Argentina
Australia
Bolivia*
Brasil
Czech Republic
France
Germany
Italy
Poland
Mexico
Slovenia
Spain
The Netherlands
United Kingdom
USA
Vietnam*
*associated

Science case

The Pierre Auger observatory

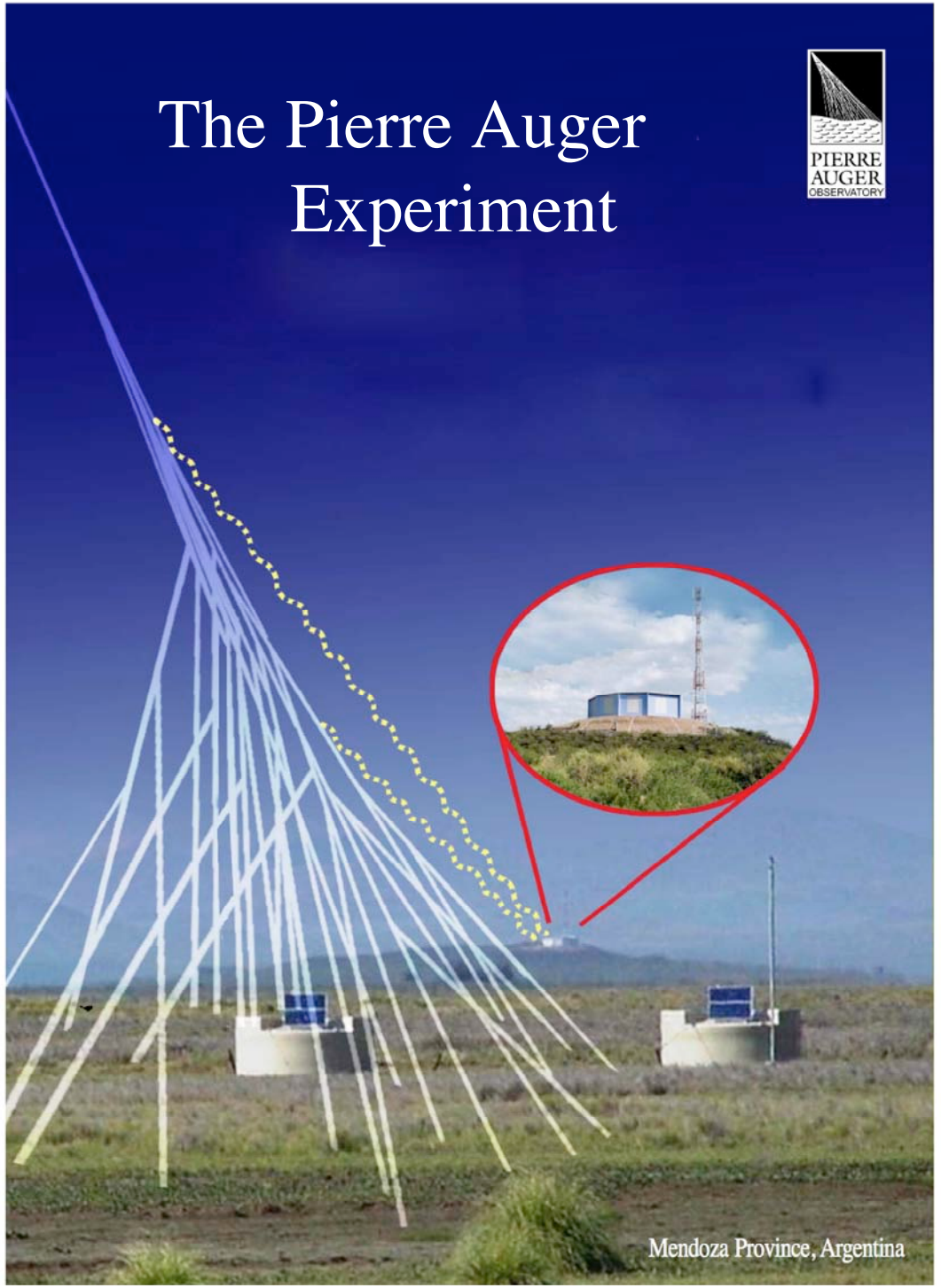
First results

17 nations & ~300 Scientists

Hartmut Gemmeke,
Forschungszentrum Karlsruhe,
Germany

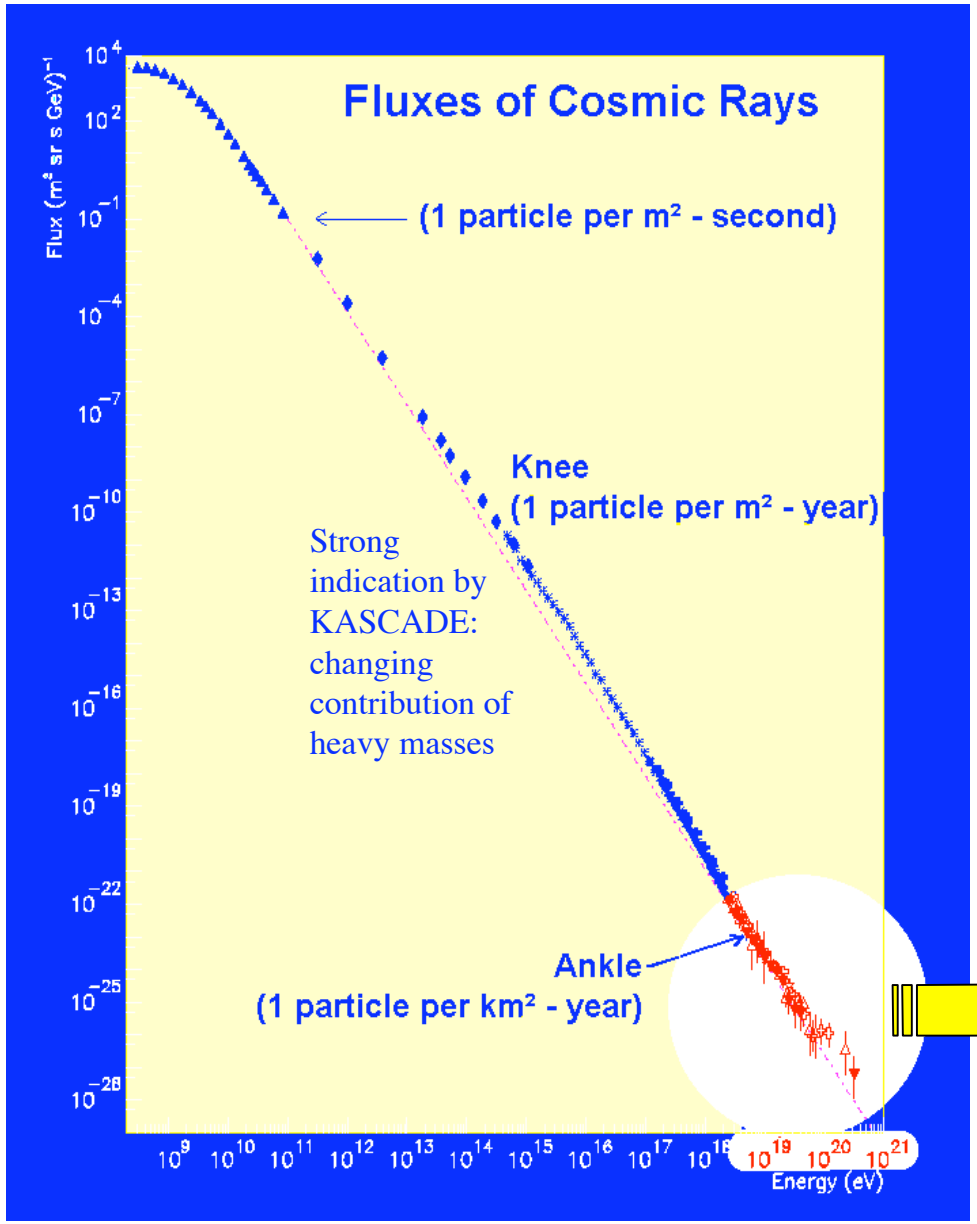
13th Lomonosov Conf. 2007

16.08.07



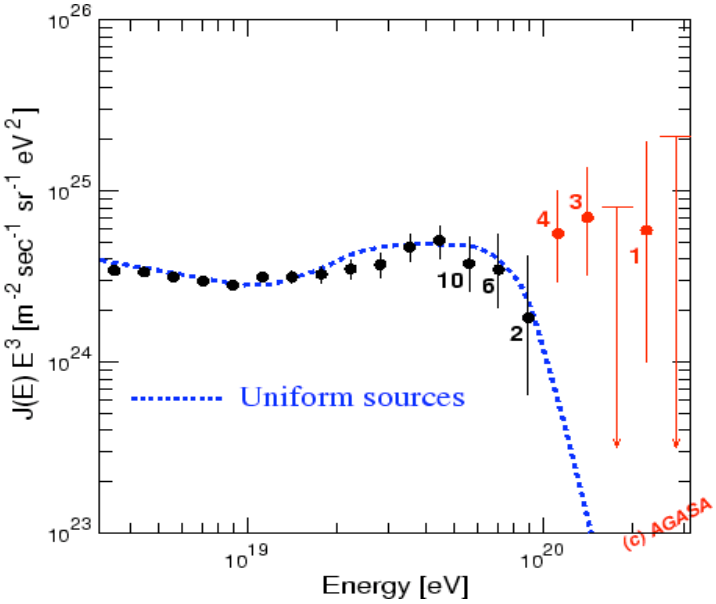
Science Objectives :

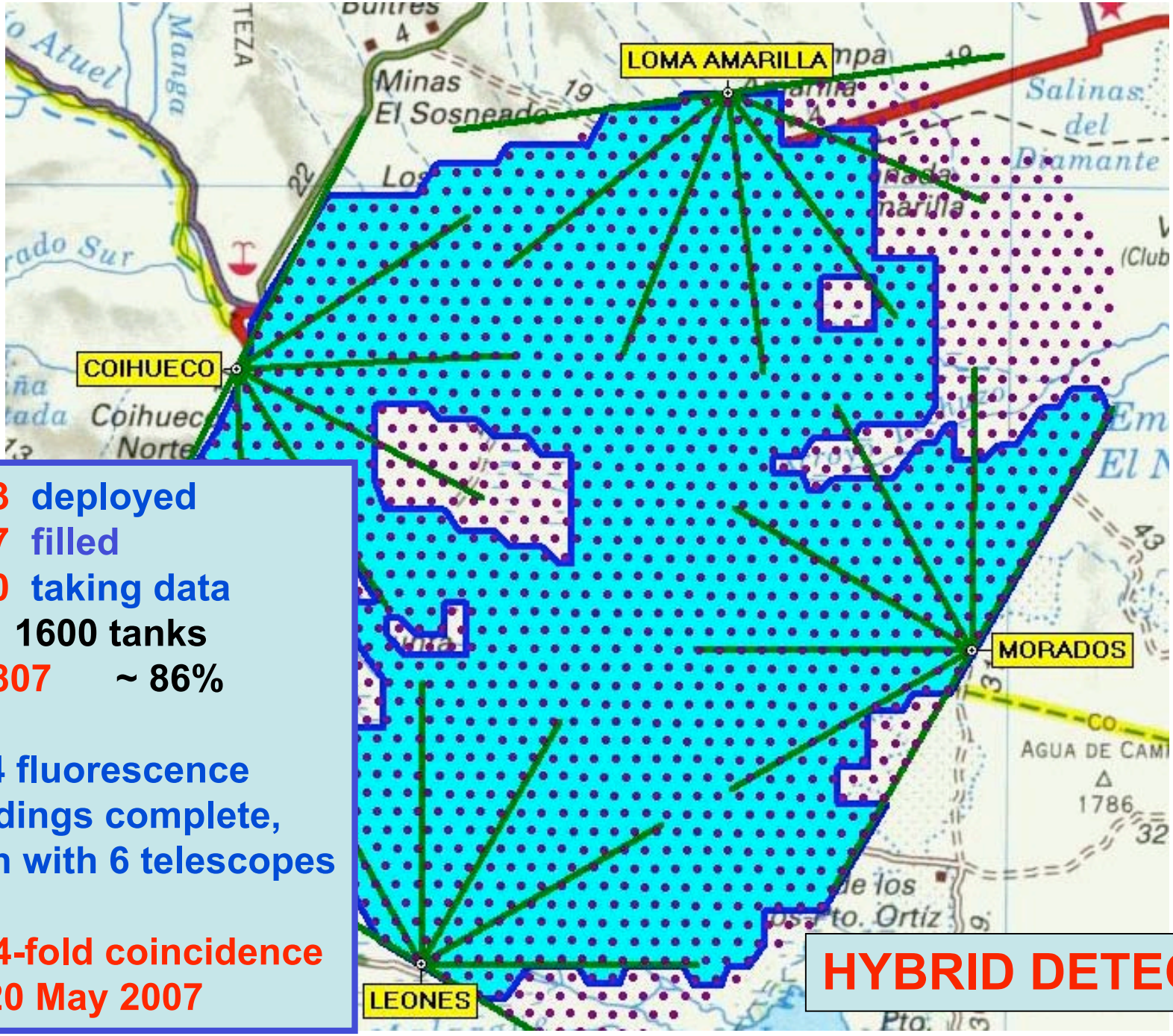
- Cosmic Ray Spectrum above 10^{19}eV ?
  - Is there a GZK* cutoff?
- Primary nature (composition) ?
  - Light or heavy nuclei ?
  - Photons ? Neutrinos? Or...?
- Arrival direction distribution ?
  - point sources ?
  - Are the sources local (< 150 Mly)?
    - ⇒ or extra galactic ?
    - ⇒ bottom-up scenario ?
  - Complete isotropy ?
    - ⇒ Top-Down scenario ?



