Visita ai Laboratori dell'INFN
9-10 Dicembre 2011
Laboratori Nazionali del Gran Sasso

Dipartimento di Fisica
Universita' di TRIESTE

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INFN Istituto Nazionale di Fisica Nucleare

Laboratori Nazionali del Gran Sasso

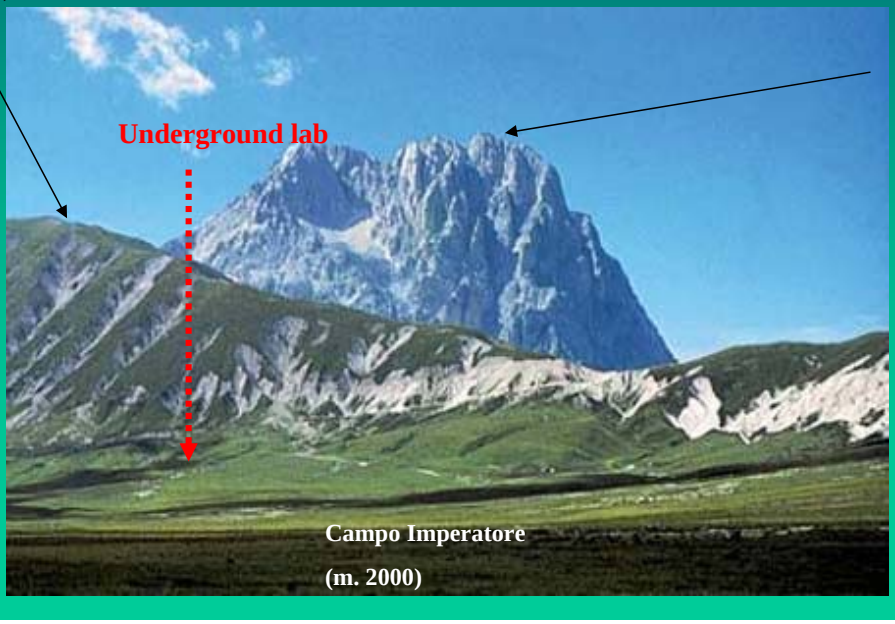
Location: Gran Sasso Tunnel (Abruzzi, Italy)

Depth: 1400 m (3800 mwe)

Operating Institution: Istituto Nazionale di Fisica Nucleare (INFN)

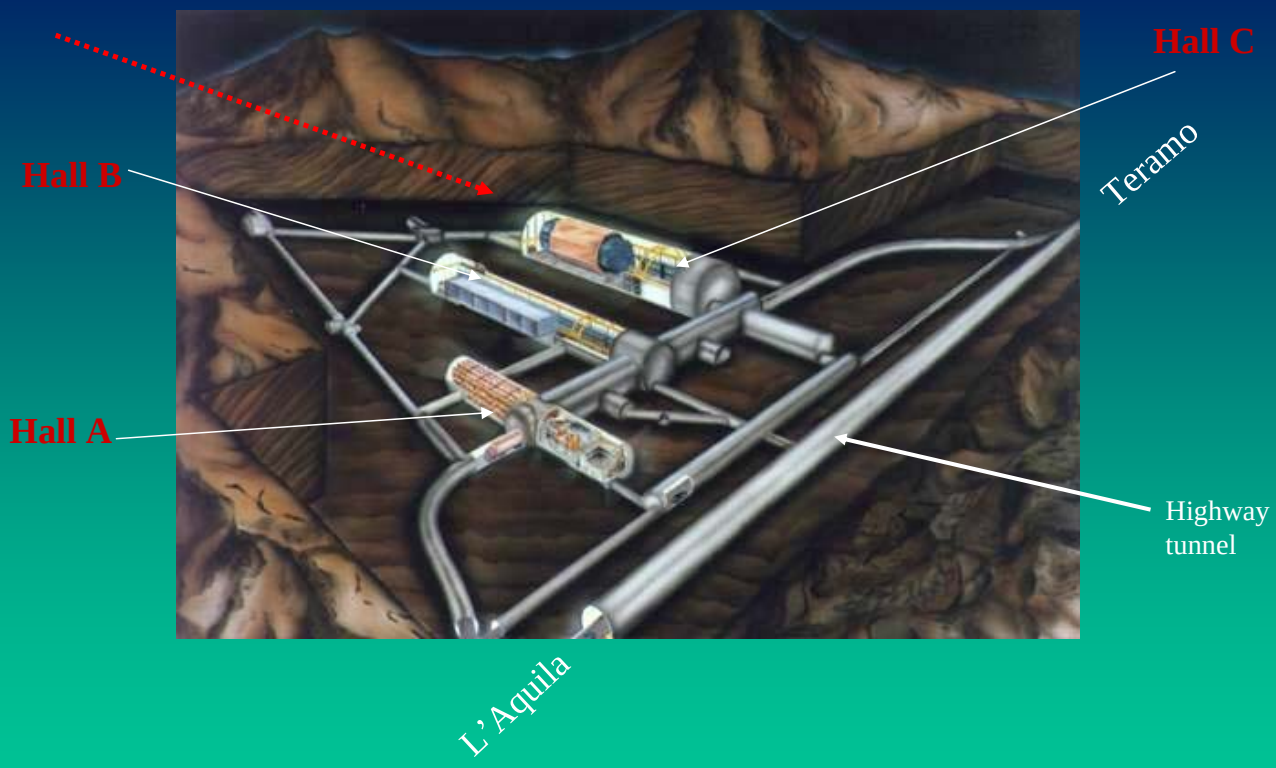
LNGS permanent staff: 60 (physicists, technicians, administration)

Scientists involved in LNGS experiments: 700 from 24 countries



The area of Campo Imperatore above LNGS

The LNGS Underground area



Underground area : 3 halls (100m x 20m x 15m) + service tunnels

Total volume : 180000 m^3

Surface: > 6000 m^2

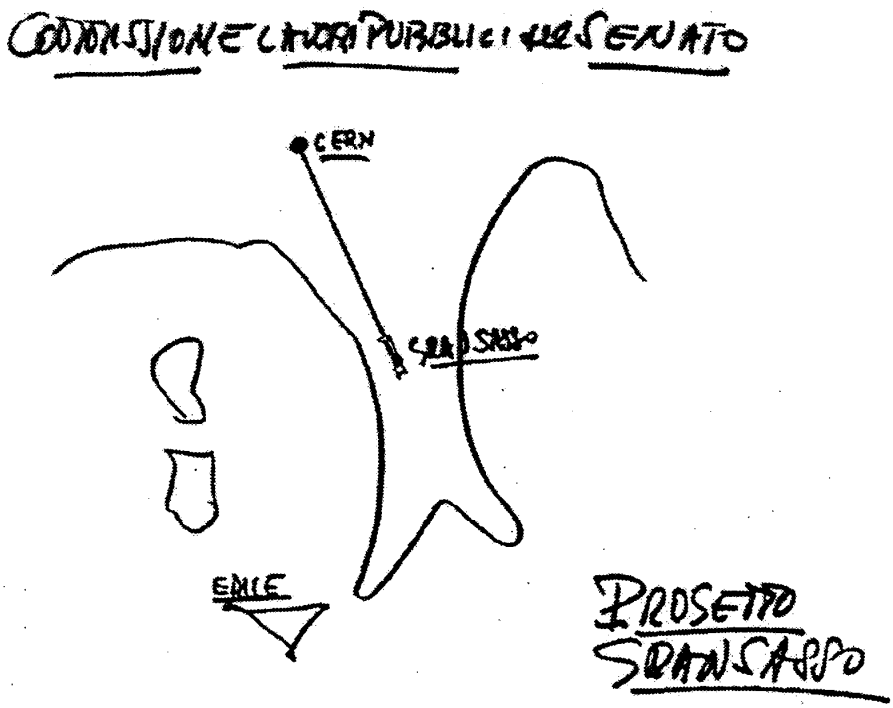
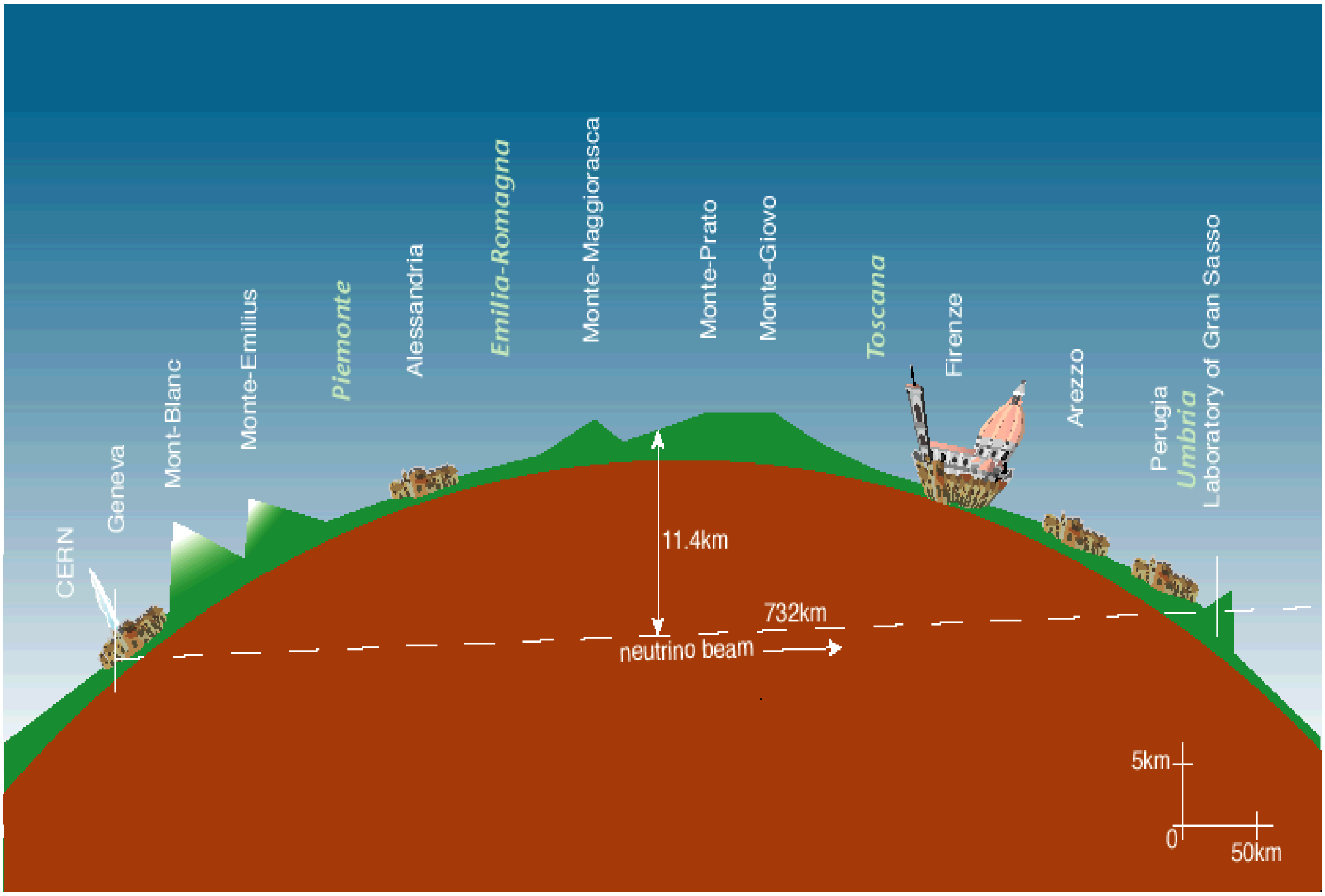
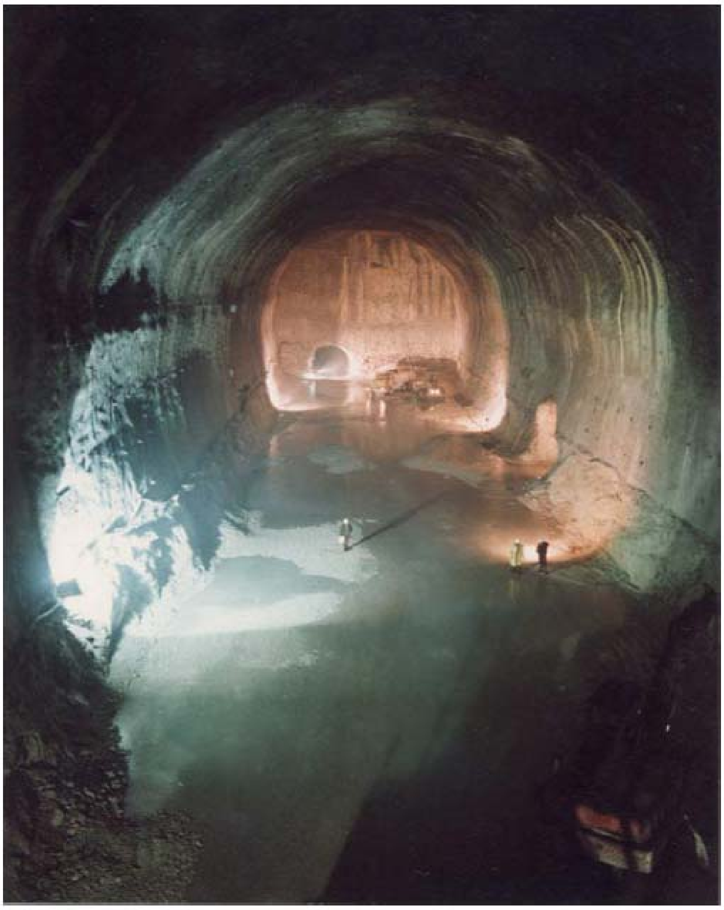


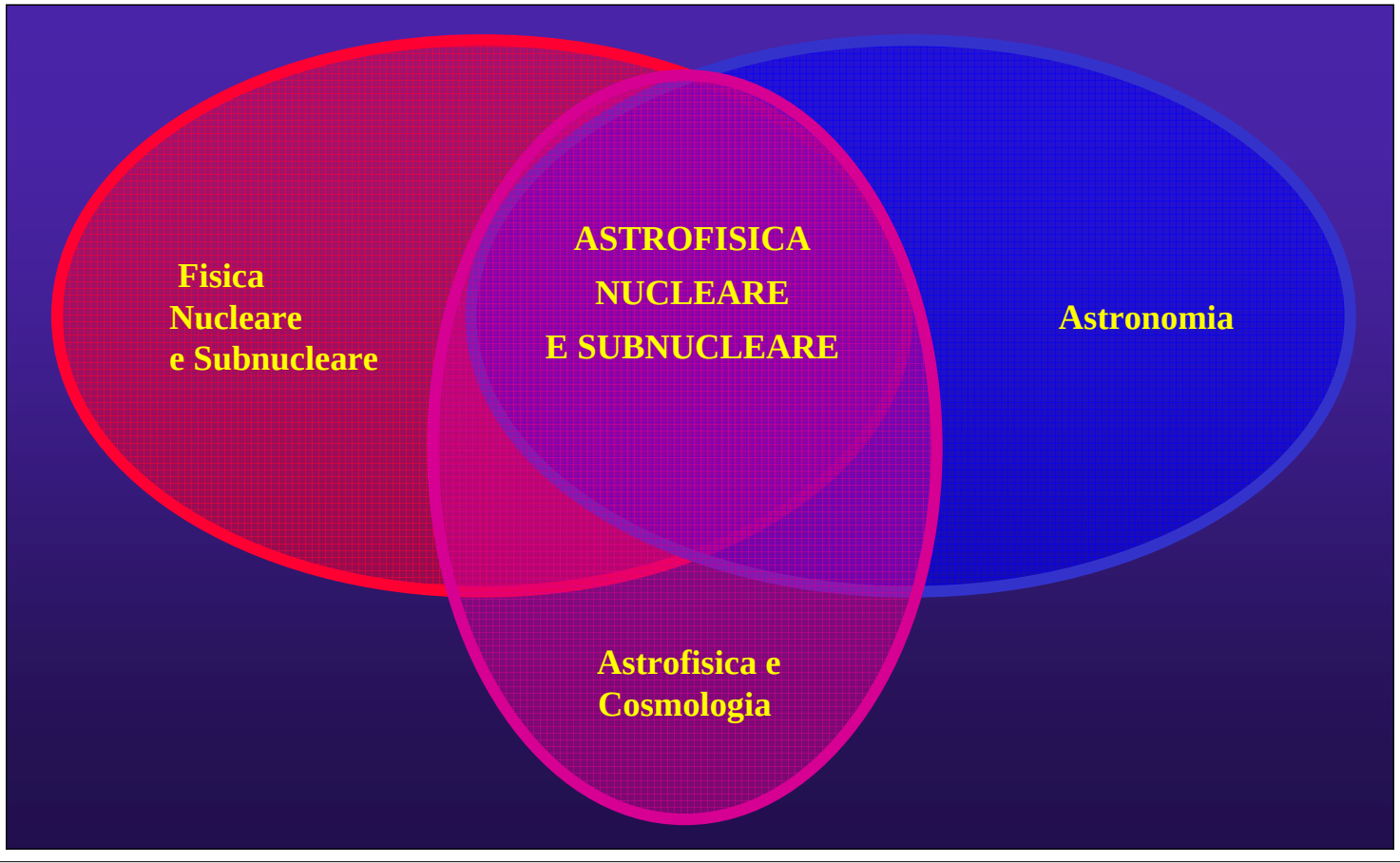
Figure 1.1.1: Sketch by A. Zichichi, 1979


CERN
Geneva
Mont-Blanc
Monte-Emilius
Piemonte
Alessandria
Emilia-Romagna
Monte-Maggiorasca
Monte-Prato
Monte-Giovo
Toscana
Firenze
Arezzo
Perugia
Umbria
Laboratory of Gran Sasso
11.4km
732km
neutrino beam
5km
0
50km

