Short distance neutrino Oscillations with BoreXino: SOX

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On behalf of the Borexino collaboration

INFN

Gran Sasso

Perugia

Heidelberg

Hamburg

Budapest

Milano

Genova

München

Kraków

Kurchatov
Moscow

the Borexino Collaboration

JINR Dubna

Princeton

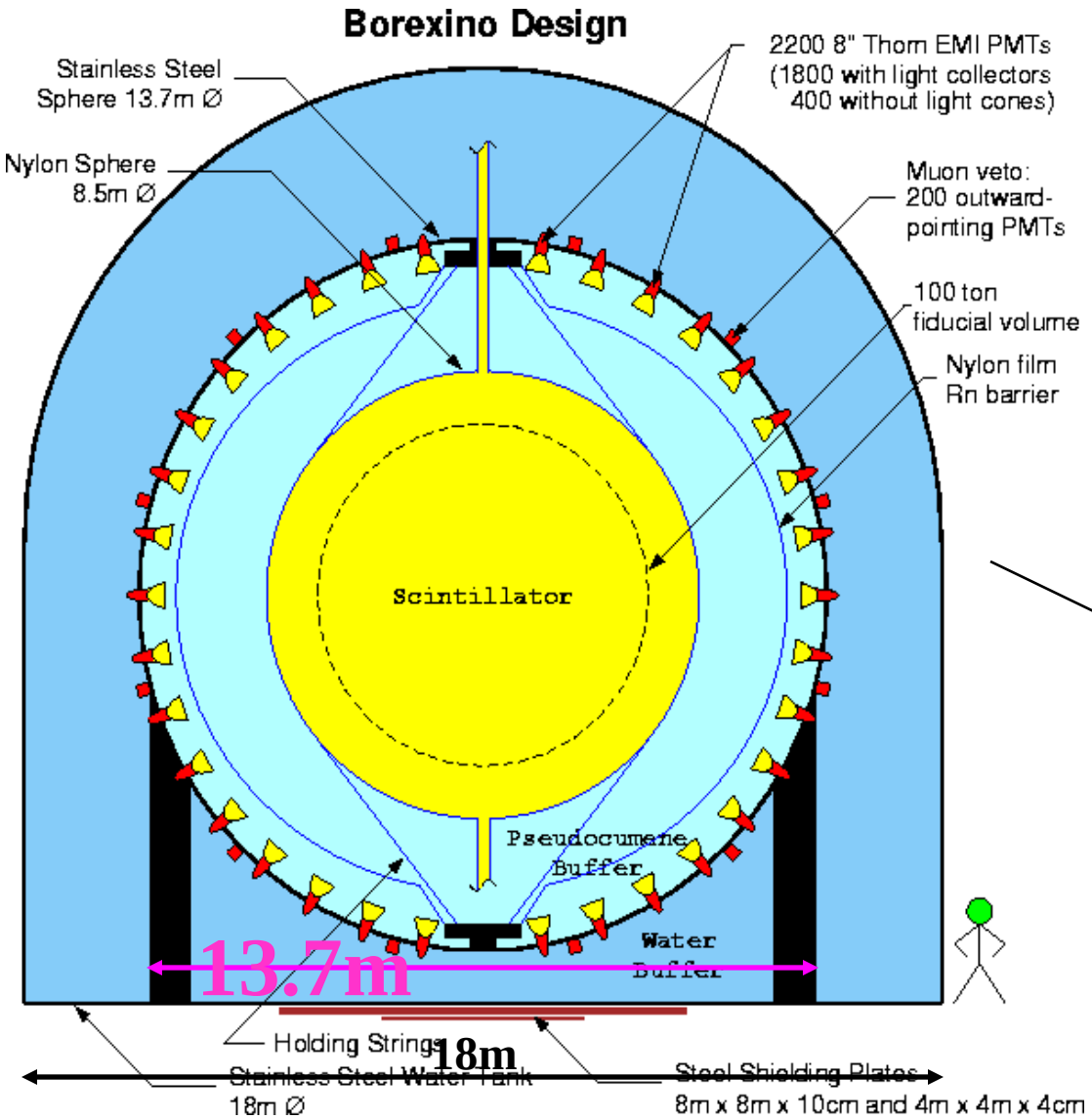
Virginia Tech

UMass
Amherst

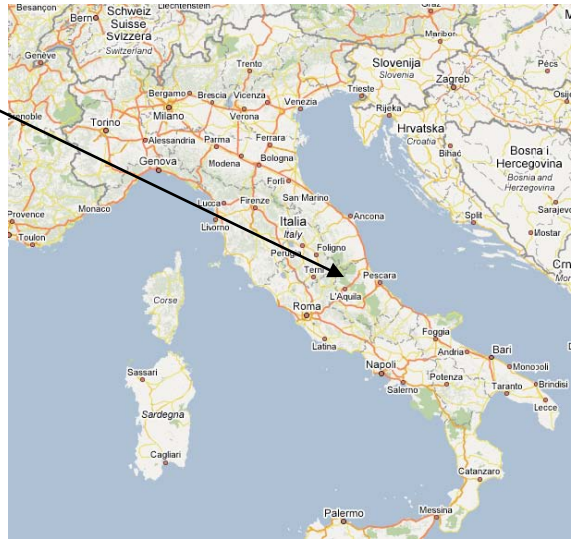
Paris

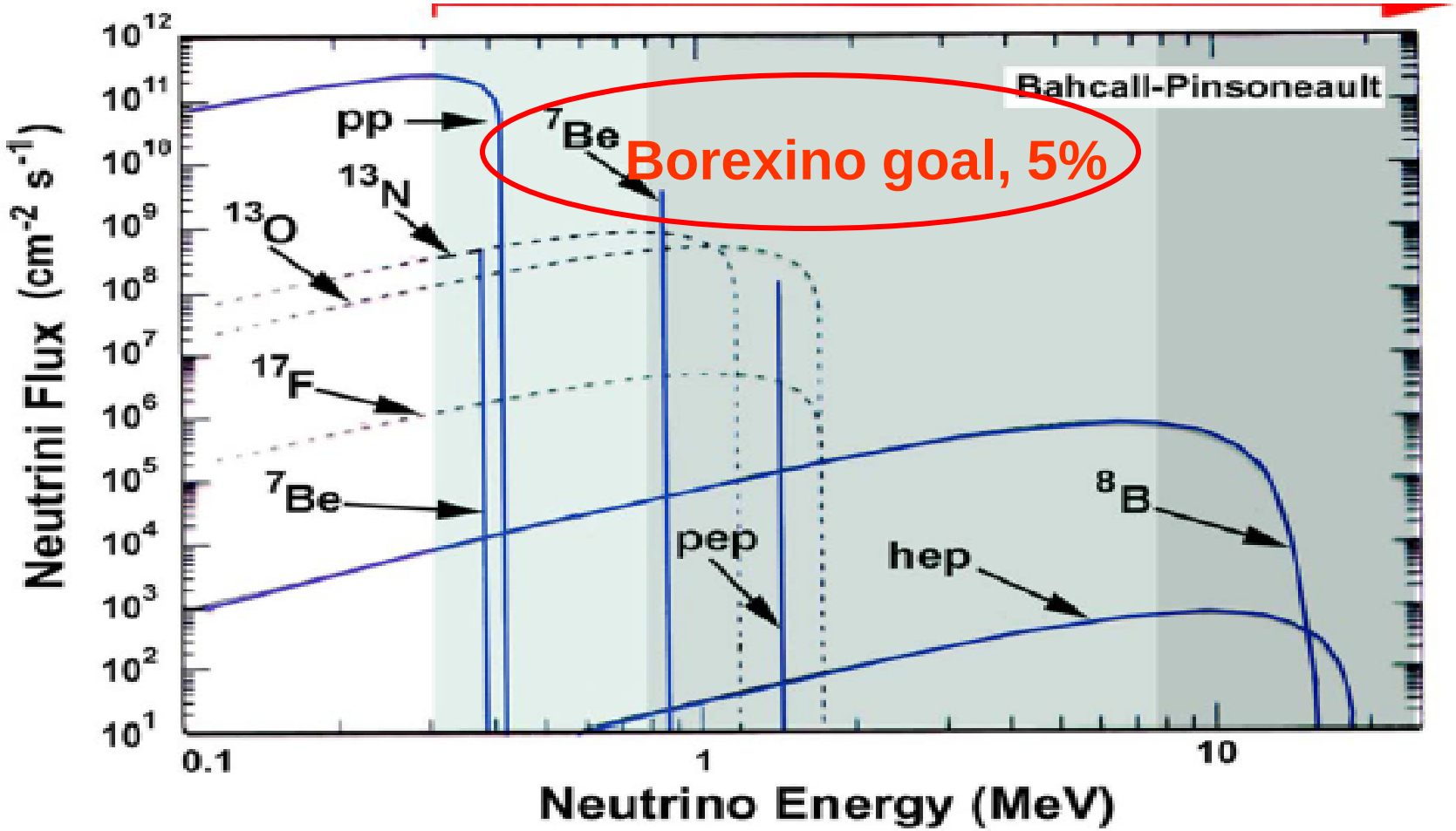
St. Petersburg

BOREXINO *(in operation from May,2007)*



- **278 t of liquid organic scintillator PC + PPO (1.5 g/l)**
- **(ν,e)-scattering with 200 keV threshold**
- **Outer muon detector**





