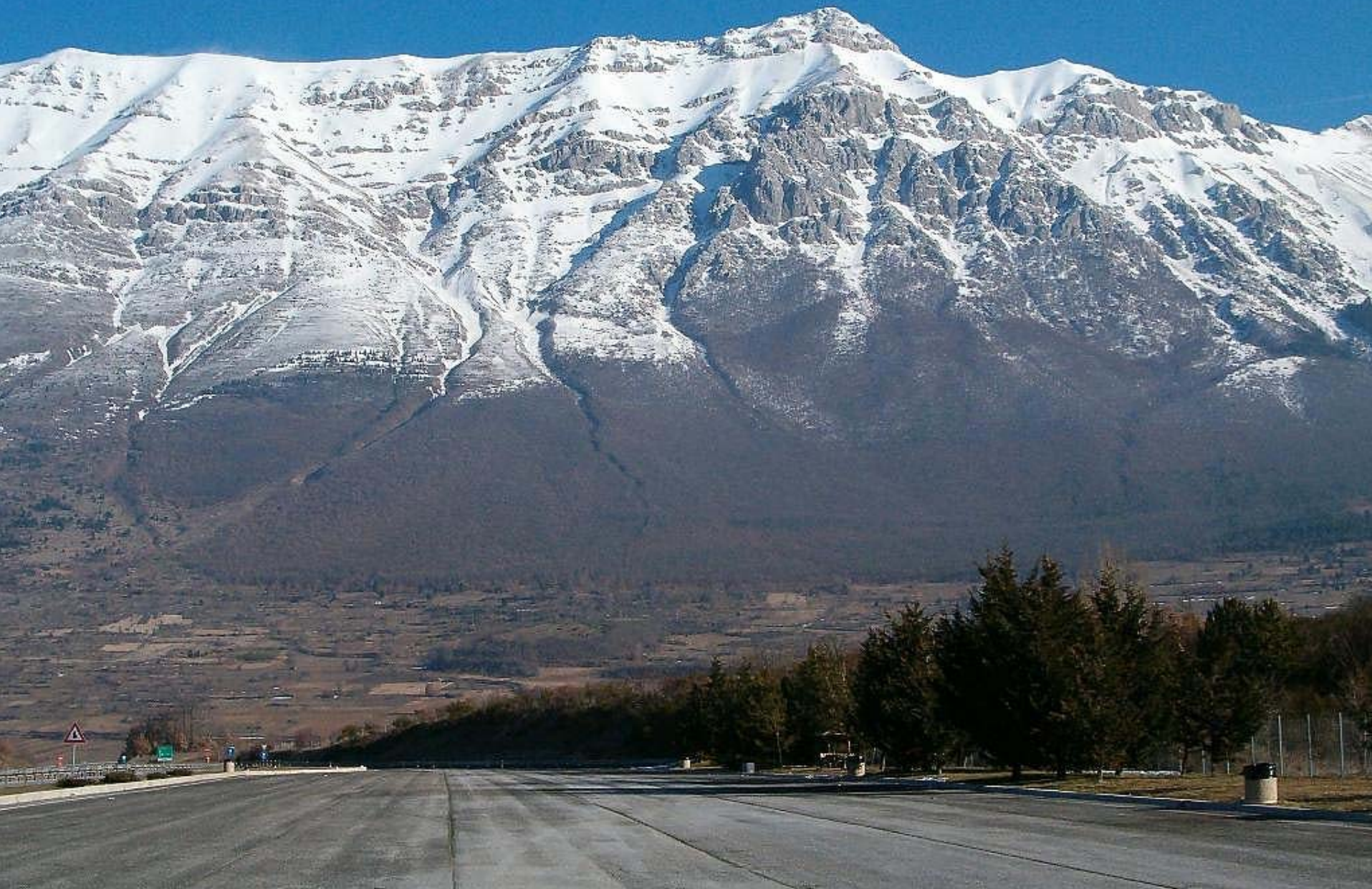




ASTRONOMIE V PODZEMÍ

Ing. arch. Ivan Havlíček, hvězdárna Zlín 2011

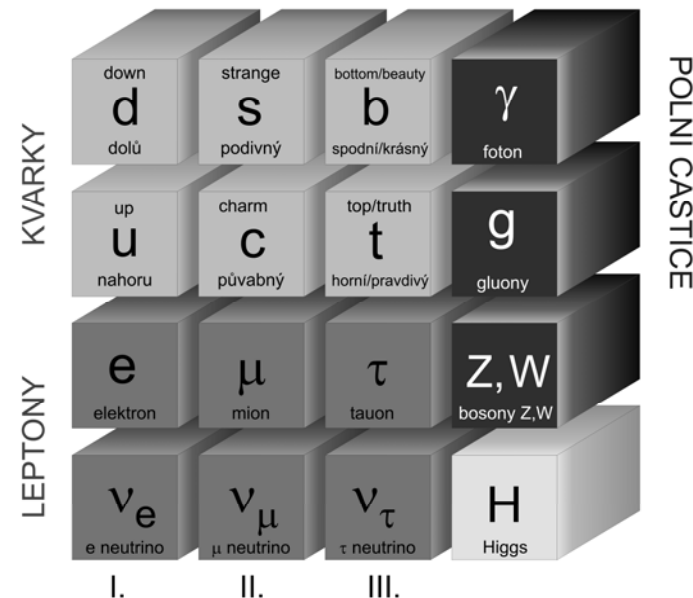
Gran Sasso



Three Generations of Matter (Fermions)

I II III

mass→	2.4 MeV	1.27 GeV	171.2 GeV	0
charge→	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	0
spin→	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1
name→	u up	c charm	t top	γ photon
Quarks	4.8 MeV	104 MeV	4.2 GeV	0
	$-\frac{1}{3}$	$-\frac{1}{3}$	$-\frac{1}{3}$	0
	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1
	d down	s strange	b bottom	g gluon
Leptons	<2.2 eV	<0.17 MeV	<15.5 MeV	91.2 GeV
	0	0	0	0
	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1
	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	Z^0 weak force
Bosons (Forces)	0.511 MeV	105.7 MeV	1.777 GeV	80.4 GeV
	-1	-1	-1	± 1
	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1
	e electron	μ muon	τ tau	$W^\pm$ weak force



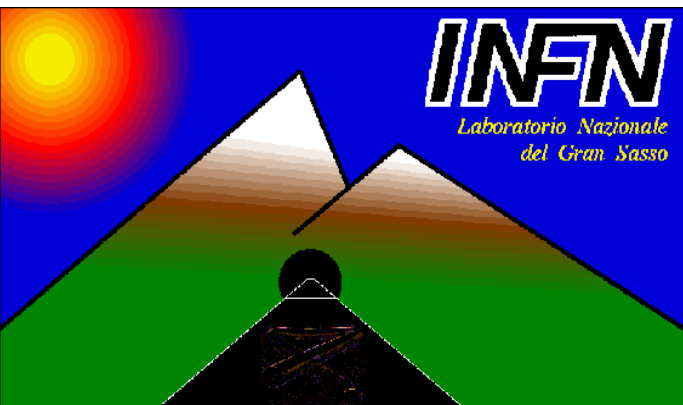
National Laboratory Gran Sasso



- Otevření: 1987
- 1400 m pod povrchem
- Mionový tok: $3 \times 10^{-4} \text{ s}^{-1} \text{ m}^{-2}$
- Experimenty: 3 haly, plocha 17 300 m², délka 100 m
- Přístup: z dálničního tunelu

Vědecké aktivity

- Neutrinová fyzika (OPERA, BOREXINO, ICARUS, LVD, GERDA...)
- Temná hmota (DAMA/LIBRA, WARP, XENON, CRESST)
- Jaderné reakce, astrofyzika (LUNA)
- Základní fyzika (VIP)
- Geofyzika (ERMES, GIGS)



Fyzika v LNGS

Výzkum Vesmíru a temné hmoty

DAMA/LIBRA
CRESST
WARP
XENON

LBL - CNGS

OPERA
Icarus T600

Vlastnosti neutrin a jejich úloha ve vývoji Vesmíru

$2\beta 0\nu$

CUORICINO
CUORE
GERDA
COBRA

Jak vypadají nitra Slunce a Země?

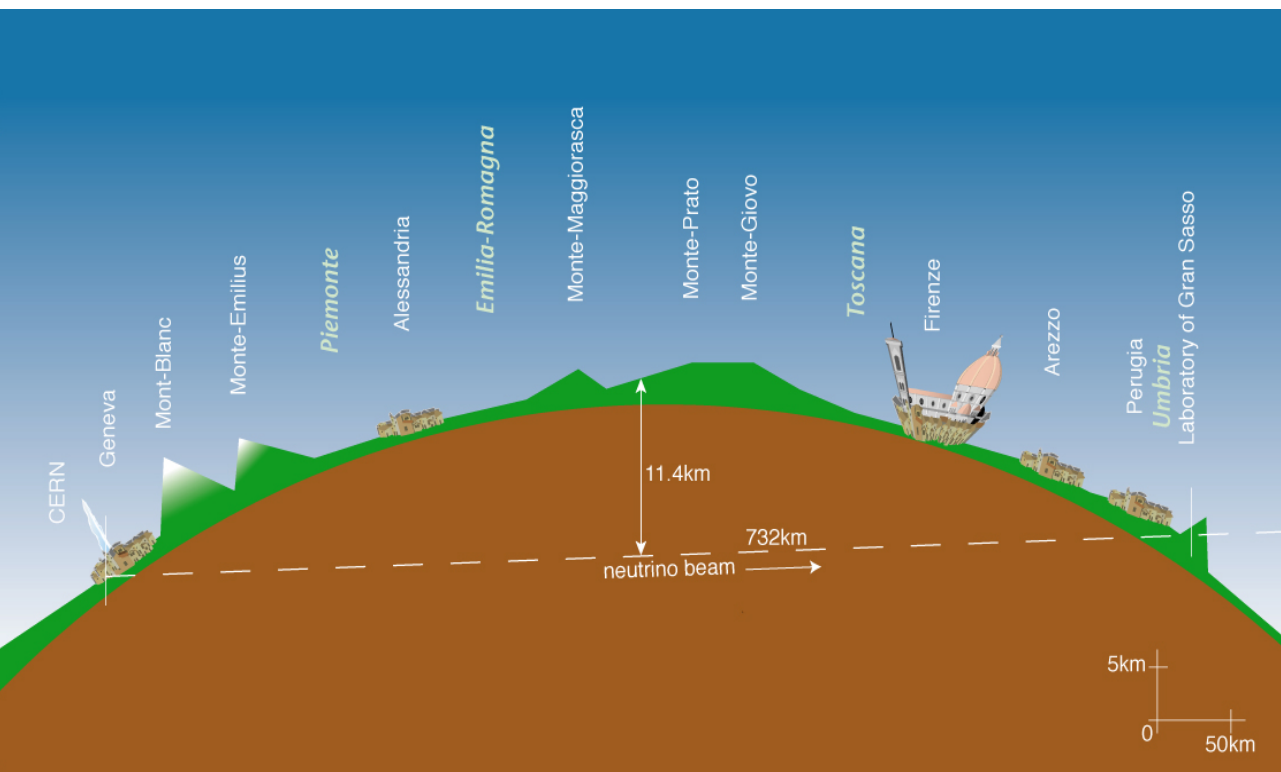
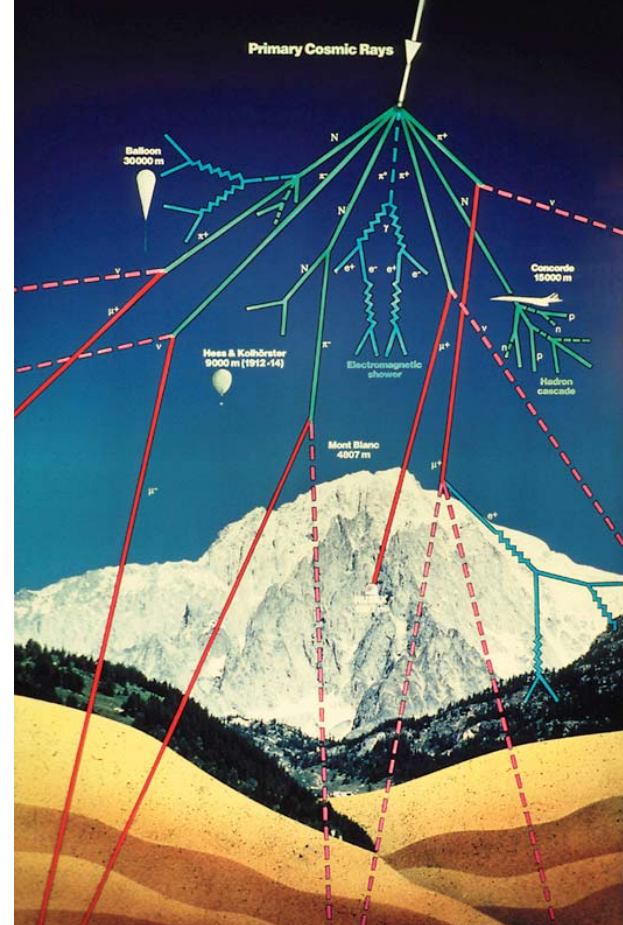
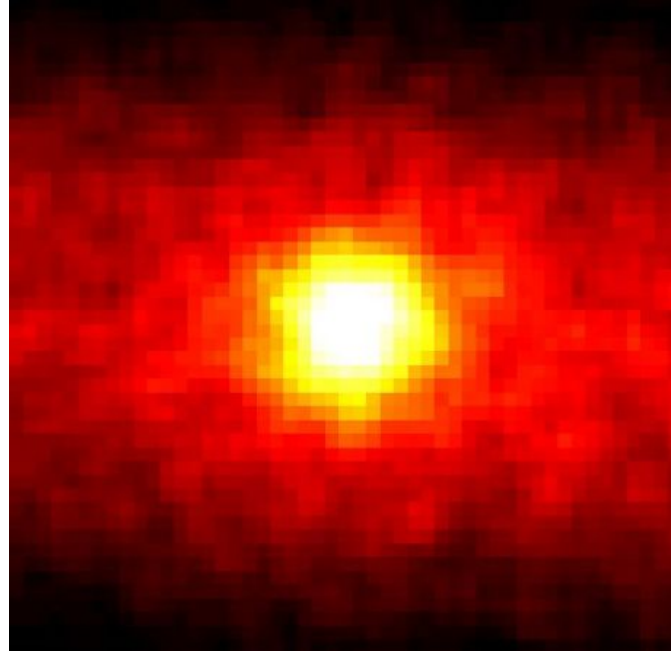
BOREXINO

