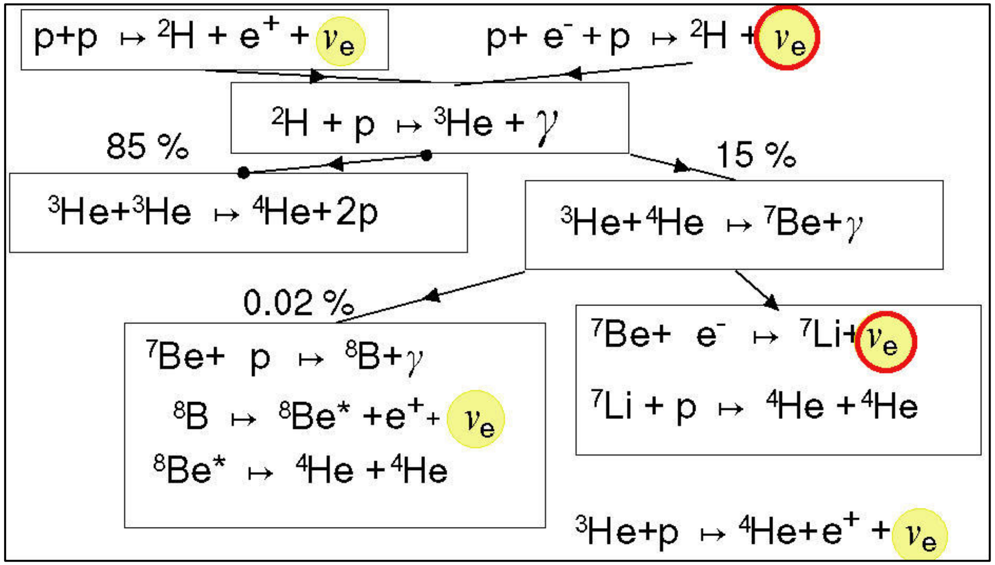
Rivelazione di neutrini solari - Borexino

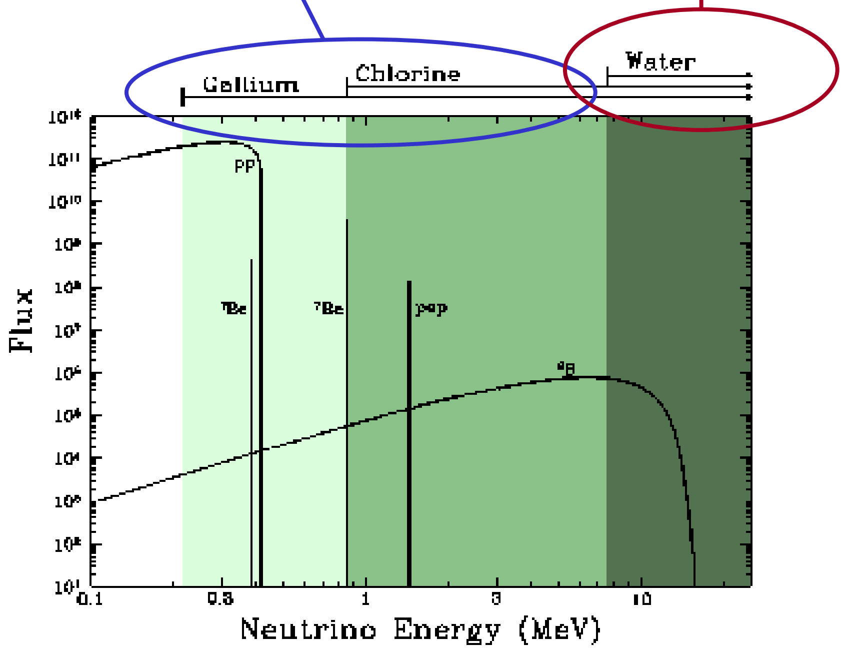
Lino Miramonti – 6 Giugno 2006 – Gran Sasso

pp cycle



RADIOCHEMICAL
Integrated in energy and time

CHERENKOV
Less than 0.01% of the solar neutrino flux is been measured in real time.



Esperimenti radiochimici:

Homestake
Gallex/Sage

Esperimenti Cherenkov

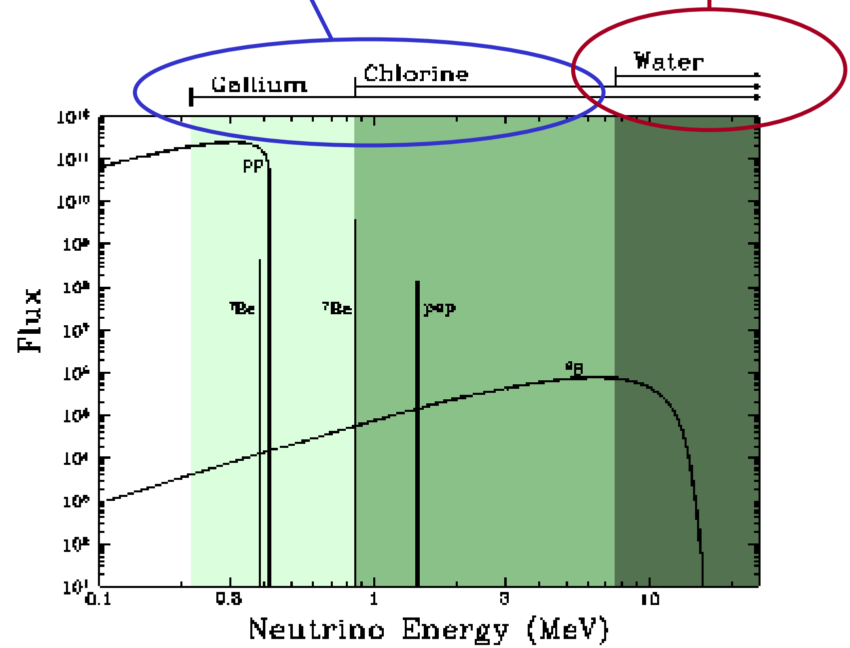
Kamiokande/SuperK
SNO

Borexino

RADIOCHEMICAL
Integrated in energy and time

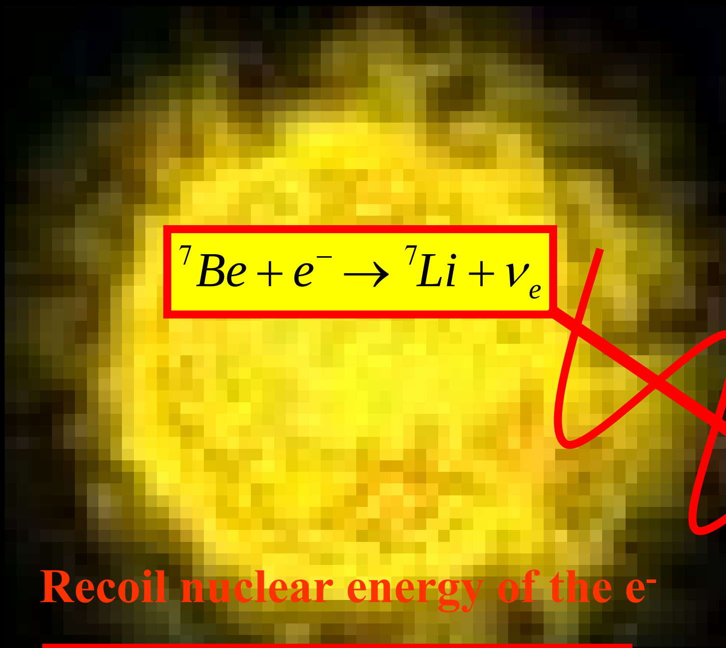
CHERENKOV
Less than 0.01% of the solar neutrino flux is been measured in real time.

The main goal of Borexino is the measurement in real time of the low energy component of solar neutrinos.



