



**Pierre Auger  
Observatory**



# Primi Dati dall'Osservatorio Pierre Auger

Stefano Argiro'

- Fisica degli UHECR
- Situazione Sperimentale
- L'Osservatorio Auger
- Performance del detector

# UHECR Physics

Ultra **H**igh **E**nergy **C**osmic **R**ay = Primary Energy  $> 10^{19}$  eV  
rate at ground  $\sim 1/\text{year}/\text{km}^2$

## Osservabili

- Direzione di arrivo -> distribuzione delle sorgenti (anisotropia)
- Energia -> spettro (flusso vs energia)
- Composizione : protoni, nuclei ,

*Problemi alla base ...*

## Accelerazione/origine

- Sorgenti Astrofisiche (AGN?) (bottom up)  
meccanismi di accelerazione ?
- Decadimento di Particelle super pesanti (top down)

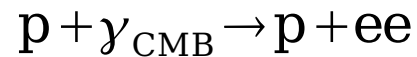
## Propagazione -

- Interazione con il CMB -> "Cutoff" GZK
- Campi Magnetici  
Effetti sullo spettro osservato e sulle direzioni di arrivo

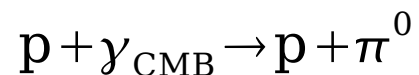
# Propagazione

... ovvero il famoso cutoff GZK

- Non fanno molta strada nel mezzo intergalattico:
  - Nuclei (fotodisintegrazione, perdono alcune unita' di A per Mpc)
  - e ,
- Ci rimangono i Protoni  
processi dominanti alle nostre energie:



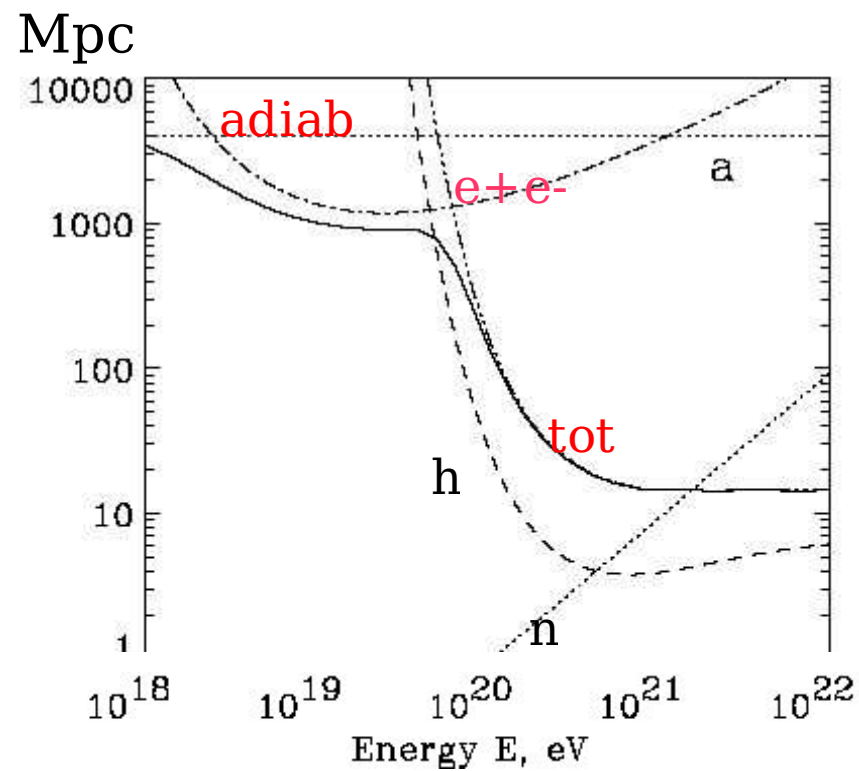
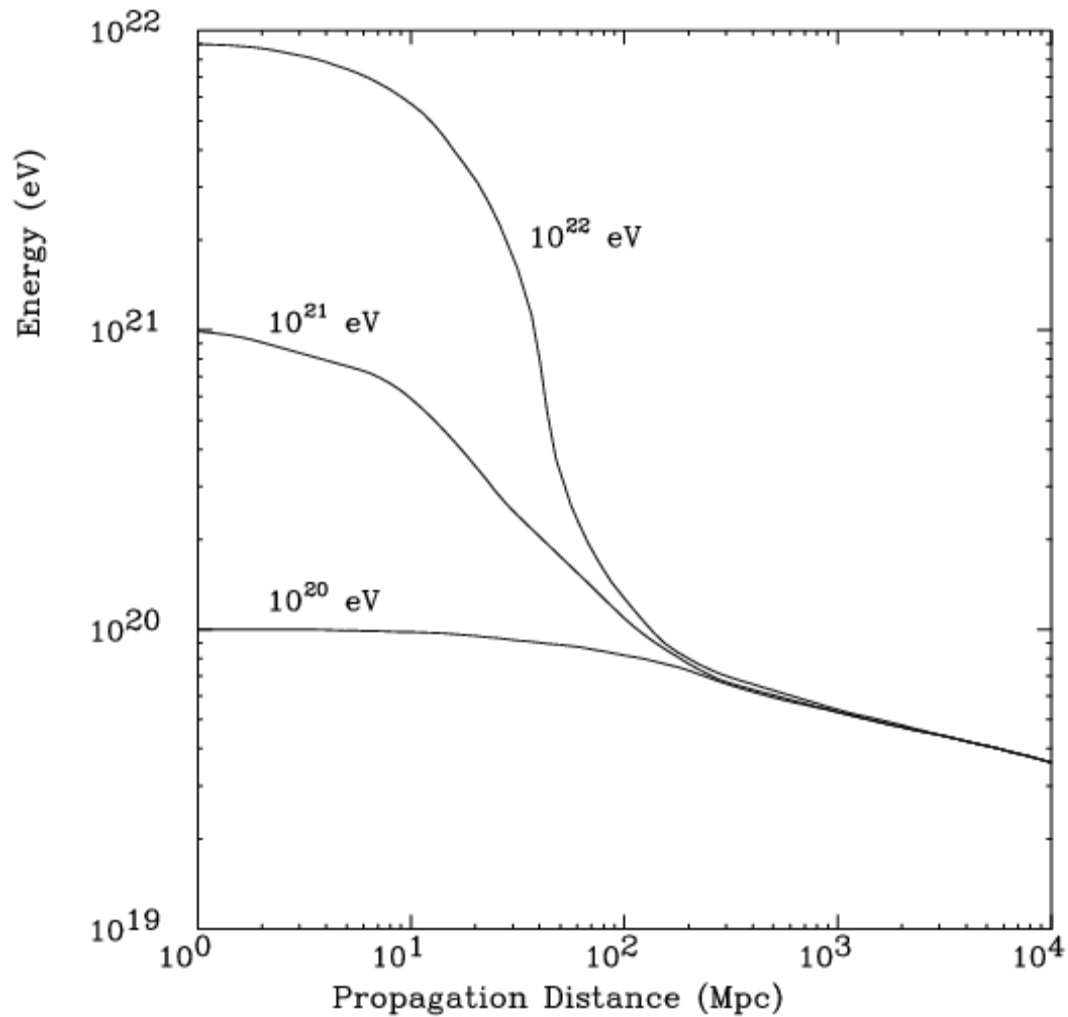
Soglia a  $5 \times 10^{17}$  eV



Soglia a  $7 \times 10^{19}$  eV

Sezione d'urto = 5 volte + piccola  
Maggiore inelasticita'

Lunghezza di interazione : 6 Mpc

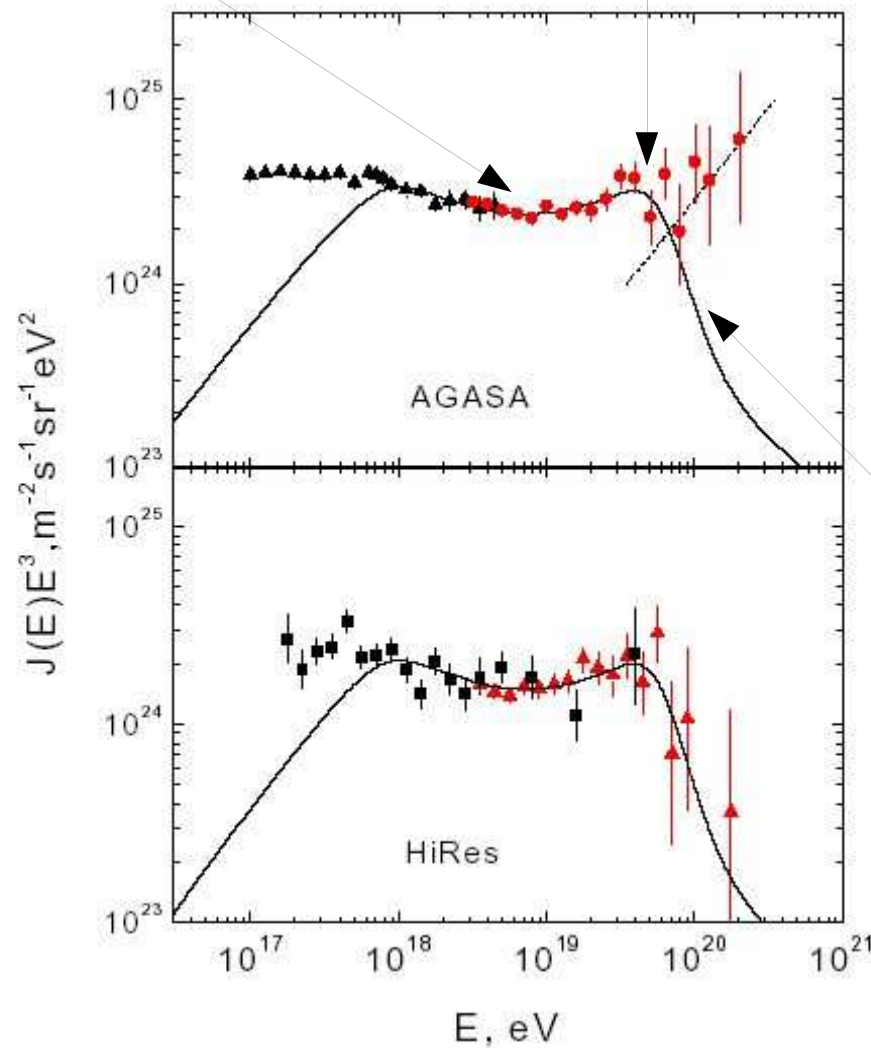


$$X_{\text{loss}} = \frac{E}{dE/dx}$$

Proton Pion photoproduction

Valle della produzione di coppie

accumulo



In caso gli UHECR siano protoni extra-galattici, si dovrebbero riscontrare queste tre "feature" nel flusso osservato.

GZK "cutoff"

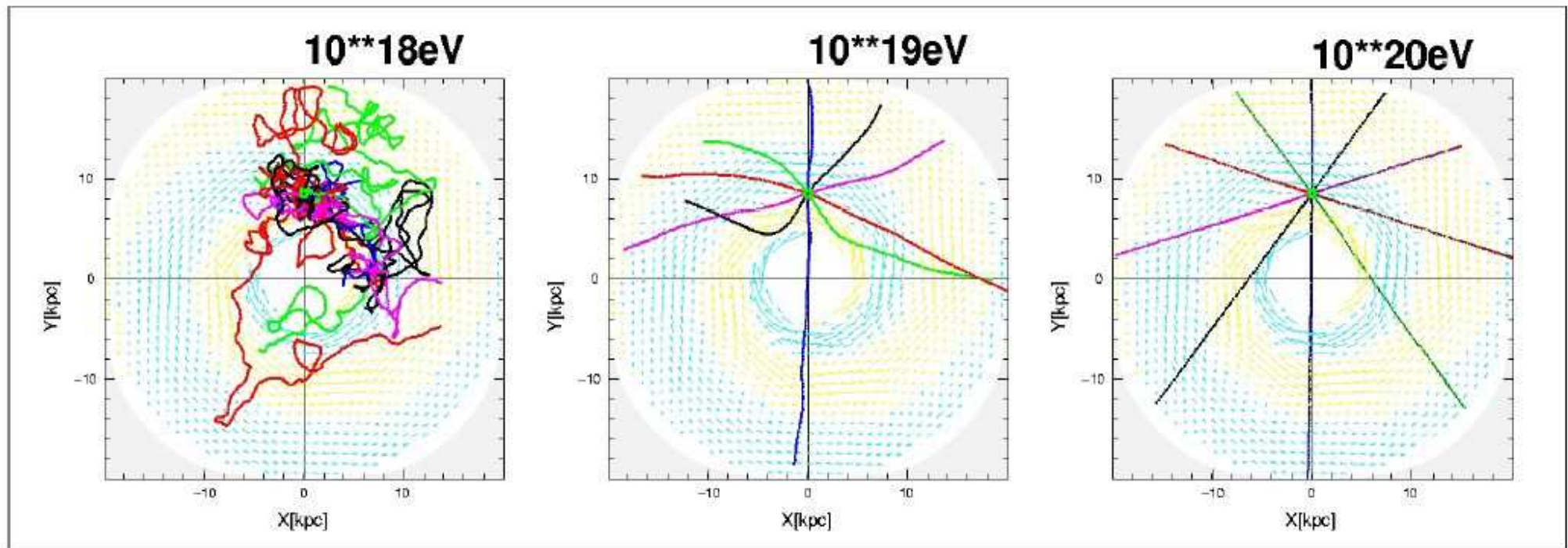
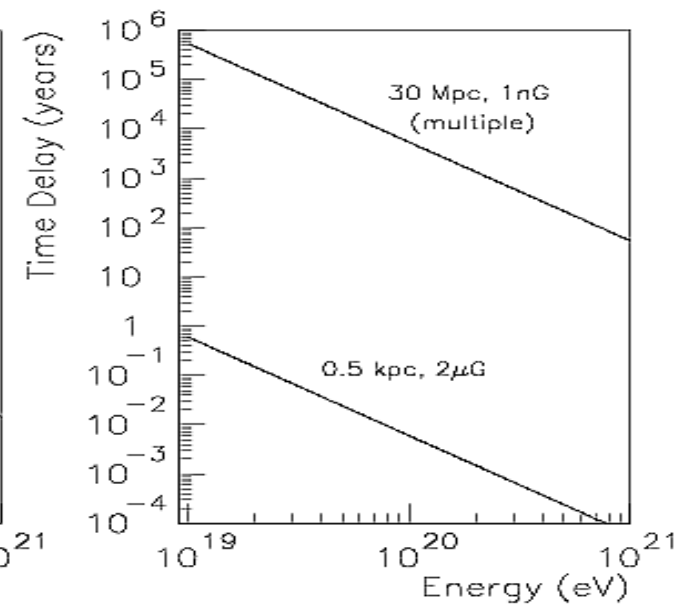
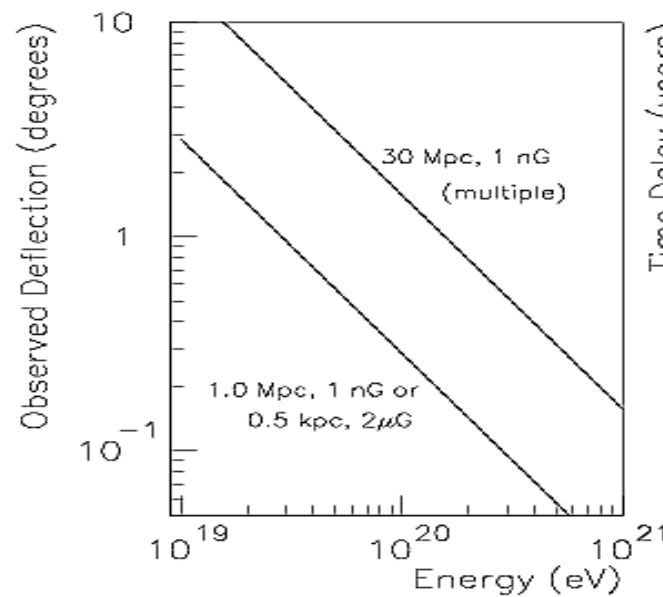
Berezinsky et al,  
arXiv:astro-ph/0410650 v1

Ipotesi sotto la linea continua:

- Sorgenti uniformemente distribuite
- Spettro  $E^{-2}$  fino  $E_c$ , poi piu' ripido
- Protoni extragalattici

# Campi magnetici

Si aspetta anisotropia nelle direzioni di arrivo nel caso di sorgenti astro-ph.  
Astronomia UHECR ?

