

# Highest energy cosmic rays and the Pierre Auger Observatory

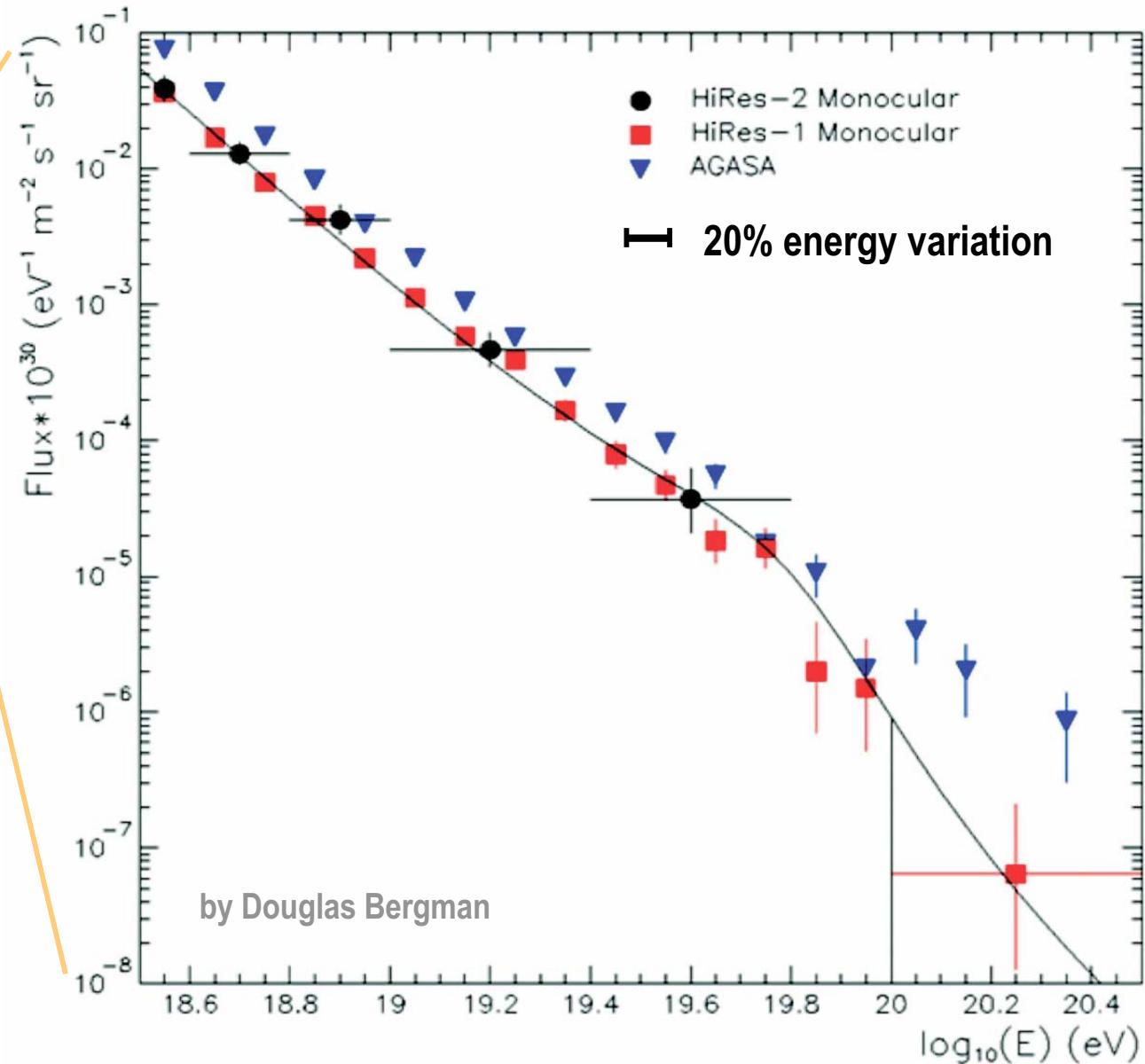
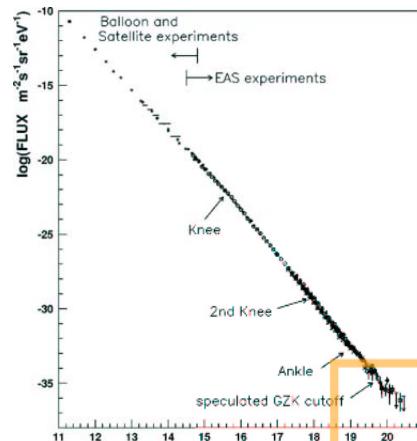
Argentina – Australia – Bolivia – Brasil – Czech Republic –  
France – Germany – Italy – Poland – Mexico – Slovenia –  
Spain – United Kingdom – USA – Vietnam

<http://www.auger.org/auger-authors.pdf>

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# Pierre Auger Observatory Science Objectives

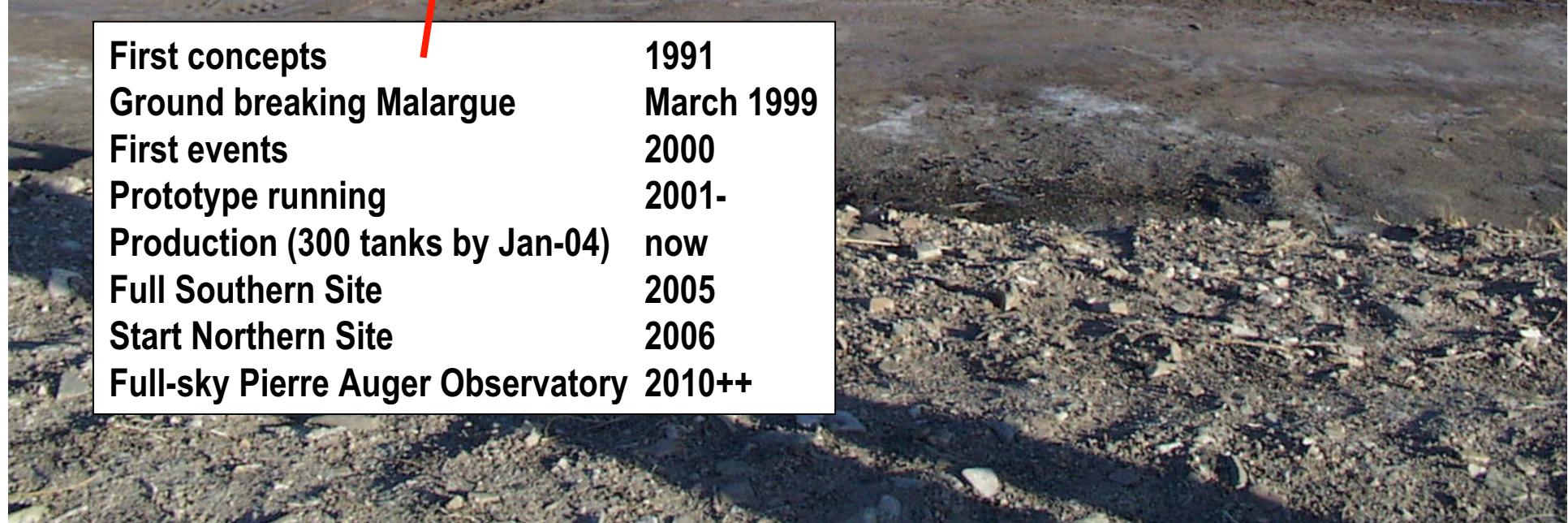
- understand the nature, origin and propagation of UHECR
  - point sources?
  - isotropic arrival directions?
  - GZK cut-off or continuing spectrum?
  - primary particle mass, type?
  - acceleration or decay of exotics?
- detect cosmic rays with high statistics
  - aperture  $>7000\text{km}^2\text{sr}$  @ $10^{19}\text{eV}$  in each hemisphere
  - full sky coverage and  $\sim$ uniform exposure
  - $\sim$ degree angular resolution,  $\theta \rightarrow 90^\circ$
  - primary particle discrimination (light, heavy,  $\gamma$ ,  $\nu$ )
  - calorimetric energy calibration



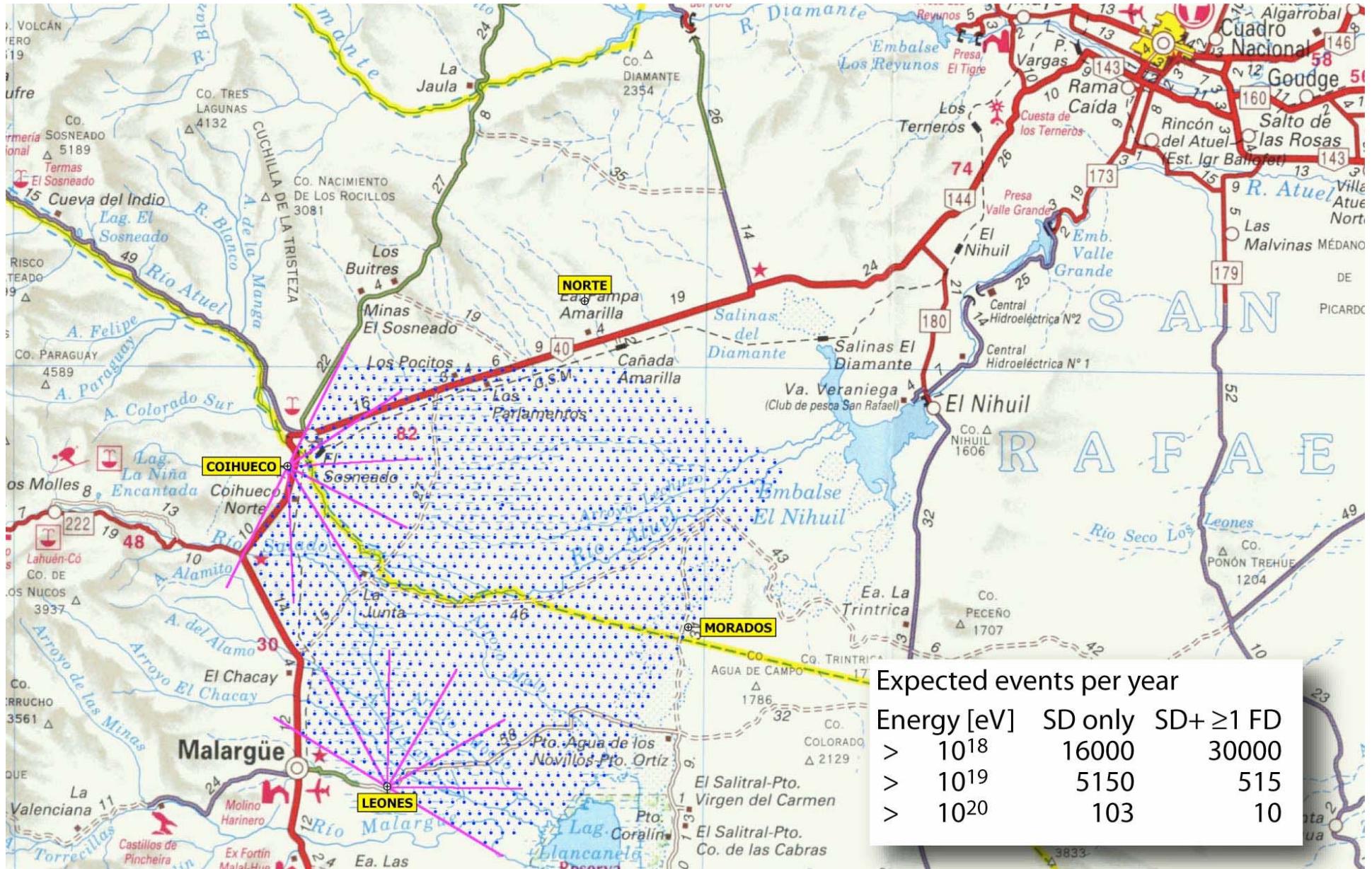
by Douglas Bergman



First concepts	1991
Ground breaking Malargüe	March 1999
First events	2000
Prototype running	2001-
Production (300 tanks by Jan-04)	now
Full Southern Site	2005
Start Northern Site	2006
Full-sky Pierre Auger Observatory	2010++



# 1600 water Cherenkov detectors with 1.5 km spacing on 3000 km<sup>2</sup> 4 stations with 24 fluorescence telescopes



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**Central assembly building**