$E_\nu = 862$ keV (monochromatic)

$\Phi_{SSM} = 4.8 \cdot 10^9\ \nu\ s^{-1}\ cm^2$

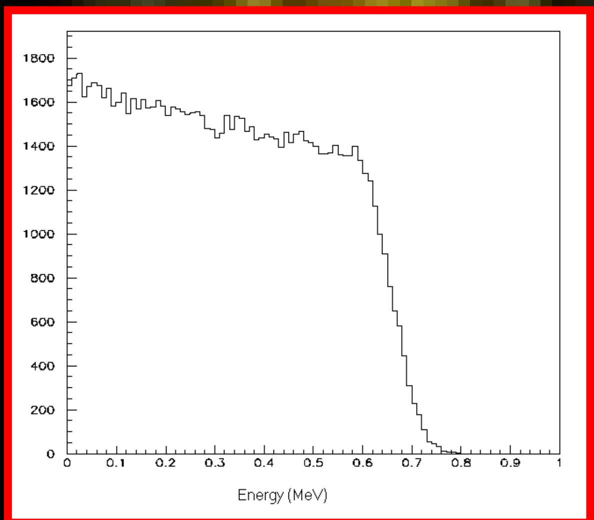


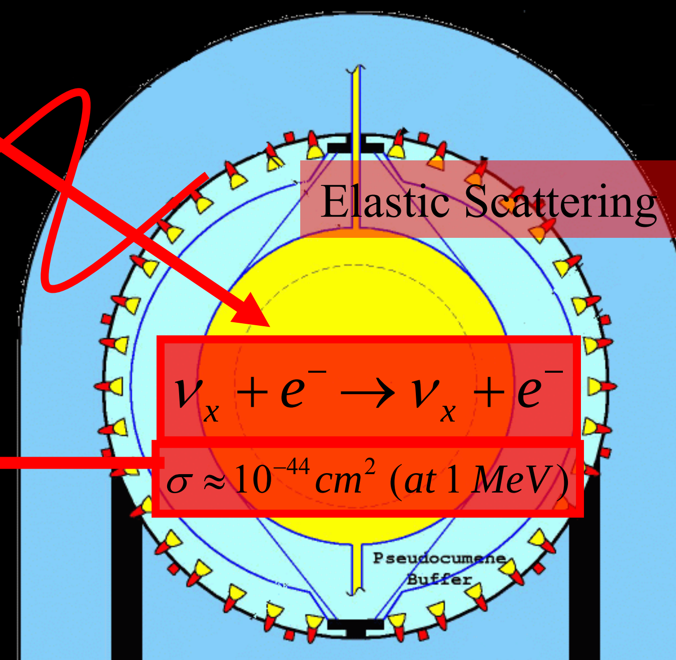
$^7Be + e^- \rightarrow\ ^7Li + \nu_e$

ν_e

ν_x

Recoil nuclear energy of the e$^-$



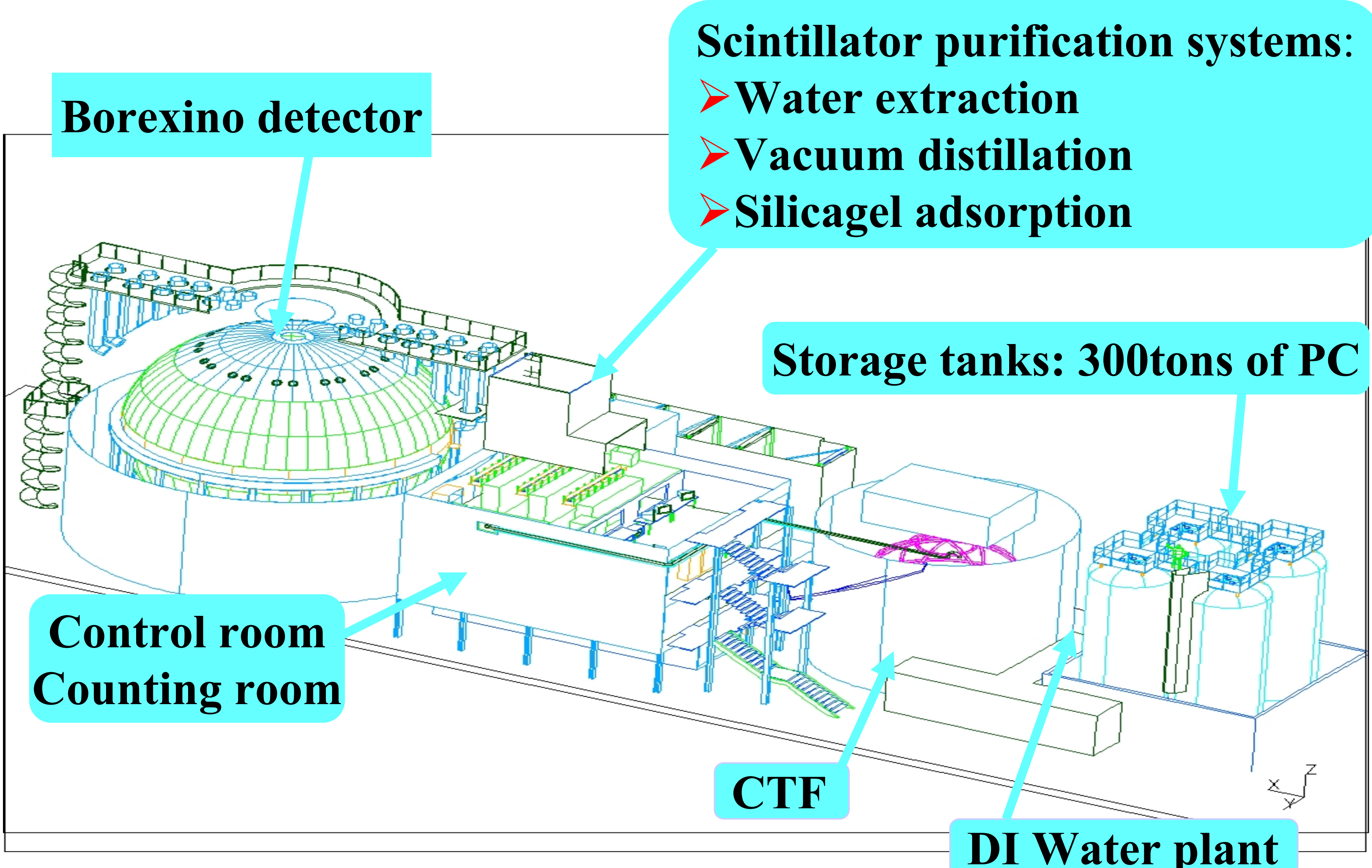


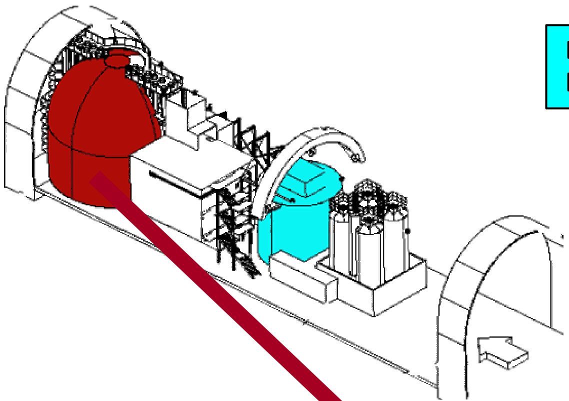
$\nu_x + e^- \rightarrow \nu_x + e^-$

$\sigma \approx 10^{-44}\ cm^2\ (at\ 1\ MeV)$

expected rate (LMA hypothesis) is 35 counts/day in the 250-800 keV energy range

BOREXINO: subsystems





Borexino design

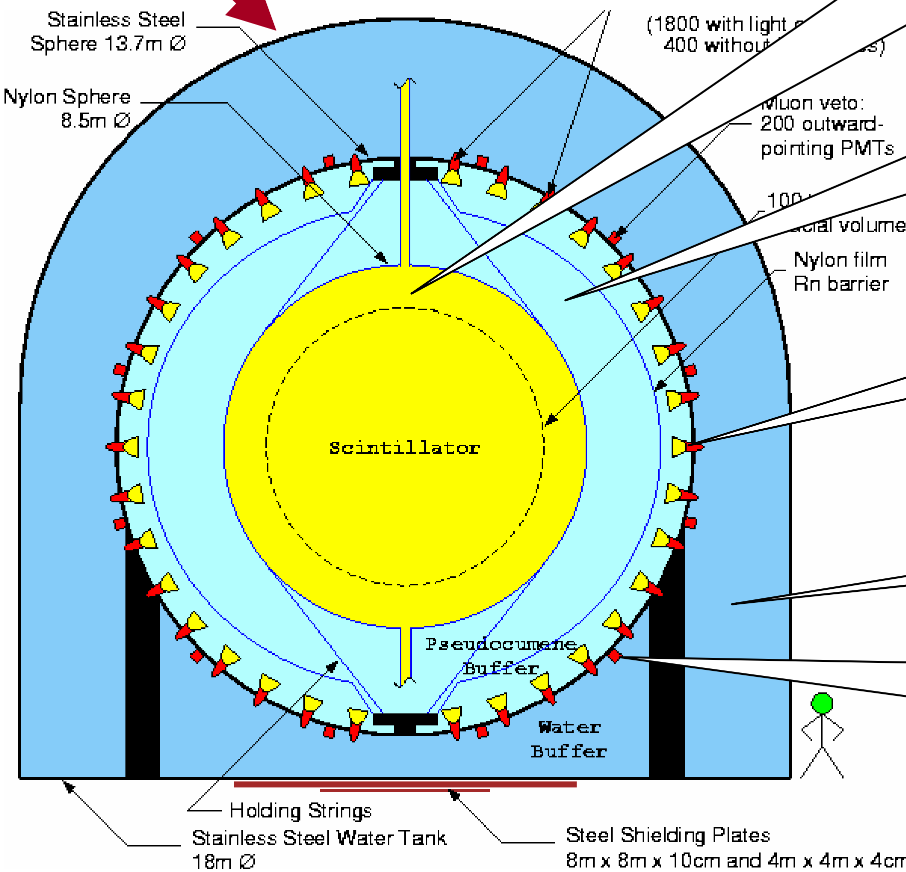
Core of the detector: 300 tons of liquid scintillator (PC+PPO) contained in a nylon vessel of 8.5 m diameter. The thickness of nylon is 125 μm.

