The Status of the Pierre Auger Observatory

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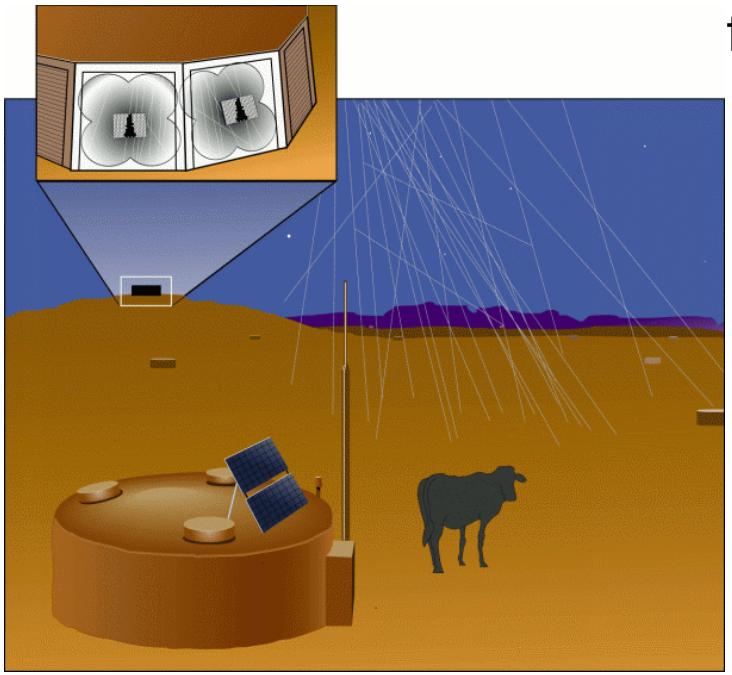
for the Pierre Auger Observatory Collaboration



PIERRE AUGER OBSERVATORY

Plan

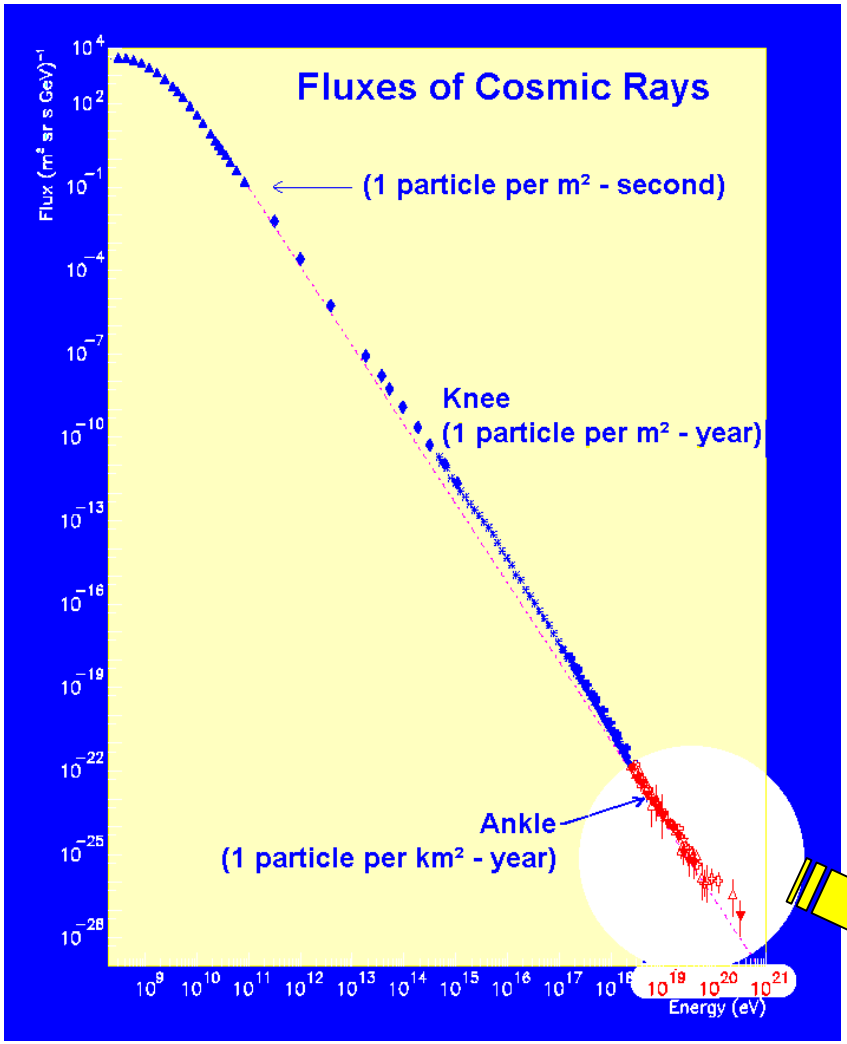
PIERRE AUGER OBSERVATORY

- Description of the observatory
- Physics aims
- History and Schedule

- A Hybrid detector - why?

- Surface Detectors - Aperture and Resolution
- Fluorescence Detectors
- Hybrid Reconstruction - Aperture and Resolution

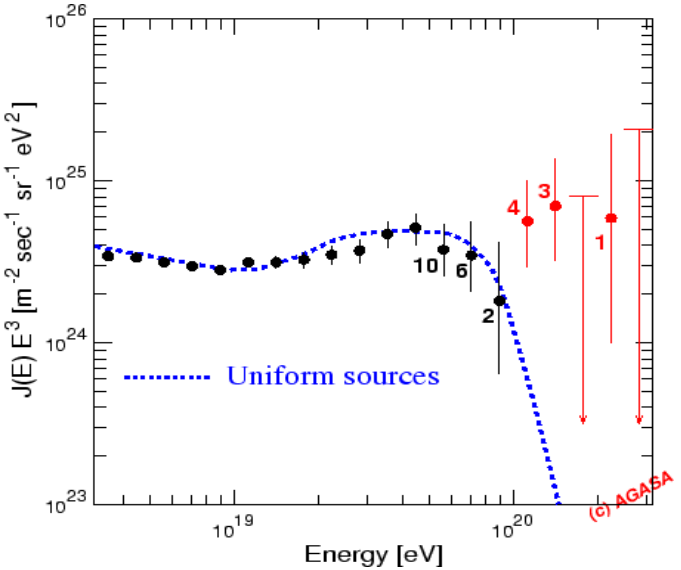
- First events and preliminary reconstruction

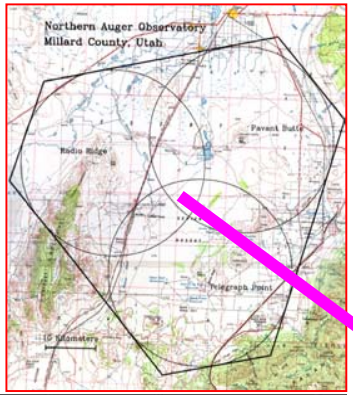


Physics issues with Auger:

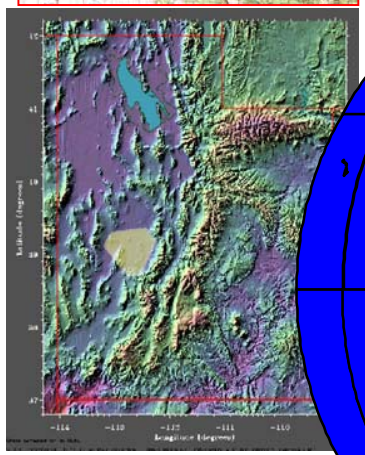
- Where does the spectrum end ?
  - Is there a GZK cutoff?
  - Are the sources local (<150 Mly)?
- Primary nature (composition) ?
  - Nuclei? Protons ?
  - Gamma rays? Neutrinos? Or...?
- What is the source of UHECR ?
  - Bottom-Up or Top-Down scenario ?

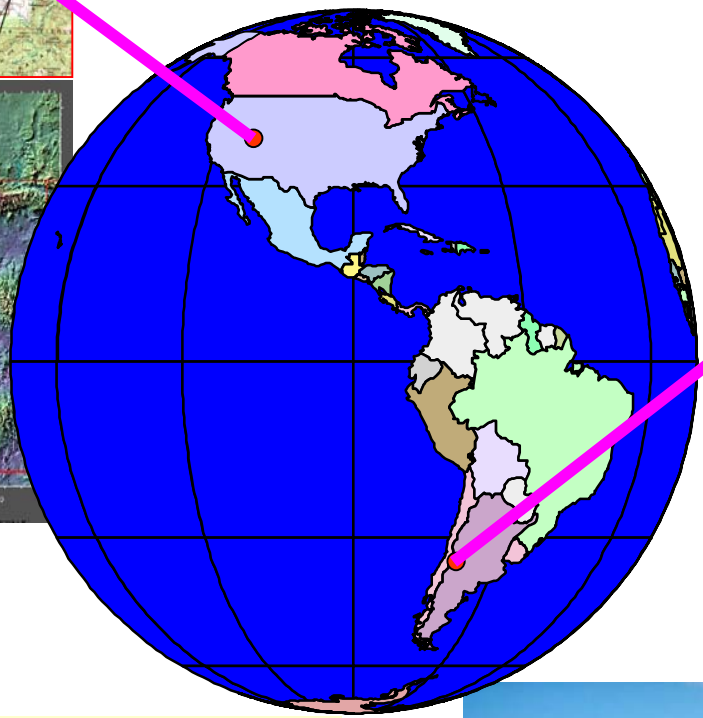
Data from Agasa: 100km² x 10 years





Northern hemisphere
Millard county
Utah, USA

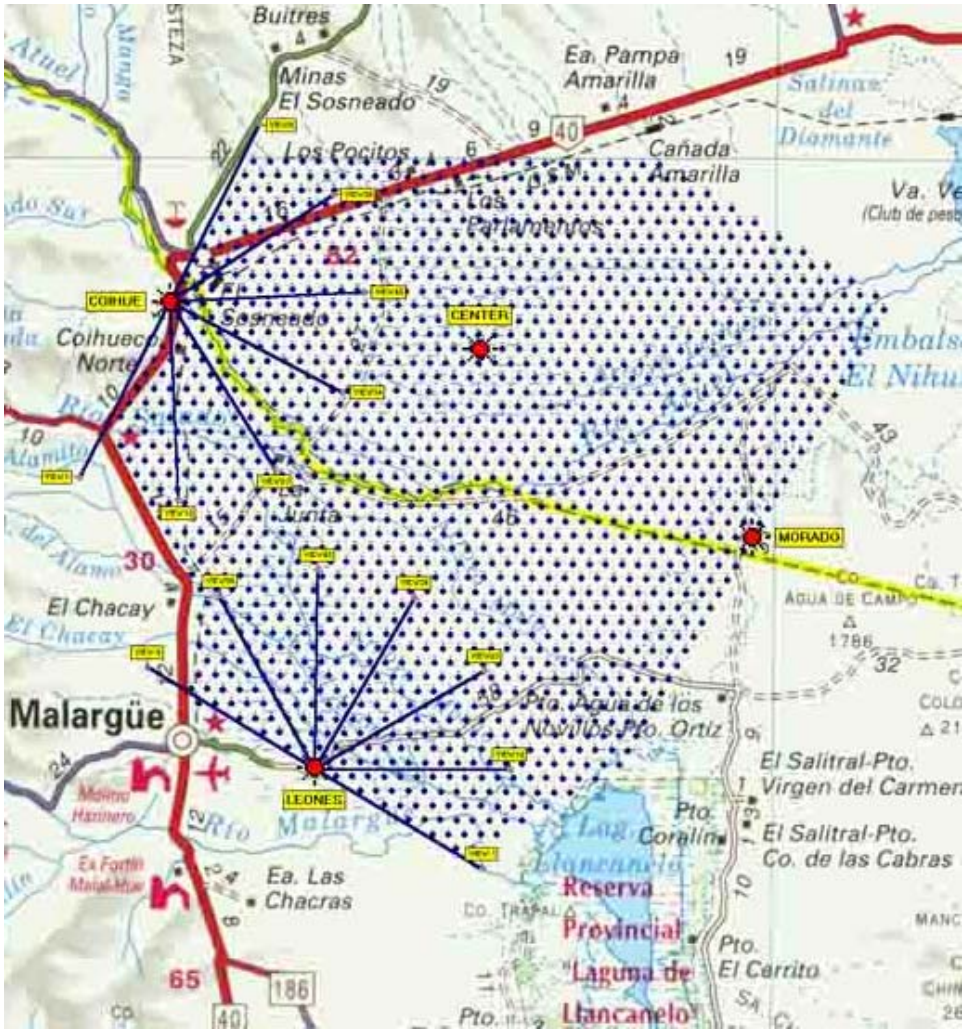




Southern hemisphere:
Malargüe
Provincia de Mendoza
Argentina

Collaboration:
>250 researchers
from 30 institutions and 19 countries:
Argentina, Armenia, Australia, Bolivia, Brazil, Chile, China, Czech Republic, France, Germany, Greece, Italy, Japan, Mexico, Poland, Russia, Slovenia, United Kingdom, United States of America, Vietnam

