The Pierre Auger Observatory Project

- Some physics background
- Past work on Auger
- R&D plans
- Major involvement possibilities
- Timeline, effort, etc.
- Summary

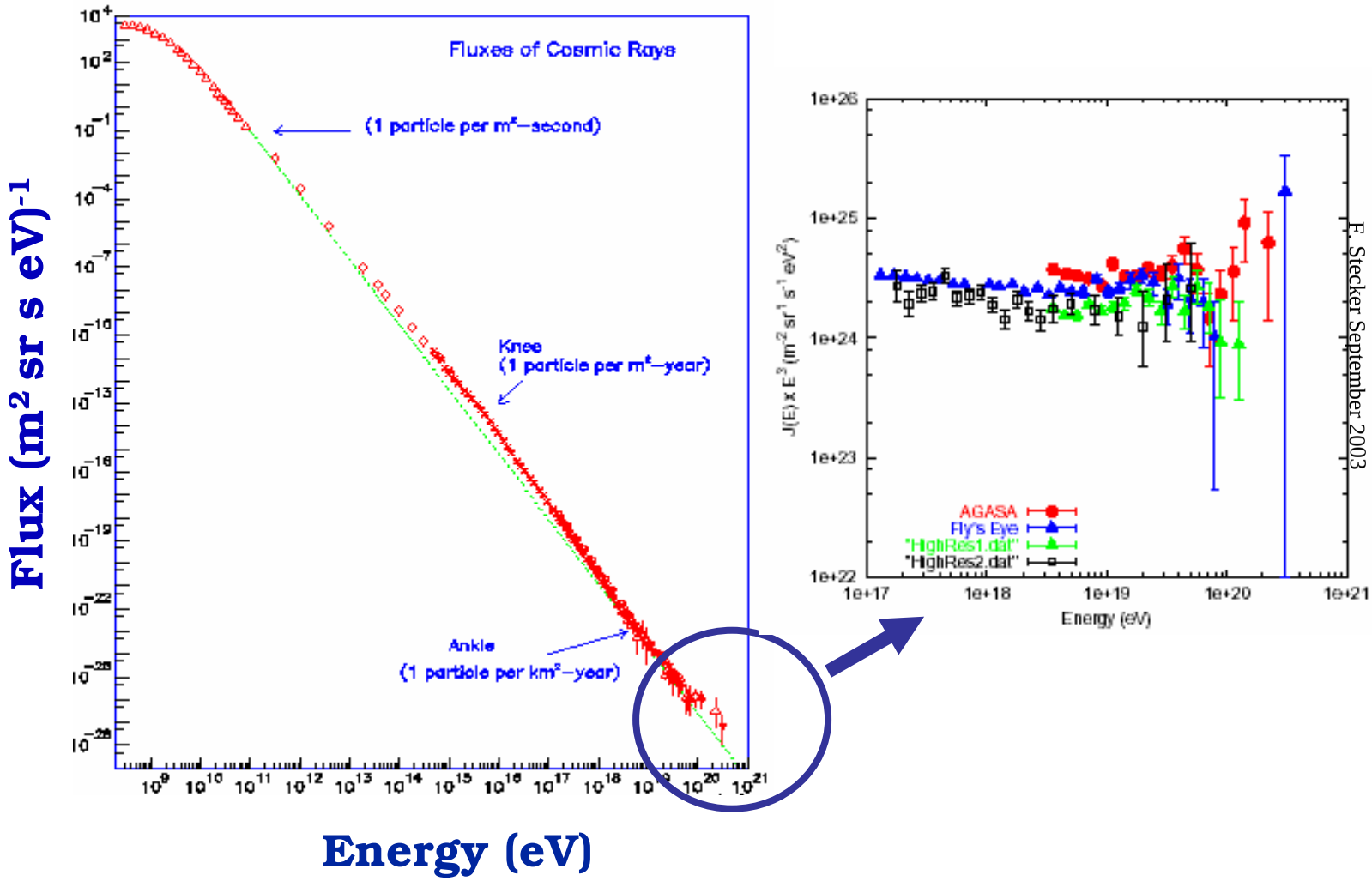
H. Spinka
9 December 2003

Some Physics Background

- At energies above ~ few × 10^{19} eV, cosmic ray protons lose energy due to photo-production of π's on the 3° K blackbody radiation. Nuclei will suffer photo-disintegration at about the same energy.
- This limits the distance such cosmic rays can travel to ~ 50 Mpc ~ 150 MLy. Such high energy particles are not believed to originate from any known astronomical objects within this distance.
- Thus, a (GZK) cutoff in the cosmic ray spectrum near this energy is expected, BUT ~ 20 such high energy events have been observed!

Therefore, New Particle Physics
or New Astrophysics
or Both

Cosmic Ray Spectrum



F. Stecker September 2003

The Highest Energy Cosmic Rays

Over the last 40 years

~20 events reported with > 10^{20} eV

50 Joules!

1991 Fly's eye detector in Utah - 3.2 x 10^{20} eV

1993 AGASA detector in Akeno, Japan - 2 x 10^{20} eV

Possible Sources

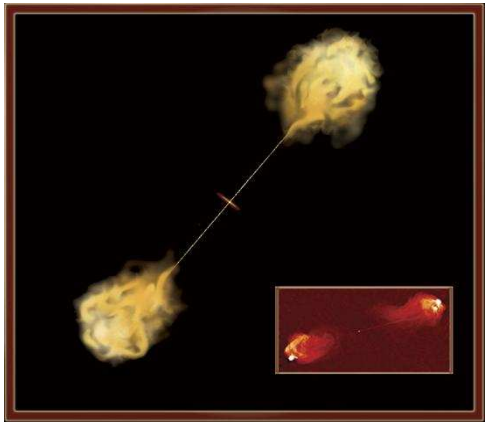
Conventional – Bottom-Up

Hot spots in radio galaxy lobes?

Accretion shocks in active galactic nuclei?

Colliding galaxies?

Supernova shocks ~10^{15} eV



Associated with gamma ray bursts ?

Neutrinos?

Exotic – Top-Down

Annihilation of topological defects?

Cold dark matter?

Evaporation of mini black holes?

Some Physics Background (cont.)

