Borexino status report

A. Ianni for the Borexino Collaboration

XLII LNGS Scientific Committee

April 13th, 2014

Publications since last SC

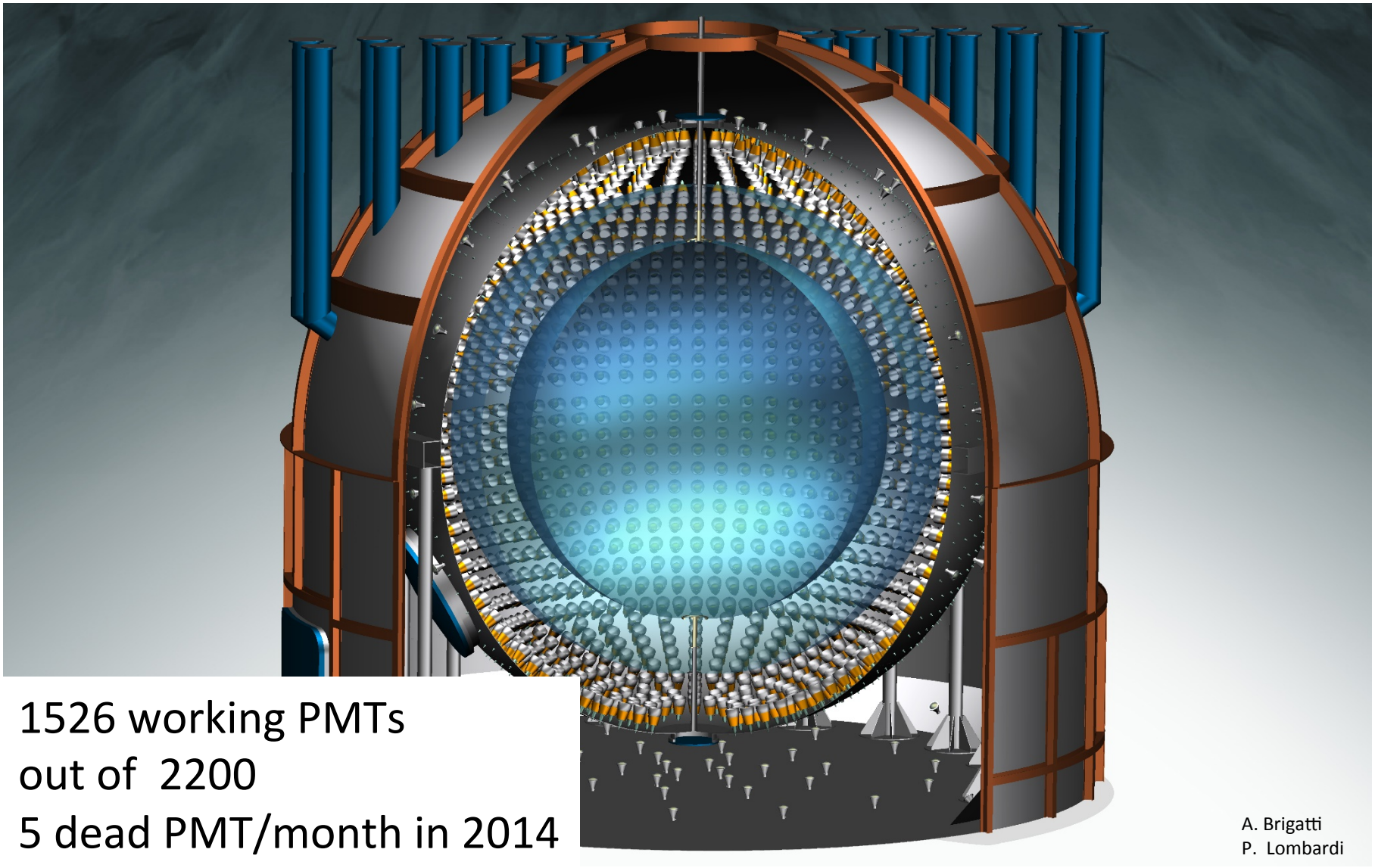
- *Final results of Borexino Phase-I on low energy solar neutrino spectroscopy*
  - **Phys. Rev. D 89, 112007 (2014)**

- *Neutrinos from the primary proton-proton fusion process in the Sun*
  - **Nature 512, 383 (2014)**

Outline

- pp neutrino measurement
  - Jan 2012 – May 2013 408 days of data Phase II
  - Data after WE purification campaign in 2010 - 2011
- next on solar neutrinos
  - Phase II data about 860 days
- SOX status report

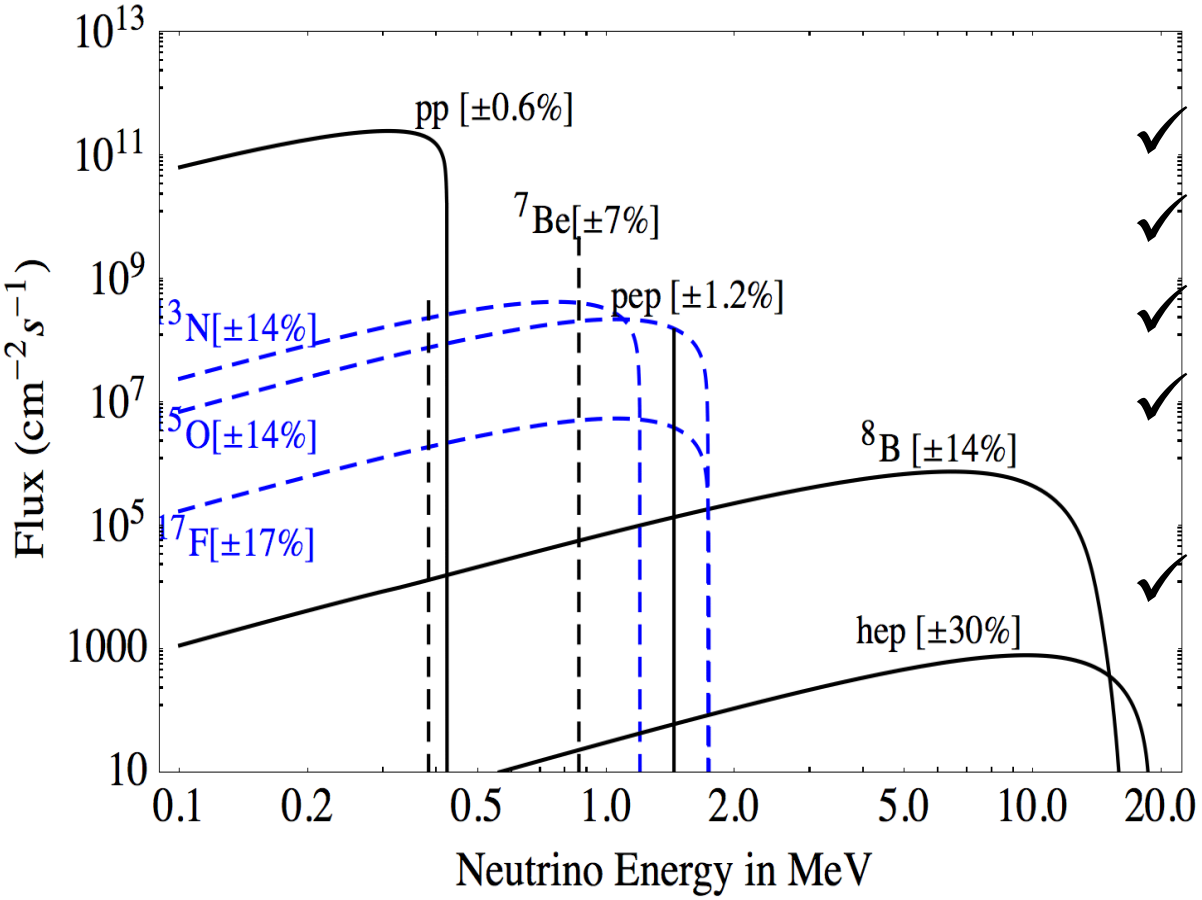
Borexino experiment overview



1526 working PMTs
out of 2200
5 dead PMT/month in 2014

A. Brigatti
P. Lombardi

Solar Neutrinos



- ✓ pp flux ~ 91%
- ✓ ^{7}Be flux ~ 7.6%
- ✓ CNO flux ~ 0.8%
- ✓ ^{8}B ~ 0.009%
- ✓ pp energy < 0.423 MeV

Why a pp solar neutrinos real time measurement?