50 events/d/100t expected (ν_e and ν_μ elastic scattering on e^-) or $5 \cdot 10^{-9}$ Bq/kg (typically: drinking water ~10 Bq/kg; human body in ^{40}K: 5 kBq)

Low energy->no Cherenkov light->No directionality,
no other tags-> extremely pure scintillator needed

Borexino technical data

1.Mass: full 278 t;

“Standard” FV (R<3.02 m && |Z|<1.67 m) ~75 tones

2.Spatial resolution 14 cm @ 1 MeV

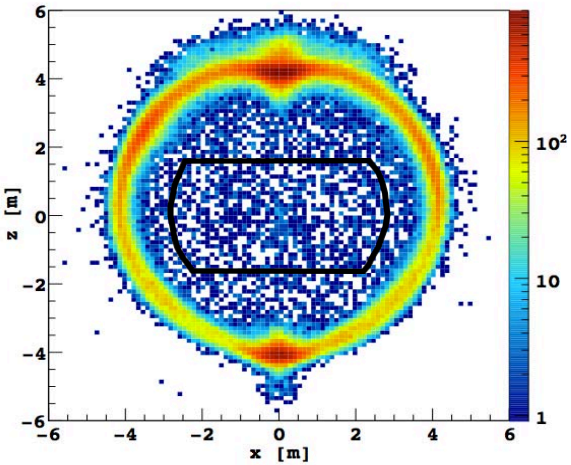
3.Light yield: >500 p.e./MeV/2000 PMTs (31% of 4π);

4.Energy resolution (1σ) within the FV: ~5% @ 1 MeV;

5.Practical threshold on the electrons recoil is 180 keV (corresponds to ~320 keV neutrino);

6.Muons detection efficiency close to 100%;

7.Triggers rate: 11 cps (mainly ^{14}C; ~100 Bq activity)



