AUGER
Detector and First Results

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The AUGER Collaboration

Participating Countries

Argentina
Australia
Bolivia*
Brazil
Czech Republic
France
Germany
Italy
Mexico
Associate

Netherlands
Poland
Portugal
Slovenia
Spain
United Kingdom
USA
Vietnam*

63 Institutions, 369 Collaborators

The Italian AUGER Group

Catania
L'Aquila
Lecce
LNGS
Milano
Napoli
Palermo
Roma II
Torino

~ 50 Physicists

Interests:

Surface Detector
PM, Electronics

Fluorescence Detector
Filters, PM, Cameras, Electronics

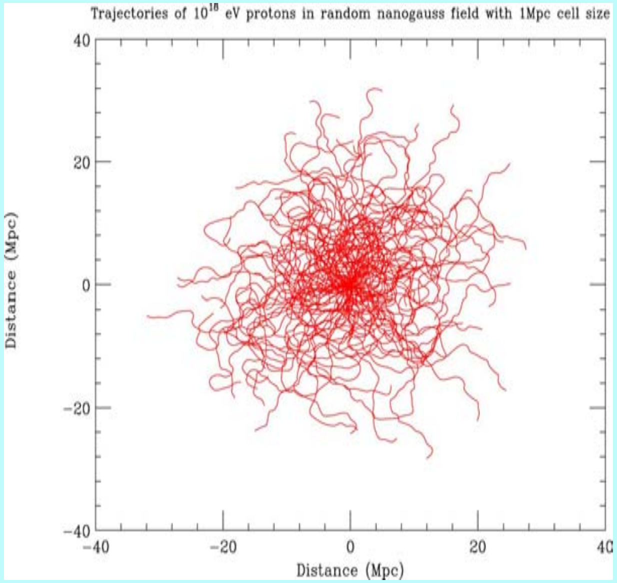
Atmospheric Monitor
LIDARs

Software
Core code, Reconstruction, Simulation,..

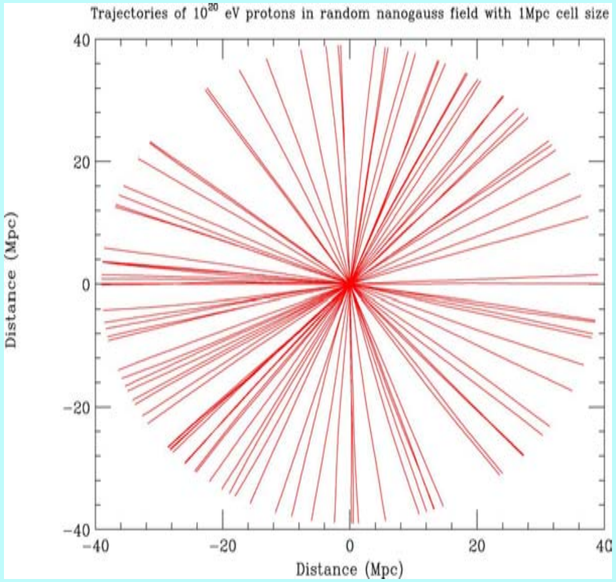
The Highest Energy Cosmic Rays

Effect of Extra-Galactic Magnetic Field
on CR trajectories – Simulation

$E = 10^{18}$ eV



$E = 10^{20}$ eV



Clearly, around 10^{20} eV a new astronomy is feasible…
…if Cosmic Rays of that energy are actually observed

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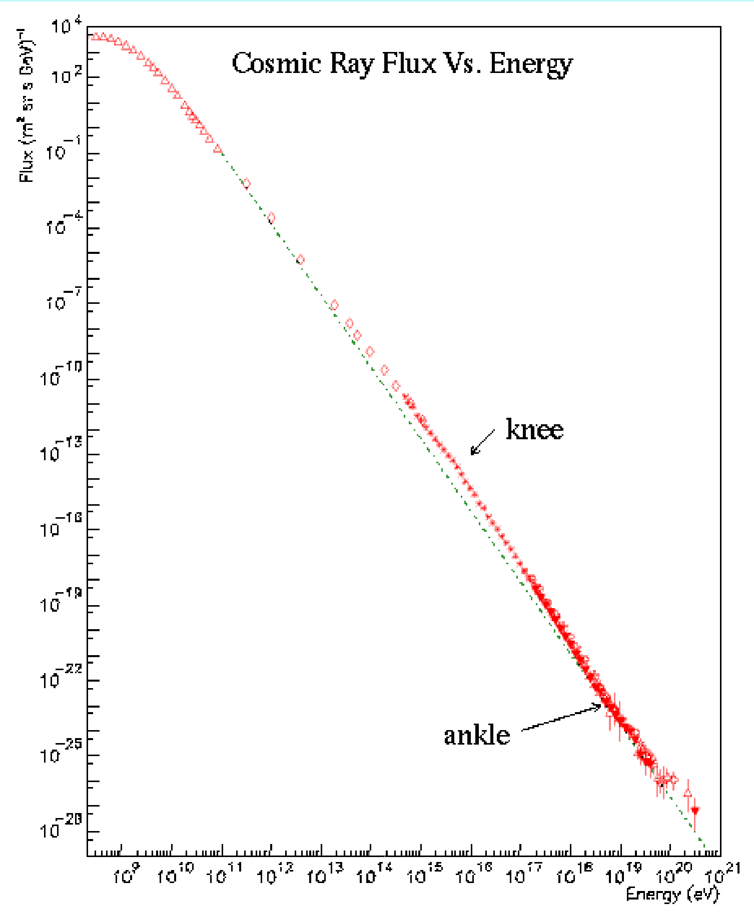
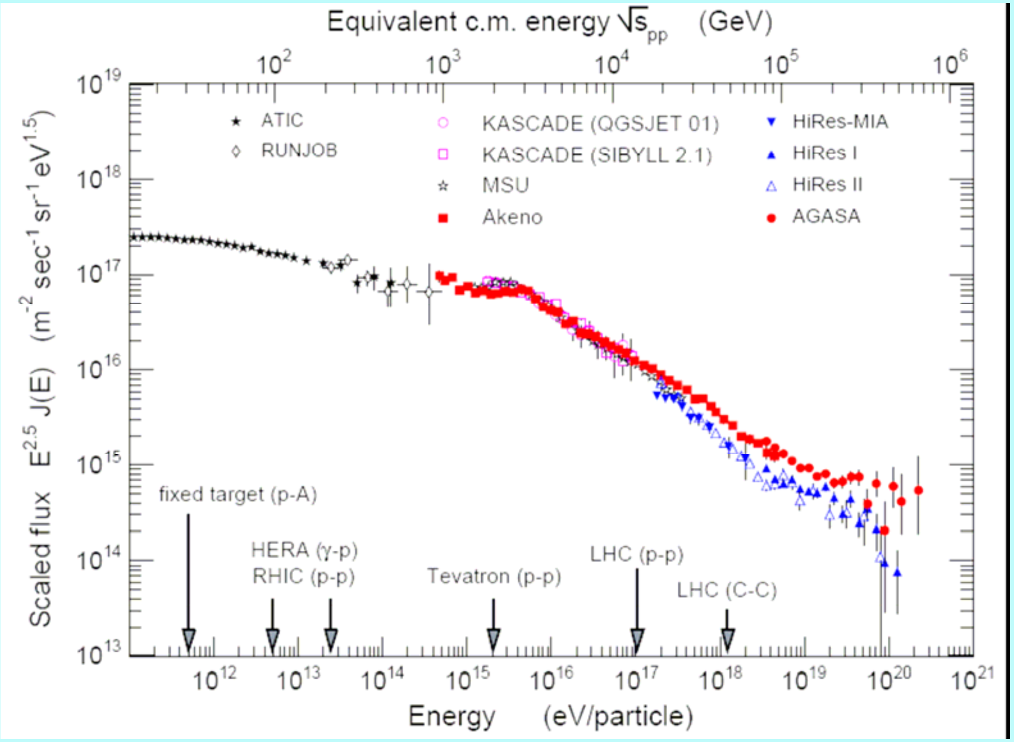
The Cosmic Ray Spectrum above 100 MeV





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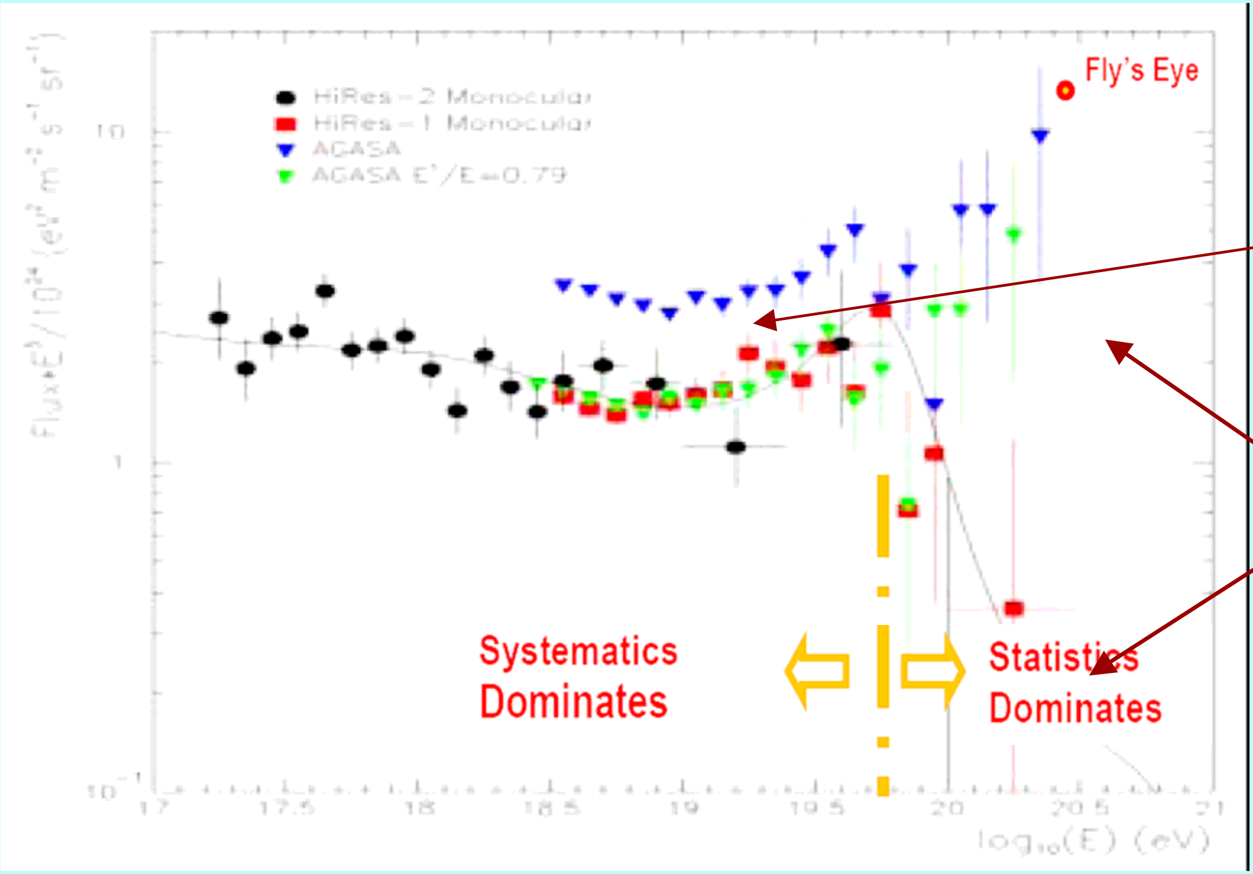
The High End of the CR spectrum: AGASA & HiRes



~ x 2 effect

~ 2 σ issue..