- Probe the slowest process which sets the evolution of the Sun in 10^9 years time scale
  - 99% of energy in the Sun from

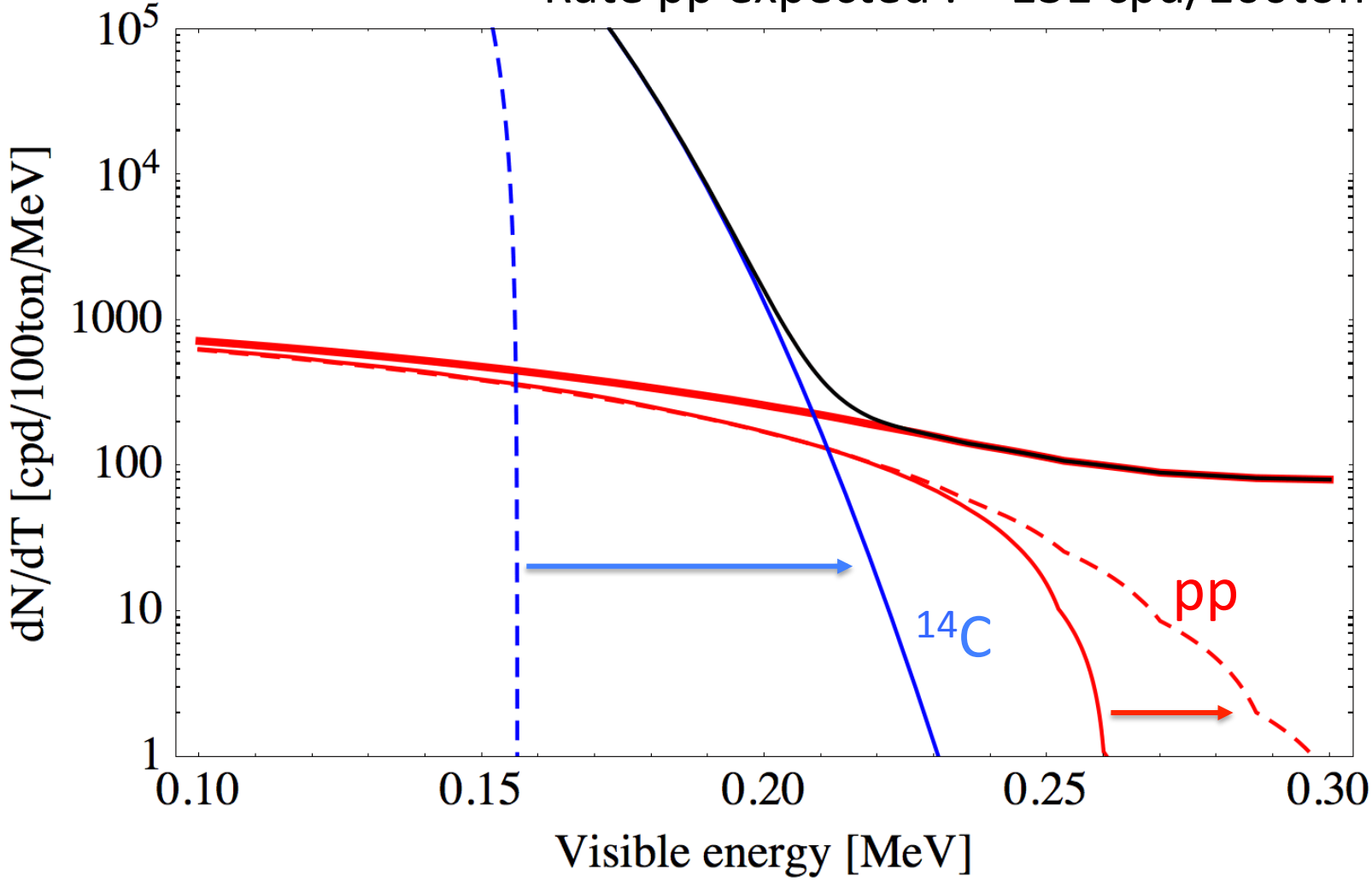
$$p + p \rightarrow d + e^+ + \nu_e + 0.42 MeV$$

- Probe solar luminosity vs neutrino luminosity

- Probe solar variability over 10^5 years time scale

Spectral measurement of pp neutrinos

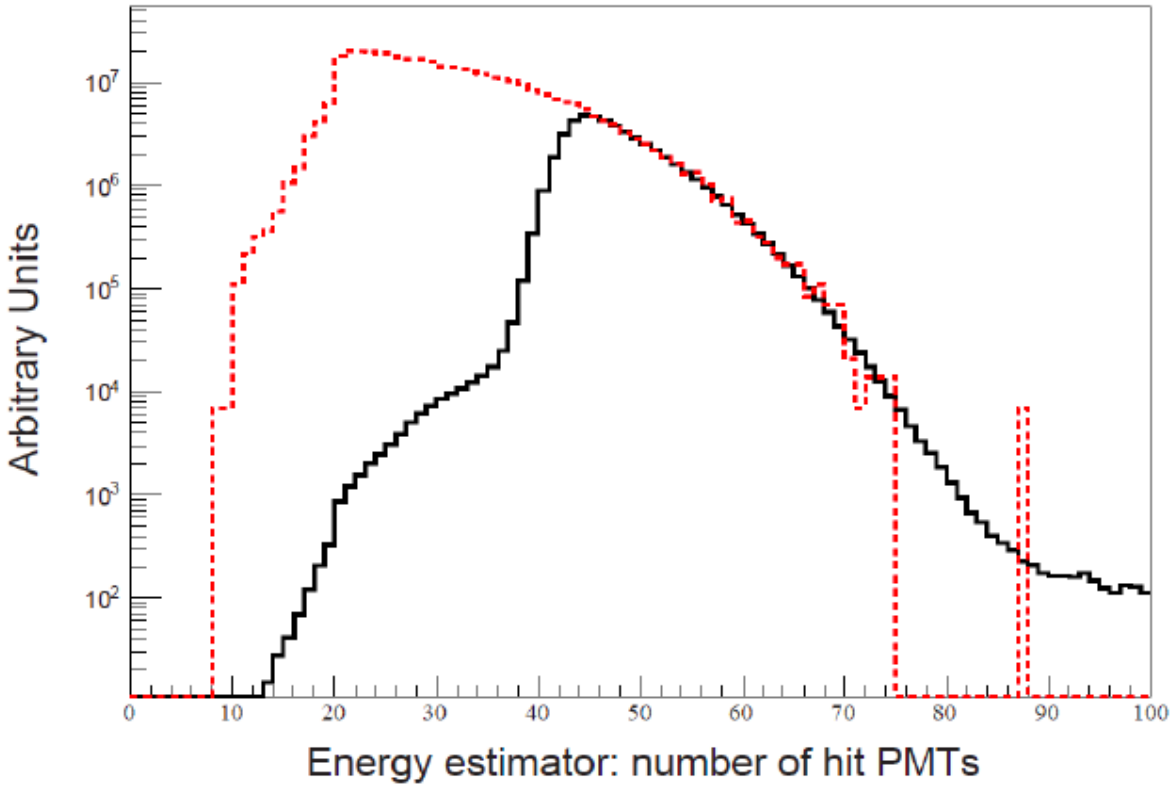
Rate pp expected : ~ 131 cpd/100ton



Challenges

- **Rate of ^{14}C**
  - Dominant rate component in Borexino, mainly at low energy
- **Pile-up of ^{14}C**
  - Expected to give a significant contribution at low energy

