

## Project 1:

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

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

from 09/02 to 11/02 2013



# The SWORD Mission Concept

(Synoptic Wideband Orbiting Radio Detector)

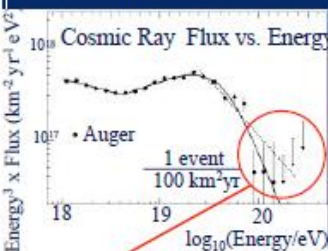
A. Romero-Wolf et al. arXiv:1302.1263v1

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

75 Mpc Science

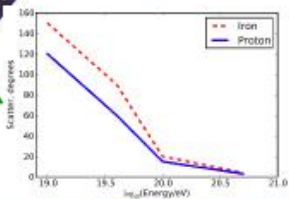


What are the sources? AGN, pulsars, radio lobes, big bang relic particles?



Increase sensitivity by a factor of  $>10$

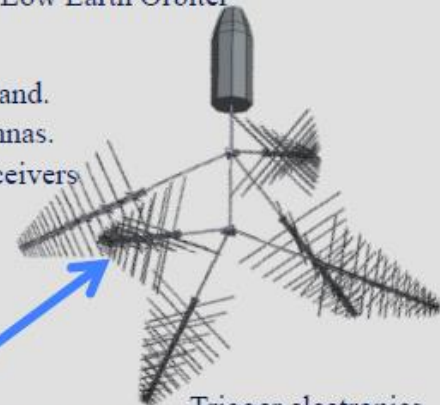
Inter-galactic Magnetic Fields



## 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.

Ionosphere

Troposphere

Dispersion

Propagation

Air shower

Reflection

Geo-synchrotron pulse

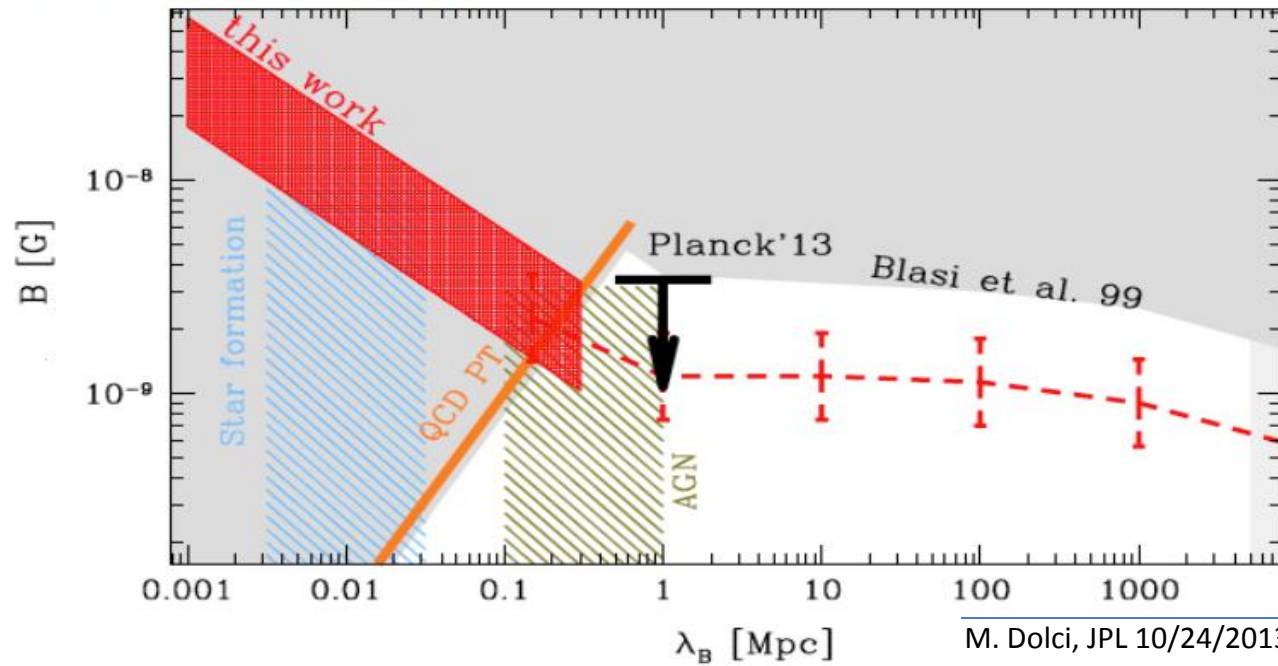
# EGMF value ( $B, \lambda_B$ )

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

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

Neronov, Semikoz, Banfsheh, 2013

**B=1nG**



# $\vartheta_{scat}$ theoretical model

**SCATTERING ANGLE (mean value):**

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

- $D \leq \lambda_B$

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

- $D \gg \lambda_B$

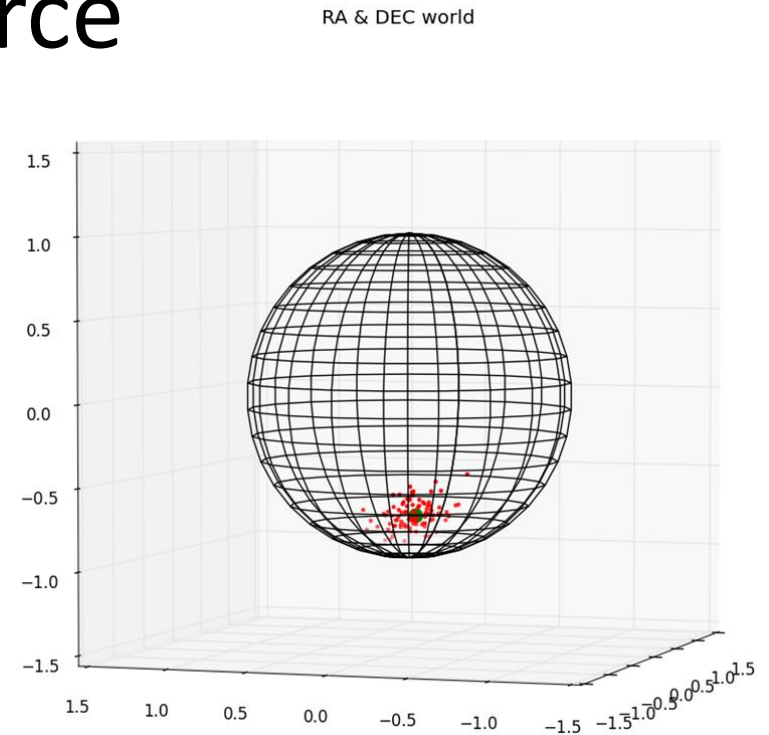
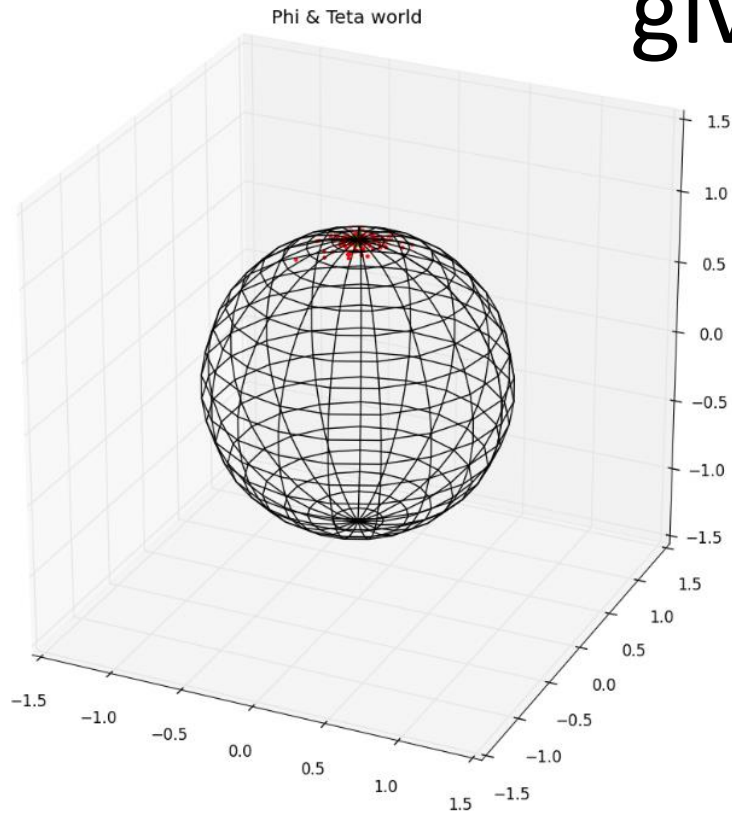
$$\vartheta_{scat} = 0.23^\circ \left( \frac{E}{10^{20} \text{ eV}} \right)^{-1} \left( \frac{D}{50 \text{ Mpc}} \right)^{0.5} \left( \frac{B}{10^{-10} \text{ G}} \right) \left( \frac{\lambda_B}{1 \text{ Mpc}} \right)^{0.5} Z$$

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

**ANGULAR RESOLUTION:**

$\vartheta_{res} = 2^\circ \text{ baseline} / 5^\circ \text{ threshold}$

# Simulation for scattering signals from a given source



Teta = Rayleigh ( $\sigma_{scat}$ ,  $\vartheta_{res}$ )  
Phi = Uniform ( $0, 2\pi$ )

