

ricap07: Roma, June 2007

**Recent results from the Pierre Auger
Observatory**

(and comparisons with AGASA and HiRes)

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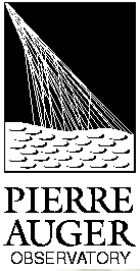
The Pierre Auger Collaboration

| | |
|----------------|-----------------------------|
| Czech Republic | Argentina |
| France | Australia |
| Germany | Brasil |
| Italy ← | Bolivia* |
| Netherlands | Mexico |
| Poland | USA |
| Portugal | Vietnam* |
| Slovenia | <i>*Associate Countries</i> |
| Spain | |
| United Kingdom | |

Roma II
Lecce
Torino
L'Aquila
Milano
Catania
Napoli
Palermo

~300 PhD scientists from
~70 Institutions and 17
countries

Aim: To measure properties of UHECR with unprecedented statistics and precision – **necessary even if no disagreement²**



Present situation

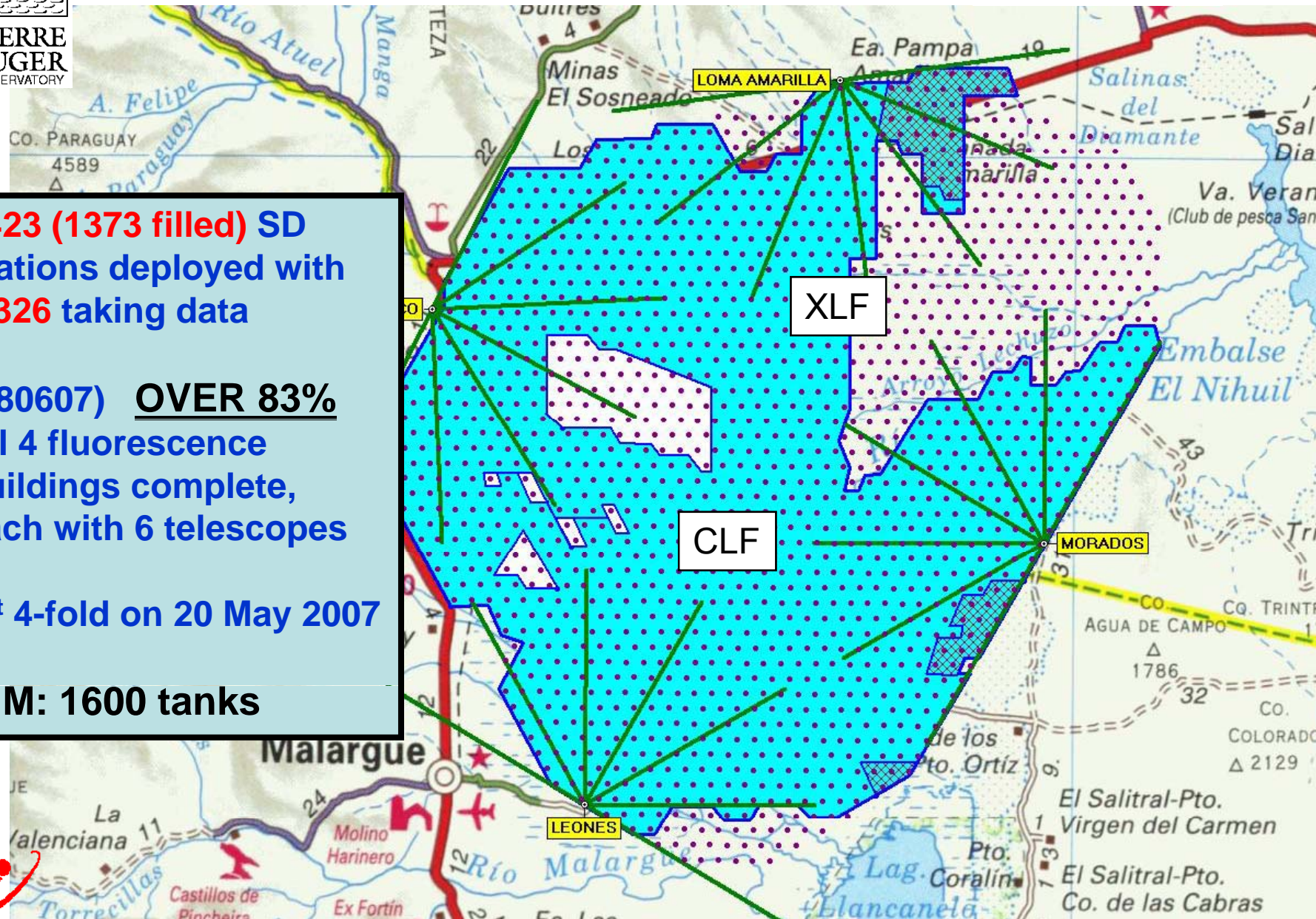
18 June 2007

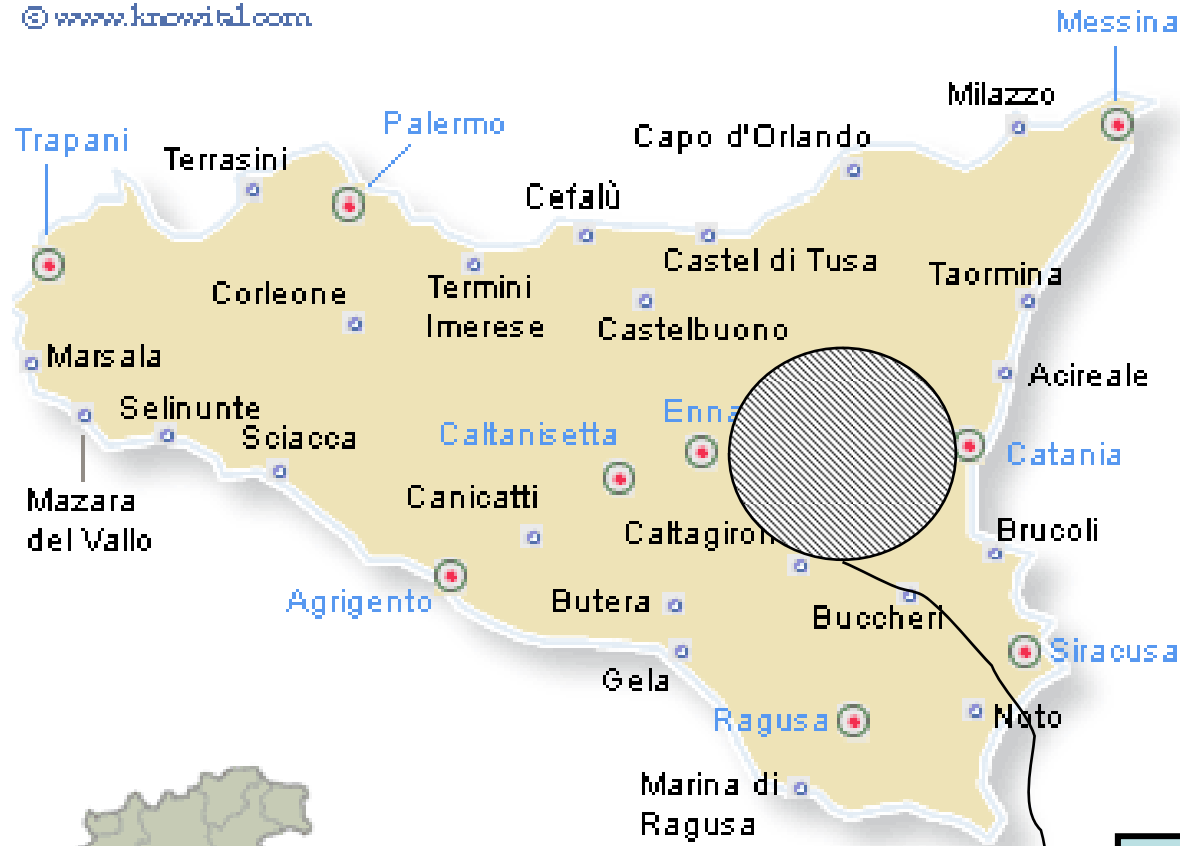
1423 (1373 filled) SD
stations deployed with
1326 taking data

(180607) OVER 83%
All 4 fluorescence
buildings complete,
each with 6 telescopes

1st 4-fold on 20 May 2007

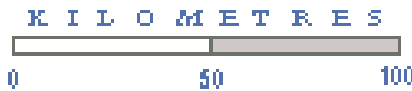
AIM: 1600 tanks





~ area of Auger Observatory
12% area of Sicily

SICILY



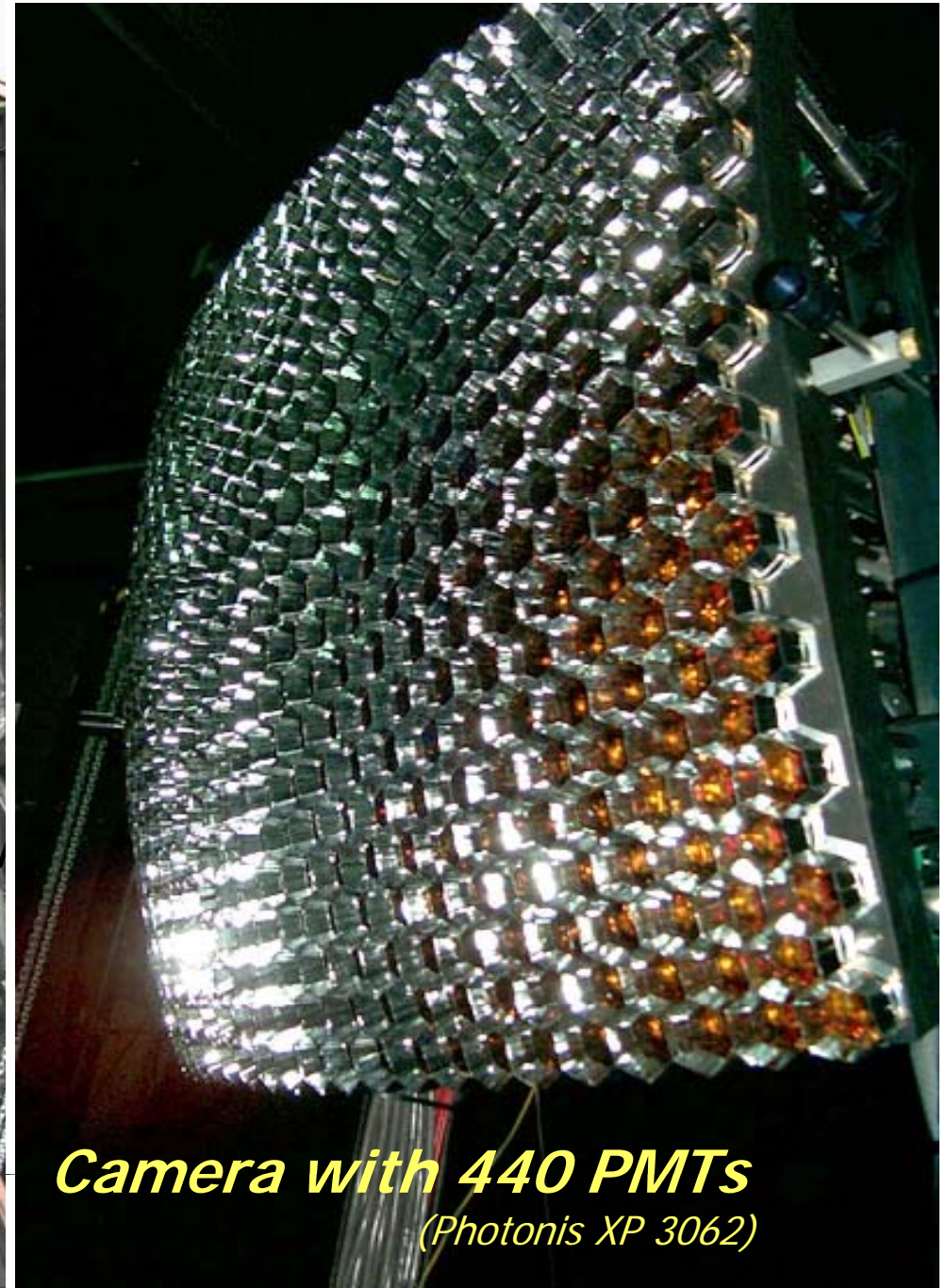
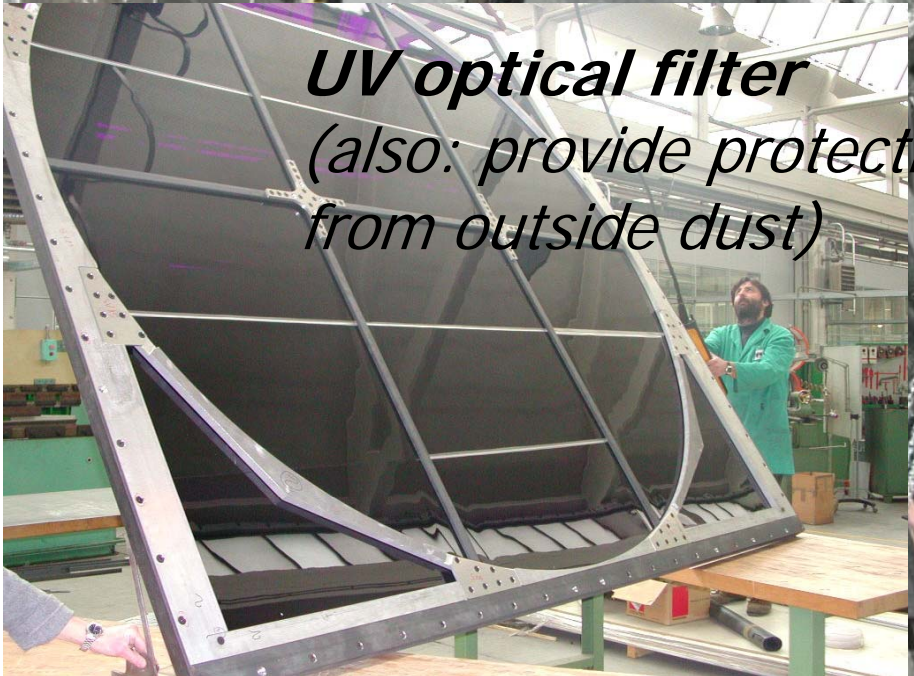
GPS Receiver
and radio transmission