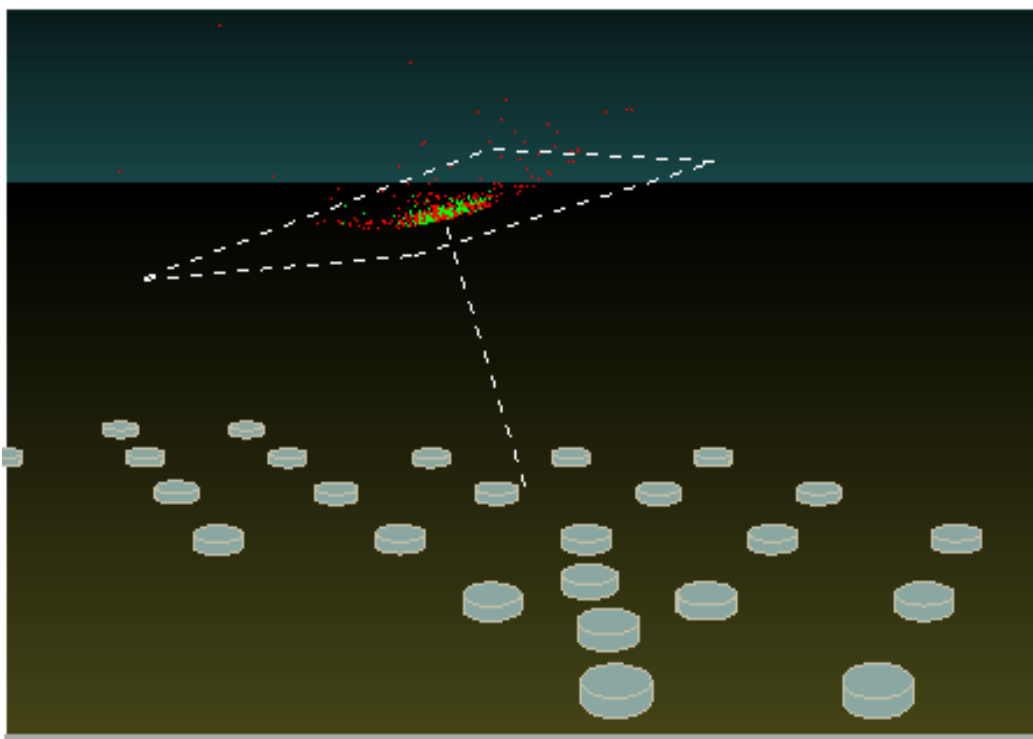


Galassie vicine: 1 Mpc  
Diametro Vialattea:  $\sim 30$  kpc, 30 pc spessore  
M87 : 20 Mpc , Centaurus A : 4 Mpc

# Tecniche Sperimentali

Due tecniche per rivelare sciami generati da primari di alta energia:

- **Array di superficie**  
misura della Lateral Distribution Function
- **Telescopi di fluorescenza atmosferica**  
misura dello sviluppo longitudinale  
e quindi misura quasi calorimetrica

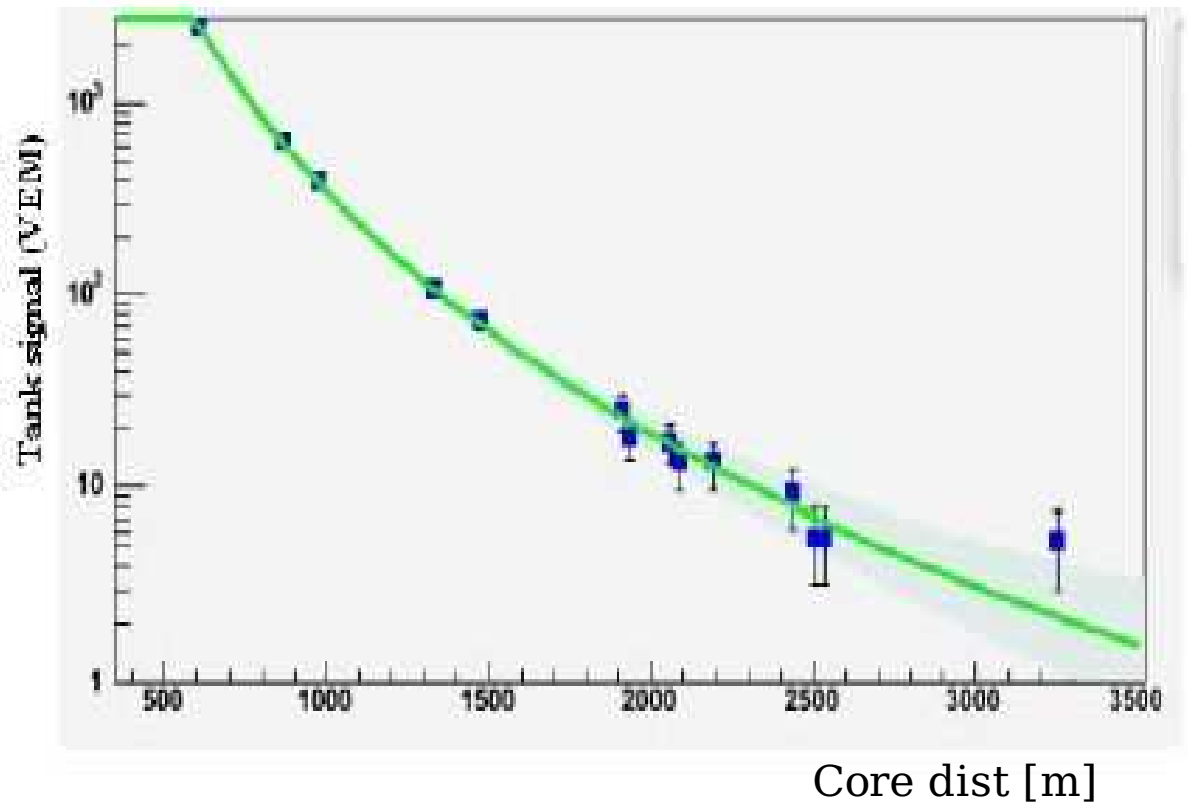


## SD

ogni tanica misura  
tempo di arrivo e  
densità di mu

## **LDF**

densita' di particelle  
vs distanza dall'asse  
dello sciame

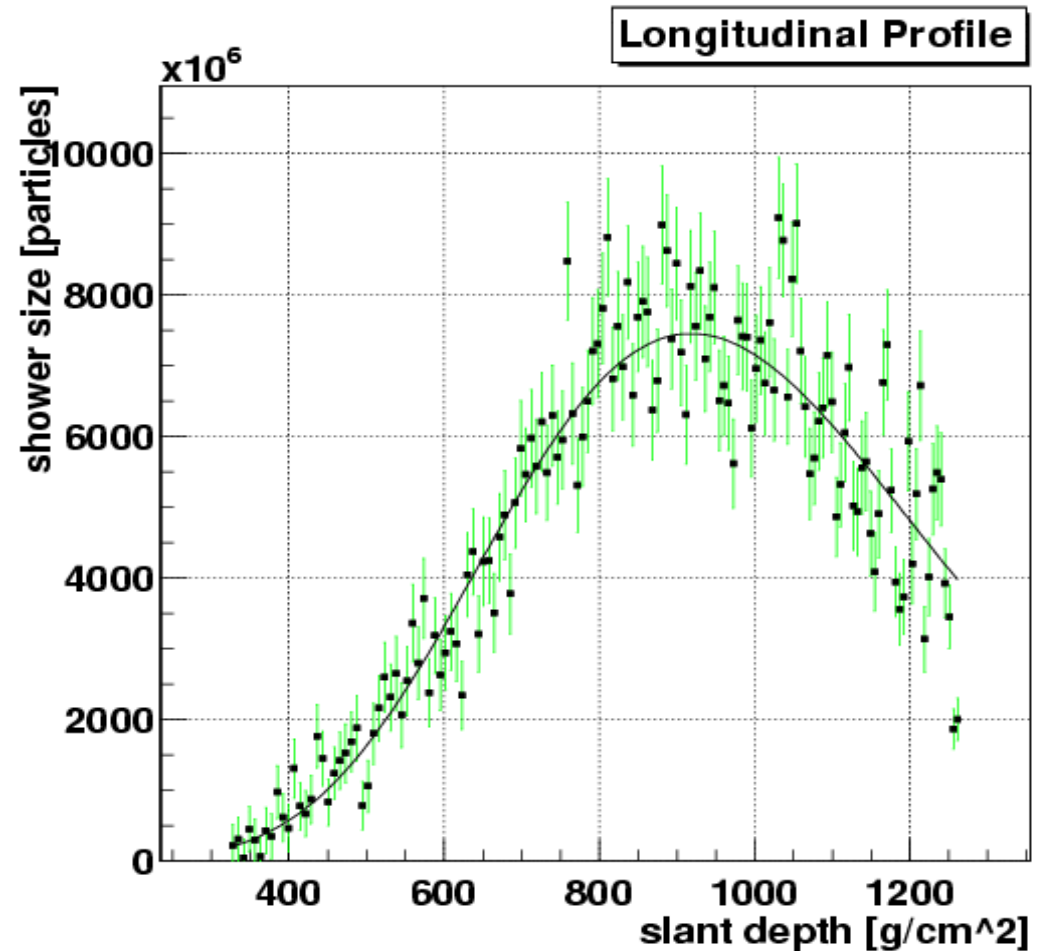




# Fluorescence Detector

- Gli e eccitano le molecole di N<sub>2</sub>, che si diseccitano emettendo fotoni tra 300 e 400 nm
  - Il rivelatore misura numero di fotoni in funzione del tempo (X)
  - Il fluorescence yield è circa costante verso temperatura e pressione
- $Y \sim 4$  fotoni/m per  $h=0:20$ Km

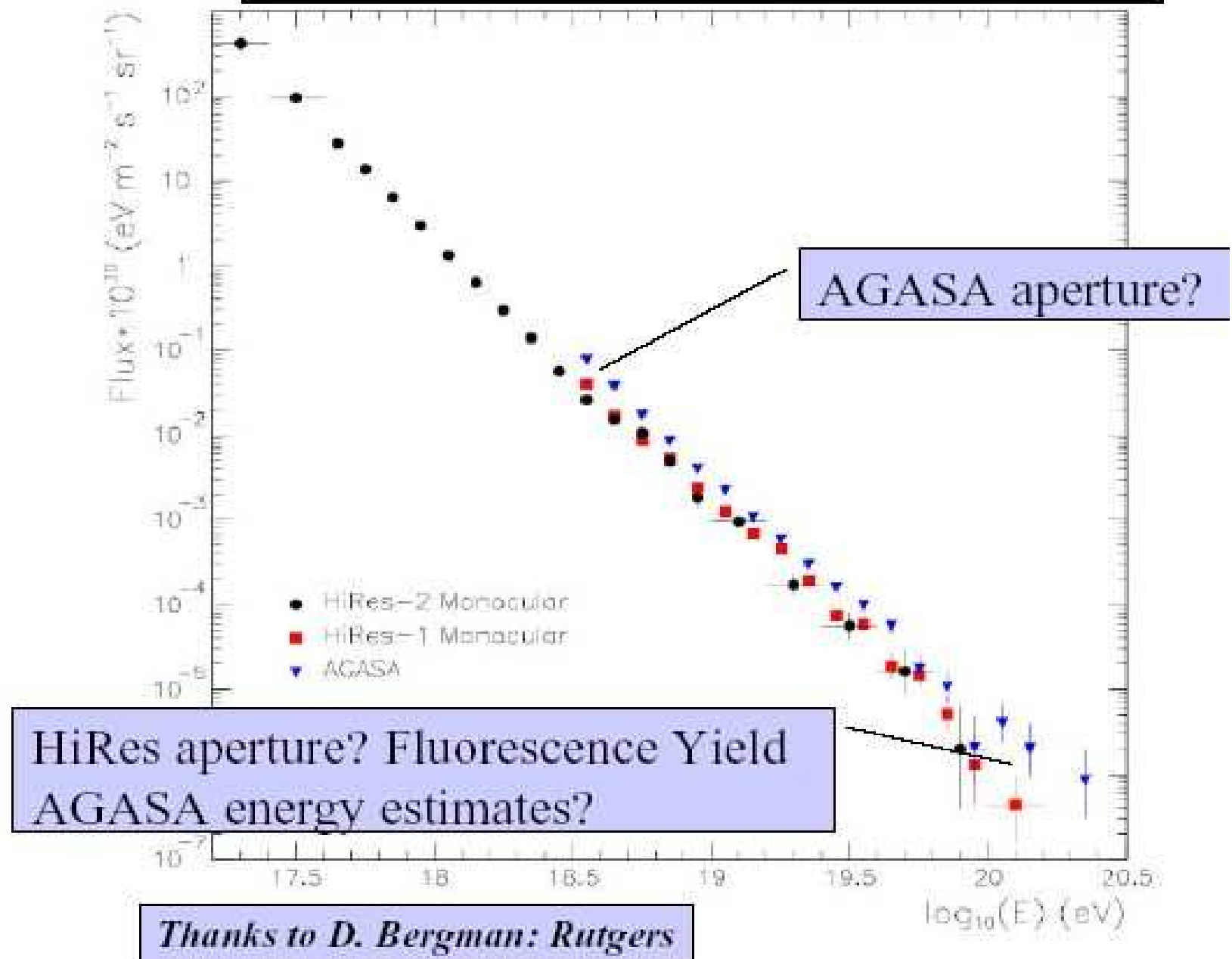
Fotoni(X) →  $n_e(X)$  (shower size)  
                  →  $dE/dX(X)$

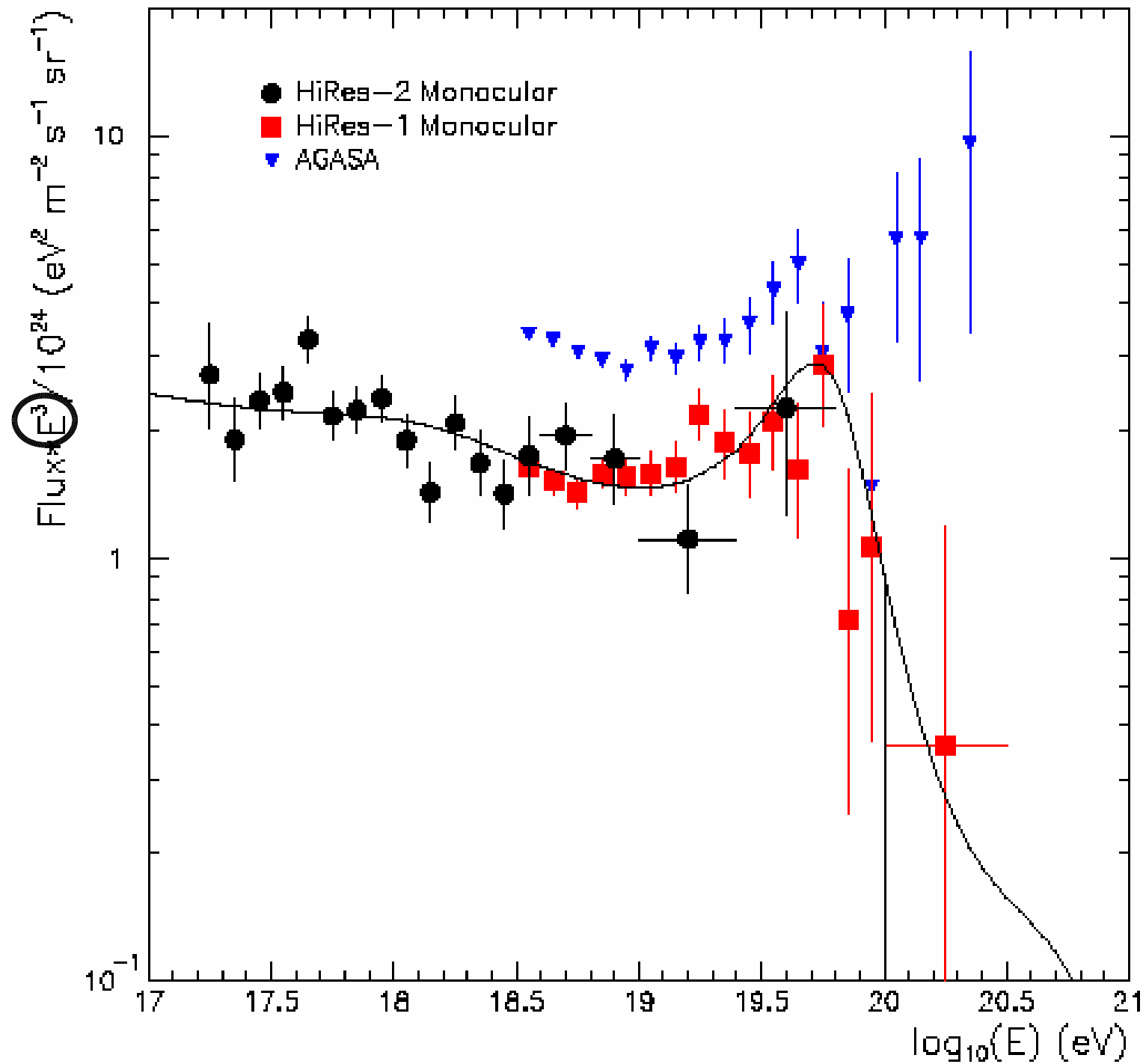


# Flusso Agasa/HiRes

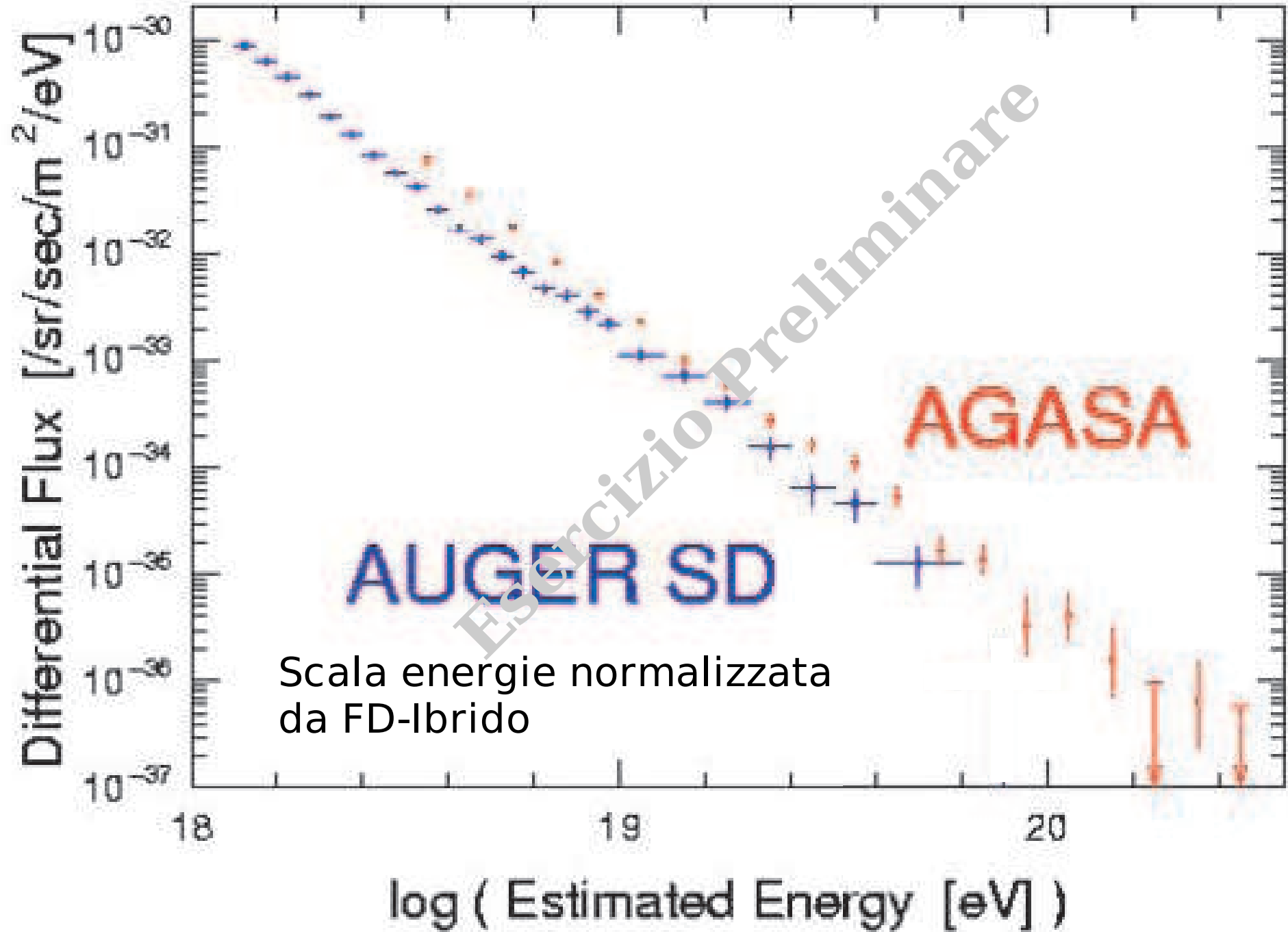
Differenza  
del 25%  
nella scala  
di energia ?

