

Visita ai Laboratori dell'INFN

23-24 Gennaio 2015

Laboratori Nazionali del Gran Sasso

Dipartimento di

Fisica



Universita' di TRIESTE

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Legnaro(PD)

Trieste

Ancona

Gran Sasso

L'Aquila

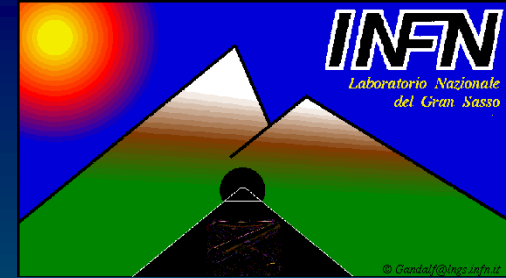
Roma



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)

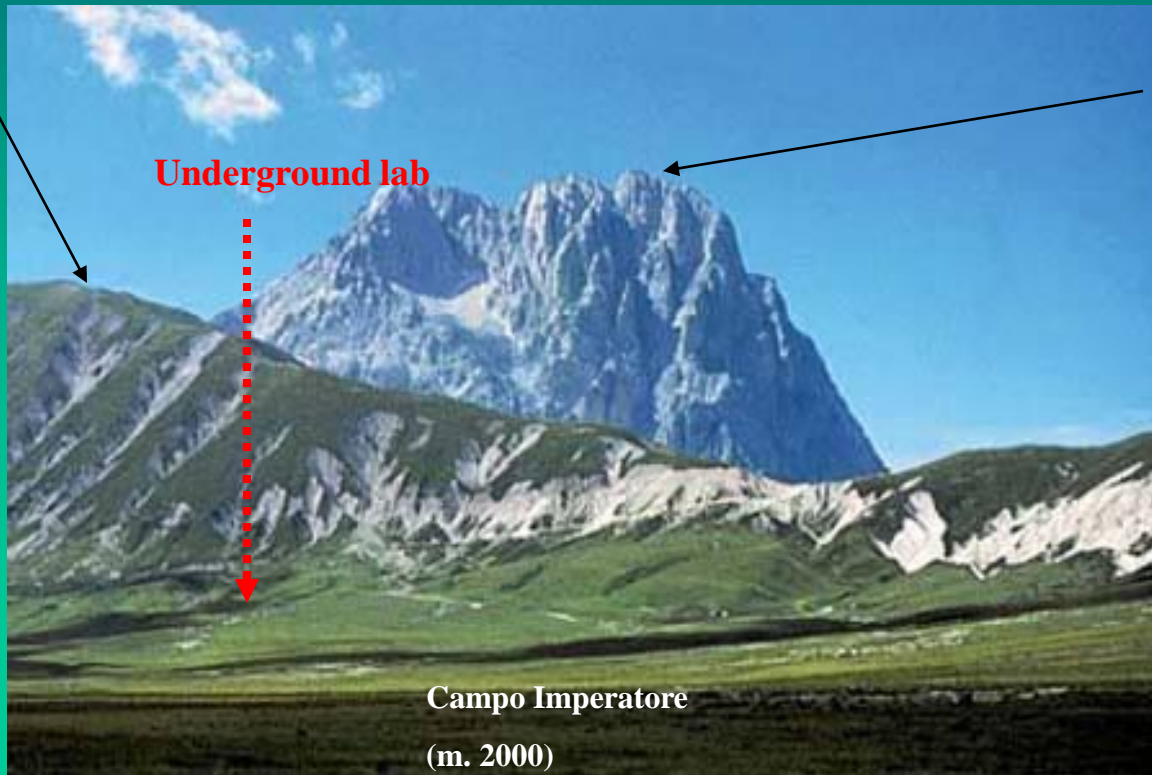
Operating Institution: Istituto Nazionale di Fisica Nucleare (INFN)

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

Scientists involved in LNGS experiments: 700 from 24 countries

Monte Aquila
(m. 2600)

Corno Grande (m. 2910)



Underground lab

Campo Imperatore
(m. 2000)

The area of Campo Imperatore
above LNGS

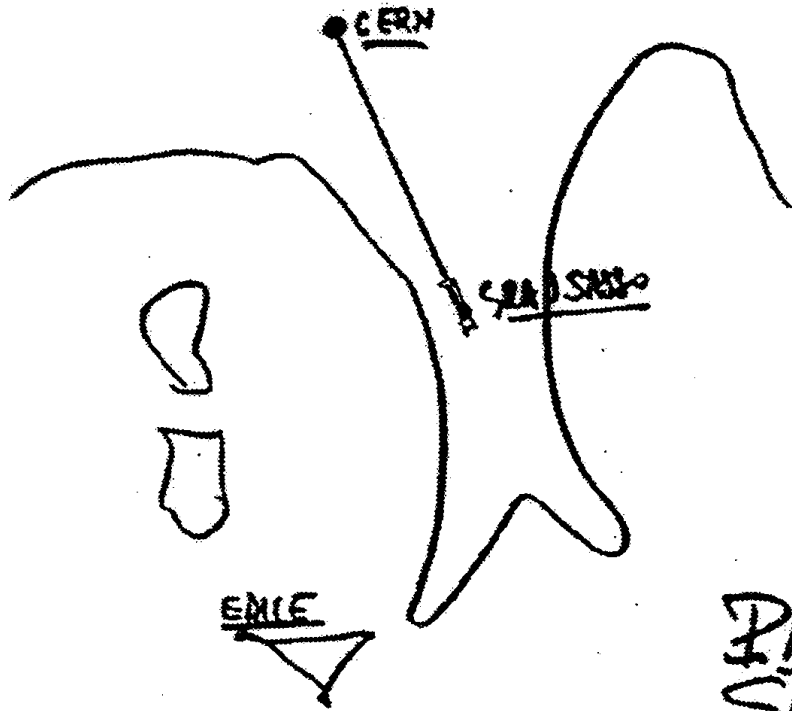
Nel **1979**, durante la costruzione della autostrada A24 fra Roma e L'Aquila, A. Zichichi ha proposto l'idea di costruire un **laboratorio sotterraneo** sotto il **Gran Sasso**

