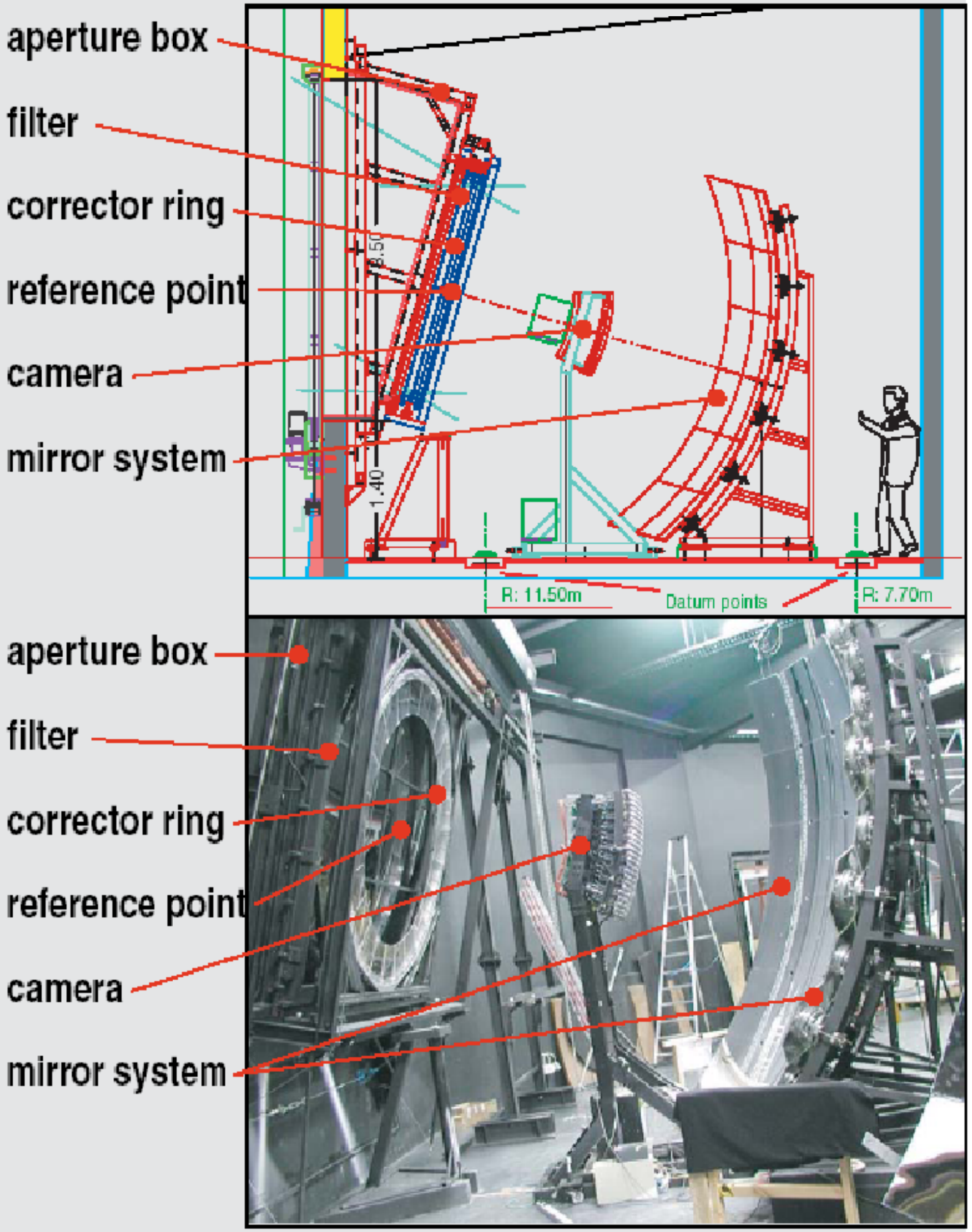
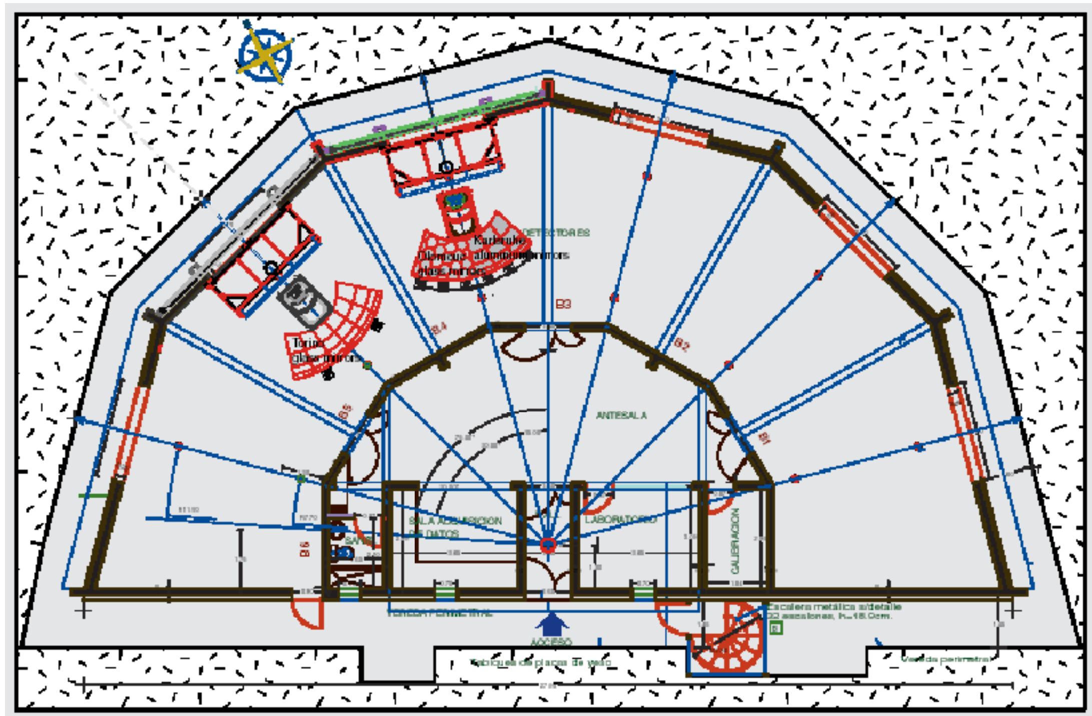
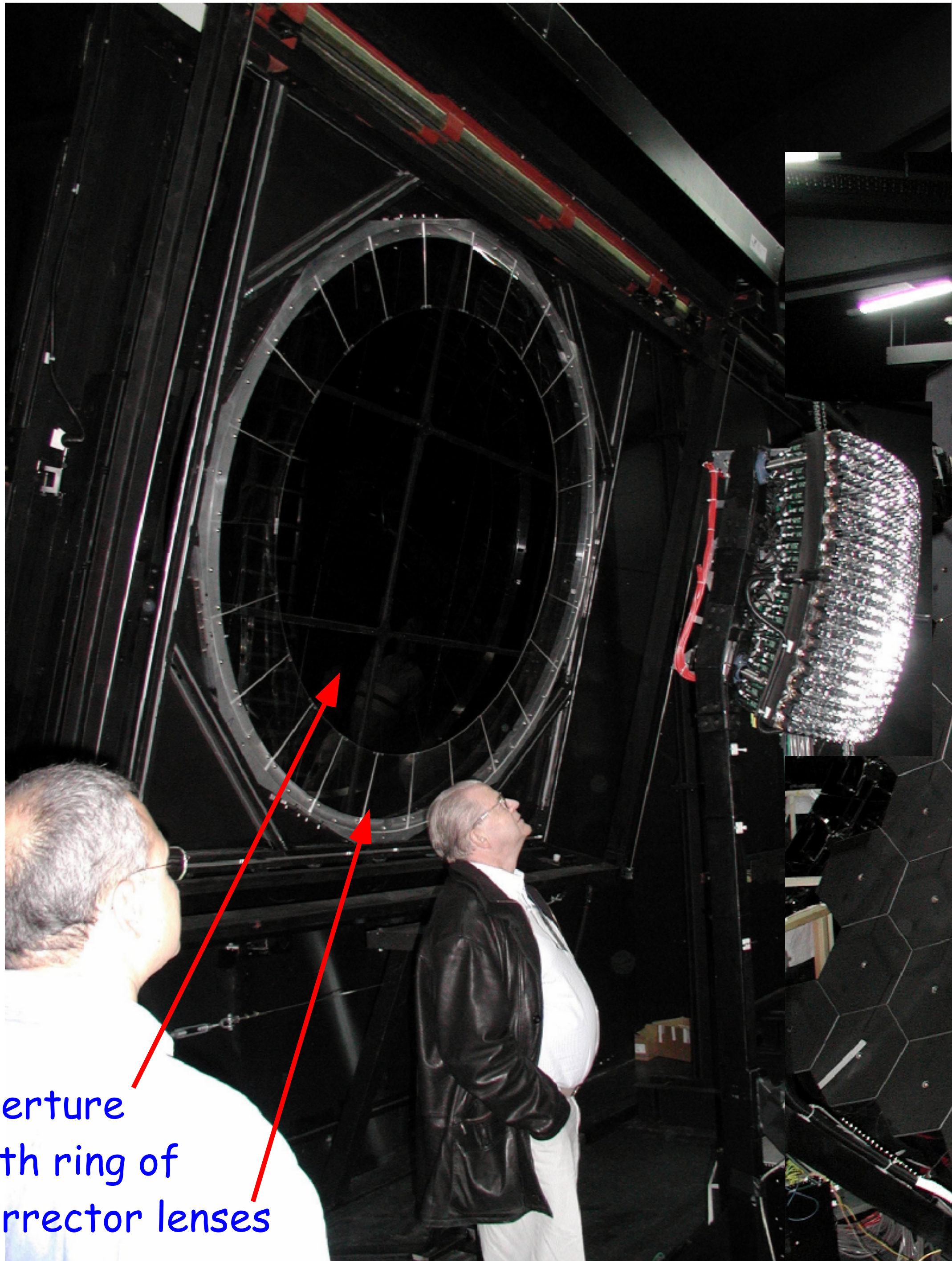
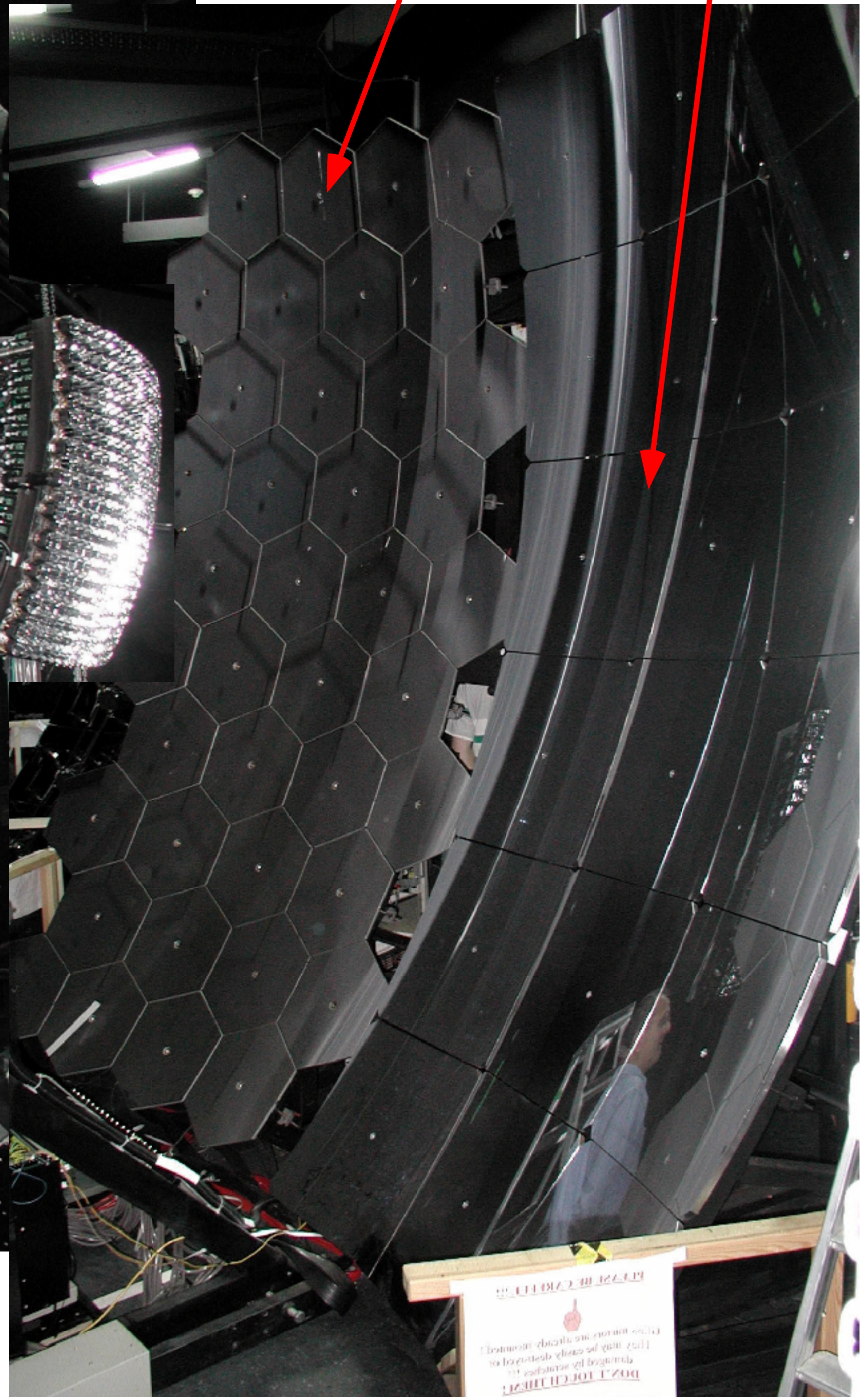
Fluorescence Detector (FD) System