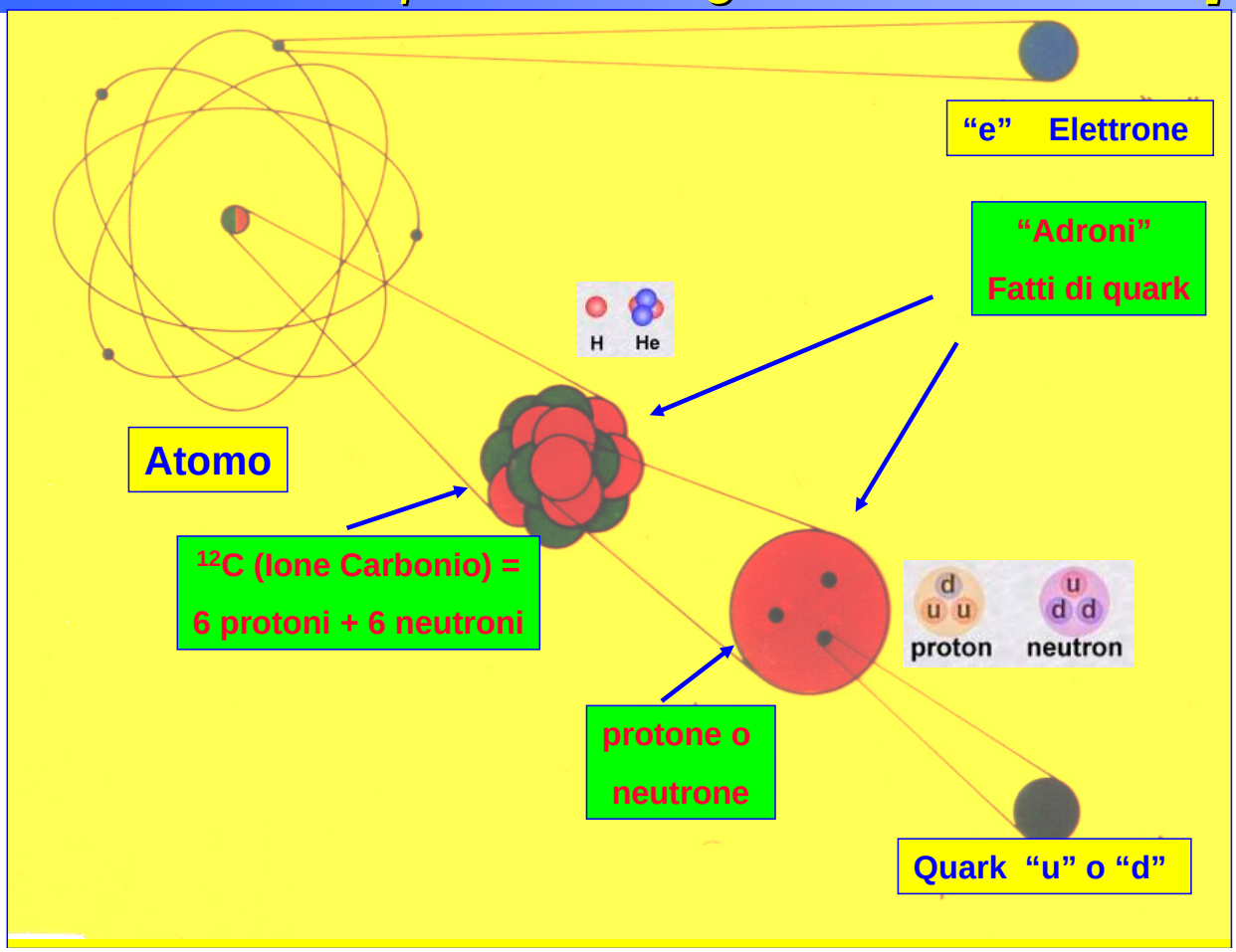


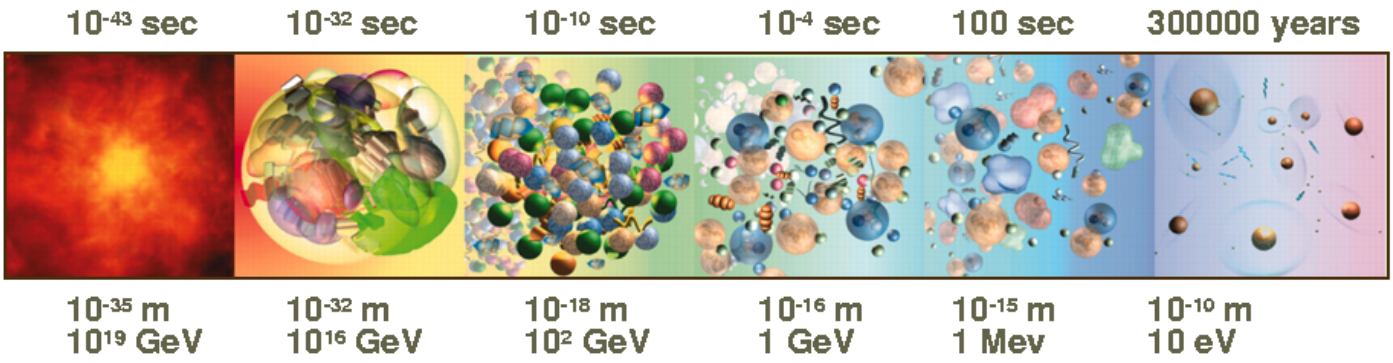
Astrofisica Nucleare e Subnucleare

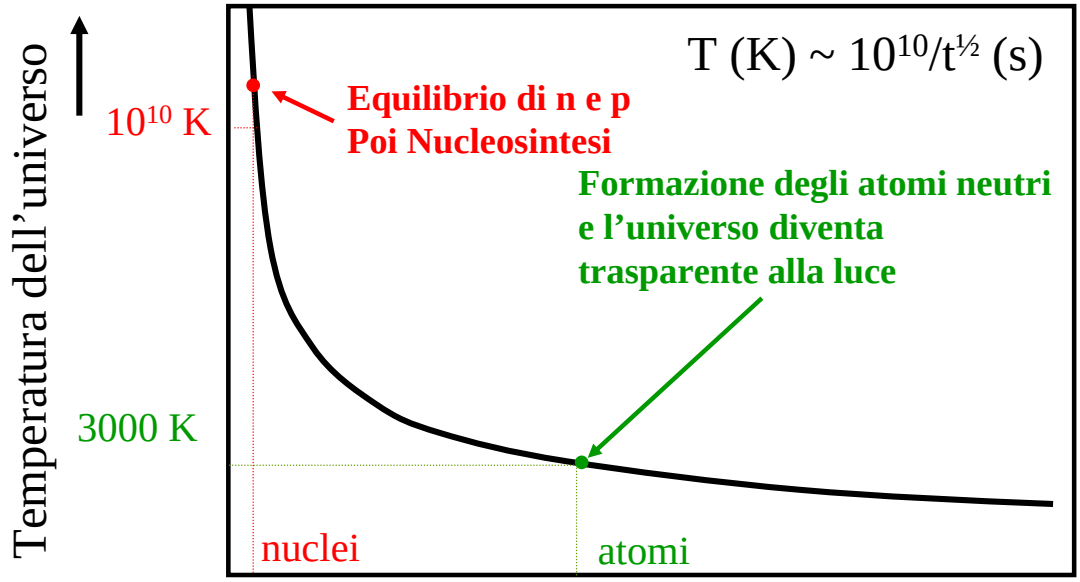
(Fisica Astroparticellare/Astrofisica Particellare)



Atomo → Nucleo → Nucleoni: protoni e neutroni, ADRONI = Fatti di quark: con legame nucleare forte]

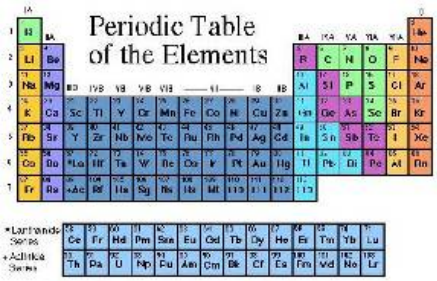


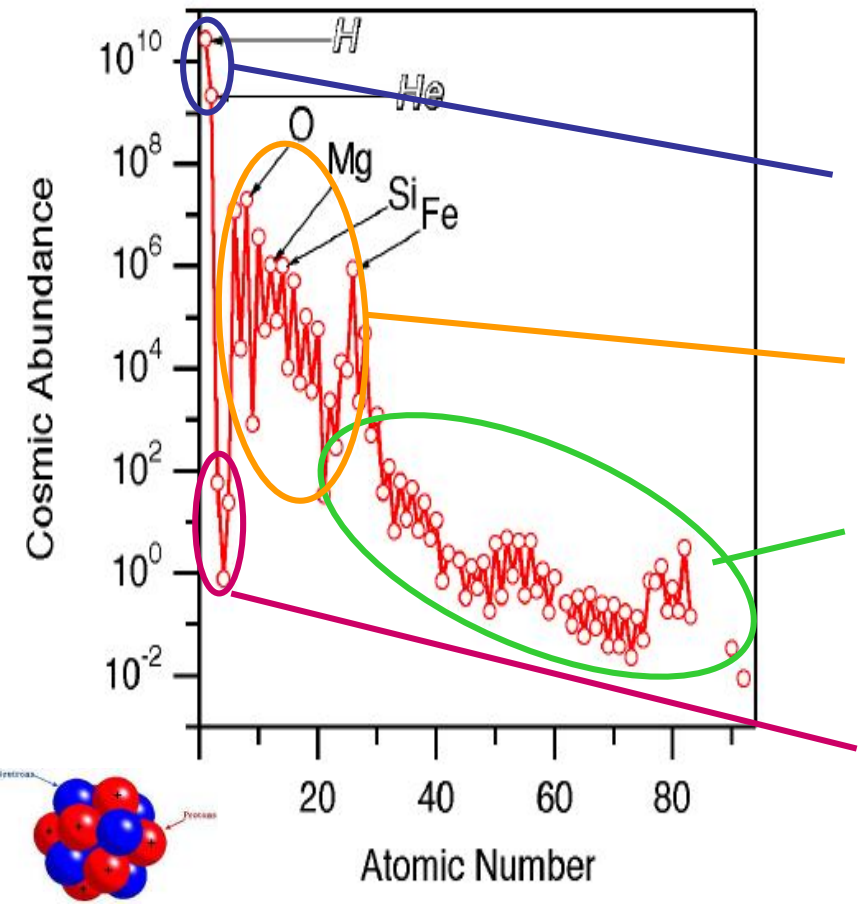




Big Bang

Tavola periodica degli elementi ========== >





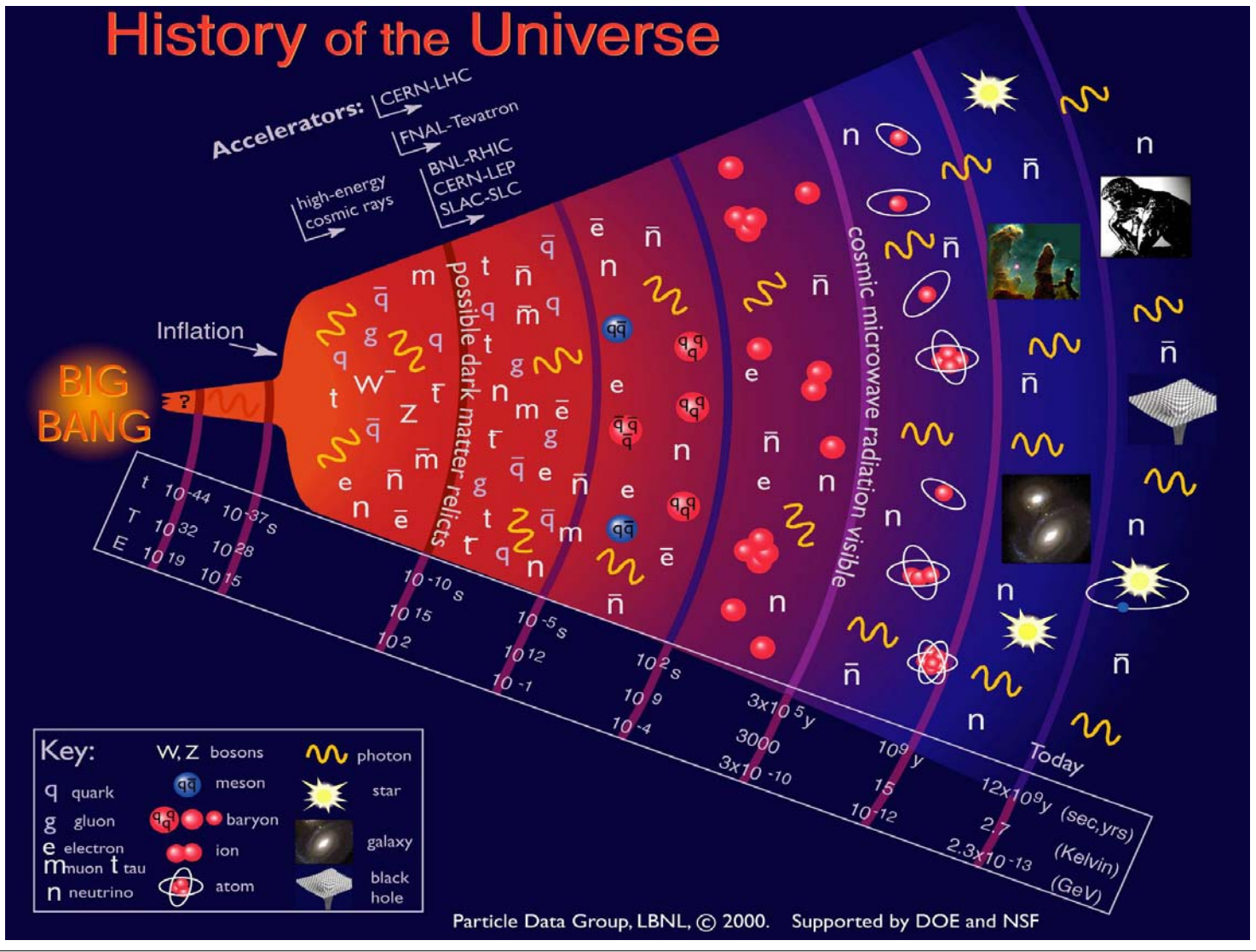
Origine

Big Bang Nucleosintesi

Stelle calde

Esplosioni di Supernova

Interazioni con raggi cosmici



Modello Standard:

FERMIONI
Leptoni e quark
Costituenti Della Materia

e BOSONI
Fotoni/W,Z, gluoni
Portatori di Forza:
Elettromagnetica/
Nucleare Debole,
Nucleare Forte
(G) Gravitazionale?

FERMIONS
matter constituents
spin = 1/2, 3/2, 5/2, ...

Leptons spin = 1/2

Flavor	Mass GeV/c^2	Electric charge
ν_e electron neutrino	$<1\times10^{-8}$	0
e electron	0.000511	−1
ν_μ muon neutrino	<0.0002	0
μ muon	0.106	−1
ν_τ tau neutrino	<0.02	0
τ tau	1.7771	−1

Quarks spin = 1/2

Flavor	Approx. Mass GeV/c^2	Electric charge
u up	0.003	2/3
d down	0.006	−1/3
c charm	1.3	2/3
s strange	0.1	−1/3
t top	175	2/3
b bottom	4.3	−1/3

BOSONS
force carriers
spin = 0, 1, 2, ...

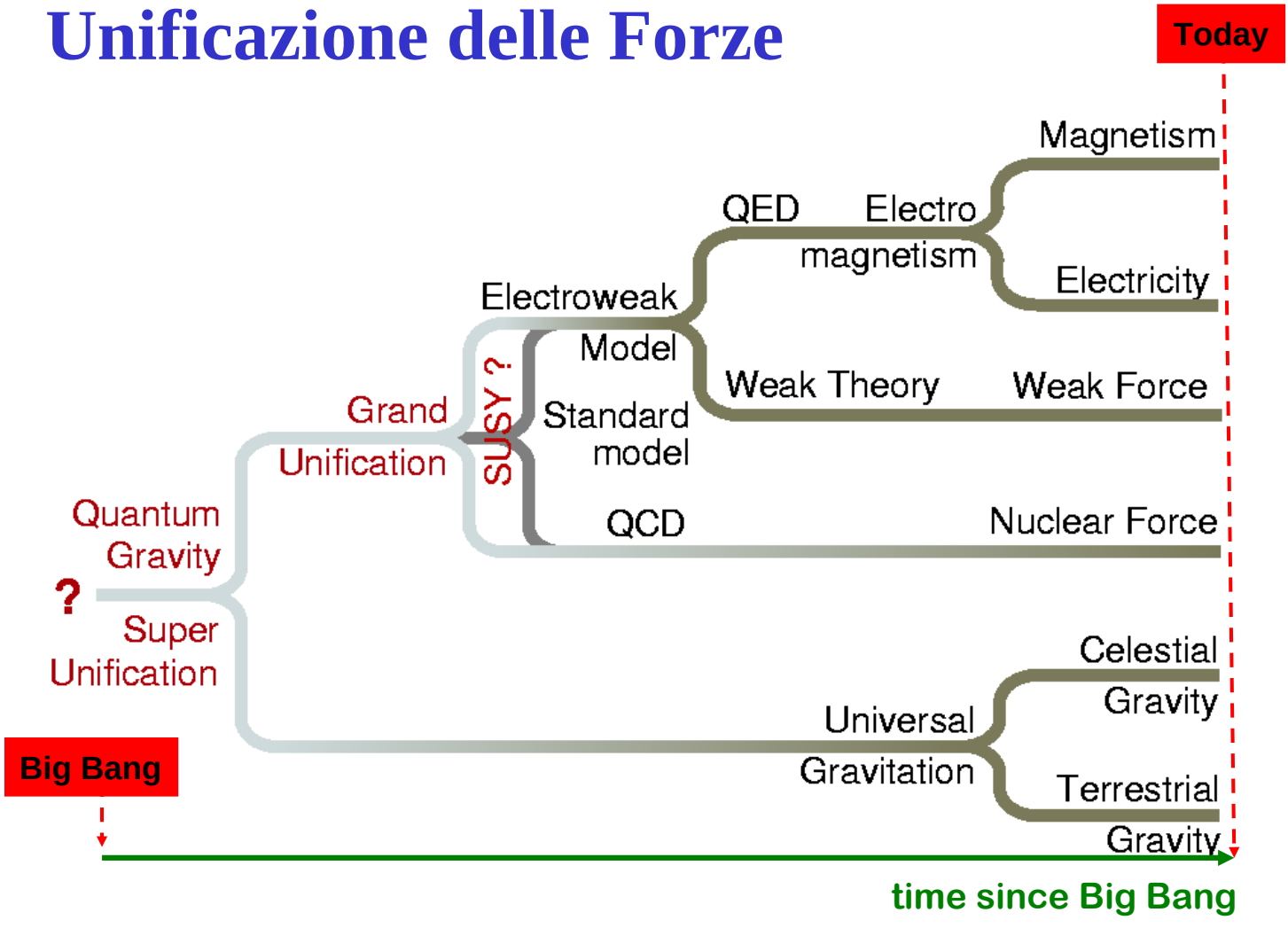
Unified Electroweak spin = 1

Name	Mass GeV/c^2	Electric charge
γ photon	0	0
W^-	80.4	−1
W^+	80.4	+1
Z^0	91.187	0