^{14}C rate



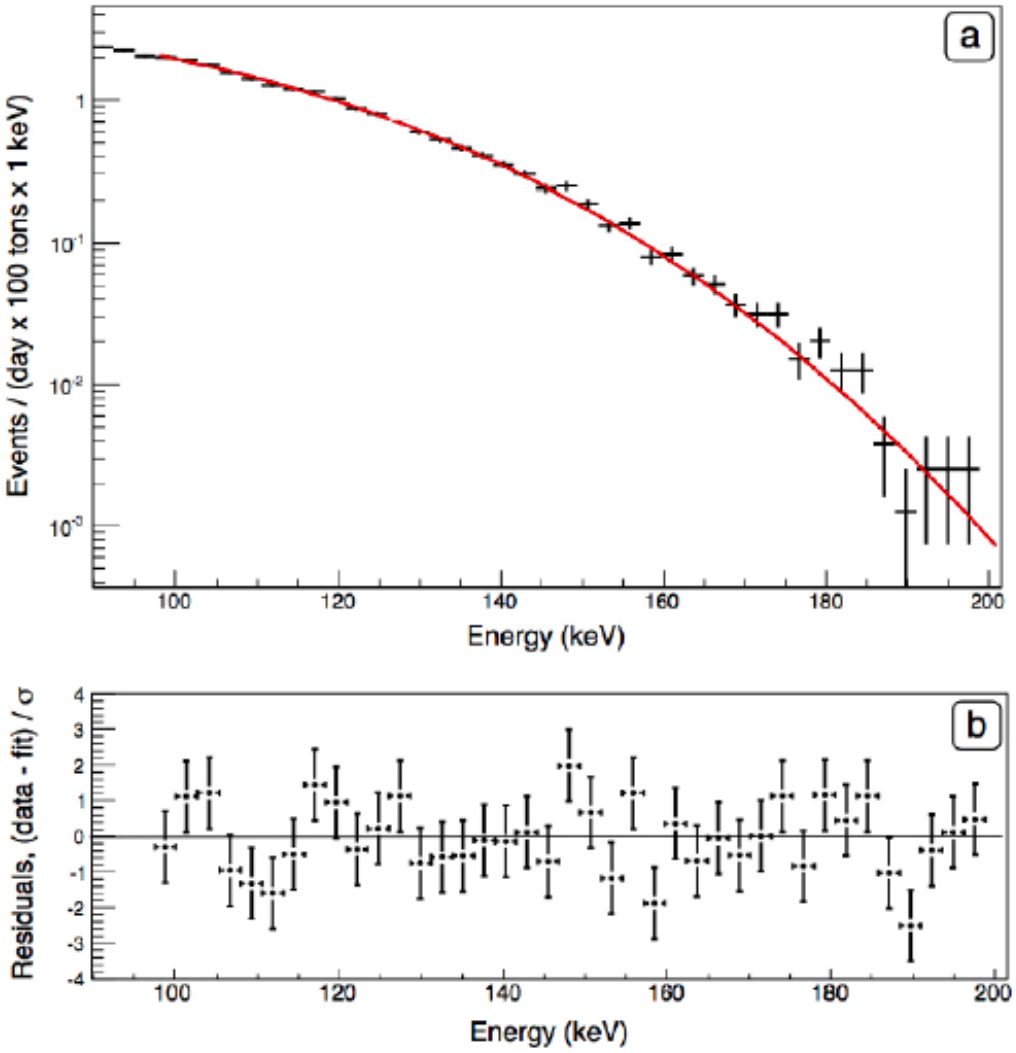
1st cluster with main trigger

2nd cluster events in 16ms with lower threshold

$$N_{PMT} \approx N_{live-PMT}\left(1 - e^{-N_{pe}/N_{live-PMT}}\right)$$

$$N_{pe} = LY \cdot E \cdot f(E;k_B)$$

^{14}C activity estimation



From 2nd cluster events > 8ms to avoid afterpulses from PMTs

40 ± 1 Bq

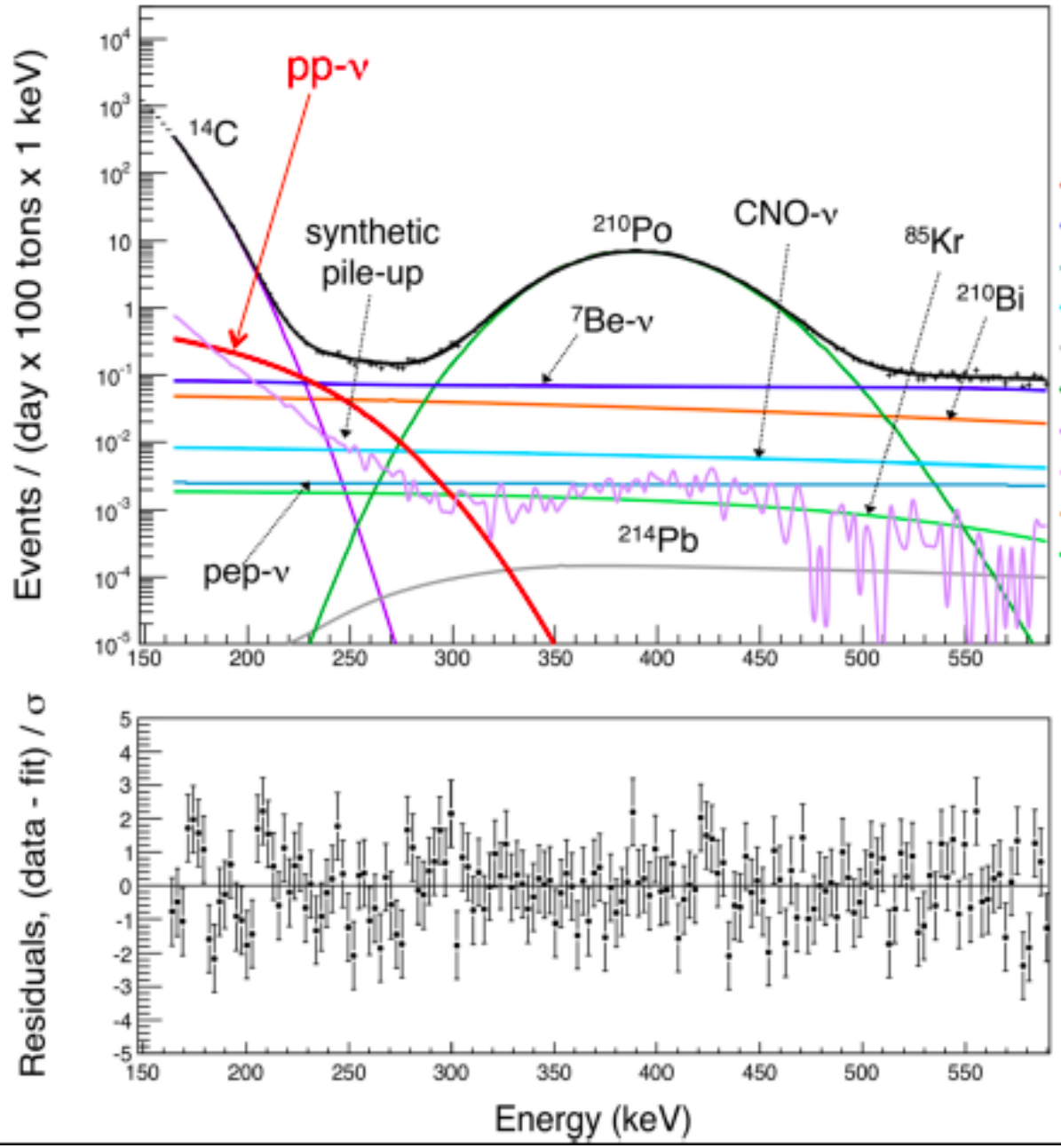
$^{14}C/^{12}C = (2.7 \pm 0.1) \times 10^{-18}$

