# Decoherence Curve and Chemical Composition in CosmoALEPH


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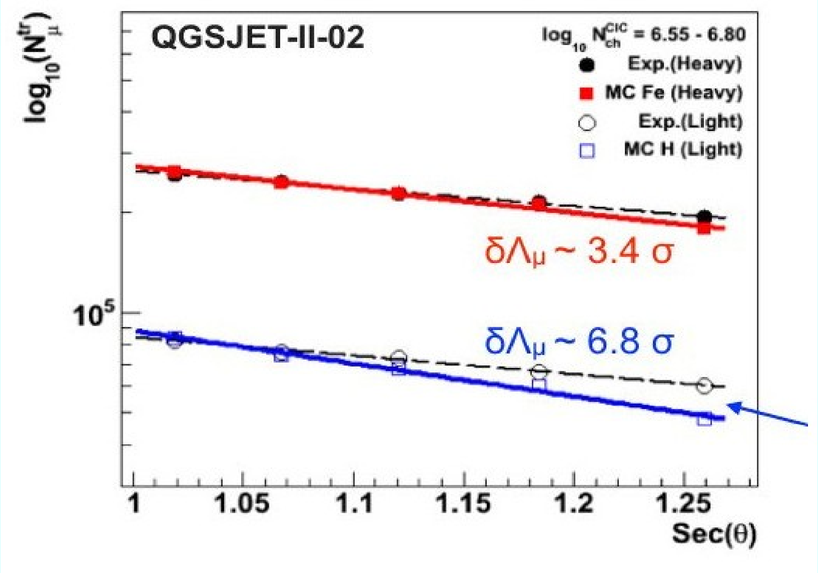
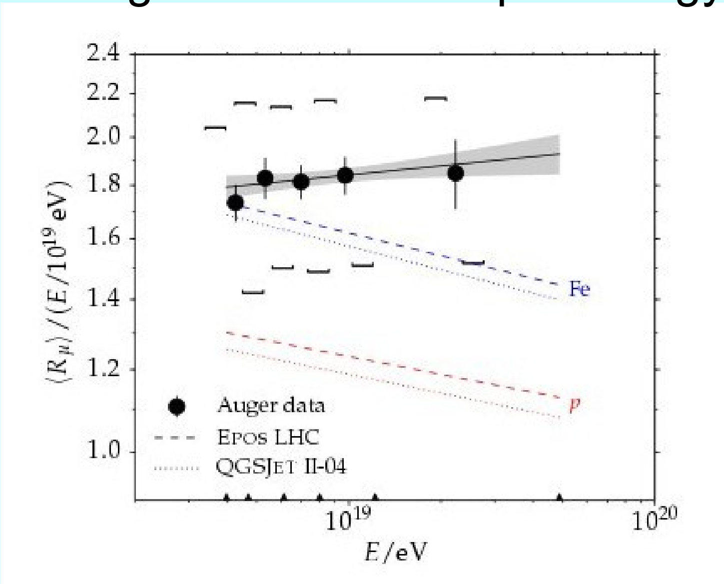
# Motivation

**The muon lateral distributions from Auger and KASCADE-Grande are not in perfect agreement with Monte Carlo predictions.**
**CosmoALEPH only measures the muon component of air showers underground.**
**Possibly CosmoALEPH can throw some light on this problem.**



