

Visita ai Laboratori dell'INFN

3-4 Febbraio 2017

Laboratori Nazionali del Gran Sasso

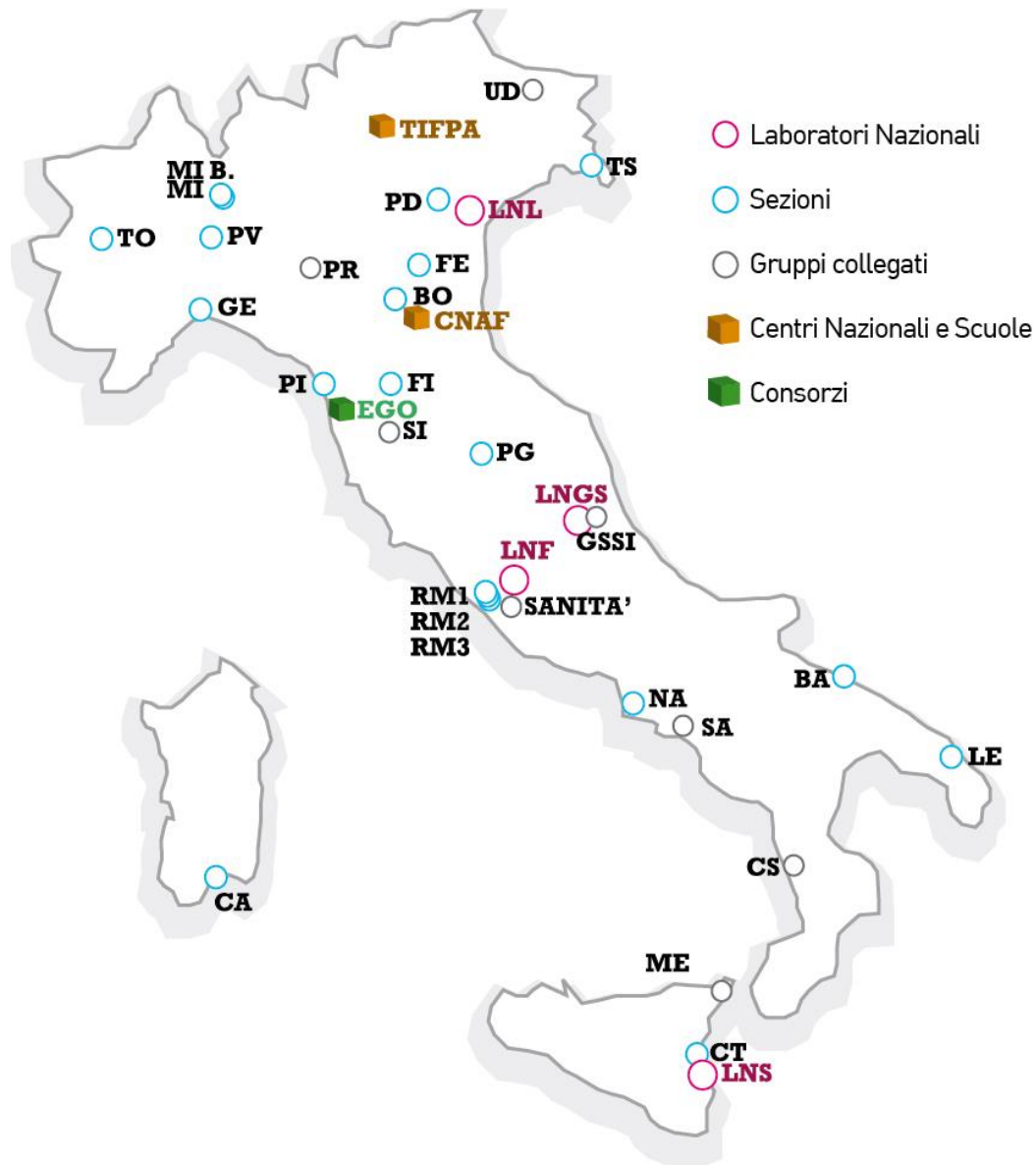


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L'Istituto Nazionale di Fisica Nucleare





Legnaro(PD)

Trieste

Ancona

Gran Sasso

L'Aquila

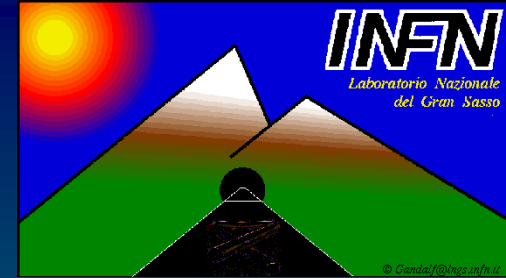
Roma



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.

Laboratori Nazionali del Gran Sasso



Location: Gran Sasso Tunnel (Abruzzi, Italy)

Depth: 1400 m (3800 mwe)

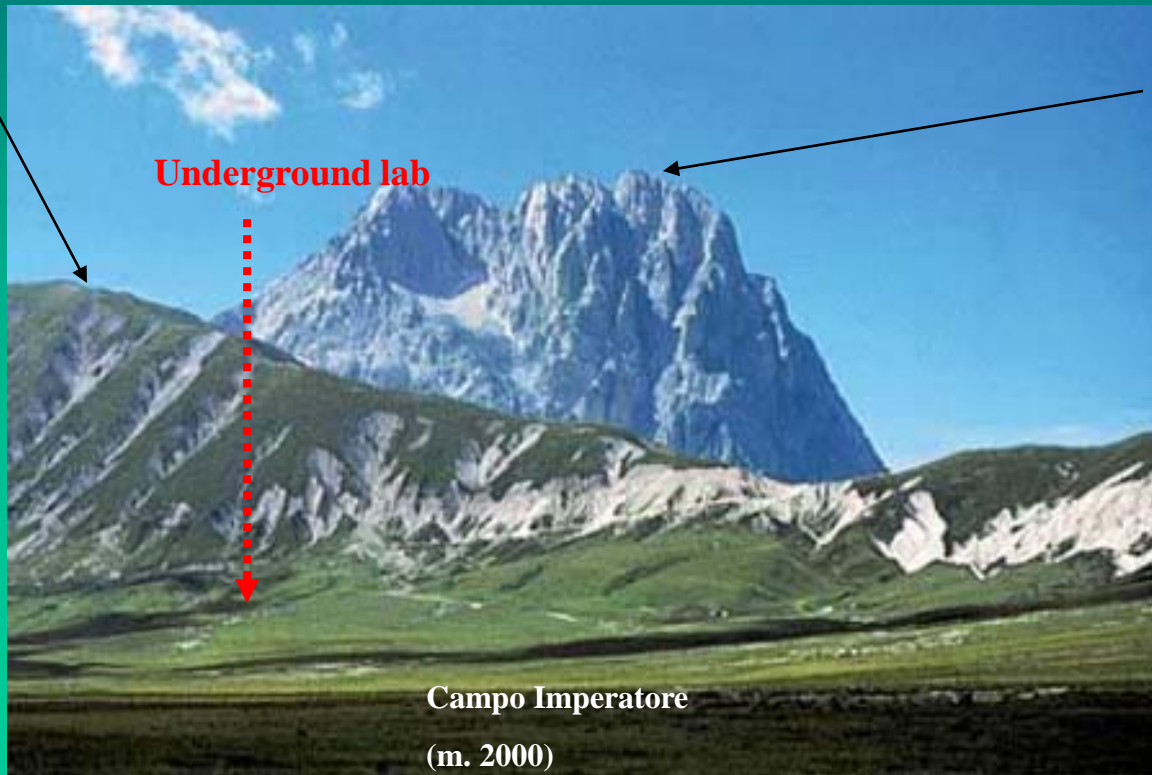
Operating Institution: Istituto Nazionale di Fisica Nucleare (INFN)

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

Scientists involved in LNGS experiments: 700 from 24 countries

Monte Aquila
(m. 2600)

Corno Grande (m. 2910)



Campo Imperatore
(m. 2000)

The area of Campo Imperatore
above LNGS

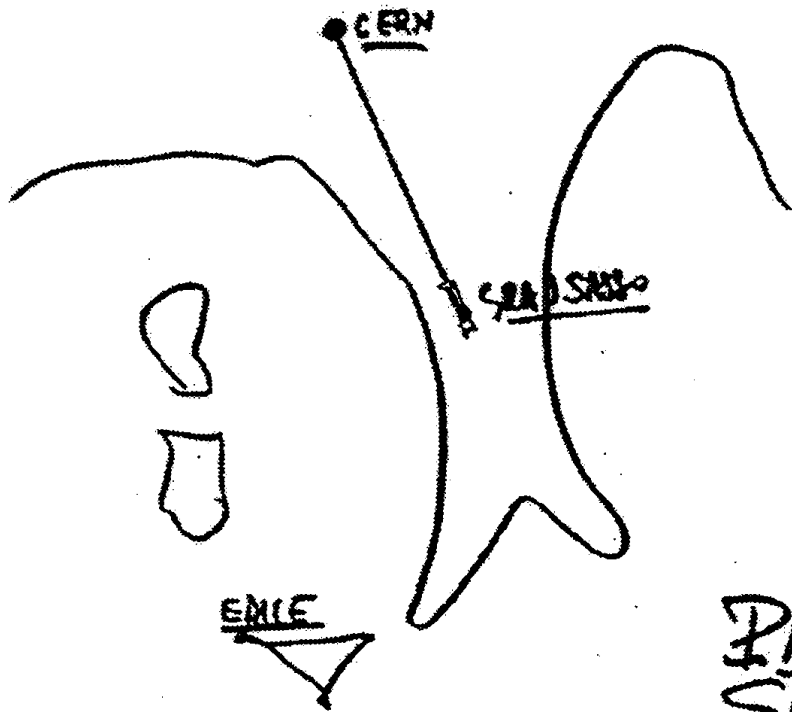
Nel **1979**, durante la costruzione della autostrada A24 fra Roma e L'Aquila, A. Zichichi ha proposto l'idea di costruire un **laboratorio sotterraneo** sotto il **Gran Sasso**

- **1982**: il Parlamento approva la costruzione
- **1984**: nuovi finanziamenti
- **1989**: il primo esperimento, MACRO, inizia a prendere dati

- Fra i primi progetti ci sono:
 - **MACRO**: Ricerca di monopoli magnetici
 - **LVD**: rivelazione di supernovae e fisica dei neutrini
 - **Gallex**: rivelazione di neutrini solari

