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

February 19, 2021 | **Alexandre Göttel** for the Borexino Collaboration | IKP-2 Fz Jülich, Institut 3.b. RWTH Aachen

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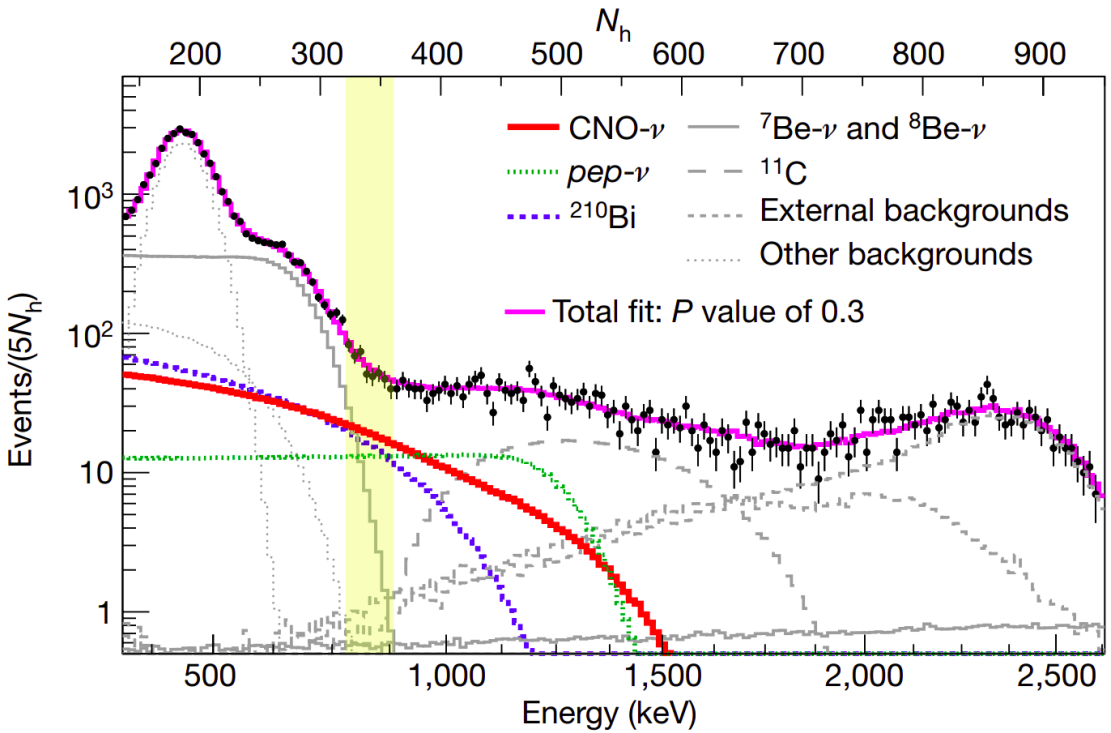
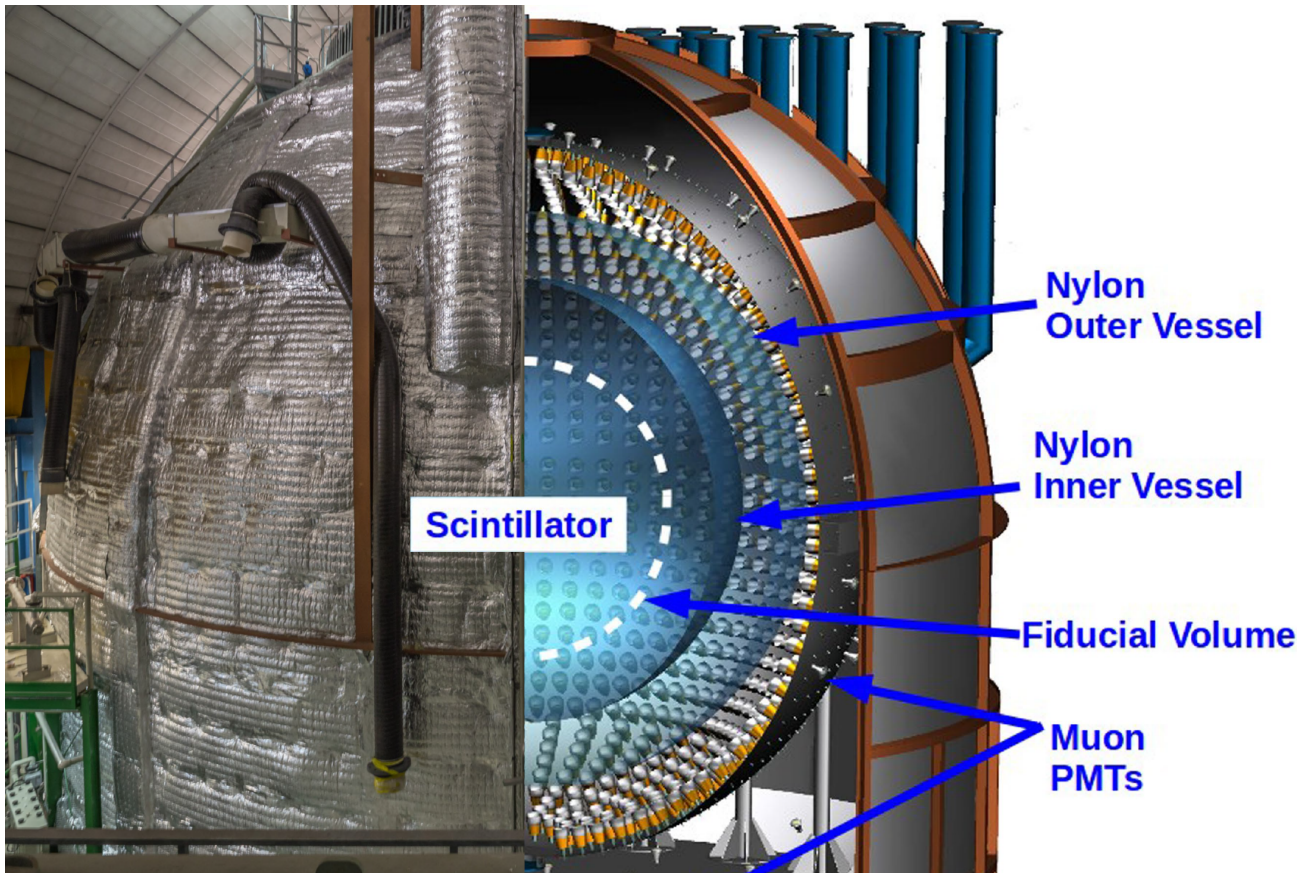
CNO discovery with Borexino