## AGASA/HiRes comparison: ICRC2003

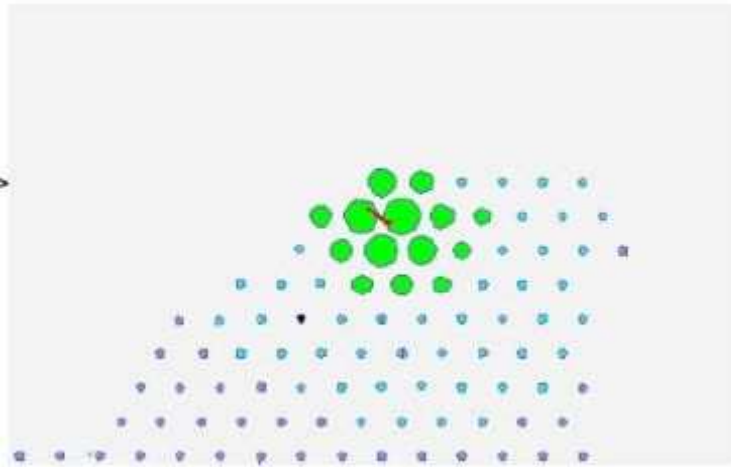




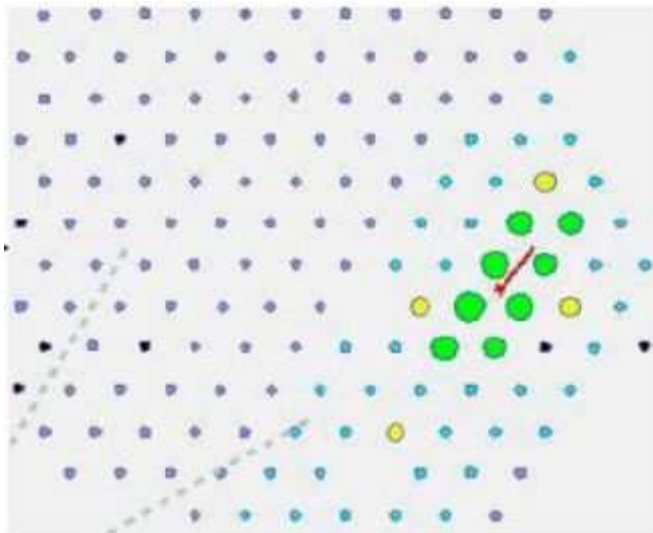
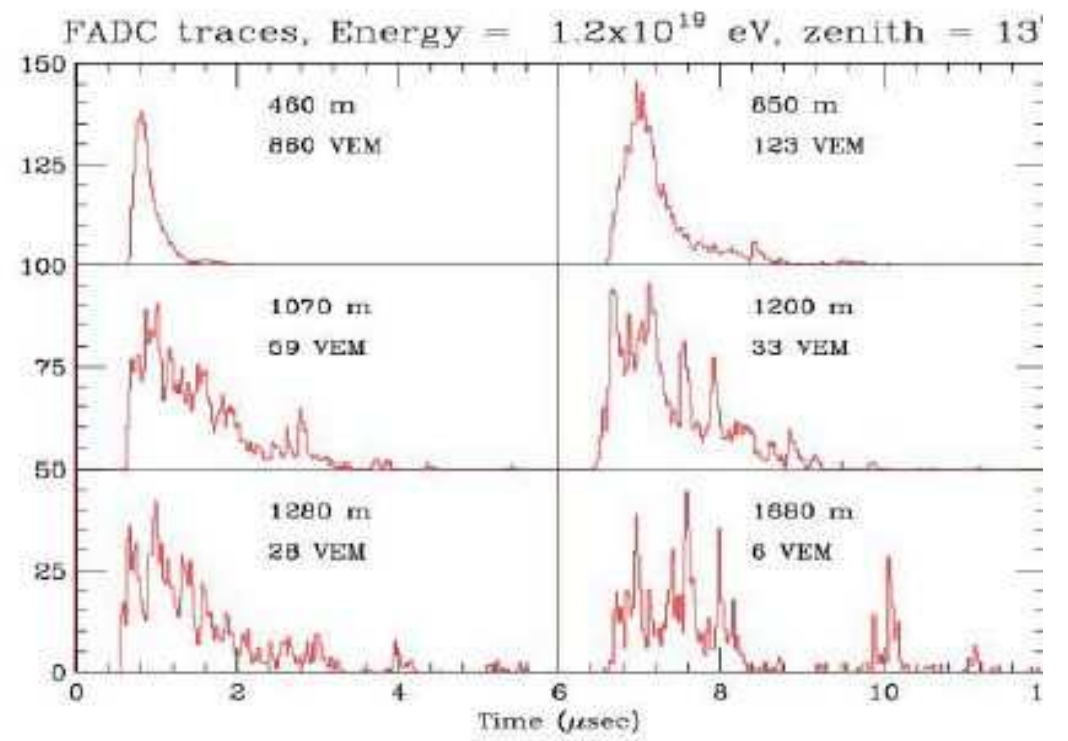
# 0.6 volte l'apertura di AGASA



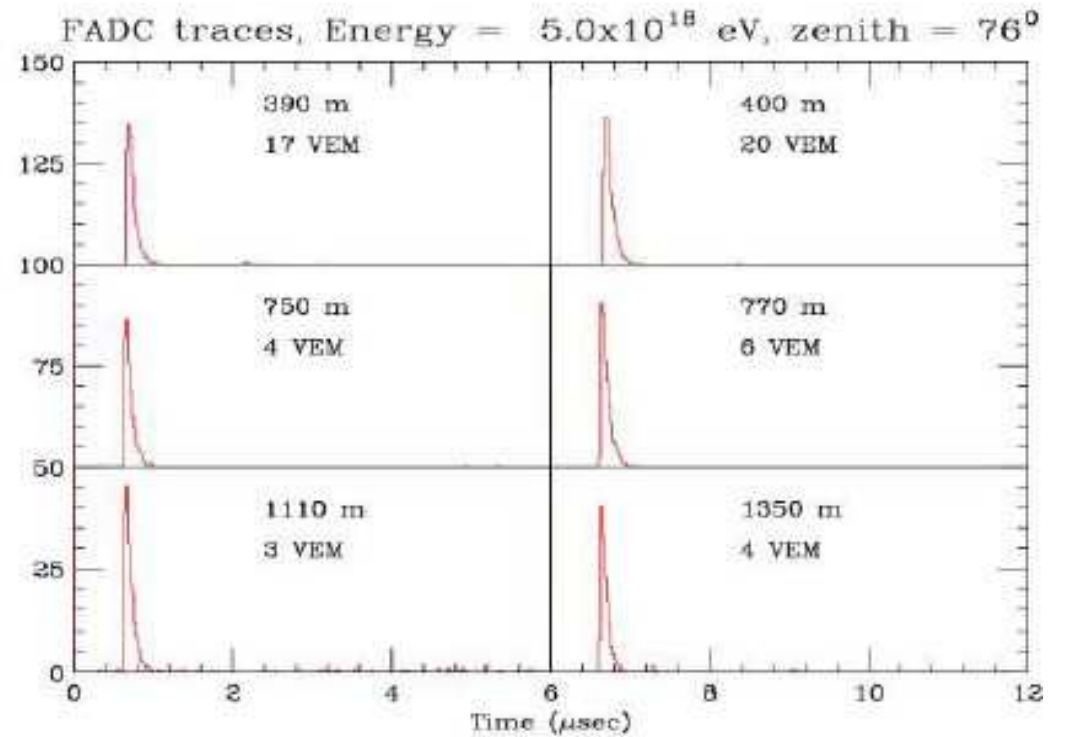
E/mu

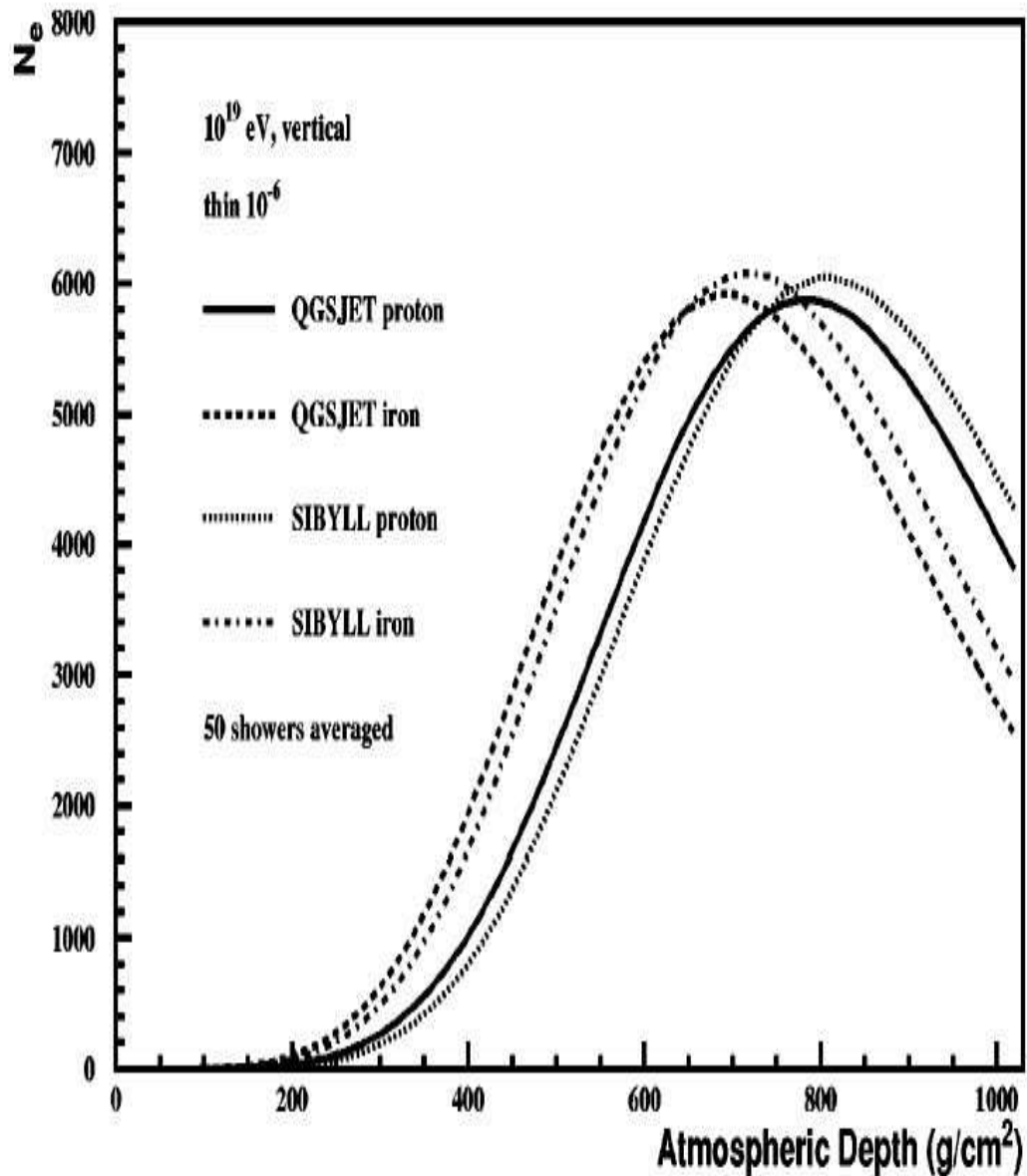


FADC amplitude (arbitrary units)



FADC amplitude (arbitrary units)



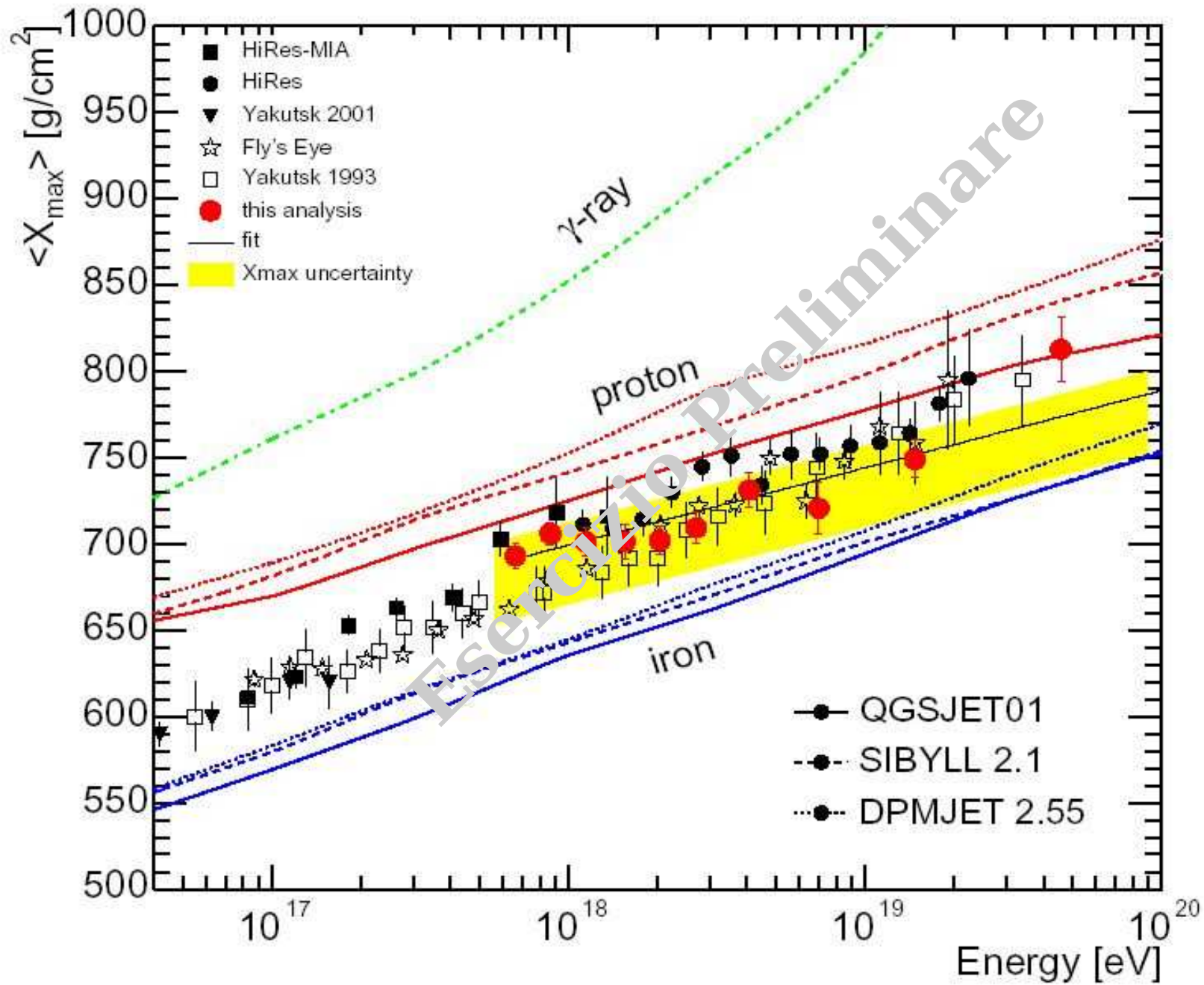


## Elongation Rate

Sciami generati da nuclei raggiungono il massimo prima di quelli generati da protoni

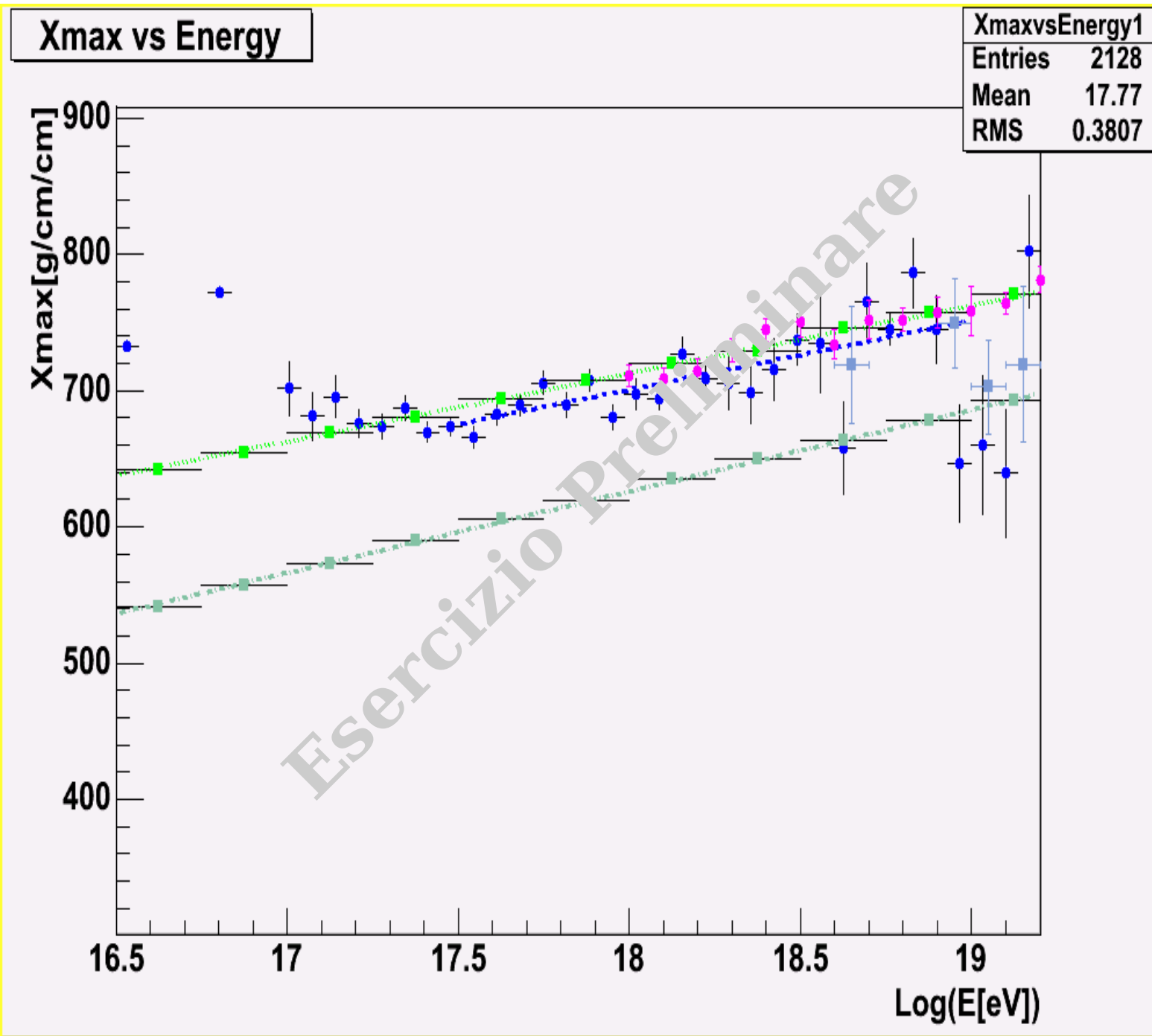
(Su base statistica, non su singolo evento)