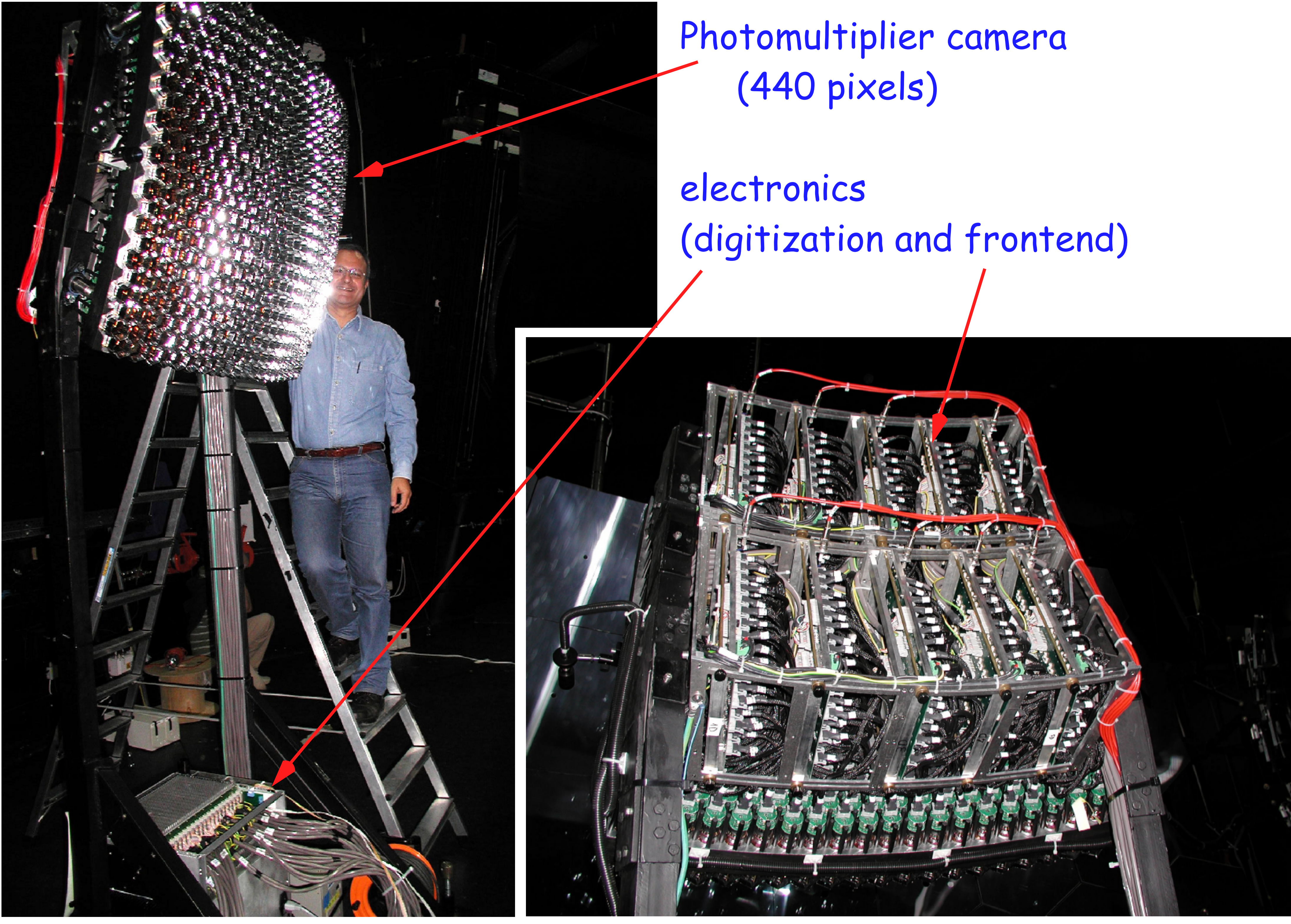
Los Leones

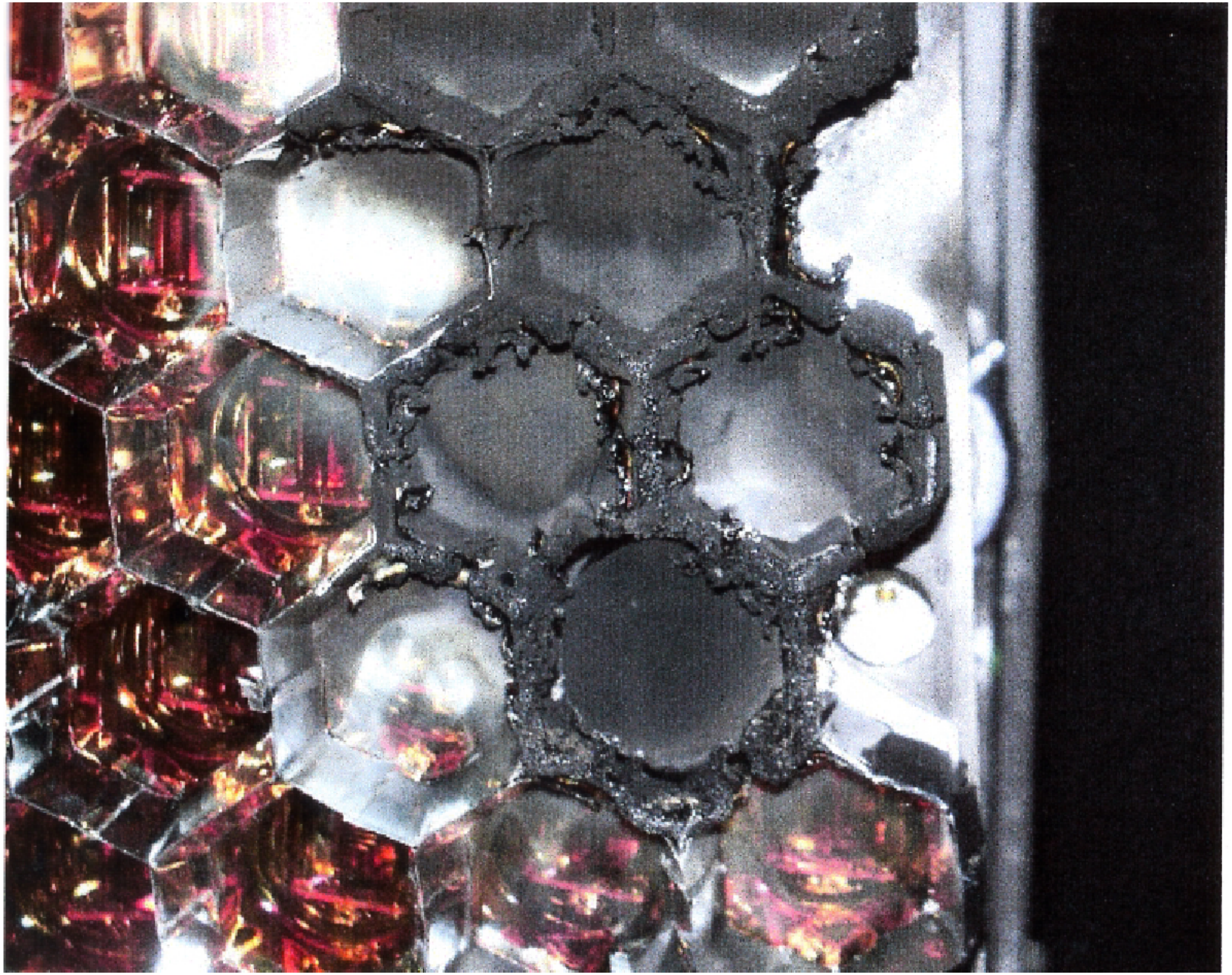





aperture
with ring of
corrector lenses


two types of mirrors (for testing)
glass
aluminum


Photomultiplier camera
(440 pixels)
electronics
(digitization and frontend)



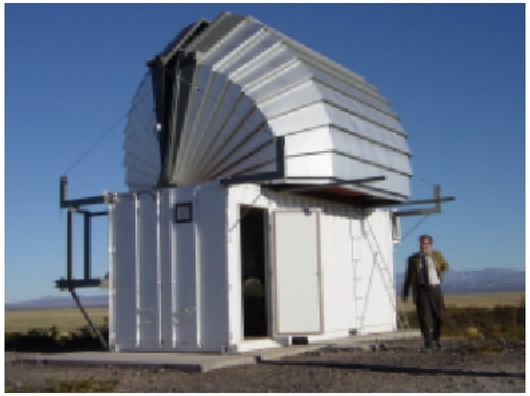
Los Leones (operational)

Los Morados

Coihueco (operational)

Lomo Amerilla
(to be built)

Atmospheric Monitoring and Calibration

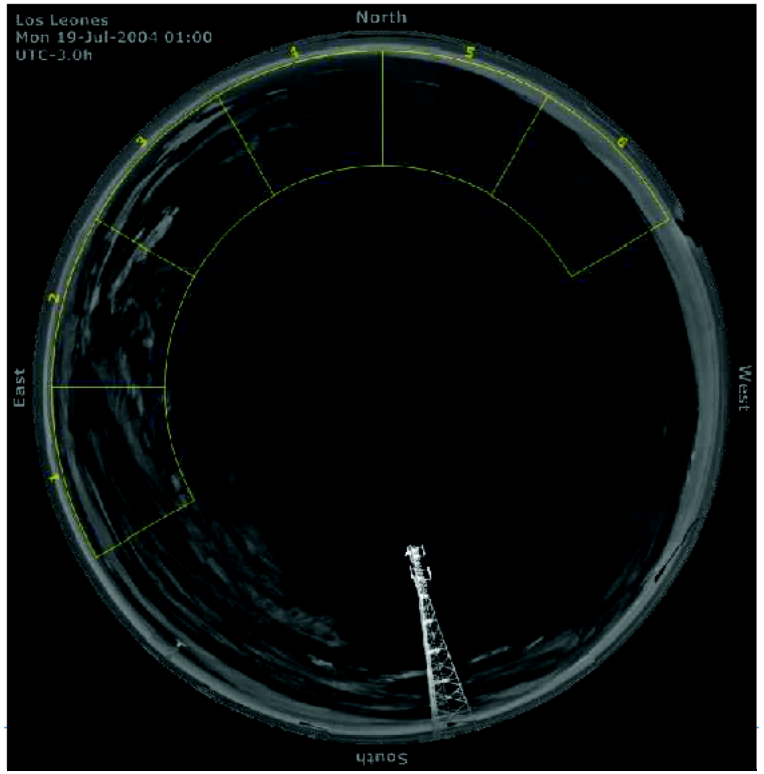


Lidar for atmospheric profiling and
“shooting the shower”
at each Fluorescence building

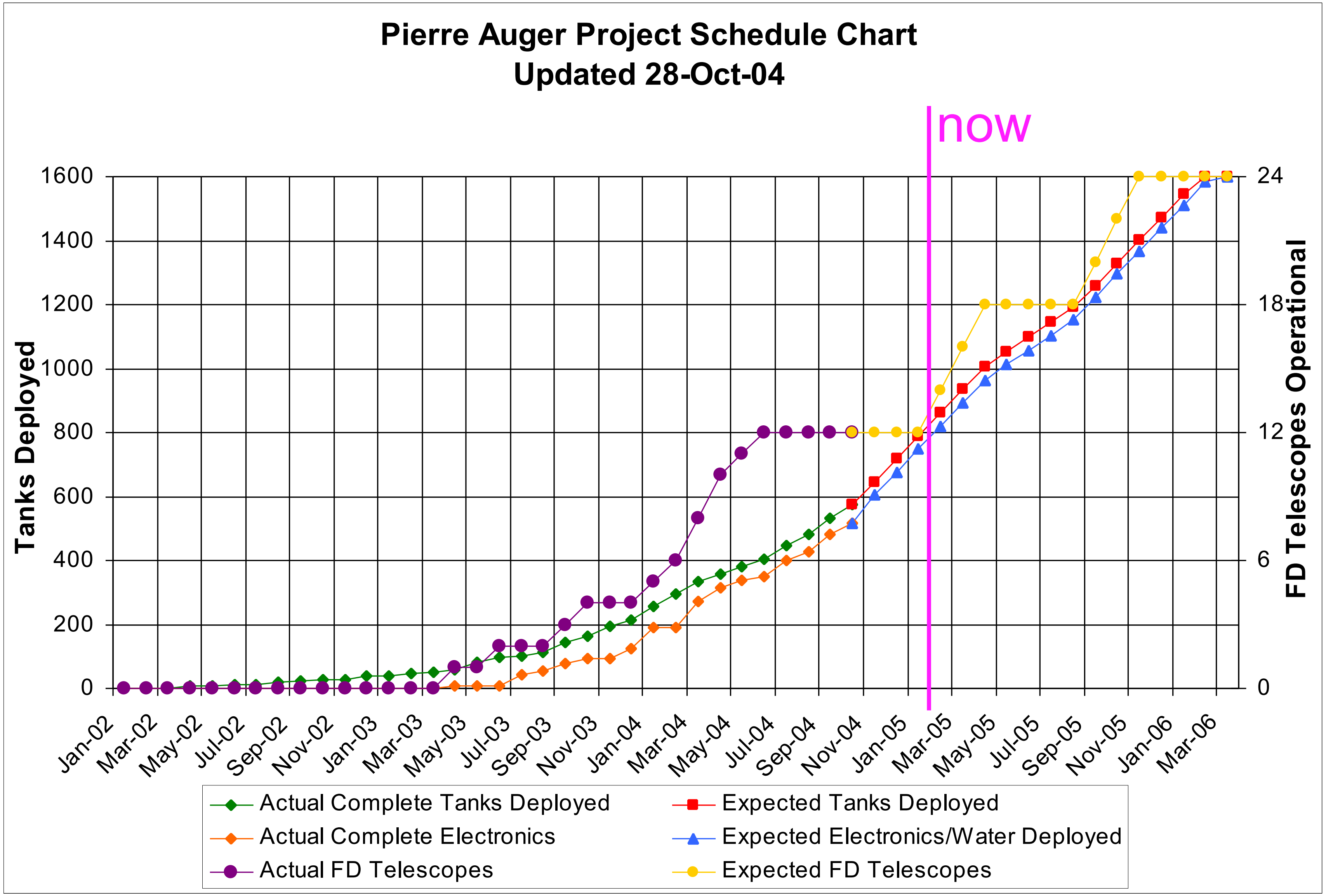
Central Laser Facility
(laser linked to adjacent tank)

End-to-end absolute calibration
(Drum for uniform illumination
of FD camera)

Cloud monitor



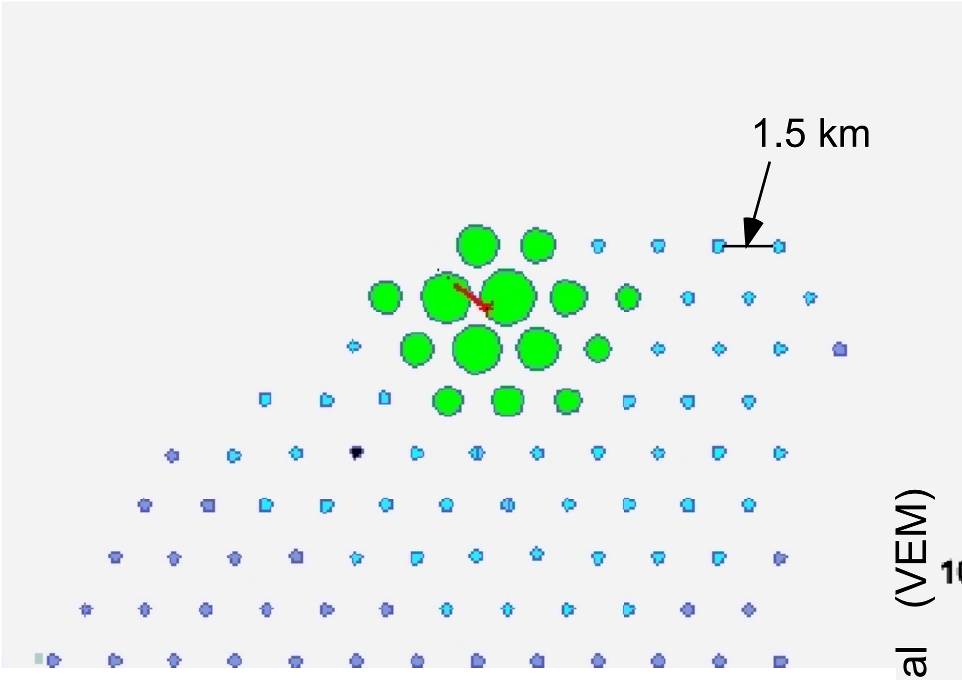
Balloon borne
atmospheric measurements


Pierre Auger Project Schedule Chart
Updated 28-Oct-04
now
Tanks Deployed
FD Telescopes Operational
1600
1400
1200
1000
800
600
400
200
0
24
18
12
6
0
Jan-02
Mar-02
May-02
Jul-02
Sep-02
Nov-02
Jan-03
Mar-03
May-03
Jul-03
Sep-03
Nov-03
Jan-04
Mar-04
May-04
Jul-04
Sep-04
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Jan-06
Mar-06
Actual Complete Tanks Deployed
Actual Complete Electronics
Actual FD Telescopes
Expected Tanks Deployed
Expected Electronics/Water Deployed
Expected FD Telescopes

Auger Event Classes

SD	SD detector only, > 6 tanks,	100% duty cycle
hybrid	one FD detector + at least on SD tank time of one tank is enough to improve geometric event reconstruction dramatically	10% duty cycle
stereo	two FD detectors	
golden	one FD detector + > 6 tanks	
platinum	>2 FD detectors + > 6 tanks	

