Systematics and fine structure in the cosmic ray electron spectrum measured by ATIC

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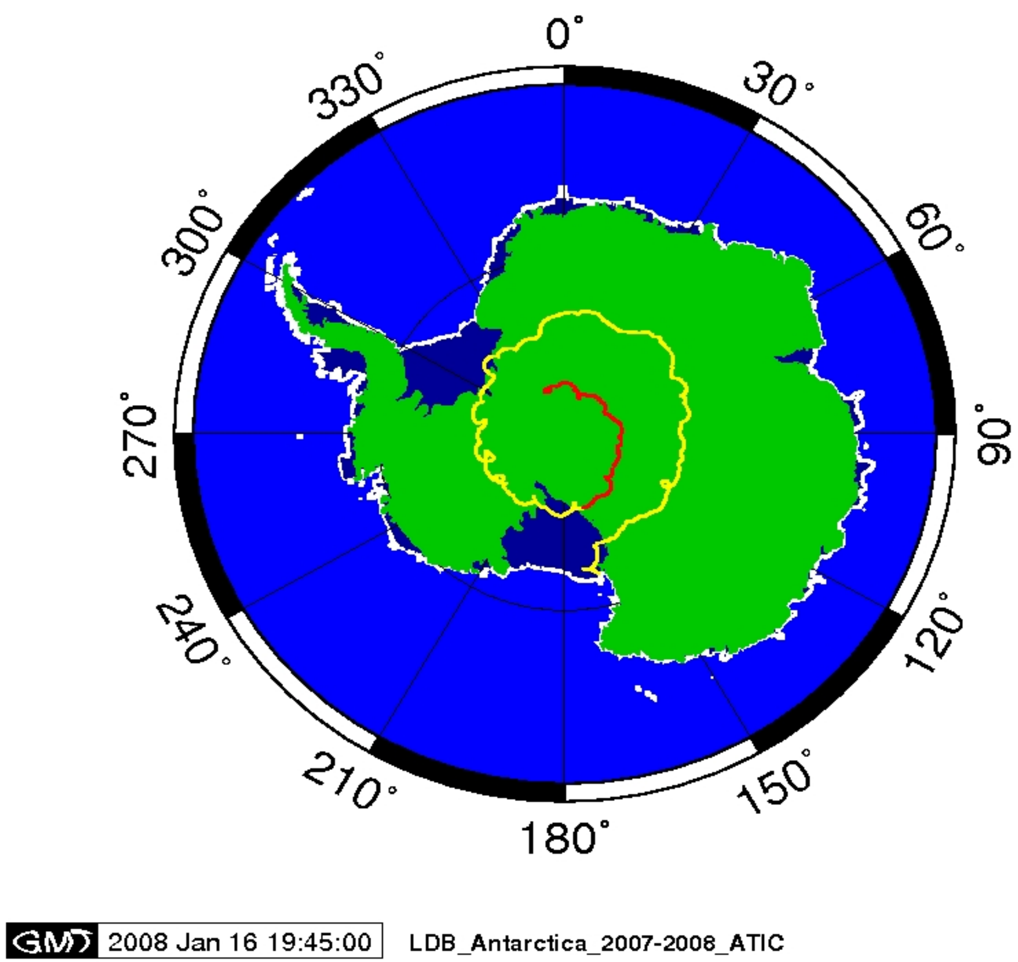
ATIC (Advanced Thin Ionization Calorimeter) flights around South Pole

Trajectory of ATIC-4



ATIC-1 28.12.2000–13.01.2001

Test flight, 0.6 m^2 sr days

ATIC-2 29.12.2002–18.01.2003

First science flight, 2.5 m^2 sr days

ATIC-3 2005

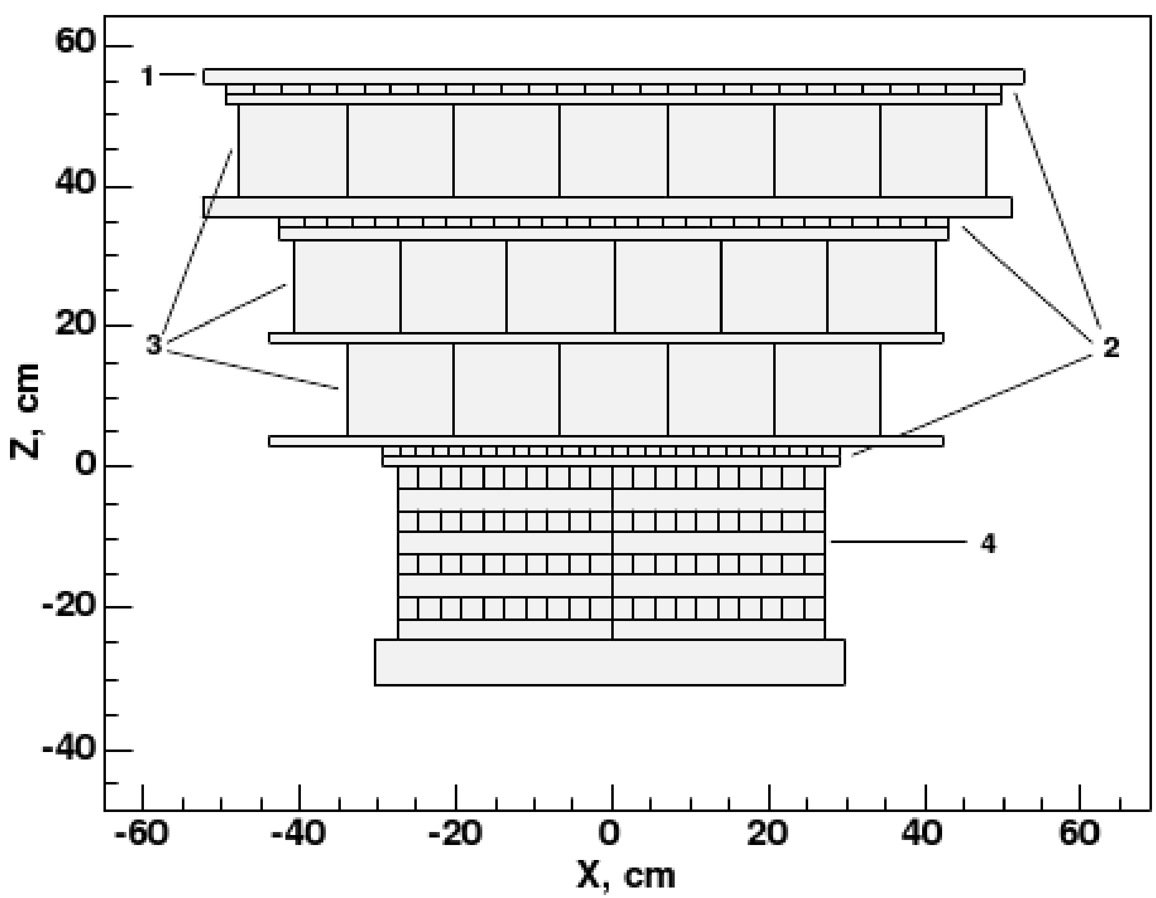
failed to rich altitude

ATIC-4 26.12.2007–15.01.2008

Second science flight,

2.2 m^2 sr days

ATIC spectrometer



1 — **Silicon matrix**

80 × 56 pixels, 1.5 × 2cm

2 — **Scintillator hodoscopes**

3 — **Carbon target**

$(1.5\ X_0)$

4 — **BGO-calorimeter**

View from above:

50 × 50 cm

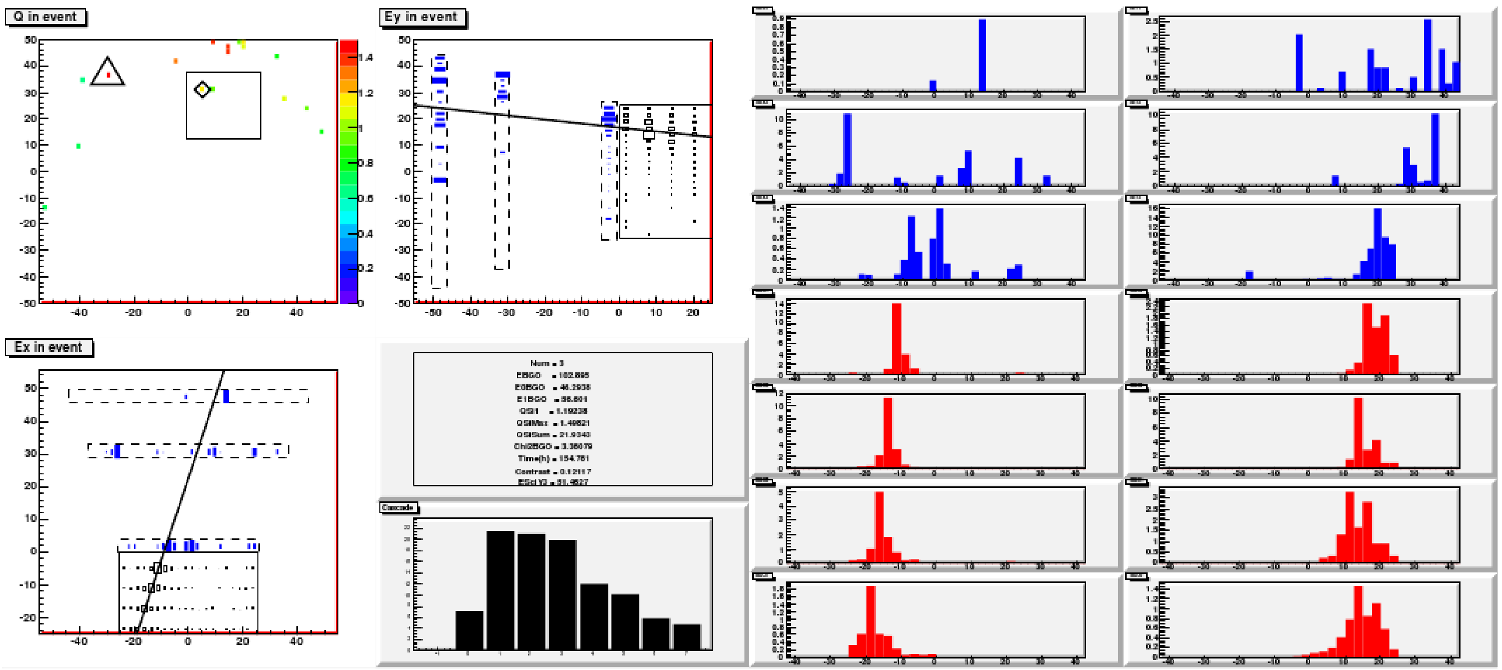
BGO crystal:

2.5 × 2.5 × 25 cm

8 layers in ATIC-2 $(18\ X_0)$

10 layers in ATIC-4 $(22\ X_0)$

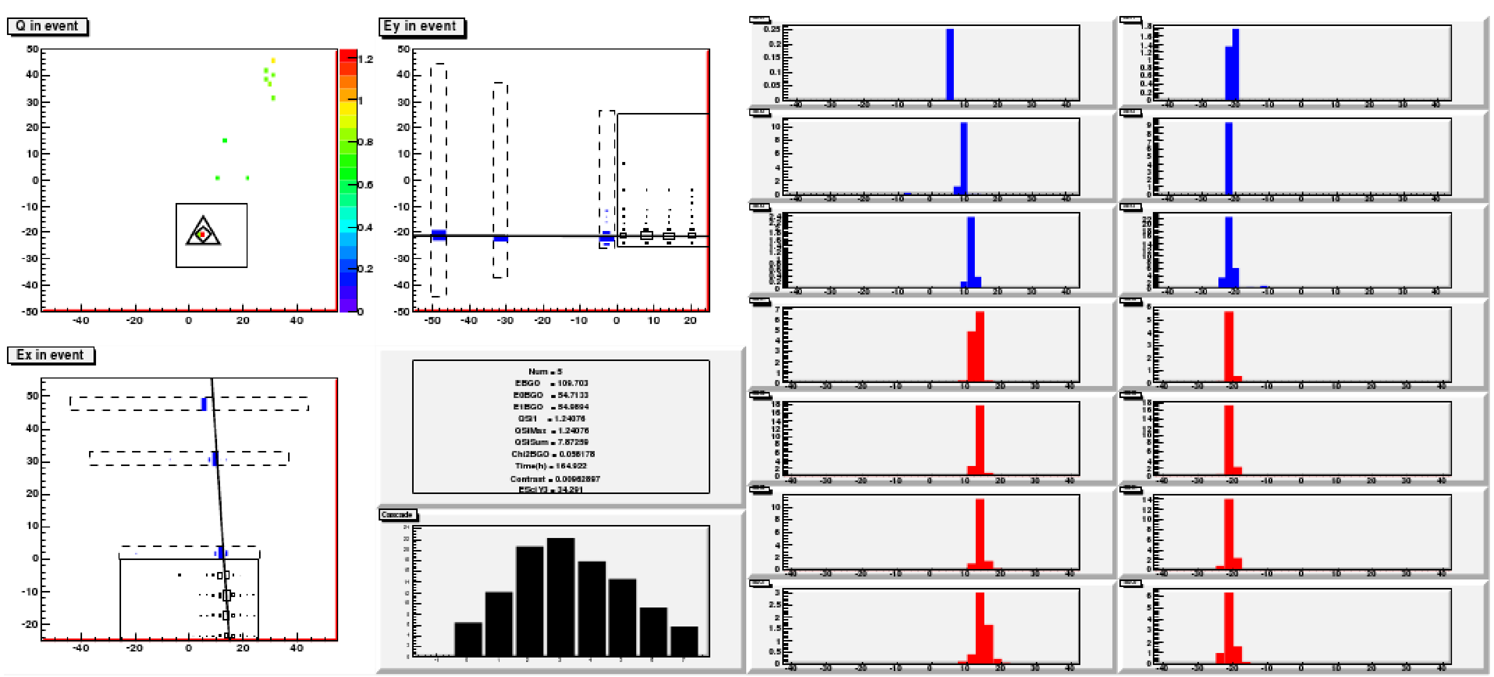
Proton event



Hodoscopes energy deposits

Calorimeter energy deposites

Electron or positron event

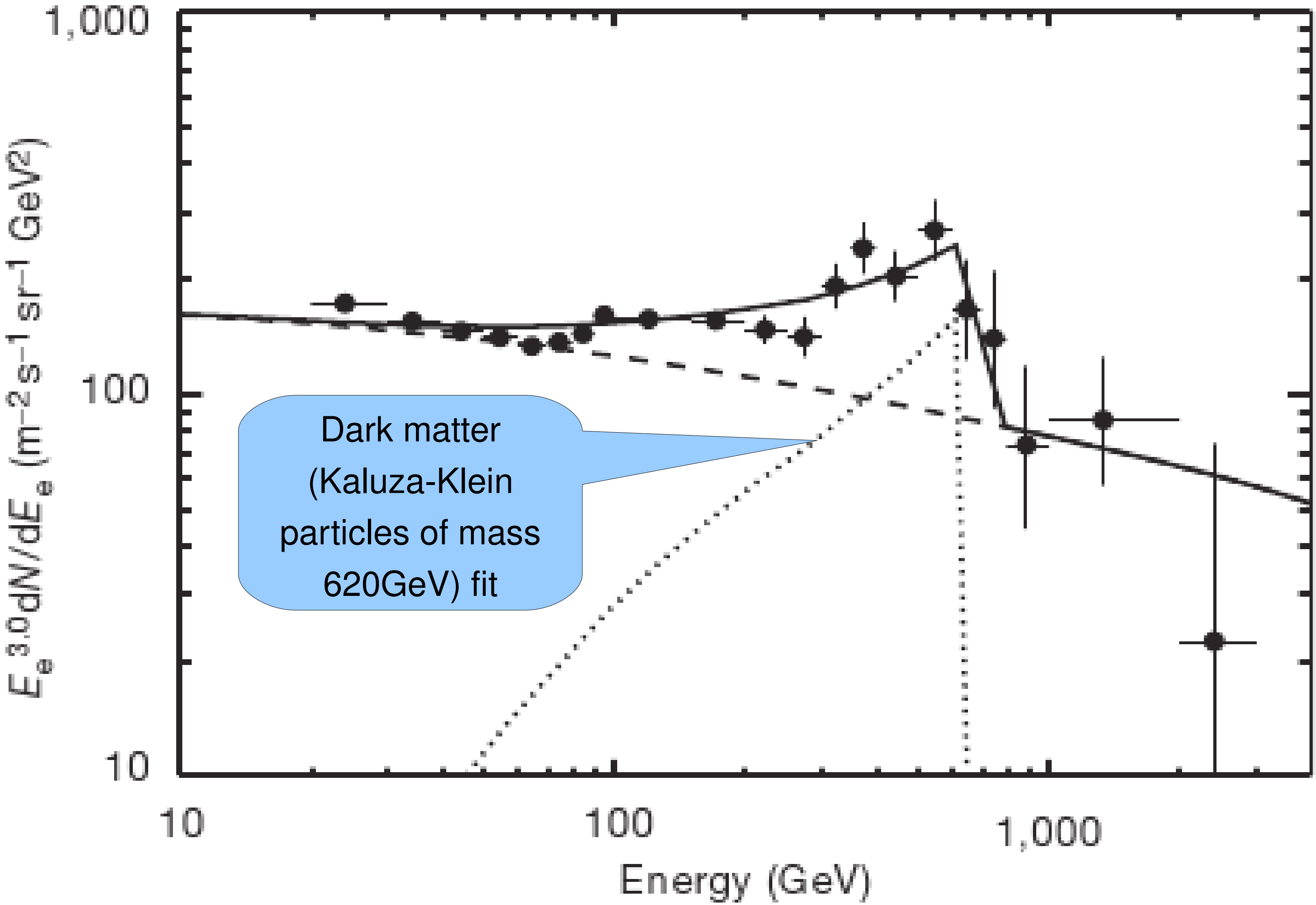


Hodoscopes energy deposites

Calorimeter energy deposites

Spectrum of cosmic rays electrons measured by ATIC:

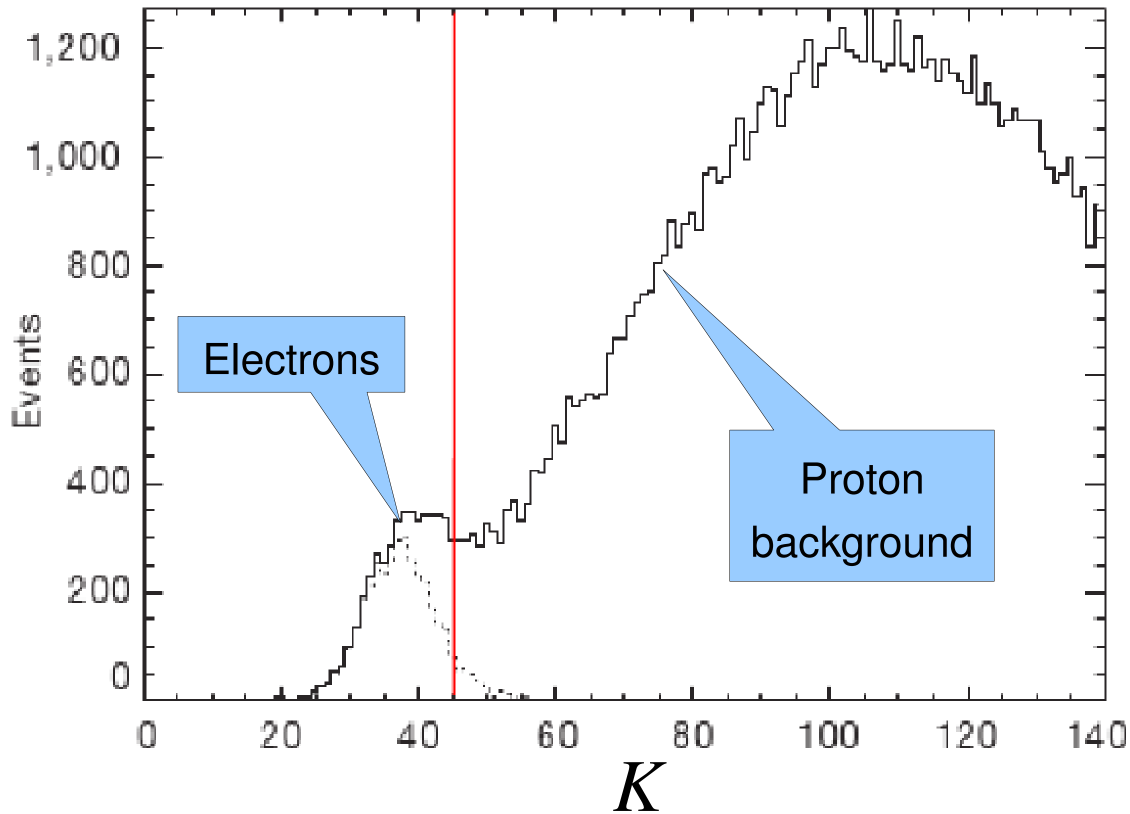
J. Chang, J. H. Adams Jr, H. S. Ahn et. al. An excess of cosmic ray electrons at energies of 300–800 GeV. Nature V.456 (2008), P.362-365



K-filter

Layers of the calorimeter from the top:

$l = 0, 1, 2, 3, 4, 5, 6, 7$



Root Mean Squares (RMS):

$$R_l = \sqrt{\frac{\sum_i E_l^i (X_i - X_l^c)^2}{\sum_i E_l^i}}$$

Cascade curve:

$$C_l = E_l / E_{BGO}$$ (relative deposit of energy in a layer l)