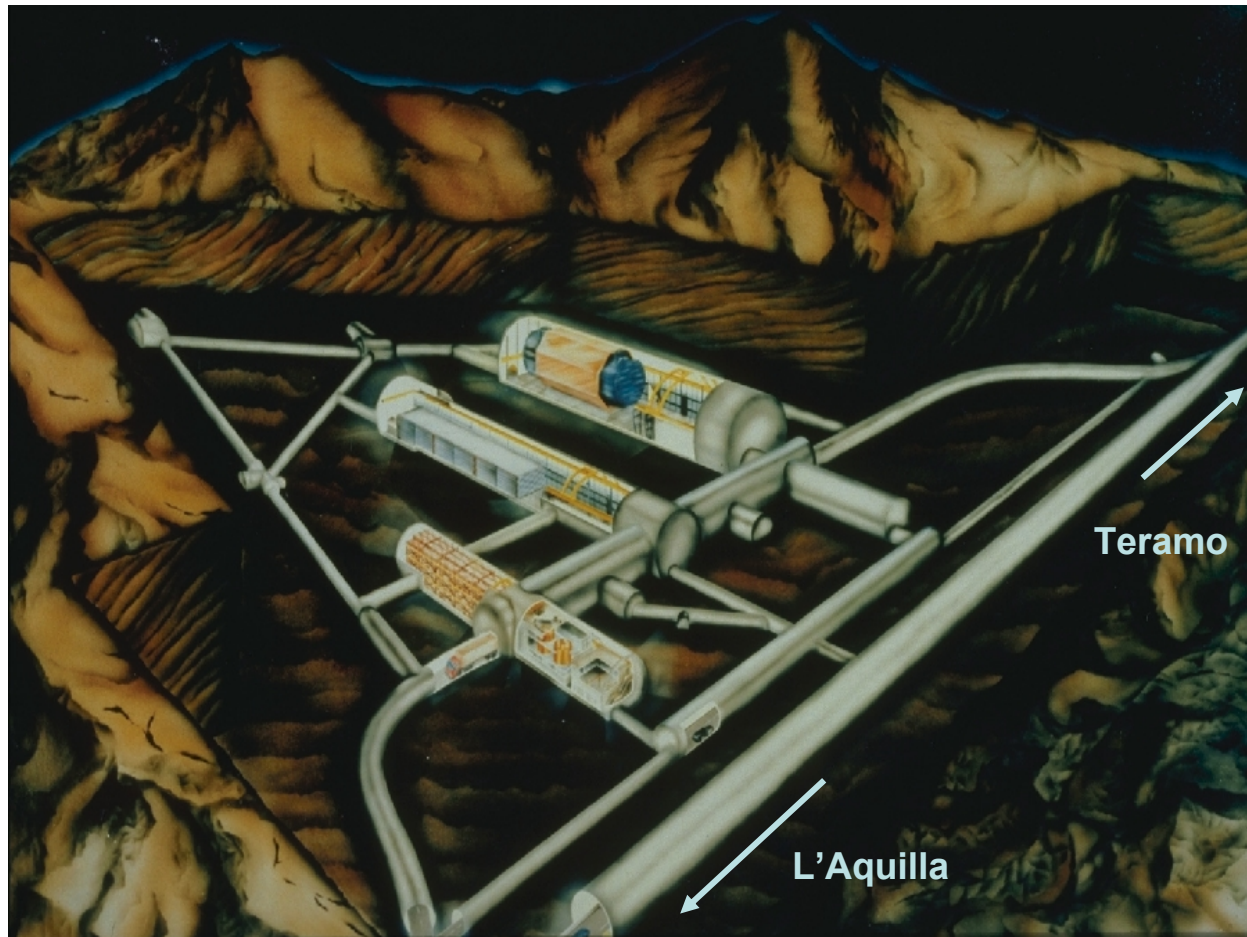
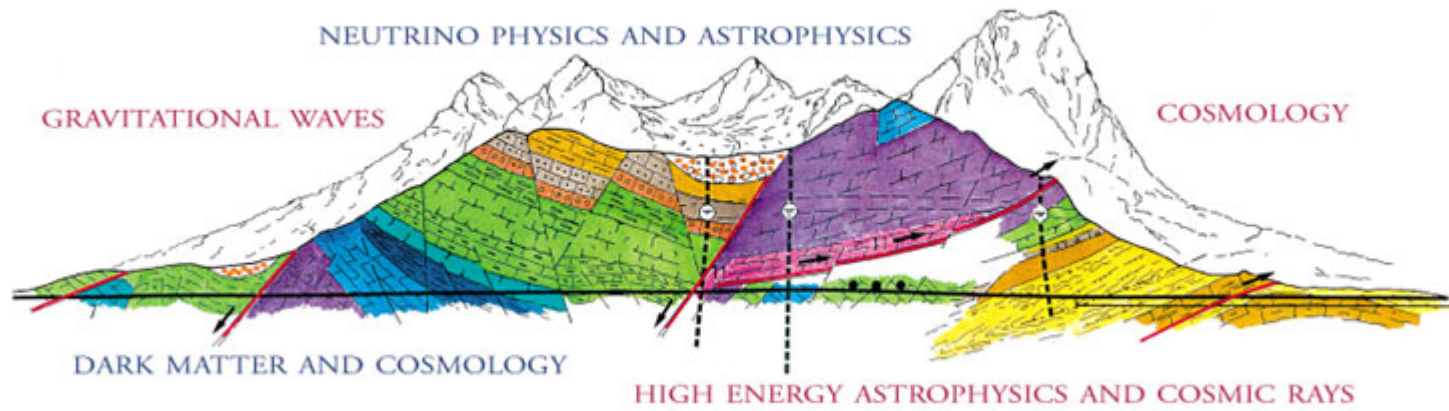
LVD

Exploze supernov

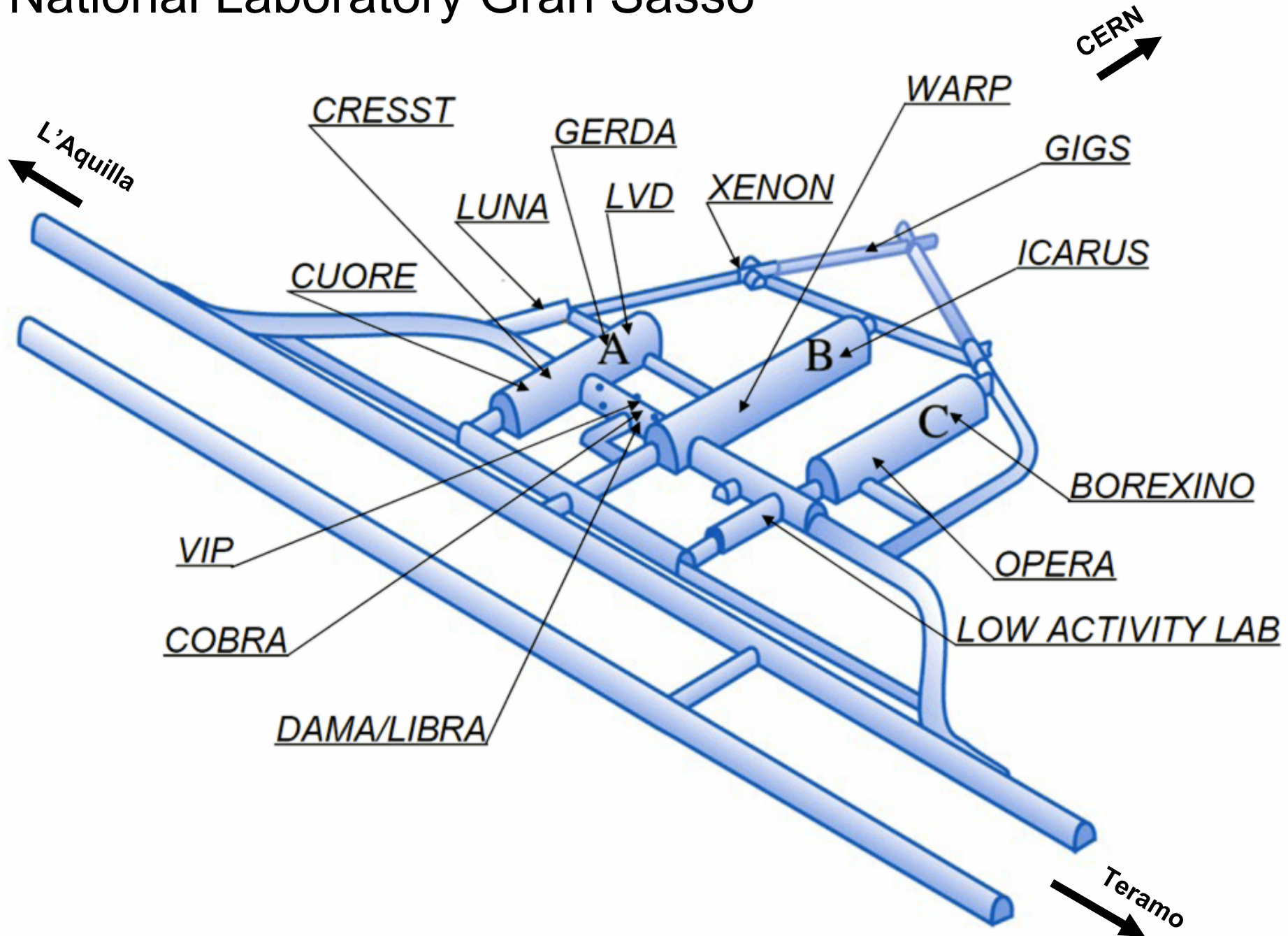
Zdroje neutrin

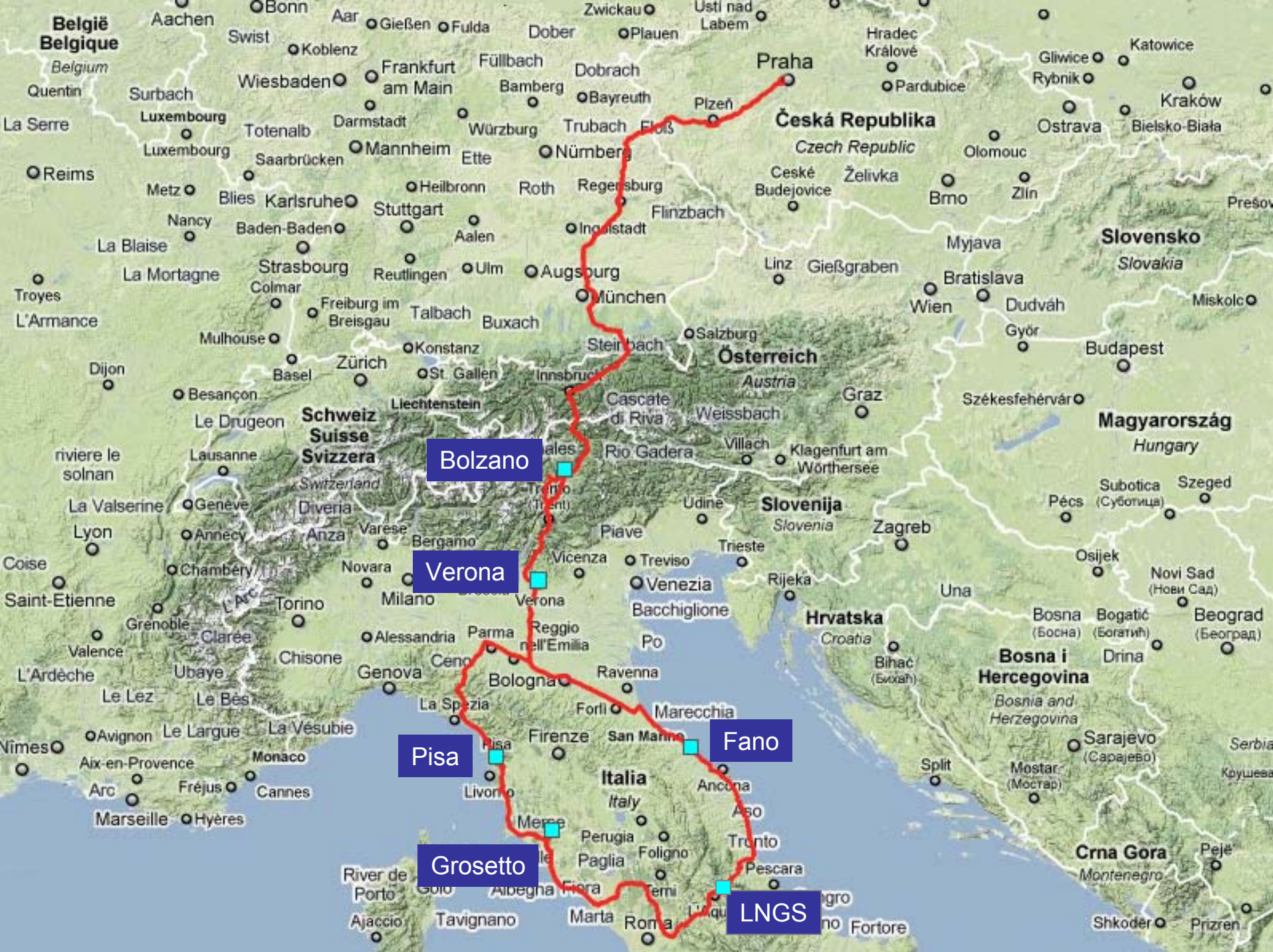
- reliktní neutrina
- Slunce
- horní atmosféra
- supernovy
- nitro Země
- jaderné reaktory
- urychlovače, CERN





