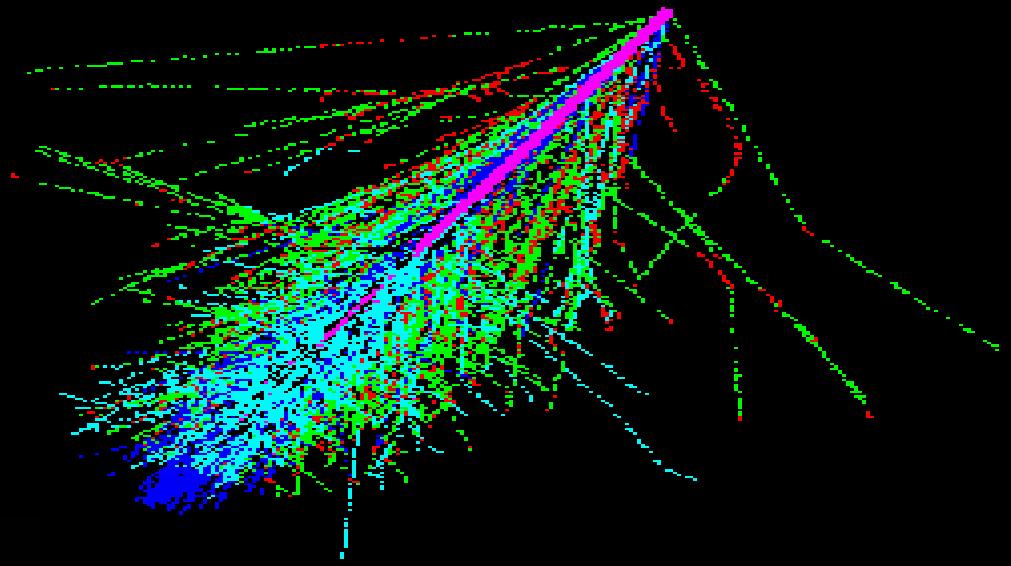


HE 1.3, 1.4, 1.5

Messengers of the Extreme Universe



Angela V. Olinto

University of Chicago

Ultra High Energy Cosmic Rays

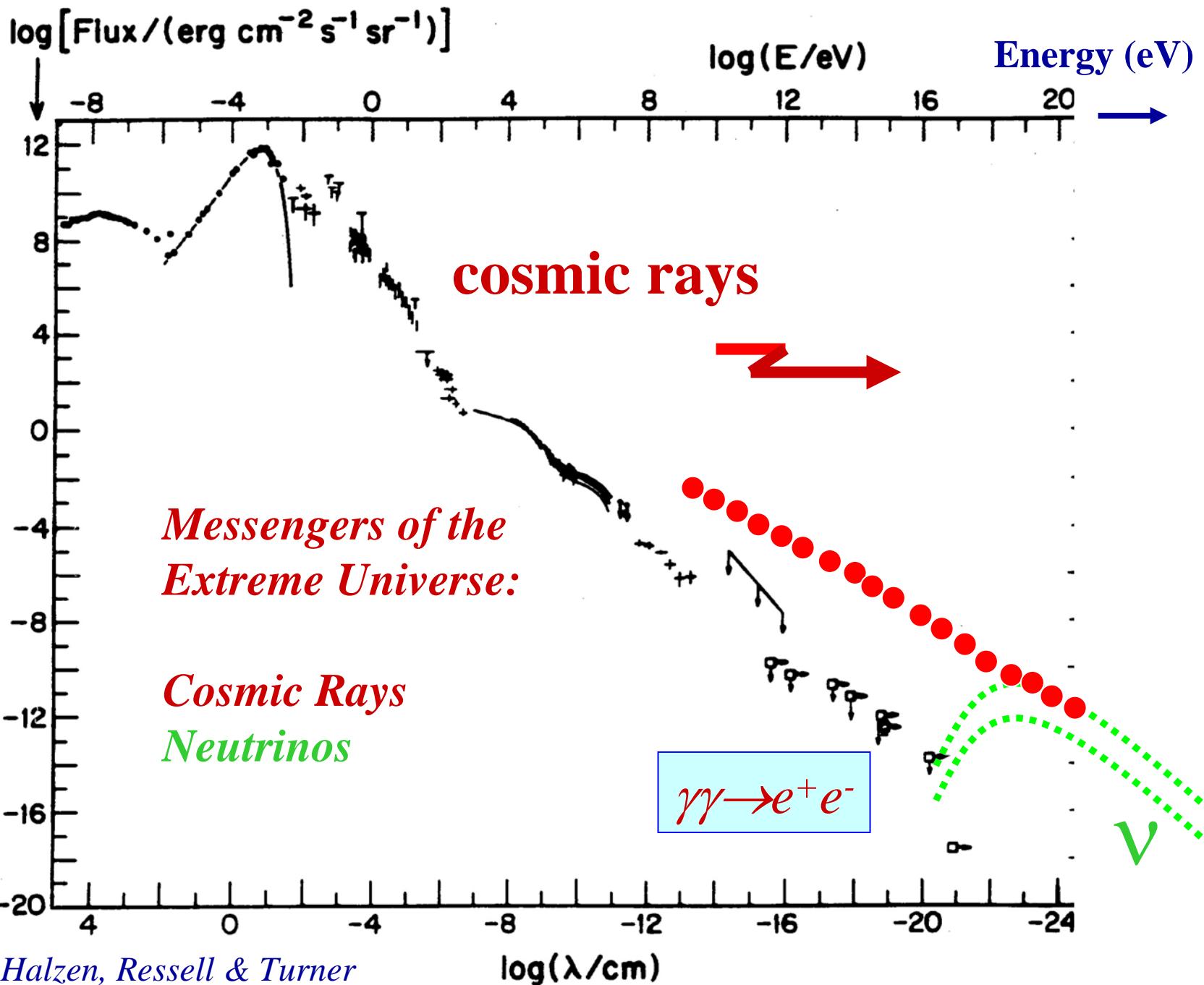
*~ 80 oral and 120 posters (~10 sec/paper)
Attest to the vitality of the field and*

the Great Opportunity for Discoveries

Origin of UHECRs still Unknown!!!

*The Best Messengers of
the Extreme Universe*



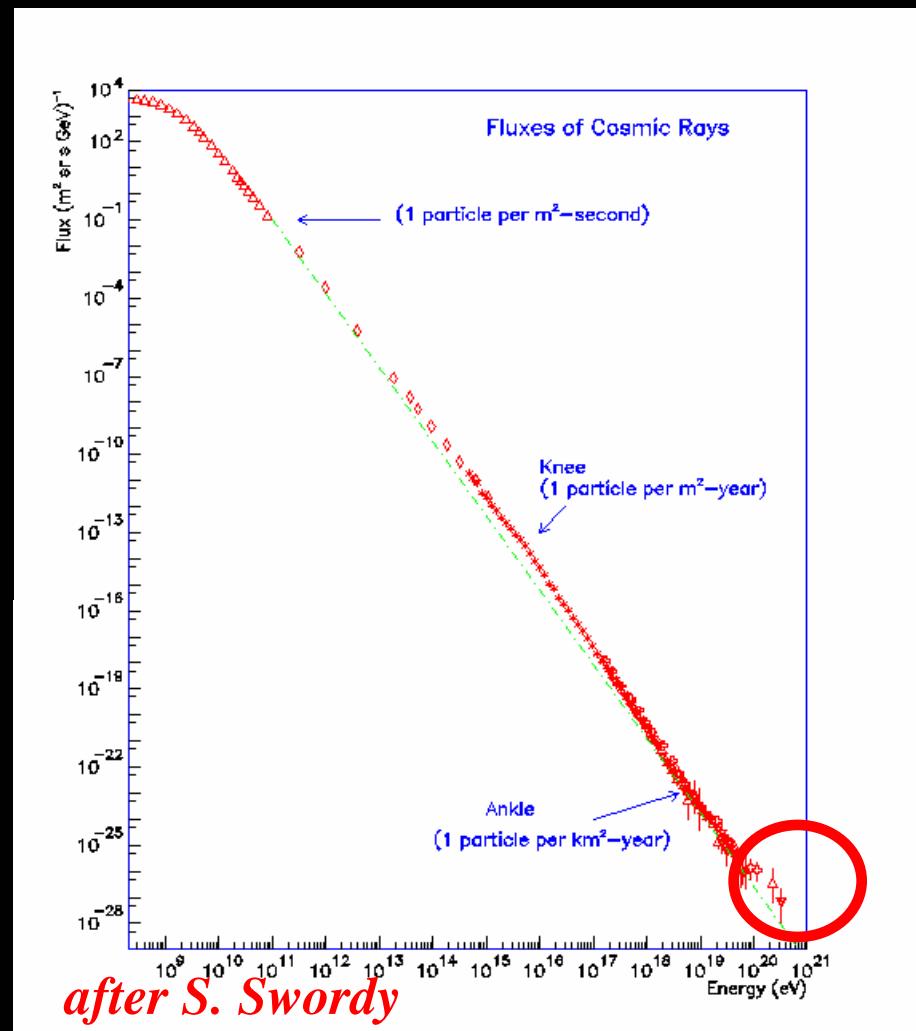
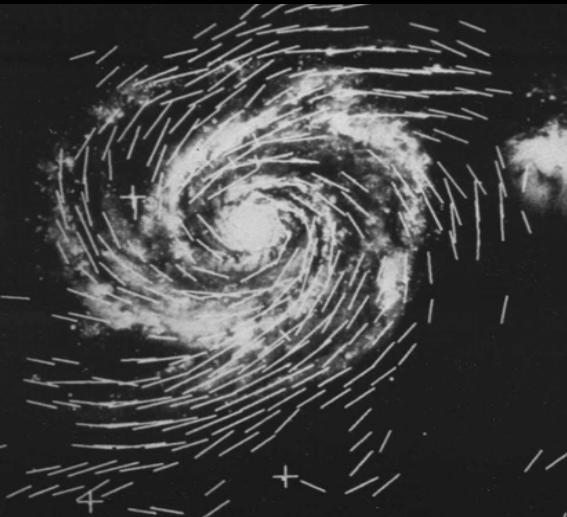


EHE Cosmic Rays should point!

Magnetic Fields less effective at EHEs
 $(\sim 10^{20} \text{ eV})$:

Simulations CDM LSS + MFs \Rightarrow
 $B_{\text{ExtraGal}} \sim 10 \text{ nG}$ D. Grasso (ICRC03)

AGASA clusters \Rightarrow constraints B_{gal}
G. Medina-Tanco (ICRC03)



AGASA

Akemo Giant Air Shower Array

Presented 3 oral + 2 posters:

11 Super-GZK events

Small Scale Clustering

*Constraints on Composition
- protons at UHEs.*



111 scintillators + 27 muon det.

AGASA

Composition:

K. Shinozaki et al. ICRC03

Muon density $E_0 \geq 10^{19} \text{ eV}$ $0 \leq 36^\circ$

Fe frac. (@90% CL): < 35% ($10^{19} - 10^{19.5} \text{ eV}$), < 76% ($E > 10^{19.5} \text{ eV}$)

Akeno 1km² : Hayashida *et al.* '95

Haverah Park: Ave *et al.* '03

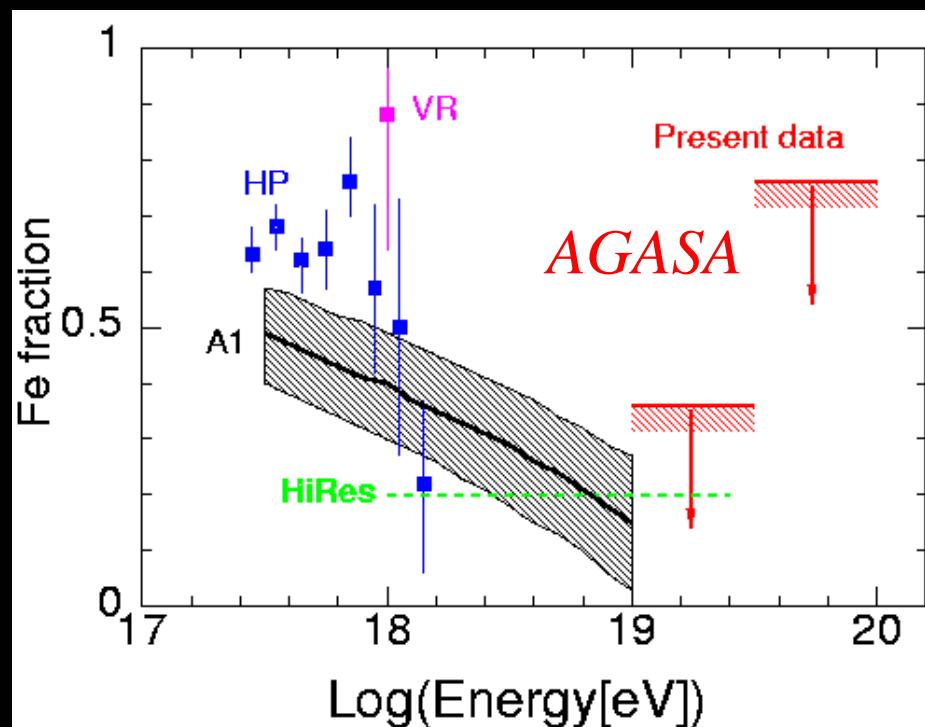
Volcano Ranch: Dova *et al.* ICRC03

HiRes: Archbold *et al.* ICRC03

Gamma-ray fraction upper limits
(@90%CL)

34% ($> 10^{19} \text{ eV}$) ($\gamma/p < 0.45$)

56% ($> 10^{19.5} \text{ eV}$) ($\gamma/p < 1.27$)





Small Scale Clustering

M. Teshima et al. ICRC03

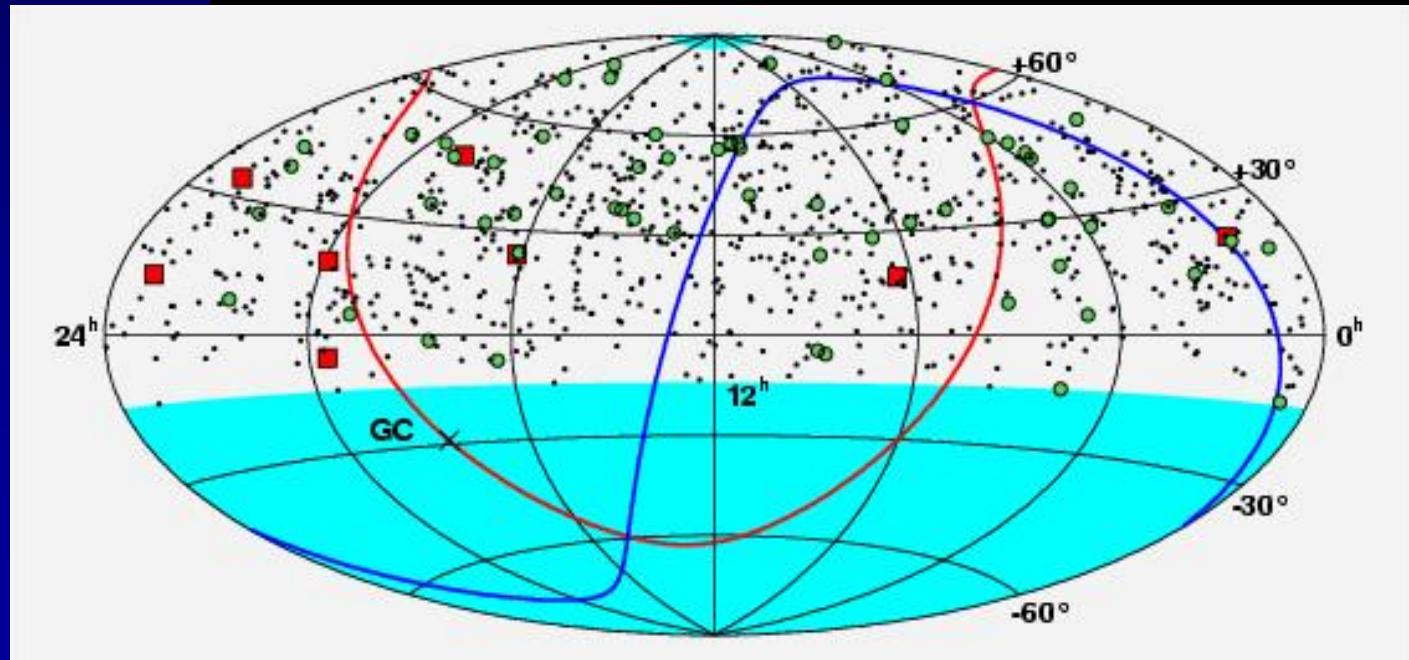
1 triplet + 6 doublets (2 triplets + 6 doublets with looser cut)

Clustering for $E \sim 10^{19}$ eV and $\sim 5 \times 10^{19}$ eV,

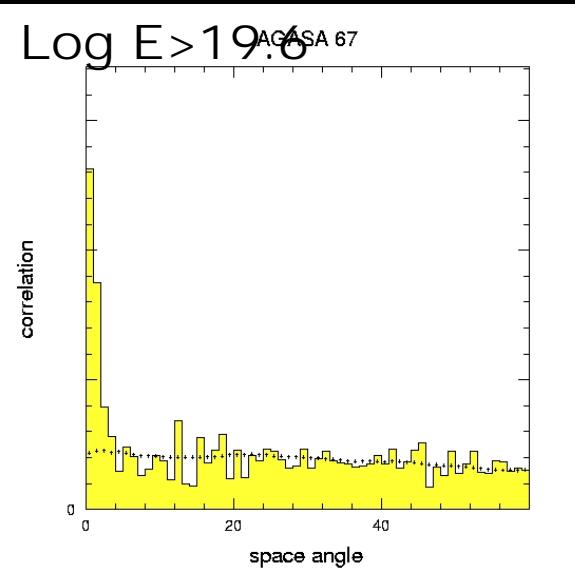
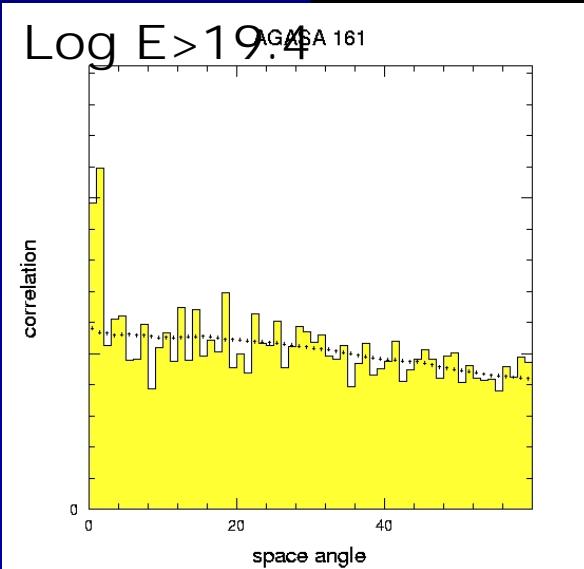
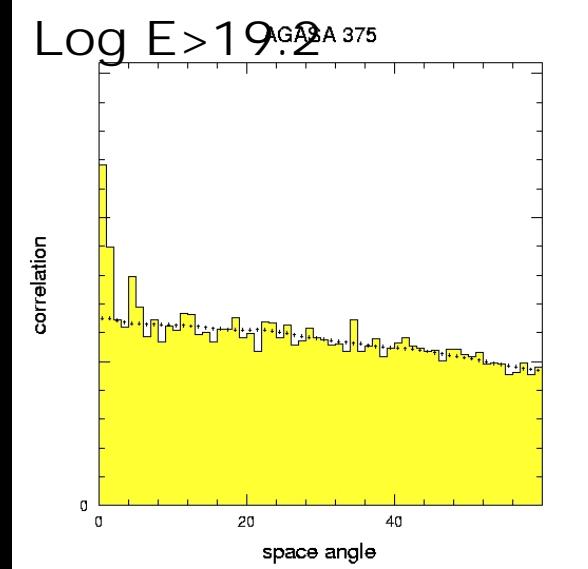
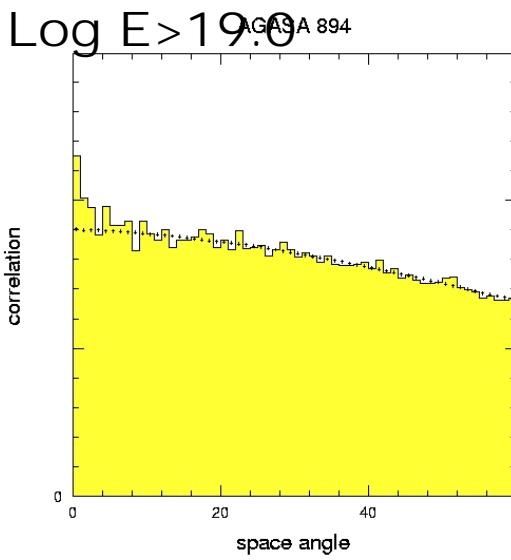
Ratio of Cluster/All increases with E up to 5×10^{19} eV

