

# Results from the Pierre Auger Observatory

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for the Pierre Auger Collaboration

# *Pierre Auger Observatory research goals are:*

**To measure the Energy Spectrum for  $E > 10^{18}$  eV**

- **We observe a change in the slope at  $\log_{10}(E/\text{eV}) = 18.61 \pm 0.01$ .**
- **There is a suppression at higher energies.**

**To obtain the Mass Composition**

- From composition studies there is an indication that CRs become heavier at higher energies (supposing models are correct).
- Limits on the flux of UHE photons and neutrinos disfavor exotic production scenarios.

**To obtain Arrival Direction Distribution**

- We observe a correlate with matter in the nearby universe above 56 EeV.

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# *The Pierre Auger Observatory is a Hybrid Detector*

**91 Institutions  
18 countries  
487 collaborators.**

**Construction in two sites:**

- Malargue, Argentina.**
- Colorado, USA.**

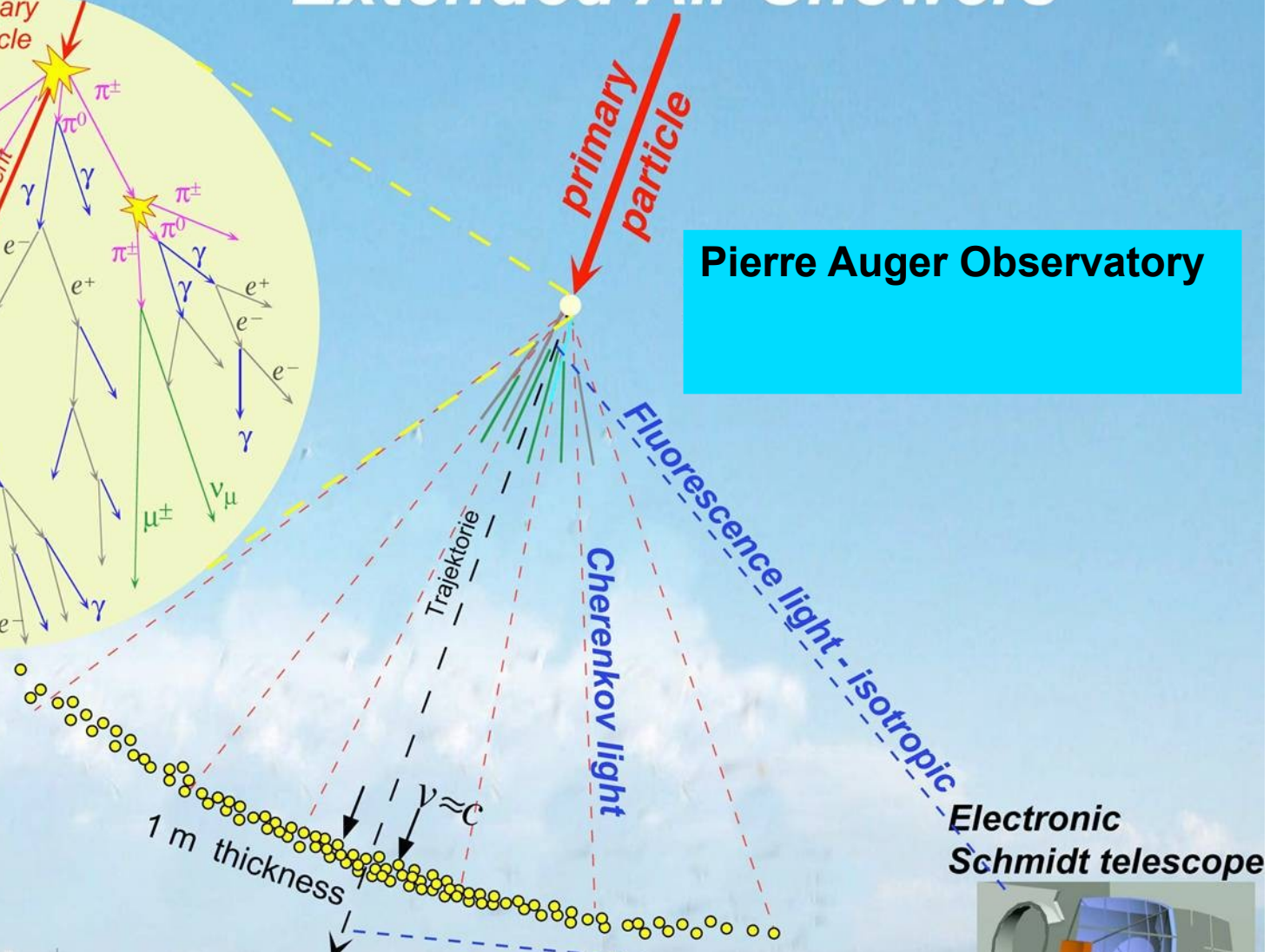
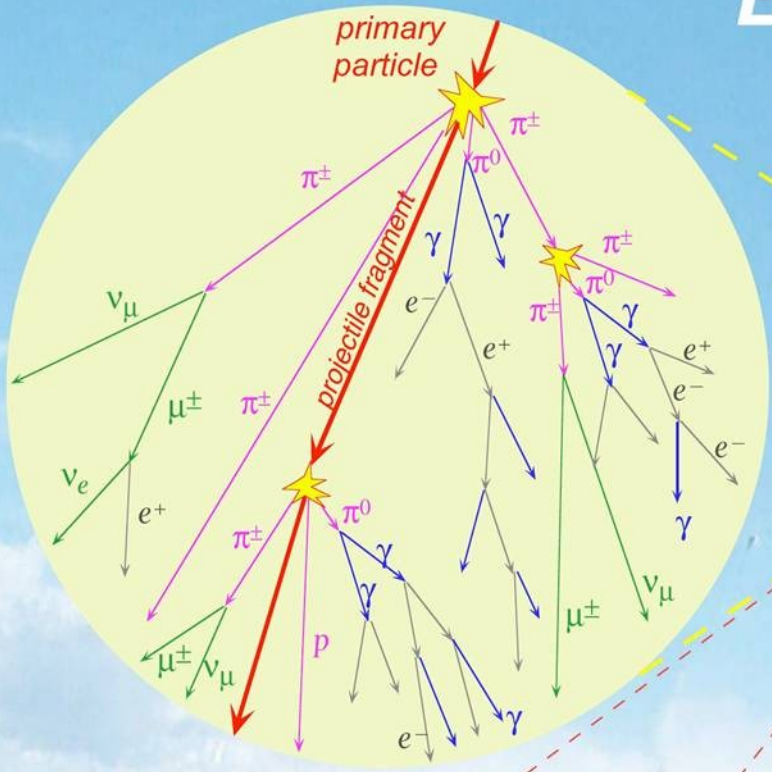
**Fluorescence Detector  
+  
Surface Detector**



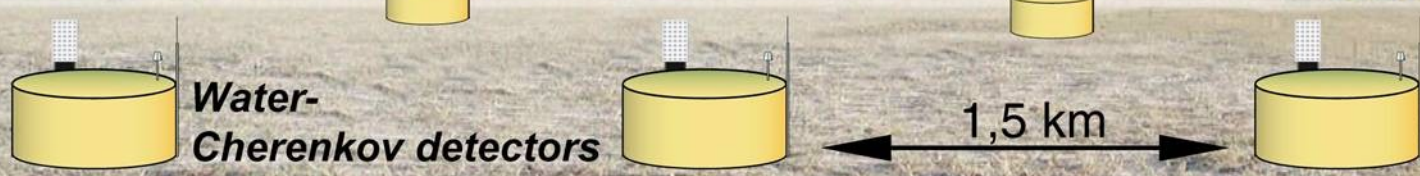
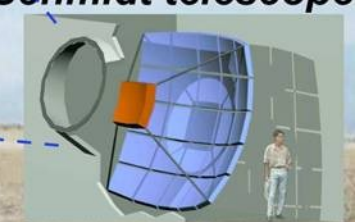


# Extended Air Showers

Pierre Auger Observatory



Electronic  
Schmidt telescope



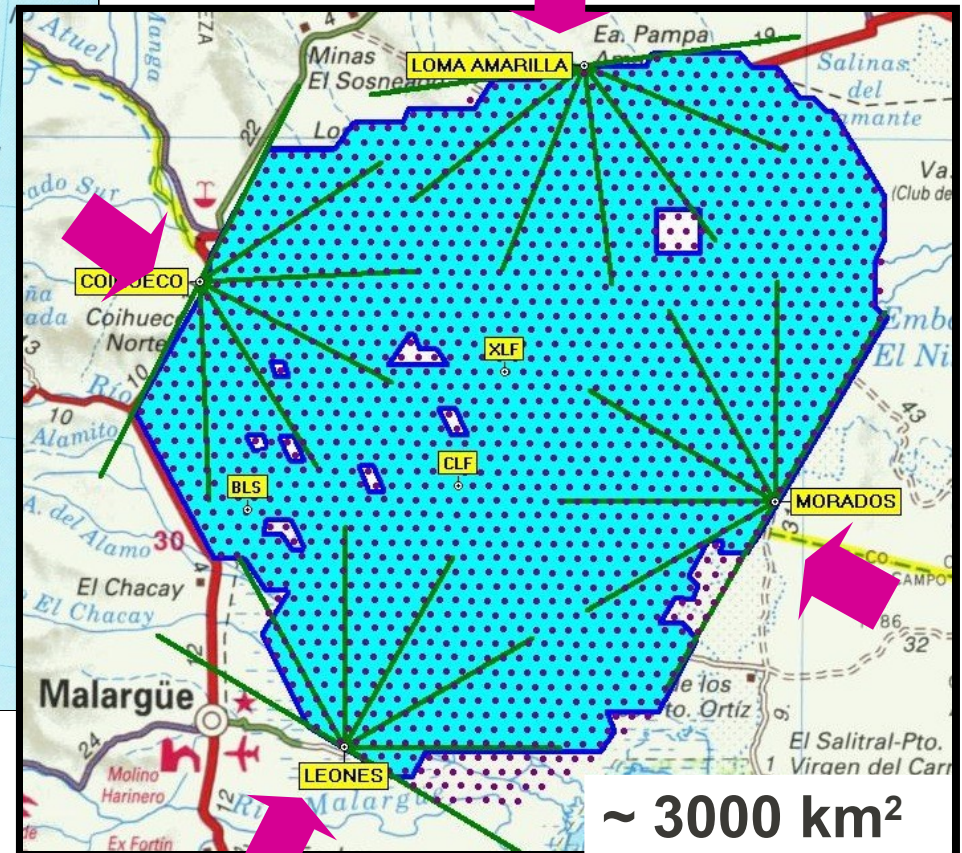
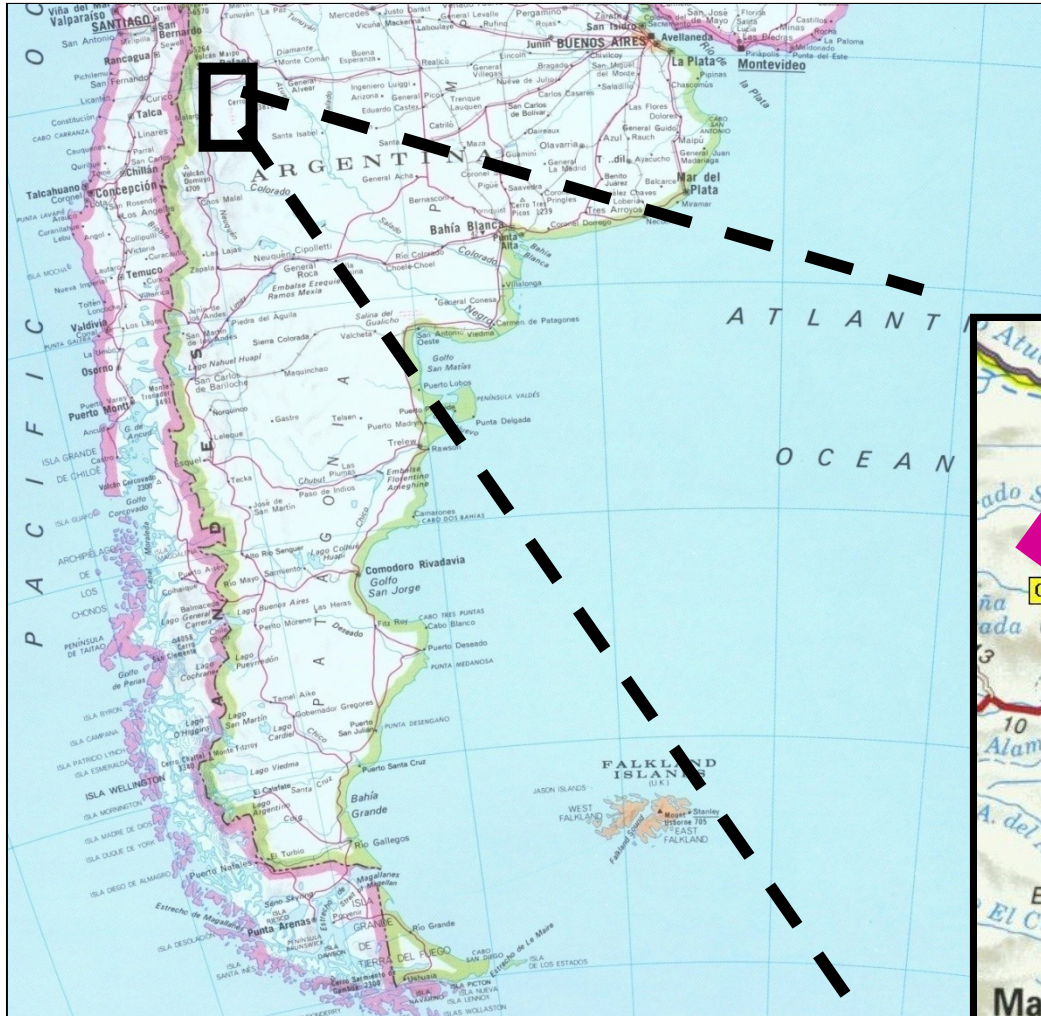


