Possible structure of the cosmic ray electron spectrum measured by the ATIC-2 and ATIC-4 experiments

A.D. Panov, E.B. Postnikov, N.V. Sokolskaya,

V.I. Zatsepin - for the ATIC collaboration.

The ATIC spectrometer

At the start position

In the flight

ATIC's flights

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

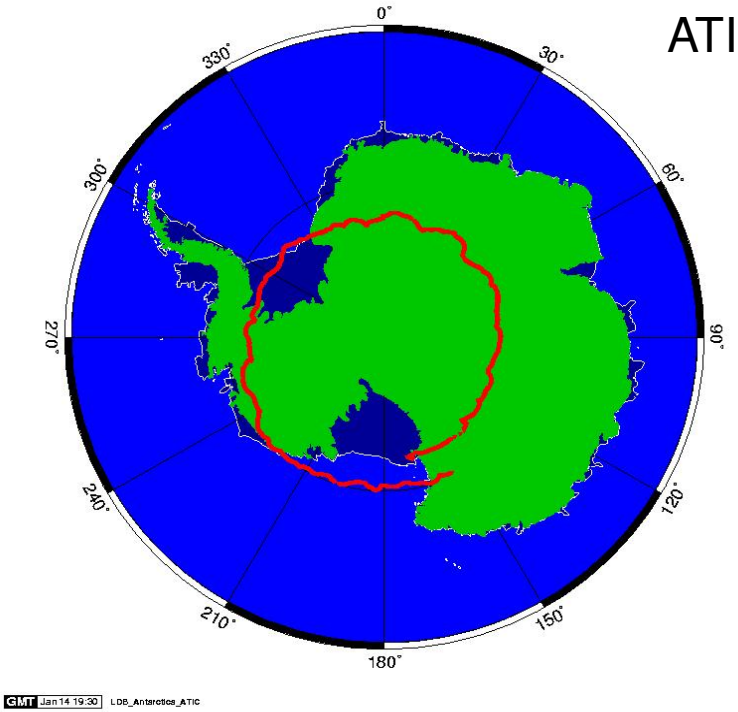