Above GZK energy (5×10^{19} eV) statistics too small

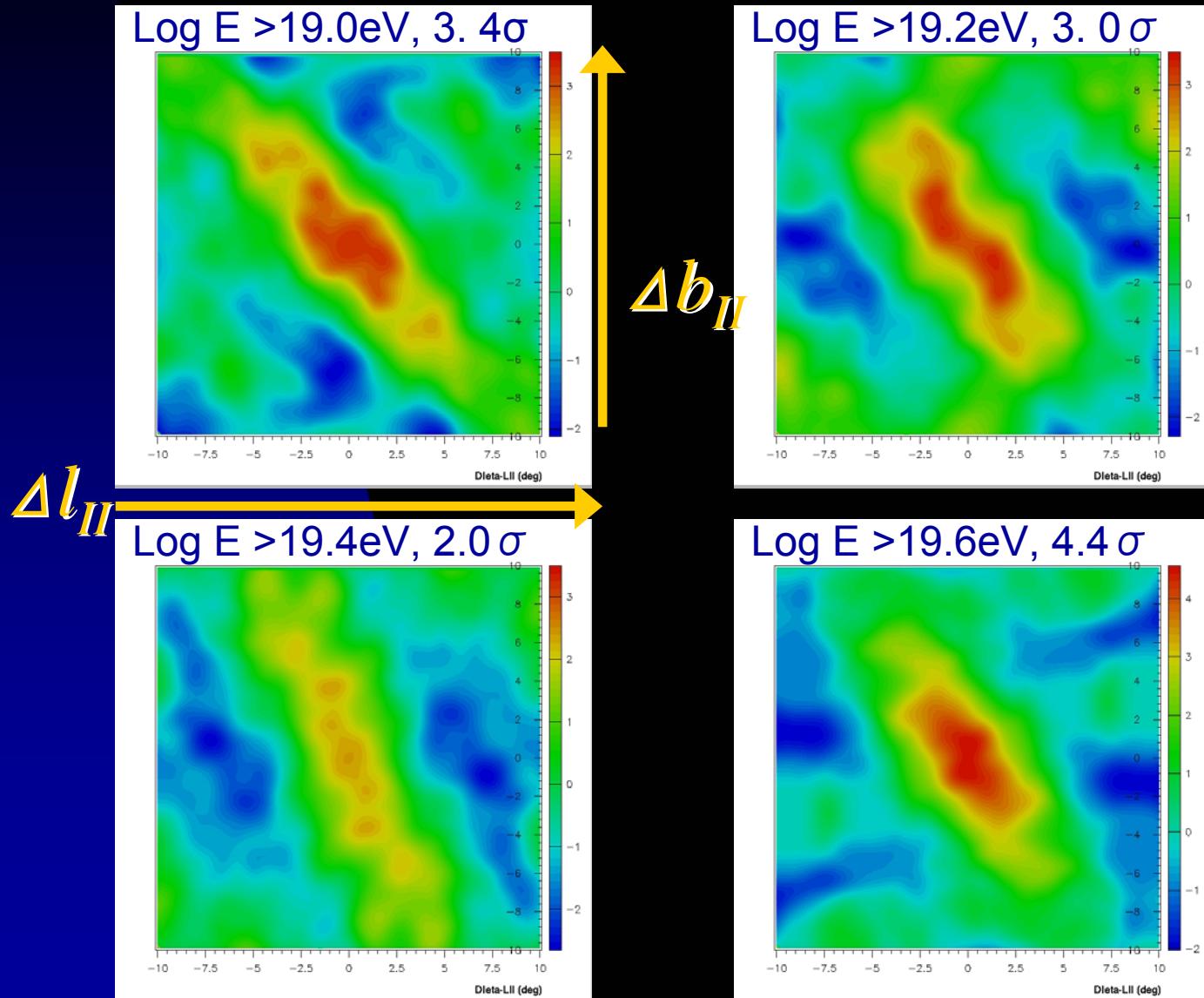
No significant time self-correlation



Angular Correlations

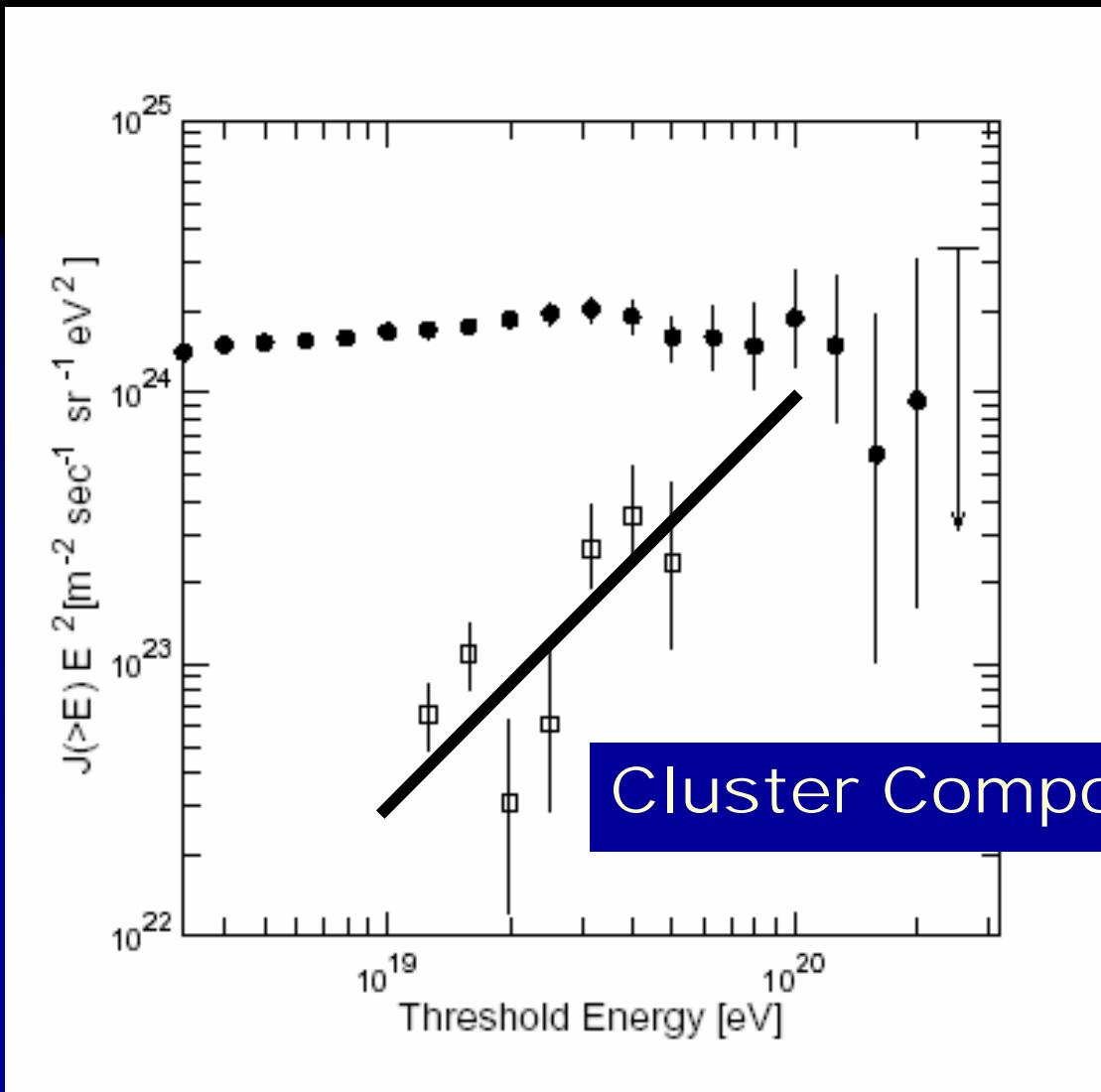


2D-Correlation Map in $(\Delta l_{II}, \Delta b_{II})$



Energy spectrum of Cluster events

$E^{-1.8 \pm 0.5}$



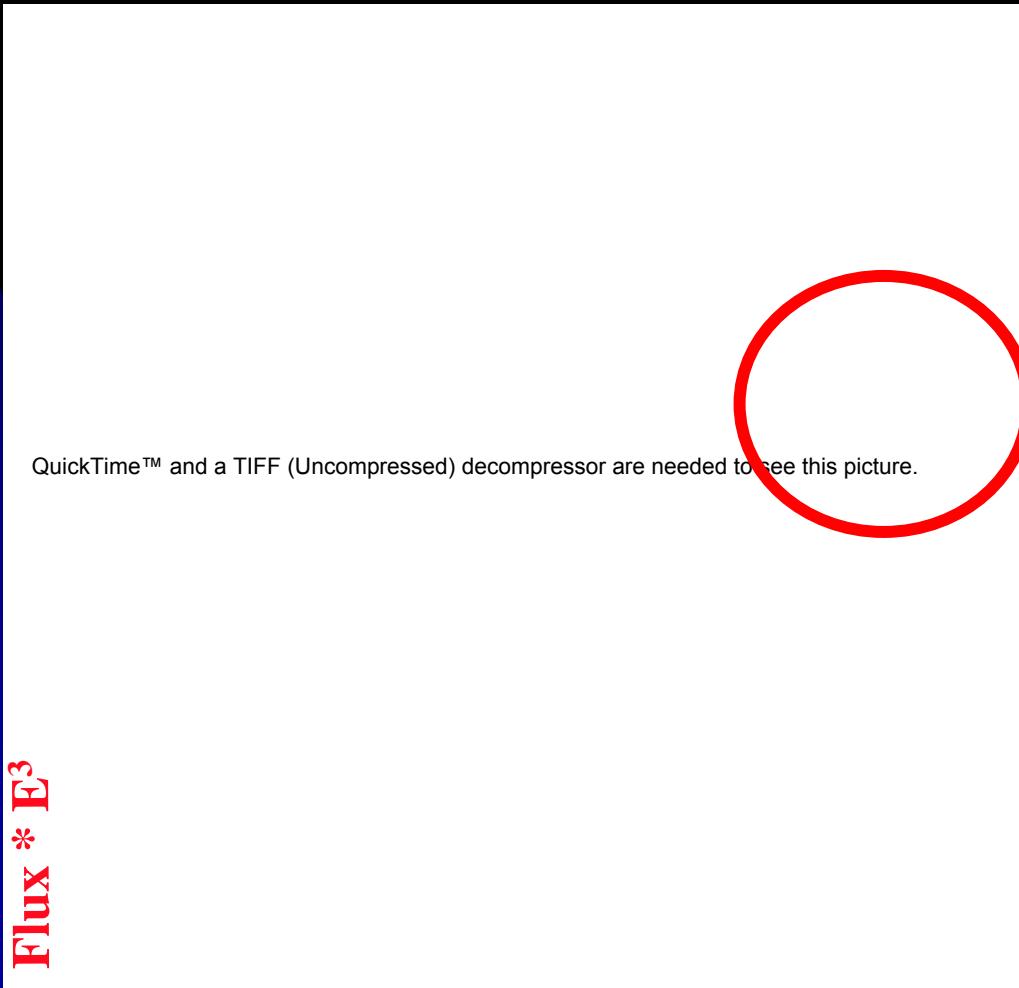
Cluster Component

AGASA

11 events with $E > 10^{20}$ eV

M. Takeda et al. ICRC03

AGASA systematic errors $\sim 18\%$



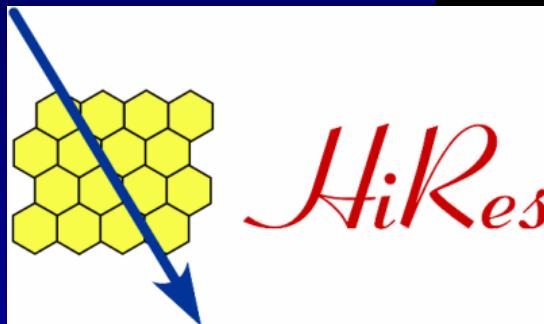
The *High Resolution Fly's Eye* (HiRes)

Pioneers of Fluorescence Technique (8 oral + 4 posters)

No Super-GZK flux

No Small Scale Clustering

Composition Change



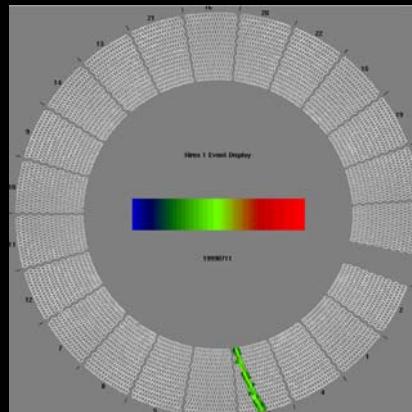
Air fluorescence detectors

HiRes 1 - 21 mirrors

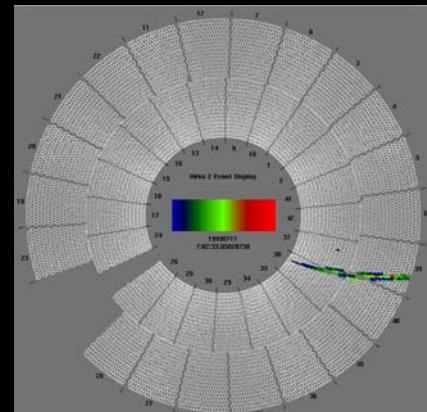
HiRes 2 - 42 mirrors

Dugway (Utah)

start '97HR1 '99HR2



HiRes 1



HiRes 2



Composition:

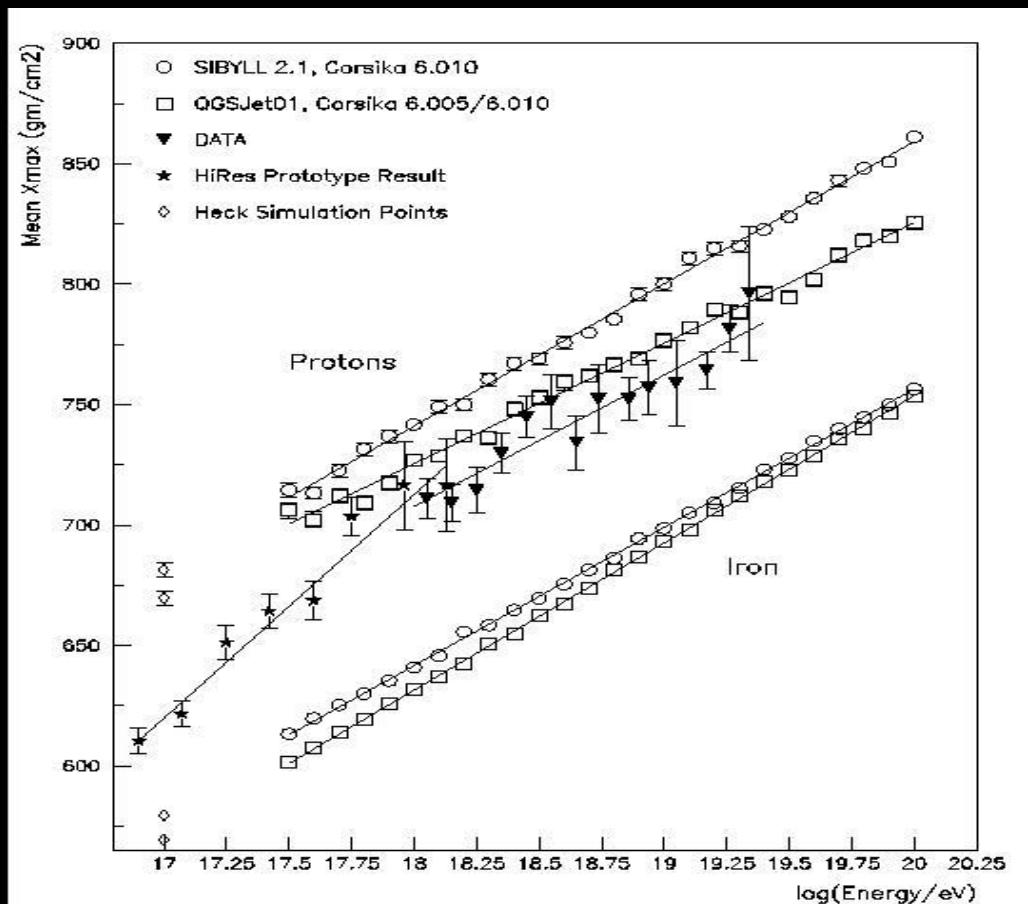
J. Mathews et al. ICRC03

HiRes Stereo: unchanging, light composition above 10^{18} eV

Stereo HiRes and HiRes Prototype-MIA consistent in overlap region

HiRes Prototype-MIA Hybrid
changing composition
(Heavy to Light)
between 10^{17} and 10^{18} eV

No significant information
near GZK region yet
Come back to 29th ICRC



Small Scale Clustering - Monocular

J. Belz et al. ICRC03

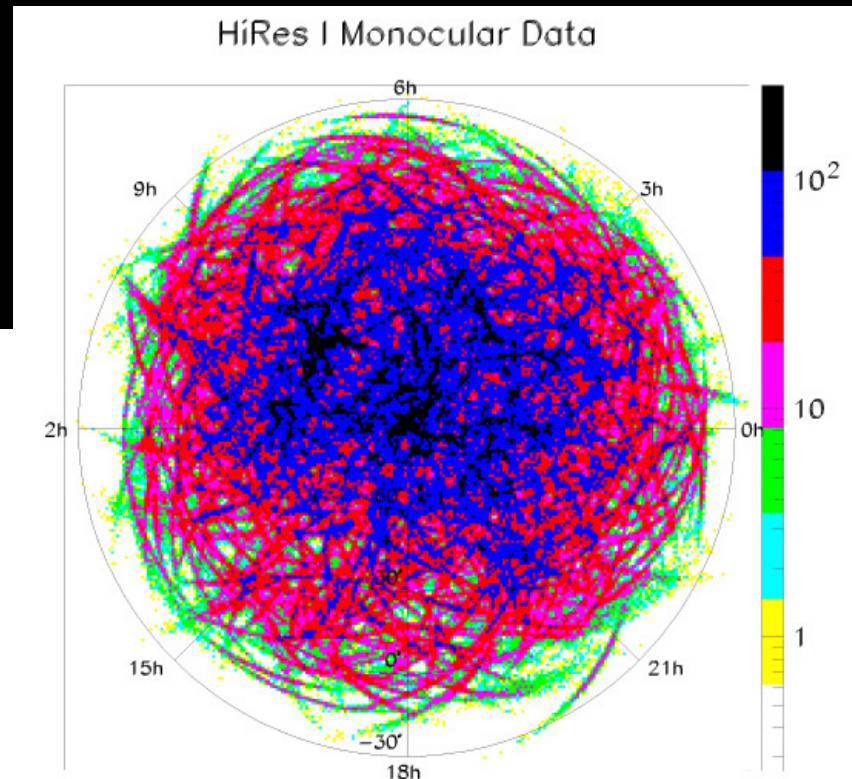
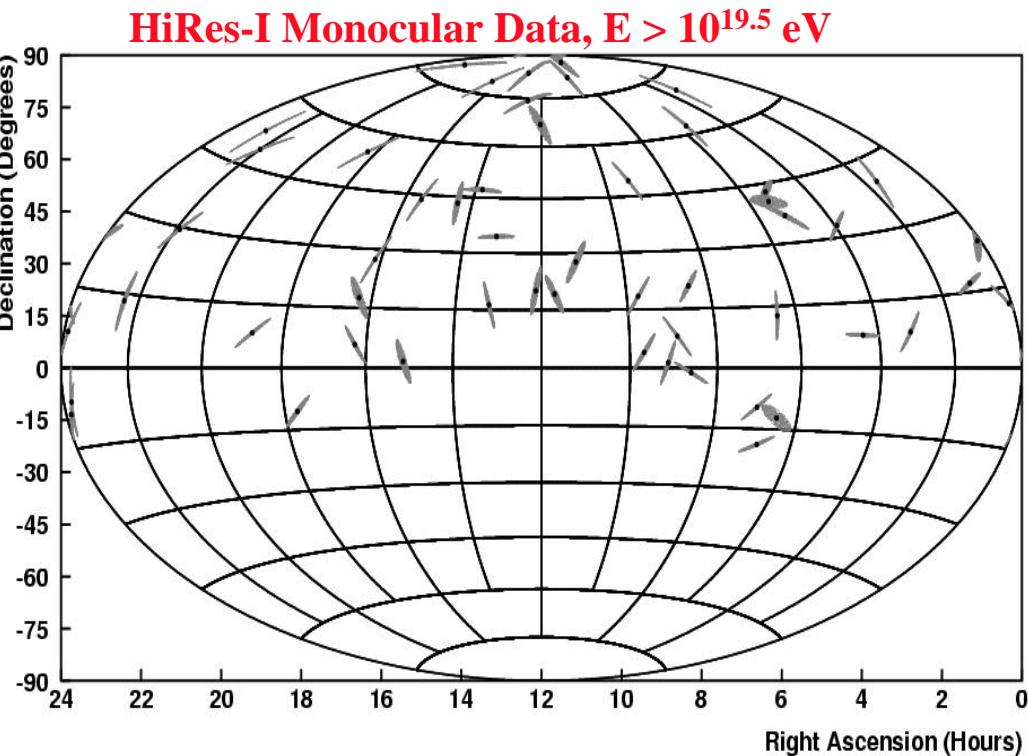
No significant clustering seen yet.

“Bananas are harder than circles...”

Flux upper limits of on point sources

with $E > 10^{18.5}$ eV Cygnus X-3

Dipole limit: Gal. Center, Centaurus A, M-87

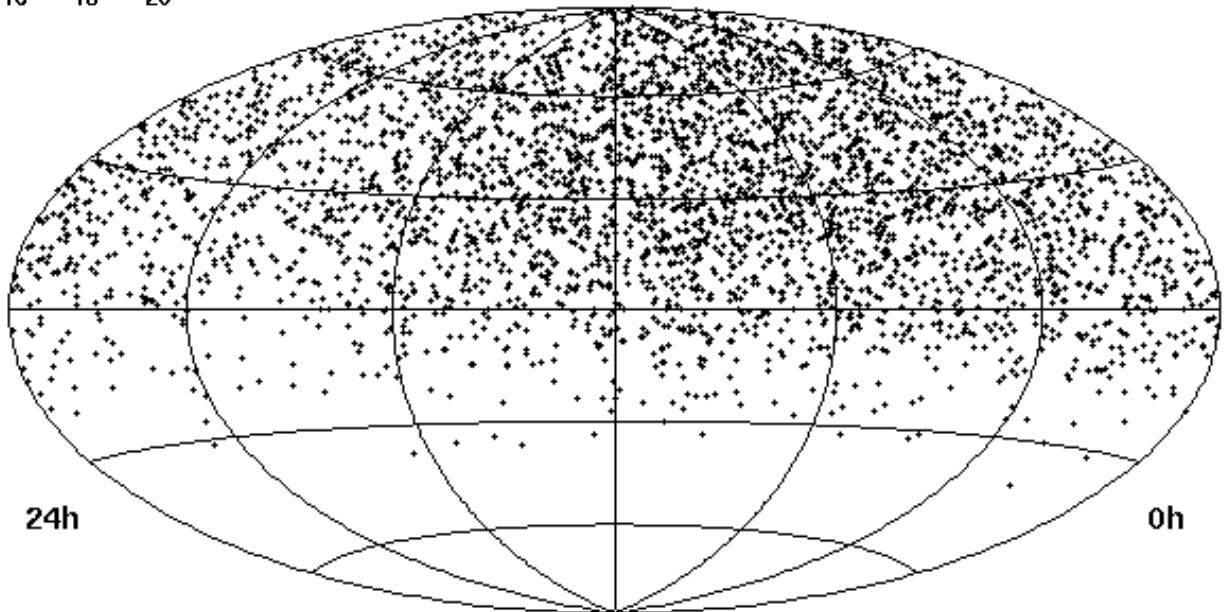
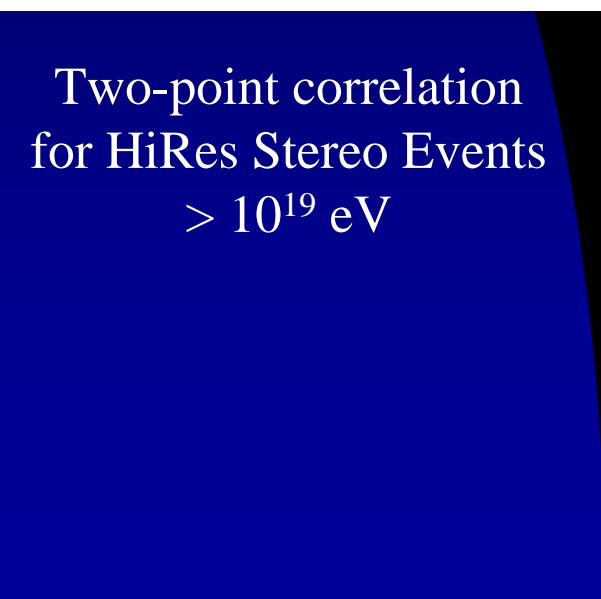
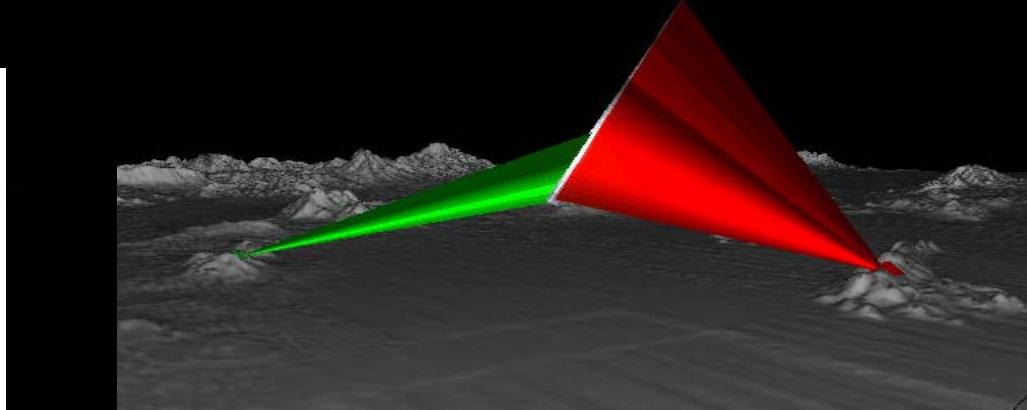
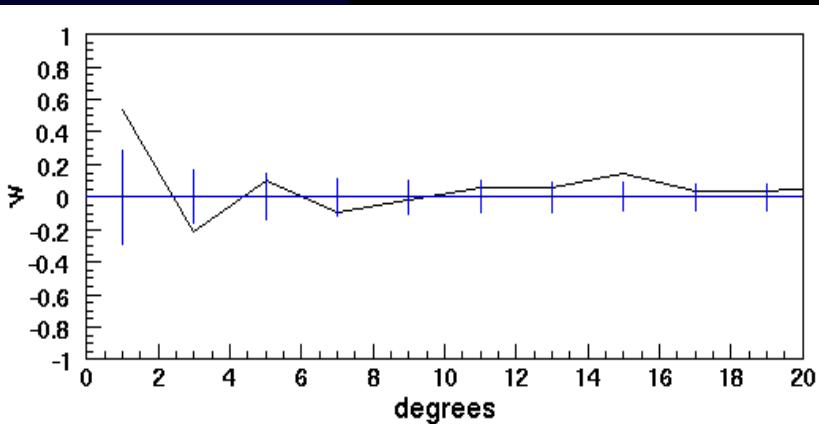


Upper limit of **4** doublets (90% c.l.)
in HiRes-I monocular dataset.

Small Scale Clustering - Stereo

No significant clustering seen yet.

