EUSO-TA

A pathfinder to a next generation cosmic ray observatory

HEUNGSU SHIN

1st workshop on YMAP
20161031

Index
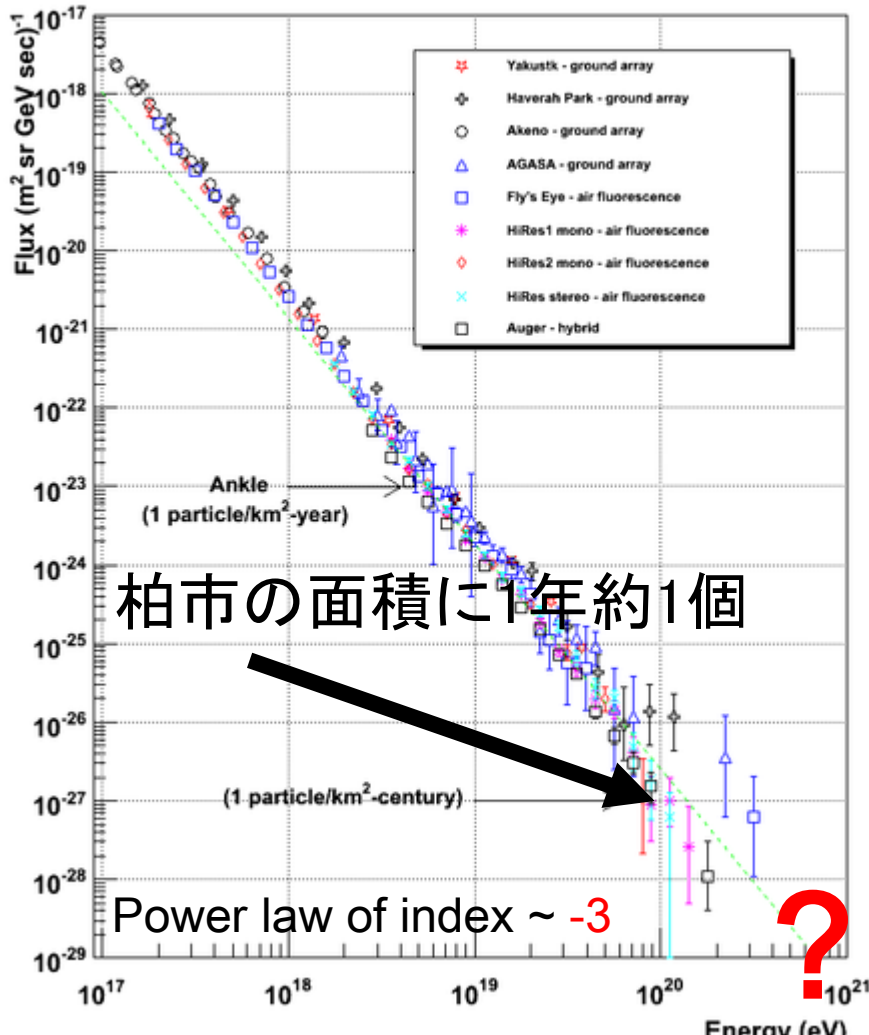
1. Introduction to EUSO-TA

2. Current status and Early result

3. Summary and Future works

Motivation

巨大（面積的に）科学が必要

Telescope Array Project
Utah, USA
~700km^2(琵琶湖ほど)

Energy spectra of Cosmic ray

Cosmic Ray Spectra of Various Experiments

柏市の面積に1年約1個

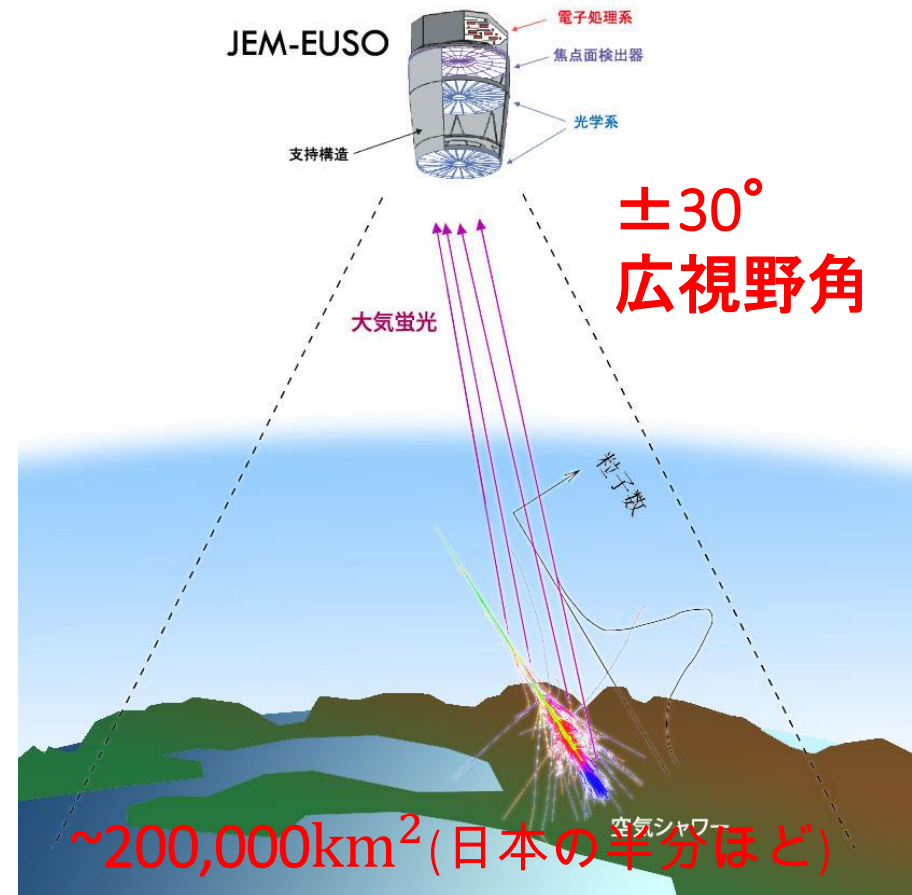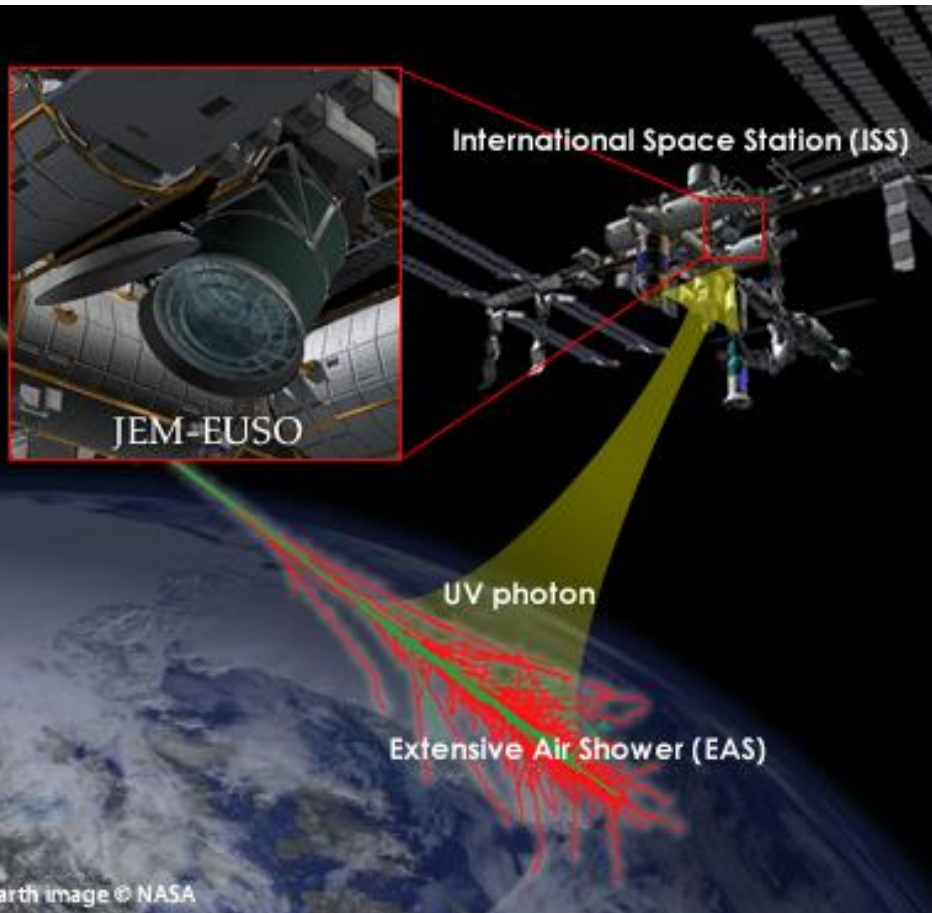Power law of index ~ -3 **?**
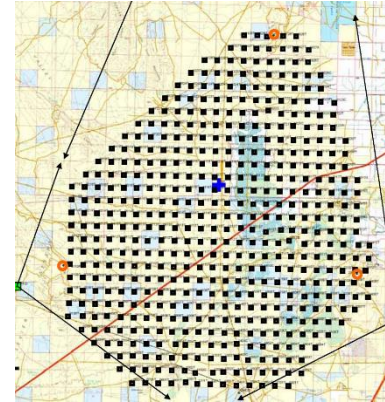
Pierre Auger Observatory
Mendoza, Argentine
~3000km^2(ルクセンブルクほど)