Fit strategy

- Nature volume 587, p 577–582 (2020)
- *pep* constrained to 1.4%
- Strong anti-correlation with ^{210}**Bi**
- ^{210}**Bi** decays into ^{210}**Po**!

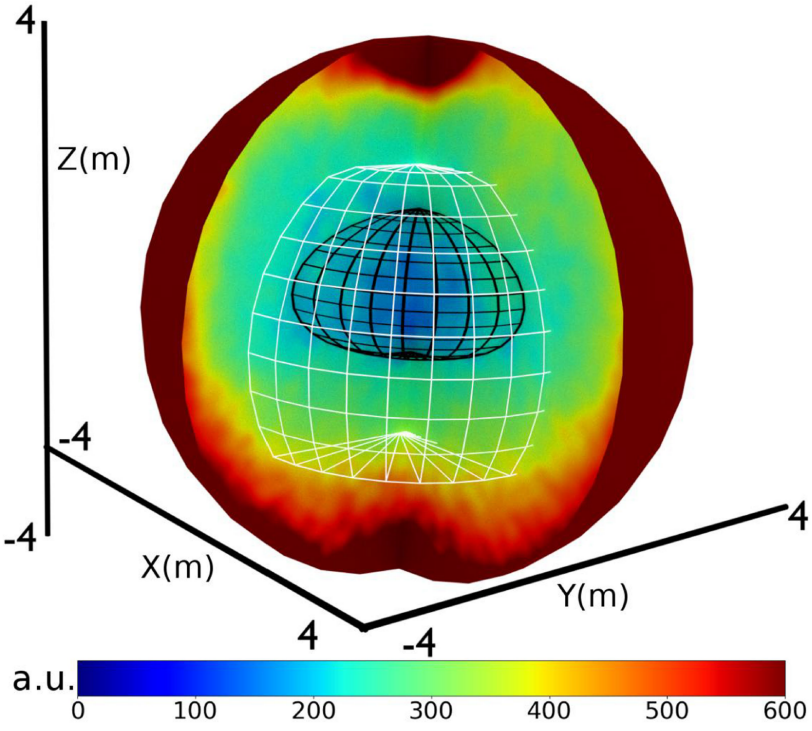


Diffusion & Convection

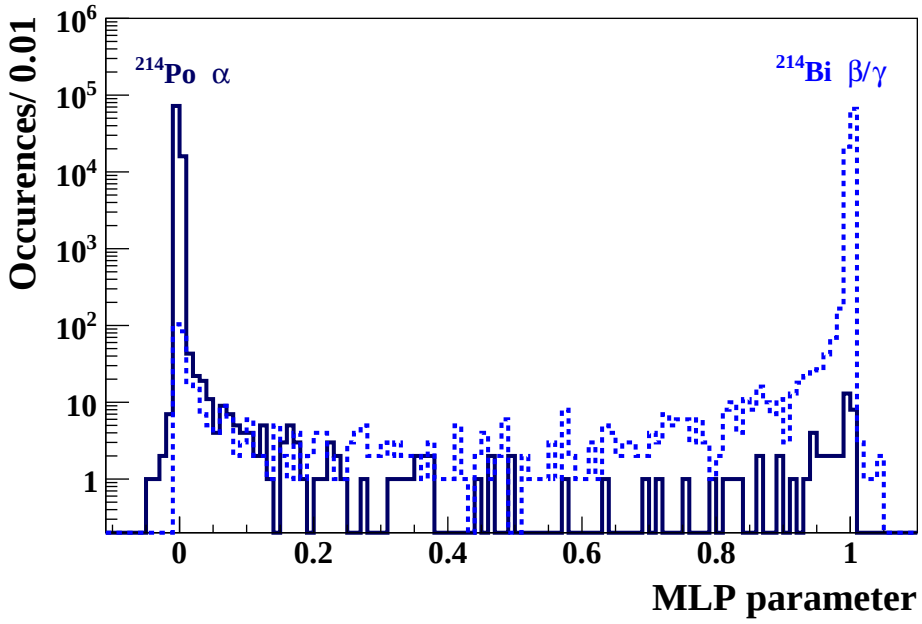


- ^{210}Po from Nylon Vessel
- Can't **diffuse** into FV
- Can be carried by **convection**
- Thermal insulation prevents convection
- **Low-Polonium field** forms!