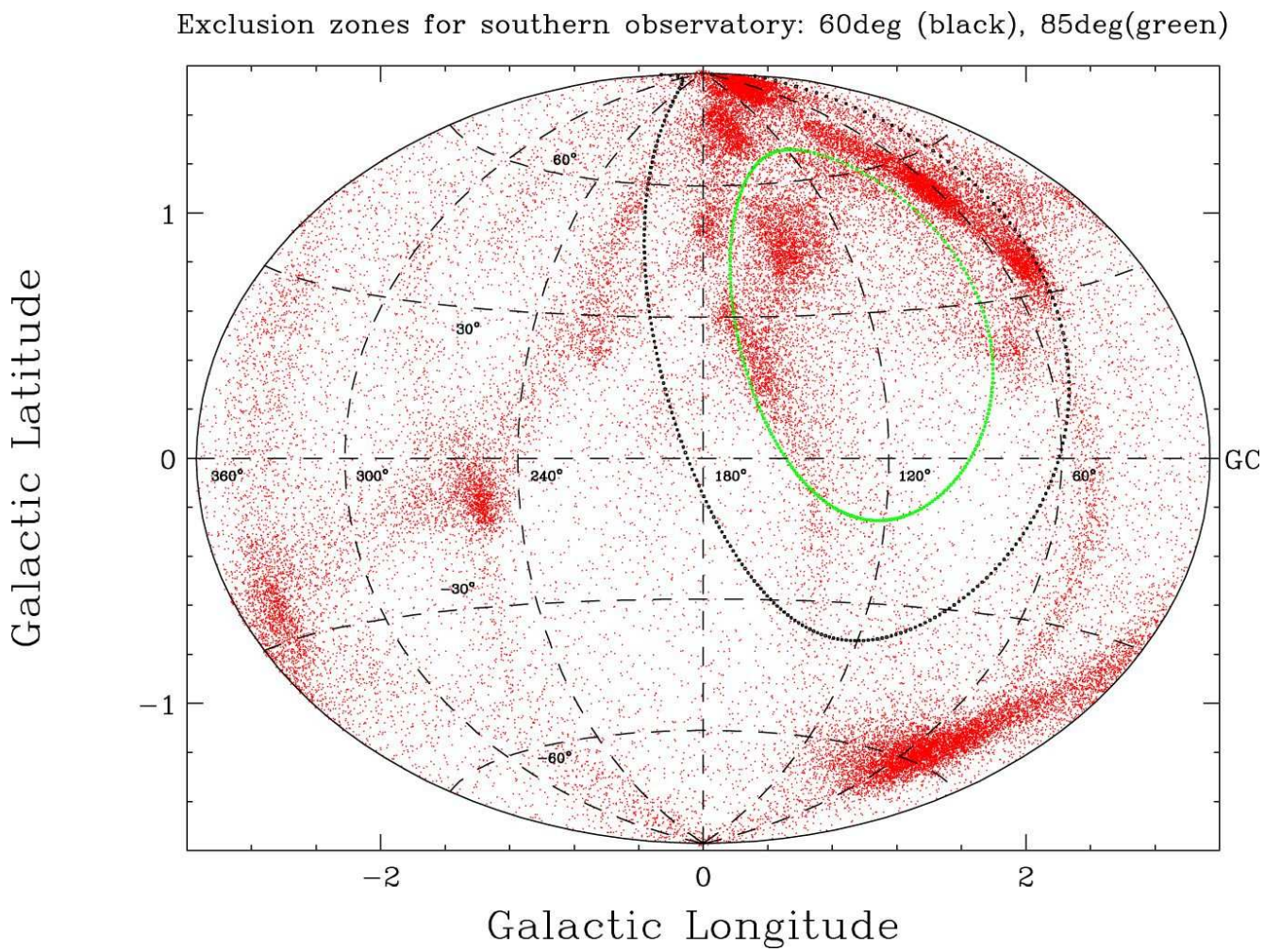
- Magnetic fields estimated within and between galaxies indicate that such ultra-high energy cosmic rays will point back to their source for distances ≤ 100 Mpc. This is not true for lower energies.
  Therefore, can do astronomy with them!

- ν-induced showers can be detected as ~ horizontal air showers, and they also point back to their source.
  Thus can do astronomy with these showers as well.

- Full sky coverage is needed to unravel the origin of these cosmic rays. Their distribution on the sky may suggest the class of objects with which they are associated and their distances.
  Therefore, 2 sites = 1 observatory.
  Instrumentation at the two sites should be as nearly identical as possible.