Typical (nice) SD Event

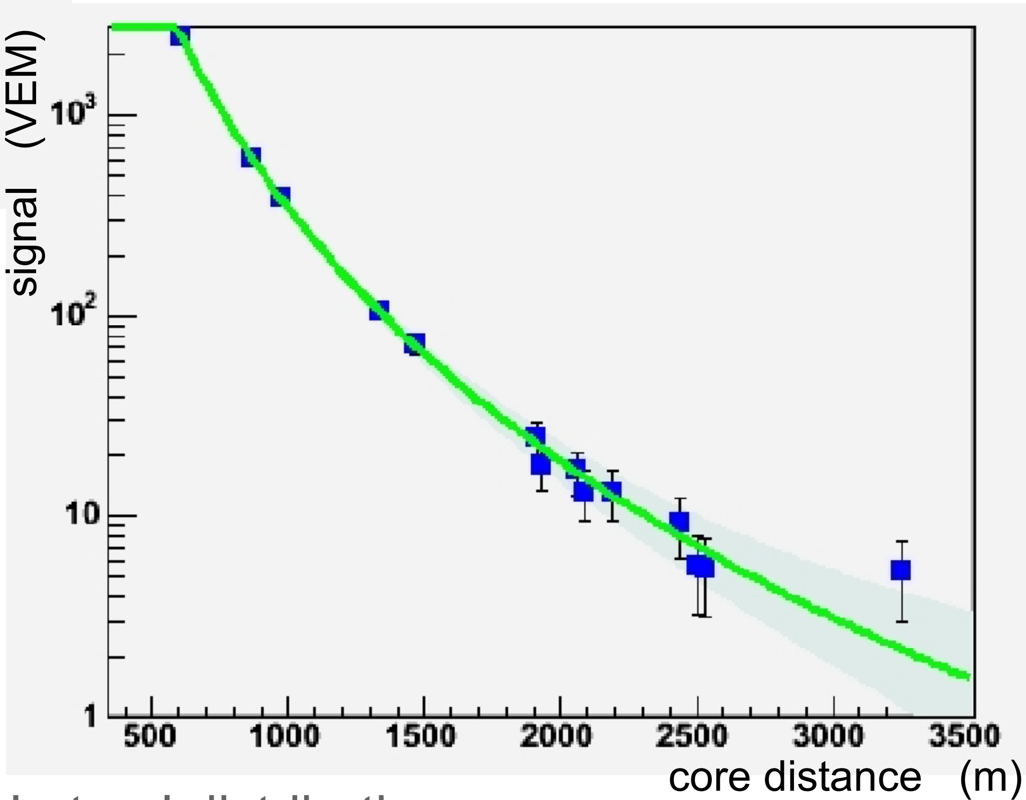


Surface array view

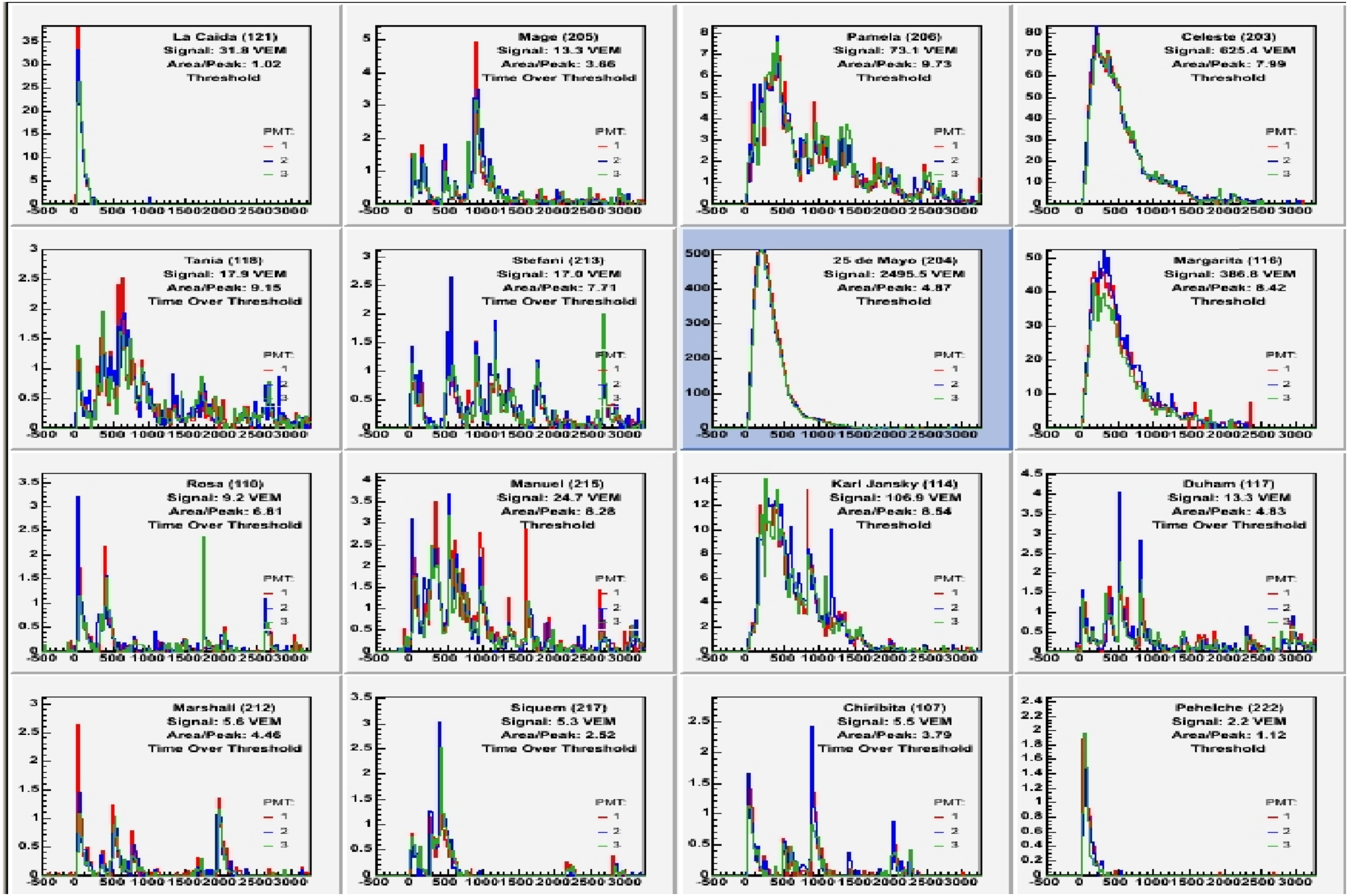
PRELIMINARY analysis

zenith angle = 34°

energy ~ 75 EeV

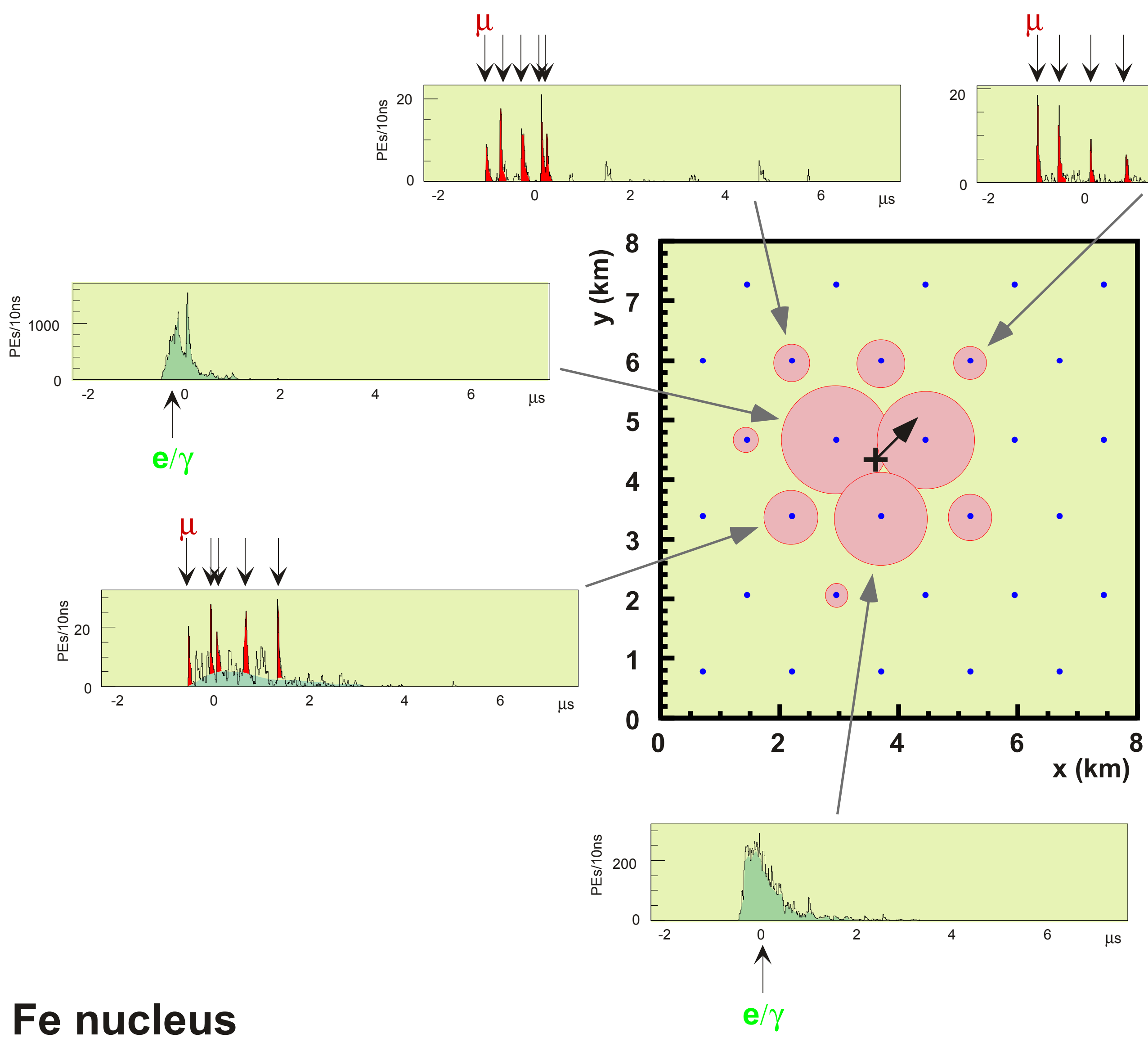


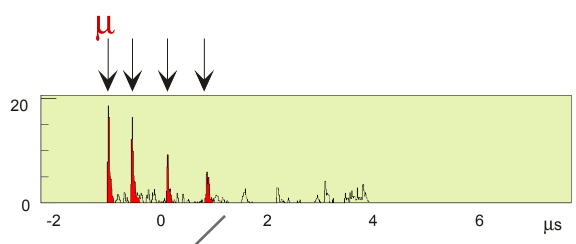
Lateral distribution

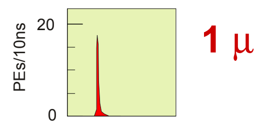


High & smooth pulses close to shower core, low & spiky pulses far away.

Pulse Shapes in Water Ch. Detectors







near core:

e/γ dominate

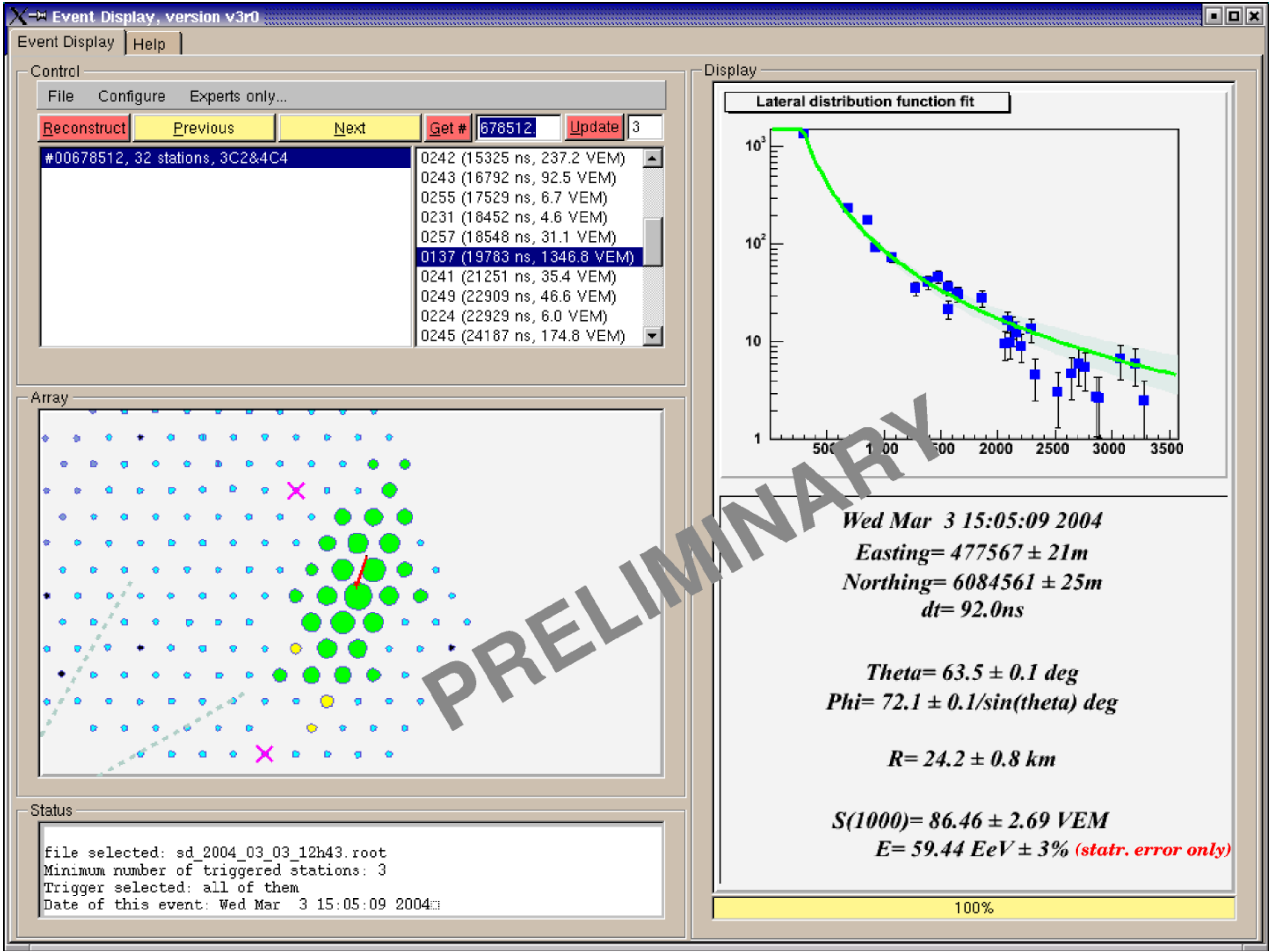
far from core:

μ spikes

μ : e/γ ratio
(mass sensitive)

Fe nucleus
E = 6×10^{19} eV
$\Theta = 19^o$

30 Tanks hit ! $\Theta \sim 63^o$ $E \sim 6 \times 10^{19}$ eV



Geometric Reconstruction (easy)

Arrival Directions (Θ,ϕ): from arrival times at each tank
a) fit shower plane (moving with c)
b) curved front
need to know shape of front and core position

Core Position (x,y): high particle densities are close to shower core;
core position depends on LDF, e.g.: $S(r) \sim S(1000)\, r^{-\nu}$

Functional form of LDF & fluctuation of S_i affect x,y

typical core resolution ~ 400 m

Energy Reconstruction (more difficult)

FD: Fluorescence light ~ energy deposit

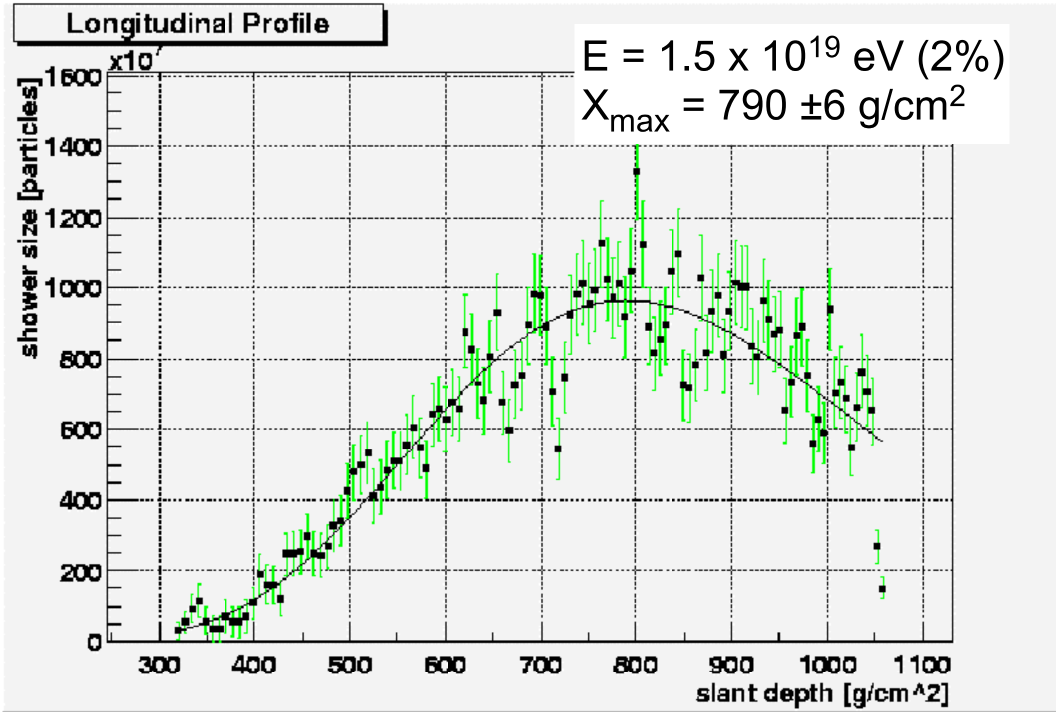
- measure profile
- integrate and account for leakage
- multiply with F-yield (E_{dep}/Fl.ph.)

measured in lab

- get calorimetric energy measurement (< 15%)

(scattered Cherenkov light,
FY(E, ρ, T, ...)
atmospheric corrections, ...
only in 10% of time available)

very good geometry reconstruction
for FD stereo observation or
for SD-FD hybrid observations



SD: Tank signal at 1000 m is good energy indicator
Conversion S(1000) to energy is model dependent. (~ 30%)

Mass Reconstruction (most difficult)

Azimuthal Asymmetry

Asymmetry:

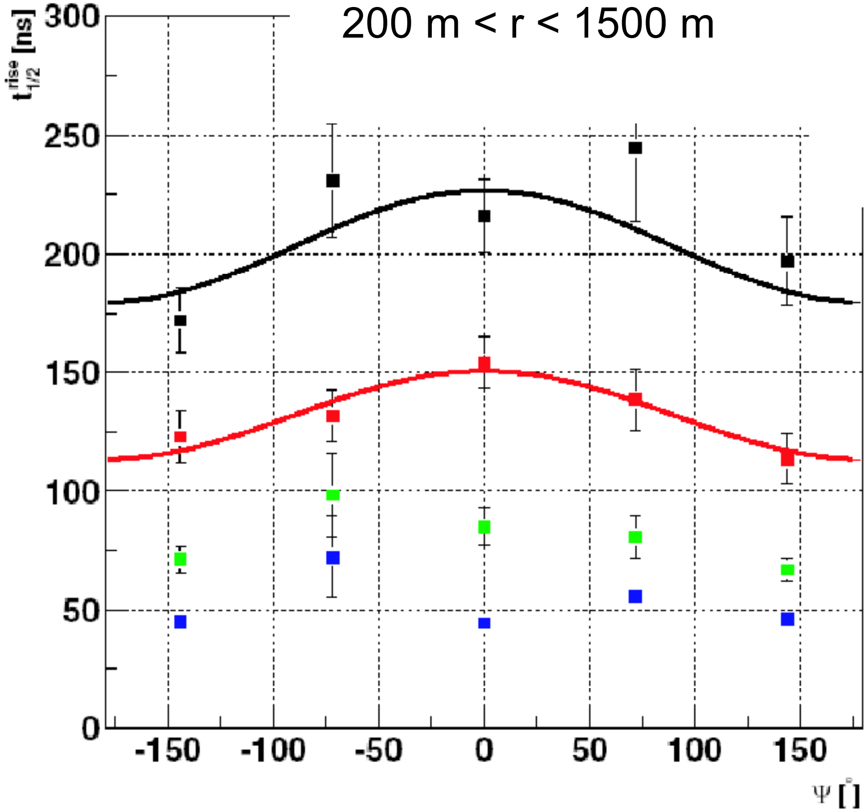
- seen in Haverah Park and Auger data quantitatively described by Monte Carlo.
- due to different behaviour of e,γ and μ component (partly absorption, partly geometry)
- is sensitive to e,γ / μ ratio (late particles are always e,γ) i.e. to primary **mass composition**

