Sensitivity of the orbiting JEM-EUSO mission to large-scale anisotropies

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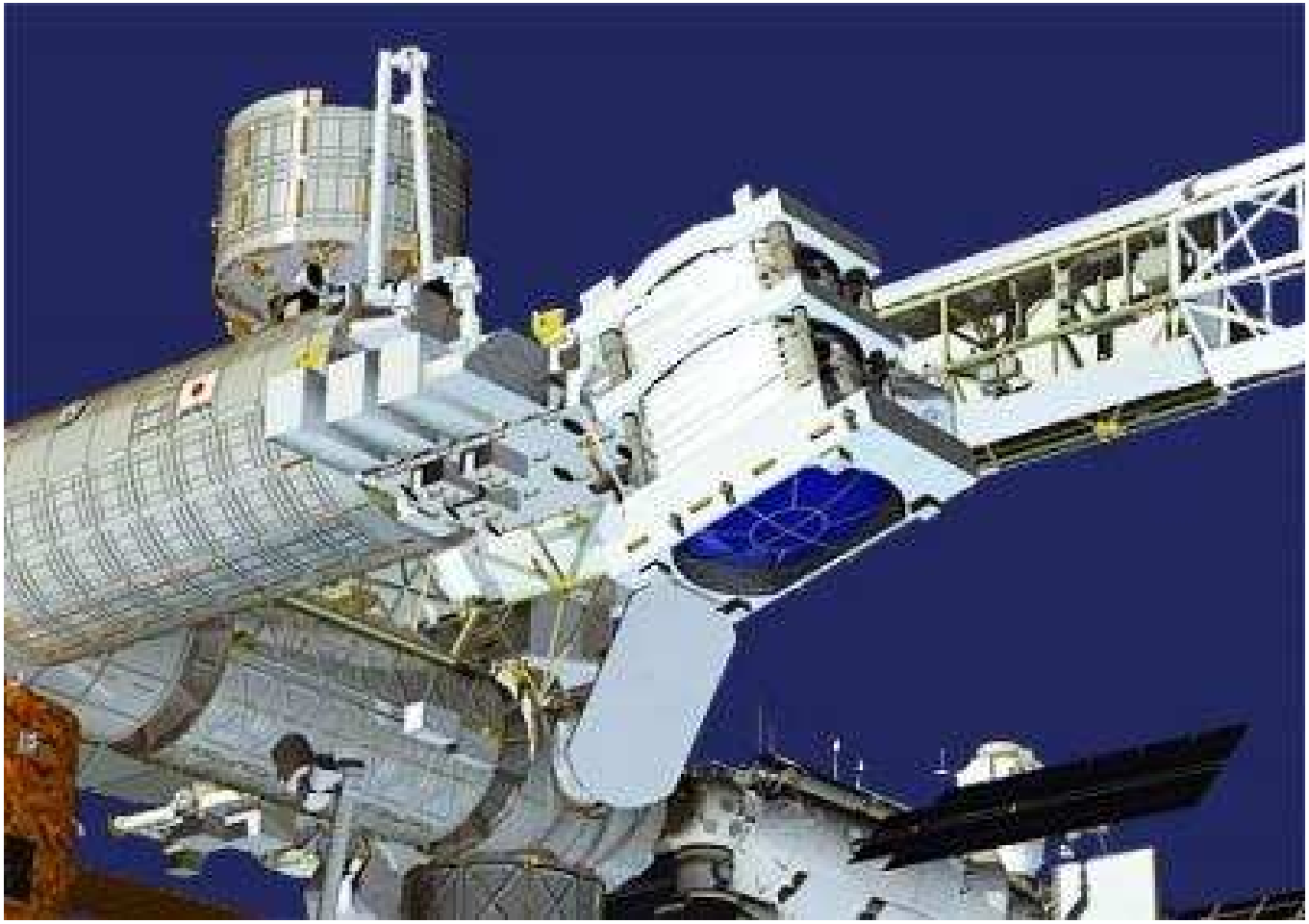
[arxiv:]13**.**** (in progress)

JEM-EUSO is BIG

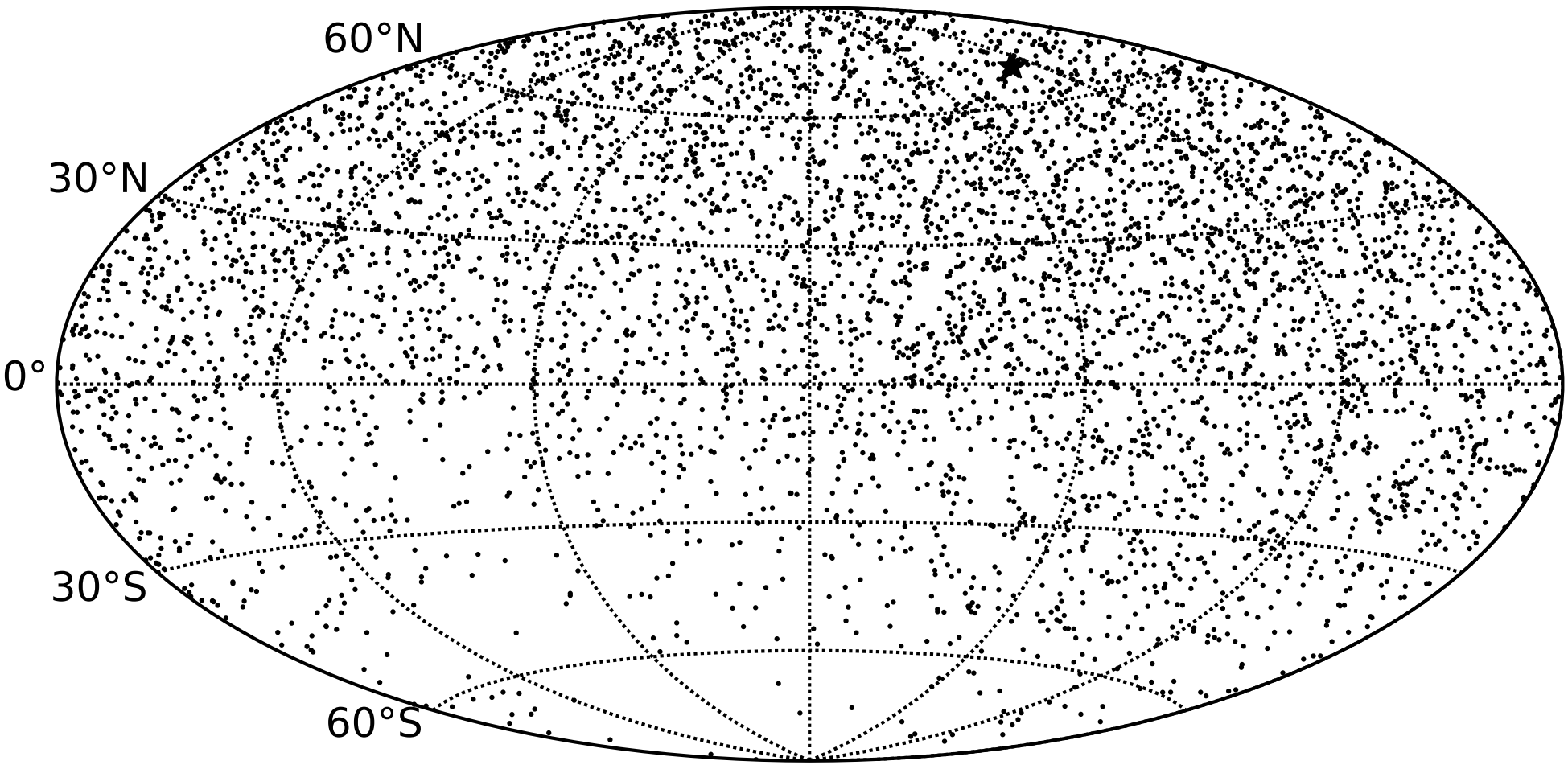


- Uniform systematics across 4π full sky coverage
- Increased average exposure: $\sim 9 \times$ Auger