***Schmidt Telescope
using 11 m² mirrors***



***UV optical filter
(also: provide protection
from outside dust)***



***Camera with 440 PMTs
(Photonis XP 3062)***

ARRIVAL DIRECTION DISTRIBUTION FROM AUGER

Typical accuracy of reconstruction $\sim 1^\circ$

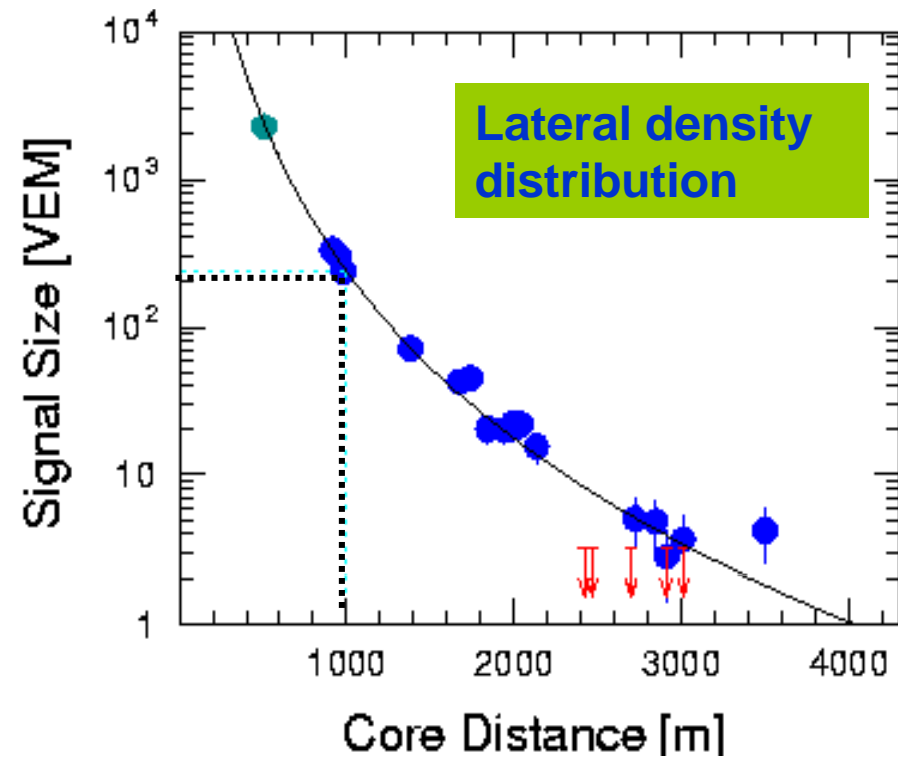
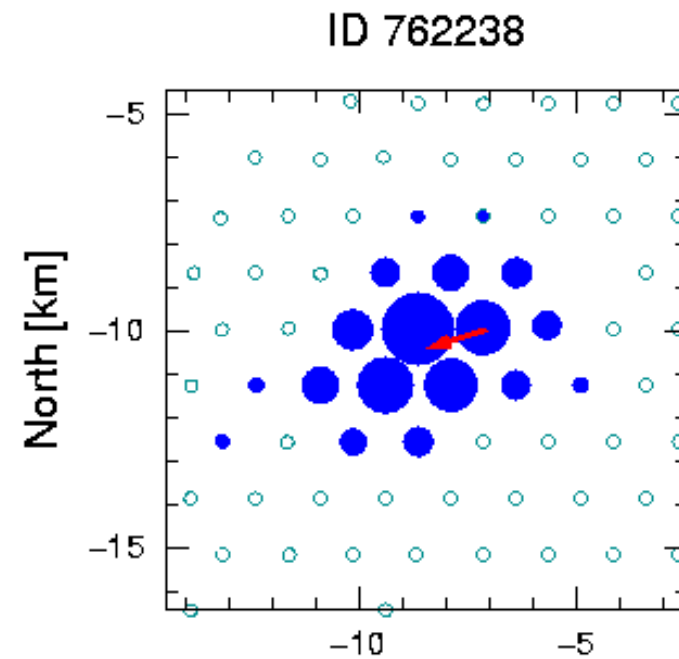
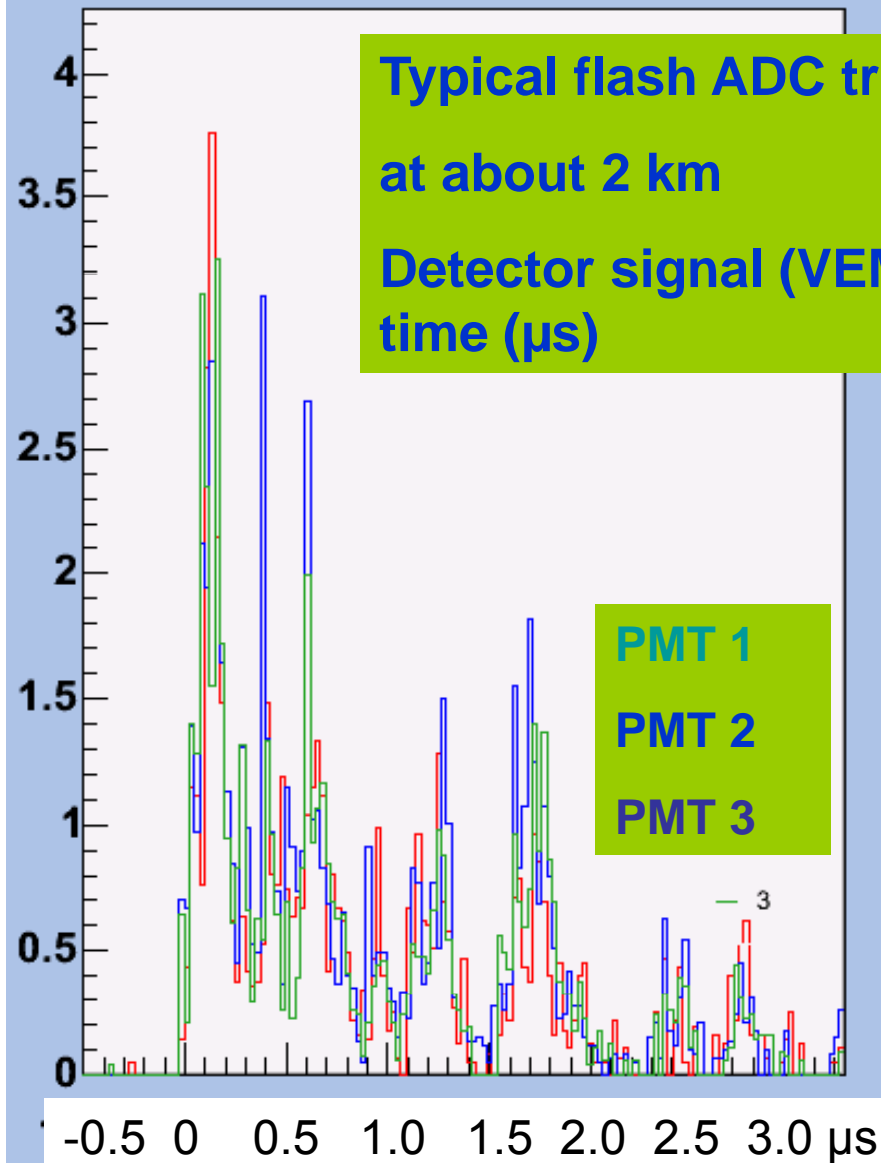
- **No significant emission from Galactic Centre**
- **No broadband signals – e.g. Dipole – at any energy above 1 EeV**
e.g. $1 < E < 3$ EeV, Amplitude $< 0.7\%$
- **No clustering of the type claimed by AGASA**
- **No signal from BL Lacs as possibly seen by HiRes**

Summary: Previous reports have not been confirmed

BUT, two prescriptions are currently being tested
– but I cannot tell you what they are

$\theta \sim 48^\circ, \sim 70 \text{ EeV}$

18 detectors triggered



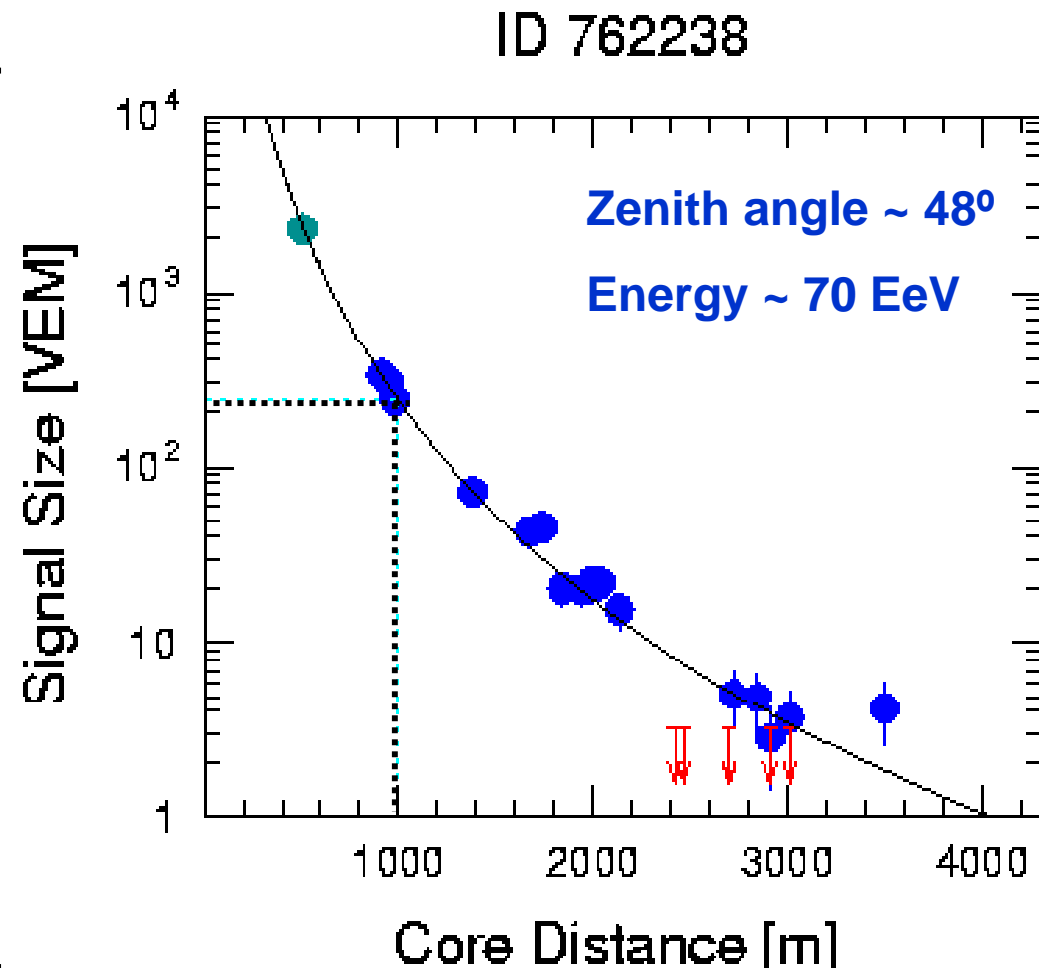
Energy Determination with Auger

The energy scale is determined from the data and does not depend on a knowledge of interaction models or of the primary composition – except at level of few %.

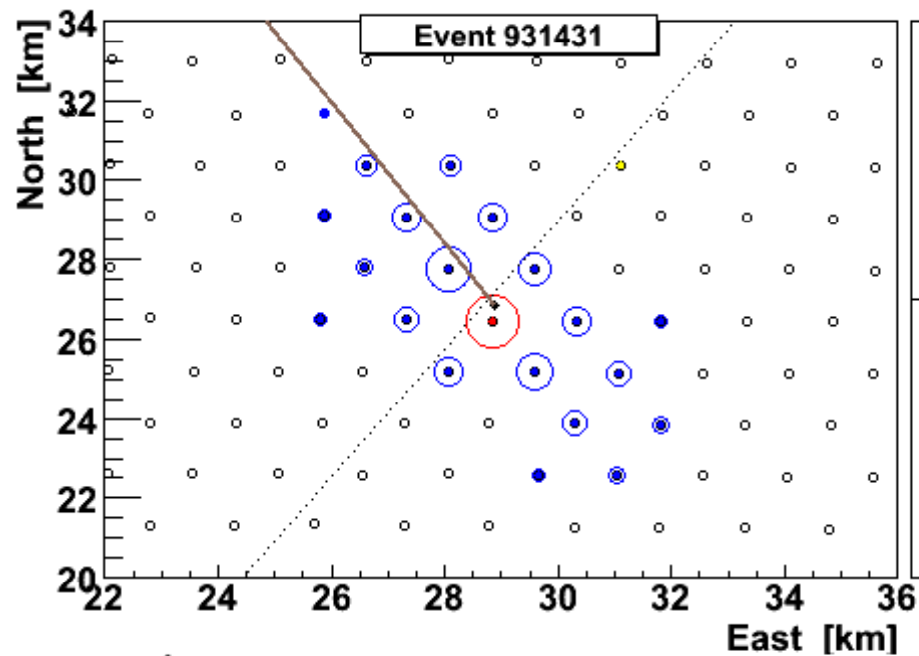
The detector signal at 1000 m from the shower core

