Review of Geo-neutrinos and Borexino

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NMR-2013, Tokyo

Outline

- Today (Jul 25): Review of Geo-neutrinos and Borexino
  - review of **Borexino** detector
  - **antineutrino** analysis
- Tomorrow (Jul 26): What we found with Borexino
  - geo-neutrino **results**
  - **implications**

Why measure geo-neutrinos?

"Direct messenger of abundances and distributions of radioactive elements within our planet"

Distribution of radioactivity in Earth

Radiogenic contribution to **heat** balance

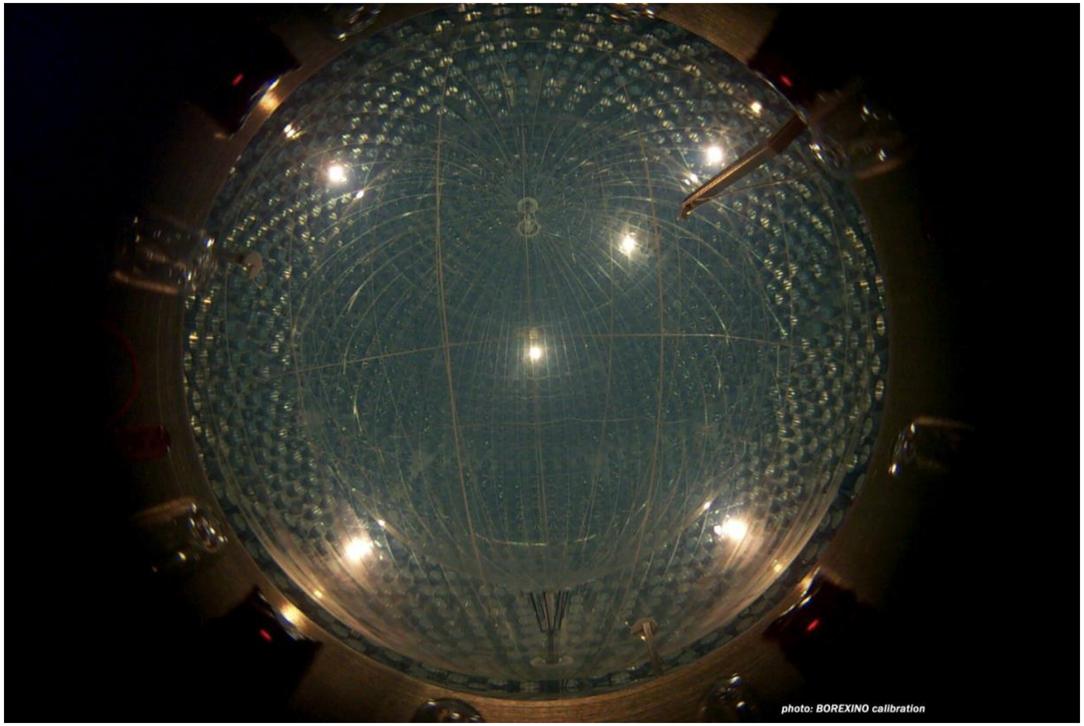
Pieces of **information** on complex geo-physical phenomena

*G. Bellini et al. (Borexino Collab.) PLB **696** (2010) 191-196*
*G. Bellini et al. (Borexino Collab.) PLB **722** (2013) 295-300*

