# THE LATEST RESULTS ON SOLAR NEUTRINOS FROM BOREXINO

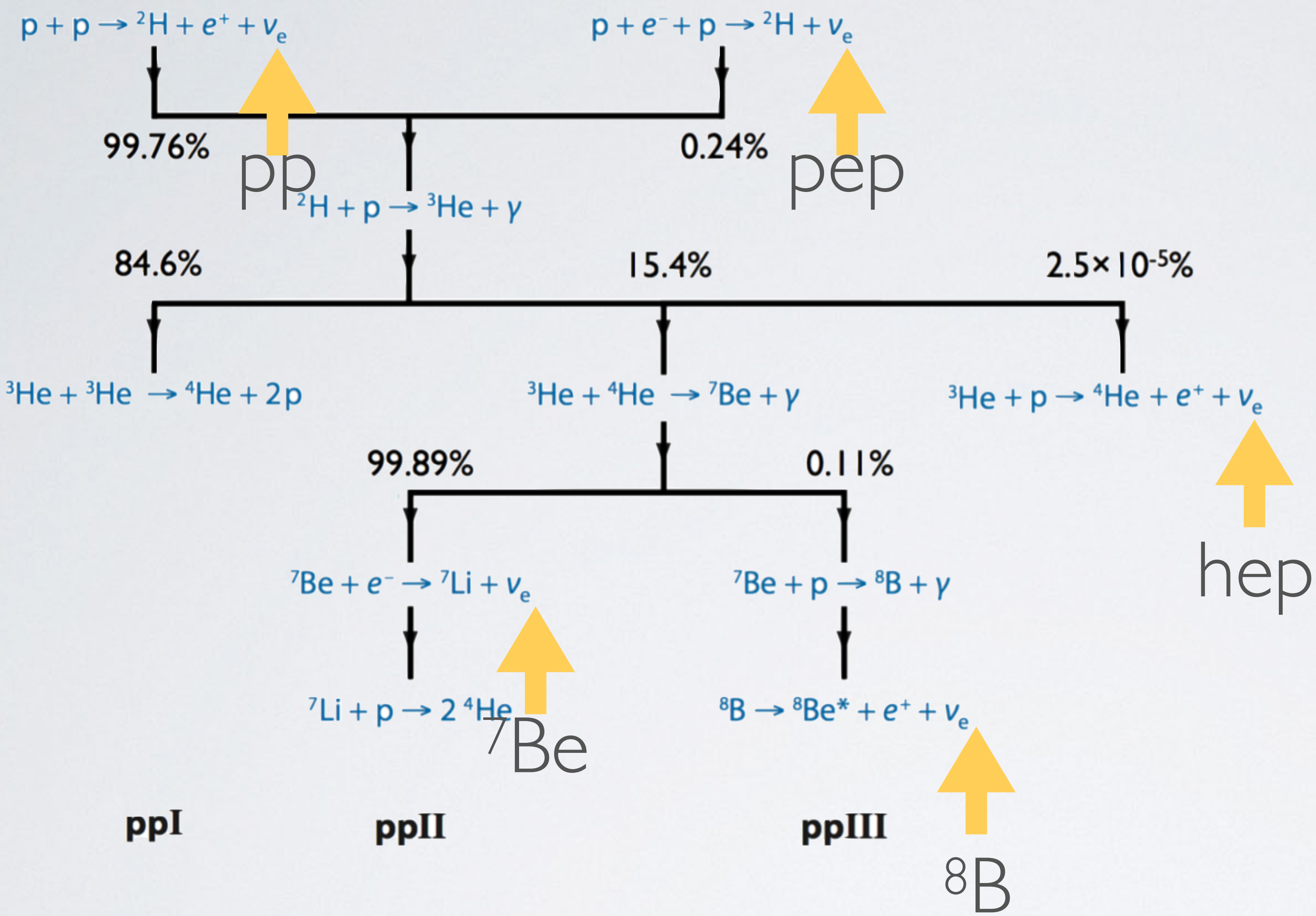
Alessio Caminata
of behalf of the Borexino collaboration

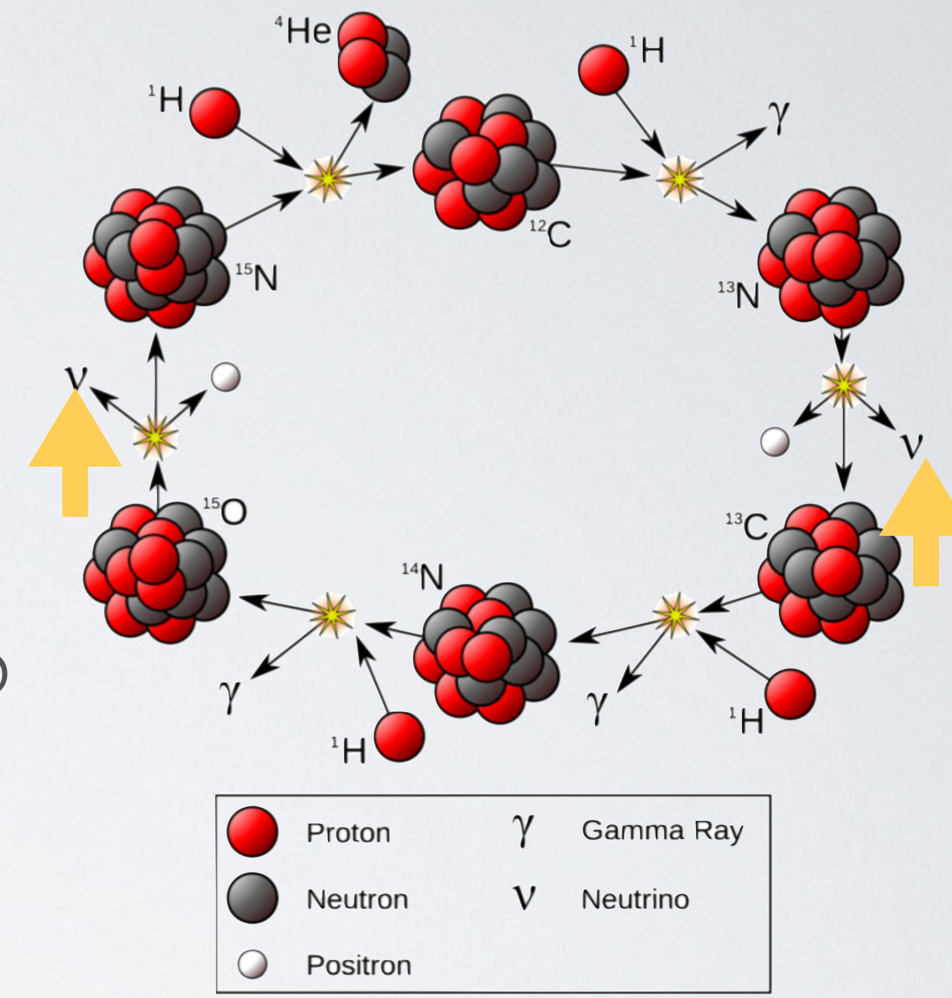
Lake Louise Winter Institute 2018

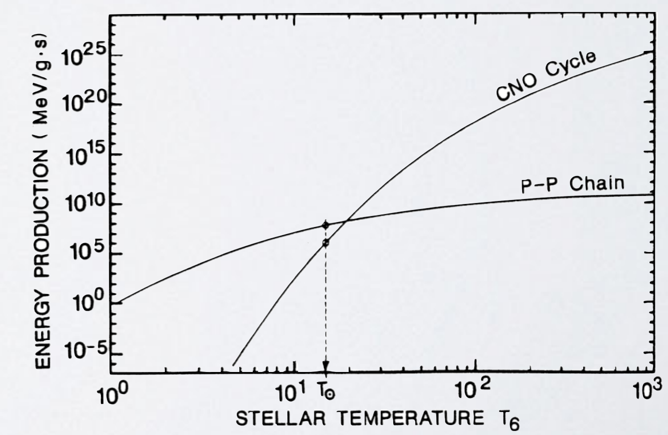
# OUTLINE

- Very short introduction to neutrinos from the Sun
- The Borexino experiment
- Global spectral fit of the solar neutrino spectrum
- Update on $^{8}B$ measurement