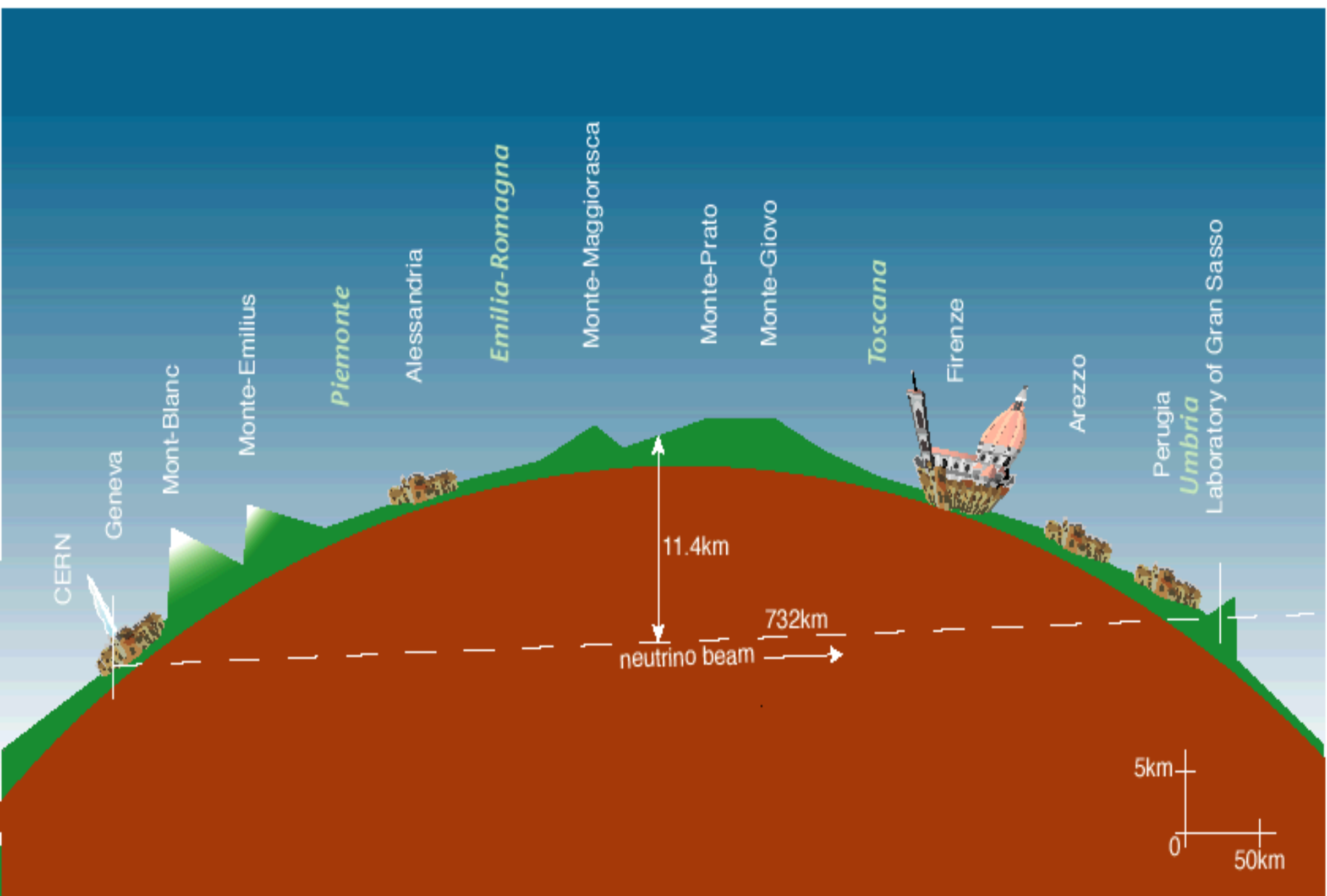


CODICIONE LAVORI PUBBLICI DEL SENATO



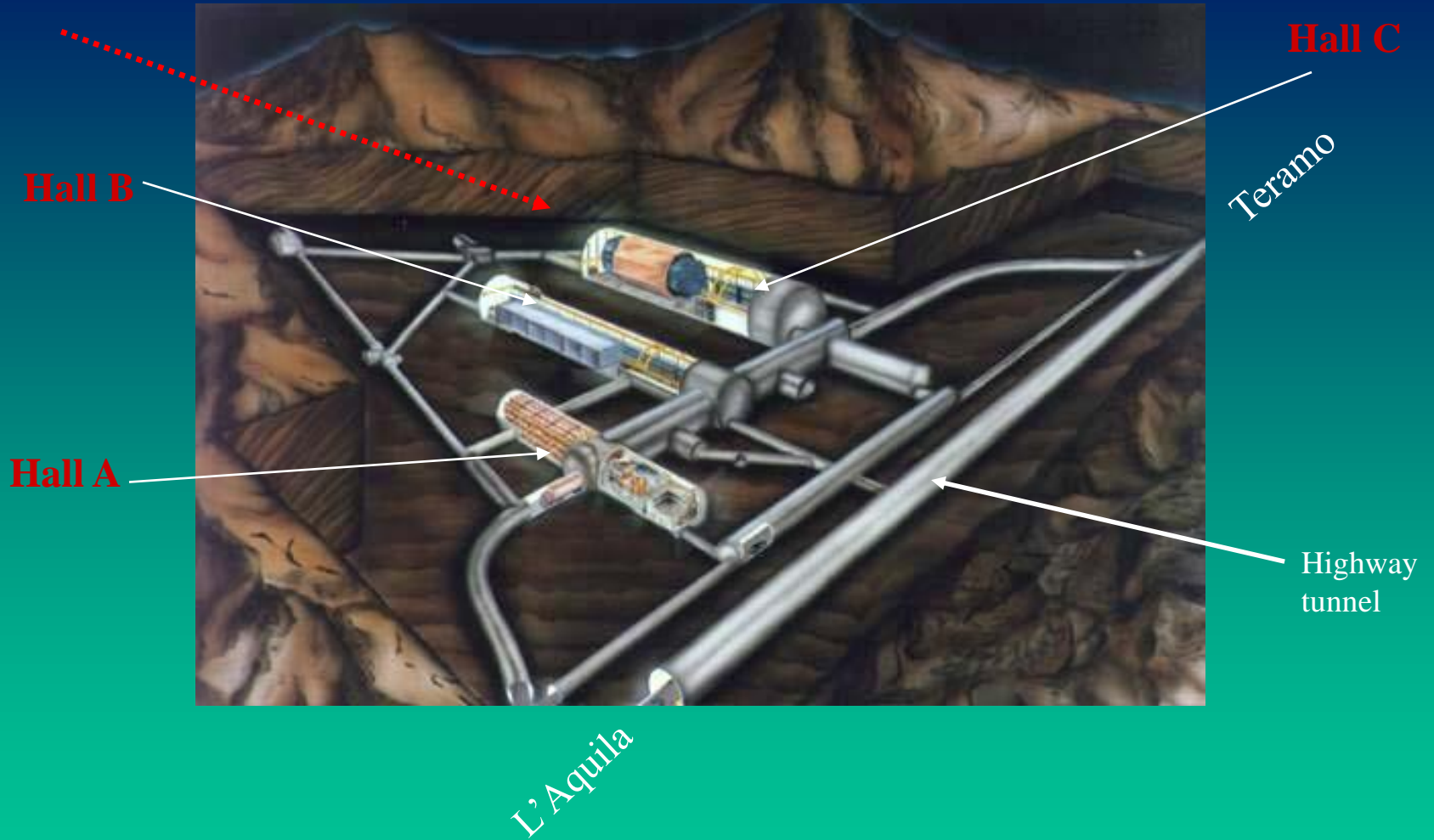
PROGETTO
SRAN CARPO

Figure 1.1.1: Sketch by A. Zichichi, 1979



CERN ν beam

The LNGS Underground area



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

Total volume : 180000 m³

Surface: > 6000 m²

La sala B durante gli scavi e appena completata

~ 1985



E' il principale Laboratorio di Fisica delle Astroparticelle del mondo

~130 Km da Roma, 1 ½ dall'aeroporto di Fiumicino

Scienza @ LNGS

■ Fisica dei neutrini

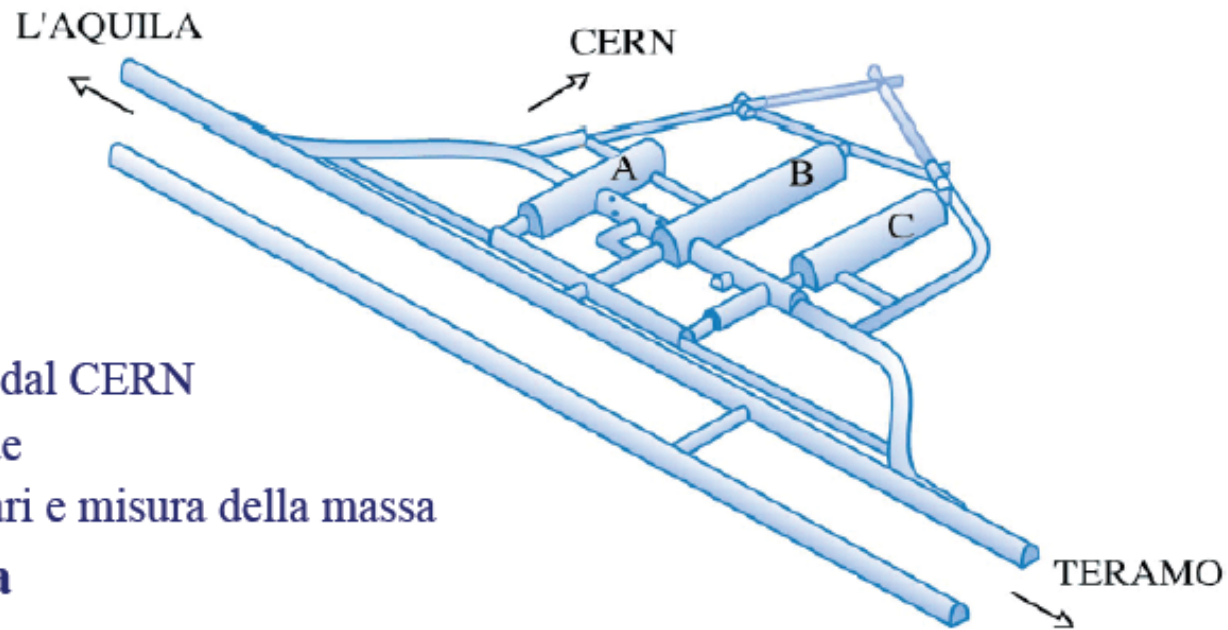
- Neutrini solari
- Esperimenti con neutrini dal CERN
- Rivelazione di supernovae
- Ricerca di decadimenti rari e misura della massa

■ Ricerca di materia oscura

■ Fisica nucleare dei processi rari

■ Geofisica

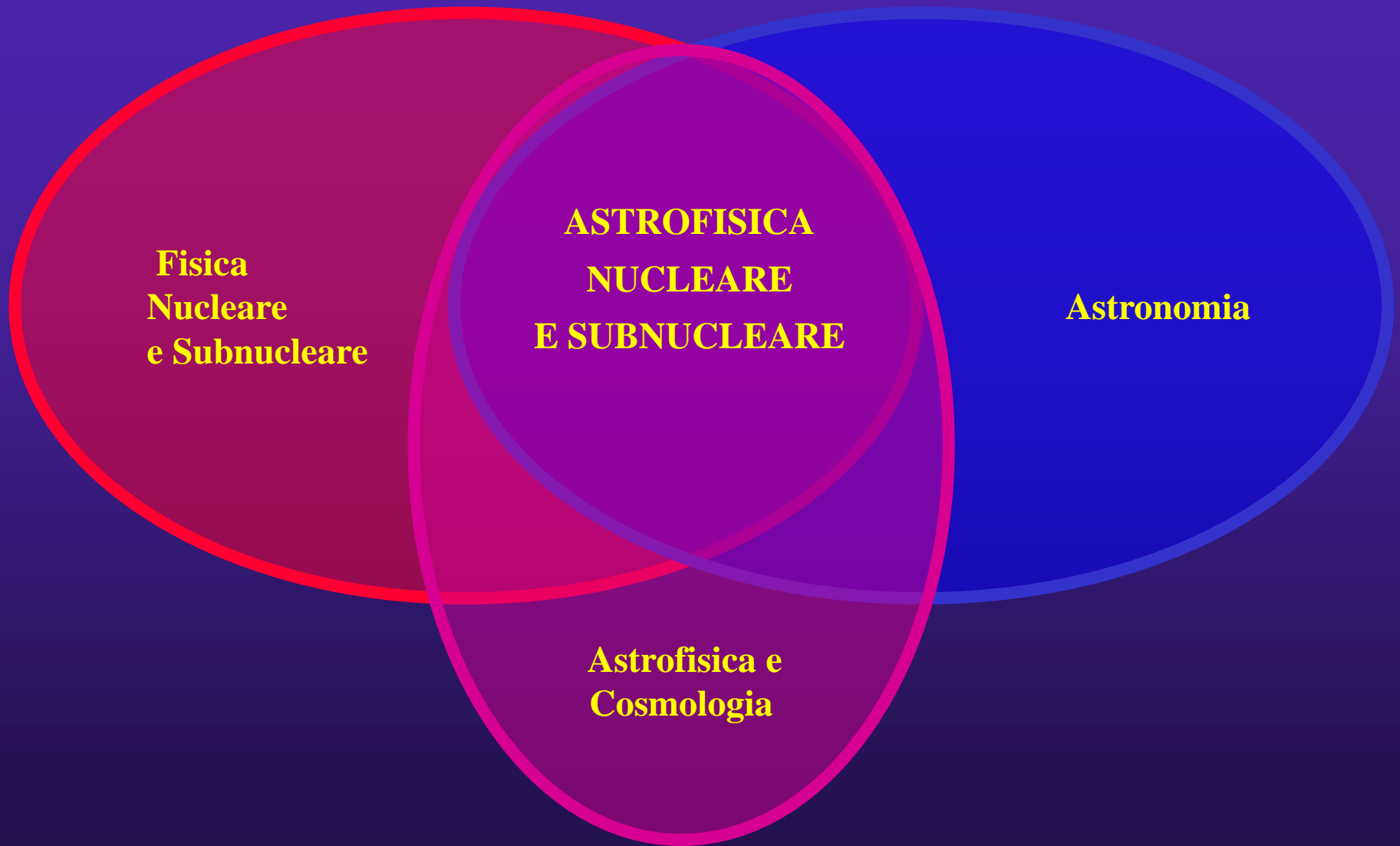
■ Biologia



Tunnel:	10.4 Km
Copertura:	~ 3200 m.w.e.
Riduzione flusso muoni:	~ 10⁶

Astrofisica Nucleare e Subnucleare

(Fisica Astroparticellare/Astrofisica Particellare)



