UNDERSTANDING THE ATMOSPHERE AS A CALORIMETER FOR UHE COSMIC RAYS

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- Hadron calorimeters
- A brief course on Extensive Air Showers (EAS)
- How to observe EASs
- Problems remaining

Quantities characterising a primary cosmic ray particle

direction

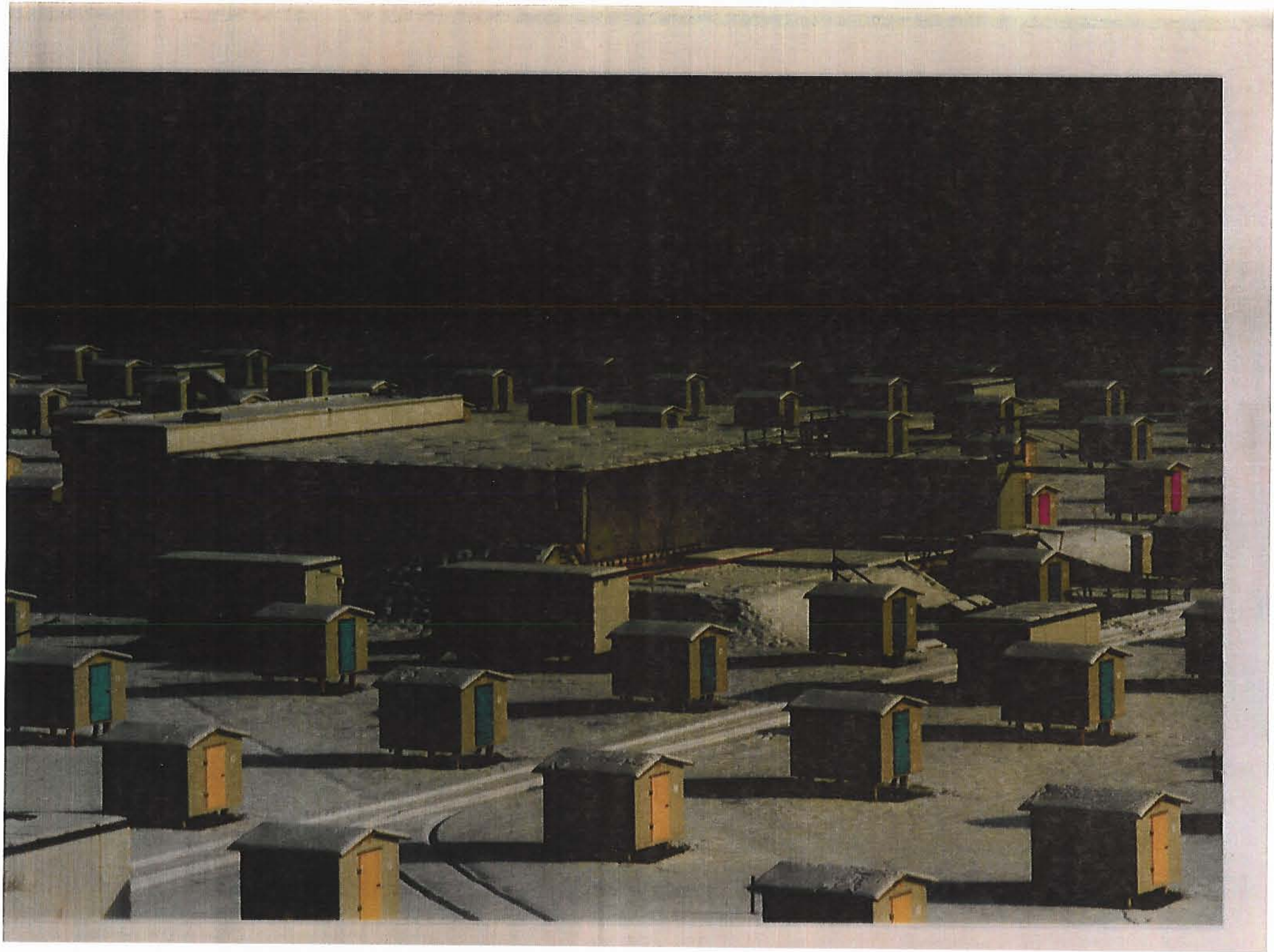
position

time

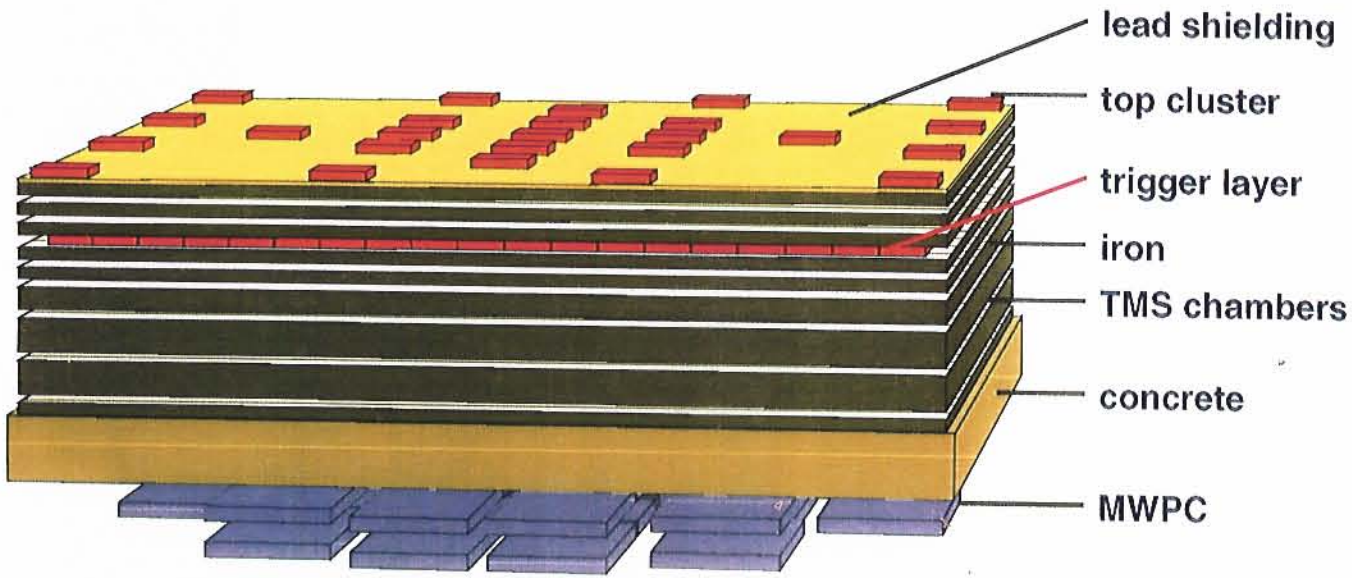
energy

mass

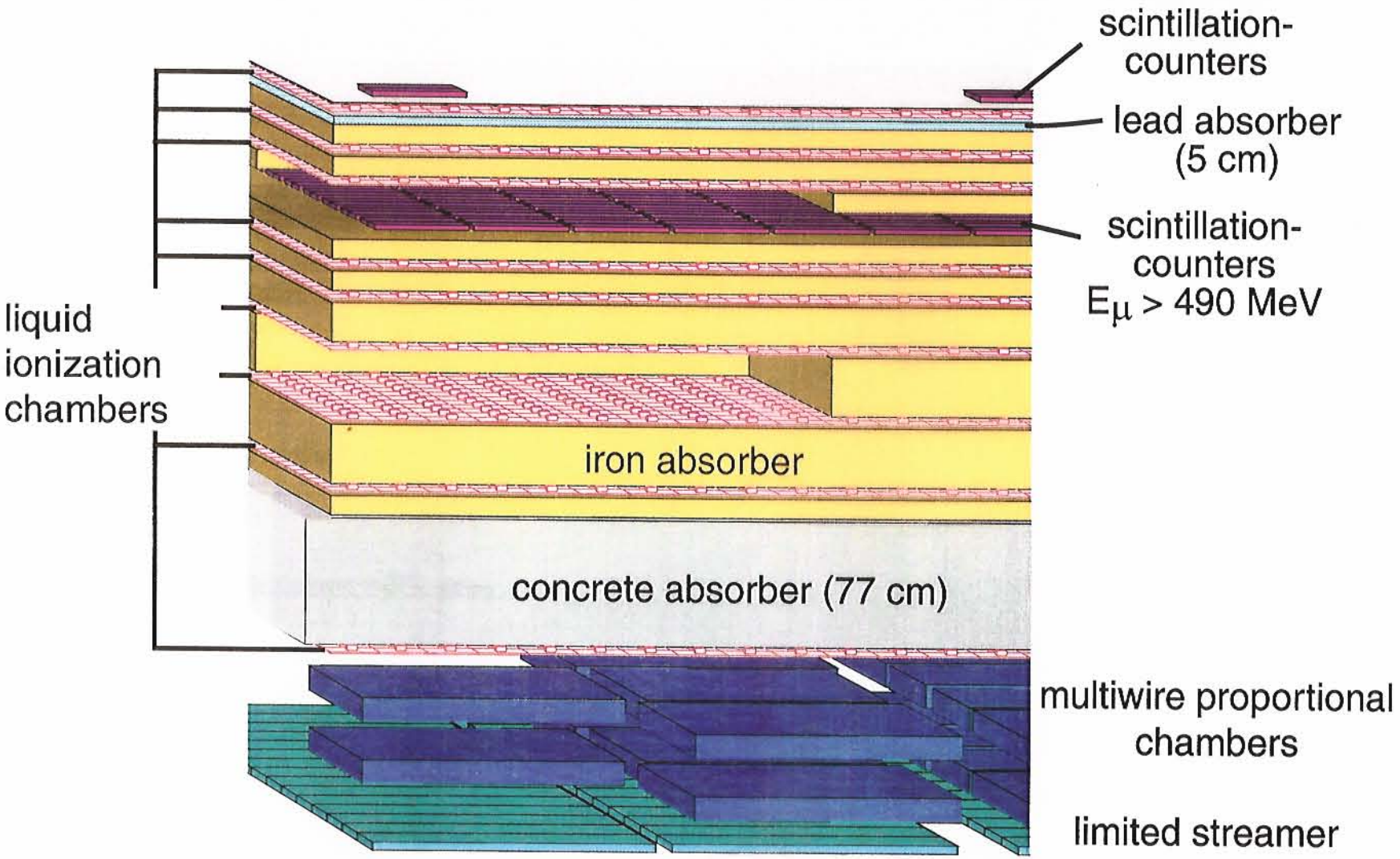
charge



KASCADE Central Detector

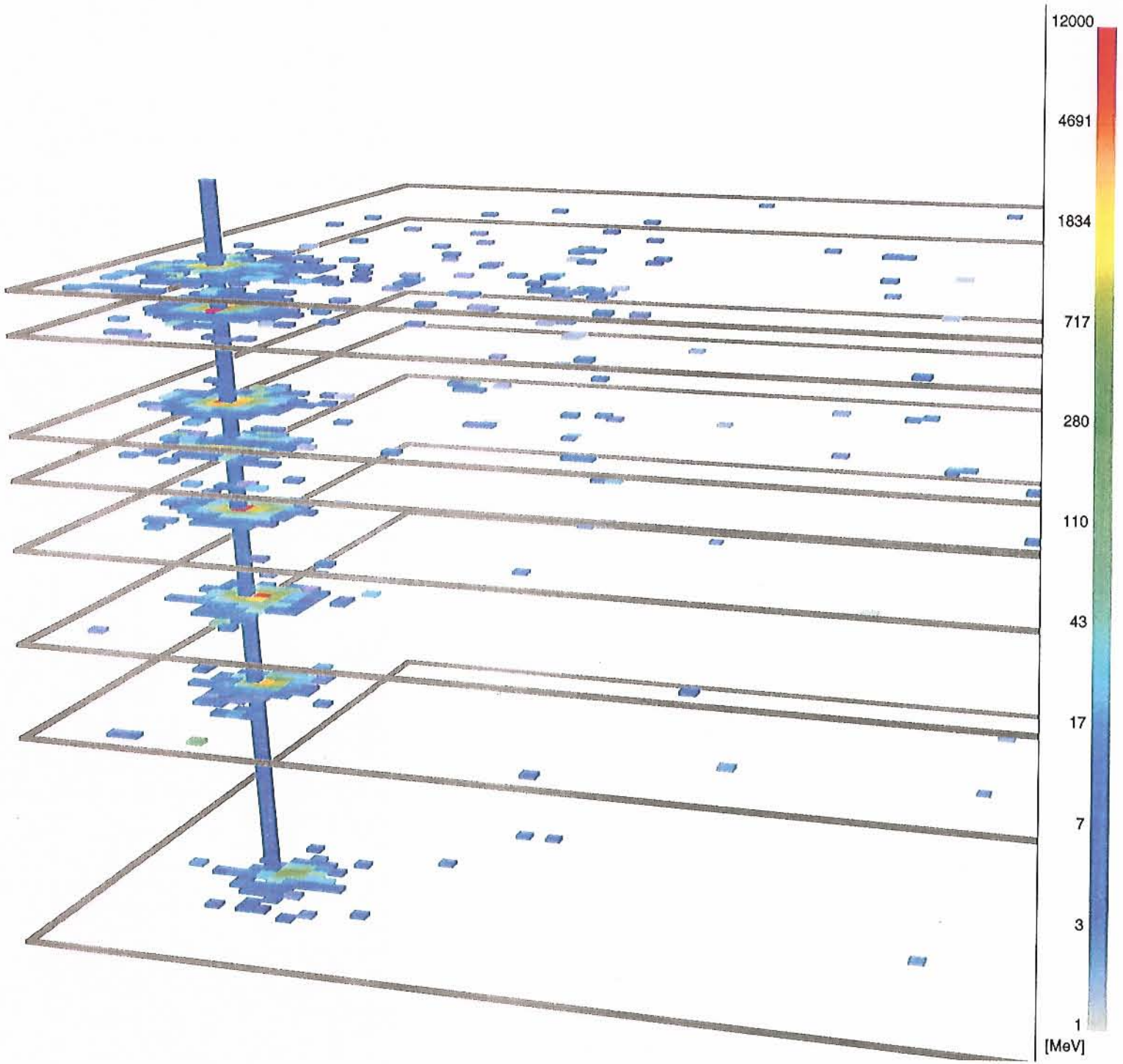


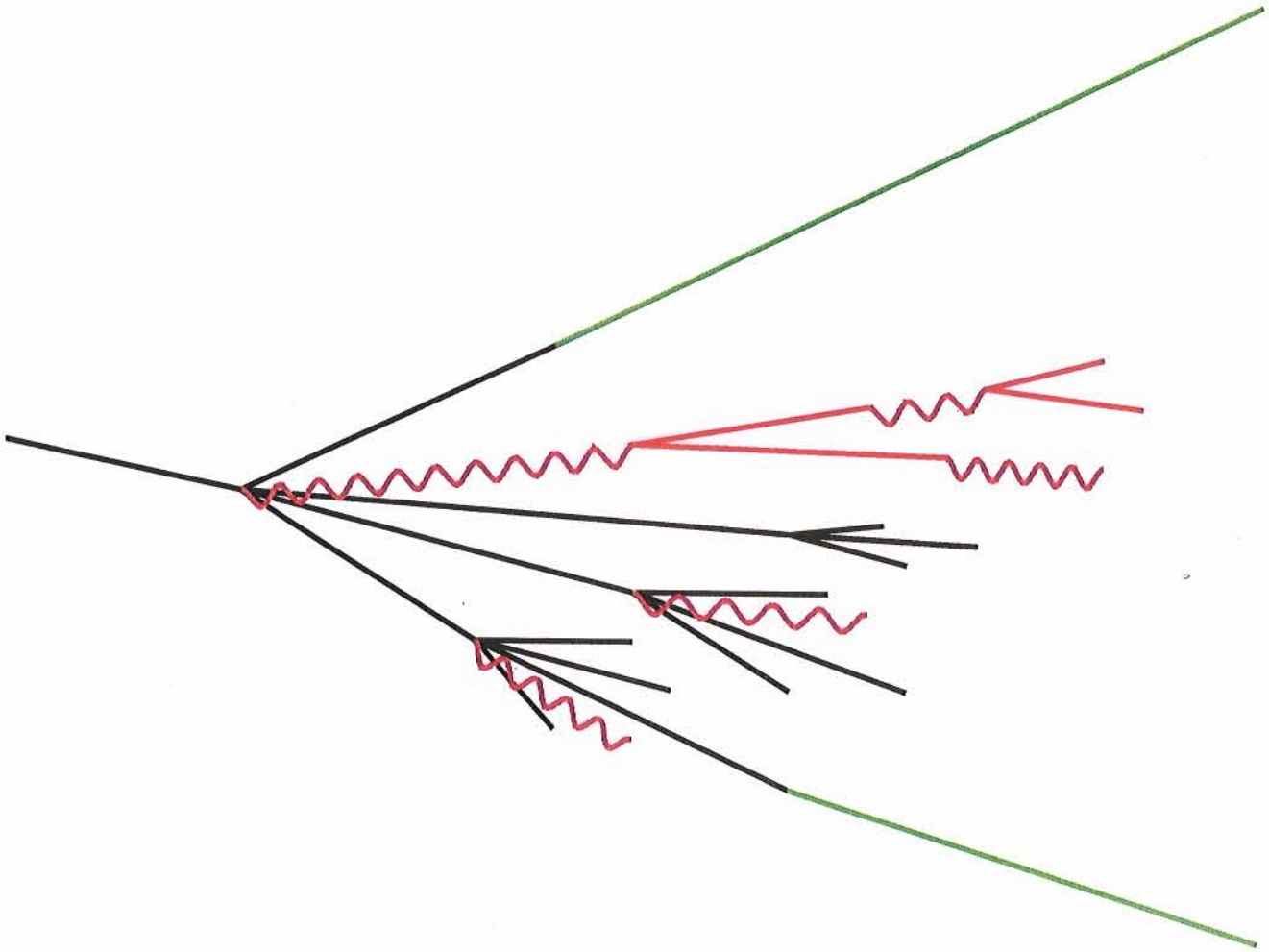
Hadron Calorimeter in the KASCADE Experiment



320 m^2 x 9 layers calorimeter
E_H > 20 GeV; 11 λ_I

J. Engler et al, Nucl. Instr. and Meth A 427 (1999)


12000
4691
1834
717
280
110
43
17
7
3
1
[MeV]



THE MOST IMPORTANT PROCESSES IN EAS

$p + N \longrightarrow$ many πs, Ks, nucleons ....