Outstanding Issues

Origin, Acceleration Mechanism

GZK, Energy Scale

Composition

Point Sources

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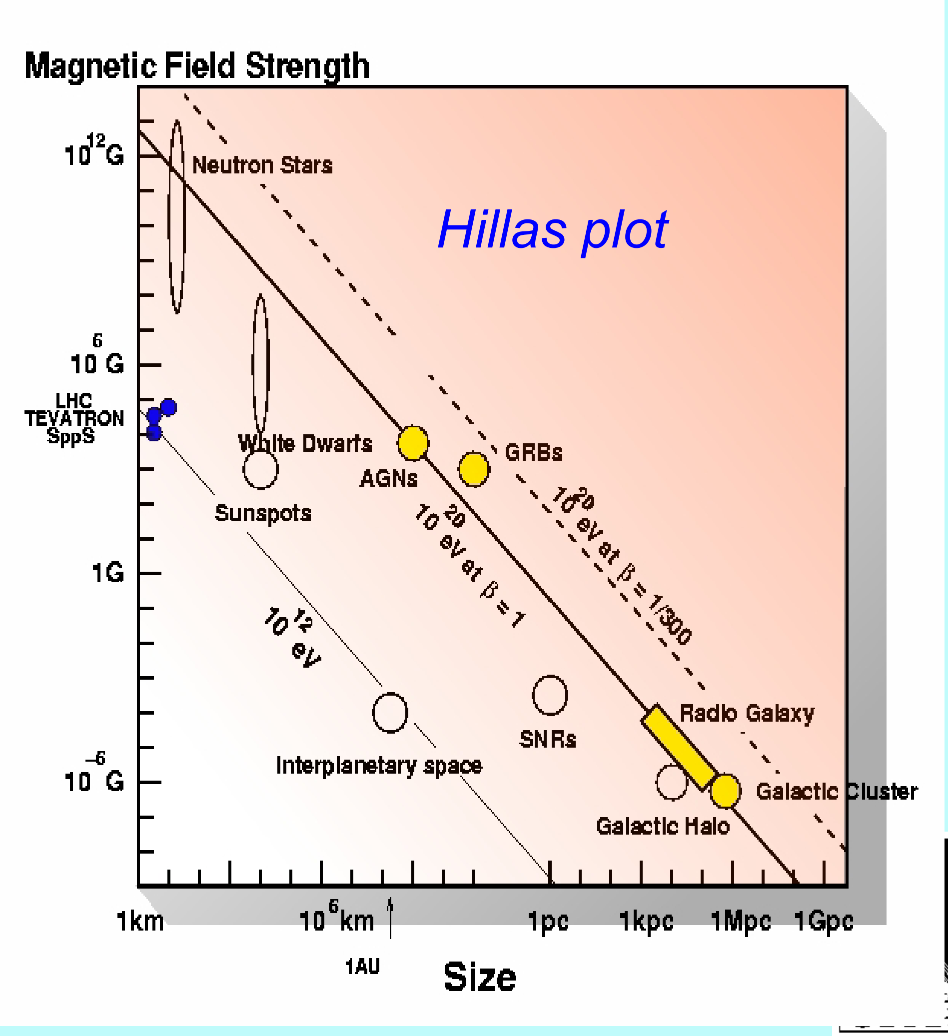
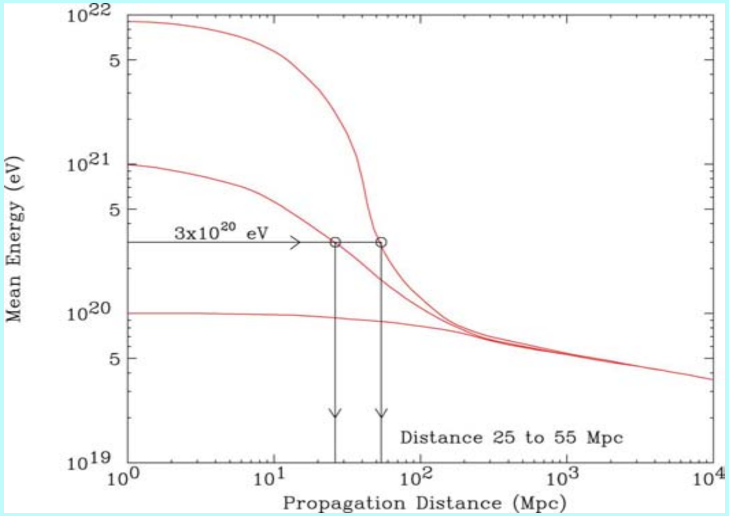
Origin, Acceleration Mechanisms

Bottom-Up models:
Astrophysical Sources

Top-Down models:
New, very heavy particles
Topological defects
General prediction:
Increasing Photon fraction

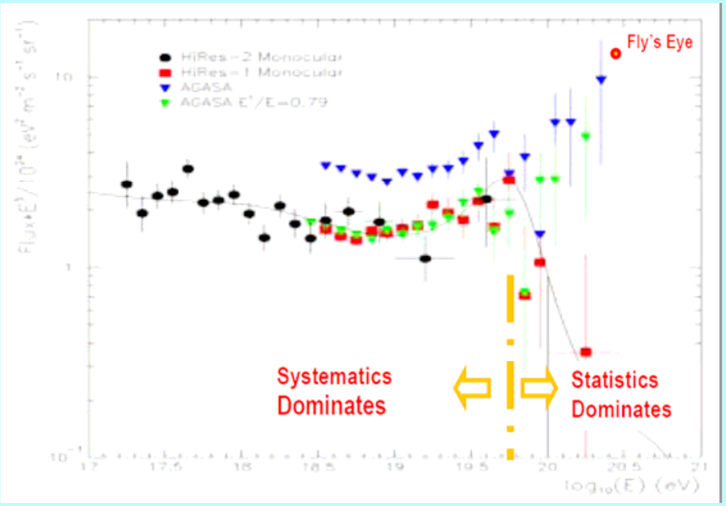


GZK, Energy Scale



Proton > 5 10^{19} eV + Photon CMB
$\rightarrow p + \pi^0$, $n + \pi^+$

Large energy loss $\rightarrow$ *Primary energy not observable when D > 50 - 100 Mpc*



25% Difference in Energy Scale?

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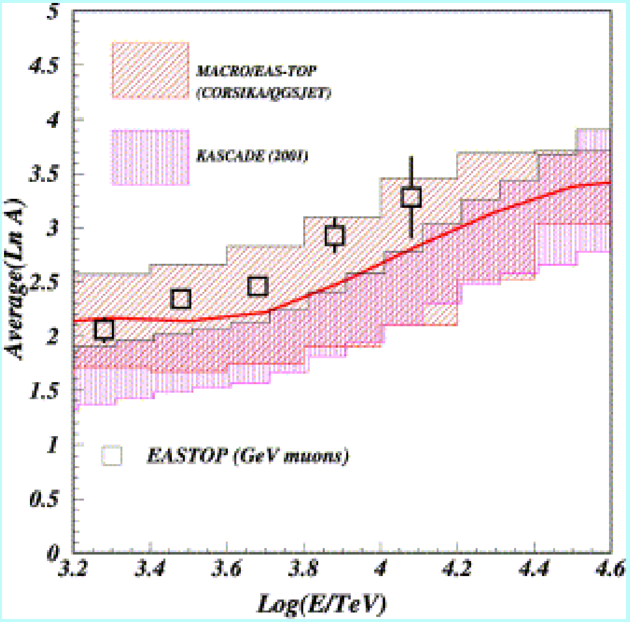
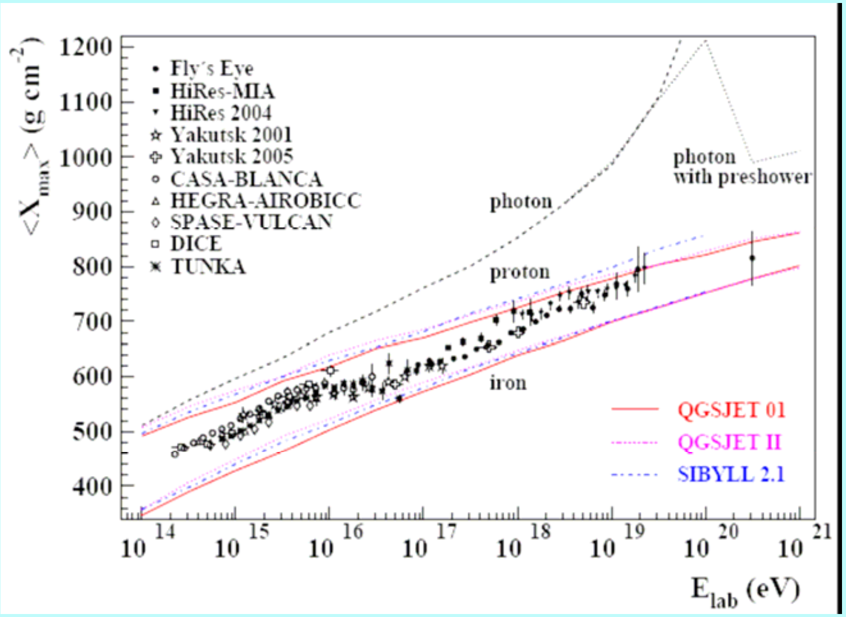
Composition

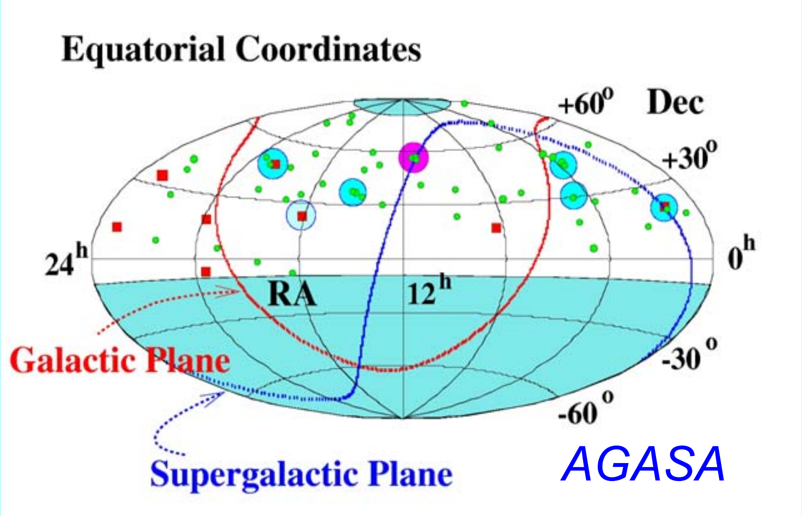
Proton/Iron Discrimination tied to Intra/Extra-Galactic origin



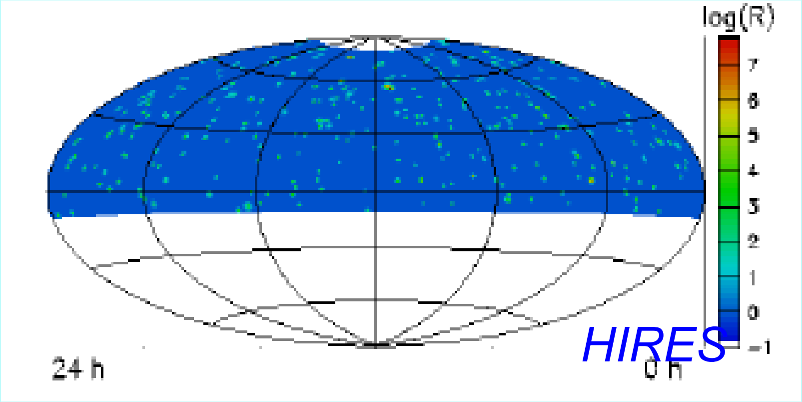


AUGER Results:
Not covered in this talk

Anisotropies, Point Sources, …

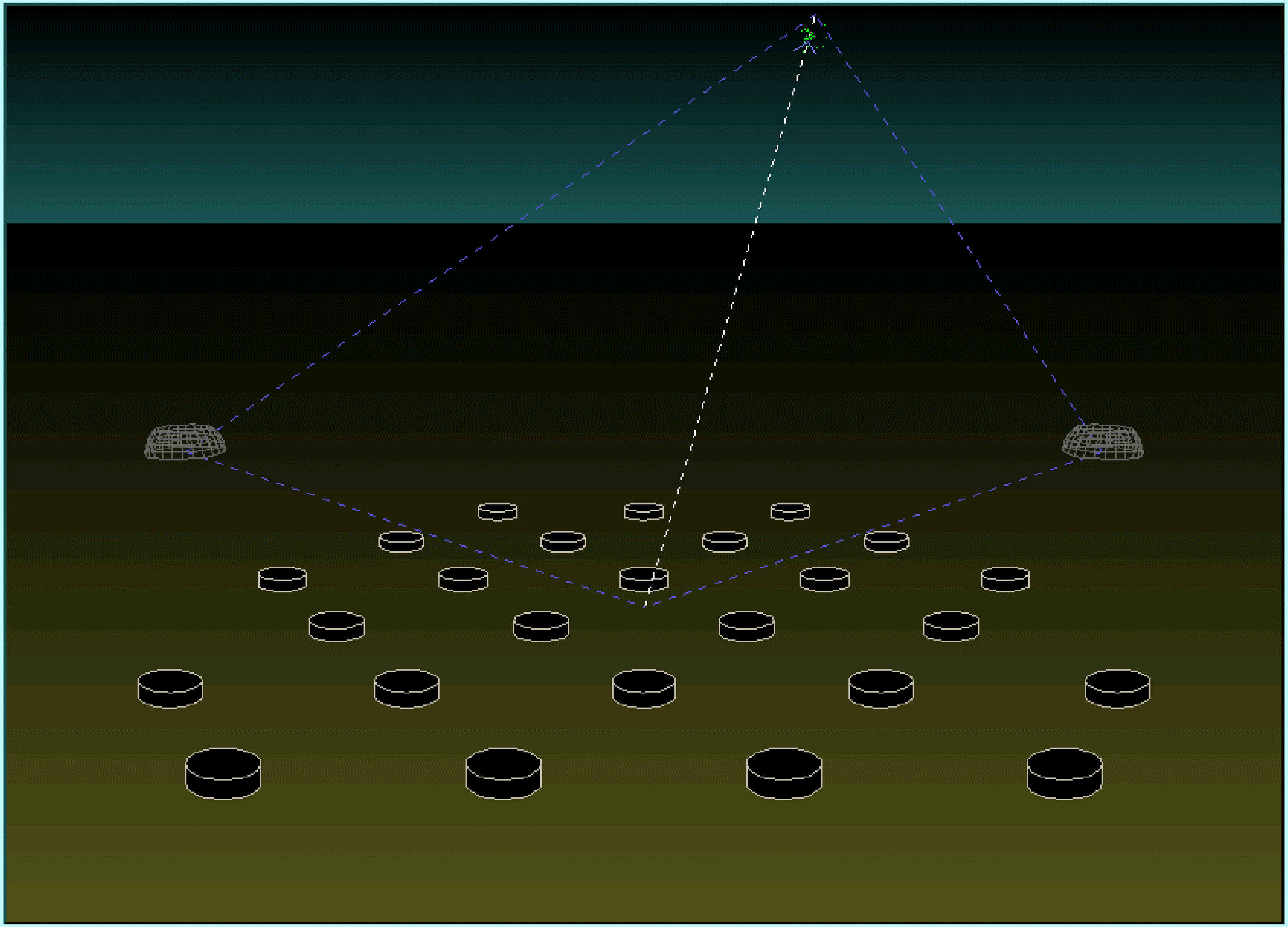


> 6 Clusters observed



No cluster

EAS: Experimental Techniques



***AGASA**: Surface Detector* ***HiRes**: Fluorescence Detector*

The AUGER Project

Large Area: **Statistics**

> 3000 km^2 / site

Hybrid Detection: **Energy Scale, Systematics**

Fluorescence + Surface

Full Sky Coverage: **Global Survey**

Two sites:

South – Malargue, Mendoza, Argentina

North – Lamar County, Colorado, USA

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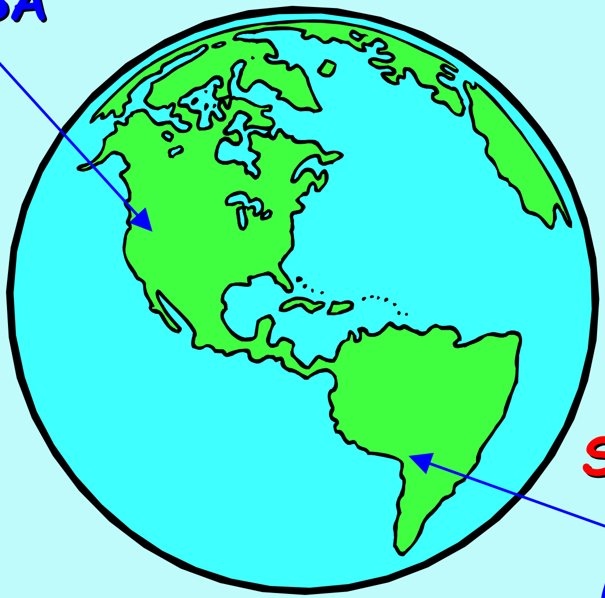
Geography

Northern Hemisphere
Lamar County
Colorado, USA
(planned)



Southern Hemisphere
Malargue
Mendoza, Argentina
(completed in 2007)

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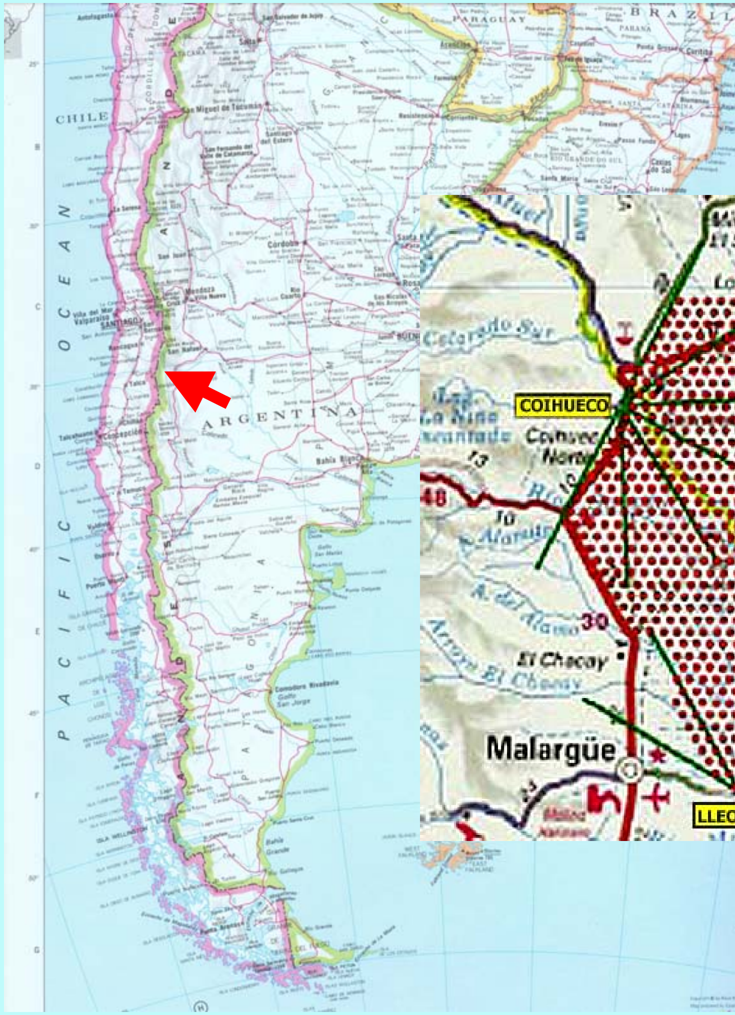
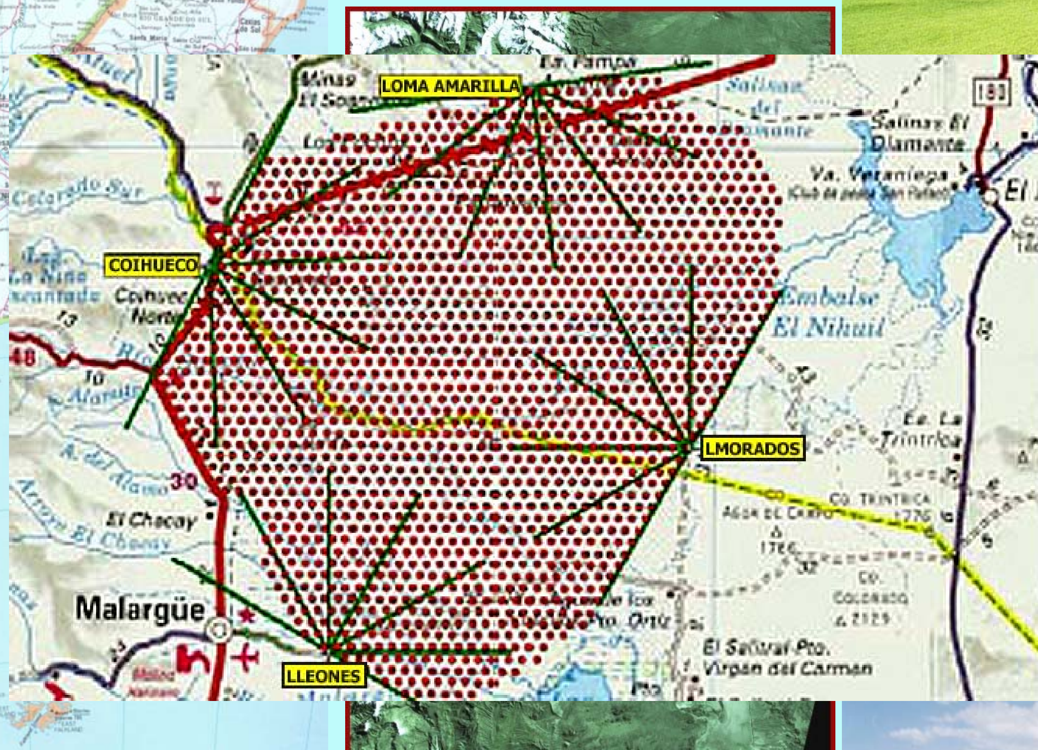
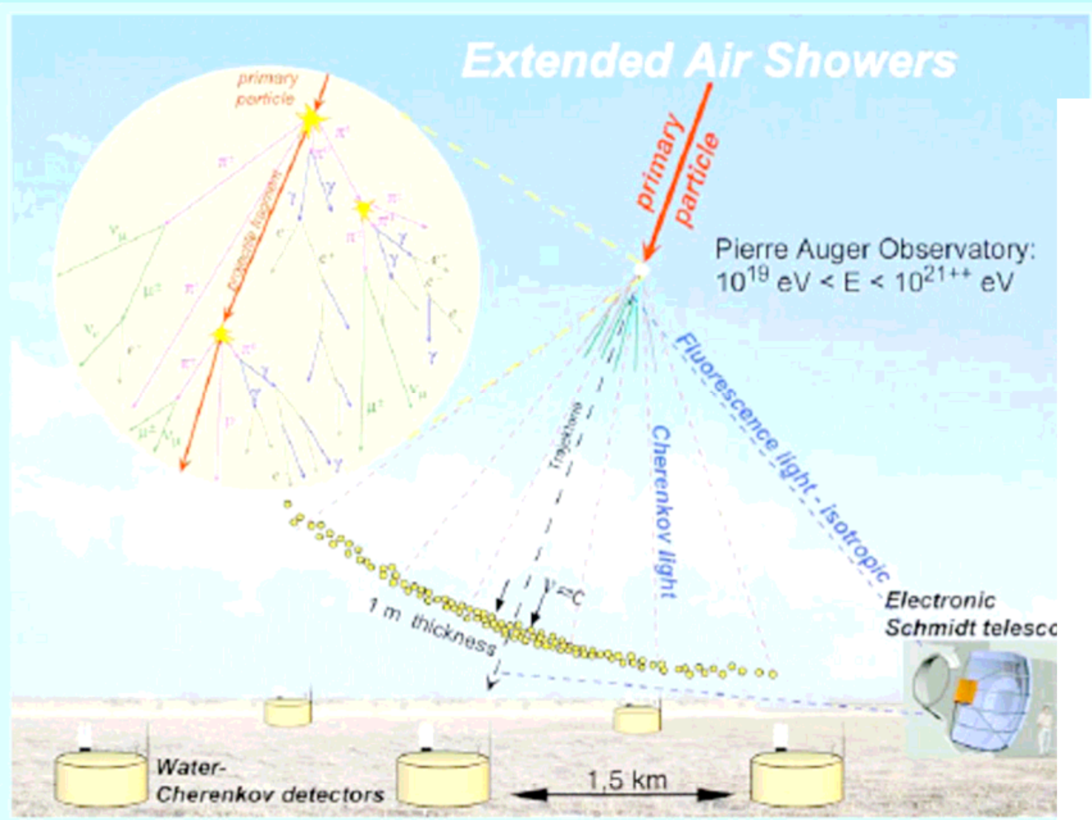
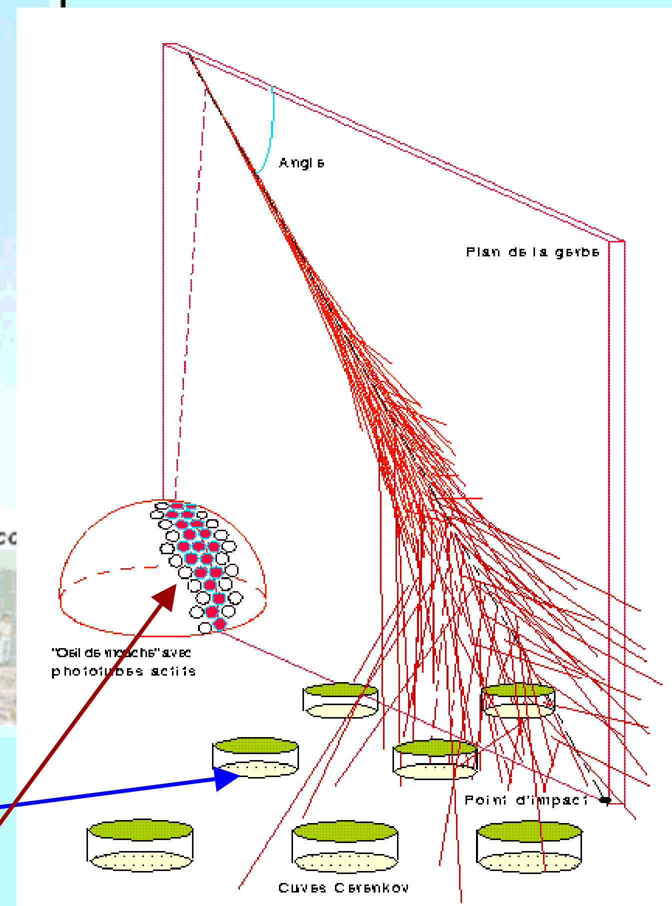
The Southern Site





EAS Development and the Hybrid Concept

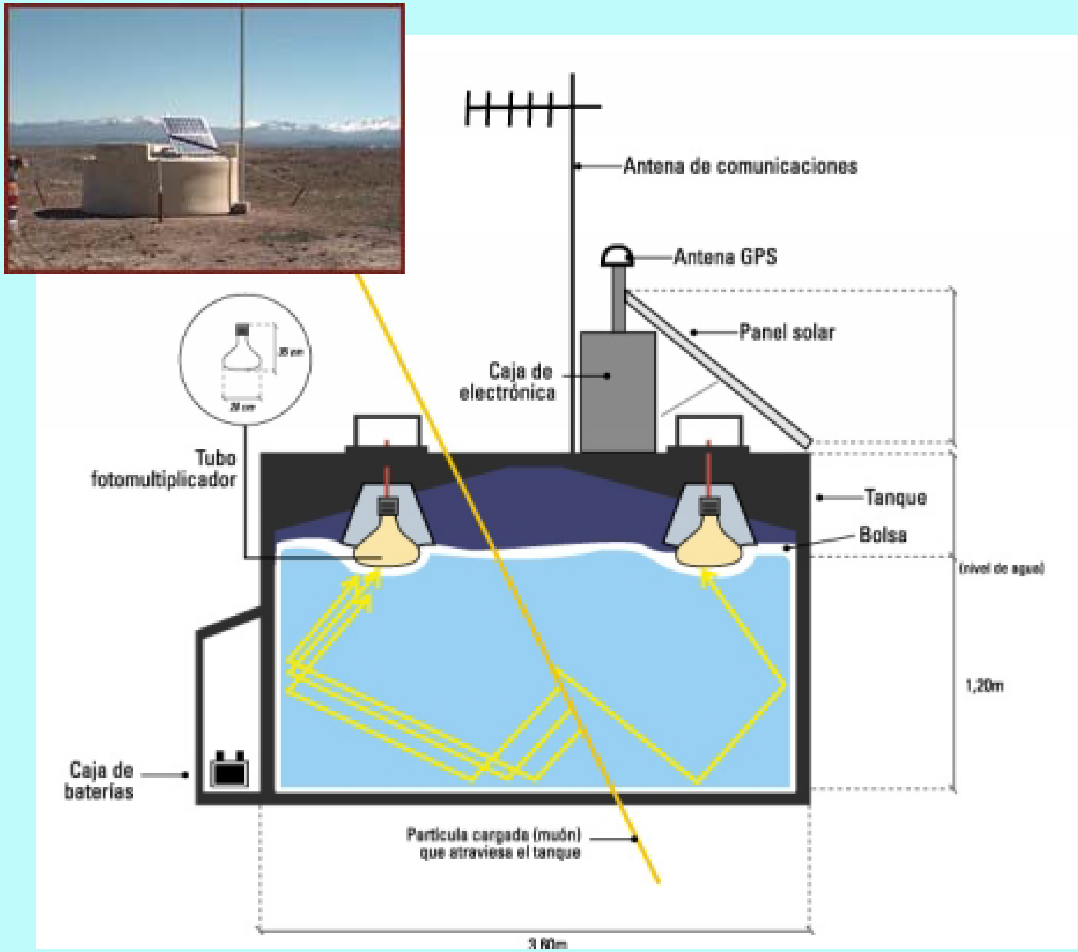




SD: Sampling Lateral Profile at ground

FD: Measuring E_{tot} & Longitudinal Profile

Surface Detector Tank



9" PM

Electronics

Black Widow Cable-Climber

Hi-Tech! Excellent T-Insulation, Solar Power, GPS Time & Place, GSM Data Link, …but not spider free