National Laboratory Gran Sasso







PAGANICA
6 April 2009















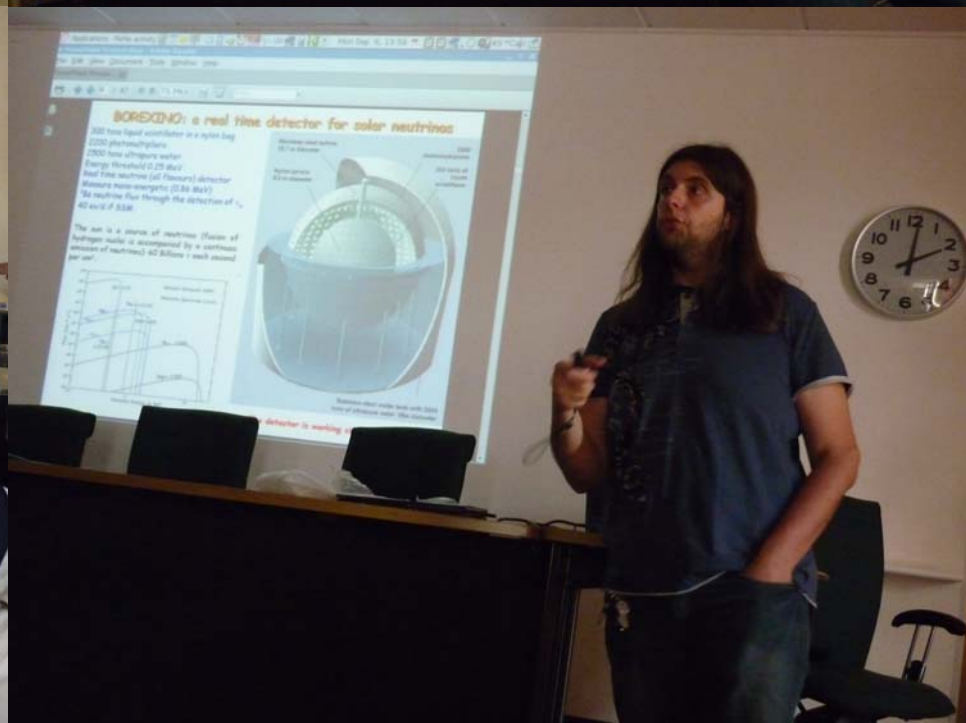
Gran Sasso
↑ 10173 m ↑



via Galilei

via Newton









I.N.F.N.
solo autorizzati



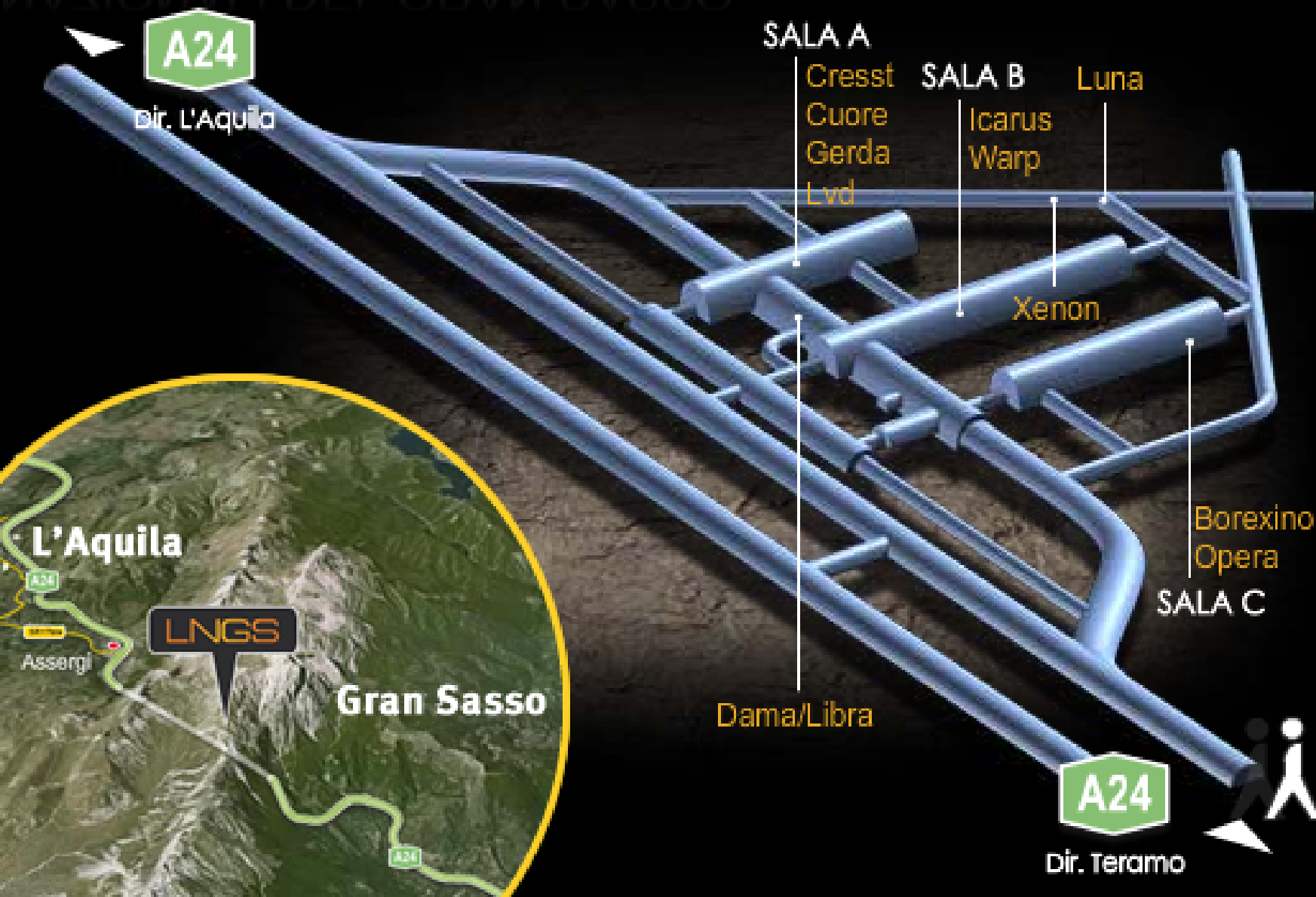
307SW

8S1 3406



INEN-LABORATORI
NAZIONALI
DEL GRAN SASSO







Oscillation Project with Emulsion-tRacking Apparatus

Cíl: sledování oscilací $\nu_\mu \rightarrow \nu_\tau$ neutrin z CERNu

<http://operaweb.lns.infn.it/?lang=en>





CERN to Gran Sasso Neutrino Beam

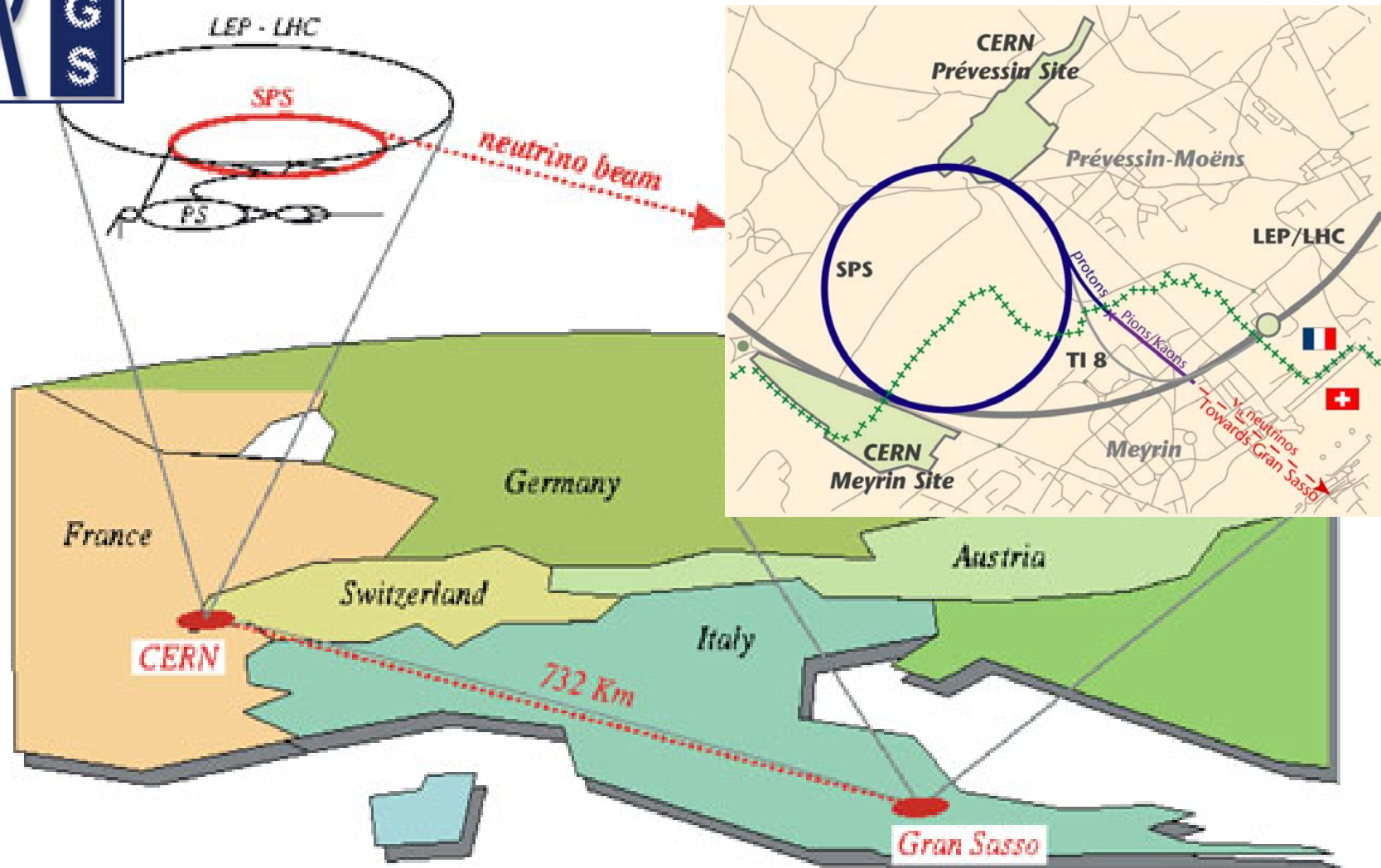
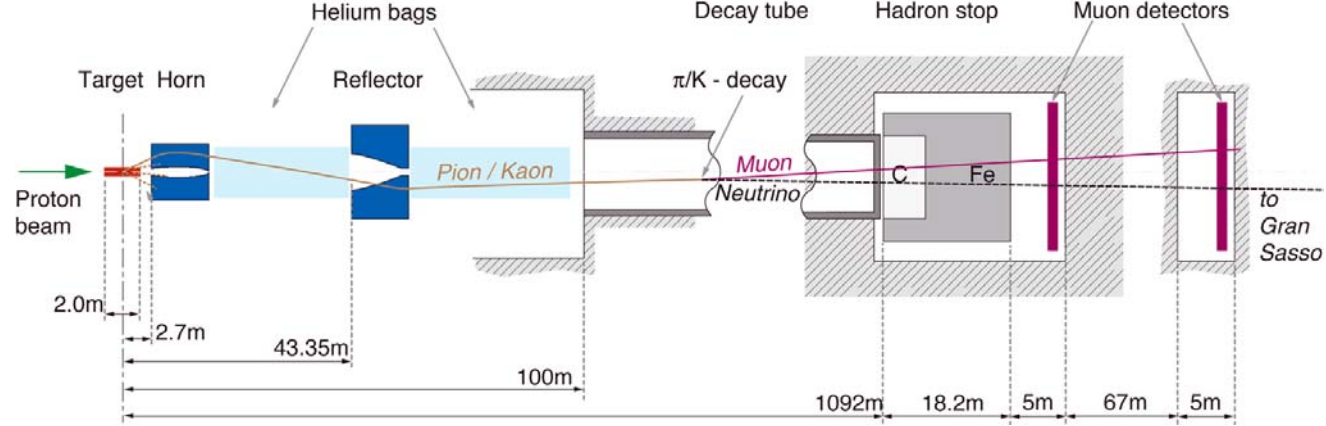
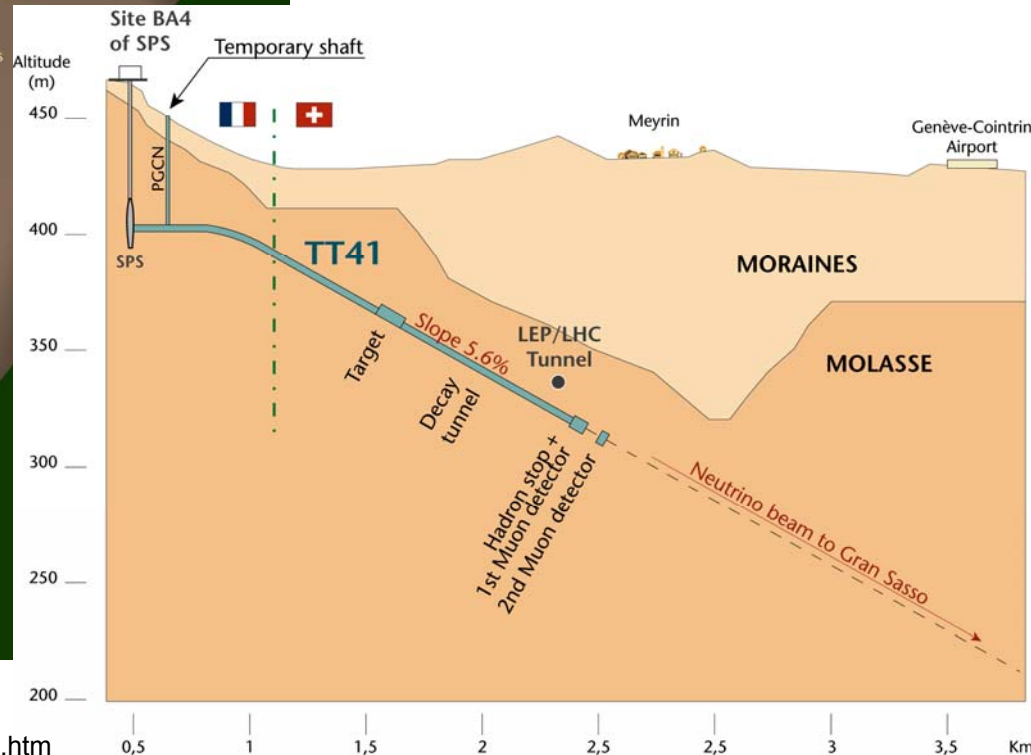
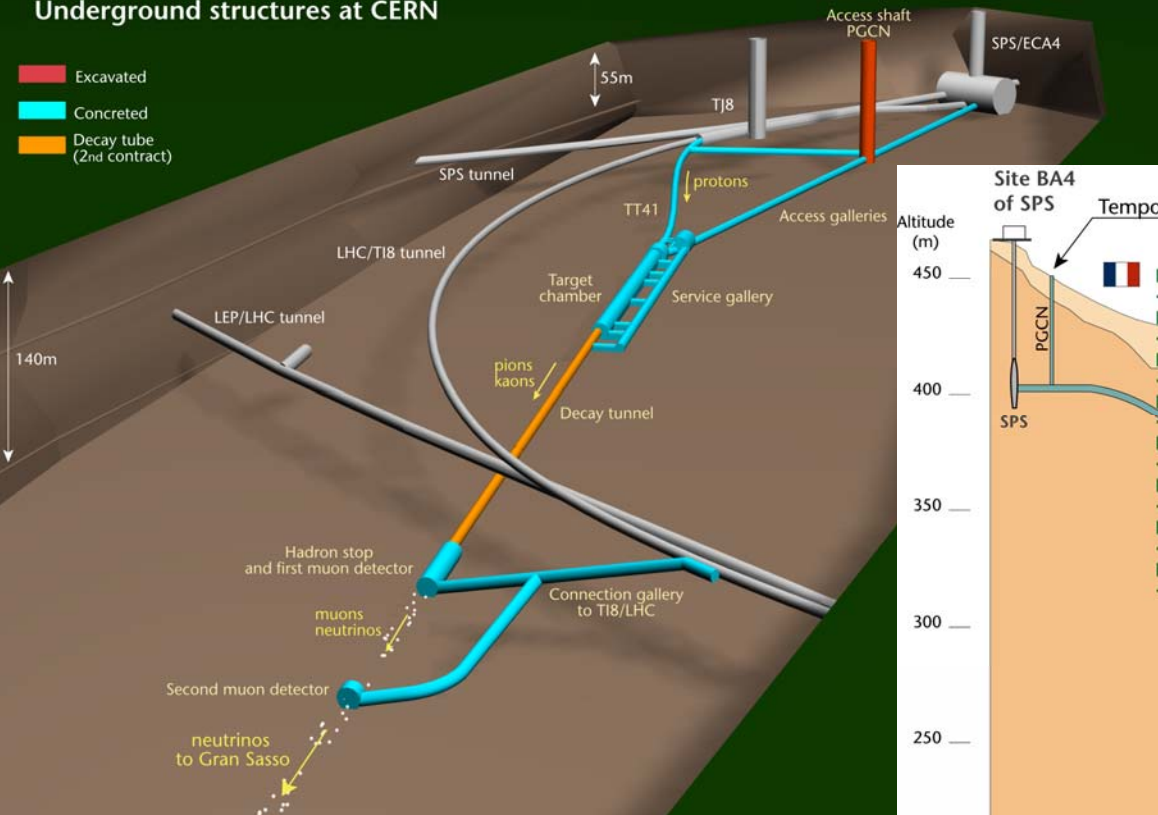