- **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

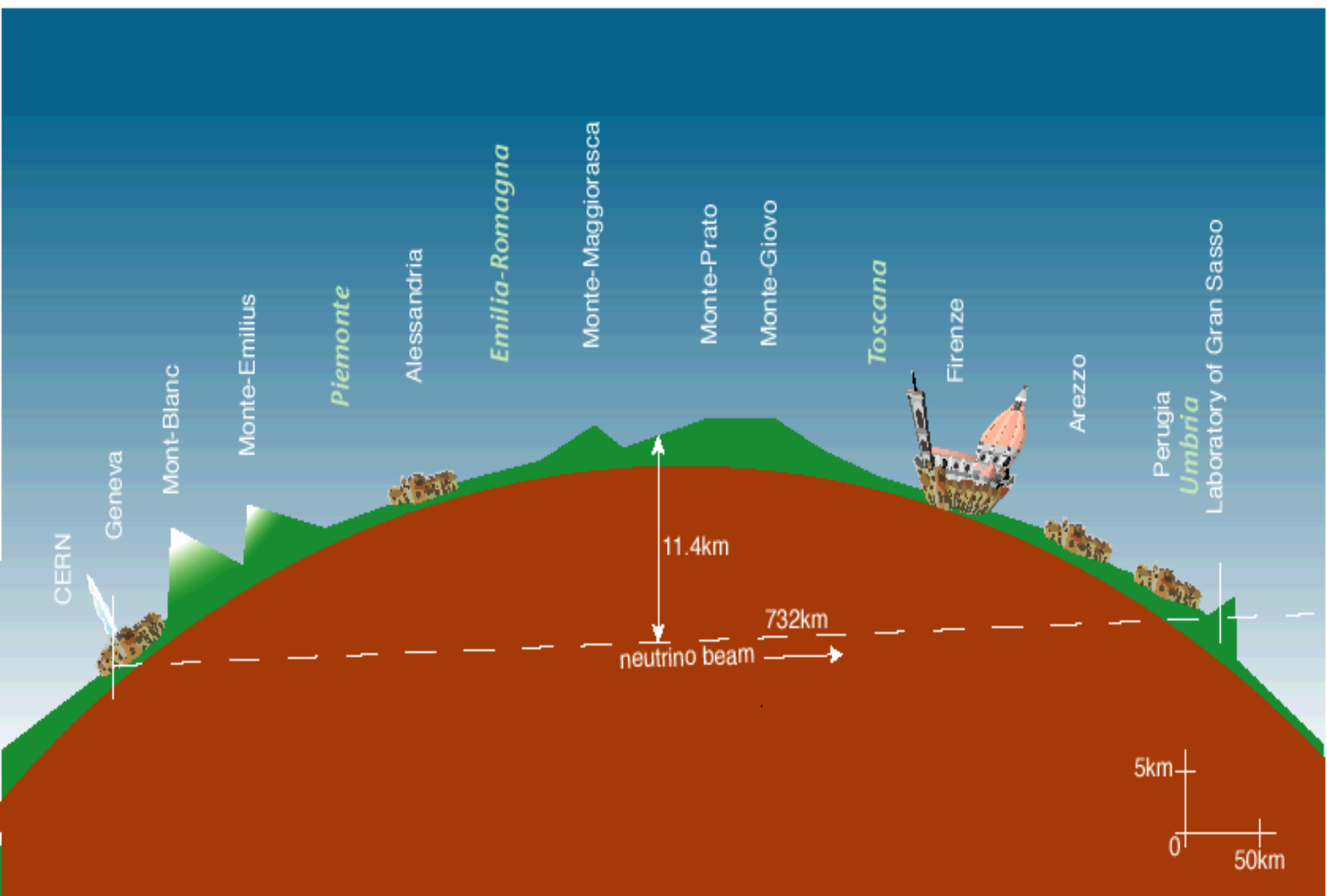


CONDIZIONE LAVORI PUBBLICI DEL SENATO



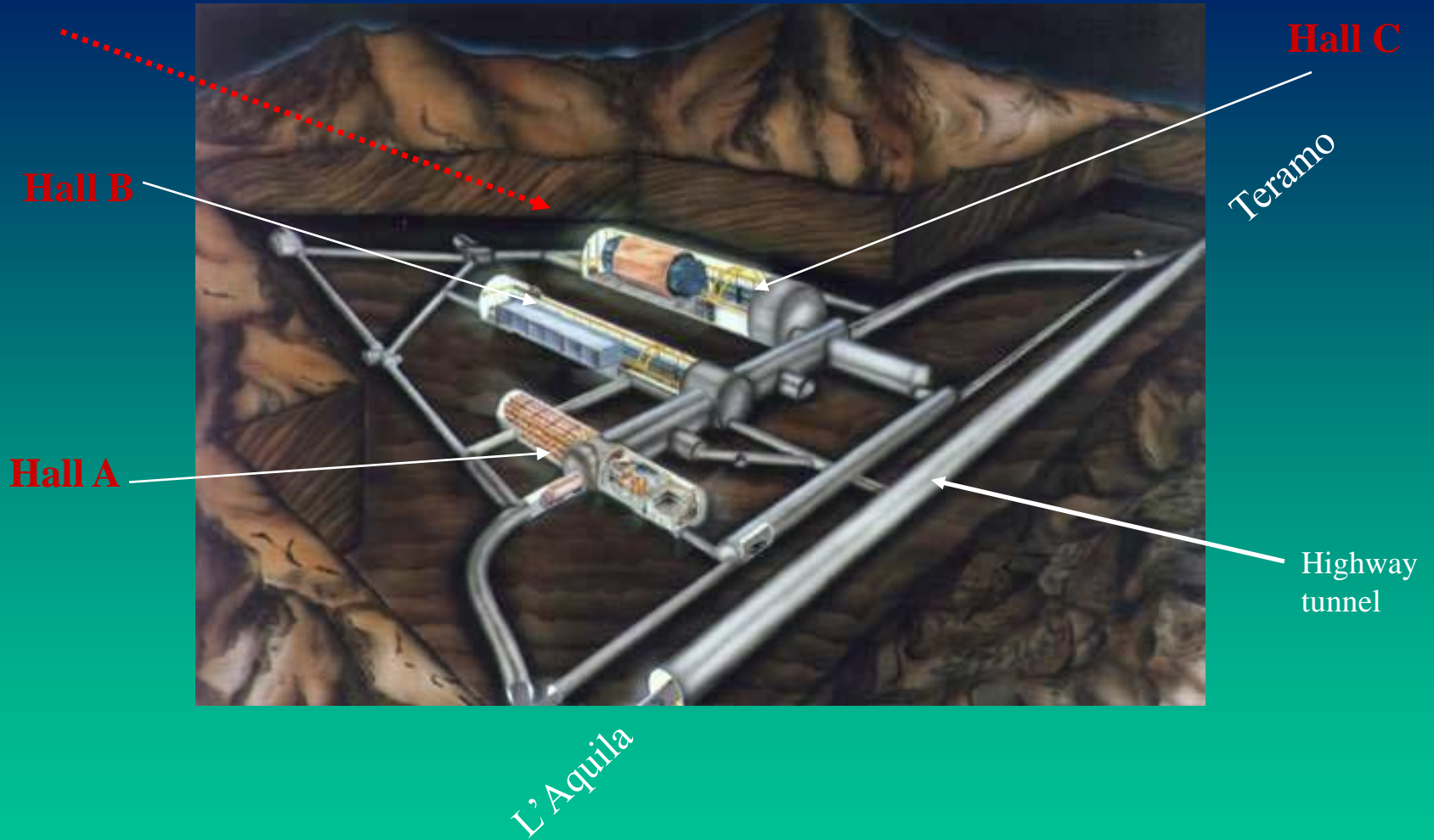
PROGETTO
GRAN SASSO

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

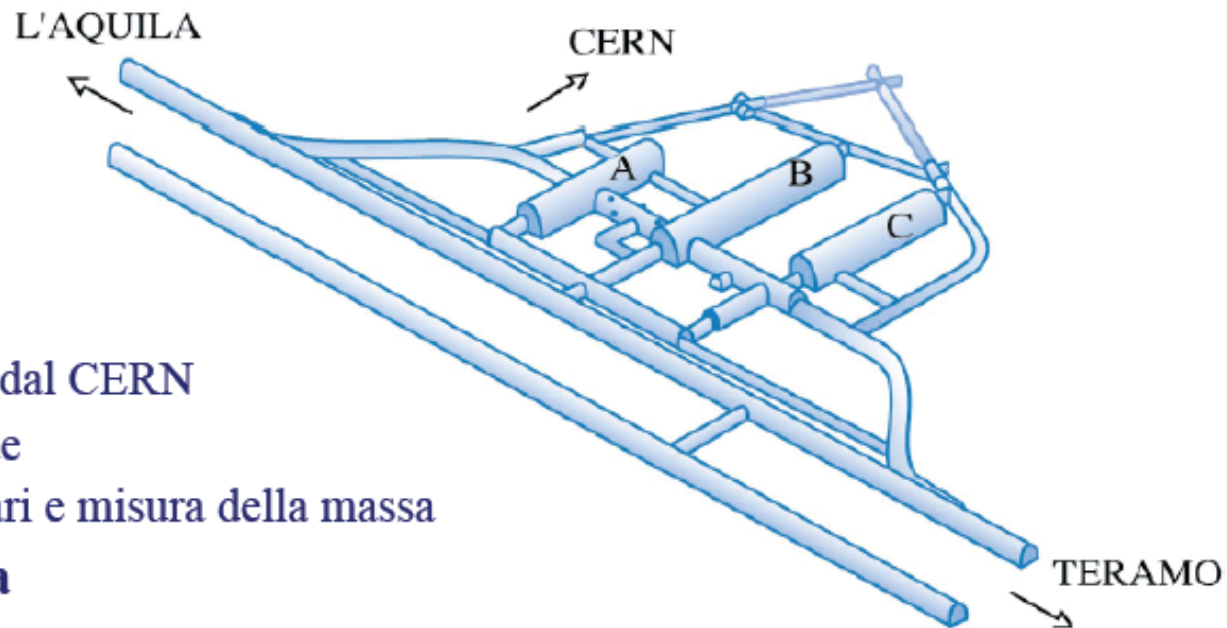
- Neutrini solari
- Esperimenti con neutrini dal CERN
- Rivelazione di supernovae
- Ricerca di decadimenti rari e misura della massa