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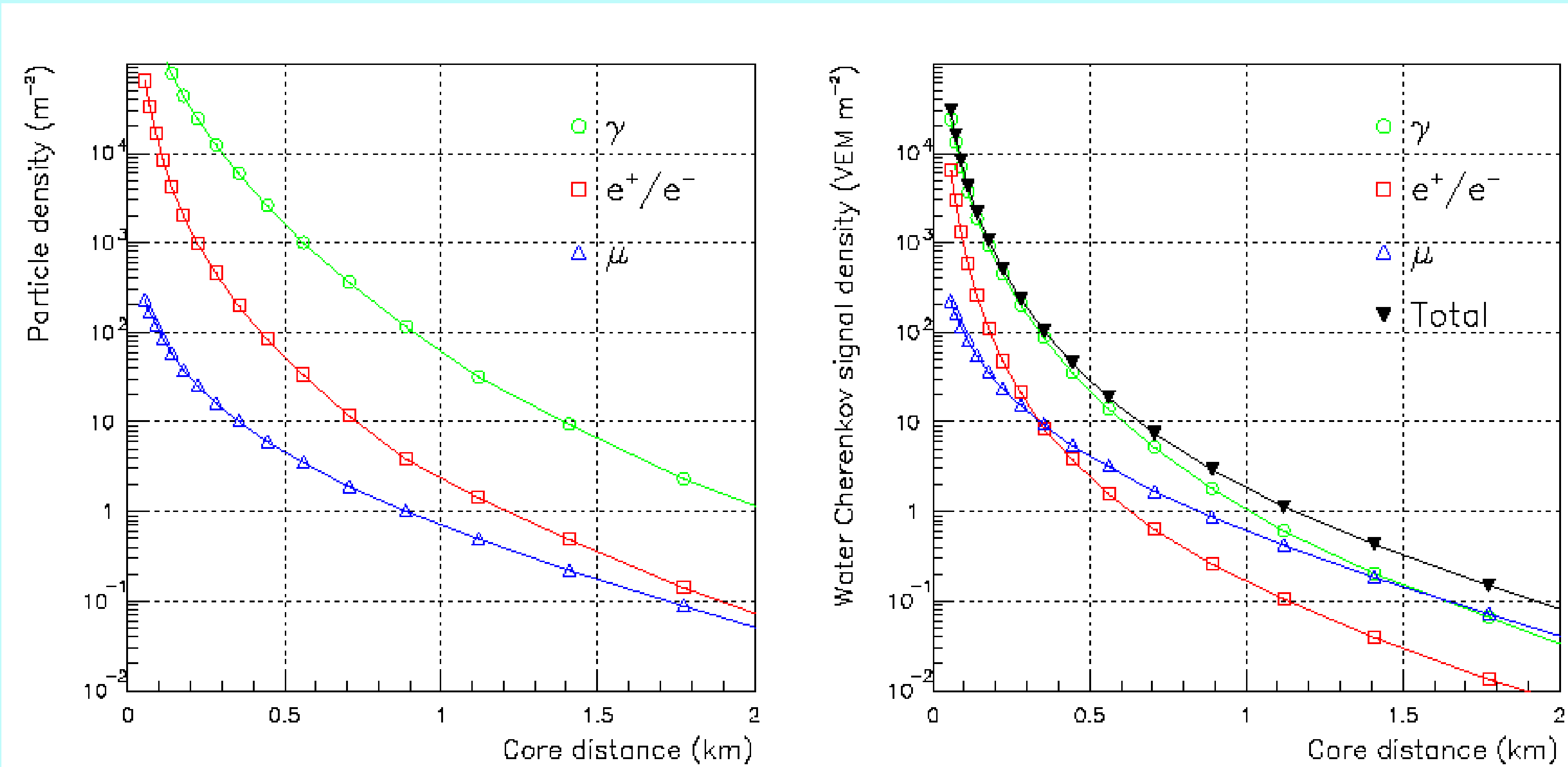
Surface Detector: Signal Components

Simulation



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SD Signal & Calibration

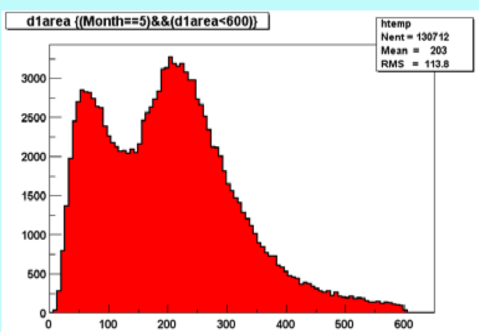
$\mu^{\pm}$ $e^{\pm}$ γ

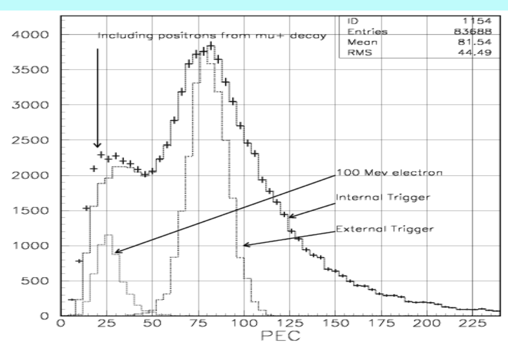
1GeV 10MeV 10MeV

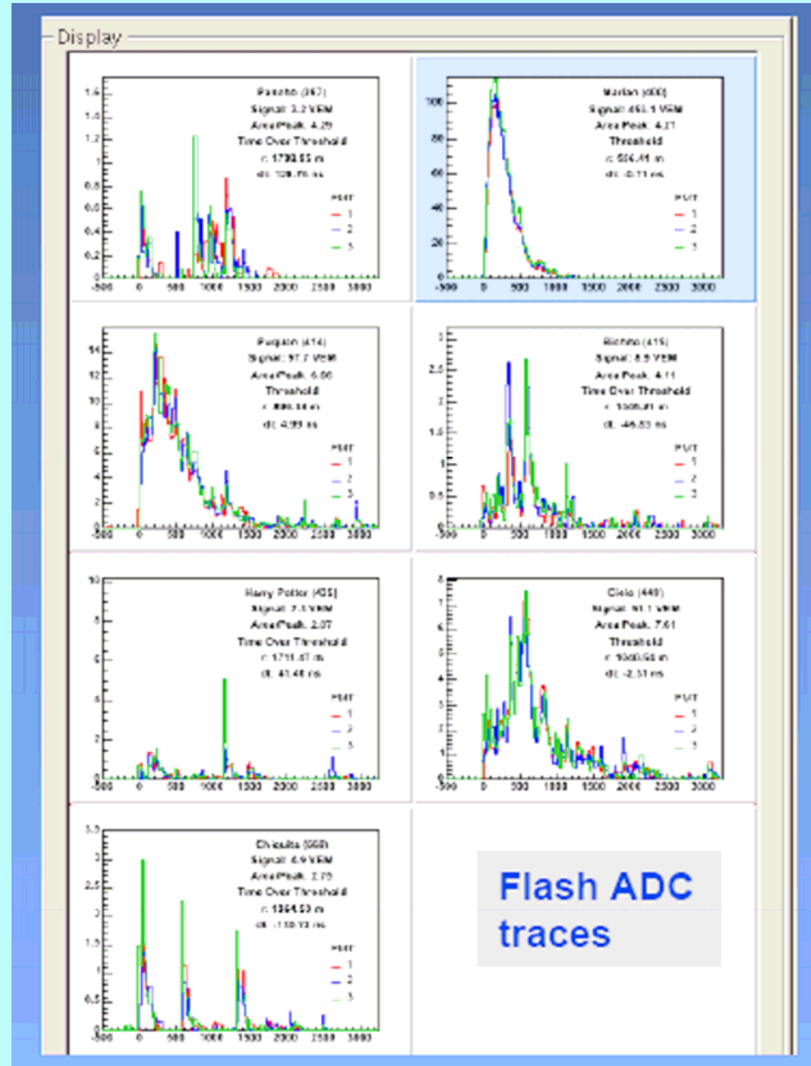
1.2m Water

240MeV 10MeV 10MeV

~track *~ energy*







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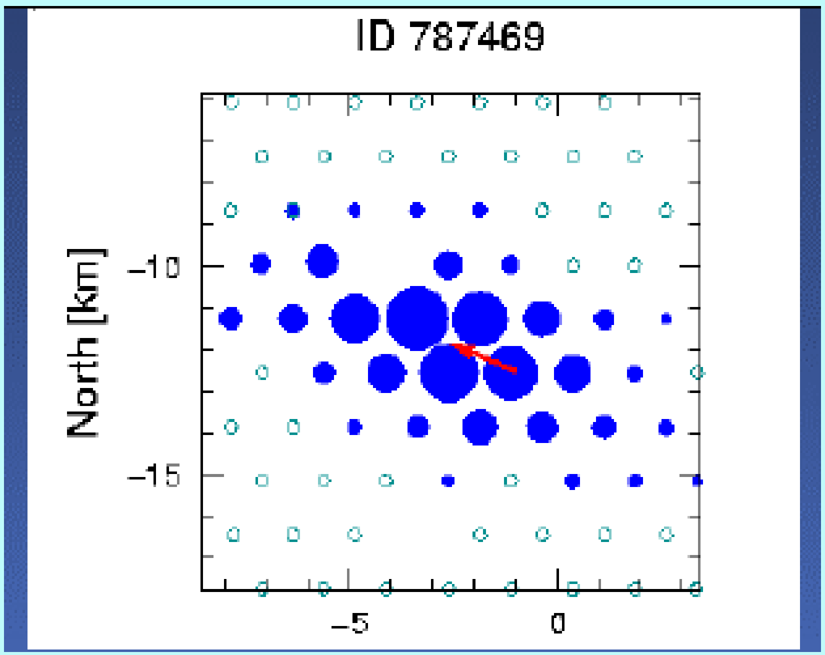
SD - Extracting the Shower Parameters

Concept: Energy from Lateral Distribution Function

1) EAS direction from tank timing and positions



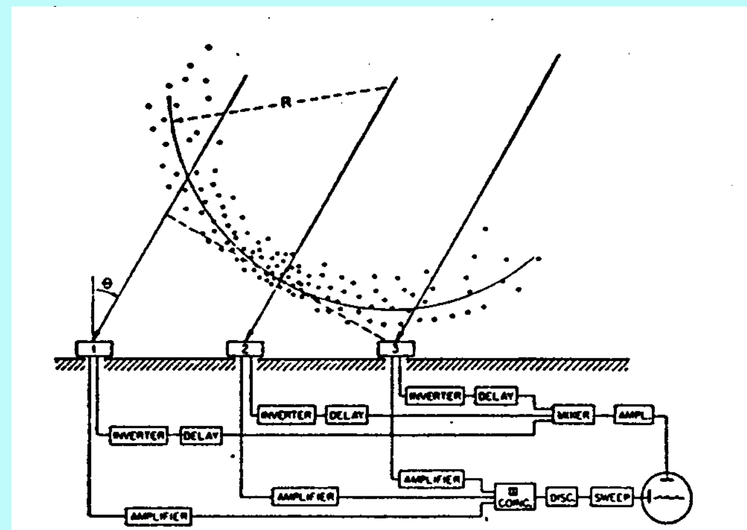
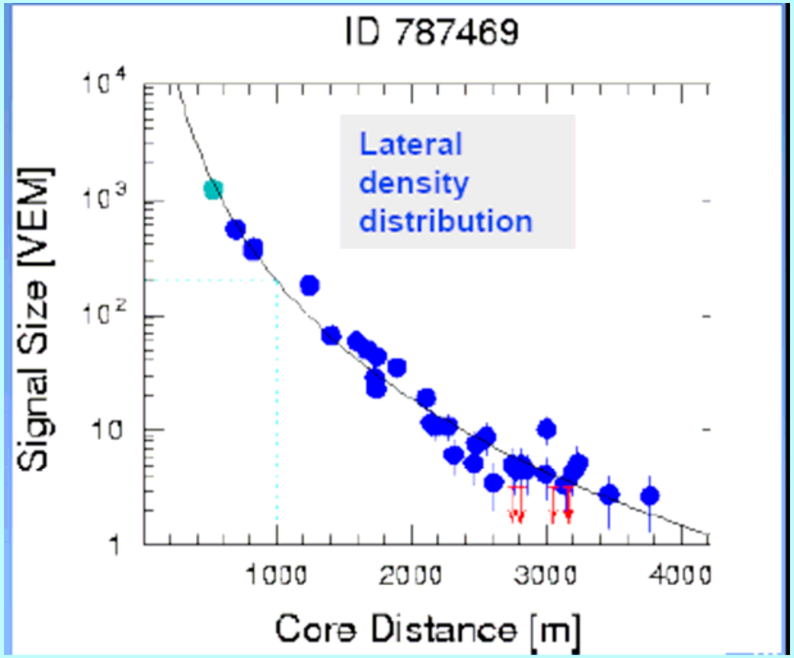


FIG. 2. Block diagram of the apparatus with a schematic representation of an air shower about to strike the counters. The counters are in arrangement II.

