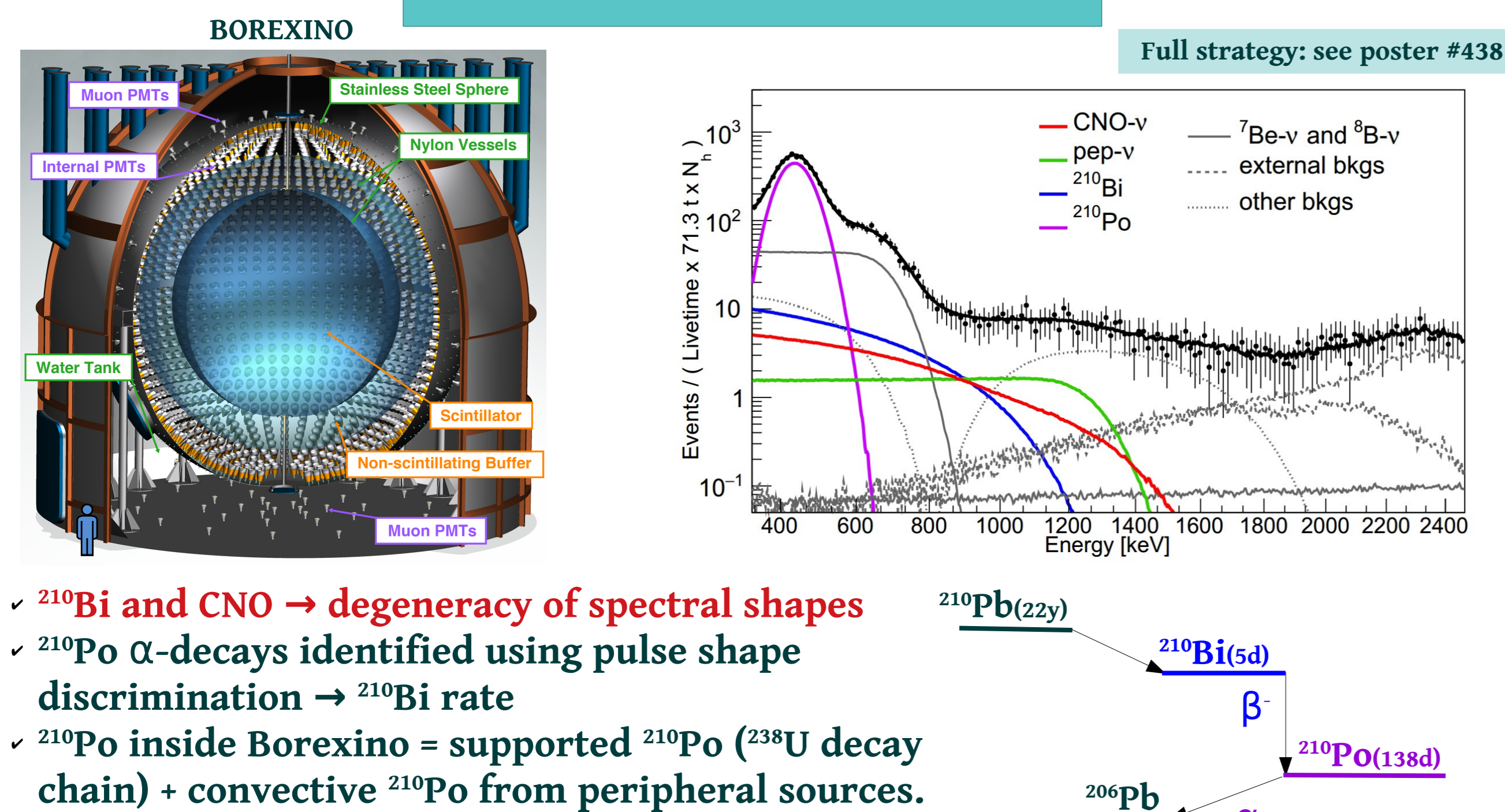


^{210}Po homogeneity in Borexino gives a ^{210}Bi upper limit for CNO neutrino detection

Extraction of ^{210}Bi via ^{210}Po for CNO neutrino detection with Borexino

Davide Basilico¹, Xuefeng Ding², Alexandre Göttel^{3,4}, Sindhujha Kumaran^{3,4}
on behalf of the Borexino collaboration

