First detection of solar neutrinos from the CNO fusion cycle with the Borexino experiment

Riccardo Biondi on behalf of Borexino Collaboration
[1] Laboratori Nazionali del Gran Sasso

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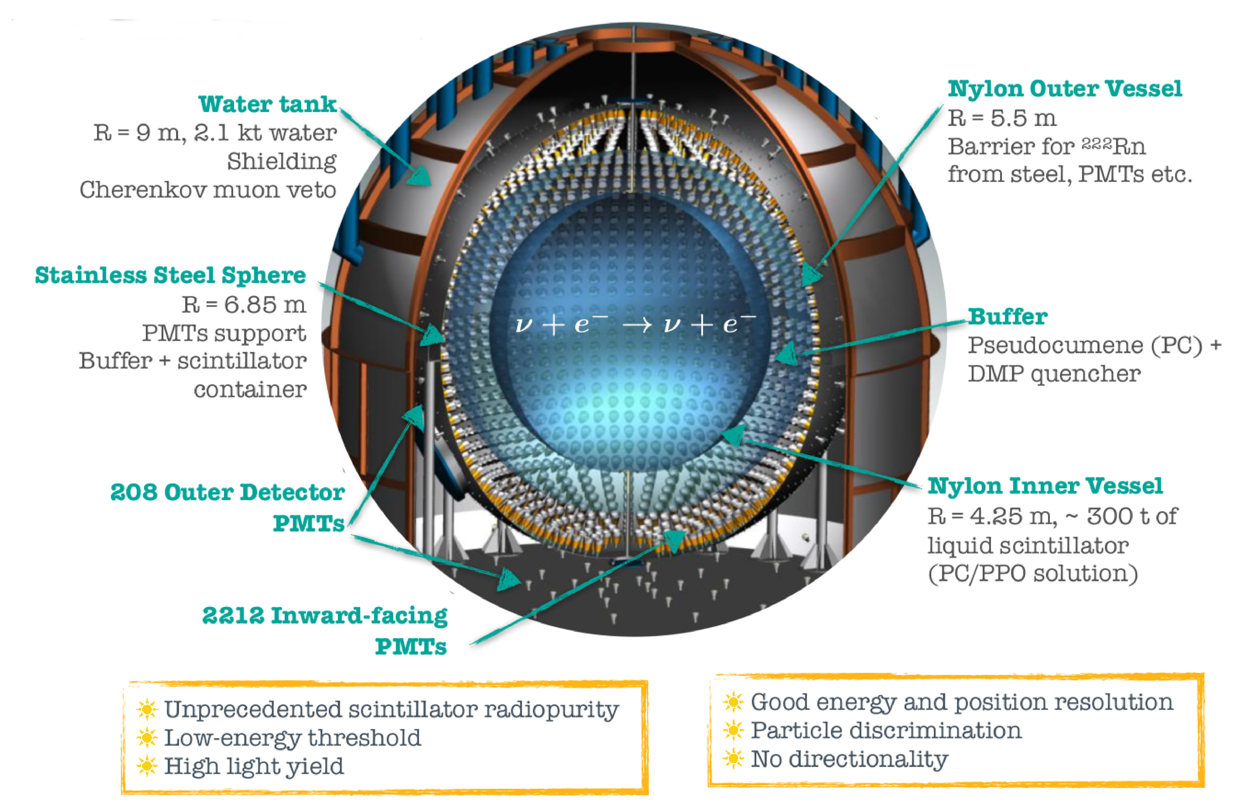
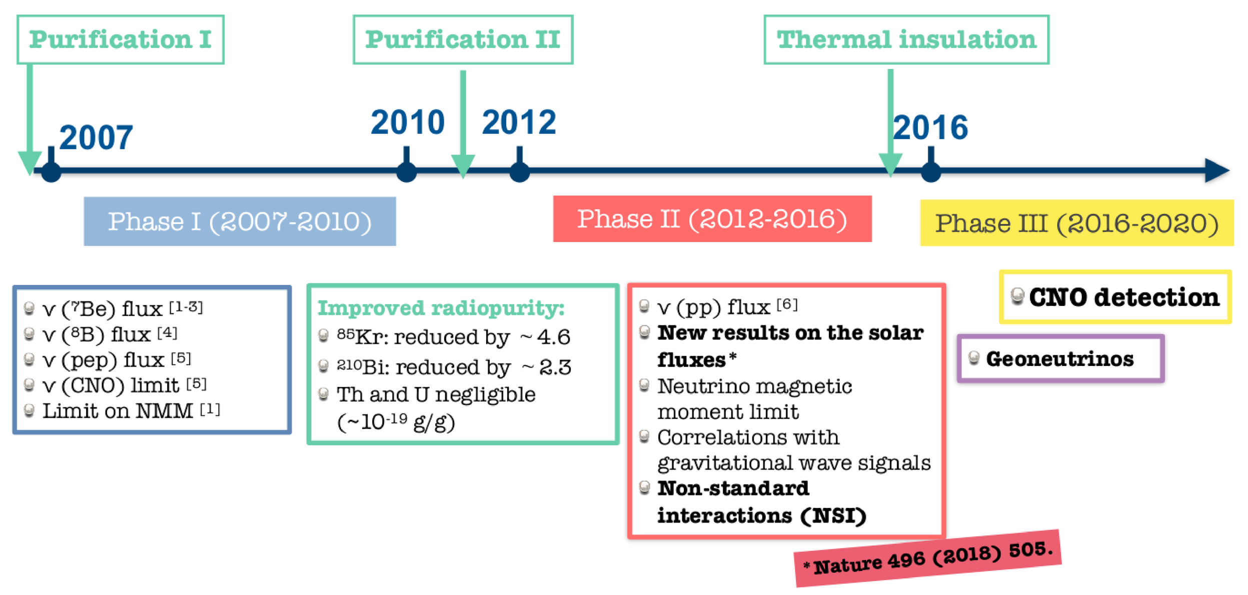
Abstract

