SERCH FOR LARGE-SCALE ANISOTROPY WITH HIRES

P. Tinyakov
for the HiRes collaboration

ULB, Brussels & INR, Moscow

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Previous anisotropy studies

1. Anisotropies
   - Clustering in AGASA and Yakutsk data at 4×10^{19} eV
     not confirmed by HiRes, AUGER
   - Excess in the direction of the Galactic center in AGASA data at 10^{18} eV
     not confirmed by AUGER
   - Anisotropy in AUGER data at high energies
2. Correlations with specific sources
   - Correlation with BL Lacs in HiRes data at 10^{19} eV
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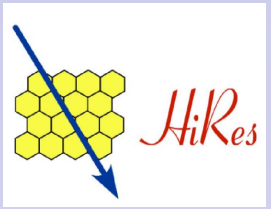
   - Correlation with AGN in AUGER data at
     5.7×10^{19} eV
     not confirmed by HiRes
   - Correlation with seyfert galaxies, colliding galaxies, pulsars, dead quasars, ...
3. Correlations with supergalactic plane



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Correlation with LSS

- "Matter tracer" model: generic model of CRs.
  Assumptions:
  - nearly straight propagation
    typical deflections do not exceed $10^\circ - 20^\circ$

$$\theta_{\rm rand} = 1.8^\circ Z \left(\frac{E}{10^{20}{\rm eV}}\right)^{-1} \left(\frac{l_c R}{50{\rm Mpc}^2}\right)^{1/2} \left(\frac{B}{10^{-9}{\rm G}}\right)$$

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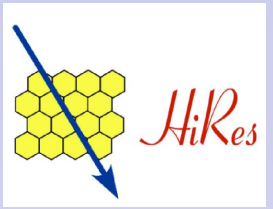
  - many sources within ~ 100 Mpc
    GZK cutoff $\Longrightarrow$ sources must be nearby ($\lesssim 100$ Mpc)

Major prediction: at scales $\lesssim 100$ Mpc matter is inhomogeneous $\Longrightarrow$

anisotropic CR flux



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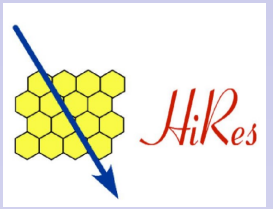

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TO COMPARE THE PREDICTIONS OF THE MATTER-TRACER MODEL WITH HIRES DATA

Data for this analysis:

- HiRes stereo data set
  - *309 events with* $E > 10$ *EeV*
  - *27 events with* $E > 40$ *EeV*
  - *10 events with* $E > 57$ *EeV*
- Angular resolution of stereo events is $\lesssim 1^\circ$
- Exposure is calculated from Monte Carlo simulations

Two main parts of the analysis:

- Calculate the expected flux
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Generating flux maps

- Matter distribution is modeled from the 2MRS catalog (2 Micron All-Sky Redshift Survey; provided by J.Huchra)
  - *complete up to K_s-magnitude $m < 11.25$ except around the Galactic plane $b < 10°$*
  - *contains spectroscopic redshifts for all but a few galaxies*
  - *accurately represents source distribution out to ~ 250 Mpc*
  - *15508 galaxies after all cuts*
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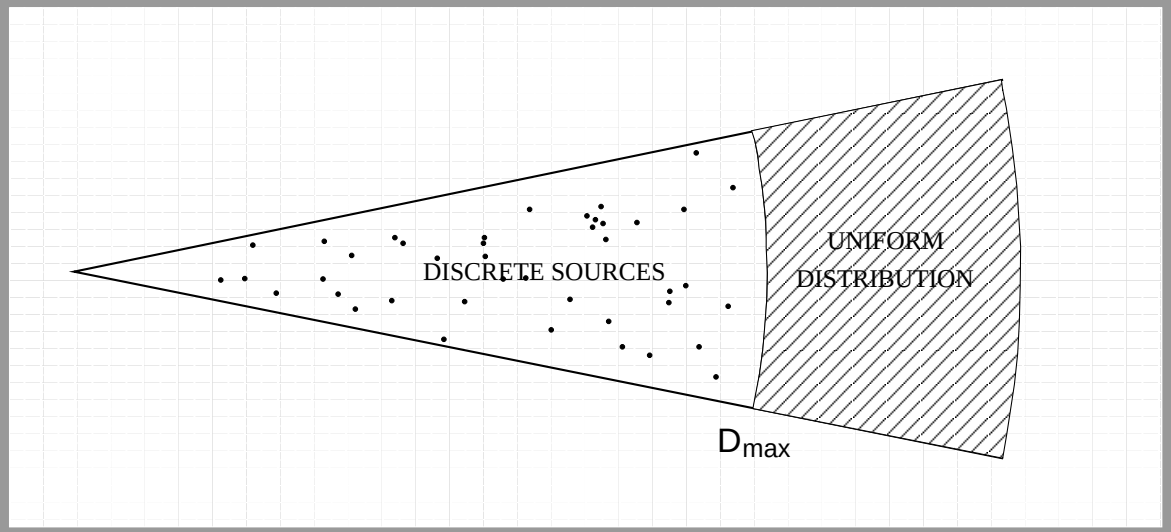
Generating flux maps

- For sources beyond 250 Mpc a uniform component is added



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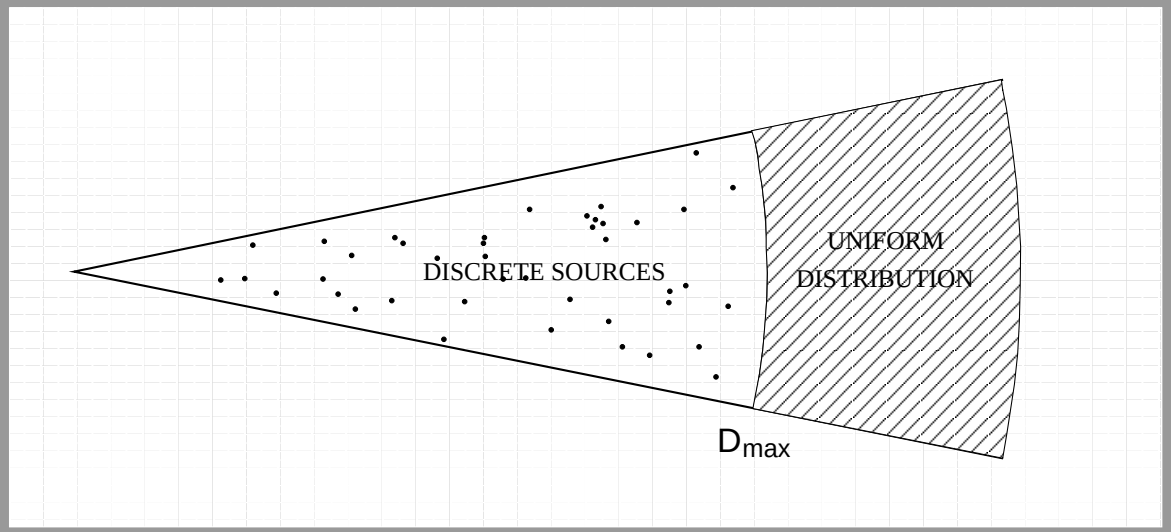

