Shower structure analysis with Telescope Array Surface Detector data

Rosa Mayta Palacios
Osaka City University

February 27, 2018

第二回 空気シャワー観測による宇宙線の起源探索勉強会

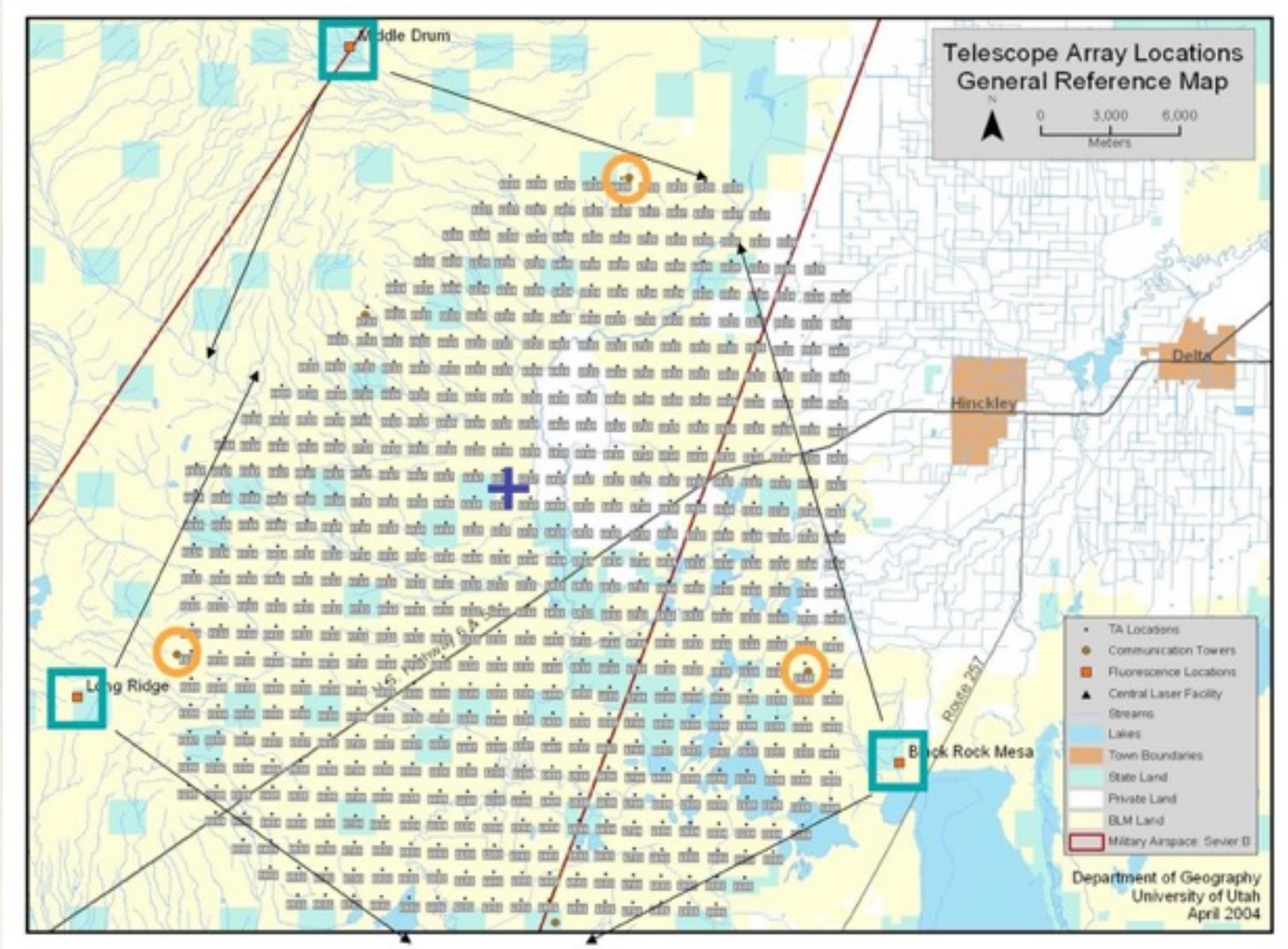
Contents

- Telescope Array
  - Surface Detector
- Purpose of Study
- Analysis of Data & MC
- Summary and Discussion

Telescope Array (TA)

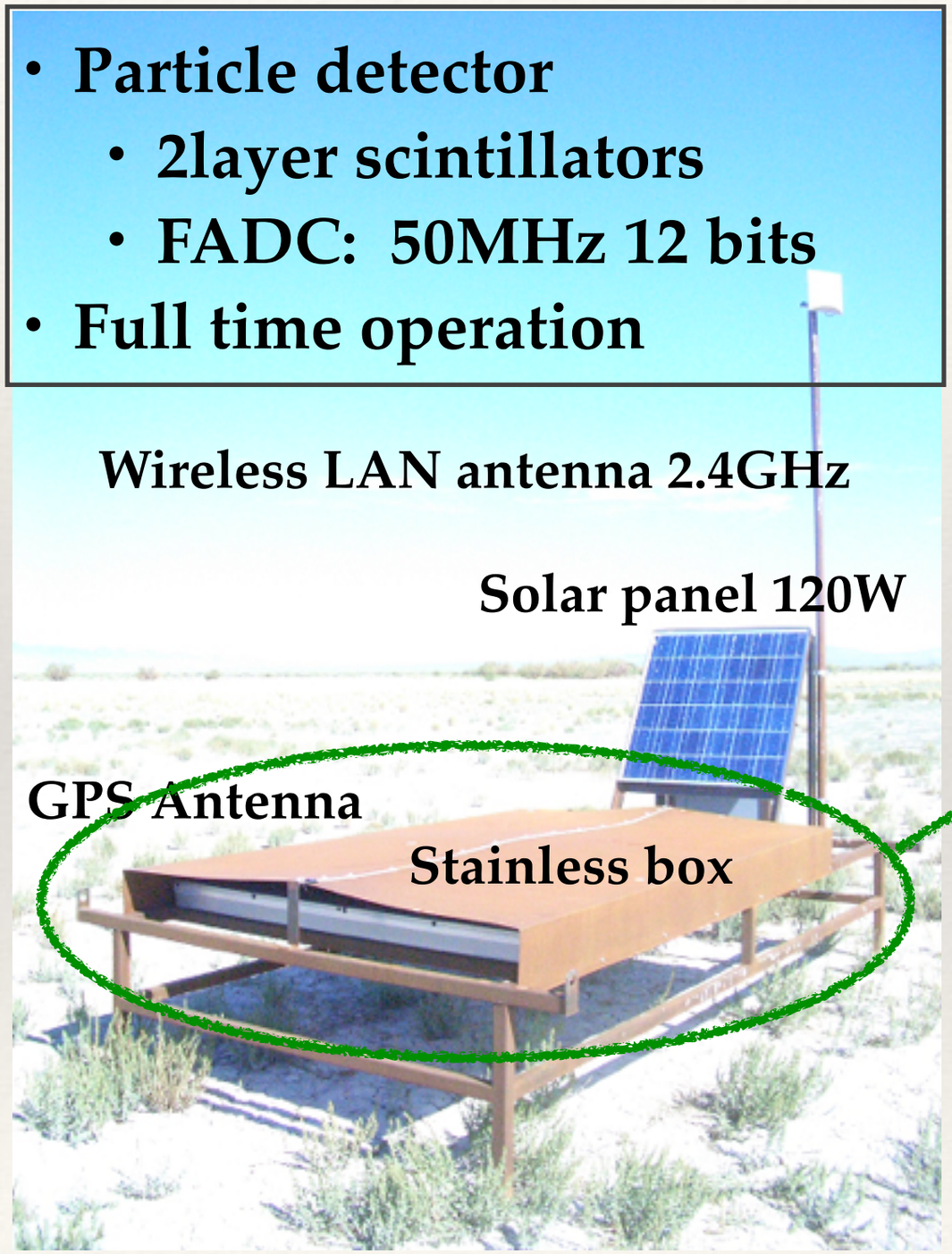
UHECR observatory with hybrid detectors

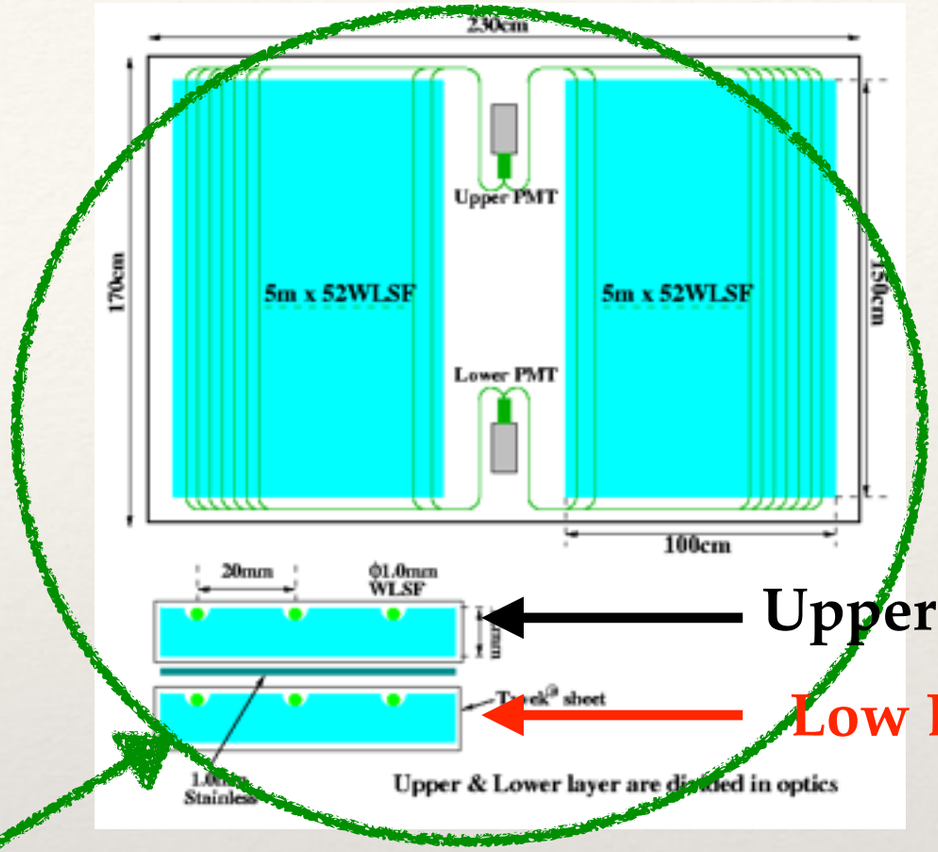
- International cooperation: 5 countries
- Hybrid detectors
  - SD: 507 scintillation counters
  - FD: 38 telescopes in 3 stations
  - ~700km^2
- Operation since 2008