# NUCLEAR FUSION IN THE SUN

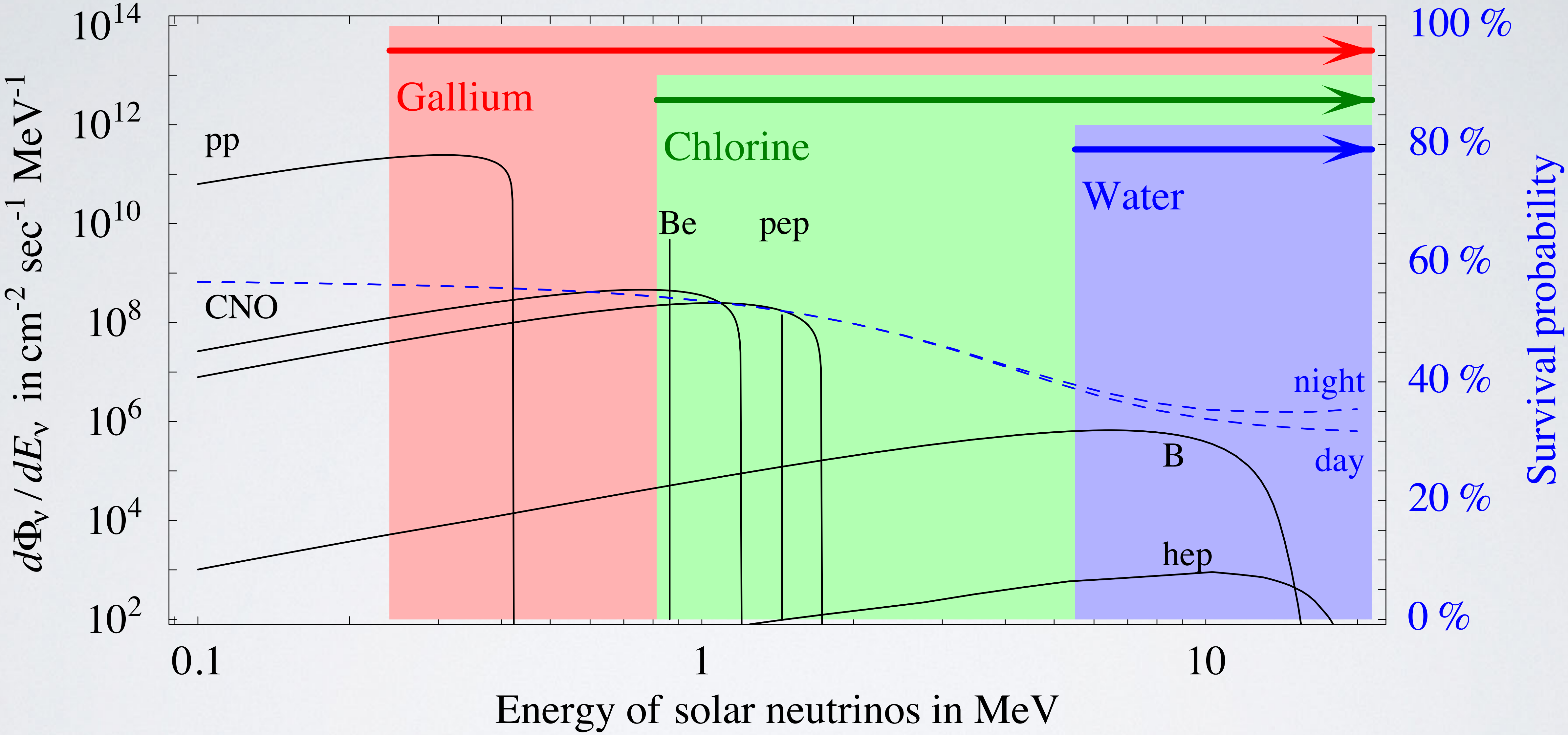



- pp-cycle: ~ 99% of energy
- CNO-cycle ~1%, never observed until now

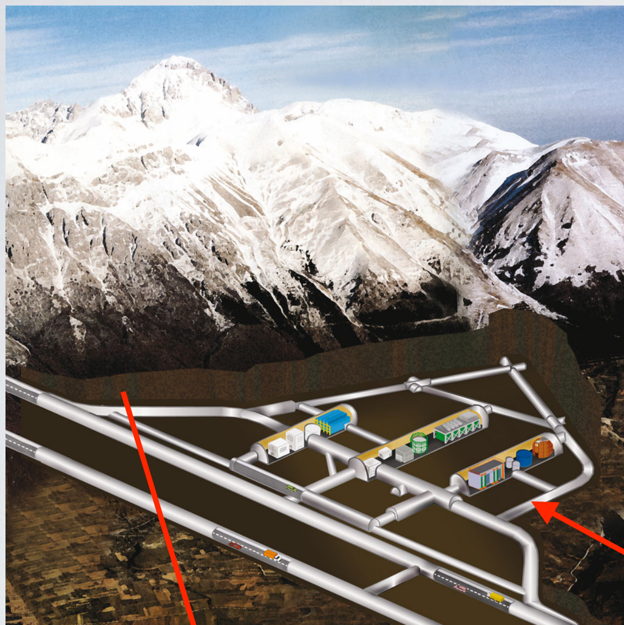
# SOLAR NEUTRINO OSCILLATION

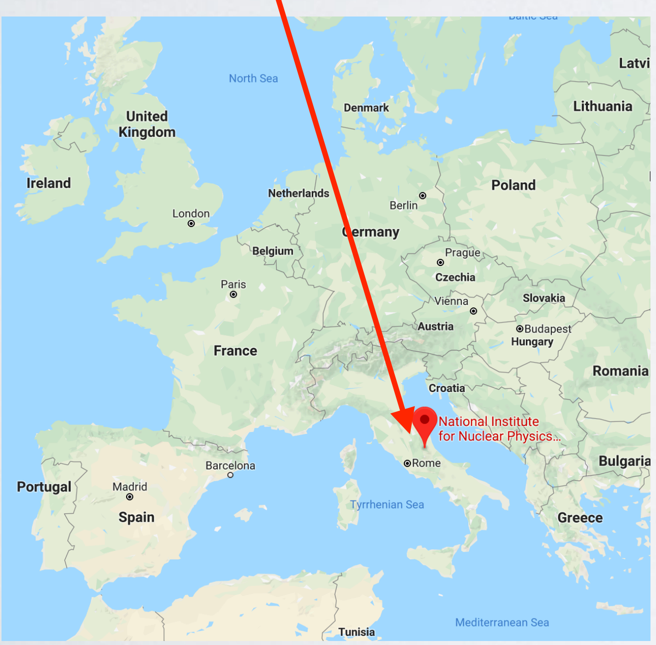



arXiv:hep-ph/0606054v3

# THE BOREXINO EXPERIMENT

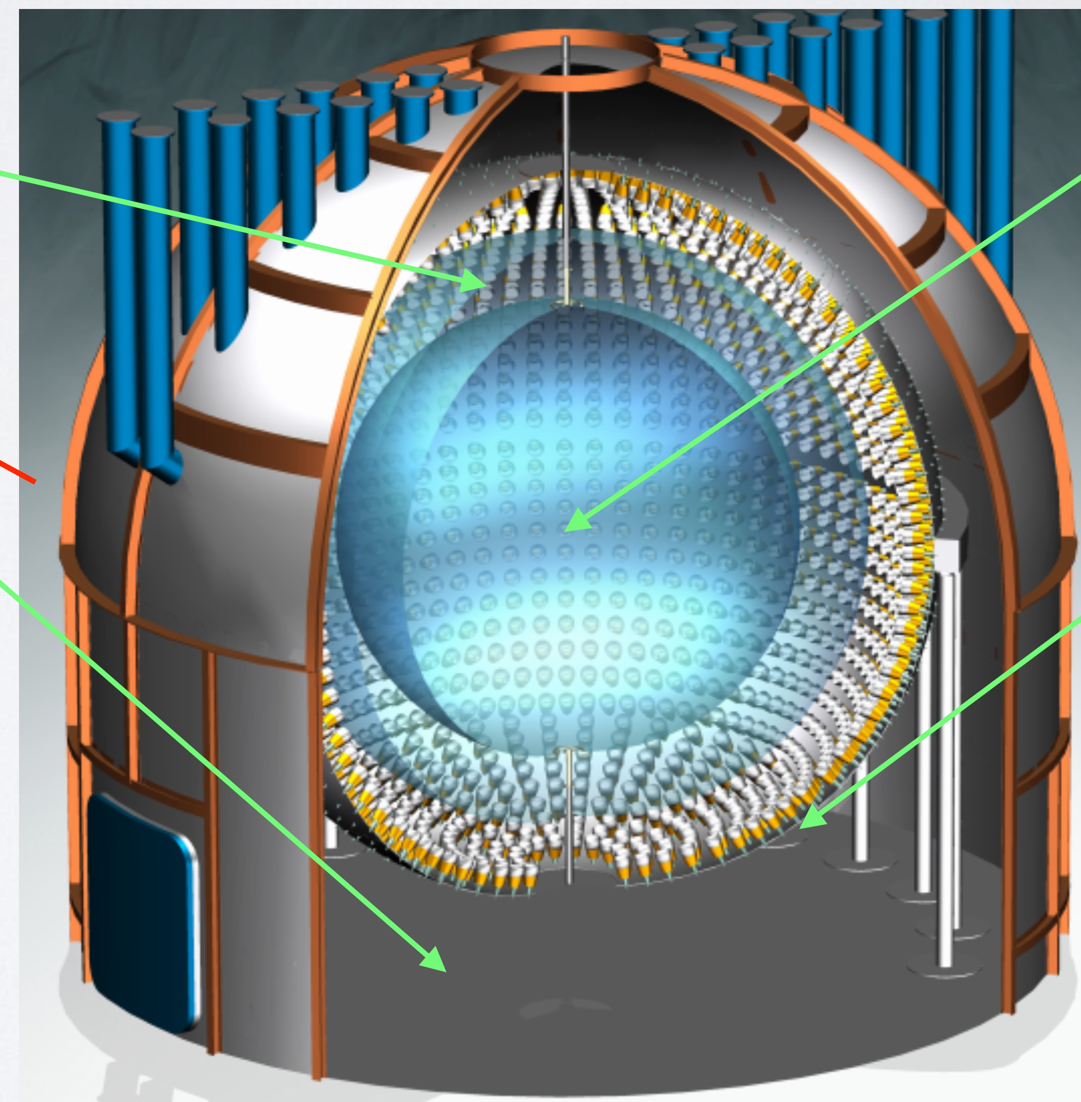
φ (μ)=3*10$^{-4}$ m$^{-2}$s$^{-1}$
3400 m.w.e.






