Invisibles18 School – Burghausen, Germany – 28 Aug to 1 Sep 2018

elusives neutrinos, dark matter & dark energy physics

Solar neutrinos with Borexino detector: future perspectives

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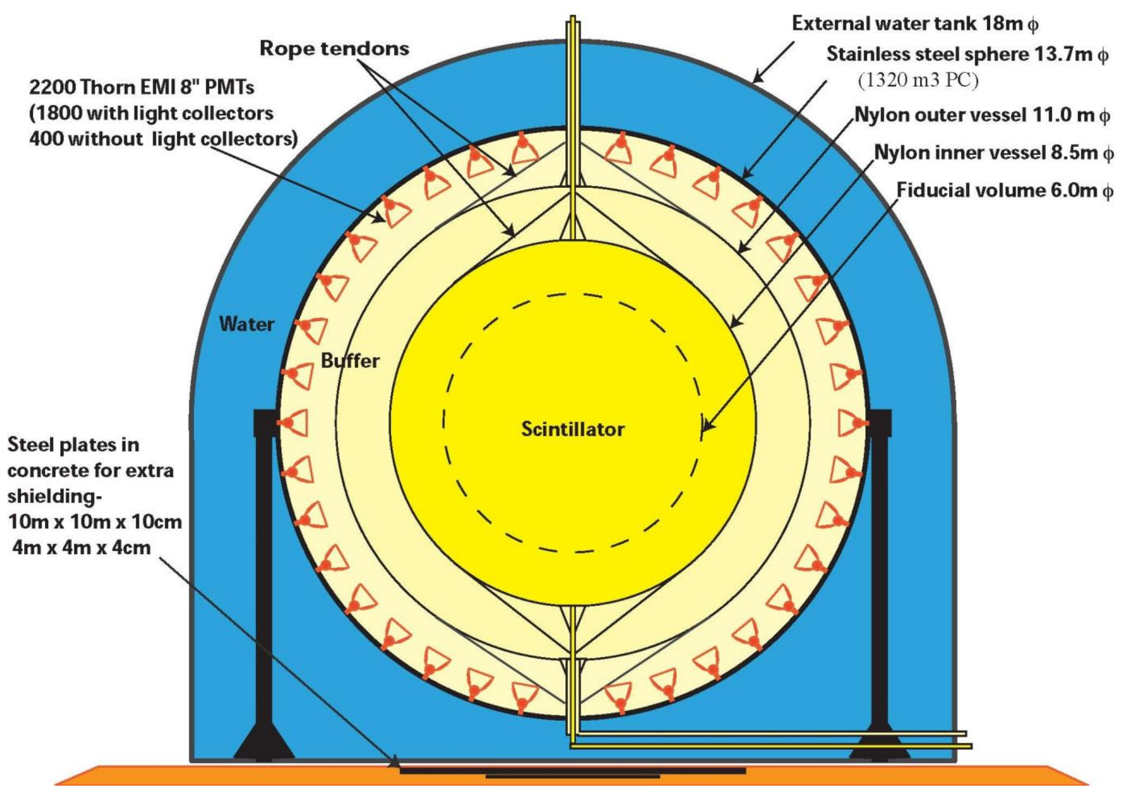
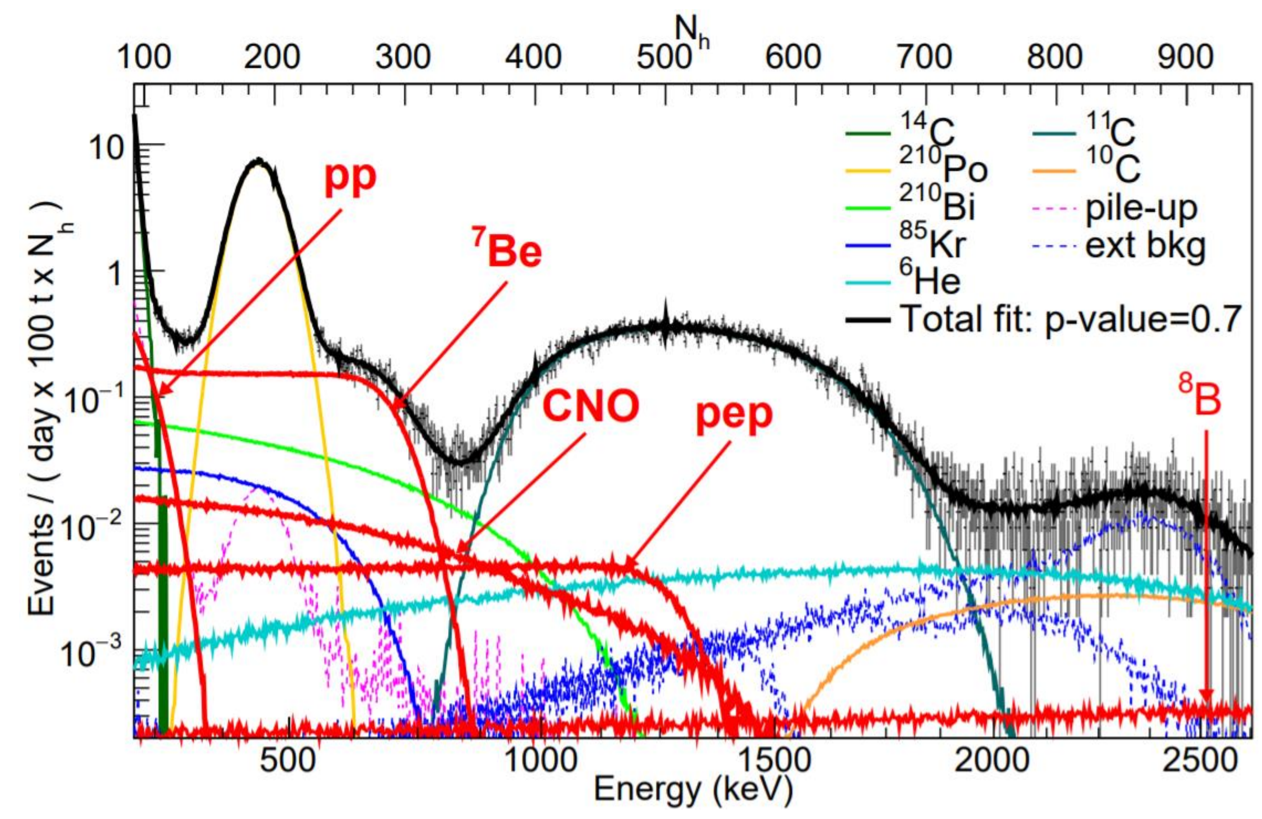
SOLAR NEUTRINOS AND BOREXINO

