Counting analysis of Borexino Phase-III data for the detection of CNO solar neutrinos

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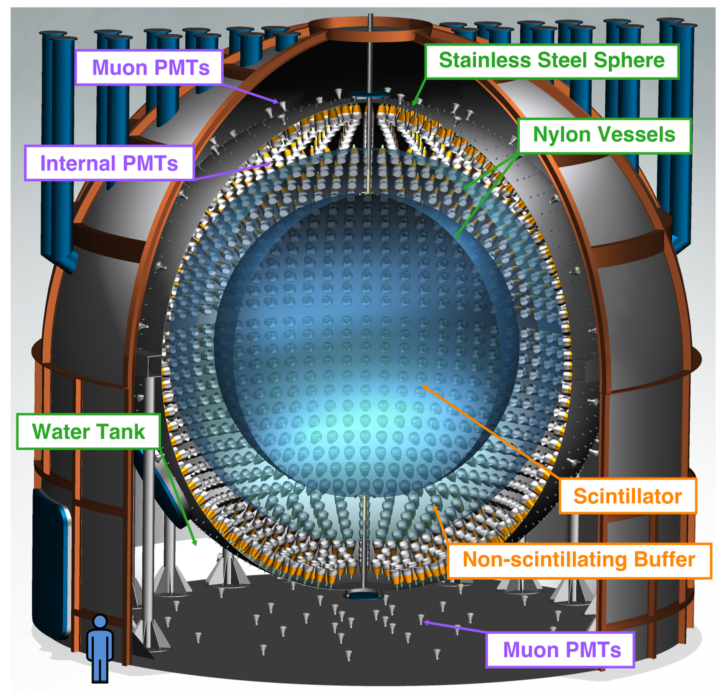
Abstract

An accurate measurement of the Solar Neutrino Flux from CNO cycle can shed light on the so called "solar abundance problem": new determinations of the photospheric abundances of heavy elements indicates that the Sun metallicity is lower than previously assumed, however Solar Models incorporating lower abundances are no more able to reproduce the helioseismic results. We propose a method for detecting the CNO interaction in the Borexino detector from a counting analysis in a Region of Interest determined maximizing a Figure of Merit and using both analytical and Monte Carlo modeling of the detector response. In such a way we can keep under control all systematics and avoid unwanted sources of uncertainties. The procedure itself is inspired by a CNO sensitivity[1] study pointing out that the sensitivity to CNO is basically given by the knowledge of the background from Bi210 and pep neutrinos, being the other backgrounds negligible or constrainable.

Mini-abstract: CNO interaction rate in the Borexino detector from counting analysis **Poster Id:** 93 **Contact:** riccardo.biondi@lngs.infn.it

Motivation and Strategy

We want to use counting analysis to determine CNO neutrinos interaction rate in Borexino detector[2].



Motivation:

- Complementary to a full spectral study[3] without the uncertainty of background and detector response modeling.
- Systematics can be reliably evaluated.
- This method could give high sensitivity[1].

Strategy:

- Choose an energy Region of Interest (ROI) where the expected discovery significance of CNO neutrinos is maximized(Figure of Merit).
- Count the events in ROI
- Subtract all identified background events
- Profile parameters to estimate uncertainties

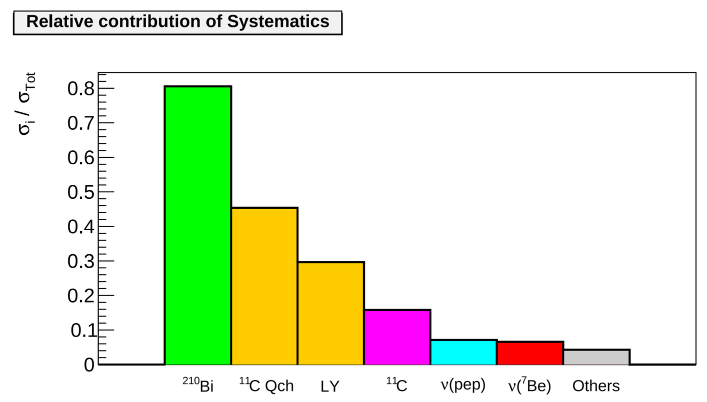
Results obtained with analytical response of the detector and Number of Photo-Electrons (Npe) as energy estimator will be shown in this poster.

