2009年8月7日
宇宙線研究所セミナー

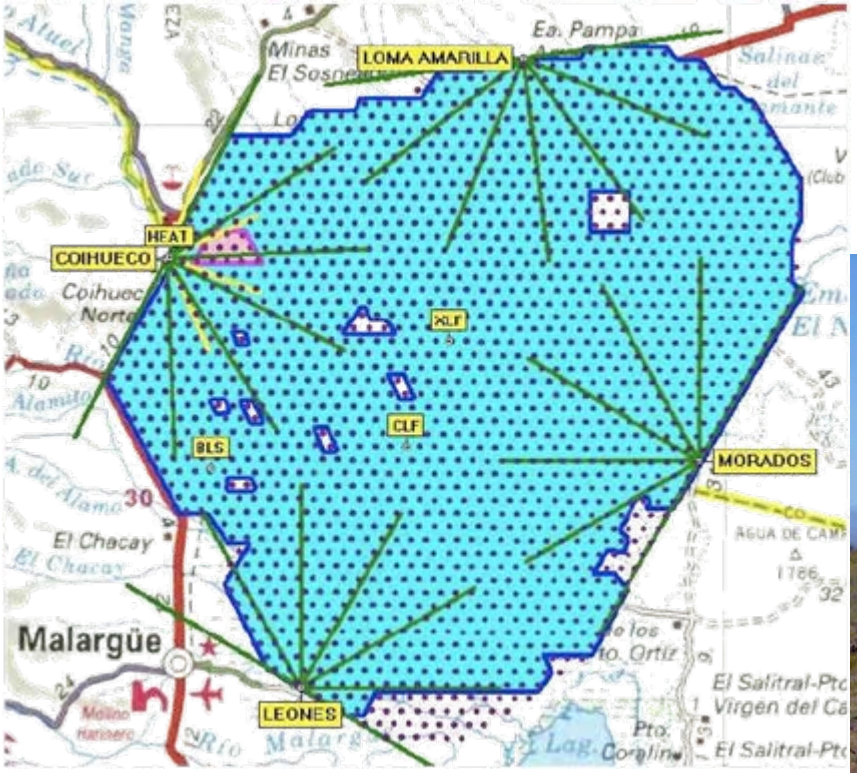
極高宇宙線測定の現状：ICRCよりの報告

宇宙線研究所・福島正己

Status of UHECR

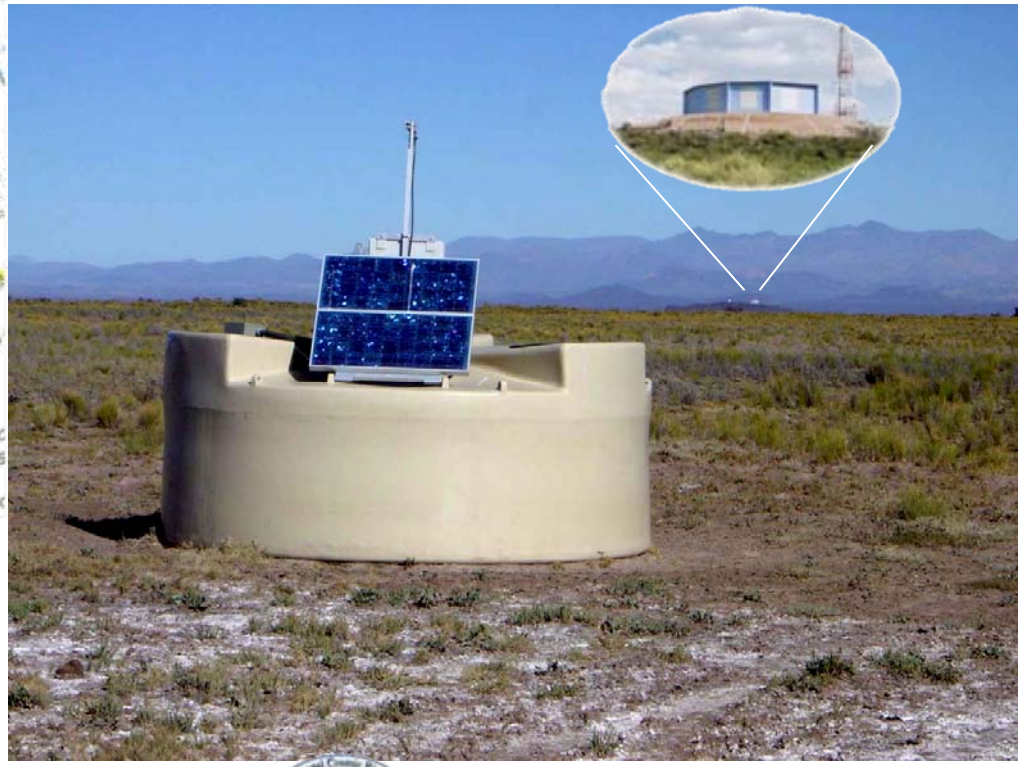
1. Energy Spectrum
2. Composition
3. Source and Anisotropy

The Auger Observatory in the Southern Hemisphere
Now fully deployed in Argentina



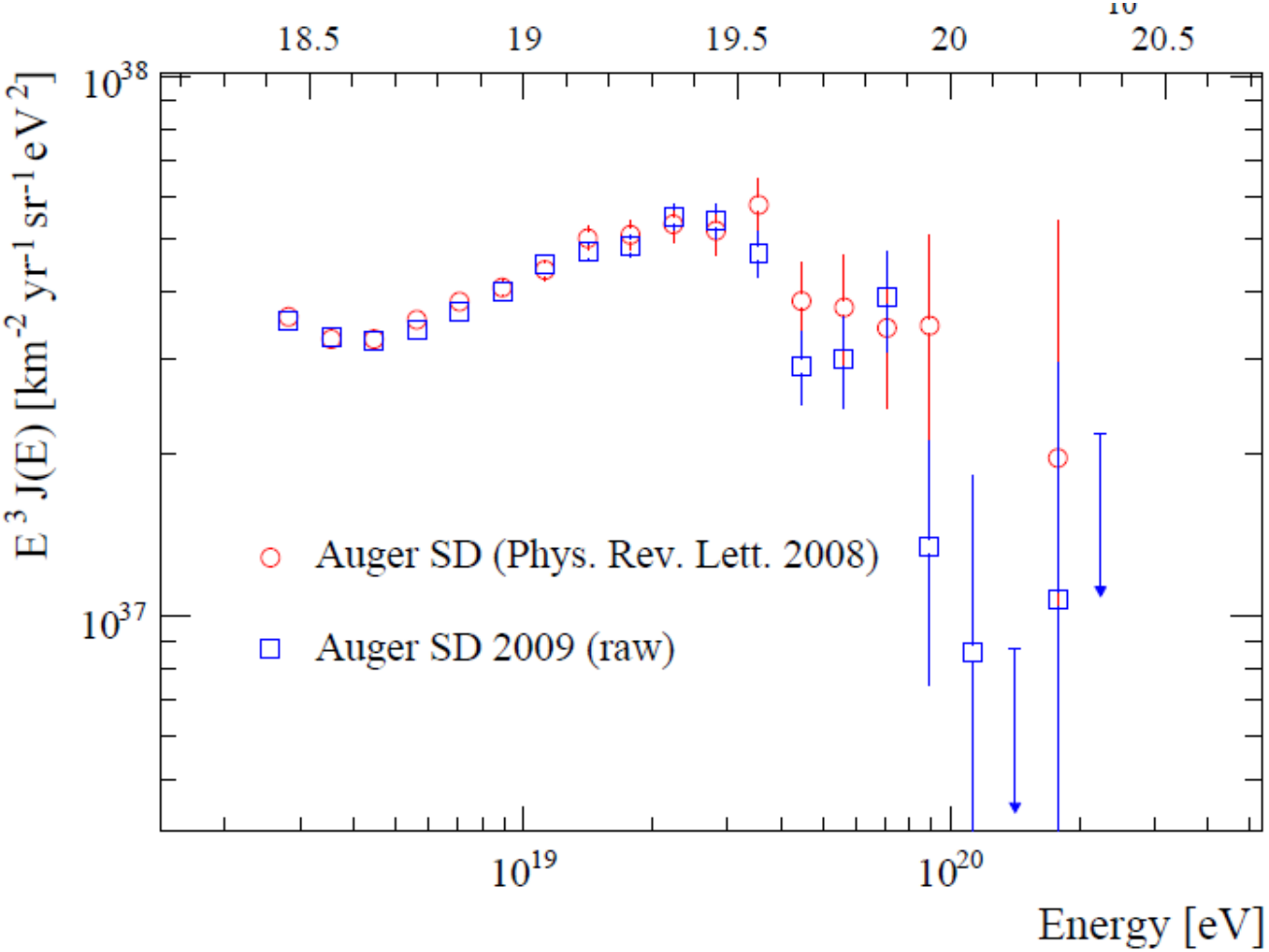
1600 water Cherenkov stations

24 fluorescence telescopes (30°x30°)



Highlight talk of P.Sommers

Auger SD: 08 vs 09

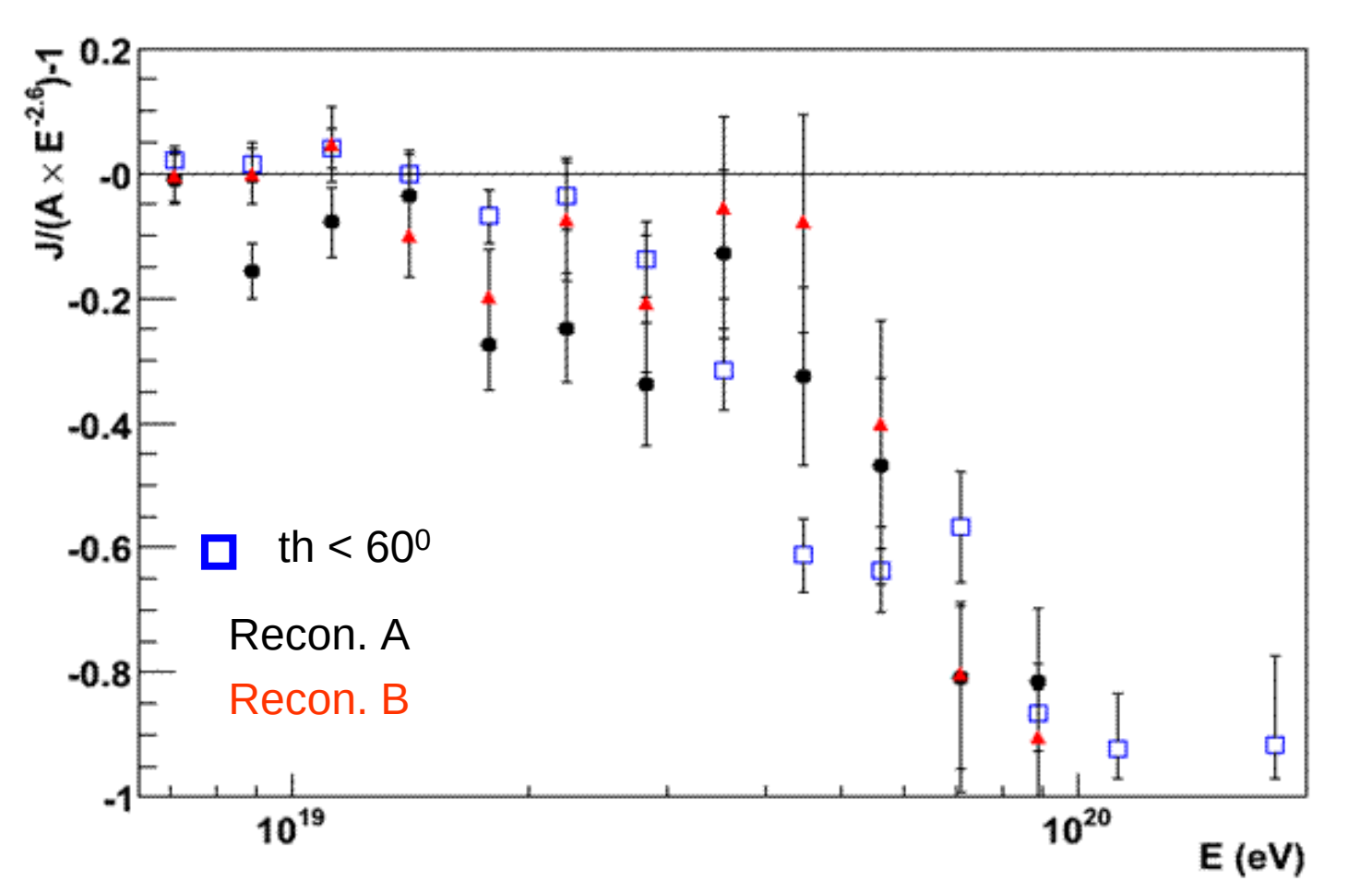


- $\mathcal{E} = 12\,790$ km^2 sr yr (PRL: 7 000 km^2 sr yr)
- energy calibration with full statistics

  C. DiGiulio (0142), this conf.

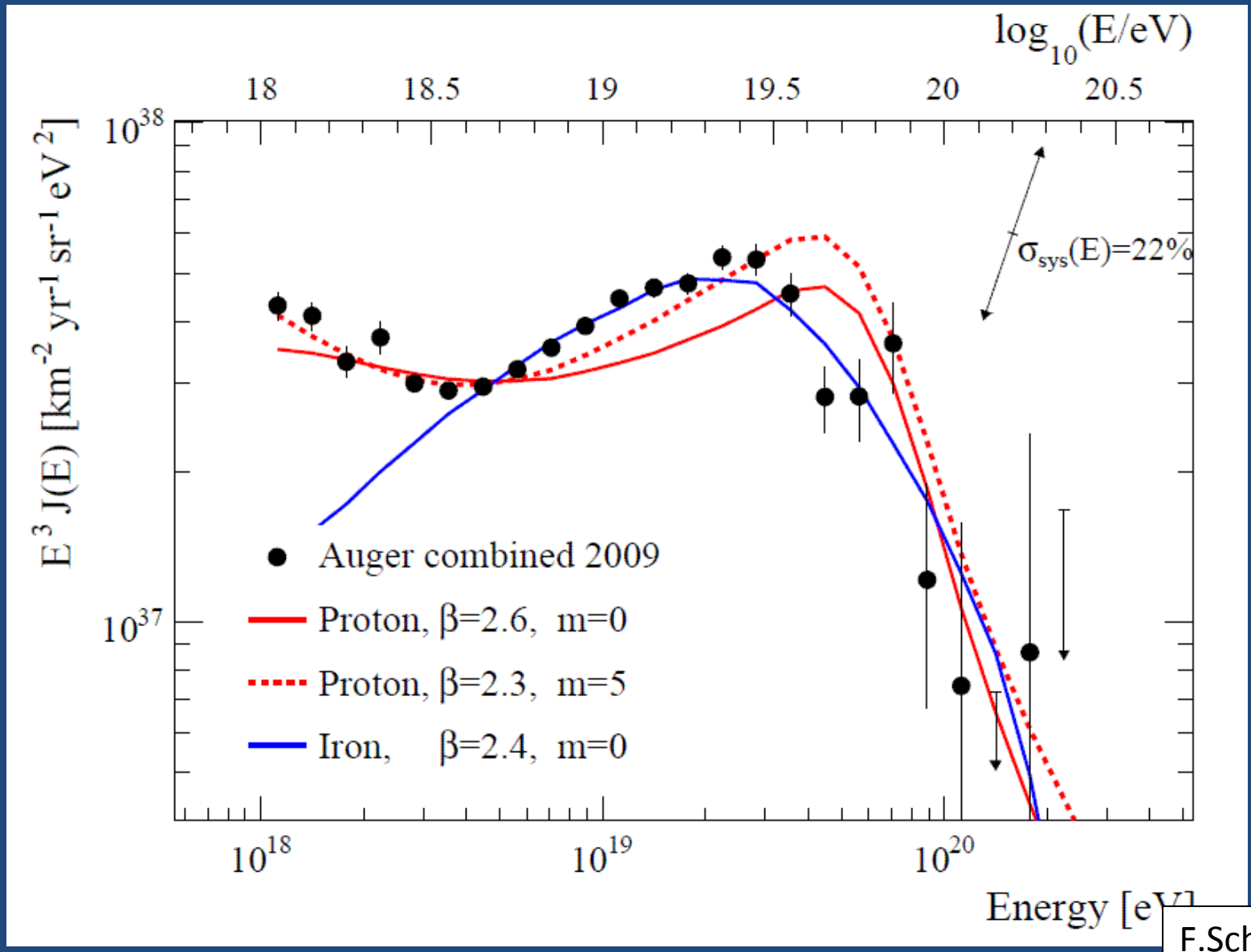
F.Schuessler

Auger SD (θ: 60^0-80^0)