Liquid buffer ~1kton of PC+DMP

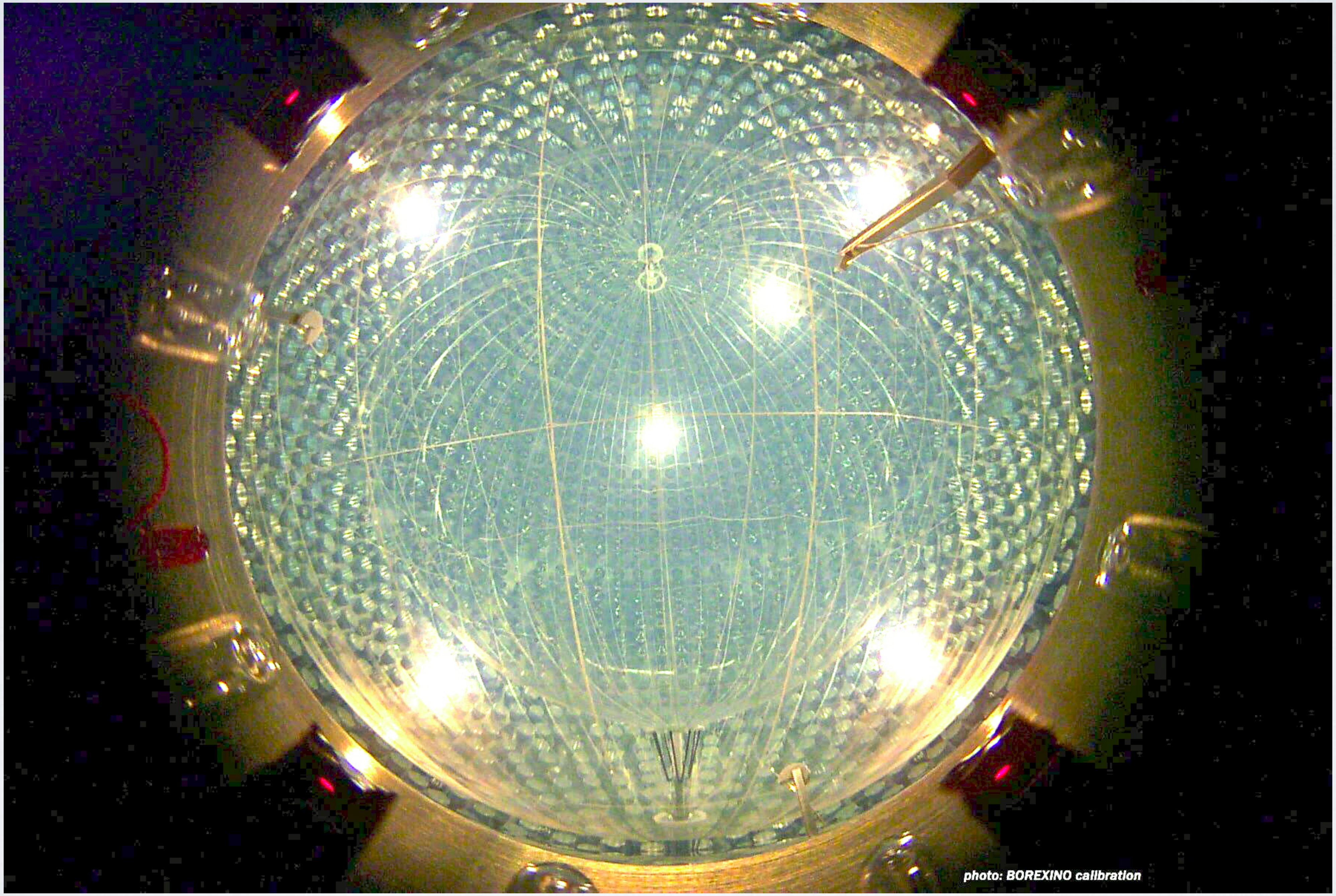
Water Cherenkov muon veto



270 tons of liquid scintillator

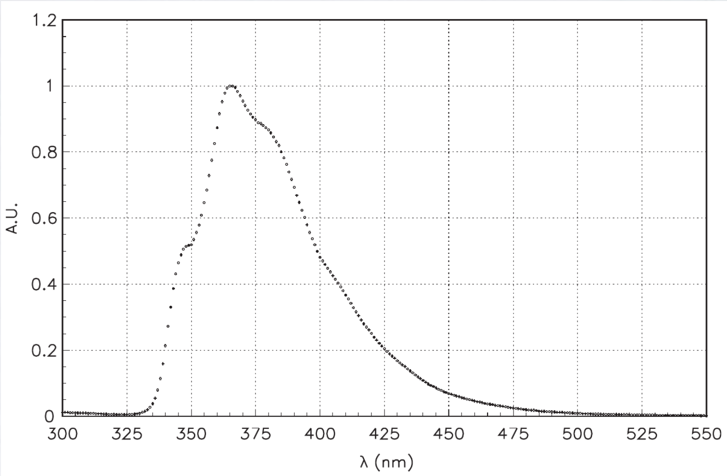
2220 PMTs

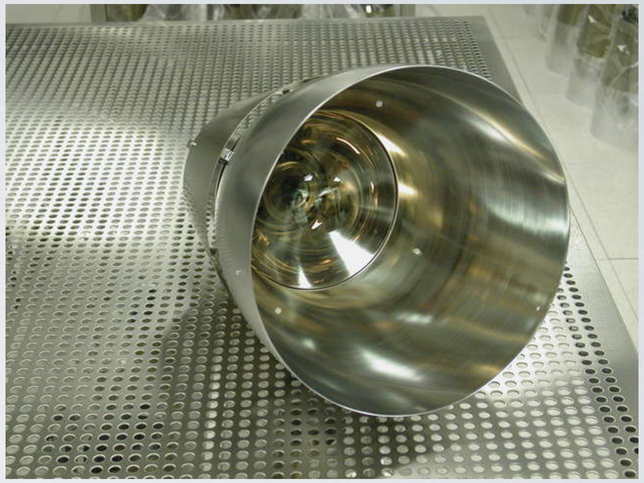
# THE BOREXINO EXPERIMENT

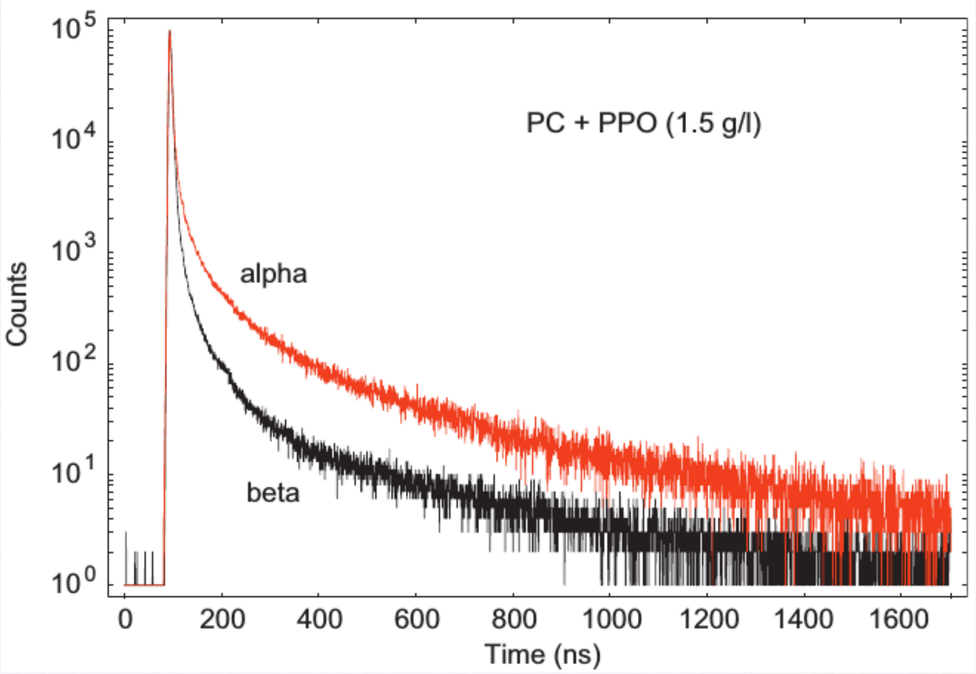


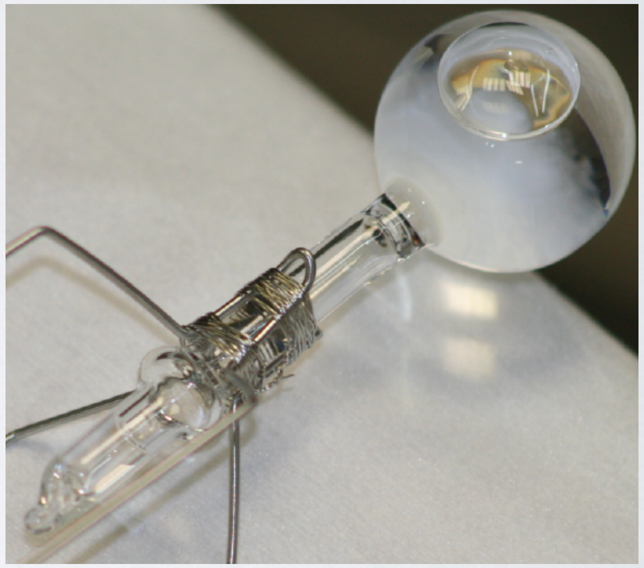
# SCINTILLATION

- Reconstruction of:
  - Event position
  - Energy
  - Particle kind
- Isotrope light:
  - No directionality
- Scintillation properties investigated using calibration sources





# BOREXINO SOLAR MEASUREMENTS

$^{85}Kr$: from 30 to 6 cpd/100 tons
$^{210}Bi$: from 41 to 17 cpd/100 tons
$^{232}Th/^{238}U$: ~$10^{-19}$ cpd/100 tons