F-parameter: $F_l = R_l^2 C_l / (2.5mm^2)$

K-filter: $K = R_0 + R_1 + F_6 + F_7$

The purpose of this work:

1. To check the results with alternate techniques of separation of electrons from protons
2. To study systematic errors.

The work was carried out comletely independently of previous analysis starting from low-level calibration procedures up to the final results in the MSU subgroup of the ATIC collaboration

We define five new (main) filters:

1. Four simple filters

$$G_l = R_l\sqrt{C_l}$$

$\bar{R}_l, \bar{G}_l$ – simulated mean values

σ_l^R, σ_l^G -simulated standard deviations

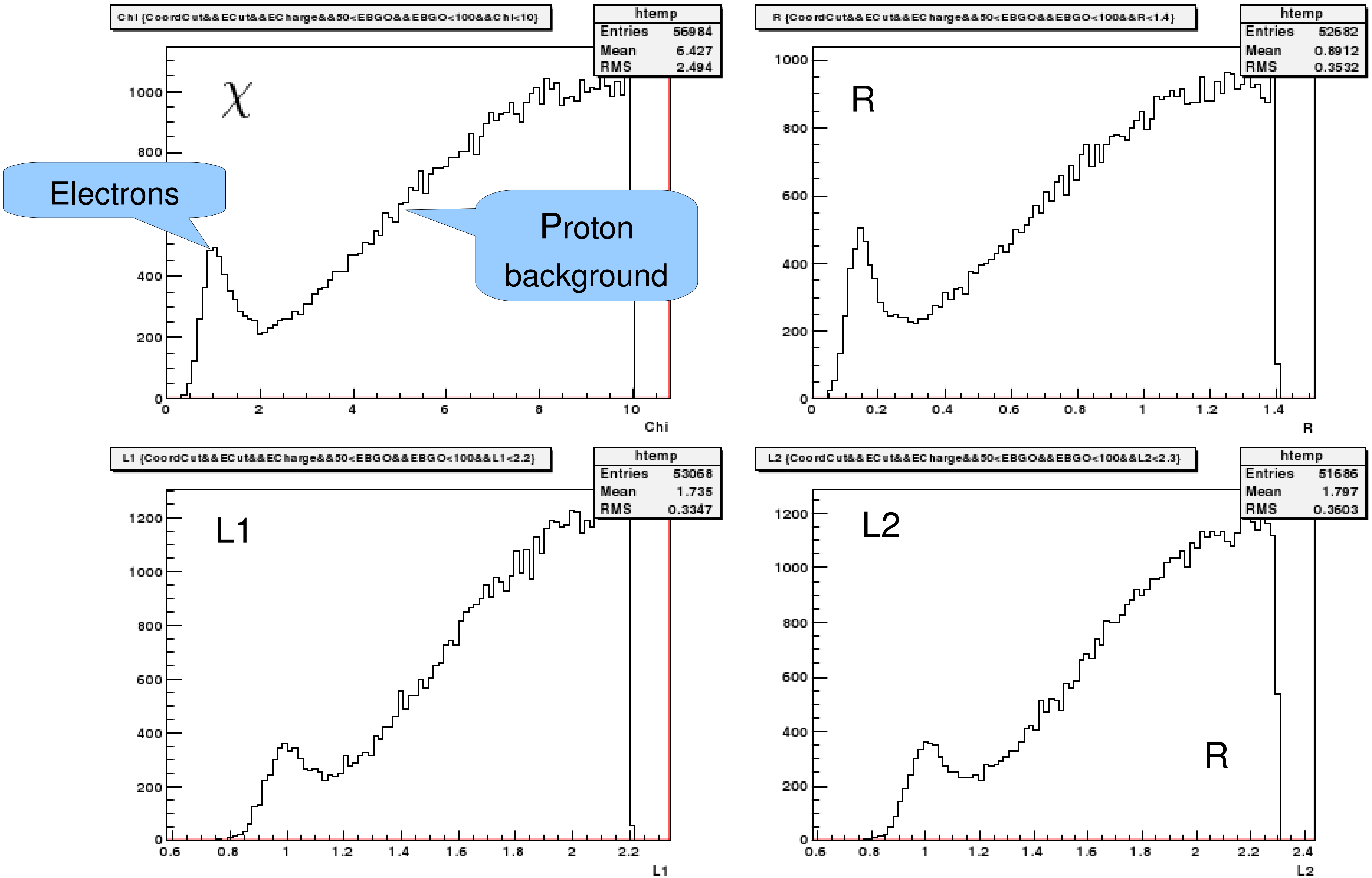
$$\chi = \sqrt{\frac{1}{8}\left[\sum_{l=0}^{3}\left(\frac{R_l-\bar{R}_l}{\sigma_l^R}\right)^2+\sum_{l=4}^{7}\left(\frac{G_l-\bar{G}_l}{\sigma_l^G}\right)^2\right]}$$

$$R = \sqrt{\frac{1}{8}\left[\sum_{l=0}^{3}\left(\frac{R_l-\bar{R}_l}{\bar{R}_l}\right)^2+\sum_{l=4}^{7}\left(\frac{G_l-\bar{G}_l}{\bar{G}_l}\right)^2\right]}$$

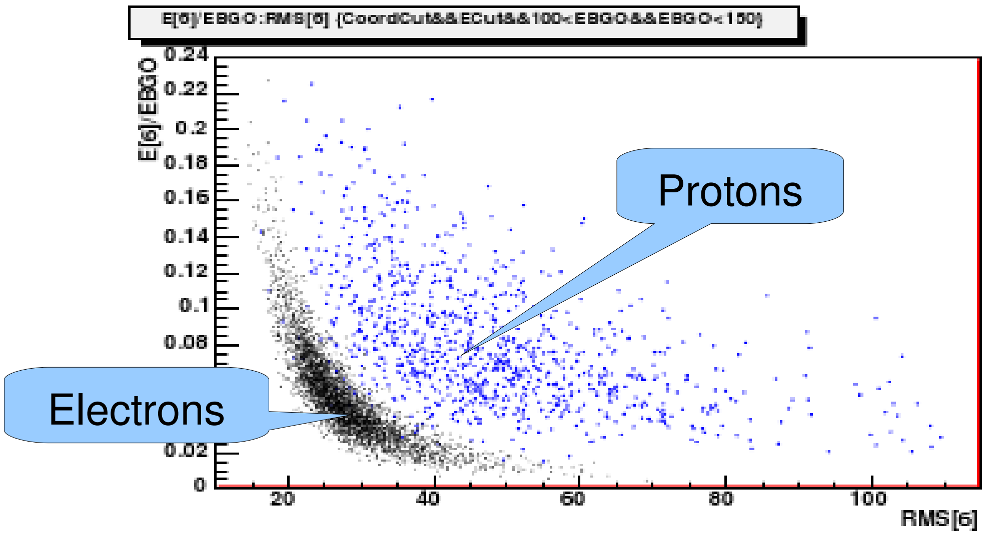
$$L1 = \frac{1}{8}\left[\sum_{l=0}^{3}\frac{R_l}{\bar{R}_l}+\sum_{l=4}^{7}\frac{G_l}{\bar{G}_l}\right]$$

$$L2 = \sqrt{\frac{1}{8}\left[\sum_{l=0}^{3}\left(\frac{R_l}{\bar{R}_l}\right)^2+\sum_{l=4}^{7}\left(\frac{G_l}{\bar{G}_l}\right)^2\right]}$$

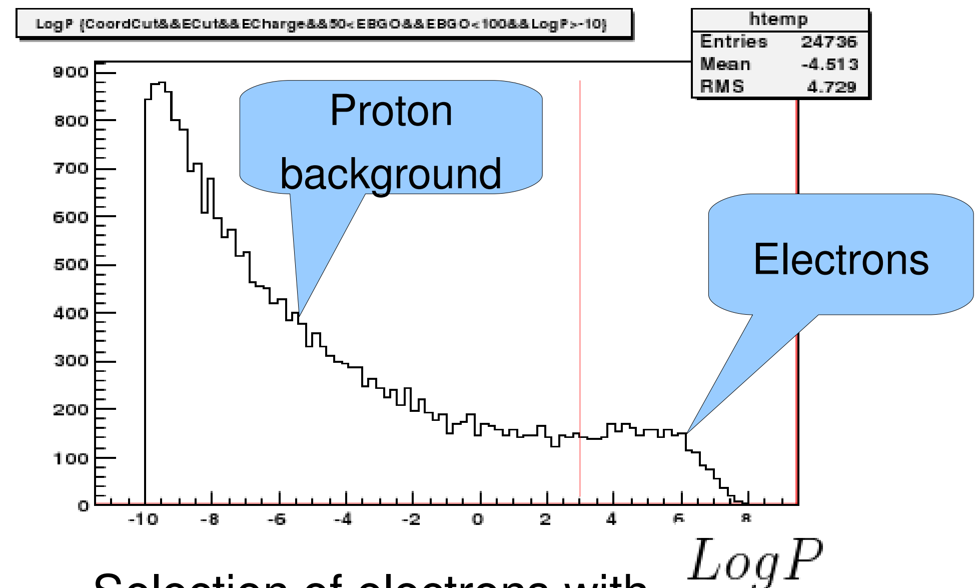
Selection of electrons with simple filters



Likelihood filter *LogP*.