C. Finley et al. ICRC03

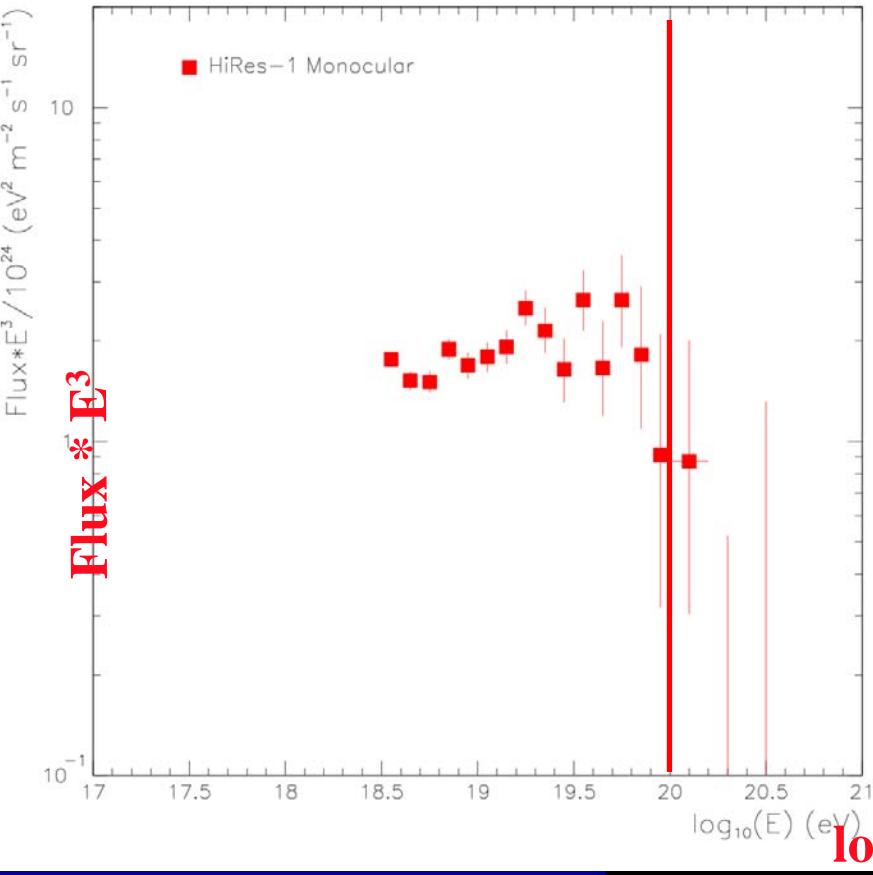


Monocular Spectra

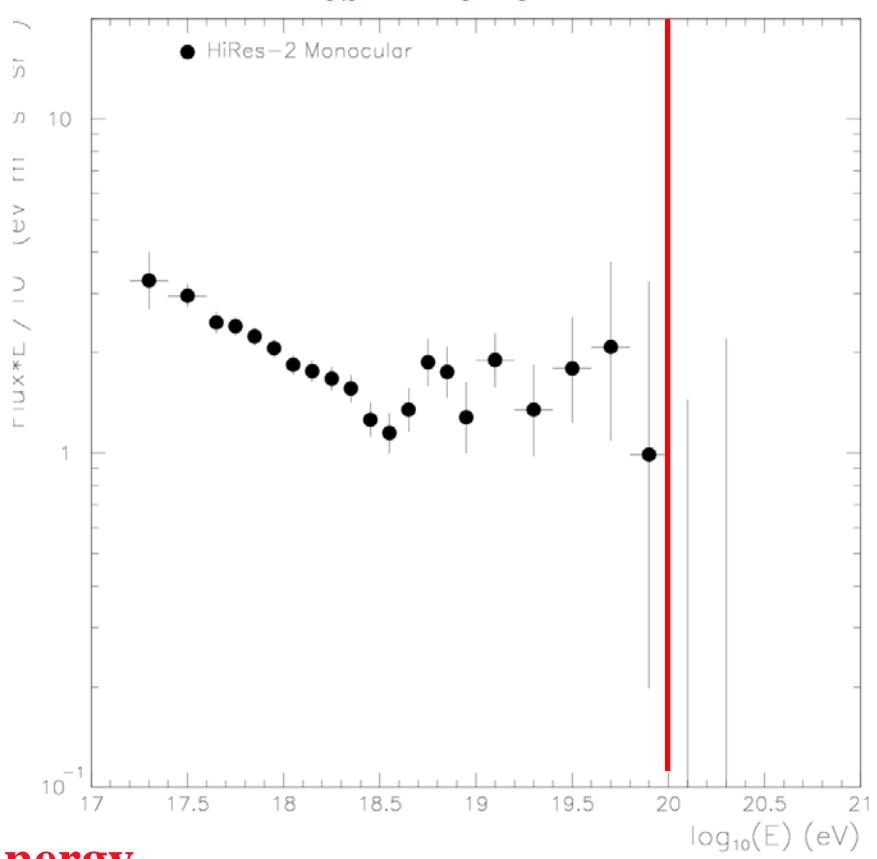
2 Events $E > 10^{20}$ eV HiRes (1 in Stereo)

D. Bergman et al. ICRC03

HiRes1 Mono



HiRes2 Mono

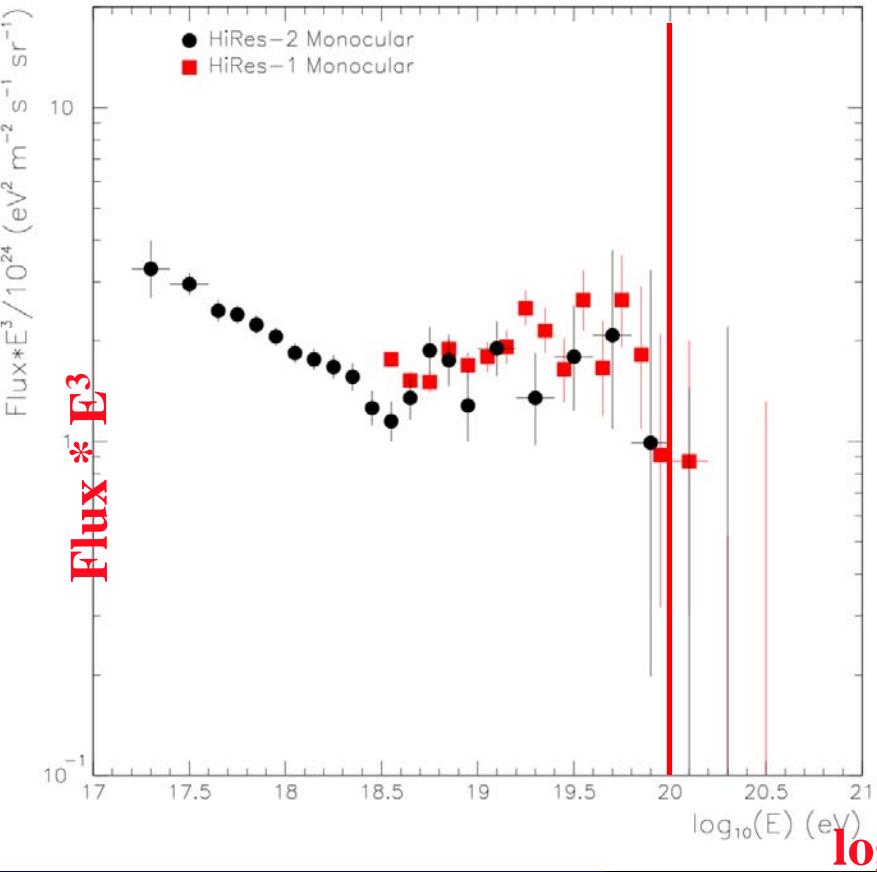


Monocular Spectra

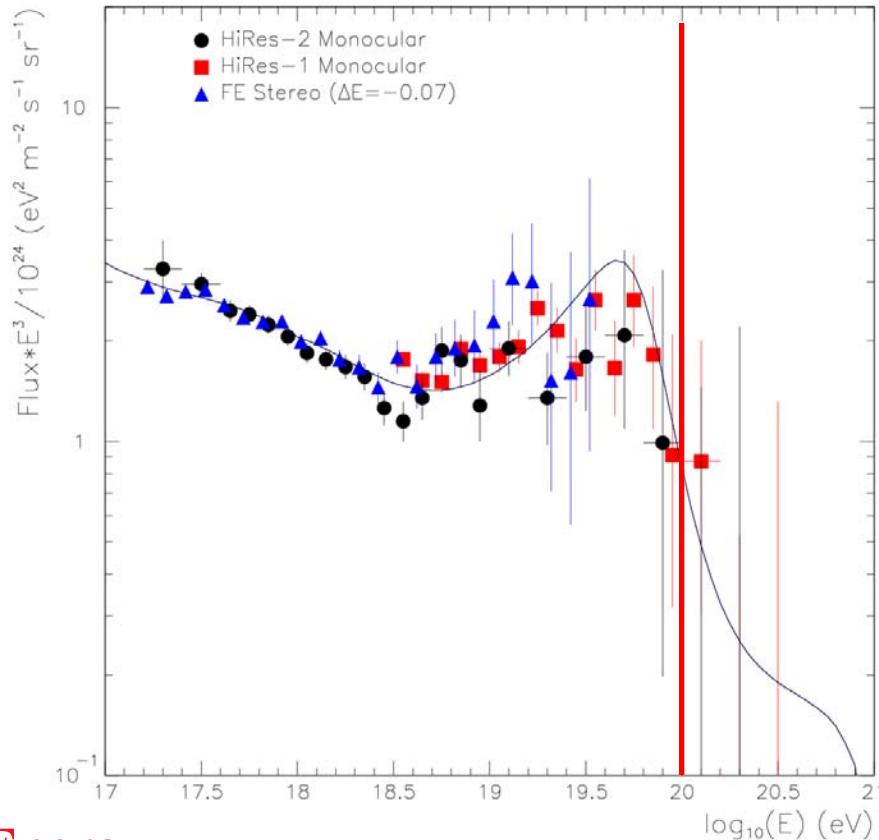
D. Bergman et al. ICRC03

Working to understand the difference in energy scales between the two sites
HiRes ~ 7% lower energy than Fly's Eye - to match spectrum

HiRes1 & HiRes 2 Mono



log Energy



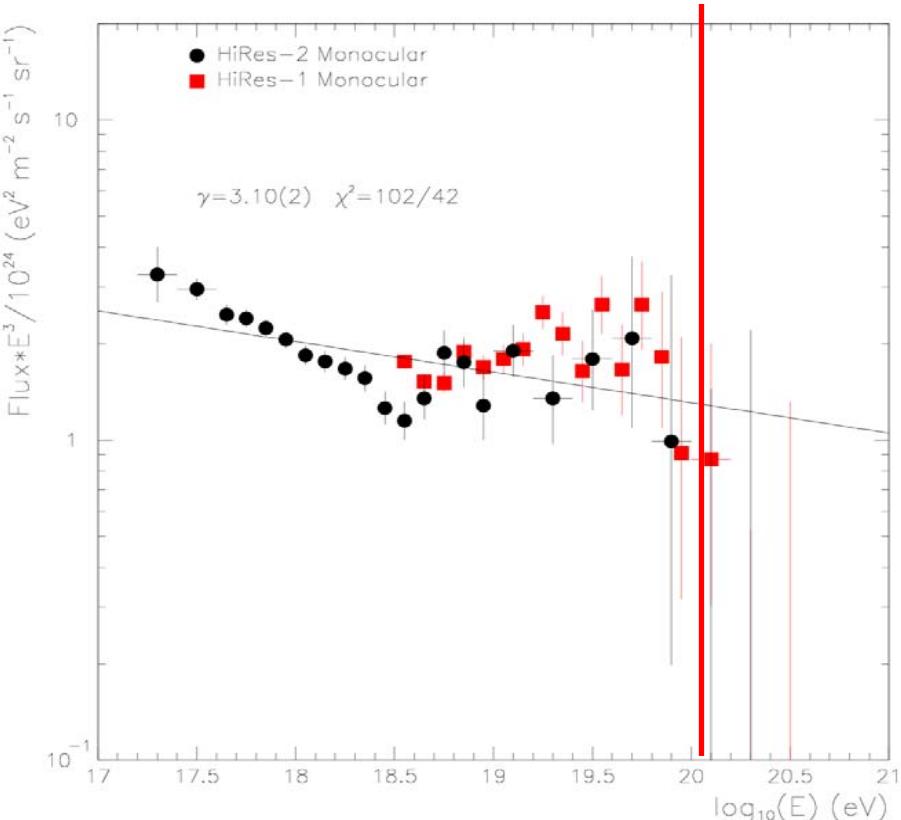
Monocular Spectra

D. Bergman et al. ICRC03

The entire HiRes spectrum is not fit well by a single power law $\chi^2 = 102/42$

Systematic discrepancy with AGASA spectrum

~ 30% Energy



QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

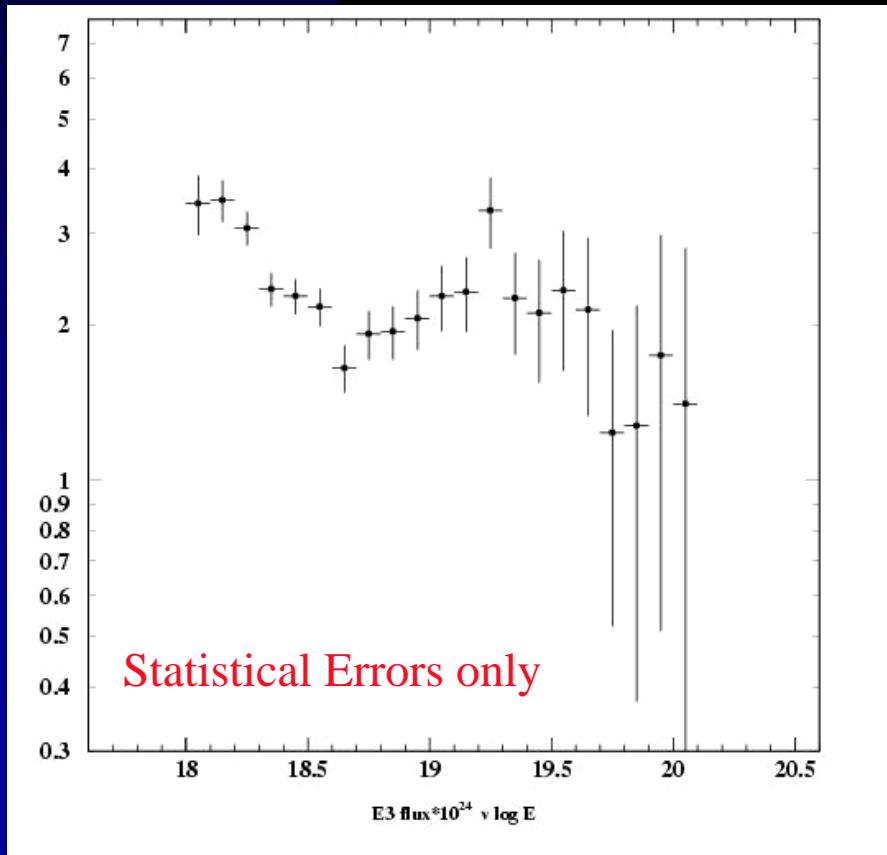
HiRes

Stereo Spectrum

R. W. Springer et al. ICRC03

Change in spectral index weakly observed at an energy of $10^{18.6}\text{eV}$

76% Proton 24% Iron mixture



Still evaluating sources of systematic uncertainty

Energy scale

Fluorescence Yield

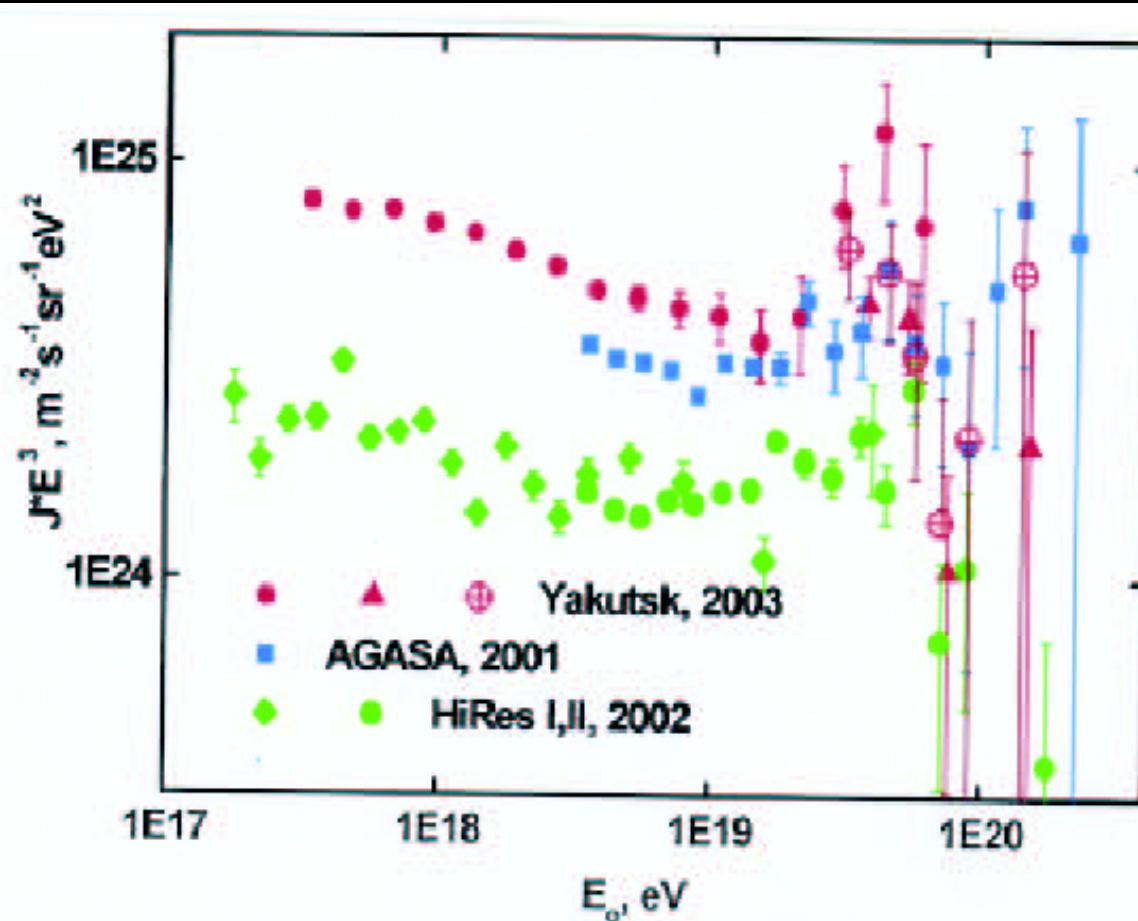
Atmospheric effects

Laser probe - L. Wiencke et al. ICRC03

Yet another discrepant spectrum...

Yakutsk

M. Pravdin et al. ICRC03



Energy spectrum at $E_0 > 10^{17} \text{ eV}$
Red closed circles – trigger-500 data; Red closed triangles – trigger-1000 max. area; Red big circle – trigger-1000 within array area

AGASA versus HiRes

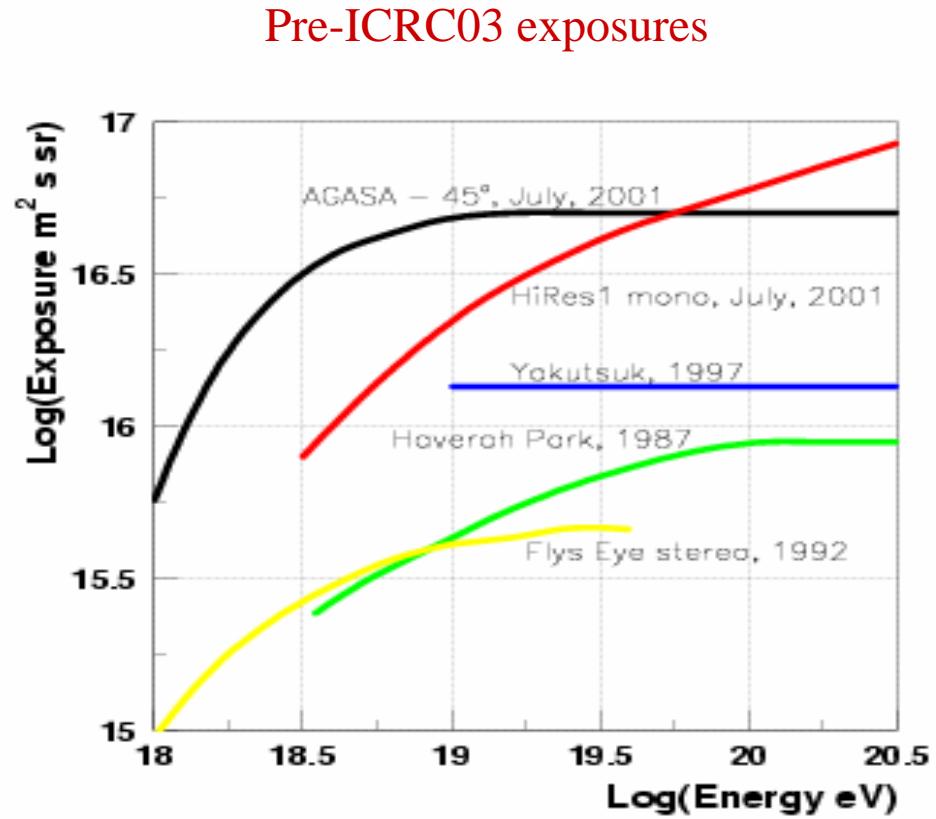
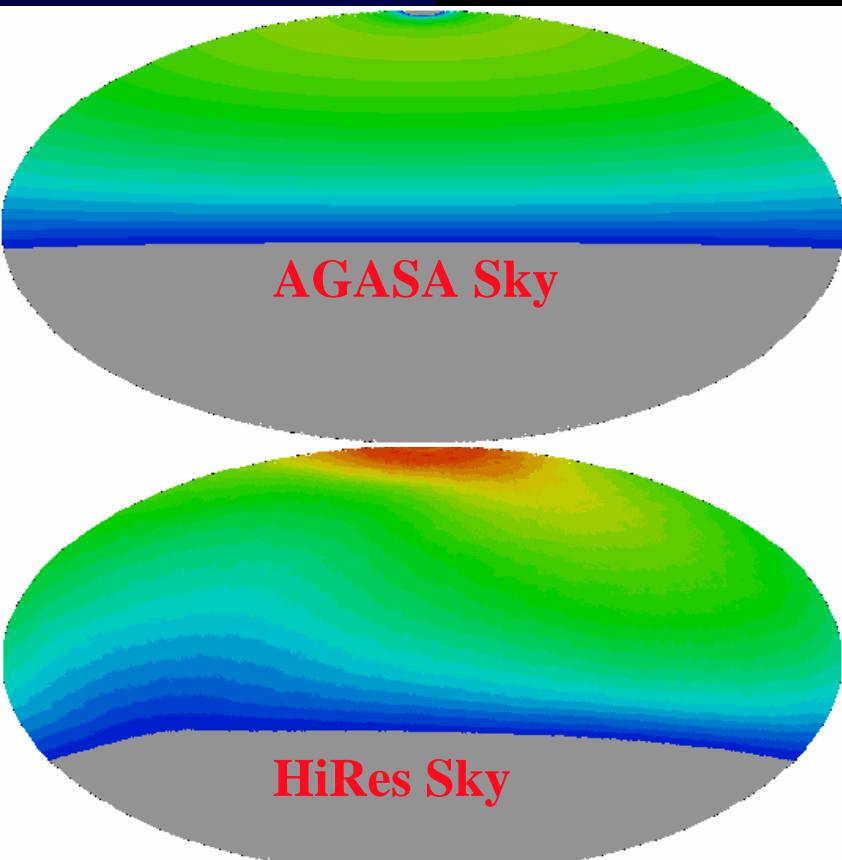
Agree on Light Composition (proton)

at the Highest Energies!!!