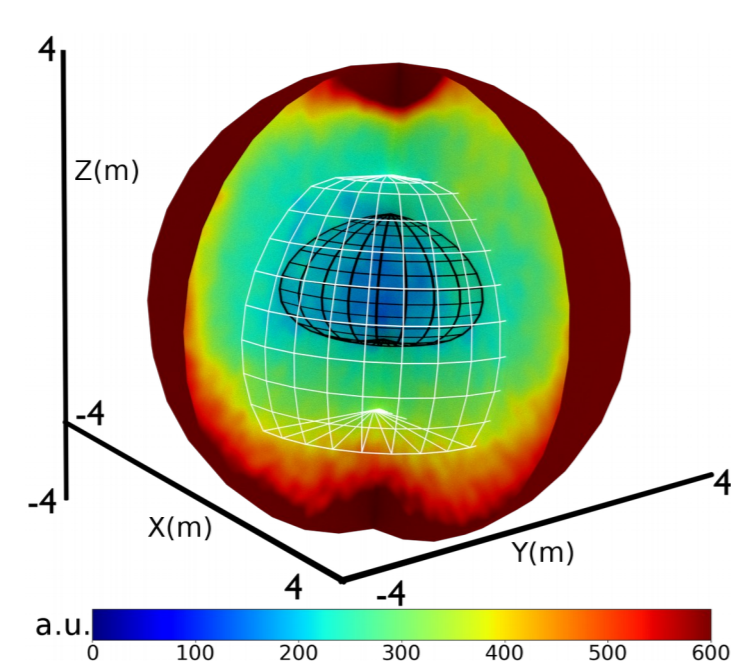
MOTIVATION



STRATEGY

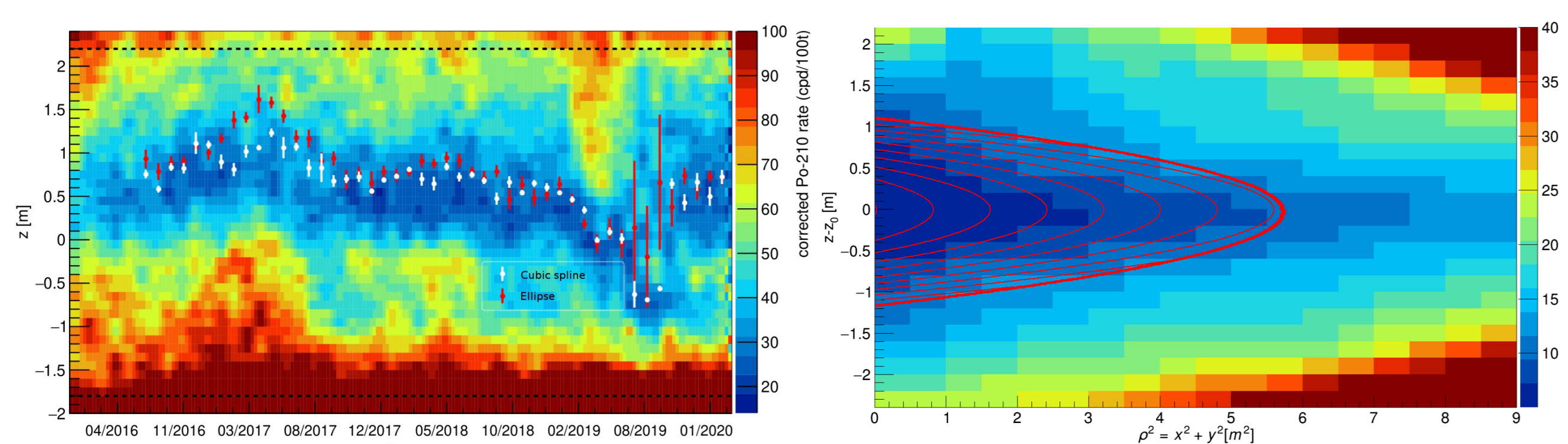
See poster #297

Thermal insulation in 2015:
Creation of **Low Polonium Field (LPoF)** of ~20 tons just above the equator of the detector, free of convective motions, resembling an ellipsoid with rotational symmetry along the x-y plane.



^{210}Po rate in LPoF = supported ^{210}Po + slowly decaying convective ^{210}Po

min. ^{210}Po rate → ^{210}Bi upper limit → CNO lower limit



Dataset used: Phase3 → July 2016 to Feb 2020 = 775.93 days x 100t

Blind alignment of data:

- Due to the small movements of the LPoF along z, the center of the ellipsoid in the z-direction (z_0) is obtained by performing the fit every month and aligning the data using the z_0 of the corresponding previous month.
- Alignment done using two methods
 - Ellipsoid
 - Ellipsoid along x-y + Cubic spline along z

METHODS

- Minimum Rate + Ellipsoid → fit to ^{210}Po data.
- Fits performed with ROOT and MultiNest

$$\frac{d^2 N}{d(\rho^2) dz} = \frac{MT}{100} \cdot (R_{\min} \cdot \text{eff}_{\alpha} + \beta_{\text{leak}}) \cdot \left[1 + \frac{\rho^2}{a^2} + \frac{(z-z_0)^2}{b^2} \right]$$