1st shield: 1000 tons of ultra-pure buffer liquid (pure PC) contained in a stainless steel sphere of 13.7 m diameter (SSS).

2200 photomultiplier tubes pointing towards the center to view the light emitted by the scintillator.

2nd shield: 2400 tons of ultra-pure water contained in a cylindrical dome.

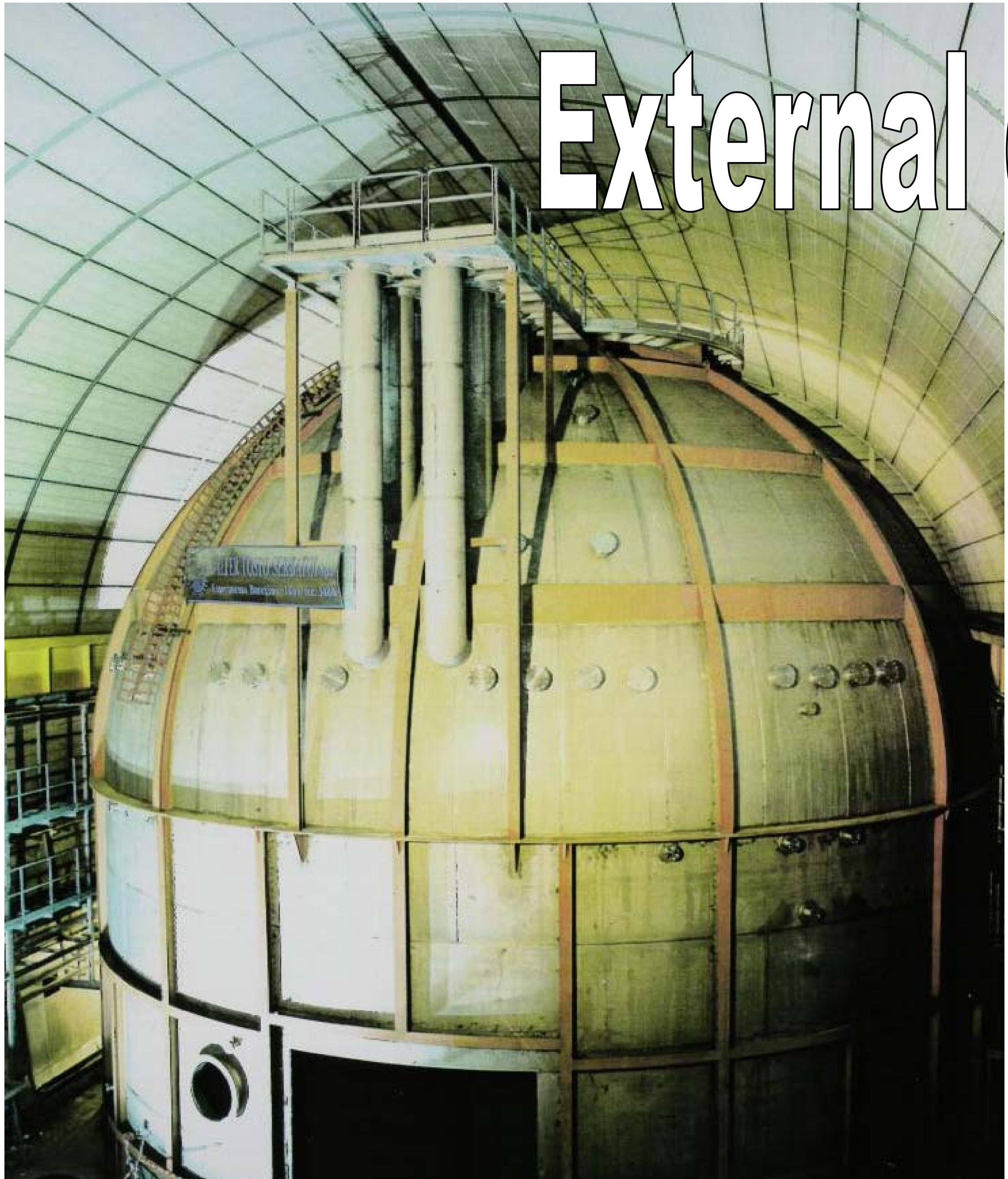
200 photomultiplier tubes mounted on the SSS pointing outwards to detect Cerenkov light emitted in the water by muons.



Experimental Hall C

External dome

18 m

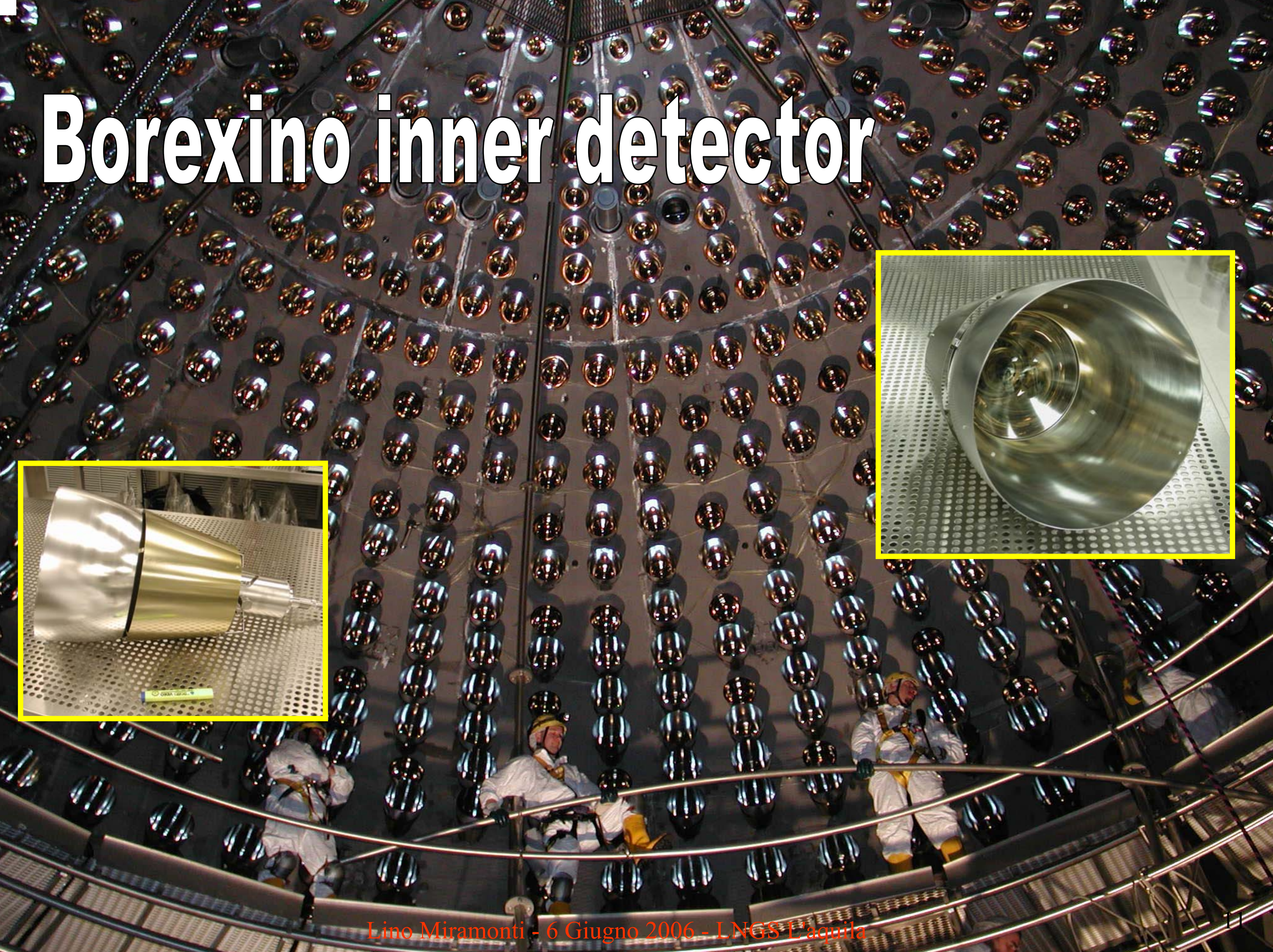


Stainless Steel Sphere (SSS)