| Phase I | Purification | Phase II |
|---|---|---|

2007 — 2010 — 2012

**Measurements:**

- $^{7}Be$
- $^{8}B$
- pep

**Limits:**

- CNO,
- ν magnetic moment

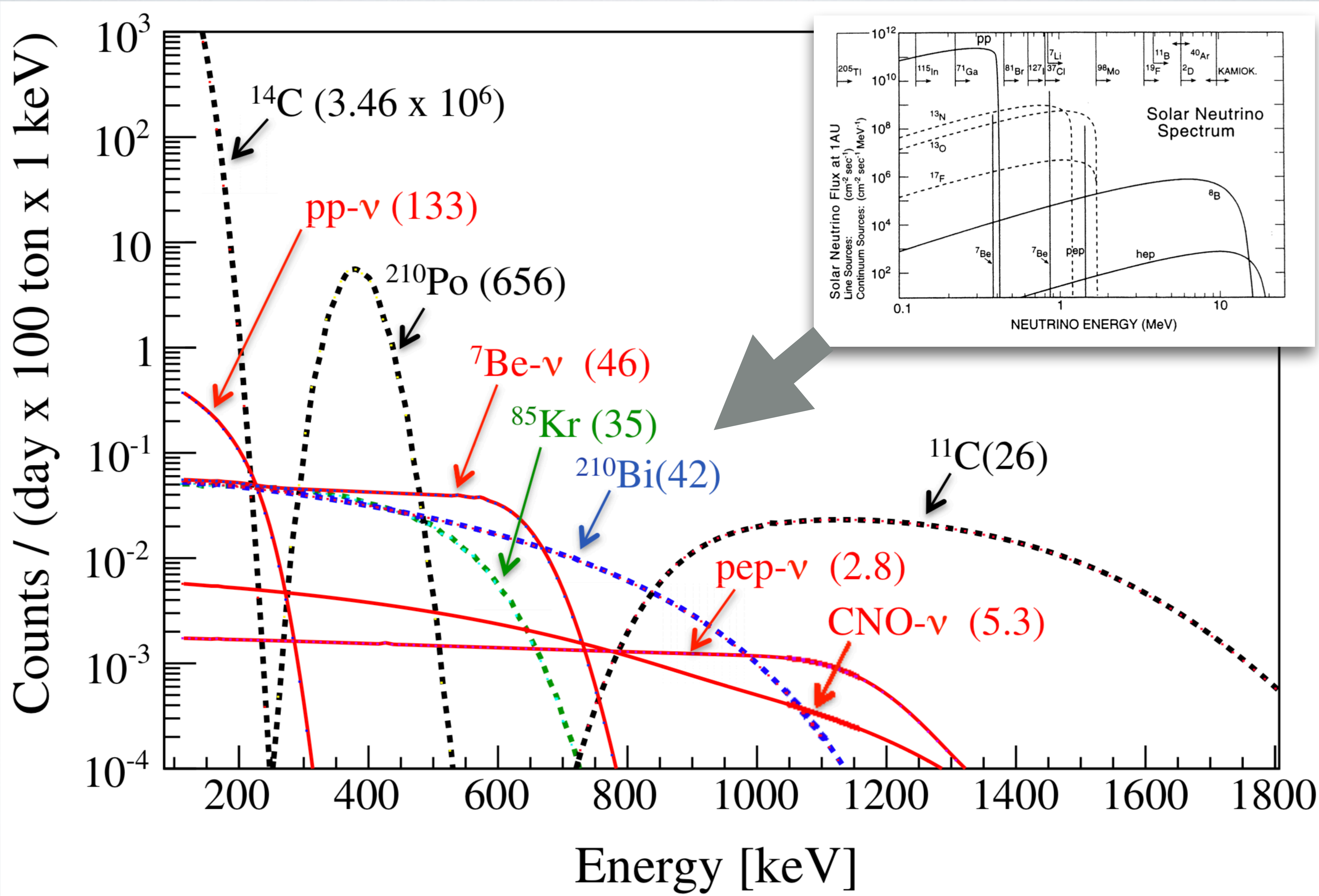
**Measurements:**

- pp
- First global spectral fit
- $^{8}B$ update
- $^{7}Be$ seasonal modulation

**Limits:**

- CNO,
- ν magnetic moment

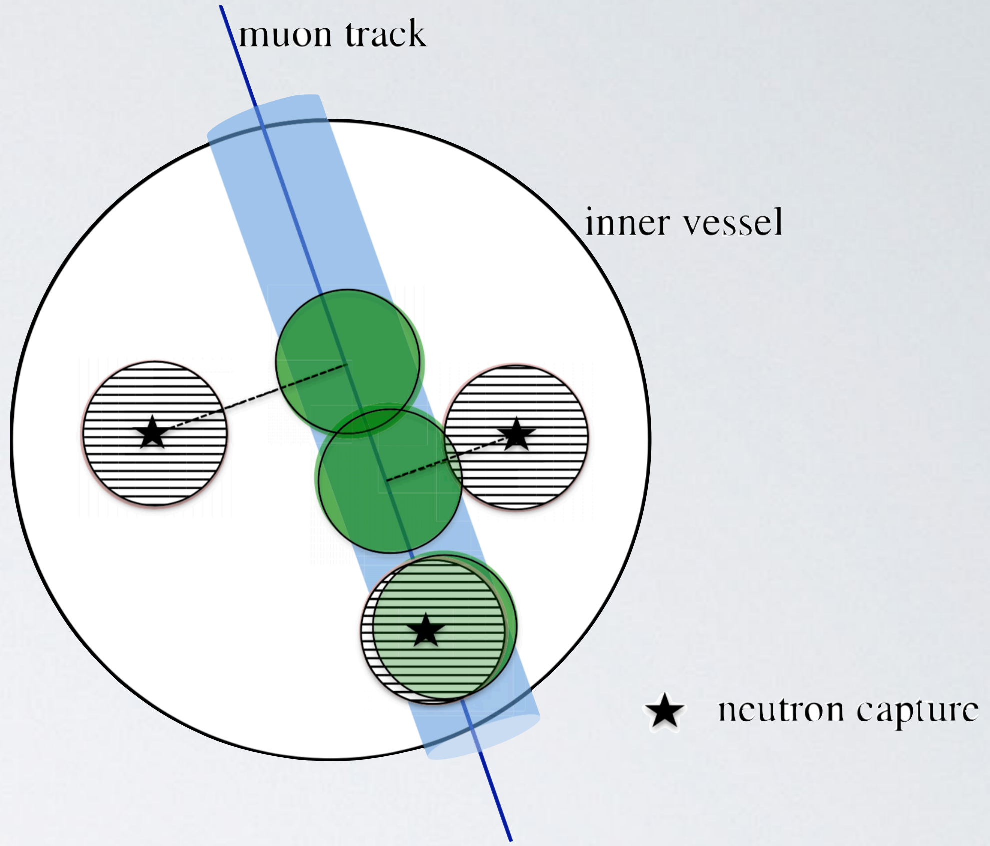
# SIGNAL IN BOREXINO



# GLOBAL SPECTRAL FIT

Analysis key parameters:

- 1291.51 days, (0.19-2.93) MeV
- $^{11}C$ decay tagging via three fold coincidence (TFC)
- e+/e- pulse shape discrimination
- Precise Monte Carlo simulation
  Astrop. Phys. 97 (2018) 136 -159
- Accurate analytical model of the detector response