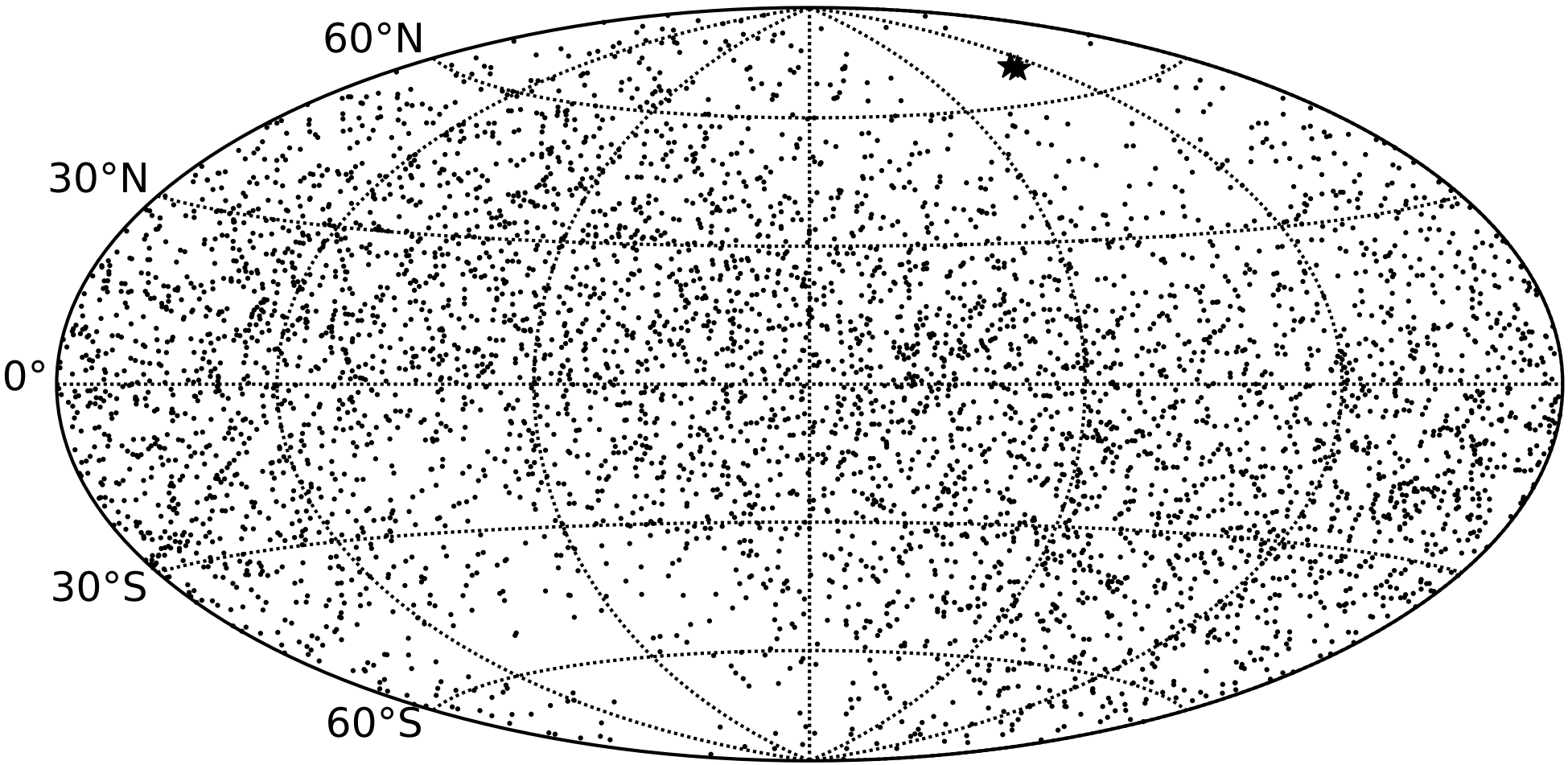
UHECR anisotropy techniques

- General structure can be quantified in terms of Y_ℓ^m's which provide an orthonormal expansion of the sky.
- Identifiable sources: Cen A, Supergalactic plane, etc. use specific Y_ℓ^m's.
  - Point source - dipole: $I \propto Y_0^0 + C_D Y_1^0$
  - Planar source - quadrupole: $I \propto Y_0^0 + C_Q Y_2^0$.
  - There exist techniques to reconstruct the direction and the anisotropy measure given a data set.
- General Y_ℓ^m's: each partitions the sky into $\sim \ell^2/2$ so $\ell_{\max} \sim \sqrt{2N}$
- 500 events gives $\ell_{\max} \sim 30$.