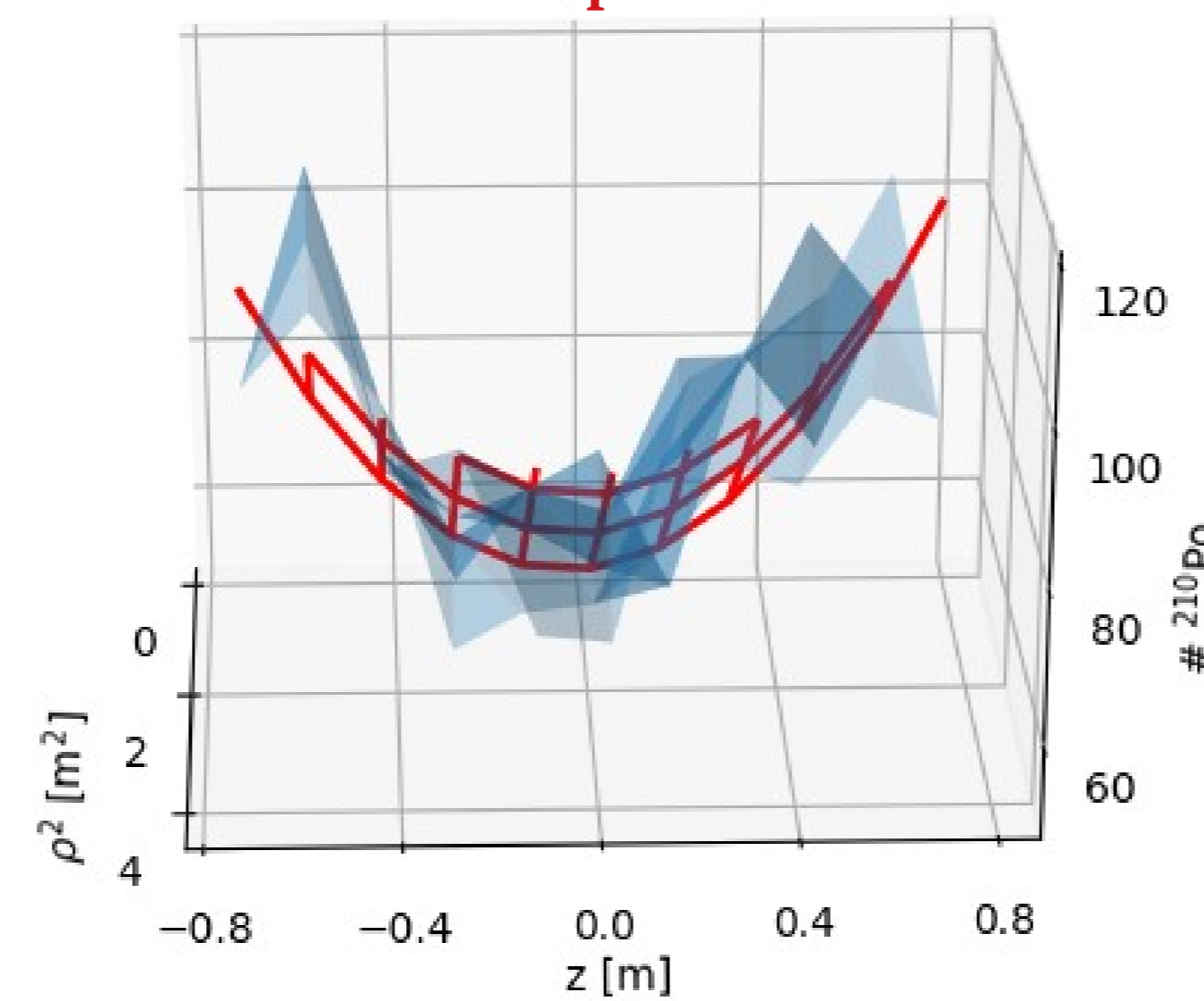
Multinest:
Nested sampling algorithm that calculates Bayesian evidence