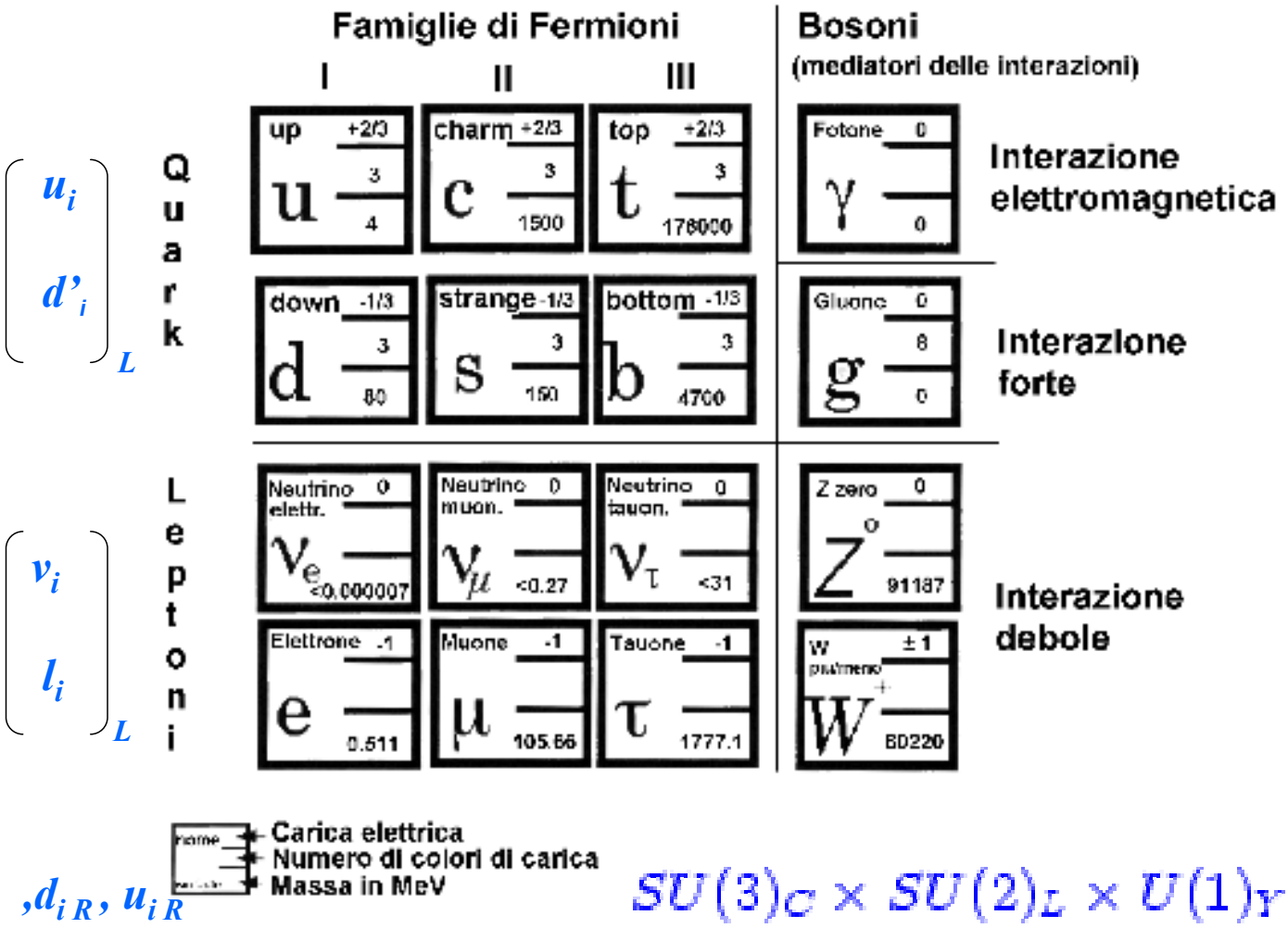
Strong (color) spin = 1

Name	Mass GeV/c^2	Electric charge
g gluon	0	0

Unificazione delle Forze

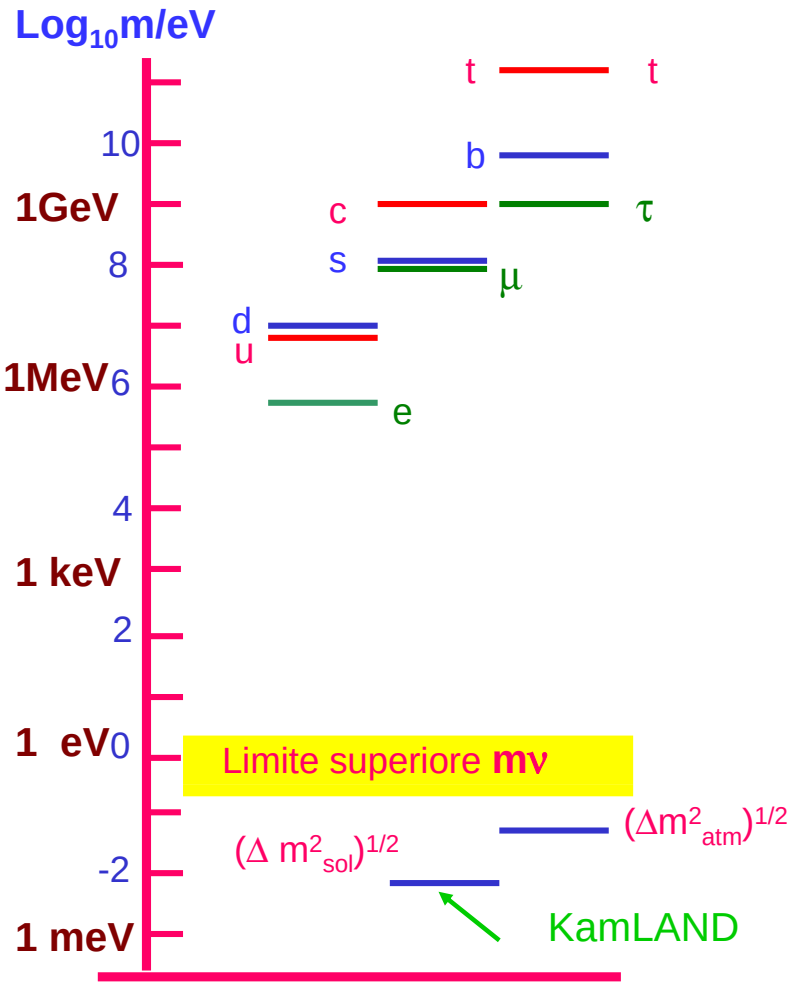


MODELLO STANDARD : Fermioni (Costituenti) e Bosoni (Mediatori)



$$\begin{pmatrix} u_i \\ d'_i \end{pmatrix}_L \qquad \begin{pmatrix} \nu_i \\ l_i \end{pmatrix}_L \qquad l_{iR}\ , d_{iR}, u_{iR}$$

$$SU(3)_C \times SU(2)_L \times U(1)_Y$$



Massa dei fermioni: Quark e Leptoni

ν : Massa=0 ?

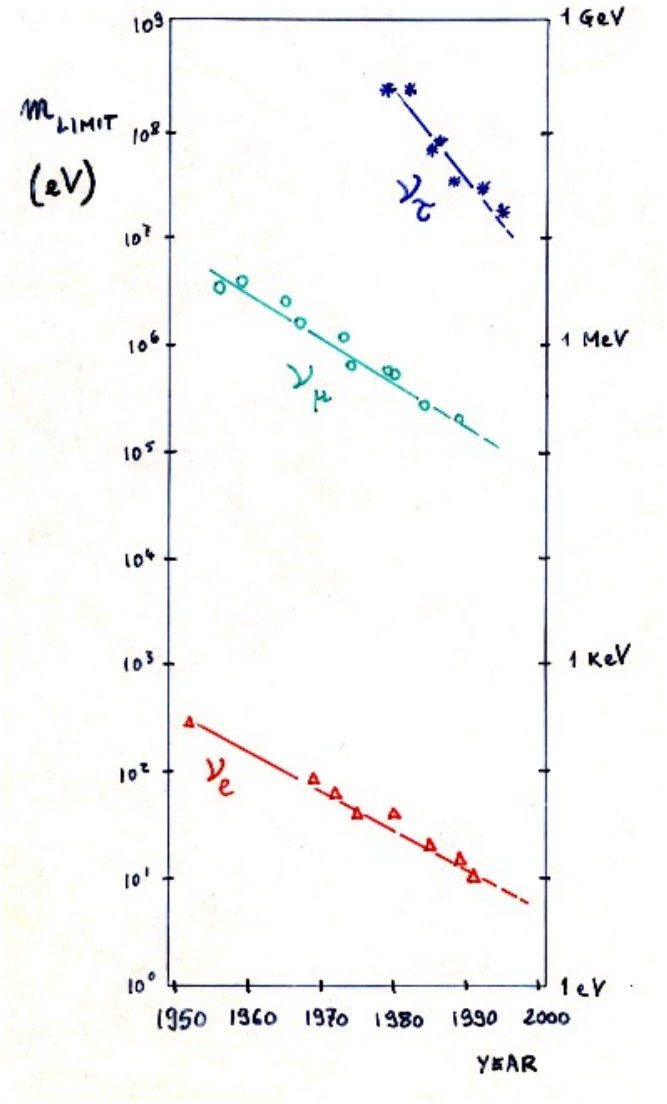
- no ν_R
- numero leptonico L conservato

ν: Massa >0 ?

- ν_R pesante
- numero leptonico L non conservato

Limiti Sperimentali per la Massa dei Neutrini

(50 anni di misure)



Oscillazioni dei Neutrini

- Idea della massa dei neutrini suggerita per la prima volta da Bruno Pontecorvo

I Neutrini Interagiscono (Produzione o Rivelazione) come Autostati dell'Interazione Debole

$|\nu_e\rangle$, $|\nu_\mu\rangle$, $|\nu_\tau\rangle$ =Autostati dell'Interazione Debole

$|\nu_1\rangle$, $|\nu_2\rangle$, $|\nu_3\rangle$ =Autostati di Massa (H → Evoluzione t)

- I Neutrini si propagano (evolvono) come sovrapposizione di autostati di **massa: MESCOLAMENTO**

Mescolamento tra neutrini: p.es. due famiglie

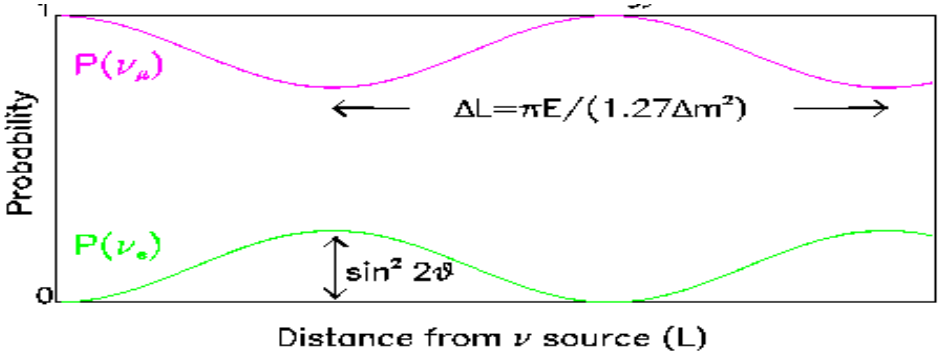
$|\nu_e\rangle = \cos\theta\,|\nu_1\rangle + \sin\theta\,|\nu_2\rangle$

$|\nu_\mu\rangle = -\sin\theta\,|\nu_1\rangle + \cos\theta\,|\nu_2\rangle$

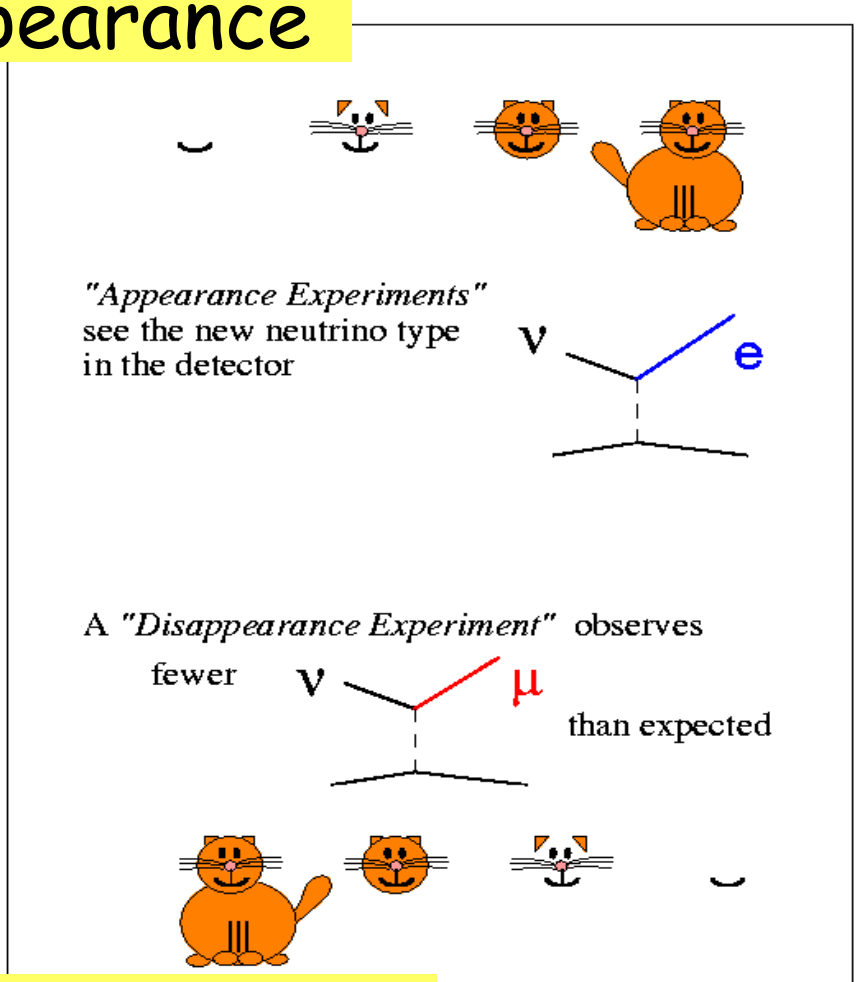
θ = mixing angle
Angolo di mescolamento

$$P_{\nu_\mu\nu_\mu} = 1 - \sin^2 2\theta \cdot \sin^2\left[1.27\frac{\Delta m^2 \cdot L}{E_\nu}\right]$$

- **Distanza percorsa** L=ct (Km)
- **Differenza di massa quadra** $\Delta m^2 = m_2^2 - m_1^2$ (eV^2)
- **Energia del neutrino** Eν (GeV)

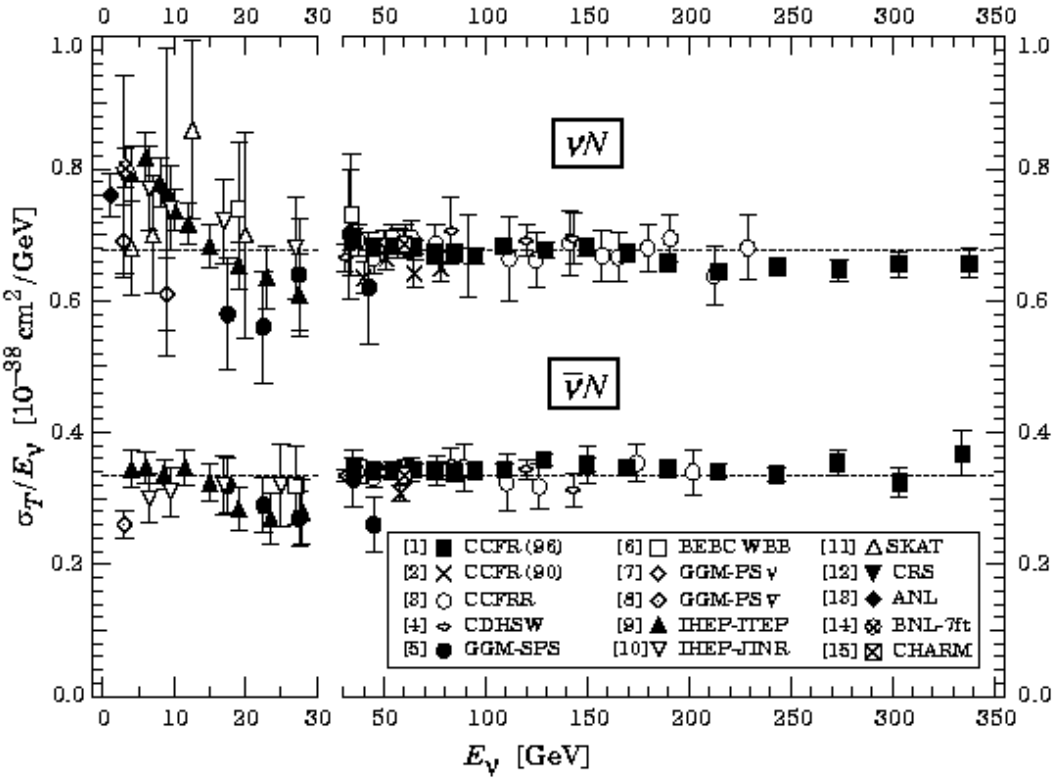


Comparsa/Appearance



Scomparsa/Desappearance

RIVELAZIONE: Interazione Neutrini con la Materia
Cross Section Neutrino-Nucleone



Cross section: $\sigma_\nu \sim 0.5\ 10^{-38}$ cm^2 $\sim 0.5\ 10^{-14}$ b $\sim 10^{-15}\sigma_{rad}$ ($\sigma_{rad} \sim 10$b)

σ_{rad} ➔ $\lambda_{rad} \sim 1$m , σ_ν ➔ $\lambda_\nu \sim 10^{15}$ m ~ 100 UA (> sistema solare)

Esperimenti con Neutrini :

1) Sorgenti (Molto) Potenti

2)Apparati (Molto) Sensibili e (Molto) Massivi

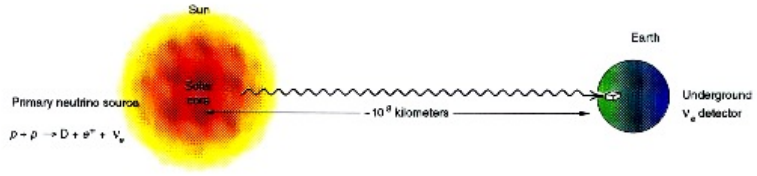
Sorgenti naturali:

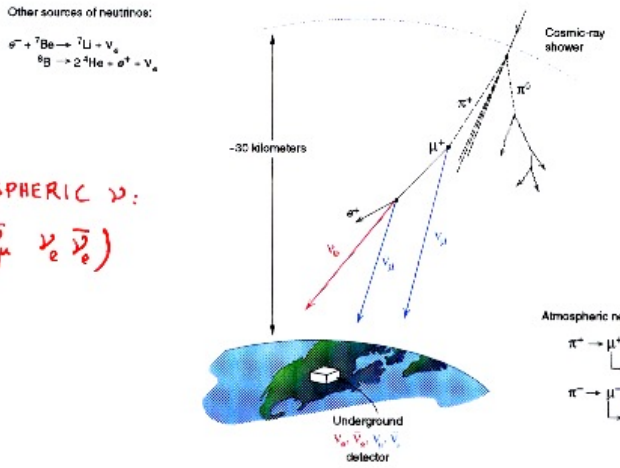
Sole, Supernovae, Raggi cosmici

Sorgenti Artificiali:

Acceleratori, Reattori Nucleari

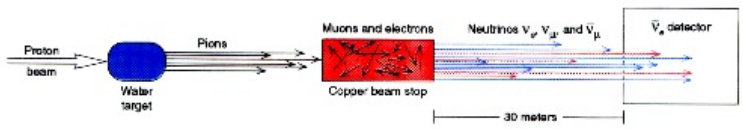
SOLAR ν : (ν_e)





ATMOSPHERIC ν:
(ν_μ $\bar{\nu}_\mu$ ν_e $\bar{\nu}_e$)

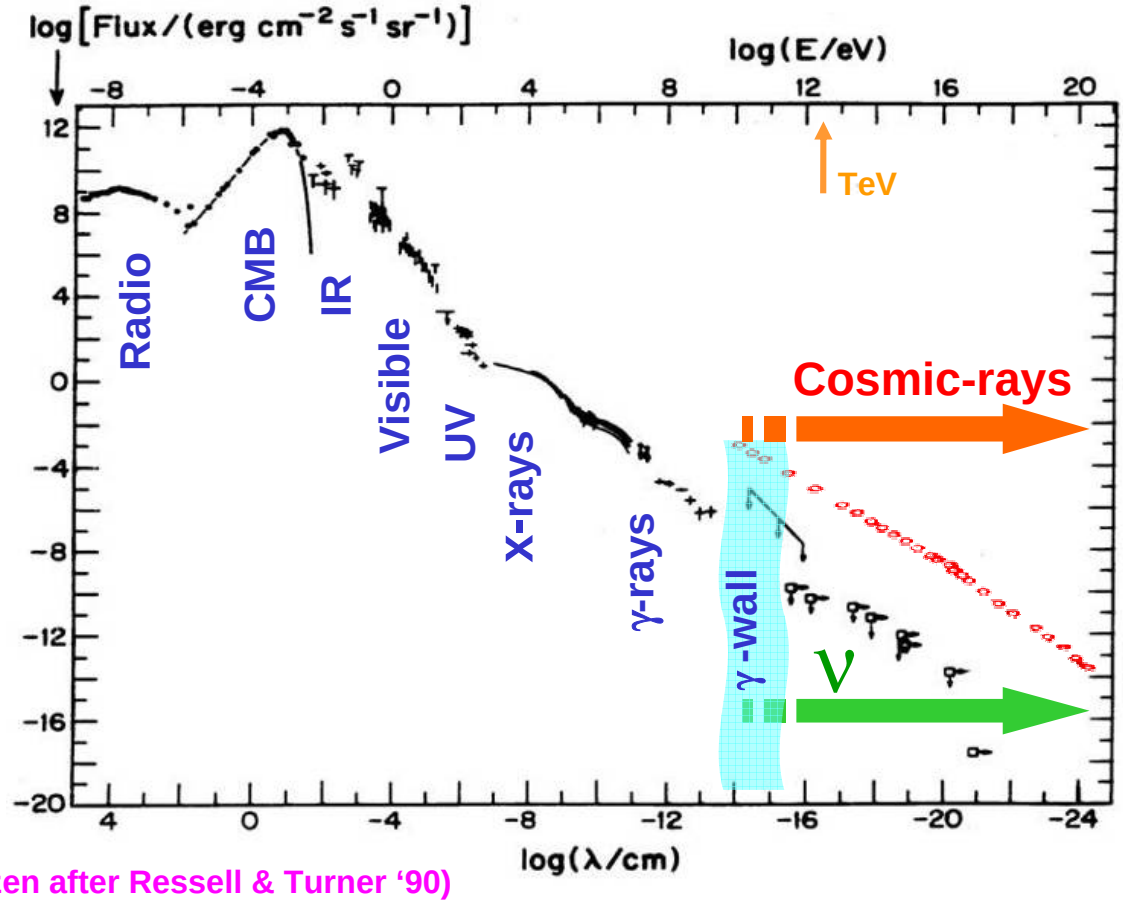
ACCELERATOR ν :
(ν_μ $\bar{\nu}_\mu$ ν_e)



REACTOR ν :
($\bar{\nu}_e$)

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

Cosmic Radiation



(by Halzen after Ressell & Turner '90)

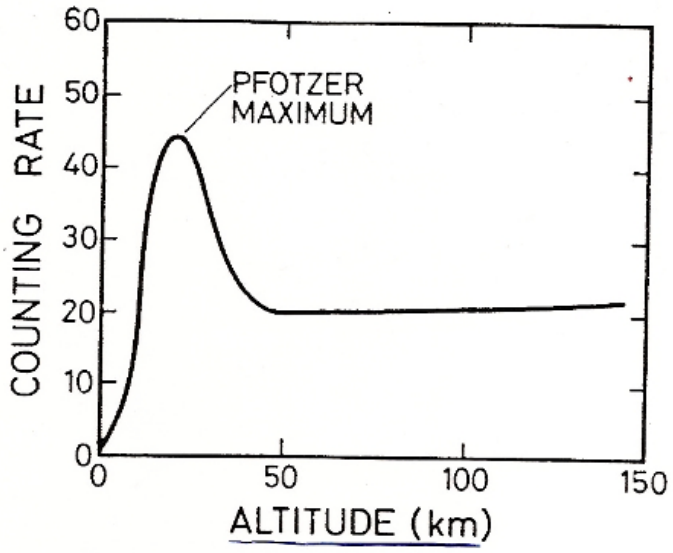
Raggi Cosmici

Colhoster 1914
@ 9km

Altitude (km)	Difference between observed ionisation and that at sea-level (ions cm^{-3}) s^{-1}
1	−1.5
2	+1.2
3	+4.2
4	+8.8
5	+16.9
6	+28.7
7	+44.2
8	+61.3
9	+80.4

Millikan scettico sui "…Raggi … Cosmici" ys"

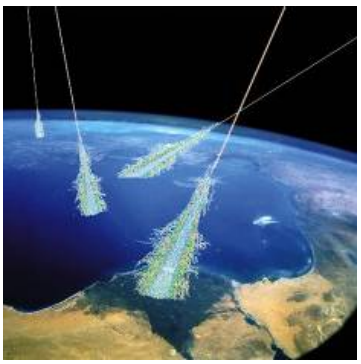
Ascese su Pallone:
Hess 1912 @ 5km

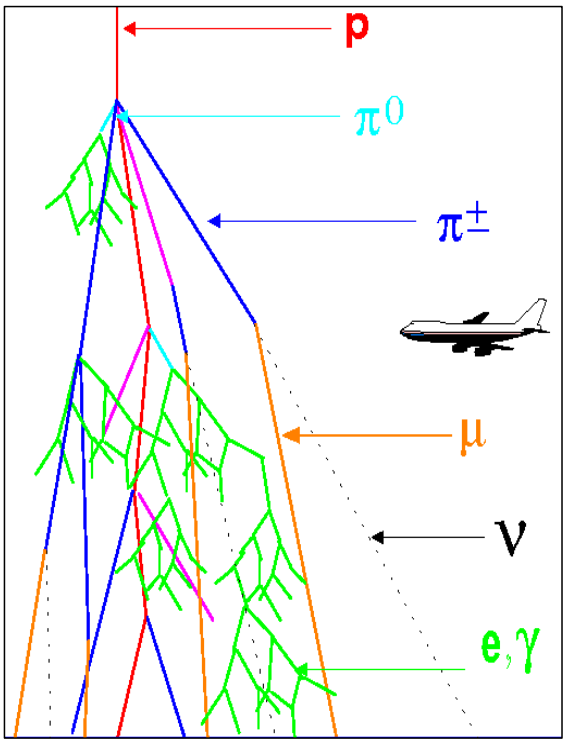


Composizione dei Raggi Cosmici

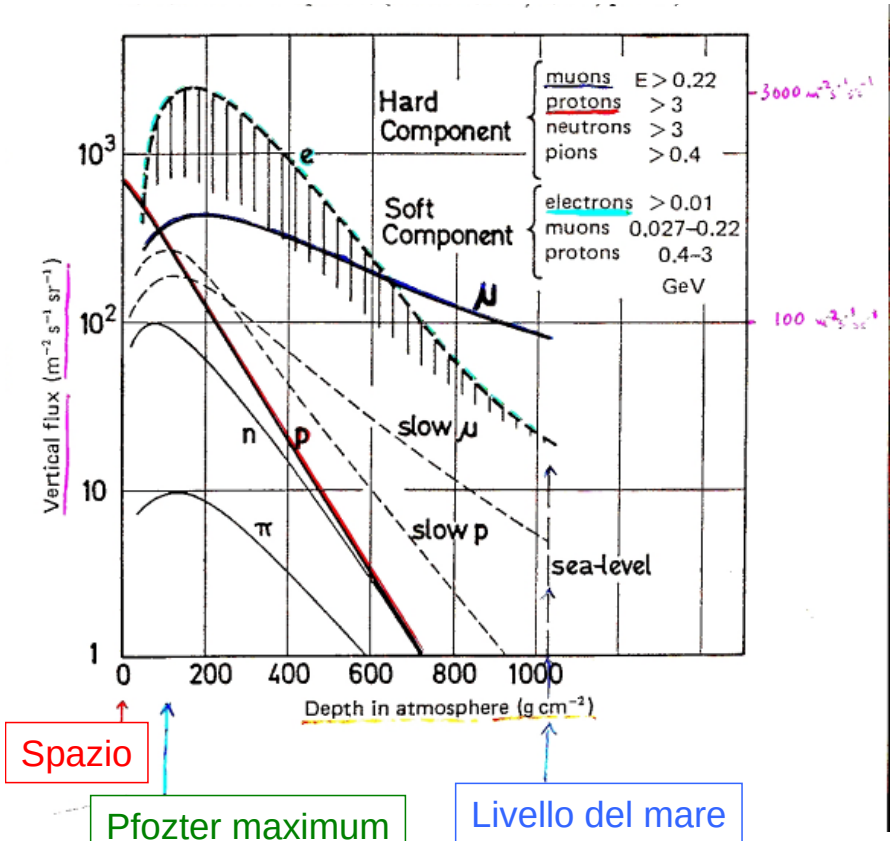
PRIMARI:
p ~ 87 %, α~10 %, N~1 %
e ~2 %
γ ~0.1 %, ν~0.1 % ?

Alta atmosfera :~ 1000/m²/s





SECONDARI al livello del mare
μ ~ 30 %
p, n, ... ~ 2 %
ν ~ 68 %



NOTE: $\tau_0(\mu) = 2.2\ \mu s$

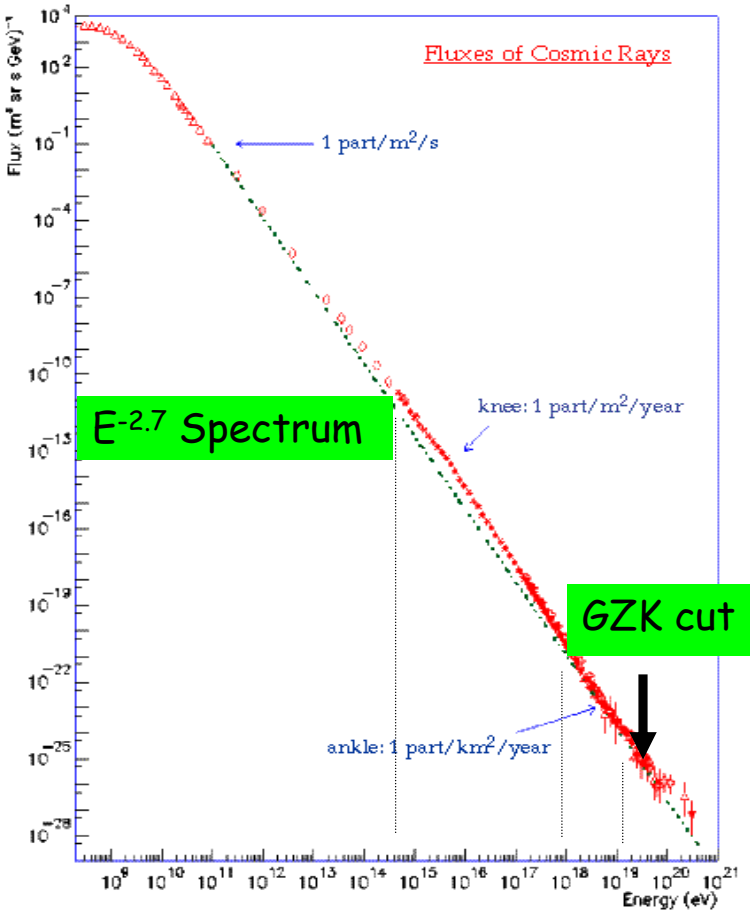
$c\tau_0(\mu) = 2.2 \cdot 10^{-6}\ s \cdot 3 \cdot 10^8\ m s^{-1} = 660\ m$

$E = \gamma m c^2$ $\quad \tau = \gamma \tau_0 \Rightarrow \gamma > 20$ RELATIVISTIC

$m_\mu \simeq 105\ MeV/c^2$

Flusso verticale di Raggi Cosmici vs. profondita' nell'atmosfera

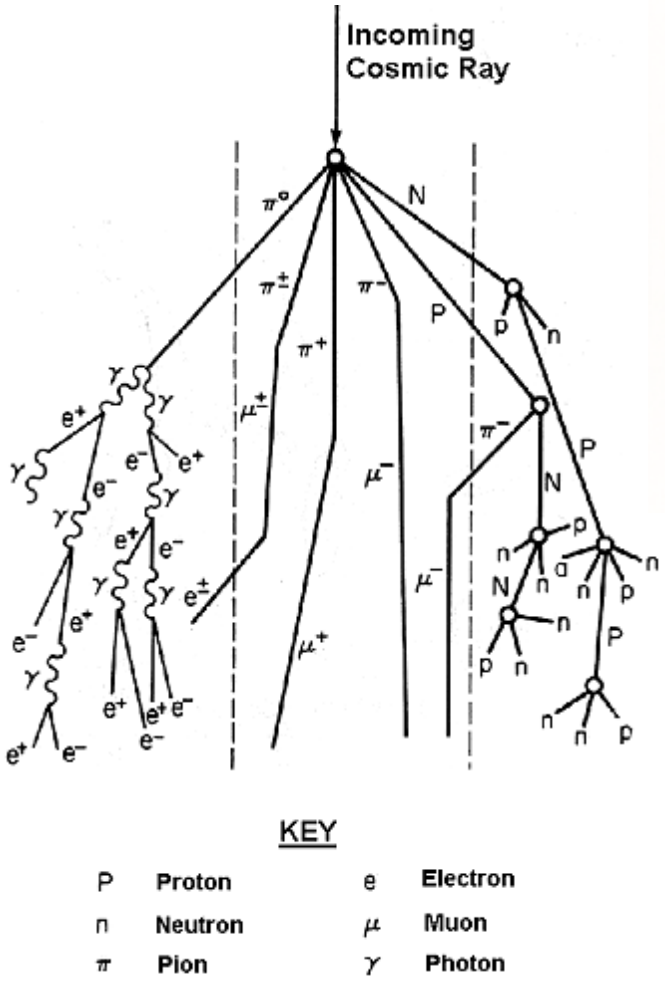
The primary spectrum

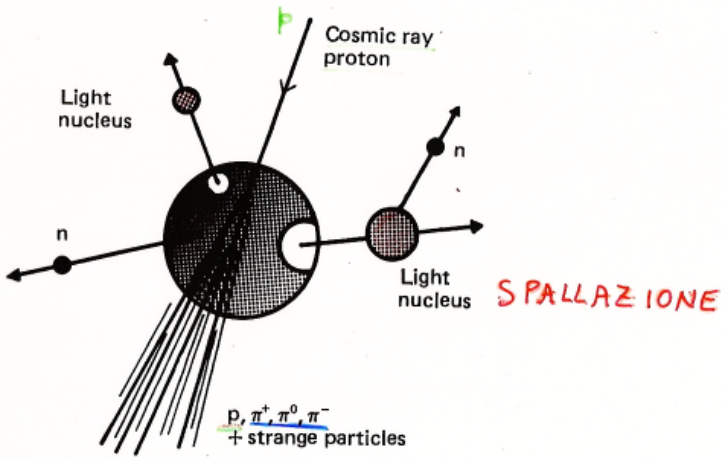


Possible Origins

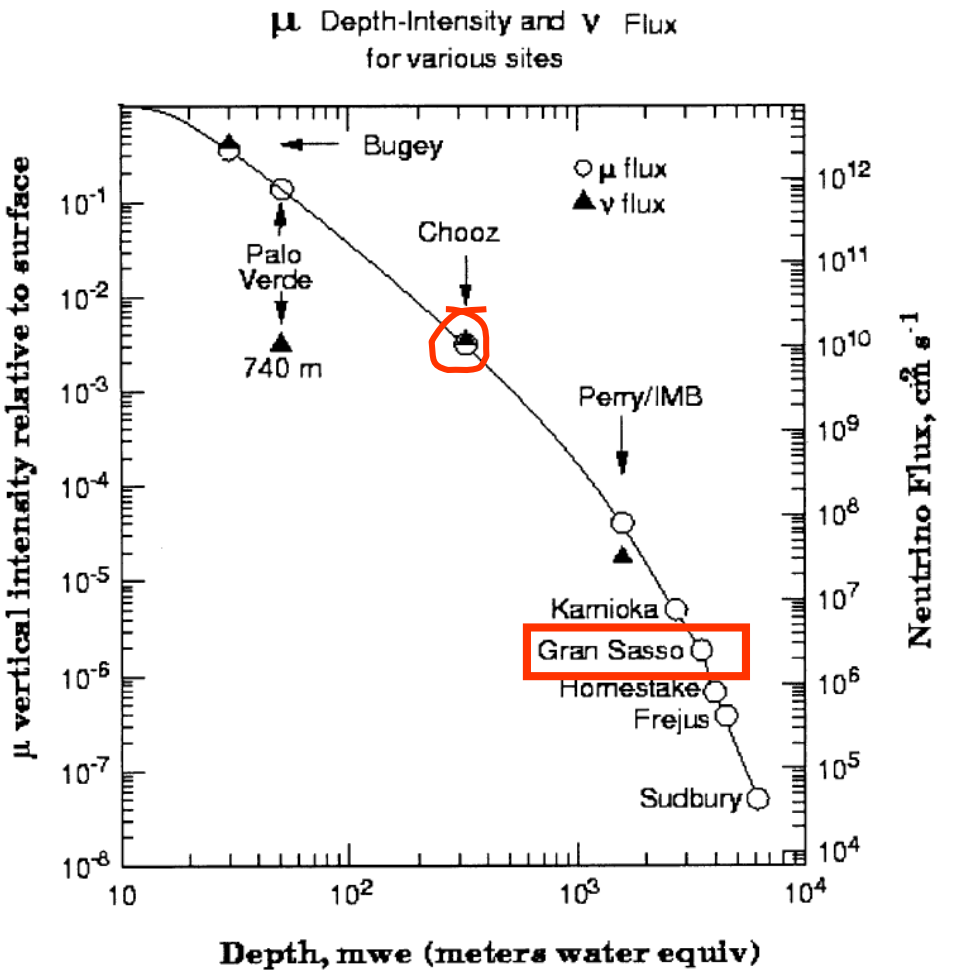
- $E < 10^{15}$ eV Galactic
- $10^{15} < E < 10^{18}$ eV Extra-galactic ?
- UHECR
- $10^{18} < E < 5.\ 10^{19}$ eV Unknown
- EECR
- $5.\ 10^{19} < E < 3.\ 10^{20}$ eV Unexpected