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

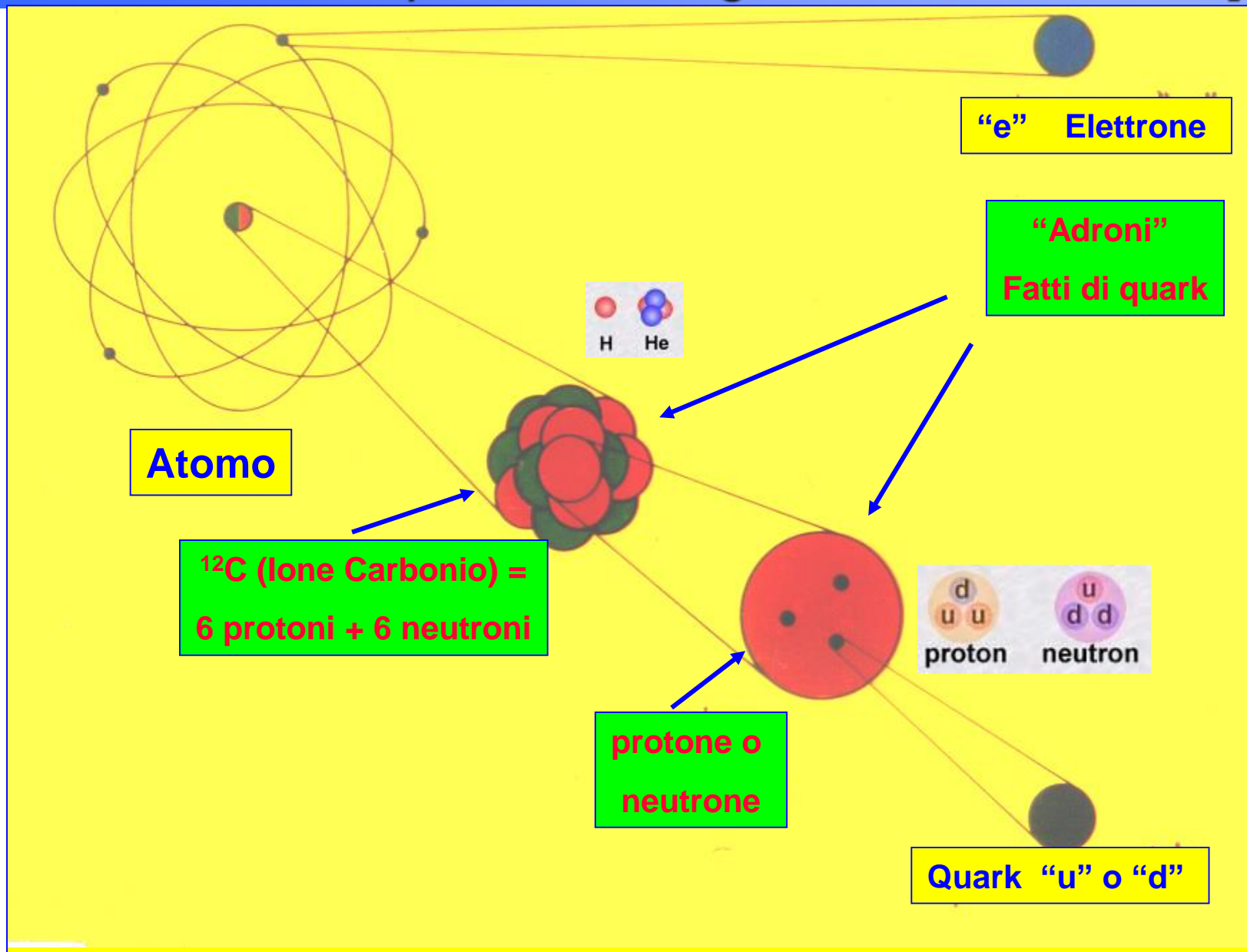


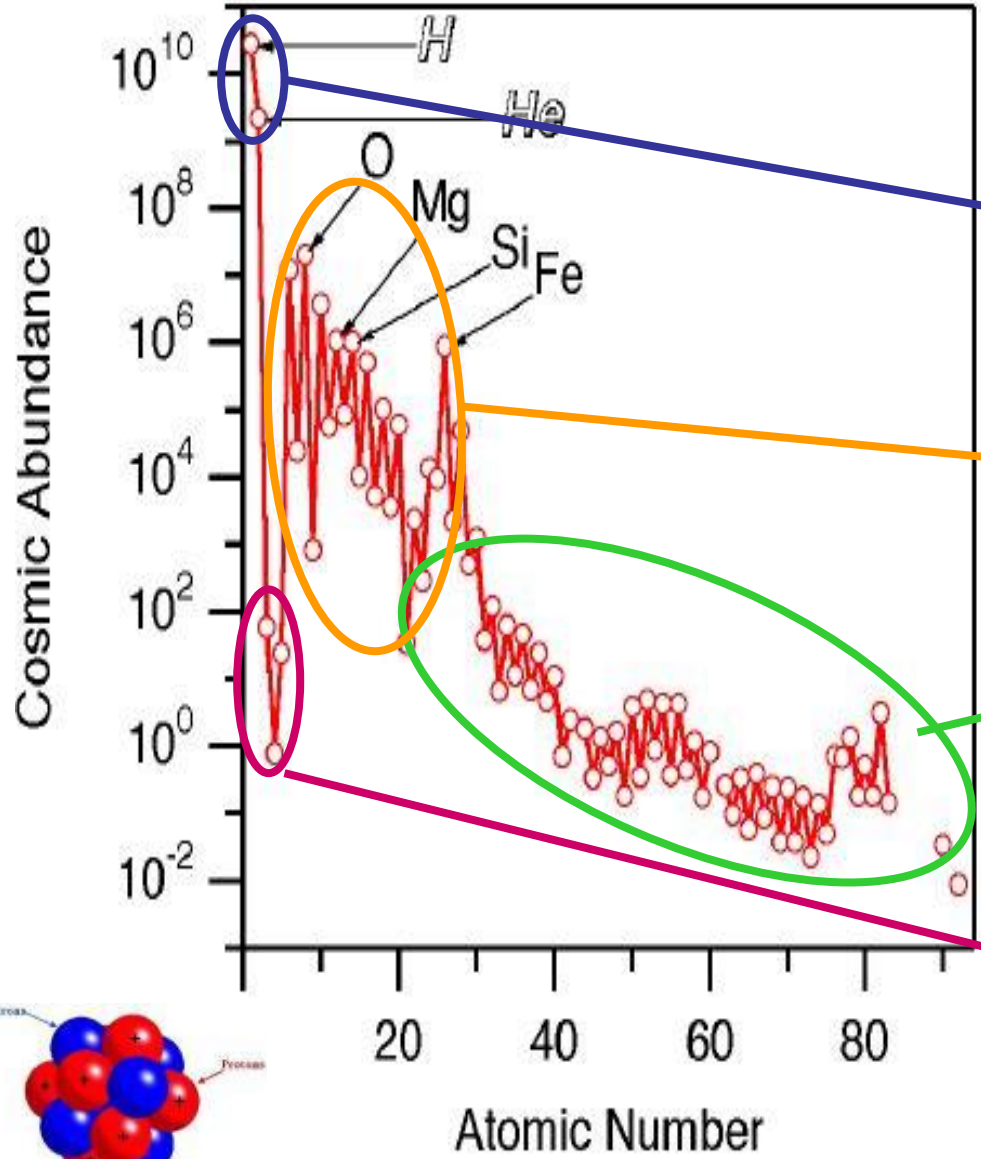
Tavola periodica degli elementi

Periodic Table of the Elements

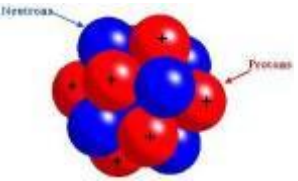
IA	IIA	IIIA	IVA	VA	VIA	VIIA	VIIIA	IXA	XA	XIA	XIIA
H	He										
Li	Be	B	C	N	O	F	Ne				
Na	Mg	Al	Si	P	S	Cl	Ar				
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg
Fr	Ra	Ac	Rf	Hs	Sg	Bh	Ht	Mt	110	111	112

*Lanthanide Series
 †Actinide Series

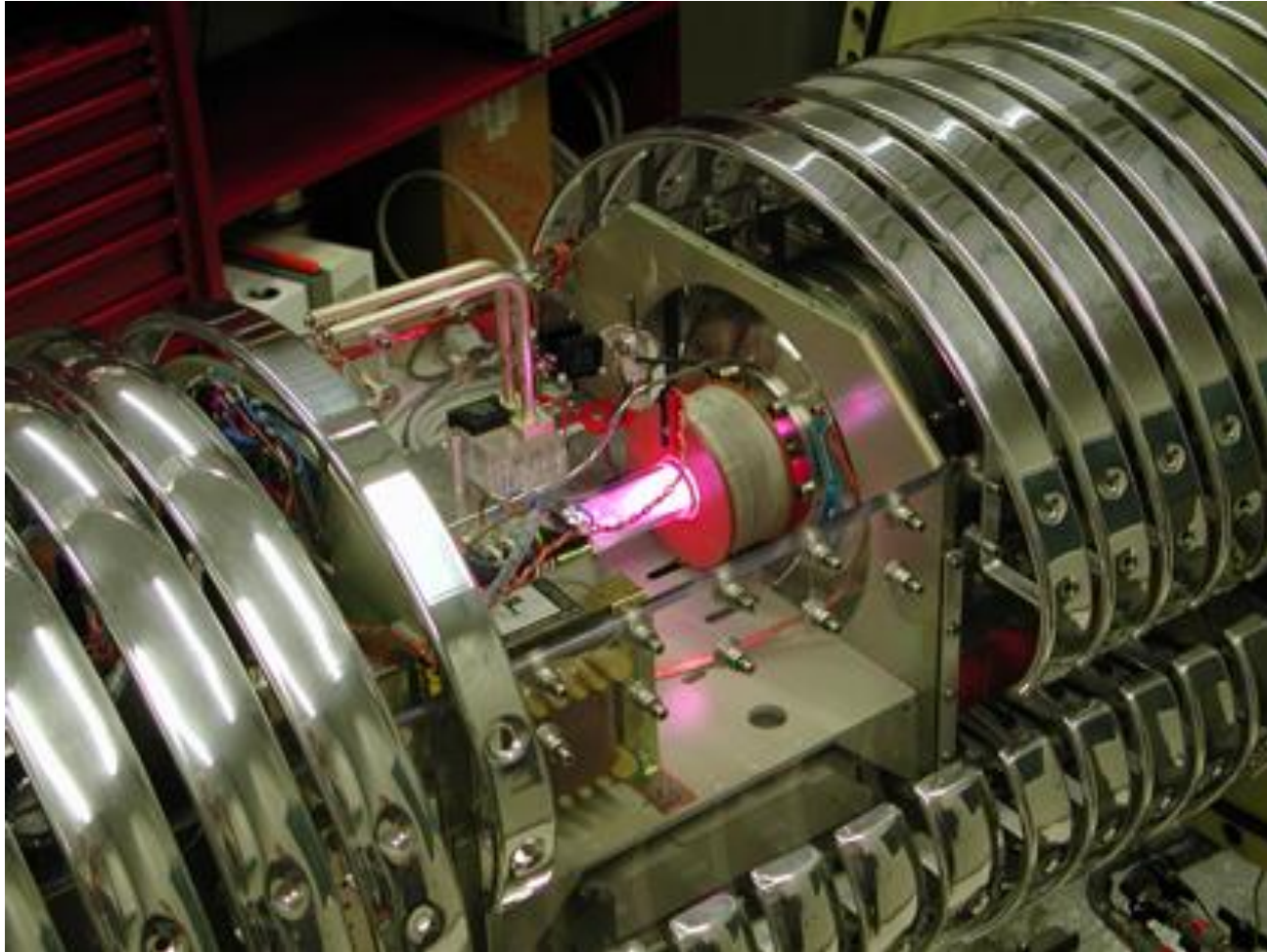
Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr



- Origine
- Big Bang Nucleosintesi
- Stelle calde
- Esplosioni di Supernova
- Interazioni con raggi cosmici