Projection of the simulated probability distribution on (R_6, C_6) - plate



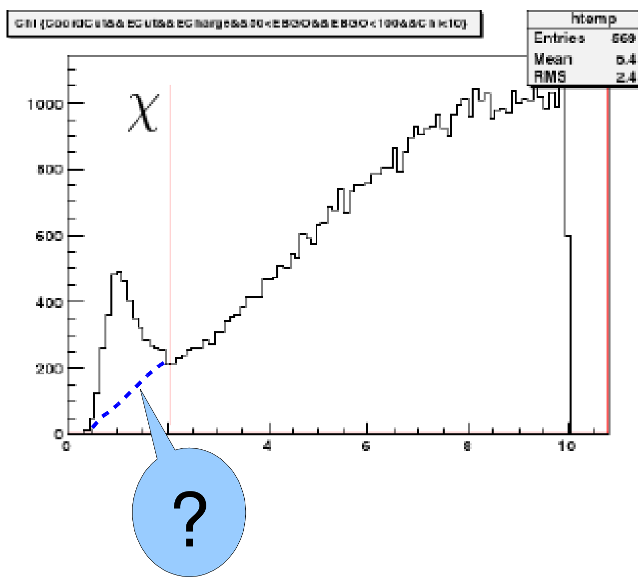
Selection of electrons with *LogP*-filter

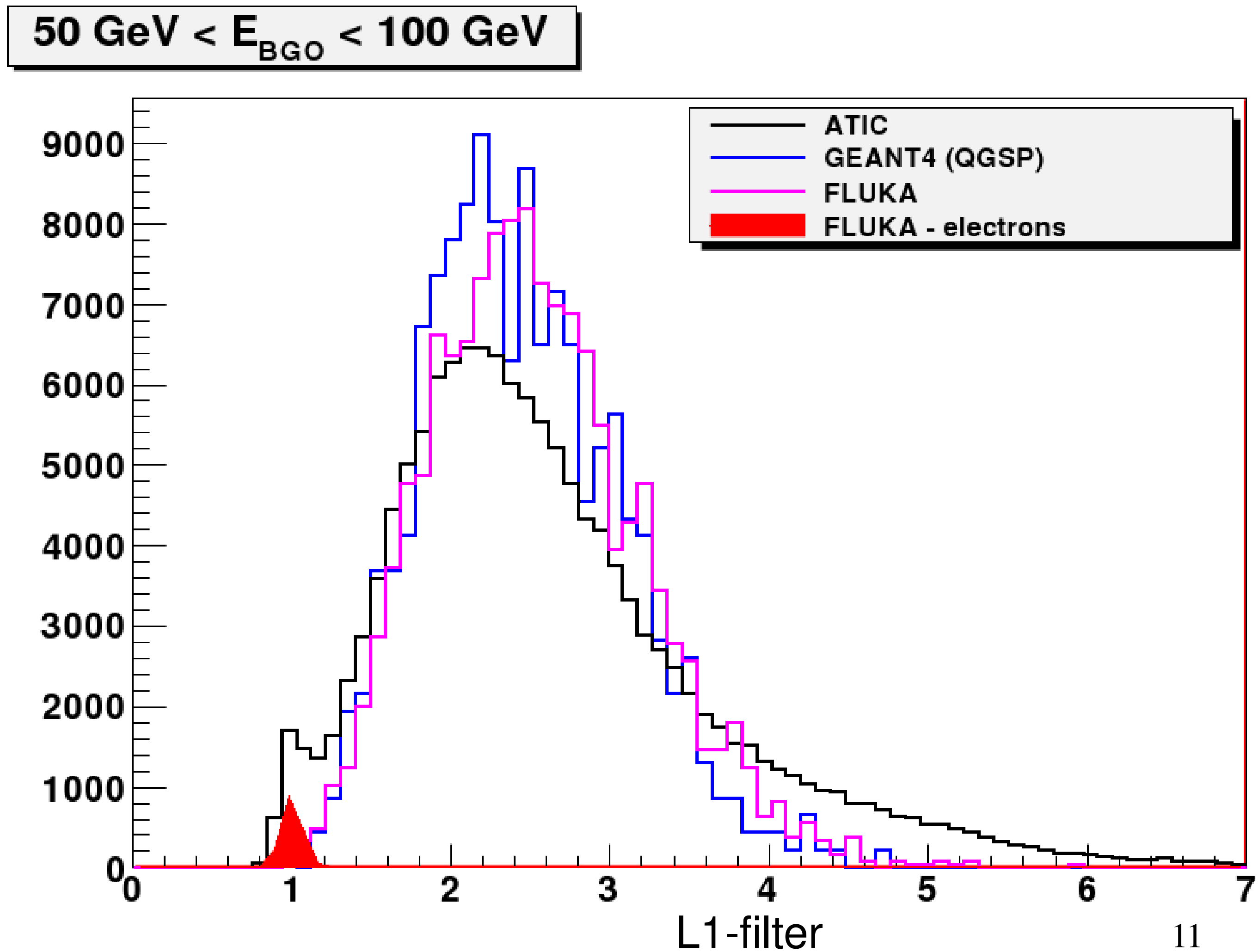
Simulated probability distribution for the shower parameters $(C_0, \ldots, C_7, R_0, \ldots, R_7)$ for incident electrons (FLUKA,. GEANT4):

$$LogP = log_{10}[P(E_{BGO}, C_0, R_0, \ldots, C_7, R_7)]$$

Systematics in proton background calculation

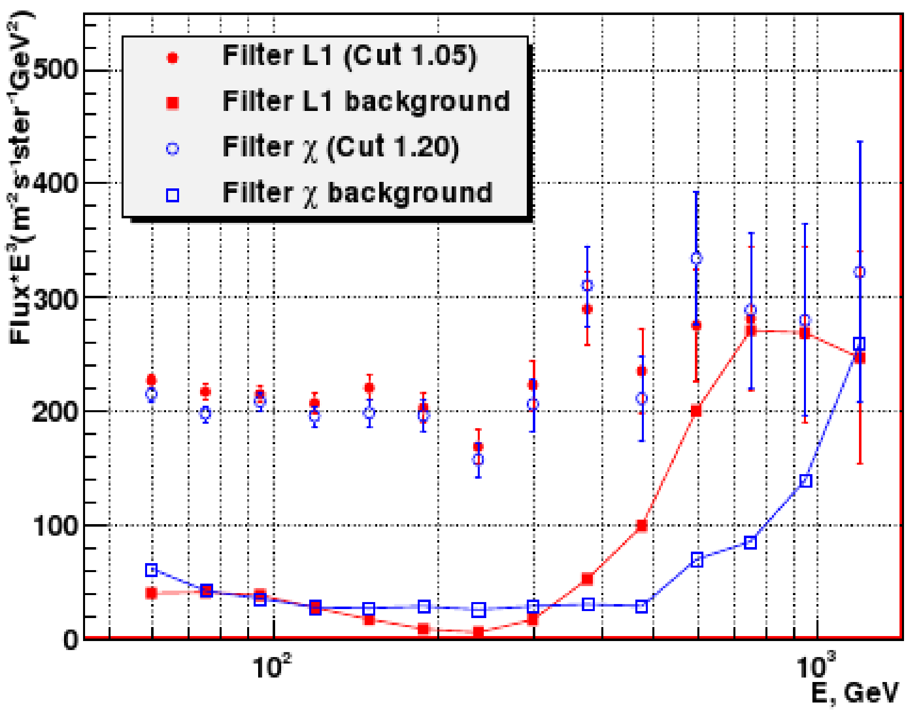
Proton background calculation using simulation is similar to ill-defined problem and may produce large systematic errors.



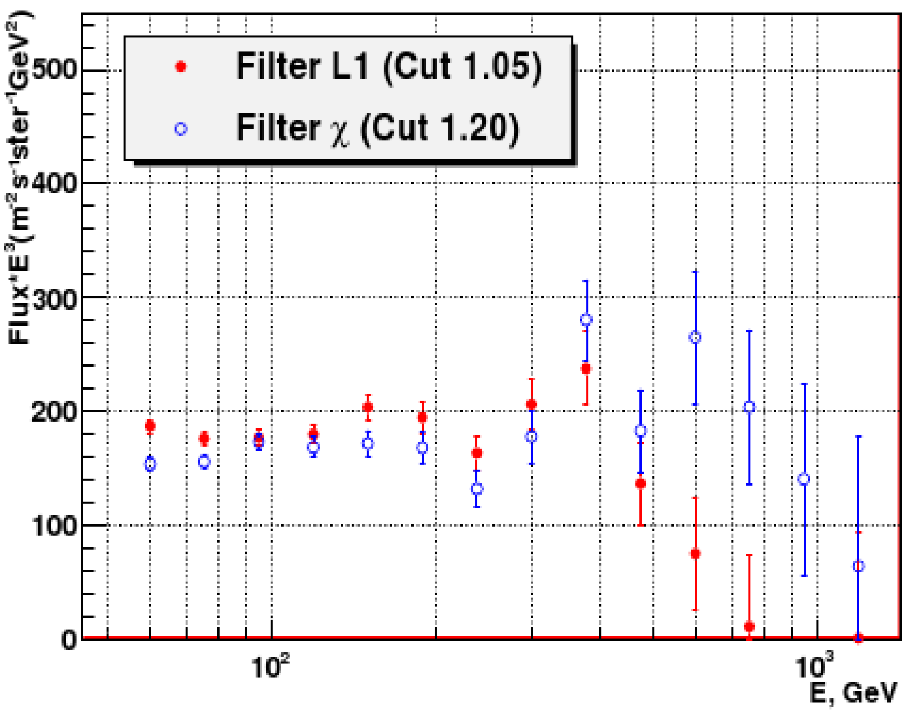


One must have very exact simulation of behaviour of filters for proton events - but it is not the case.

Inadequate background calculations with FLUKA for different filters



Different backgrounds



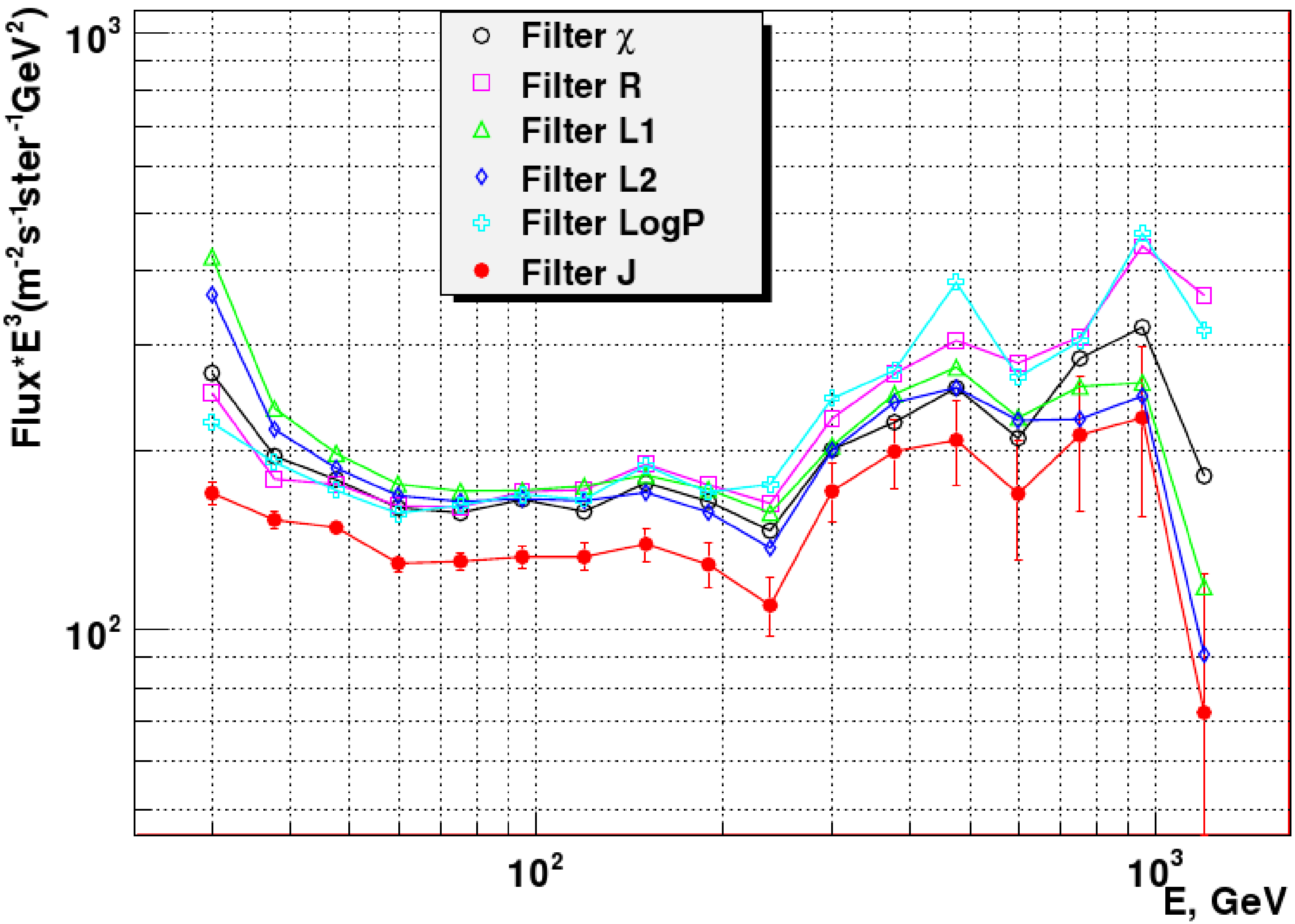
Different results after background subtraction

We do not try to subtract proton backgrounds from the spectrum of selected 'electron-like' events.

