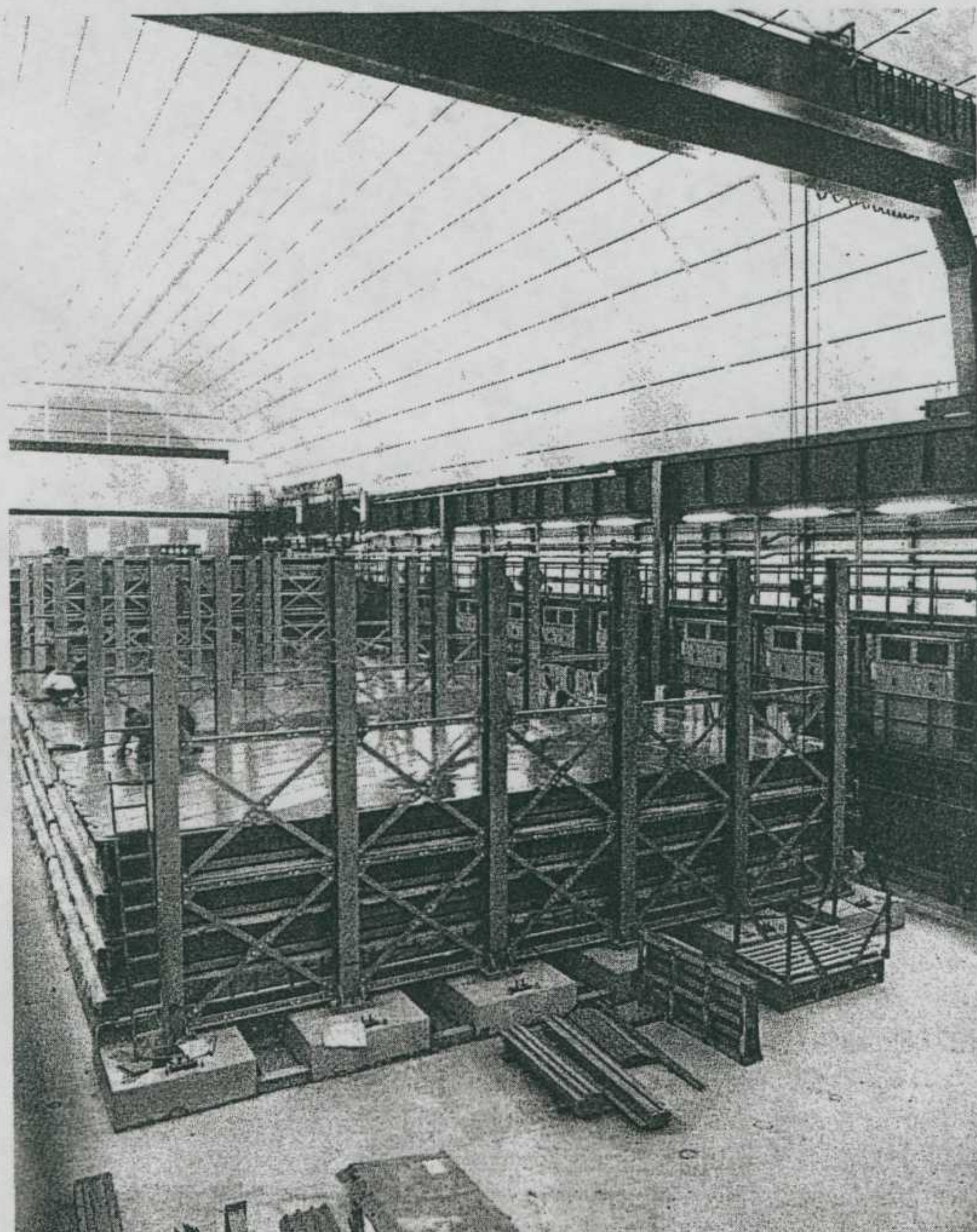


FIGURE 11.5

A photograph of the MACRO (Monopole Astrophysics and Cosmic Ray Observatory) being assembled in a huge underground laboratory located next to the automobile tunnel under Mont Blanc, between France and Italy. (Photo by