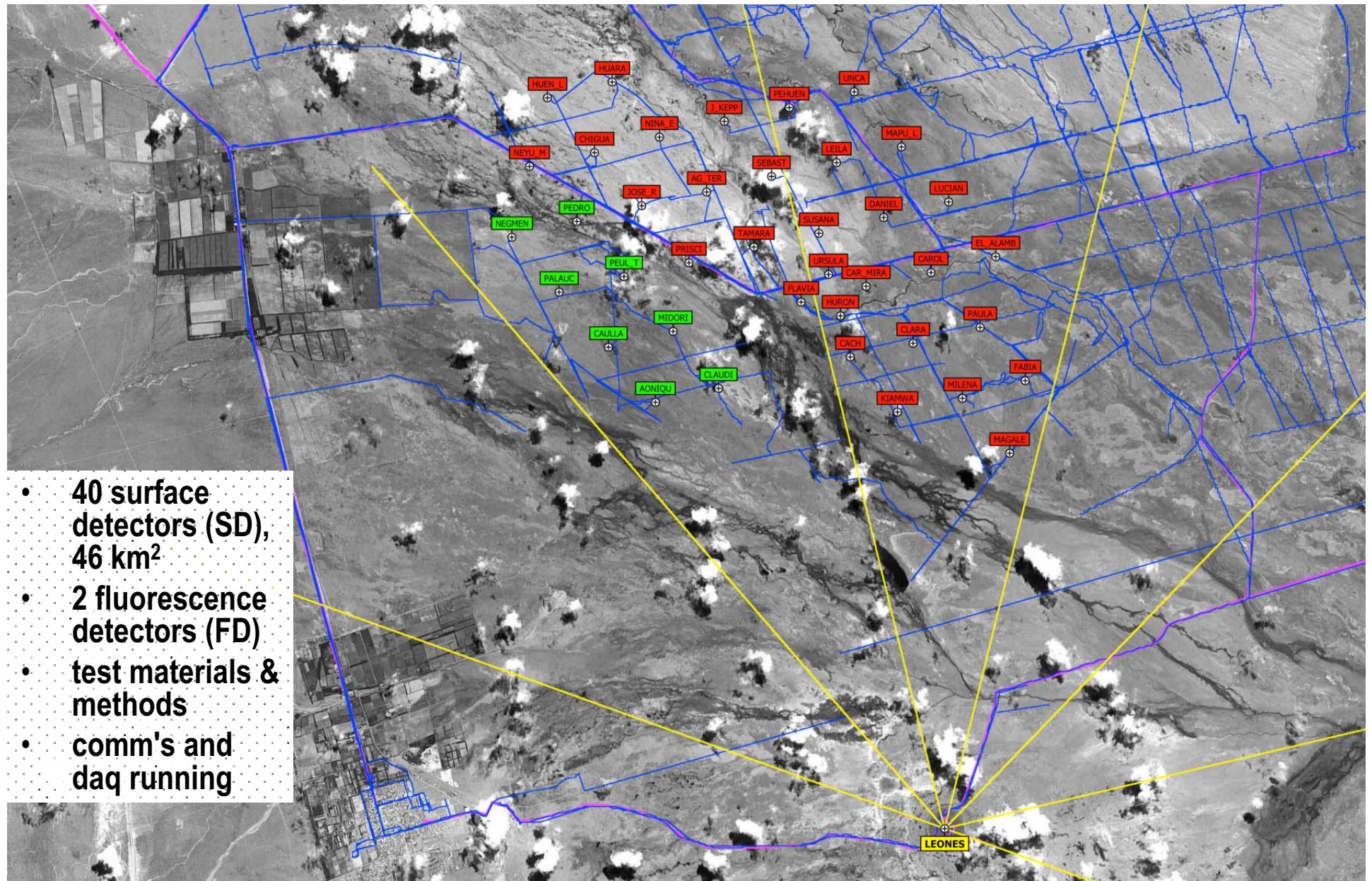


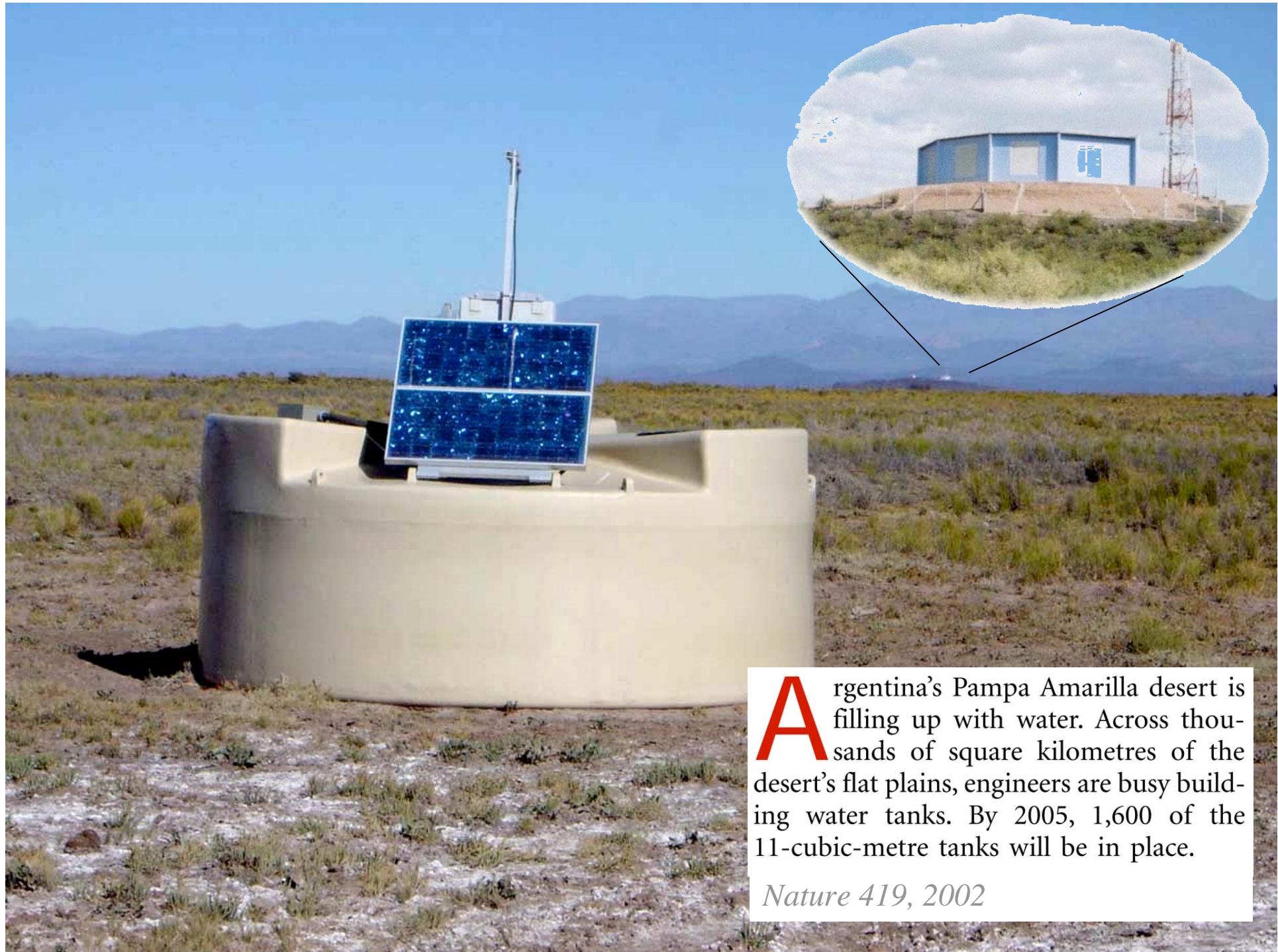
tanks awaiting deployment



Central campus main office building

# The Engineering Array (EA)

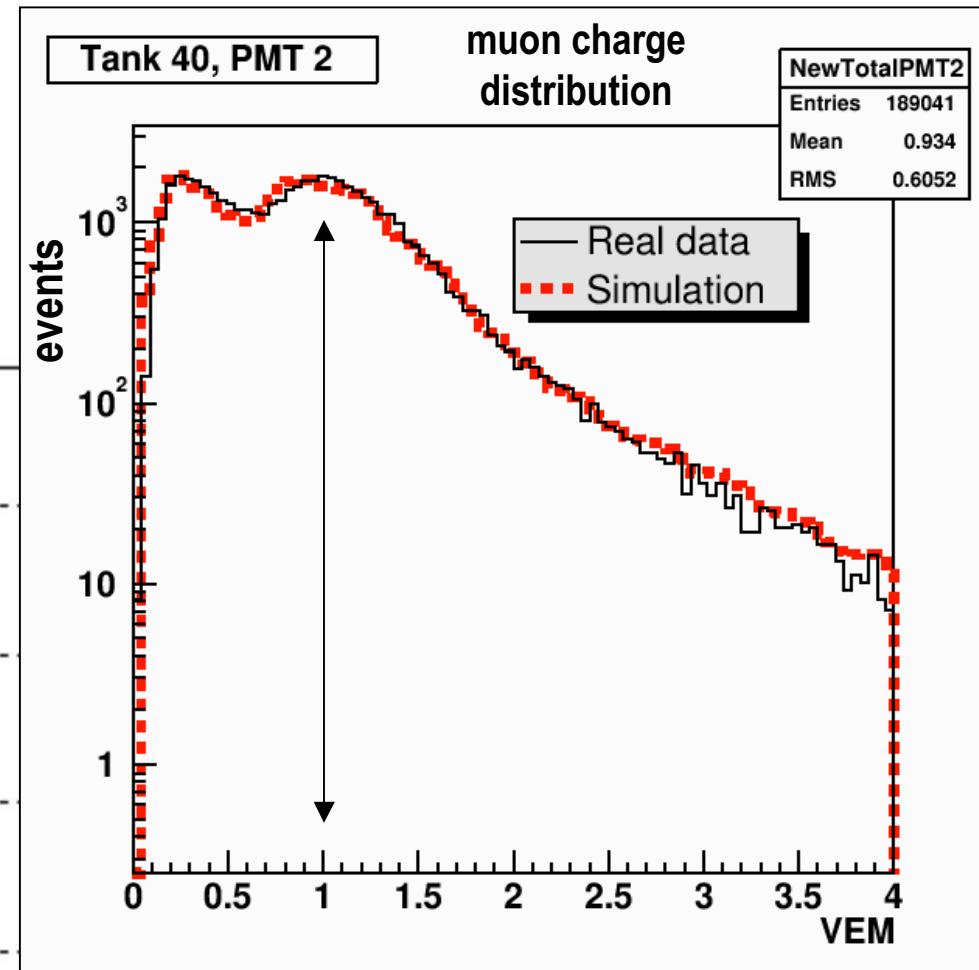
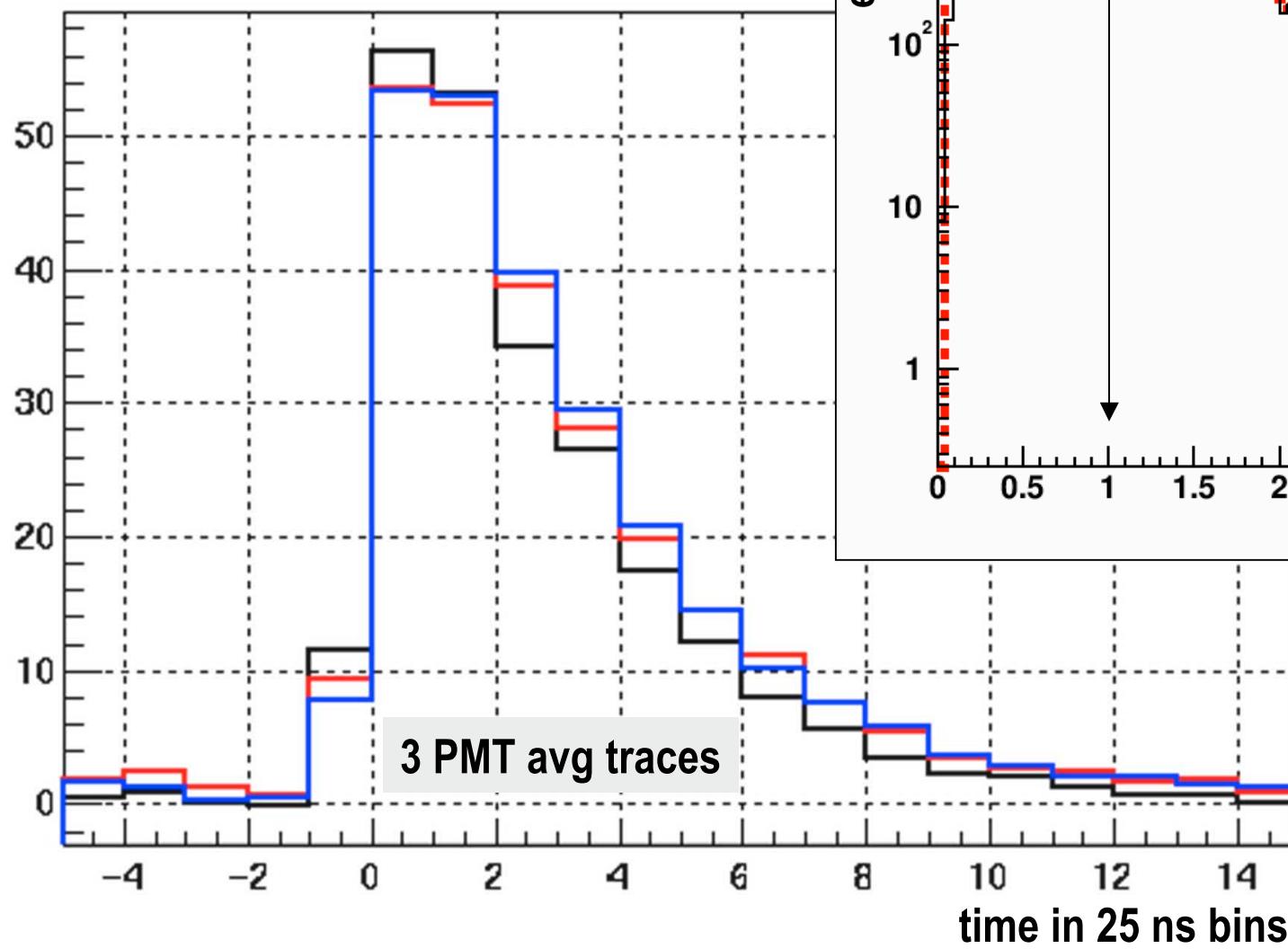




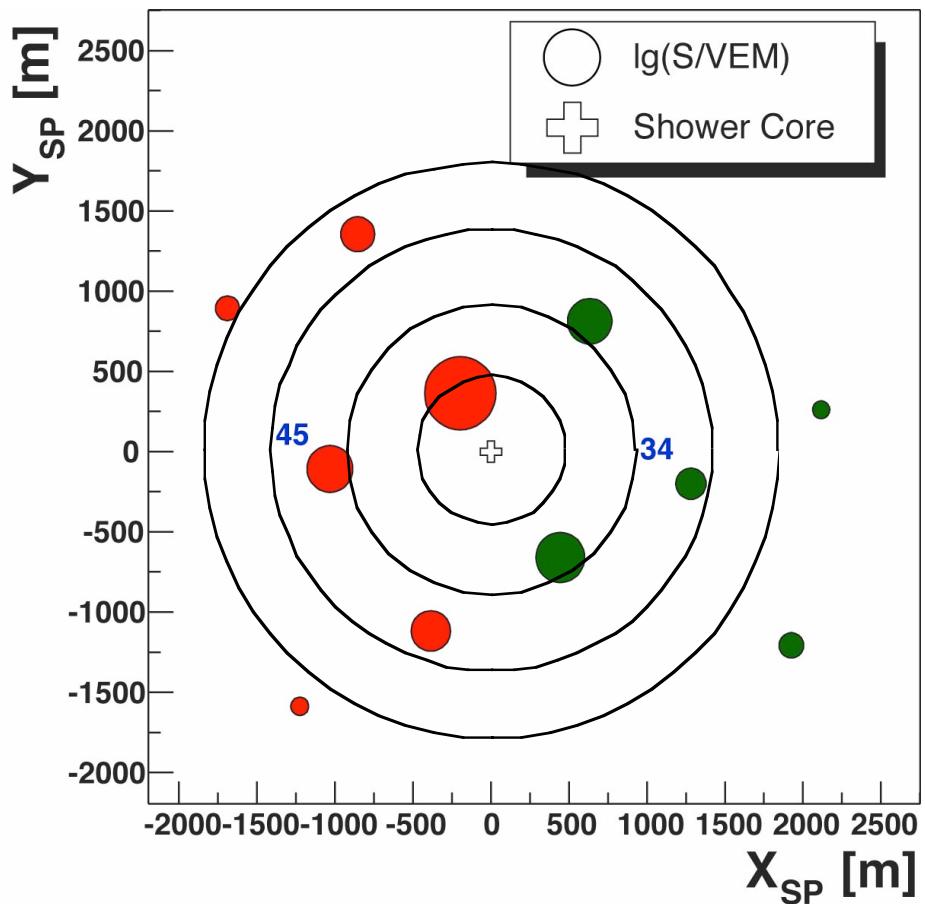
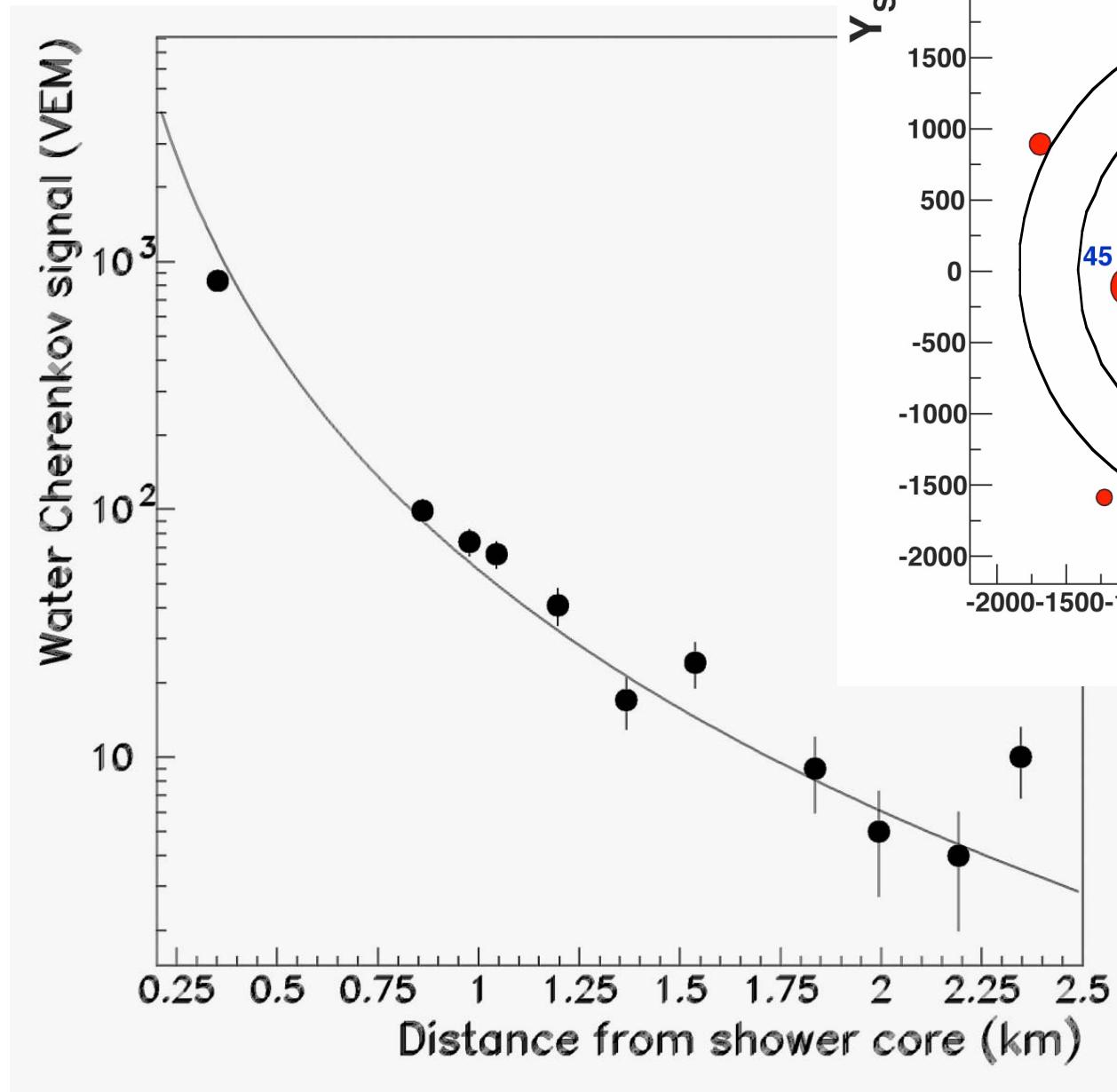
**A**rgentina's Pampa Amarilla desert is filling up with water. Across thousands of square kilometres of the desert's flat plains, engineers are busy building water tanks. By 2005, 1,600 of the 11-cubic-metre tanks will be in place.