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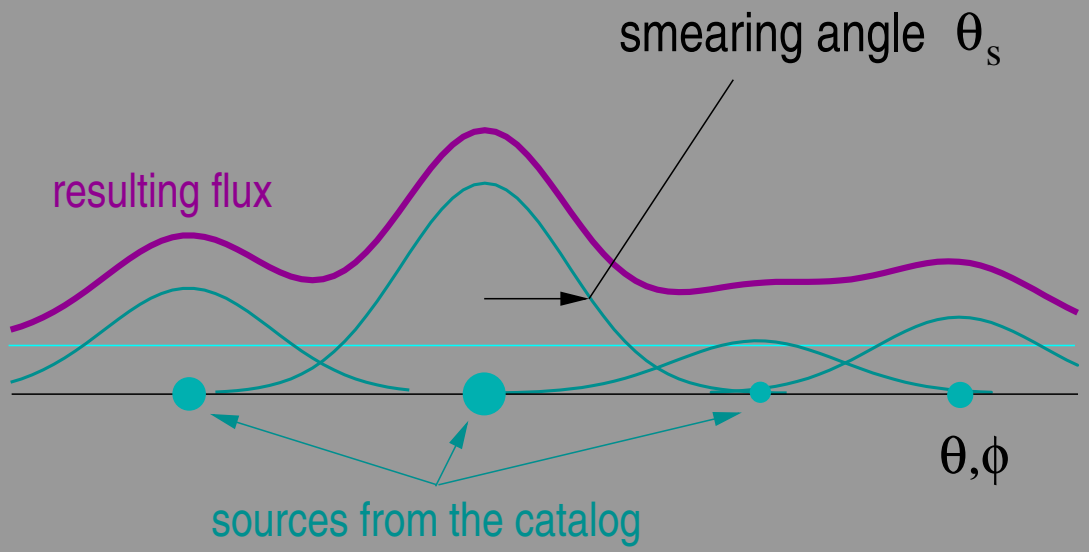
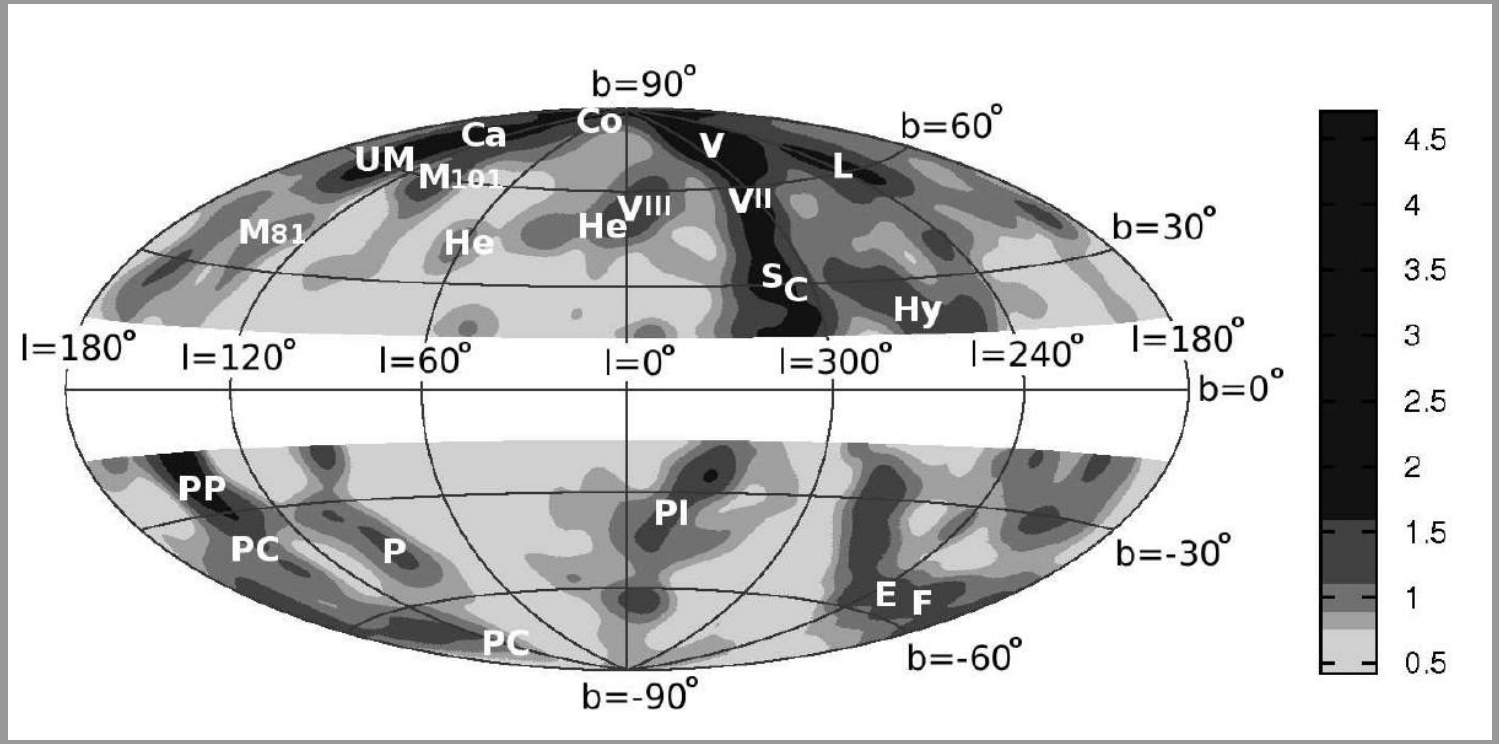
Generating flux maps

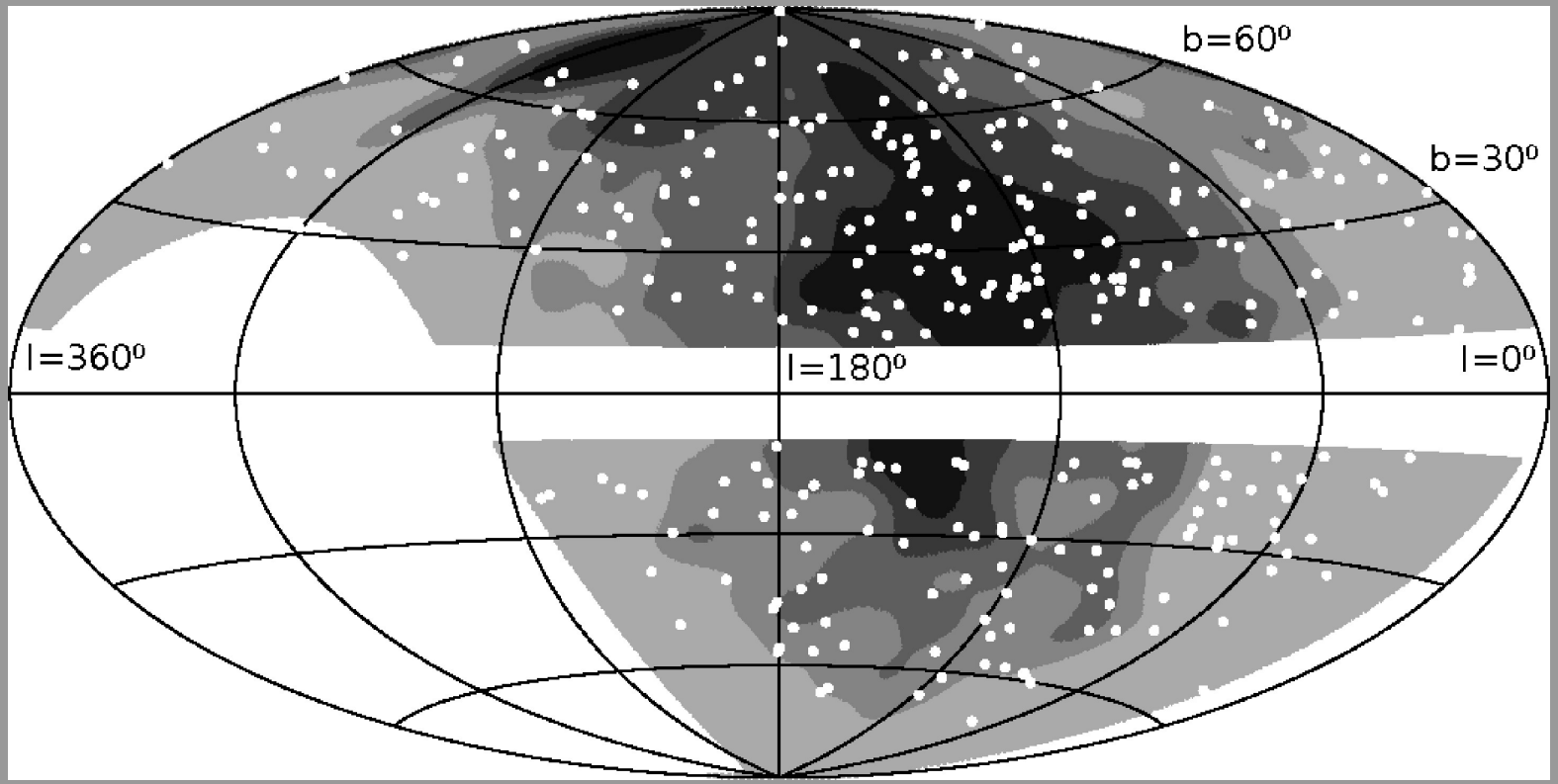
- For a given direction, we sum contributions of point sources and uniform component