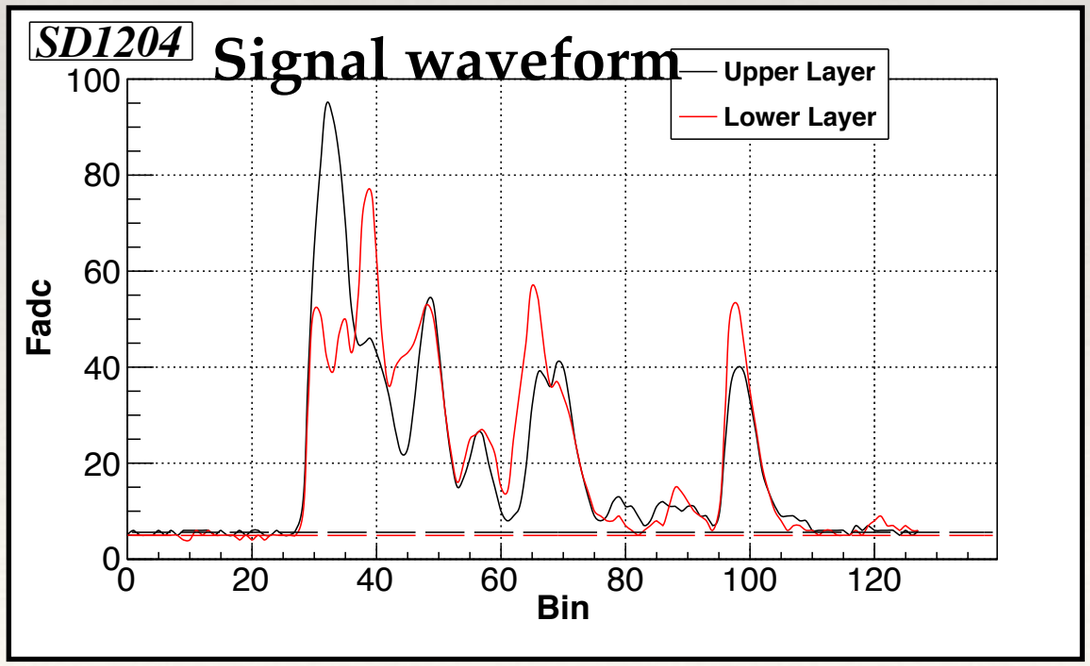


Surface Detector (SD) of TA

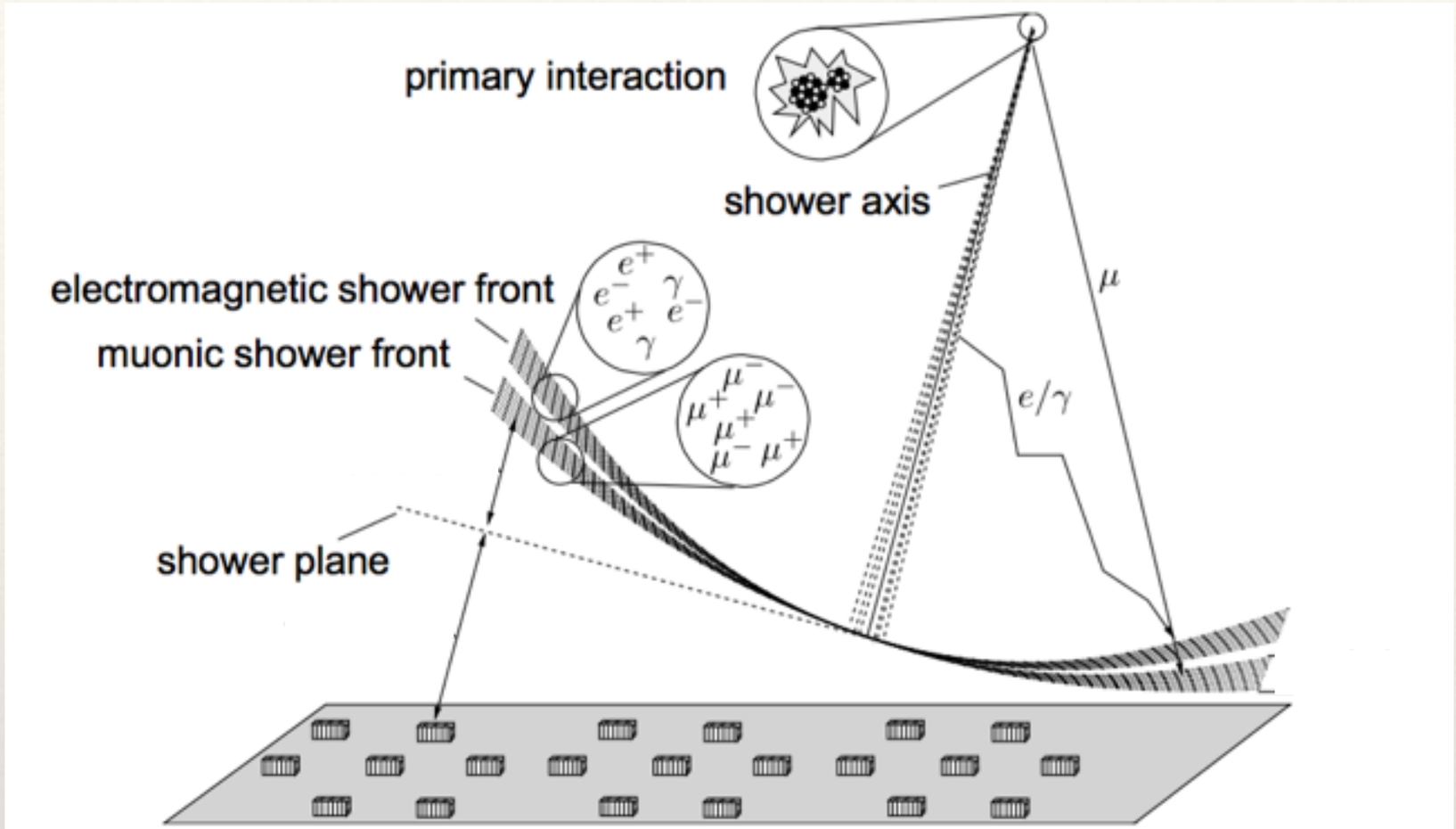
- **Particle detector**
  - **2layer scintillators**
  - **FADC: 50MHz 12 bits**
- **Full time operation**

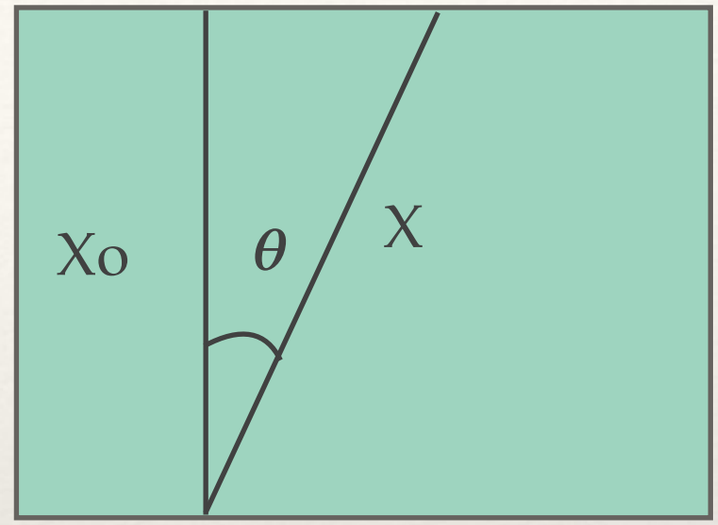






Purpose of AS Structure analysis with SD data



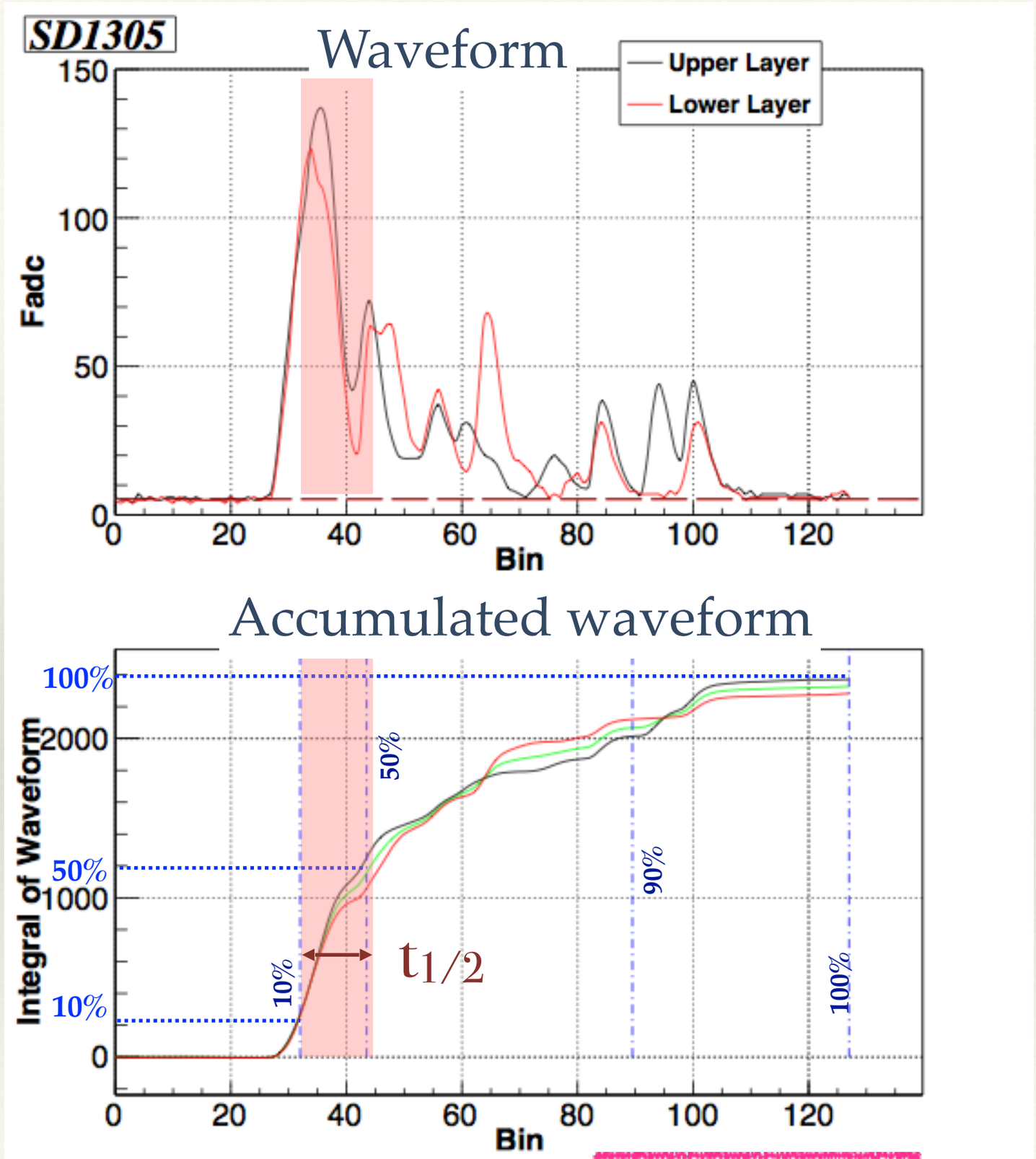


$$X = Xo \sec(\theta)$$

- Study the shower structure with SD data based on time by FADC traces.
- This observable $t_{1/2}$ based on the thickness of the disk of particles.
- The azimuthal asymmetry:
  - Composition Study
  - $t_{1/2}$ depend on composition,
  - Ref. Dova et. el. ICRC 29th

Definition of $t_{1/2}$

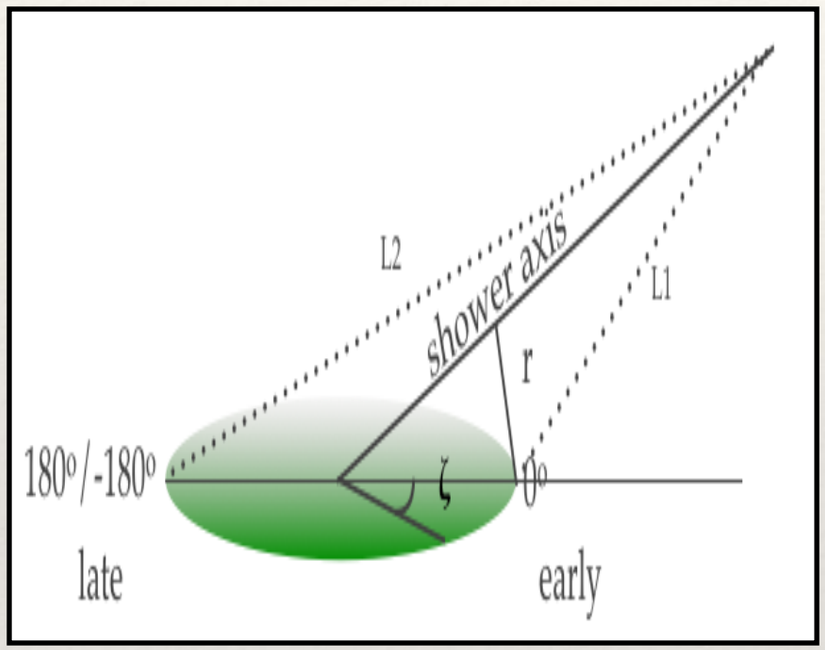
- $t_{1/2}$: equivalent to Thickness
  - Analyzed with signal waveform
- Defined as the time of signal increase from 10% to 50%

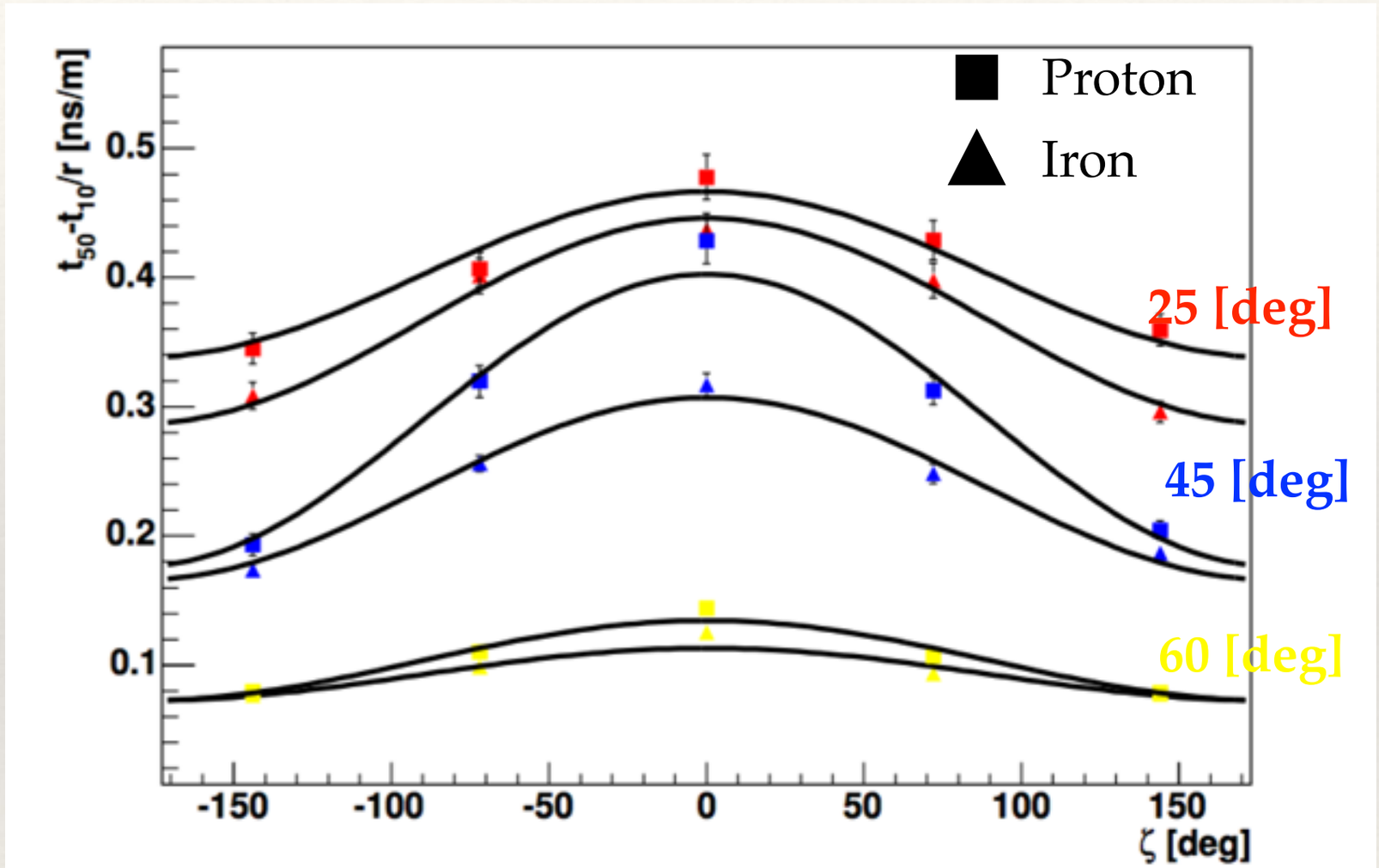


1 bin= 20 ns

Reference

Extensive Air Shower Peter K. F. Grieder p. 380





Rise-time as a Function of ζ for100EeV

Result MC study by M.T. Dova et el. ICRR 29th

Conditions of SD analysis

- Data: 9 years (May 2008 - May 2017)
- MC: 6 years (May 2008 - May 2014) Primary: Proton,

