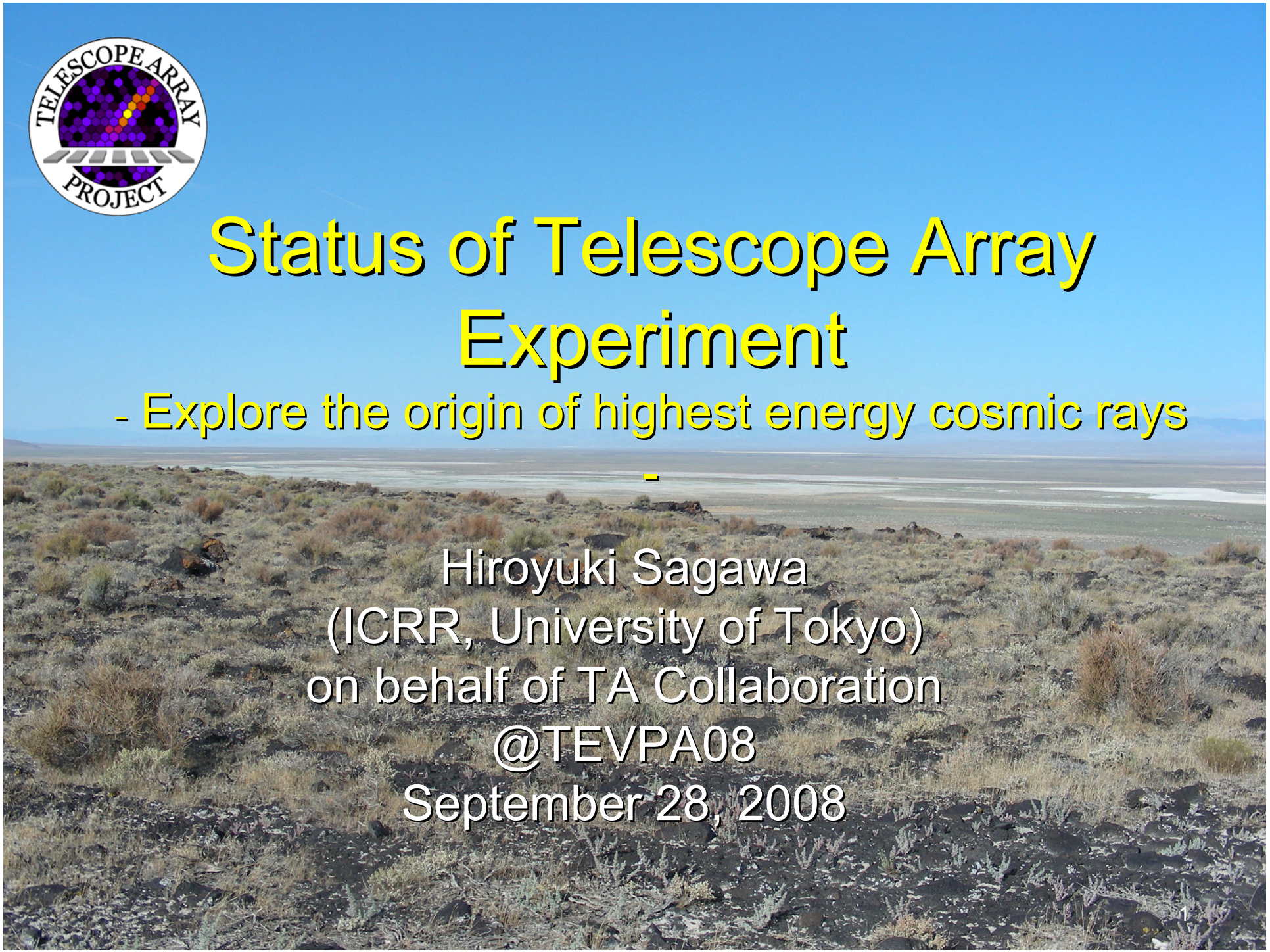


Status of Telescope Array Experiment

- Explore the origin of highest energy cosmic rays -

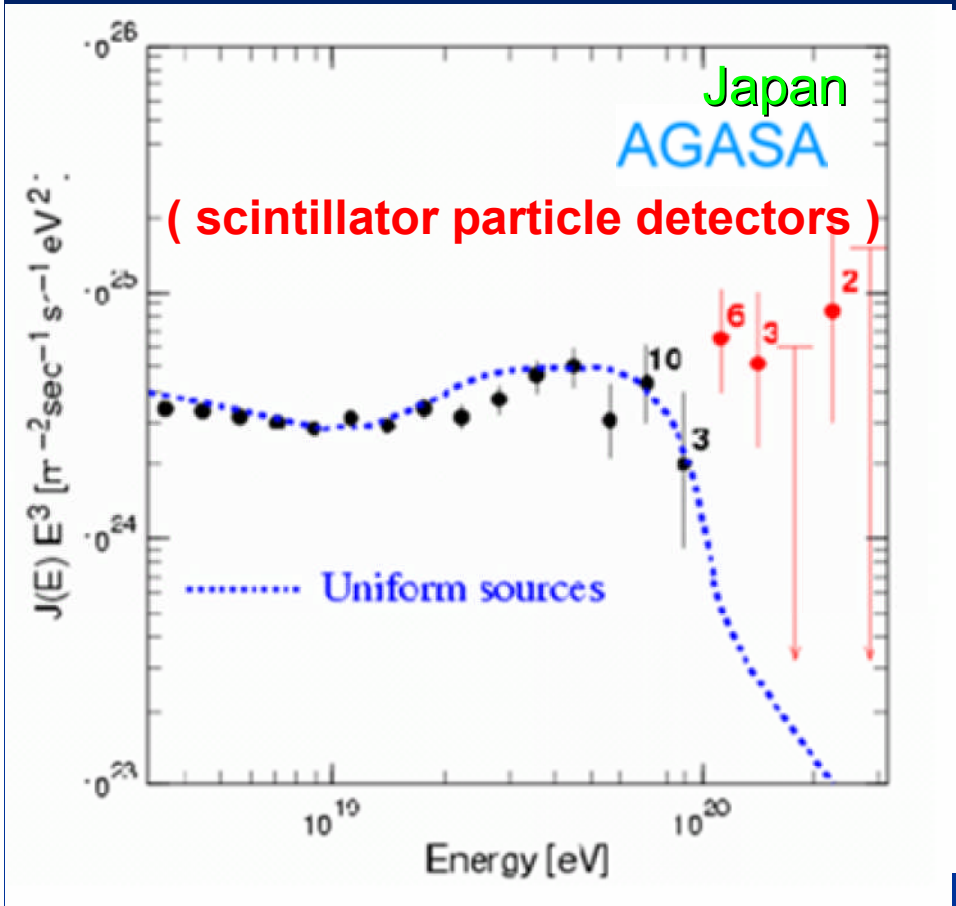
Hiroyuki Sagawa
(ICRR, University of Tokyo)
on behalf of TA Collaboration

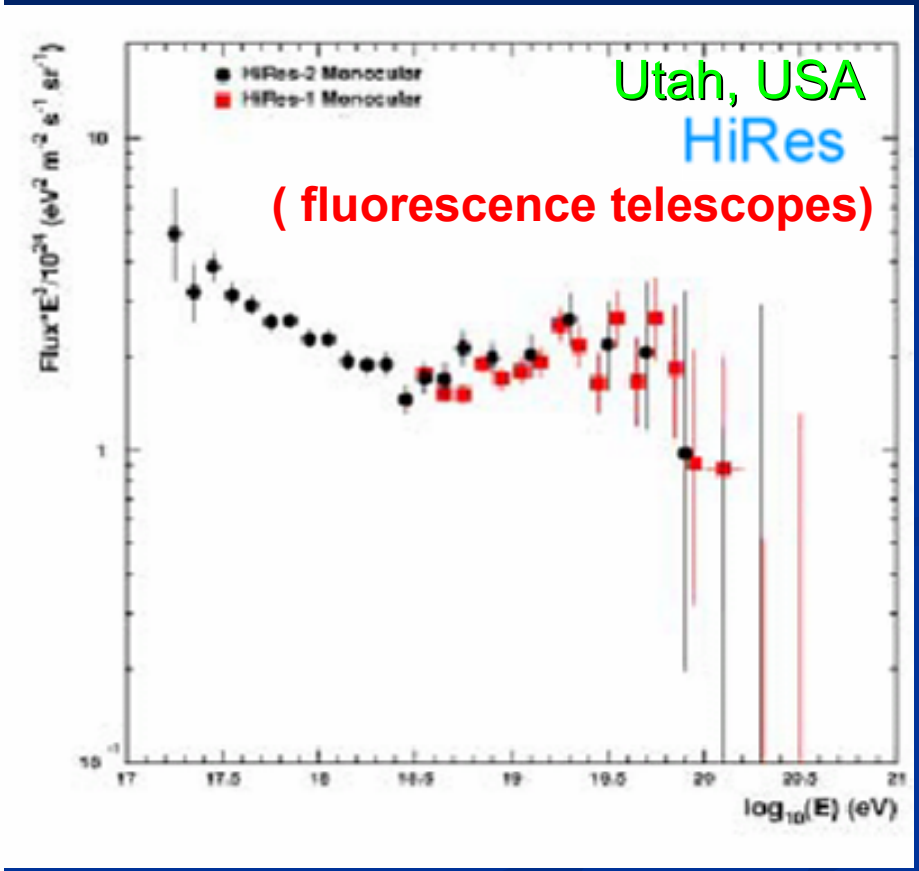
@TEVPA08
September 28, 2008

Content

- Telescope Array（TA）experiment
  - Search for the origin of highest energy cosmic rays (~10^{20}eV)
- **Roles and characteristics of TA**
- **TA detectors**
- **Status of observation**
- **Summary**

Energy spectrum of extremely high energy cosmic rays





=>next generation detector (Telescope Array, Auger)

Confirmation of existence or inexistence of GZK cutoff

$p+\gamma_{CMB} \rightarrow \Delta^{+}, N+\pi$

TA : hybrid detector

- Fluorescence telescopes (FD)
  - HiRes-type FD
- Surface Detector (SD) array
  - AGASA-type Plastic Scintillator detector

- DAQ of wave form data with Flash ADC for SDs and new two TA FDs

Mission of TA

- Purpose
  - Energy spectrum → Super GZK ?
  - Arrival direction → anisotropy、clusters ?
  - Chemical composition of primary cosmic rays
    - observation of longitudinal profile with FD (Xmax)
      - proton, iron, gamma ?
- Method
  - Observatory of about 10 times larger size of AGASA
  - Hybrid detector (FD, SD)

Telescope Array Collaboration

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(15) Musashi Institute of Technology
(16) National Institute of Radiological Sciences
(17) Osaka City University
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(19) Rutgers University (20) Saitama University
(21) Tokyo Institute of Technology
(22) Tokyo University of Science
(23) University of Denver
(24) University of New Mexico
(25) University of Utah
(26) Utah State University
(27) Yamanashi University
(28) Yonsei University
(29) Institute for Nuclear Research of Russian Academy of Science

Japan, USA, Korea, recently Russia
29 institutes
~120 collaborators

Characteristics of TA

As a hybrid detector,

- **Surface detector array with plastic scintillators** (SD)
  - AGASA-type plastic scintillator detector
  - **Energy determination independent of FD**
- Fulorescence telescope (FD)
  - **HiRes-I was moved to one of TA FD stations. → compare with new TA telescopes**
  - **Electron beam accelerator** : end-to-end absolute calibration of telescopes with air shower induced by electron beam at the TA site

Telescope Array

Millard county, Utah, USA
N 39.1° , W 112.9°
1350~1500 m

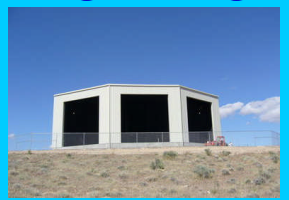
Communcation Tower

Middle Drum
HiRes-I was moved.

1.2km interval
Surface detector
503 SDs

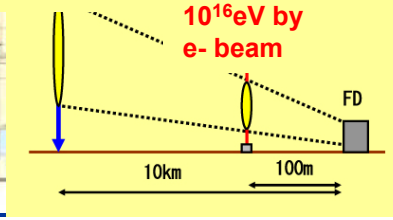
Black Rock Mesa
FD station

Long Ridge



30km

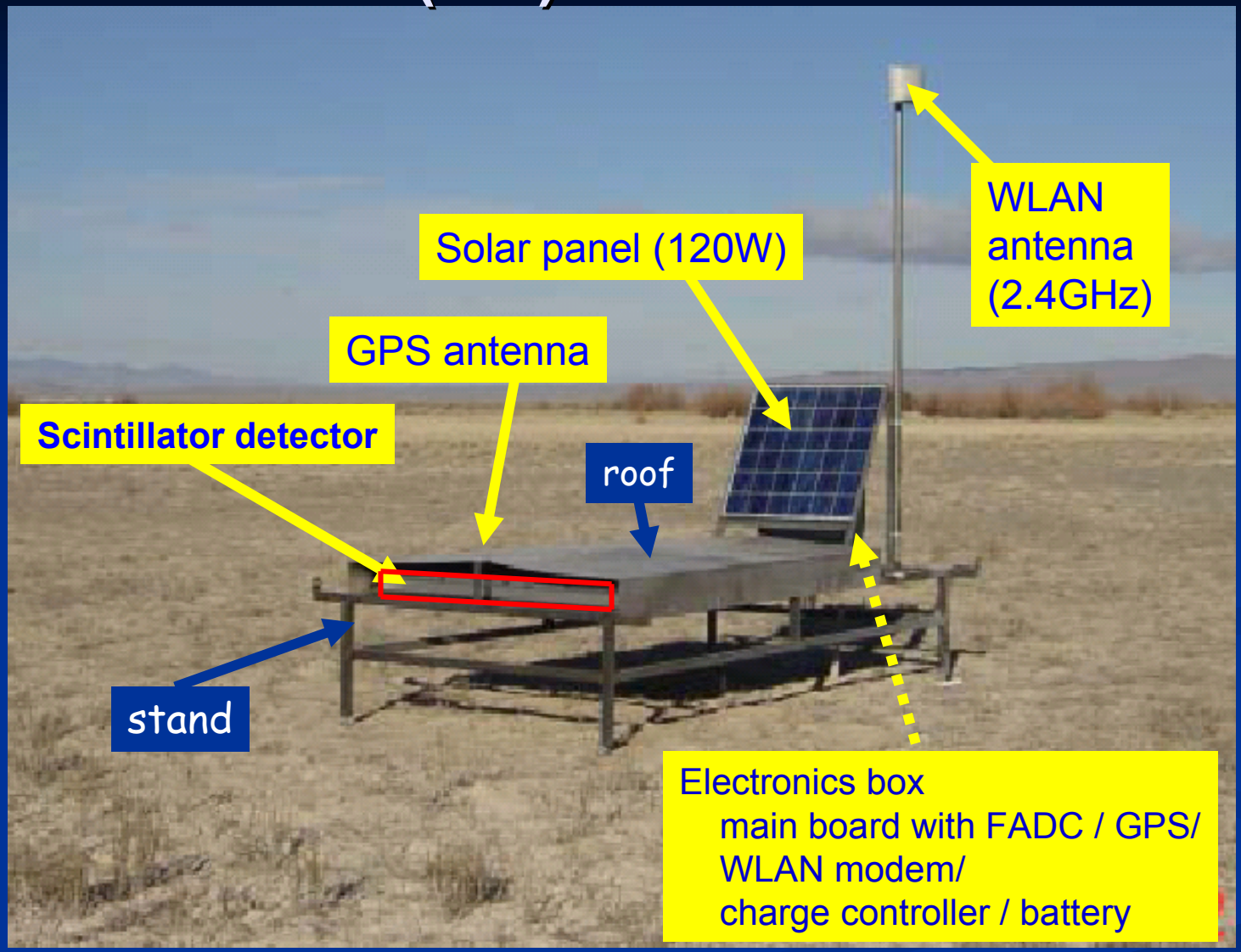
e- LINAC : be installed next spring



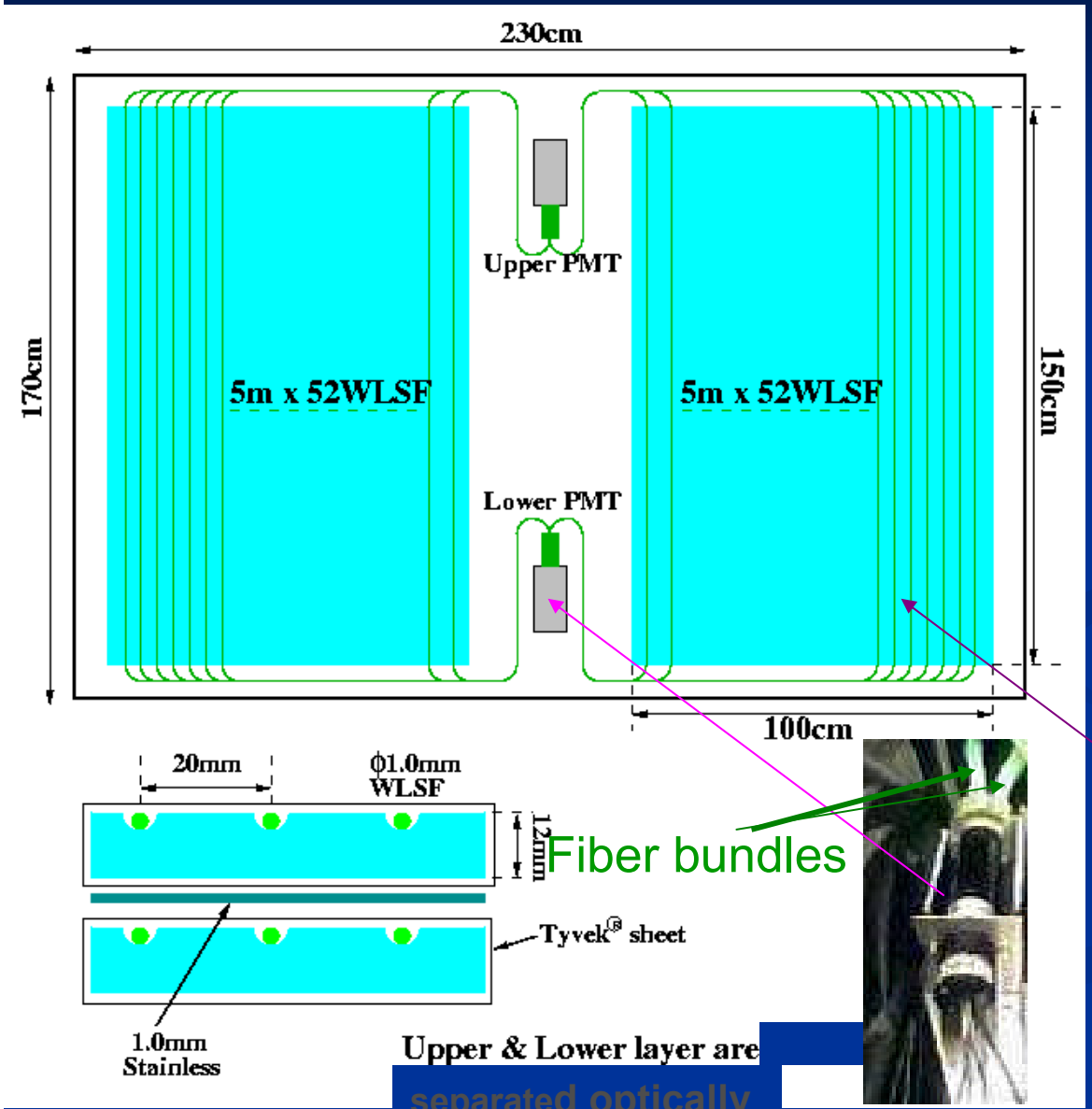
Surface detectors (SD)

