Project 1:

Can SWORD mission detect the sources of the highest energy cosmic rays?

Marco Dolci

Internship at JPL NASA (J. Booth)
Pasadena (USA)

from 09/02 to 11/02 2013

agenzia spaziale italiana

Jet Propulsion Laboratory
California Institute of Technology

NASA

ISSNAF
The Italian Scientists and Scholars of North America Foundation

The SWORD Mission Concept

(Synoptic Wideband Orbiting Radio Detector)

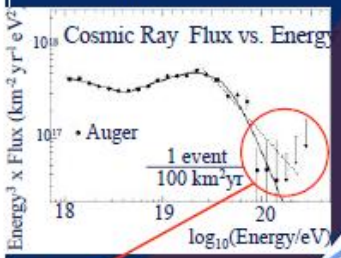
A. Romero-Wolf et al. arXiv:1302.1263v1

Science

Cosmic radio and light backgrounds make the Universe opaque to energies >4e19 eV above this distance.

75 Mpc

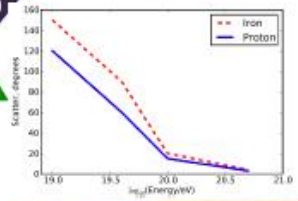
What are the sources? AGN, pulsars, radio lobes, big bang relic particles?



Increase sensitivity by a factor of >10

Inter-galactic Magnetic Fields

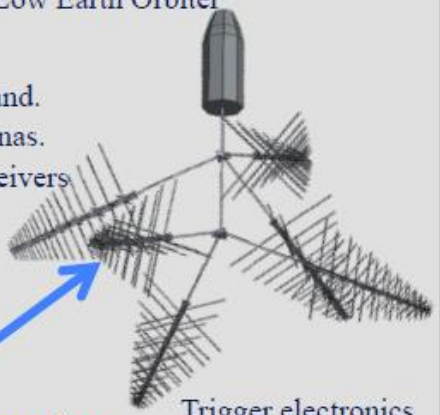
Experiment



Instrument

- 30 – 300 MHz (VHF) band.
- Array of LPDA antennas.
- Dual-polarized receivers

Low Earth Orbiter



Trigger electronics digitized and de-disperse radio signals in real time.

Dispersion

Ionosphere

Troposphere

Air shower

Propagation

Reflection

Geo-synchrotron pulse

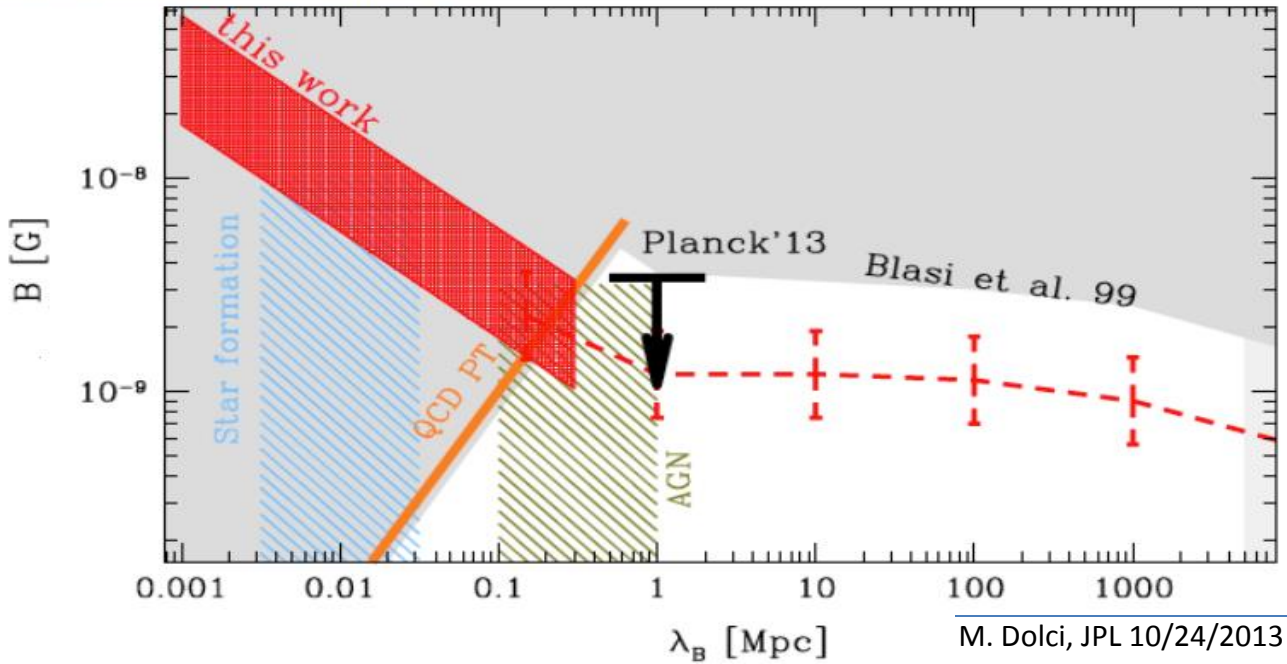
EGMF value (B, λ_B)

Parameters	Range value of interest
E	60 EeV ($10^{18} - 10^{20}$ eV)
B	1-100 nG
λ_B	0.1-10 Mpc
D	< 75 Mpc
Z	1 (protons) / 26 (iron nuclei)

Degeneration btw source position (ϑ_{ad}) and $B\sqrt{\lambda_B}$

B=1nG

Neronov, Semikoz, Banfsheh, 2013



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ϑ_{scat} theoretical model

SCATTERING ANGLE (mean value):

$E > 10^{18}$eV [1 EeV], $\vartheta_{scat} \leq 10°$ (Lee, Olinto & Sigl, 1995)

- $D \leq \lambda_B$

$$\vartheta_{scat} = 2.6° \left(\frac{E}{10^{20} eV}\right)^{-1} \left(\frac{D}{50 Mpc}\right) \left(\frac{B}{10^{-10} G}\right) Z$$

- $D \gg \lambda_B$

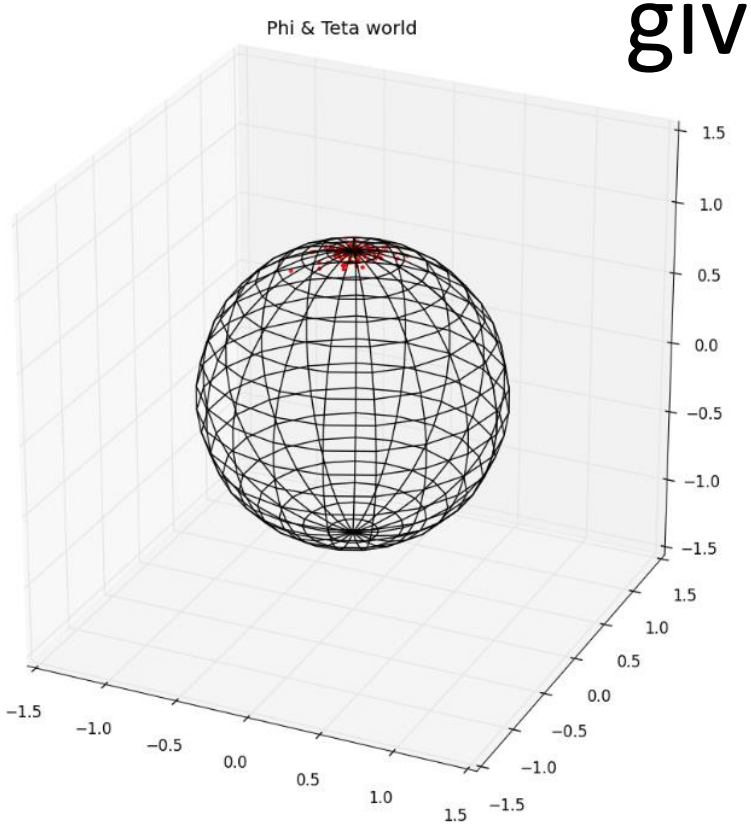
$$\vartheta_{scat} = 0.23° \left(\frac{E}{10^{20} eV}\right)^{-1} \left(\frac{D}{50 Mpc}\right)^{0.5} \left(\frac{B}{10^{-10} G}\right) \left(\frac{\lambda_B}{1 Mpc}\right)^{0.5} Z$$

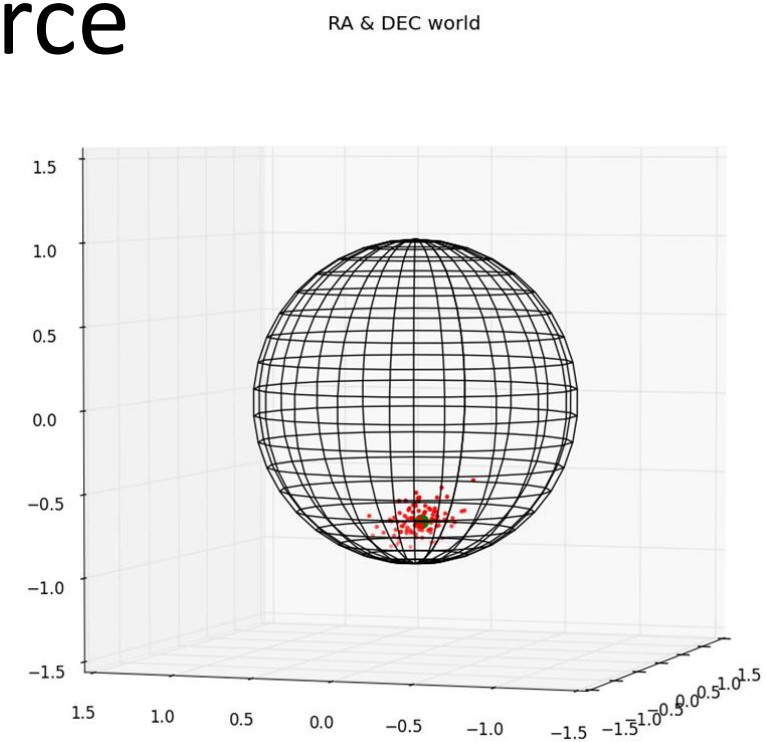
Assumption: Rayleigh distribution to find $\boldsymbol{\sigma_{scat}} = \vartheta_{scat} \sqrt{\frac{2}{\pi}}$