$\pi^0 \longrightarrow \gamma + \gamma$

$\gamma + N \longrightarrow e^+ + e^- + N$

$e^\pm + N \longrightarrow e^\pm + \gamma + N$

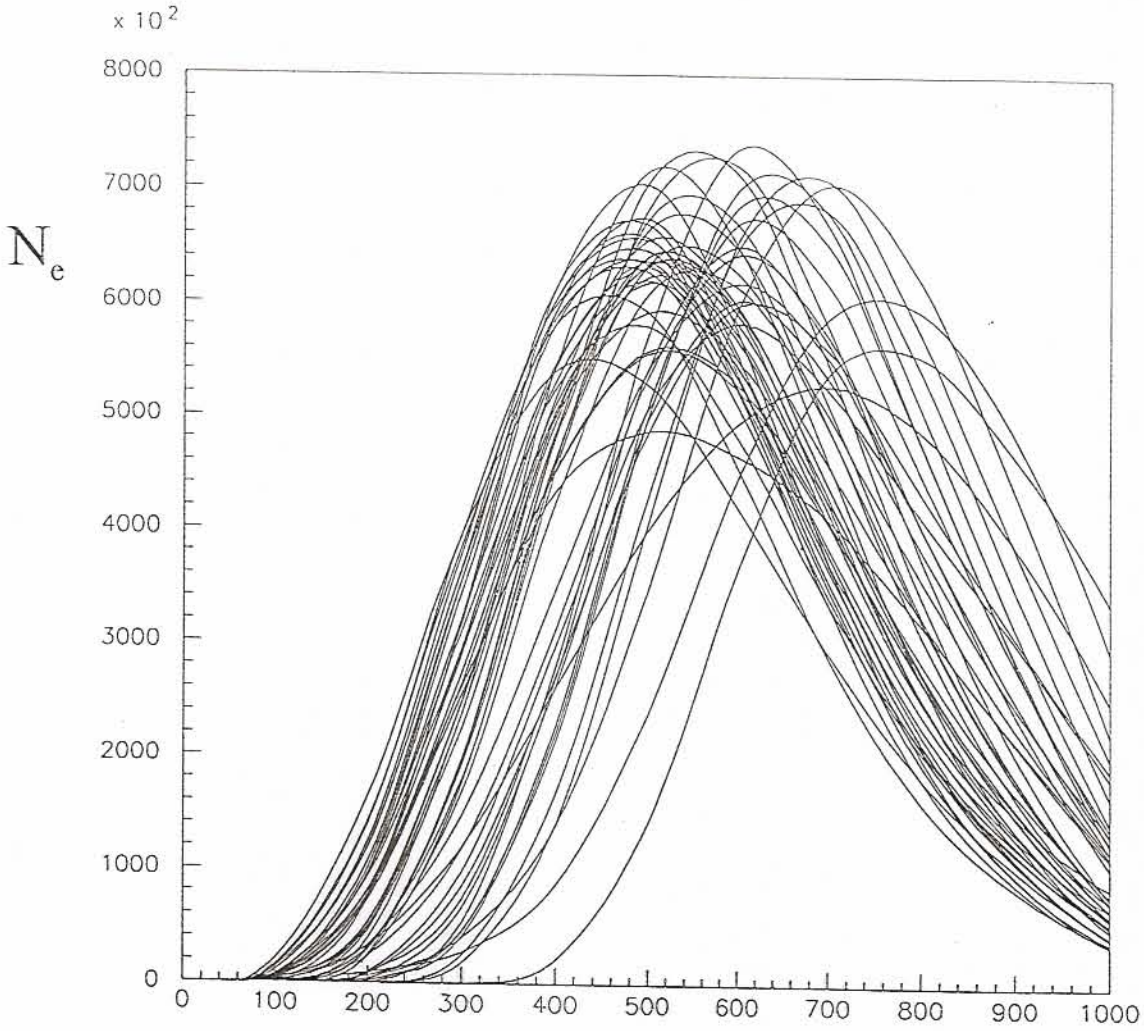
$\pi^\pm \longrightarrow \mu^\pm + \nu_\mu$

$\mu^\pm \longrightarrow e^\pm + \nu_e + \nu_\mu$

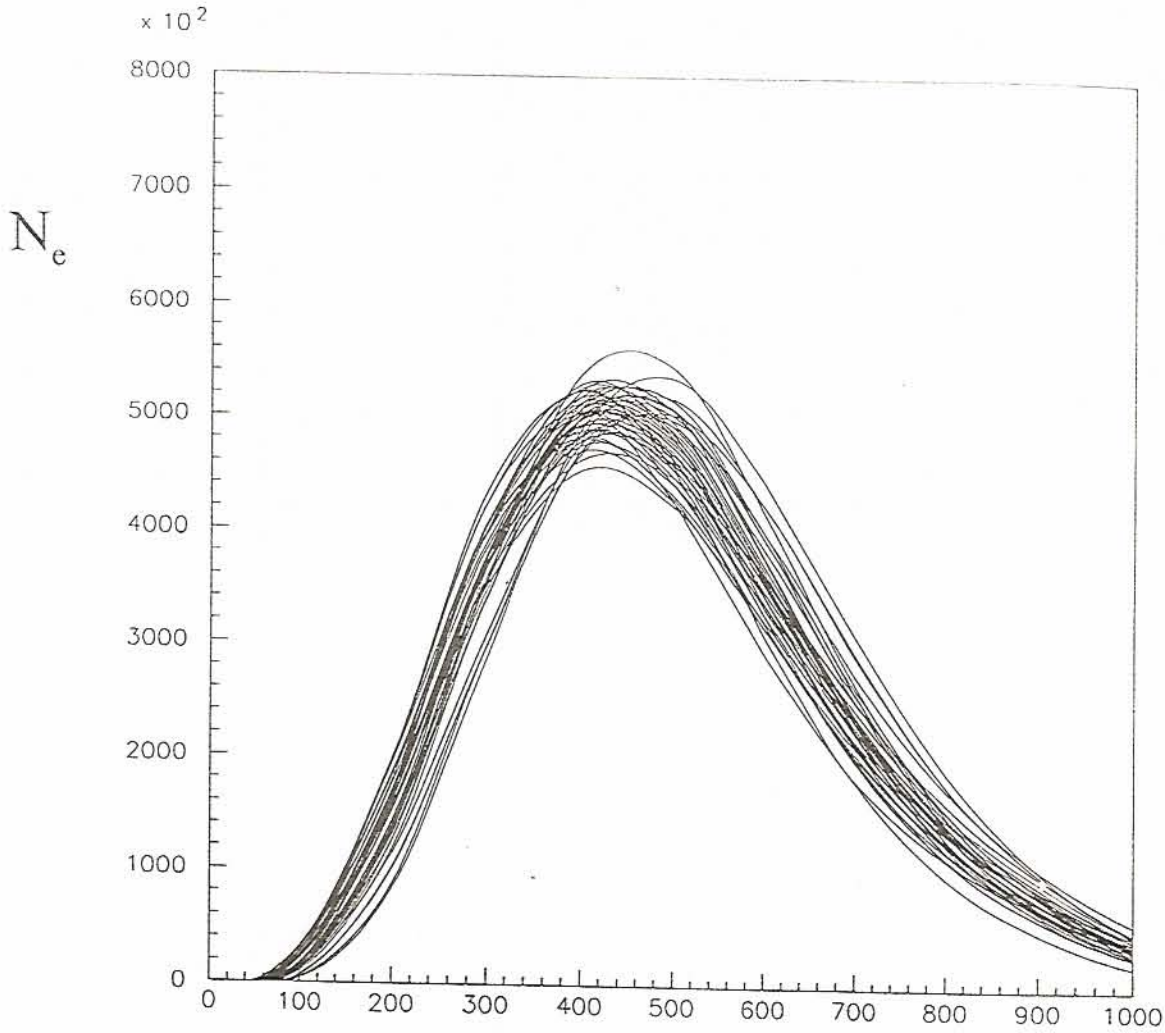
$\pi^\pm + N \longrightarrow$ many πs, Ks, nucleons ....