# South Hemisphere Site

## Malargüe, Mendoza (Argentina)

● 1600 water Cherenkov tanks

➡ 4 Fluorescence Buildings

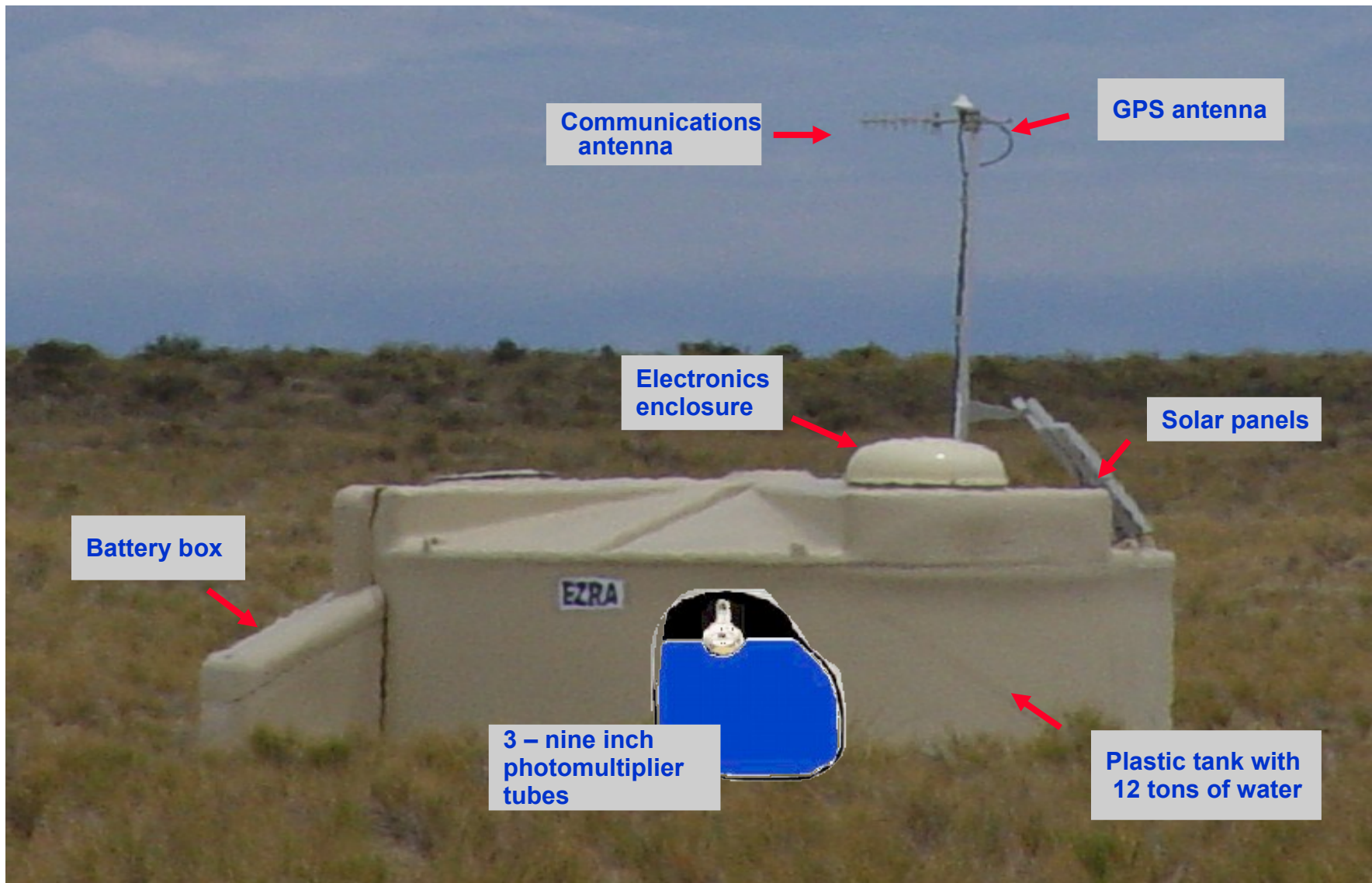


35.5° S, 69.3° W  
1400 m a.s.l. (880 g cm<sup>-2</sup>)

Auger Coll. NIMA A523 (2004), 50.

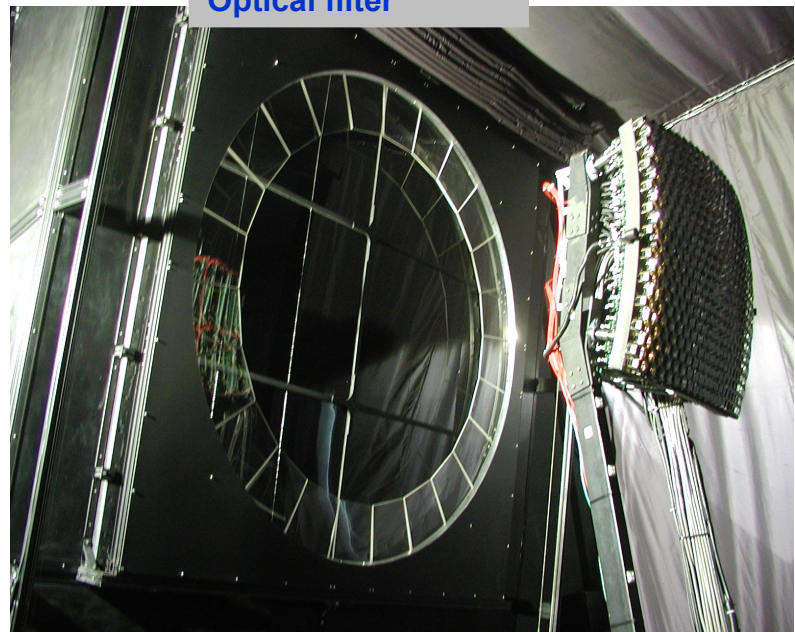
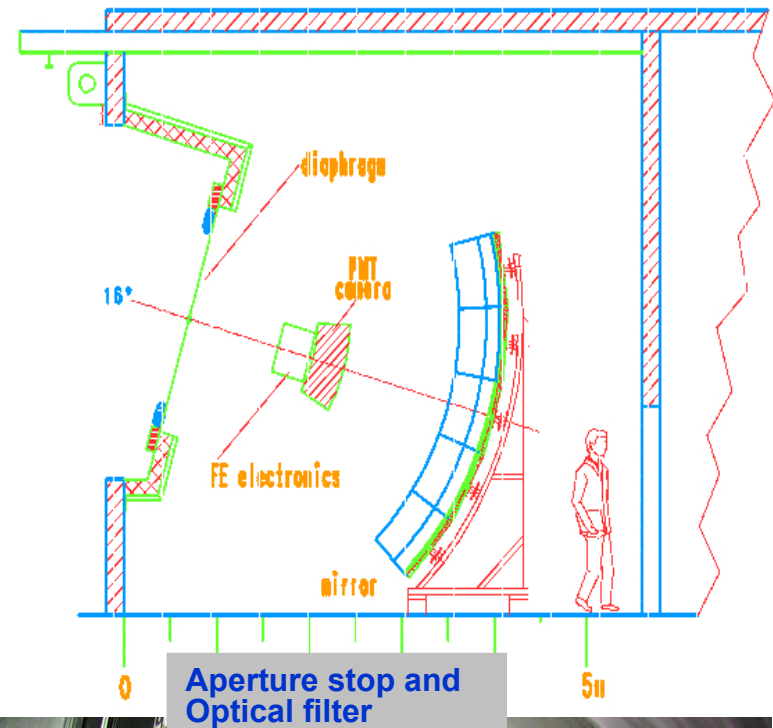
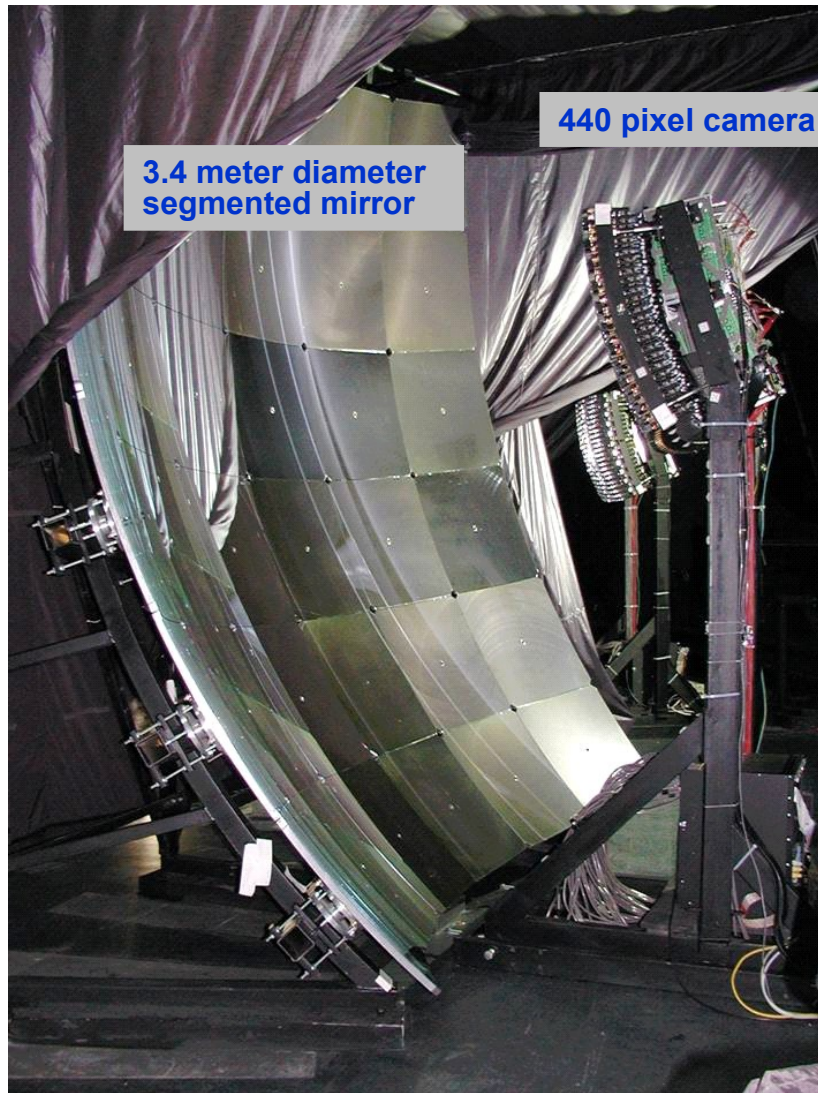


# *The Surface Detector Station*





# The Fluorescence Telescope



# Energy Spectrum

# SD event reconstruction below $60^\circ$

## Reconstruction procedure:

- Shower direction  $(\theta, \phi)$ :