ANGULAR RESOLUTION:

$\vartheta_{res} = 2°$ baseline / 5° threshold

Simulation for scattering signals from a given source





Teta = Rayleigh (σ_{scat}, ϑ_{res})

Phi = Uniform (0, 2 π)

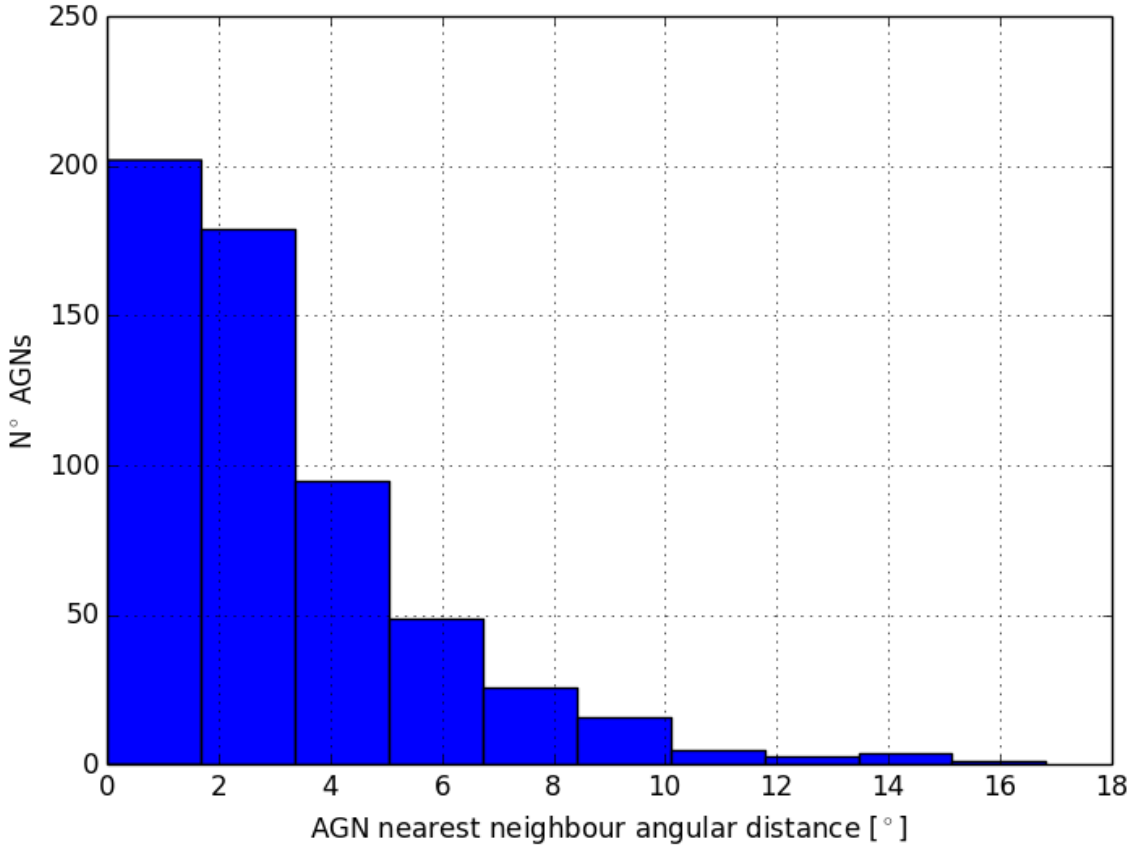
Matrix rotation

M=M($\alpha_{src}, \delta_{src}$)

Equatorial coordinates (α, δ)

ϑ_{ad}

AGN nearest neighbour angular distance ϑ_{nnad} (AGN clustering)

