Borexino

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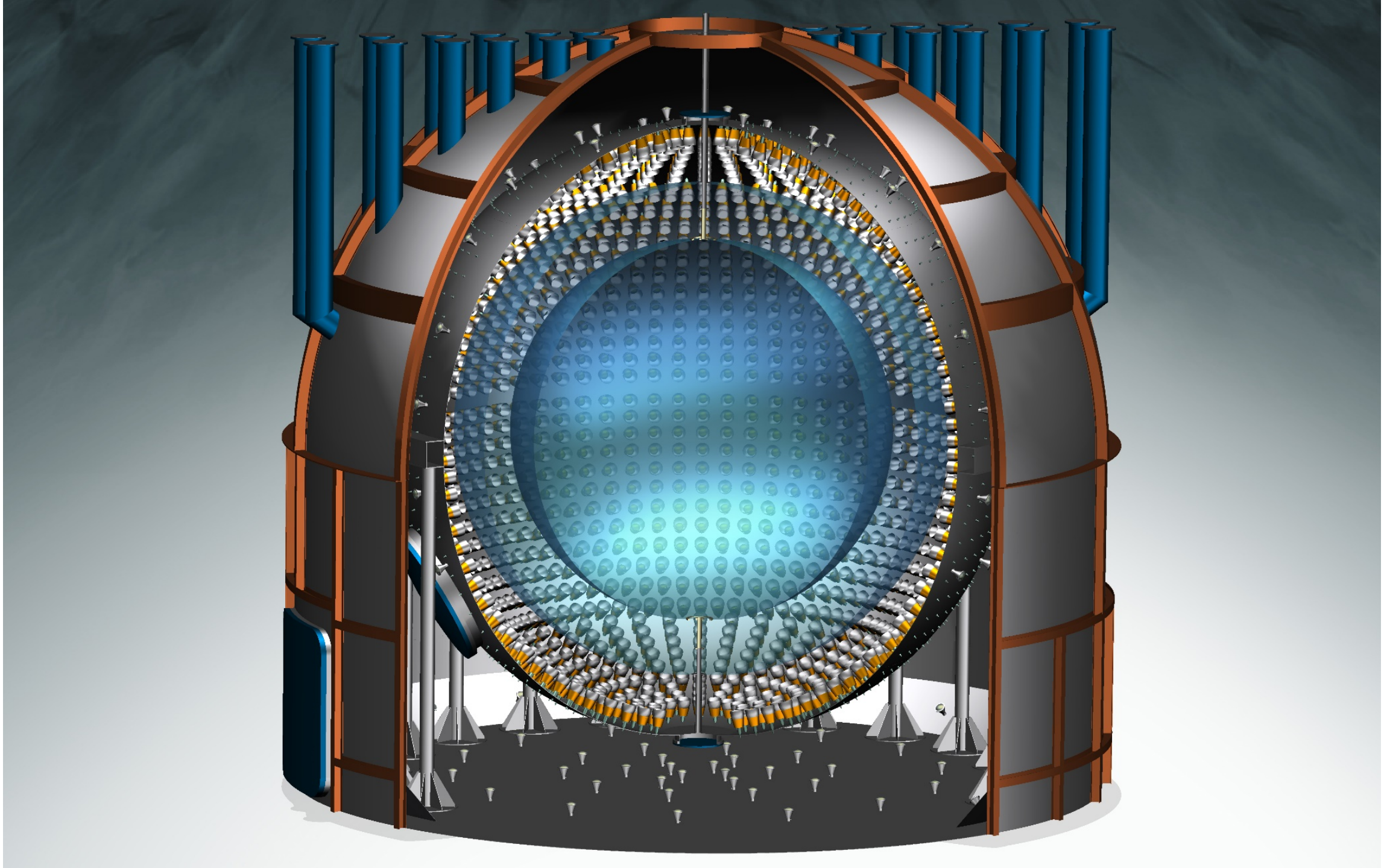
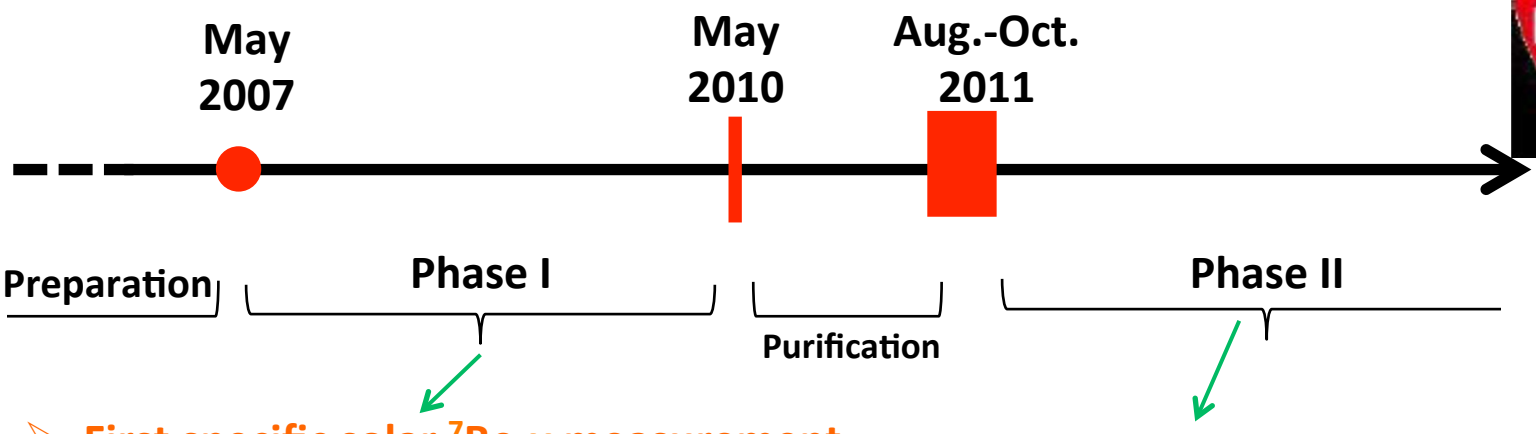
On behalf of the Borexino Collaboration

LNGS Scientific Committee
29 April 2015



Borexino program at a glance



physicsworld TOP 10 BREAKTHROUGH 2014

Totally unprecedented accomplishment in the solar neutrino arena: almost complete solar n spectroscopy by a single experiment

CNO flux and SOX (source experiment for sterile neutrinos) are the next Borexino frontiers

- First specific solar ^{7}Be-ν measurement
- ^{7}Be-ν day-night asymmetry
- Low-threshold ^{8}B-ν
- First pep-ν detection
- Best upper limit on CNO-ν
- ^{7}Be-ν seasonal modulation

- Geo-ν observation at 4.5 σ (initial phase II data included)

- Muon seasonal variations
- Limits on rare processes
- Neutrons and other cosmogenics

- Measurement of pp-n flux most recent achieved milestone towards the full solar-n spectroscopy

Perspective for the future of Borexino

- New round of the previous measurements with improved precision (in progress - new Calibration campaign to be performed)
- Short-baseline n oscillation: **SOX**
- With the possible adoption of two "weapons"