We could not provide exact values of absolute intensity and slope, but we still could study structrures in the electron spectrum.

“Product” filter *J*

$$J = \chi \times R \times L1 \times L2 \times LogP$$



Systematics in the accounting for the scattering of the electrons in the atmosphere

Residual atmosphere: 4.5 $\mathrm{g/cm^2}$, $1/7\ X_0$.

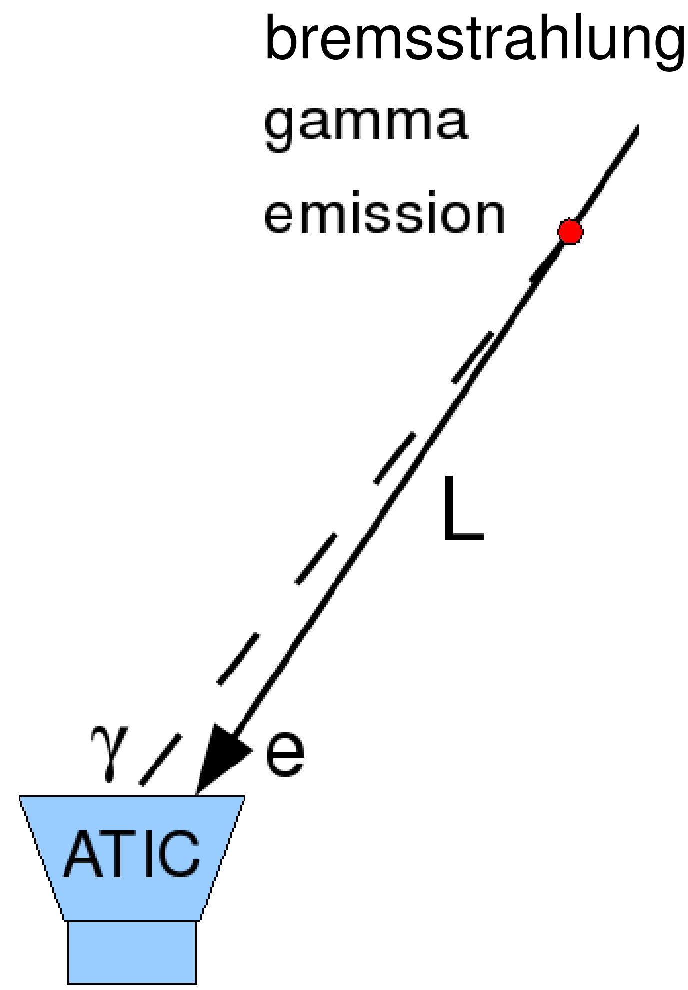
$L \sim 8$ km

For energies from 50 GeV to 1 TeV:

$$\phi \sim \frac{m_e c^2}{E_{prim}} = 1 \times 10^{-5} \div 0.5 \times 10^{-6}$$

$\Delta x \sim 10 \div 0.5$ cm

Apperture of the calorimeter $50 \times 50\ \mathrm{cm}^2$



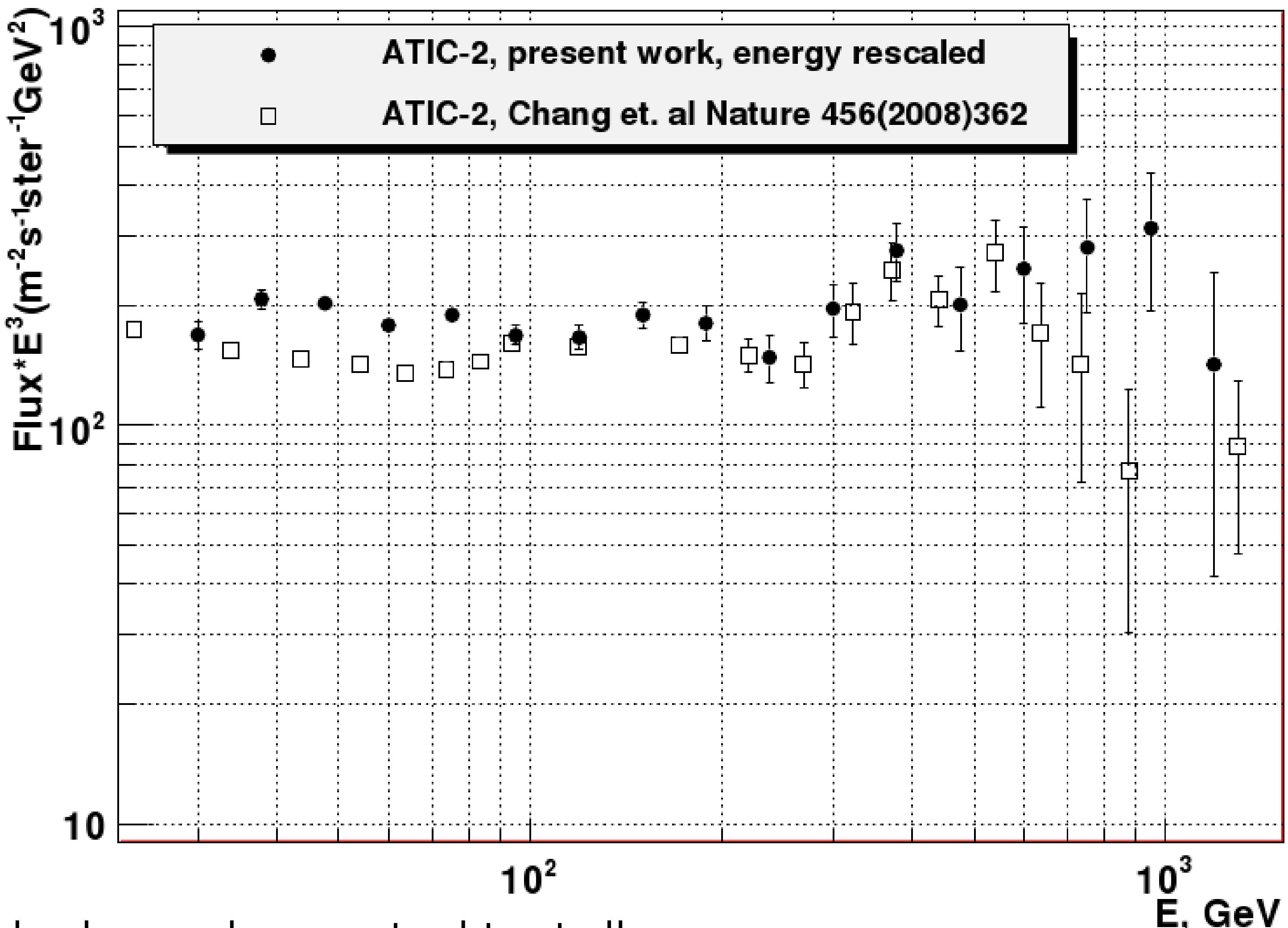
Small loss of energy (should be studied)

Inefficency may exist (should be studied)

Supposition: No loss of energy, no inefficiency.

The supposition is expected to be valid at least at energses > n × 100 GeV

Comparison of the spectrum of this work and the published one in Nature

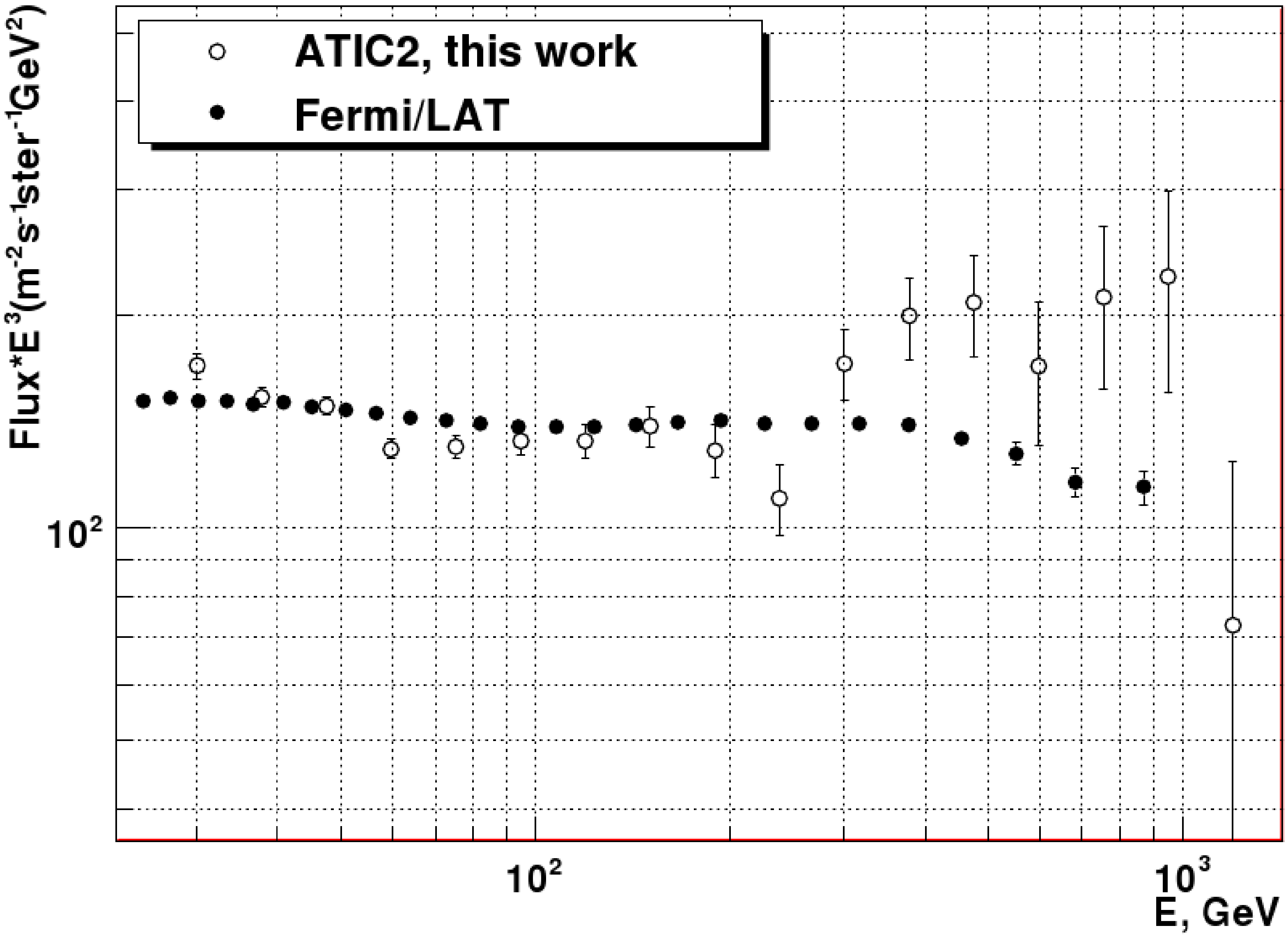


This work – backgrounds are not subtracted!