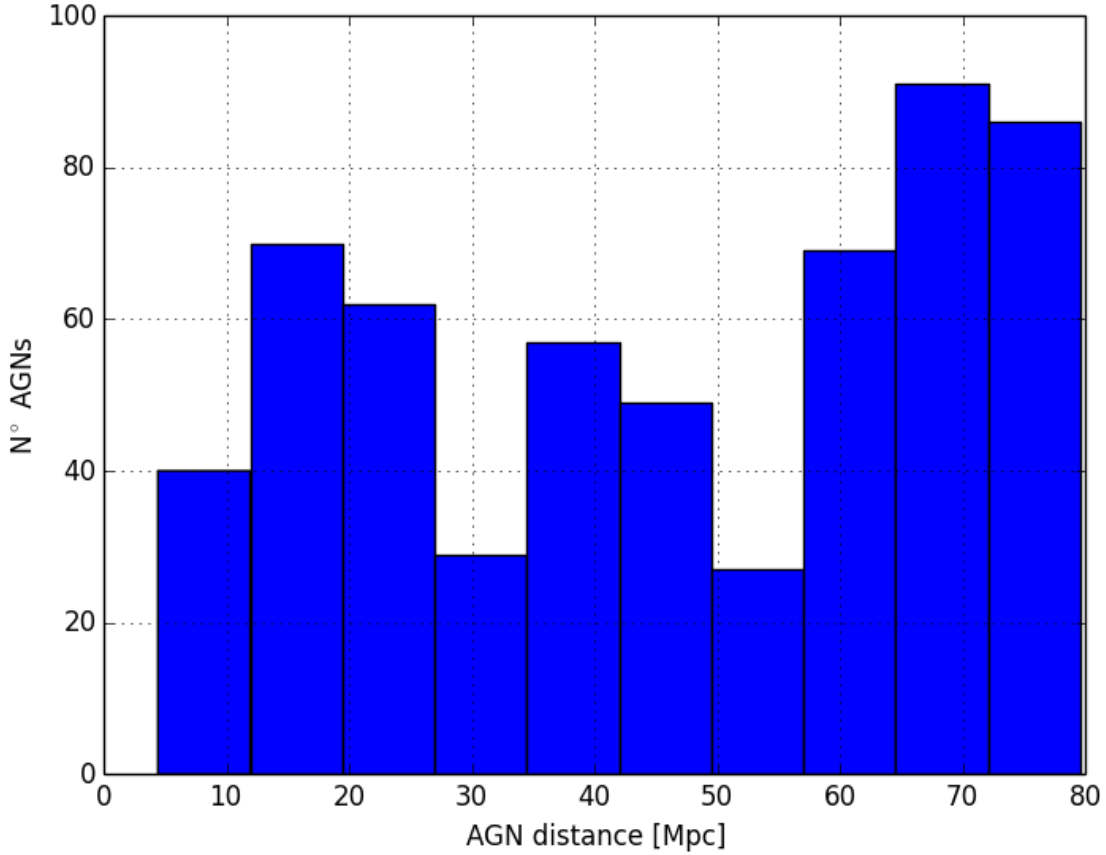


~65% AGNs $\vartheta_{nnad} \geq 2°$

~20% AGNs $\vartheta_{nnad} \geq 5°$

ϑ_{res}=2 °

AGN distance distribution



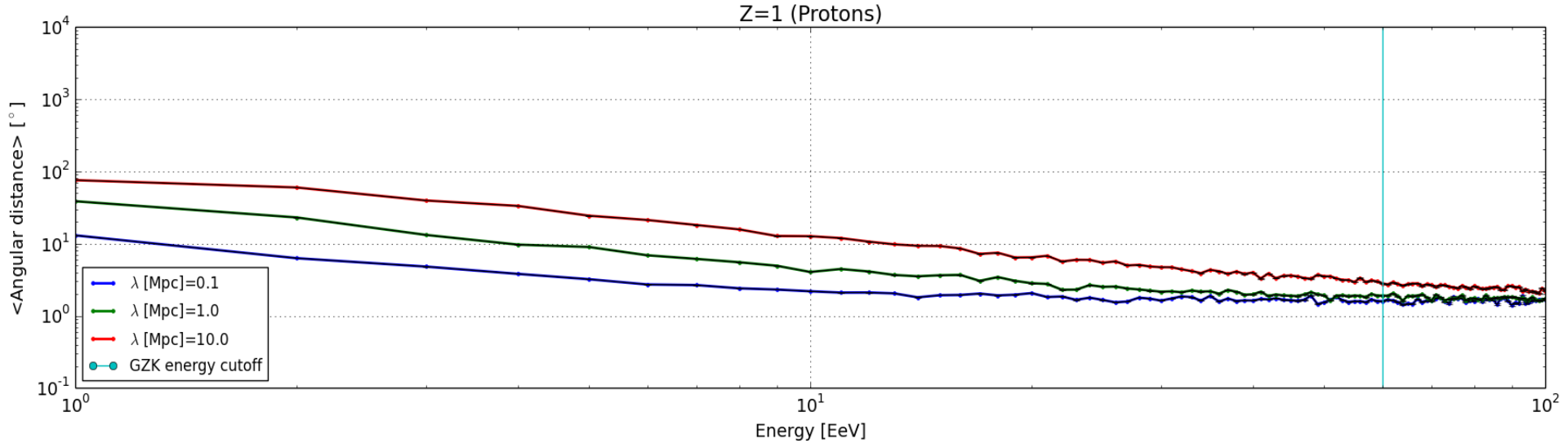
~7% AGNs $D \leq 10$Mpc

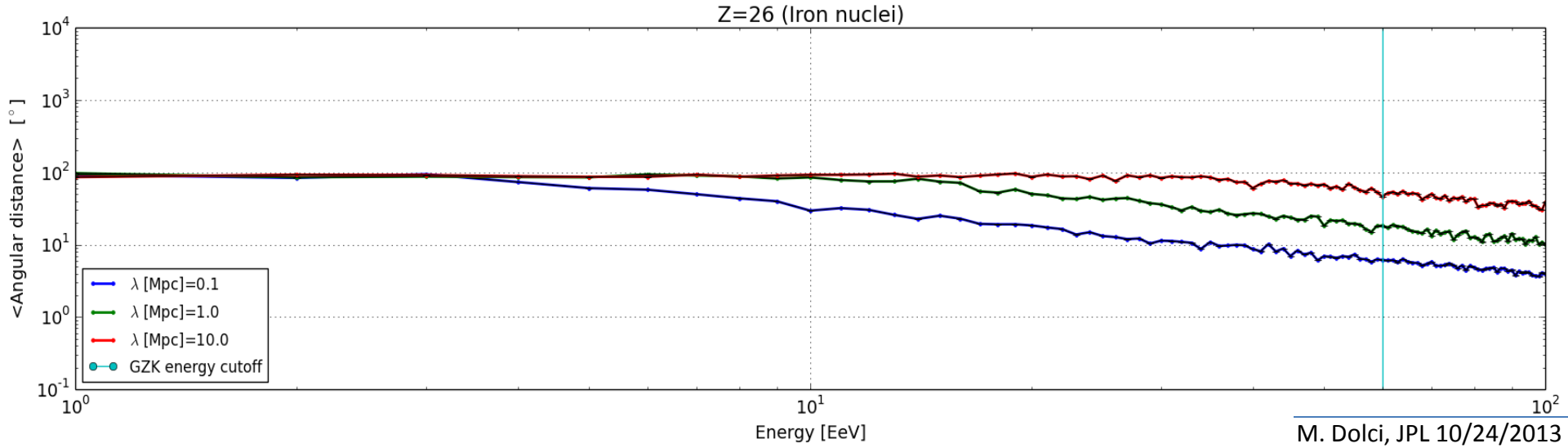
~20% AGNs $D \leq 20$Mpc

~47% AGNs 50Mpc $\leq D \leq$ 80Mpc (GZK limit)

Angular distance

CenA (3.8Mpc), ϑ_{res}=2 °





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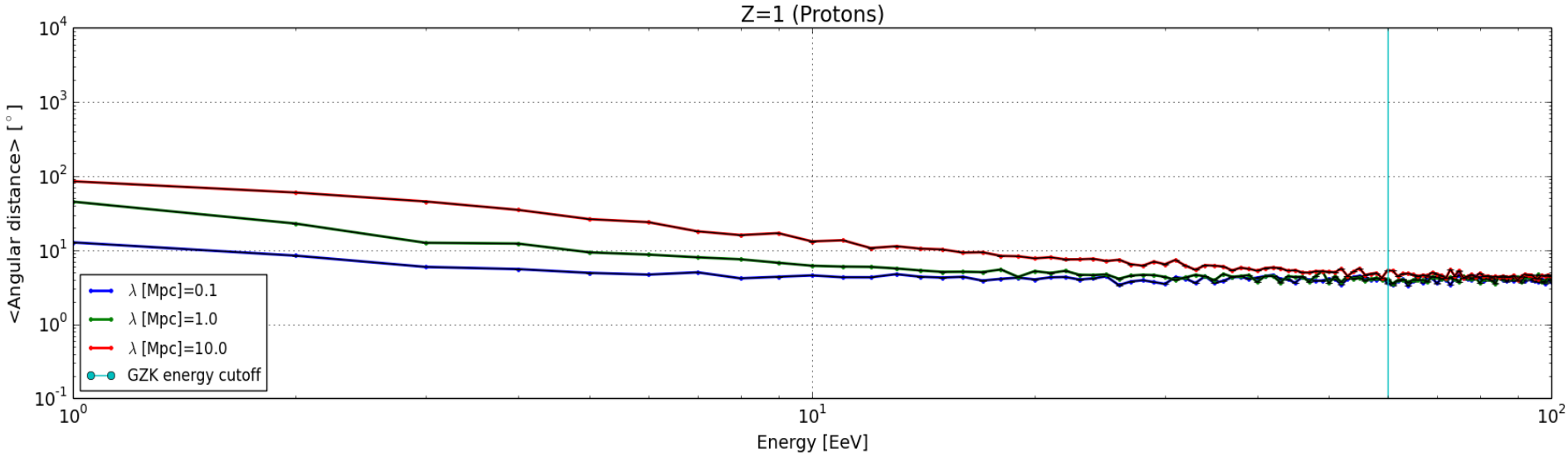
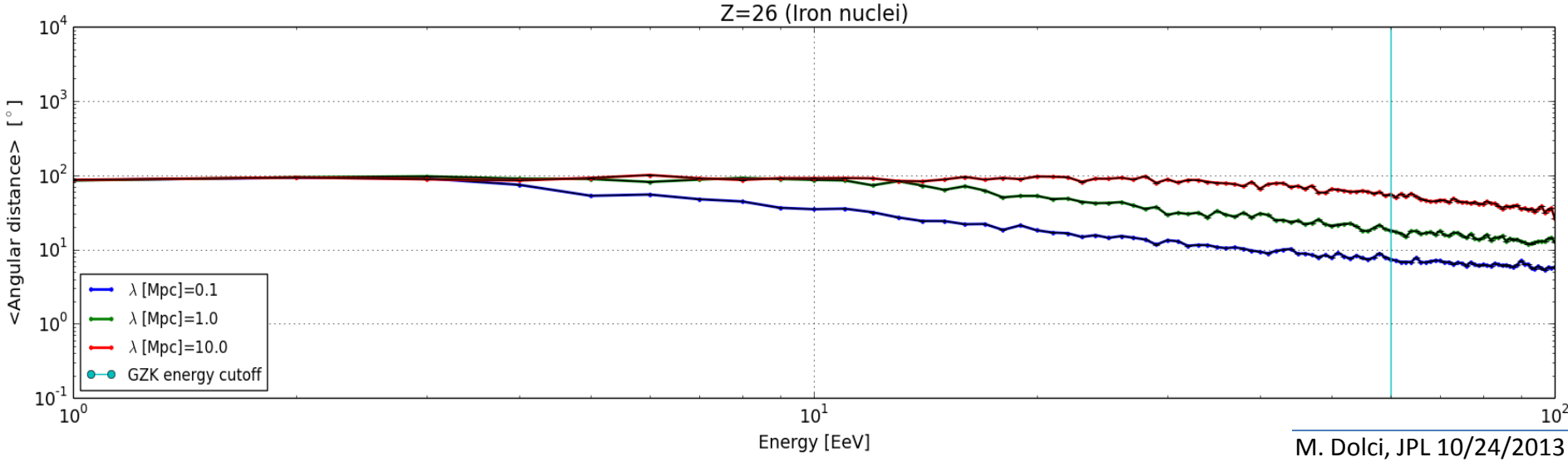
Angular distance

CenA (3.8Mpc), ϑ_{res}=5 °





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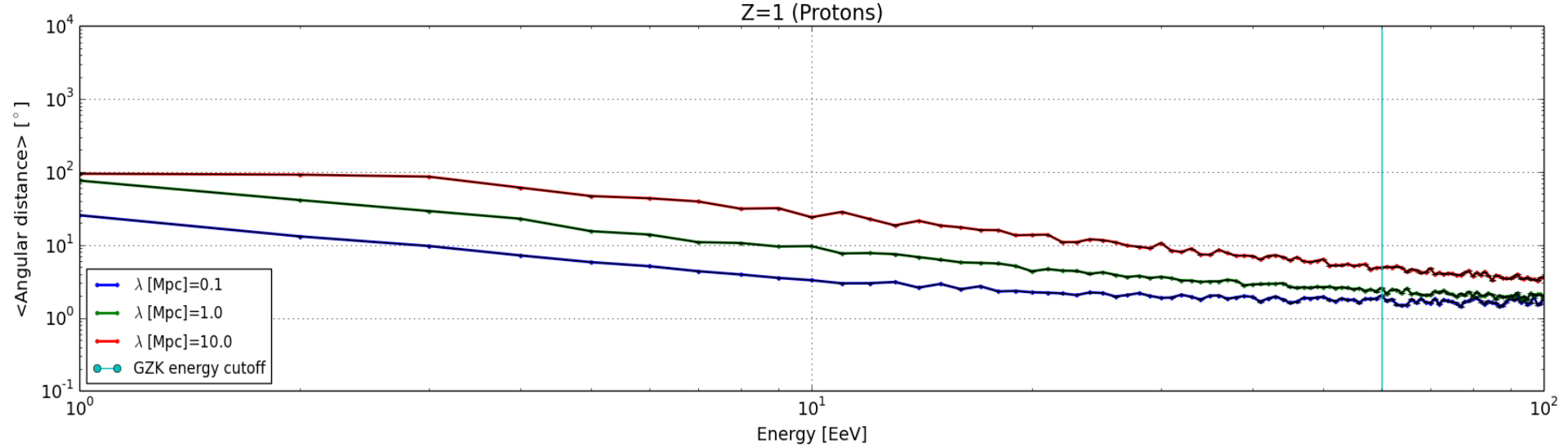
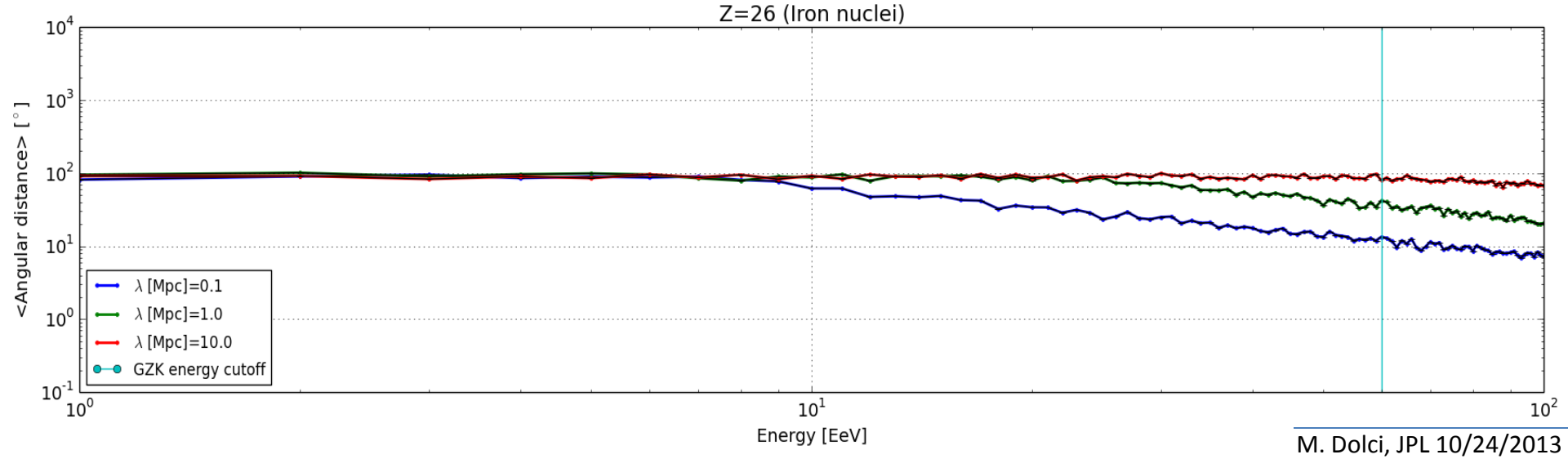
Angular distance