Interazione di Raggi Cosmici primari nell'atmosfera





Flusso di μ



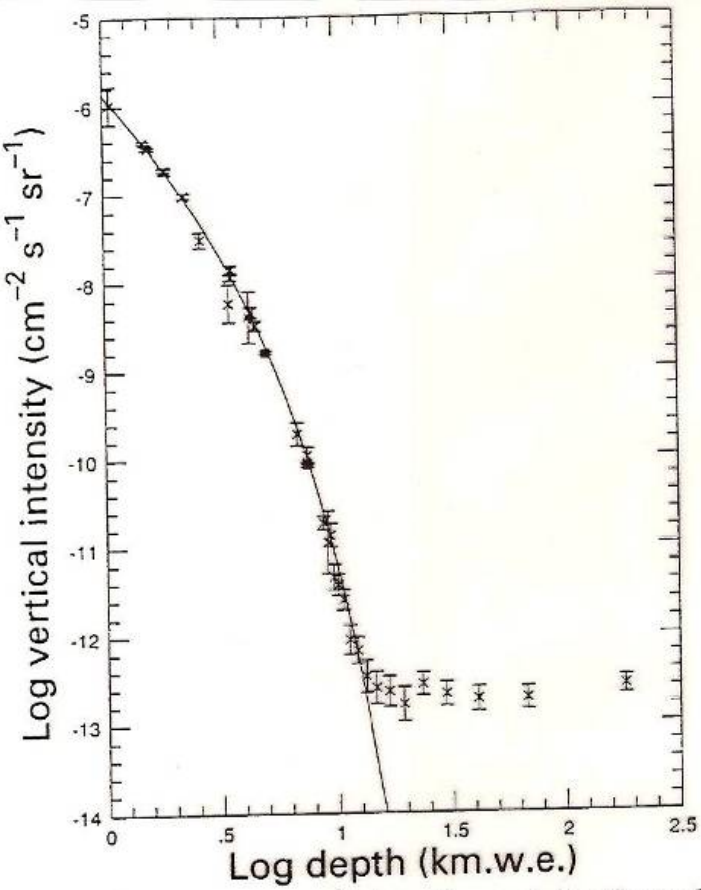
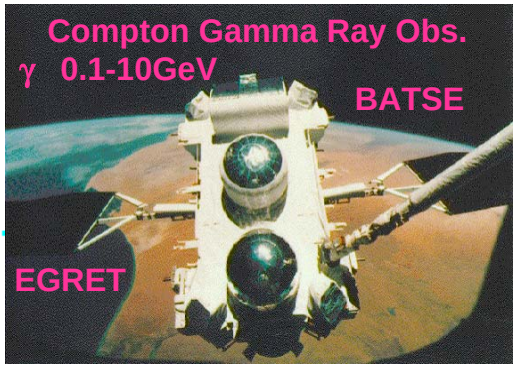


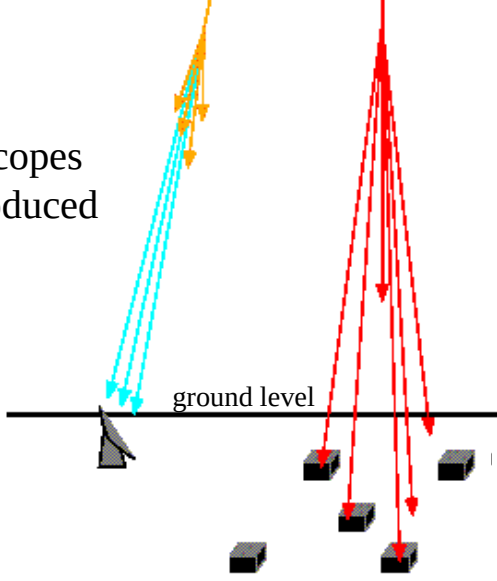
Figure 6.3: Relation between muon intensity and depth underground. The data are taken from a summary by Crouch (1987) with the addition of recent data from the Frejus experiment (Berger et al., 1989 – filled squares).

Rivelatori di raggi cosmici

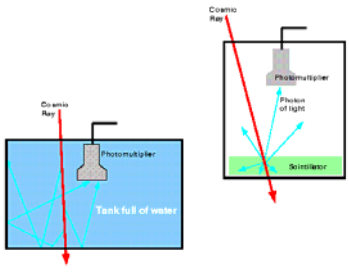
Satellites



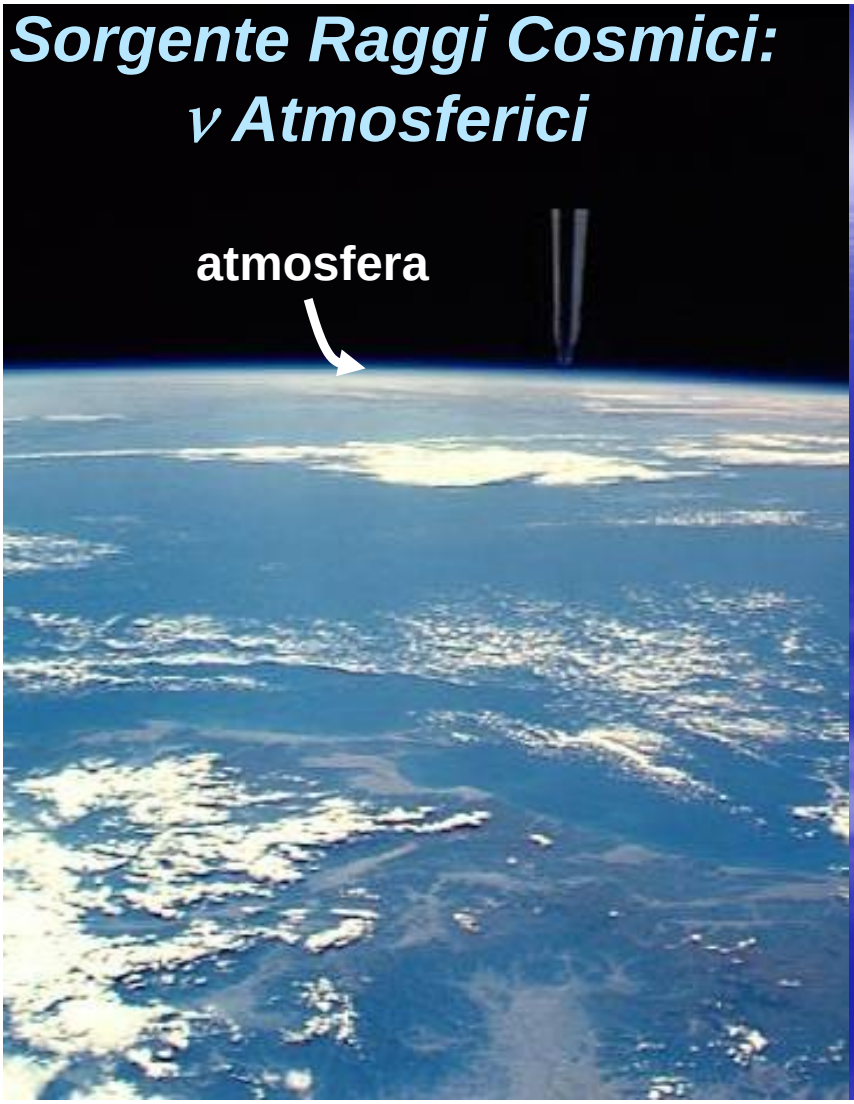
Ground based telescopes looking at light produced in atmosphere

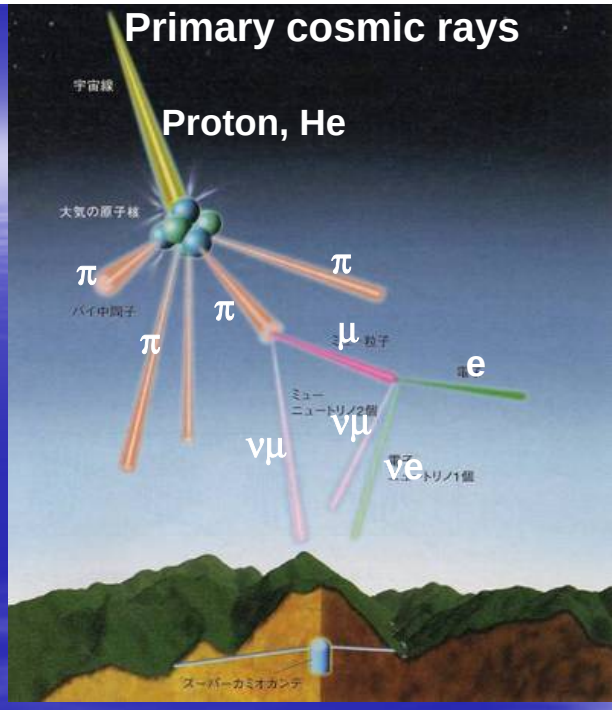


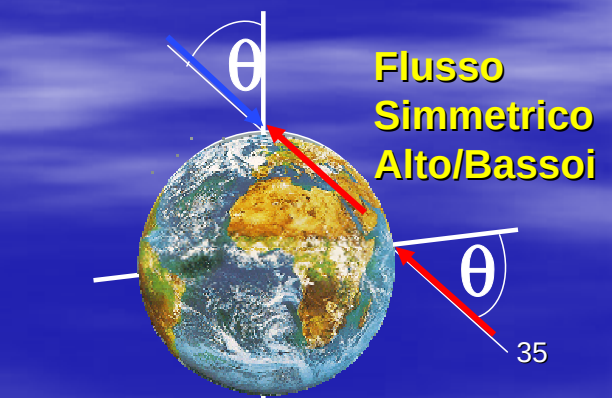
Arrays of particle detectors



Sorgente Raggi Cosmici: ν Atmosferici







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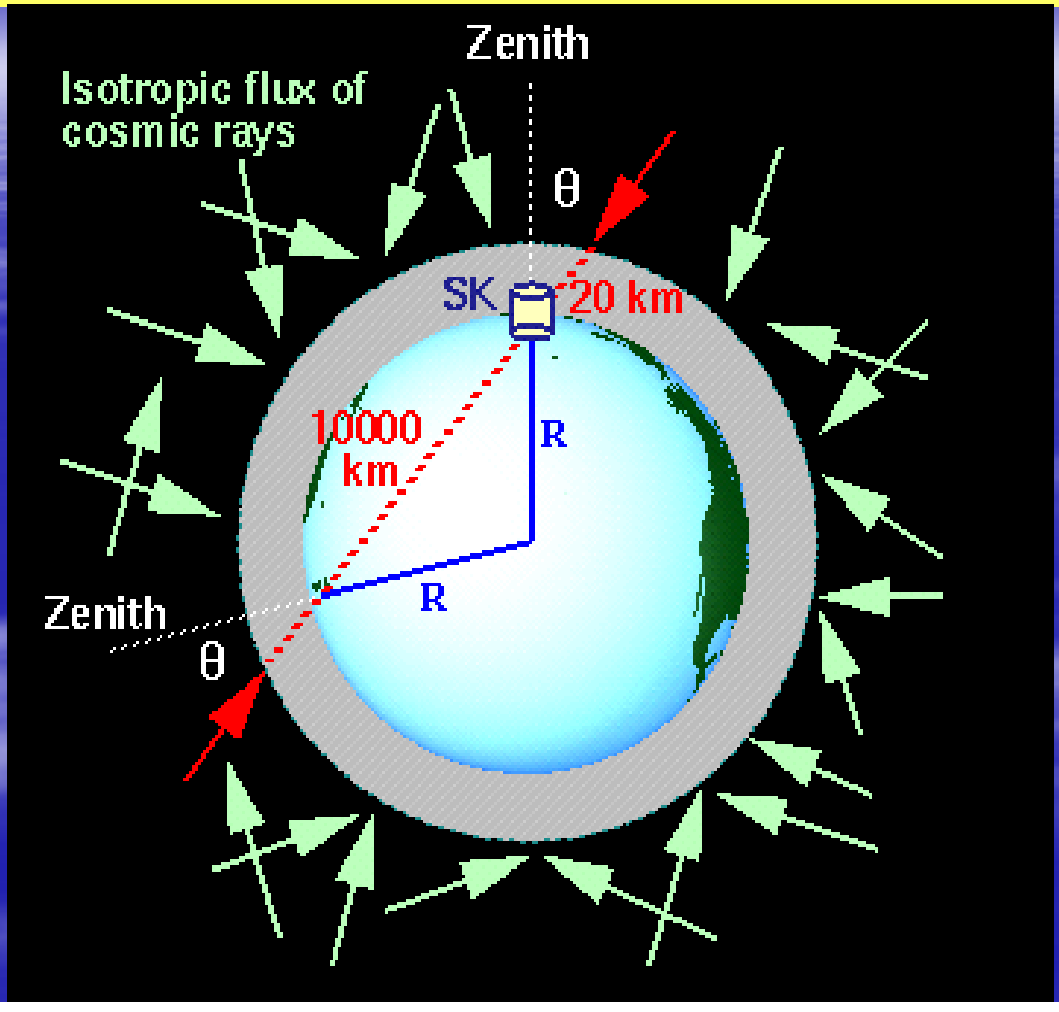
Simmetria Alto/Basso