PMTs ready to be mounted

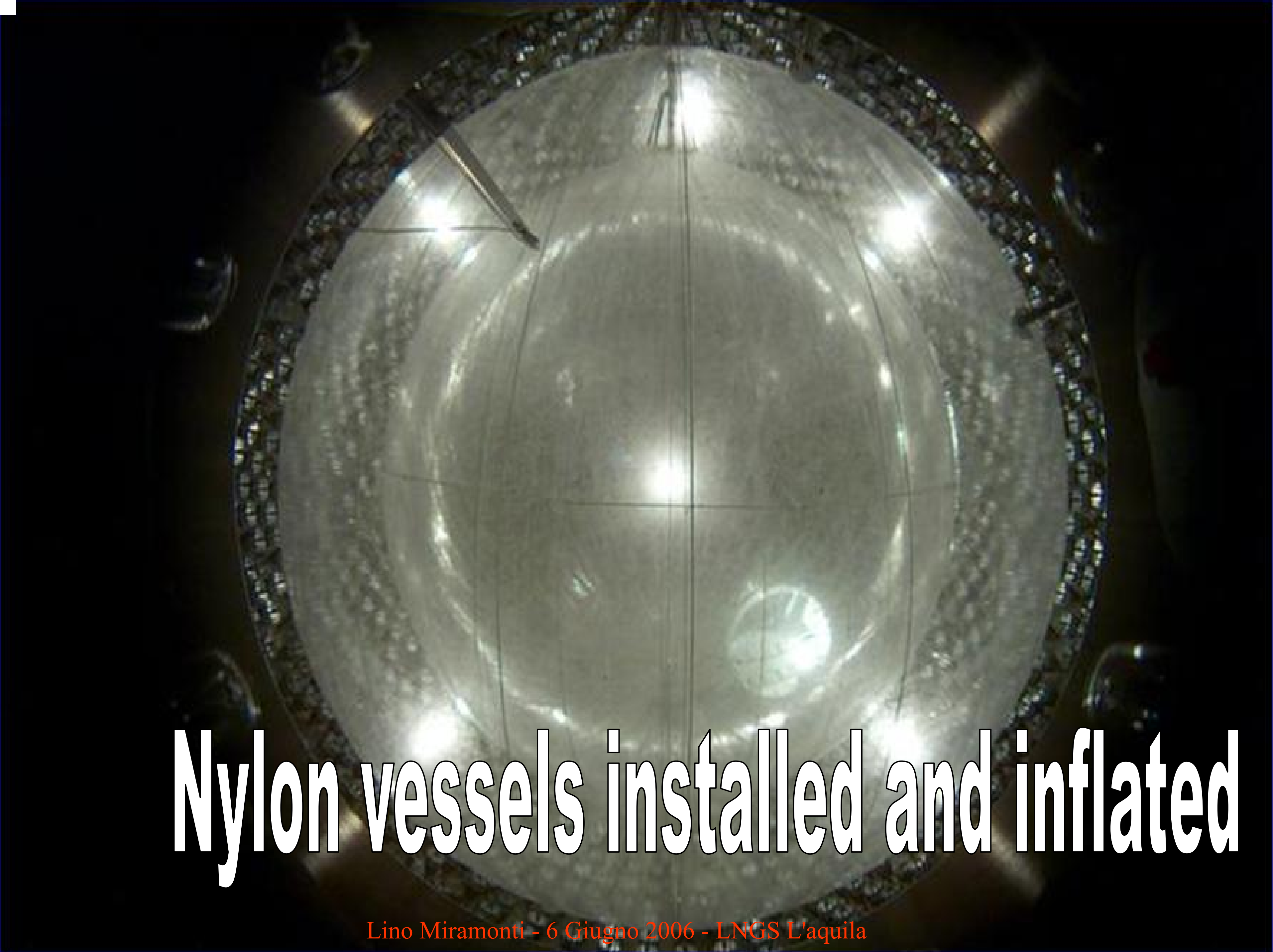
Clean Room

Borexino inner detector



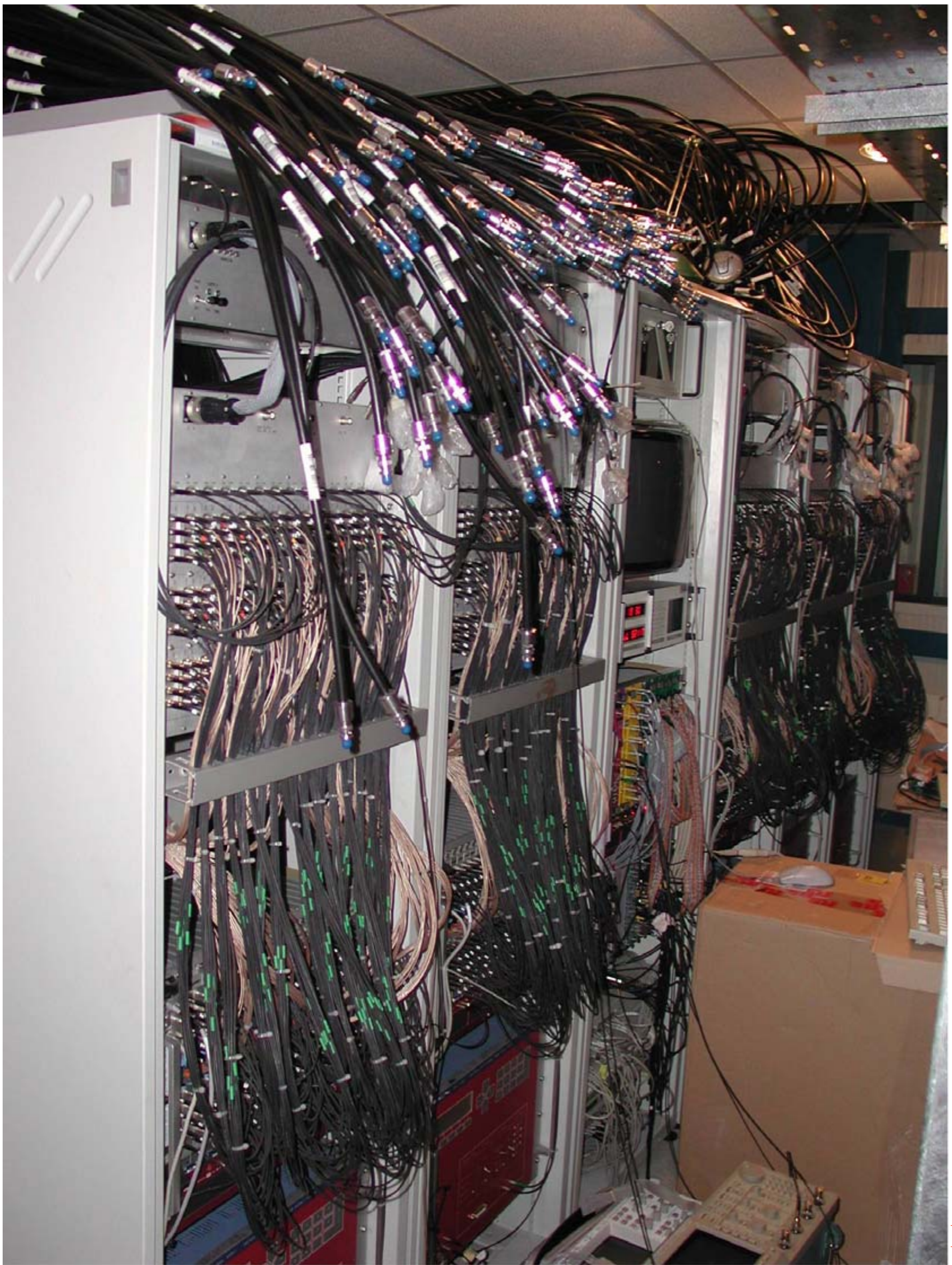
Borexino inner detector

Nylon vessels installation



Nylon vessels installed and inflated

Cables installation



Counting Room

Clean Room (on top of the Water Tank) for the insertions of lasers and sources for **calibrations**.