ATIC-3 2005

Failed to rich altitude

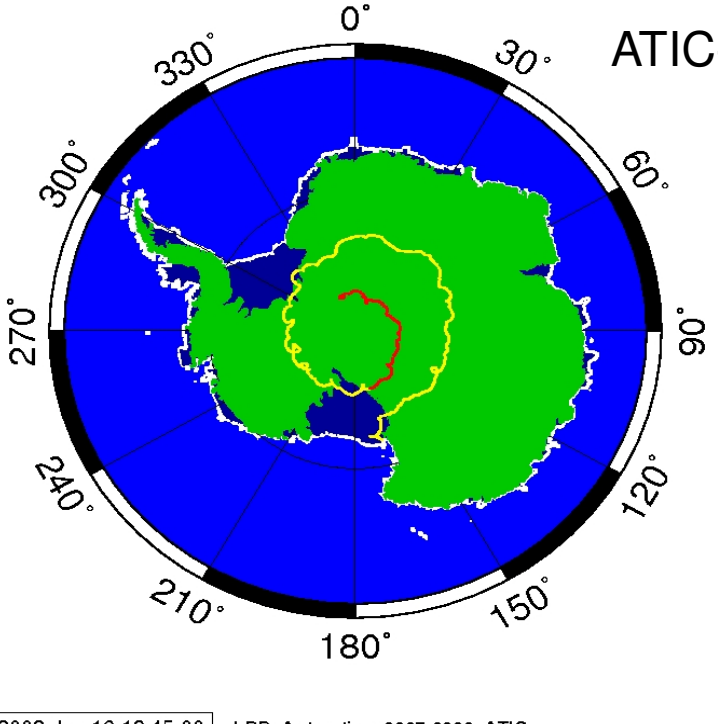
ATIC-4 26.12.2007–15.01.2008

Second science flight, 2.2 m^2 sr days

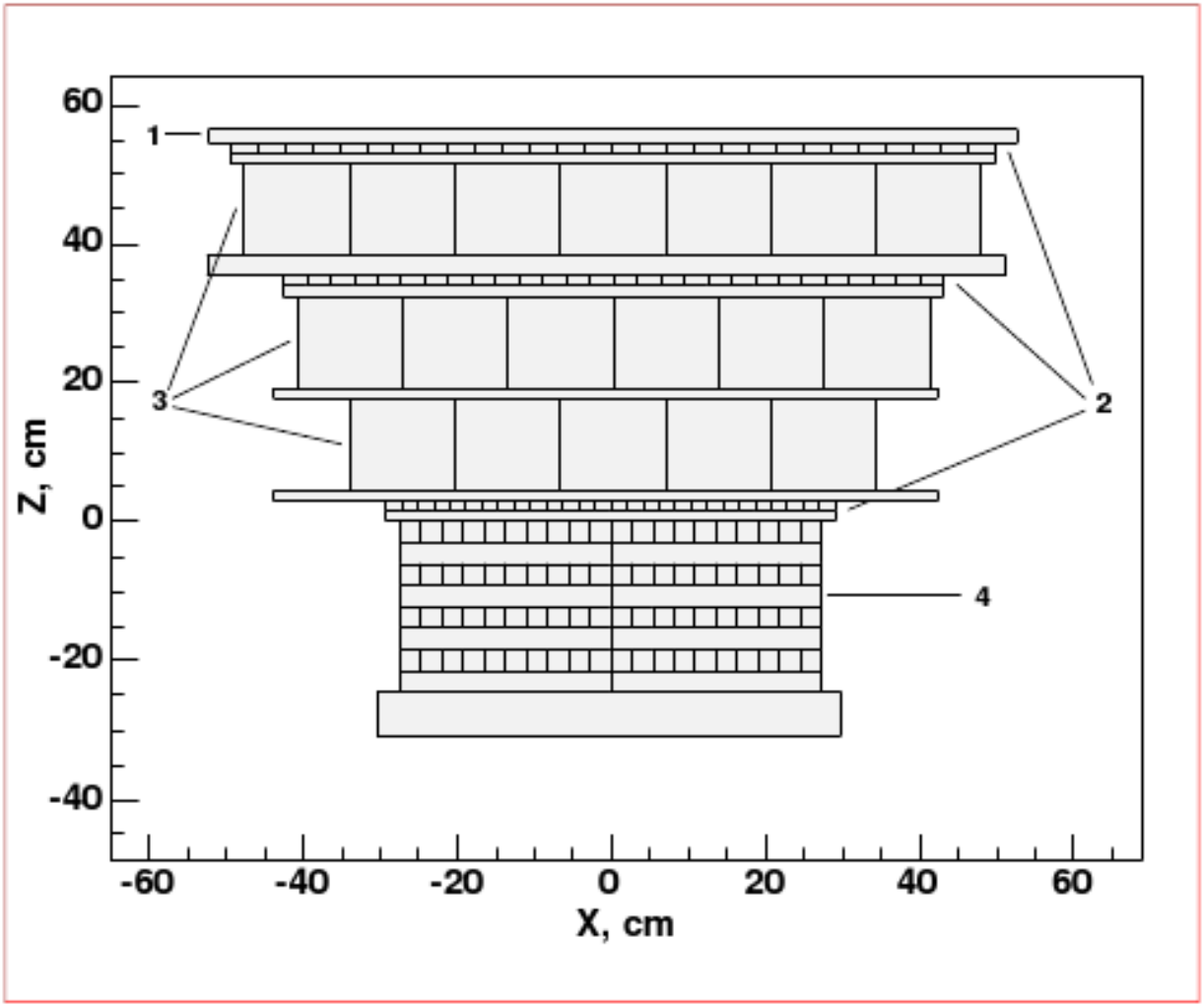
ATIC-2



ATIC-4



ATIC (Advanced Thin Ionization Calorimeter)



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

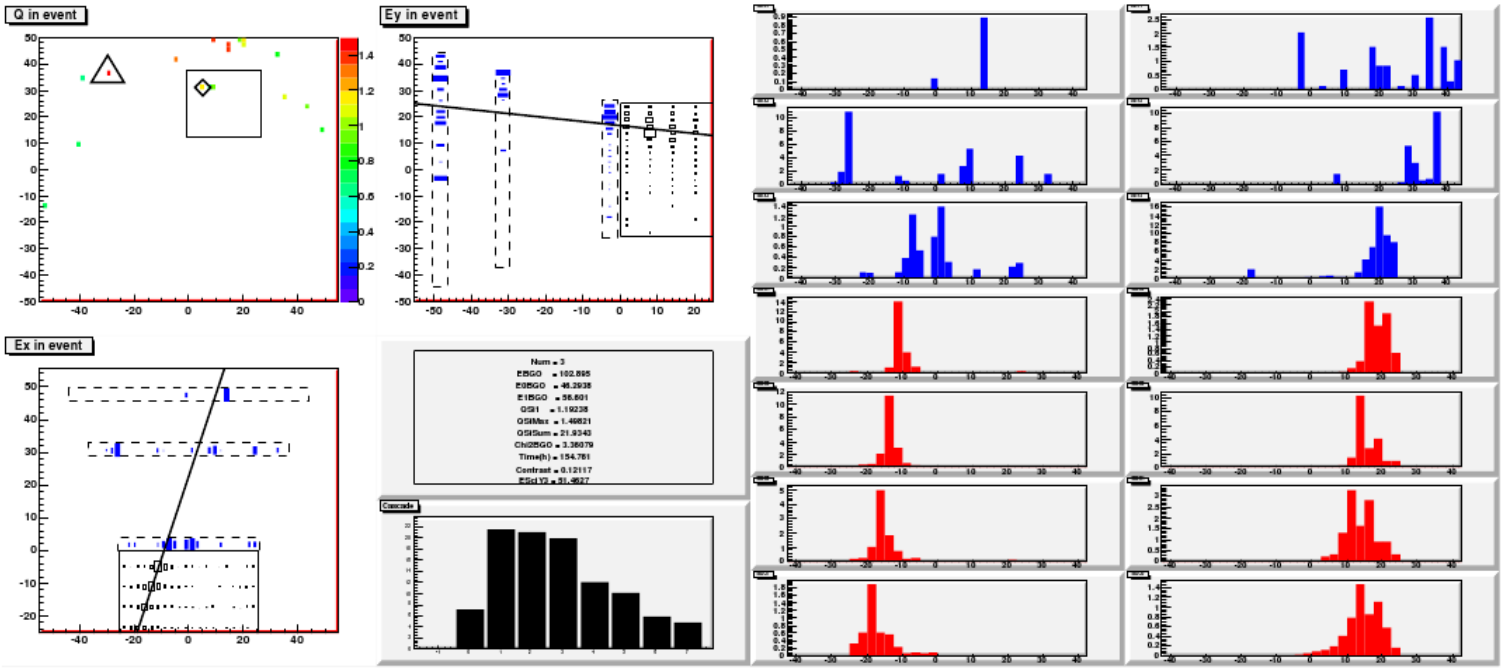
BGO crystal:

$2.5 \times 2.5 \times 25$ cm

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

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

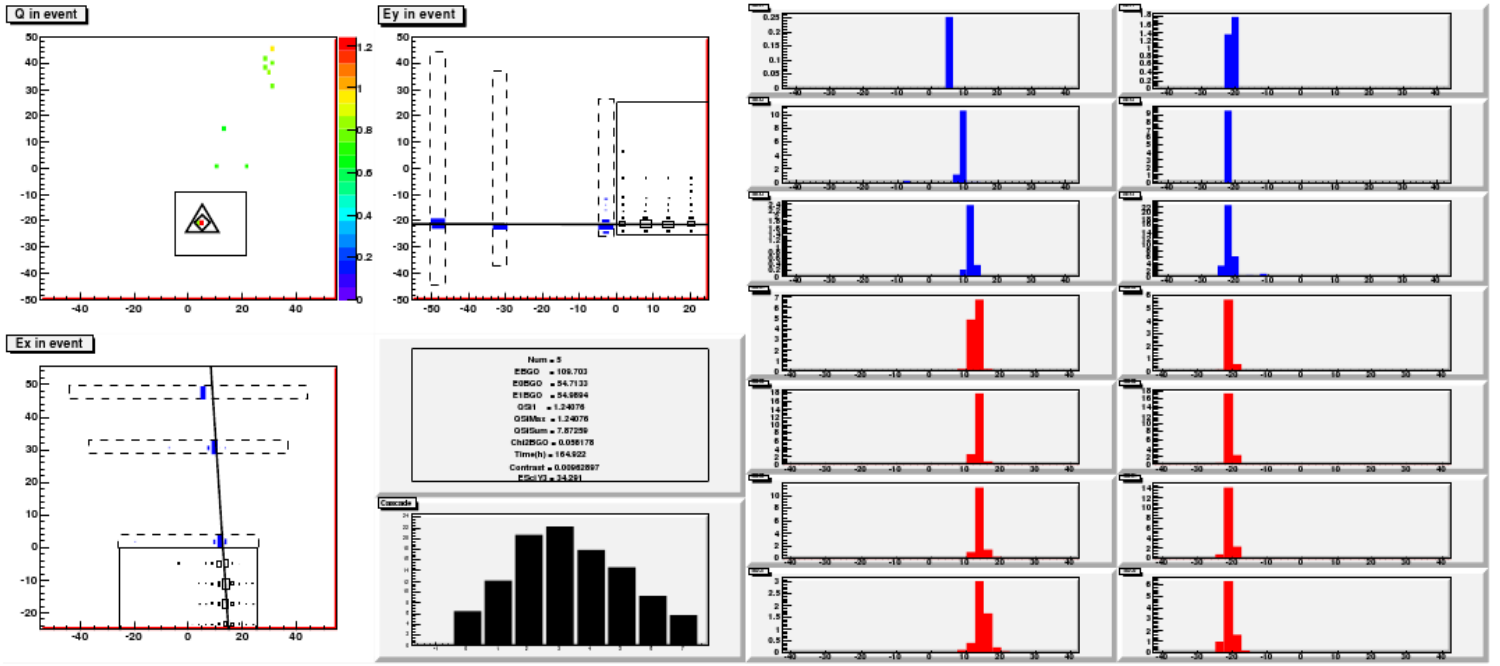
Proton event



Hodoscopes energy deposits

Calorimeter energy deposits

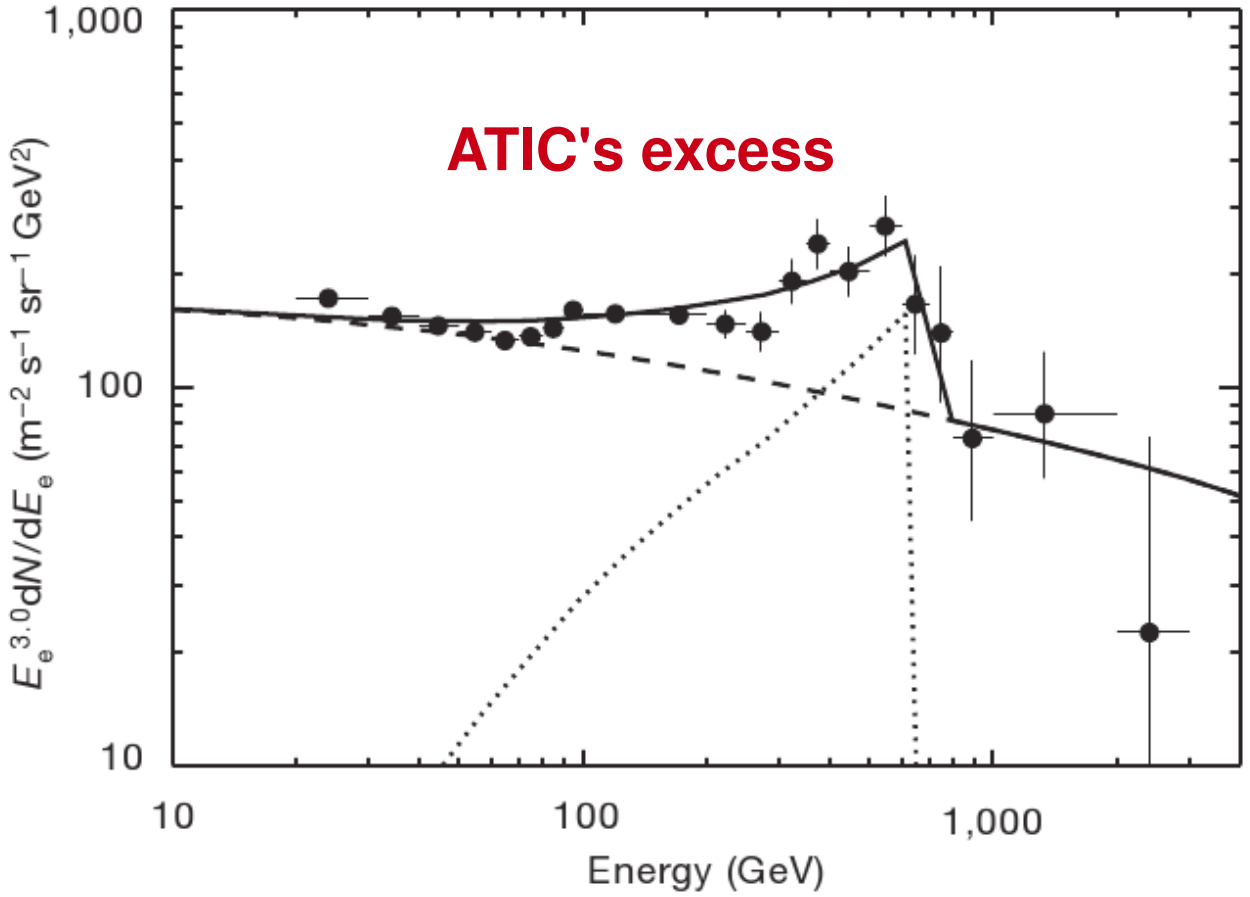
Electron or positron event



Hodoscopes energy deposits

Calorimeter energy deposits

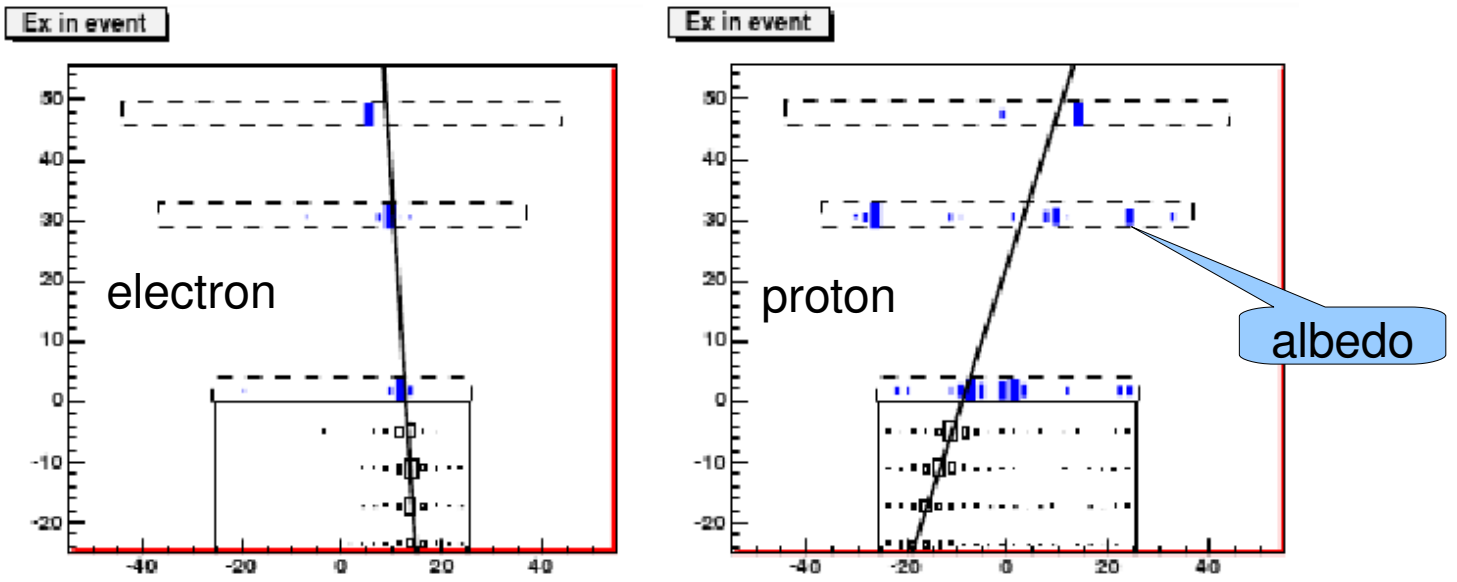