Sample dipole



Sample quadrupole



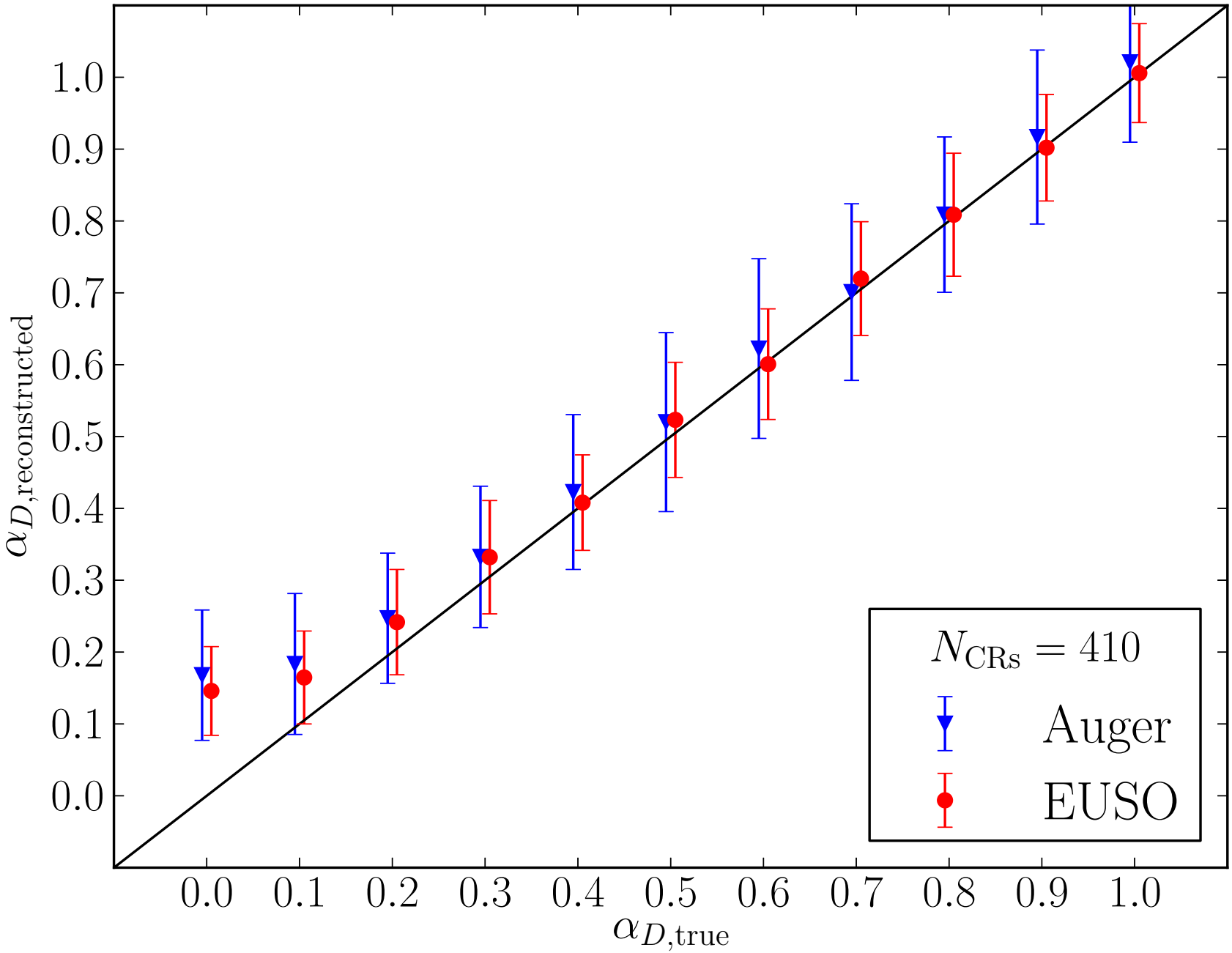
Dipole/quadrupole reconstruction power

How well can the anisotropy be reconstructed for a simulated dipole or a quadrupole assuming knowledge of a pure dipole/quadrupole?

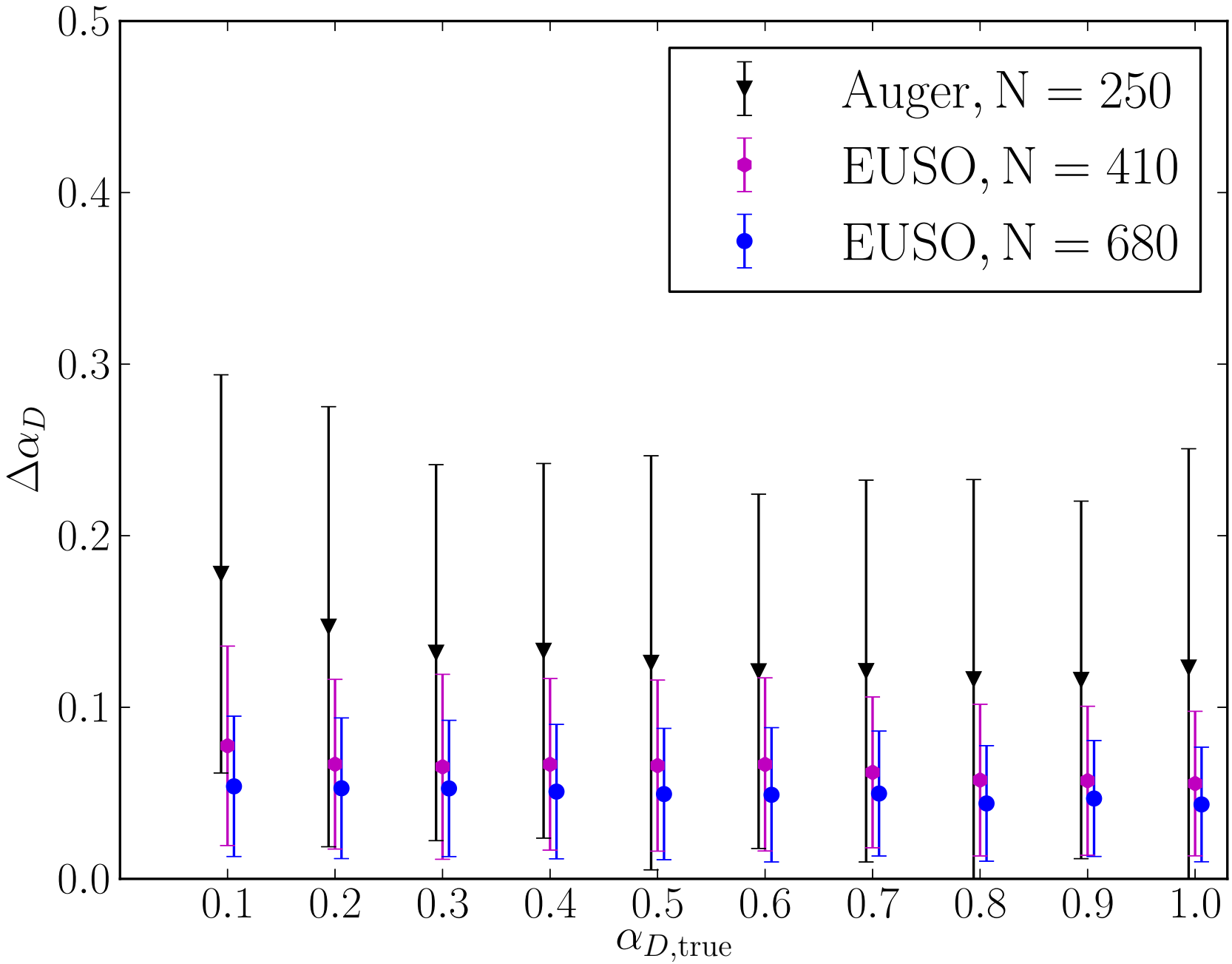
- Over its lifetime, Auger might see 250 events with energies $E > 55$ EeV. EUSO might see 410 or 680 events over its lifetime of 3 or 5 years respectively.
- I simulated either a dipole or a quadrupole with either 250, 410, or 680 events and reconstructed the direction and strength of the anisotropy:

$$\alpha = \frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}} \in [0, 1]$$