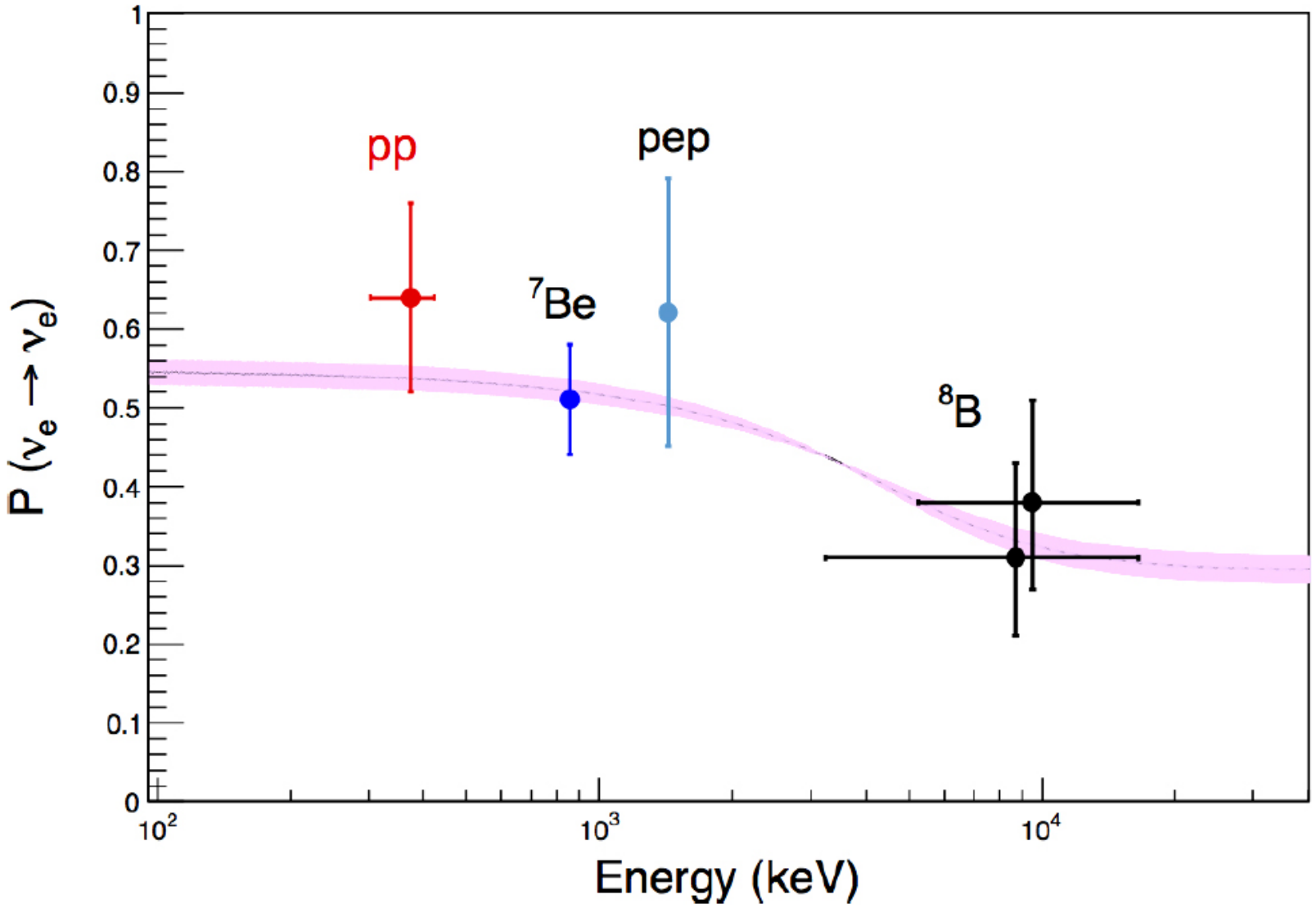
1-temperature stabilization and constraint of the ^{210}Bi from the ^{210}Po 2-further purification to remove instead the residual ^{210}Bi contamination

→ **Measurement of CNO-ν flux**

- Improve significance of Geo-n detection

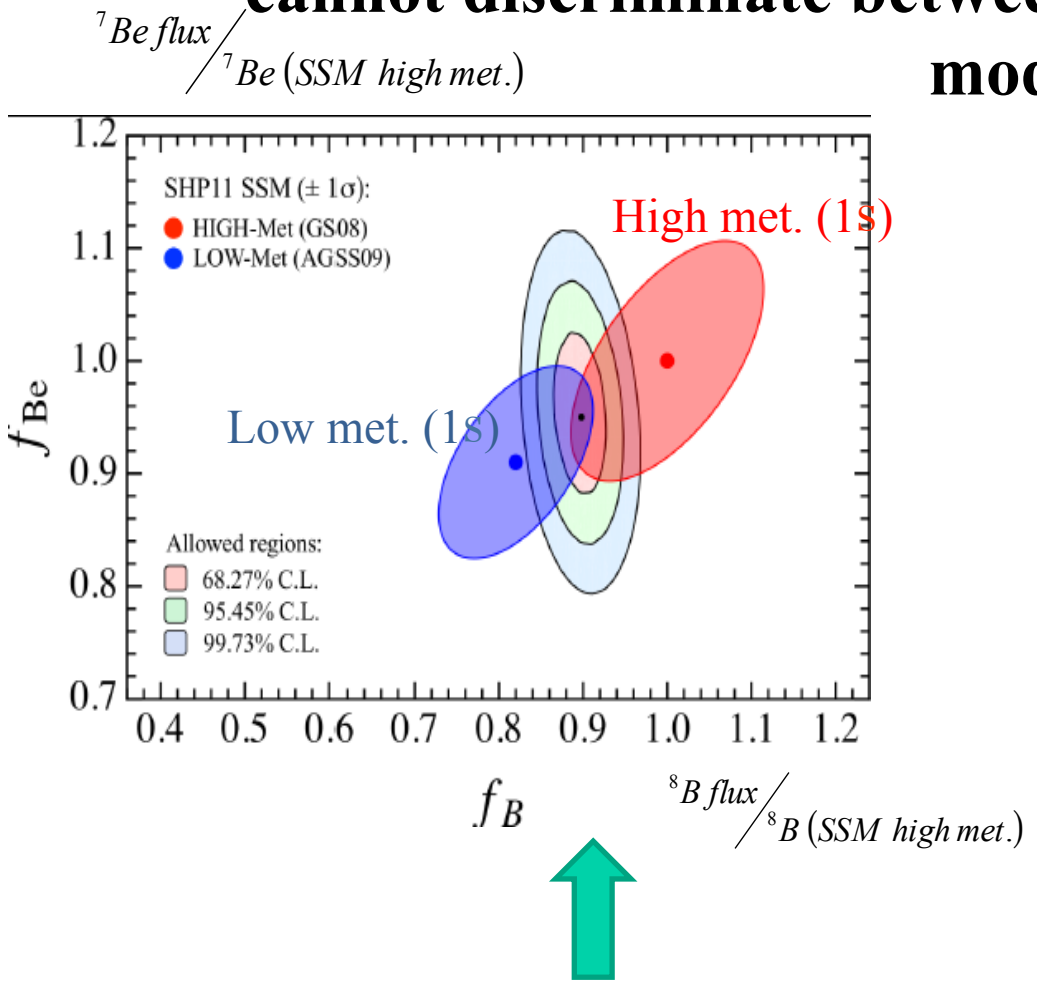
Borexino measured electron neutrino survival probability for 4 different nuclear reactions

Now Borexino alone provides the validation of the MSW – LMA neutrino oscillation paradigm over the entire solar neutrino spectrum



The missing point is CNO for which we have only an upper limit so far

The long standing metallicity puzzle - the current data cannot discriminate between high and low metallicity models



The Borexino data cannot disentangle between the two models

n	Diff. %
pp	0.8
pep	2.1
^{7}Be	8.8
^{8}B	17.7
^{13}N	26.7
^{15}O	30.0
^{17}F	38.4

The major predicted difference is in the CNO flux ⟶ the ultimate "solar" frontier for BX

Perspectives for phase II

Further possible achievements based on improved **backgrounds** after the purification

Th< 9 10^{-19} g/g 95% C.L.
U < 8 10^{-20} g/g 95% C.L.
Kr< 7.1 cpd/100 tons 95% C.L.

Purification (water extraction and nitrogen stripping) astonishingly effective in further reducing the already ultralow background!! Evaluated through the delayed coincidence tag

^{210}Bi=25. ± 2 cpd/100t

^{210}Po = varying in the range 50 to 100 cpd/100 t

Only residual backgrounds

^{210}Po factor 100 less than at the beginning of data taking

^{210}Bismuth (**the most relevant)** factor 2 less than in phase I

Improved ^{7}Be, ^{8}B, and pep More stringent test of the profile of the Pee survival probability sub-leading effect in addition to MSW, new physics, NSI?

Improved ^{7}Be some hint about metallicity?