- TA : plastic scintillation detector
  - Sensitive to electromagnetic part
    - about 90% of energy of air shower
    - Less sensitive to hadron interaction model and chemical composition than muons
  - Determine energy scale by using SD independent of fluorescence telescope
- Pierre Auger : water tank
  - More sensitive to muons
    - Sensitive to hadron interaction model and chemical composition
  - AUGER's energy scale is obtained by FD

Surface Detector (SD) of TA



Scintillation detector part



Scintillator

3m^2 area 1.2cmt 2 layers

WLS fibers

1.0mm diameter 2 cm interval

PMTs (Electrontubes 9124SA)

2PMTs (one for upper layer, the other for lower layer)

Scintillator box

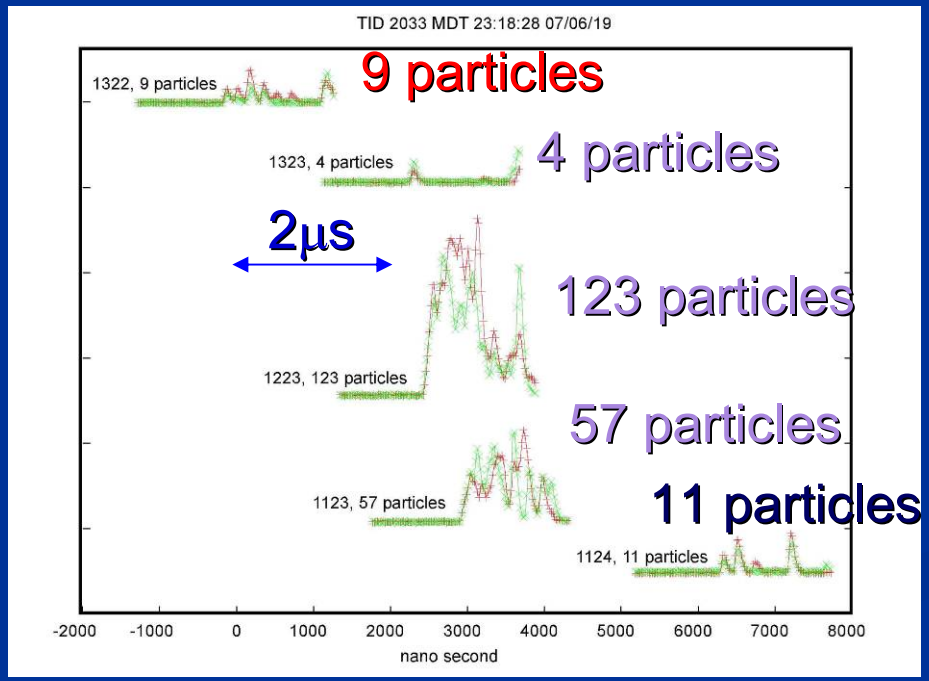
stainless steel

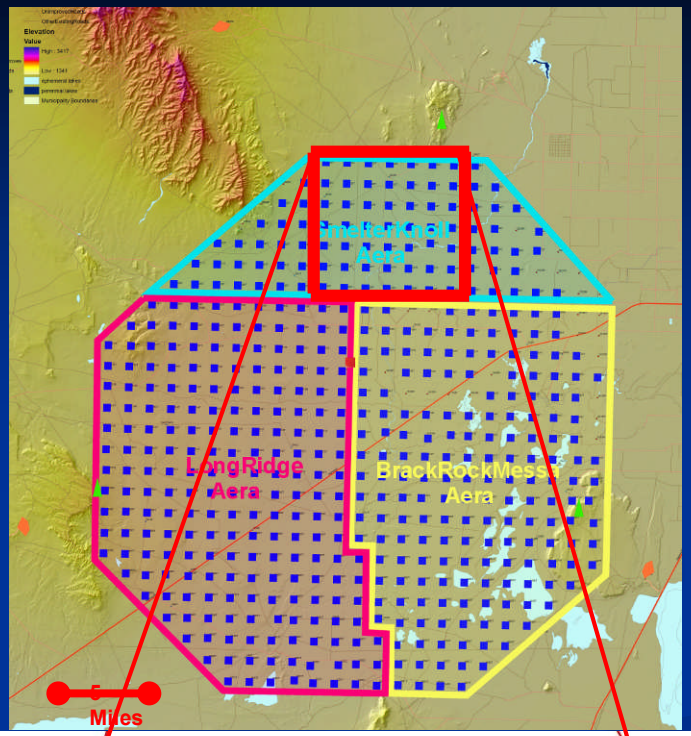
230 x 170 x 10(cm^3)

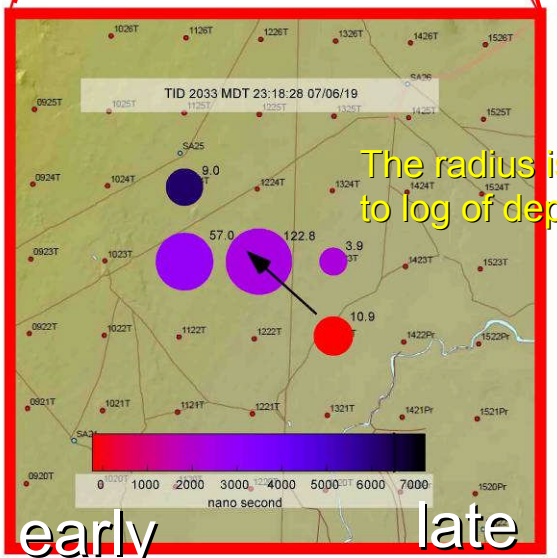
(1.2mm, 1.5 mm thick)

Total weight ~200 kg

Example I : air shower with surface detectors



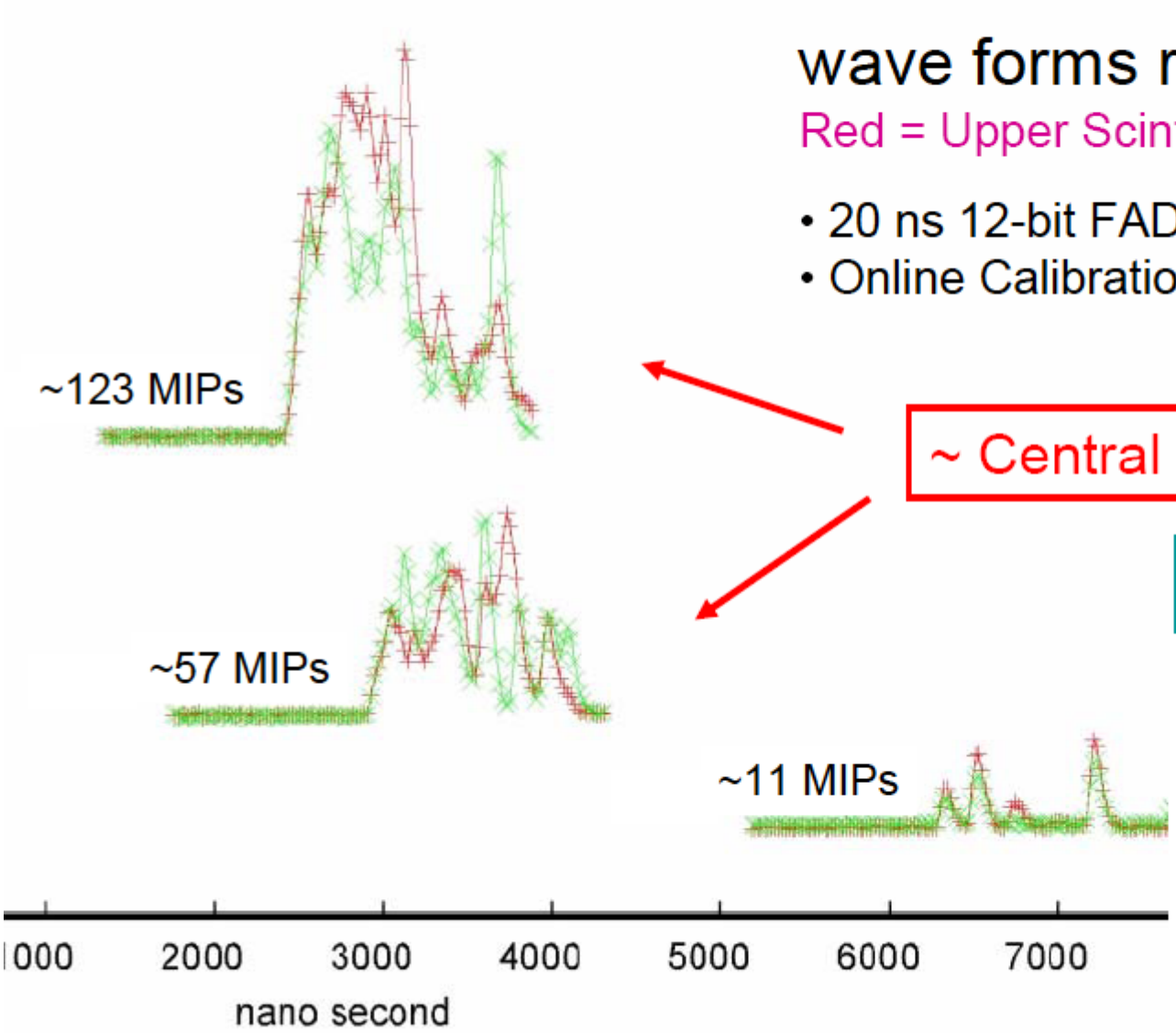




The radius is proportional to log of deposited energy

TID 2033 MDT 23:18:28 07/06/19:

One of the first TA/SD events



wave forms recorded

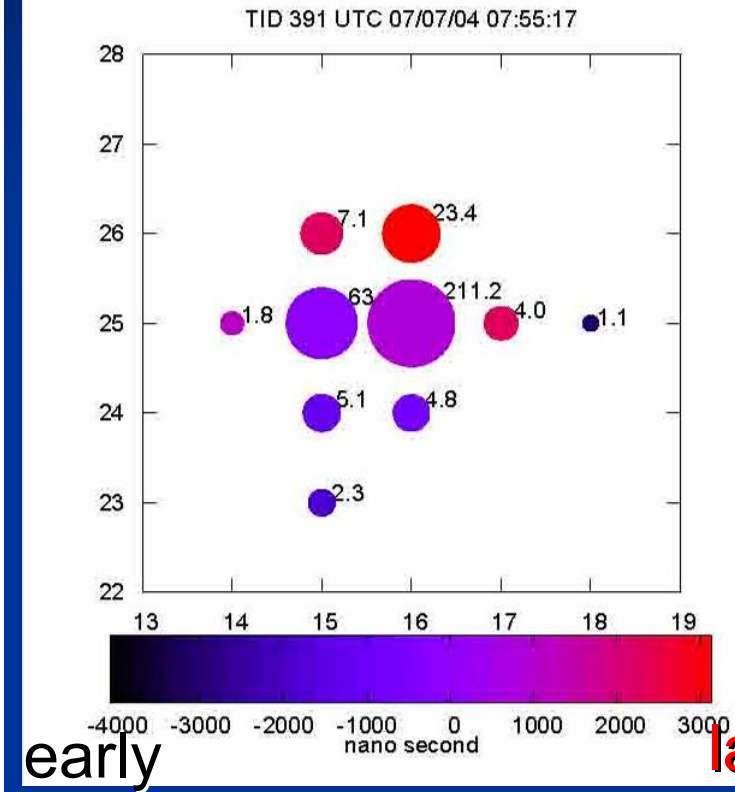
Red = Upper Scint, Green = Lower Scint.