J. Chang et al. An excess of cosmic ray electrons at energies of 300–800 GeV. Nature, 456(2008)362



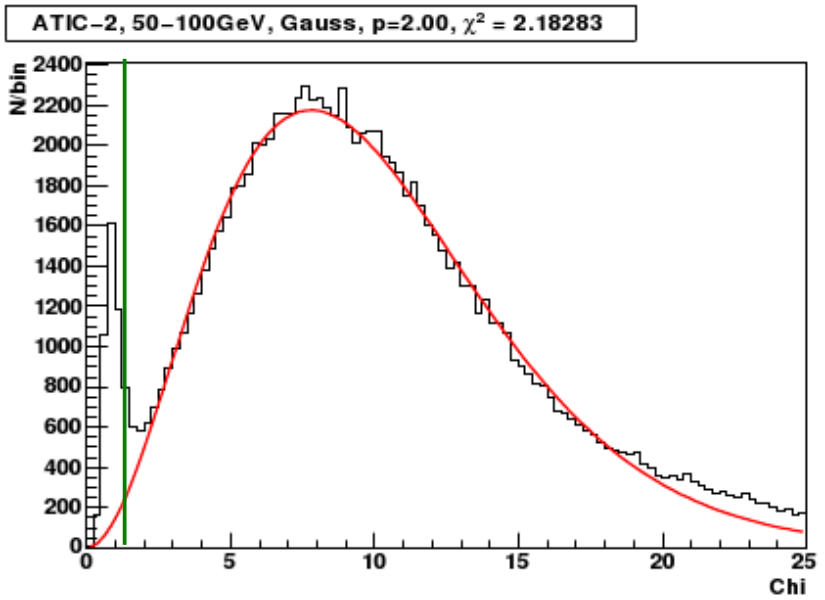
Dark matter,
Kaluza-Klein particles
M = 620 GeV,
dencity = 0.43 GeV cm^{-3},
cross section rate 1 x 10^{-23} cm^3 s^{-1}
(boost factor ~200)

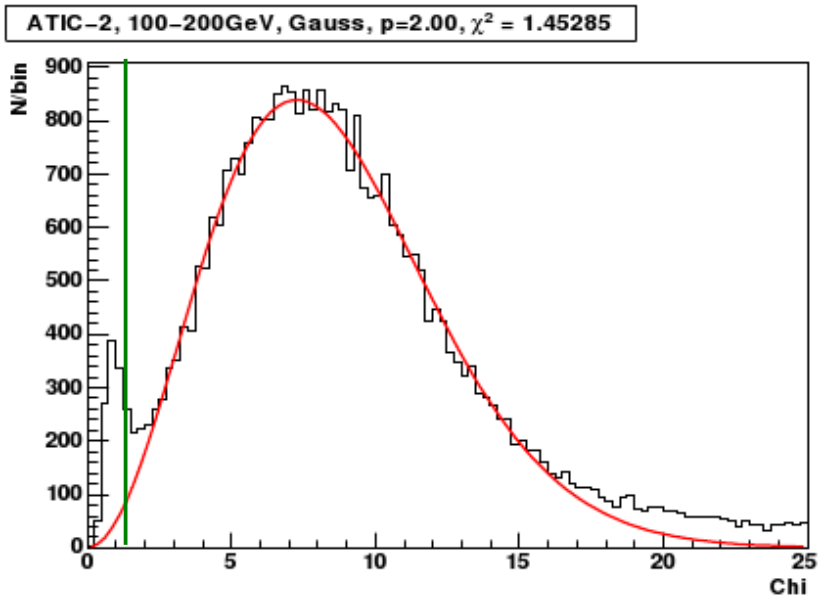
Five different filters for cross checking of the results