Small Scale Clustering seen in AGASA not in HiRes

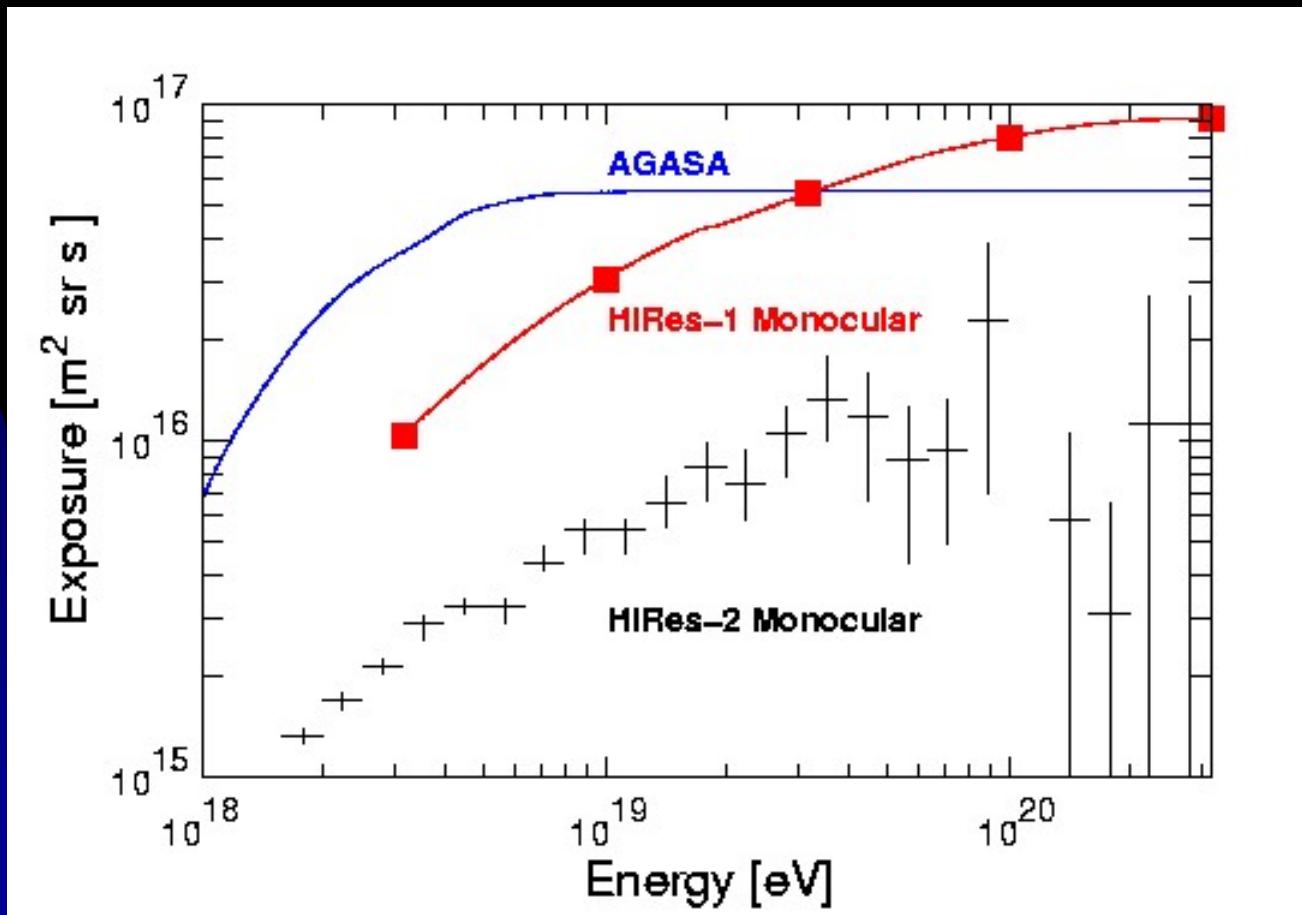
Systematic off-set in Spectrum

Exposures & Systematic Errors



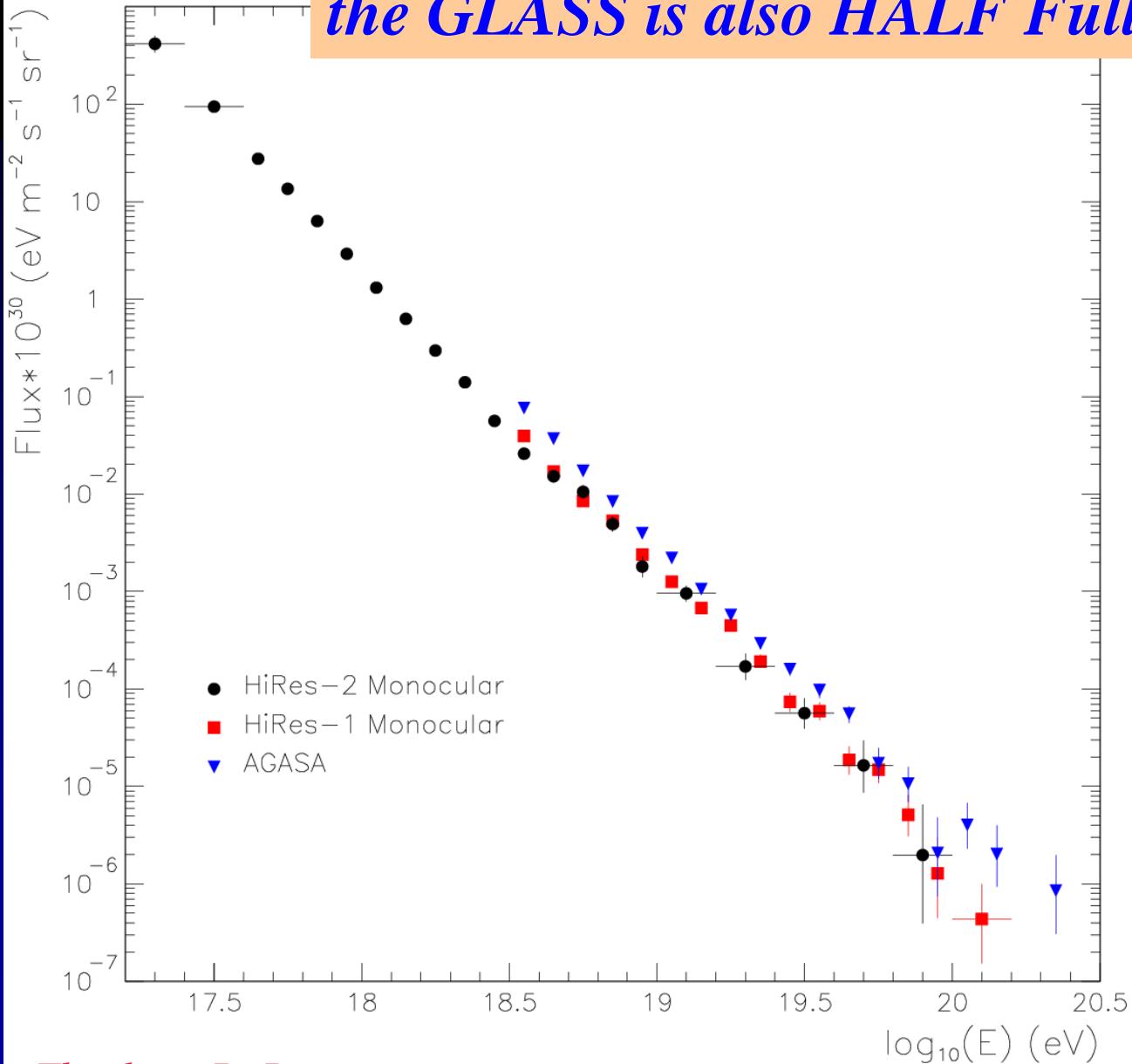


Most Recent Exposures



Thanks to HiRes and AGASA Collaborations

*The Glass is Half Empty but
the GLASS is also HALF Full...*



Thanks to D. Bergman

Clearly Need to Control Systematics

Fluorescence is a challenging technique!

Atmospheric Monitoring necessary (not an average)

Full telescope calibration - from filters to DA

Fluorescence Yields need direct measurement

Composition studies are highly model dependent

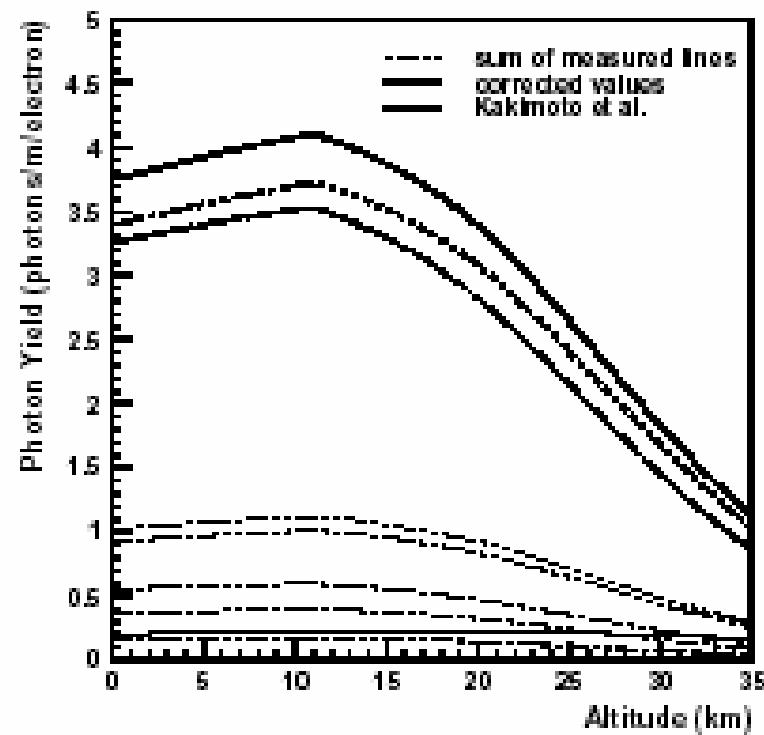
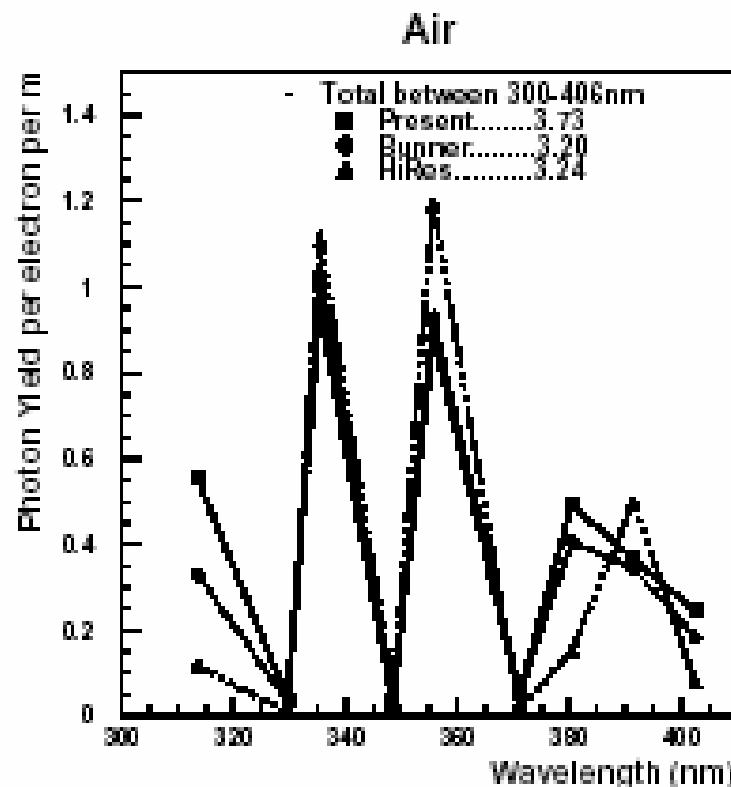
Fluorescence in the Lab

Kakimoto *et al.* (1995): total yield between 300 and 400 nm, 337 nm, 357 nm, 391 nm lines, > 10 % error

Nagano *et al.* (2003):

measurement of six wavelengths, systematic error of ~13.2% in overall yield and in individual spectral lines

N. Sakaki *et al.* HE1.5-7



Fluorescence in the Lab

Kakimoto *et al.* (1995): total yield between 300 and 400 nm, 337 nm, 357 nm, 391 nm lines, > 10 % error

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N. Sakaki et al. HE1.5-7

FLASH at SLAC

P. Hüntemeyer et al HE1.5-8

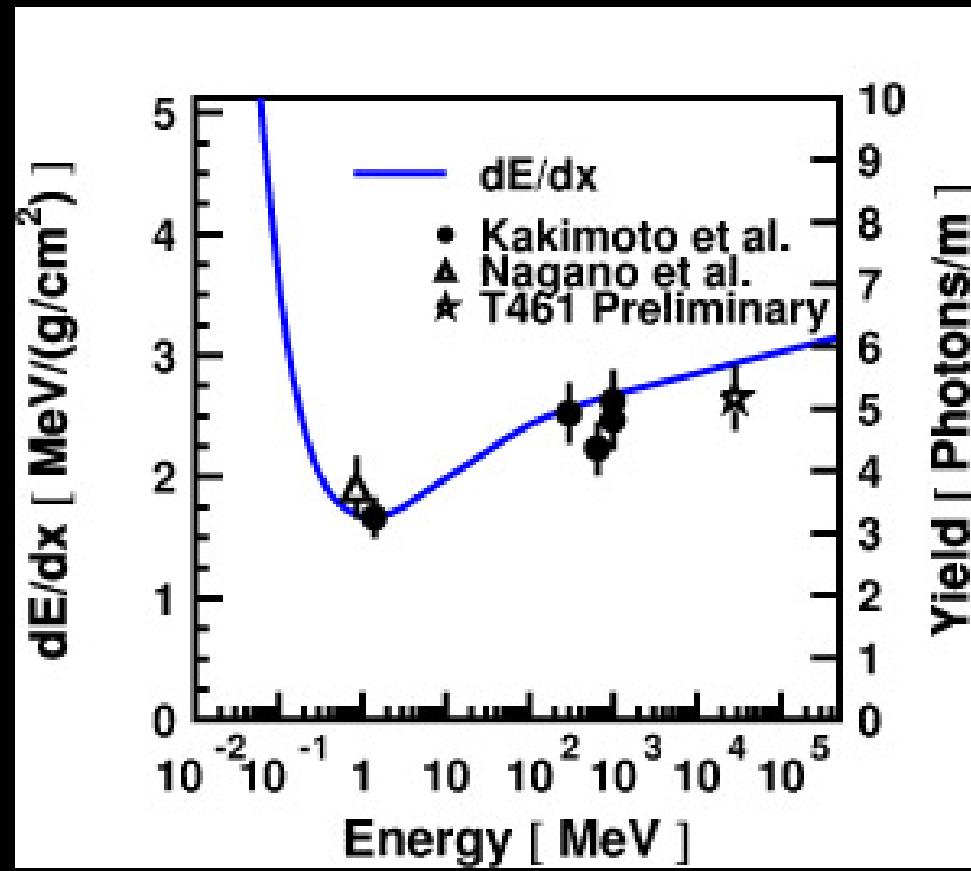
(FLuorescence from Air in Showers)

Thin target: September 2003

preliminary T-461

FLASH goal:

< 10% accuracy in the total fluorescence yield and individual spectral lines



Model Uncertainties

EXPERIMENTS should use the **SAME SIMULATION** codes!!
There are way too many moving parts... pick ONE (CORSIKA, or...)

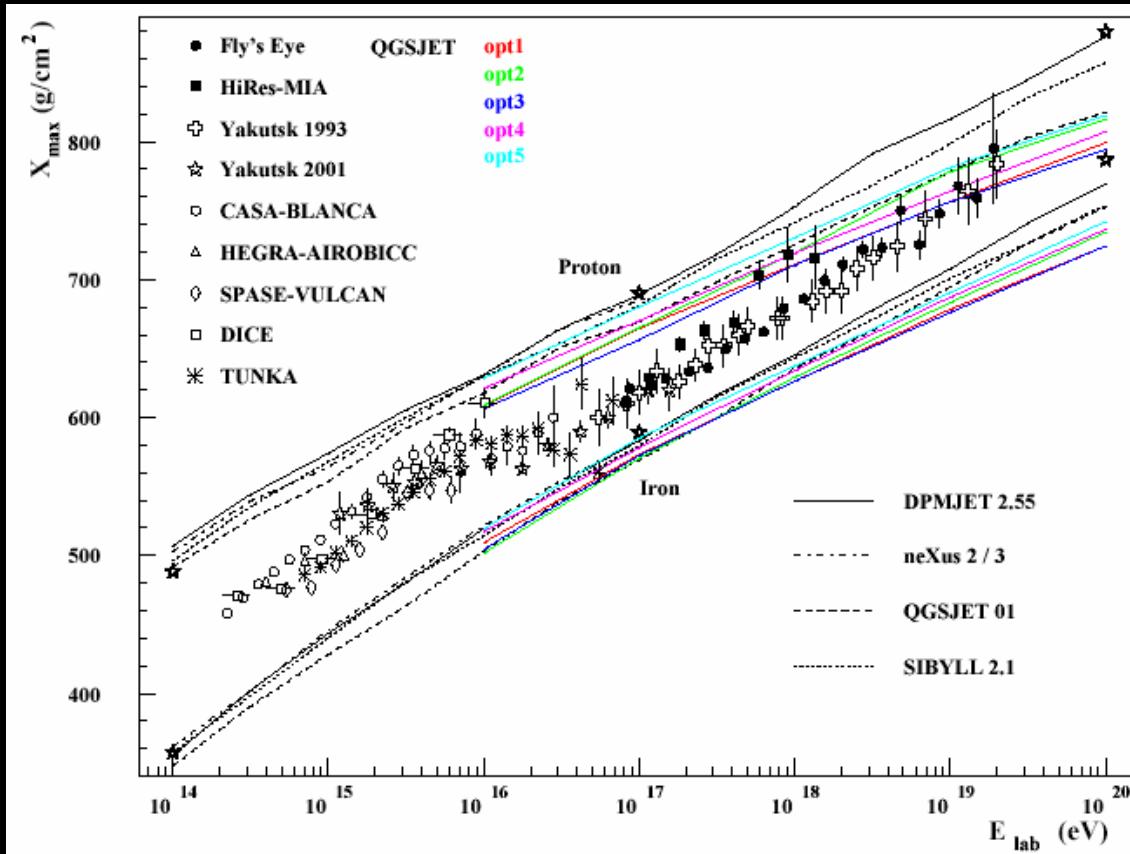
Hybrid Codes- H.J. Drescher ICRC03

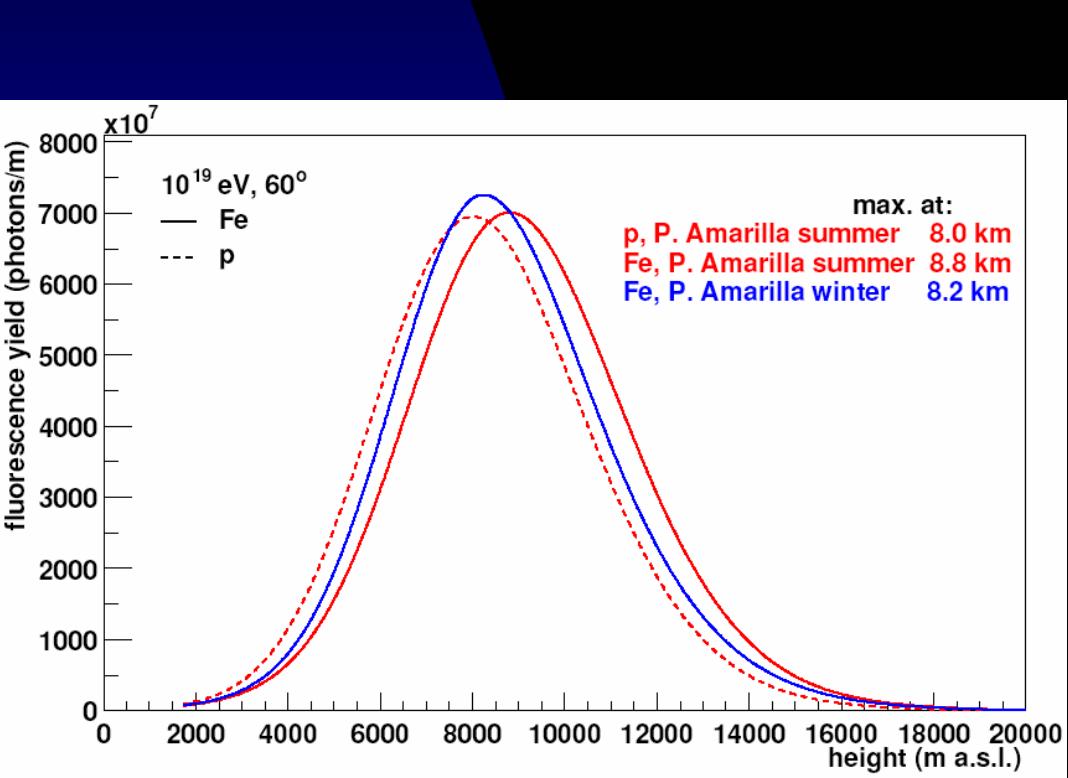
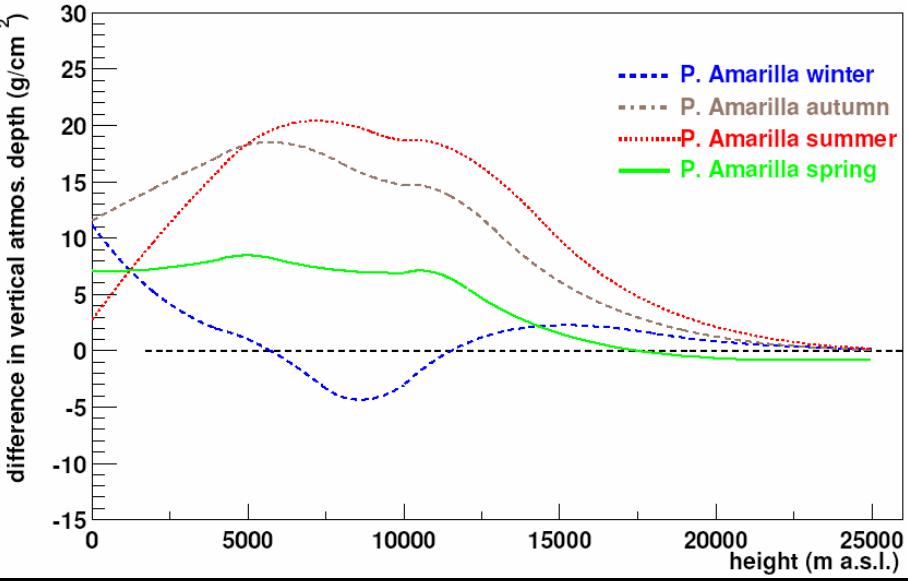
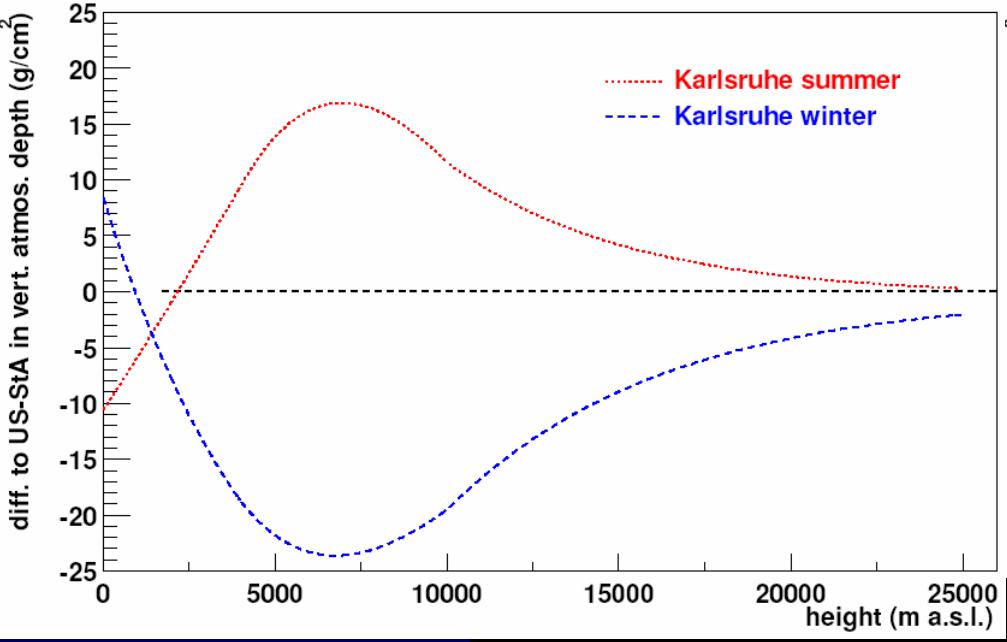
FLUKA - R. Engels ICRC03

best description of Low Energy - important water tanks far from core

*An extreme comparison
in composition studies
with QGSJet...*

J. Knapp ICRC03

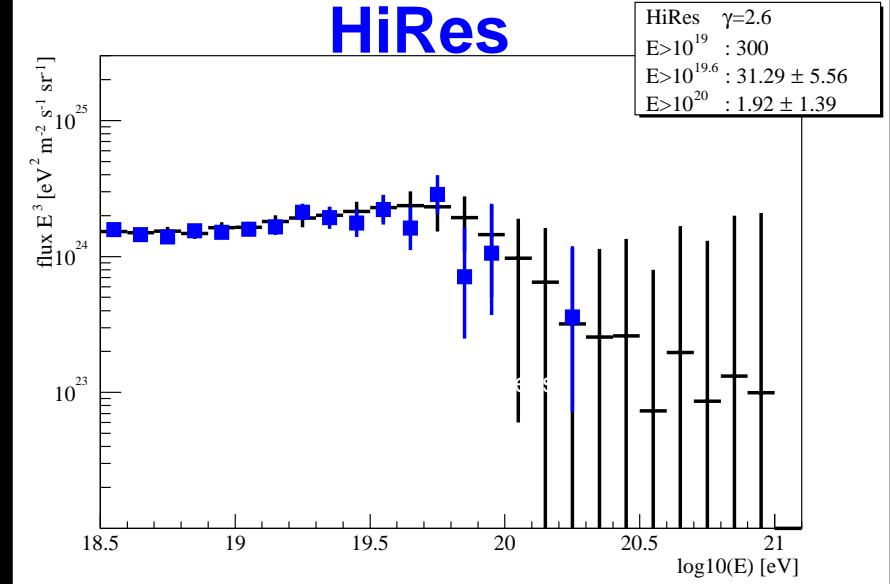
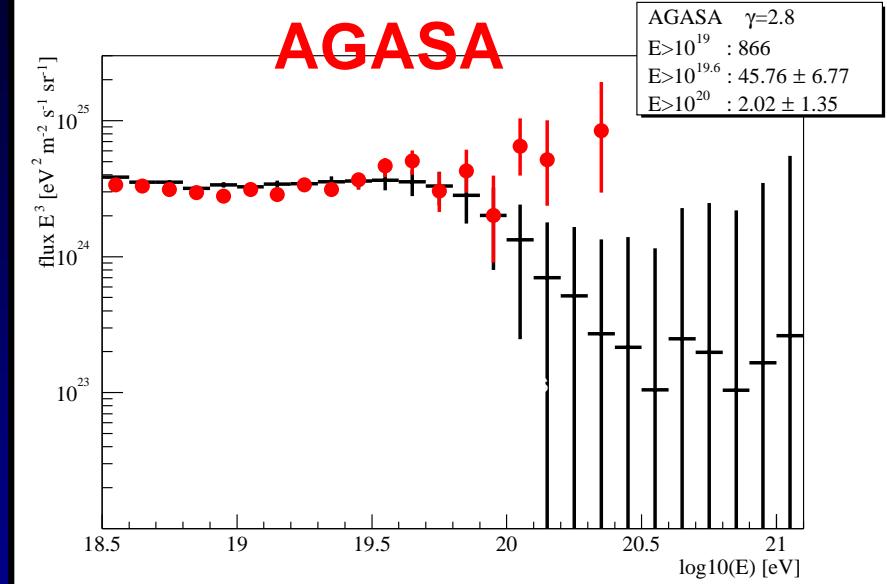