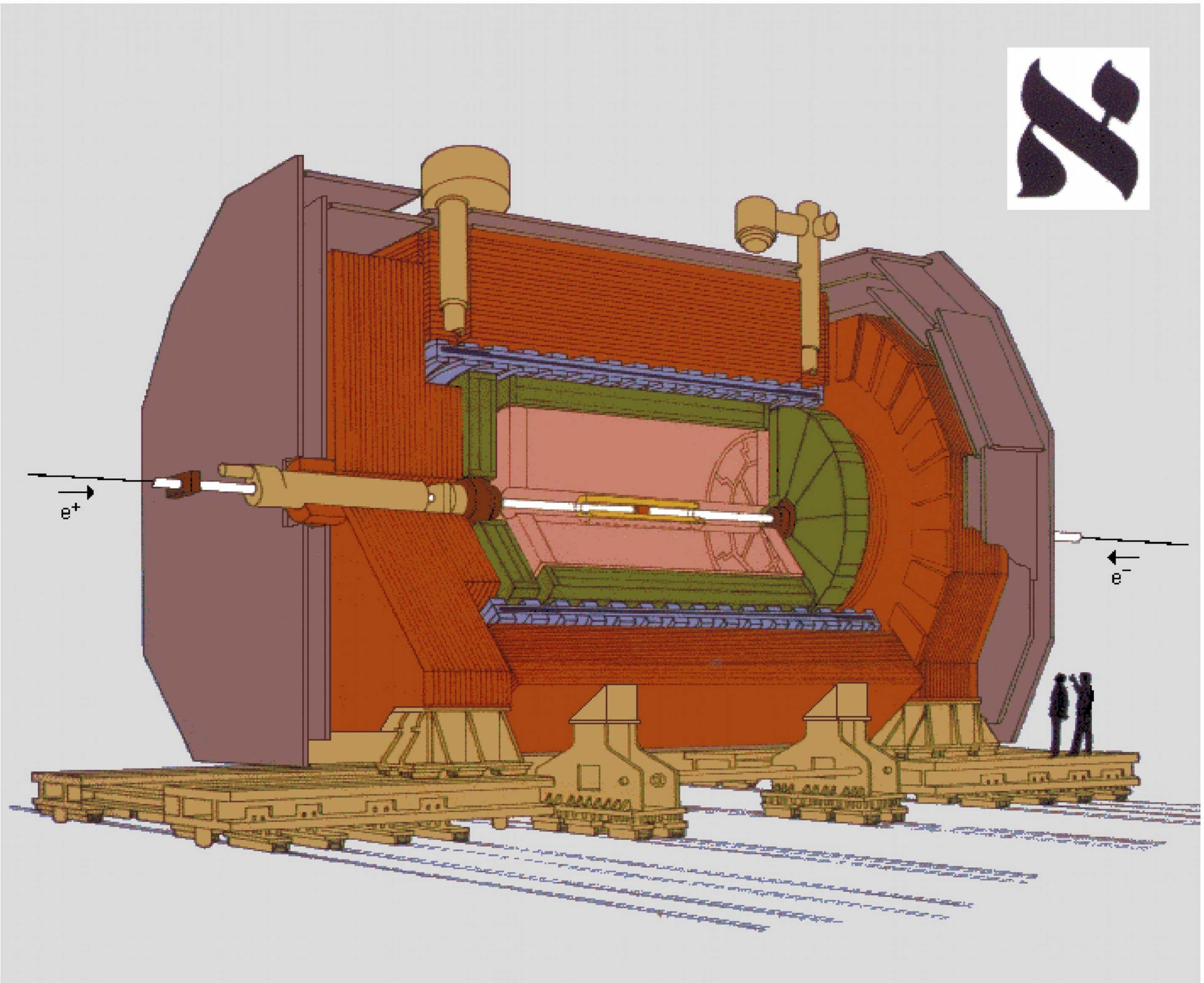

Juan Carlos Arteaga, KASCADE-Grande

Average muon content per energy



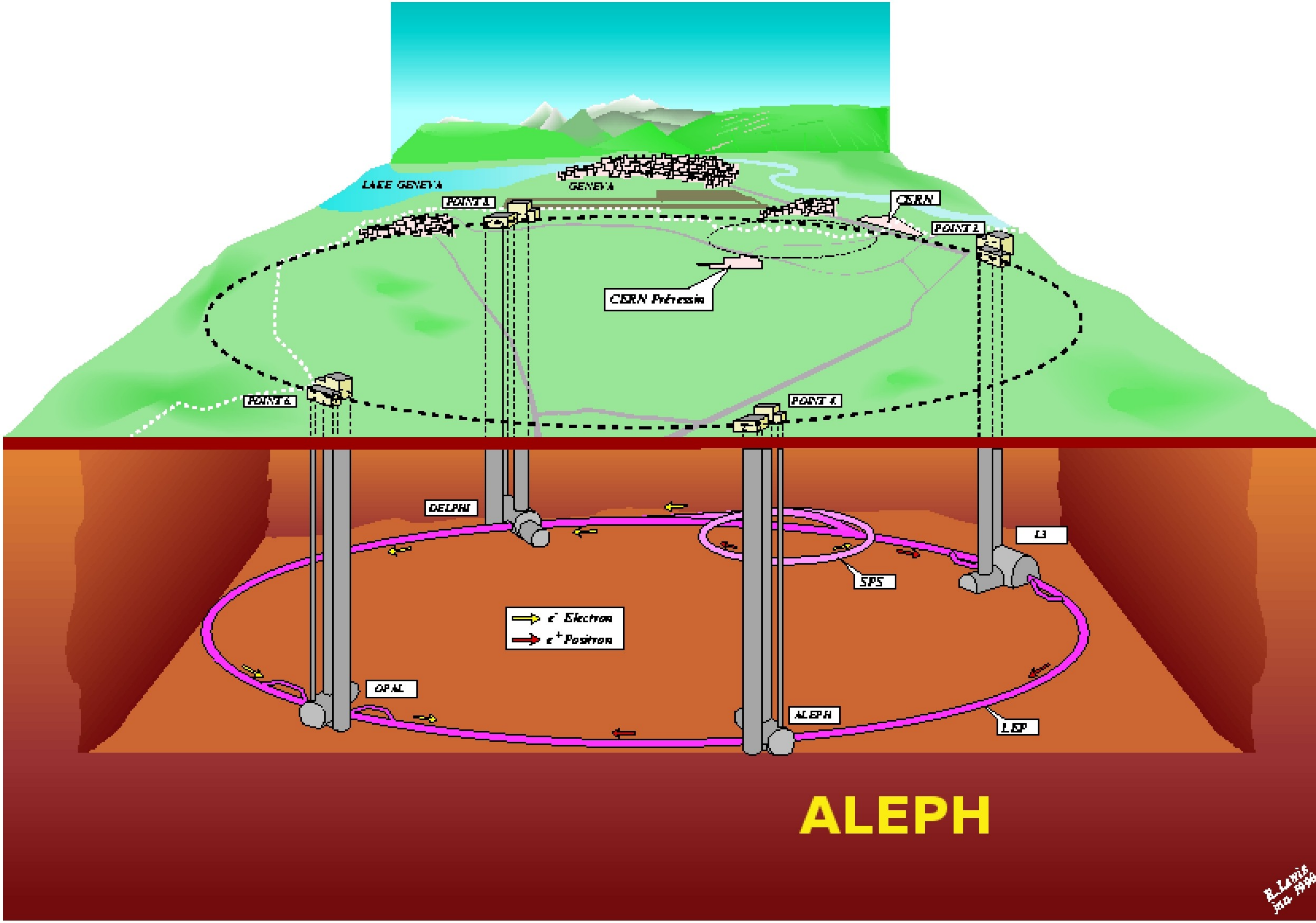

Auger (A. Aab et al. Phys. Rev. D 2015)

# The ALEPH-experiment



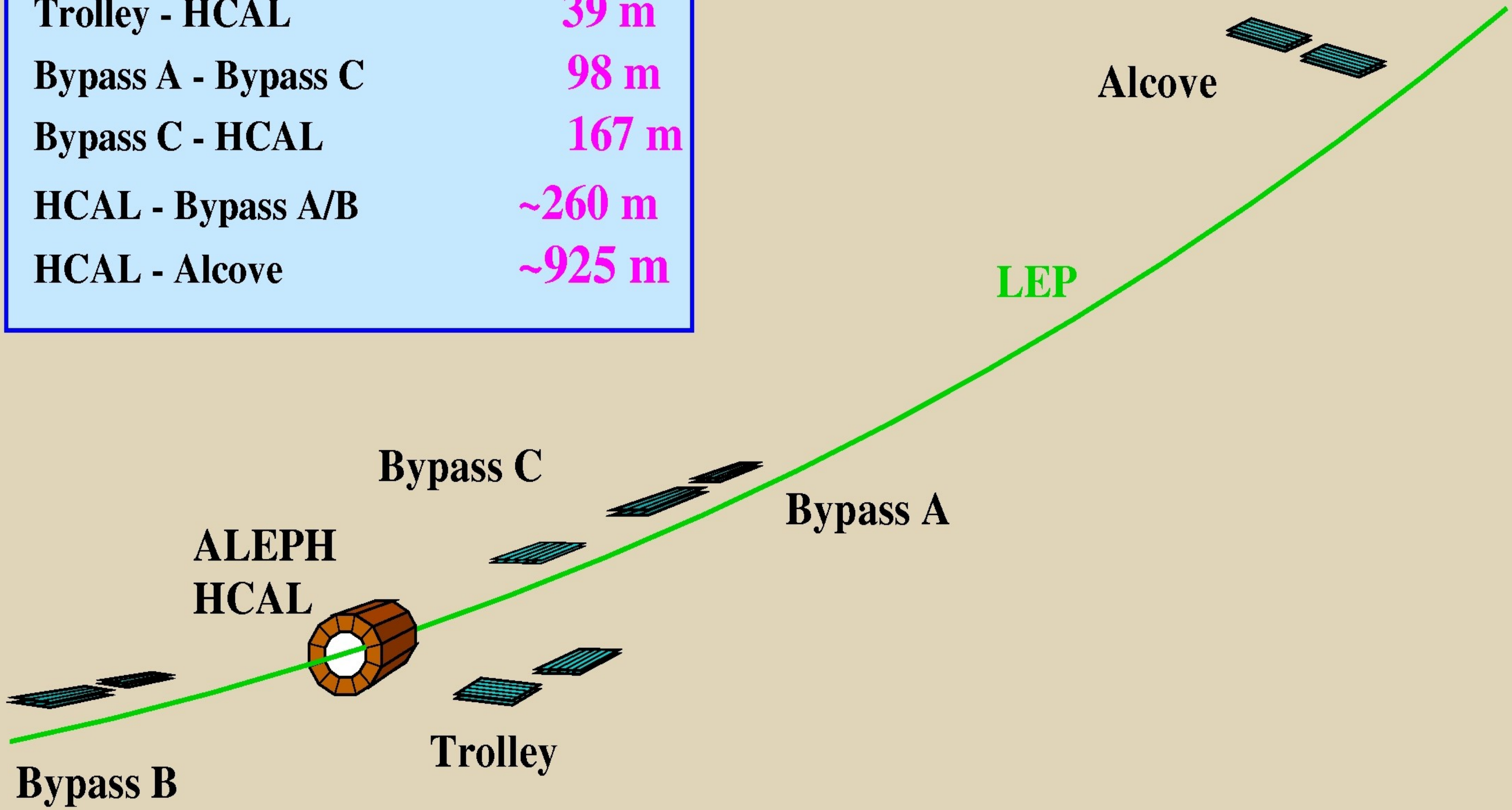

- Vertex Detector
- Inner Tracking Chamber
- Time Projection Chamber
- Electromagnetic Calorimeter
- Superconducting Magnet Coil
- Hadron Calorimeter
- Muon Chambers
- Luminosity Monitors

LEP at CERN (Geneva) , CosmoALEPH -320 m.w.e.



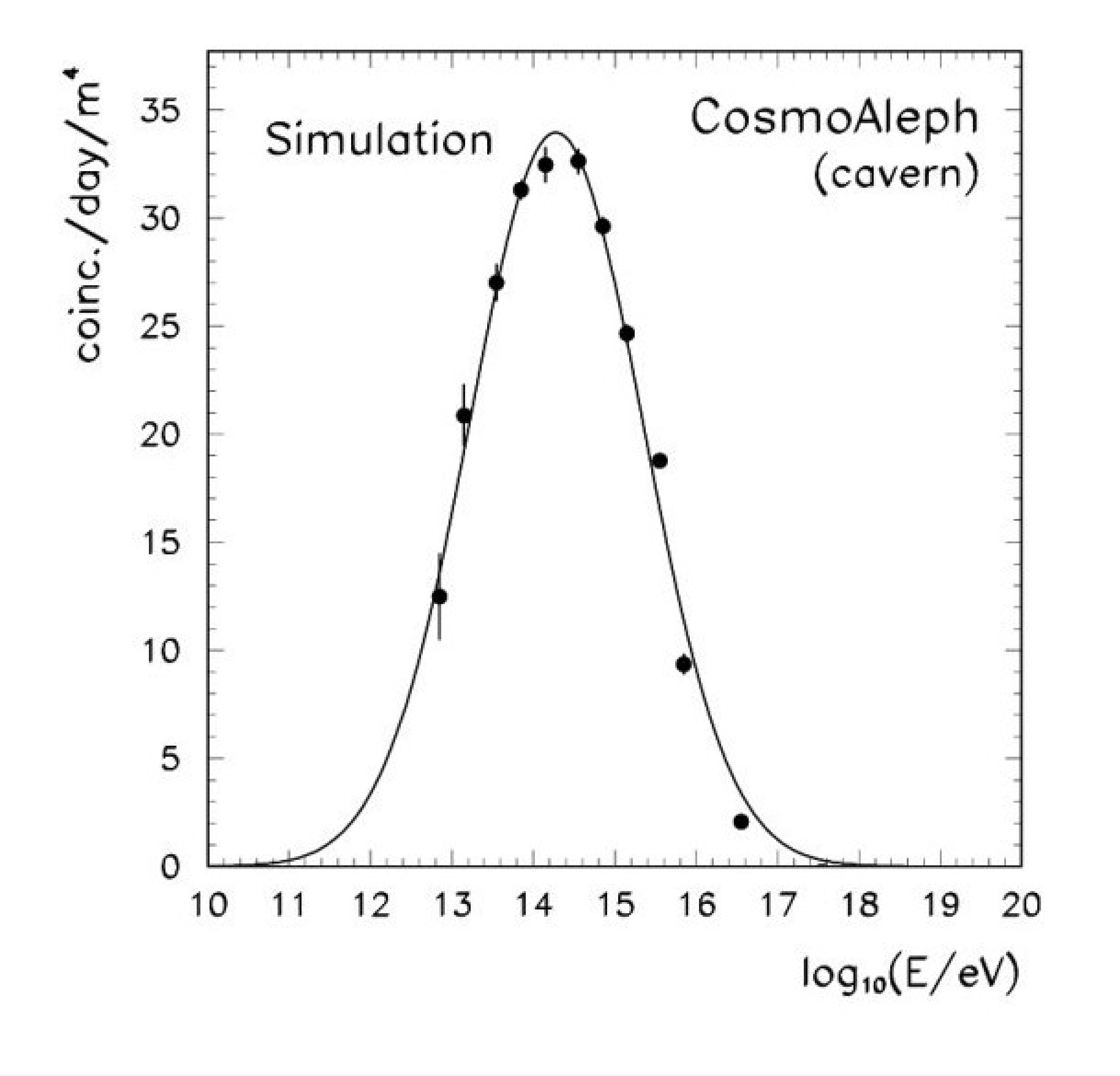
## Distances:

| | |
|---|---|
| Trolley - HCAL | 39 m |
| Bypass A - Bypass C | 98 m |
| Bypass C - HCAL | 167 m |
| HCAL - Bypass A/B | ~260 m |
| HCAL - Alcove | ~925 m |

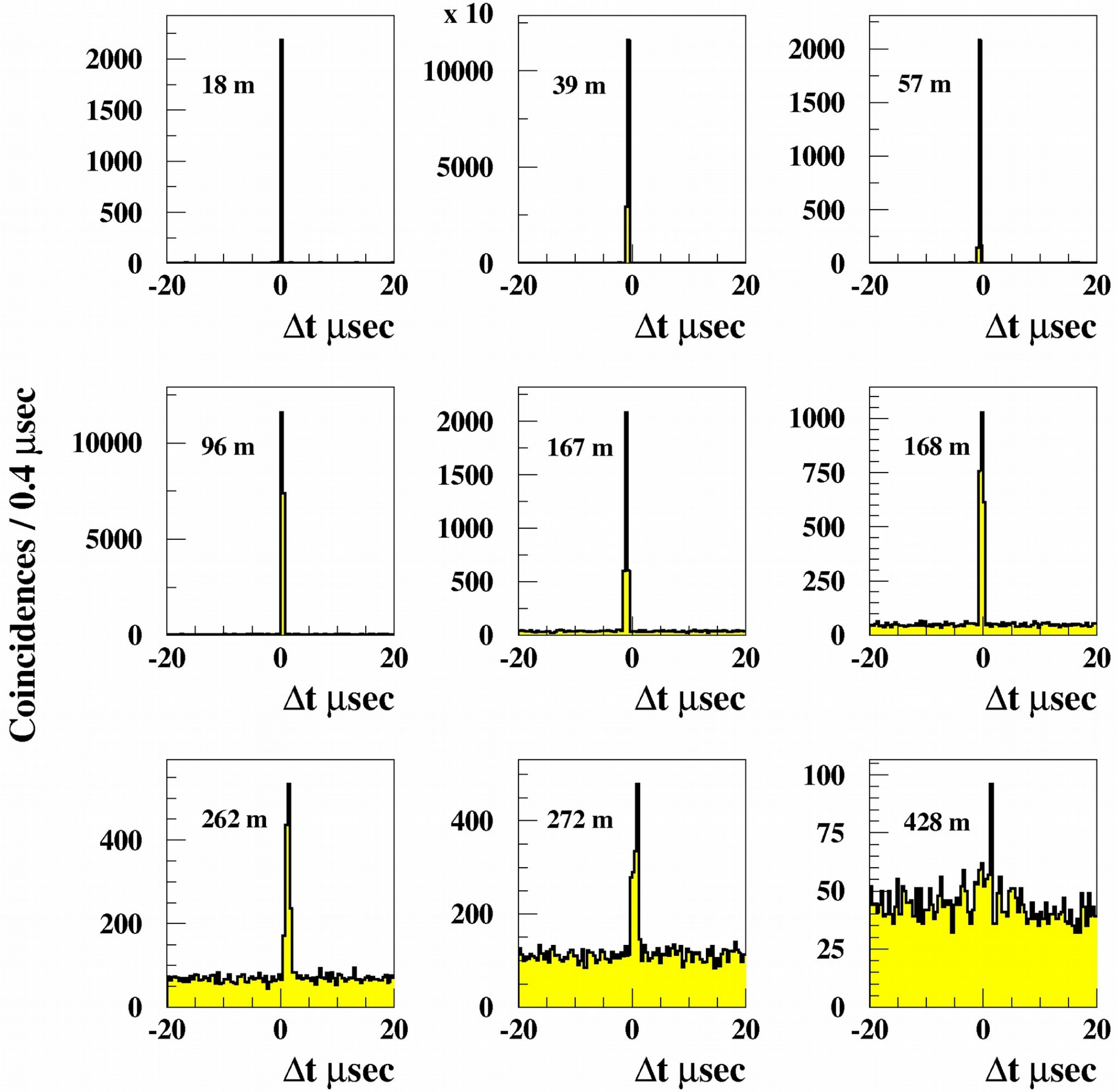


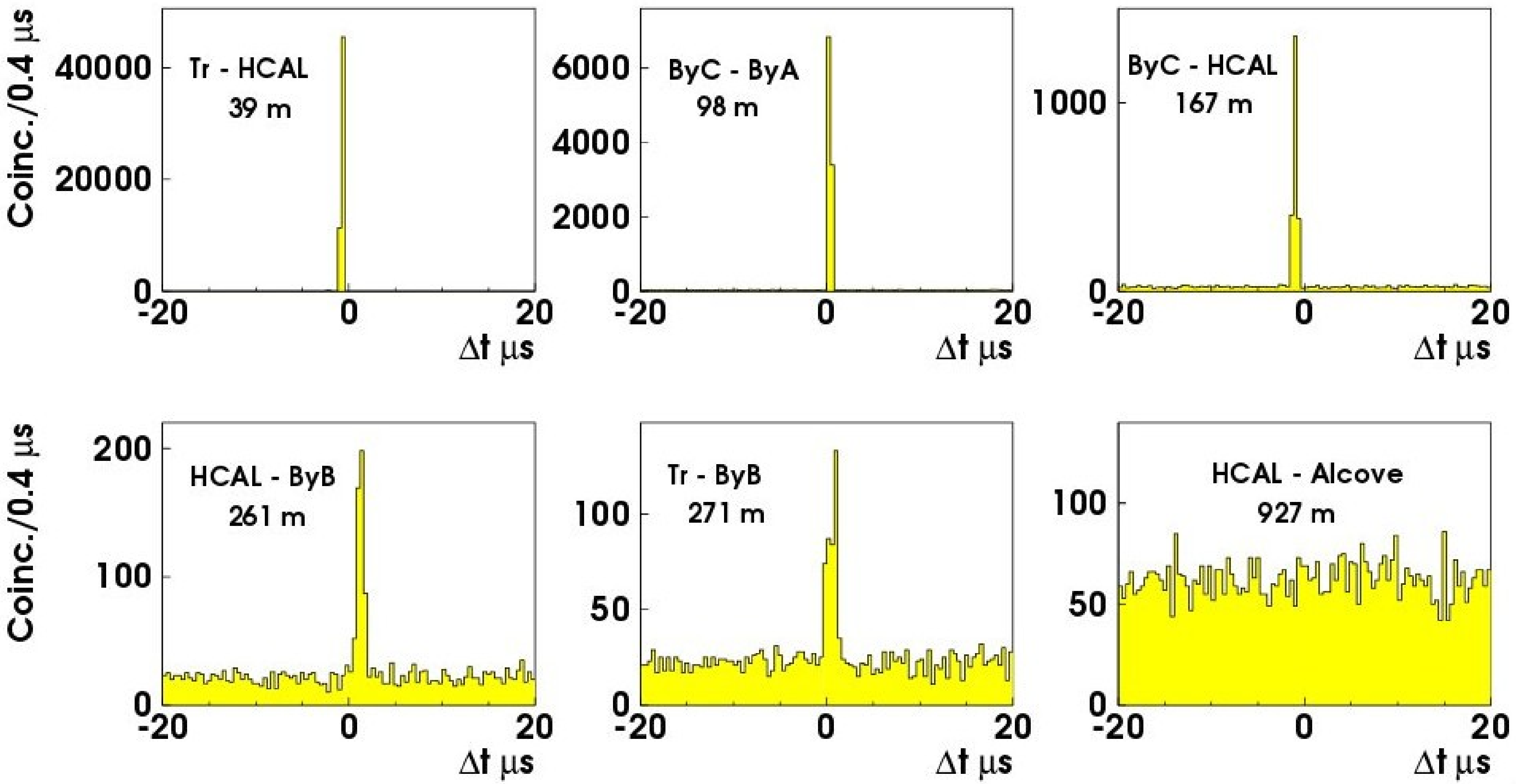

**Layout of CosmoALEPH**

# Sensitivity of CosmoALEPH



# CosmoALEPH (years 1995-2000)



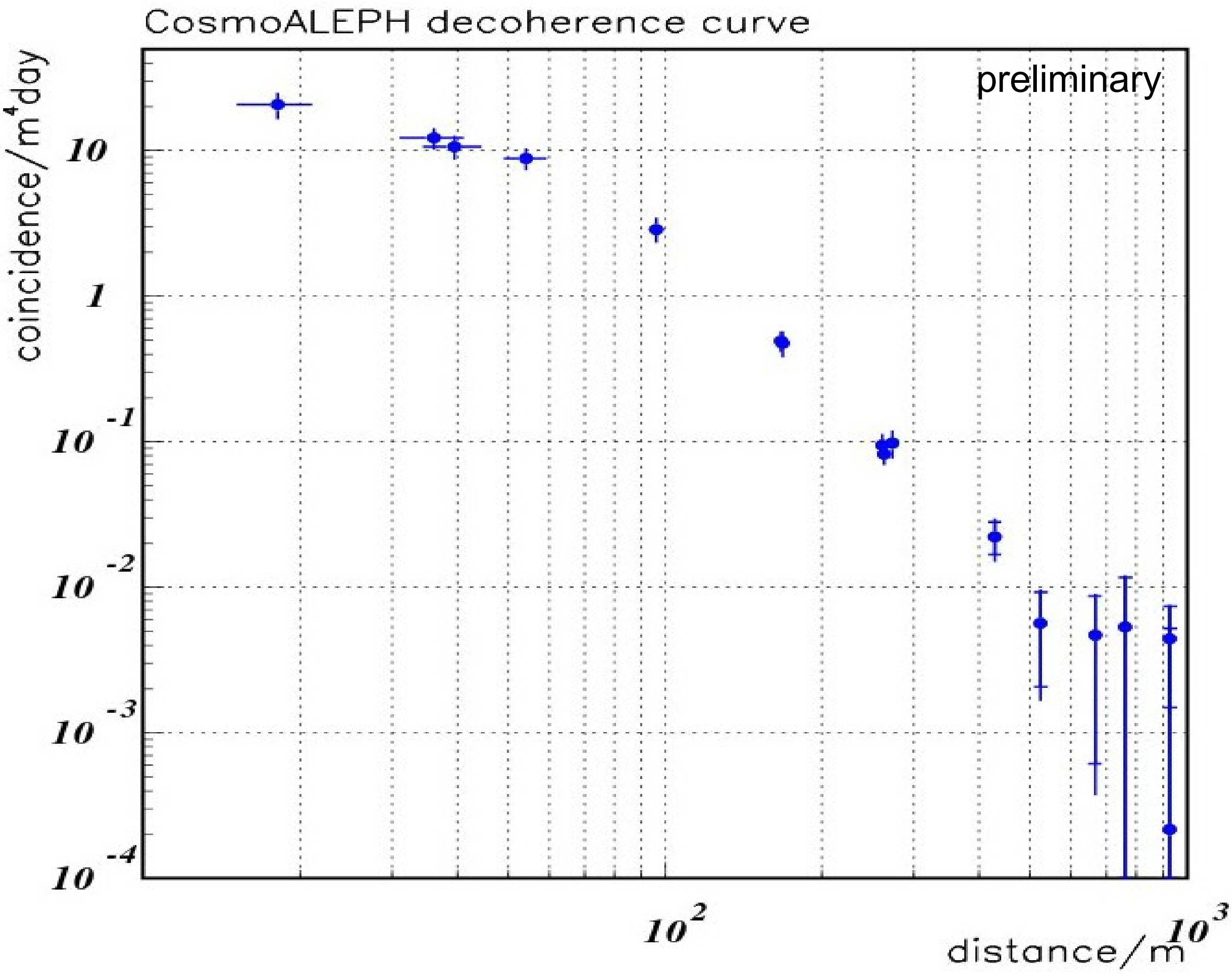


Coinc./0.4 µs
Tr - HCAL
39 m
ByC - ByA
98 m
ByC - HCAL
167 m
HCAL - ByB
261 m
Tr - ByB
271 m
HCAL - Alcove
927 m
40000
20000
6000
4000
2000
1000
200
100
50
0
-20
20
Δt µs

# Decoherence results

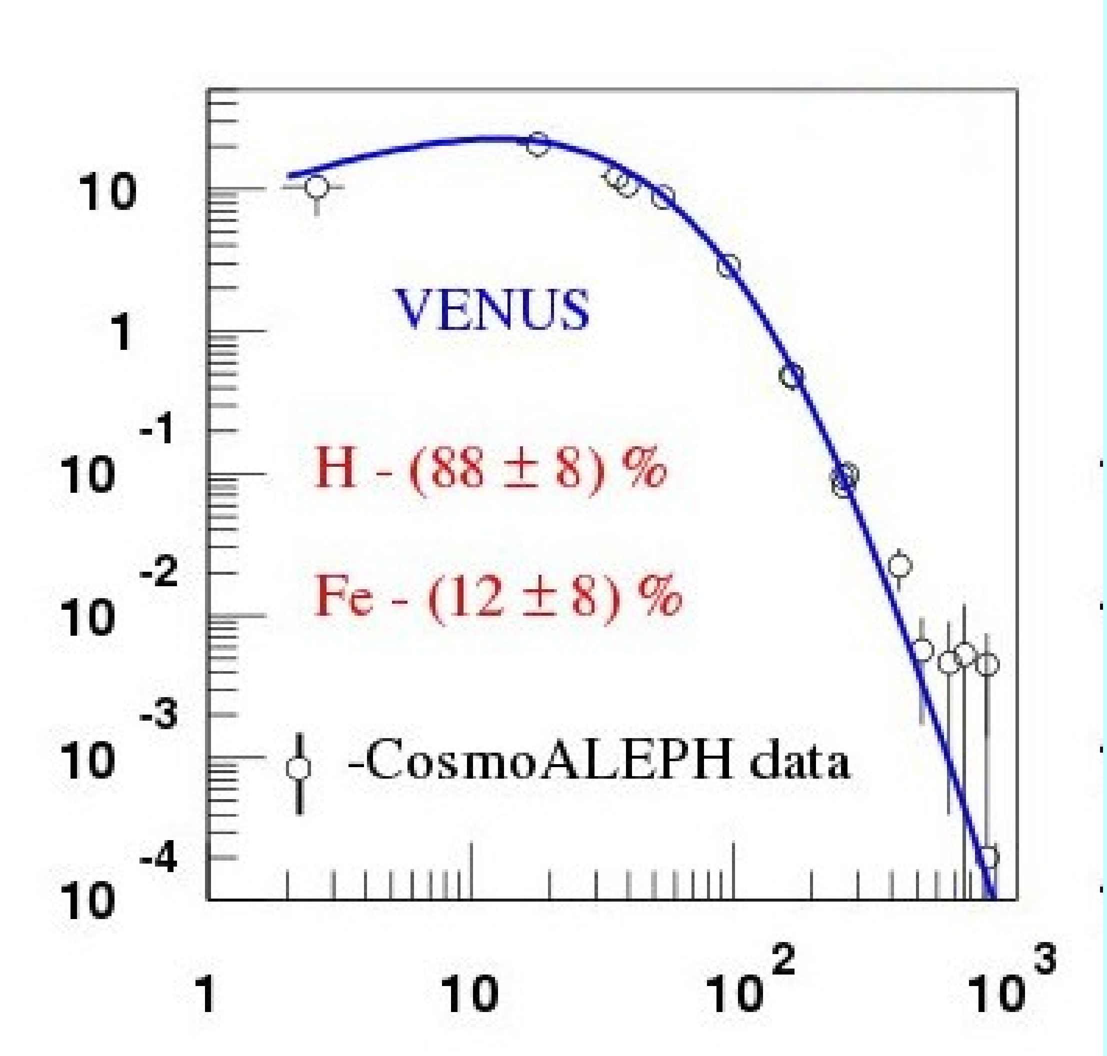
$$D(d_{ij}) = \frac{c_{ij}}{T_{ij}\, F_i\, F_j\, A_i^{\perp}\, A_j^{\perp}\, g_i\, g_j\, \rho_{ij}\, \varepsilon_i\, \varepsilon_j}$$

| | | |
|---|---|---|
| $d_{ij}$ | : | distance between centers of stations $i$ and $j$ |
| $c_{ij}$ | : | coincidences between stations $i$ and $j$ |
| $T_{ij}$ | : | common open time |
| $F_{i,j}$ | : | overburden corrections: flux(station)/flux(320mwe) |
| $A_{i,j}^{\perp}$ | : | vertical areas of the two stations |
| $g_{i,j}$ | : | geometrical acceptances of the stations |
| $\rho_{ij}$ | : | combined effective area/product of effective areas |
| $\varepsilon_{i,j}$ | : | single muon efficiencies |