Beta spectrum with shape factor: $1+1.24(Q_b-T)$

^{14}C pile-up

- Rate ^{14}C = 40 Bq
- Cluster window = 230 ns
- Expected pile-up rate ~ 100 cpd/100tons
- Expected pp rate ~ 130 cpd/100tons
- Syntethic pile-up: real triggered events overlapped with random data and processed with reconstruction code: **154 ± 10 cpd/100tons**

The results of the standard spectral fit

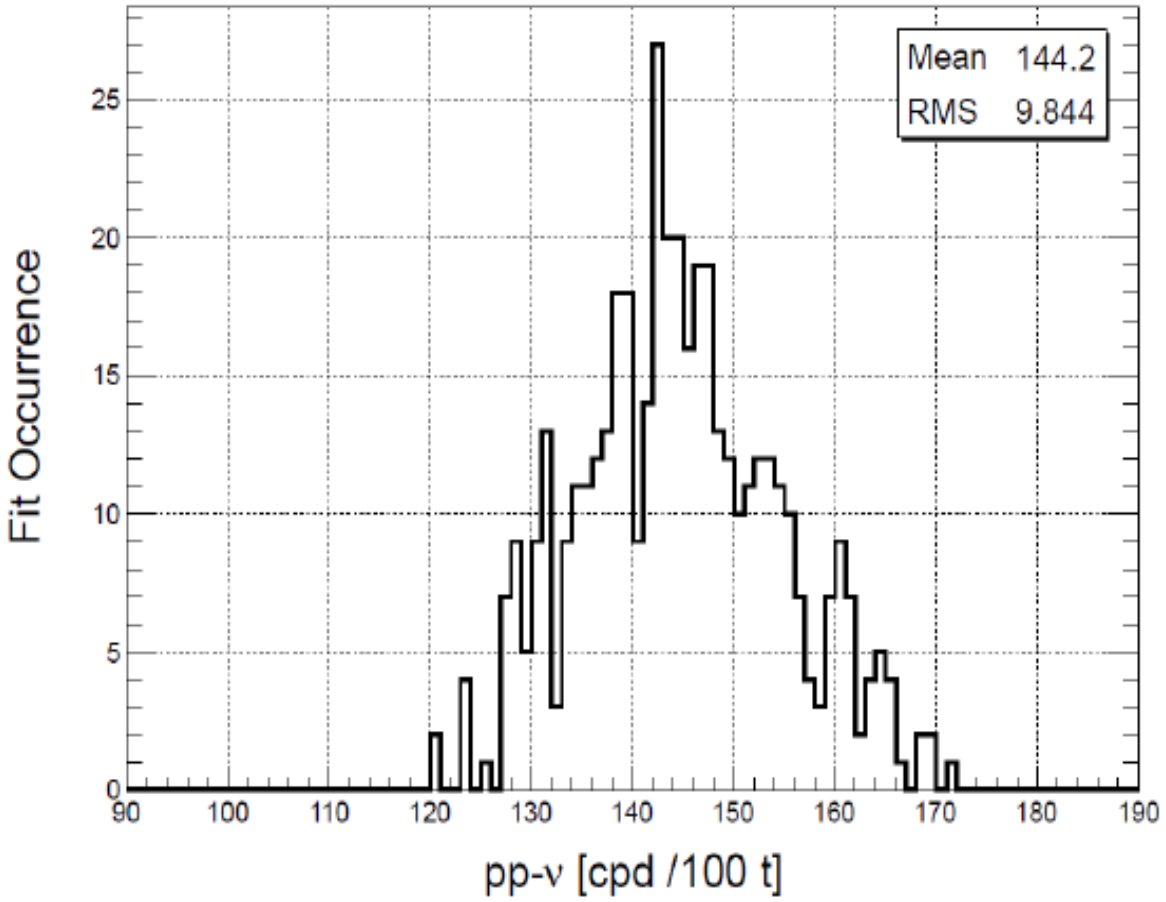


χ^2/d.o.f = 172.3/147

- pp ν: 144 ± 13 (free)
- ^{7}Be ν: 46.2 ± 2.1 (constrained)
- pep ν: 2.8 (fixed)
- CNO ν: 5.36 (fixed)
- ^{214}Pb: 0.06 (fixed)
- ^{210}Po: 583 ± 2 (free)
- ^{14}C: 39.8 ± 0.9 (constrained)
- Pile-up: 321 ± 7 (constrained)
- ^{210}Bi: 27 ± 8 (free)
- ^{85}Kr: 1 ± 9 (free)

Fit range: 165-590 keV

Systematics estimation



Varying the fit conditions
Perform fit and plot distribution of results for pp rate