*“Standard” Atmospheres
can bias composition*

M. Risse et al ICRC03

Too Low Statistics for clear GZK or no-GZK determination

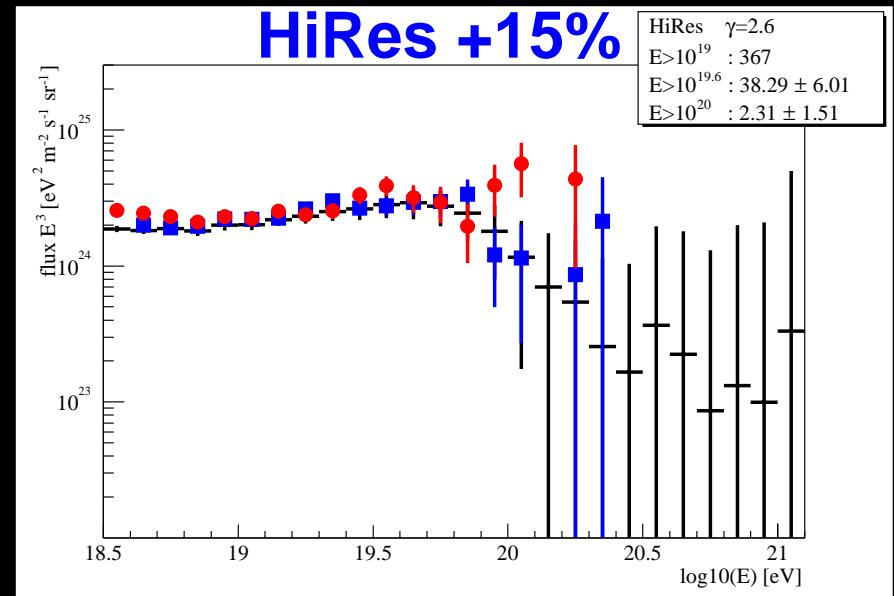
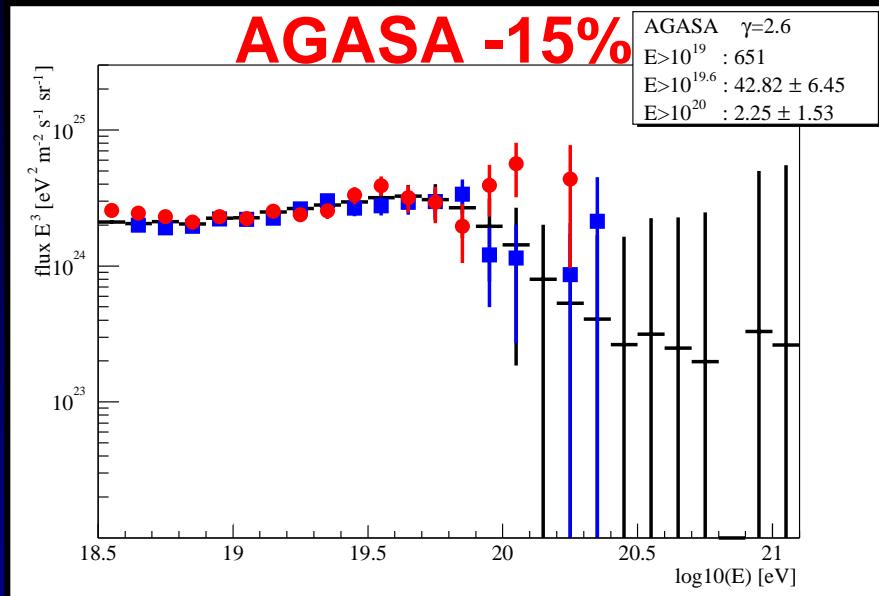


number of events above 10^{20} eV:
no GZK @ 2.5 sigma

number of events above 10^{20} eV:
GZK cutoff

systematic errors in by hand...

- 30% in order to reconcile low energy data ($10^{18.5}$ - $10^{19.5}$ eV)
- 15% within limits allowed by both collaborations

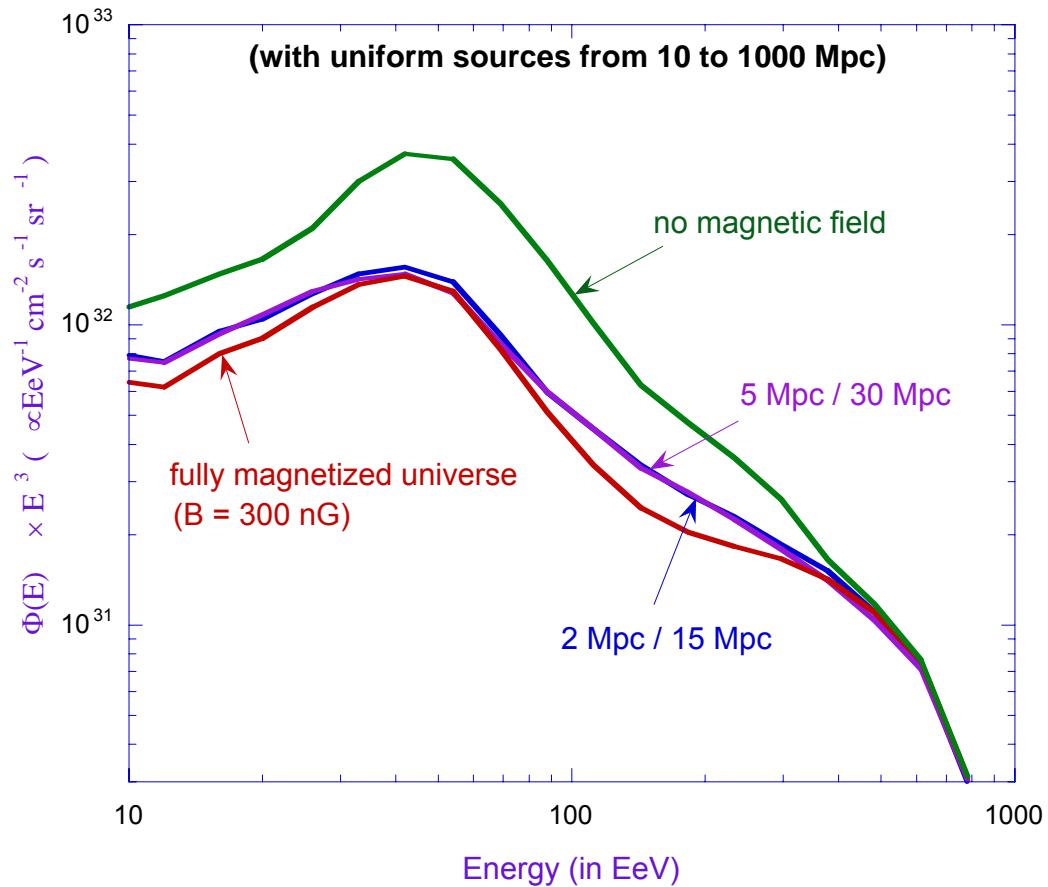


best fit slope: 2.6

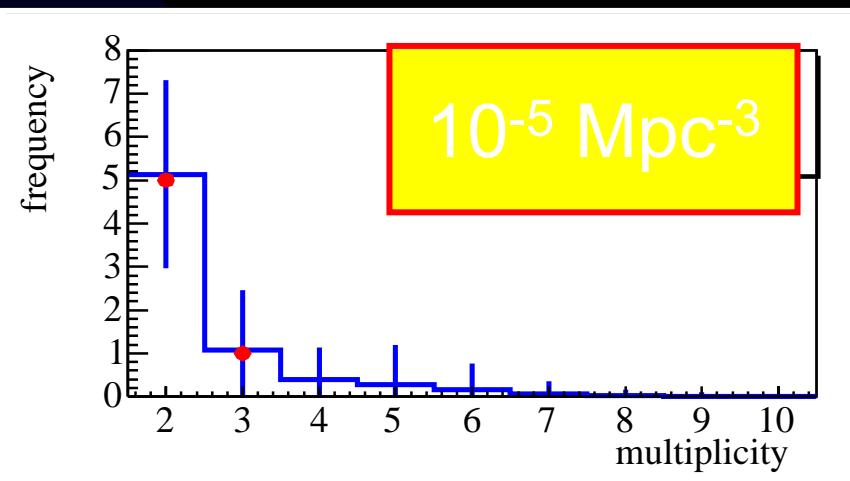
number of events above 10^{20} eV:
no GZK @ 1.5 sigma

number of events above 10^{20} eV:
GZK cutoff

GZK cut-off is model and B dependent...



AGASA multiplets



simulations with
point sources

$B=0$ resol.= 2.5° $\gamma=2.6$ $m=0$

$E > 4 \cdot 10^{19} \text{ eV}$ - 57 events

Blasi, DDM 2003, AP in press

AUGER multiplets $E > 10^{20} \text{ eV}$ - 70 events in 5 yrs

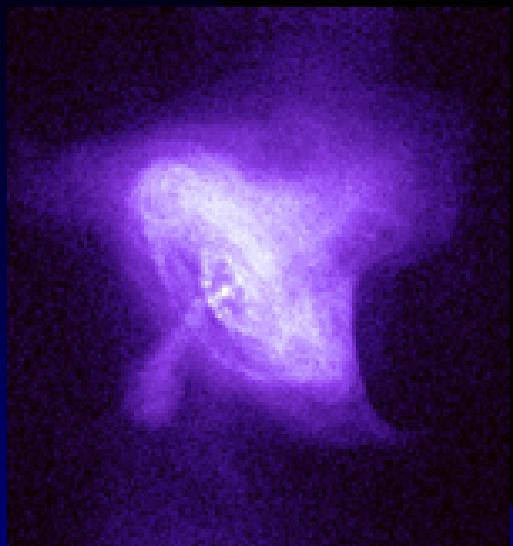
EUSO multiplets $E > 10^{20} \text{ eV}$ - 180-360 events in 3 yrs

10^{-5} sources/Mpc³

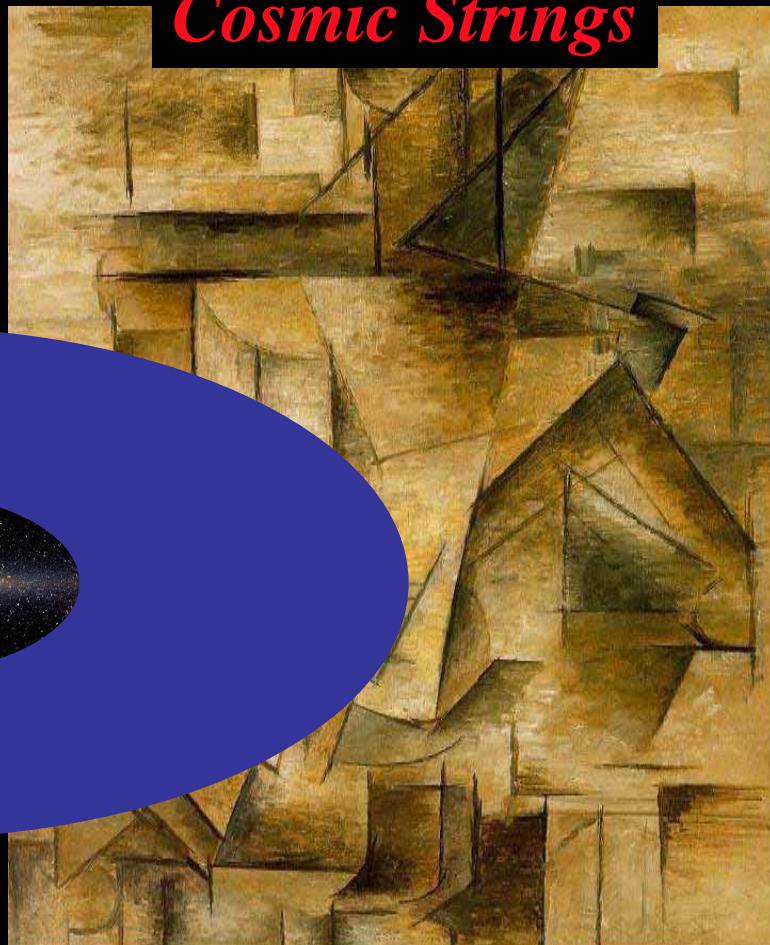
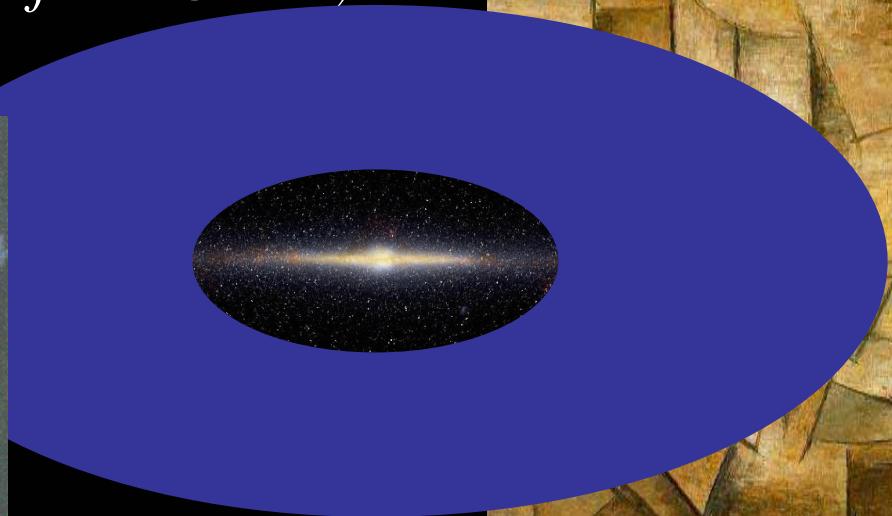
from AGASA Small Scale Anisotropy w/ large uncertainties.
Auger & EUSO will greatly reduce the uncertainties.

DeMarco et al (ICRC03)

Are the sources Astrophysical or New Physics?



Super Heavy
Dark Matter Relics
*in the Dark Halo
of our Galaxy*



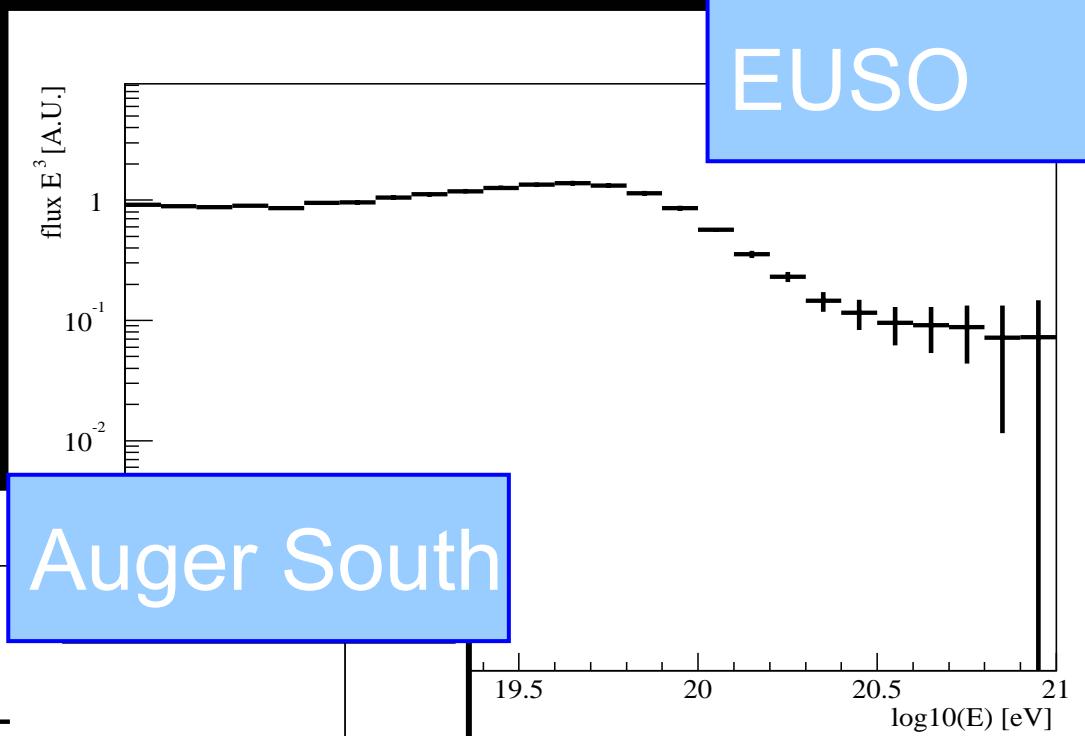
Relics from Early Universe

Time to get the Heavy Artillery



Auger & EUSO

EUSO



Pierre Auger Project

2 Giant AirShower Arrays

South – Argentina Funded

North – Not Funded Yet

**1600 particle detectors over
3000 km²**

+ 4 Fluorescence Detectors

**Will Measure Direction,
Energy, & Composition of**

~ 60 events/yr E > 10²⁰eV

~ 6000 events/yr E > 10¹⁹eV

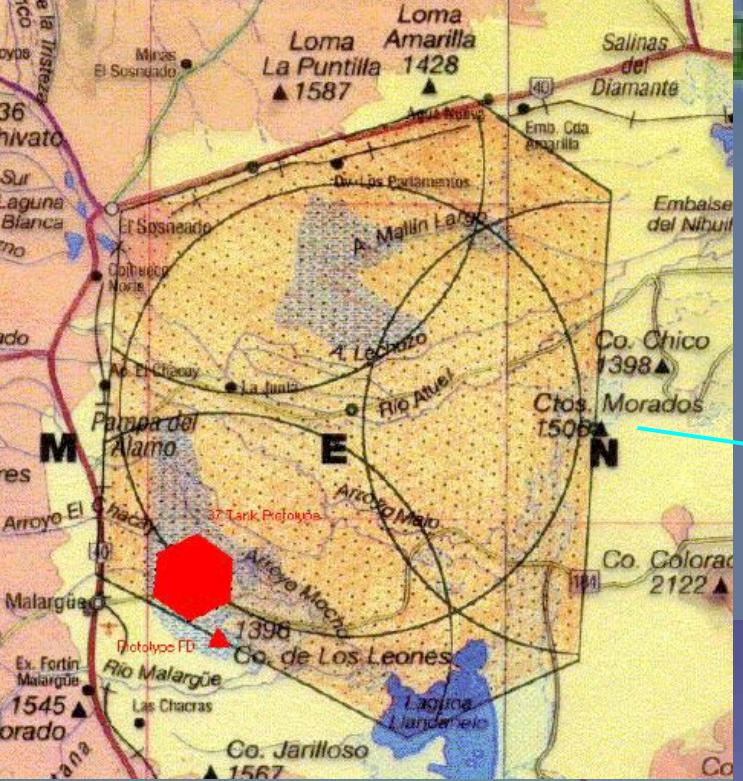
> 250 scientists from 19 countries

J. Cronin and T. Yamamoto

The New Samurais in the Block are BLACK BELT!



