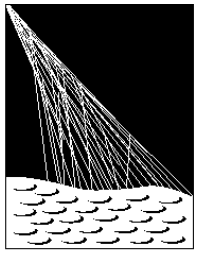

PIERRE
AUGER
OBSERVATORY

UHE Cosmic Ray Charge ID Using Template Backtracking Simulations

Michael Sutherland (on behalf of Azadeh Keivani)
[part of AK Thesis Work]

Auger US analysis meeting
October 2013

Outline

- Develop and test a method to assign individual cosmic ray charge assuming a source and GMF model
- Generate rigidity ($R = E / Z$) simulations from a specific source to determine arrival direction distributions
- Compare event reconstruction with individual rigidity arrival distributions
- Best match (overlap) corresponds to a charge value Z
  - Explicitly dependent on hypotheses that source is correct and GMF is an accurate representation

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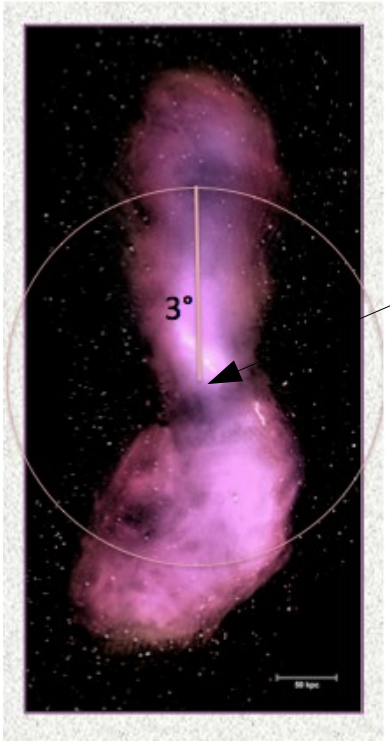
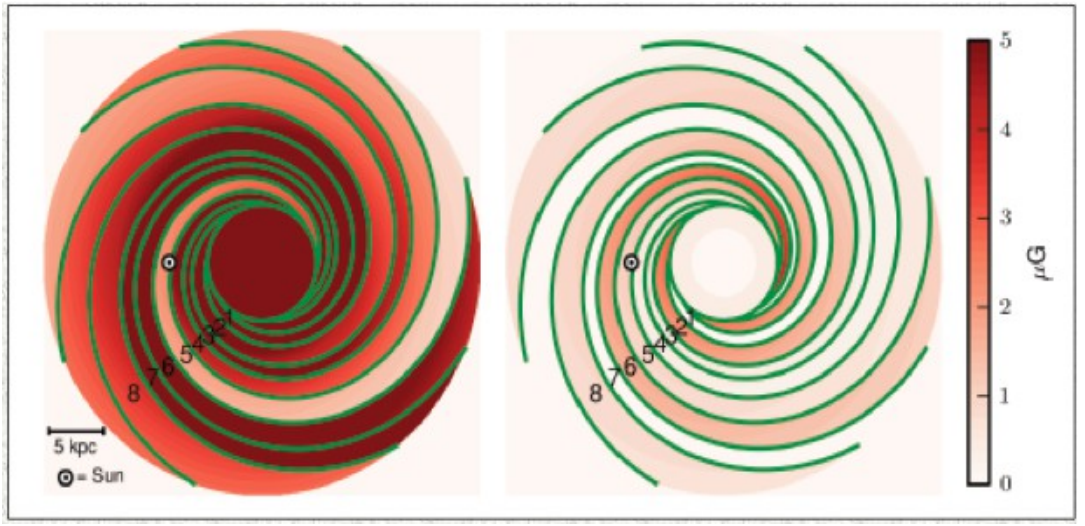
- Quick look at effect of a turbulent Kolmogorov random field on arrival directions