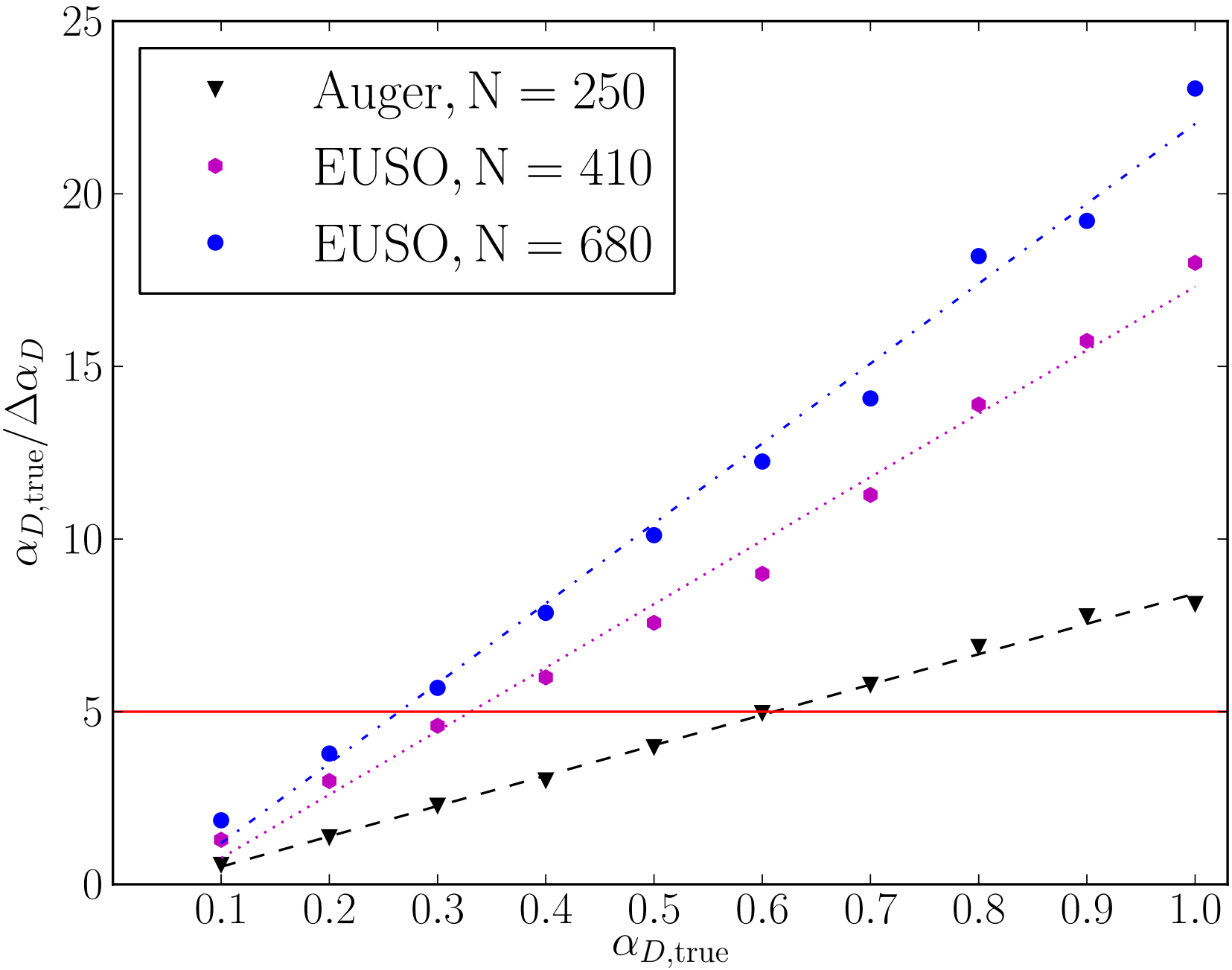
Dipole anisotropy: earth (partial-sky) vs. space (full-sky)