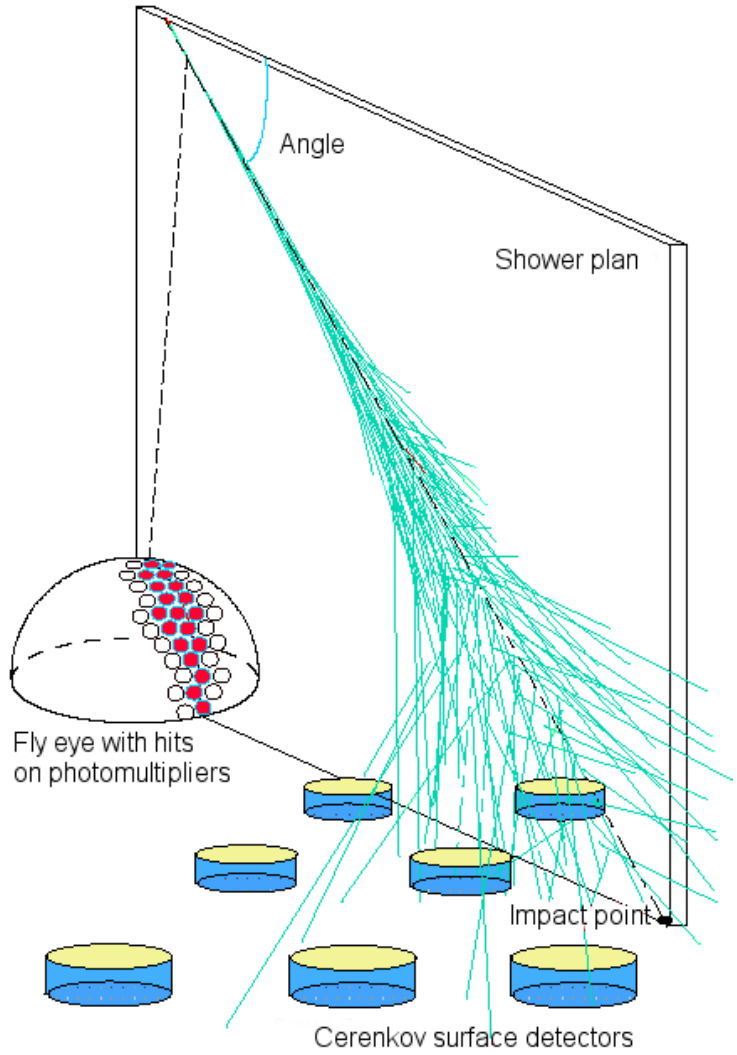
The Observatory



- Mendoza Province, Argentina
- 3000 km^2, 875 g cm^{-2}
- 1600 water Cherenkov detectors 1.5 km grid
- 4 fluorescence eyes - total of 30 telescopes each with 30^o x 30^o FOV

Pierre Auger - a major step

- Need high statistics
  large detection area : 2 x3000 km²
- Uniform sky coverage
  2 sites located in each hemisphere
  Argentina and USA
- Hybrid detector :
  surface array (water Cerenkov tanks)
  + fluorescence detector
  ⇒ Good energy and pointing resolution
  Improved sensitivity to composition
  Energy cross calibration



History and Schedule

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- August 1991 - concept born
- October 1995 - base design complete
- March 1999 - ground-breaking at southern site

History and Schedule

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- January 2000 - beginning of construction
- Feb 21, 2000 - deployment of first detector

- May 23, 2001 - observation of first fluorescence event
- August 2, 2001 - first surface detector event observed

Schedule at Southern site

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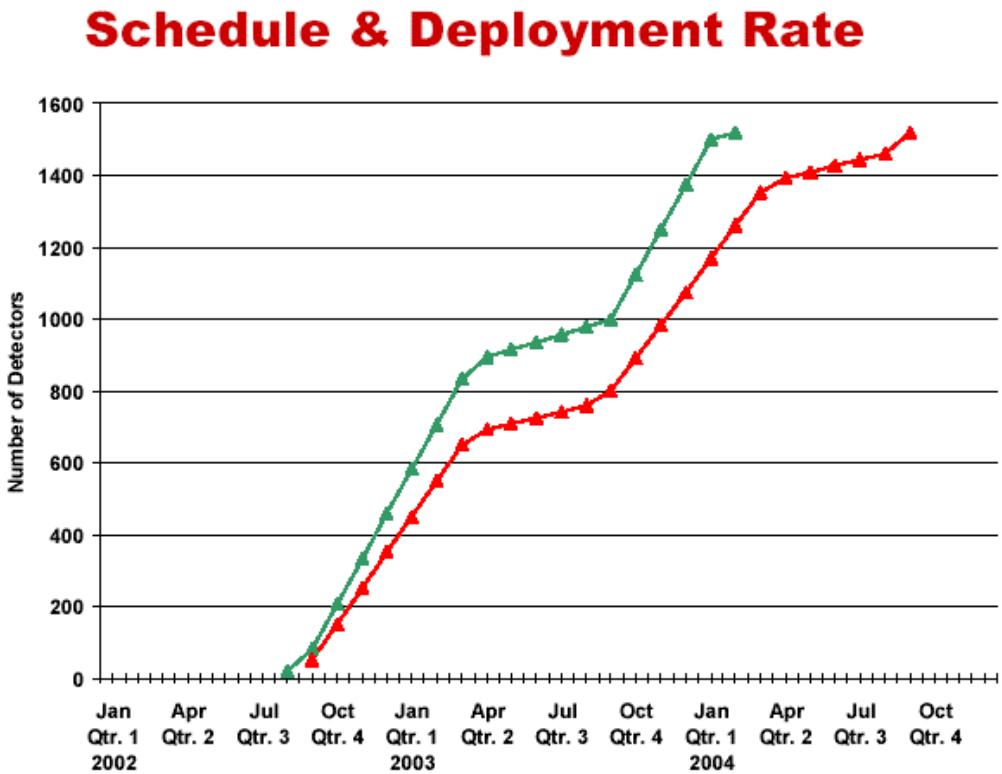
- 2000 and 2001 - “Engineering Array” 40 surface detectors and two fluorescence telescopes

- 2002-2004
  - full production and deployment, and staged turn on of data-taking



Reason for winter slow-down

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Engineering Array

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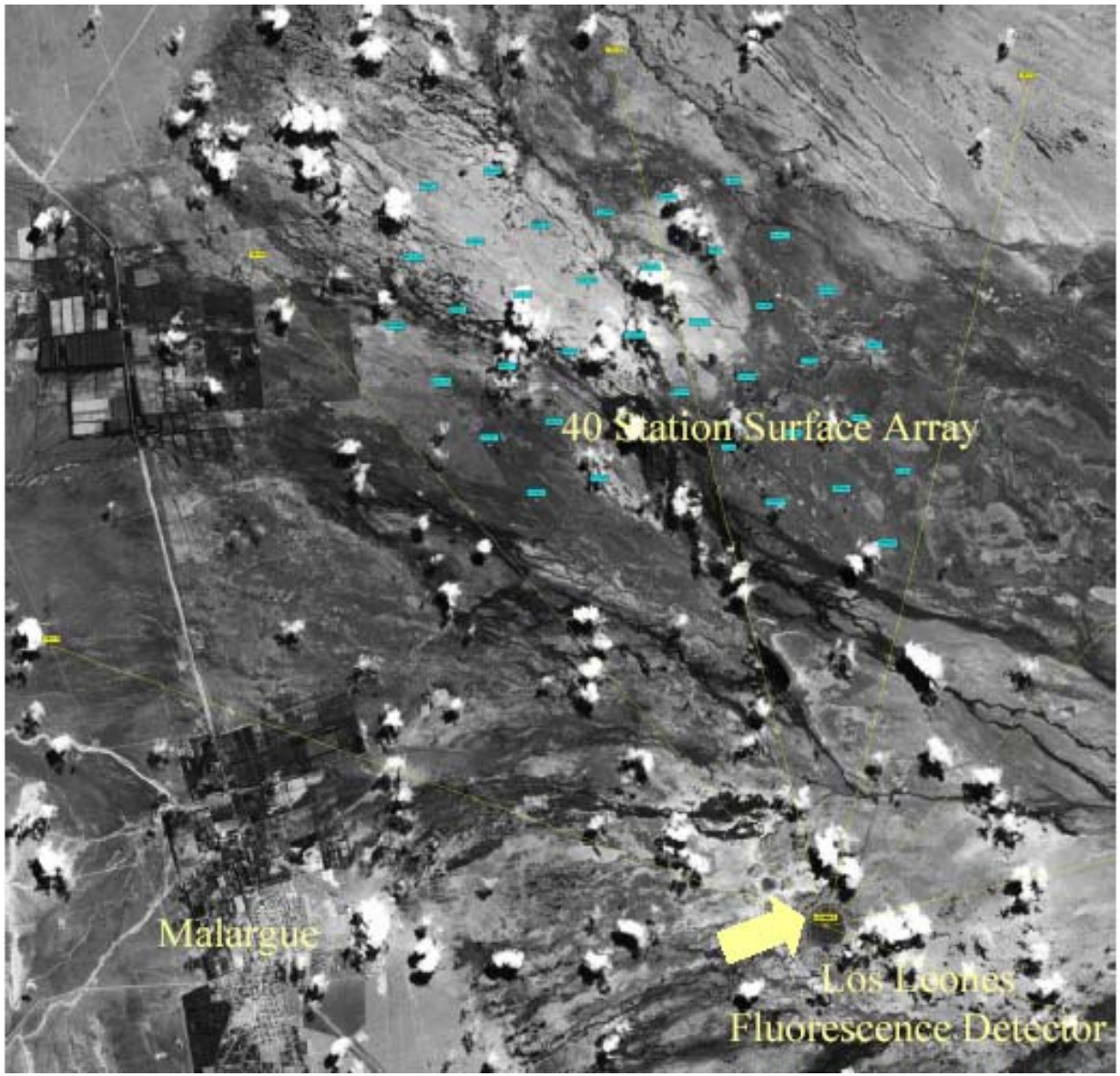
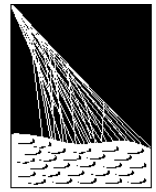


Why a Hybrid Observatory?

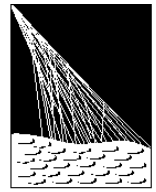


- Hybrid resolution of arrival directions, energies and masses is superior to that achieved by the SD or a single FD eye independently
- Rich set of measurements on each hybrid EAS

- SD and FD measure cosmic ray parameters using different methods with different systematic errors
  - Cross-checks and control of systematics.