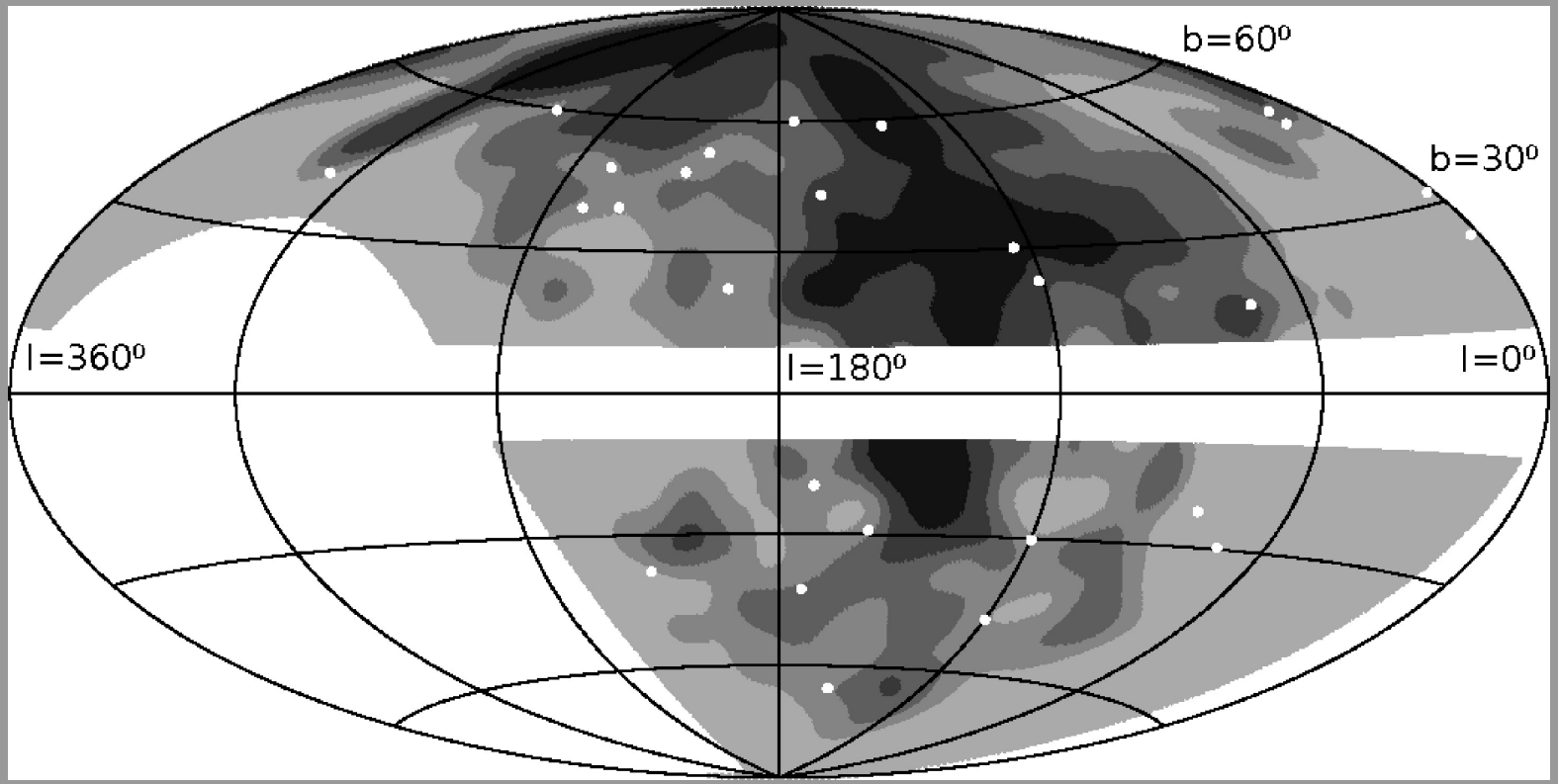
- Modulate with exposure



C: Centaurus supercluster (60 Mpc); Ca: Canes I group (4 Mpc) and Canes II group (9 Mpc); Co: Coma cluster (90 Mpc); E: Eridanus cluster (30 Mpc); F: Fornax cluster (20 Mpc); He: Hercules superclusters (140 Mpc); Hy: Hydra supercluster (50 Mpc); L: Leo supercluster (130 Mpc), Leo I group (10 Mpc), and Leo II group (20 Mpc); M81: M81 group (4 Mpc); M101: M101 group (8 Mpc); P: Pegasus cluster (60 Mpc); PI: Pavo-Indus supercluster (70 Mpc); PC: Pisces- Cetus supercluster (250 Mpc); PP: Perseus-Pisces supercluster (70 Mpc); S: Shapley supercluster (200 Mpc); UM: Ursa Ma jor supercluster (240 Mpc), Ursa Ma jor North group (20 Mpc), and Ursa Ma jor South group (20 Mpc); V: Virgo cluster (20 Mpc); VII: Virgo II group (20 Mpc); VIII: Virgo III group (20 Mpc).