CNO is the ideal metallicity discriminator but the residual content of **^{210}Bi is the challenge**

The CNO ^{210}Bi and ^{210}Po trilogy

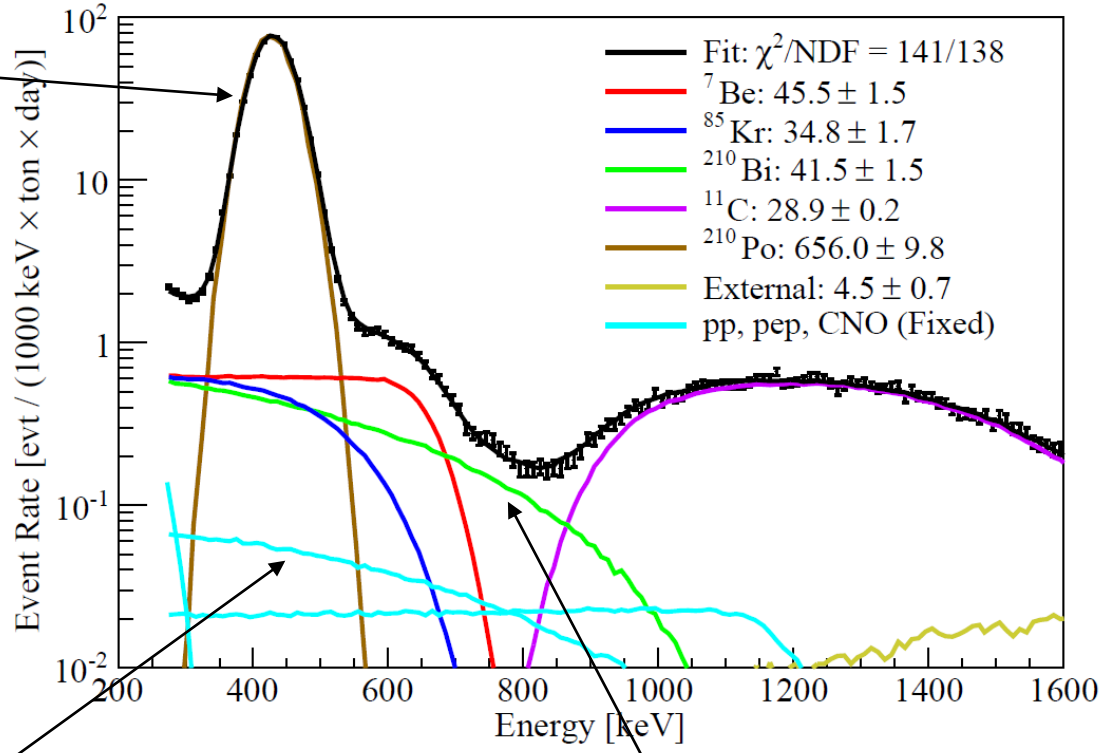
^{210}Po

not a concern per se, easy spectral identification plus PSD (alpha particle)

^{210}Bi is its immediate precursors therefore, if equilibrium

^{210}Po rate equal to ^{210}Bi rate and such a constraint could be used in the fit -> CNO could be inferred!

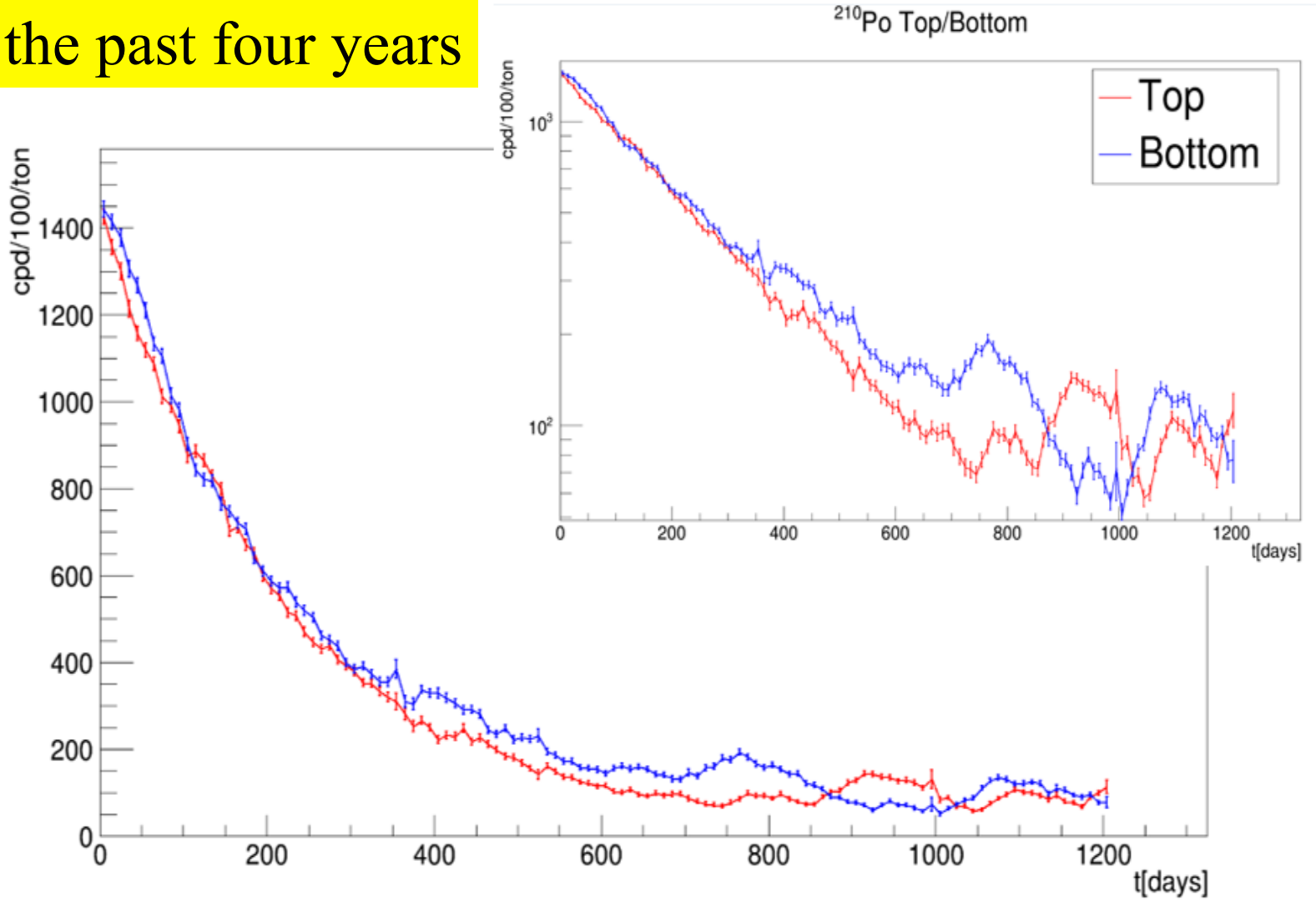
Further purification approach to attempt the full removal of the masking ^{210}Bi – improvement in progress for the distillation of the water used in the water extraction