The Low-Polonium Field



^{210}Po rate

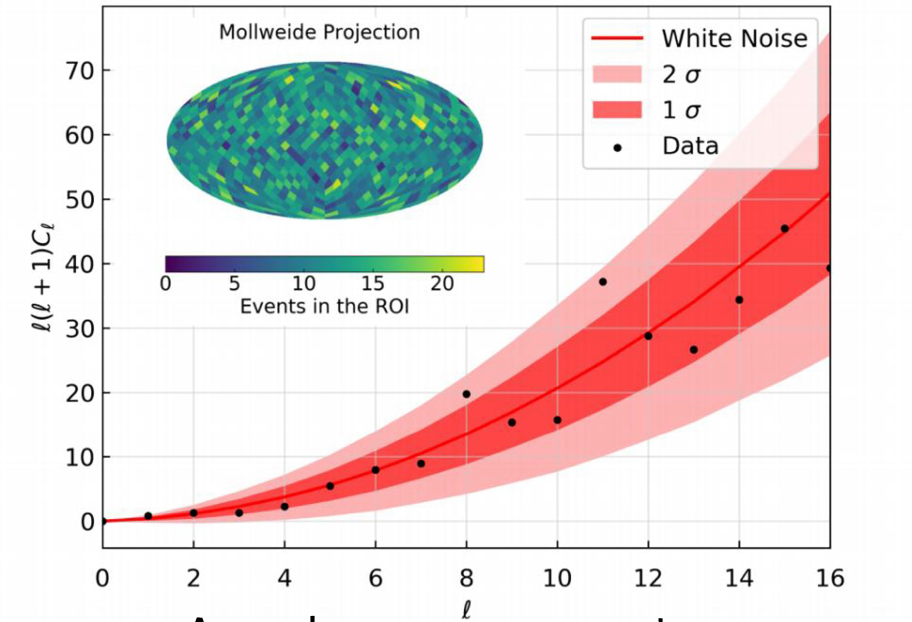


- Select ^{210}Po data with **PSD^2**
- White grid: Fiducial volume
- Black grid: **Low-Polonium field**
- How do we extract the constraint?

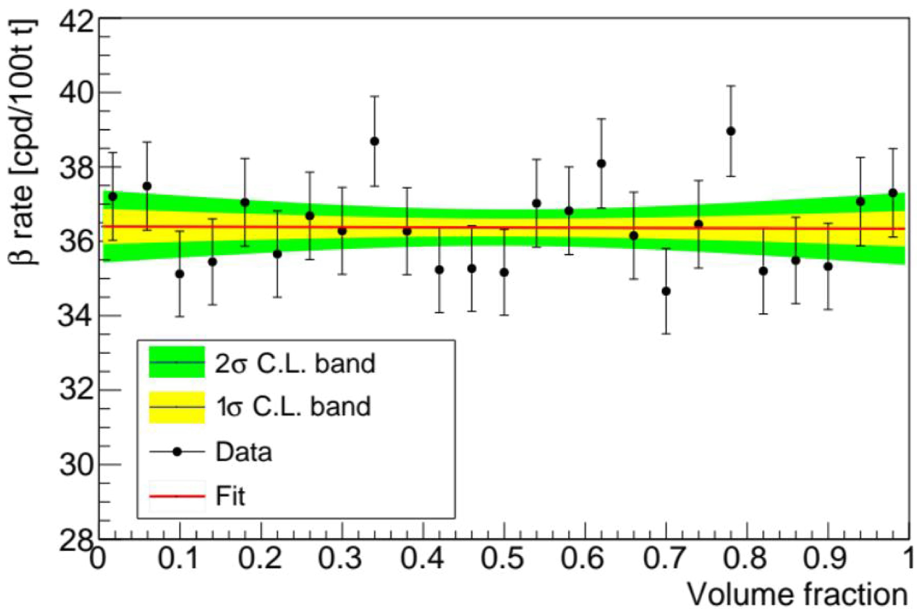
Bi-homogeneity

“Cosmic” CNO

We can only extrapolate the ^{210}**Bi** rate to the entire FV if and only if the rate of β^- decays is **homogeneous**.