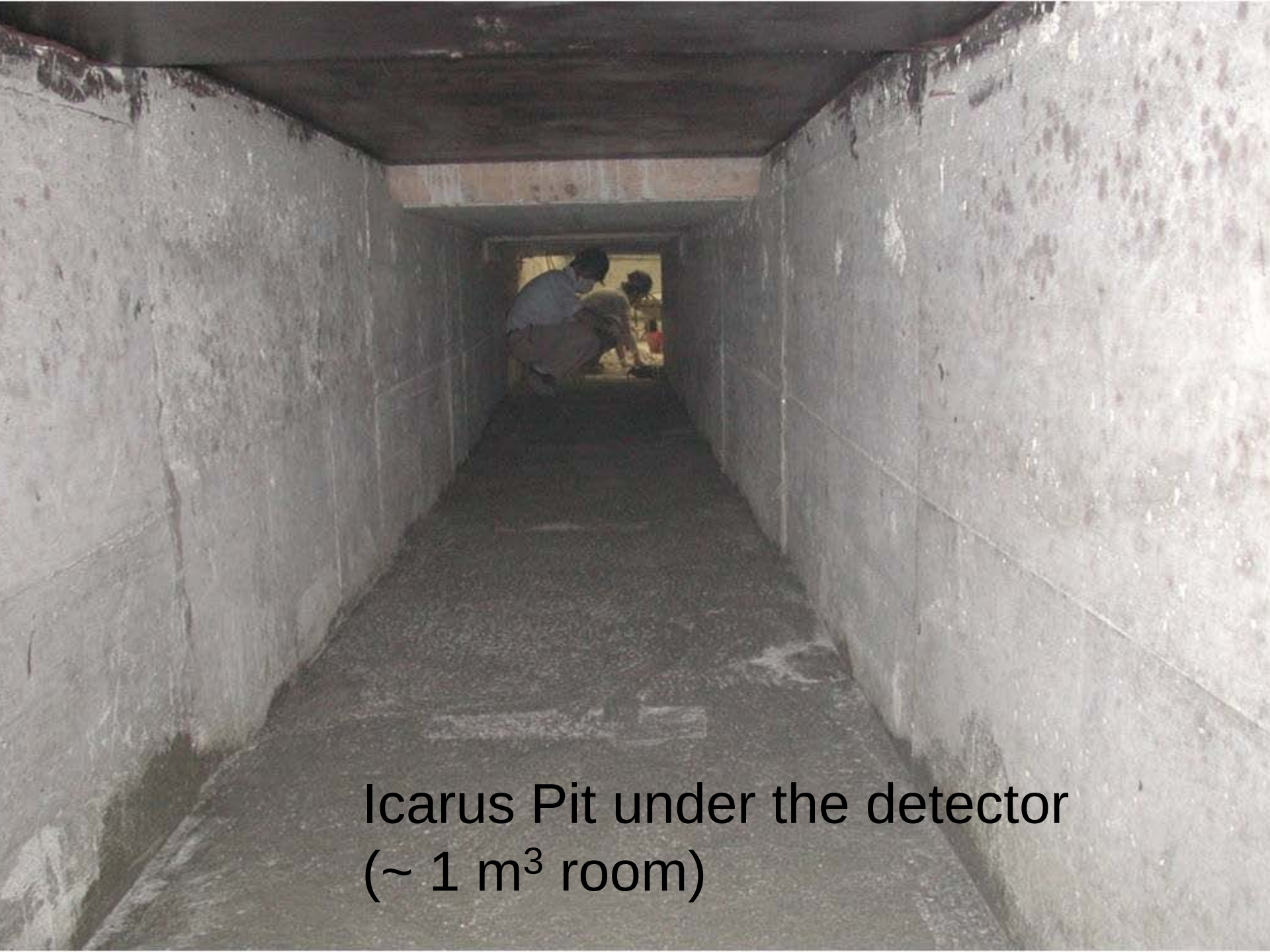
The Borexino is perfectly suited to host a short baseline neutrino oscillation experiment with E~1 MeV and L~1 m