CNO

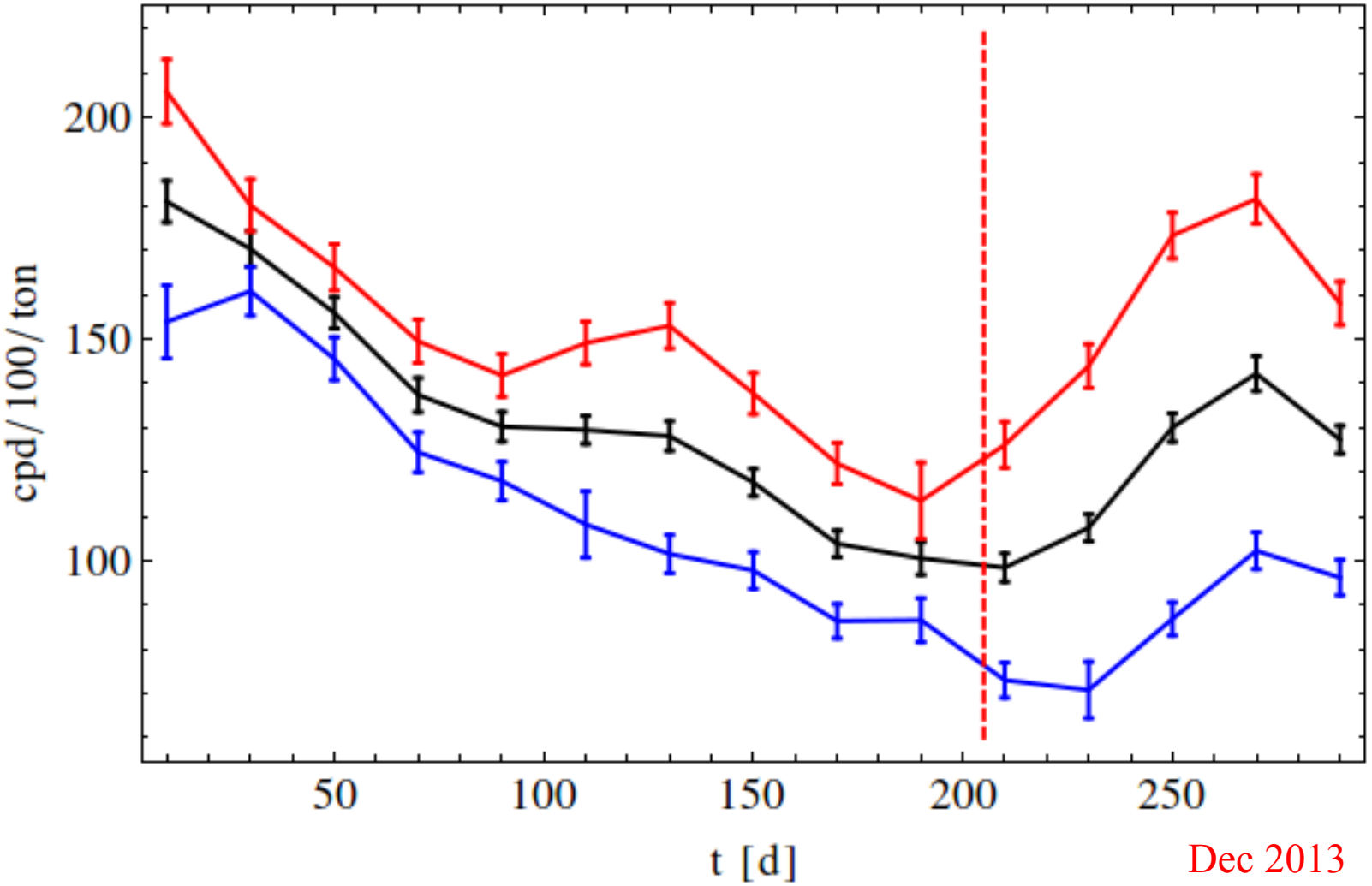
^{210}Bi

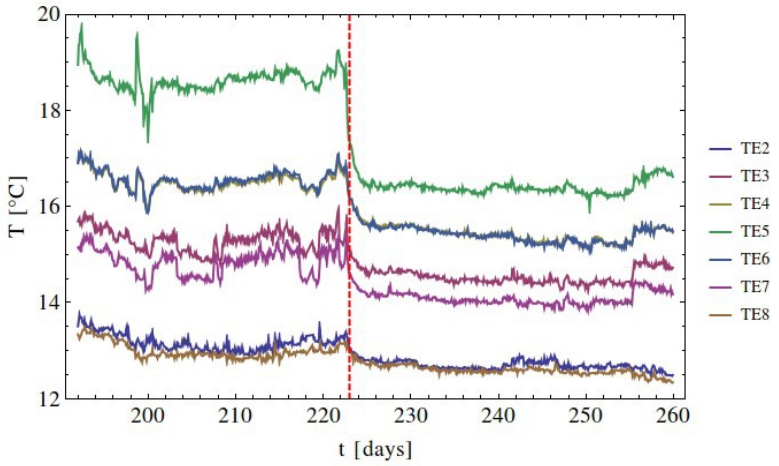
Evolution of the Polonium rate over the past four years



Now that the rate is low and approaching the plateau value we experience fluctuations which prevent to infer the intrinsic ^{210}Po level

Impact on the Polonium-210 behavior in the FV



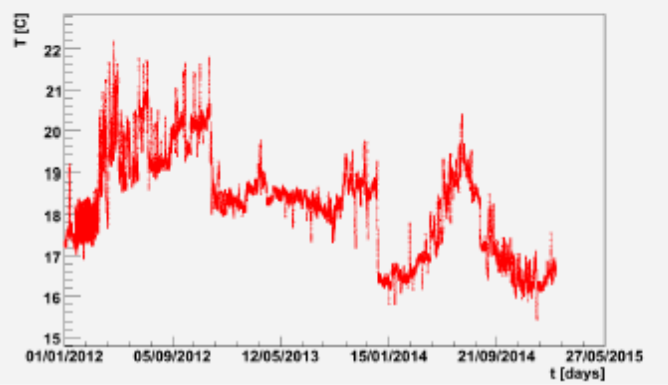


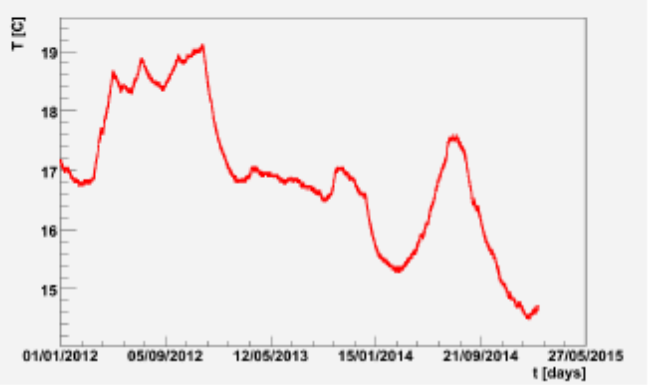
- FV
- FV North
- FV South

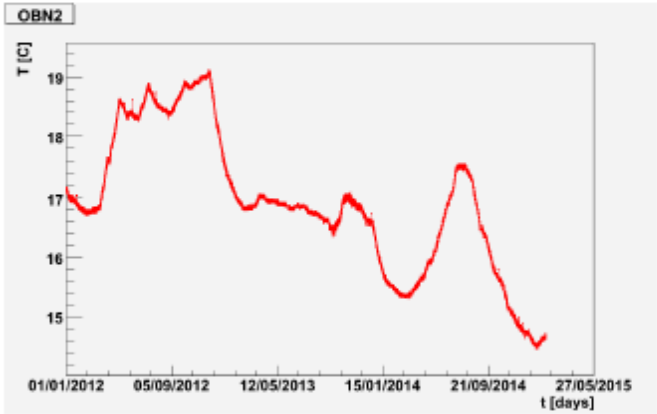
Dec 2013

Convective motion triggered by the change of the temperature gradient across the liquid [illegible] Polonium sitting on the surface of the Vessel brought back into the FV [illegible] seriously affects the constrain of ^{210}Bi through the asymptotic plateau of the ^{210}Po [illegible] **temperature stability essential to attempt CNO via the ^{210}Po- ^{210} Bi constraint**

Temperatures in Hall C over the past three years







"Seasonal" variations difficult to predict and to control

SSS

Isolation procedure

- The Water Tank will be covered starting from the floor, all around the circumference, up to 14m of height;
- The final thickness will be 200mm;
- The first layer in contact with the tank will be a naked roll of rock wool;
- The second layer of insulation will be a roll with reinforced grid and aluminum outside;
- The total insulation layer will be kept in place using proper pins that will be glued to the Water Tank wall using epoxy;
- 7-8 pins will be installed for square meter of insulation;

The upper part of installation will be done using proper scaffolding

We guess 6-8 months to understand if the attempt work and if the ^{210}Bi level can be inferred by the ^{210}Po rate