MACRO-scope

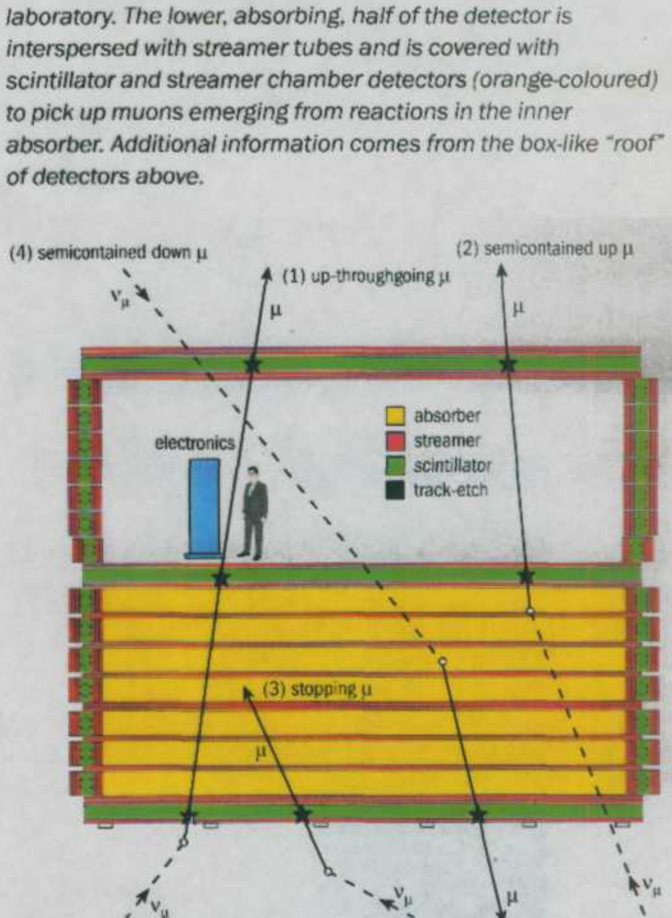
The Monopole, Astrophysics and Cosmic Ray Observatory (MACRO) is an underground muon detector at Gran Sasso, which is now adding to the evidence for neutrino oscillations.

Fully operational since 1994–95, MACRO's bread-and-butter physics is the detection of cosmic-ray muons, but its ultimate objective is to search for new phenomena and to pick up particles from cosmic sources such as supernovae. In its search for cosmic signals, MACRO is assisted by the EAS-TOP array on the mountain 1400 metres above.

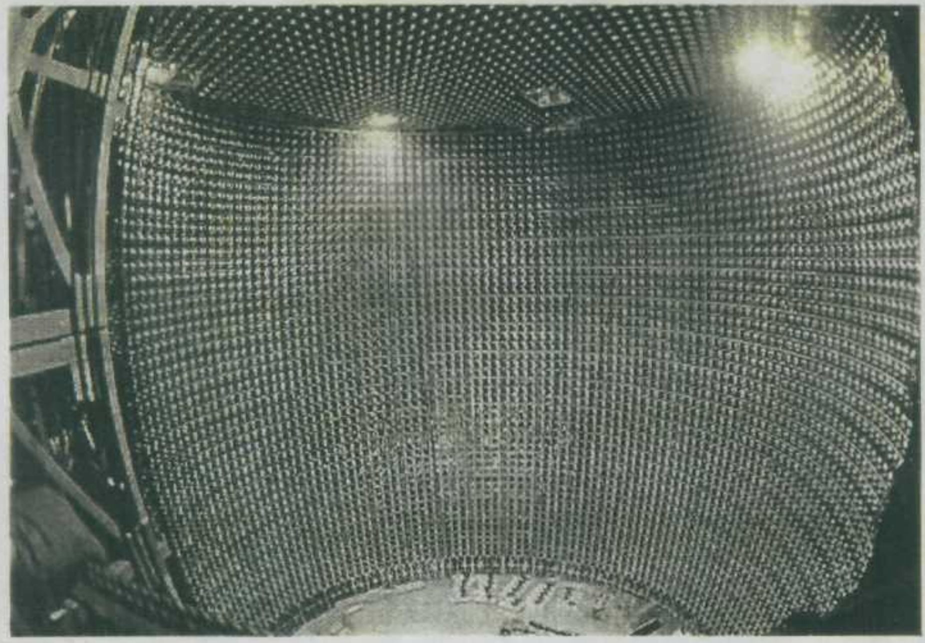
MACRO intercepts particles which pierce the overhead rock shield. 77 metres long, 12 metres across and 9 metres high, the detector is divided lengthways into six modules. The bottom half of the detector is composed of seven layers of crushed rock absorber interspersed with streamer tubes, together with an outer cladding of scintillator and streamer tube detectors and a box-like top layer with scintillator and streamer chamber walls and roof running the length of the detector.