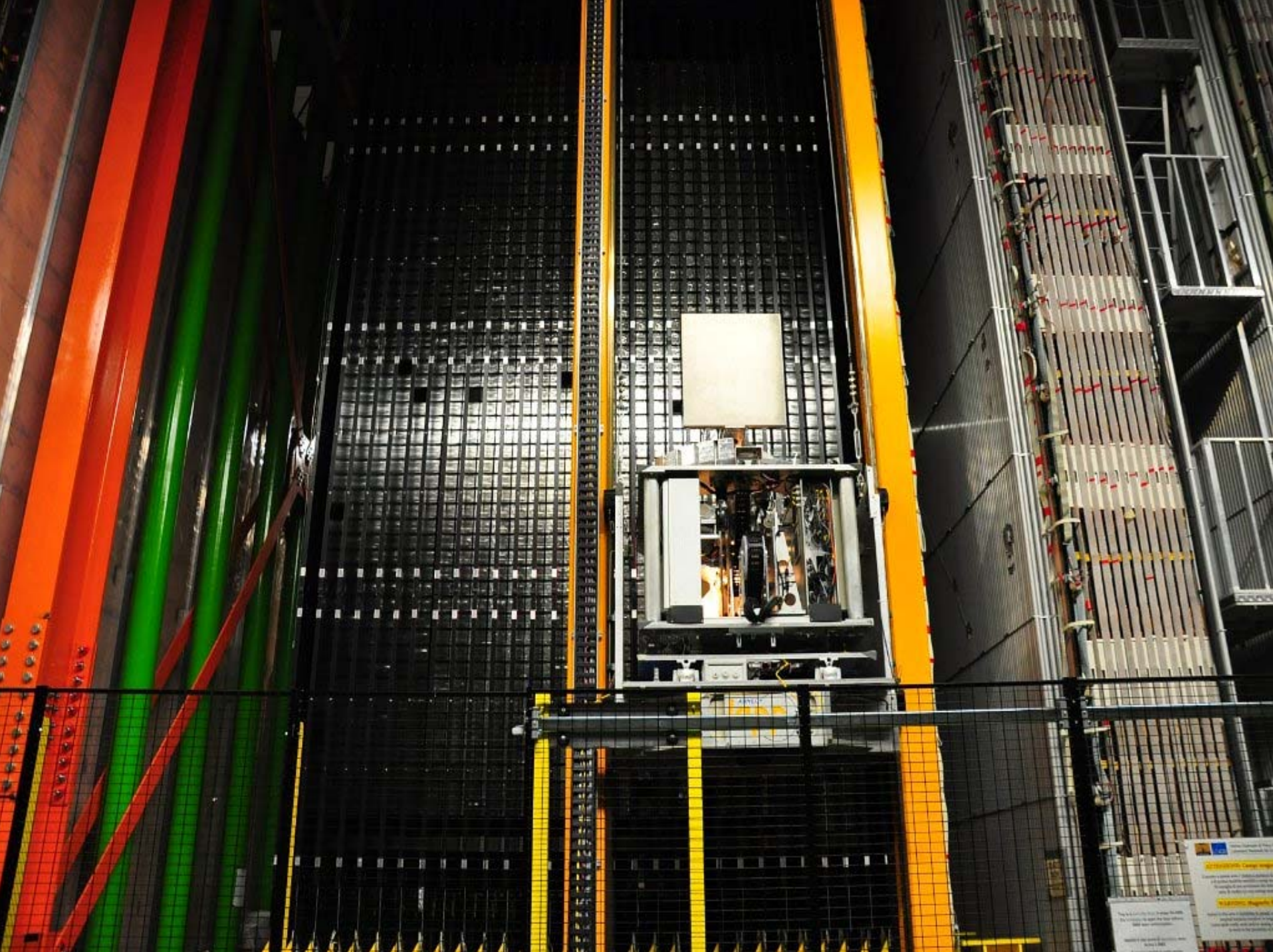
Fig. 2: Sketch of the 732 km distance from CERN in Geneva to Gran Sasso (near Rome).

The CNGS (CERN Neutrinos to Gran Sasso) project aims at investigating the 'oscillation' of neutrinos. The project is motivated by the results obtained at the Superkamiokande detector in Japan and supported by other experiments, observing neutrinos produced by cosmic rays in the atmosphere. These experiments measure a significant deficit in the flux of detected muon-type neutrinos.



CERN NEUTRINOS TO GRAN SASSO Underground structures at CERN

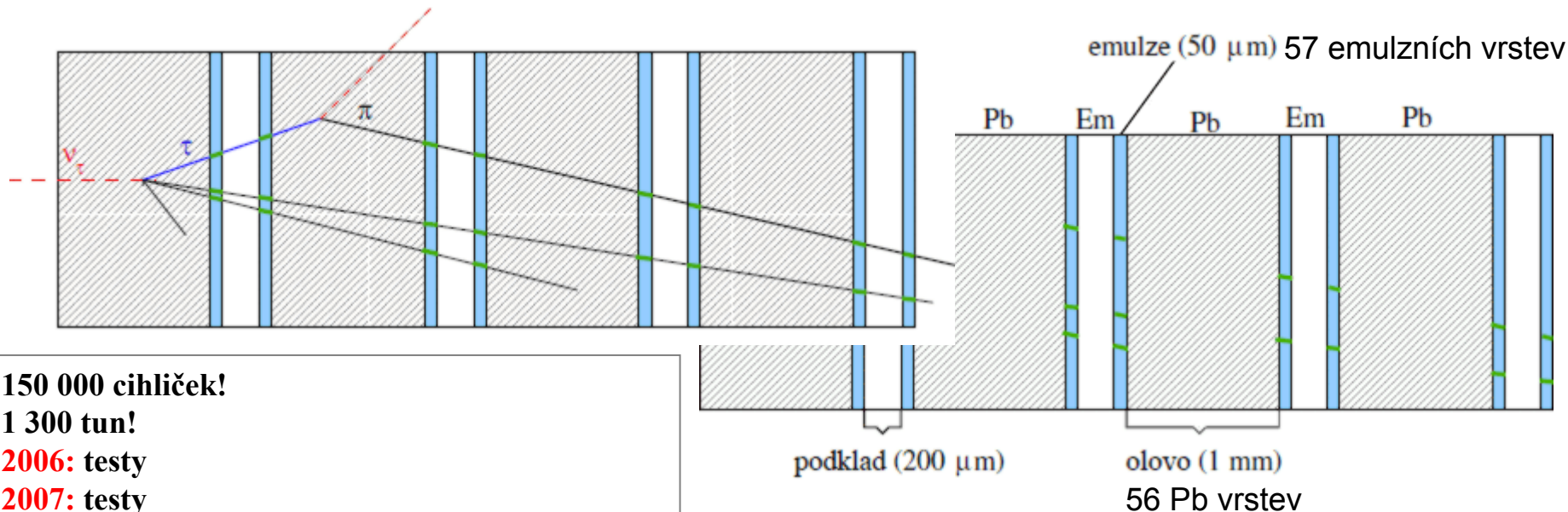












150 000 cihliček!

1 300 tun!

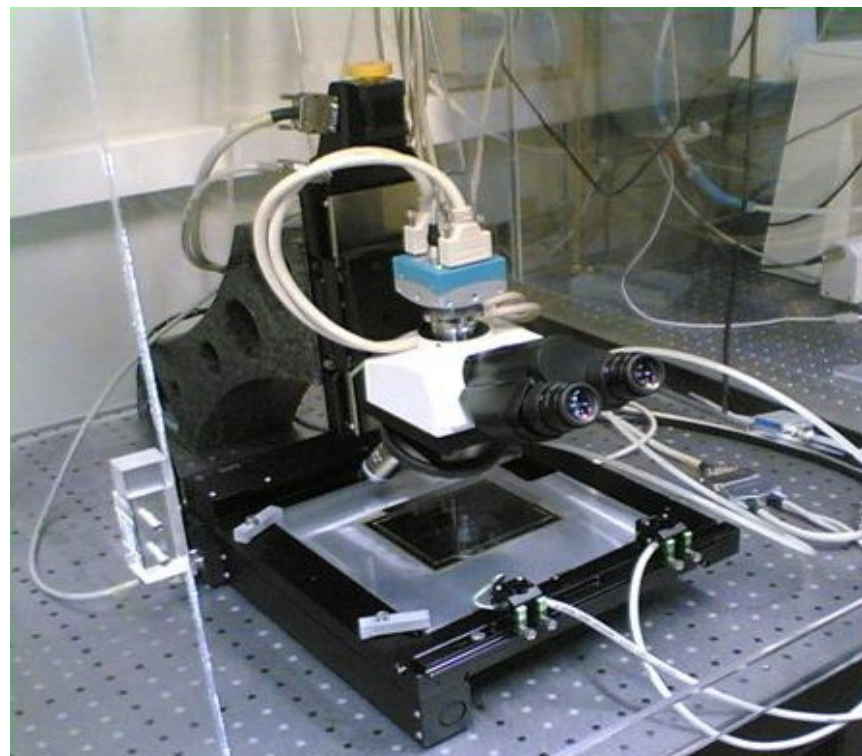
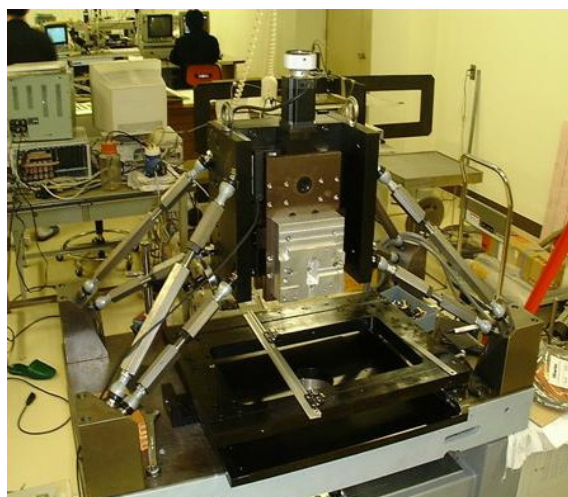
2006: testy

2007: testy

2008: 1698 interakcí

2009: 3500 interakcí

31. 5. 2010: oznámení o prvním detekovaném tau neutrinu. historicky první tau neutrino detekované jako produkt oscilace. celkem by v posbírané kolekci dat mohla být tři