*Simulazioni di sciami iniziati da protoni e ferri*



$$D_{\text{HiRes}} = 54.6 \pm 6.5$$

$$D_{\text{auger}} = 45 - 49$$

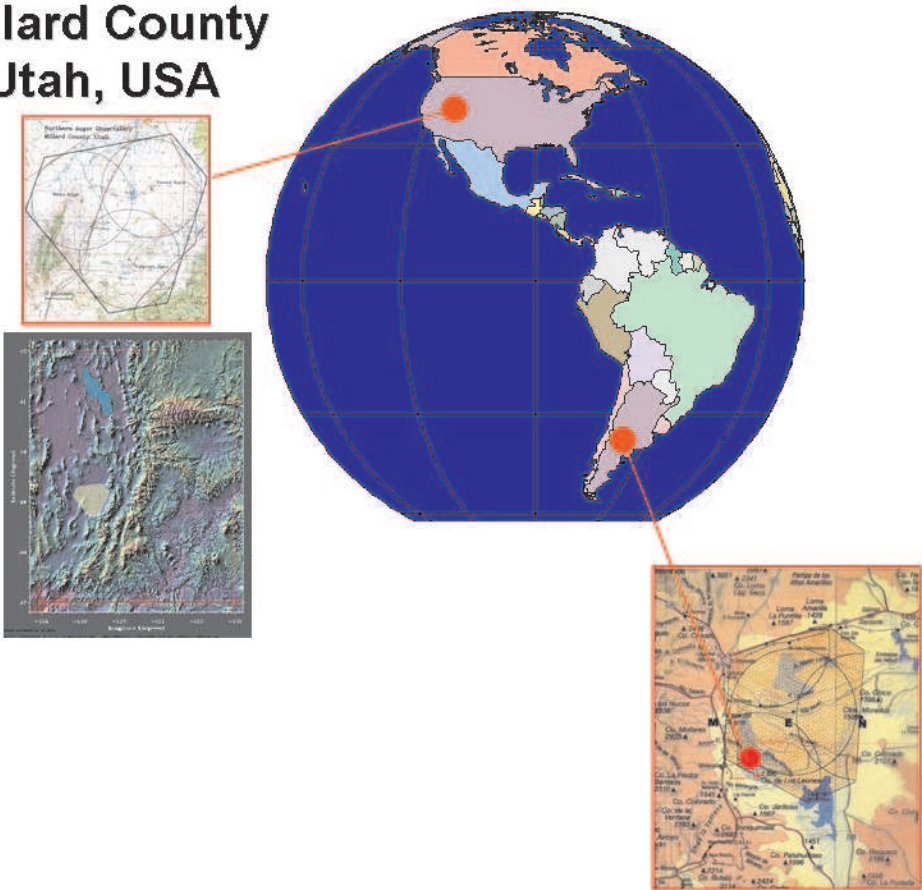


Analisi con tagli meno stringenti

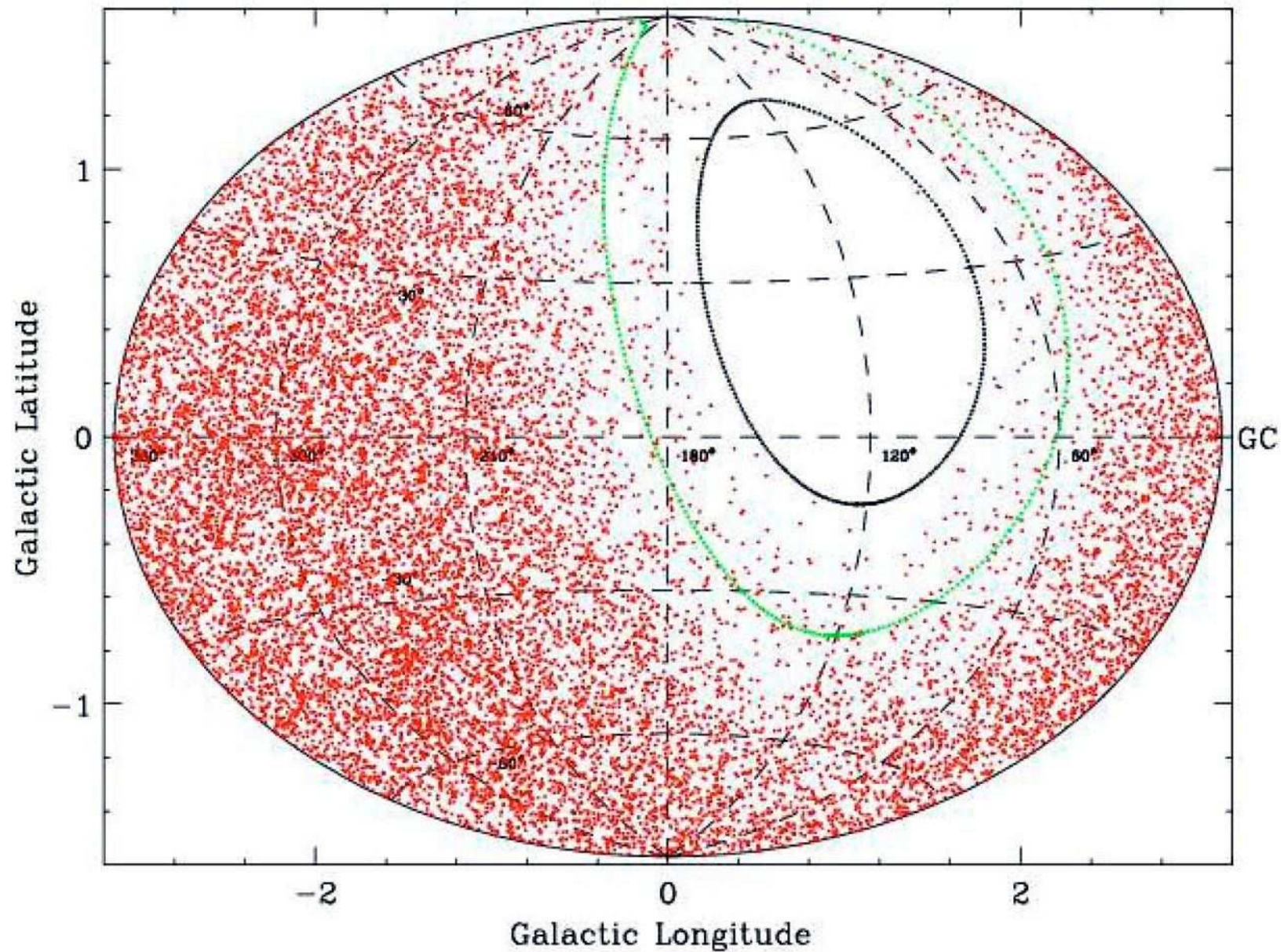


# Auger

Northern site  
Millard County  
Utah, USA



Distribution of Auger events: 60 deg bound (green), 85 deg bound (black)



# Auger

## Rivelatore Ibrido

- **Surface Array**

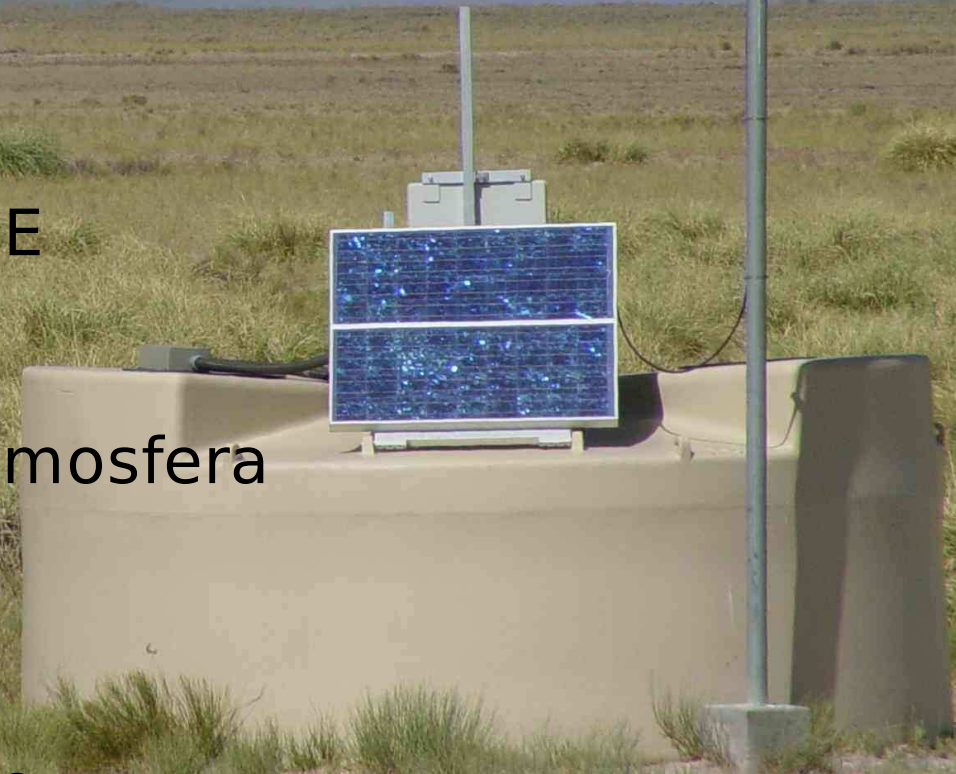
Riv. Semplici e affidabili  
100% duty cycle  
Stima energia model dependent

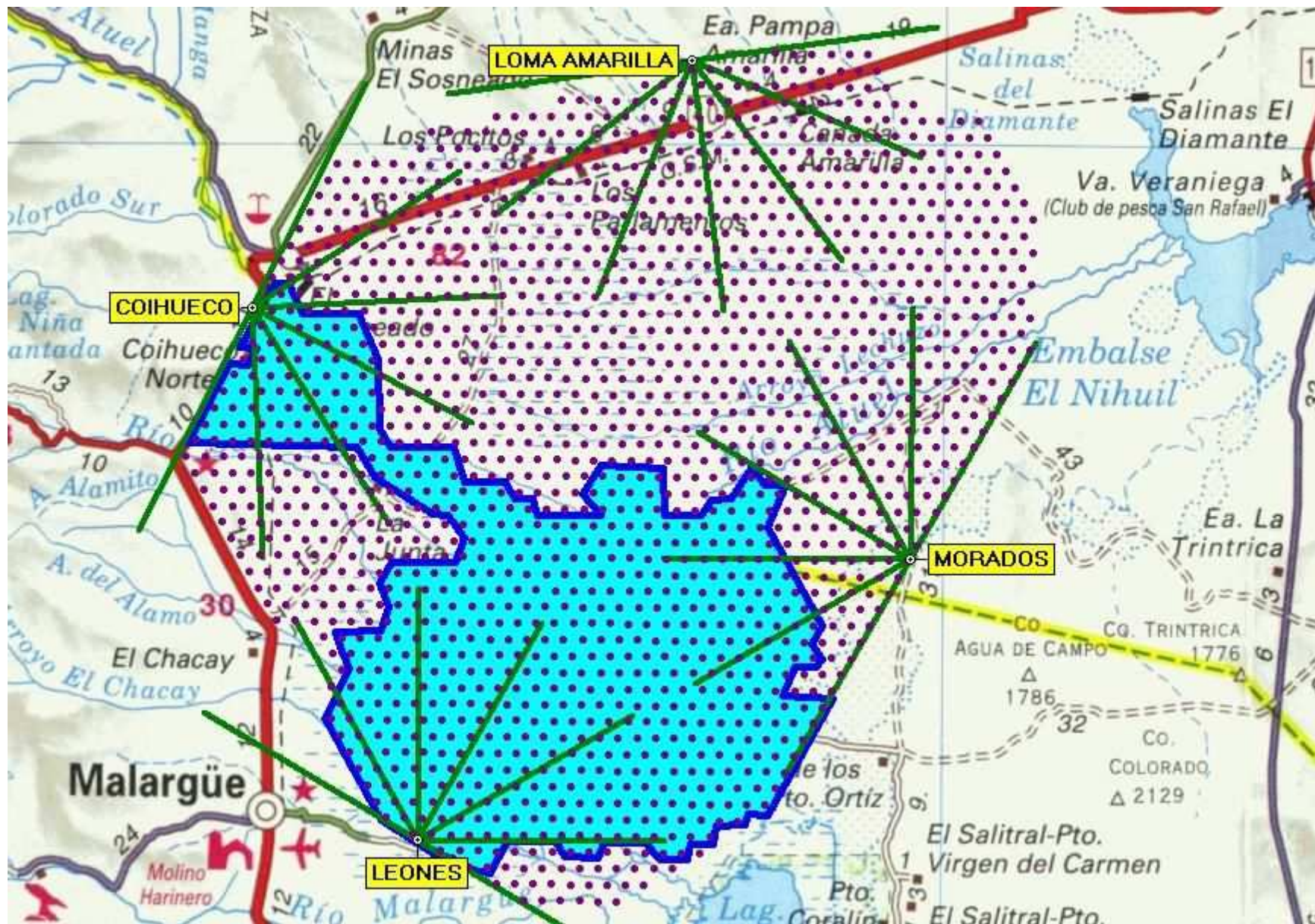
- **Fluorescence Detector**

Misura quasi-calorimetrica di E  
Sviluppo dello sciame  
10-15 % duty cycle  
Sistematiche : trasparenza atmosfera

- **Ibrido**

Cross Calibration  
Controllo delle sistematiche  
Risoluzione Angolare superiore  
Misura indipendente di energia e composizione

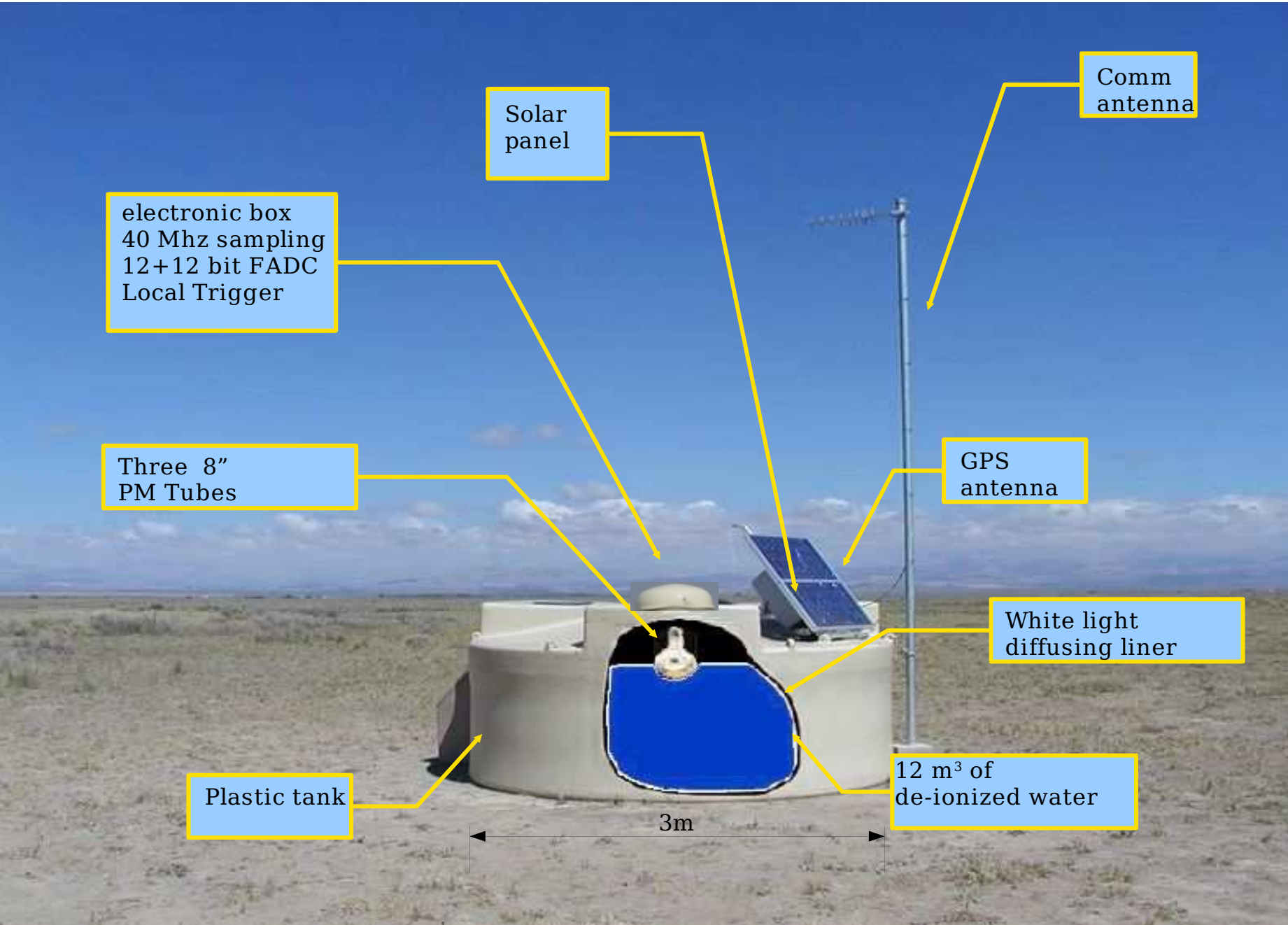


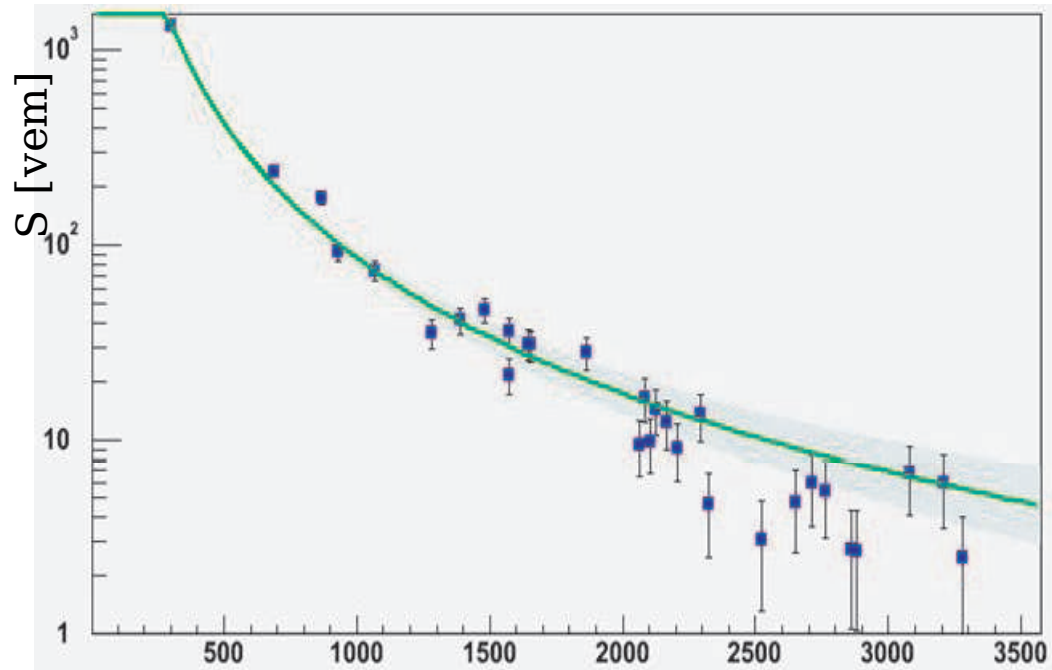


- 3500 km<sup>2</sup>
- 1600 Taniche spaziate di 1.5 km
- 4 rivelatori di fluorescenza
- Monitoraggio Atmosferico