Backgrounds we have to fight

1. Natural radioactivity
2. Muon Induced reactions
3. Cosmogenic induced isotopes
4. ^{14}C
5. Air contaminants: ^{222}Rn, ^{85}Kr, ^{39}Ar

1. Natural radioactivity

Primordial radioactivity: (about 20 radioisotopes with half-life > Earth life)

between them:

^{238}**U** and ^{232}**Th** (α and β emitters)

^{40}**K** (β emitter with end-point = 1.3 MeV)

- **Selection of materials**
- **Surface treatment to avoid dust and particulate**
- **Purification:**
  - **Water extraction,**
  - **Vacuum distillation,**
  - **Ultra filtration**
  - **Nitrogen sparging**

Hardware

- **Alpha/Beta Discrimination**
- **Delayed Coincidence**

Software

	Typical Conc.	Borexino level
^{238}U, ^{232}Th	~ 1ppm in dust ~ 1ppb stainless steel ~ 1ppt IV nylon	~ 10^{-16}g/g (PC) ~ 10^{-14}g/g (water)
K_{nat}	~ 1ppm in dust	< 10^{-13}g/g (PC)

Purification of the Scintillator (with US Skids):

- **Water extraction**: Impurity with high solubility in aqueous phase such as **K** and heavy metals in **U Th chains**.

- **Vacuum distillation**: Low volatility components such as **metals** and **dust particles**.

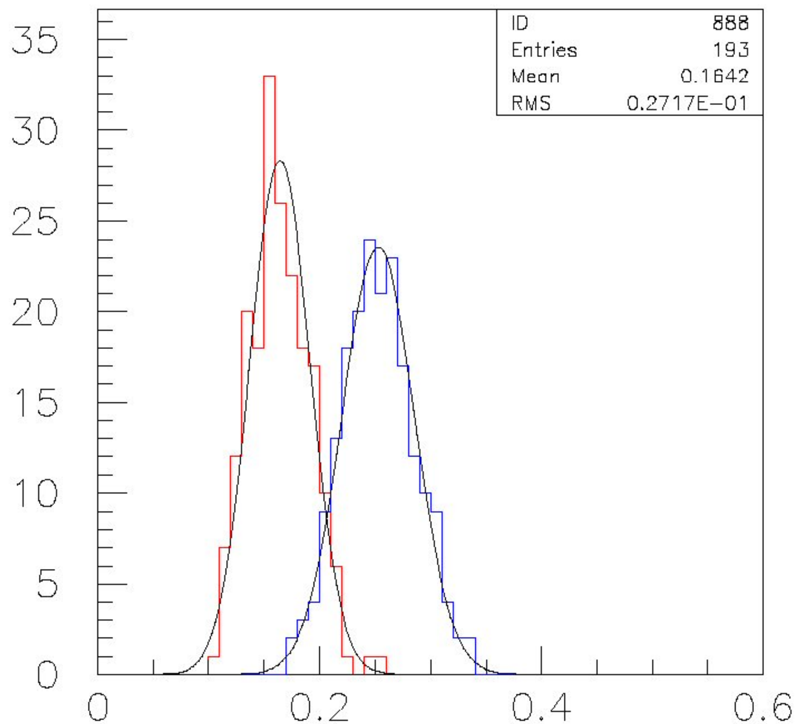
- **Ultra filtration**: Particle dust.

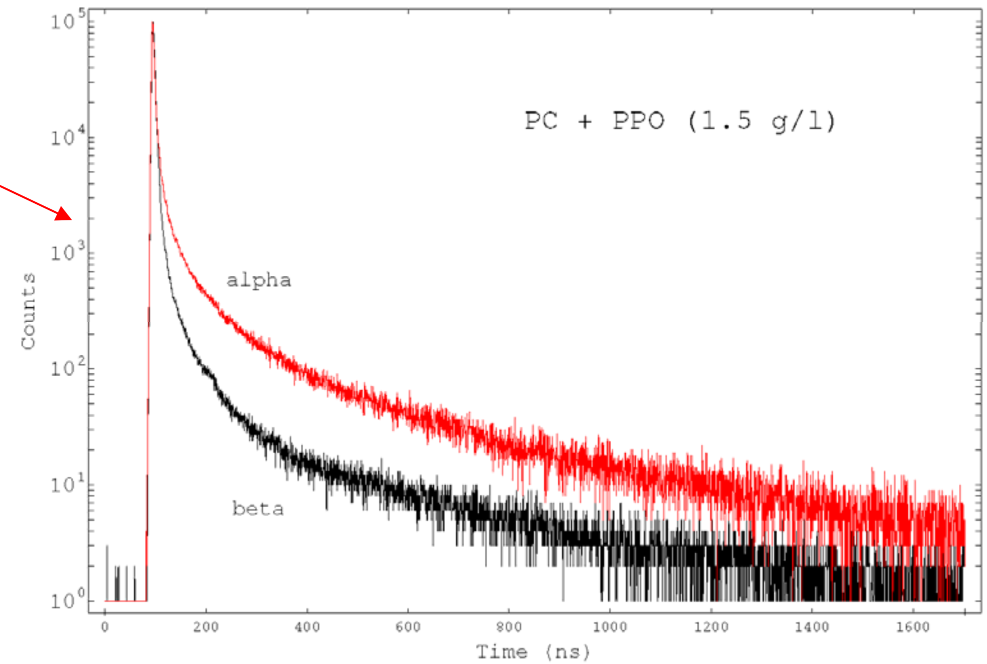
- **Nitrogen stripping**: Nobles gases.

alpha/beta discrimination

The excitation of the scintillator depends on many factors including the **energy loss density** – a large **dE/dx** enhances the slow component of the **decay curve**