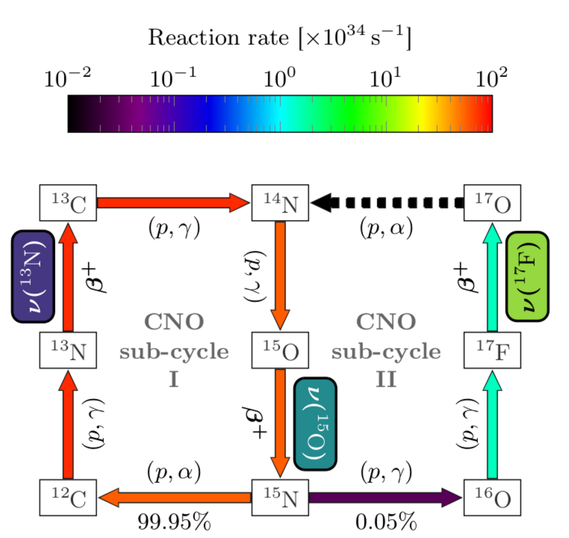
Borexino is a large-volume liquid-scintillator experiment designed for real-time detection of low energy solar neutrinos. It is located at Laboratori Nazionali del Gran Sasso (INFN) and started taking data in May 2007. This poster will report about the latest results of Borexino: the direct observation of neutrinos produced in the carbon-nitrogen-oxygen (CNO) fusion cycle in the Sun. The measurement was possible only after a dedicated campaign of hardware improvement aimed at stabilizing the thermal condition of the detector and at reducing the intrinsic radioactive backgrounds.The CNO cycle is the main nuclear engine in massive stars: this result is therefore crucial for the modeling of solar physics and confirms the existence of this process in the Universe. The details of the detector stabilization and the analysis strategy used by the Borexino collaboration for disentangling the spectral component of the CNO neutrinos from the residual backgrounds will be presented. **Contact:** riccardo.biondi@lngs.infn.it

Borexino Detector





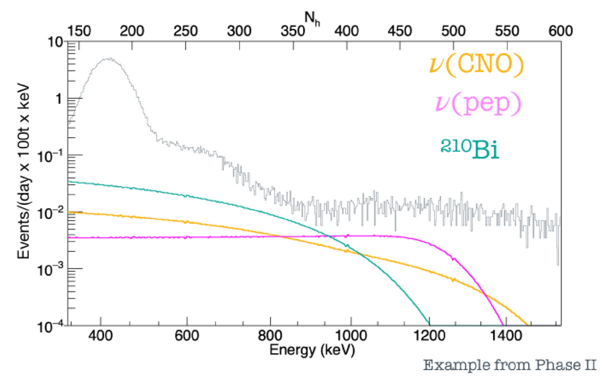
CNO Neutrinos



- Proof energy production in stars via CNO cycle.
- Expected to be dominant in stars heavier the the Sun.