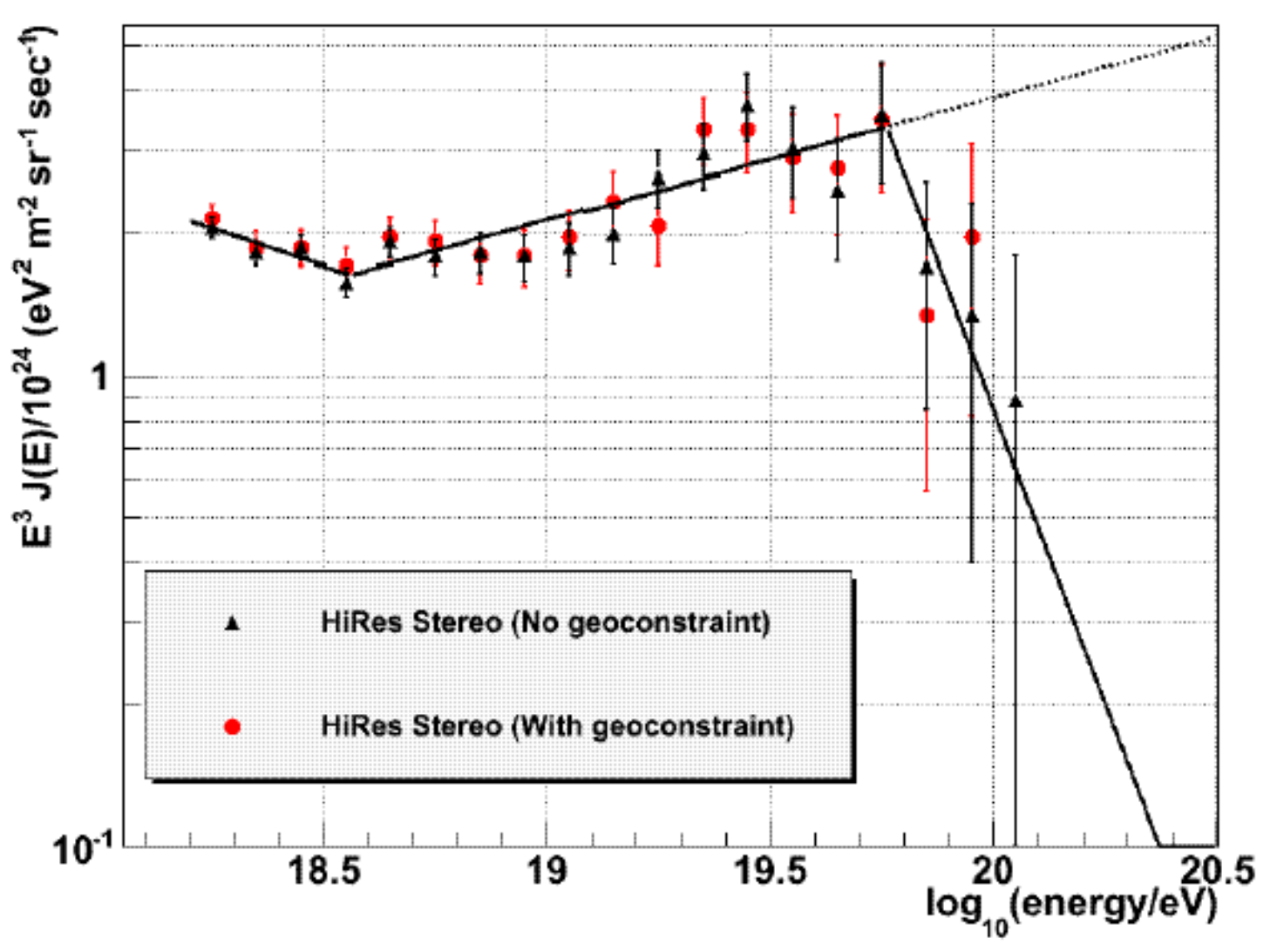
R.A.Vazquez

Auger-09



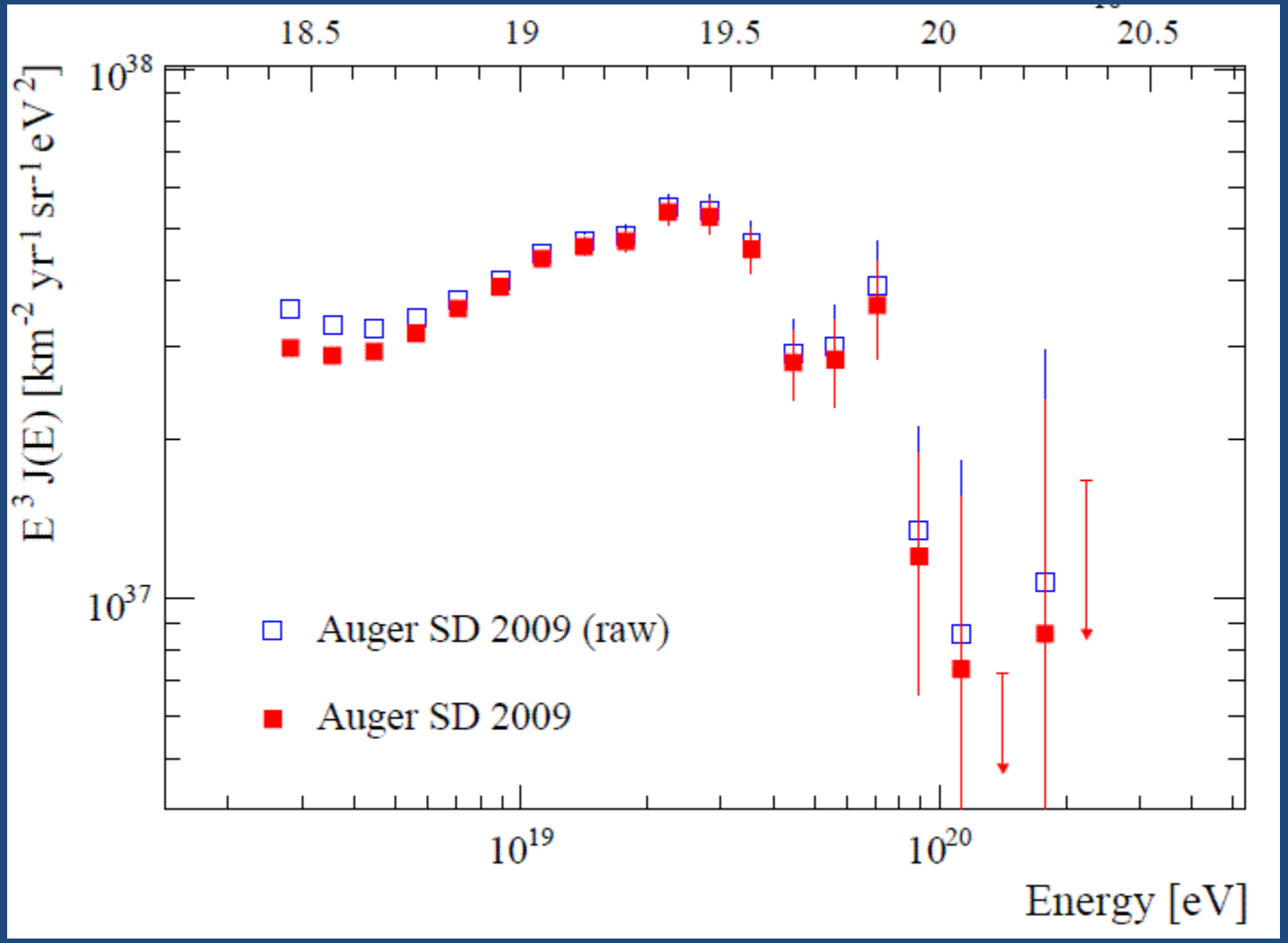
F.Schuessler

HiRes Stereo



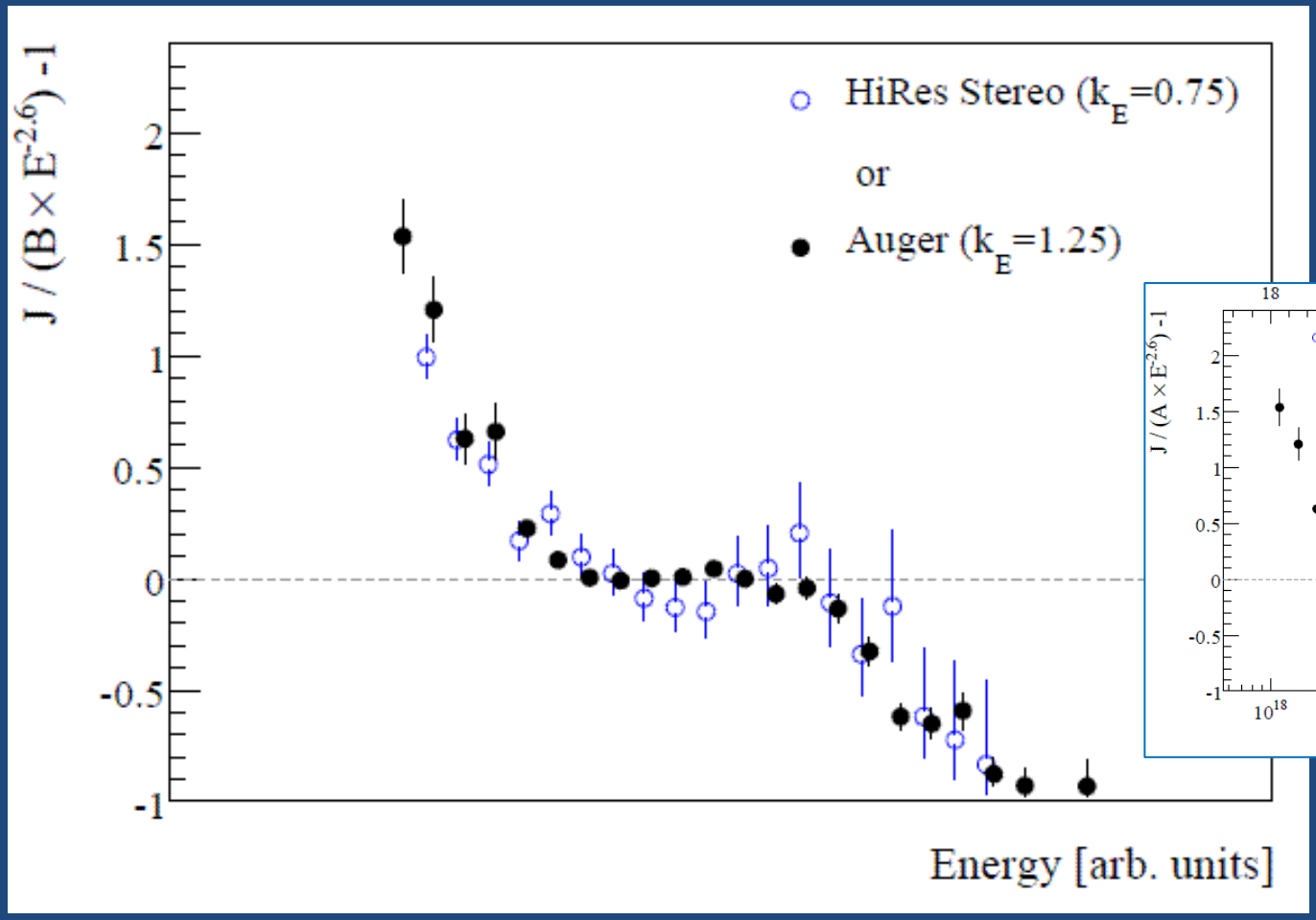
D.Bergman

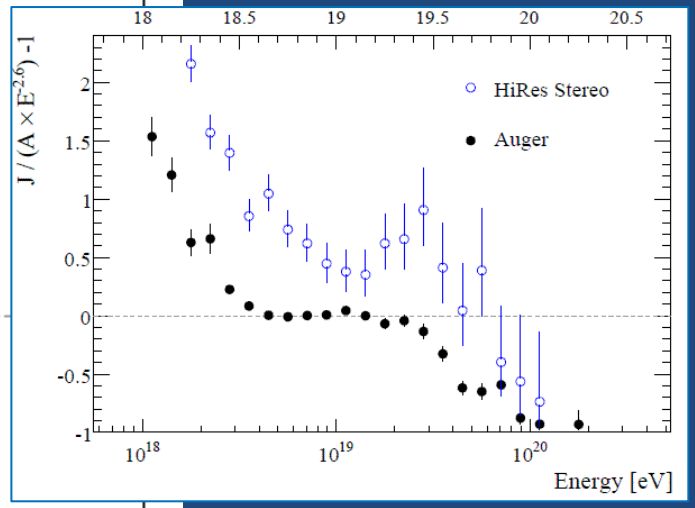
Auger SD, resolution effect



F.Schuessler

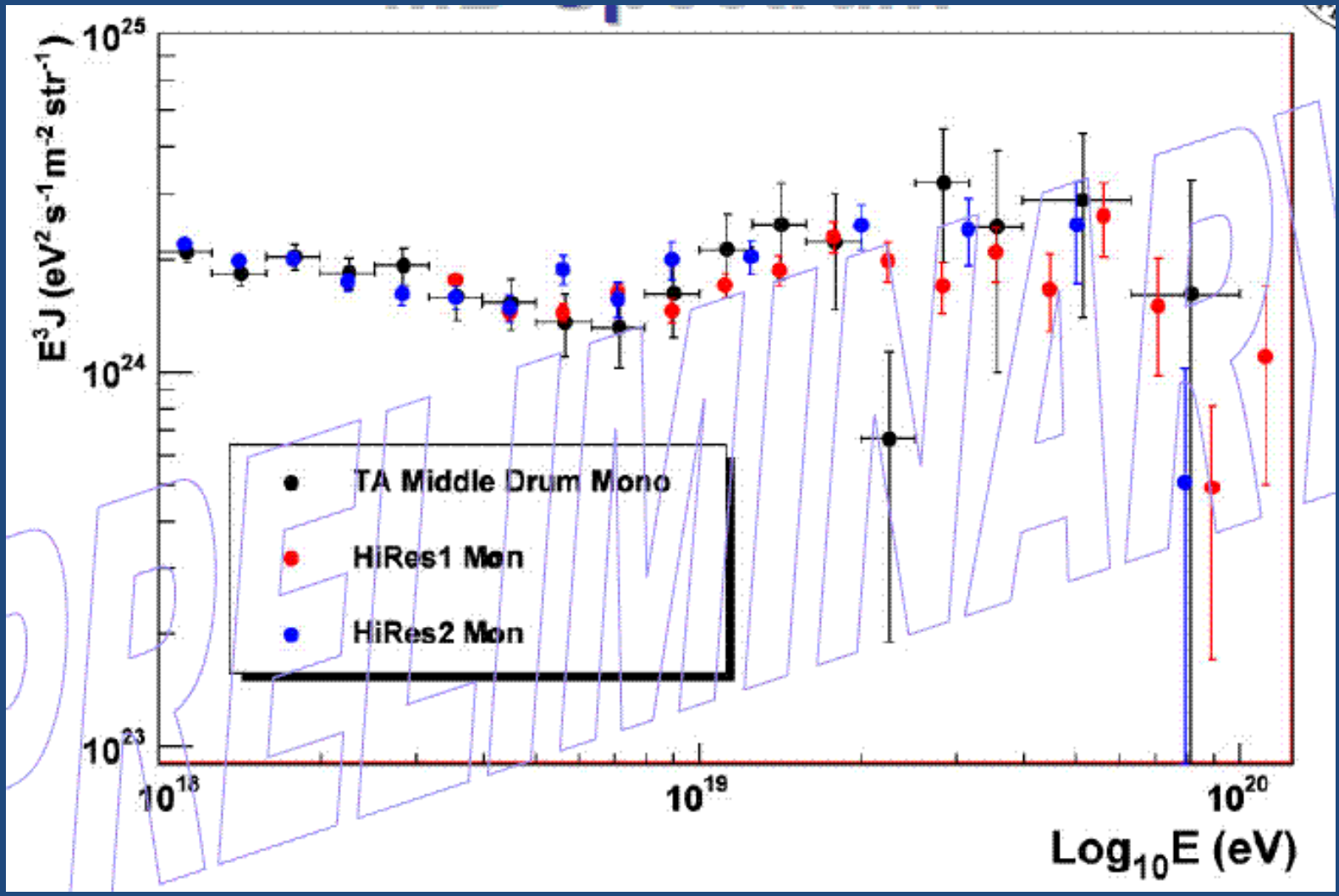
Auger-09 vs HiRes-stereo





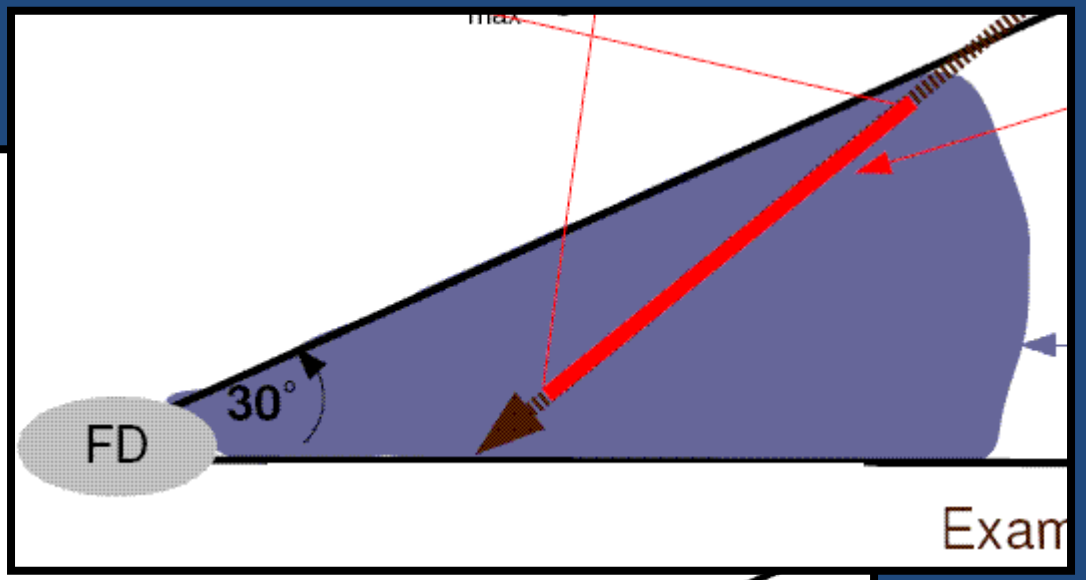
F.Schuessler

TA Mono (HiRes transfer)