The ratio tail over total is expected to be greater for alpha than for electrons

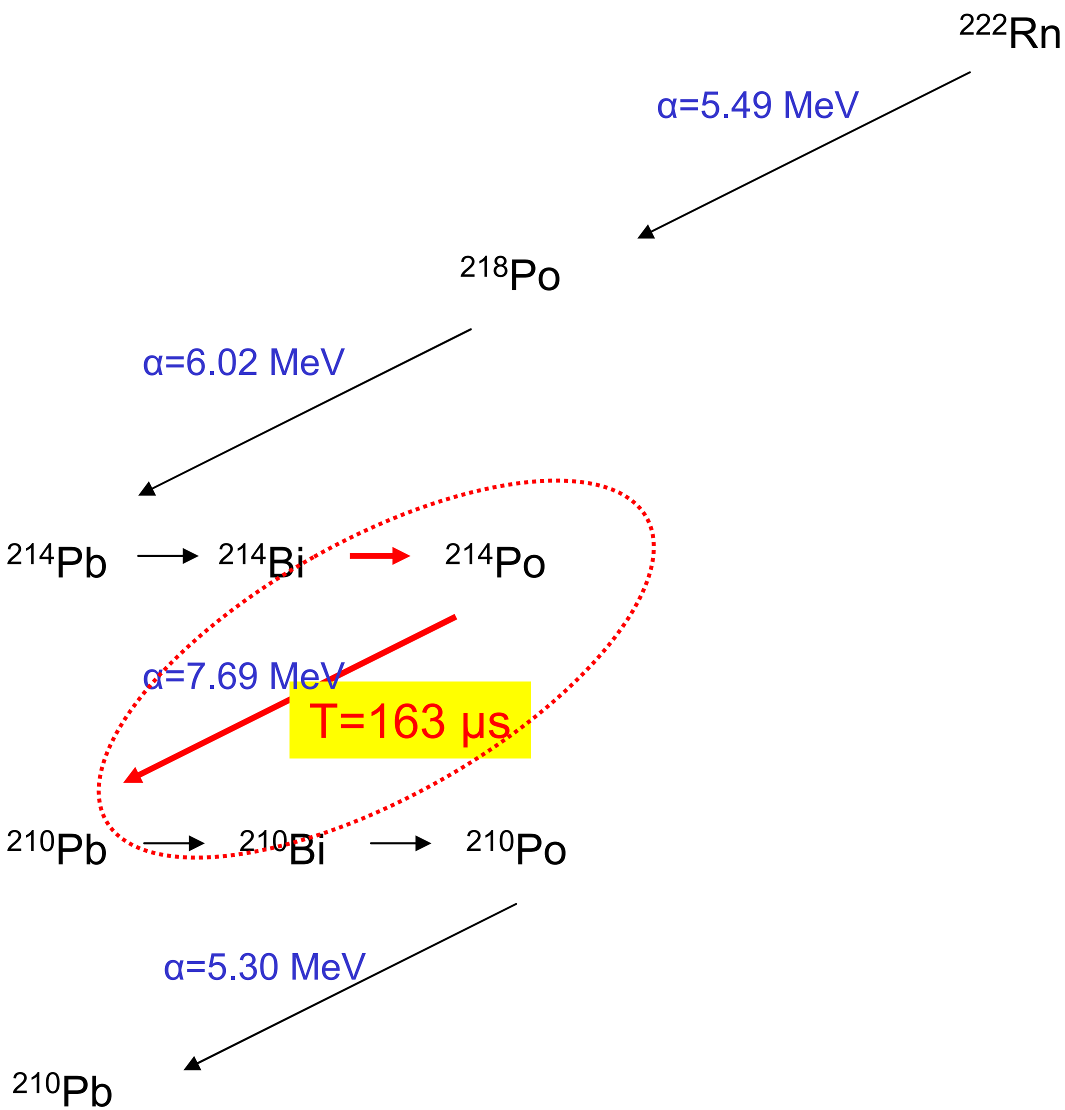




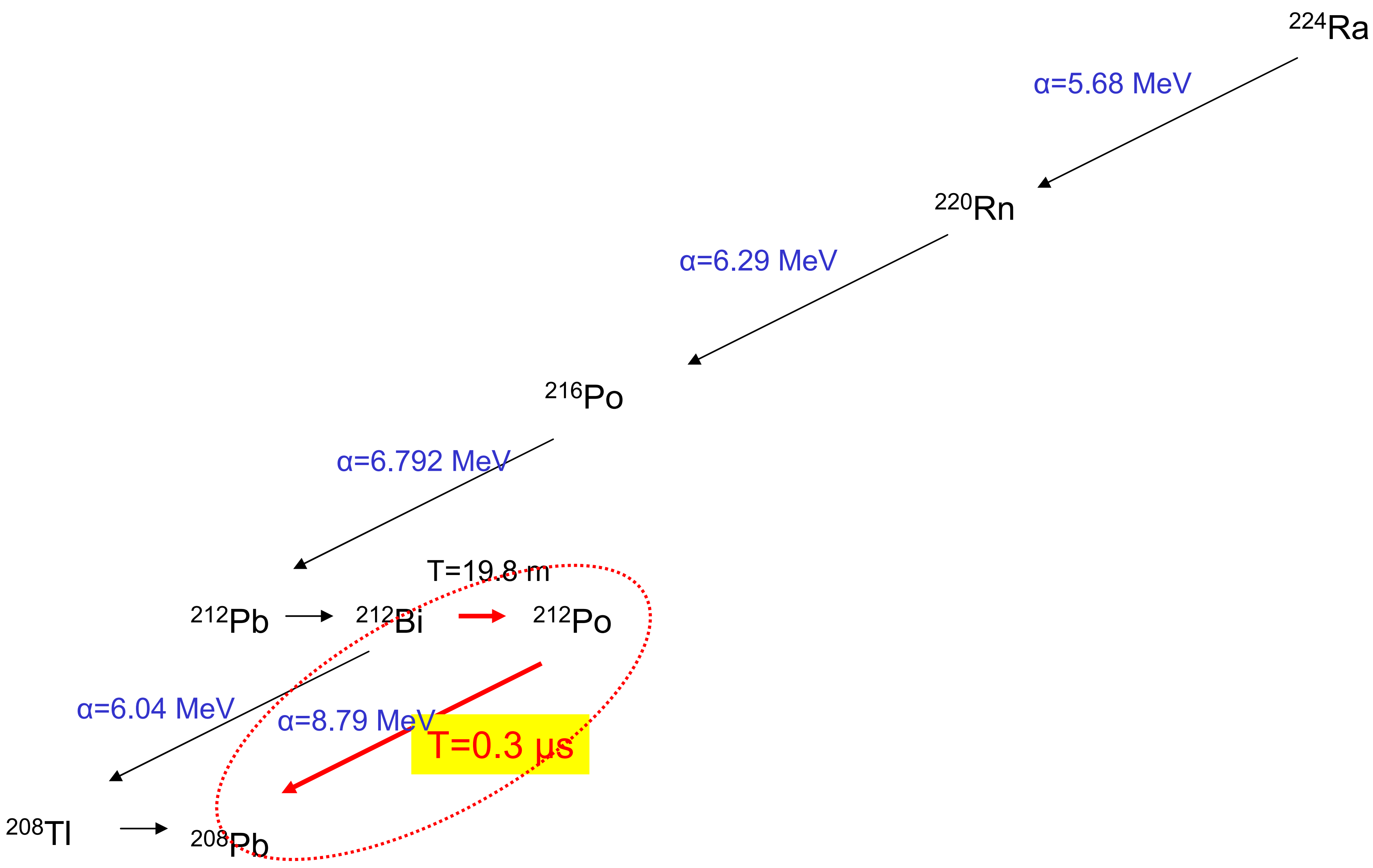
An efficiency for alpha identification of ~ 97% at 751 keV with an associated beta misidentification of ~ 2.5%.

At low energies (300-600 keV) the alpha I dentification efficiency range from 90 to 97 % with an associated beta misidentification of ~ 10%.

Delayed Coincidence in U238 chain



Delayed Coincidence in Th232 chain



2. Muon Induced reactions

At LNGS we have $1.1\ \mu\ m^2\ h^{-1}$ with a $<E_\mu> = 320$ GeV

A muon-veto system (The outer water shielding serves at the same time as water Cerenkov detector for atmospheric muons) reduce this number by a factor 5000-10000

Interacting with ^{12}C of the organic scintillator they give:

^{11}Be	$\tau = 13.8$ s	β^-
^{7}Be	$\tau = 53.3$ d	β^- EC
^{11}C	$\tau = 20.4$ m	β^- EC
^{10}C	$\tau = 19.3$ s	β^- EC

These elements having a $\tau > 1$ s is not possible to tag them

Ultrarelativistic μ can produce n which after been captured by p give a 2.2 MeV γ ray:

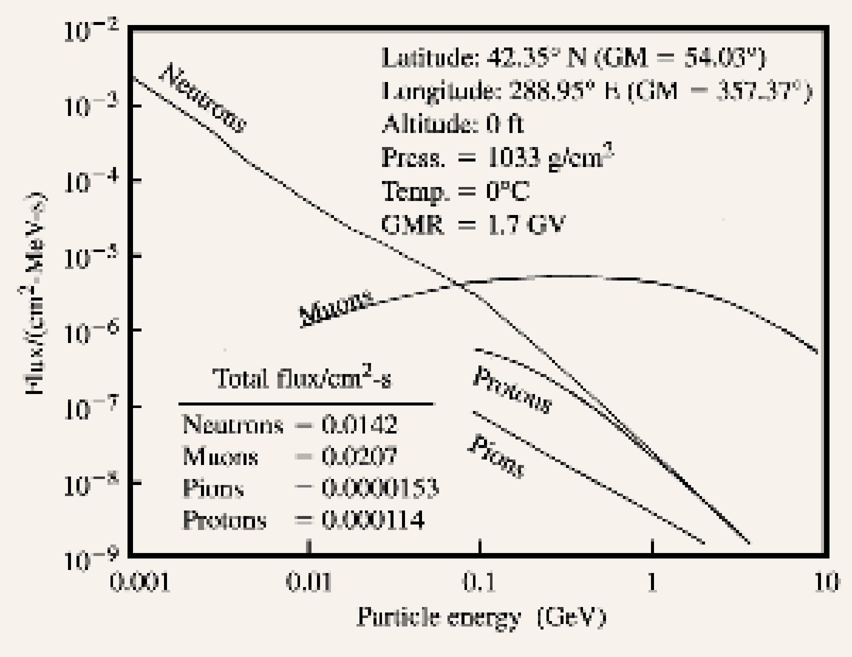
$$n + p \rightarrow d + \gamma\ (2.2\ MeV)$$