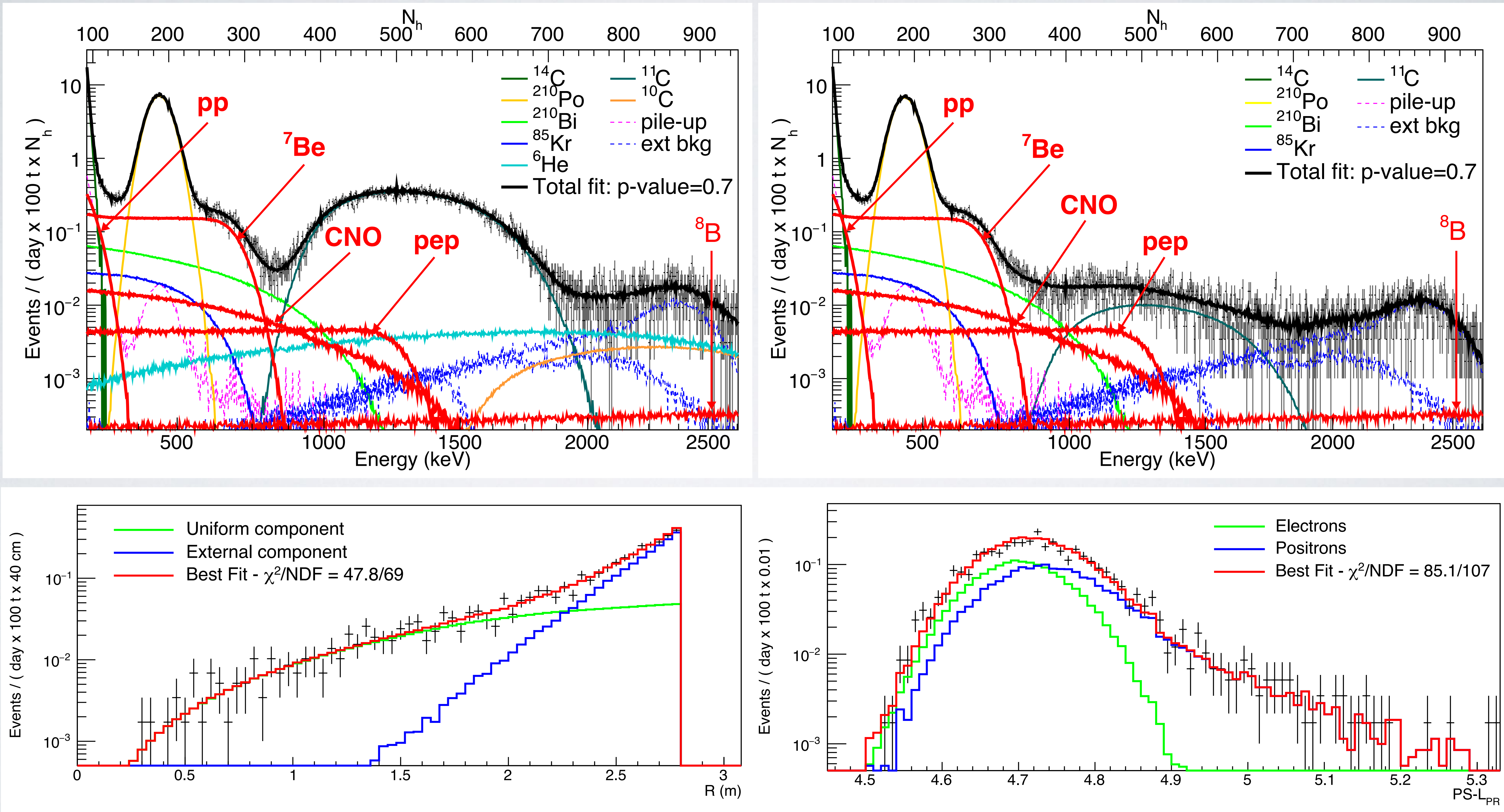



$\mu + {}^{12}C \rightarrow \mu + {}^{11}C + n$

$^{11}C \rightarrow {}^{11}B + e^+ + \nu_e$ $\quad \tau \sim 30$ min

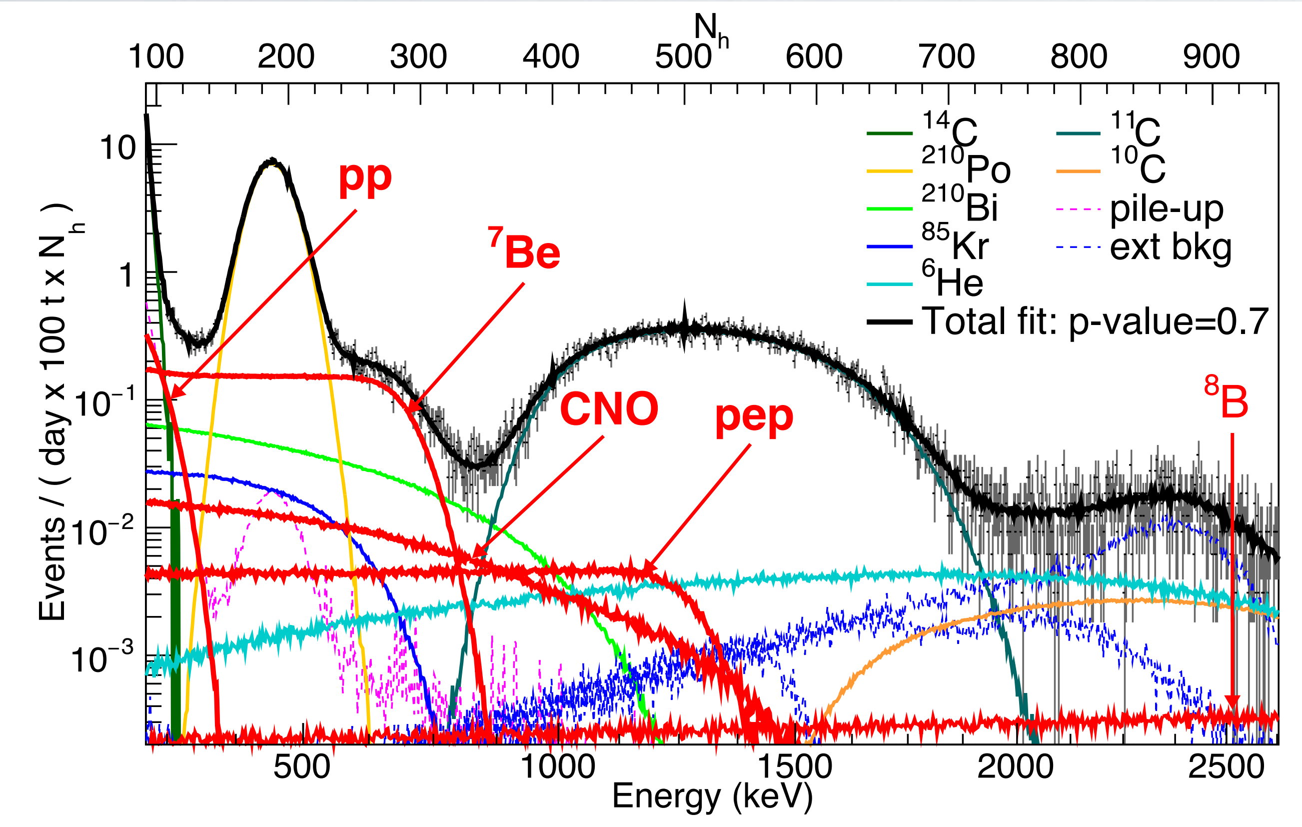
$n + p \rightarrow d + \gamma$ $\quad \tau \sim 0.26$ msec