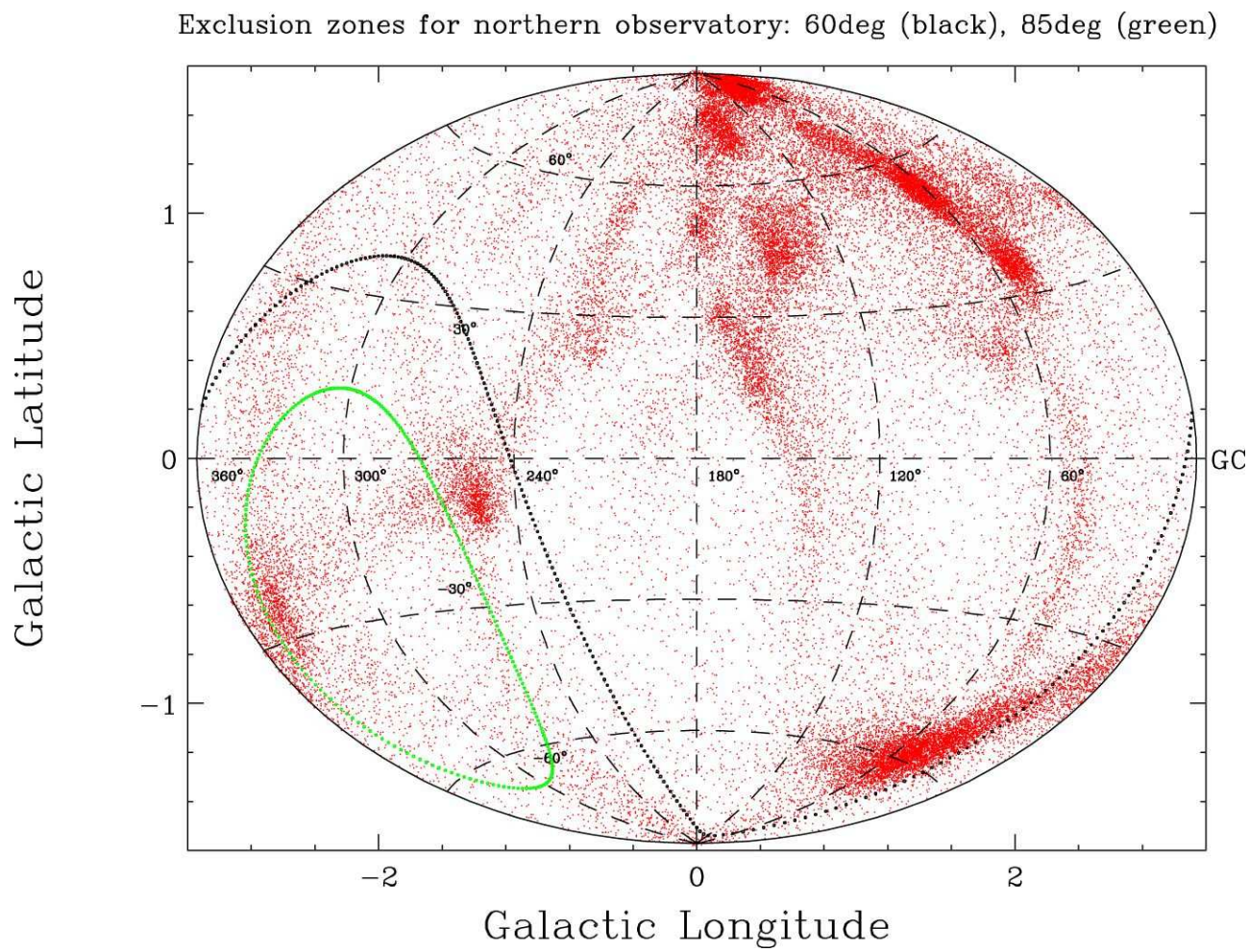
Galaxy Distribution 7-21 Mpc

Visible from the southern site



Galaxy Distribution 7-21 Mpc

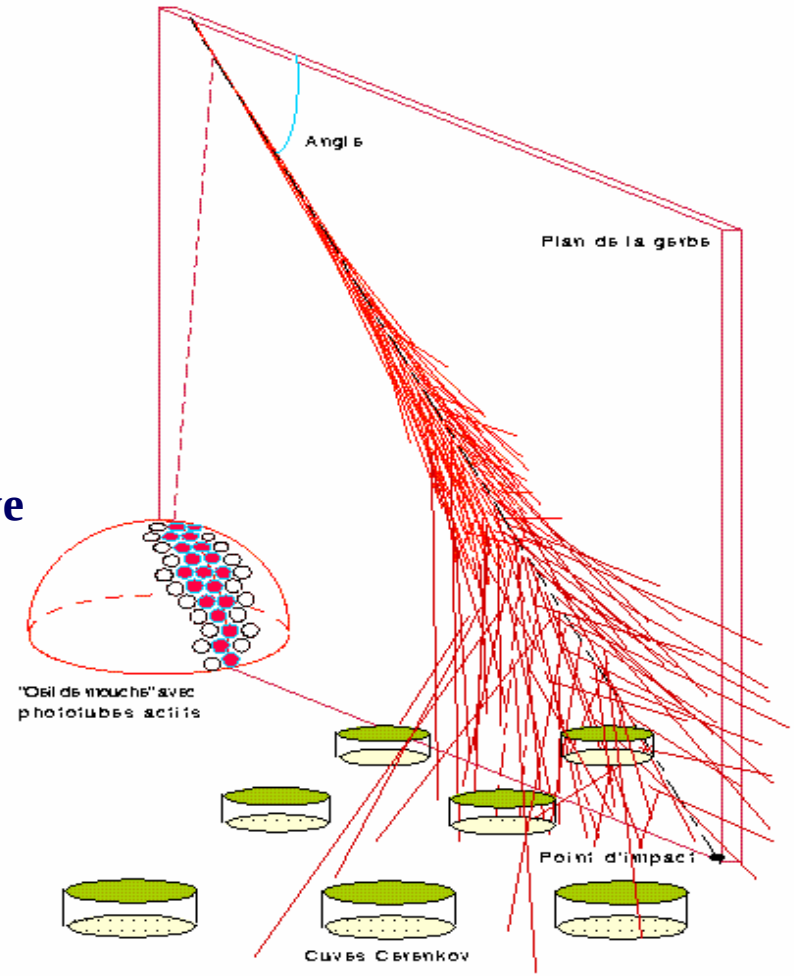
Visible from the northern site



Some Physics/Detector Background (cont.)

- These ultra-high energy cosmic rays are rare, so a detector sensitive to a large area is needed.
  ~ 1 event / km^2 / sr / century
- Water Cerenkov tanks sample showers laterally, and then the energy is reconstructed. Timing gives the arrival direction. (Mostly sensitive to EM energy.)
- Observe N_2 fluorescence on dark, cloudless nights with PMTs ("Fly's Eye" style). This is a calorimetric measurement, but atmospheric attenuation and limited (~ 10%) duty factors are problems.
- Some events are seen with more than one type of detector. This allows the primary composition to be determined statistically, and also permits a cross comparison of the energy scales.