Event Selection

ENERGY LogE:		
1: 18.55 - 18.85	11,971 (Data)	88,766(MC)
2: 18.85 - 19.15	5,477 (Data)	41,325(MC)
3: 19.15 - 19.45	1,746 (Data)	11,445(MC)

ZENITH sec(θ)		
1.2 - 1.4	3,300(Data)	26,650(MC)
1.4 - 1.6	2,204(Data)	14,597(MC)
1.6 - 1.8	1,367(Data)	8,570(MC)
1.8 - 2.0	904(Data)	4,159(MC)

ZENITH sec(θ)		
1.2 - 1.4	1,290(Data)	10,548(MC)
1.4 - 1.6	872(Data)	7,019(MC)
1.6 - 1.8	716(Data)	4,737(MC)
1.8 - 2.0	518(Data)	2,659(MC)

ZENITH sec(θ)		
1.2 - 1.4	396(Data)	2,854(MC)
1.4 - 1.6	269(Data)	1,776(MC)
1.6 - 1.8	200(Data)	1,087(MC)
1.8 - 2.0	221(Data)	914(MC)

SD Selection

Azimuthal angle, ζ: -180 ~ 180 [deg] step: 60 [deg] (Data)
step: 45 [deg] (MC)

Chi-2/ndf ≦ 4 chi

$\sigma(800)/S(800) \leqq 1.25$

Good SD ≧ 5

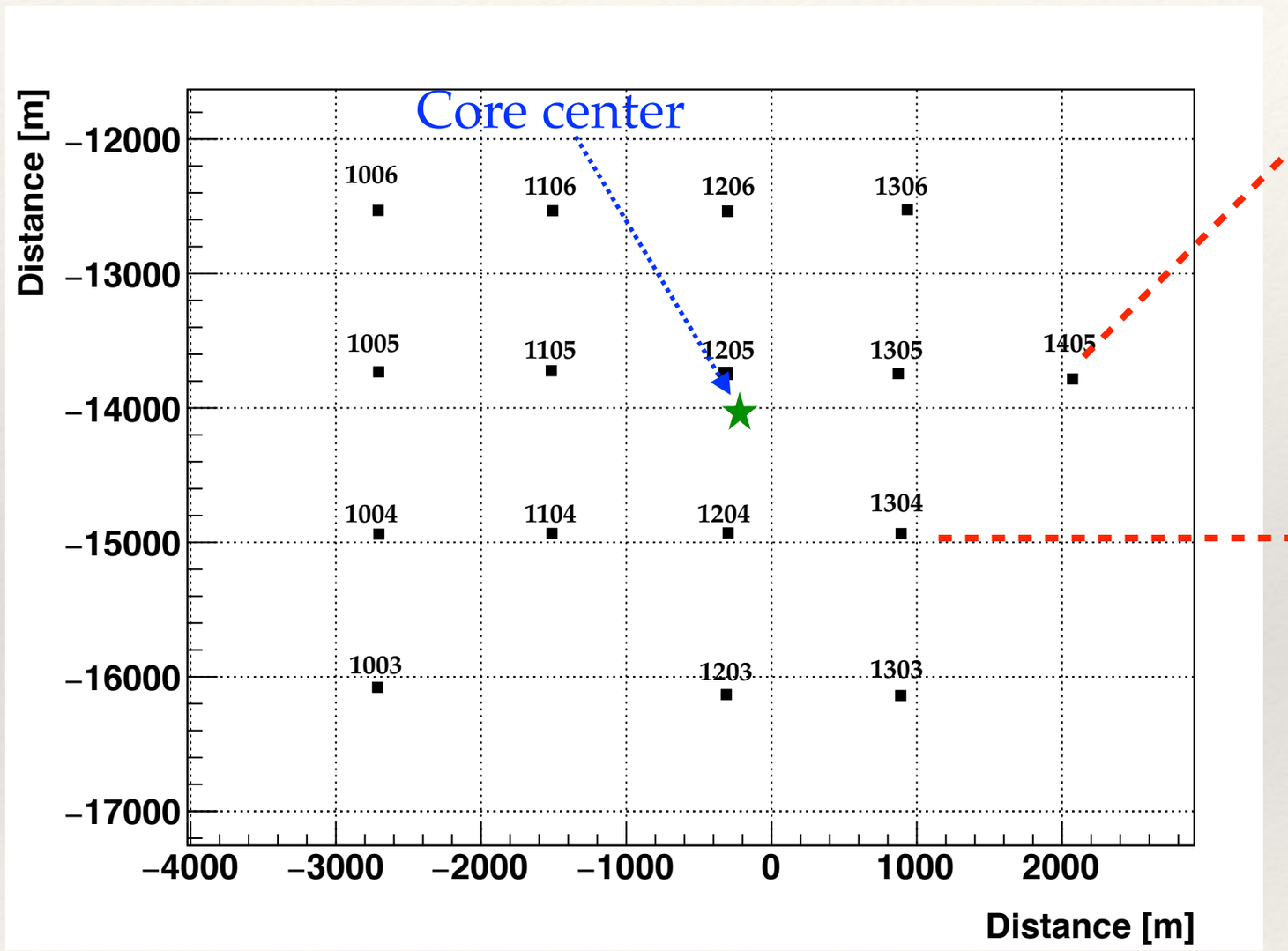
Border Cut: 1,200 m

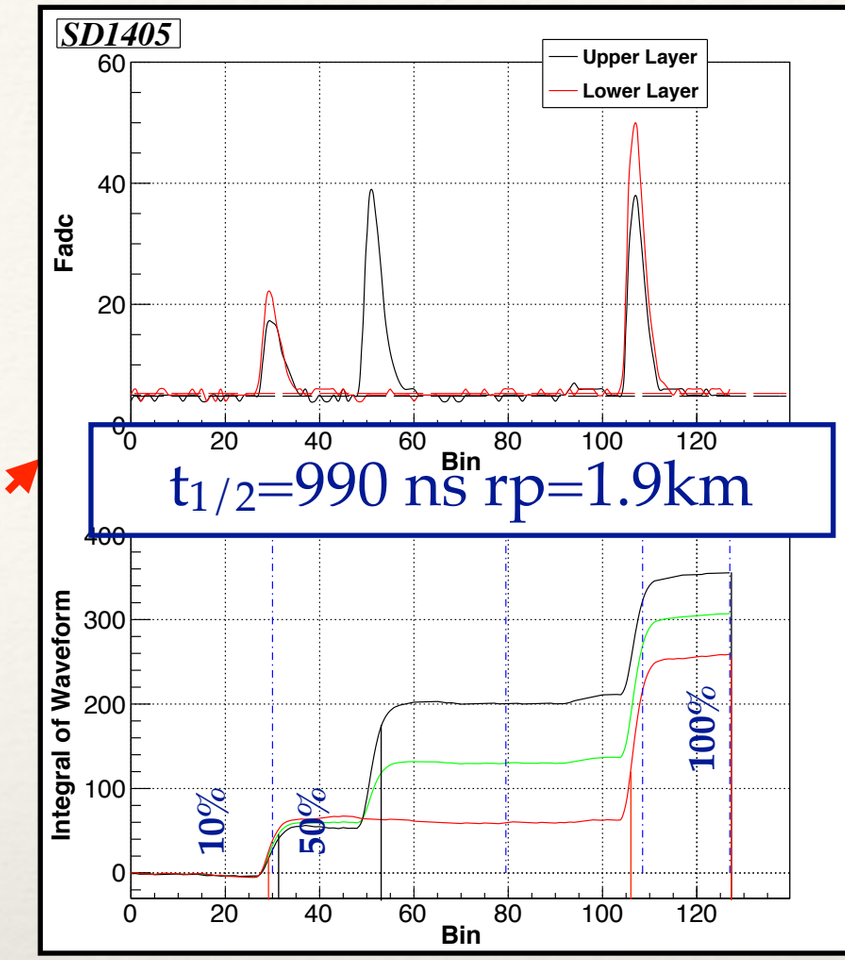
Example of 1 Event

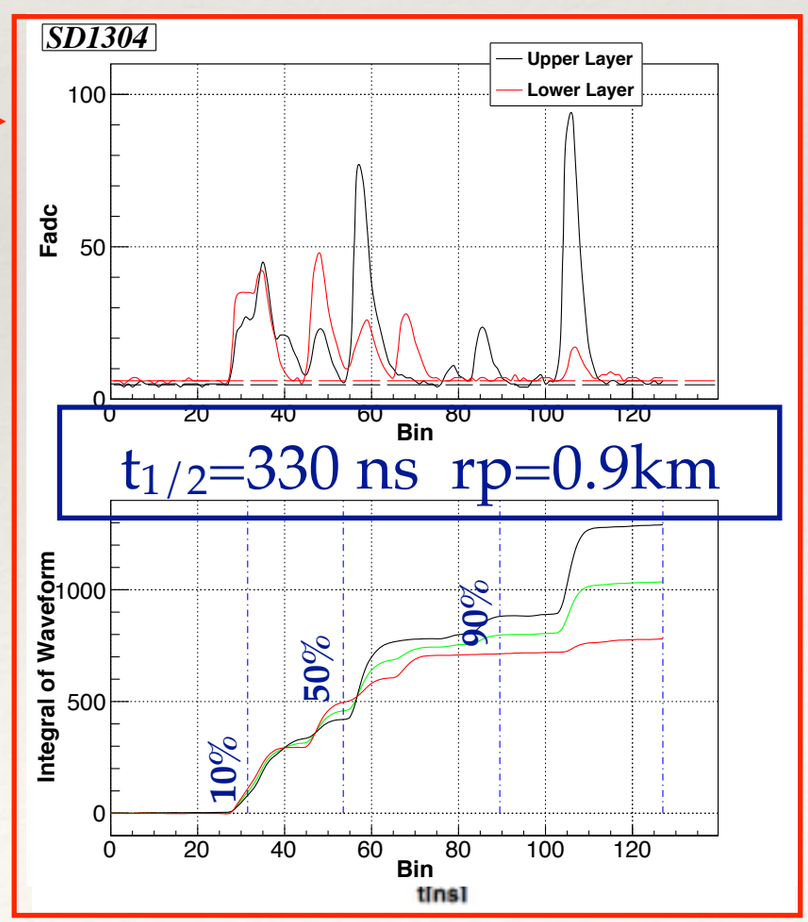
Date: 2008/05/11 Time: 05:54:16:43062

θ: 34.6[deg] φ: 170.6[deg]