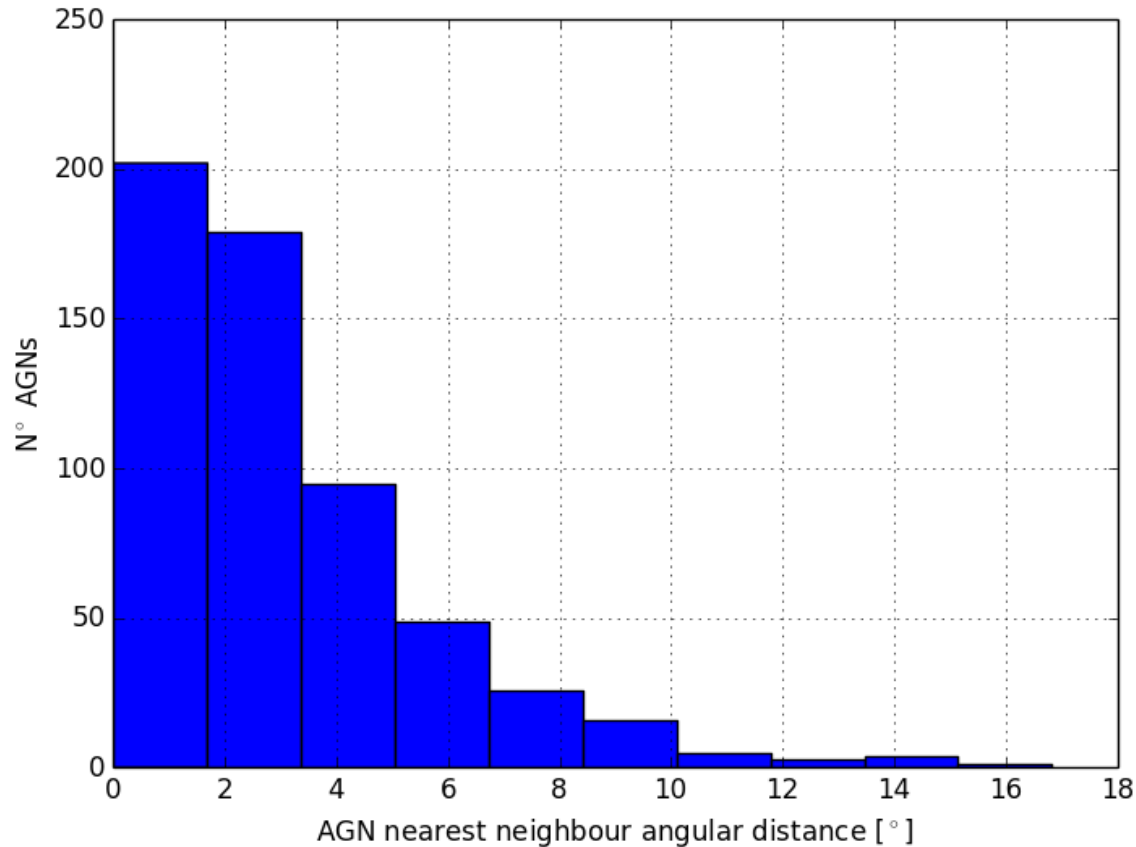
Matrix rotation  
 $M = M(\alpha_{src}, \delta_{src})$



Equatorial coordinates ( $\alpha, \delta$ )

$\vartheta_{ad}$

# AGN nearest neighbour angular distance $\vartheta_{nnad}$ (AGN clustering)



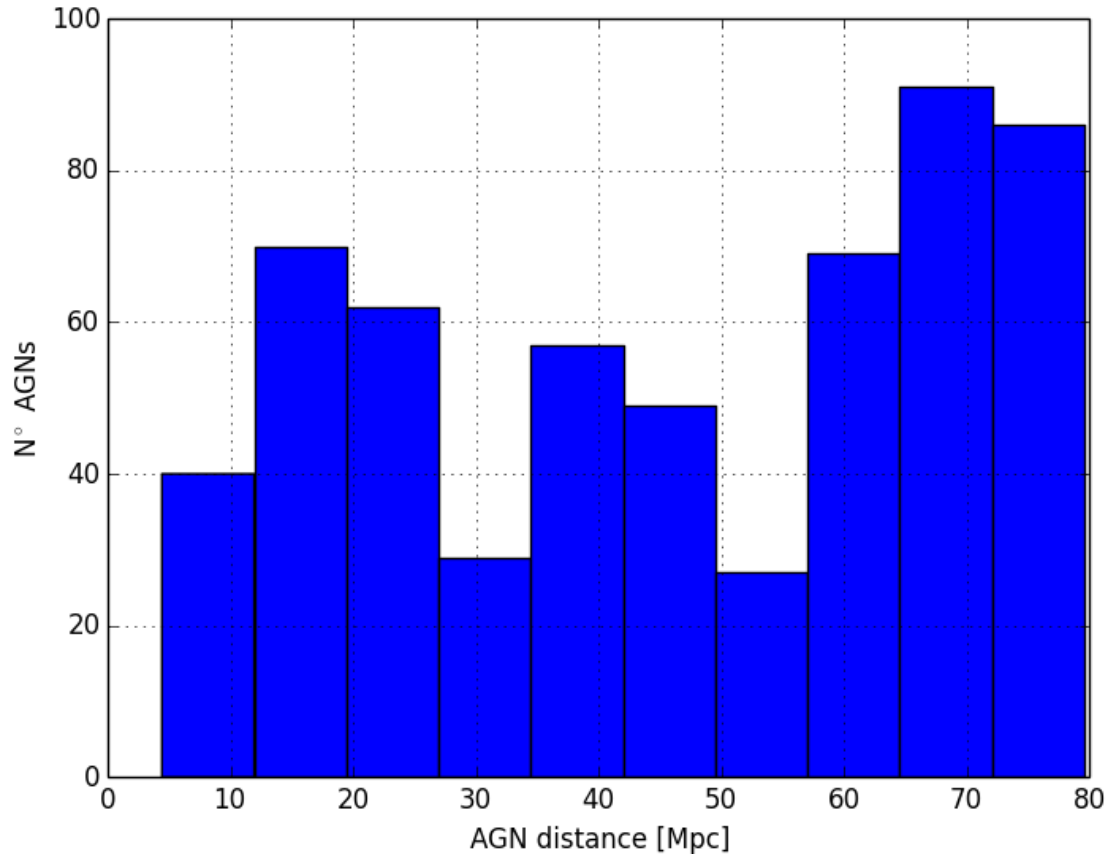
~65% AGNs  $\vartheta_{nnad} \geq 2^\circ$

~20% AGNs  $\vartheta_{nnad} \geq 5^\circ$



$\vartheta_{res} = 2^\circ$

# AGN distance distribution



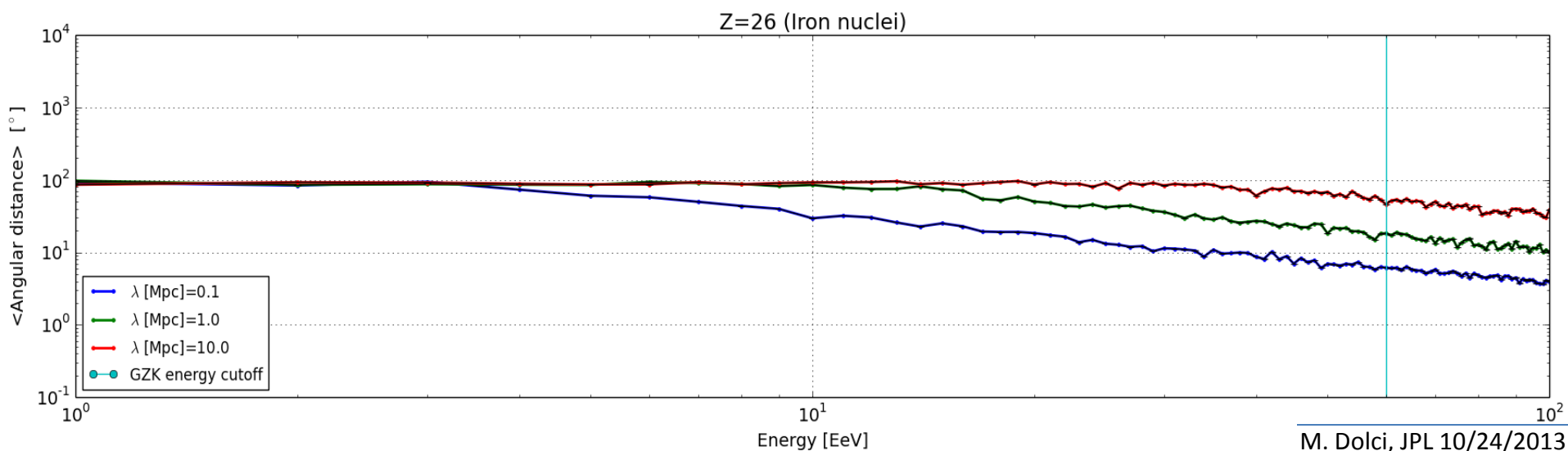
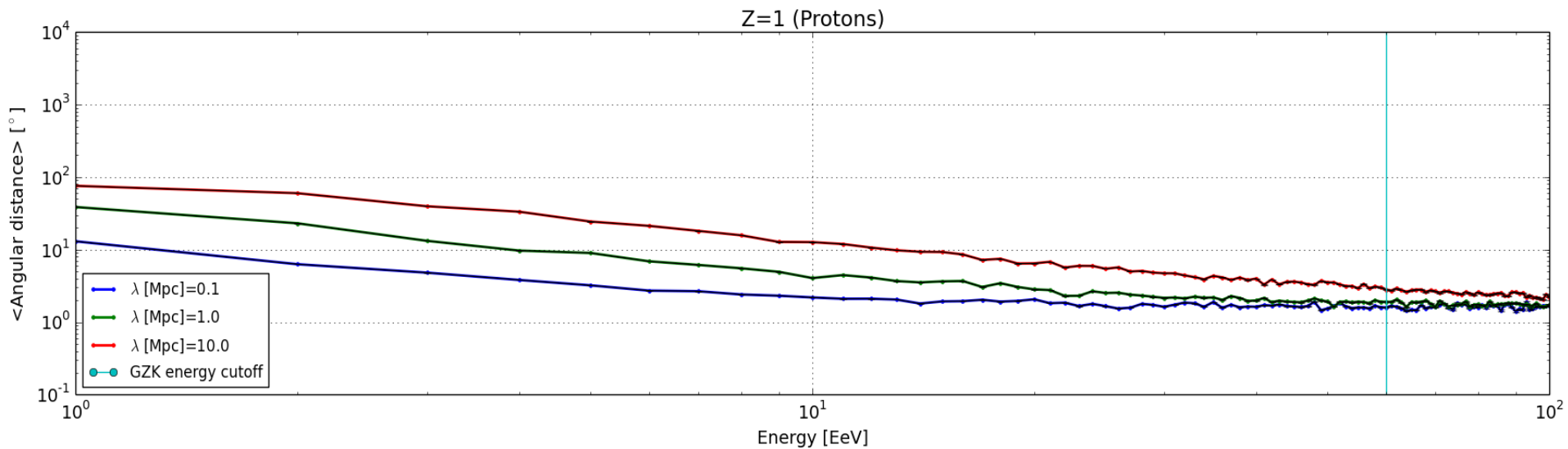
~7% AGNs  $D \leq 10\text{Mpc}$