Simulation Parameters – GMF and Source



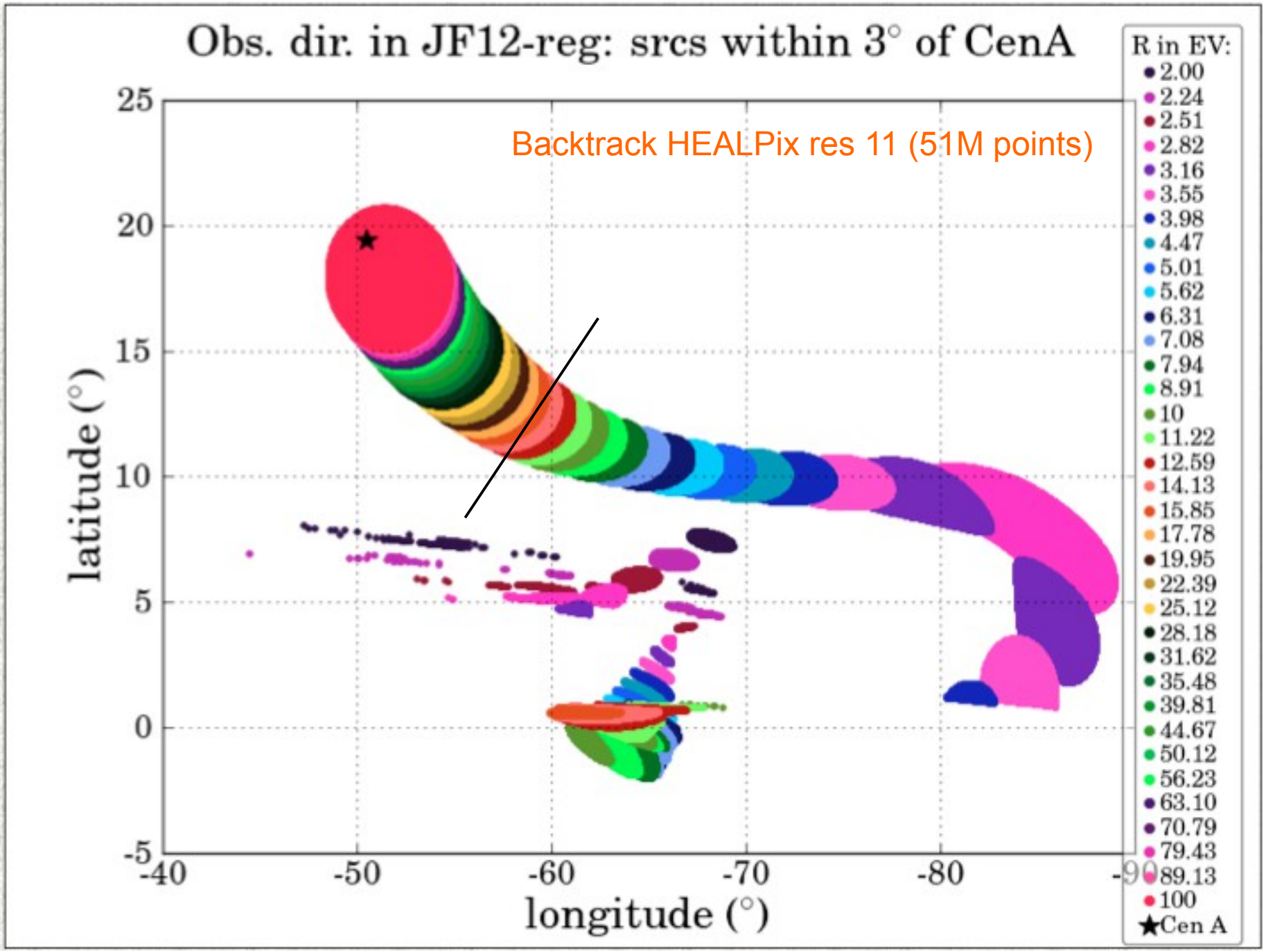
Assume Cen-A is a powerful sole source
(l, b) = (-50.5°, 19.4°)

Jansson-Farrar GMF [ApJ 761(2012)]
- regular (coherent), striated random, turbulent random
- only consider regular here for Cen-A study
- regular+turbulent for last slide (no striated)