3
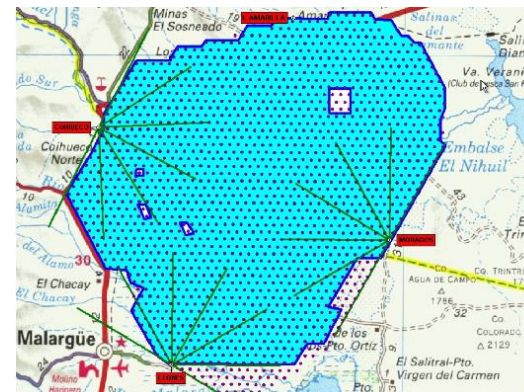
Motivation

Observing Extensive Air Shower from Space!:
Extreme Universe Space Observatory

±30°
広視野角

~200,000km^2(日本の半分ほど)

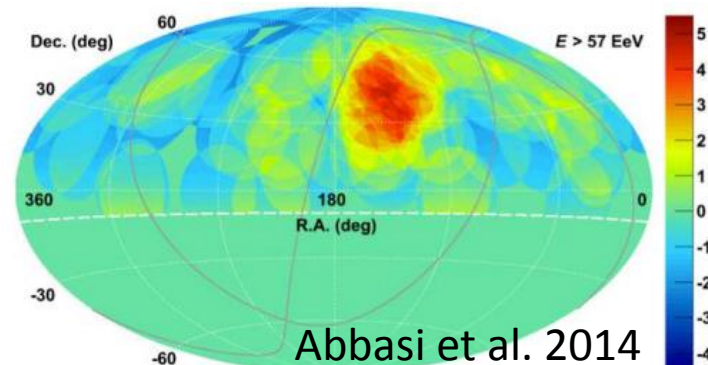# Motivation

Scientific Goals

- **UHECRの点源決定、同一線源からのMulti-events観測によるSpectrum of individual sourceの測定**
  →観測5年間で1000個以上と期待されるUHECR event dataを用いて線源を決定
  →線源における加速機構の情報取得

P. Gorodetzky 2012
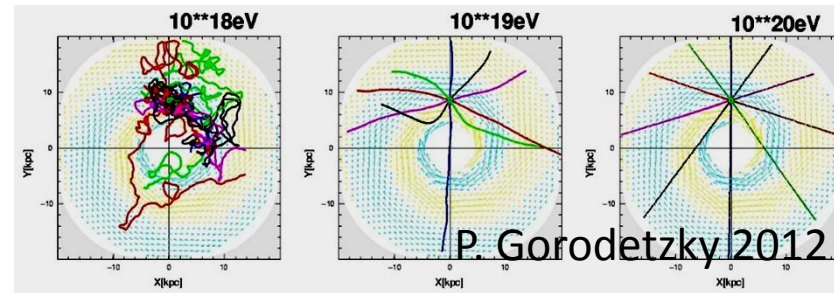
- **UHECRの全天異方性の探索**

  →TAやPAOはそれぞれ北と南半球に位置するため、全天観測ができない
  →ISSは傾斜角51.6°の軌道に乗っているため、EUSOは全天観測が可能
  →TAで報告されている異方性の兆候を確認することが期待される

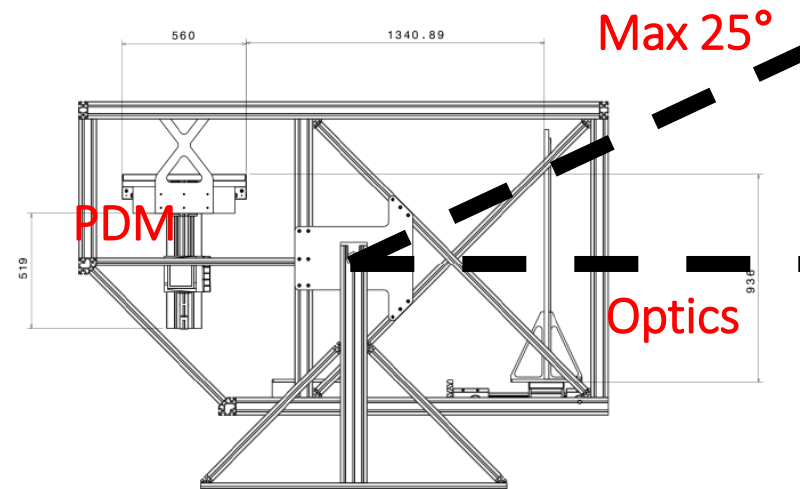Abbasi et al. 2014

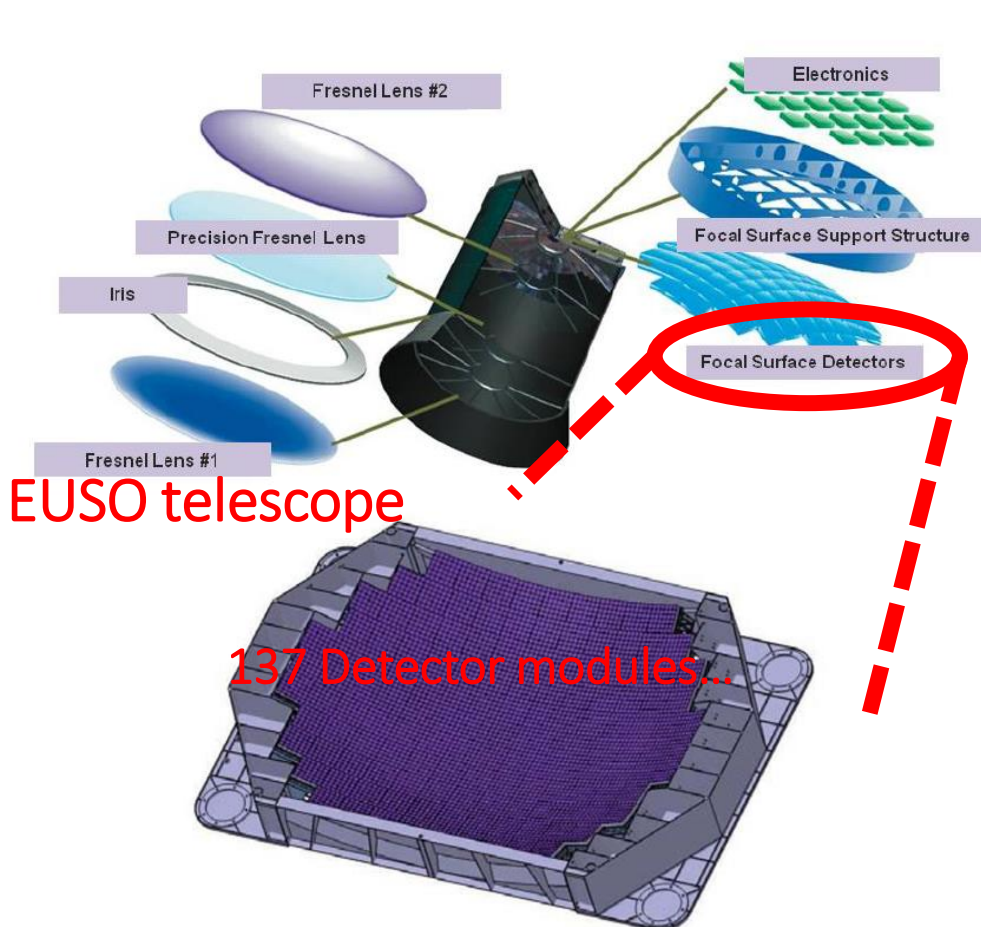- **ほかUltra High Energy Neutrino eventの観測など**