MAIN CHARACTERISTICS OF EAS

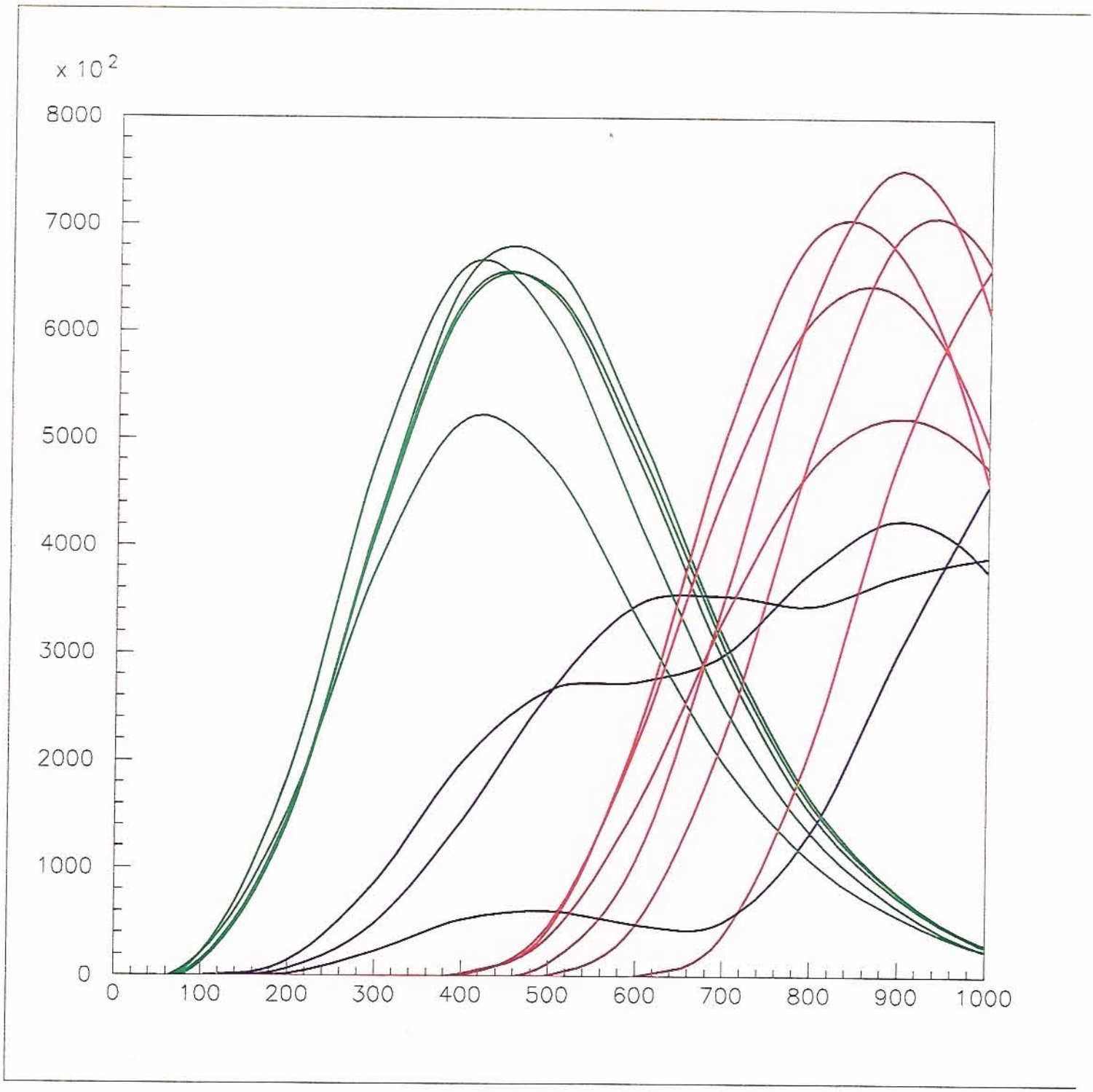
- Complete fragmentation of primary energy
- Energy flows from hadrons to e.m. particles
- Some energy lost due to νs and μs
- Huge fluctuations

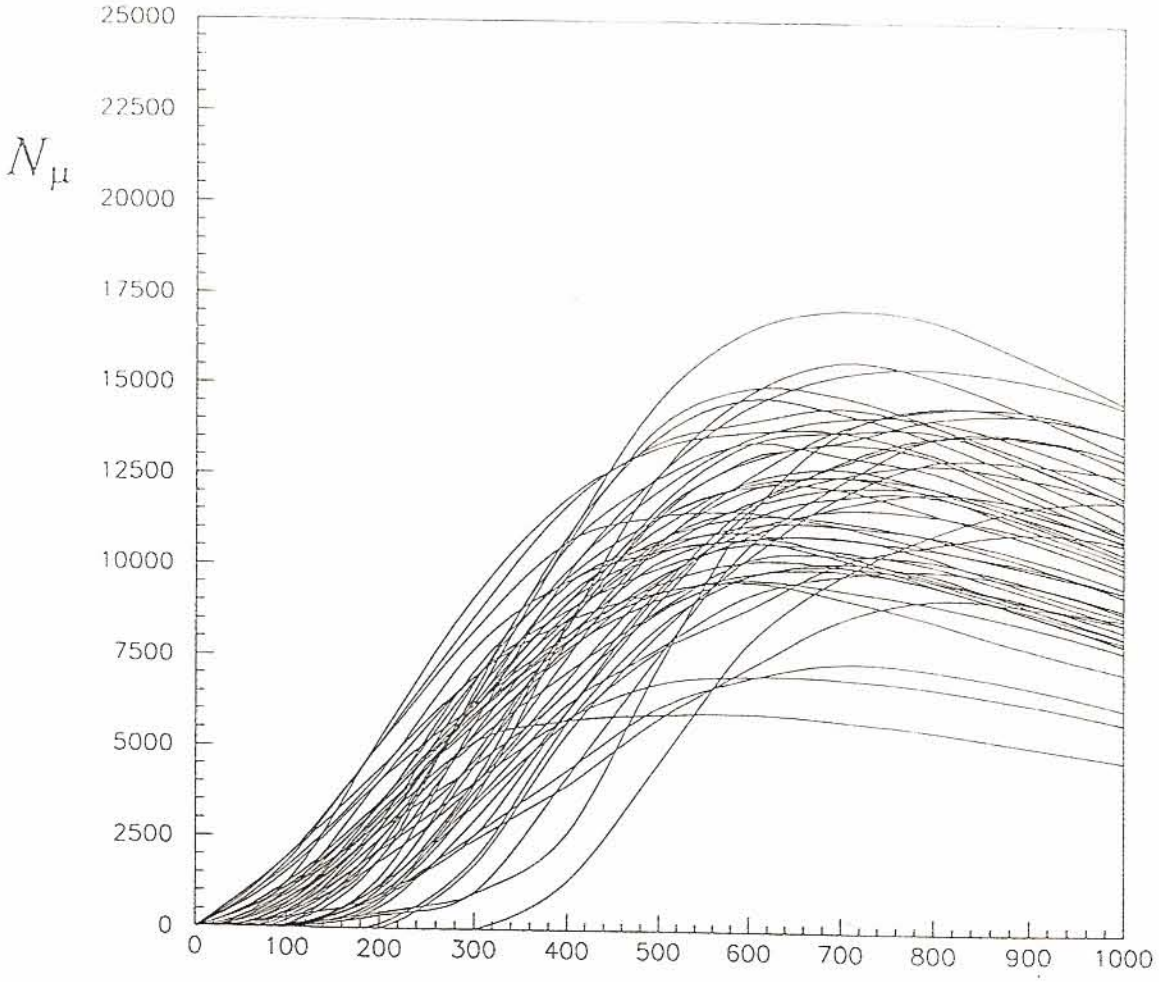


p, 1 PeV, vertical, QGS-NKG



Fe, 1 PeV, vertical, QGS-NKG


x 10 2
8000
7000
6000
5000
4000
3000
2000
1000
0
0
100
200
300
400
500
600
700
800
900
1000