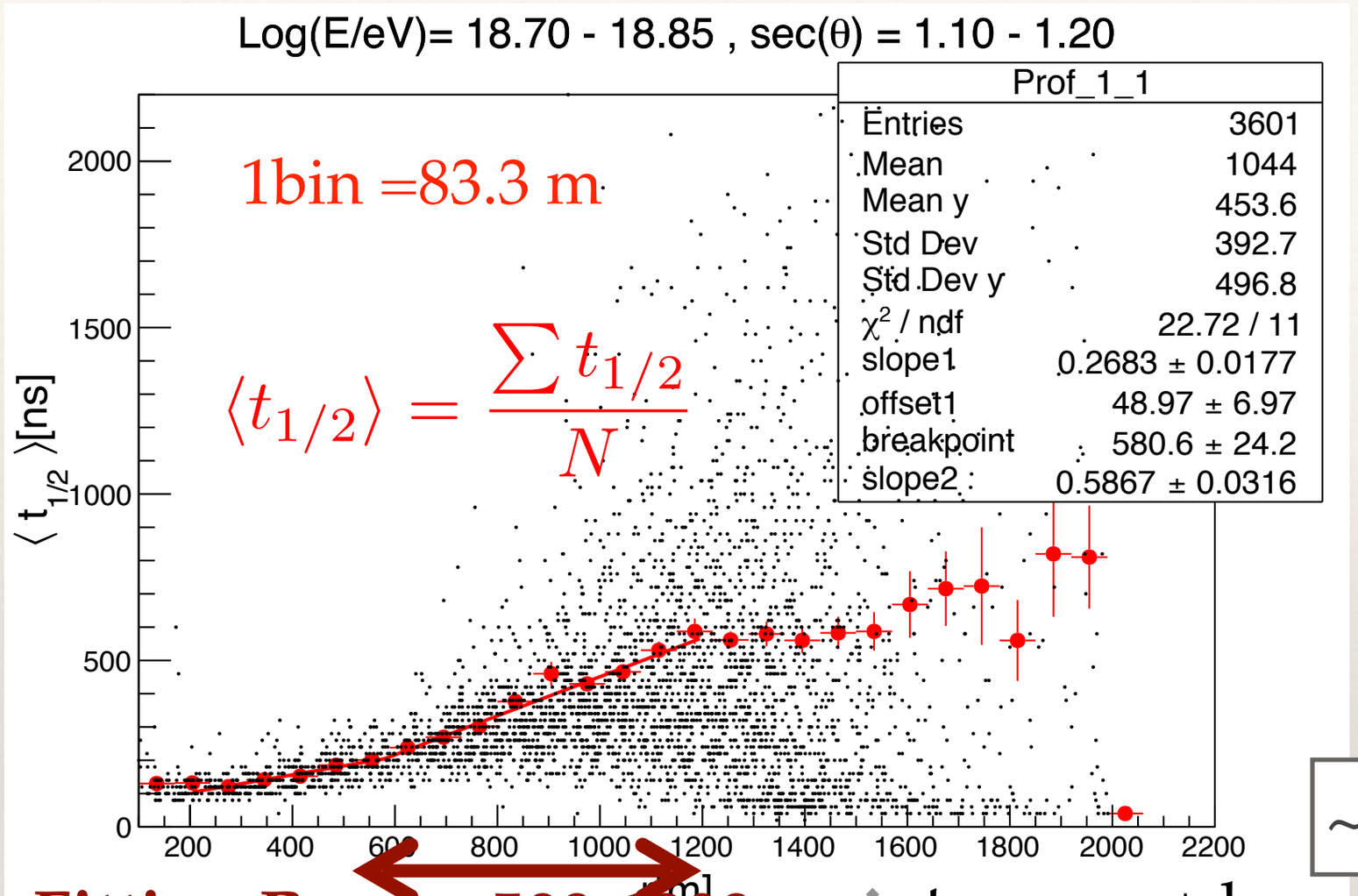
Log(E/eV): 11.1EeV

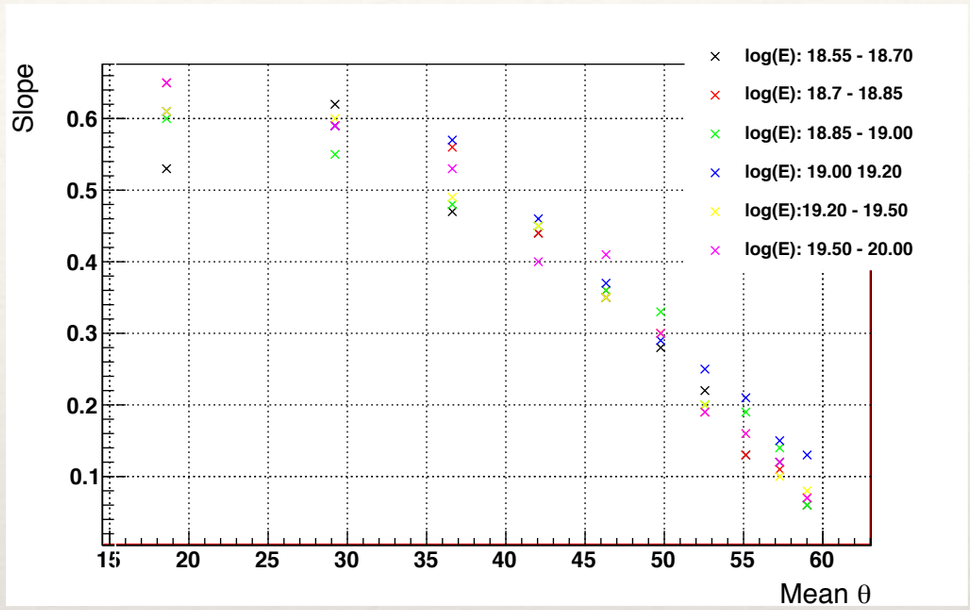






Definition of slope $t_{1/2}/r$



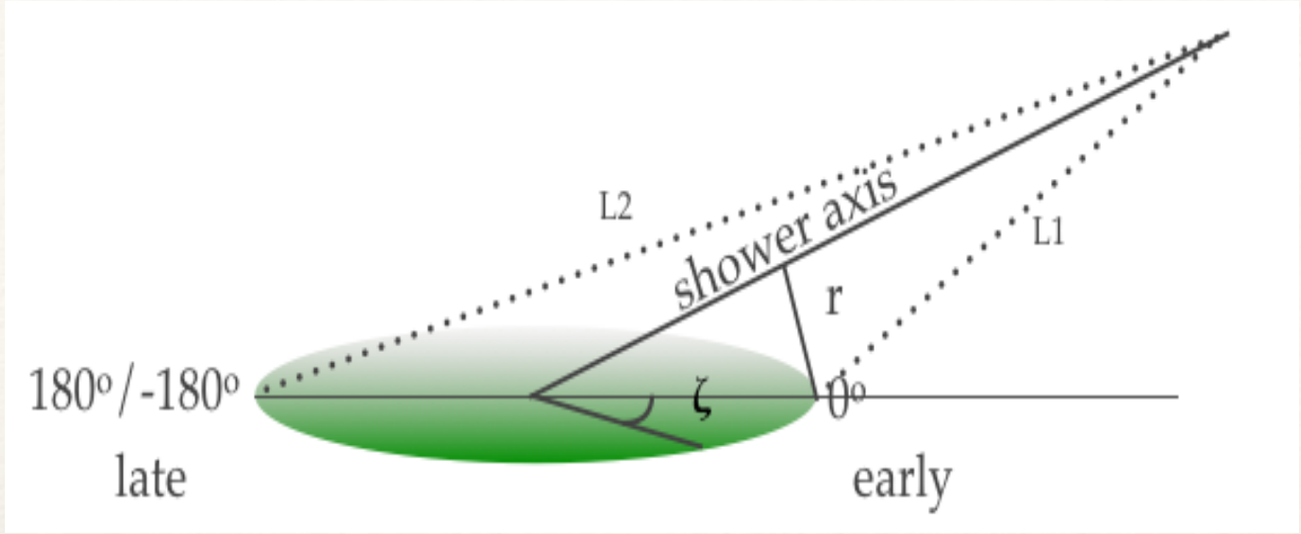


~860 events

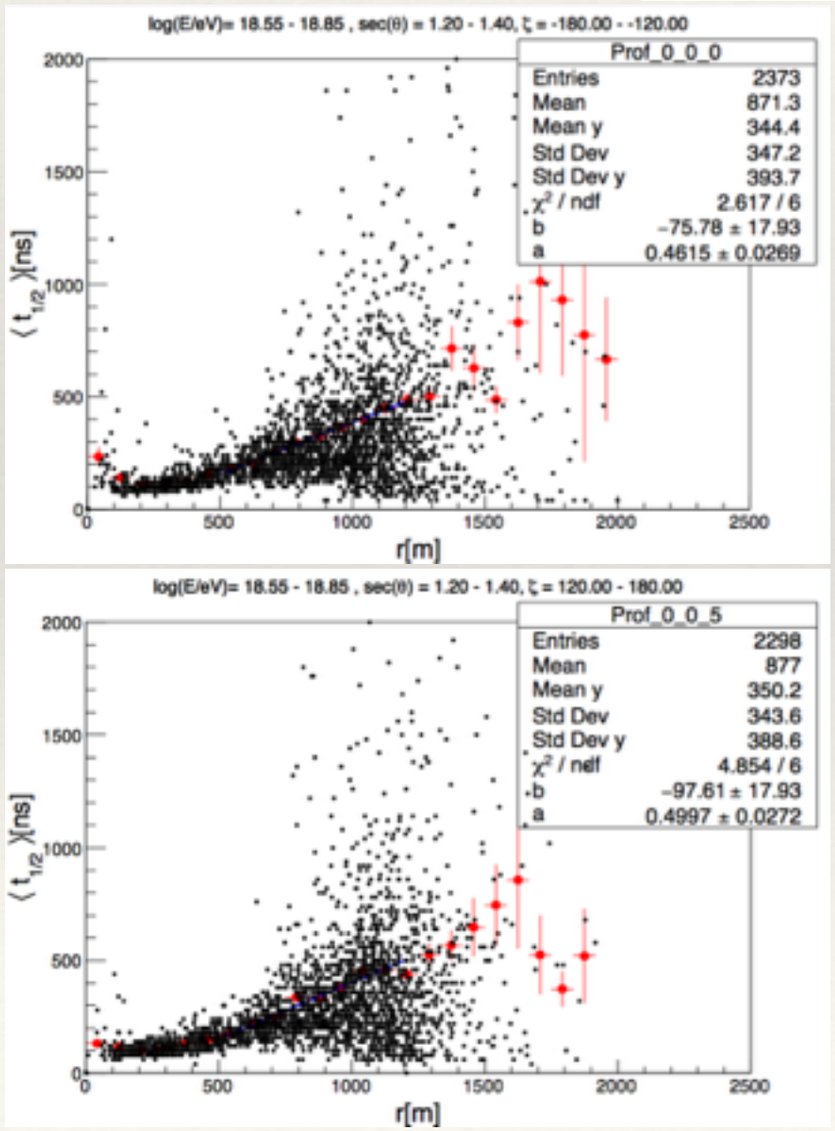
- $t_{1/2} = ar + b$
- Linear fitting 500 ~ 1200 [m]
- Slope is asymmetry parameter that depends on
  - Energy particle, Zenith angle, azimuthal angle, Rp