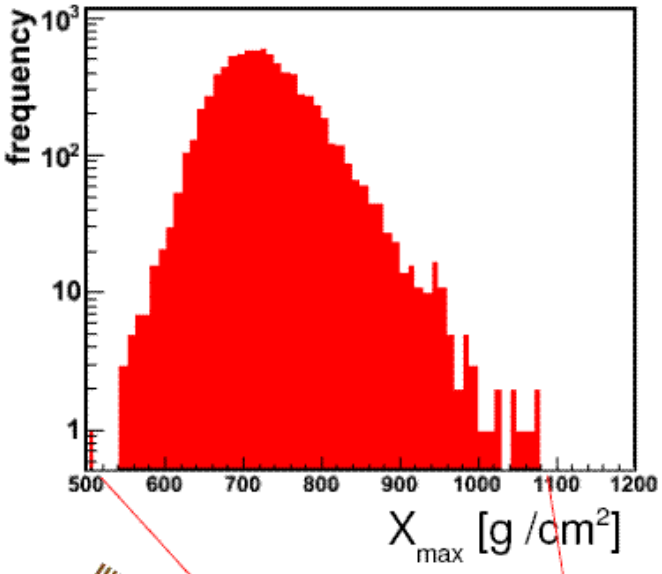


C.C.H.Jui

Auger, Xmax



Raw X_{max} distribution above 1 EeV



Example of **bad geometries** for sampling the Xmax distribution

Conclusions

* The data favor a break in the X_{max} Vs energy curve at :

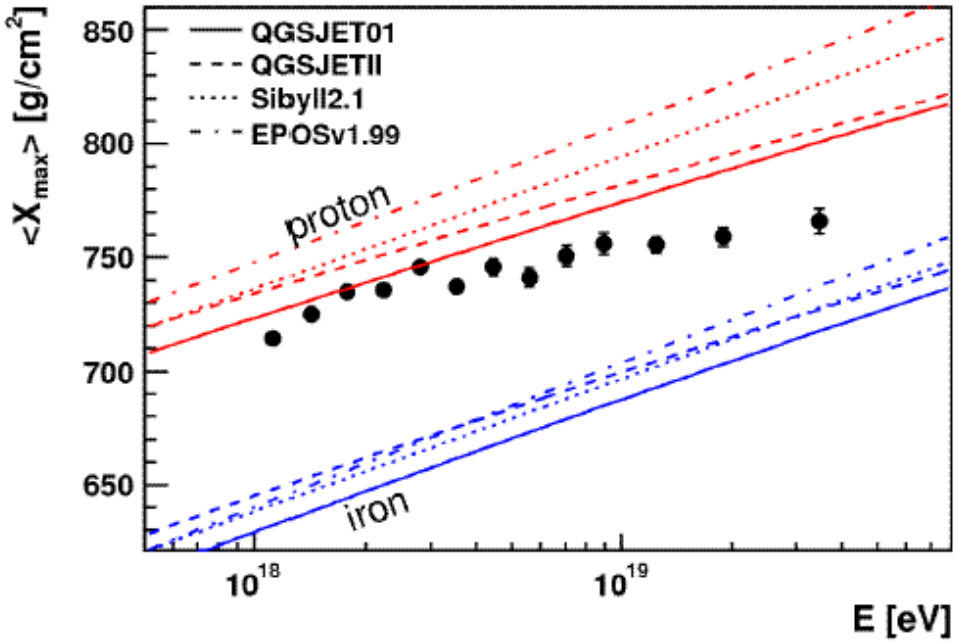
$$E_b = 10^{18.25\pm0.05}\ eV$$

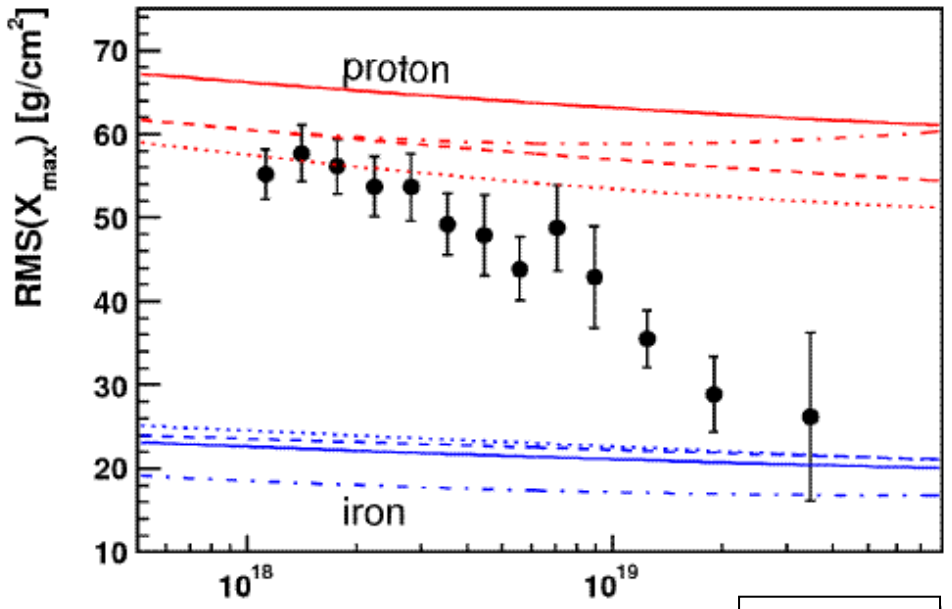
this energy is close to the ankle in the energy spectrum.

* At energies above $E=2\times10^{18}$ eV the small elongation rate,

$$D_{10}=24\pm3\ g\ cm^{-2}\ /\ decade$$

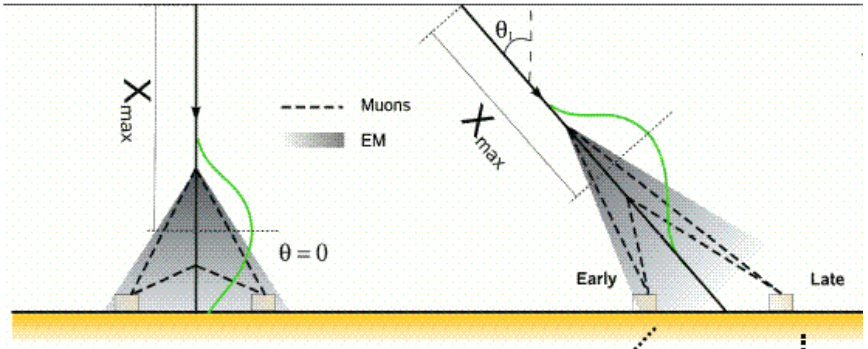
and the decreasing trend of the $RMS(X_{max})$ suggest a composition change towards a heavier composition



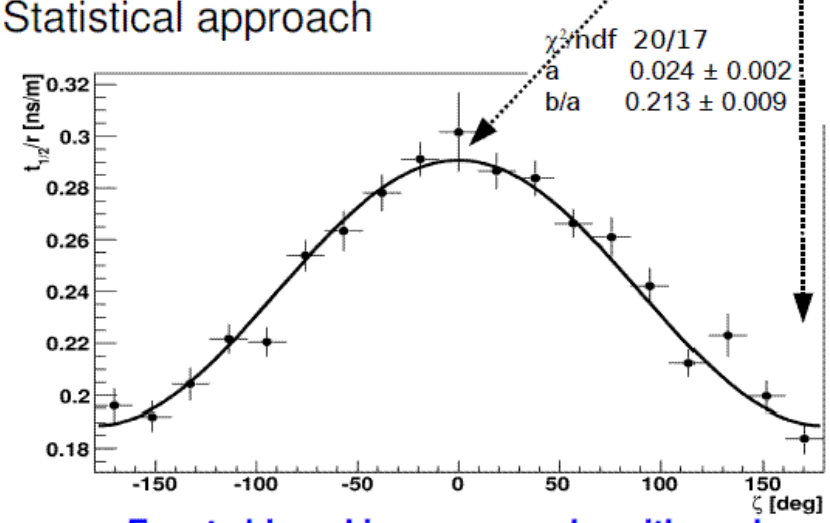


J.Bellido

Indications from Auger SD



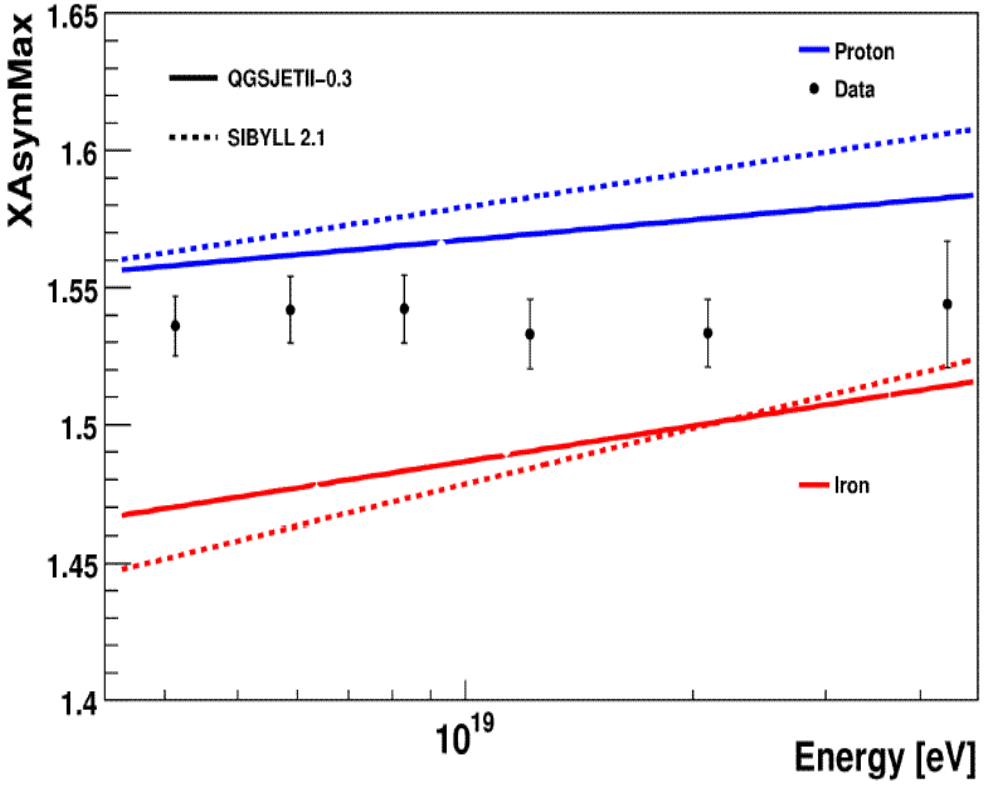
Statistical approach



Events binned in energy and zenith angle

$$\tau(R,\Theta) = a + b\cos(\zeta)$$

asymmetry factor = b/a



- Timing Asym.
- Muon content

H.Wahlberg

A.Castellina

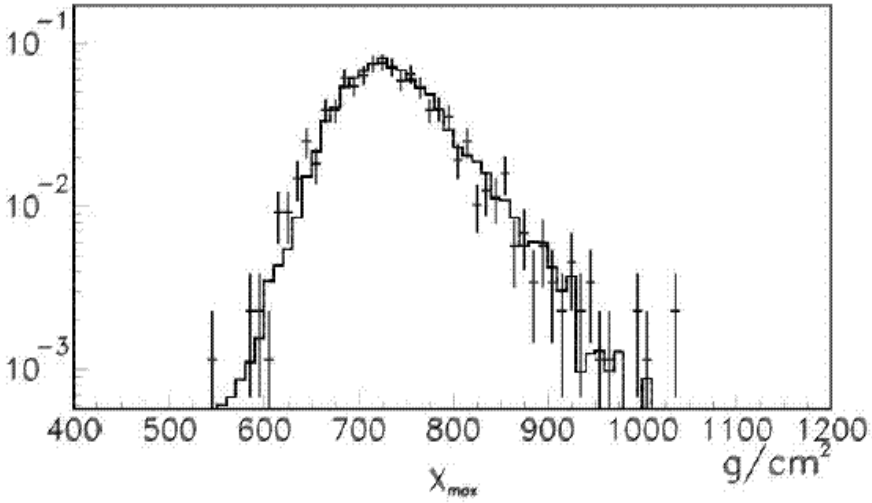
(Study of had. Int. Model)

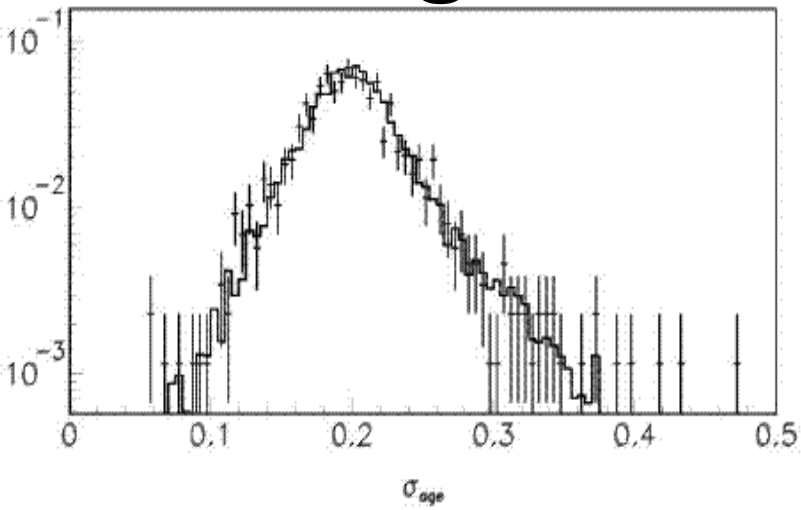
HiRes Xmax: Data vs MC (QGSJET-2)