- S(1000)
- determined for each surface detector event

S(1000) is proportional to the primary energy

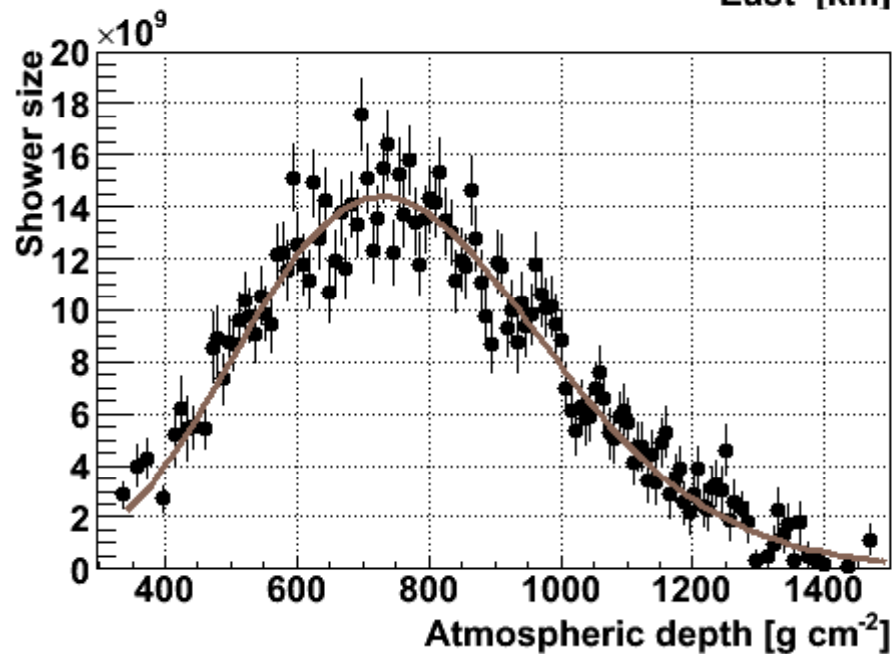


A Hybrid Event

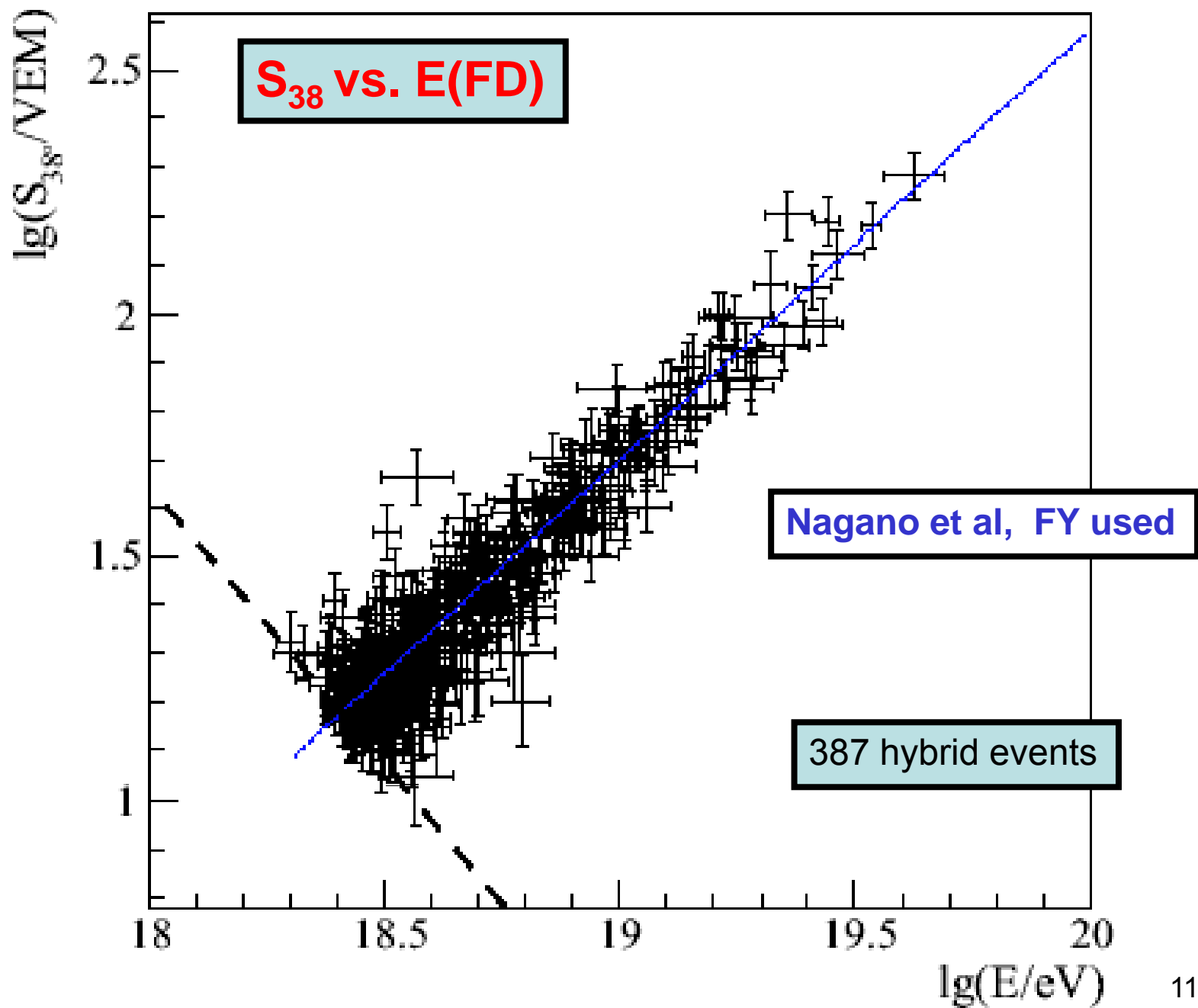


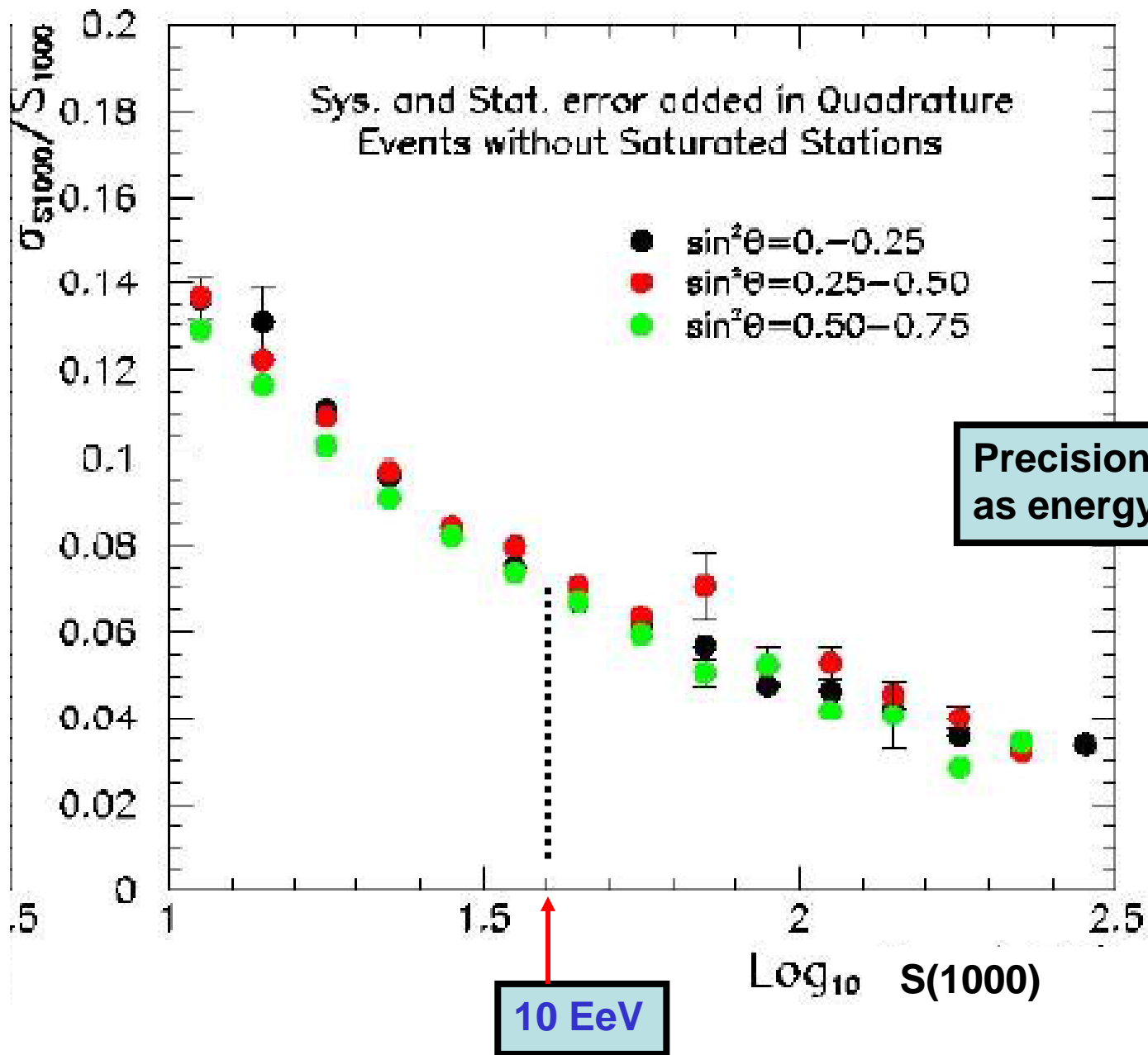
Core location
Easting 468693 ± 59
Northing 6087022 ± 80
Altitude = 1390 m a.s.l.

Shower Axis
 $\theta = (62.3 \pm 0.2)^\circ$
 $\phi = (119.7 \pm 0.1)^\circ$

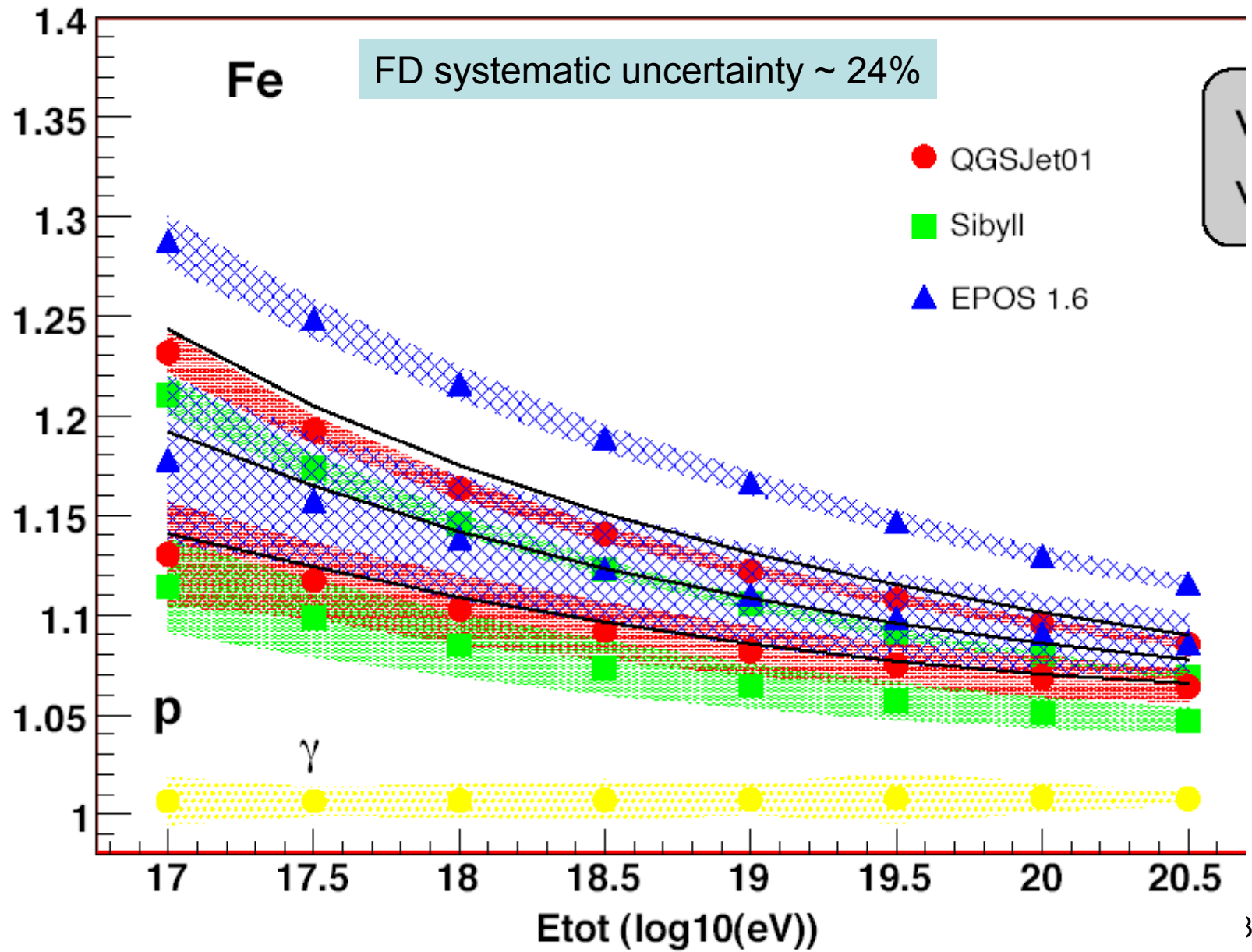


Energy Estimate:
 $X_{\text{max}} = (728 \pm 20) \text{ g cm}^{-2}$
 $\chi^2/\text{dof} = 258 / 134$
 $E_{\text{em}} = (21 \pm 5) \text{ EeV}$
 $E_{\text{tot}} = (23 \pm 6) \text{ EeV}$