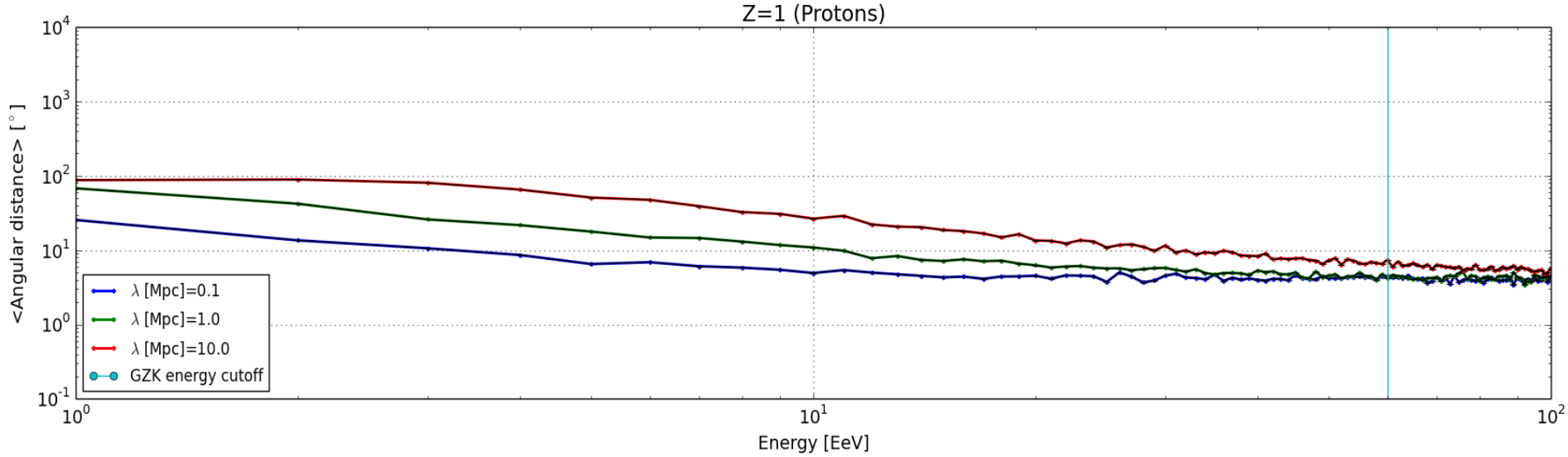
Virgo (16.5Mpc), ϑ_{res}=2 °

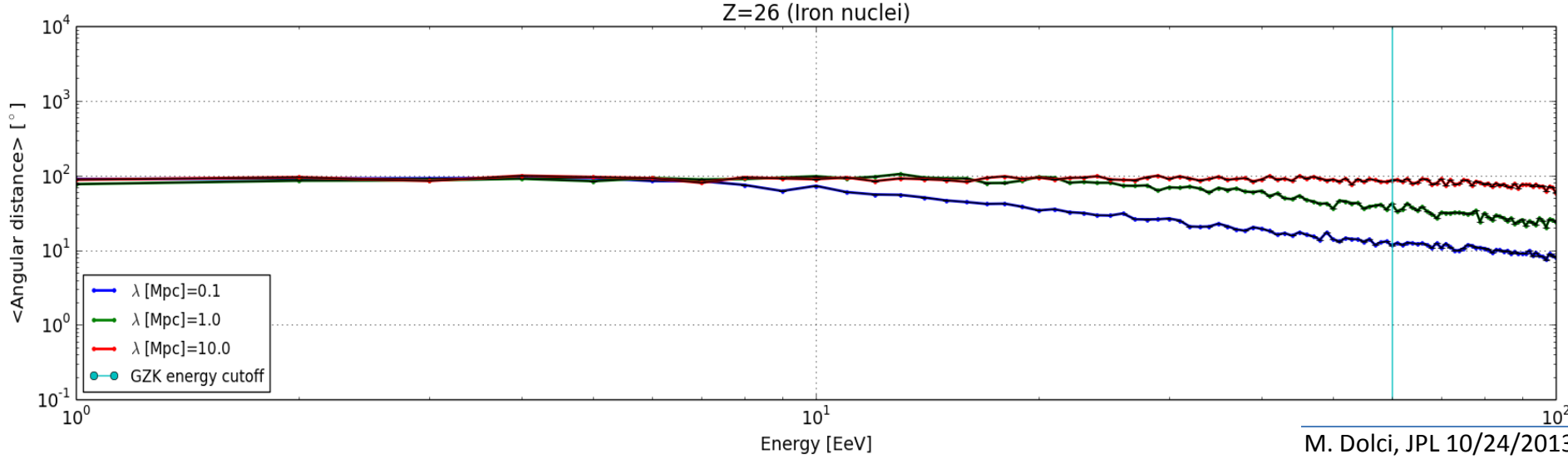




Angular distance

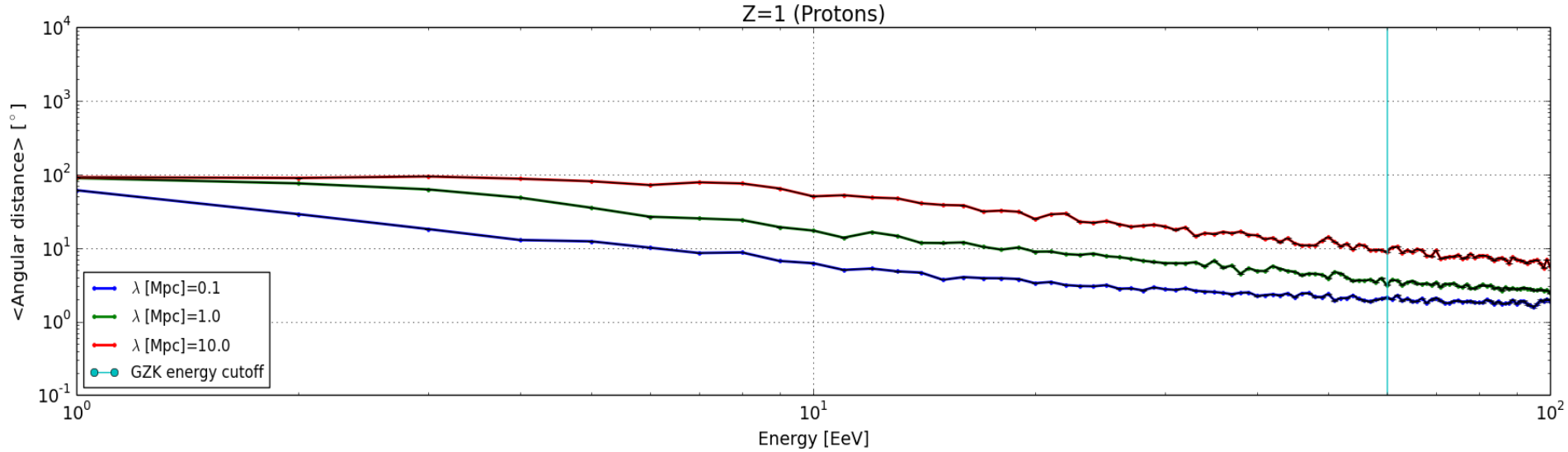
Virgo (16.5Mpc), ϑ_{res}=5 °

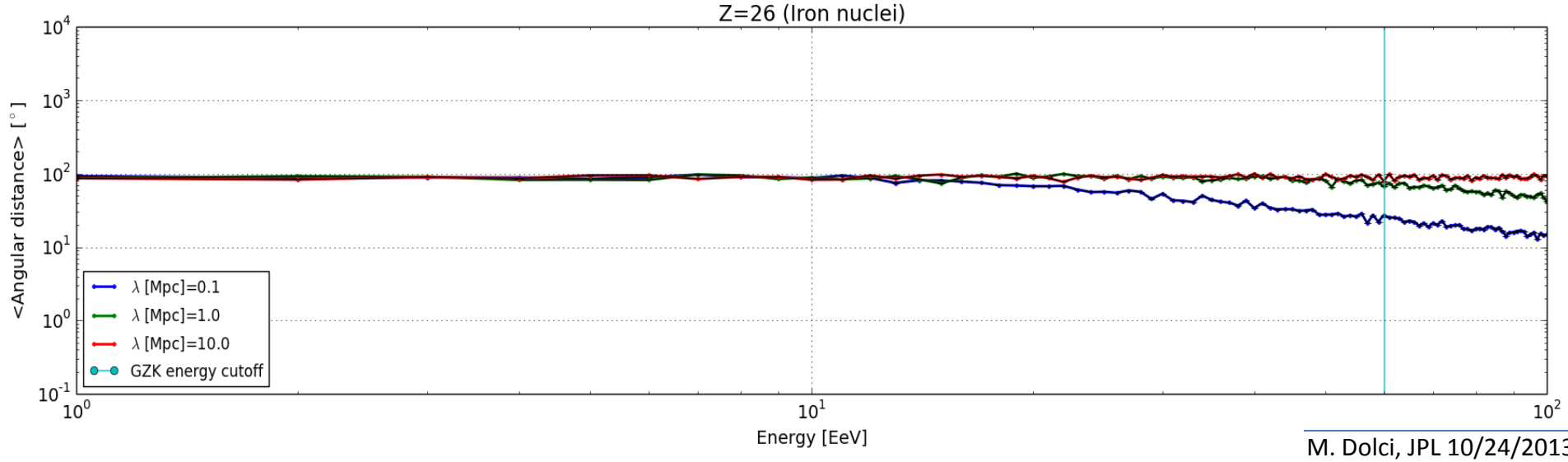




Angular distance

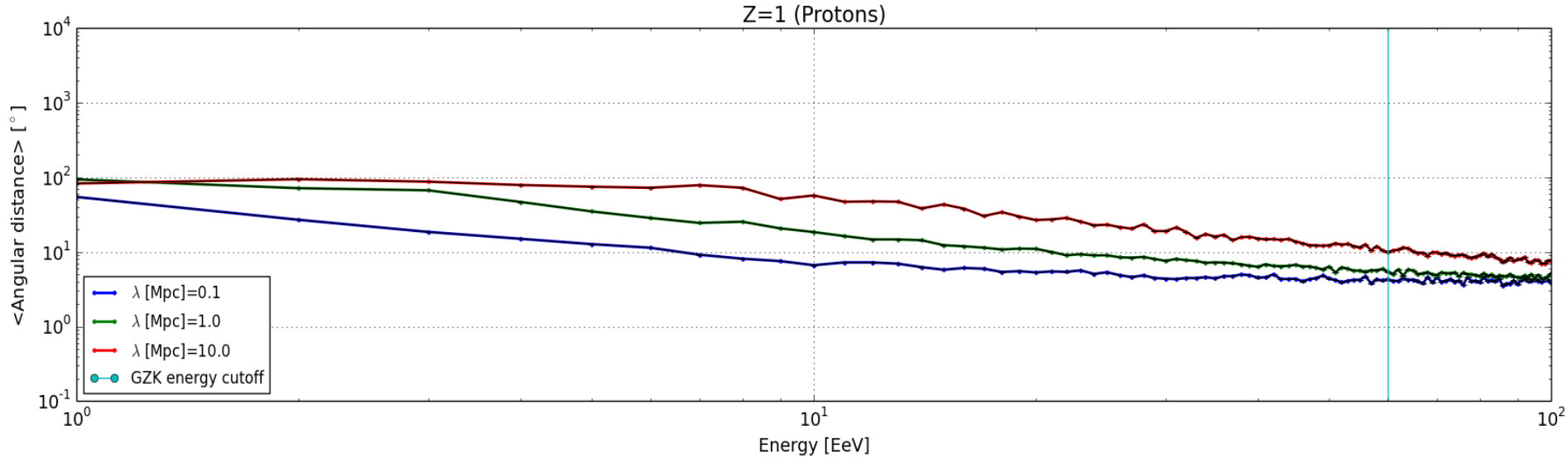
Perseus (73.6Mpc), ϑ_{res}=2 °

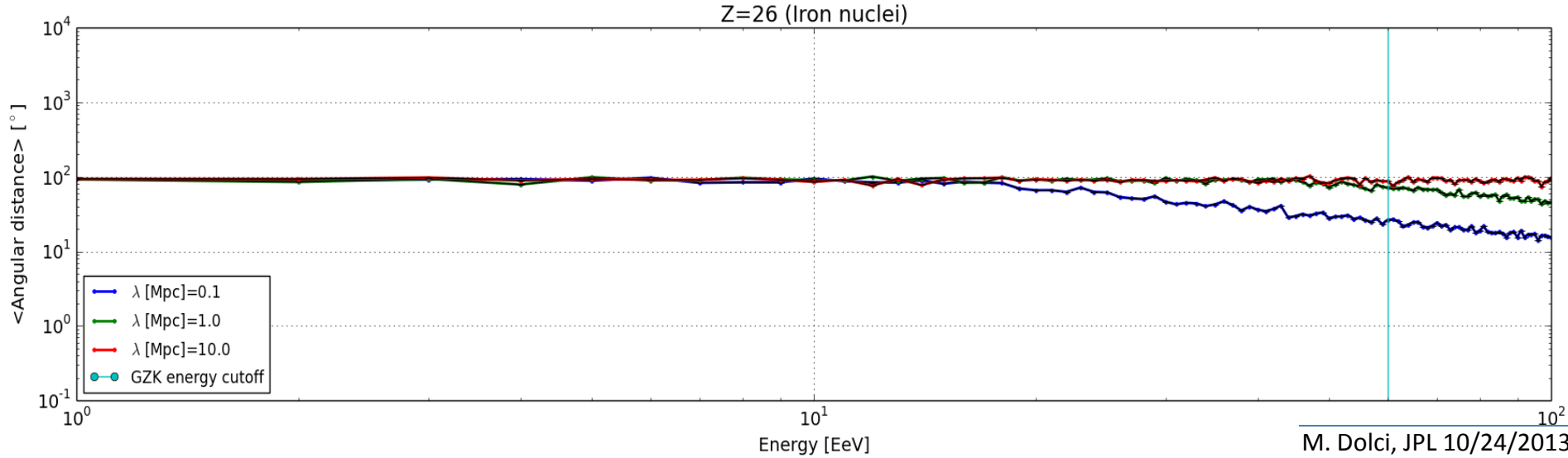




Angular distance

Perseus (73.6Mpc), ϑ_{res}=5 °





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Source-CR event mean angular distance (**CenA**)

Distance[Mpc]	Z	ϑ_{res}[°]	λ_B[Mpc]	<ϑ_{ad}> @10^{20}eV[°]