- 20 ns 12-bit FADC
- Online Calibration of Gain and Timing

~ Central EM showers

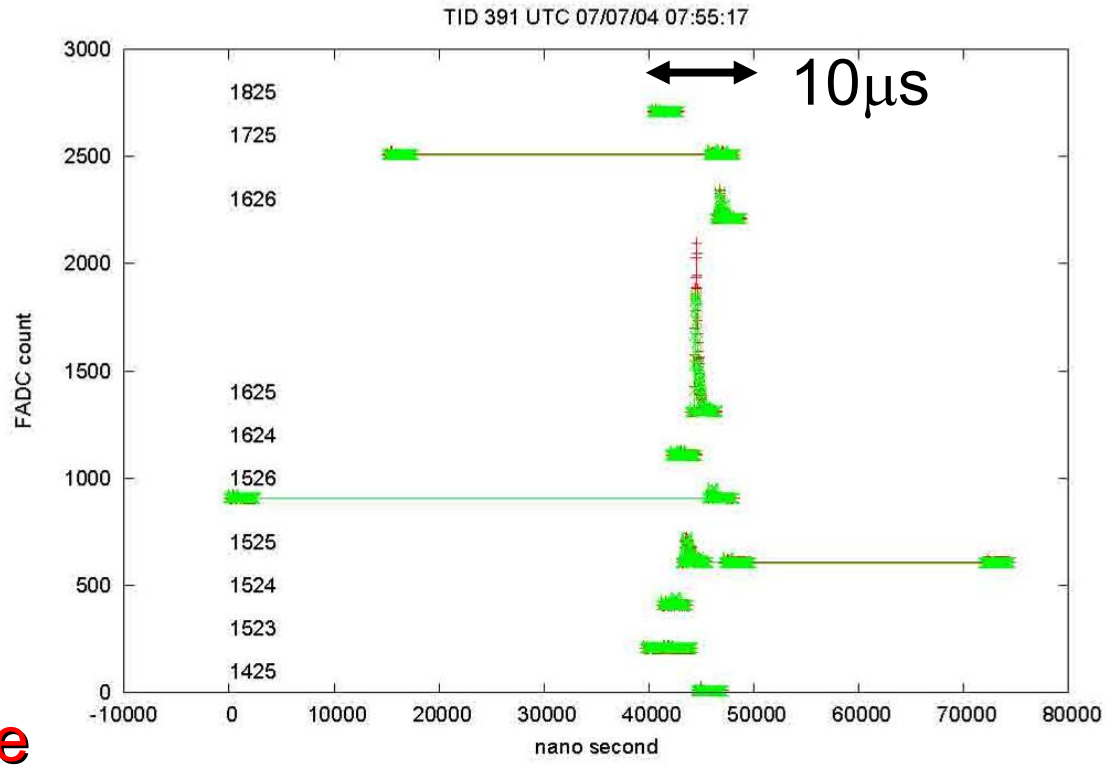
~ Peripheral Muons

Example 2

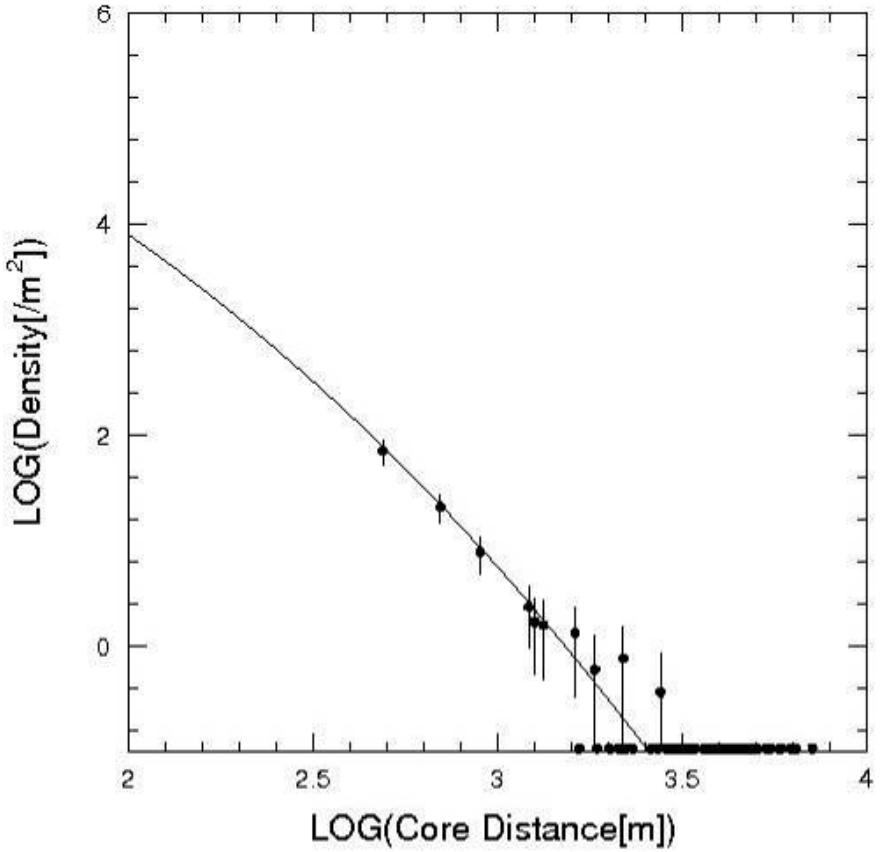


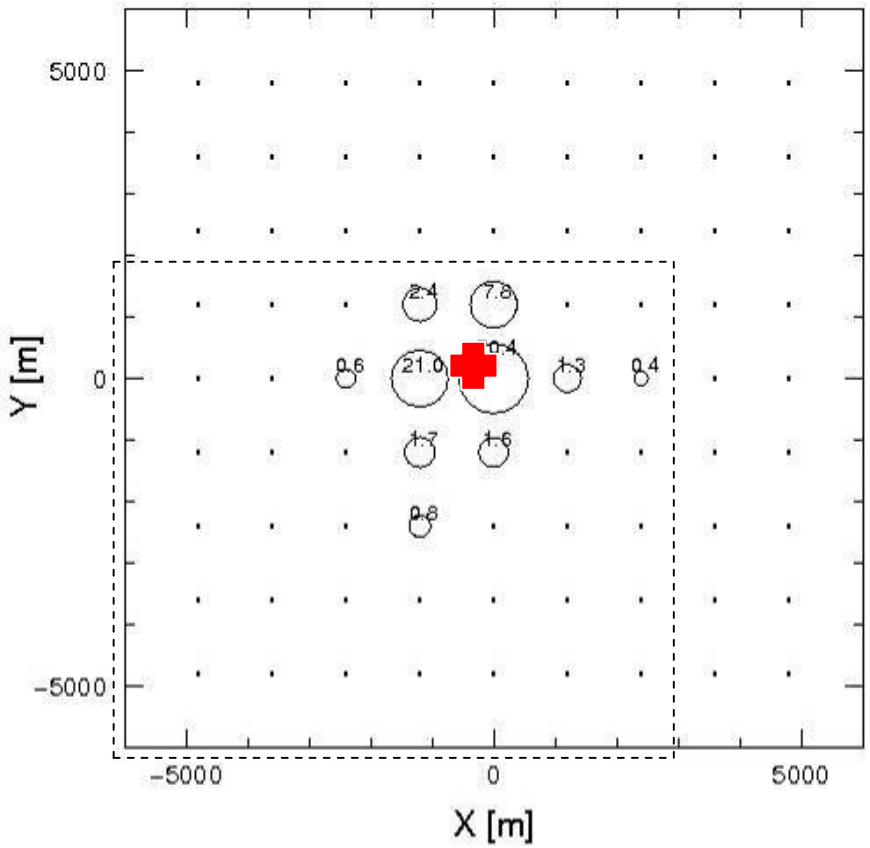
early

late



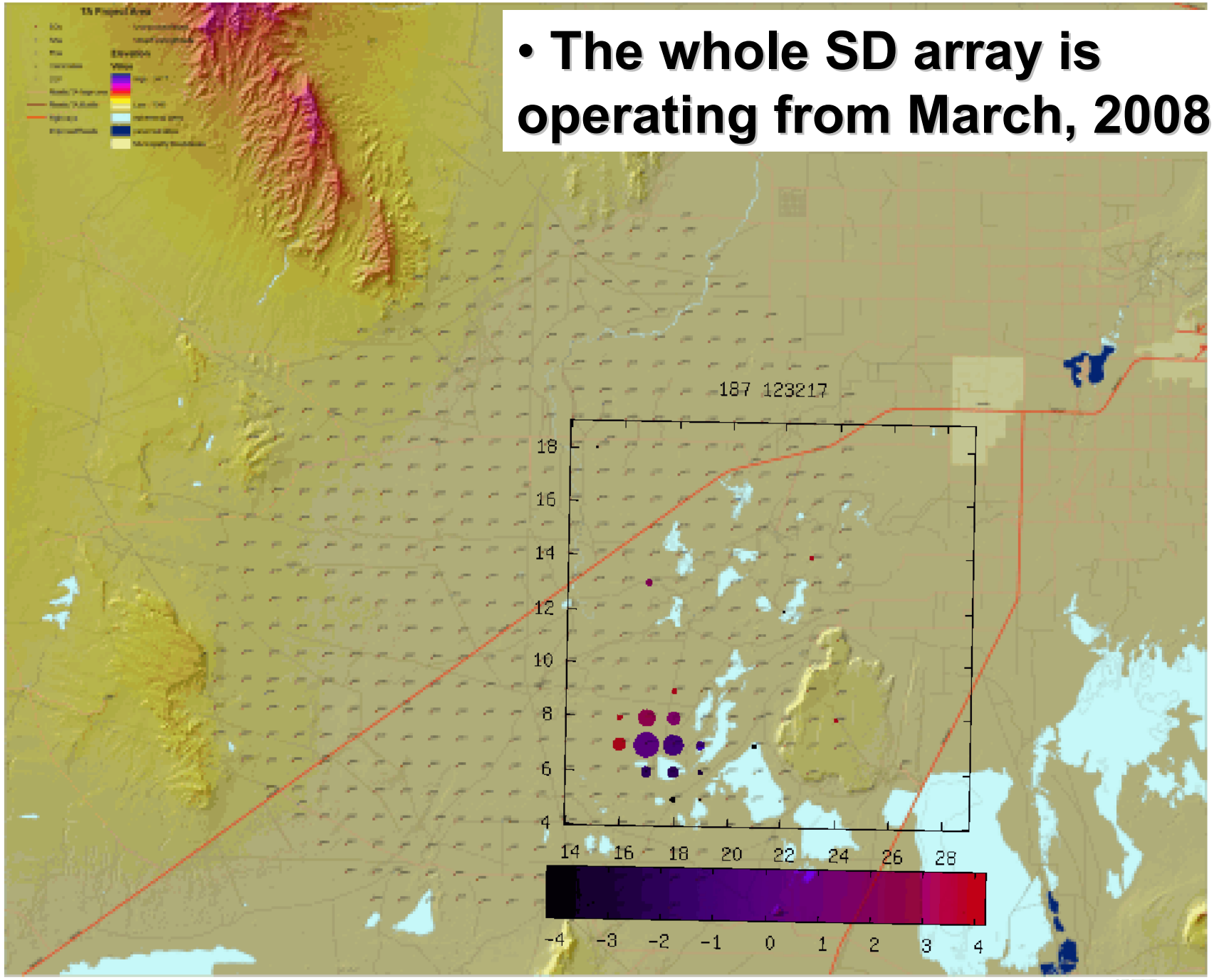
Example 2

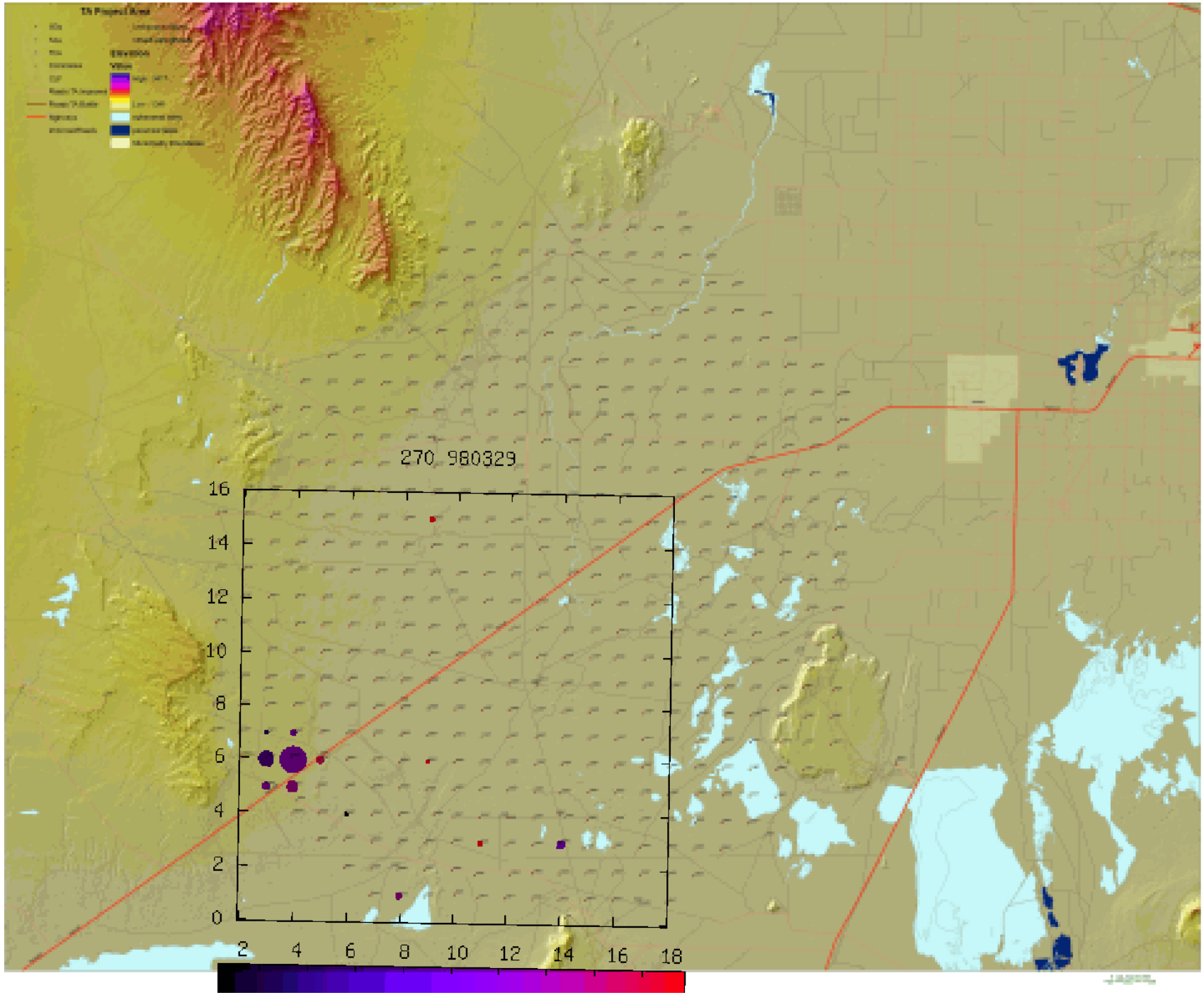


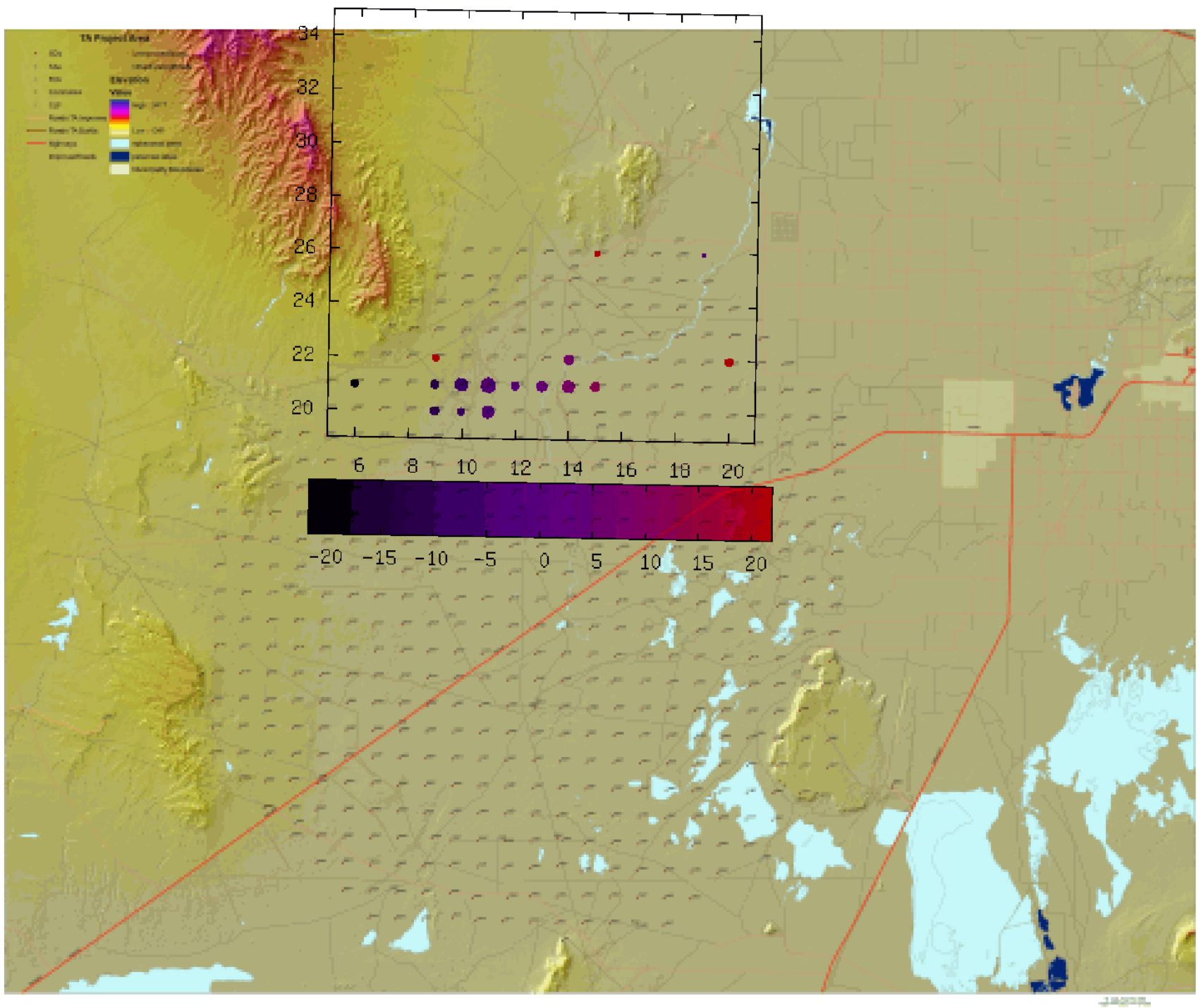


Very preliminary

Zenith=36.3[deg]
Azimuth=241.2[deg]


• The whole SD array is operating from March, 2008.
187 123217
18
16
14
12
10
8
6
4
14 16 18 20 22 24 26 28
-4 -3 -2 -1 0 1 2 3 4


