Cosmic Rays - in Poland

Maria Giller - University of Łódź

Institutions:

1. Institute of Nuclear Physics – Kraków,
2. University of Łódź,
3. Andrzej Sołtan Institute for Nuclear Studies -
   - Cosmic Ray group in Łódź

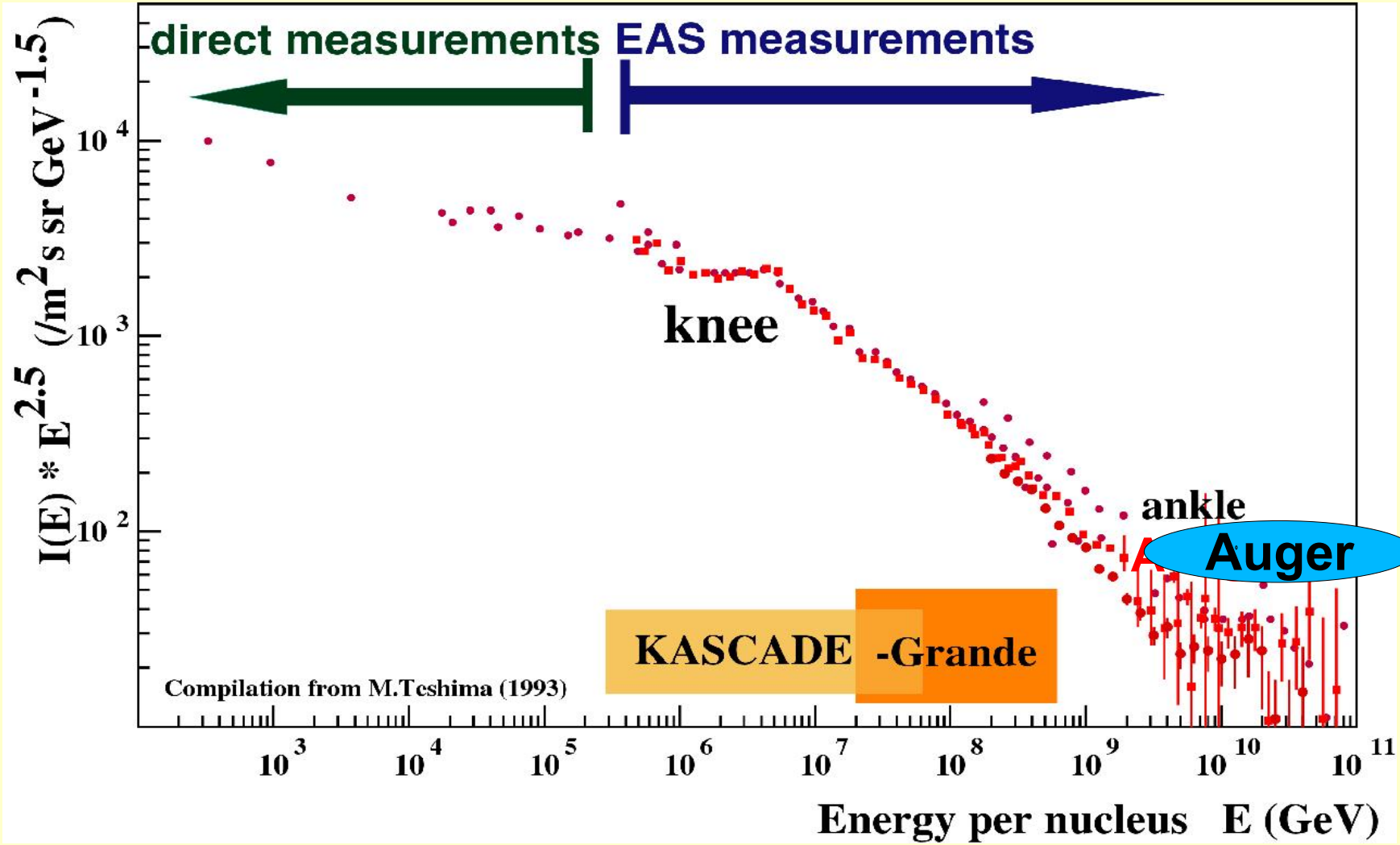
Studies of the Extensive Air Showers

Big international experiments with Polish participants:

1. **The Pierre Auger Observatory - South site in Argentina,**

2. **KASCADE-Grande - Forschungszentrum in Karlsruhe**

Energy spectrum x $E^{2.5}$ of Cosmic Rays



The Pierre Auger Observatory

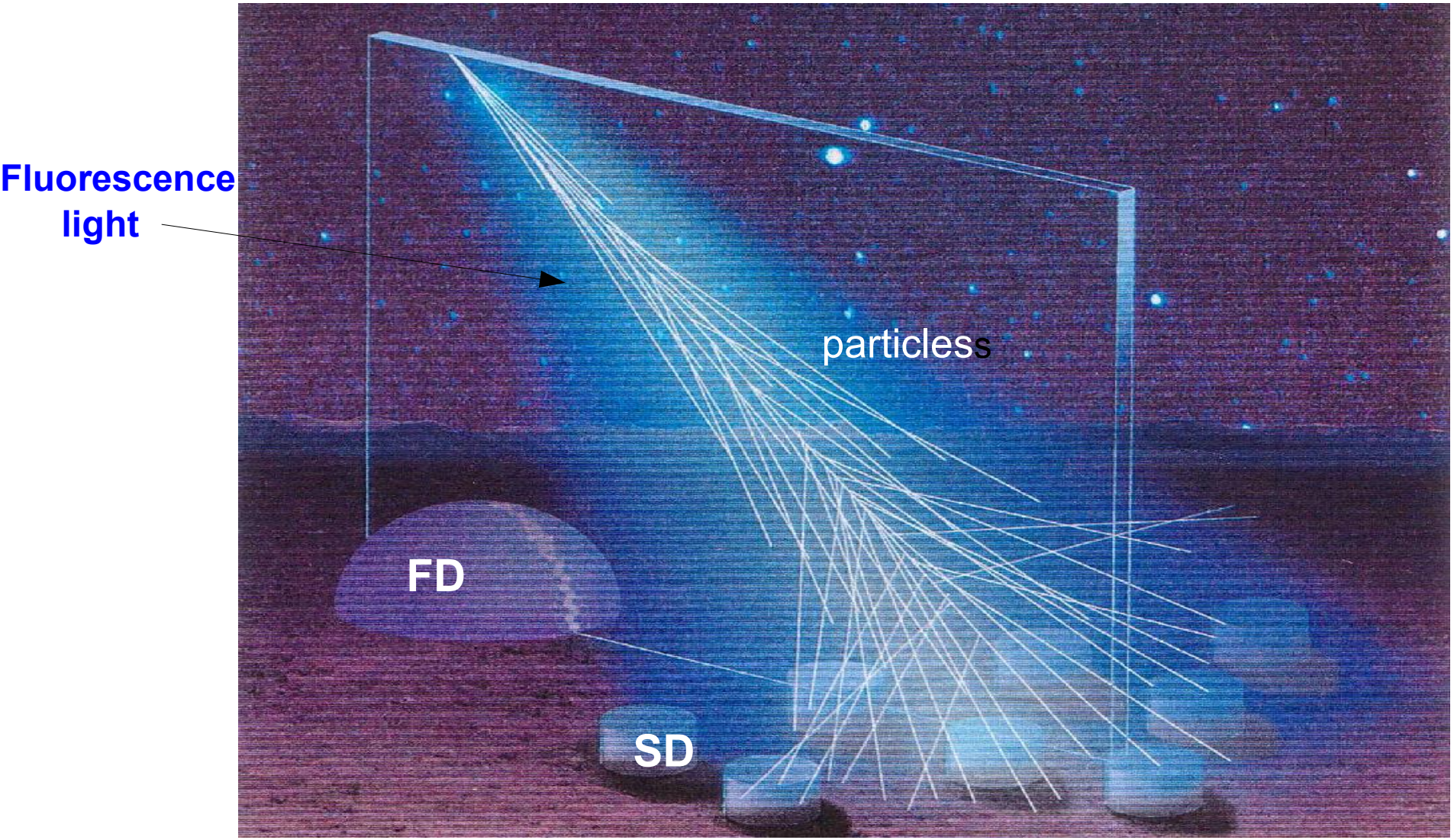
The Objectives are to measure
Ultrahigh Energy Cosmic Rays $E > 3 \times 10^{18}$ eV

- **energy spectrum** high statistics **is there the GZK cutoff?**
  Galactic/ extragalactic origin ;

- **direction distribution** full sky (with two sites) - **large scale anisotropy , point sources ;**

- **primary mass (?)** whole shower curve seen **origin !**

Artist View of an Extensive Air Shower



Previous experiments :

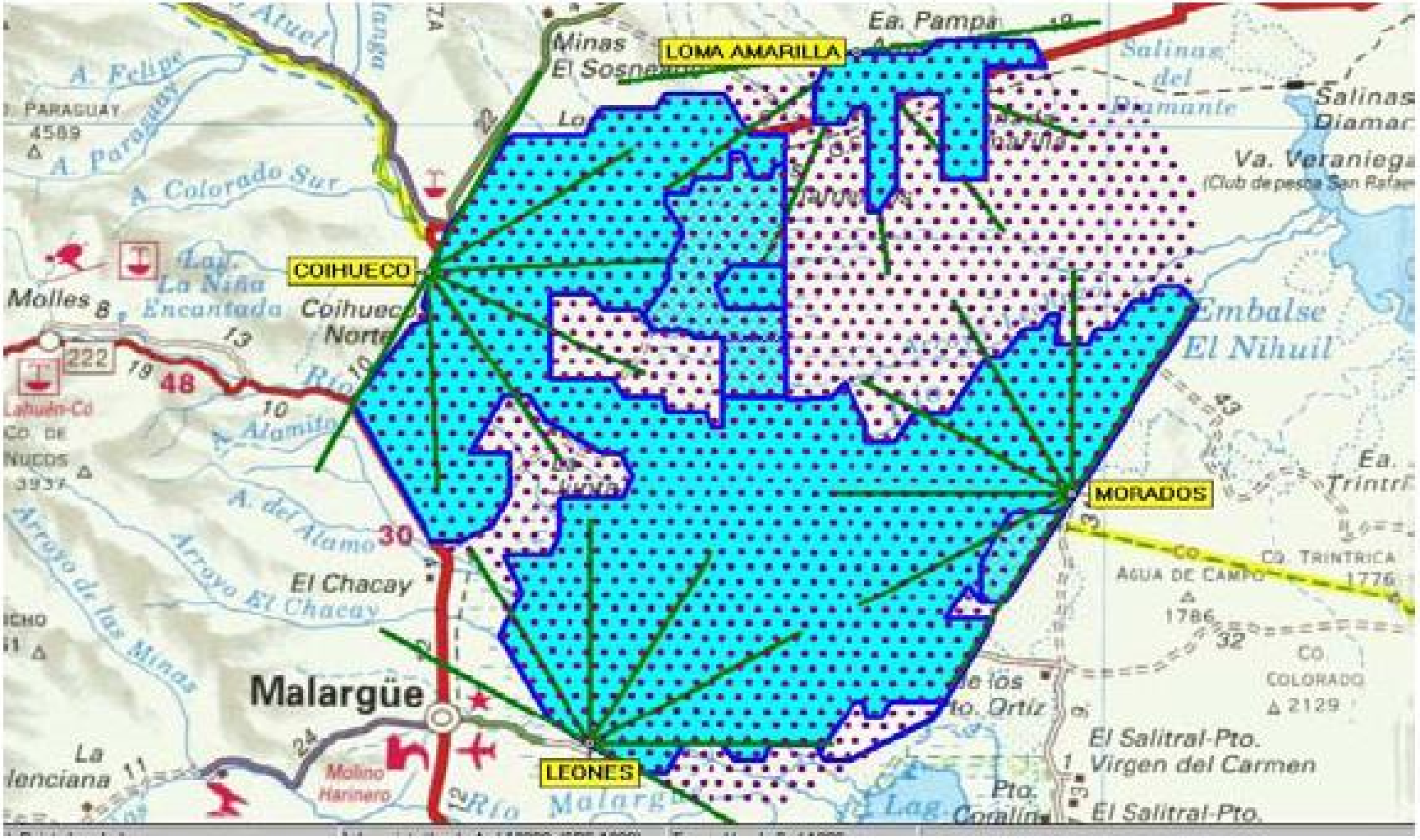
AGASA (Japan) has only particle detectors,
HiRes (USA) has only fluorescence detectors

The Pierre Auger Observatory has both !

↓

Possible calibration of SD with FD

The Observatory Plan (March 2006)

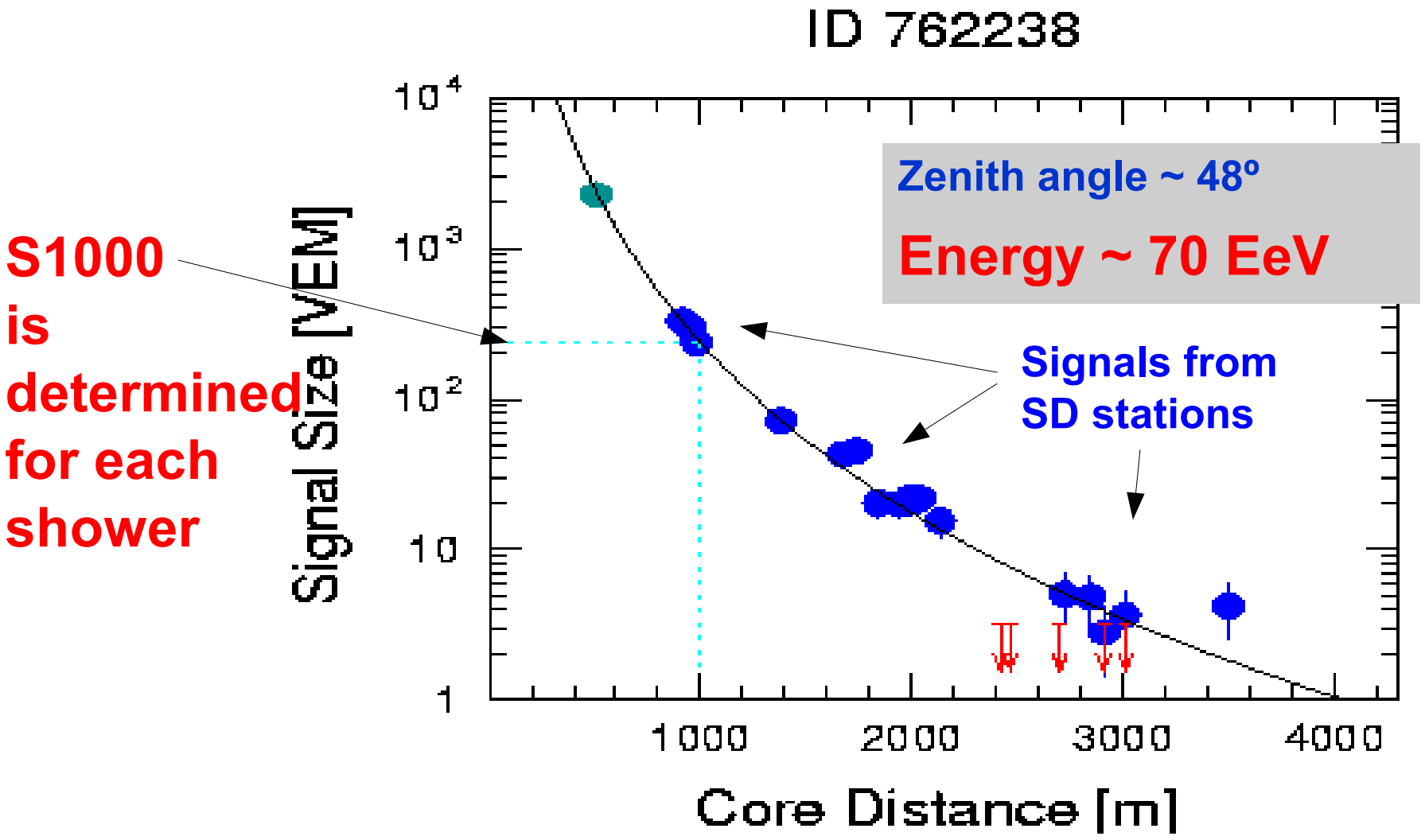


1600 water Cherenkov detectors, 1113 deployed, 953 working

4 Eyes: each has 6 telescopes (30∠x 30∠each) - 3 Eyes ready

One of 1600 particle detectors

Lateral distribution of signals in a shower



Evaluation of the Energy Spectrum

Assigning energy to the SD event - in two steps:

1. **S(1000) → S38 = S(1000) that the shower would have produced if it had arrived at zenith angle=38∠**

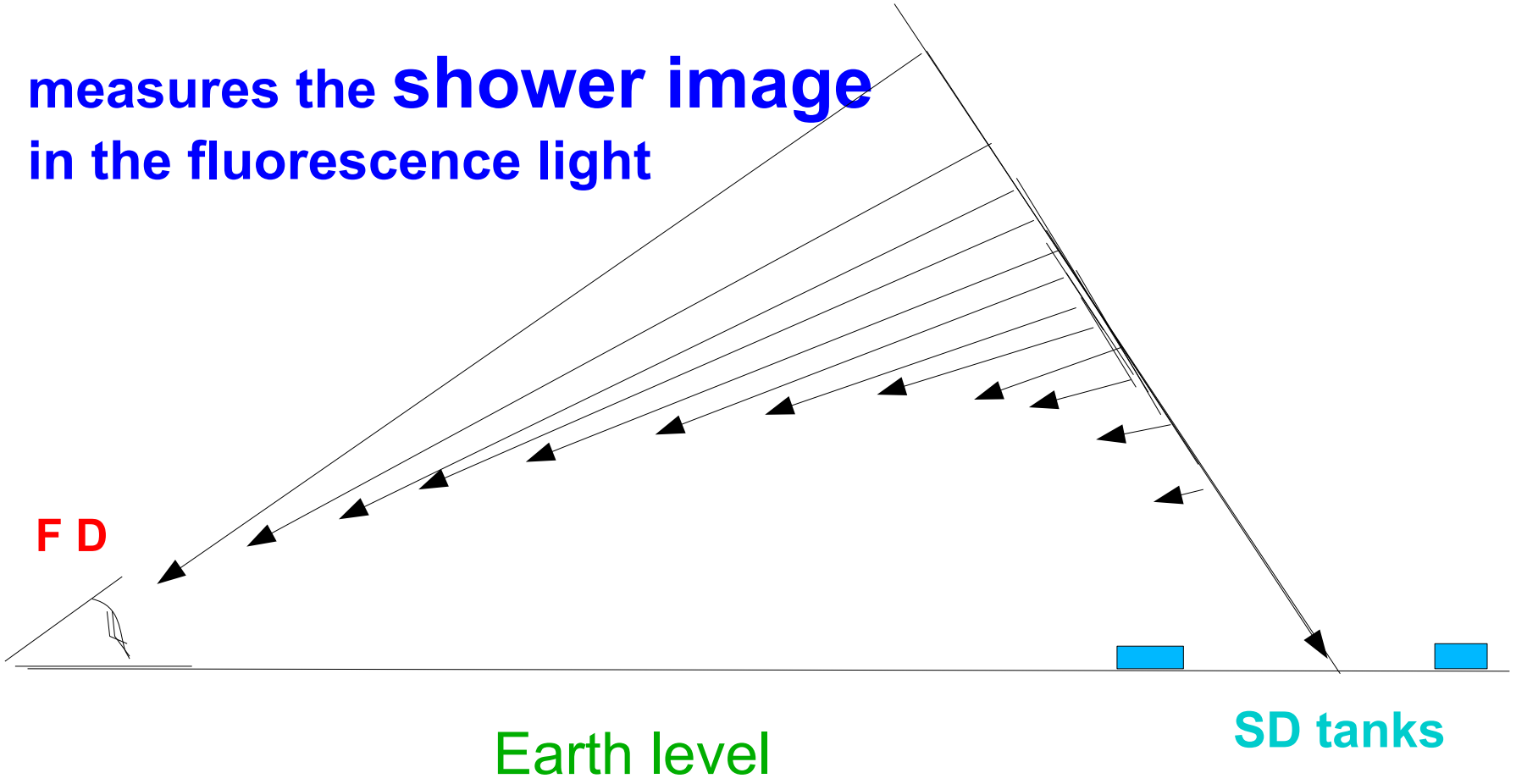
,

;

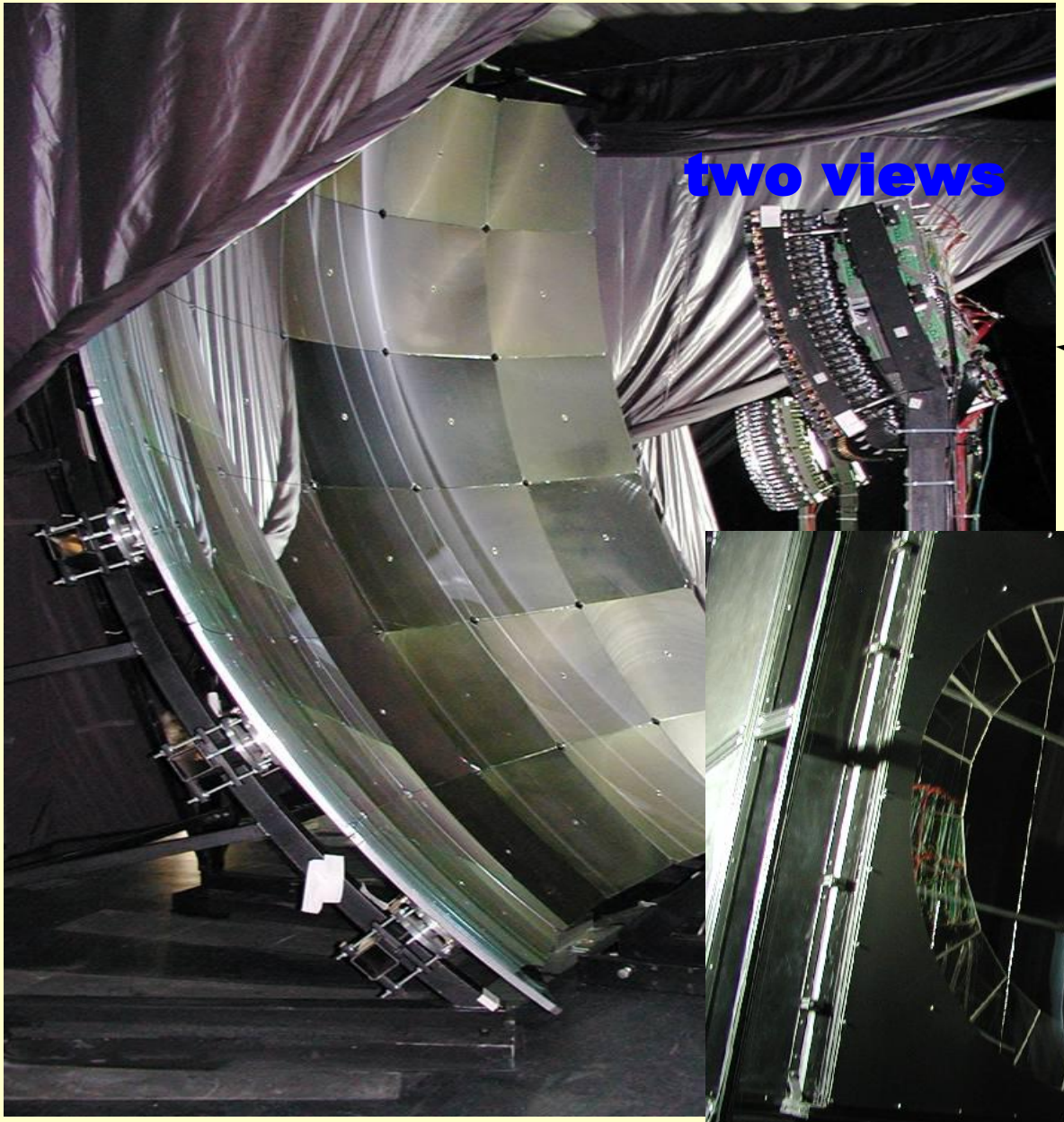
2. **S38 → Eo from SD calibration curve**
   obtained from hybrid shower sample

The Fluorescence Detector

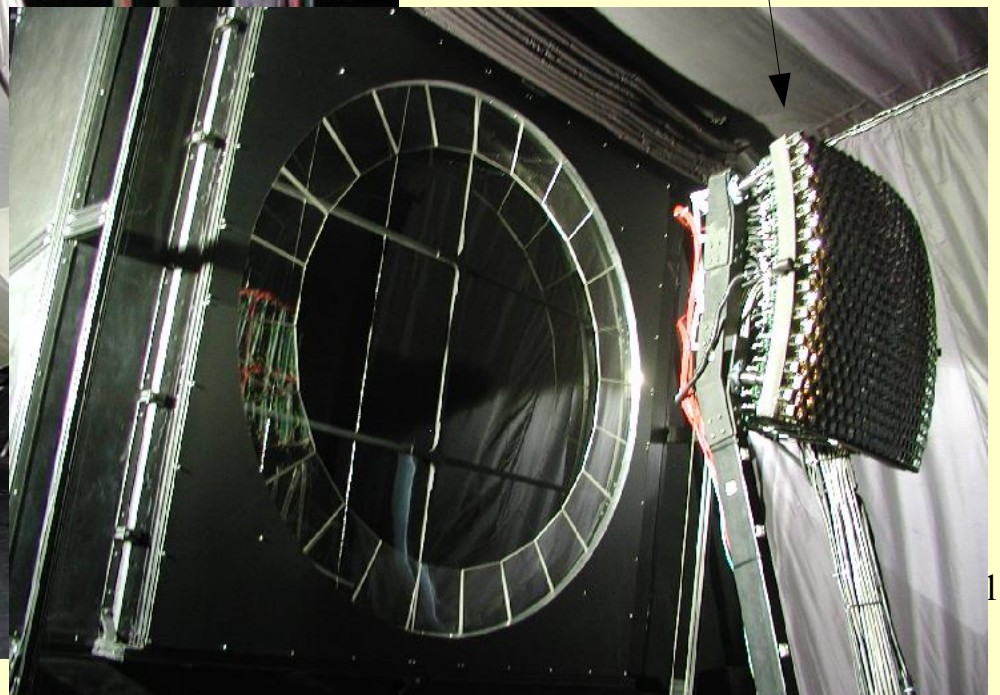
measures the **shower image**
in the fluorescence light