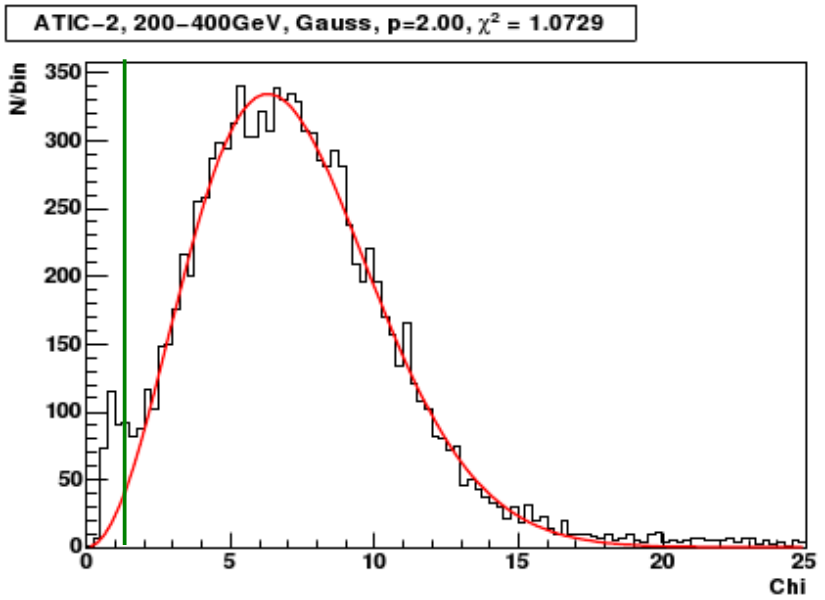
1. **Chi** — Euclidein distance to the center of simulated probability distribution for electrons, RMS of the shower from axis in layers of the **calorimeter**
2. **LogP** — Amplitude of the electron probability distribution, same parameters
3. **CCF** — Euclidein distance to the center of simulated probability distribution, concentrations of energy deposit in layers
4. **DA** — Discriminant analysis methods, Mahalanobis distance
5. **ConSci** — Concentrations of energy deposit in **hodoscopes** (albedo current)