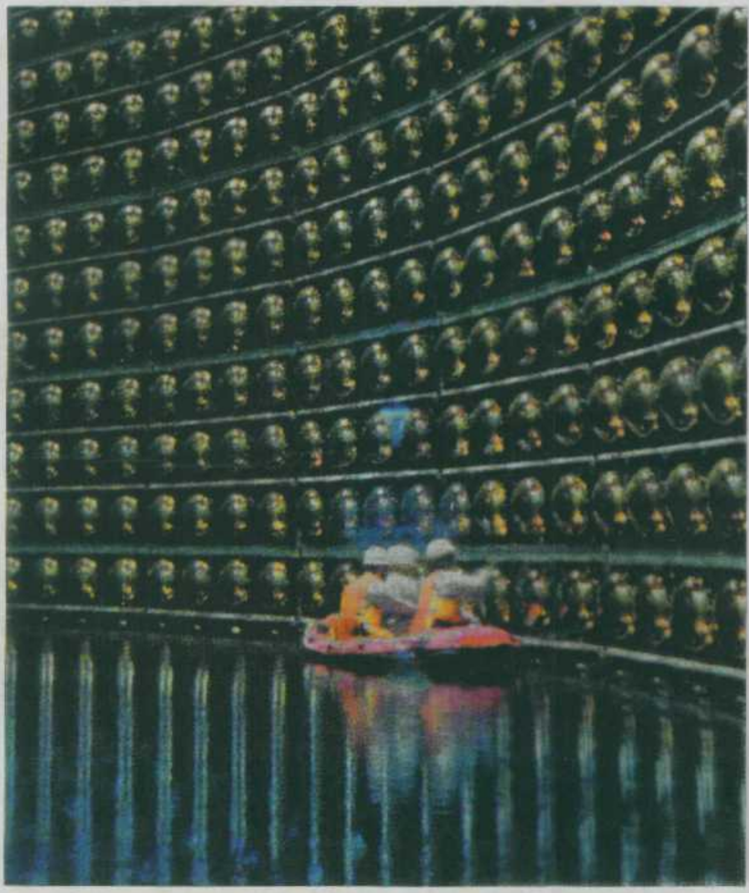
While magnetic monopoles continue to be elusive, a bonanza for MACRO is the study of muons produced by neutrino interactions inside the detector, confirming an intriguing effect seen in other detectors (September, page 1). These studies show a marked difference between the signals due to upward- and downward-moving neutrinos.

The MACRO detector in the Italian Gran Sasso underground laboratory. The lower, absorbing, half of the detector is interspersed with streamer tubes and is covered with scintillator and streamer chamber detectors (orange-coloured) to pick up muons emerging from reactions in the inner absorber. Additional information comes from the box-like "roof" of detectors above.