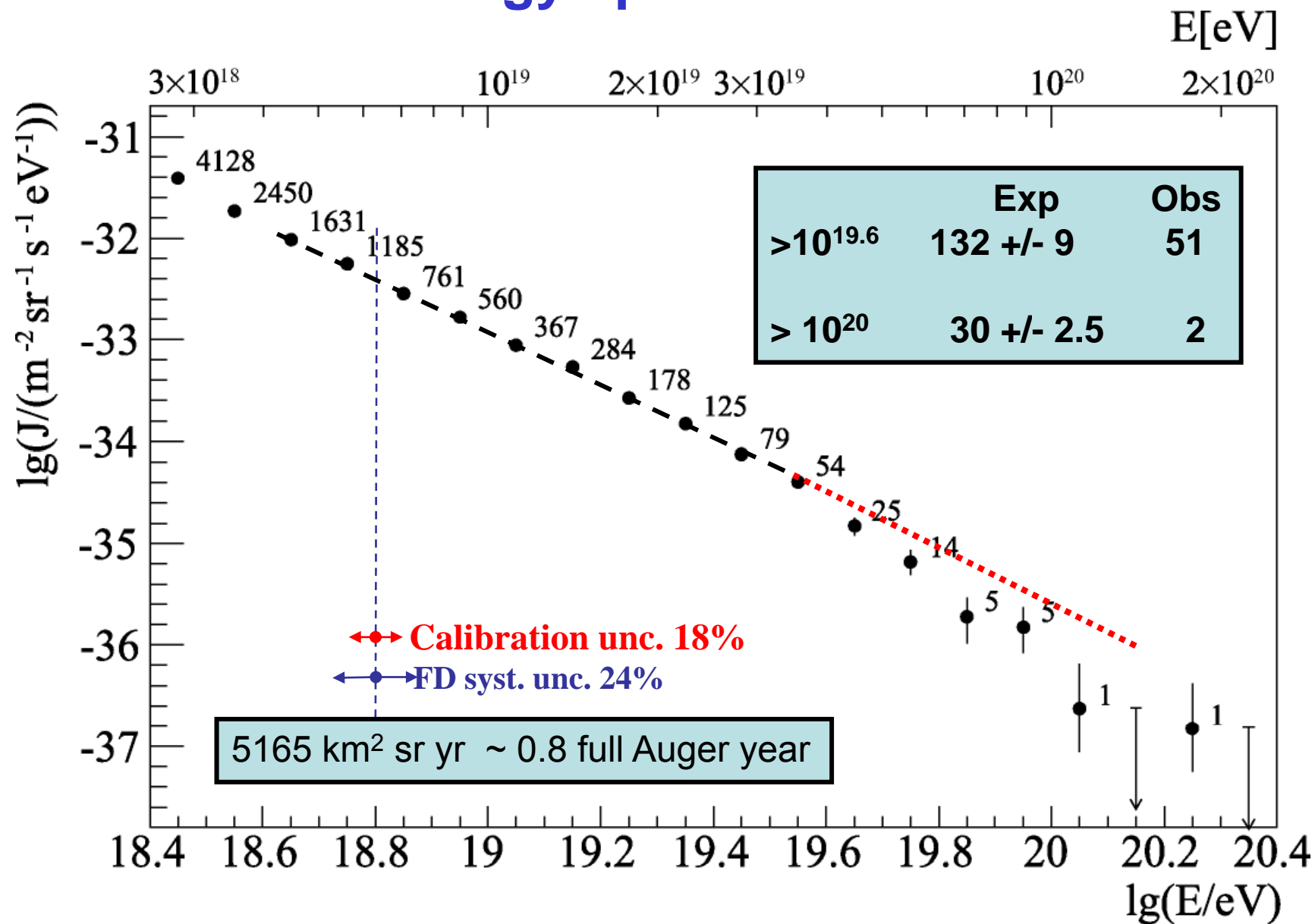


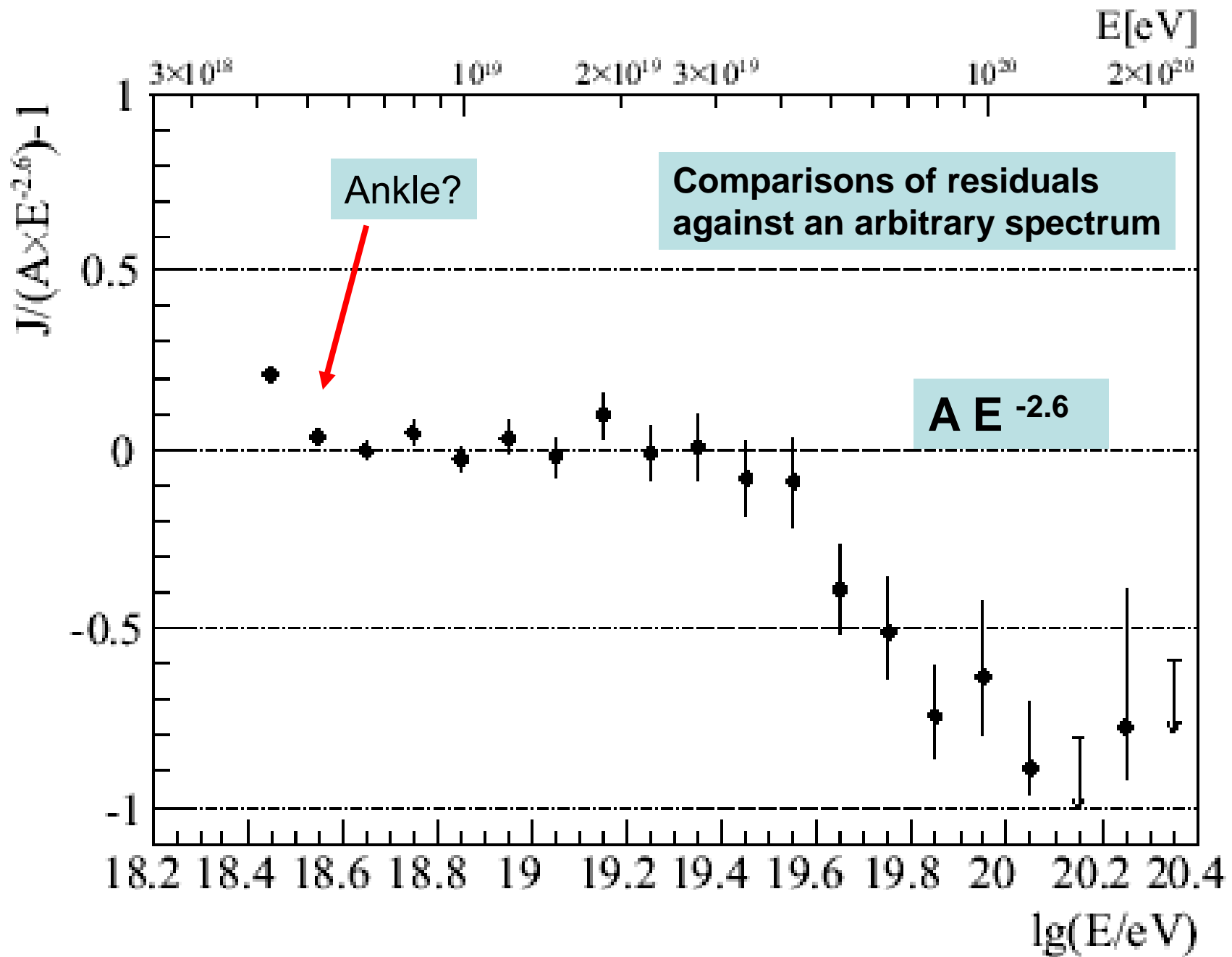


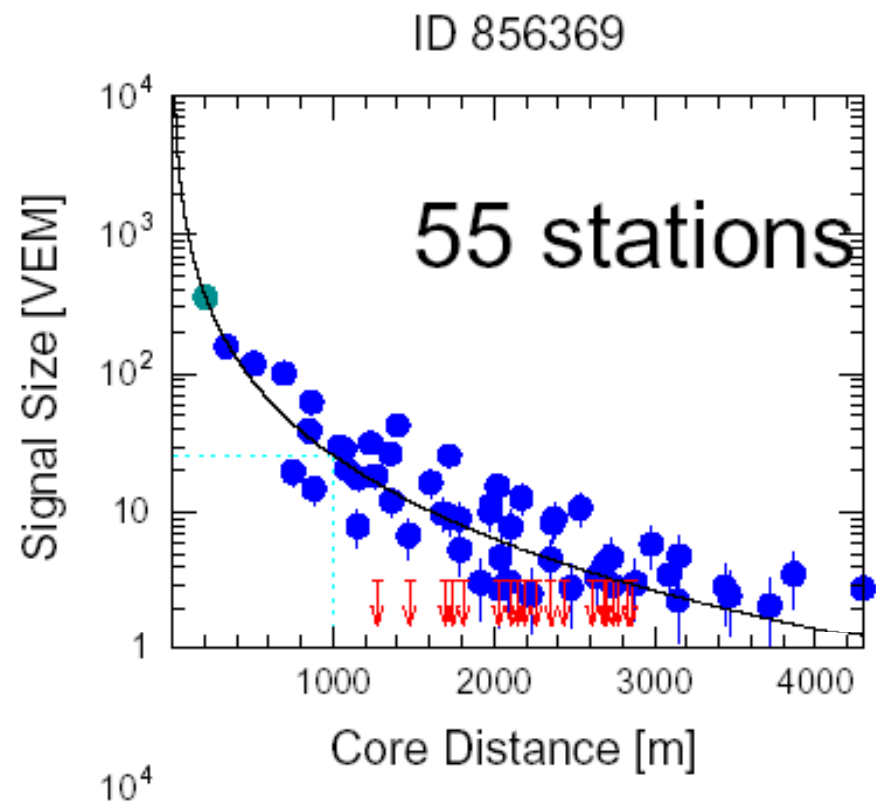
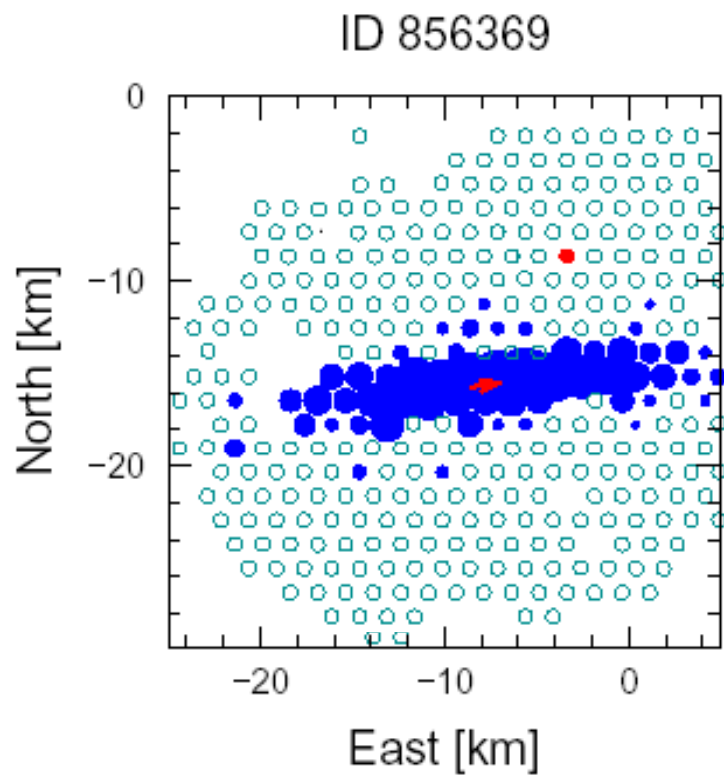
$$f = E_{tot}/E_{em}$$



Energy spectrum from SD





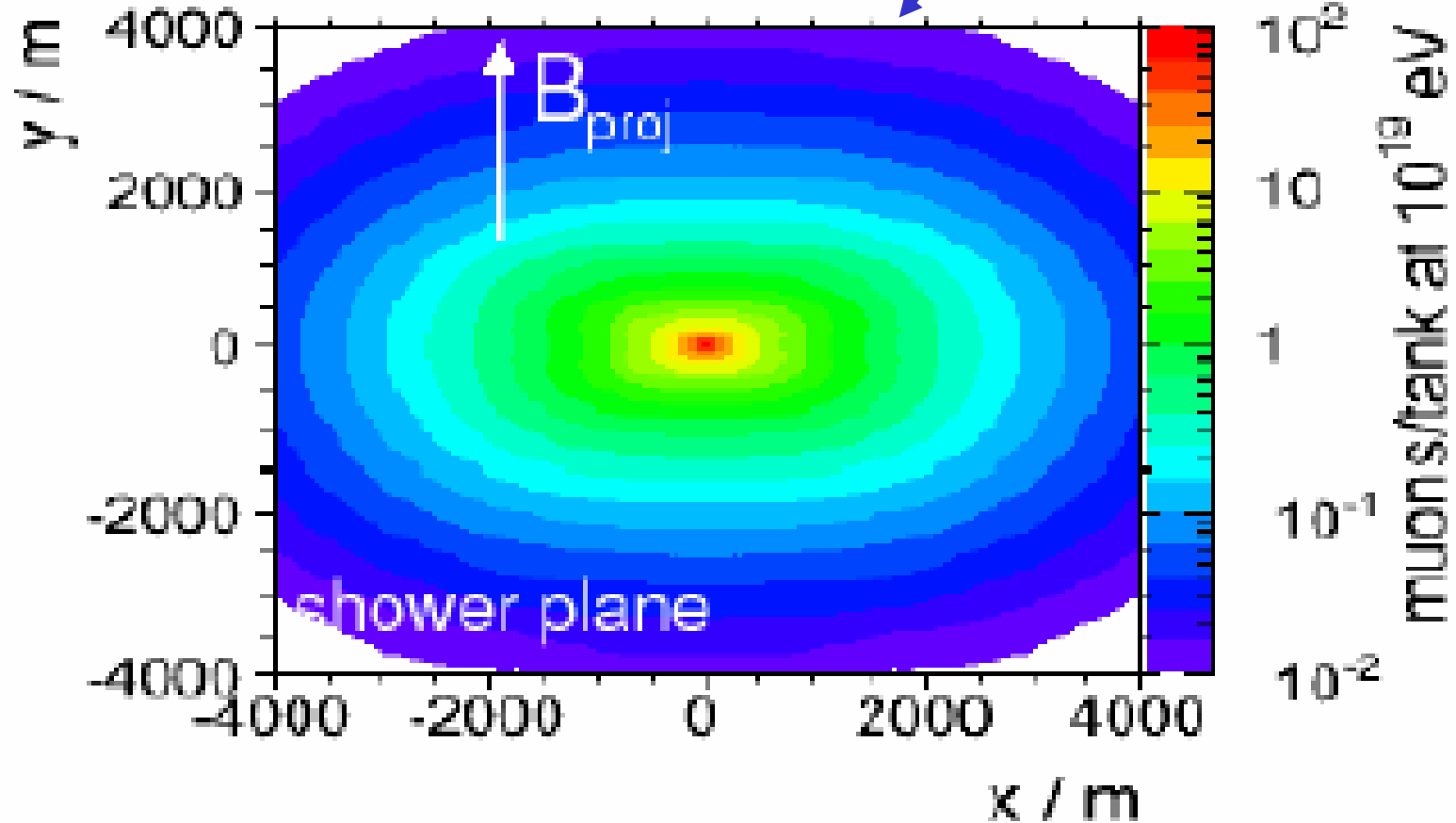


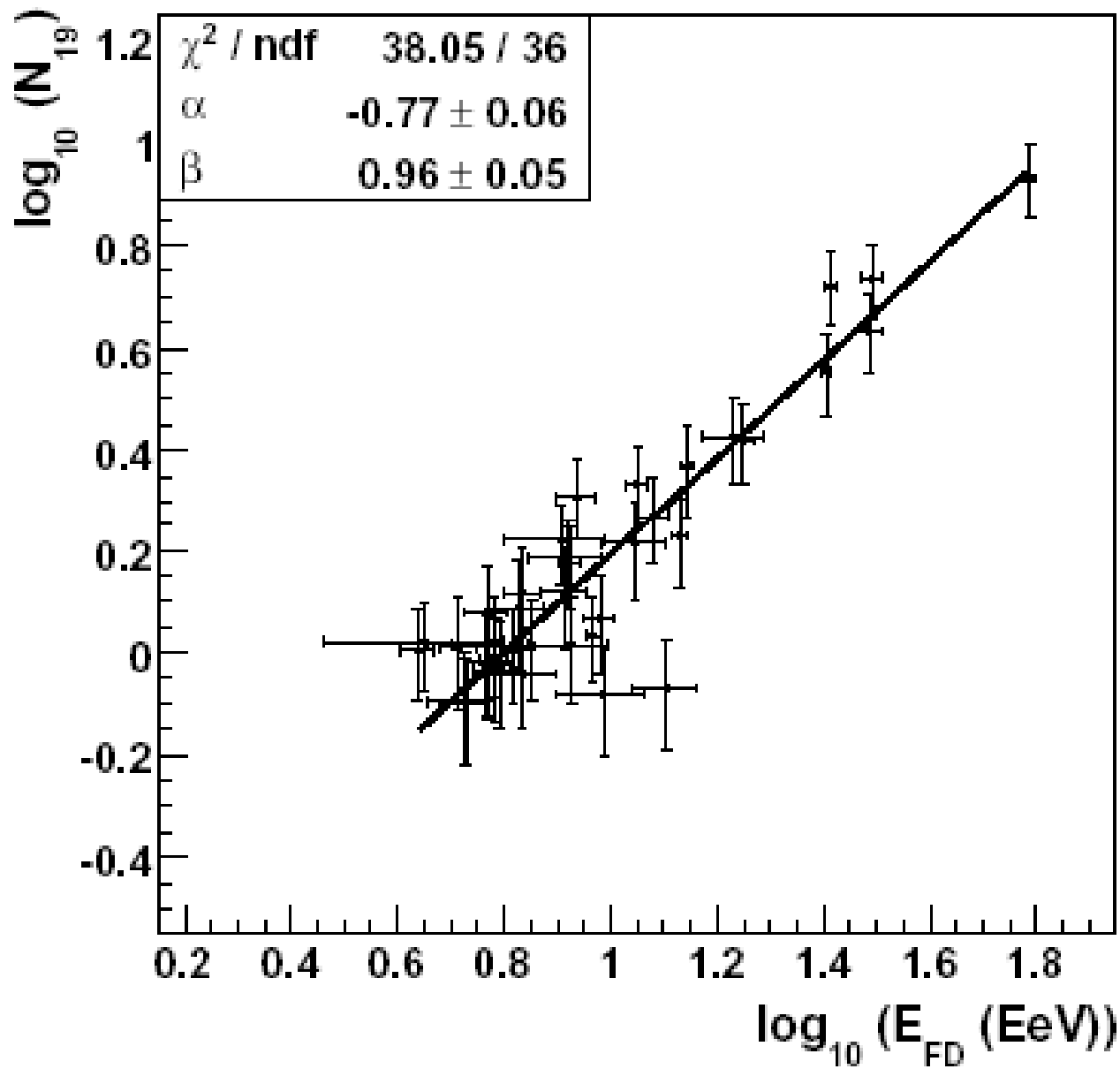
Santiago zenith $50^\circ - 89^\circ$

- AIRES, QGSJET-I, **Protons**
- Full simulation without magnetic field
- 100 shower / map
- Magnetic distortion: Added by model
- Attenuation is not currently parameterised