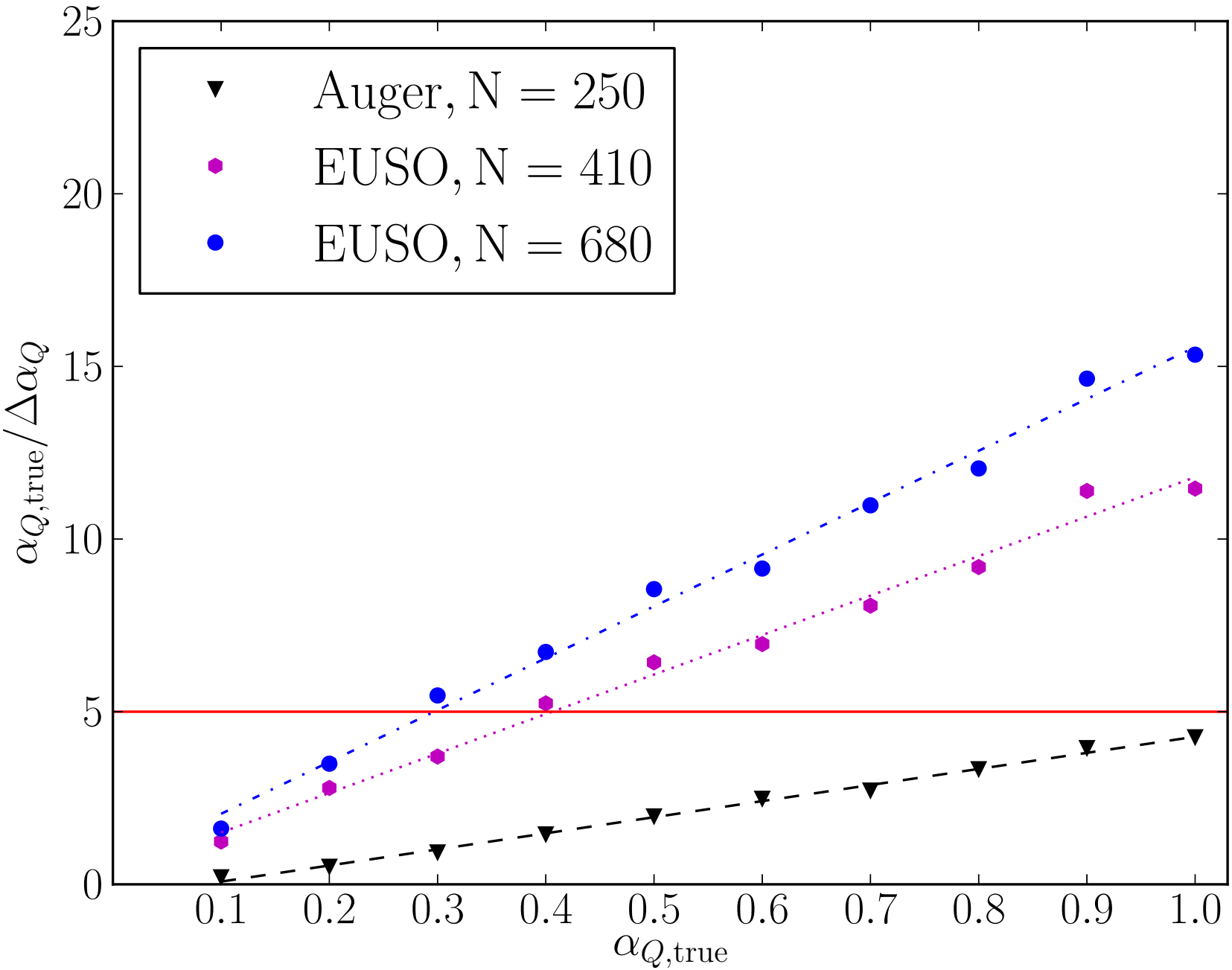
Dipole anisotropy: N_{CRs}



Dipole anisotropy: discovery power



Quadrupole anisotropy: discovery power



Spherical harmonics: formulas

Spherical harmonics are orthonormal. An intensity profile can be expanded as

$$I(\theta, \phi) = \sum_{\ell m} a_{\ell m} Y_\ell^m(\theta, \phi)$$

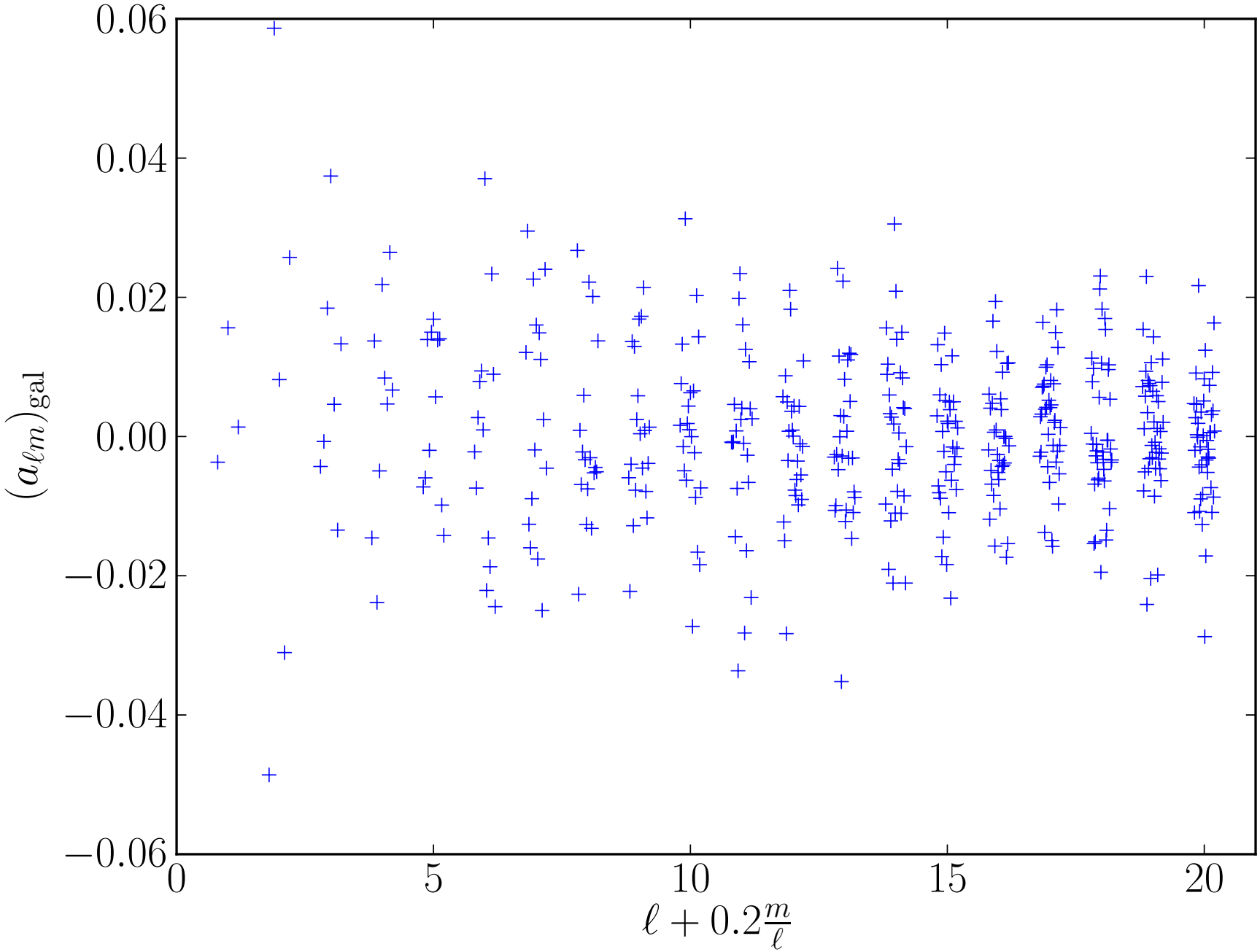
where