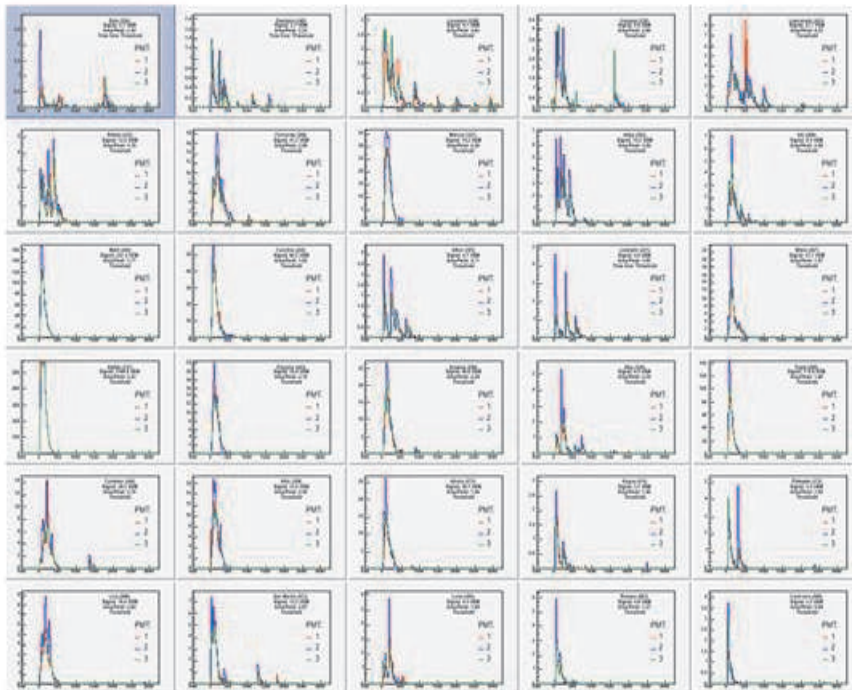
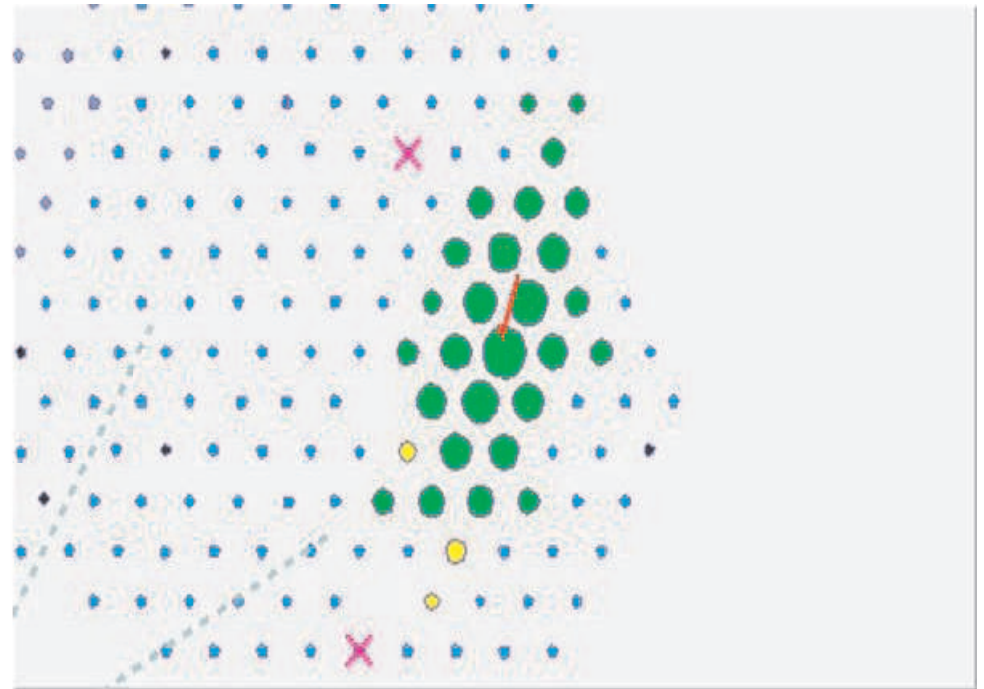
**Updated November 16:**  
**593 detectors in the field**  
**550 detectors filled with water**  
**539 detectors operational**  
**2 fluorescence eyes**

# Surface Detector





Core distance [m]



*Wed Mar 3 15:05:09 2004*

*Easting= 477567 ± 21m*

*Northing= 6084561 ± 25m*

*dt= 92.0ns*

*Theta= 63.5 ± 0.1 deg*

*Phi= 72.1 ± 0.1/sin(theta) deg*

*R= 24.2 ± 0.8 km*

**PRELIMINARY**

*S(1000)= 86.46 ± 2.69 VEM*

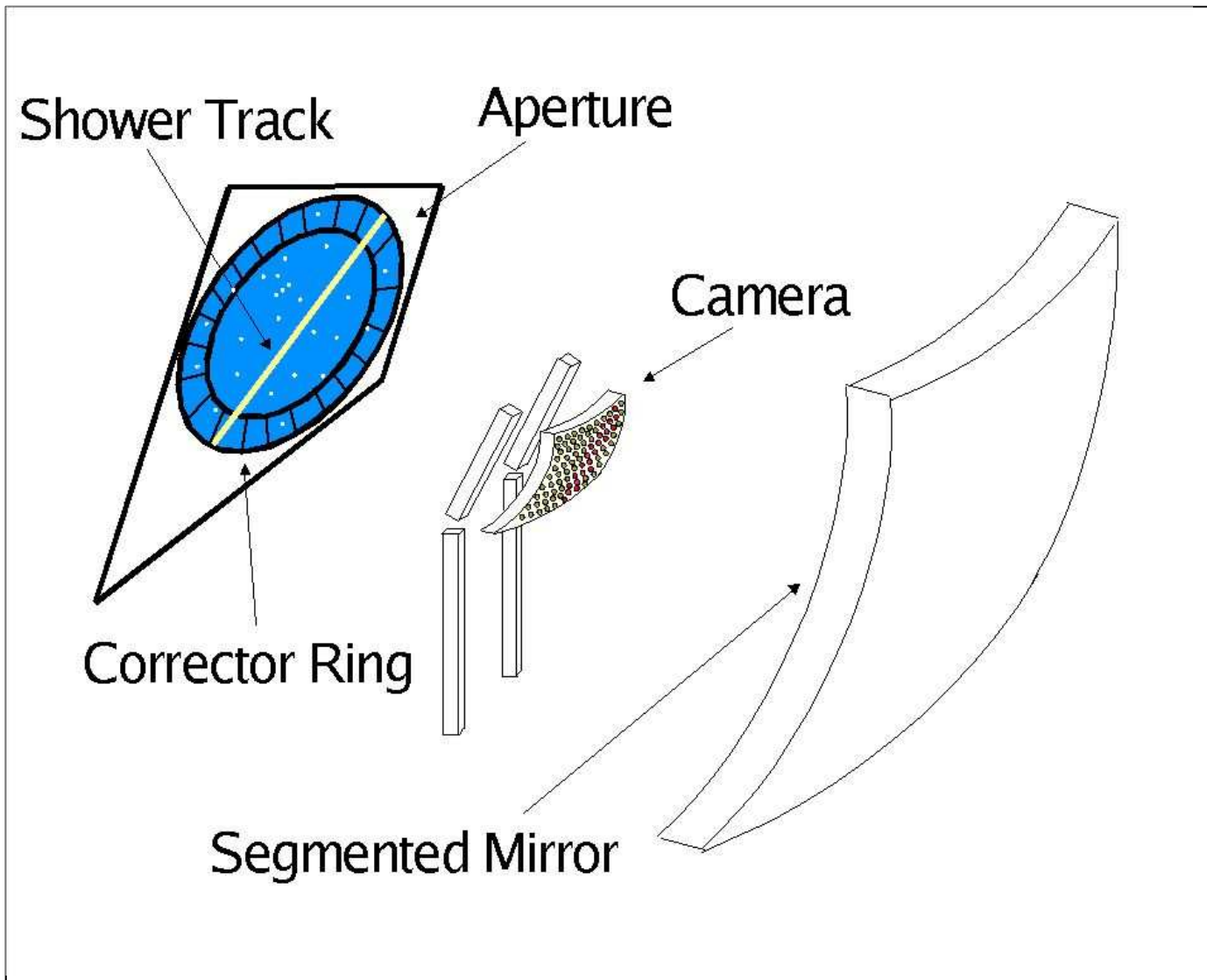
*E= 59.44 EeV ± 3% (stat. error only)*

## Da S1000 a Energia

- A 1000 metri dal core le fluttuazioni sono minime  
Vicino al core dominano quelle dovute allo sviluppo dello sciame e tipo di interazione  
Più lontano domina la statistica
- Da modelli:

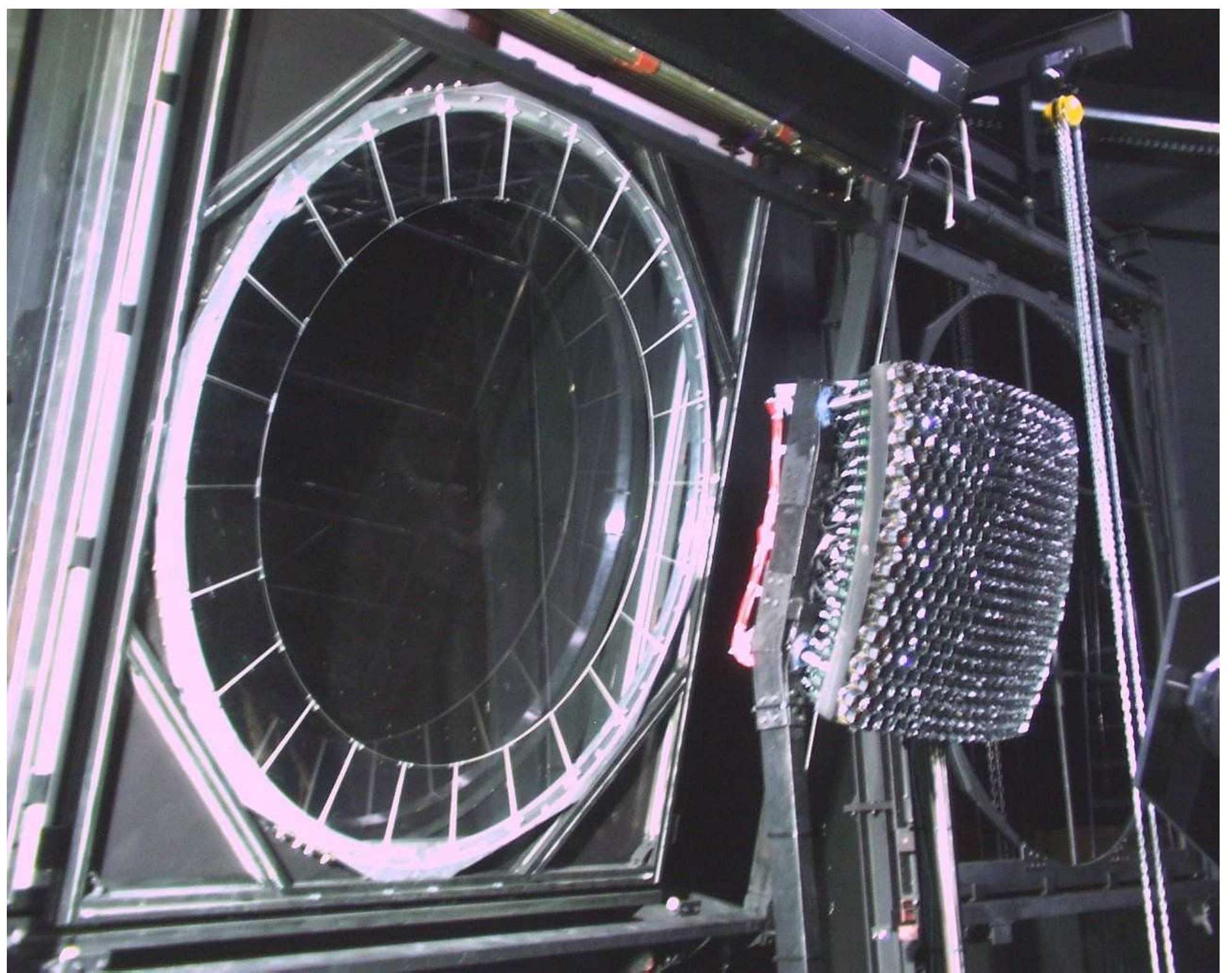
$$E_p = A \cdot S(1000)^B$$

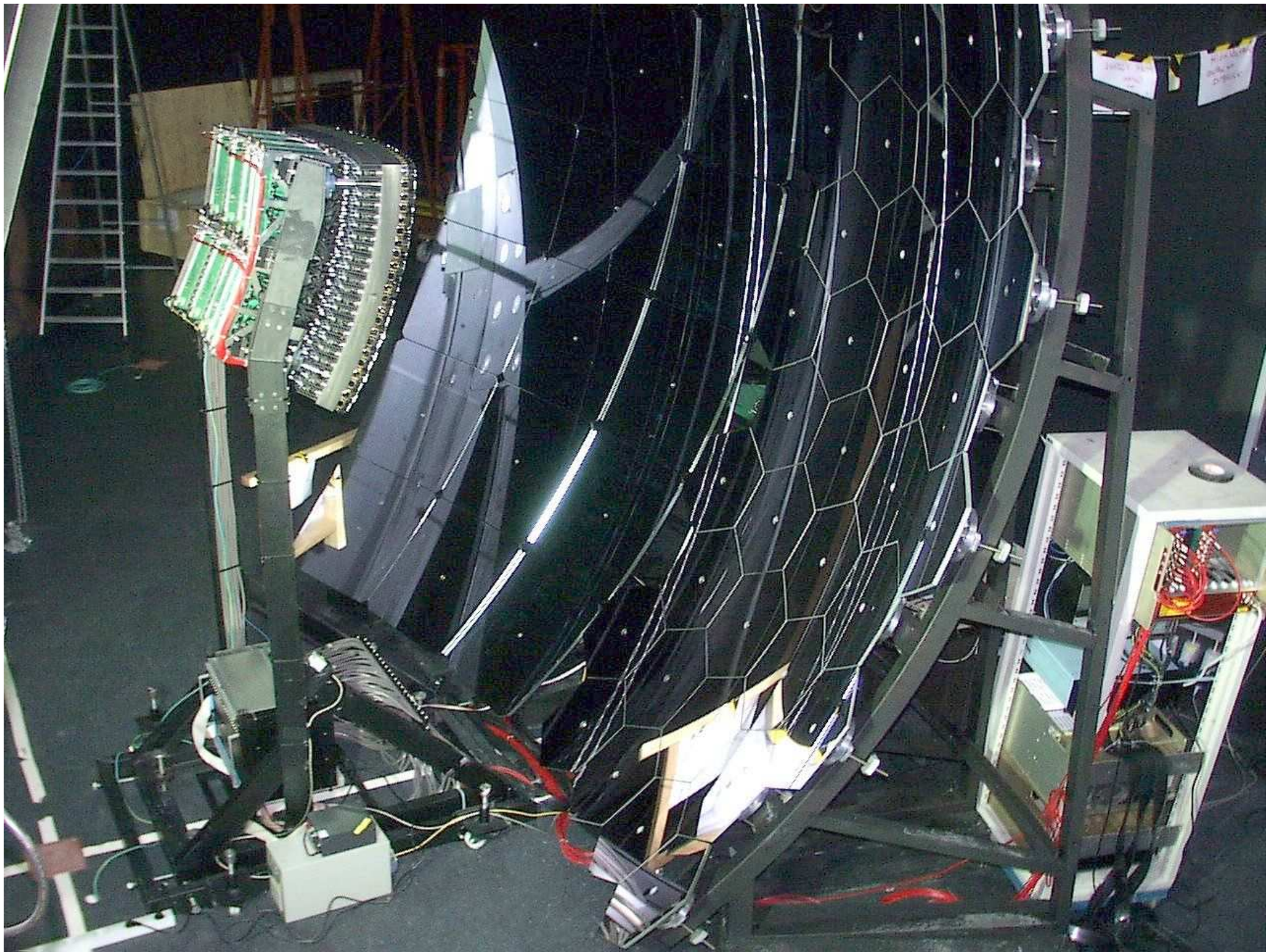
# Fd

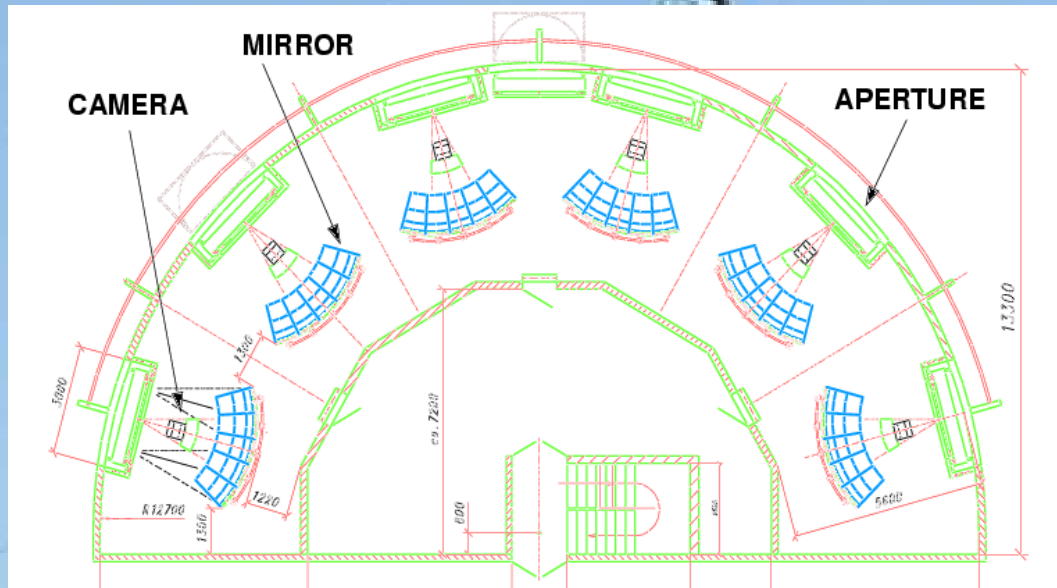


- $30^\circ \times 30^\circ$  fov
- Schmidt optics
- 440 pixels
- $1.5^\circ \text{ } \emptyset$  pixel
- 12 bit FADC
- $10 \text{ Mhz } f_s \Rightarrow$   
 $< 4 \text{ g/cm}^2$
- Digital trigger