(B.Rossi et al, 1953)

PIERRE AUGER OBSERVATORY

SD - Extracting the Shower Parameters



2) Reconstruct LDF
Fit to empirical formula

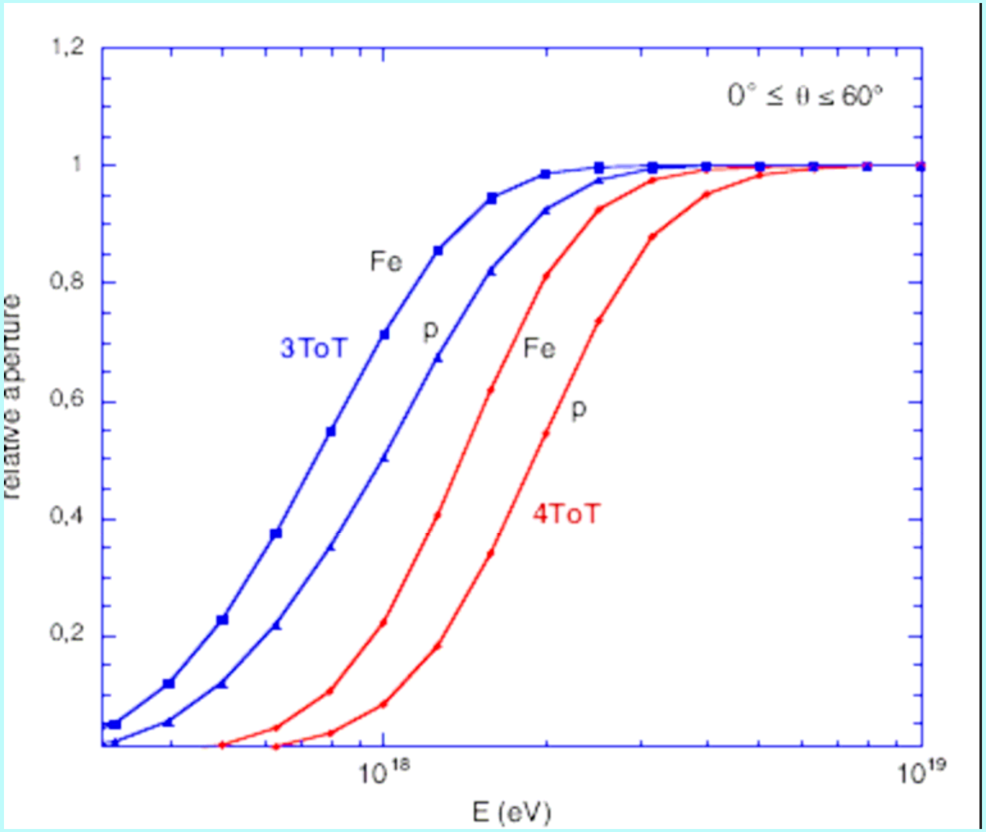
3) Get *S(1000)*
Detector signal at ground, 1 km off the core

4) Correct for slant depth→ $S_{38}(1000)$
Constant Intensity Cut→Take 38^0 Zenith as a Reference

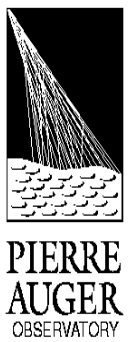
Previous experiments, MCarlo: $E = k\, S_{38}(1000)$

AUGER Unique Capability: <u>Get k constant from FD</u>

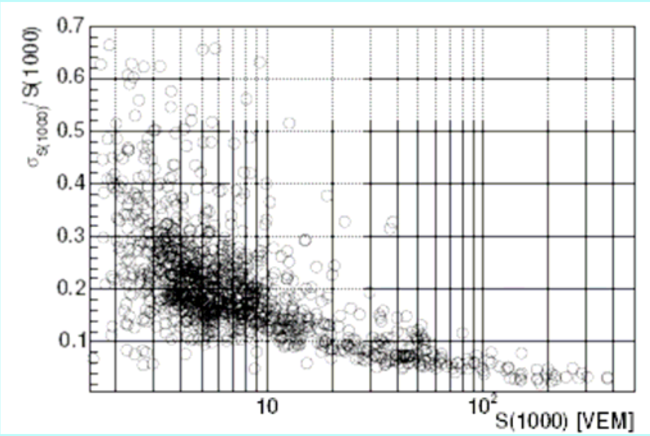
SD Aperture



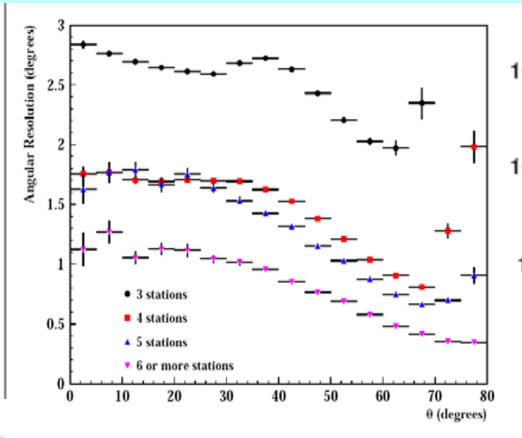
Relative aperture (trigger included) vs. Energy
Full efficiency above 3 EeV



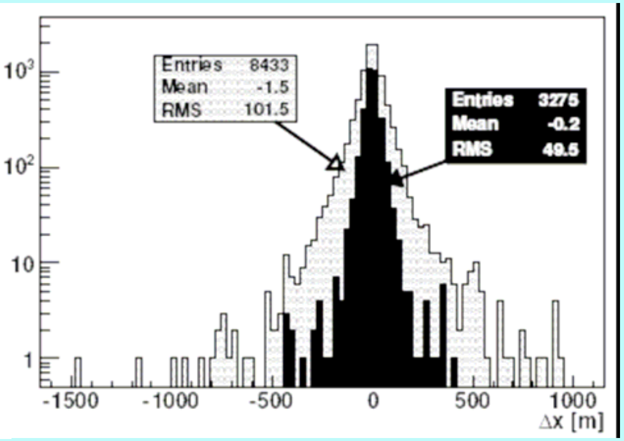
SD – Resolution



S(1000)



Zenith



Core Position

S(1000)>30VEM

Several sources of systematic uncertainty

1. *VEM calibration*
2. *Timing*
3. *S(1000) slant depth effects (CIC)*

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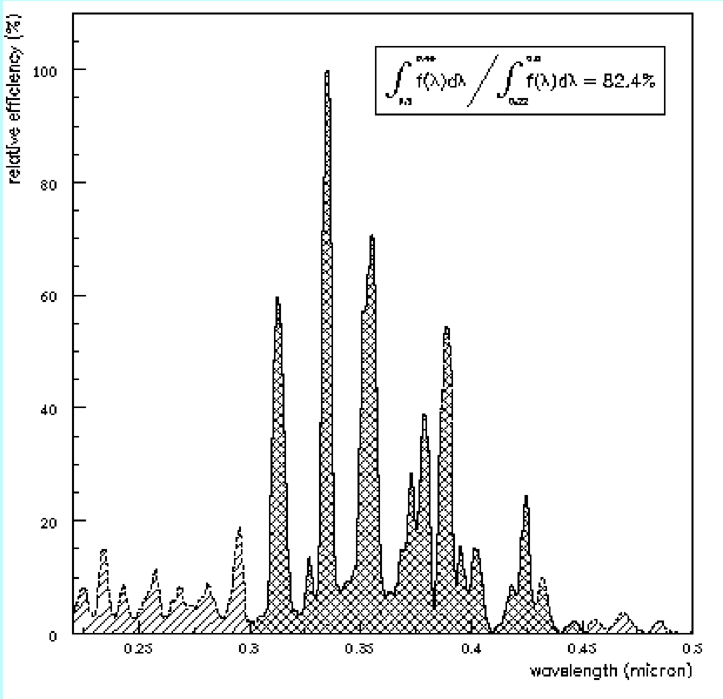
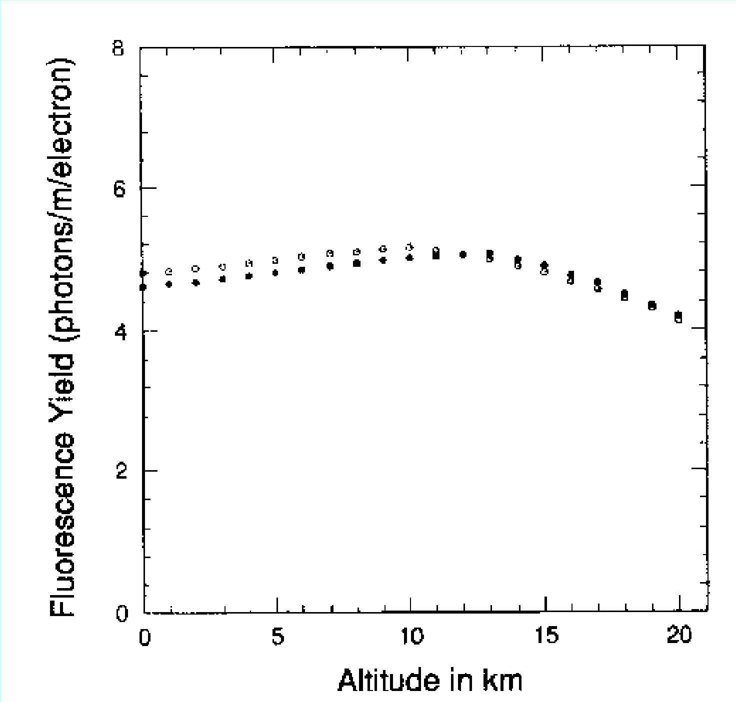
FD – Fluorescence Yield