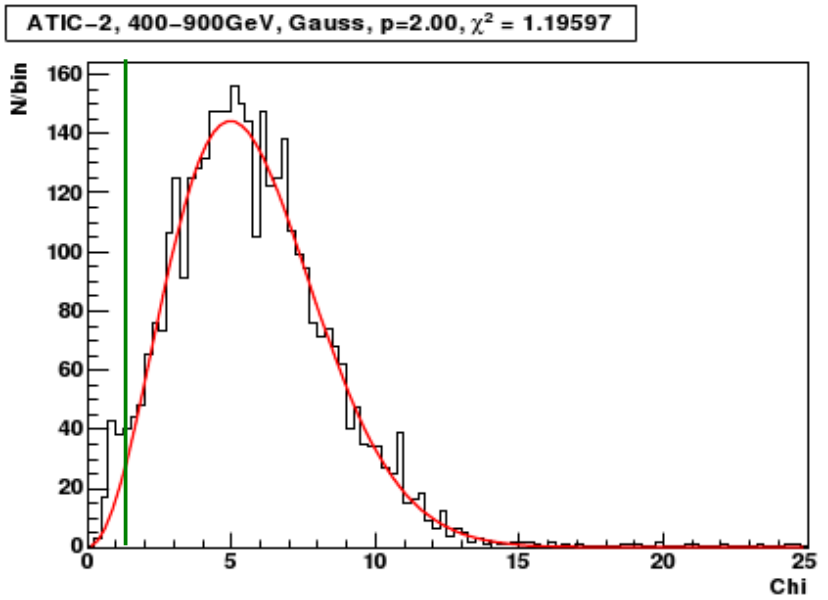


Distributions for the filter Chi — various energies

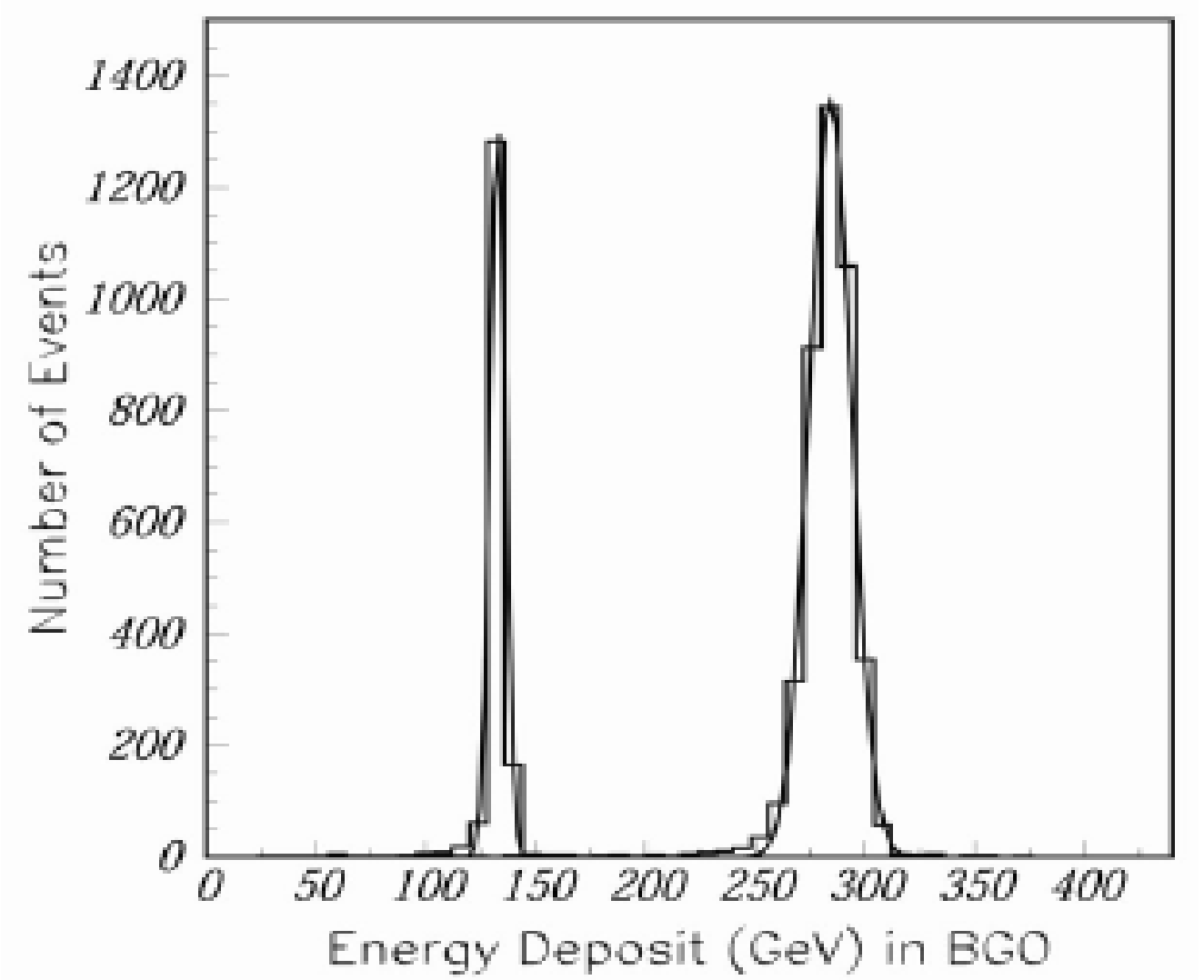








Energy resolution of ATIC — beam test in CERN and simulation



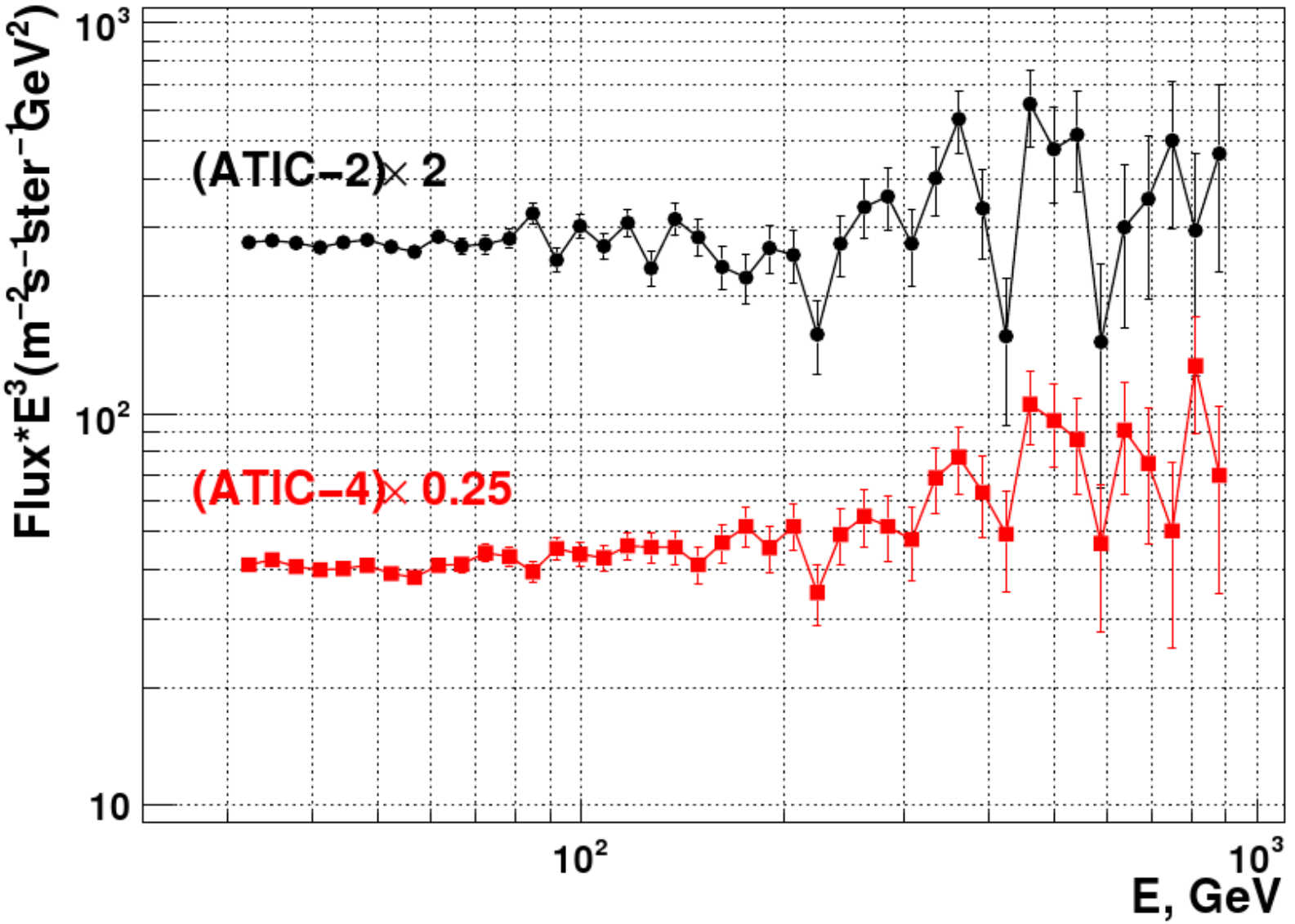
Beam test: Resolution ~3% (half width at half height)

Simulation: dependence of energy is weak

Structrures on scale 0.1-0.2 decade of energy may be studied!

Possible structure in the electron spectrum — ATIC-2 and ATIC-4.