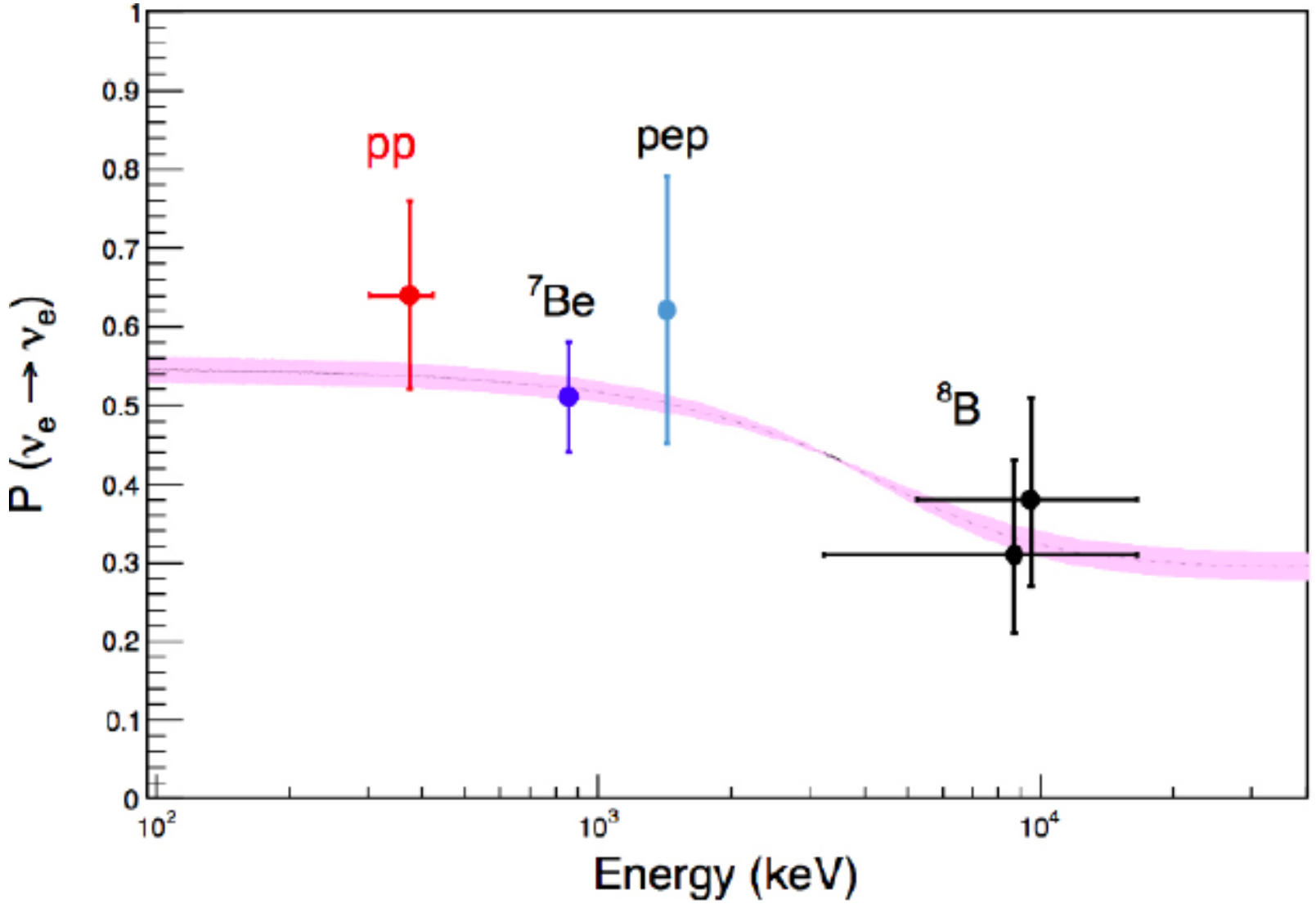
pp rate result

- Rate-pp = 144 ± 13(stat) ± 10(sys) cpd/100tons
  - Prediction = 131 ± 2 cpd/100tons
- Neutrino flux = $(6.6 \pm 0.7) \times 10^{10}$ $cm^{-2}s^{-1}$
  - Prediction = $(5.98 \pm 0.04) \times 10^{10}$ $cm^{-2}s^{-1}$
- Null hypothesis excluded at 10s

Solar Neutrino fluxes: observations vs predictions

Source	Flux [$cm^{-2}s^{-1}$] SSM-HZ	Flux [$cm^{-2}s^{-1}$] SSM-LZ	Flux [$cm^{-2}s^{-1}$] Data
pp	$5.98(1\pm0.006)\times10^{10}$	$6.03(1\pm0.006)\times10^{10}$	$6.02(1^{+0.002}_{-0.01})\times10^{10}$ **$6.6(1\pm0.11)\times10^{10}$[BX]**
pep	$1.44(1\pm0.012)\times10^{8}$	$1.47(1\pm0.012)\times10^{8}$	**$1.63(1\pm0.21)\times10^{8}$[BX]**
^{7}Be	$5.00(1\pm0.07)\times10^{9}$	$4.56(1\pm0.07)\times10^{9}$	**$4.99(1\pm0.05)\times10^{9}$[BX]**
^{8}B	$5.58(1\pm0.13)\times10^{6}$	$4.59(1\pm0.13)\times10^{6}$	$5.33(1\pm0.026)\times10^{6}$
^{13}N	$2.96(1\pm0.15)\times10^{8}$	$2.17(1\pm0.15)\times10^{8}$	
^{15}O	$2.23(1\pm0.16)\times10^{8}$	$1.56(1\pm0.16)\times10^{8}$	
^{17}F	$5.52(1\pm0.18)\times10^{6}$	$3.40(1\pm0.16)\times10^{6}$	
CNO	5.24×10^{8}	3.76×10^{8}	$<6.8\times10^{8}$ (2s) **$<7.7\times10^{8}$ (2s) [BX]**

Neutrino Survival Probability
Only Borexino



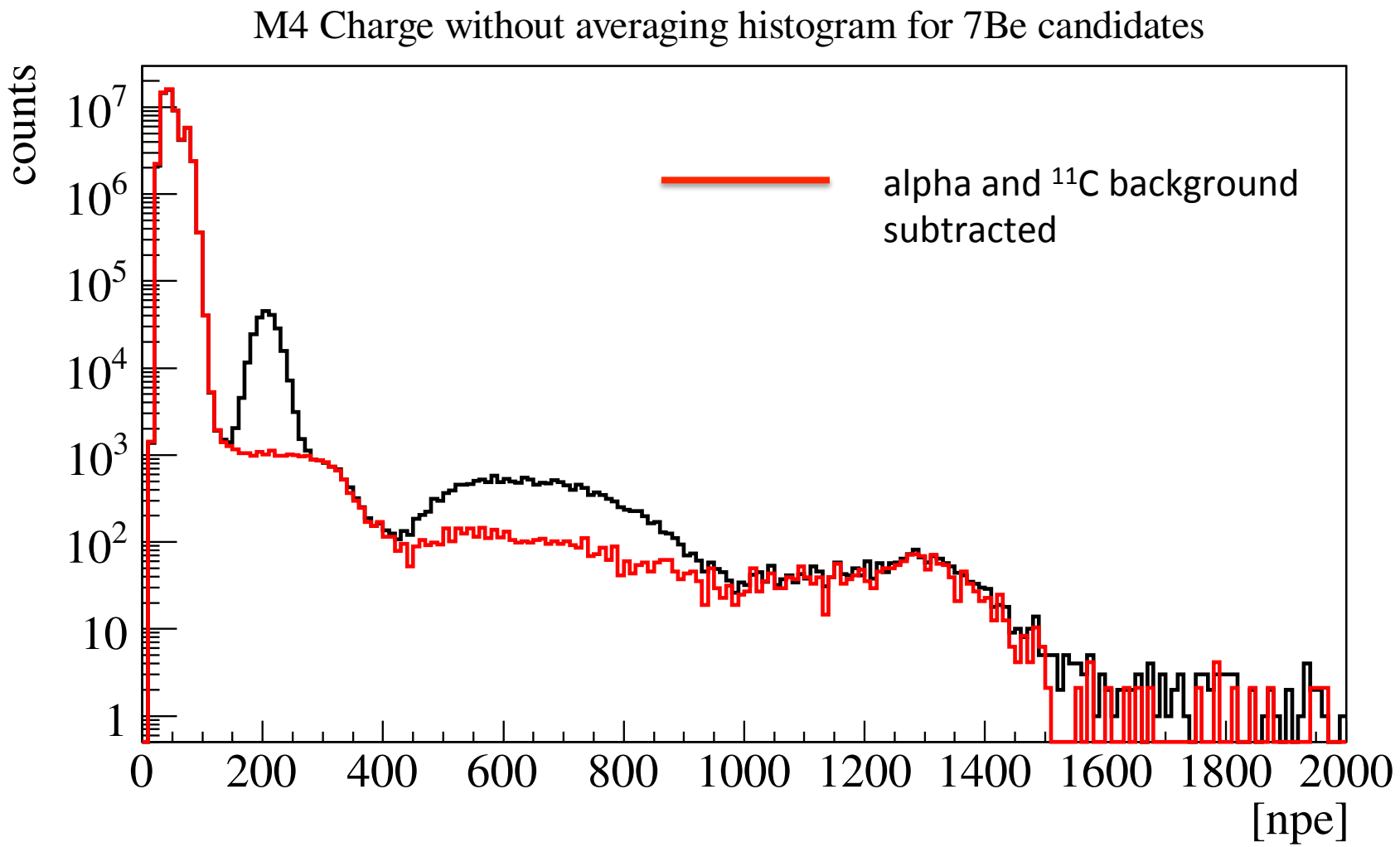
Next on Solar Neutrino Search

- **Phase II**: about 860 livedays since Dec 11th 2011
- Unprecedented low background on ^{85}Kr and ^{210}Bi
  - See last SC meeting
- **Calibration campaing** under planning
  - Schedule will be fixed at general meeting in Dec 2014
- **Main goal**: improve sensitivity to 7Be, 8B, pep and CNO neutrinos, neutrino effective magnetic moment
- **Purification campaign** (see next slide)
  - Schedule will be fixed at general meeting in Dec 2014