$$P(\Theta|D, M) = \frac{P(D|\Theta, M) P(\Theta|M)}{P(D|M)}$$

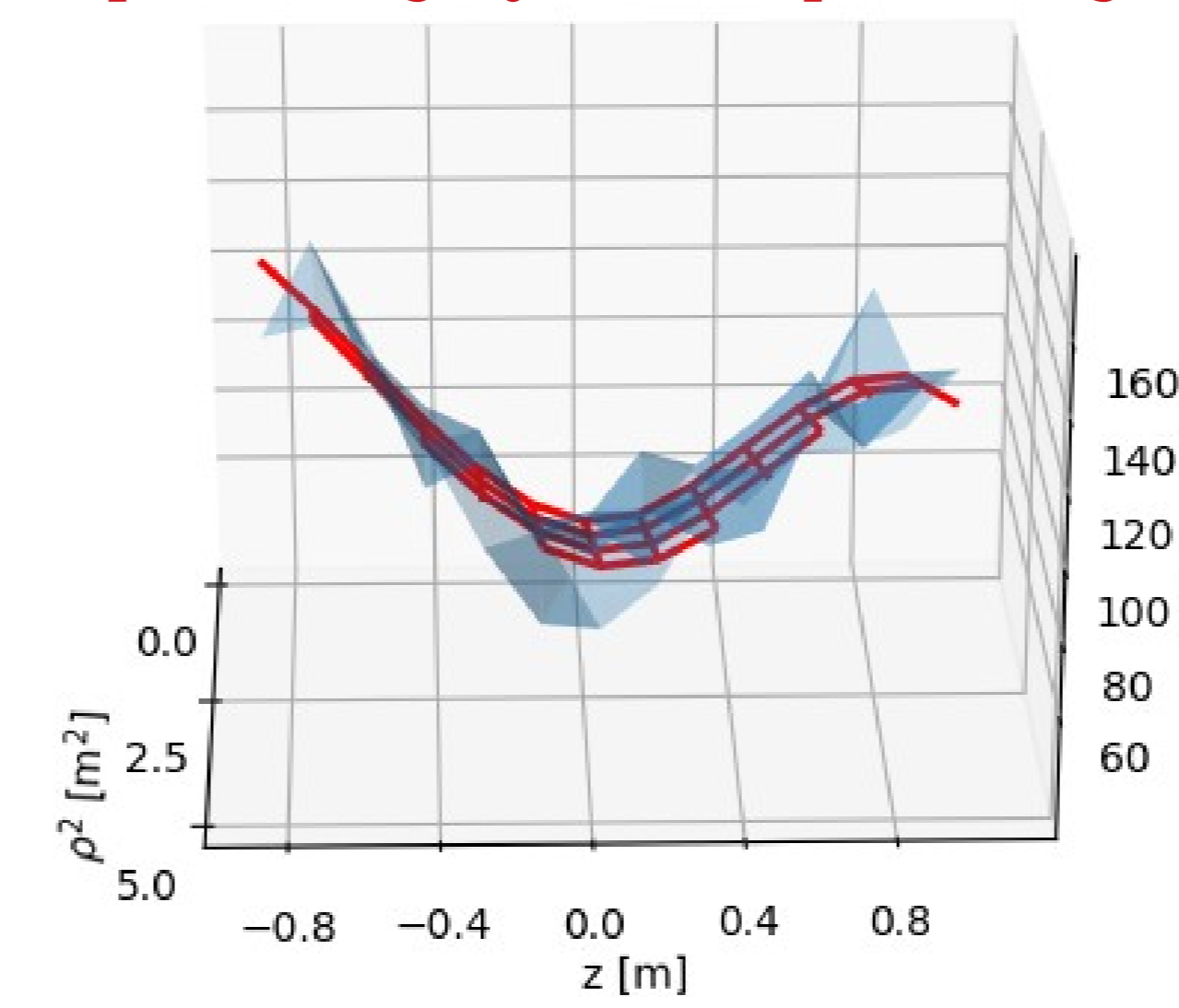
Evidence (Marginal Likelihood)

- Applications for high dimensional models
- Implementation of cubic splines to explain the complexity of data along z → calculate z_0 using knots and the corresponding minimum ^{210}Po rate
- Complexity of every month varies between 4 and 10 knots (average = 7 knots).
- Better Bayesian evidence than a simple ellipsoid
- Complexity of aligned dataset = 5 knots