X_{max}

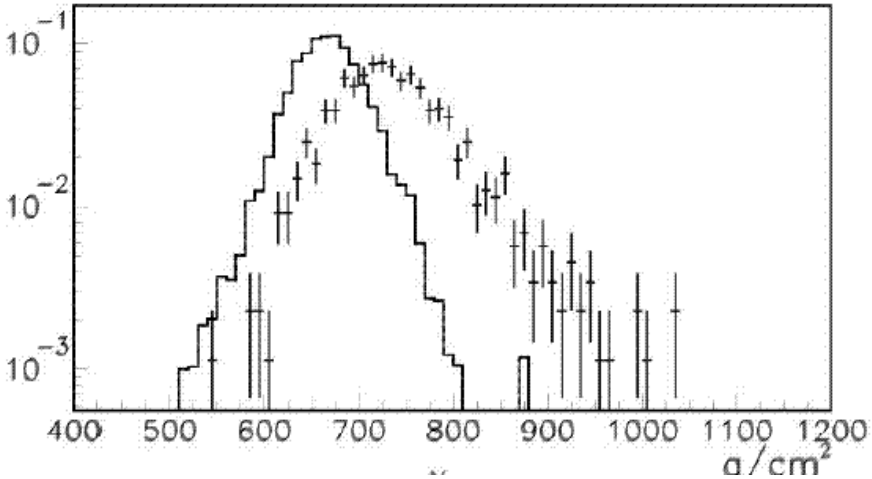
σ_{age}

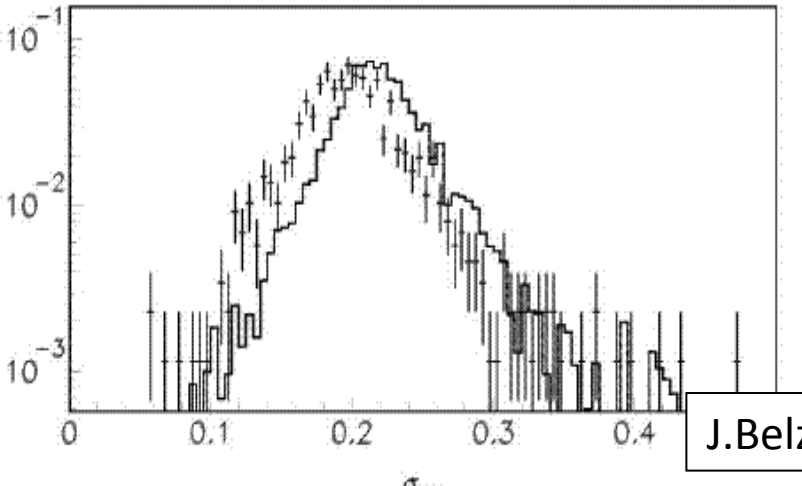
p





Fe

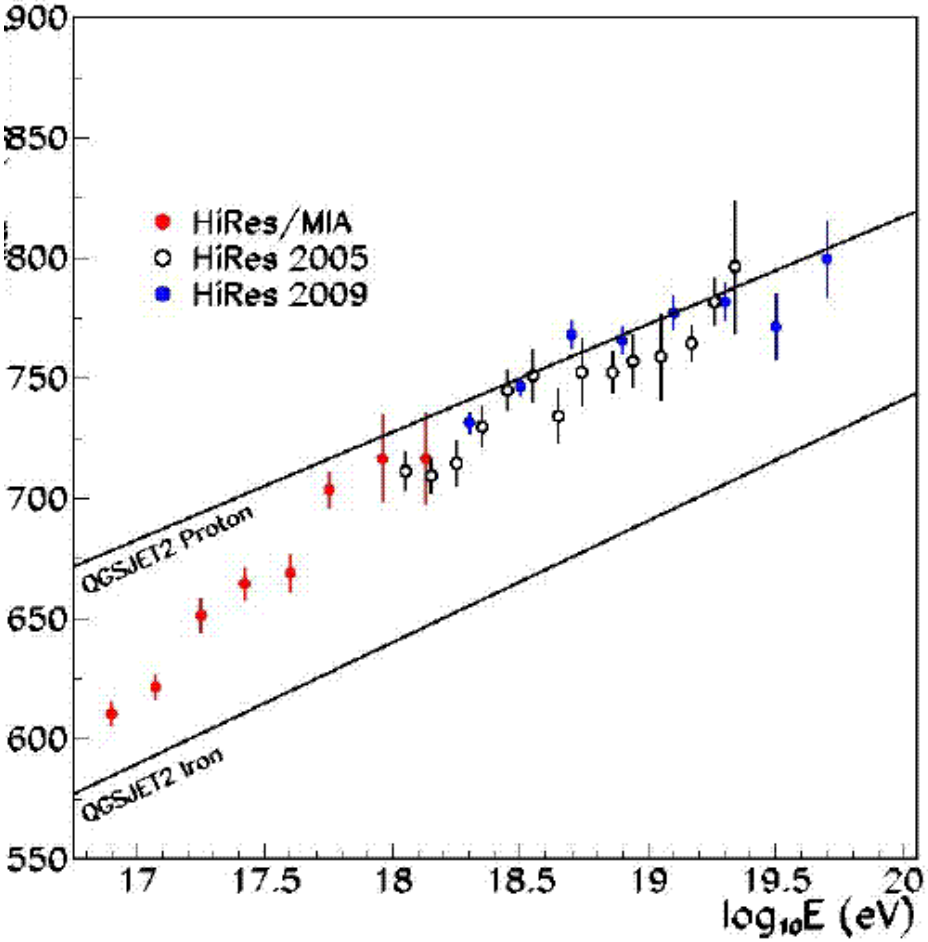




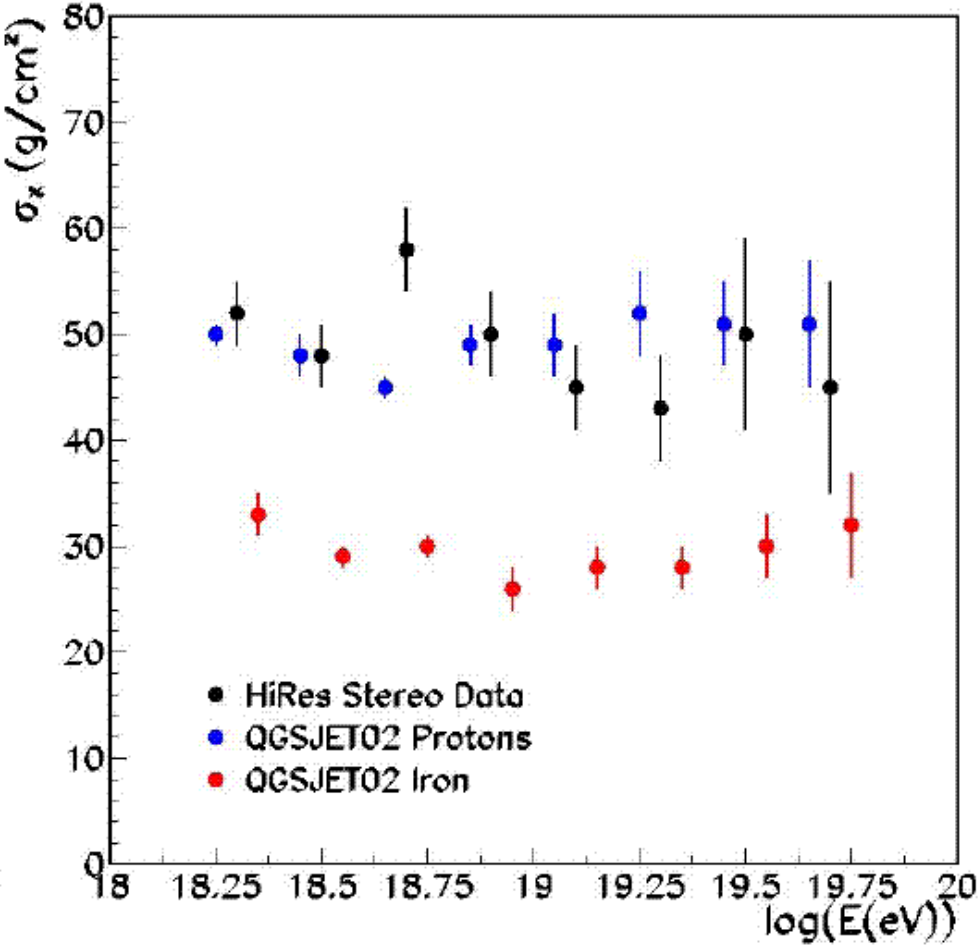
J.Belz

HiRes Xmax: Data vs MC (QGSJET-2)

X_{max}



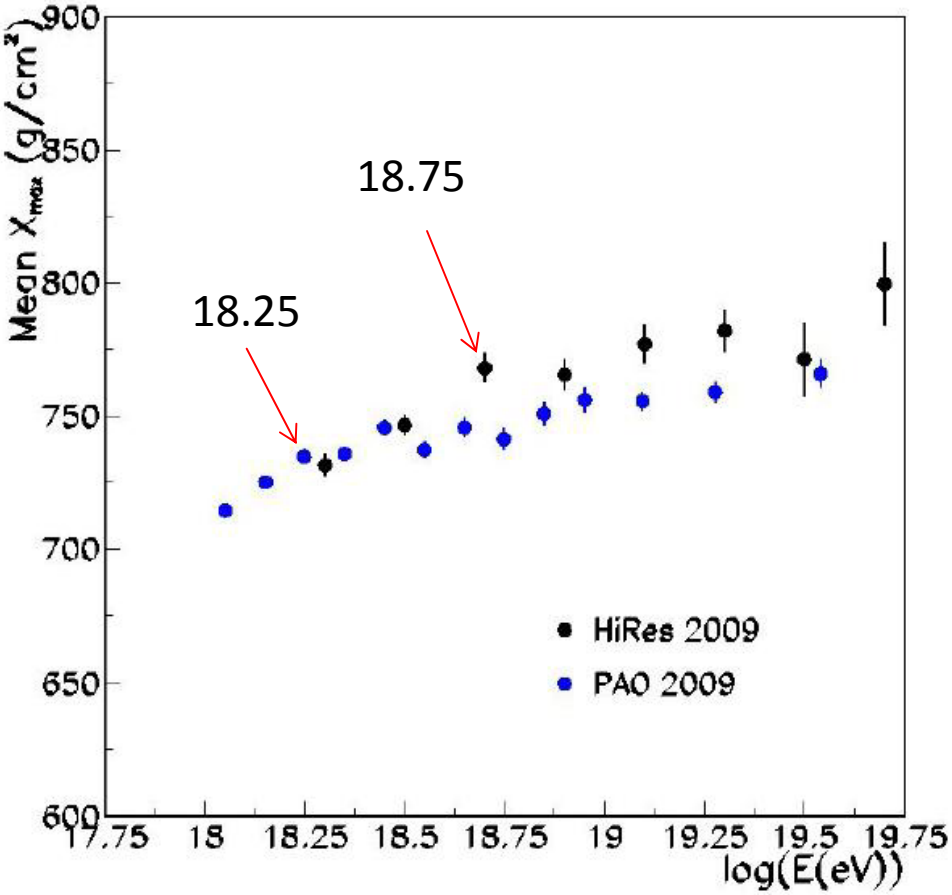
$\sigma_{X max}$



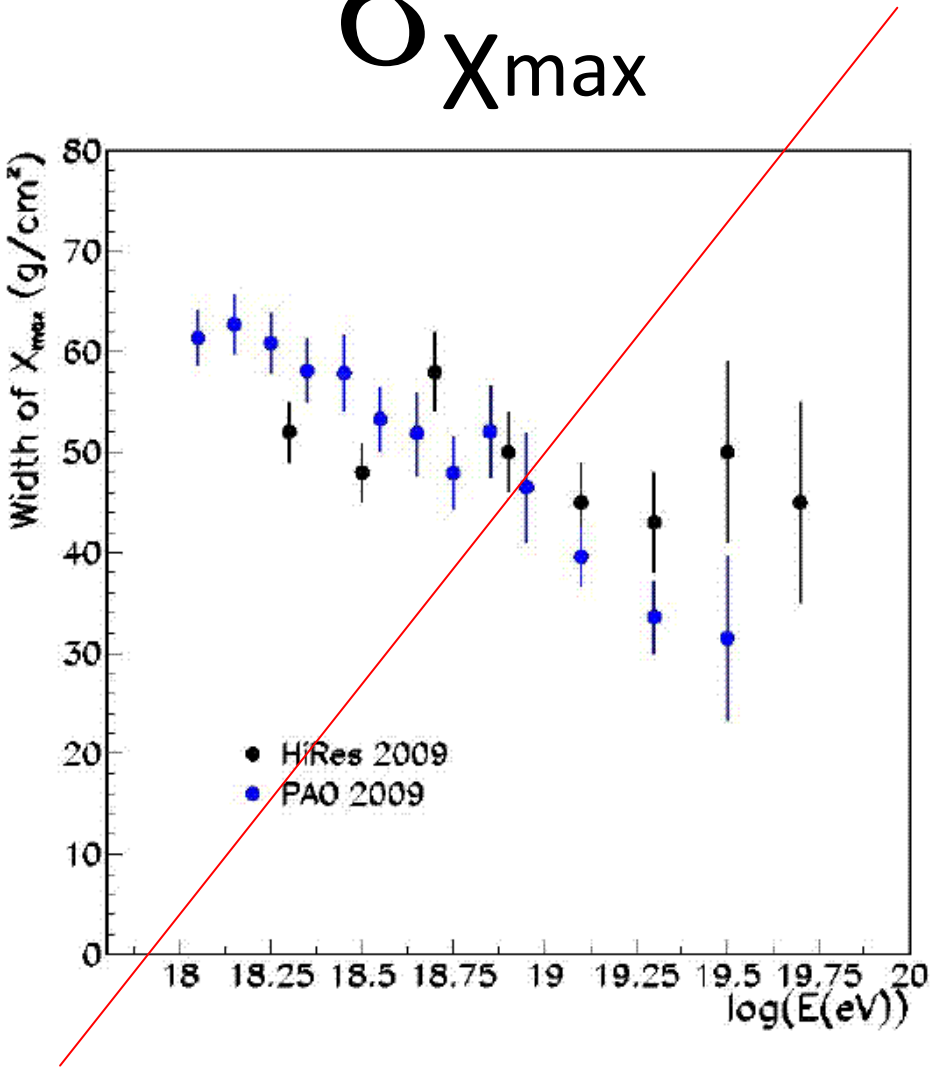
J.Belz

AUGER vs HiRes

X_{max}



$\sigma_{X_{max}}$



HiRes: acceptance corrected
Auger: no accept. corr. necessary

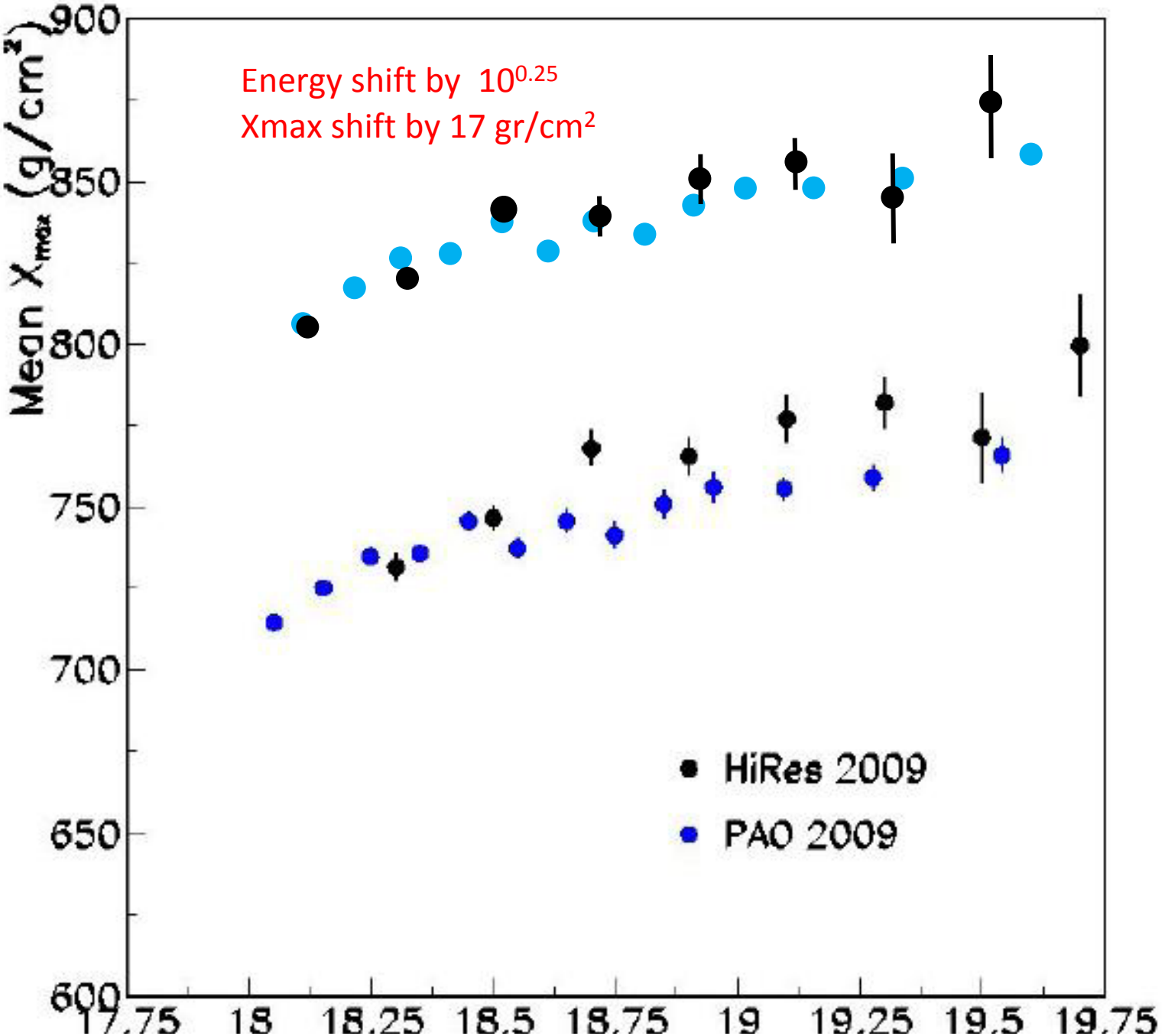
HiRes: acceptance not corrected
Definition of “width” differs.

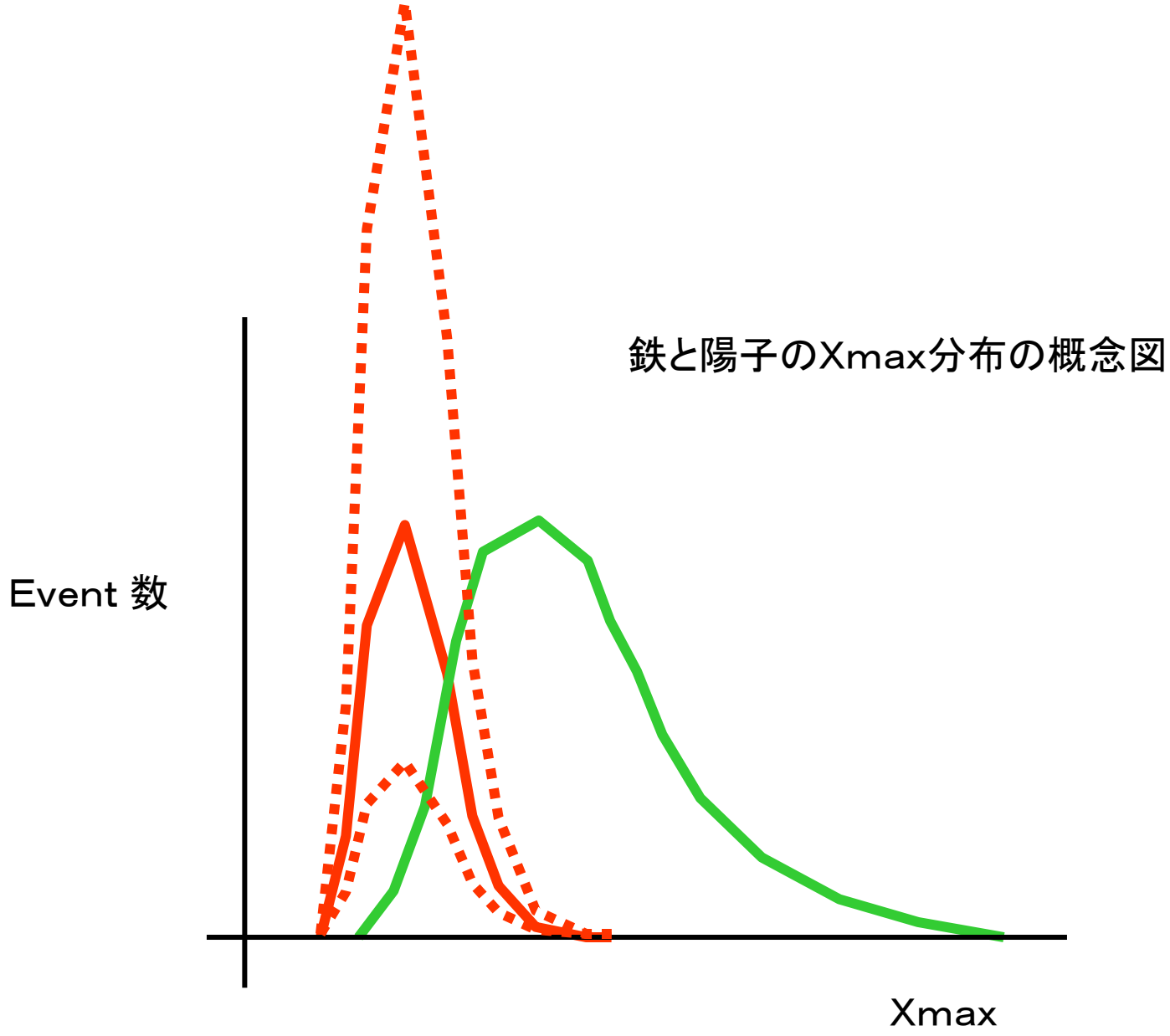
Composition : 10^{18}eV – $10^{19.7}$eV

HiRes	Auger
FD Stereo	FD/SD Hybrid
Strict comparison of Data & MC	Little reliance on MC
Acceptance correction estimated by MC	Event geometry selected such that “no” acceptance correction is necessary
Data consistent with constant elongation rate, and Xmax fluctuations consistent with QGSJET2 protons, slight tendency towards heavier primaries within QGSJET1 model. (J.Beltz)	A change towards a heavier composition suggested (J.Bellido)
Stay with PROTON	Change to IRON
Northern hemisphere	Southern hemisphere

