# GZK prediction at UHECR, half a century later

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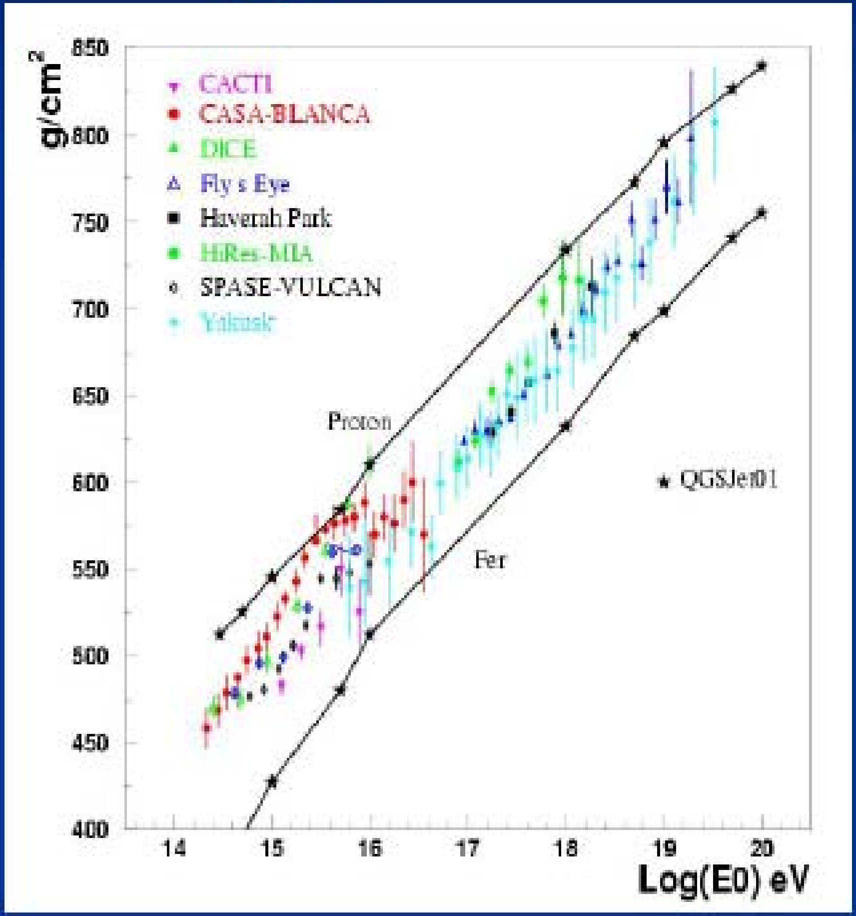
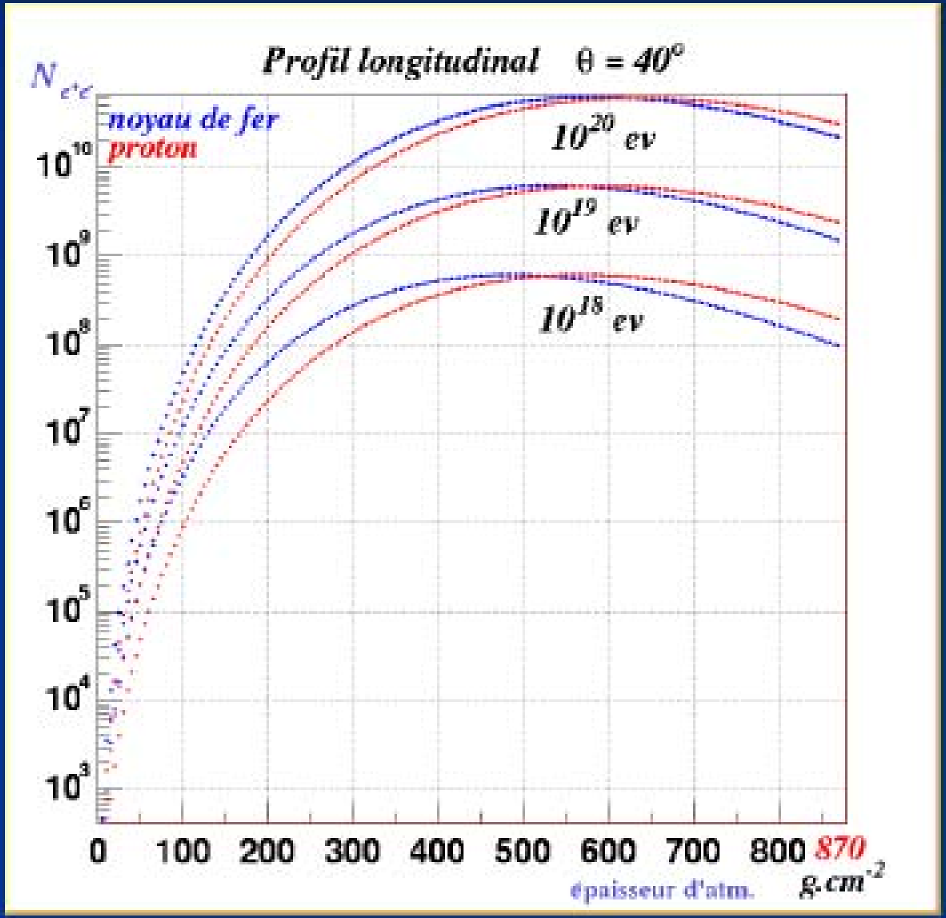
# Outline

- General properties of giant EAS
- The extrapolation at UHE
- The treatment of inclined GAS in AGASA
- The treatment of the vertical energy estimator
- Amendments of experimental data and general convergence to GZK prediction
- Mass composition at UHE

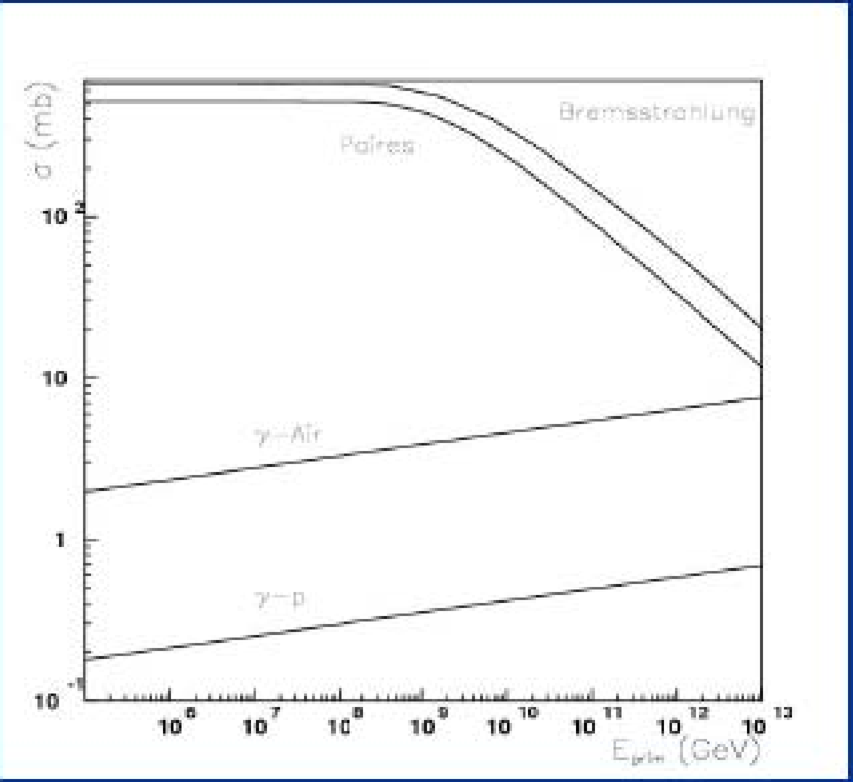
# Xmax (g/cm2) and Nmax for p, Fe initiated showers

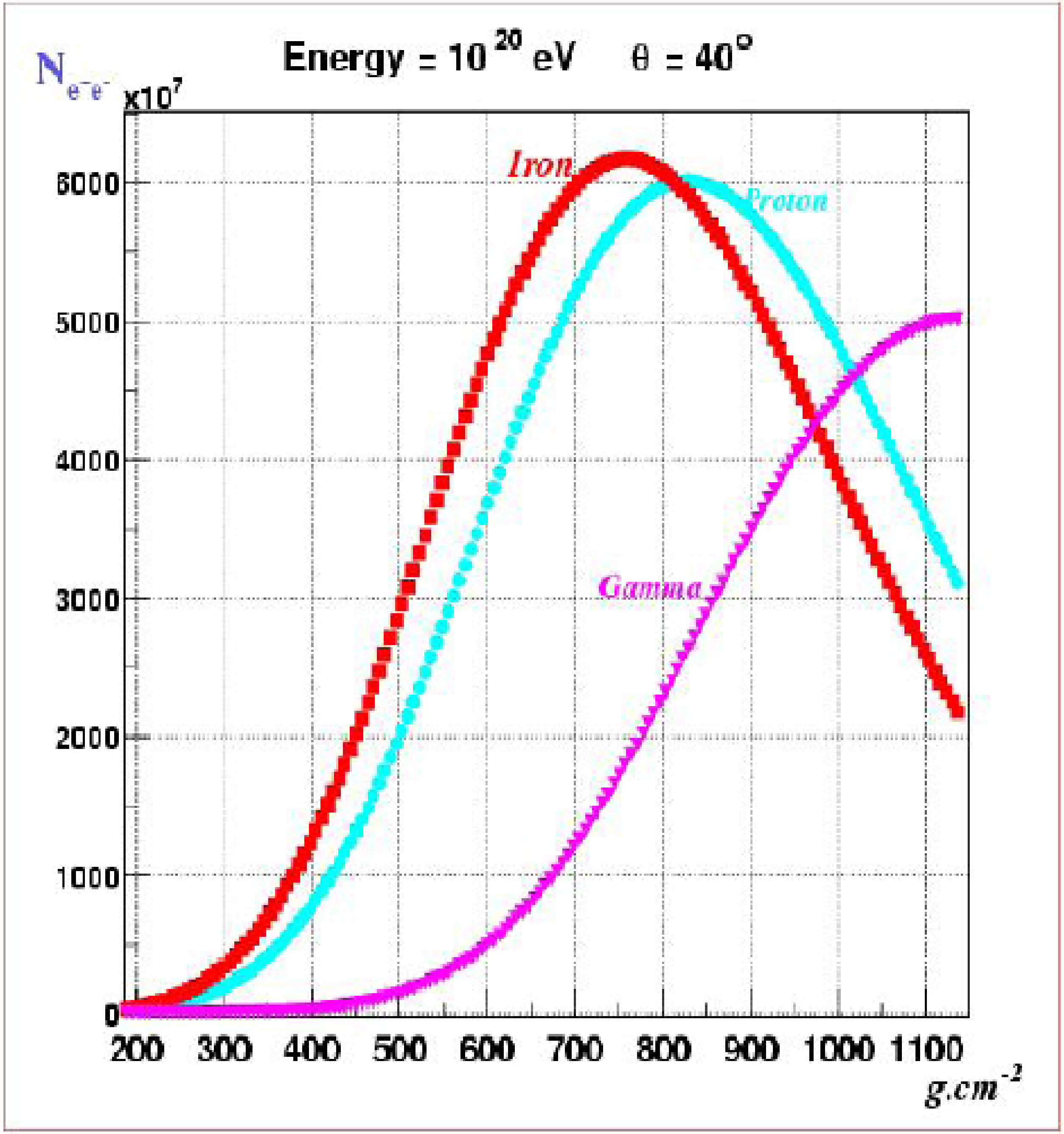


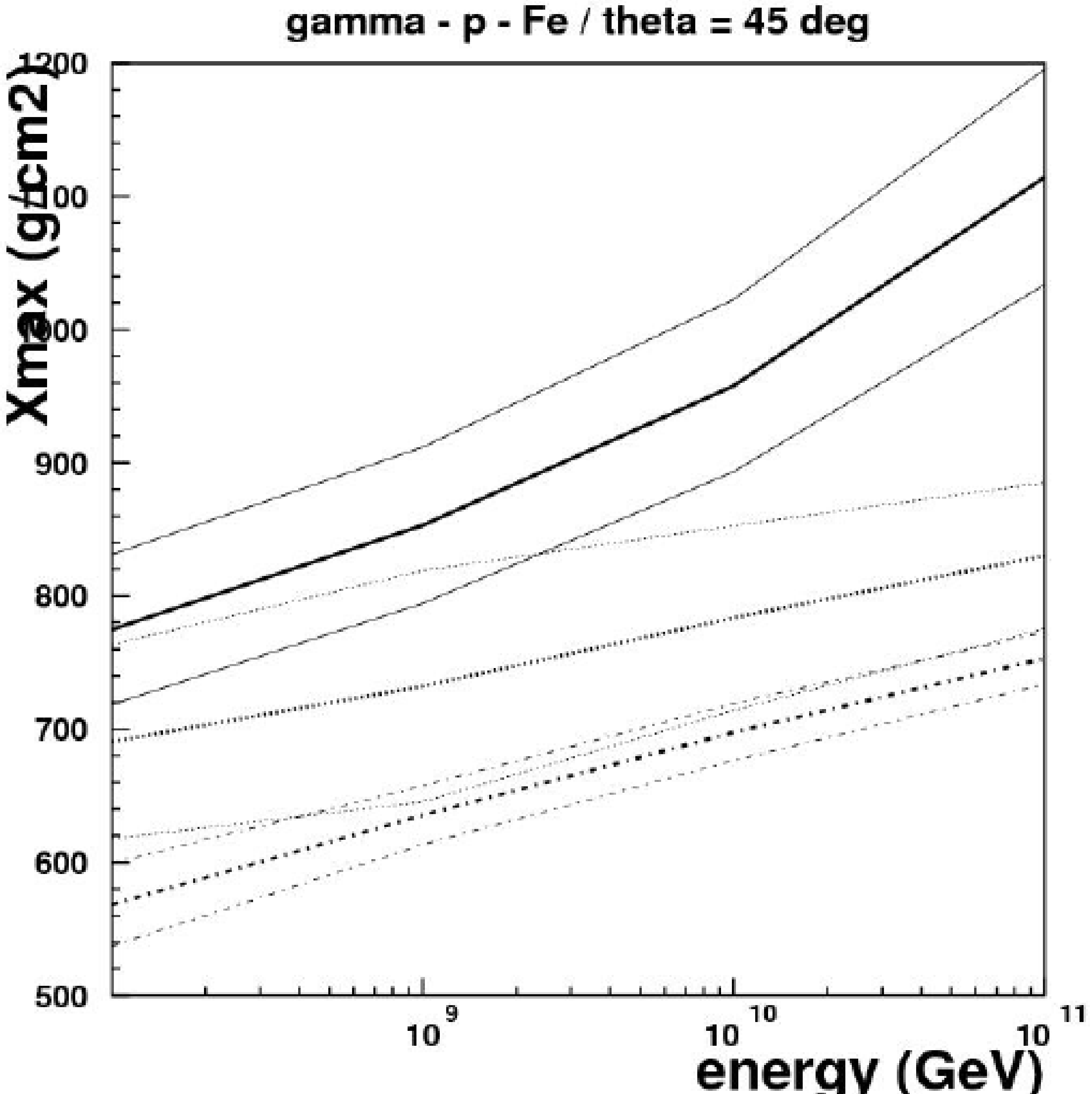
# LPM effect

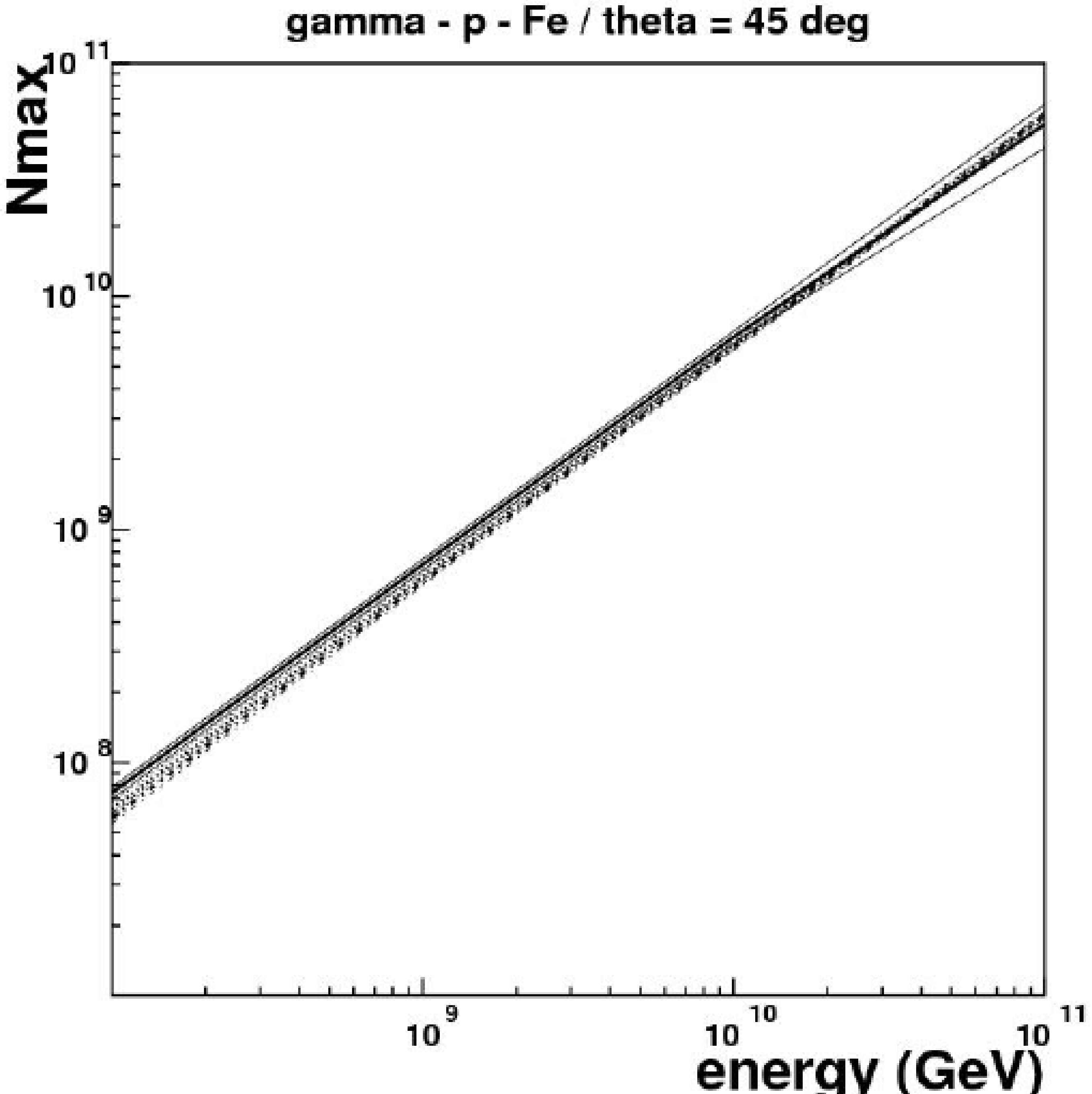
- Maximum deeper in atmosphere for pure e.m. cascades
- trigger more difficult for registration of near vertical e.m. cascade with surface arrays



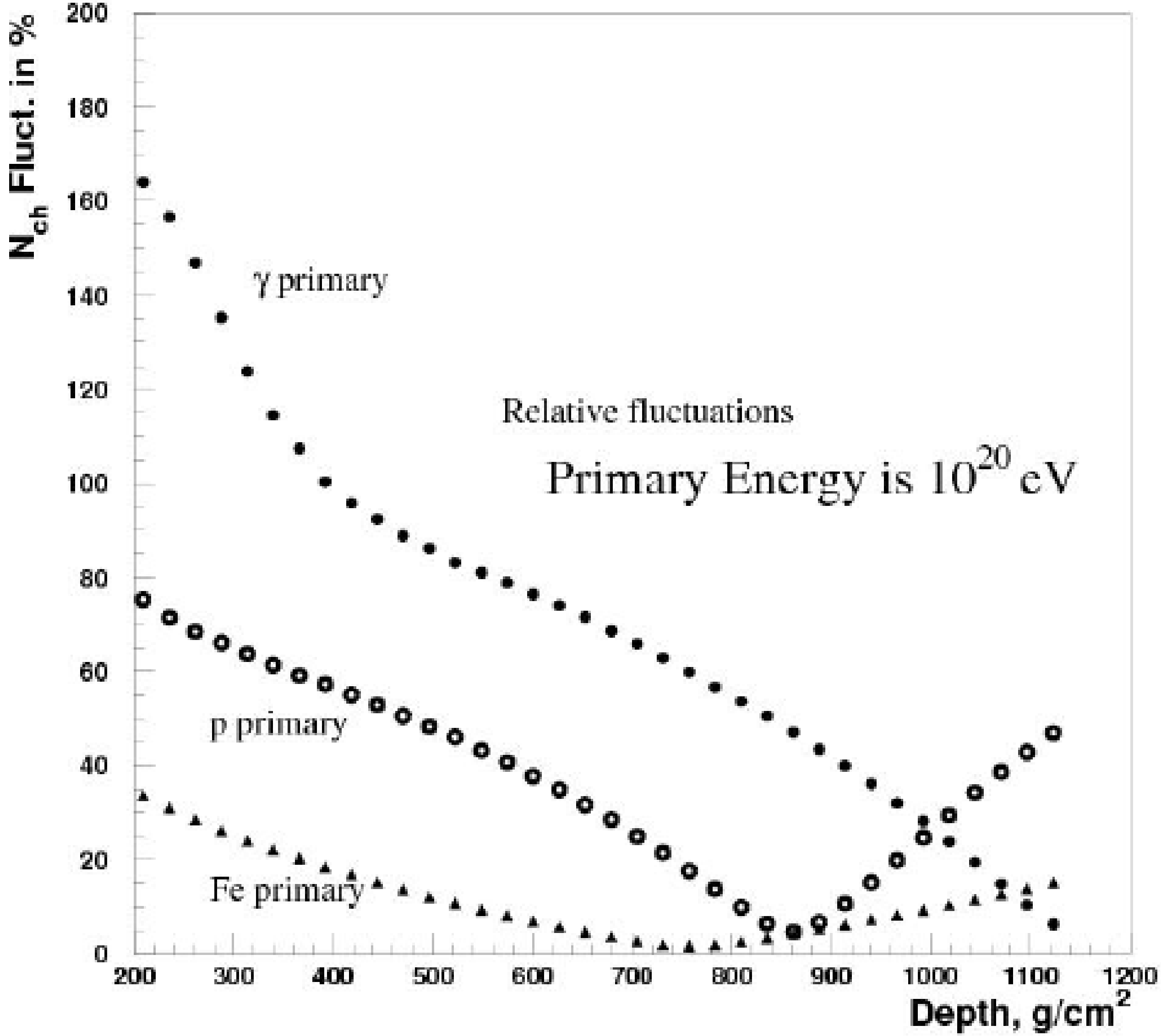


Energy = 10 20 eV θ = 40°
$N_{e^-e^-}$ x10^7
Iron
Proton
Gamma
6000
5000
4000
3000
2000
1000
0
200 300 400 500 600 700 800 900 1000 1100
g.cm^-2

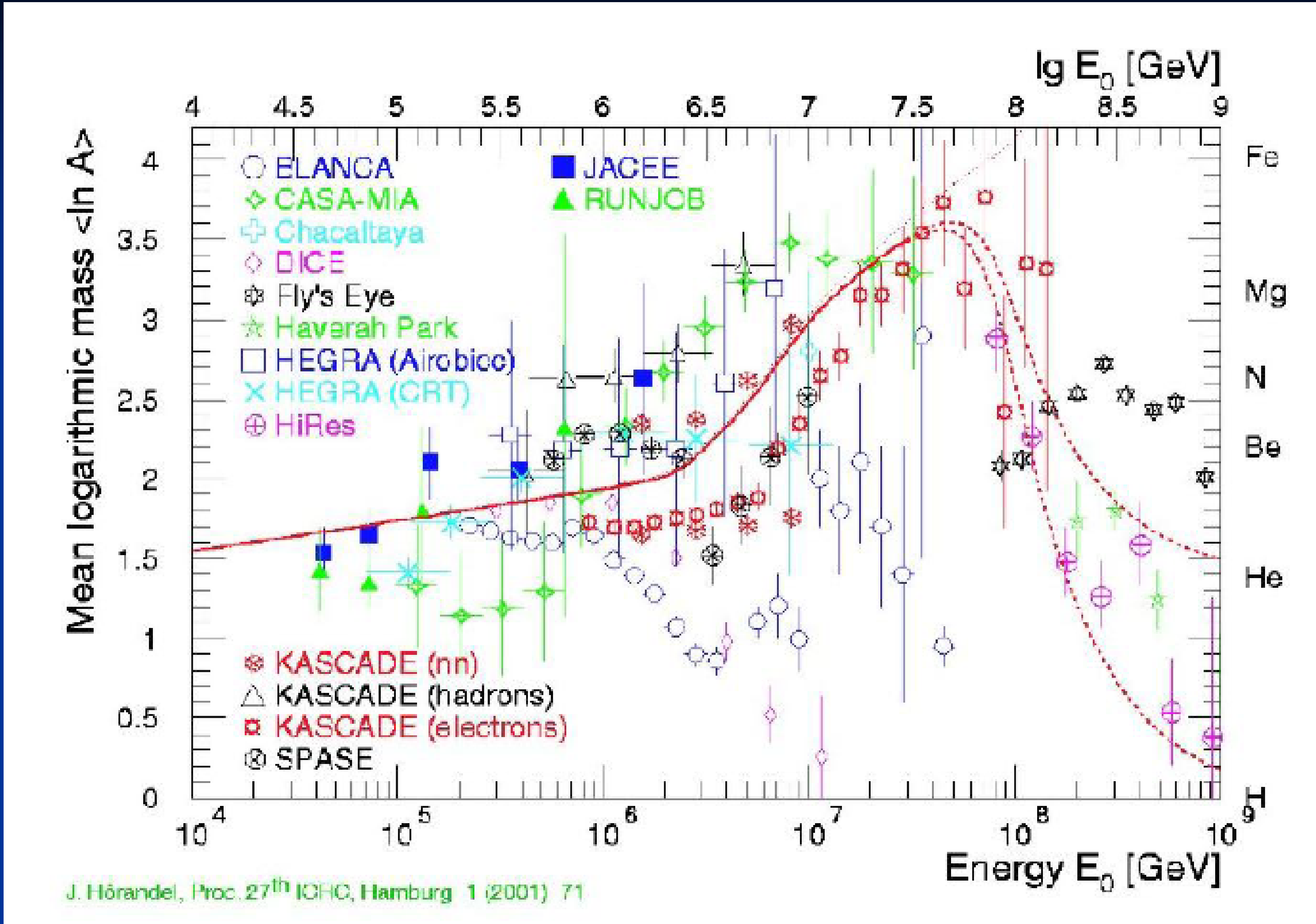

gamma - p - Fe / theta = 45 deg
Xmax (g/cm2)
1200
1100
1000
900
800
700
600
500
10^9
10^10
10^11
energy (GeV)

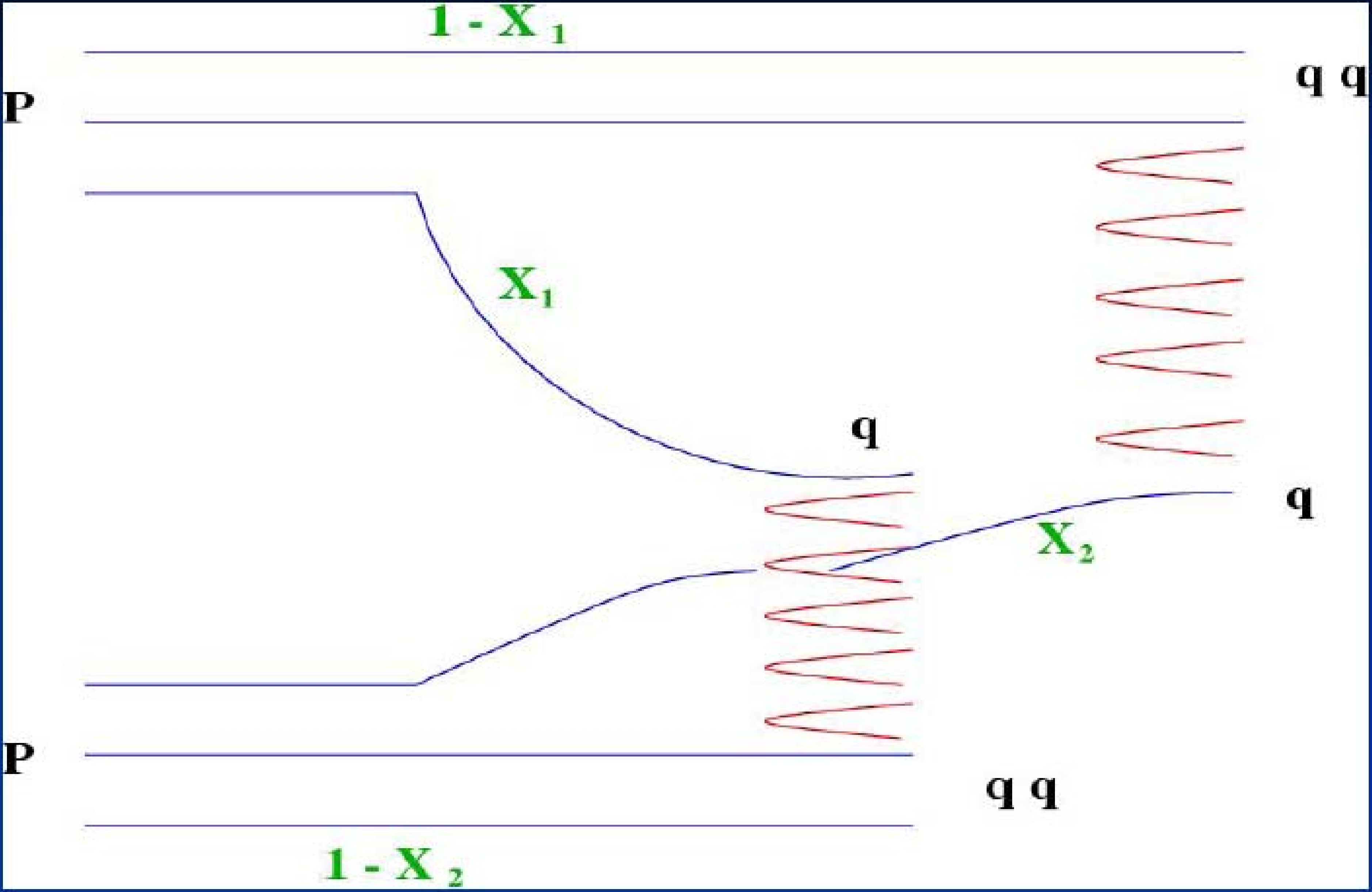


gamma - p - Fe / theta = 45 deg
Nmax
$10^{11}$
$10^{10}$
$10^{9}$
$10^{8}$
$10^{9}$
$10^{10}$
$10^{11}$
energy (GeV)