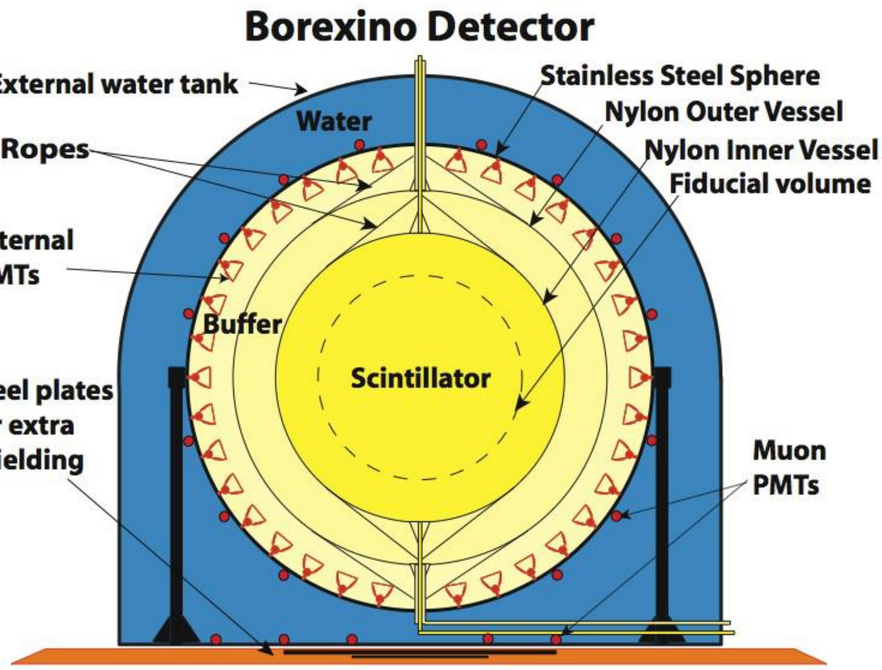
The Borexino Experiment

Laboratori **N**azionali del **G**ran **S**asso
(Gran Sasso National Labs)
Assergi,
ITALY

Underground Experiment
Under *3500*
Meters **W**ater
Equivalent



The Borexino Detector



Ultrapure organic liquid scintillator

~**278** tons of **scintillator** (PC)

~75 tons of fiducial mass

~**2200 PMTs** on the SSS

External Water Tank

shielding for n and γ

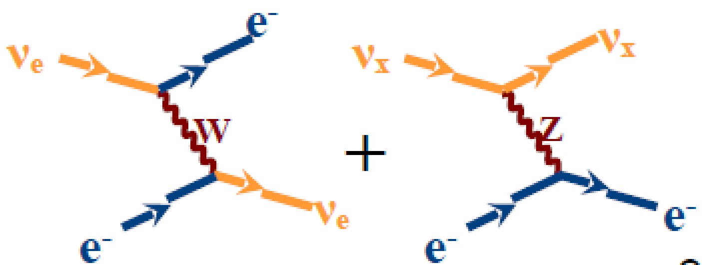
Cherenkov detector for μ

Borexino scintillator

9-10 orders of magnitude

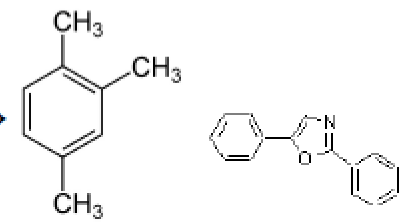
more **radiopure** than anything on Earth

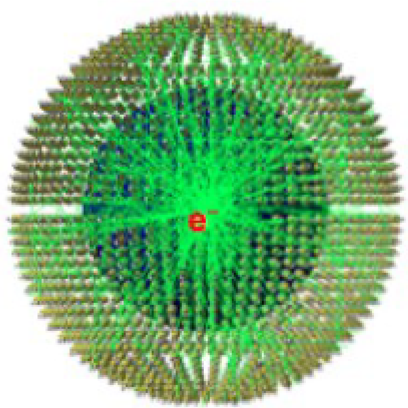
Neutrino detection in Borexino



Neutrinos detected via **elastic scattering** on **electrons**

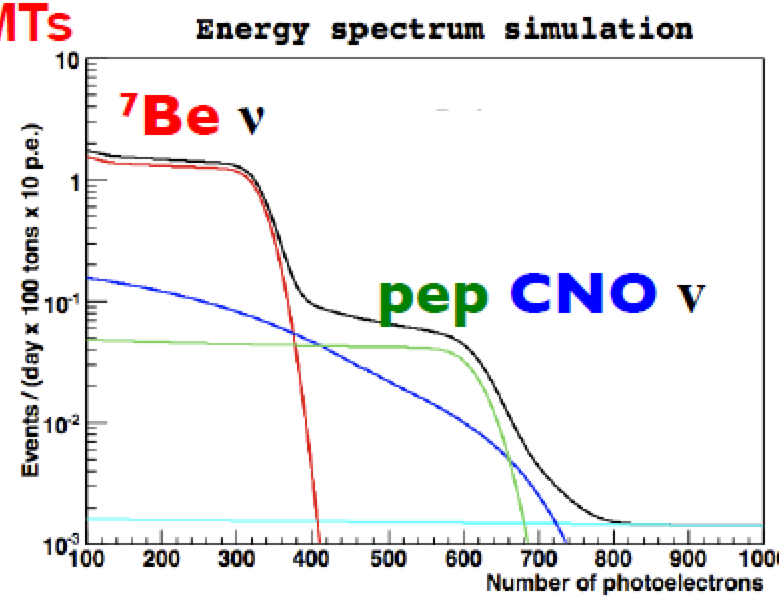
Recoil electron excites **scintillator** → **emission of light**