- while the FD only operates with a duty cycle of 10%, the Hybrid observations will allow confident analysis of SD data taken without FD coverage.

e.g. Measurements of Energy



- SD alone: E from estimates of water Cherenkov density 1000m from the shower core
  - requires conversion factor from EAS simulations
- FD alone: E from estimates of energy deposition in the atmosphere (light α dE/dX).
  - requires knowledge of atmospheric transmission.
- two methods can be compared with Hybrid
  - Checks simulations and measurement systematics

Surface Detectors

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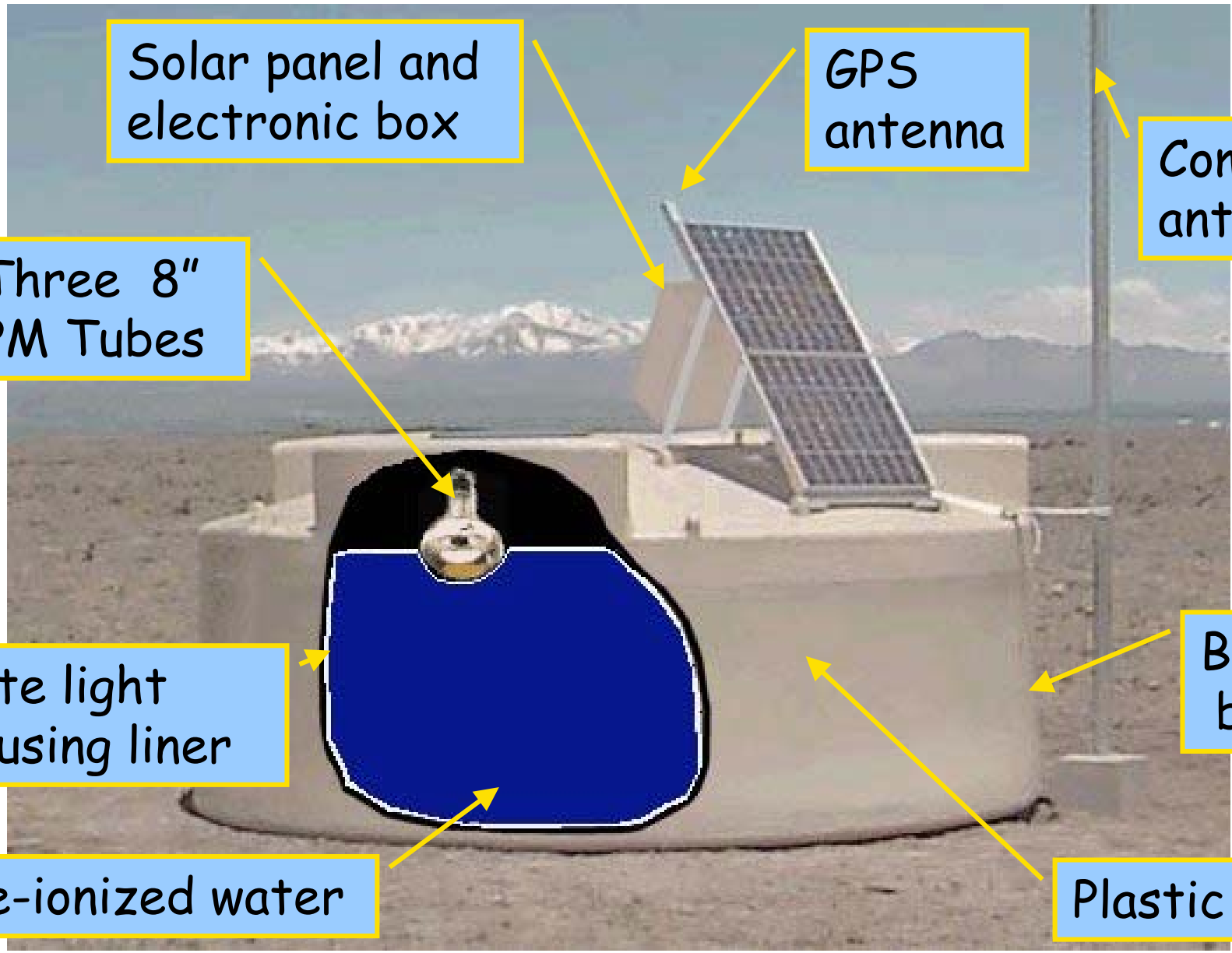
- 10 m^2, 1.2 m depth, 3 PMTs, 40 MHz FADC
- Integrated signal expressed in units of vertical equivalent muons (1 vem ~ 100 pe)

- for SD-only operation, typically will require 5 stations at the 4 vem trigger level (< 20 Hz per station)
- standard techniques for direction and core finding. Several LDFs under study, including a modified Haverah Park function.


Solar panel and electronic box
GPS antenna
Comm antenna
Three 8" PM Tubes
White light diffusing liner
Battery box
De-ionized water
Plastic tank

Surface Detectors

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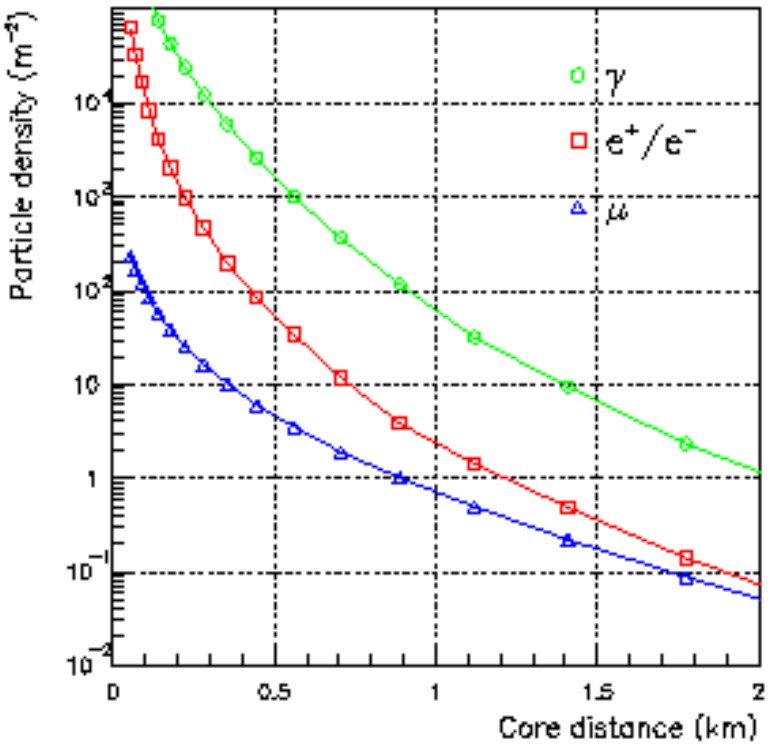
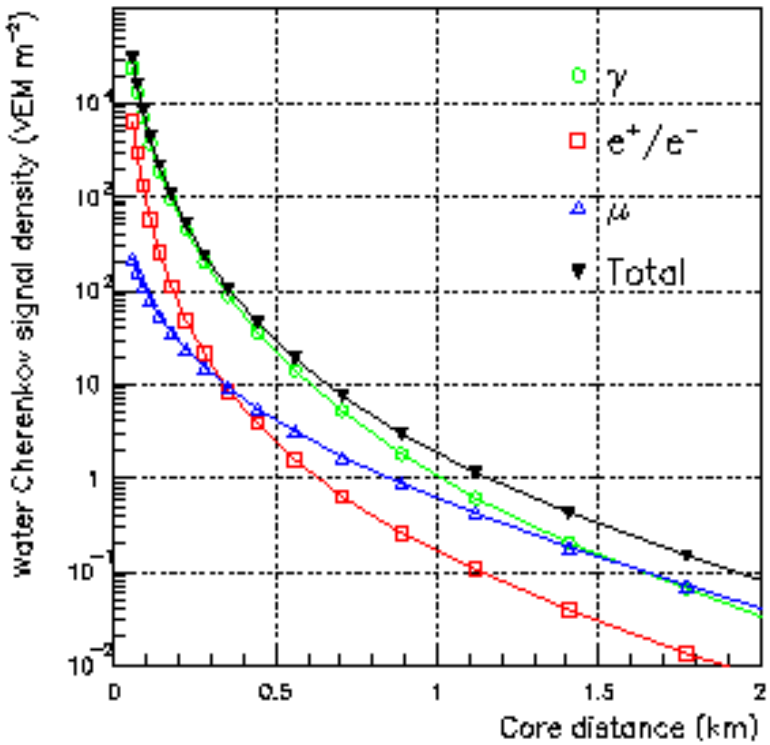
10^{19}eV proton





- SD water Cherenkov detectors measure muon, electron and gamma components of EAS, the latter especially important at large core distances

Surface Detector Resolution

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- SD Angular resolution: $E > 10^{19}$eV

θ (deg)	Proton/Iron		Photon
	$E>10^{19}$eV	$E>10^{20}$eV	$E>10^{19}$eV
20º	1.1º	0.6º	4.0º
40º	0.6º	0.5º	2.5º
60º	0.4º	0.3º	1.0º
80º	0.3º	0.2º	1.0º

space angle containing 68% of events

Surface Detector Resolution

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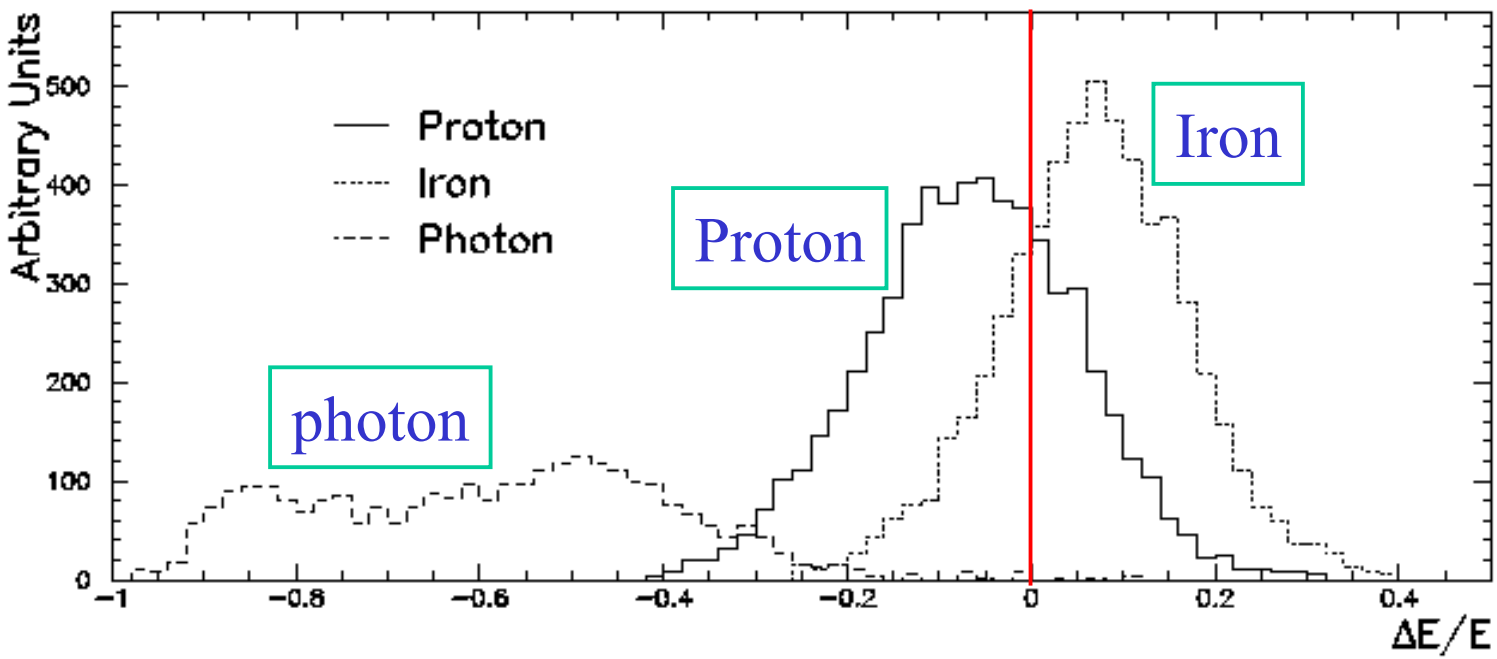
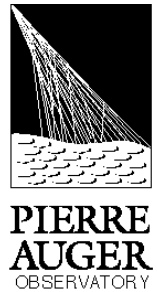
- Energy determined from fitted density at 1000m, $\rho(1000)$. Conversion factor from simulations; averaged for p and Fe primaries. $E > 10^{19}$ eV



rms E resolution ~12% (assuming p/Fe mixture)