Muon map for 10^{19} eV and 80°

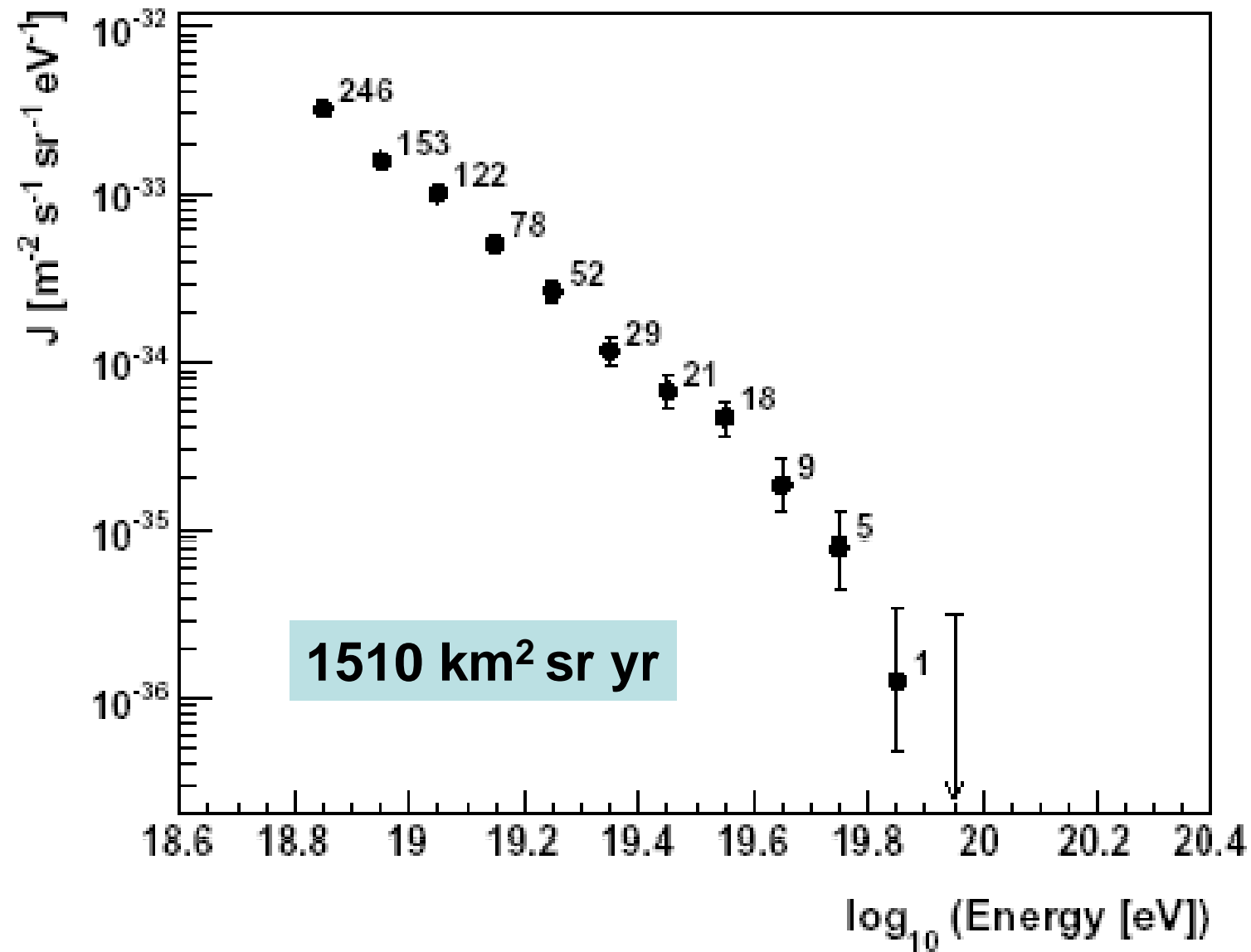
Shape is mass and model independent





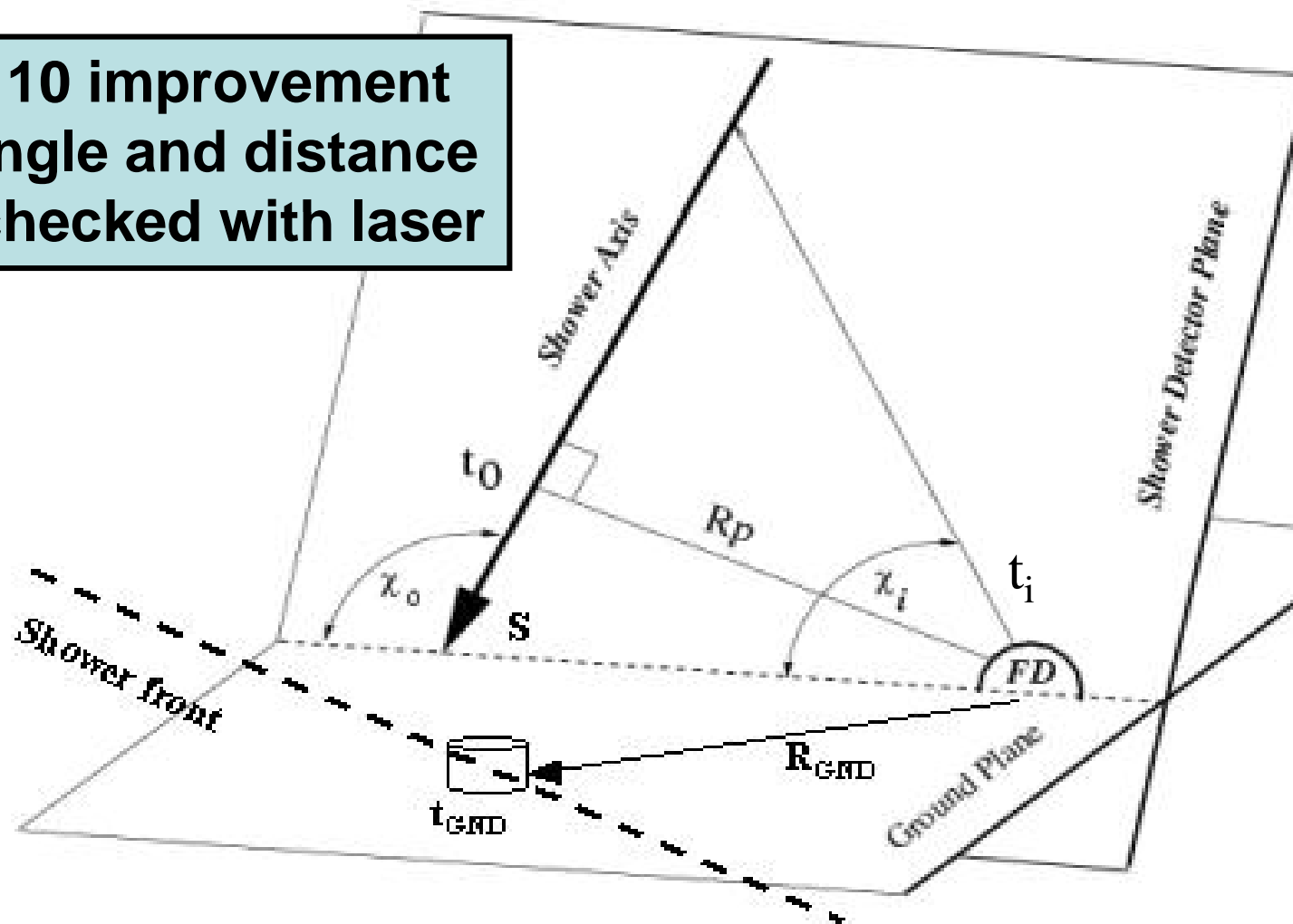
Calibration curve for
Inclined showers

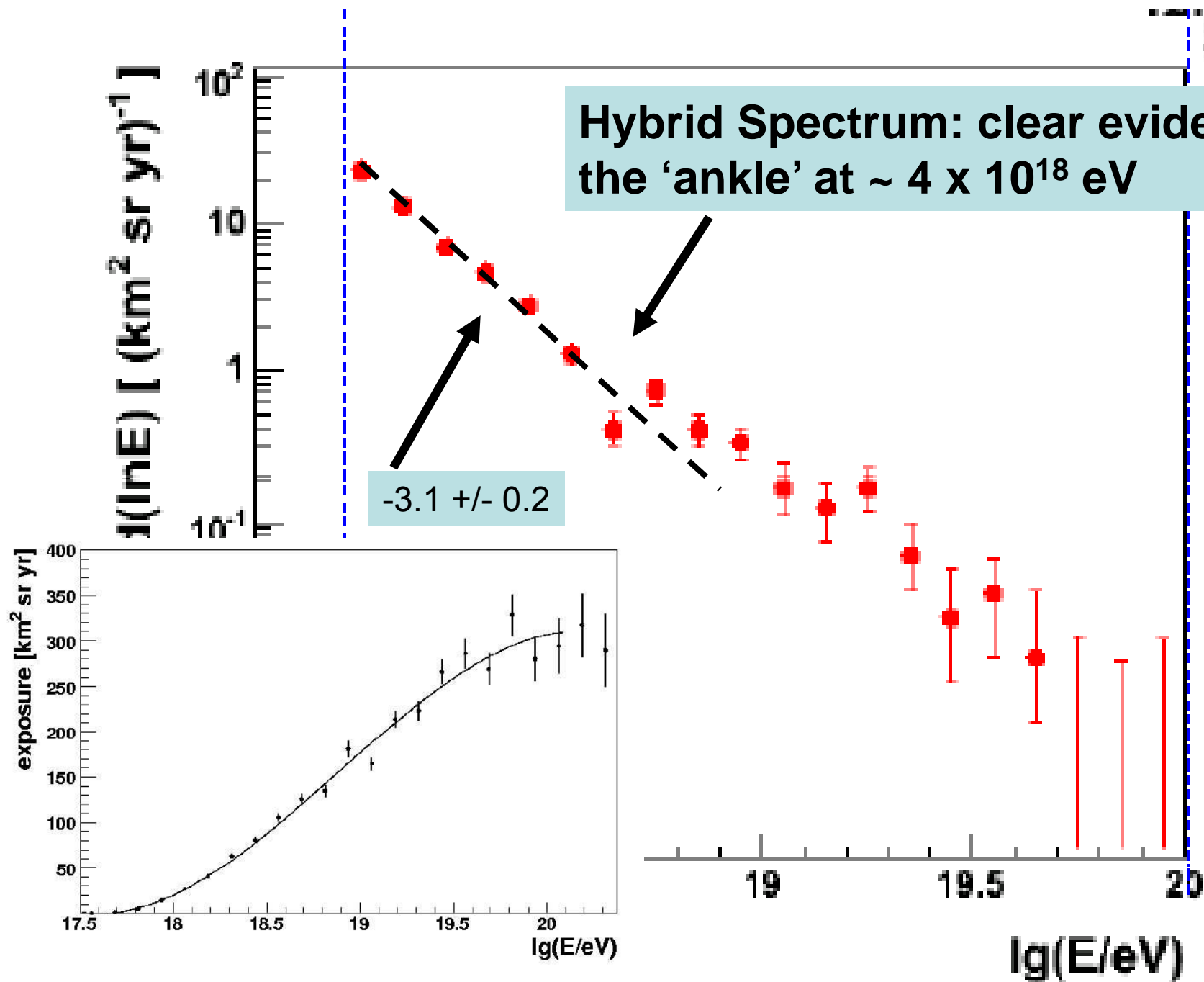
Energy Spectrum from $60^\circ < \theta < 80^\circ$: 734 events