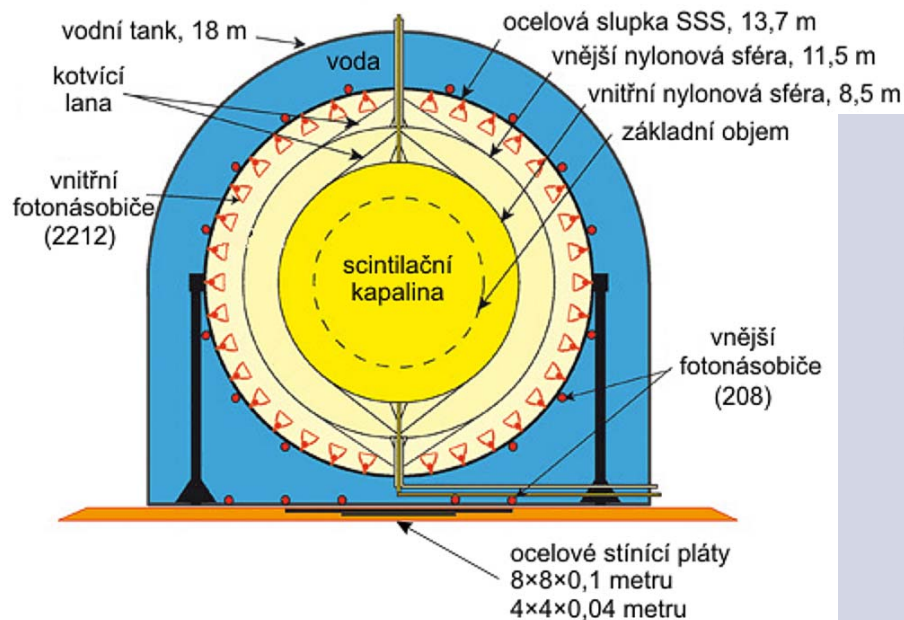
BOREXINO



sluneční neutrína (pp, CNO, Be7)
detekce v reálném čase, tok $65 \times 10^9 \text{ s}^{-1} \text{ cm}^2$
možná detekce i zemských antineutrín

http://www.e15.physik.tu-muenchen.de/research_and_projects/borexino/

Borexino



provoz: 2007

scintilátor: C¹⁴

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

$e^+ + e^- \rightarrow \text{foton (511 keV)}$

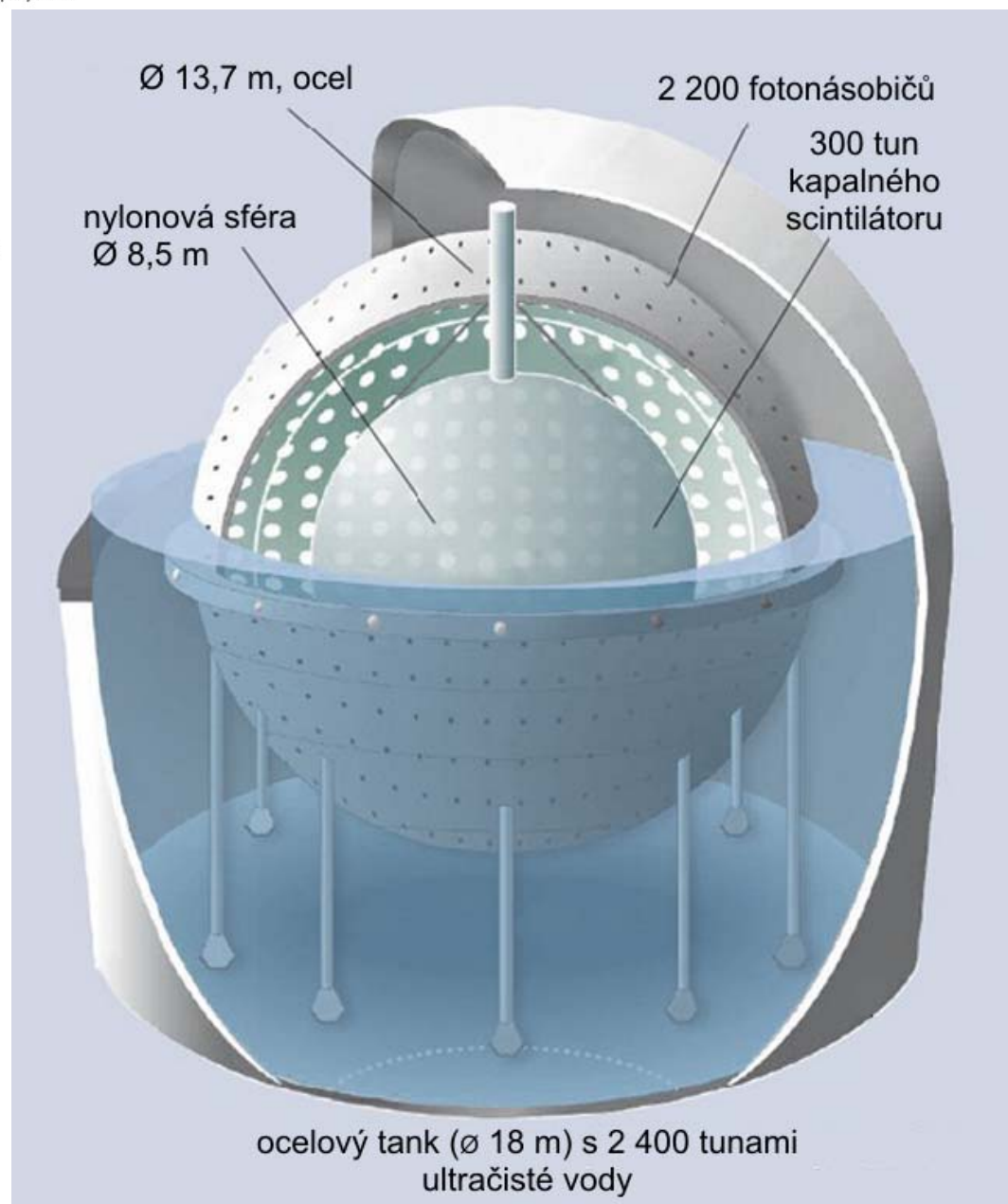
$n + p \rightarrow \text{foton (2,2 MeV)}$