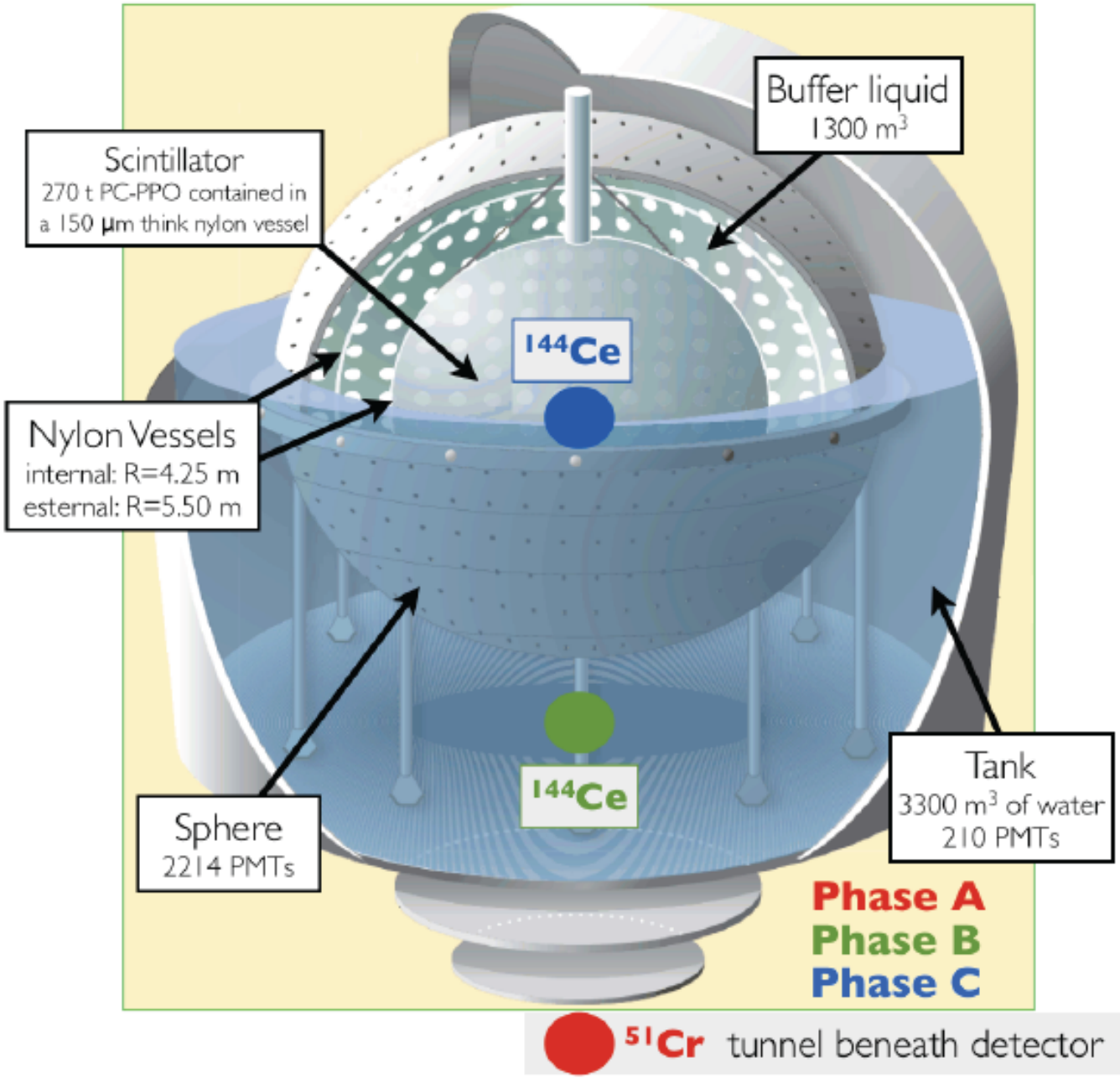
Borexino status

- **The basic physics program fulfilled (but no measurements with neutrino sources). A number of important physics results are obtained beyond the original program, as a result of much better purification in U-Th than needed for Be-7 neutrino measurement (Final results:** arXiv:1308.0443v1 [hep-ex])
- **After successful detector calibration campaign in 2010 scintillator repurification campaign was performed. In few cycles of purification, the Kr-85 (the main source of systematics in Be-7 spectral fit) was removed. Bi-210 content was reduced down to 20 events/day per 100 tones of LS (yesterday's F.Calaprice talk)**
- **Borexino Phase II: about 2 years of data with "pure" scintillator has been collected, data taking continues.**

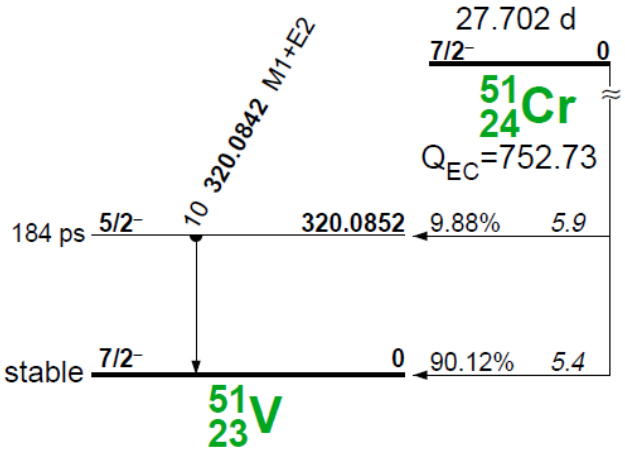
Borexino Phase II Physics program

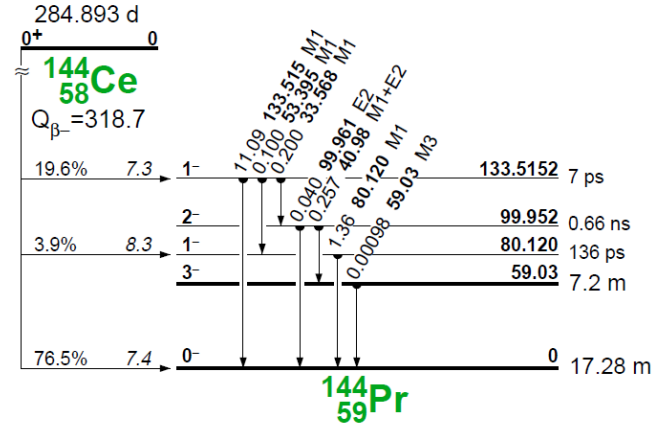
- **Improvement of ^{7}Be neutrino flux measurement (3%) and seasonal variations.**
- **pp-neutrino flux measurement with 10% precision**
- ***pep* neutrino measurement with better precision (>3σ)**
- **Geoneutrino flux measurement with higher statistics**
- **B-8 neutrino measurement with x4 statistics (10%)**
- **Measurement (or establishing strong limits) on the CNO neutrino flux.**
- **Measurements with artificial neutrino sources (search for sterile neutrino, neutrino magnetic moment, other nonstandard neutrino interactions). Project SOX: Short distance Oscillations with BoreXino. EU grants for source.**