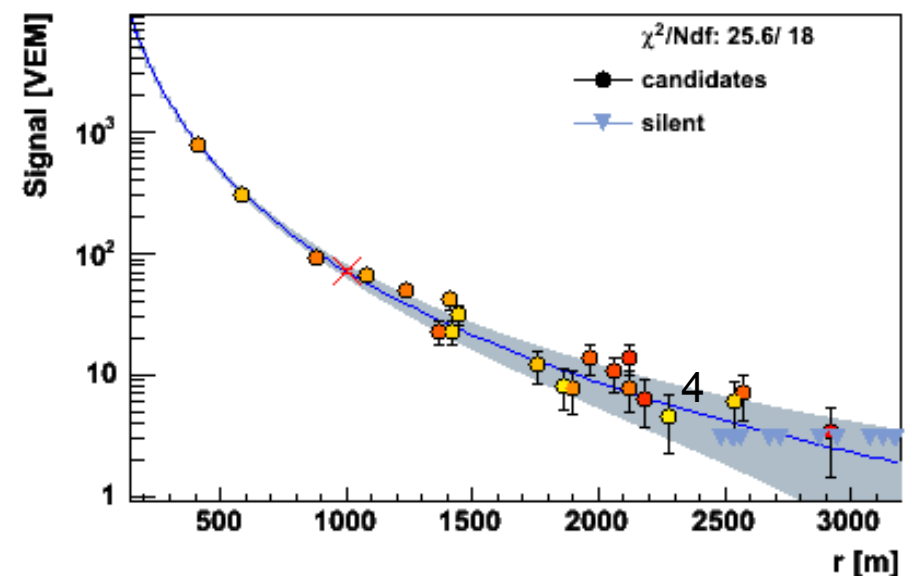
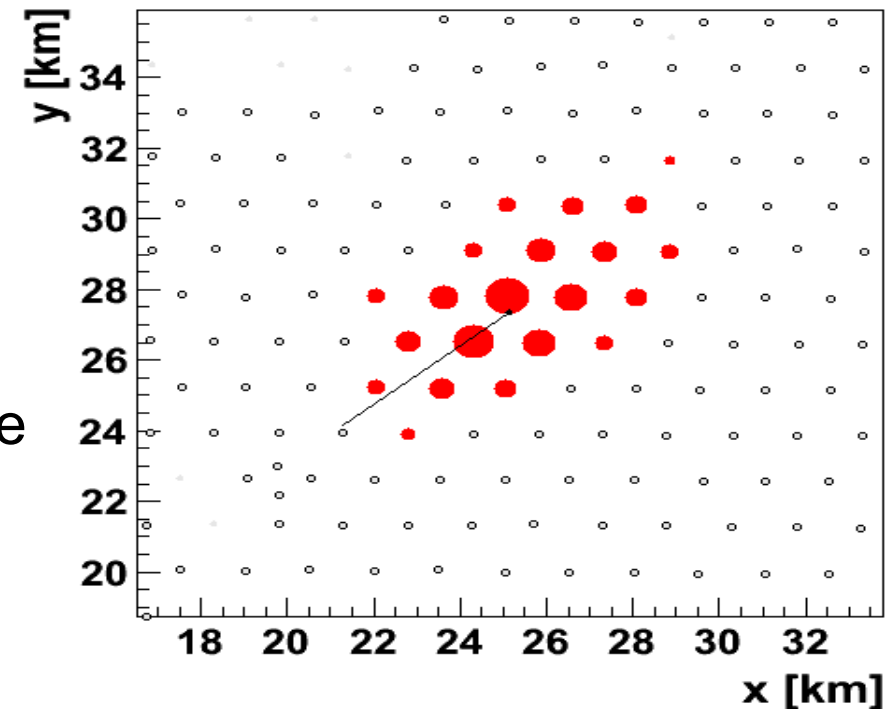
The starttime of the signals are use in a  $\chi^2$  fit to a shower front including curvature

- Likelihood method to fit a NKG function

### Fitting parameters

- Core position
- Size parameter (we call  $S(1000\text{m})$ )

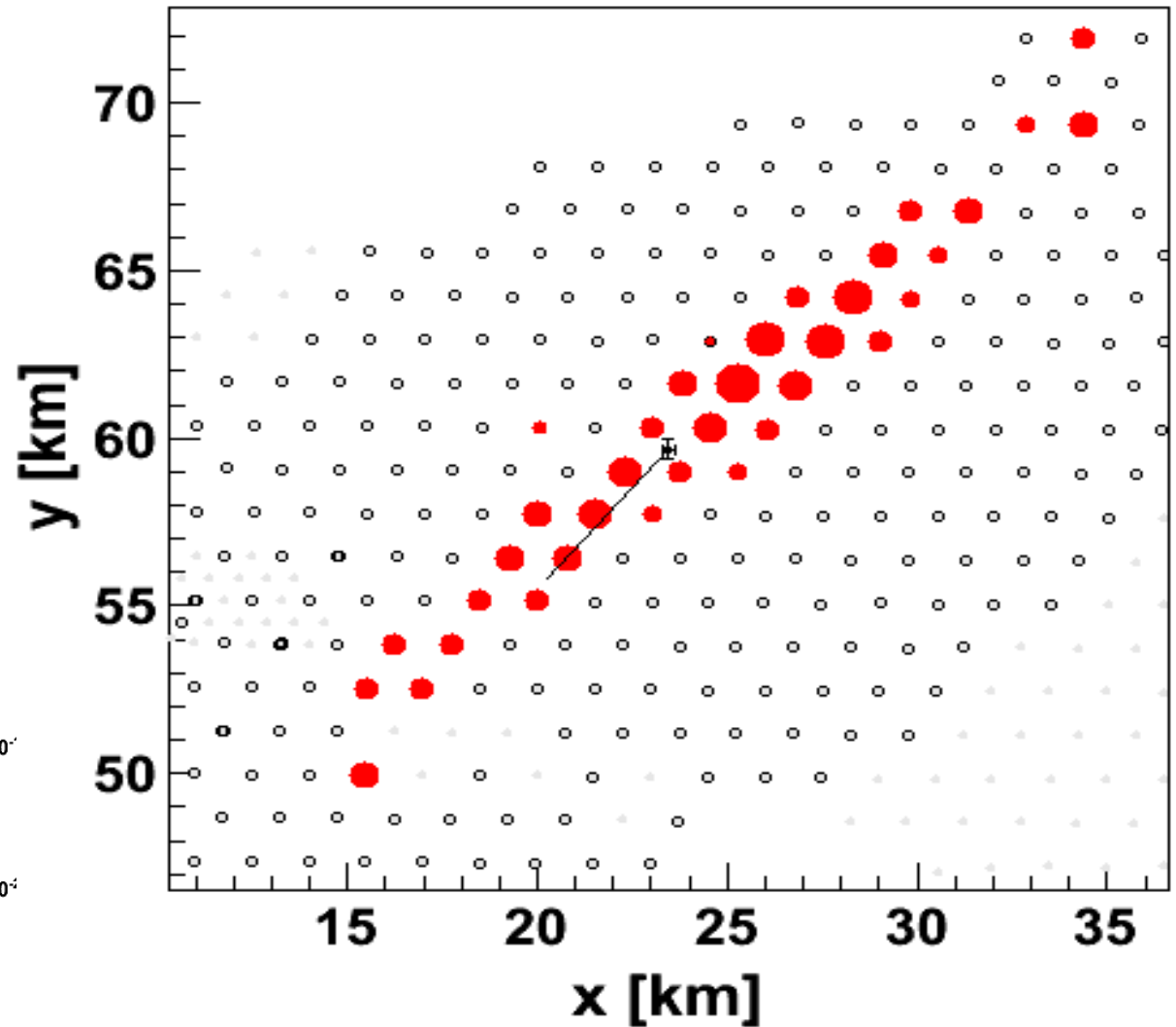
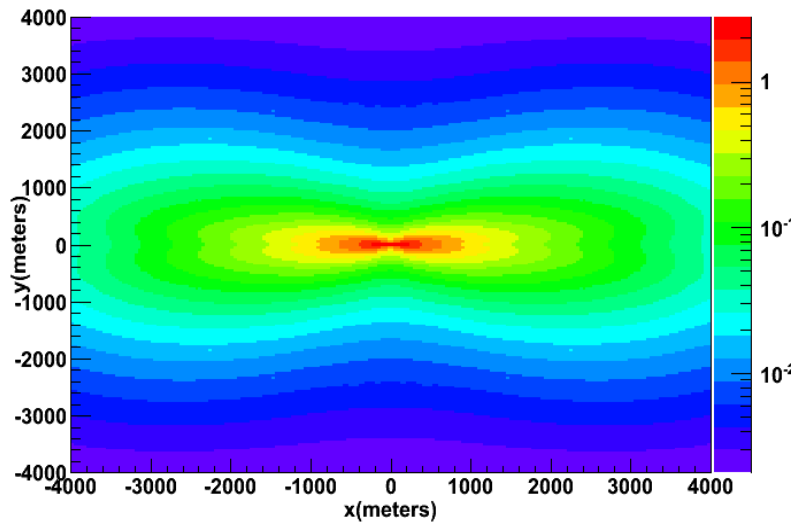
**From the size parameter we get the energy.**





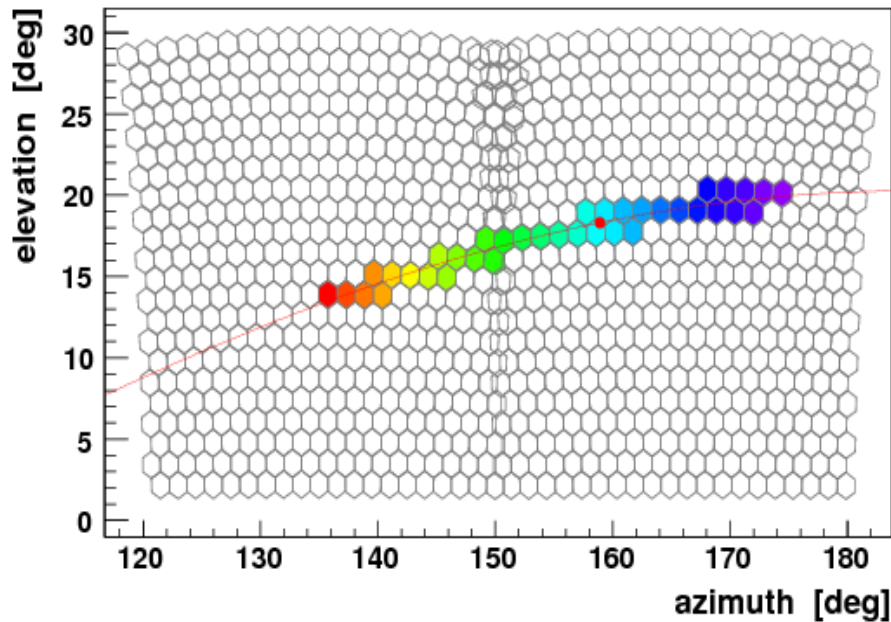
# SD event reconstruction above $60^0$

- EM component is absorbed in the atmosphere.
- Signals in the tanks are produced by muons
- Cylindrical symmetry is broken due to earth magnetic field
- Background for neutrino showers