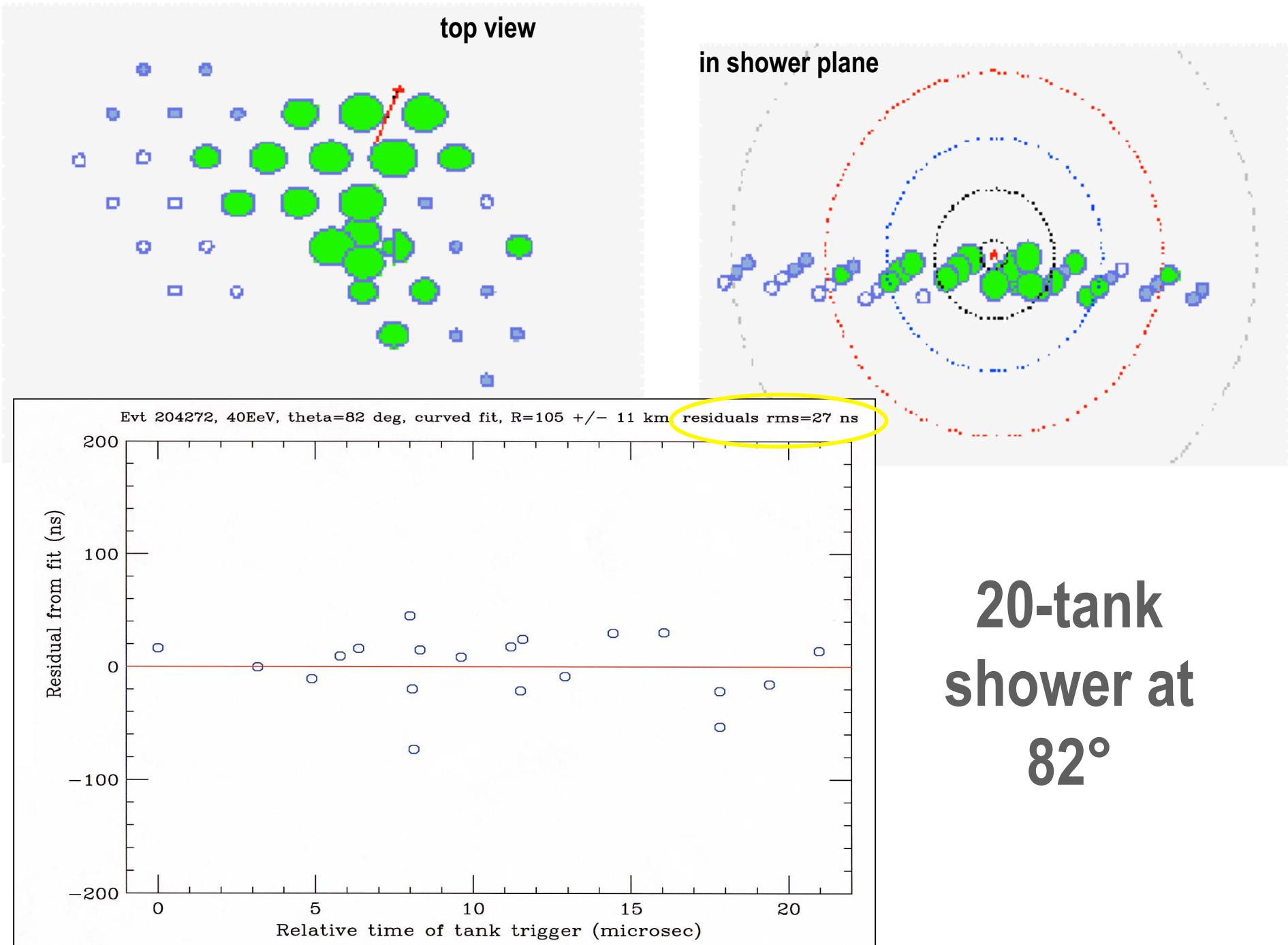
*Nature 419, 2002*

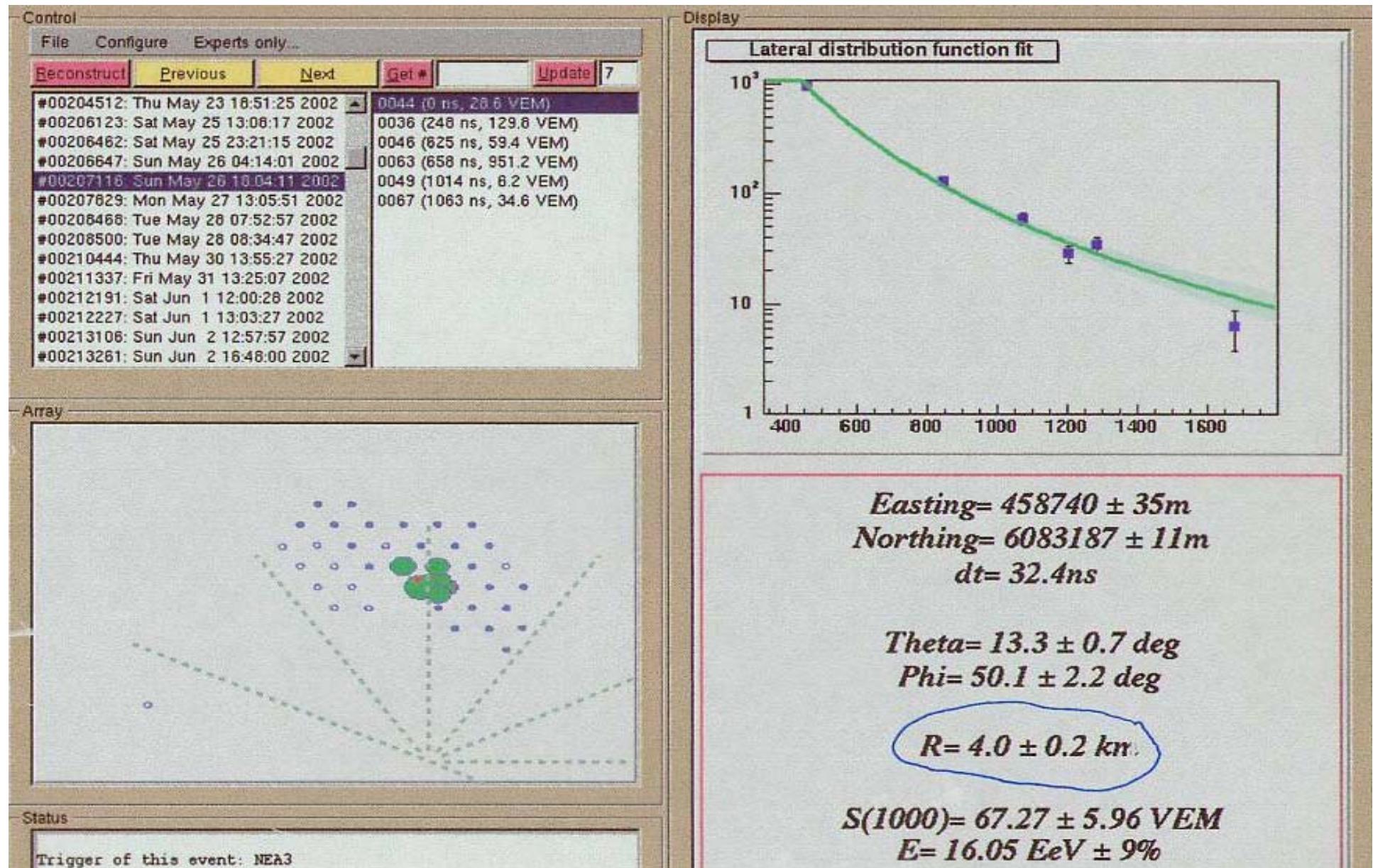
# self-calibrating detectors...

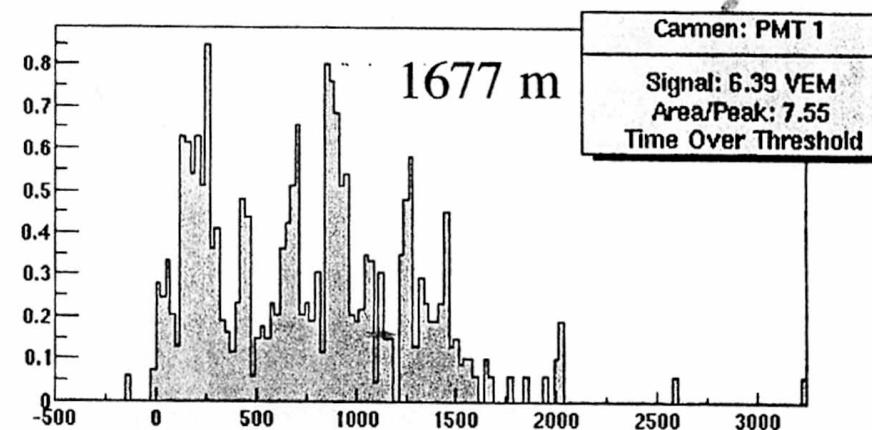
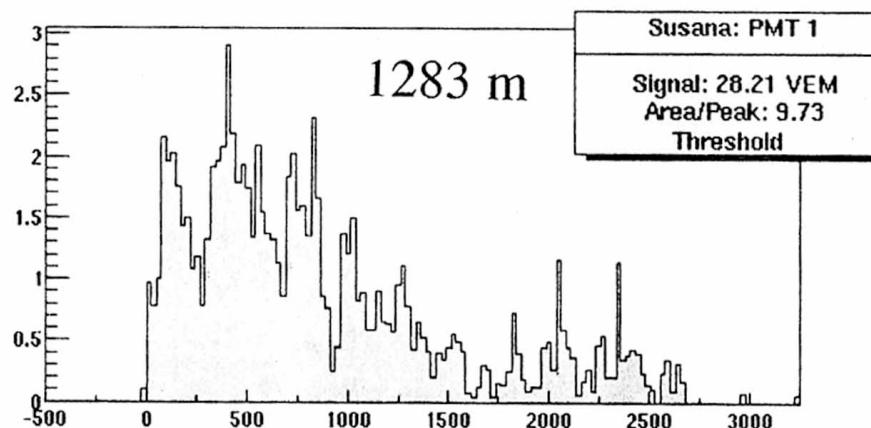
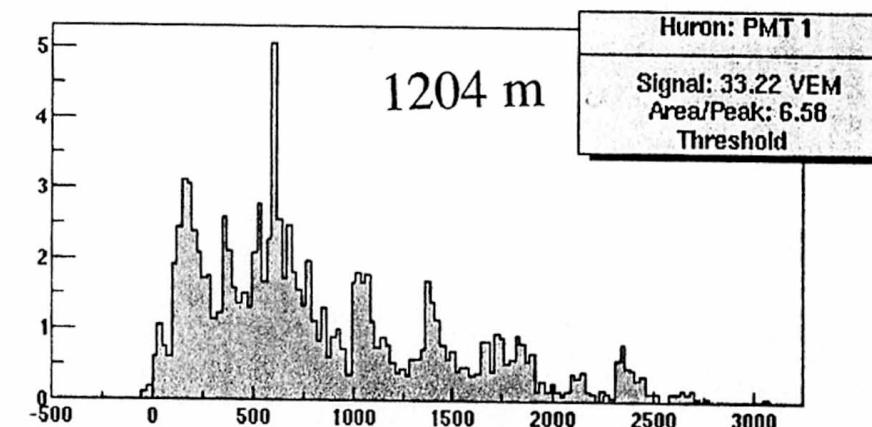
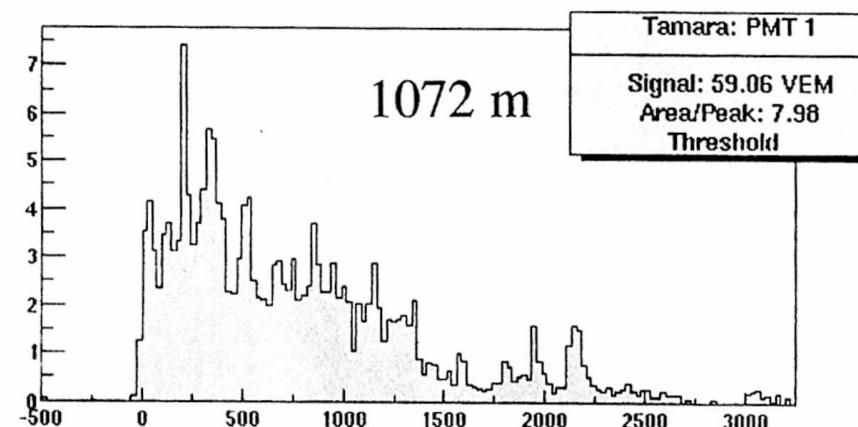
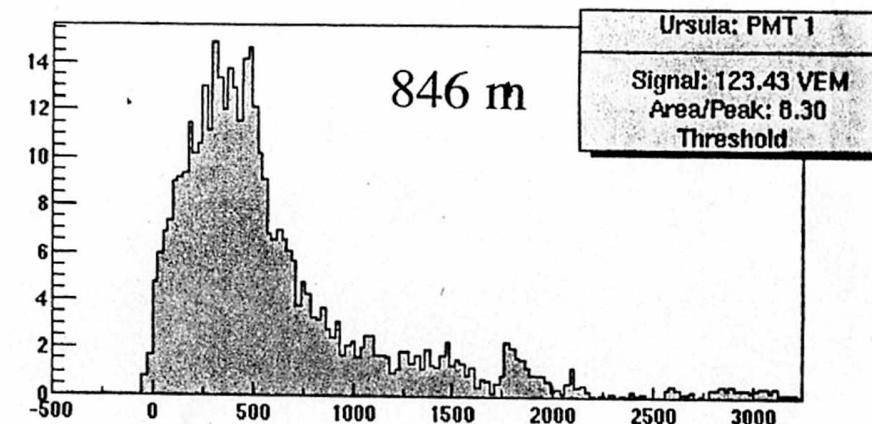
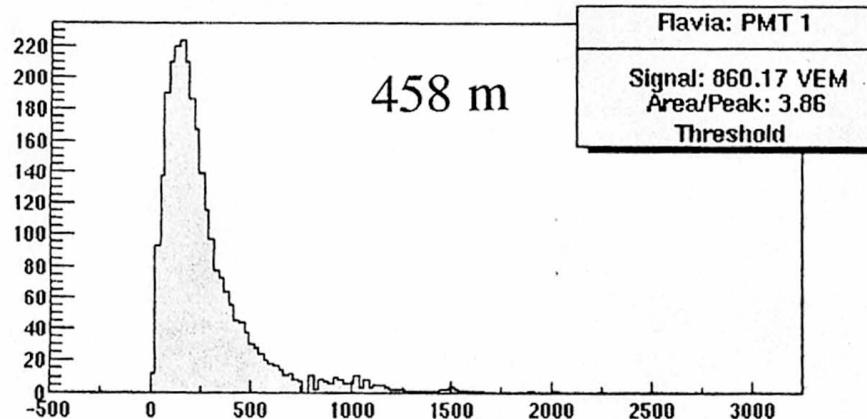