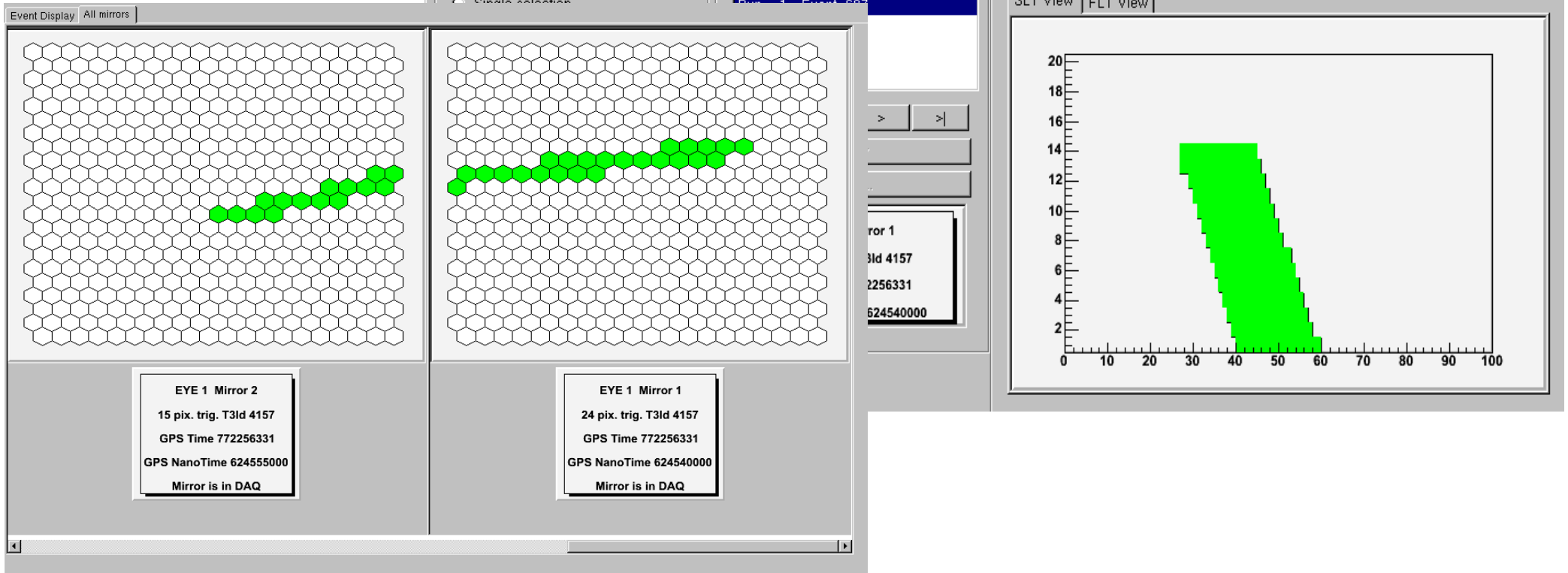
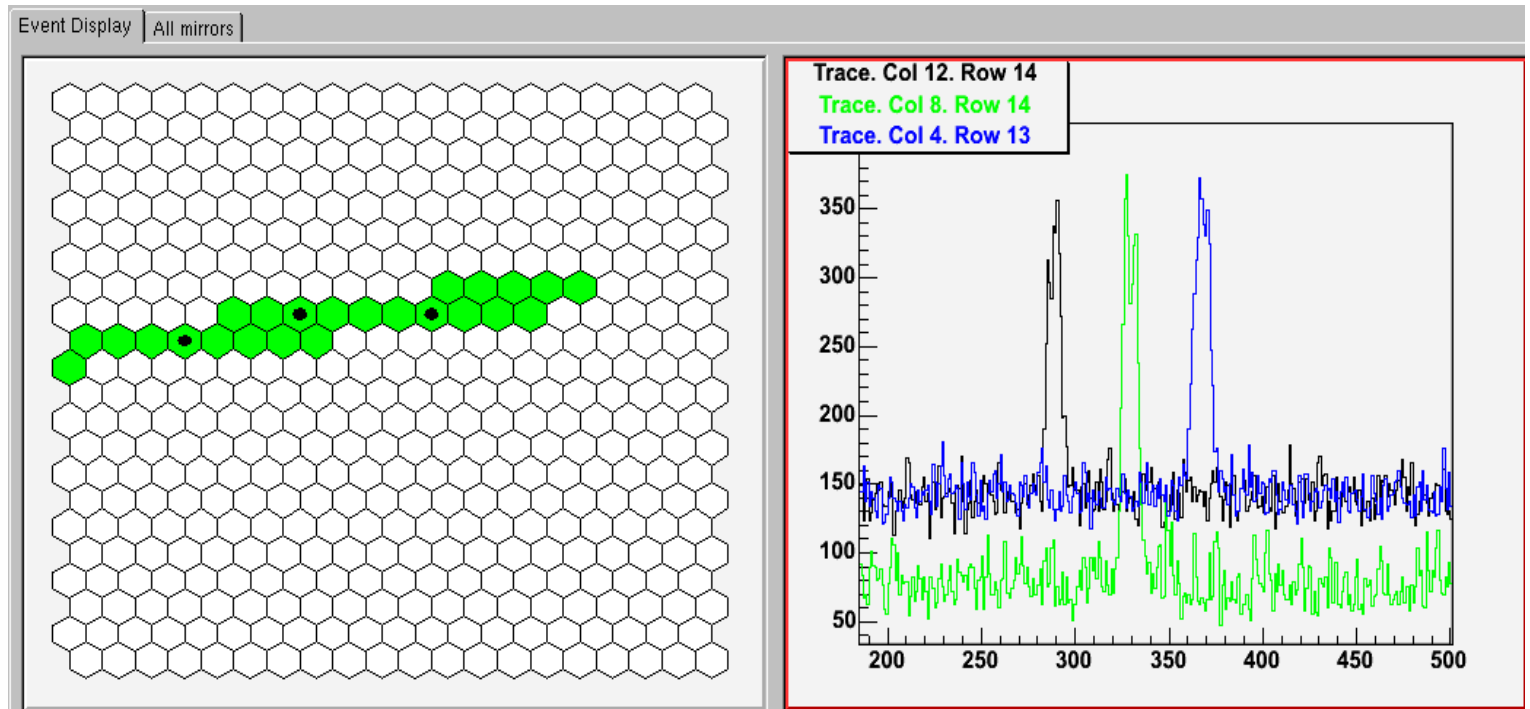