* Greisen, Zatsepin, Kuz´min

Data from Agasa: 100 km² x 10 years

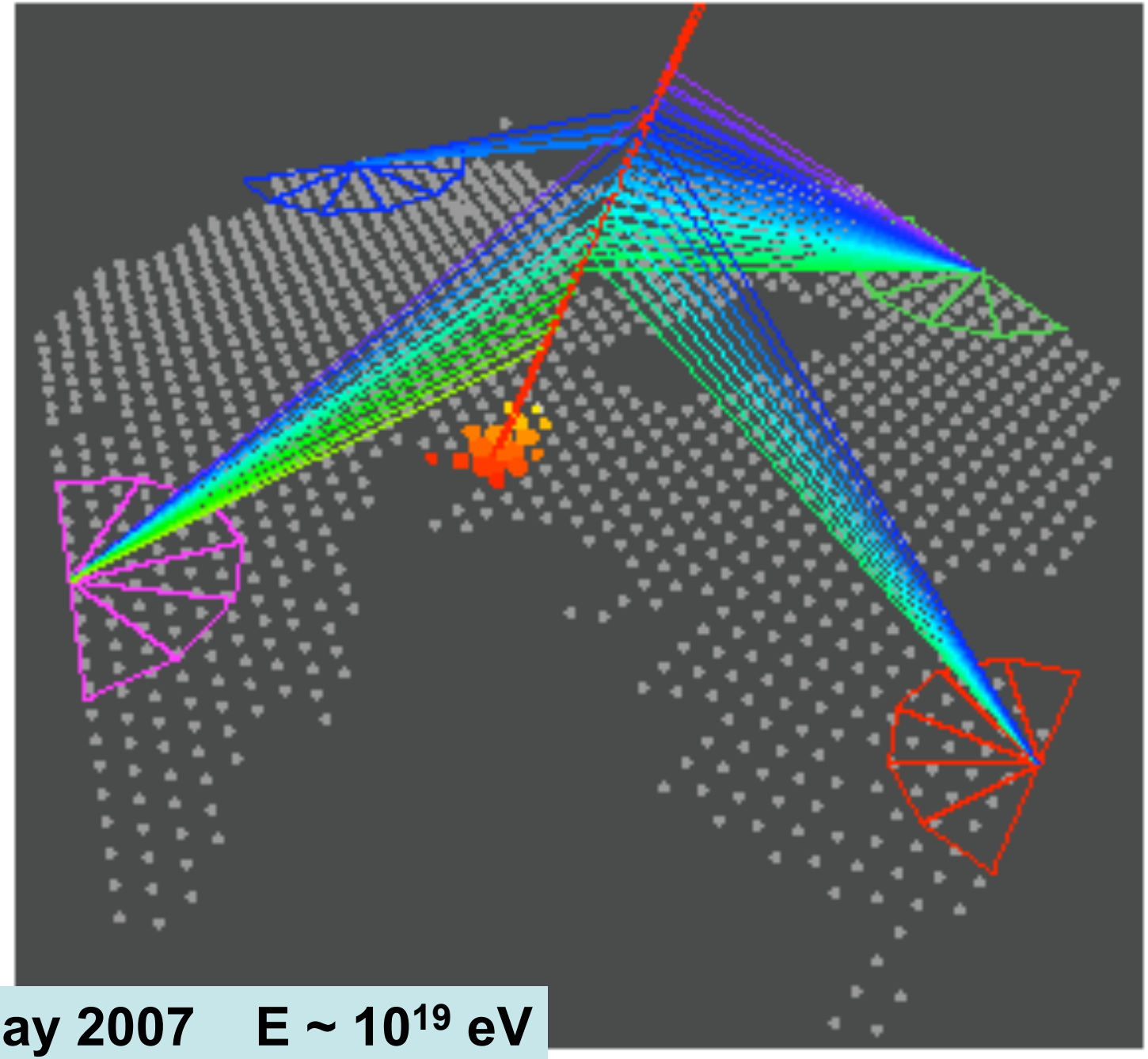




1483 deployed
1427 filled
1370 taking data
aim: 1600 tanks
090807 ~ 86%

All 4 fluorescence buildings complete, each with 6 telescopes

1st 4-fold coincidence on 20 May 2007



20 May 2007 E ~ 10^{19} eV

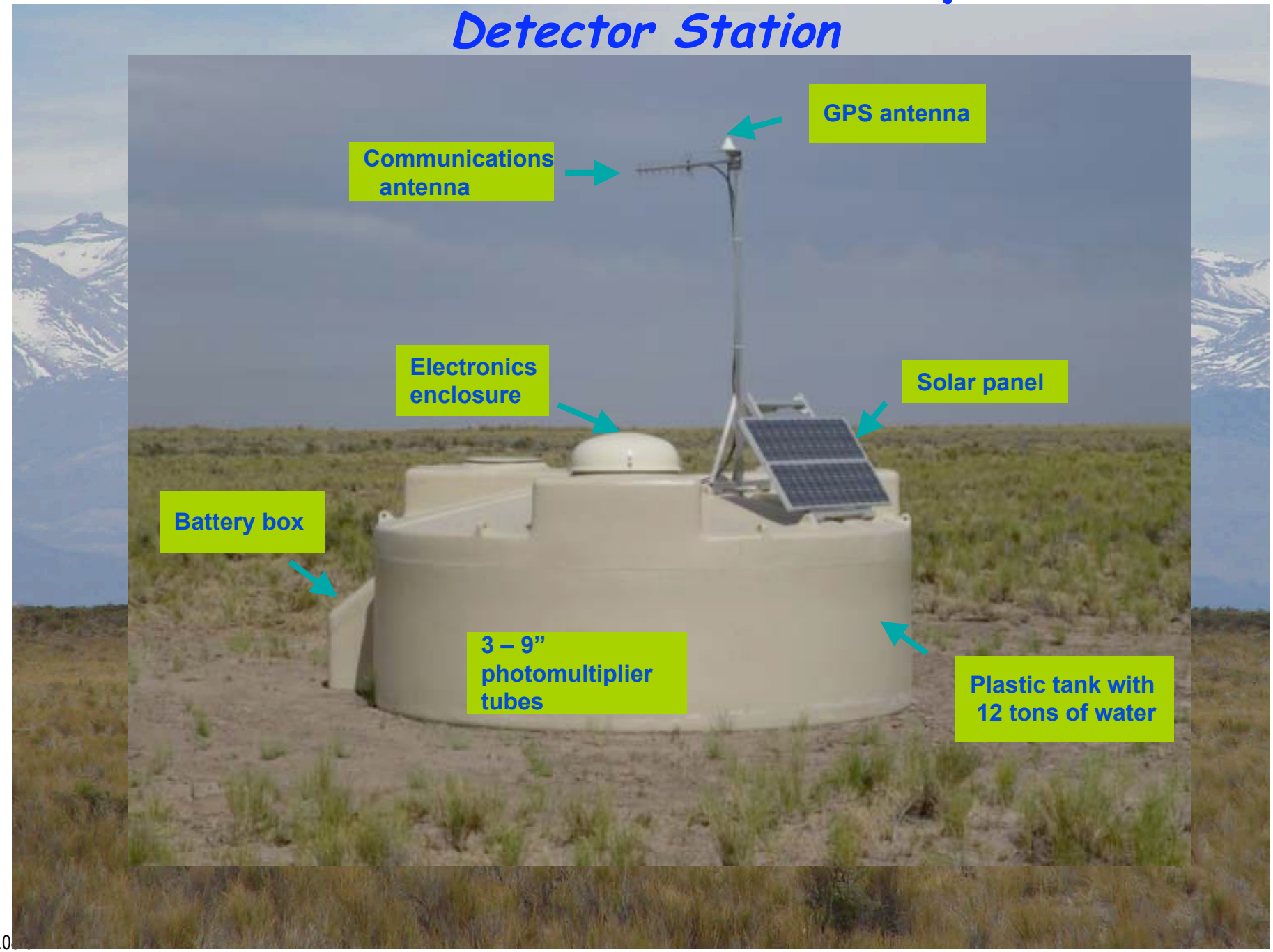
Experimental techniques detecting air showers

Surface detector (SD) (e.g. AGASA)	Fluorescence detector (FD) (e.g. HIRes)	Hybrid detectors (e.g. Auger)
⊖ angular resolution ~ 1 - 2°	⊖ angular resolution ~ 3 - 5°	⊕ angular resolution ~ 0.2°
⊕ 100% duty cycle	⊖ 10-15% duty cycle (clear, moonless nights)	⊕
⊕ acceptance = geometric	⊖ acceptance depends on distance and atmosphere	⊕
⊖ only last stage of shower development observed	⊕ full observation of longitudinal shower development	⊕
⊖ energy scale model dependent	⊕ (almost) model independent	⊕

Auger hybrid detector: Calibrate SD with FD
⇒ keeping only the complementary good things