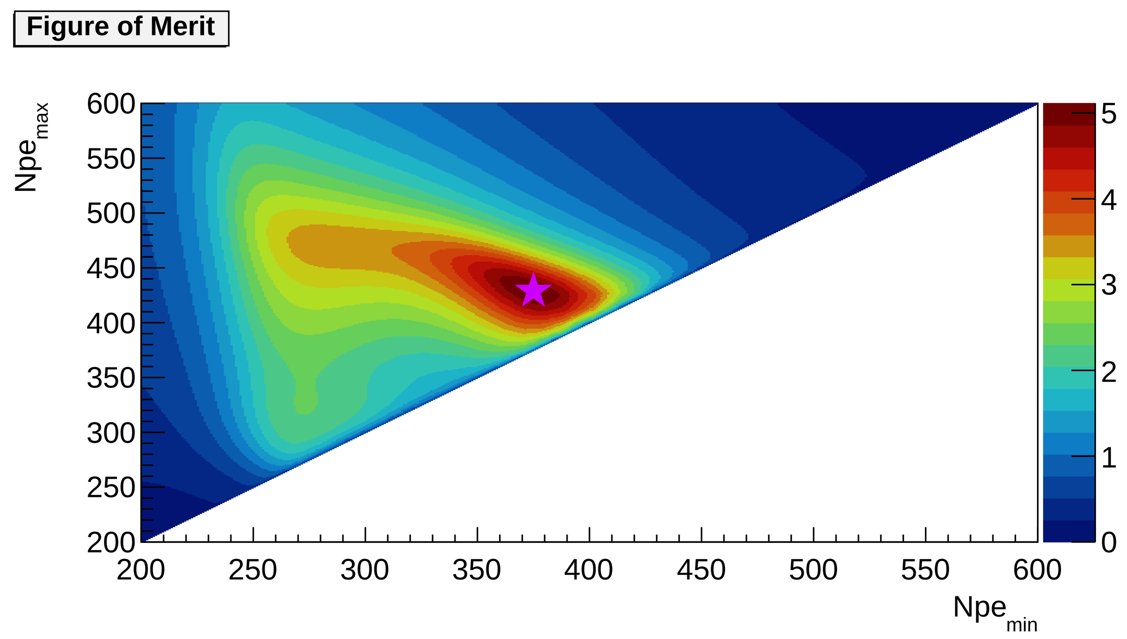
Figure of Merit

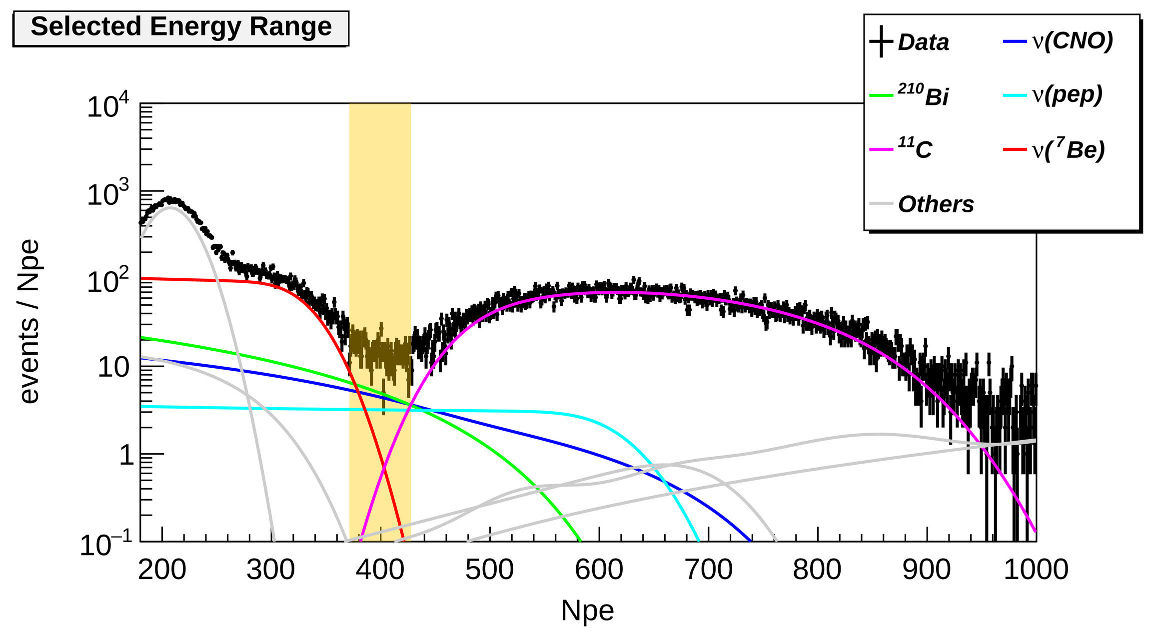
Figure of Merit is defined as:

$$\mathcal{F} = \frac{N_{\mathrm{CNO}}}{\sigma_{\mathrm{CNO}}\,(\mathrm{Sys.}\oplus\mathrm{Stat.})}$$