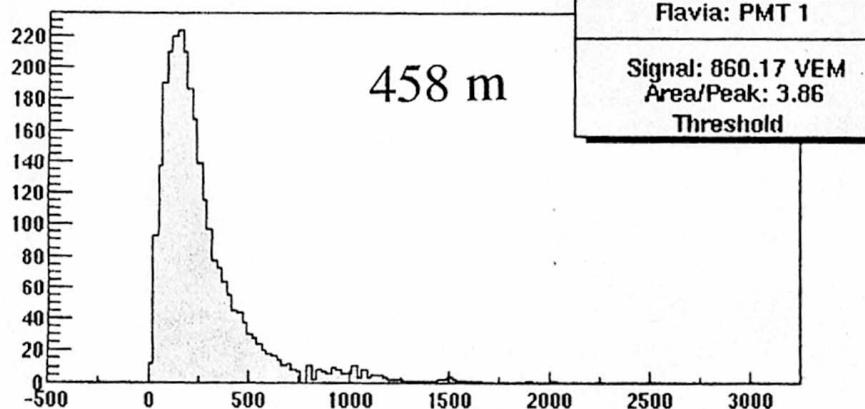
# 11-tank event









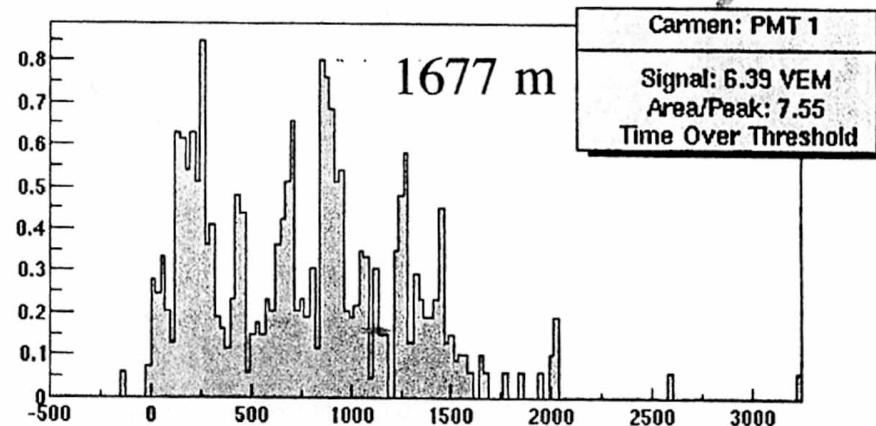


458 m

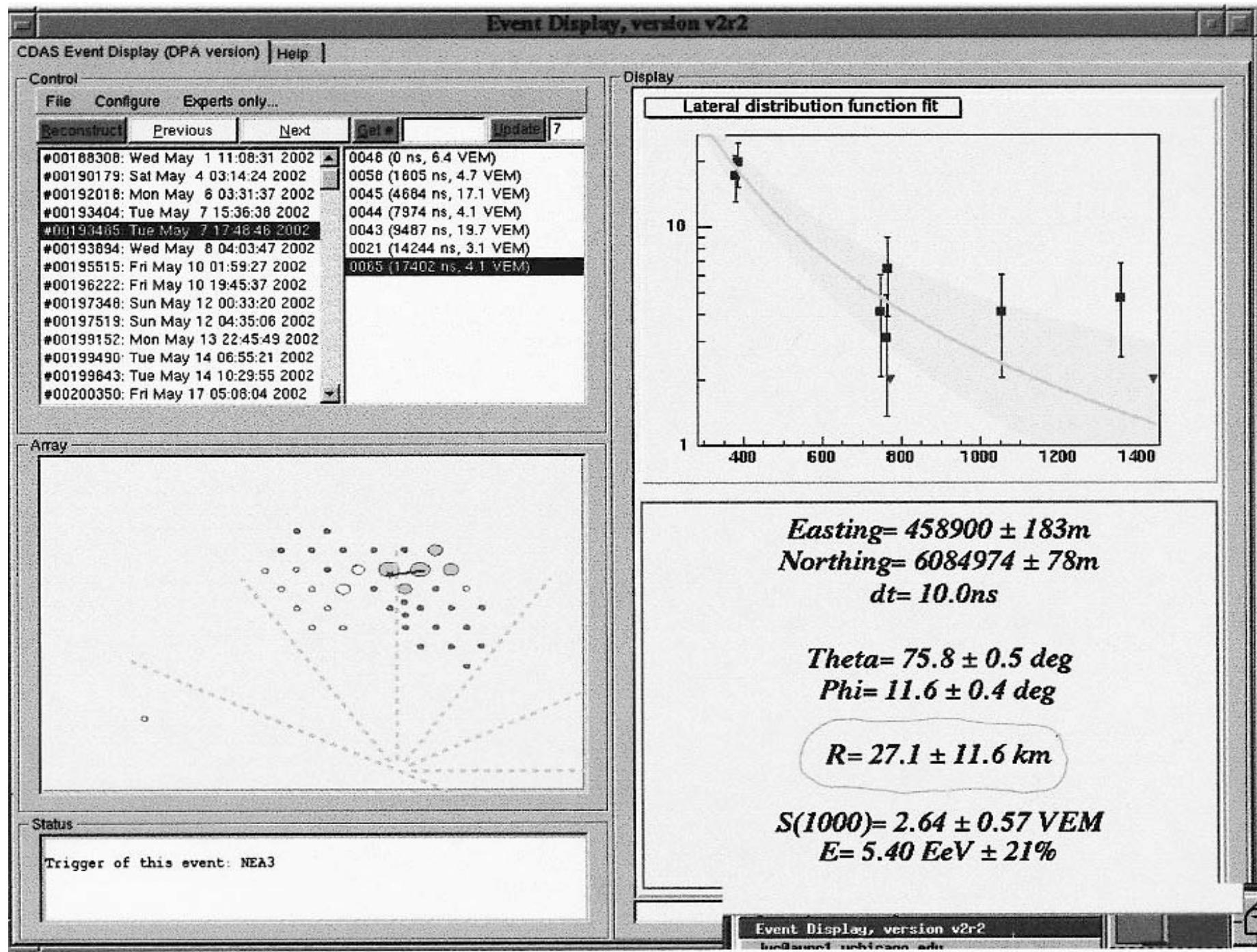
Near PMT

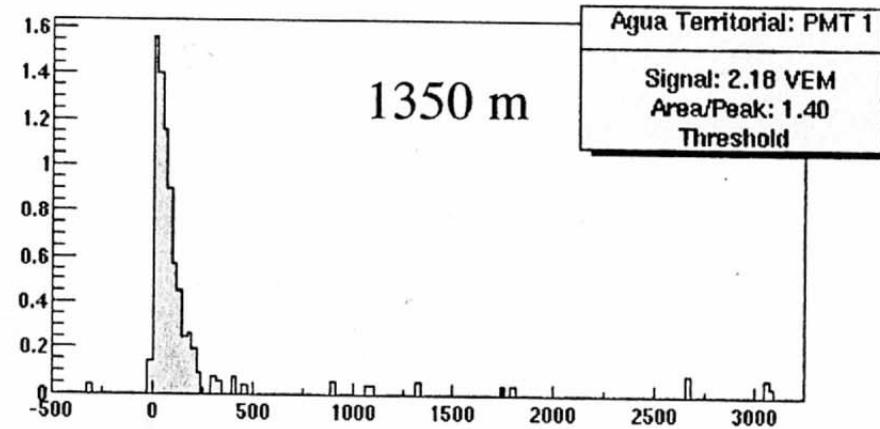
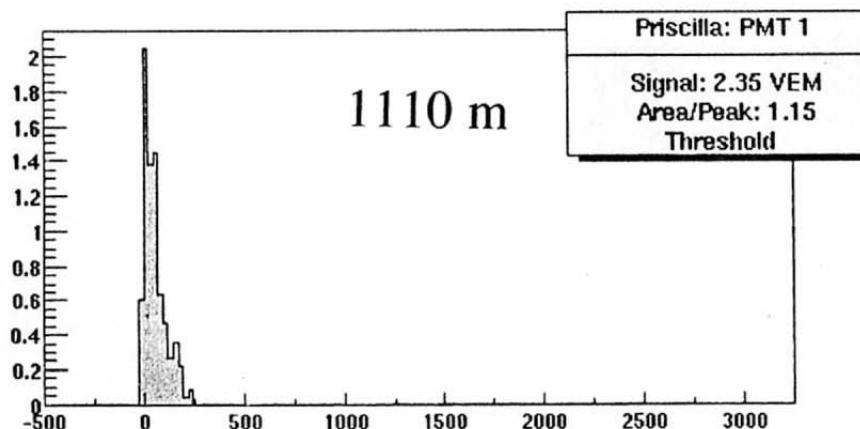
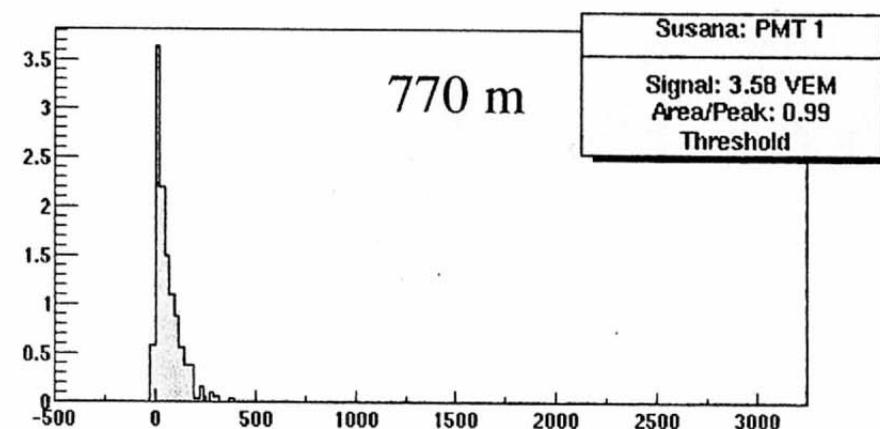
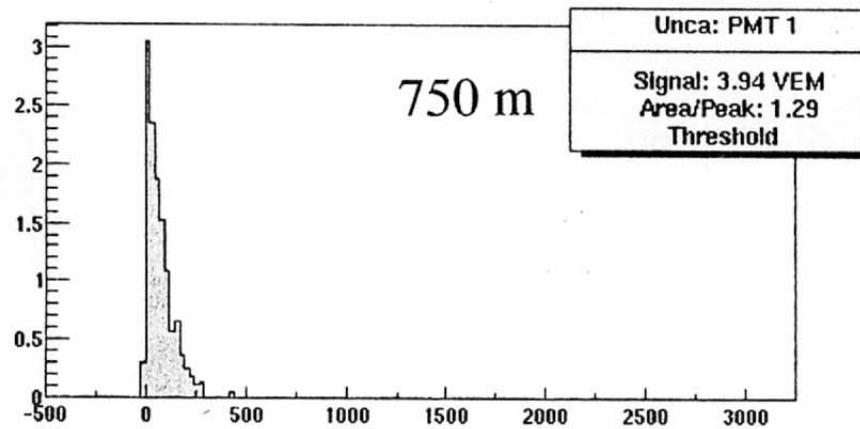
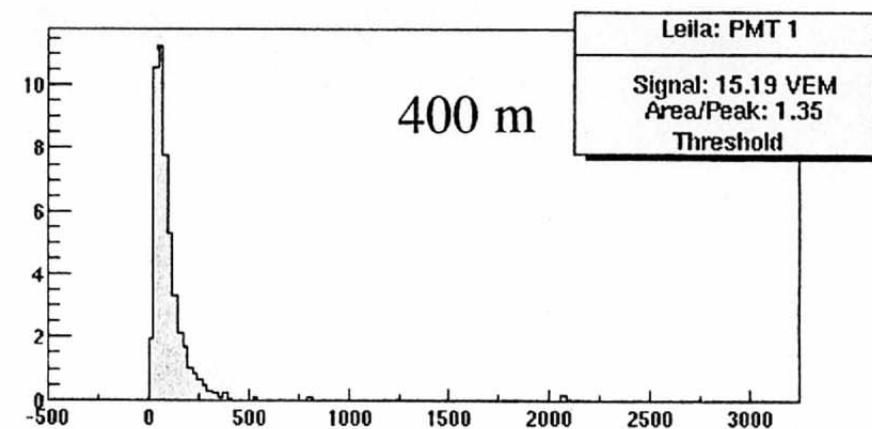
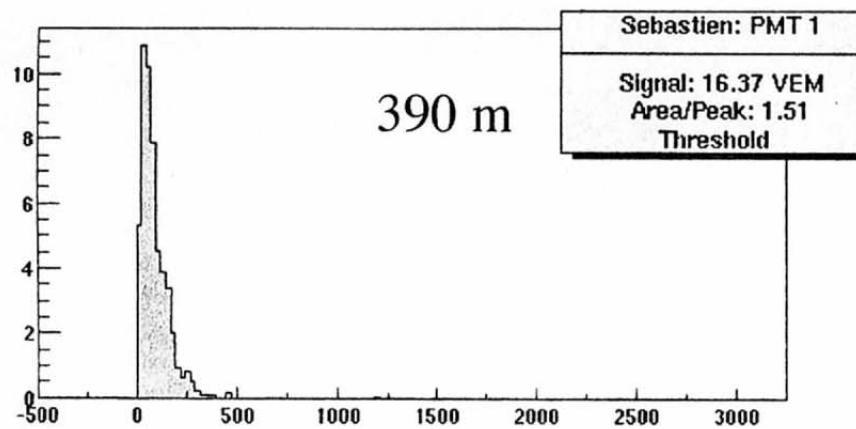
Distance ratio = 3.7 Density ratio = 134  
this is a 'young shower', lots of electrons