Astrofisica Nucleare - LUNA



10^{-43} sec

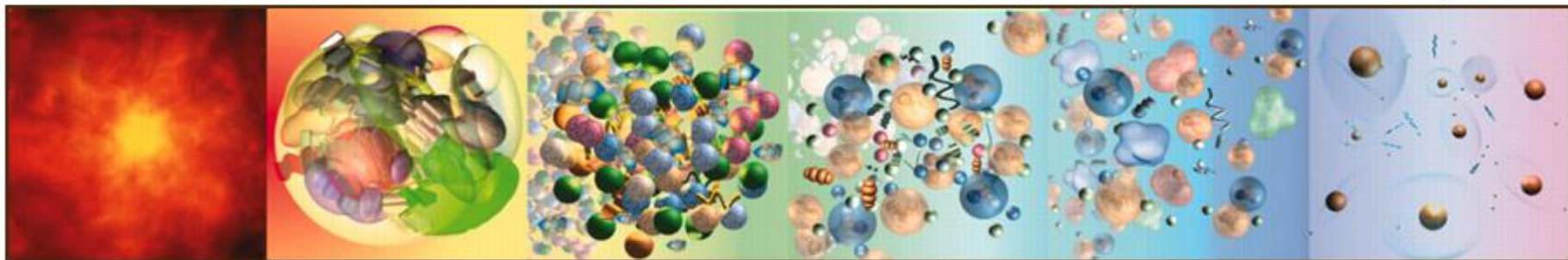
10^{-32} sec

10^{-10} sec

10^{-4} sec

100 sec

300000 years



10^{-35} m
 10^{19} GeV

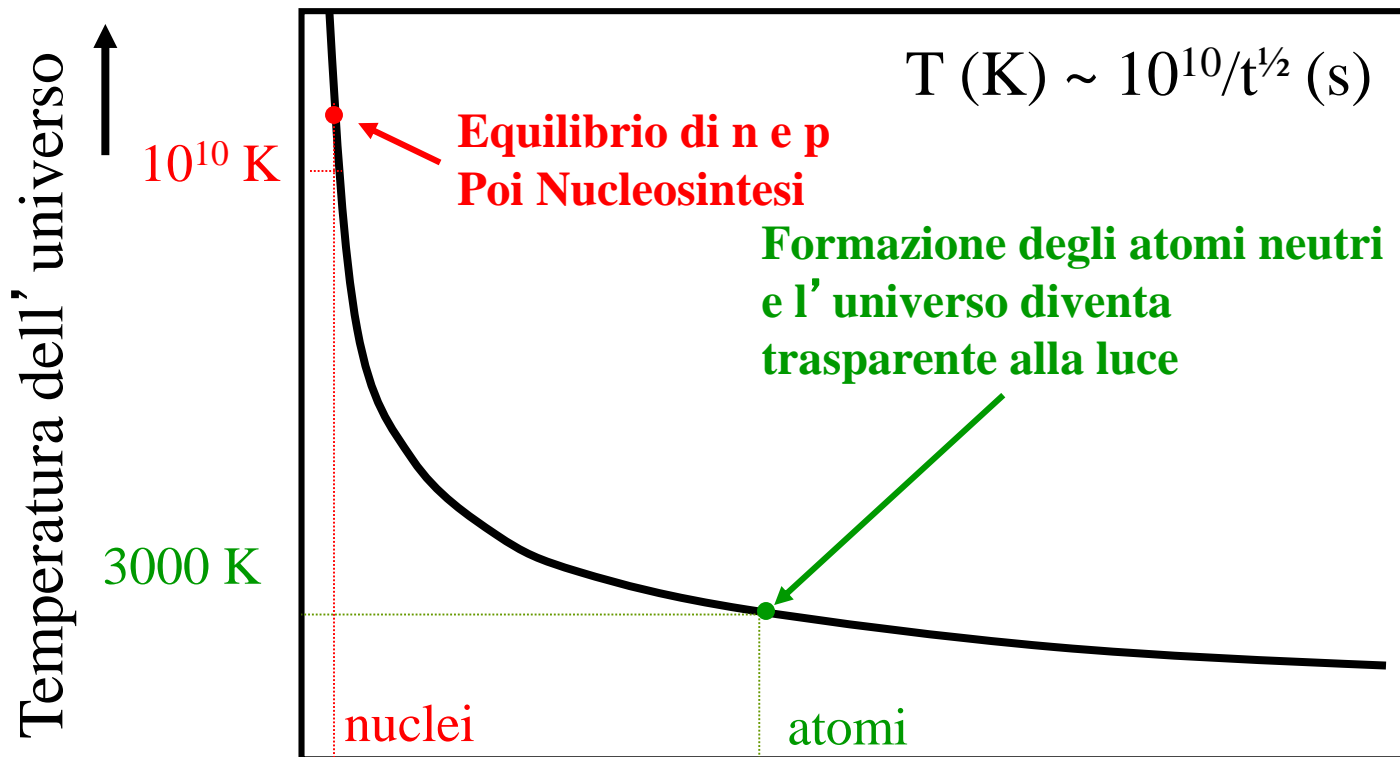
10^{-32} m
 10^{16} GeV

10^{-18} m
 10^2 GeV

10^{-16} m
1 GeV

10^{-15} m
1 MeV

10^{-10} m
10 eV



100 s

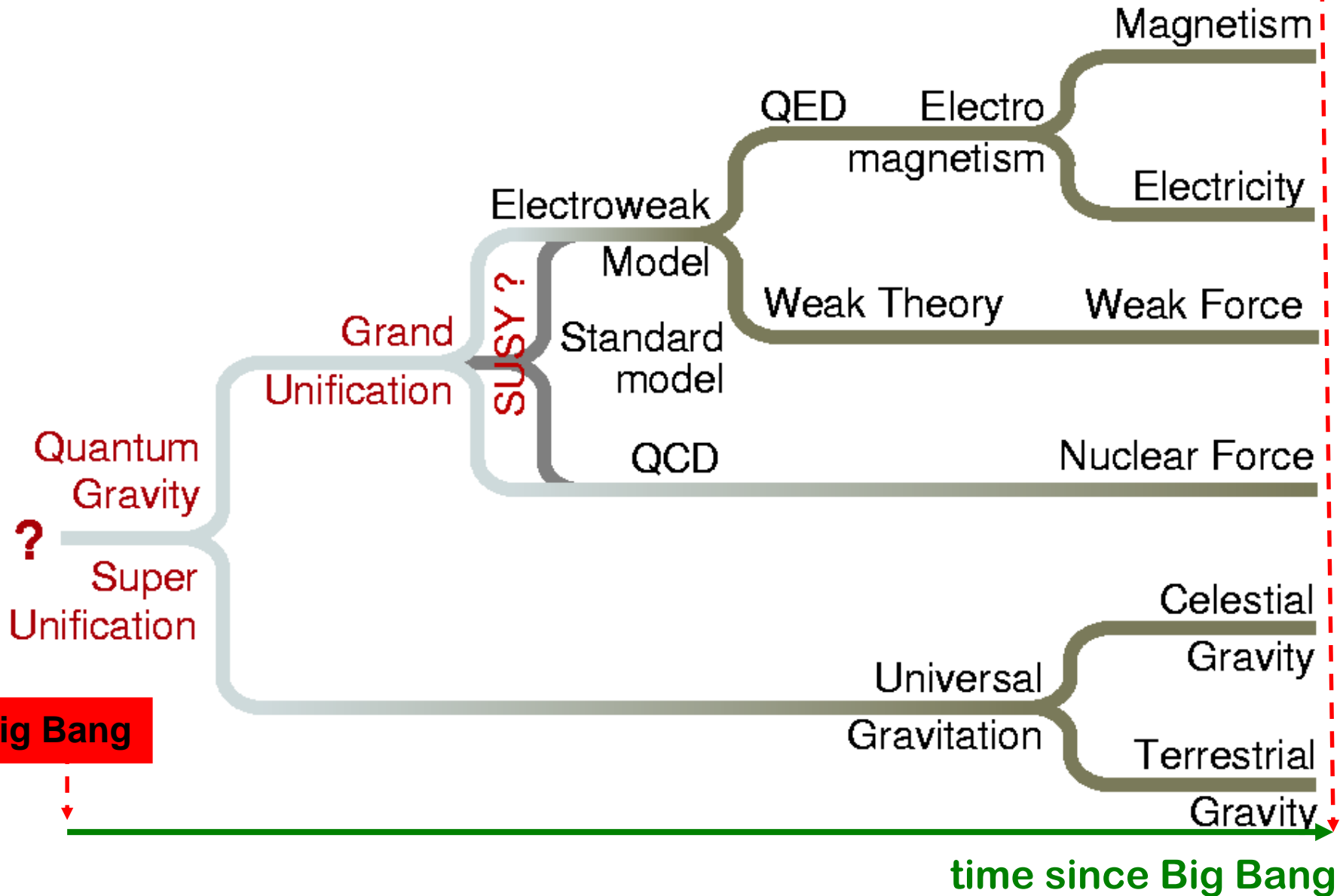
300000 anni

tempo dopo il big bang →

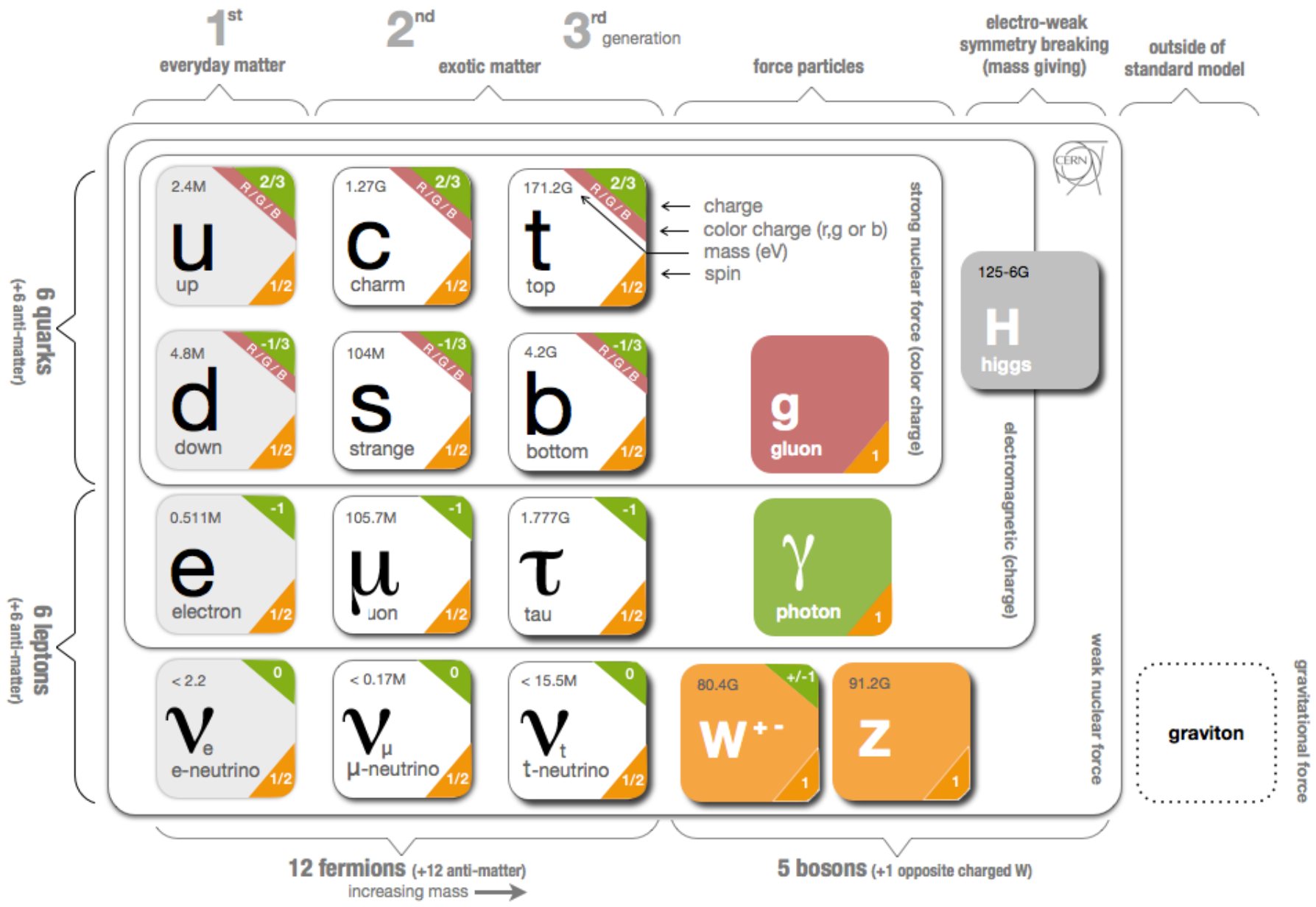
Big Bang

Unificazione delle Forze

Today

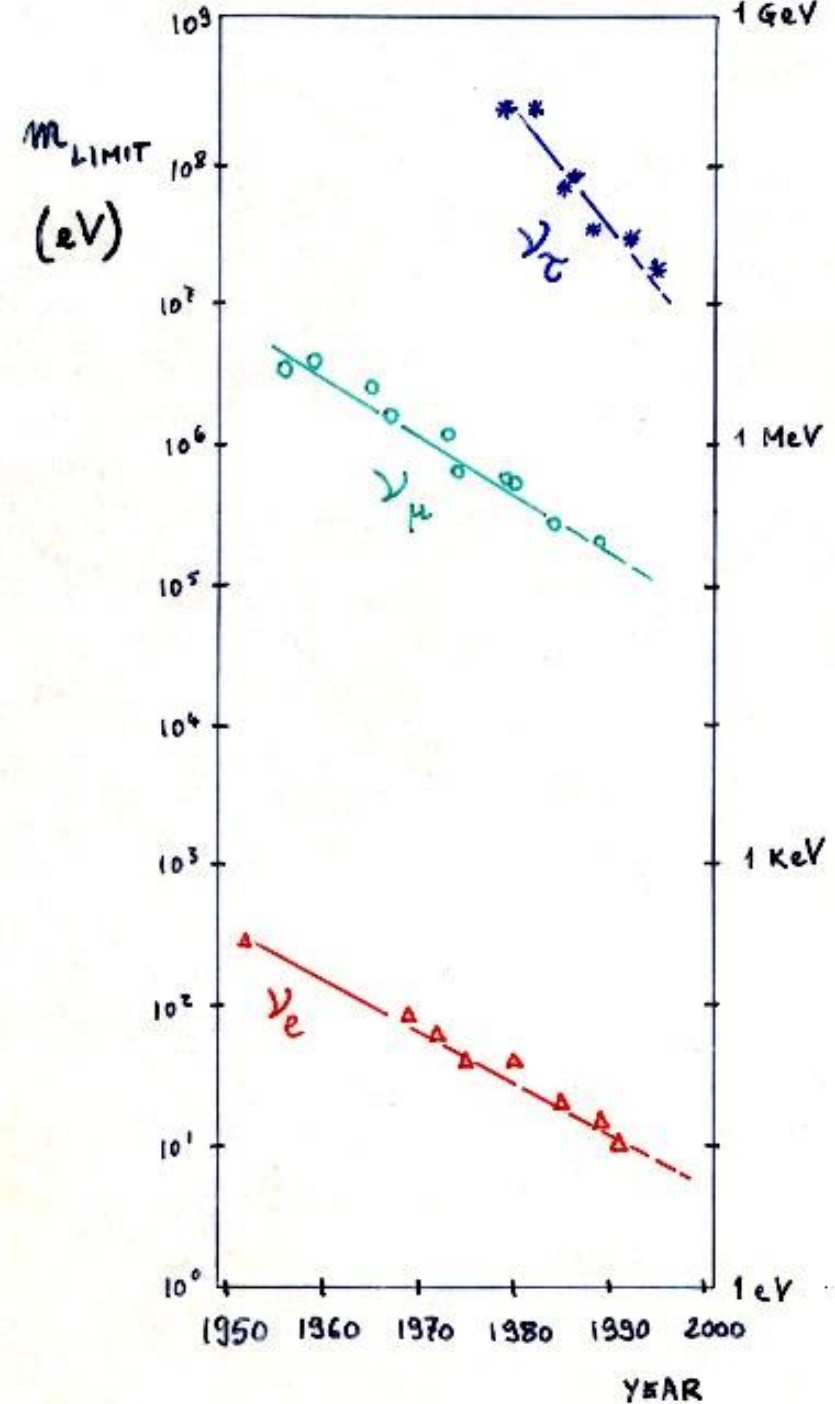


MODELLO STANDARD : Fermioni (Costituenti) e Bosoni (Mediatori)



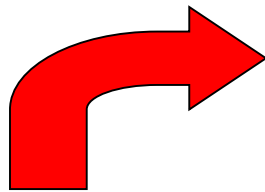
Limiti Sperimentali per la Massa dei Neutrini

(50 anni di misure)



Oscillazioni dei Neutrini

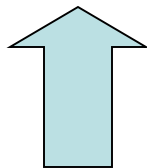
- Idea della massa dei neutrini suggerita per la prima volta da Bruno Pontecorvo



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

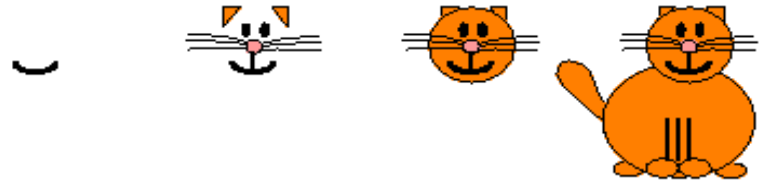
$|v_e\rangle$, $|v_\mu\rangle$, $|v_\tau\rangle$ = Autostati dell'Interazione Debole

$|v_1\rangle$, $|v_2\rangle$, $|v_3\rangle$ = Autostati di Massa (H \rightarrow Evoluzione t)



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

Comparsa/Appearance

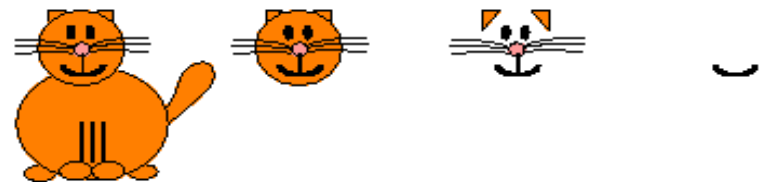


"Appearance Experiments"
see the new neutrino type
in the detector



A "Disappearance Experiment" observes

fewer ν μ than expected



Scomparsa/Desappearance

Esperimenti con Neutrini :

- 1) Sorgenti (Molto) Potenti
- 2) Apparatati (Molto) Sensibili
e (Molto) Massivi

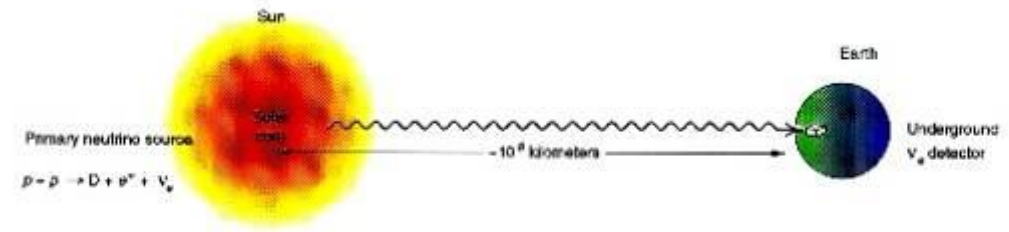
Sorgenti naturali:

Sole, Supernovae, Raggi cosmici

Sorgenti Artificiali:

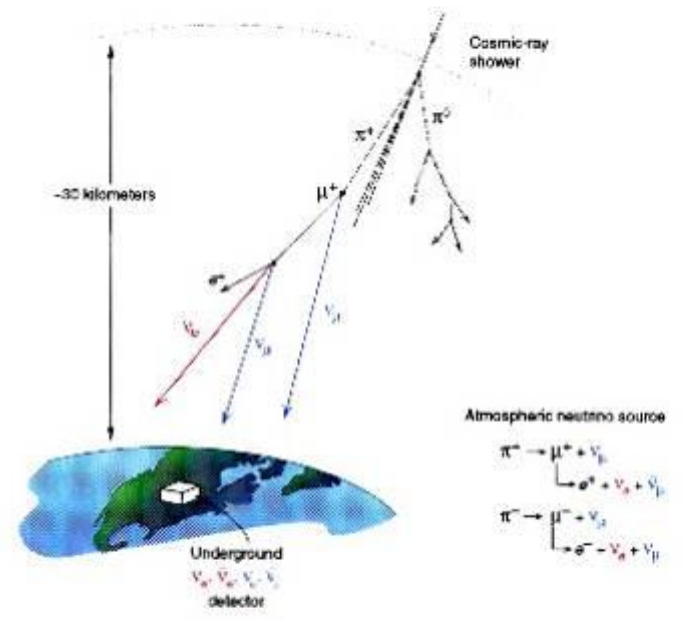
Acceleratori, Reattori Nucleari

SOLAR ν : (ν_e)

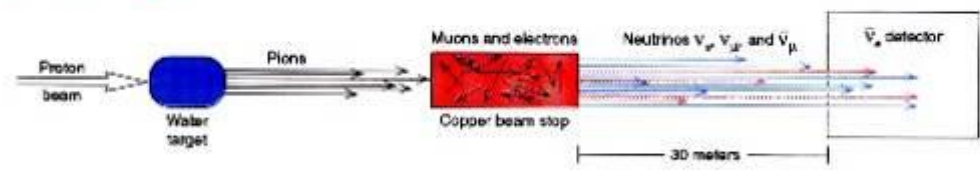


Other sources of neutrinos:
 $e^- + {}^7\text{Be} \rightarrow {}^7\text{Li} + \nu_e$
 ${}^8\text{g} \rightarrow 2{}^4\text{He} + e^+ + \nu_e$

ATMOSPHERIC ν :
 ($\nu_\mu \bar{\nu}_\mu \nu_e \bar{\nu}_e$)



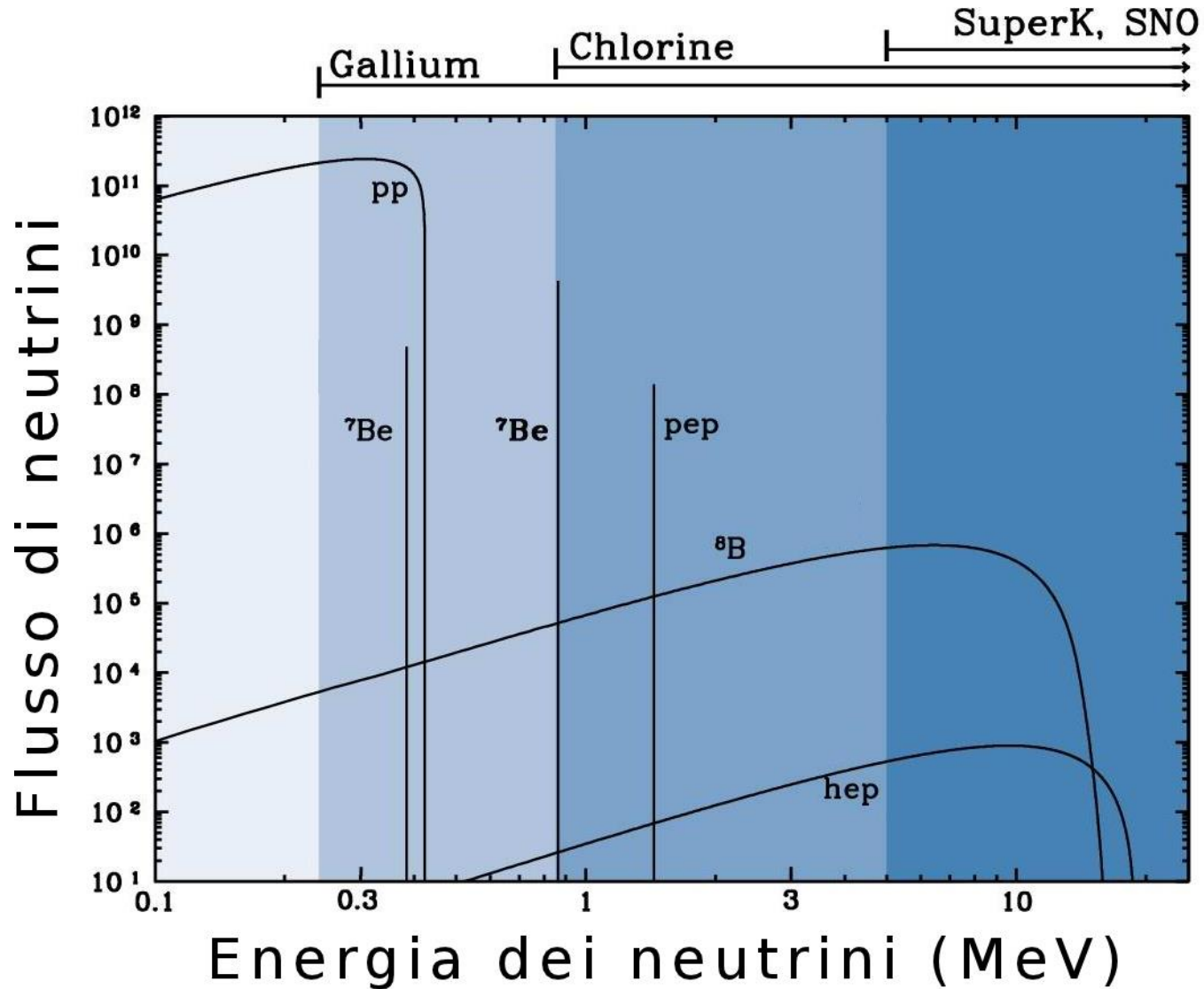
ACCELERATOR ν :
 ($\nu_\mu \bar{\nu}_\mu \nu_e$)



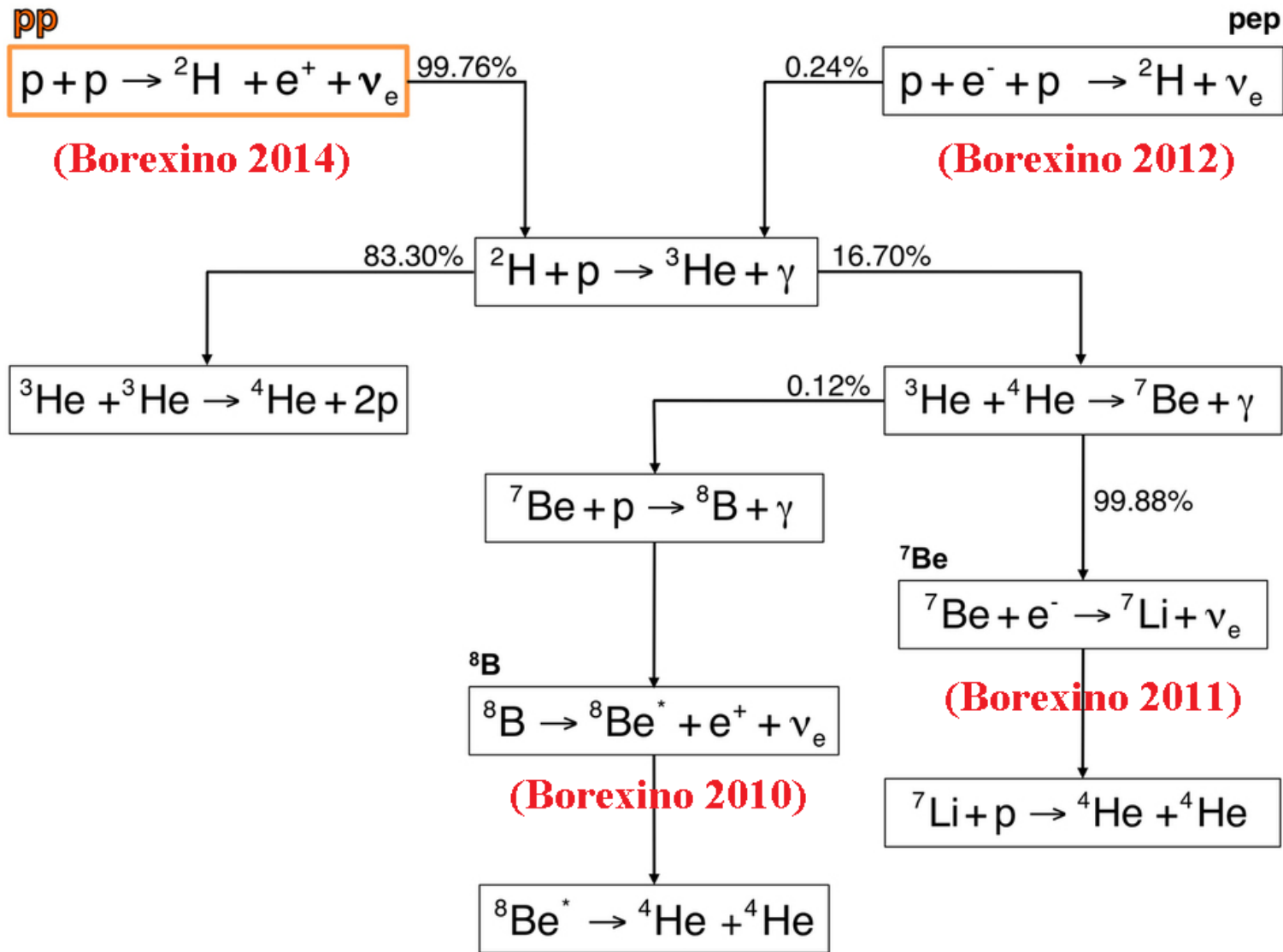
REACTOR ν :
 ($\bar{\nu}_e$)