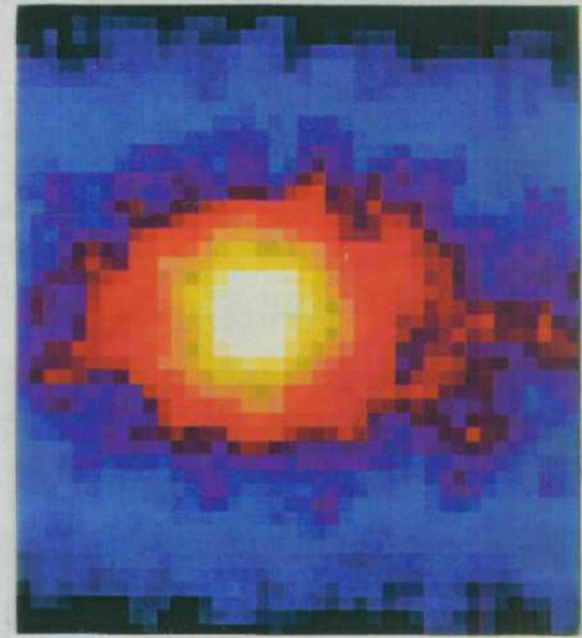


Different types of neutrino interactions in MACRO: (1) An upward throughgoing muon hits three layers of scintillator and 14 streamer tube planes. (2) A "semicontained" upward muon – an upward muon neutrino (which has passed right through the Earth) interacts in the detector, producing an upward muon. (3) An upward "stopping" muon – an upward neutrino produces a muon which is absorbed inside the detector. (4) A downward neutrino produces an muon which emerges from the bottom of the detector. As far as MACRO is concerned, interaction types 3 and 4 are indistinguishable.