■ Ricerca di materia oscura

■ Fisica nucleare dei processi rari

■ Geofisica

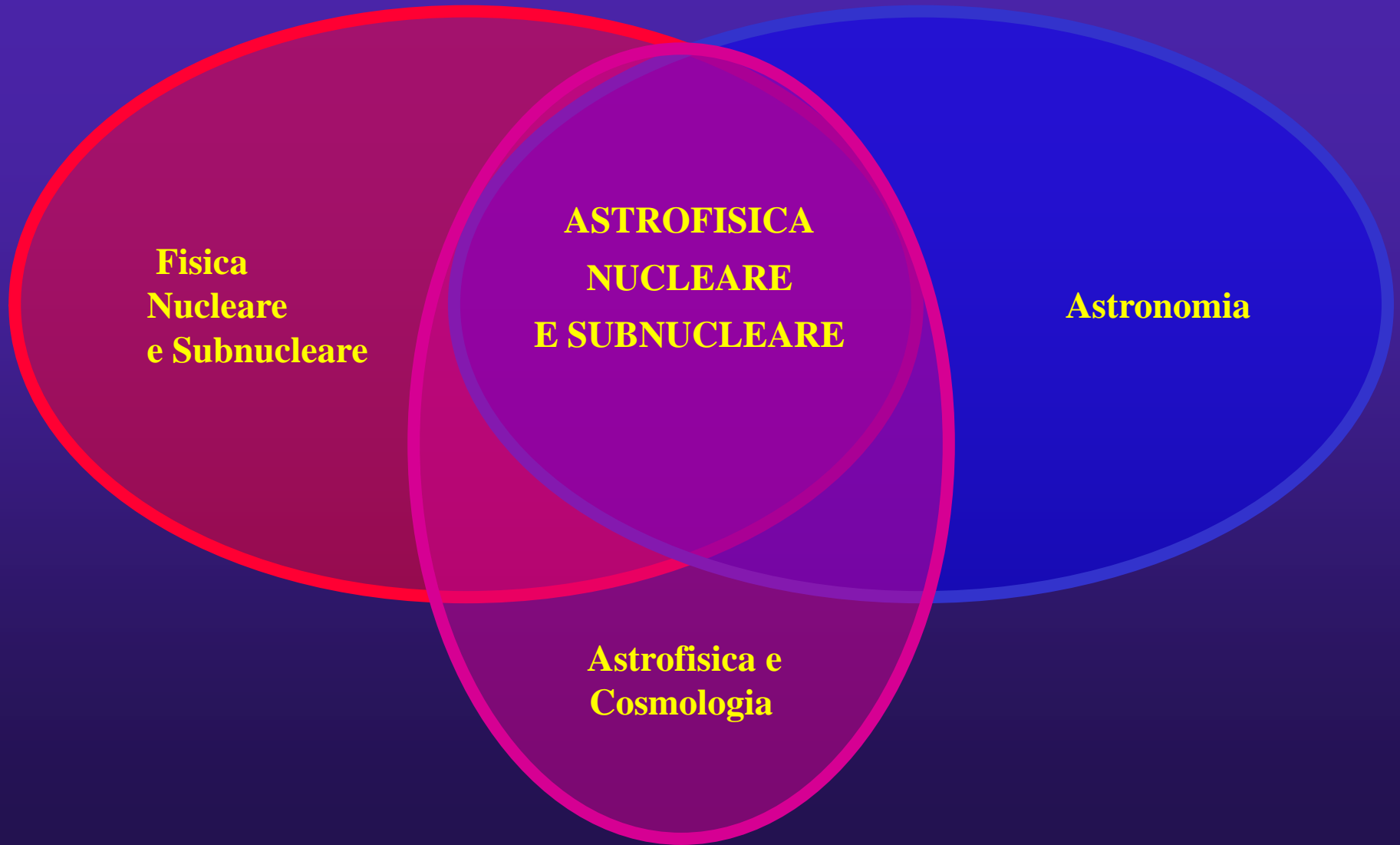
■ Biologia



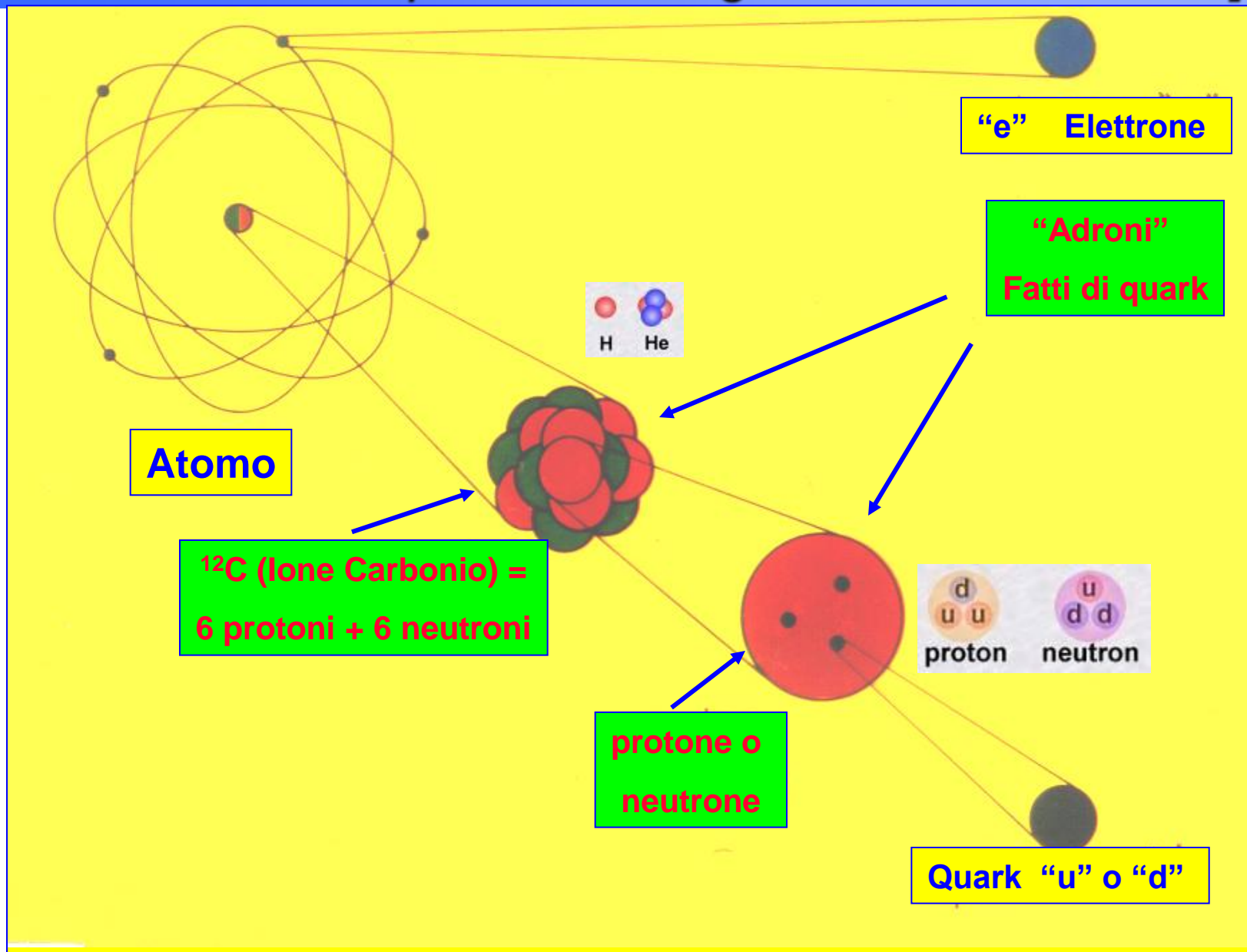
Tunnel:	10.4 Km
Copertura:	~ 3200 m.w.e.
Riduzione flusso muoni:	~ 10⁶

Astrofisica Nucleare e Subnucleare

(Fisica Astroparticellare/Astrofisica Particellare)