Detecting Cosmic Ray Air Showers



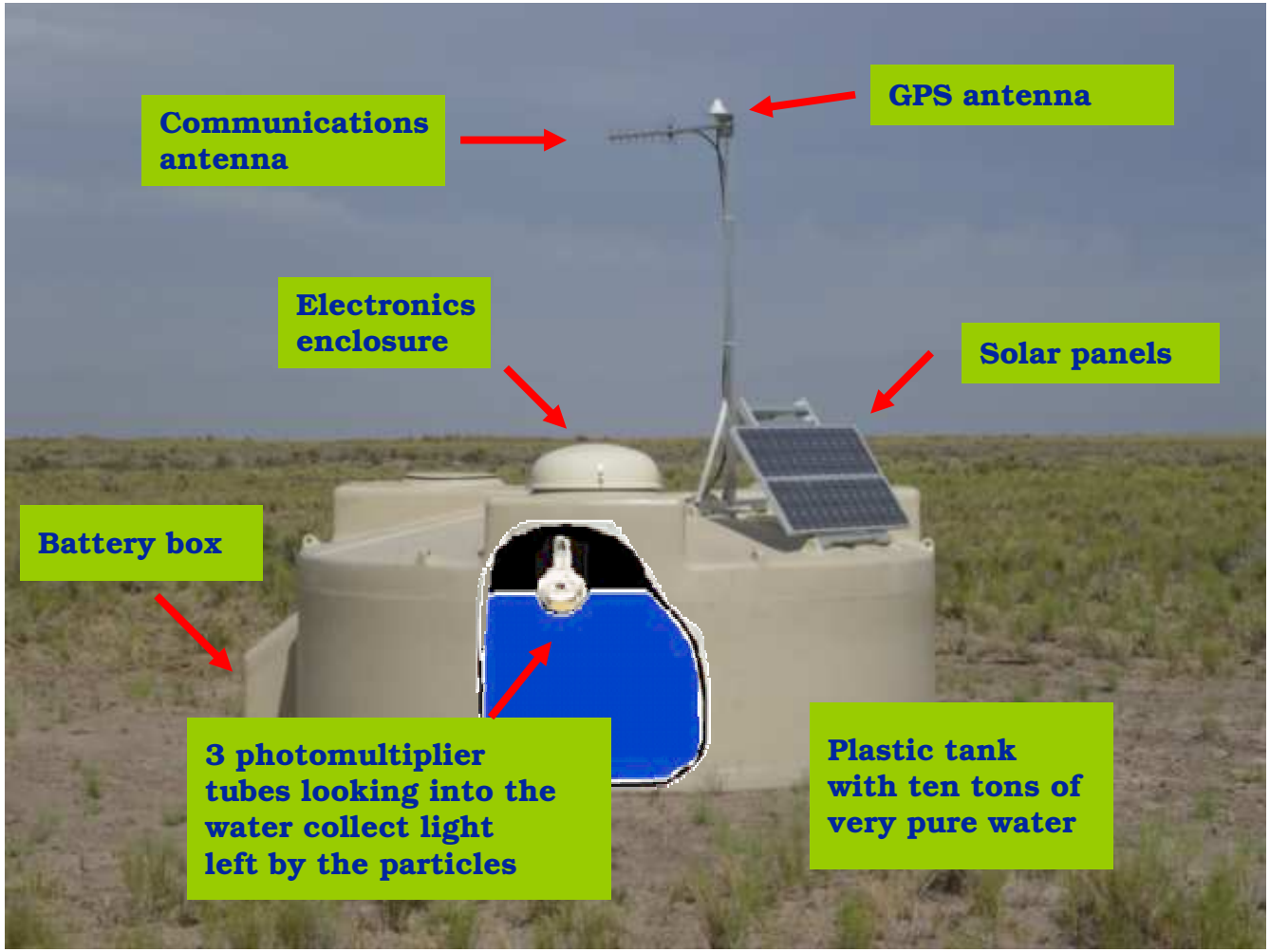
Fly's Eye

Surface Array

Air shower measurements are made by two techniques

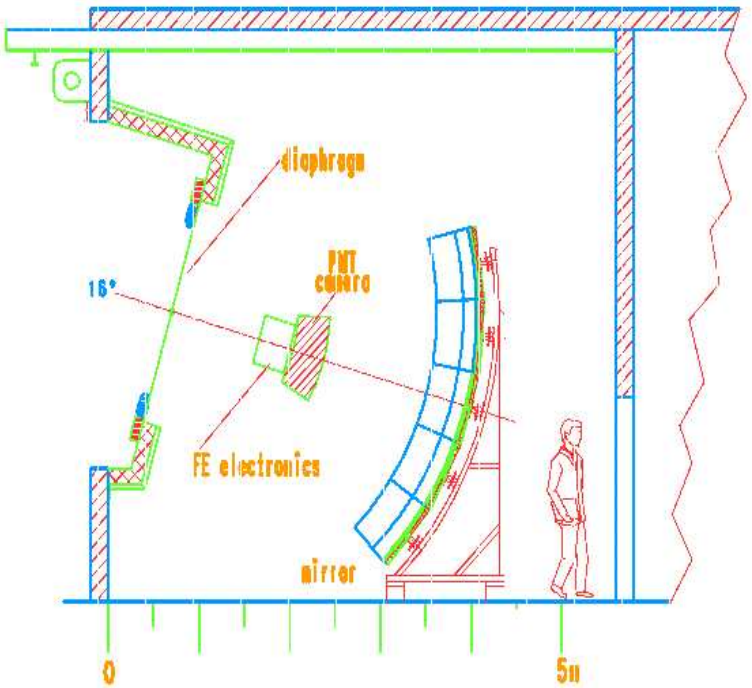
1) **Surface Arrays**
2) **Fluorescence Telescopes (Fly's Eyes)**