Angular power spectrum



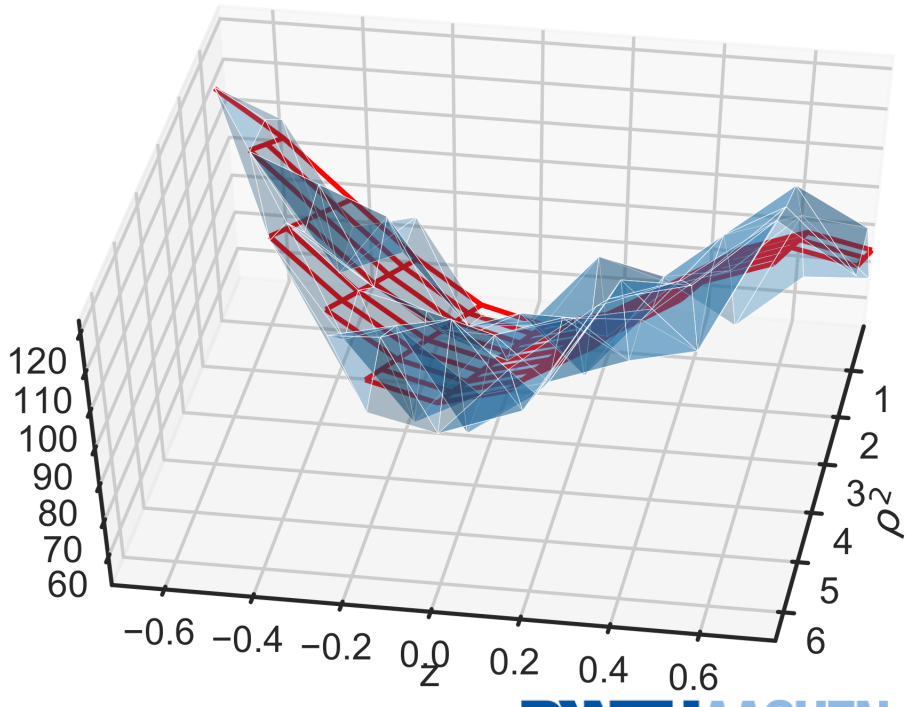
Radial distribution

Fit example

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

In blue, **data**, in red, **fit**:

$$\frac{d^2R(^{210}Po)}{d(\rho^2)dz} = [R_{min}(^{210}Po)\epsilon + R_\beta] \times \left(1 + \frac{\rho^2}{a^2} + \frac{(z - z_0)^2}{b^2} \; OR \; spline(z)\right)$$



- Least-Squares fit with parabolæ
- Also Bayesian approach:
  - Recusive 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
- β-leakage

Estimated with:

- Variation of fit region
- Variation of bin size
- Associated inhomogeneity
- α/β discrimination efficiency

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

$R_{min}(^{210}Po)$	$\sigma_{stat.}$	σ_{mass}	σ_{binw}	$\sigma_{Bi-homog}$	$\sigma_{\beta-leak}$	σ_{Total}
11.5	0.83	0.40	0.20	0.78	0.30	1.3

Questions?

Thank you for your attention!

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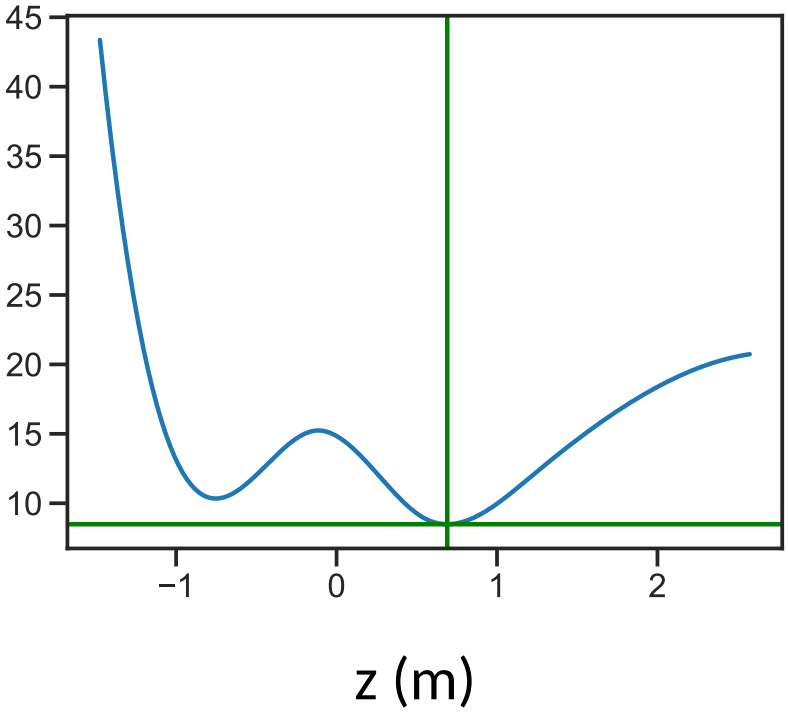
Related talks @NeuTel:

- **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

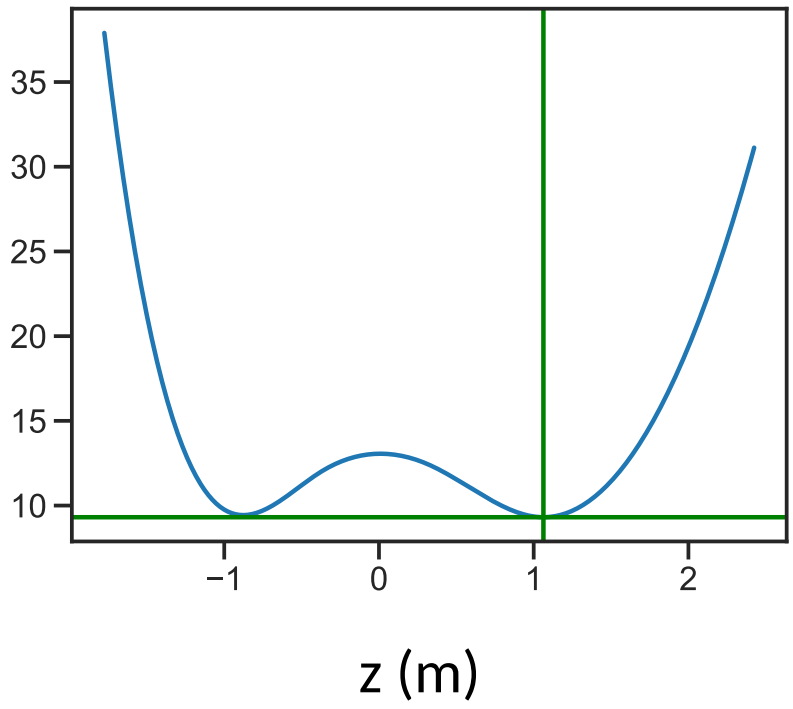
Backup

Solutions in the disruption period

October 2019

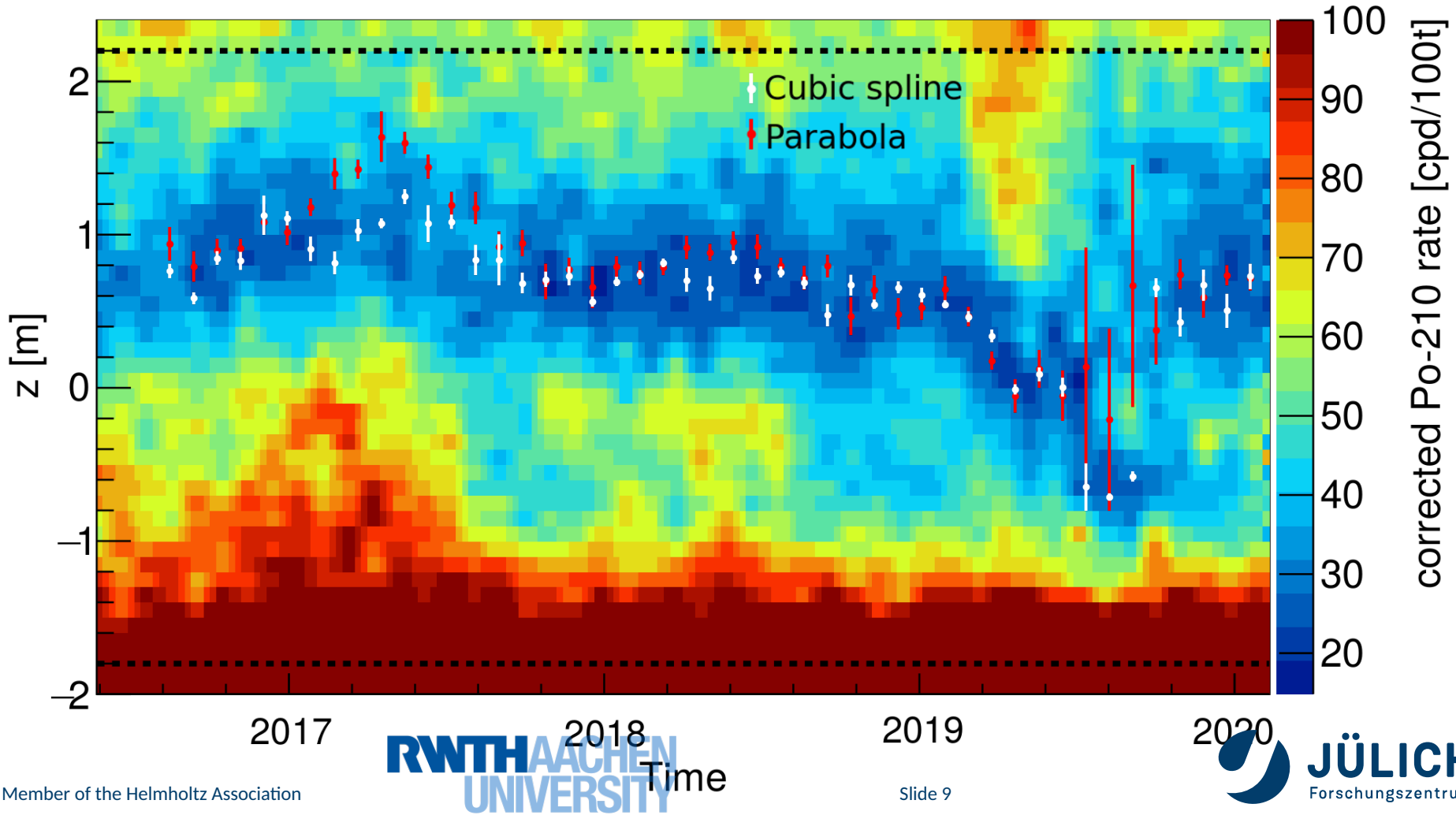


June 2019



Visualising results