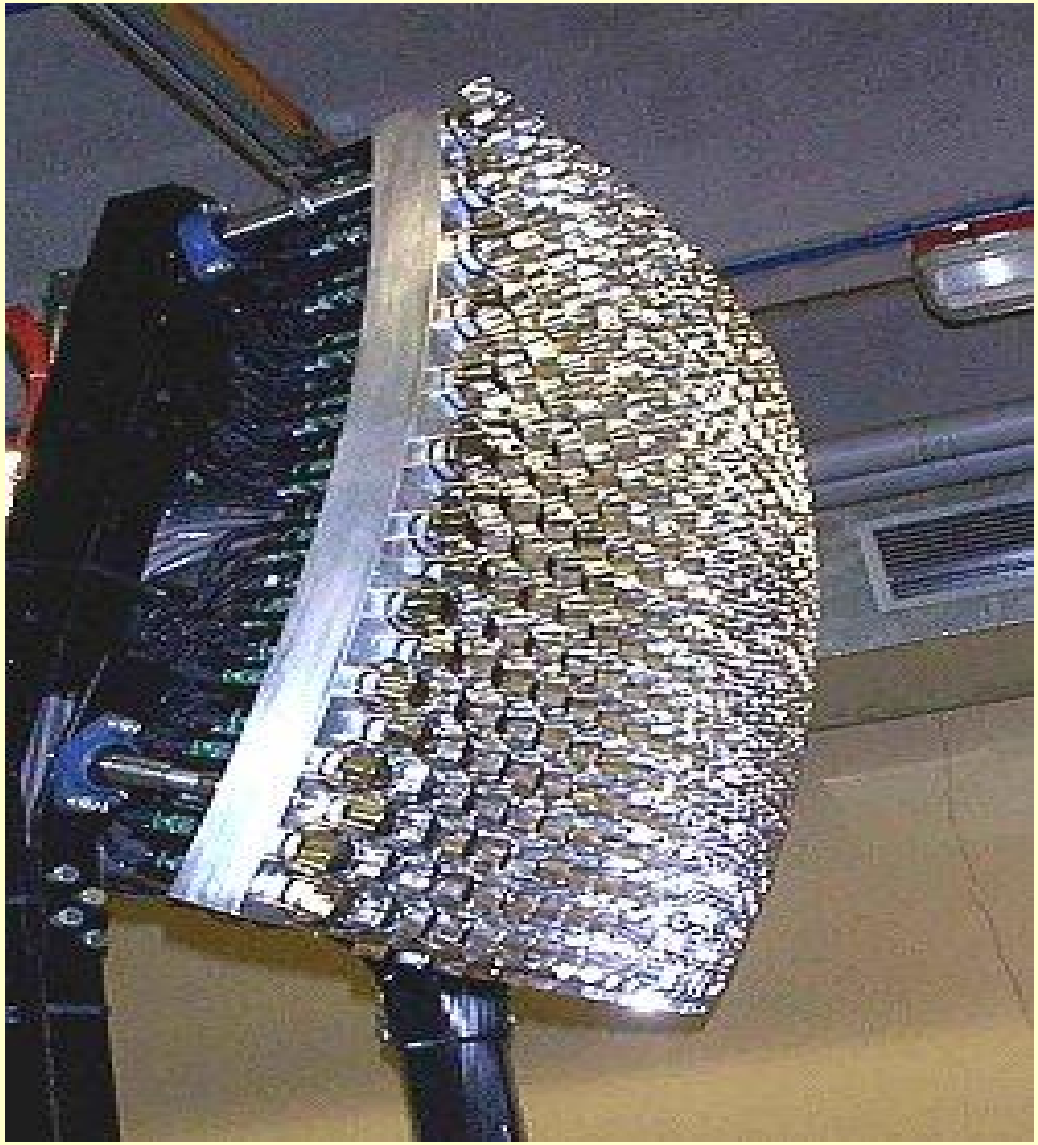


The Fluorescence Detector



440 PMT camera



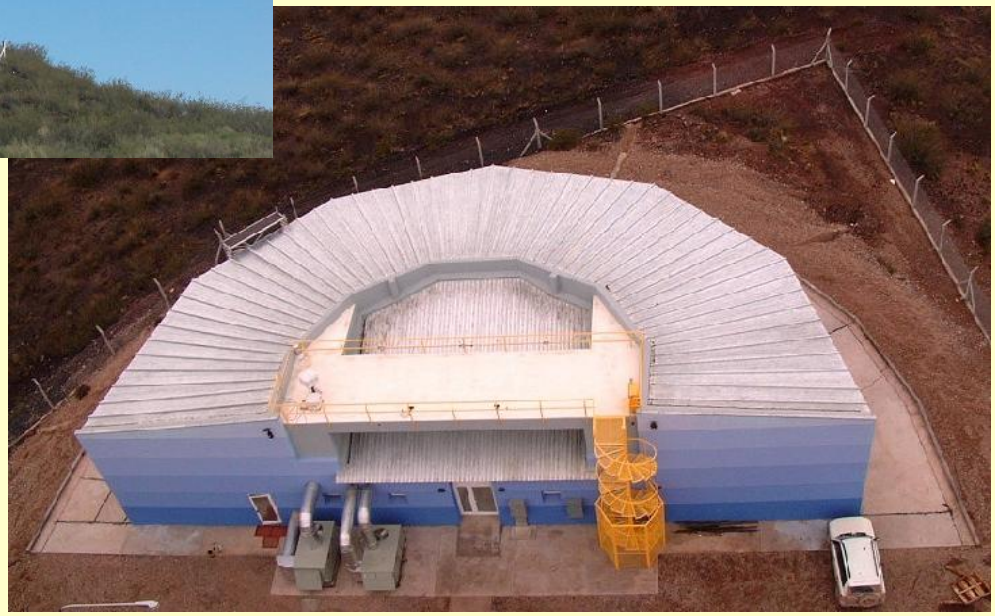


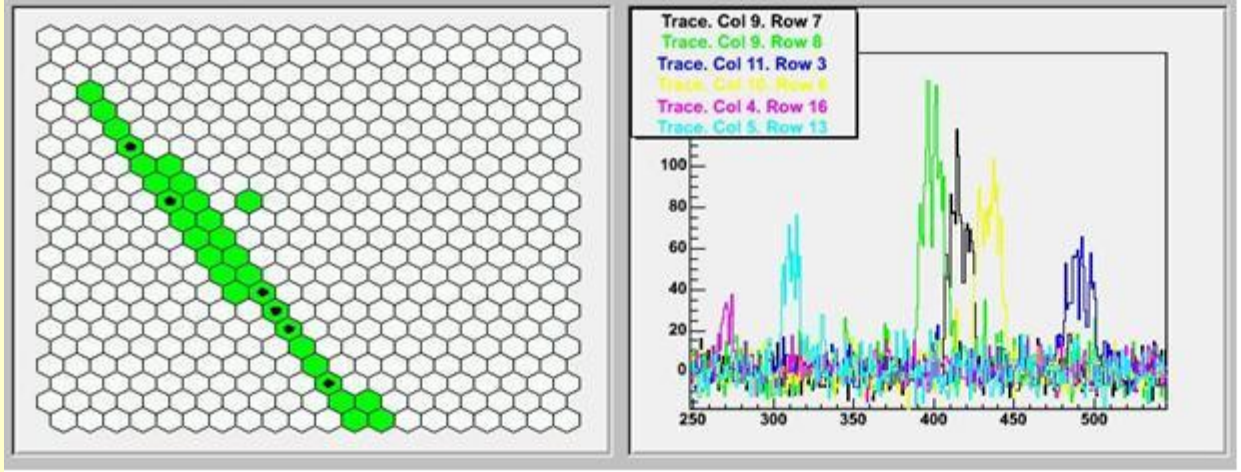
Camera of the telescope

440 PMTs
each 1.5∠ field of view

The Fluorescence Detector

Los Leones- one of the 4 FD

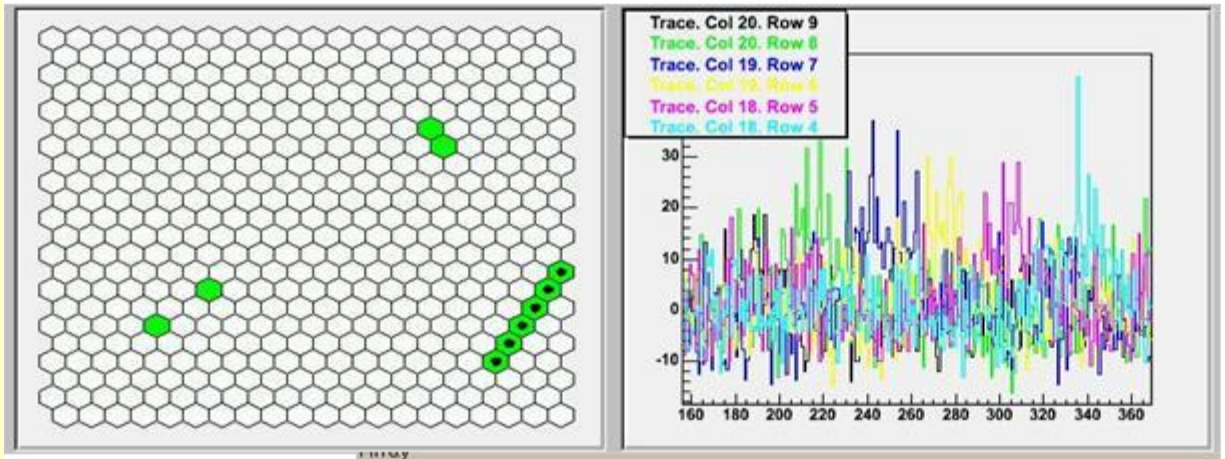


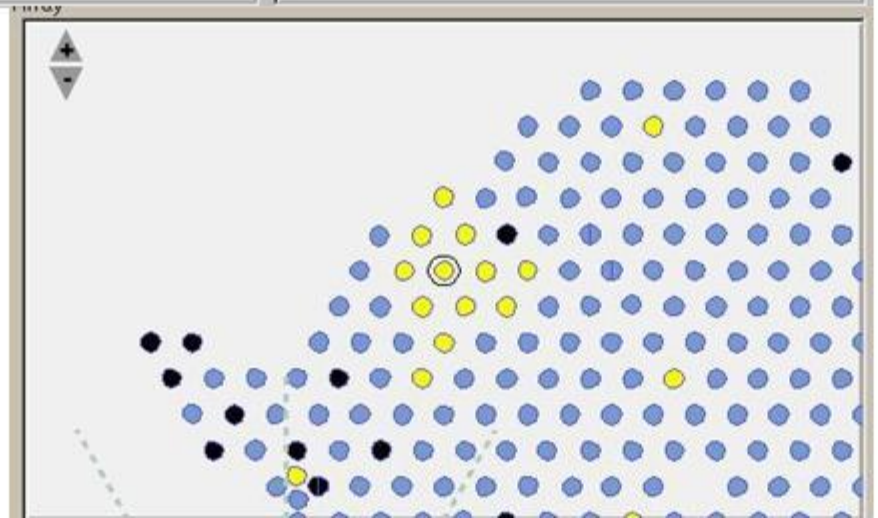


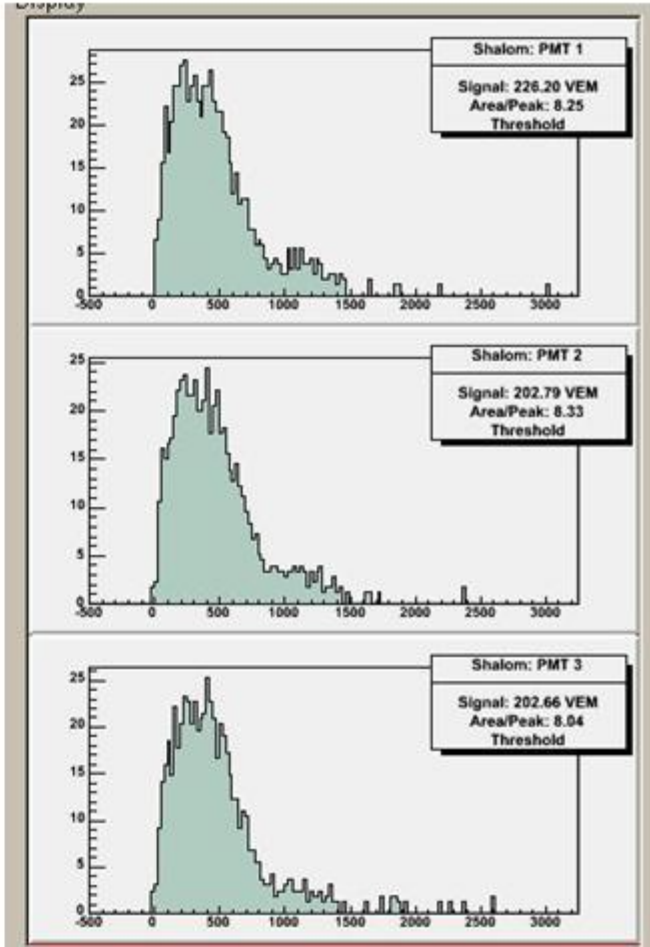
Platinum Event

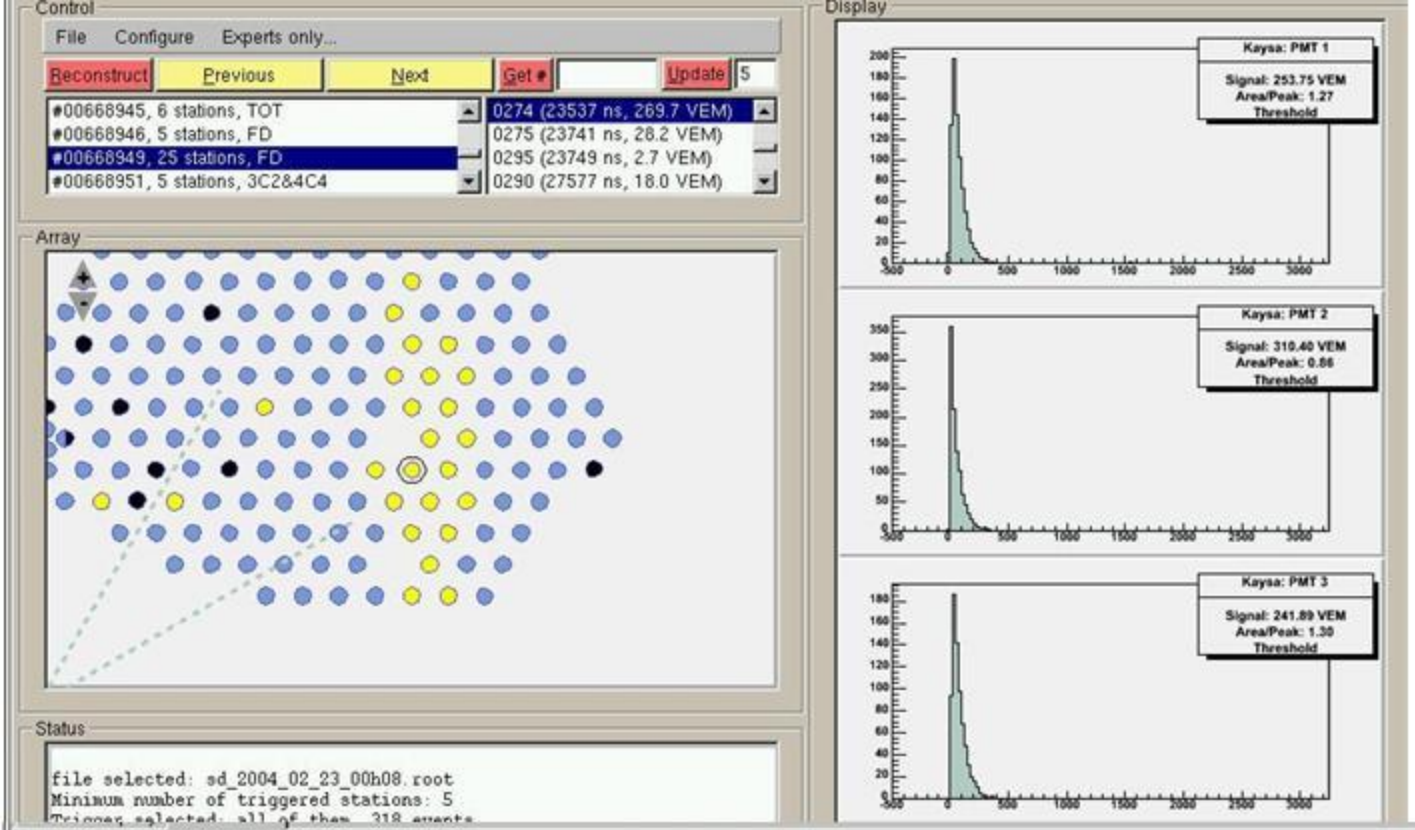
#673411

(10 tanks in fit)