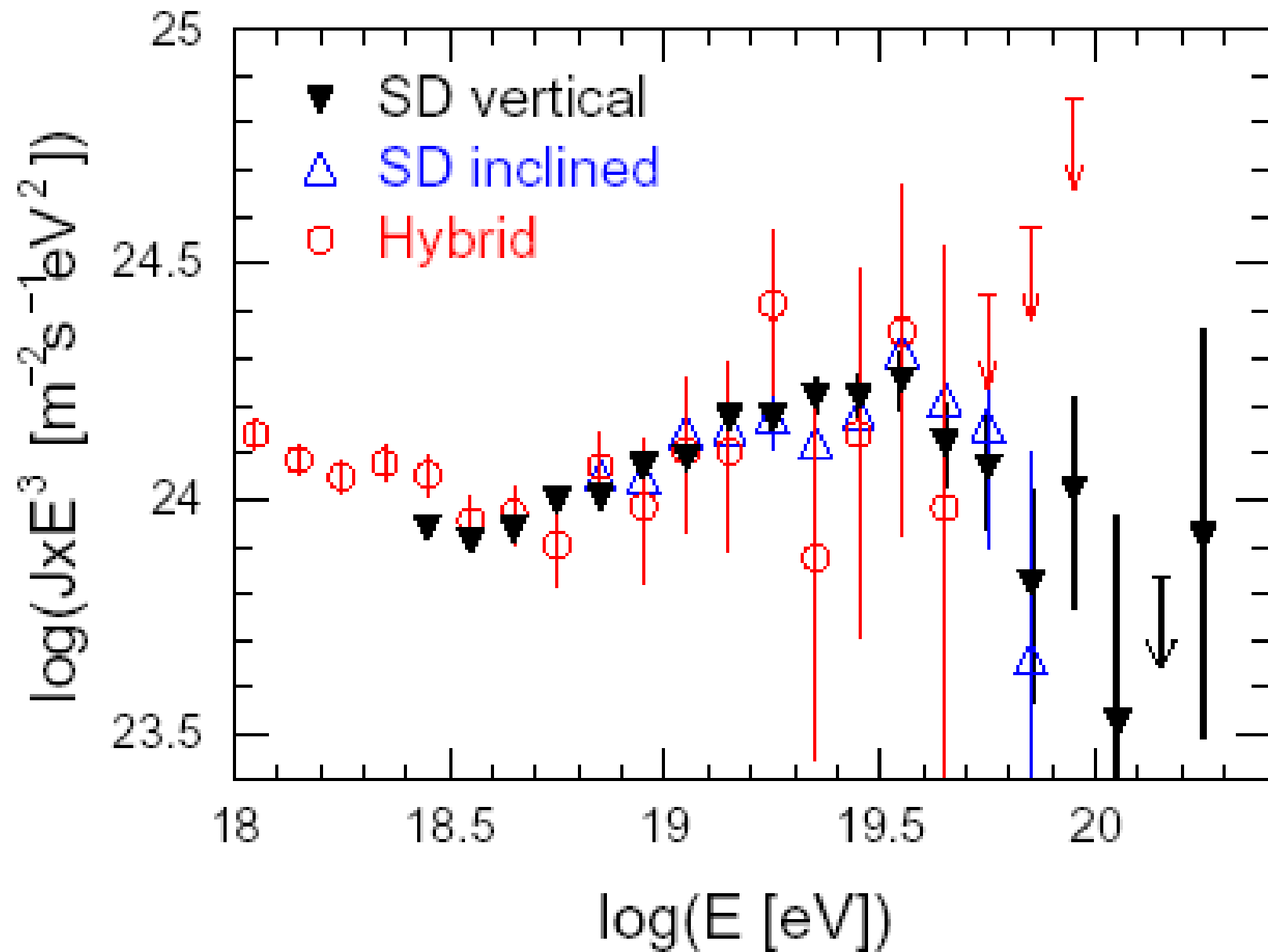


The 'hybrid' spectrum

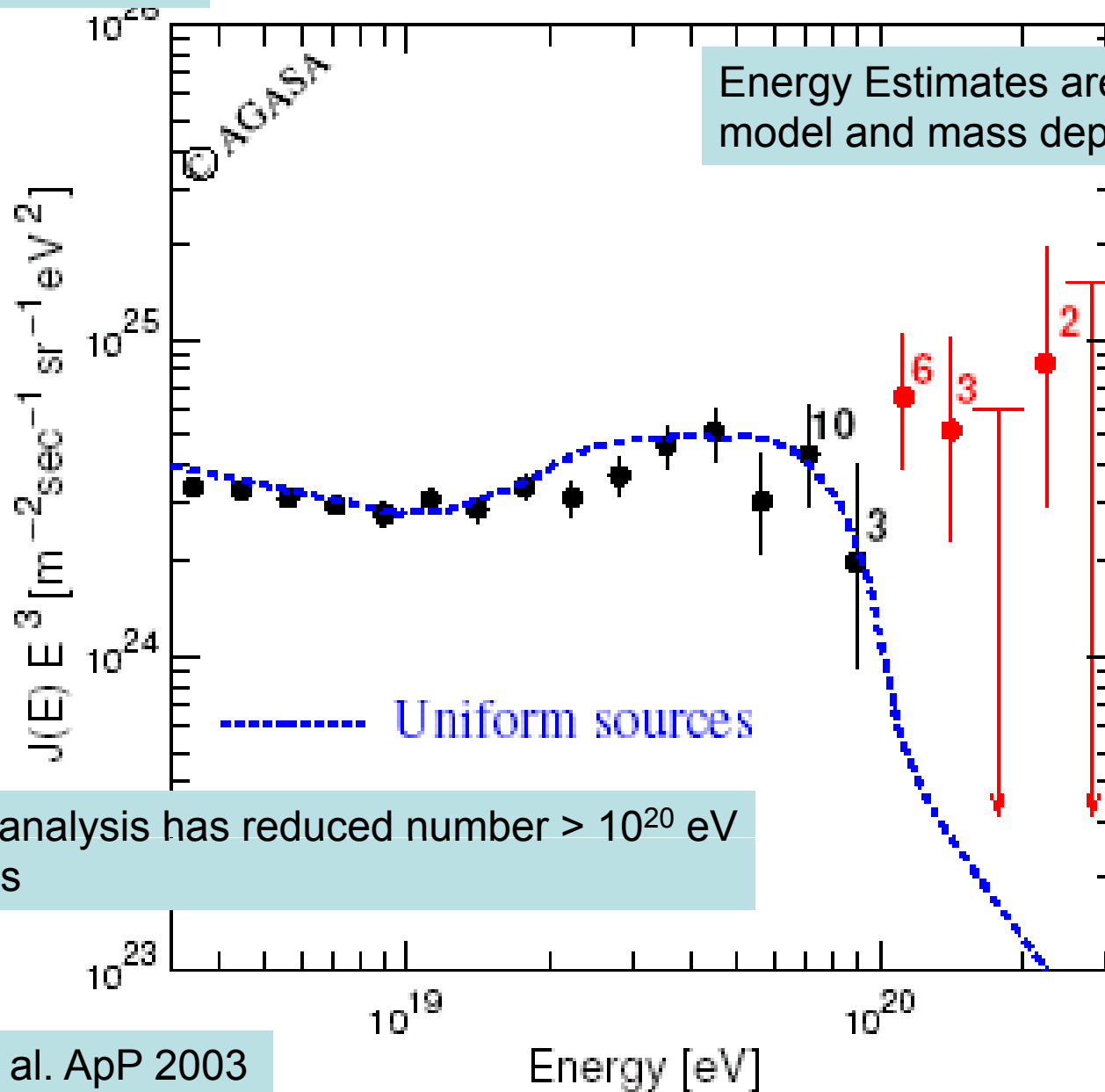
~ X 10 improvement
in angle and distance
as checked with laser





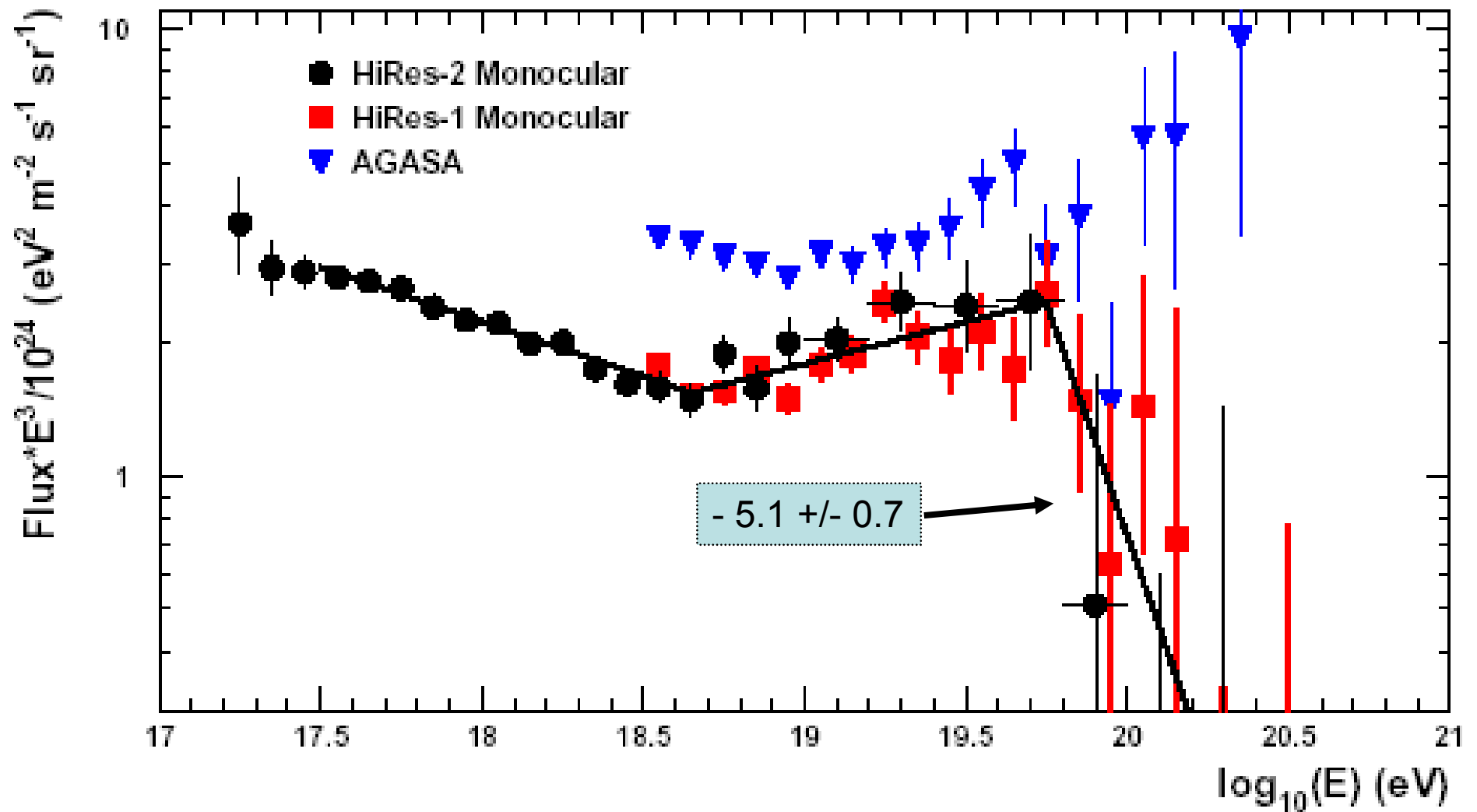


Surface Detectors



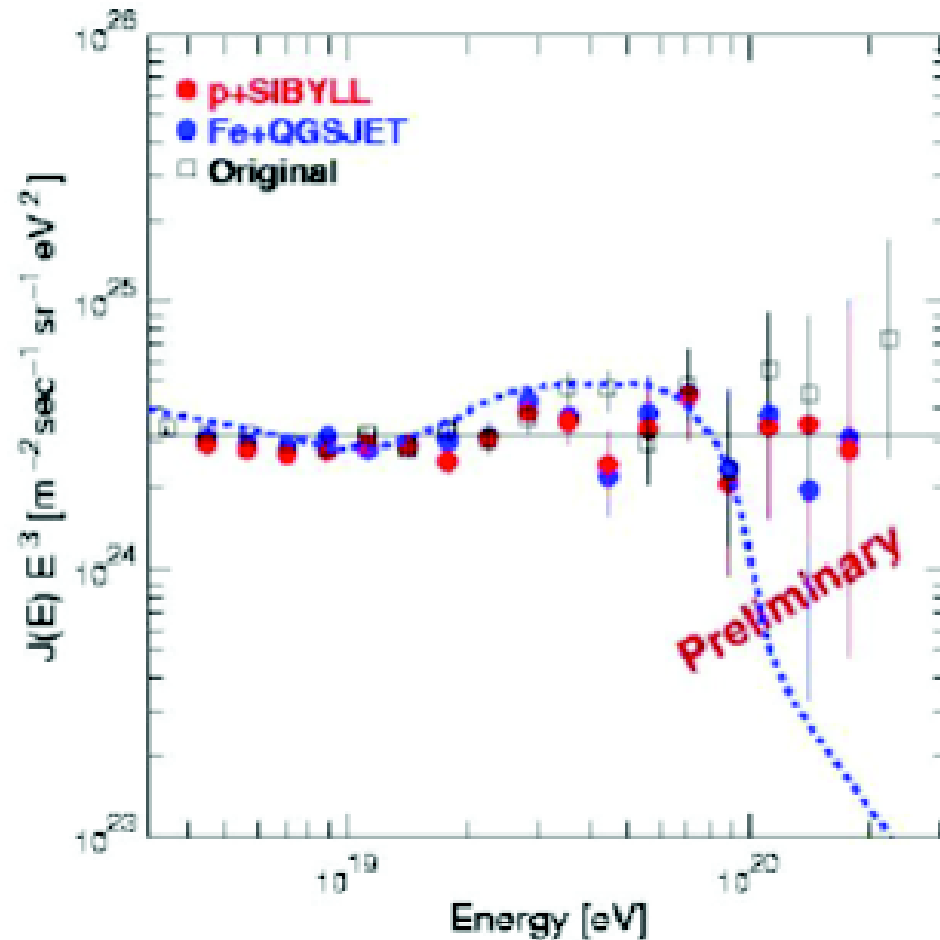
Recent reanalysis has reduced number $> 10^{20}$ eV to 6 events

Takeda et al. ApP 2003



HiRes Group: astro-ph/0703099

Preliminary spectra with recent Corsika



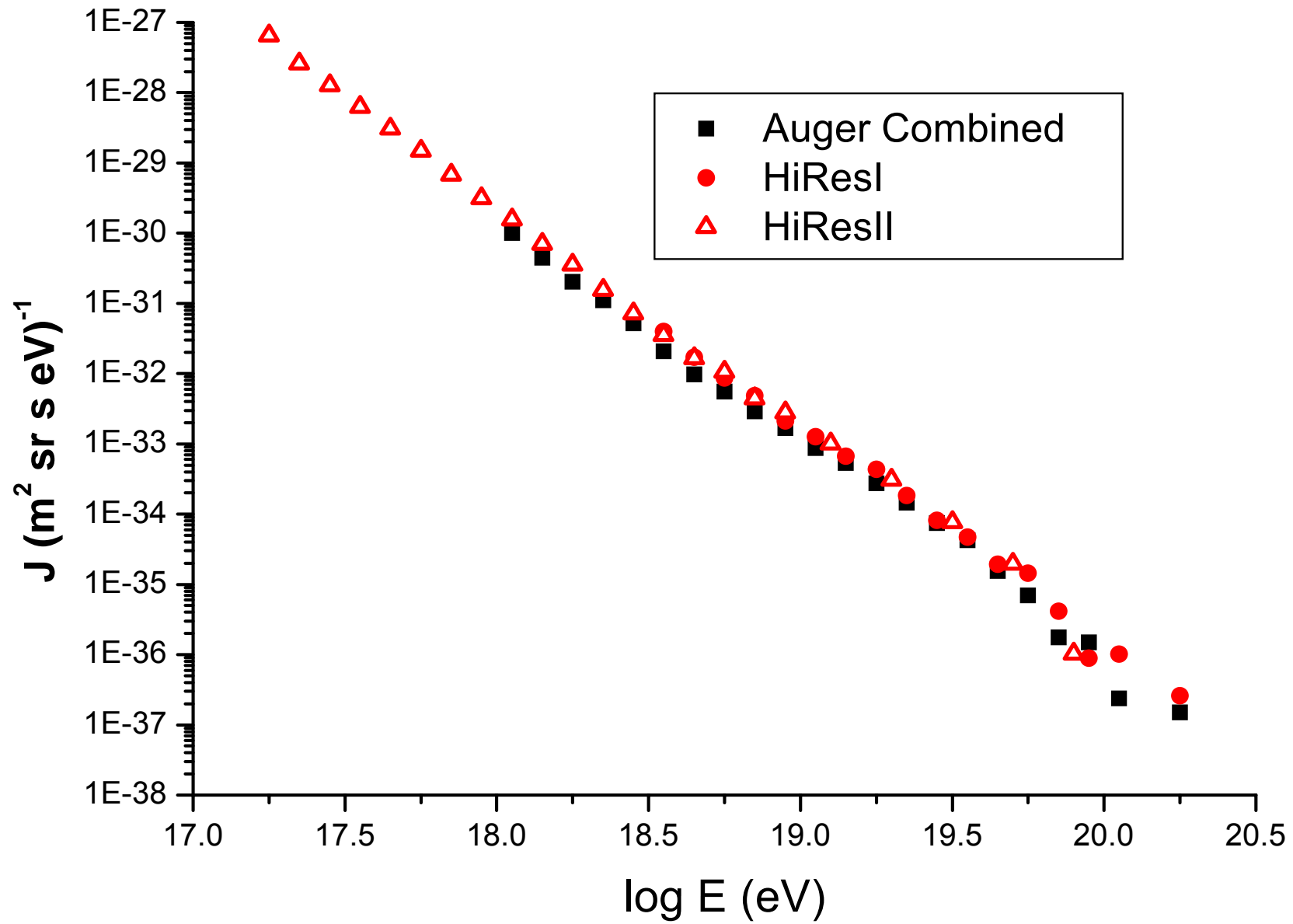
Featureless spectrum
very close to E^{-3}

P-SIBYLL (above 10^{19} eV)
 $\gamma = 2.95 \pm 0.08$
($\chi^2 / \text{NDF} = 8.5/11$)