$$a_{\ell m} = \frac{1}{N} \sum_i Y_\ell^m(\mathbf{u}_i)$$

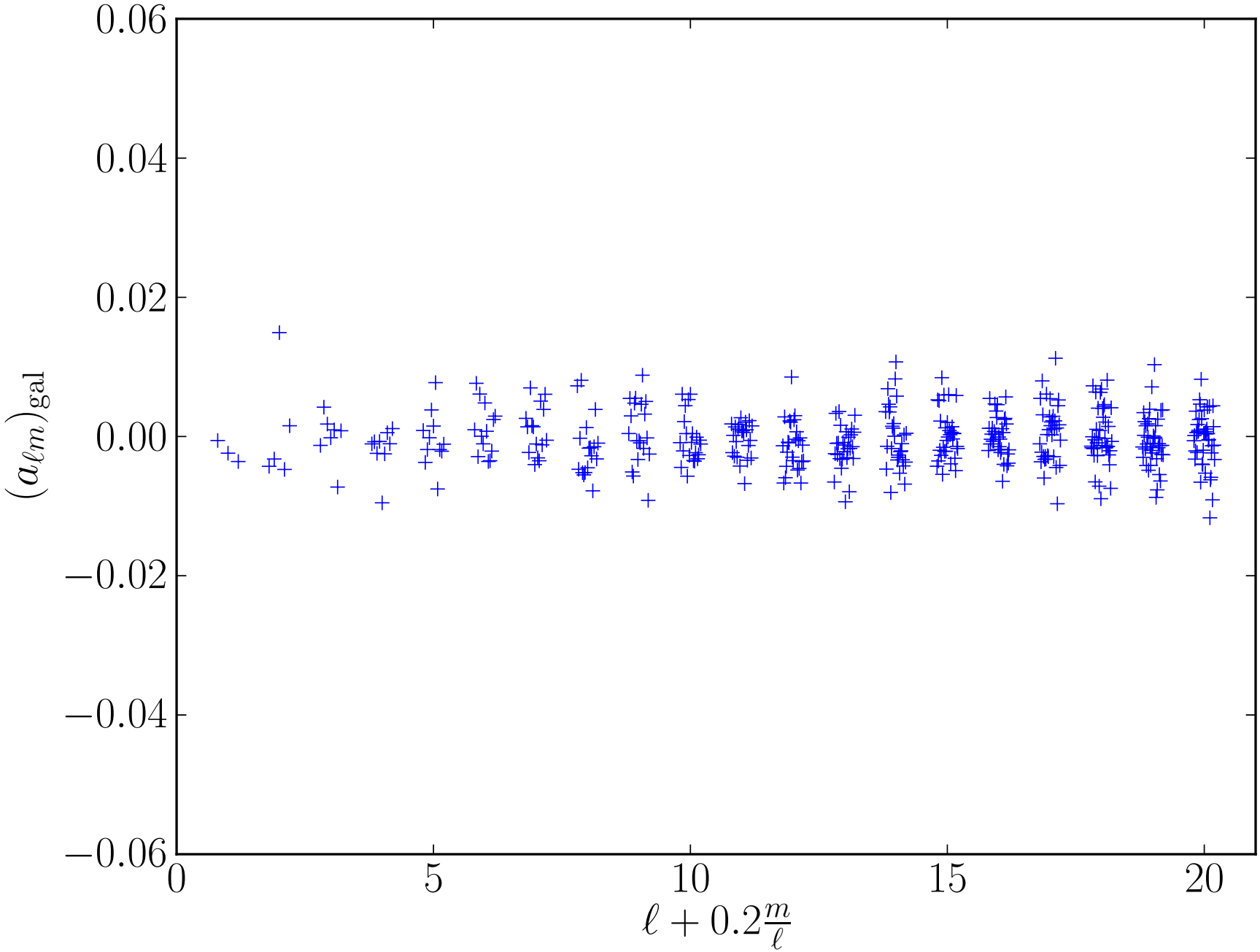
We also define the power spectrum as

$$c_\ell = \frac{1}{2\ell + 1} \sum_m a_{\ell m}^2$$

Spherical harmonics of 5310 nearby galaxies $z < 0.03$

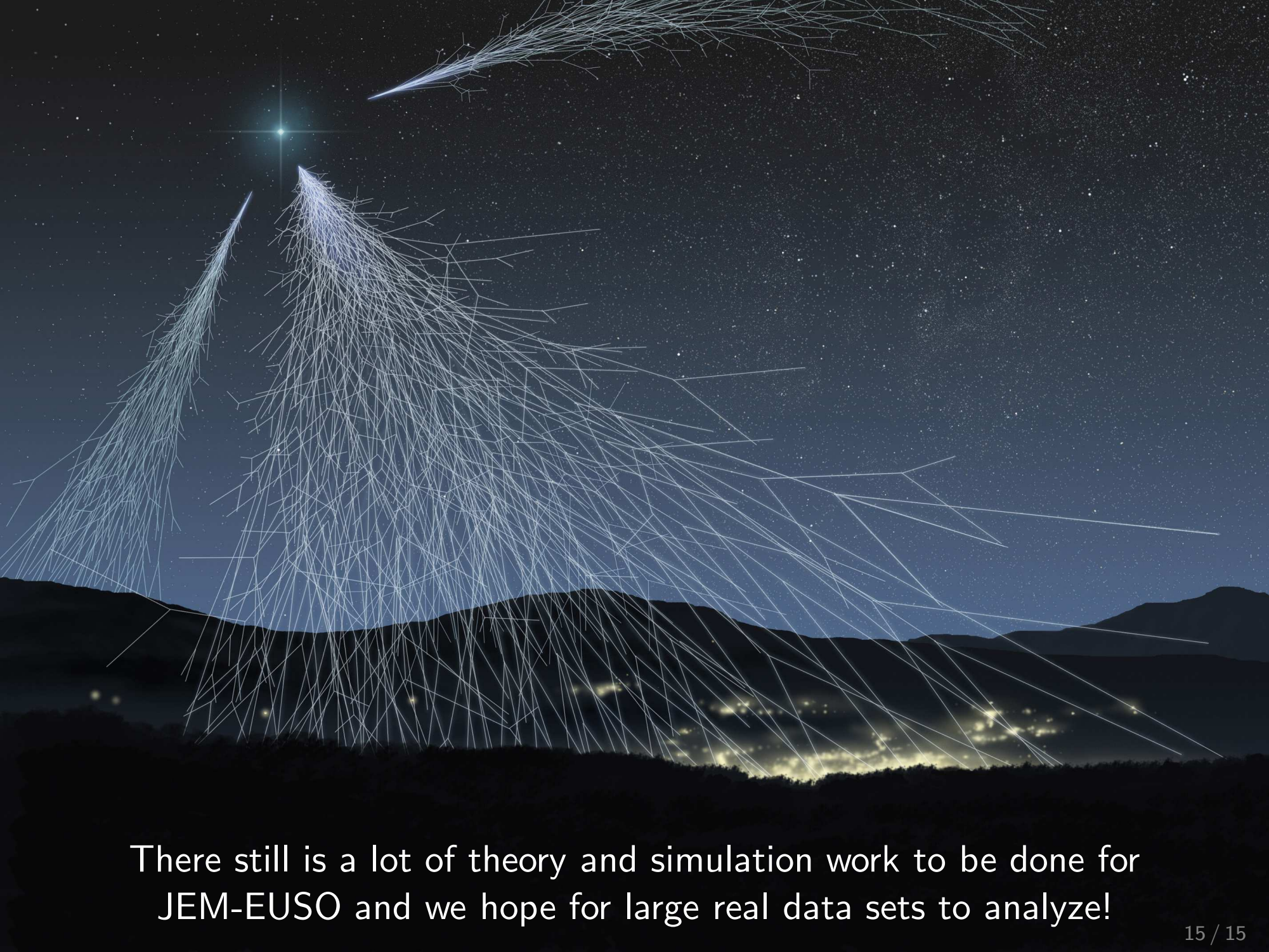


Spherical harmonics of 5310 random directions



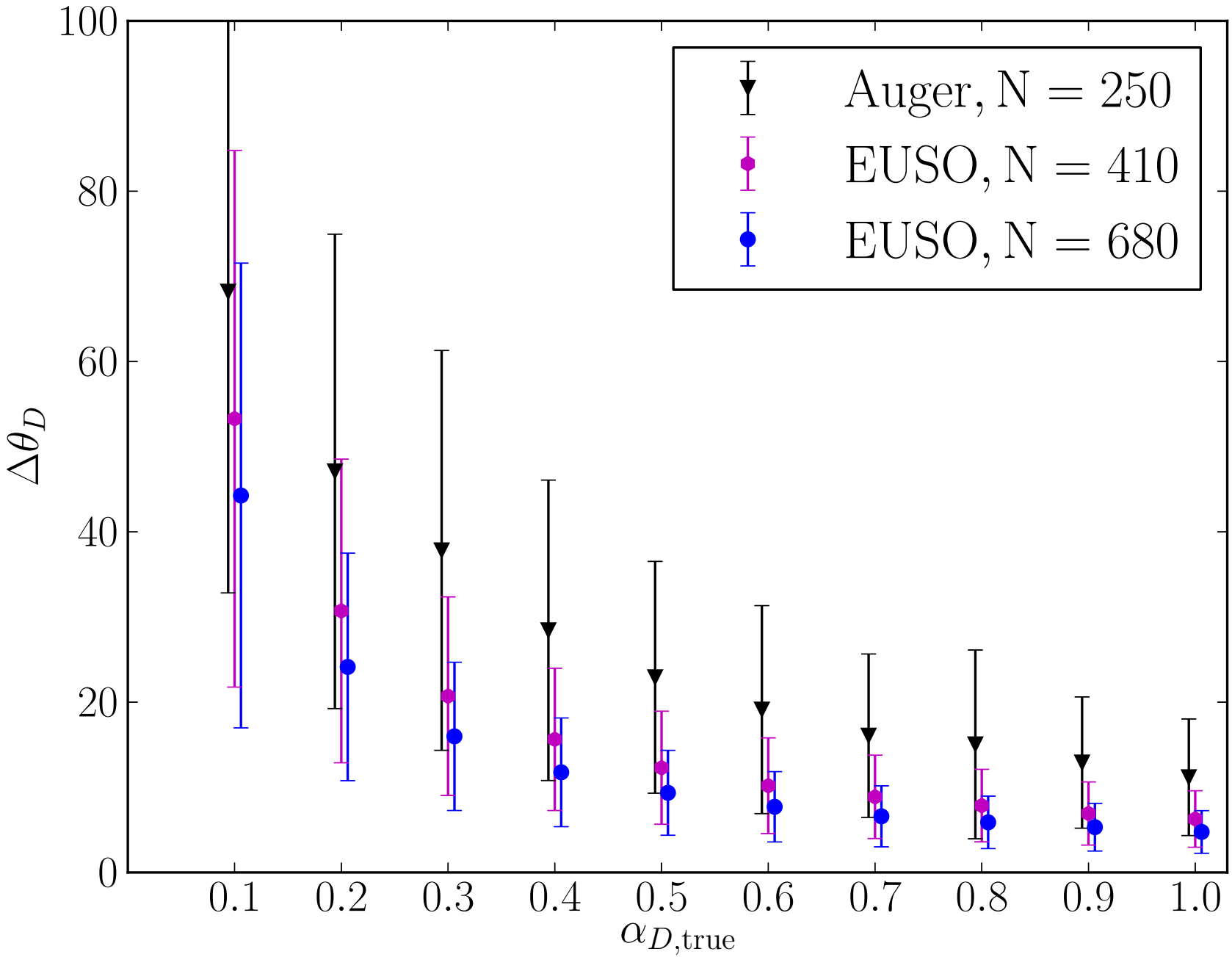
Future work