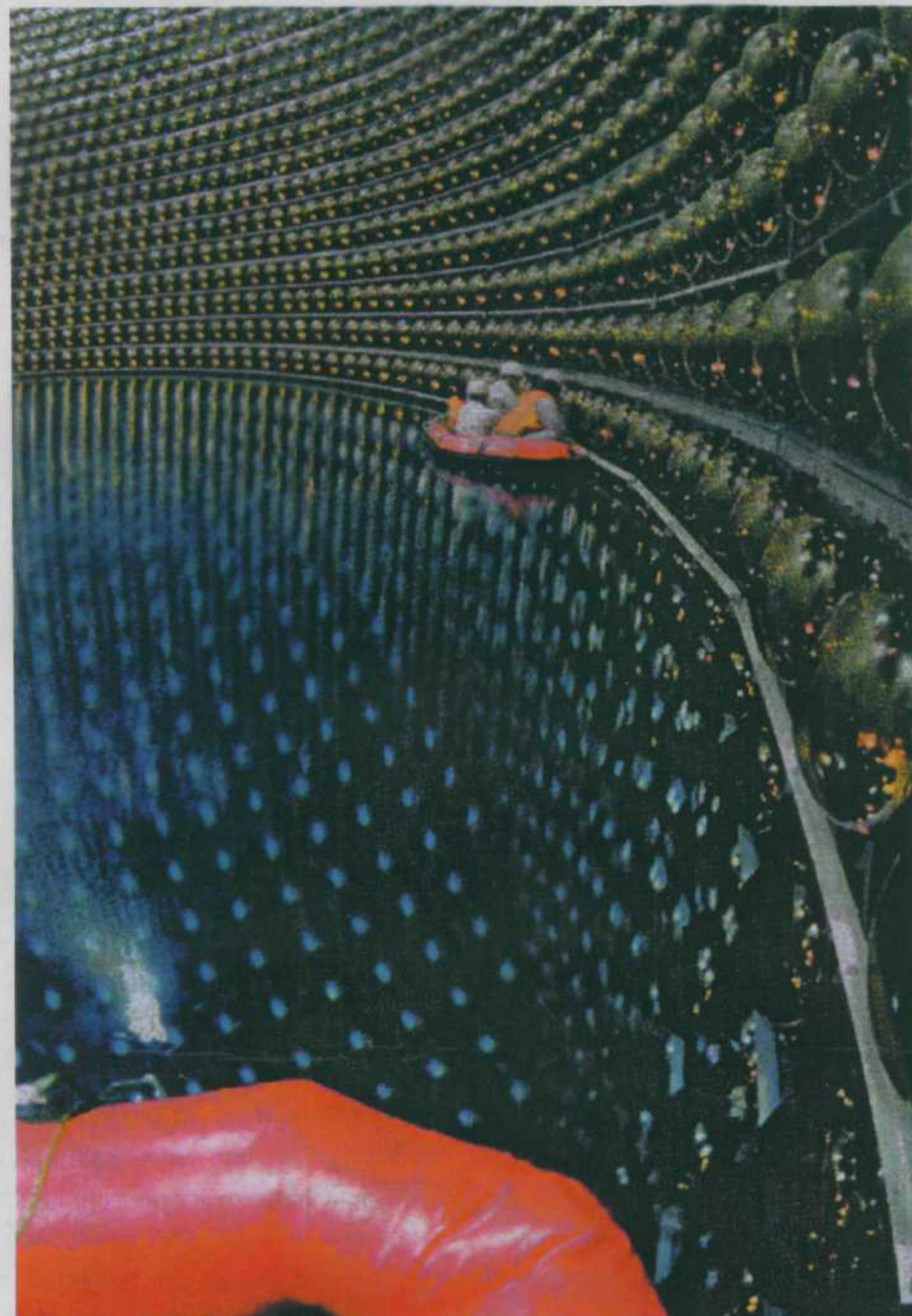




One of the clients of the new Japanese proton facility would be the Superkamiokande underground neutrino experiment, 300 km from the Tokai site. Here, researchers are carefully cleaning the photodetectors as the neutrino target volume is filled with water.