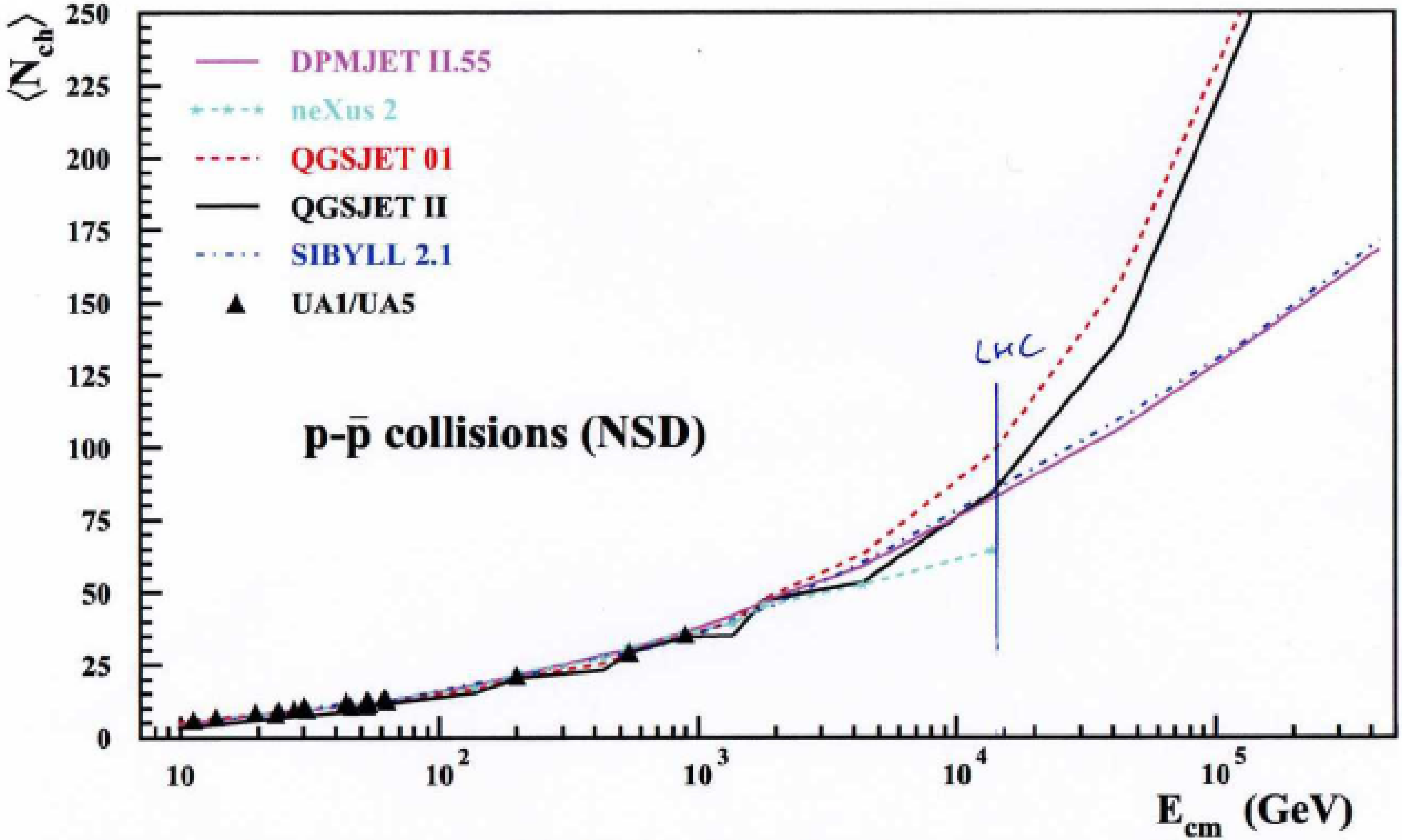


$N_{ch}$ Fluct. in %
γ primary
Relative fluctuations
Primary Energy is $10^{20}$ eV
p primary
Fe primary
Depth, g/cm$^2$
0
20
40
60
80
100
120
140
160
180
200
200
300
400
500
600
700
800
900
1000
1100
1200


lg E0 [GeV]
4
4.5
5
5.5
6
6.5
7
7.5
8
8.5
9
Mean logarithmic mass <ln A>
0
0.5
1
1.5
2
2.5
3
3.5
4
Fe
Mg
N
Be
He
H
ELANCA
CASA-MIA
Chacaltaya
DICE
Fly's Eye
Haverah Park
HEGRA (Airobicc)
HEGRA (CRT)
HiRes
JACEE
RUNJOB
KASCADE (nn)
KASCADE (hadrons)
KASCADE (electrons)
SPASE
10^4
10^5
10^6
10^7
10^8
10^9
Energy E0 [GeV]
J. Hörandel, Proc. 27th ICRC, Hamburg 1 (2001) 71

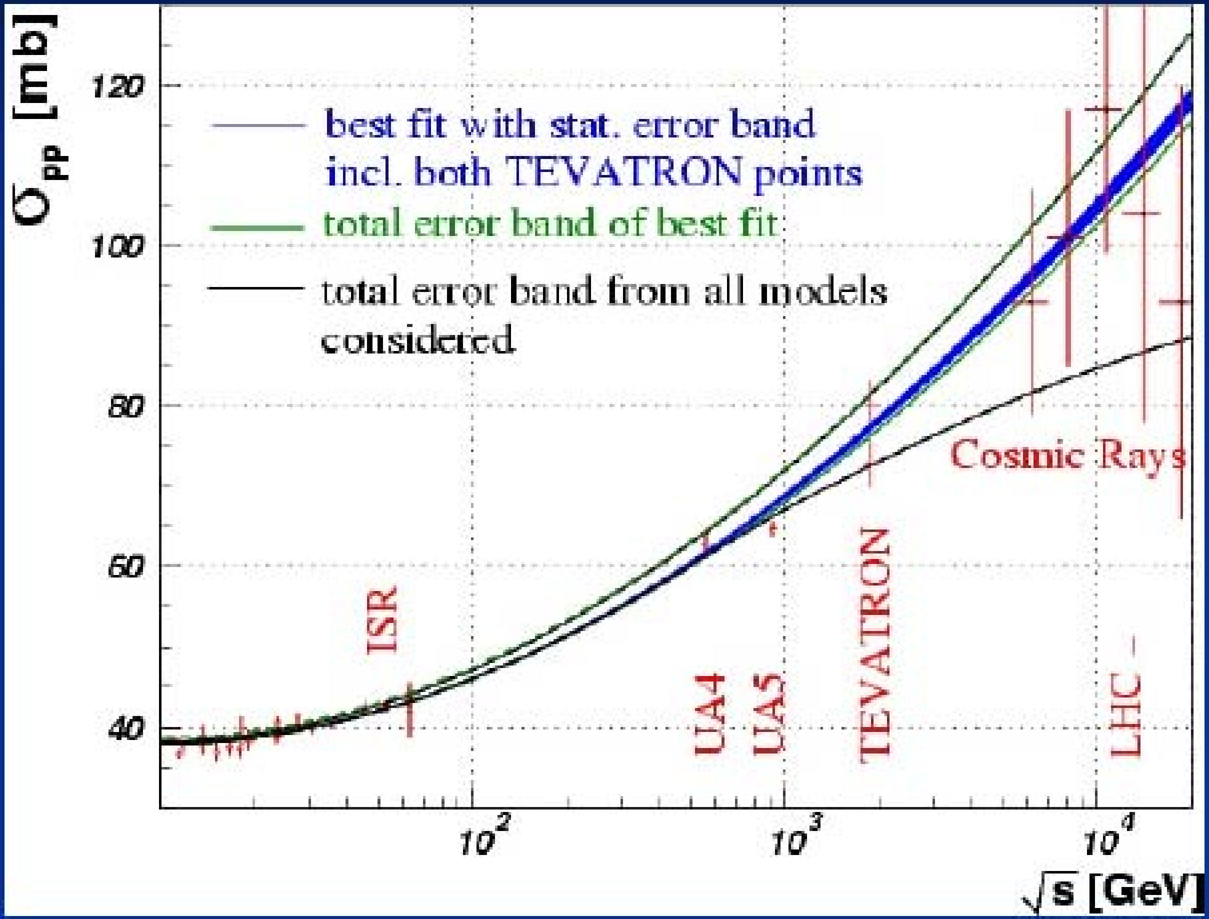

1 - X 1
P
q q
X1
q
q
X2
P
q q
1 - X 2

# p-p̄ Interactions: Multiplicity




**Charged particle multiplicity distribution in p-p̄ collisions.**

# Total p-p Cross-Section




$\sim \ln^2 s$

Current models predictions: 90-130 mb

Aim of TOTEM: **~1%** accuracy

COMPETE Collaboration fits all available hadronic data and predicts:

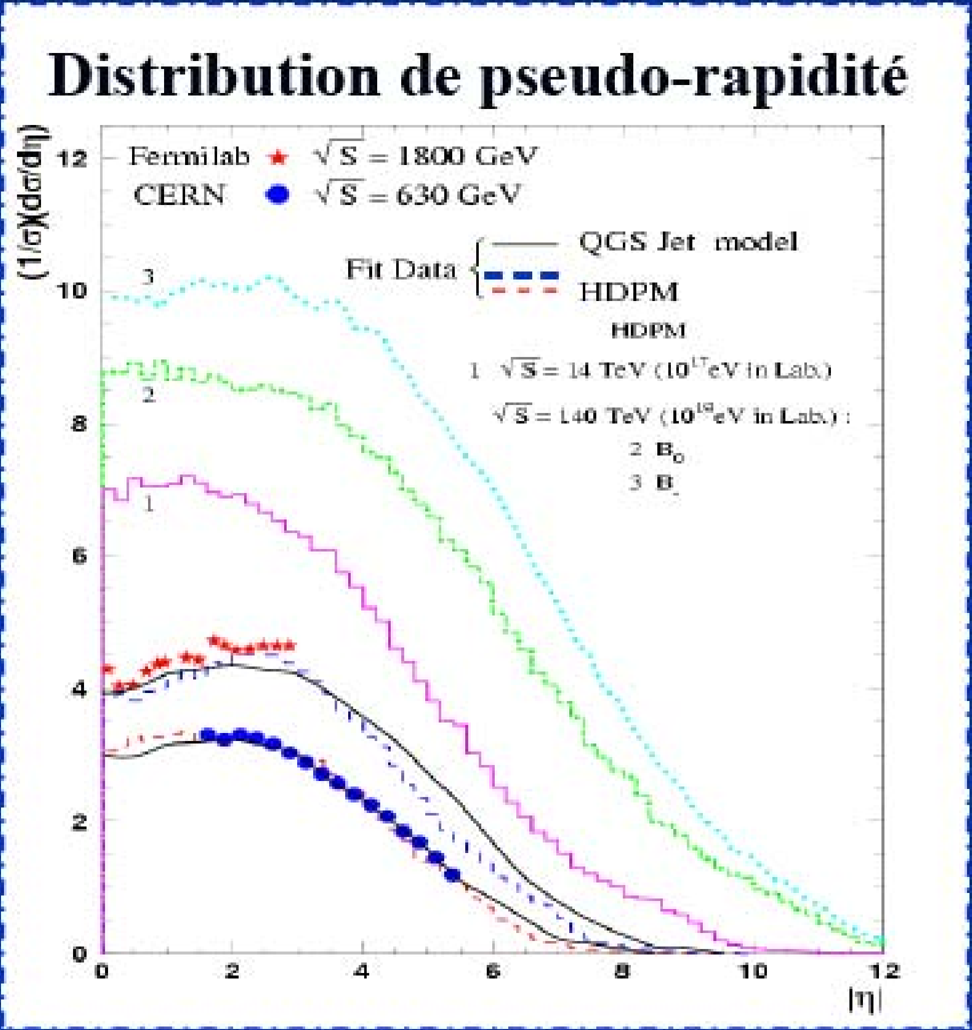
LHC: $$\sigma_{tot} = 111.5 \pm 1.2 \;{}^{+4.1}_{-2.1} \text{ mb}$$

[PRL 89 201801 (2002)]

# Extrapolation des modèles d'interactions hadroniques

**Première interaction importante**
**→ donne les caractéristiques générales de la gerbe (Nmax, Xmax et profil latéral)**

**Modèles théoriques sont ajustés sur les données expérimentales**
**→ Or pas de données au-delà de 1,8 TeV dans le centre de masse (collisions pp)**
**→ extrapolation**

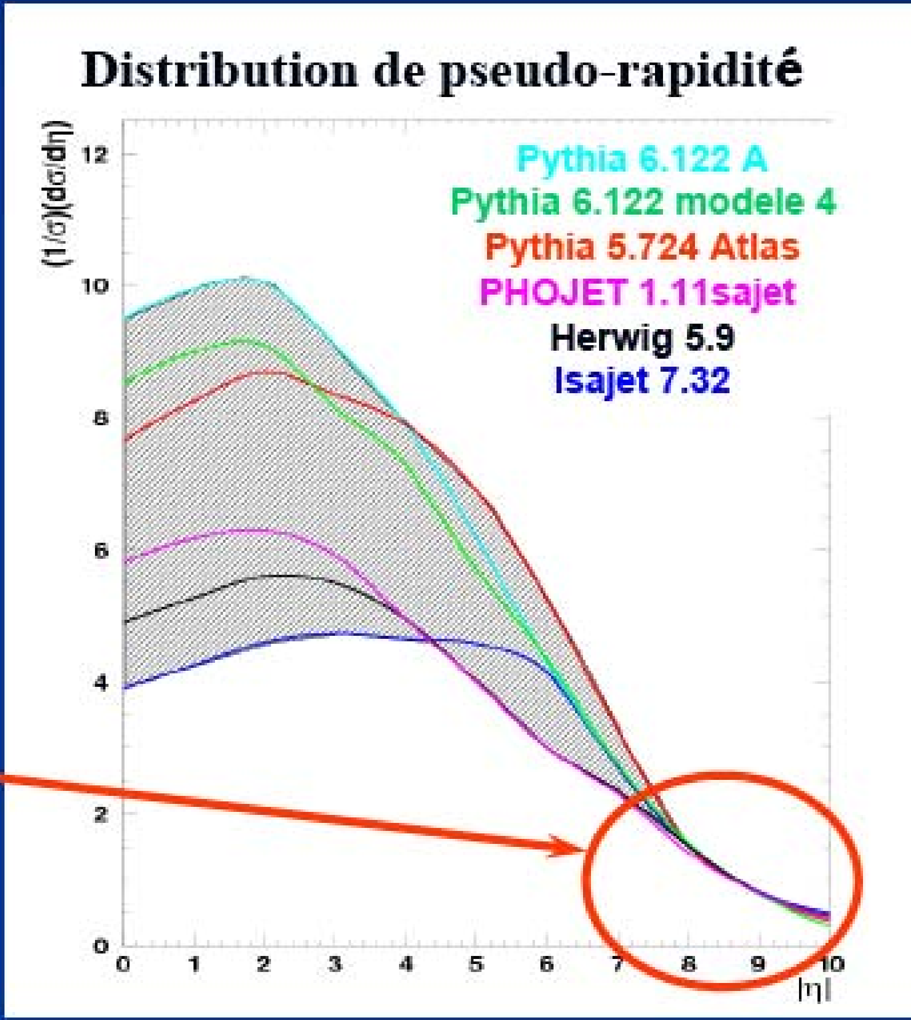


# Incertitudes

*Prédictions pour le LHC*
*à 14 TeV dans le centre de masse*

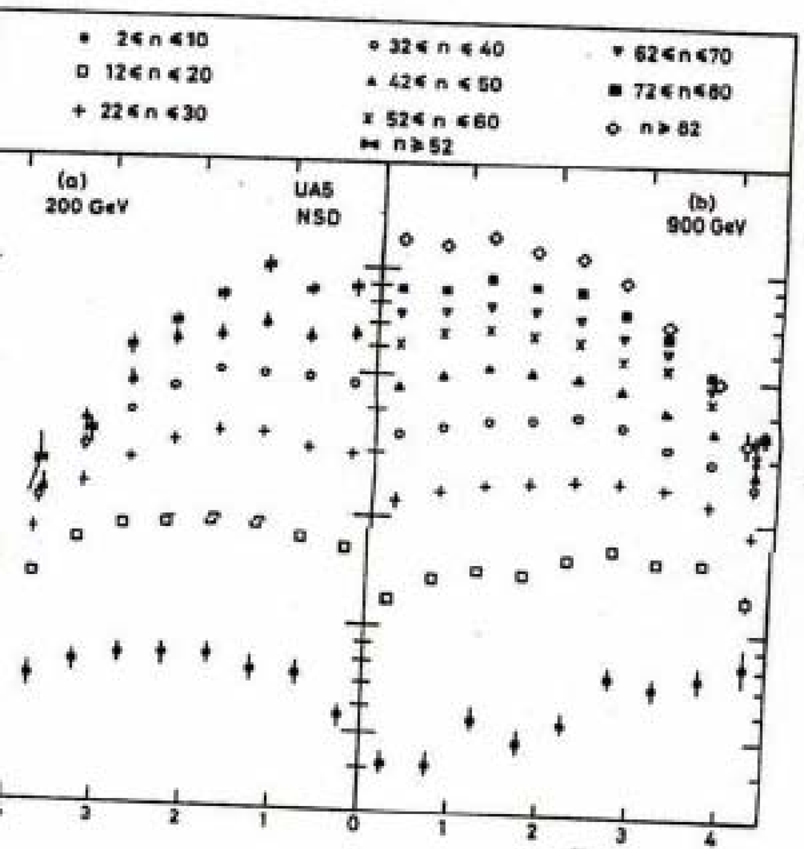
*Multiplicité entre 70 (Isajet )*
*et 125 (Pythia 6.122A)*

- Combien de particules ?
- Quelle énergie emportée par la particule leader



KNO scaling violatiin !

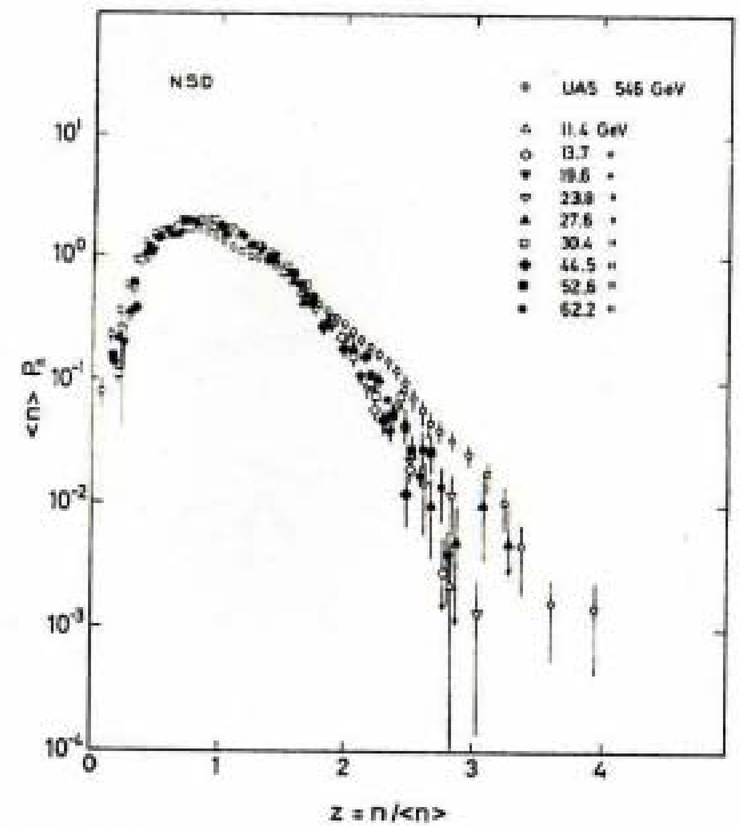
Sem:-inclusive data



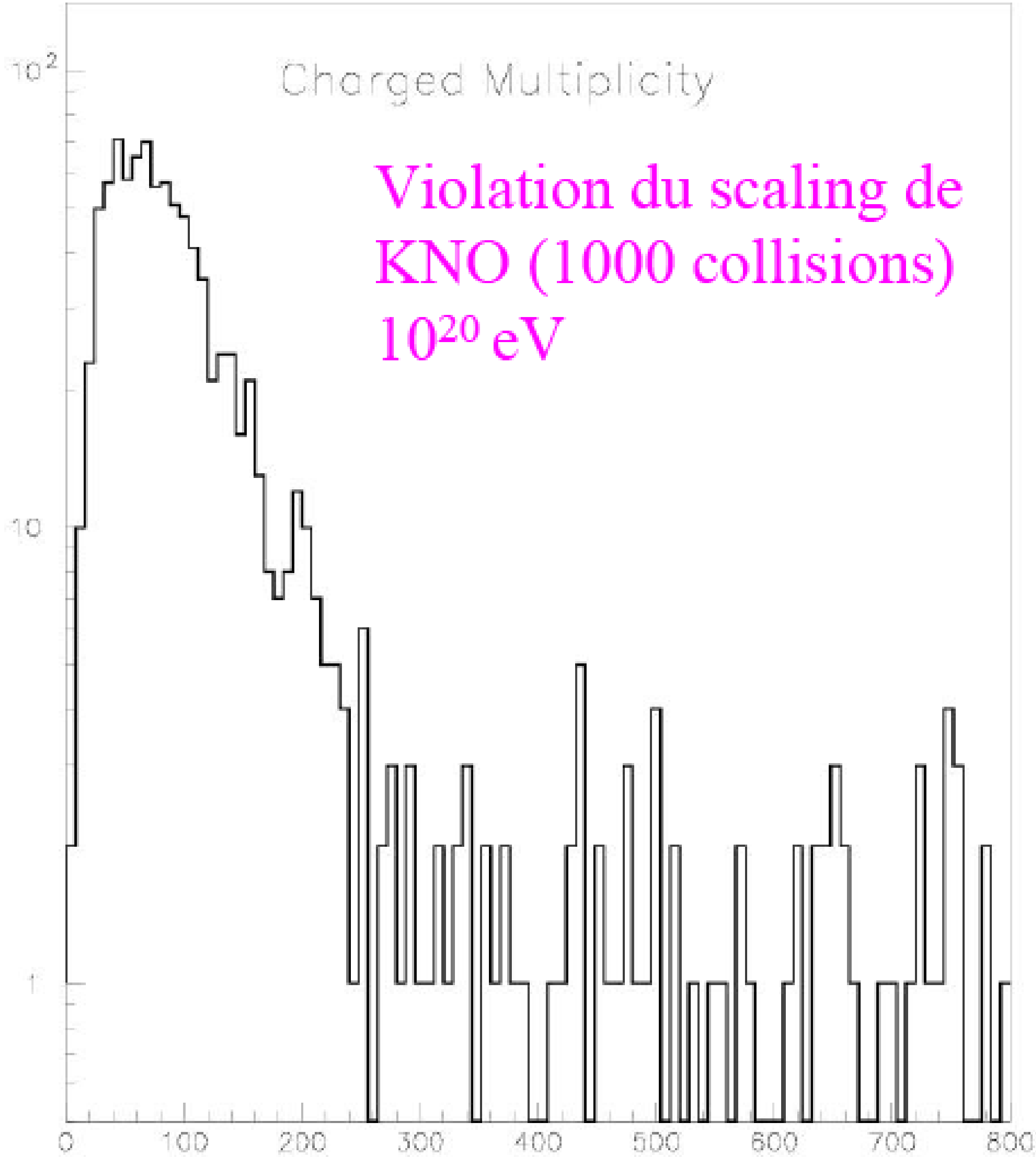

i-inclusive pseudorapidity distributions for charged particles (NSD events) ervals of charged multiplicity n at $\sqrt{s}$ = 200 and 900 GeV [176].

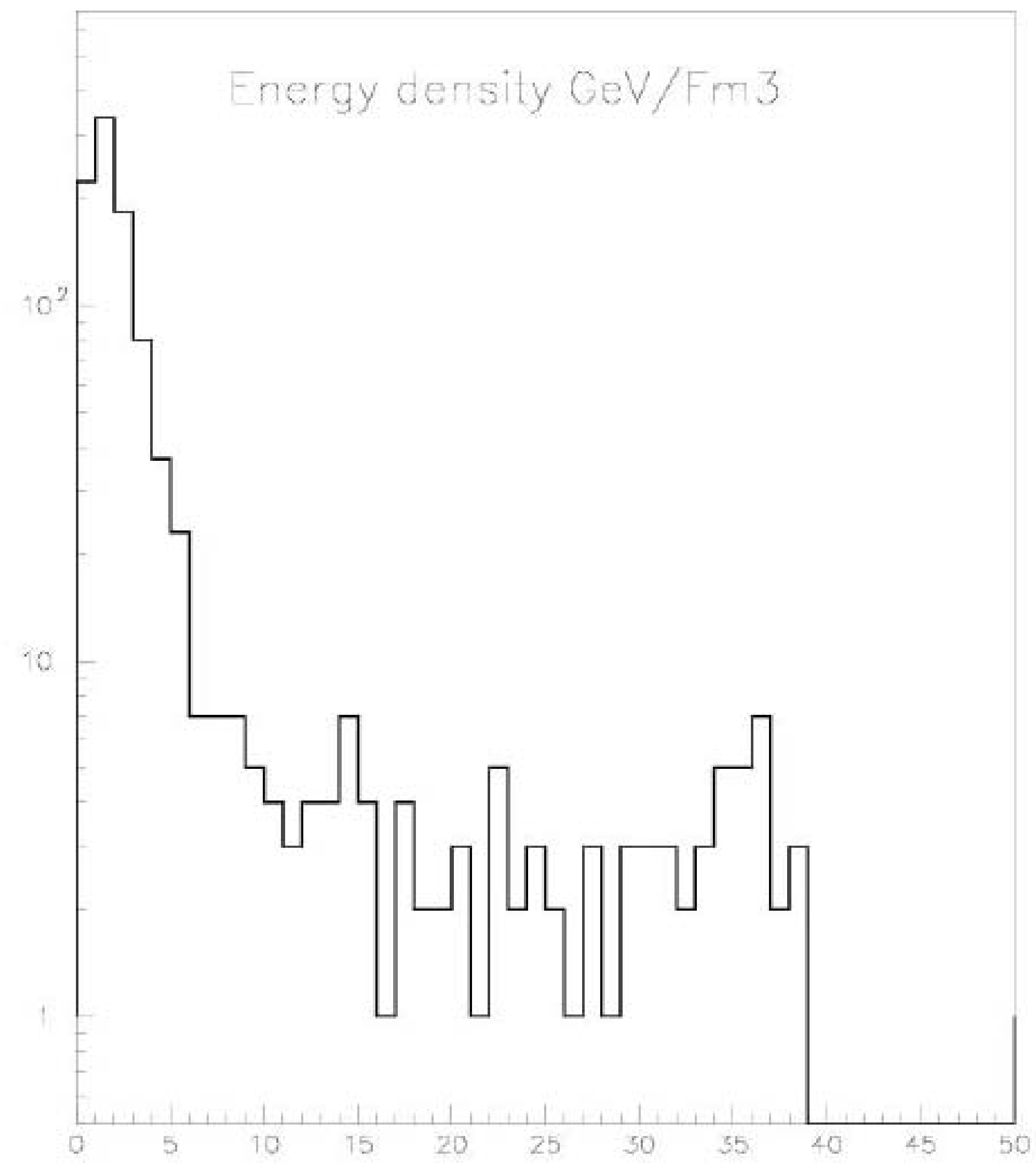
UA semi incl dat

*UA5 Collaboration. UA5: A general study of proton–antiproton physics at $\sqrt{s}$ = 546 G*



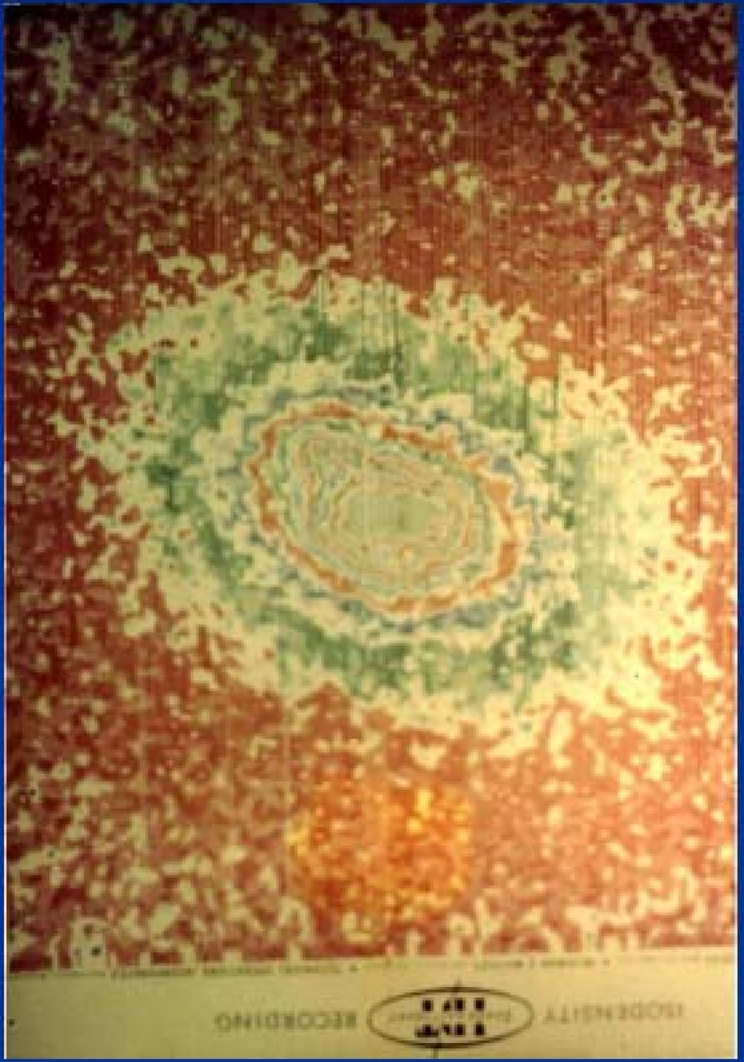

Charged multiplicity distribution in NSD events plotted as a function of z for UA5 data at $\sqrt{s}$ = 546 GeV, co ISR [138], and from Serpukhov and FNAL [139–144].