- Dipole and quadrupole rejection.
- Combine a CR propagation code with GZK and magnetic bending effects with galactic surveys and a power spectra analysis.
- Possibly relating specific galaxy types and and a signal in the power spectrum.

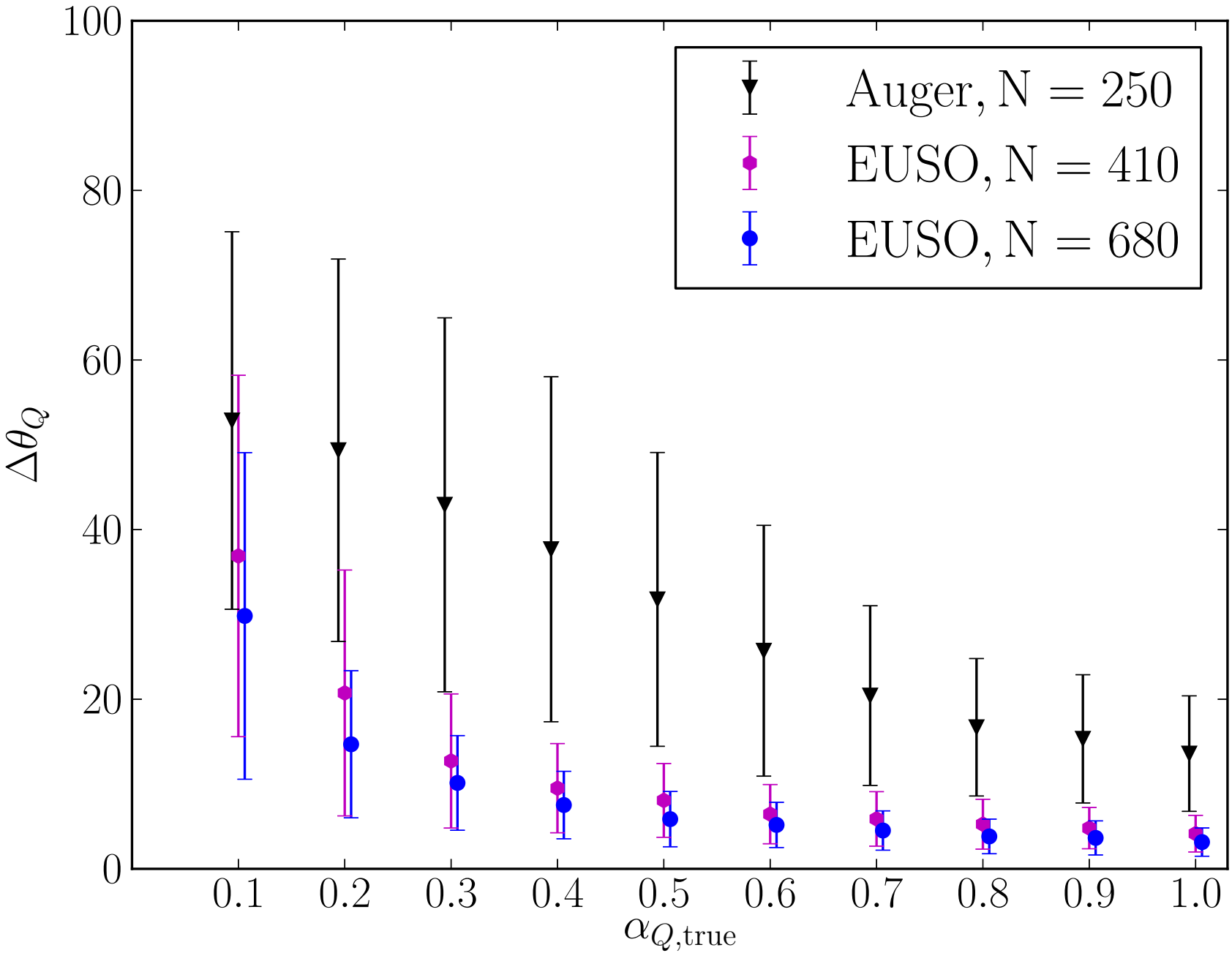


There still is a lot of theory and simulation work to be done for JEM-EUSO and we hope for large real data sets to analyze!