Introduction

EUSO-TA:

A pathfinder for JEM-EUSO, collaboration with TA (There are many others!!!)
目的：JEM-EUSO望遠鏡の技術実証プロトタイプ
　　　　Simplified opticsとDetectorの最小単位1つをTA projectの現場に設置

EUSO telescope

137 Detector modules...

Max 25°

PDM

Optics

1 Detector module
2304pixels

Introduction

Black Rock Mesa FD station
FOV : ±8° (1 camera)

EUSO-TA
Telescope

External
trigger

TAFD Camera6-7 FOV

25°

15°

10°

FOV : ±5.3°
Pointing Azimuth : 305°
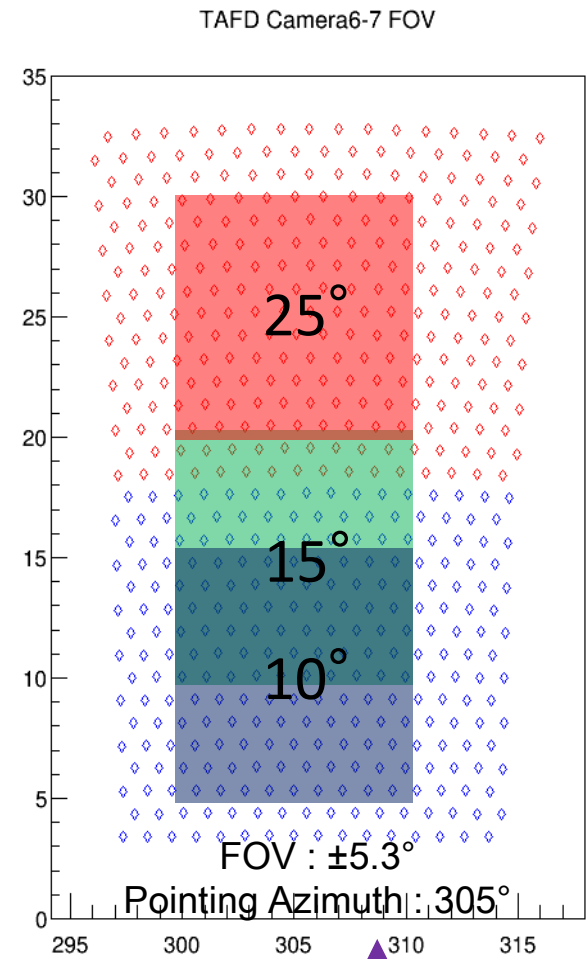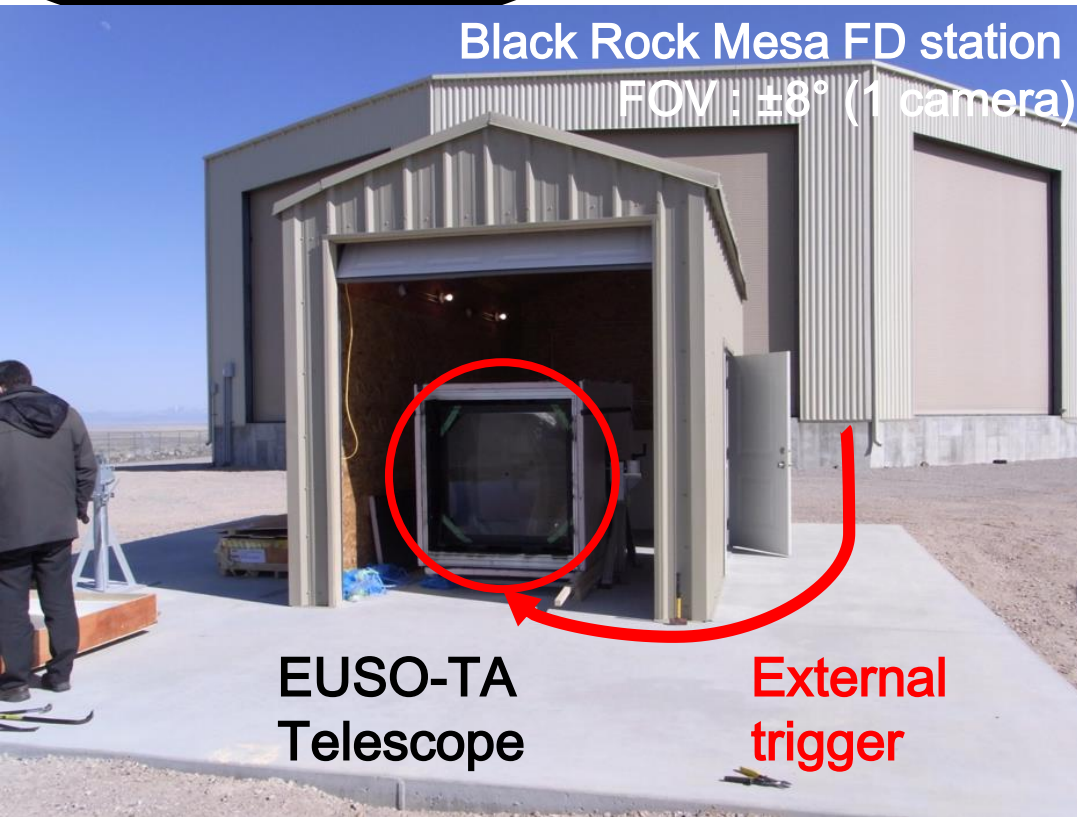
TAFD Telescope (1 camera)
FADC
100ns time bin

EUSO-TA Telescope
Photoelectron counting
2500ns time bin

~10m

TA UV LASER

EAS
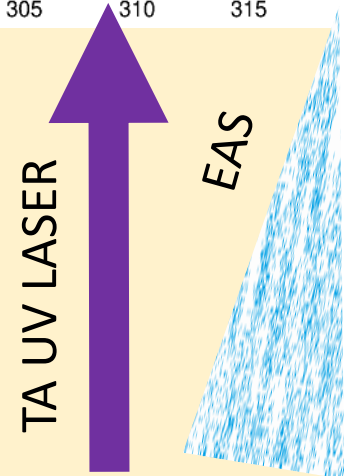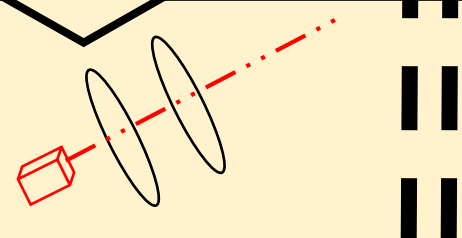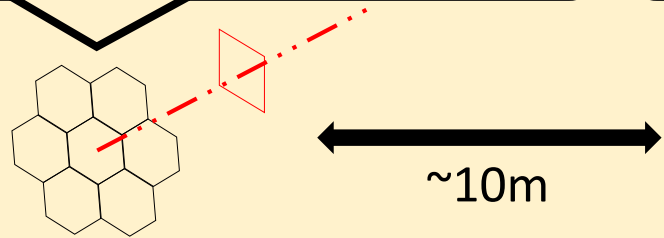
Status