Charged Multiplicity
Violation du scaling de
KNO (1000 collisions)
10^20 eV
10^2
10
1
0
100
200
300
400
500
600
700
800

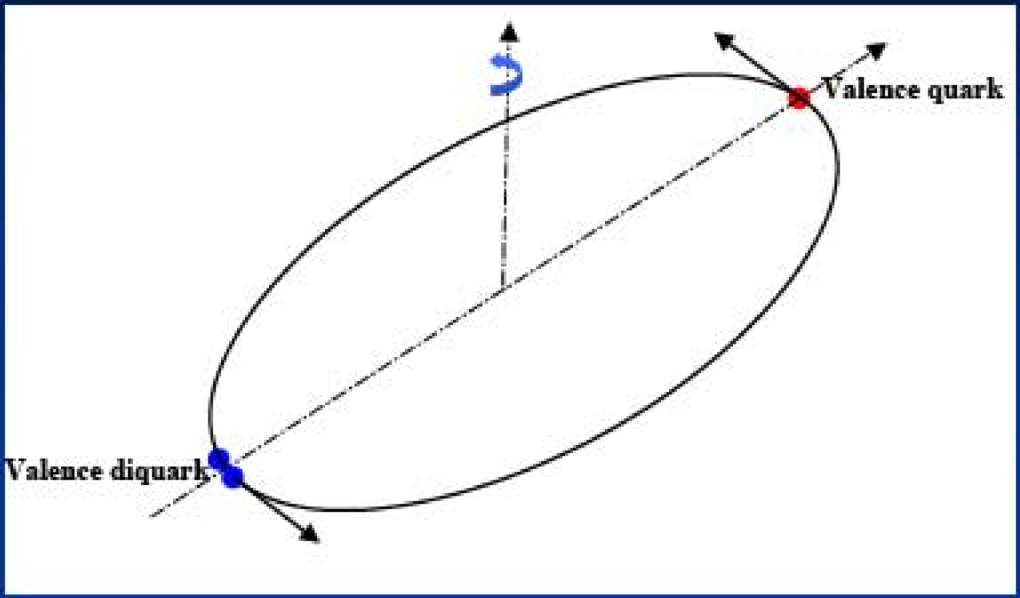

Energy density GeV/Fm3
10²
10
1
0
5
10
15
20
25
30
35
40
45
50

# Chambres à émulsion sur Concorde

- Impact d 'un photon de 200 TeV, l 'un des 211 γ d 'une collision de $10^7$ GeV.
- Evènement à émission coplanaire.
- 50ch sur A80 5000H
- 500 p  1PeV, 7  10 PeV
- 250 familles  γ , 10 PeV , 3 au LHC (100 PeV)



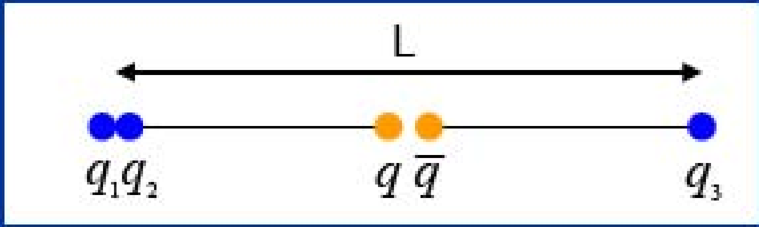
# String Model and di-quark breaking




$$\text{Tension } \kappa = \frac{1}{2\pi\,\alpha'} \cong 1\,\text{GeV}/\text{fm}$$

$\alpha'$ : Regge Slope

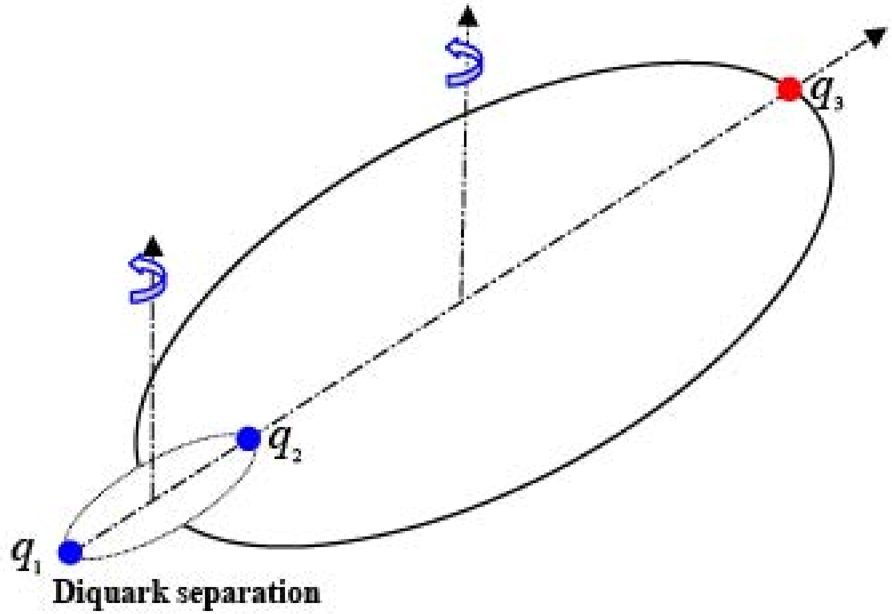
$$\sqrt{\langle p_T \rangle^2} = \sqrt{\frac{\kappa}{\pi}}$$




The pair $q\,\bar{q}$ is created when the distance L exceeds a threshold value.

Above a threshold energy, the di-quark is broken excluding recombination of the leading cluster.

# Very large tension for the diquark partners ?




Maximal tension when the 3 valence quarks are at the largest distance from each other, then aligned.

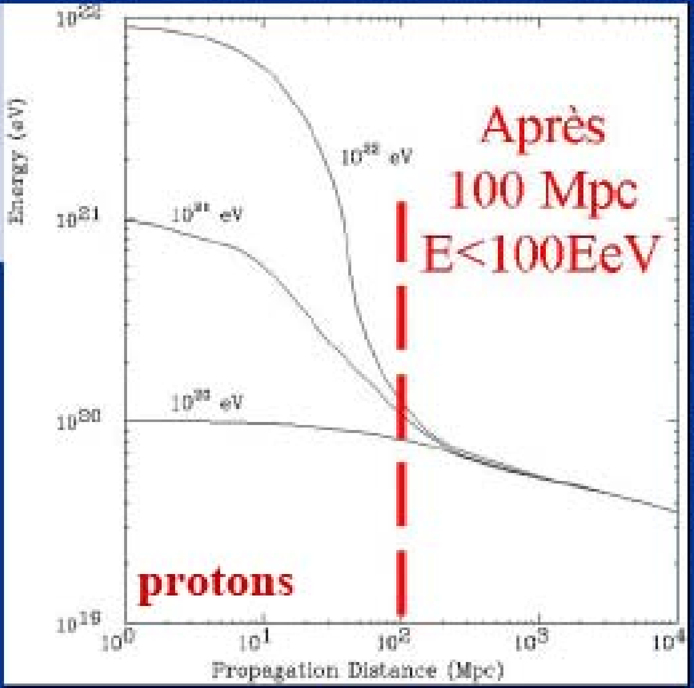
# Propagation : coupure GZK

## Greisen, Zatsepin, Kuzmin

**Interaction des hadrons avec le fond de photons à 3K (CMB)**

$$p\,\gamma \rightarrow \Delta^{+} \rightarrow \begin{cases} p\,\pi^{0} \rightarrow p\,\gamma\,\gamma \\ n\,\pi^{+} \rightarrow n\,\nu_{\mu}\,\mu^{+} \rightarrow n\,\nu_{\mu}\,\bar{\nu}_{\mu}\,\nu_{e}\,e^{+} \end{cases}$$

$$E_{seuil} = 70\ \text{EeV}$$

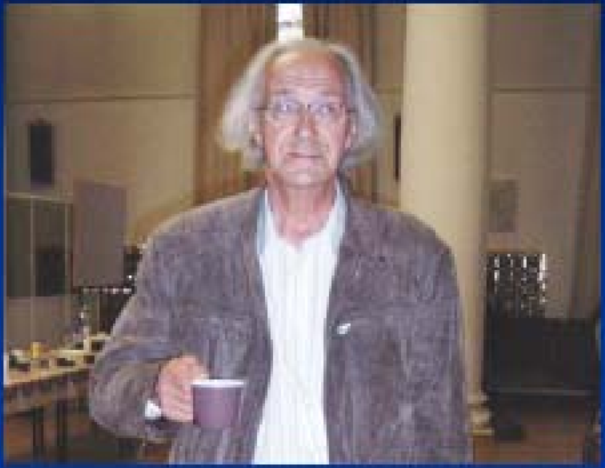



***Les sources doivent être proches !***

# Treatment of inclined EAS data from surface arrays and GZK prediction

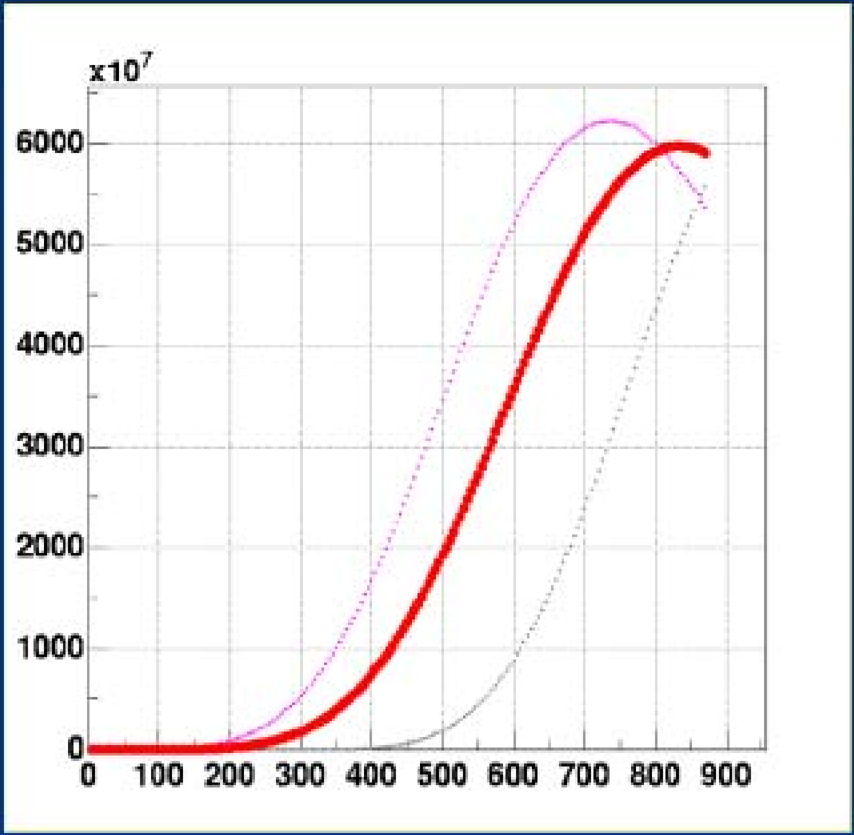
Jean Noël CAPDEVIELLE, F.COHEN, B.SZABELSKA, J.SZABELSKI

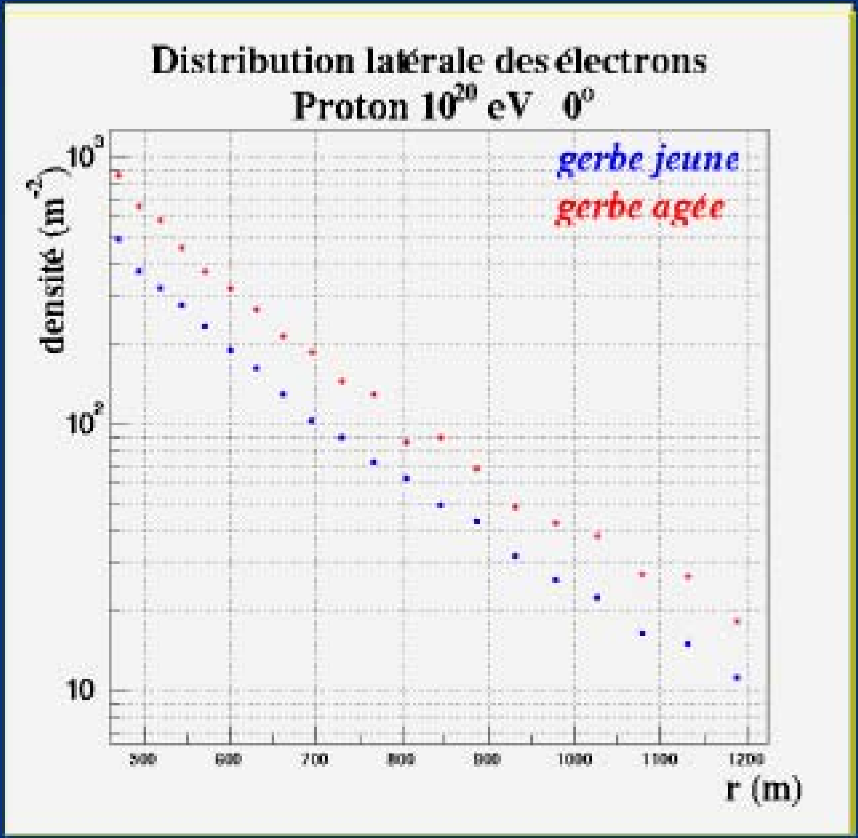
**Georgi Timofeevich Zatsepin (2006)**



**Vadim Alekseyevich Kuzmin (2006)**

# Individual showers



# Fonction Gaussienne hypergéométrique

*Électrons*

$$f(x) = N_e\, x^{s-a}\,(1+x)^{s-b}(1+d.x)^{-c}$$

Avec $x = r / r_o$ et $d = r_o / r_1$

*Muons*

$$f(x) = N_\mu\, x^{-\alpha}\,(1+x)^{-(\eta-\alpha)}(1+\gamma.x)^{-\beta}$$

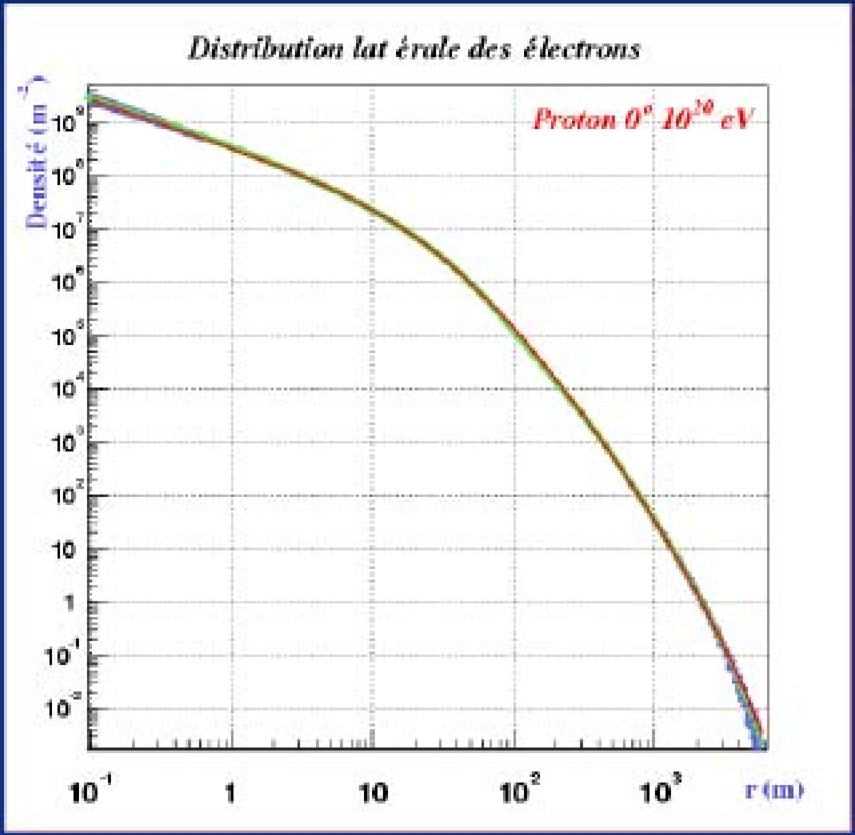
Avec $x = r / r'_o$ et $\gamma = r'_o / r'_1$

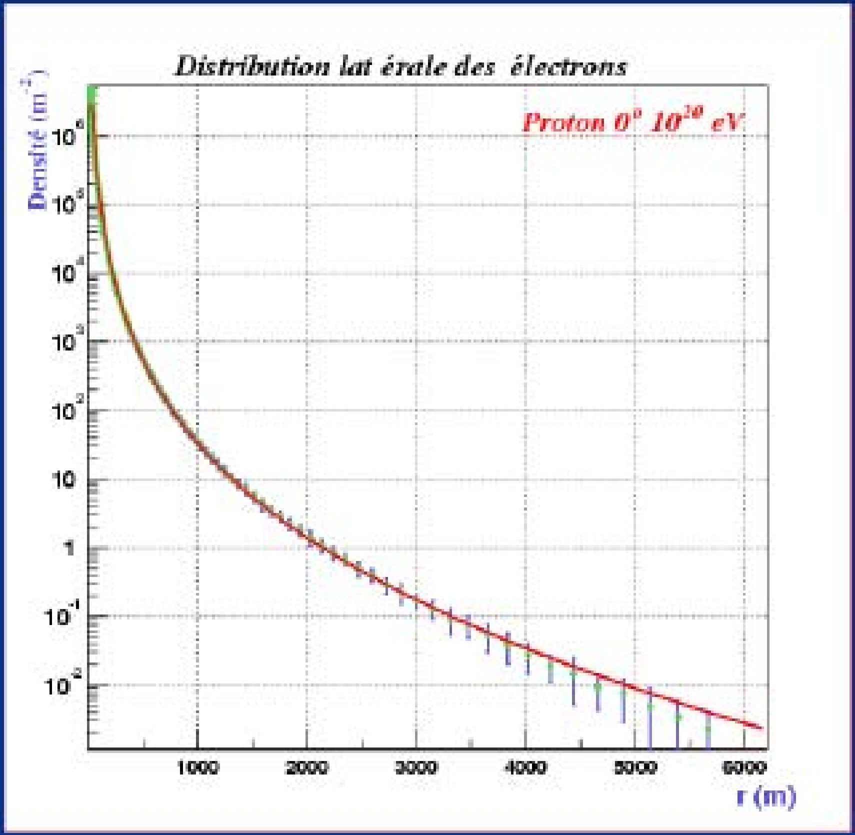
À angle fixe, il va falloir ajuster les paramètres :

a, b, c, $r_0$, $r_1$, $\alpha$, $\eta$, $\beta$, $r'_0$ et $r'_1$

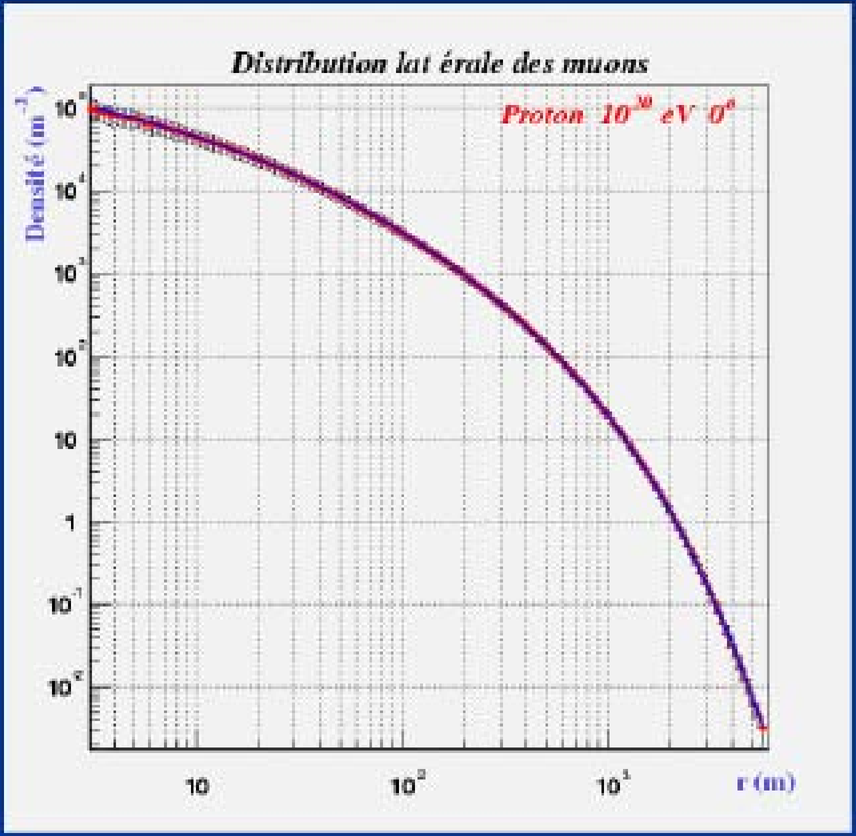
$N_e$ , $N_\mu$ et “s” sont donnés par la simulation

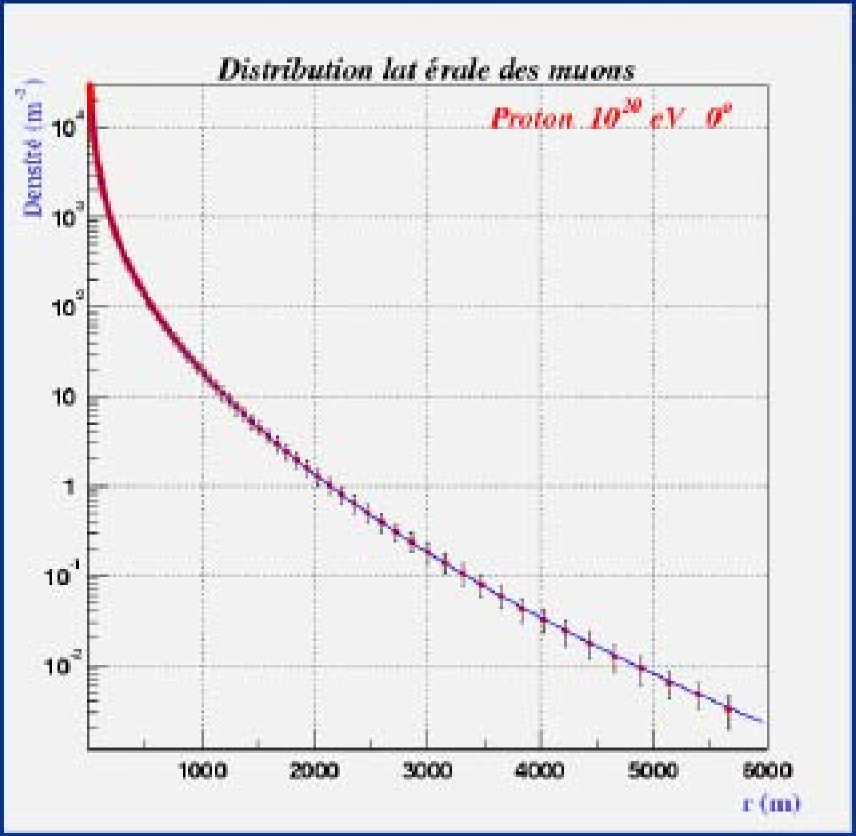
# Résultats des ajustements

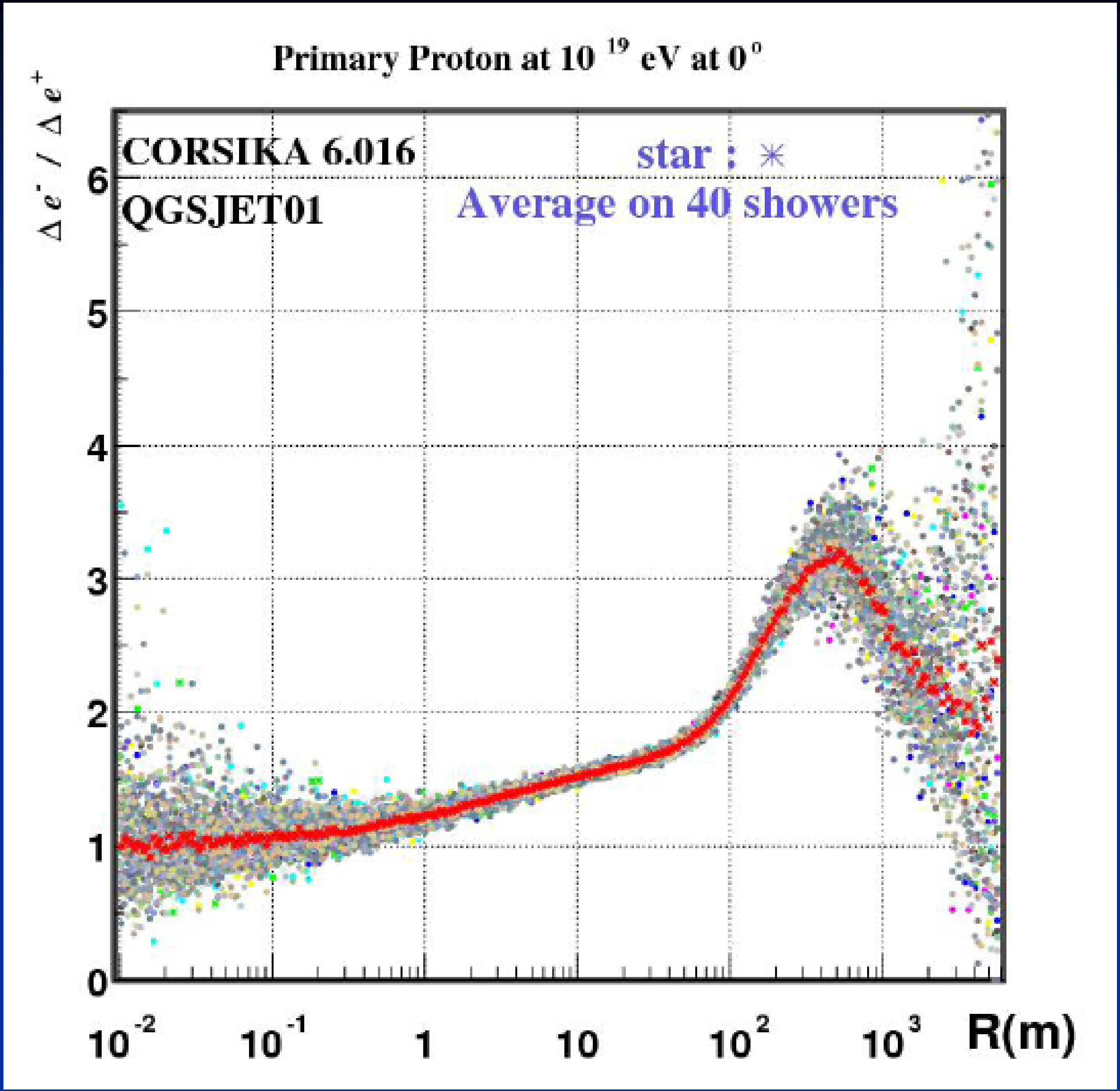


# Résultats des ajustements





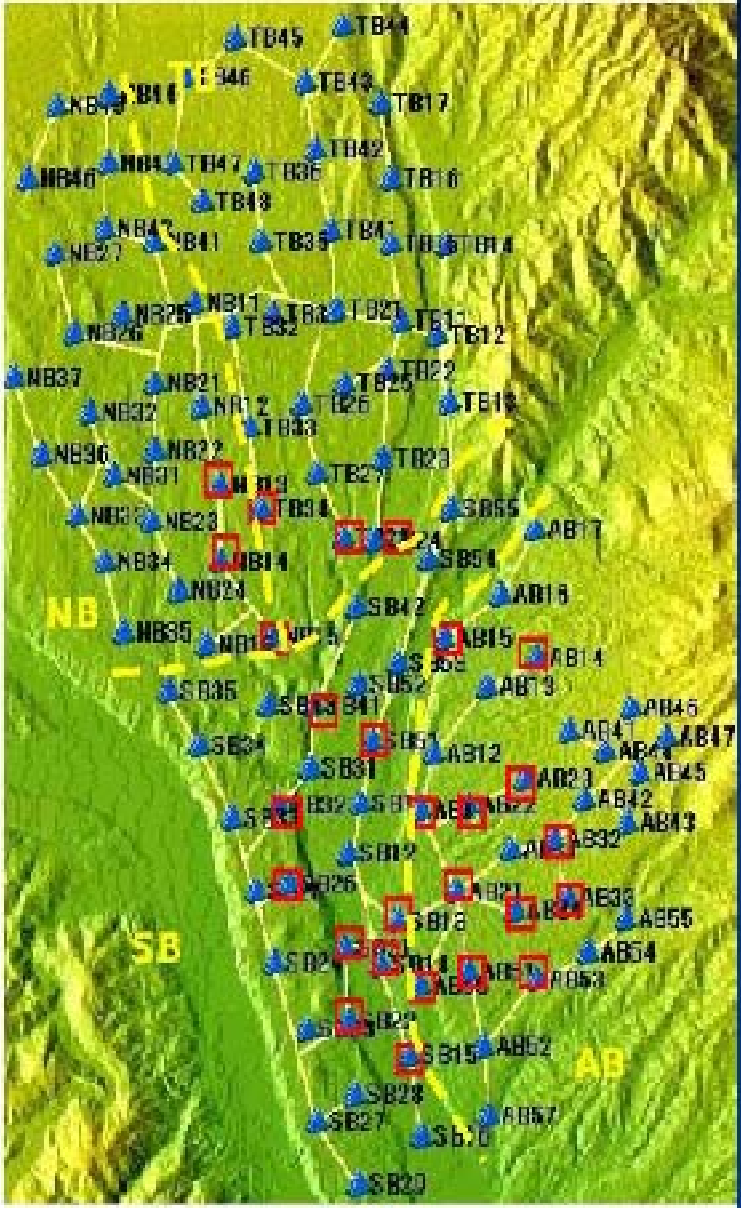
Primary Proton at 10 19 eV at 0°
Δe- / Δe+
CORSIKA 6.016
QGSJET01
star : *
Average on 40 showers
0
1
2
3
4
5
6
10-2
10-1
1
10
102
103
R(m)