The Borexino detector



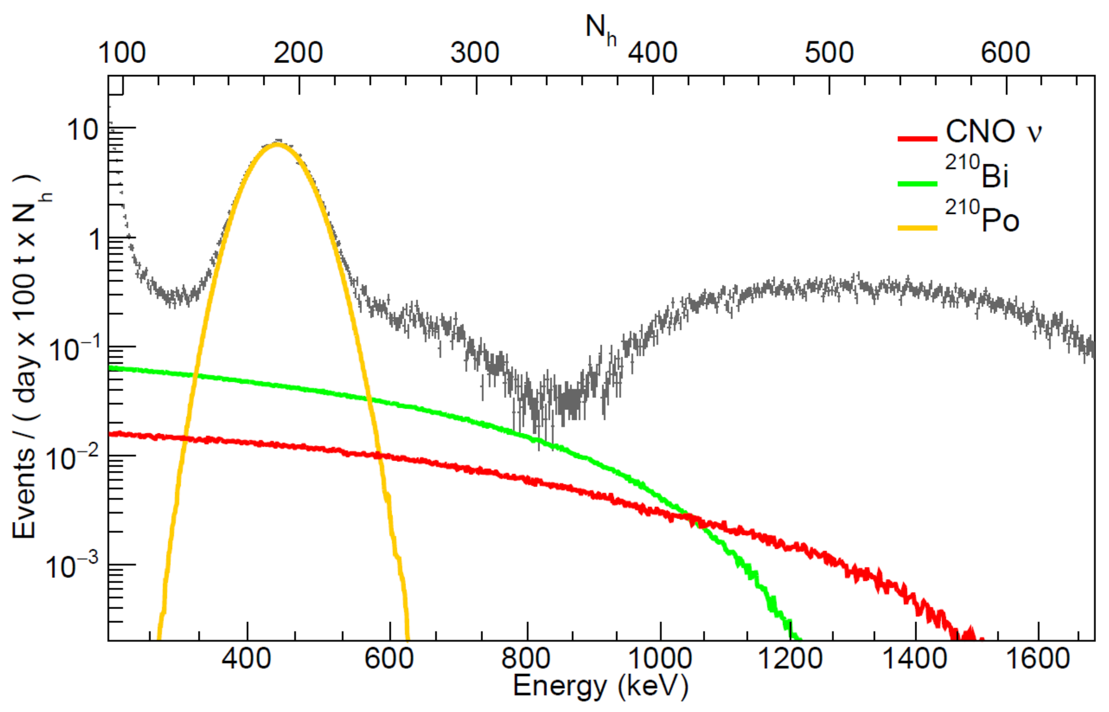
- Borexino is a **large volume liquid scintillator detector** whose primary purpose is the real-time spectroscopy of **low energy solar neutrinos** [1], located underground at the Laboratori Nazionali del Gran Sasso, in Italy.
- The Gran Sasso mountain shielding, the graded shielding design and the ultrapurity of the scintillator allow to **measure neutrino rates of few counts per day (cpd).**
- **Double scientific importance. Solar physics**: test the Standard Solar Model (SSM) predictions. **Particle physics**: neutrino flavor oscillations.