The Surface Array

Detector Station



Installation Chain

Installation Chain

Tank Preparation and Assembly

Installation Chain

Transportation into the field

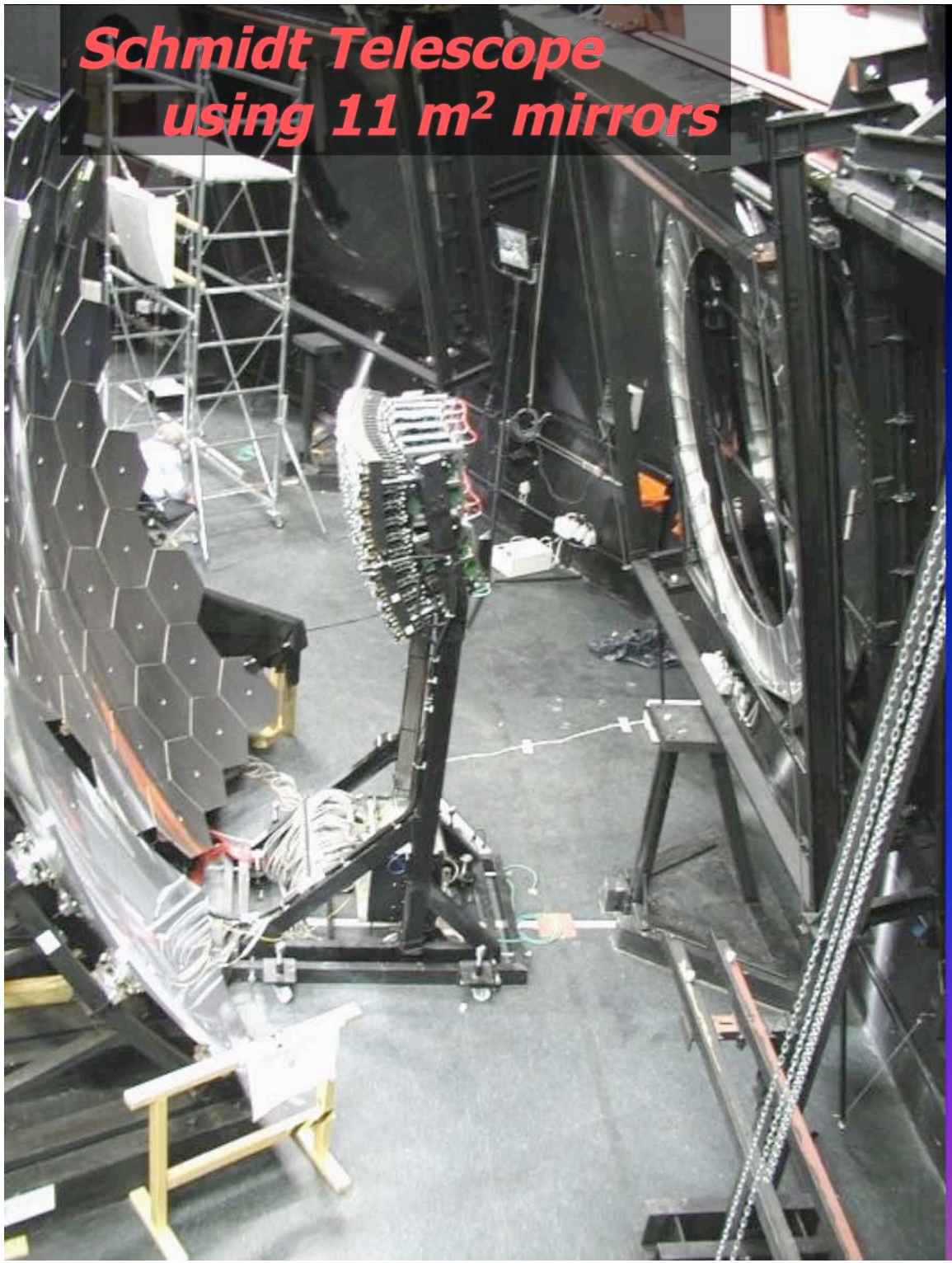
Installation Chain

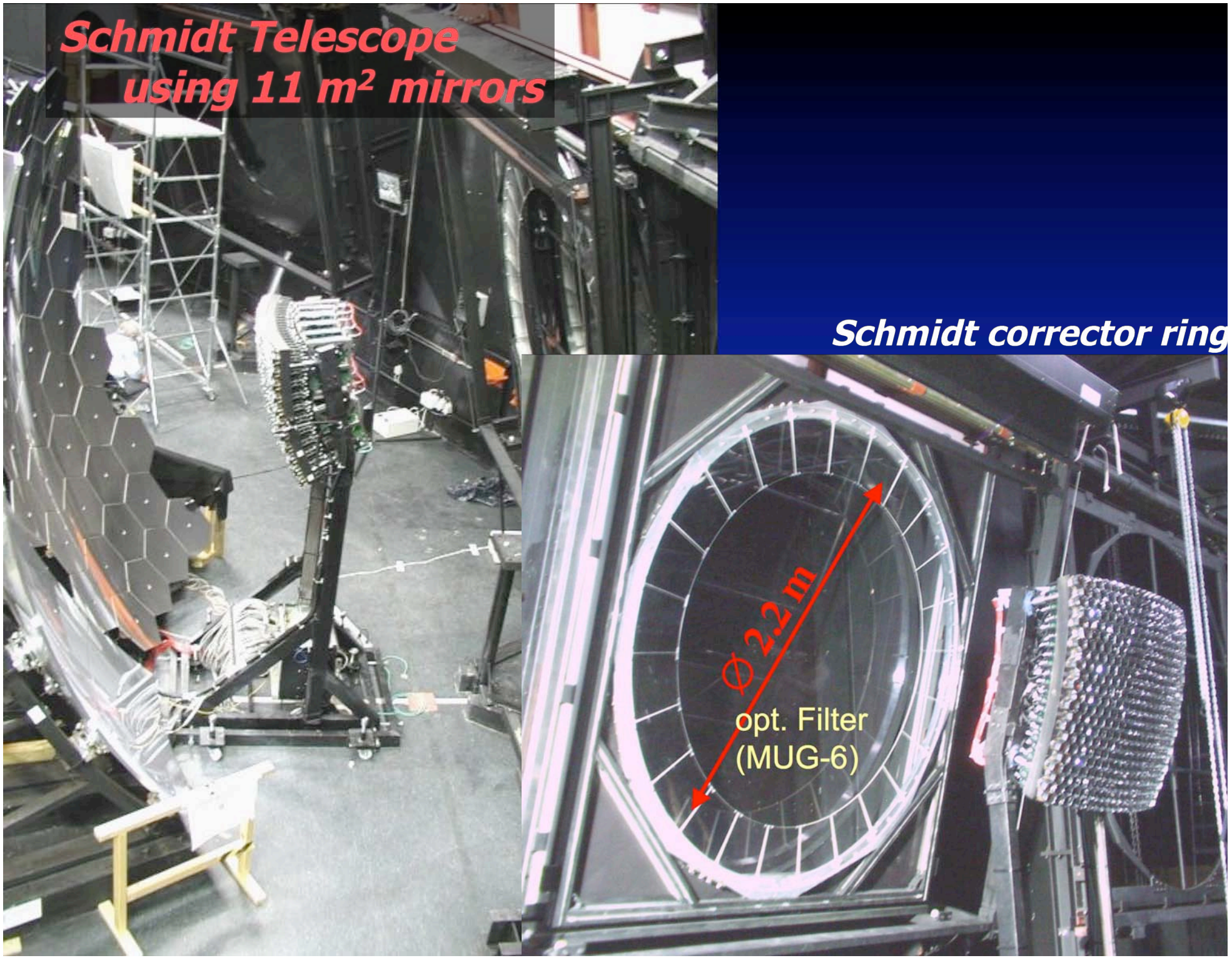
Installation Chain

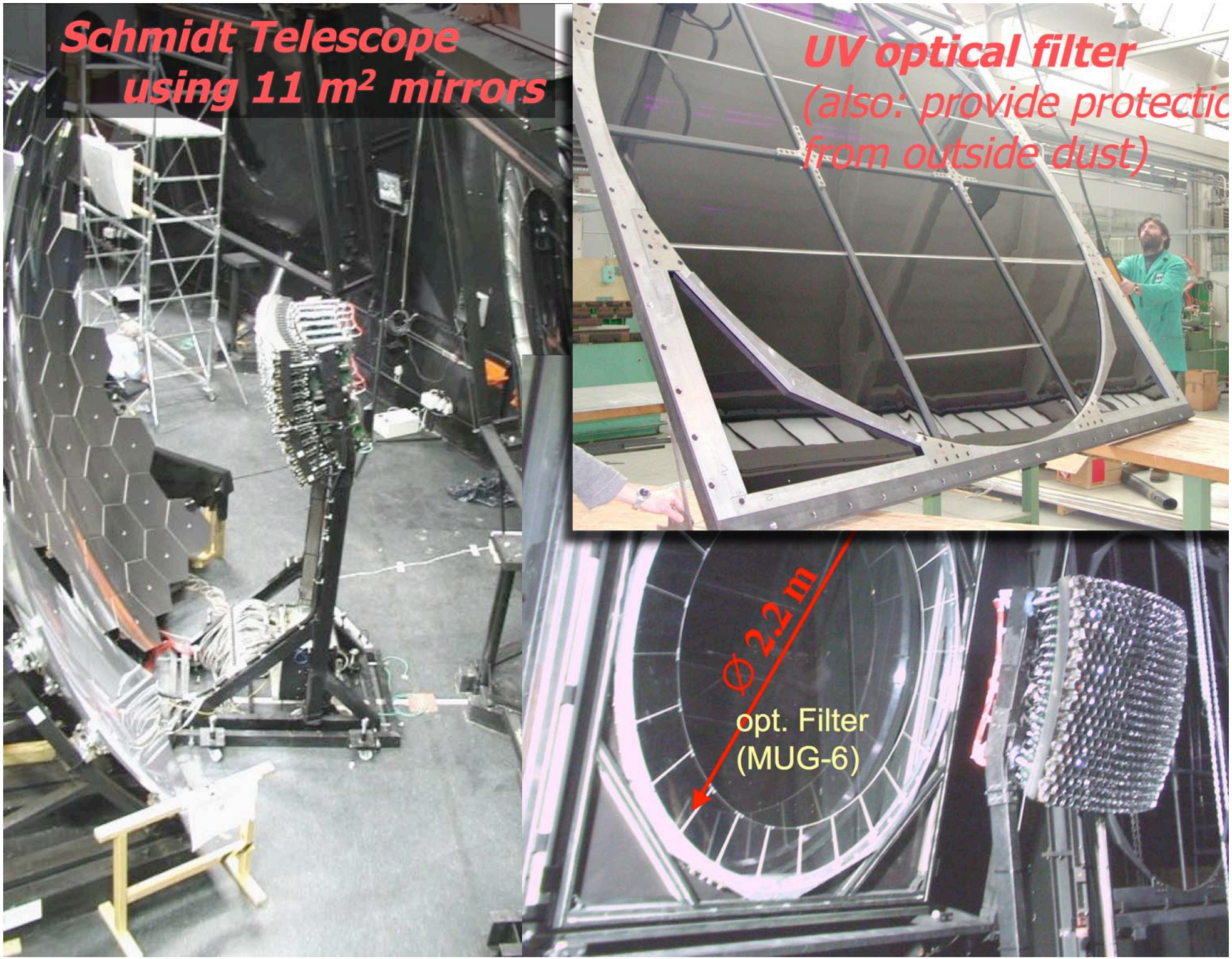
Installation Chain

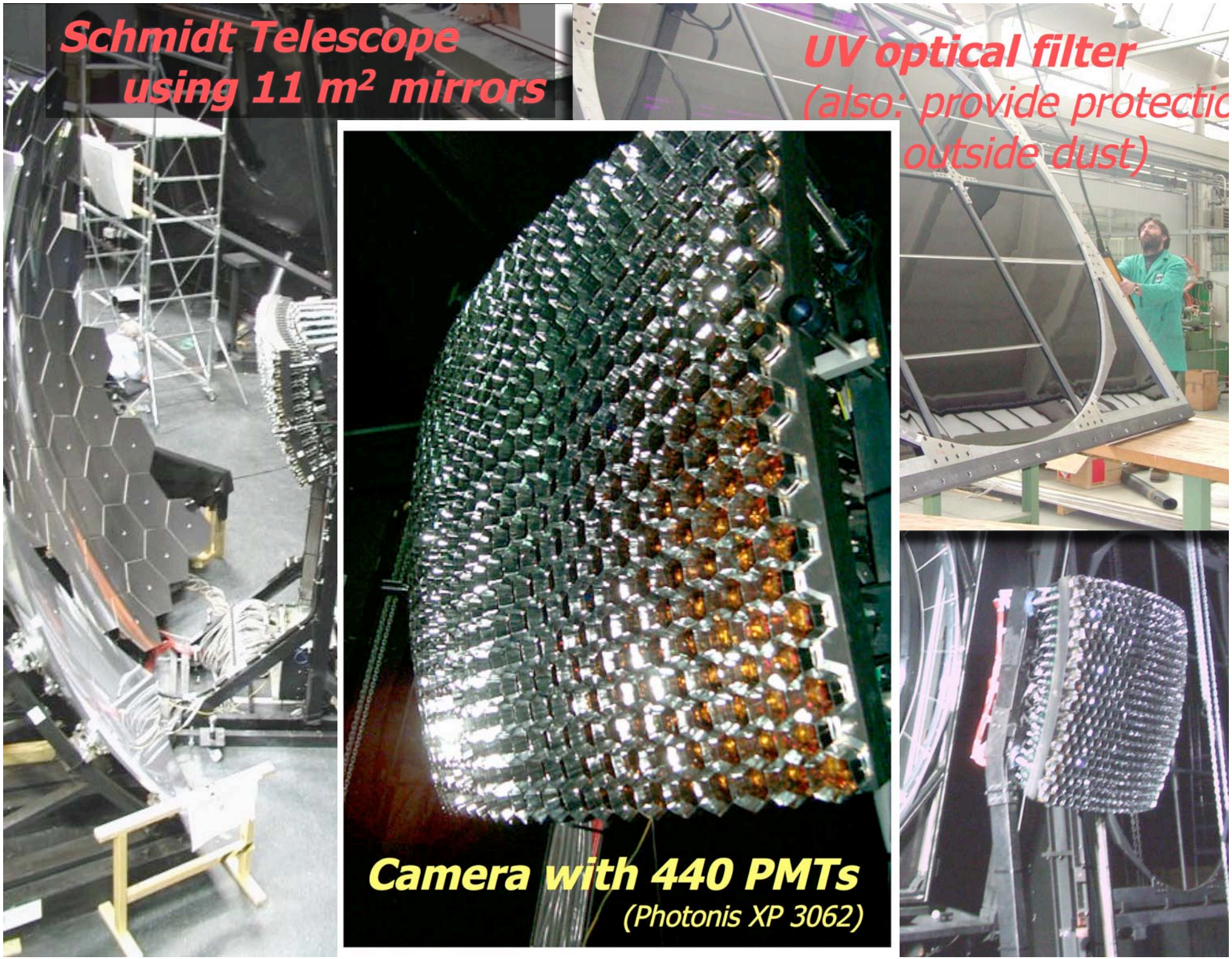
Installation Chain

16.08.07


Schmidt Telescope
using 11 m² mirrors


Schmidt Telescope
using 11 m² mirrors
Schmidt corrector ring
Ø 2.2 m
opt. Filter
(MUG-6)


Schmidt Telescope
using 11 m² mirrors
UV optical filter
(also: provide protectio
from outside dust)
Ø 2.2 m
opt. Filter
(MUG-6)


Schmidt Telescope
using 11 m² mirrors
UV optical filter
(also: provide protectio
outside dust)
Camera with 440 PMTs
(Photonis XP 3062)


Los Leones
(fully operational)


Coihueco
(fully operational)


Morados
(fully operational)


6 Mirror systems per FD
Loma Amarilla
(fully operational)

Atmospheric Monitoring and Fluorescence Detector Calibration

Atmospheric Monitoring

Central Laser Facility
(laser optically linked to adjacent surface detector tank)