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The MACRO experiment

1984 : Proposal

1987 : Construction starts

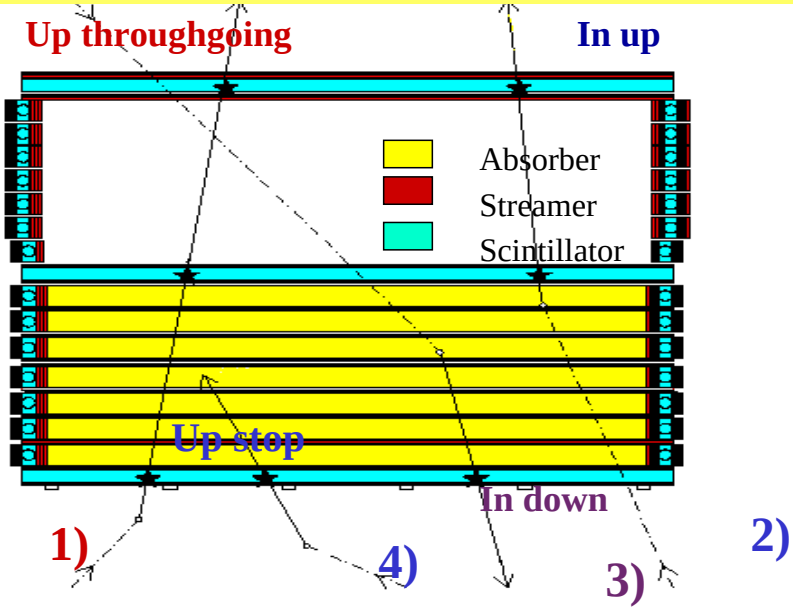
1989 : First Supermodule ON

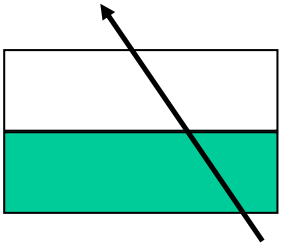
4/1994 : Full detector ON

12/2000 : Rest In Peace

Neutrino event topologies in MACRO

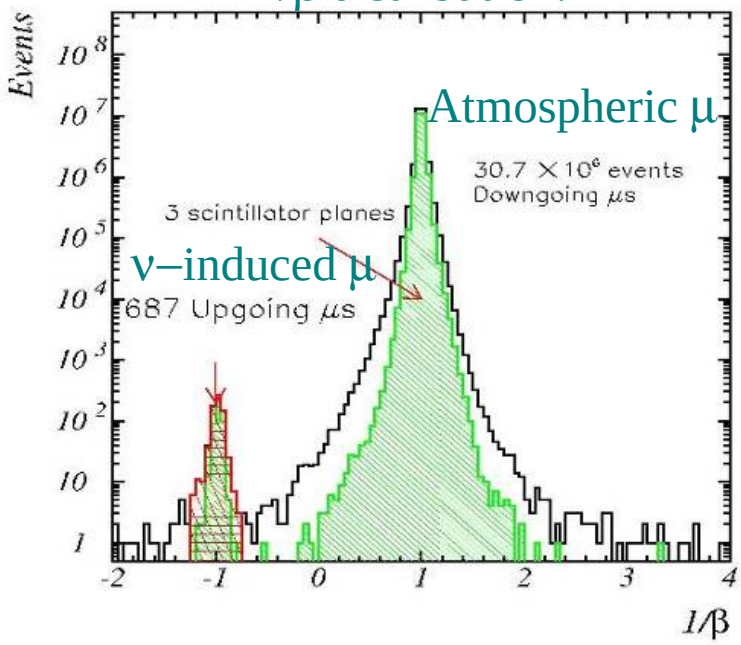
Detector mass ~ 5.3 kton

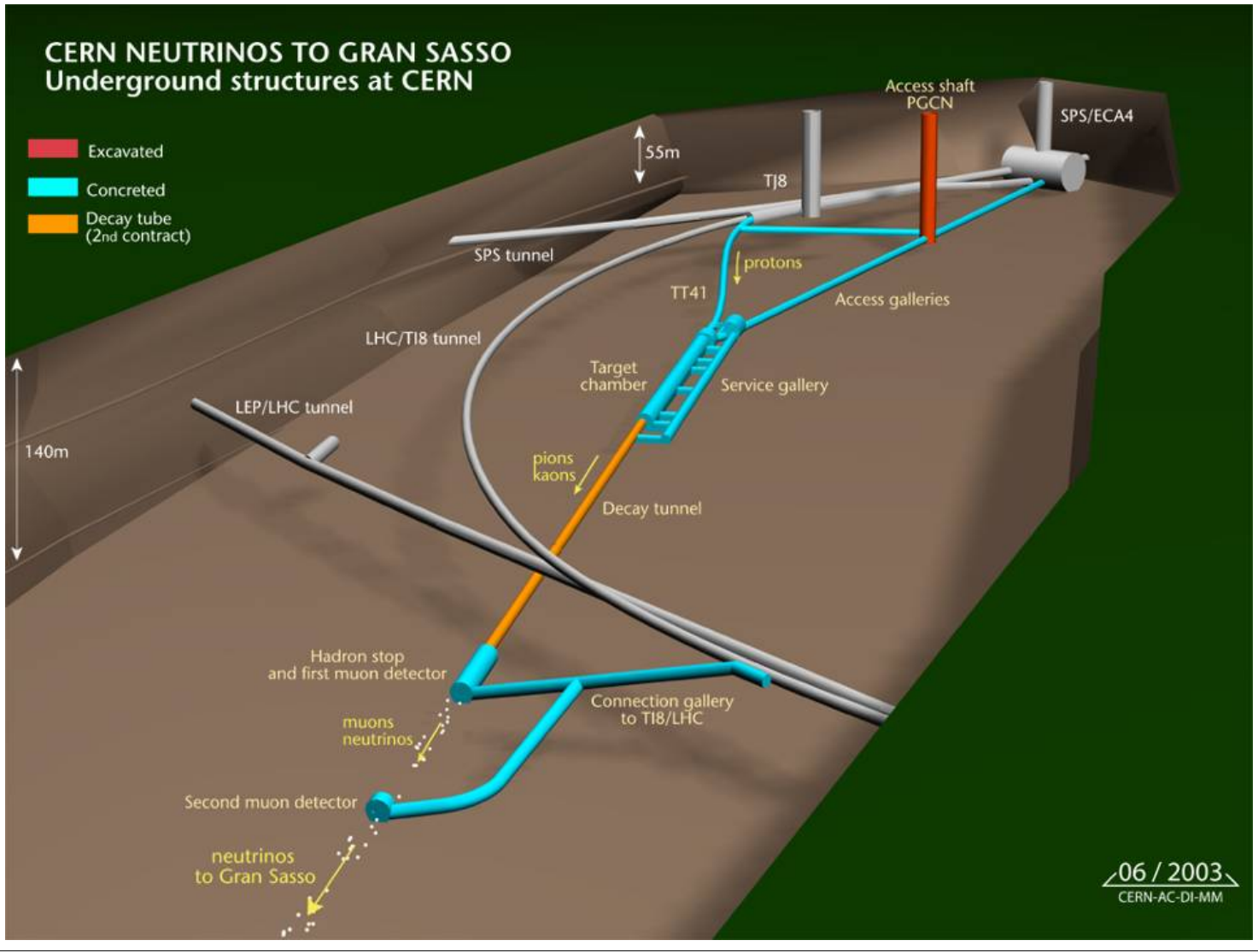




MACRO Upward throughgoing muons

1/β distribution:

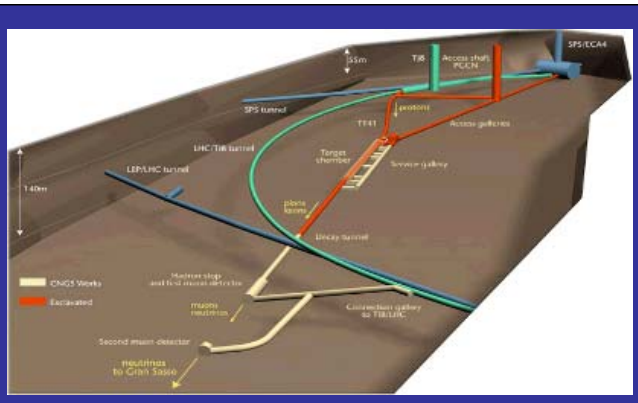




ν beam from CERN:

OPERA

ICARUS



Fundamental physics

VIP

PRESENT EXPERIMENTS

ββ decay and rare events

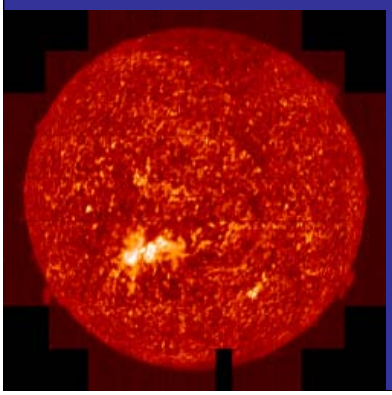
Cuoricino

CUORE; GERDA

Dark Matter

DAMA/LIBRA; CRESST

WARP; Xenon test



Solar ν

Luna

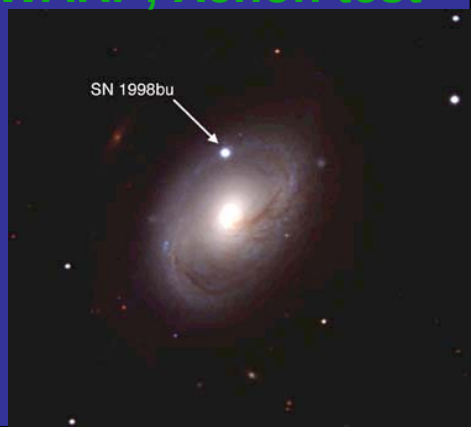
Borexino

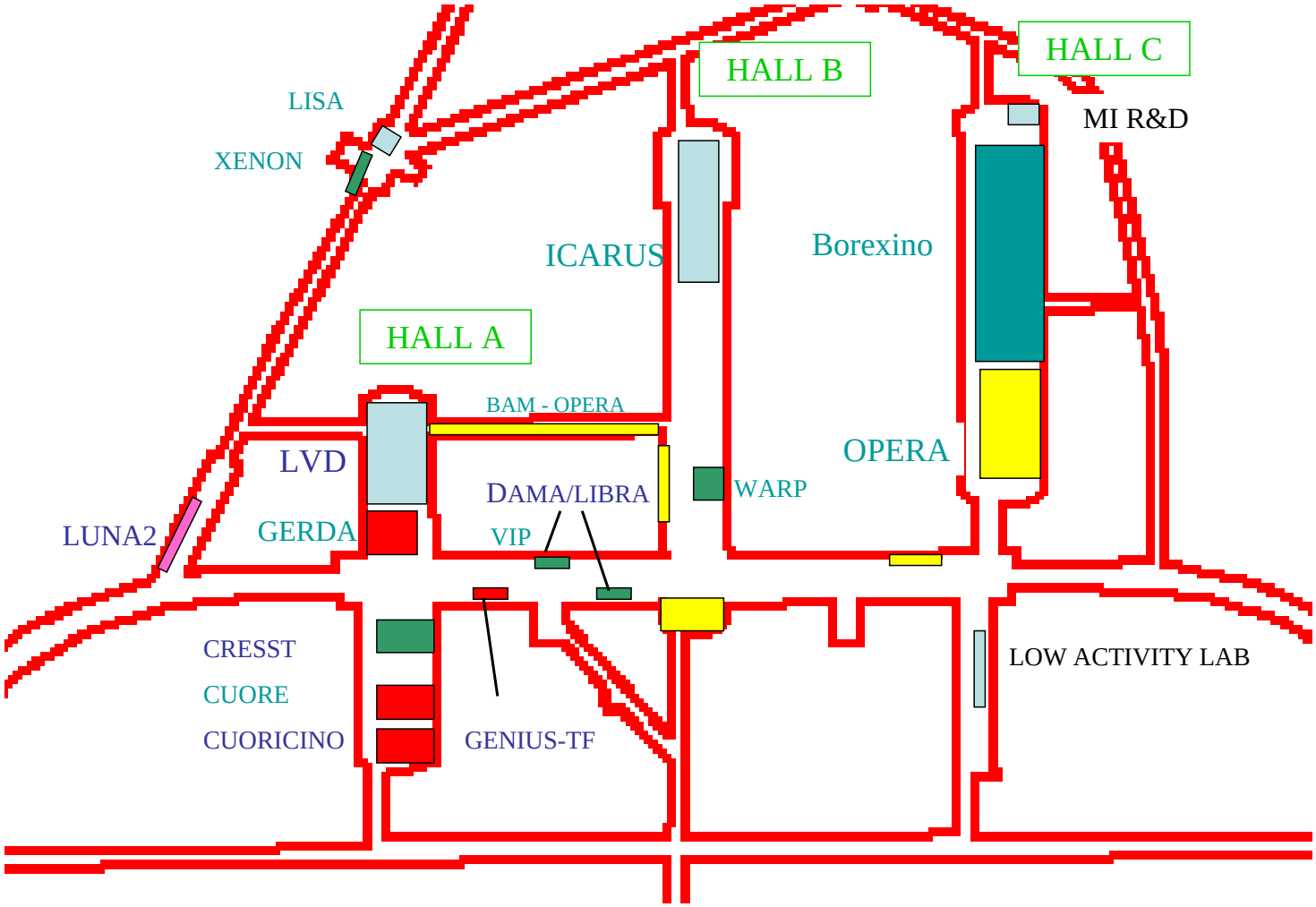
ν from Supernovae

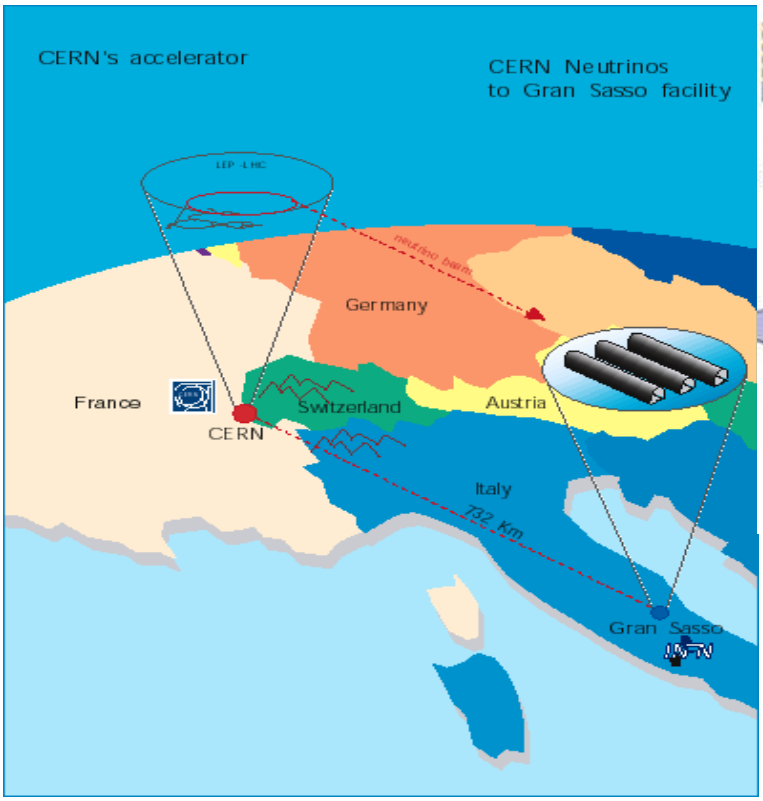
LVD

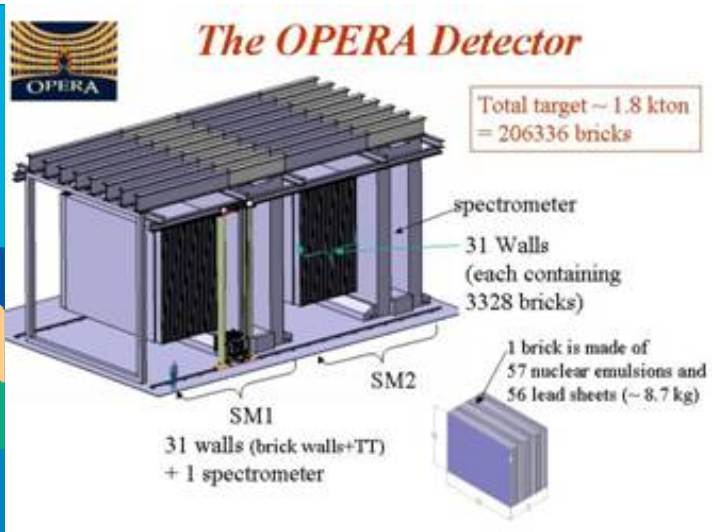
Borexino

ICARUS









OPERA

detector: 1.8 kton of Pb sheets and nuclear emulsions in the form of 230000 emulsion cloud chambers + 2 spectrometers (RPC and scintillating fibers)

goal: detection of ν_τ appearance from the ν_μ beam from CERN

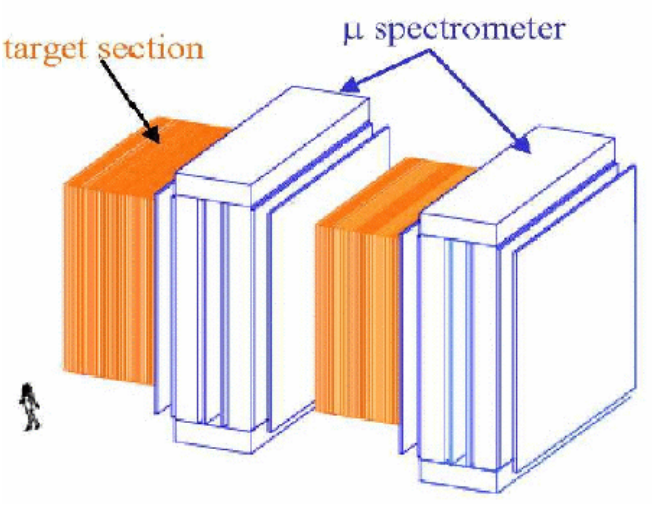
technique: identification of the tracks from decay of the τ emitted by the ν_τ interaction

status: under construction; spectrometers completed

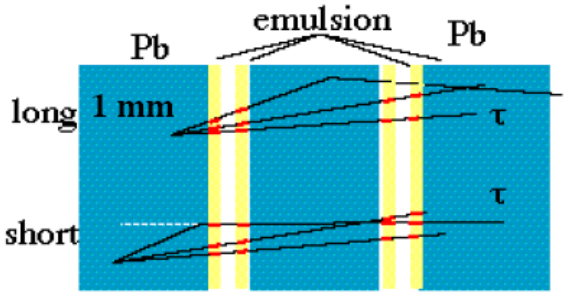
detector should be completed in 2006, ready for the ν beam from CERN

OPERA

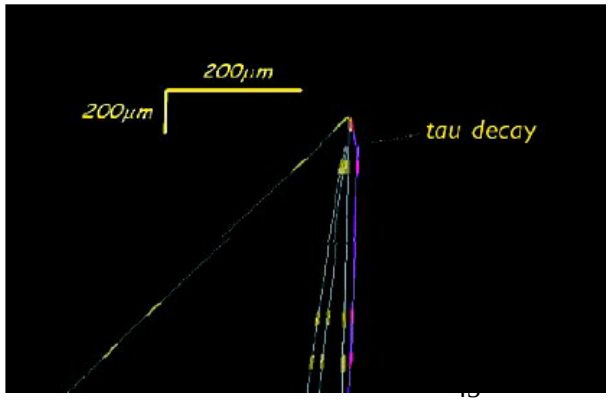
Collab.:
Italy, France, China, Germany, Belgium, Turkey, Switzerland, Russia, Japan, Israel, Croatia



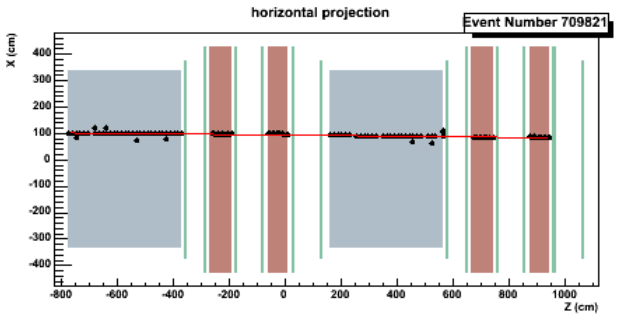
Layers of emulsions and Lead

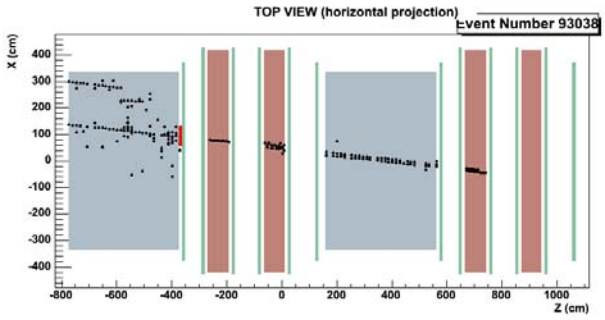


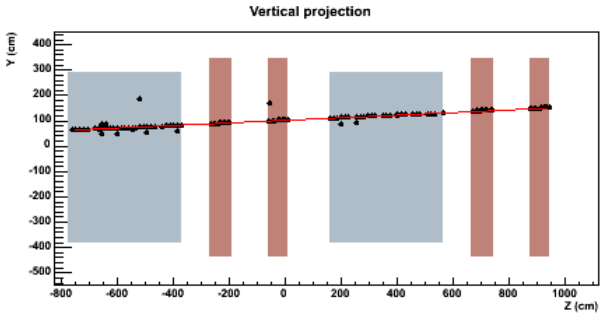
2 super-modules
1800 t sensitive mass
To detect τ is necessary a μm resolution because the τ decays in a really short time