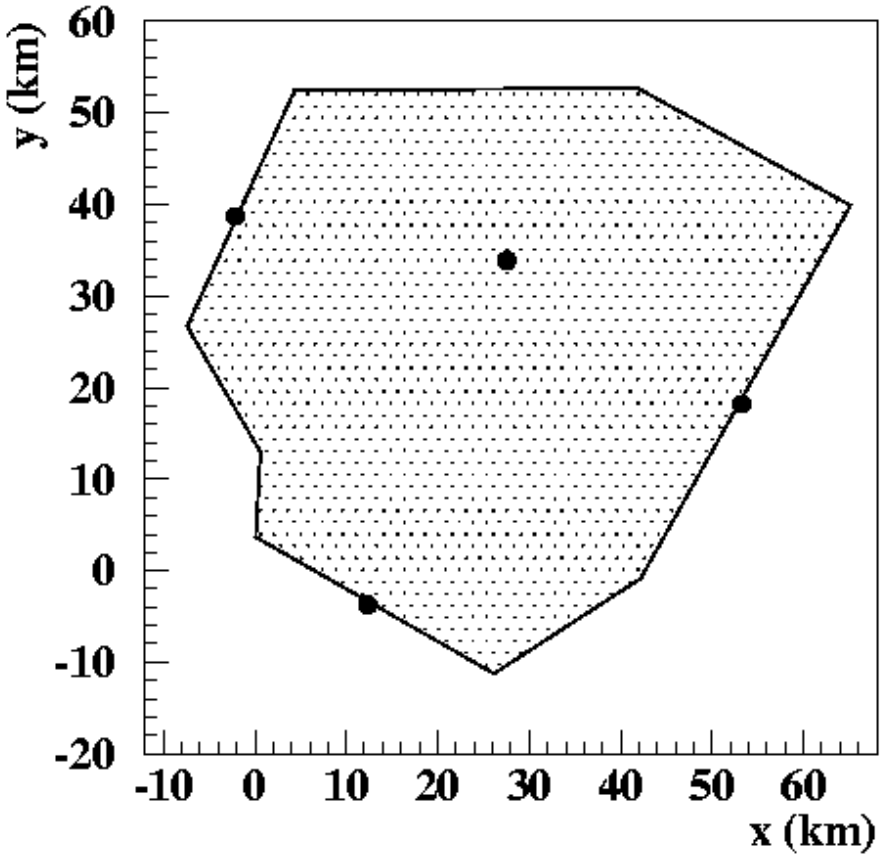
SD Aperture and Event Rate



E_o (eV)	Trig Aperture km^2sr	Rate per year $> E_o$
10^{18}	0	0
$3x10^{18}$	2200	15000
10^{19}	7200	5150
$2x10^{19}$	7350	1590
$5x10^{19}$	7350	490
10^{20}	7350	100
$2x10^{20}$	7350	30

- Zenith < 60°, based on AGASA spectrum (Takeda et al 1998)
  - (Zenith > 60° adds about 50% to event rate)

Auger Southern Site



• = Fluorescence site

- Hybrid reconstruction works when a shower is recorded by the surface array and at least one eye
- This multiple-eye design reduces our reliance on precise knowledge of atmospheric attenuation of light
- Mean impact parameter at 10^{19}eV is 13km

The completed FD building will house
6 telescope/ camera arrays

Fluorescence Detector

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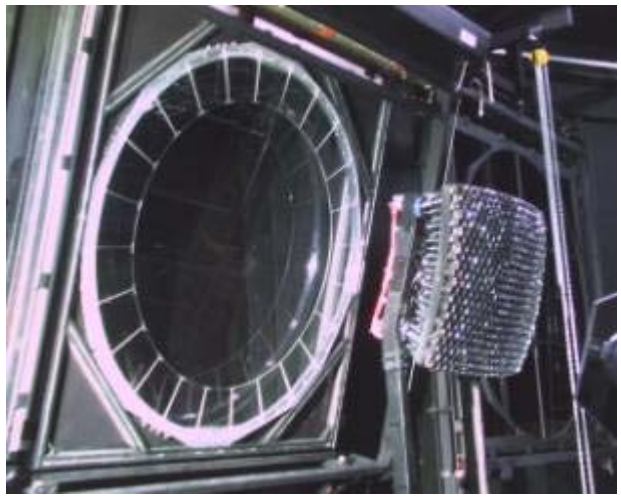
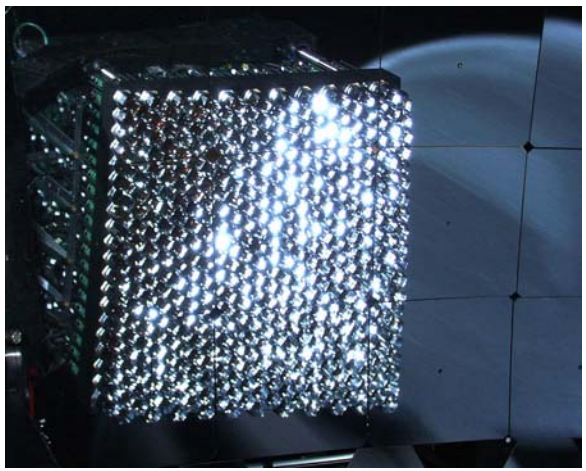
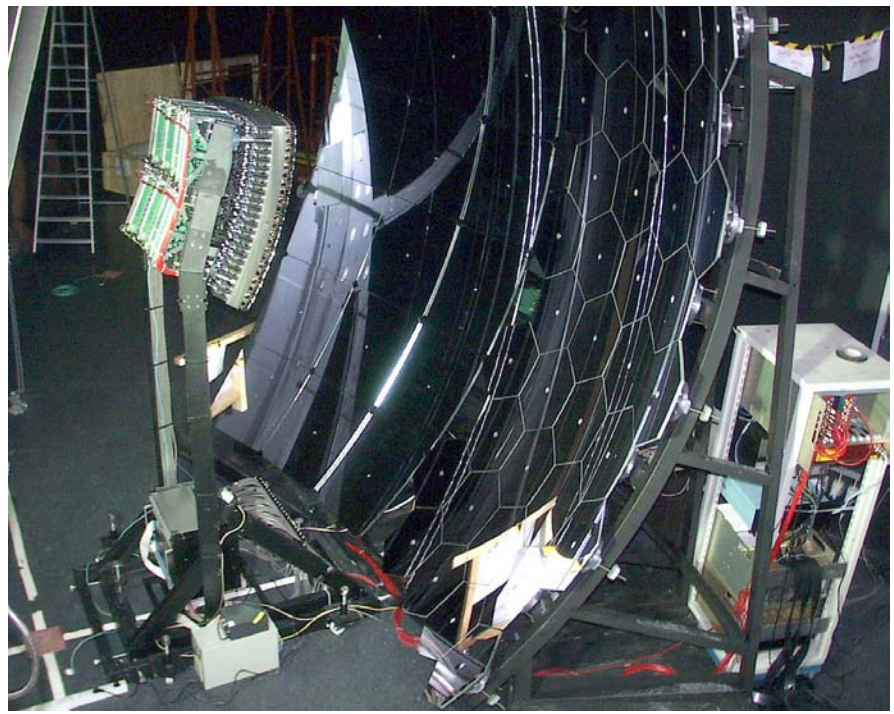


Schmidt aperture stop

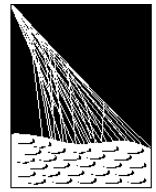


440 pixel camera 30ºx30º



3.8m x 3.8m prototype mirror and camera

Hybrid Reconstruction of Axis

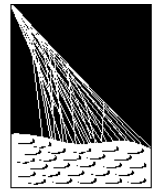


- good determination of shower axis is vital for origin studies, but also vital as first step towards good energy and mass composition assignment

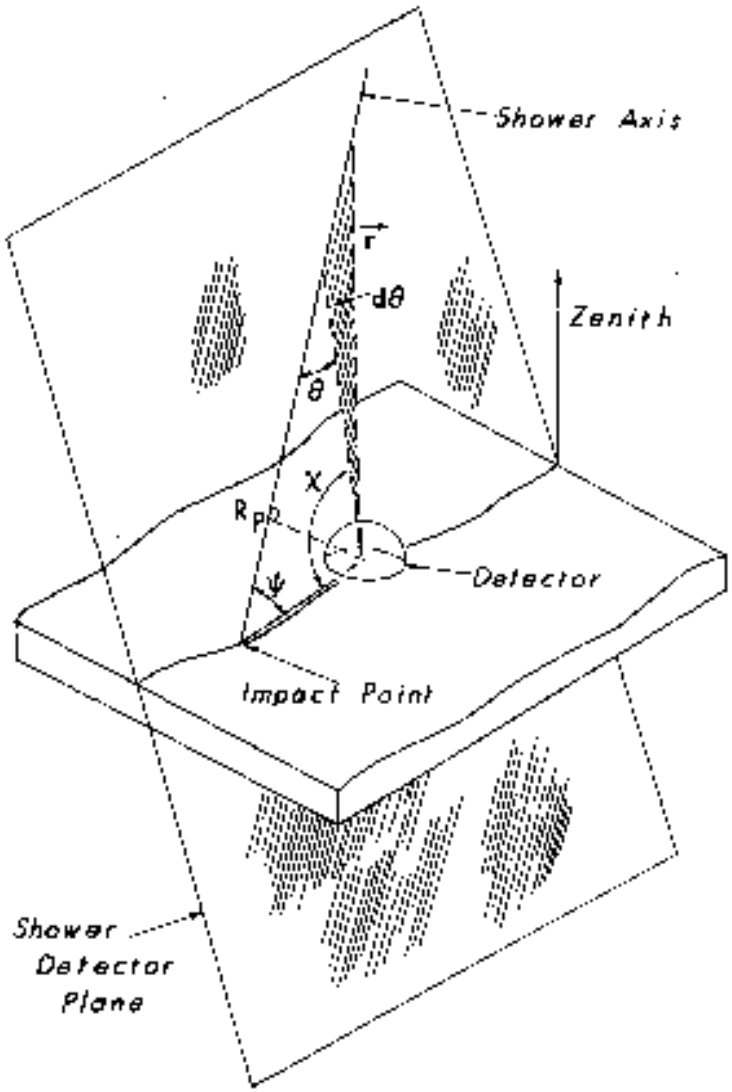
- use eye pixel timing and amplitude data together with timing information from the SD.
  - GPS clocks in SD tanks and at FDs.

- Hybrid methods using one eye give angular resolution comparable to “stereo” reconstruction

Hybrid Reconstruction (Cont.)



- eye determines plane containing EAS axis and eye
  - plane normal vector known to an accuracy of ~ 0.2°
- to extract R_p and ψ, eye needs to measure angular velocity ω and its time derivative $d\omega/dt$
  - but difficult to get $d\omega/dt$, leads to degeneracy in (R_p,ψ)
- degeneracy broken with measurement of shower front arrival time at one or more points on the ground
  - eg at SD water tank positions



Hybrid Reconstruction (Cont.)

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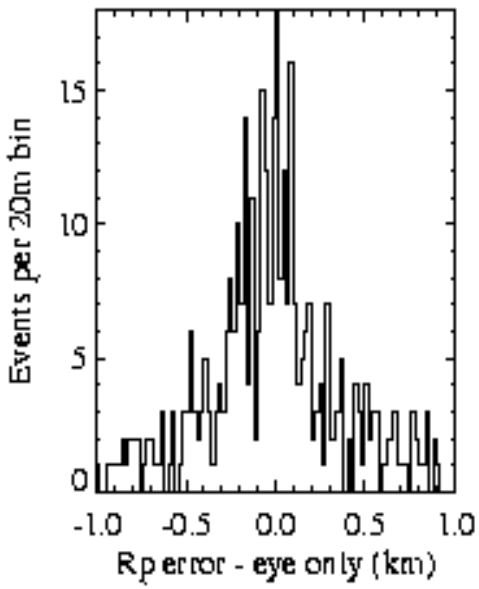
- Simulations at 10^{19}eV
- Reconstruct impact parameter Rp. Dramatic improvement with Hybrid reconstruction

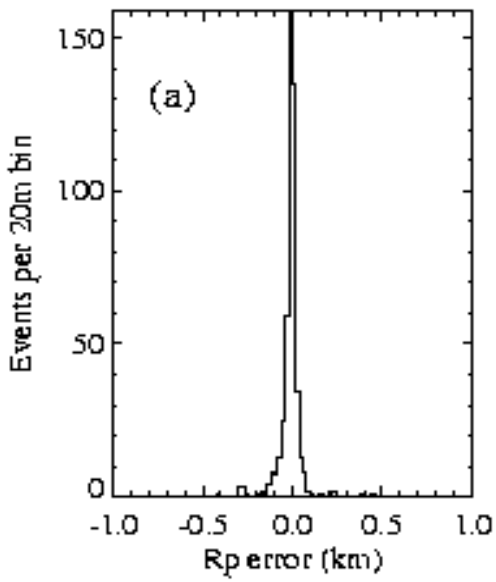
median R_p error = 350m

strong dependence on angular "Track Length"