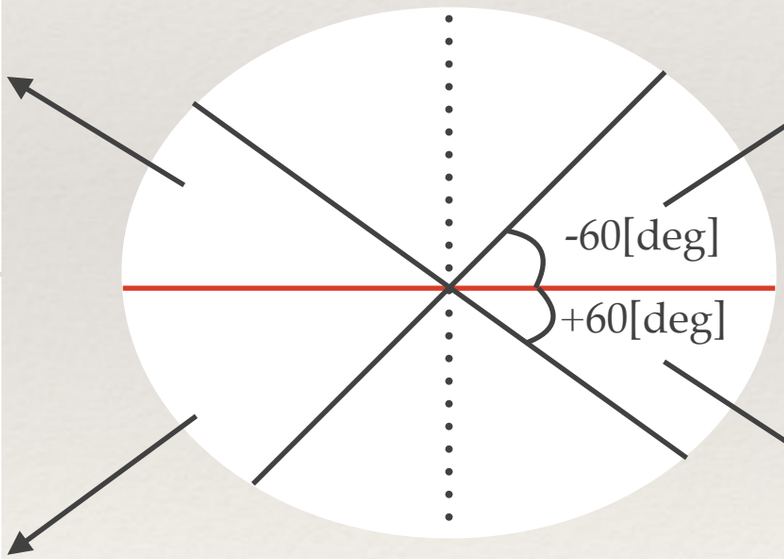
Early and late showers

$a = f(\zeta)$

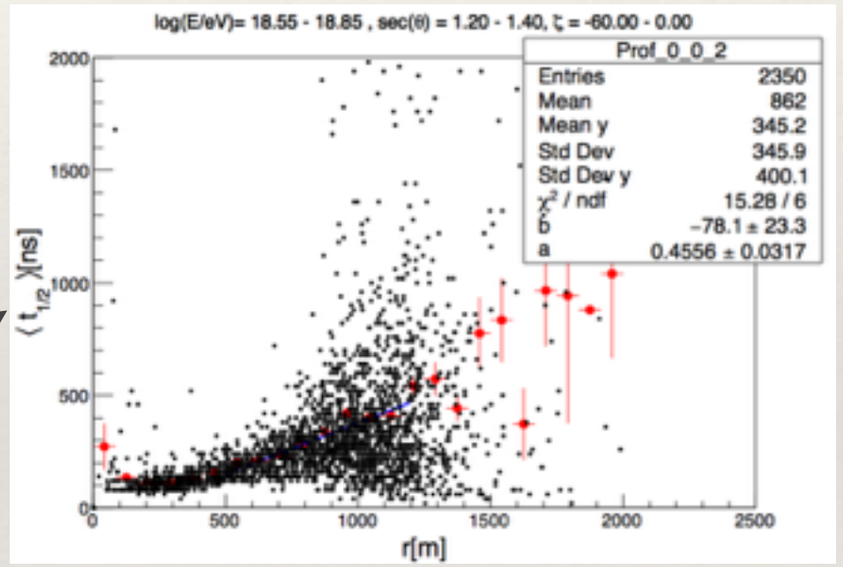


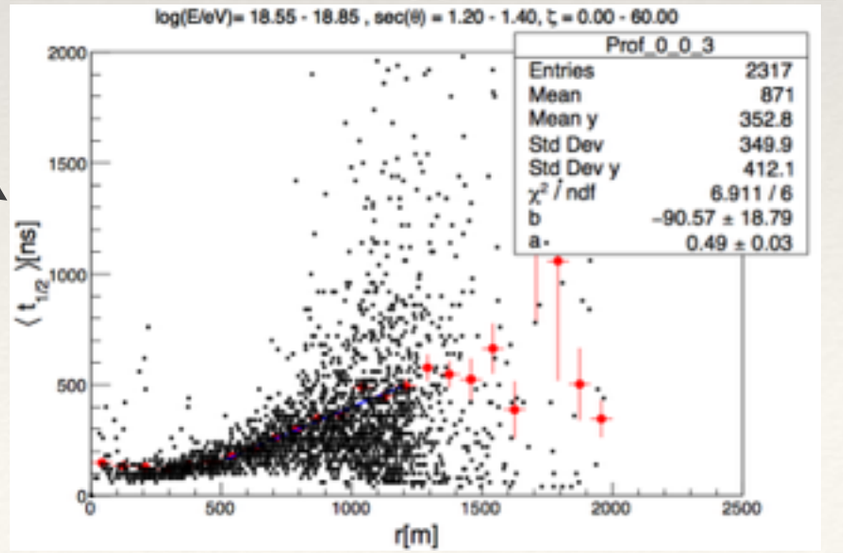
Zeta = 180





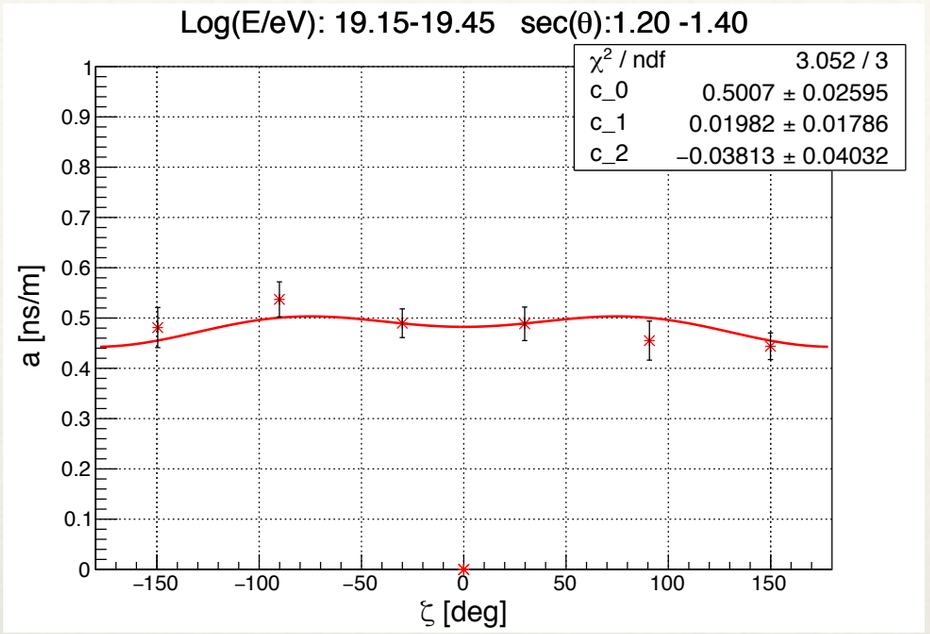
Zeta = 0

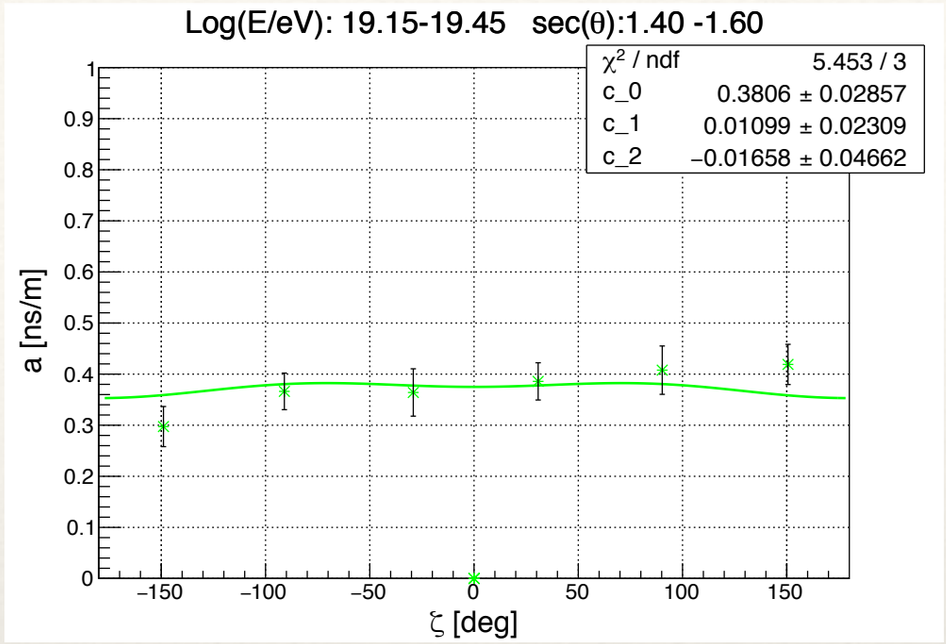


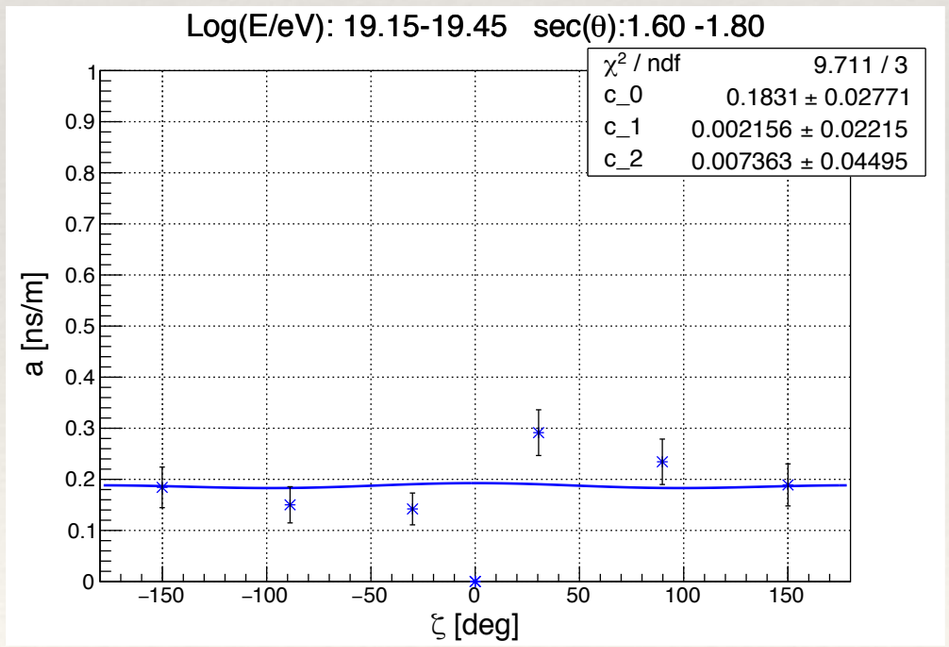


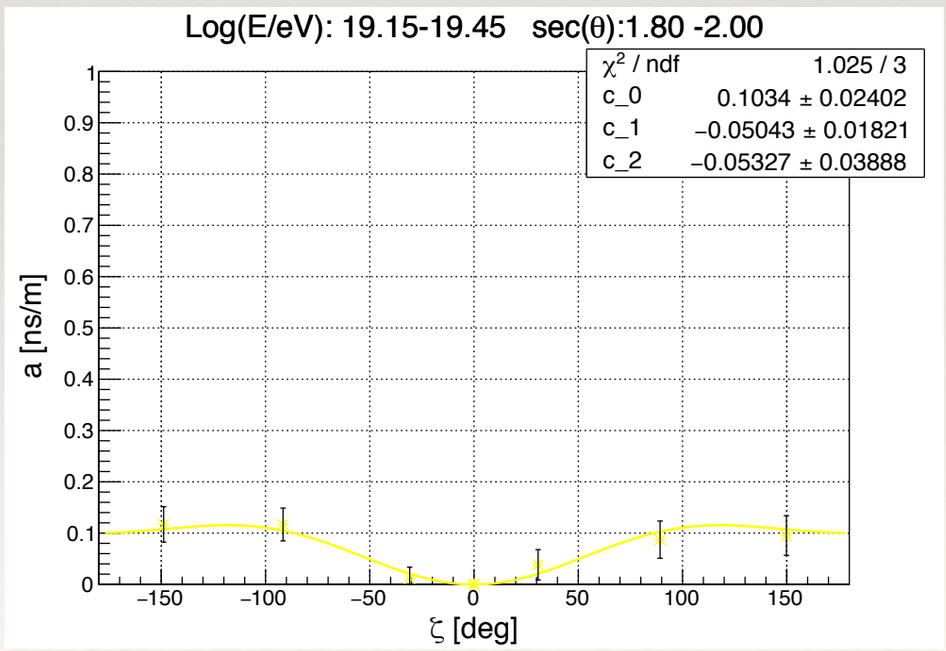
Asymmetry Analysis

$a = f(\zeta)$ $\quad a = c0 + c1^{*}\cos(\zeta) + c2^{*}\cos^{2}(\zeta)$