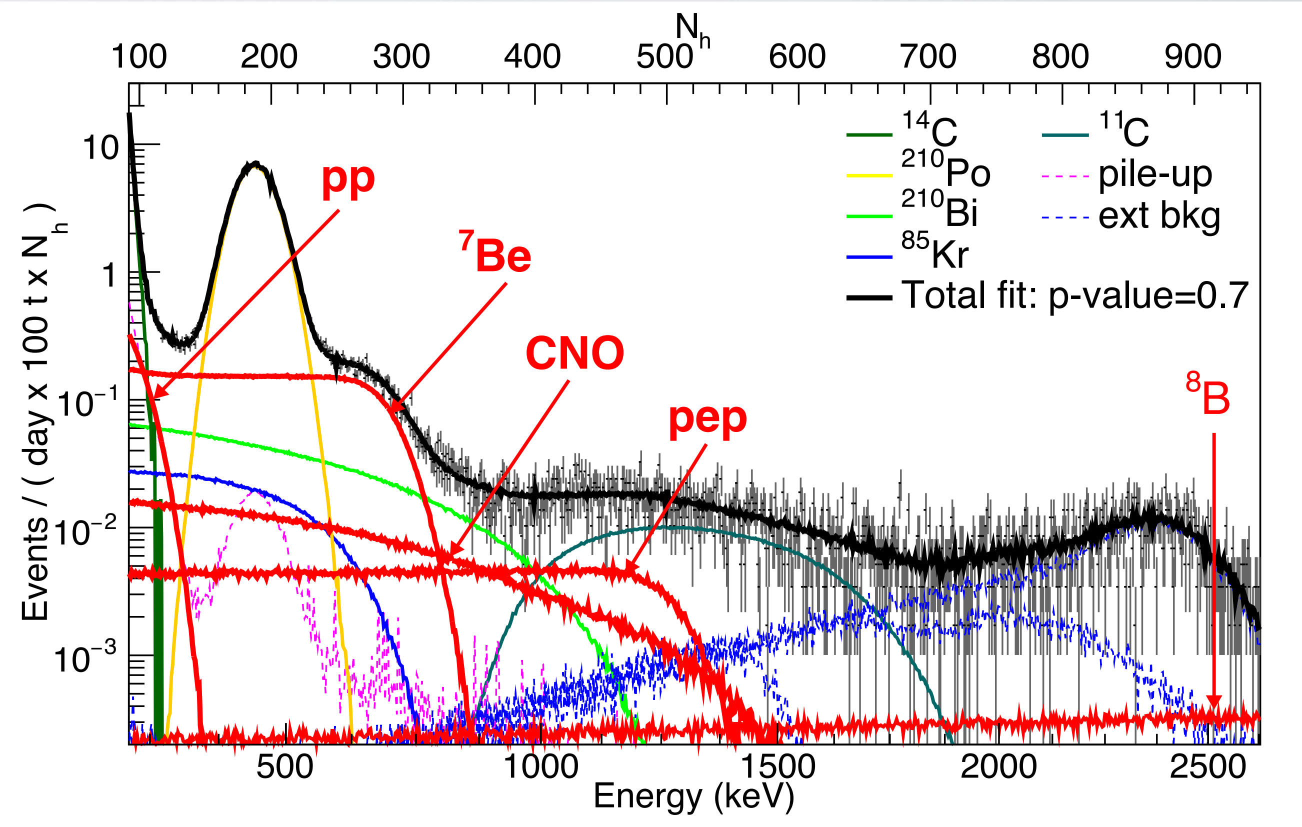
# GLOBAL SPECTRAL FIT




https://arxiv.org/abs/1707.09279

# GLOBAL SPECTRAL FIT




$$rate(pp) = 134 \pm 10\,(stat)\,^{+6}_{-10}\,(sys)\,cpd/100\,t$$

$$rate(^7Be) = 48.3 \pm 1.1\,(stat)\,^{+0.4}_{-0.7}\,(sys)\,cpd/100\,t$$

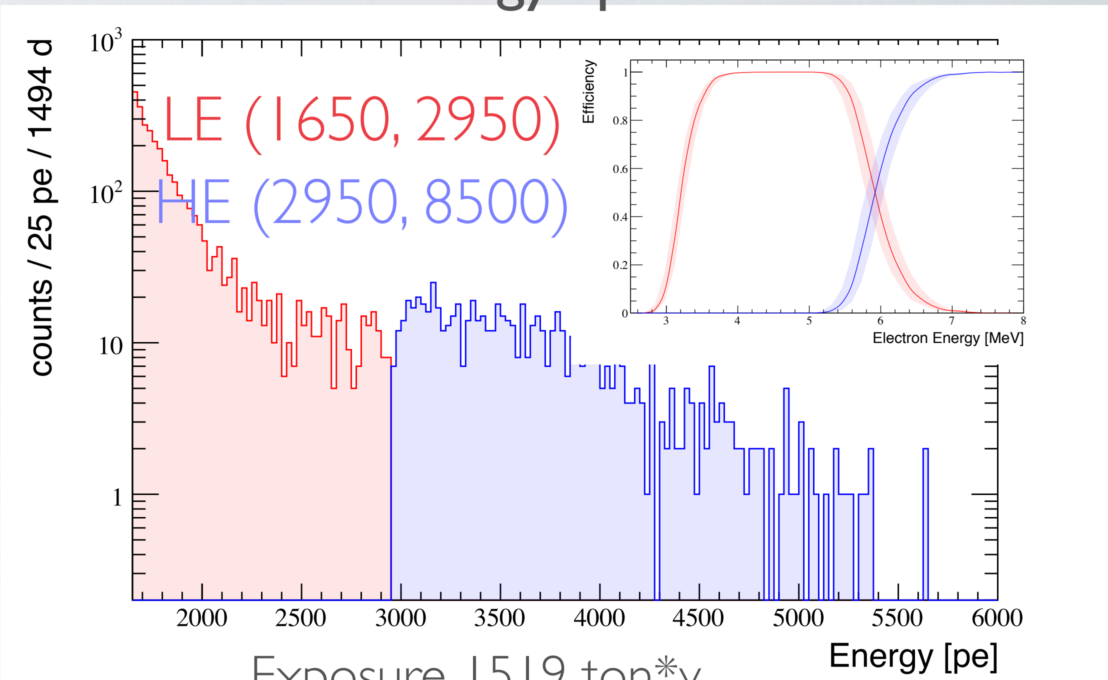
$$rate(pep) = 2.43 \pm 0.36\,(stat)^{+0.15}_{-0.22}\,(sys)\,cpd/100\,t$$

https://arxiv.org/abs/1707.09279

# NEUTRINOS FROM $^{8}$B DECAY

- Energy spectrum divided into two energy region with different backgrounds
- Energy threshold set to 3.2 MeV (50% efficiency) to reject 2.614 MeV γ-rays