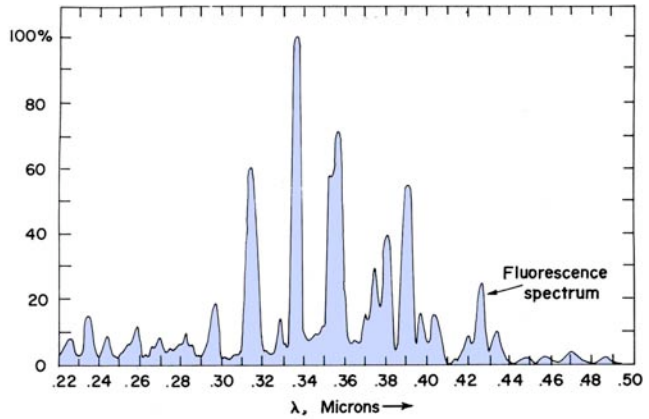
- Calibration checks
- Timing checks

Balloon probes ⇘
(T,p)-profiles

Absolute Calibration

Drum for uniform illumination of each fluorescence camera

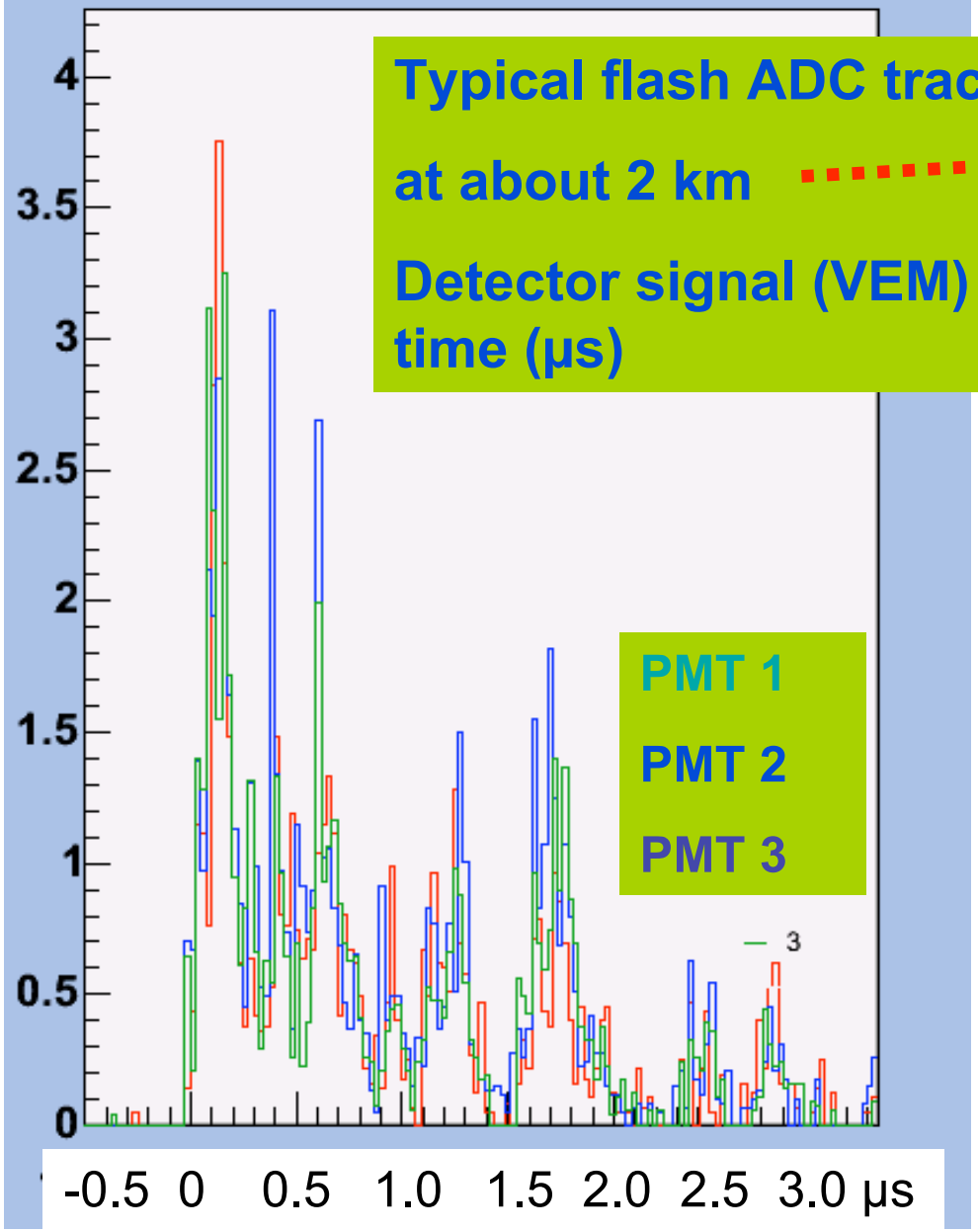
Meas. N_2-fluorescence

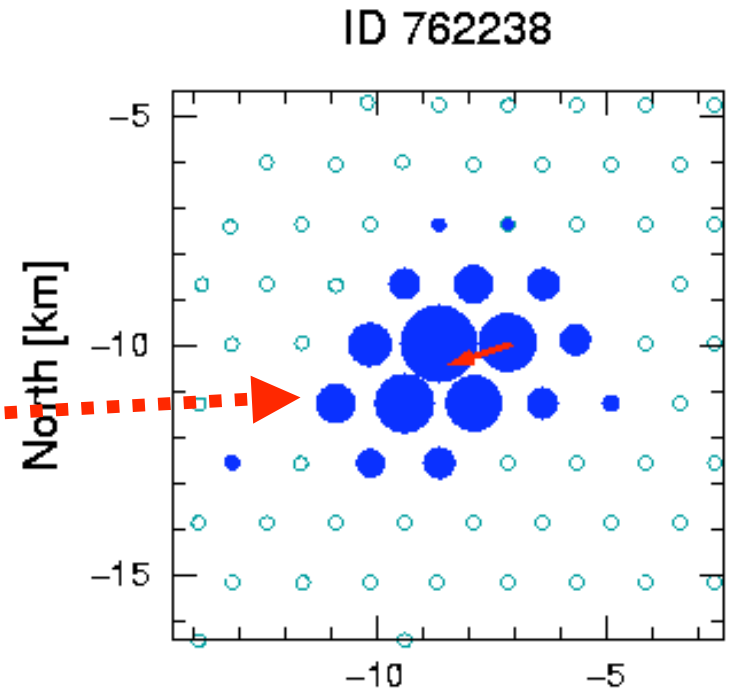


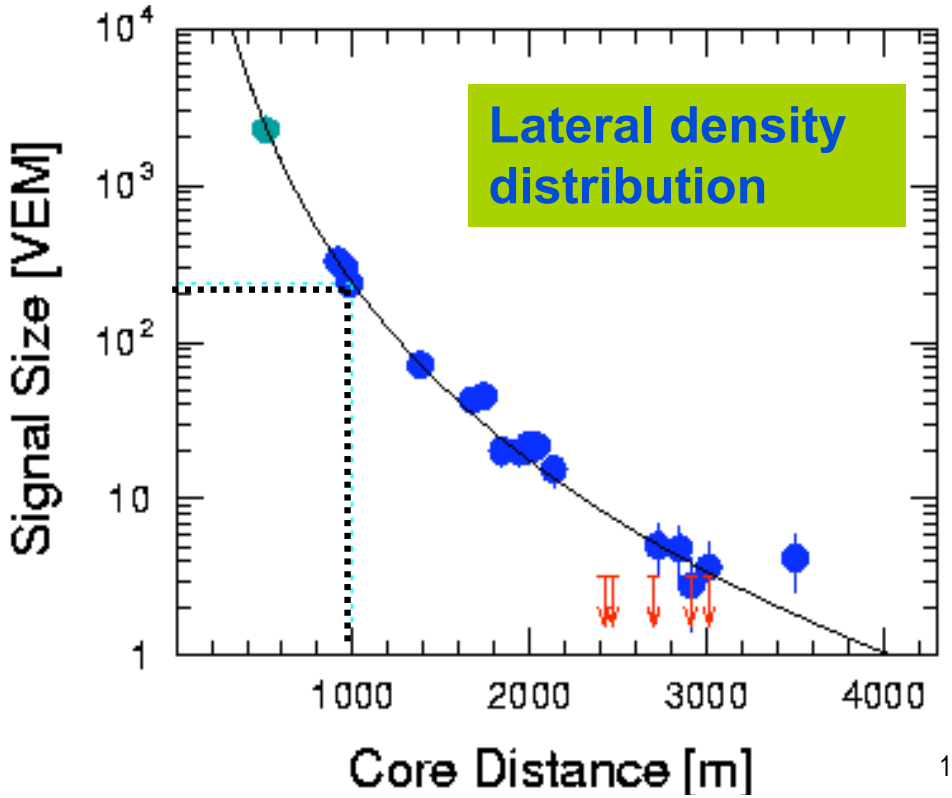
Steerable Lidar at each fluorescence eye for atmospheric profiling - "shooting the shower"