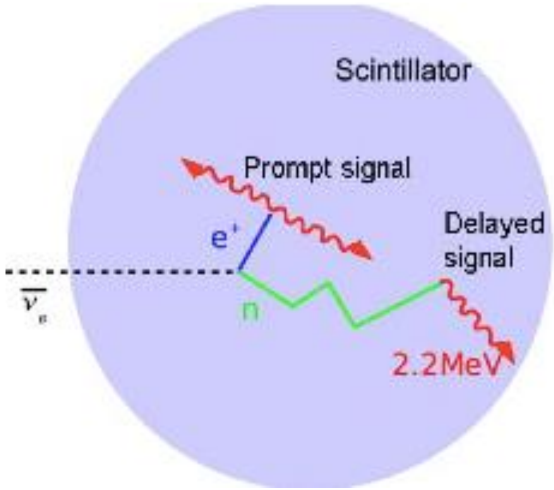


Scintillation light detected by **PMTs**

Number of **hit PMTs**
→ **Energy**
Pattern of **hit PMTs**
→ **position**



Anti-neutrinos detection in Borexino



Coincident delayed event

Prompt $\bar{\nu}_e + p \rightarrow e^+ + n,$

Threshold $E_{thr} = 1.8\ MeV$

Energy of anti-nu

$$E_{\text{prompt}} = E_{\bar{\nu}_e} - 0.784\,\text{MeV}.$$

Delayed (τ ~254 μs) $n + p \rightarrow d + \gamma$

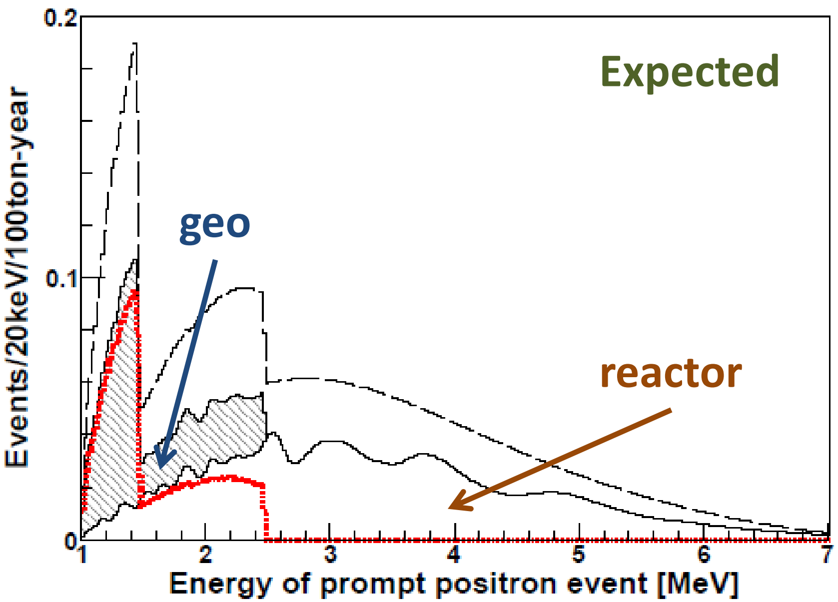
Detected energy: *2.2 MeV*

Time-Spatial **coincidence**: clear **signature** of anti-nu **detection**

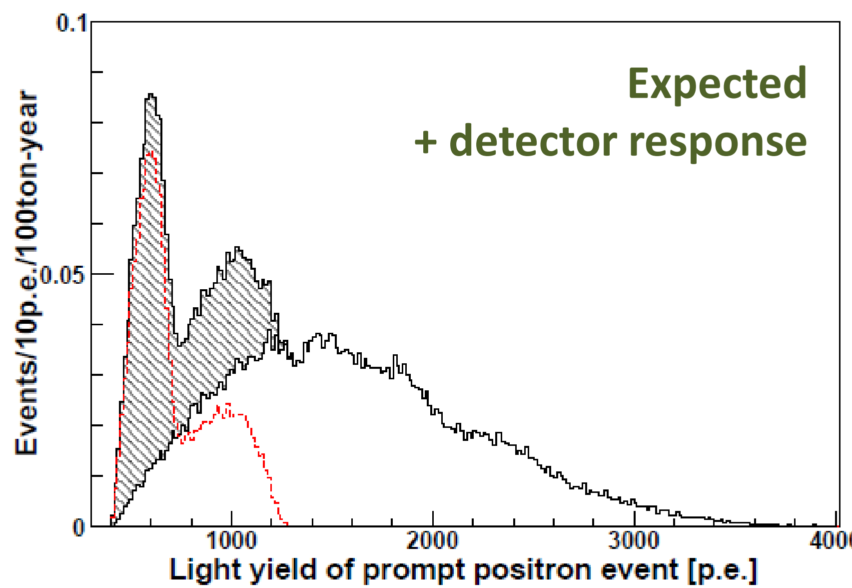
Some anti-nu from **238U** and **232Th** **above energy threshold**