$E > 10$ EeV



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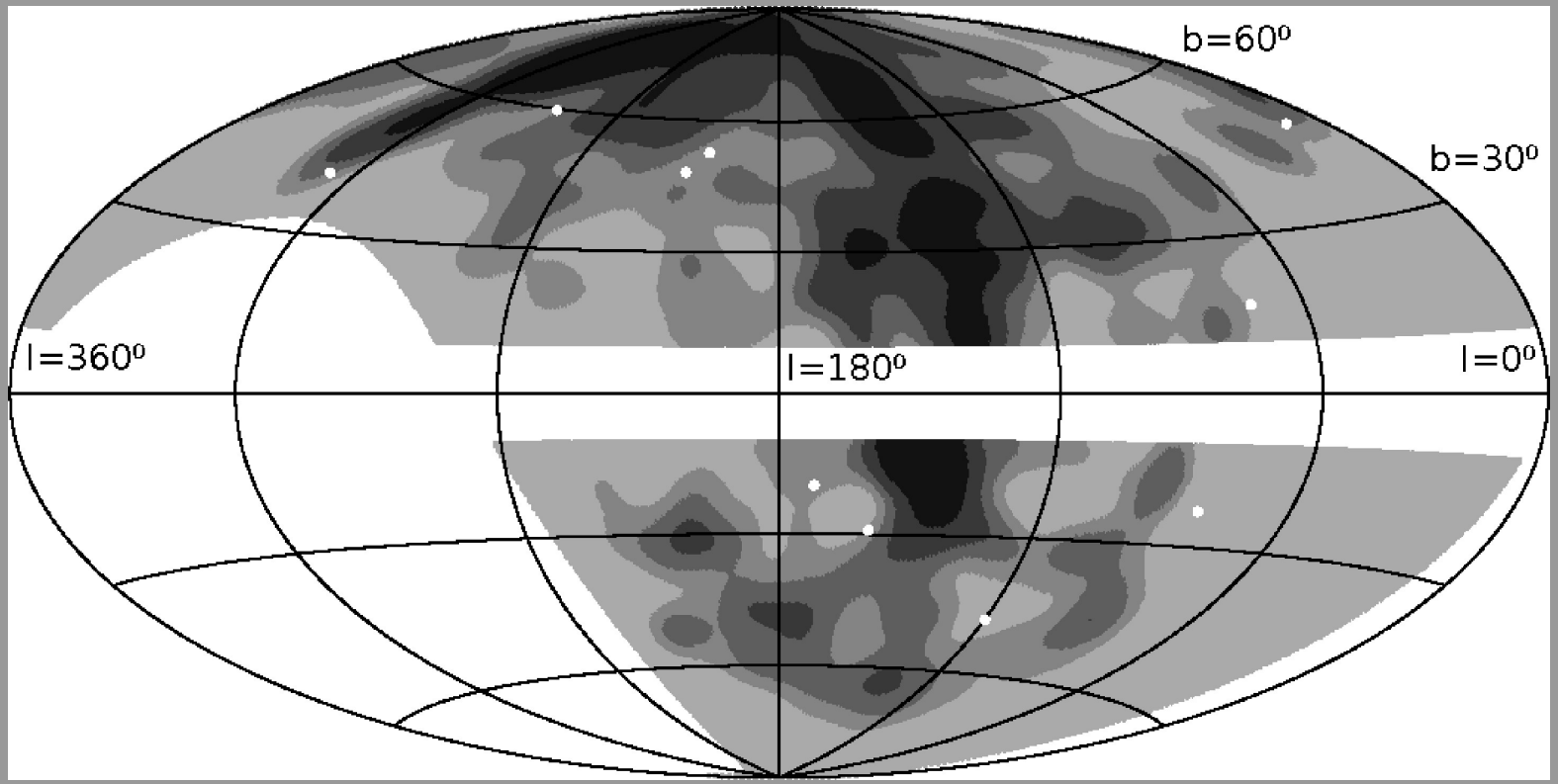

$E > 57$ EeV

Flux sampling test

- Events following the model would produce uniform distribution over the bands
- No binning is needed (on the picture it is for illustration only): two distributions may be compared by the KS test

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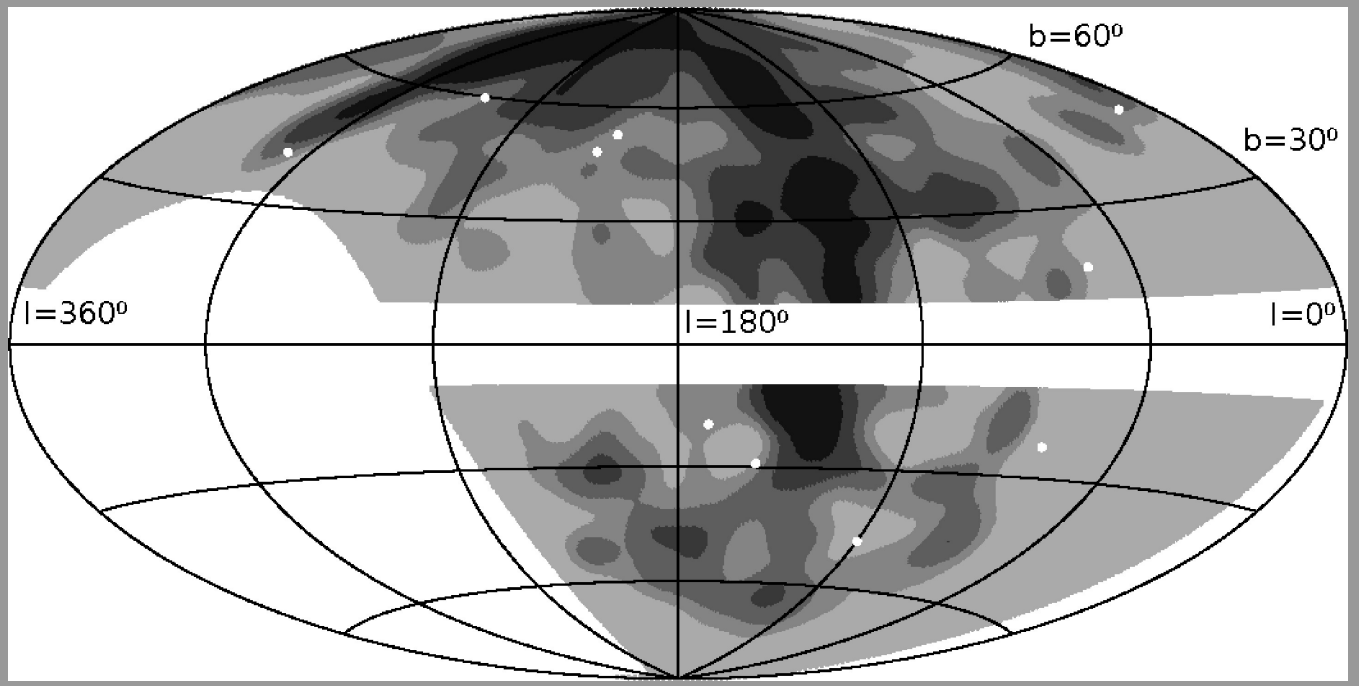

