Strategy of detection for solar CNO neutrinos and temperature stabilization of the borexino detector

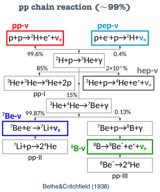
Riccardo Biondi[1] on behalf of Borexino Collaboration

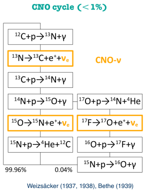
[1] Laboratori Nazionali del Gran Sasso

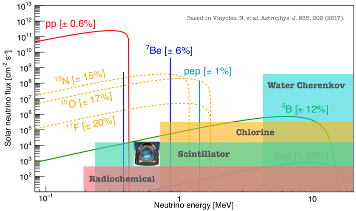
106^{o} National Congress of SIF

A window into the core of the Sun

As we already know, the Sun is powered by Nuclear Fusion:



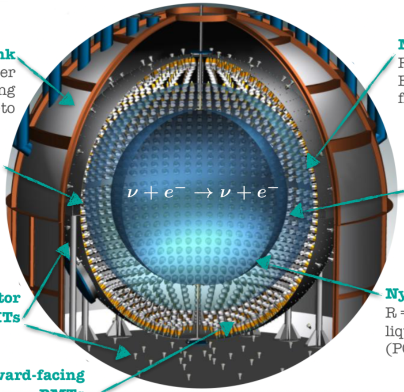




This reactions produce a total neutrino flux of $\sim\ 10^{11}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$.

- Precise measurement of the different components of the Solar Neutrino Flux can be used to address many intersting topics in astroparticle pysics.

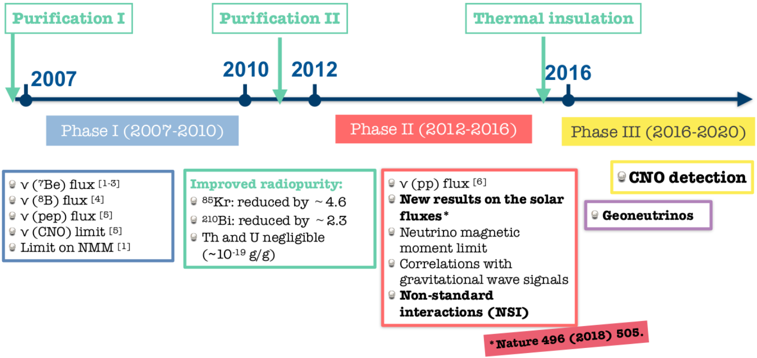
Borexino Detector



- Unprecedented scintillator radiopurity
- Low-energy threshold
- High light yield

- Good energy and position resolution
- Particle discrimination
- No directionality

Borexino Story



Borexino will be decommissioned soon, but...

“We end with a Bang!”

Motivations

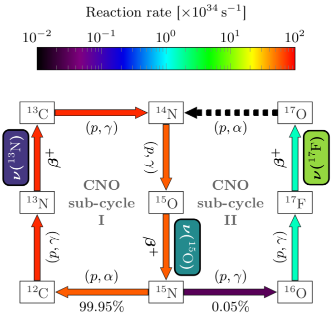
Solar Neutrinos

Borexino Detector

Strategy for CNO neutrinos Detection

Conclusions

Why CNO neutrino detection is so important?



- Proof energy production in stars via CNO cycle.
- It is expected to be dominant in stars heavier than the sun.
- Sensitive to Sun metallicity (HZ vs LZ models)

With the CNO detection, Borexino will completely unveil the two processes powering the Sun.

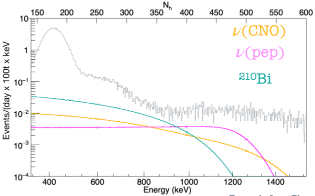
Detection Challenge

Solar Neutrinos

Borexino Detector

Strategy for CNO neutrinos Detection

Conclusions



Example from Phase II

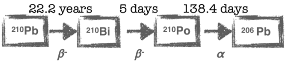
- Low rate of CNO neutrinos: $\sim 3-5 cpd/100ton$.
- Shape similar to $^{210}\mathrm{Bi}$ and $\nu(\mathrm{pep})$.

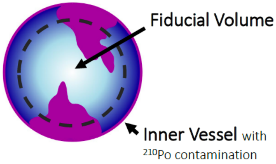
This implies a strong correlation between the three species that needs independent constraints of the two backgrounds to disentangle them from the CNO signal.

■ $\nu(\mathrm{pep})$ 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 most recent oscillation parameters.