Ellipsoid

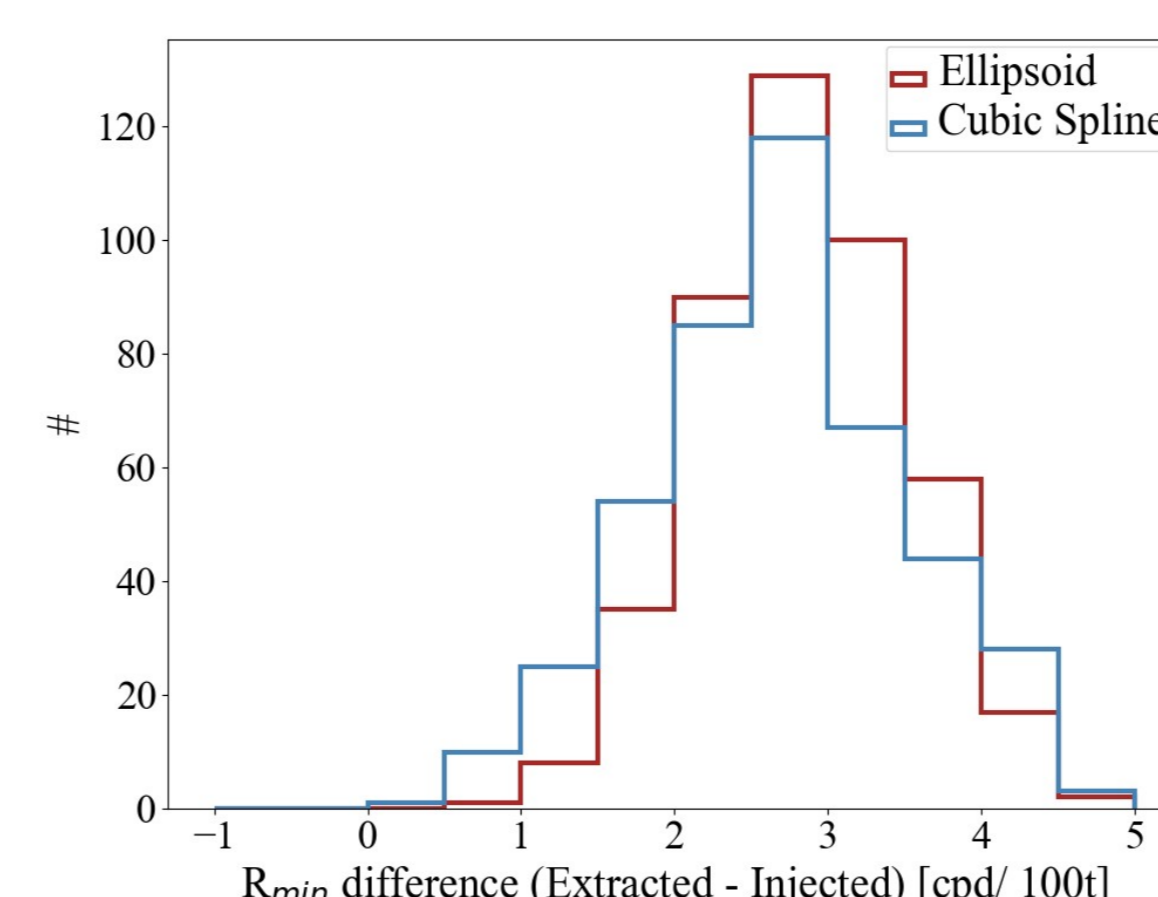


Ellipsoid along x-y + Cubic spline along z



Toy MC validation:

- Datasets of 2 years livetime each with supported and convective ^{210}Po
- Perfectly ellipsoidal LPoF with rotational symmetry
- Low complexity of cubic spline in toyMC (4 knots) to describe the ellipsoid
- No negative bias in both methods → conservative ^{210}Bi upper limit → no false enhancement of CNO rate