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



10^{-43} sec

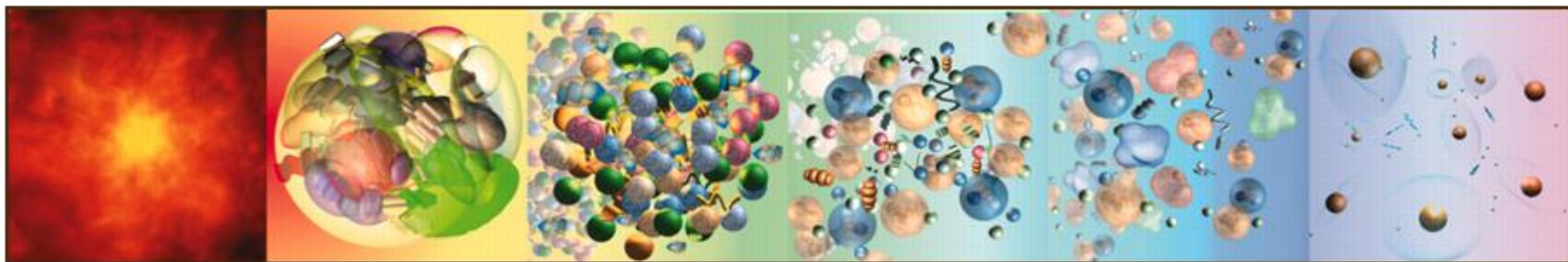
10^{-32} sec

10^{-10} sec

10^{-4} sec

100 sec

300000 years



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

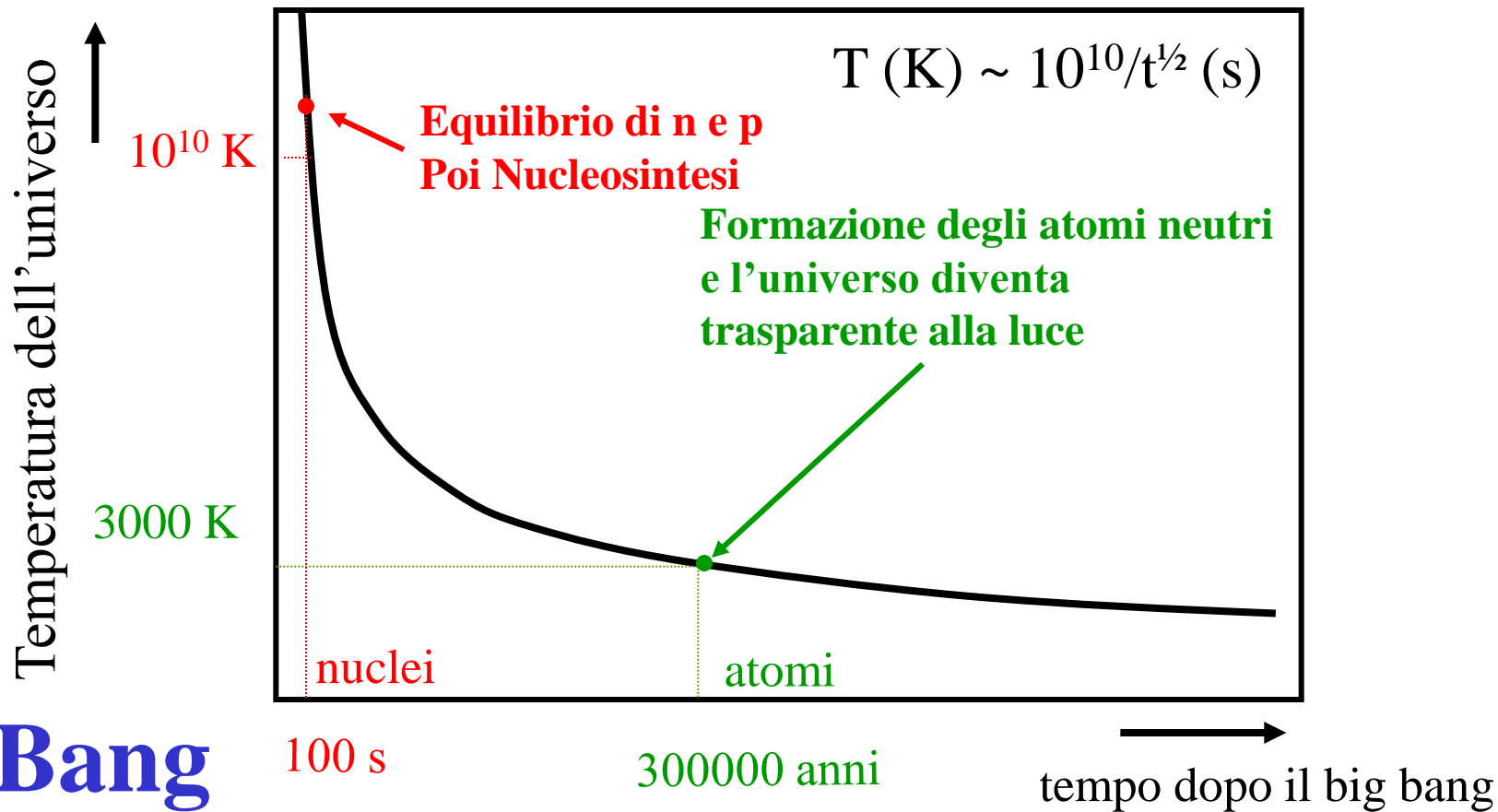
10^{-32} m
 10^{16} GeV

10^{-18} m
 10^2 GeV

10^{-16} m
1 GeV

10^{-15} m
1 MeV

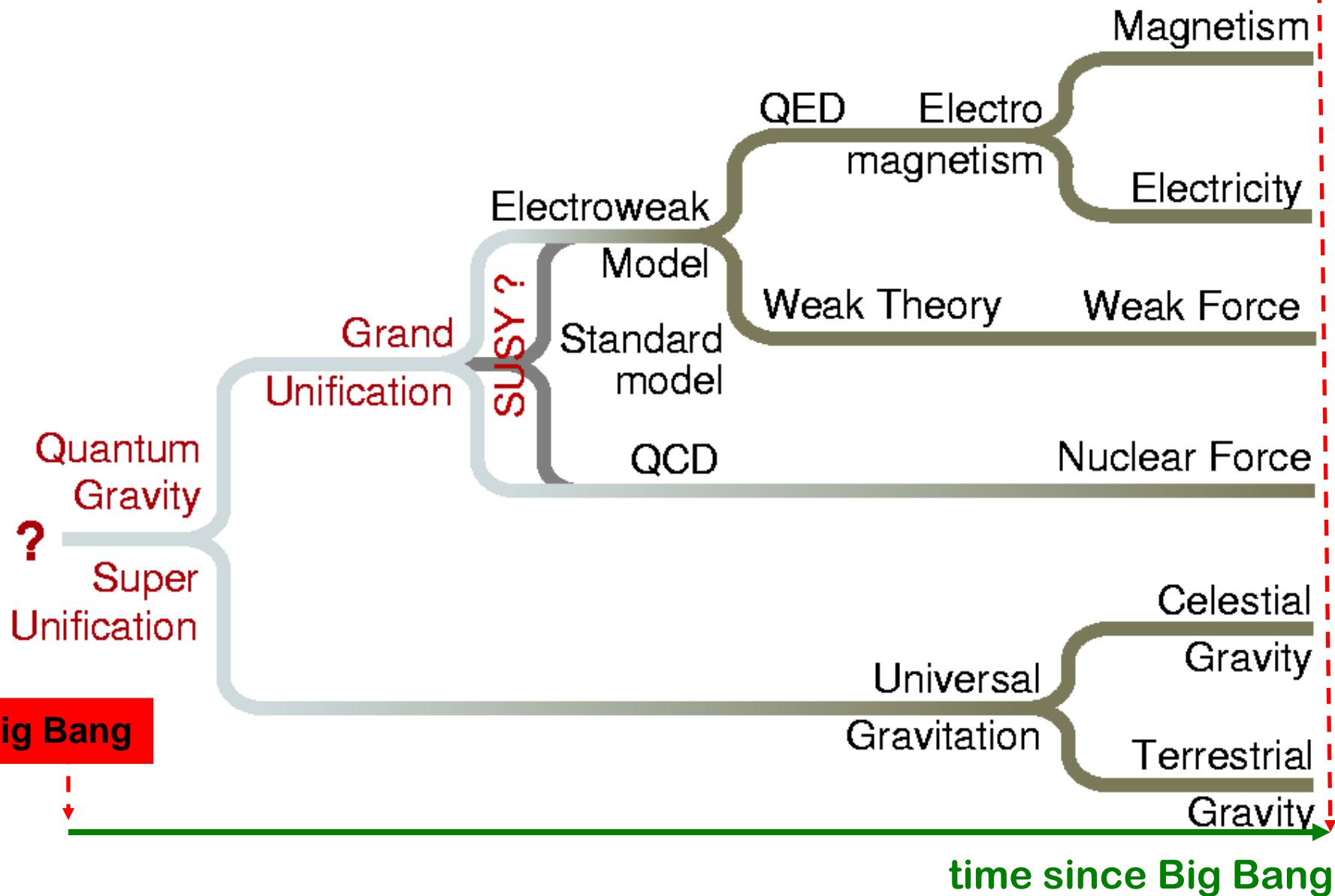
10^{-10} m
10 eV



Big Bang

Unificazione delle Forze

Today



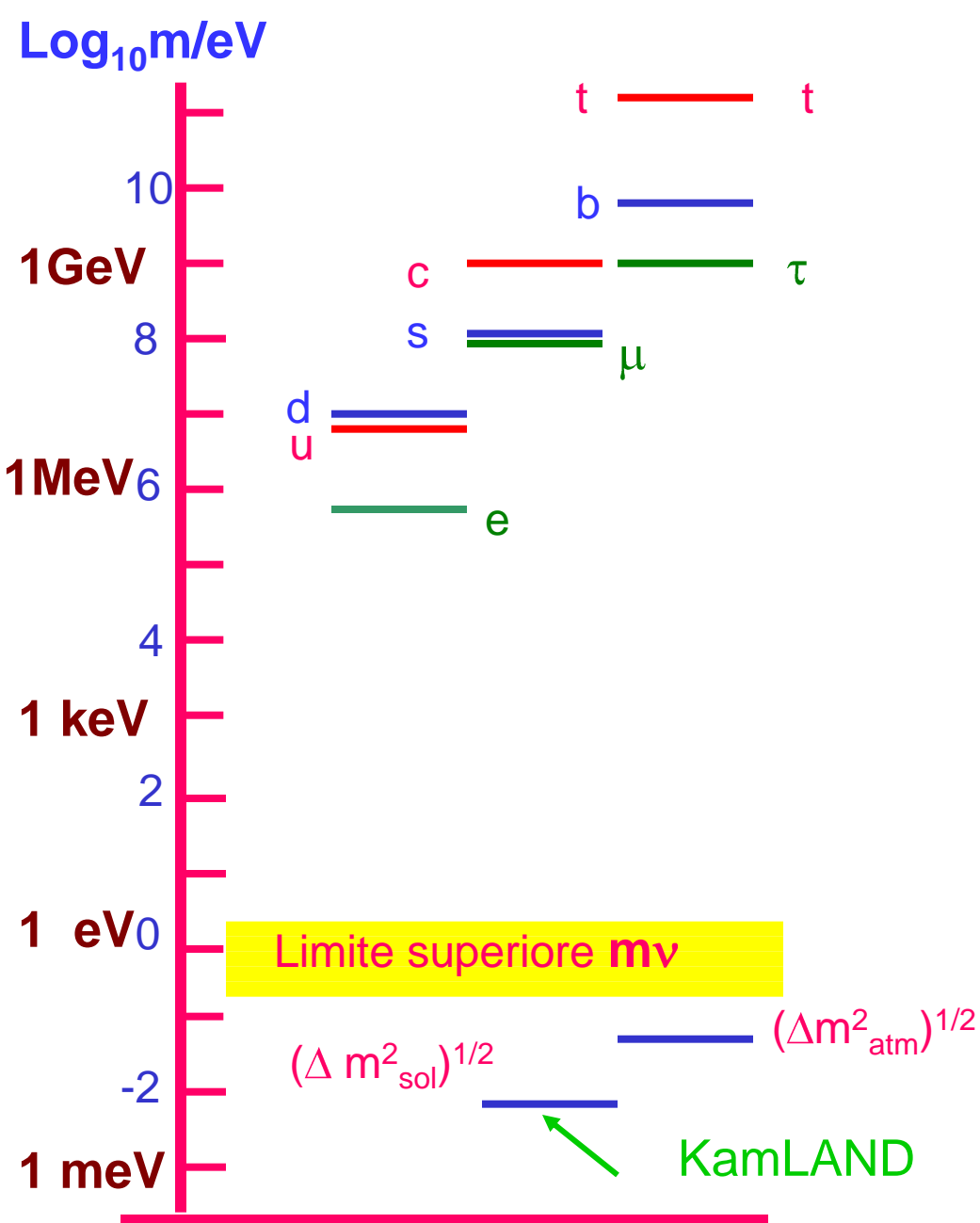
MODELLO STANDARD : Fermioni (Costituenti) e Bosoni (Mediatori)