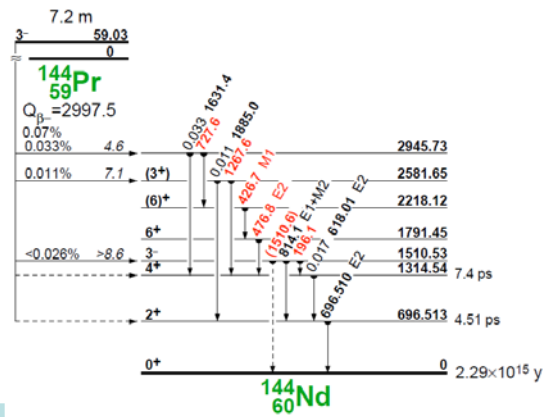

Icarus Pit under the detector
(~ 1 m^3 room)


Buffer liquid
1300 m3
Scintillator
270 t PC-PPO contained in
a 150 µm think nylon vessel
144Ce
Nylon Vessels
internal: R=4.25 m
esternal: R=5.50 m
144Ce
Sphere
2214 PMTs
Tank
3300 m3 of water
210 PMTs
Phase A
Phase B
Phase C
51Cr tunnel beneath detector

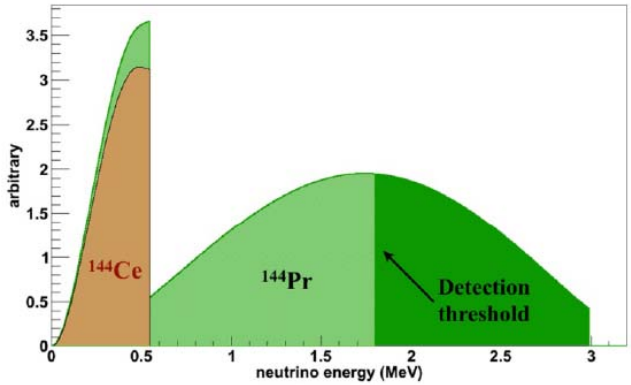
Sources



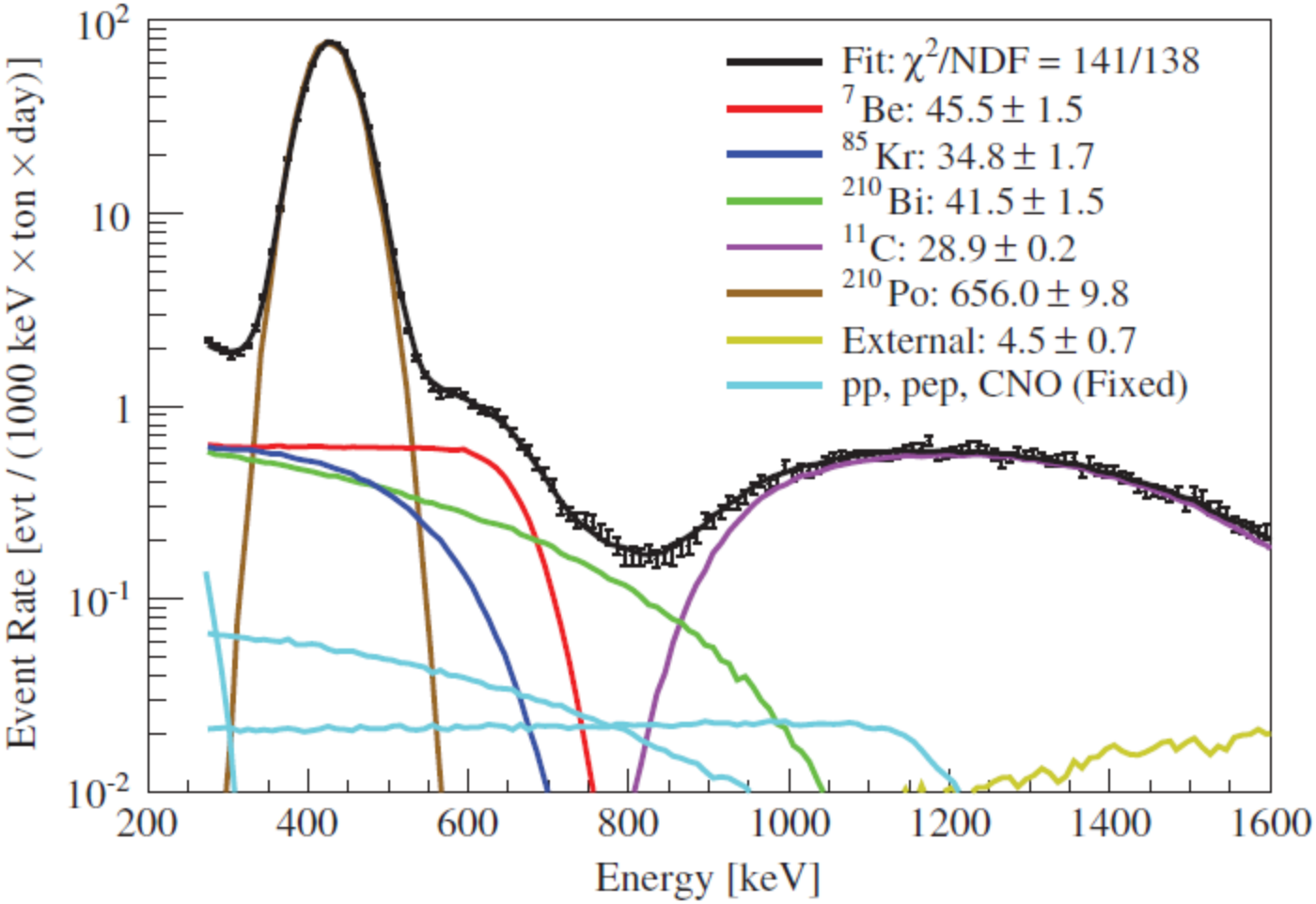




Source	decay	τ [days]	Energy [MeV]	Kg/MCi	W/kCi
^{51}Cr	e-capture (E_γ=0.32 MeV 10%)	40	0.7 90%	0.011	0.19
^{144}Ce-^{144}Pr	Fission product β^-	411	<2.9975 MeV 97.9%	0.314	7.6