Feb 2015   : First light!
May, Sep, Oct, Nov 2015 : Continuous observation
Sep 2016   : Most recent observation

EUSO-TA has observed…

Flat light board using UV LED for calibration
Portable UV laser with various distance reaching 100km (GPS trigger)
TA's vertical UV laser (CLF) 21km away from the station (TA trigger)
Cosmic ray air shower candidates (TA trigger)

Result (CLF)

Central Laser Facility

I. Placed at the center of Telescope Array observatory
II. 355nm Nd:YAG pulsed laser (Pulse width <10ns)
III. Single laser set consists of 300 shots, 10Hz
IV. Twice in an hour, (hh:00, hh:30)
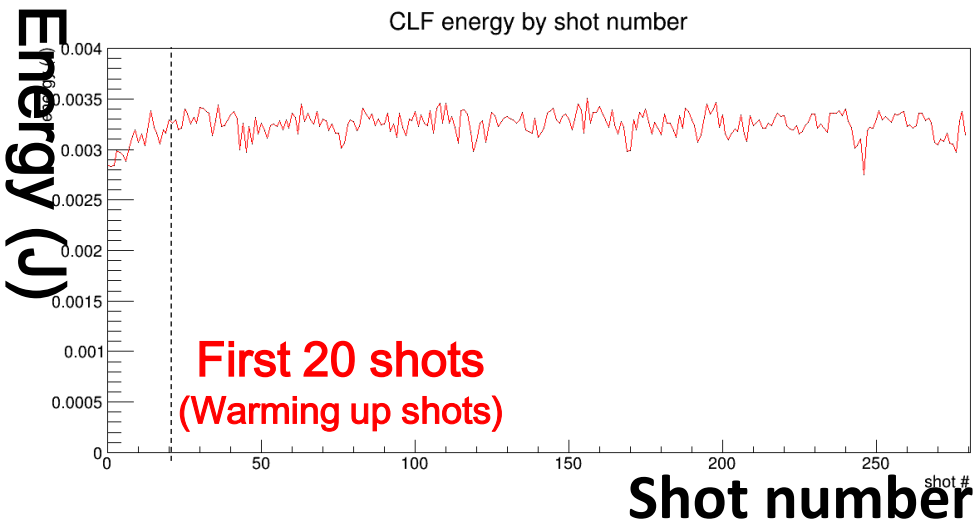

~21km Away

CLF energy by shot number

First 20 shots
(Warming up shots)

Energy (J)

Shot number

shot #
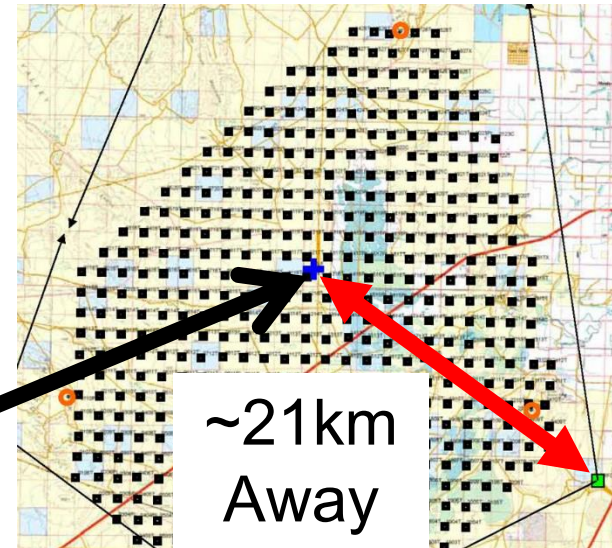
20150313-0730set energy distribution

Shot energy distribution	
Entries	280
Mean	0.003244
RMS	0.0001228

Mean : 3.2mJ

Energy (J)

frequency

energy (J)
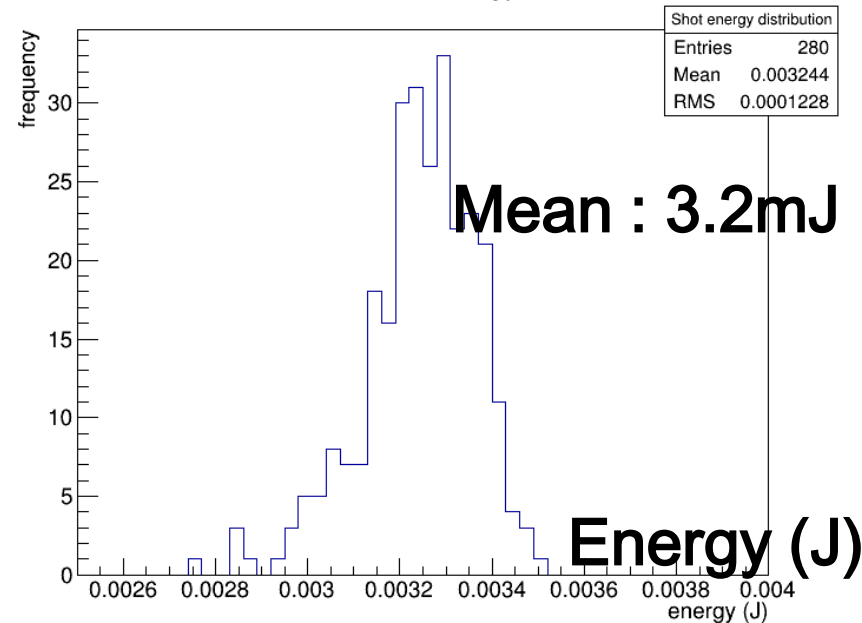
Result (CLF)

Event view
2015年3月13日のUTC7時と7時半に取ったイベント、スケールは有意度

TA   EUSO-TA (CLF column)