~20% AGNs  $D \leq 20\text{Mpc}$

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

# Angular distance

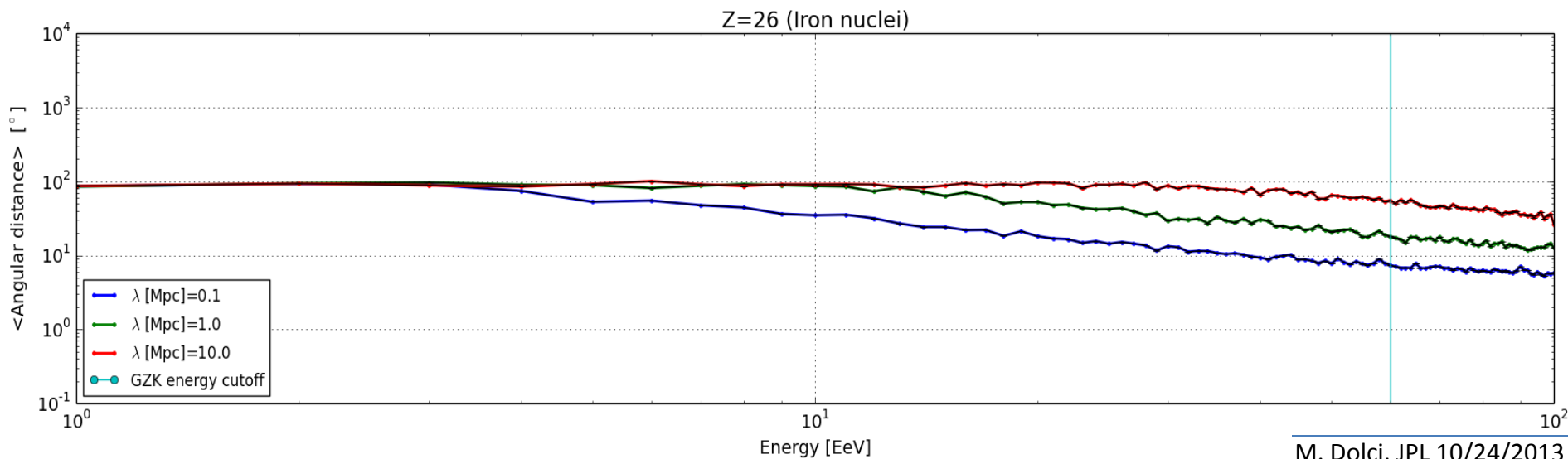
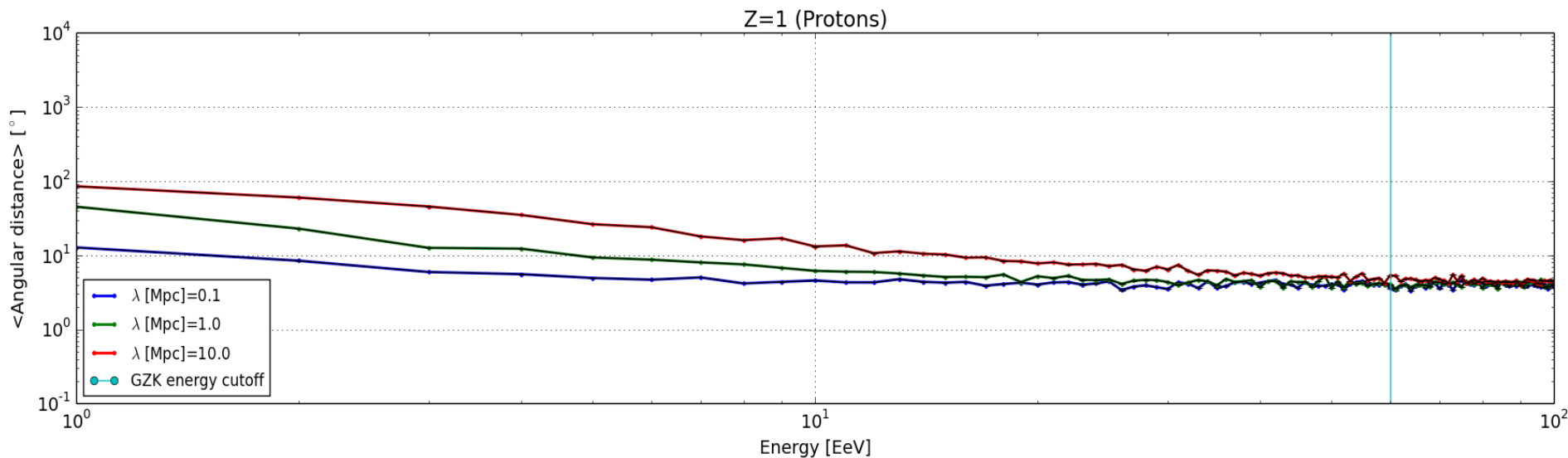
CenA (3.8Mpc),  $\vartheta_{res}=2^\circ$





# Angular distance

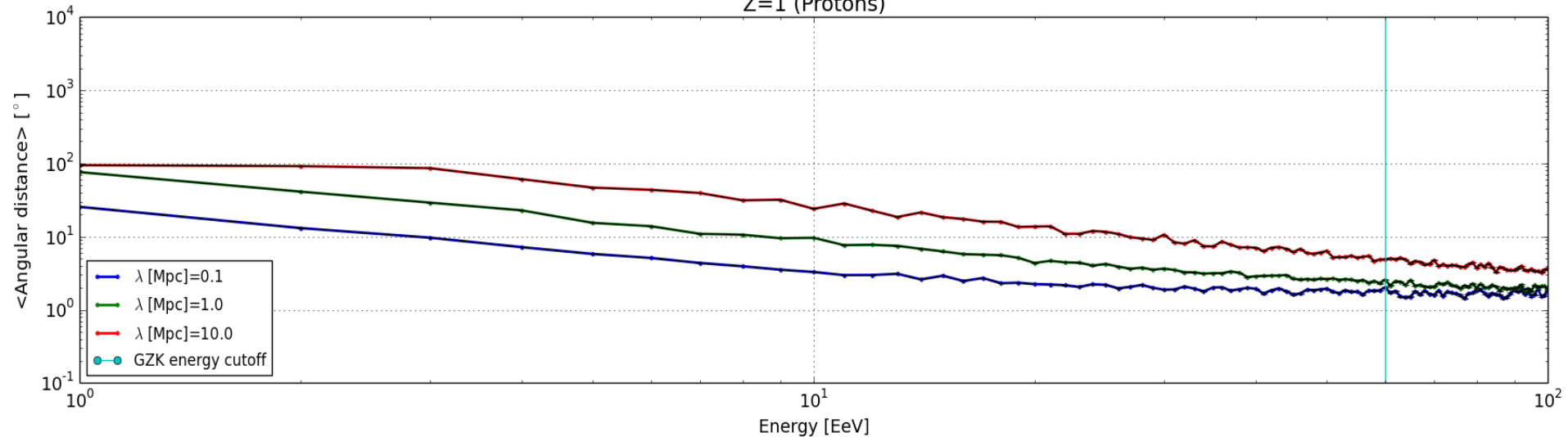
CenA (3.8Mpc),  $\vartheta_{res}=5^\circ$