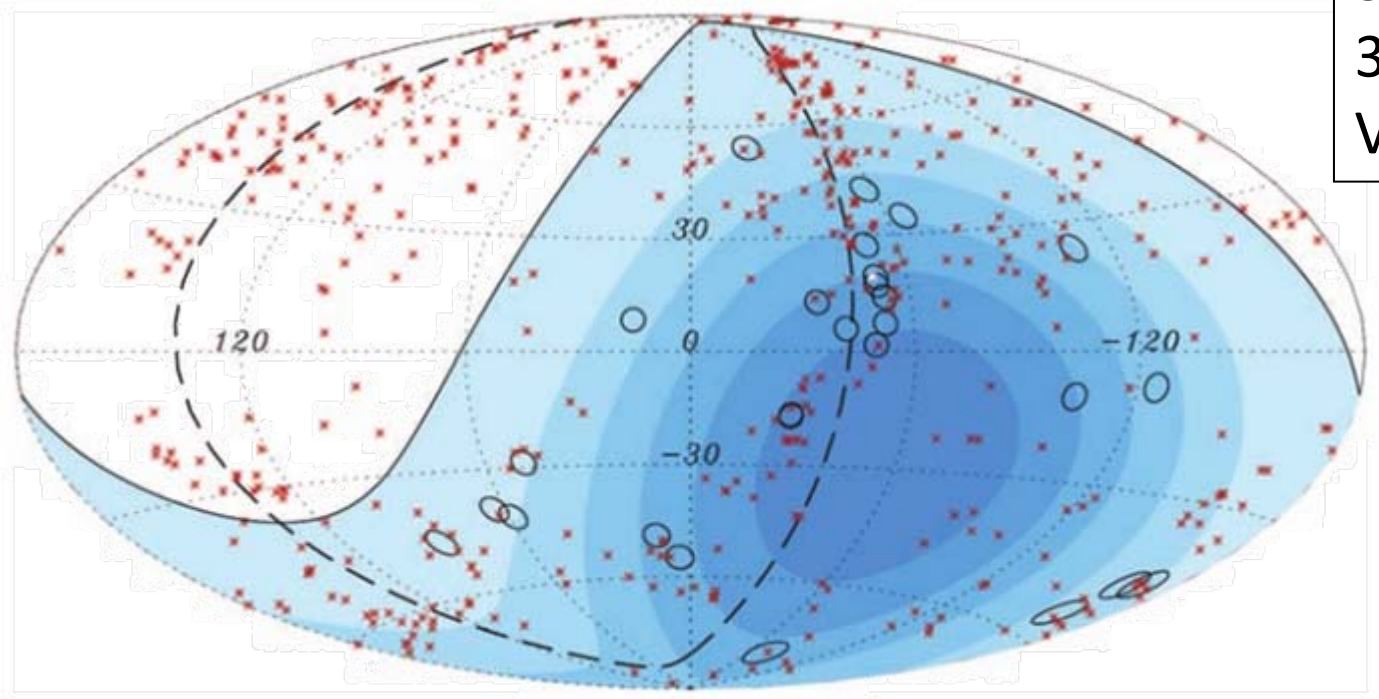
South : Iron
North : Proton
Are we really happy with it?

A careful examination of experimental problem is necessary.


Energy shift by $10^{0.25}$
Xmax shift by 17 gr/cm^2
Mean X_{max} (g/cm^2)
900
850
800
750
700
650
600
17.75
18
18.25
18.5
18.75
19
19.25
19.5
19.75
HiRes 2009
PAO 2009


鉄と陽子のXmax分布の概念図
Event 数
Xmax

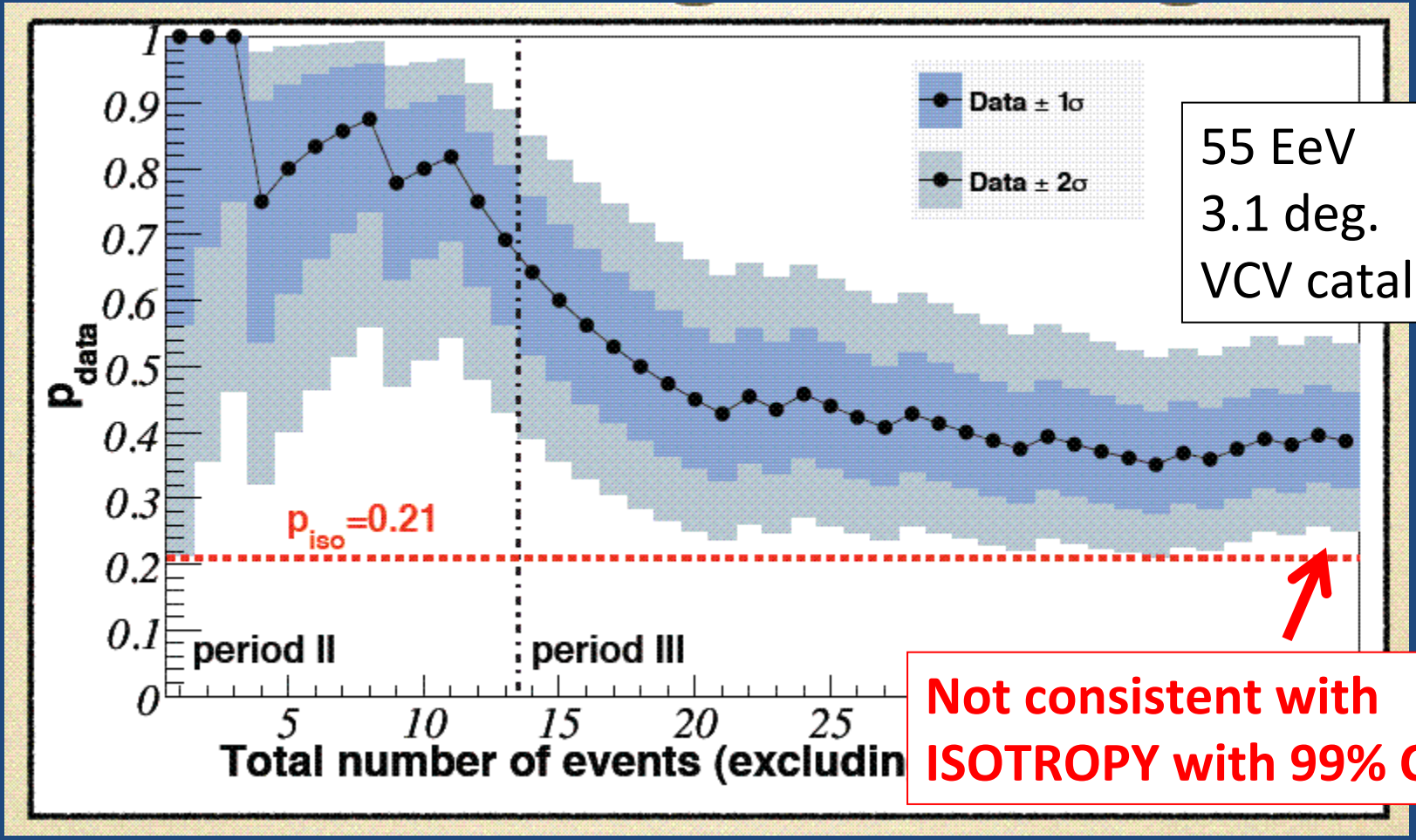
Auger AGN correlation



55 EeV
3.1 deg.
VCV catalog

27 events as of November 2007

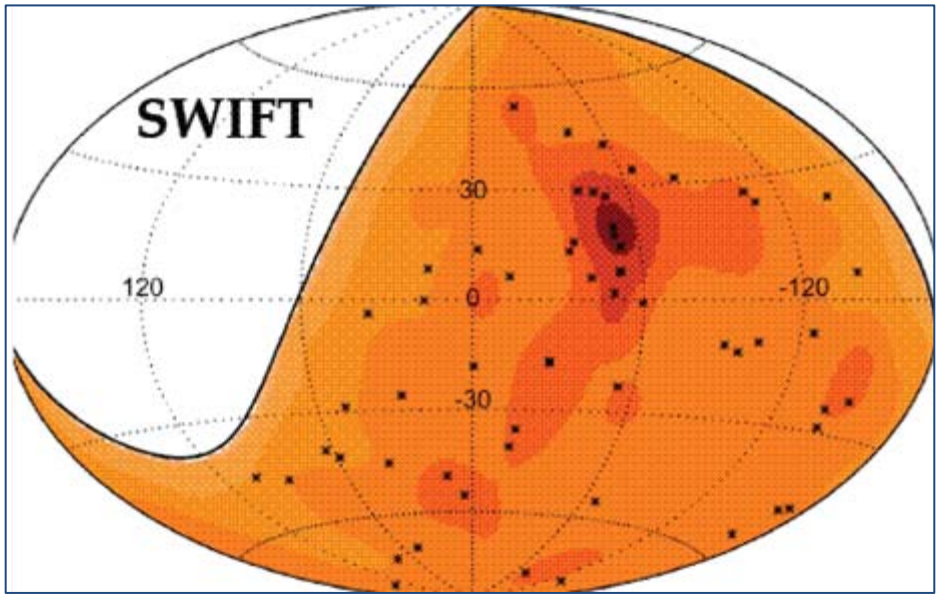
Correlation update

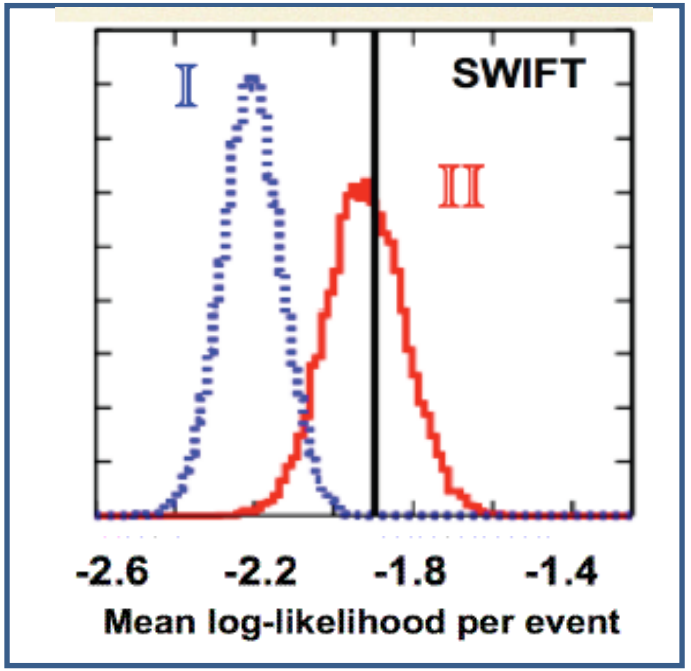


	Decide cut		Check		update
Correlated / TOT.	9 / 14	⇨	9 / 13	⇨	8 / 31

J.D.Hague

Correlation with Galaxy catalogues persists





(1) 22 Months SWIFT-BAT Catalogue

(2) 2MRS Catalogue* (~ 23000 galaxies)

(3) HIPASS Catalogue* (~3000 galaxies):

(4) HIPASS* High Luminosity Catalogue (HIPASS HL):

(2') 2MASS Redshift Survey

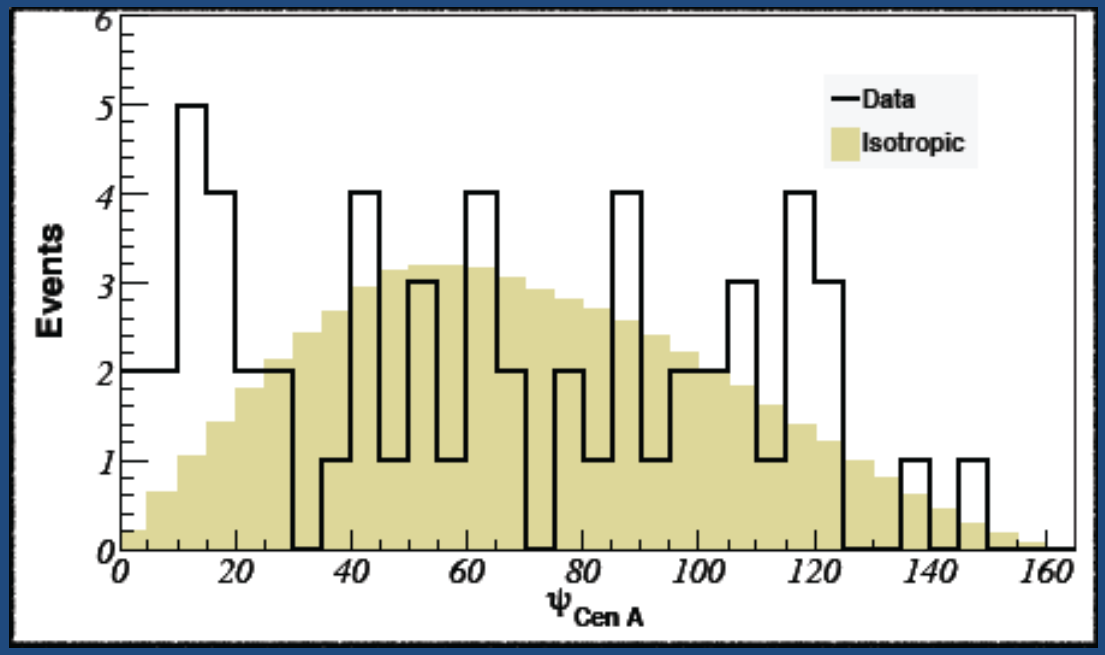
(5) Cen-A (within 18^0, 12/2.7 event, 2% prob.)

J.D.Hague

J.Aublin

G.Farrar

CEN-A からの separation angle 分布

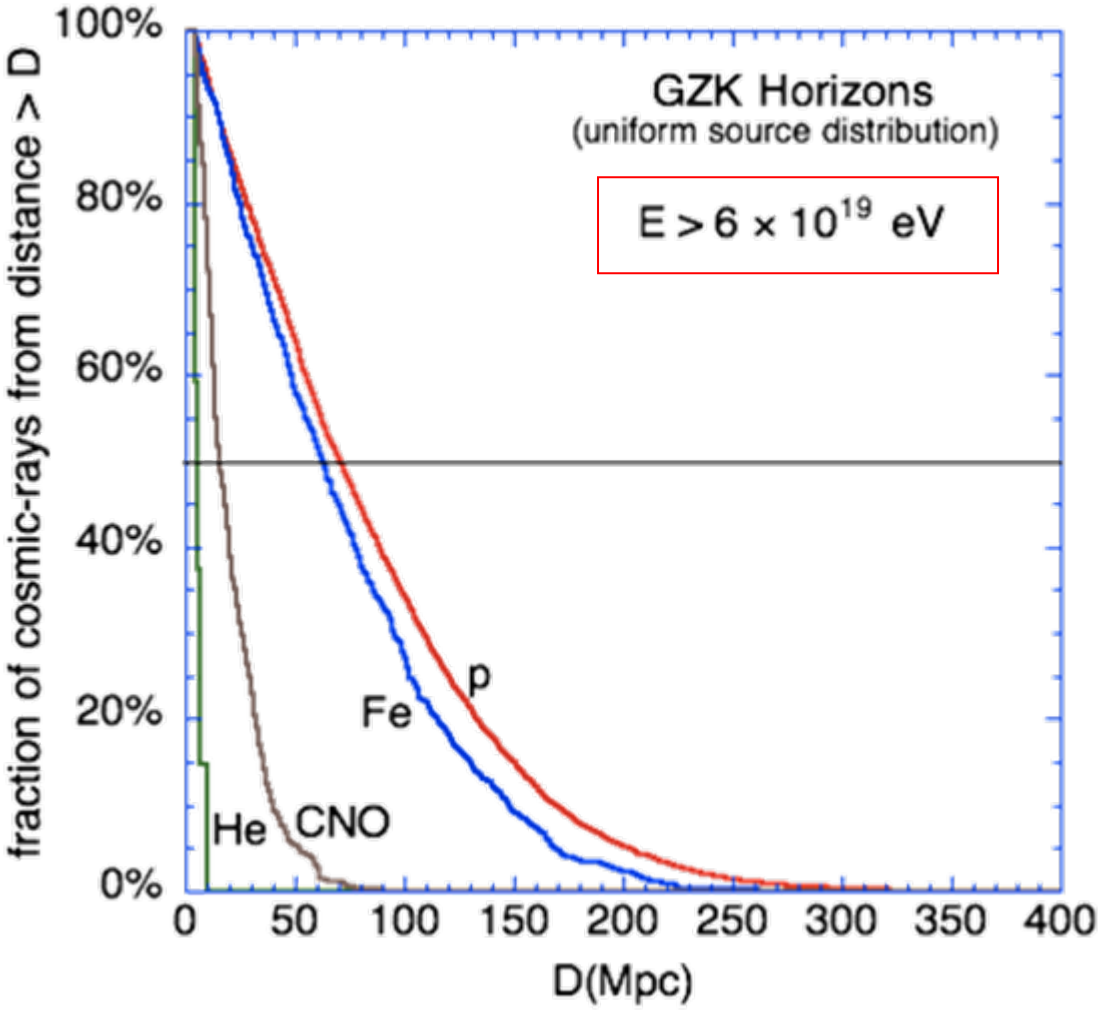


Trans-GZK composition is simpler

Light and intermediate nuclei photodisintegrate rapidly.