Chang et. al – backgrounds are subtracted! But the spectra at mean energies are the same.

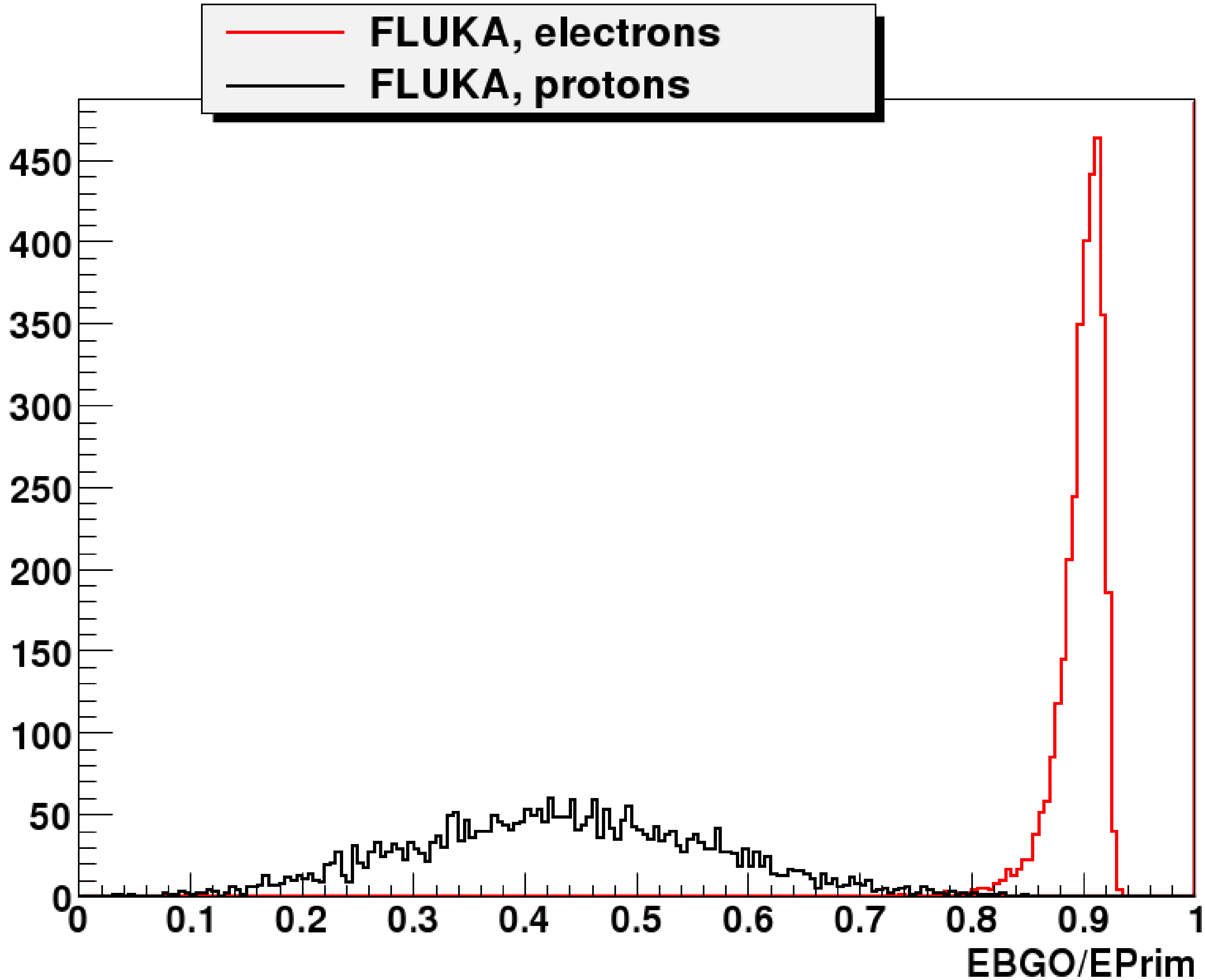
The background is low in present work or it was underestimated in Nature paper.

ATIC-2 (this work) and Fermi/LAT

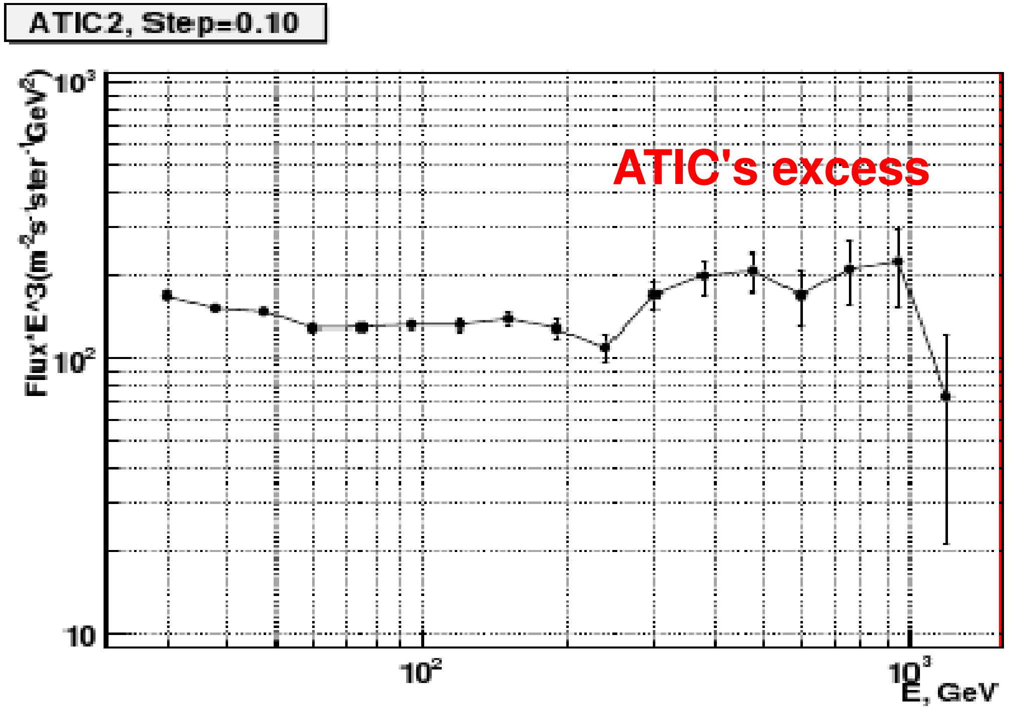


There are no signs of contradiction ATIC-2 and Fermi/LAT

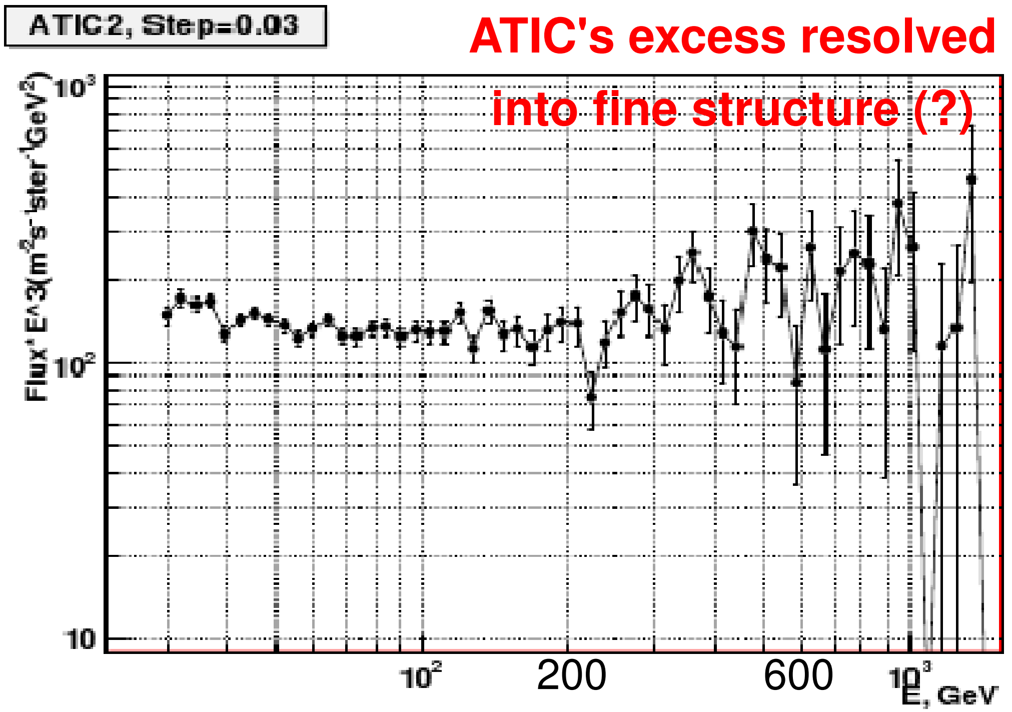
Energy resolution of ATIC for electrons is about 2%