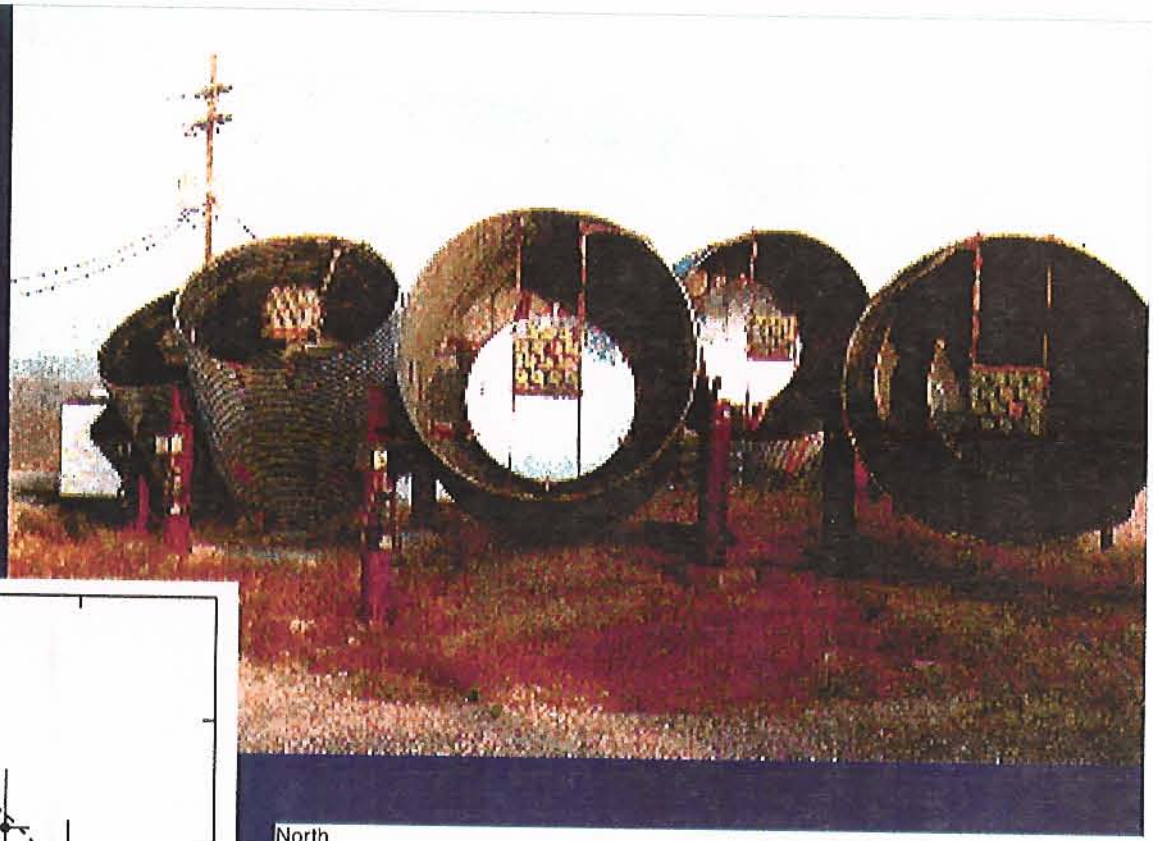


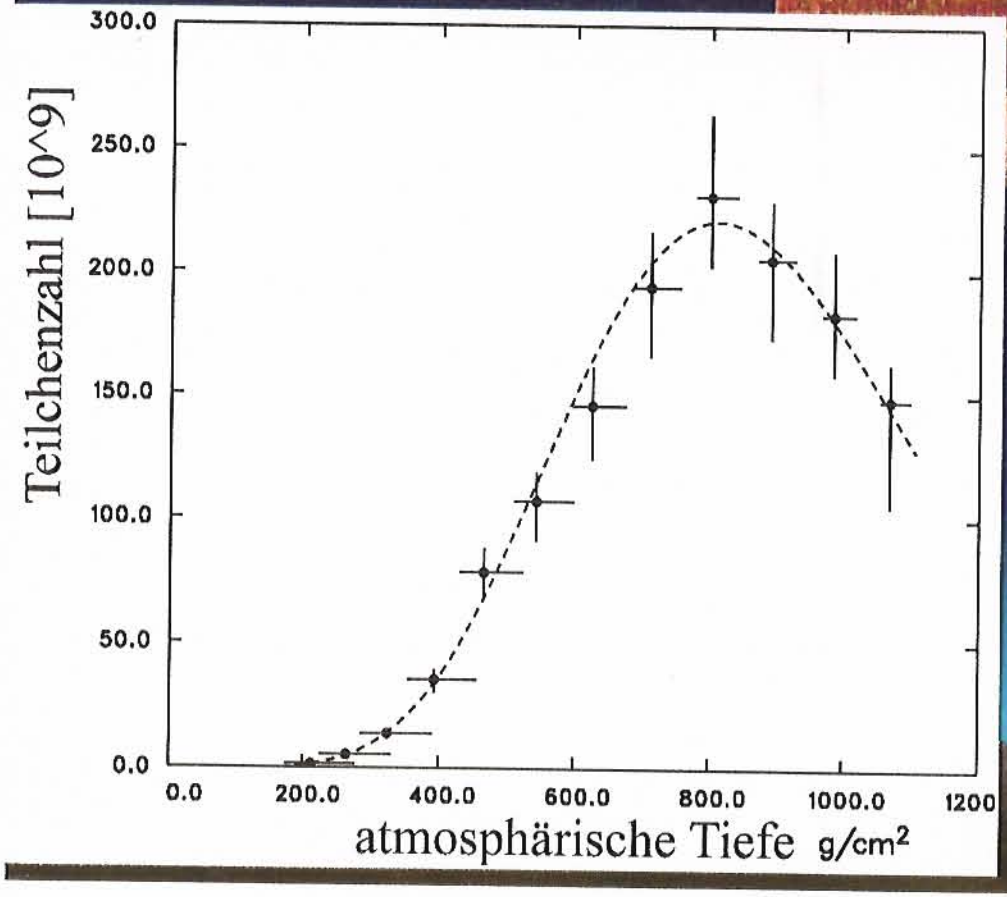
p, 1 PeV, vertical, QGS-NKG

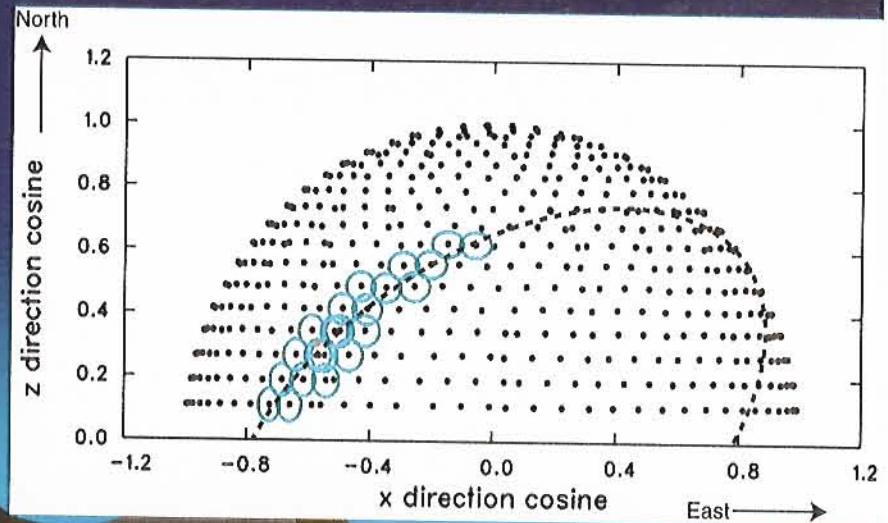
Fly's Eye

more details...

one event had 3.2×10^{20} eV
50 Joules in a single particle !