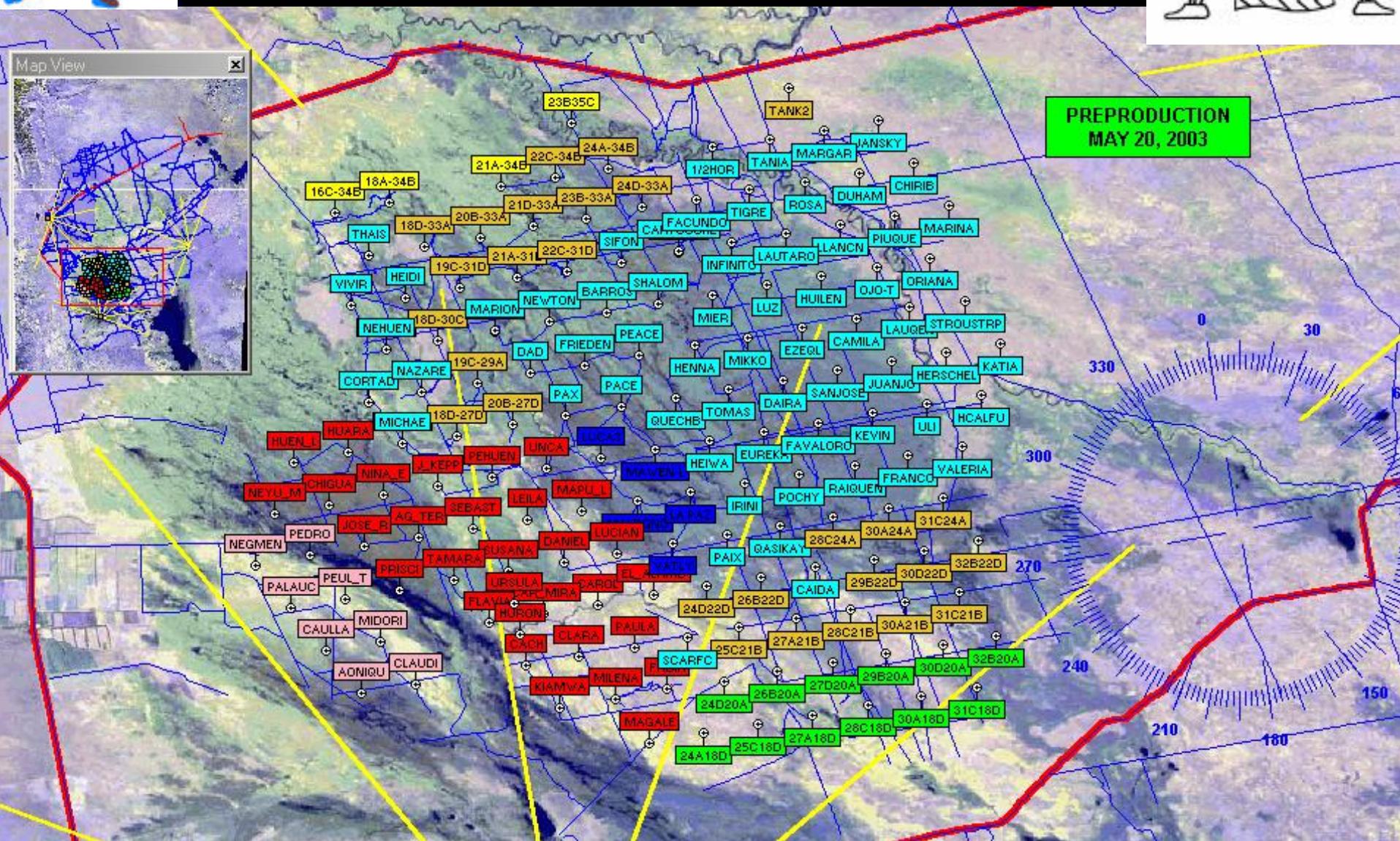
Auger South



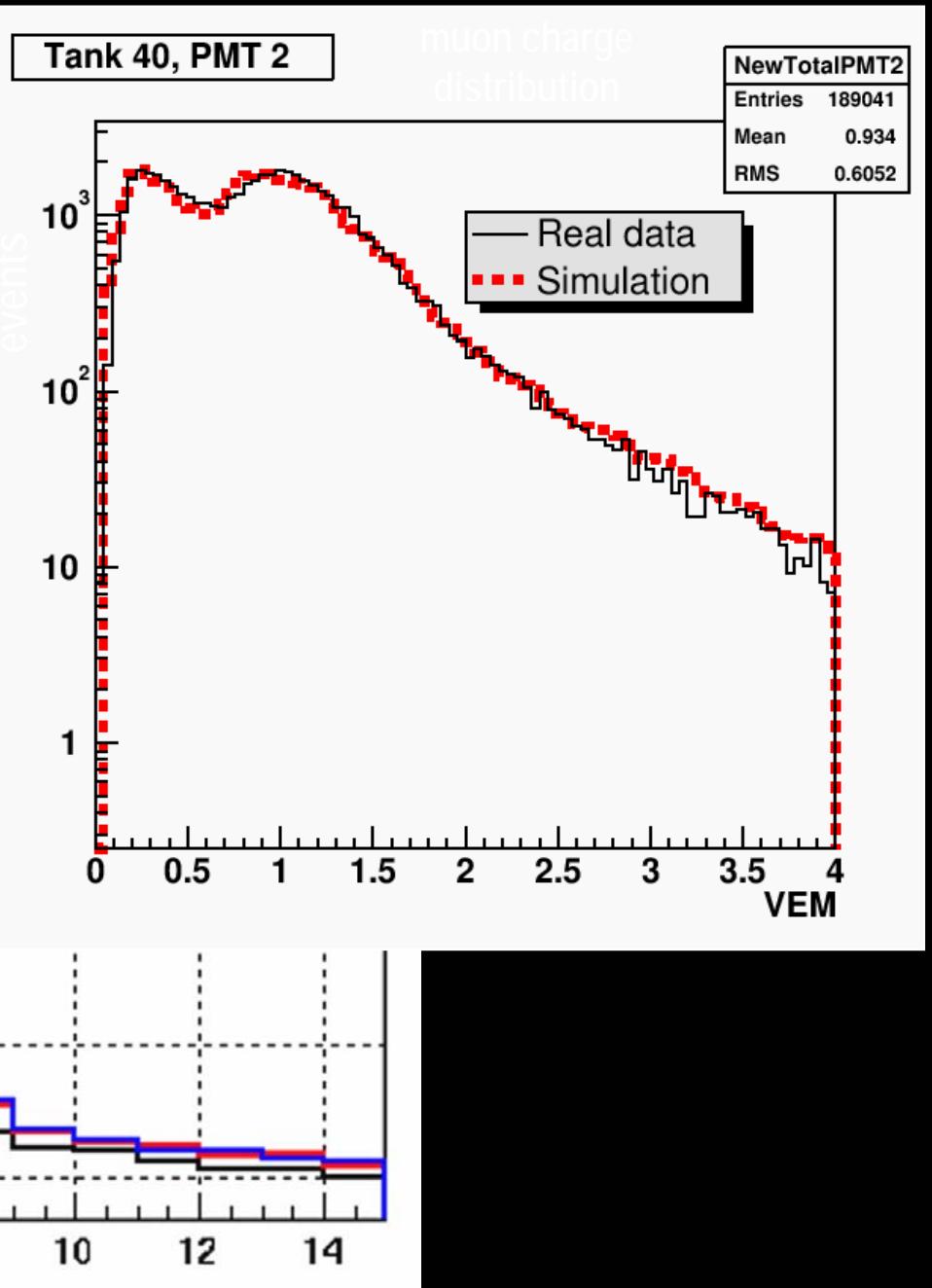
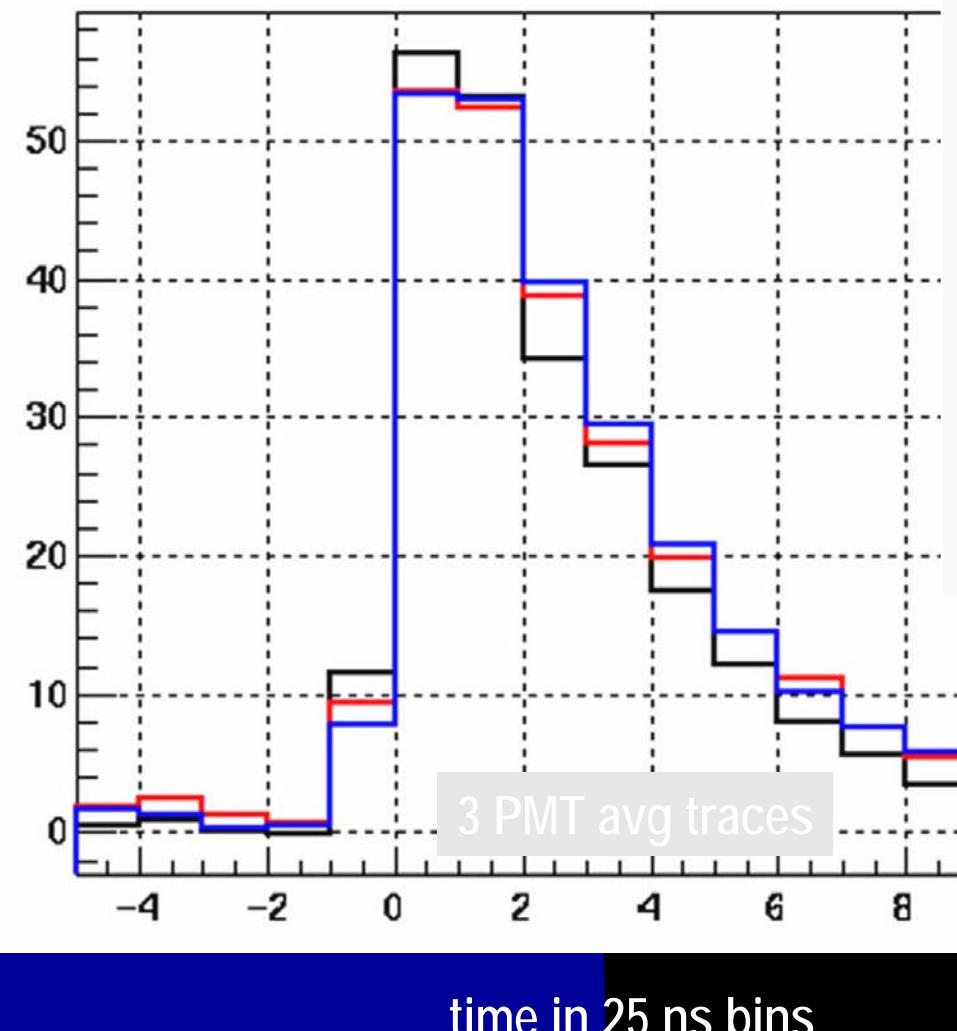


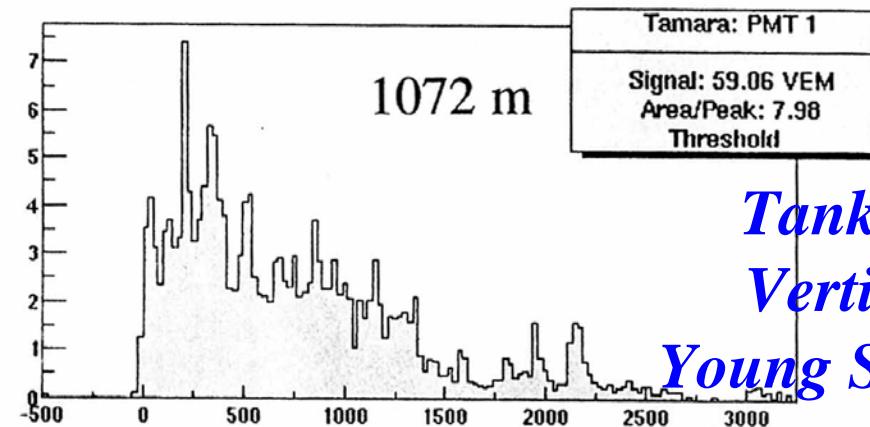
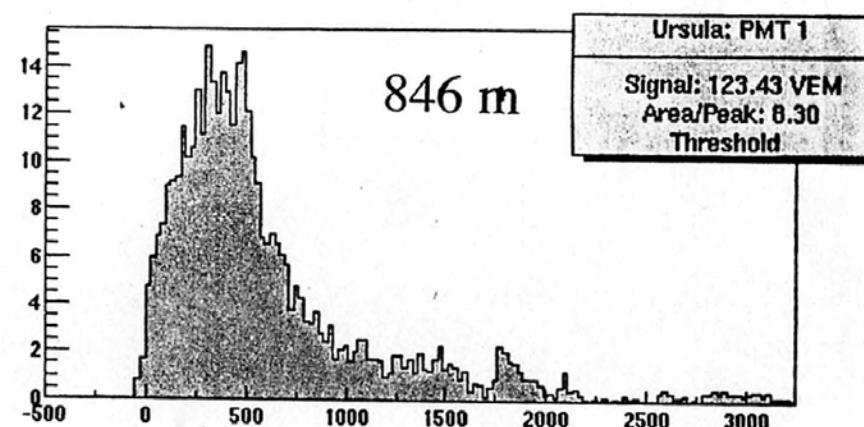
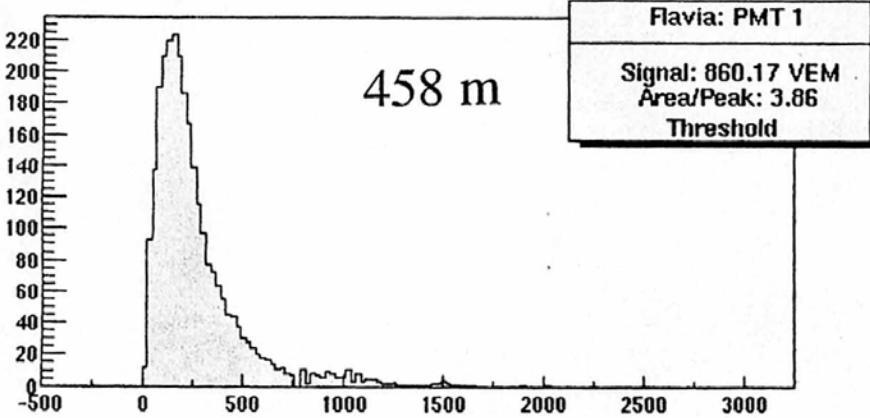
Current status

140 tanks + 65 with electronics

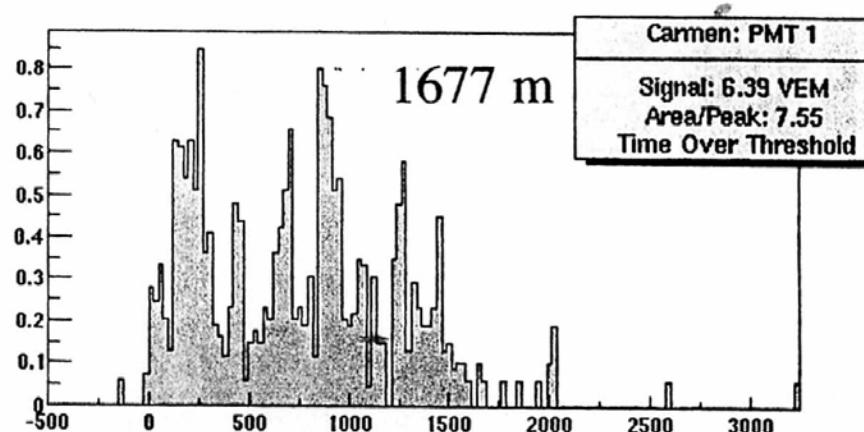
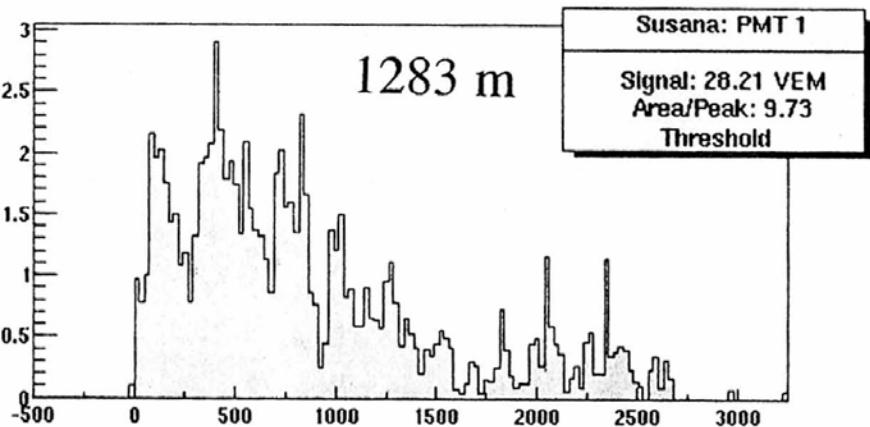
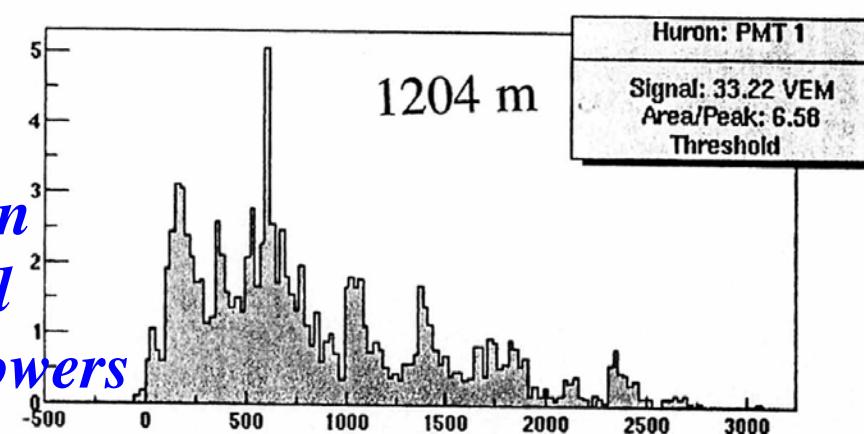


self-calibrating surface detectors

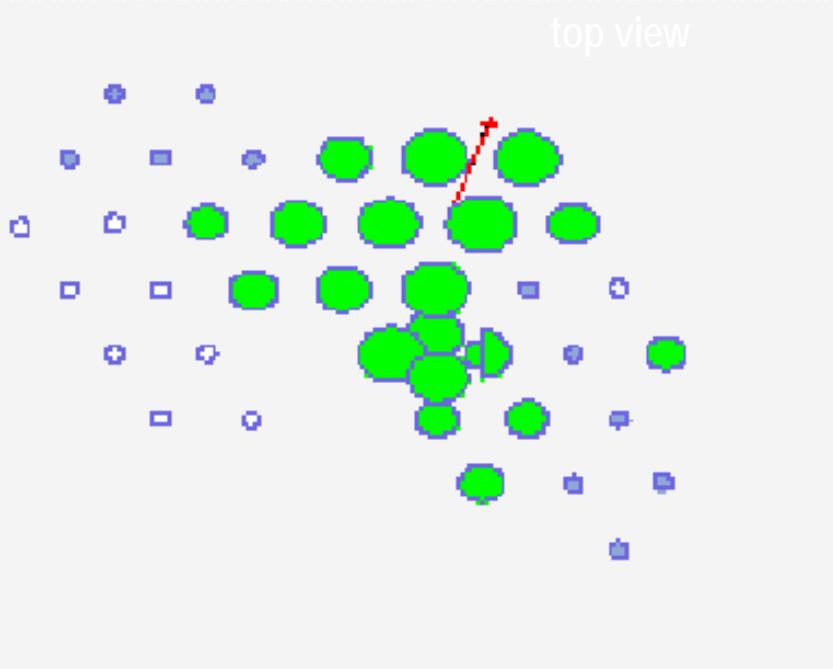




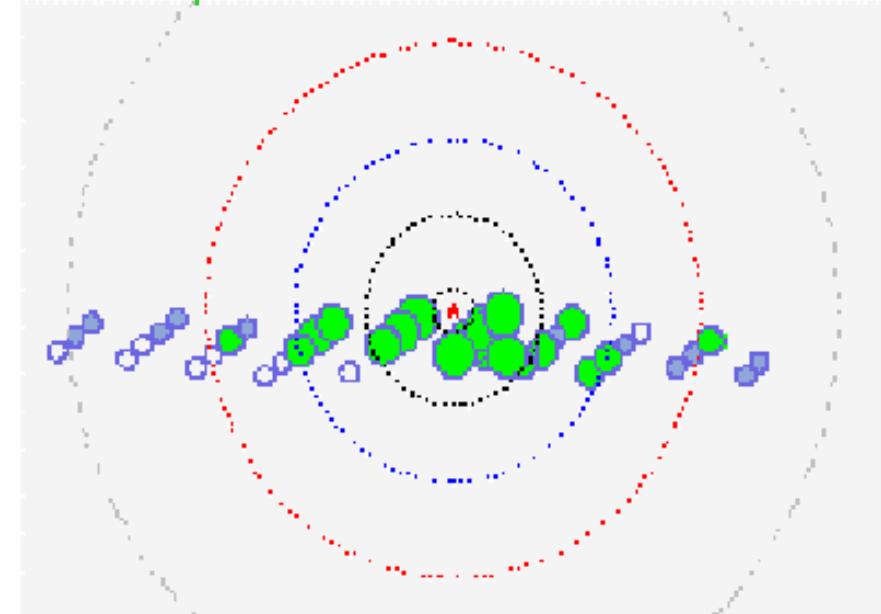
*Tanks in
Vertical
Young Showers*



Inclined showers

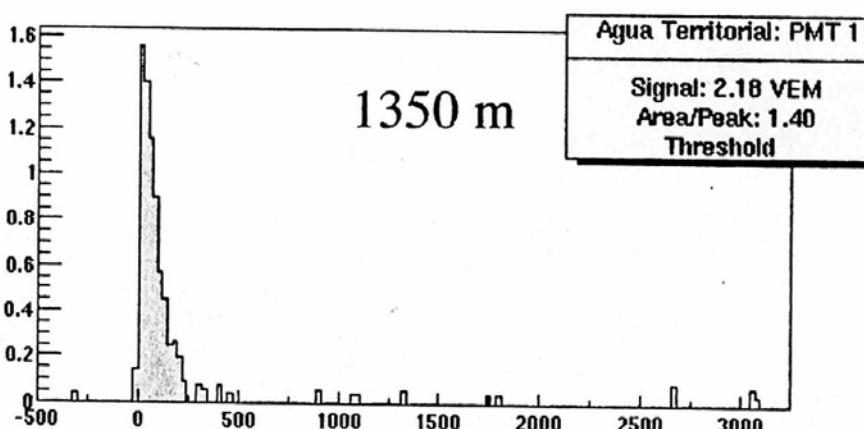
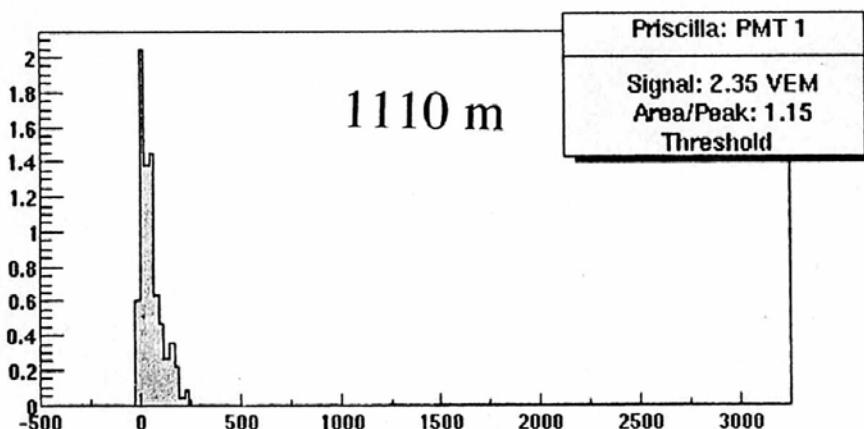
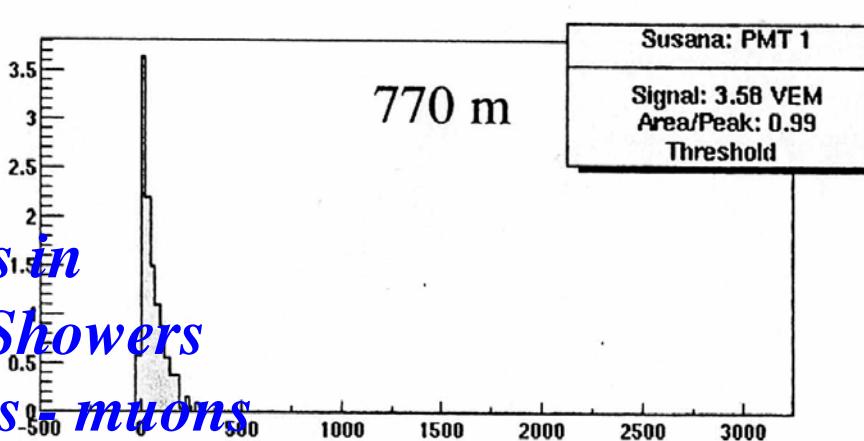
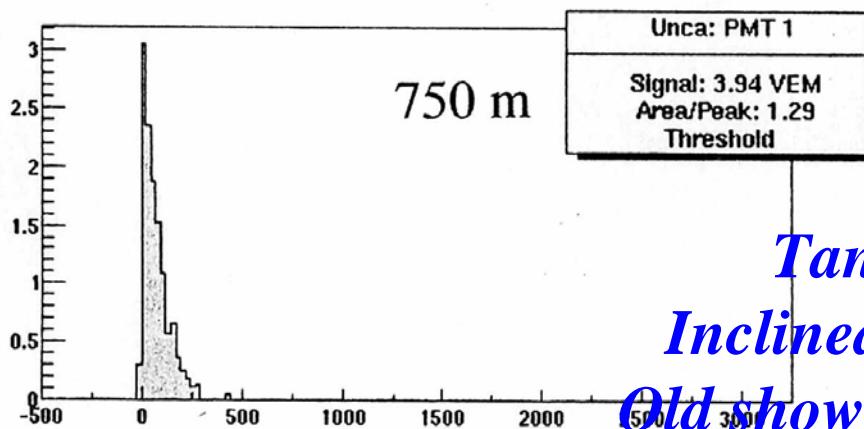
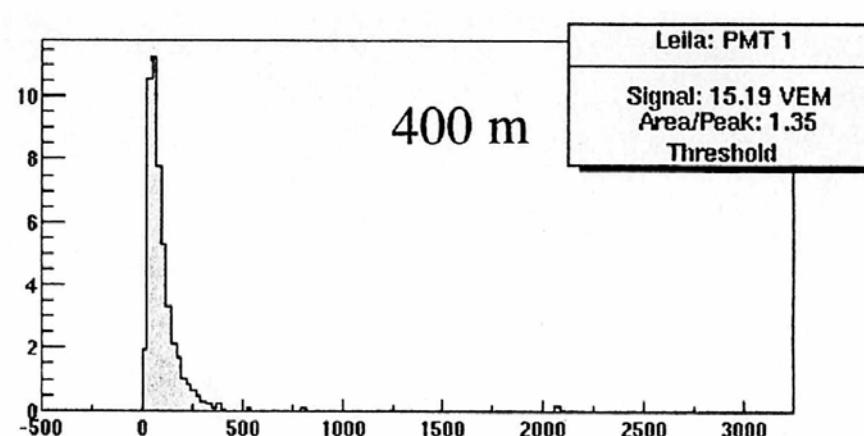
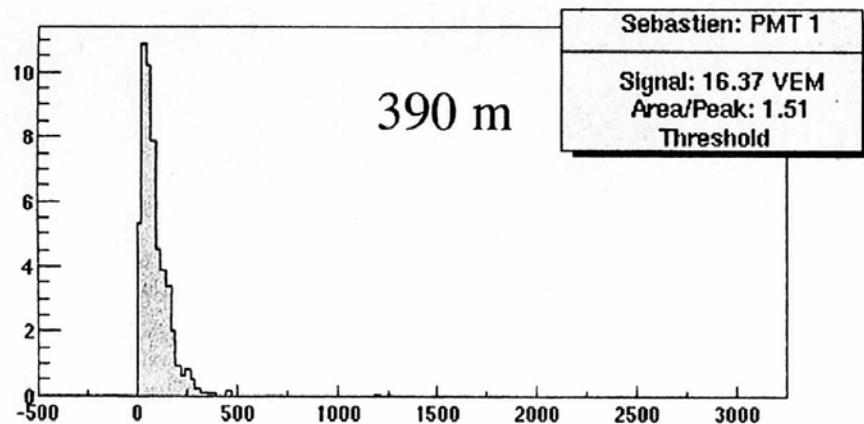


in shower plane



Great Resource for
Asymmetry of Showers
which lead to novel
Composition Studies

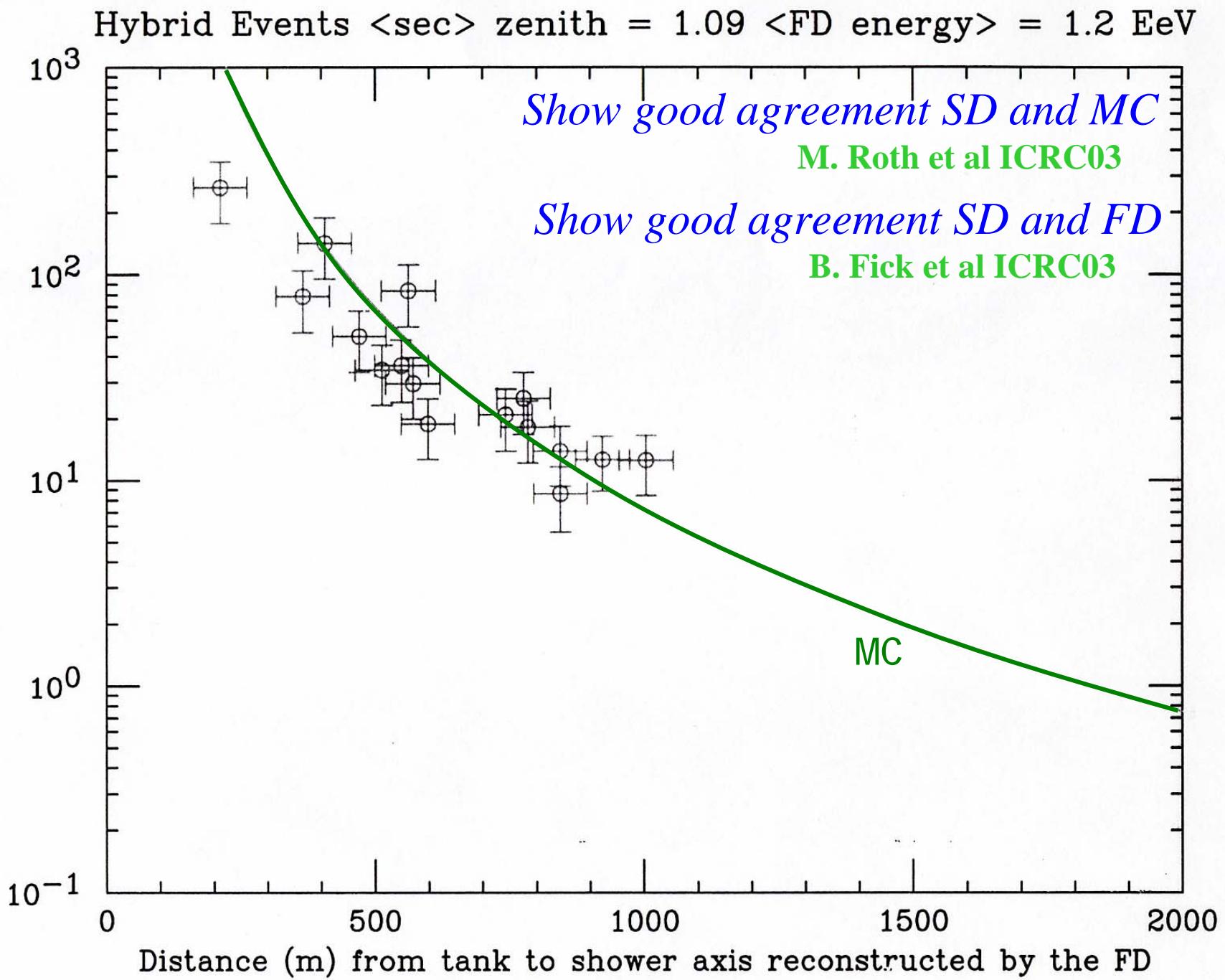
M. T. Dova et al ICRC03
M. Ave et al ICRC03