Major contributions of systematics comes from ^{210}Bi and detector response parameters such as ^{11}C quenching and Light Yeld







Optimum Range: [375 - 429] Npe

Region of Interest

Species (S_i)	Events	Fraction
N	823 ± 28.7	
^{210}Bi	261.5 ± 29.6	0.31
ν(pep)	171.7 ± 2.4	0.21
$\nu(^7$Be)	86.8 ± 2.6	0.10
^{11}C	57.9 ± 5.8	0.07
Others	15.6 ± 1.6	0.02
$\sum_i S_i$	593.5 ± 30.4	0.71

In the selected ROI we have a total of 823 ± 28.7 events. The expected values and errors on number of events for each species is calculated according to bounds coming from independent studies[4][5][6] and using a reference response model of the Detector.

If we subract the sum of the species S_i from the total N we are left with the sought after signal:

$$\mathrm{N_{CNO}} = \mathrm{N} - \sum_i \mathrm{S_i} = 229.5 \pm 41.8 \text{ events}$$

Systematics

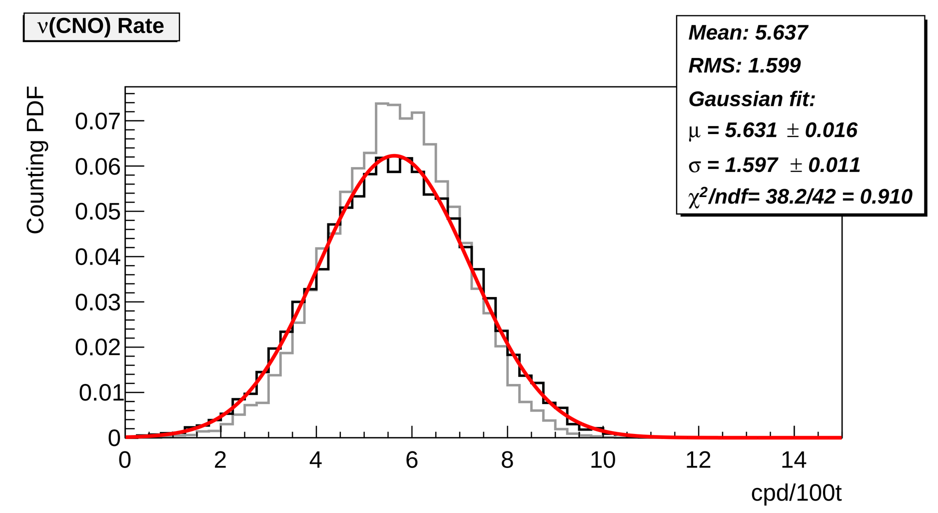
Systematics are obtained as the width of the distribution of CNO rate after varying parameters on 10^4 Toy-MC realizations where we determine the number of CNO events subtracting all the other species from the total events in the ROI. Parameters are varied according to:

- ^{210}Bi: independent determination[4].
- ν(pep) Luminosity constraint [5].
- $\nu(^7$Be) rate according to Solar Models[6].
- Light Yeld: generated according to its correlation with $\nu(^7$Be) rate, adding a 0.7 % smearing.

All the other species and detector response parameters are varied in a conservative way with respect to the reference detector response model.

Results

The distribution is then smeared according to the Statistical Error $\sigma_{\mathrm{stat}} = 0.83$ cpd/100t



$$R_{\nu(\mathrm{CNO})} = (5.6 \pm 1.6)\,\mathrm{cpd/100t} \quad [\sim 3.5\,\sigma]$$

Conclusions

A Counting Analysis can be used as a complementary tool for the measurement of the CNO solar neutrinos interaction rate, side by side with the Monte-Carlo Fit, and could have a significance of 3.5 σ.

References

[1] M. Agostini *et al.*, "Sensitivity to neutrinos from the solar CNO cycle in Borexino," [arXiv:2005.12829 [hep-ex]].

[2] X.F. Ding, "Stretegy of detection of solar CNO neutrinos with Borexino Phase-III data" [Poster: 438].

[3] Z. Bagdasarian, "Spectral fit of Borexino Phase-III data for the detection of CNO solar neutrinos" [Poster: 238].

[4] S. Kumaran, "Extraction of Bi-210 via Po-210 for CNO neutrino detection with Borexino" [Poster: 212].

[5] J. Bergström et al., J. High Energy Phys **2016**, 132 (2016)

[6] N. Vinyoles *et al.* Astrophys. J. **835**, no.2, 202 (2017) [arXiv:1611.09867 [astro-ph.SR]].