θ~ 48°, ~ 70 EeV

18 detectors triggered

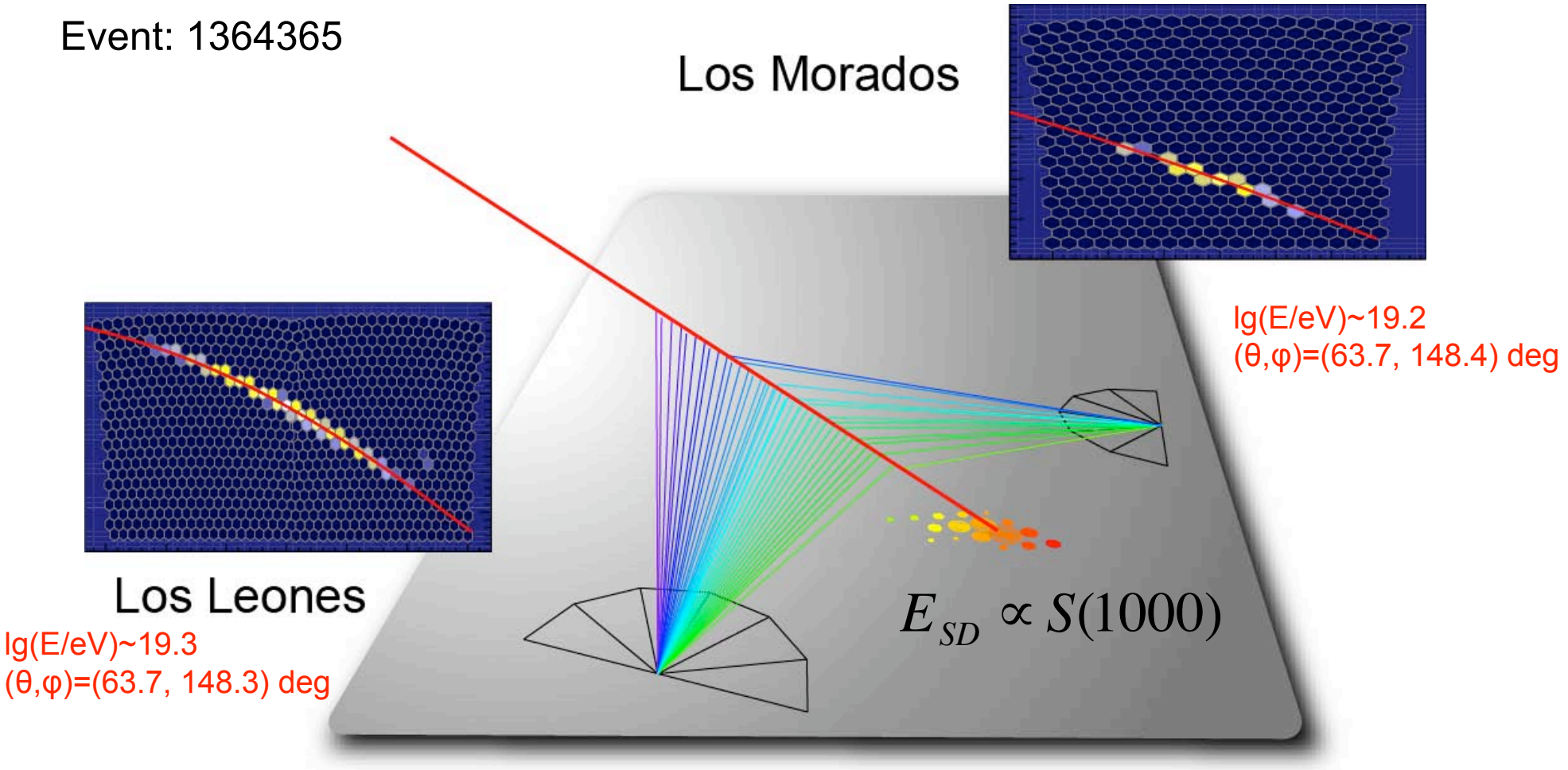






Stereo hybrid measurement

Event: 1364365



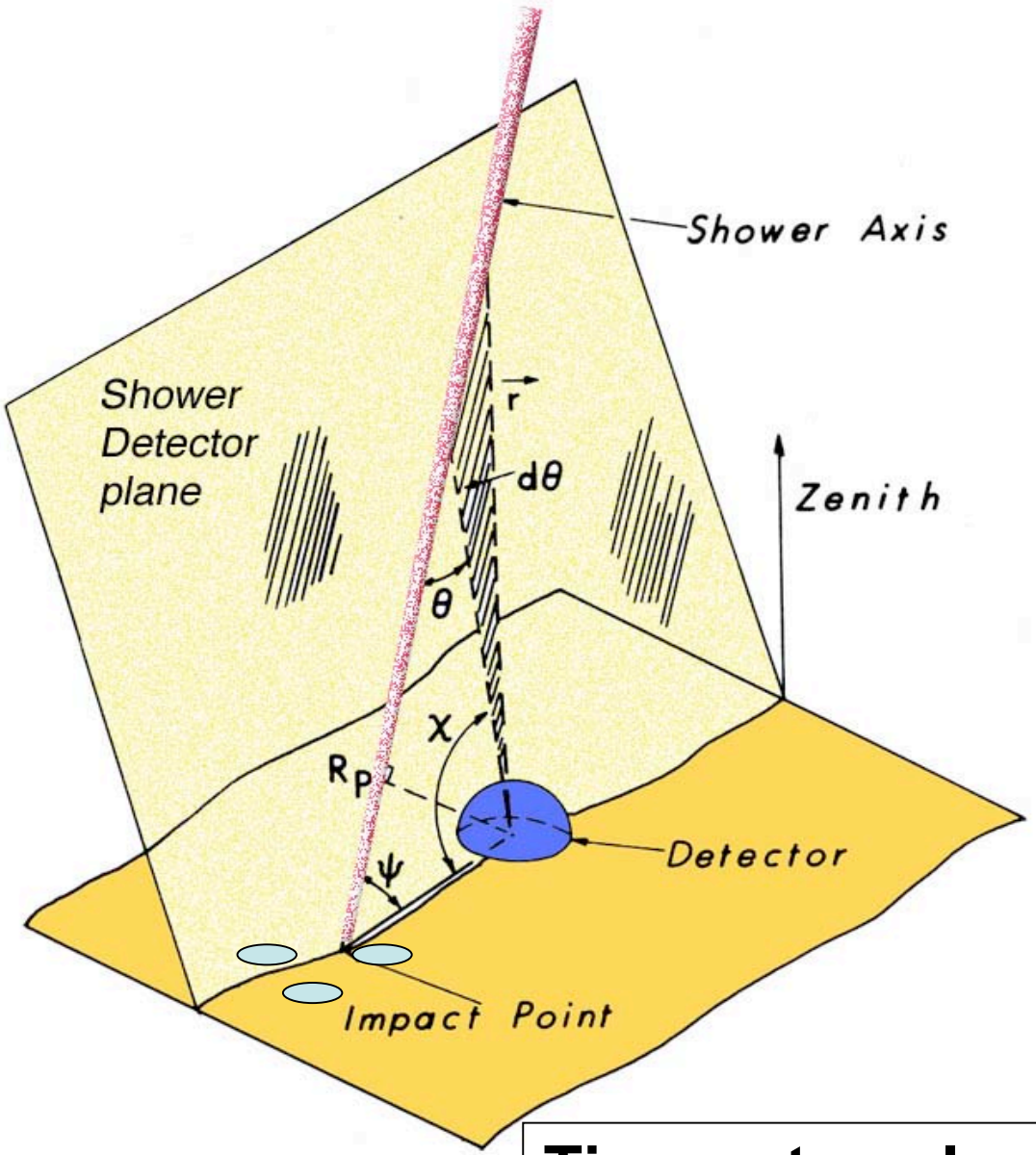
lg(E/eV)~19.2
(θ,φ)=(63.7, 148.4) deg

lg(E/eV)~19.3
(θ,φ)=(63.7, 148.3) deg

lg(E/eV)~19.1
(θ,φ)=(63.3, 148.9) deg

$$E_{FD} \propto \int \frac{dE}{dX}(X)dX$$

The Essence of the Hybrid Approach

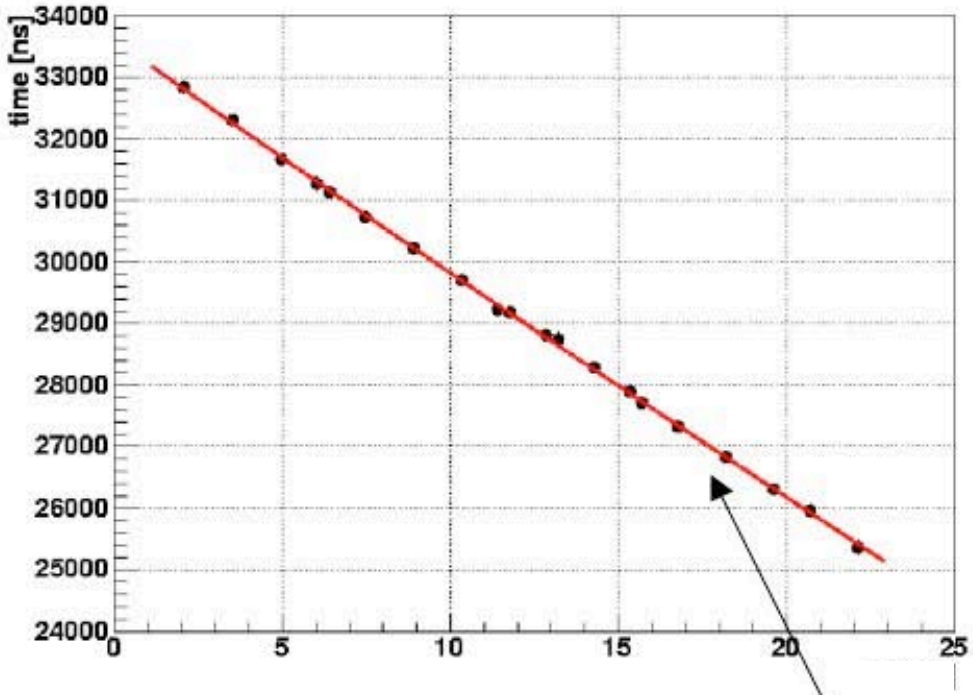


Precise shower geometry from degeneracy given by SD timing

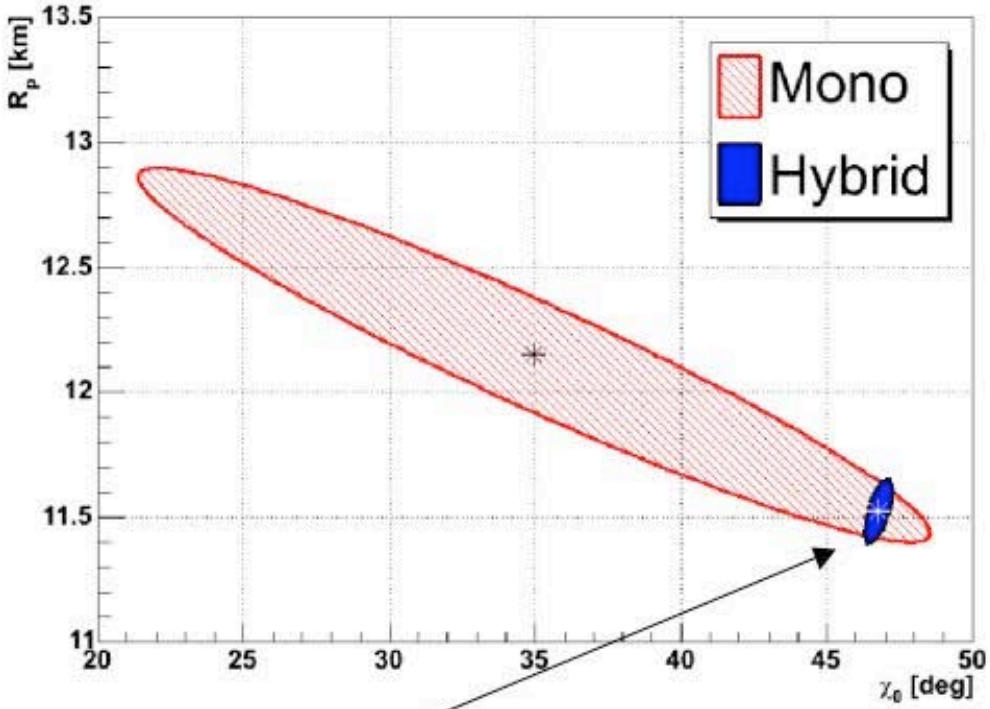
Times at angle χ are key to find R_p

Hybrid Reconstruction

Time, t



R_p km



χ

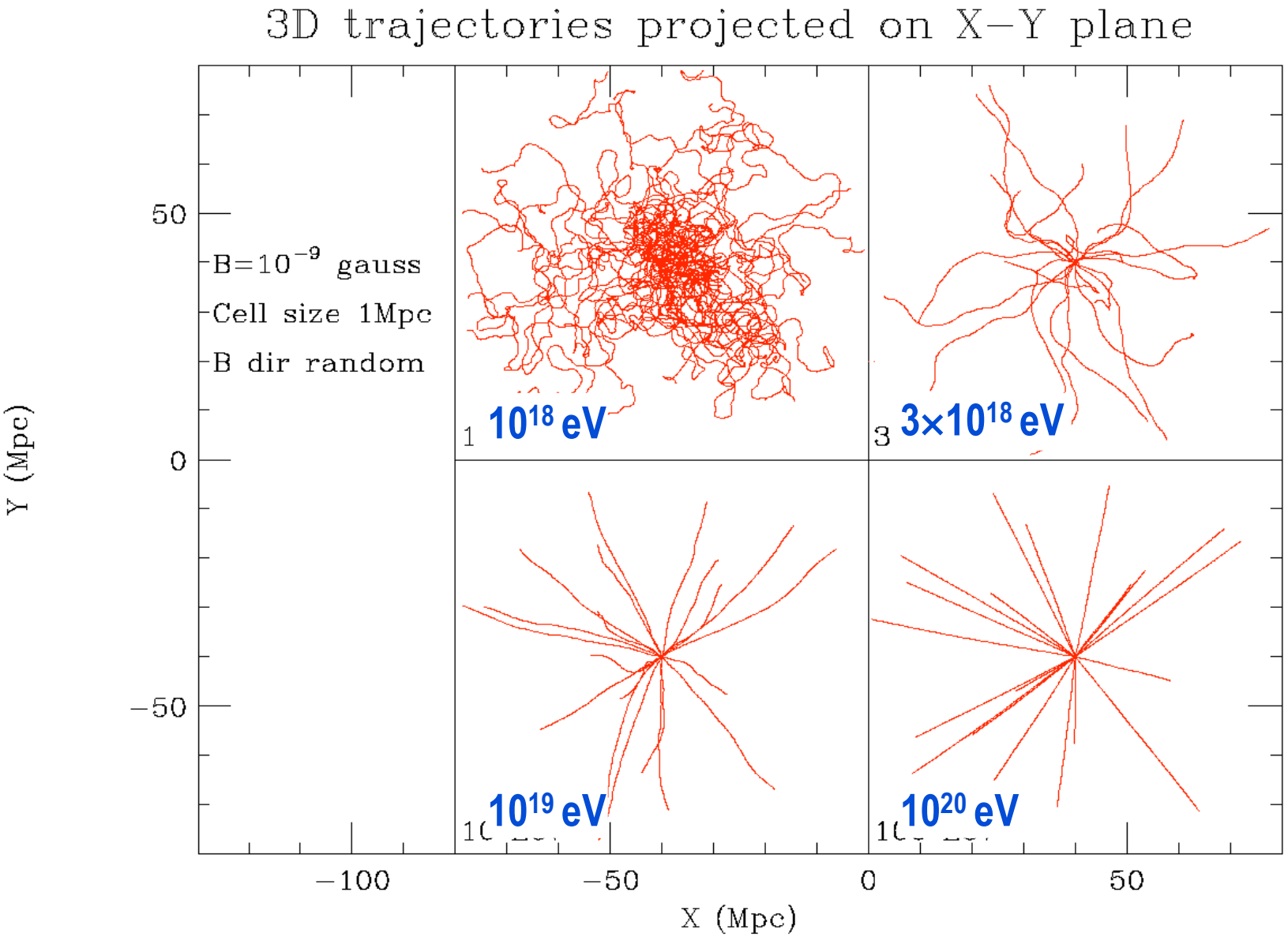
$\approx$ line but

3 free parameters

T_0 from tank!

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

Trajectories of Protons in Inter-Galactic Space

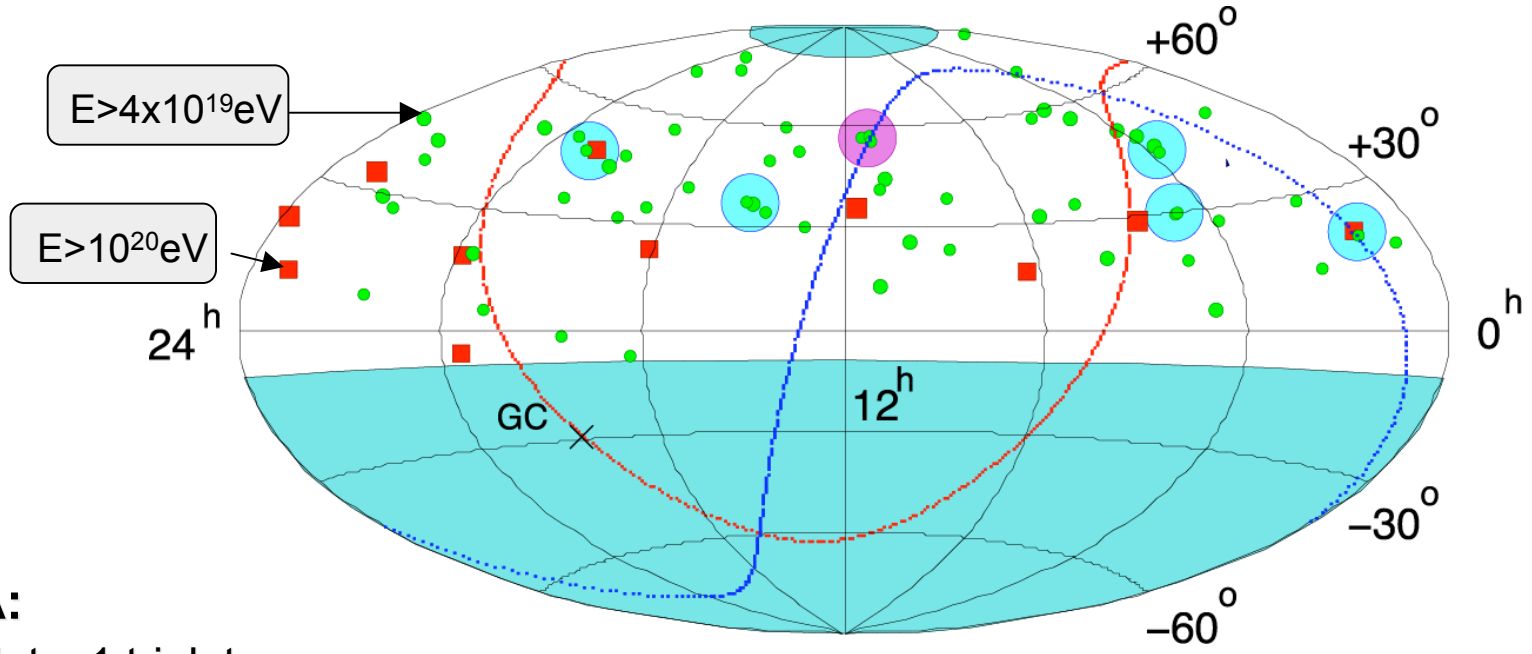


Jim Cronin, astro-ph/0402487

Cosmic ray astronomy is an allowed wording

Arrival direction distribution

Can sources of UHECRs be identified?

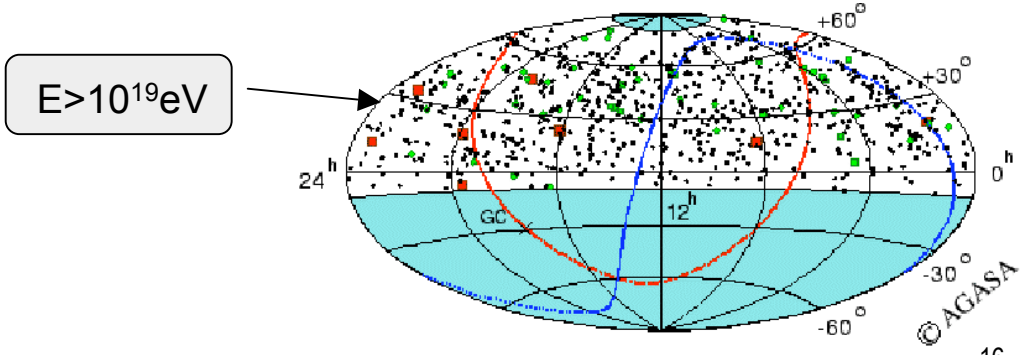


AGASA:

- 5 doublets, 1 triplet
  $\Delta\theta < 2.5°$
- $E > 4 \times 10^{19}$eV

HiRes:

- No confirmation
- Different statistics & systematics



Arrival Direction Distribution

Typical accuracy of reconstruction < 1°

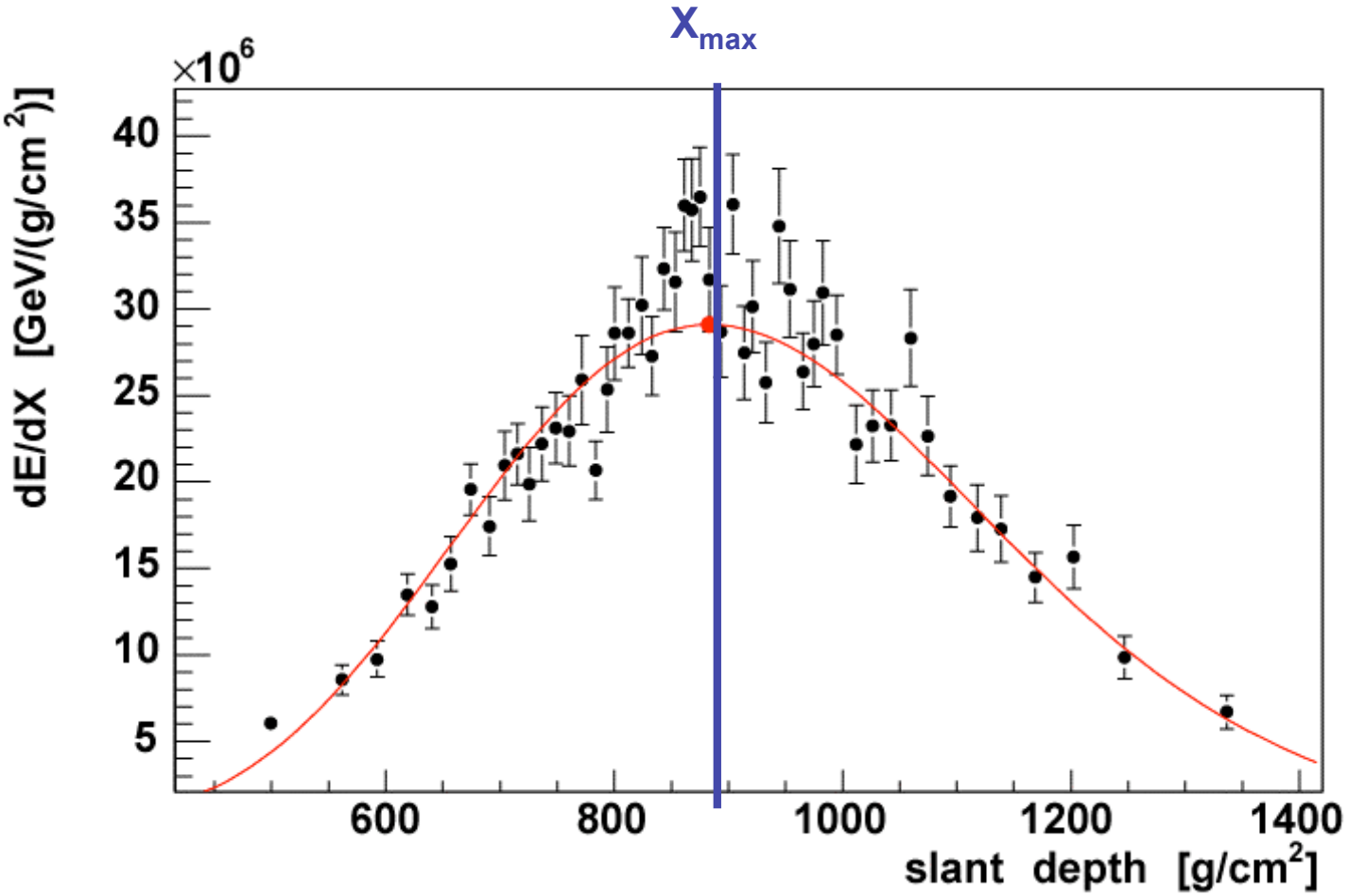
- **No significant emission from Galactic Centre**
- **No broadband signals – e.g. Dipole – at any energy above 1 EeV, e.g. 1 < E < 3 EeV, Amplitude < 0.7%**
- **No clustering of the type claimed by AGASA**
- **No signal from BL Lacs as possibly seen by HiRes**

Summary: Previous reports have not been confirmed

- **But who expects,**
  that particle astronomy works below few 10^{19} ???

2 'prescriptions' are under test

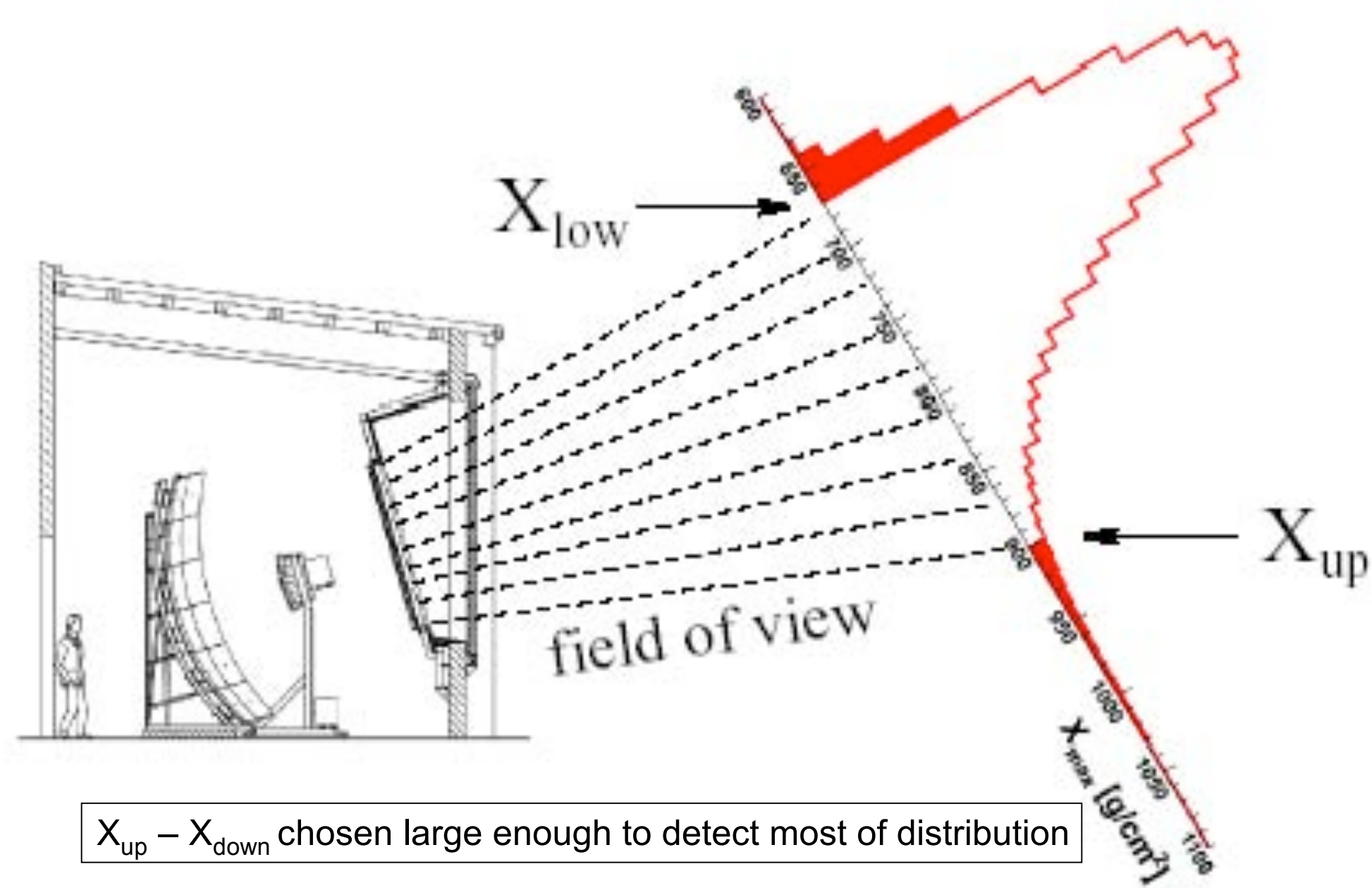
Stereo hybrid event: FD measurement



Event: 1364365

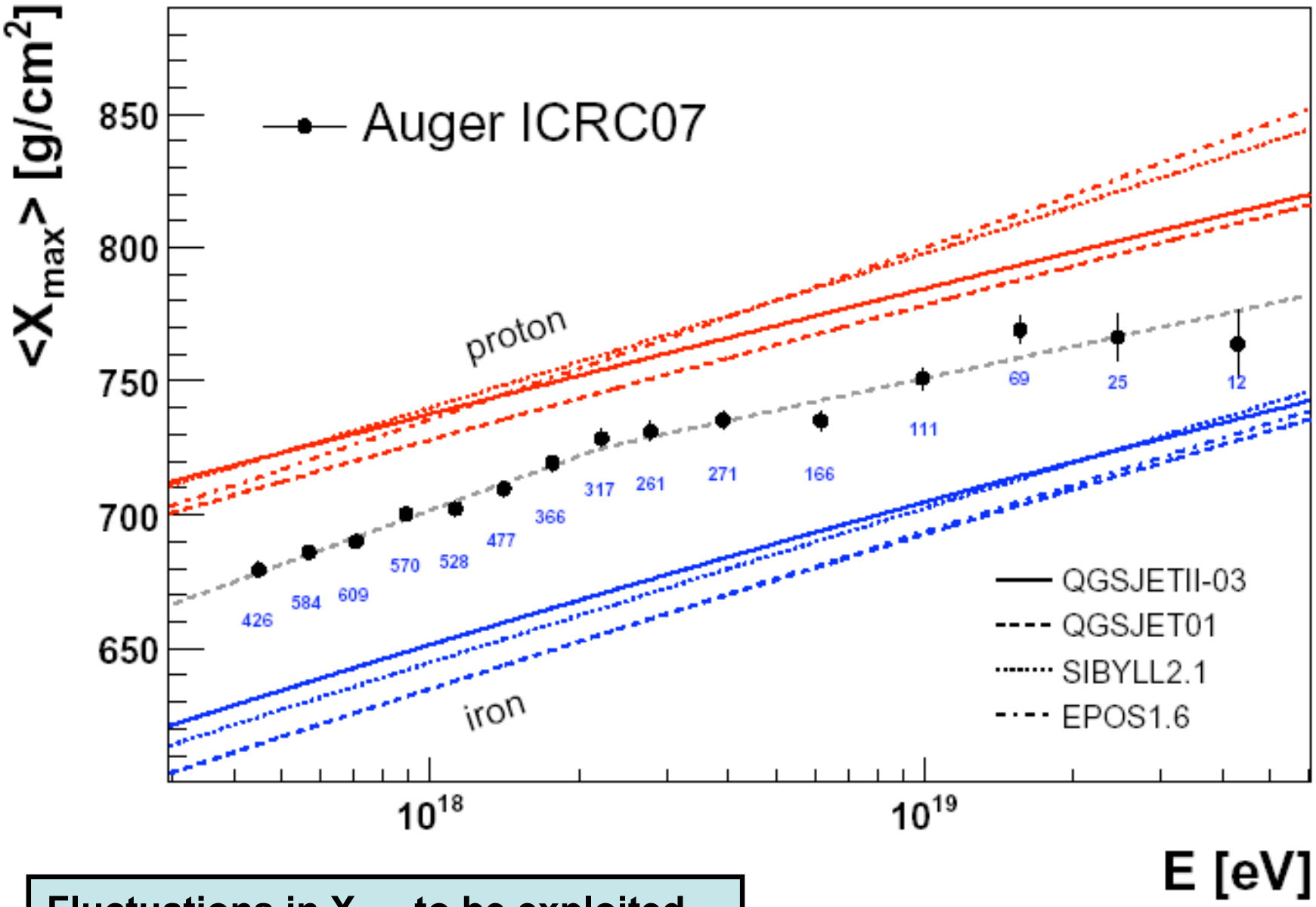
- depth of shower maximum: $X_{max} \sim \lg(E/A)$
- integral → E

Selection of events for X_{max}



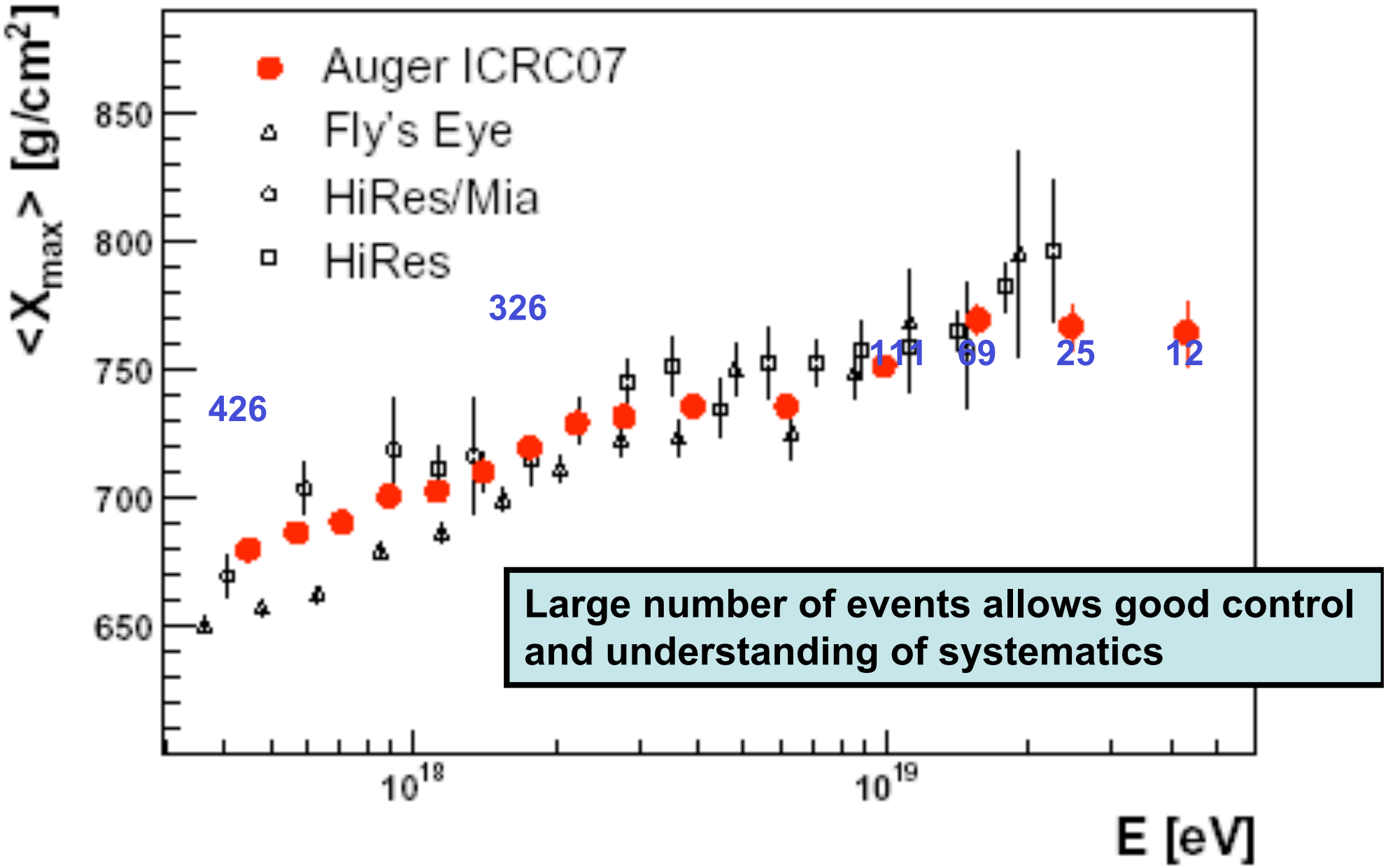
$X_{up} - X_{down}$ chosen large enough to detect most of distribution