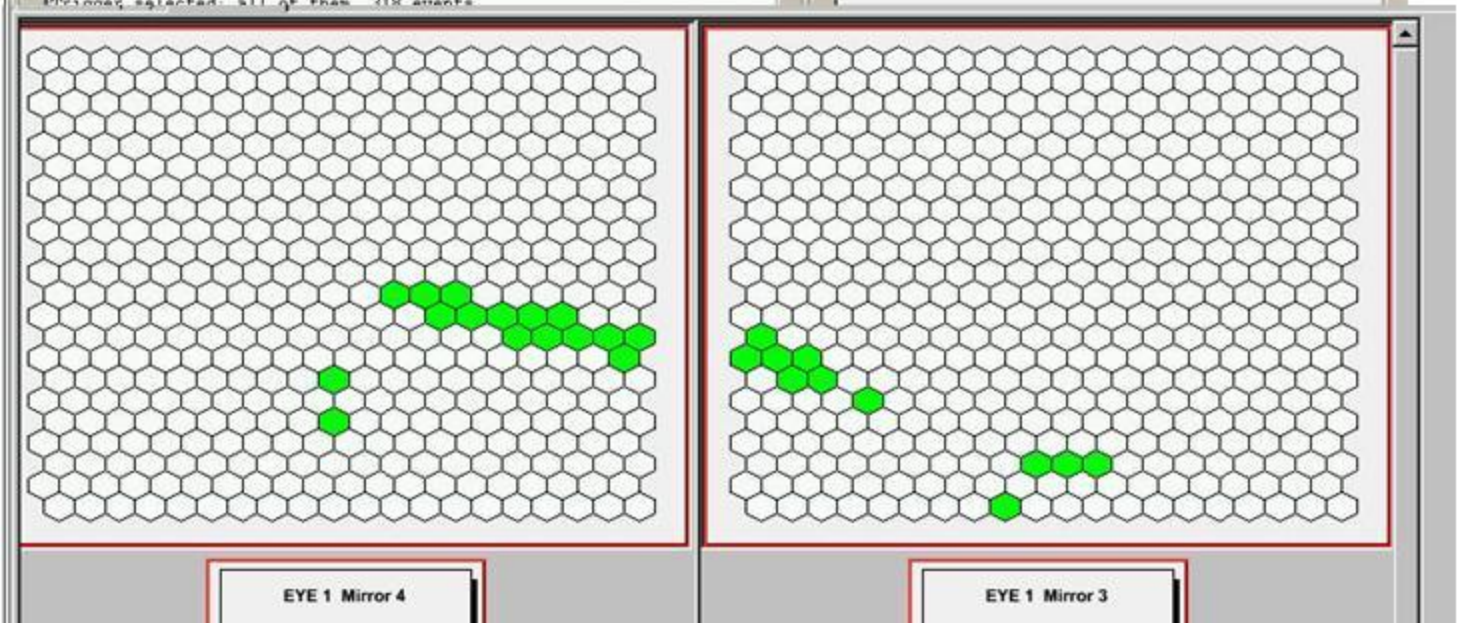




2-Telescope

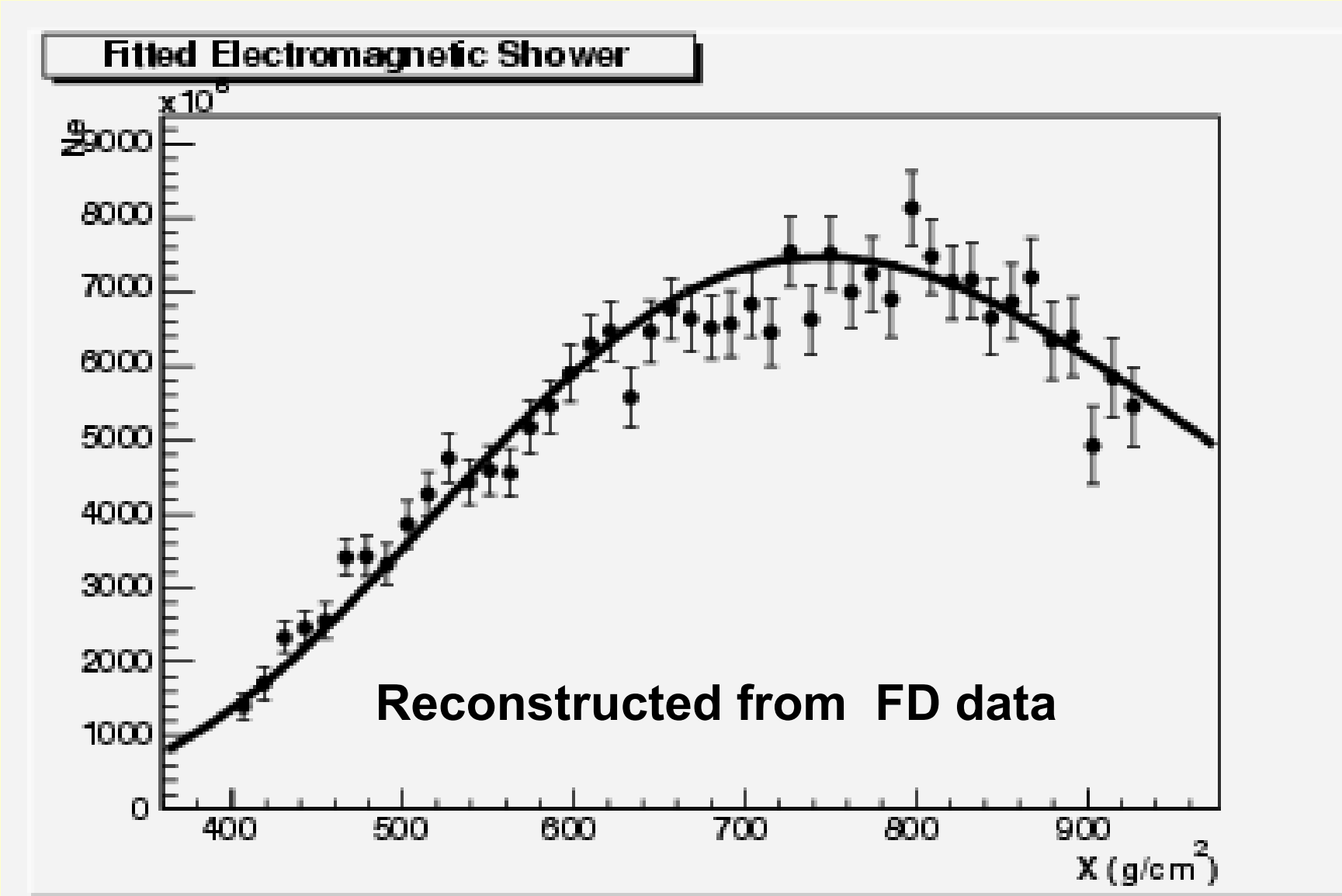
Golden Hybrid

Event #668949



Los Leones

Number of electrons vs depth X in the atmosphere



Calibration curve : S38 → Eo

logEo(**FD**) (EeV)

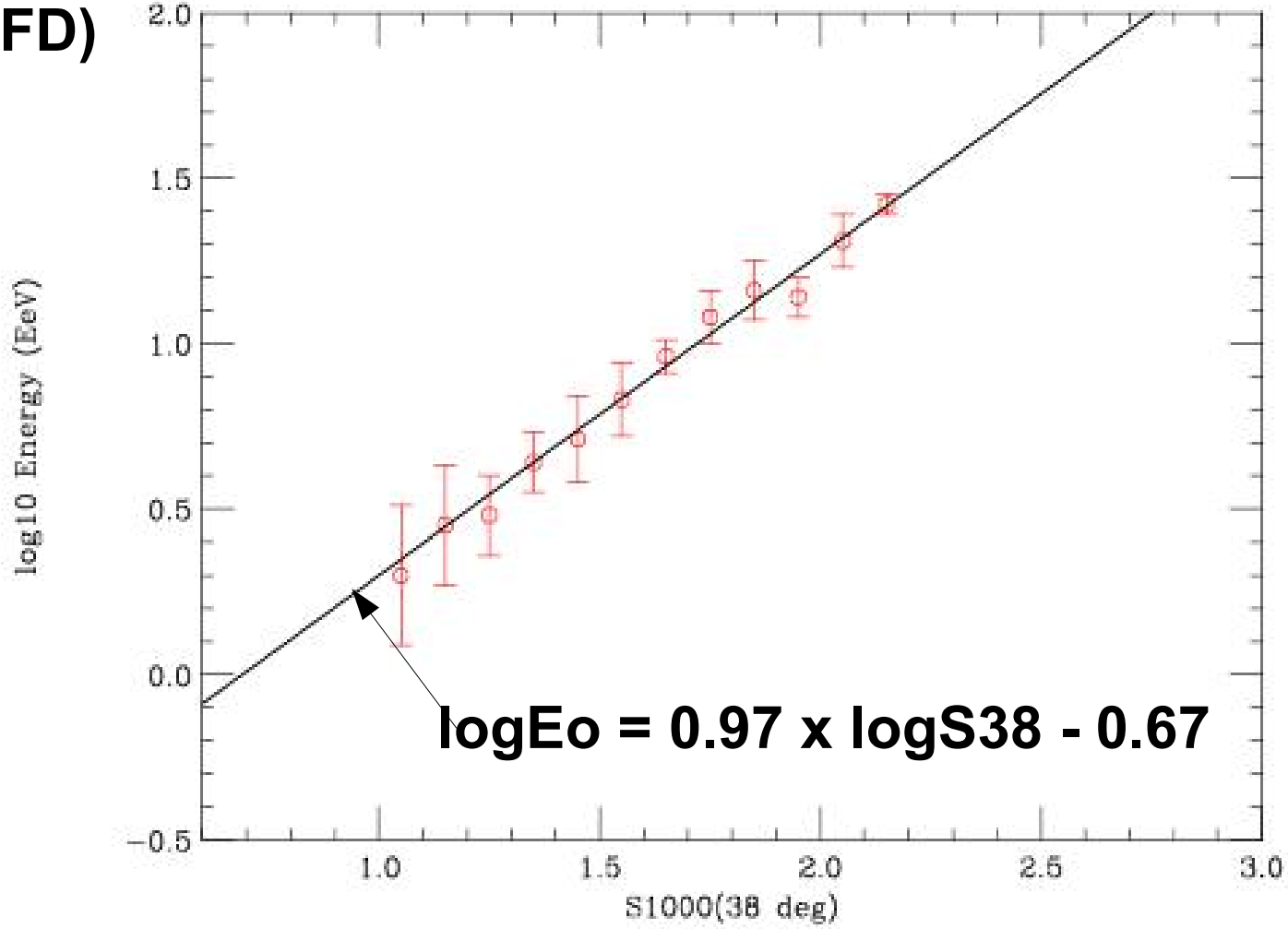
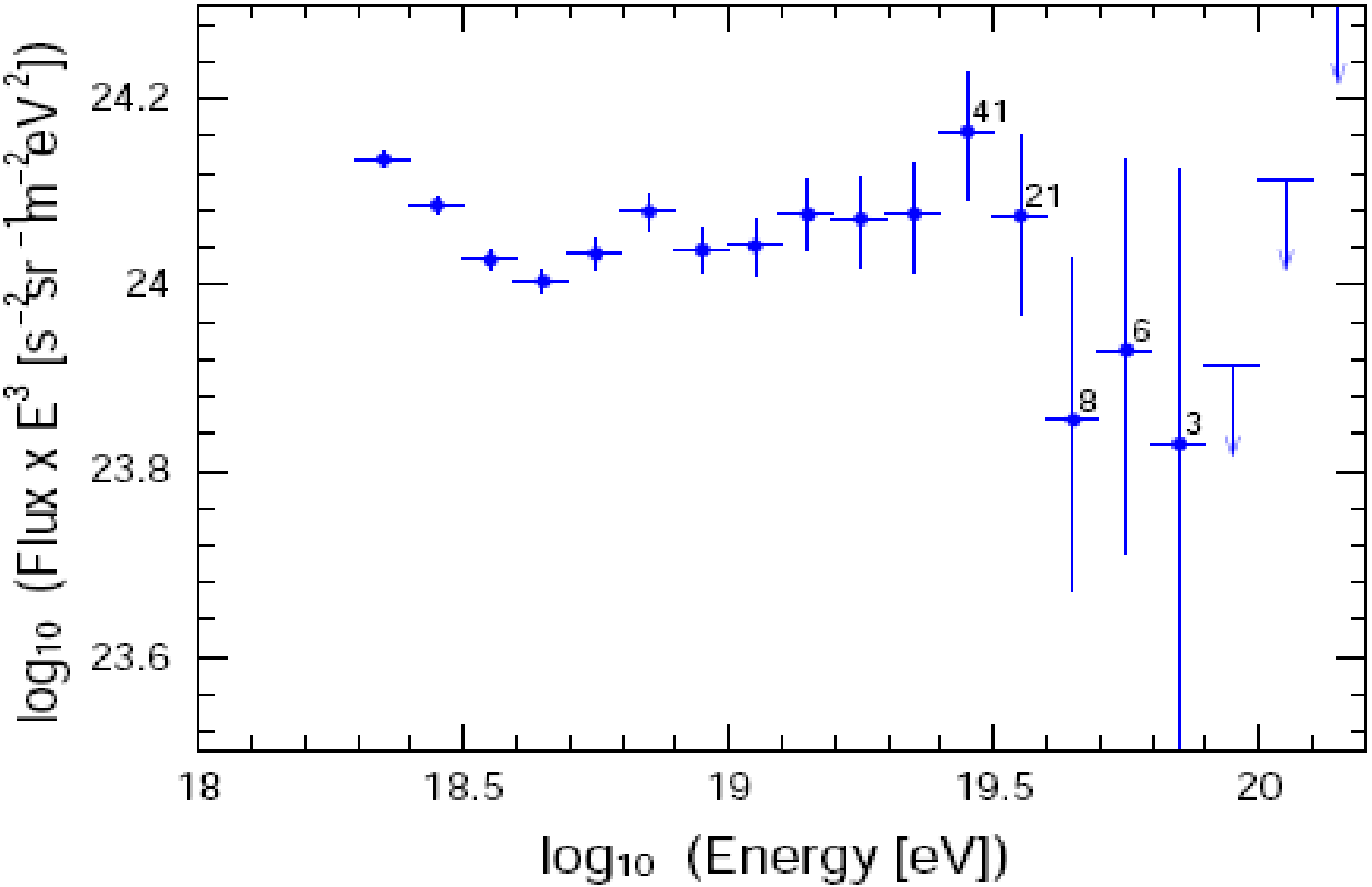
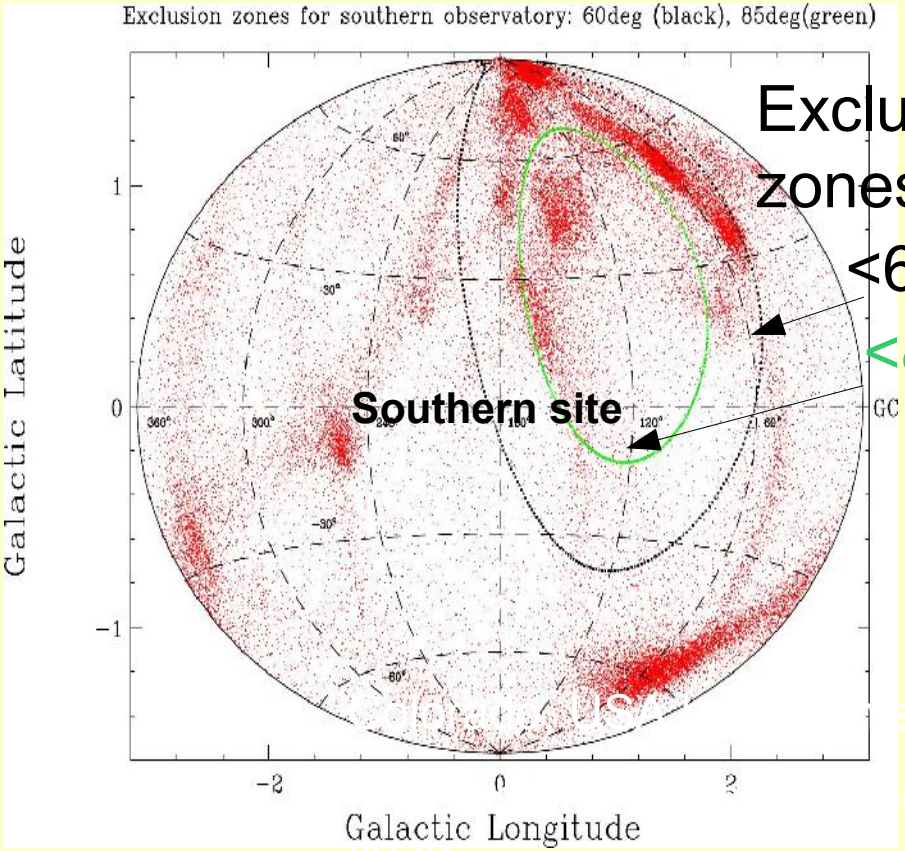


Figure 7: Plot of $\log_{10}$ FD energy vs $\log_{10}$ S1000(38°) for hybrid events binned in units of 0.1 in $\log_{10}$ S1000.