EUSO-TA FOV

UTC 070015.8

TA   EUSO-TA (CLF column)
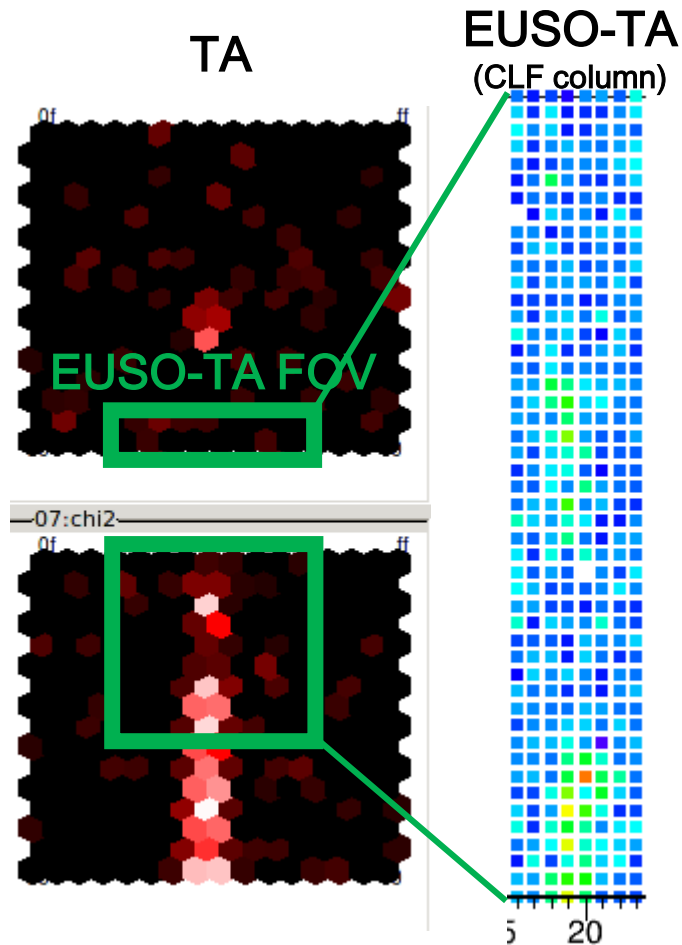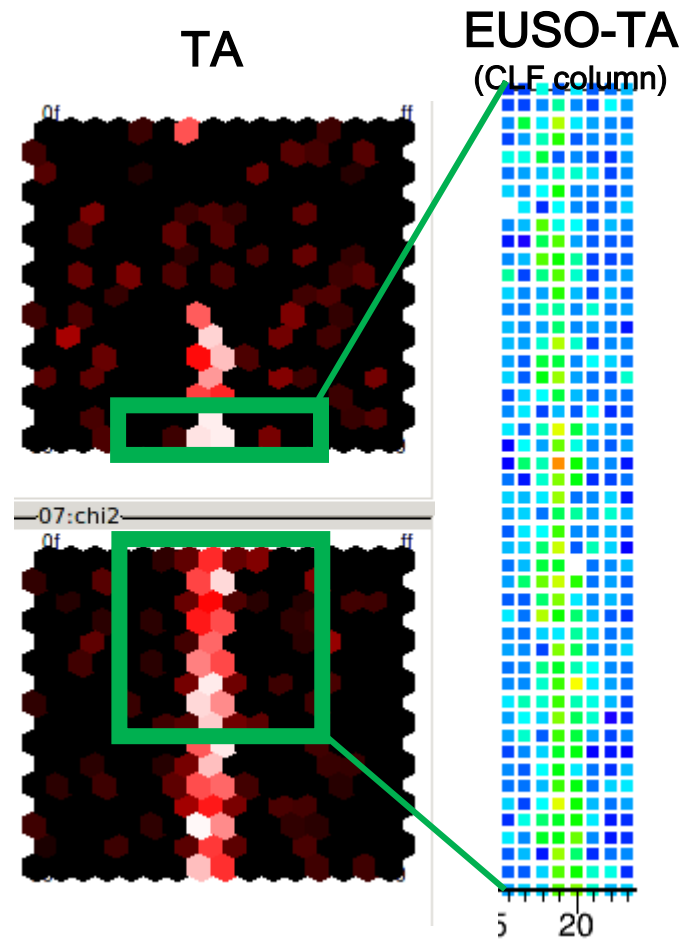
UTC 073001.7

Result (CLF)

Quantitative comparison between two different telescopes

FADC waveform、PE countingと二つの望遠鏡のDAQ方法が異なるため、
二つの望遠鏡の定められた領域から得られた1CLFイベントごとの光電子数を比較
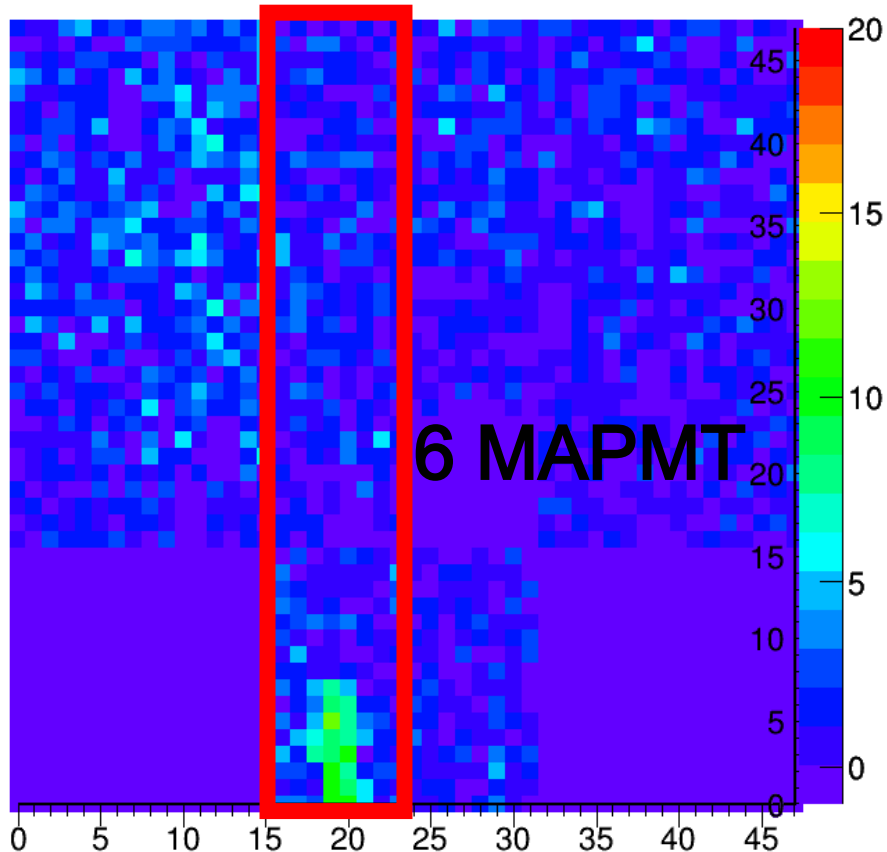
6 MAPMT
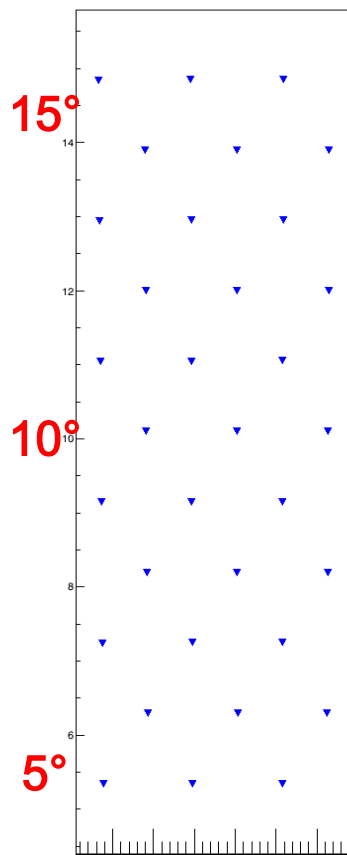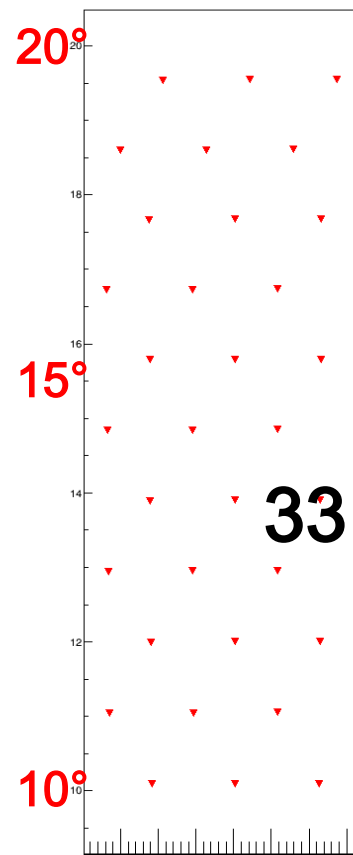
33 PMT

EUSO-TA@10°   EUSO-TA@15°

Result (CLF)

Event sets for comparison

Condition	# of CLF set
External trigger run with newest ASIC settings (17th May 2015 ~ 15th Nov 2015)	185
Cloud cut (Clear vertical lined signal in TA w/o bump, block)	153
EUSO-TA elevation angle cut (10 and 15 degrees only)	134
Timestamp cut (TA CLF data in <1ms coincidence with EUSO-TA data)	51
Total **"CLF with TA"** events	**12836 evts in 51 sets**