# *AGASA (Akeno Giant Air Shower Array)*

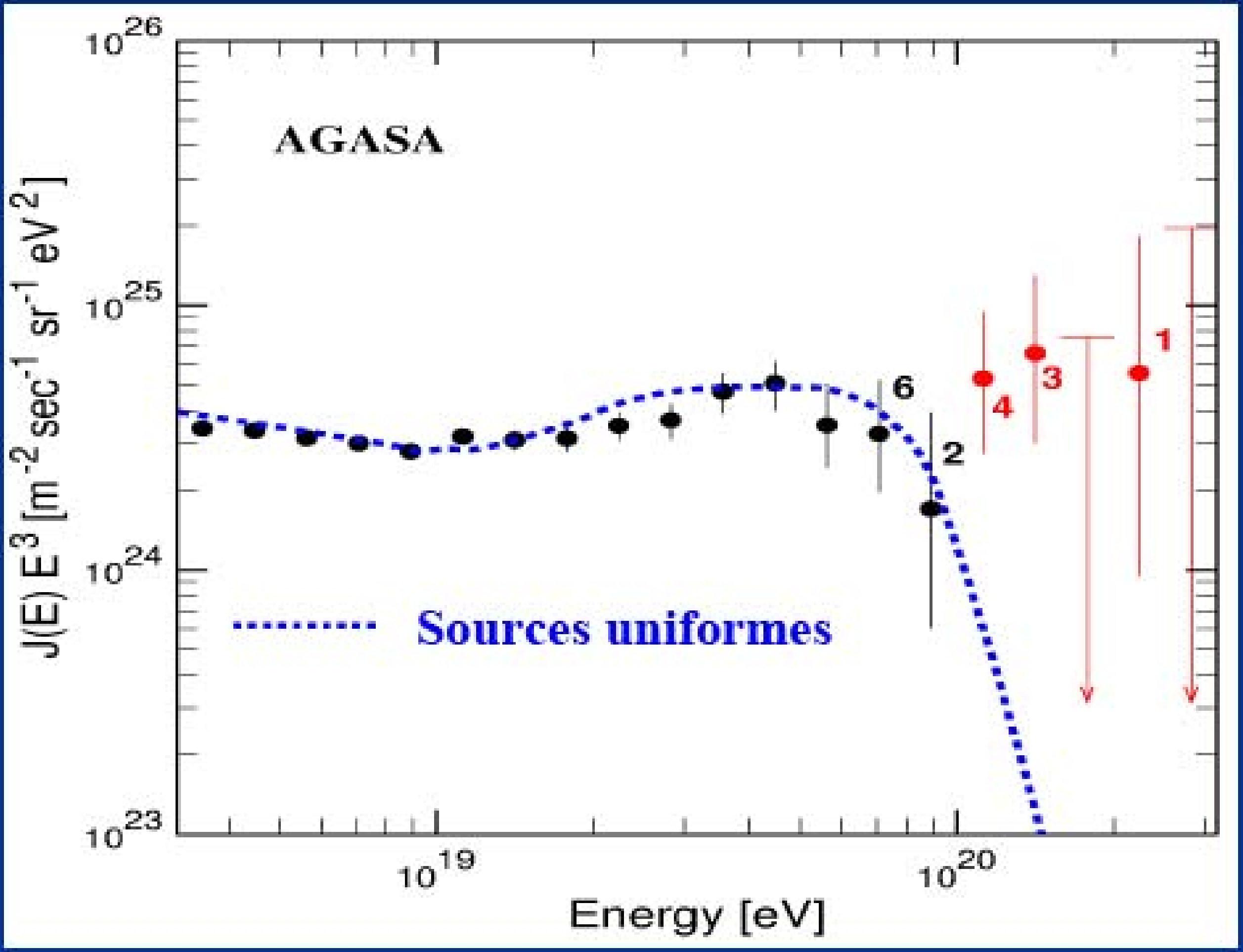
- **Operation (1990—2004)**
  - Feb 1990—Sept 1993
    4 branches operation
  - Sept 1993—Nov 1995
    2 sub-arrays operation
  - Dec 1995—Jan 2004
    Unified 1-array operation

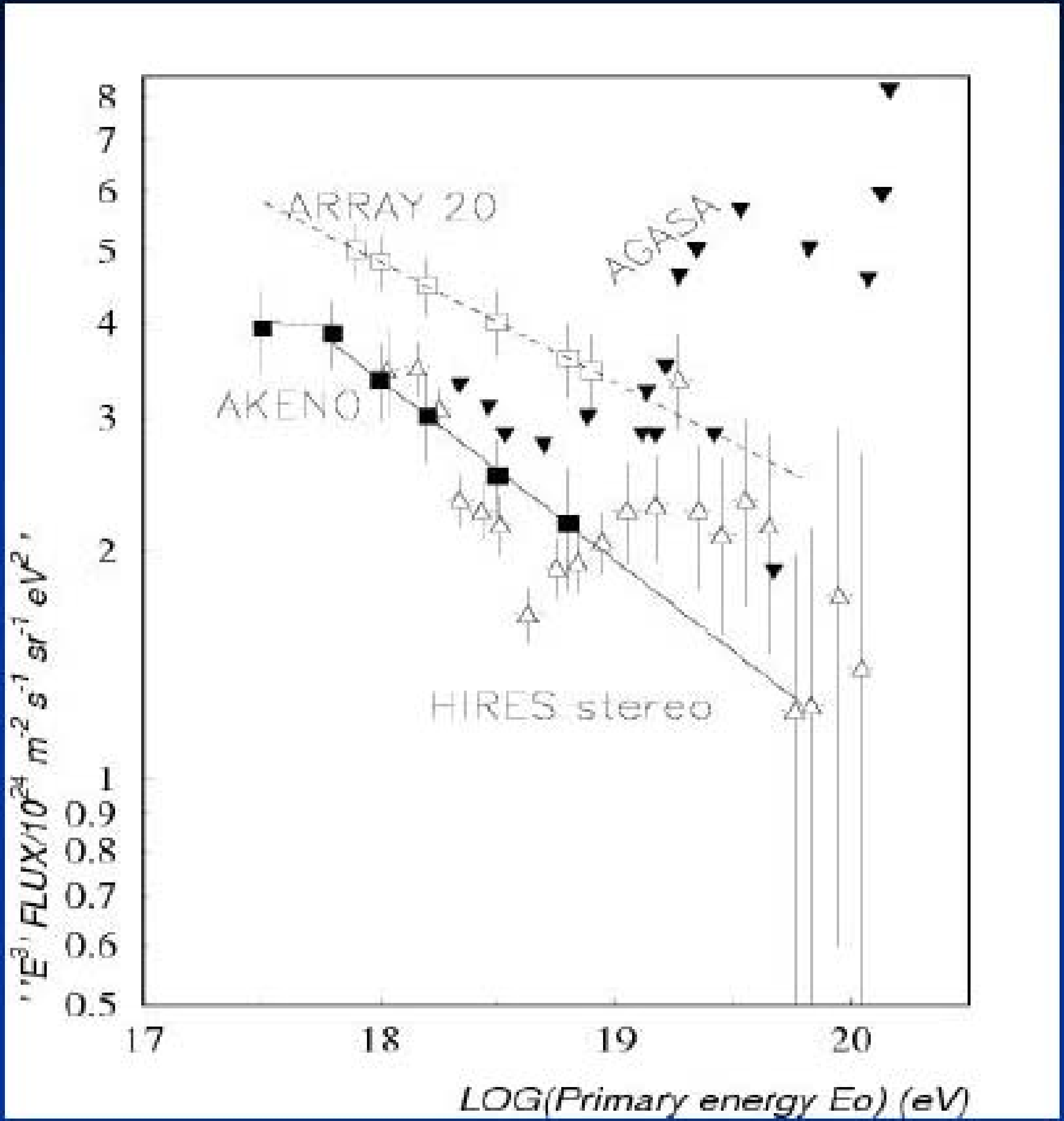
- **Detector station**
  - 111 surface detectors
    - Effective area ~100km$^2$
    - Optical fibre cable connection to observatory

    Triggered by 5-neighbouring hit detector within 25μ s
  - 27 muon detectors
    - Southern region ~30km$^2$ coverage



# *Spectre des Cosmiques*





ARRAY 20
AGASA
AKENO
HIRES stereo
''E$^3$' FLUX/10$^{24}$ m$^{-2}$ s$^{-1}$ sr$^{-1}$ eV$^2$'
LOG(Primary energy Eo) (eV)
17
18
19
20
0.5
0.6
0.7
0.8
0.9
1
2
3
4
5
6
7
8

# Treatment of inclined EAS data from surface arrays and GZK prediction

*Jean Noël CAPDEVIELLE, F.COHEN, B.SZABELSKA, J.SZABELSKI*

Measured: lateral distribution + direction $(\theta, \varphi)$

Density $(600m, \theta)$ → Density$(600m, 0)$ → Energy

AGASA conversion $\Delta_{600}(\theta) \to \Delta_{600}(0)$:

$$S_{600}(\theta) = S_{600}(0) \times \exp\left( -\frac{t_0}{\Lambda_1}\left( \sec(\theta) - 1 \right) - \frac{t_0}{\Lambda_2}\left( \sec(\theta) - 1 \right)^2 \right)$$

$\Lambda_1 = 500\ g/cm^2$ $\Lambda_2 = 594\ g/cm^2$

That conversion is energy/size independent

# Primary energy estimators

$$E_0 = 1.96\ 10^{19}\left(\frac{S_{600}(0)}{100}\right)^{1.02}$$

AGASA 600m 0°

AUGER 1000m 38°

$$E_0 = 1.49 \cdot 10^{17}\,(S_{35^\circ})^{1.078}$$

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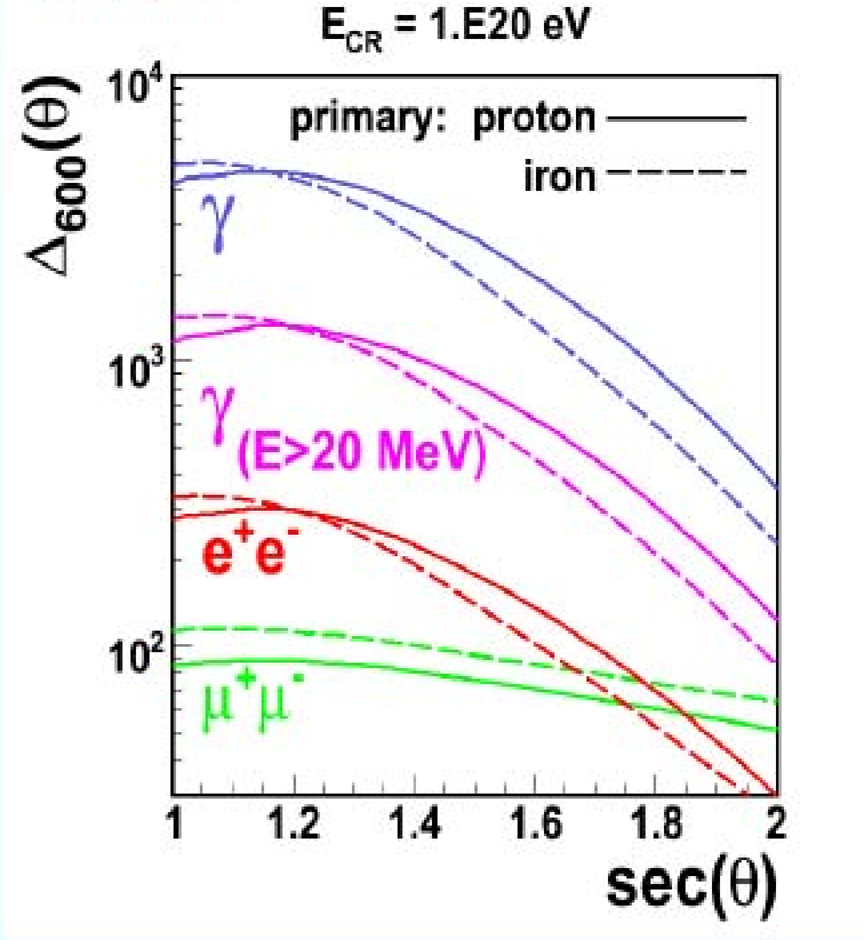
# Conversion to "vertical density"

**Results of CORSIKA simulations show complicated and energy dependent form**

example:



**Treatment of inclined EAS data from surface arrays and GZK prediction**

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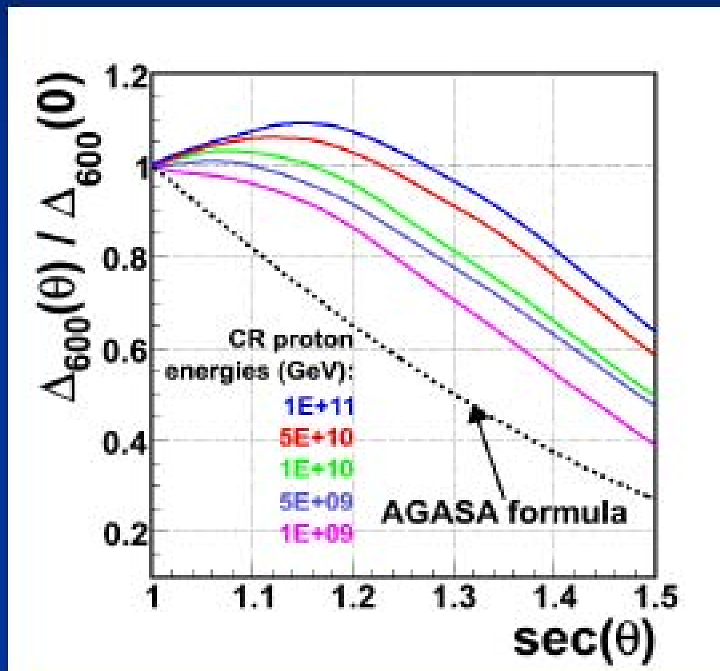
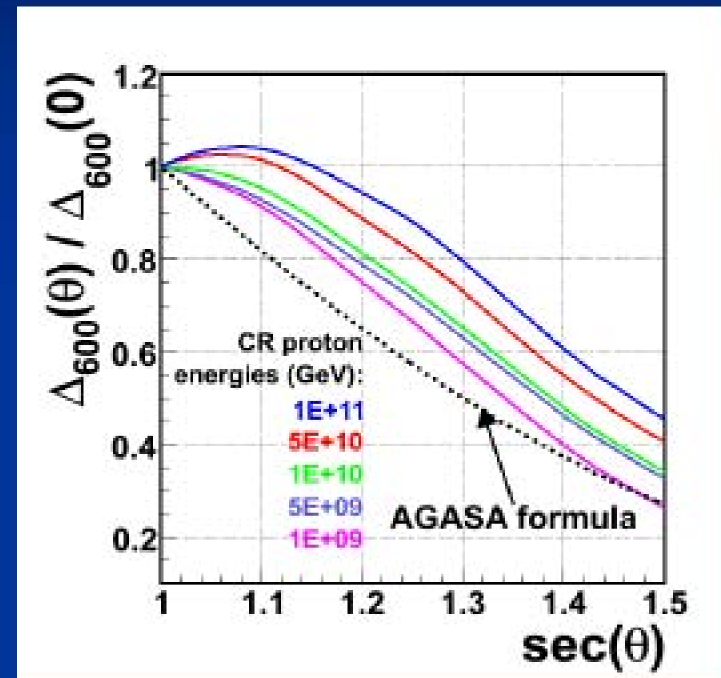
## Cascade theory and CORSIKA simulations




results for the highest energies
depend on interaction model,
but **suggest overestimation of energy at AGASA**

Table 2. Table of coefficients $A$, $< l >$, $\sigma$, $s$ and $k$ versus energy for AUGER

| $E_0$ (eV) | $A$ | $< l >$ | $\sigma$ | $s$ | $k$ |
|---|---|---|---|---|---|
| $10^{18}$ | 1.0 | 0.998 | 0.363 | $0.208 \cdot 10^{-1}$ | $0.179 \cdot 10^{-3}$ |
| $5 \cdot 10^{18}$ | 1.011 | 1.029 | 0.354 | $0.131 \cdot 10^{-1}$ | $0.242 \cdot 10^{-3}$ |
| $10^{19}$ | 1.032 | 1.090 | 0.345 | 0.101 | $0.300 \cdot 10^{-4}$ |
| $5 \cdot 10^{19}$ | 1.06 | 1.116 | 0.342 | 0.153 | $0.244 \cdot 10^{-5}$ |
| $10^{20}$ | 1.1 | 1.150 | 0.339 | $0.332 \cdot 10^{-1}$ | $0.140 \cdot 10^{-5}$ |

Table 3. Table of coefficients $A$, $< l >$, $\sigma$, $s$ and $k$ versus energy for AGASA

| $E_0$ (eV) | $A$ | $< l >$ | $\sigma$ | $s$ | $k$ |
|---|---|---|---|---|---|
| $10^{18}$ | 1.00 | 1.016 | 0.308 | 0.462 | $5.909 \cdot 10^{-2}$ |
| $5 \cdot 10^{18}$ | 1.00 | 1.011 | 0.340 | 0.335 | $1.526 \cdot 10^{-2}$ |
| $10^{19}$ | 1.00 | 1.005 | 0.333 | 0.372 | $4.911 \cdot 10^{-3}$ |
| $5 \cdot 10^{19}$ | 0.933 | 1.130 | 0.304 | 0.566 | $3.317 \cdot 10^{-2}$ |
| $10^{20}$ | 1.006 | 1.145 | 0.309 | 0.485 | $4.249 \cdot 10^{-2}$ |

$$f(l) = A \times \exp\left(\frac{k}{8} - \frac{s\delta}{2} - \frac{1}{4}(2+k)\delta^2 + \frac{1}{6}s\delta^3 + \frac{1}{24}k\delta^4\right)$$

$$l = sec(\theta), \;\; \delta = (l - < l >)/\sigma$$

Distorted Gaussian Function

Treatment of inclined EAS data from surface arrays and GZK prediction

Jean Noël CAPDEVIELLE, F.COHEN, B.SZABELSKA, J.SZABELSKI

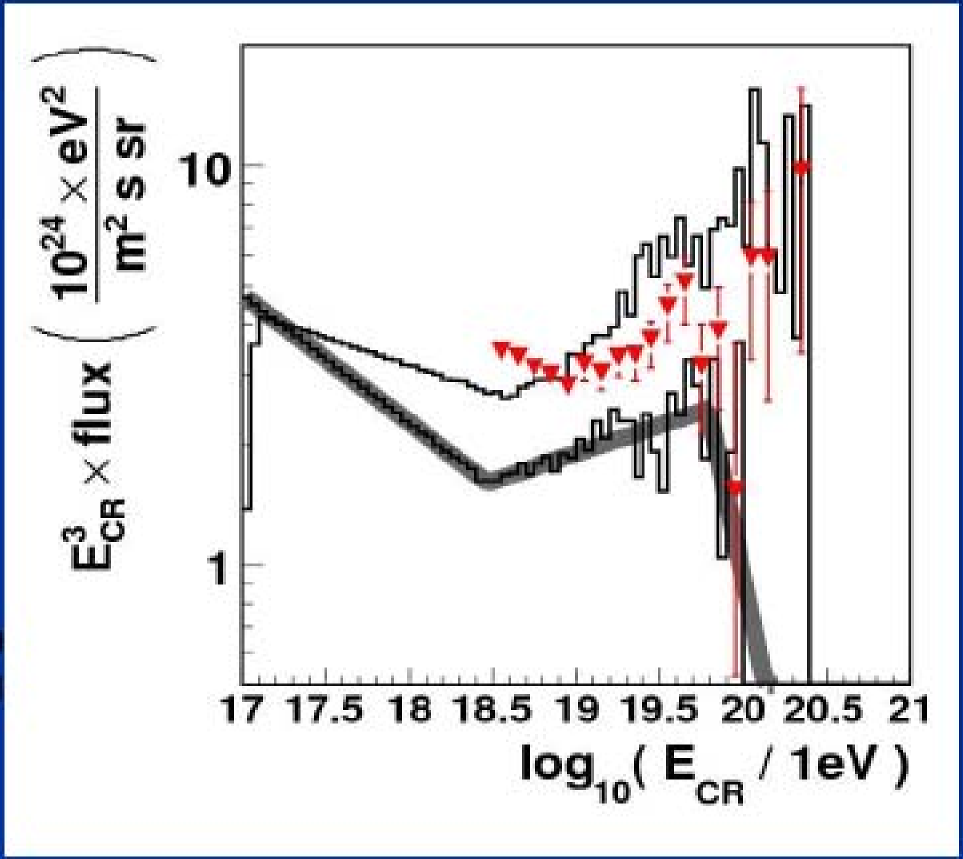
## From Bergman spectrum to AGASA spectrum using AGASA conversion

Red points: AGASA energy spectrum

Grey area: D.R.Bergman et al. (HiRes Collaboration) 29th ICRC, Pune, India, 2005

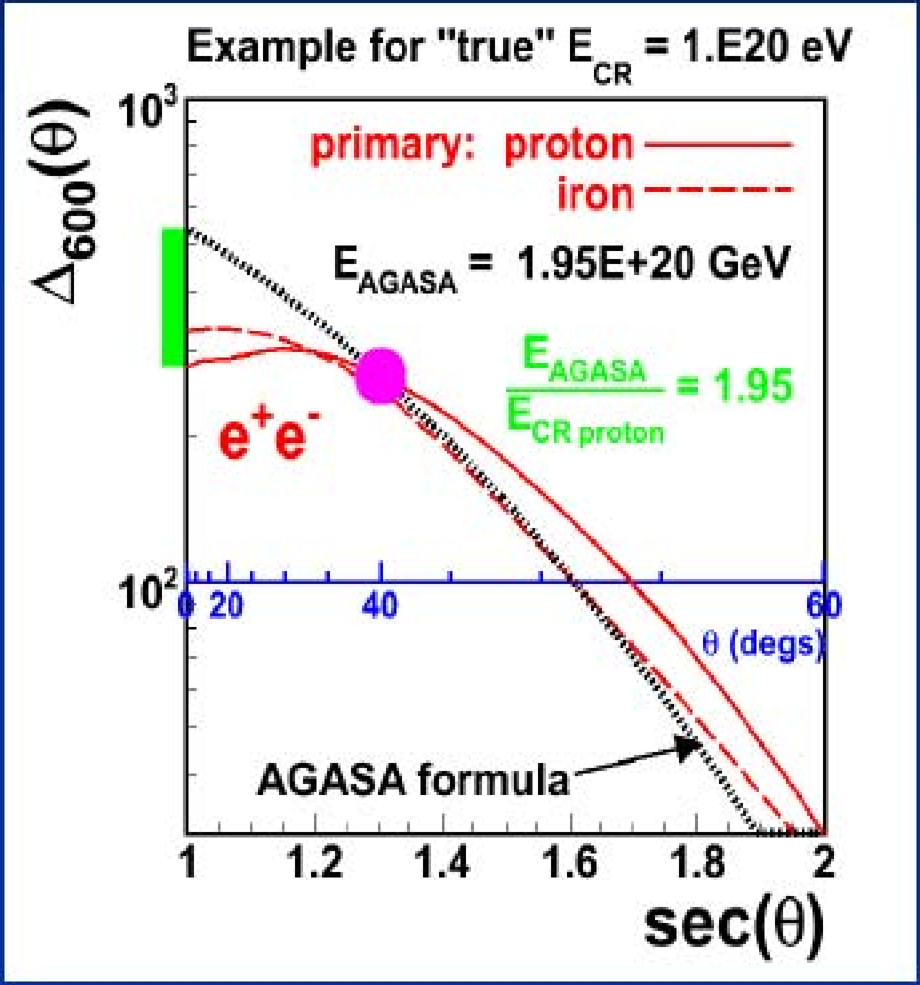
histograms:

- MC generated spectrum following Bergman
- approximately recalculated spectrum using AGASA conversion

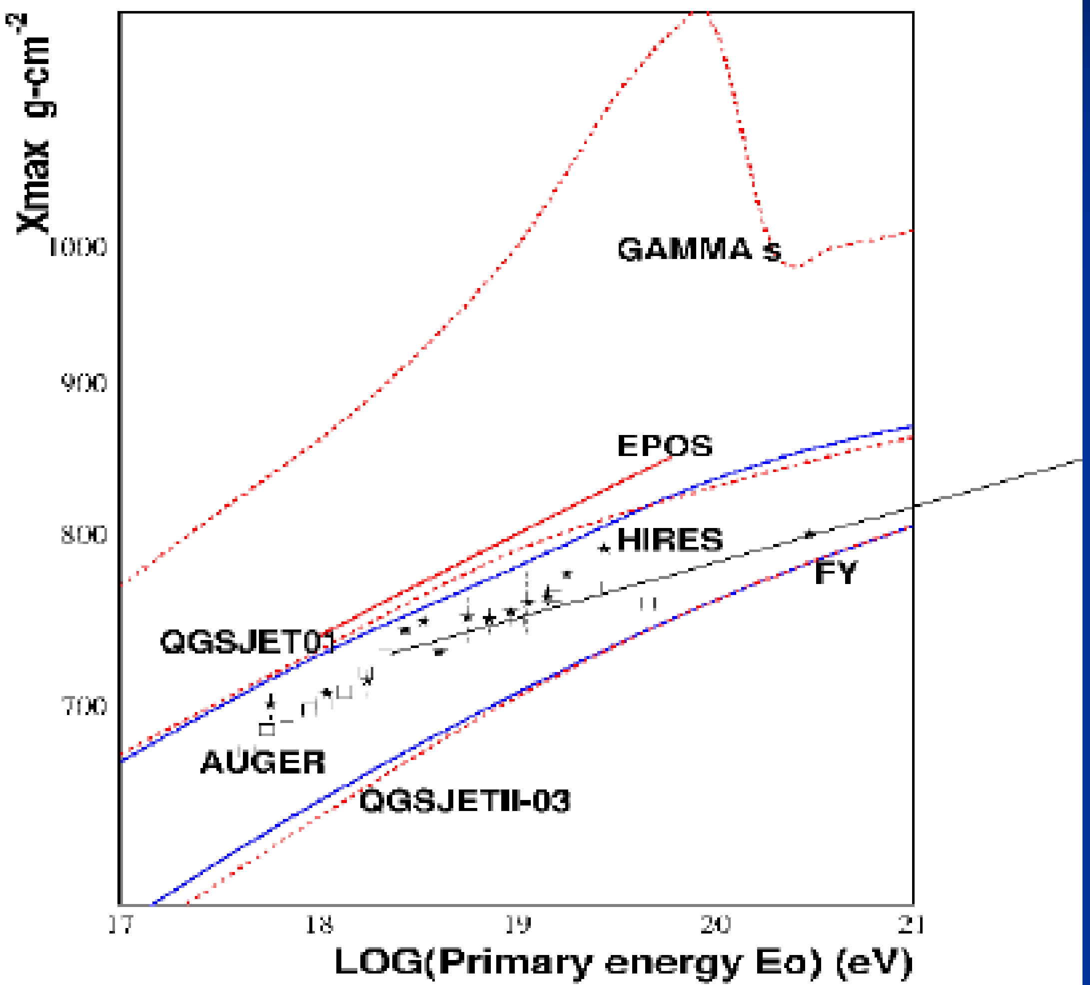


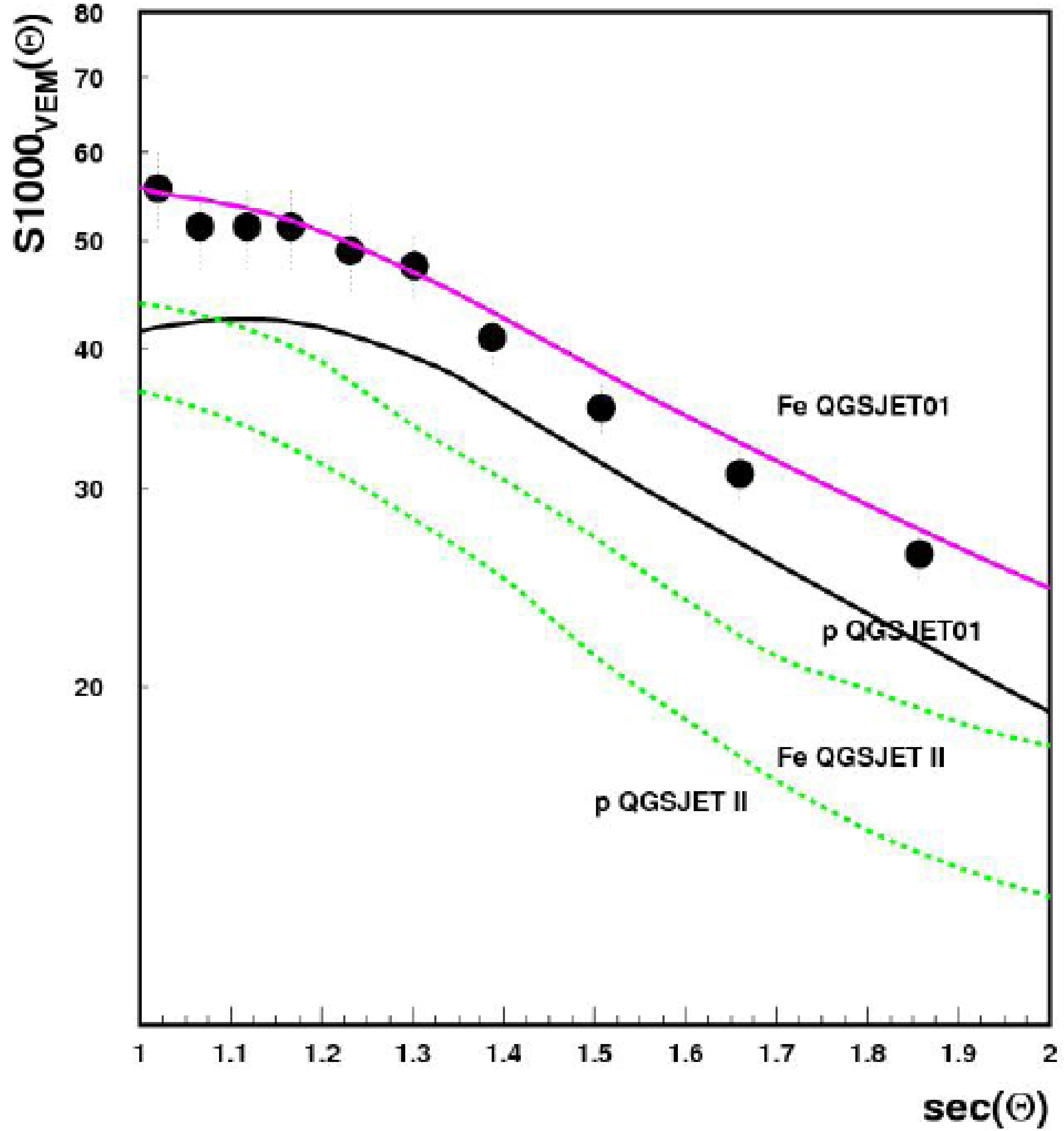
Jean Noël CAPDEVIELLE, F.COHEN, B.SZABELSKA, J.SZABELSKI