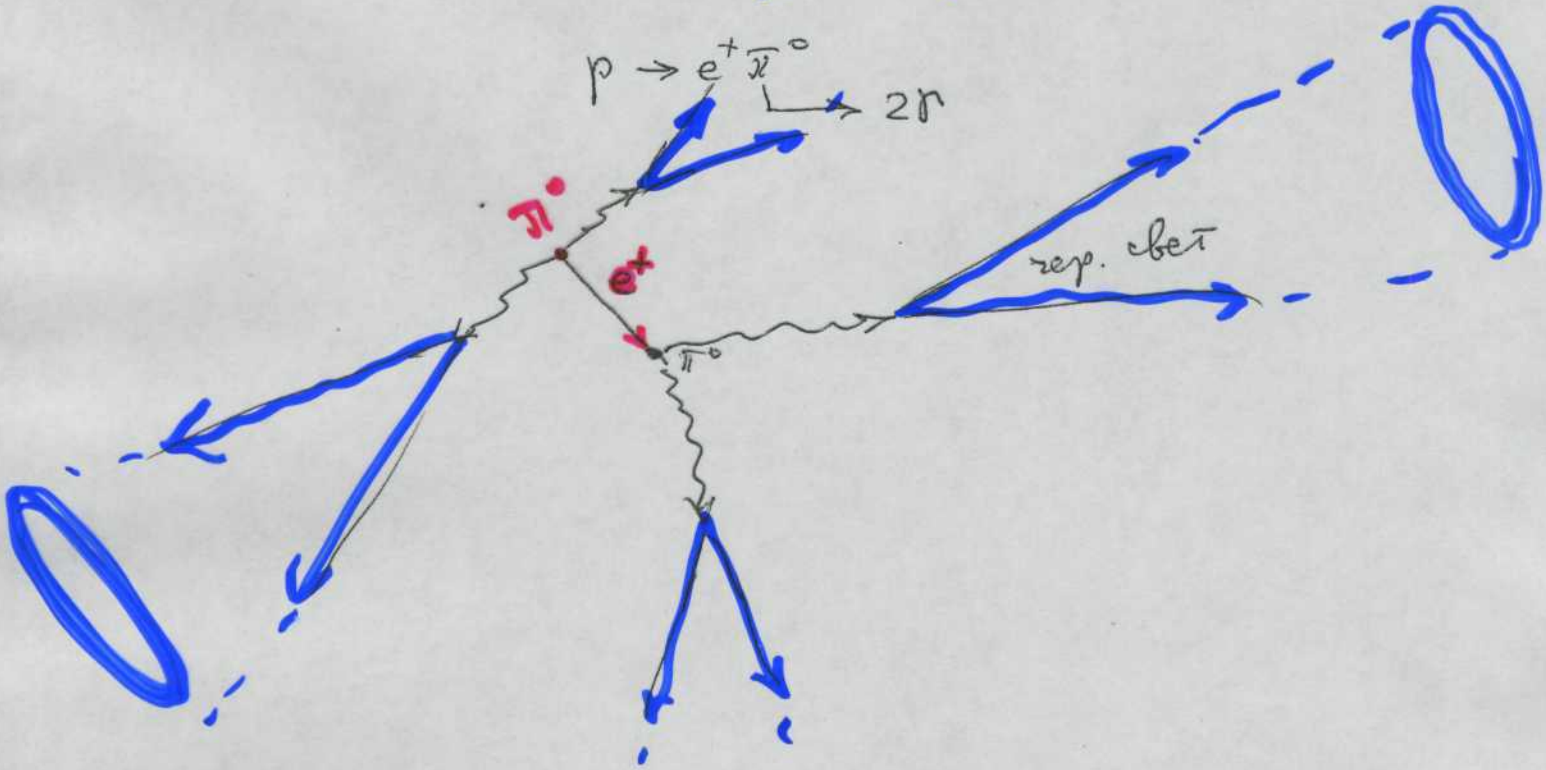


Another view of the Sun – the Super-Kamiokande 50 000 ton water Cerenkov detector, 1 km underground in Japan, took this "photograph" of the sun in "neutrino light". The exposure time was 503.8 days and each pixel represents about 1 degree of the sky. (R Svoboda, Louisiana State.)



Отбор событий.

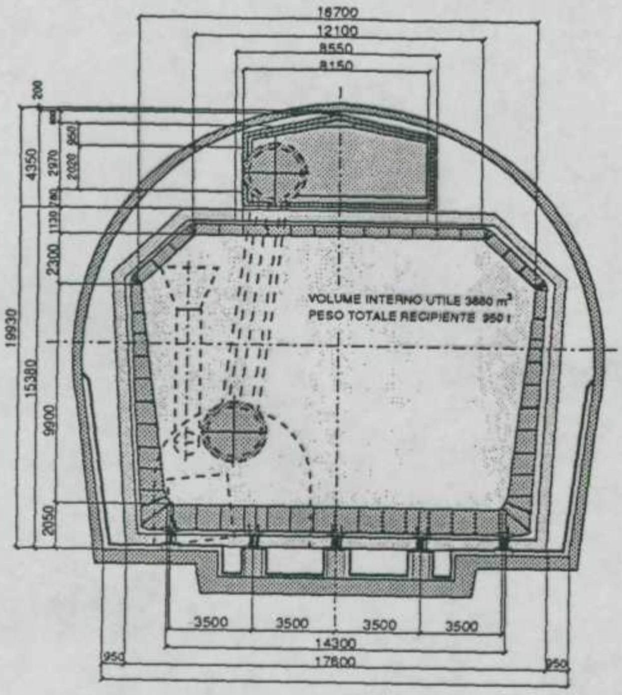
1. $\Delta E = 0.5 \div 1.0$ ГэВ
2. $\sum\limits_i \vec{p} = 0$ – p в покое
3. измерение пробега продуктов распада ⇒ иденти-ия



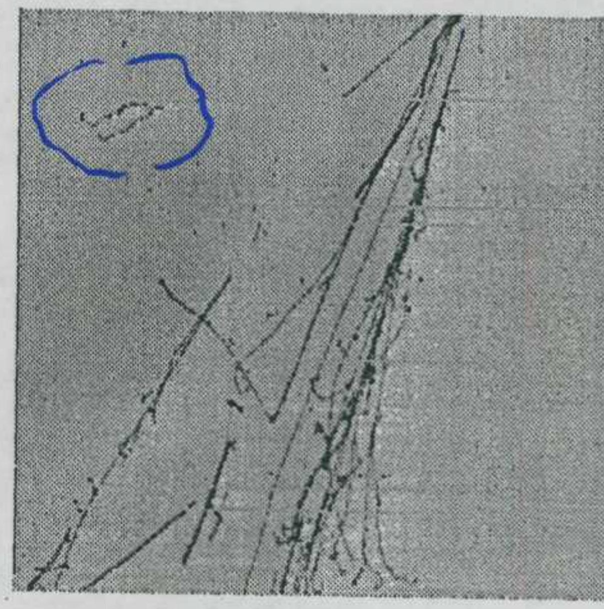
4 кольца в черенковском водяном детекторе.