Azimuthal Asymmetry in Signal and Rise Time

M Roth

$t_{1/2}$

Auger data
200 m < r < 1500 m

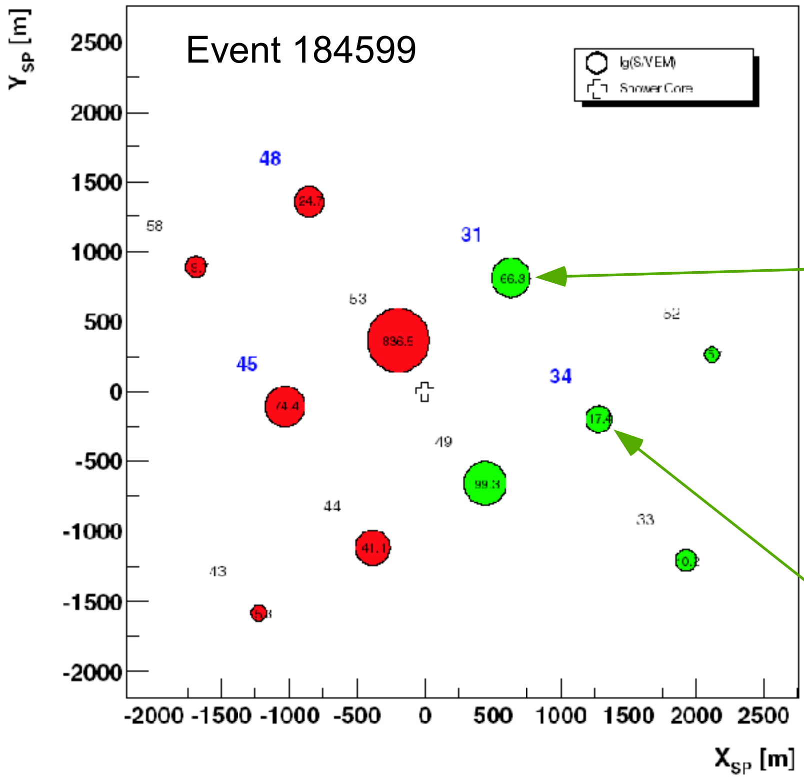


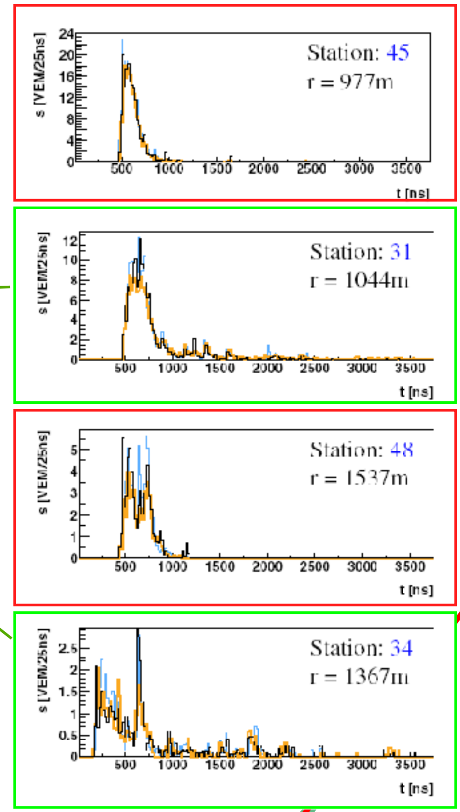
1 < sec Θ < 1.3

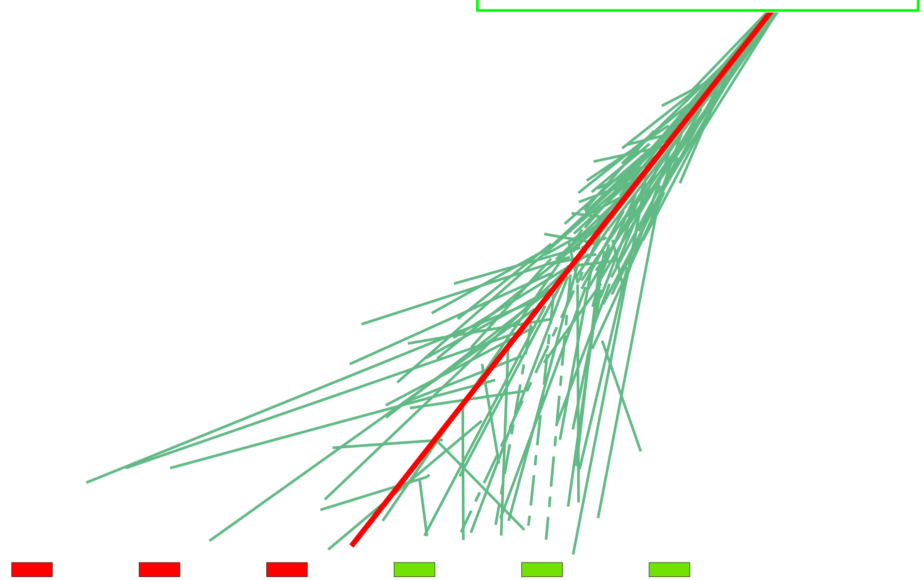
1.3 < sec Θ < 1.9

1.9 < sec Θ < 2.8

2.8 < sec Θ



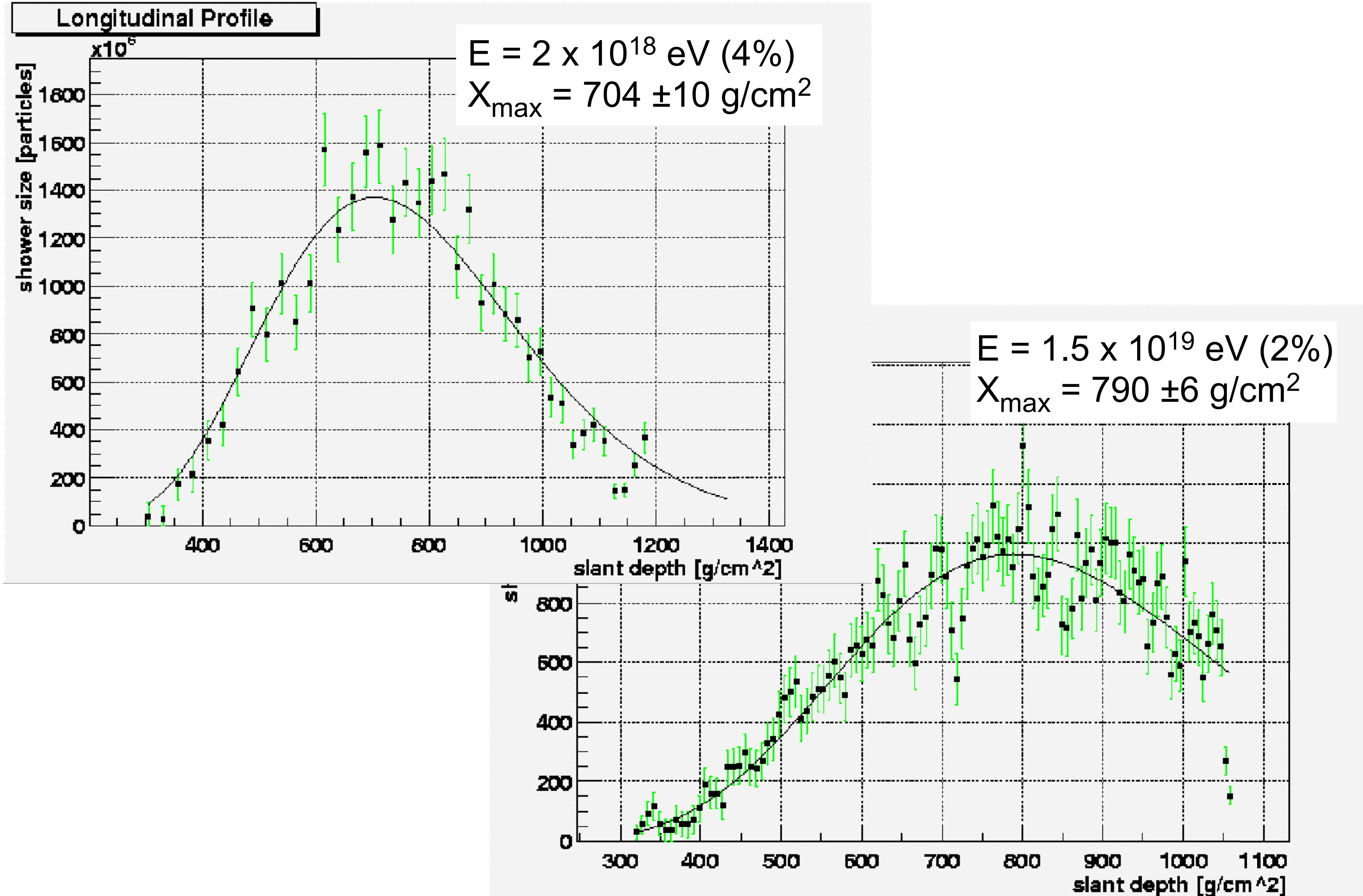




no trailing particles
faster pulses

trailing particles (> 1μs)
slower pulses

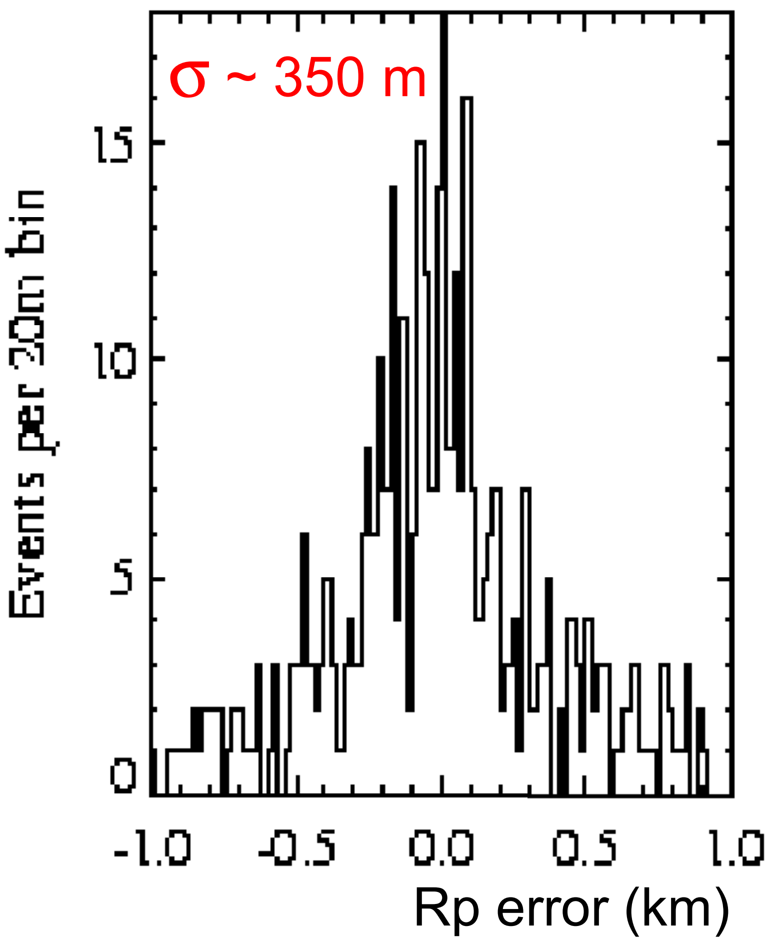
FD longitudinal distributions



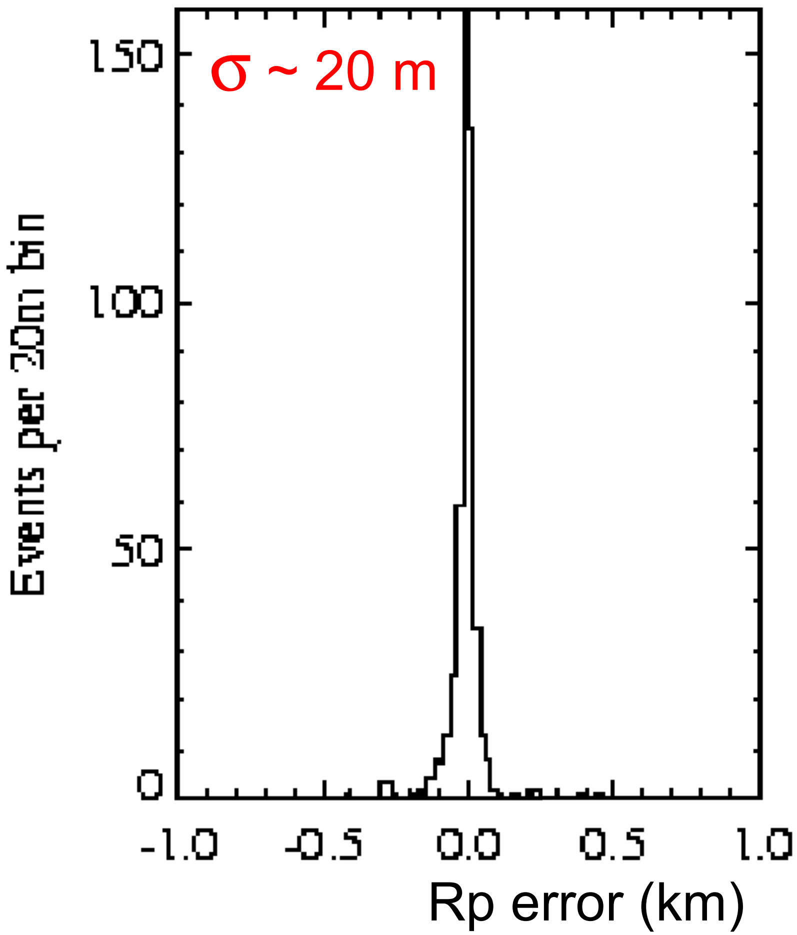
Hybrid Reconstruction at 10^{19} eV

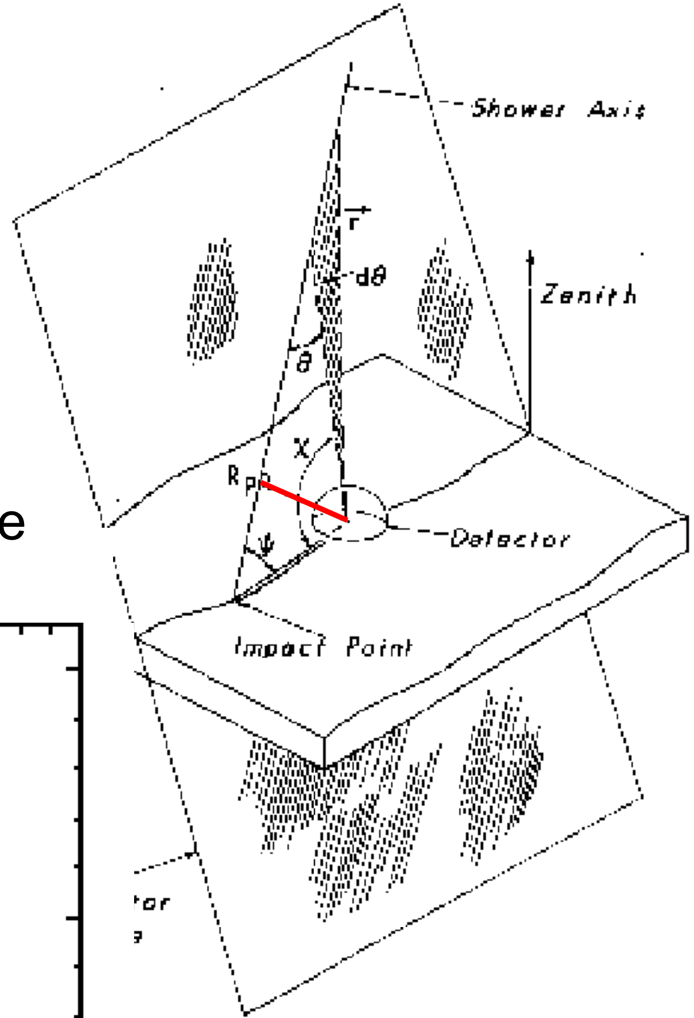
e.g. impact parameter R_p:

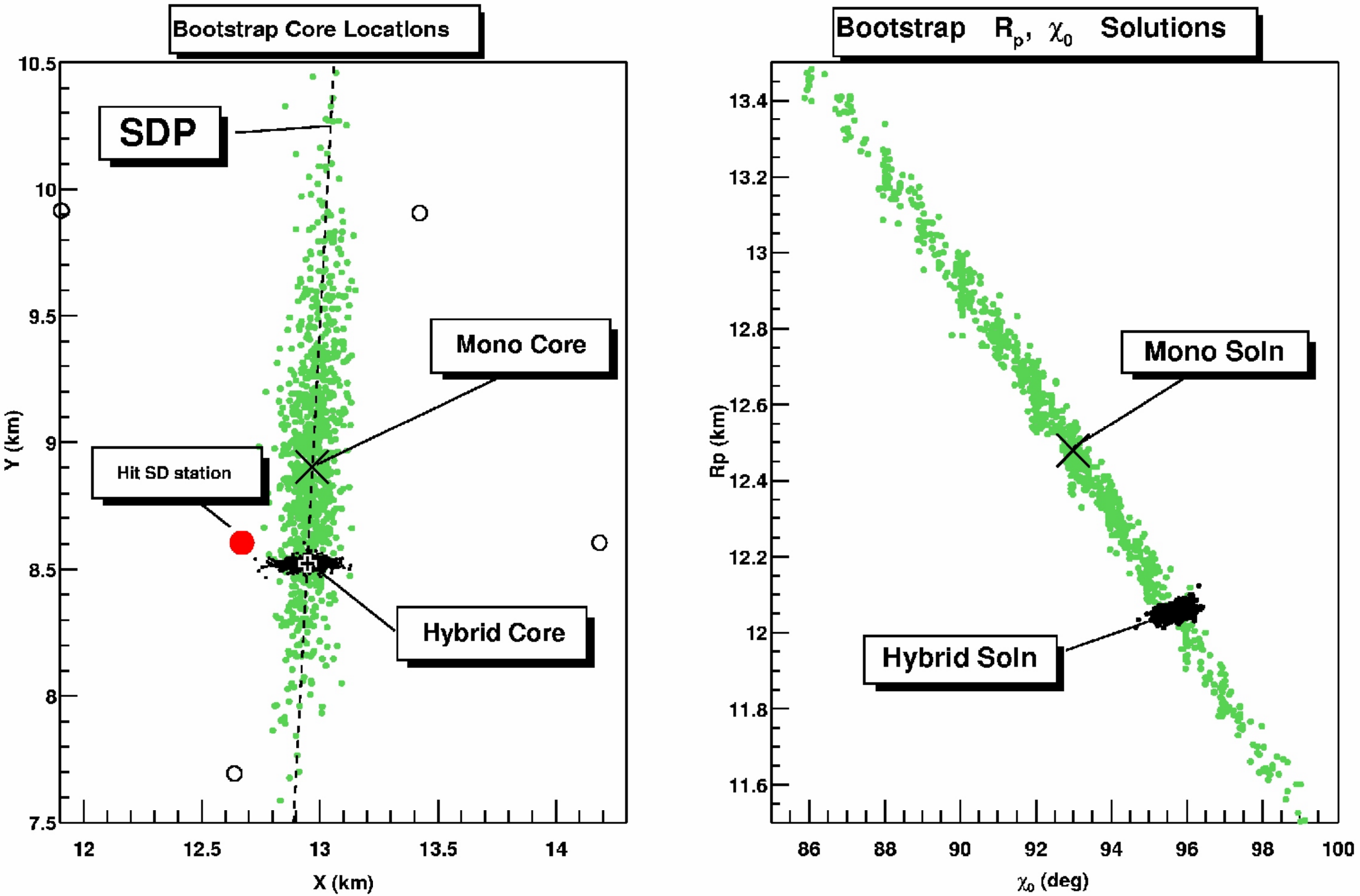
one FD only



one FD + one SD time
(minimum Hybrid)