Auger energy spectrum x E^3



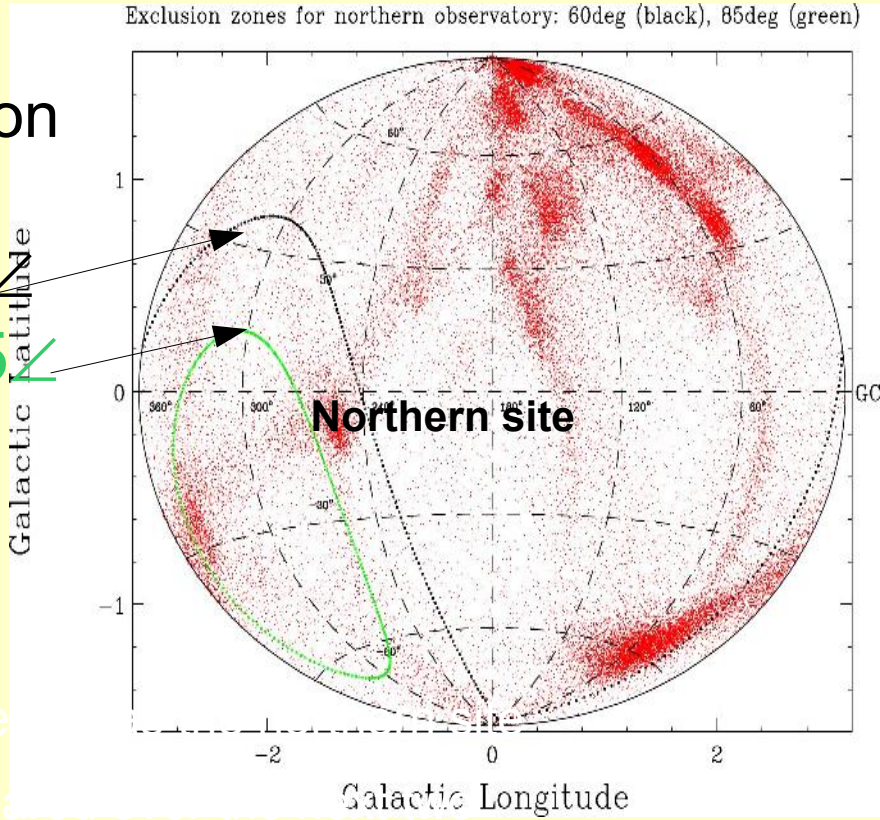
Galaxy Distribution
7-21 Mpc



Exclusion zones

<60∠

<85∠



Needed: Full sky coverage

Anisotropy Studies

- First search of the Southern Sky since SUGAR,

- 10 times bigger statistics,

- Galactic Center and Galactic Plane ?

No positive deviation from isotropy found
(so far)

Large scale anisotropies should be searched for in small energy bins - statistics still too small !

Photon Fraction for E>Eo

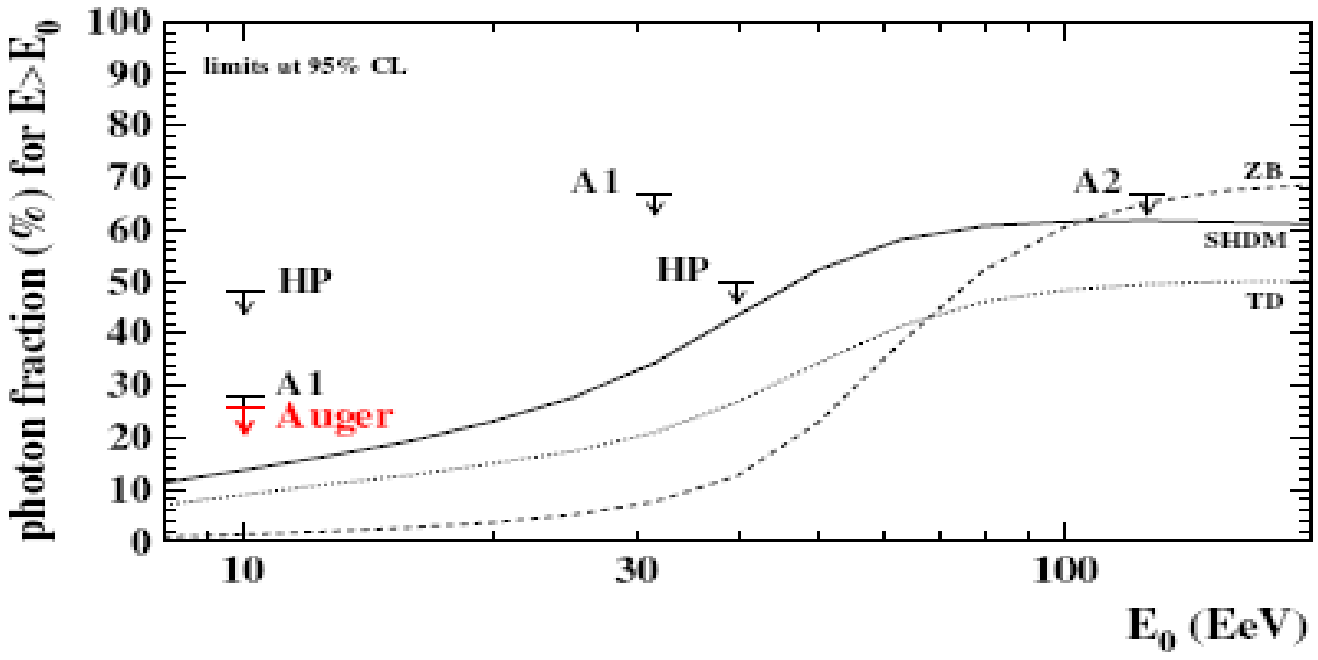
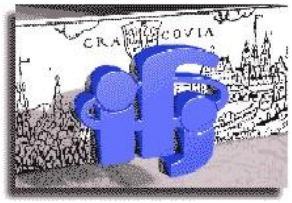


Figure 2. Upper limits (95% CL) on cosmic-ray photon fraction derived in the present analysis (Auger) and previously from AGASA (A1) [3], (A2) [4] and Haverah Park (HP) [2] data compared to some estimates based on non-acceleration models [1].



IFJ PAN Kraków
participation in Auger
9 people (1 PhD thesis, 1 in progress)

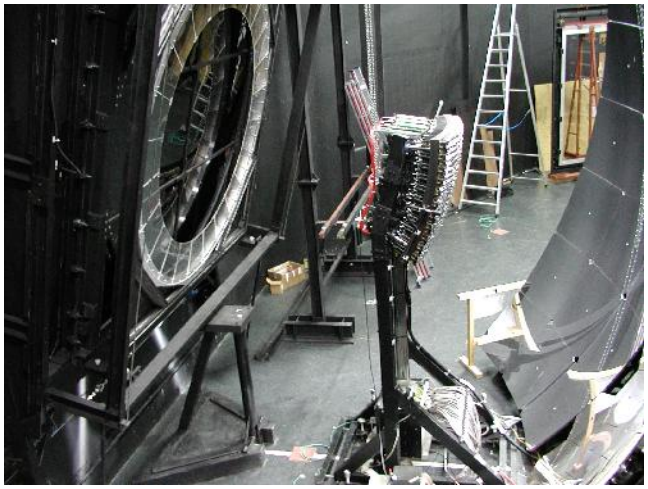
Construction of the Auger Observatory
- **parts of fluorescence detector hardware**

Improvements of cosmic ray detection and measurement technique: study of
- optical image of extensive air shower
- influence of variation of the atmosphere on shower detection
- scattering of light in the atmosphere

Data analysis
- data processing - shower reconstruction
- identification of photons in ultra-high energy cosmic rays

Study of particle acceleration in compact galactic sources

IFJ PAN participation in Auger - hardware



Construction of the Observatory:

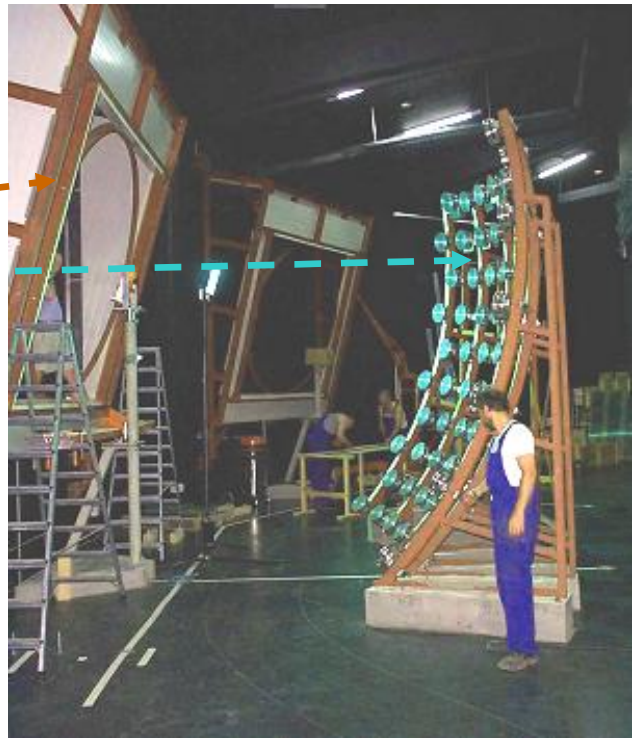
provided parts for mechanical structure

of the fluorescence detector telescopes

Aperture box structure

Mirror mounts

External shutters



Shower optical image in the fluorescence detector

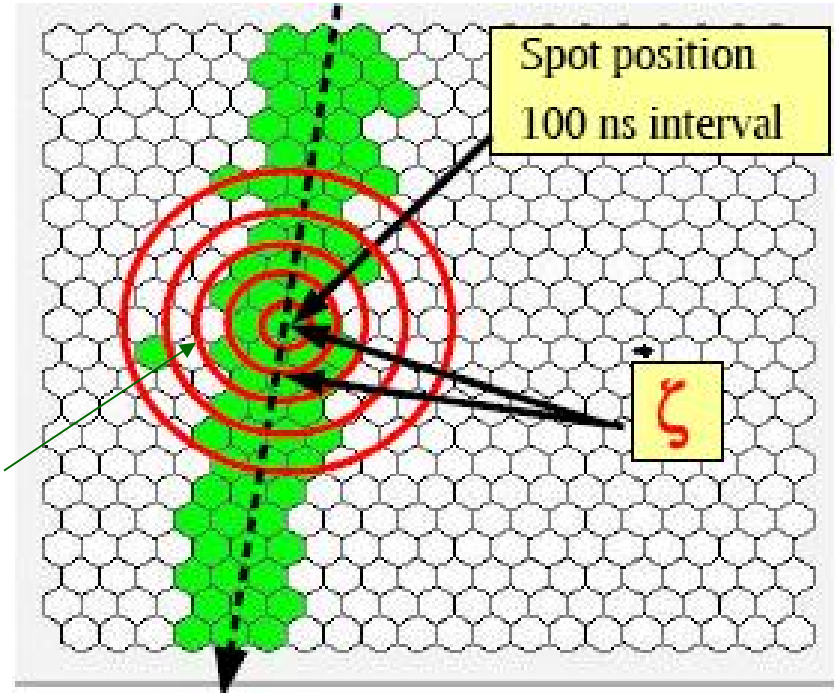
introduced improvements in shower description/simulation:

- shower as an extended source of light, instead of point source approximation;
- fluorescence signal proportional to ionization energy deposit, instead of number of particles

derived

- fraction of shower signal within integration angle ζ
- correction to procedure of shower energy determination

implemented the correction in shower reconstruction software



D.Góra et al., Astropart. Phys. 16, 129 (2001)
D.Góra et al., Astropart. Phys. 22, 29 (2004)
D.Góra et al., Astropart. Phys. 24, 484 (2006)

Variation of the atmosphere

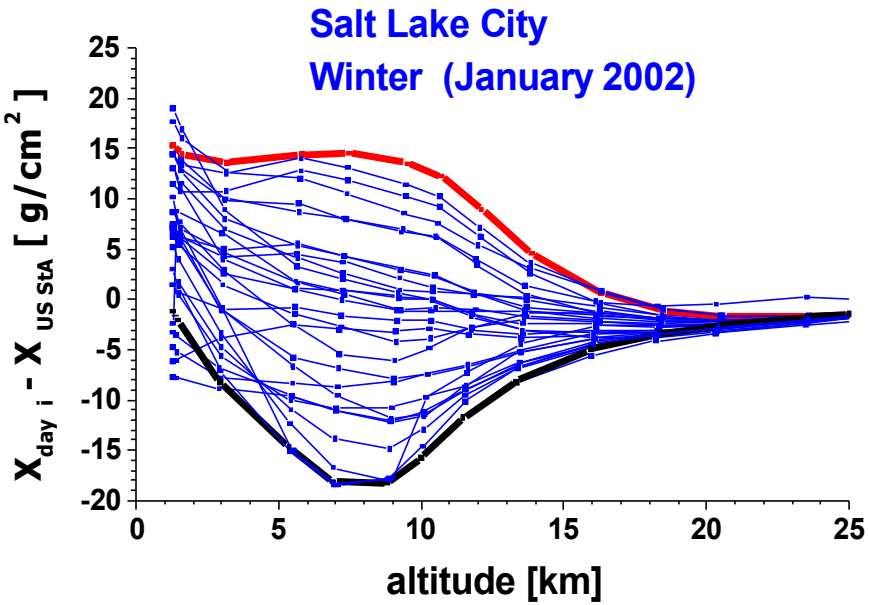
Analysis of balloon radiosounding data from UK MetOffice and local Auger measurements