«Fine structure»

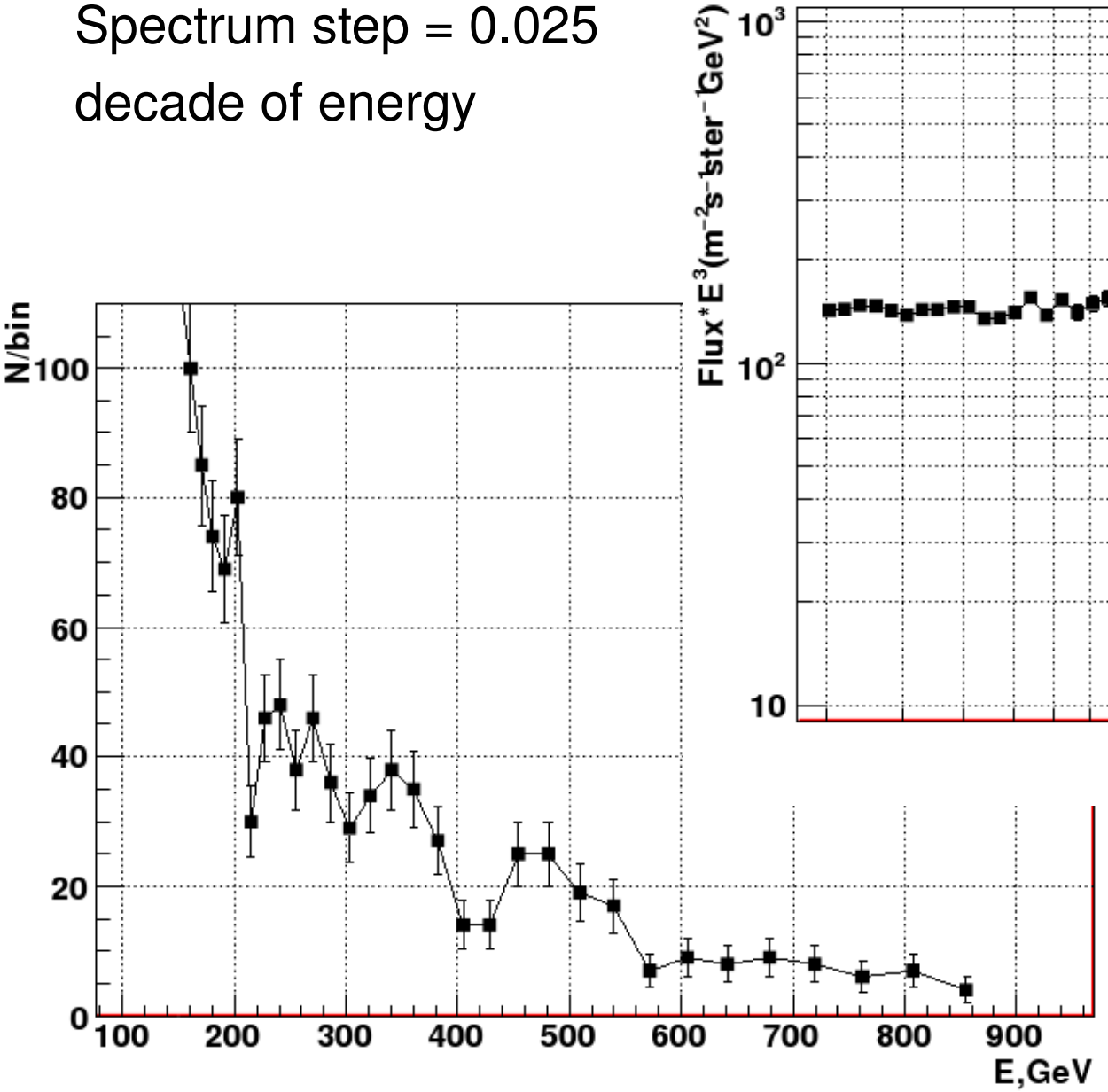


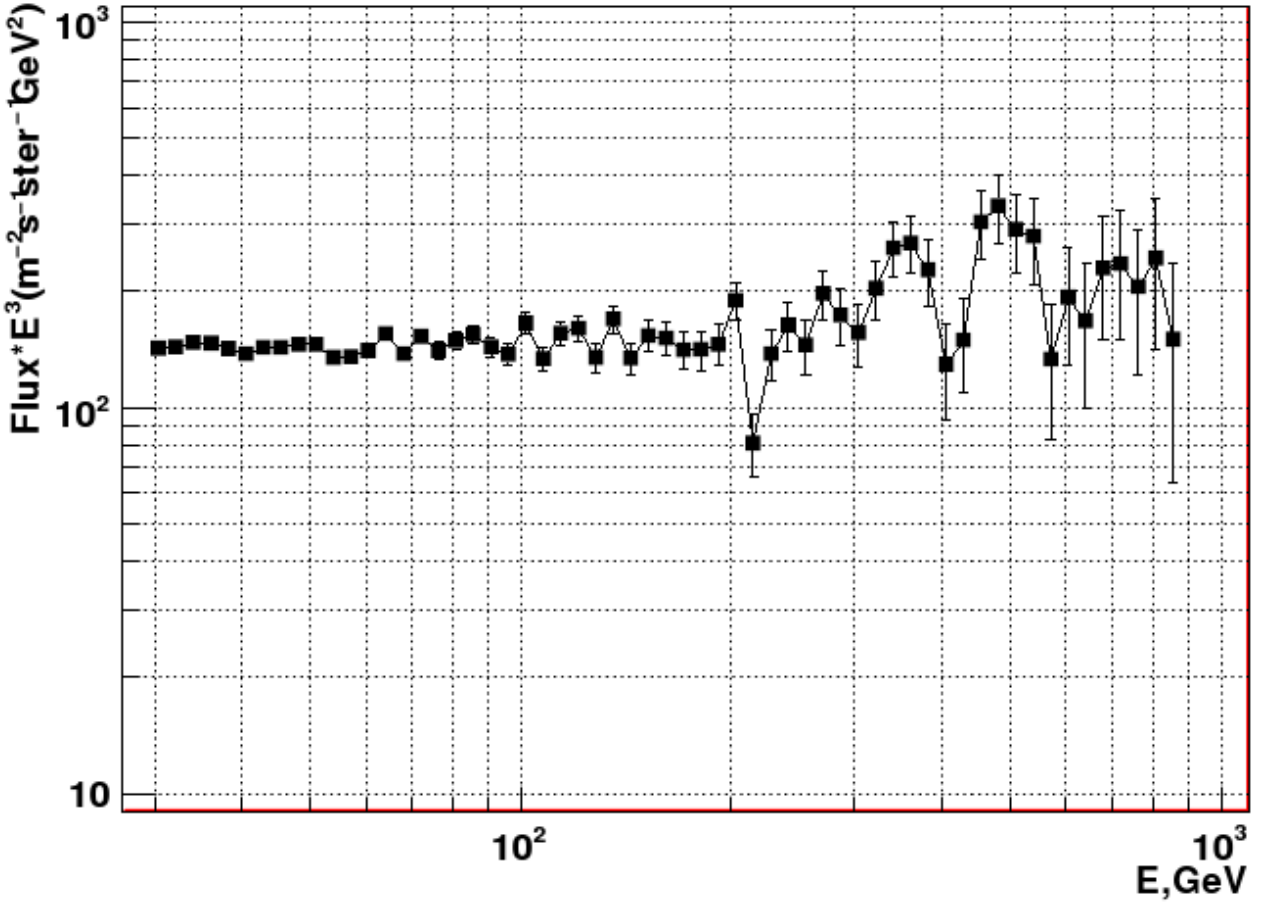
Spectrum step = 0.035 decade of energy

No background subtraction and atmospheric correction

Fine structure of the electron spectrum — ATIC-2 + ATIC-4