Only protons and/or heavy nuclei survive more than 20 Mpc distances.

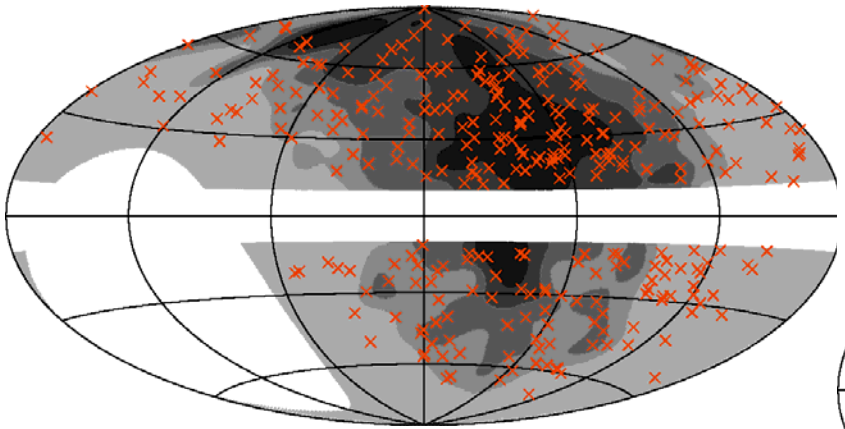
Cosmic magnetic fields should make highly charged nuclei almost isotropic.



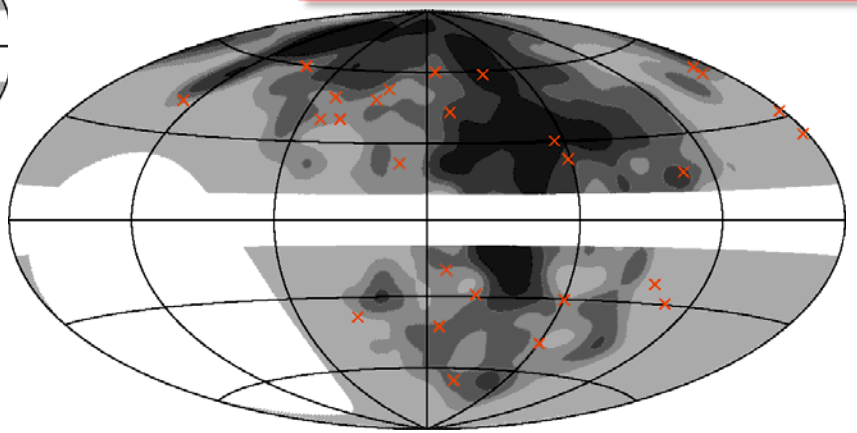
Highlight talk of P.Sommers

Hires stereo Sky Plots

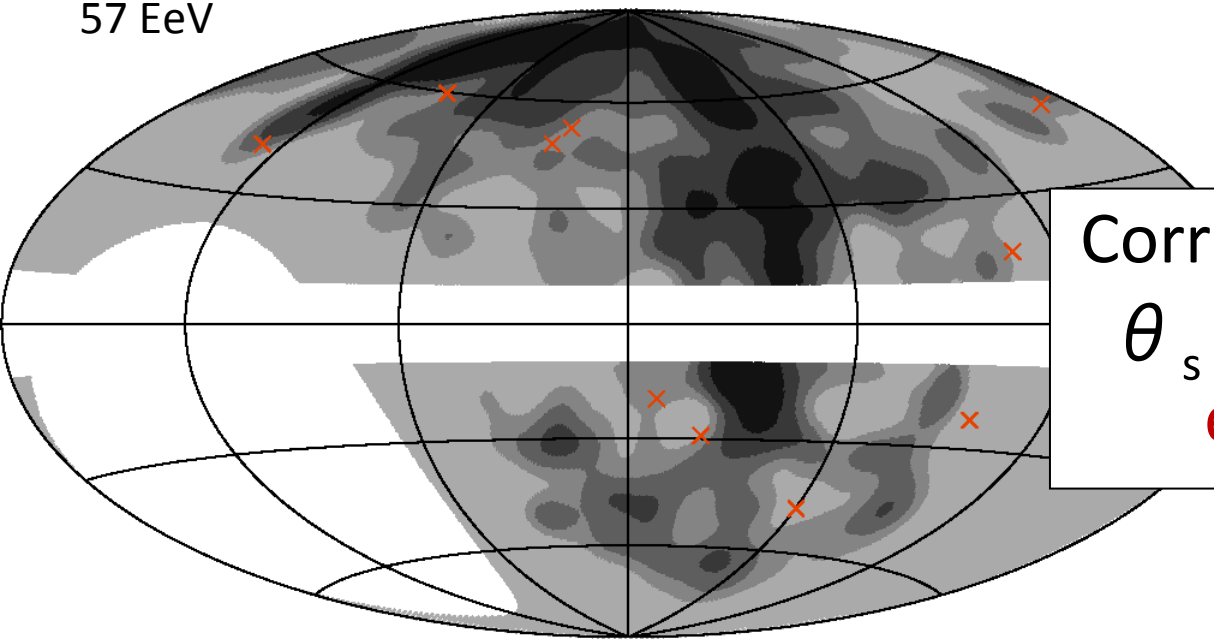
10 EeV



40 EeV



57 EeV

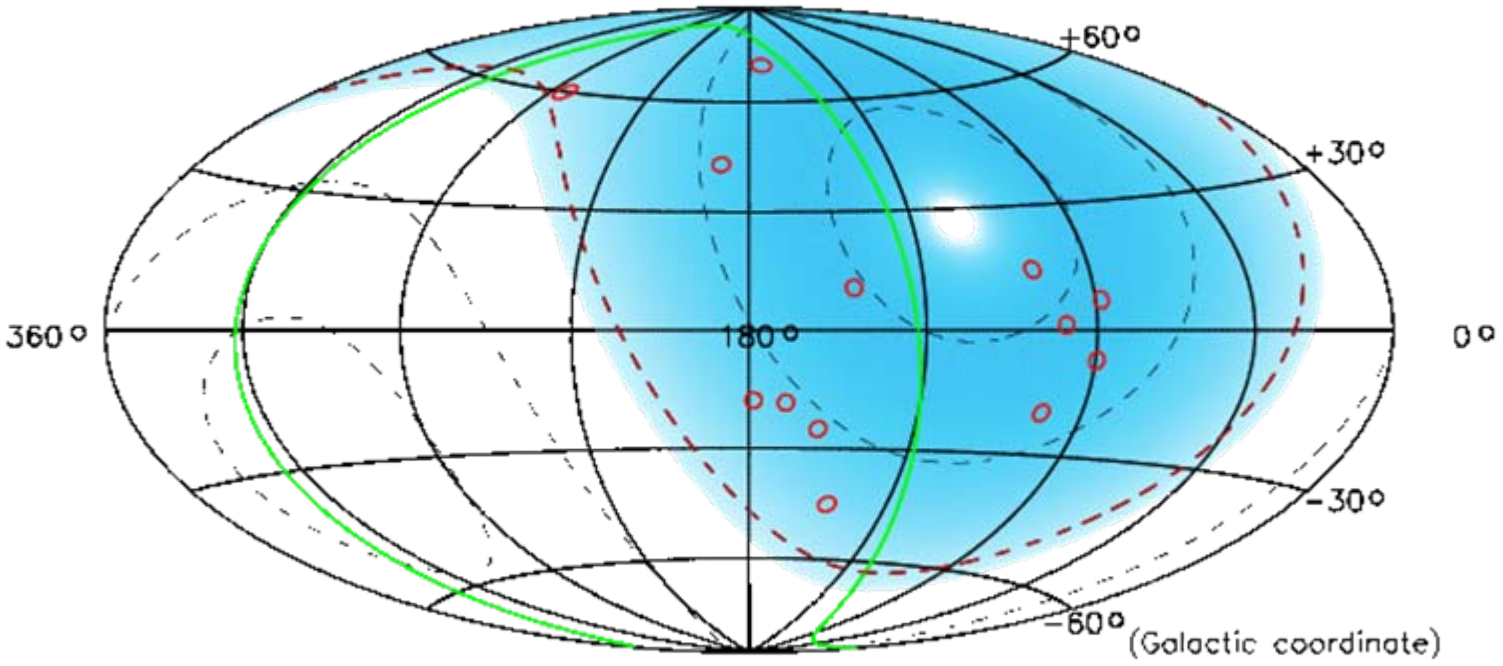


Expectation from
2MRS CATALOGUE
(x HiRes acceptance)

Correlation with 2MRS for
$\theta_s < 10^0$ and $E \geq 40$ EeV
excluded by 95% CL.

G.Thomson

First Skymap of TA for $E > 10^{19.5}$eV and $\theta < 45^0$



Data : May 11 2008 → Nov. 30 2008 (204days)
Exposure : 2.0 x10^{16} m2 sr sec

N.Sakurai

31st ICRC@Lodz の時点で

（スペクトル）・到来方向・粒子種、についての
観測データに矛盾あり

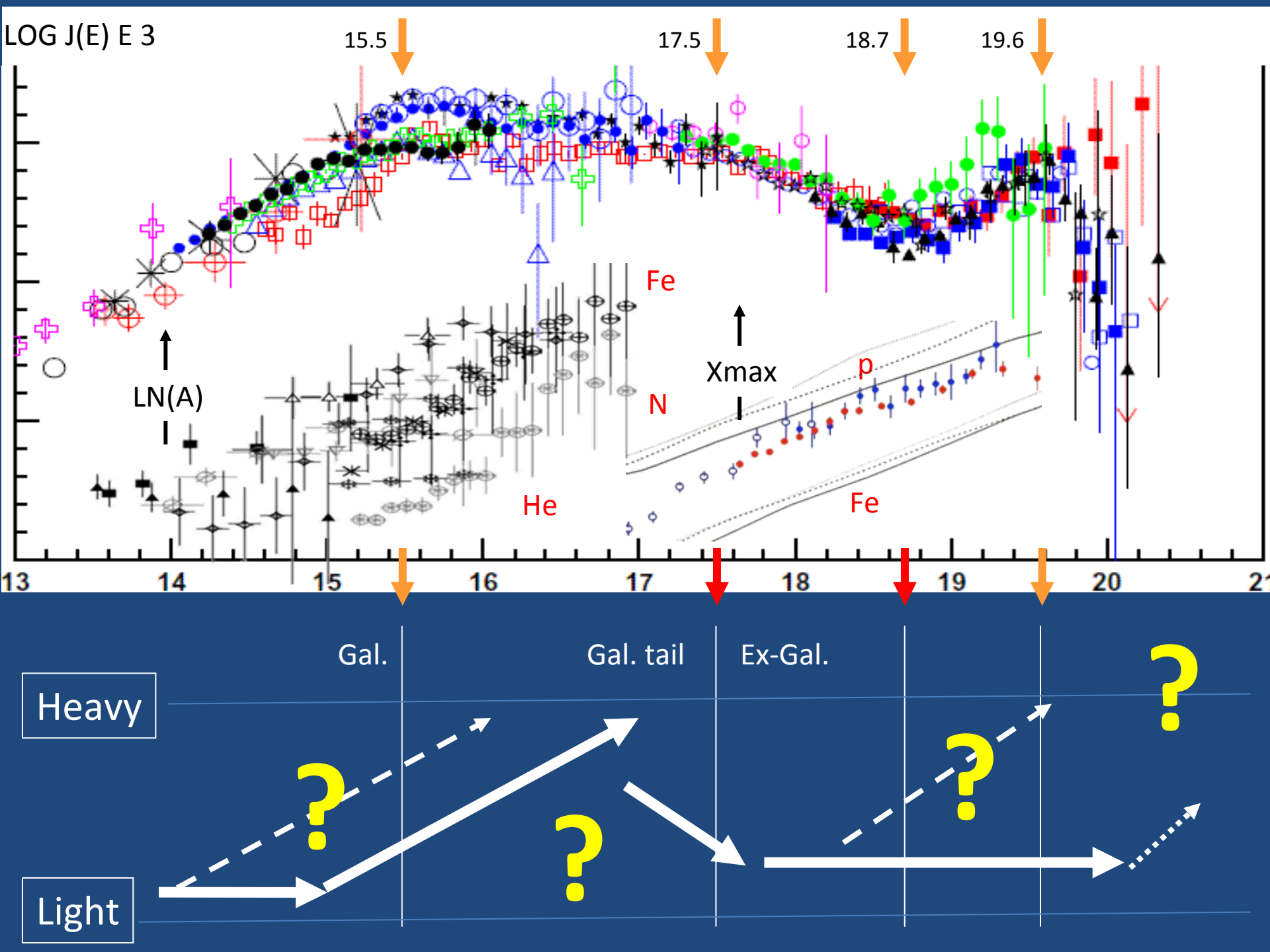
UHECRの「標準的解釈」は液状化

TAは独自の地点から
正しい測定を行う

Iron, "Cutoff," LSS correlation…

A simple (+happy) paradigm of UHECR may be forced to change.

- UHECR is extra-galactic proton
- It creates GZK cutoff and e^+e^- dip
- in collision with CMB
- It originates from AGNs in GZK horizon or, at least, it follows LSS.
- Universe is north/south symmetric


LOG J(E) E 3
15.5
17.5
18.7
19.6
LN(A)
Xmax
Fe
N
He
p
Fe
13
14
15
16
17
18
19
20
Gal.
Gal. tail
Ex-Gal.
Heavy
Light
?
?
?
?

Recent Reviews

- M.Nagano, New J. Phys. 11 065007
- J.Bluemer, R.Engel and J.R.Hoerandel
  arXiv: 0904.0725

Energies are rescaled in Nagano's spectra plot;

AGASA 2003 x 0.75, Auger 2008 x 1.2, Yakutsk 2004 x 0.625
Akeno 1984 x 0.85, Akeno 1992 x 0.85, RUNJOB 2005 x1.2,
Blanca 1999 x 1.1, CASA-MIA 1999 x 1.1, HiRes 2008 = 1.00

Telescope Array
Hybrid detector

Battery of Telescopes | Particle Detector | Communications Tower | CLF

0 1 2 4 Miles

TA wide area network:
Talk by T.Nonaka ID=977

3 communication towers

~30 km

507 Plastic Scintillator Detectors cover ~700 km^2 (1.2km spacing)

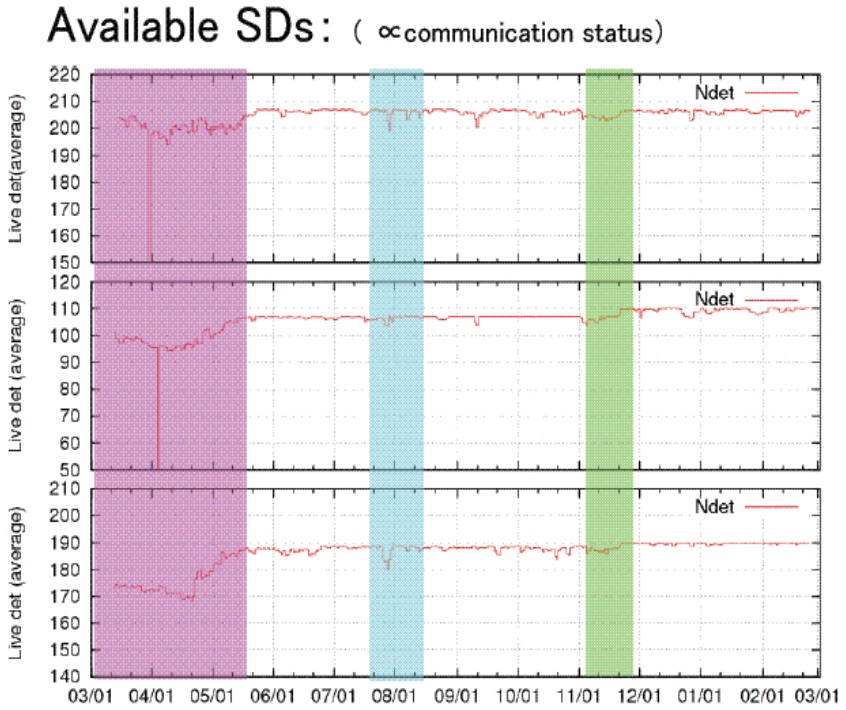
3 Fluorescence Telescope Stations overlook the array.