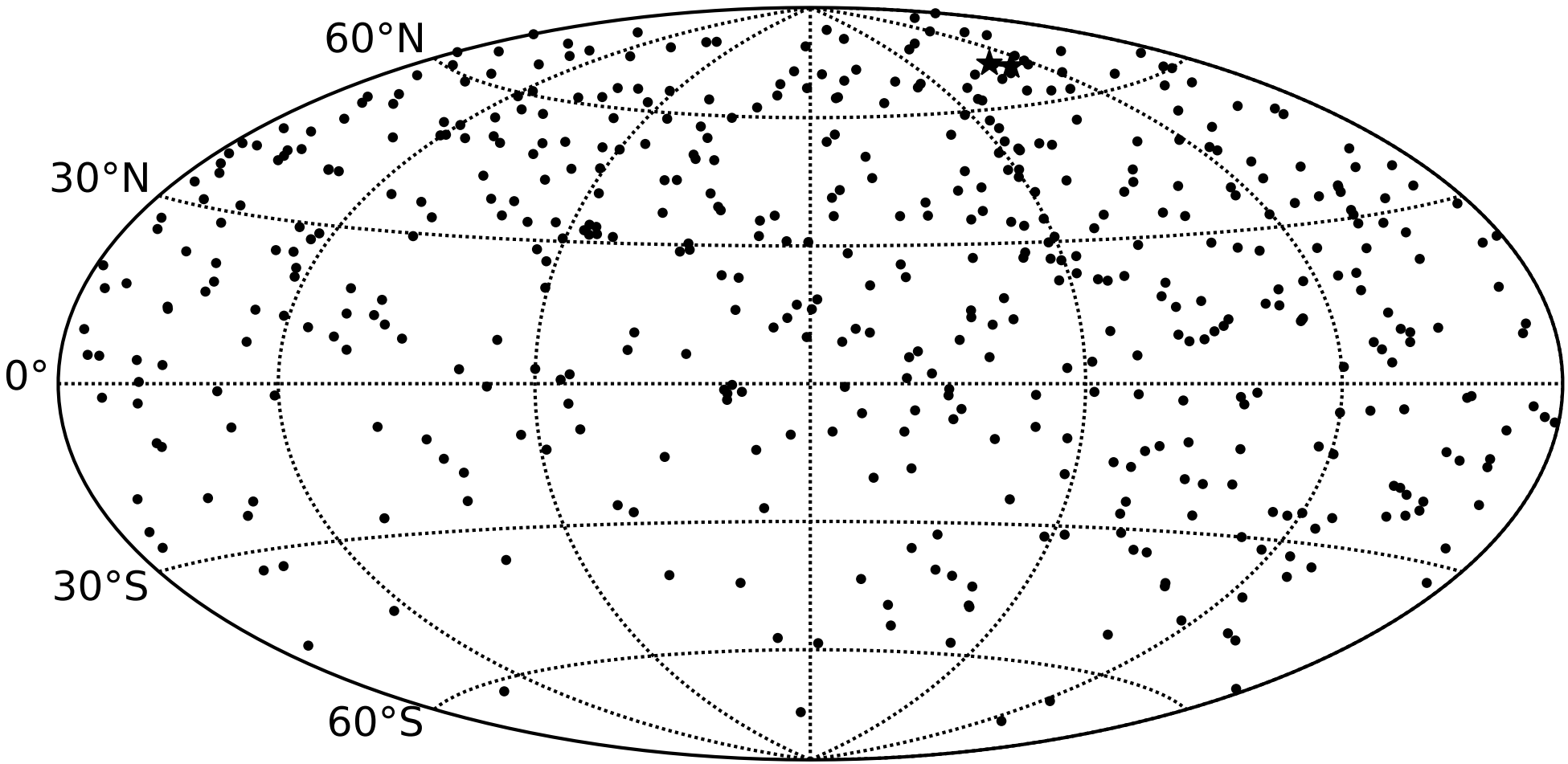
Dipole anisotropy: directional accuracy



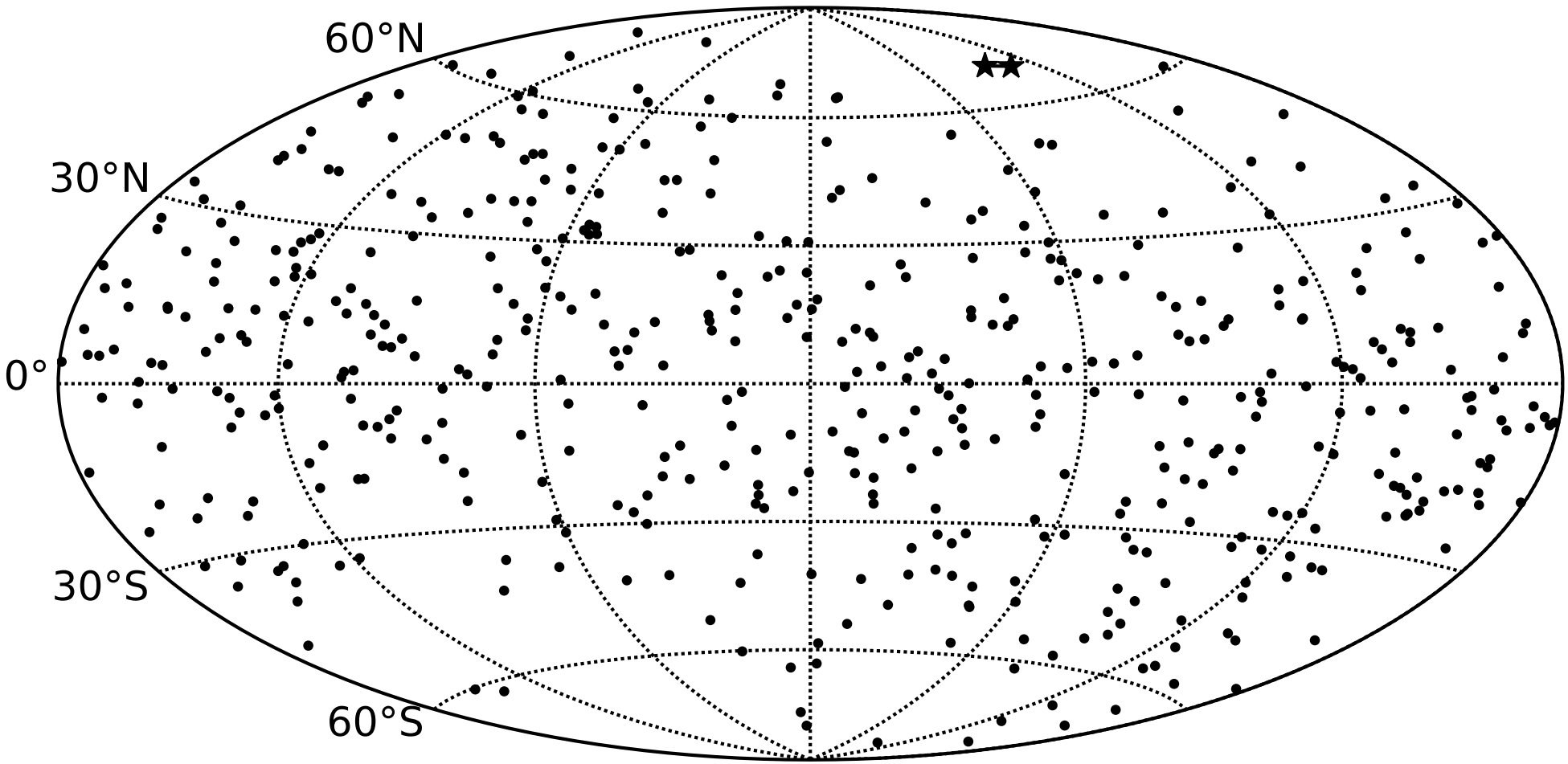
Quadrupole anisotropy: directional accuracy



Sample dipole



Sample quadrupole



Relative JEM-EUSO exposure