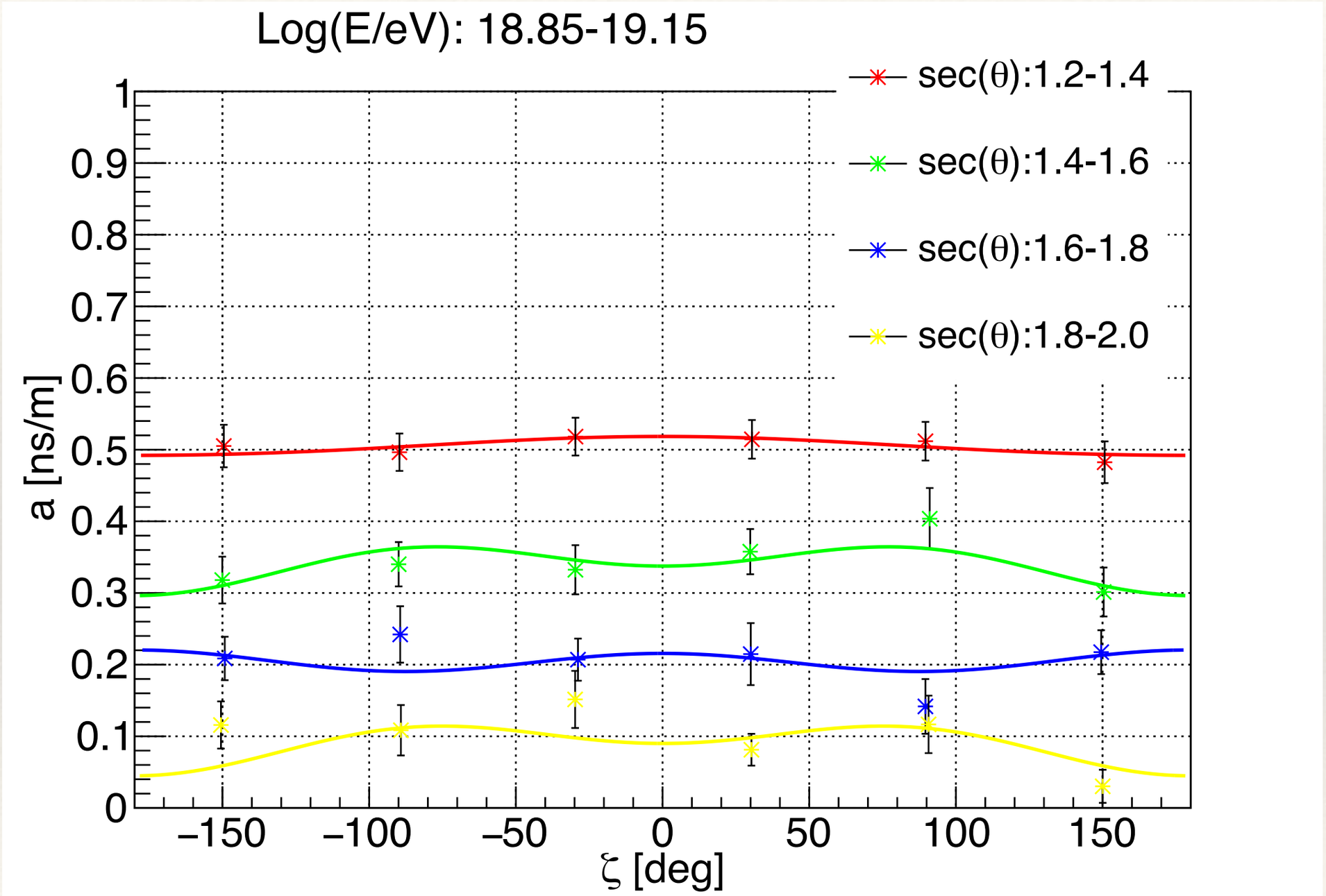








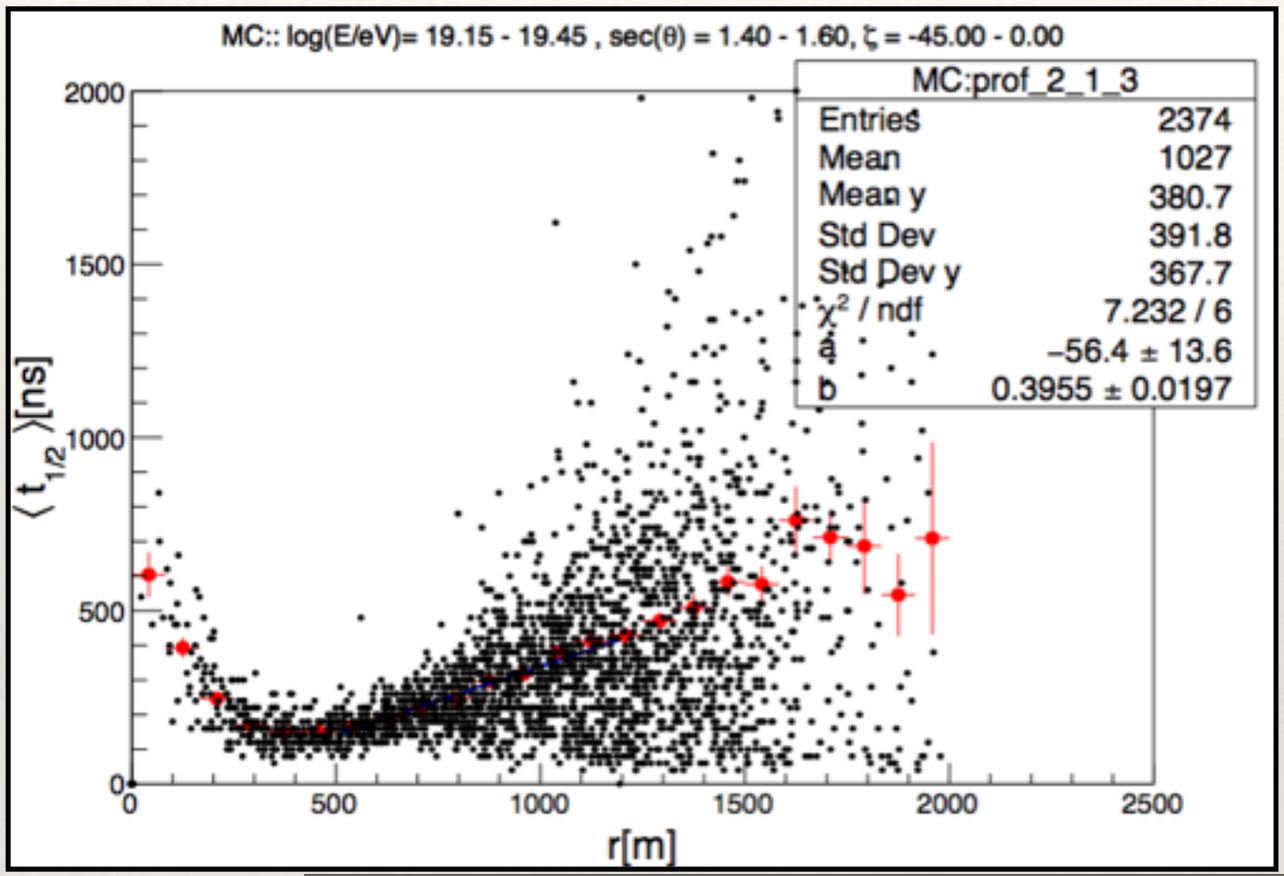
Analysis of SD data



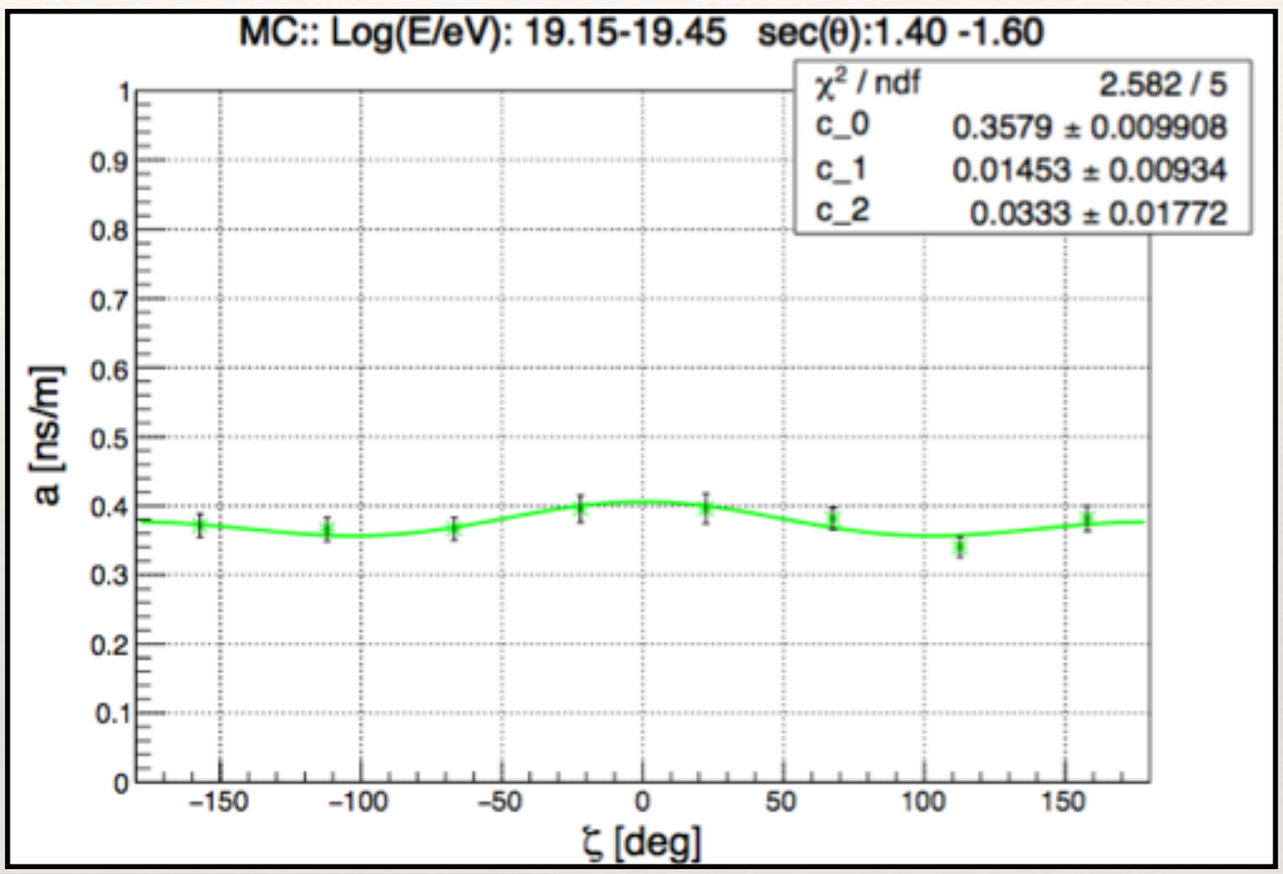
No asymmetry cannot be seen.

Analysis with MC

MC R vs t1/2



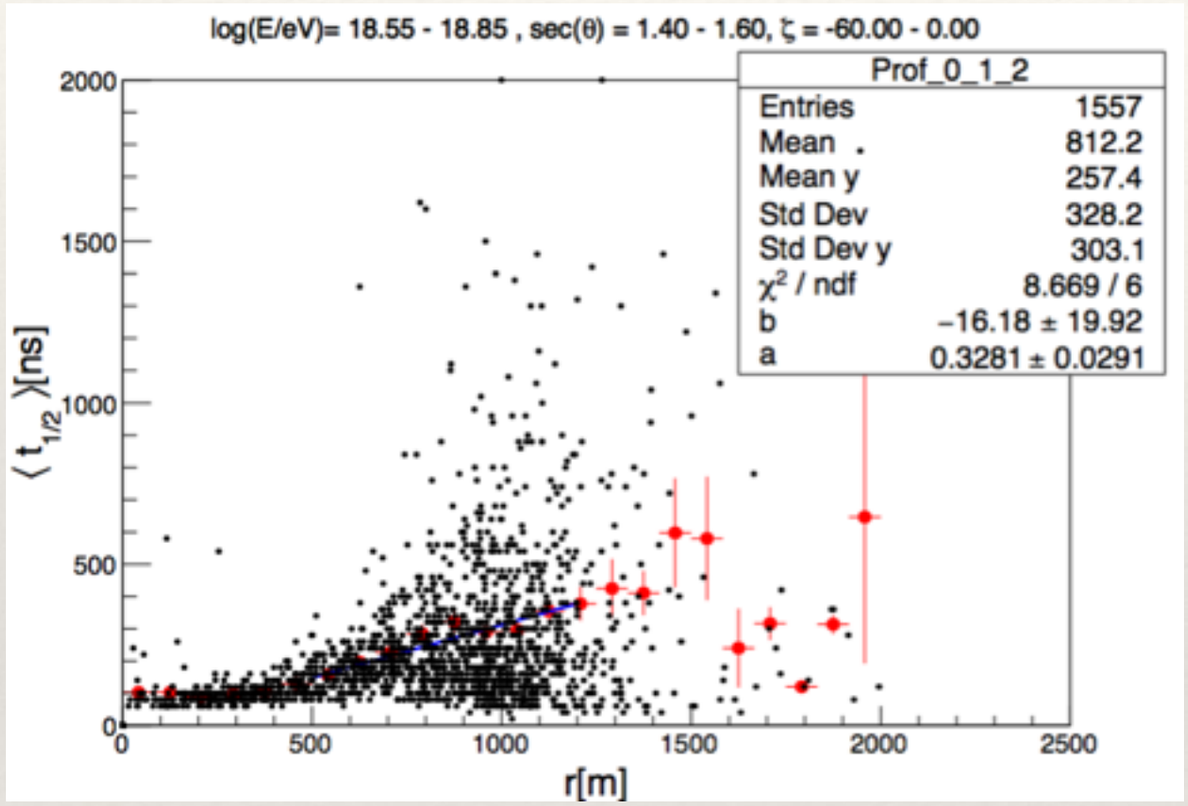
Zeta vs t1/2/R

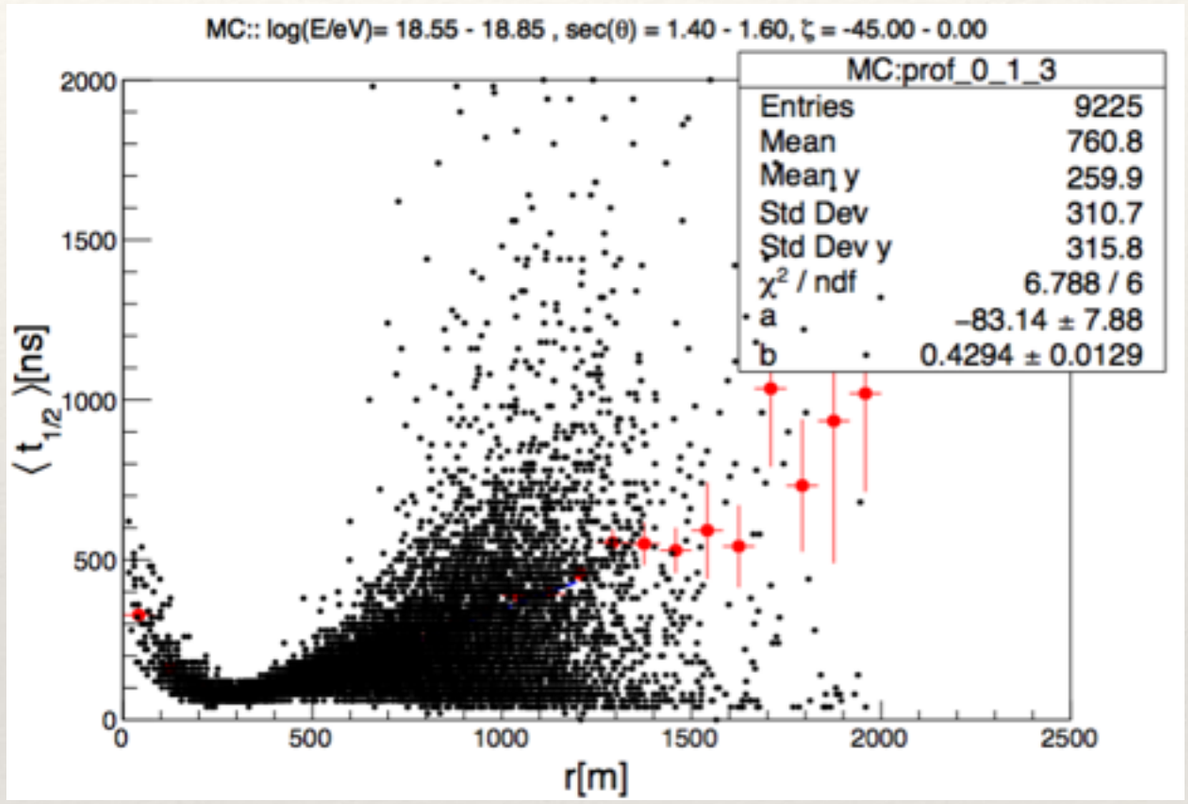


Linear fitting range: r:: 500 ~ 1200 [m]
ENERGY: Log(E/eV): 19.15 - 19.45
ZENITH: 44.42 - 51.32 [deg]