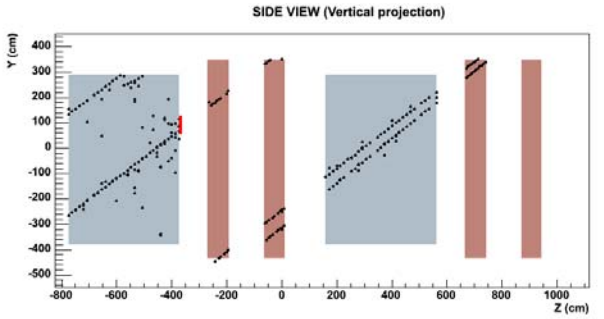


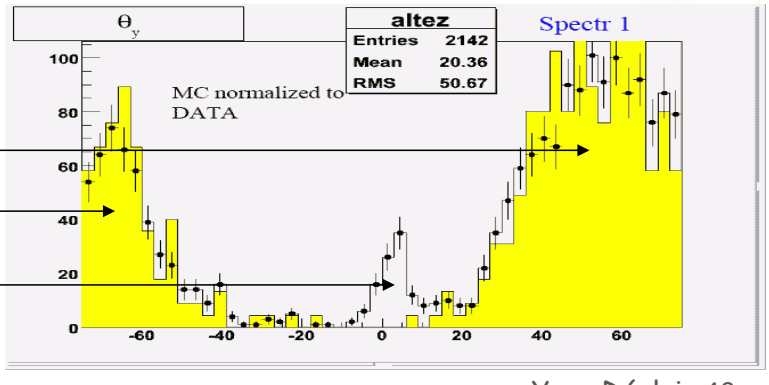
INFN









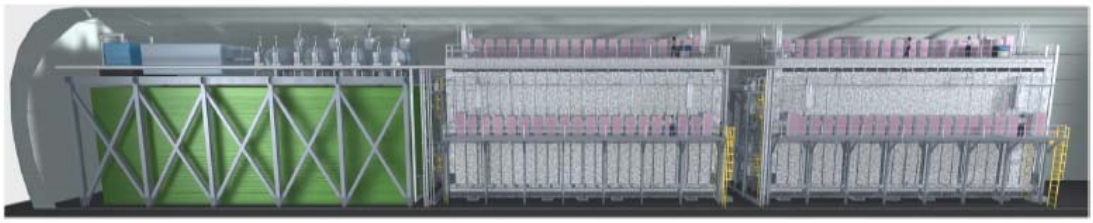


Cosmic rays induced events: Mostly down going

Beam events: ~horizontal tracks

ICARUS Imaging Cosmic and Rare Underground Signals

First Unit T600 | T1200 | T1200

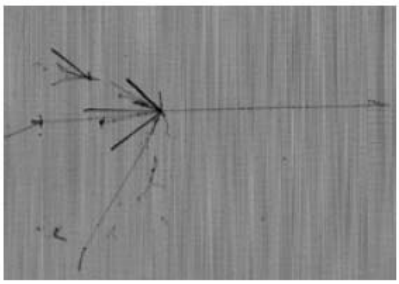


Liquid Argon (-176 °C)

Collaboration:
Italy, Poland, China
Spain, Switzerland, USA

First half of T600 module successfully operated in Pavia
Expect to install T600 in 2004
T3000 detector proposed as a series of five T600 modules

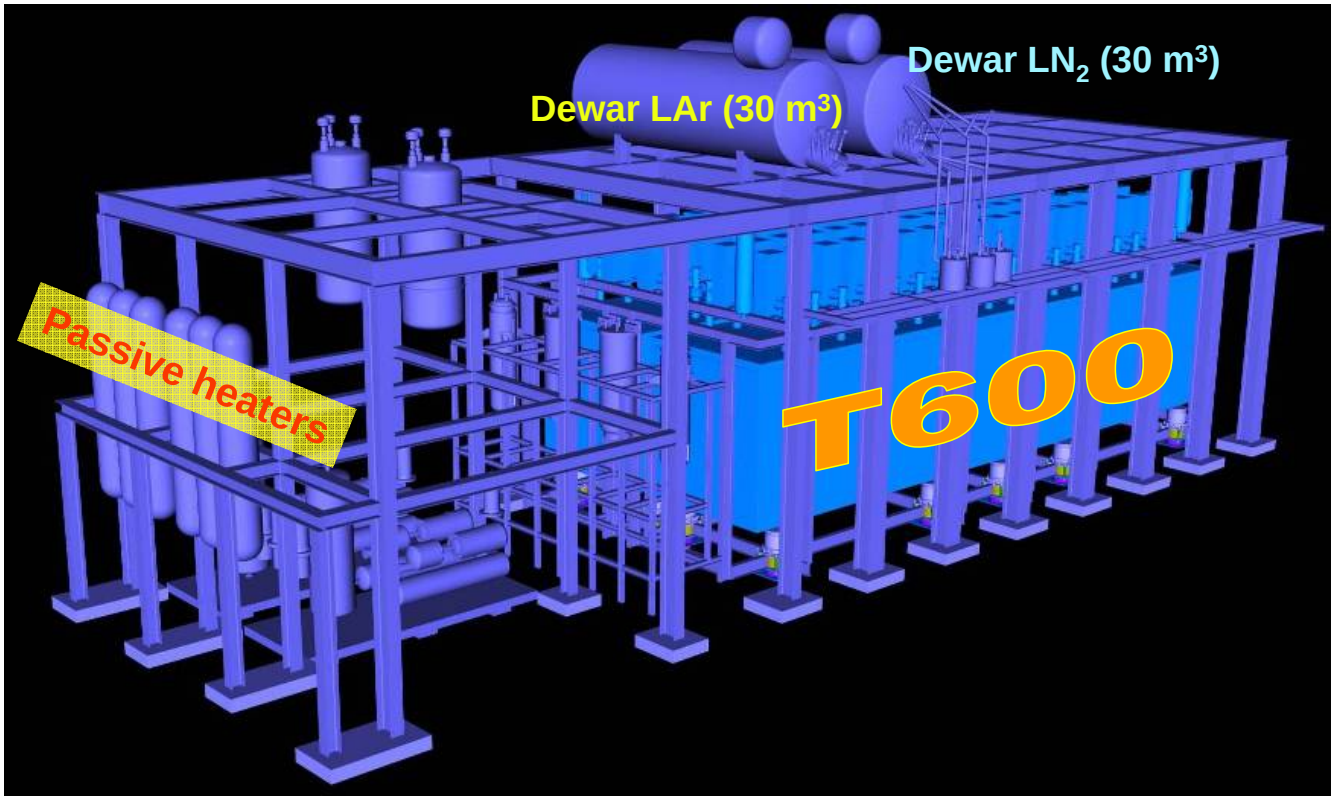
- Wide physics program
  - ν_τ and ν_e appearance on CNGS
  - atmospheric neutrinos
  - supernova neutrinos
  - solar neutrinos
  - proton decay



INFN 17 m

ICARUS
detector: 600 t and later 3000 tons of liquid Ar operated as a large time projection chamber
goal: detection of ν_τ appearence from the ν_μ beam from CERN
detection of solar neutrinos
technique: kinematic identification of the decay of the τ emitted by the ν_τ interaction
status: 600 t detector tested and ready to be installed at LNGS
Installation of 3000 t requires major works at the underground infrastructure

ICARUS T600 General layout



Installation in progress in Gran Sasso Hall B, commissioning after summer 2007

LUNA Laboratory for Underground Nuclear Astrophysics

udy of the cross section of nuclear reactions at stellar ergies

particular for pp chain

pp chain

2 accelerators: 50kV - 400kV

400 kV accelerator

$^{14}N(p,\gamma)^{16}O$ (CNO cycle)

Collab.:
Italy, Germany, Hungary
USA, Portugal

$p + p \rightarrow d + e^+ + \nu_e$

$d + p \rightarrow {}^3He + \gamma$

84.7 %

13.8 %

$^3He + {}^3He \rightarrow \alpha + 2p$

$^3He + {}^4He \rightarrow {}^7Be + \gamma$

13.78 %

0.02 %

$^7Be + e^- \rightarrow {}^7Li + \gamma + \nu_e$

$^7Be + p \rightarrow {}^8B + \gamma$

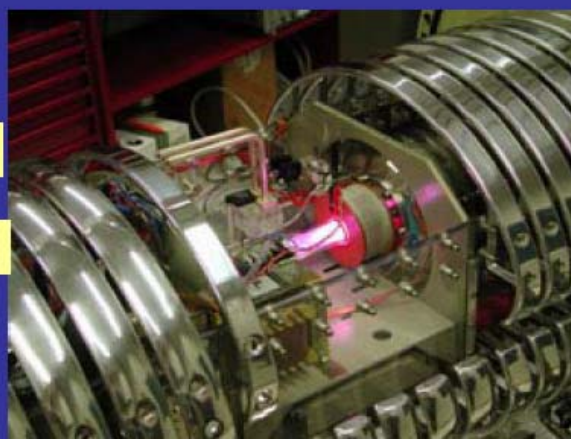
$^7Li + p \rightarrow \alpha + \alpha$

$^8B \rightarrow 2\alpha + e^+ + \nu_e$

50 kV accelerator
3He(3He,2p)4He - D(p,γ)^{3}He

in 2003

INFN



LVD Large Volume Detector

Collab.:
Italy, Brazil, Russia, USA, Japan

Running since 1992

1000 billions ν in 20s from the SN core

Measurement of neutrinos spectra and time evolution provides important information on ν physics and on SN evolution.

Neutrino signal detectable from SN in our Galaxy or Magellanic Clouds

2 - 5 SN/century expected in our Galaxy.

Plan for multidecennial observations

1000 tons liquid scintillator + layers of streamer tubes

300 ν from a SN in the center of Galaxy (8.5 kpc)

SN1987A

Early warning of neutrino burst important for astronomical observations with different messengers (photons, gravitational waves)

SNEWS = Supernova Early Warning System

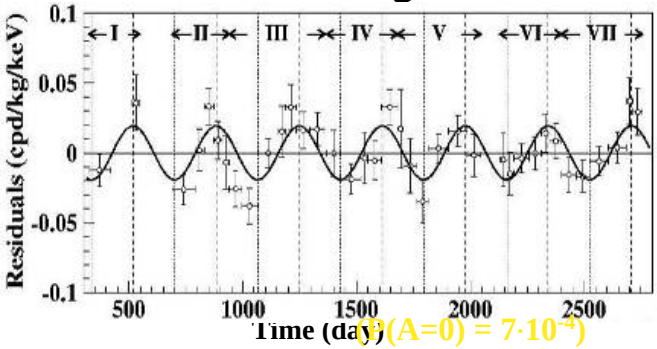
LVD, SNO, SuperK

in future: Kamland, BOREXINO

INFN

Dark matter search: DAMA

~100 kg NaI(Tl) high purity- ended 7/02



$C_0(A=0) = 7 \cdot 10^{-4}$

Annual modulation==> evidence for WIMPS

Final analysis: total **107731 kg·d**

(Riv. N. Cim. 26 n. 1 (2003) 1-73)

fitted (all parameters free):
$A = (0.0200 \pm 0.0032)$ cpd/kg/keV ;
$t_0 = (140 \pm 22)$ d ; $T = (1.00 \pm 0.01)$ y

6σ

... ora DAMA/LIBRA

New apparatus - installed 2002 - 2003
~250 kg more radiopure NaI(Tl)

(Large sodium Iodide Bulk for RAre processes)

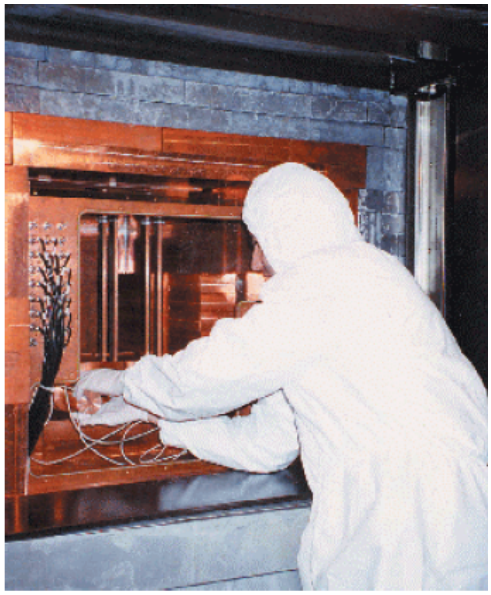
it will offer unique radiopurity, increased mass and deep control of the running parameters

NEW R&D for ultimate NaI(Tl) radiopurification started towards a possible 1 ton set-up DAMA proposed since 1996

DAMA

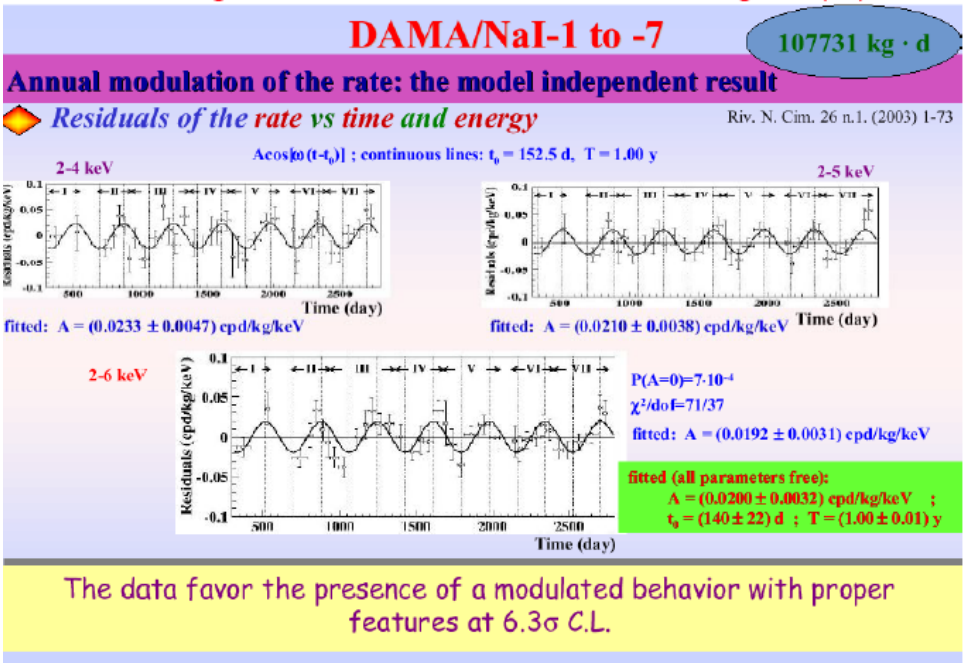
Dark Matter Search

Collab.:
Italy, China, Ukraine



Detection of WIMPs (Weakly Interacting Massive Particle) through the flash of light produced by a Iodine nucleus recoiling after having been hit by the WIMP.

DAMA looking for annual modulation with 100 kg NaI(Tl)

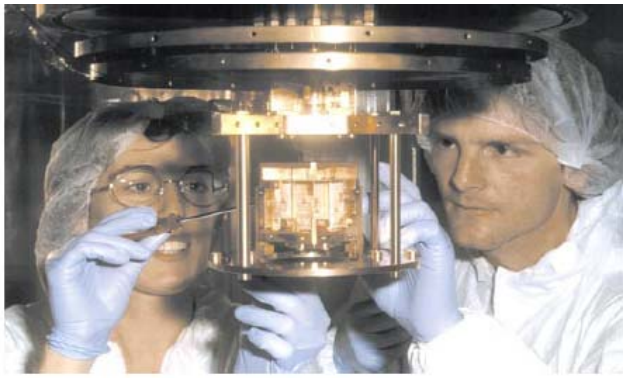


Present:

LIBRA

250 kg NaI(Tl)

Collab.:
Italy, Germany, UK



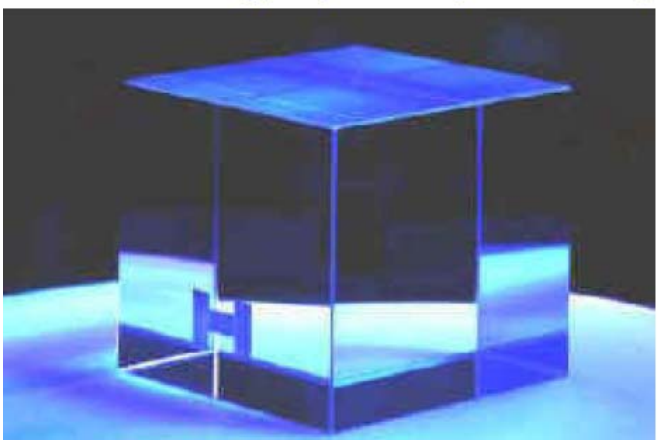
CRESST

(Cryogenic Rare Events Search with Superconducting Thermometers)

4 sapphire crystals= 1 kg

WIMPs search with cryogenic technique (running at 15 mK)

Looking for a very tiny temperature increase in the detector due to the energy deposited by nuclei hit by the WIMPs



Run until 2005

INFN

ββ decay neutrinoless experiments

β decay n --> p + e- + $\bar{\nu}$

2β0ν is a very rare decay: T(half life) ≥ 10^{-25} years)

$\nu = \bar{\nu}$

→Upper limit on the mass of ν_e 0,39 eV

Majorana neutrino

MIBETA (Milan)
20 detectors of natural TeO_2 crystals
^{130}Te mass = 2.3 kg

CUORICINO
Sensitive ^{130}Te mass = 40 kg
Status: running

CUORE
proposal presented in 2003
^{130}Te mass = 250 kg

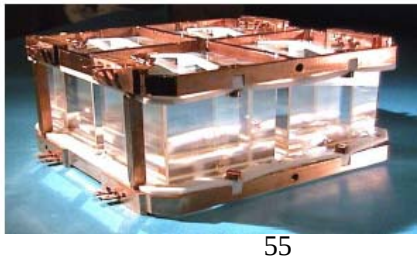
Collab.:
Italy, Netherland, Spain, USA

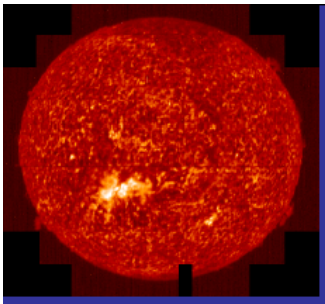
Heidelberg-Moscow
11 kg of enriched ^{76}Ge detect.
The most sensitive experiment in the world
^{76}Ge -->^{76}Se + 2e$^-$