*Due to GPS problem, almost all CLF events in November didn't pass Timestamp cut

Result (CLF)

Scatter plot for PE number for each CLF event
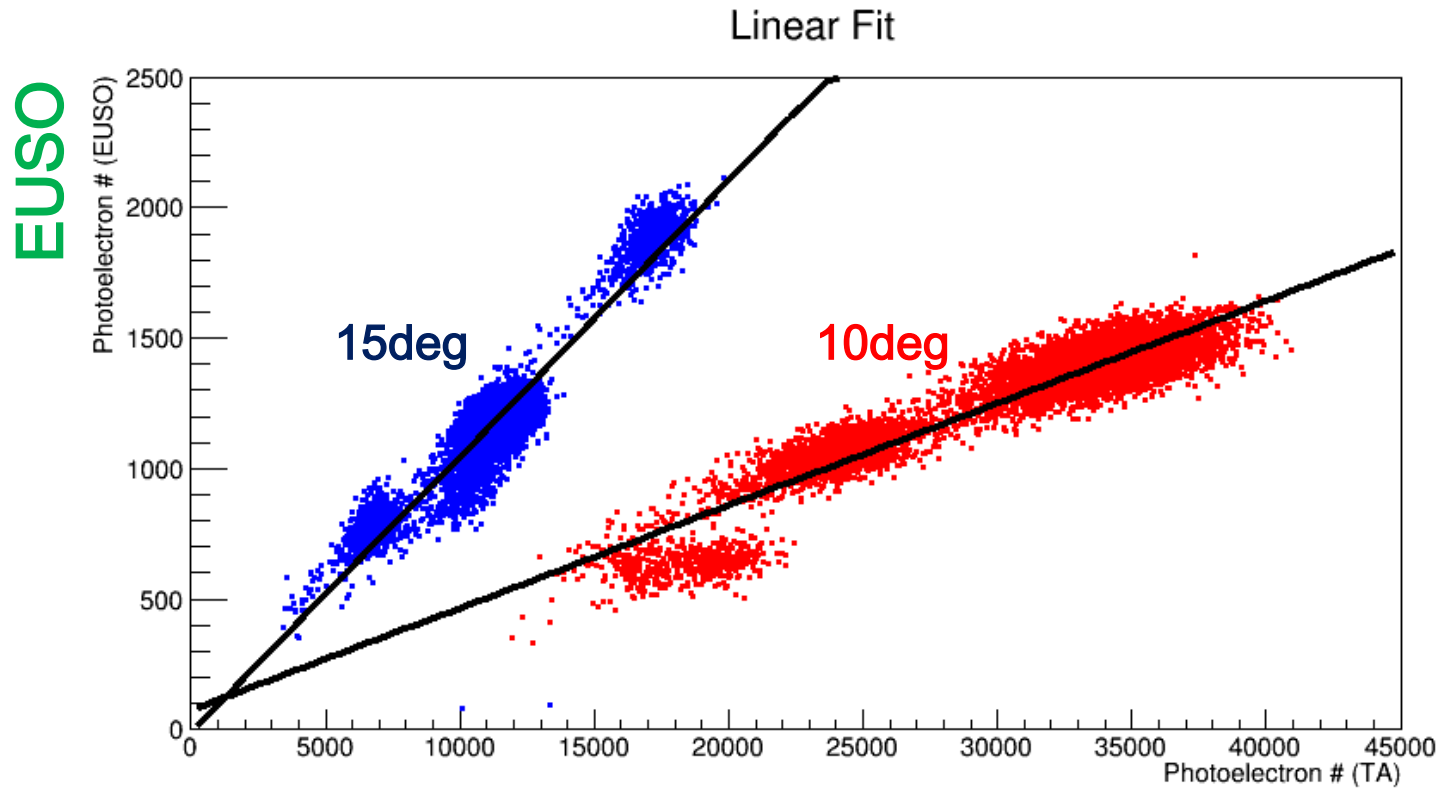
Linear相関が見受けられる
Cluster構造は大気状態によると考えられている
EUSO-TA望遠鏡の仰角ごとに相関関係も異なってくる
(EUSO-TA望遠鏡のPile-up saturation + Spot sizeによる)

Result (CR)

4 CR track candidates with TAFD data together
with TA preliminary reconstruction results
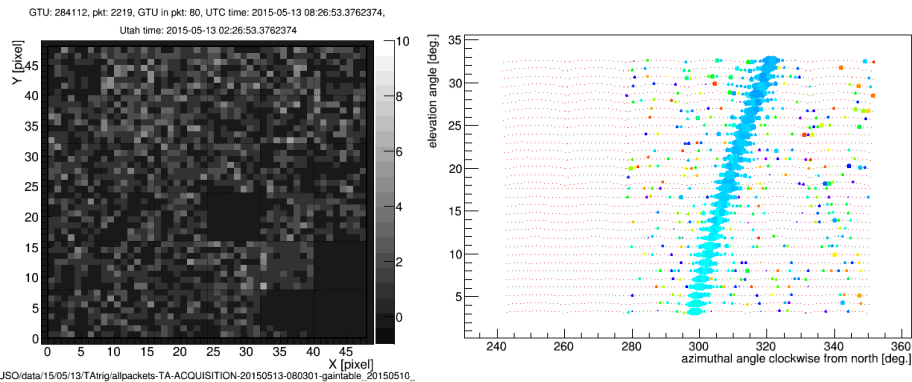
20150513-08:26:50.356

logE = 18.06 Rp = 2.5km Psi = 100.7°
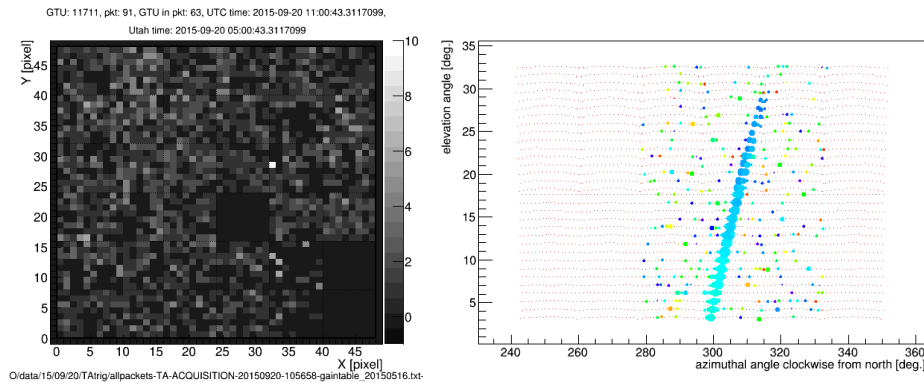
20150920-10:59:19.309

logE = 18.38 Rp = 6.7km Psi = 121.6°
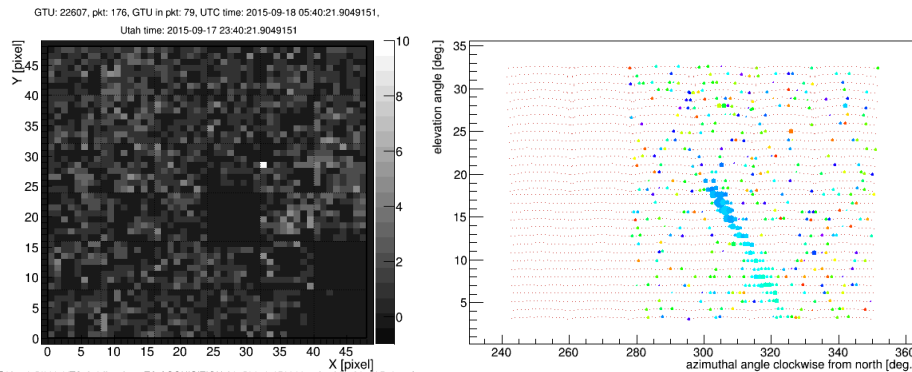
20150918-05:40:19.904