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



Bayesian evidence

Sidenote

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

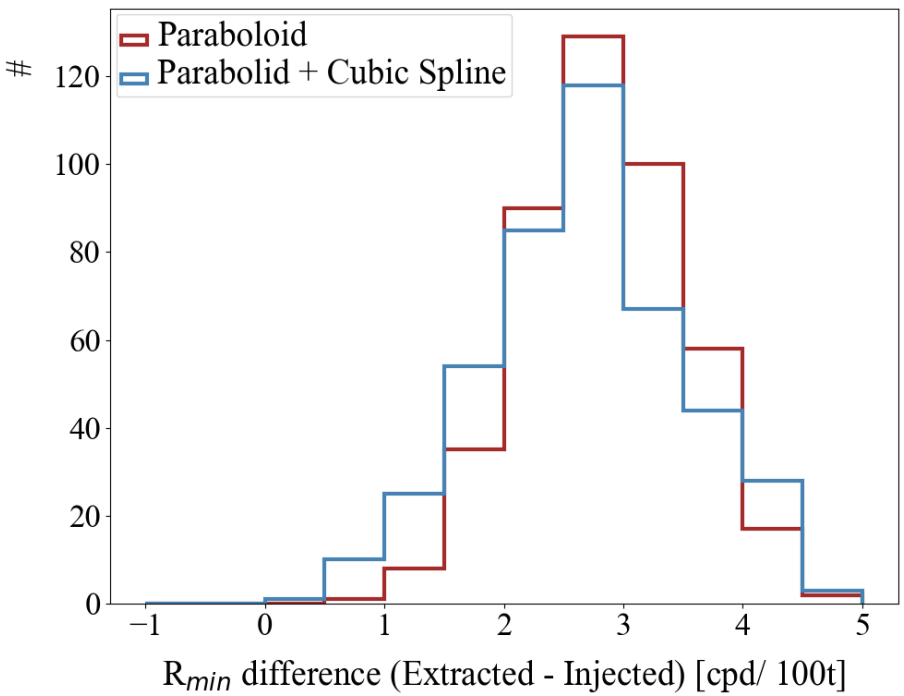
$$P(D|M) = \int d^N\theta \mathcal{L}(D|\theta,M)\pi(\theta|M)$$