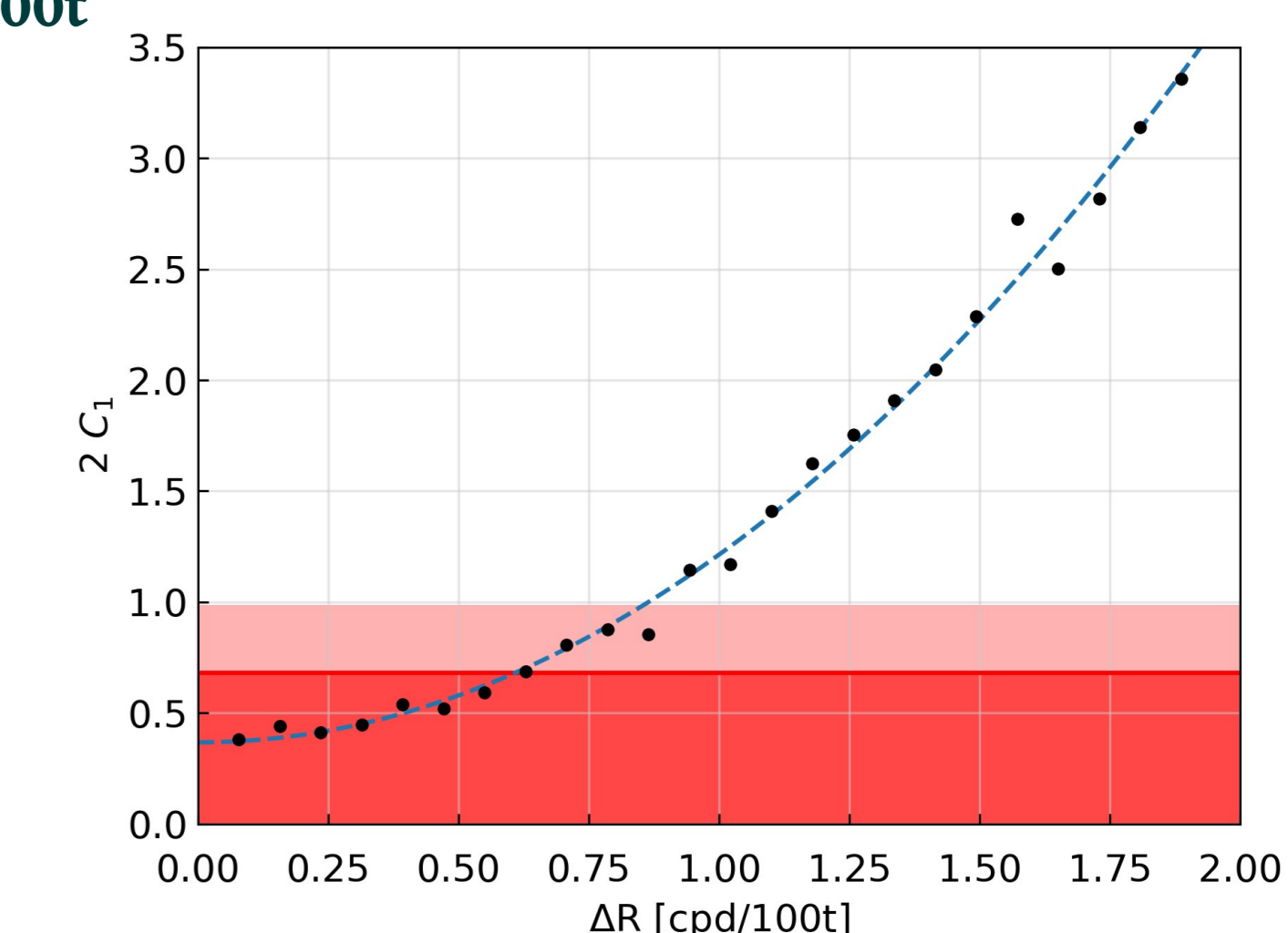
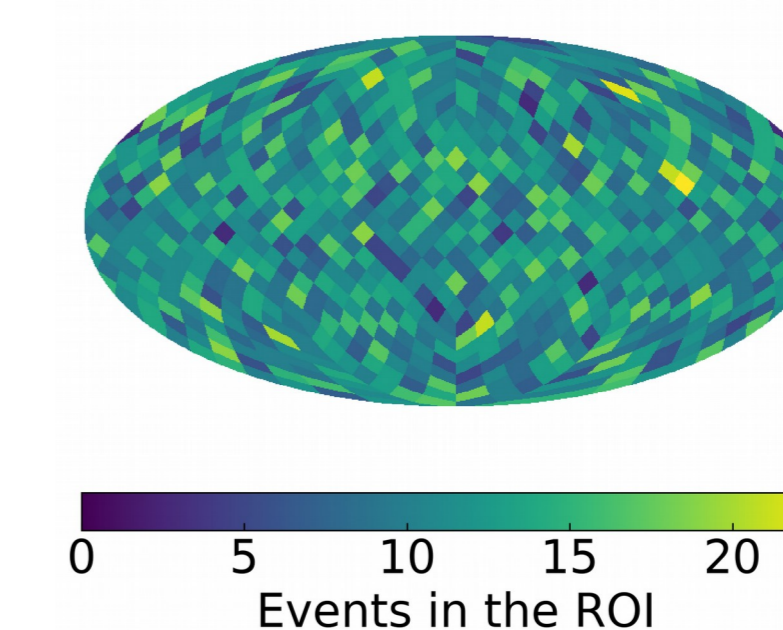