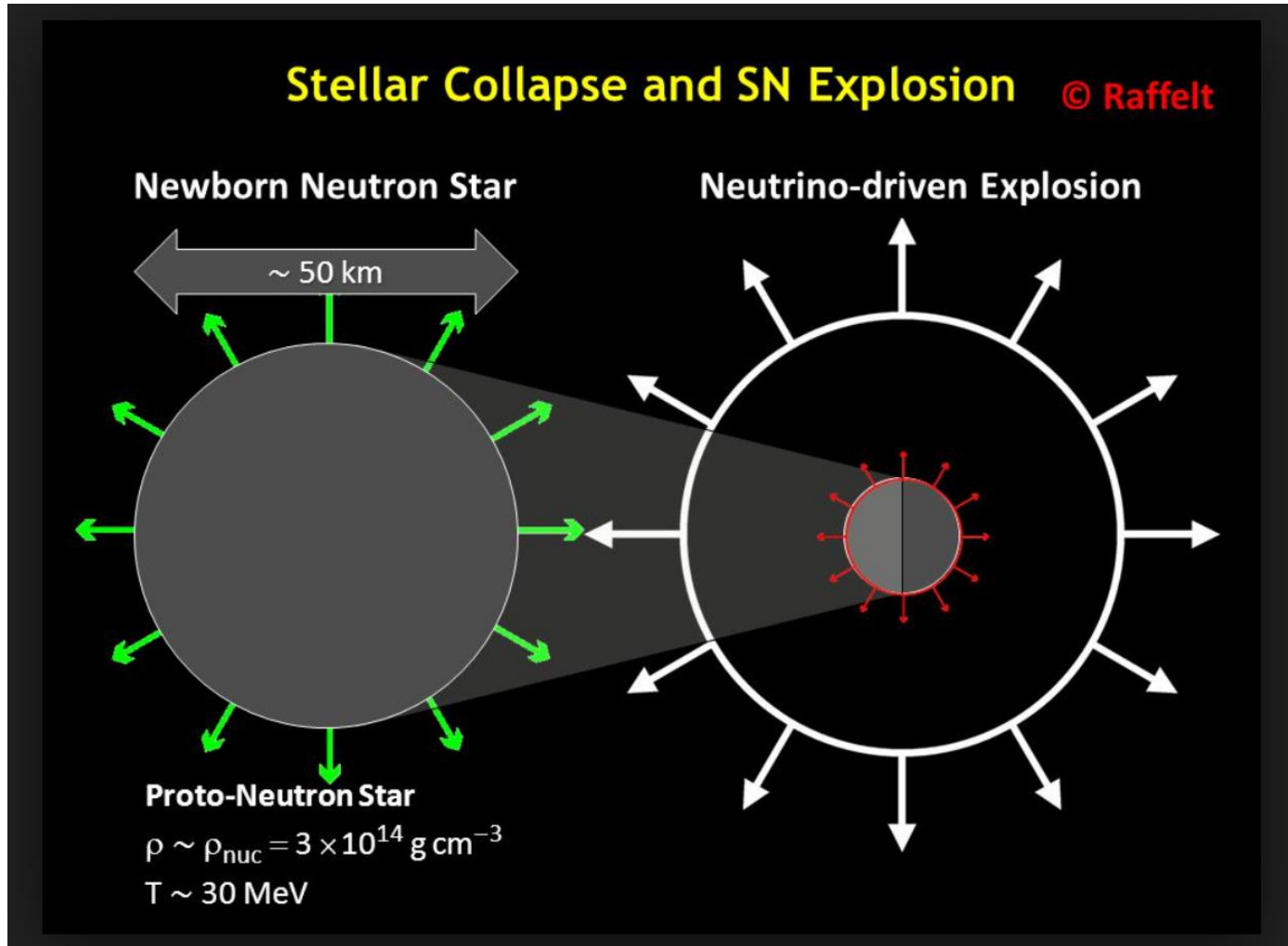
Neutrini Solari



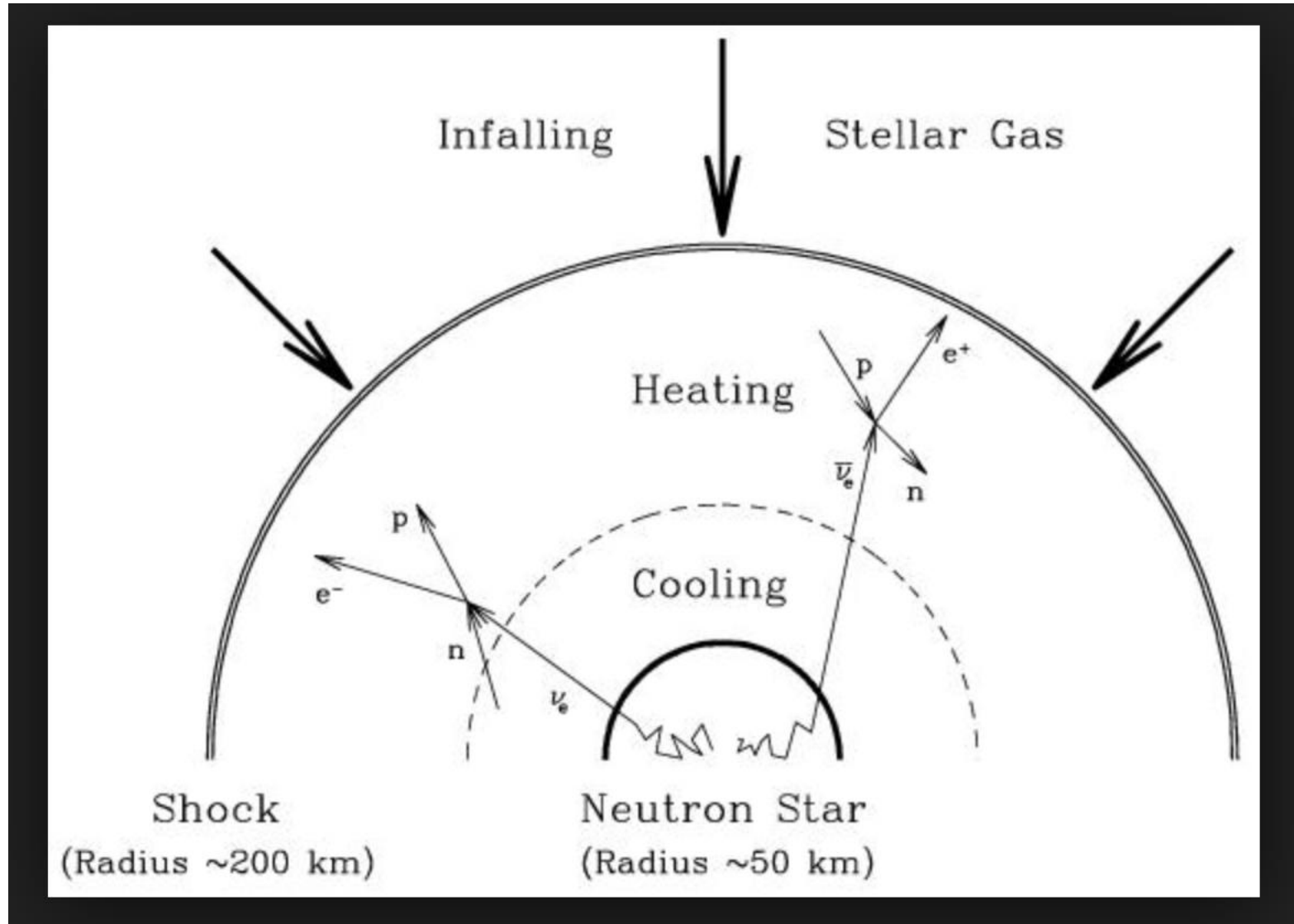
Neutrini Solari



Neutrini da Supernova

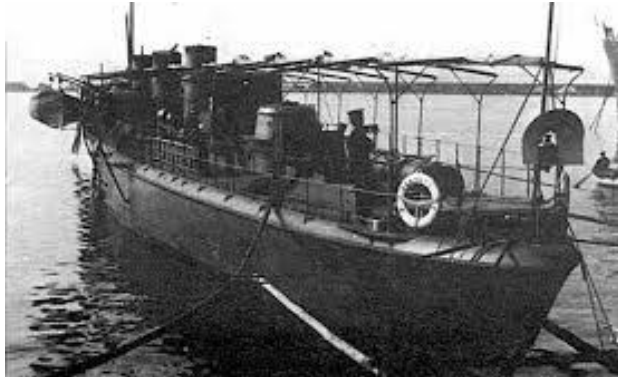


Neutrini da Supernova



Raggi Cosmici

Nel fondo di laghi e del mare:
Pacini 1911!



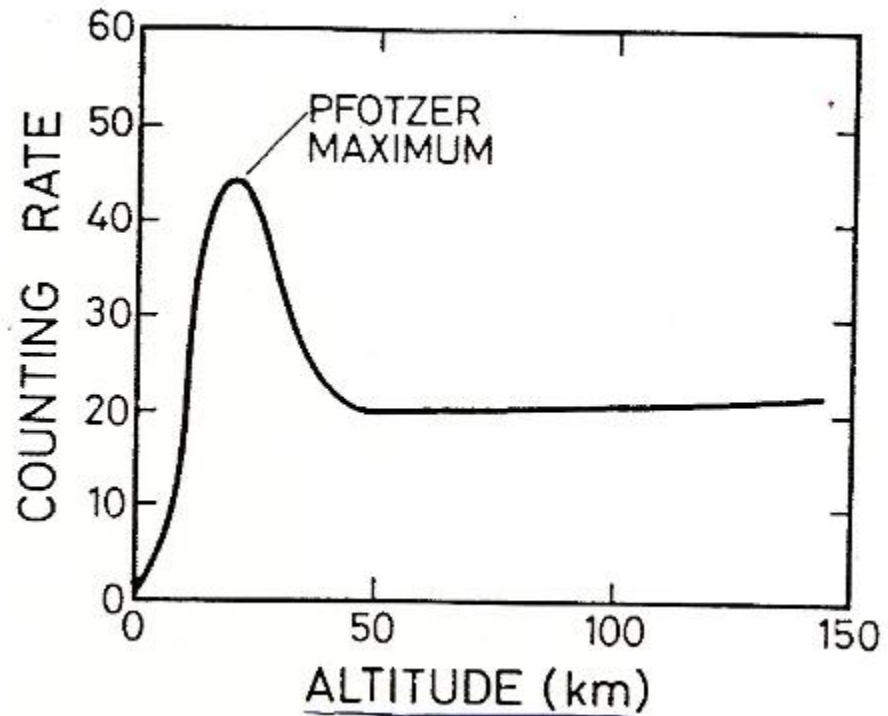
Ascese su Pallone:
Hess 1912 @ 5km



<u>Altitude</u> (km)	<u>Difference between observed ionisation and that at sea-level</u> (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

Colhoster 1914
@ 9km

Millikan scettico sui "...Raggi ... Cosmici"



Composizione dei Raggi Cosmici

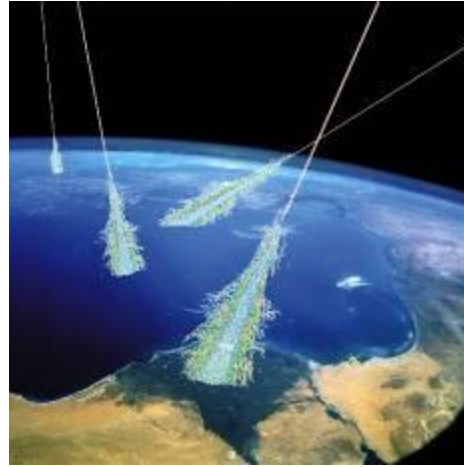
PRIMARI:

$p \sim 87 \%$, $\alpha \sim 10 \%$, $N \sim 1 \%$

$e \sim 2 \%$

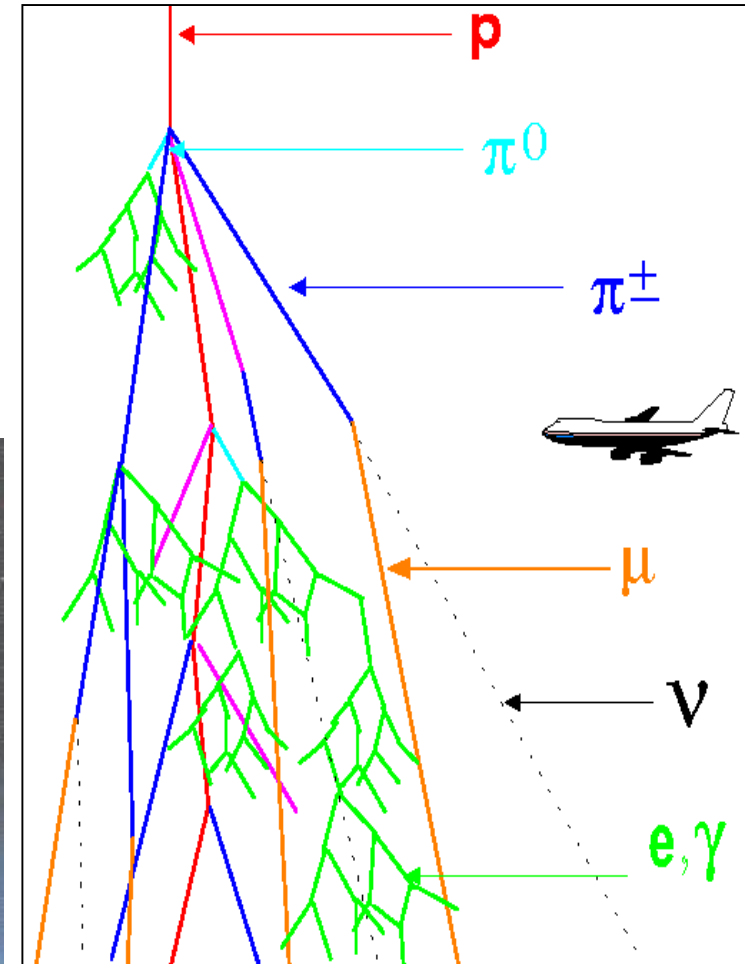
$\gamma \sim 0.1 \%$, $\nu \sim 0.1 \%$?

Alta atmosfera : $\sim 1000/m^2/s$



I Raggi Cosmici Primari producono sciami di secondari in atmosfera

A livello del mare : $\sim 100/m^2/s$



SECONDARI al livello del mare

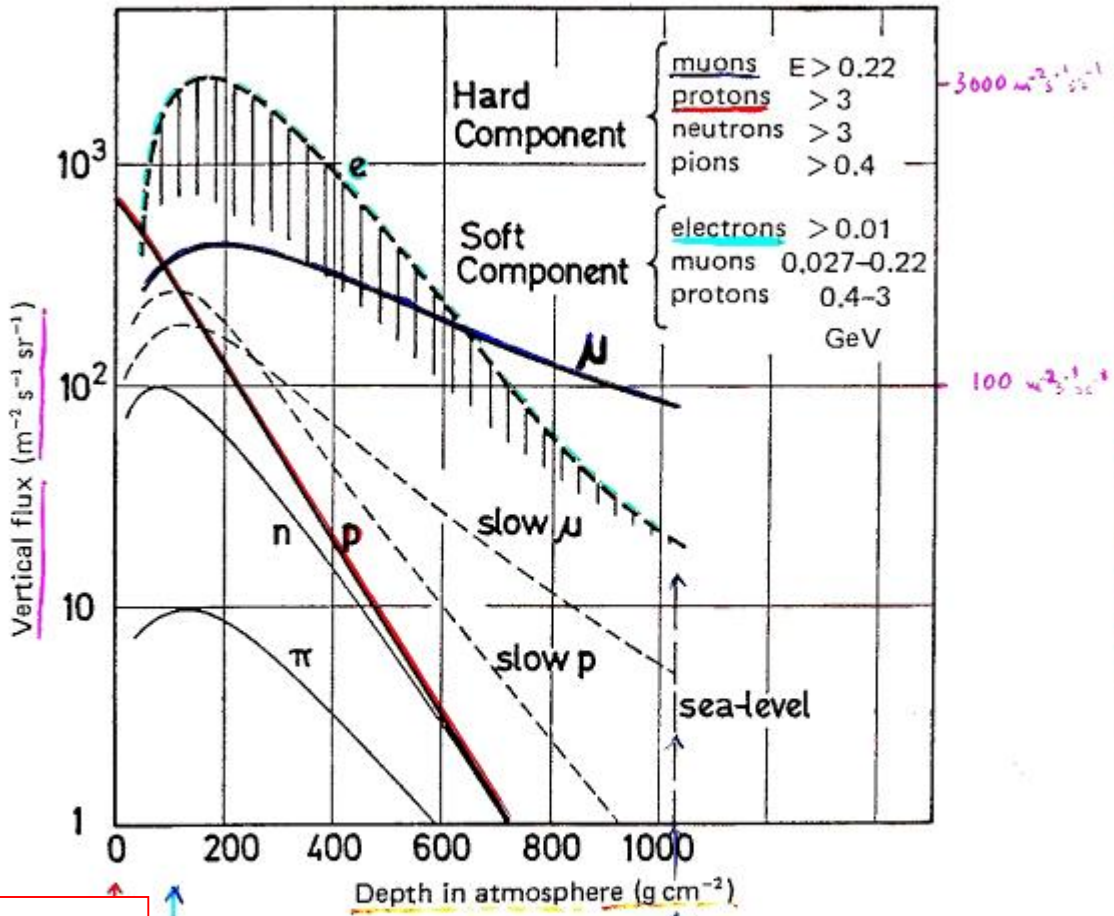
$\mu \sim 30 \%$

$p, n, \dots \sim 2 \%$

$\nu \sim 68 \%$

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

Fig. 5.5. The vertical fluxes of different components of cosmic rays within the atmosphere. (From Hillas, 1972, p. 50.)