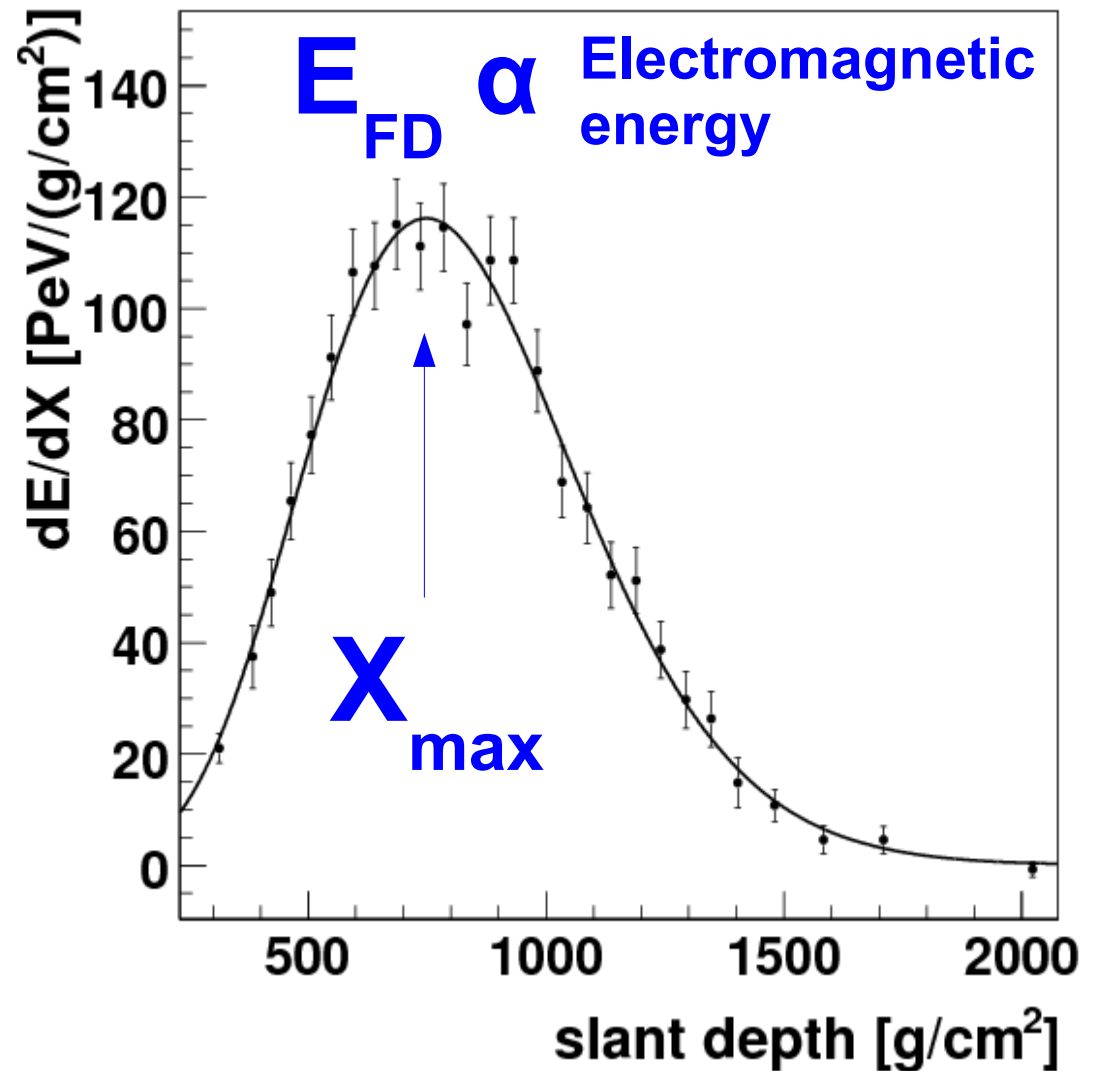


- The core position and size parameter are obtained using 2D muon density profiles.
- The size parameter is related with the number of muons at  $10^{19}$  eV.

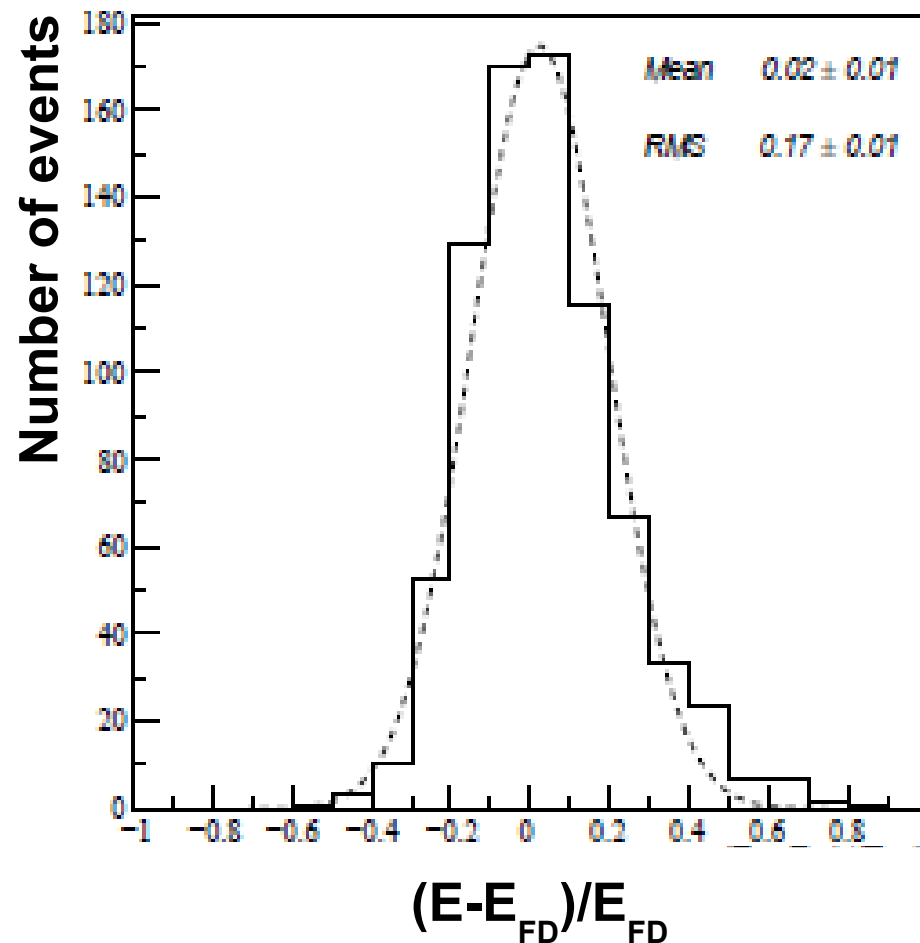
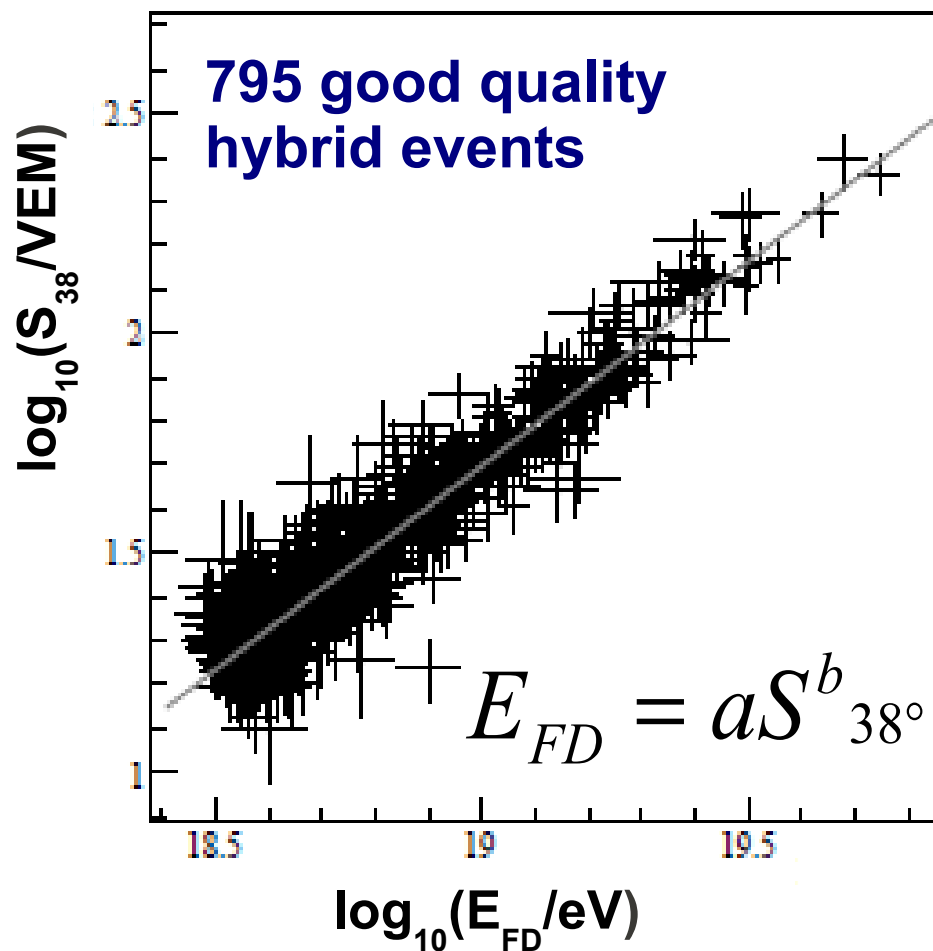
# FD event reconstruction



- Reconstruct geometry.
- Fit longitudinal shower profile.
- Calorimetric measurement
- Fluorescence energy independent of model.



# Energy calibration (Model Independent)



$a = 1.49 \pm 0.06(\text{stat}) \pm 0.12(\text{syst}) \times 10^{17} \text{ eV}$   
 $b = 1.08 \pm 0.01(\text{stat}) \pm 0.04(\text{syst})$   
 $\chi^2/\text{n.d.f.} = 1.1$