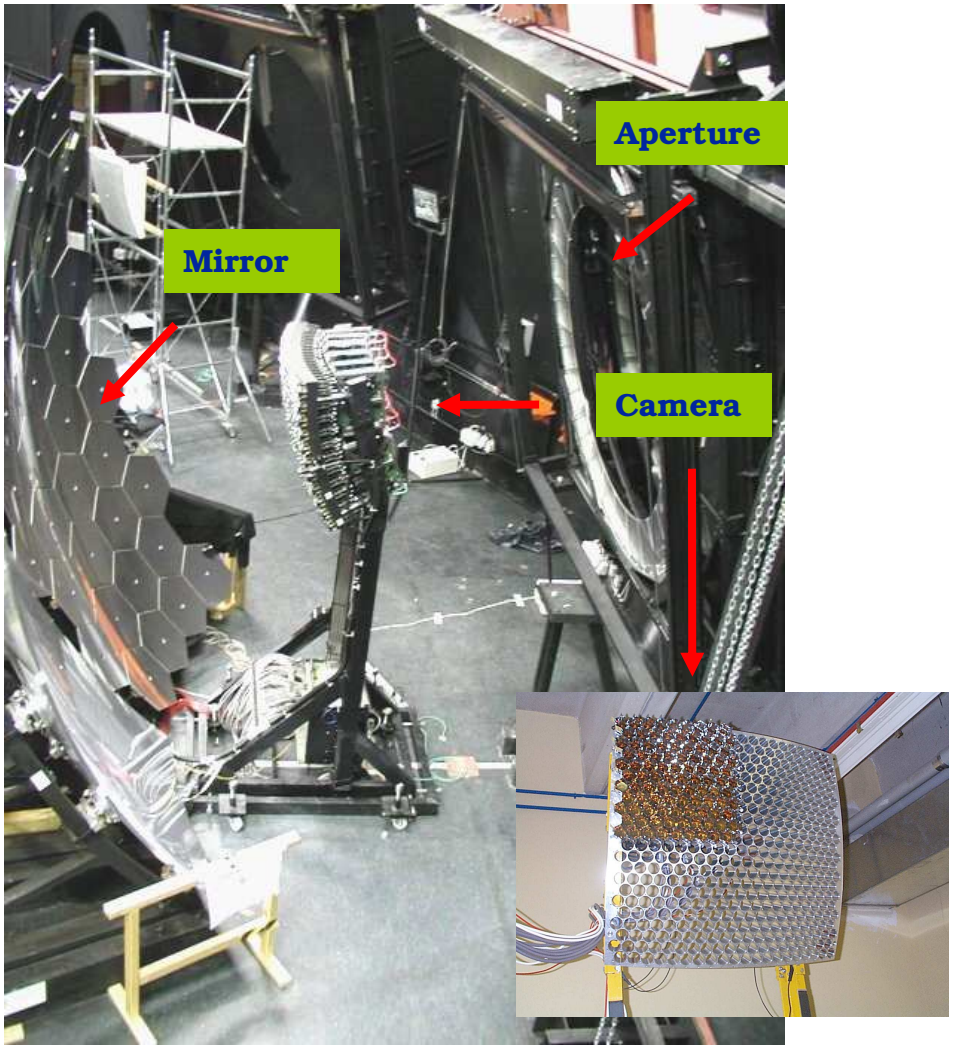
The Auger Surface Detector Station



The Auger Fluorescence Detector

3.4 meter diameter mirrors
440 pixels per camera





Past ANL Work on Auger

- I worked on many tasks before and after the first proposal for Auger was submitted.
  - Water tank testing at FNAL
  - Water quality studies
  - Cost estimates and other help with the proposal
- LDRD funding was obtained for:
  - A postdoctoral fellow (Andrej Filipcic)
  - Equipment for the water tank tests
  - Water purification study
- Auger notes were written on various topics
  - GAP- 1999-046 (water purification study)
  - GAP- 2000-001 (time stability of a small water tank)
  - GAP- 2001-005 (LED flasher inside a water tank)

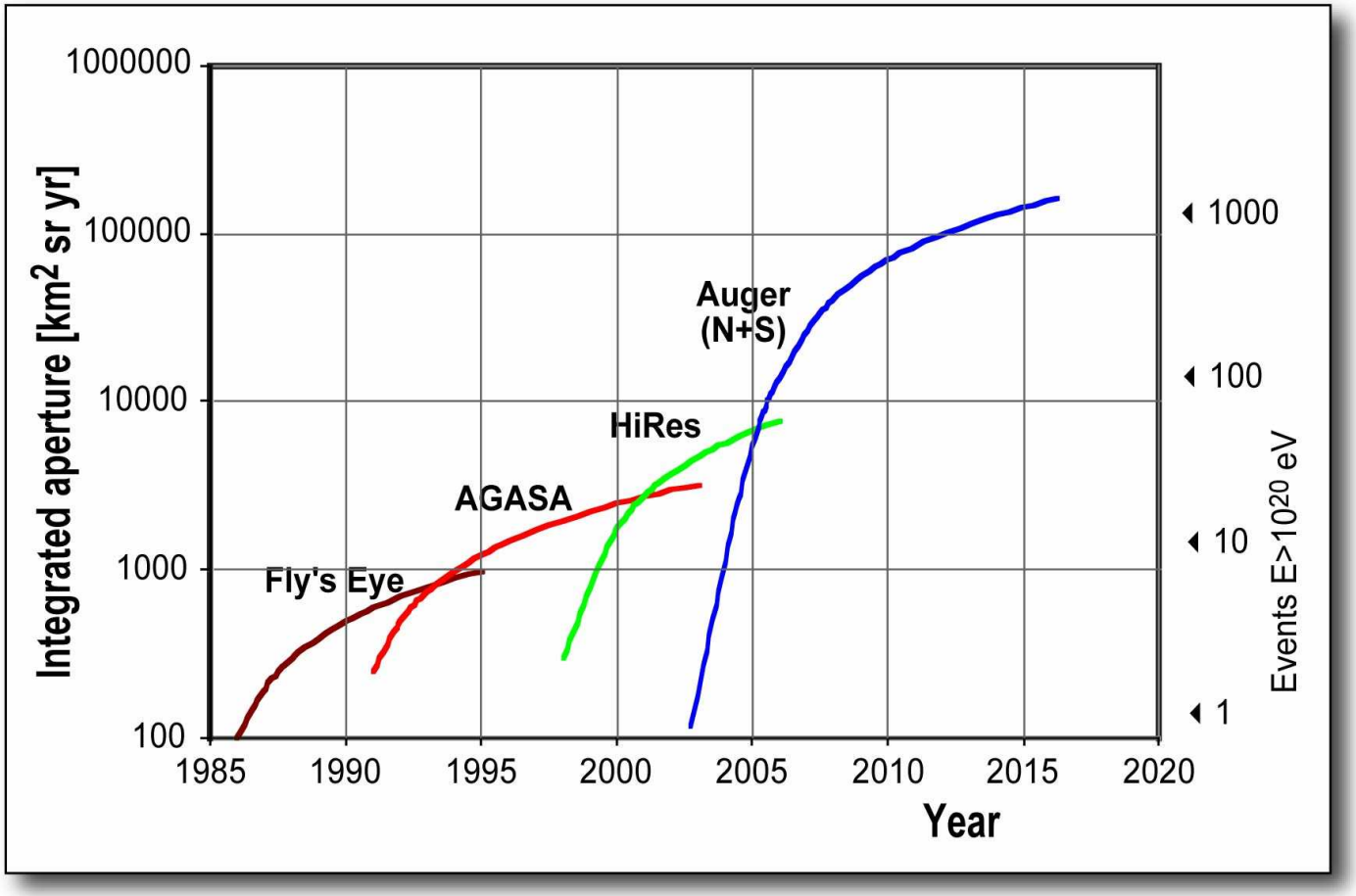
R&D Plans

- An R&D proposal should be written for the northern site in the next few months for three classes of tasks:
  - Essential tasks for the northern site to “duplicate” the southern site, such as water tank insulation.
  - Evaluate possible qualitatively new improvements/additions, such as cosmic ray shower detection with RF or Cerenkov light.
  - Consider other possible improvements/additions, such as muon detectors, less sensitive to the EM component of showers, to be situated beneath the water tanks:
    - Wire chambers
    - Plastic scintillation counters
    - Resistive plate chambers (RPC’s)
- The estimated request for ~ couple $100K will be for a number of R&D tasks at several institutions, and would be written partially by ANL physicist(s).