Elongation Rate measured over two decades of energy



Fluctuations in X_{max} to be exploited

Comparison of $\langle X_{max} \rangle$ with other measurements

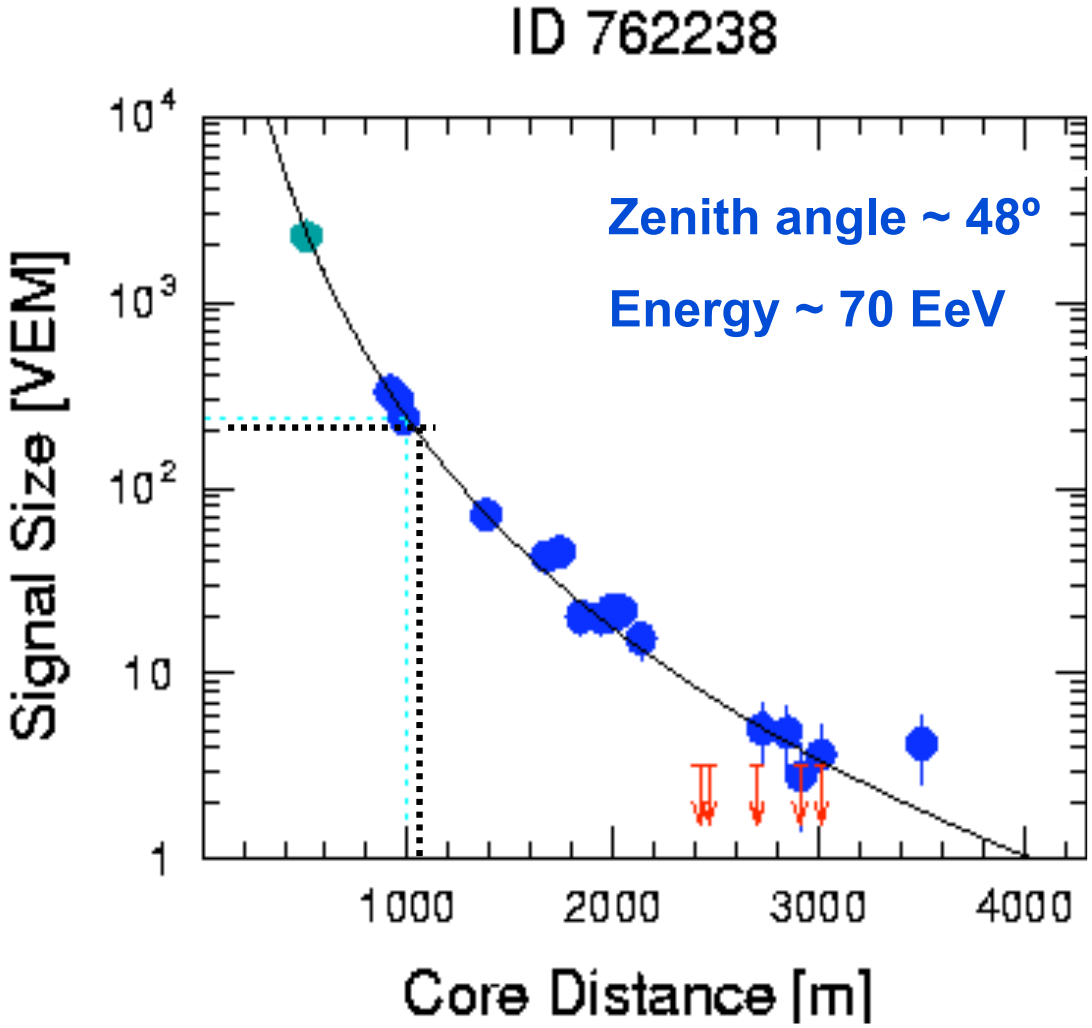


Large number of events allows good control and understanding of systematics

Energy Determination with Auger

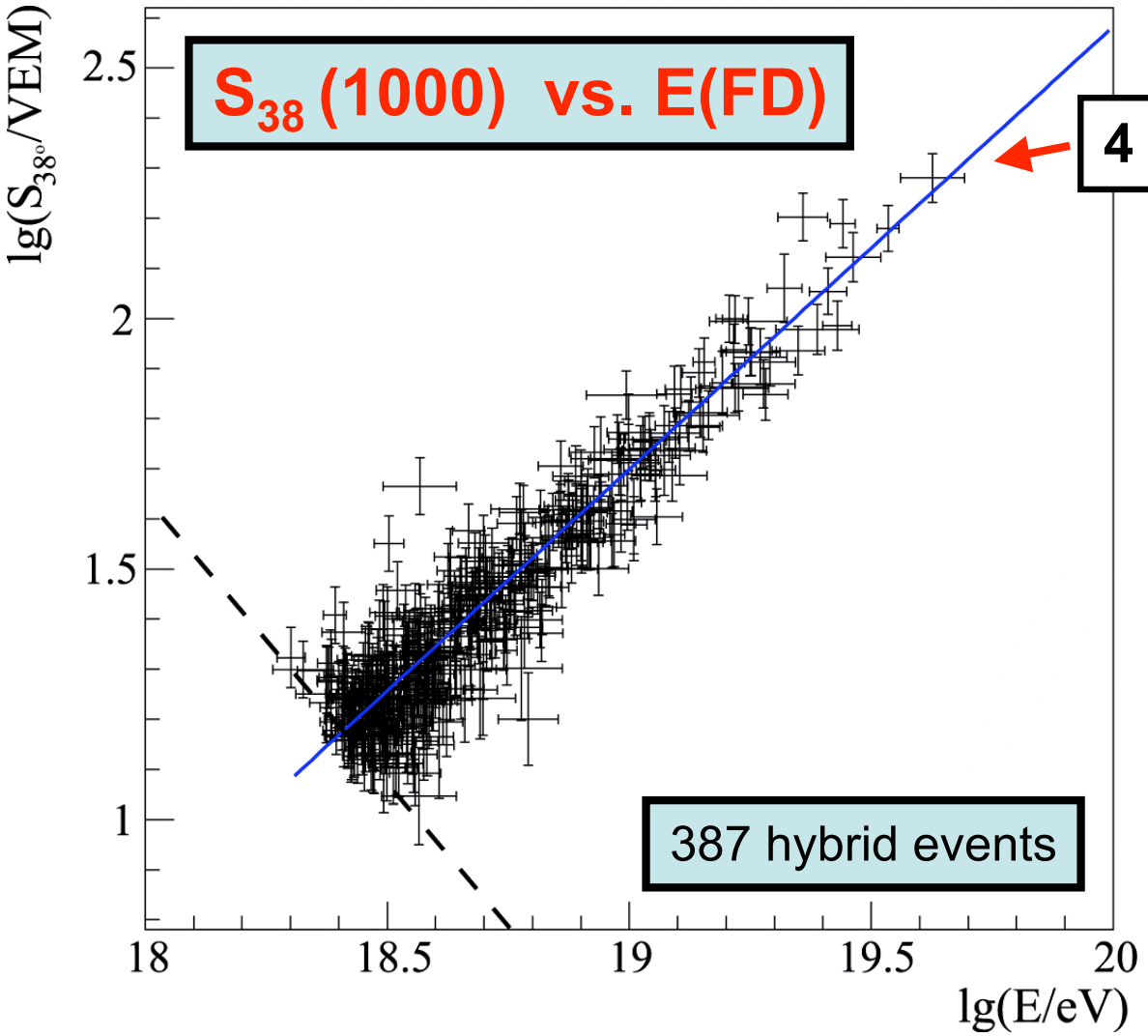
The energy scale is determined from the data
The dependence on knowledge of interaction models or of the primary composition is at level of a few %.

- 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



Advantage of the hybrid method

M.Roth for the Auger Collab., ICRC07



Cross calibration Between FD and SD detector relying on measurements only!

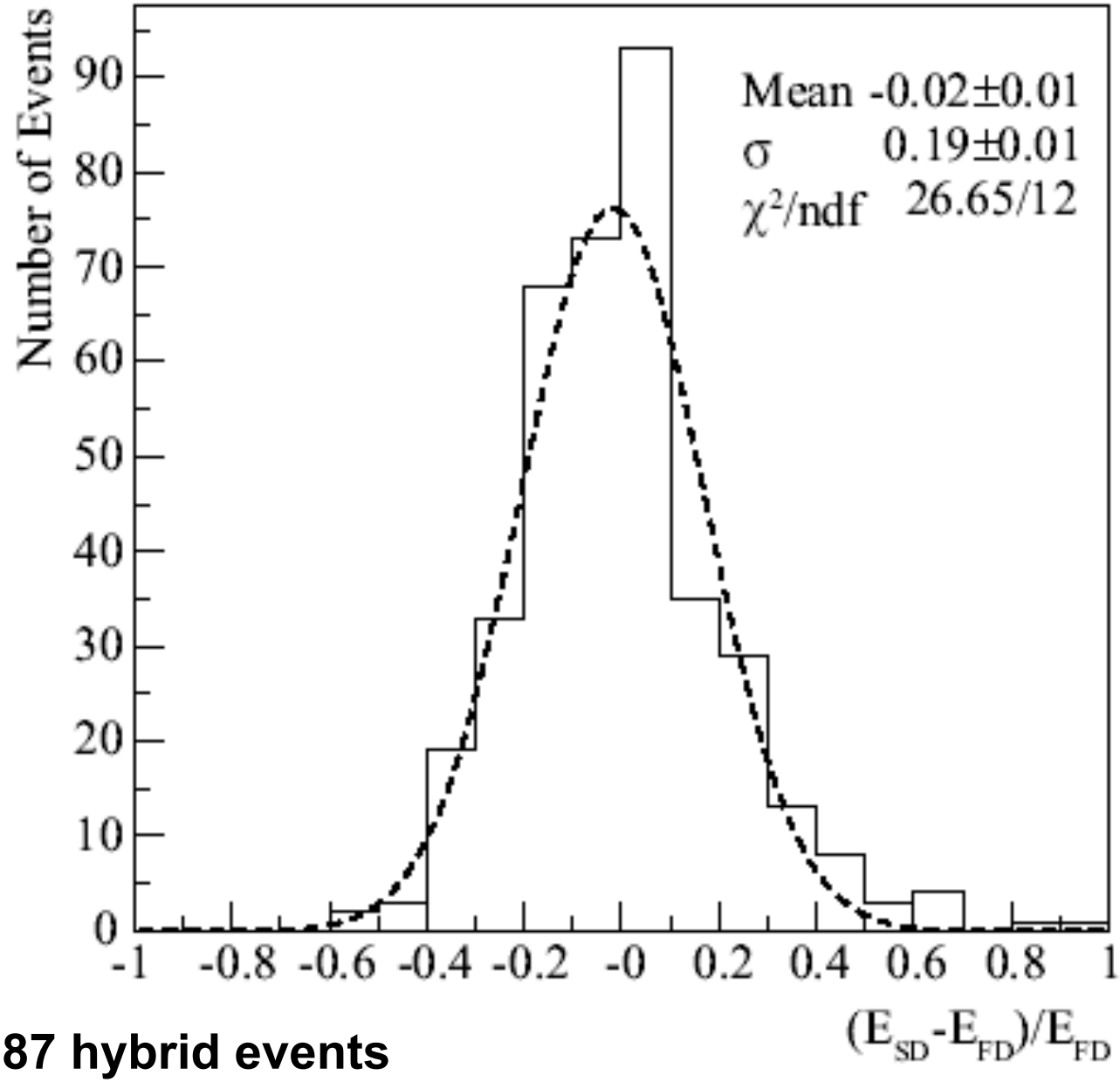
Energy resolution: 20%
Systematic uncertainty: 22%