270 980329
16
14
12
10
8
6
4
2
0
2
4
6
8
10
12
14
16
18

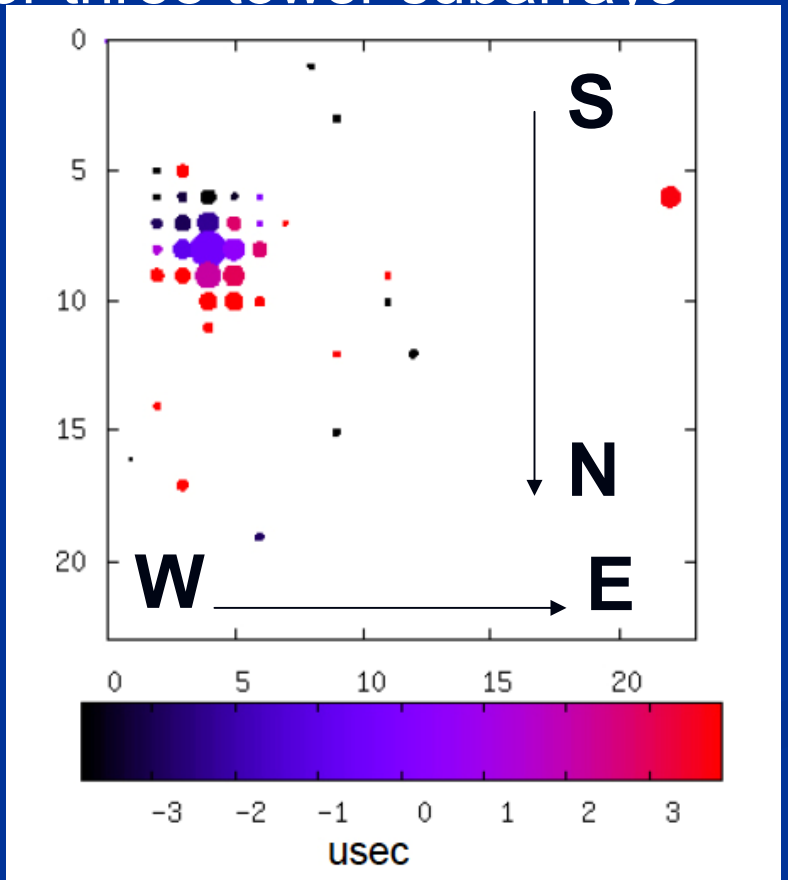

34
32
30
28
26
24
22
20
6 8 10 12 14 16 18 20
-20 -15 -10 -5 0 5 10 15 20

SD shower trigger condition

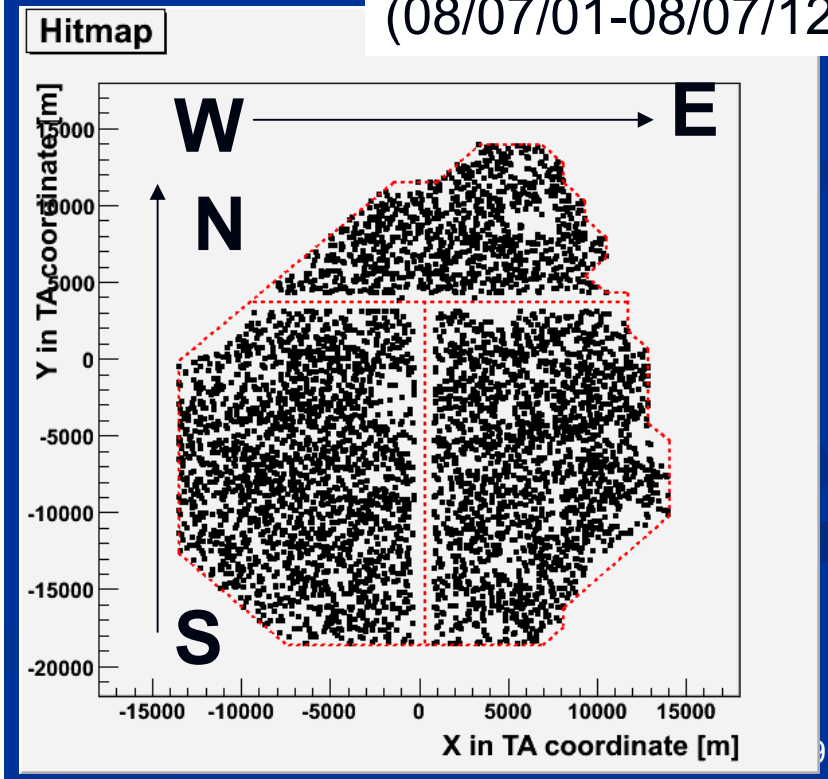
- >3MIP
- adjacent 3detectors
- coincidence width: 8 usec
- Wave Fform +- 32usec
- Independent Trigger, Data collection for three tower subarrays

Data :～2GB/Day

～600 event /day(after gain adjust)

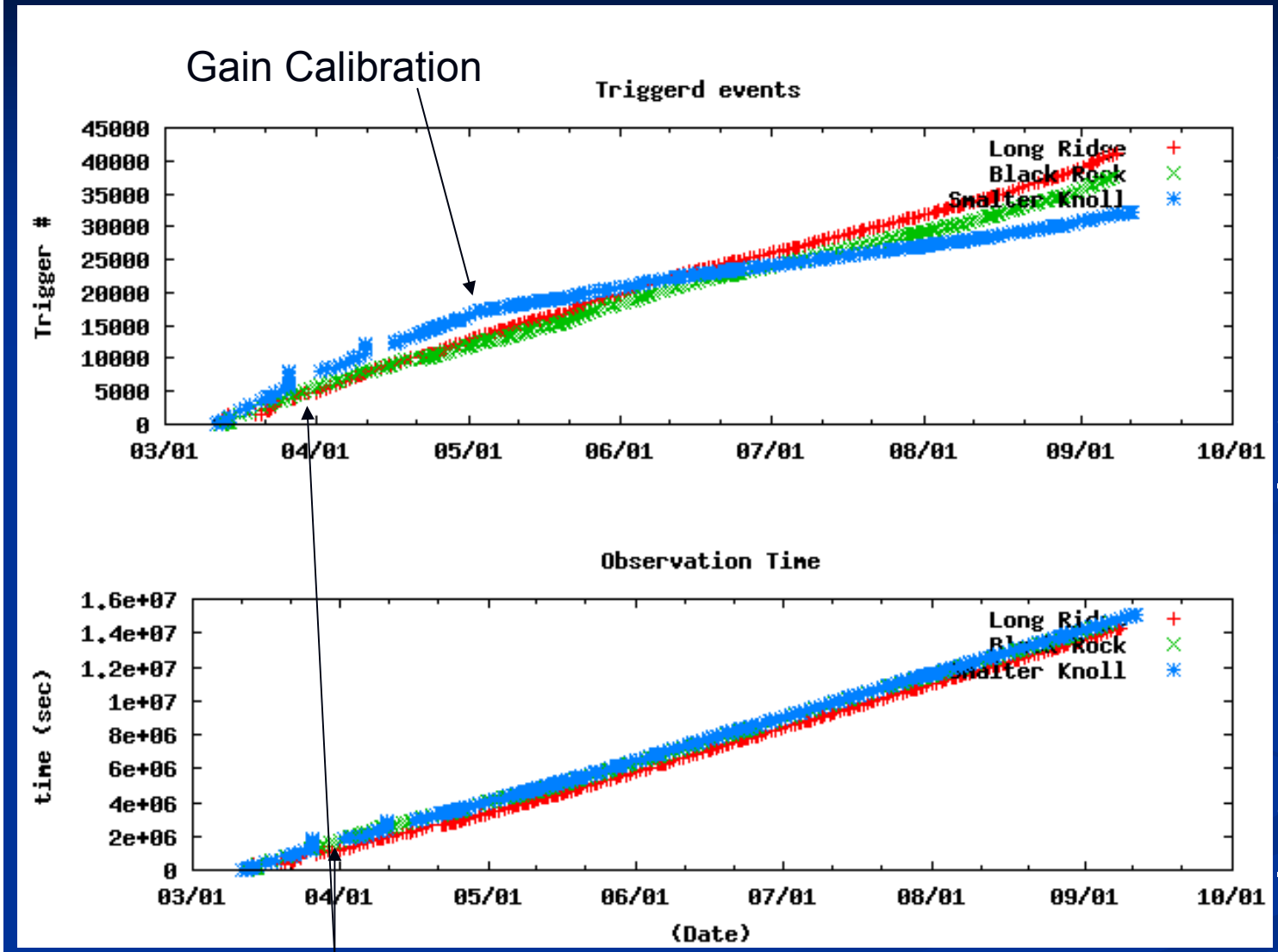


Core position map
(08/07/01-08/07/12)



SD Trigger rate and run time

Full observation started 14 Mar. 2008



Shower trigger rate(Hz)

LR : $2.9*10^{-3}$

BR : $2.7*10^{-3}$

SK : $1.5*10^{-3}$

Run time ratio:

LR : 92%

BR : 95%

SK : 95%

Monitoring information @ each SD

Every second

- # of clock pulse between each 1 PPS from GPS
- Time stamp of GPS
- # of trigger above 3 MIP.

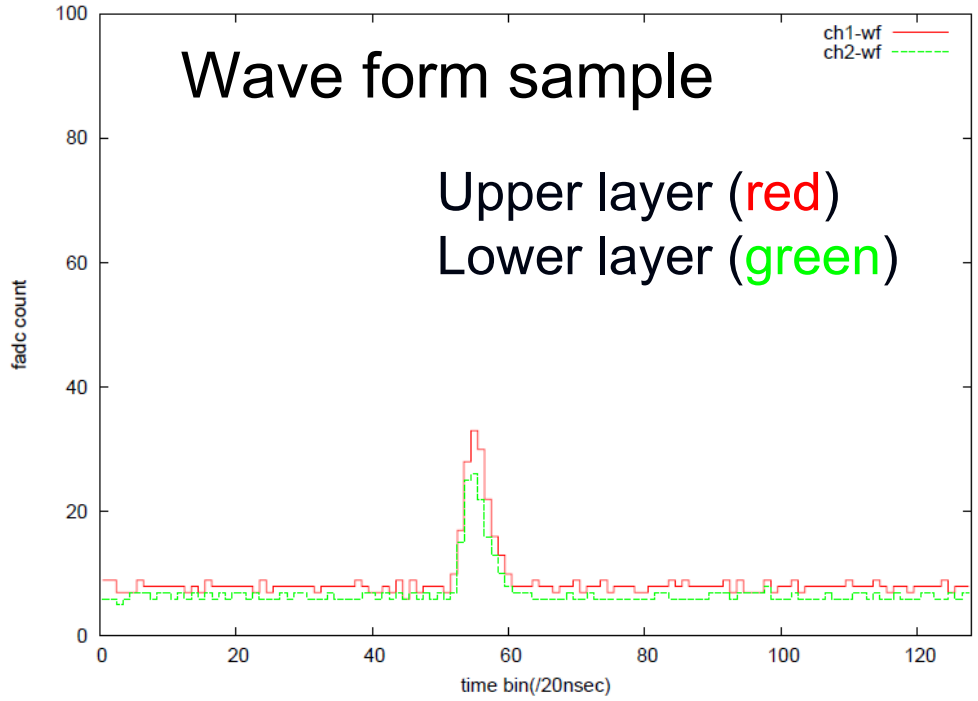
Every minute

- # of trigger above 0.3 MIP
- Envorinmental monitor
  - Battery voltage, charge current
  - Solar panel output voltage
  - Temperatures of SD equipments
  - Humidity in the detector box

Every 10 minutes

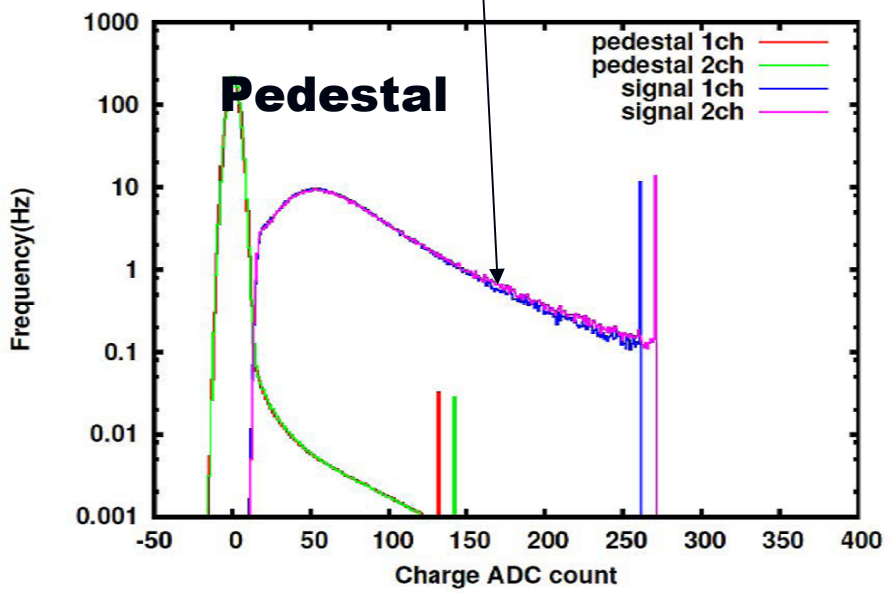
- Histograms of cosmic rays & pedestal distributions
- Histograms to check PMT linearity
- # of satellites used by GPS.

Detector response of SD



20nsec 2V/12bit resol

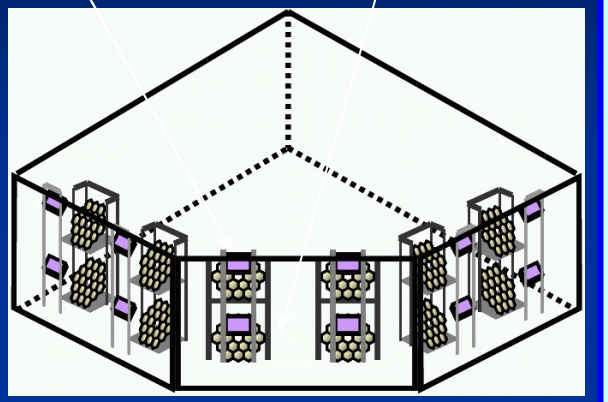
Distribution of Integrated FADC Value（10min）

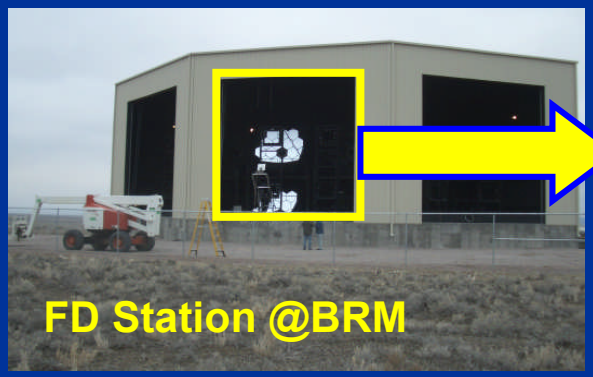


Trigger-frequency .
>0.3mip ～720Hz
>3mip 30Hz,(20Hz)

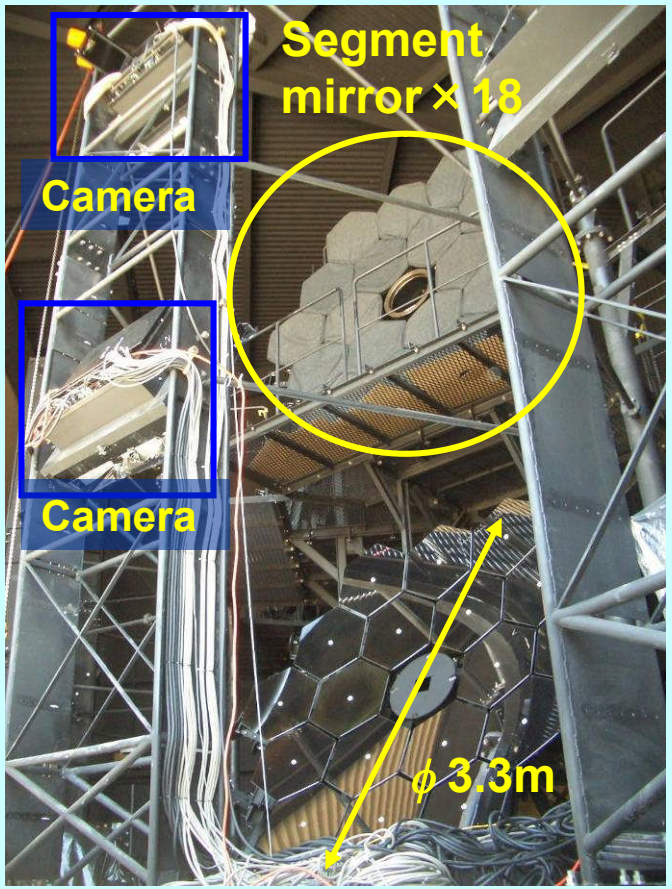
TA FD station & Fluorescence Telescopes

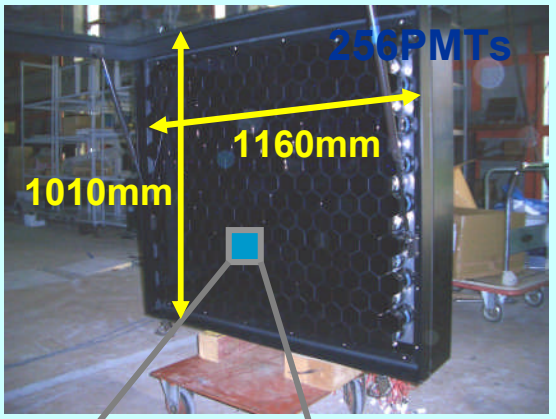
12 telescopes / station
(upper x 6 lower × 6)

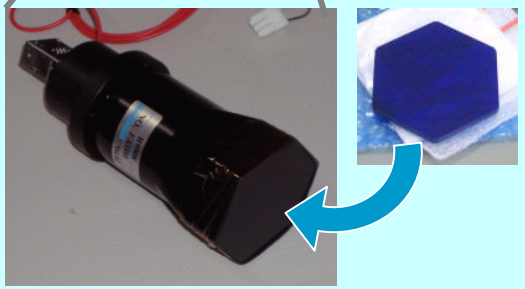




fluorescence telescope







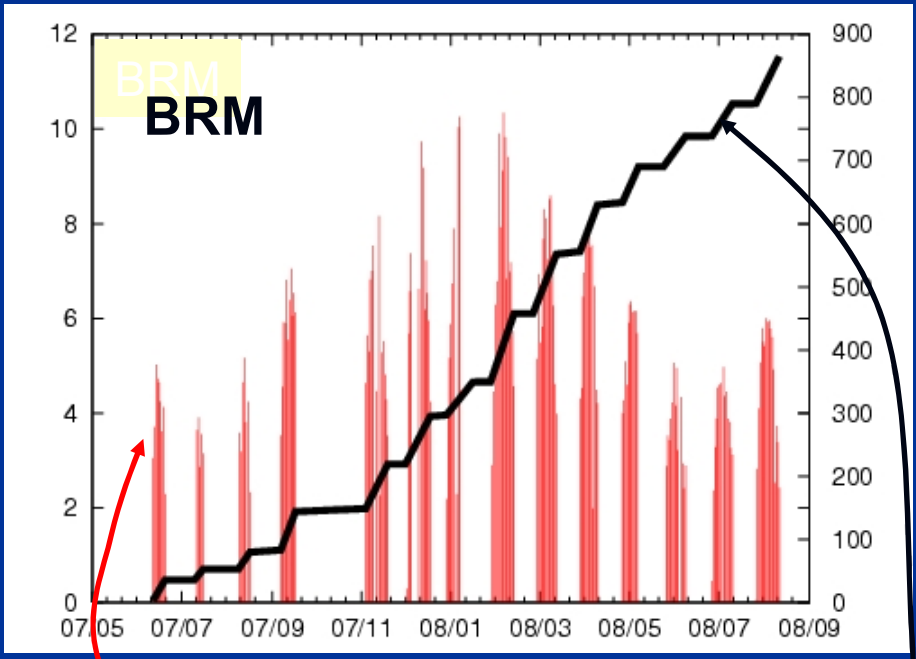
hexisagonal PMT+BG3 filter
(Hamamatsu R9508)