Atmosphere working as a large scale calorimeter

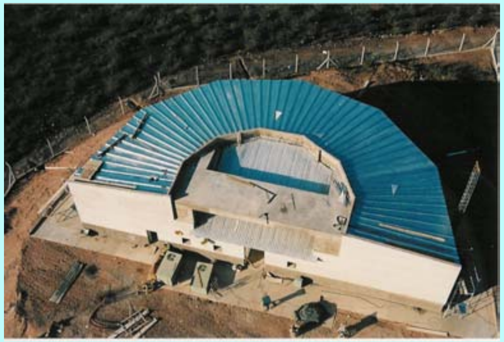




FD – Telescope

Four FD Eyes

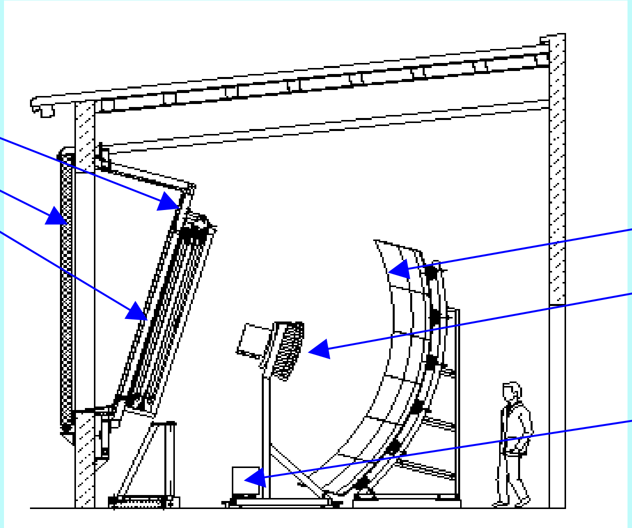
6x4=24 Telescopes



Shutter

Corrector Ring

Optical UV Filter



Mirror

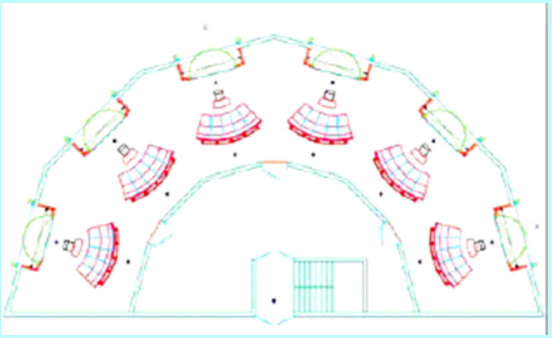
Pixel Camera

Light Collectors,440 PM

Electronics

Analog Chain, FADC

12 bit, 10 MSPS



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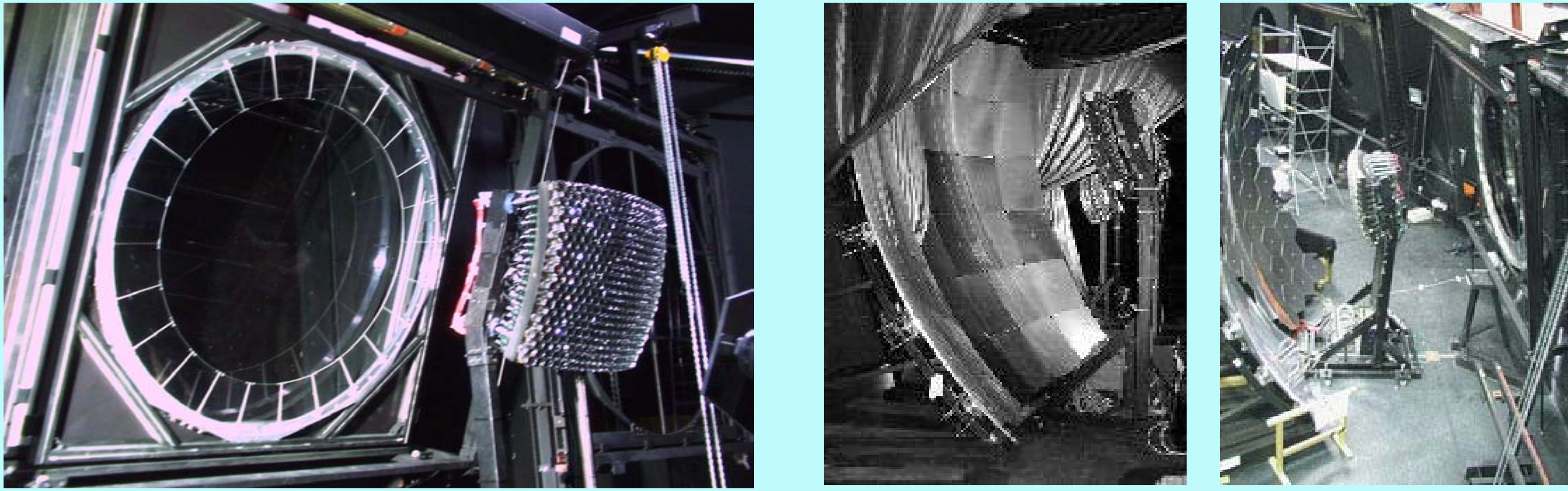
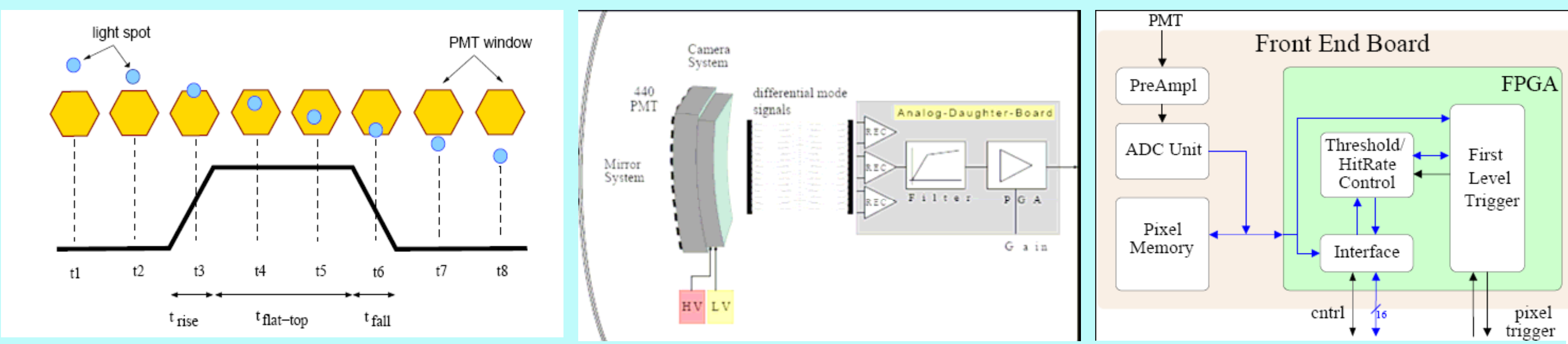
FD – From Shower to Data



Aperture, Corrector Ring,UV Filter, Pixel Camera, Mirror



Signal Formation, Front-End Electronics

E.Menichetti – SIF 2006

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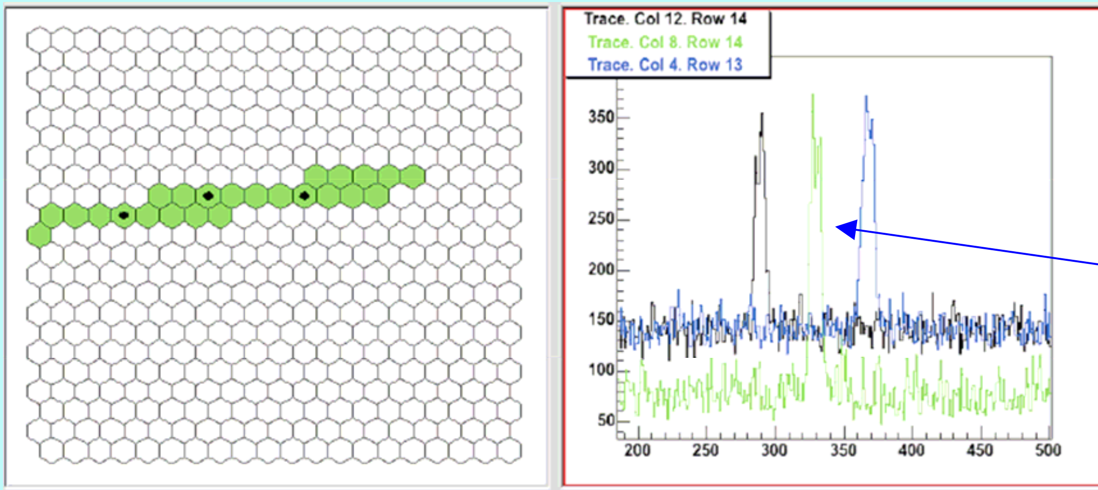
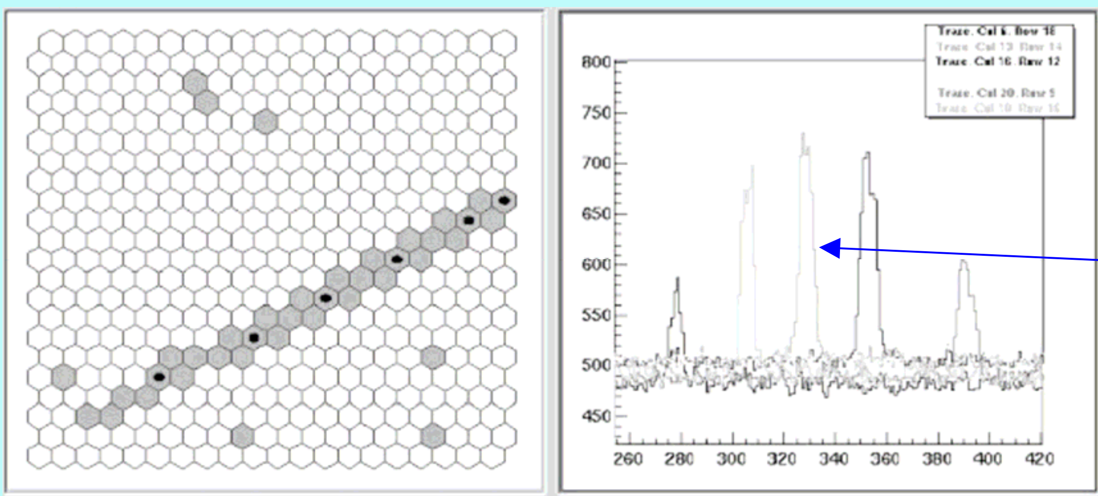
FD – From Shower to Data



Pixel signals – CLF
~Uniform amplitude



Pixel Signal – EAS
Longitudinal profile

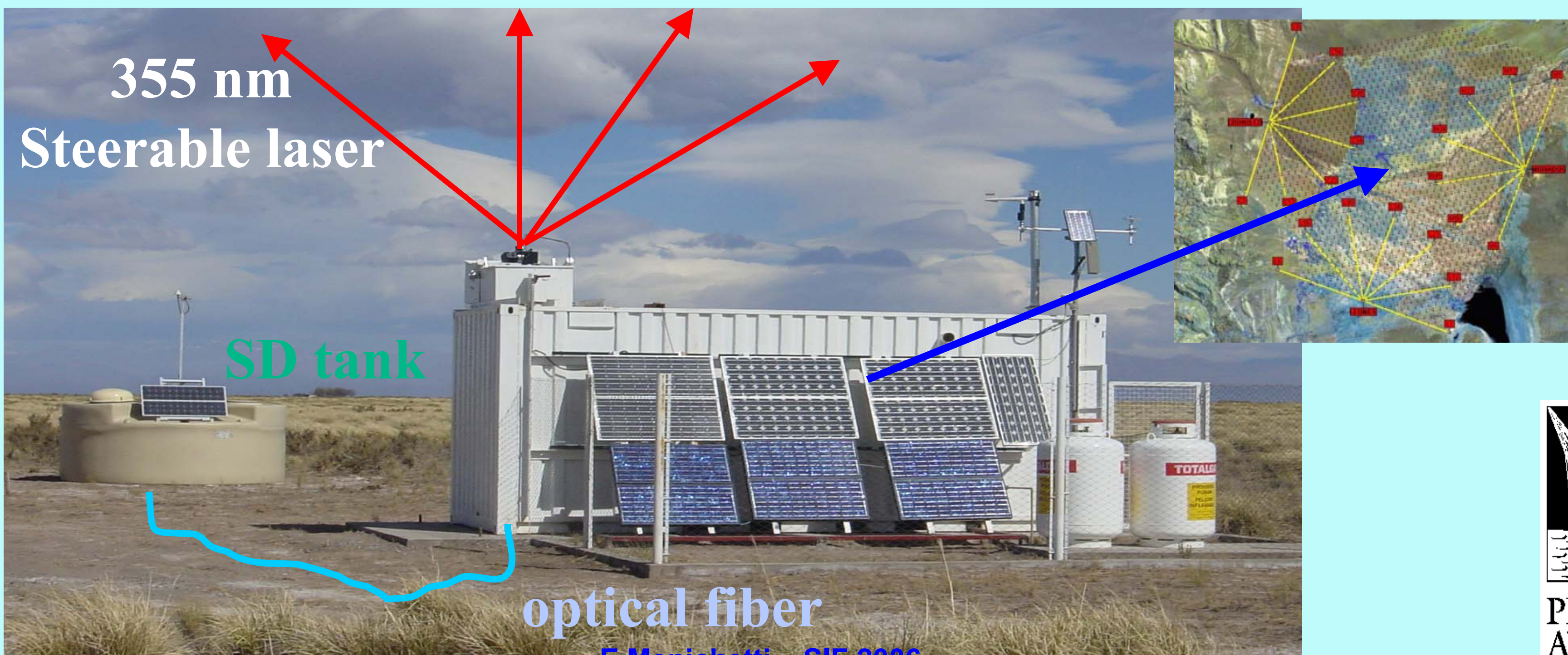
FD – Calibration

Drum

Diffuse, uniform camera illumination

Central Laser Facility

AUGER "Calibration Beam"



FD – Corrections

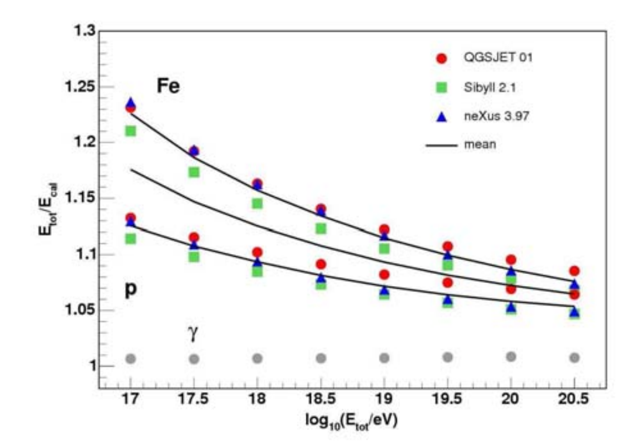
Atmospheric Monitoring: Density, Transparency, Aerosols

Several Gadgets:

Horizontal Attenuation Monitor
Balloon Radiosondes
CLF
LIDAR
Phase Function Monitor

Cerenkov subtraction

Based on track geometry, iterative



Unseen Energy

Neutrinos, …
MCarlo: ~ 10 % @ 10 EeV

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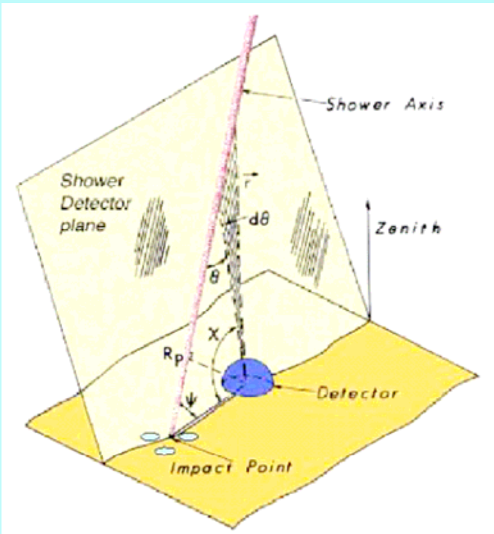
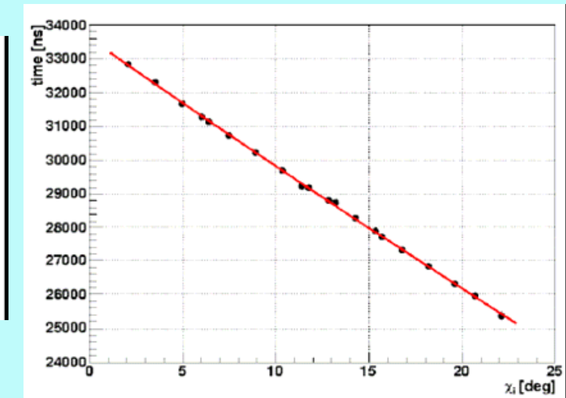
FD – Geometry, Energy, Longitudinal Profile

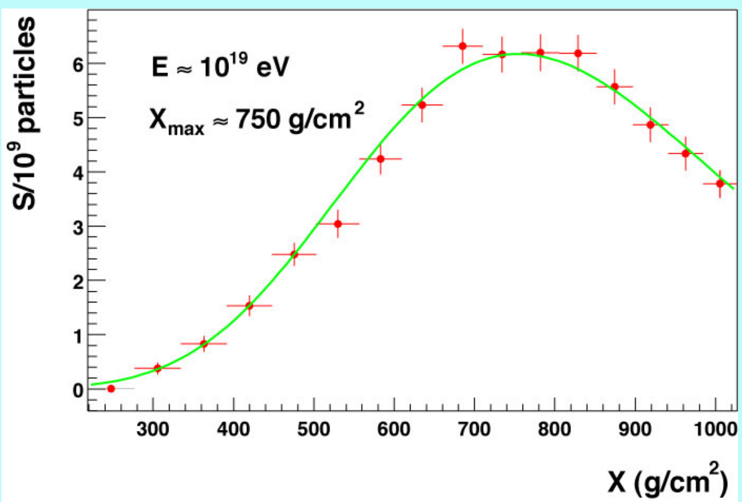


SDP: Time fit…..and its problems for 1-eye evts

$$t(\chi) = T_0 + \frac{R_p}{c} \tan\left[\frac{(\chi_0 - \chi)}{2}\right]$$

$$\chi_0 = 180° - \psi$$





Abs. Calib. ~ ***5 γ/ADC count***

FY ~ ***4.2 γ/m*** ***Electron Track***

But: New results expected soon

AIRFLY (LNF, Argonne, ..)