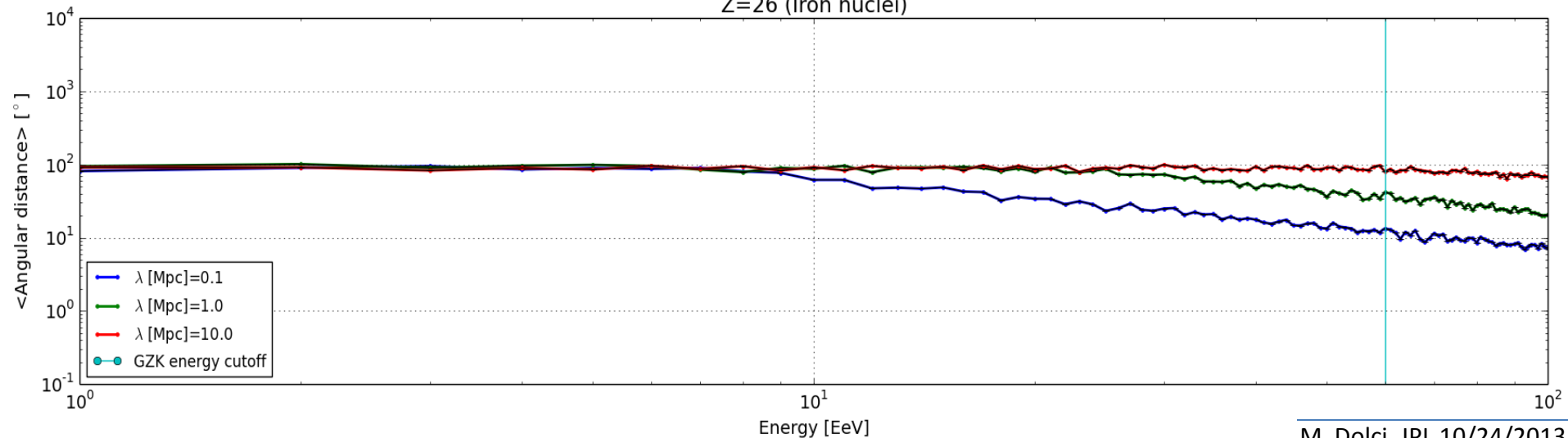
# Angular distance

Virgo (16.5Mpc),  $\vartheta_{res}=2^\circ$

Z=1 (Protons)

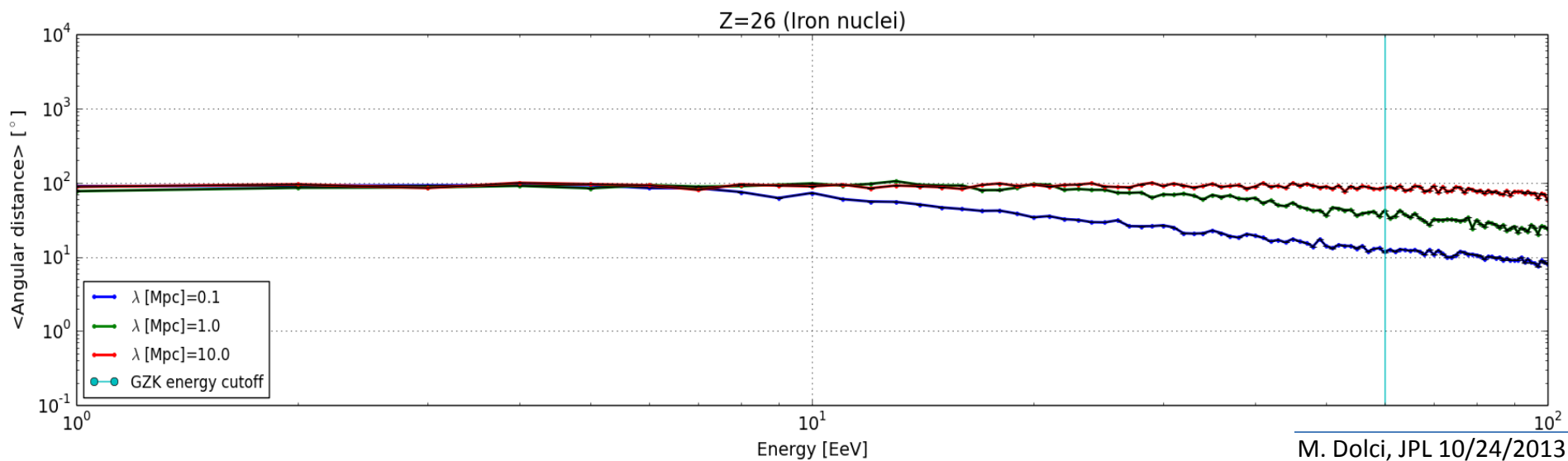
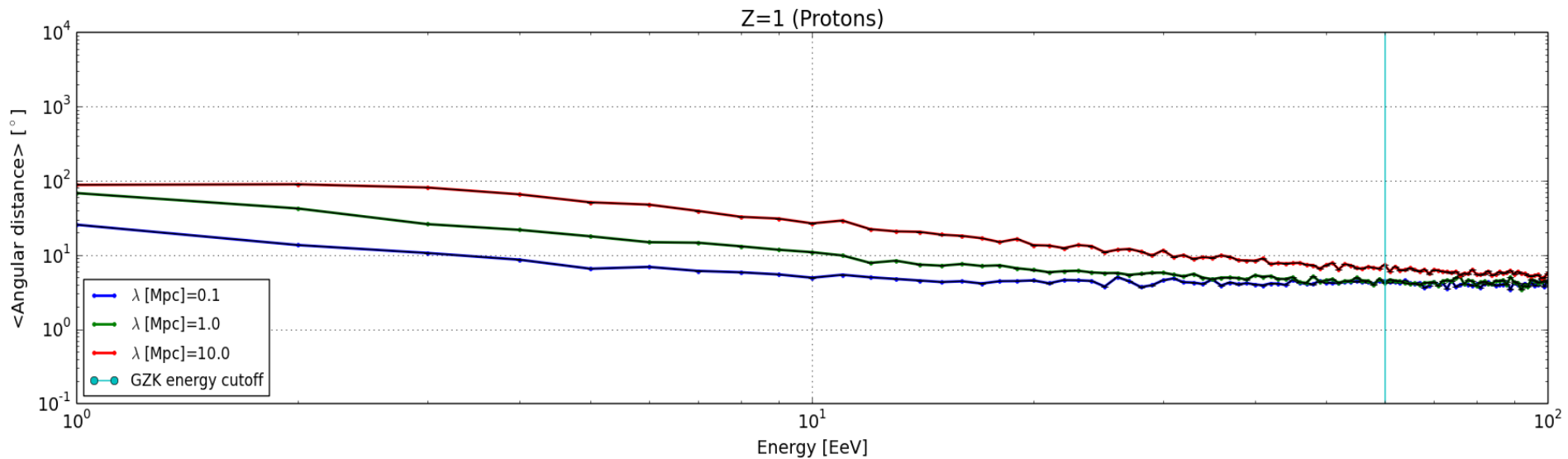


Z=26 (Iron nuclei)



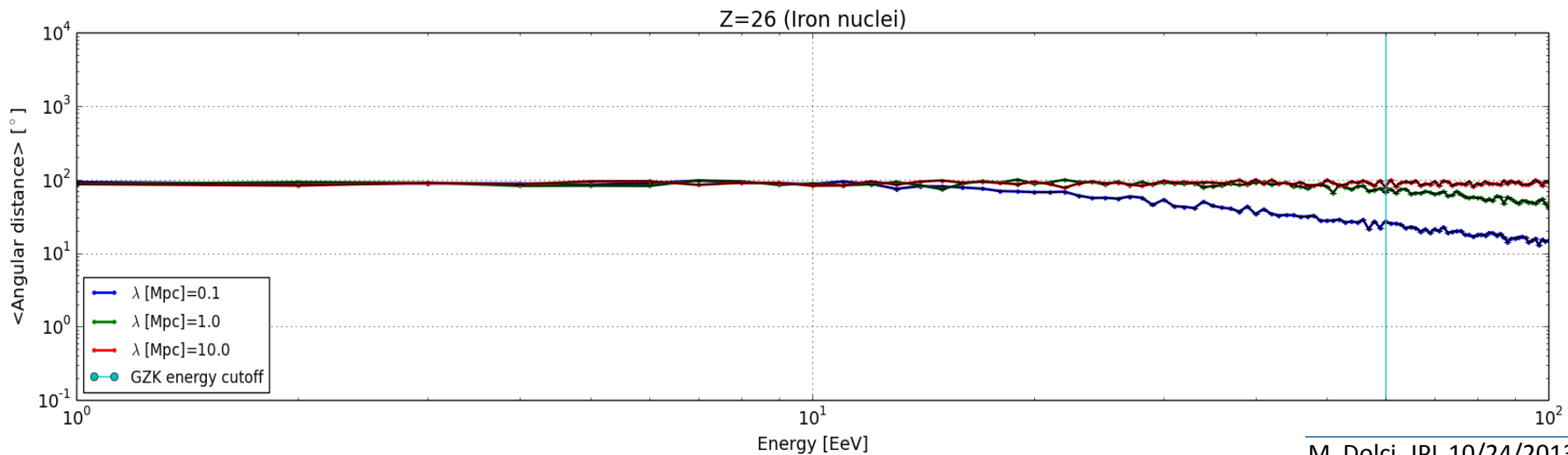
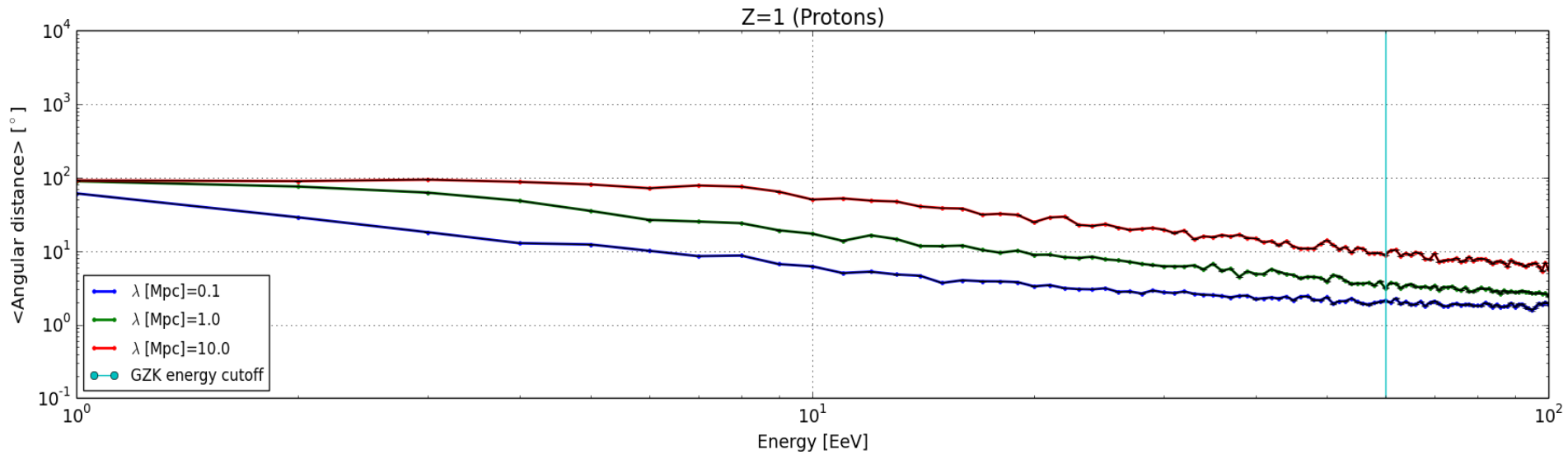
# Angular distance