3. Cosmogenic induced isotopes

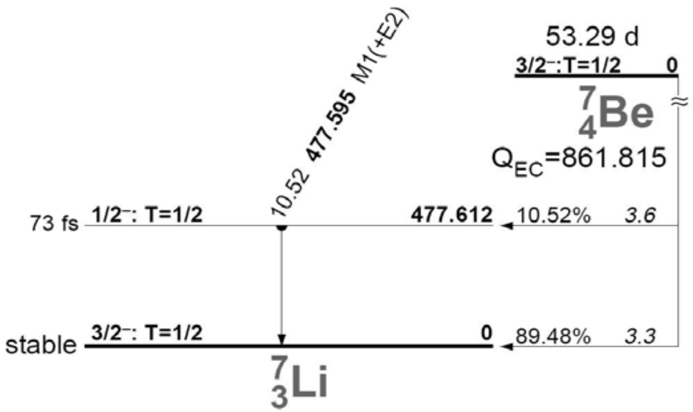
During transportation, pseudocumene is exposed to cosmic neutrons.
Pseudocumene is produced in Sardinia and the voyage to LNGS take about one day.
During transportation cosmic neutrons interact with ^{12}C producing ^{7}Be:

$$n + {}^{12}C \rightarrow {}^{7}Be + X$$

Theoretical sea-level Cosmic Ray Flux
(Latitude New York City ≈ LNGS)

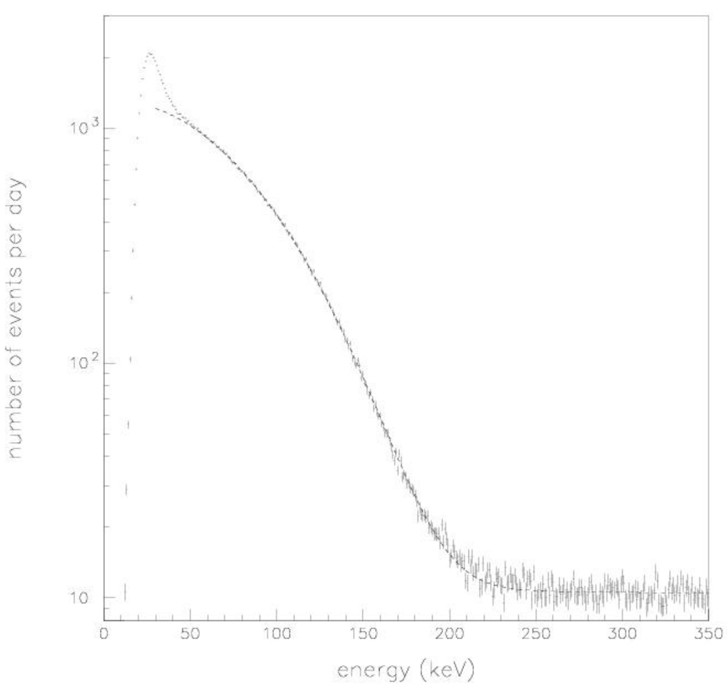


Be-7 decays by electron capture to Li-7 and emits (with a 10.52% branching fraction) a 478 keV gamma.
This line is a potential background in the Borexino neutrino window.



^{7}Be is efficiently removed by distillation!

4. ^{14}C



The reactions expected to contribute the most to 14C production in deep underground geological formations are:

$$^{17}O(n,\alpha)^{14}C$$

$$^{14}N(n,p)^{14}C$$

$$^{13}C(n,\gamma)^{14}C$$

$$^{11}B(\alpha,n)^{14}C$$

Typical Conc.	Borexino level
$^{14}C/\,^{12}C < 10^{-12}$	$^{14}C/\,^{12}C \sim 10^{-18}$

The ^{14}C content depend on the site of extraction. There is no possibility to eliminate this radionuclide, the only thing we can do, is to test, in CTF, samples of pseudocumene before to transport it to LNGS.

Our threshold (at 250 keV) is due to the ^{14}C!

5. Air contaminants: ^{222}Rn, ^{85}Kr, ^{39}Ar

Regular N_2
High Purity N_2
LAK (Low Ar/Kr content) N_2

To reduce the effect of emanation we used only electroplisched stainless steel, applied orbital weldings.

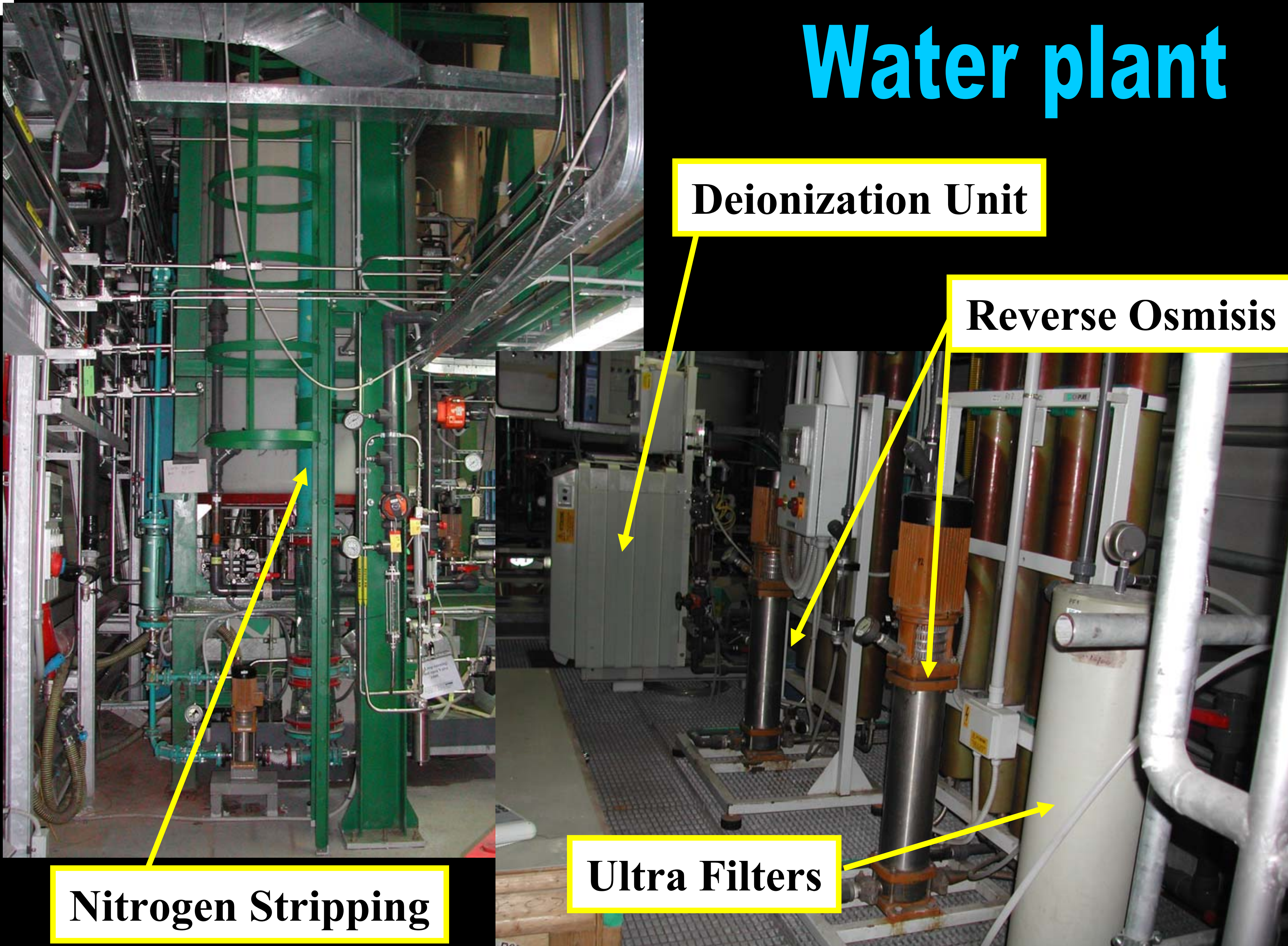
^{85}Kr
β emitter: E_{max} = 687 keV
($E\gamma$ = 514 keV)
Half-life: 10.8 years

^{39}Ar
β emitter: E_{max} = 565 keV
(no gamma)
Half-life: 269 years

	Origin	Typical Conc. (in air)	Borexino level
^{222}Rn	^{238}U chain	10-100 Bq/m³	~ 70 μBq/m³ in PC
^{85}Kr	Anthropogenic origin (nuclear fue reprocessing)	1 Bq/m³	0.16 μBq/m³ in N_2
^{39}Ar	Cosmogenic production	11 mBq/m³	0.5 μBq/m³ in N_2