		Famiglie di Fermioni			Bosoni (mediatori delle interazioni)																	
		I	II	III																		
$\left(\begin{matrix} u_i \\ d'_i \end{matrix} \right)_L$	Q u a r k	<table border="1"> <tr><td>up</td><td>+2/3</td></tr> <tr><td>u</td><td>$\frac{3}{4}$</td></tr> </table>	up	+2/3	u	$\frac{3}{4}$	<table border="1"> <tr><td>charm</td><td>+2/3</td></tr> <tr><td>c</td><td>$\frac{3}{1500}$</td></tr> </table>	charm	+2/3	c	$\frac{3}{1500}$	<table border="1"> <tr><td>top</td><td>+2/3</td></tr> <tr><td>t</td><td>$\frac{3}{170000}$</td></tr> </table>	top	+2/3	t	$\frac{3}{170000}$	<table border="1"> <tr><td>Fotone</td><td>0</td></tr> <tr><td>γ</td><td>0</td></tr> </table>	Fotone	0	γ	0	Interazione elettromagnetica
		up	+2/3																			
u	$\frac{3}{4}$																					
charm	+2/3																					
c	$\frac{3}{1500}$																					
top	+2/3																					
t	$\frac{3}{170000}$																					
Fotone	0																					
γ	0																					
<table border="1"> <tr><td>down</td><td>-1/3</td></tr> <tr><td>d</td><td>$\frac{3}{80}$</td></tr> </table>	down	-1/3	d	$\frac{3}{80}$	<table border="1"> <tr><td>strange</td><td>-1/3</td></tr> <tr><td>s</td><td>$\frac{3}{160}$</td></tr> </table>	strange	-1/3	s	$\frac{3}{160}$	<table border="1"> <tr><td>bottom</td><td>-1/3</td></tr> <tr><td>b</td><td>$\frac{3}{4700}$</td></tr> </table>	bottom	-1/3	b	$\frac{3}{4700}$	<table border="1"> <tr><td>Gluone</td><td>0</td></tr> <tr><td>g</td><td>$\frac{8}{0}$</td></tr> </table>	Gluone	0	g	$\frac{8}{0}$	Interazione forte		
down	-1/3																					
d	$\frac{3}{80}$																					
strange	-1/3																					
s	$\frac{3}{160}$																					
bottom	-1/3																					
b	$\frac{3}{4700}$																					
Gluone	0																					
g	$\frac{8}{0}$																					
$\left(\begin{matrix} \nu_i \\ l_i \end{matrix} \right)_L$	L e p t o n i	<table border="1"> <tr><td>Neutrino elett.</td><td>0</td></tr> <tr><td>ν_e</td><td><0.000007</td></tr> </table>	Neutrino elett.	0	ν_e	<0.000007	<table border="1"> <tr><td>Neutrino muon.</td><td>0</td></tr> <tr><td>ν_μ</td><td><0.27</td></tr> </table>	Neutrino muon.	0	ν_μ	<0.27	<table border="1"> <tr><td>Neutrino taun.</td><td>0</td></tr> <tr><td>ν_τ</td><td><31</td></tr> </table>	Neutrino taun.	0	ν_τ	<31	<table border="1"> <tr><td>Z zero</td><td>0</td></tr> <tr><td>Z^0</td><td>91187</td></tr> </table>	Z zero	0	Z^0	91187	Interazione debole
		Neutrino elett.	0																			
ν_e	<0.000007																					
Neutrino muon.	0																					
ν_μ	<0.27																					
Neutrino taun.	0																					
ν_τ	<31																					
Z zero	0																					
Z^0	91187																					
<table border="1"> <tr><td>Elettrone</td><td>-1</td></tr> <tr><td>e</td><td>0.511</td></tr> </table>	Elettrone	-1	e	0.511	<table border="1"> <tr><td>Muone</td><td>-1</td></tr> <tr><td>μ</td><td>105.66</td></tr> </table>	Muone	-1	μ	105.66	<table border="1"> <tr><td>Tauone</td><td>-1</td></tr> <tr><td>τ</td><td>1777.1</td></tr> </table>	Tauone	-1	τ	1777.1	<table border="1"> <tr><td>W positivo</td><td>± 1</td></tr> <tr><td>W^+</td><td>80220</td></tr> </table>	W positivo	± 1	W^+	80220			
Elettrone	-1																					
e	0.511																					
Muone	-1																					
μ	105.66																					
Tauone	-1																					
τ	1777.1																					
W positivo	± 1																					
W^+	80220																					

Carica elettrica
 Numero di colori di carica
 Massa in MeV

l_{iR}, d_{iR}, u_{iR}

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

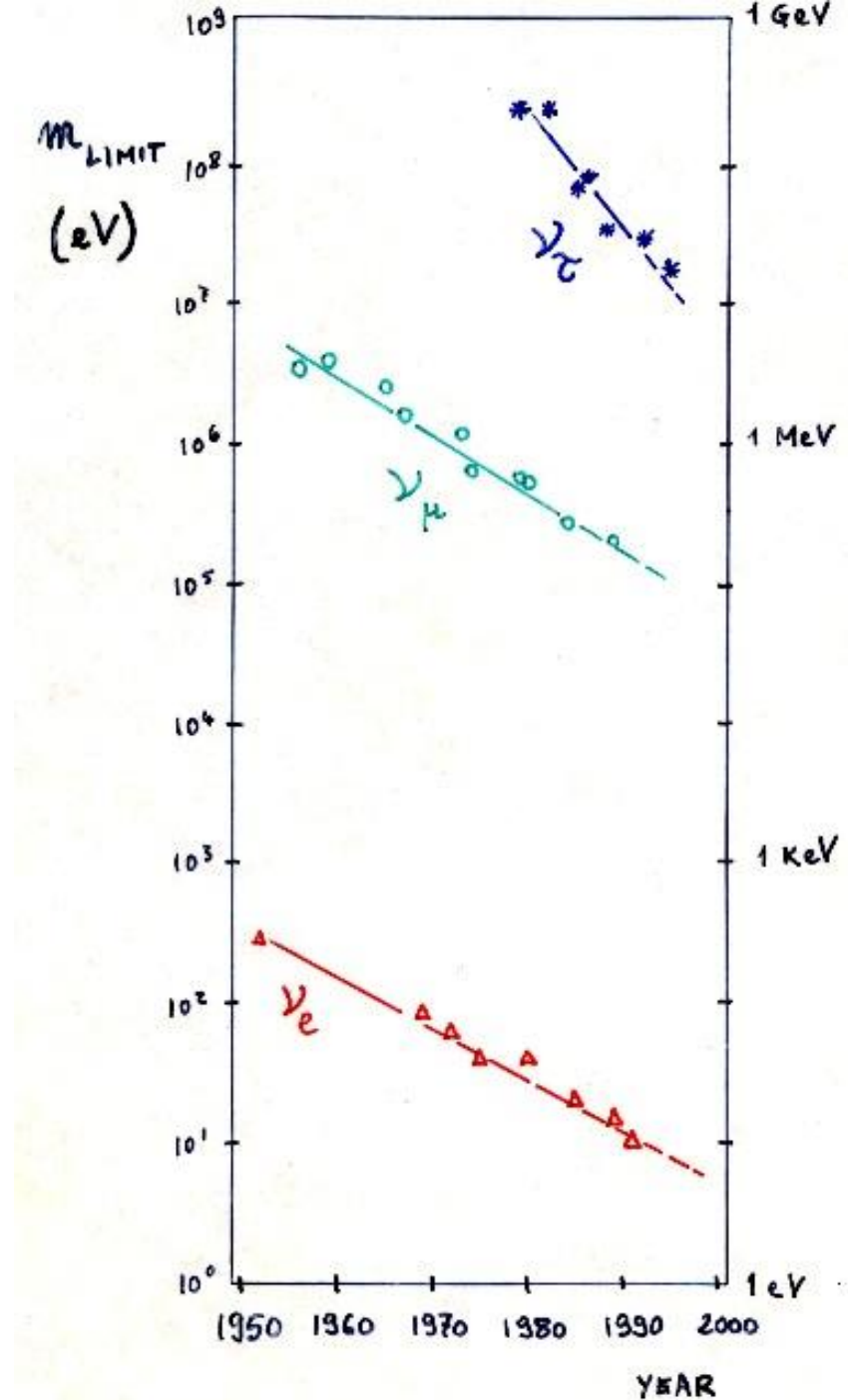


Massa dei fermioni: Quark e Leptoni

- 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

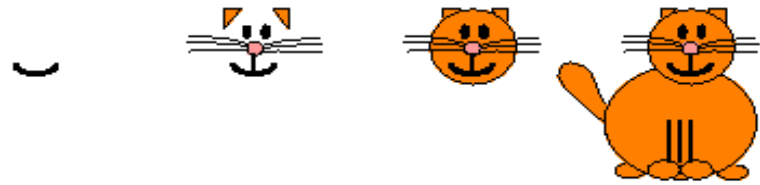
**I Neutrini Interagiscono
(Produzione o Rivelazione) come
Autostati dell'Interazione Debole**

$|v_e\rangle$, $|v_\mu\rangle$, $|v_\tau\rangle$ = 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

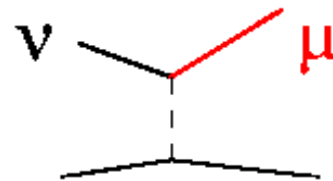


"Appearance Experiments"
see the new neutrino type
in the detector

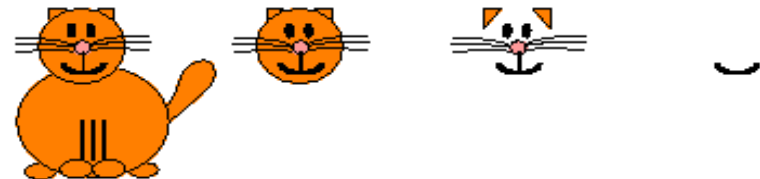


A *"Disappearance Experiment"* observes

fewer



than expected



Scomparsa/Desappearance

Esperimenti con Neutrini :

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

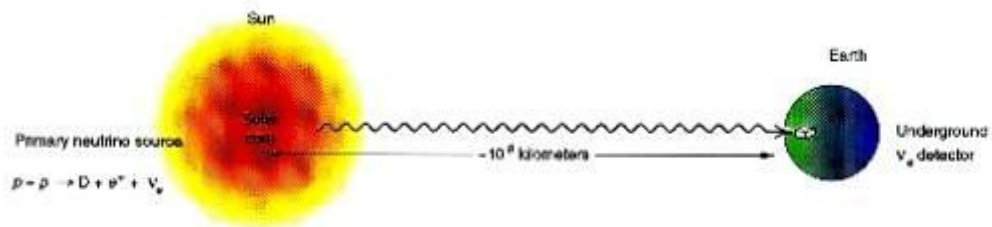
Sorgenti naturali:

Sole, Supernovae, Raggi cosmici

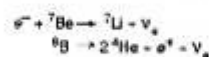
Sorgenti Artificiali:

Acceleratori, Reattori Nucleari

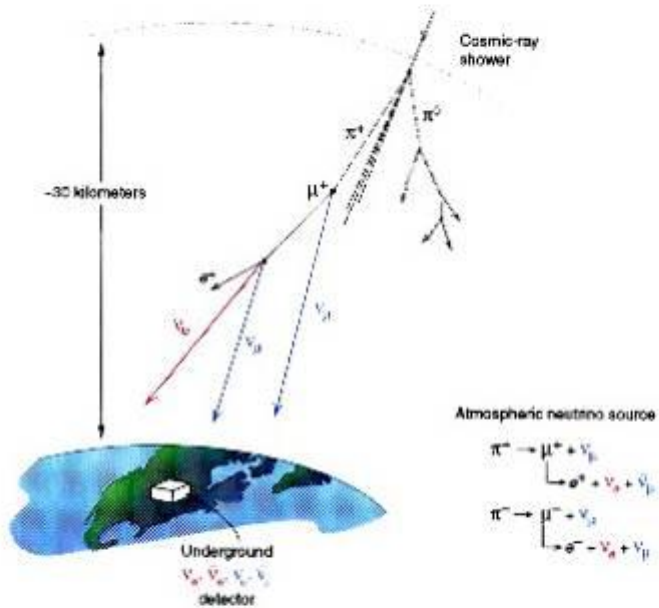
SOLAR ν : (ν_e)