New Purification

- **Goal**: Reduce ^{210}Pb-^{210}Bi-^{210}Po decays by in-line re-purification of scintillator:
  - Reduce rate of ^{210}Bi from 20 cpd/100t to < 2 cpd/100t.
  - Comparable to CNO rate: 3 – 5 cpd/100t
- **Method**:
  - Water extraction with upgraded water radio-purity.
    - LNGS de-ionized water was found to have ^{210}Po and ^{210}Pb
    - Recent research shows that micro-organisms in ground water convert poloniun to volatile compound, dimethyl polonium with B.P. of 138 C.
    - Water extraction plant at LNGS supplemented with distillation column to remove dimethyl polonium
    - Tests done in Princeton had good results

Phase – II spectrum: preliminary



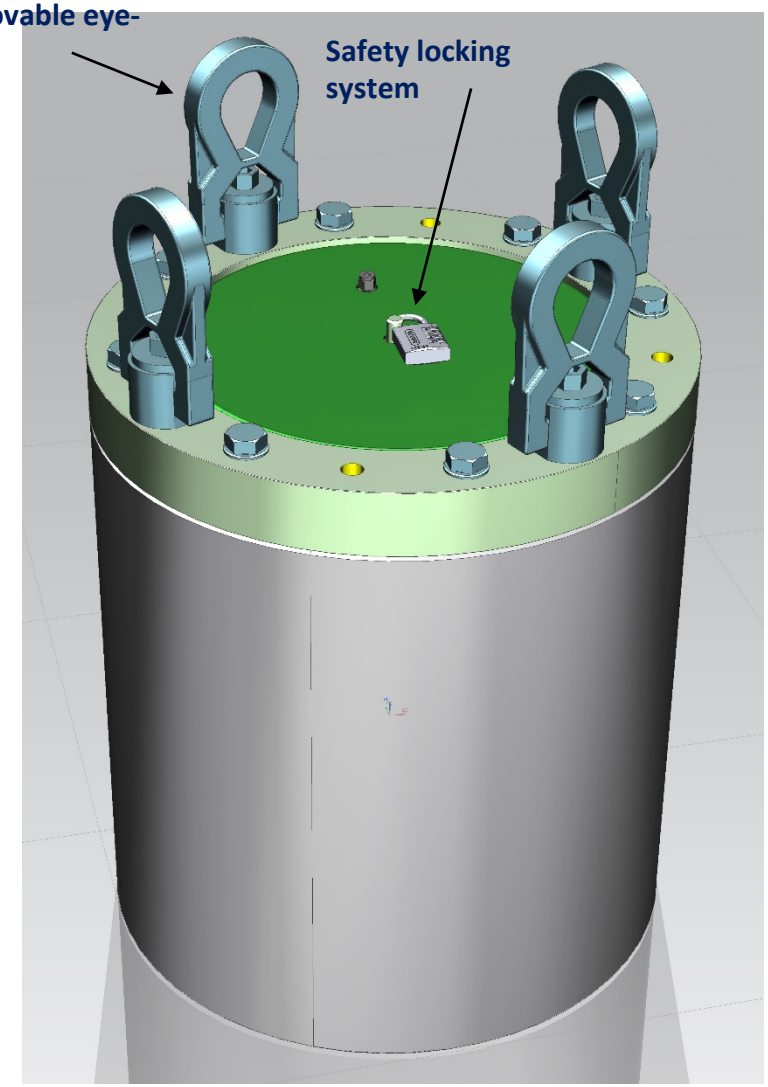
SOX: Short Distance Neutrino Oscillations with BoreXino

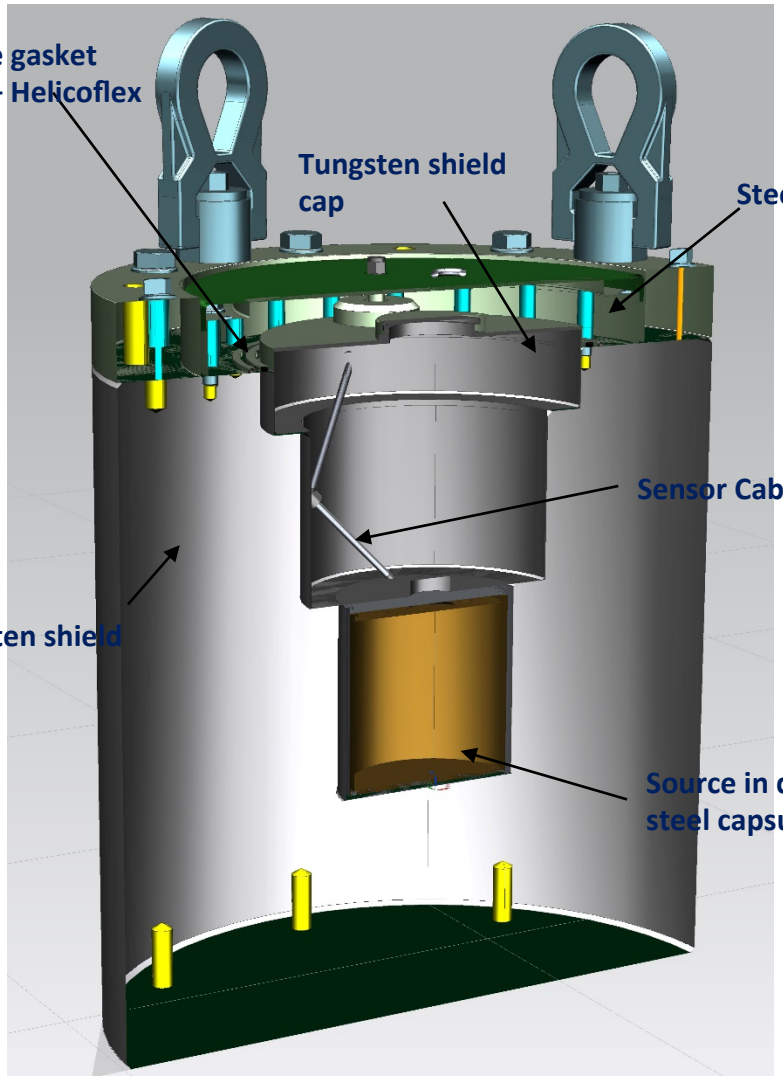
- Main focus on ^{144}Ce source
- The Cerium Anti Neutrino Generator (**CeANG**) will be manufactured in Russia and will be property of CEA-Saclay
- INFN will be responsible for the proper care of the CeANG at LNGS and for legal steps required to use the CeANG underground
- The CEA-Saclay will take care of transportation to and from LNGS; to assume responsability of the CeANG after use at LNGS
- Approval time for authorization ~ 1 year

Production of ^{144}Ce source

- Start with 2.8 t of spent fuel from Kola Nuclear Power Plant to Mayak around end of 2014
- Extraction of Ce isotopes ~ 8 kg
- Production of CeO_2 and insertion in shielding
  - 19cm of tungsten (2.3 t) mainly for 2.185 MeV gamma-rays
  - Source activity ~ 100kCi
- Source ready for transportation in Fall 2015