# How does the conversion to "vertical density" work ?

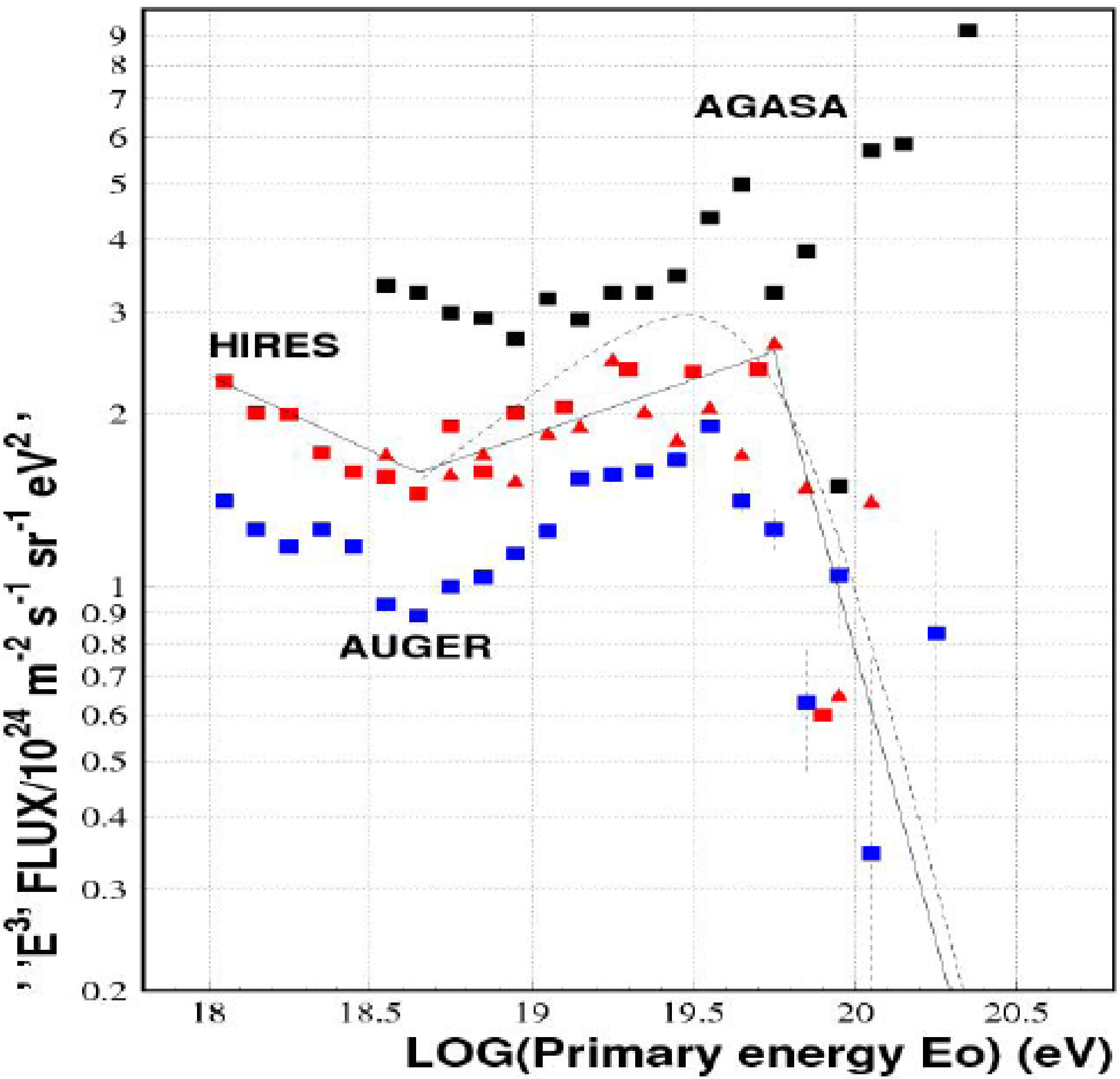


Maximum depth and Gamma ray Astronomy at UHE

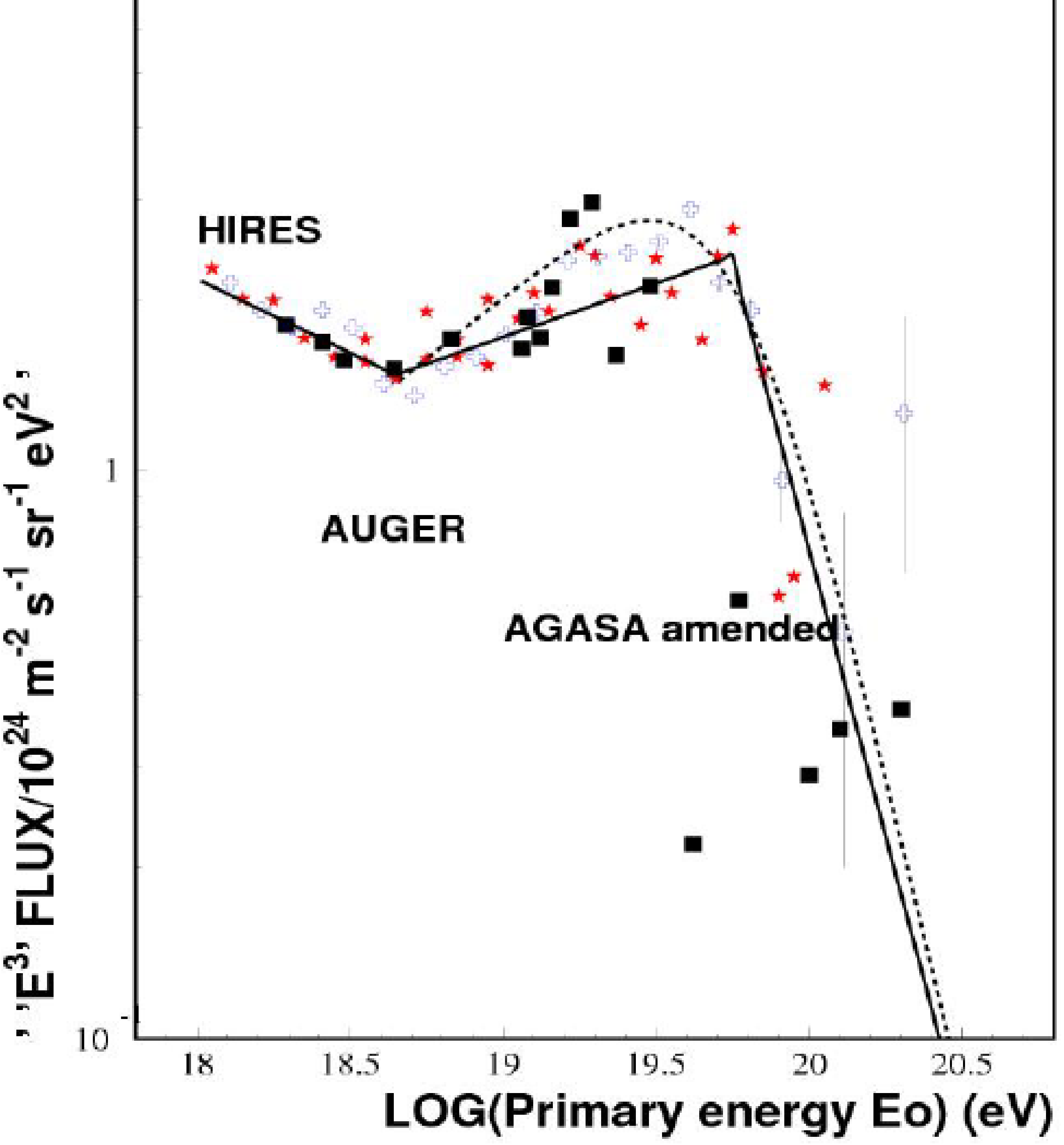




S1000$_{VEM}$($\Theta$)
80
70
60
50
40
30
20
Fe QGSJET01
p QGSJET01
Fe QGSJET II
p QGSJET II
1
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2
sec($\Theta$)



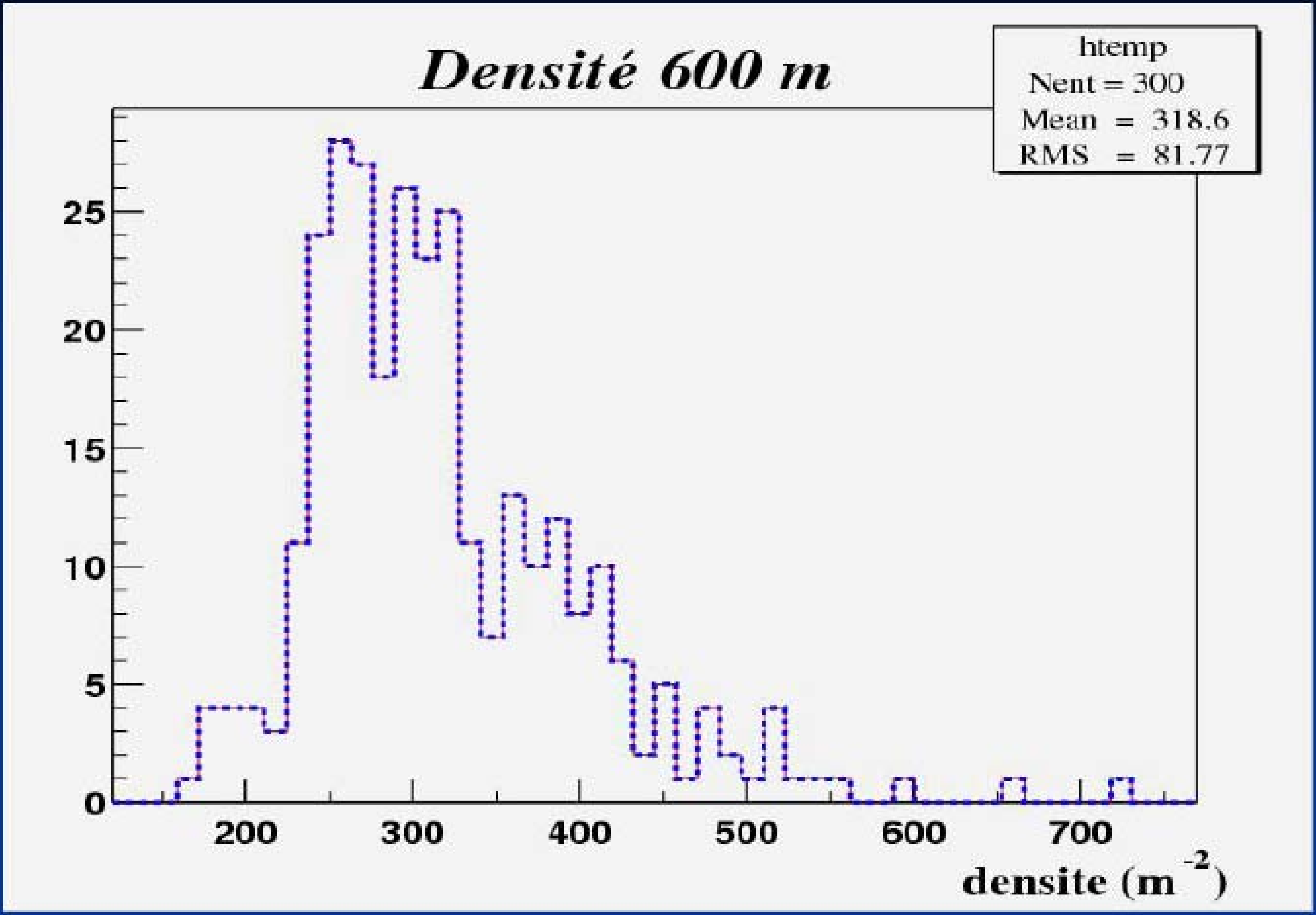
AGASA
HIRES
AUGER
9
8
7
6
5
4
3
2
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
18
18.5
19
19.5
20
20.5
LOG(Primary energy Eo) (eV)
E³ FLUX/10²⁴ m⁻² s⁻¹ sr⁻¹ eV²



HIRES
AUGER
AGASA amended
'E^3' FLUX/10^24 m^-2 s^-1 sr^-1 eV^2
1
10^-1
18
18.5
19
19.5
20
20.5
LOG(Primary energy Eo) (eV)

# Treatment of inclined EAS data from surface arrays and GZK prediction

- The spectrum from surface array has to be corrected from the overestimation of the primary energy between 10°-35° in the last decade
- the amended spectrum of AGASA (ISVHECRI aug. 06) is progressing in this direction
- GZK after 4 decades is going to be confirmed by HIRES, AUGER, AGASA...
- The overestimation in AGASA data was mainly coming of the special properties of 3D Electromagnetic cascade near maximum



Densité 600 m
htemp
Nent = 300
Mean = 318.6
RMS = 81.77
0
5
10
15
20
25
200
300
400
500
600
700
densite (m^-2)

$$s = \exp[\frac{2}{3} \times \{1 + \frac{\alpha}{t} - \tau\}]$$

$$\text{with } \tau = \frac{t_{max}}{t} \quad \alpha = \ln \frac{N_{max}}{N_c}$$

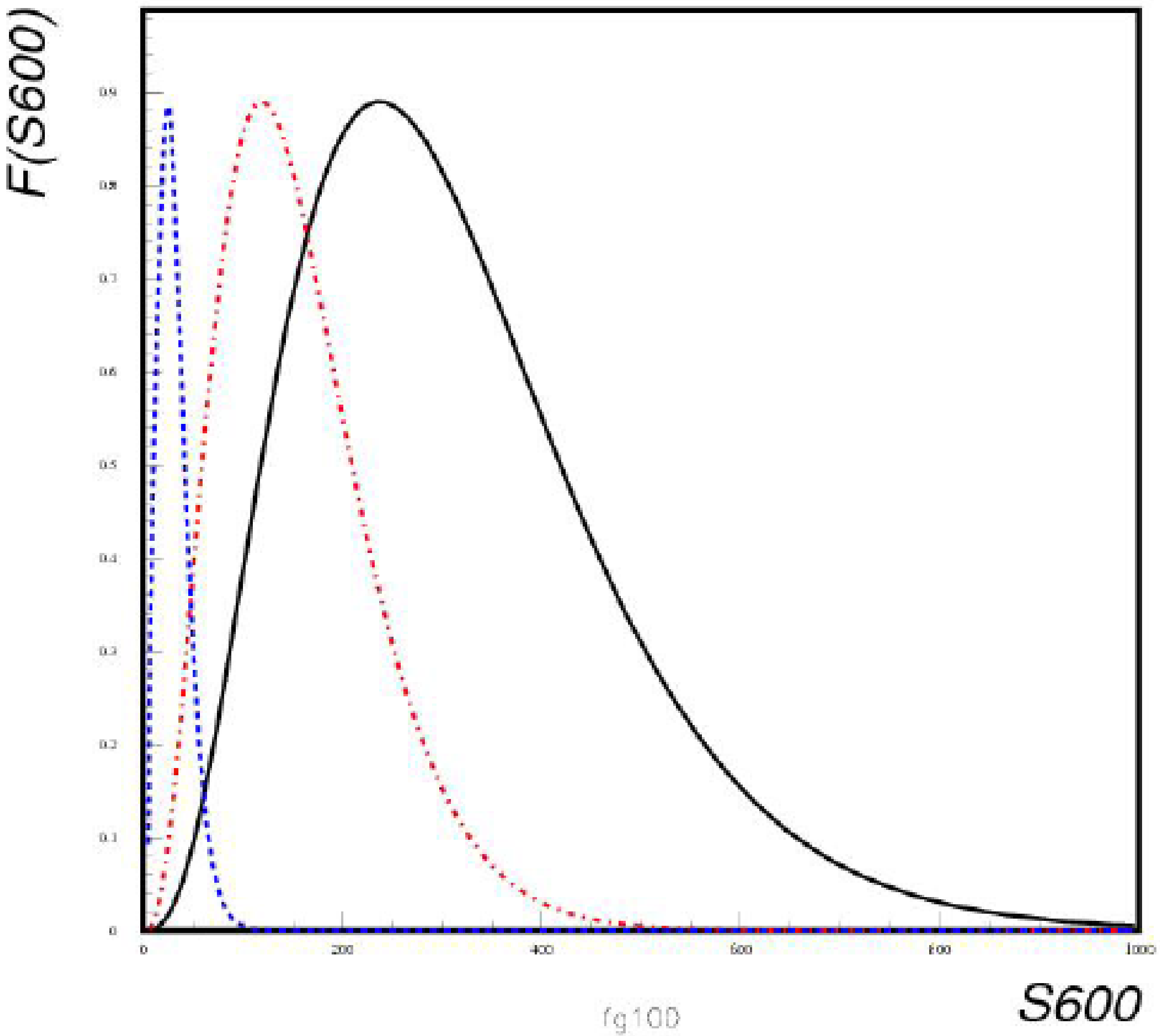
E.M. Longitudinal Devt in CORSIKA via EGS

$$f(S) = \frac{a(aS)^{b-1} exp(-aS)}{\Gamma(b)}$$

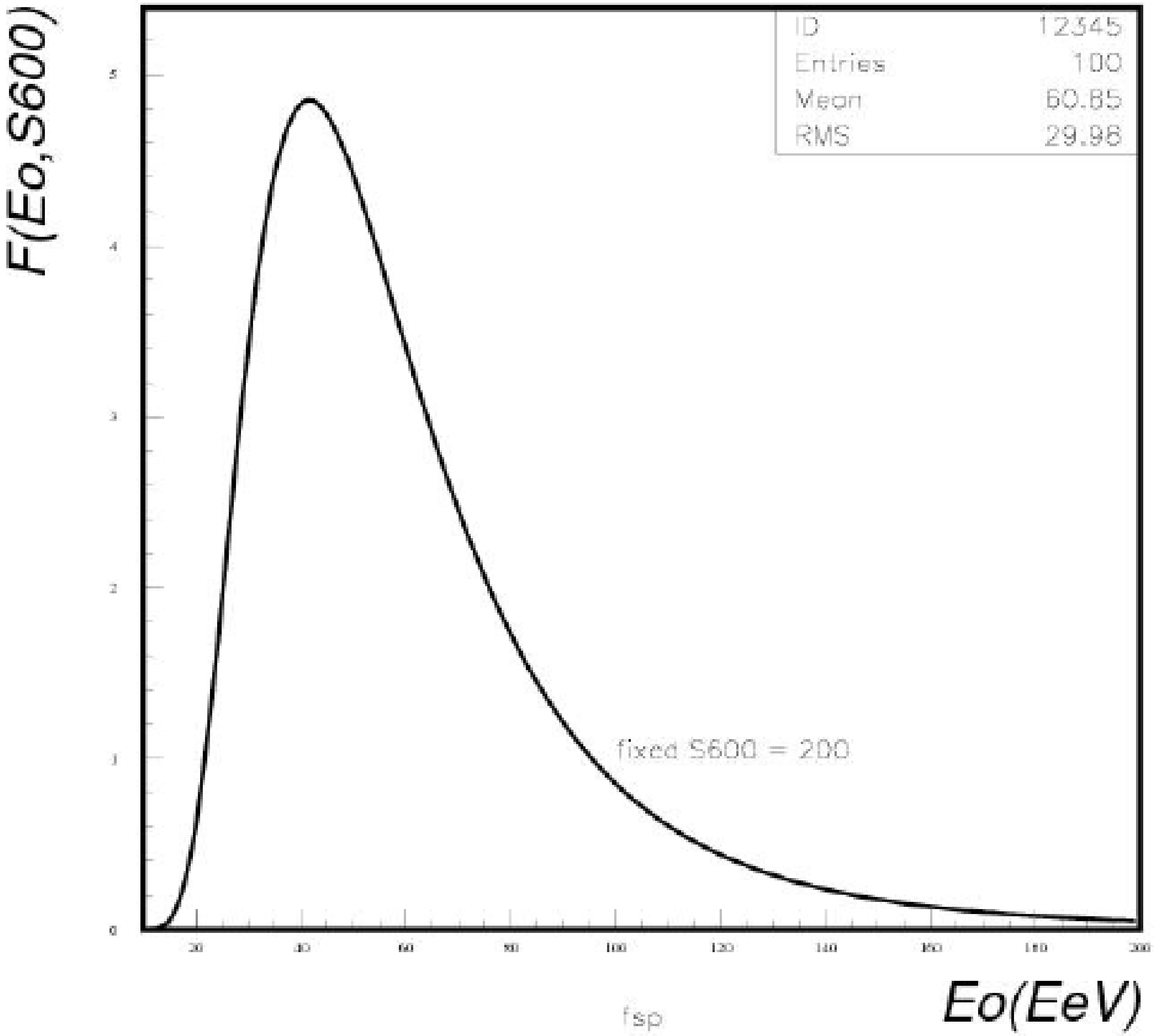
$\Gamma$ distribution for $S_{600}$

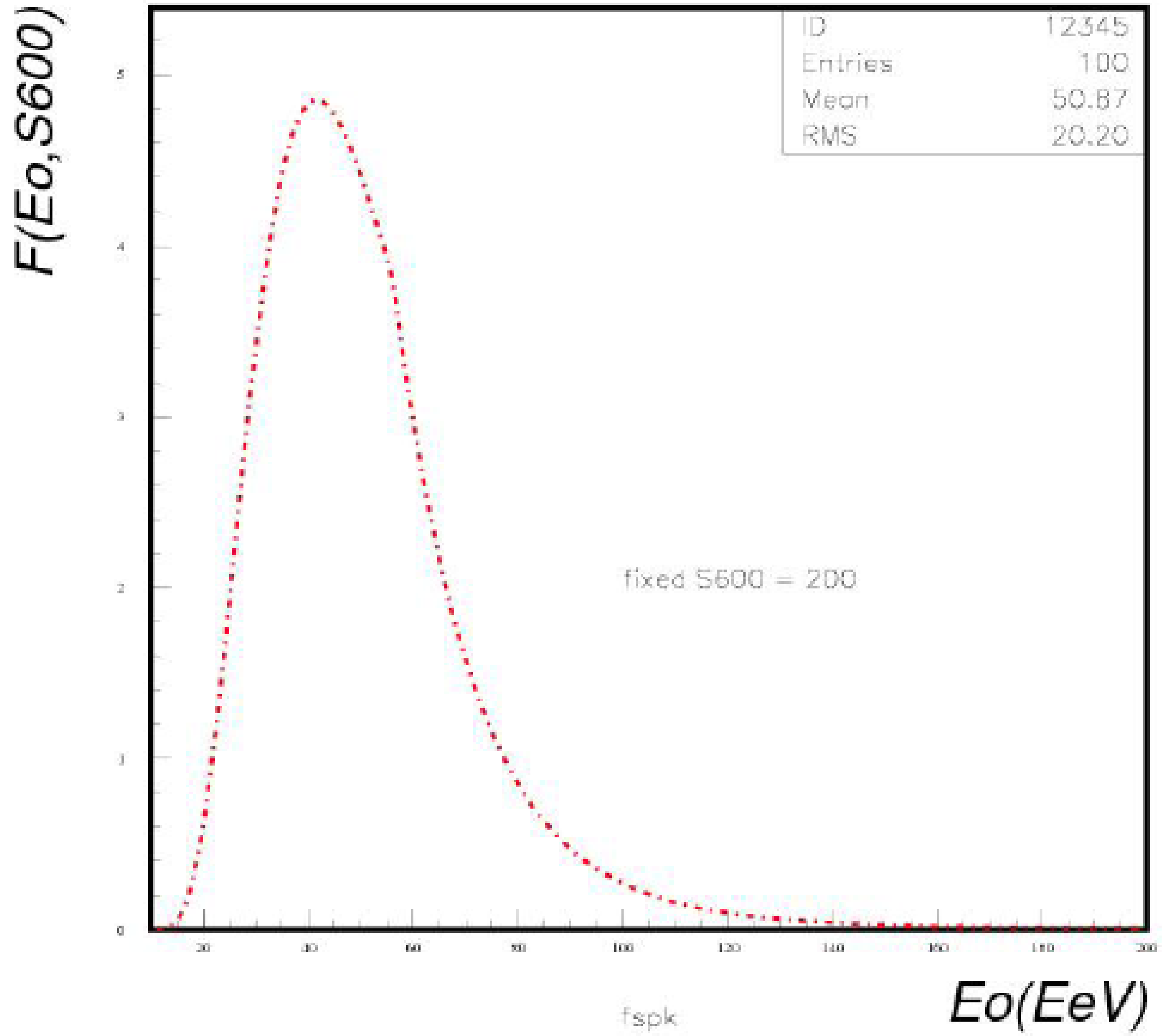
$$\bar{S} = \frac{b}{a} \qquad V(S) = \frac{b}{a^2}$$

max for $S = \frac{b-1}{a}$



F(S600)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
200
400
600
800
1000
S600
fg100


F(Eo,S600)
ID 12345
Entries 100
Mean 60.85
RMS 29.96
fixed S600 = 200
0
1
2
3
4
5
20
40
60
80
100
120
140
160
180
200
Eo(EeV)
fsp


F(Eo,S600)
ID 12345
Entries 100
Mean 50.87
RMS 20.20
fixed S600 = 200
fspk
Eo(EeV)

$$J(E_0) = A \times \left(\frac{E_0}{E_c}\right)^{-\gamma}$$

$$\begin{cases} E_c = 10^{18.65}\ eV & \gamma = 3.26 \quad A = 1.65110^{-32} \\ E_c = 10^{18.65}\ eV & \gamma = 2.81 \quad A = 1.65110^{-32} \\ E_c = 10^{19.75}\ eV & \gamma = 5.1 \quad A = 2.99210^{-37} \end{cases}$$

for $E_0 < 10^{18.65}\ eV$

for $10^{18.65}\ eV \leq E_0 \leq 10^{19.75}\ eV$

for $E_0 > 10^{19.75}\ eV$

Another possible parameterization could be

for $E_0 < 10^{18.65}$ eV and for $E_0 > 10^{18.65}$ eV.