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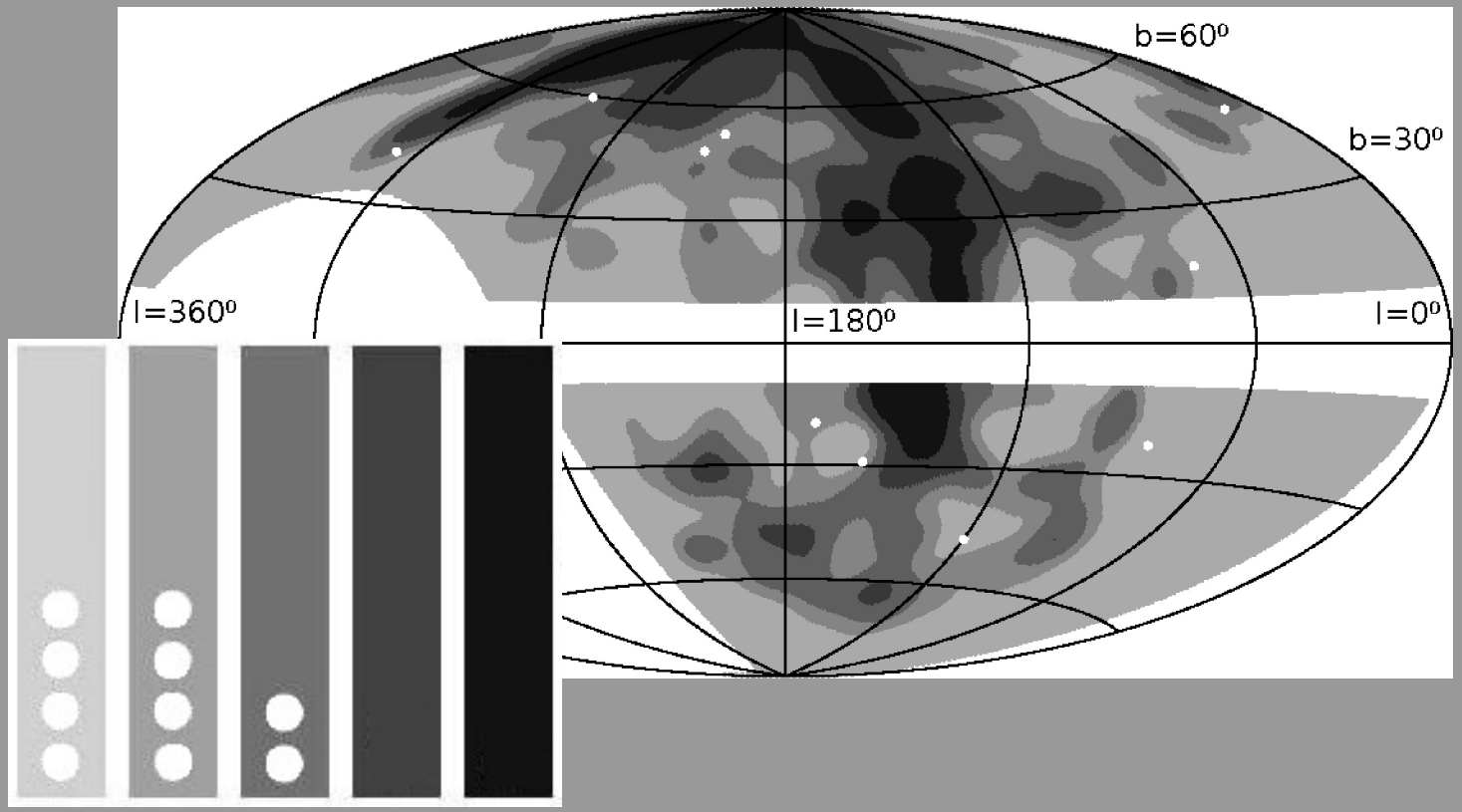

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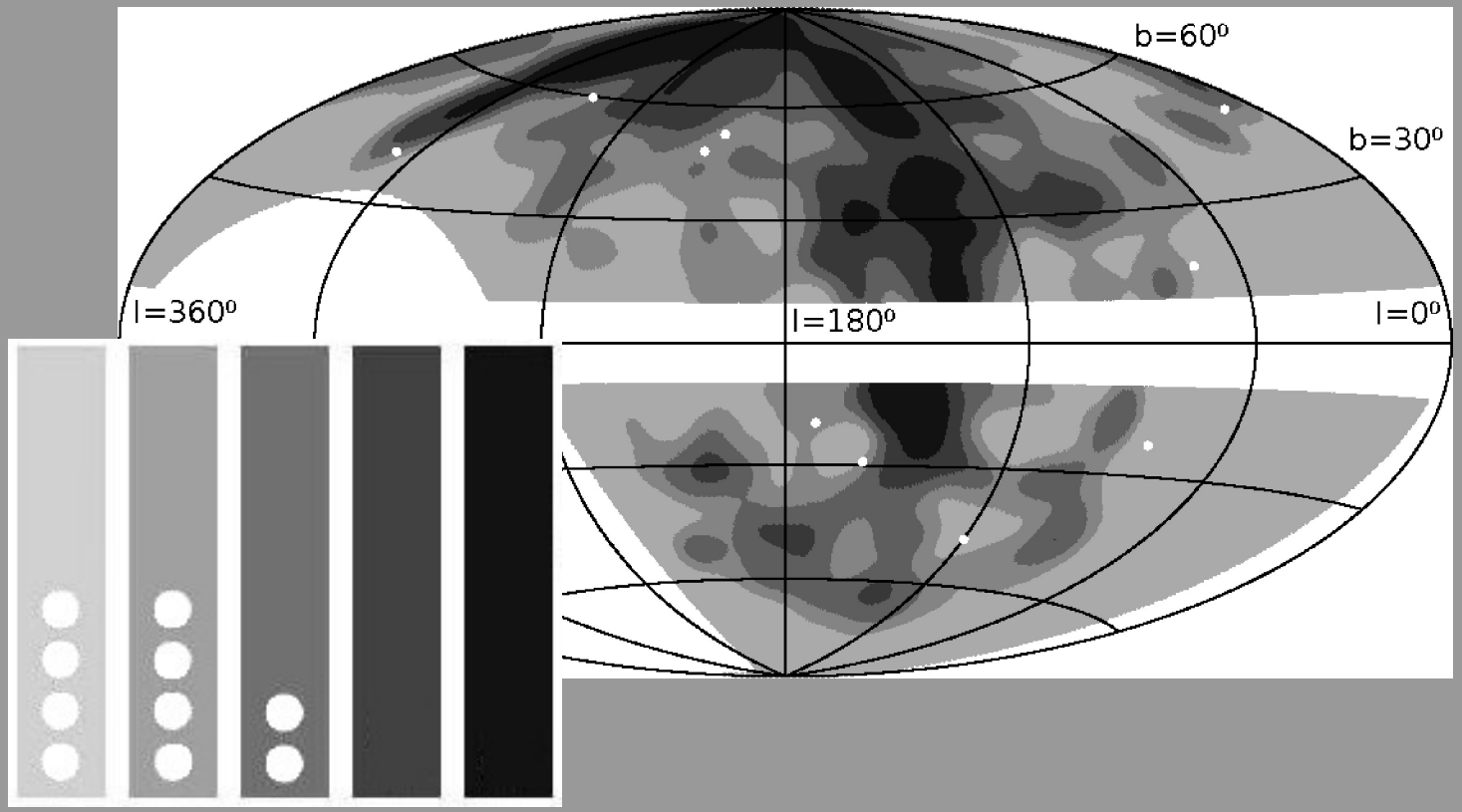

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Results

For this analysis we choose:

- Three energy thresholds: $E > 10$ EeV, $E > 40$ EeV, $E > 57$ EeV
- Confidence level CL=95%
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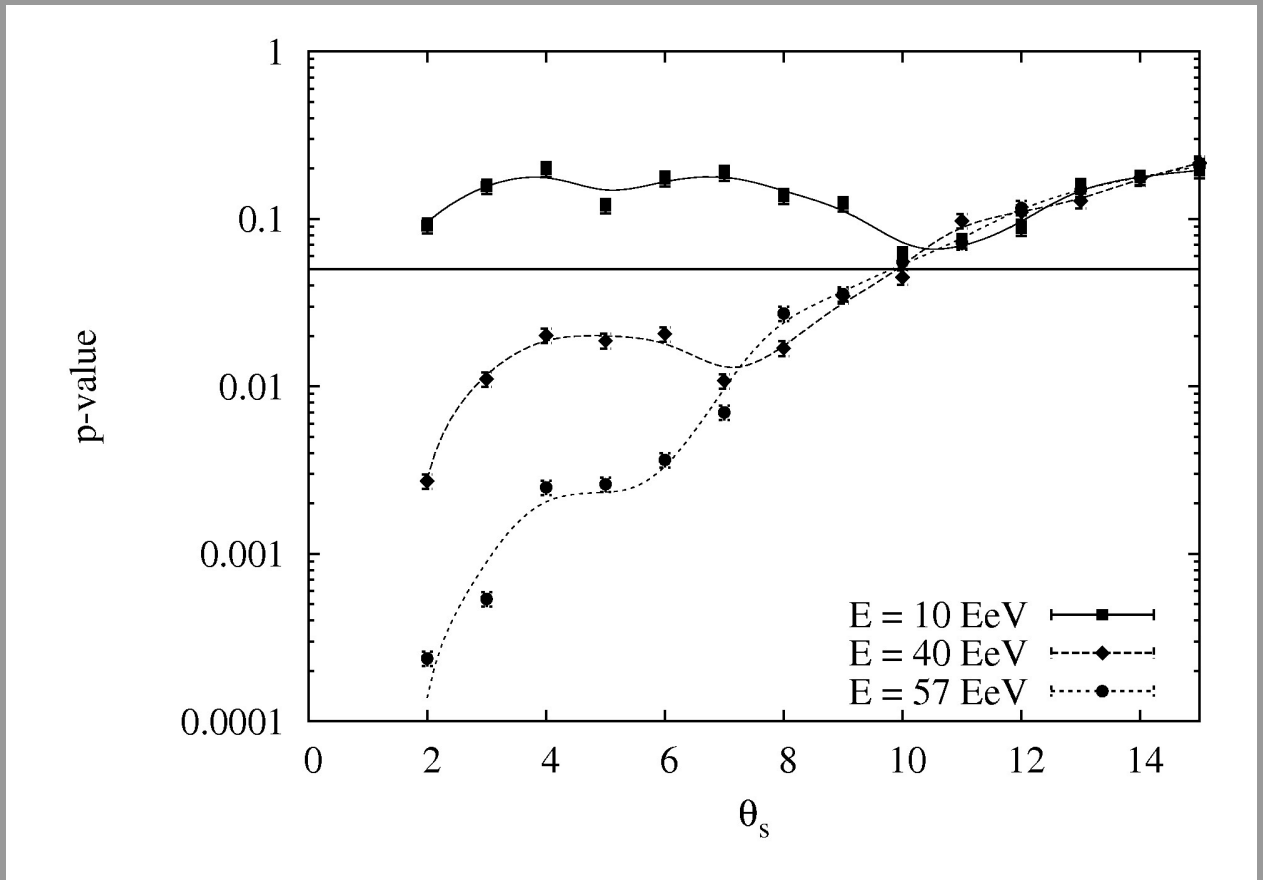

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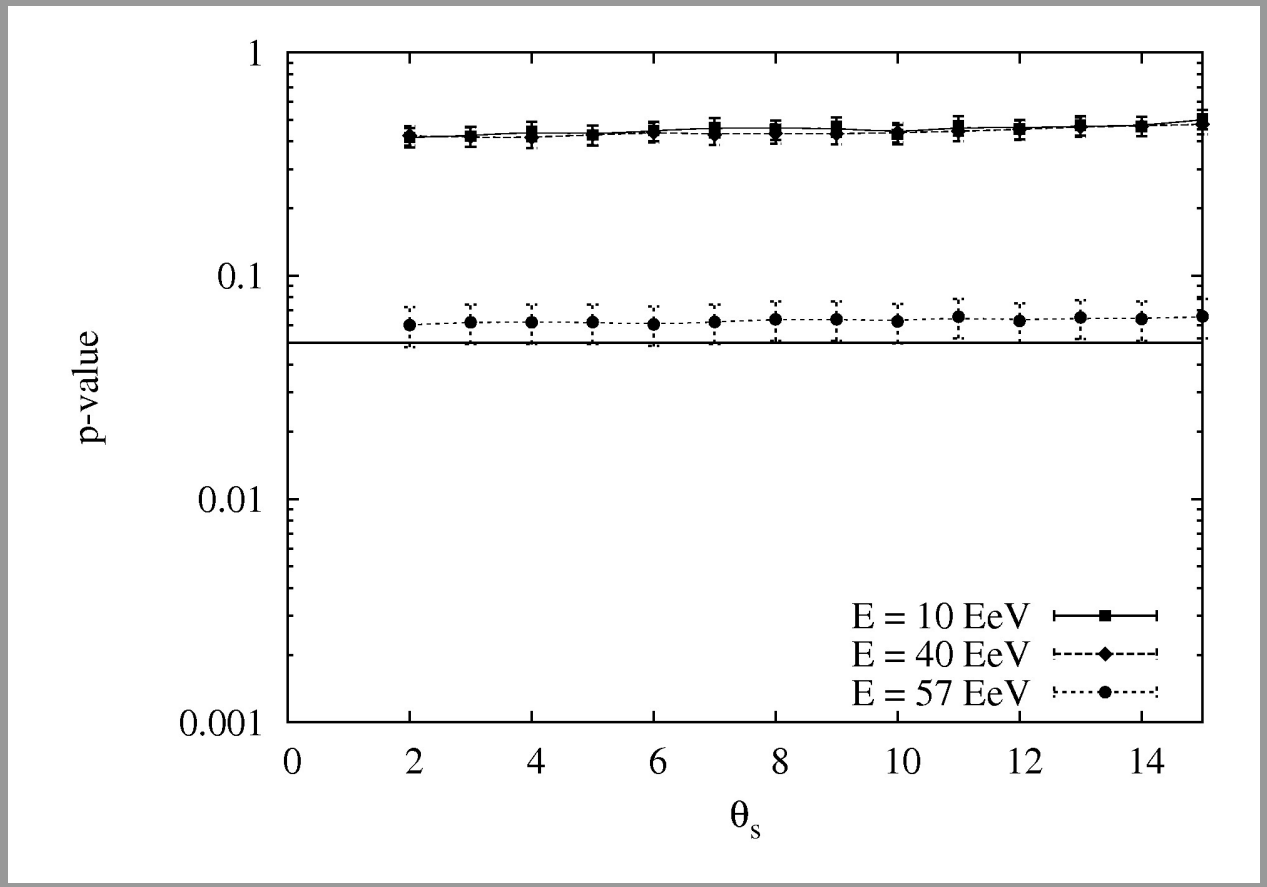

Data vs. isotropic distribution.