3.8	1	2	0.1	2
3.8	1	2	1	2
3.8	1	2	10	3
3.8	26	2	0.1	7
3.8	26	2	1	16
3.8	26	2	10	50
3.8	1	5	0.1	5
3.8	1	5	1	5
3.8	1	5	10	5
3.8	26	5	0.1	8
3.8	26	5	1	20
3.8	26	5	10	60

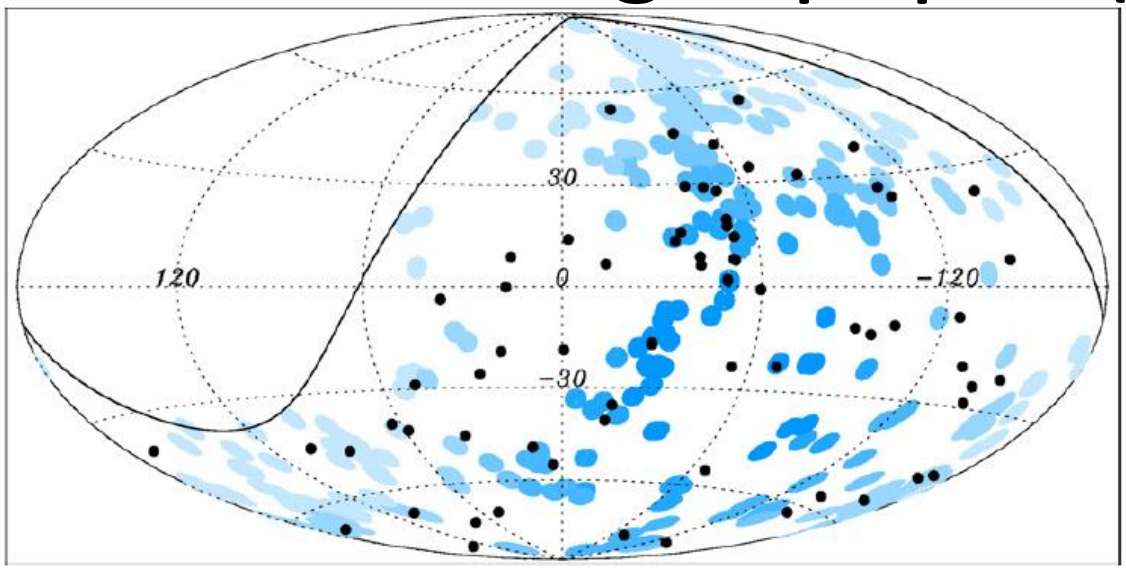
Source-CR event mean angular distance (**Virgo**)

Distance[Mpc]	Z	ϑ_{res}[°]	λ_B[Mpc]	<ϑ_{ad}> @10^{20}eV[°]
16.5	1	2	0.1	2
16.5	1	2	1	2
16.5	1	2	10	5
16.5	26	2	0.1	14
16.5	26	2	1	40
16.5	26	2	10	90
16.5	1	5	0.1	5
16.5	1	5	1	5
16.5	1	5	10	7
16.5	26	5	0.1	12
16.5	26	5	1	40
16.5	26	5	10	90

Source-CR event mean angular distance (**Perseus**)