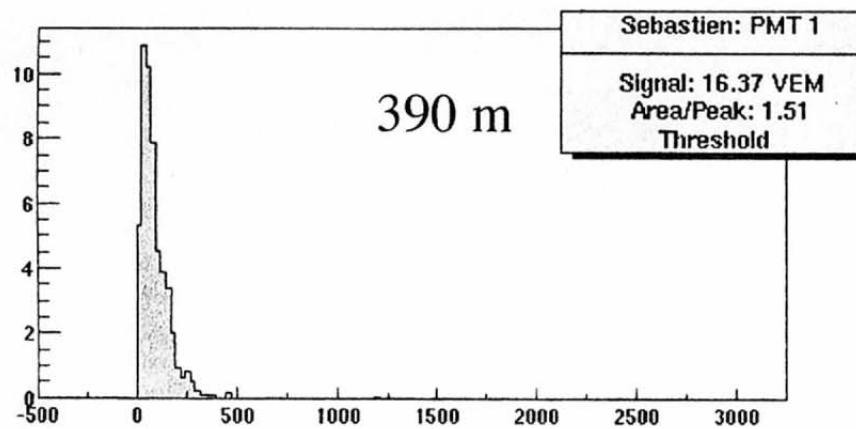
Far PMT



1677 m



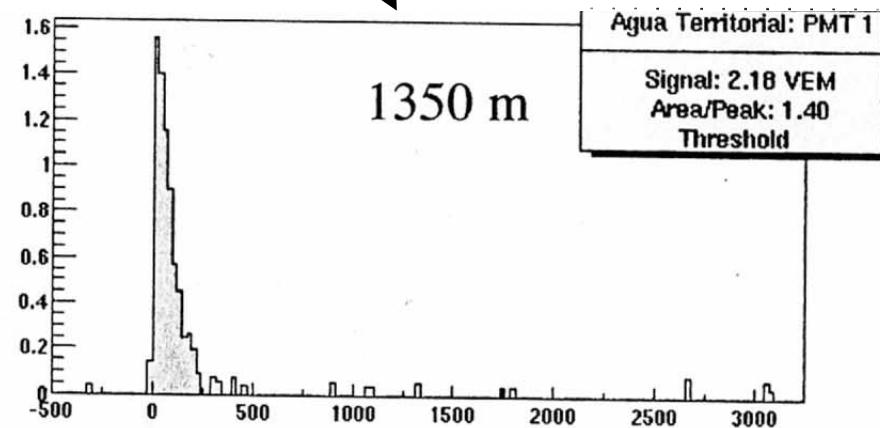


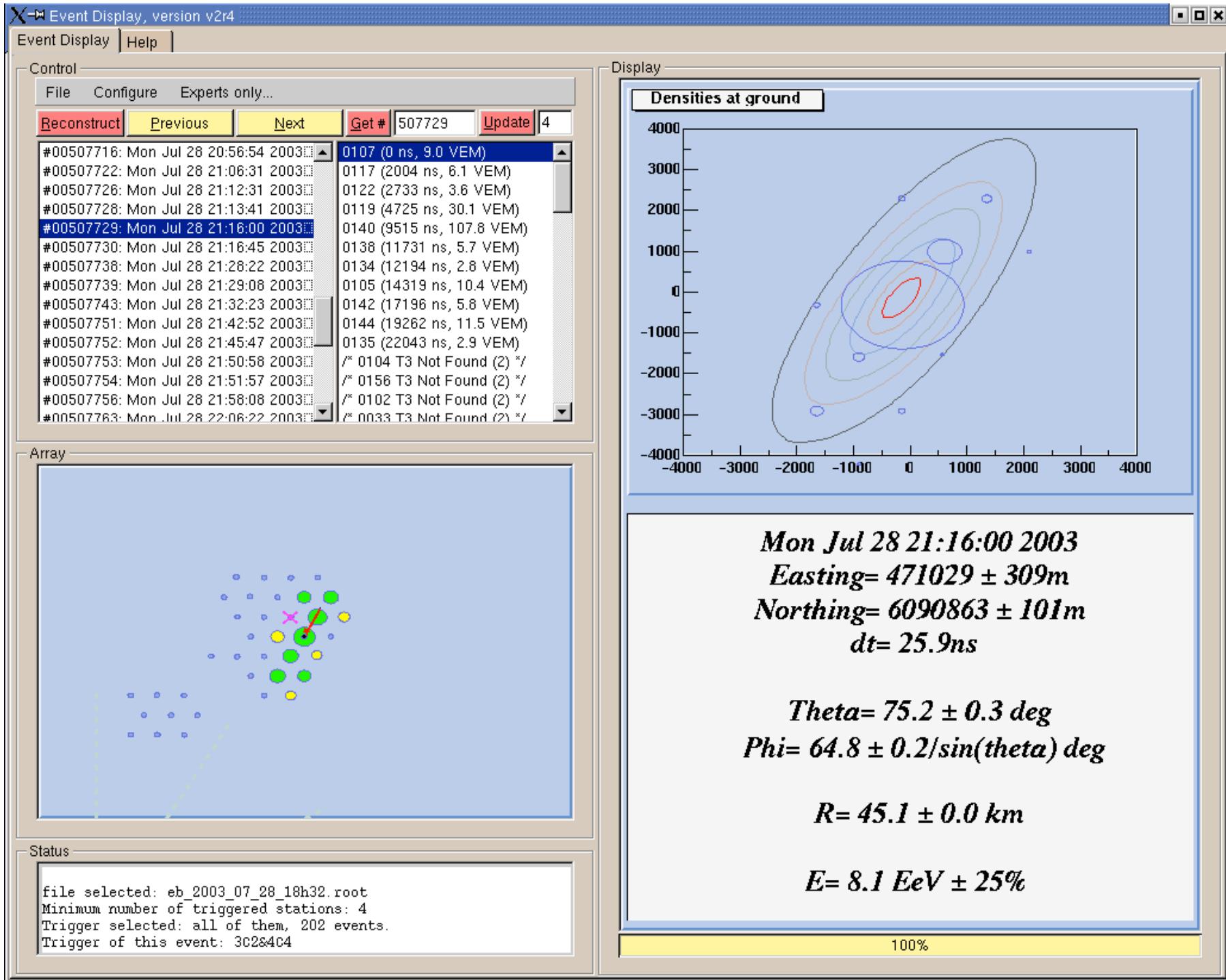


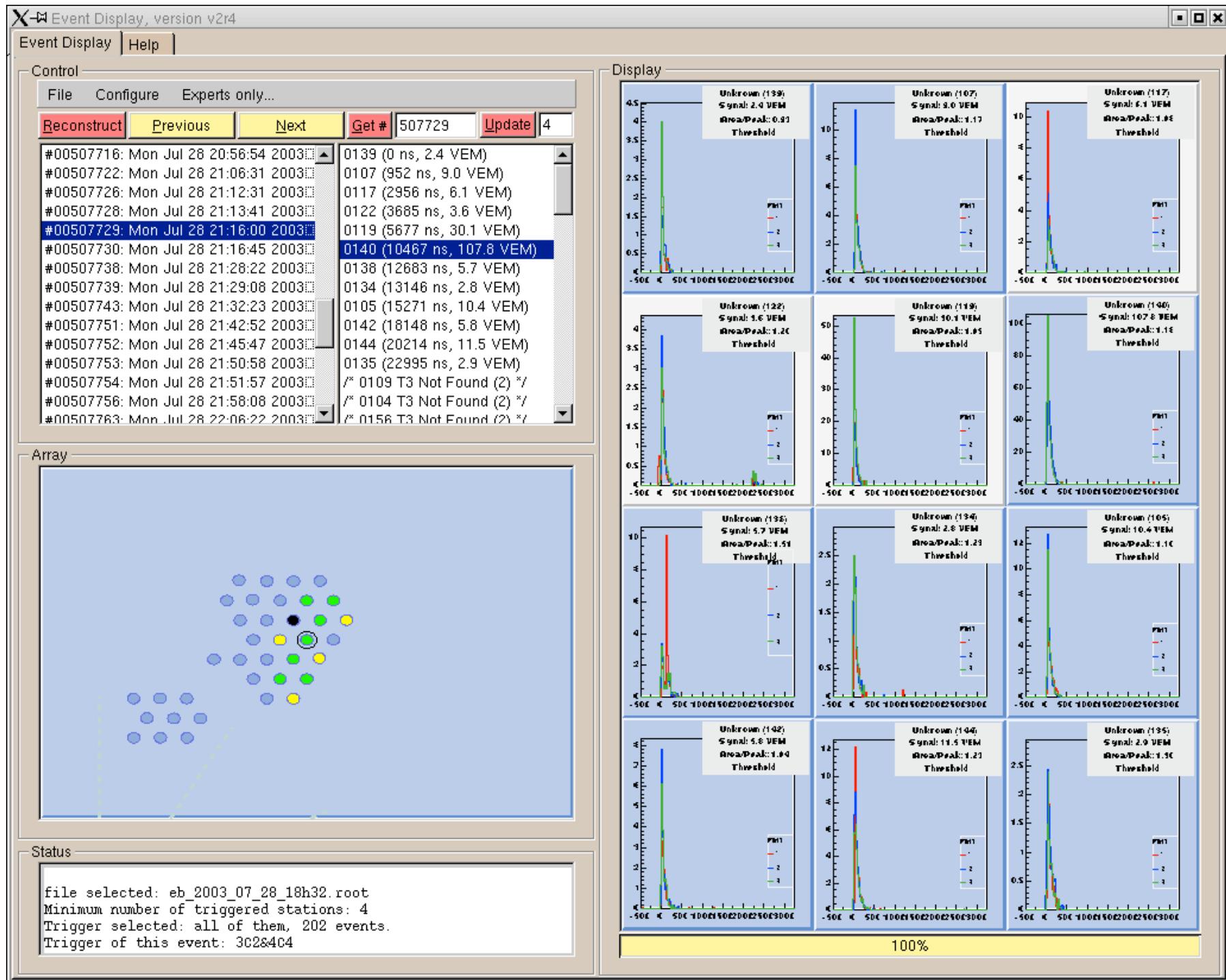
Near PMT

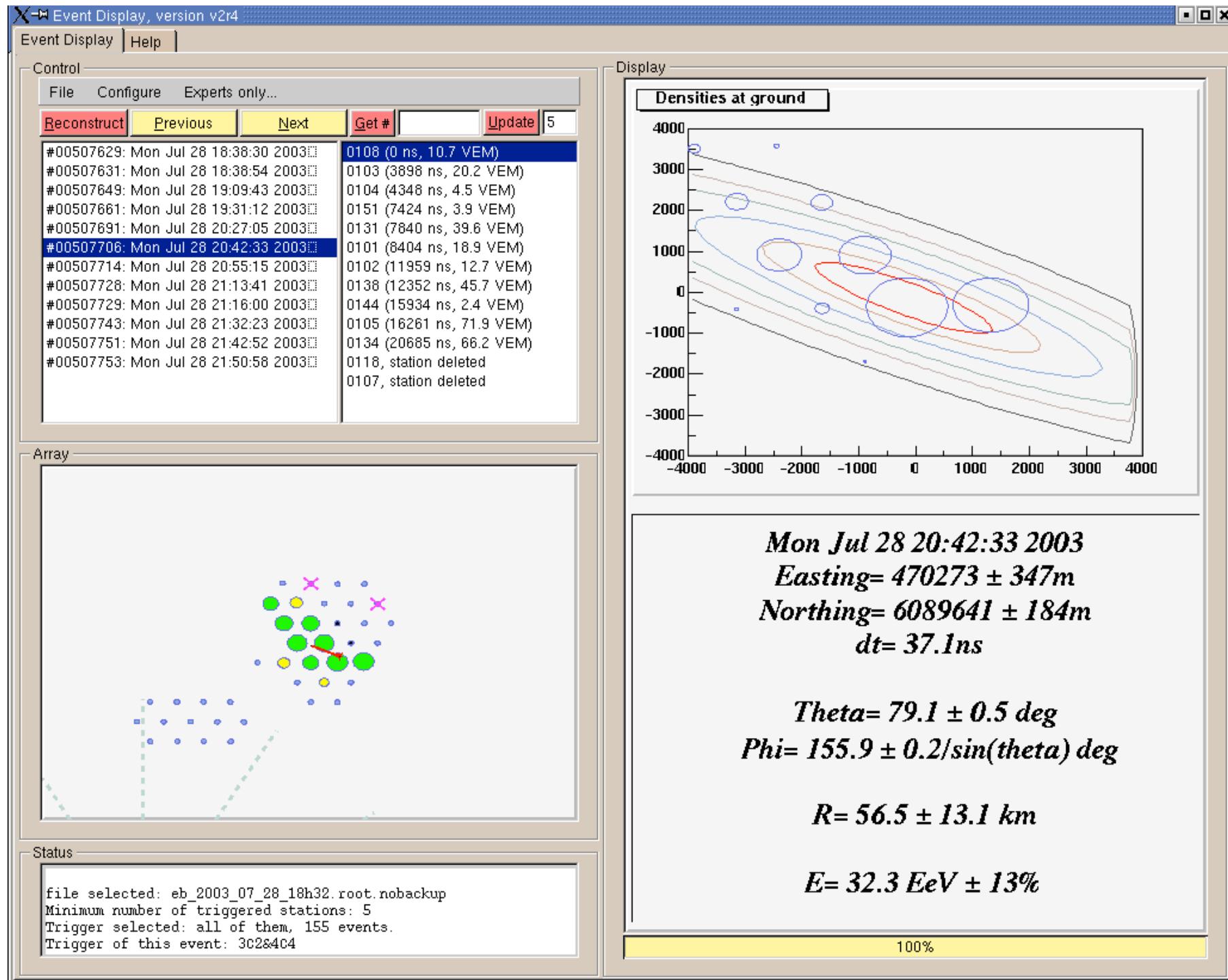
Distance ratio = 3.5 Density ratio = 7.5  
this is an old shower', mostly muons