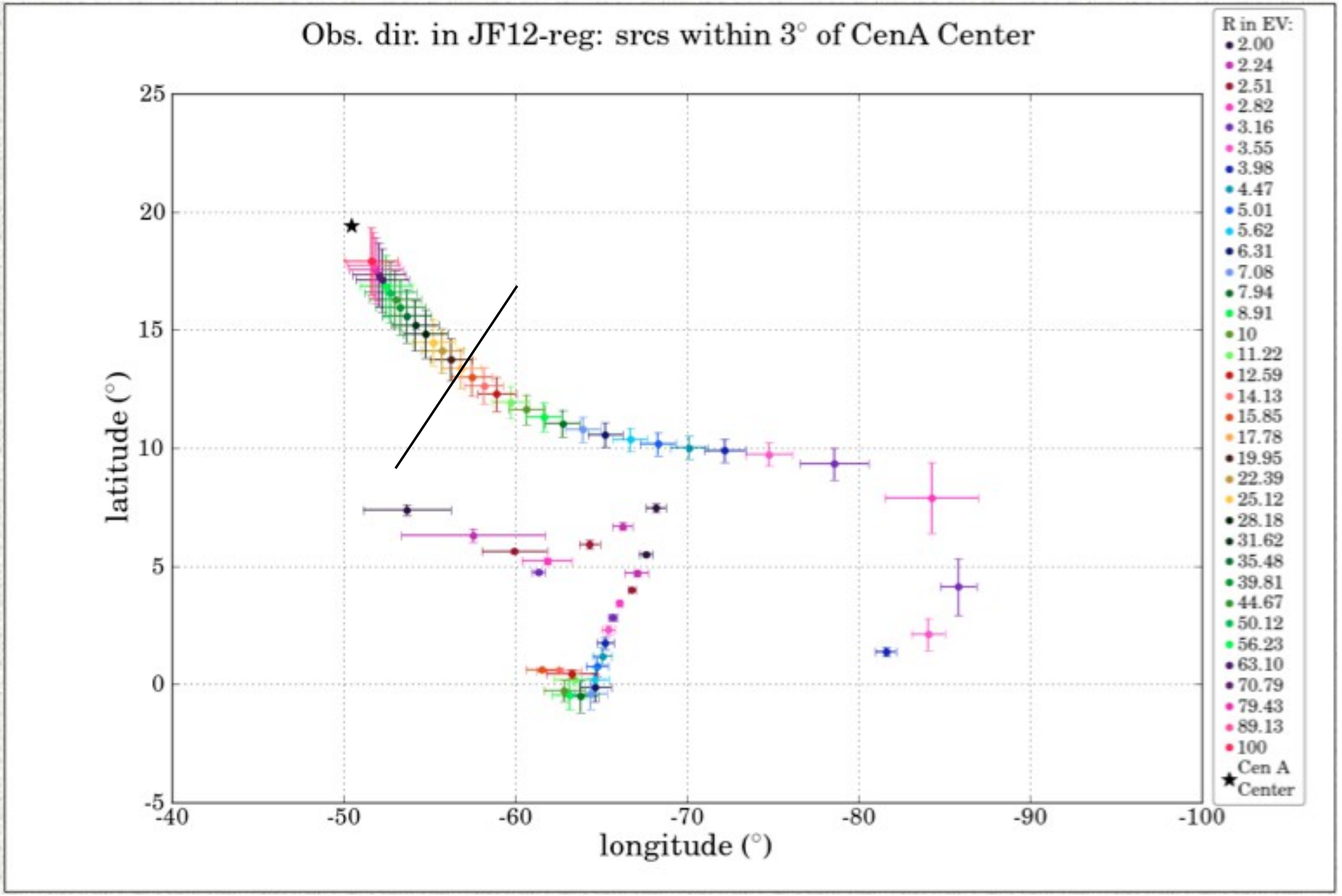


Rigidity Maps – Actual Directions

Simulations part of GF NASA grant

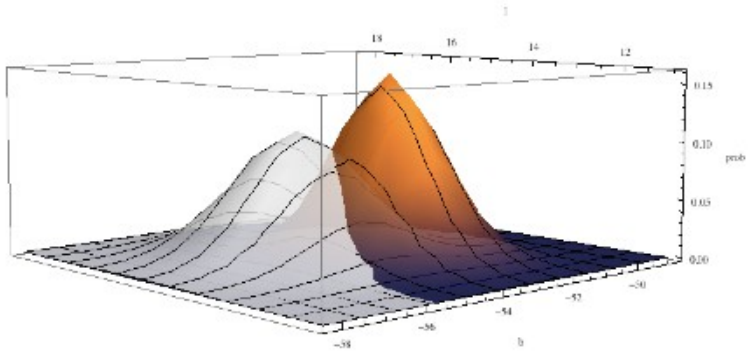


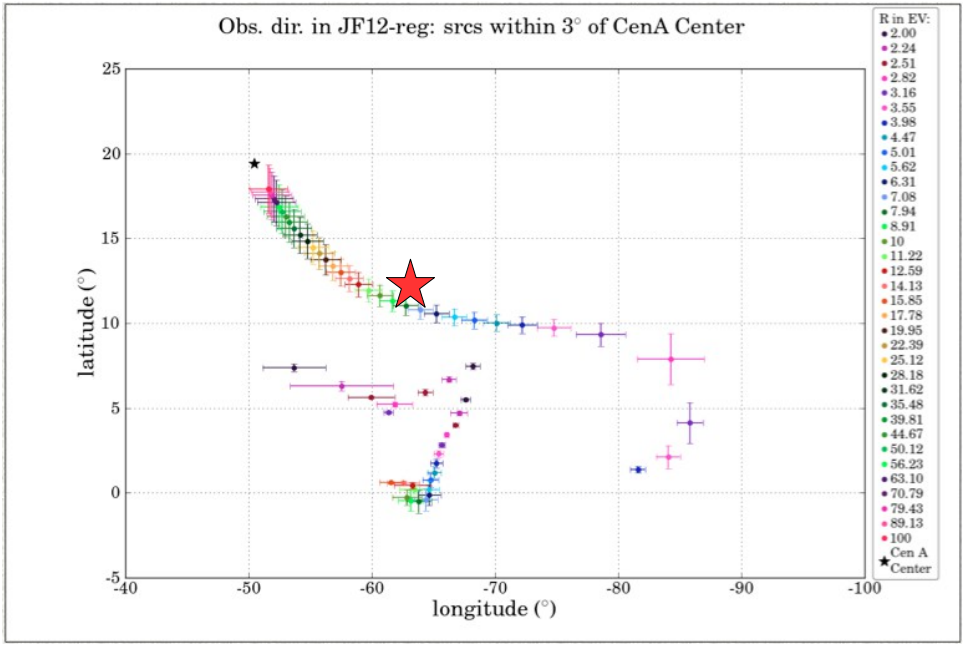
Rigidity Maps - Centroids



Charge Assignment Procedure

- The red star is an event with measured energy and direction with uncertainties
- Consider a 2D normalized Gaussian with mean (l_g, b_g) and standard deviations (σ_g, σ_g), for the event and each rigidity simulation
  - event σ corresponds to the measurement uncertainties (1°, 14% energy)
  - Simulation σ corresponds to the distribution's σ
- Calculate overlap value between event and individual simulations
  - Maximum value indicates most consistent rigidity → *Z*