Borexino detected energy spectrum of Phase II data taking (2011-2016)



- The main contribution of the solar neutrino flux (~99%) comes from pp chain reactions, while the CNO cycle should be secondary.
- Borexino has measured all the **pp-chain reaction rates** [2] (pp, ^{7}Be, pep, ^{8}B) through event selection techniques and a complex likelihood fit analysis (see the figure: red lines for the neutrino components, other colors lines for the detector backgrounds)
- Set an **upper limit** on the **CNO neutrinos rate. Next goal: measure it!**

THE ^{210}Bi-^{210}Po-CNO CONNECTION



CNO, ^{210}Bi and ^{210}Po energy spectral shapes and the Borexino detected events (black)

CNO-^{210}Bi anticorrelation] the **CNO neutrinos** and the **^{210}Bi radioactive background** present in the scintillator have **nearly degenerated spectral shapes**: the **anti-correlation** prevent the fit algorithm to disentangle the two components!

Independent ^{210}Bi measurement strategy] ^{210}Bi decays in ^{210}Po, becoming then ^{206}Pb through α decay, that can be easily identified with pulse shape discrimination techniques. If all the ^{210}Bi is found in radioactive equilibrium with ^{210}Po, an independent measurement of the latter decay rate gives the ^{210}Bi one.

$$^{210}\mathrm{Pb} \xrightarrow[32\ \mathrm{y}]{\beta^-} \boxed{^{210}\mathrm{Bi} \xrightarrow[7.23\ \mathrm{d}]{\beta^-} {}^{210}\mathrm{Po} \xrightarrow[199.1\ \mathrm{d}]{\alpha} {}^{206}\mathrm{Pb}}$$

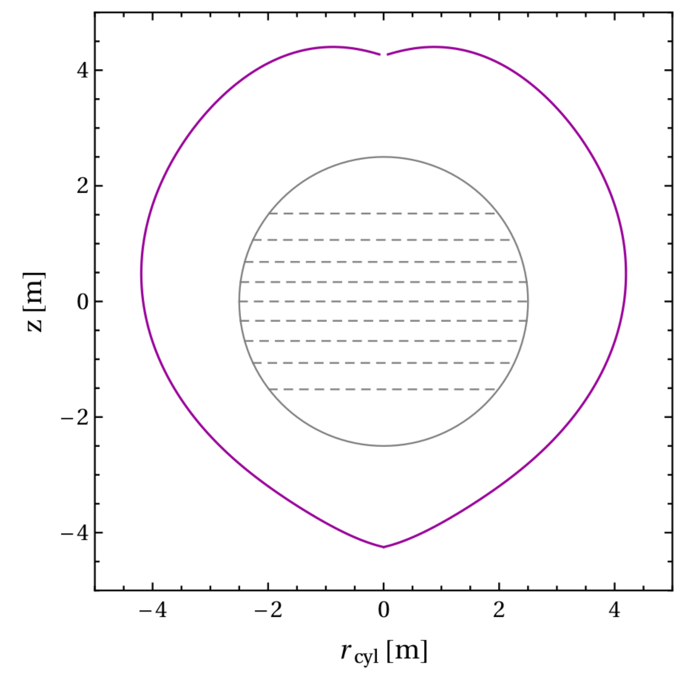
^{210}Po equilibrium and B-term] In the scintillator there are contributions of ^{210}Po **both in equilibrium and out of equilibrium, the latter** due to residual ^{210}Po from detector purifications and convective motions, thus **not related to the radioactive chain equilibrium.**
Goal: to **separate the two ^{210}Po contributions** according to the decay law

