DATA ANALYSIS OF A LOW-POLONIUM-FIELD FOR THE DISCOVERY OF CNO NEUTRINOS IN BOREXINO

RWTH Aachen
CNO discovery with Borexino

Fit strategy

- pep constrained to 1.4%
- Strong anti-correlation with $^{210}$Bi
- $^{210}$Bi decays into $^{210}$Po!
Diffusion & Convection

- $^{210}$Po from Nylon Vessel
- Can’t diffuse into FV
- Can be carried by convection
- Thermal insulation prevents convection
- Low-Polonium field forms!
The Low-Polonium Field

Select $^{210}$Po data with PSD$^2$
- White grid: Fiducial volume
- Black grid: Low-Polonium field
- How do we extract the constraint?

We can only extrapolate the $^{210}\text{Bi}$ rate to the entire FV if and only if the rate of $\beta^-$ decays is homogeneous.
Fit example

Project data on $\rho^2 - z$ plane

In blue, data, in red, fit:

$$\frac{d^2 R(2^{10} Po)}{d(\rho^2)dz} = \left[R_{\text{min}}(2^{10} Po) \epsilon + R_\beta\right] \times \left(1 + \frac{\rho^2}{a^2} + \frac{(z - z_0)^2}{b^2} \text{ OR spline}(z)\right)$$

- Least-Squares fit with parabolæ
- Also Bayesian approach:
  - Recursive strategy
  - Use Bayesian Factor Analysis
  - Fit spline functions with Markov Chains
Results & Systematics
Fitting the aligned dataset

Sources of systematics:
- Mass
- Binning
- $^{210}$Bi homogeneity
- $\beta$-leakage

Estimated with:
- Variation of fit region
- Variation of bin size
- Associated inhomogeneity
- $\alpha/\beta$ discrimination efficiency

Both methods agree (values in cpd/100 ton):

<table>
<thead>
<tr>
<th>$R_{\text{min}}(^{210}\text{Po})$</th>
<th>$\sigma_{\text{stat.}}$</th>
<th>$\sigma_{\text{mass}}$</th>
<th>$\sigma_{\text{binw}}$</th>
<th>$\sigma_{\text{Bi-homog}}$</th>
<th>$\sigma_{\beta-\text{leak}}$</th>
<th>$\sigma_{\text{Total}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.5</td>
<td>0.83</td>
<td>0.40</td>
<td>0.20</td>
<td>0.78</td>
<td>0.30</td>
<td>1.3</td>
</tr>
</tbody>
</table>
Questions?

Thank you for your attention!
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Related talks @NeuTel:

■ **A. C. Re** (next talk): A successful strategy for the CNO measurement with Borexino: the MultiVariate Fit

■ **D. Basilico** (previous talk): How the CNO neutrinos detection can unravel the solar metallicity problem?

■ **Ö. Penek**: Sensitivity to CNO cycle solar neutrinos in Borexino

■ **G. Bellini**: Neutrino, Solar and star physics with Borexino
Backup

Solutions in the disruption period

October 2019

June 2019

\[ z \ (m) \]
Visualising results

Fit monthly, use results to „blindly align” data (shift on z with the value from the previous month).
Bayesian evidence

Sidenote

\[ P(\theta|D, M) = \frac{\mathcal{L} \cdot \pi}{P(D|M)} \]

\[ P(D|M) = \int d^N \theta \mathcal{L}(D|\theta, M) \pi(\theta|M) \]

Bayesian evidence is the average of the Likelihood over the prior. It is used as a quantitative Occam’s Razor in model selection. A higher value means the model is more probable.
Are we biasing the results?
Toy-MC check with perfect paraboloid

Only positive bias observed that would decrease the CNO discovery power.
A proposal to perform fit complex data: use cubic splines! Locally, splines are parabolæ but they have more freedom far from the minimum.

- Piecewise cubic functions
- Defined by „Knots”
- More Knots $\rightarrow$ complexity
- Not trivially „fittable”
- With MCMC, very easy!
Fit examples and performance

Bayesian spline fit