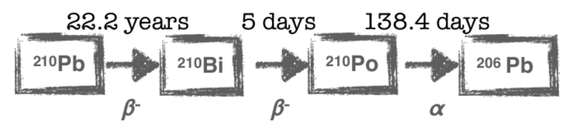
Sensible to Sun metallicity

Detection Strategy

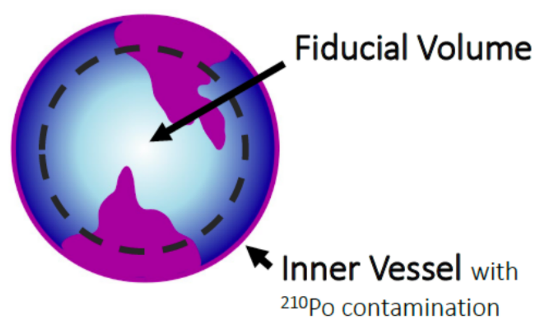


- Low rate of CNO neutrinos: $\sim 3-5 cpd/100tons$.
- Shape similar to ^{210}Bi and ν(pep).

Correlation between the three species: an independent constraints of the backgrounds is needed to disentangle them from the CNO signal.
ν(pep) **flux:** can be constrained at the 1.4 % level through the solar luminosity constraint coupled with robust assumptions on the pp to pep neutrino rate ratio, existing solar neutrino data, and the oscillation parameters.
^{210}Bi **rate** can be constrained from its daughter nucleus ^{210}Po decay rate.



- Assuming Secular Equilibrium the intrinsitc rate of ^{210}Po and ^{210}Bi are equal
- ^{210}Po events can be easily detected: monoenergetic α that can be discriminated from β events, using pulse shape.

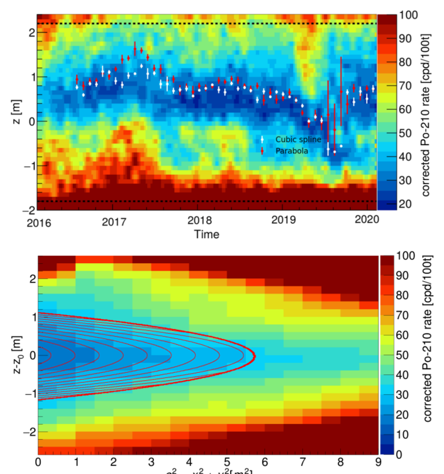


■ Stability challenges: ^{210}Po intrinsic rate is perturbed by the presence of strong convective motions, that contaminate the fiducial volume with additional ^{210}Po. To avoid this, the collaboration have made a huge effort to stabilize experimental hall temperature and insulate the detector.

The quest for CNO is turned into the quest of ^{210}Bi through ^{210}Po

We can infer the intrinsic ^{210}Po rate finding a region in the Fiducial Volume where its rate is minimal. In this region, contamination is negligible (confirmed by simulations). Taking also into account systematic uncertainties on the ^{210}Bi uniformity in the Fiducial Volume, we have the following constraint:

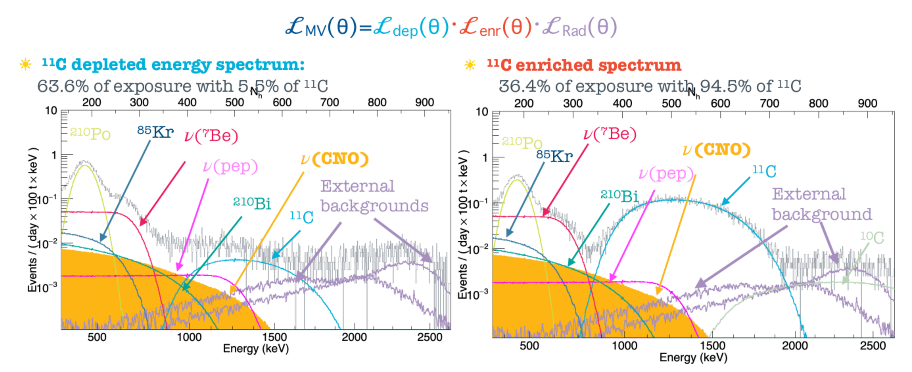
$$R(^{210}\text{Bi}) \leqslant (11.5 \pm 1.3)\text{cpd}/100\text{t}$$