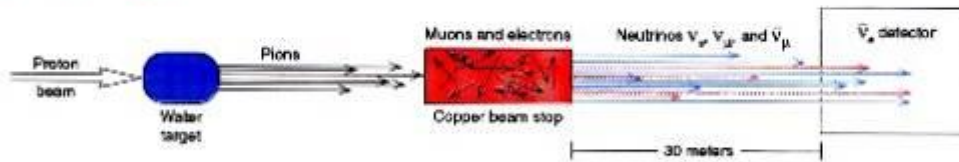
Other sources of neutrinos:



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



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



REACTOR ν :
 ($\bar{\nu}_e$)



Raggi Cosmici

Colhoster 1914
@ 9km



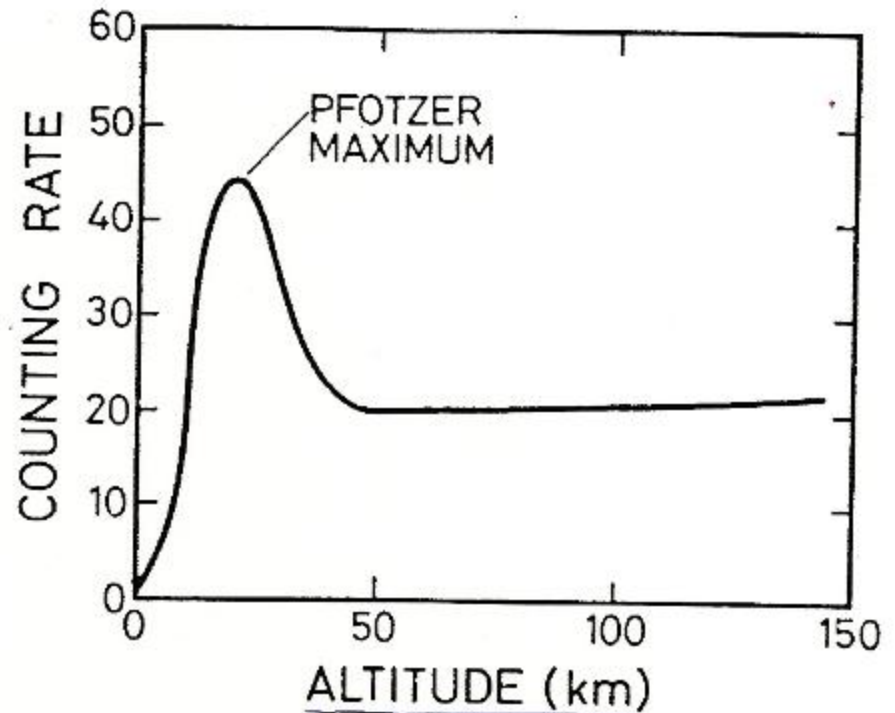
Altitude
(km)

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" $\gamma\text{s}''$

Ascese su Pallone:
Hess 1912 @ 5km



Composizione dei Raggi Cosmici

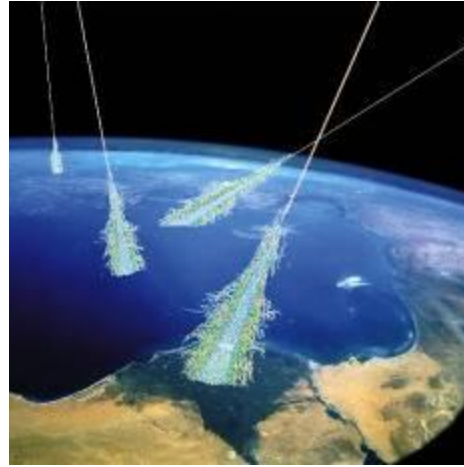
PRIMARI:

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

$e \sim 2 \%$

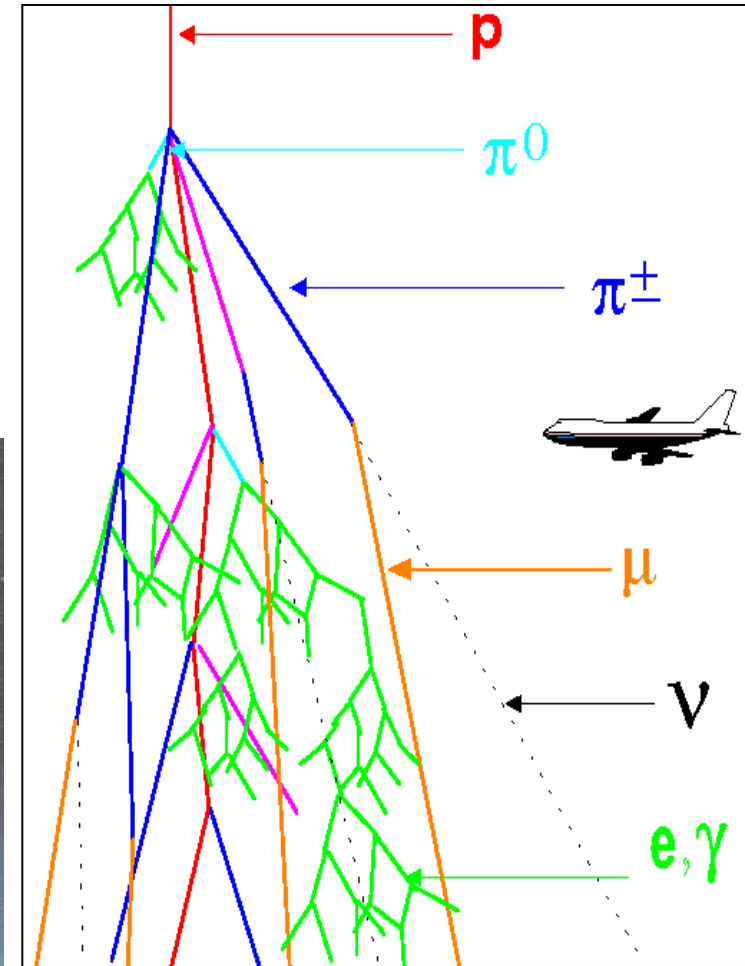
$\gamma \sim 0.1 \%$, $\nu \sim 0.1 \%$?