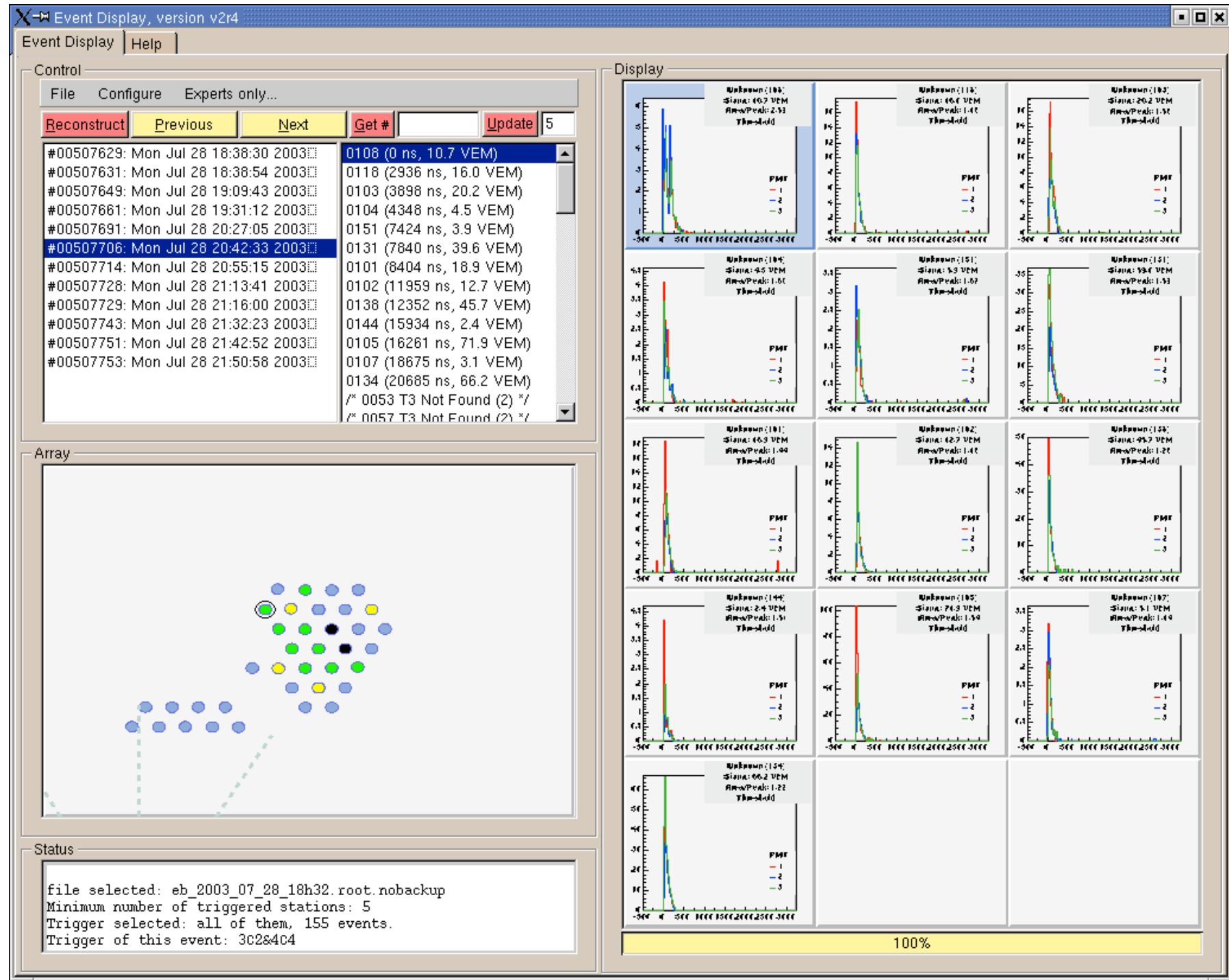
Far PMT

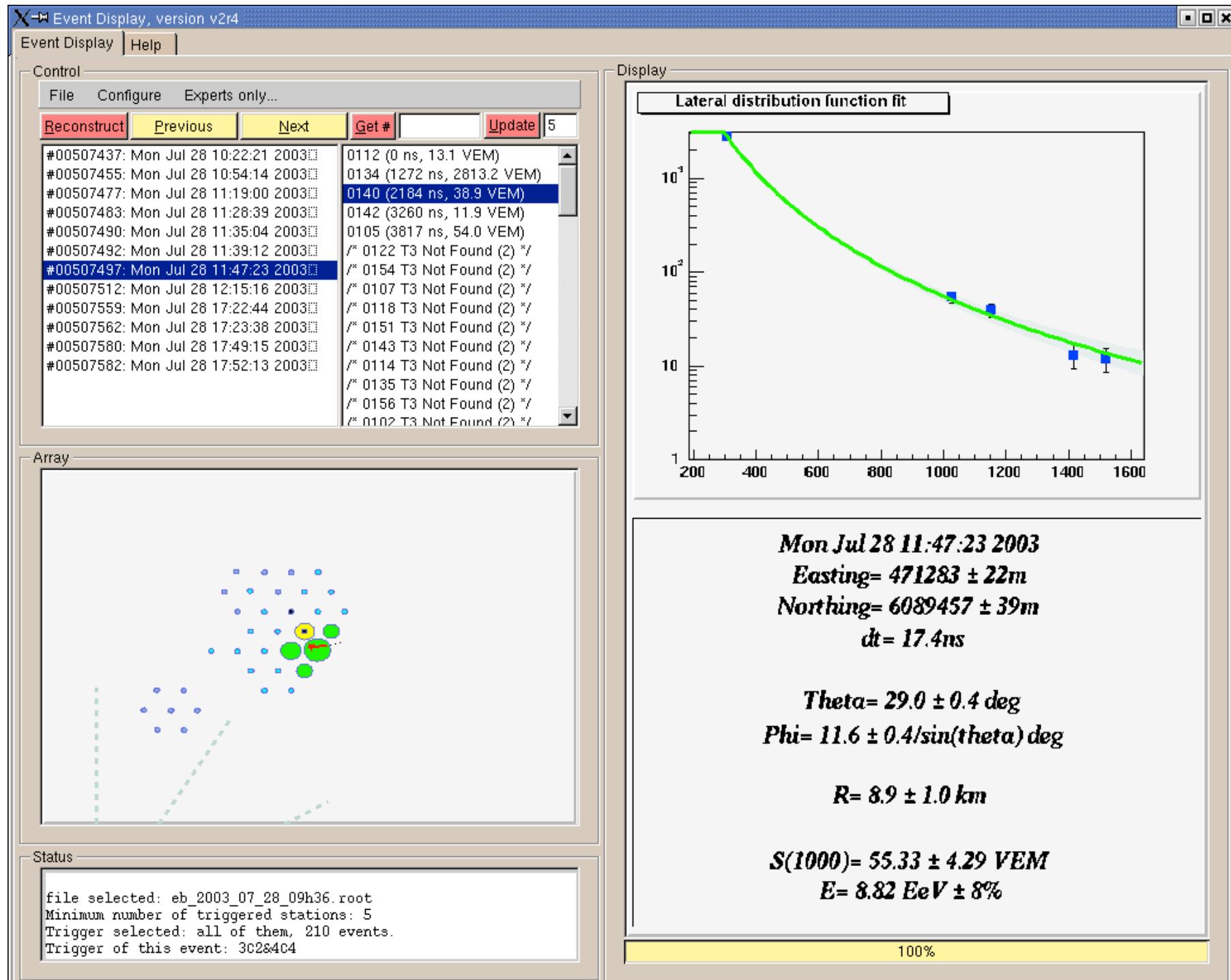


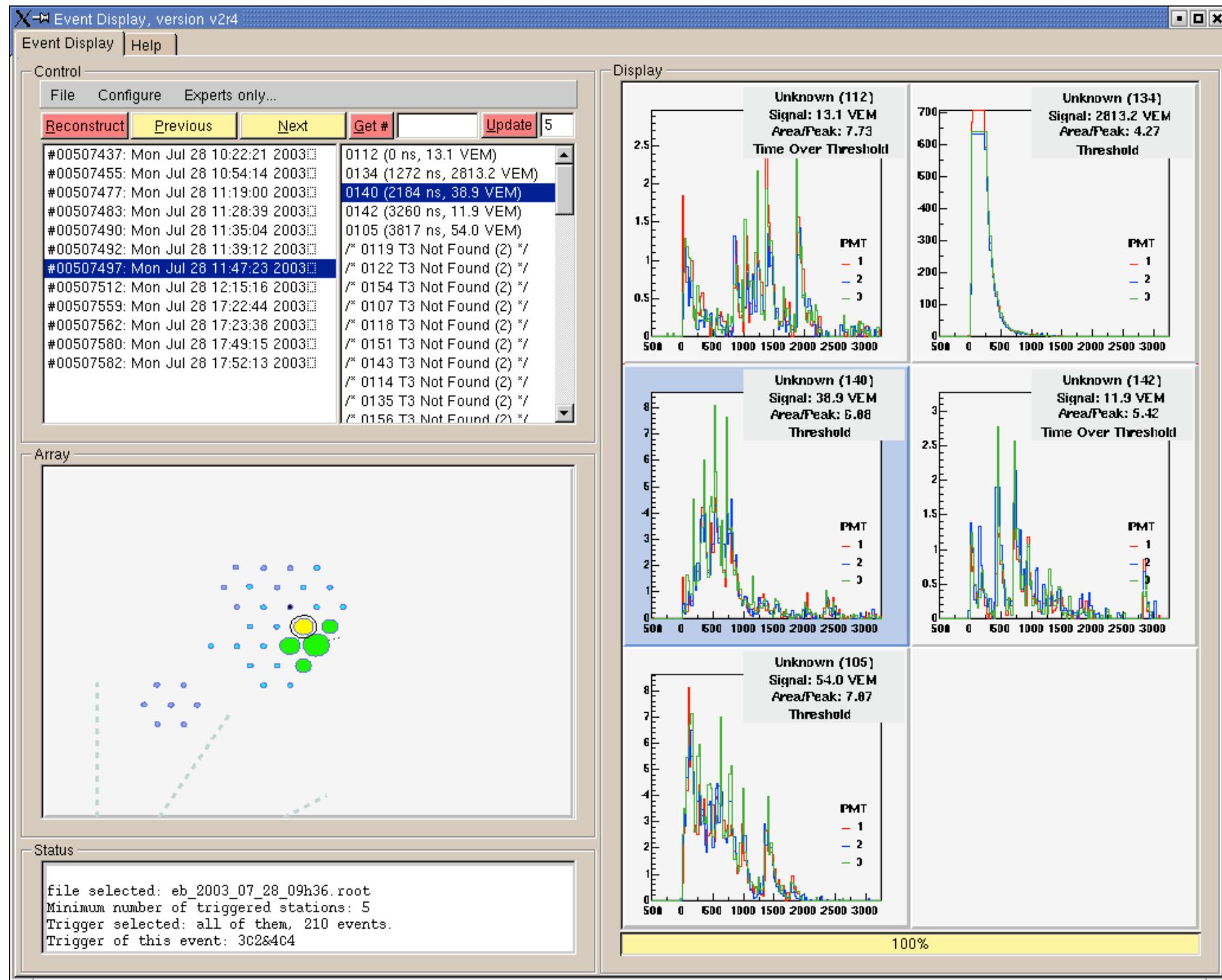


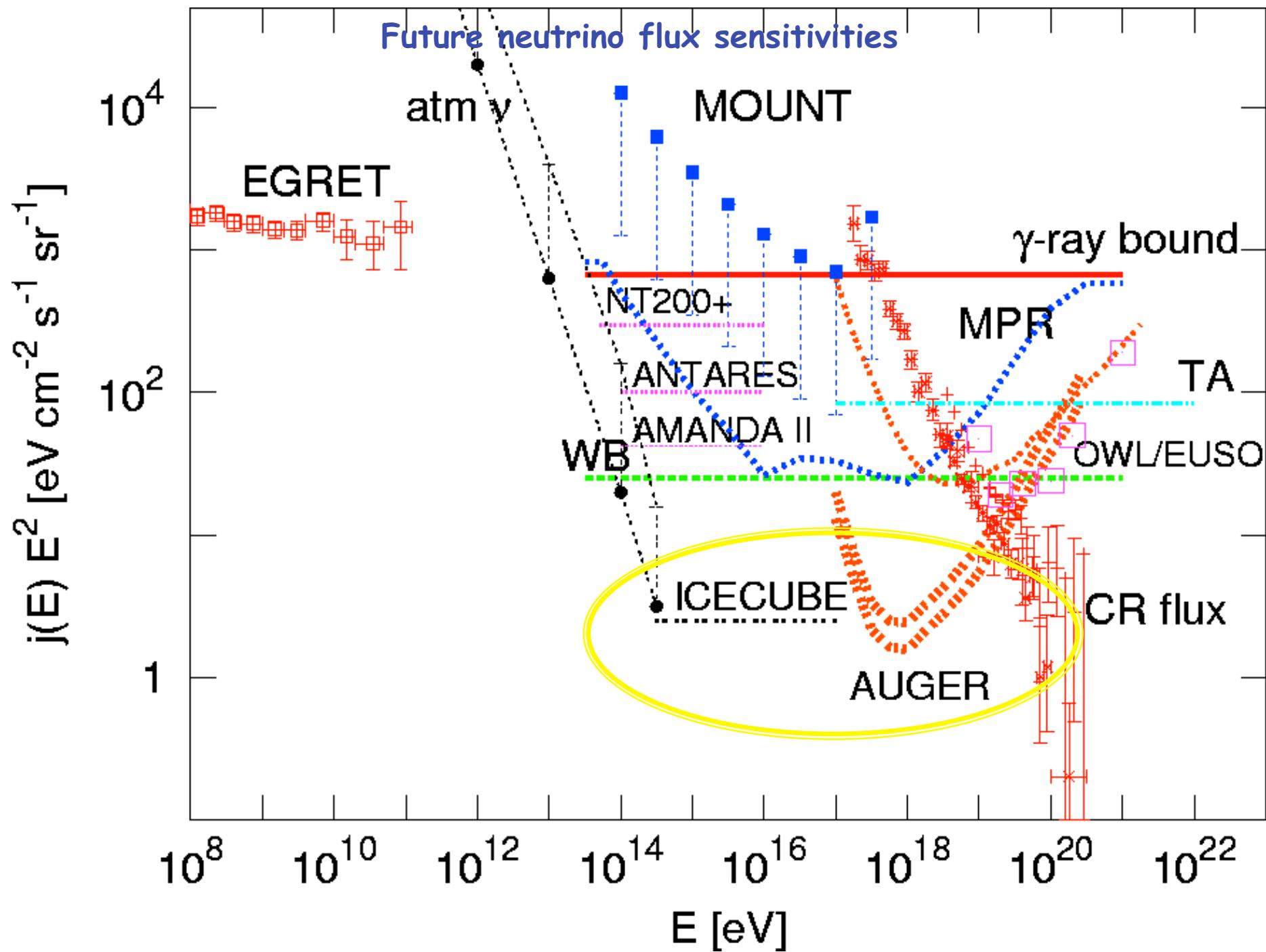


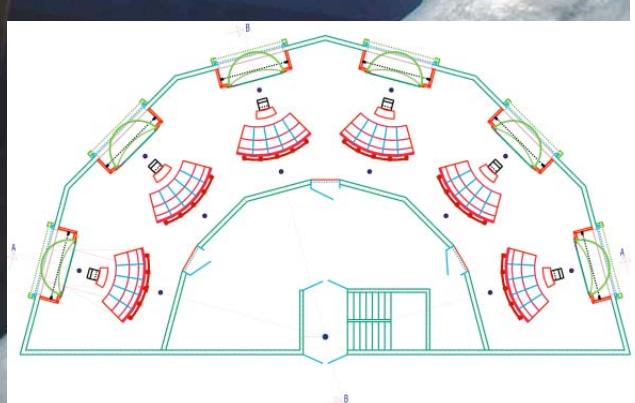
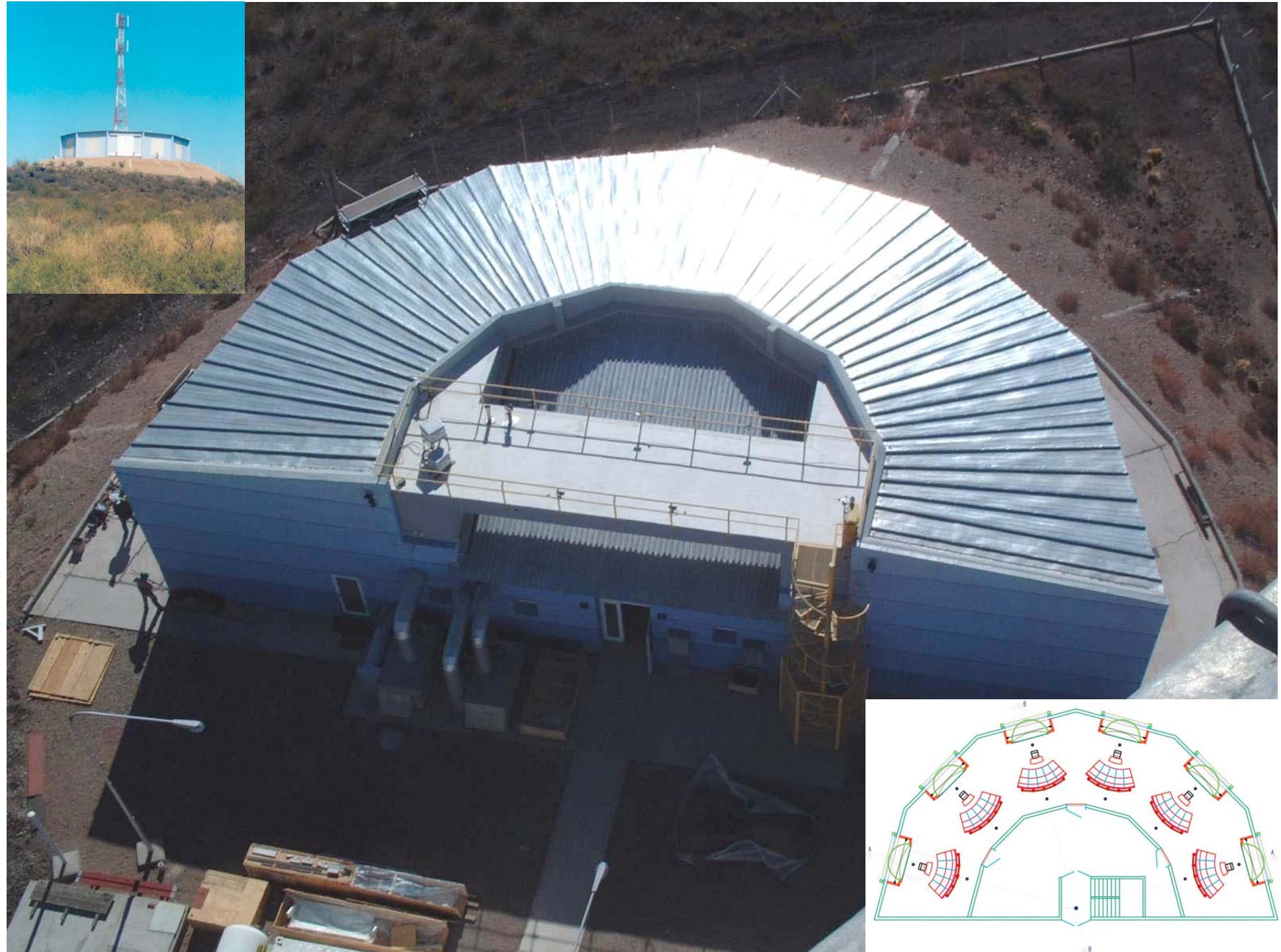