Meanwhile the modification for the improved water extraction will continue

Calibration schedule to be decided according to the evolution of the data

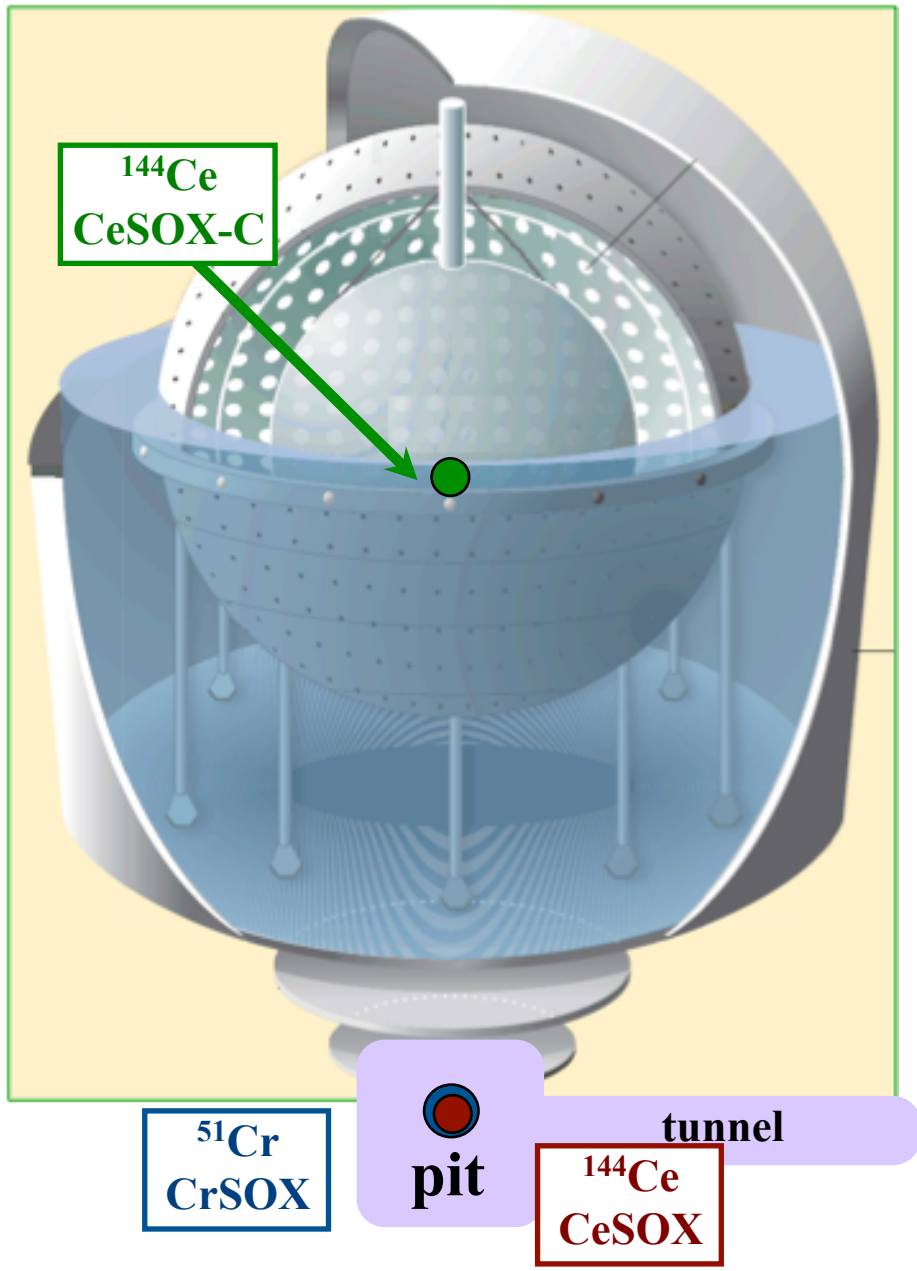
SOX: the potential full ^{144}Ce and ^{51}Cr program

- **Mission: test the existence of low L/E ν_e and/or $\bar{\nu}_e$ anomalies by placing well known artificial sources close to or inside Borexino**

- **CrSOX**
  - **^{51}Cr** source in pit beneath detector
  - **8.25 m** from center
  - **Activity 10 MCi**

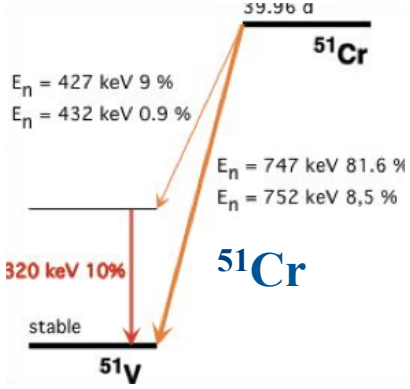
- **CeSOX First to be accomplished**
  - **^{144}Ce-^{144}Pr** source in in pit beneath detector
  - **8.25 m** from center
  - Activity 100 kCi
  - **Planned start-up date 1/10/2016**

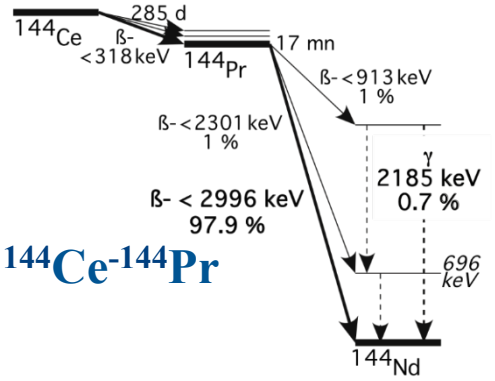
- **CeSOX-C**
  - ^{144}Ce-^{144}Pr source in the center
  - Would imply a full refurbishment of the detector (suited also for a possible future Double Beta Decay exp. with Xenon)



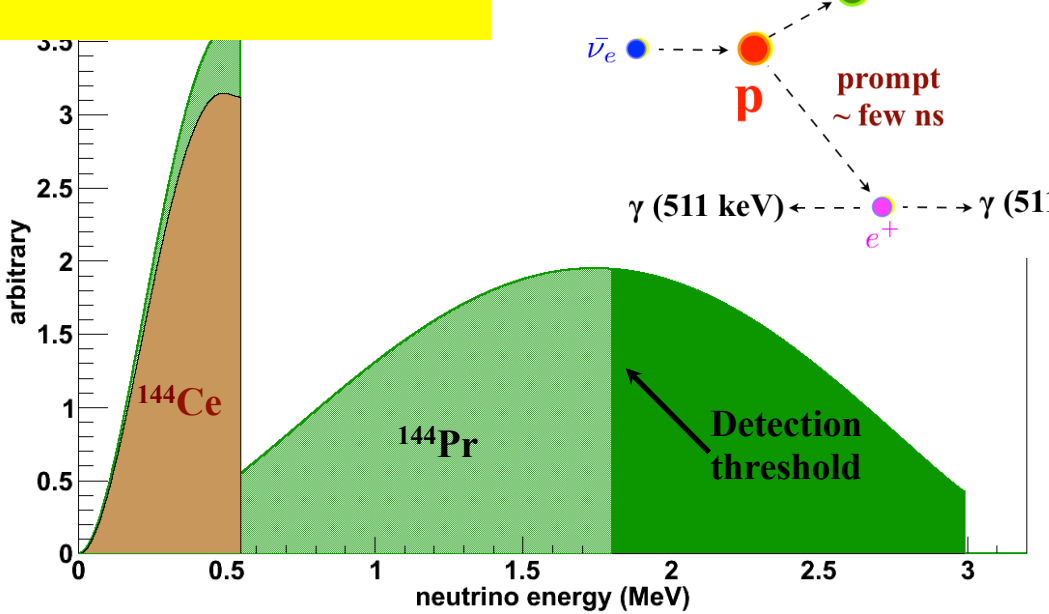
Artificial neutrino sources

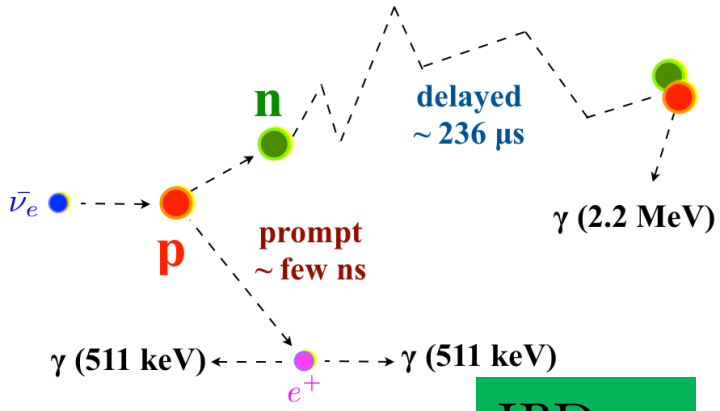
Source	Production	t (days)	Decay mode	Energy [MeV]	Mass [kg/MCi]	Heat [W/kCi]
^{51}Cr ν_e	Neutron irradiation of ^{50}Cr in reactor $\Phi_n \gtrsim 5.\ 10^{14}$ cm^{-2} s^{-1}	40	EC γ 320 keV (10%)	0.746	1.1	0.19
^{144}Ce-^{144}Pr $\bar{\nu}_e$	Chemical extraction from spent nuclear fuel	411	β-	<2.9975	0.314	7.6





ne scattering for Cr source as solar neutrinos





IBD tag for Ce source as geoneutrinos

CeSOX is progressing along the following lines of activities

Negotiation with Mayak for the finalization of the contract for the Cerium preparation, specification already agreed, activity in the range 85-100 kCi