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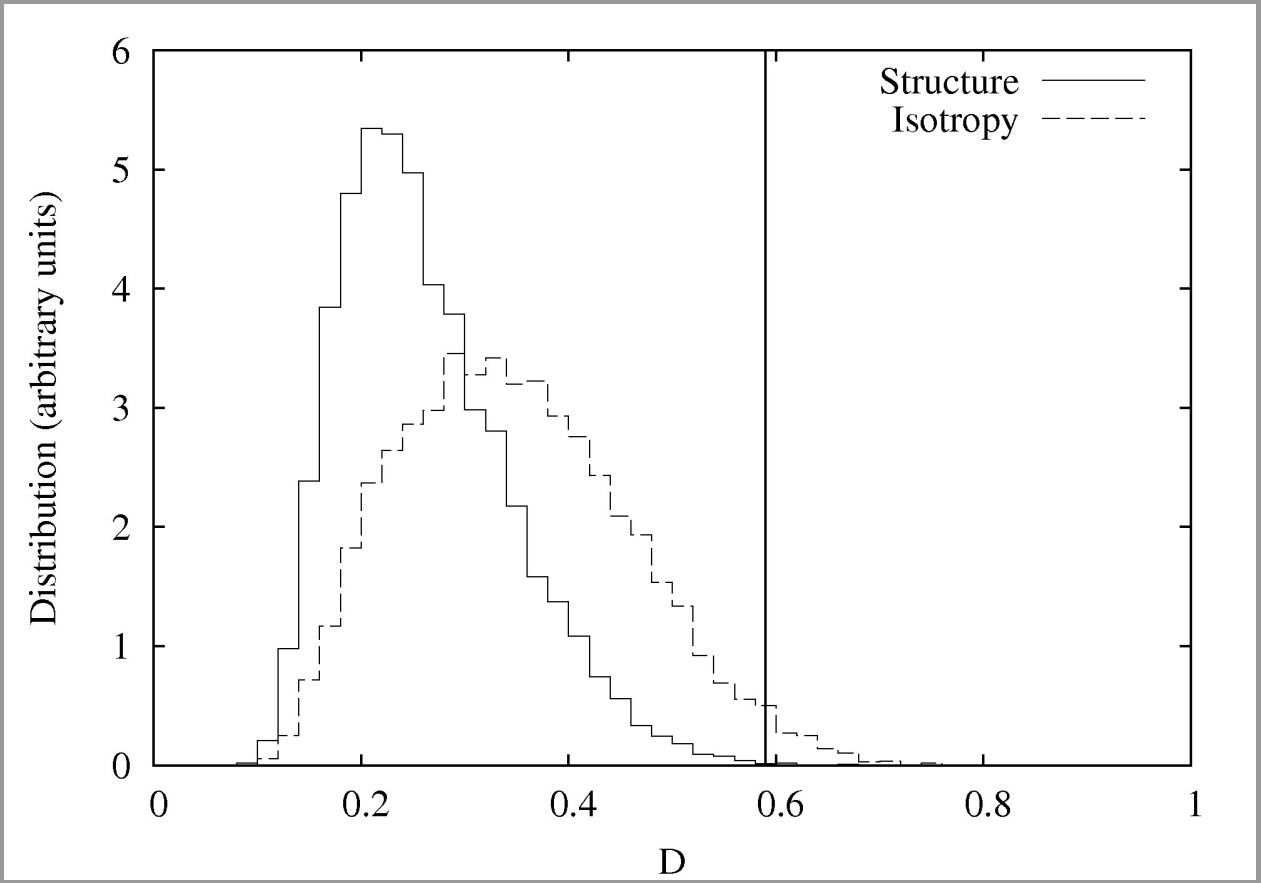

Distribution of KS test statistics for matter tracer model ("Structure") and isotropic distribution ($E = 57$ EeV and $\theta_s = 3.2°$).

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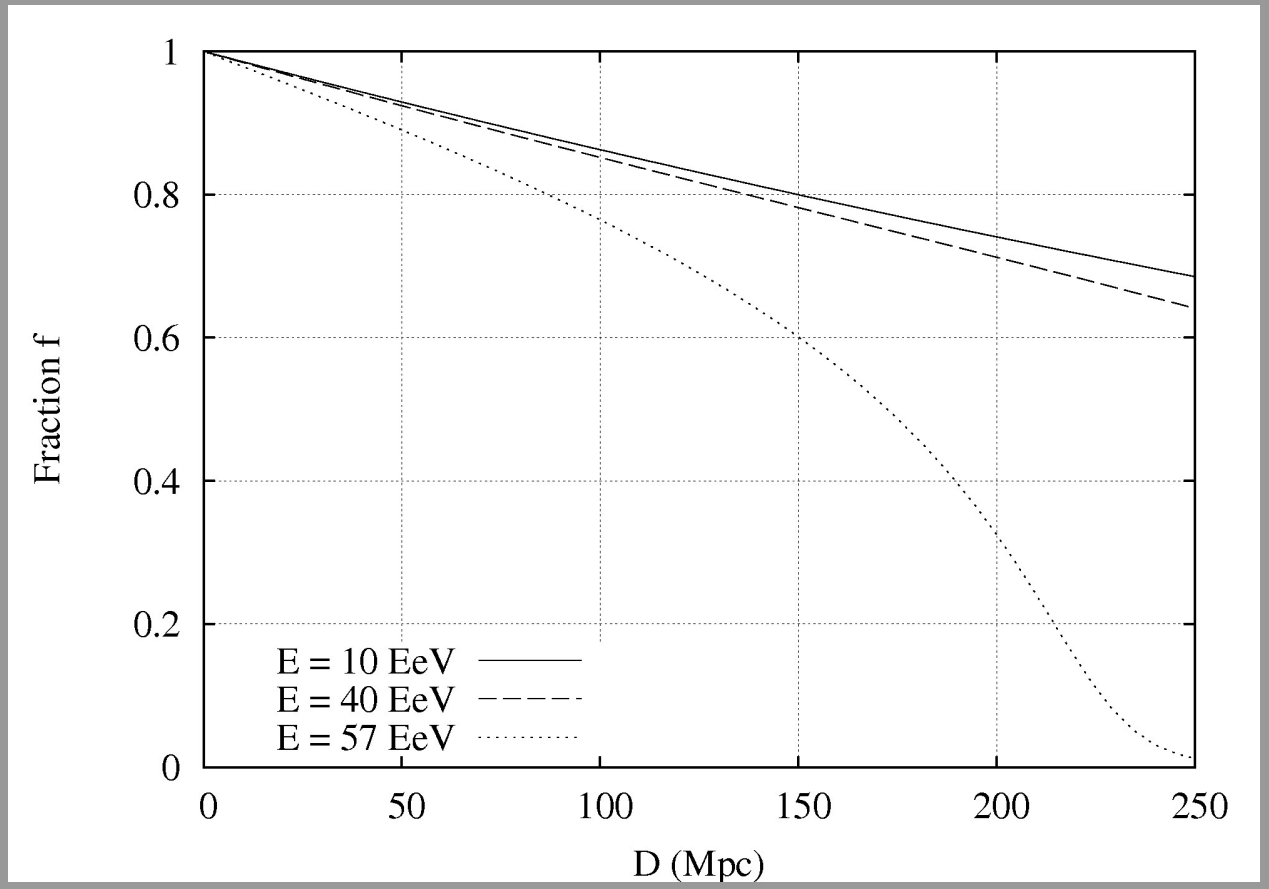

Fraction of integral CR flux that survives after traveling distance *D*.