Bx energy spectrum




Exposure 1519 ton*y

Applied cuts

Neutron cut following μ

Fast cosmogenics cut

$^{10}$C cut

$^{214}$Bi-Po cut

LE

8B solar-ν

Neutron captures

$^{208}$Tl bulk, emanation and surface

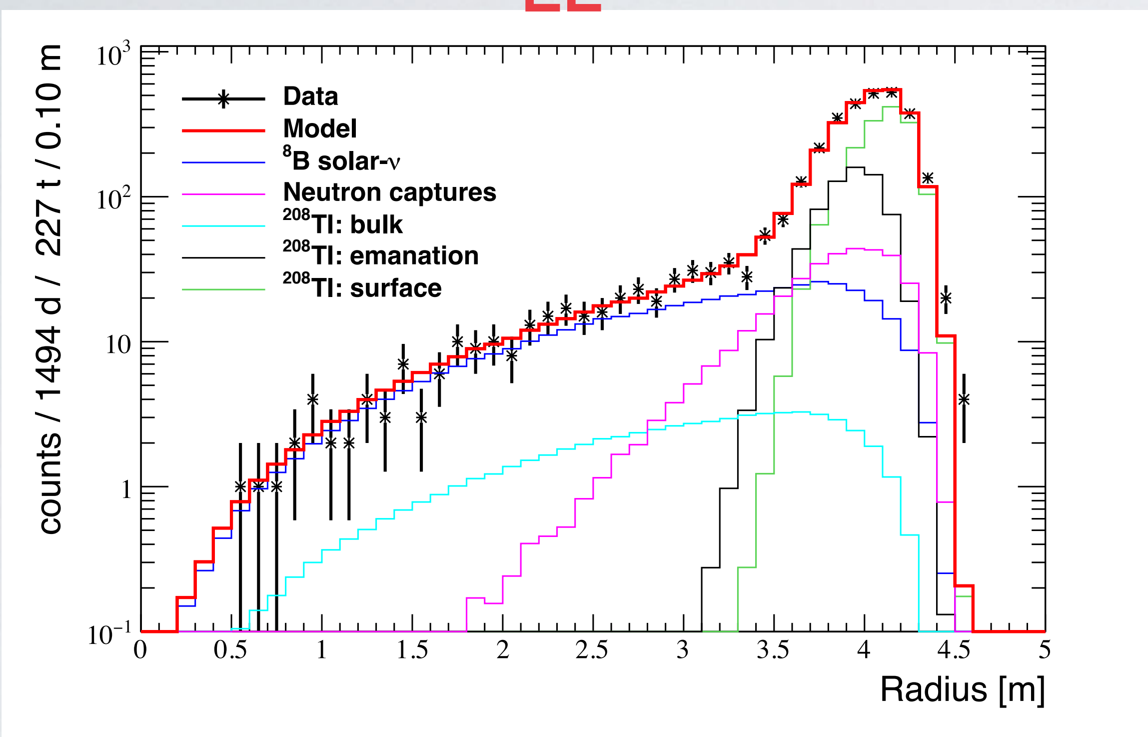
HE

8B solar-ν

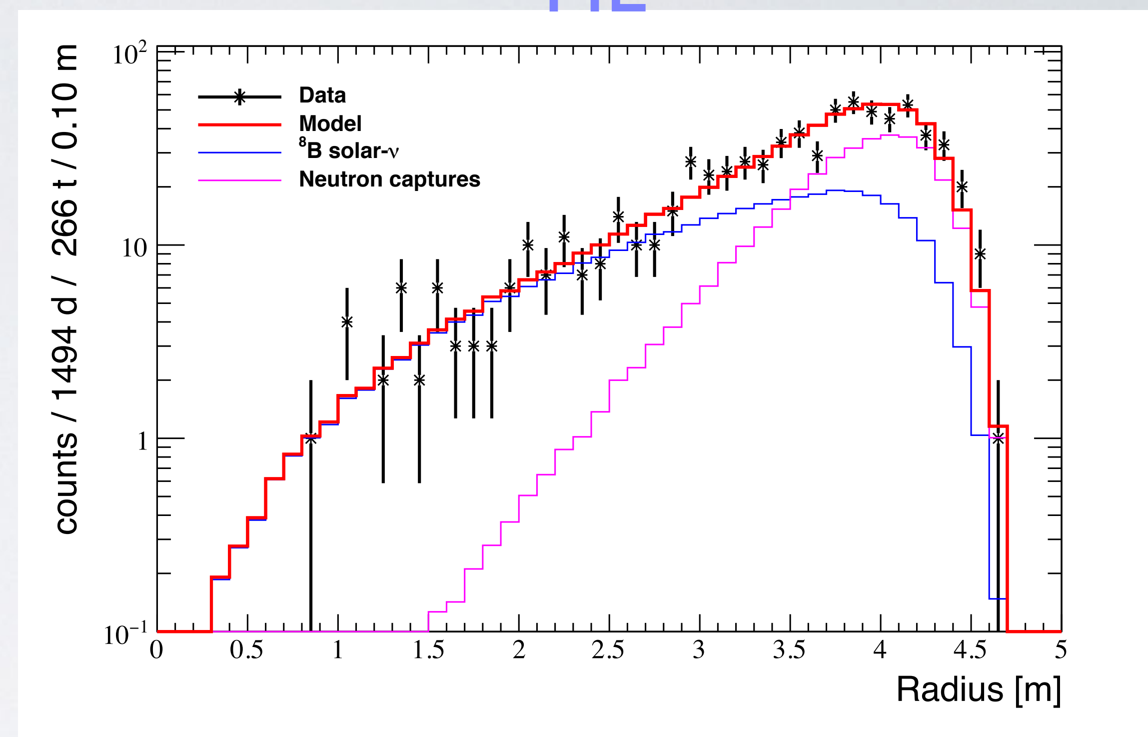
Neutron captures

# NEUTRINOS FROM $^{8}$B DECAY

LE




HE



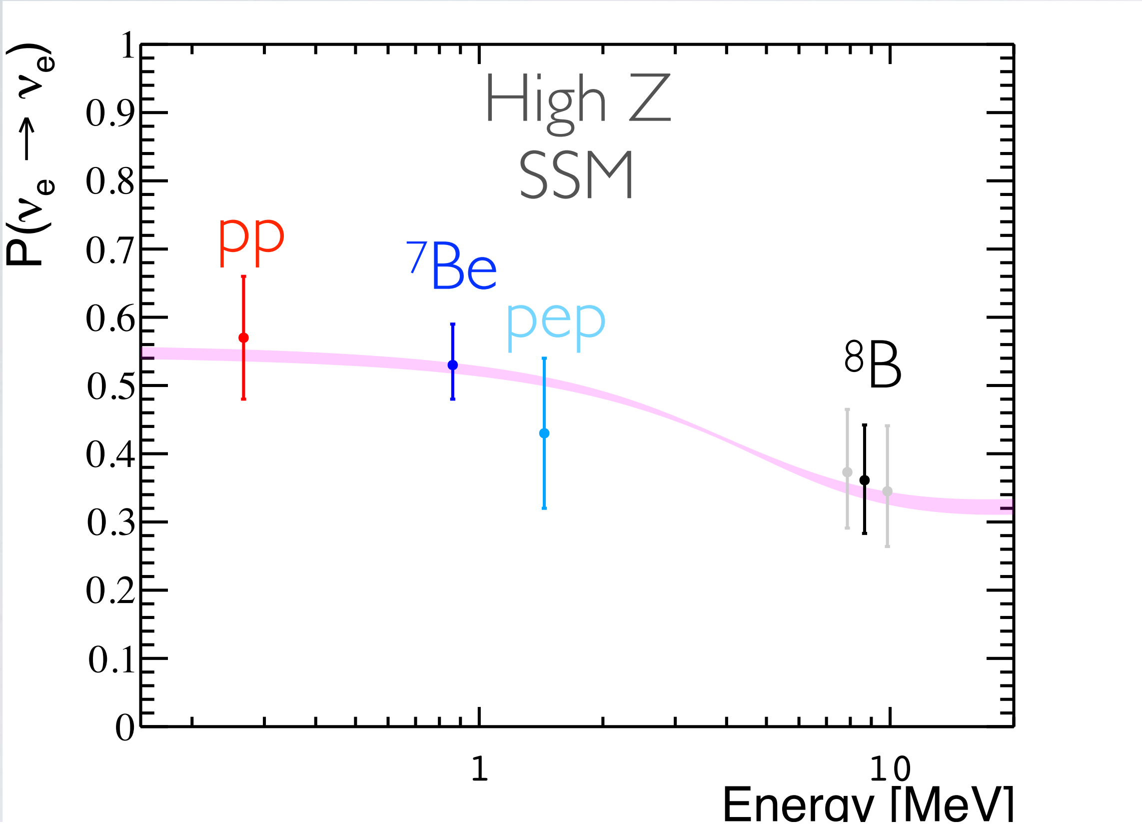

$$R_{LE} = \quad 0.133^{+0.013}_{-0.013}\,(stat)\,^{+0.003}_{-0.003}\,(syst)\ \mathrm{cpd}/100\,\mathrm{t},$$

$$R_{HE} = \quad 0.087^{+0.08}_{-0.010}\,(stat)\,^{+0.005}_{-0.005}\,(syst)\ \mathrm{cpd}/100\,\mathrm{t},$$

$$R_{LE+HE} = \quad 0.220^{+0.015}_{-0.016}\,(stat)\,^{+0.006}_{-0.006}\,(syst)\ \mathrm{cpd}/100\,\mathrm{t}$$

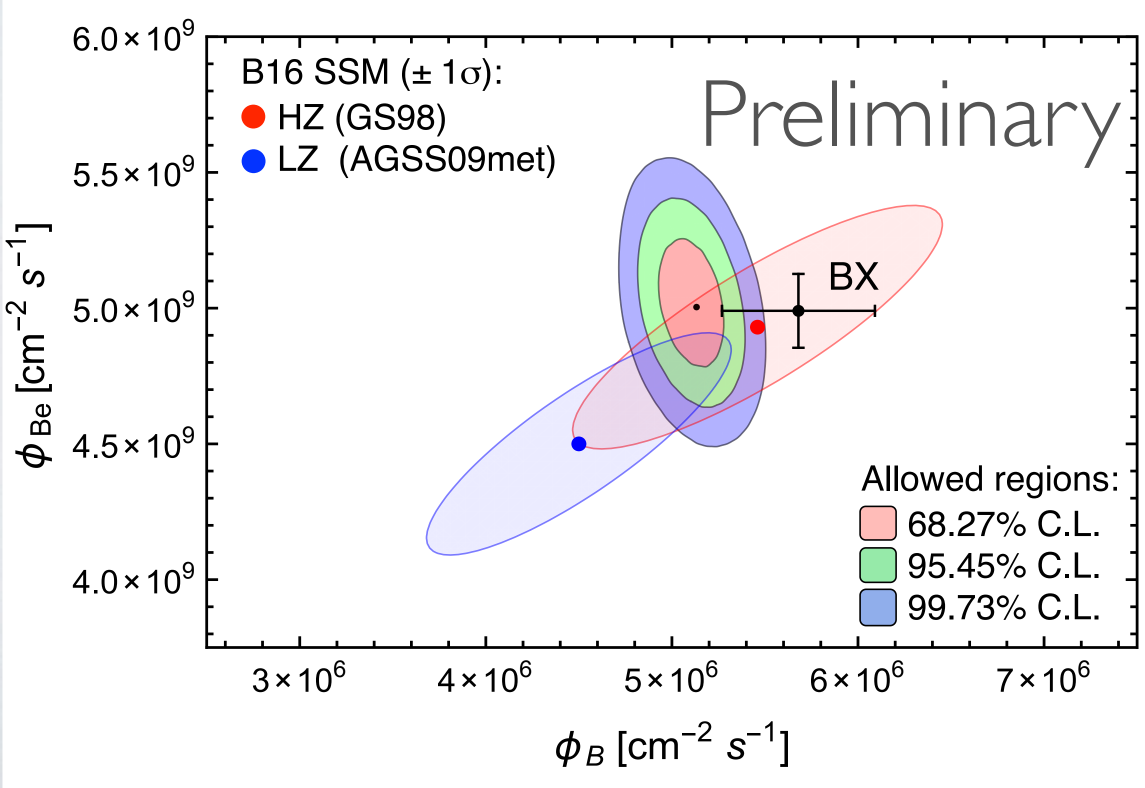
https://arxiv.org/abs/1709.00756

# RESULTS & GLOBAL ANALYSIS




Borexino results in good agreement with the MSW-LMA schema

Thanks to it's energy threshold, Borexino is able to measure all the neutrinos emitted by the pp chain (but really rare hep)




<u>Updated global analysis</u>:

$^7$Be+$^8$B from Borexino

Radiochemical

SuperK

SNO

KamLAND