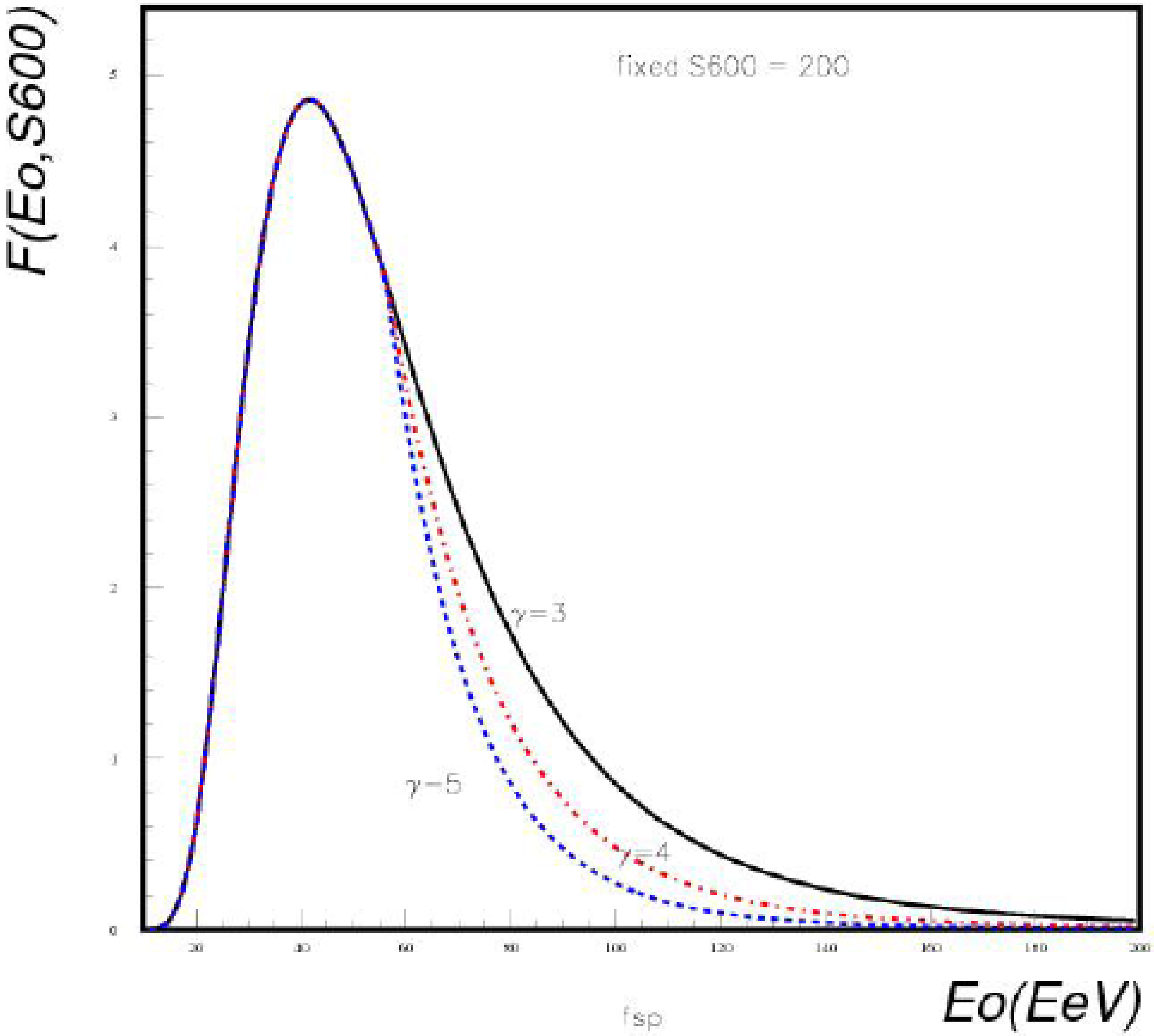
Another possible parameterization could be

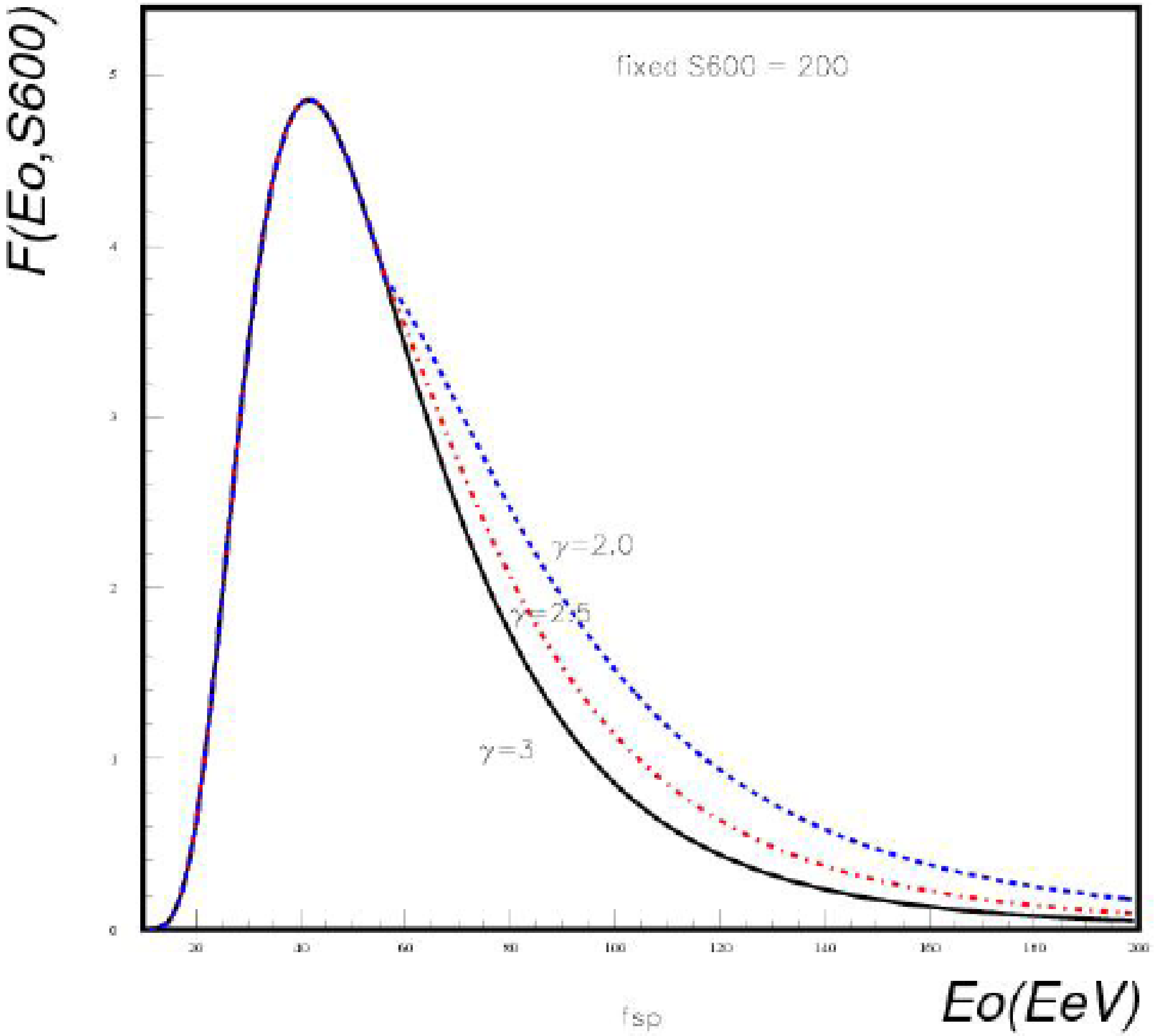
for $E_0 < 10^{18.65}$ eV and for $E_c > 10^{18.65}$ eV:

$$J(E_0) = A \times \left(\frac{E_0}{E_c}\right)^{-\gamma} \times \frac{1}{1 + exp\left(\frac{lg(E_0) - lg(E_c)}{W_c}\right)}$$

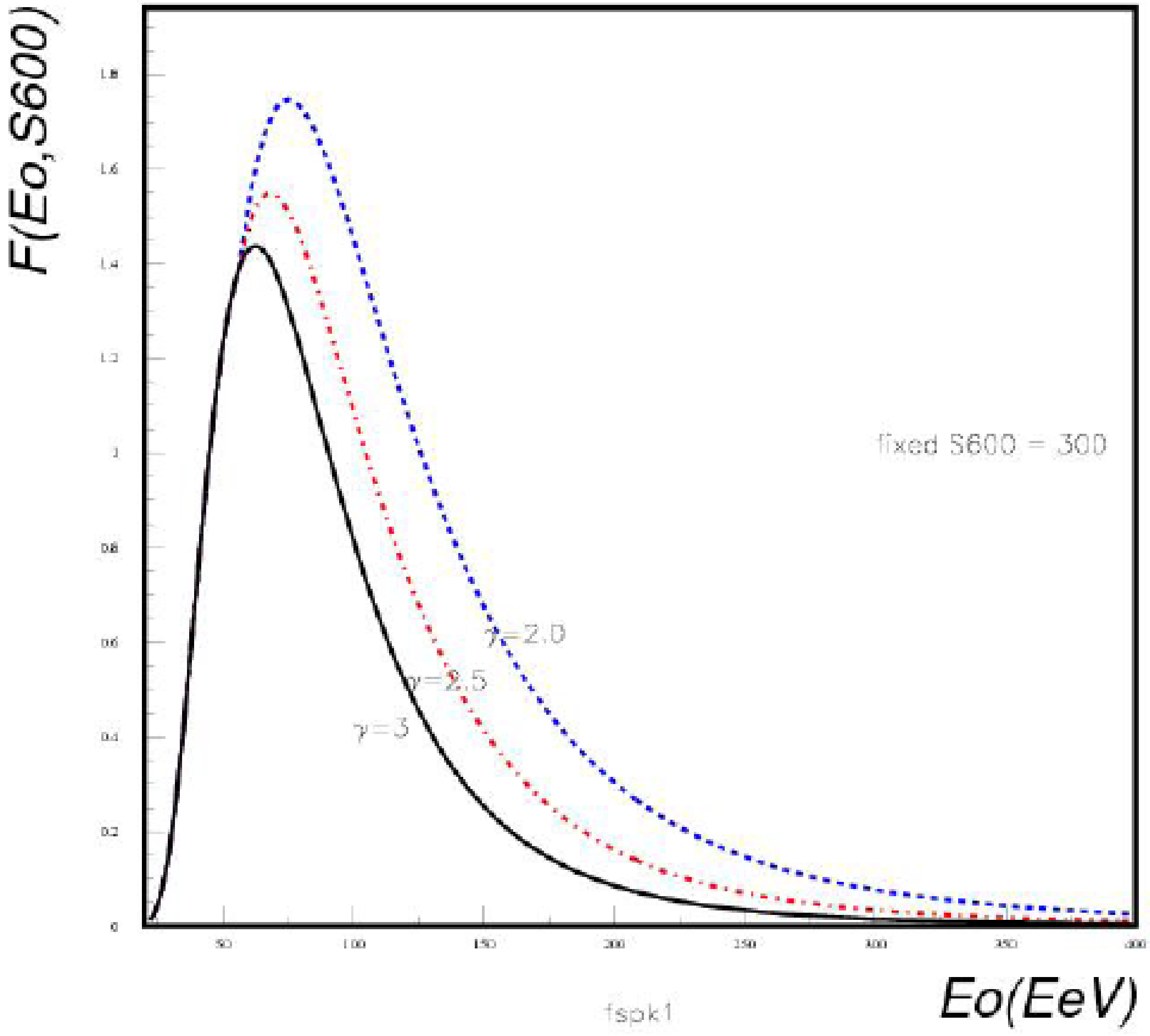
$$\gamma = 2.56,\ E_c = 10^{19.75}\ \text{eV},$$

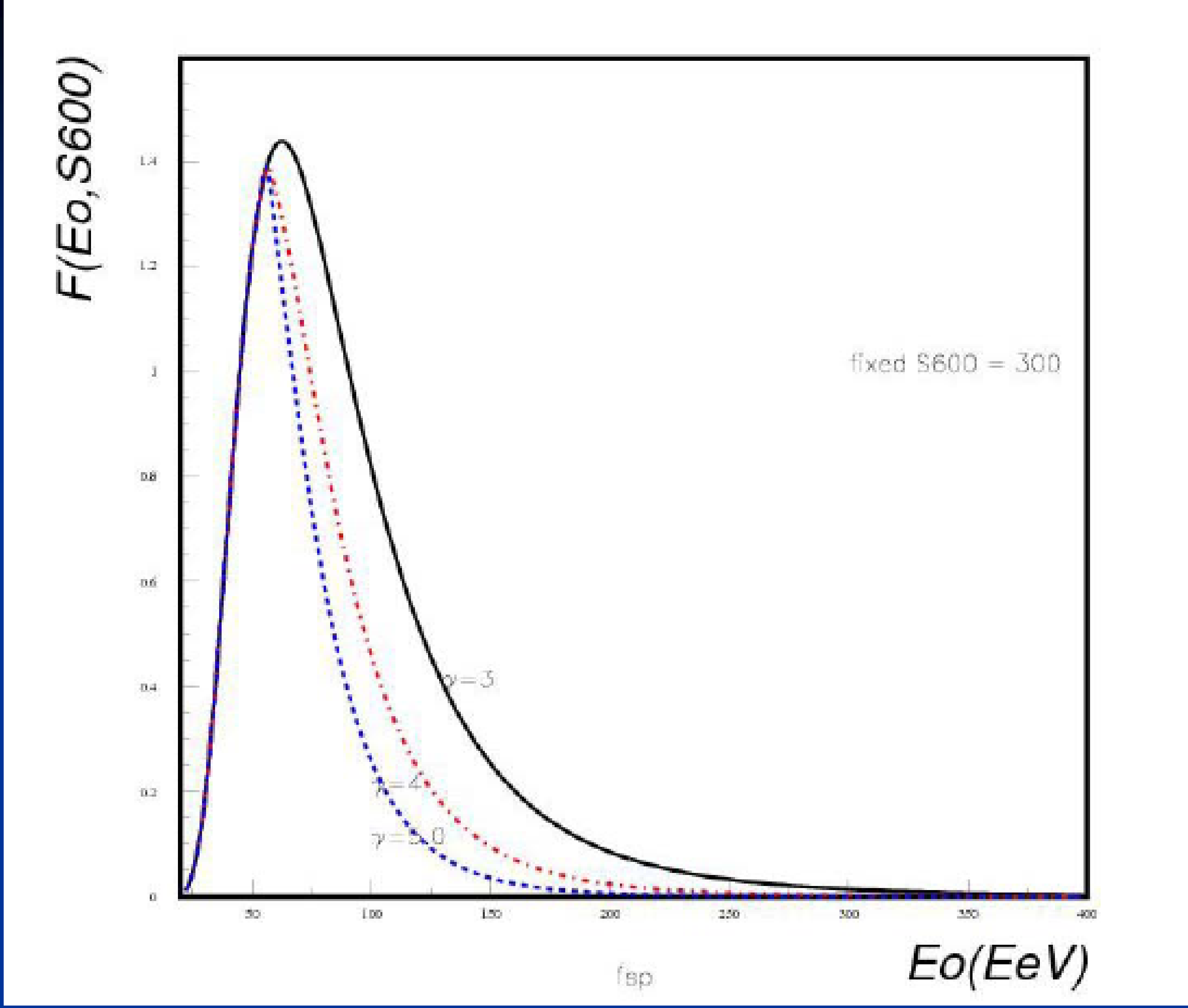
$$W_c = 0.16 \text{ and } A = 2.636\ 10^{-32}$$

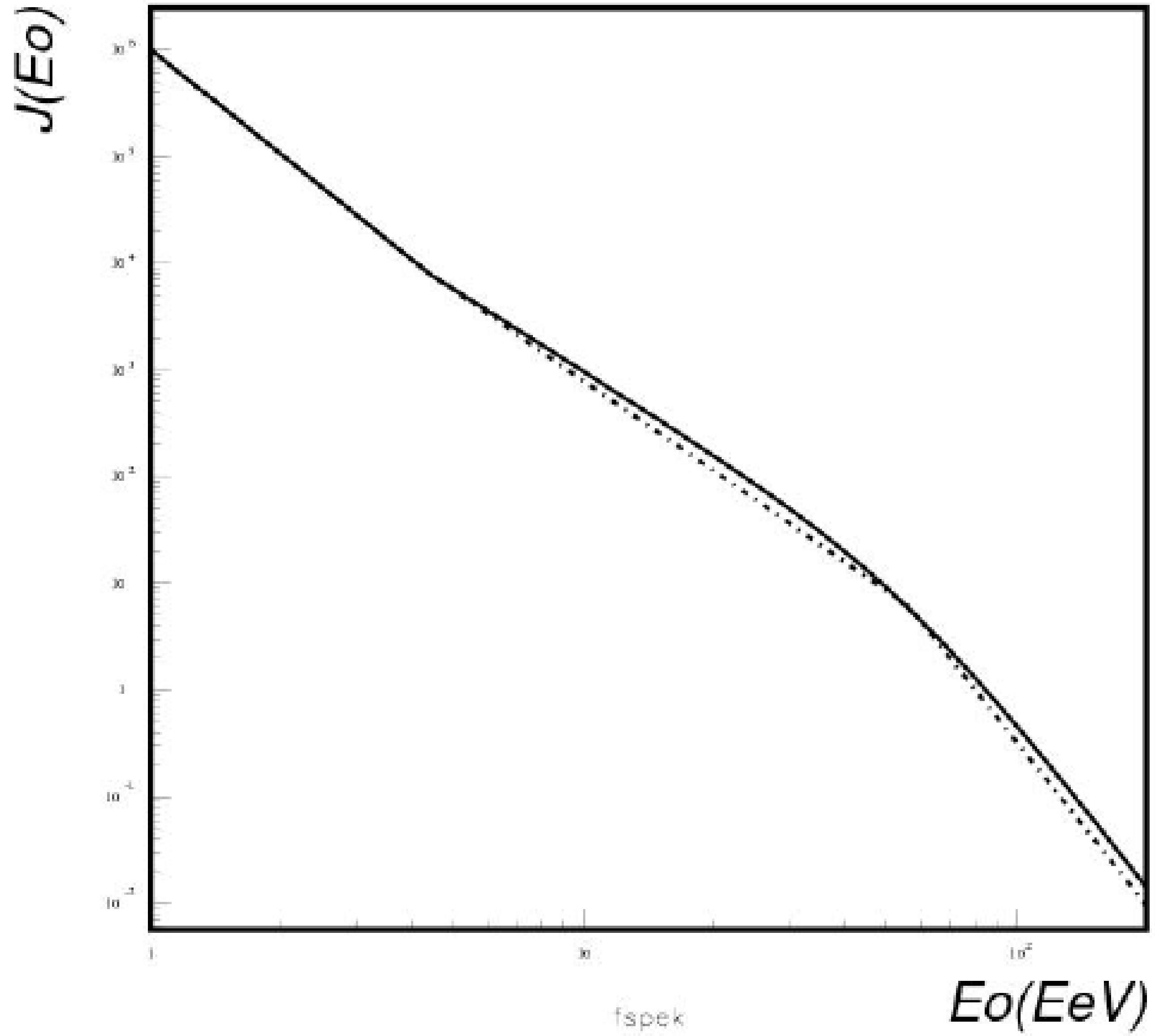

F(Eo,S600)
fixed S600 = 200
γ=3
γ=5
γ=4
0
1
2
3
4
5
20
40
60
80
100
120
140
160
180
200
fsp
Eo(EeV)

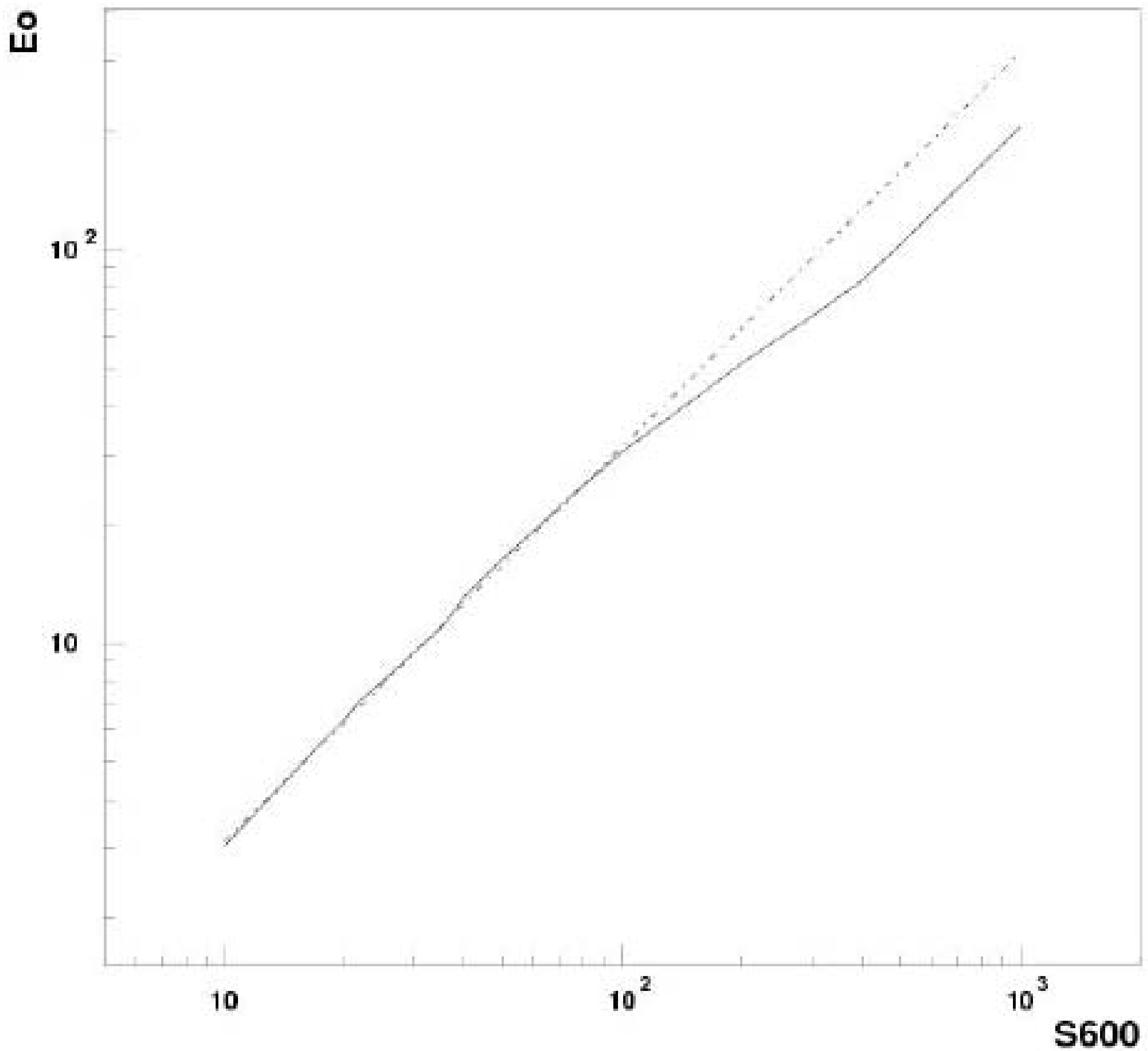


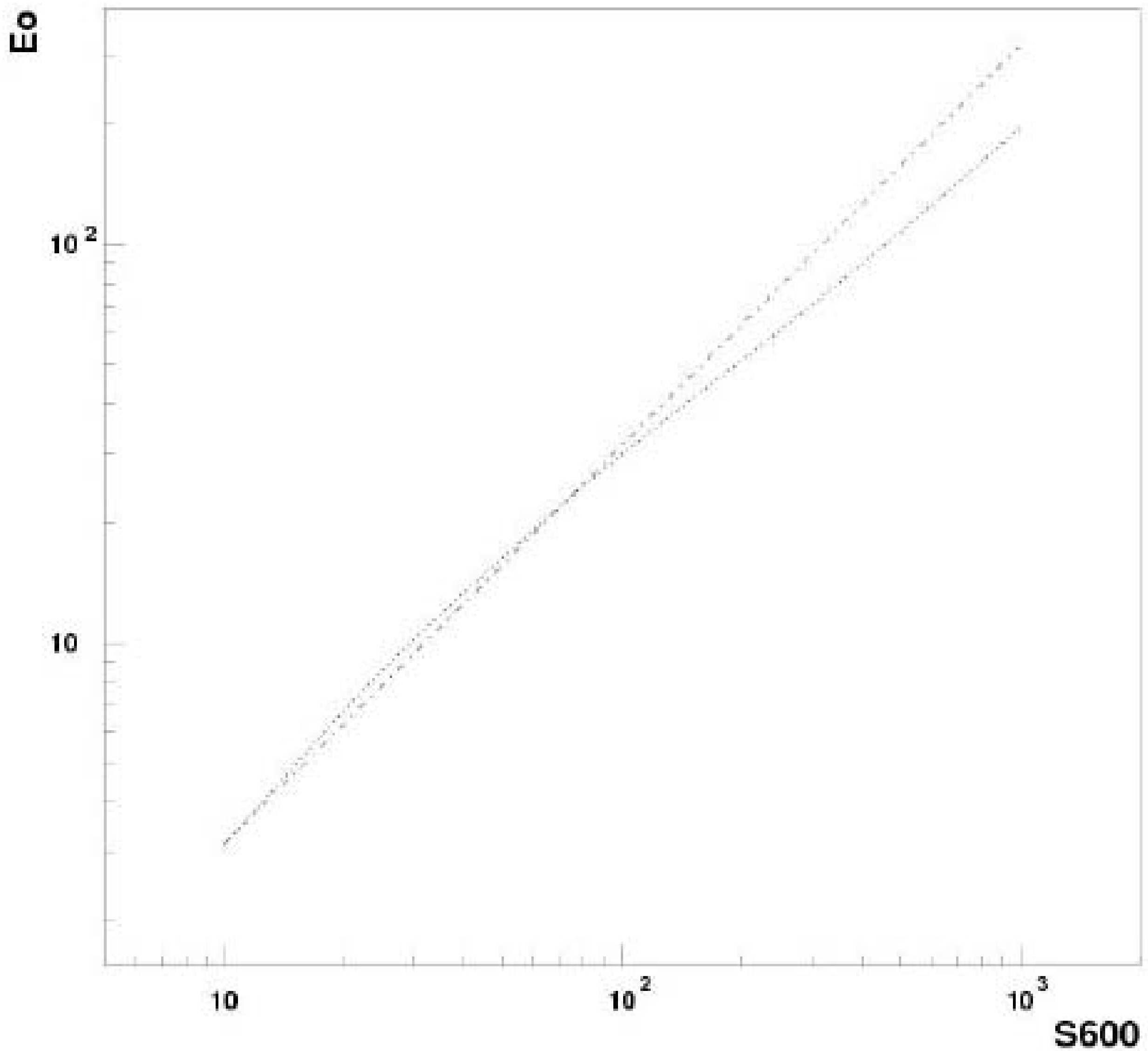
F(Eo,S600)
fixed S600 = 200
γ=2.0
γ=2.5
γ=3
Eo(EeV)
fsp

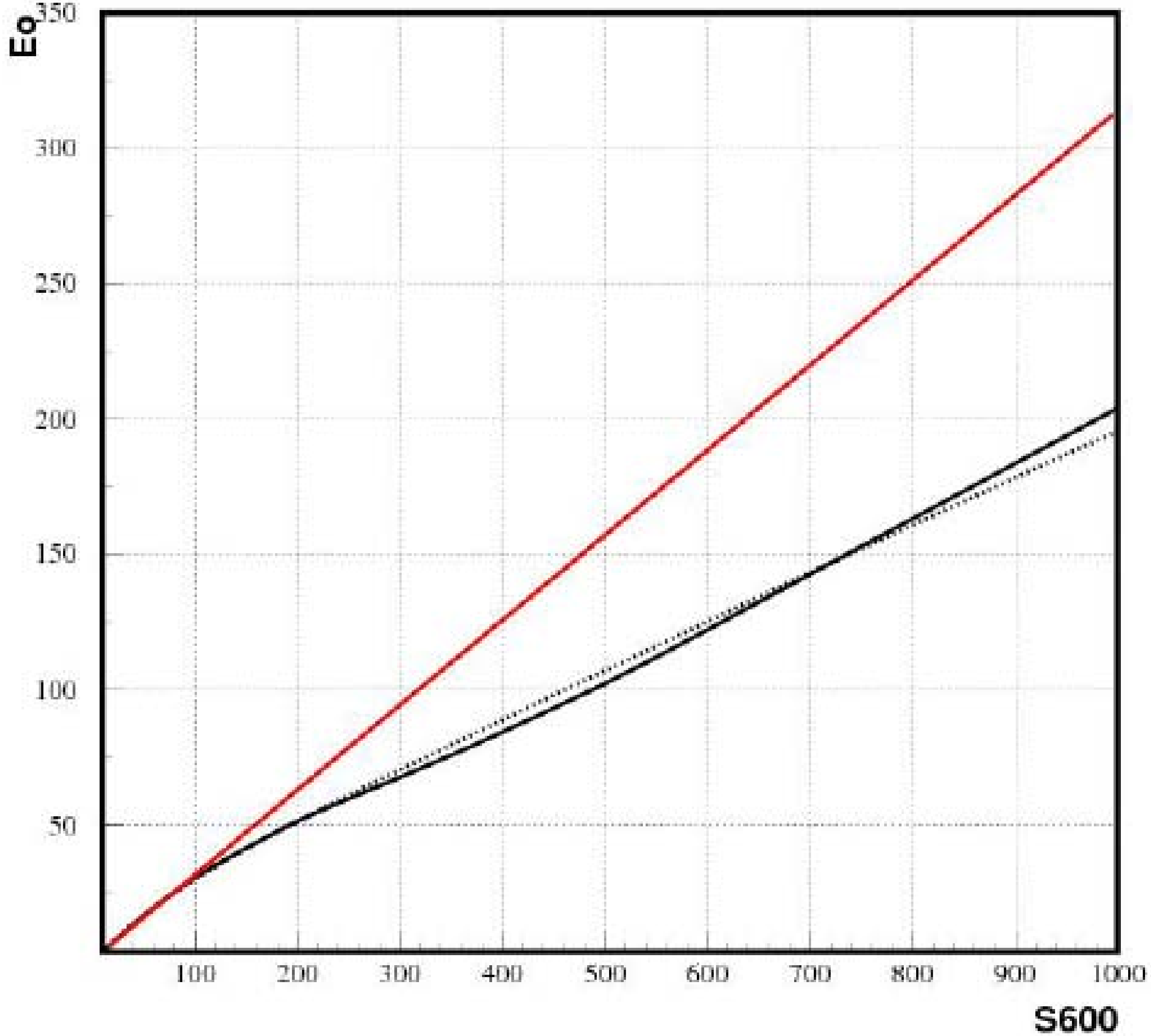

F(Eo,S600)
fixed S600 = 300
γ=2.0
γ=2.5
γ=3
Eo(EeV)
fspk1


F(Eo,S600)
fixed S600 = 300
γ=3
γ=4
γ=5.0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
50
100
150
200
250
300
350
400
fsp
Eo(EeV)