Single FD only



Hybrid



Simulated Hybrid Aperture

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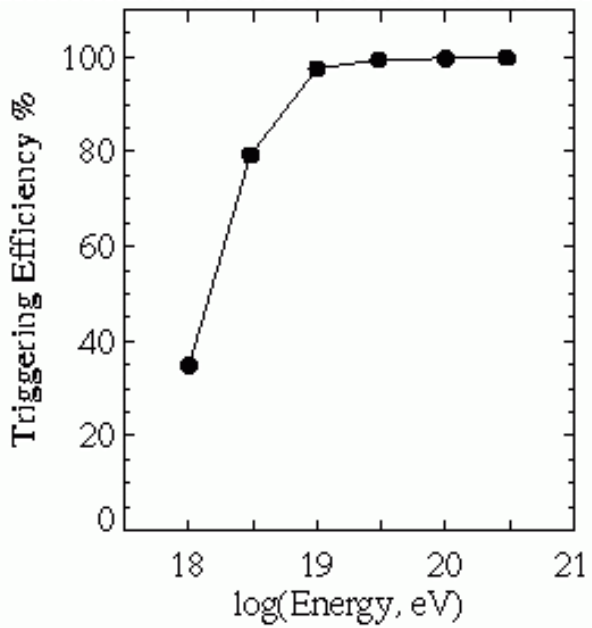
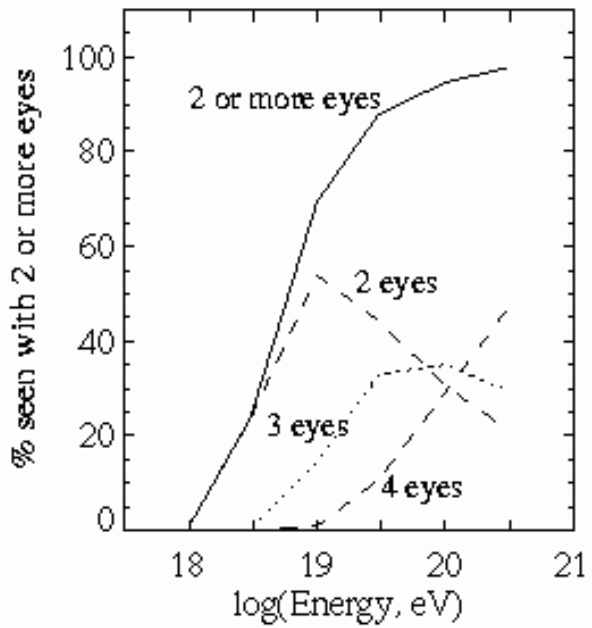
Hybrid Trigger Efficiency





"Stereo" Efficiency

- Note the significant aperture at 10^{18}eV, and the stereo aperture at the higher energies

- Trigger requirement: at least one eye triggering on a track length of at least 6 degrees; two surface detectors. $\theta < 60^{\circ}$
- Hybrid Aperture = Hybrid Trigger efficiency x 7375 km^2sr

Hybrid Reconstruction Quality

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E(eV)	Δdir (º)	ΔCore (m)	ΔE/E (%)	ΔXmax g/cm²
10^{18}	0.7	60	13	38
10^{19}	0.5	50	7	25
10^{20}	0.5	50	6	24

statistical errors only

zenith angles < 60^{o}

- 68% error bounds given
- detector is optimized for 10^{19}eV, but good Hybrid reconstruction quality at lower energy

Assembly Building

Open house for the public

Official ribbon cutting, Nov. 2000

Office Building Opening Nov 2001

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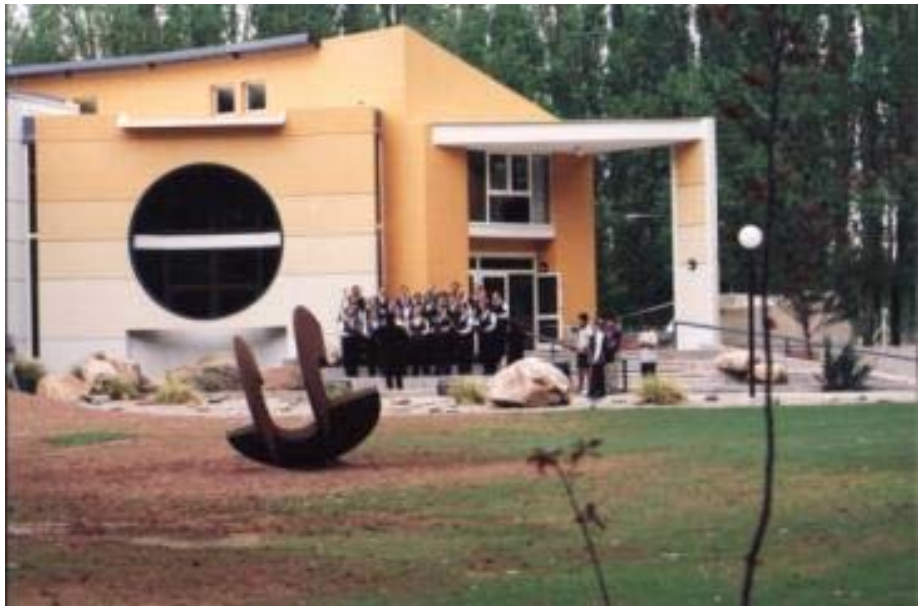
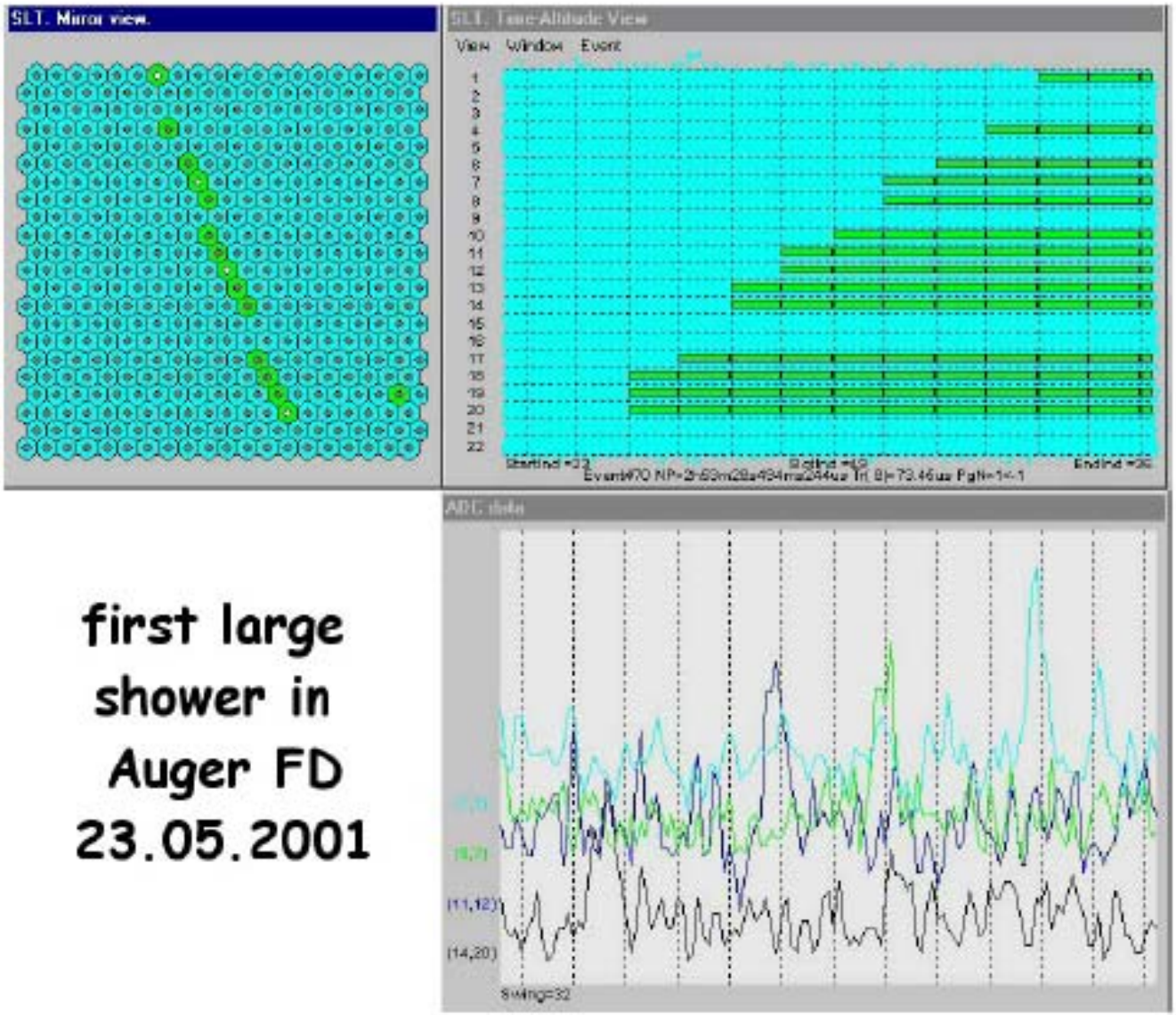