# CONCLUSIONS

- Using improved MC and analytical description of the detector, a simultaneous measurement of the $^{7}Be$ pp and pep $\nu$ fluxes has been performed
- Exploiting the longer exposure and a better understanding of the detector's response at large radii, the measurement on 8B $\nu$ has been improved

# BOREXINO COLLABORATION

UNIVERSITÀ DEGLI STUDI DI MILANO

INFN Istituto Nazionale di Fisica Nucleare

LNGS

PRINCETON UNIVERSITY

UNIVERSITÀ DEGLI STUDI DI GENOVA

NATIONAL RESEARCH CENTER "KURCHATOV INSTITUTE"

St. Petersburg Nuclear Physics Inst.

TUM Technische Universität München

University of Houston

JAGIELLONIAN UNIVERSITY IN KRAKÓW

JÜLICH FORSCHUNGSZENTRUM

Virginia Tech

JG|U JOHANNES GUTENBERG UNIVERSITÄT MAINZ

UHH Universität Hamburg

SKOBELTSYN INSTITUTE OF NUCLEAR PHYSICS LOMONOSOV MOSCOW STATE UNIVERSITY

University of Massachusetts Amherst 1863

Joint Institute for Nuclear Research

GSSI GRAN SASSO SCIENCE INSTITUTE CENTER FOR ADVANCED STUDIES Istituto Nazionale di Fisica Nucleare

Università degli Studi di Ferrara

The University of California UCLA

TECHNISCHE UNIVERSITÄT DRESDEN

APC

Studium Generale Civitatis Perusii

POLITECNICO MILANO 1863


Thank you for your attention