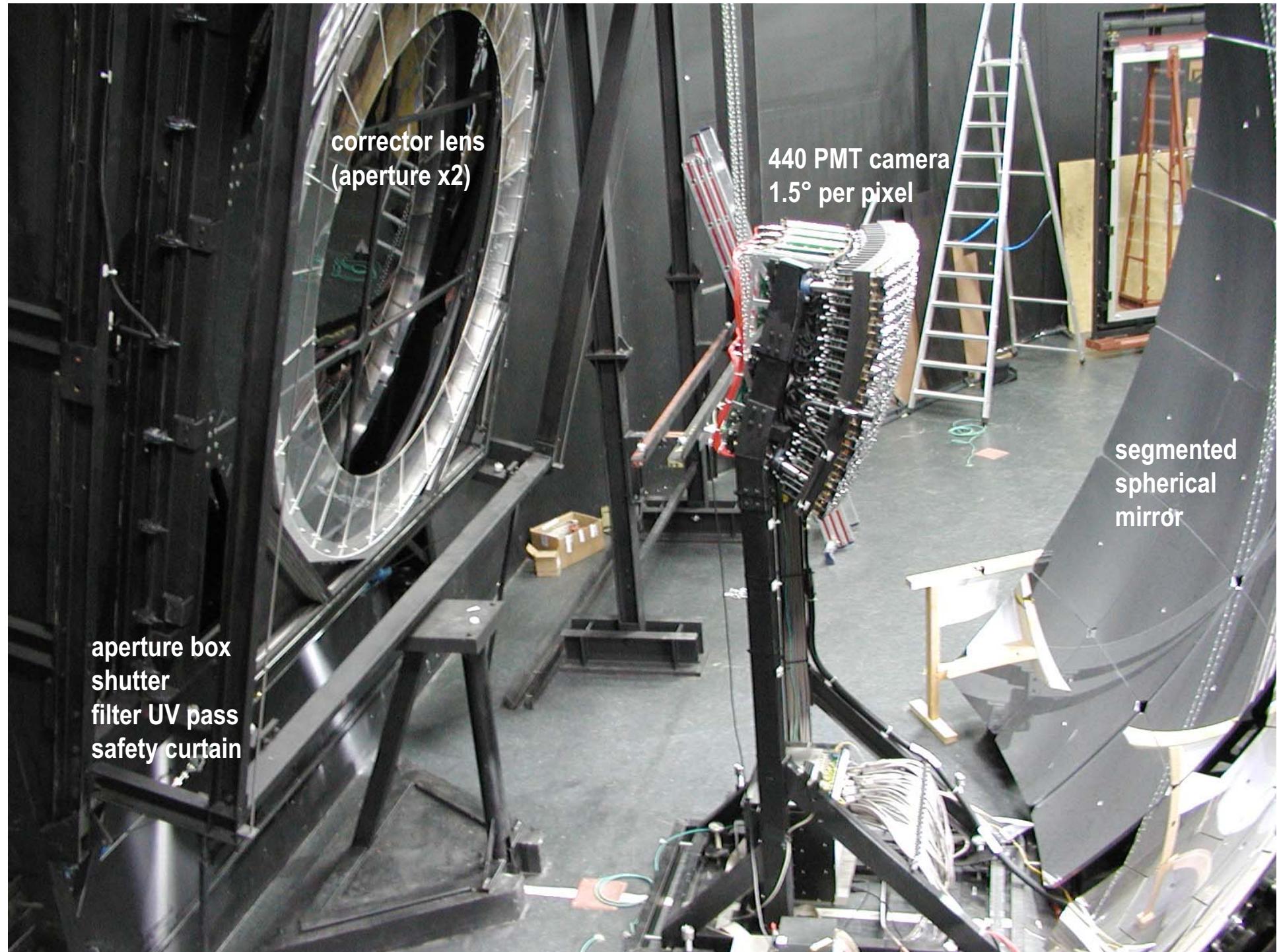






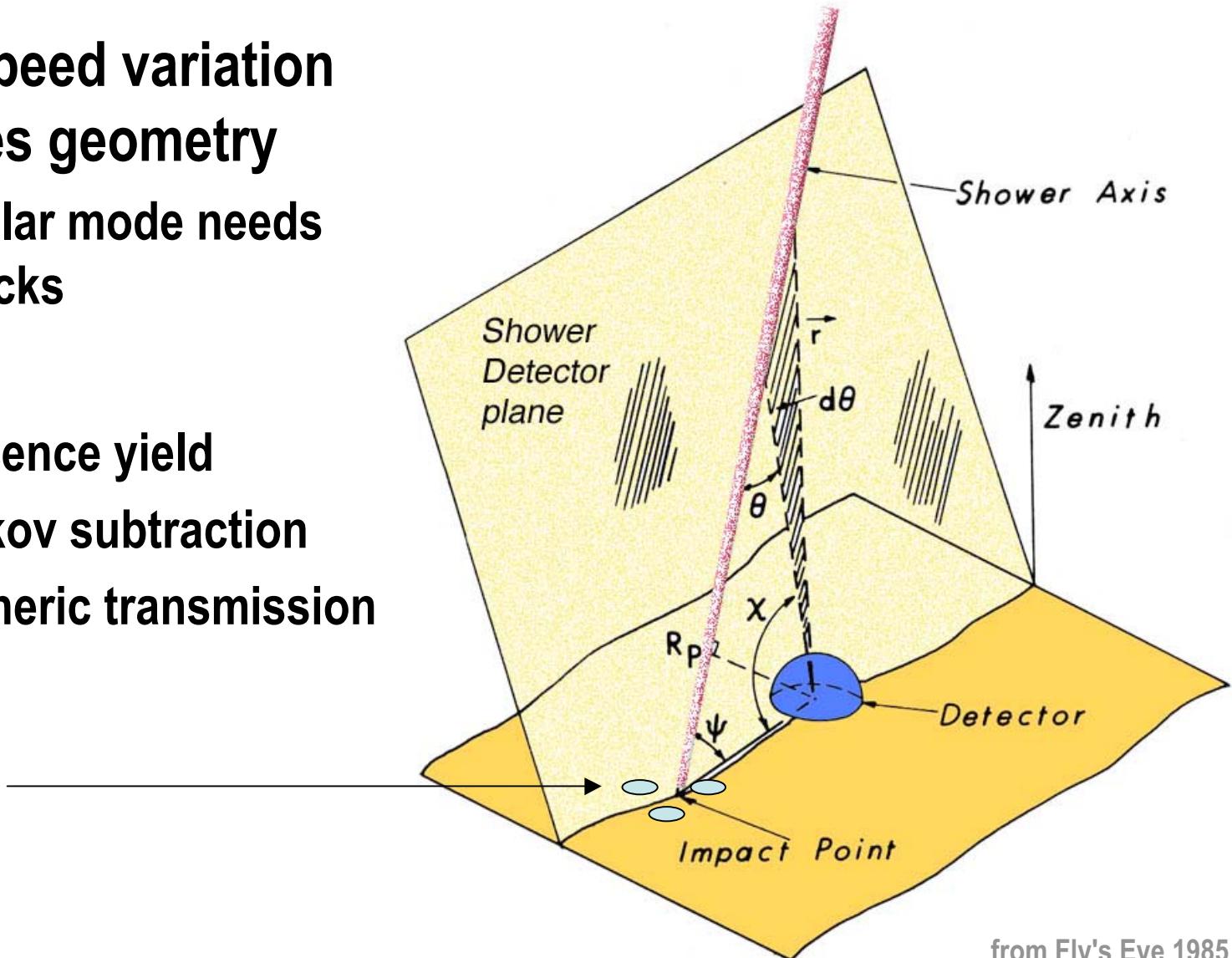






# Fluorescence track reconstruction

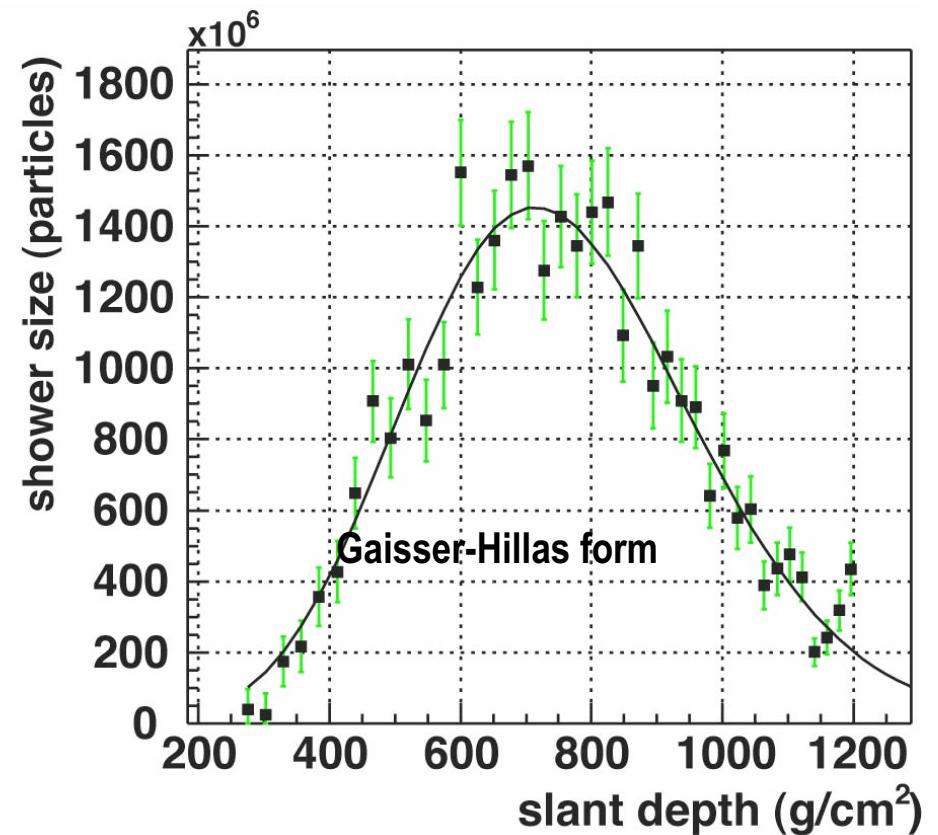
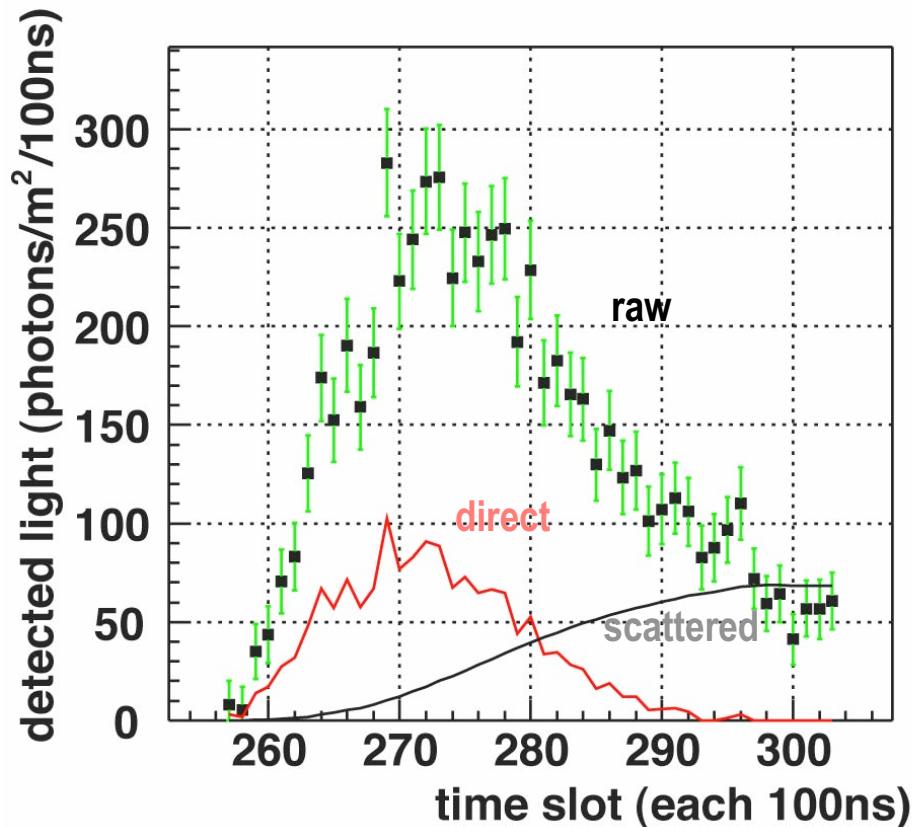
- angular speed variation determines geometry
  - monocular mode needs long tracks
- Issues:
  - fluorescence yield
  - Cherenkov subtraction
  - atmospheric transmission
- Stereo!
- Hybrid!

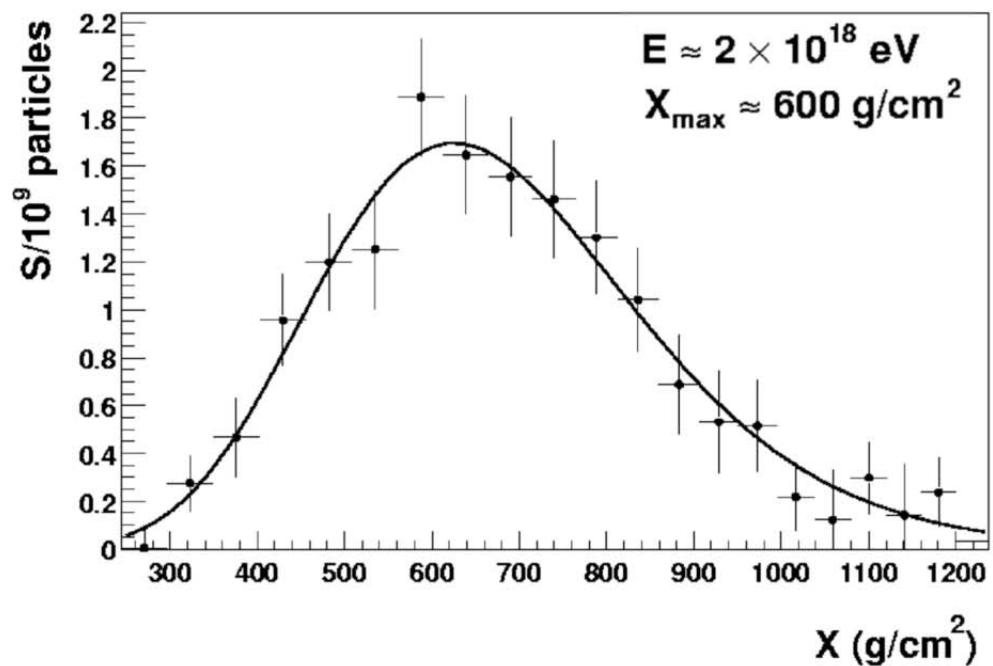
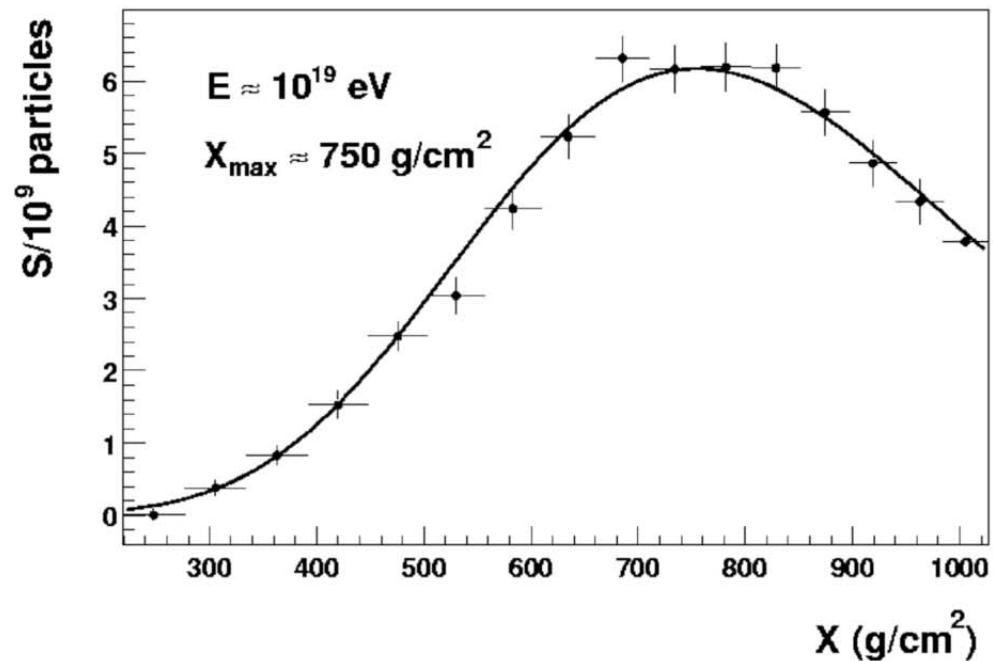


from Fly's Eye 1985

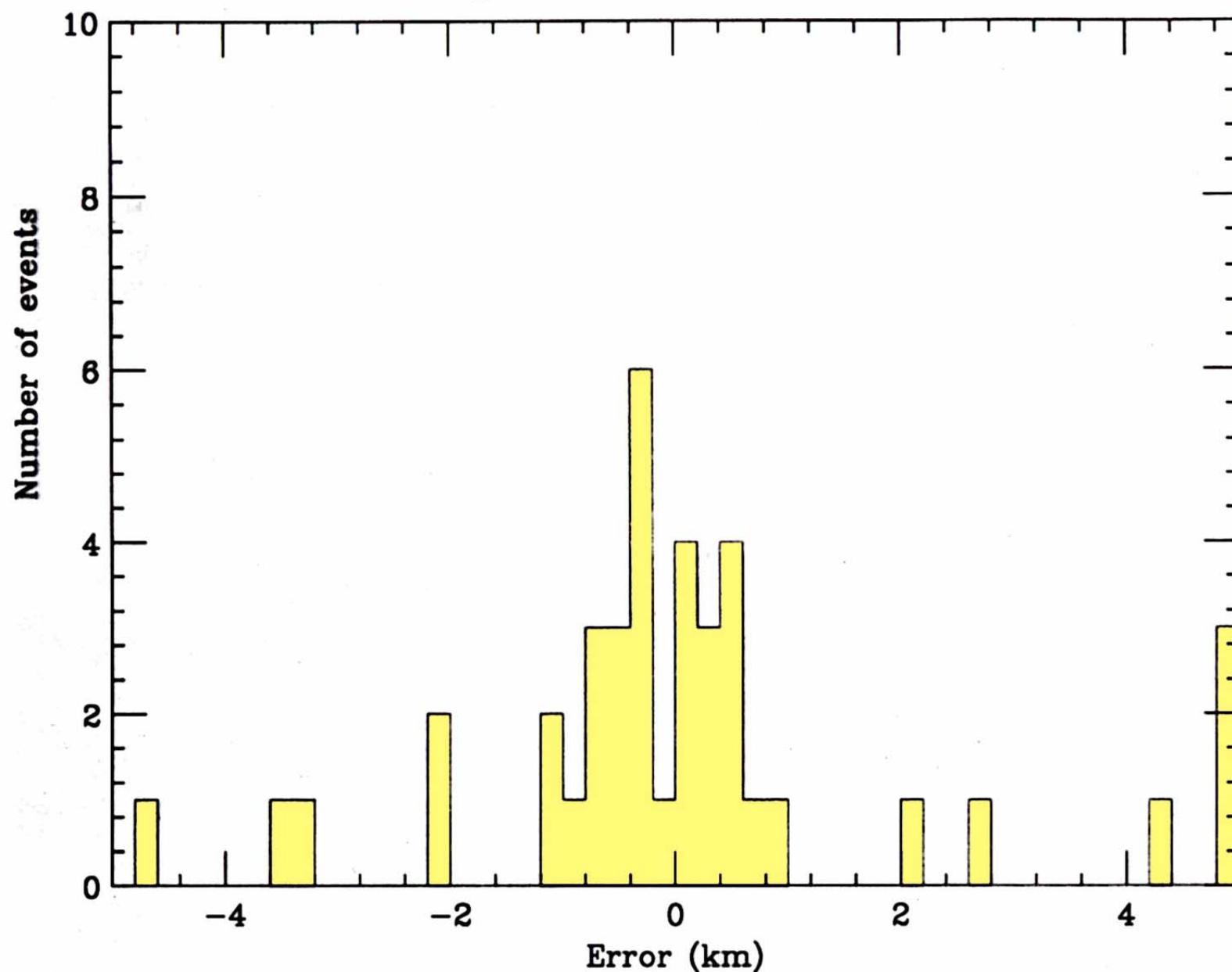
# Analysis procedures with the FD

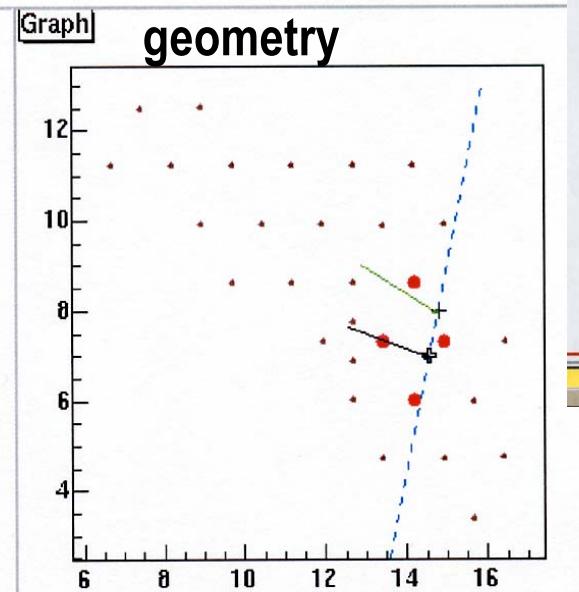
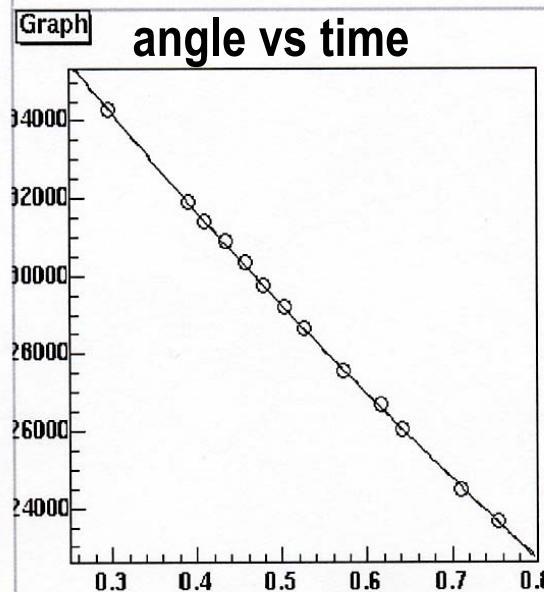
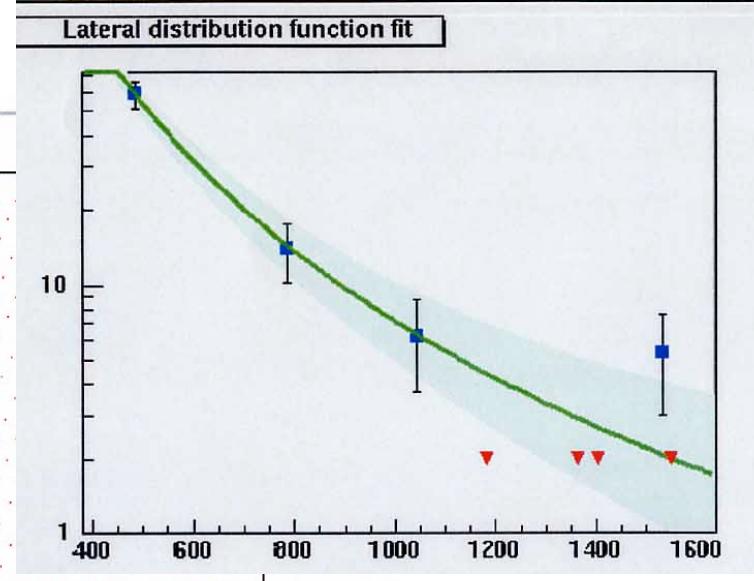
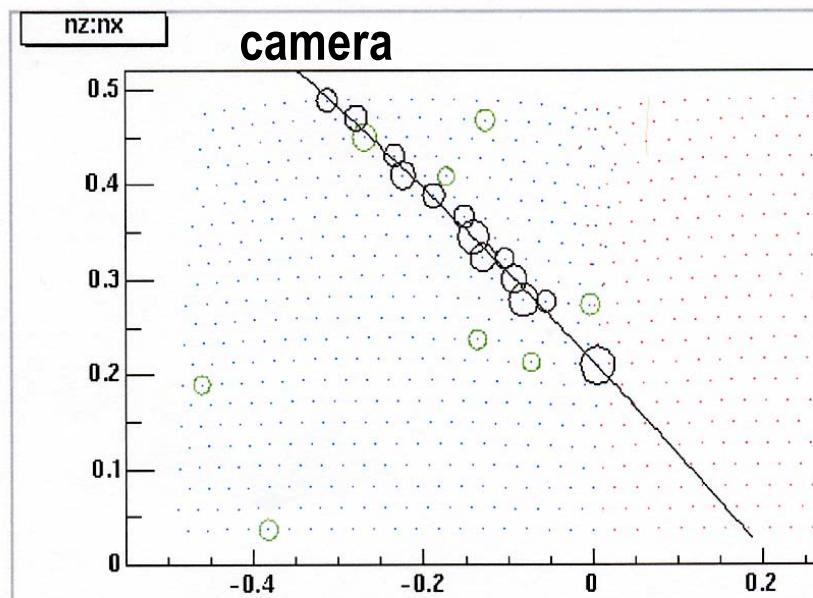
this event: initial viewing angle  $15^\circ$ , i.e. large direct Cherenkov contribution  
iterative procedure, converges in <4 steps; suggested energy here  $2\text{e}18 \text{ eV}$





Mono Core Error (positive means overestimate energy)