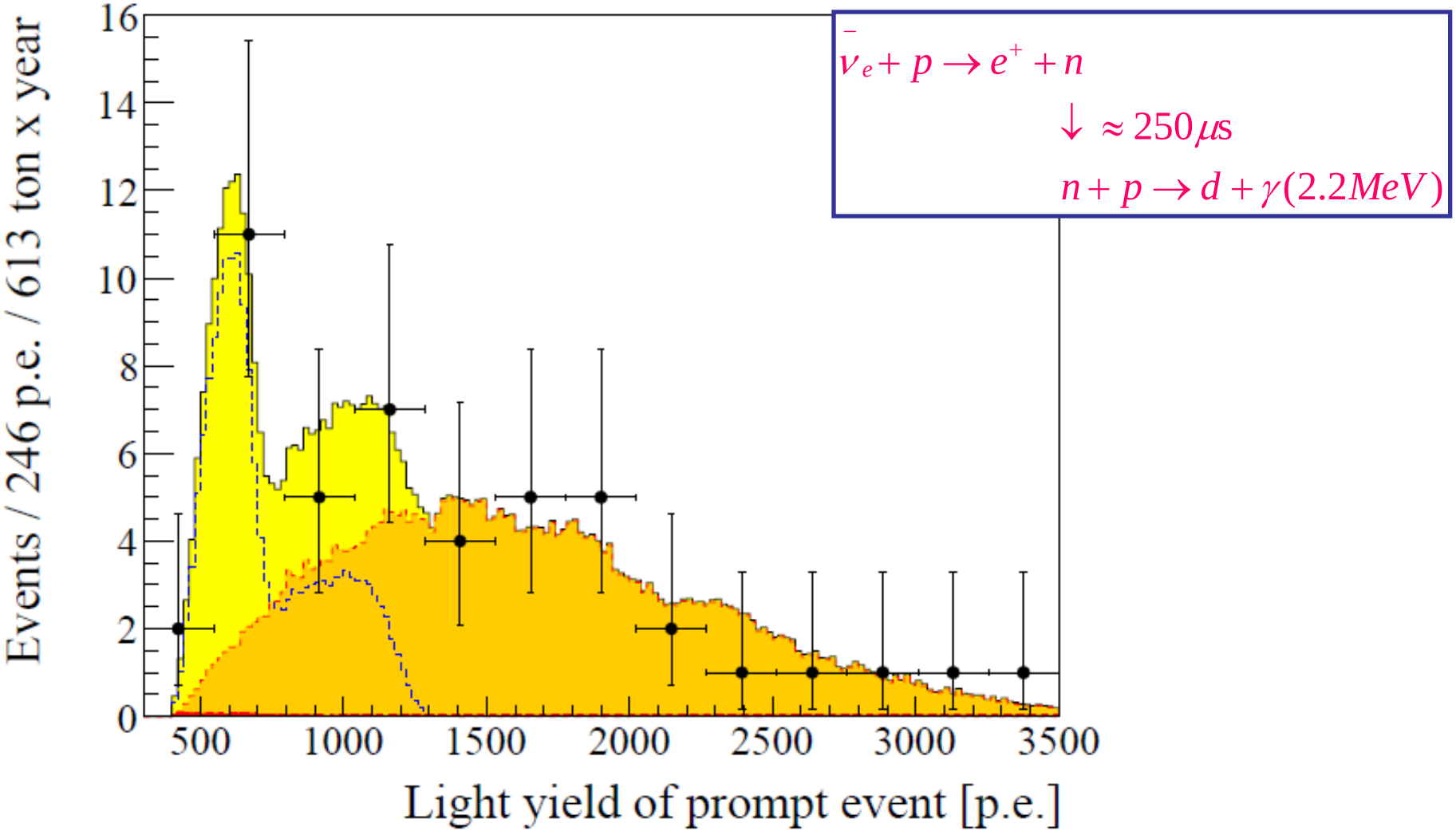


Backgrounds for neutrino source experiment



"Precision Measurement of the ^{7}Be Solar Neutrino Interaction Rate in Borexino"
PRL 107, 141302 (2011)