Michael Schmelling 2006

Coincidences per $m^4$ and day




Distance between two detectors [m]

VENUS model:
H.J. Drescher et al.
Nucl. Phys. Proc. Suppl.
75A (1999) 275

**Some excess at large separations:**
**All used models have this problem.**

Rodica Tcaciuc 2006

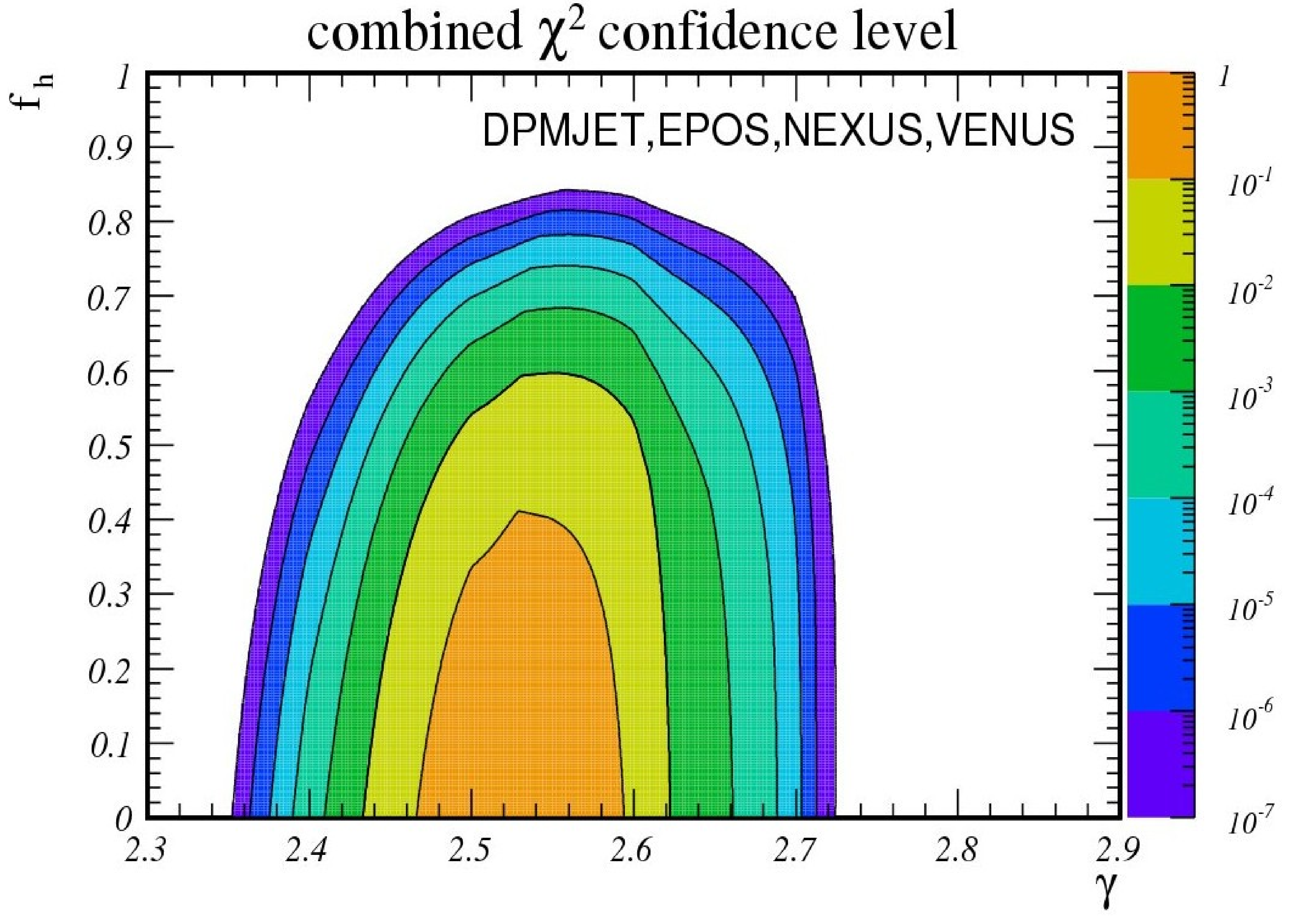
# Fit to the CosmoALEPH data

## (muon spectra and charge ratio)

power law assumed for the primary spectra,
$\gamma$ spectral index
$f_h$ fraction of heavy nulcei
assumption for heavy nuclei in the Monte Carlo:
30 % He, 20% N, 30% Mg, 20% Fe (constant mass composition)

$$\frac{dn}{dE_h} = K\, f_h\, E^{-\gamma} \quad \text{and} \quad \frac{dn}{dE_p} = K\,(1 - f_h)\, E^{-\gamma}$$

Models assumed: DPMJET, EPOS, NEXUS, VENUS:
**fit for $f_h$ against $\gamma$**




M. Schmelling et al. Astropart. Phys. 49 (2013) 1 - 5

# Result of the fit:

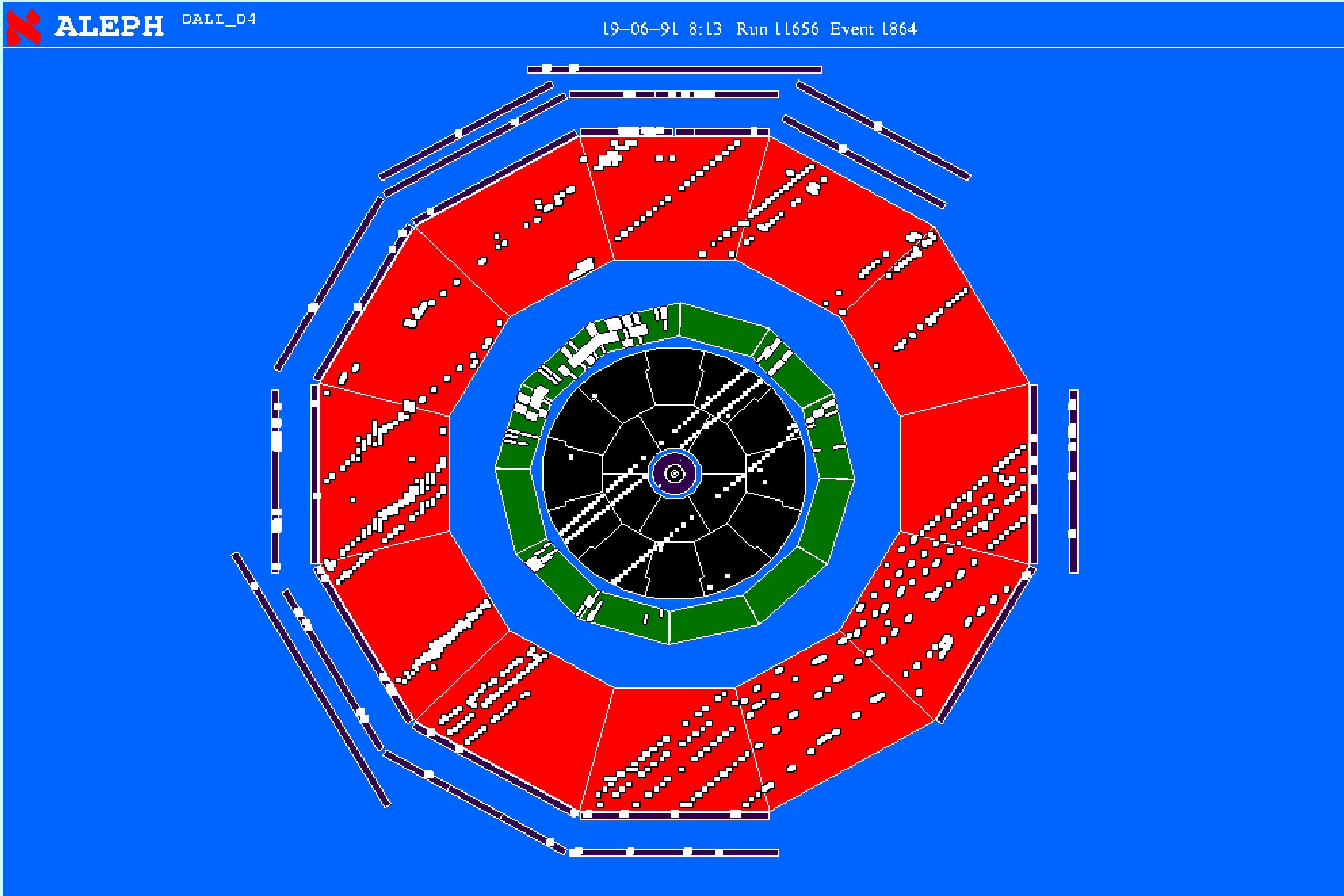
**$f_h < 0.41$ and $2.47 < \gamma < 2.59$**