“First Light” 23 May 2001



first large shower in Auger FD 23.05.2001

85 degree zenith angle event

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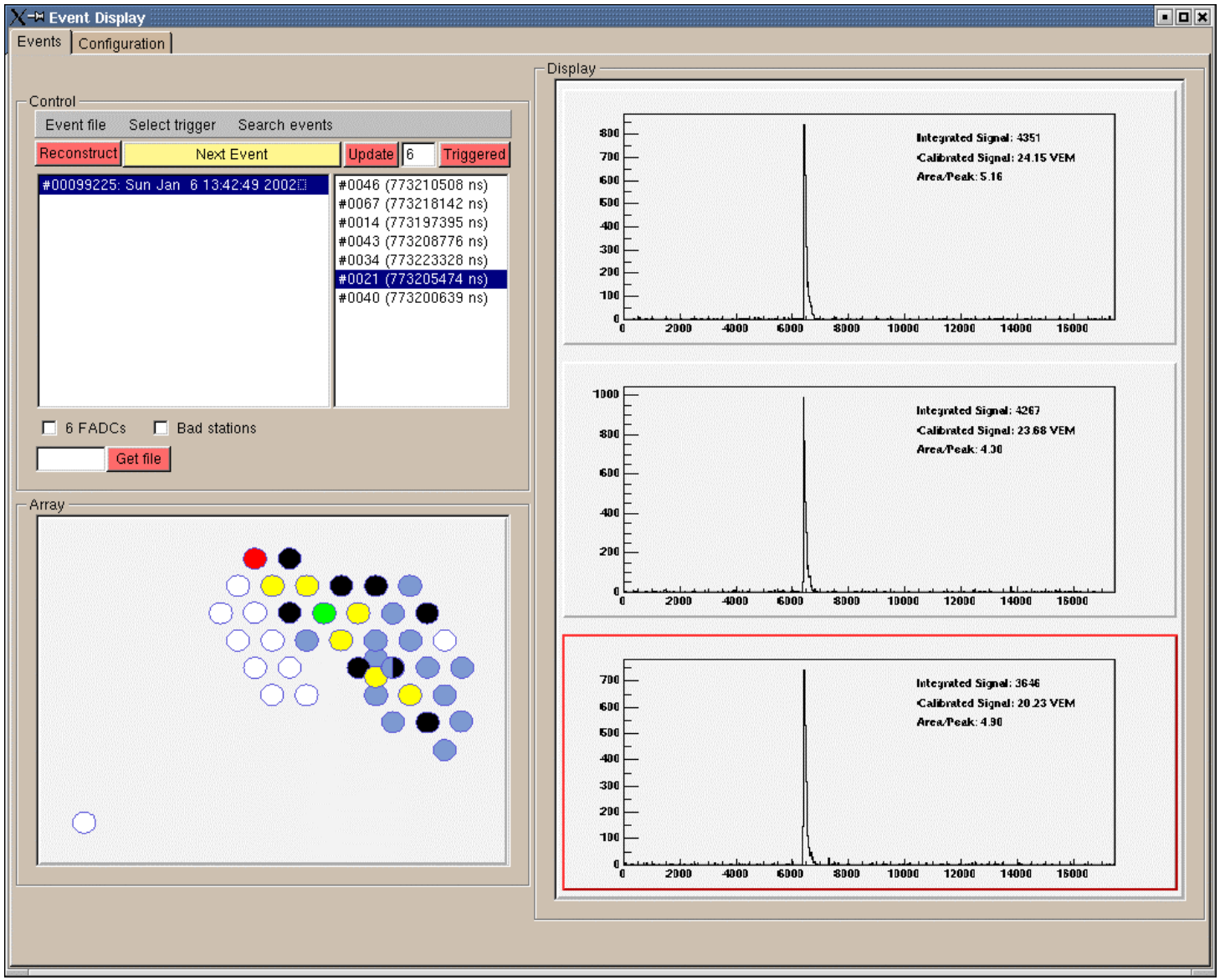
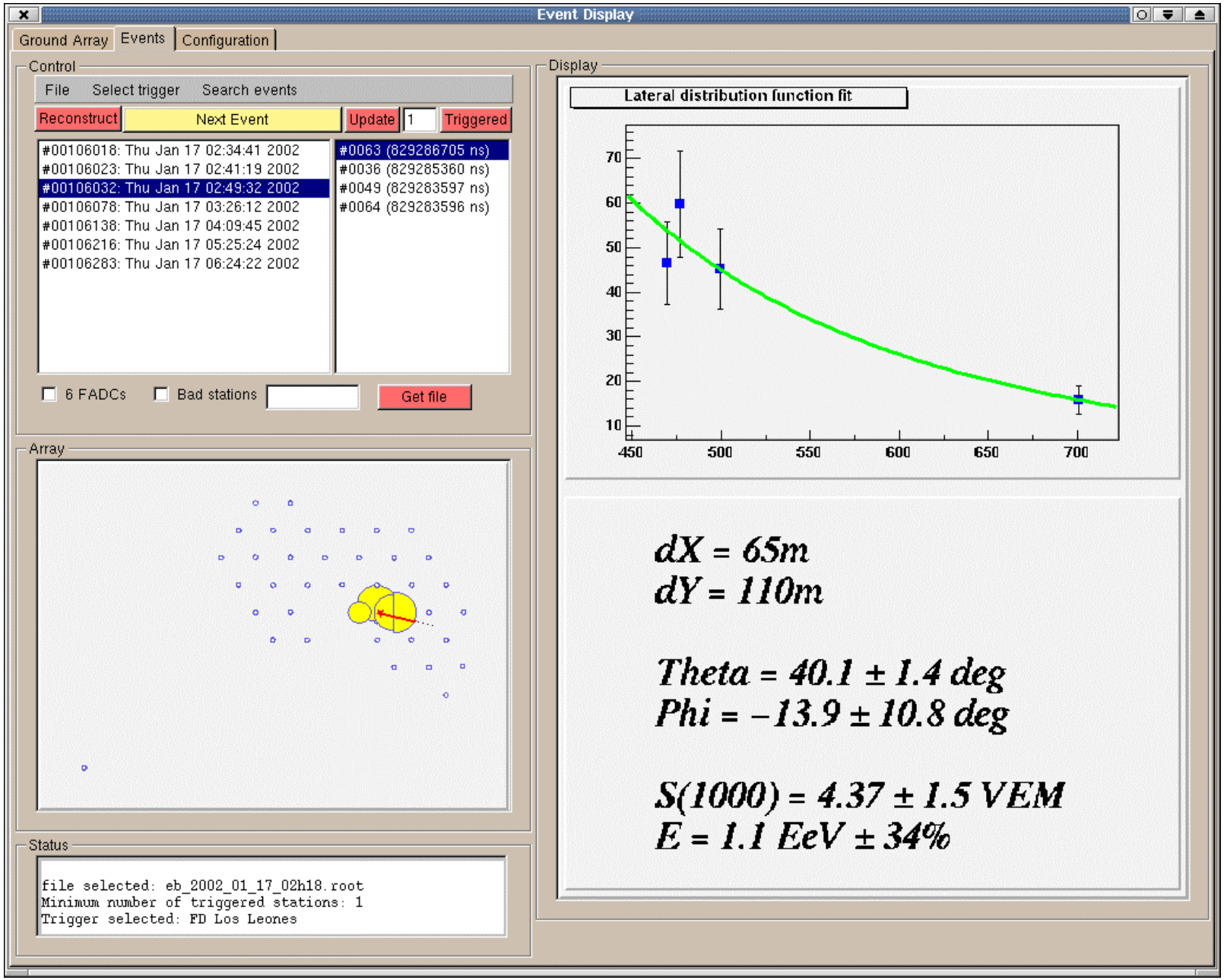


Jan 6 2002

First 7-fold coincidence

All tank signals sharp in time (as expected)



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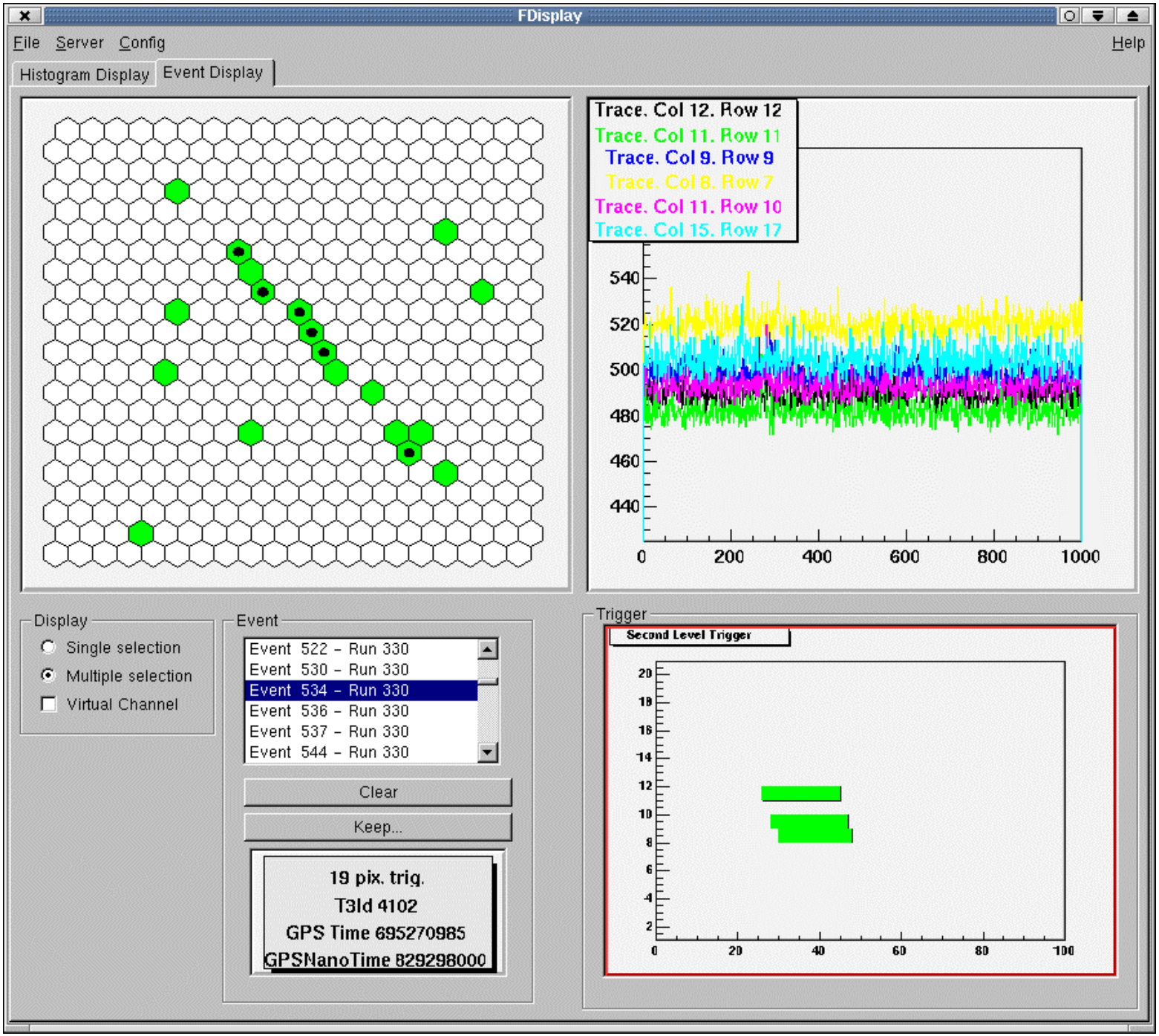
"Gold" event Jan 17 2002



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"Gold" event Jan 17 2002

Laser Shots

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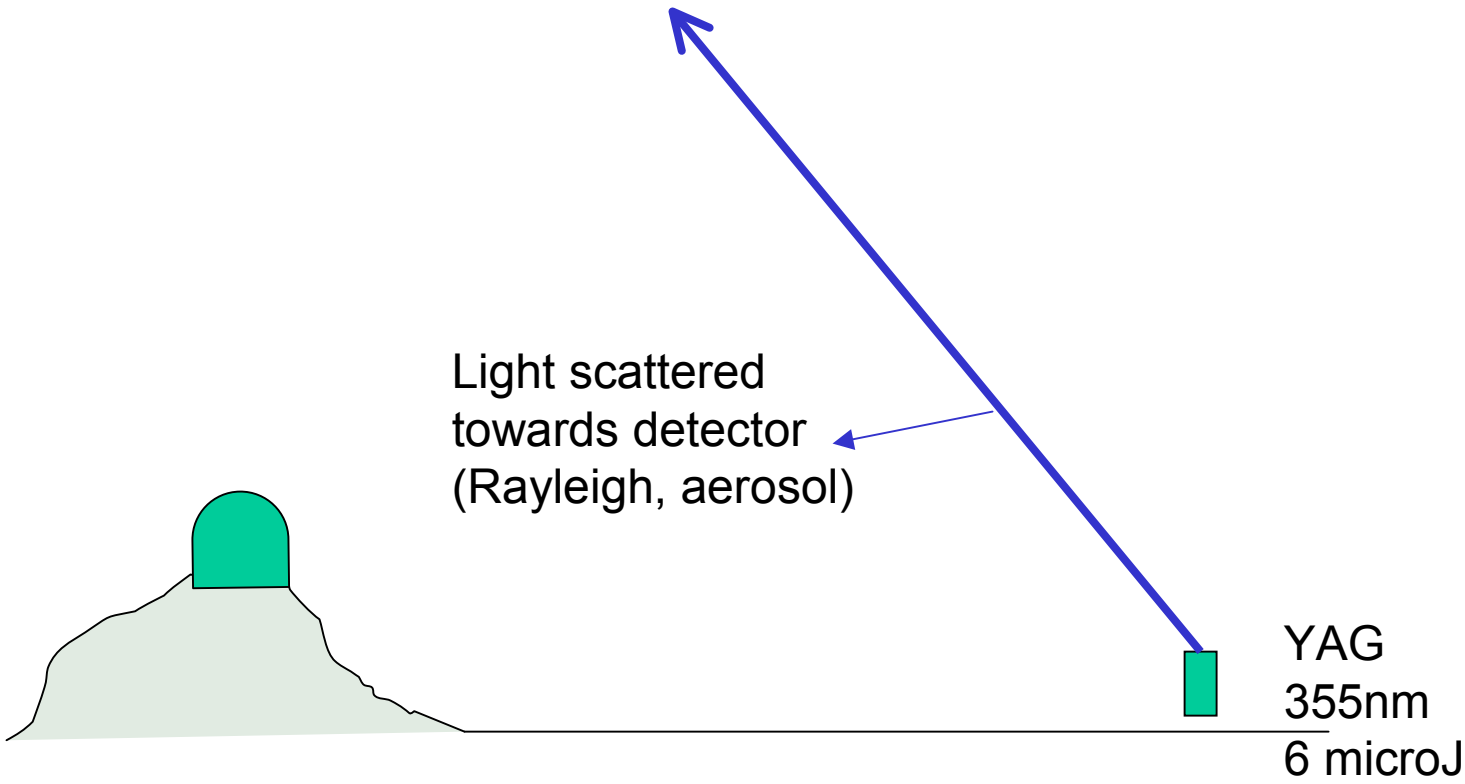
- Probing atmospheric transmission 300-400 nm
- Calibration tool