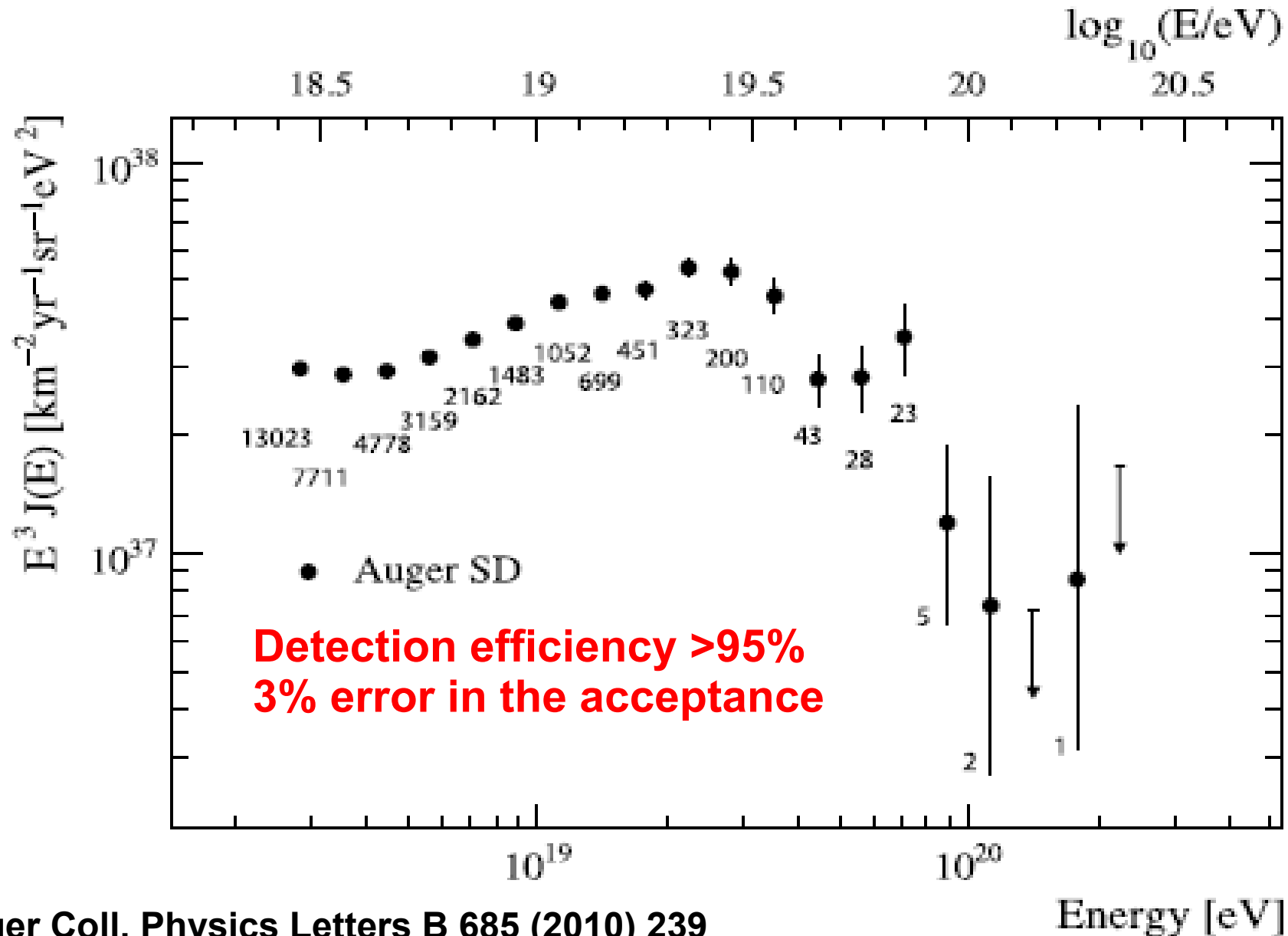
**Energy Resolution : 17%**



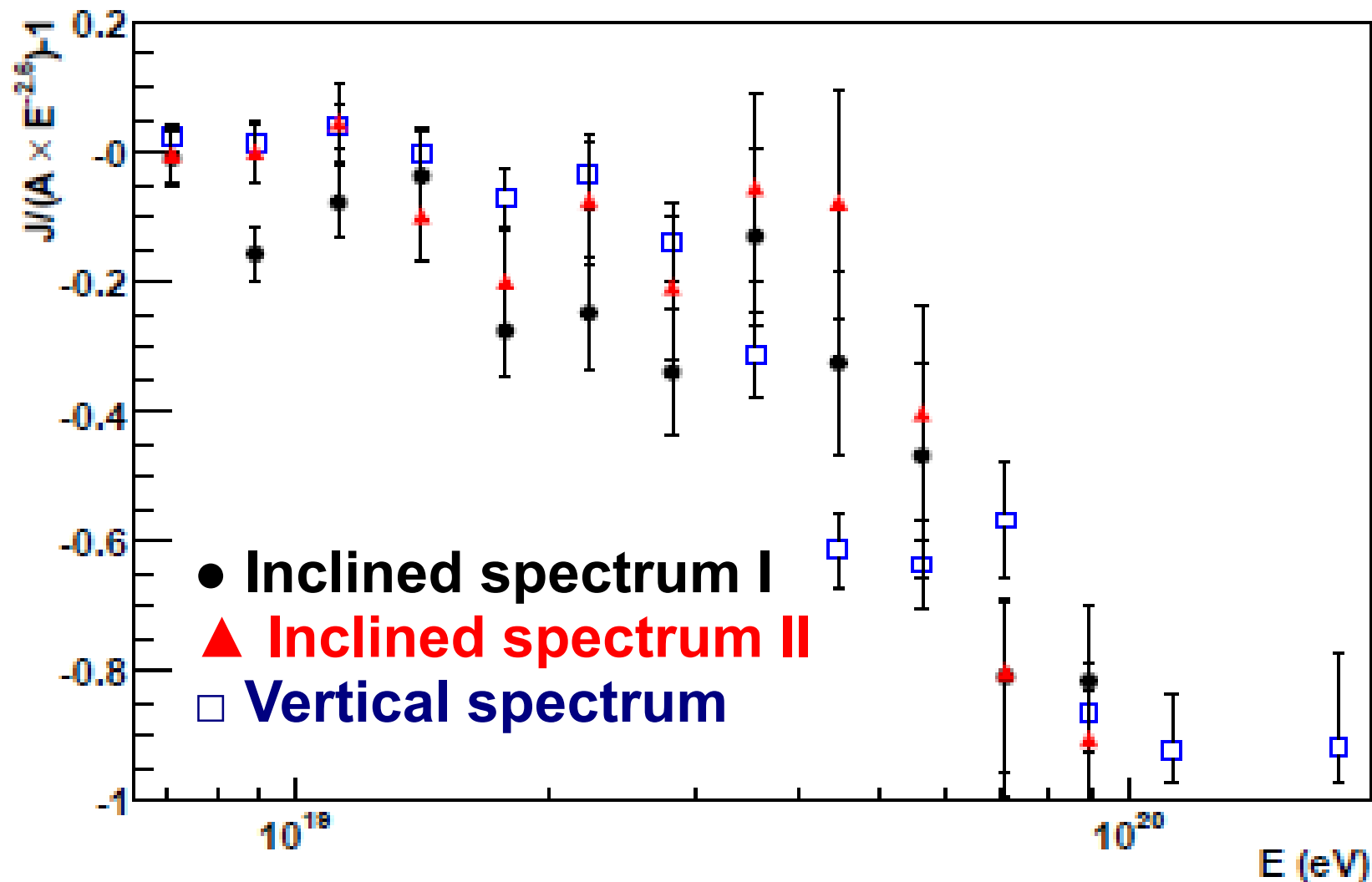
# Systematic uncertainties in the FD energy measurement

Source	Systematic uncertainty
- Fluorescence yield	14%
- P,T and humidity effects on yield	7%
- Calibration	9.5%
- Atmosphere	4%
- Reconstruction	10%
- Invisible energy	4%
<b>TOTAL</b>	<b>22%</b>

# Energy Spectrum with SD events below $60^\circ$

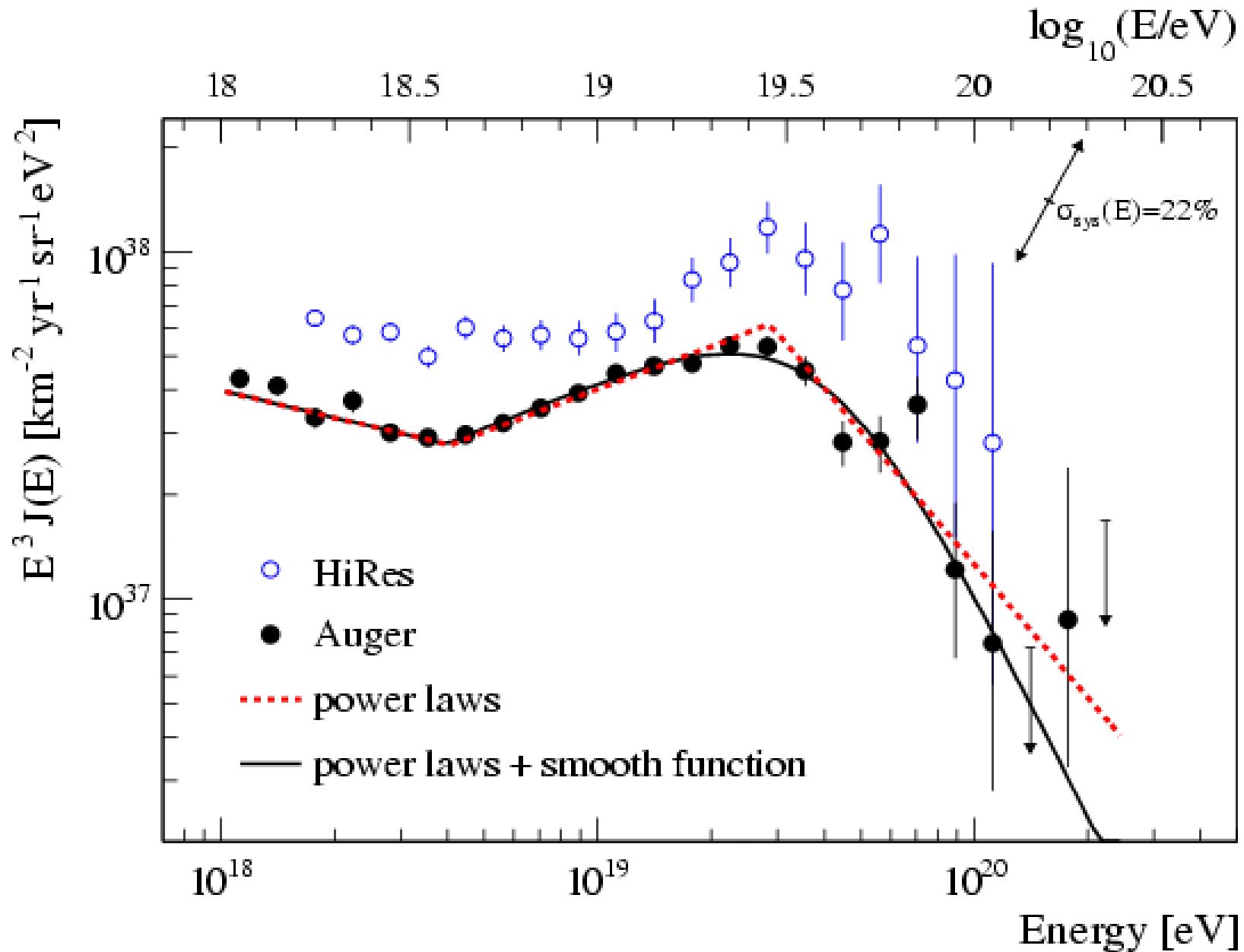


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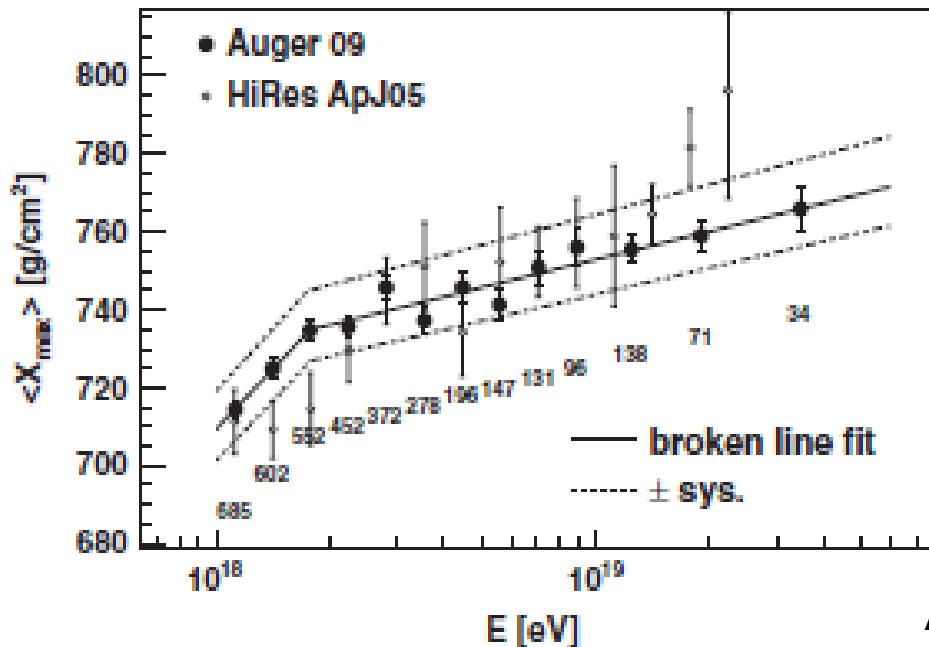
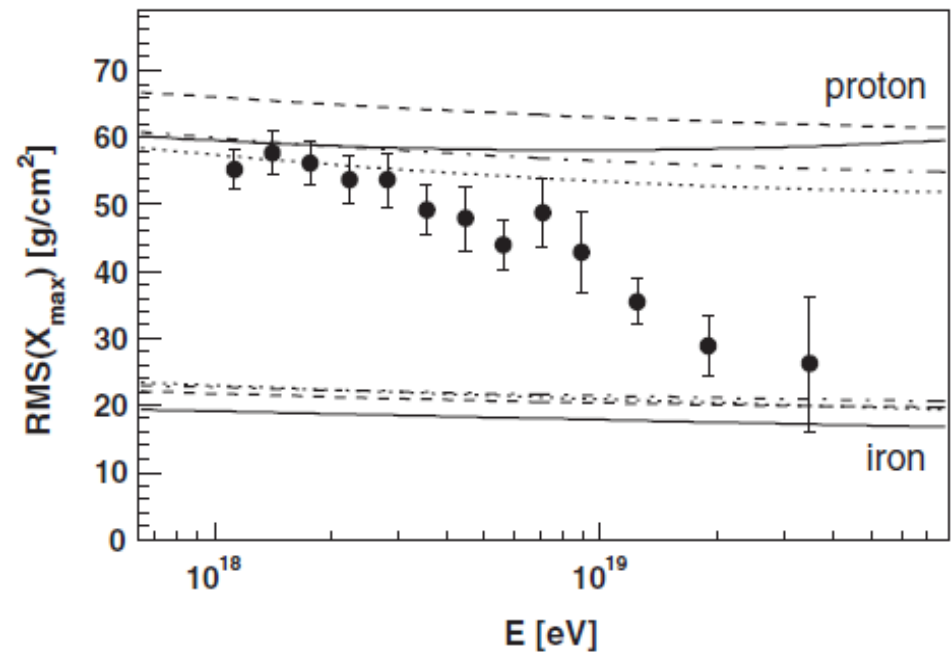
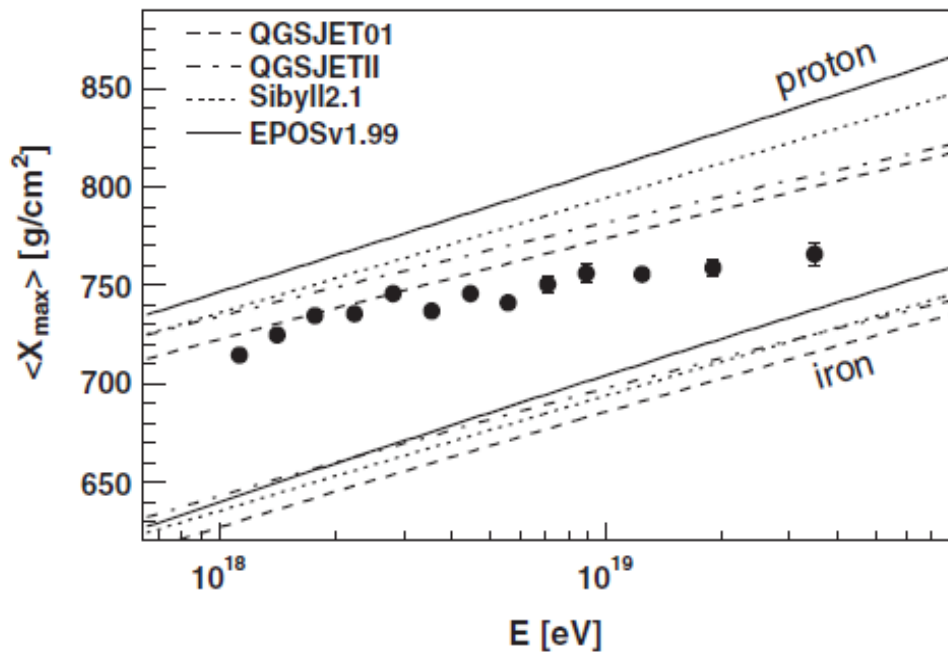