Virgo (16.5Mpc),  $\vartheta_{res}=5^\circ$



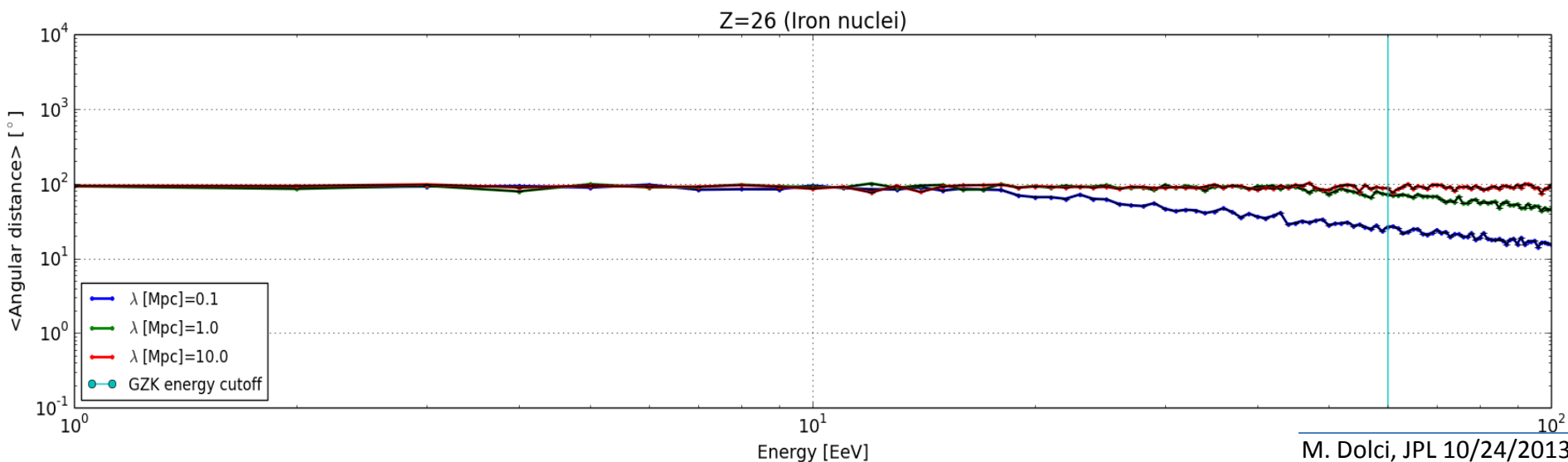
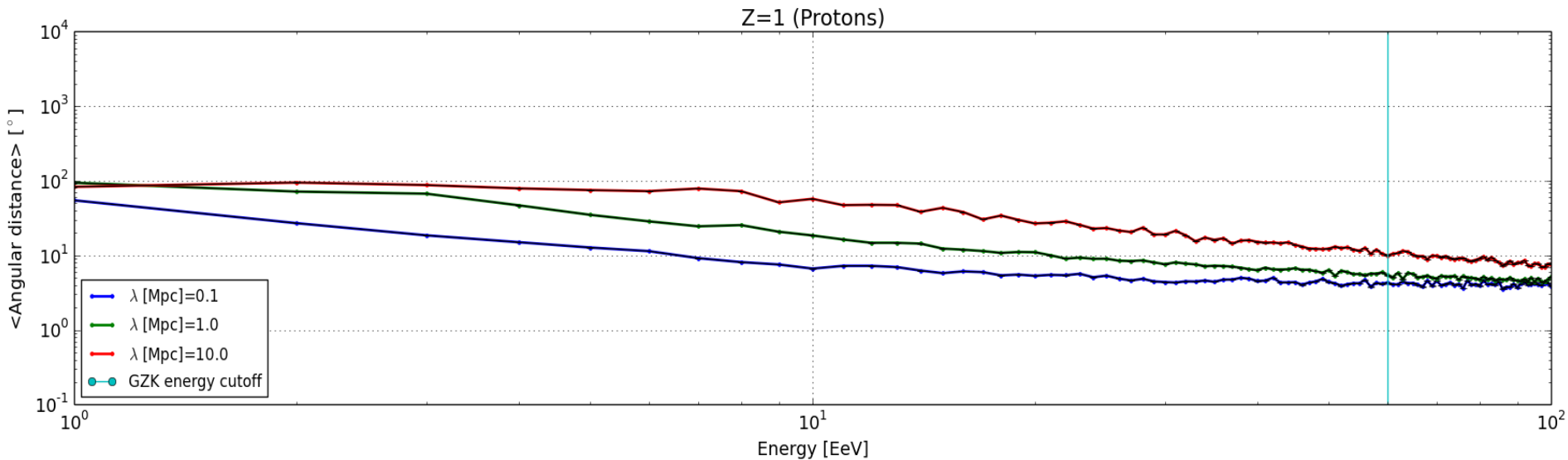
# Angular distance

Perseus (73.6Mpc),  $\vartheta_{res}=2^\circ$



# Angular distance

Perseus (73.6Mpc),  $\vartheta_{res}=5^\circ$



# Source-CR event mean angular distance (CenA)

Distance[Mpc]	Z	$\vartheta_{res}$ [°]	$\lambda_B$ [Mpc]	$\langle\vartheta_{ad}\rangle @10^{20}\text{eV}$ [°]
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**)

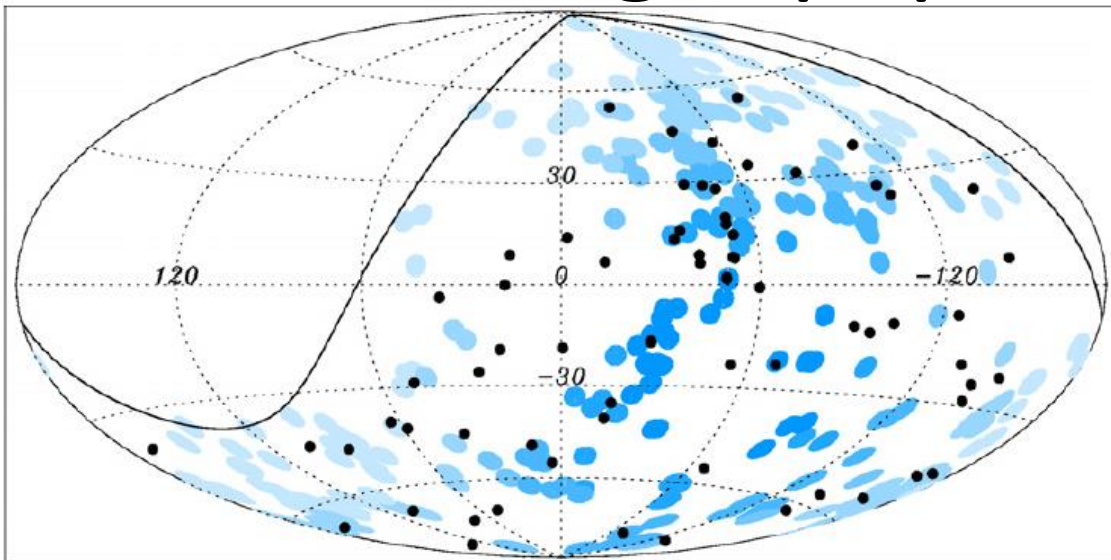
Distance[Mpc]	Z	$\vartheta_{res} [^\circ]$	$\lambda_B$ [Mpc]	$\langle \vartheta_{ad} \rangle @ 10^{20} \text{eV} [^\circ]$
16.5	1	2	0.1	2
16.5	1	2	1	2
16.5	1	2	10	5
16.5	26	2	0.1	14
16.5	26	2	1	40
16.5	26	2	10	90
16.5	1	5	0.1	5
16.5	1	5	1	5
16.5	1	5	10	7
16.5	26	5	0.1	12
16.5	26	5	1	40
16.5	26	5	10	90

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

Distance[Mpc]	Z	$\vartheta_{res}$ [°]	$\lambda_B$ [Mpc]	$\langle\vartheta_{ad}\rangle @10^{20}\text{eV}$ [°]
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