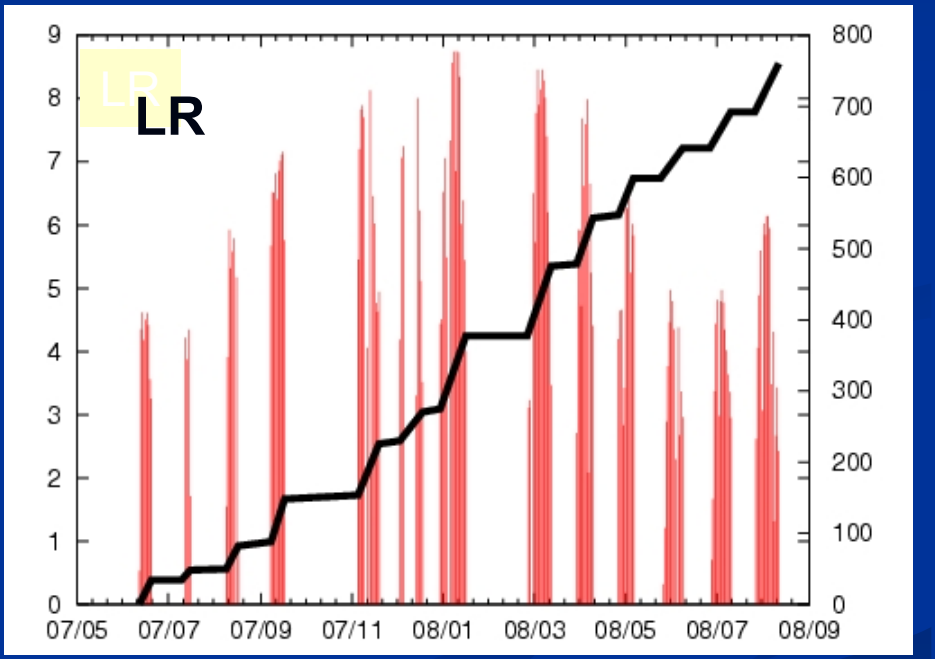
FOV
Azimuth: 18°×6=108°
elevation:
- **Upper side: 3°～18°**
- **Lower side:17.7°～33°**

Status of FD Observation

2007/06 start FD(BRM,LR) observation

2007/11 start observation with all the three FD stations



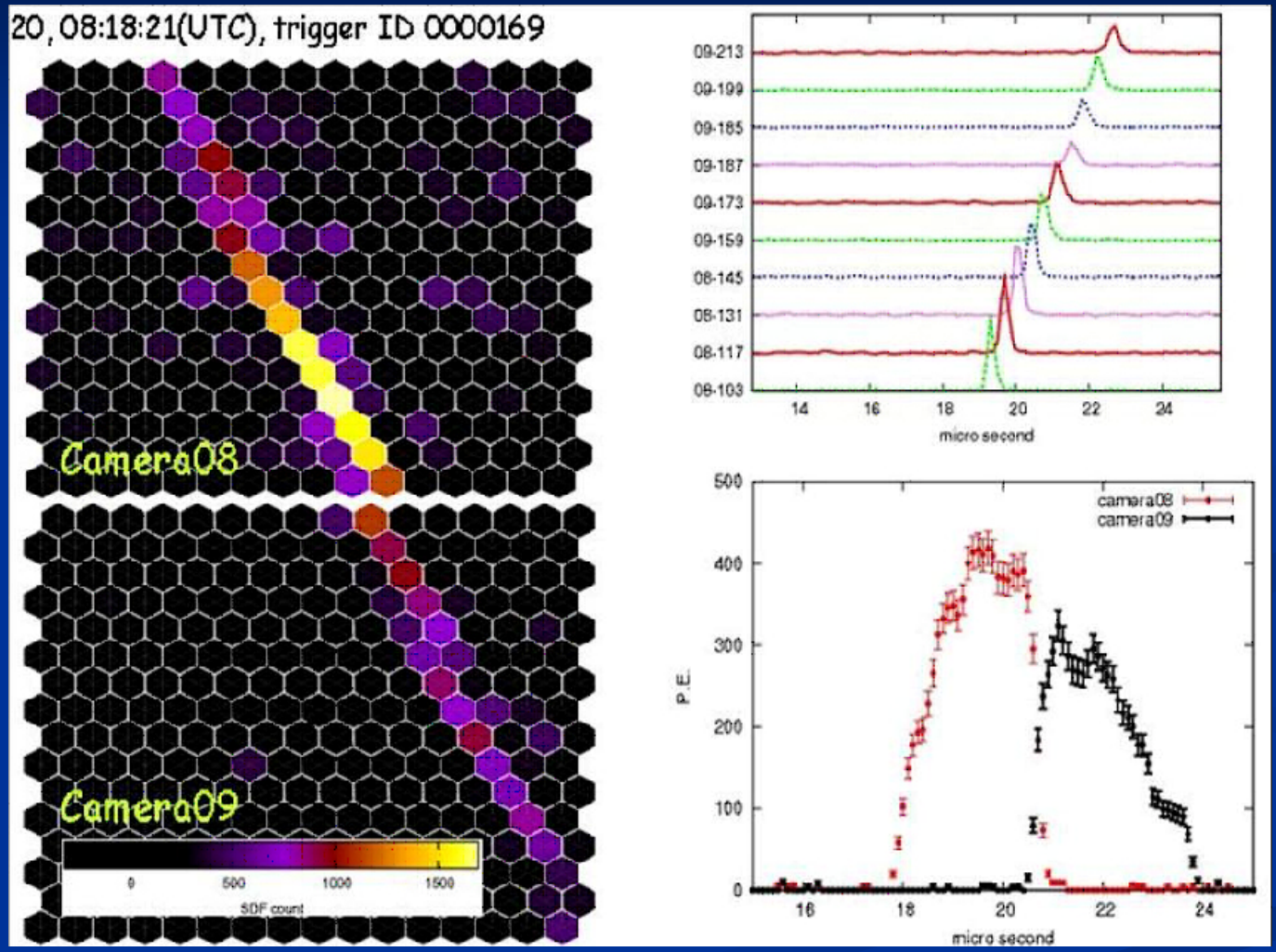


Total observation time

BRM: 860 hr

LR: 760 hr_{24}

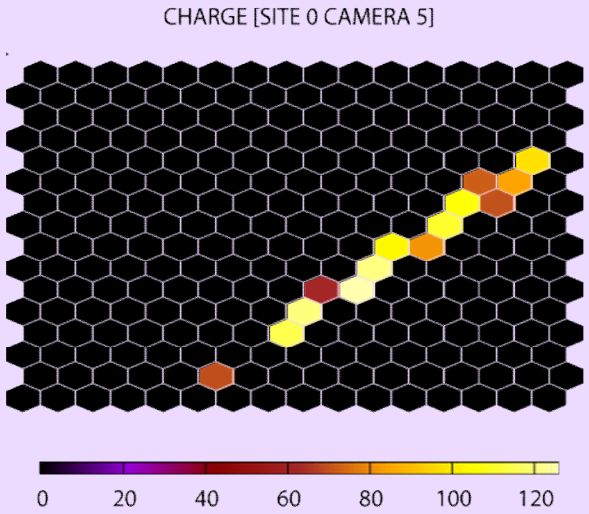
FD observation



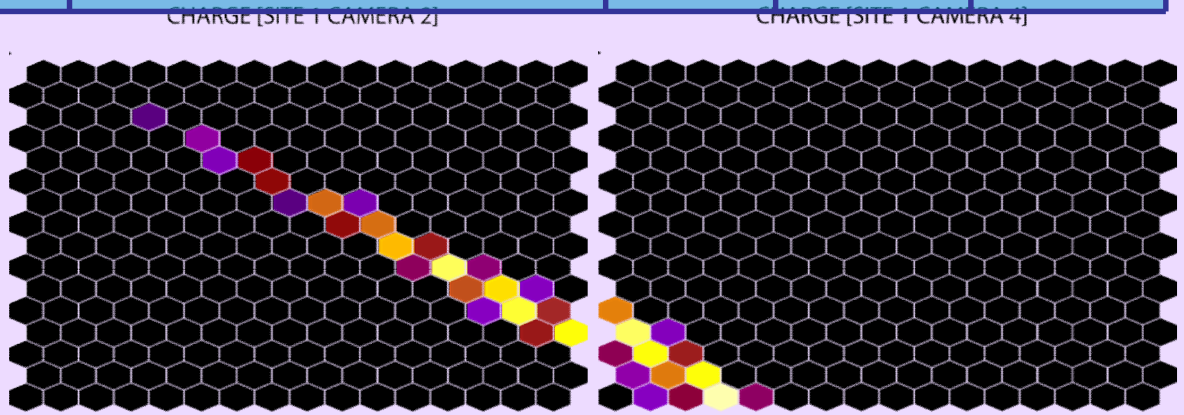
Charge

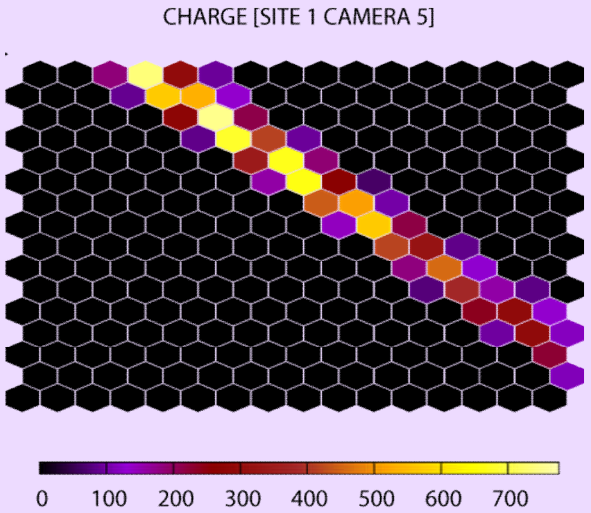
	Time(UTC)	RUN-ID	TRIG-ID	CAM-ID
BRM	07/11/19 09:03:09.753991850	111905	107	5
LR	07/11/19 09:03:09.753955600	111907	4641	2, 4, 5

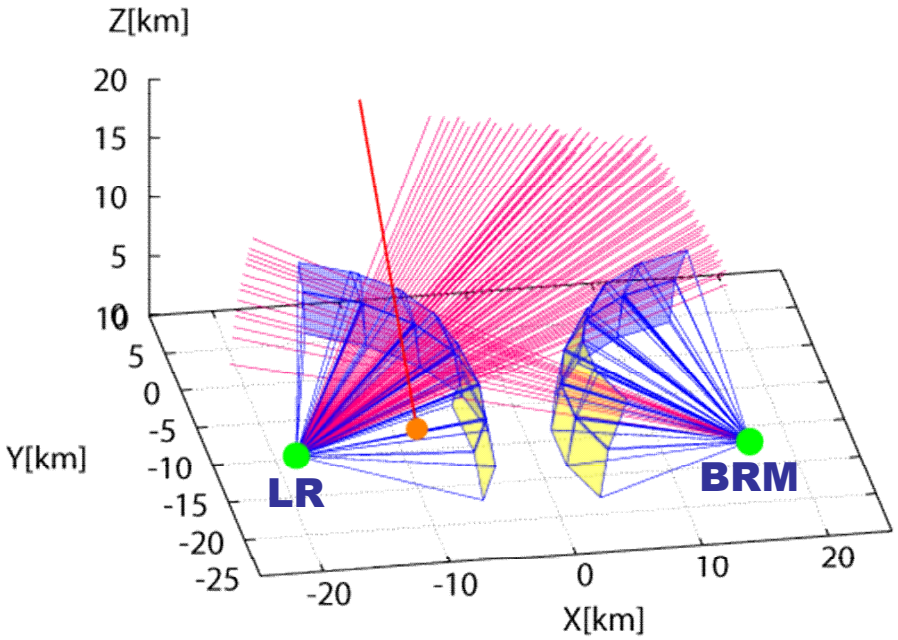
BRM



LR

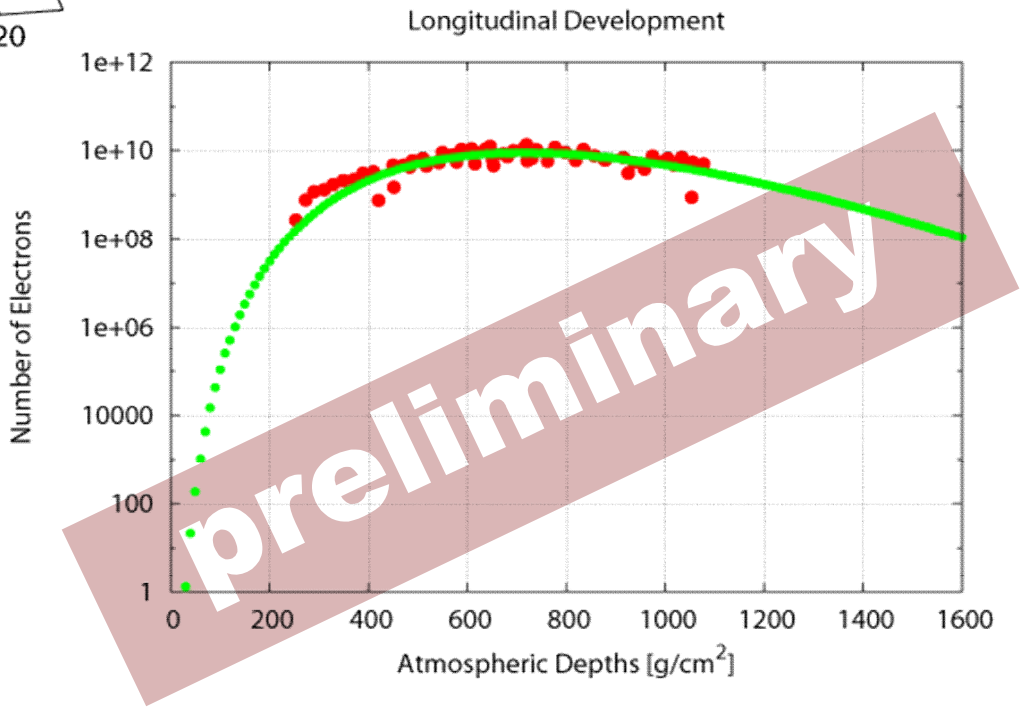




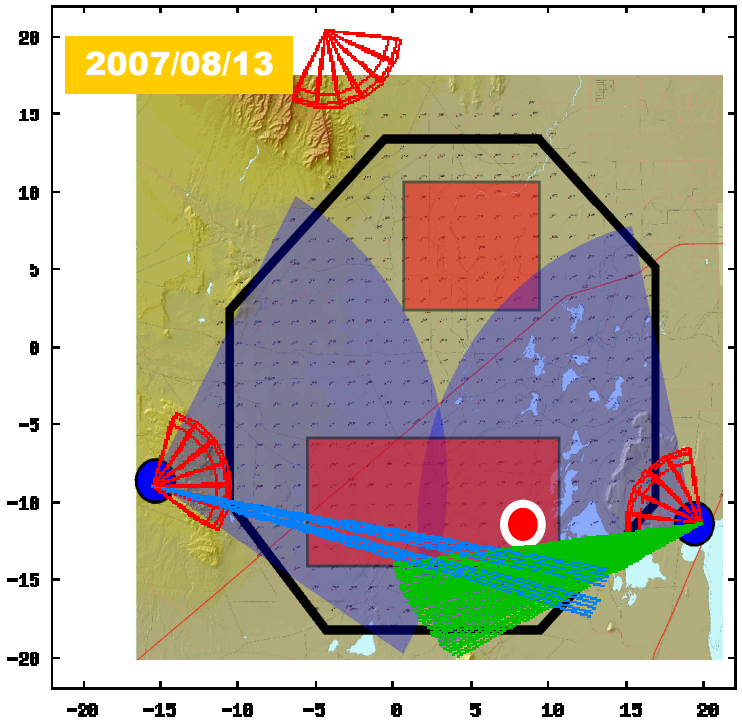


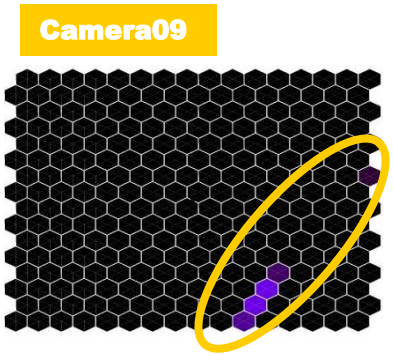
θ [deg]	ϕ [deg]	core position (x, y) [km]
45.8	−0.5	(−8.2, −7.4)