FLASH (SLAC)

σ_{Xmax} ~ ***30 g cm^{-2}***

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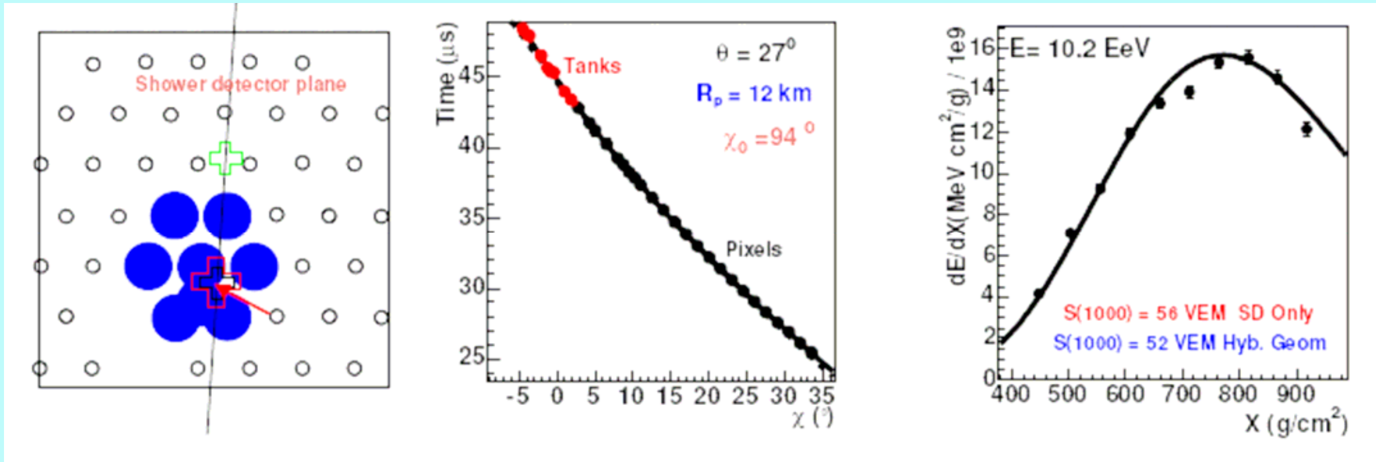
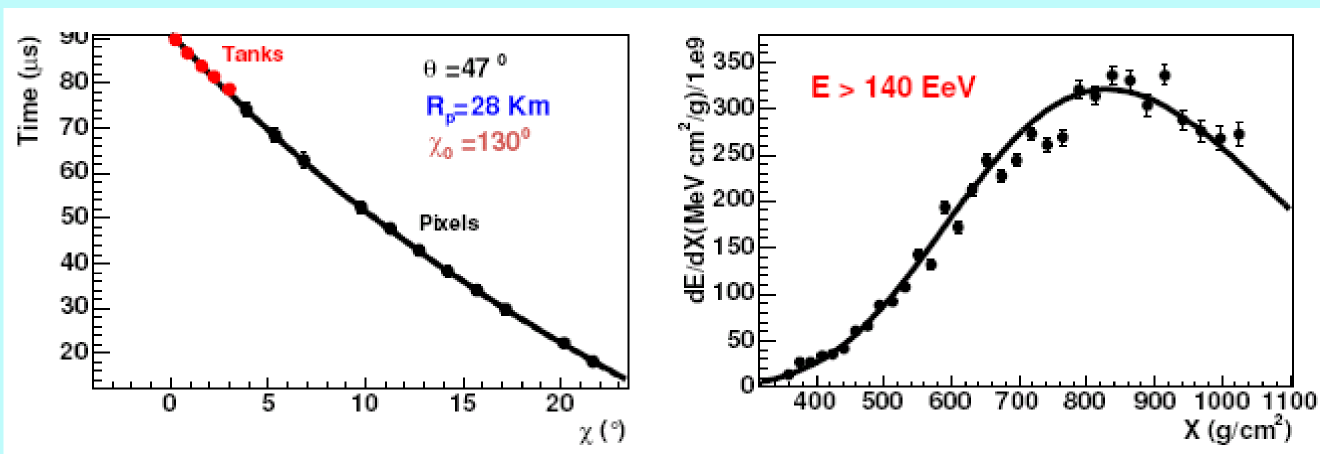
Hybrid Reconstruction

Typical

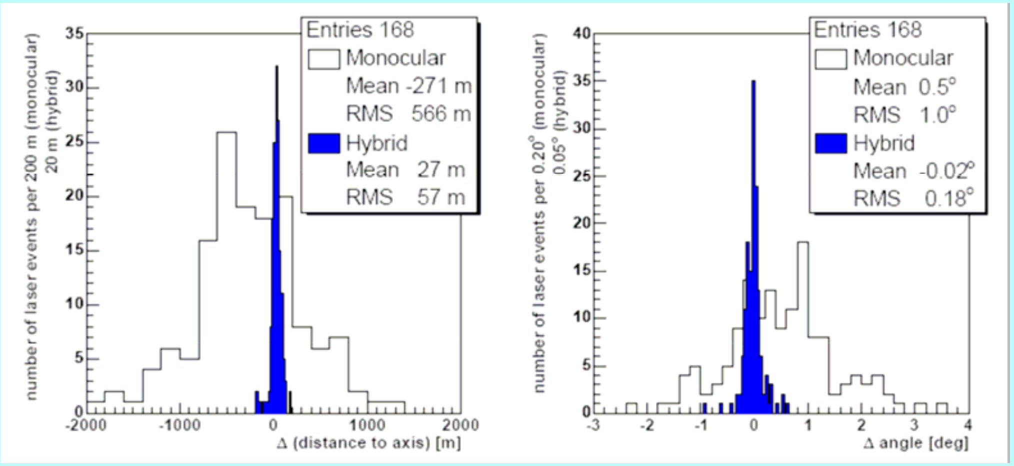


SD SD + FD *FD*

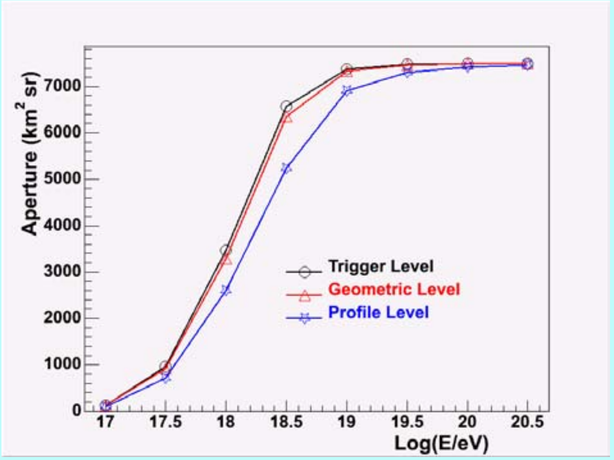
Top Hybrid…
Not included
in the sample



Hybrid Performance



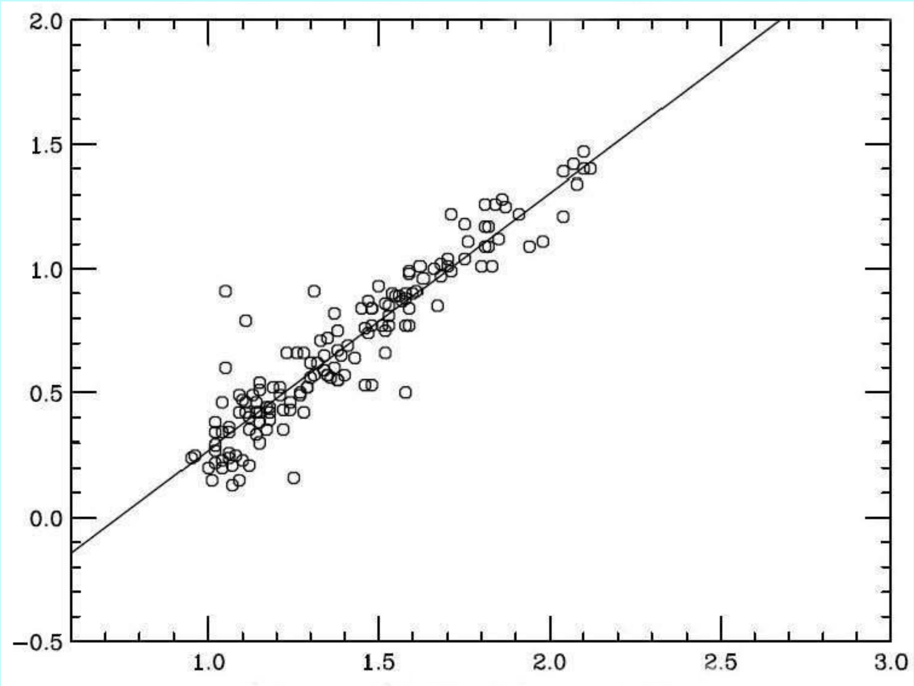
From Laser Shots



Effective Aperture

Energy Calibration with Hybrids

$\log_{10} E_{FD}$ (EeV)



$\log_{10} S_{38}(1000)$

E Systematics Budget (expected)

FD

Fluorescence Yield 15% (↓ 8%)
Abs/Rel Calibration 12%
Atmosphere 11 % (↓ 6%)
Other 12 %

Total ***25 %*** *(↓ 17%)*

SD

Detector calibration 10%
$S_{38}(1000)$ 8 %
Other 7 %

Total ***16 %***

Energy Scale

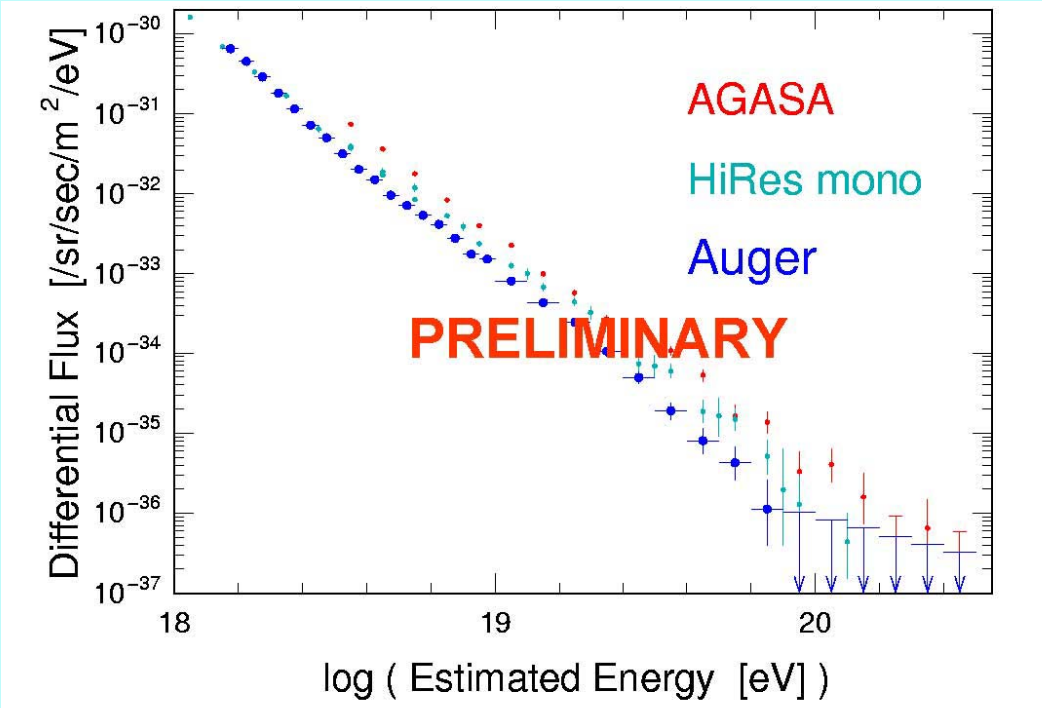
(Includes Hybrid Statistics)

E dependent ***30÷50 %***
Expected to ↓ to 25 ÷ 35 %

PIERRE AUGER OBSERVATORY

Spectrum

This Statistics: ~ ½ year of full Observatory (~7000 km^2 sr yr)