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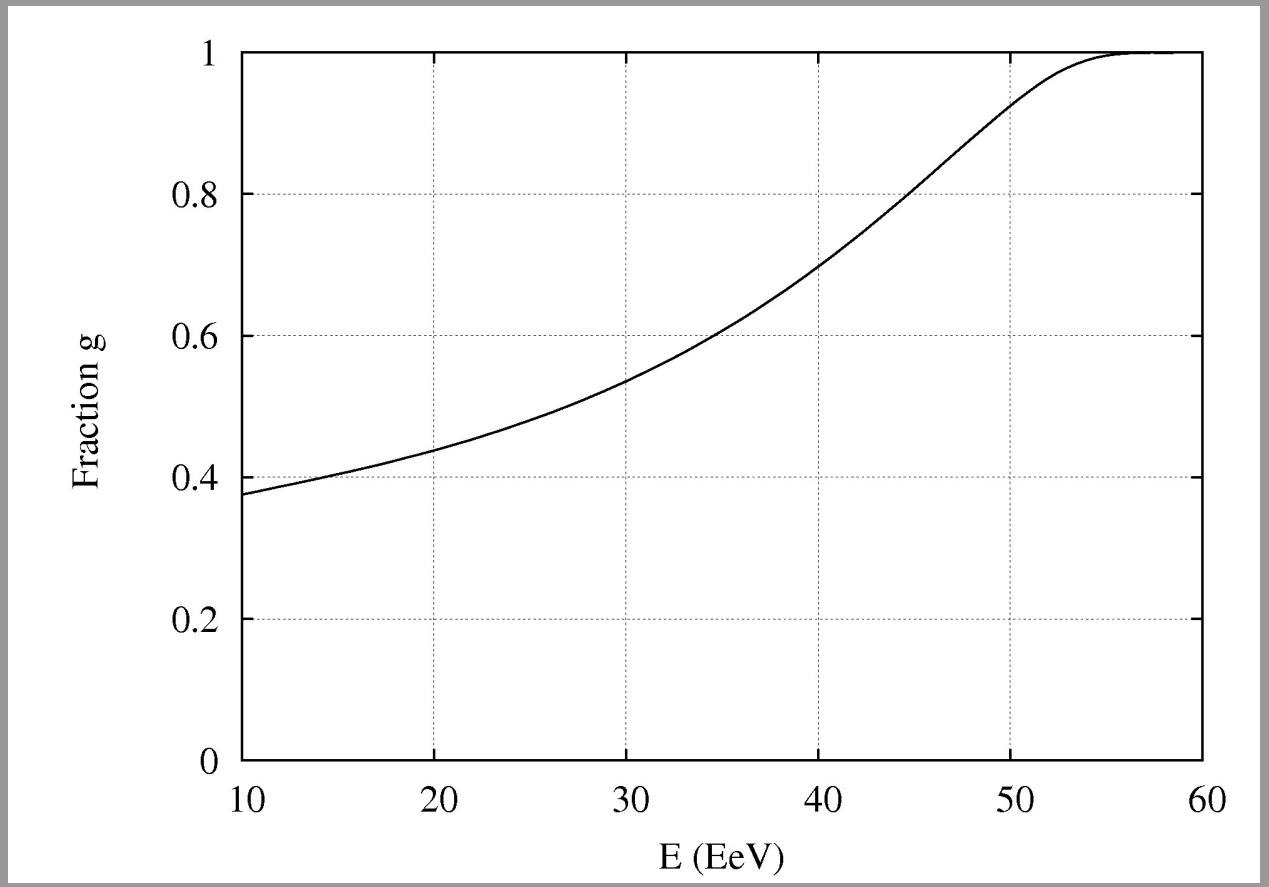

Fraction of the total CR flux collected from distances within 250 Mpc.

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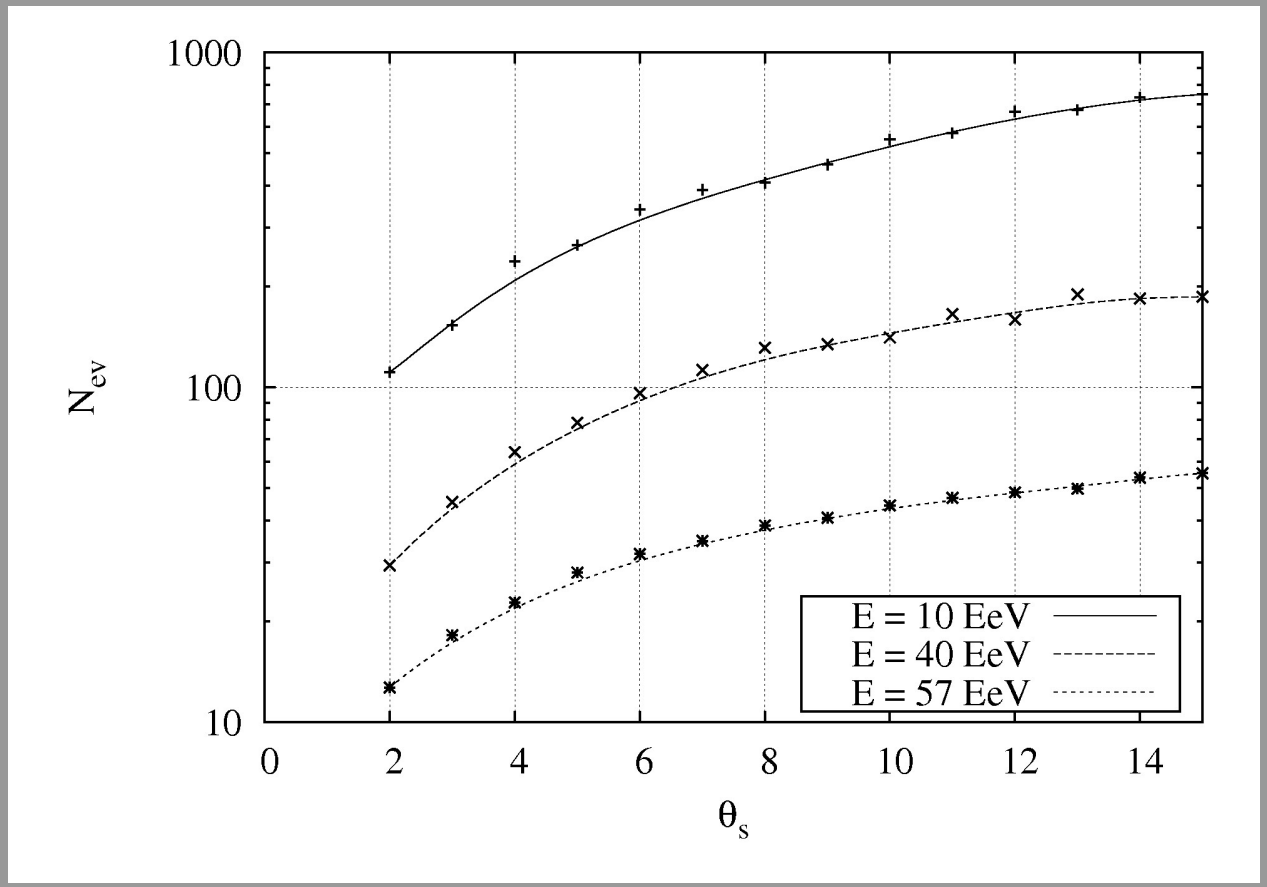

Number of events required for 50% chance to rule out the matter tracer model if the true flux is isotropic.