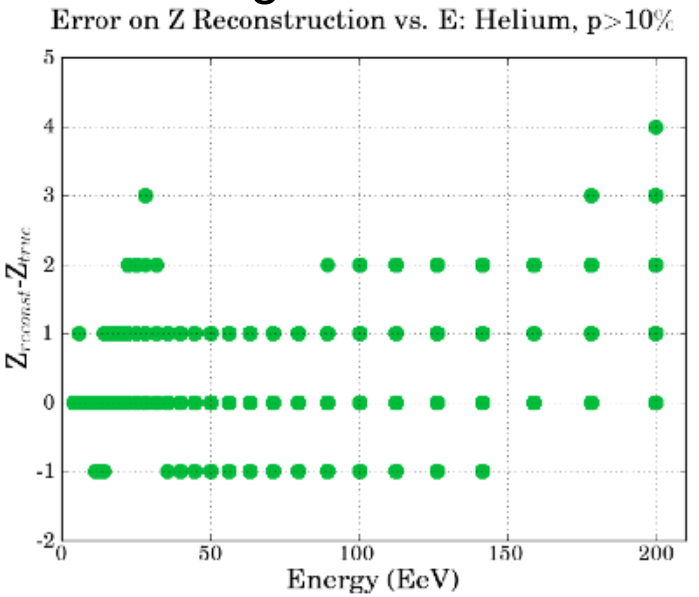


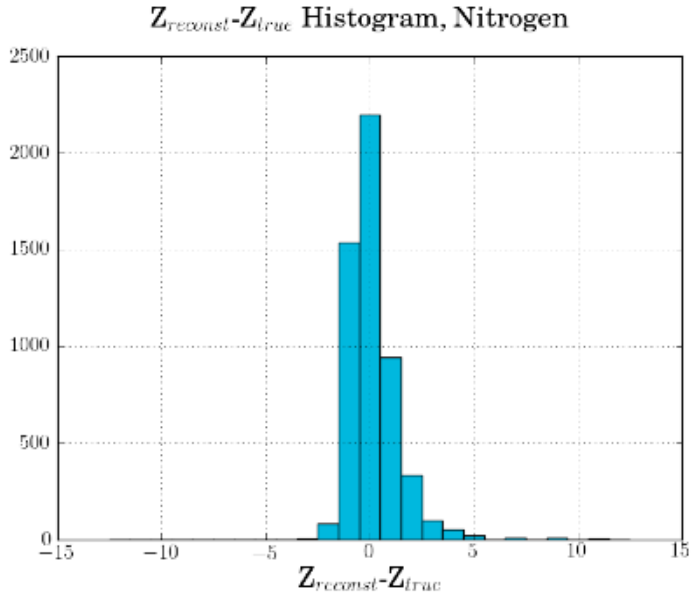


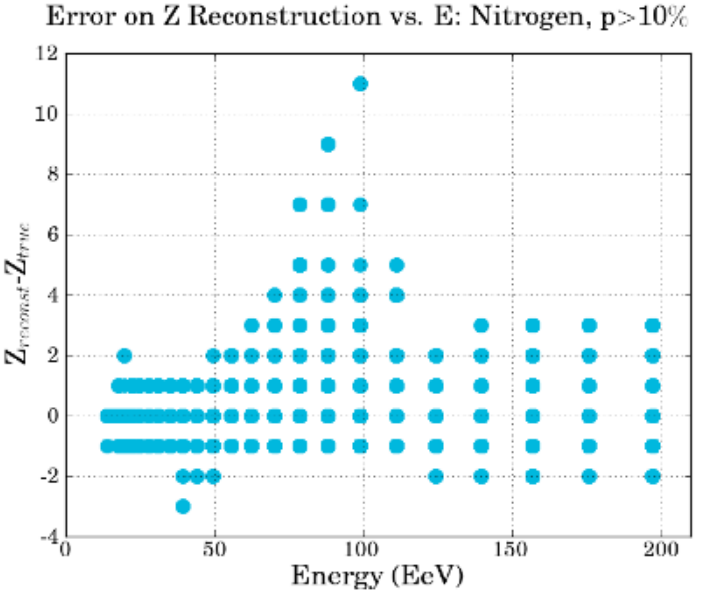
Charge Assignment – Sanity Checks and Uncertainties

- Select random event from simulations and assign “truth” charges

Element	$Z_{reconstruct}$	Counts (%)
H	H	91
H	He	8
He	He	68
He	H	10
He	Li	17
He	Be	5
N	N	42
N	C	29
N	O	18
N	F	6
Fe	Fe	63
Fe	V	23
Fe	Cu	11