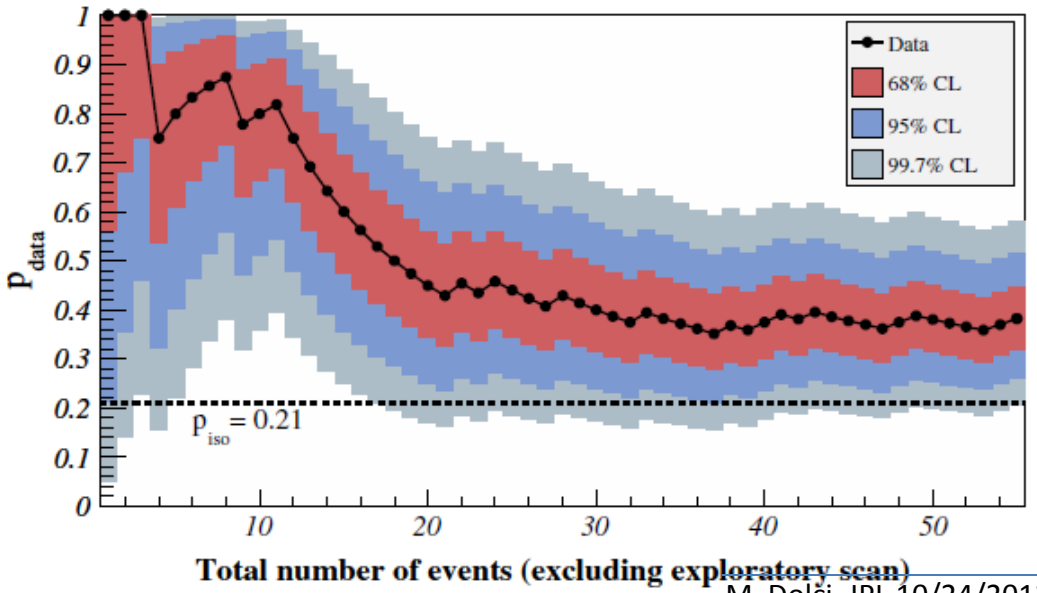
Distance[Mpc]	Z	ϑ_{res}[°]	λ_B[Mpc]	<ϑ_{ad}> @10^{20}eV[°]
73.6	1	2	0.1	2
73.6	1	2	1	4
73.6	1	2	10	10
73.6	26	2	0.1	22
73.6	26	2	1	70
73.6	26	2	10	90
73.6	1	5	0.1	5
73.6	1	5	1	6
73.6	1	5	10	10
73.6	26	5	0.1	30
73.6	26	5	1	80
73.6	26	5	10	90

Auger paper (2010)

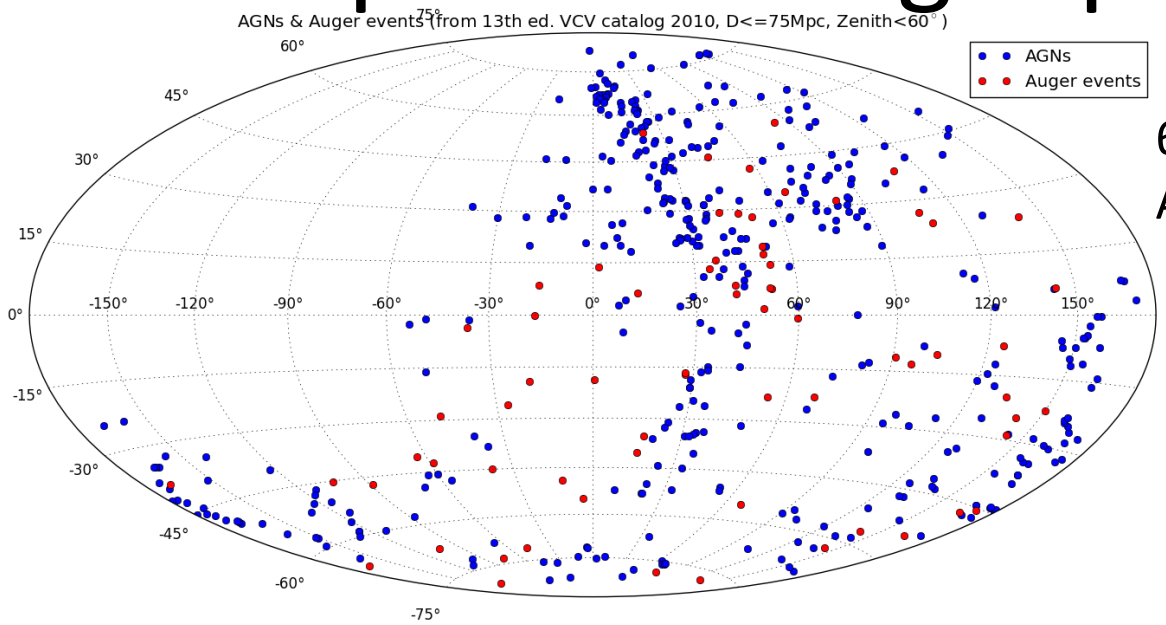


69 UHECR events
AGNs from VCV catalog 12th ed.

The correlating fraction is (38^{+7}_{-6})%
The isotropic fraction is 21%



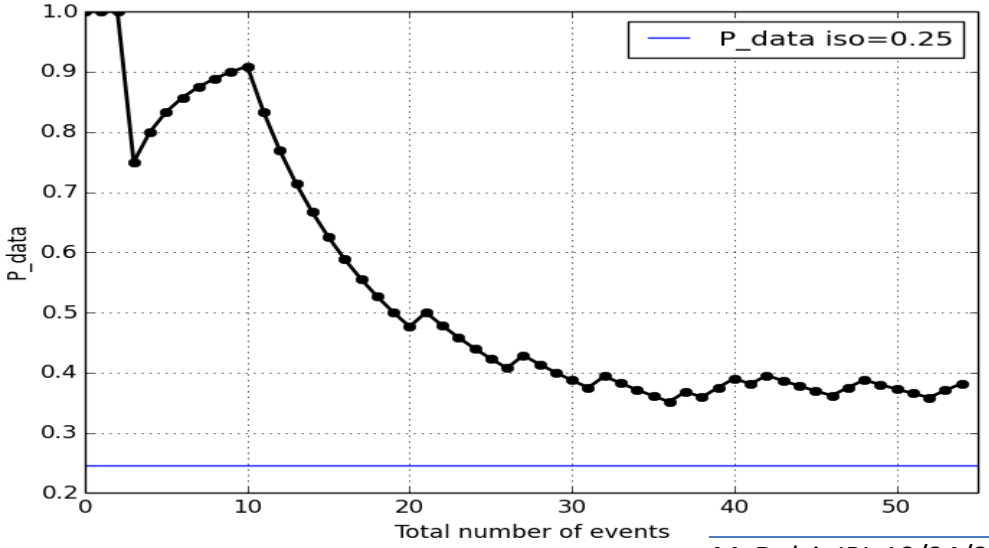
Reproduce Auger paper (2010)