Tanks in
Inclined Showers
Old showers - muons

Hybrid Events <sec> zenith = 1.09 <FD energy> = 1.2 EeV

VEM/[FD energy (EeV)], MC expectation in green

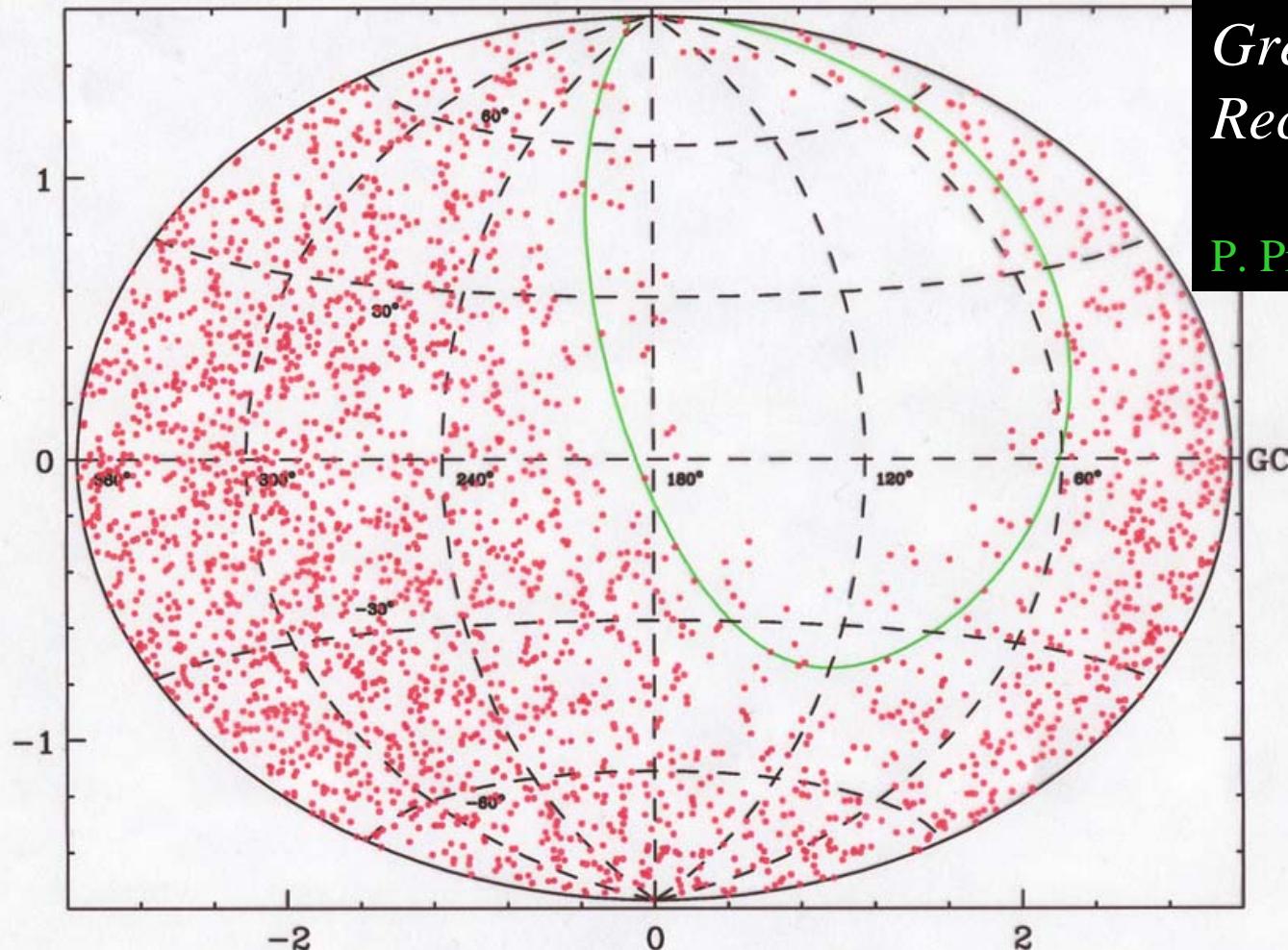


Hybrid detector can reach $10^{18}eV$ for Clustering studies

P. Ghia et al ICRC03

Auger data: 2548 events of all energies, 60 deg exclusion zone in green

Galactic Latitude



Great Angular Reconstruction

P. Privitera et al ICRC03

J. Cronin

Galactic Longitude

Fluorescence Telescopes

Complete Calibration from Atmosphere to Telescope

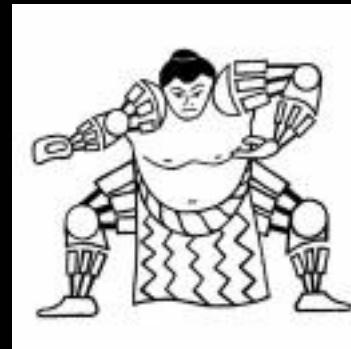
LASERS

LIDARS

Telescope and Mirrors Calibs...

M. Roberts et al ICRC03

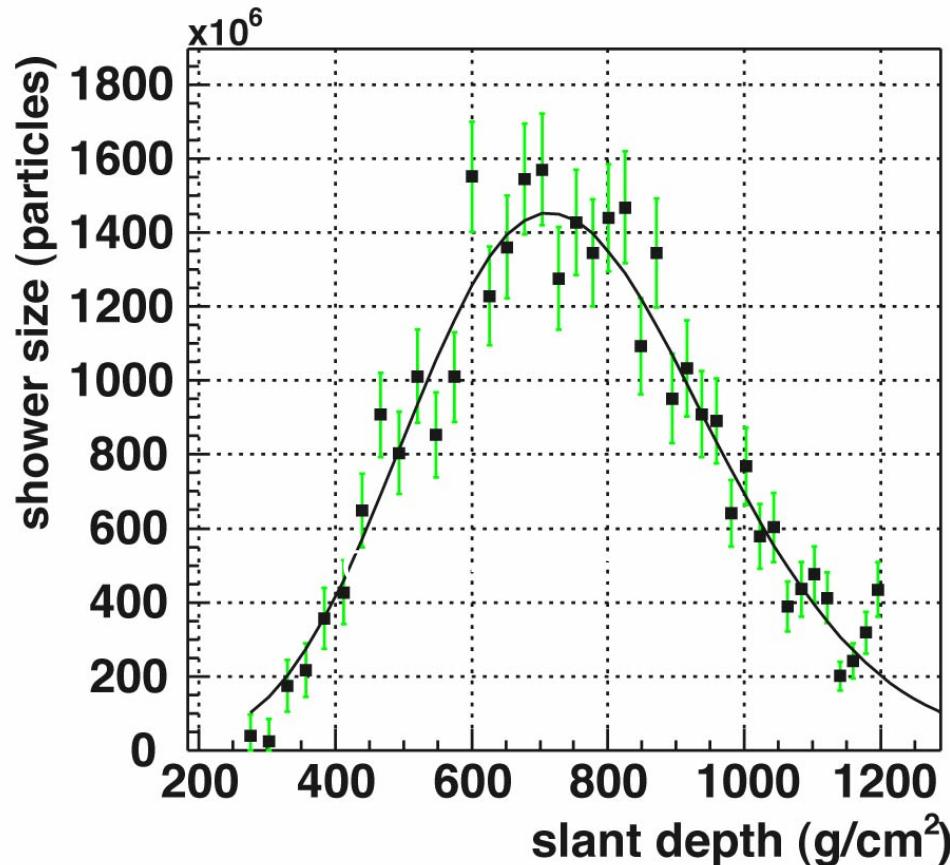
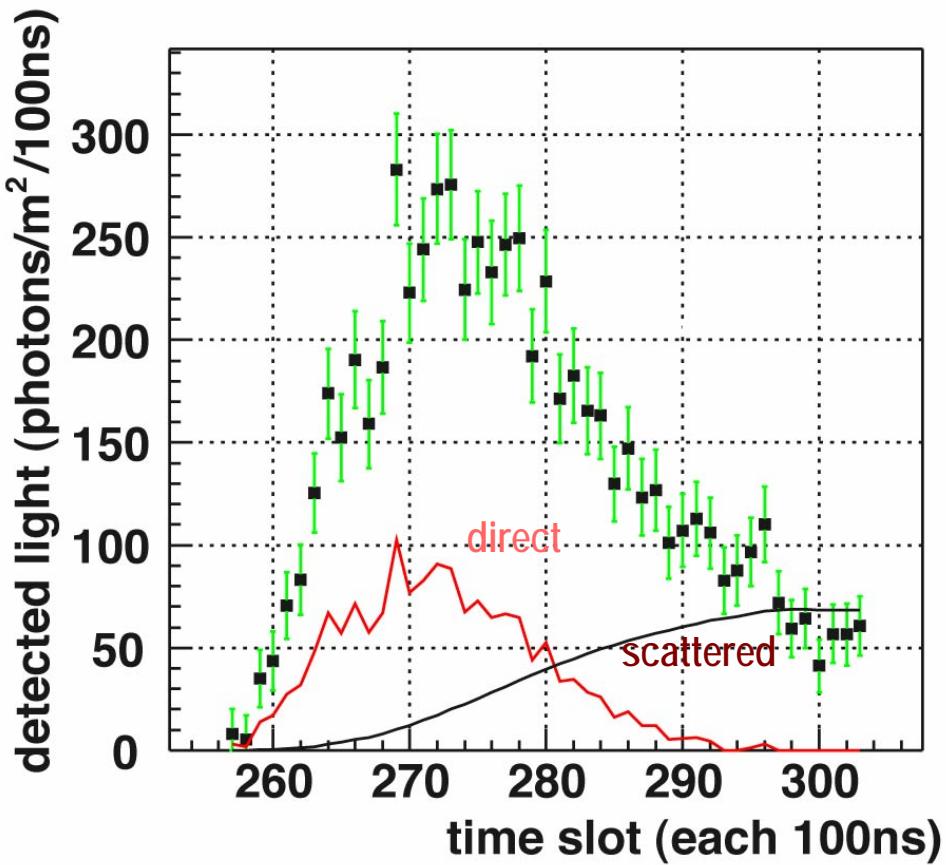
M. Mustafa et al ICRC03

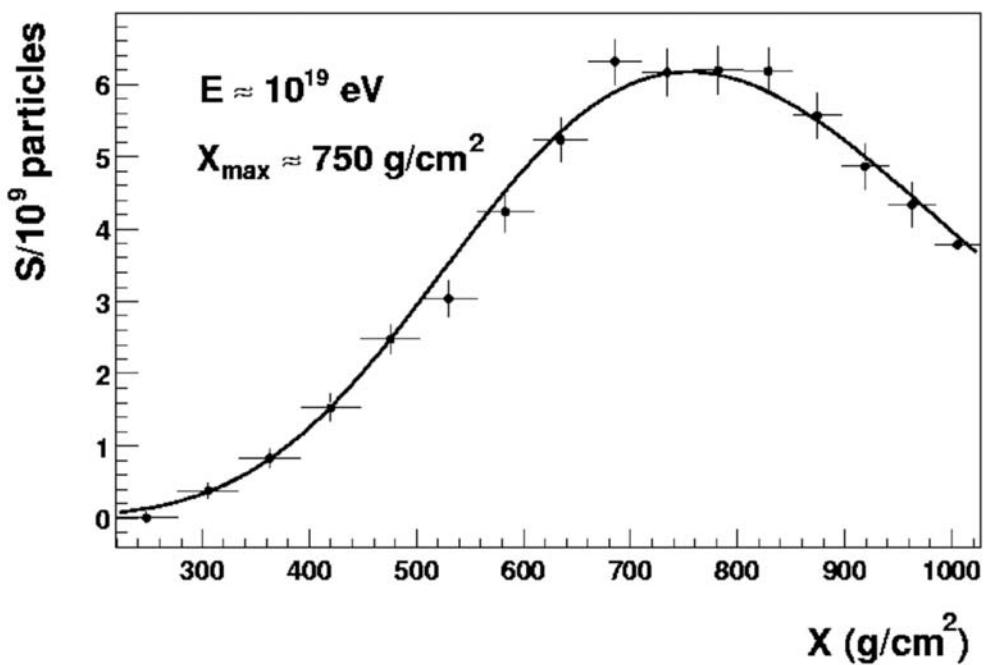


Analysis procedures with the FD

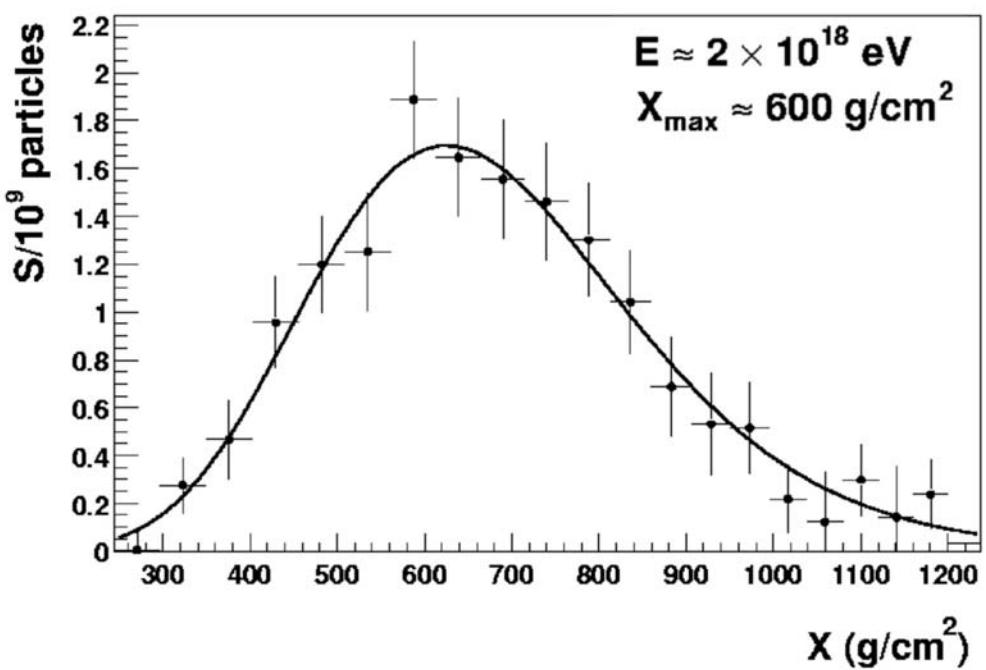
J. Bluemer et al ICRC03

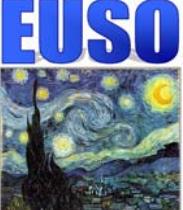
this event: initial viewing angle 15° , i.e. large direct Cherenkov contribution
iterative procedure, converges in <4 steps; suggested energy here $2\text{e}18 \text{ eV}$





J. Bluemer et al ICRC03

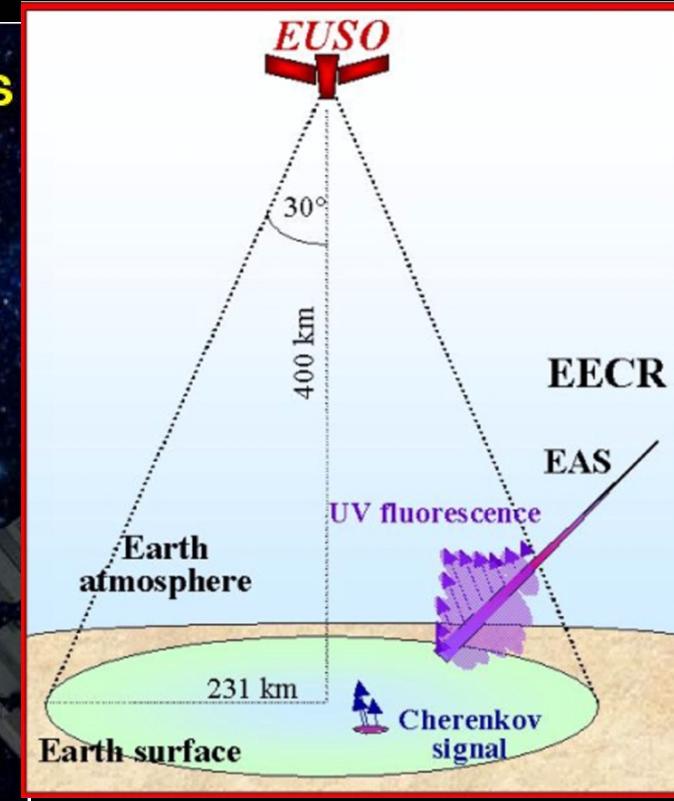
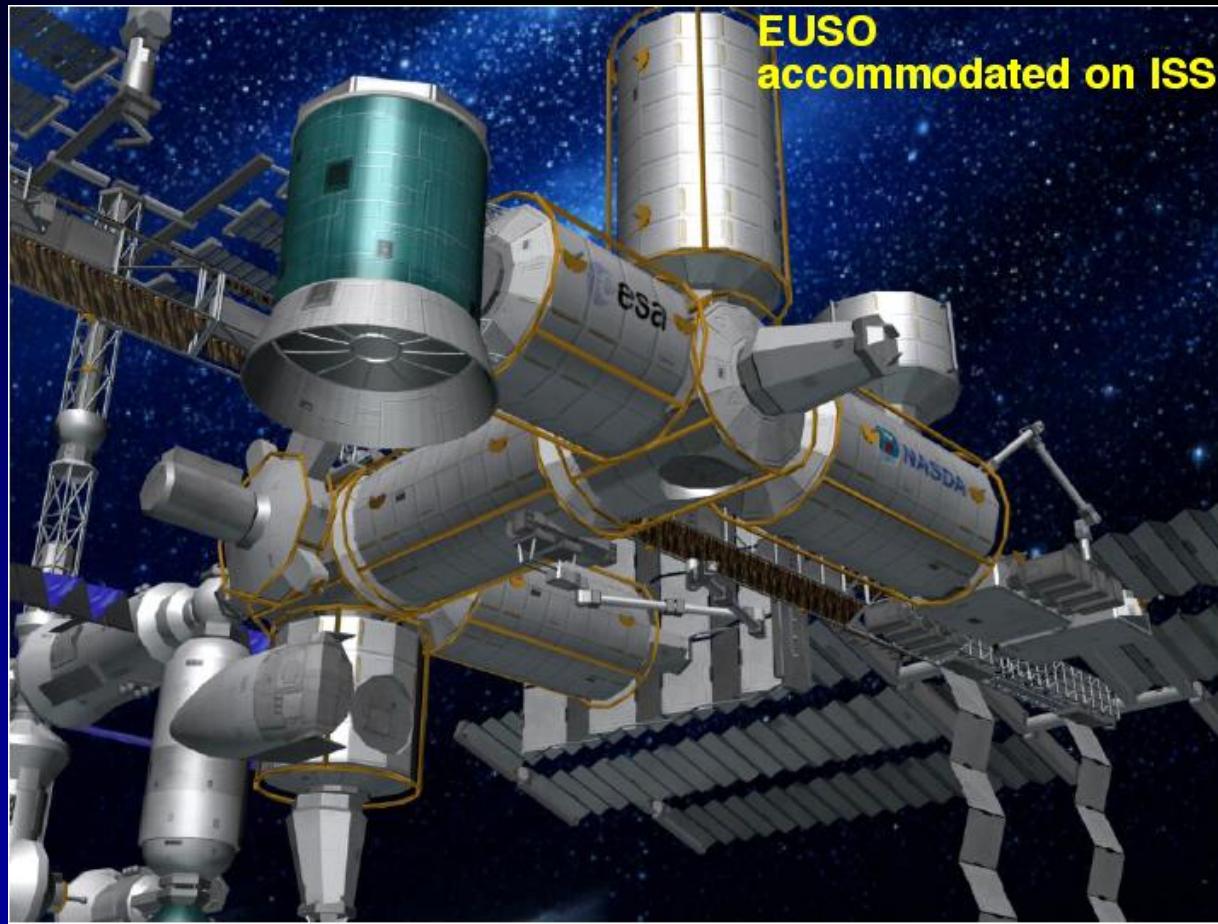




EUSO

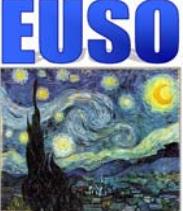
Extreme Universe Space Observatory

for Extremely High Energy Cosmic Ray Observation



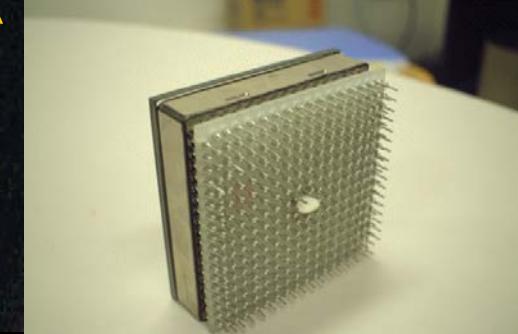
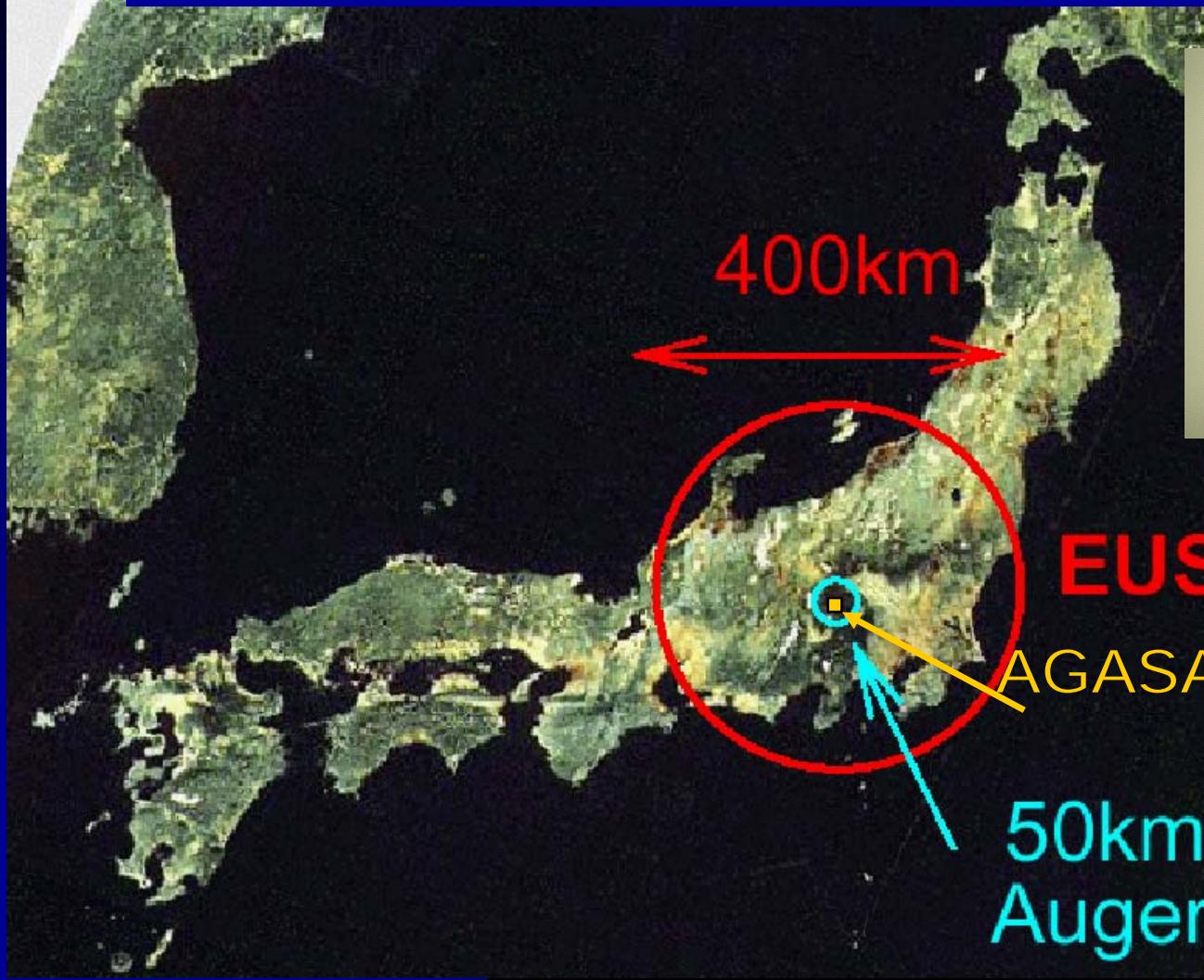
10 oral + 18 posters - becoming a reality! Phase A to Phase B





EUSO ~ 300 x AGASA ~ 10 x Auger

EUSO (Instantaneous) ~3000 x AGASA ~ 100 x Auger



Some David's face Golias...