Possibilities for Major Involvement

- A funding proposal will be written for the northern Auger site in ~ 1 ½ years. This is at about the time of the first release of major results with integrated "exposure" comparable to the maximum from previous detectors.
- The expected U.S. request will be for ~ ½ of the total cost, or about $ 25 – 40 M.
- Possible ANL roles include:
  - Some part of the tank system engineering and construction
  - Responsibility for some tasks at the northern site
  - A portion of the new improvements if funded (RF or Cerenkov detection)
  - Simulations and data analysis
- In addition, ANL could share in the data from the southern site and the related physics.

Aperture of Air Shower Detectors



Timeline, Effort, etc.

- Few months (~0.5 FTE physicist, some engineering)
  - Assist in writing R&D proposal
  - Gain experience working at the southern site
  - Attend collaboration meeting
  - Help with FNAL test tank studies
- Summer 2005 (~1 – 1.5 phys., 0.5 – 1 mech. tech, 0.25 mech eng., 0.5 elec. tech, 0.25 elec. eng.)
  - Help in writing funding proposal
  - R&D work
  - Continued work at southern site, collaboration meetings
  - Physics analysis
- 2006, 2007 ?? (~5 phys., 2 mech. tech, 0.5 mech. eng., 2 elec. tech, 0.5 elec. eng.)
  - Construction
  - Site work
  - Physics analysis

Timeline, Effort, etc. (cont.)

- Interested ANL physicists
  - Rich Talaga
  - Steve Kuhlmann
  - HMS
  - (also engineers, …)
  - …

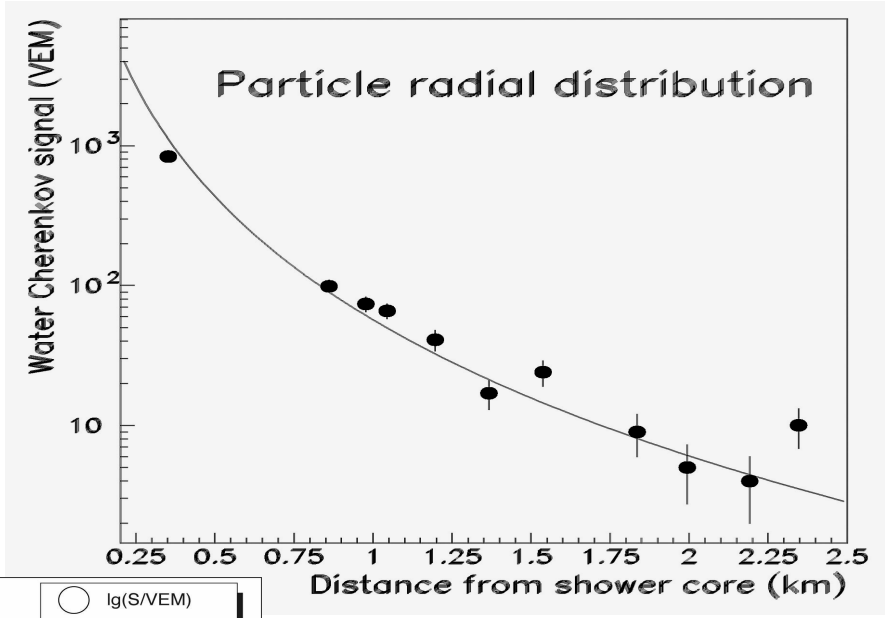
- More details to come (Jan. 2004)
  - Angela Olinto (physics) - U. of C. Astr. Dept. head
  - Jim Cronin (Auger detector) - U. of C.
  - Paul Mantsch (possible tasks for ANL) - FNAL, project manager
  - Perhaps physicist for RF detection of cosmic rays

Summary

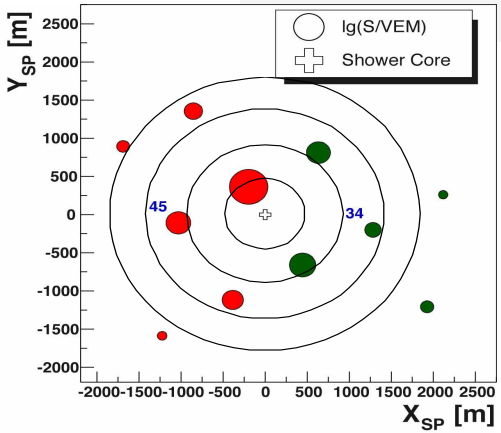
- Outstanding physics
- Excellent collaboration
- Connection to the University of Chicago
- Good timing for construction
- Great opportunity to begin astrophysics
- More details coming in Jan. 2004

Cosmic Ray Air Shower Measurements

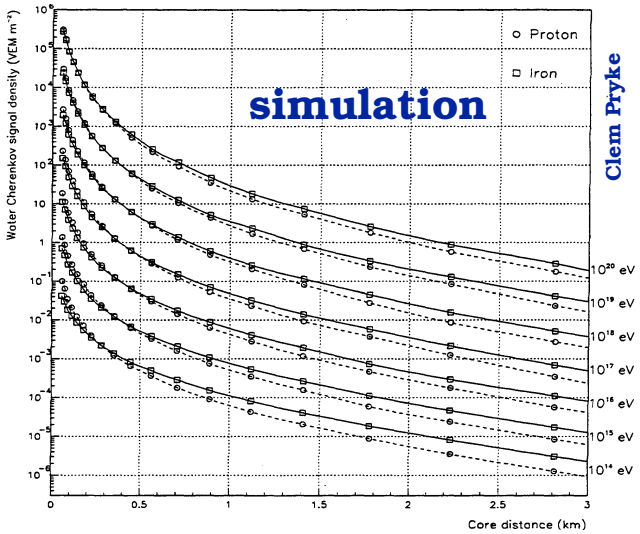
Energy – surface array



Surface Array:
Measure radial particle density distribution on the shower plane.