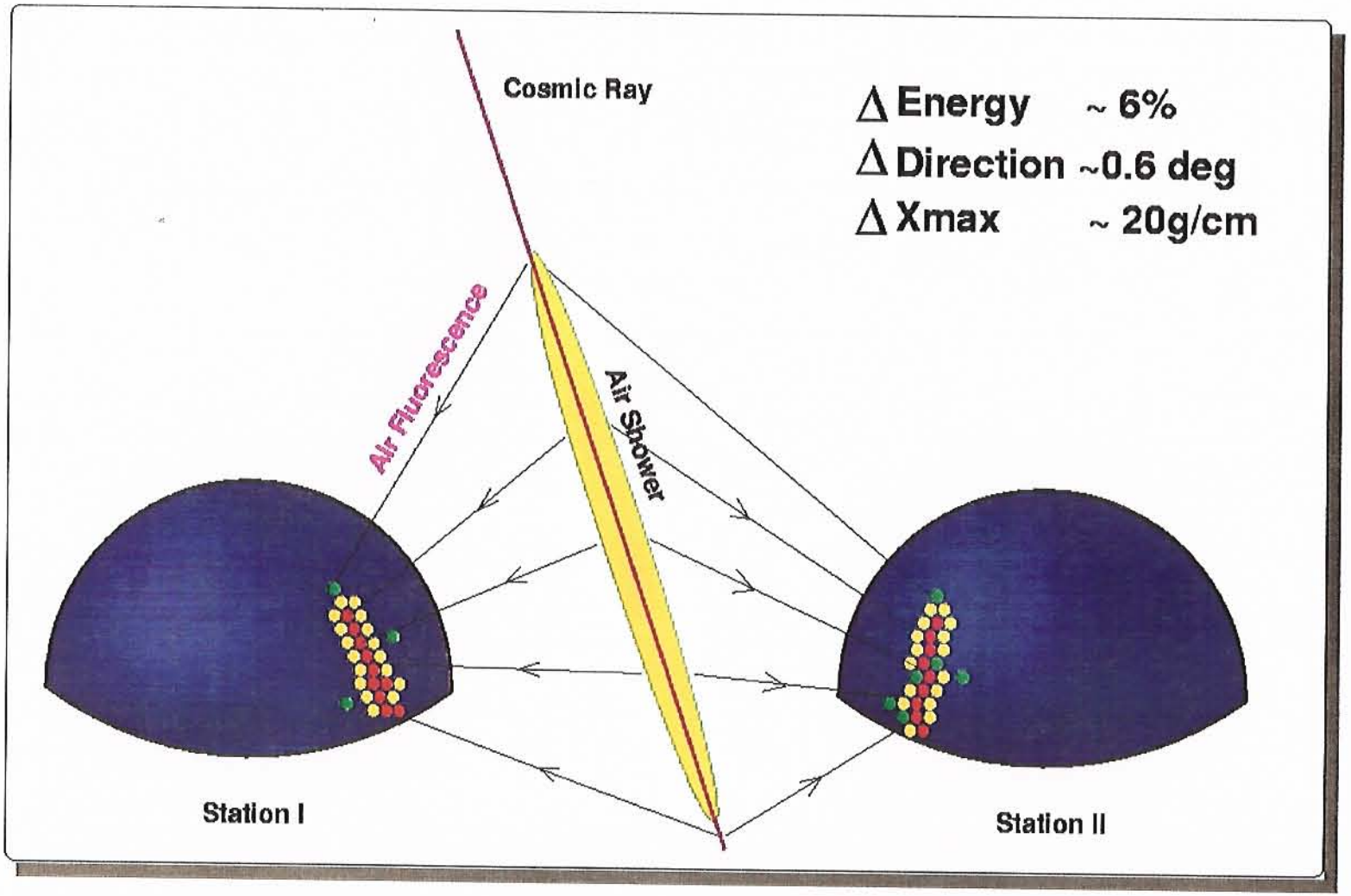






stereo reconstruction

excellent angular resolution & energy determination



INPUT REQUIRED FOR EAS SIMULATIONS

- Particle decay properties

  well known

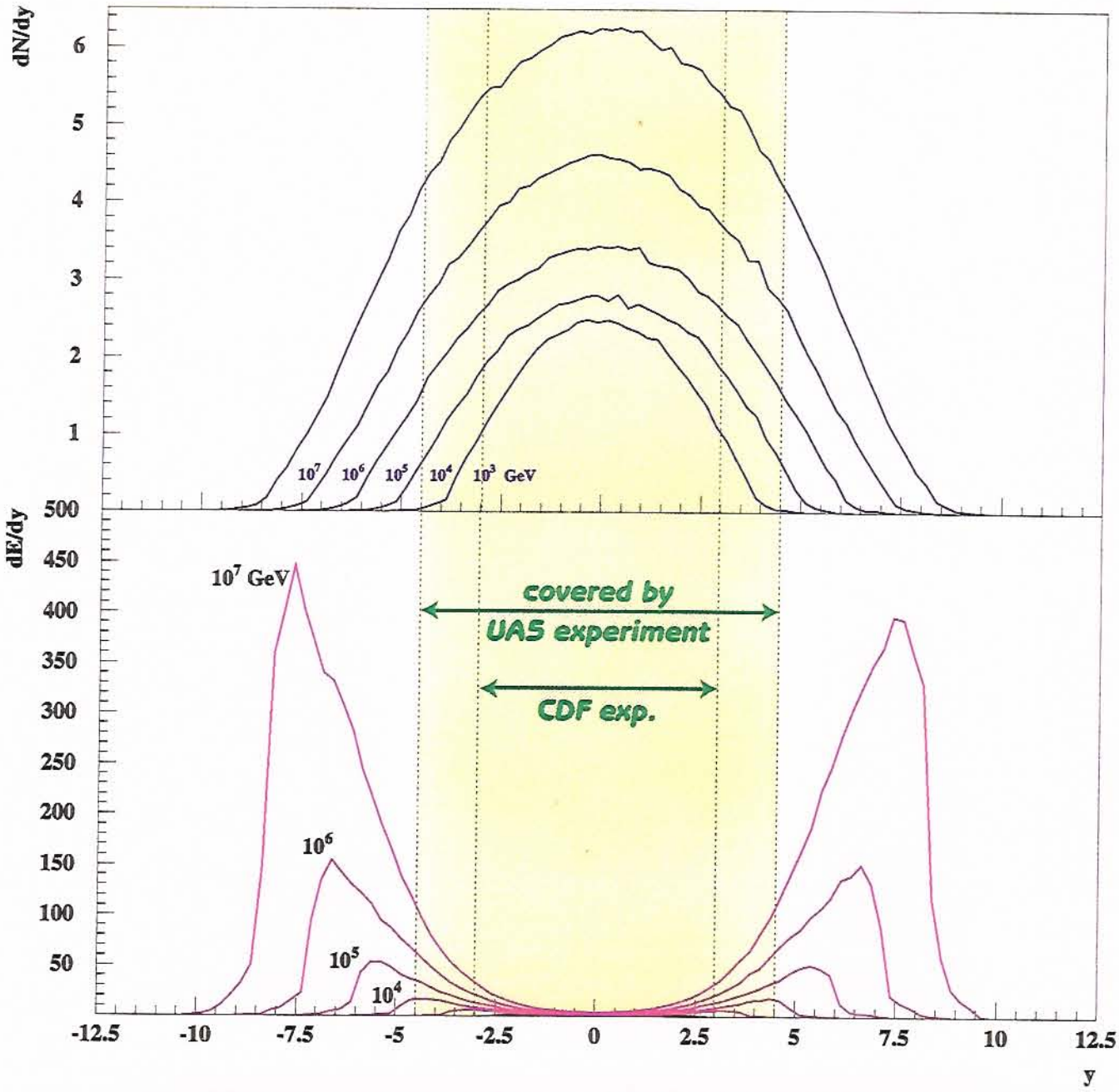
- e.m. cross sections

  well known

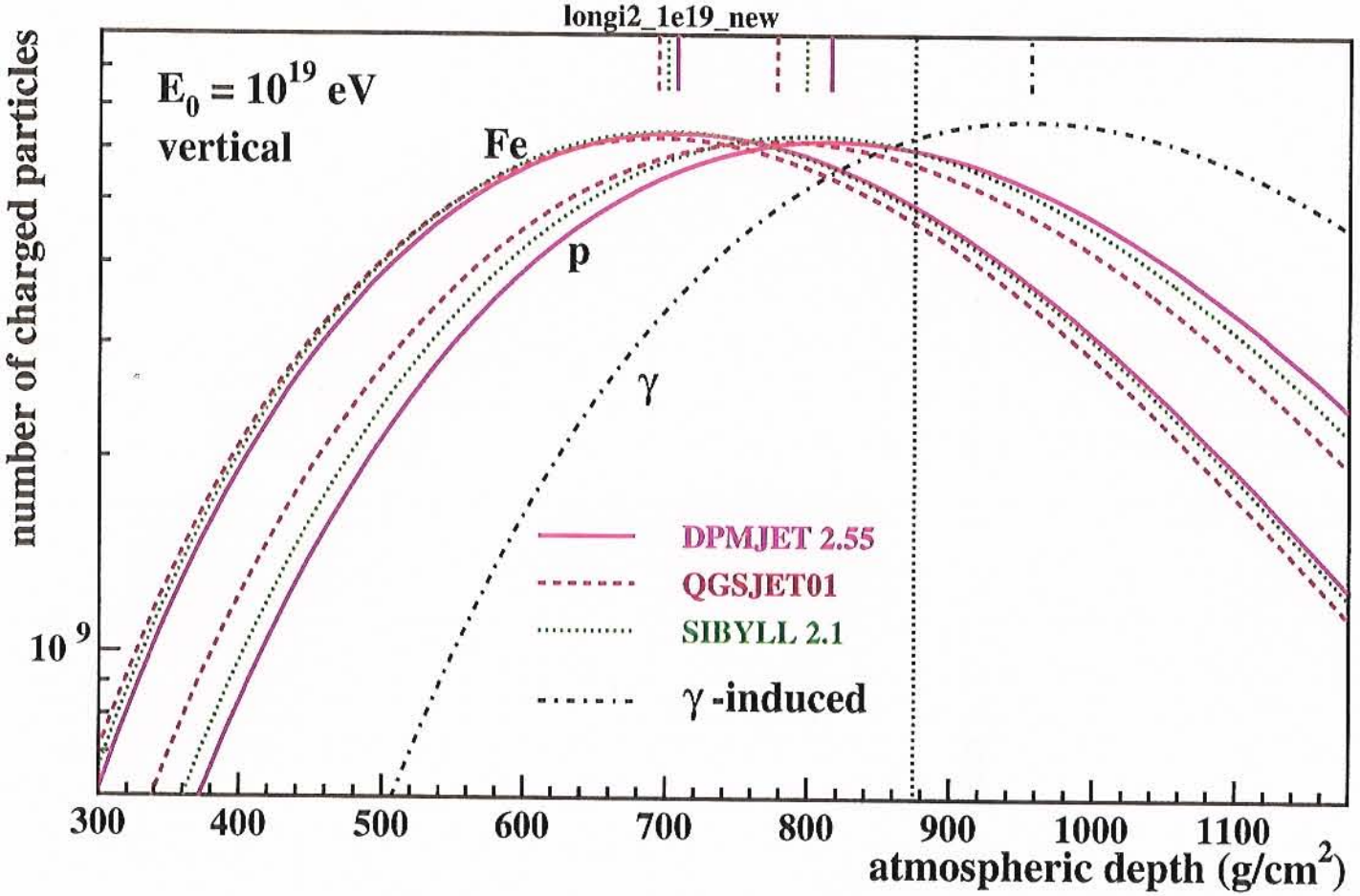
- cross sections of hadron nucleus interactions

  not (well) known

Particle and Energy Flow in $p\bar{p}$-Interactions



Most energy in collider experiments remains unseen...!!


longi2_1e19_new
$E_0 = 10^{19}$ eV
vertical
Fe
p
γ
DPMJET 2.55
QGSJET01
SIBYLL 2.1
γ -induced
number of charged particles
10^9
300
400
500
600
700
800
900
1000
1100
atmospheric depth (g/cm^2)