1770 events

Comparison Slope

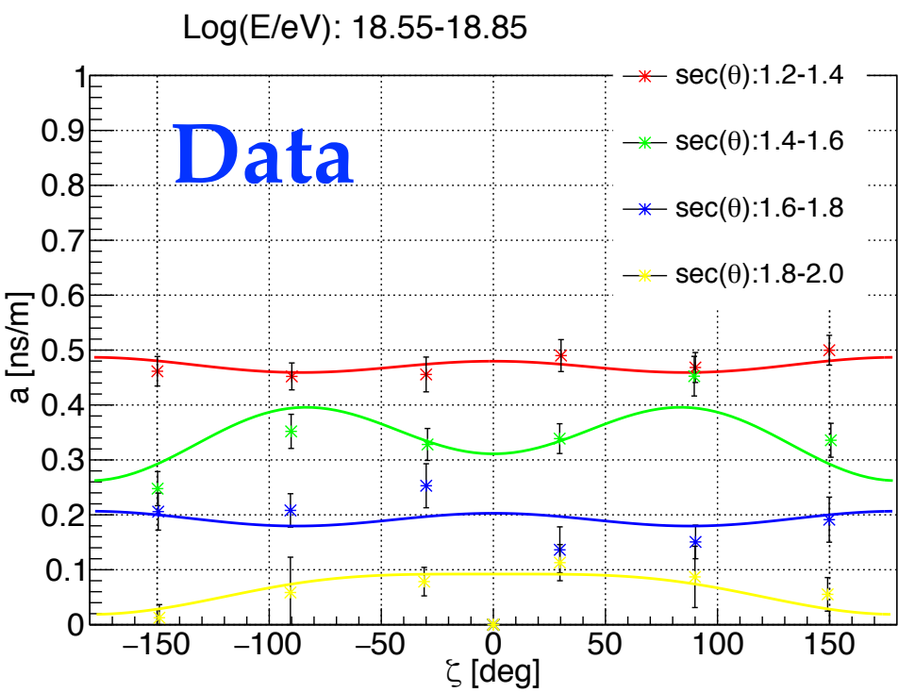


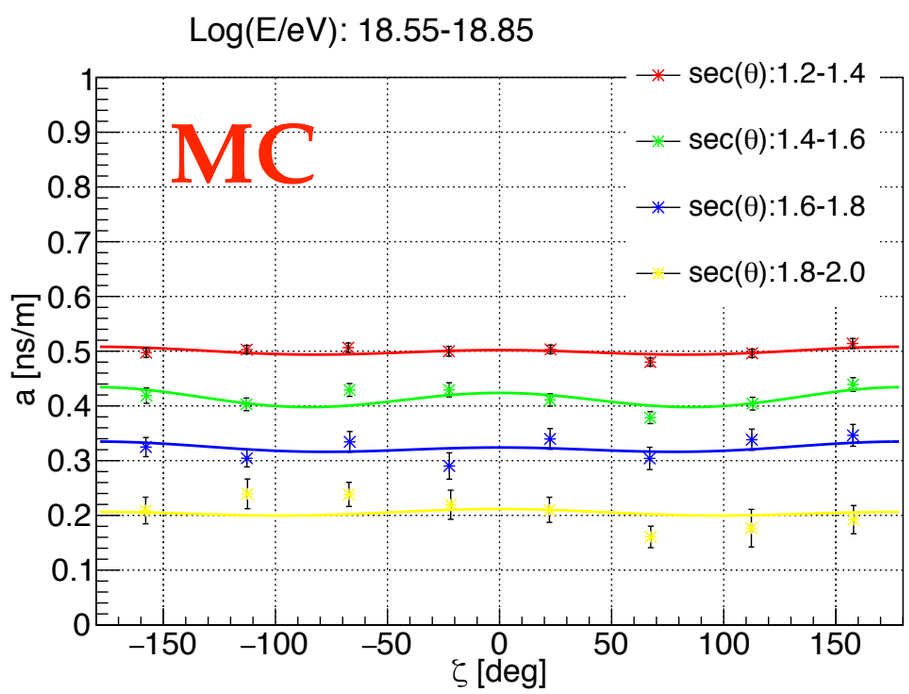


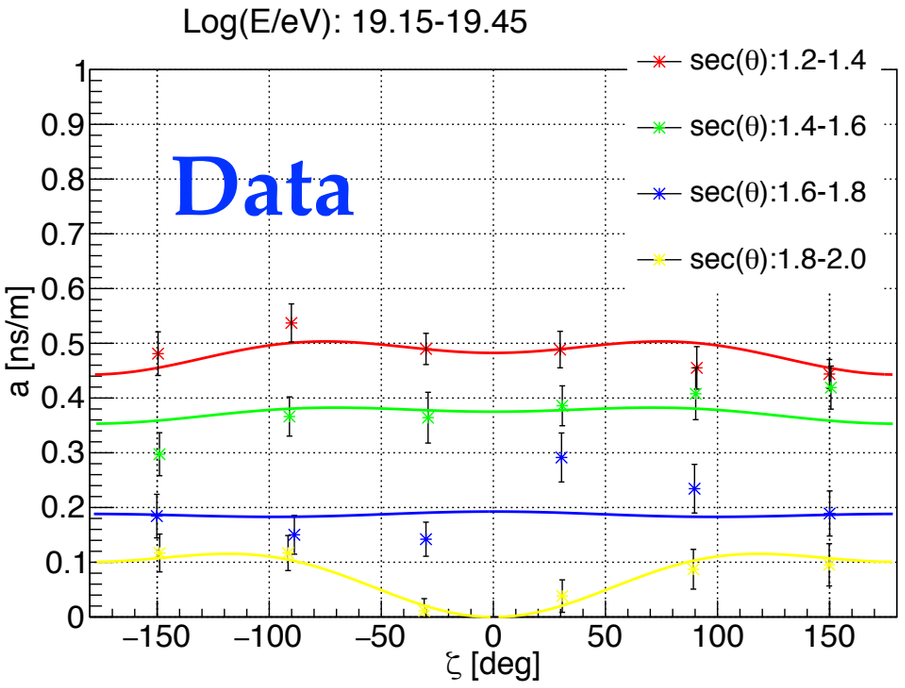
2,193 events

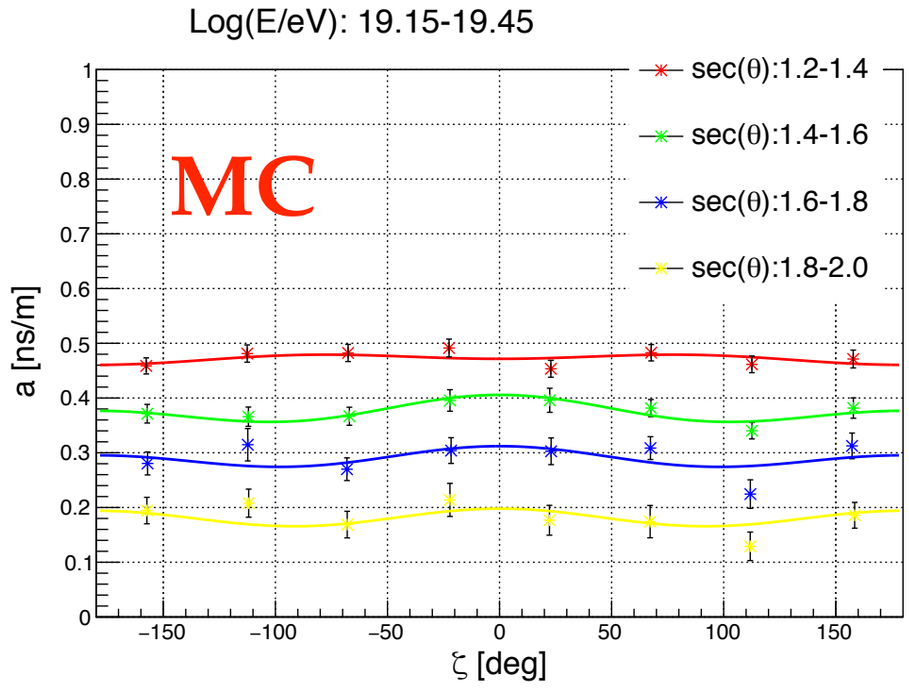
14,561 events

Comparison Asymmetry





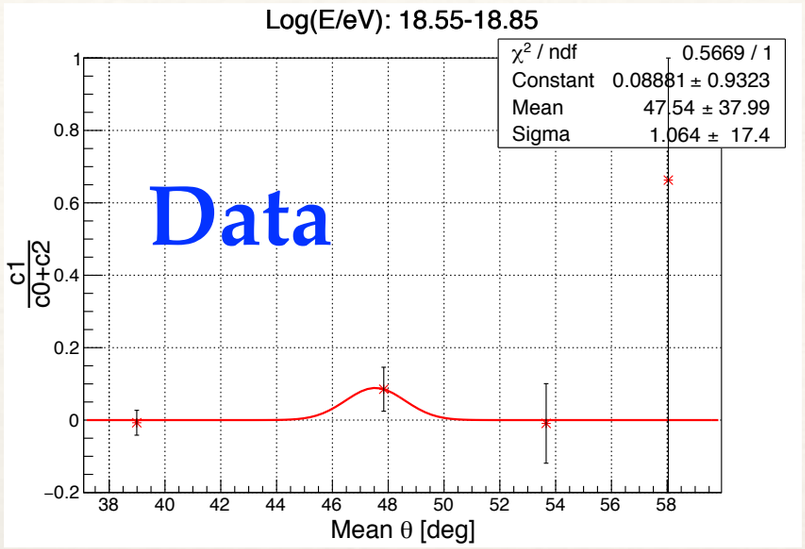


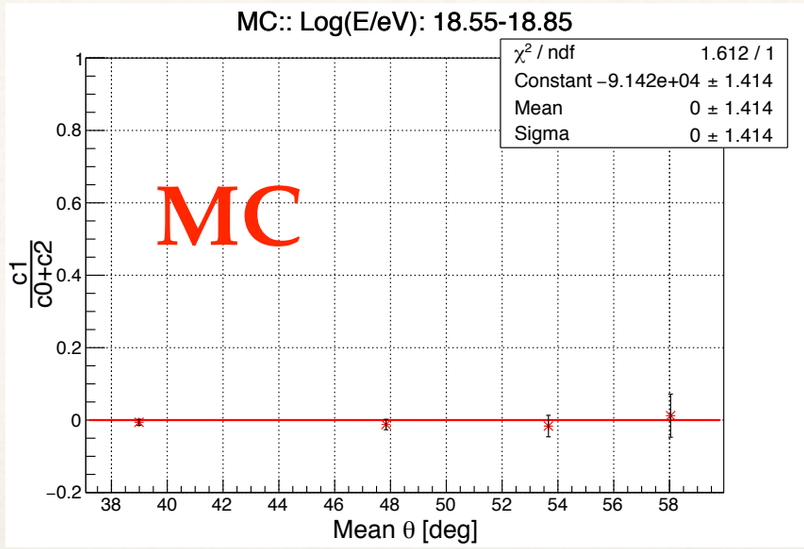


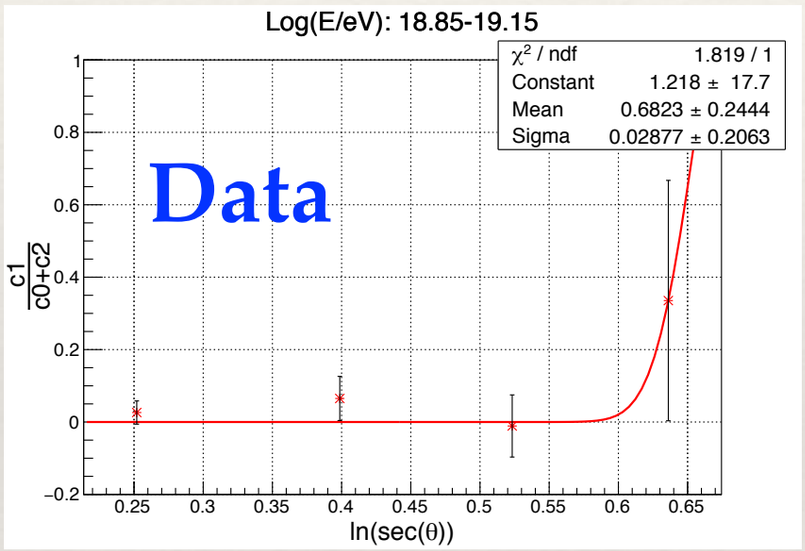
Using MC also, asymmetry cannot be seen.

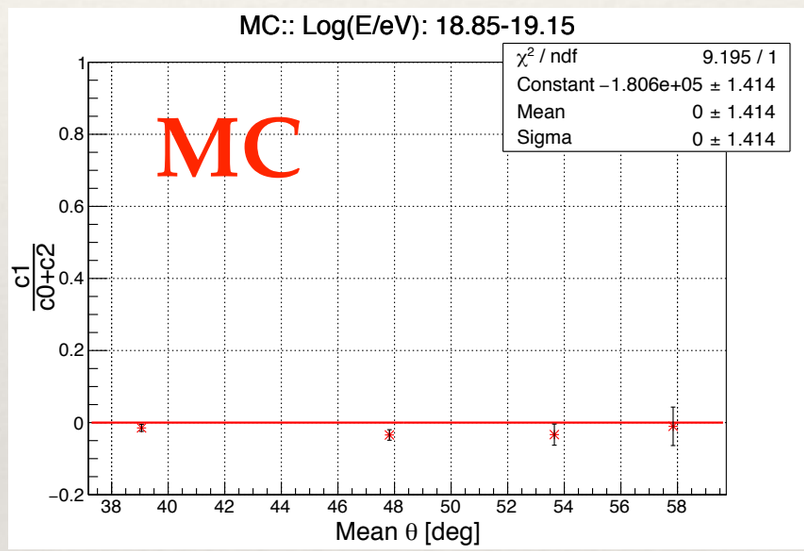
Asymmetry Factor

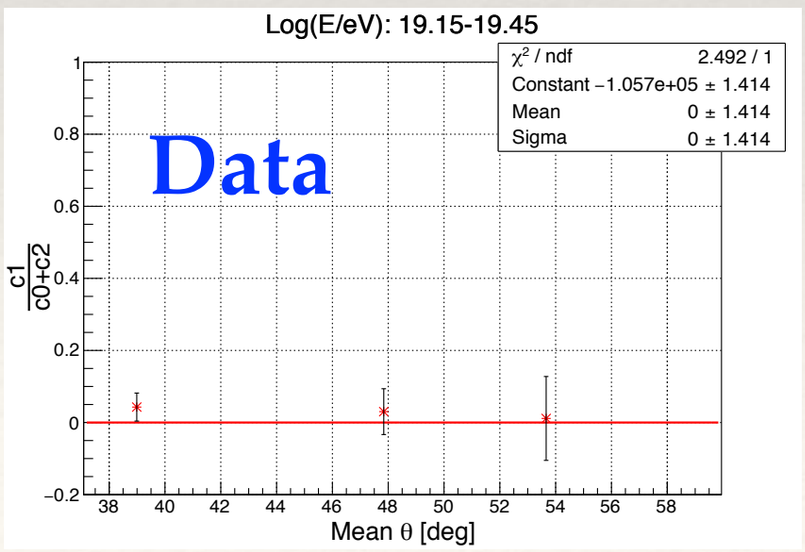
$$a = c0 + c1^{*}\cos(\zeta) + c2^{*}\cos^{2}(\zeta)$$