# Combined Energy Spectrum: SD + Hybrid



# Composition

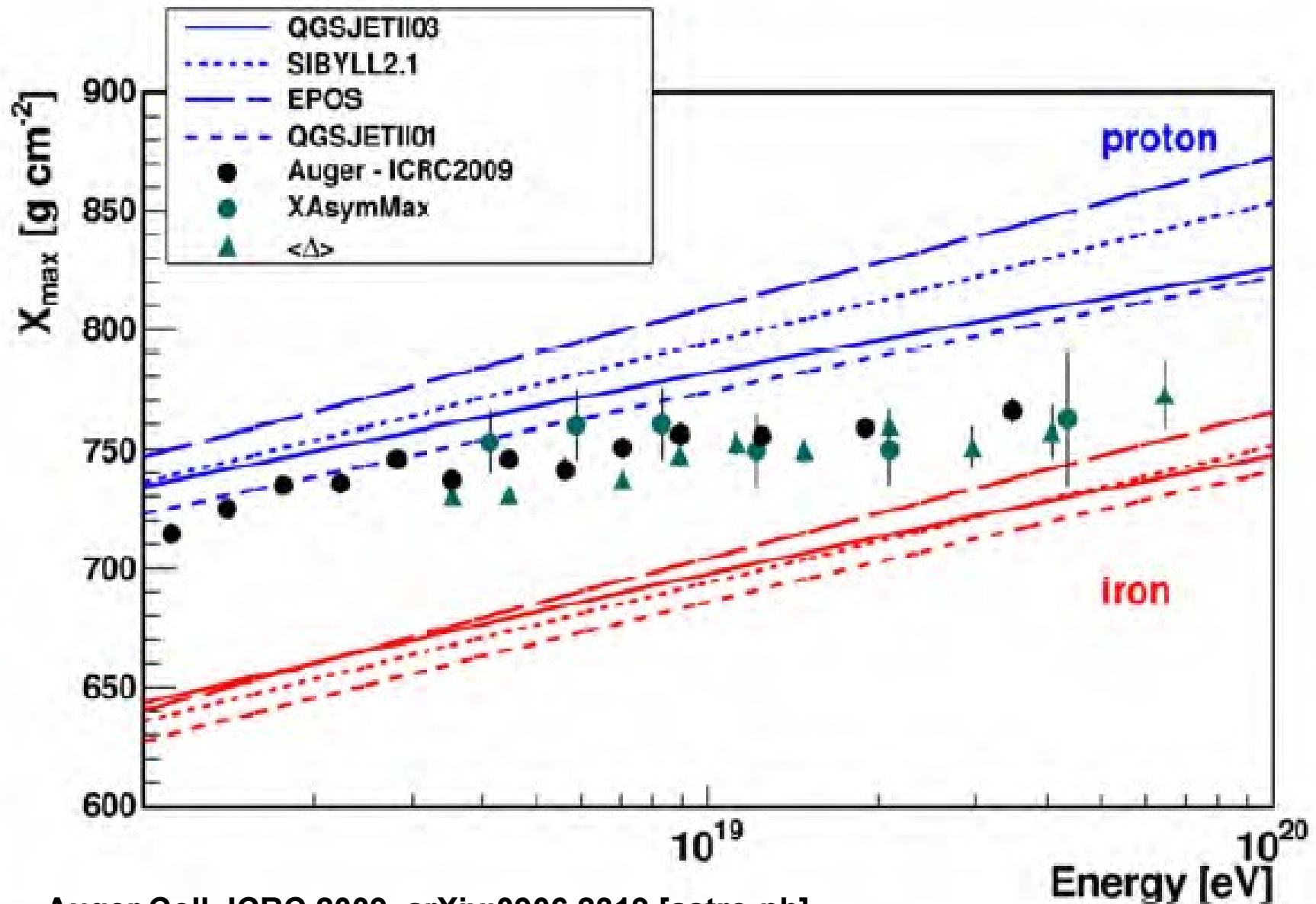
# Composition from FD events



$$\langle X_{\max} \rangle = D_{10} \log(E/A) + C$$

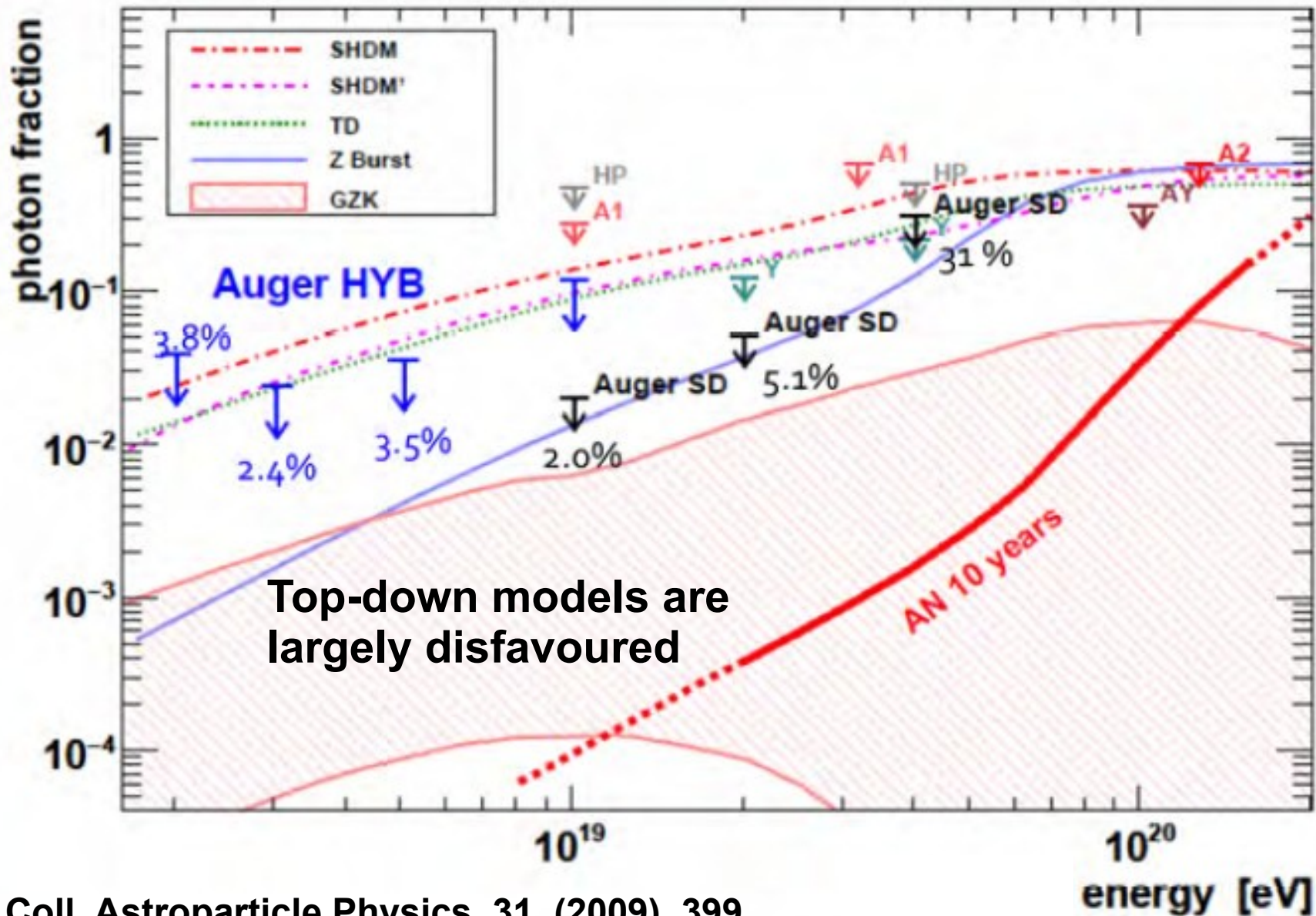
Data suggest a break around the ankle energy