Monte Carlo Multivariate Fit

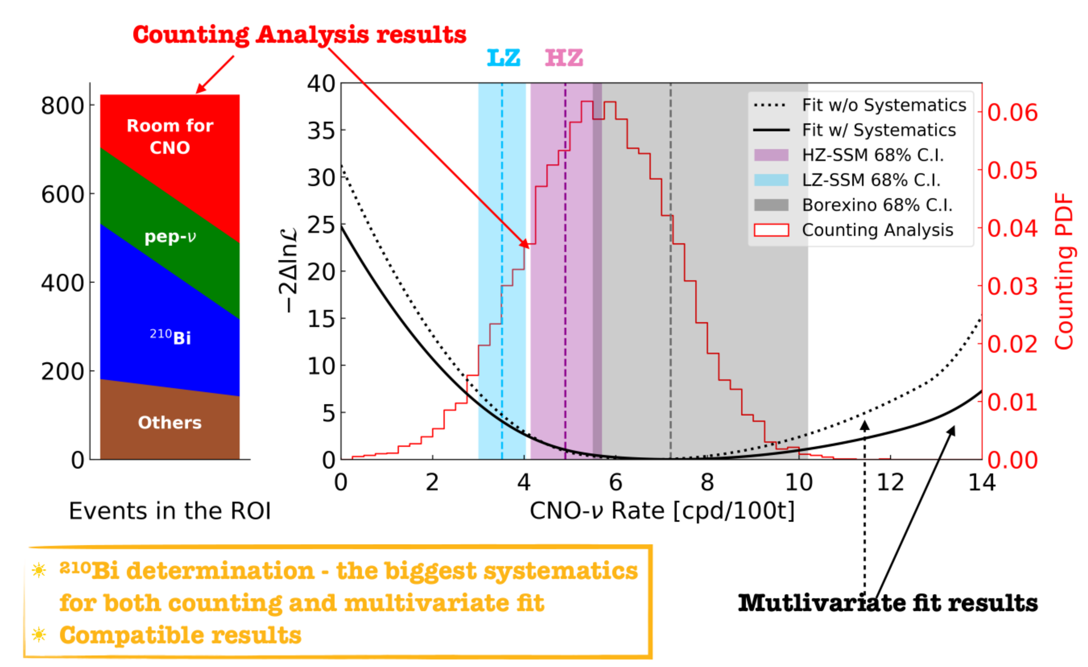
Exposure: 1071,95 days x 71.3 tons, Radial distribution exploited to disentangle external from the internal contaminant.

- μ and μ daughter cuts(300 ms after crossing μ)
- Fiducial volume cut: R $\leqslant$ 2.8 m, -1.8m $\leqslant$ z $\leqslant$ 2.2m.
- Three fold coincidence tag (^{11}C depleted spectrum).



Results

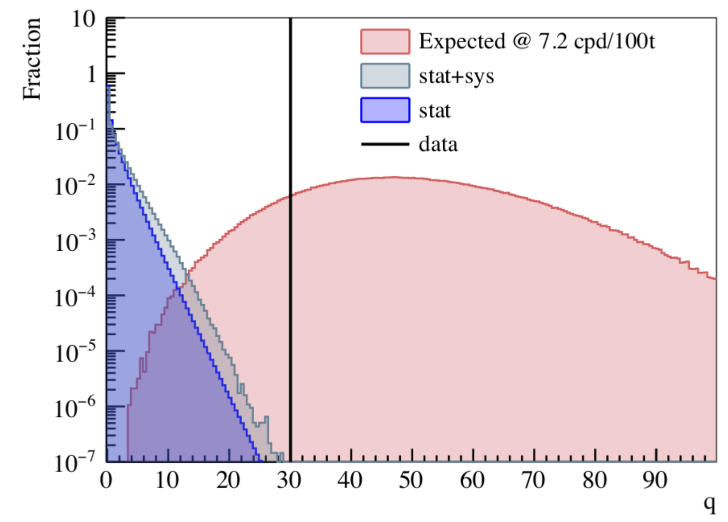
Results from Multivariate Fit have been independently validated via a Counting Analysis approach:



$$\nu(\text{CNO}) = 7.2^{+3.0}_{-1.8}\,(\text{stat} + \text{sys})\,\text{cpd}/100\text{t}$$

To evaluate the significance of our result in rejecting the no-CNO hypothesis, we performed a frequentist hypothesis test using a profile likelihood test statistics q defined as:

$$q = -2\log\left(\frac{\mathcal{L}(no\ CNO)}{\mathcal{L}(CNO)}\right)$$



Conclusions

We exclude the absence of a CNO solar neutrino signal, a result stemming from a robust multivariate fit of the data with a significance of 5.0σ and independently confirmed by the simple counting analysis. This is the first direct detection of CNO solar neutrinos.

References

[1] M. Agostini *et al.* [BOREXINO], Eur. Phys. J. C **80**, no.11, 1091 (2020) doi:10.1140/epjc/s10052-020-08534-2

[2] M. Agostini *et al.* [BOREXINO], Nature **587**, 577-582 (2020) doi:10.1038/s41586-020-2934-0