logE = 18.51 Rp = 9.1km Psi = 125.9°
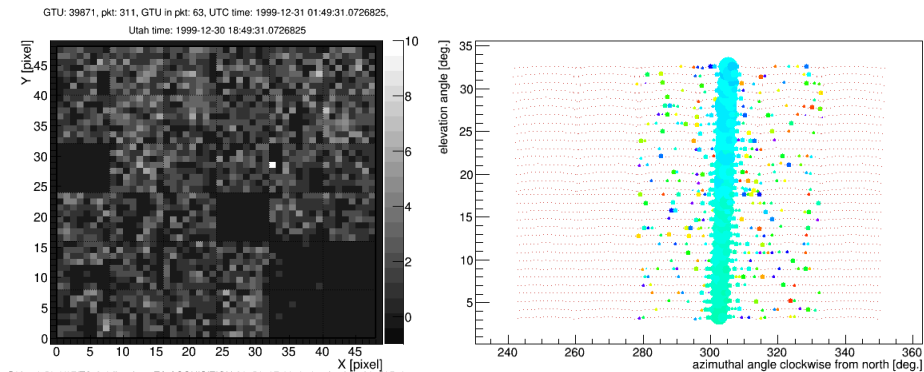
20151107-09:15:06.732

logE = 18.42 Rp = 2.65km Psi = 84°

14

Simulation

Simulation frameworks is under development

Telescope Array reconstruction
- Zenith = 35°
- Azimuth = 7° (clockwise from N)
- $E = 10^{18}$ eV
- Rp = 2.5 km
- Core = (14.8 km, -10.9 km) respect CLF

EUSO-TA configuration
- EUSO-TA elevation = 15°

Sum simu event and background data

pixel-y / pixel-x — pe
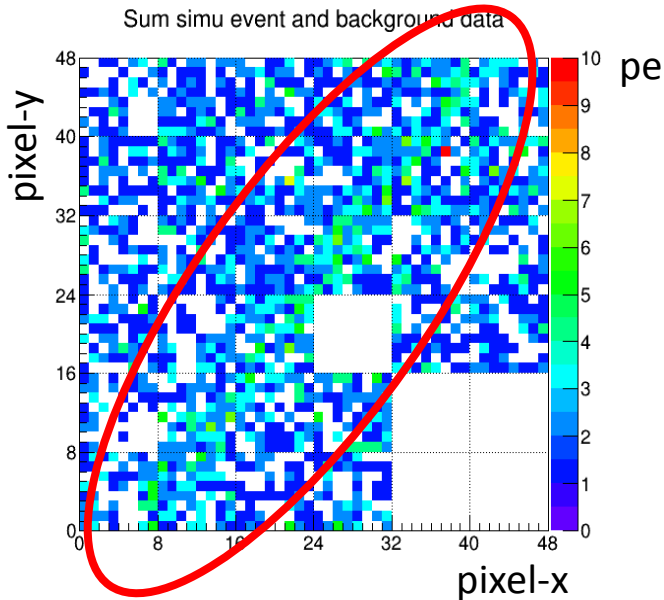
Data vs simulations
13th May 2015

Data

pixel-y / pixel-x — pe
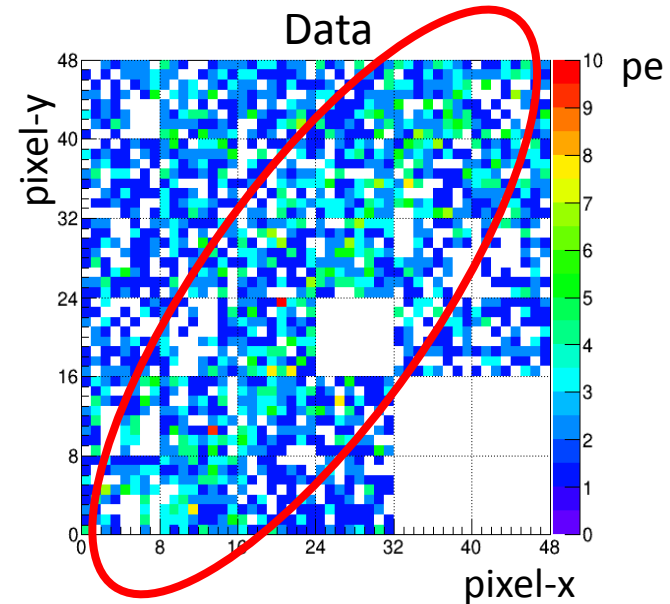
Offline simulation
+ data background

Simulation

Simulation frameworks is under development

Detected and not detected events

Figure by B. Francesca, KIT
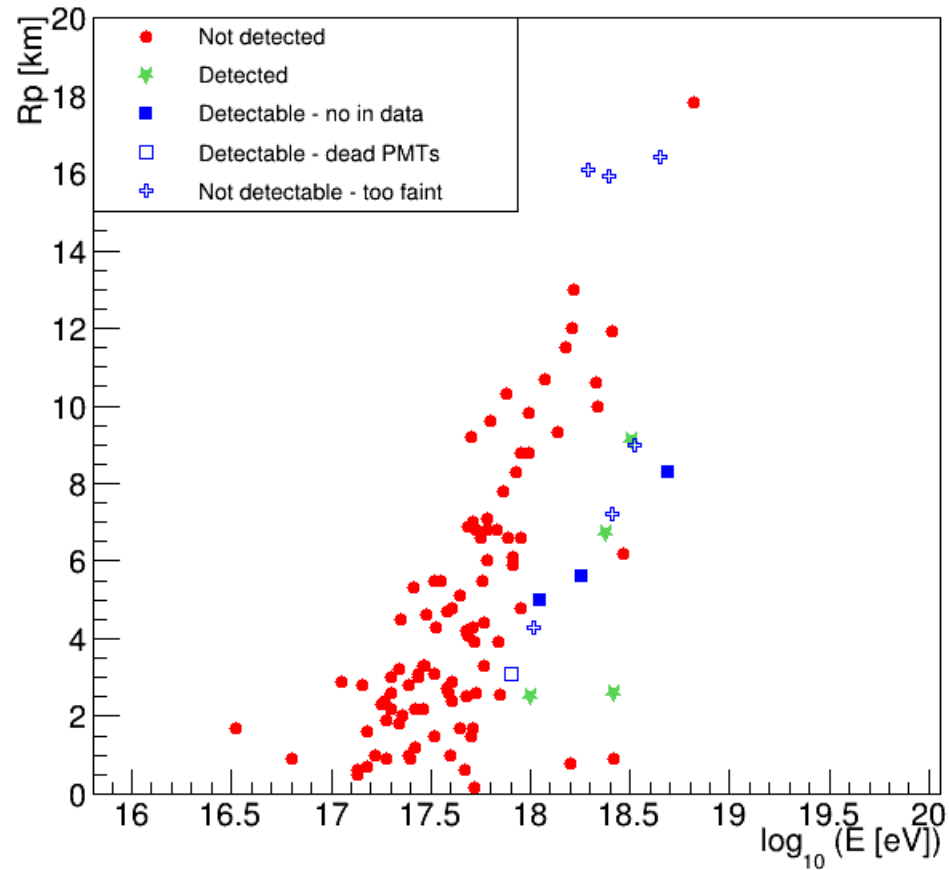
Summary

- JEM-EUSO is a next generation UHECR observatory on ISS
  EUSO-TA is its pathfinder mission

→JEM-EUSO detects Fluorescence from EAS using Photoelectron counting method

→EUSO-TA is the first step to realize JEM-EUSO (Space-borne EAS observatory)
  (Technical realization, Cross-calibration with TAFD)