Laser Shots - calibration

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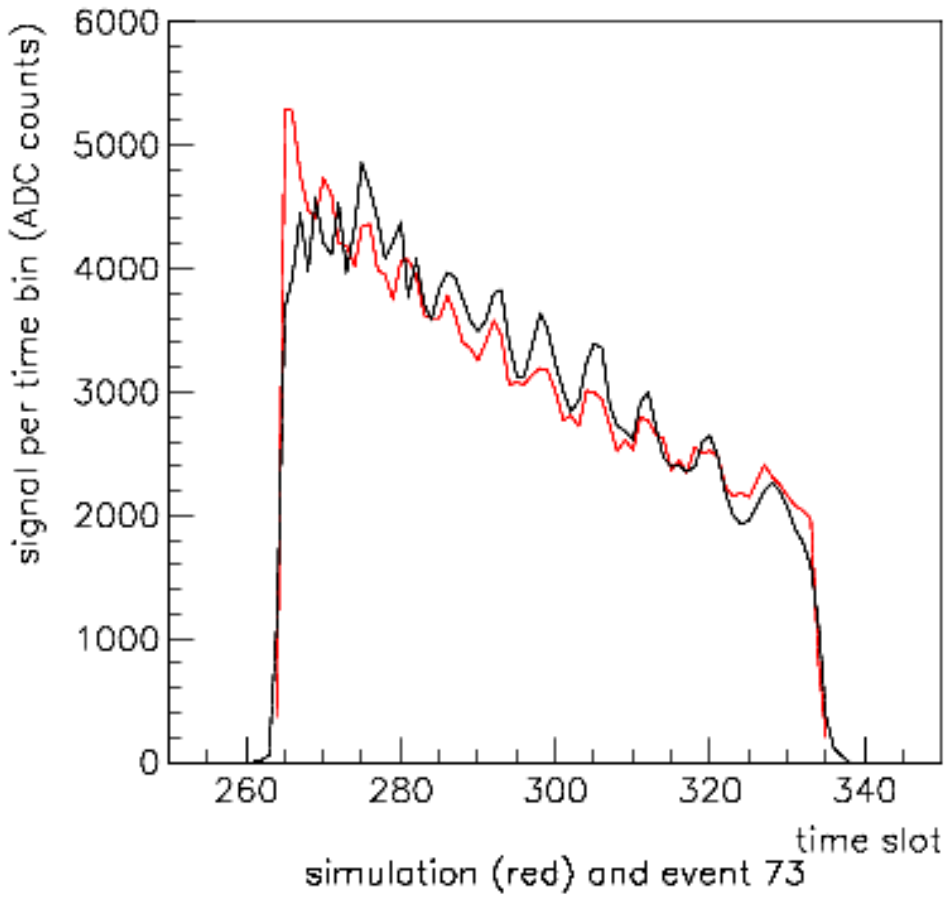
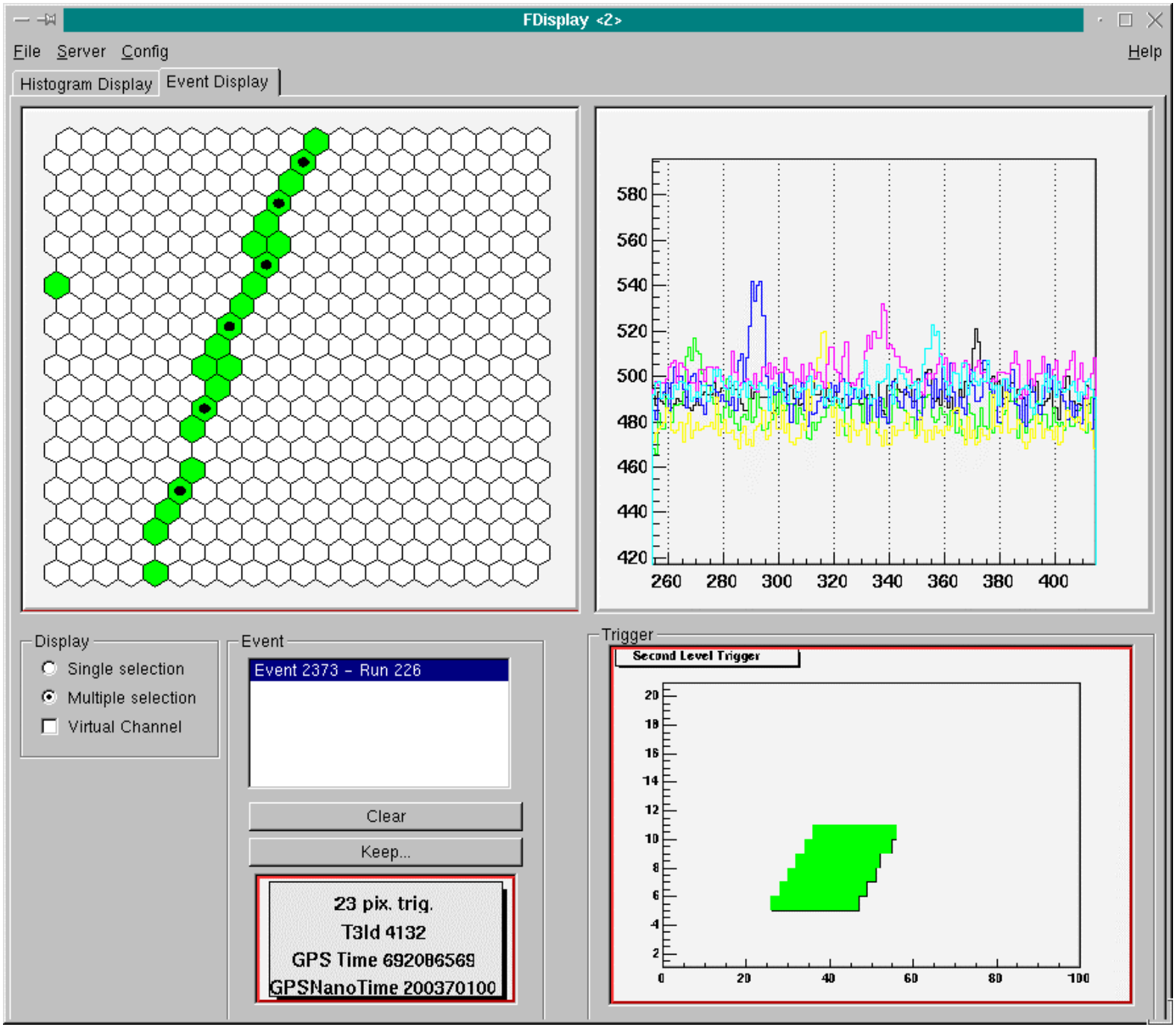
- 355nm vertical laser 3km from detector



Black - real data
Red - simulation



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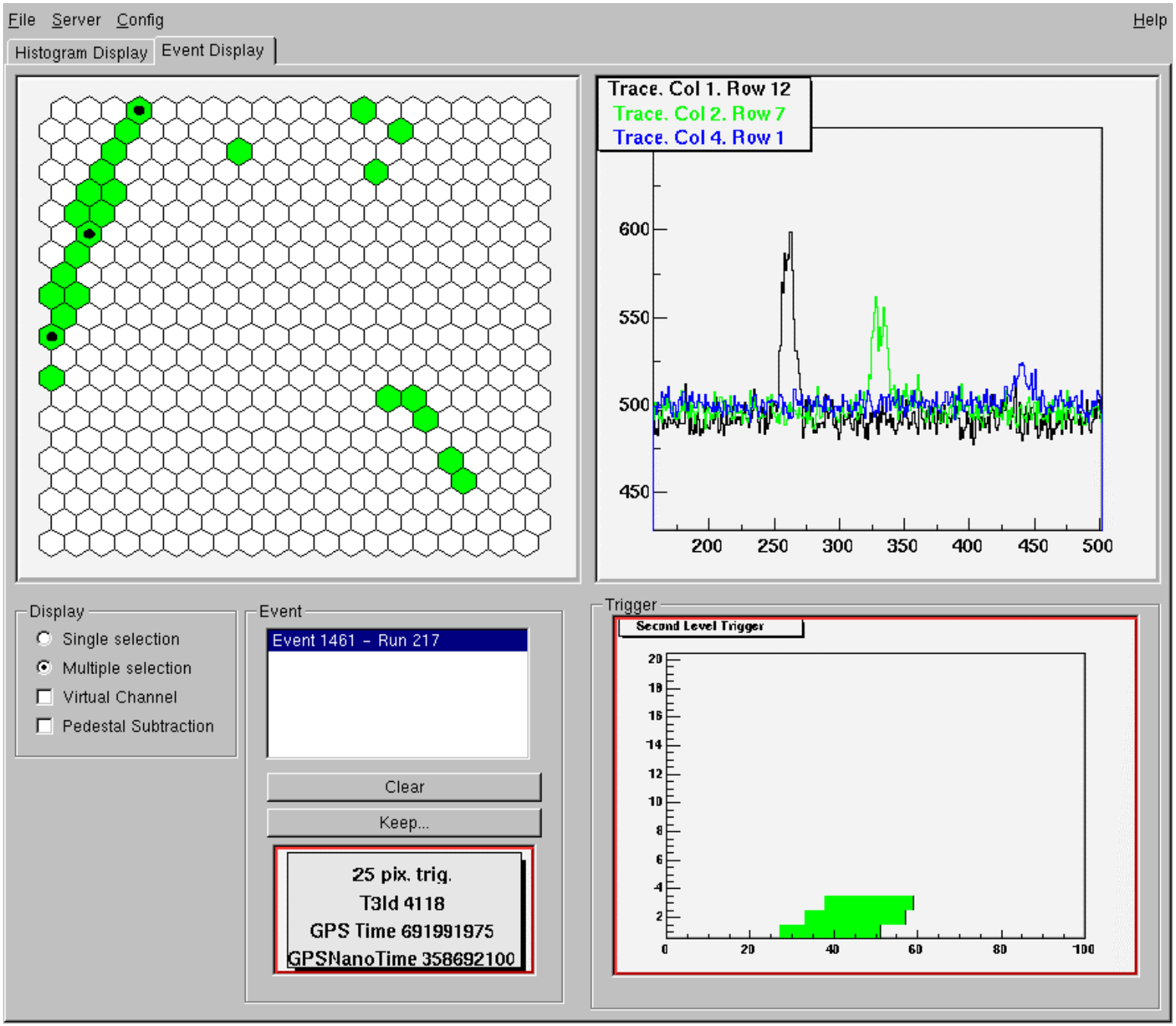
Hybrid event.