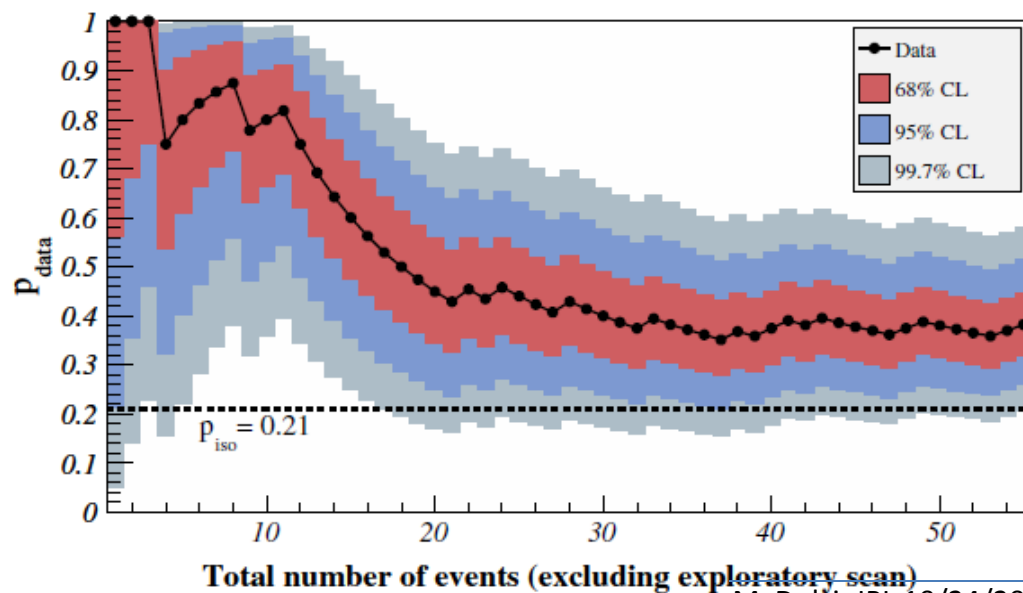


# Auger paper (2010)



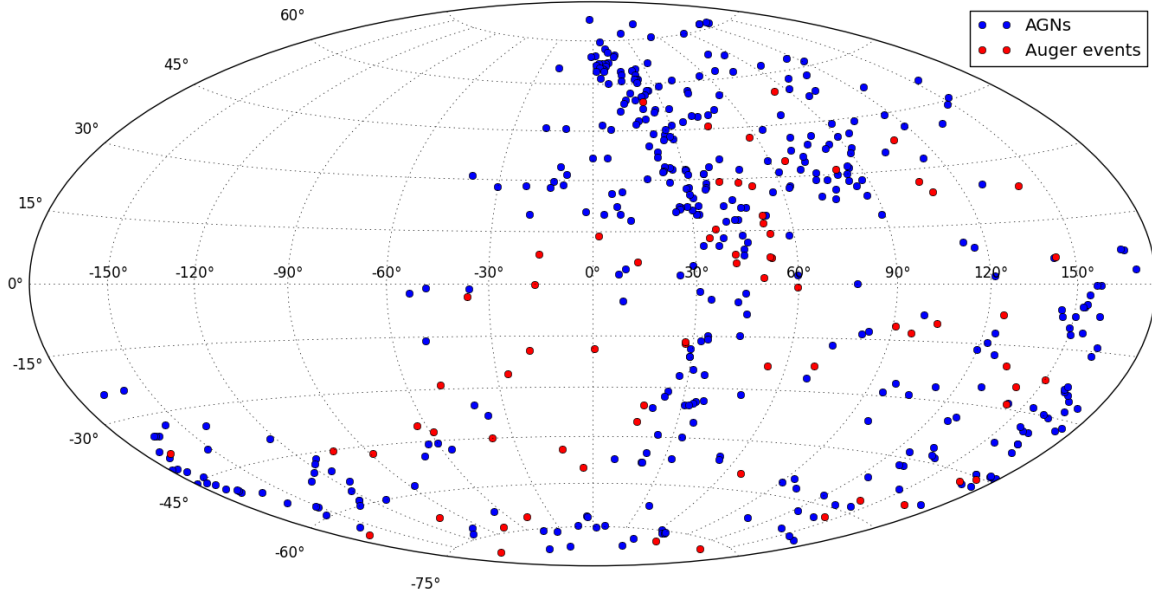
69 UHECR events  
AGNs from VCV catalog 12th ed.

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



# Reproduce Auger paper (2010)

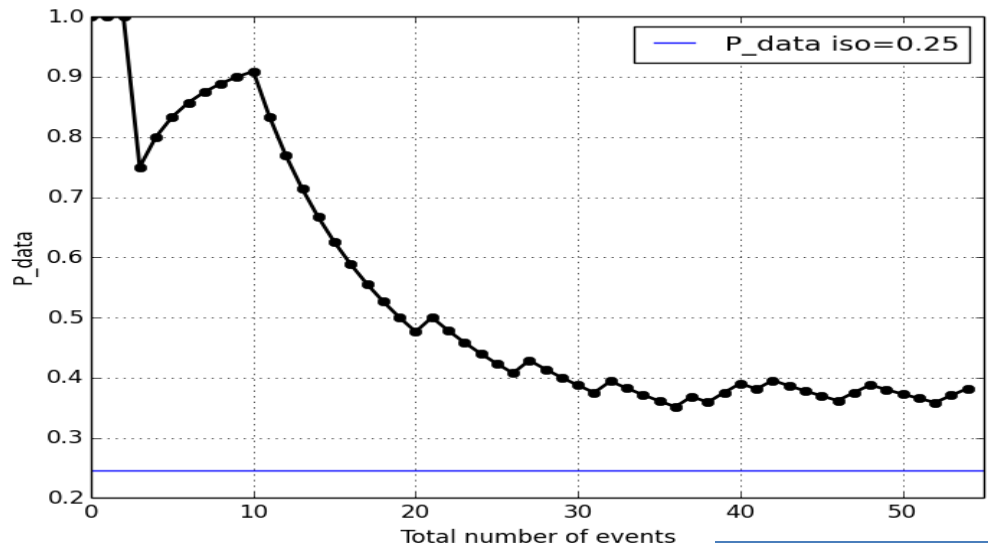
AGNs & Auger events (from 13th ed. VCV catalog 2010,  $D \leq 75 \text{Mpc}$ , Zenith  $< 60^\circ$ )