# Composition from SD events



# Photon upper limits:

## Very good $\gamma$ -Hadron Discrimination

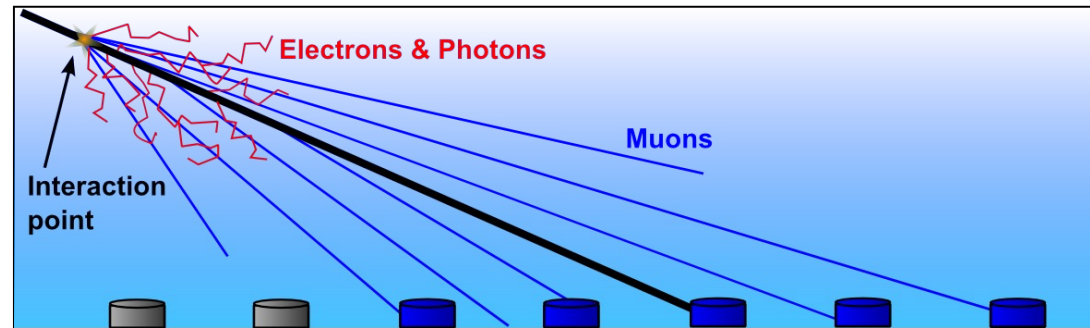




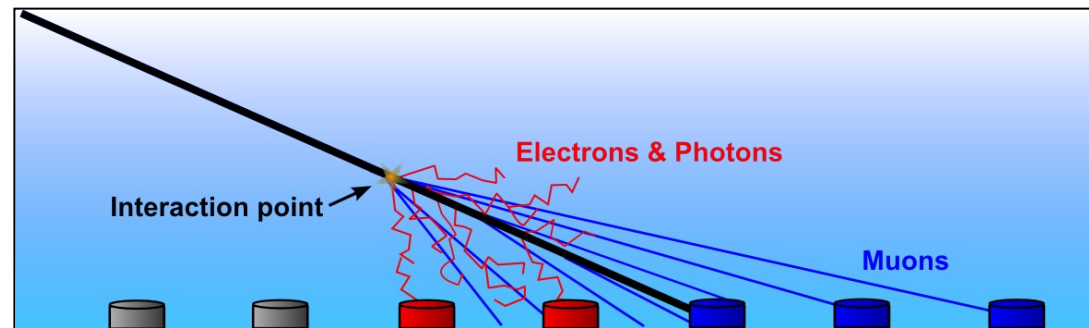
# Neutrino searches

## Inclined & Deep Showers

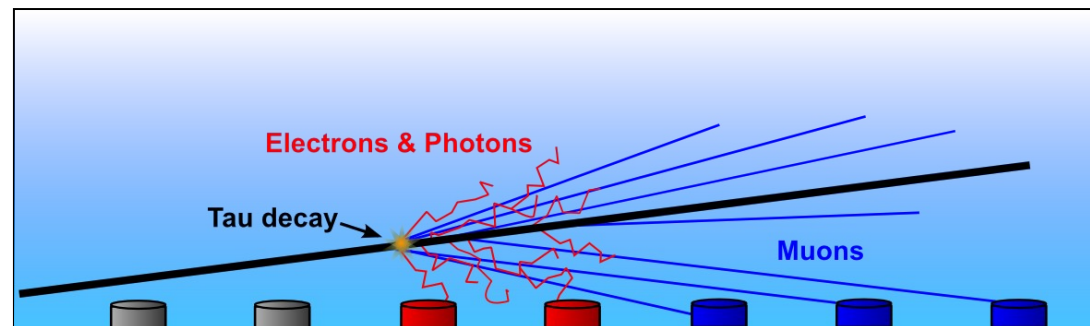
Regular hadronic shower



Deep downgoing neutrino shower



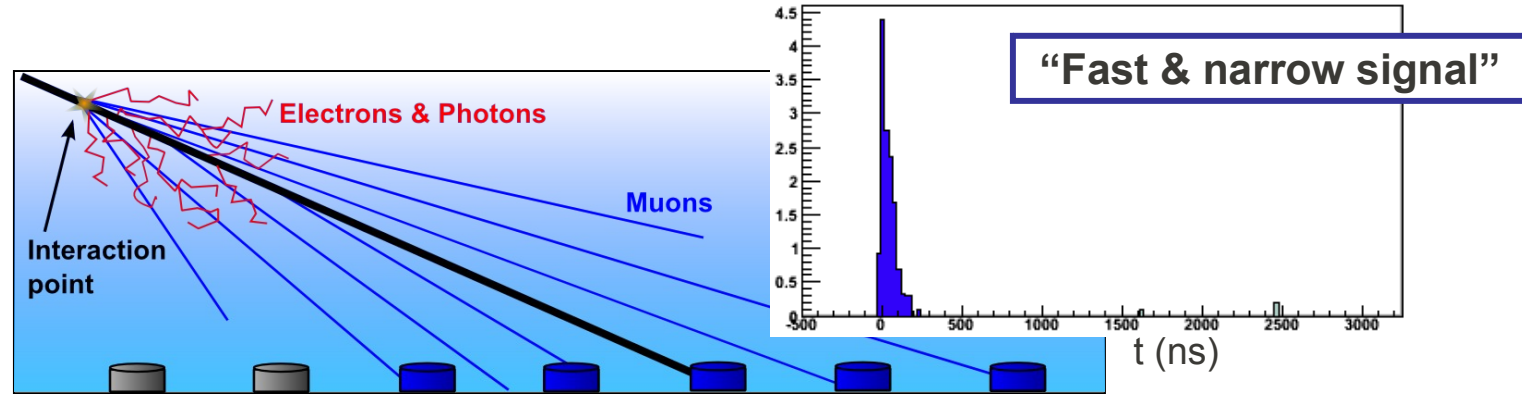
Deep upgoing neutrino shower



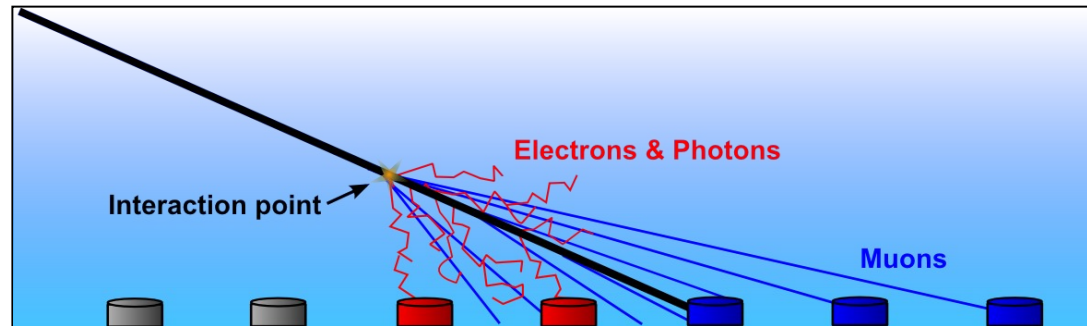
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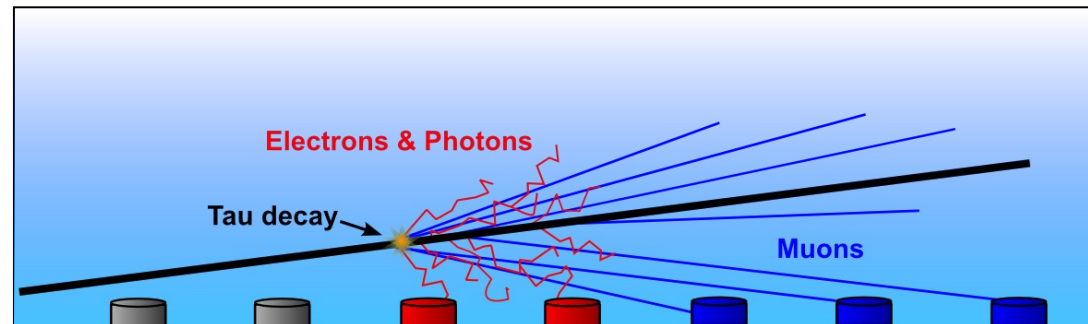
Regular  
hadronic shower



Deep downgoing  
neutrino shower



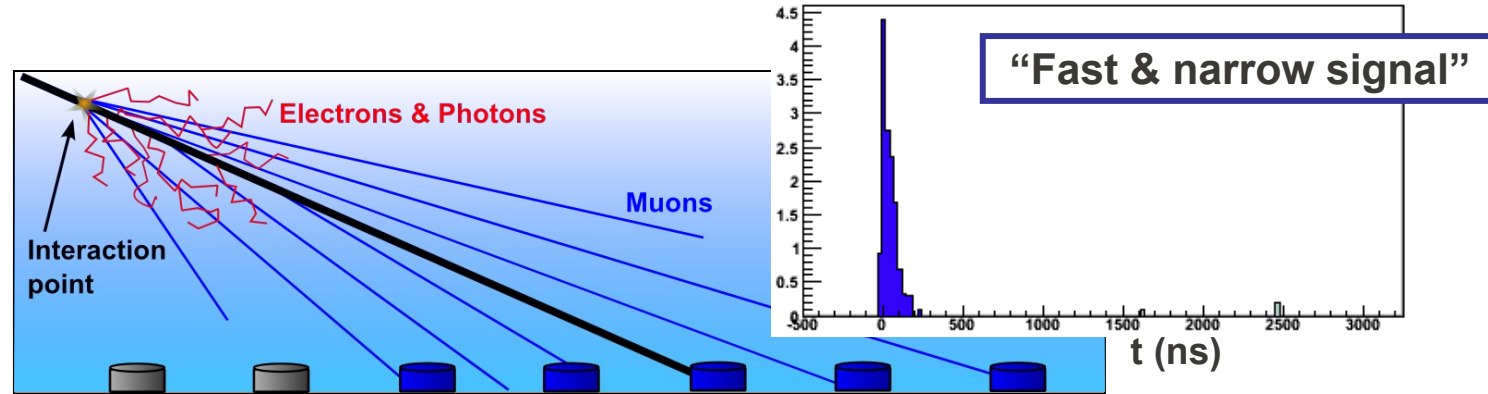
Deep upgoing  
neutrino shower



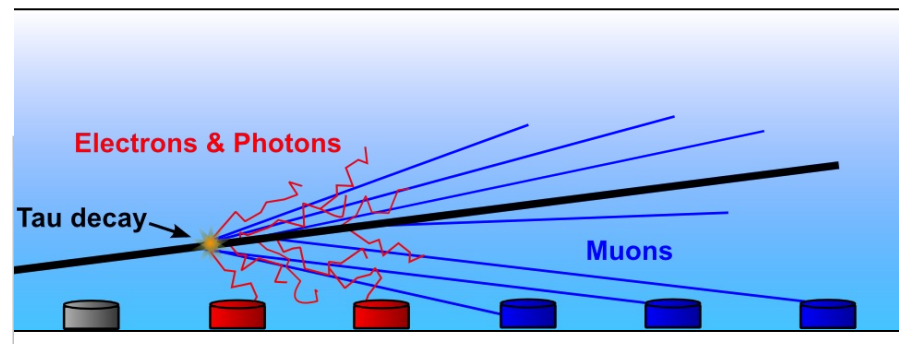
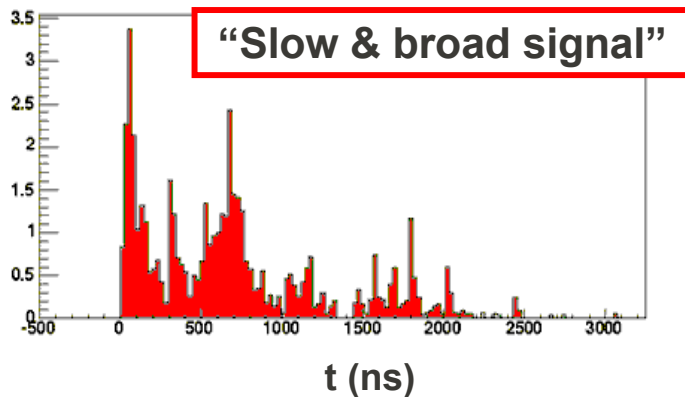
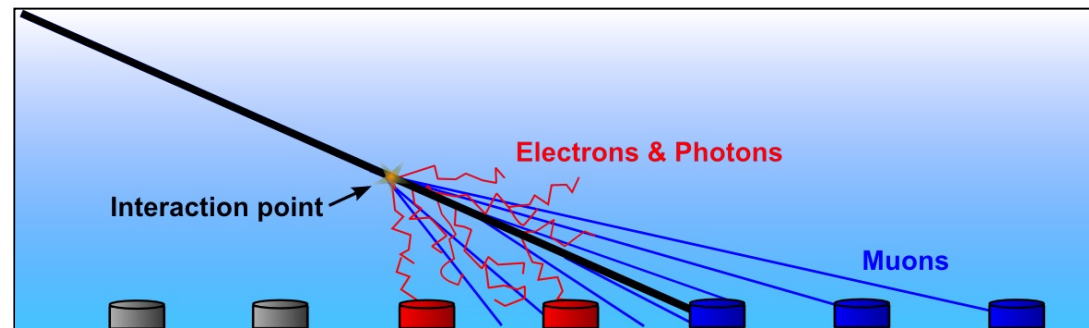
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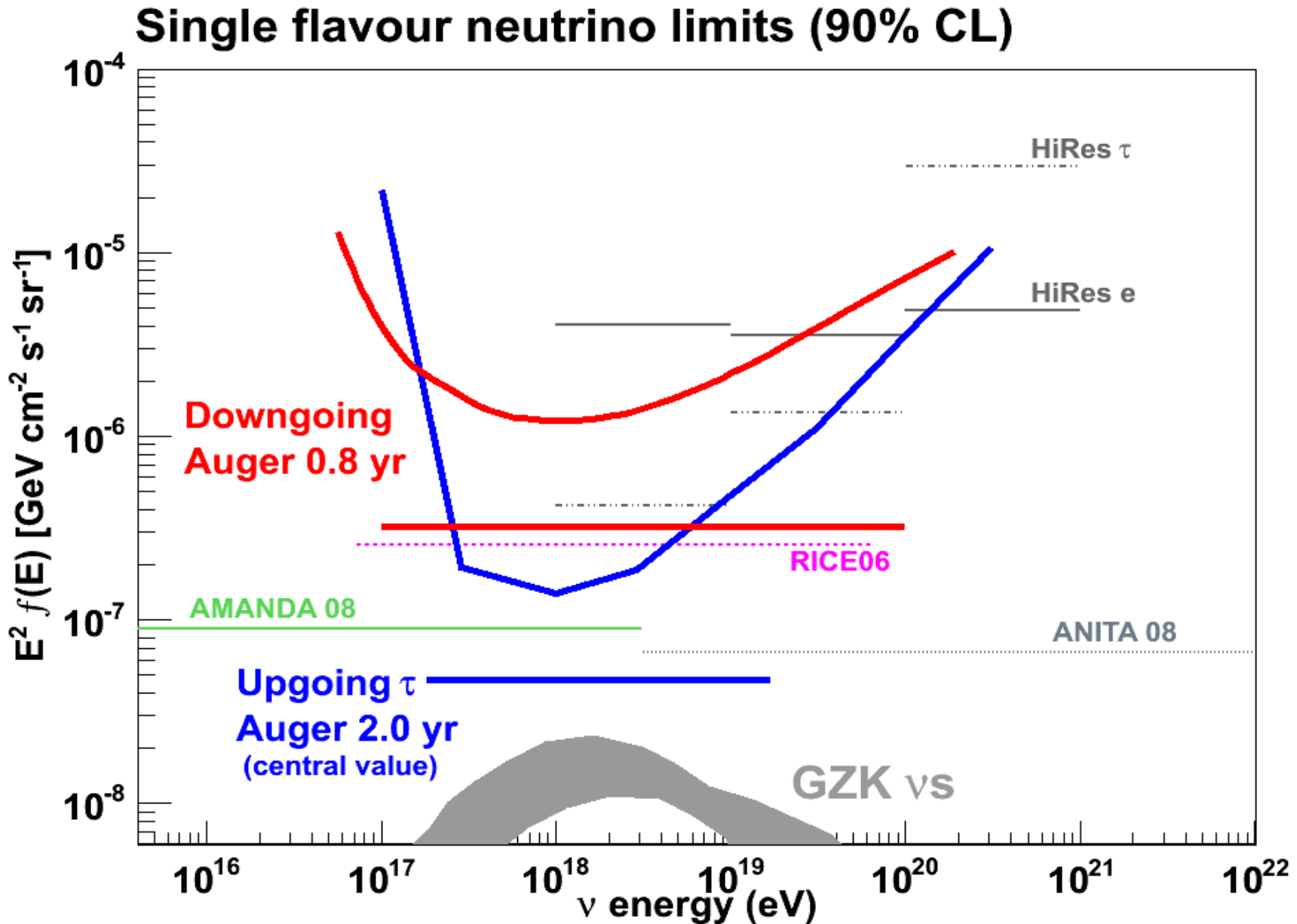
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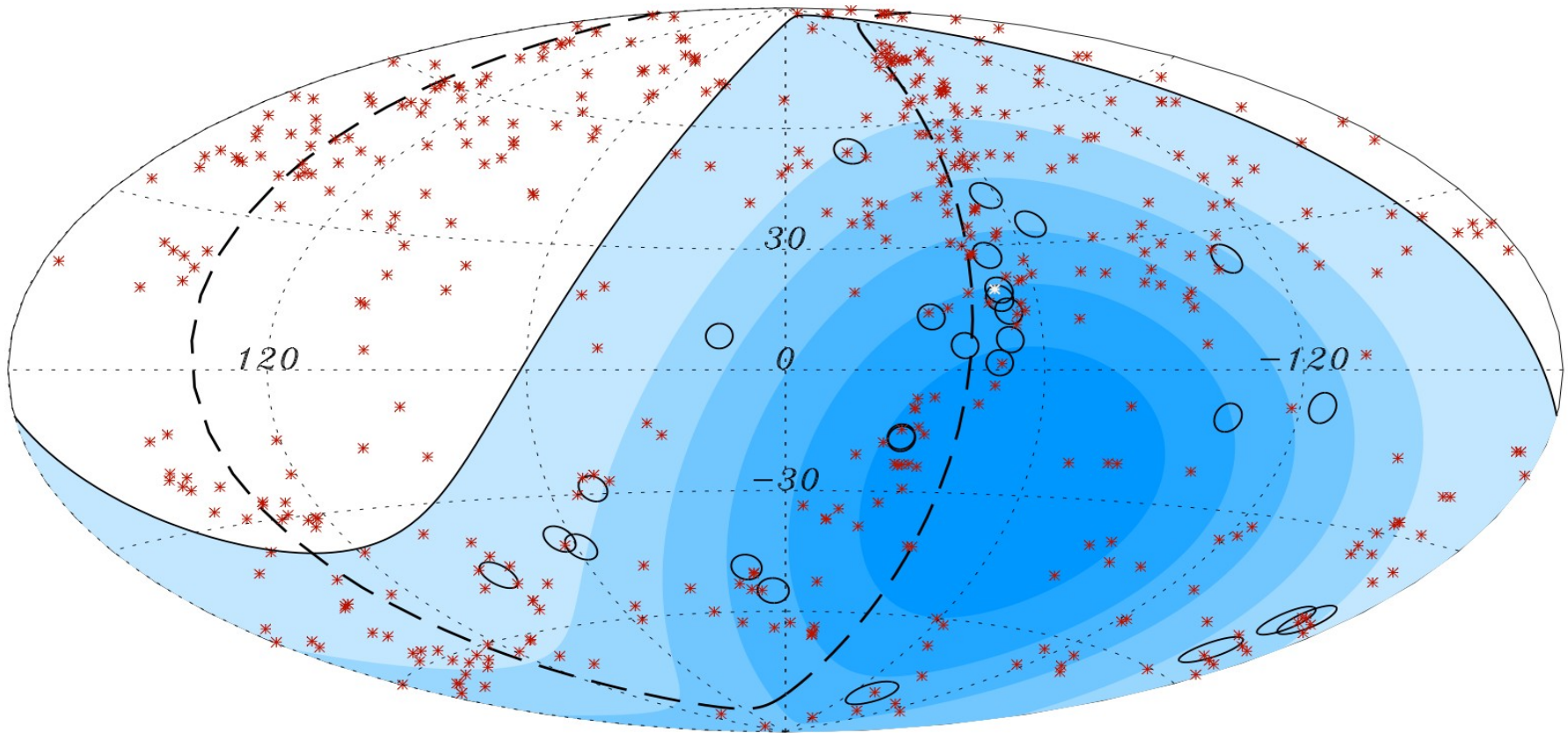
# Neutrino flux upper limits