$$R_{\mathrm{Po}}(t) = (A - B)e^{-t/\tau_{\mathrm{Po}}} + B$$

A is the "unsupported term" (out of equilibrium) and **B is the "supported term", directly related to the ^{210}Bi parent,** while τ_{Po}=199.1 d is the ^{210}Po decay mean life (fixed parameter). **The core of the analysis is to understand the validity and the features of this relation, quantifying this B-term.**

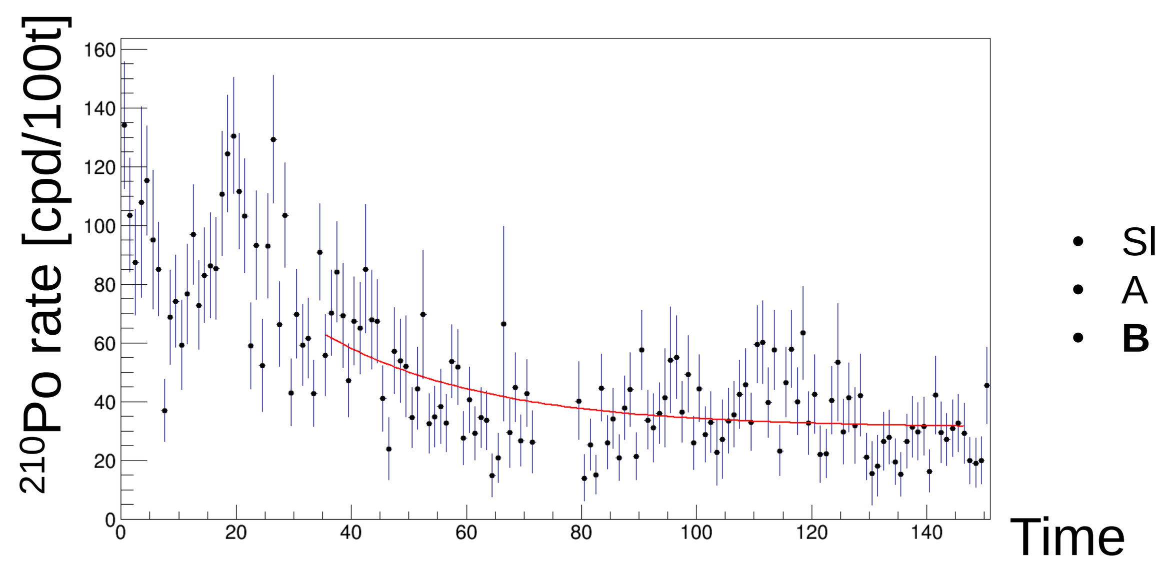
References:
[1] G. Alimonti et al., NIM.A600 (2009), pp. 568–593. doi: 10.1016/j.nima.2008.11.076. arXiv: 0806.2400
[2] G. Bellini et al., JHEP 08 (2013), p. 038. doi: 10.1007 / JHEP08(2013) 038. arXiv: 1304.7721.