Short scale systematically independent features



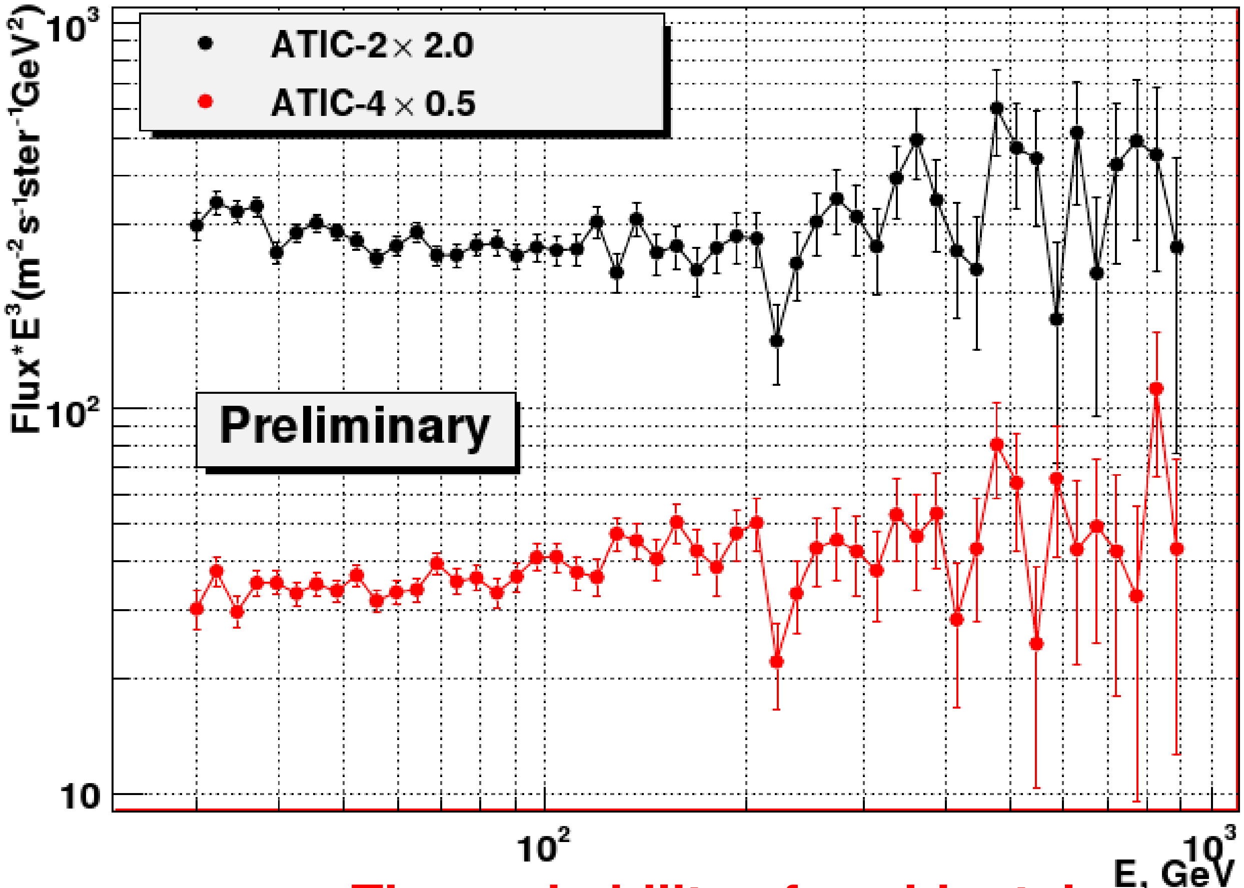
Rough energy step



Fine energy step

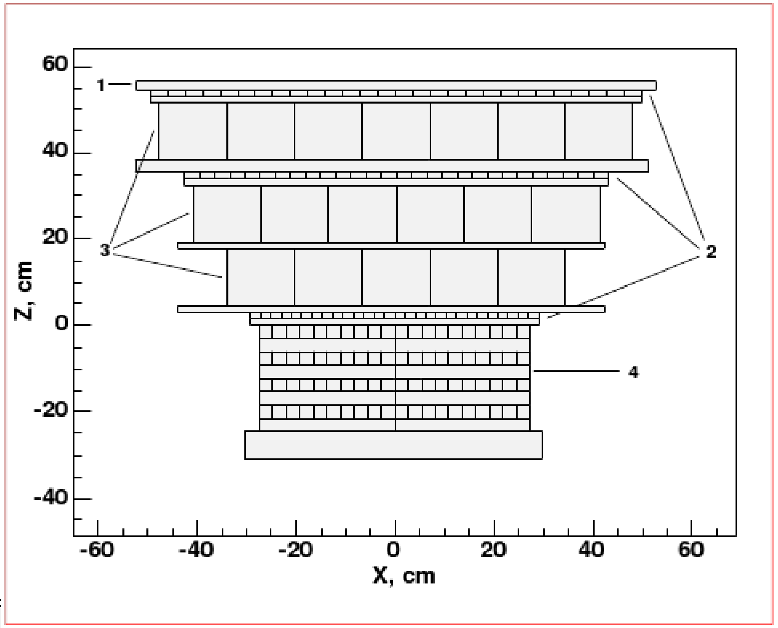
Fine structure in the electron spectrum?

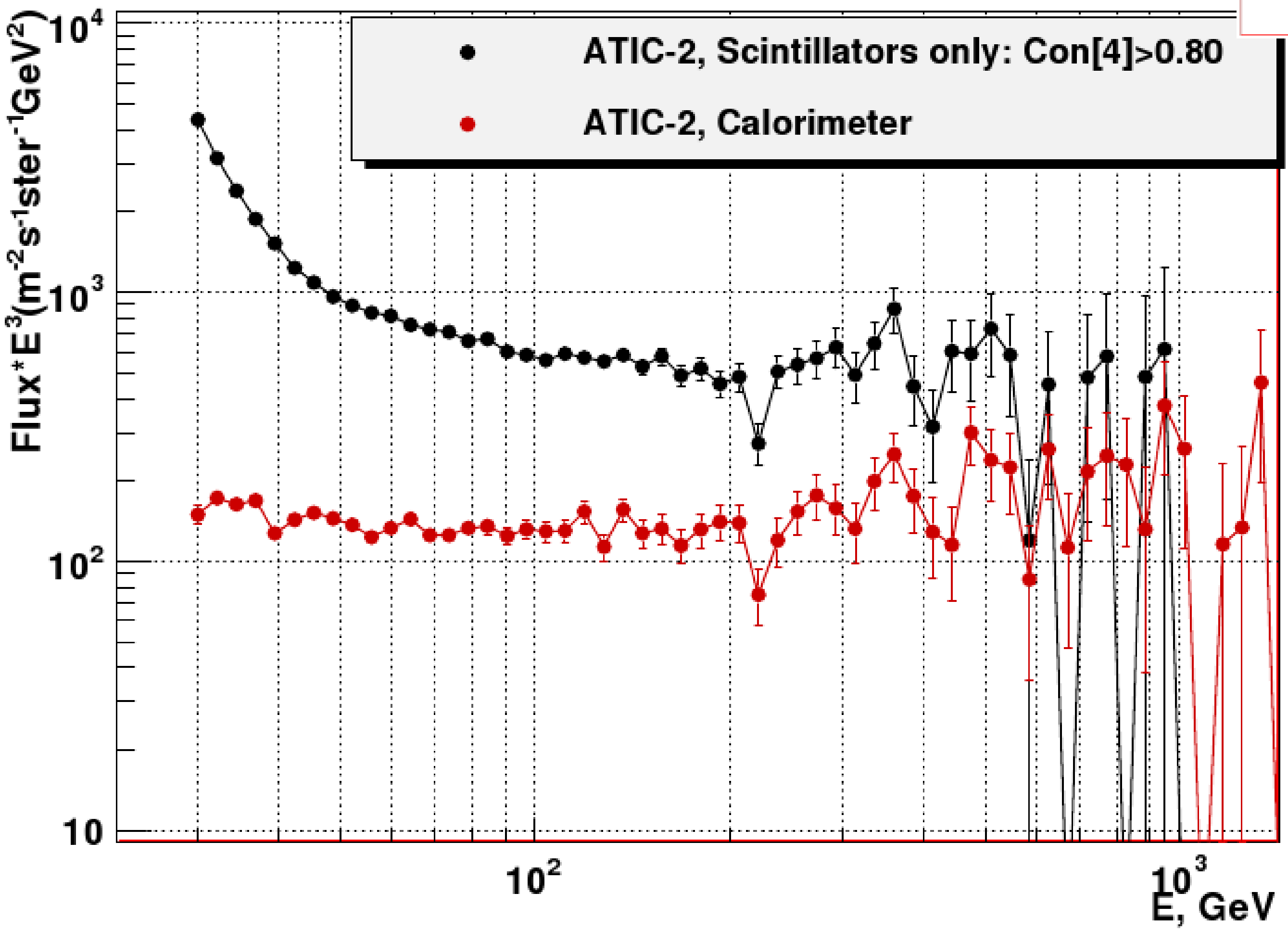
ATIC-2 and ATIC-4, step(in log energy)=0.03



The probability of accidental correlation of ATIC-2 and ATIC-4 fine structures was estimated as P = 0.00064

Selection of electrons with the measured level of current of albedo particles in the hodoscopes (not calorimeter).



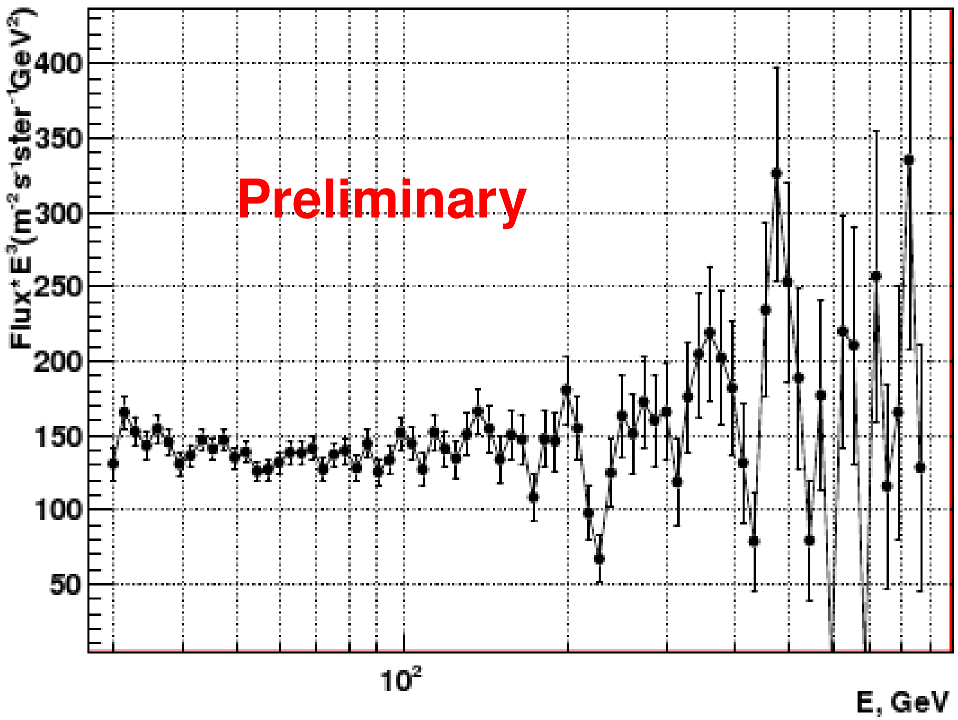


The fine structure does not depend on the level of background!