FY of Nagano et al used

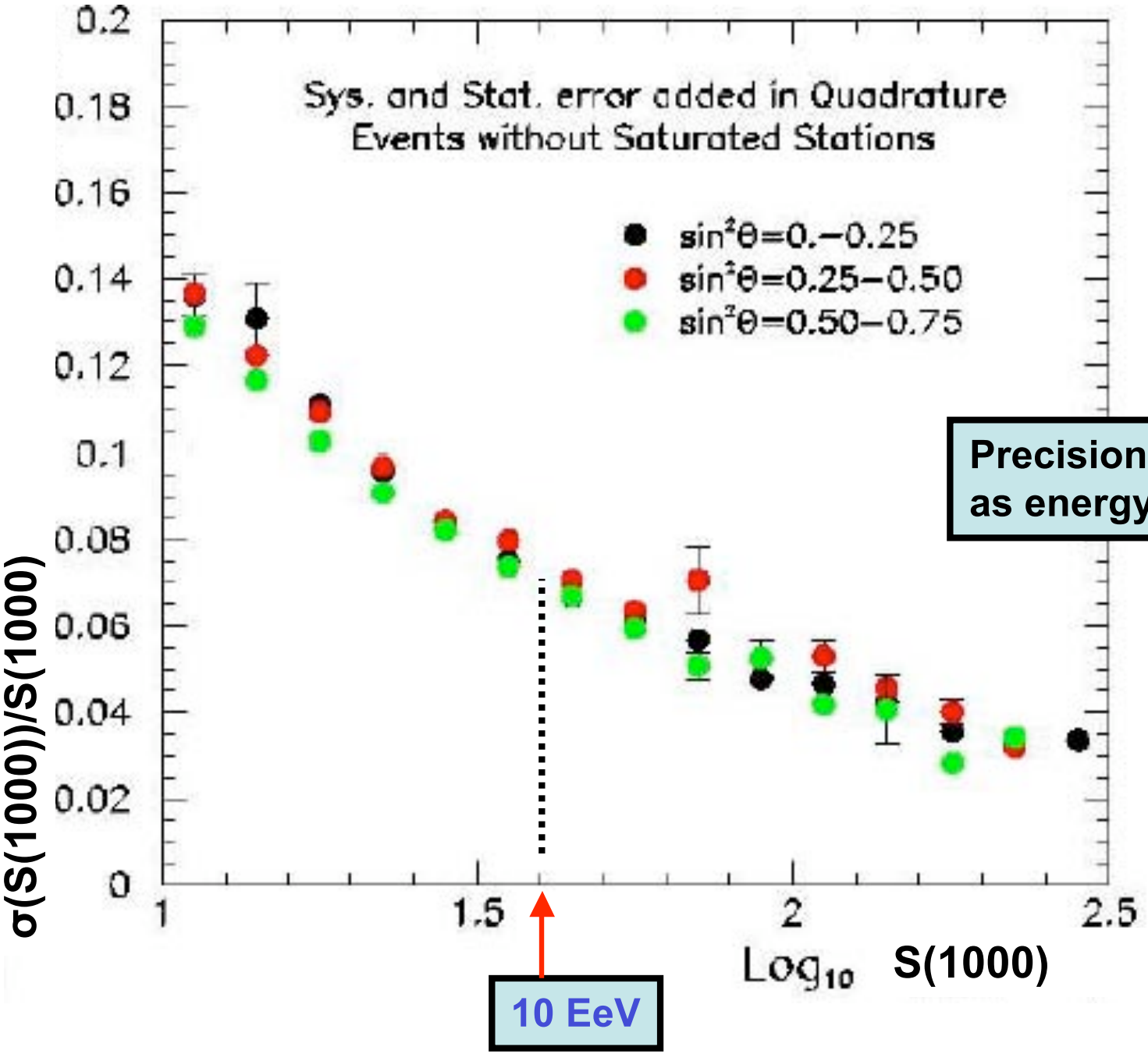
$$S_{38^\circ} = f(S1000)$$

f(S1000) compensates the angular dependence due to attenuation

Fractional difference between FD and SD energy

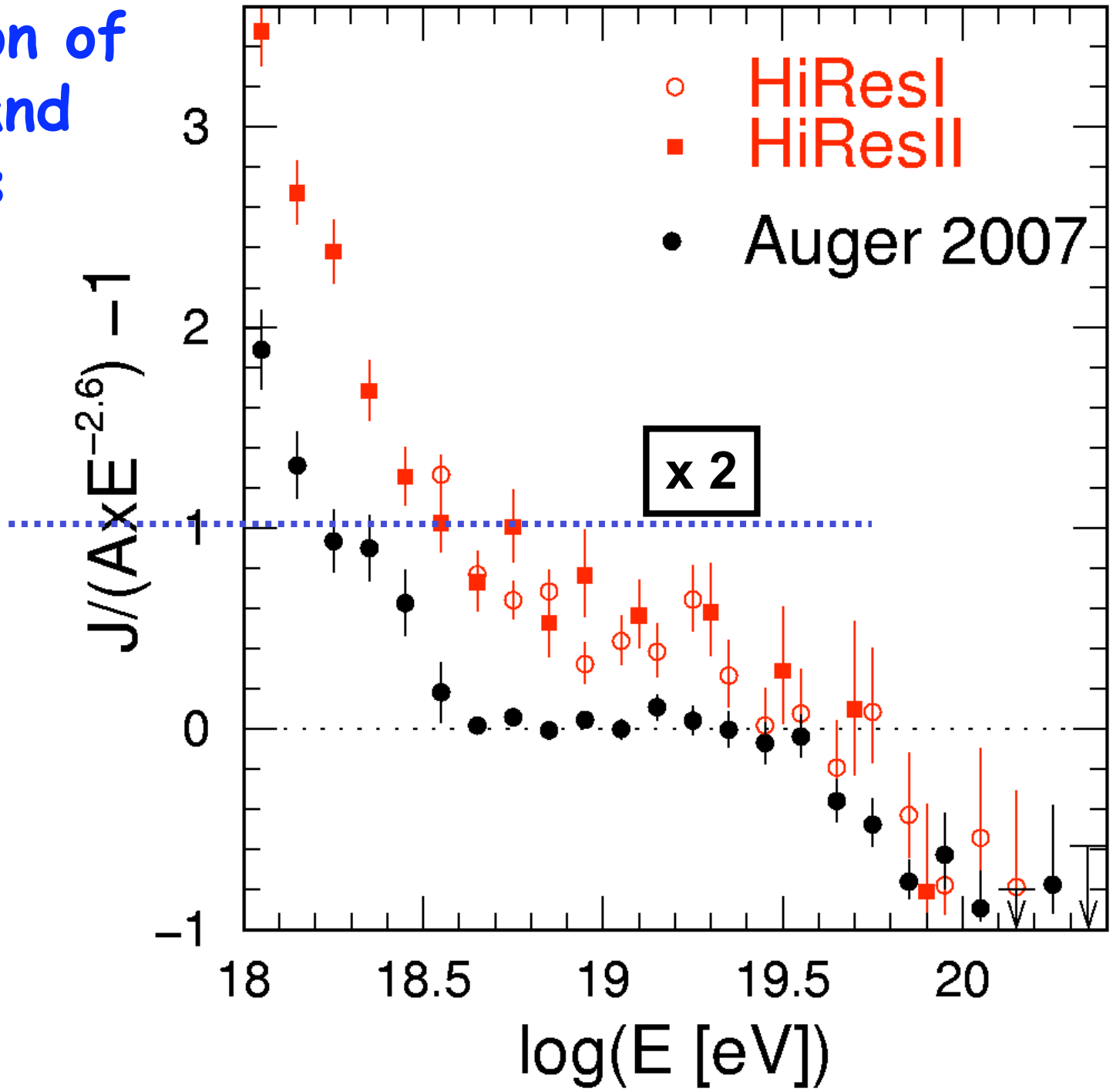


387 hybrid events



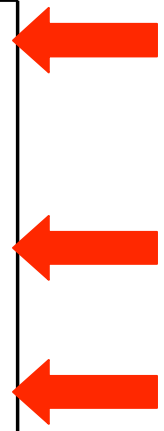
Precision of S(1000) improves as energy increases

Comparison of Auger and HiRes



Summary of systematic uncertainties

Source	Systematic uncertainty
Fluorescence yield	14%
P,T and humidity effects on yield	7%
Calibration	9.5%
Atmosphere	4%
Reconstruction	10%
Invisible energy	4%
TOTAL	22%

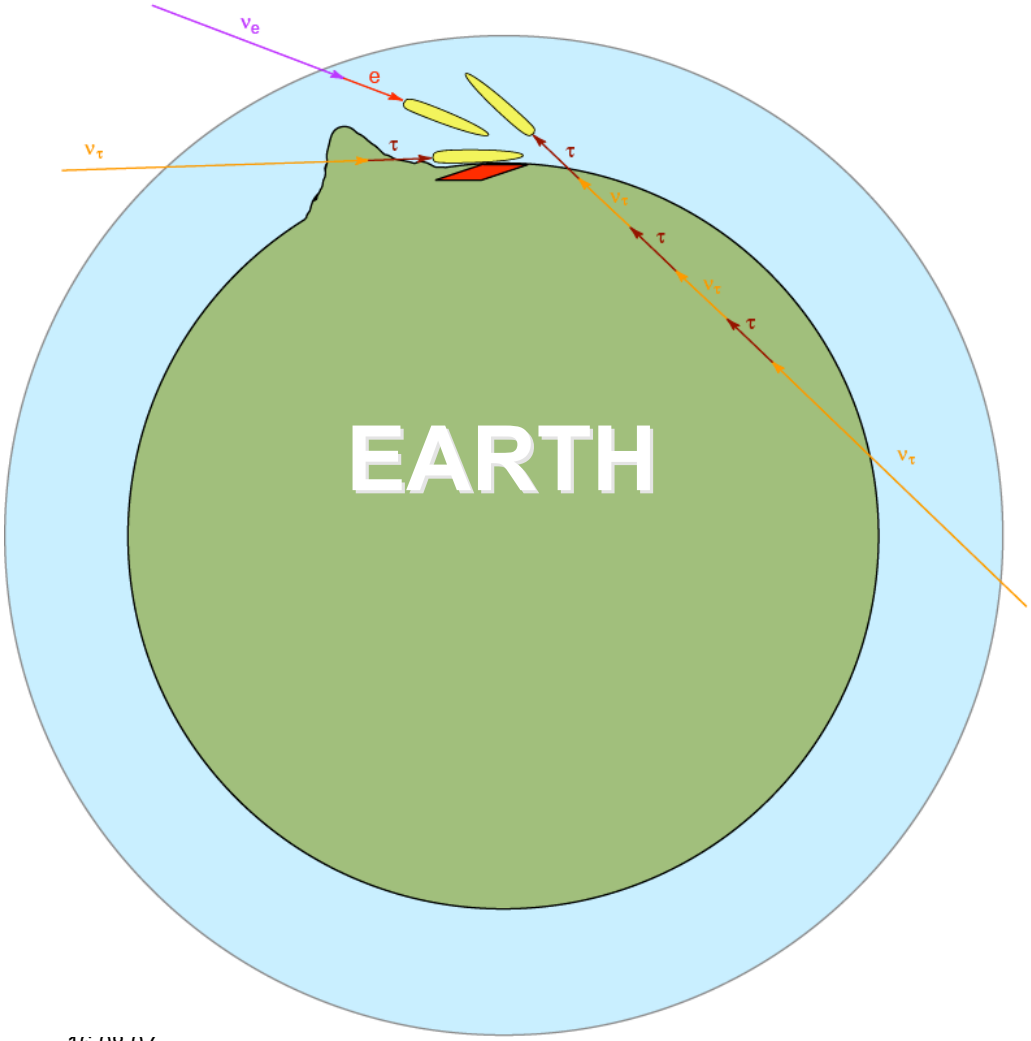


Note: Activity on several fronts to reduce these uncertainties

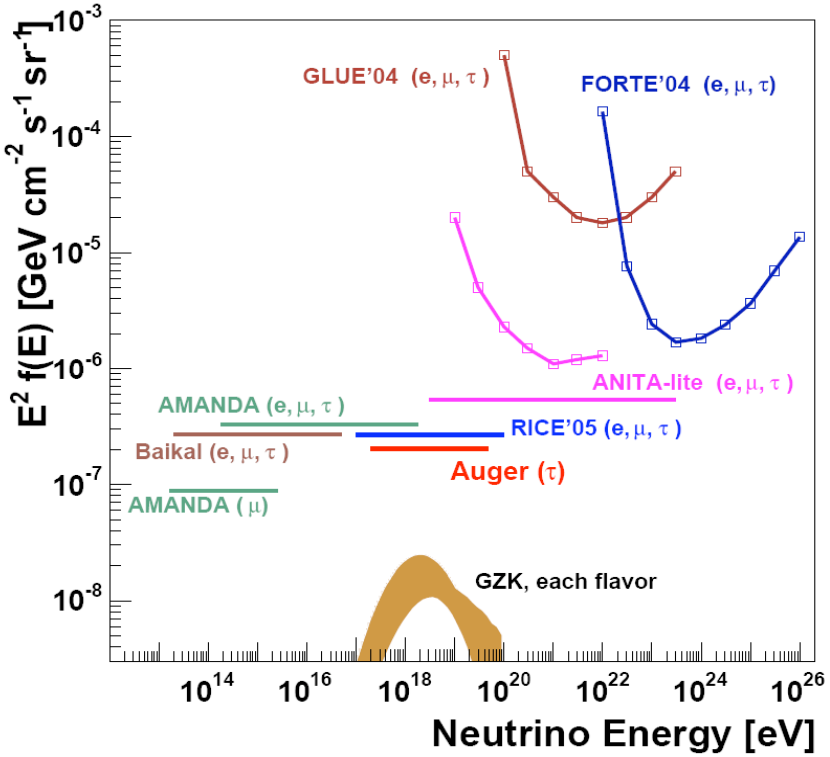
Fluorescence Detector Uncertainties Dominate

Neutrino limit on up-going tau-neutrinos

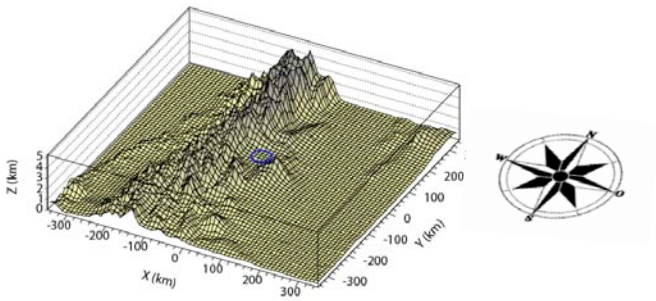
- **Neutrino interaction in Earth and Andes**
- **Detection of a τ initiated shower**



O. Blanch-Bigas for the Auger Collab., ICRC07



$$E_\nu^2 \cdot dN_{\nu\tau}/dE_\nu < 1.5^{+0.5}_{-0.8} \cdot 10^{-7} GeV cm^{-2} sr^{-1} s^{-1}$$



Summary of Auger Highlights:

- **Auger-South more than 85% complete**

- **Statistics:**
  - **Number of events of Auger with E > 10 EeV comparable to AGASA + HiRes together with superior angular and energy resolution**

- **Arrival Directions:**
  - **No evidence of point sources – but relatively few events at the very highest energies: Auger is just starting**

- **Spectrum:**
  - **ankle and steepening seen - with model-independent measurement and analysis at ~ 4.5 x 10^{18} and ~ 3.6 x 10^{19} eV**

Interpretations ?

- Is the ankle marking a galactic/extra-galactic change?
- Have we seen the GZK effect?
- Is it a 'bump' from a more local effect?
- Are the accelerators just 'tired'?
- **Deducing the MASS is crucial:**
  - **mixed at highest energy?**
- Certainly not expected – do hadronic models need modification?
- **Would it help to reconcile AGASA with HiRes and Auger at the highest energies**

Future for Auger Collaboration

- **Auger statistics will totally dominate after another year**
- **Complete Auger-South in ~ 5 months and provide reliable & extensive experimental data for many years**

- **Commence construction of high elevation FD (up to 60°), dense SD array, and muon detectors, at the day 1600th tank is deployed (designed and fully funded) for hybrid work to 10^{17} eV**

- **Submit Auger-North proposal within a year**

Thanks

I would like to thank all my Auger Colleagues, especially M. Roth and A. Watson providing me with lots of material.