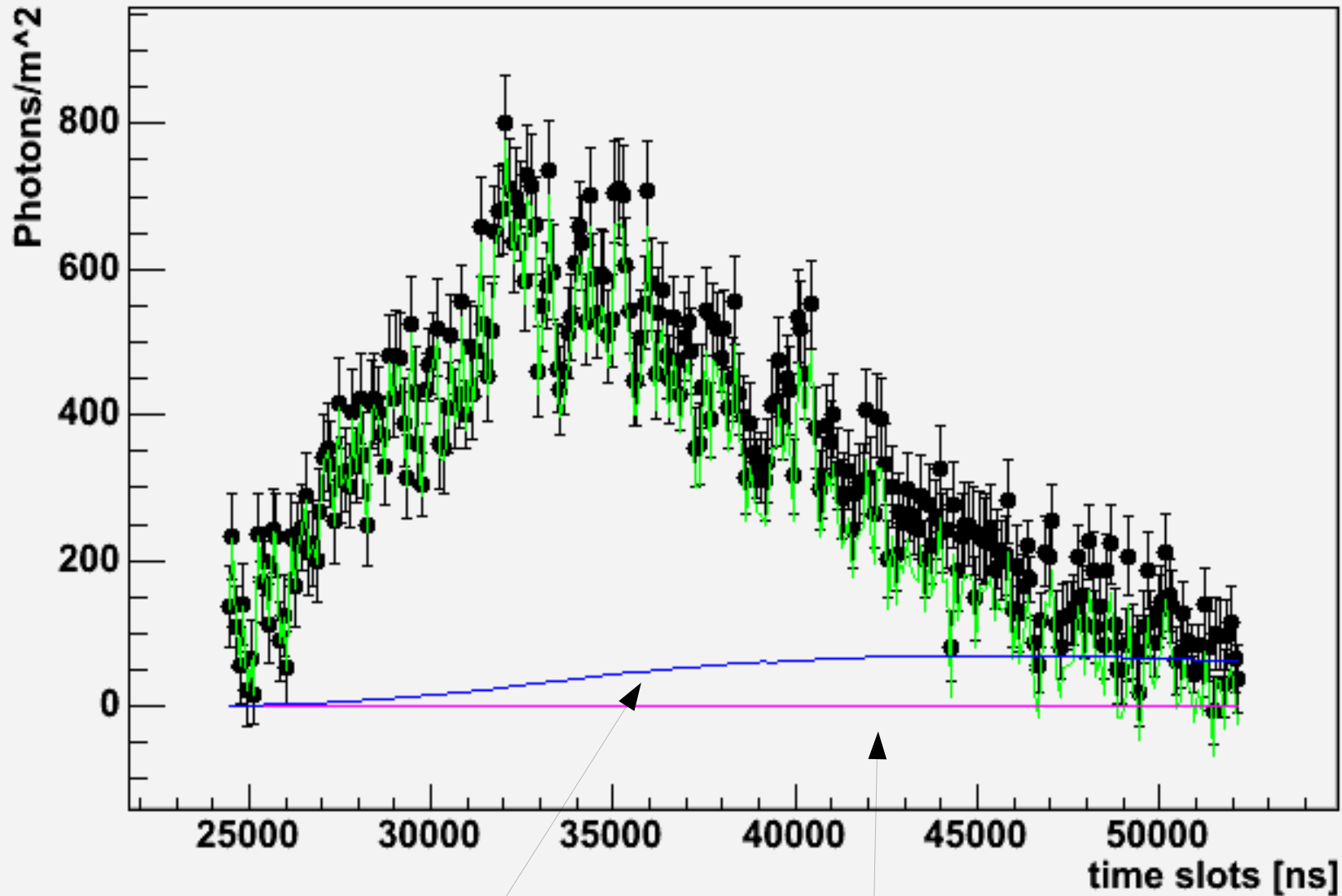


# Event display fd



Light Flux 850018

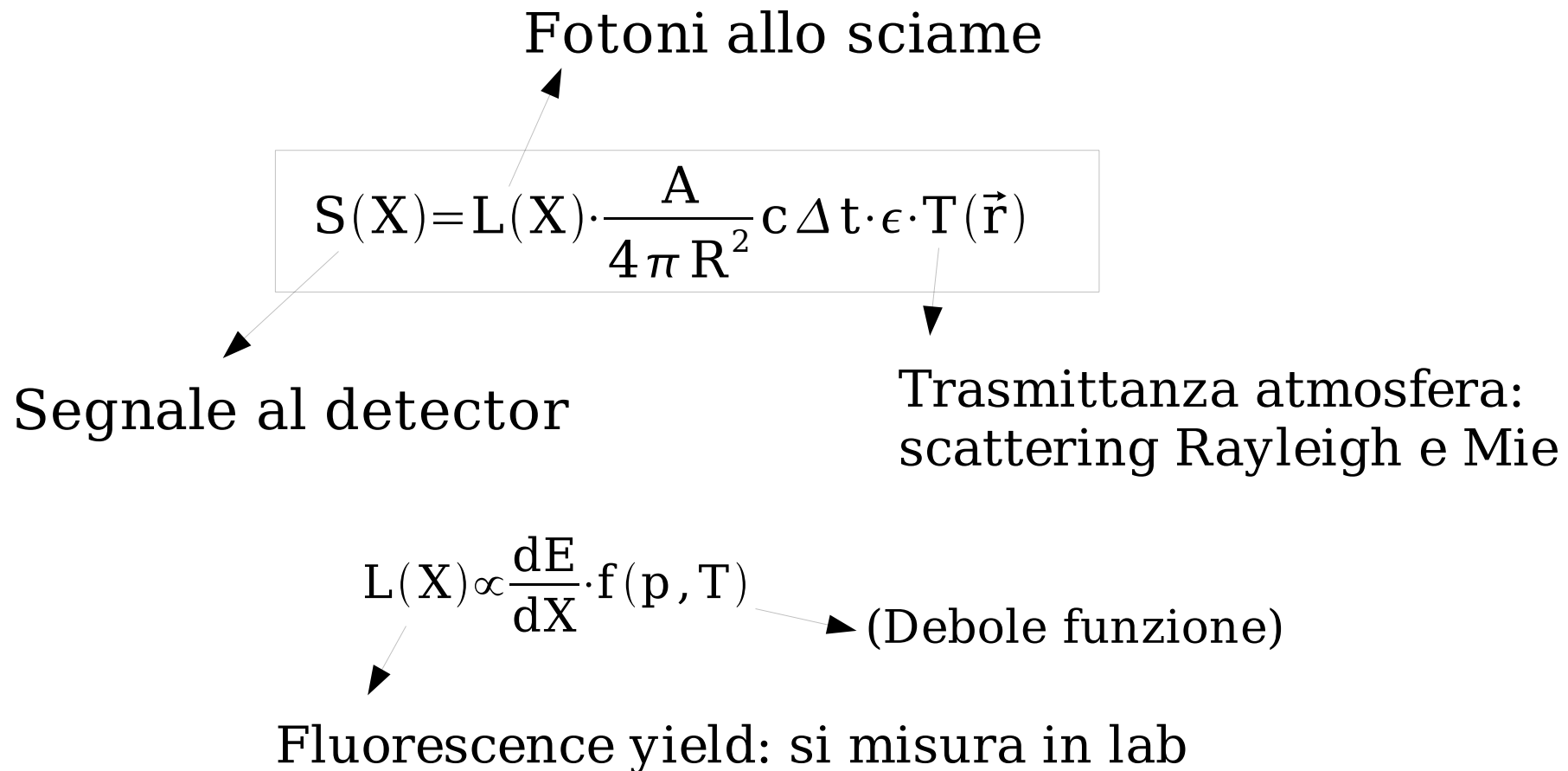
Luce ricevuta al detector



Scattered Cherenkov

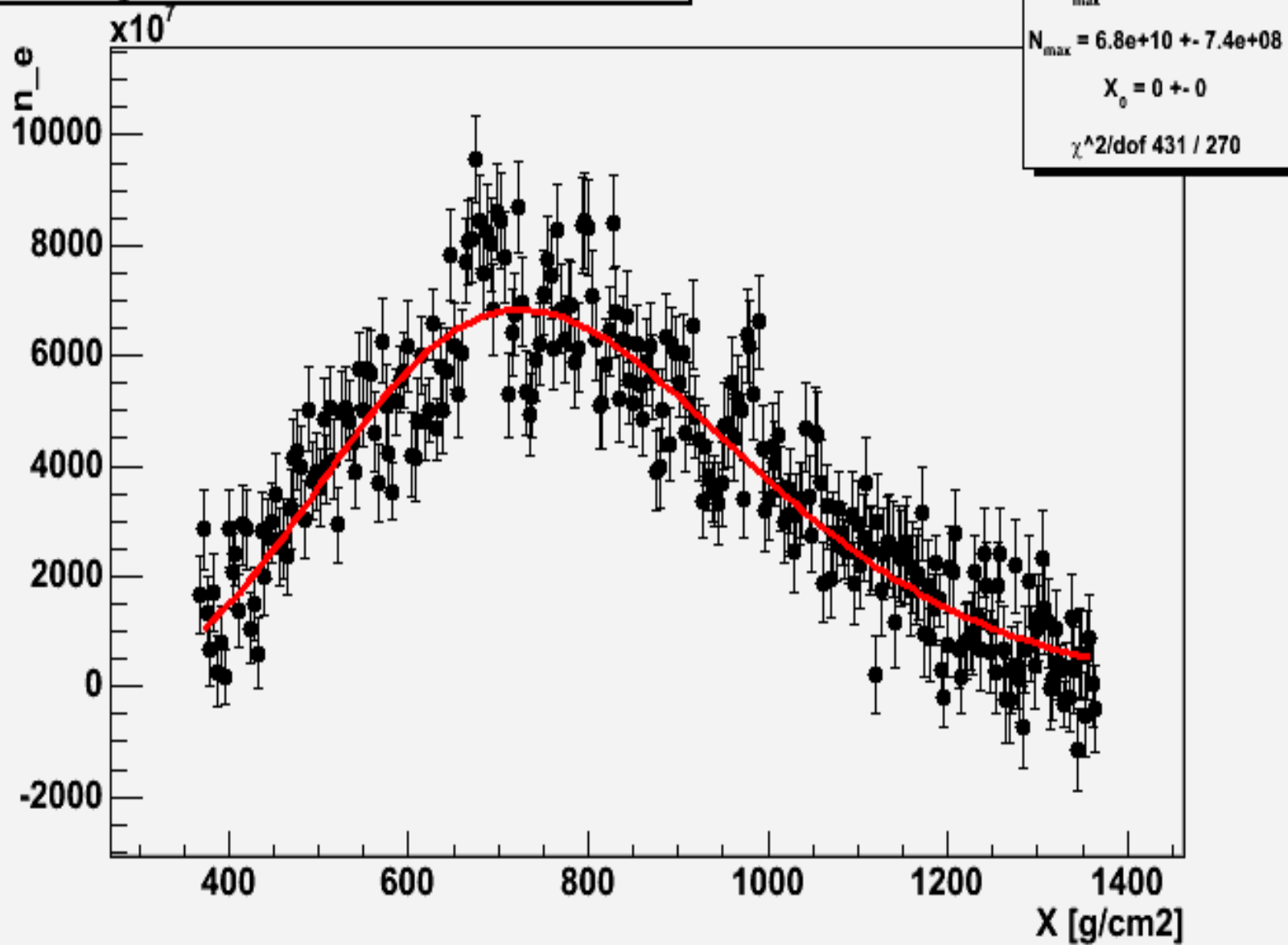
Direct Cherenkov

# Da segnale a sviluppo longitudinale



Sottrazione iterativa della componente Cerenkov

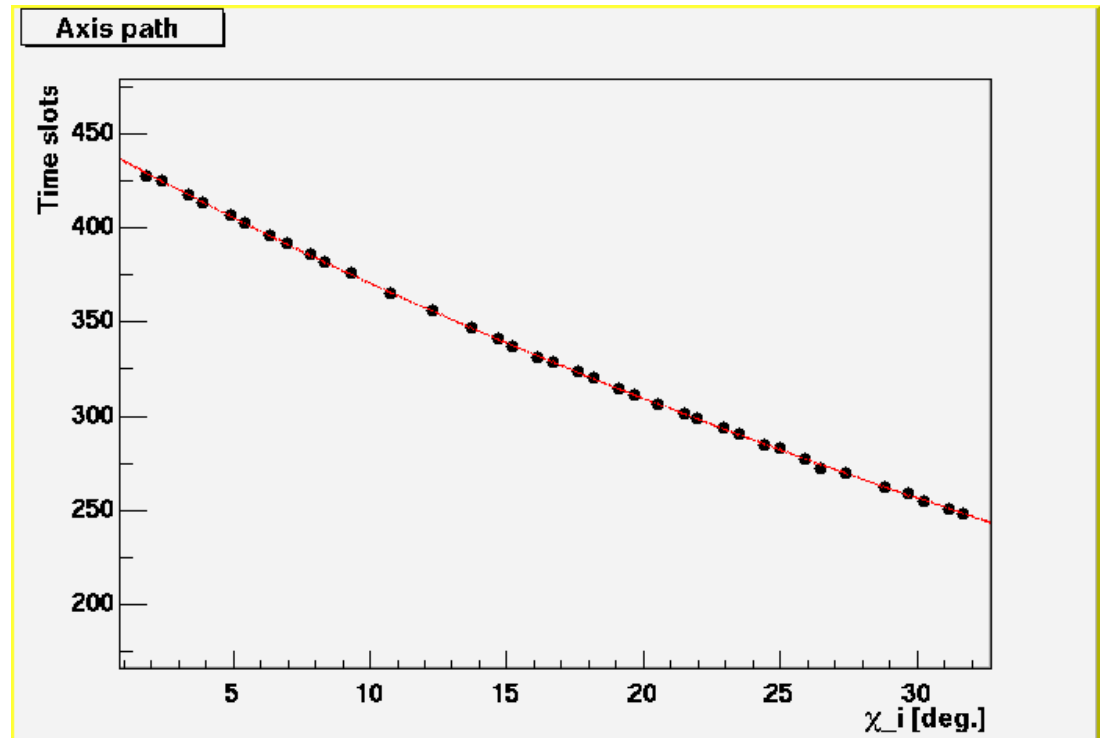
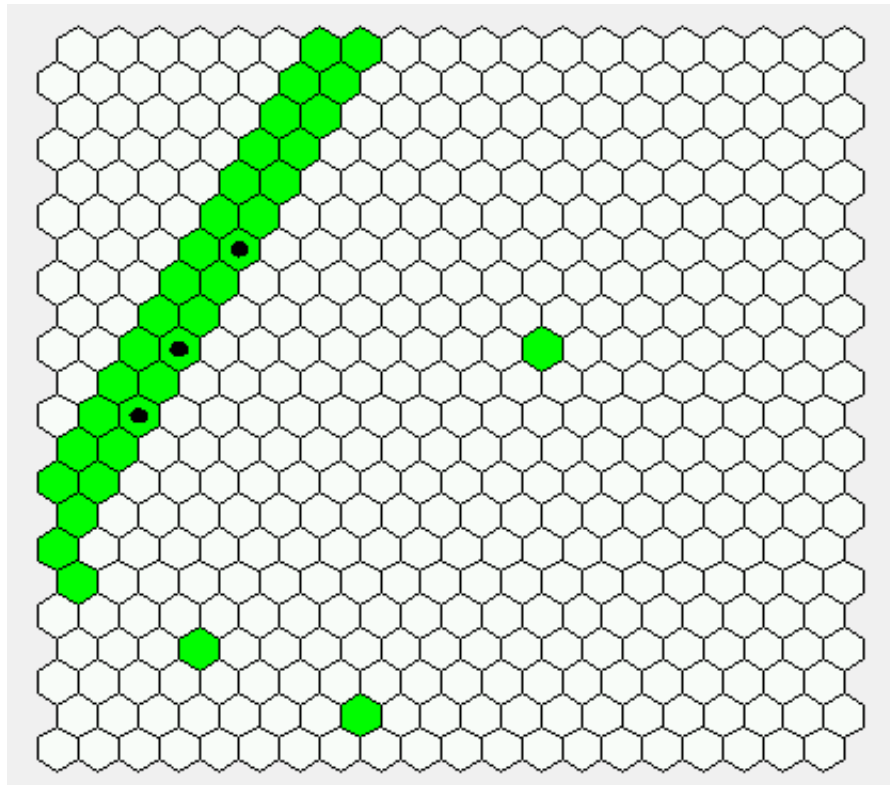
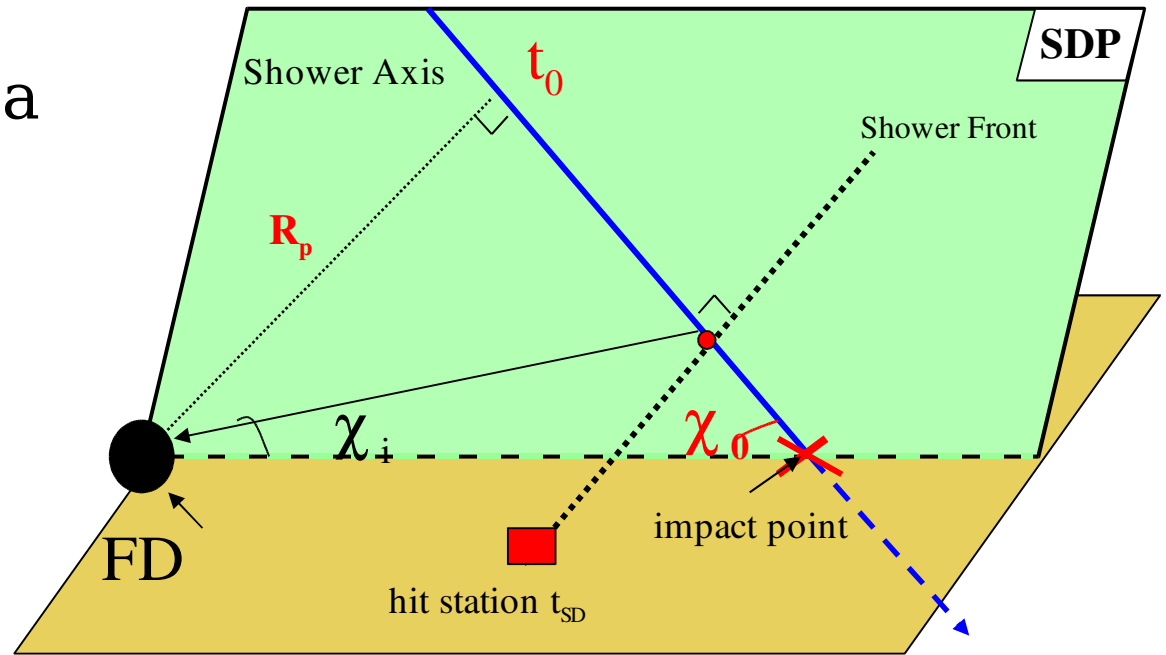
# Longitudinal Profile Run1Event687



# Ricostruzione Geometrica

FD

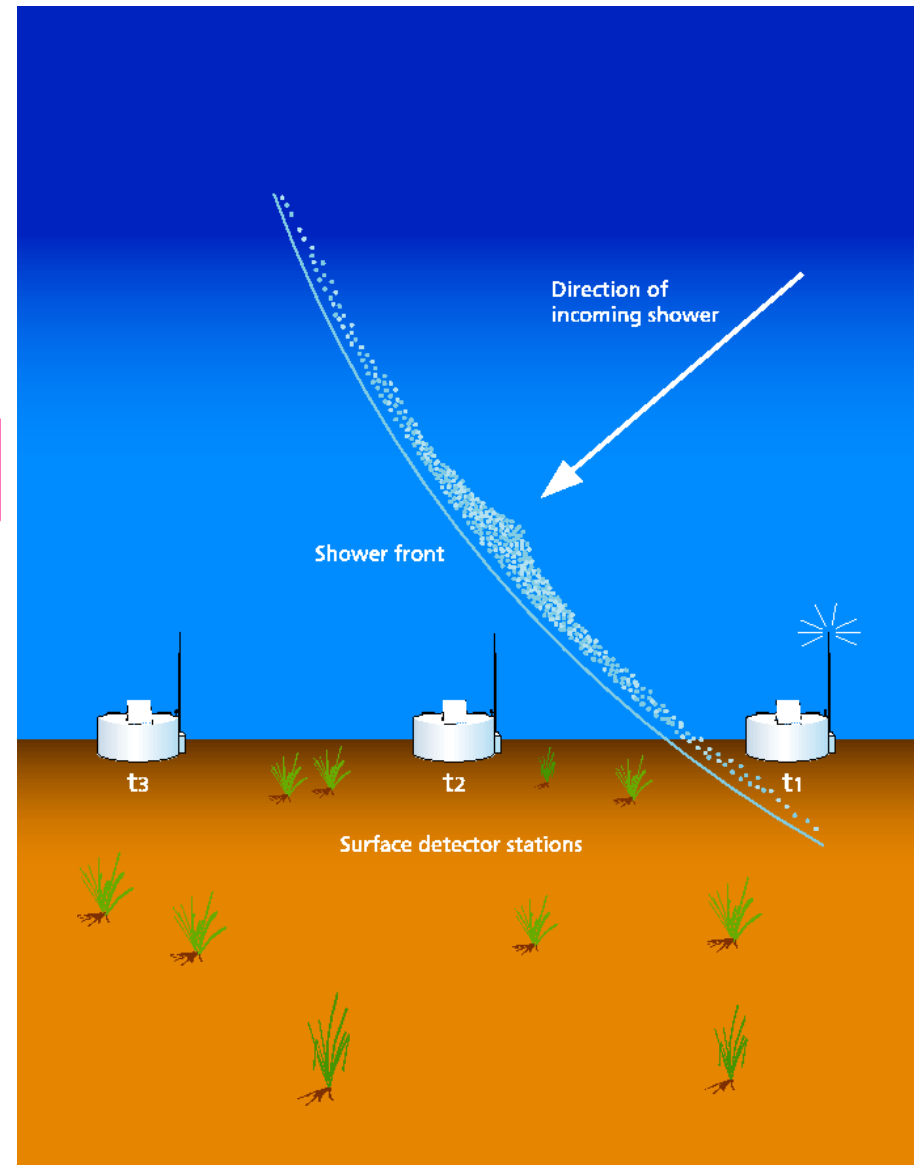
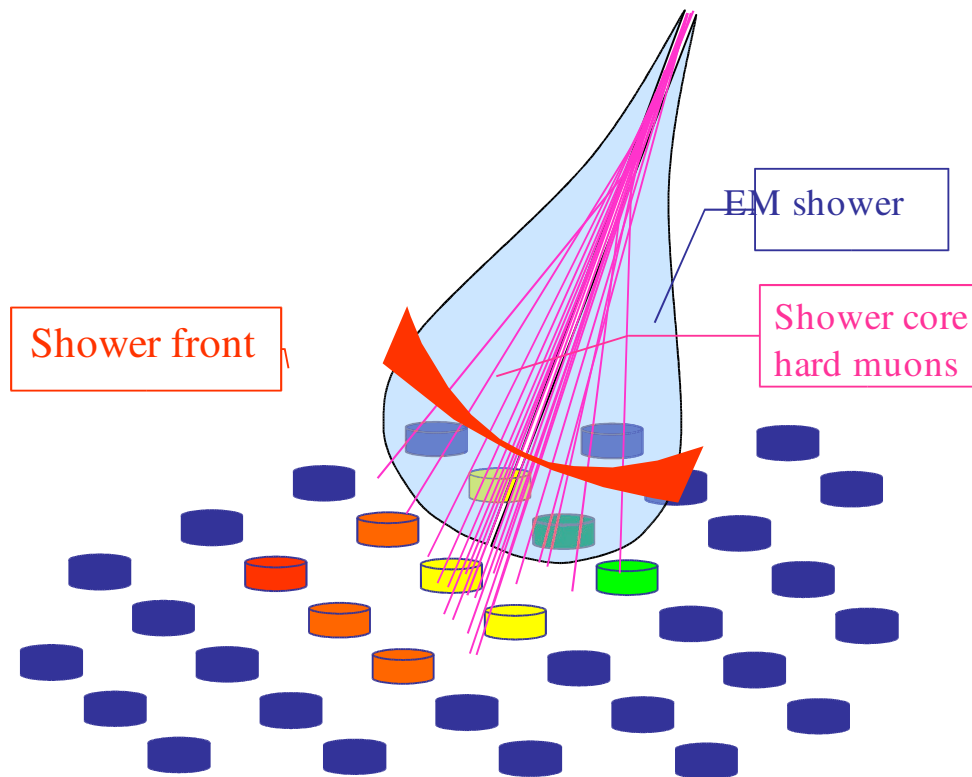
## Shower-Detector Plane



$t_0, X_0, R_p$

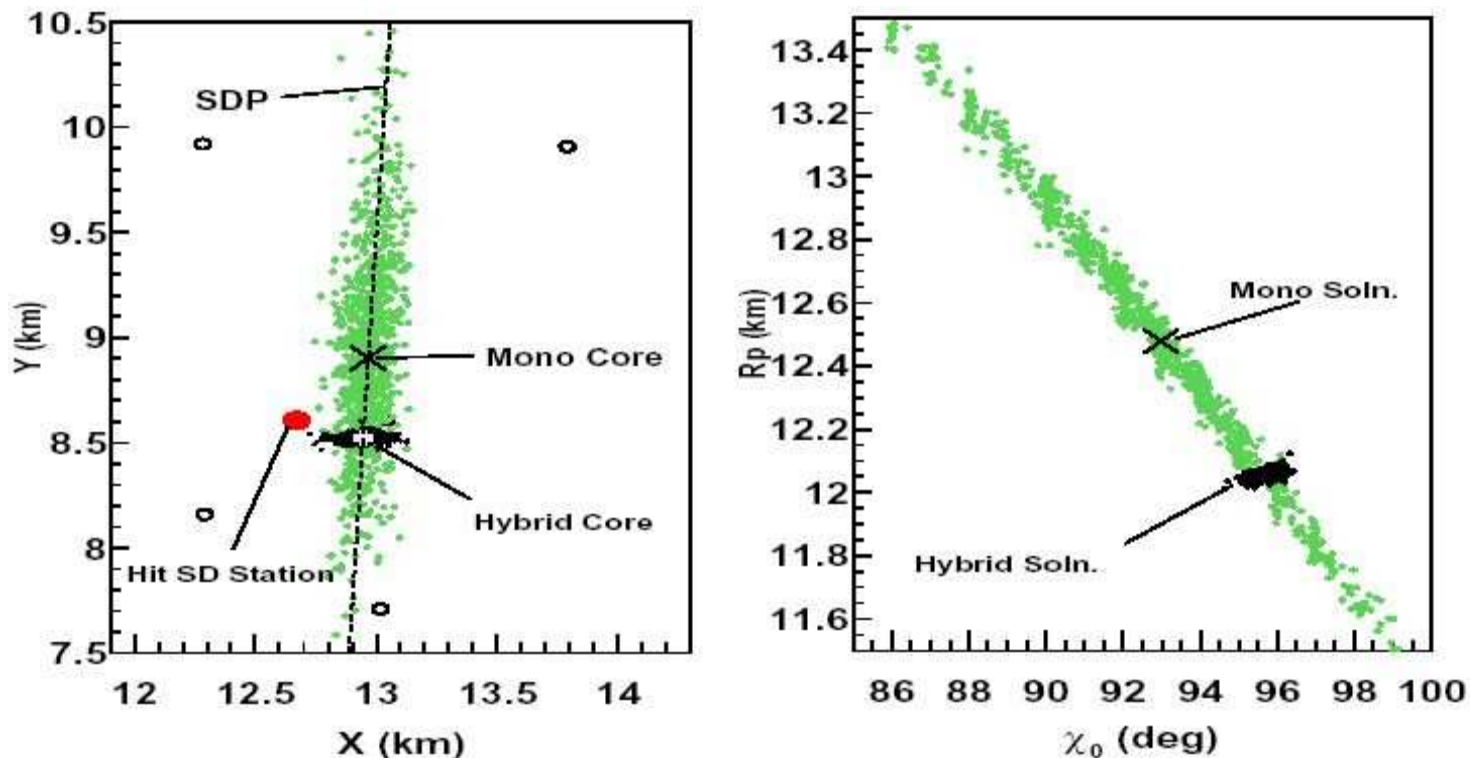


# Ricostruzione geometrica SD



# Ricostruzione Ibrida

La presenza di informazione dalla superficie o da un secondo FD permette di eliminare le ambiguita'