^{210}Po RATE «SLICES ANALYSIS» STRATEGY



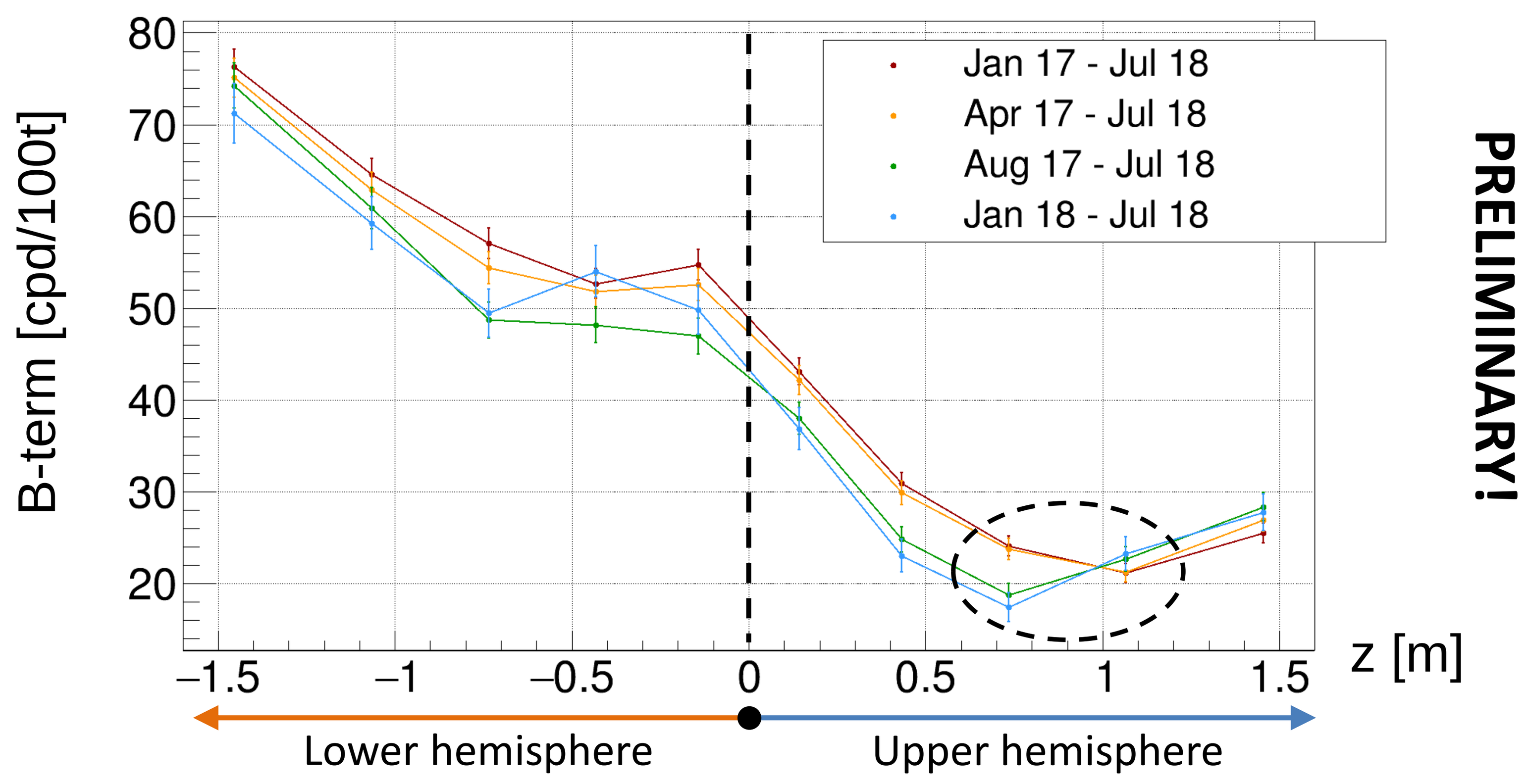
1) «Slicing» the Fiducial Volume
- **Borexino Inner Vessel 2D shape**: the IV contains the liquid scintillator
- **Fiducial Volume for the analysis divided in slices**: ^{210}Po events selection

2) Fit in time for each slice: extract the ^{210}Po B-term (example)



Example of fit:
- Slice 0.28 m < z < 0.59 m
- A = 141 cpd/100ton
- **B = 30.9 cpd/100ton**

3) Study of B-term as a function of vertical slice coordinate, for many time ranges



The B-term increases towards the South because of the impurities and the convective motions. The **lowest B-term region (around 20 cpd/100ton)** is found between z=0.5 m and z=1 m according to 2017-2018 time range.

We hope in the future to improve the analysis and **find a broad well-stable region in time**, so that we can extract a solid B-term value.