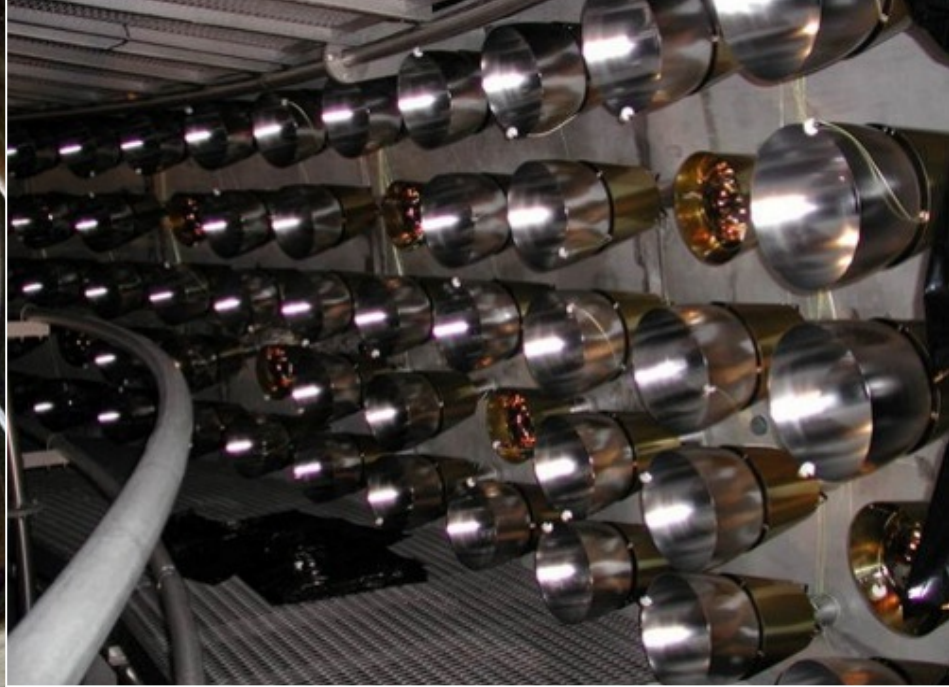
$\Delta t = 256 \mu s$

Čerenkovovo záření

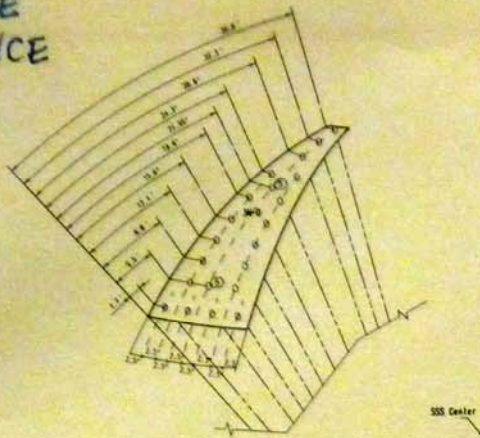
miony

208 vnějších fotonásobičů

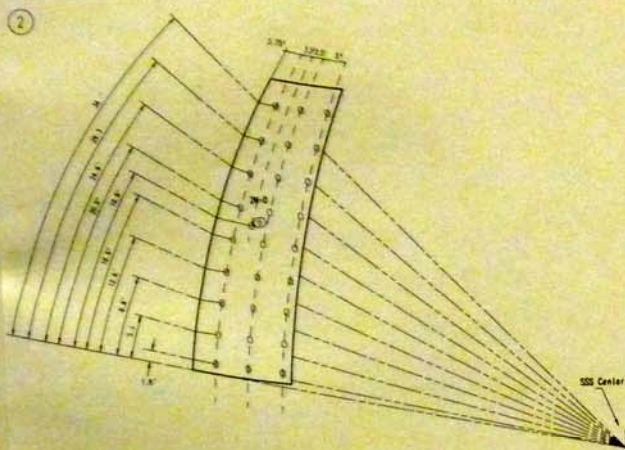




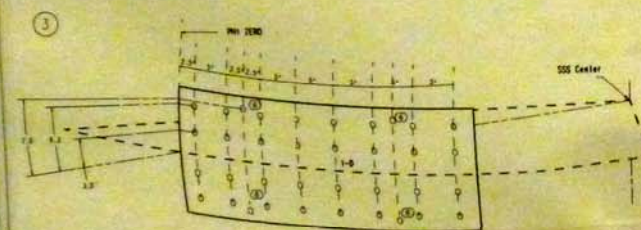
DATABASE REFERENCE FRAME



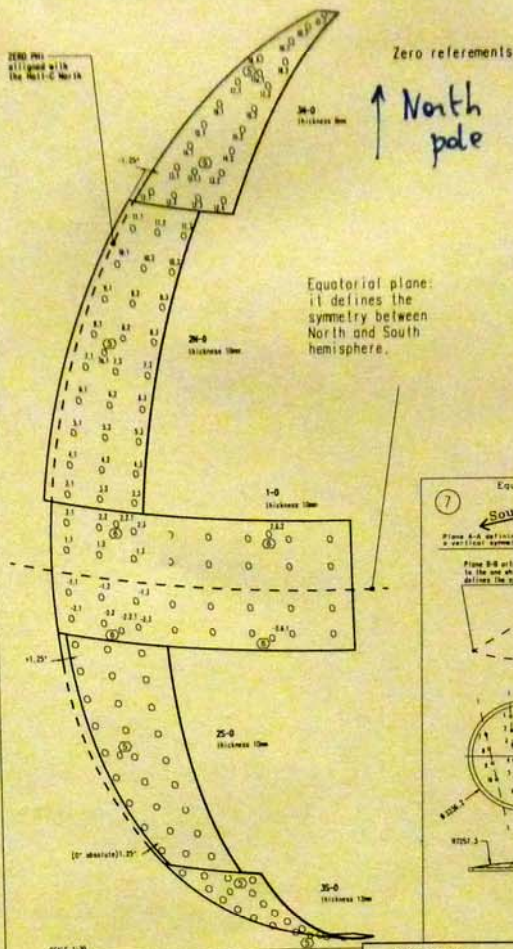
SCALE 1:10



SCALE 1:10

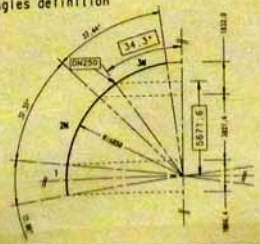


SCALE 1:10



SCALE 1:10

Plates angles definition



20000 Cover angles

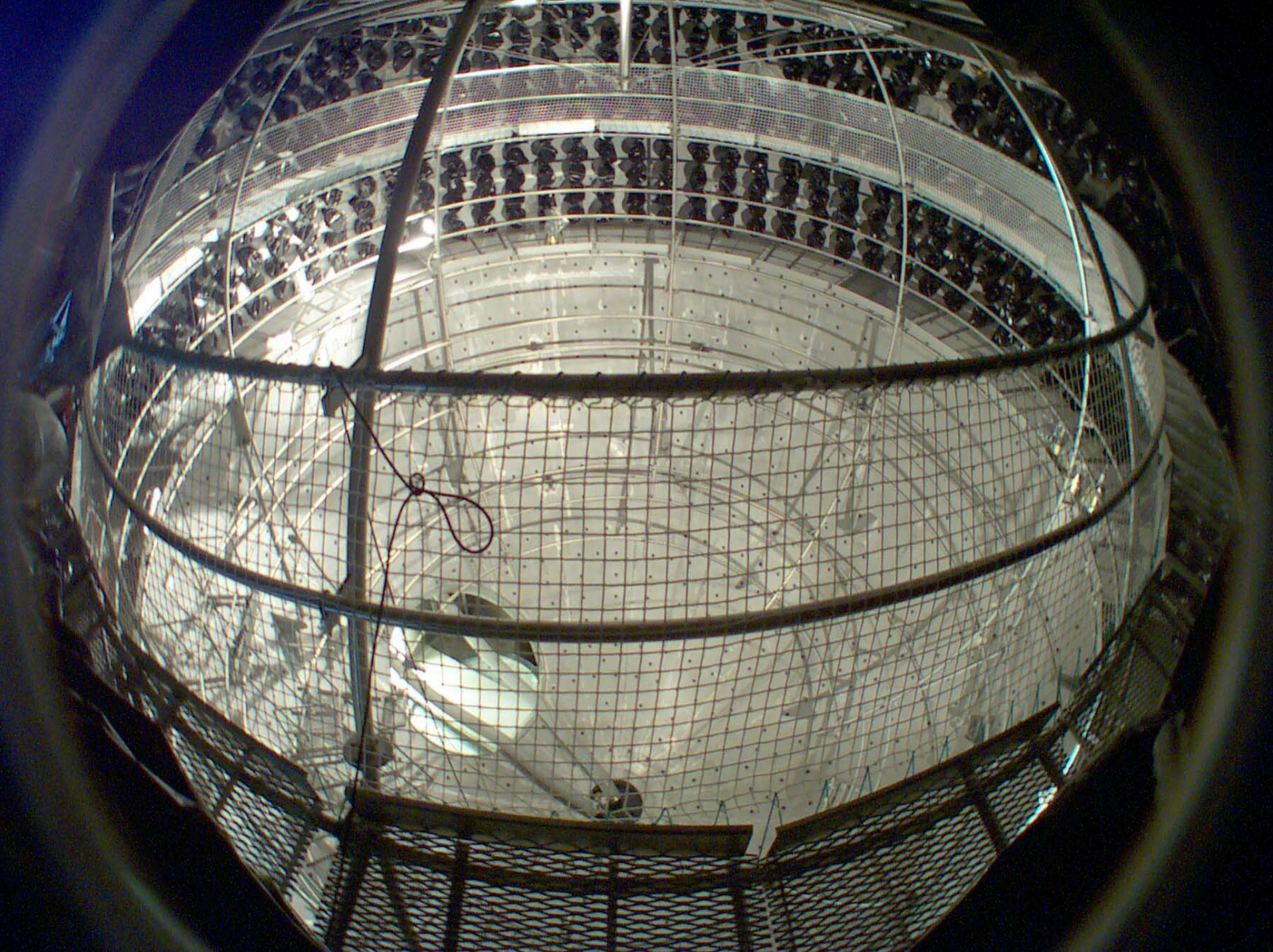
Plane B-B angle = α°	Plane A-A angle = α°
1 -5.25°	-9.32°
2 -2.96°	-5.92°
3 -2.71°	-2.81°
4 -2.46°	-0.90°
5 -2.14°	-4.90°
6 -1.78°	-8.90°
7 -8.91°	-2.90°
8 -4.01°	-1.81°
9 -7.28°	-1.84°
10 -4.36°	-5.51°

20000 Cover angles

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2 -2.96°	-5.92°
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6 -1.78°	-8.90°
7 -8.91°	-2.90°
8 -4.01°	-1.81°
9 -7.28°	-1.84°
10 -4.36°	-5.51°

All the SSS holes have a diameter of 50 mm

SSS Center	SSS Center	SSS Center
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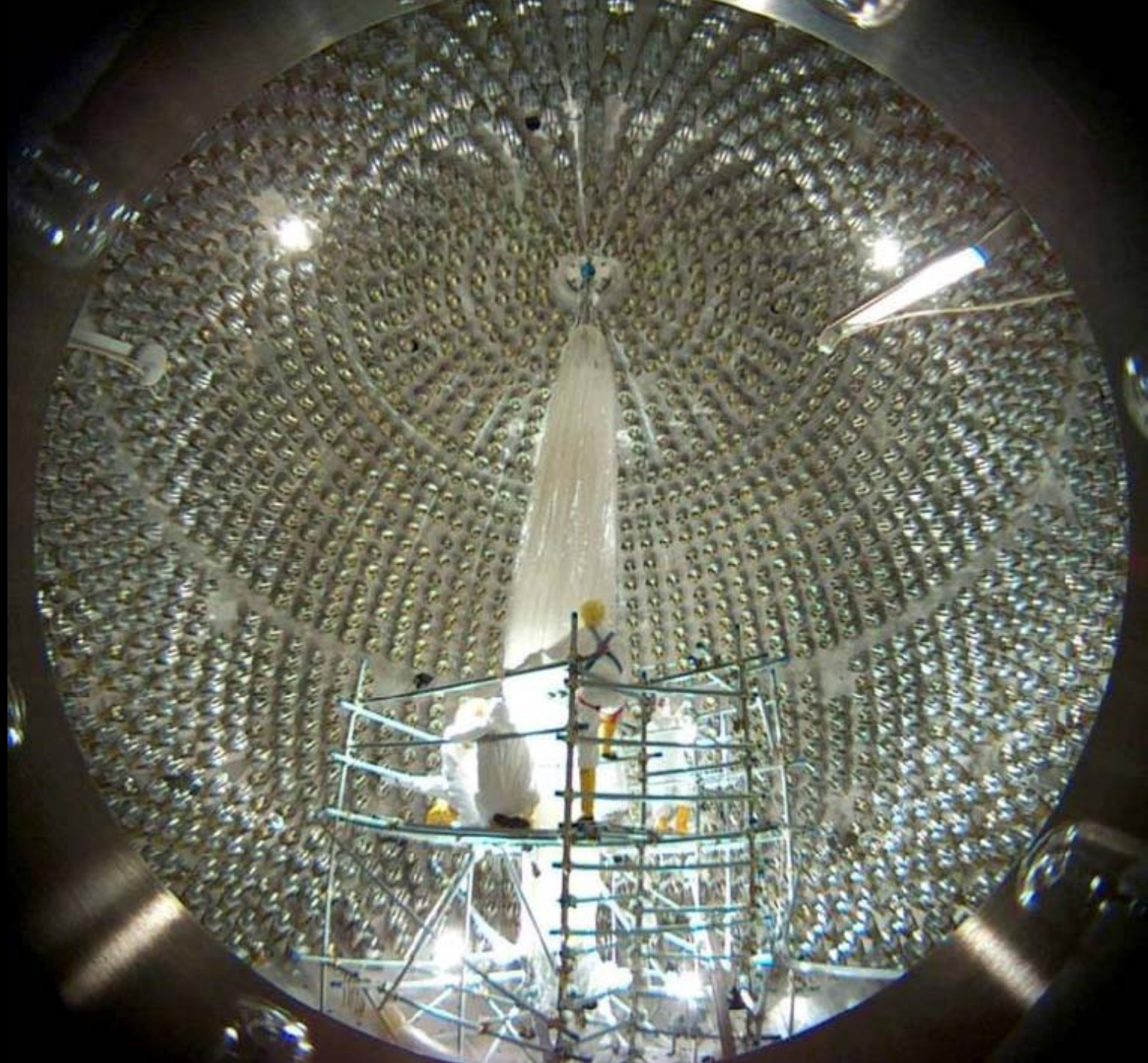
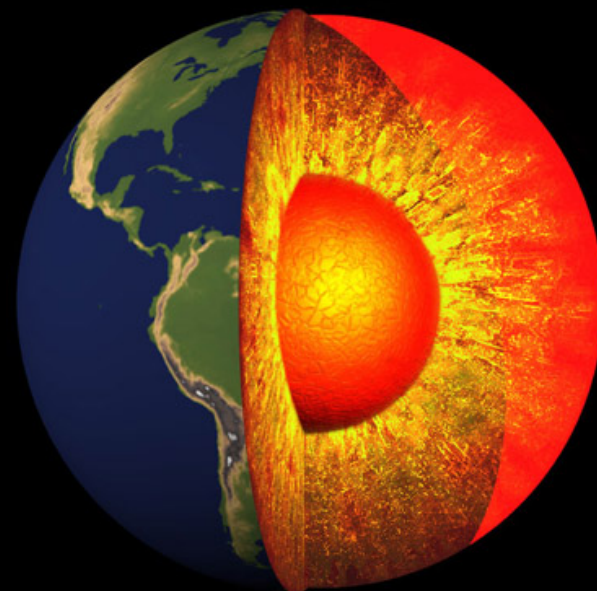
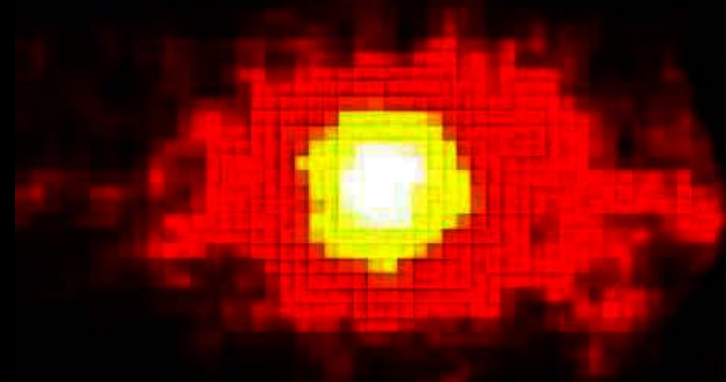
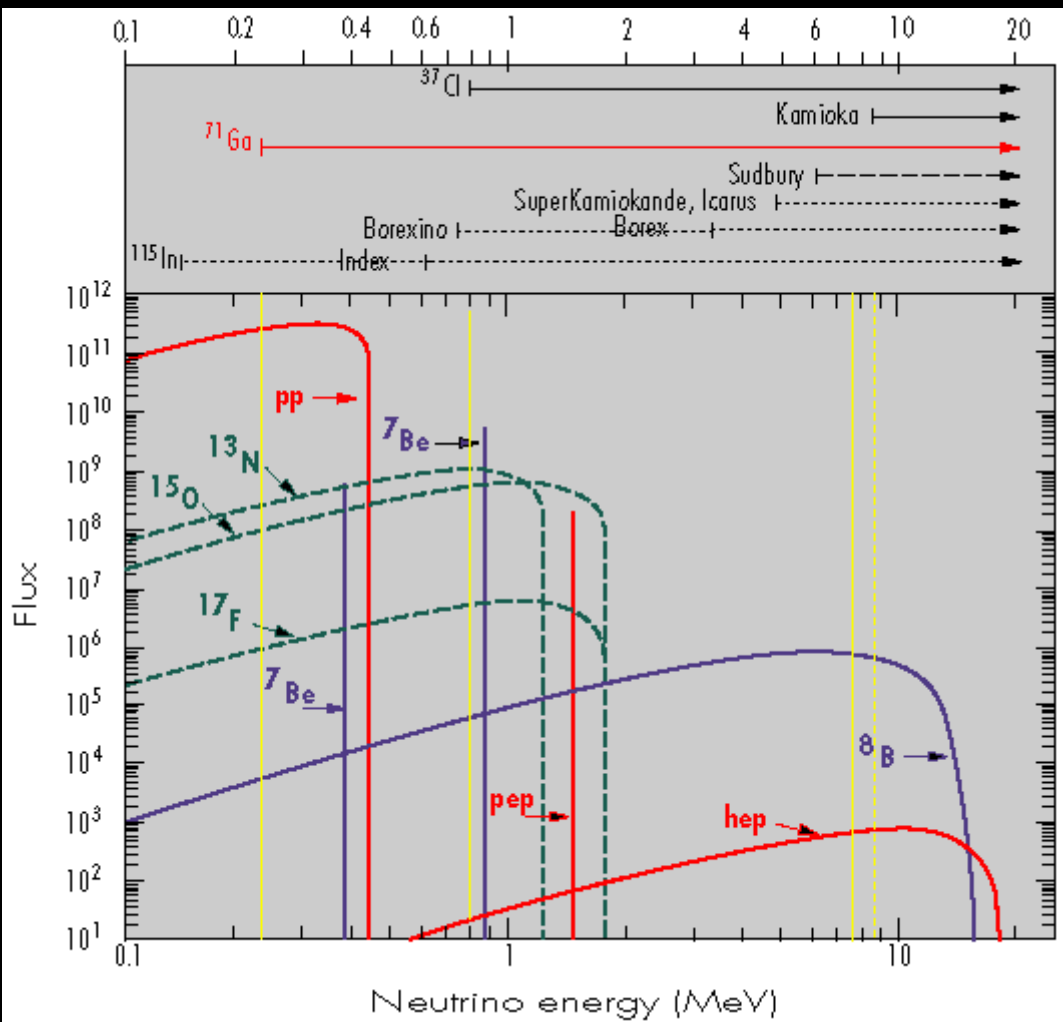