→UV vertical laser and air shower data could be obtained together with TAFD

→Simulation framework is now under development

Future works

- ## EUSO-TA

→Fix broken pixels, improve optics (Φ2.5mm spot size)

→Observe ELS with 0.2° angular resolution
    (Fluorescence from 40MeV electron)

→Development and establishment of analysis method

- ## EUSO-SPB (Flight in Apr 2017)

→Next stage pathfinder
    (Realize the "looking-down" schematics, Data telemetry, Self-trigger)

- ## Mini-EUSO

→Space environmental test, will be attached Russian part in ISS
    (Measure the background level from ISS, Study transient glow events in
     atmosphere)

JEM-EUSO

J.H. Adams Jr.md , S. Ahmadbb, J.-N. Albertba , D. Allardbc, L. Anchordoquimf , V. Andreevme, A. Anzalonedh,dn, Y. Araiev, K. Asanoet , M. Ave Pernaskc, P. Baragattido, P. Barrillonba , T. Batschhc, J. Bayercd , R. Be¸chinidl, T. Belenguerkb, R. Bellottida,db, K. Belovme, A.A. Berlindmh, M. Bertainadk,dl, P.L. Biermanncb, S. Biktemerovaia, C. Blaksleybc, N. Blancla , J. Błe¸ckihd , S. Blin-Bondilbb, J. Blumer ¨ cb, P. Bobikj a , M. Bogomilovaa , M. Bonamentemd , M.S. Briggsmd , S. Brizkd , A. Brunoda , F. Cafagnada, D. Campanadf , J-N. Capdeviellebc, R. Carusodc,dn, M. Casolinoew,di, C. Cassardodk,dl, G. Castellinidd , C. Catalanobd , O. Catalanodh,dn, A. Cellinodk,dm, M. Chikawaed , M.J. Christlmg, D. Clineme, V. Connaughtonmd , L. Contido, G. Corderoga , H.J. Crawfordma , R. Cremoninidl, S. Csornamh, S. Dagoret-Campagneba, A.J. de Castrokd , C. De Donatodi, C. de la Taillebb, C. De Santisdi,dj , L. del Peralkc, A. Dell'Orodk,dm N. De Simonedi, M. Di Martinodk,dm, G. Distratiscd , F. Dulucqbb, M. Dupieuxbd , A. Ebersoldtcb, T. Ebisuzakiew, R. Engelcb, S. Falkcb, K. Fangmb, F. Fenucd , I. Fernandez-´ Gomez ´ kd , S. Ferraresedk,dl, D. Fincodo, M. Flaminido, C. Fornarodo, A. Franceschide, J. Fujimotoev , M. Fukushimaeg, P. Galeottidk,dl, G. Garipovic, J. Gearymd , G. Gelminime, G. Giraudodk , M. Goncharia , C. Gonzalez Alvarado ´ kb, P. Gorodetzkybc, F. Guarinodf,dg, A. Guzman´ cd , Y. Hachisuew, B. Harlovib, A. Haungscb, J. Hernandez Carretero ´ kc, K. Higashideer,ew, D. Ikedaeg, H. Ikedaep, N. Inoueer, S. Inoueeg, A. Insoliadc,dn, F. Isgro`df,dp, Y. Itowen, E. Jovenke, E.G. Juddma , A. Jungf b, F. Kajinoei, T. Kajinoel, I. Kanekoew, Y. Karadzhovaa , J. Karczmarczykhc, M. Karuscb, K. Katahiraew, K. Kawaiew, Y. Kawasakiew, B. Keilhauercb, B.A. Khrenovic, Jeong-Sook Kimf a , Soon-Wook Kimf a , SugWhan Kimf d , M. Kleifgescb, P.A. Klimovic, D. Kolevaa , I. Kreykenbohmca , K. Kudelaj a , Y. Kuriharaev, A. Kusenkome, E. Kuznetsovmd , M. Lacombebd , C. Lachaudbc, J. Leef c, J. Licandroke, H. Limf c, F. Lopez ´ kd , M.C. Maccaronedh,dn, K. Mannheimce, D. Maravillaga , L. Marcellidj , A. Marinide, O. Martinezgc, G. Masciantoniodi,dj , K. Maseea , R. Matevaa , G. Medina-Tancoga , T. Mernikcd , H. Miyamotoba , Y. Miyazakiec, Y. Mizumotoel, G. Modestinode, A. Monacoda,db, D. MonnierRagaigneba , J.A. Morales de los R´ıoska,kc, C. Morettoba , V.S. Morozenkoic, B. Motbd , T. Murakamief , M. Naganoec, M. Nagataeh, S. Nagatakiek , T. Nakamuraej , T. Napolitanode, D. Naumovia , R. Navaga , A. Neronovlb, K. Nomotoeu, T. Nonakaeg, T. Ogawaew, S. Ogioeo, H. Ohmoriew, A.V. Olintomb, P. Orleanski ´ hd , G. Osteriadf , M.I. Panasyukic, E. Parizotbc, I.H. Parkf c, H.W. Parkf c, B. Pastircakj a , T. Patzakbc, T. Paulmf , C. Pennypackerma , S. Perez Canokc, T. Peterlc, P. Picozzadi,dj,ew, T. Pierogcb, L.W. Piotrowskiew, S. Pirainocd,dh, Z. Plebaniakhc, A. Pollinila , P. Pratbc, G. Prev´ ot^ bc, H. Prietokc, M. Putisj a , P. Reardonmd , M. Reyeske, M. Riccide, I. Rodr´ıguezkd , M.D. Rodr´ıguez Fr´ıaskc, 16 Exp Astron (2015) 40:3–17 F. Rongade, M. Rothcb, H. Rothkaehlhd , G. Roudilbd , I. Rusinovaa , M. Rybczynski ´ ha , M.D. Sabaukb, G. Saez Cano ´ kc, H. Sagawaeg, A. Saitoej , N. Sakakicb, M. Sakataei, H. Salazargc, S. Sanchez ´ kd , A. Santangelocd , L. Santiago Cruz´ ga , M. Sanz Palominokb, O. Saprykinib, F. Sarazinmc, H. Satoei, M. Satoes, T. Schanzcd , H. Schielercb, V. Scottidf,dg, A. Segretodh,dn, S. Selmanebc, D. Semikozbc, M. Serrake, S. Sharakinic, T. Shibataeq , H.M. Shimizuem, K. Shinozakiew,cd , T. Shirahamaer, G. Siemieniec-Ozie¸błohb, H.H. Silva Lopez ´ ga , J. Sleddmg, K. Słominska ´ hd , A. Sobeymg, T. Sugiyamaem, D. Supanitskyga , M. Suzukiep, B. Szabelskahc, J. Szabelskihc, F. Tajimaee, N. Tajimaew, T. Tajimacc, Y. Takahashies, H. Takamiev, M. Takedaeg, Y. Takizawaew, C. Tenzercd , O. Tibollace, L. Tkachevia , H. Tokunoet , T. Tomidaew, N. Toneew, S. Toscanolb, F. Trillaudga , R. Tsenovaa , Y. Tsunesadaet , K. Tsunoew, T. Tymienieckahc, Y. Uchihorieb, M. Ungercb, O. Vaduvescuke, J.F. Valdes-Galicia ´ ga , P. Vallaniadk,dm, L. Valoredf,dg, G. Vankovaaa , C. Vigoritodk,dl, L. Villasenor ˜ gb, P. von Ballmoosbd , S. Wadaew, J. Watanabeel, S. Watanabees, J. Watts Jr.md , M. Webercb, T.J. Weilermh, T. Wibighc, L. Wienckemc, M. Willeca , J. Wilmsca , Z. Włodarczykha , T. Yamamotoei, Y. Yamamotoei, J. Yangf b, H. Yanoep, I.V. Yashinic, D. Yonetokuef , K. Yoshidaei, S. Yoshidaea , R. Youngmg, M.Yu. Zotovic, A. Zuccaro Marchiew