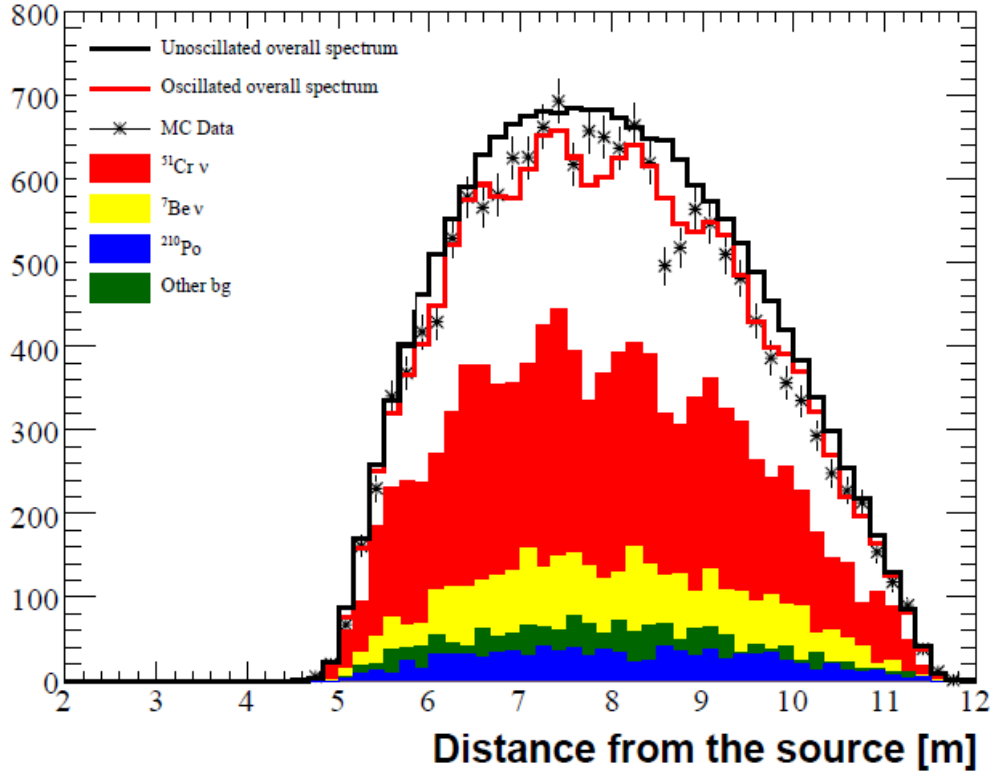
Backgrounds for antineutrino source experiment



Measurement of geo-neutrinos from 1353 days of Borexino
Physics Letters B722 (2013) pp 295–300

SOX Phase A (2014-2015)

- **^{51}Cr neutrino source of 200-400 PBq activity deployed at 8.25 m from the detector center. Uninvasive to detector, can be done in parallel to the regular solar neutrino data-taking.**
- **Recycling material used in Gallex calibration experiment. Activation can be performed in Russia or USA. Both option are in the negotiations stage. Works on source are funded by EU grants and grant in Russia.**



Geant-4 simulation:
$\sin^2(2\Theta_{14})=0.3$
and $\Delta m^2_{41}=2$ eV^2.

The signal (red band) is dominating at all distances from the source. The oscillatory behavior allows to reconstruct Θ_{14} and Δm^2_{41}

Sensitivity is enhanced by exploiting the fact that the life-time of the ^{51}Cr is relatively short (assuming constant background).

^{51}Cr source experiment.

Inputs for MC modeling:

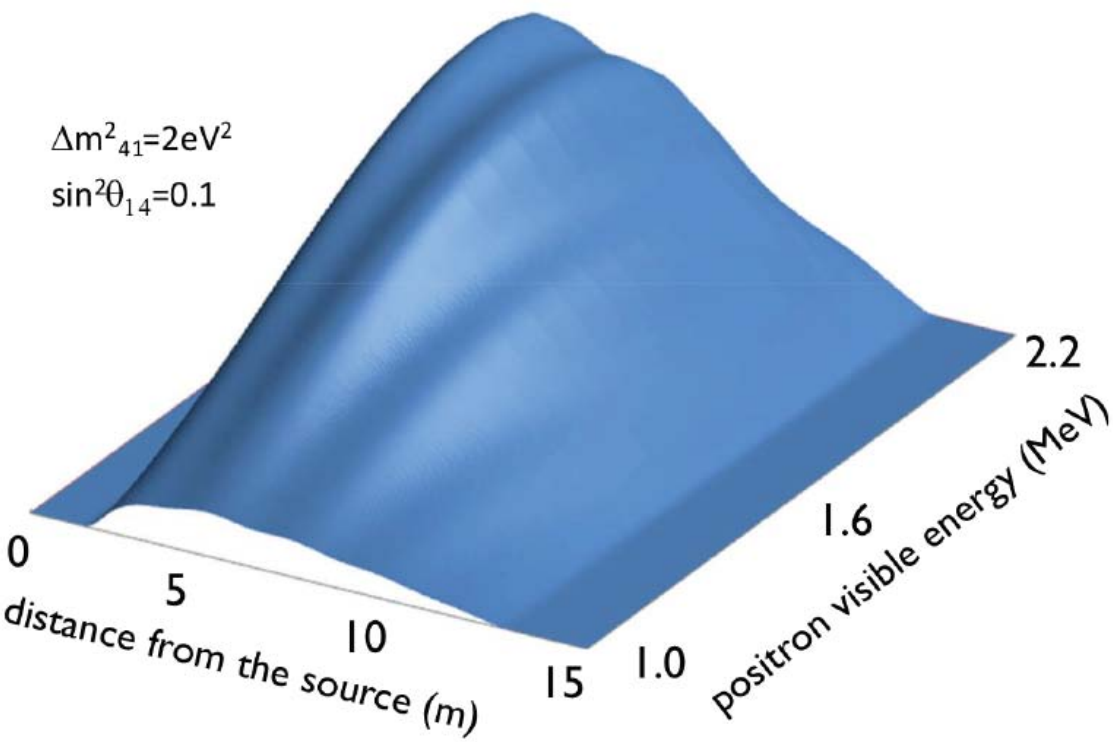
- 370 PBq (10 Mci) at 8.25 m from the center
- a period of 15 weeks of stable data taking before the source insertion (to constrain the background)
- 100 days of data taking with 90% duty cycle
- Assumed: 1% error in the measurement of the source activity, which is challenging but feasible (in 1995 Gallex experiment obtained about 2% precision).
- 1% error on FV: with a careful calibration by means of standard sources (already foreseen for solar physics), the achievement of better than 1% knowledge of fiducial volume is realistic.