J(Eo)
Eo(EeV)
fspek


Eo
10 2
10
10
10 2
10 3
S600

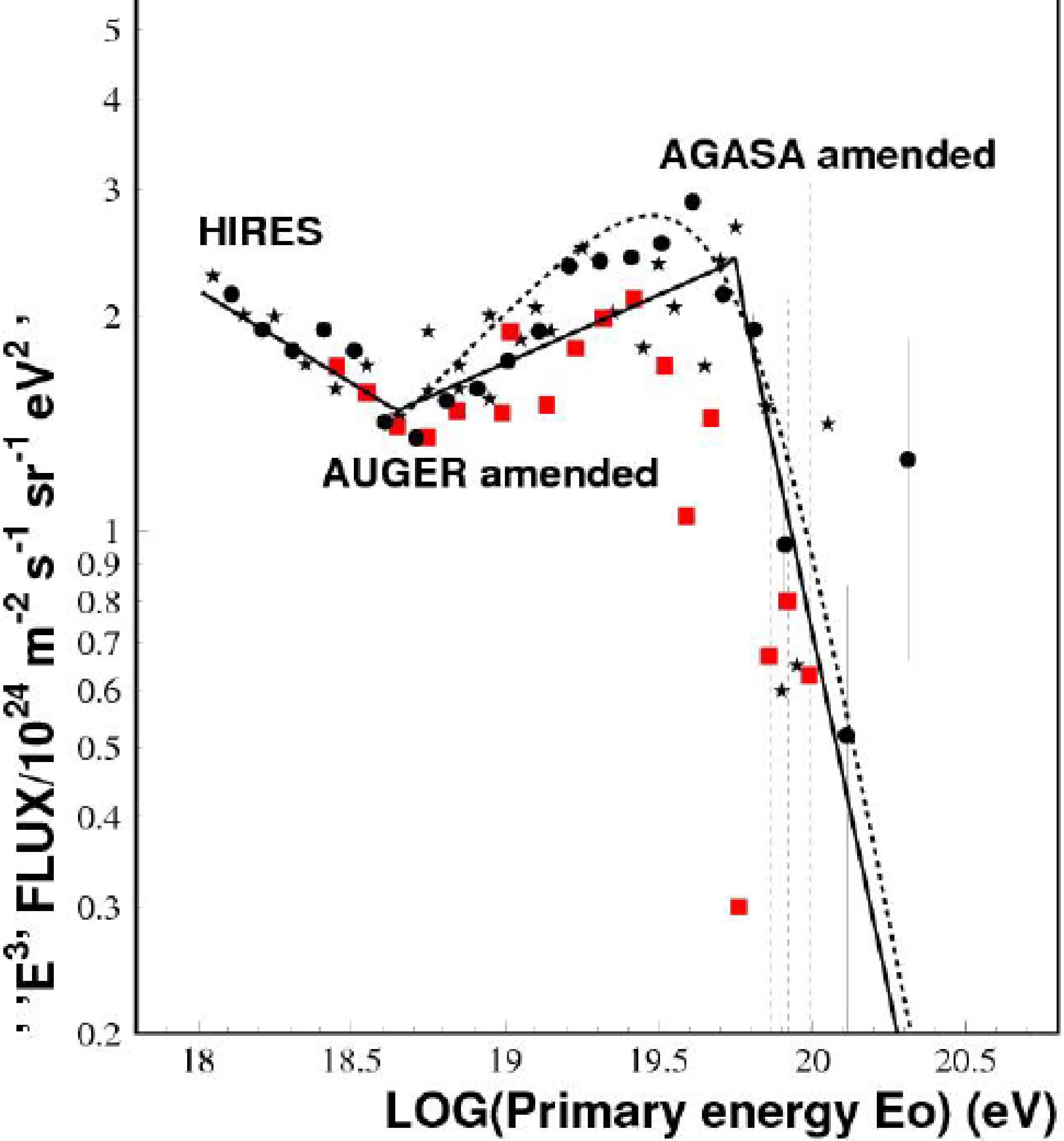

Eo
10 2
10
10
10 2
10 3
S600

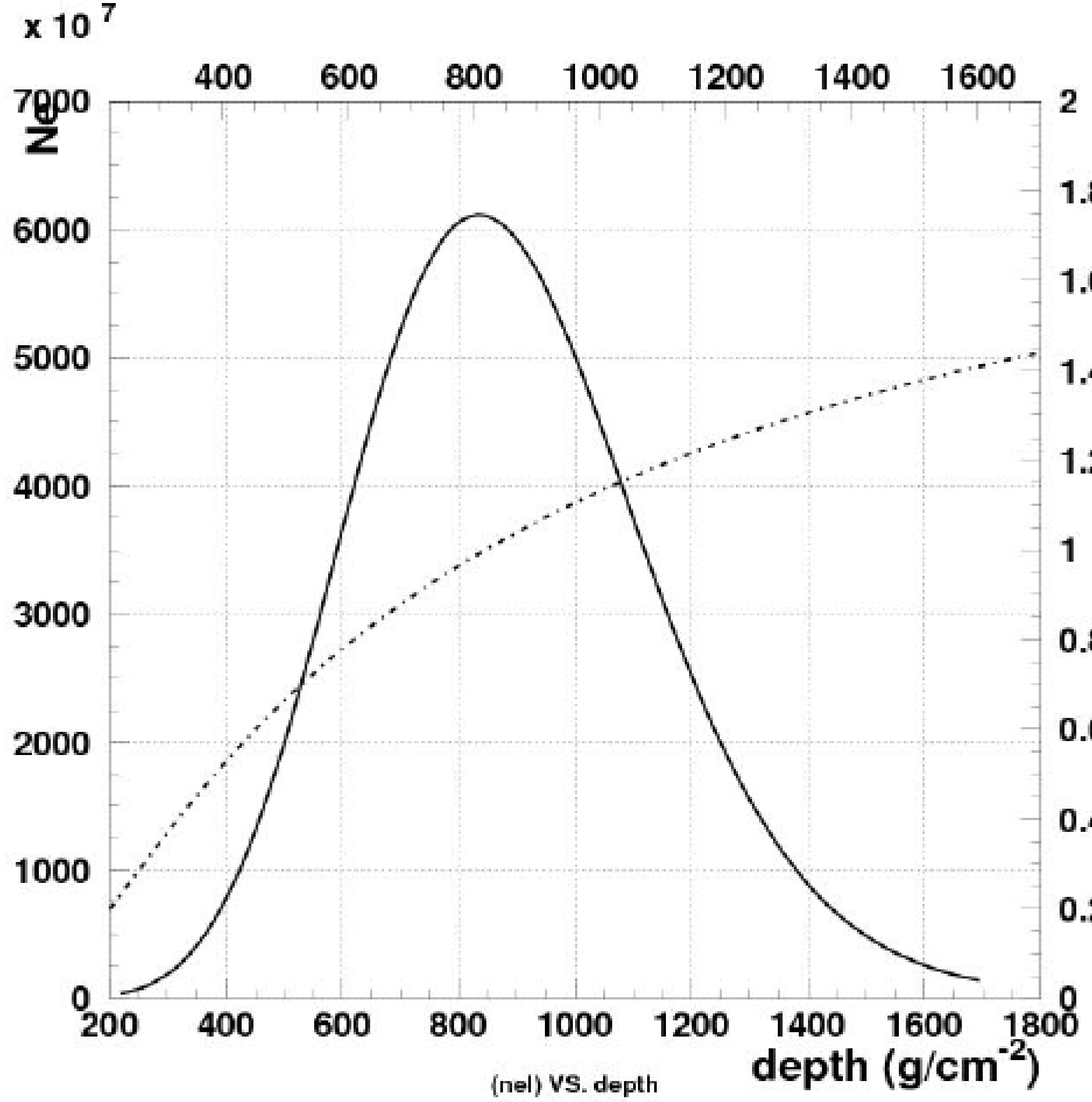


Eo
350
300
250
200
150
100
50
100
200
300
400
500
600
700
800
900
1000
S600

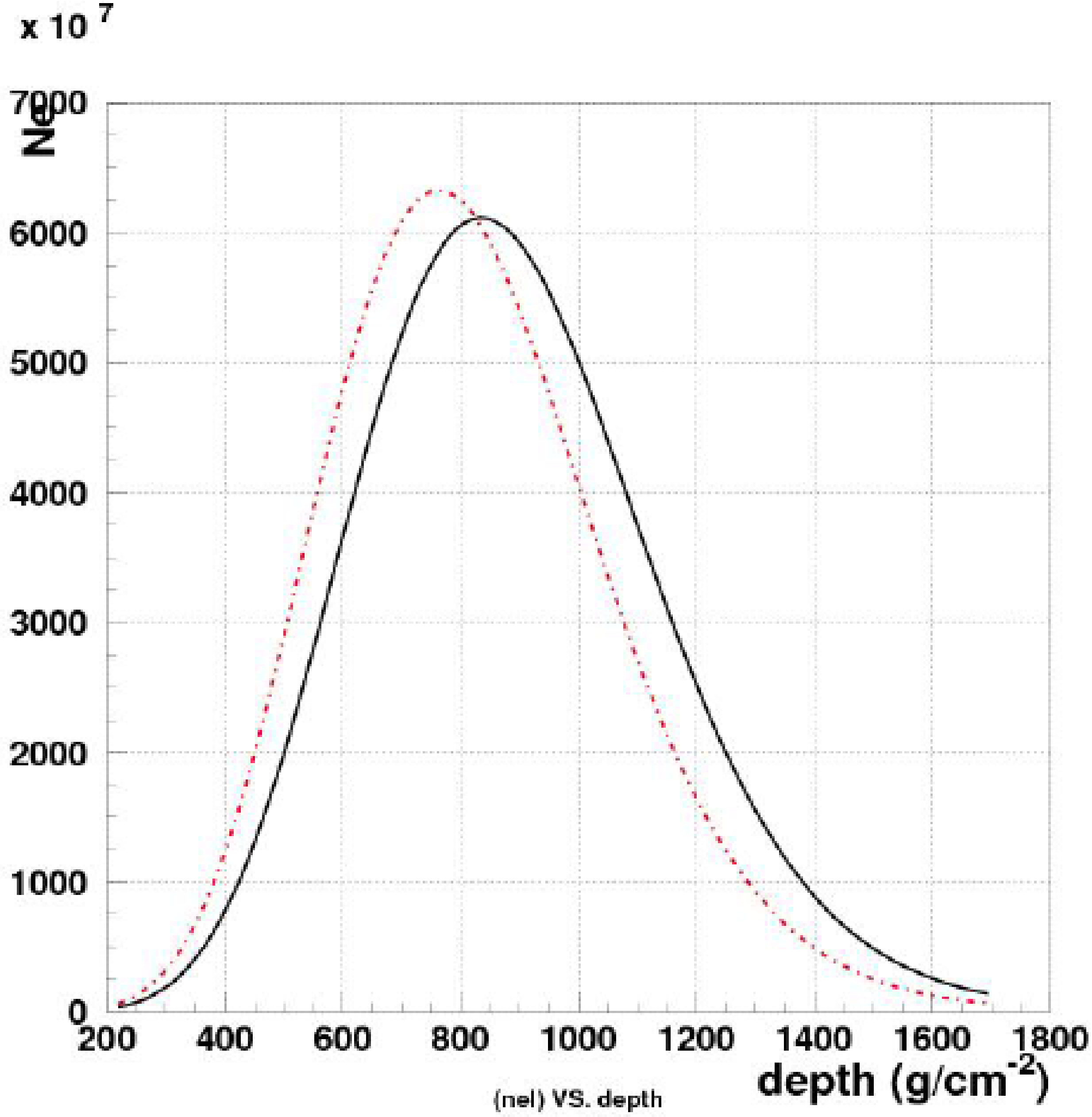
Table 4. List of 11 most energetic AGASA events [3] and results of energy reconstruction. Energies are in $10^{19}$ eV. Particle densities $\rho_{600}$ are per m². Evaluated corrected energies $E_{QGS}$ and $E_{SIB}$ refer to models with low and high multiplicity (Figures 5 and 6).

| AGASA data | | | | | evaluation - this work | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| date and time | | R.A. | δ(°) | $E_{AG}$ | θ(°) | $\rho_{600}(\theta)$ | $\rho_{600}(0°)$ | $E_{QGS}$ | $E_{SIB}$ | $E_{AGSA}$ + Vertical Correction |
| 1993/01/21 | 02:41 | 08h 17m | 16.8 | 10.1 | 39 | 480 | 256 | 6.69 | 5.40 | 4.48 |
| 1993/12/03 | 21:32 | 01h 15m | 21.1 | 21.3 | 22 | 1087 | 882 | 17.11 | 16.49 | 10.93 |
| 1994/07/06 | 20:34 | 18h 45m | 48.3 | 13.4 | 39 | 656 | 380 | 8.96 | 7.69 | 6.43 |
| 1996/01/11 | 09:01 | 16h 06m | 23.0 | 14.4 | 14 | 707 | 667 | 15.29 | 13.07 | 7.99 |
| 1996/10/22 | 15:24 | 19h 54m | 18.7 | 10.5 | 34 | 518 | 335 | 7.39 | 6.40 | 6.06 |
| 1997/03/30 | 07:58 | 19h 38m | -5.8 | 15.0 | 44 | 735 | 290 | 0.26 | 7.04 | 6.69 |
| 1998/06/12 | 06:43 | 23h 16m | 12.3 | 12.0 | 27 | 591 | 465 | 9.21 | 8.02 | 6.0 |
| 1999/09/22 | 04:43 | 23h 03m | 33.0 | 10.4 | 35 | 514 | 316 | 7.14 | 6.15 | 6.5 |
| 2001/04/30 | 19:00 | 11h 44m | 35.8 | 12.2 | 24 | 601 | 509 | 9.80 | 8.34 | 6.14 |
| 2001/05/10 | 11:05 | 23h 54m | 23.3 | 24.6 | 07 | 1194 | 605 | 15.33 | 13.16 | 10.96 |
| 2000/04/03 | 17:58 | 05h 36m | 29.0 | 12.1 | 22 | 598 | 511 | 9.99 | 9.60 | 6.06 |


AGASA amended
HIRES
AUGER amended
E³, FLUX/10²⁴ m⁻² s⁻¹ sr⁻¹ eV²
LOG(Primary energy Eo) (eV)
5
4
3
2
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
18
18.5
19
19.5
20
20.5

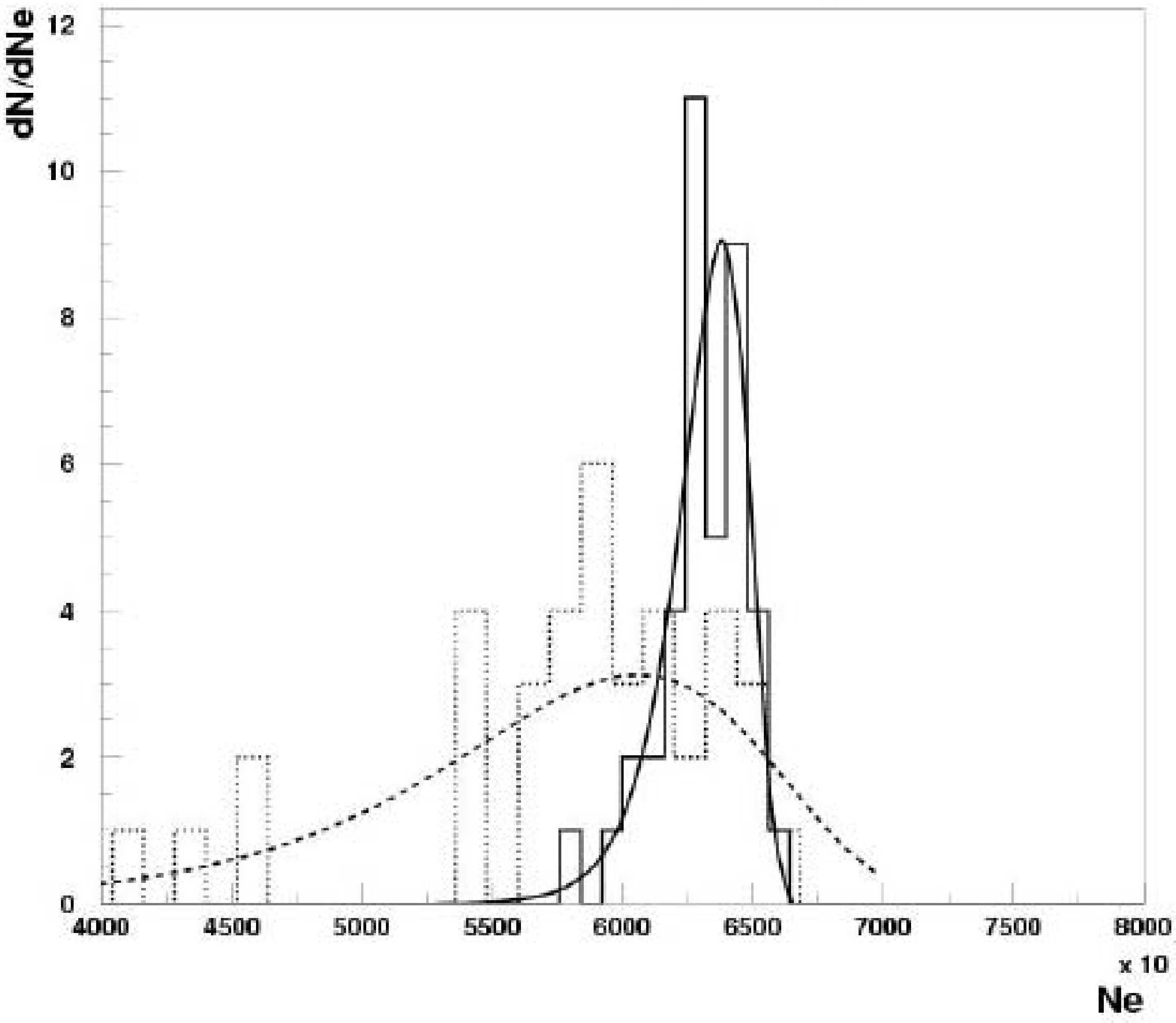


x 10 7
400 600 800 1000 1200 1400 1600
Ne
7000
6000
5000
4000
3000
2000
1000
0
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
200 400 600 800 1000 1200 1400 1600 1800
depth (g/cm-2)
(nel) VS. depth



x 10 7
Ne
7000
6000
5000
4000
3000
2000
1000
0
200
400
600
800
1000
1200
1400
1600
1800
depth (g/cm-2)
(nel) VS. depth

# Ne distributions at 745g/cm2 p and Fe



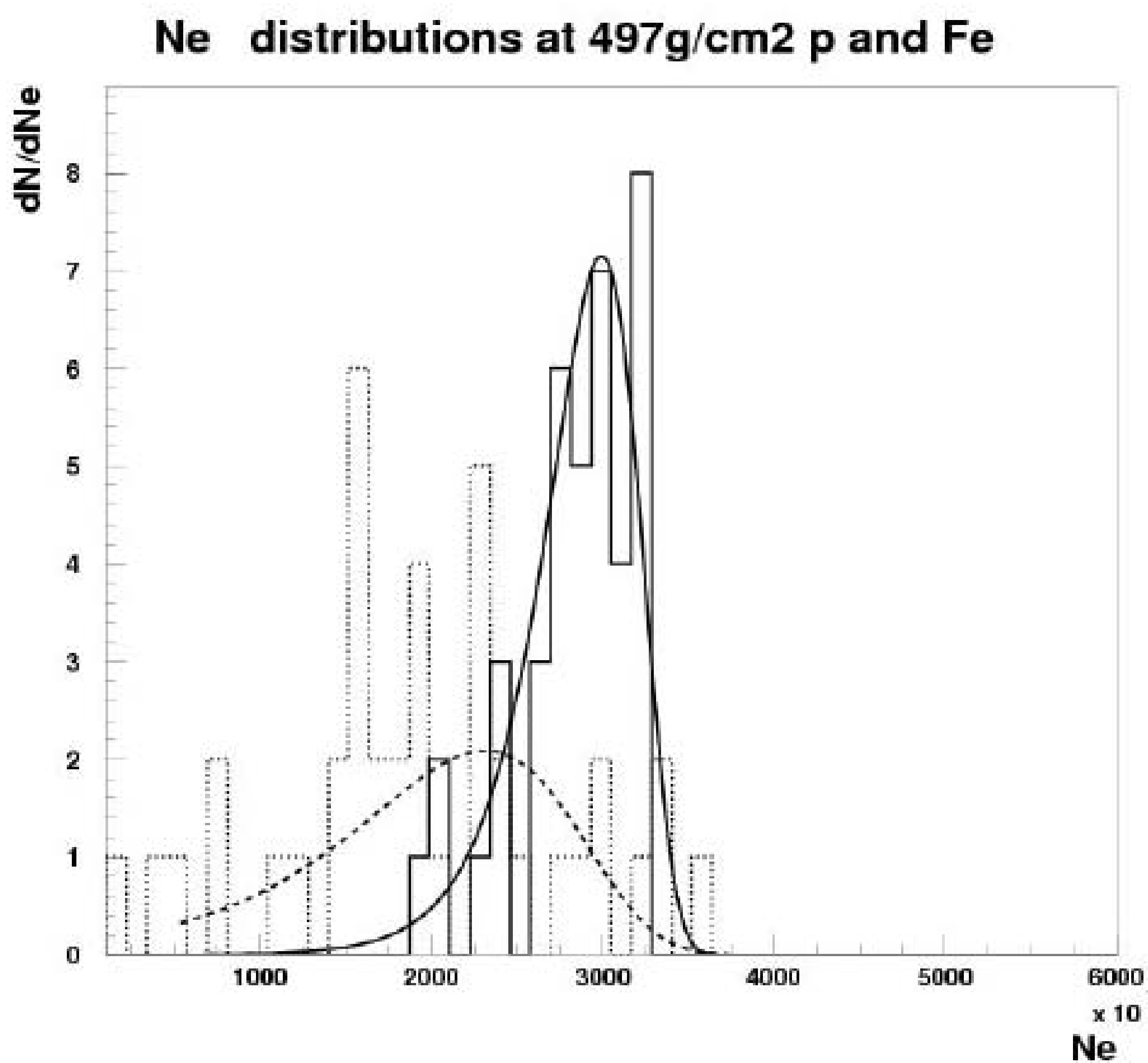
*Size fluctuations at different depths*

Extreme value distributions (E.V. D.

$$f(N_e) = \frac{1}{\sigma} \exp\left( \pm \frac{\mu - N_e}{\sigma} - e^{\pm \frac{\mu - N_e}{\sigma}} \right)$$

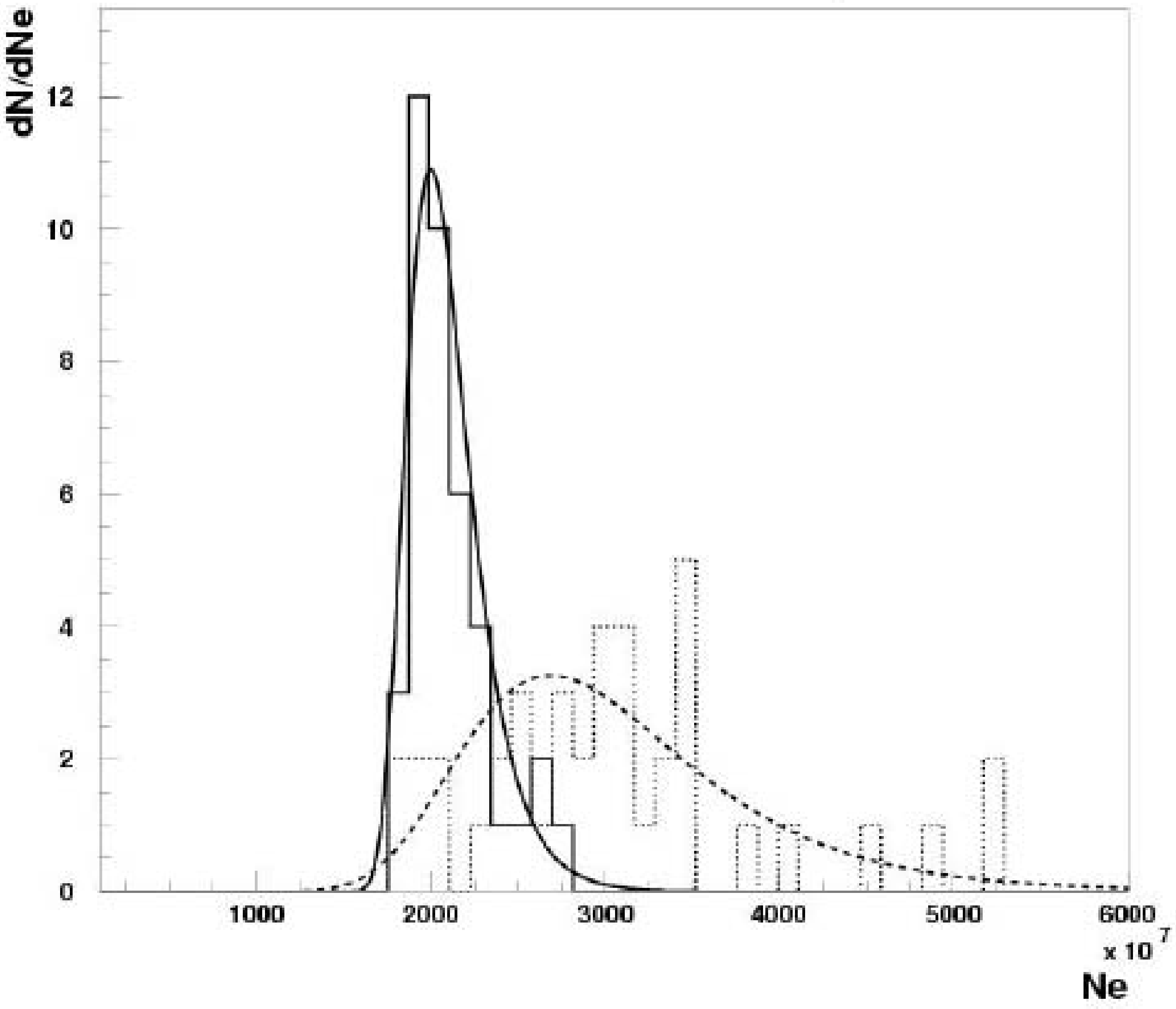
where the parameters $\mu$ and $\sigma$ are relat

$\overline{N_e} = \mu \pm 0.577\sigma$ and $V_{N_e} = 1.645\sigma^2$

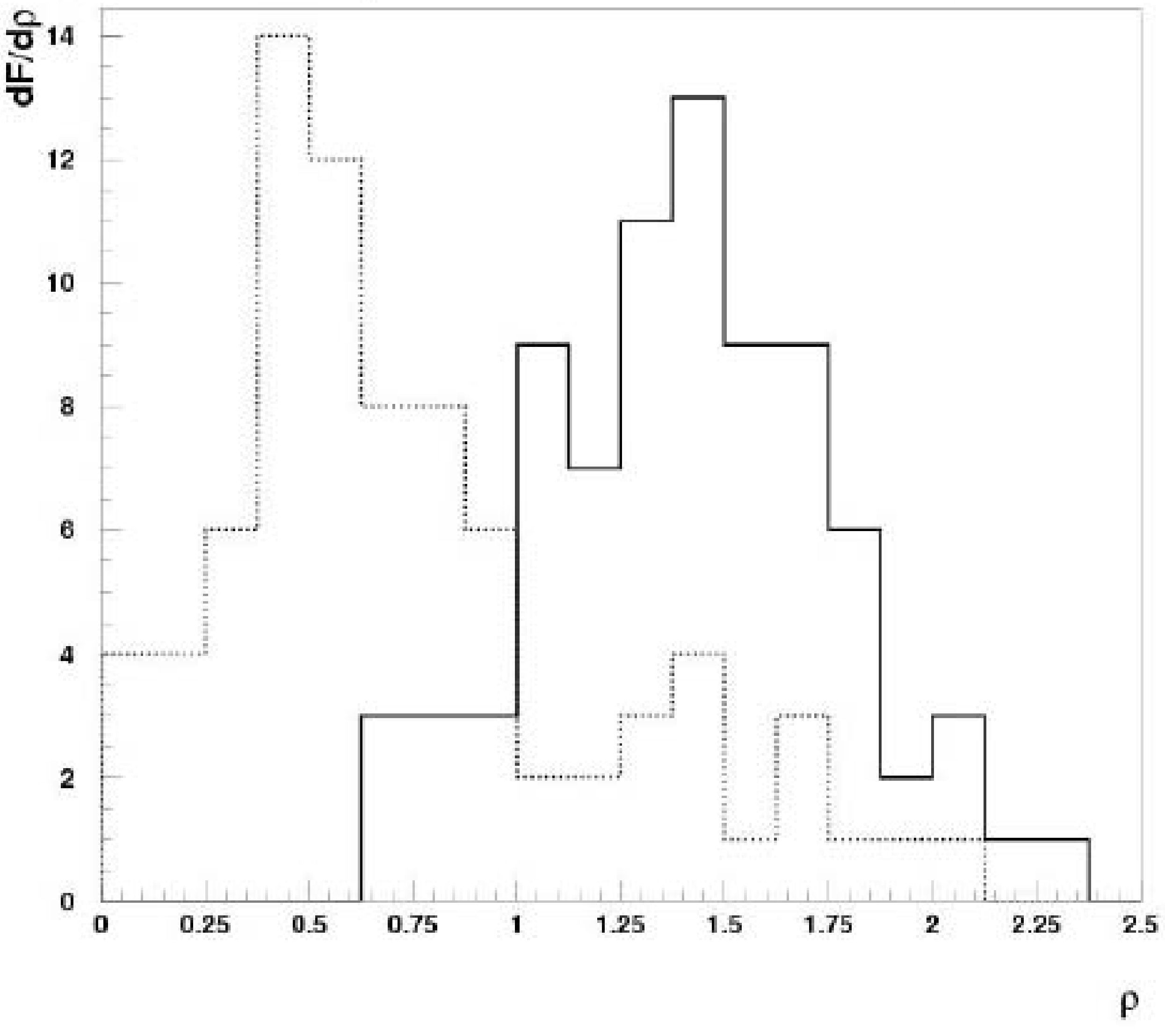


Ne distributions at 497g/cm2 p and Fe
dN/dNe
0
1
2
3
4
5
6
7
8
1000
2000
3000
4000
5000
6000
x 10^7
Ne