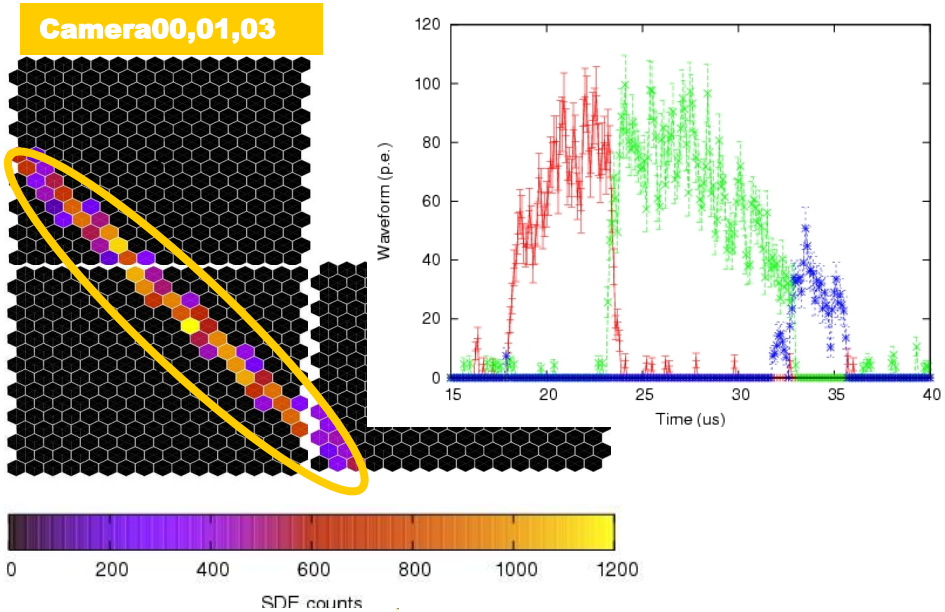
X_1 [g/cm^2]	X_{max} [g/cm^2]	N_{max}	E_0 [eV]
0.0	720.0	$2.4*10^9$	$3.0*10^{18}$

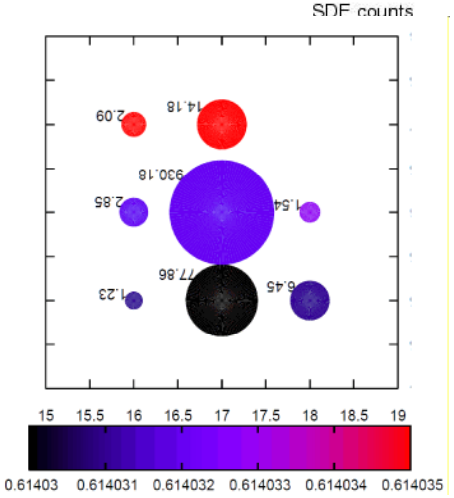


Stereo hybrid event

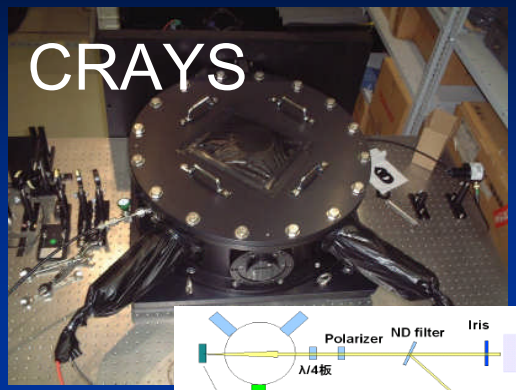


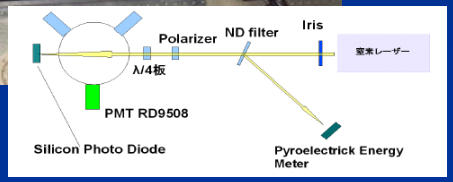


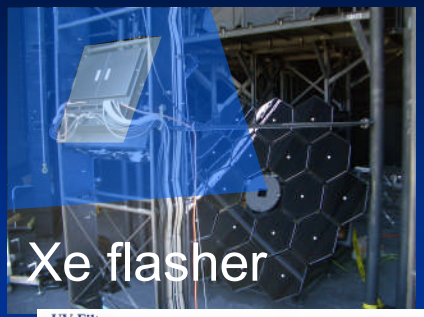


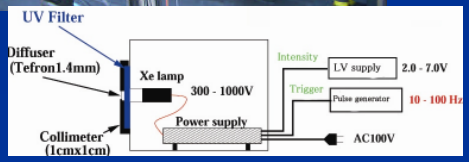


FD calibration





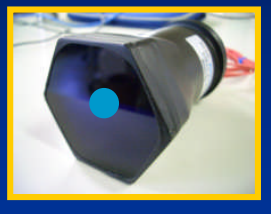


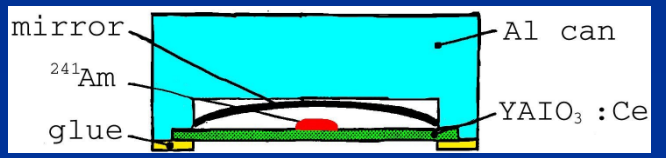


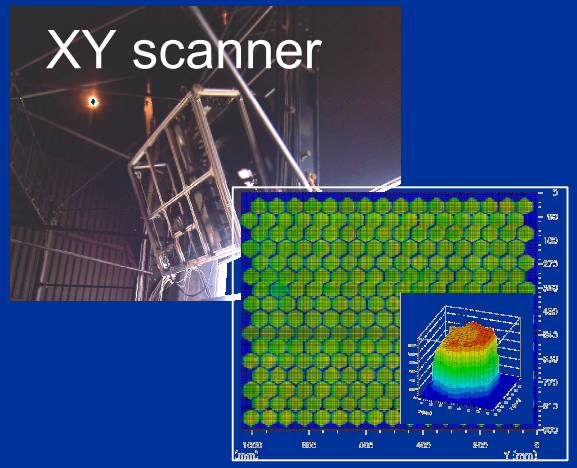
YAP pulser

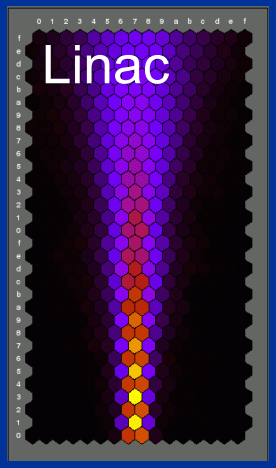
($YAlO_3$:Ce+^{241}Am)

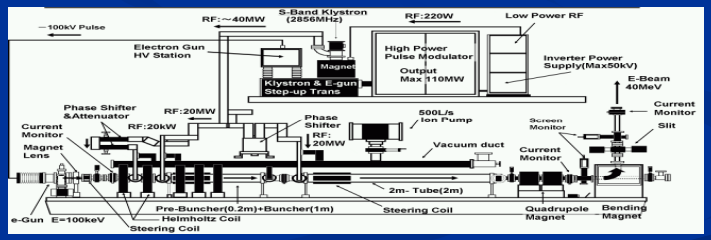
Peak 365nm
50Hz～100Hz











10MeV~40MeV 10^9 e-

10^{16}eV @ 100m from FD station

FD as "Art of Calibration"

Energy Deposit =

1. Fluorescence Efficiency
2. x Rayleigh and Mie Scattering Loss
3. x Obscuration (by camera and supporting structures)
4. x Mirror Area and Reflectivity
5. x Transparency of Camera Window (UV transp. lucite)
6. x Transmittance of BG3 Filter (against Night Sky bg)
7. x PMT Gap
8. x PMT Quantum Efficiency
9. x PMT (dinode) Collection Efficiency
10. x PMT Gain
11. x Preamplifier Gain
12. x Cable Attenuation
13. x Shaper/Amplifier Gain
14. x FADC Conversion Gain
15. x FADC Count

5%? x SQRT(15) ~ 20% ???

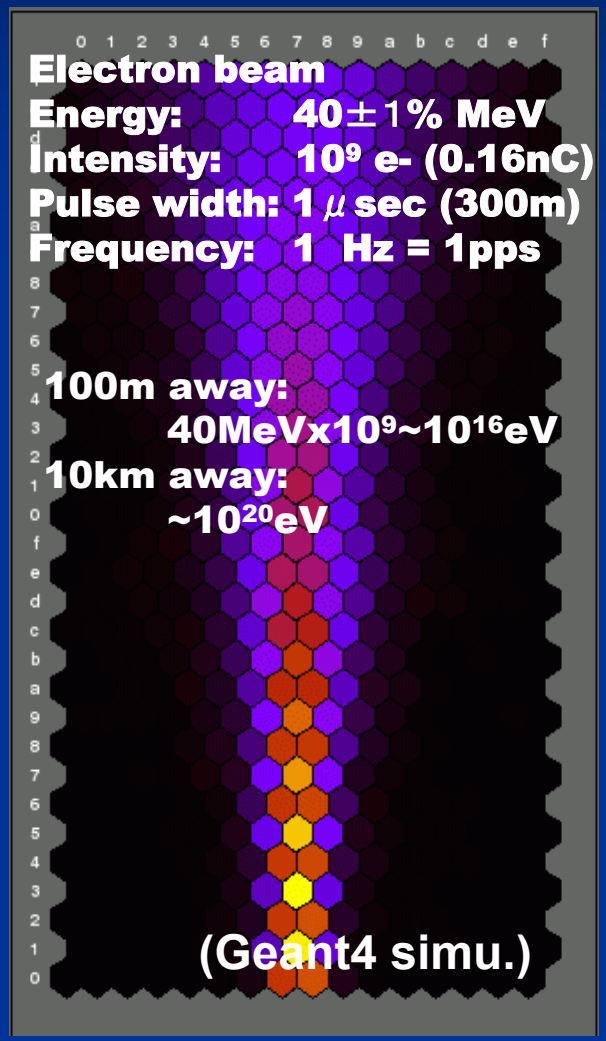
Piece to Piece Calibration is needed.
We also have Xe flasher, YAP and LED but....

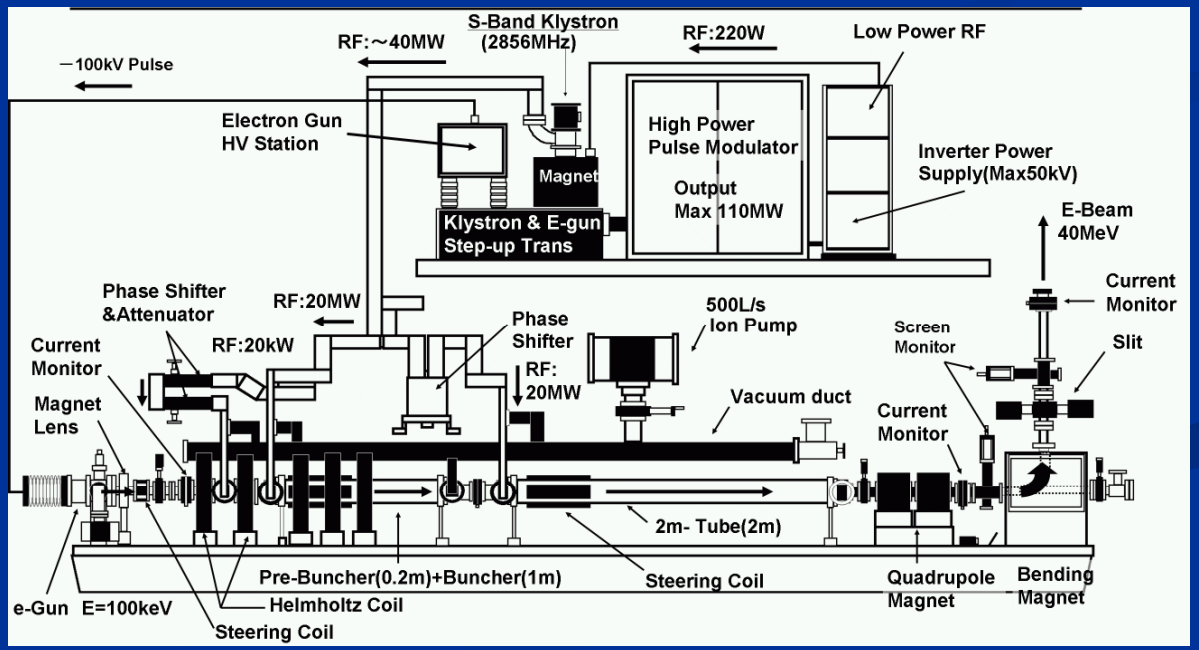
Energy Deposit → FADC count

Direct End to End Calibration is wanted.