Found large geographic and temporal variability of vertical profiles of the atmosphere:
- source of inaccuracies in shower reconstruction

The monthly models of the atmosphere introduced into the Auger database for shower reconstruction

B.Wilczyńska et al.,
Astropart. Phys. 25, 106 (2006)

Difference of measured atmospheric depth and that of US Standard Model



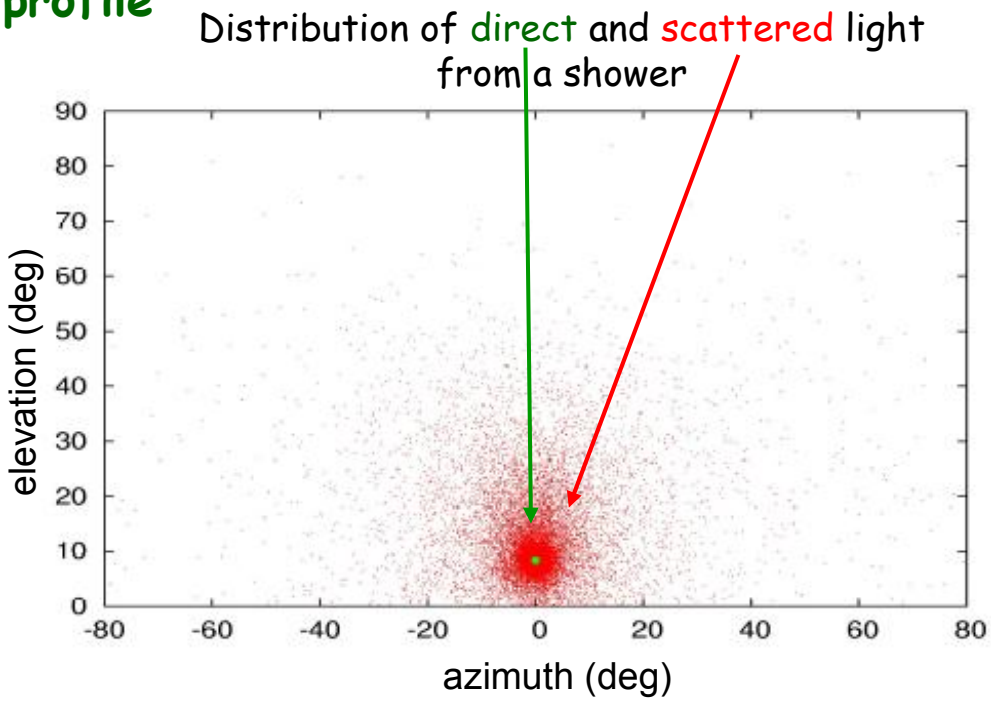
Atmospheric scattering of light

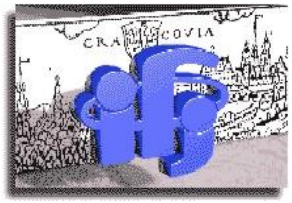
A comprehensive study of atmospheric scattering of light emitted from air shower:

- scattering of both fluorescence and Cherenkov light
- scattering on air molecules and on aerosols
- account for multiple scattering
- account for varying aerosol distribution
- account for varying atmospheric profile
-

Work in progress; results so far in

J.Pękala et al., Proc. 28th ICRC, Tsukuba, 2, 551 (2003)
J.Pękala et al., Proc. 29th ICRC, Pune, 7, 207 (2005)

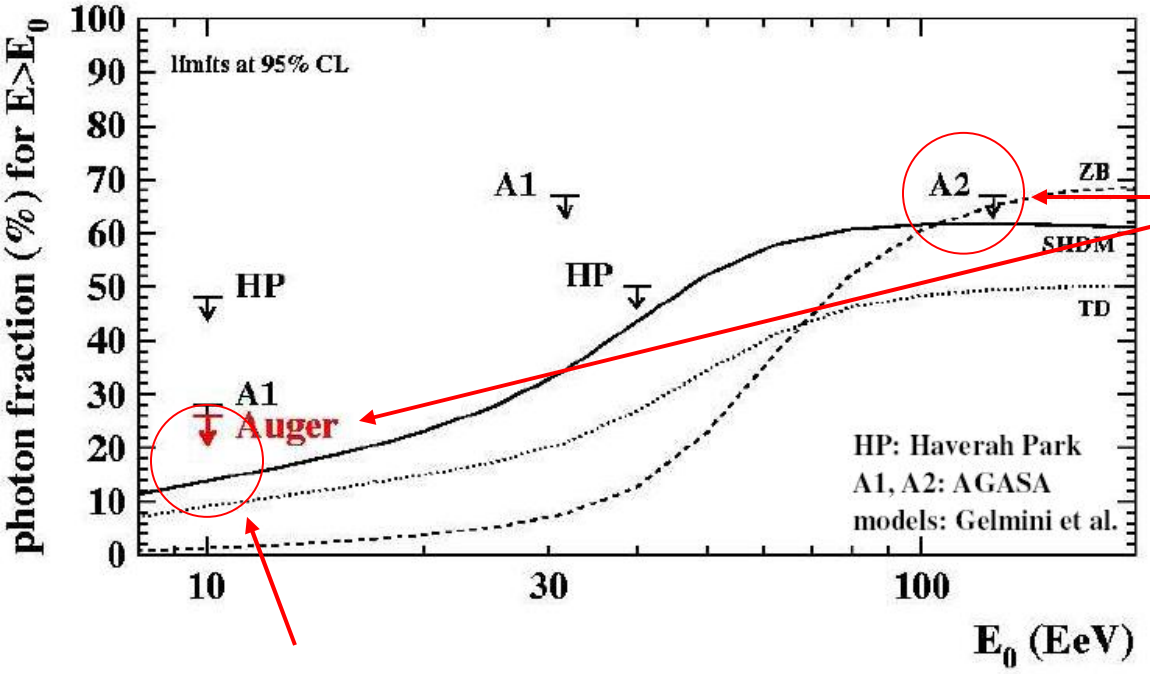




Photon limit in UHECR

application of preshowering simulation to analysis of Fly's Eye, AGASA and Auger data

Current experimental limits on photon fraction



A1,A2: from AGASA data
HP: from Haverah Park data

circled: limits derived using our preshower analysis

One of the first science results from Auger

M.Risse et al., Astropart. Phys. 21, 479 (2004)
M.Risse et al., Phys. Rev. Lett. 95, 171102 (2005)
M.Risse et al., Proc. 29th ICRC, Pune, 7, 147 (2005)

University of Łódź - Contribution to the Pierre Auger Experiment

9 people (2 PhD in progress)

1. **Reconstruction methods of the shower cascade curve Ne(X) from Fluorescence detectors data ;**

2. **Design and prototype construction of electronic systems for trigger of the Auger detectors (both FD and SD) – in collaboration with:**
   Forschungszentrum Karlsruhe,
   Michigan Technological University,
   Wuppertall University

Ad.1
Reconstruction methods

a) all showers are similar -
if described by age parameter
(distributions of energy, angle and lateral distance of electrons at a given level in the atmosphere depend on shower age only!)

→ Allows to predict **exactly**
total light (Fl and Ch) emitted from any point on the shower once Ne(X) is assumed *M.Giller at al. J.Phys .2004 and 2005*

b) Analytical solutions of the multiple scattering of light
(from shower to detector) *M.Giller and M A.Śmiałkowski -conf.paper*

c) Numerical studies of shower image width (different effects),
M.Giller at al. Astroparticle Phys.2003

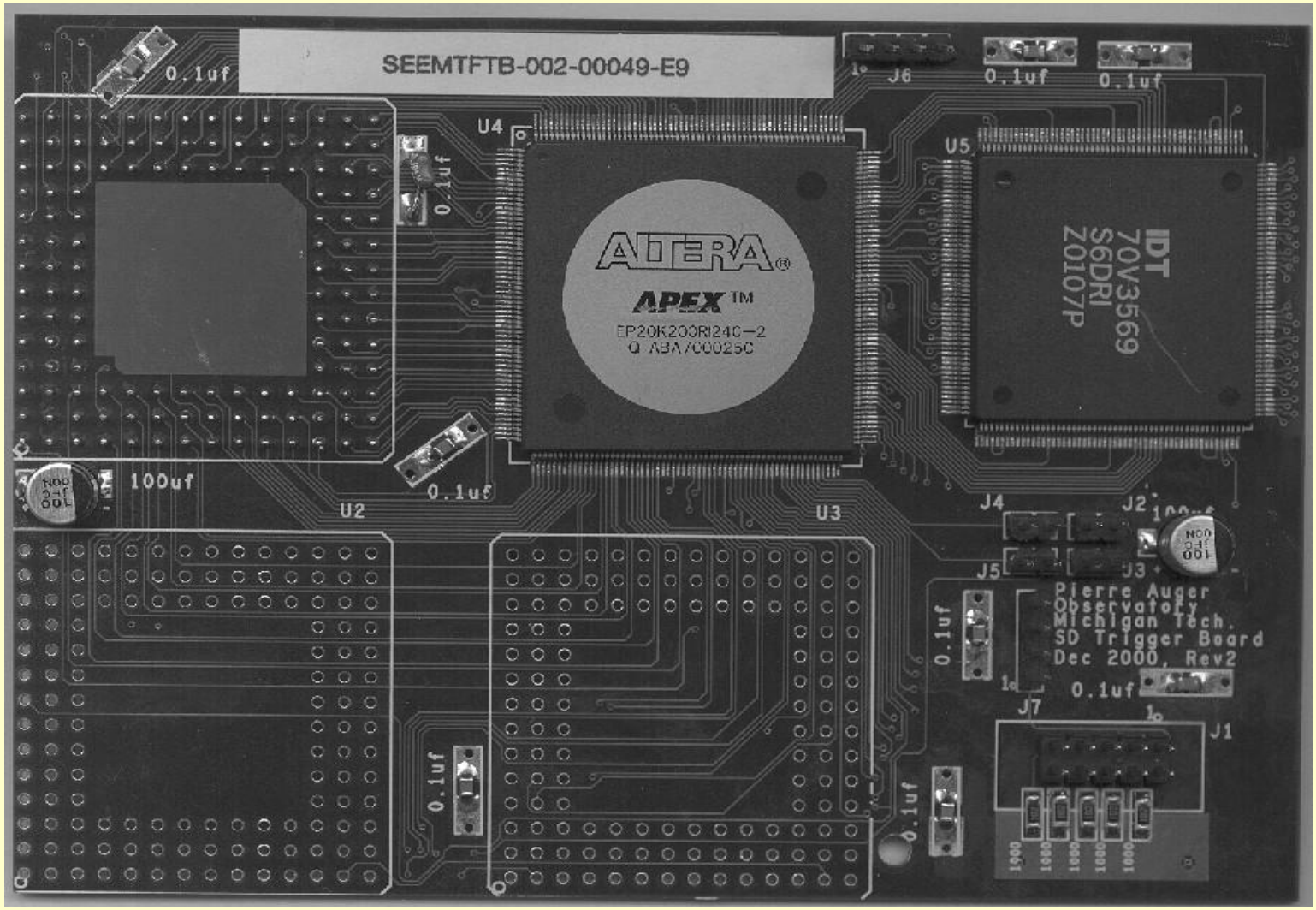
University of Łódź - Contribution to the Pierre Auger Experiment, cntd

2. Design and prototype construction of electronic systems for trigger of the Auger detectors

a) Design of second level trigger for Fluorescence Detectors,
b) Design of first level trigger for Surface Detectors (PLD chips –- APEX and ACEX),
c) More sophisticated design of new triggers (FFT) for SD (FPGA chips - Cyclone)

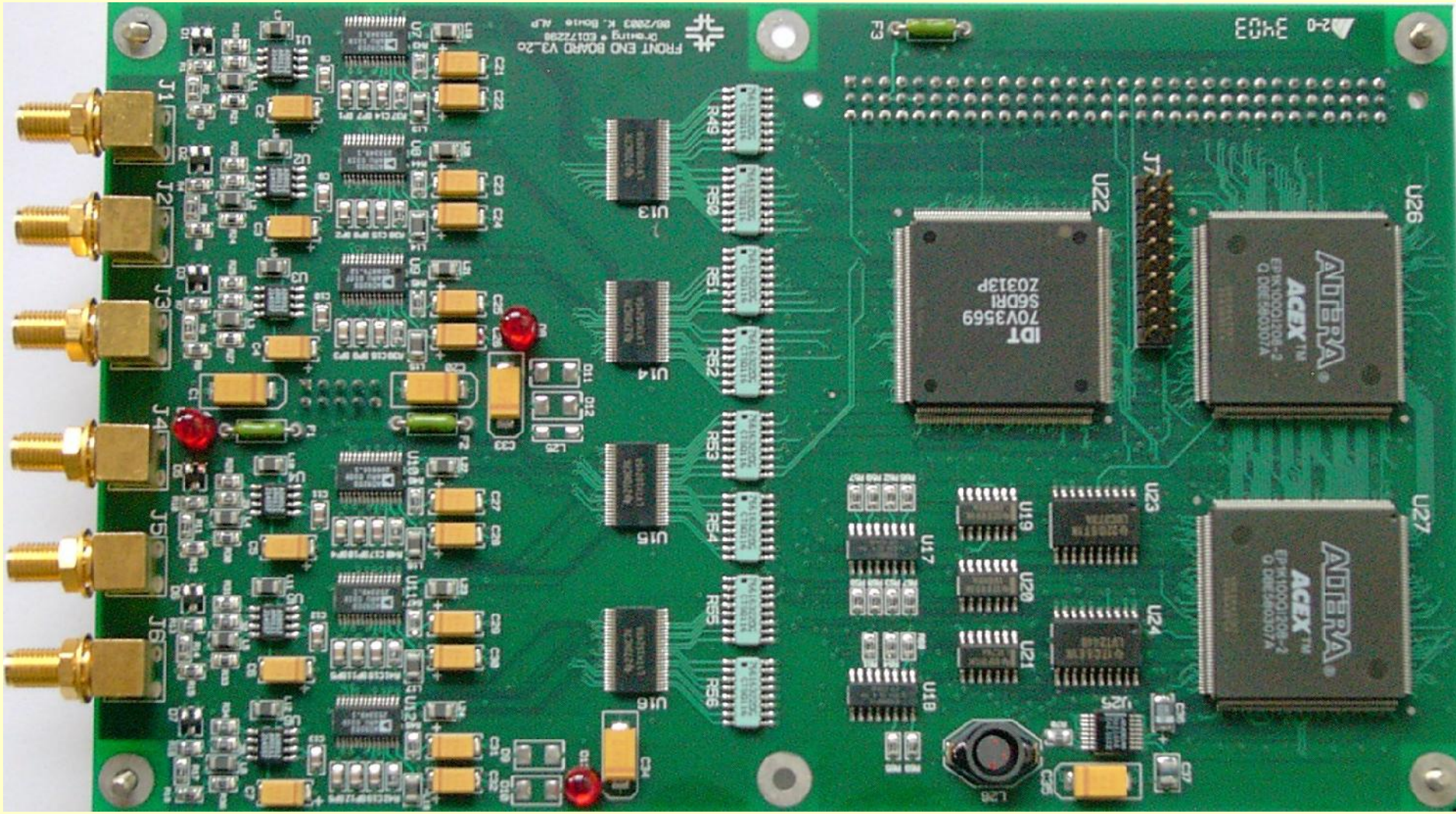
Surface detector trigger board - APEX, with Michigan Tech.Univ.