Utah, USA
39.3 ° N, 112.9 ° W
alt. 1400 m

TA overview: poster by J.N.Matthews ID=138

H.Sagawa

TA SD stable and well calibrated



(05/17～)

Running time

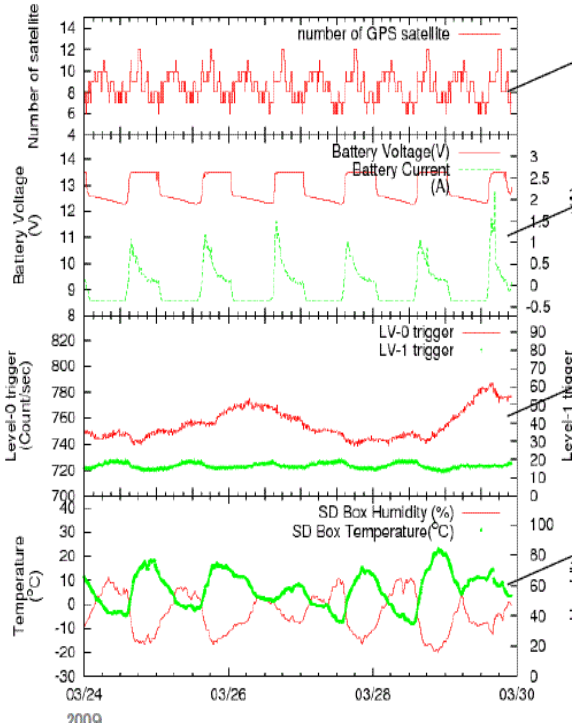
LR:97%

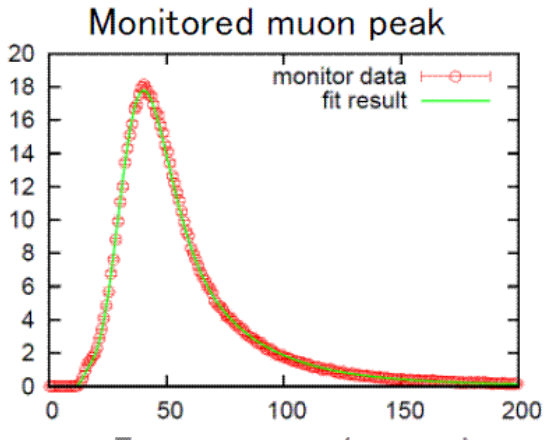
SK:96%

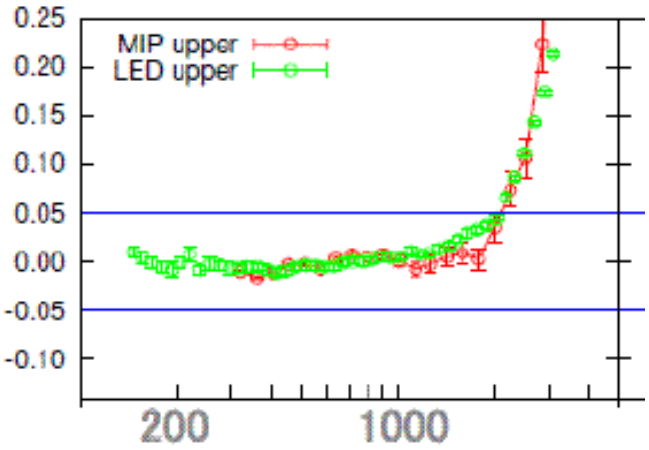
BR:97%

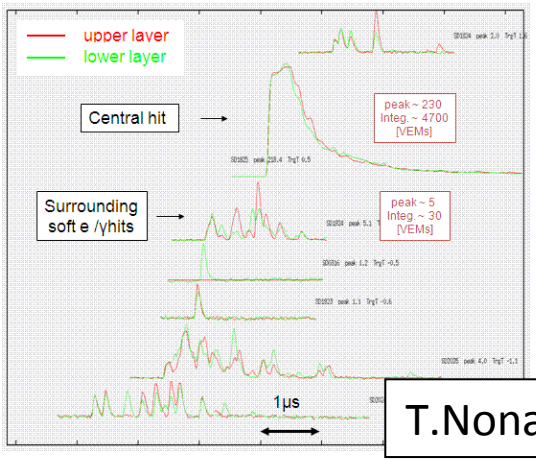
Available SD:

>98%









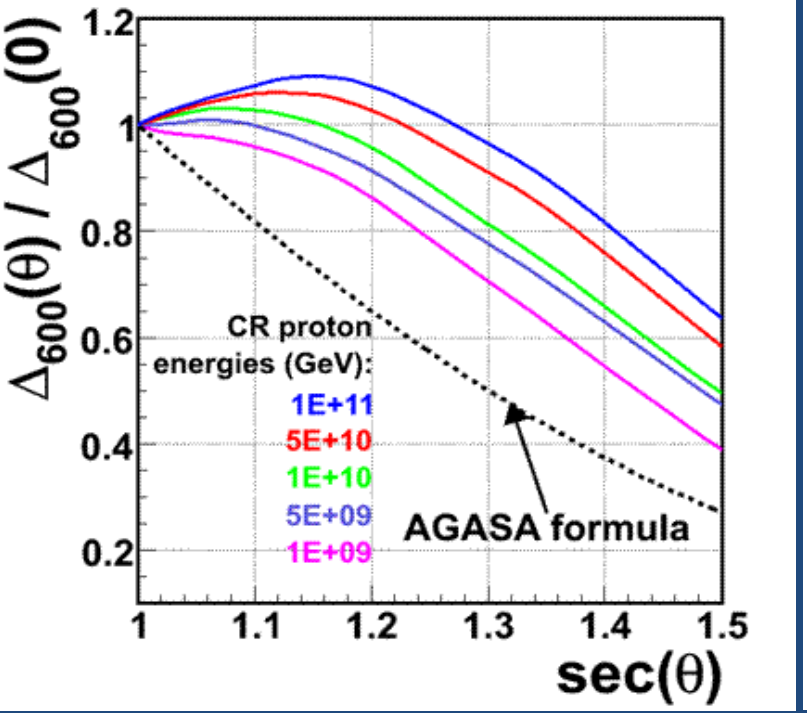
T.Nonaka

Progress of AS simulation

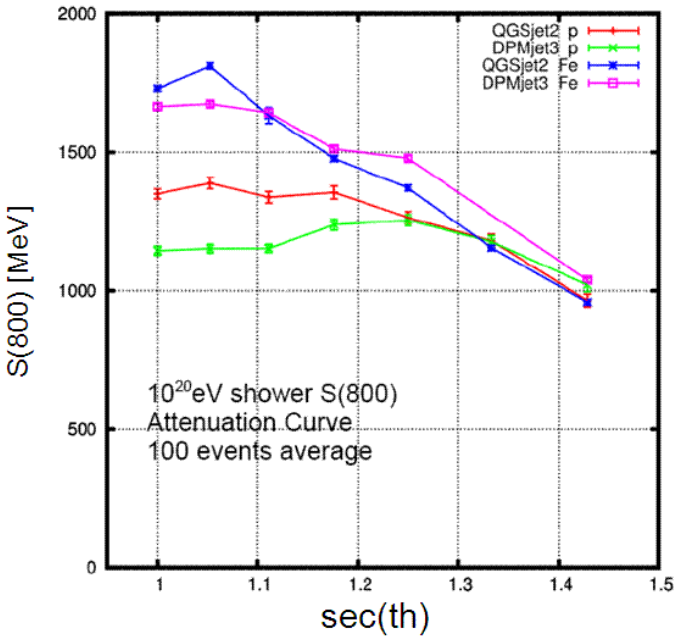
TA

(1) Make fully simulated AS data base

- Cosmos, ~130 events for 10^{17} – 10^{19} eV, -10^{20} eV (qF)
- Corsika, ~100 events for $10^{18.5}$ – $10^{19.5}$ eV



Zenith attenuation of S(800)



- p / Fe
- Model dep.

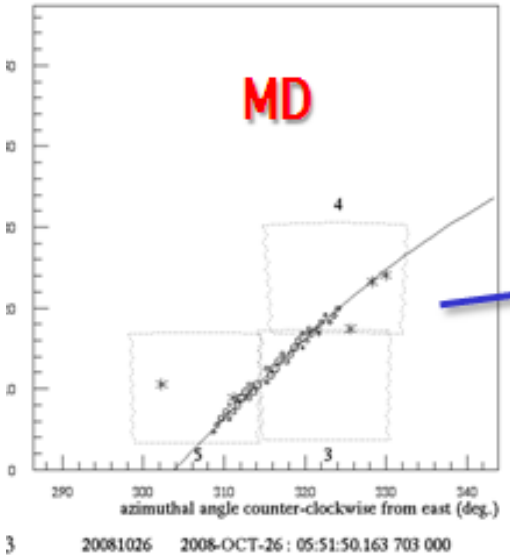
S cos(th) integration for [0, 45°]

QGS p: =1.00
DPM p: 0.91
QGS Fe: 1.15
DPM Fe: 1.16

Study by ft-Cosmos

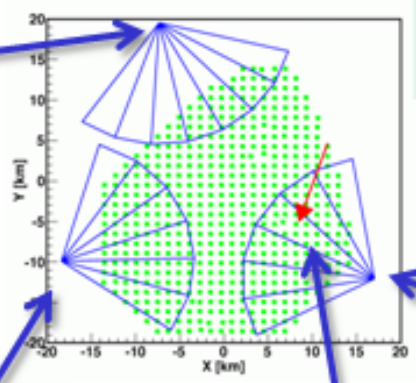
J.-N.Capdevielle | B.Stokes | E.kido

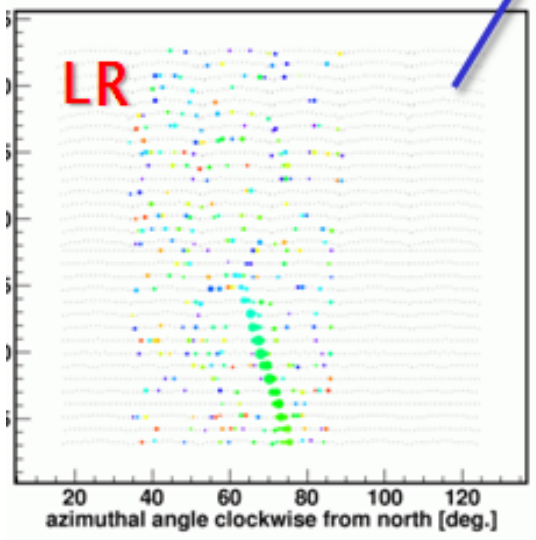
TA Triple Hybrid Event

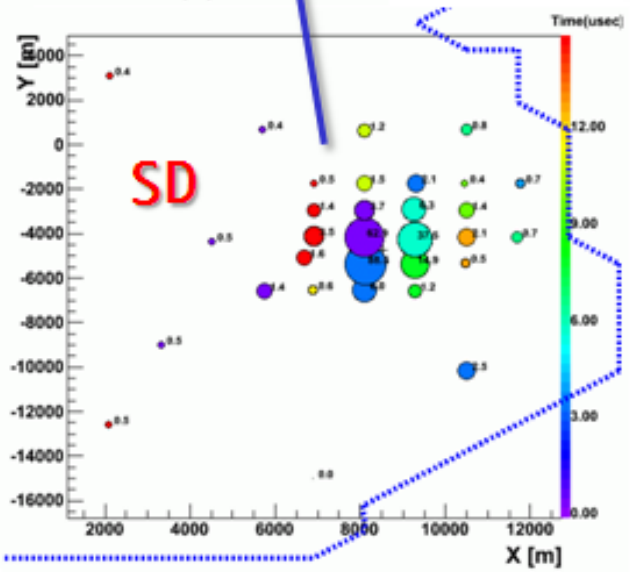


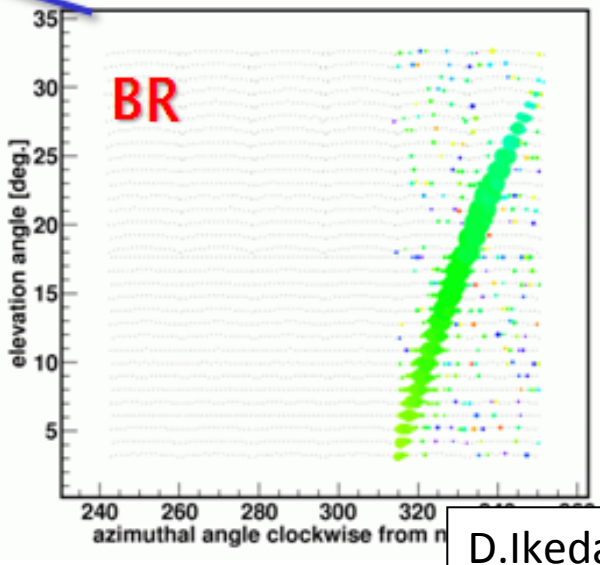
	Zen[deg]	Azi[deg]	X[km]	Y[km]
MD	51.43	73.76	7.83	-3.10
BR mono	51.50	77.09	7.67	-4.14
Stereo (BR&LR)	50.21	71.30	8.55	-4.88