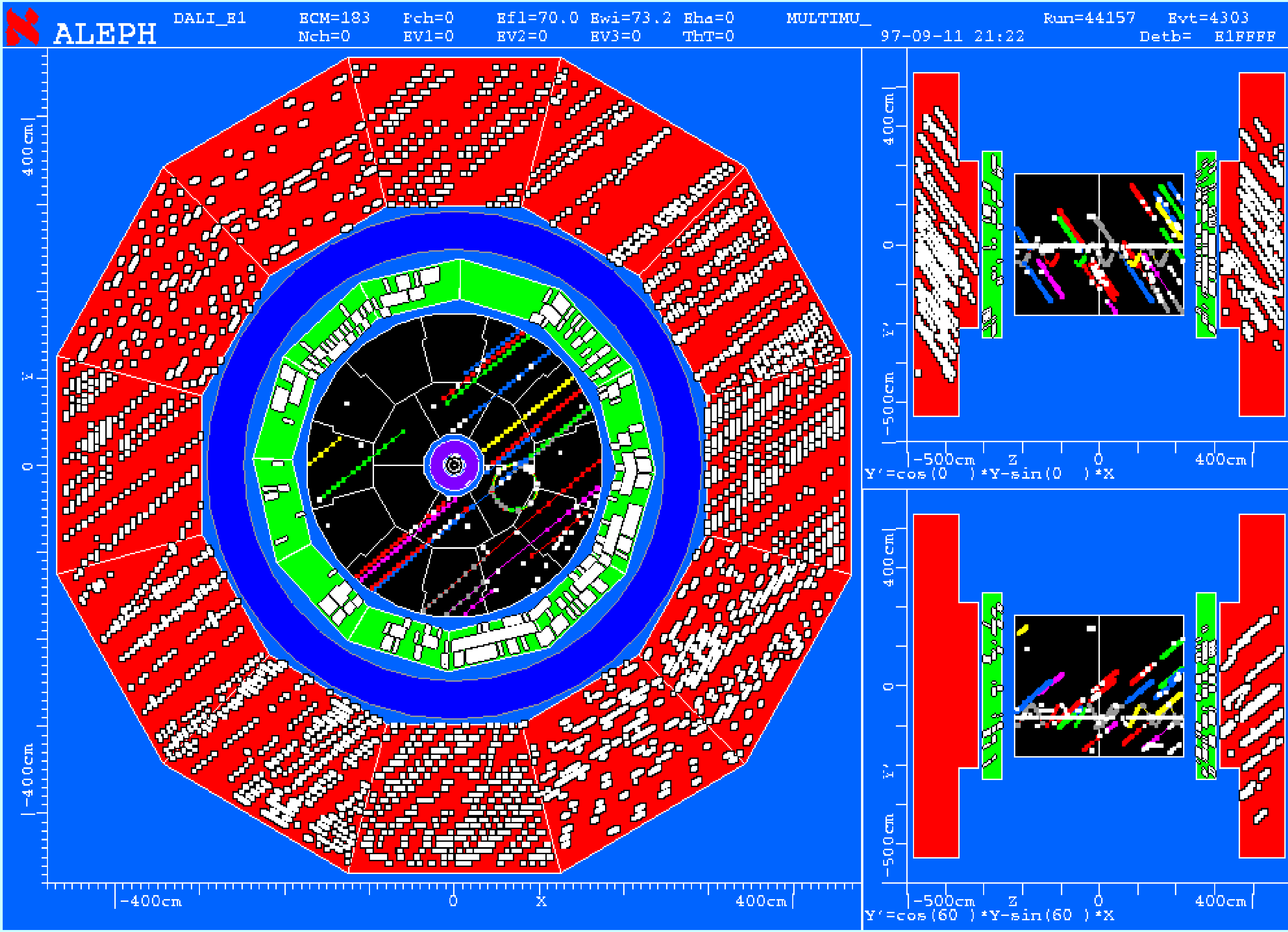
**A number on the flux of cosmic ray primaries above 100 GeV comes out to be**

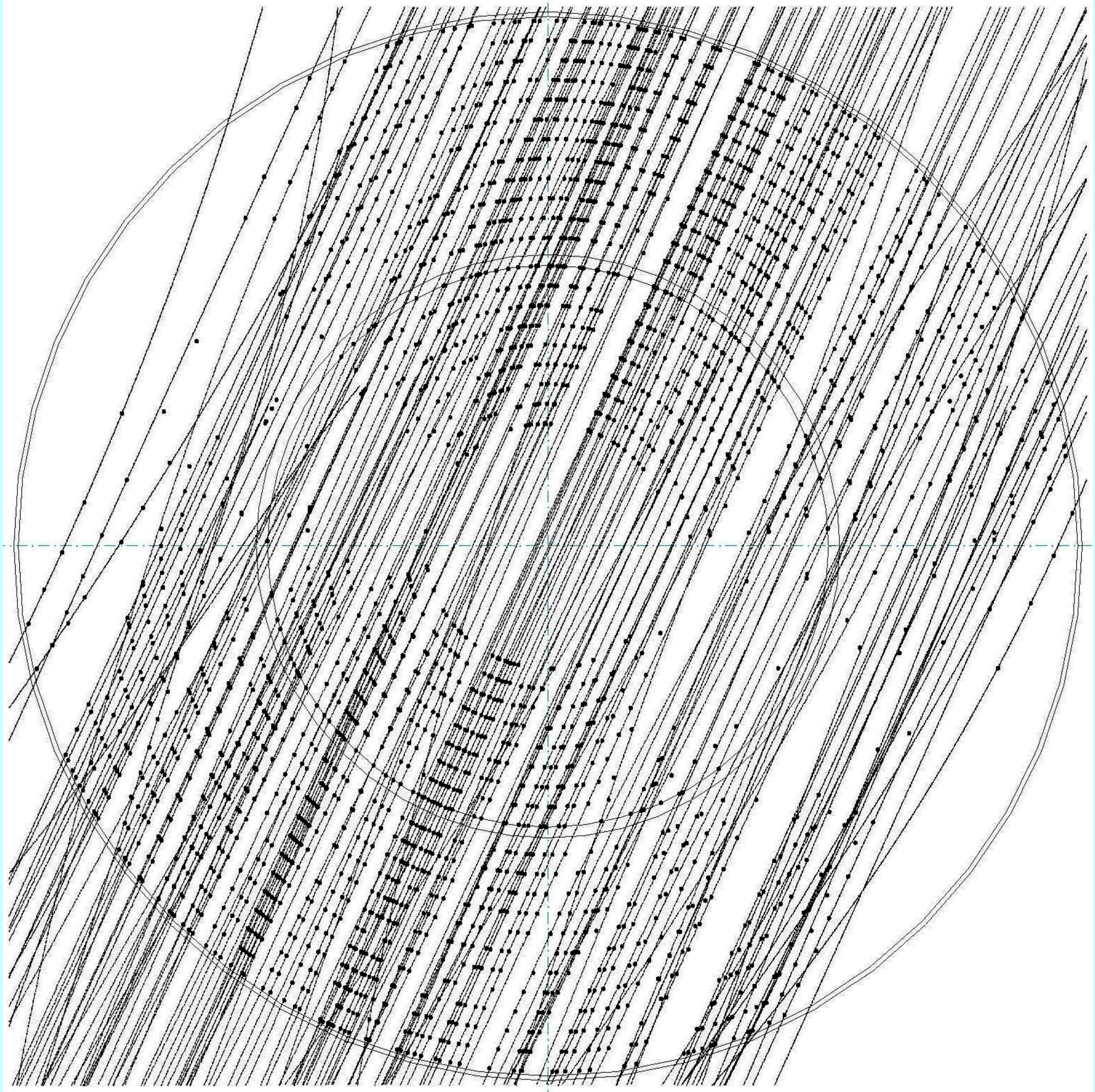
$$\Phi = 3.74 \pm 0.61 \ m^{-2} \ s^{-1} \ sr^{-1}$$