11 tank event



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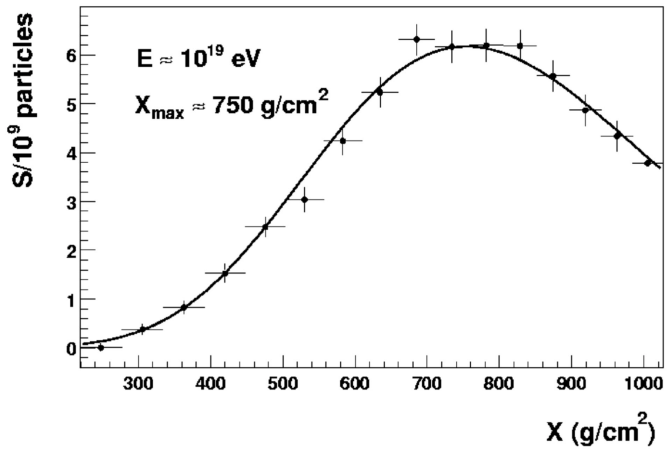
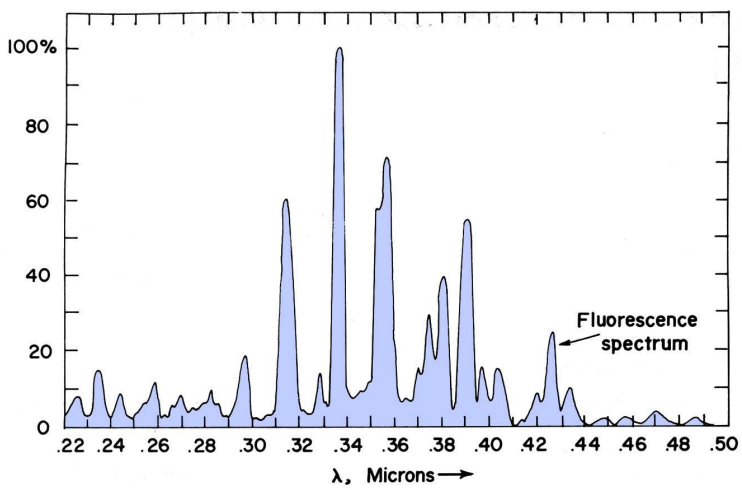
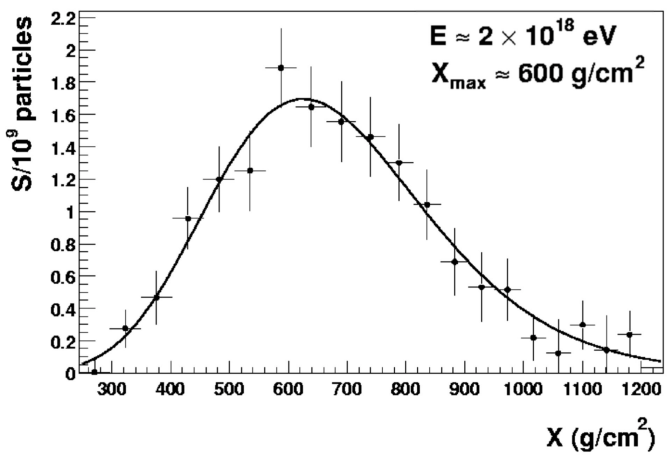
Cosmic Ray Air Shower Measurements

Energy – fluorescence detectors

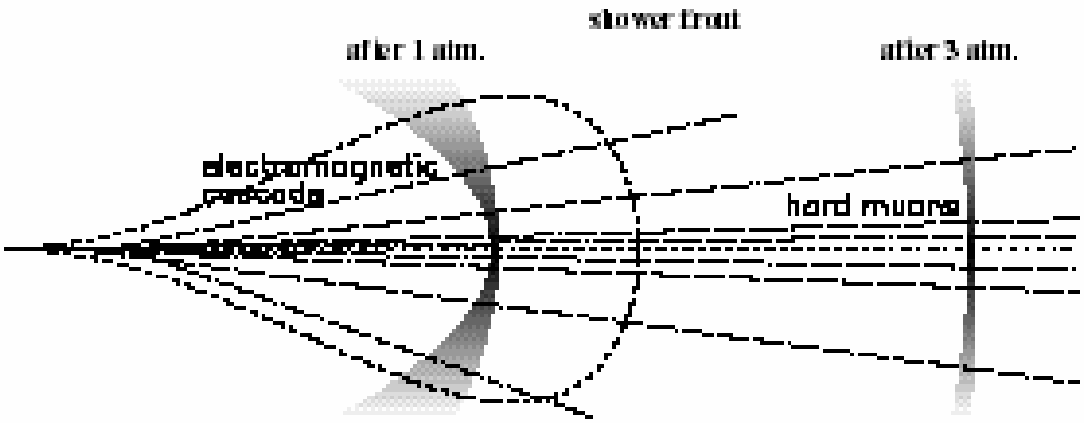
Fluorescence Detectors: Measure the light produced by the shower