Since Dec 2001



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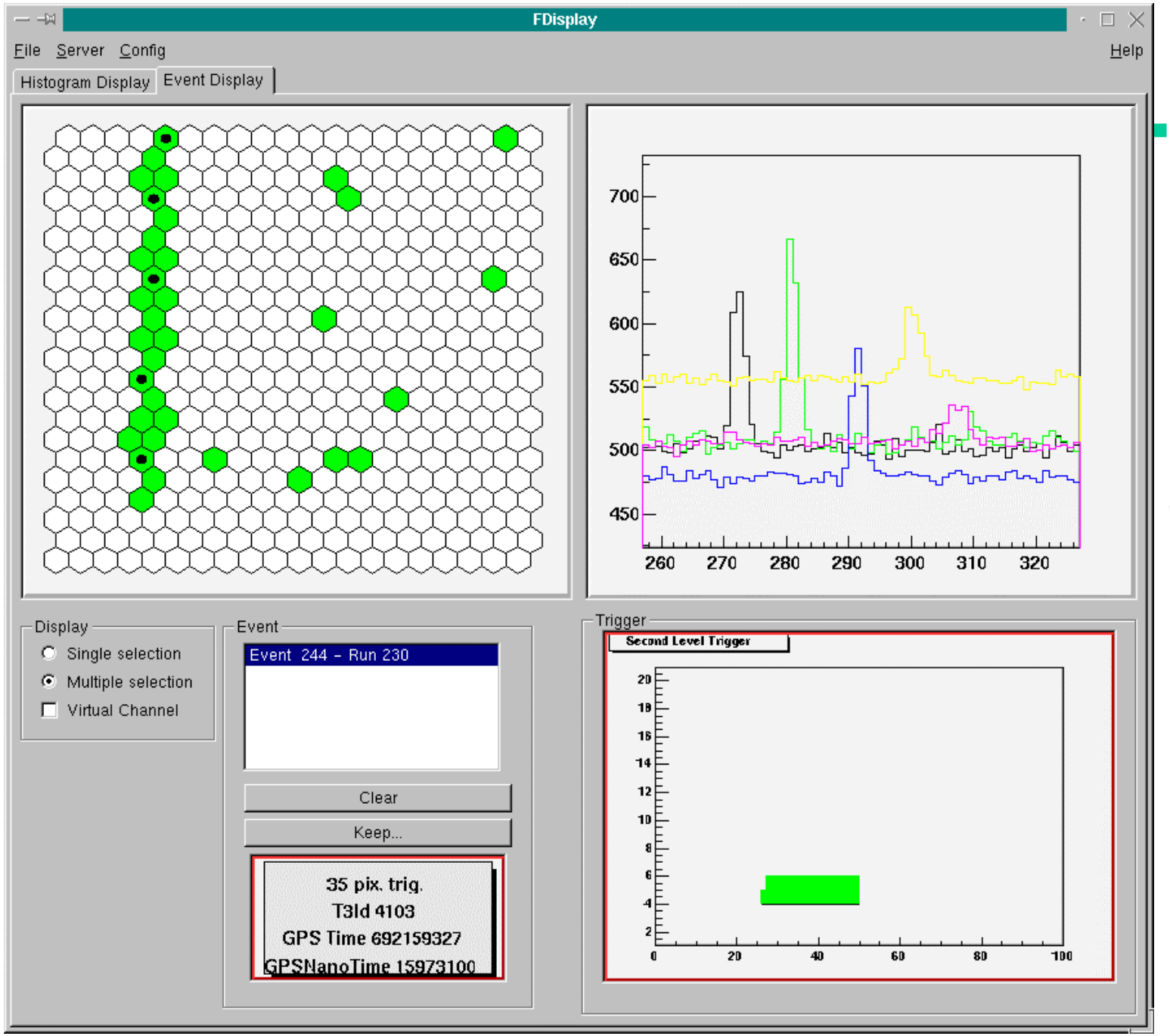
Hybrid event rate ~ 1 per two hrs



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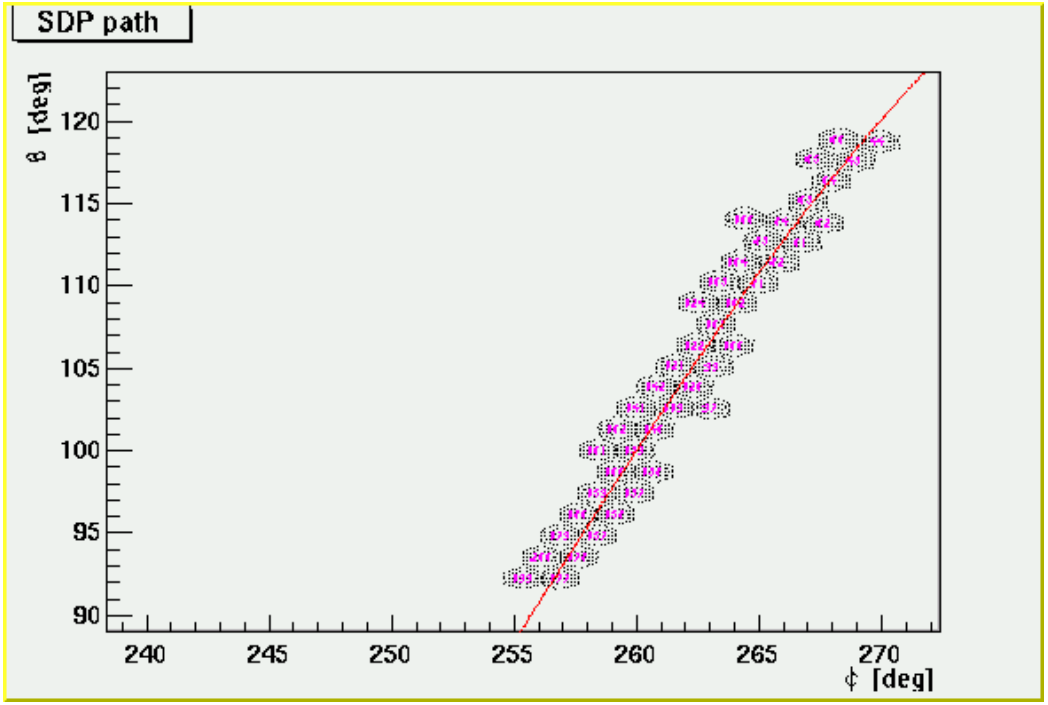
Cerenkov contaminated

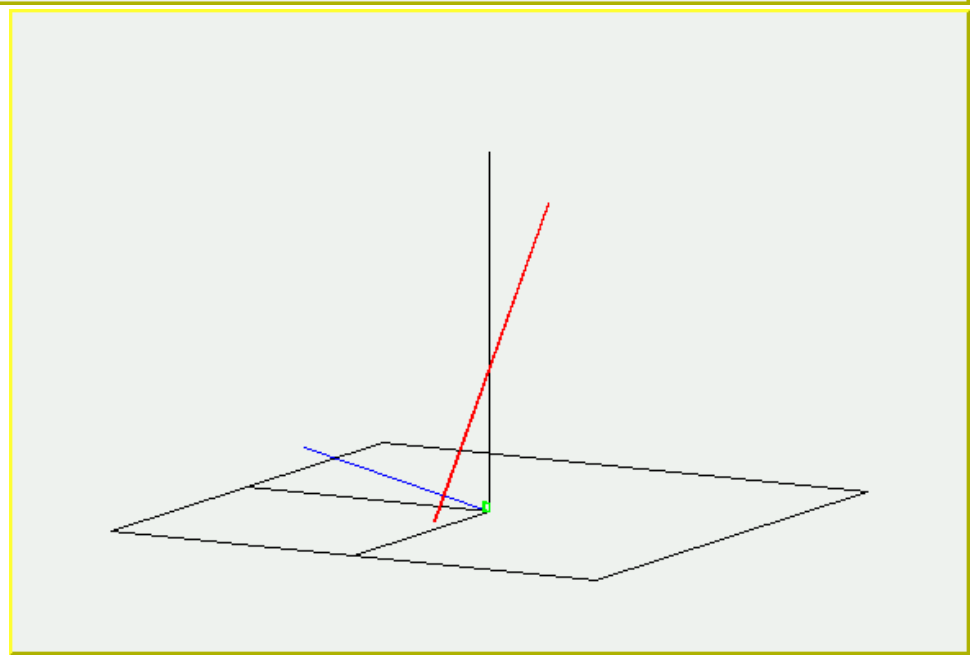
Dec 12, 2001
Hybrid trigger

43 fired pixels
in camera



Result of hybrid
geometric
reconstruction

zenith angle = 25.8 deg
core distance =11300 m



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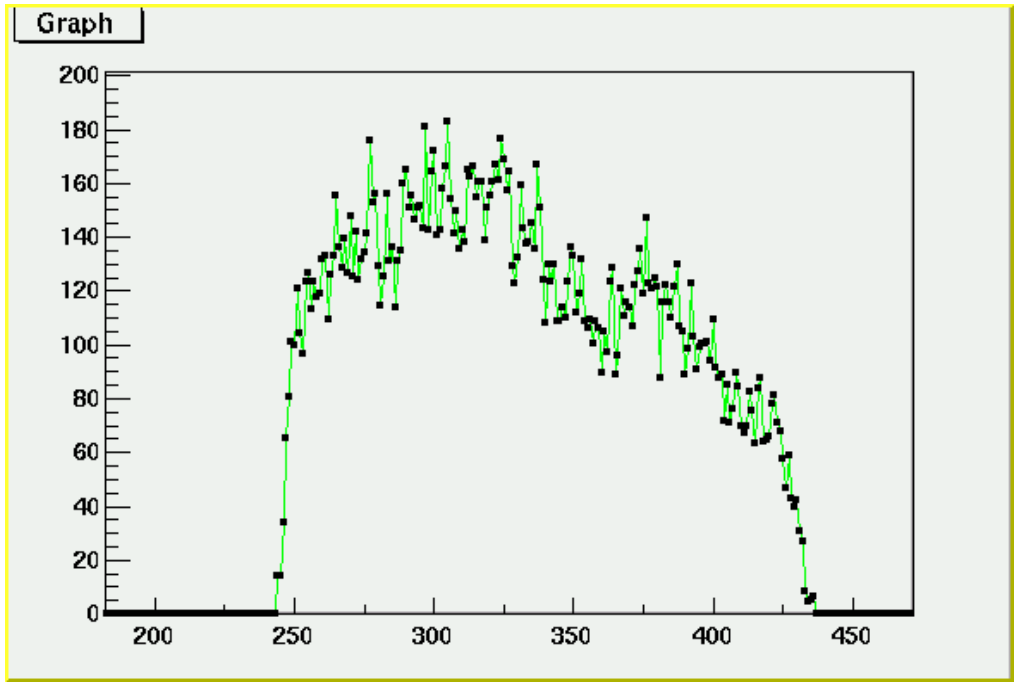
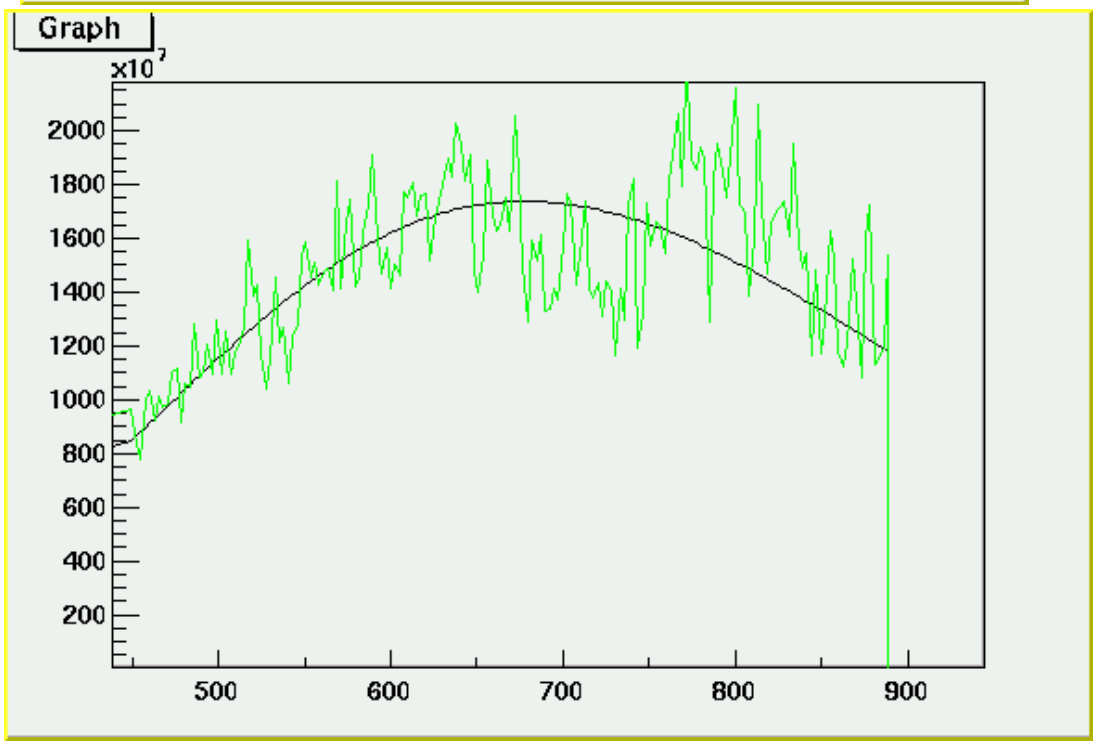
collected charge (photoelectrons) vs time.

Total time approx 20μs



transformed to shower charged particle number vs atmospheric depth (g/cm^2)



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Conclusion

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- Engineering array is built and operating well.
- second FD building being constructed now, first site fully instrumented (6 telescopes) by Oct 2002.
- next 100 SD installed starting Sep 2002
- expect full observatory complete by last quarter 2004
- but data will be pouring in well before from partially completed system.