It is systematic independent effect.

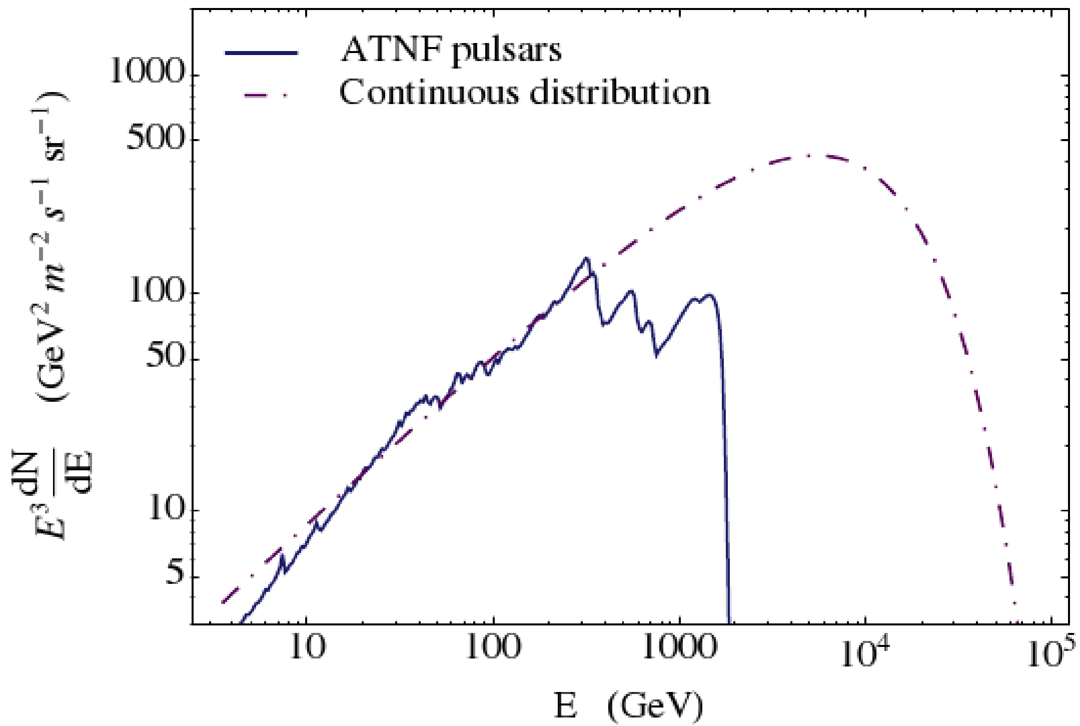
ATIC-2 + ATIC-4,

step(in log energy)=0.02

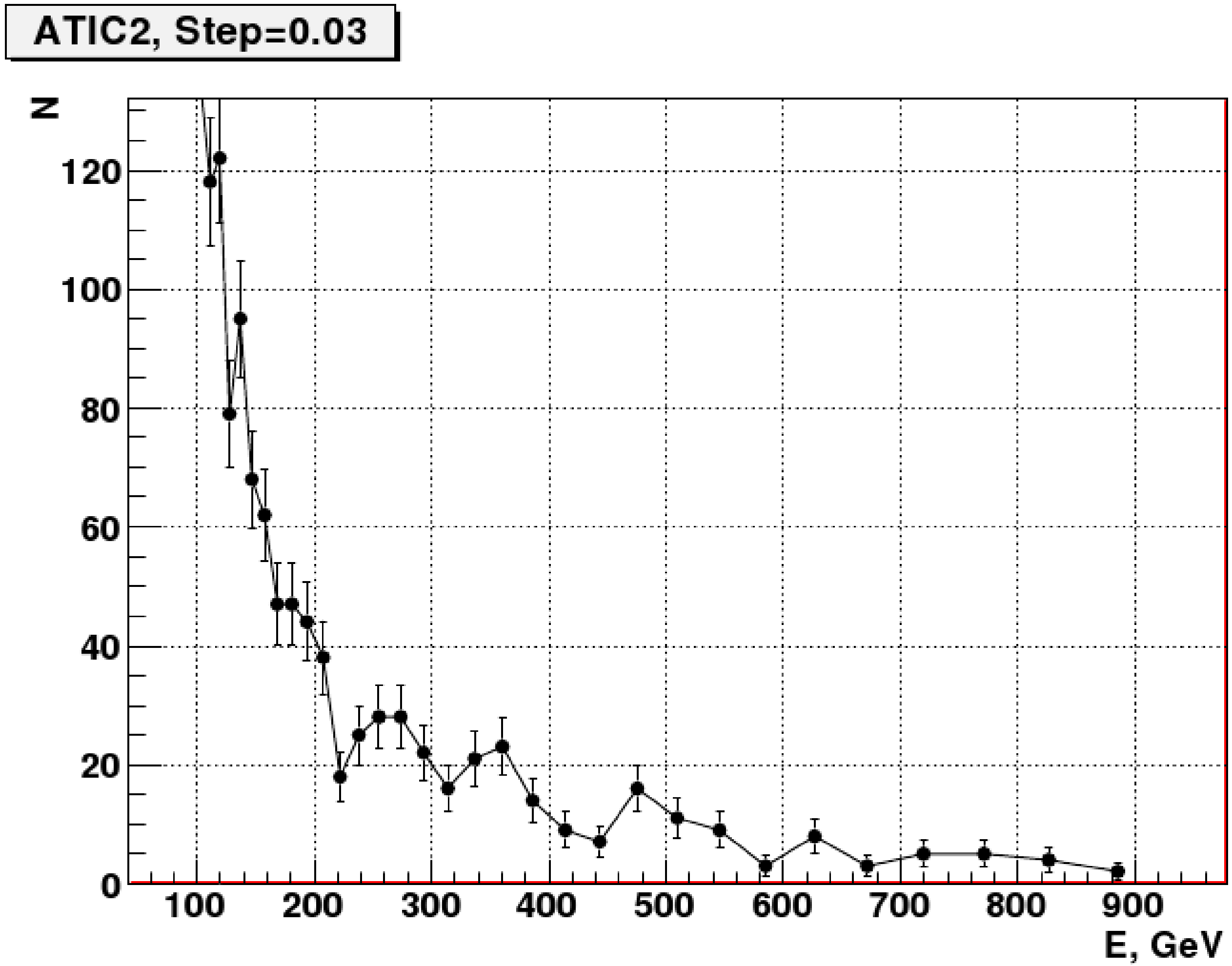


If the fine structure is real, what it may be?

D. Malyshev et al. arXiv:0903.1310



ATIC-2 electron spectrum for (number of events)/bin



Electron + positron spectrum from pulsars of ATNF catalog

Dmitry Malyshev,

Ilias Cholis,

Joseph Gelfand

arXiv:0903.1310

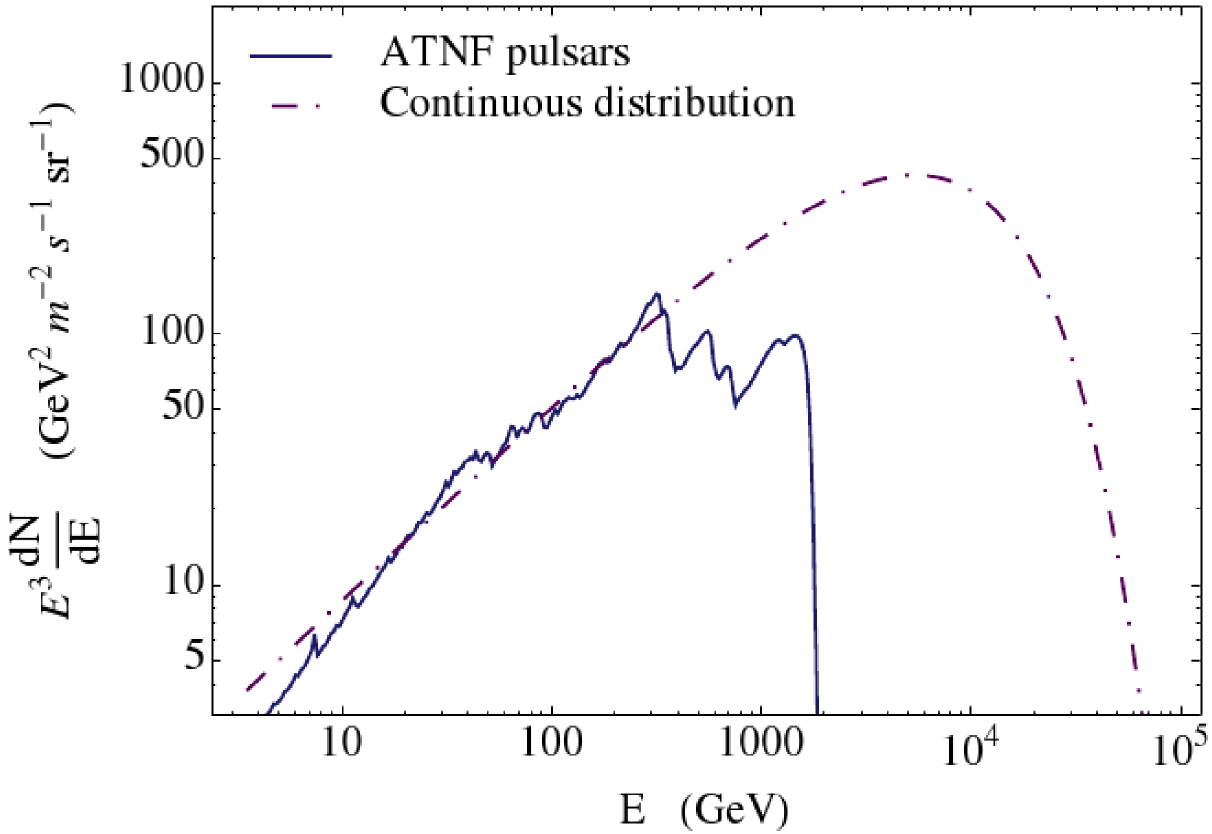


FIG. 3: Continuous distribution versus the ATNF catalog pulsars [28] (see text for the discussion of assumptions and parameters). Several hundred pulsars contribute below 300 GeV and the continuous distribution provides a good approximation for these energies. Above 300 GeV, there is only of order 10 contributing pulsars. The fluctuations in the flux become significant above 300 GeV. The reason for the discrepancy above 2 TeV is discussed in Section III B