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



I Raggi Cosmici Primari producono sciami di secondari in atmosfera

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

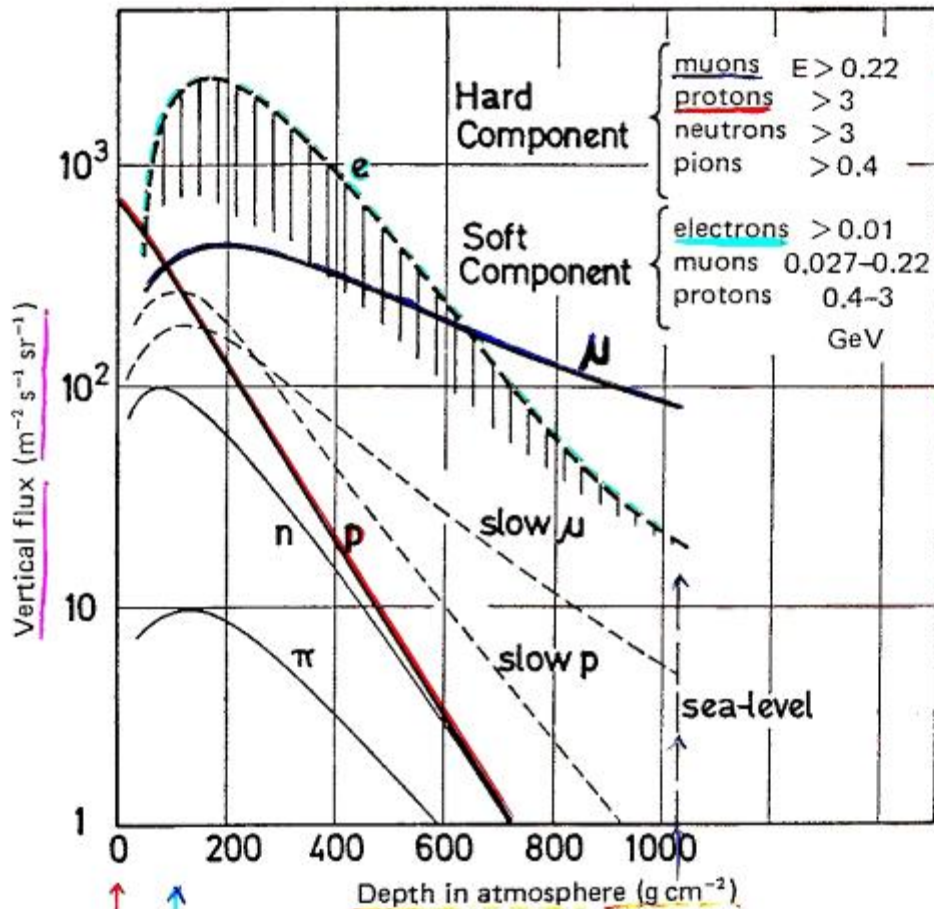


SECONDARI al livello del mare

$\mu \sim 30 \%$

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

$\nu \sim 68 \%$



$3000 \text{ m}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$

$100 \text{ m}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$

Spazio

Pfozter maximum
@ ~ 20 km

Livello del mare

NOTE: $\tau_0(\mu) = 2.2 \mu\text{s}$

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

$E = \gamma m_0 c^2$

$\tau = \gamma \tau_0 \Rightarrow \gamma > 20$

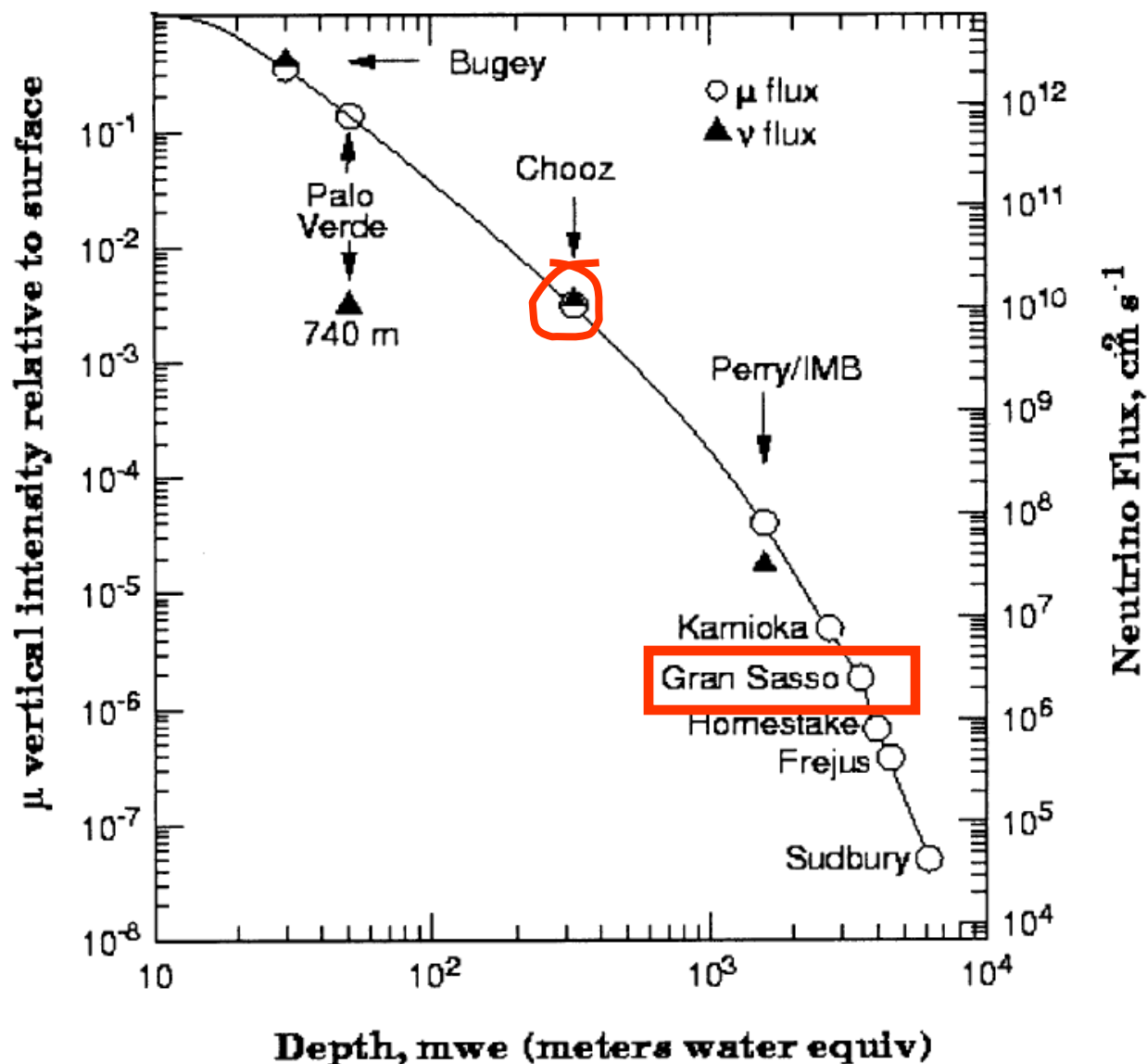
$w_\mu = 10^5 \text{ MeV}/c^2$

RELATIVISTIC

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

Flusso di μ

μ Depth-Intensity and ν Flux
for various sites



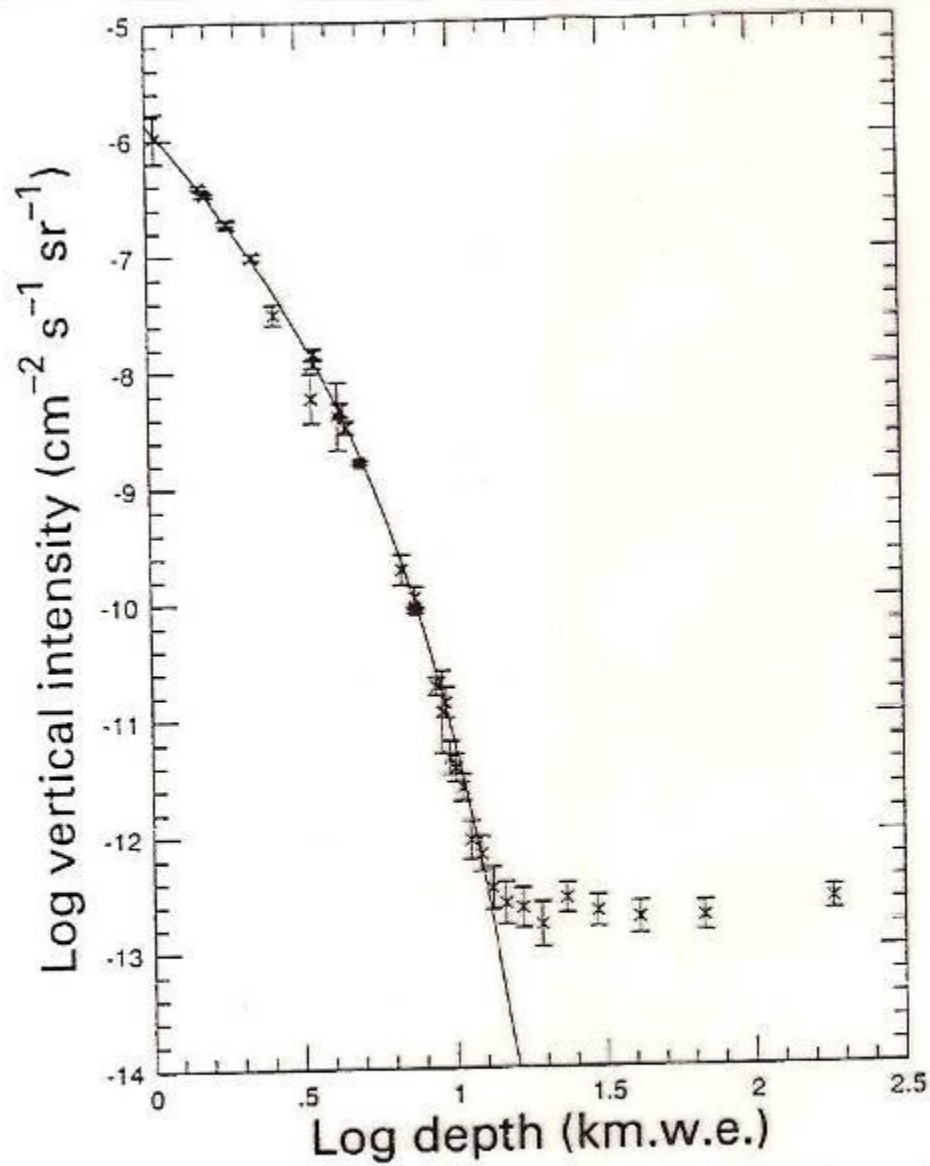
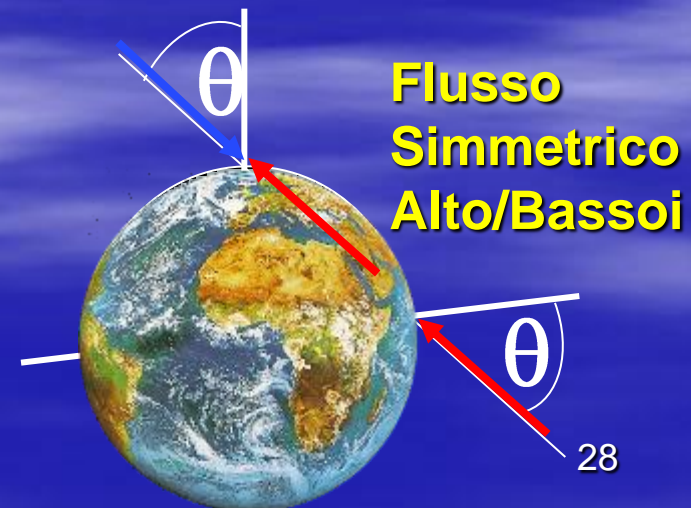
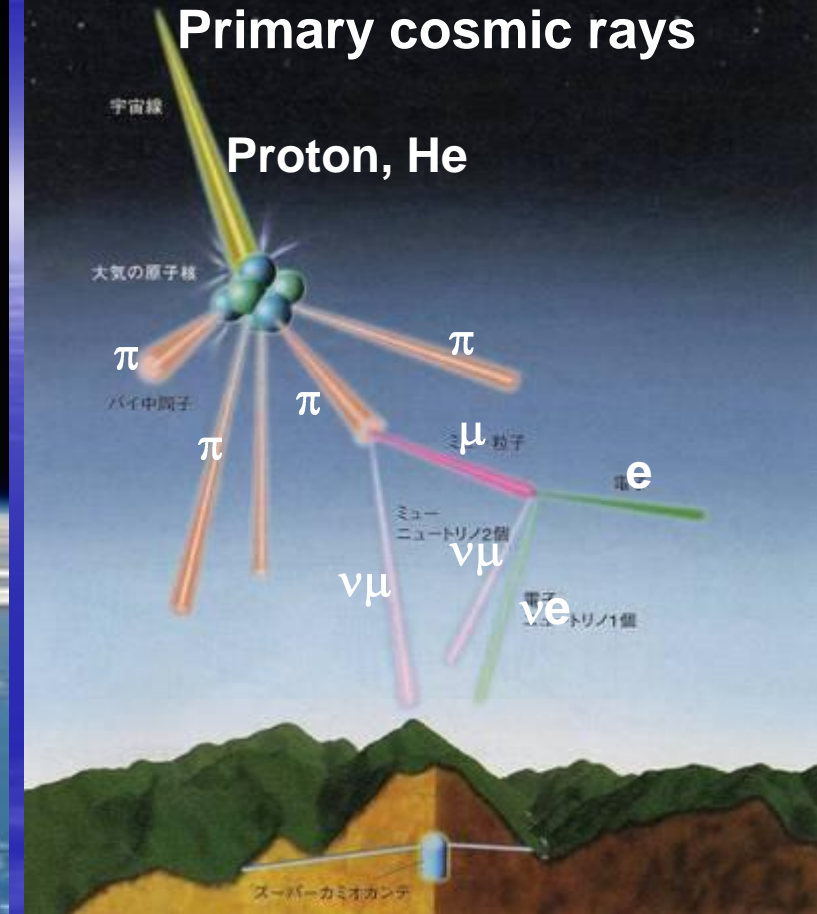


Figure 6.3: Relation between muon intensity and depth underground. The data are taken from a summary by Crouch (1987) with the addition of recent data from the Frejus experiment (Berger et al., 1989 – filled squares).