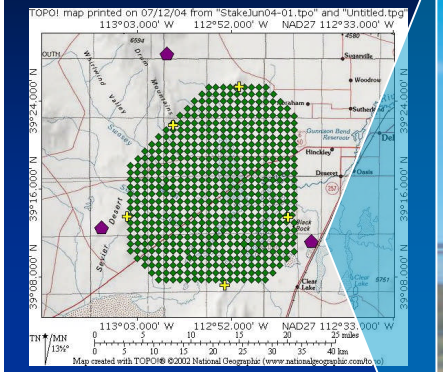
Electron linear accelerator

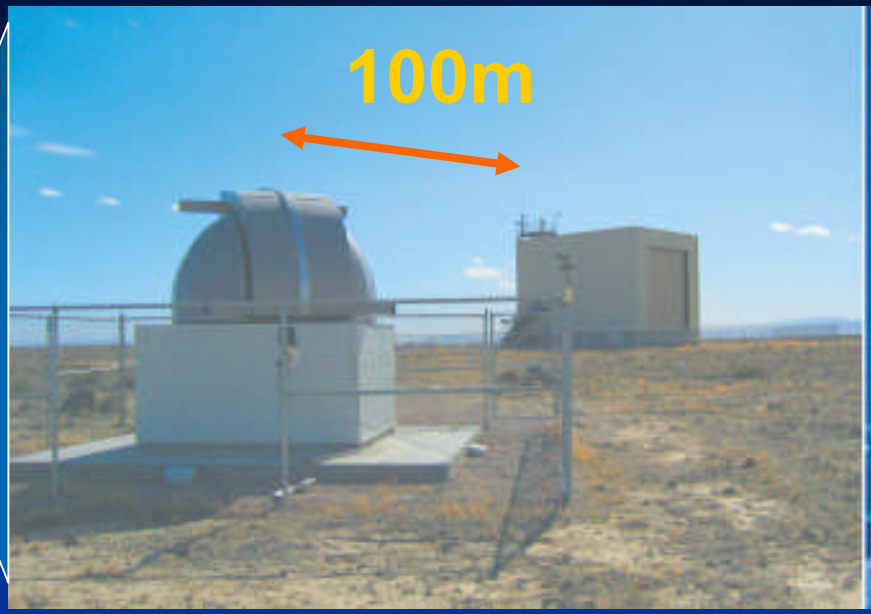
Next spring at the TA site





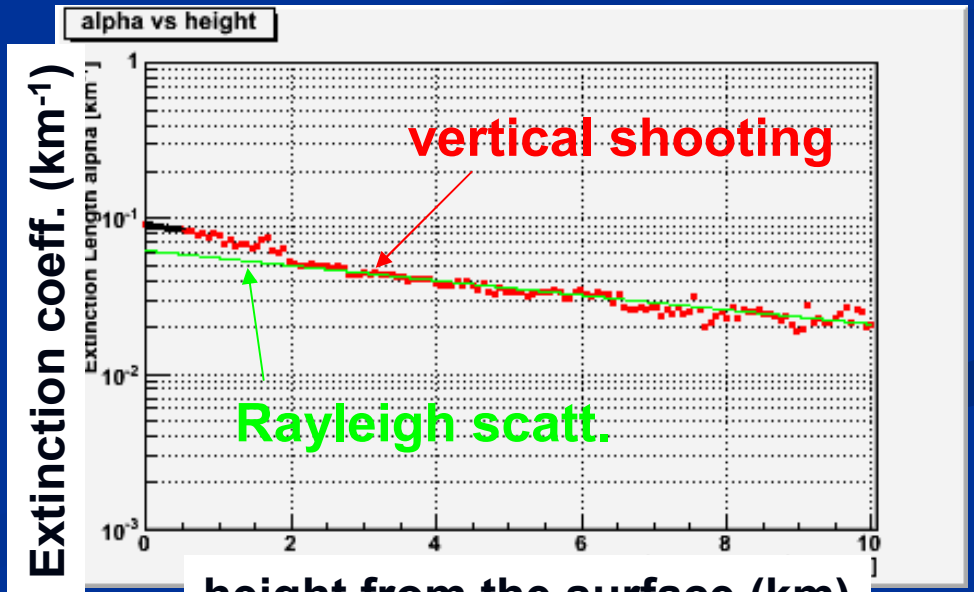
LIDAR





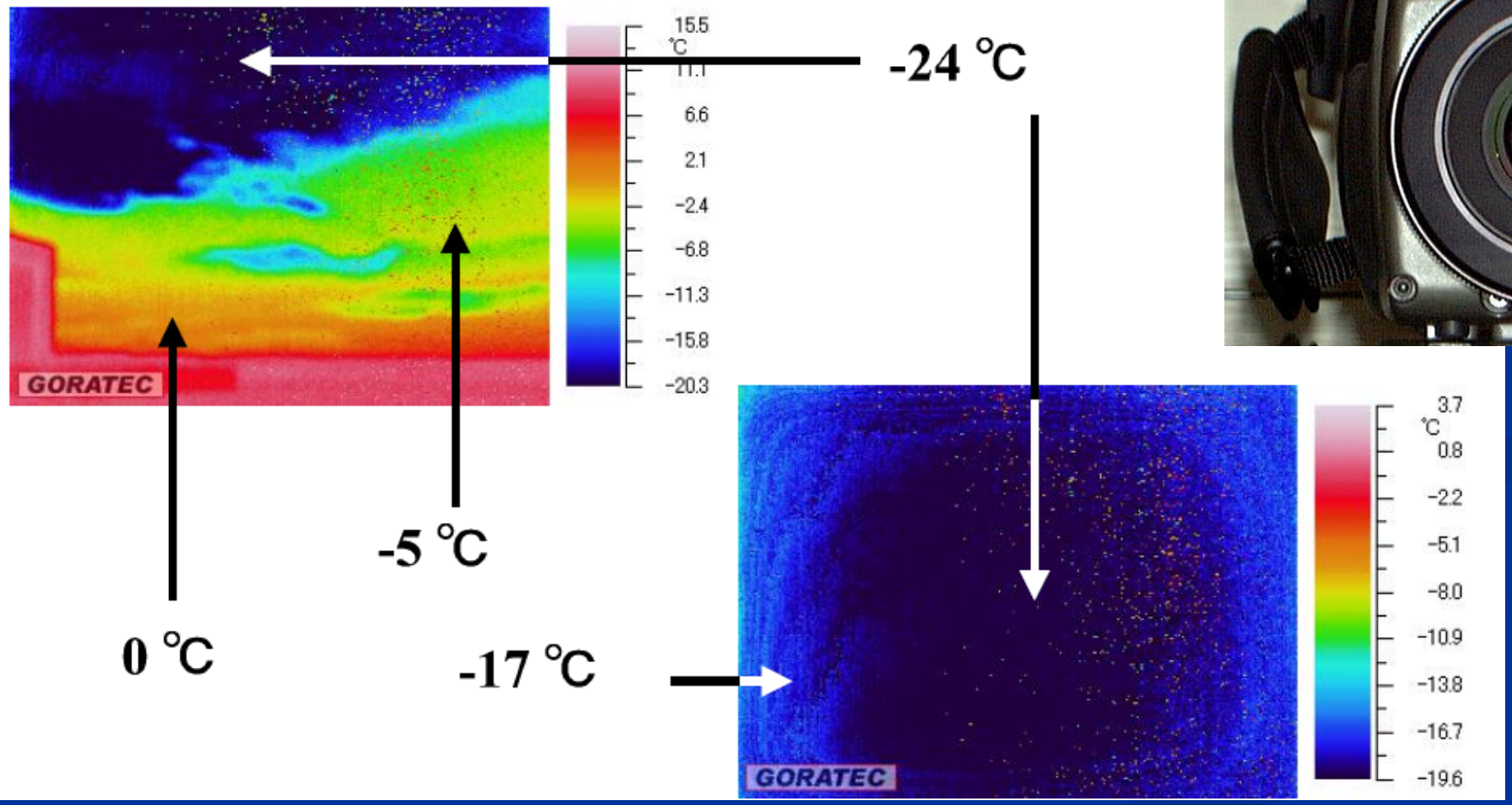
Detect backscattered light

Extinction coefficient
Vertical Aerosol Optical Depth
(*VAOD*)

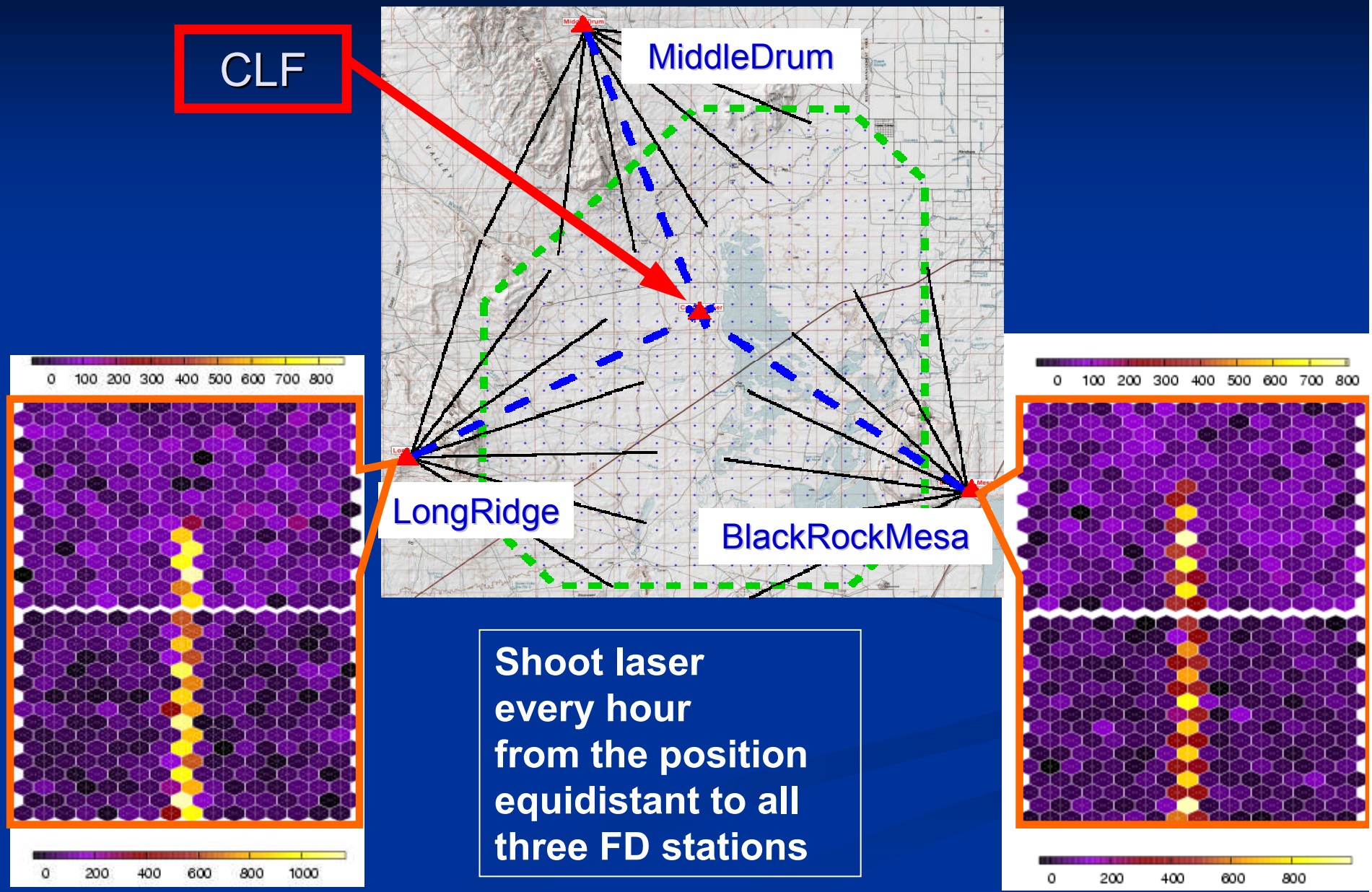


IR camera , Cloud monitoring

- Sensitivity: $8\mu m$–$14\mu m$ (-20°C–300°C)
- FoV: $25.8°(H)\times19.5°(V)$ (320×236pixels)



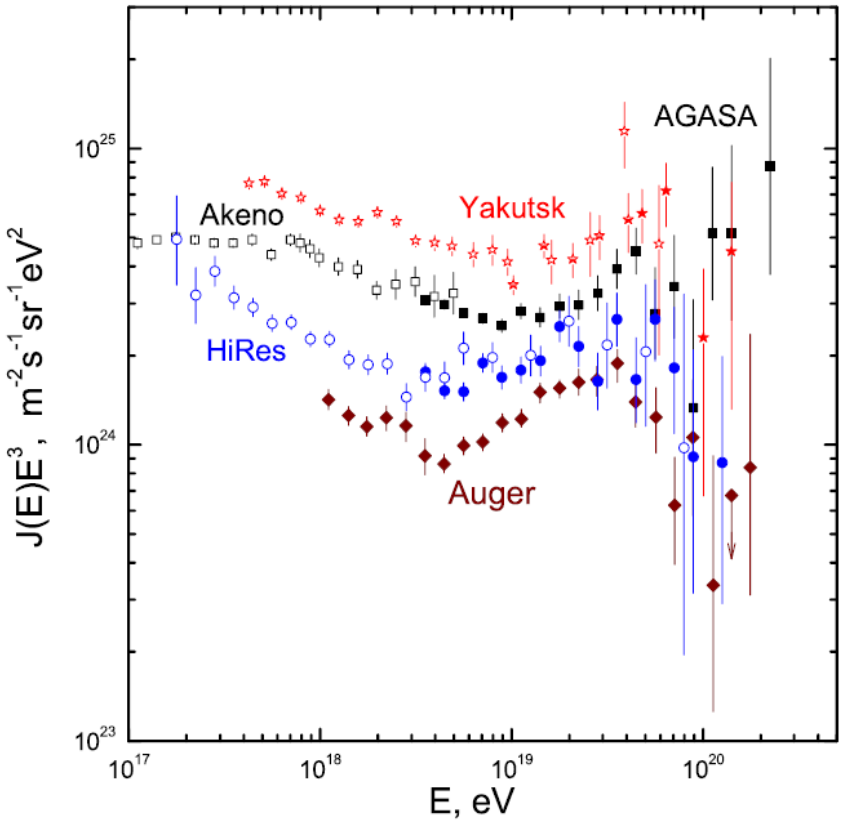
Central Laser Facility (CLF)

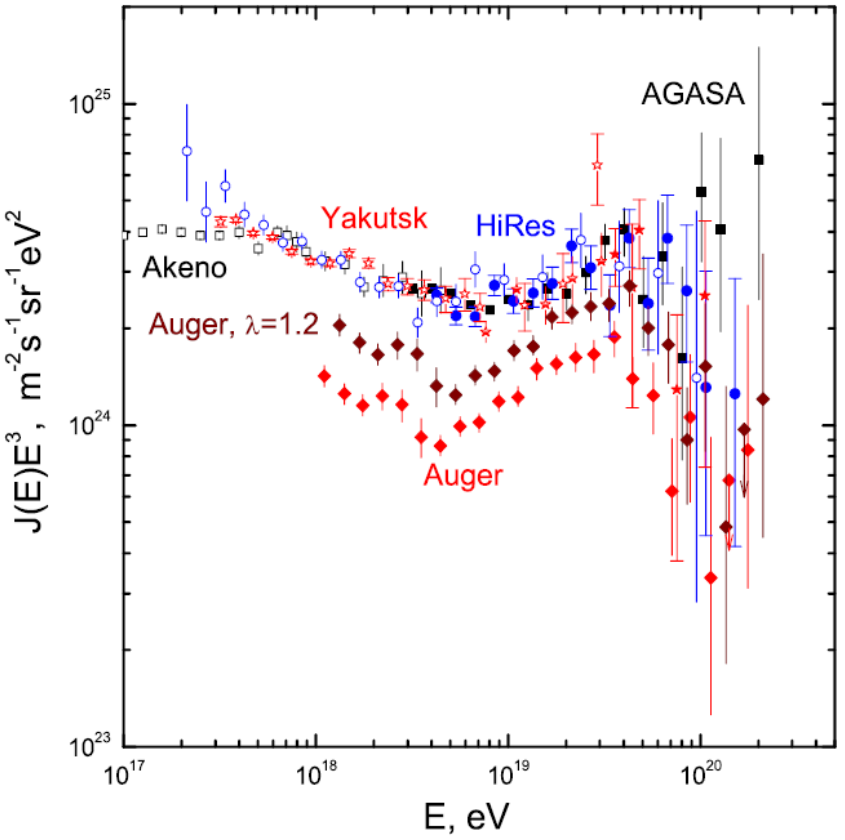


Shoot laser every hour from the position equidistant to all three FD stations

Results from other experiments

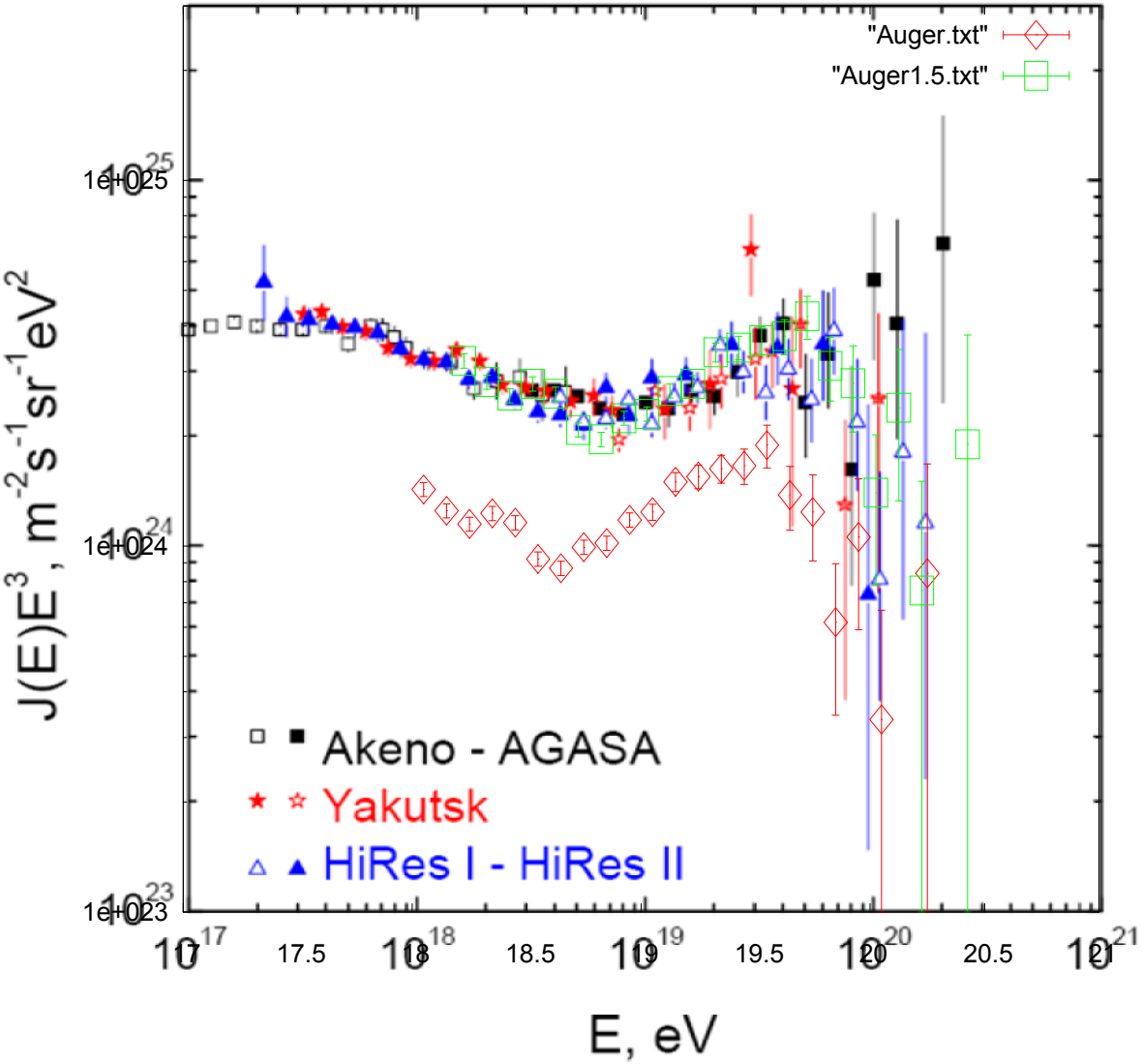
Pair Creation Dip ($p+g_{CMB} \rightarrow p+e^{-}+e^{+}$) by V.Berezinsky

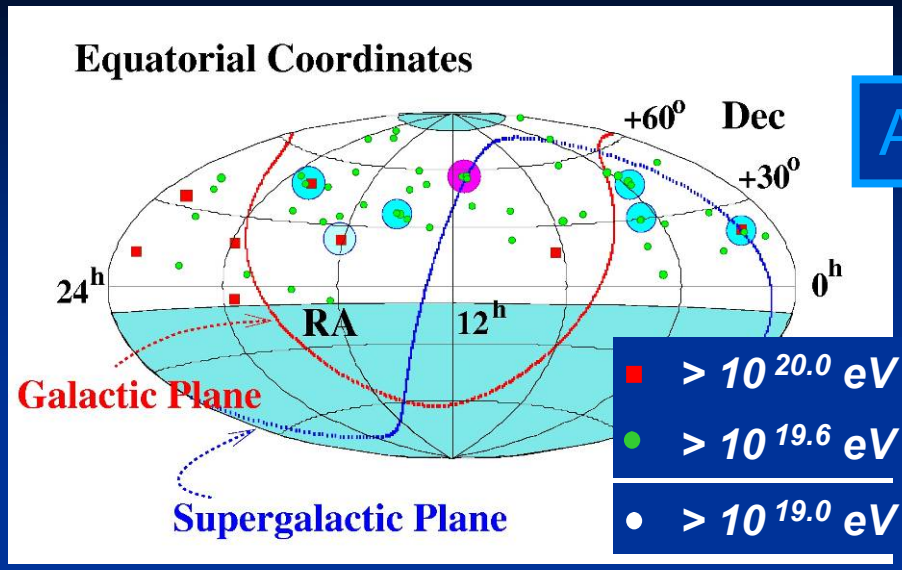




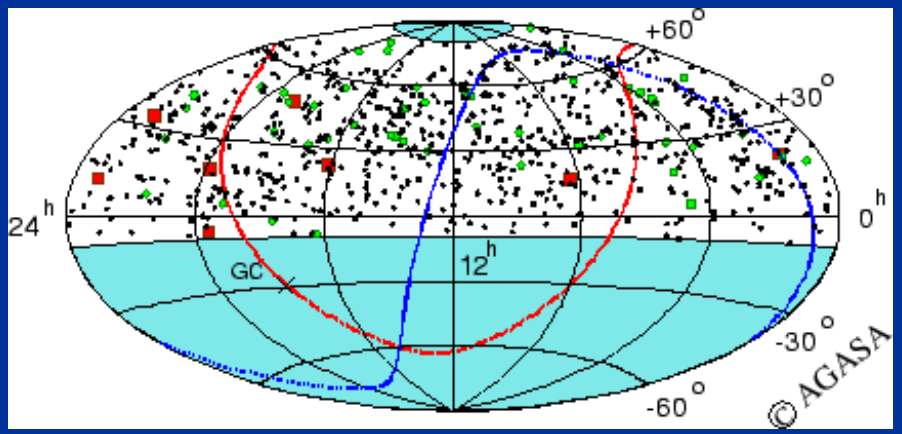
Auger Spectrum x 1.5 (by M.Teshima)