# Arrival Direction



# Correlation with AGNs (12<sup>th</sup> VCV)



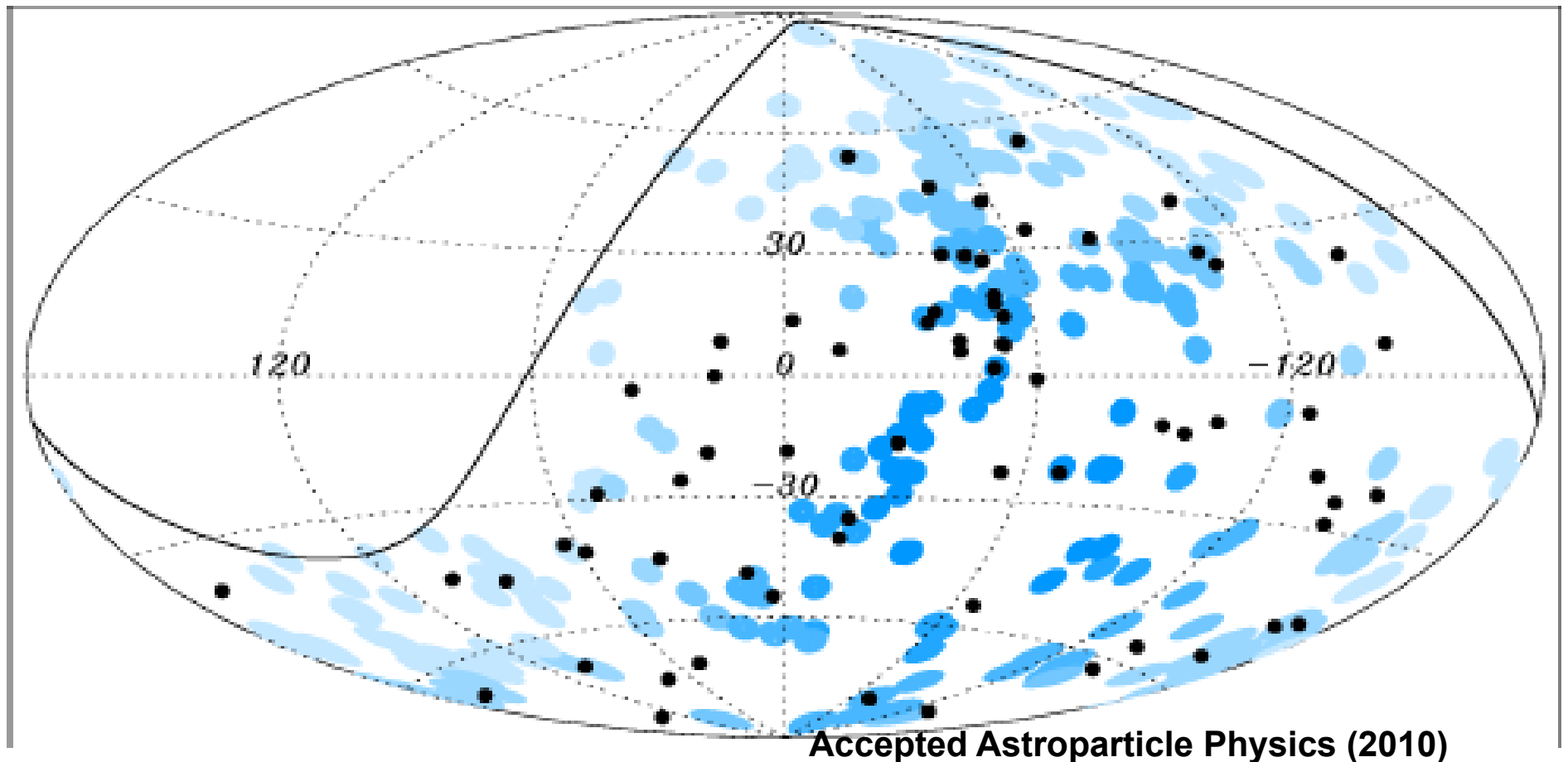
- From Jan/2004 to May/2006 → a scanning was performed
- We found a minimum at parameter:

$$E_{th} = 56 \text{ EeV}, D_{max} = 75 \text{ Mpc} (z_{max} = 0.018) \text{ and } \psi = 3.1^{\circ}.$$

- For this values: 13 out of 15 correlated with AGNs
- Fraction expected under isotropic hypothesis:  $P_{iso} = 21\%$
- Test with later data, until 31/August/2007, we found 8 out 13 events

**Isotropy rejected at 99% C.L.**

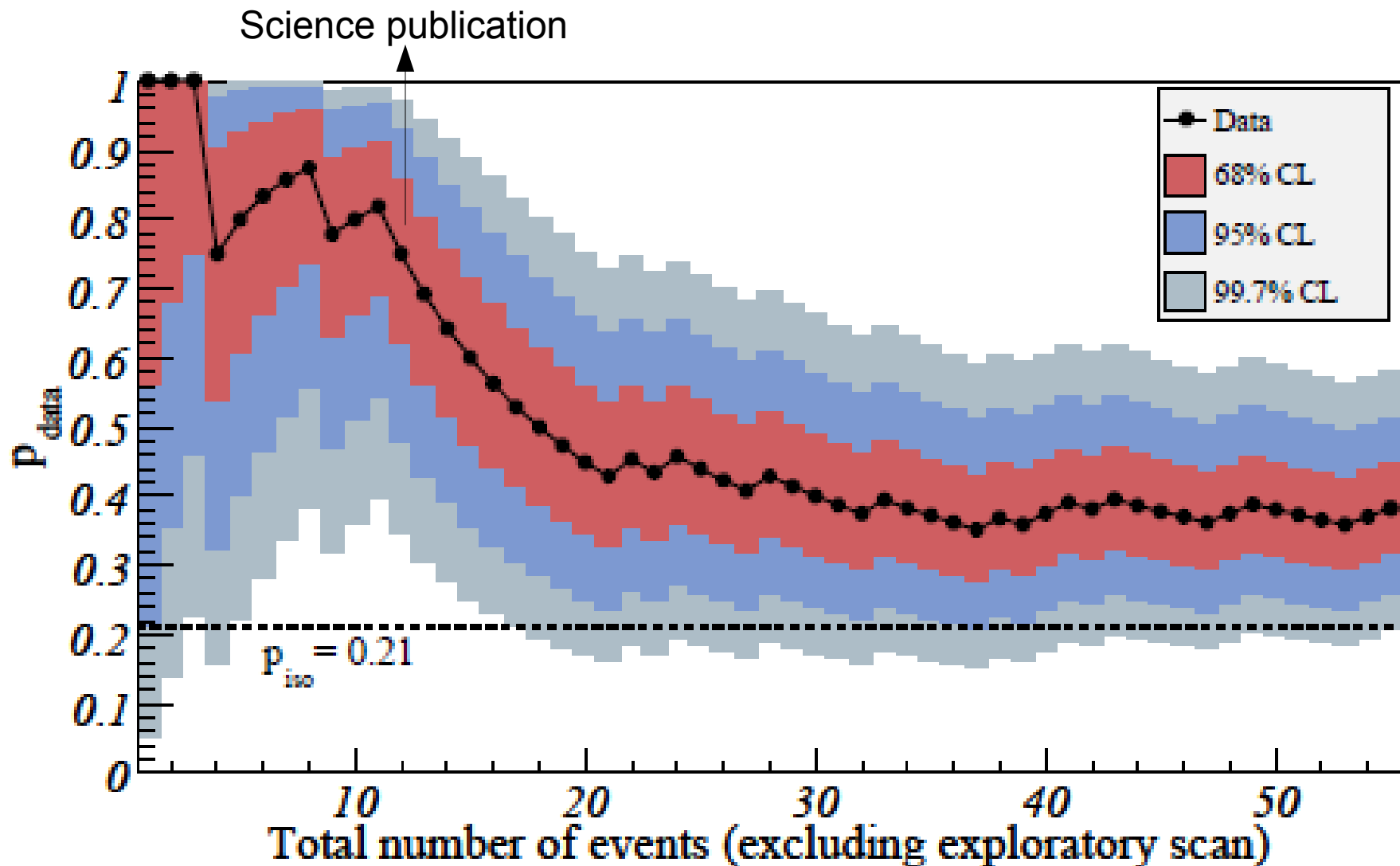
# Update



- 21 out of 55 events correlate with AGNs.
- Correlation decreased from  $(69 \pm 12)\%$  to  $(38 \pm 7)\%$
- Fraction expected under isotropic hypothesis: 21%

# Update

## Degree of correlation



# Conclusions

## Energy Spectrum for $E > 10^{18}$ eV

- We observe a change in the slope at  $\log_{10}(E/\text{eV}) = 18.61 \pm 0.01$ .
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## Mass Composition

- From composition studies there is an indication that CRs become heavier at higher energies.
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## Arrival Direction Distribution

- We observe a correlate with matter in the nearby universe above 56 EeV.