Construction of the biological tungsten shield – tender won by a Chinese supplier

Arrangement of the transportation from Mayak to Gran Sasso

Preparation of the site in Hall C

Authorization process (both in France and Italy)

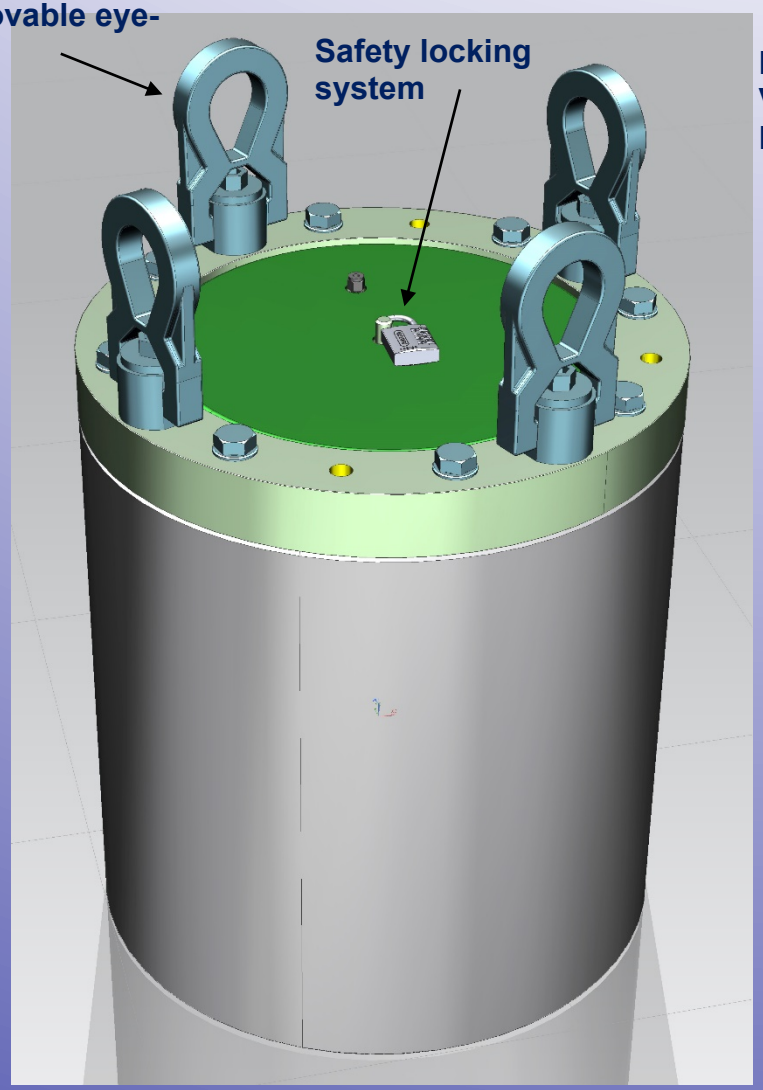
Calorimeters for precision measurement of the source activity

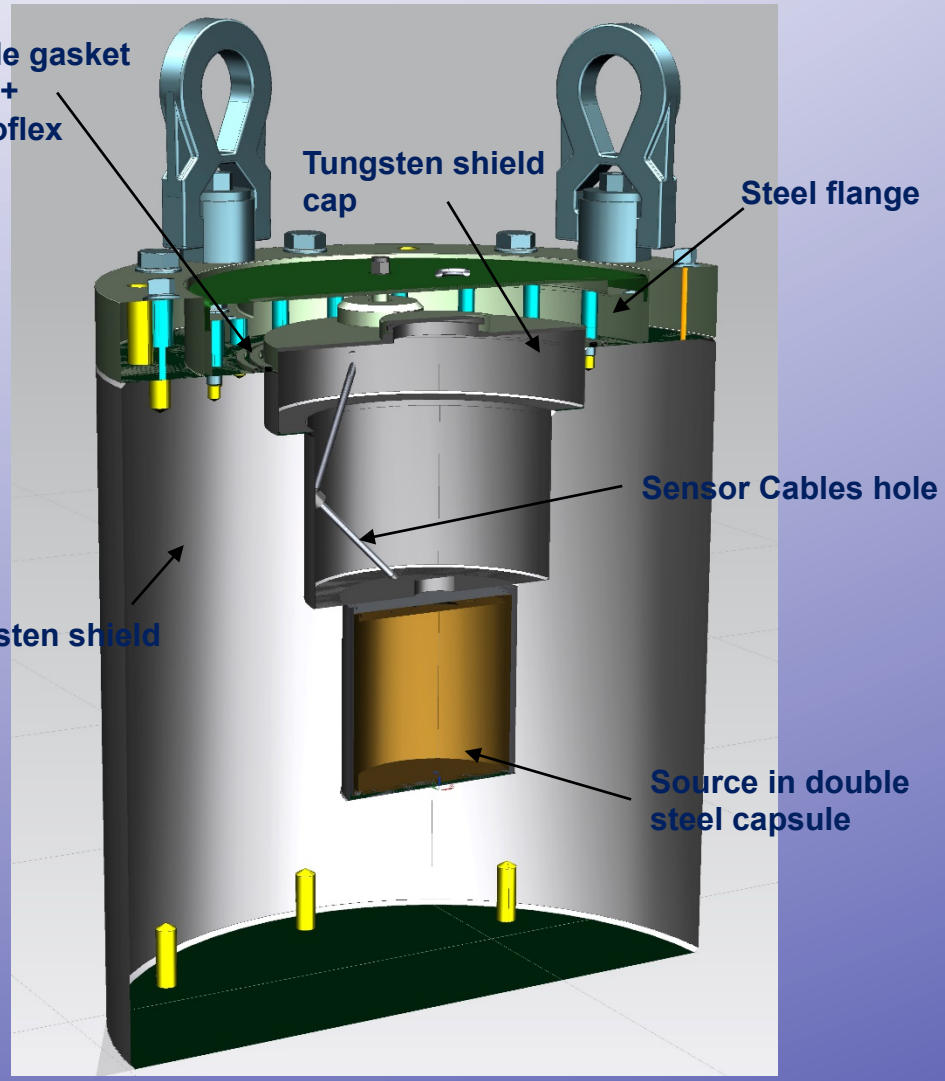
Production of Cerium source

One company can produce such a source: the Russian FSUE Mayak PA.

1. Start with 2.8 t of fresh spent fuel (1.65 year of cooling time) from Kola NPP
2. Cutting, digestion and PUREX® process ⇒ lanthanides and actinides concentrate
3. Displacement chromatography ⇒ extraction of all cerium isotopes ∼ 5 kg
4. Precipitation, calcination in CeO_2, pressing, encapsulation and insertion in shield

Source capsule and tungsten shield





SOX-Ce: production of the ^{144}Ce- ^{144}Pr source

Complicated trasportation logistic in order to comply with safety regulations for transport of radioactive material:

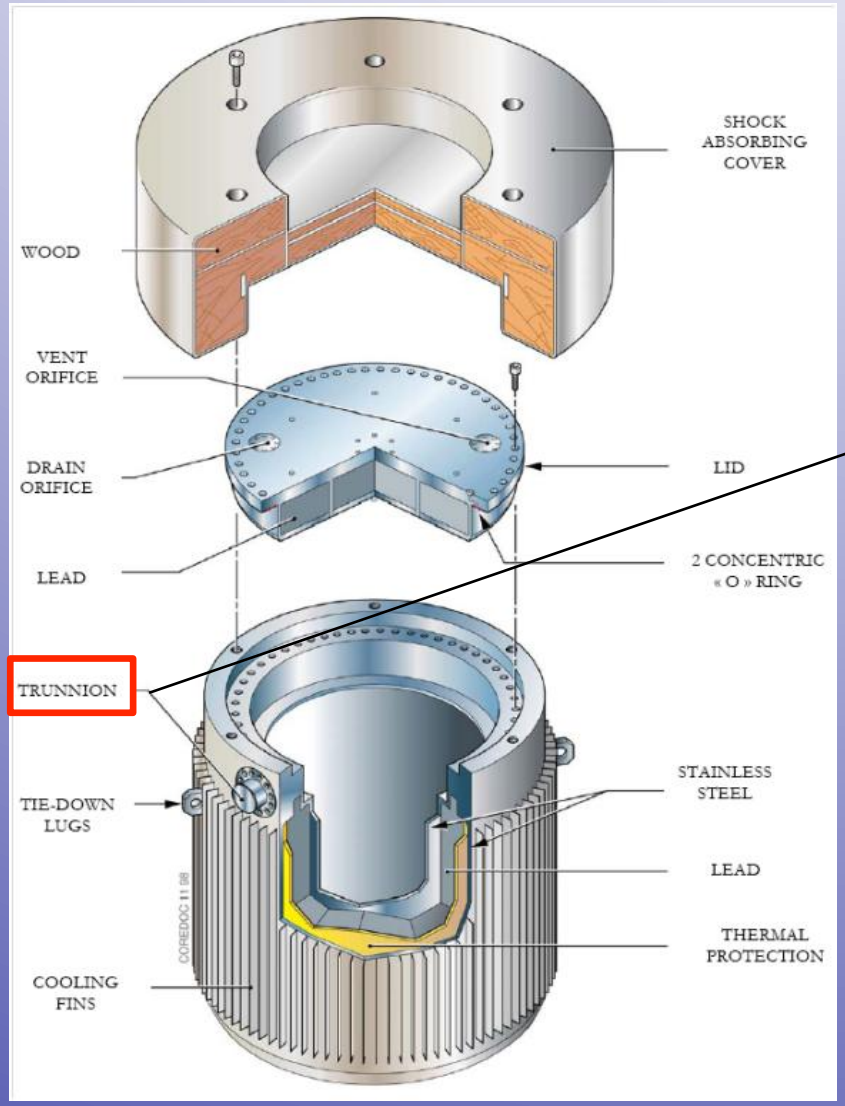
Spent nuclear fuel from Kola reactor to Mayak February 2015

^{144}Ce source ready at the St. Petersburg harbor on August 2016

Arrival to Gran Sasso at beginning of October 2016

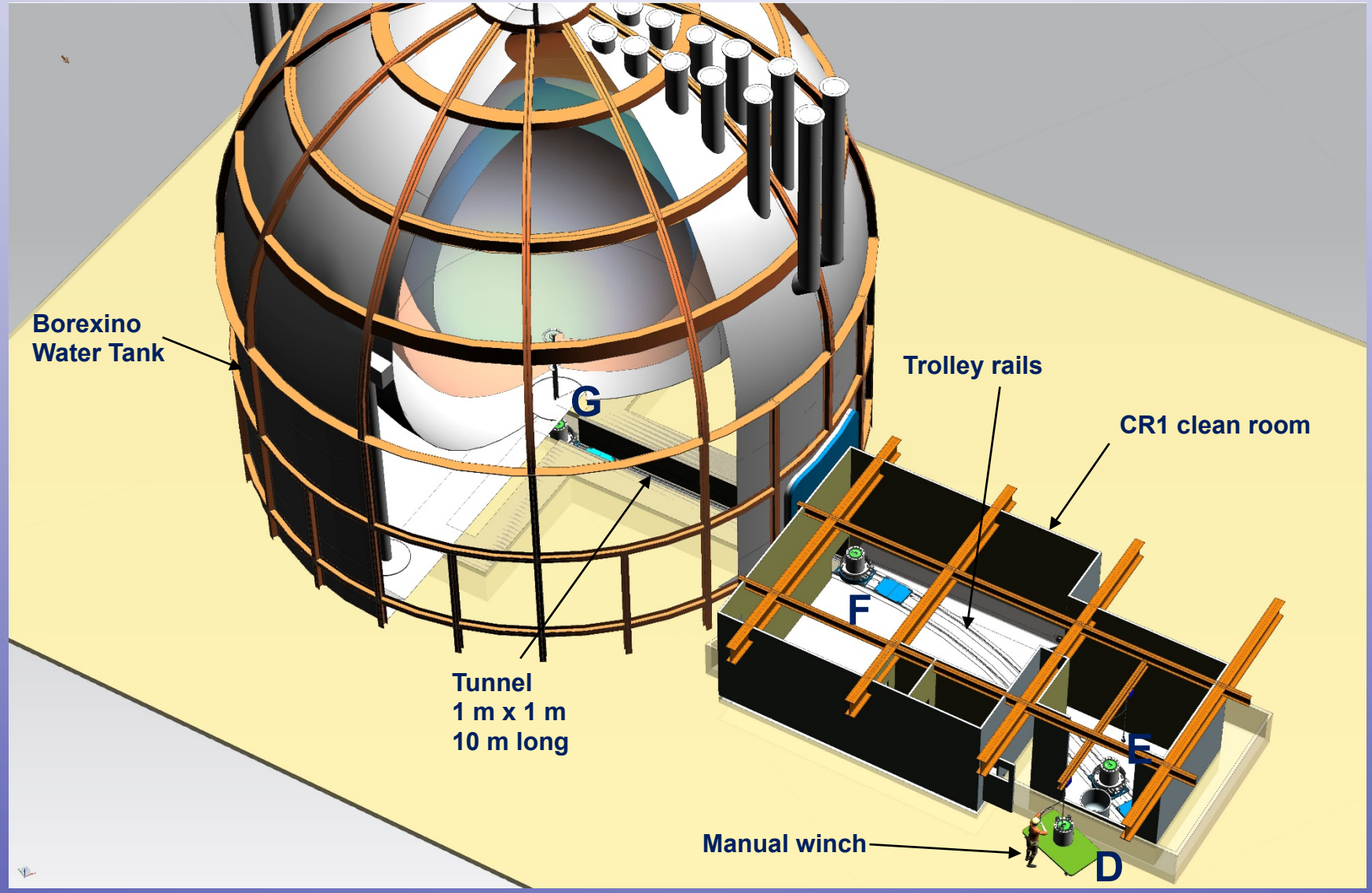
IAEA rules on Safe Transportation of Radioactive Material