SYSTEMATIC SOURCES

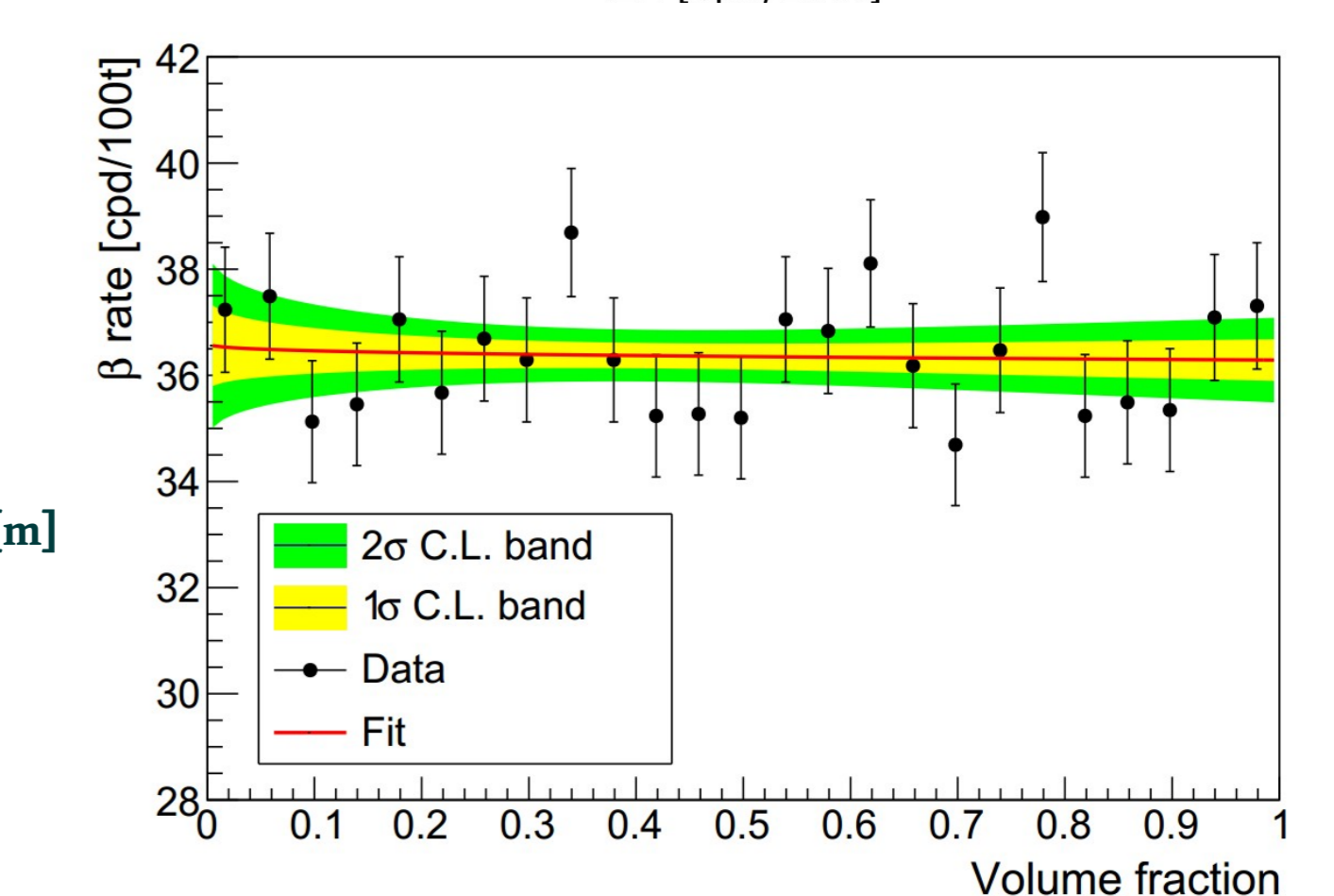
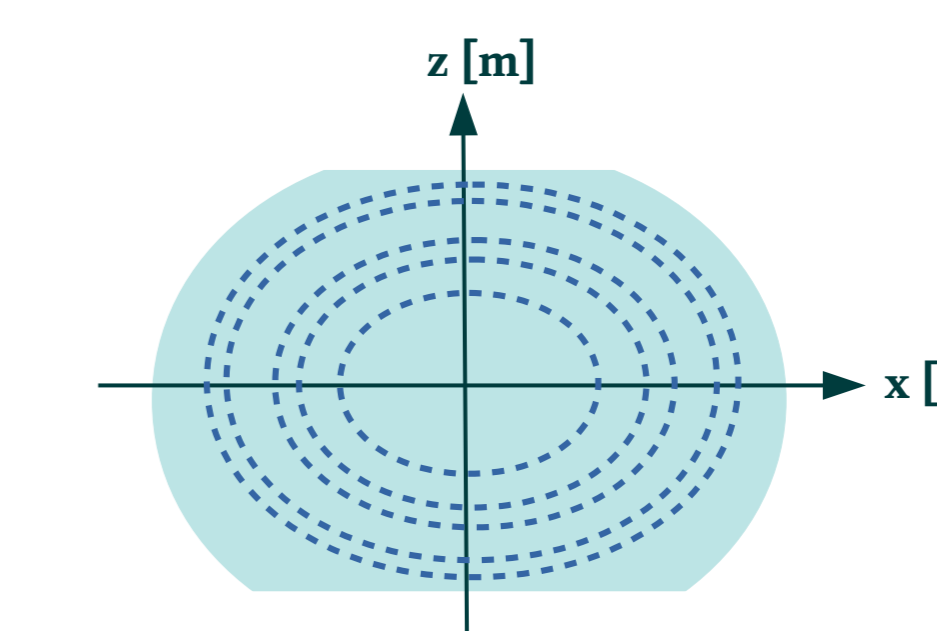
1. ^{210}Bi homogeneity = 0.8 cpd/100t