Sorgente Raggi Cosmici: ν Atmosferici

atmosfera



Gli esperimenti “storici”

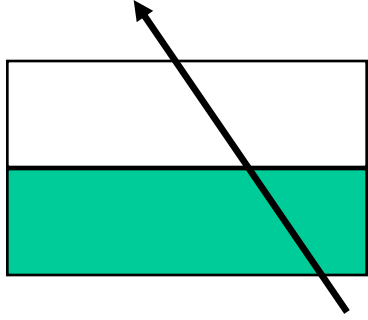
- Macro
 - Ricerca dei monopoli magnetici

- LVD
 - Ricerca di supernovae

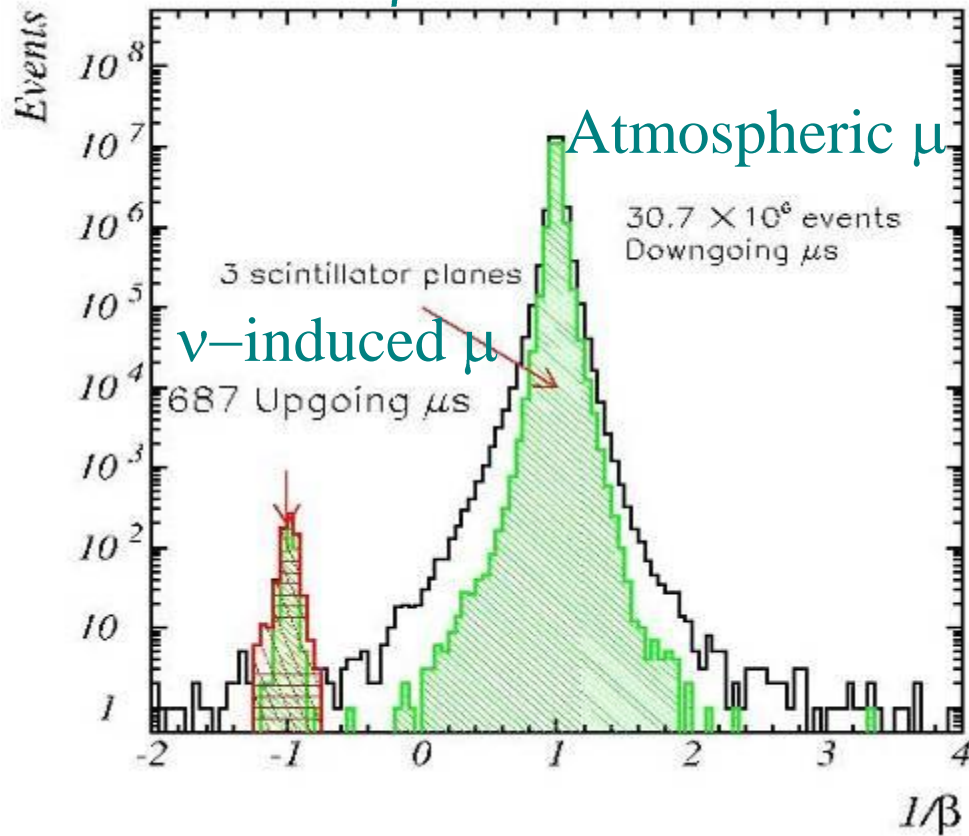
- Gallex
 - Studio di neutrini solari

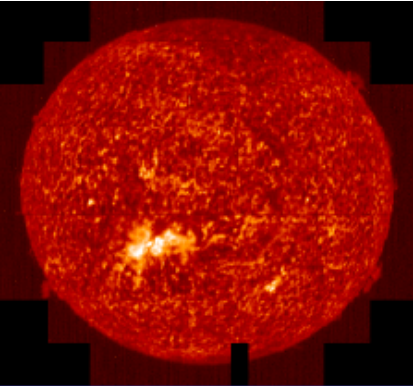


MACRO Upward throughgoing muons



$1/\beta$ distribution:





GNO

Collab.:
Italy, France, Germany

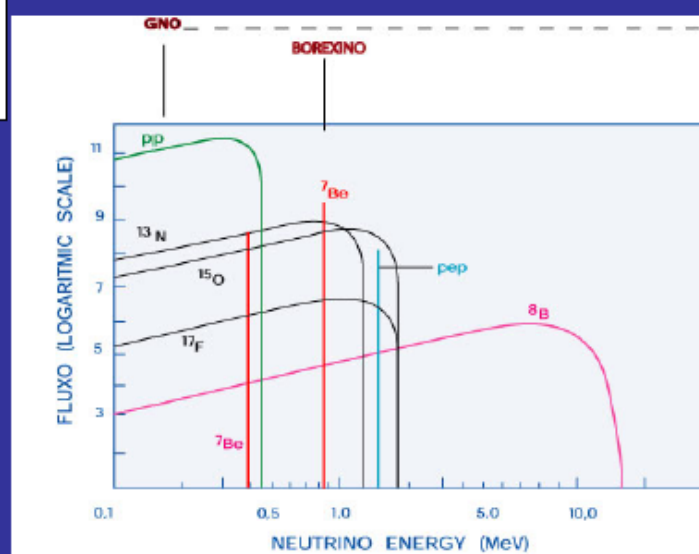
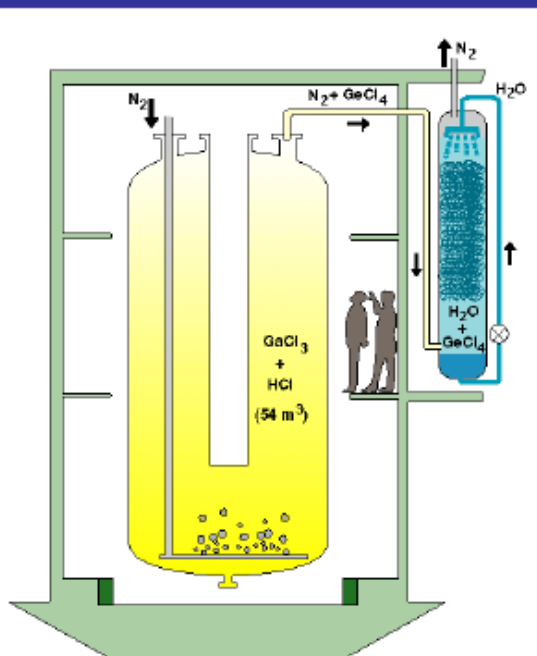
Goals: measurement of the interaction rate with an accuracy of 4-5% and monitoring the neutrino flux over a complete solar cycle.

101 tons Gallium Chloride solution

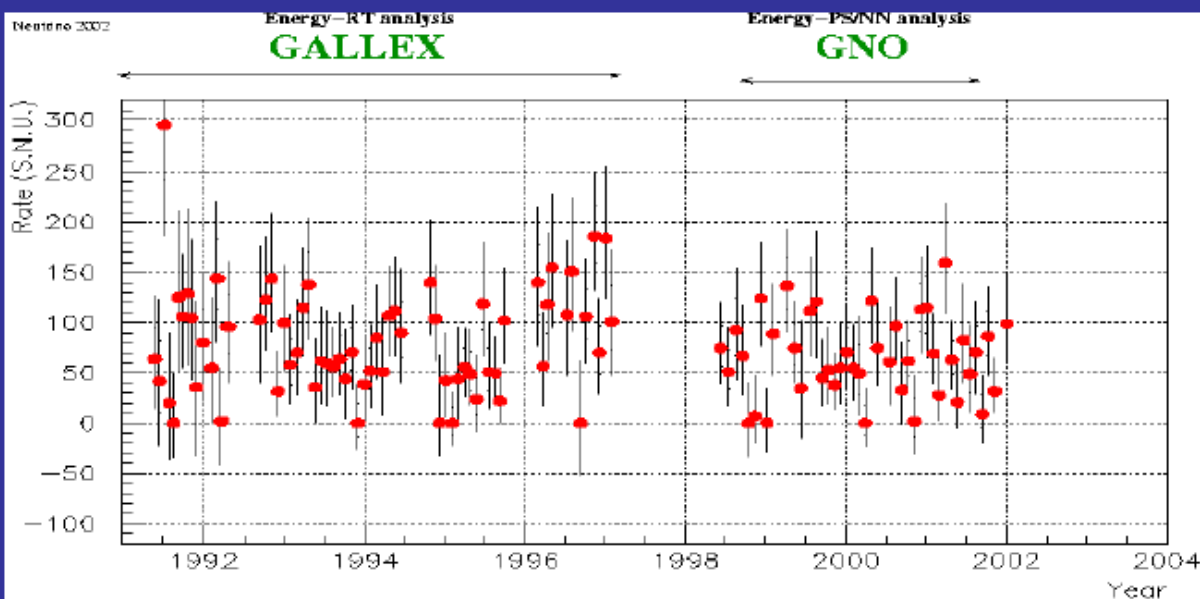
$^{71}\text{Ge}(\nu_e, e)^{71}\text{Ge}$

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