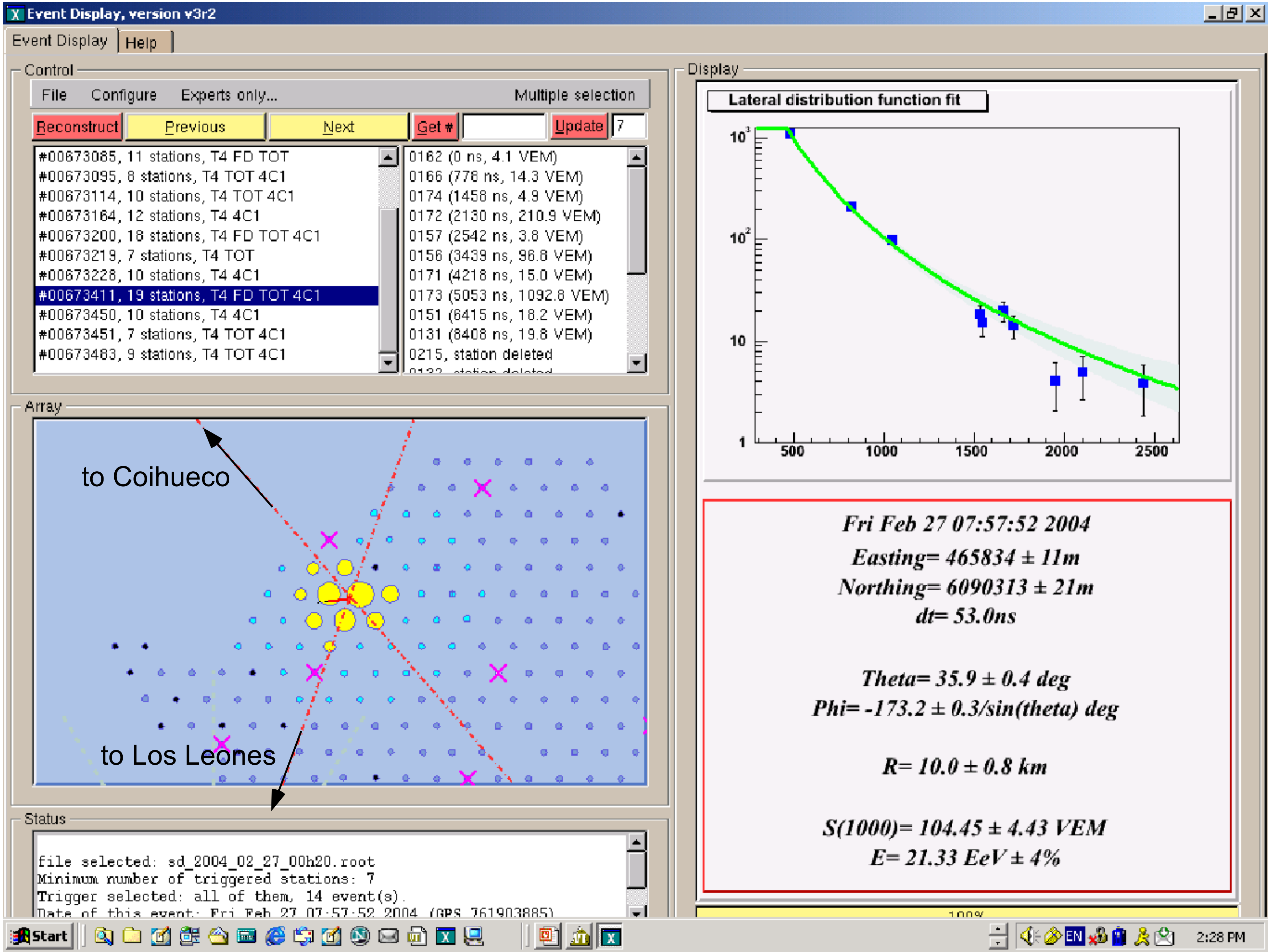


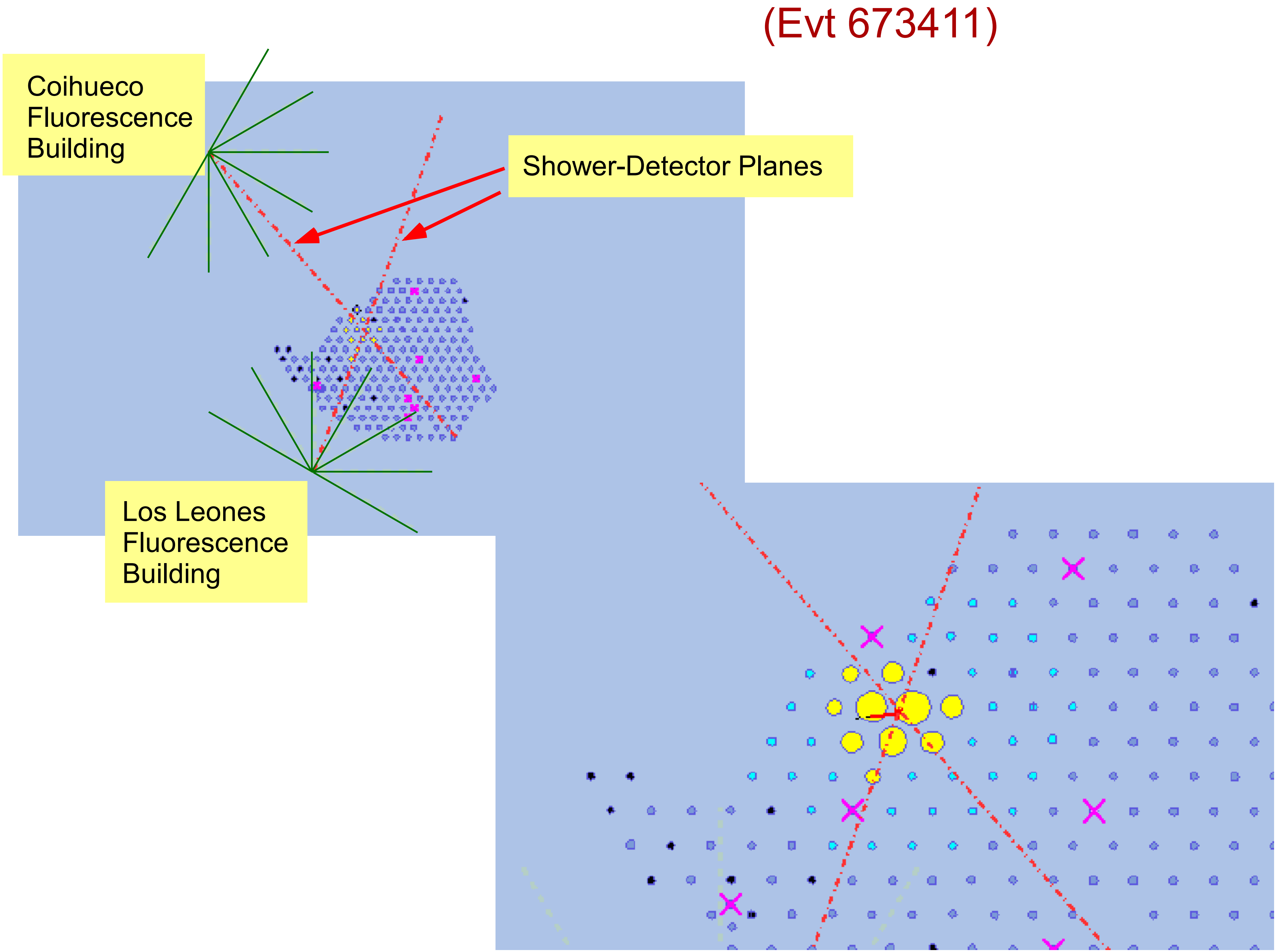




Bootstrap Core Locations
SDP
Mono Core
Hit SD station
Hybrid Core
Y (km)
X (km)
10.5
10
9.5
9
8.5
8
7.5
12
12.5
13
13.5
14
Bootstrap R_p, χ_0 Solutions
Mono Soln
Hybrid Soln
Rp (km)
χ_0 (deg)
13.4
13.2
13
12.8
12.6
12.4
12.2
12
11.8
11.6
86
88
90
92
94
96
98
100

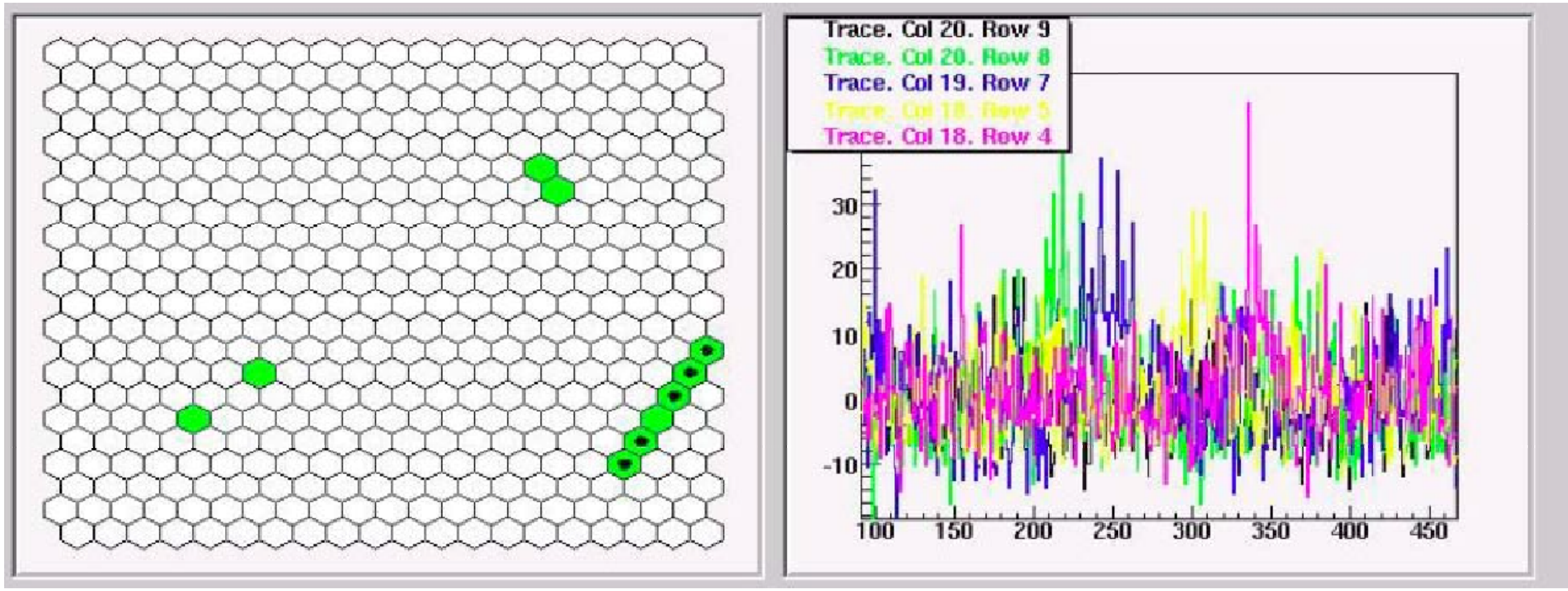
A Double Hybrid Event (673411) "platinum" seen by 2 FD detectors > 6 tanks in SD



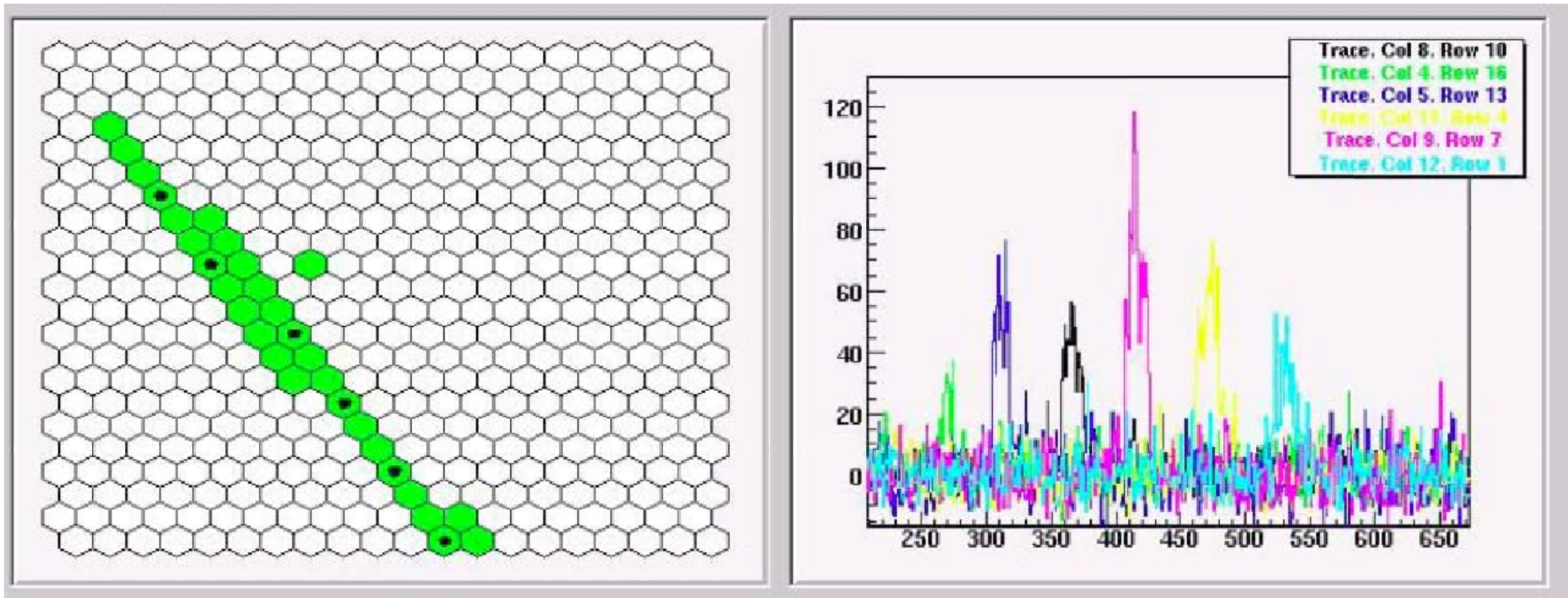

(Evt 673411)
Coihueco Fluorescence Building
Shower-Detector Planes
Los Leones Fluorescence Building

(Evt 673411)

Fluorescence Detector (Coihueco) 6 pixel track



Fluorescence Detector (Los Leones) 29 pixel track



Hybrid Reconstruction

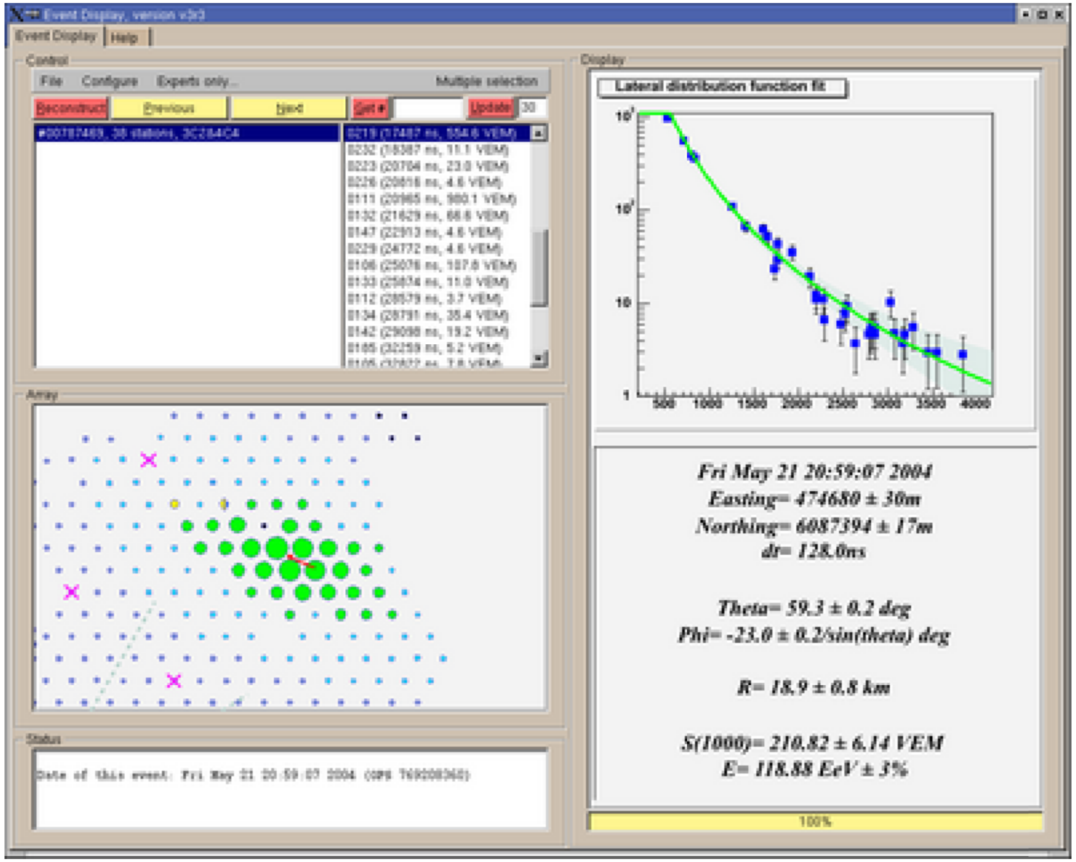
E(eV)	Δdir (°)	ΔCore (m)	ΔE/E (%)	ΔXmax g/cm²
10^{18}	0.7	60	13	38
10^{19}	0.5 1.1	50 400	7 15	25
10^{20}	0.5 0.6	50	6	24