*CHICOS
SCROD
ASHRA ...*

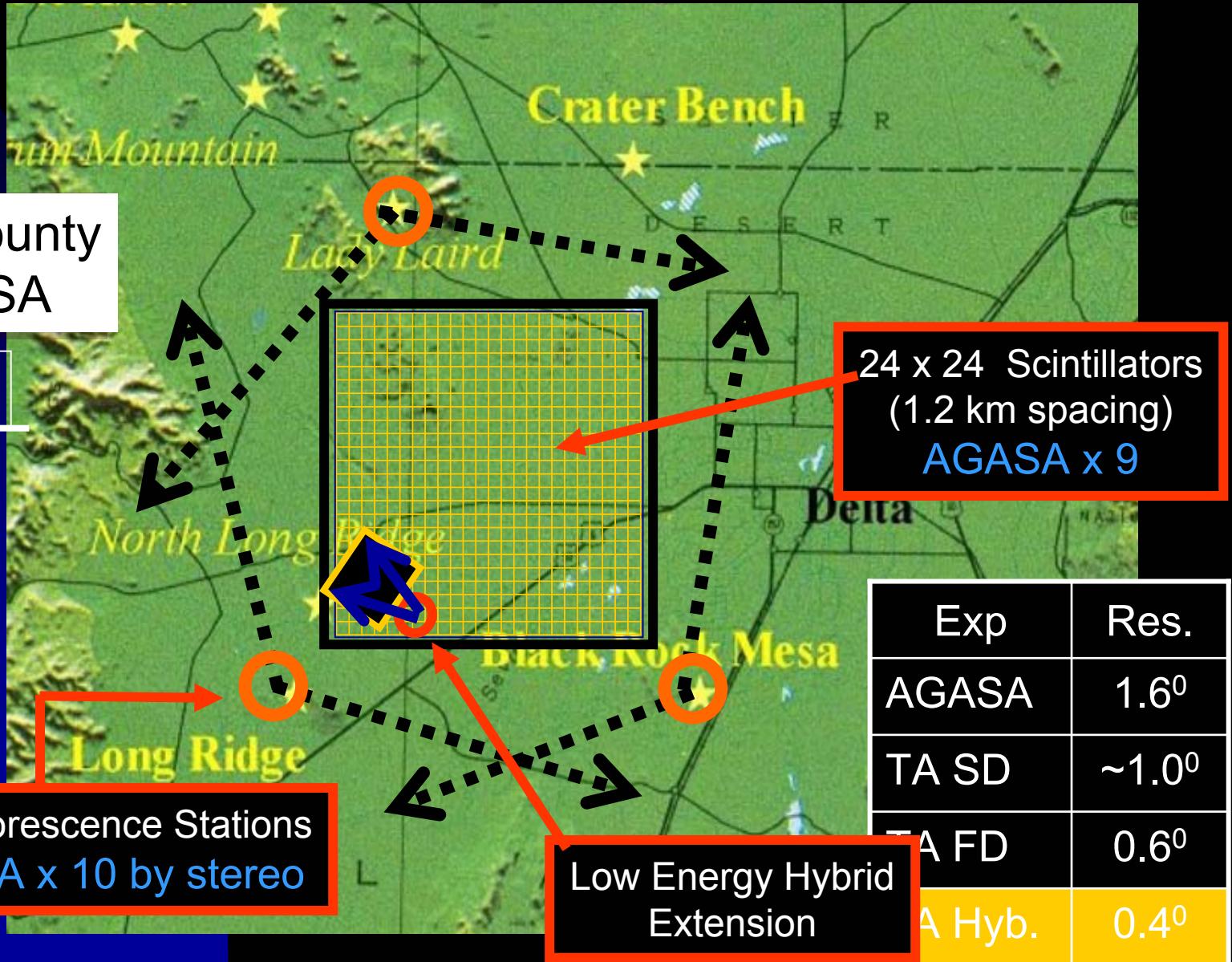


Telescope Array - toward precision low energy UHECRs

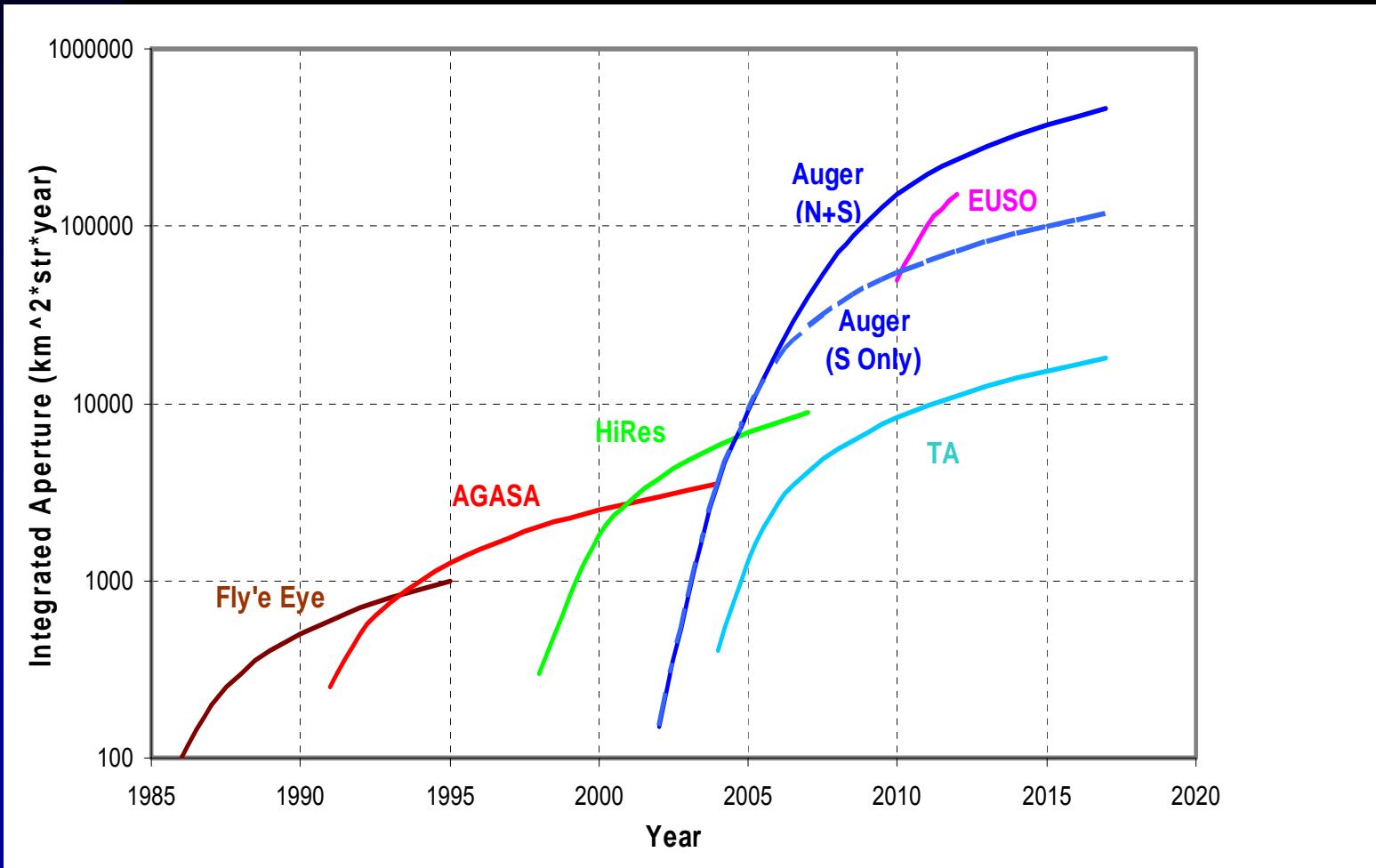
3 oral
+ 1 poster

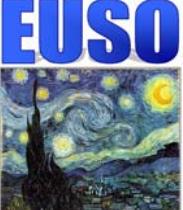
Millard County
Utah/USA

20 km

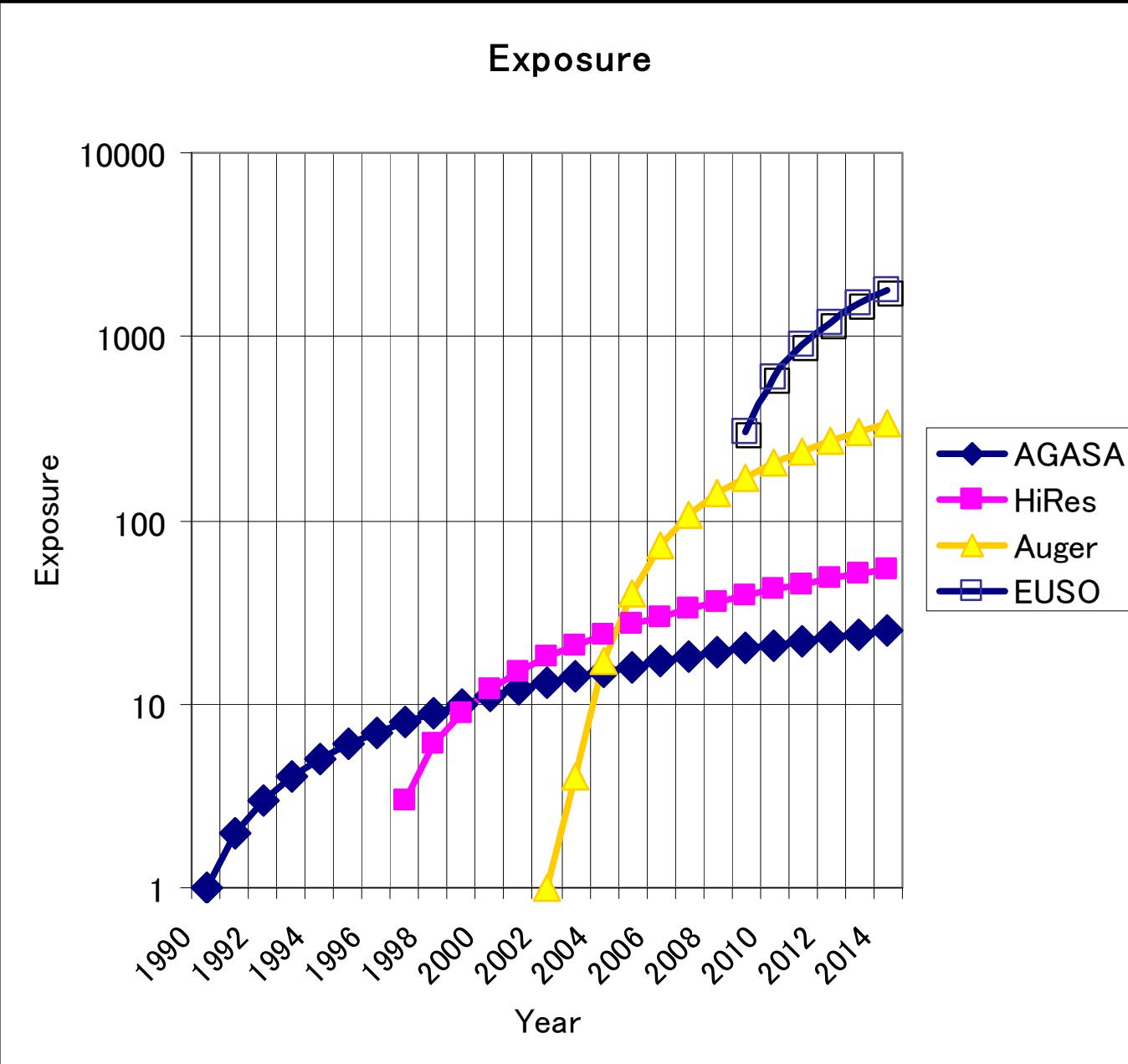


Expected Integrated Apertures

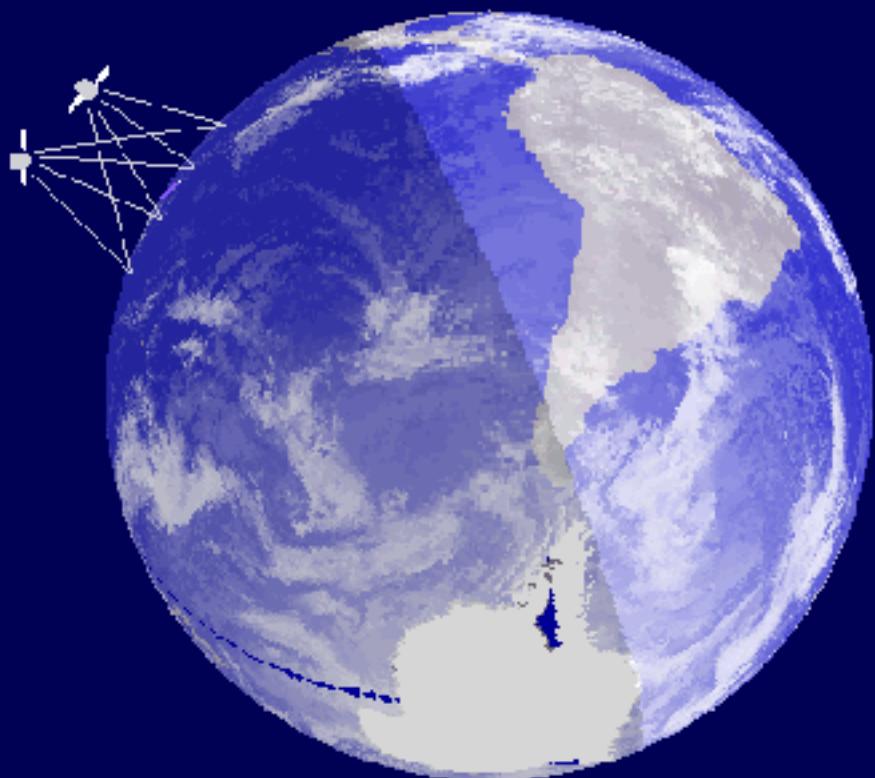




Expected Exposures



OWL



STEREO
Ni Fluorescence
from ABOVE!

**3000 events/year
 $E > 10^{20}$ eV !!!**

UHE Neutrinos!

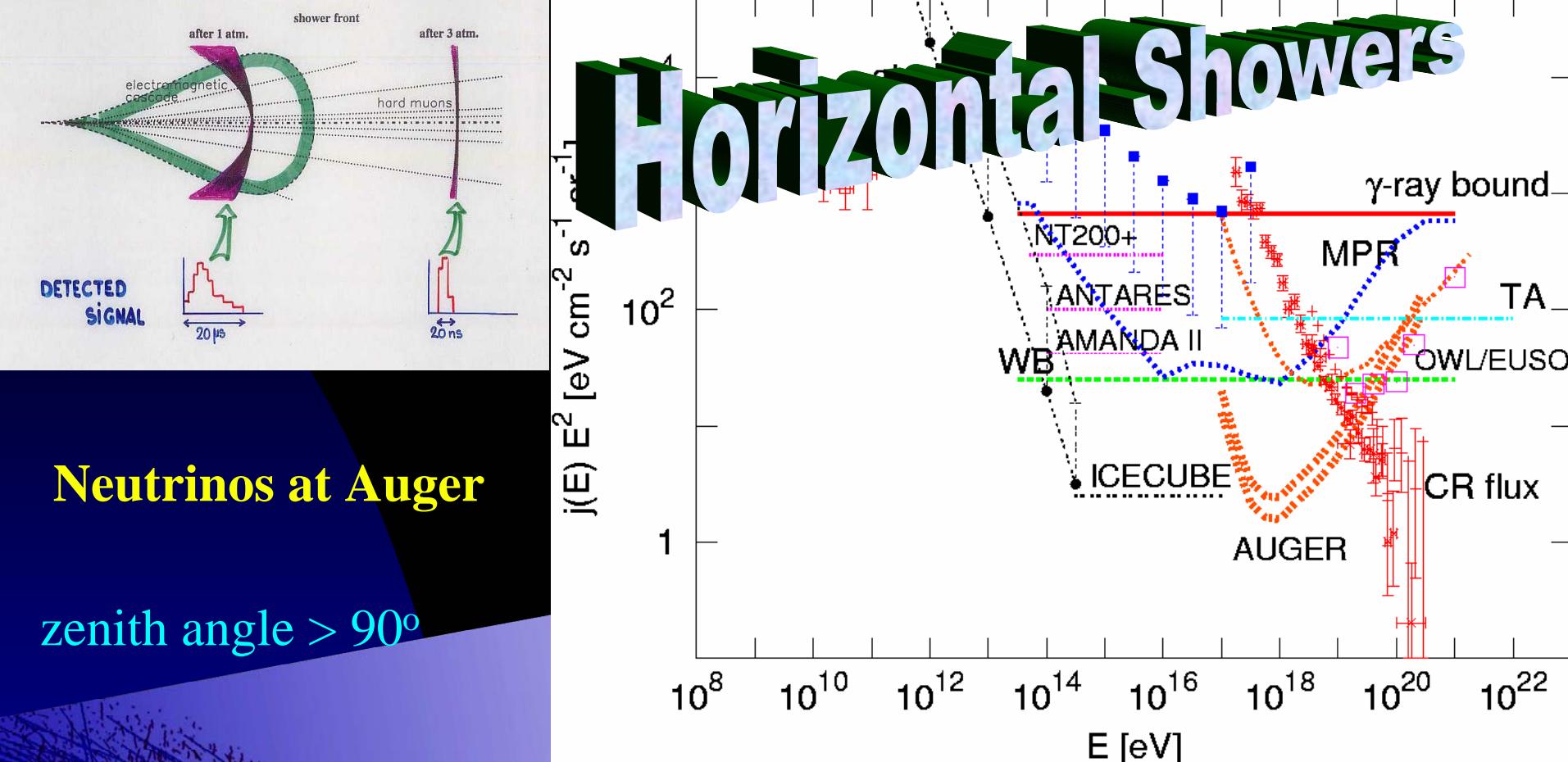
Auger Project North & South & EUSO

*will search the sky for the
Highest Energy Accelerators
ever observed since the*

Big Bang

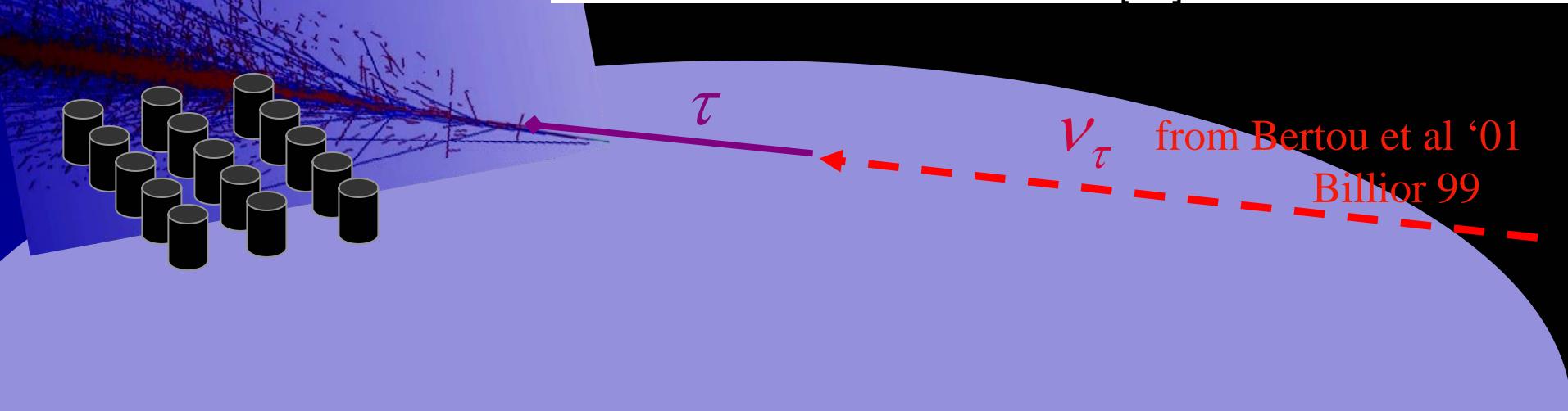


A sumo wrestler

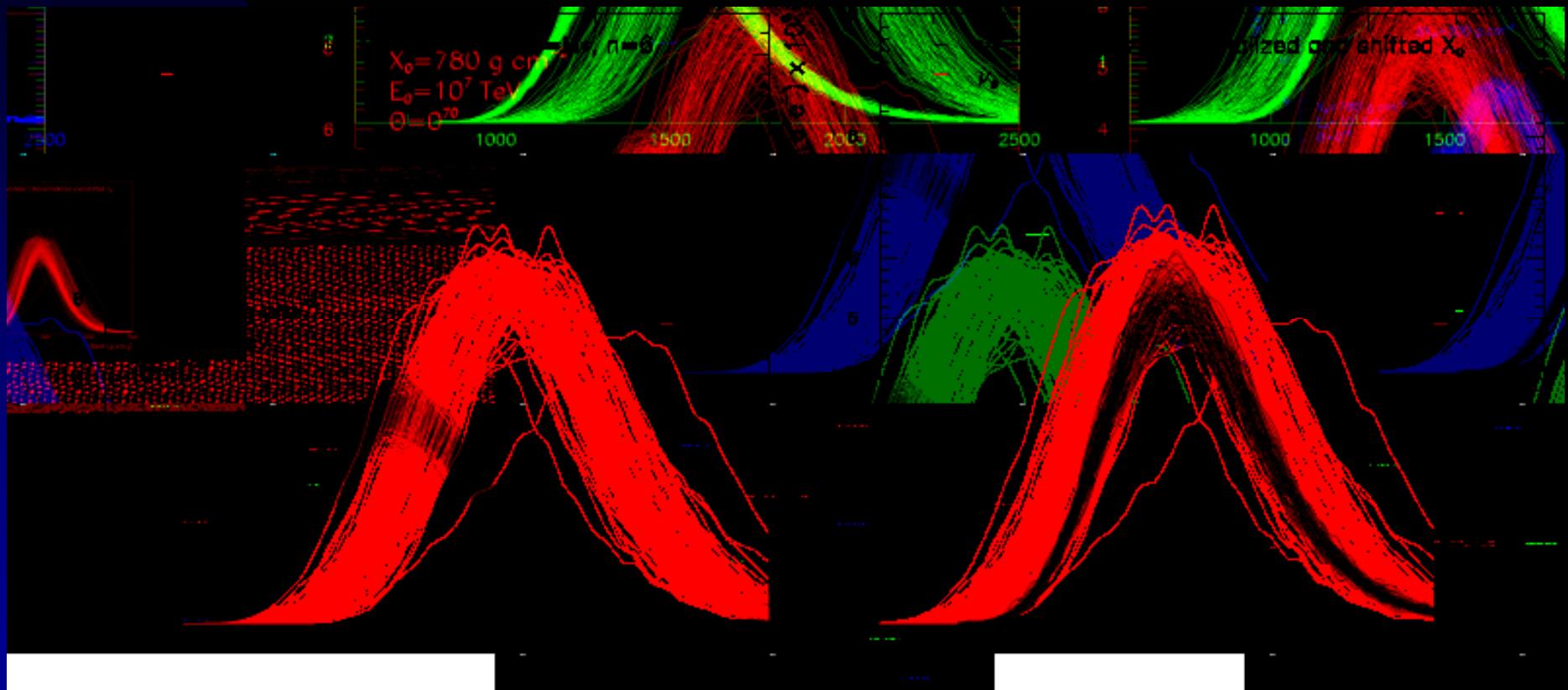


Neutrinos at Auger

zenith angle $> 90^\circ$



Large Extra Dimensions TeV Gravity



Ahn, Ave, Cavaglia, AO ICRC03

ありがとうございました。



また 2005年の時...
よろしくおねがい申い
あけます。