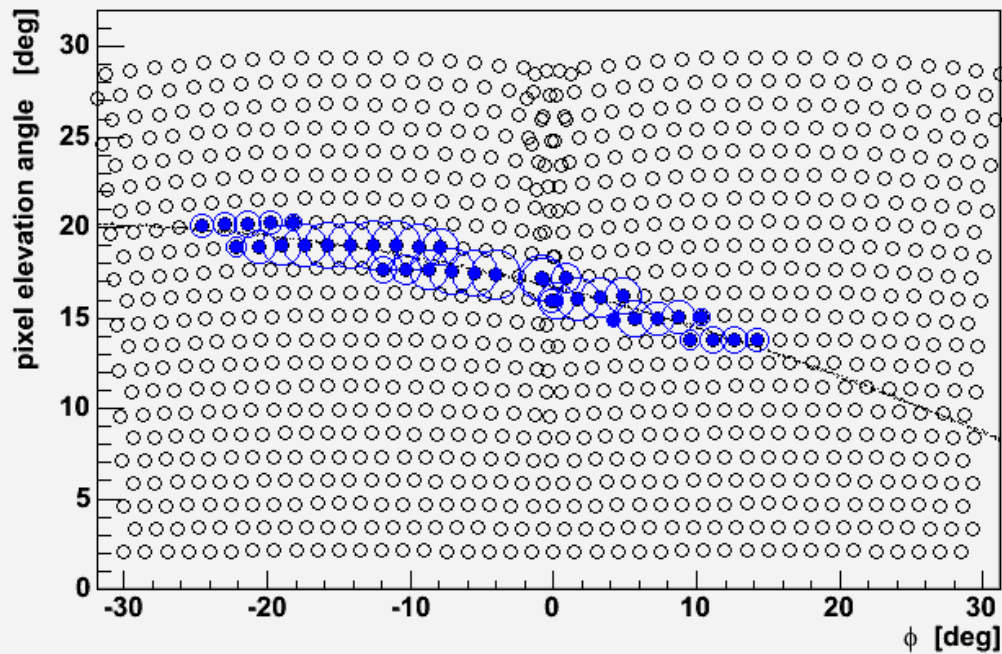


Risoluzione direzione asse  $< 1$  grado

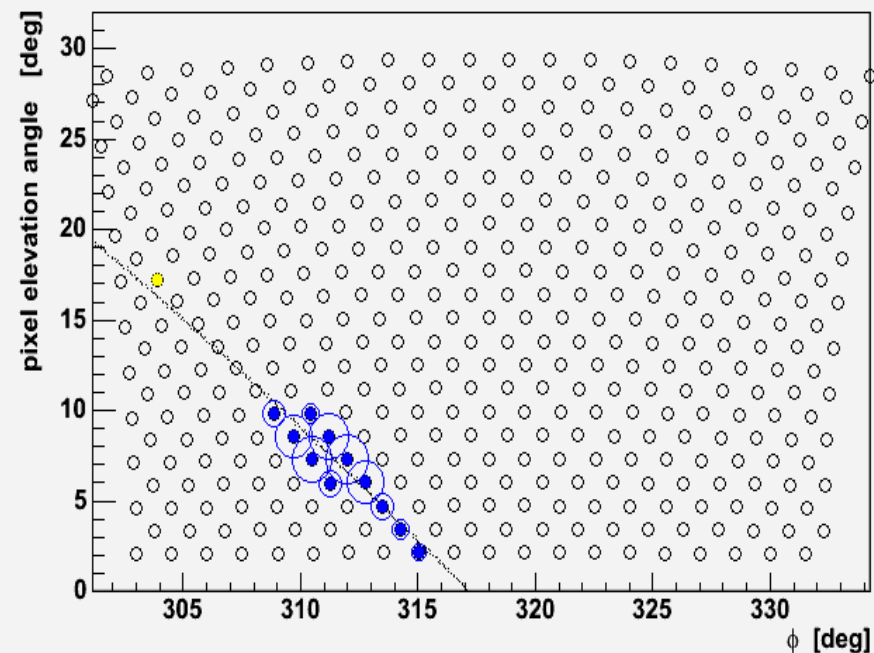
Posizione punto di impatto  $< 50$  m

Sistematiche controllabili con spari laser

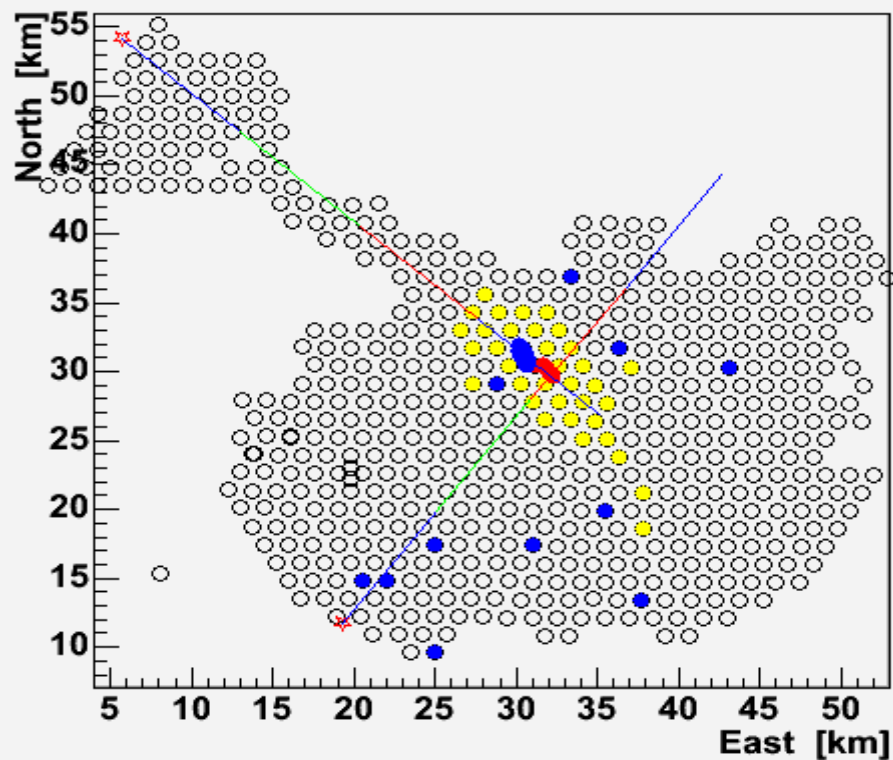
SDP Id 850018 Run 1 Event 687 Eye Id: 1



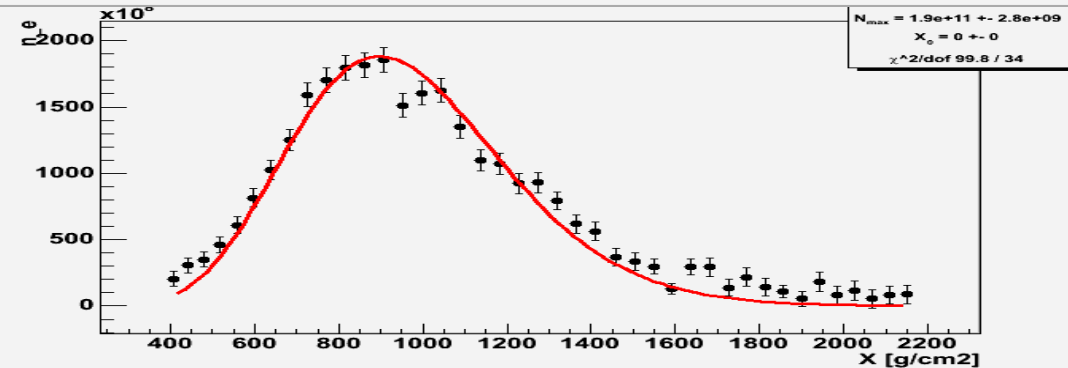
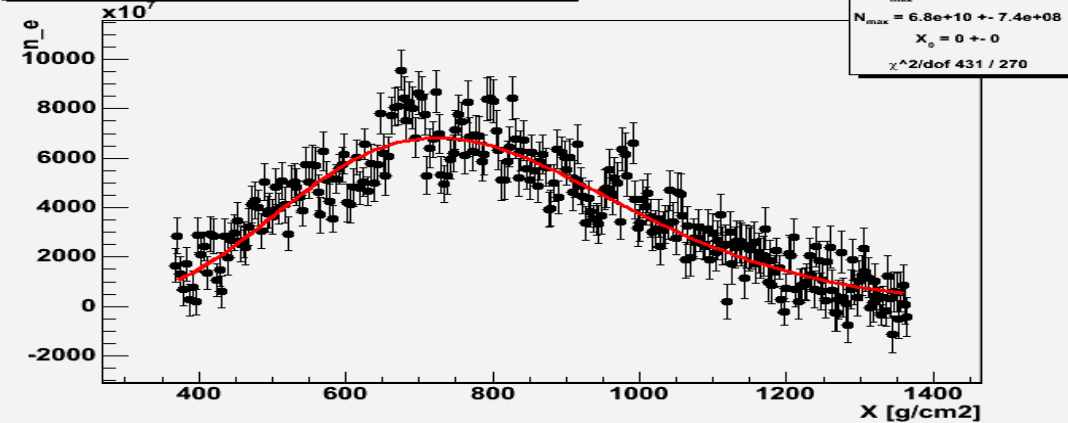
SDP Id 850018 Run 469 Event 197 Eye Id: 4



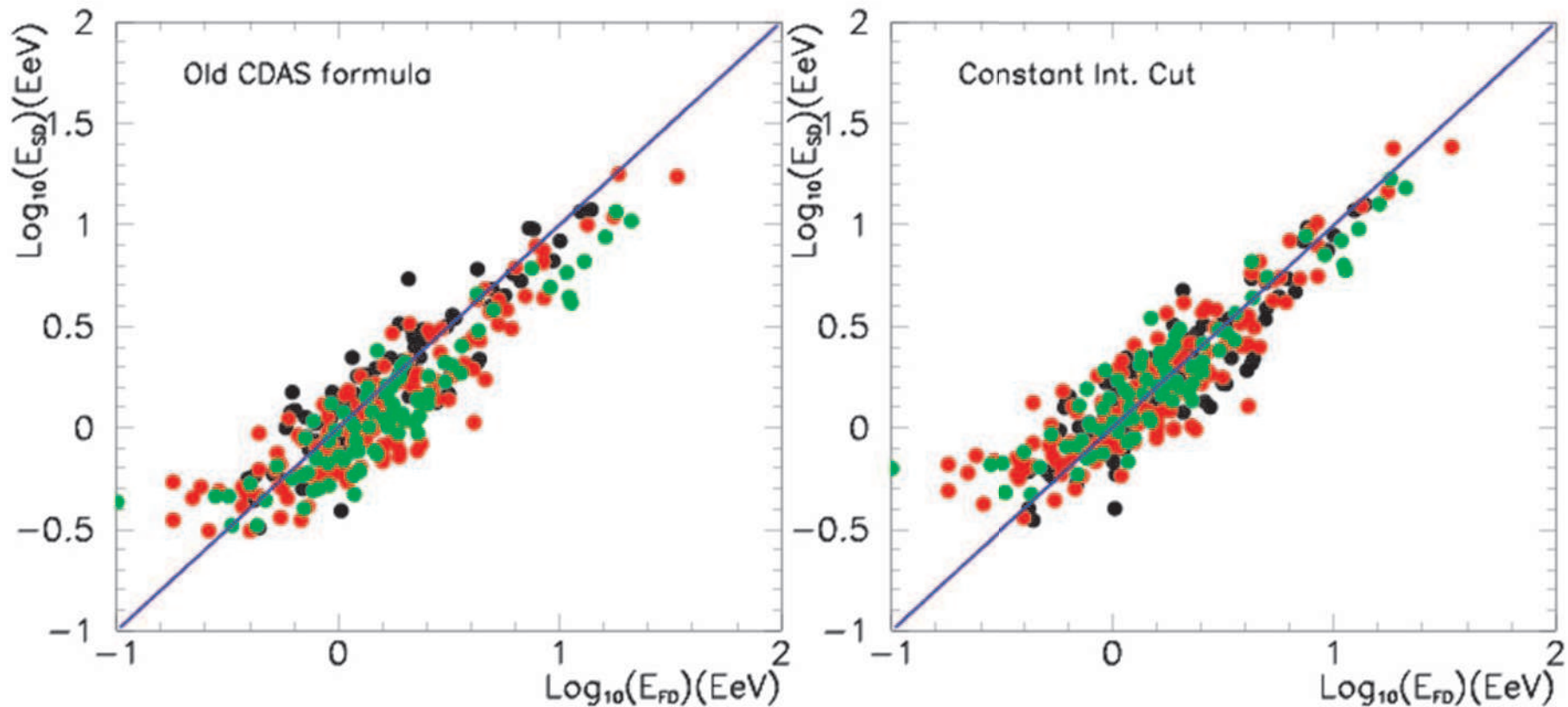
Stations-SDP Event Id: 850018



Longitudinal Profile Run1Event687



# FD energy vs SD energy from hybrid analysis



- 0-25 degrees
- 25-45 degrees
- 45-60 degrees

Clear correlation between SD and FD energy estimates

## Sistematiche FD sulla misura di energia

- Trasparenza dell'atmosfera
- Calibrazione assoluta



Don't want to get stuck in the mud !



# Monitoraggio Atmosfera

Lidar

Central Laser Facility

Palloni sonda

Aerosol Phase Function

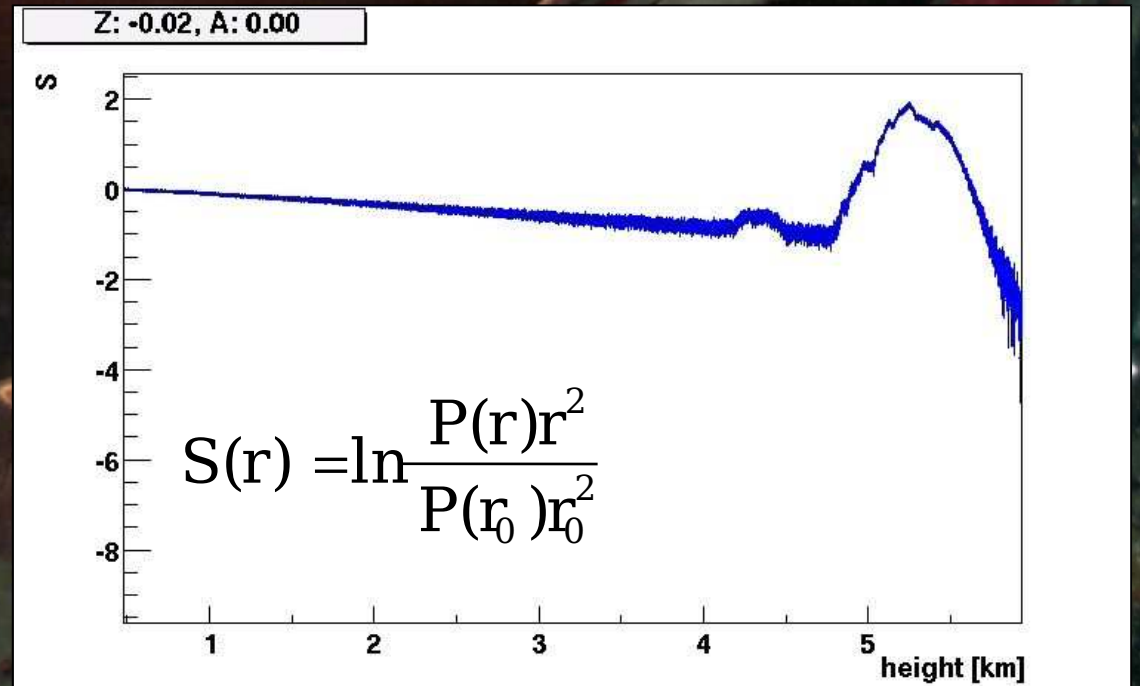
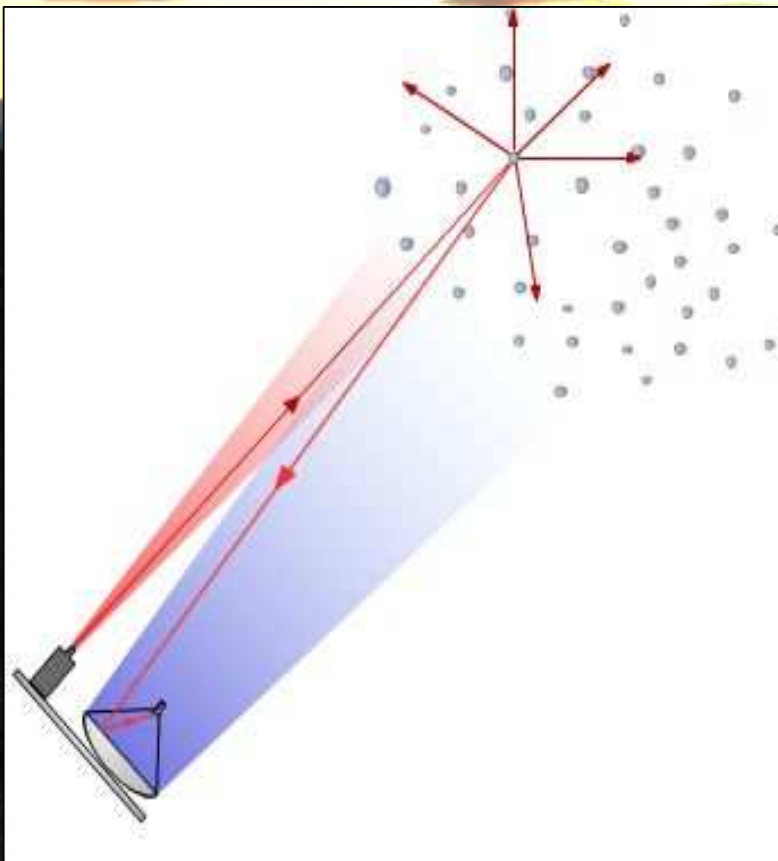
Cloud cameras

Horizontal Att Monitor



Misura di T(r)

“Shoot the Shower”





# **A Torino:**

## **SD:**

Basi PMT

Caratterizzazione PMT

Deployment e sistema di test pre-deployoment

Studi sul trigger

Analisi tracce FADC

## **FD:**

filtri UV

Elettronica analogica di lettura + test

Meccanica Lidar, analisi

Prototipo telescopio

Framework C++ sim/rec

Ricostruzione FD

DAQ FD