Anti-nu from **40K** **under energy threshold**

Energy Spectrum of anti-neutrinos in Borexino

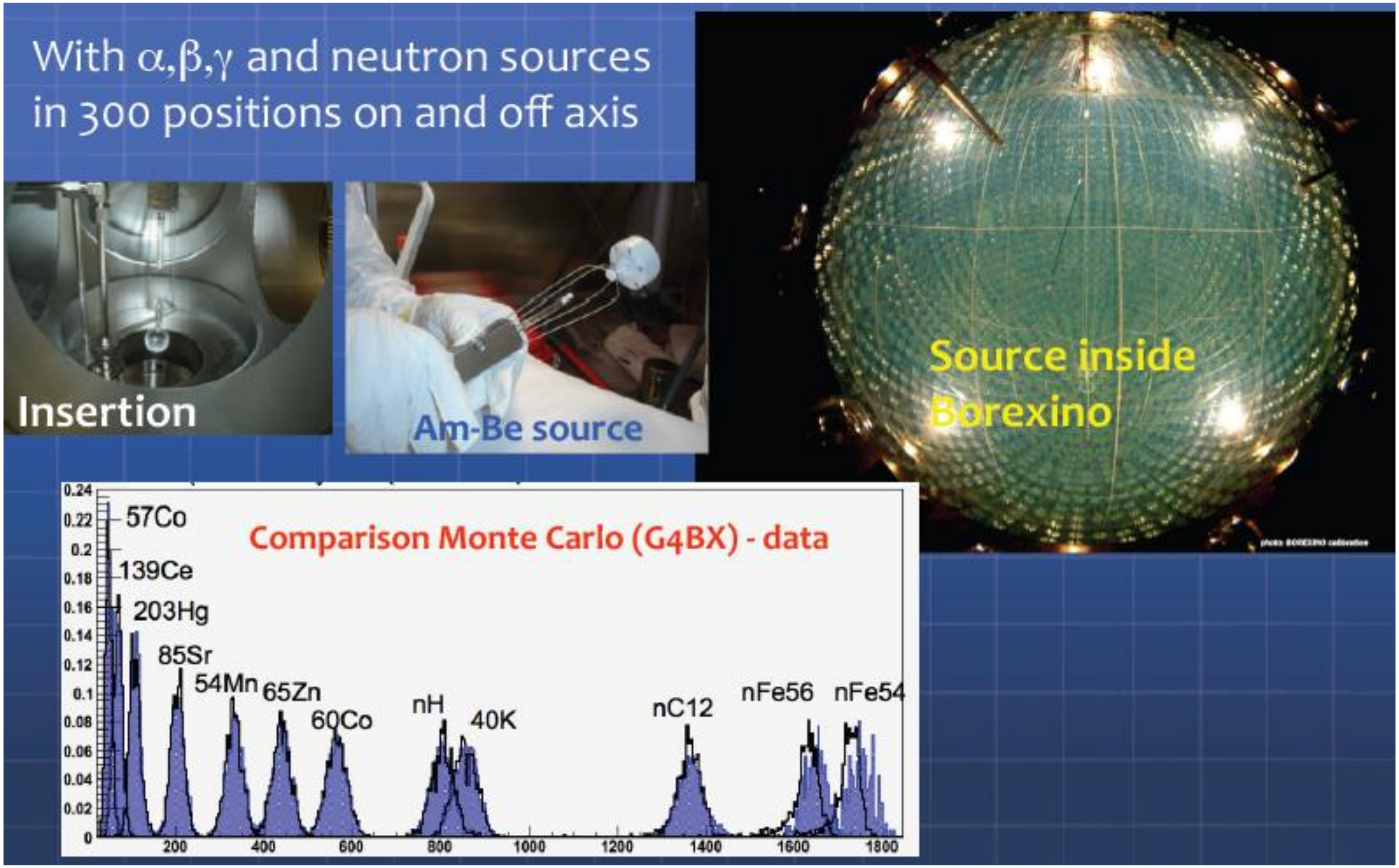


Expected geo-nu rate (BSE):
~2.5 counts per year/100 t



See details in:
*Borexino Collab. PLB **696** (2010) 191-196*
*Borexino Collab. PLB **722** (2013) 295-300*

Borexino Detector response and calibration



Borexino Collab. JINST 7 (2012) P10018

Reactor antineutrinos (1)

Main **background** for geo-nu searches.
In **Italy** there are **NO** active **nuclear** power **plants**,
so this background in **Borexino** is **low**.

$$N_{react} = \sum_{r=1}^{R} \sum_{m=1}^{M} \frac{\eta_m}{4\pi L_r^2} P_{rm} \times$$