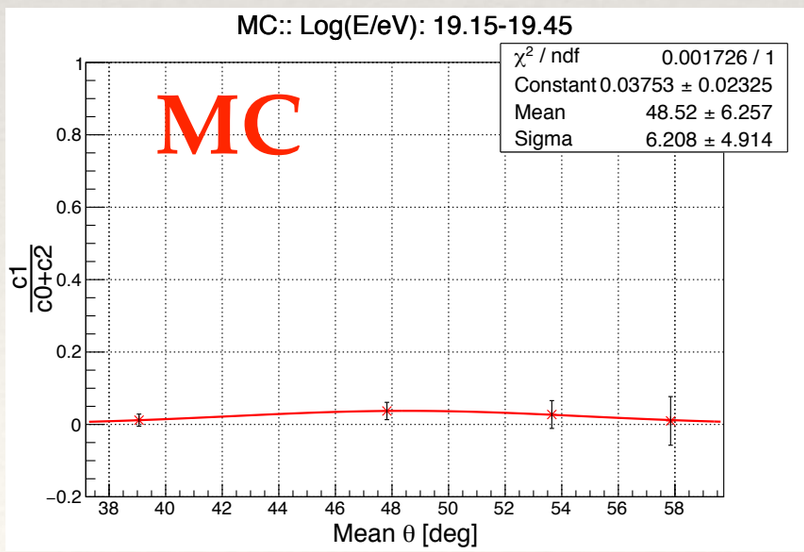






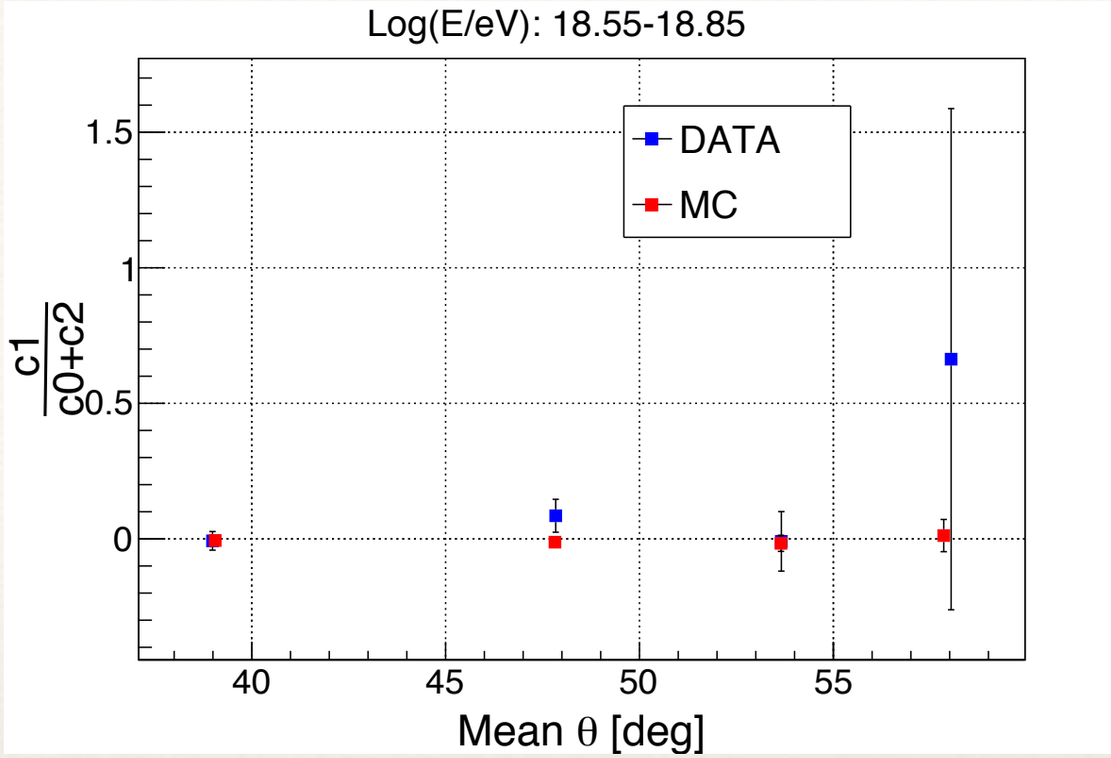


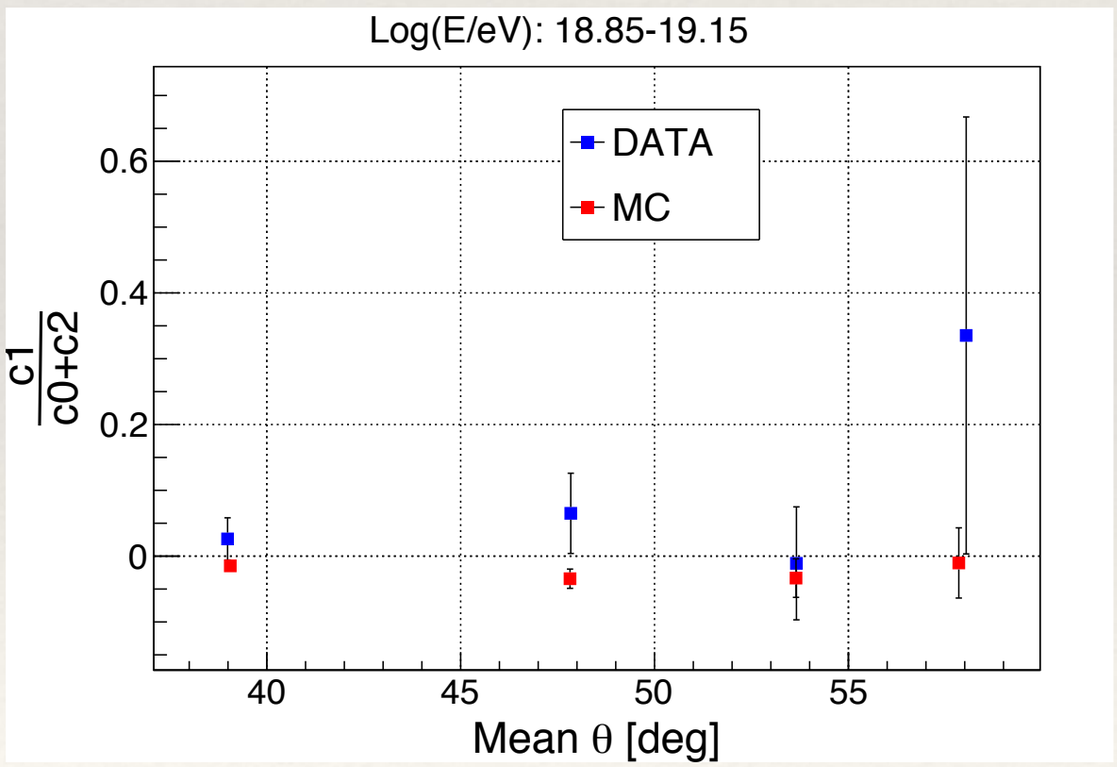


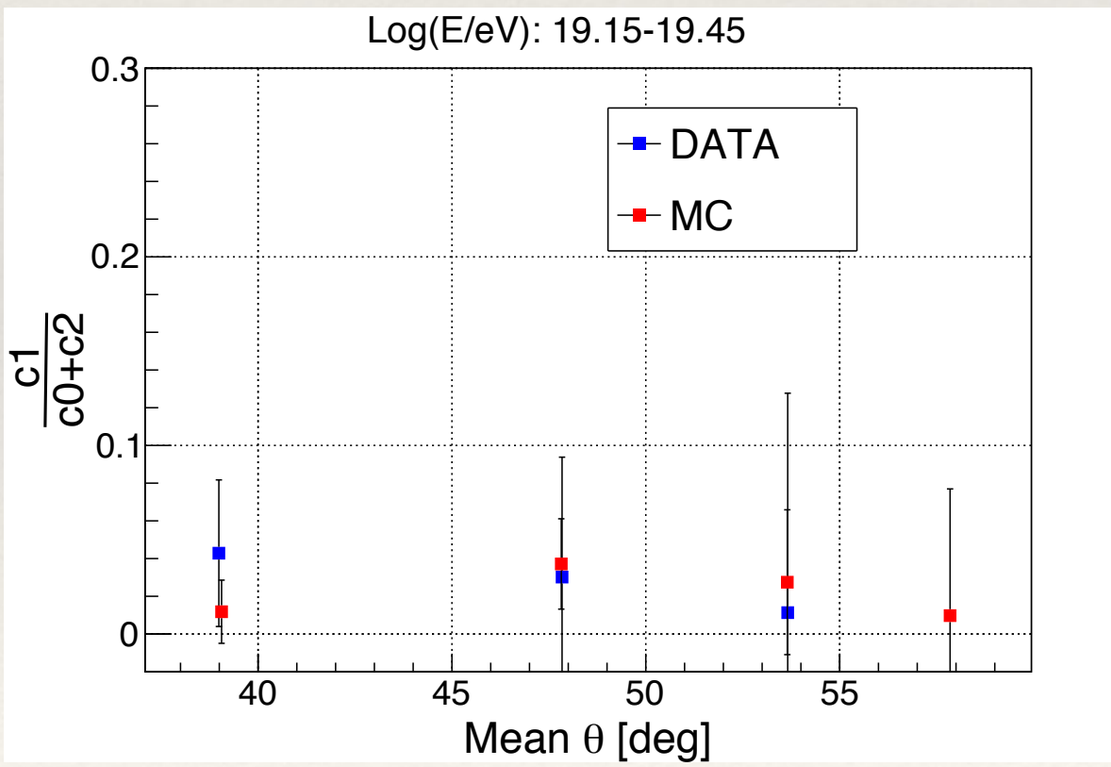


Comparison of Asymmetry Factor

$$a = c0 + c1^{*}\cos(\zeta) + c2^{*}\cos^{2}(\zeta)$$

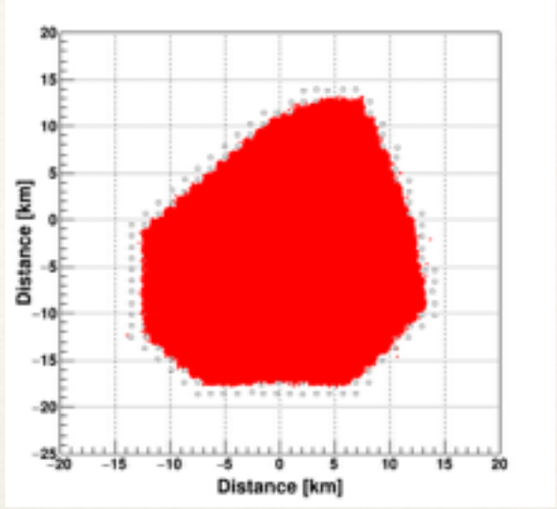




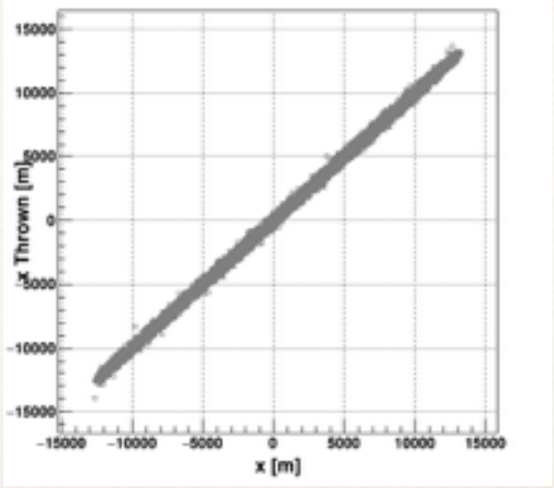


Thrown MC Distribution

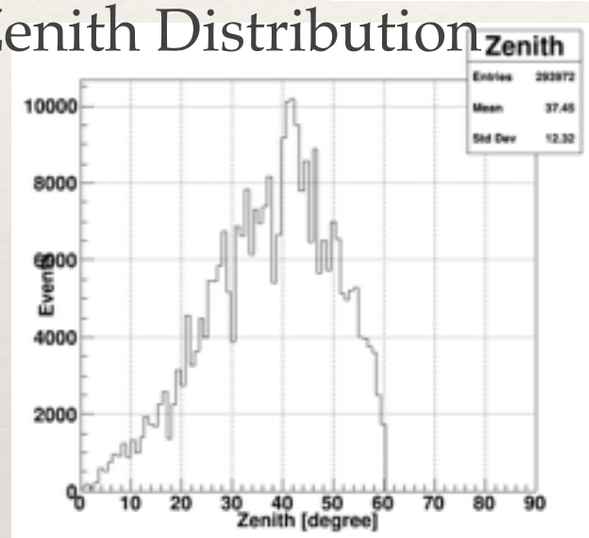
Core Pos. Distribution



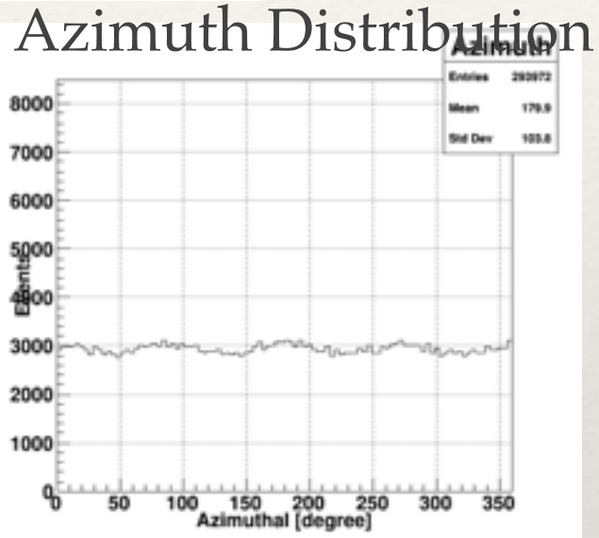
X rec. Vs Xtrue Distribution



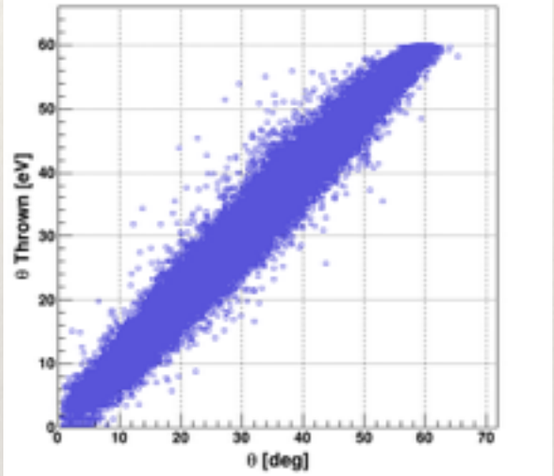
Zenith Distribution



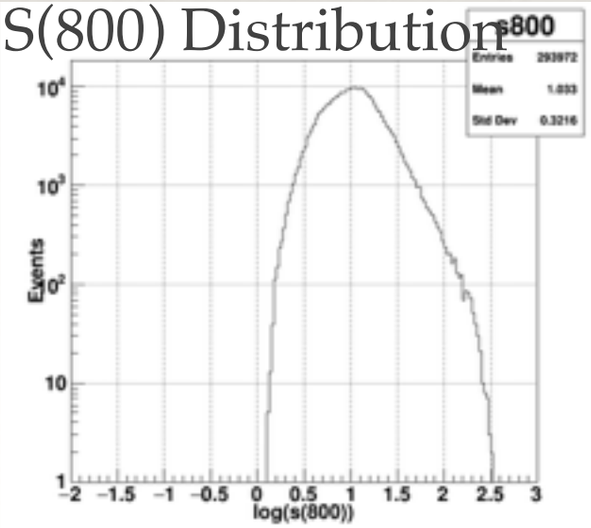
Azimuth Distribution



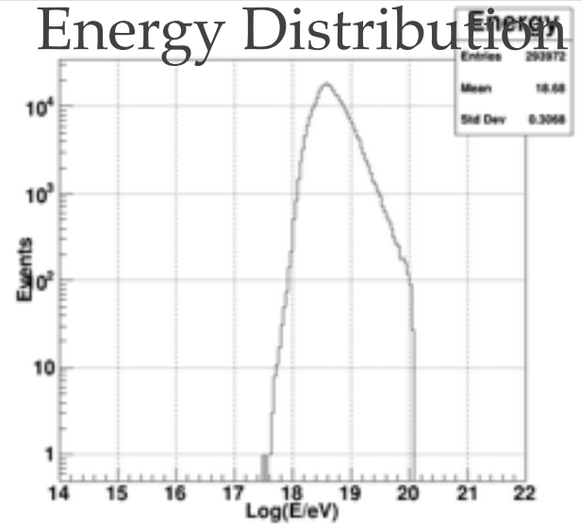
Zenith rec. Vs Zenith true Dist.



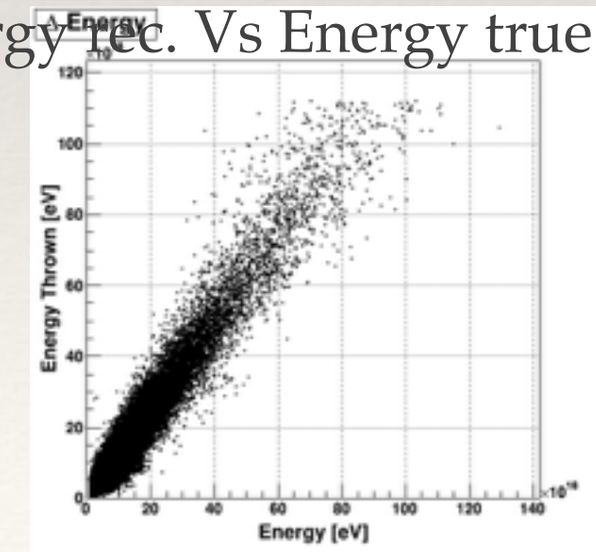
S(800) Distribution



Energy Distribution



Energy rec. Vs Energy true Dist.



Why TA cannot see?

- Detector sensitivity of TA SD is low
- Size of detector
- More studies need to confirm this no asymmetry based on Detector sensitivity.

Summary

- It was analyzed SD data of 9 years (May 11, 2008 - May 11 2017)
  - No asymmetry is can be seen along shower plane
- MC dataset of 6 years was used to confirm this symmetry of shower plane by TA SD.
  - Confirm not be observe asymmetry in shower $10^{18.55}$ - $10^{19.45}$eV
- Analyze MC dataset higher than 10^{20}eV