69 UHECR events
AGNs from VCV catalog 13th ed.

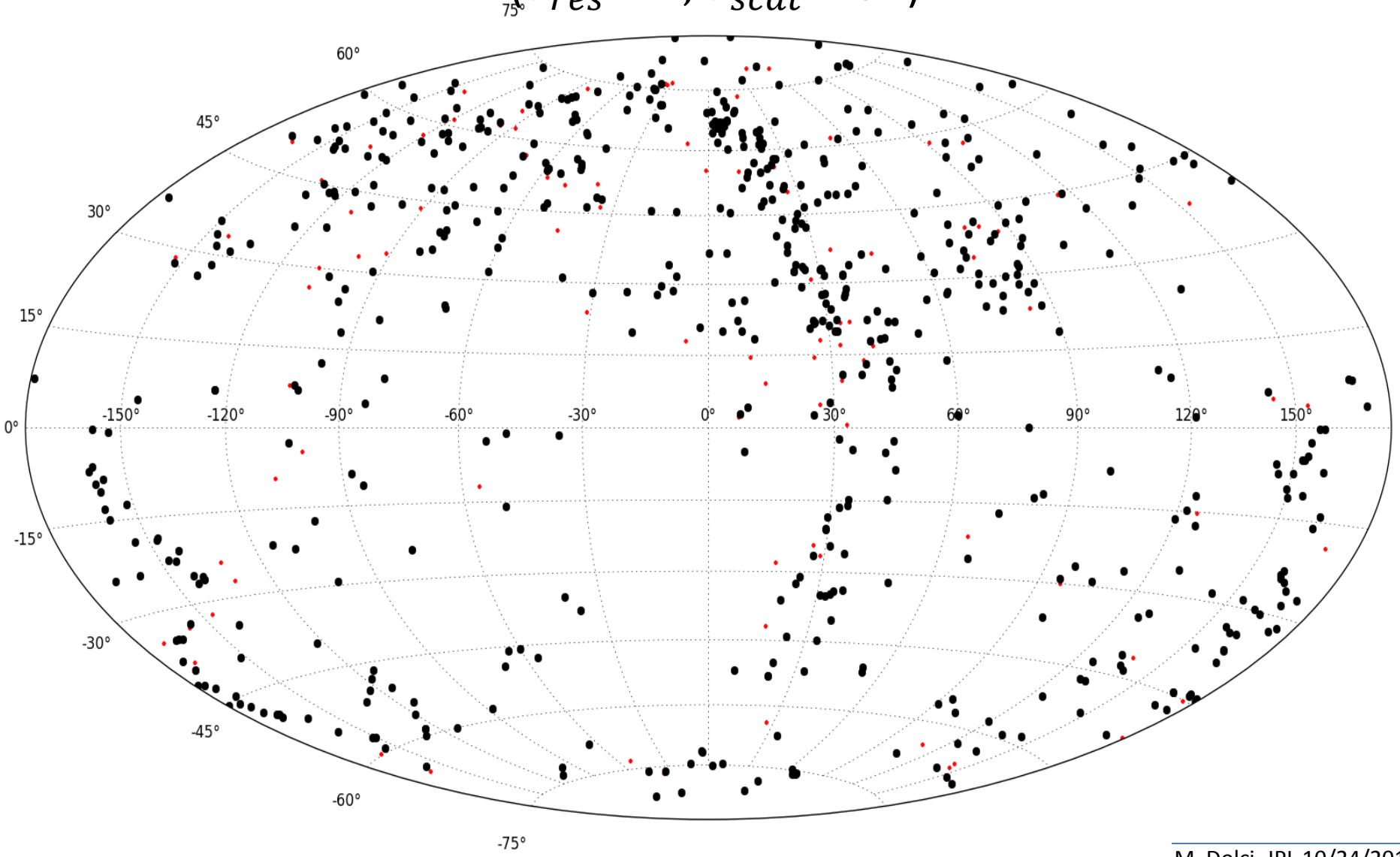
ROTATIONAL OFFSET NOT YET SOLVED

The correlating fraction is 38.18%
The isotropic fraction is 25%

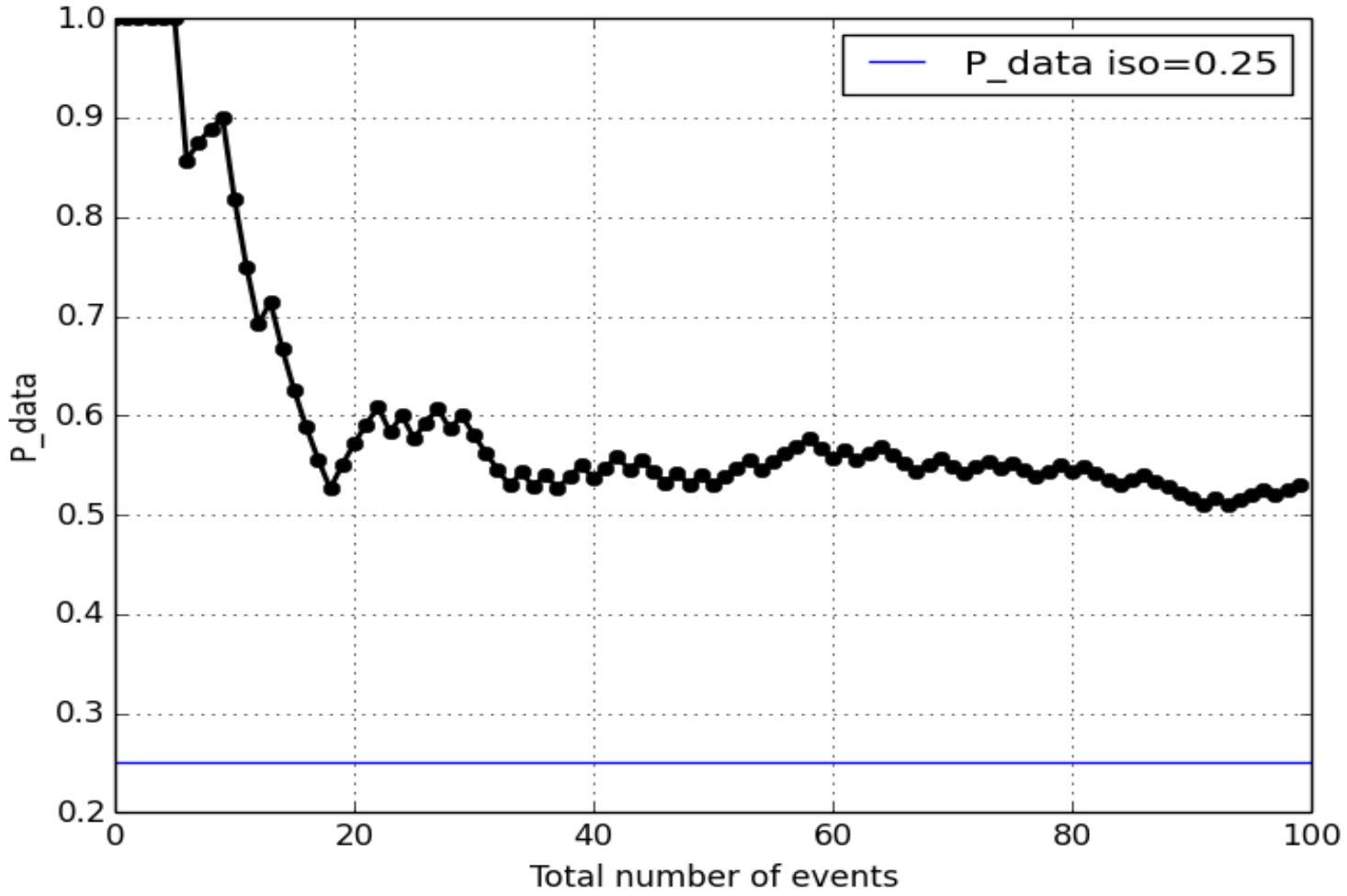


100 CR events random simulation

(ϑ_{res}=2 °, ϑ_{scat}=10 °)



Sensitivity analysis of simulated data

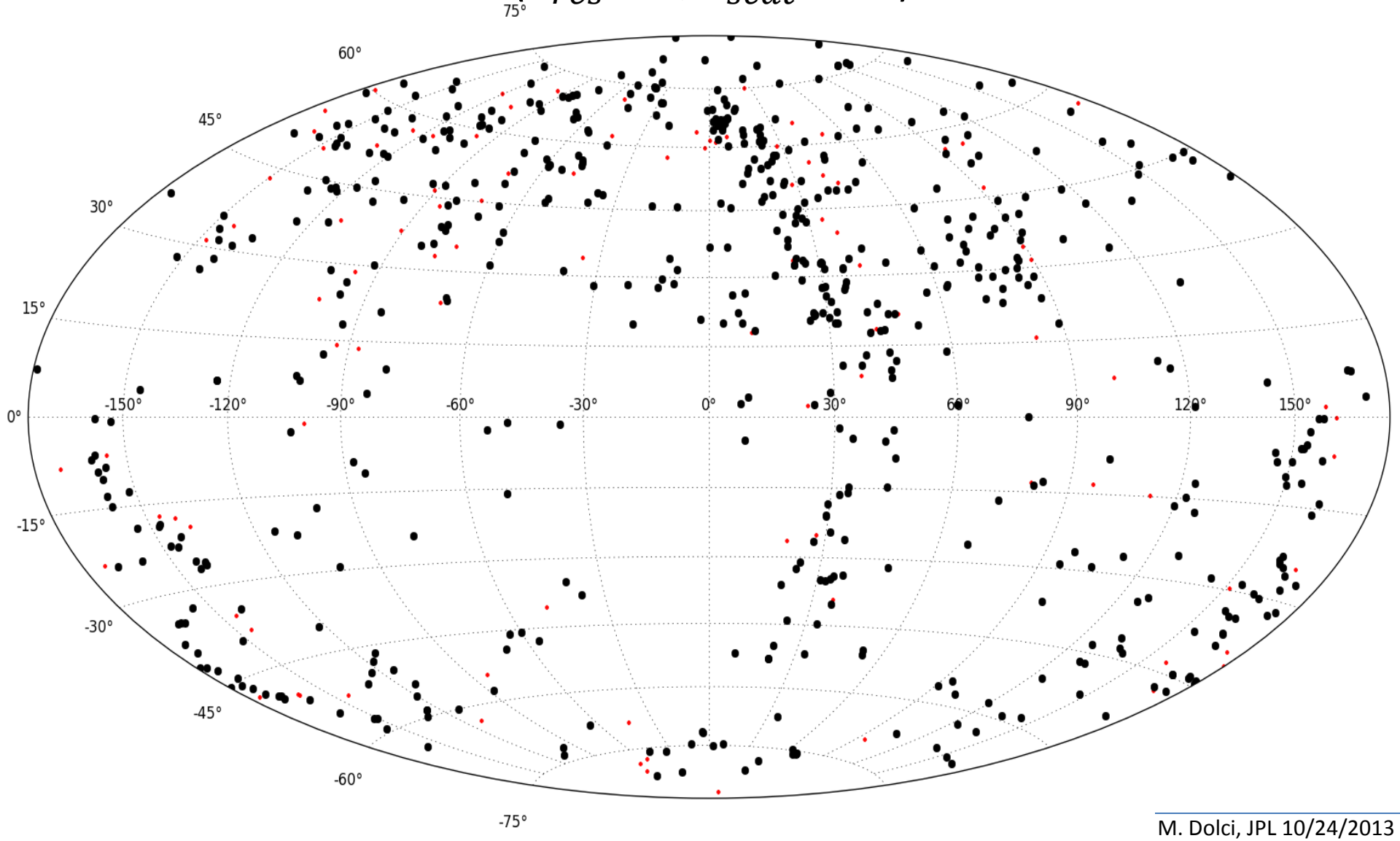


The correlating fraction is 59%

The isotropic fraction is 25%

100 CR events random simulation

(ϑ_{res}=5 °, ϑ_{scat}=10 °)