$$\times \int dE_{\bar{\nu}_e} \sum_{i=1}^{4} \frac{f_i}{E_i} \phi_i(E_{\bar{\nu}_e}) \sigma(E_{\bar{\nu}_e}) P_{ee}(E_{\bar{\nu}_e}; \hat{\theta}, L_r),$$

To **estimate** the number of **reactor anti-nu** in **Borexino**
we considered **all** 446 nuclear **cores** in the **world**
operating in the period used for the analysis (2007-2012)

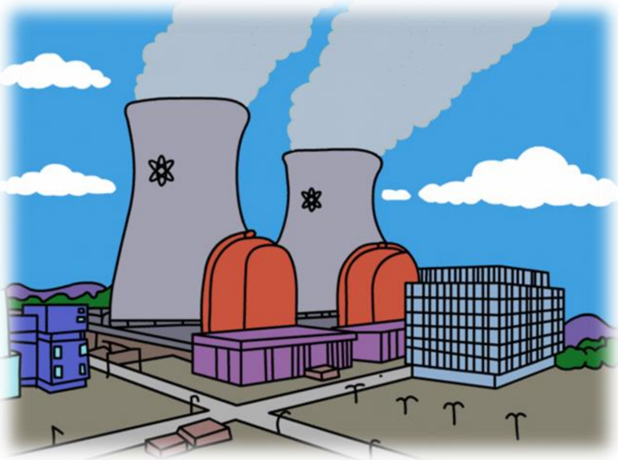
Reactor antineutrinos (2)

We expect in Borexino

S reactor = (90.3 ± 5.2) TNU
N reactor = (33.3 ± 2.4) events

1 TNU = 1 event/year/10^{32} protons
Data analysis exposure: (613 ± 26) ton *year
N protons= $(3.69 \pm 0.16)*10^{31}$

Source	Uncertainty [%]
$\phi(E_{\bar{\nu}})$	3.5
Fuel composition	3.2
θ_{12}	2.3
P_{rm}	2.0
Long–lived isotopes	1.0
E_i	0.6
θ_{13}	0.5
L_r	0.4
$\sigma_{\bar{\nu}p}$	0.4
δm^2	0.03
Total	5.8