photo: BOREXINO calibration



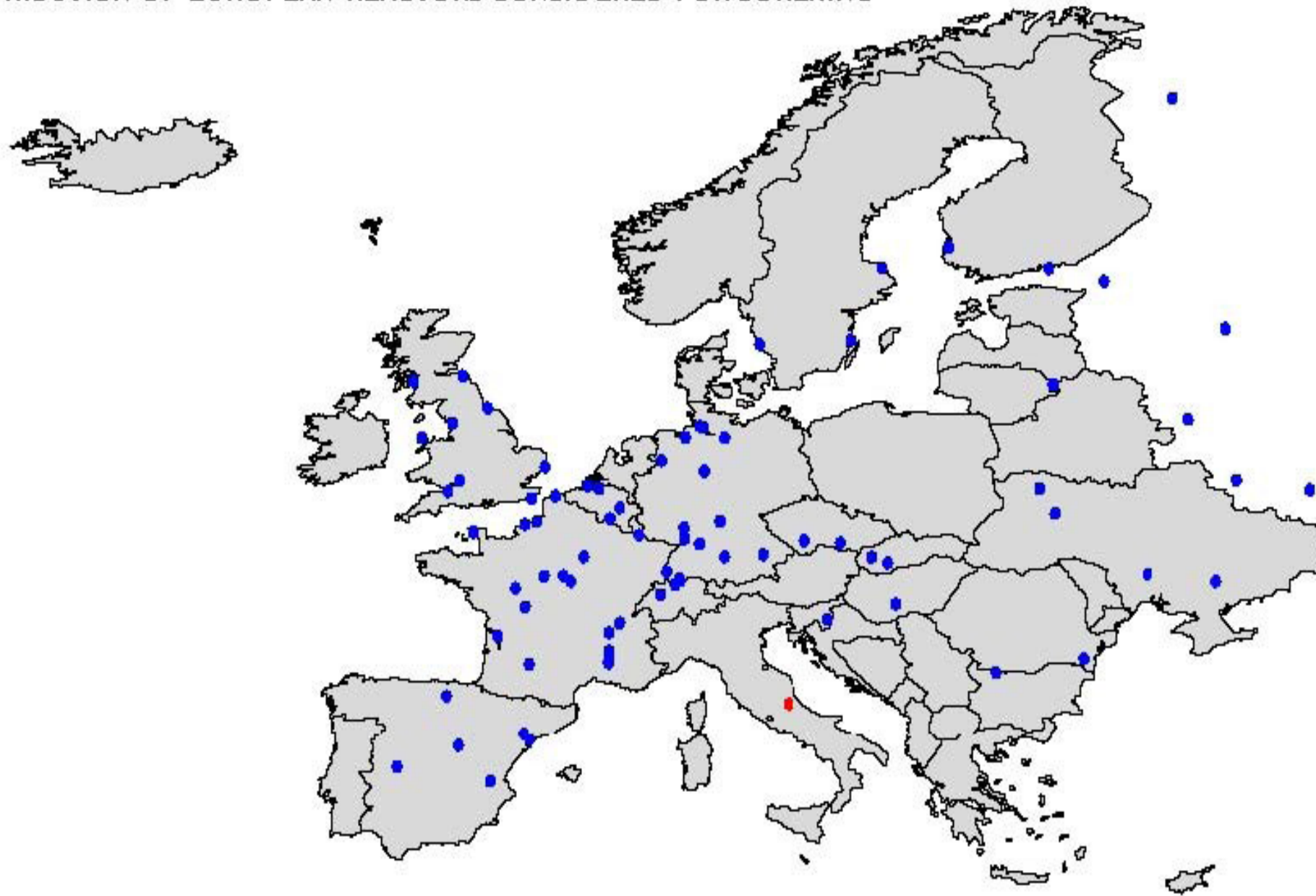
BOREXINO

výzkum procesů probíhajících uvnitř Slunce

výzkum oscilací neutrin

výzkum geoneutrin

DISTRIBUTION OF EUROPEAN REACTORS CONSIDERED FOR BOREXINO

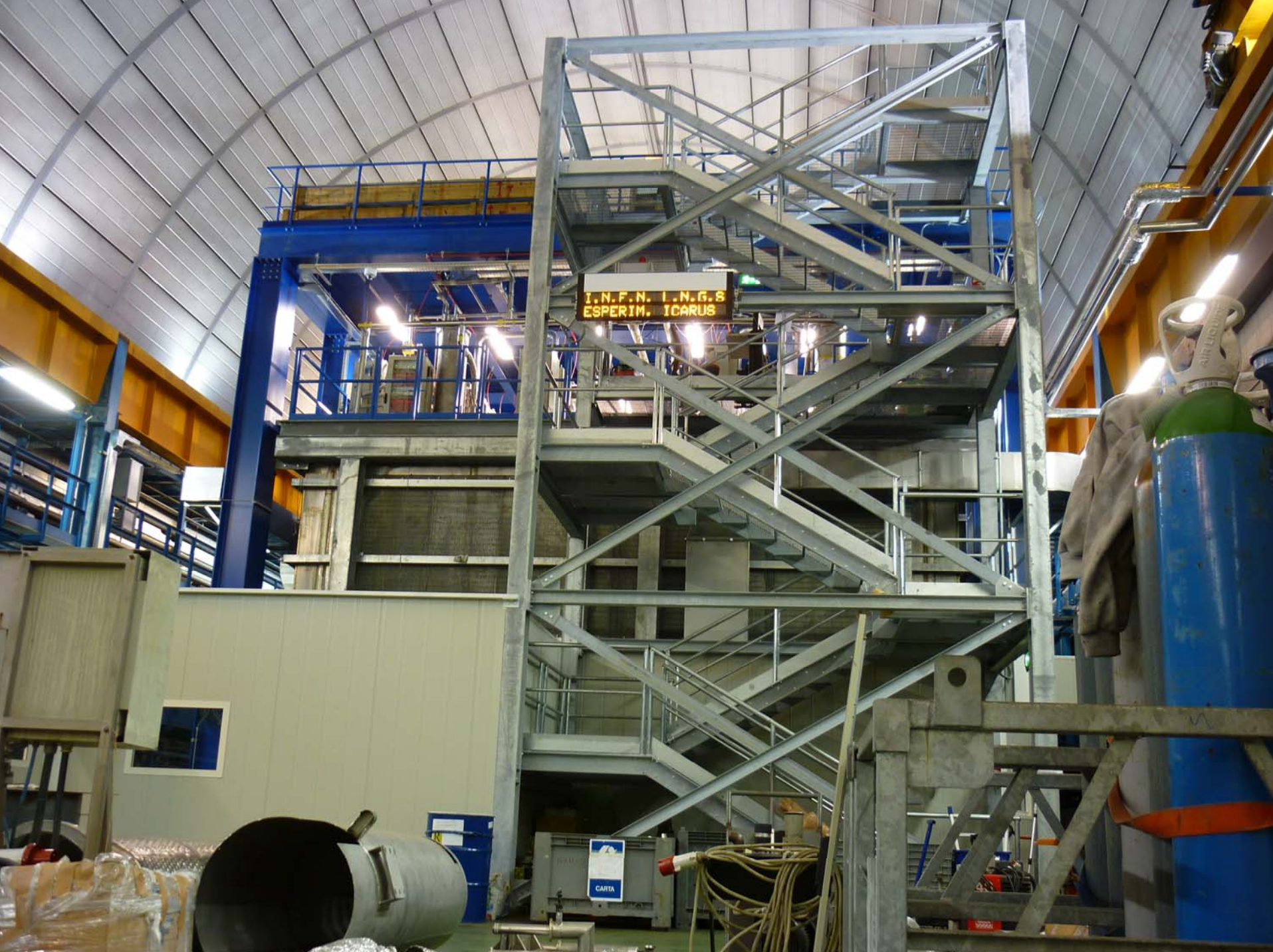




Imaging Cosmic And Rare Underground Signals

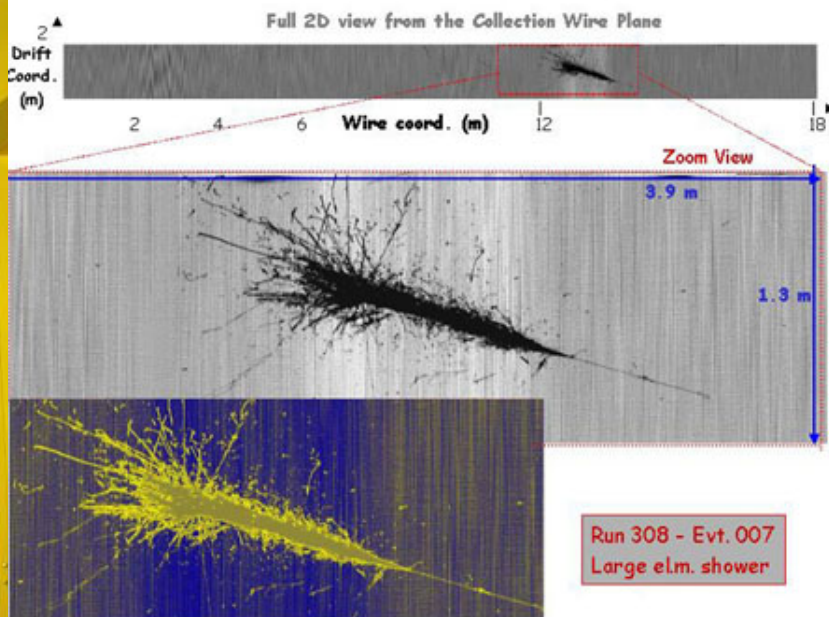
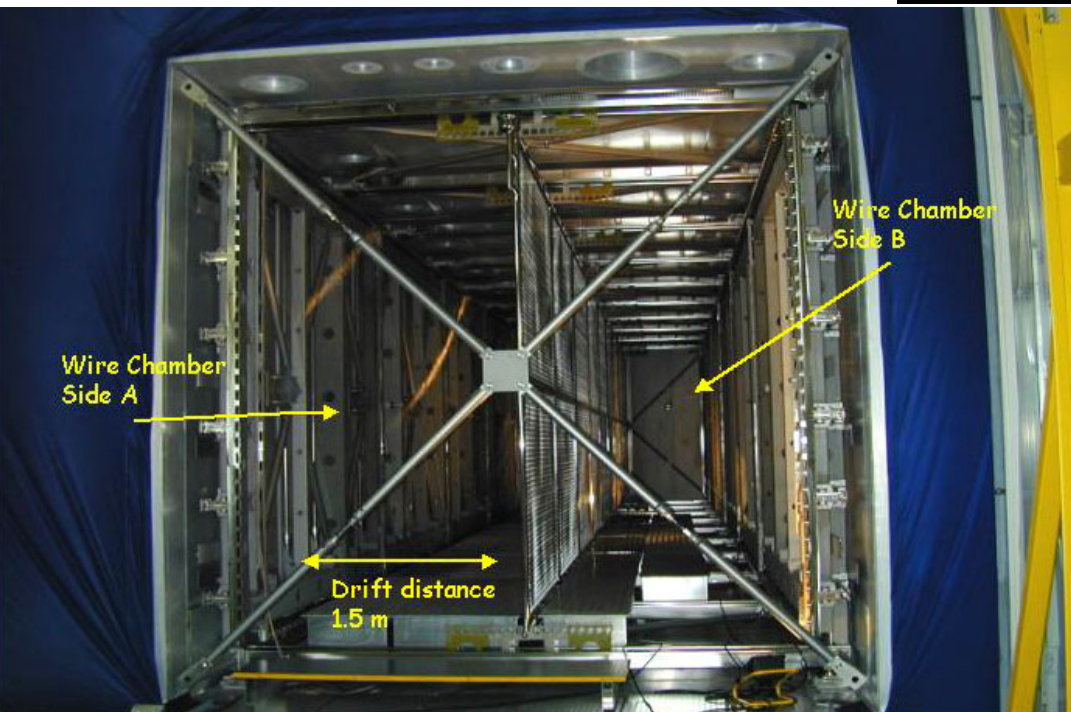
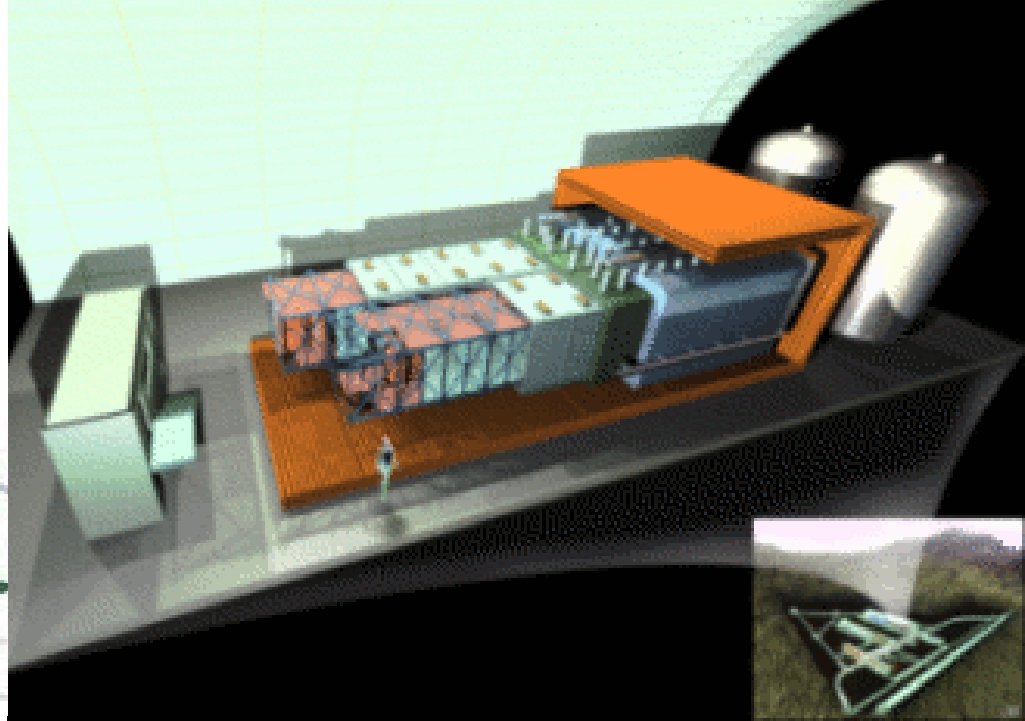
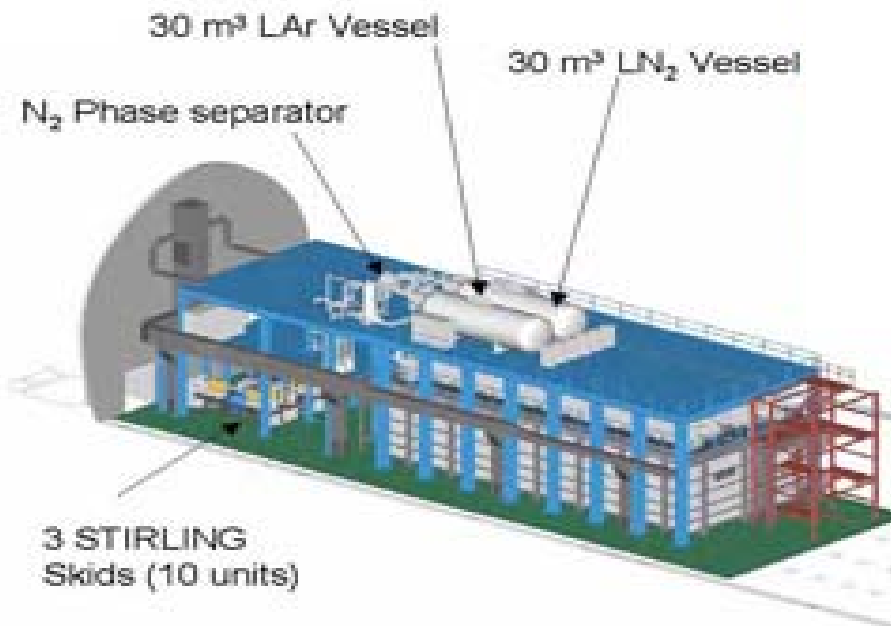


The **ICARUS** program concerns the usage of Liquid Argon (LAr) detector for studies of neutrinos from CNGS beam. The ICARUS detector filled with 600 tons of liquid argon, T600, has started data taking this year (2010).