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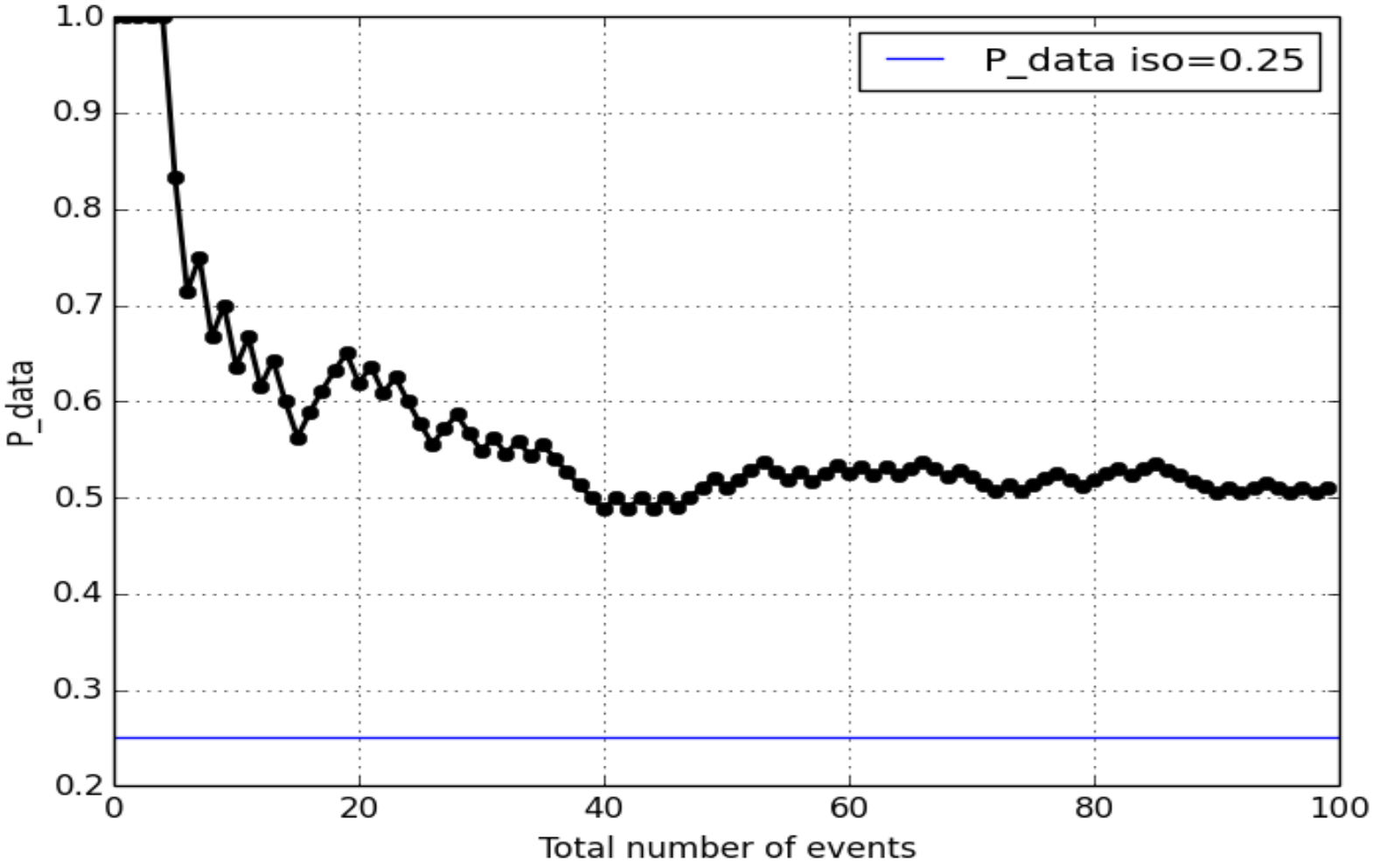
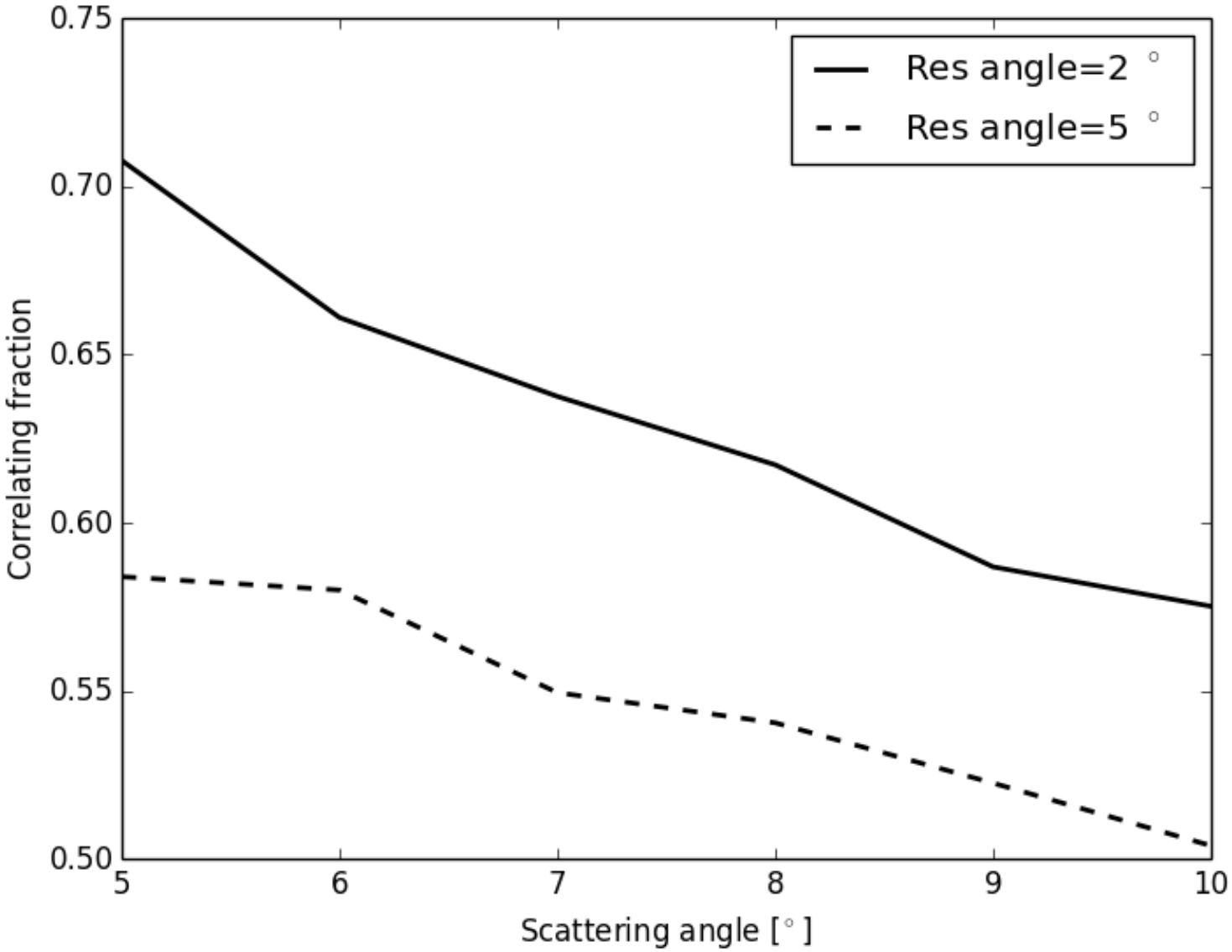
Sensitivity analysis of simulated data



The correlating fraction is 57%

The isotropic fraction is 25%

Sensitivity analysis of simulated data



Outlooks

- Obtain the confidence level for SWORD mission
- Insert in the ϑ_{scat} the EGMF coherence length (λ_B)
- Study a model for $\vartheta_{scat} > 10°$ (*Z=26*)
- Study the distribution of UHECR charge number (*Z*)

Project 2:

Global NASA CubeSat Database

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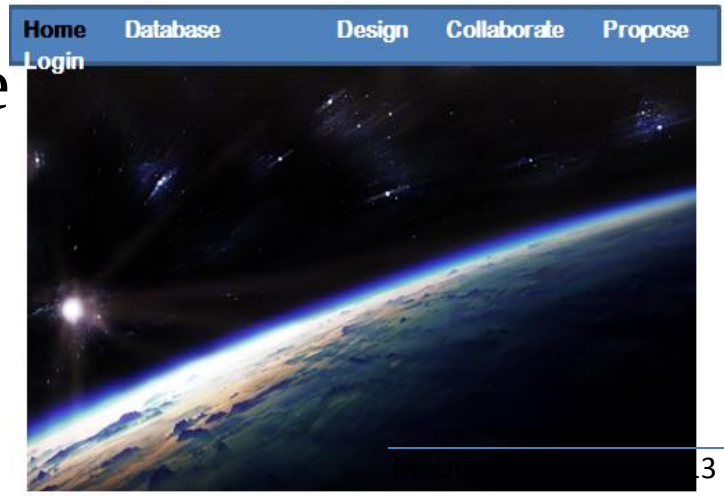
Database Infos

- Data Type: Mission and Part-level data
- “Required”: Subsystem, Mass, Volume, Power, Data Provider
- “Additional”: Data Rates, Flight Heritage, Cost, Lessons, etc.
- User-interface where users can add/ edit, view all, or search
- Database is extensible, compatible with other JPL databases



My work

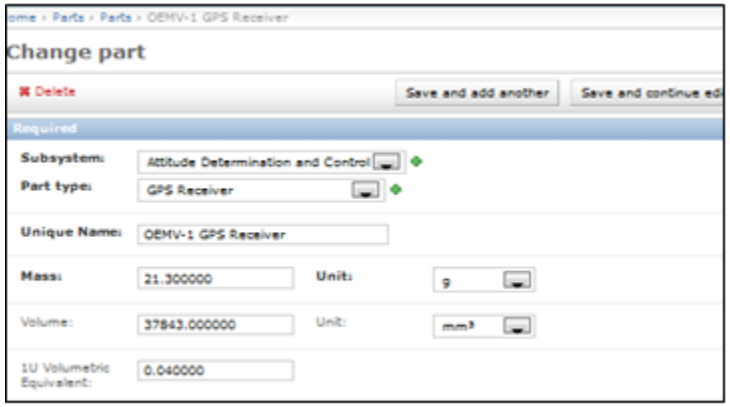


Fig. 1: Adding/ Editing a new CubeSat Part

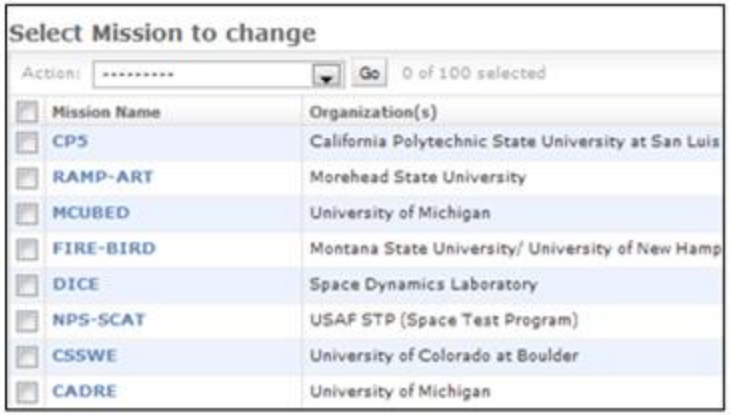


Fig. 2: Viewing all CubeSat Missions

Fig. 3: Searching for Parts Based on Criteria

Acknowledgements

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- ASI
- JPL (J. Booth, J. Smith, Dr. A. Romero-Wolf, Dr. S. Spangelo)