AGASA: pre-Vulcano

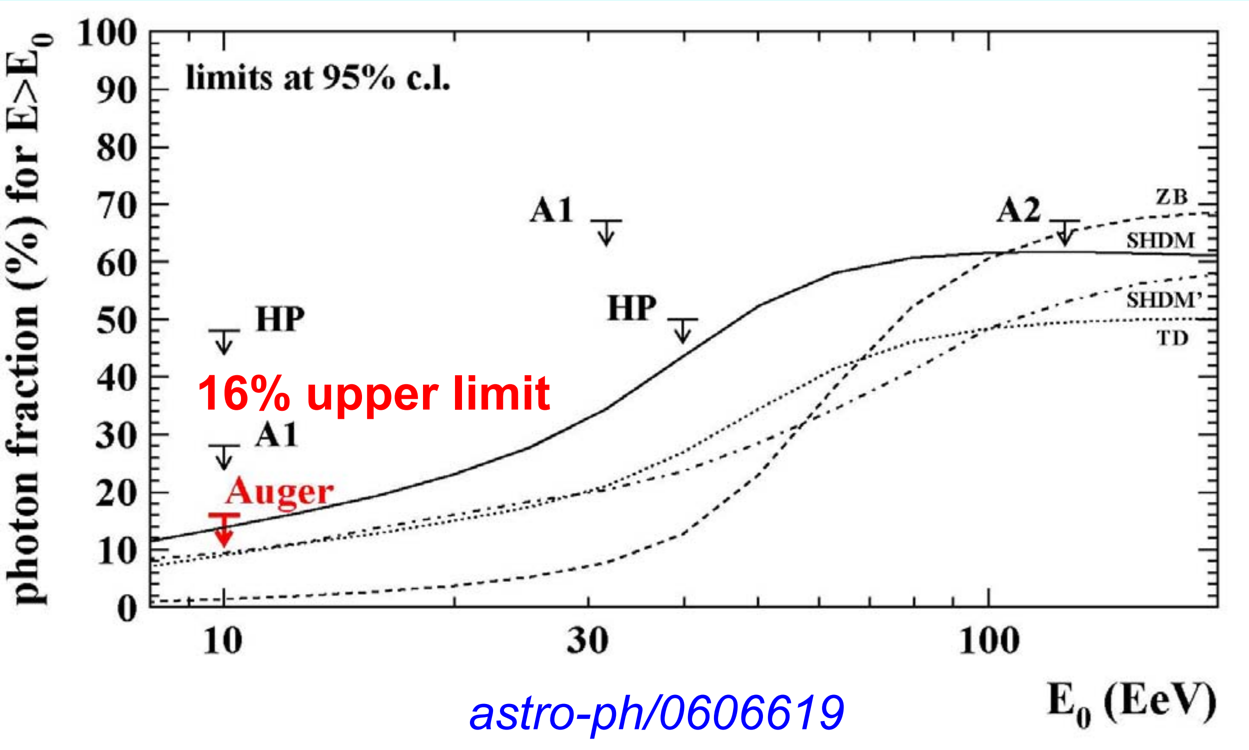
Still investigating systematics (e.g.Energy Scale still uncertain)

Preliminary:
Data difficult to reconcile with AGASA (pre/post-Vulcano)

But:
Wait for statistics, reduced systematics

Energy: Systematics ~ ±30-50 %; Statistical Error ~15 - 10%
Efficiency =100% above 3 EeV
A few high energy events

Limit on Photon Fraction



Ruling out a few Top-Down models…

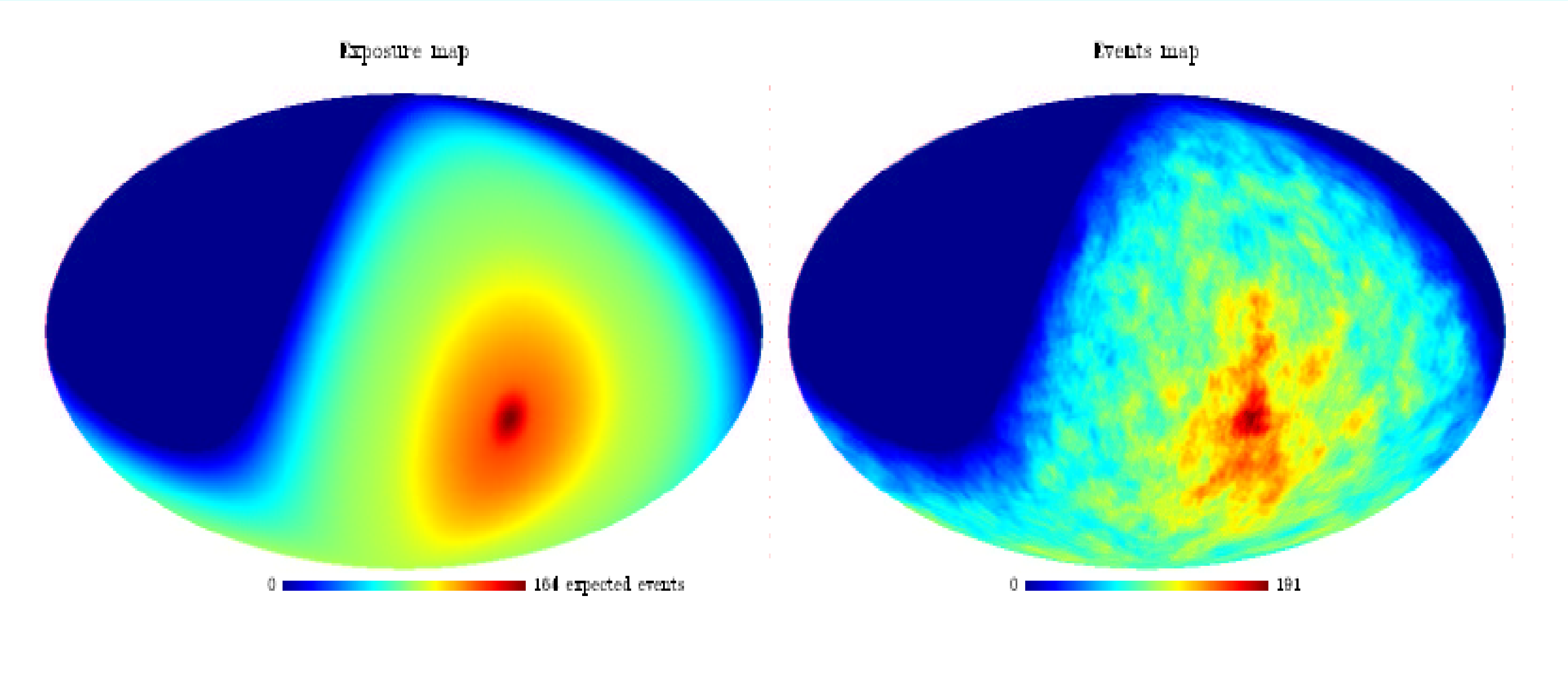
Method:

X_{max} from FD

$\sigma_{X_{max}} \approx 25$ g cm^{-2} (does not include shower-to shower fluctuations)

29 events

Anisotropies: Exposure, Rates

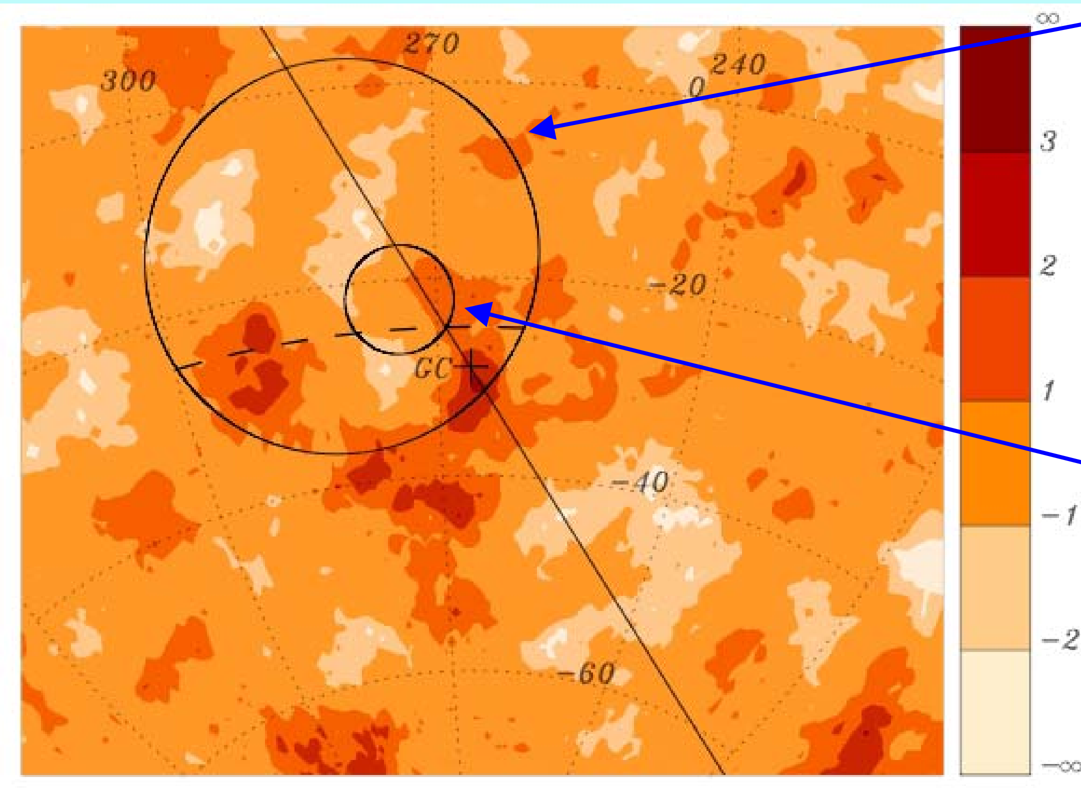


Galactic Coordinates; E=1÷5 EeV

PIERRE AUGER OBSERVATORY

Anisotropies: Compare to AGASA, SUGAR excess

astro-ph/0607382



AGASA

Angular range: 20°
Energy interval (1.0 – 2.5 EeV)

2116 / 2159.5
ratio = 0.98 ± 0.02 ±0.0
(22% excess projection:
2634 evts, 10-σ effect)

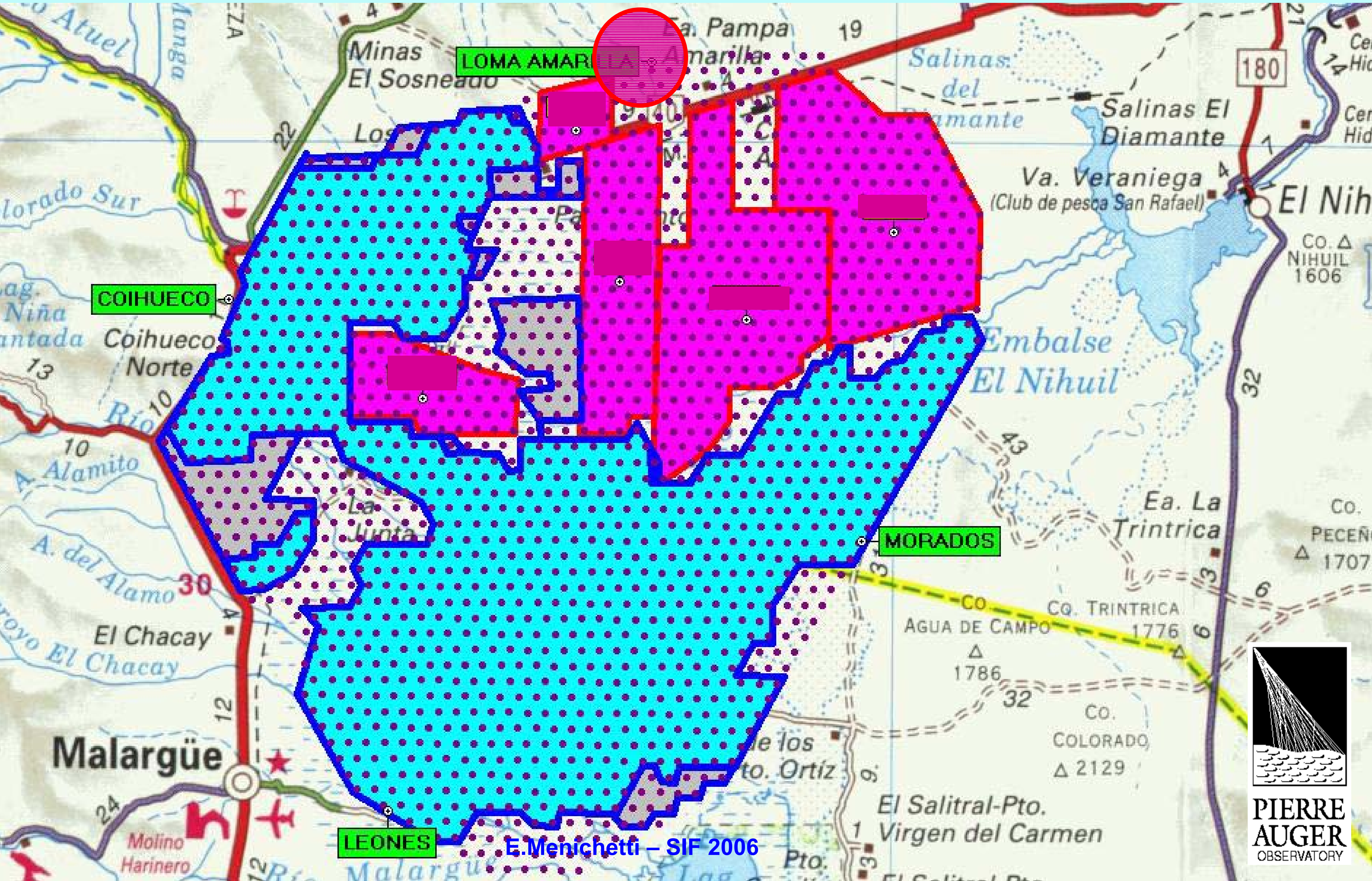
SUGAR

Angular range 5°
Energy interval (0.8 – 3.2 EeV)

286 / 289.7
ratio = 0.98 ± 0.06 ± 0.
(85% excess projection:
536 evts, 14.5-σ effect)

PIERRE AUGER OBSERVATORY

September 2006: - 442 tanks, -1 FD Eye !



E.Menichetti – SIF 2006