**in good agreement with other measurements**

# Multiplicity Distributions



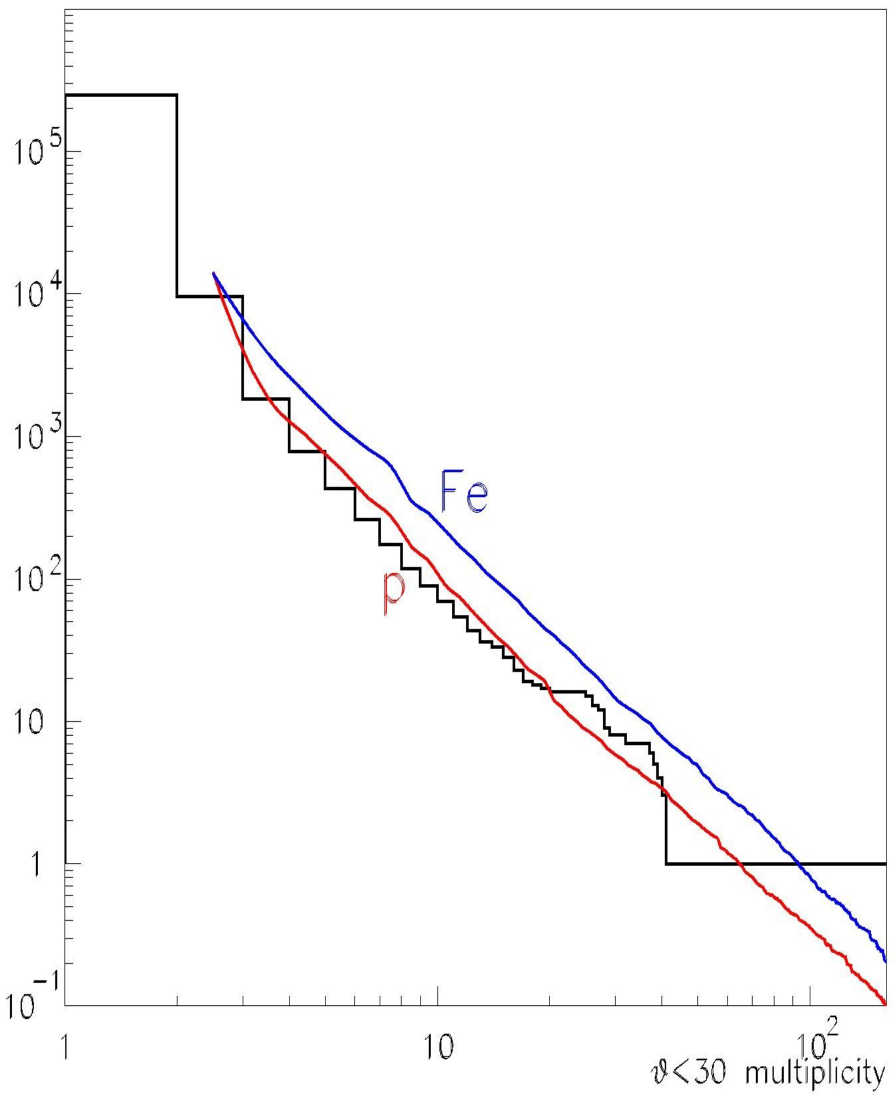

ALEPH
DALI_E1
ECM=183
Nch=0
Pch=0
EV1=0
Efl=70.0
EV2=0
Ewi=73.2
EV3=0
Eha=0
ThT=0
MULTIMU_
97-09-11 21:22
Run=44157
Evt=4303
Detb= E1FFFF
400cm
Y
0
-400cm
-400cm
0
X
400cm
400cm
0
Y'
-500cm
-500cm
Z
0
400cm
Y'=cos(0 )*Y-sin(0 )*X
400cm
0
Y'
-500cm
-500cm
Z
0
400cm
Y'=cos(60 )*Y-sin(60 )*X