I.N.F.N. I.N.G.S
ESPERIM. ICARUS

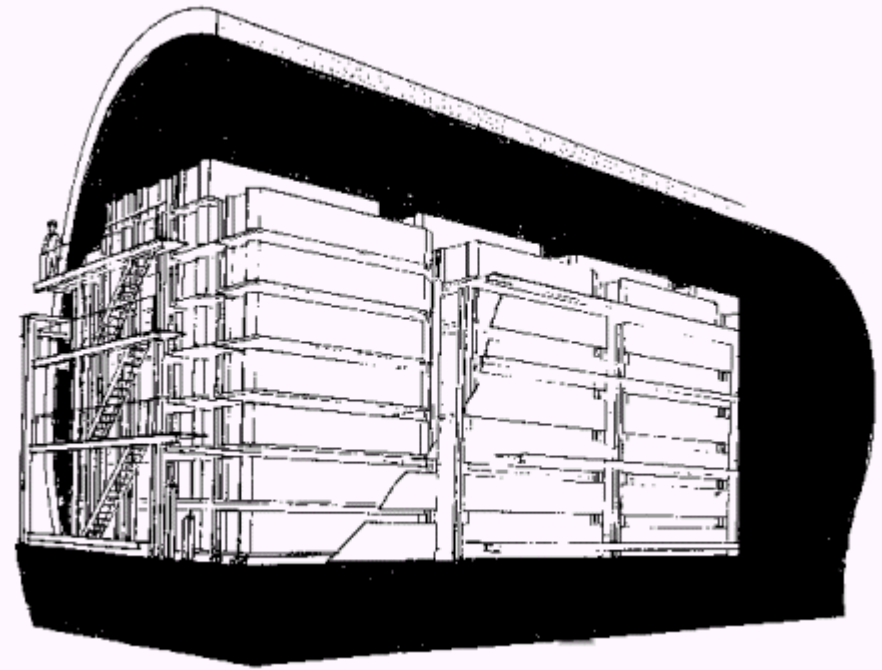
CARTA



Large Volume Detector



LVD is an array of stainless steel tanks, $1.0 \times 1.0 \times 1.5 \text{ m}^3$, filled with liquid scintillator ($\text{C}_n \text{H}_{2n+2}$, $\langle n \rangle = 9.6$, with $r = 0.8 \text{ g/cm}^3$), rise time 5 ns, attenuation length 15 m ($\lambda = 420 \text{ nm}$), with the activator POP (1g/l) and the wavelength shifter POPOP (0.03 g/l). The tanks have their inner surfaces covered with mylar. In its final configuration, the experiment has 840 tanks, with an active mass of $\sim 1.0 \text{ kton}$.
<http://www.bo.infn.it/lvd/>





Je neutrino totožné se svou antičásticí?
(Žádný takový fermion zatím není znám)
Jakou mají neutrina hmotnost?
 $^{76}\text{Ge} \rightarrow ^{76}\text{Se}$



2010: spuštění detektoru
Ge detektory v kapalném argonu
($\varnothing$ 4 m) kolem vodní tank ($\varnothing$ 10 m)

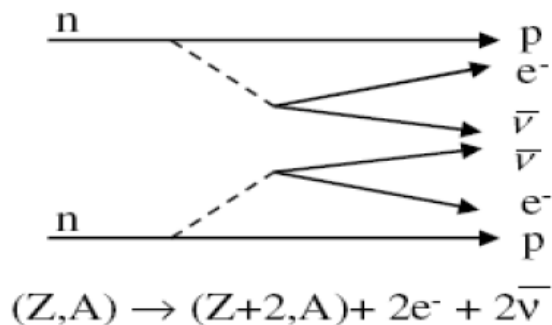


2β rozpad

Candidate Q(MeV) Abund(%)

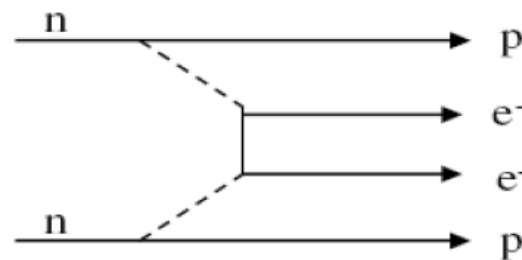
$^{48}\text{Ca} \rightarrow ^{48}\text{Ti}$	4.271	0.187
$^{76}\text{Ge} \rightarrow ^{76}\text{Se}$	2.040	7.8
$^{82}\text{Se} \rightarrow ^{82}\text{Kr}$	2.995	9.2
$^{96}\text{Zr} \rightarrow ^{96}\text{Mo}$	3.350	2.8
$^{100}\text{Mo} \rightarrow ^{100}\text{Ru}$	3.034	9.6
$^{110}\text{Pd} \rightarrow ^{110}\text{Cd}$	2.013	11.8
$^{116}\text{Cd} \rightarrow ^{116}\text{Sn}$	2.802	7.5
$^{124}\text{Sn} \rightarrow ^{124}\text{Te}$	2.228	5.64
$^{130}\text{Te} \rightarrow ^{130}\text{Xe}$	2.533	34.5
$^{136}\text{Xe} \rightarrow ^{136}\text{Ba}$	2.479	8.9
$^{150}\text{Nd} \rightarrow ^{150}\text{Sm}$	3.367	5.6

2νββ decay

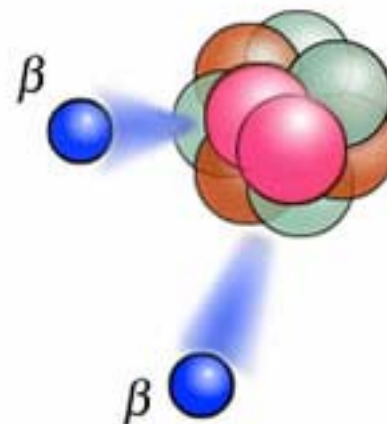
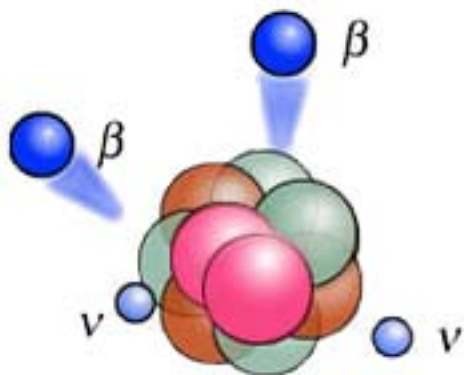


$$T_{1/2} \sim 10^{21} \text{y}$$

0νββ decay

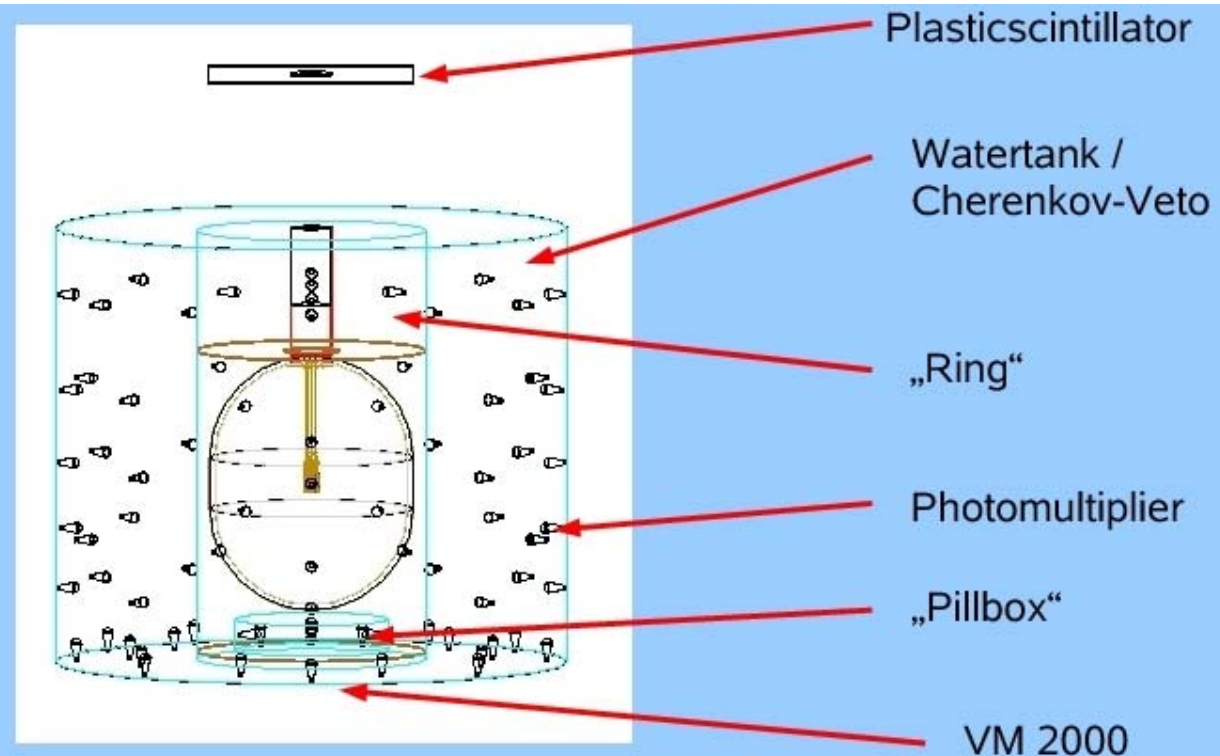
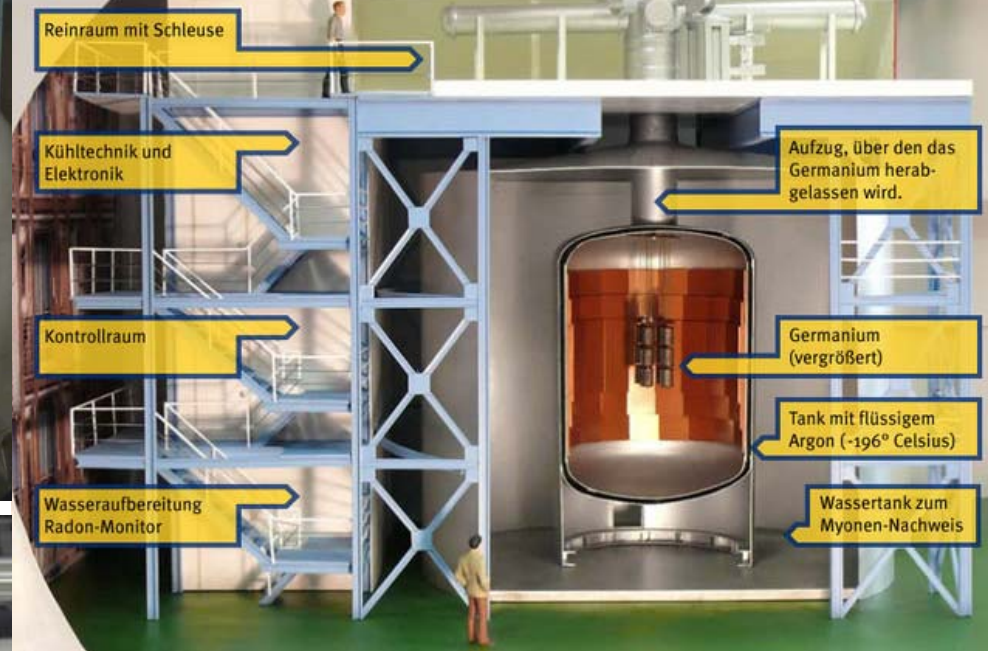


$$T_{1/2} > 10^{25} \text{y}$$



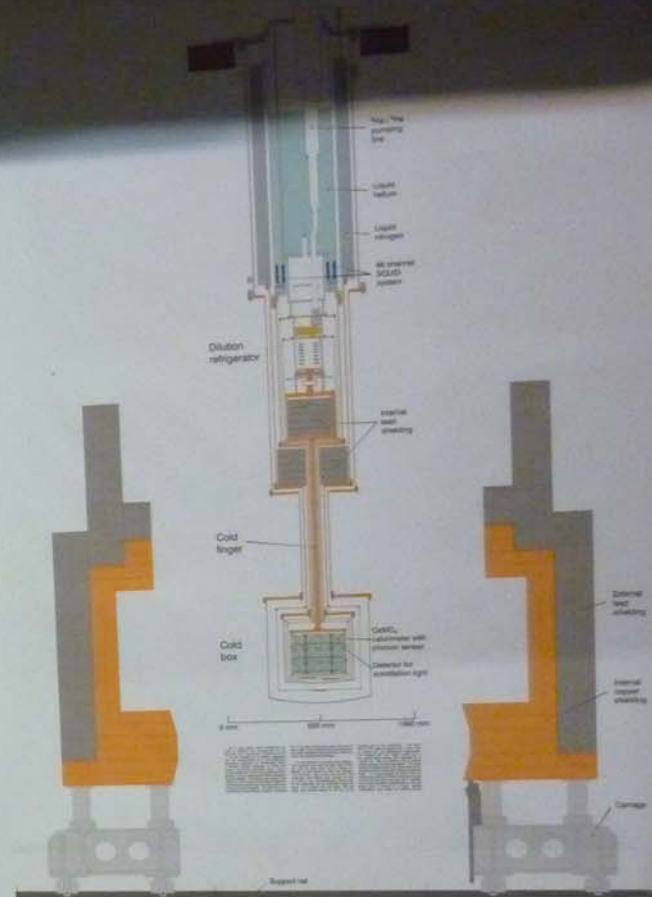


GERDA





CRESST Cryostat



Ingresso vietato

presa dati in corso

No entry

measurement running

In caso di emergenza contattare l'ingegnere Carlo Bacci, 0432





VIRGO

<https://www.cascina.virgo.infn.it/>



VIRGO



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