SOX Phases B and C (2016-2017)

- ^{144}Ce–^{144}Pr antineutrino source with 2-4 PBq activity.

B) at 7.15 m from the detector center (in water buffer);

C)at the detector's geometrical center;



Compared to neutrino source:
very low background and larger cross-section.

Needs cooling,
needs to prevent convection
Stronger shielding requirements

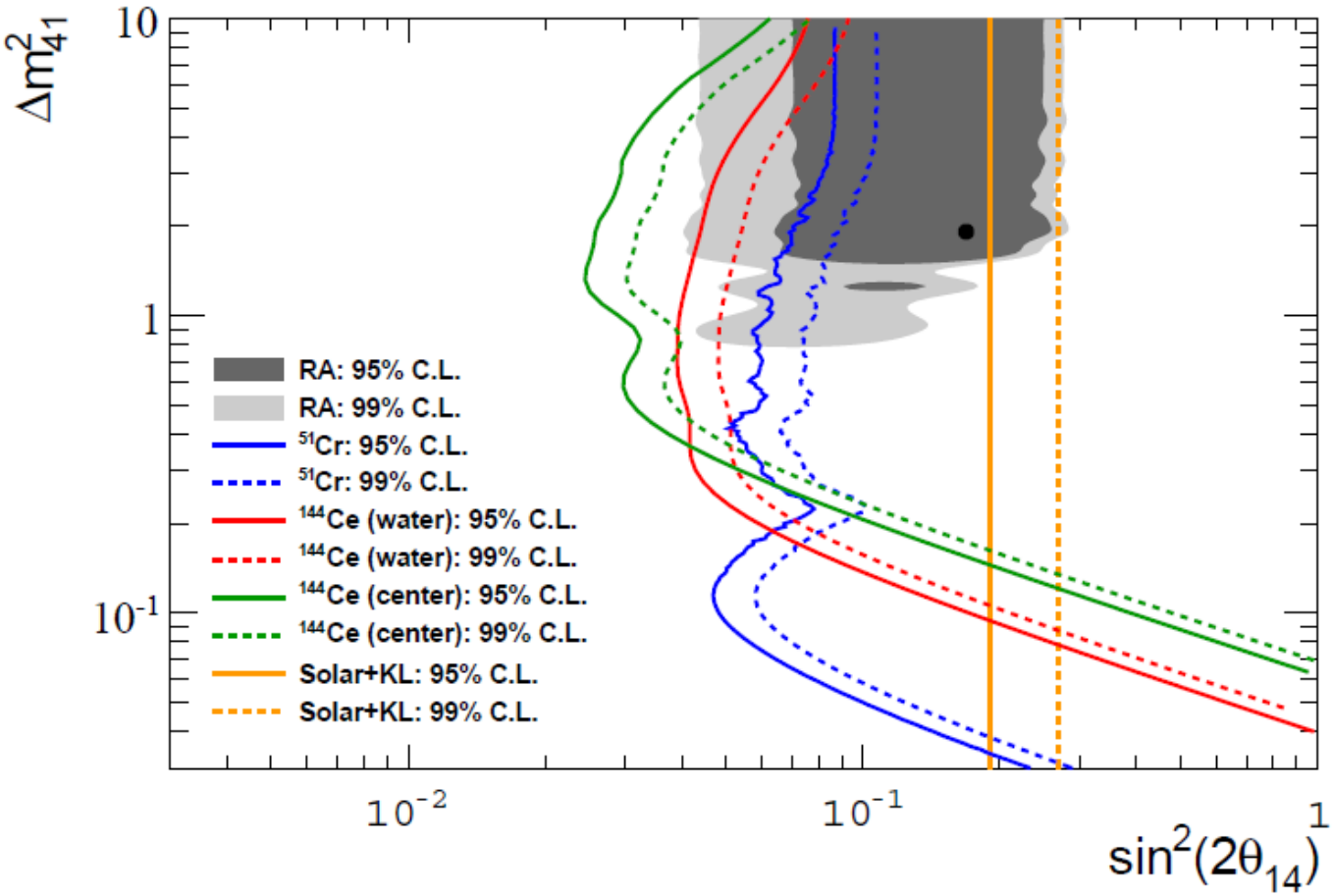
Needs modifications of detector- after solar program (>2016-17)

^{144}Ce–^{144}Pr source experiment.

Inputs for MC modeling:

- 2.3 PBq (75 kCi)
- 1.5 yr of data taking with enlarged active volume (from actual 4.25 to 5.5 m)
- 1.5% source intensity knowledge;
- no fiducial volume cut and therefore no corresponding error. However, a 2% experimental systematic error is considered, uncorrelated between energy and space bins, to account for residual systematic effects.

SOX: sensitivity



Phase A (blue), Phase B (red) and Phase C (green). The grey area is the one indicated by the reactor anomaly, if interpreted as oscillations to sterile neutrinos. Both 95% and 99% C.L. are shown for all cases.

Journal of High Energy Physics, 08(2013)038

Conclusions

- **Borexino is an ideal detector to test the sterile neutrinos through the the disappearance/wave effects**
- **The proposed staged approach (^{51}Cr source and two ^{144}Ce–^{144}Pr experiments) is a comprehensive sterile neutrino search which will either confirm the effect or reject it in a clear and unambiguous way.**
- **In particular, in case of one sterile neutrino with parameters corresponding to the central value of the reactor anomaly, SOX will surely discover the effect, prove the existence of oscillations and measure the parameters through the "oscillometry" analysis.**

13th International Conference on Topics in Astroparticle and Underground Physics, Asilomar, California USA
September 8-13, 2013