## Ne distributions at 1155g/cm2 p and Fe



# growth-absorption ratio at 500 and 1155g/cm2



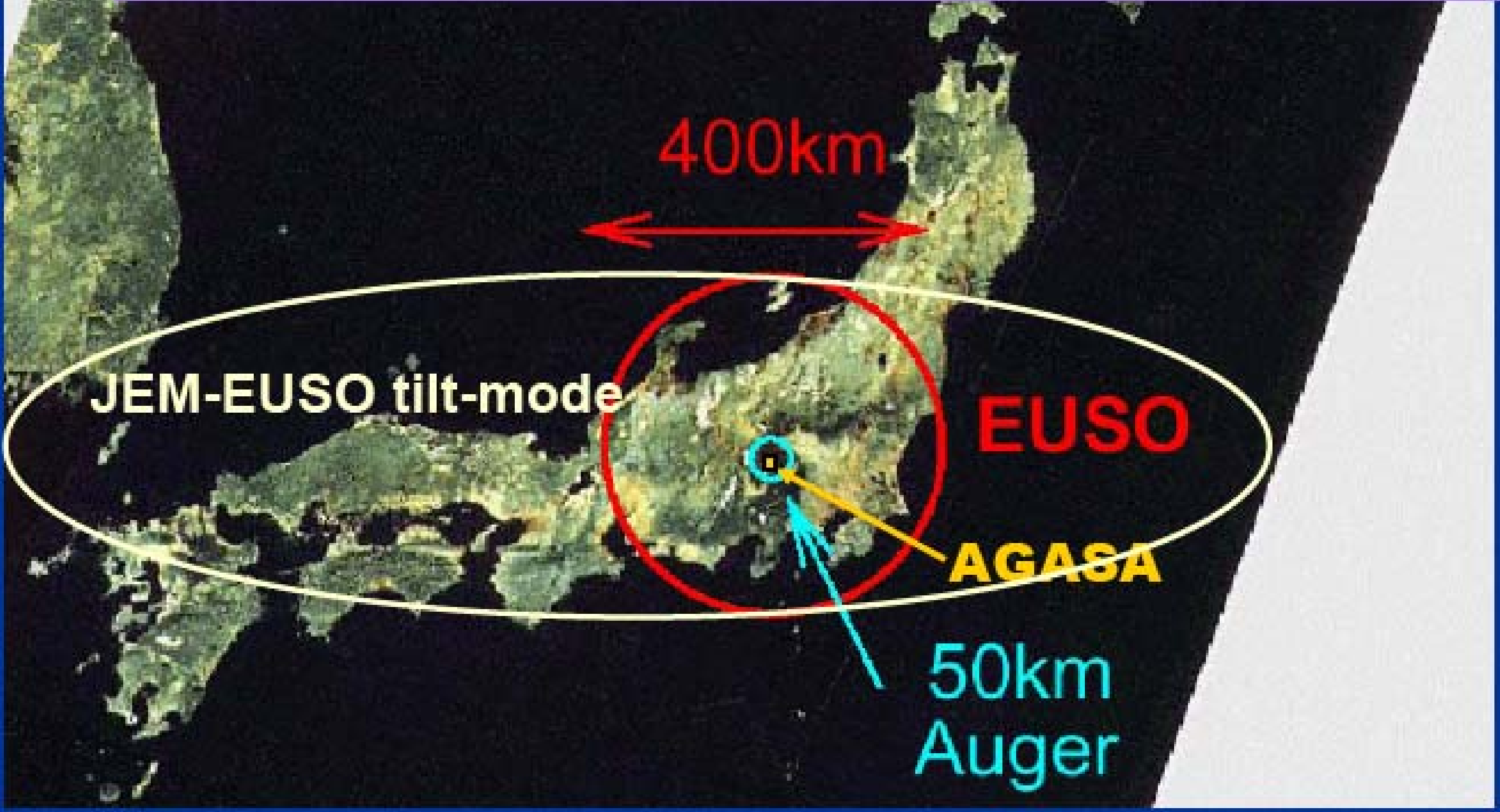
statistics of different variables $Ne$, $\rho$ for $E_0$ =$10^{20}$eV

| *Variable* | *Average* | *r.m.s.* | *comment* |
|---|---|---|---|
| Ne | $1.941 \cdot 10^{10}$ | $0.838 \cdot 10^{10}$ | p, 500. g/cm |
| Ne | $2.83 \cdot 10^{10}$ | $0.344 \cdot 10^{10}$ | Fe, 500. g/c |
| Ne | $3.07 \cdot 10^{10}$ | $0.8545 \cdot 10^{10}$ | p, 1155. g/c |
| Ne | $2.079 \cdot 10^{10}$ | $0.24 \cdot 10^{10}$ | Fe,1155. g/c |
| $\rho$ | 0.75 | 0.4656 | p |
| $\rho$ | 1.413 | 0.3532 | Fe |
| $\rho$ | 0.758 | 0.5097 | p (15% error on |
| $\rho$ | 1.414 | 0.4251 | Fe (15% error on |

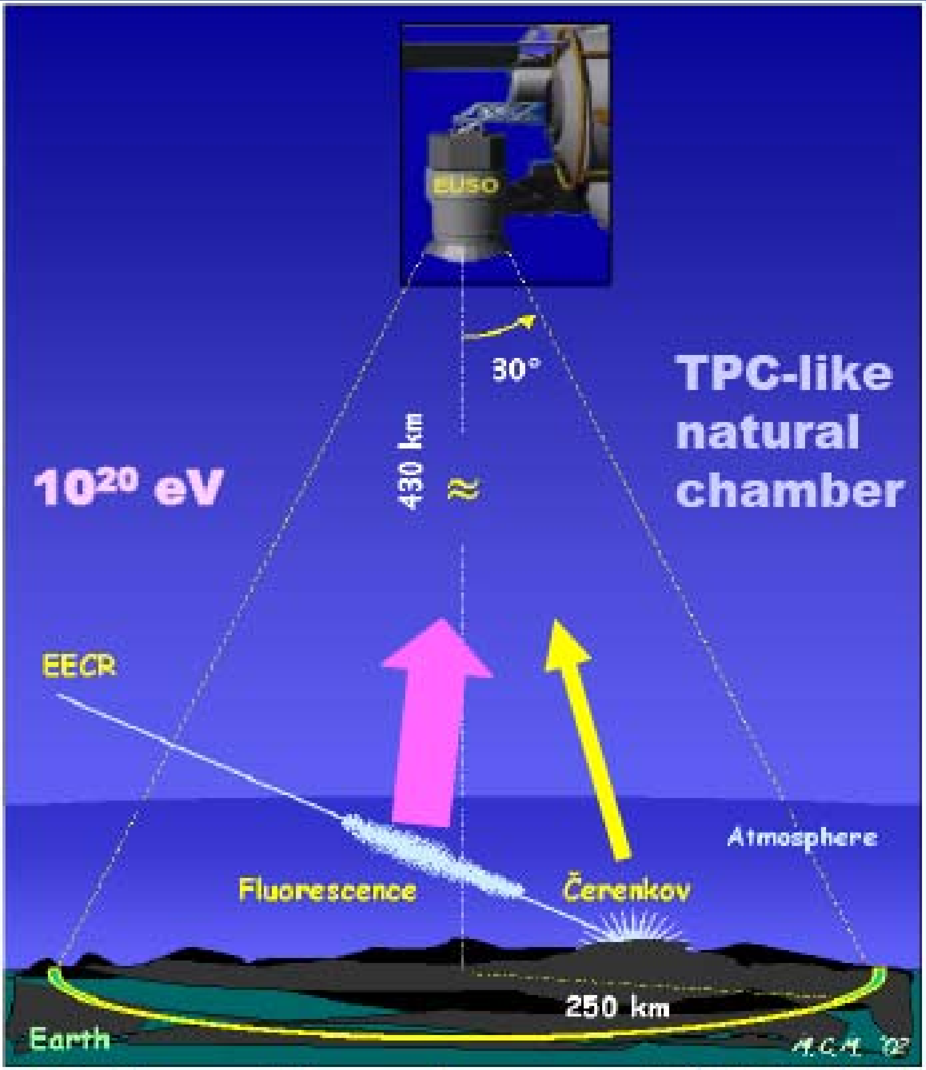
$\rho$ fraction of light at 500 g/cm² to 1155 g/cm²

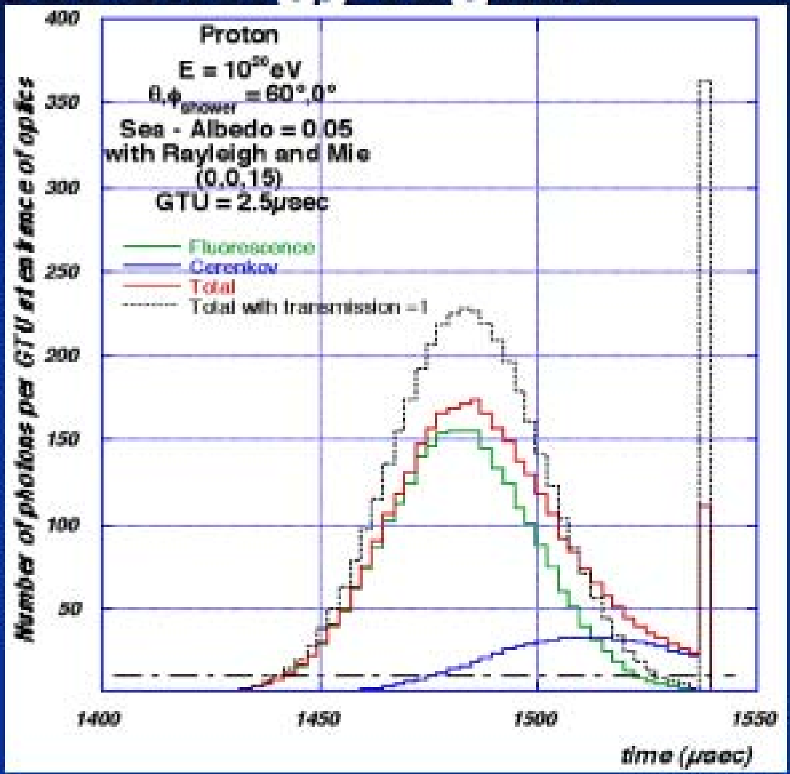
# JEM-EUSO FoV

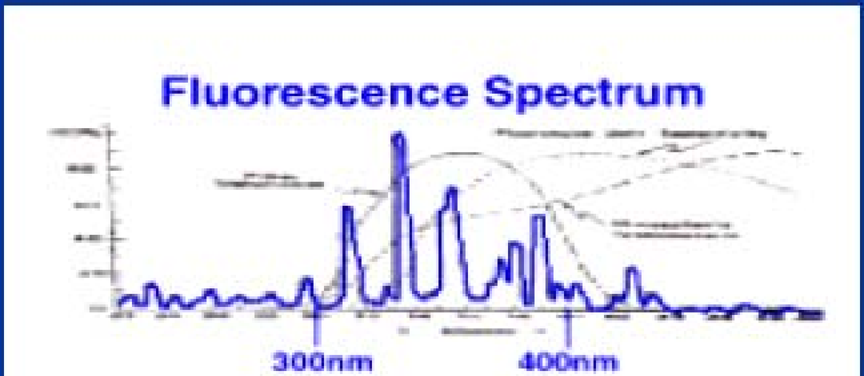
EUSO ~ 1000 x AGASA ~ 30 x Auger
EUSO (Instantaneous) ~ 5000 x AGASA
~ 150 x Auger



# Principle of EUSO
## - first *remote-sensing* from space, opening a new window for the highest energy regime



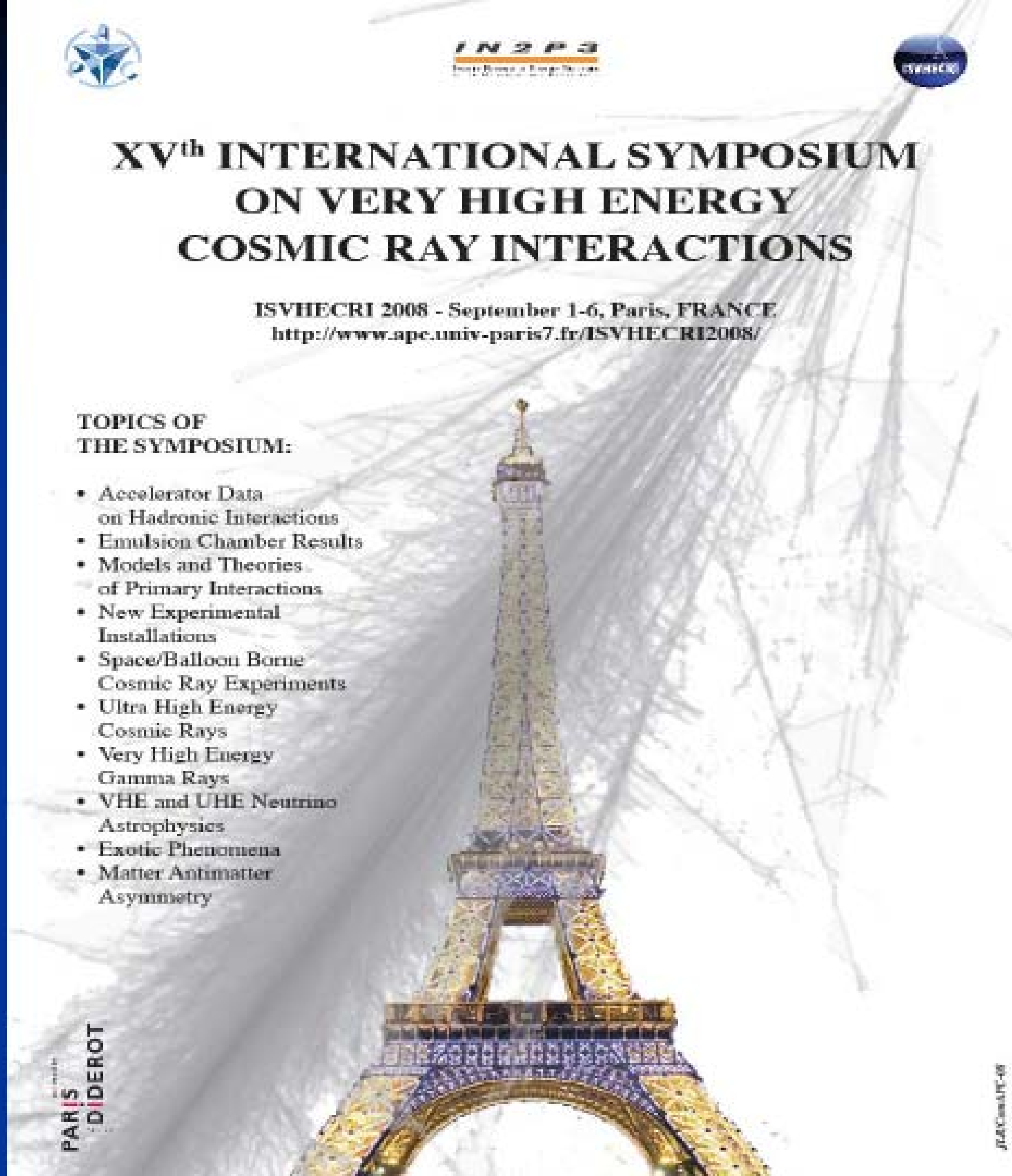

**Cf: Ground-based arrays < 100 EUSO**

(1) Scintillator array,(2)Fluorescence telescope array

**From College de France: better data now**

# Conclusions

- New chances for Proton &Gamma ray Astronomy at UHE from ISS with JEM-EUSO
- New results of LHC updating the simulation
- GZK tendancies confirmed after specific treatment of inclined EAS and particular procedure in the conversion of vertical signal to primary energy.
- Xmax behaviour and change in p-Air interaction above 3 EeV?
- Ratio of light at 500g/cm2 to 1100g/cm2 depends on mass (in favour of p composition at UHE for HIRES


IN2P3
XVth INTERNATIONAL SYMPOSIUM
ON VERY HIGH ENERGY
COSMIC RAY INTERACTIONS
ISVHECRI 2008 - September 1-6, Paris, FRANCE
http://www.apc.univ-paris7.fr/ISVHECRI2008/
TOPICS OF
THE SYMPOSIUM:
• Accelerator Data on Hadronic Interactions
• Emulsion Chamber Results
• Models and Theories of Primary Interactions
• New Experimental Installations
• Space/Balloon Borne Cosmic Ray Experiments
• Ultra High Energy Cosmic Rays
• Very High Energy Gamma Rays
• VHE and UHE Neutrino Astrophysics
• Exotic Phenomena
• Matter Antimatter Asymmetry
PARIS DIDEROT

Ne

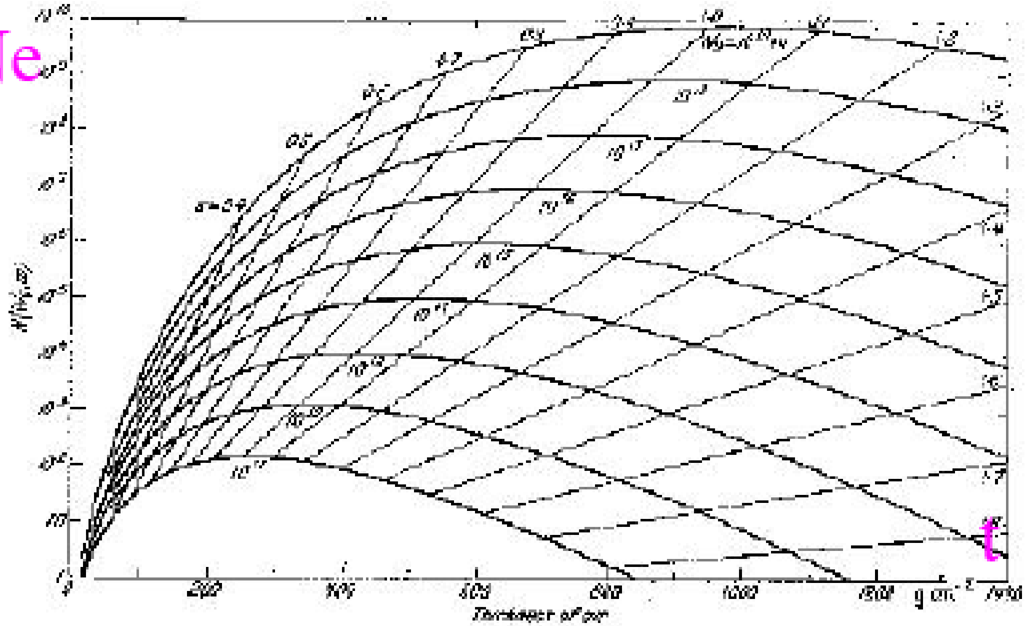
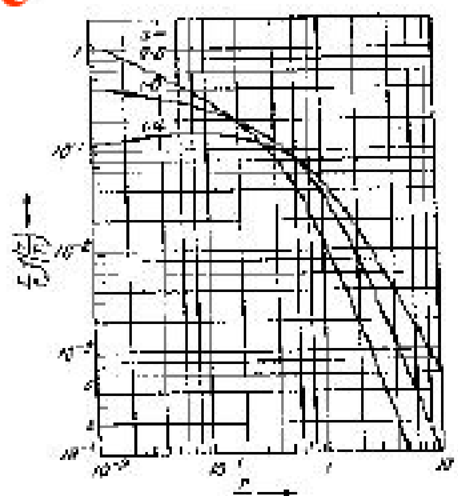
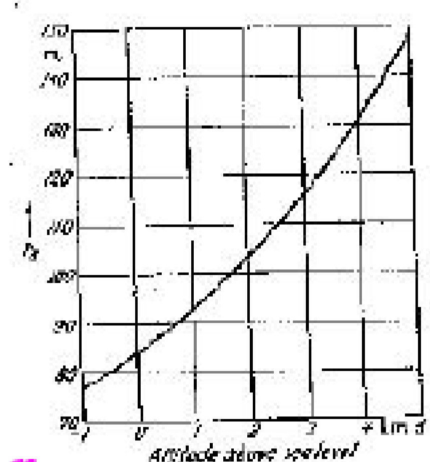



Fig. 1. The total number of electrons, as a function of the thickness in g cm⁻² of air crossed, produced by photons of various energies, $W_0$, in eV. The parameter s is the age of the shower at different stages of its development.

G.COCCONI, 1961

Δe






r

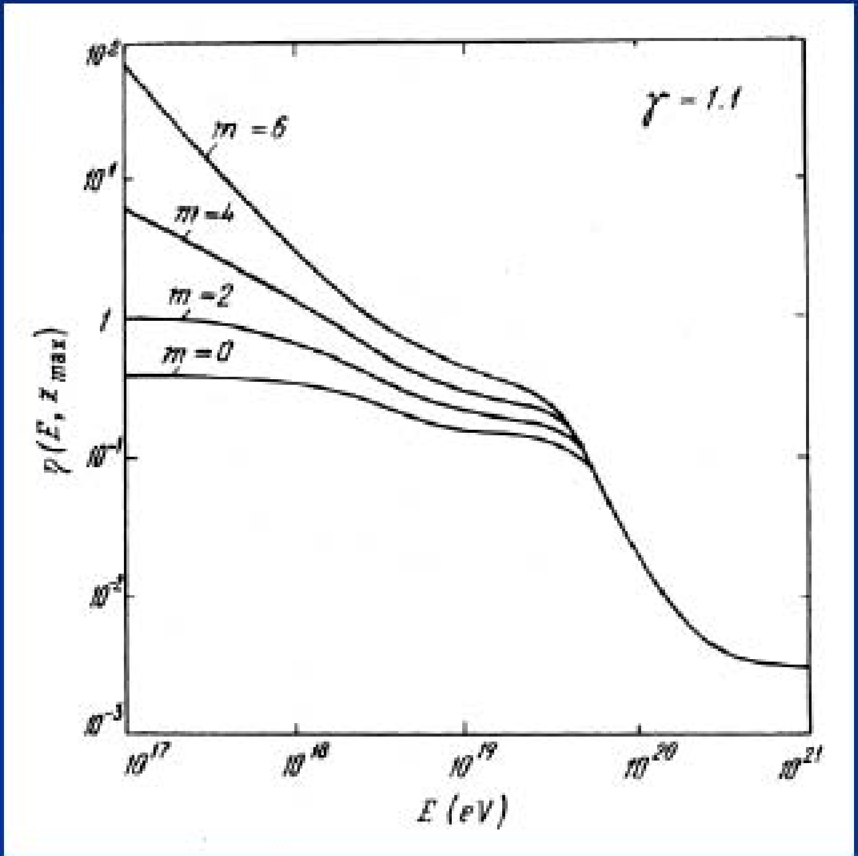
# Signal dans Auger

Simulation → densité de particules
Détecteurs Auger → signal en Vertical Equivalent Muons (VEM)

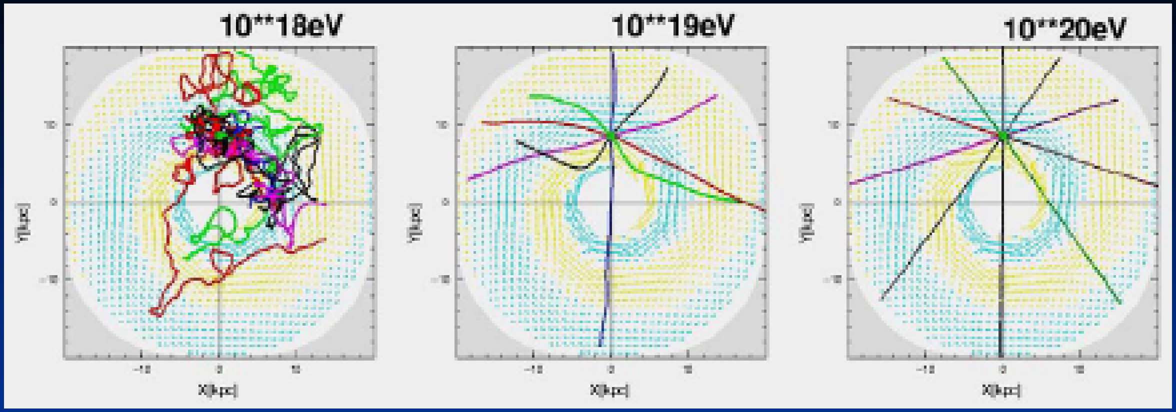
$$\rho^{Signal}_{VEM}(r) = C_1\, \rho_{e+e-}(r) + C_2\, \rho_{\mu}(r)$$

Des simulations avec géant4 de la cuve d'Auger :
$C_1 = 0{,}47$
$C_2 = 0{,}9 - 1$

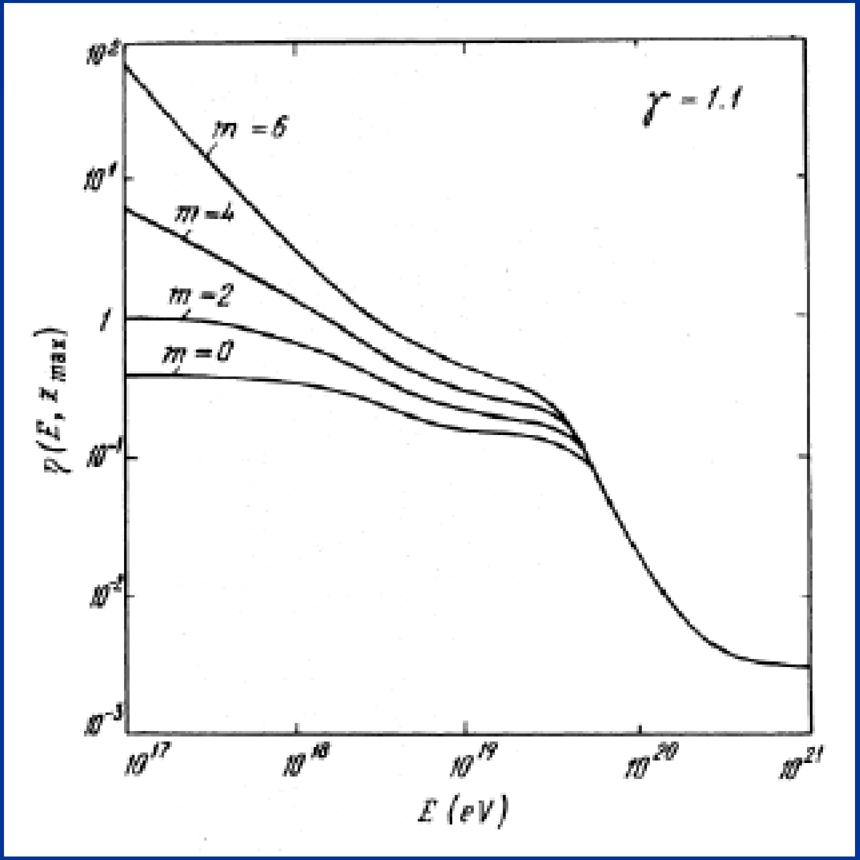
# Trans GZK AREA



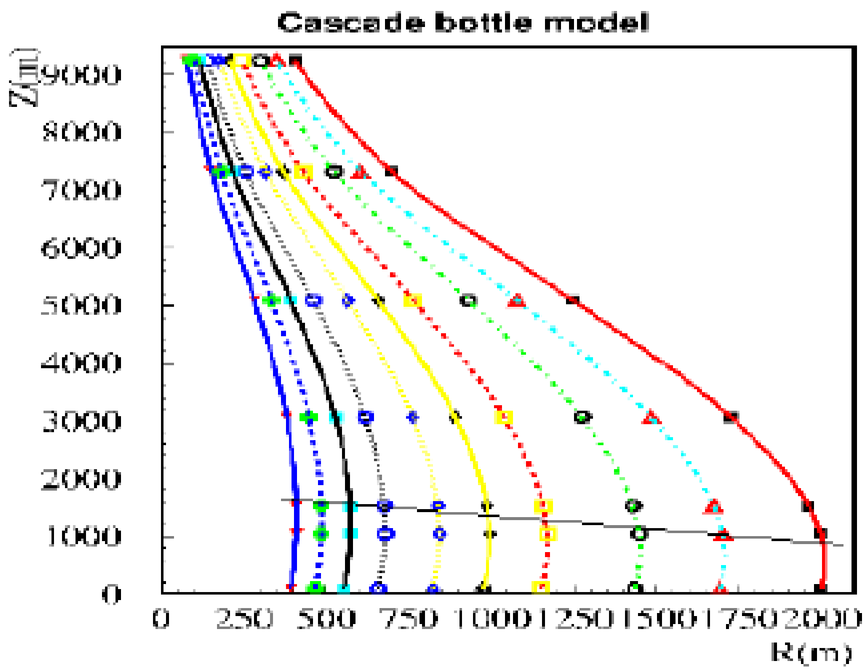

- New scales
- Adequate Advanced Technologies
- Milesbornes to Quantum Gravity
- earliest approaches, EUSO and JEM-EUSO




# Astronomie proton




1000 evts à répartir sur un certain nombre de sources éventuelles avec leur spectre respectif




Isodensity curves  Δe= 400, 200, 100, 50, 20, 10, 5, 2, 1, 0.5 electrons/m2 for 100 γ-ray initiated cascades

(CORSIKA fastened via « NKG » option)