Collab.:
Germany, Russia

GENIUS-TF
Test facility for GENIUS
40 kg HM Ge

GENIUS (project)
Sensitive mass: 1 ton enriched Ge crystals in Liquid N_2
Status. Experimental tests requested (GENIUS-TF)

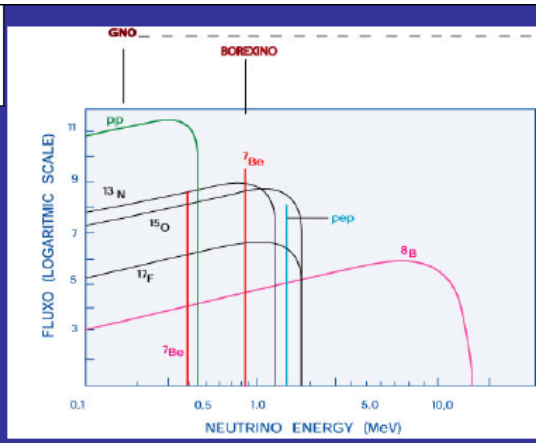




GNO

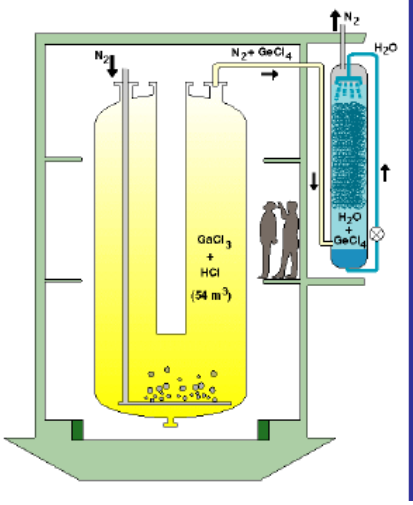
Collab.:
Italy, France, Germany

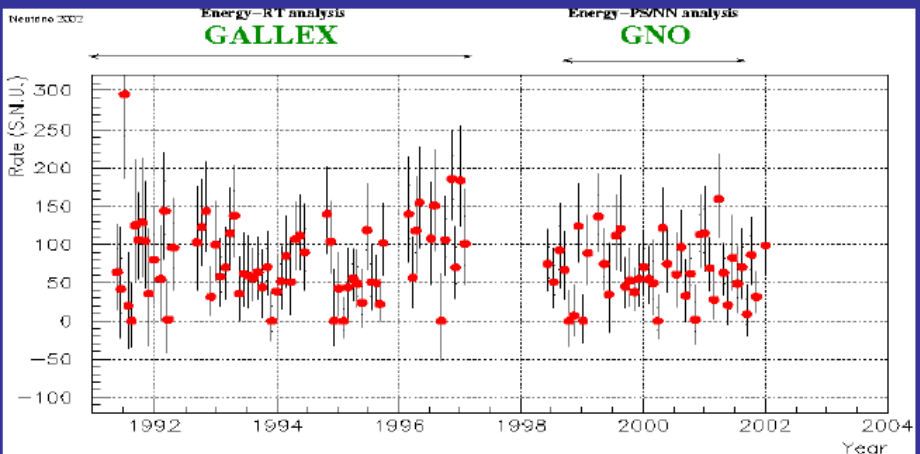
Goals: measurement of the interaction rate with an accuracy of 4-5% and monitoring the neutrino flux over a complete solar cycle.



101 tons Gallium Cloride solution
^{71}Ge(ν_e,e)^{71}Ge
Energy threshold > 233 keV
Sensitive mainly to pp -neutrinos

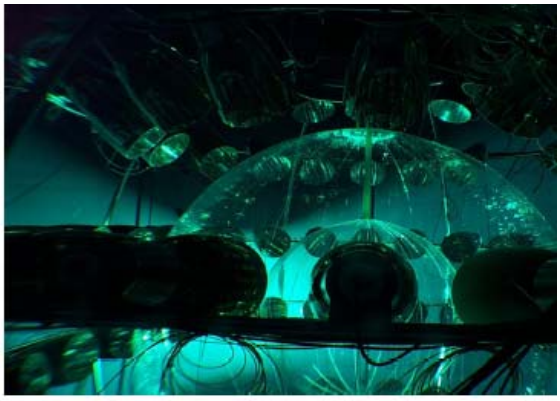
SSM ⟹ 115 -135 SNU





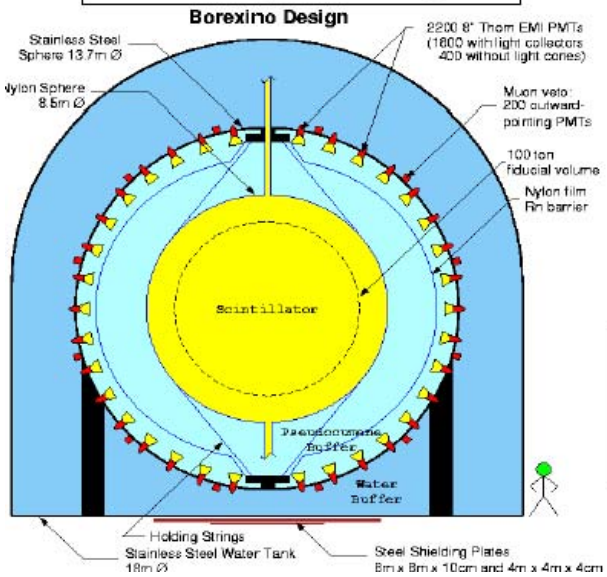
GALLEX	65 SR	77.5 +– 6.2 (stat) +– 4.5 (sys) SNU
GNO	43 SR	65.2 +– 6.4 (stat) +– 3.0 (sys) SNU
GNO+GALLEX	108 SR	70.8 +– 4.5 (stat) +– 3.8 (sys) SNU

BOREXINO



300 tons liquid scintillator in a nylon bag
2200 photomultipliers
2500 tons ultrapure water
Energy threshold 0.25 MeV
Real time neutrino (all flavours) detector
Measure mono-energetic (0.86 MeV) ^{7}**Be** neutrino flux through the detection of ν-e.
40 ev/d if SSM

18 m diam., 16.9 m height



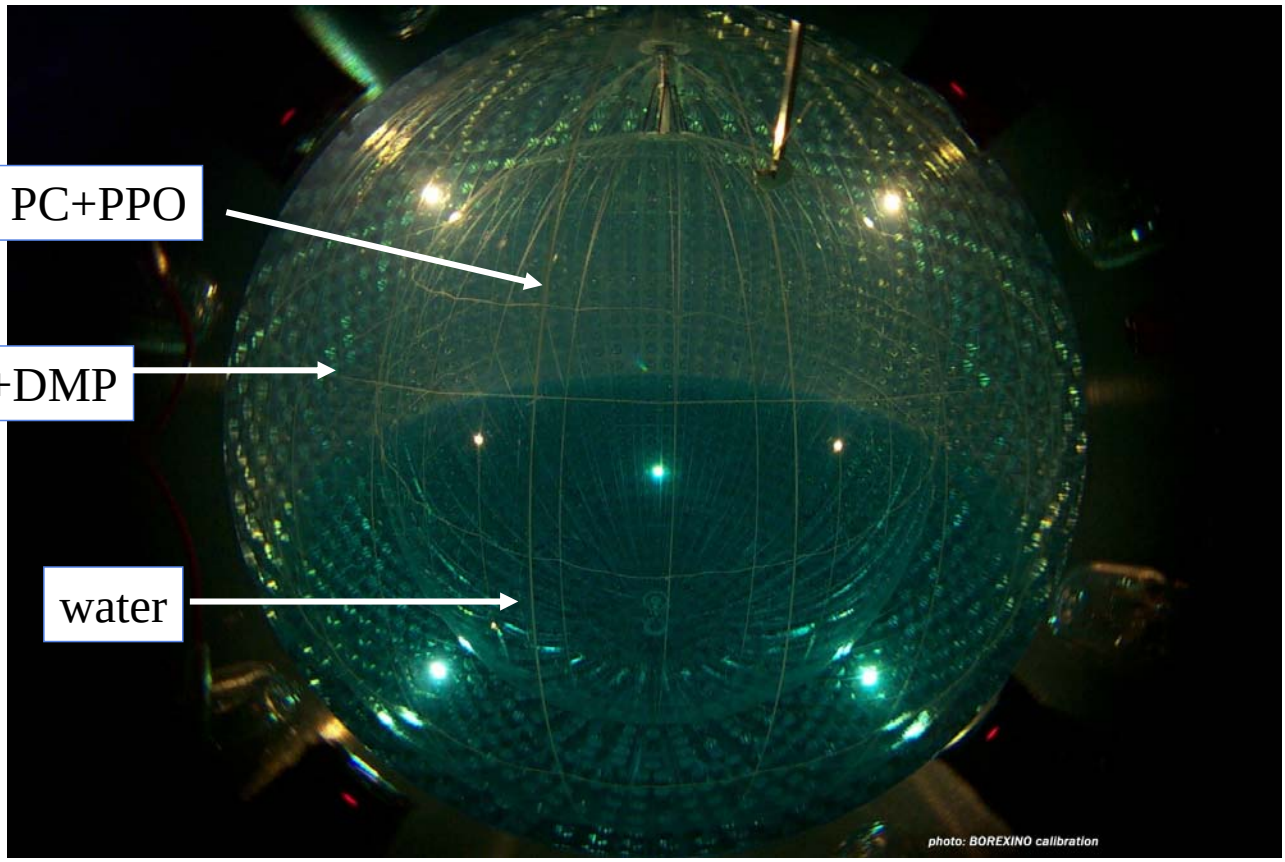
Sphere 13.7 m diam. Supports the P□M
optical concentrators
Space inside the sphere contains purifie
Purified water outside the sphere

running in 2005

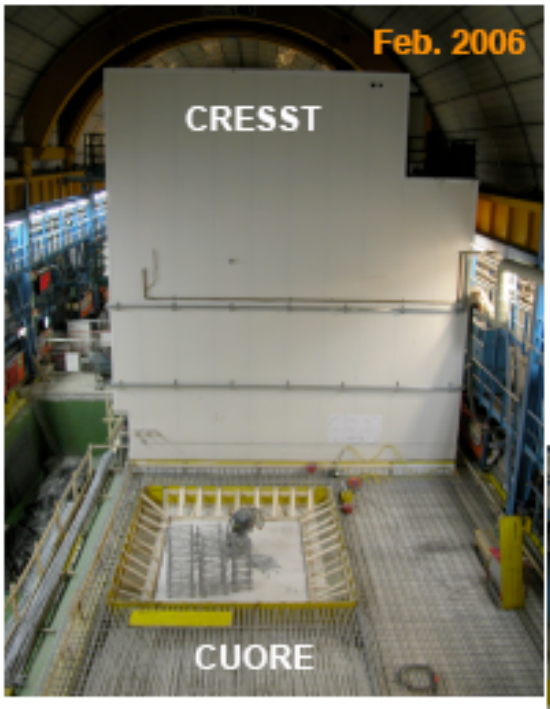
Collab.:
Italy, France, USA, Germany, Hungary, Russia, Belgium Poland, Canada

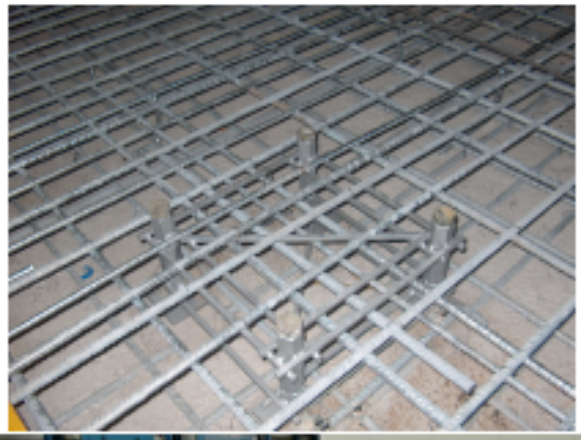
INFN

March 2, 2007 10:12: inside of the SSS



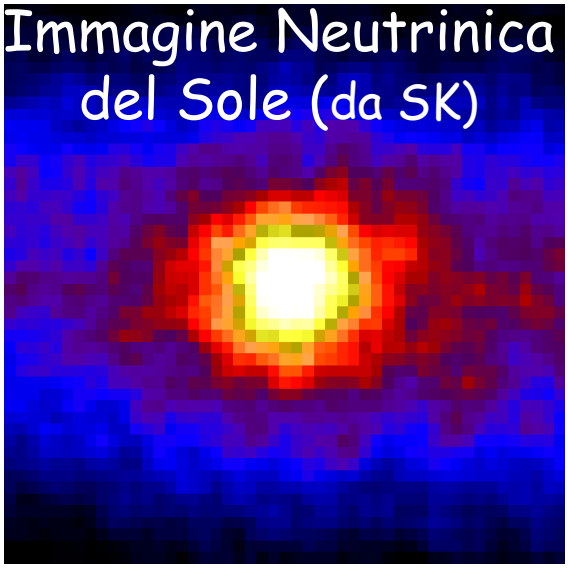
CUORE Site in Hall A at LNGS



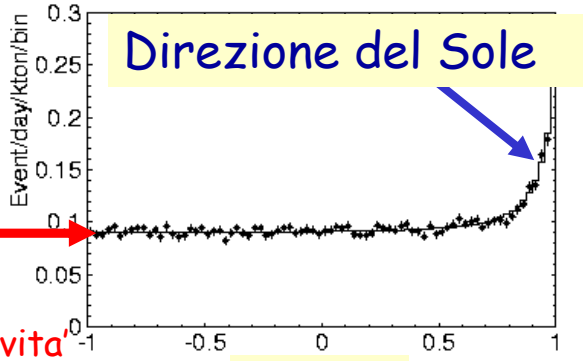


Neutrino 2006

Immagine Neutrinica del Sole (da SK)

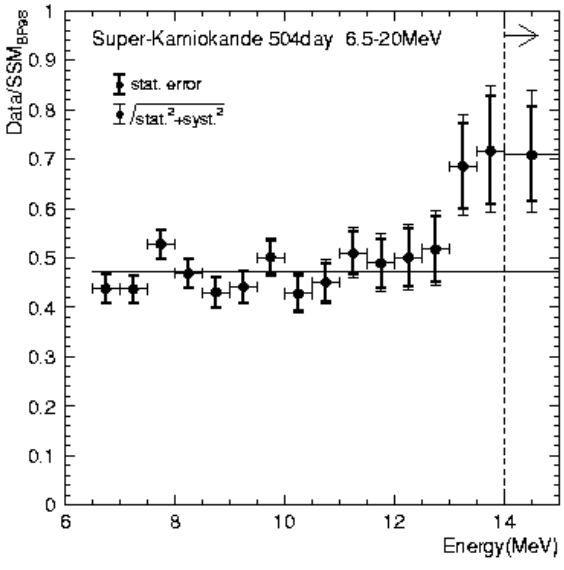


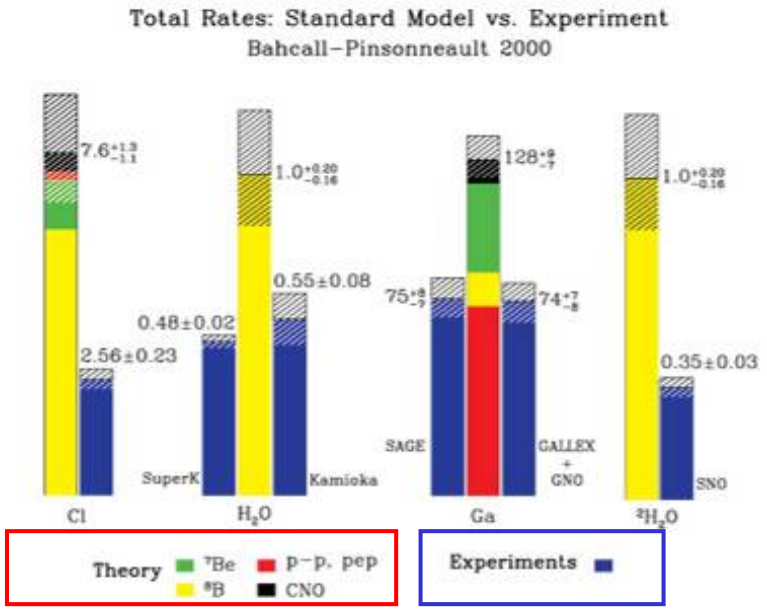
Fondo: Radioattivita'

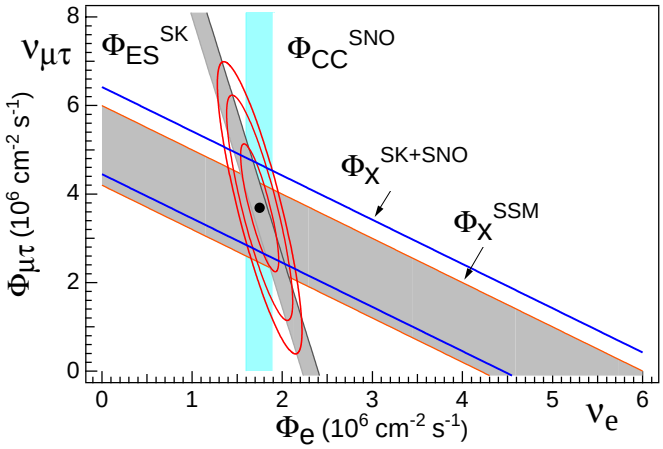


Rapporto:
osservati/attesi SSM

~ 0.5







Gran Sasso Monti della Laga
Parco Nazionale

Il Parco Nazionale del Gran Sasso e Monti della Laga, istituito nel giugno del 1995, e' una delle aree protette più estese e preziose d'Europa.

Il Parco, con un'area di circa 150.000 ettari, si estende in tre regioni (Abruzzo, Marche e Lazio) e cinque province (L'Aquila, Teramo, Ascoli Piceno, Pescara e Rieti). Comprende 44 comuni.


TERAMO
A24
FONTECERRETO
A24 | ASSERGI
ASSERGI
CAMARDA
ROMA
A24
A24 | AQ EST
S17
L'AQUILA
PAGANICA
BAZZANO