69 UHECR events  
AGNs from VCV catalog 13th ed.

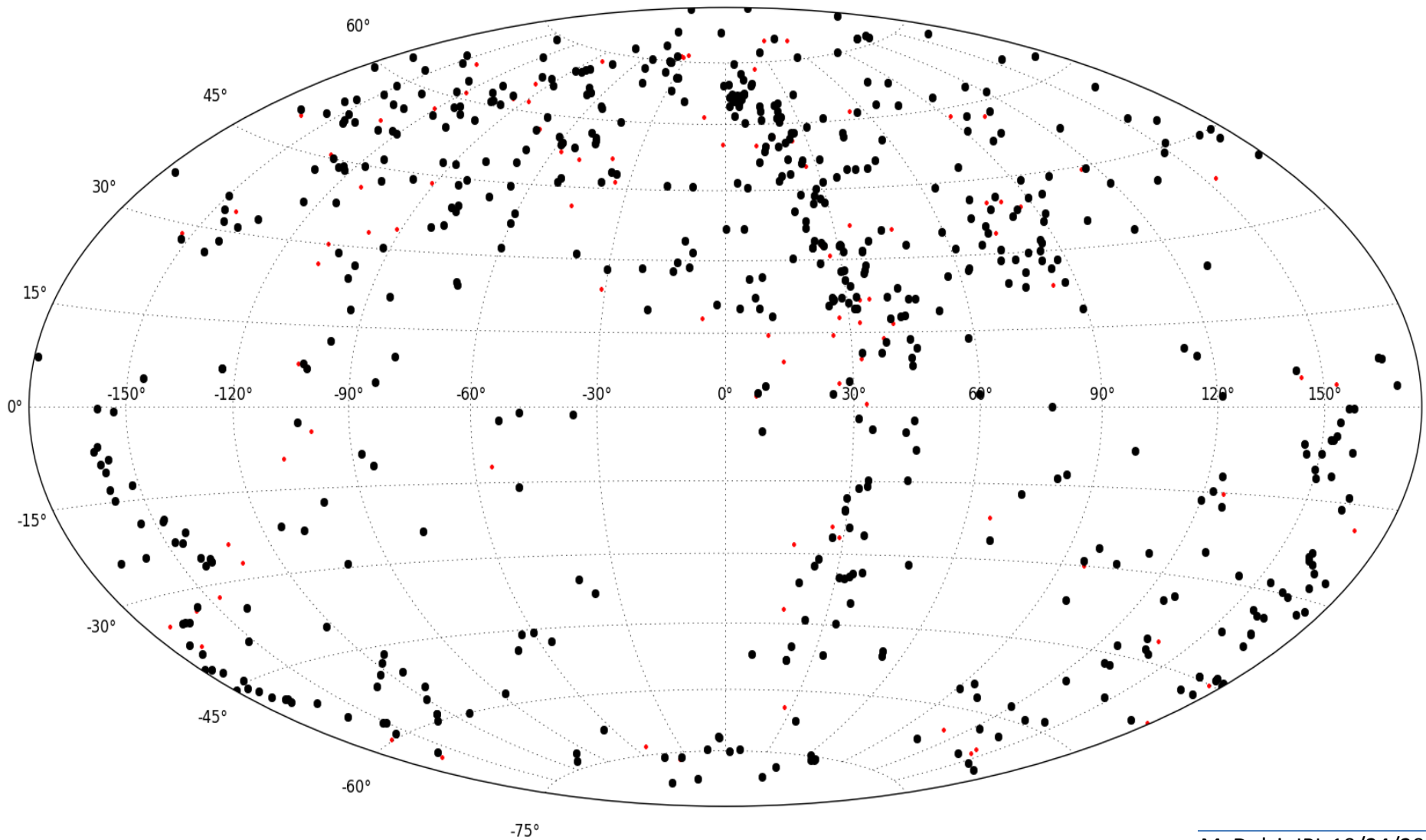
**ROTATIONAL OFFSET NOT YET SOLVED**

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

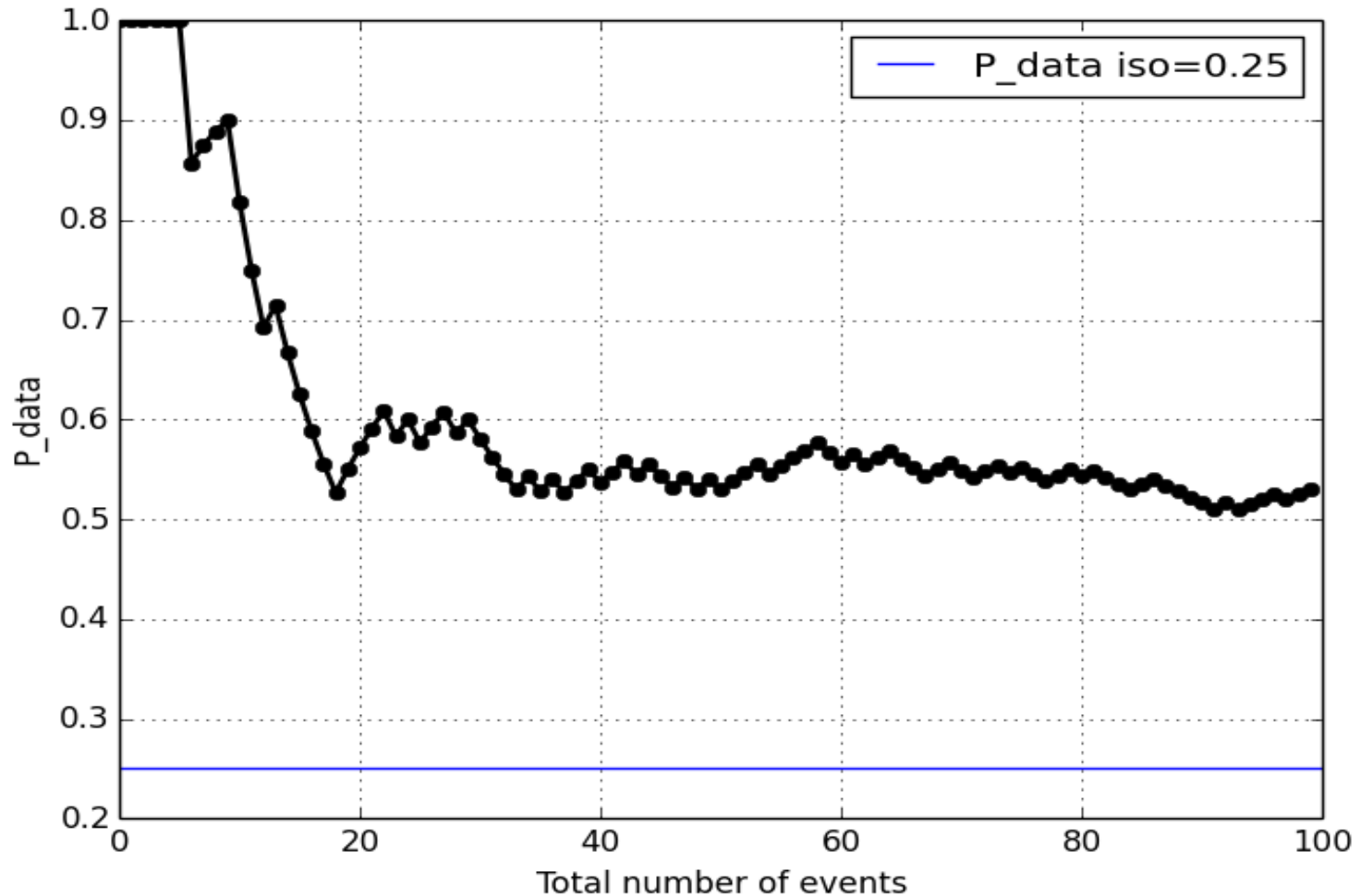


# 100 CR events random simulation

$$(\vartheta_{res}=2^\circ, \vartheta_{scat}=10^\circ)$$



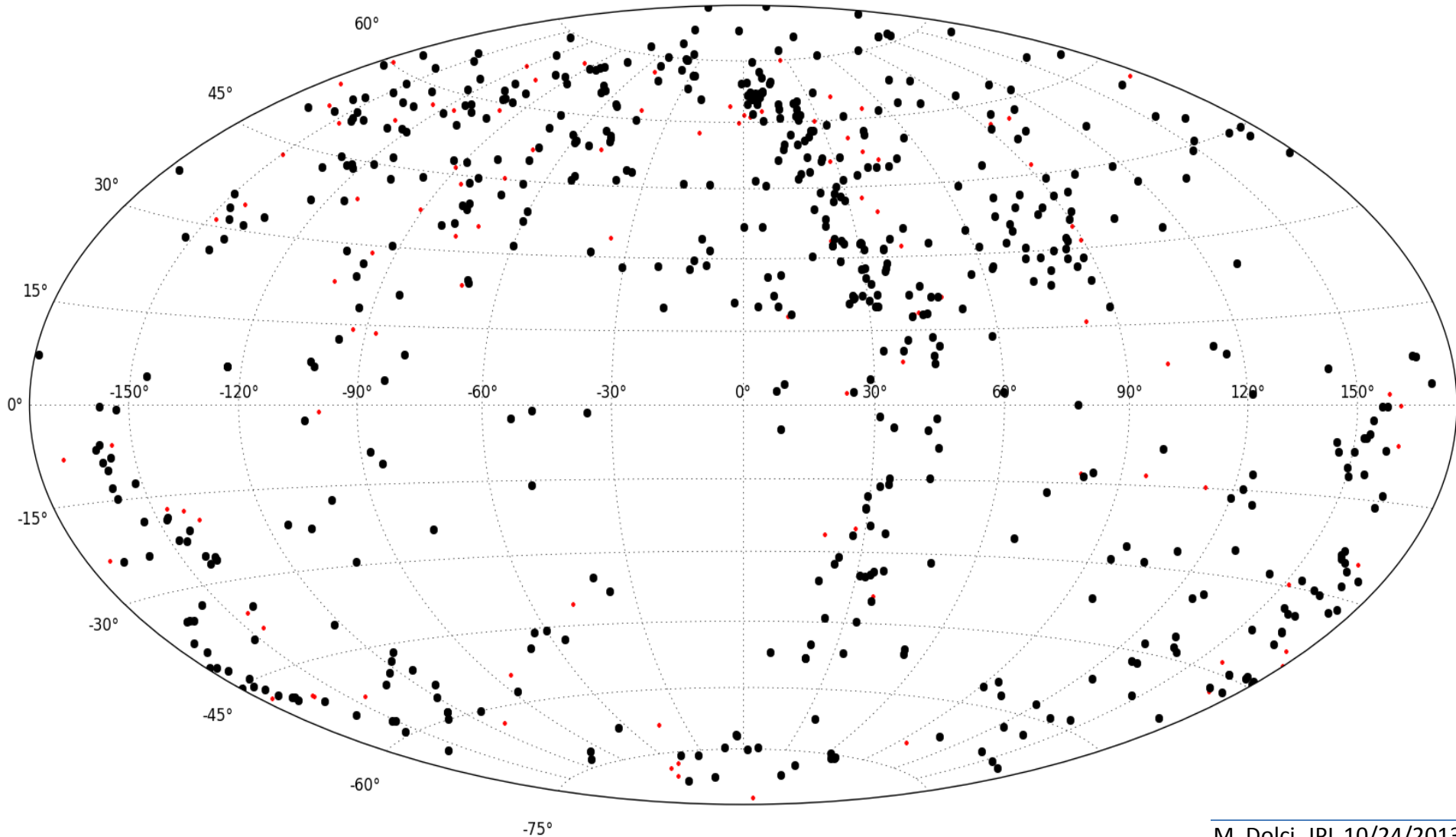
# Sensitivity analysis of simulated data