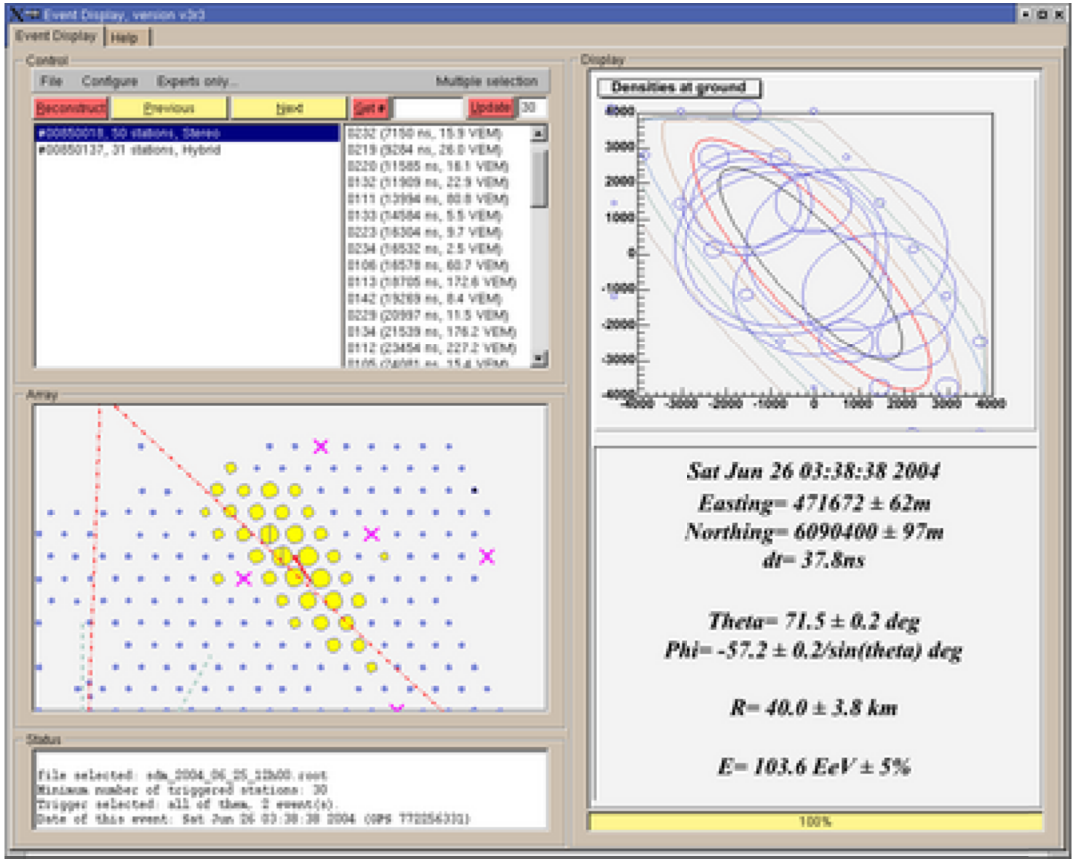
SD only

68% error bounds given, statistical errors only, $\Theta < 60^{o}$

Largest SD event:
35 triggered tanks
60º

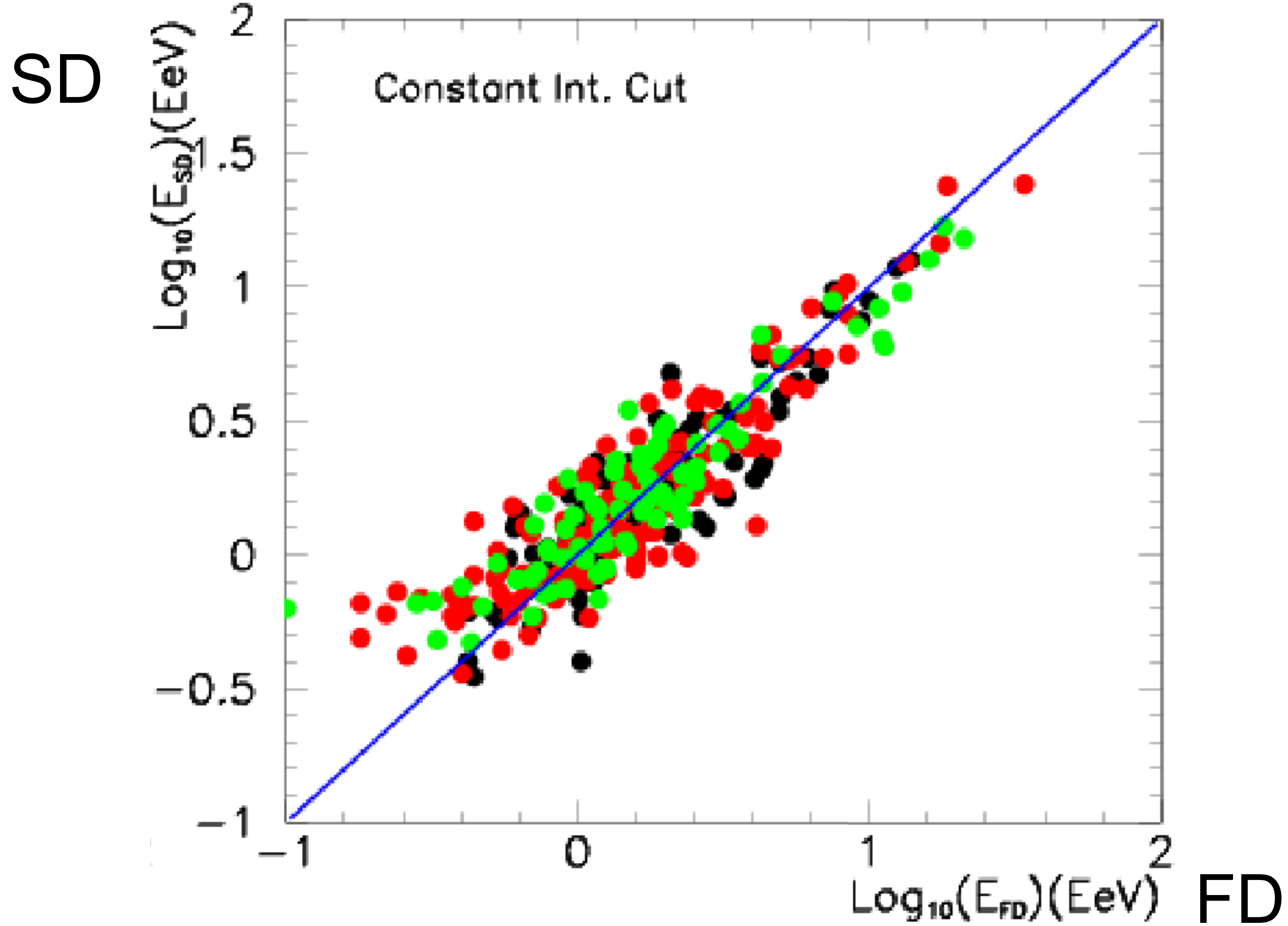
Largest hybrid event:
35 triggered tanks
71º





PRELIMINARY Energy ~ 100 EeV

FD vs SD energy

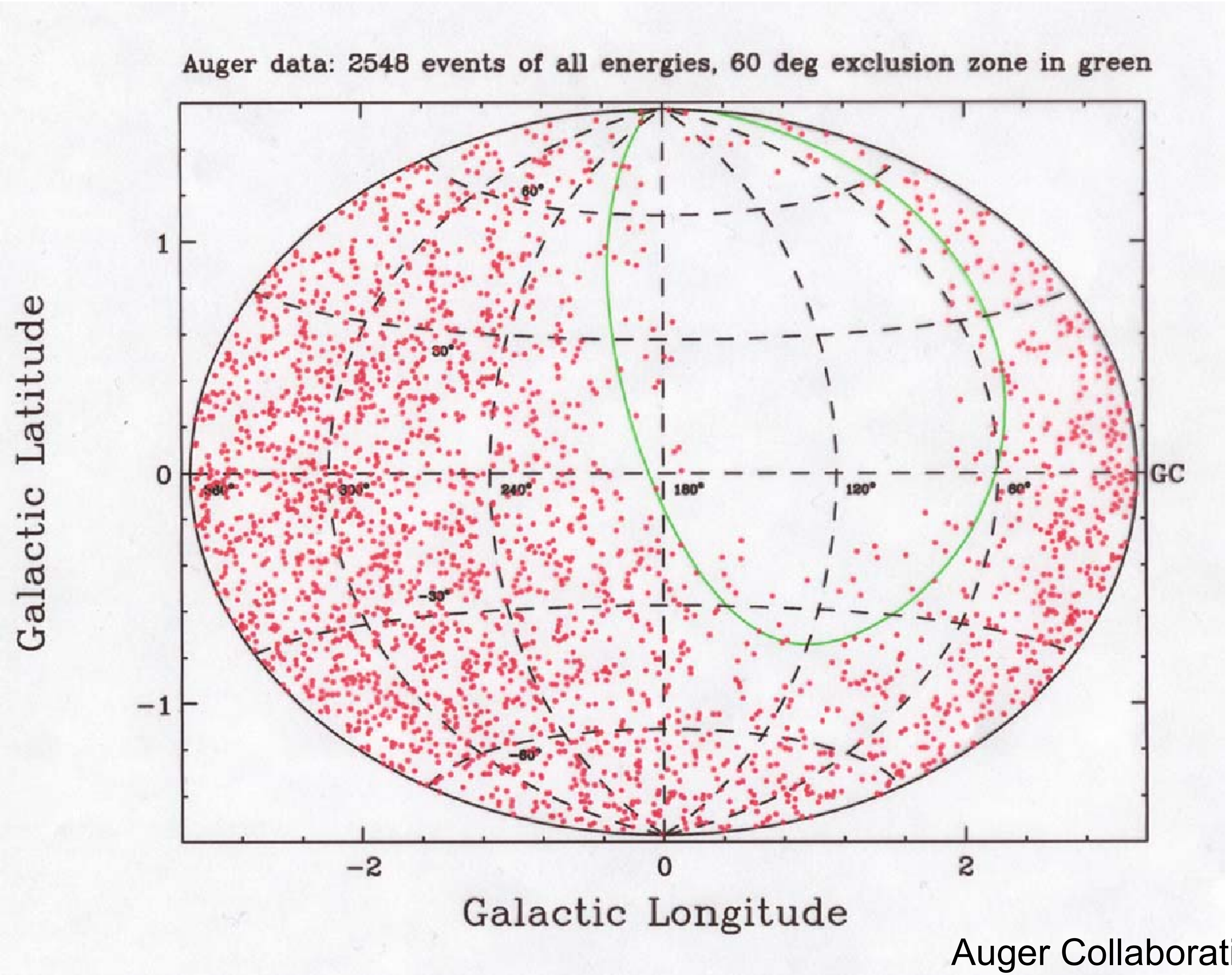


- 0 - 25 deg
- 25 - 45 deg
- 45 - 60 deg

Clear correlation between SD and FD energy estimates, i.e. shower models are about right.

Skyplot Auger

more than half the sky covered due to reconstruction of large zenith angle showers



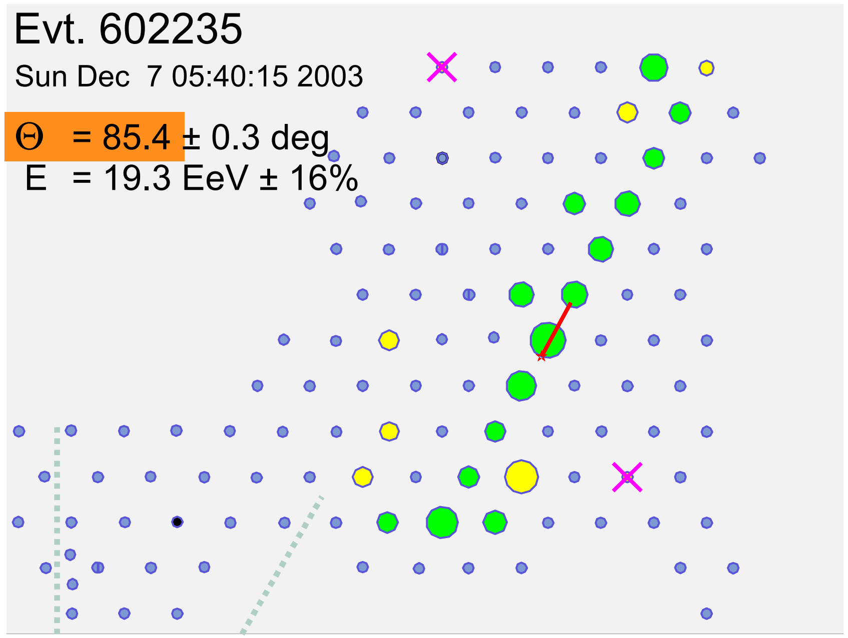
Auger Collaboration 2003

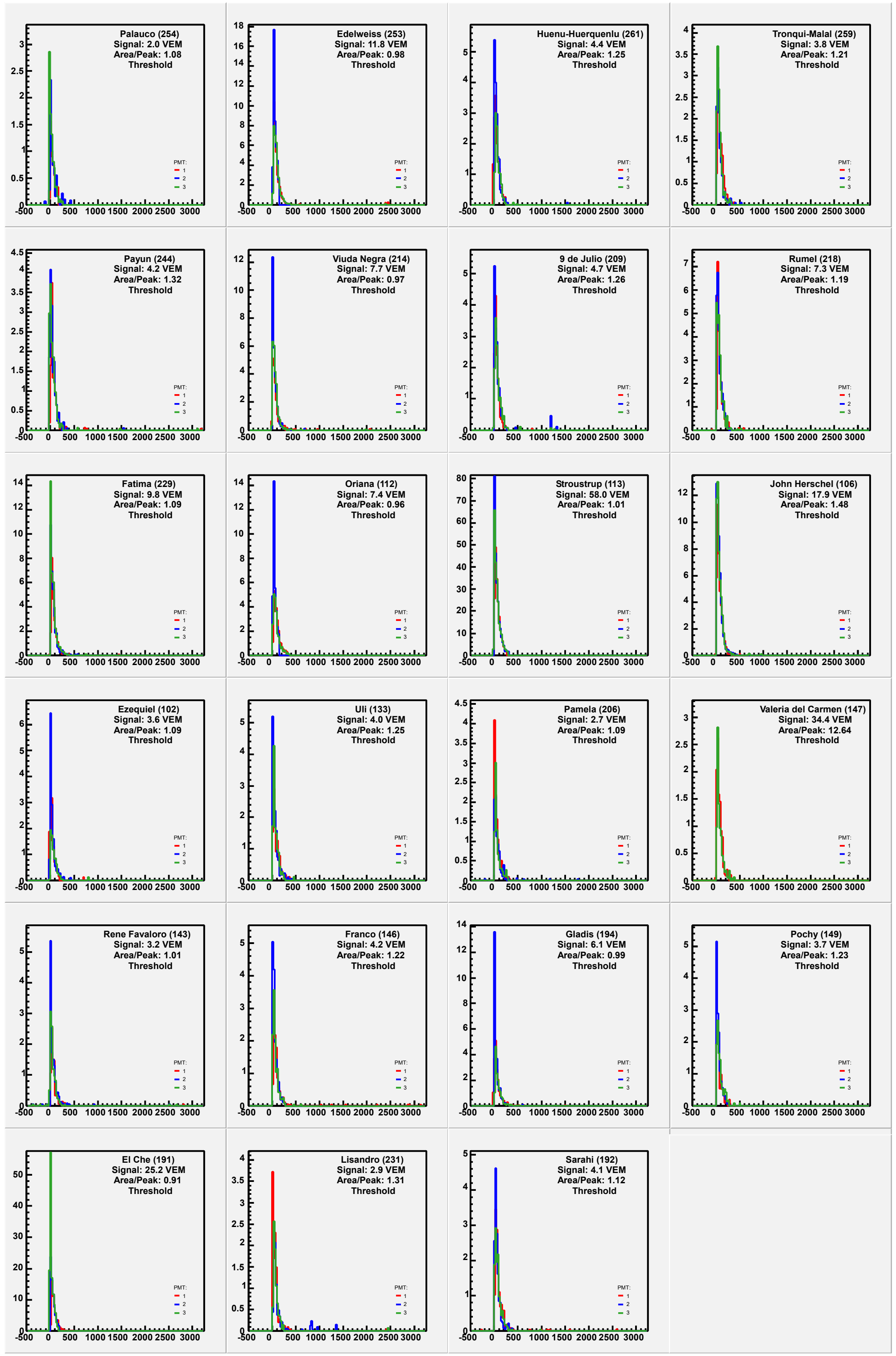
Horizontal showers

Due to water tanks (1.2 m high) the Auger SD has sensitivity for nearly-horizontal showers ($\Theta > 60^o$)

Special event reconstruction techniques
(by Ave, Watson, Zas et al.)
first applied to Haverah Park data