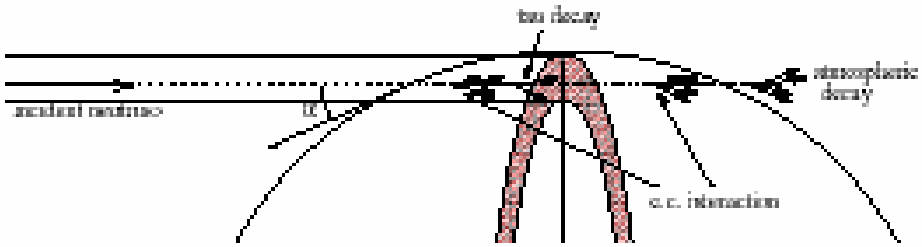


Cosmic Ray Air Shower Measurements
Sensitivity to Neutrinos



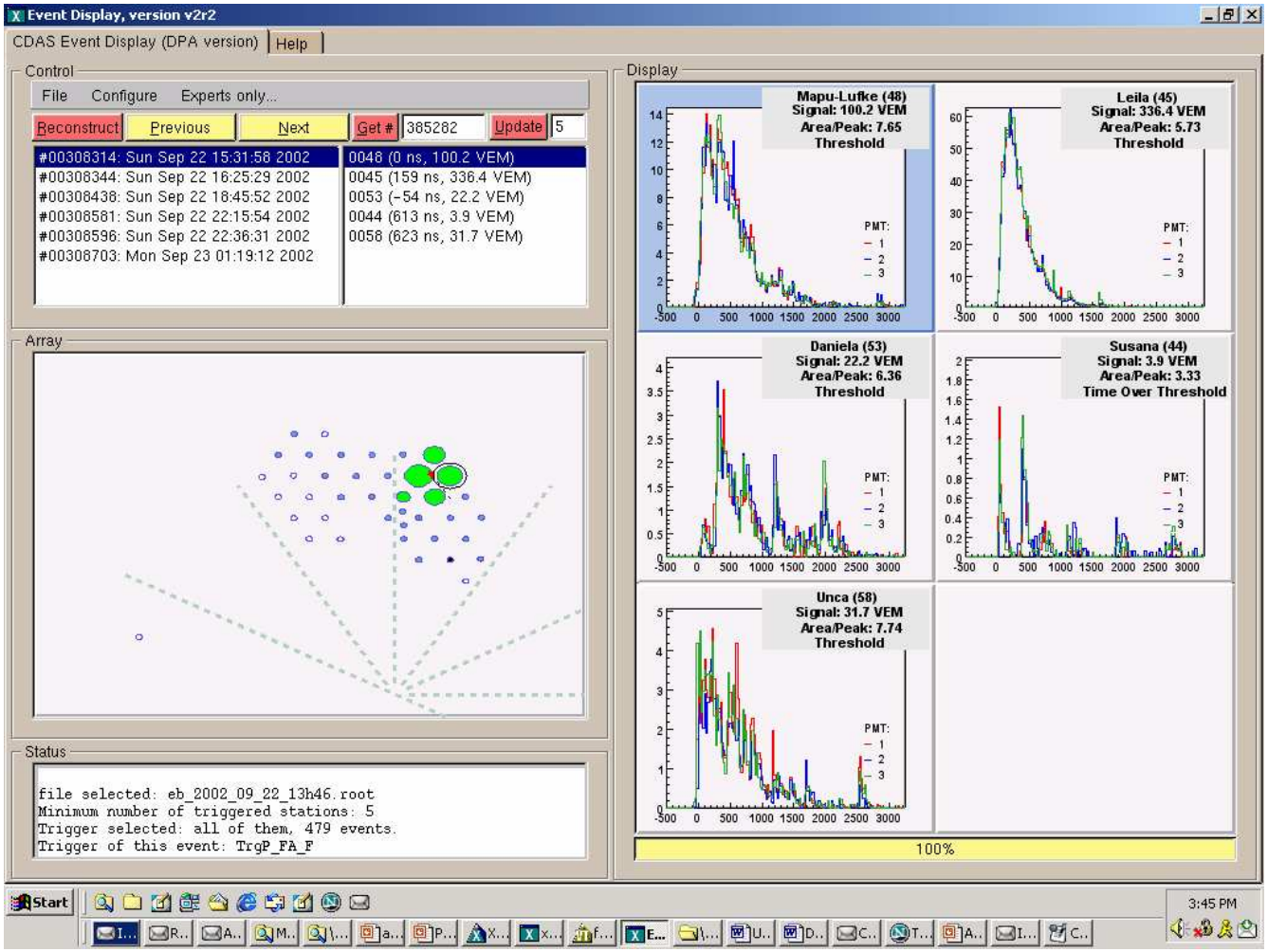
Large zenith angle (>60 degrees) hadron showers have lost most of their electromagnetic component.

Tau neutrinos can interact in the mountains or in the crust of the earth to produce taus that decay and shower over the detector.



Typical Event

From the on-line event display



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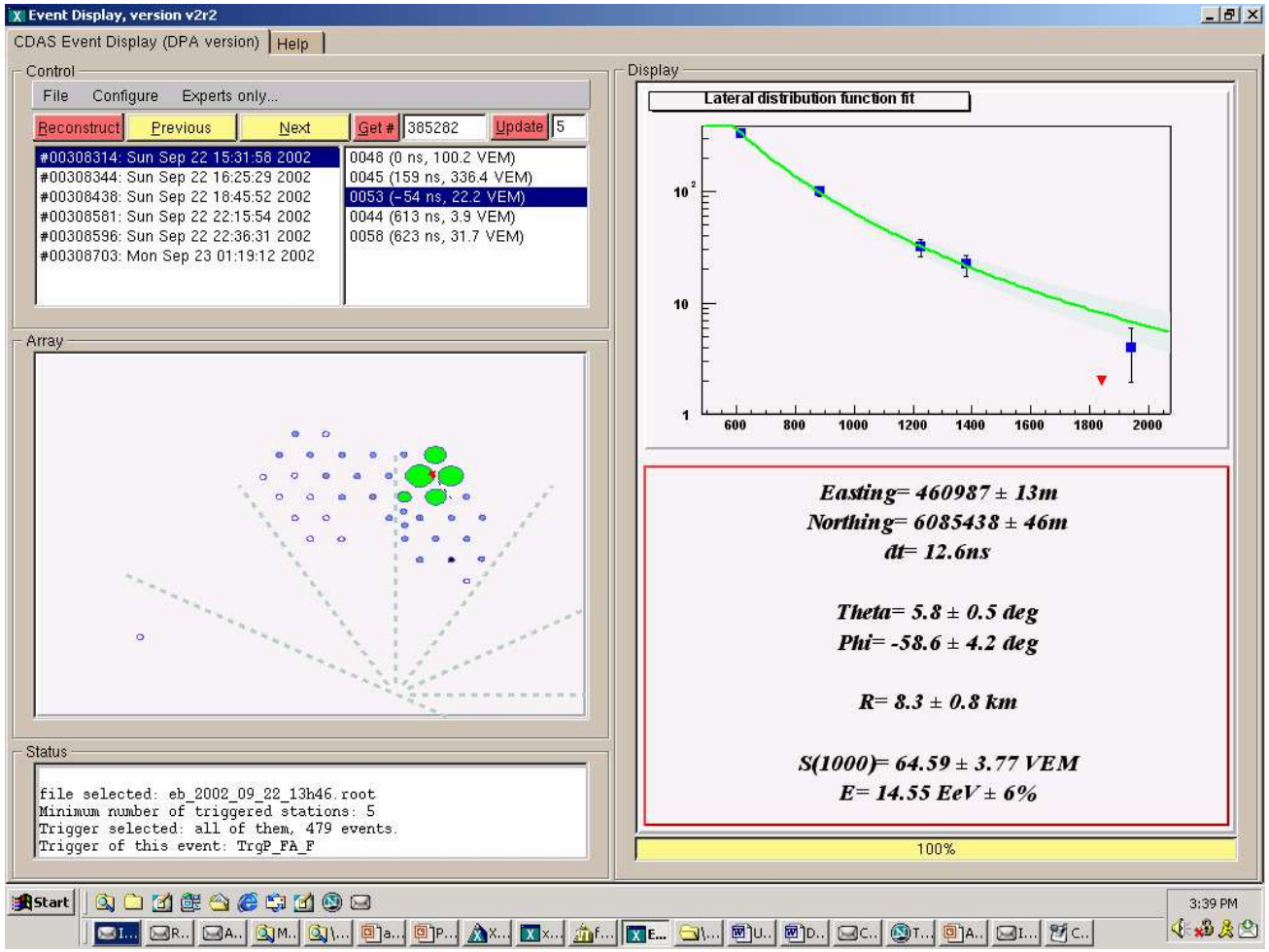
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