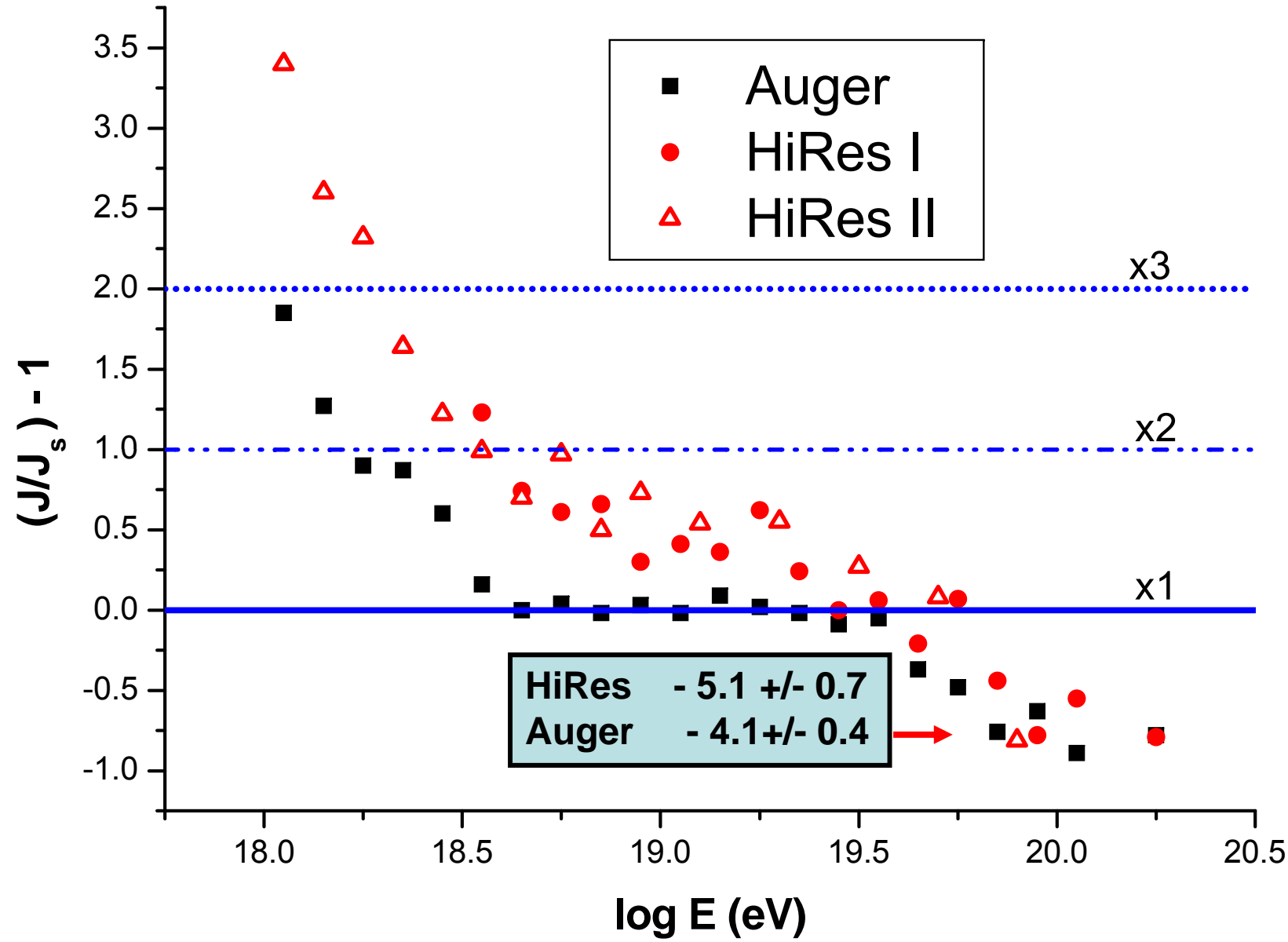
Fe-QGSJET (above 10^{19} eV)
 $\gamma = 2.90 \pm 0.08$
($\chi^2 / \text{NDF} = 8.5/11$)

There is some wiggle in the
spectrum, but not significant

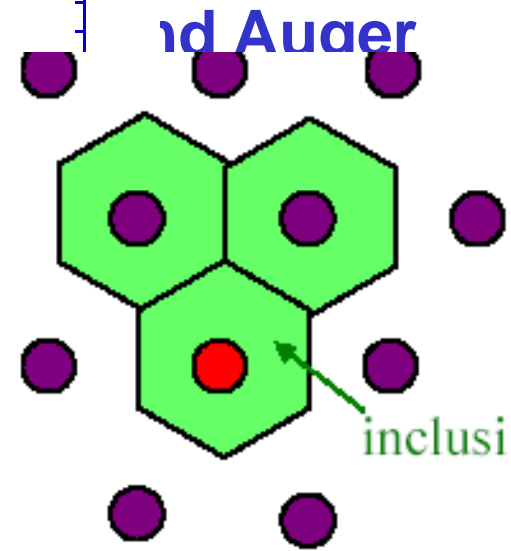
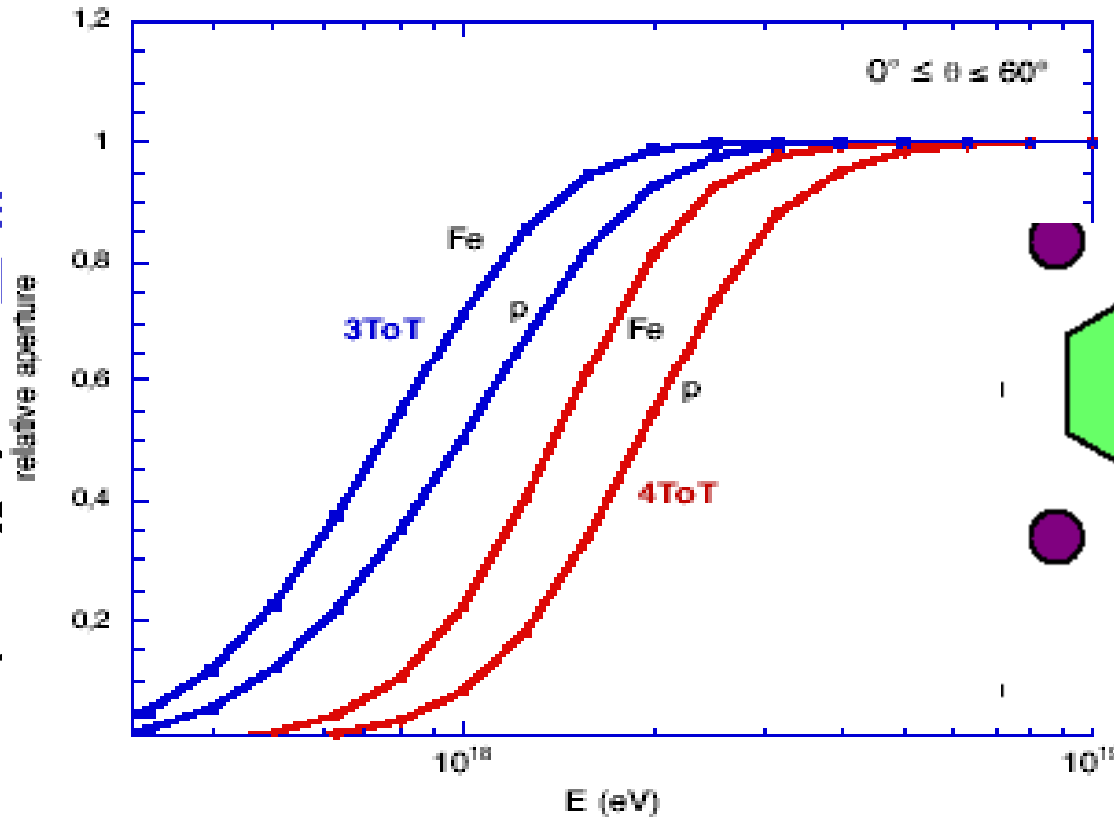
Teshima: Roma 2006



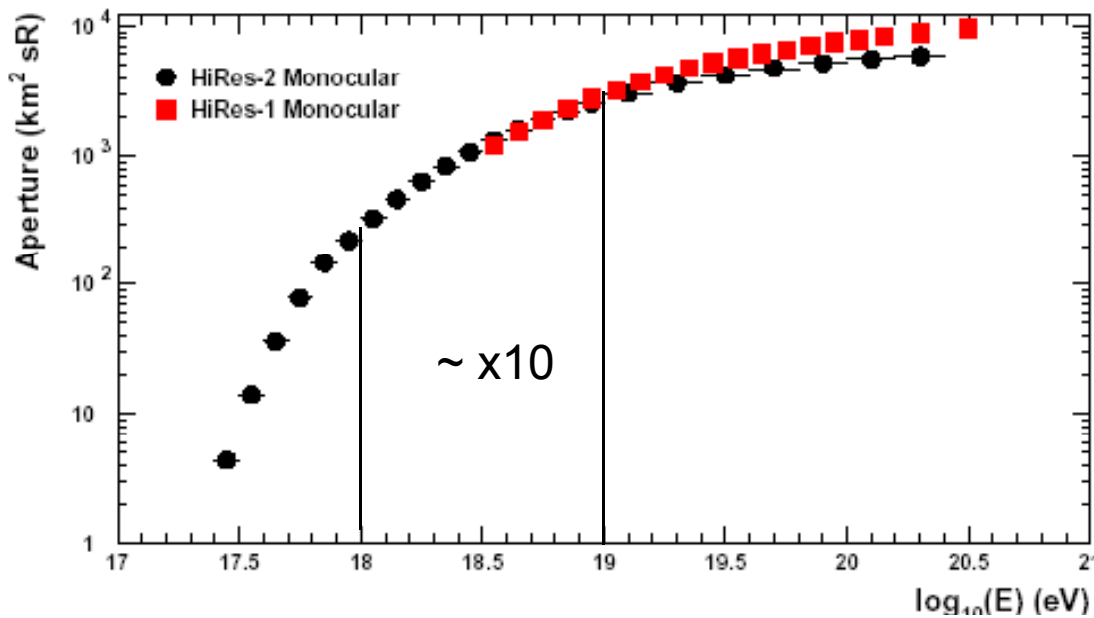
Plot of residuals of individual spectra compared to standard, $J_s = A E^{-2.6}$



- Se
- in t
- Au
- mas
- Tr



- Hi
- pro
- C



isions with
solved

S

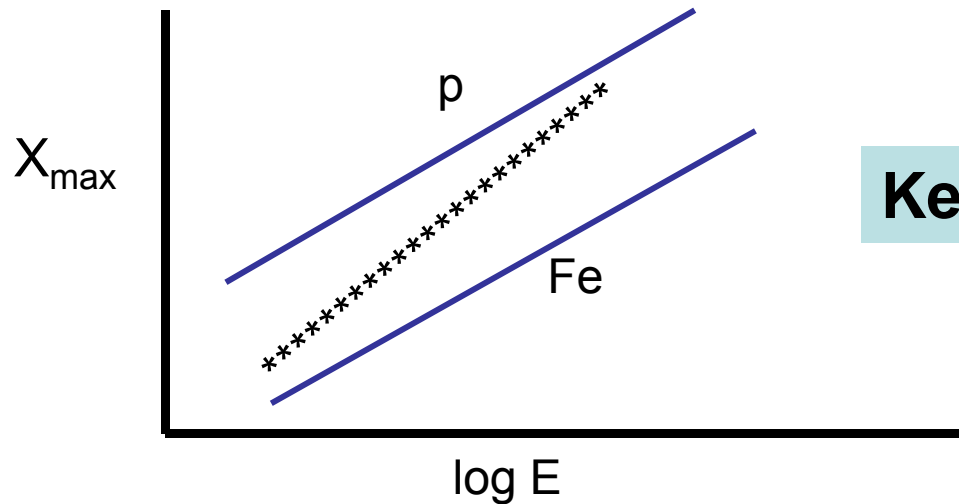
Immensely important **IF** it was to be established that slopes at highest energy are different in
northern $(- 5.1 \pm 0.7)$ and
southern hemispheres $(- 4.1 \pm 0.4)$

But, MUCH TOO EARLY TO DRAW CONCLUSIONS

- **Uncertainties about HiRes aperture**
- **Poorer energy and angular resolution
in HiRes than Auger**
- **Low number of events –
and no more to come to from HiRes**
- **Issue will be addressed with more Auger data**

Inferring the Primary Mass: Crucial for Interpretation

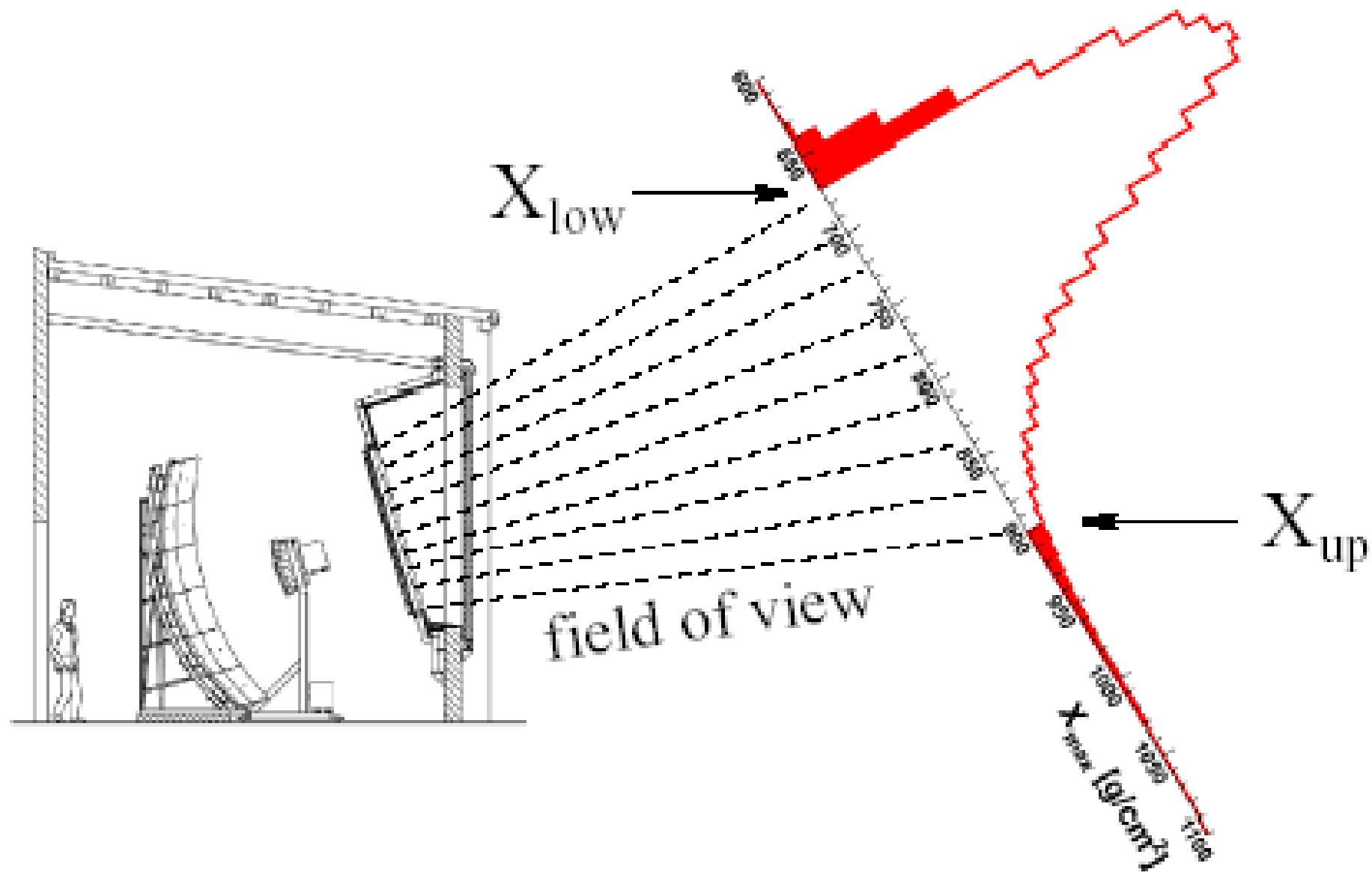
Variation of Depth of Maximum with Energy