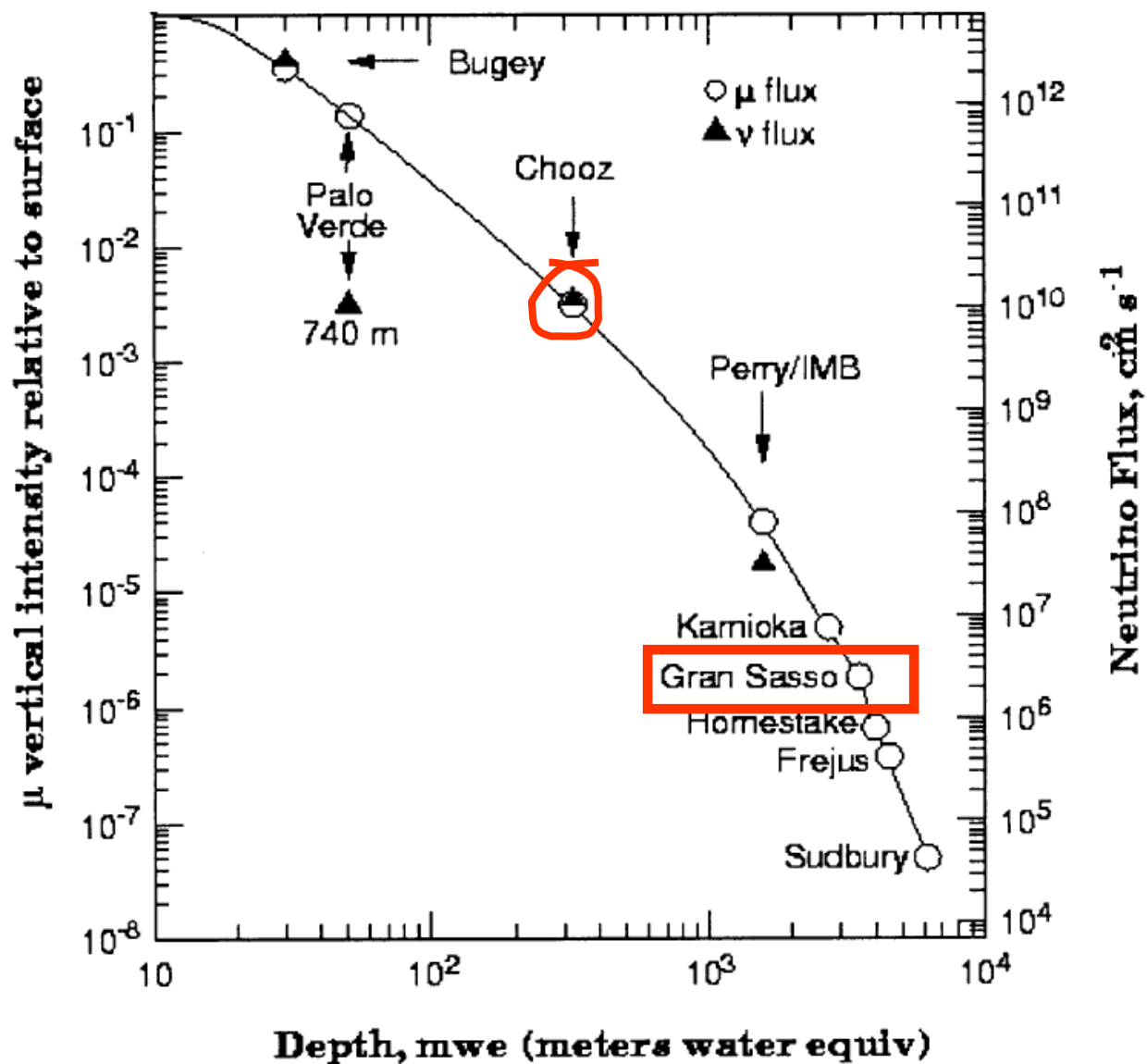
Spazio

Pfozter maximum @ ~ 20 km

Livello del mare

Flusso di μ

μ Depth-Intensity and ν Flux
for various sites



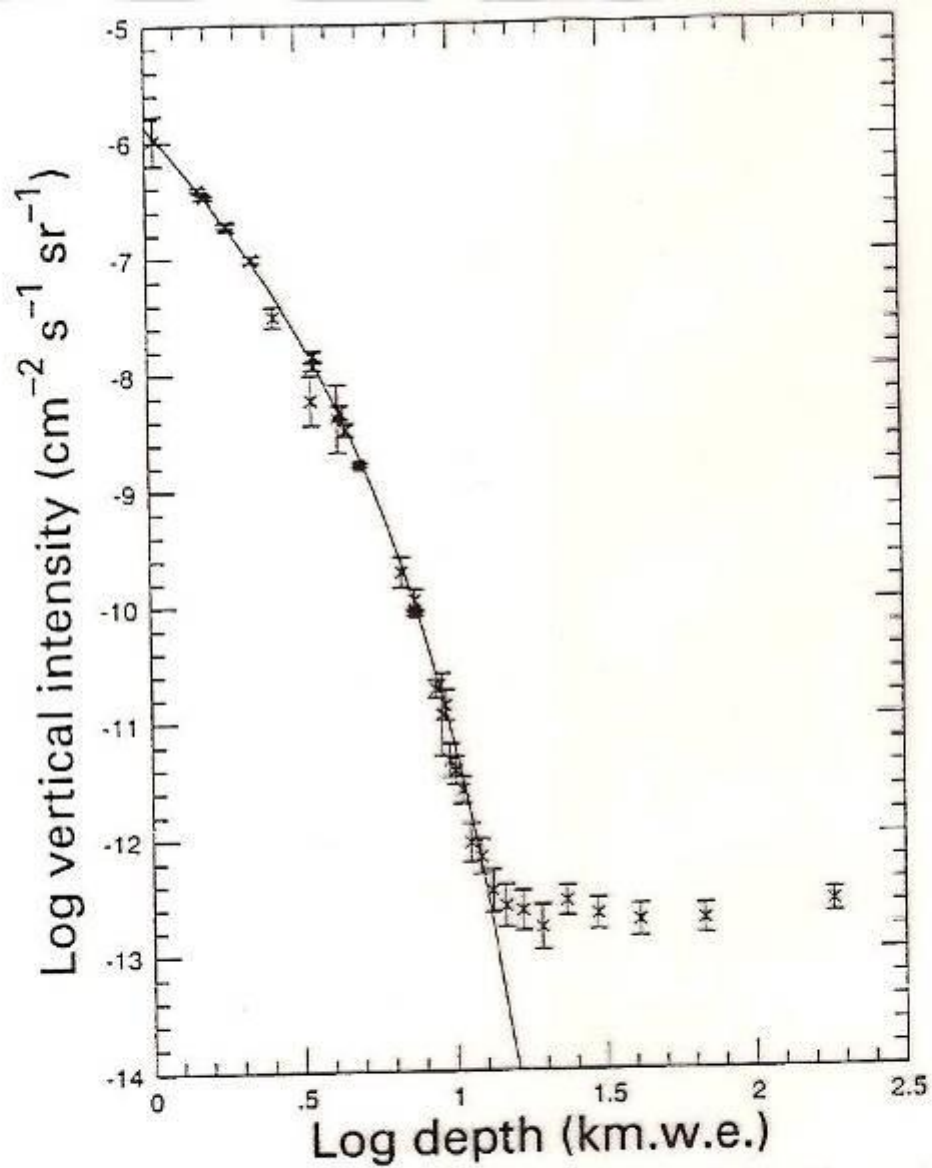
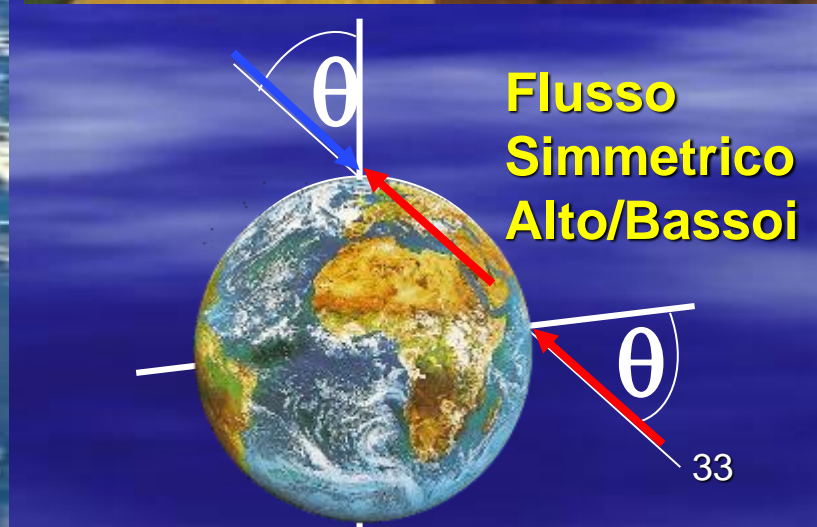
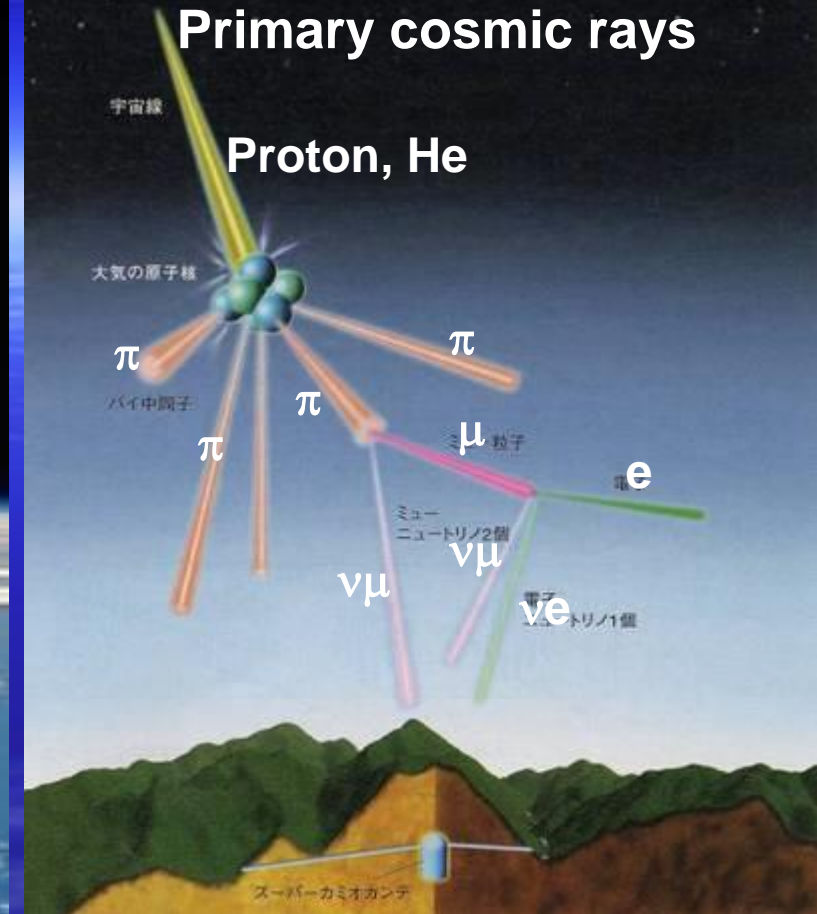


Figure 6.3: Relation between muon intensity and depth underground. The data are taken from a summary by Crouch (1987) with the addition of recent data from the Frejus experiment (Berger et al., 1989 – filled squares).

Sorgente Raggi Cosmici: ν Atmosferici

atmosfera



Gli esperimenti “storici”

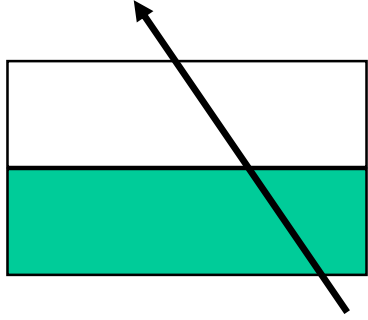
- Macro
 - Ricerca dei monopoli magnetici

- LVD
 - Ricerca di supernovae

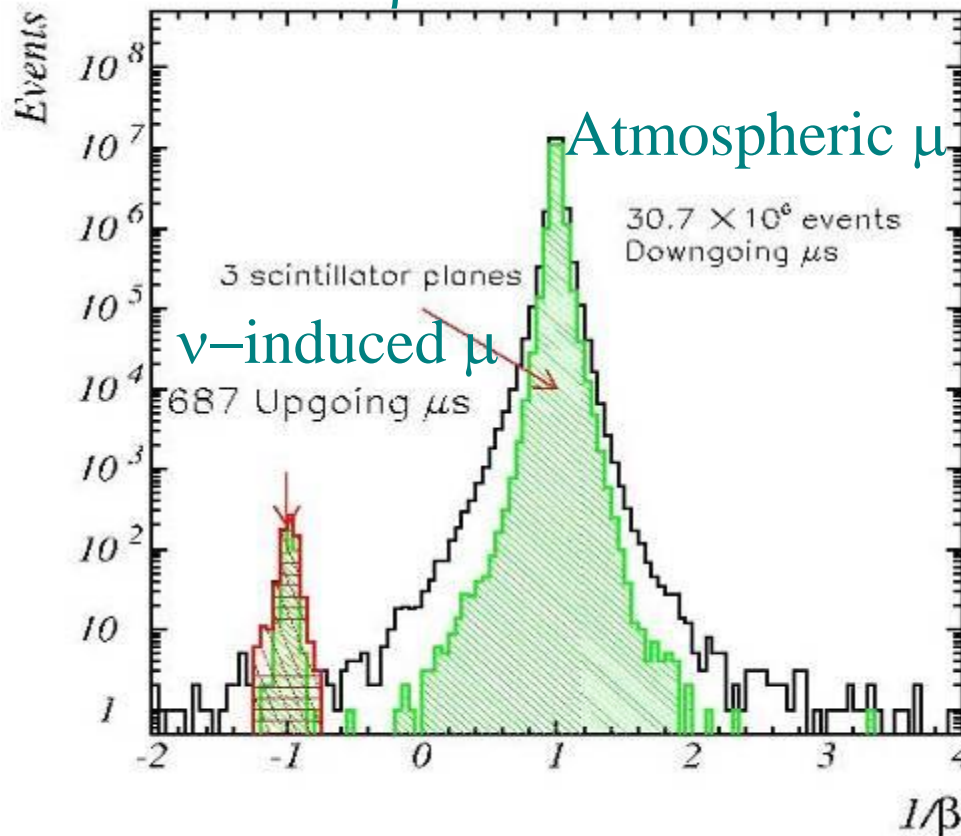
- Gallex
 - Studio di neutrini solari

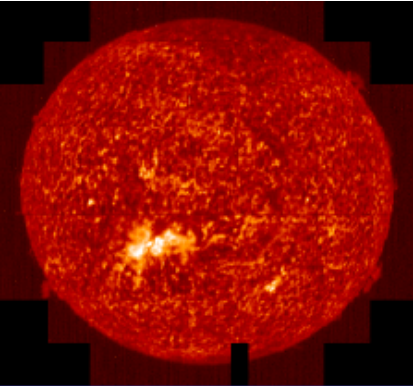


MACRO Upward throughgoing muons



$1/\beta$ distribution:





GNO

Collab.:
Italy, France, Germany

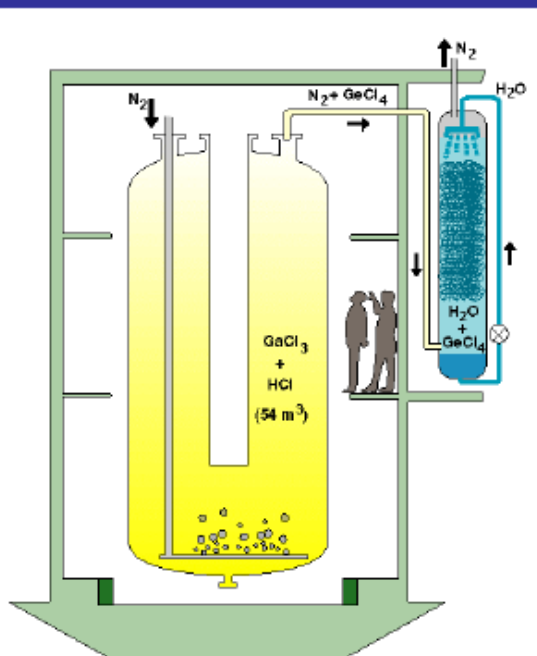
Goals: measurement of the interaction rate with an accuracy of 4-5% and monitoring the neutrino flux over a complete solar cycle.

101 tons Gallium Chloride solution

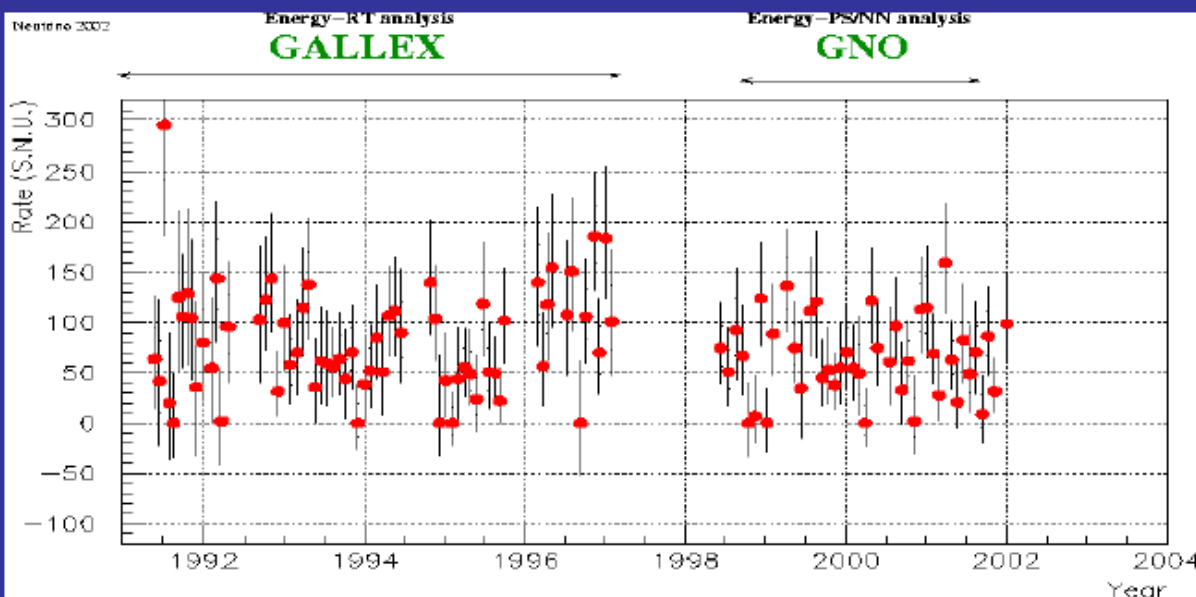
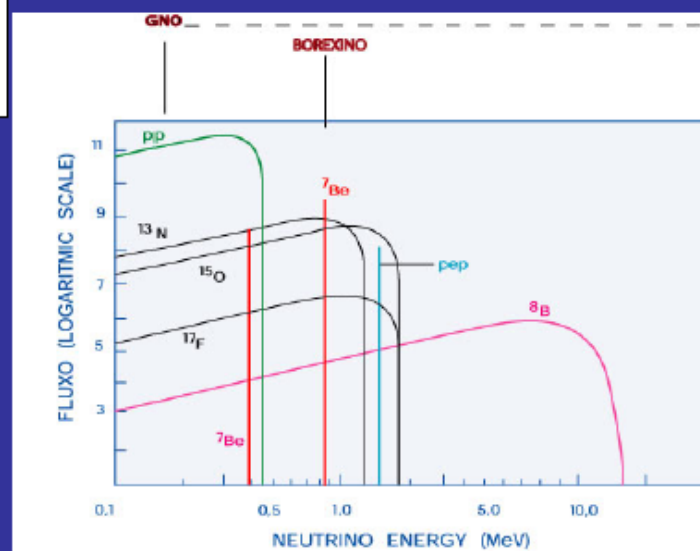
$^{71}\text{Ge}(\nu_e, e)^{71}\text{Ge}$

Energy threshold > 233 keV

Sensitive mainly to pp -neutrinos

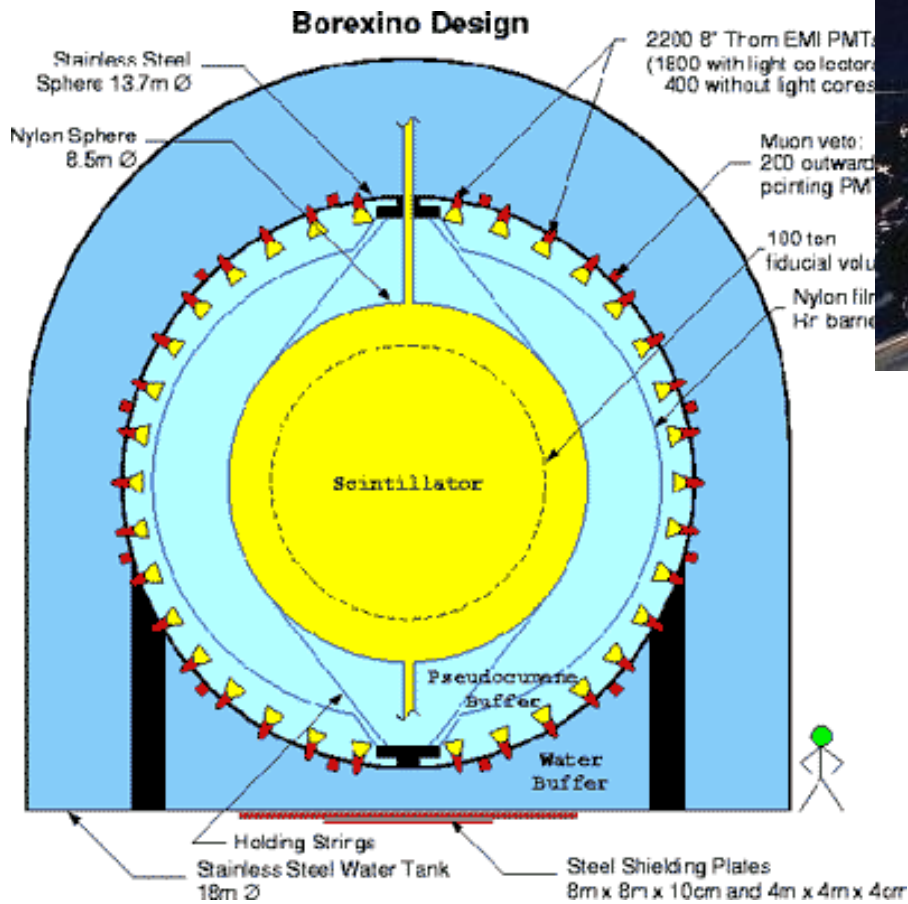


SSM → 115 -135 SNU



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

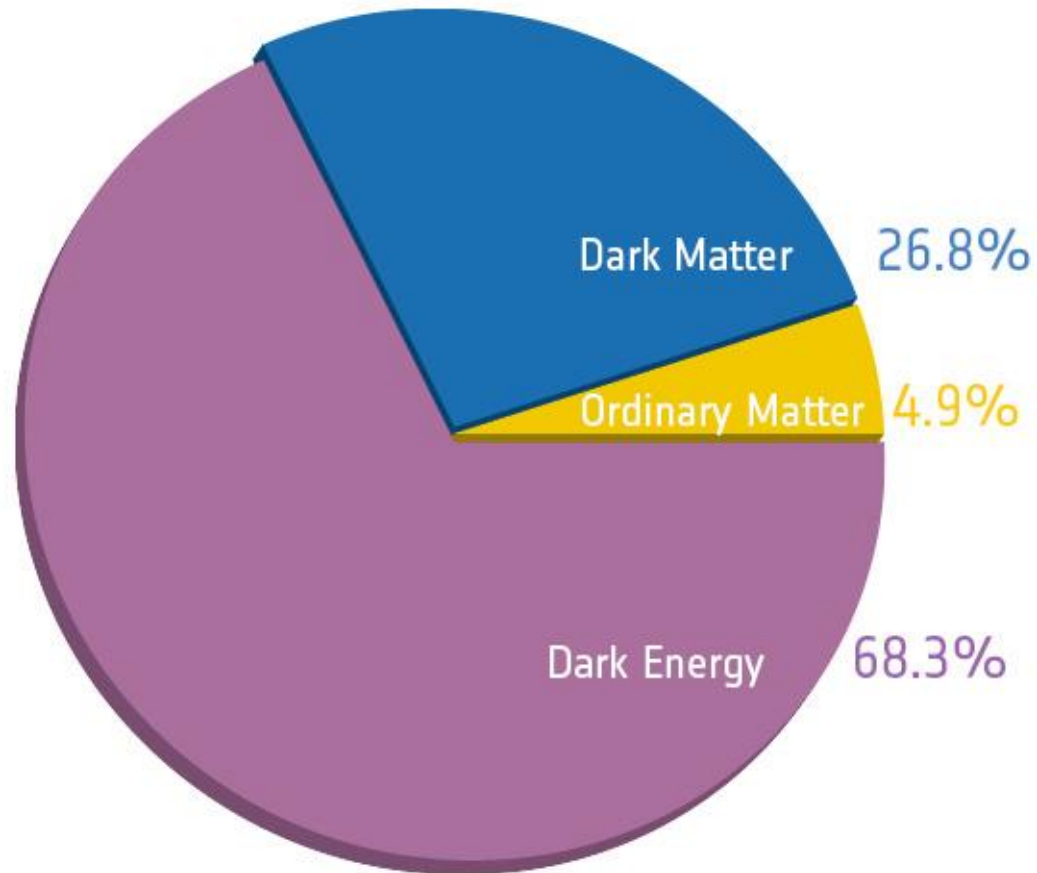
Borexino



Materia Oscura

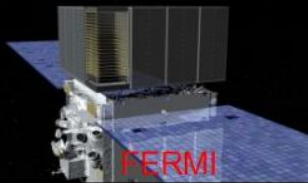


Materia Oscura

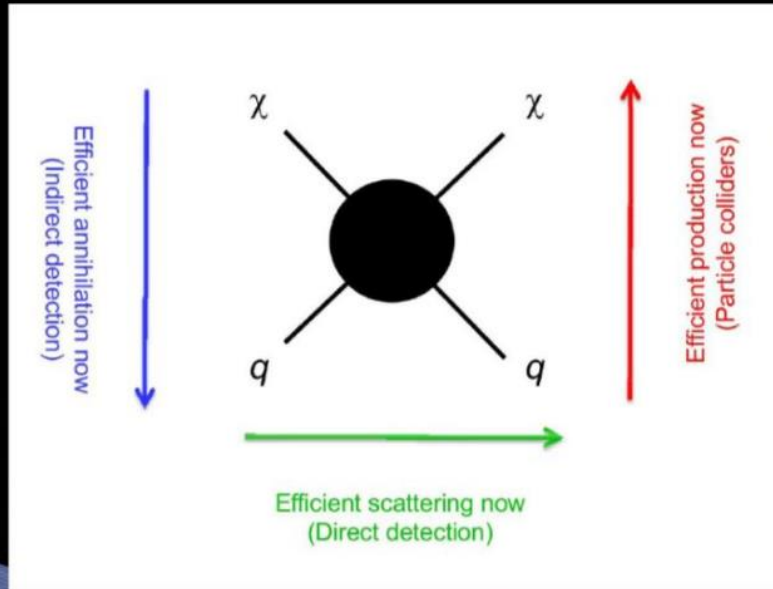


Materia Oscura

Come cercare la materia oscura



Nello spazio



Con acceleratori di particelle



Sottoterra

Adapted from P. Lipari