Zenith > 45deg





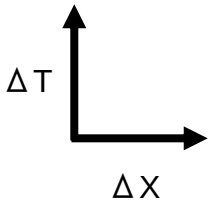




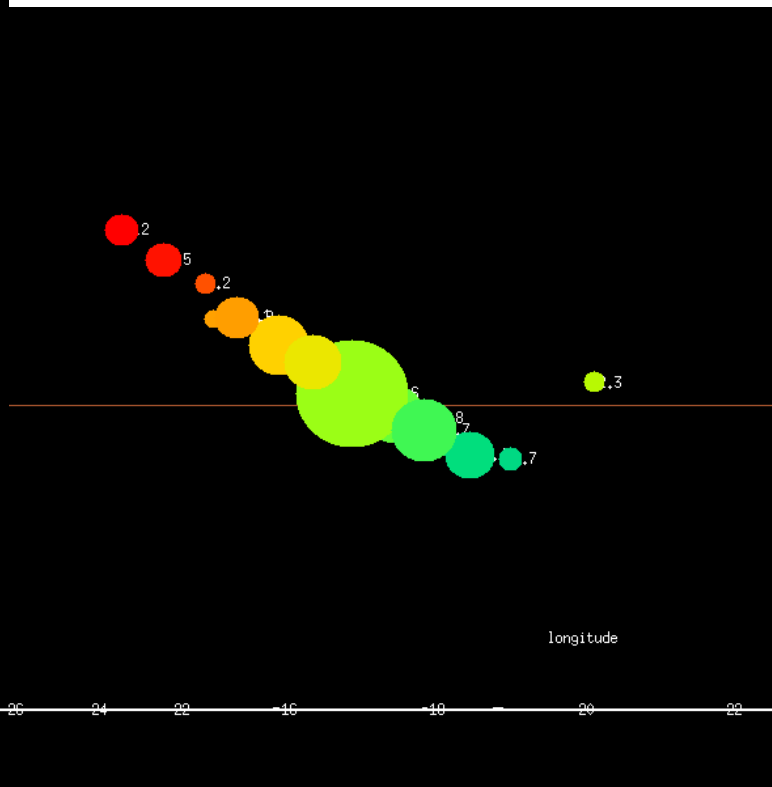
D.Ikeda

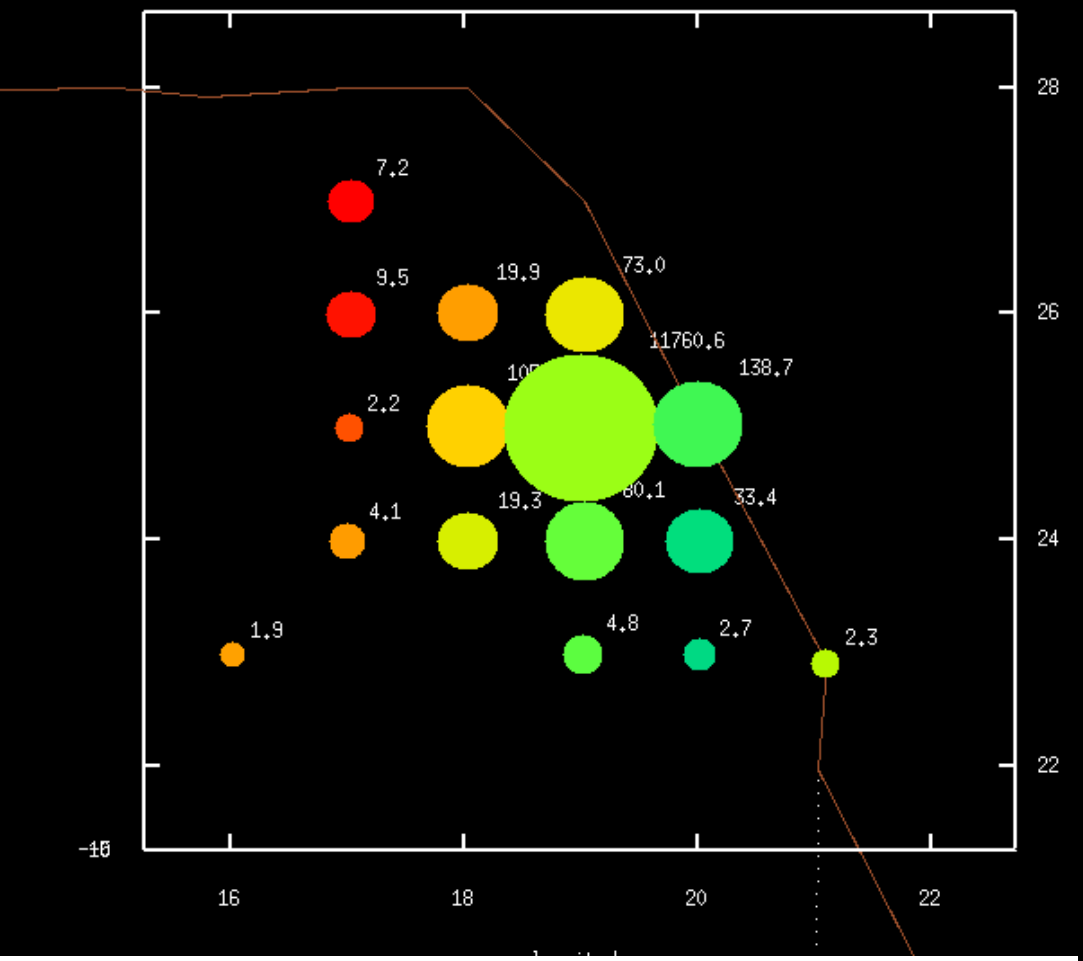
090301-135836

$\theta \sim 40^0$



Event "Side" View

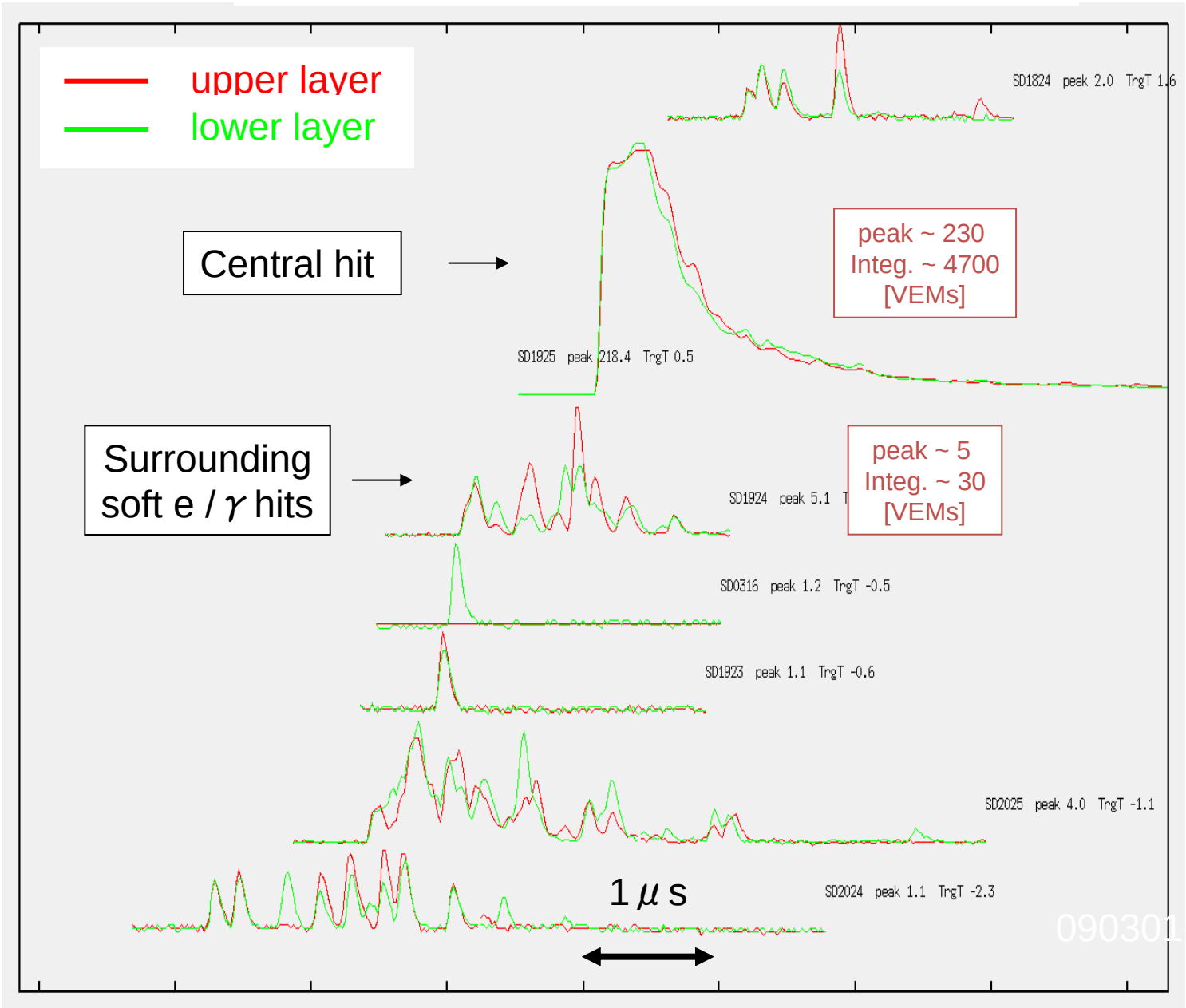




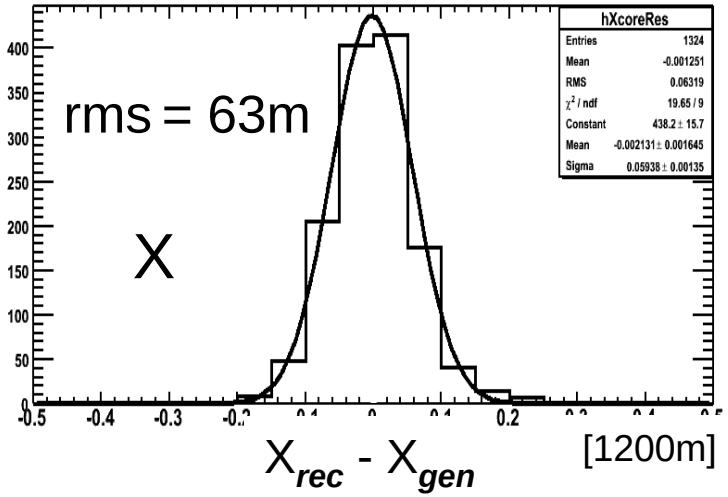
Event Top View

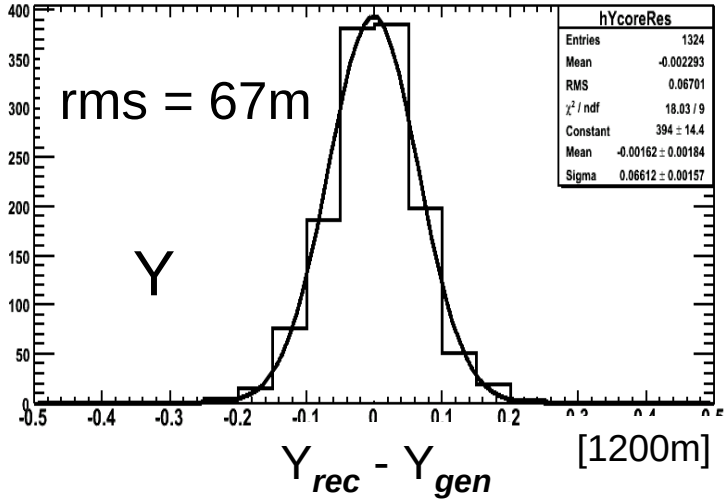
number = MeV energy deposit (av U+D)
~ 2.5 MeV for vertical mu

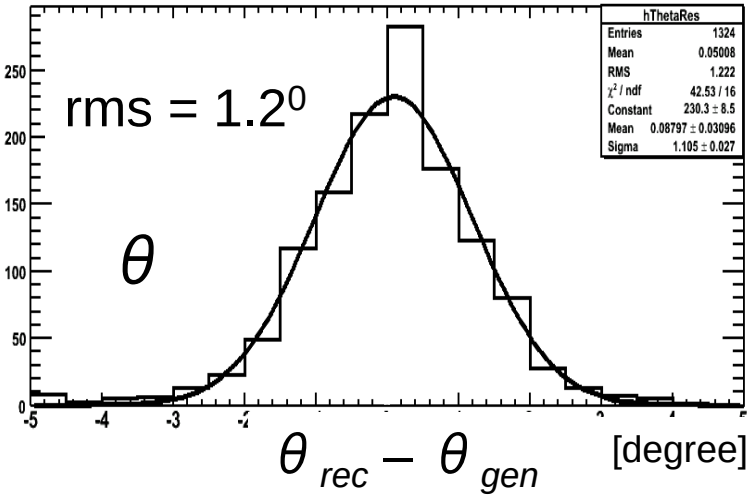
Wave Form Example

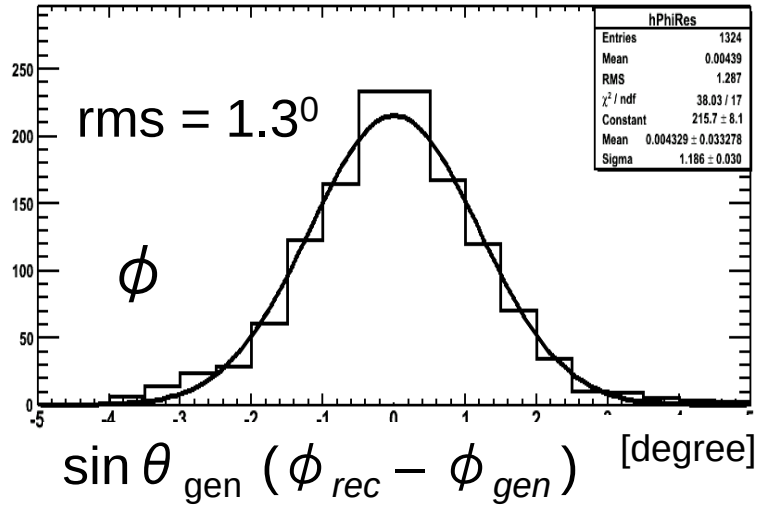


Reconst. Accuracy: core position & angle



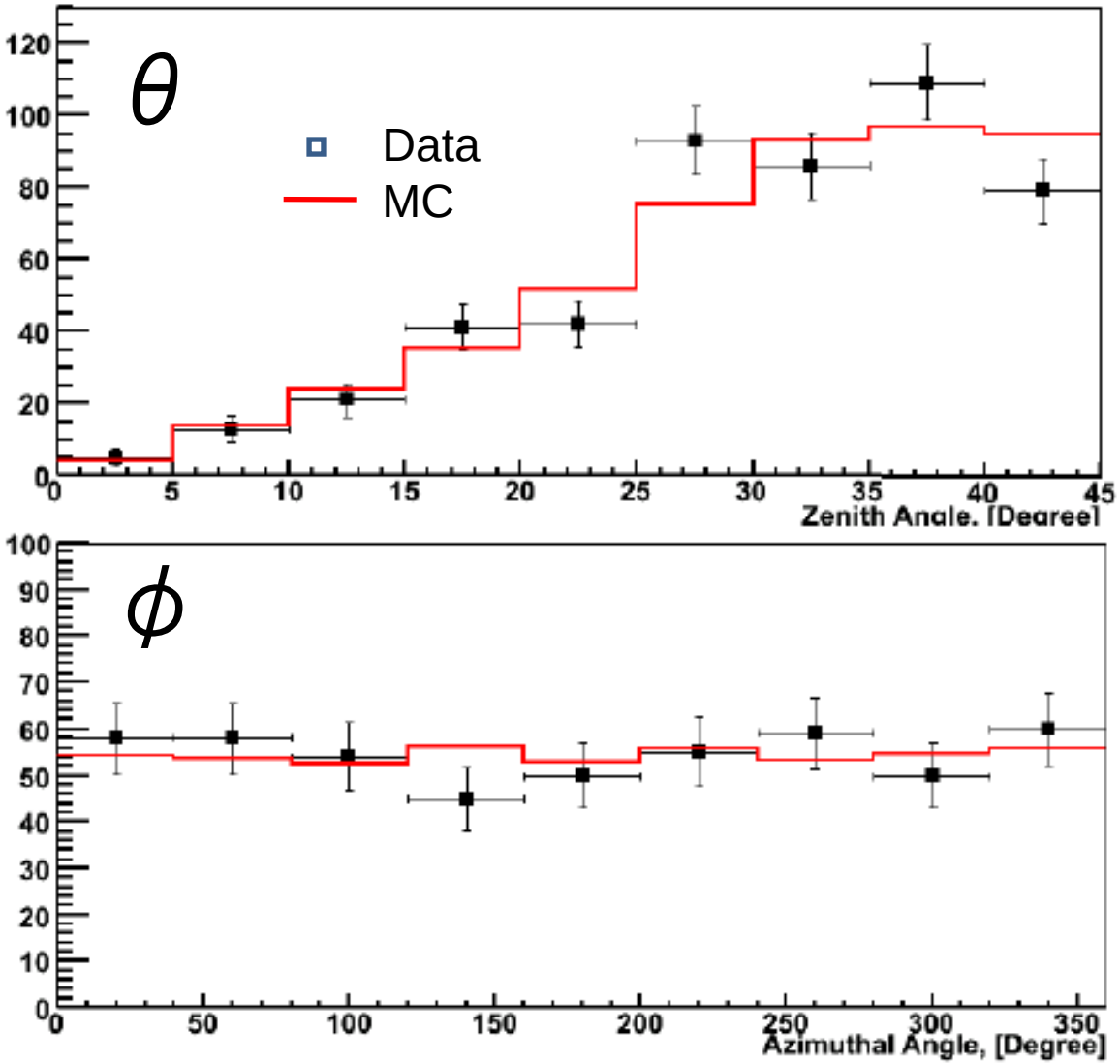






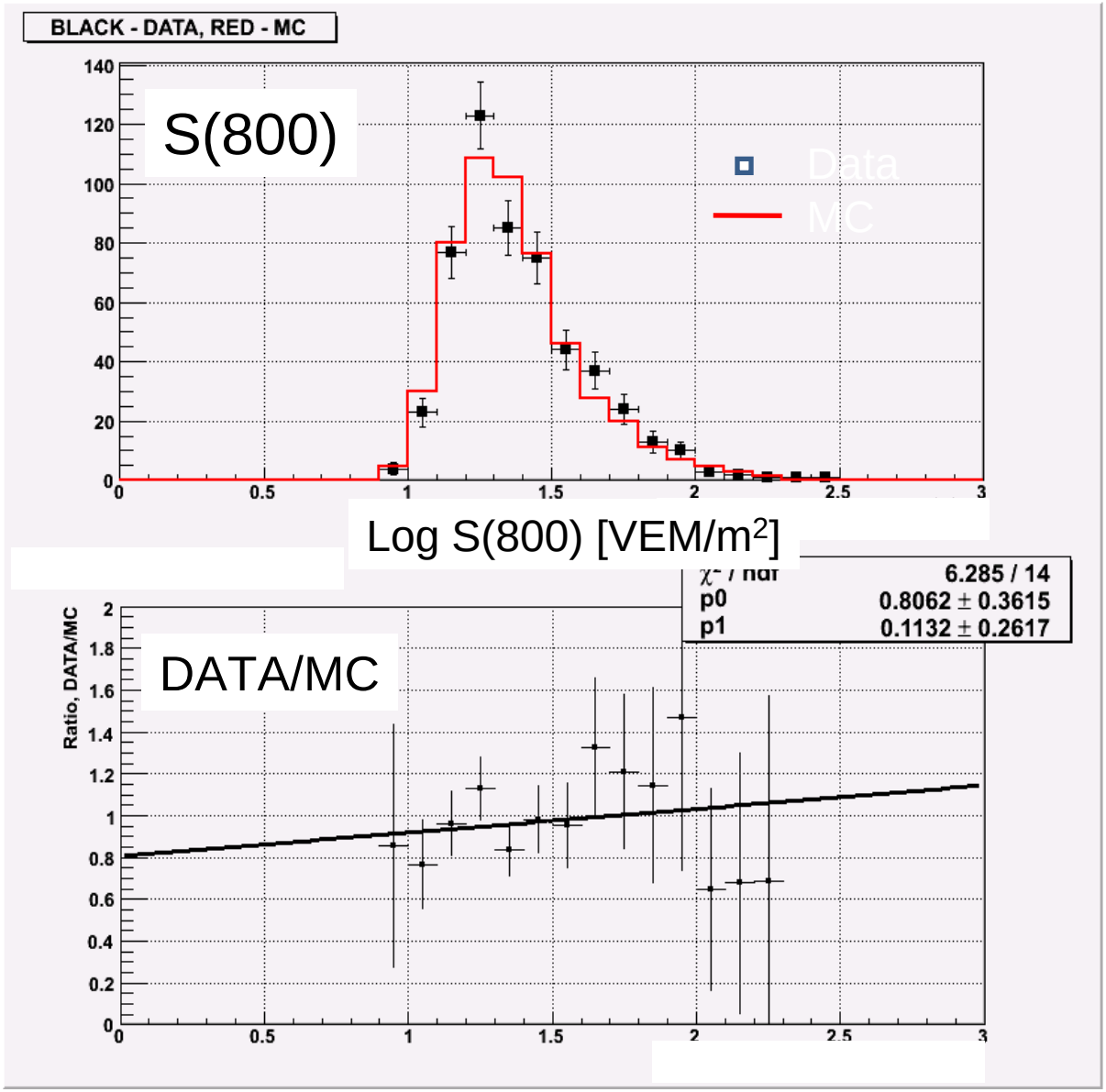
MC by dt-Corsika

θ and ϕ distributions



MC by dt-Corsika

S(800) distribution



MC spectrum:

- $E^{-2.81}$ above ankle
  $E^{-3.25}$ below ankle
- ankle @ $10^{18.65}$ eV
- QGSJET2, proton
  dt-Corsika
- # ev norm. to data

Data:

- May~Nov, 2008
- ~1.0 x 10^{16} m^2 sr s

SDスペクトル解析の

Prospects and Summary

- Check with two “full” Air Shower simulations
- Test reconstruction methods
  (1) average S(800)
  (2) LDF (r, E, θ , ϕ)
- Estimate systematics from
  (a) had. models, (b) p/Fe, (c) reconstruction
- Improve calibration < ~3%
- Improve efficiency at E ~ 10^{19}eV or less

- Check energy scale by SD / FD coin. event

- Wait for more data :
  AGASA total exposure (13y) reached by spring 2010