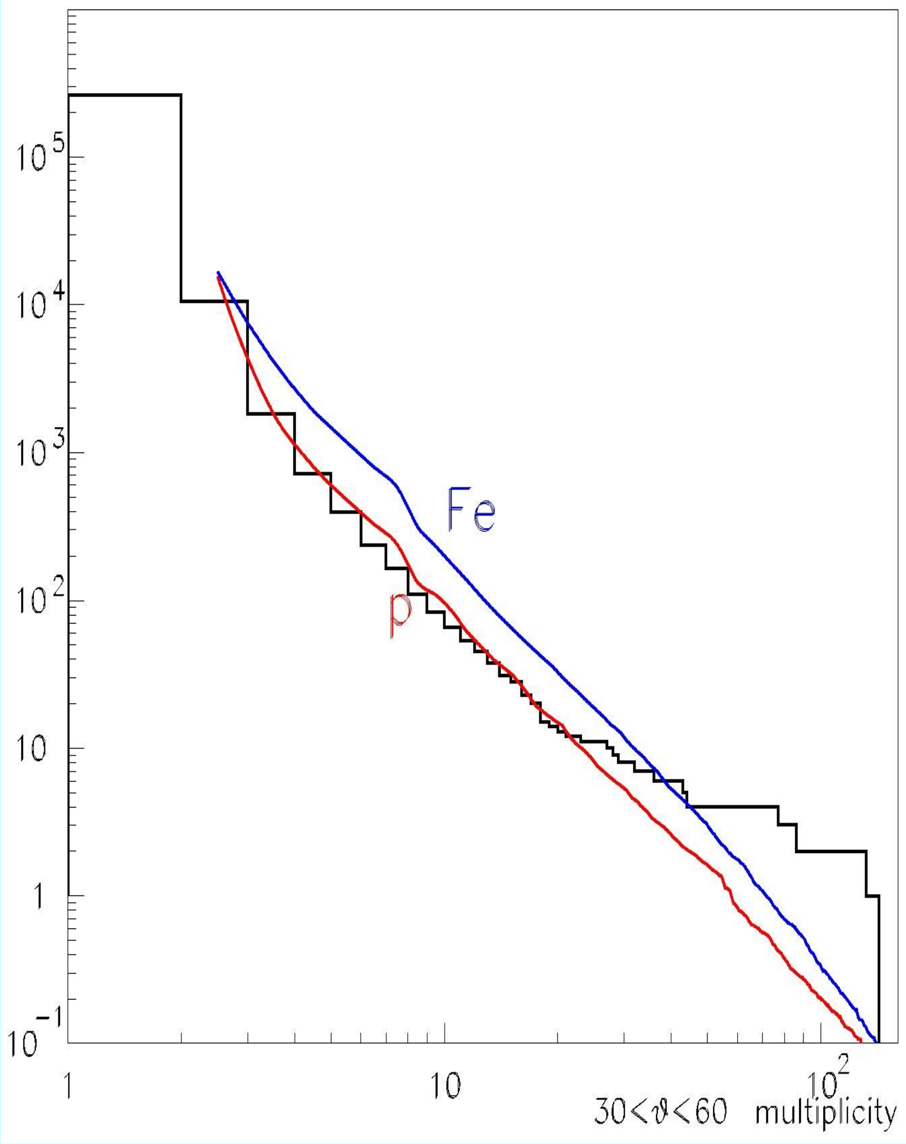


high multiplicity Event in the ALEPH TPC

> 150 tracks

# CORSIKA, QGSJET; $p_\mu$ > 70 GeV




V. Avati et al. Astropart. Phys. 19 (2003) 513- 523

# Conclusions

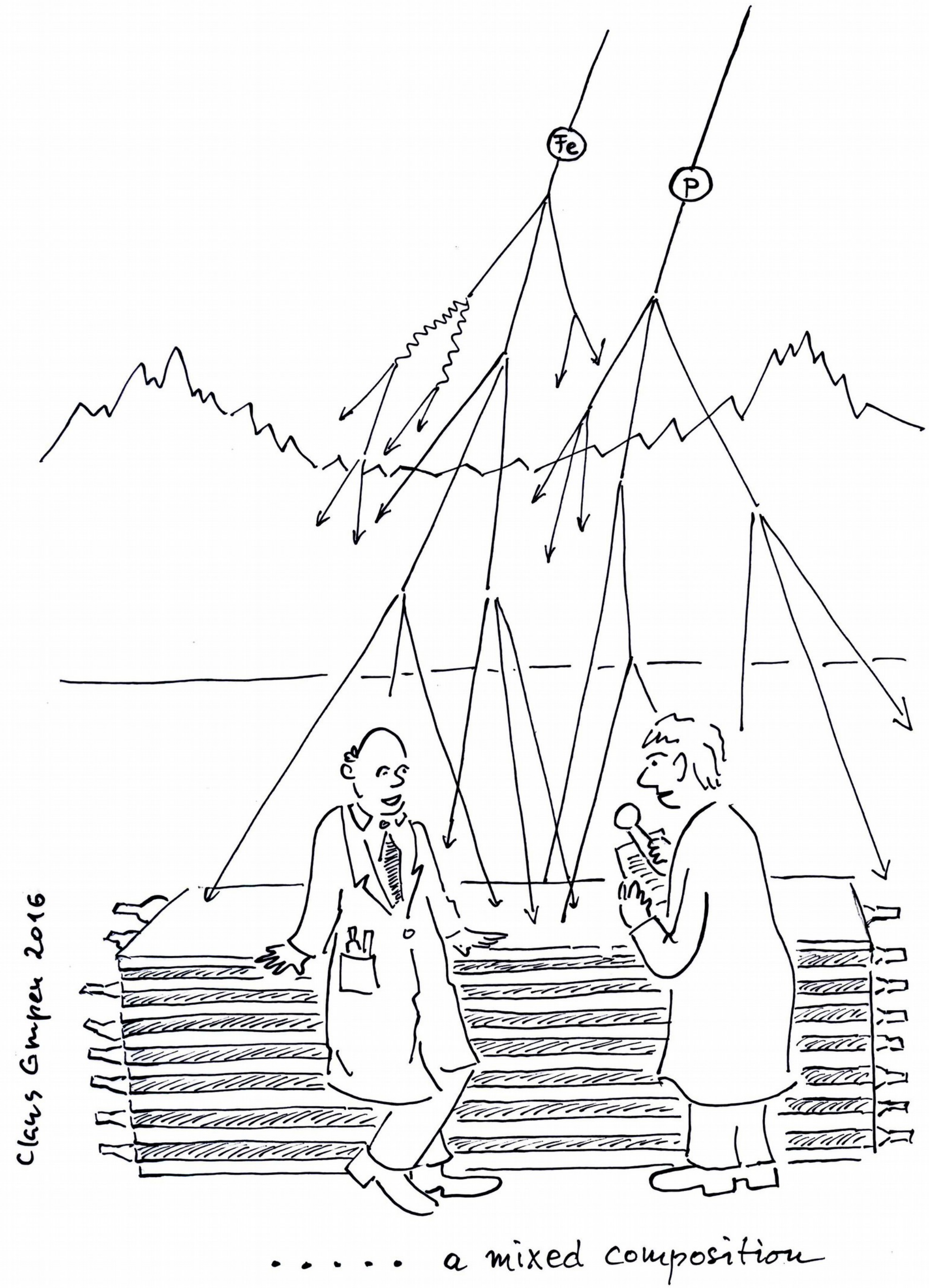
The decoherence curve – sensitive to the PeV region favours a dominantly light composition

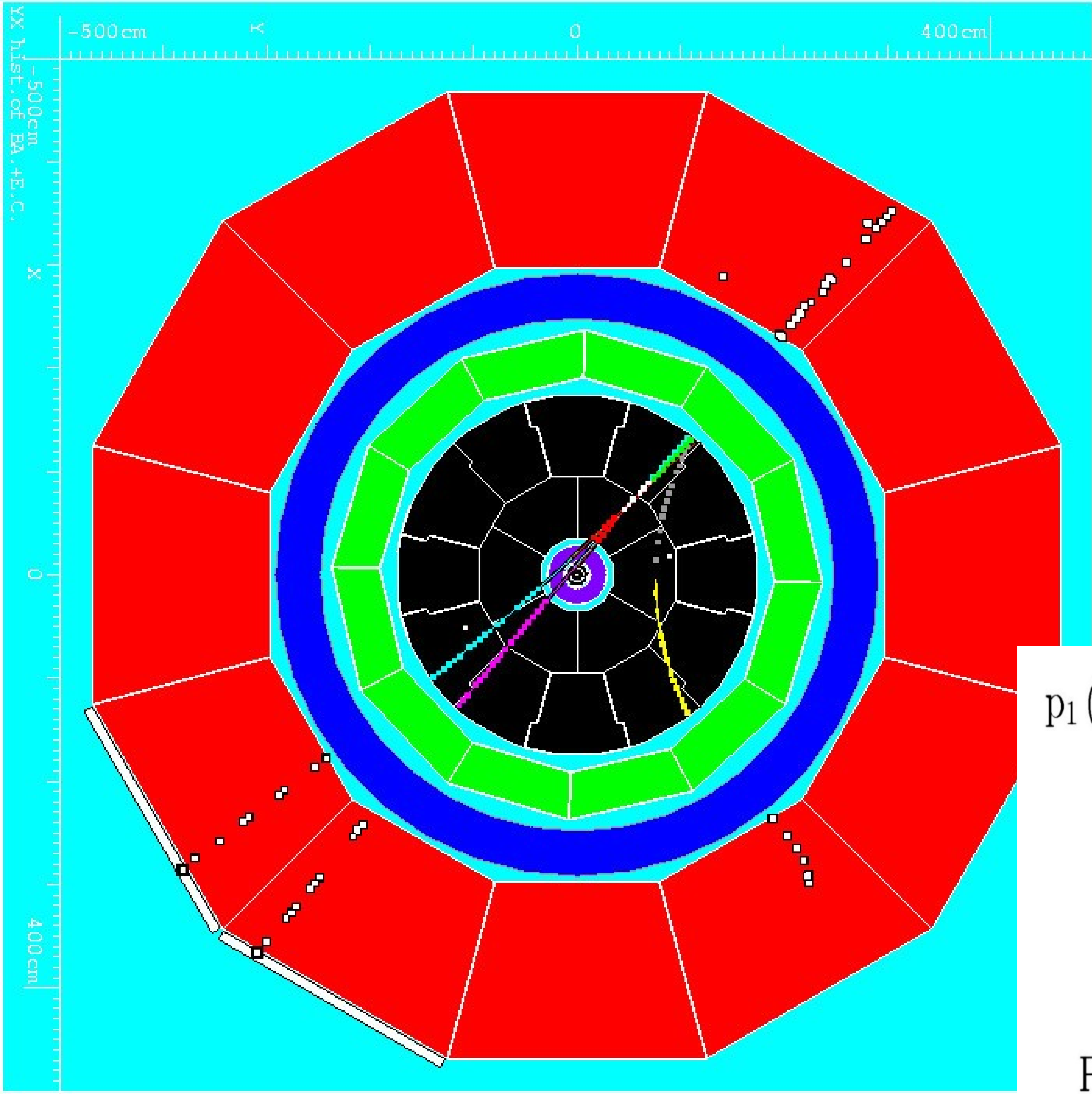
The derived primary energy spectrum is in agreement with expectations

The high-end of the multiplicity distribution indicates a higher fraction of heavy primaries

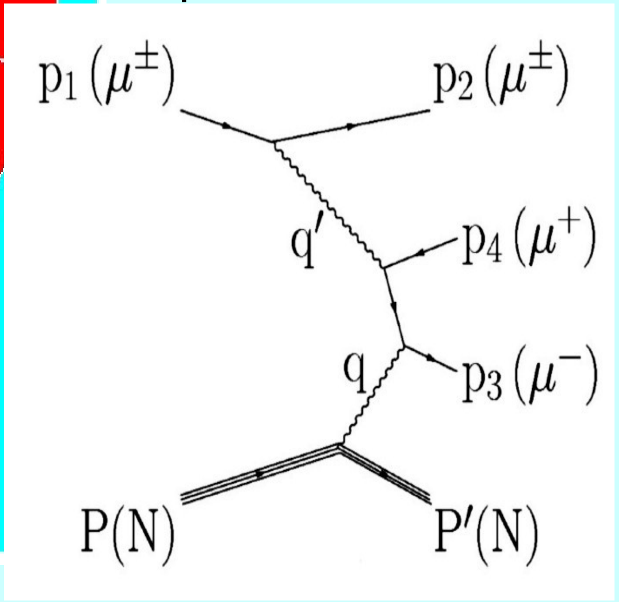
High-resolution detectors allow precise results in cosmic rays studies

# graphic conclusions






muon trident production




F. Maciuc et al. Phys. Rev. Lett. 96 (2006) 021801