Working in the Engineering Array



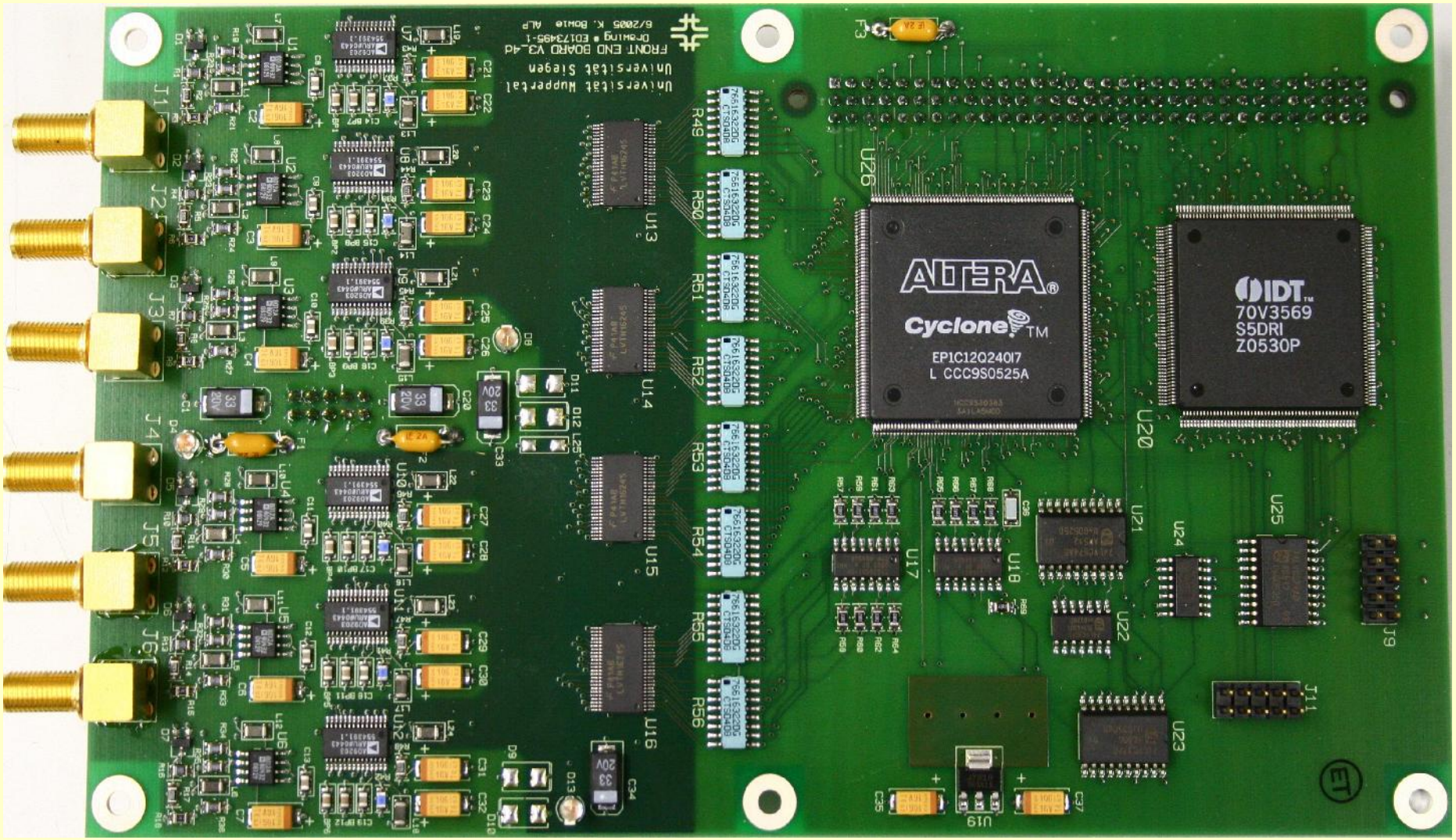
Z.Szadkowski , D.Nitz - NIM 2004

Front End Board (cost effective design)- with two ACEX chips working in ~ 900 tanks of the surface array



Z.Szadkowski- NIM 2005

Front End Board - with Cyclone chips (University of Wuppertal) to work with the rest of tanks



Z.Szadkowski, K-H.Becker, K-H.Kampert –– NIM 2005

Summary

of the Auger part

New SD detectors are being deployed,
Fourth Eye (FD) - in progress,
Statistics is growing quickly,
Analysis methods have been improving all the time

↓

The Non/ Existence of the GZK cutoff will be solved soon!

IPJ – The Andrzej Sołtan Institute for Nuclear Studies
Cosmic Ray Laboratory ,– Łódź

- **Experimental studies in high energy cosmic rays (CR):**
  - **The Roland Maze Project – school based network of CR detectors**
  - **methodical studies of Extensive Air Showers: registration of neutron component**
  - **registration of muon flux variation - "Space weather"**

Facilities :

(shared with University of Łódź)

- **Extensive Air Shower array triggered above 10^{14}eV**
- **60m^2 underground (15m) laboratory (low background registrations, muons E>5 GeV)**
- **directional underground muon telescope**
- **electronical, mechanical, glass workshops**

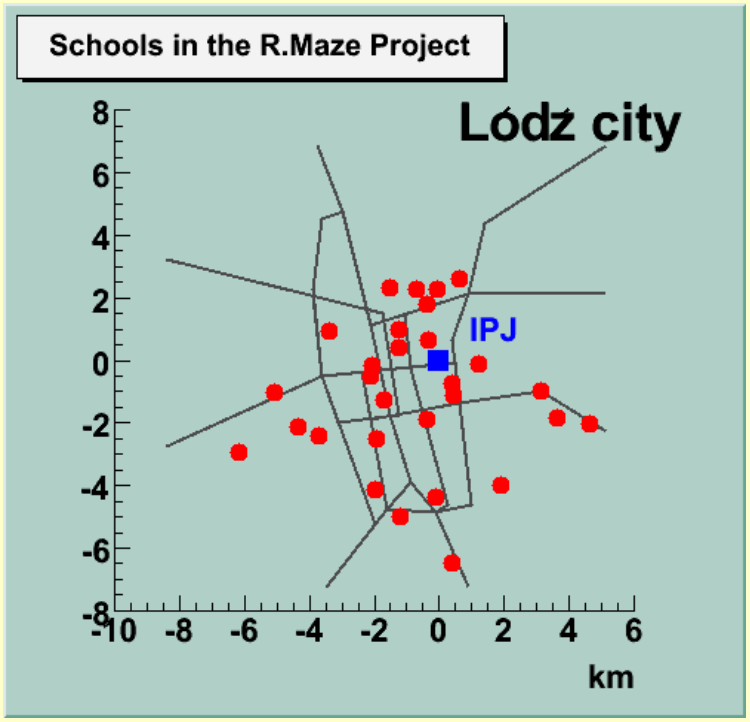
IPJ – The Andrzej Sołtan Institute for Nuclear Studies
Cosmic Ray Laboratory – Łódź

The Roland Maze Project -
network of cosmic ray detectors at high schools in Łódź

Plan: 30 schools
Ist stage: 10 schools

Science + Education
students participate in experiment

Assembling 1m^2 detector:



scintillator ← IHEP Protvino (Russia)

selfmade electronics
cost ~ 7000 Euro / school unit
~ 1000 Euro / 1m^2 detector

IPJ – The Andrzej Sołtan Institute for Nuclear Studies
Cosmic Ray Laboratory – Łódź

CERN COURIER

May 2006:

European network of the school based cosmic ray experiments: **EuroCosmics**

First meeting at NIKHEF

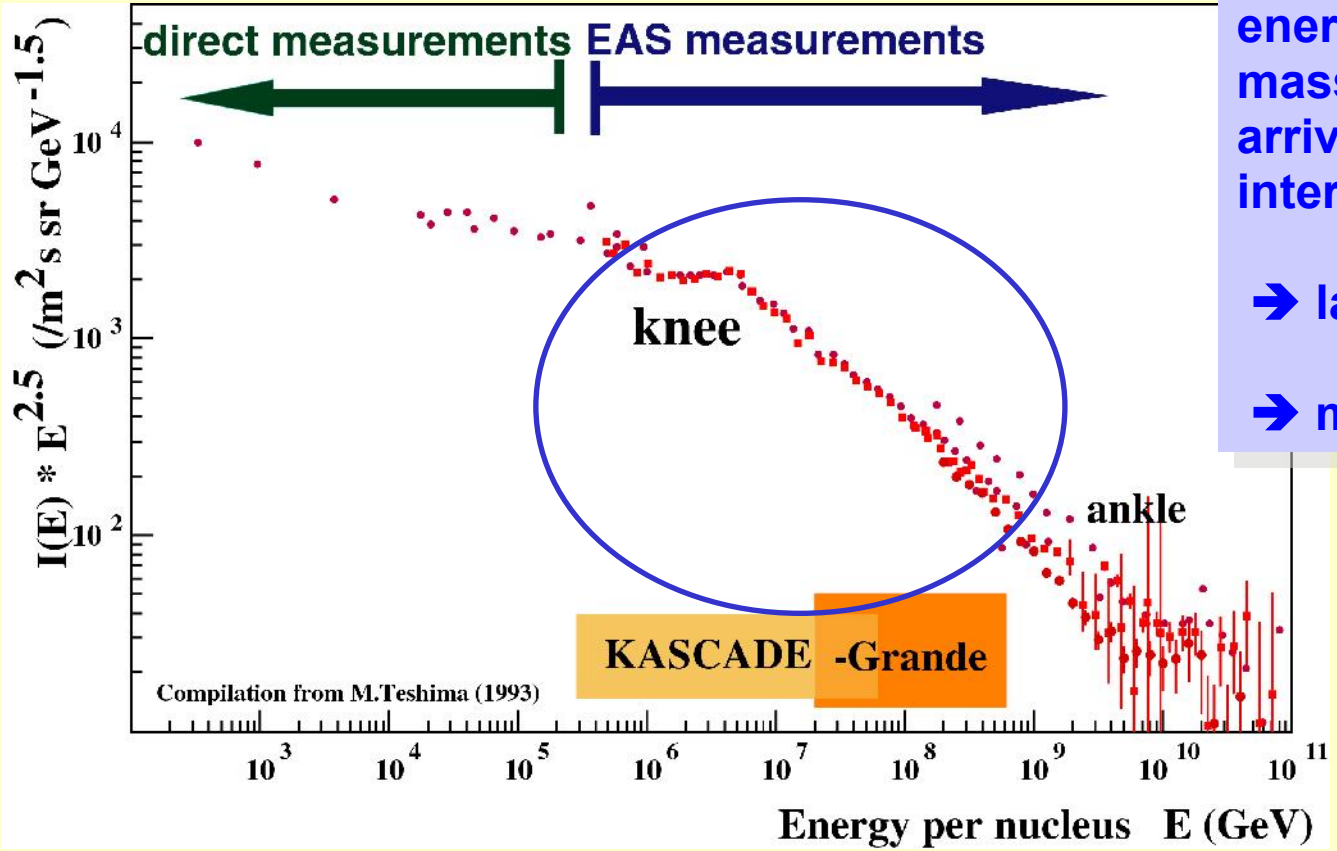
Scientific targets:

- cosmic rays at 10^{18}eV
- γ-ray bursts at 10^{11}eV
- space weather
- cosmic rays at knee energies

US/Canadian network:

Motivation for KASCADE

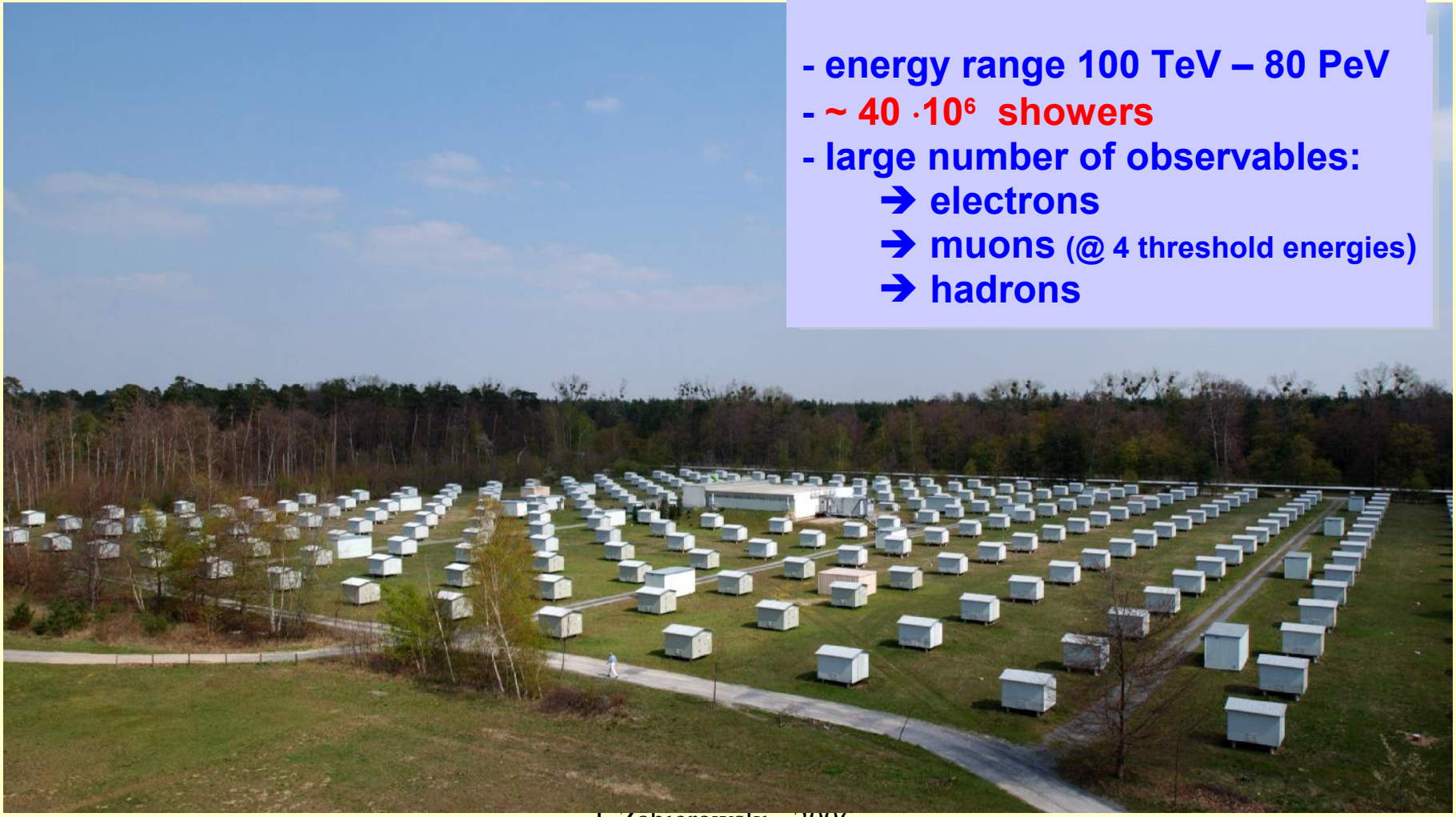
Cosmic Rays around the knee:
What is the origin of the knee(s)?



energy ?
mass ?
arrival directions ?
interaction mechanism ?