Source capsule and tungsten shield

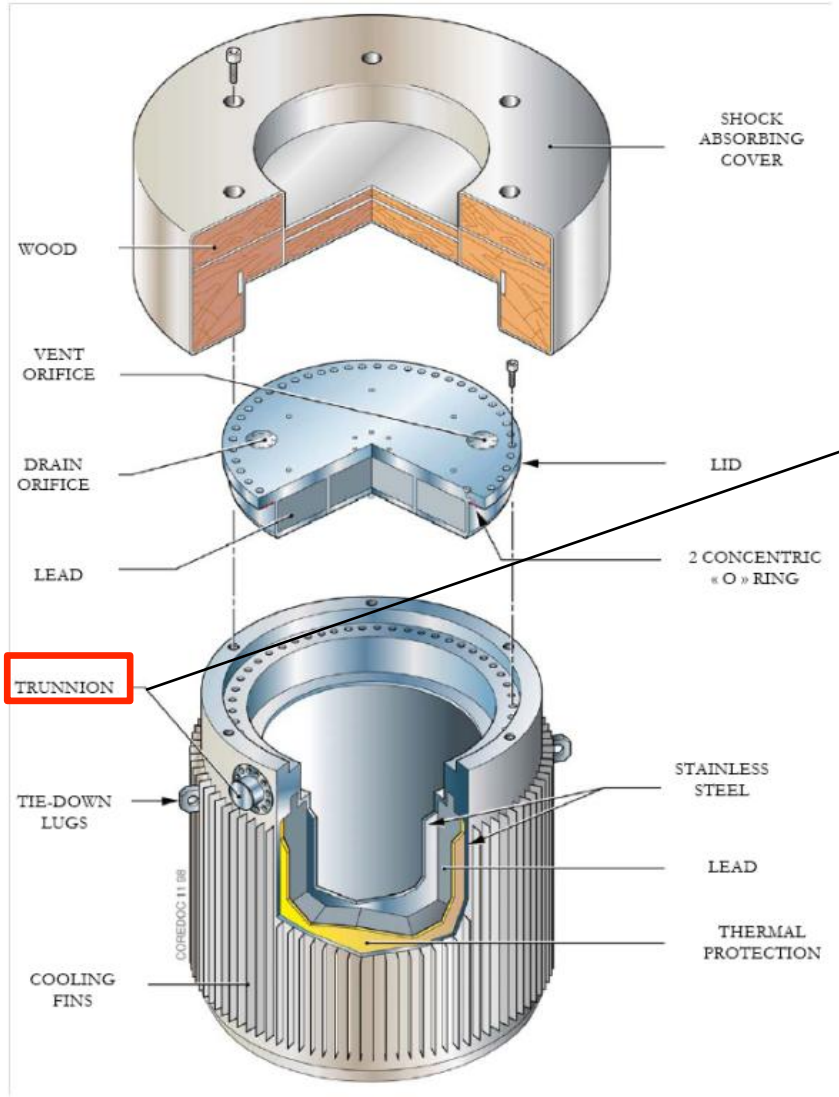




Transportation of Ce source

- From Mayak to San Petersburg by train
- To France by boat
- To Saclay and to Gran Sasso by truck
- Supervised by Areva TN

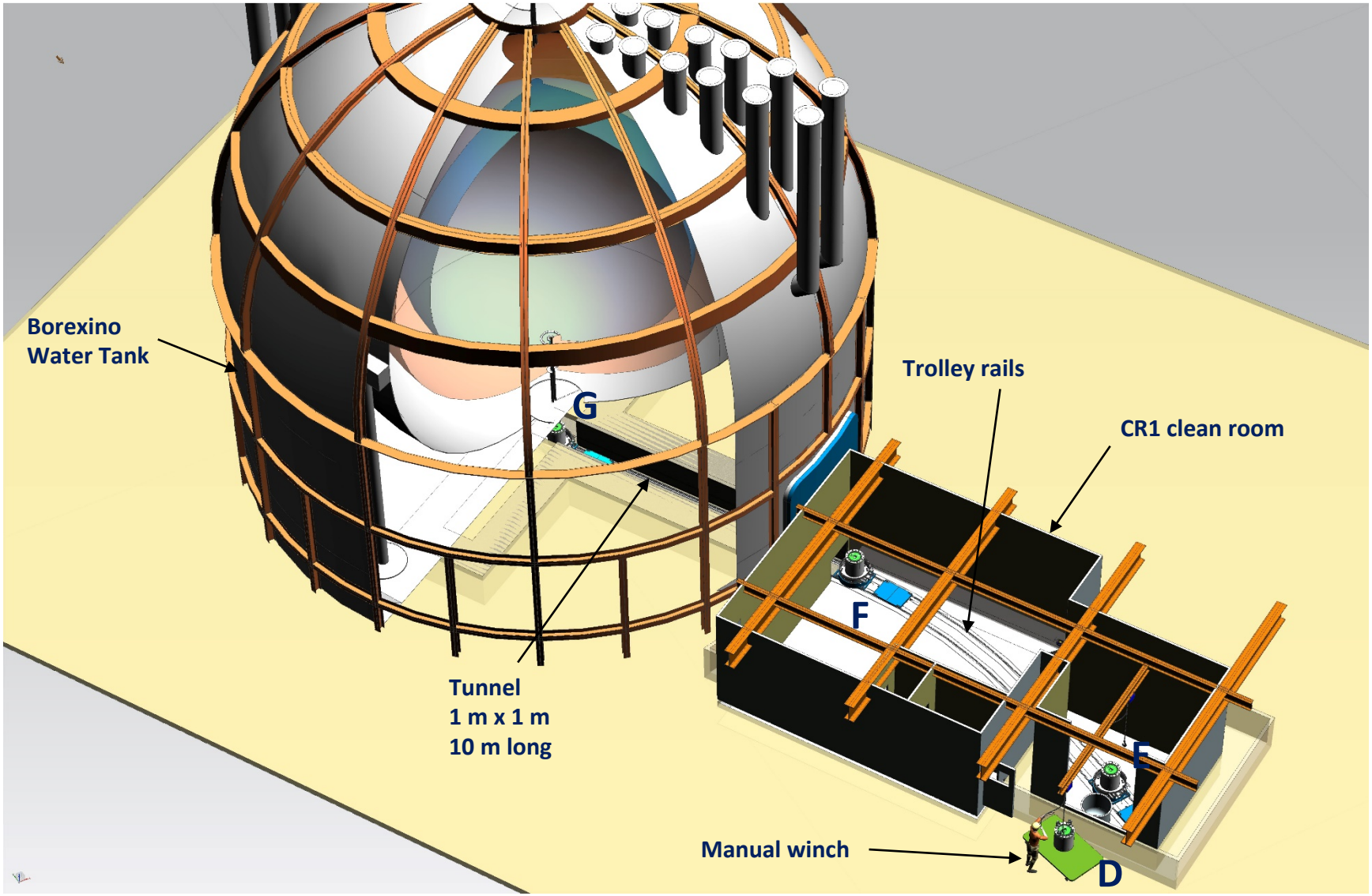
Transportation container: TN-MTR



Custom AREVA spreader

190mm Pb shielding

Source logistic inside SOX pit @ LNGS



Summary of Ce source test

- The CeANG test is fully defined in term of design, schedule and funding (by two ERC grants: 3.219 + 1.550 M€)
- Documentation for the authorization is ready and being sent by the LNGS Director soon to keep one year time scale
- CeANG expected in Nov 2015 at LNGS
- Dec 2015 calorimeter measurement in CR1
- 18 months of data taking