Angular homogeneity (θ, ϕ)

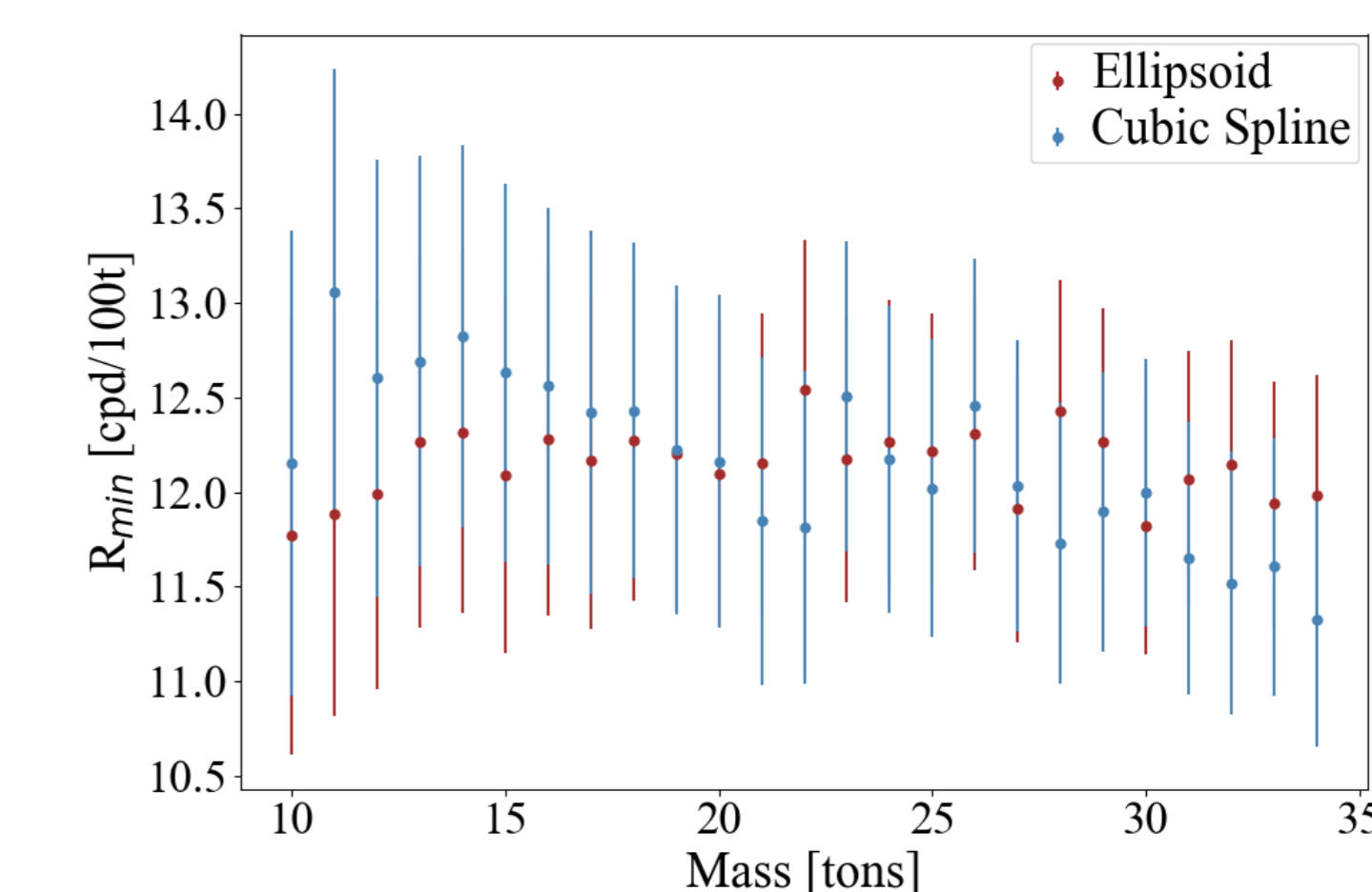
Mollweide Projection



Radial homogeneity
(iso-volumetric shells)



2. Mass of the fit region of ^{210}Po data = 0.4 cpd/100t



- 3. Bin-width of the ^{210}Po data histogram (10-20cm) = 0.2 cpd/100t
- 4. Estimation of leak of β -events in ^{210}Po region using pulse-shape discrimination = 0.3 cpd/100t

CONCLUSION

The final ^{210}Bi upper limit used in the spectral fit for the CNO detection with Borexino is

See poster #238 11.5 ± 0.8 (stat.) ± 1.0 (syst.) cpd/100t