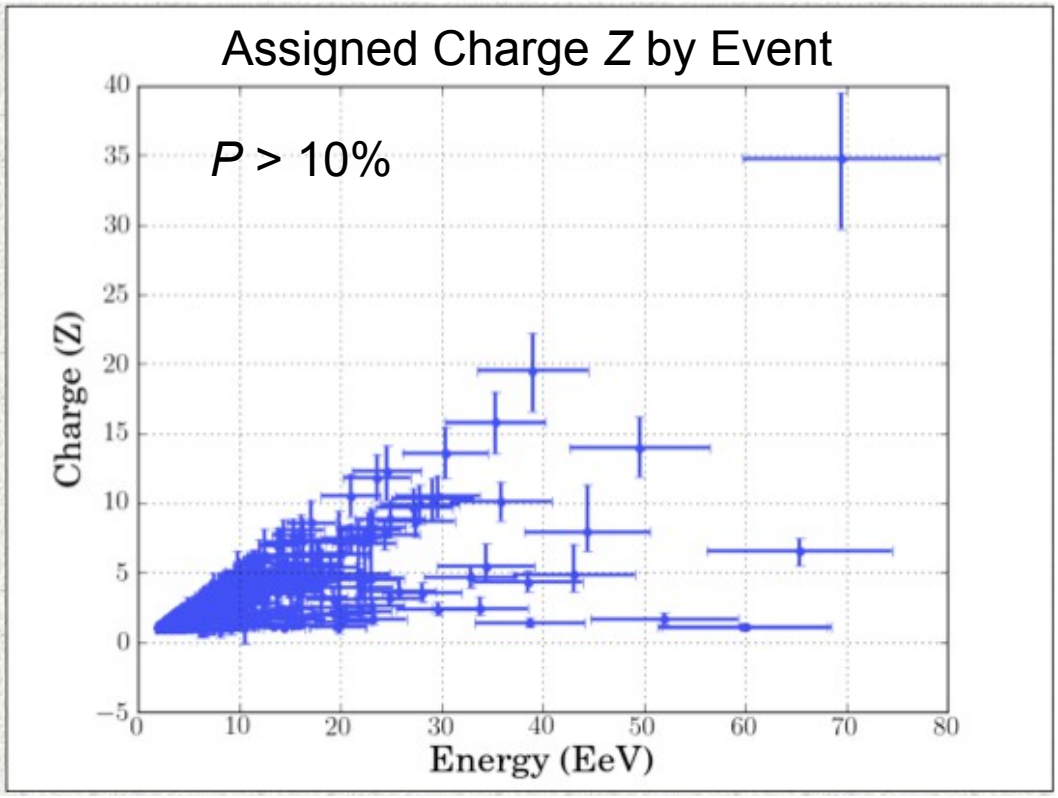


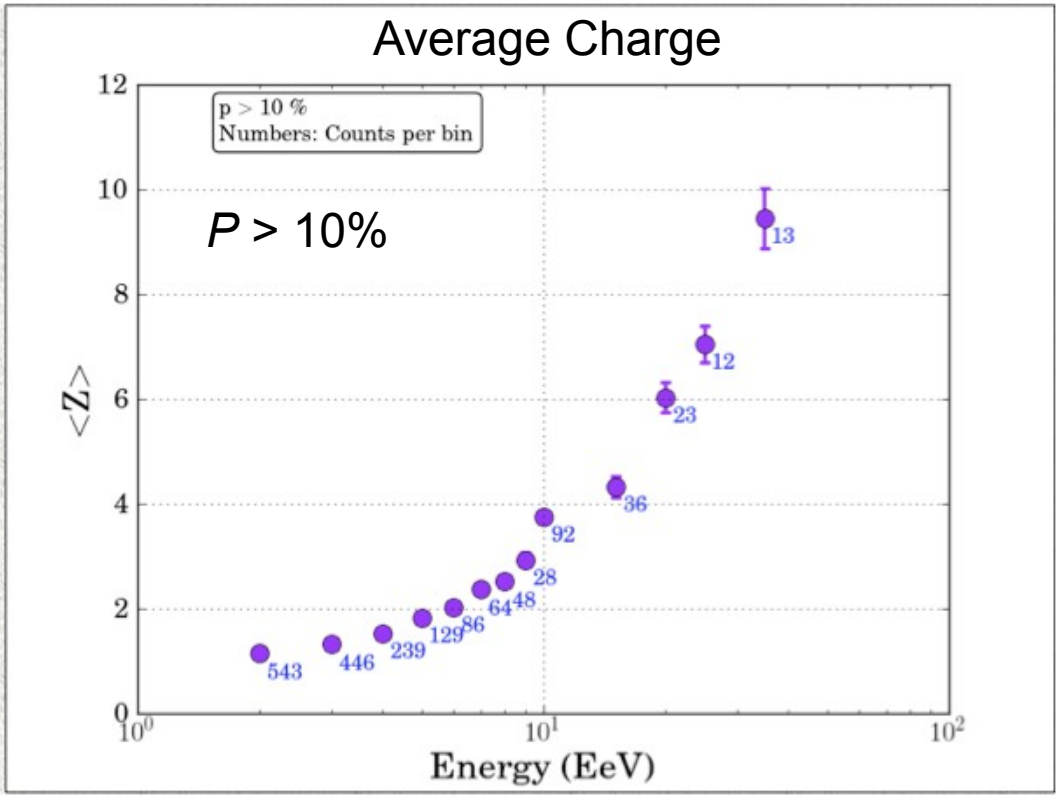




Charge Assignment – Results from Data

- Herald until mid September 2013, latest reconstructions, $E > 2$ EeV
- This would be the charge if Cen-A origin and GMF model were true





Effect of Turbulent Field on Arrival Directions

- A. Keivani has developed a CRT module for implementing turbulent Kolmogorov spectra random fields