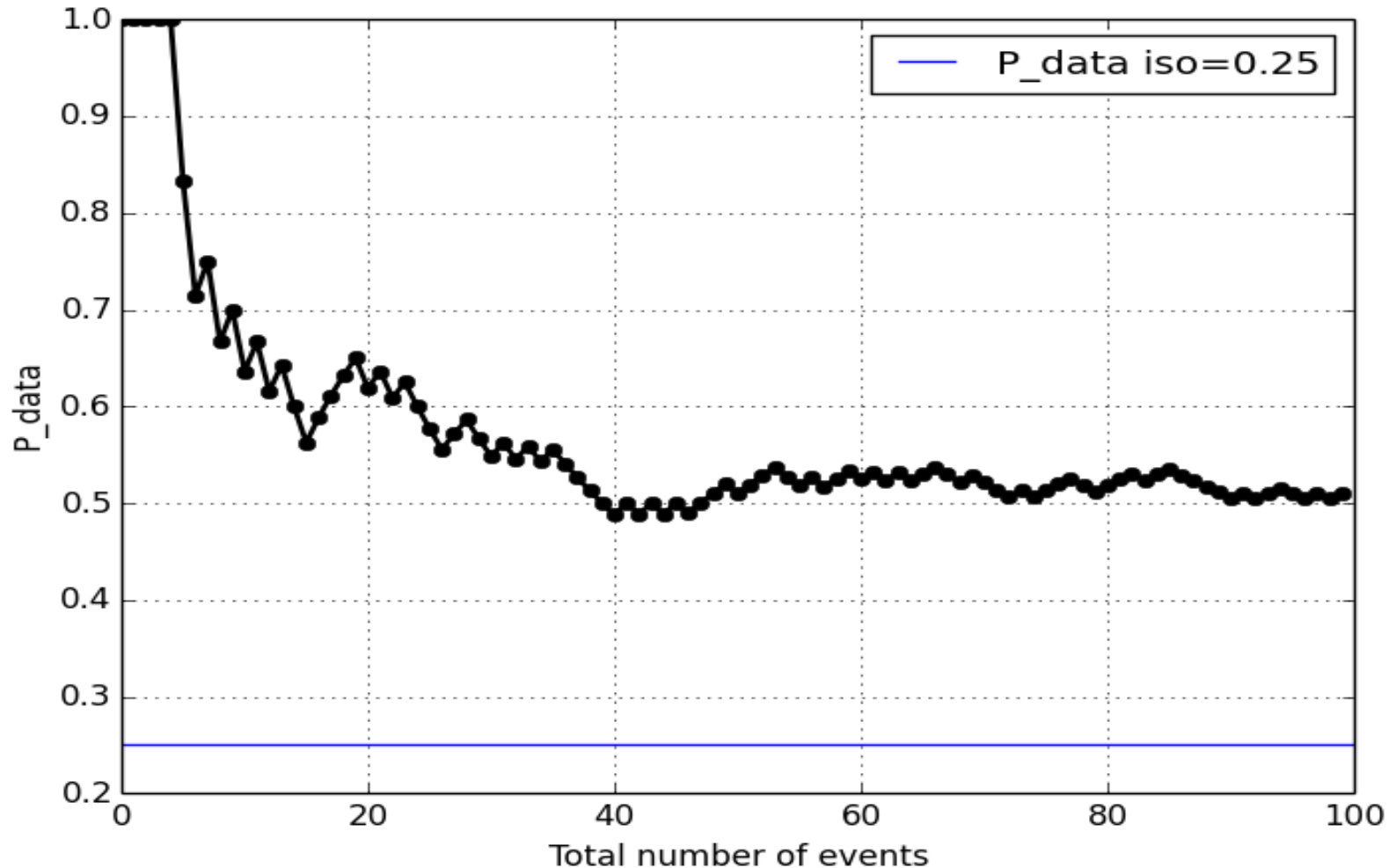
**The correlating fraction is 59%**  
The isotropic fraction is 25%

# 100 CR events random simulation

$$(\vartheta_{res}=5^\circ, \vartheta_{scat}=10^\circ)$$

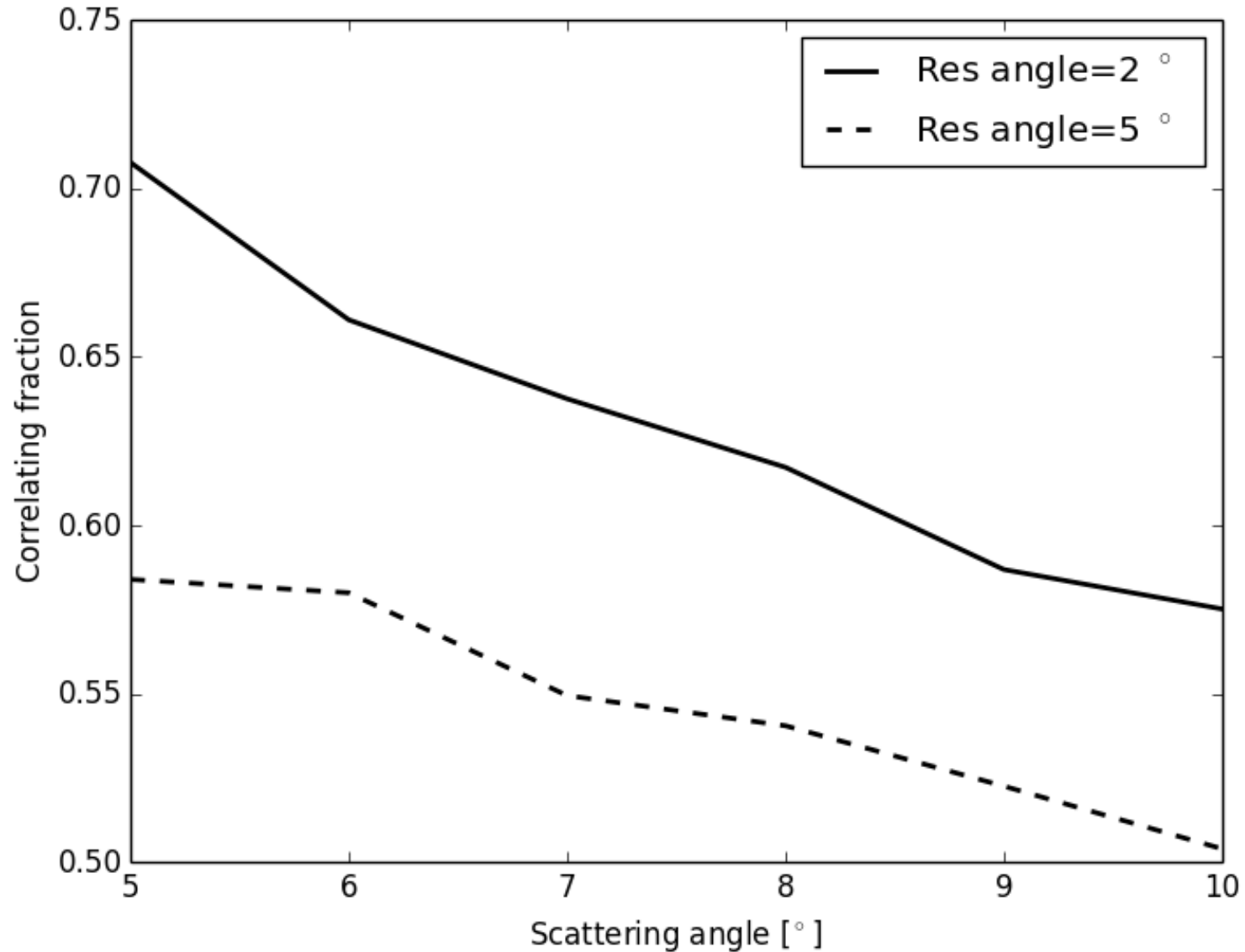


# Sensitivity analysis of simulated data



**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  $\vartheta_{scat}$  the EGMF coherence length ( $\lambda_B$ )
- Study a model for  $\vartheta_{scat} > 10^\circ$  ( $Z=26$ )
- Study the distribution of UHECR charge number ( $Z$ )



# Project 2: Global NASA CubeSat Database

Marco Dolci

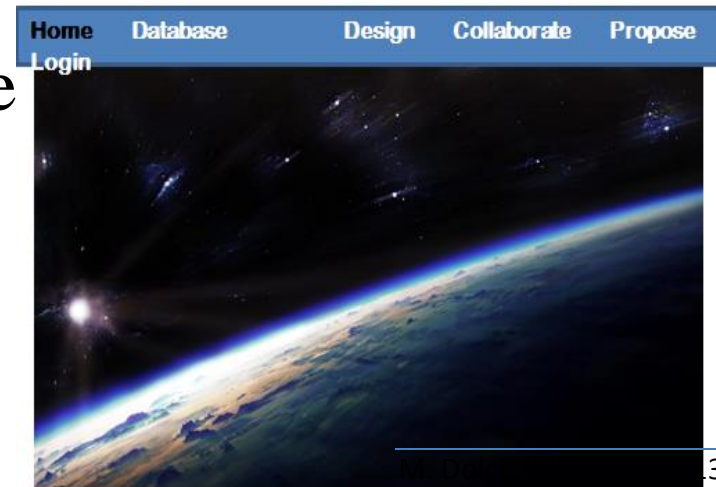
Internship at JPL NASA (J. Smith)  
Pasadena (USA)

from 09/02 to 11/02 2013



# 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

Home > Parts > Parts > OEMV-1 GPS Receiver

## Change part

[Delete](#) [Save and add another](#) [Save and continue editing](#)

**Required**

Subsystem:

Part type:

Unique Name:

Mass:  Unit:

Volume:  Unit:

IU Volumetric Equivalent:

**Fig. 1: Adding/ Editing a new CubeSat Part**

## Select Mission to change

Action:  [Go](#) 0 of 100 selected

<input type="checkbox"/>	Mission Name	Organization(s)
<input type="checkbox"/>	CP5	California Polytechnic State University at San Luis
<input type="checkbox"/>	RAMP-ART	Morehead State University
<input type="checkbox"/>	MCUBED	University of Michigan
<input type="checkbox"/>	FIRE-BIRD	Montana State University/ University of New Hamp
<input type="checkbox"/>	DICE	Space Dynamics Laboratory
<input type="checkbox"/>	NPS-SCAT	USAF STP (Space Test Program)
<input type="checkbox"/>	CSSWE	University of Colorado at Boulder
<input type="checkbox"/>	CADRE	University of Michigan

**Fig. 2: Viewing all CubeSat Missions**

Filter Components To search, enter your criteria for any of the fields below and press "Filter"

Subsystem:  Part Type:

Mass:

Volume:

IU Volumetric Equivalent:

Average Power:

Generate/Calculate Power:  Generate  Calculate

[Clear](#) [Filter](#)

Component Name	Subsystem	Part Type	Mass	Volume	IU Equiv	Avg Power
Salpico Analog	Instruments	Camera	84 g	30,320 mm³	0.2303	0.24 W
Salpico Digital	Instruments	Camera	270 g	119,220 mm³	0.176220	0.8 W
SAT Orbital Camera	Instruments	Camera	250 g	700.4 mm³	0.000750	0.3.3 W
RED Navcam	Instruments	Camera	200 g	107,100 mm³	0.110710	0.2.2 W
NavCam 510	Instruments	Camera	100 g	401,000 mm³	0.401	0.3.3 V @ 50 mA

**Fig. 3: Searching for Parts Based on Criteria**

# Acknowledgements

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