Constraint on $^{210}\mathrm{Bi}$ rate:

$^{210}\mathrm{Bi}$ rate can be constrained from its daughter nucleus $^{210}\mathrm{Po}$ decay rate.



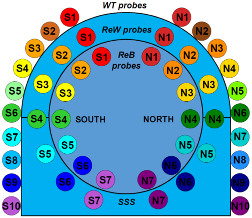


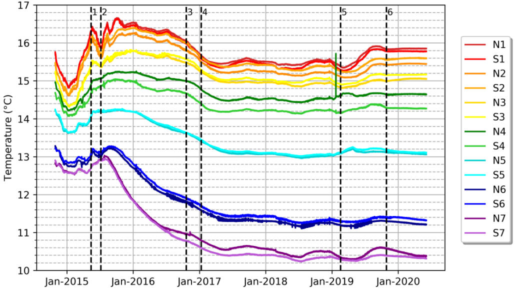
- At secular equilibrium the rate of $^{210}\mathrm{Bi}$ is equal to that of $^{210}\mathrm{Po}$
- $^{210}\mathrm{Po}$ events can be easily detected: they produce monoenergetic α (clear gaussian peak in the spectra) and can be discriminated from β events, using pulse shape.

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

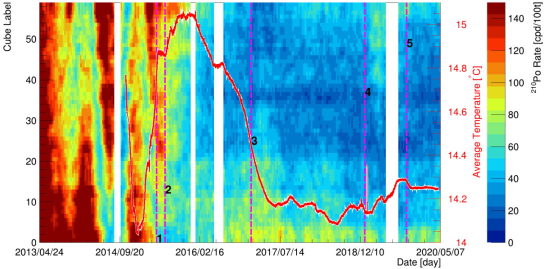
Thermal insulation and Temperature Monitoring

- Double layer of mineral wool (thermal conductivity:0.03 W/m/K)
- Temperature probes (Resolution: 0.07 K)
- Active Control Temperature System of Hall C





^{210}Po Mapping



Convective motions before insulation

1. Beginning of the insulation
2. Water recirculation off
3. Completion of the insulation

Stabilized after insulation

4. Start of active control temperature system (ACTS)
5. Change of ACTS set points

- With the achieved Stability, we can procede to evaluate the ^{210}Po intrinsic rate.

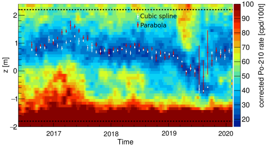
$^{210}\mathrm{Bi}$ from $^{210}\mathrm{Po}$

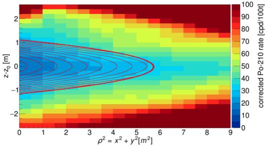
The quest for CNO is turned into the quest of $^{210}\mathrm{Bi}$ through $^{210}\mathrm{Po}$

We need to find the region in the Fiducial Volume where the rate of $^{210}\mathrm{Po}$ is at it's minimum.

From that we can infer the intrinsic $^{210}\mathrm{Po}$ rate and hence the $^{210}\mathrm{Bi}$ rate.

- The key assumption is that, in this region, the $^{210}\mathrm{Po}$ contamination in the fiducial volume is negligible (confirmed by fluid dynamics simulations).





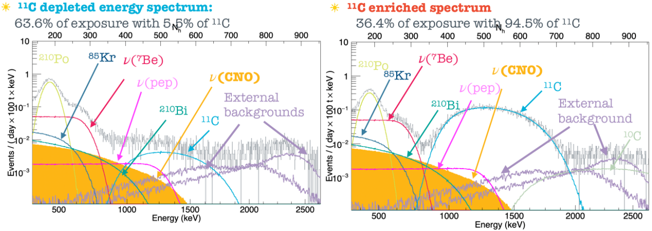
Taking also into account systematic uncertainties on the $^{210}\mathrm{Bi}$ uniformity in the Fiducial Volume, we have the following constraint:

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

Conclusions

Now we can plug the $^{210}\mathrm{Bi}$ contstraint into the Multivariate Fit to find the CNO neutrino rate in our detector.

$$\mathcal{L}_{MV}(\theta)=\mathcal{L}_{dep}(\theta)\cdot\mathcal{L}_{enr}(\theta)\cdot\mathcal{L}_{Rad}(\theta)$$



All the details about this will be shown in the presentation of Luca Pelicci *"First direct detection of CNO neutrinos: the multivariate fitting strategy"* (atticon12484)

Thank you!