Vacuum Chamber of Calorimeter at TUM

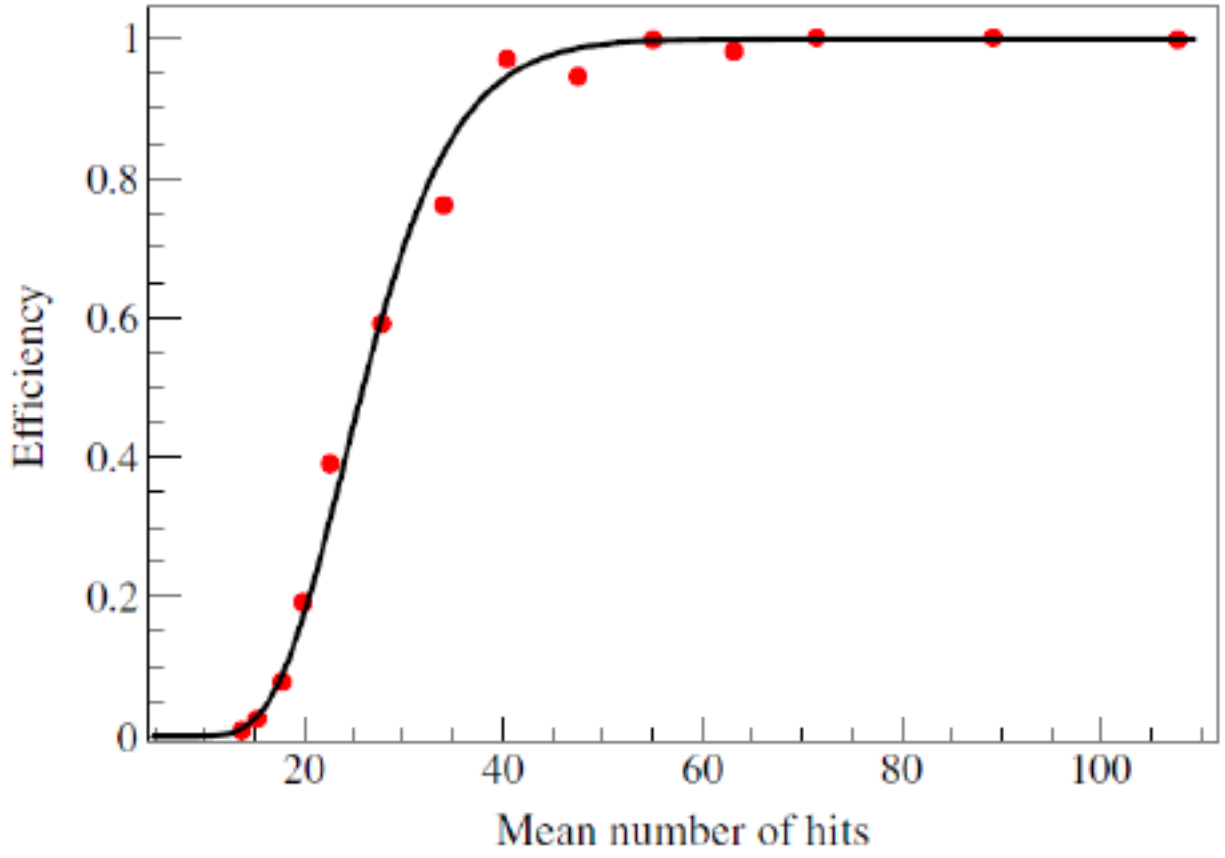
^{51}Cr source test

- Crucial decision still to be made about where to perform the irradiation (goal ~ 10 MCi)
  - Mayak atomic complex in Russia
  - Oak Ridge USA (1st priority)
- VT and Kurchatov groups strongly engaged
- Enriched Cr used in Gallex stored in Italy at Nucleco
- Needed more funding expected from INFN and USA (~ 3.5M€)

Summary

- Activities 2015
  - Analysis of Phase II data
    - Goal: improve sensitivity on 7Be, 8B, CNO and pep solar neutrinos
  - Calibration campaign
    - Schedule to be agreed in Dec 2014
  - Install and test new purification plant to reduce ^{210}Bi, purification campaign
    - Schedule to be agreed in Dec 2014
- CeANG
  - Source production and transportation

Spare


Efficiency
1
0.8
0.6
0.4
0.2
0
20
40
60
80
100
Mean number of hits

Background in Phase-II

• after 6 cycles of purification with water extraction performed between May 2010 and August 2011:

1) ^{85}Kr: strongly reduced: consistent with zero cpd/100 ton from the spectral fit;

2) ^{210}Bi : reduced from ~70 cpd/100 tons to ~20 cpd/100 ton;

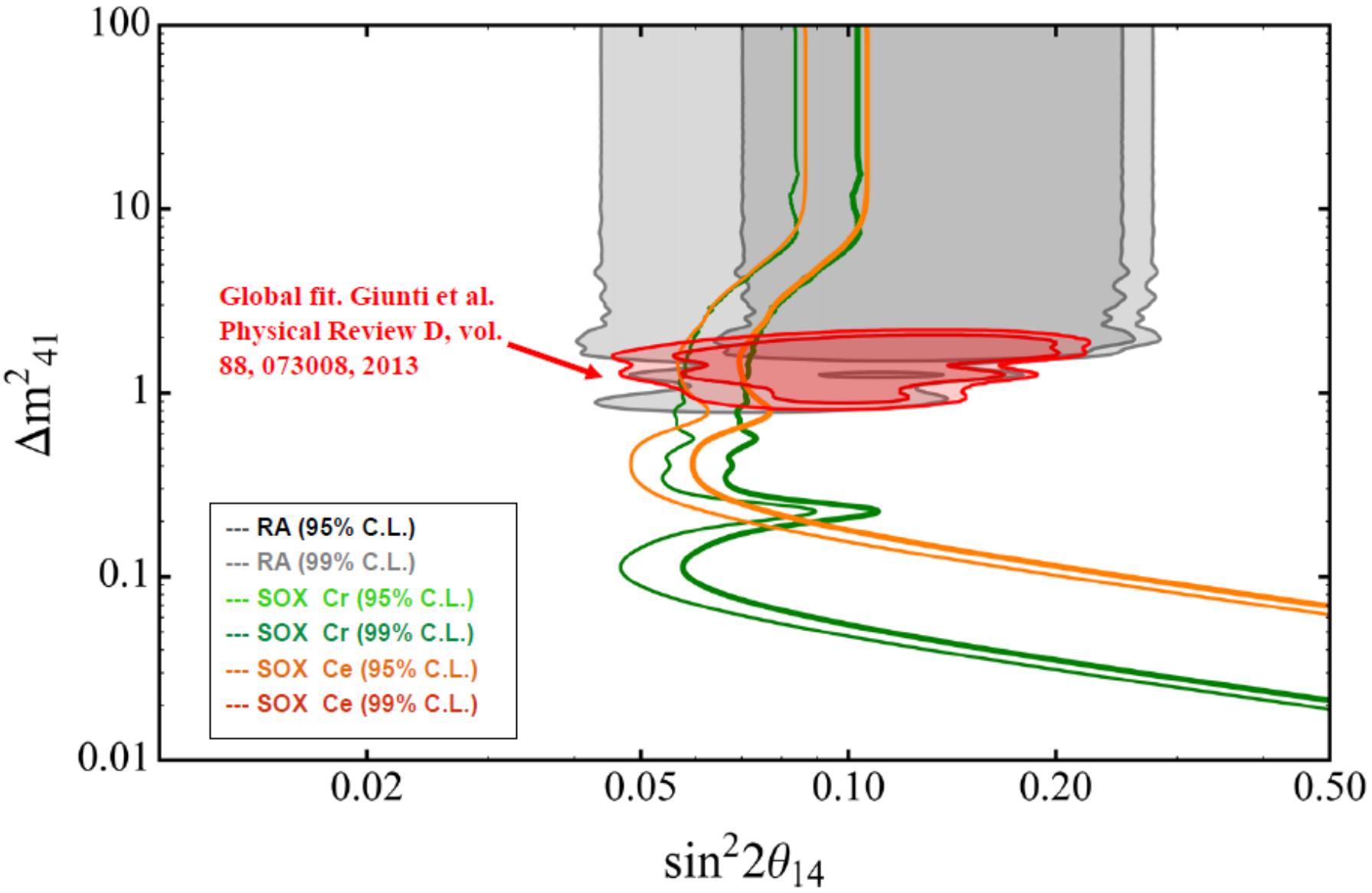
3) ^{238}U (from ^{214}Bi - ^{214}Po tagging) $< 1.2\ 10^{-19}$ g/g at 95% C.L.

4) ^{232}Th: $< 1.2\ 10^{-18}$ g/g at 95% C.L. (2 events in ~600 days)

5) ^{210}Po decaying, currently about 120 cpd/100 ton

6) Radon: $(5.8 \pm 1.2)\ 10^{-2}$ cpd/100 ton

SOX: sensitivity to sterile neutrino



Borexino Water Extraction Systems

Current & Proposed Upgrade with 2 Fractional Distillation Columns