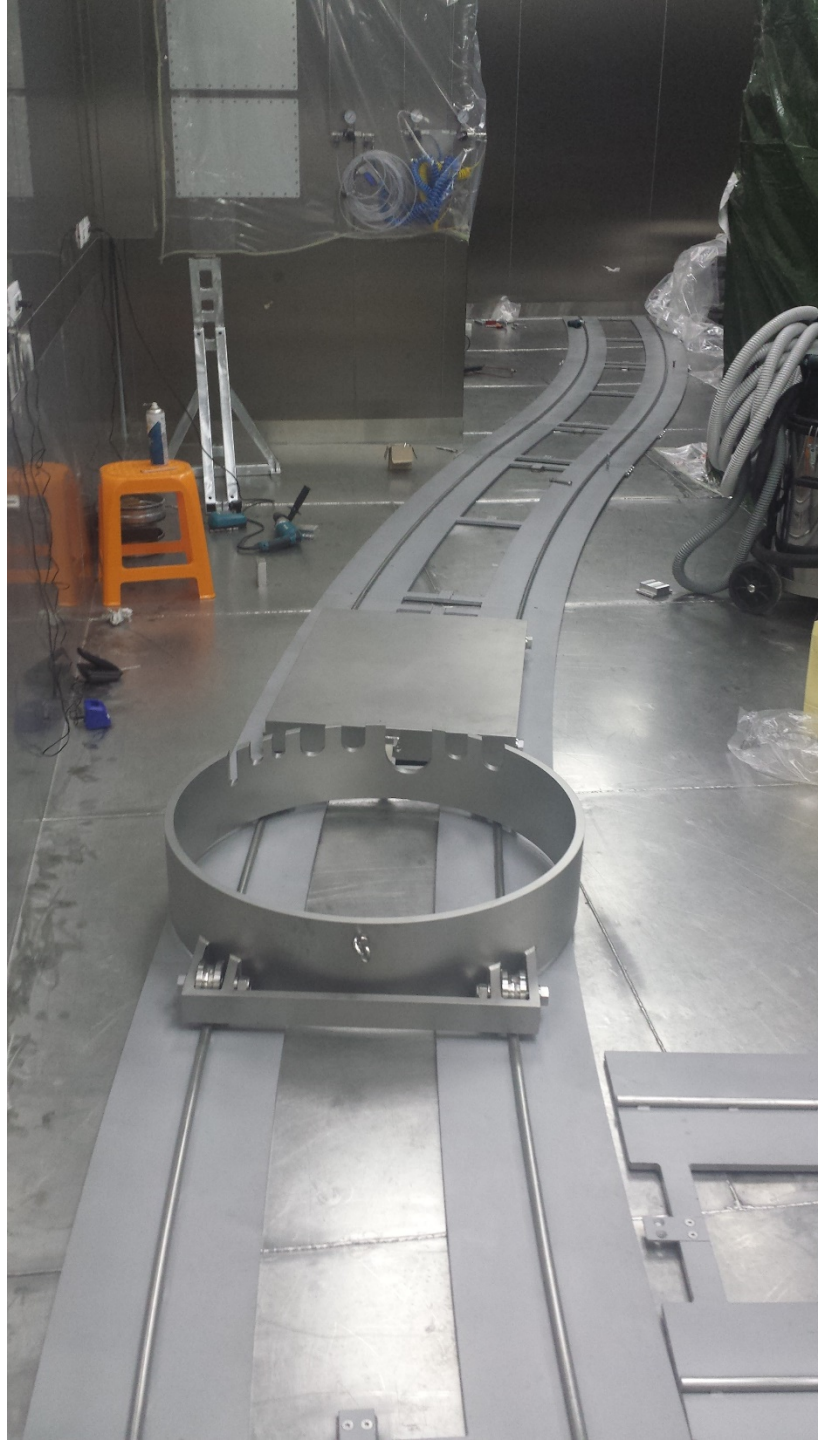
Transportation container: TN-MTR



Custom AREVA spreader

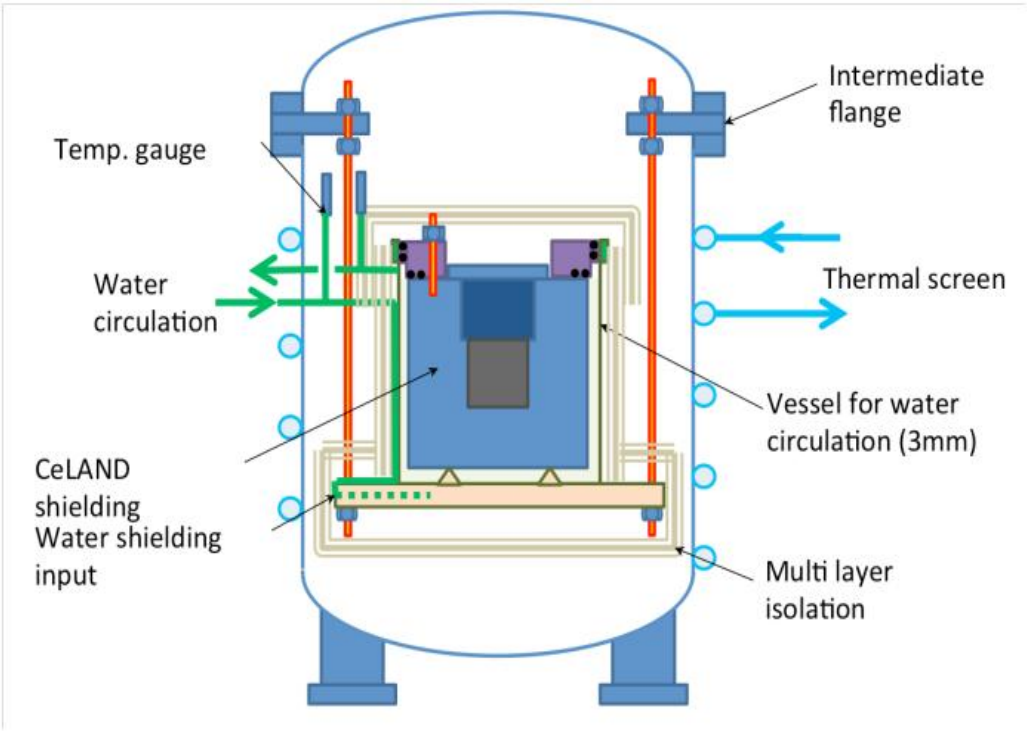
Source logistic inside SOX pit @ LNGS



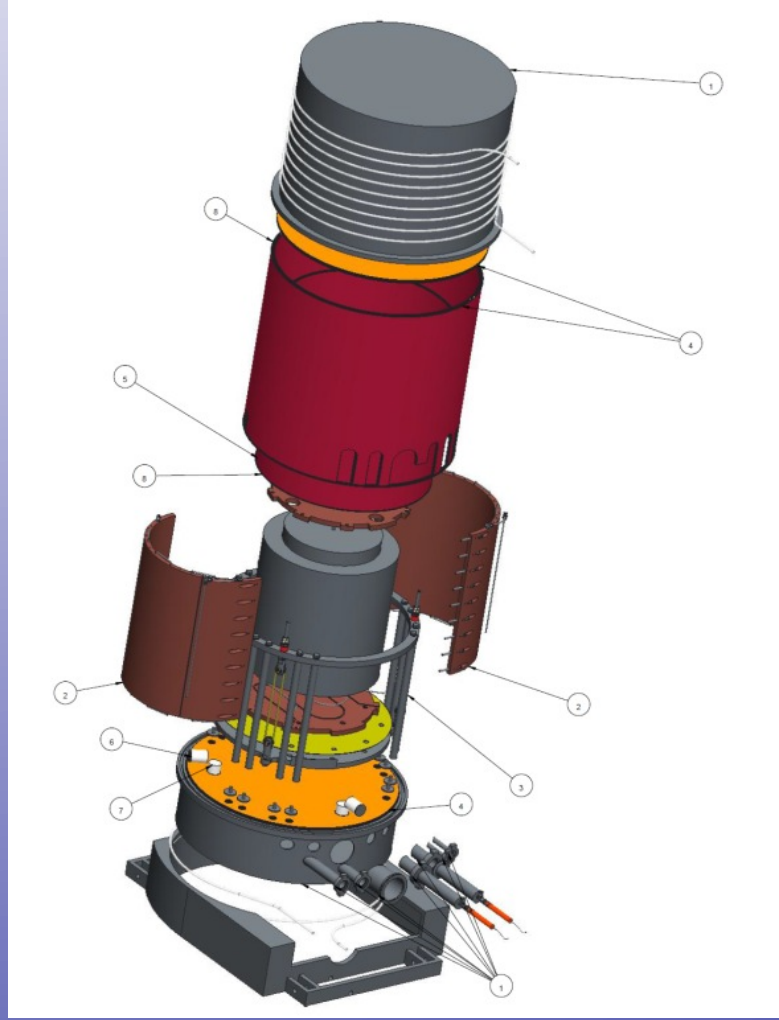


Calorimeters

First calorimeter CEA



Second calorimeter Genova-TUM



Authorization process

Category A authorization → Government
Involved Ministers

- Sviluppo economico (Economy) (coordinator)
- Salute (Health)
- Lavoro (Job)
- Ambiente (environment)
- Interni (Internal Affairs)

Moreover

Abruzzo Region
Ispra (Institute for environmental research and protection, one of its department is delegated to Nuclear Safety)

Formal request sent by the Gran Sasso Director in November 2014
Tentative time to get the approval: one year

Summary

Borexino has the ambition to crown its solar program not only with an improved release of the fluxes previously measured but also with the challenging attempt to perform the “ultimate” CNO measure

Moreover with SOX Borexino is determined to be the first to shed light to the long standing puzzles which led to the sterile suggestion

A good program to complete s tory of success

Milano

München

Heidelberg

Hamburg

Mainz

Gran Sasso

Perugia

Genova

Napoli

TU Dresden

Jagiellonian
Kraków

the Borexino Collaboration

JINR
Dubna

Virginia Tech

Houston

Paris

Moscow

Los Angeles

Princeton

UMass
Amherst

St. Petersburg

Kurchatov
Moscow