N_2 used to sparge scintillator

Water plant


Deionization Unit
Reverse Osmisis
Nitrogen Stripping
Ultra Filters

Counting Test Facility (CTF)

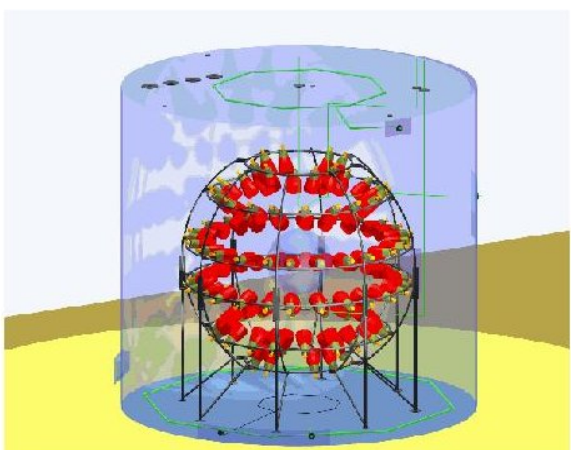
CTF is a prototype of Borexino. Its main goal was to verify the capability to reach the very low-levels of contamination needed for Borexino

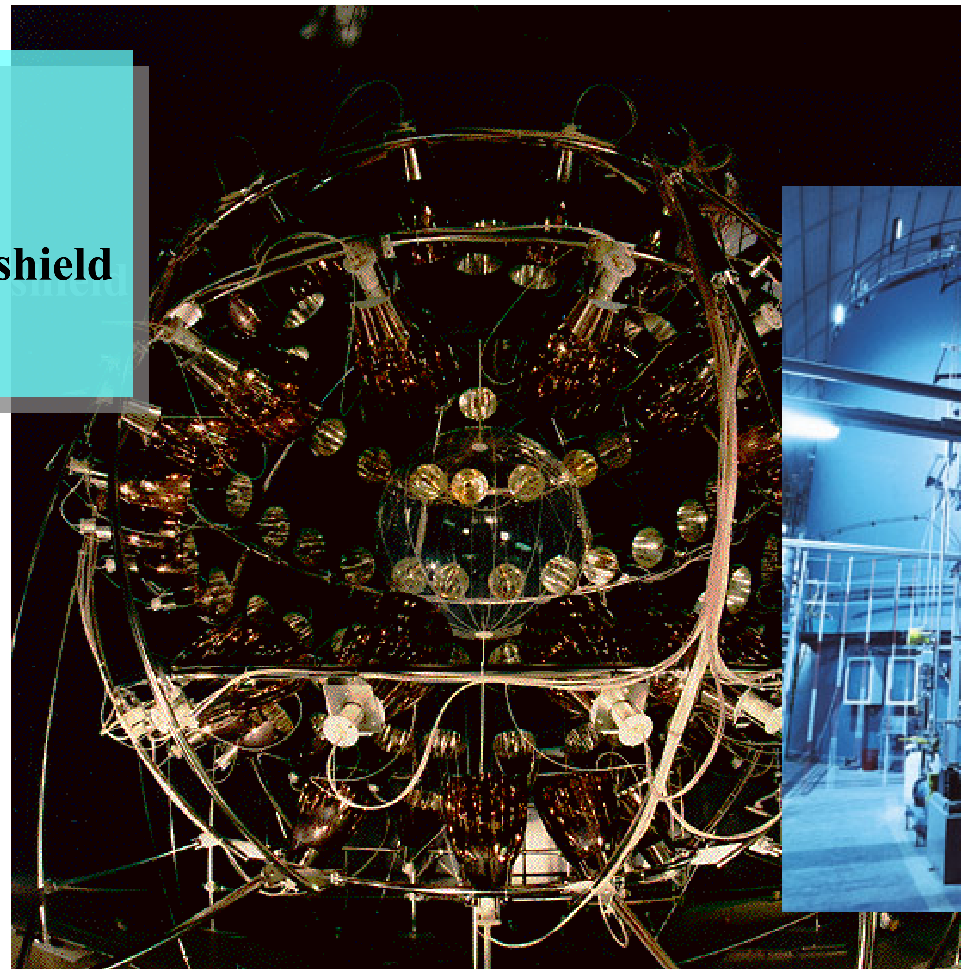
100 PMTs

4 tons of scintillator

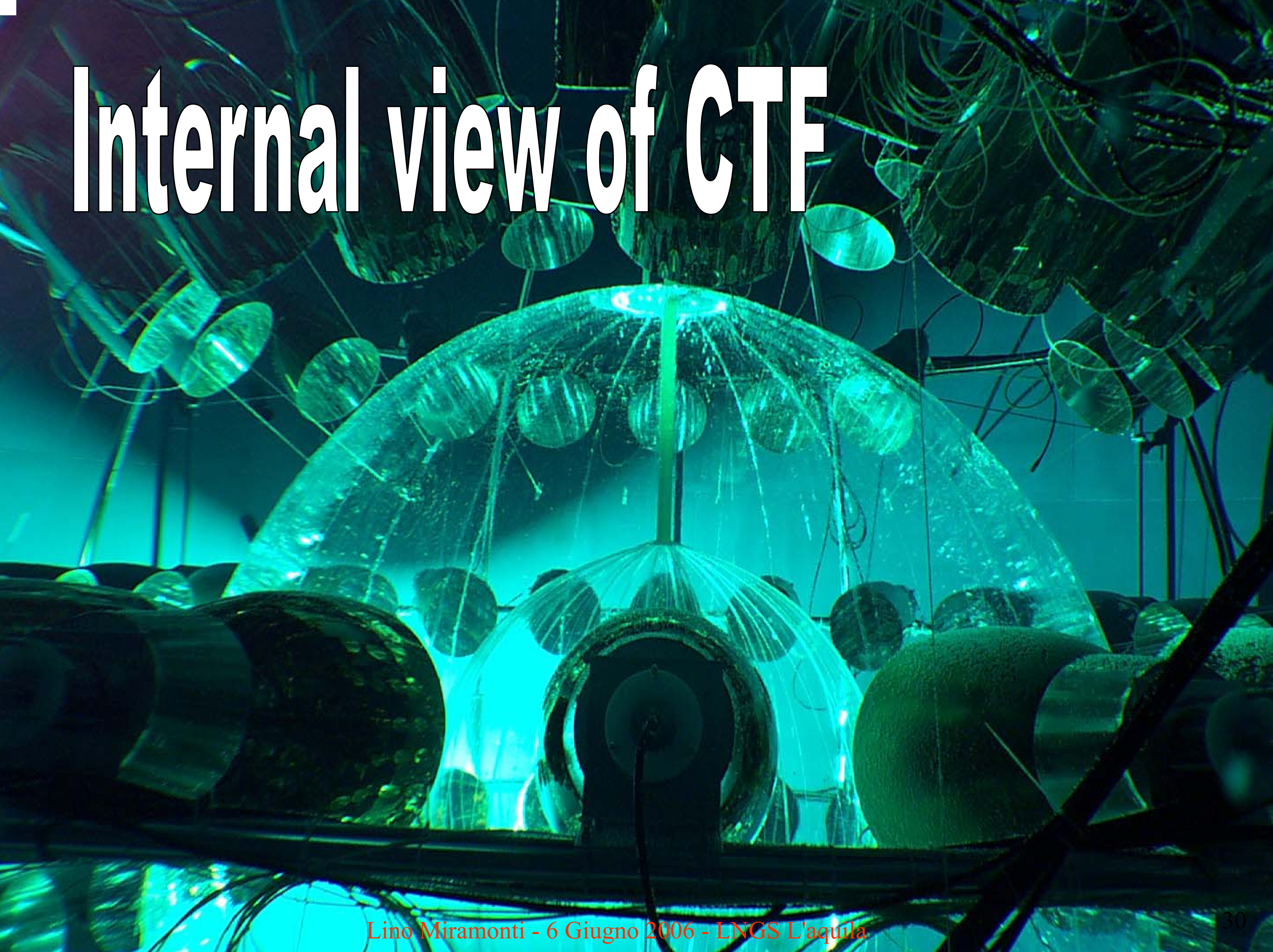
4.5m thickness of water shield

Muon-veto detector





Internal view of CTF



The CTF as a tool for tuning the apparatus before filling

In this moment we use the CTF in order:

- To asses the performances of the different BOREXINO sub-systems.

- To test the ^{14}C content in the PC

- To test the efficiency of the purification methods (Water extraction, Vacuum distillation, Silicagel adsorption)

- To test the cleanliness of the apparatus