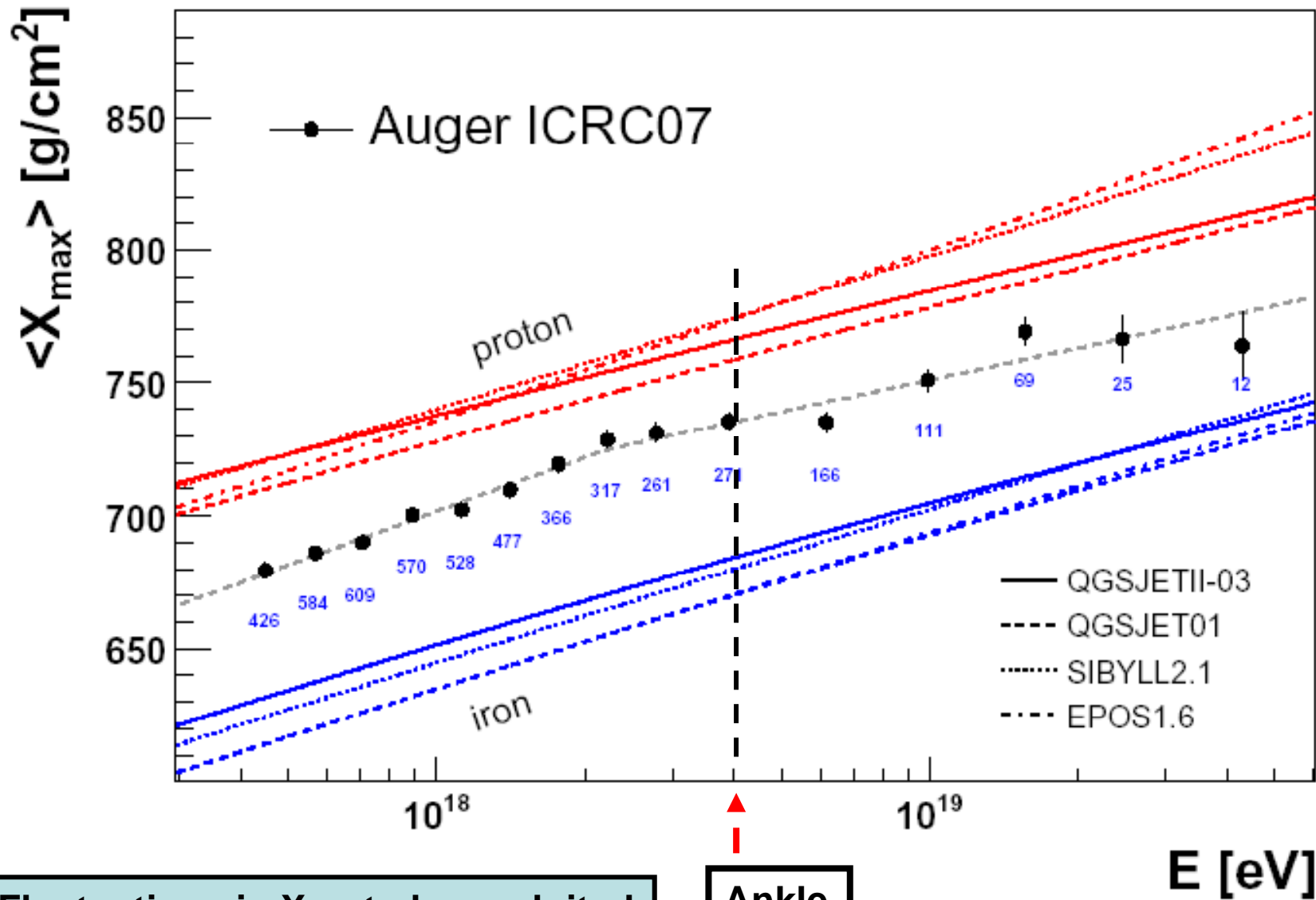
Key is energy per nucleon

protons
nuclei
neutrinos
photons

all are expected at some level
- at different energies

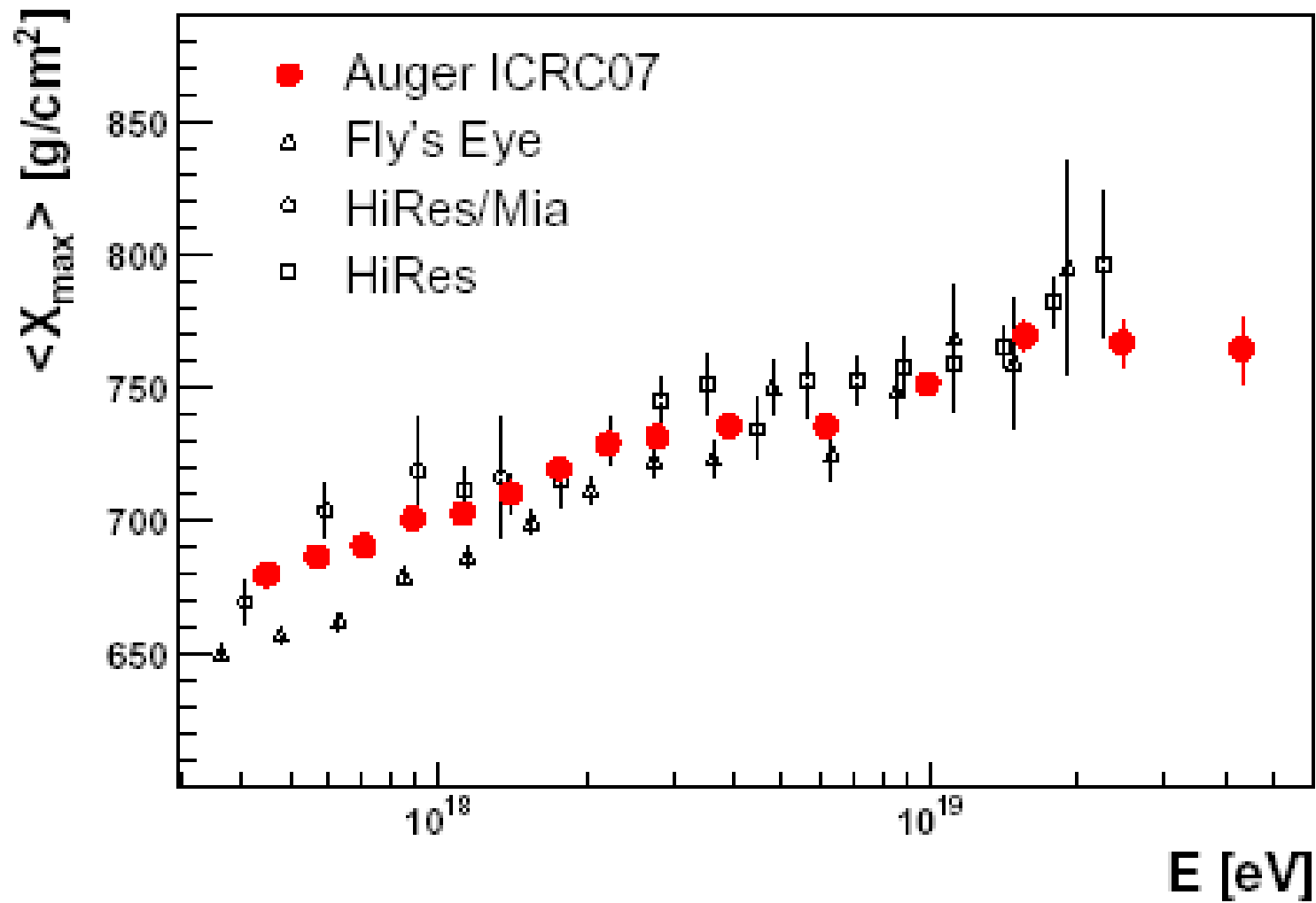


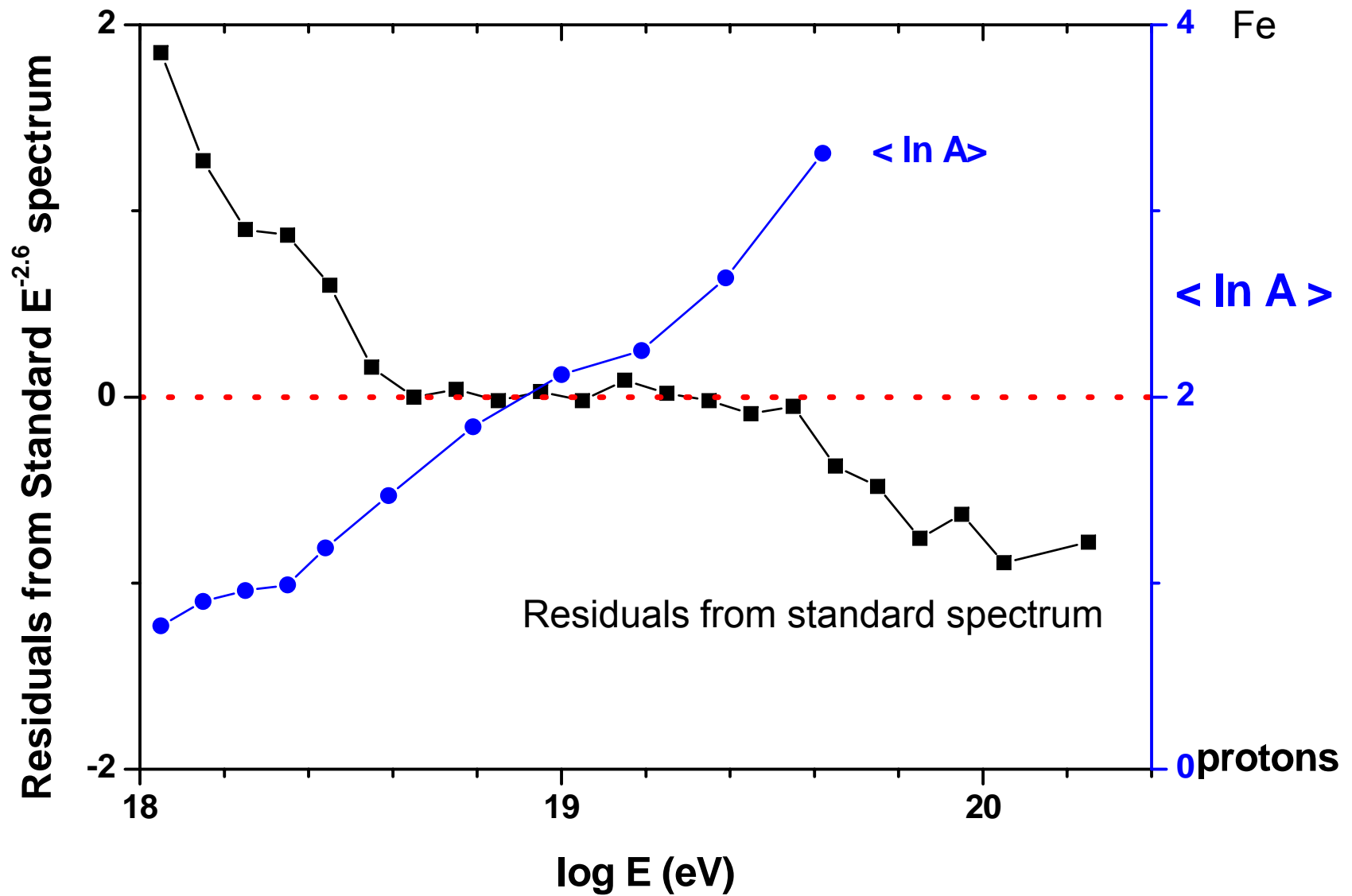
Elongation Rate measured over two decades of energy



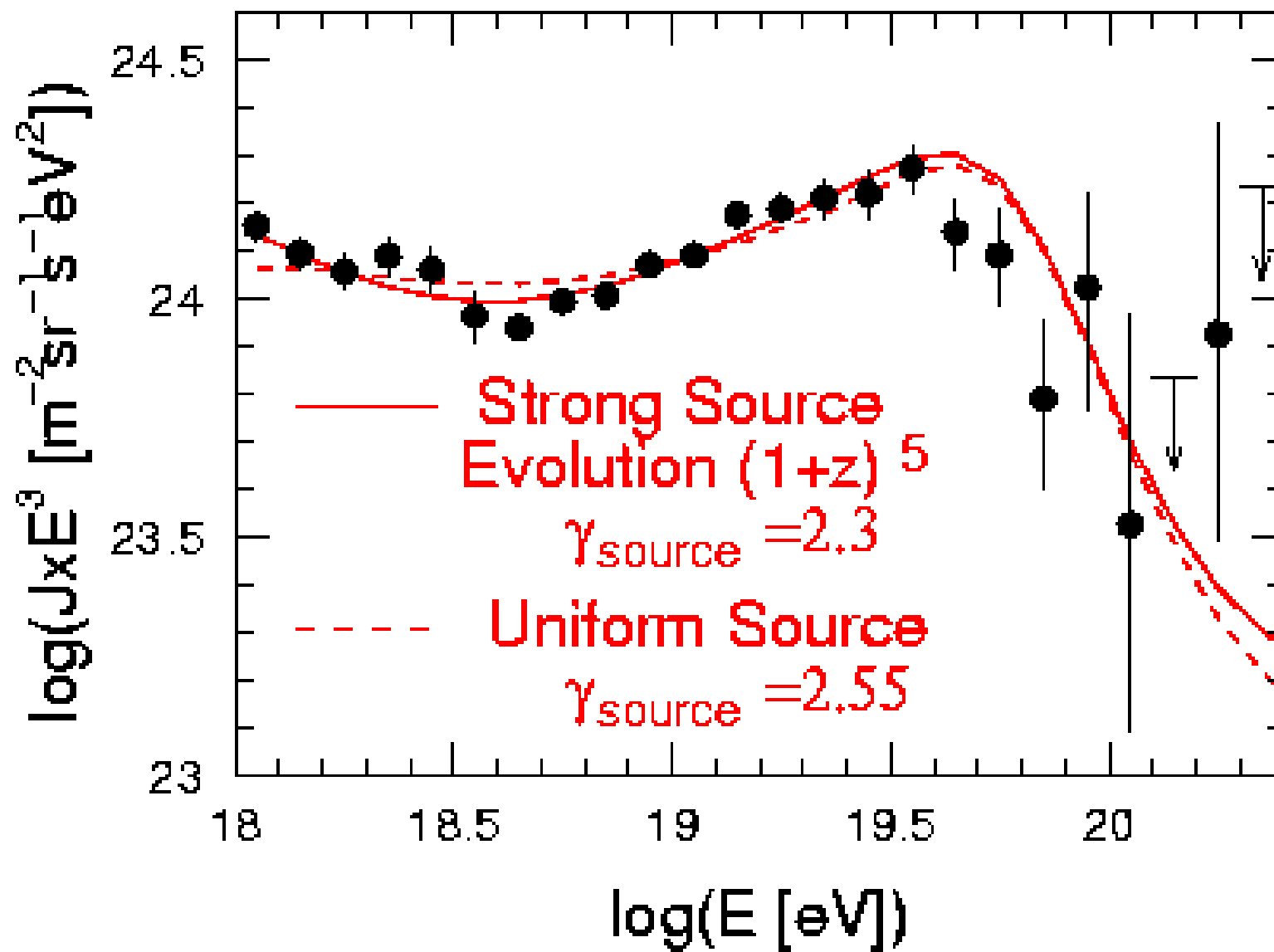
Fluctuations in X_{\max} to be exploited

Ankle





with $\langle X_{\max} \rangle = D_p [\ln (E/E_0) - \langle \ln A \rangle] + c_p$



Summary:

- **More events > 10 EeV than from AGASA and HiRes combined**
- **Auger-South more than 80% complete**
- **Arrival Directions:**
No evidence of point sources – but relatively few events at the very highest energies
- **Spectrum:** ankle and steepening seen - in model-independent measurement and analysis at $\sim 5 \times 10^{18}$ and $\sim 4 \times 10^{19}$ eV

But what does this all mean?

Is the ankle marking a galactic/extra-galactic
change?

Have we seen the GZK effect?

Or is it a 'bump' from a more local effect?

Are the accelerators just 'tired'?

Can we deduce much from propagation models?

Deducing the **MASS** is crucial: mixed at highest energy?

Certainly not expected – do hadronic models may
need modification?

Larger cross-section and/or more muons

Would help to reconcile AGASA with HiRes and Auger at the
highest energies

Auger statistics will totally dominate after another year