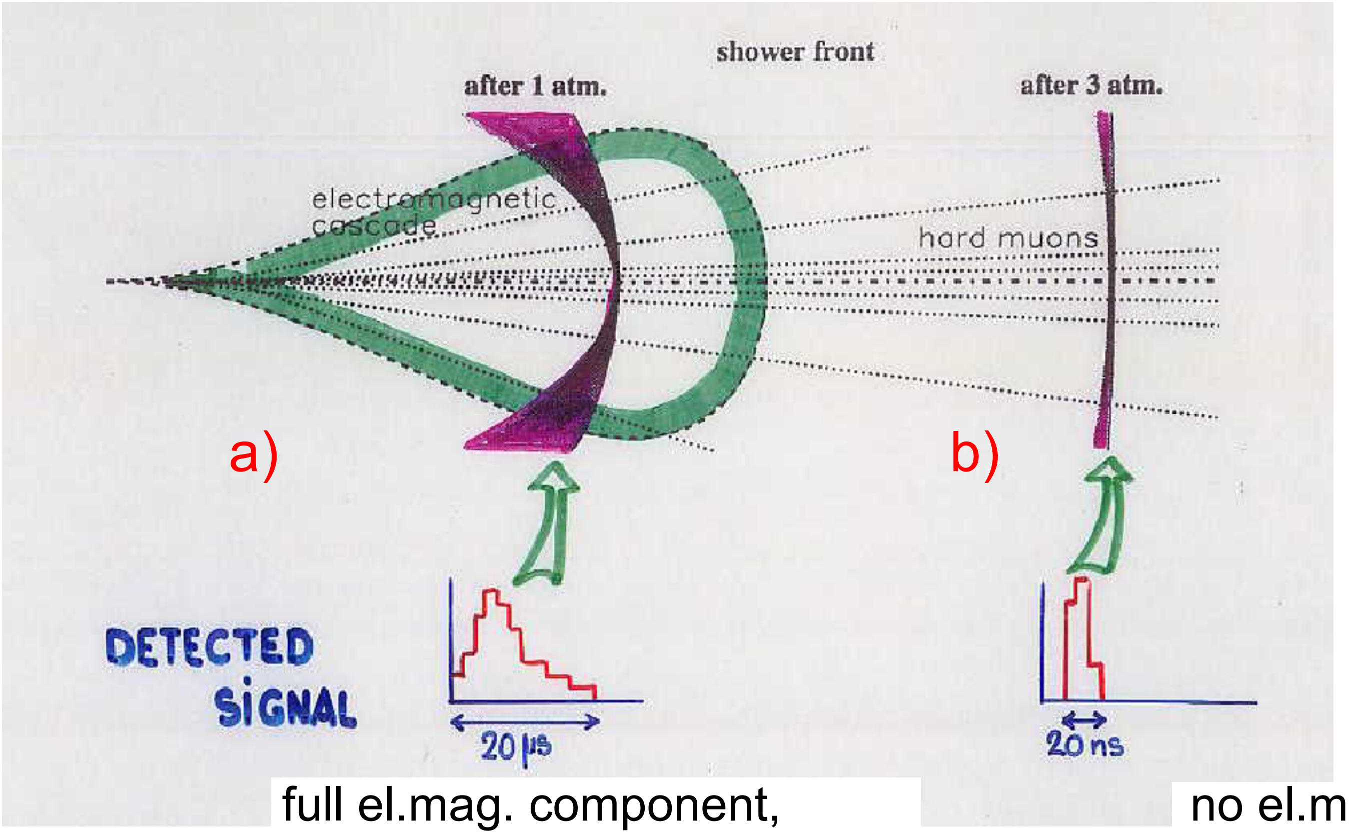
~ doubles aperture for CR events
increases sky coverage
sensitivity also to neutrinos





Neutrino detection with Auger

horizontal showers from hadrons: el.mag. component absorbed, muons only

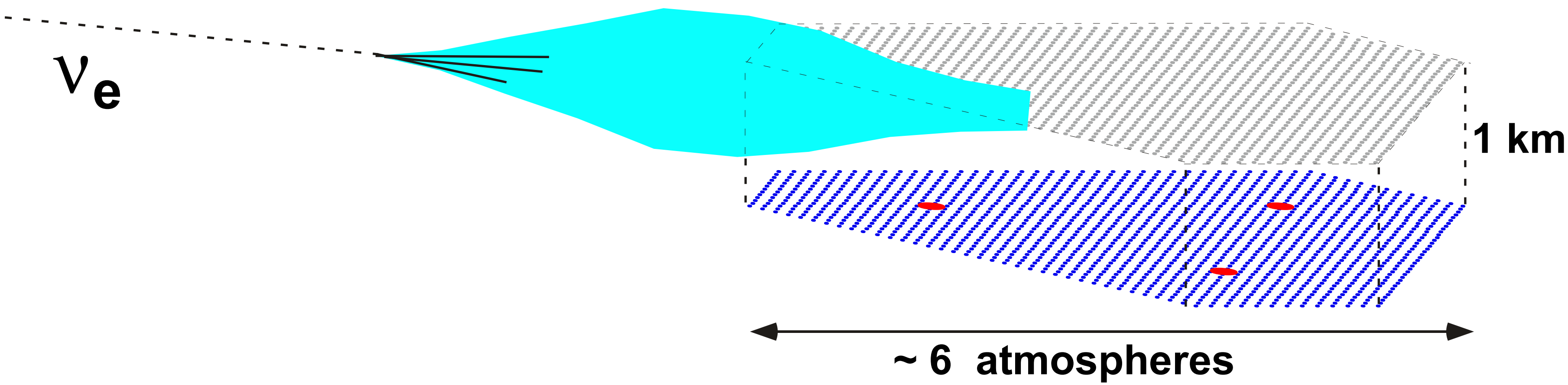


full el.mag. component,
curved shower front,
broad arrival time distribution

no el.mag. component,
plane shower front,
sharp arrival times

horizontal showers from neutrinos: look like a) after > 3 atmospheres
also visible by FD detectors

AUGER as ν Detector



Acceptance	> 10^4 km^3 sr for E > 10^{18} eV
Target mass	~ 1 km^3 water
Rate (>10^{19} eV)	~ a few per year

(~ 3 from int. of CR with CMBR,
~ 50 from Topological Defects)

i.e. no neutrino signal expected soon

Horizontal CR showers are dominated by muons.

Deflection in Earth magnetic field causes deformed footprint.

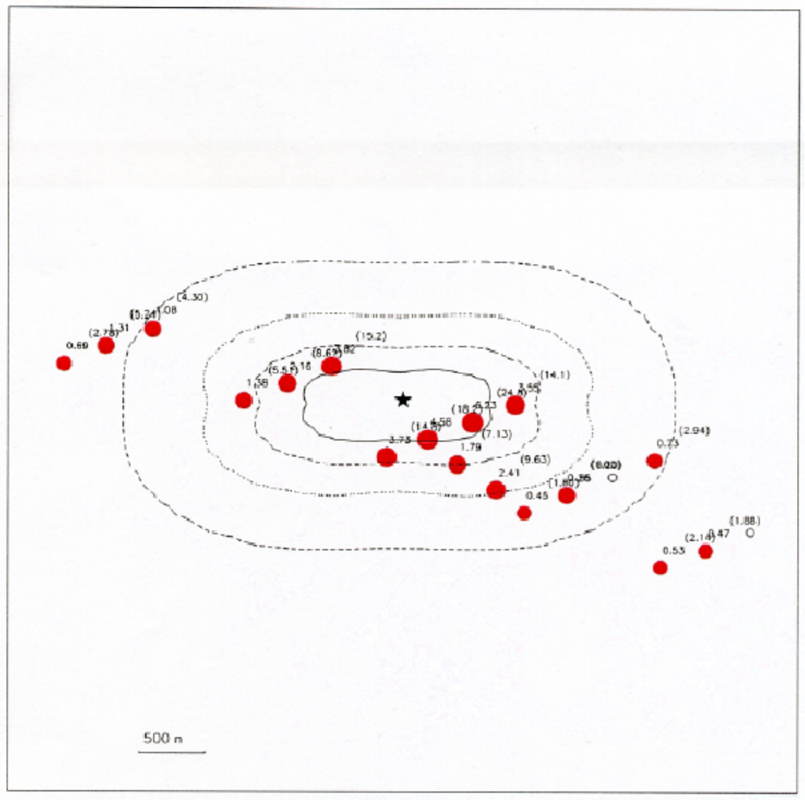
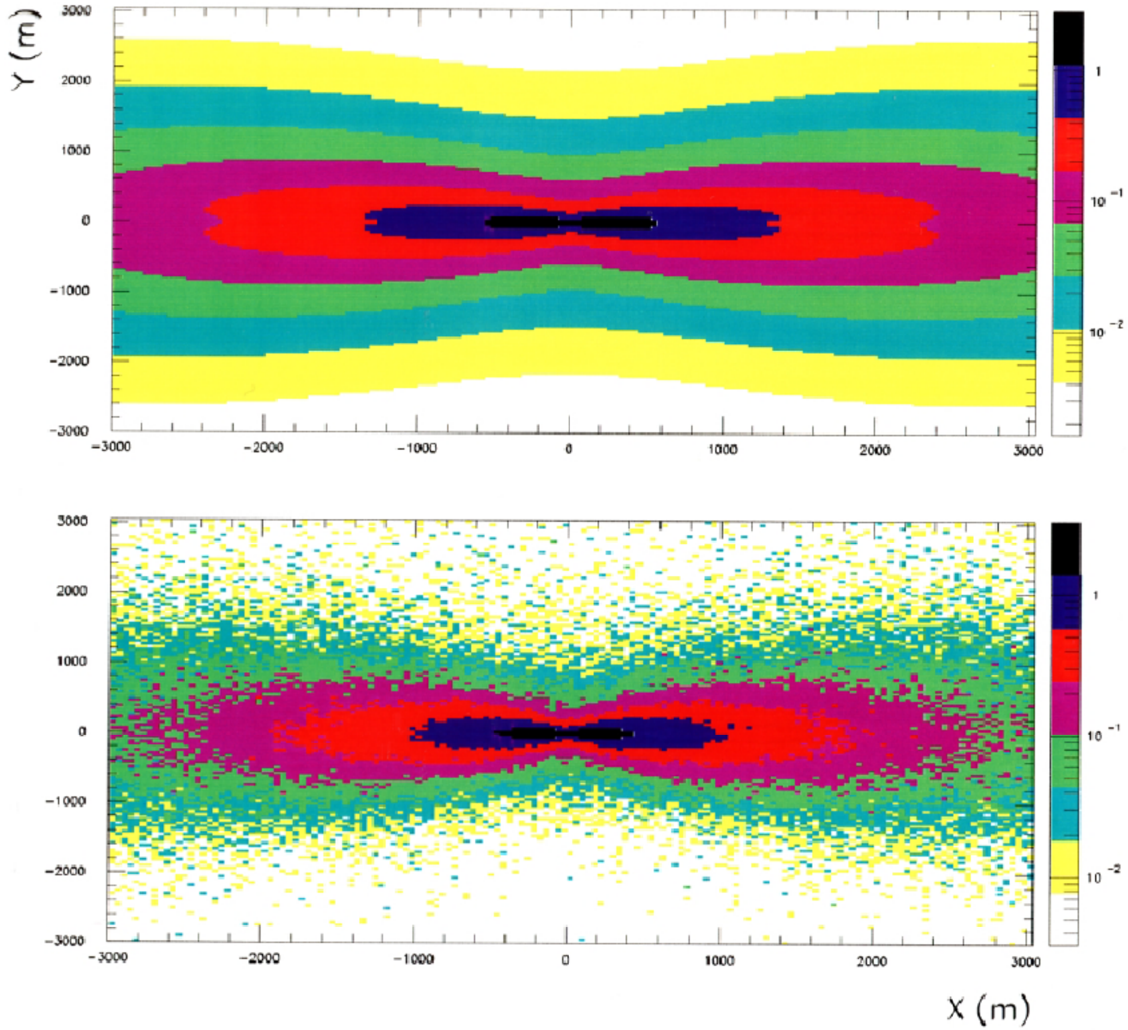


Figure 15: Density map.EVENT: 204272

$\theta = 81.7°$

$\varphi = 251.3°$



Primary γ's, e.g. from decays of topological defects ??

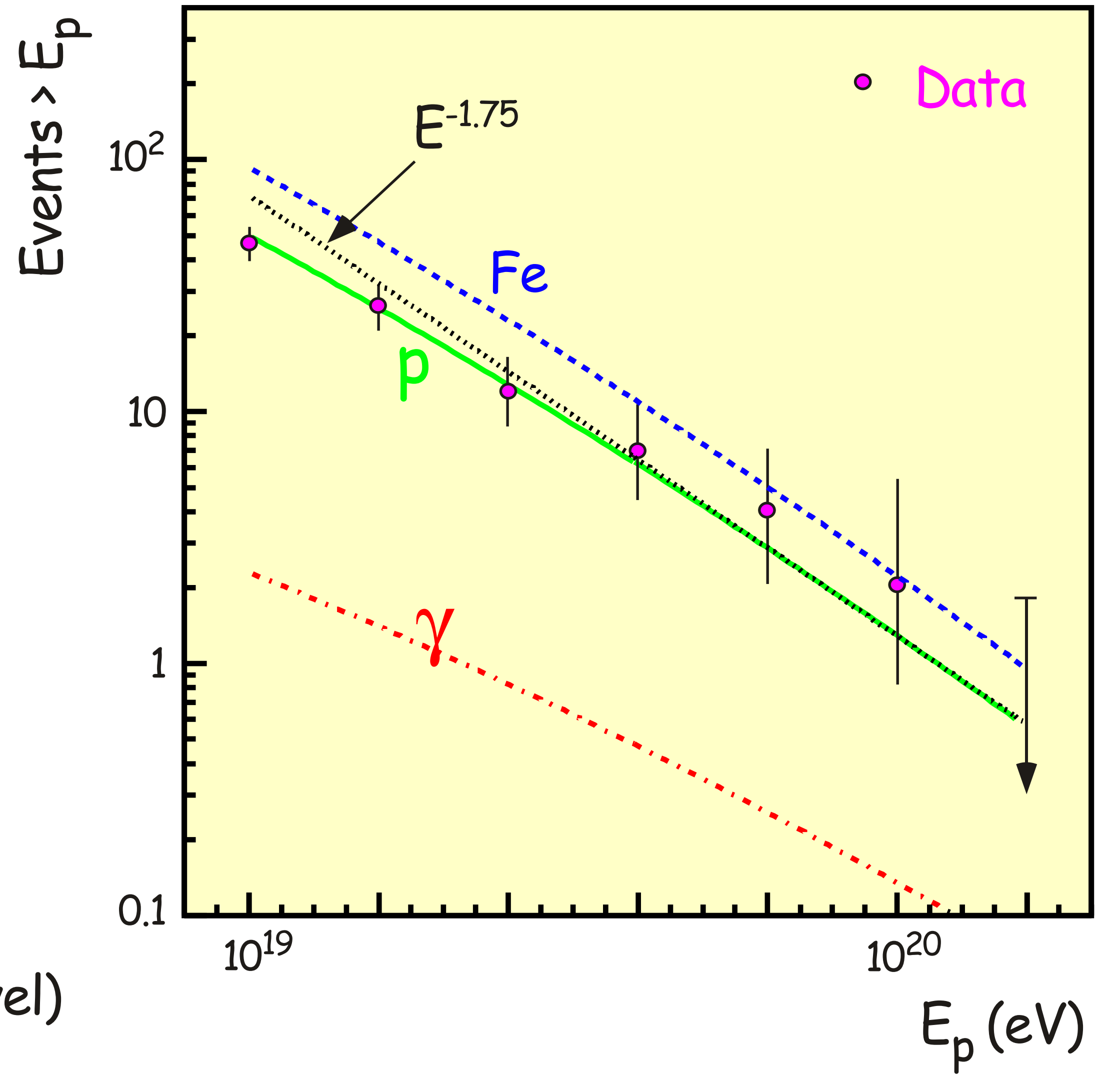
Haverah Park,
Ave et al., PRL 85 (2000) 2244

49 Events $> 10^{19}$ eV

$60^o < \theta < 80^o$

thick atmosphere:
only muons arrive at ground

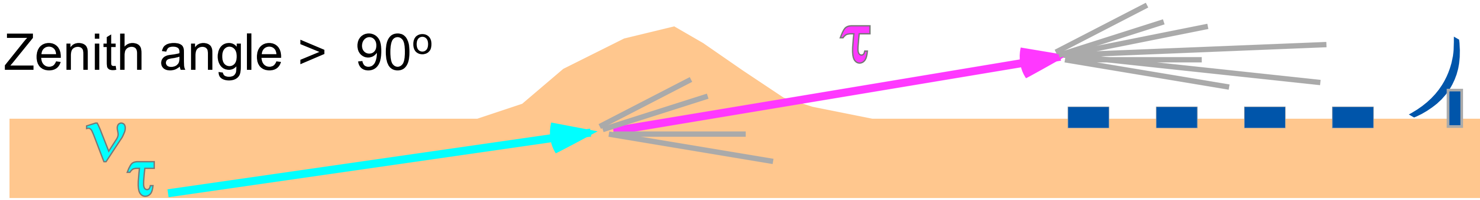
$\gamma/p < 40\%$
$Fe/p < 54\%$ (95% conf. level)



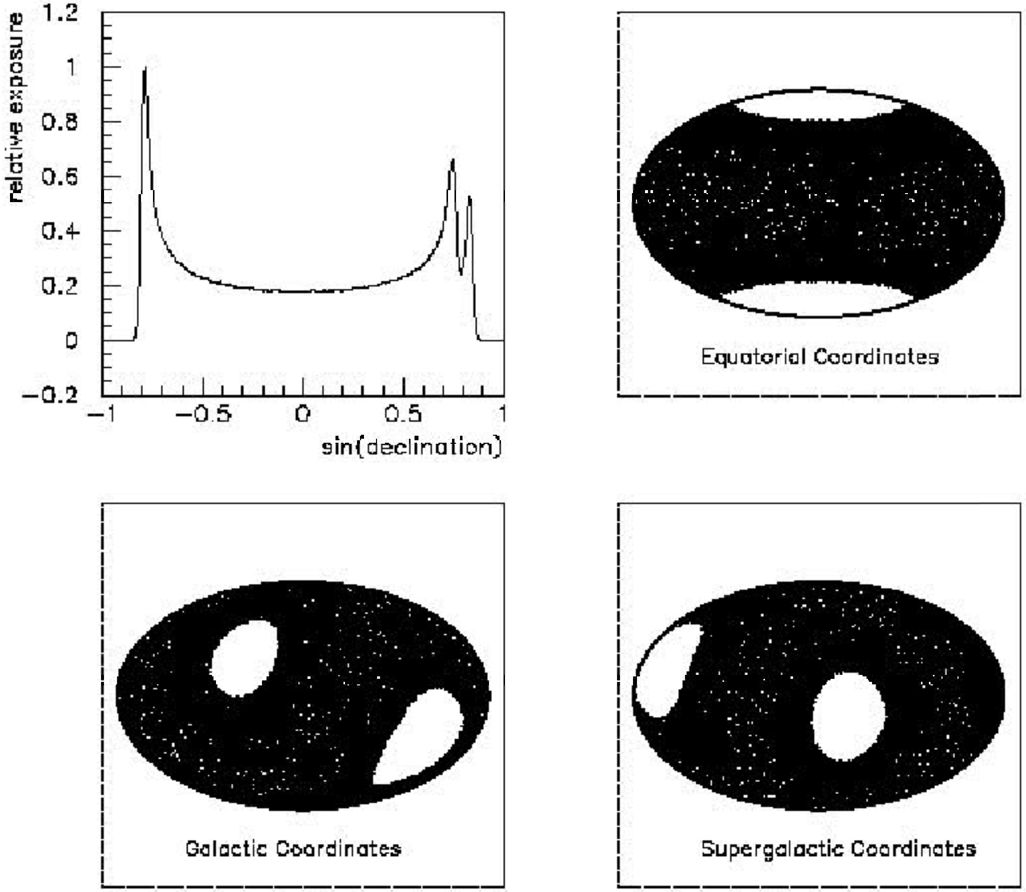
To be repeated for Auger data.
Also: put limit on photons, based on shower form from FD.