*Borexino Collab. PLB **722** (2013) 295-300*

Data Selection

2010: *256 ton* year*, data between December 2007 and December 2009
2013: *616 ton * year*, data between December 2007 and August 2012

Energy cuts

Select geo-nu and reactor-nu **energy region** (slide 8)

Space-Time cuts

Select only **delayed coincidences** (slide 7)
2 consecutive events distance < 1 meter
With time delay between 20-1280 μs

Cosmogenic cuts:

Remove events after a muon crossing Borexino

Pulse shape cuts

Remove alphas

Details in
*Borexino collab. PLB **722** (2013) 295-300*

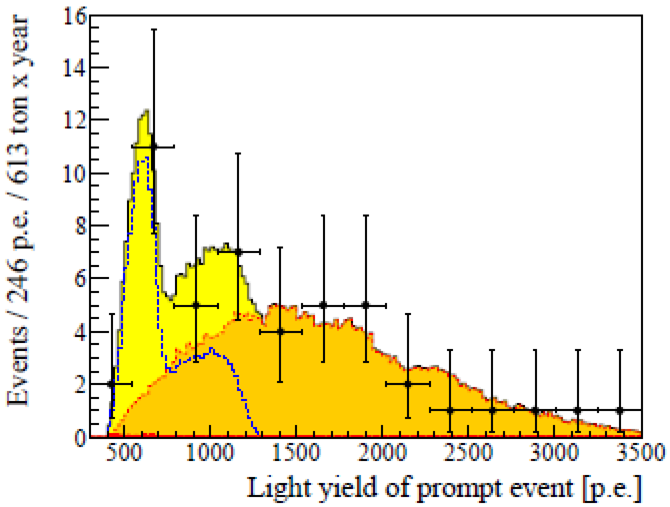
Backgrounds mimicking anti-nu interactions in Borexino

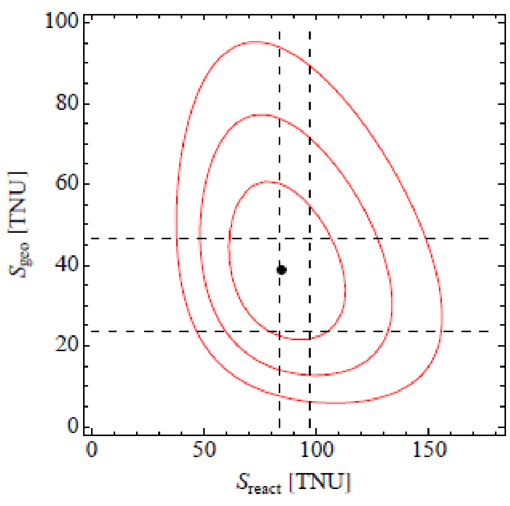
Background source	Events
Cosmogenic ^{9}Li and ^{8}He	0.25 ± 0.18
Fast neutrons from μ in Water Tank (measured)	< 0.07
Fast neutrons from μ in rock (MC)	< 0.28
Non-identified muons	0.080 ± 0.007
Accidental coincidences	0.206 ± 0.004
Time correlated background	0.005 ± 0.012
(γ,n) reactions	< 0.04
Spontaneous fission in PMTs	0.022 ± 0.002
(α,n) reactions in the scintillator [^{210}Po]	0.13 ± 0.01
(α,n) reactions in the buffer [^{210}Po]	< 0.43
TOTAL	0.70 ± 0.18

Conclusion …

Borexino is suited for detecting geo-neutrinos:
low backgrounds, high mass, no nuclear reactor nearby

See my talk *What we found with Borexino*
for the results!
Parallel Section *Mantle and deep Earth*, Jul 26, 14:10





THANK YOU!!!

Milano

Genova

Perugia

APC Paris

Mugiwara

Princeton University

Virginia Tech. University

Dubna JINR (Russia)

Kurchatov Institute (Russia)

Munich (Germany)

Heidelberg (Germany)

Jagiellonian U. Cracow (Poland)