➔ **large number of observables**
➔ **multi-detector system**

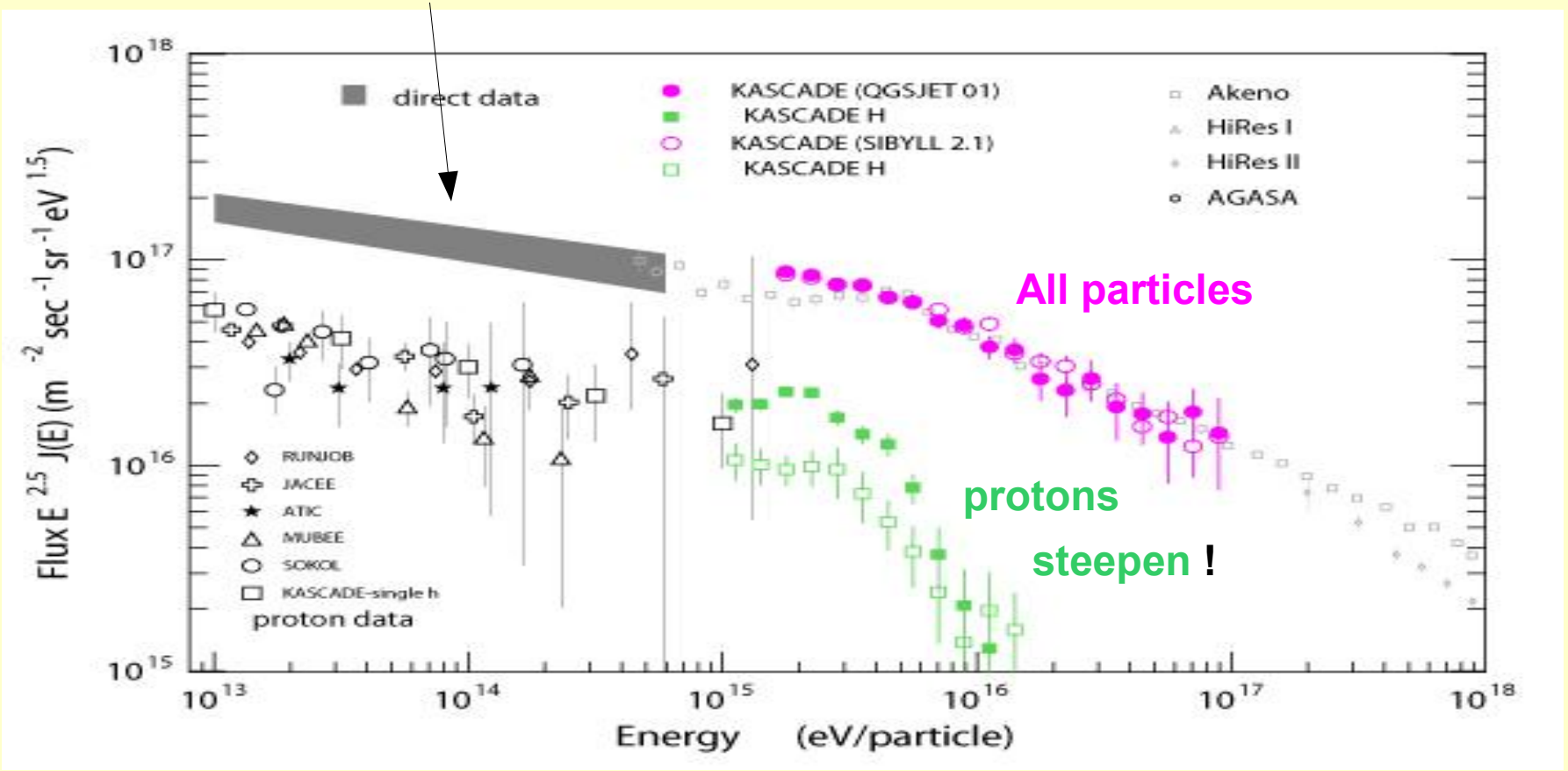
KASCADE : multi-parameter measurements



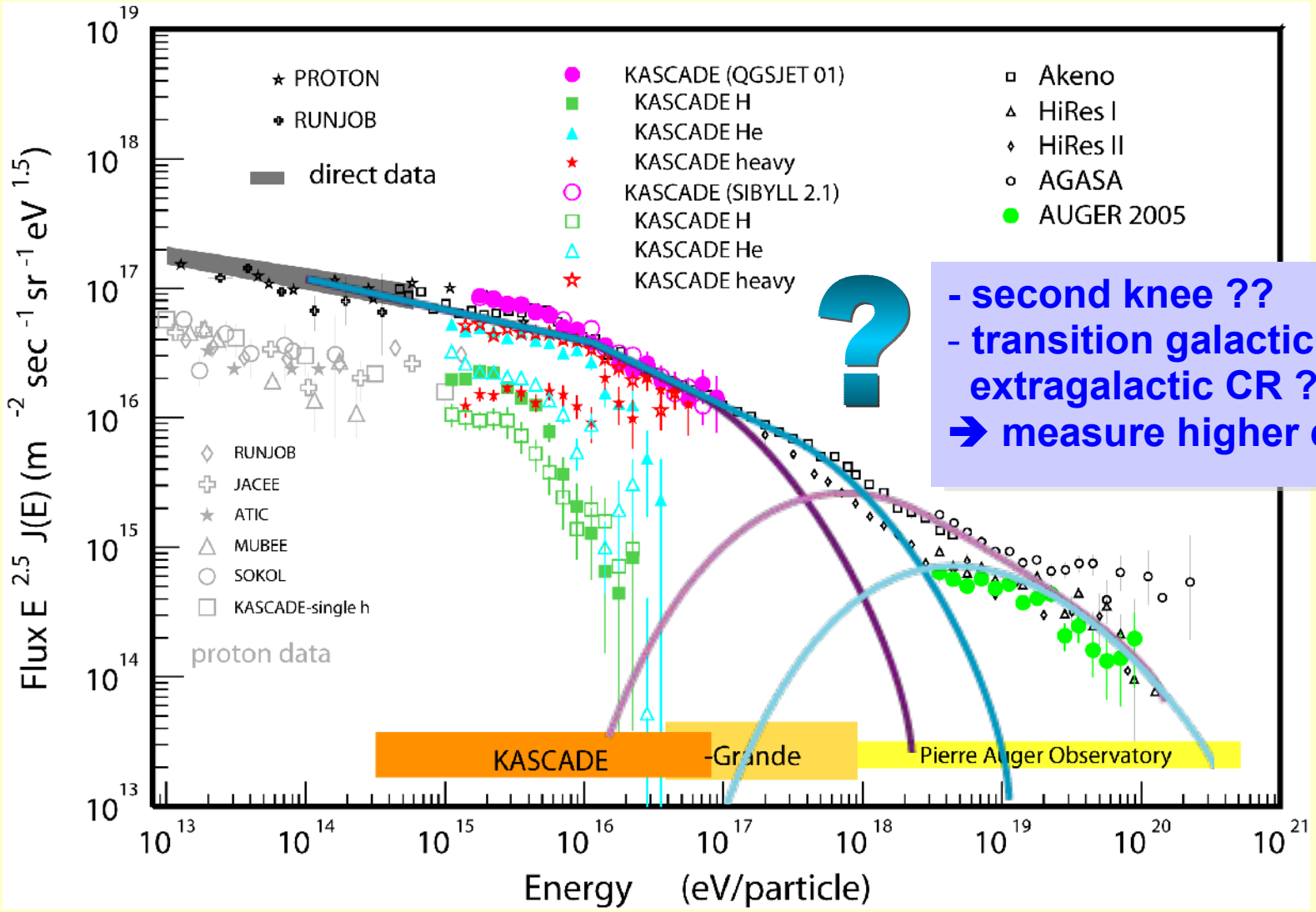
- energy range 100 TeV – 80 PeV
- ~ 40 ·10^6 showers
- large number of observables:
  - ➔ electrons
  - ➔ muons (@ 4 threshold energies)
  - ➔ hadrons

Primary cosmic ray spectrum as determined by KASCADE

Comparison with direct measurements



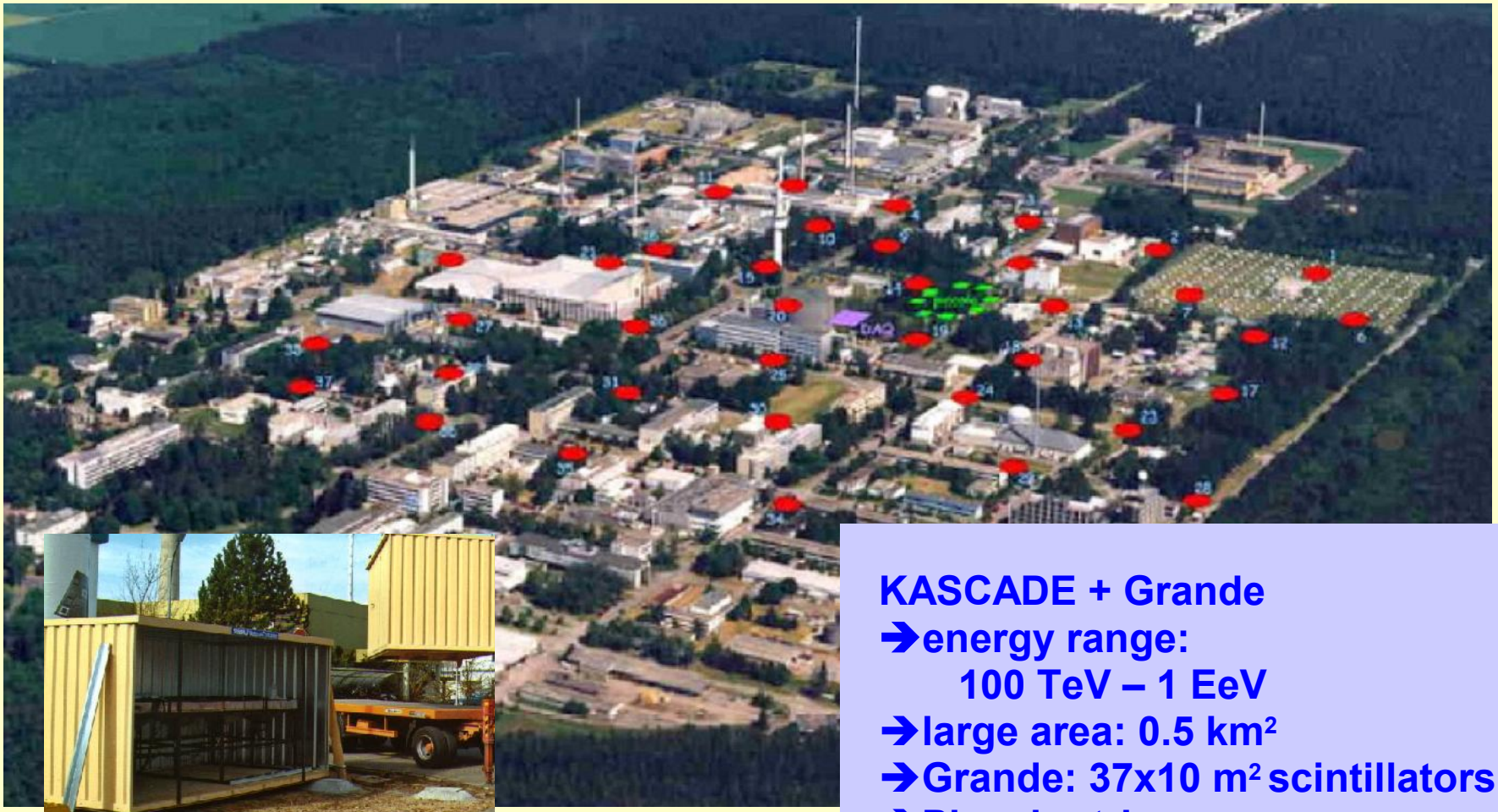
Motivation for KASCADE-Grande



- second knee ??
- transition galactic-extragalactic CR ??

➔ measure higher energies !

KASCADE-Grande : multi-parameter measurements



KASCADE + Grande
- ➔ **energy range: 100 TeV – 1 EeV**
- ➔ **large area: 0.5 km^2**
- ➔ **Grande: 37x10 m^2 scintillators**
- ➔ **Piccolo: trigger array**

►**KASCADE-Grande** first experimental data - **summer 2000**

► Operation of the experiment **until 2008** and **possibly longer**...

►**LOPES** (KASCADE-Grande is its main component)
is a test installation for
development of radio detection technique
for EAS investigation.

Paper in Nature 2005

Main Polish contributions to KASCADE / KASCADE-Grande

* 10 scientists from Lodz participated over the whole period

* 2 PhD theses completed

* Hardware contributions:
  > Main trigger electronics for KASCADE
  (110 VME modules, designed and built in Lodz)

  > Front-end electronics for Muon Tracking Detector (24576 channels);
  design and prototypes made in Lodz, automated mass production in Germany , supervised by us.
  > Modifications of the main trigger in the KASCADE-Grande environment

* Data analysis and development of analysis software

* Tests of hadronic interaction models at high energy

Theoretical Studies:

1. Jagiellonian University

Cosmic ray acceleration (relativistic jets)

M.Ostrowski and collaborators, papers in Ap.J, A&A..

`

2. University of Łódź

Cosmic ray sources and
propagation in Galactic and extragalactic magnetic fields

T.Wibig and W.Bednarek, MG,and collaborators, papers in J.Phys.G.

3. Andrzej Soltan Institute for Nuclear Studies

EAS simulations, C R propagation...

J.Szabelski and collaborators, papers in AstrPart.Phys.

Conclusions

Significant contributions in the Cosmic Ray field;

Lack of money -- – main obstacle in a broader participation in international experiments;

International (IUPAP) recognition: – the biggest CR conference ICRC will be organized in Poland (Łódź) in 2009.