Фоны.

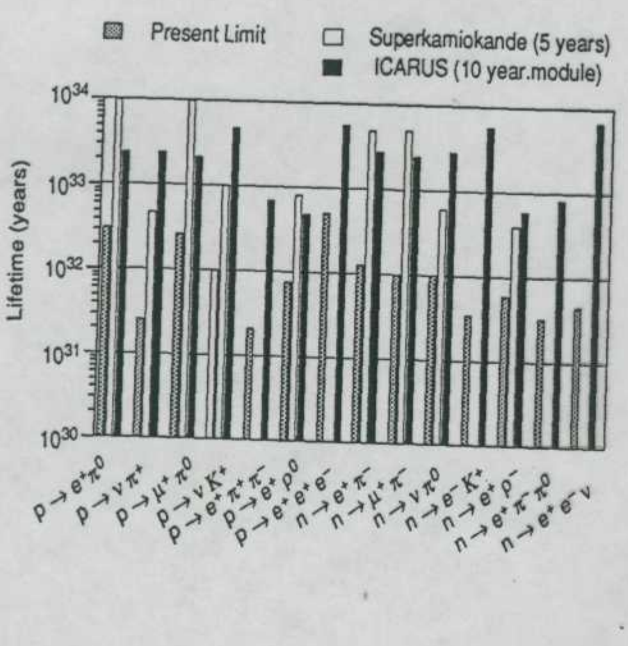
1. Естественная радиоактивность
2. Космические μ
3. Атмосферные и Солнечные нейтрино.
4. $\bar{n}$ – из окружающей детектор породы.

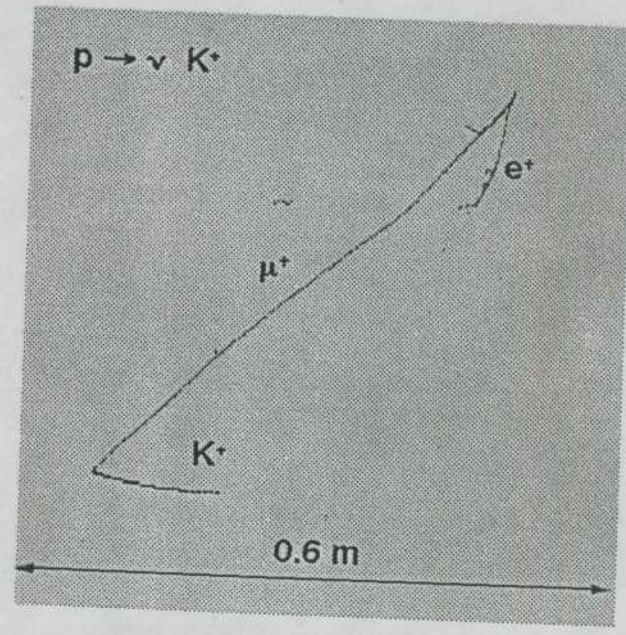


Schematic view of the ICARUS detector to be built in the Gran Sasso Laboratory.



Cosmic ray shower observed in the ICARUS 3-ton prototype at CERN. The drift direction is along the horizontal axis spanning a distance of about 40 cm. The vertical axis corresponds to 192 sense wires with a 2 mm pitch. Each electron in the conversion pair visible at the upper left corner of the picture has about 5 MeV of energy and corresponds to the energy range of ^8B solar neutrinos in ICARUS. Also clearly visible near the center of the figure is a $\pi^+ \to \mu^+(\nu_\mu) \to e^+(\nu_e\bar{\nu}_\mu)$ candidate as well as a clear electromagnetic shower.





Simulation in the ICARUS detector of a proton decay in the Supersymmetrically preferred mode $p \to \bar{\nu}K^+$, where a μ^+ is produced in the K^+ decay, followed by an e^+ produced in the subsequent μ^+ decay.