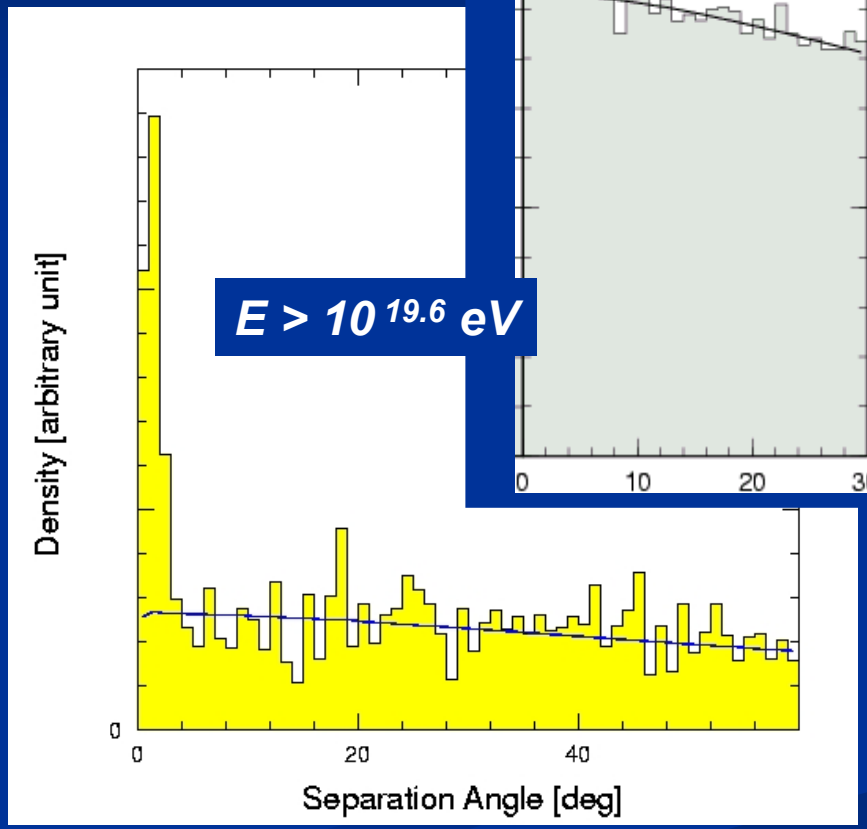
ICRC07





AGASA





Arrival direction and separation angle → clusters for E>$10^{19.6}$eV ?

No corresponding objects (~<50Mpc)

GZK Cutoff ?

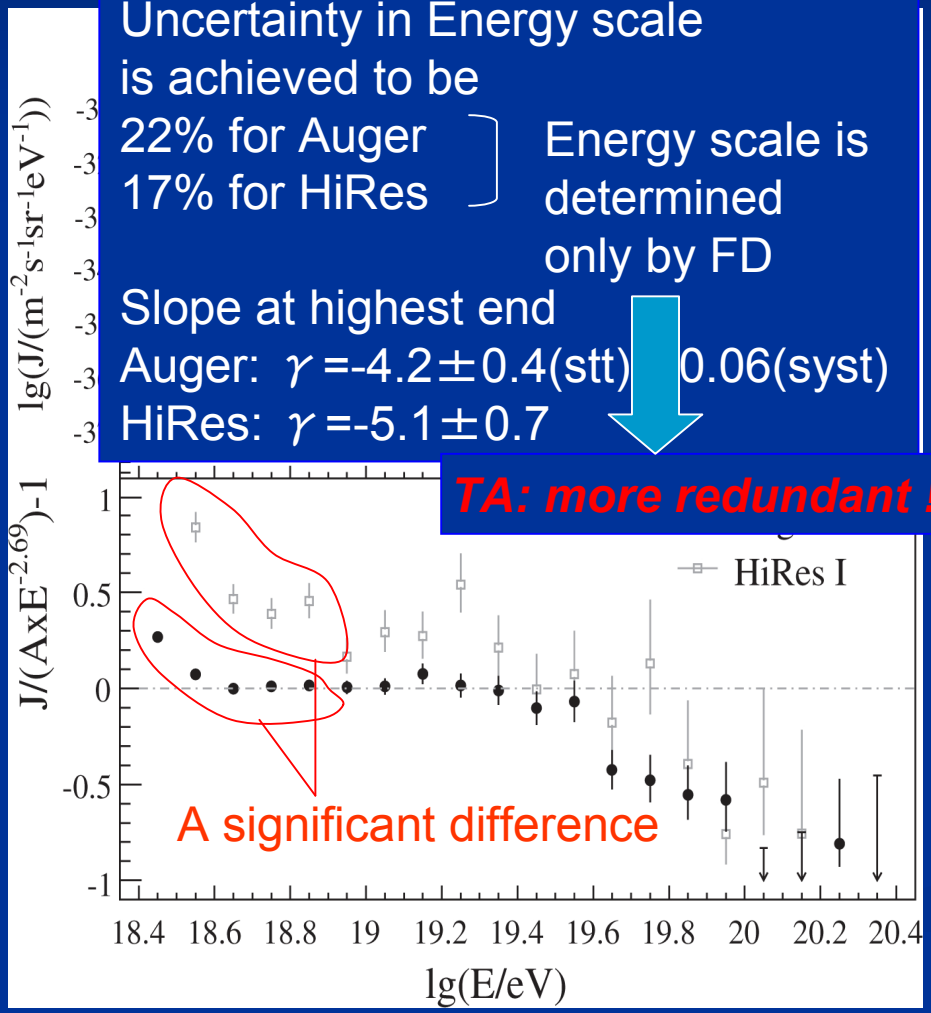
PRL 101, 061101 (2008)

Uncertainty in Energy scale is achieved to be
22% for Auger
17% for HiRes

Energy scale is determined only by FD

Slope at highest end
Auger: γ =-4.2±0.4(stt) 0.06(syst)
HiRes: γ =-5.1±0.7

TA: more redundant !

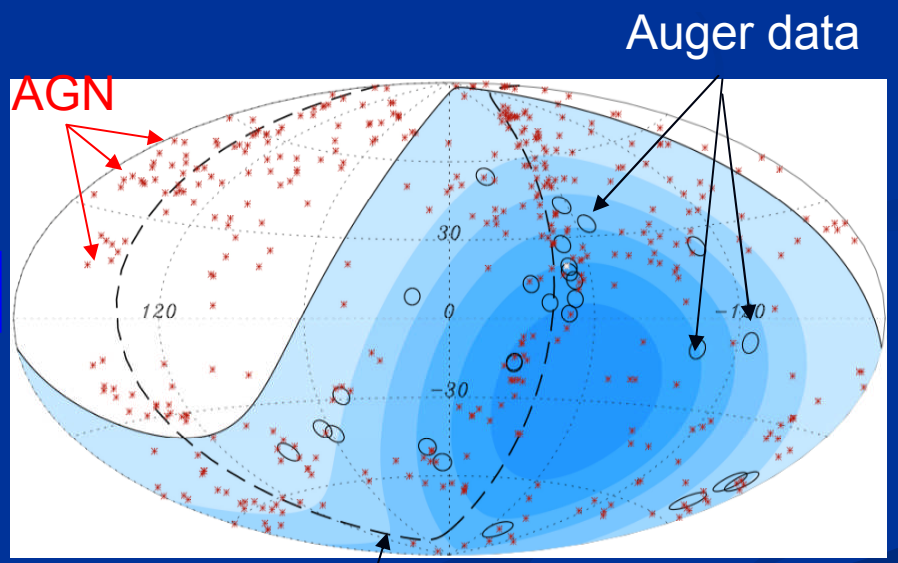


Correlation ?

HiRes: no significant correlation with AGN (astro-ph/0804.0382)

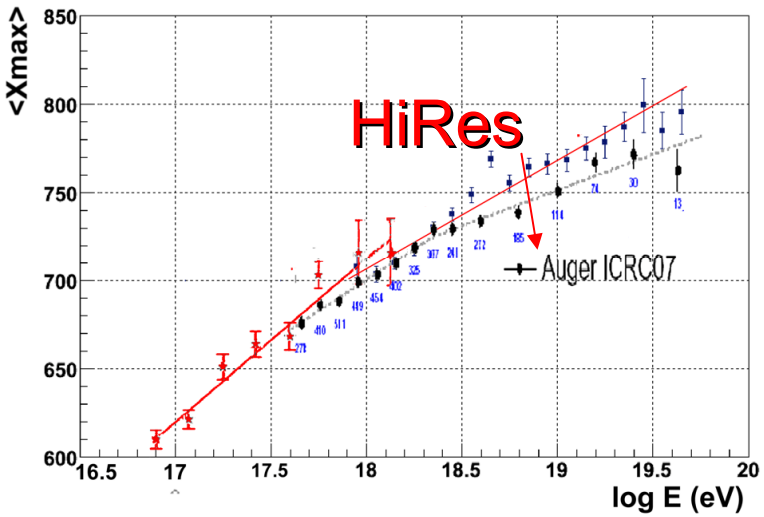
Science **318**, 939 (2007) from Auger

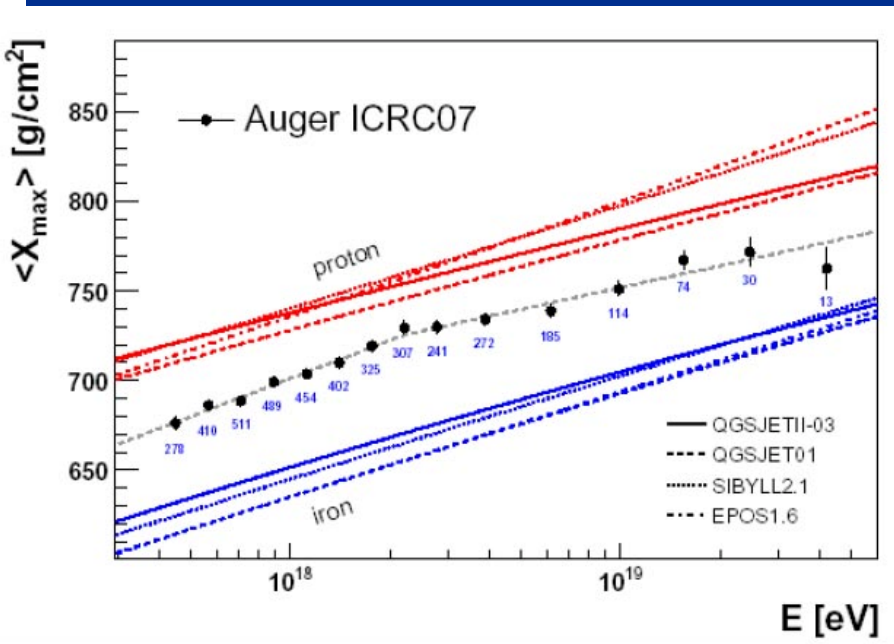
Anisotropy: 3σ level (>~60 EeV)



TA: northern hemisphere

Xmax : Auger and HiRes





TA will measure Xmax for chemical composition.

TA and Auger

- TA : Utah in USA (northern hemisphere)
  - TA, AGASA, HiRes : 35^{o}~40^{o}N
- Auger : Argentina (southern hemisphere)

→ complementary

Air shower simulation

- Use quasi-full air shower MC simulation (COSMOS by Kasahara)
  - Will mplement LHCf data to air shower full MC
  - Will implement recent knowledge of hadron interaction to MC
  - compare with Corsika

TA will present the first result at ICRC09 with data equivalent of about 1 AGASA !

Summary

- Fluorescence Detectors (FD)
  - All the three FD stations are operating from November, 2007.
- Surface Detectors (SD)
  - **503** SDs were deployed by the end of 2007.
  - The whole SD array is operating from March, 2008.
- **We are taking data to explore the origin of highest energy cosmic rays.**
- characteristics
  - Energy determination both with SD and FD
  - HiRes-I telescope was moved to the TA site.
  - electron LINAC will be installed at the TA site for absolute calibration of the telescope.

END

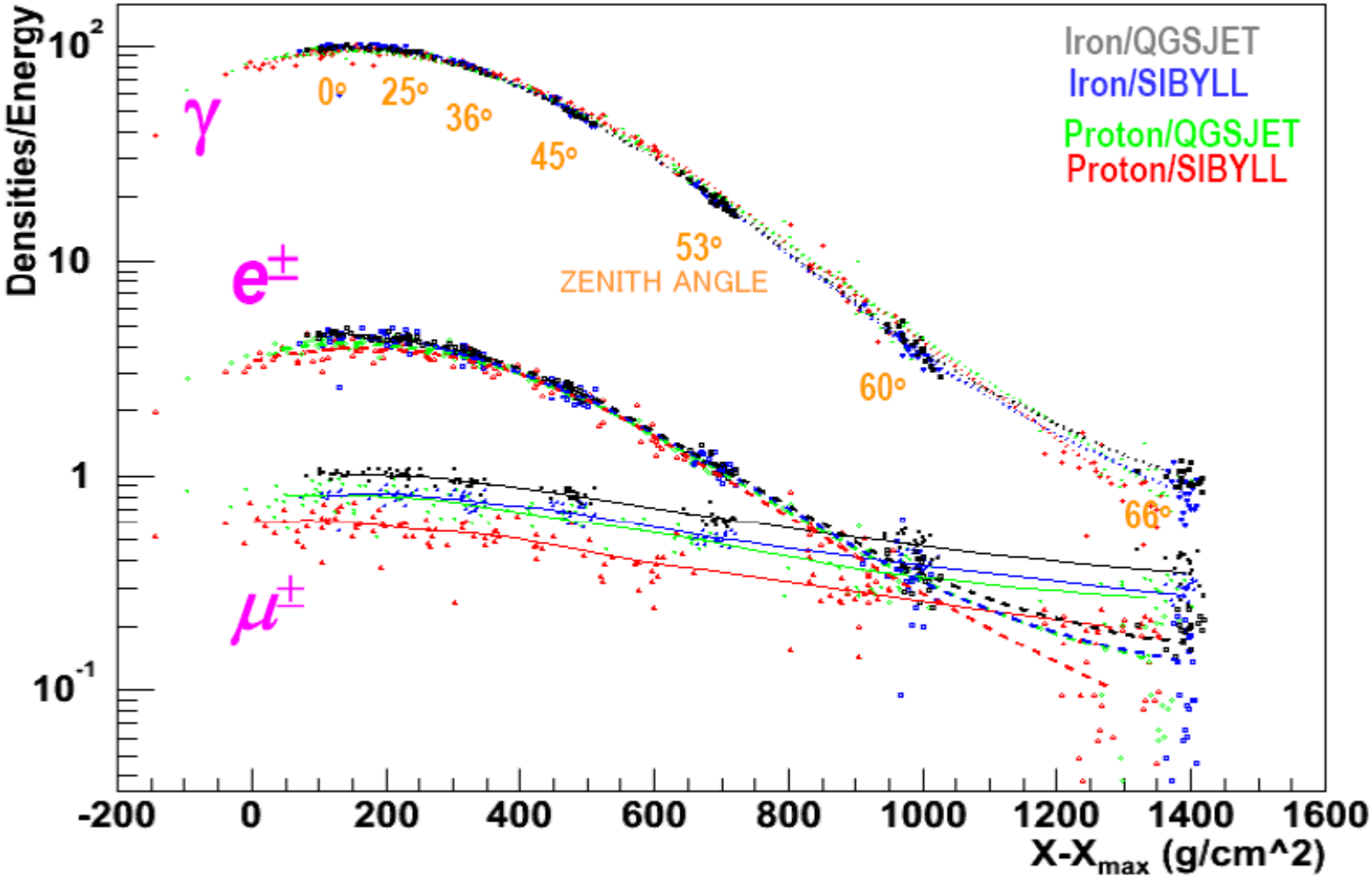
Performance of TA

	AGASA		
Total Acceptance		1,550	km^2 sr
SD Acceptance	140 km^2 sr	1,200	km^2 sr
FD Acceptance (stereo)		290	km^2 sr
FD Acceptance (mono)	FD →	470	km^2 sr
Hybrid Acceptance		120	km^2 sr
Energy Resolution	25 %	25	% or better
Energy Scale Uncertainty	18 %	10	%
SD Angular Resolution	2^0	2.0	degree or better
FD Angular Resolution (stereo)	→	0.6	degree
Hybrid Angular Resolution		0.5	degree
FD Xmax Resolution (stereo)	→	17	g cm^{-2}

Table 1: Projected Performance of TA. The values are estimated at 10^{20} eV. The total acceptance is the summation of the SD and the monocular FD acceptances. The energy resolution is derived from the SD and the energy scale uncertainty is from the FD.

AUGER

Particle density at 540m from shower core vs X - Xmax



ARISAKA
GAP 2004-037