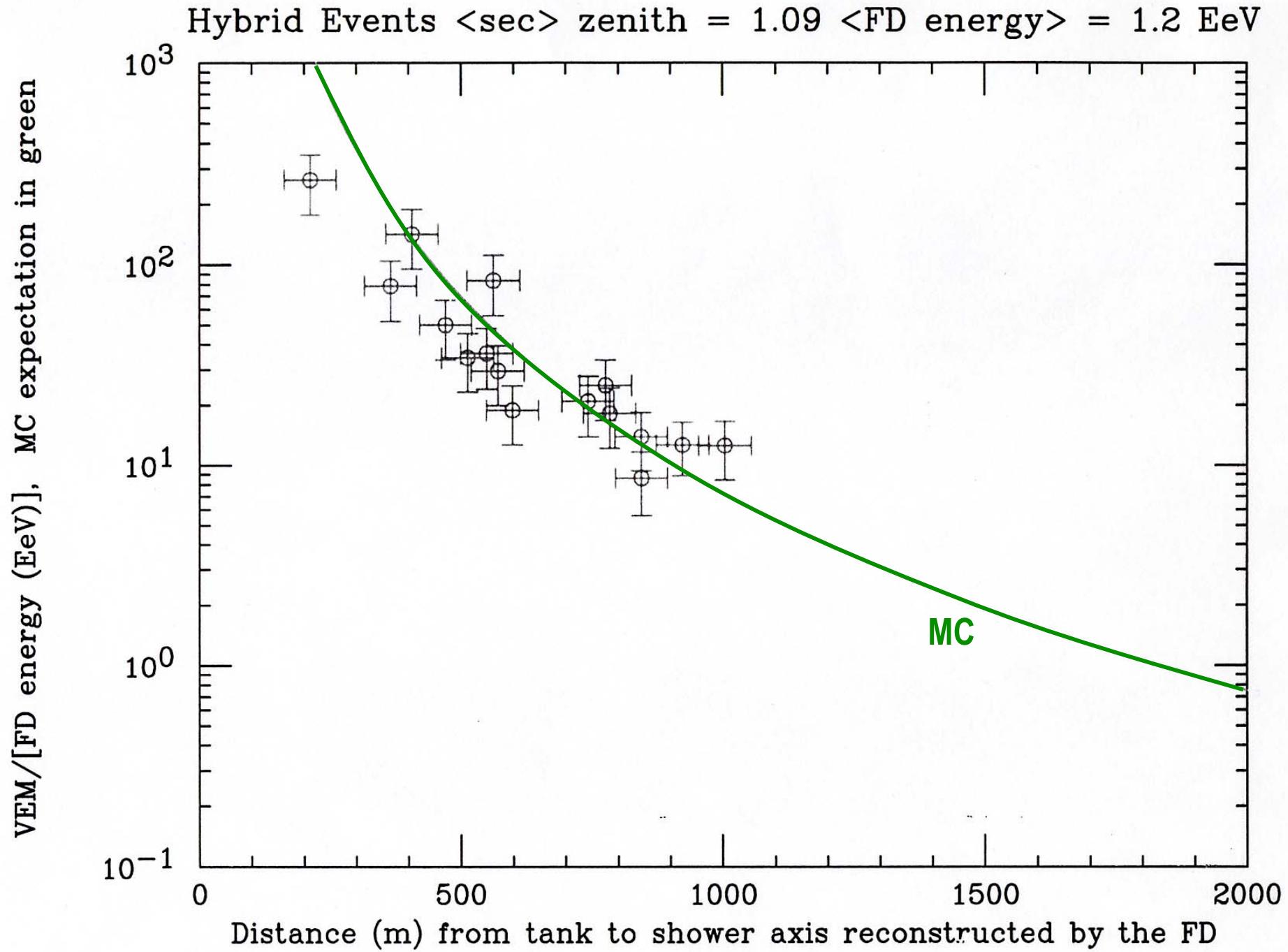
Easting=  $461438 \pm 97\text{m}$   
 Northing=  $6082453 \pm 104\text{m}$   
 $dt = 0.5\text{ns}$

$\Delta Y = 3\text{m}$   
 $\Theta = 44.1$   
 $\Phi = 161.9$

$R = 11.1 \pm 2.0\text{ km}$

SD energy=  $1.60 \pm 0.34$   
 FD energy=  $1.29 \pm 0.08$

100%



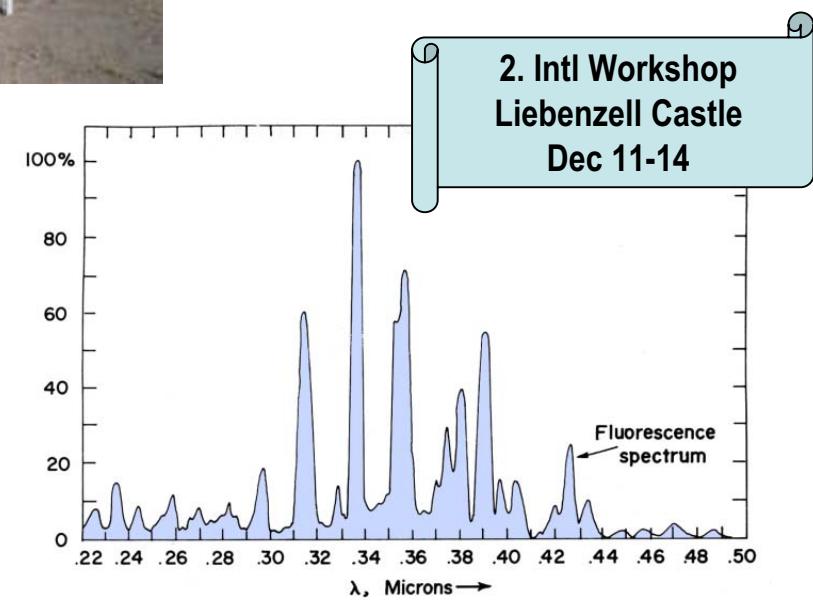
# Atmosphere

calibrated (movable) light sources  
cloud monitors

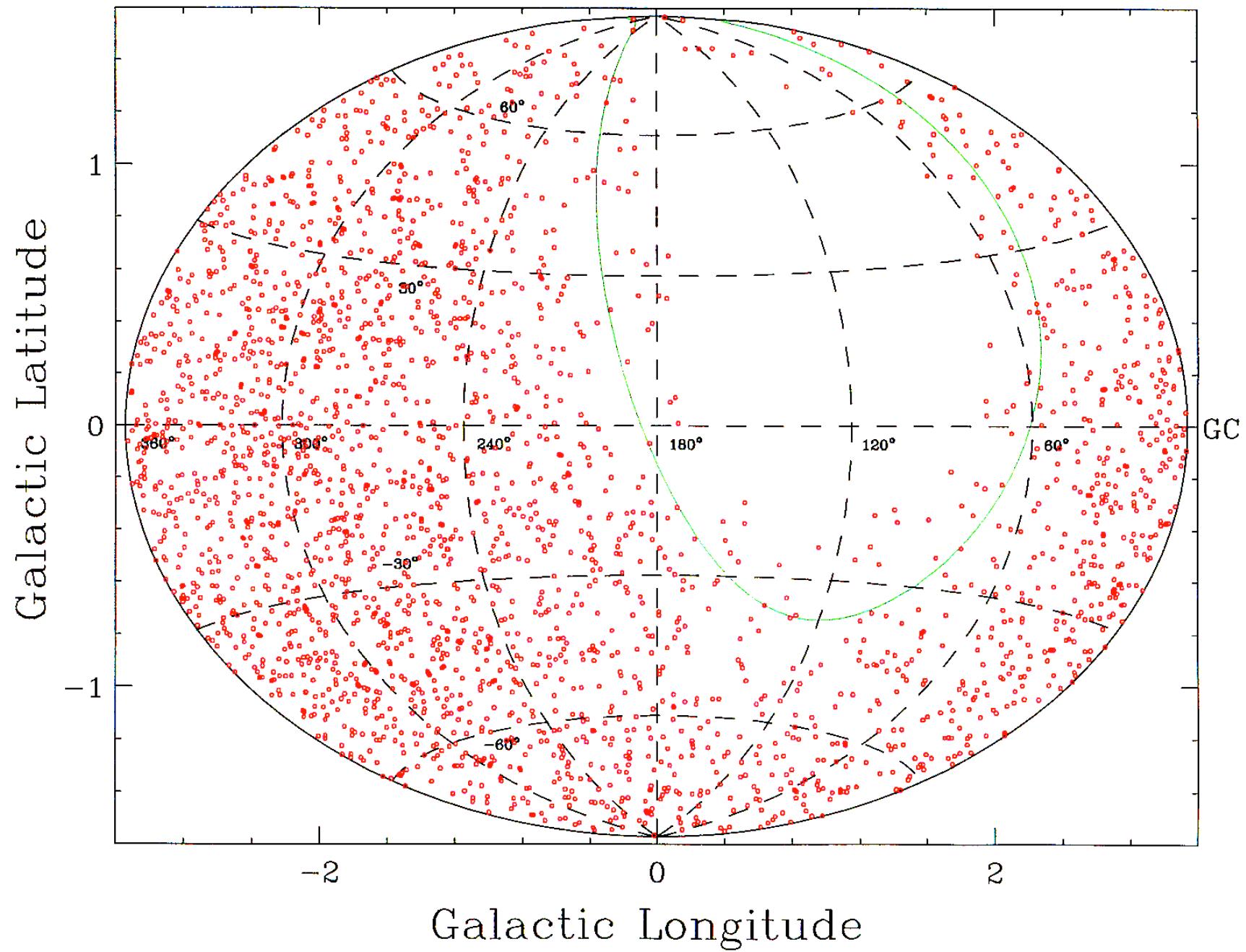
LIDAR  
lasers



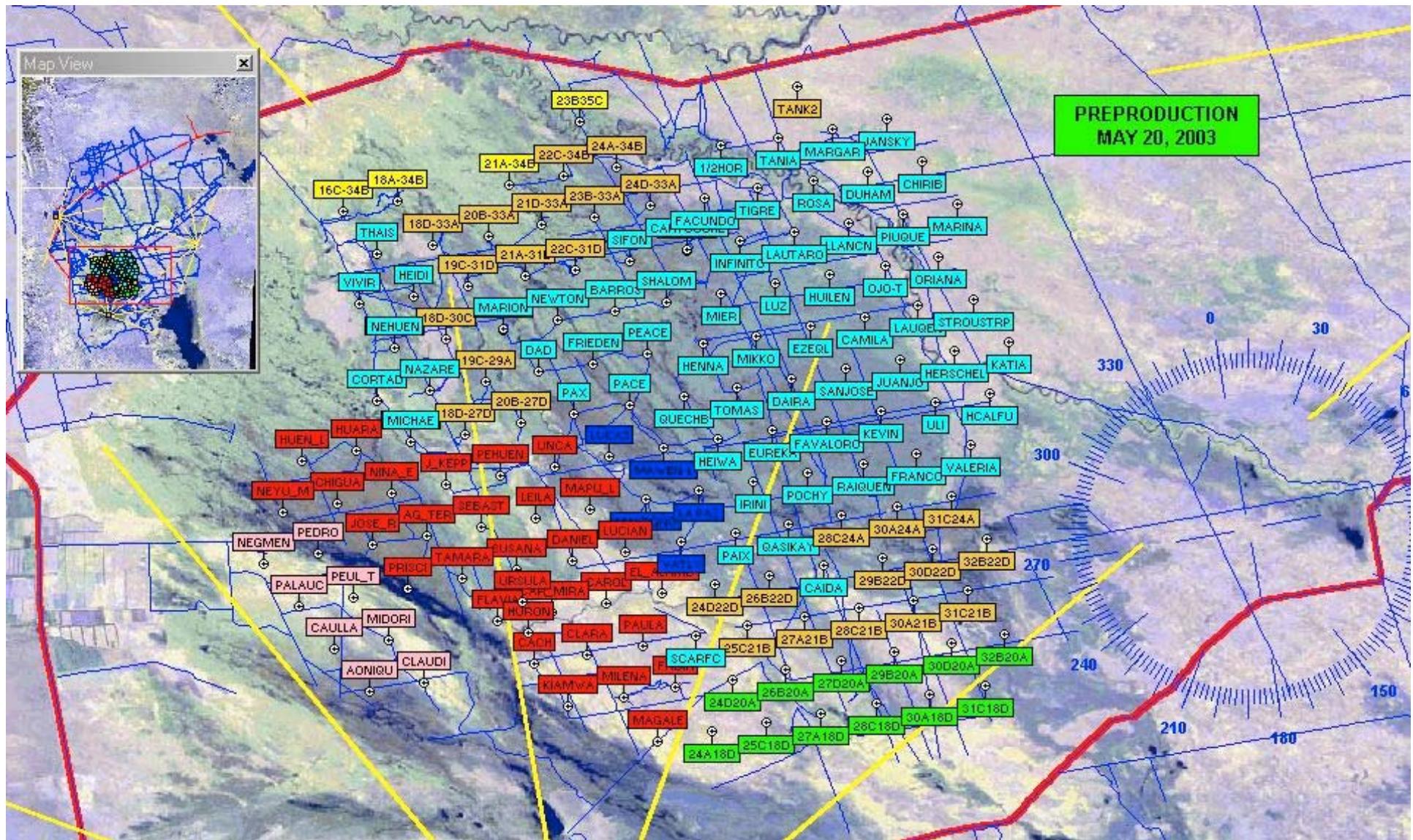
balloon sondes



Auger data: 2548 events of all energies, 60 deg exclusion zone in green



# Current status

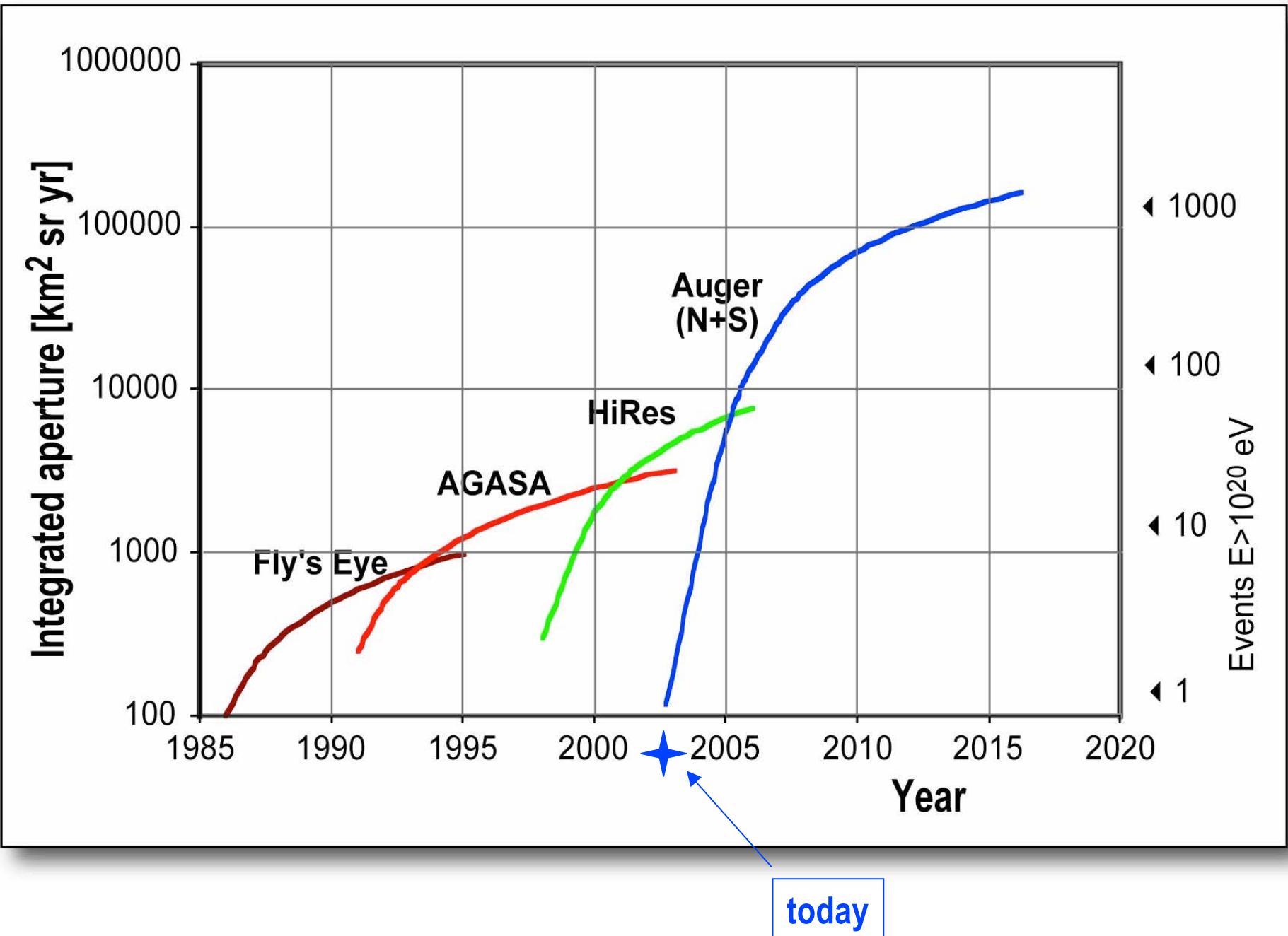


# Perspectives

- EA phase done
  - design validated, all objectives achieved
- Entering the production phase
  - +100 production tanks in the field, electronics being added
  - hybrid operations w 3 telescopes in Los Leones next dark period
  - setting up for stereo with 2 Coihueco telescopes
  - Coihueco communications tower running, Morados being built
- production until end 2005
  - deployment & continuous running ►physics report ICRC 2005
  - commitment to build the full-scale Southern Observatory
- Towards full-sky coverage...

# Towards full-sky coverage

- The Northern Site
  - compelling **scientific case**
  - start planning now for **Utah or Colorado**
  - layout as in Mendoza for seamless **data integration**
  - expand to **larger aperture** and use new technologies
    - discuss variable detector spacing, higher tanks for increased neutrino sensitivity; cost-effective hardware; ...
    - radio detection; KASCADE-Grande at Karlsruhe @  $10^{17}$  eV
  - open forum discussion : **tonight 7-9pm here**  
**►please join**



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