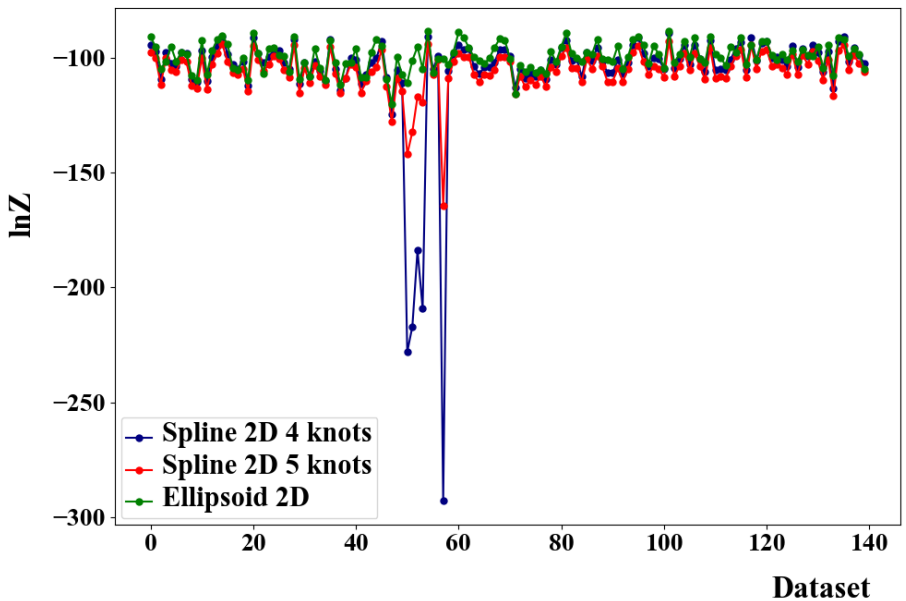
Bayesian **evidence** is the average of the Likelihood over the prior. It is used as a quantitative **Occam's Razor** in model selection. A higher value means the model is more probable.

Are we biasing the results?

Toy-MC check with perfect paraboloid

Only positive bias observed that would decrease the CNO discovery power.



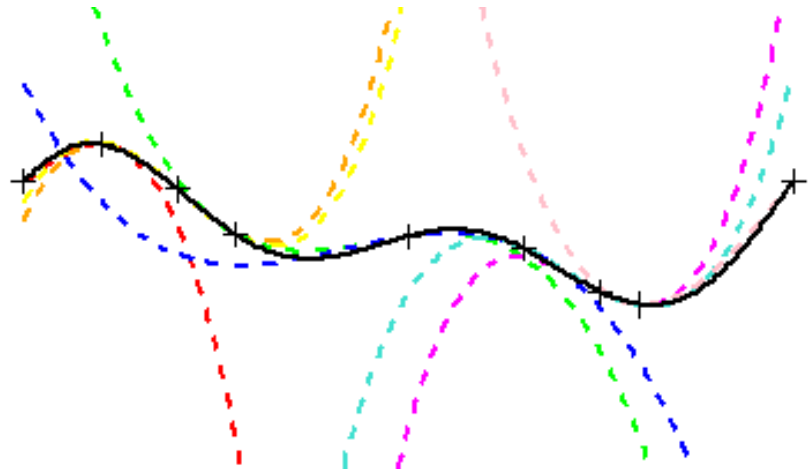


Cubic spline interpolation

Sidenote

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