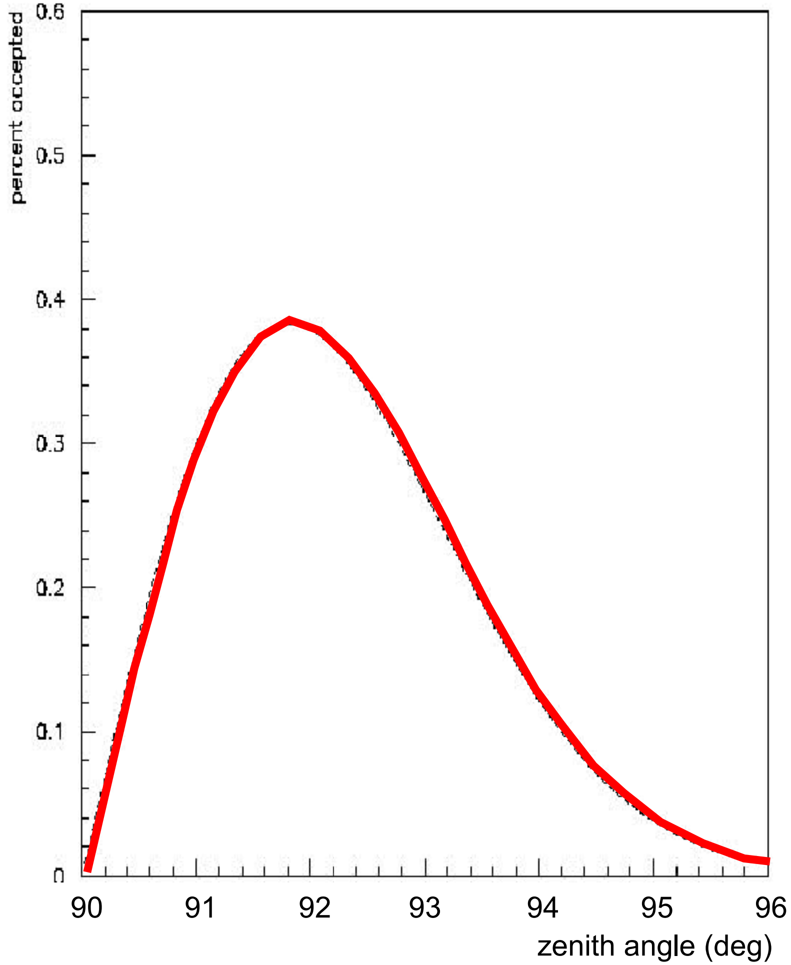
Auger exposure to Earth skimming ν_τ

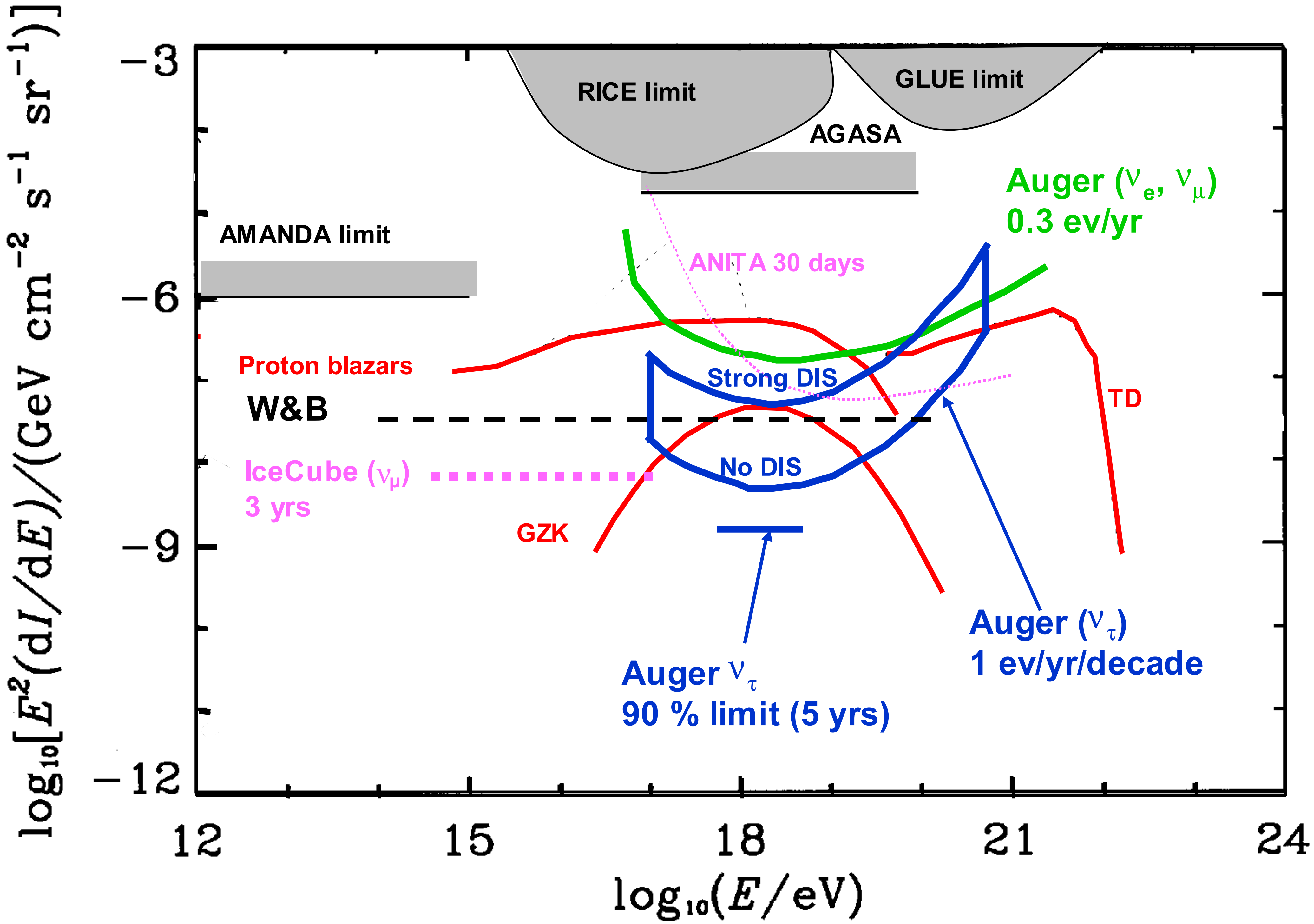
Zenith angle > 90^o



τ at 10^{18} eV $\gamma = 5.9 \times 10^8$ decay length ~50 km







Stephane Coutu

Auger-S construction is progressing well.
Data taking runs smoothly.
Performance better than anticipated.

First Auger Science Results:

Int. Cosmic Ray Conference, August 2005

by then: Auger Exposure ~ AGASA Exposure (1993-2003)

Near future: completion of construction in early 2006,
rapid increase of statistics,
improved control of systematics,
many results on UHECRs from Auger-S

What then? Auger North ?
Extension(s) to Auger South ?
Infill ? ....

talk by Hans Blümer

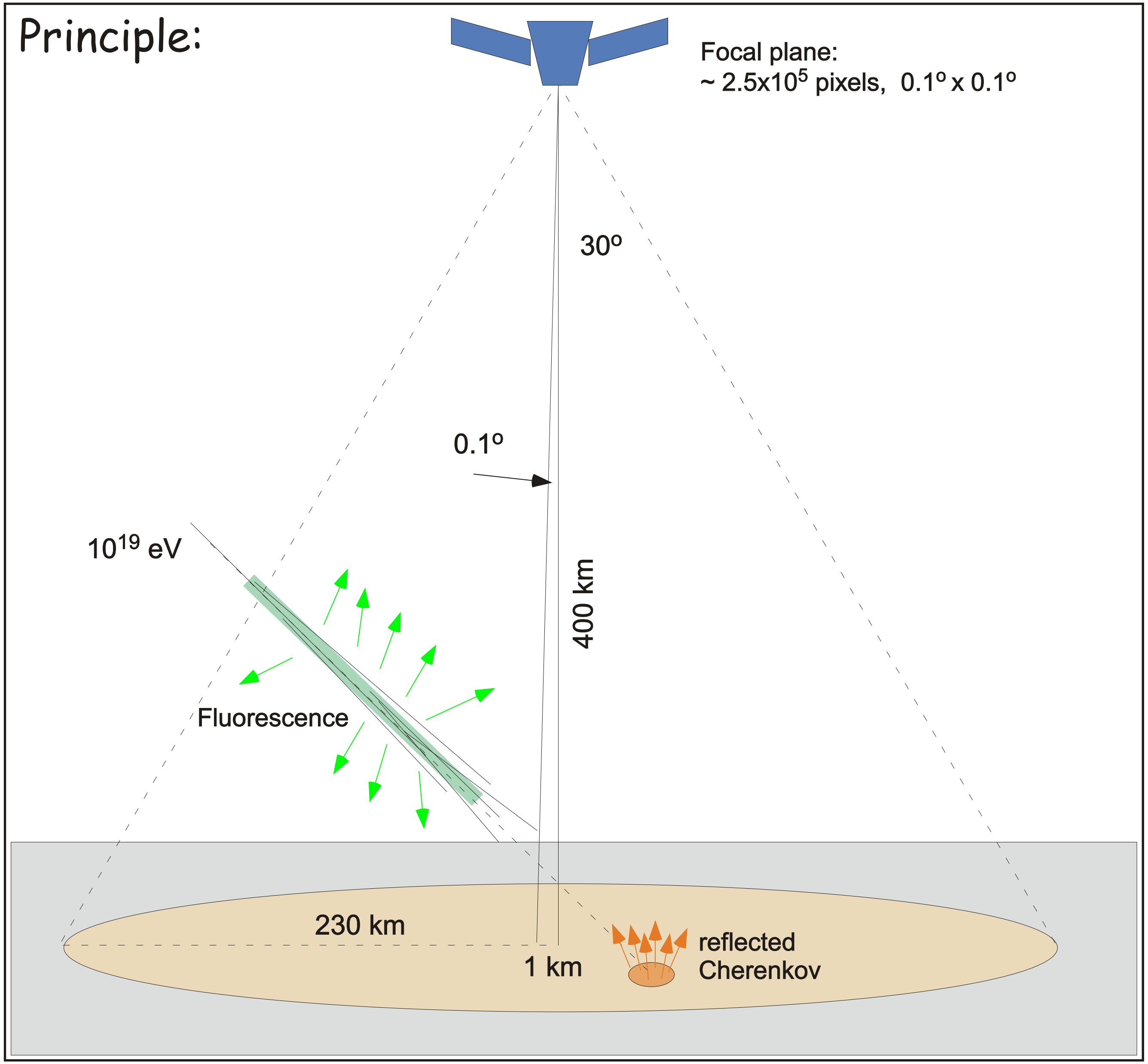
Space-based UHECR Experiments:
e.g. Extreme Universe Space Observatory EUSO or OWL

$A\Omega \sim 10^6\ km^2\ sr$

$\sim 10^4$ Events/year
with $E > 10^{20}$ eV

(20-30x Auger)

OWL: 2 satellites for
stereo observations



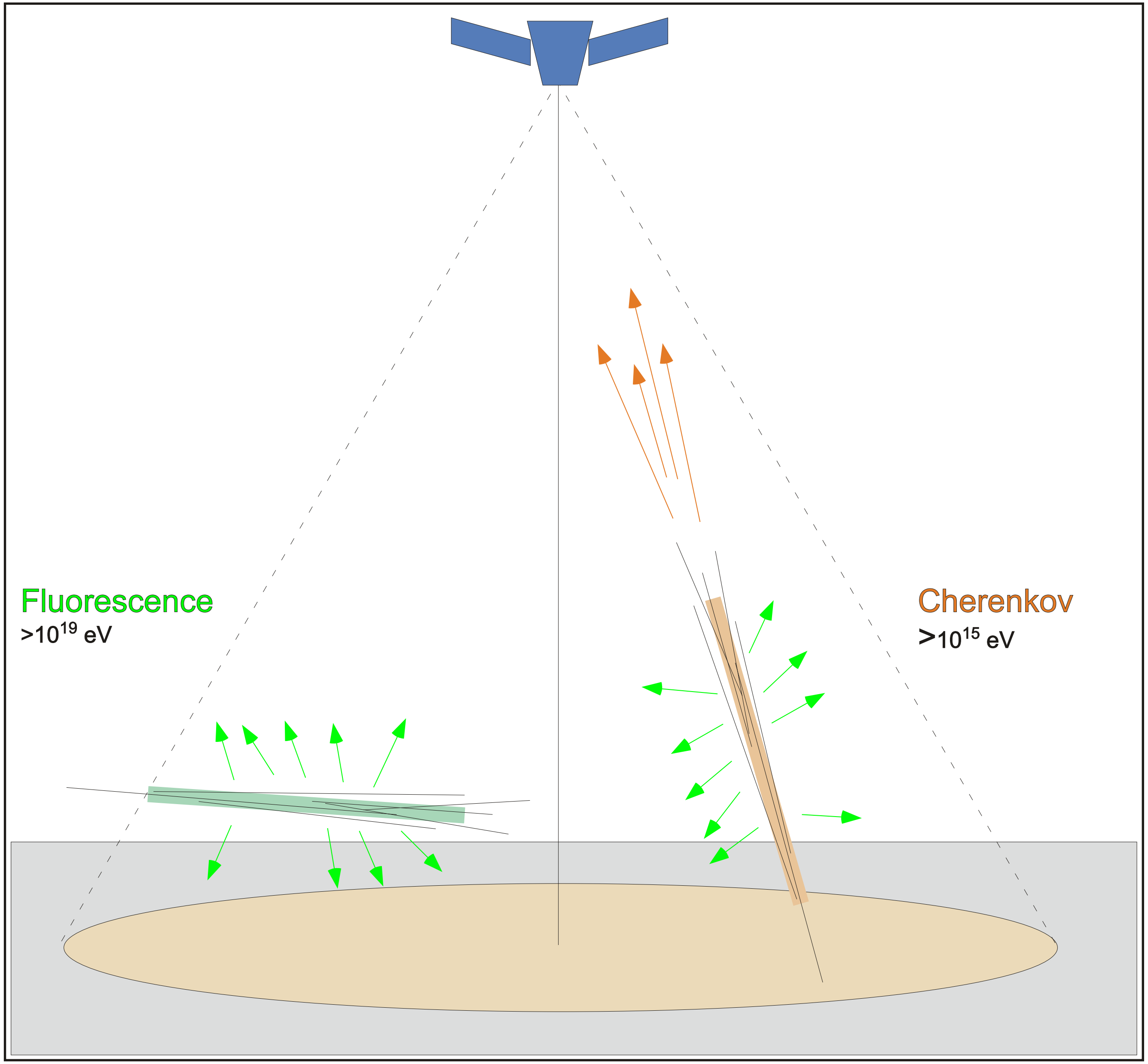
EUSO / OWL as ν Detector:

Target mass:

~ 2x10^{15} kg Air !!!

~2000 km^3 Ice

~2000x IceCube



Time line: ???

Summary & Outlook:

CR paradigm (SNR, Fermi acceleration, propagation) still holds,
though some questions are still open.

Direct measurements (with particle identification) are likely to go up to knee, soon.

Spectrum & composition at knee is getting clearer.
(rigidity dependent cut-off, mixed composition, changing with energy)

Great improvements at ultra high energies are immanent with the Auger experiment
(spectrum, skyplot, composition, ...)

CR data constrain hadronic interaction models (particle physics up to 10^{20} eV).

UHECR detectors have good ν sensitivity (unique for ν_τ).

High-quality multi-parameter measurements are vital.

Better statistics, higher energies, smaller anisotropies, ν physics

require to instrument even larger volumes efficiently.
Are there new & efficient techniques ?