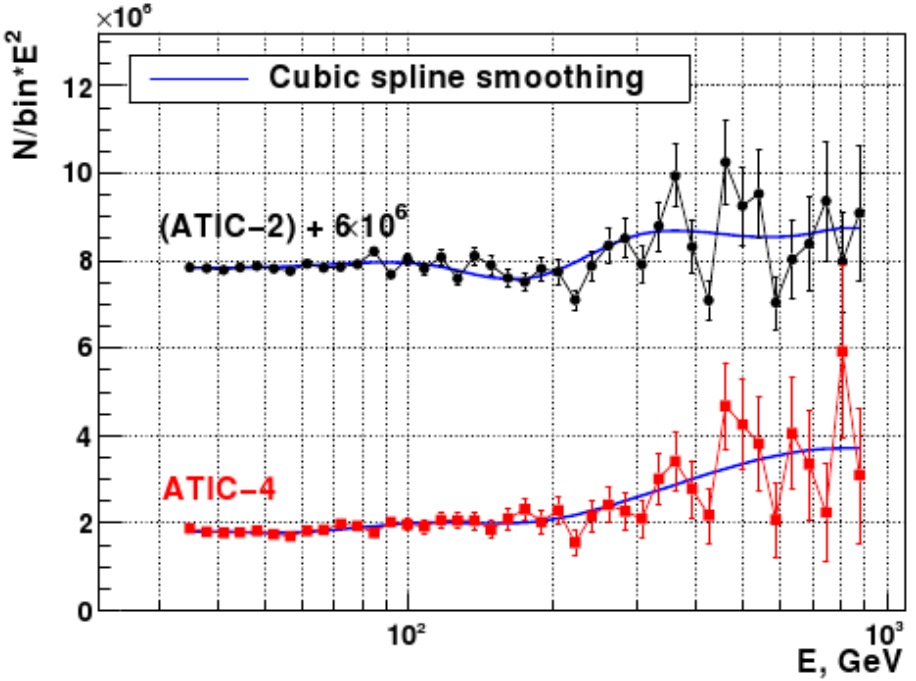
Spectrum step = 0.025 decade of energy

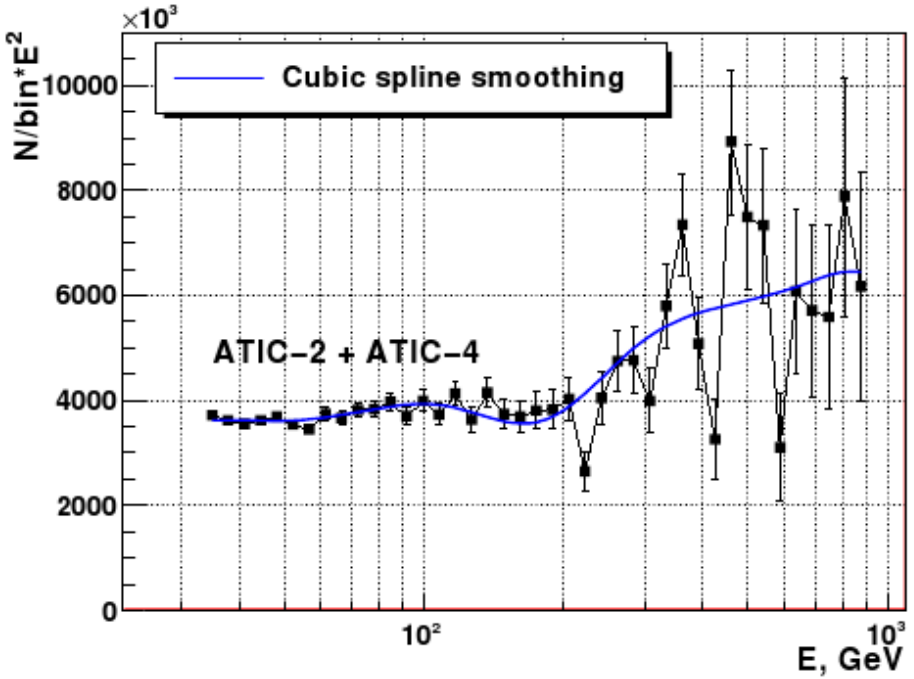




The statistics per one bin is not small !

Statistical significance





Statistical significance of correlation of the structures of ATIC-2 and ATIC-4:

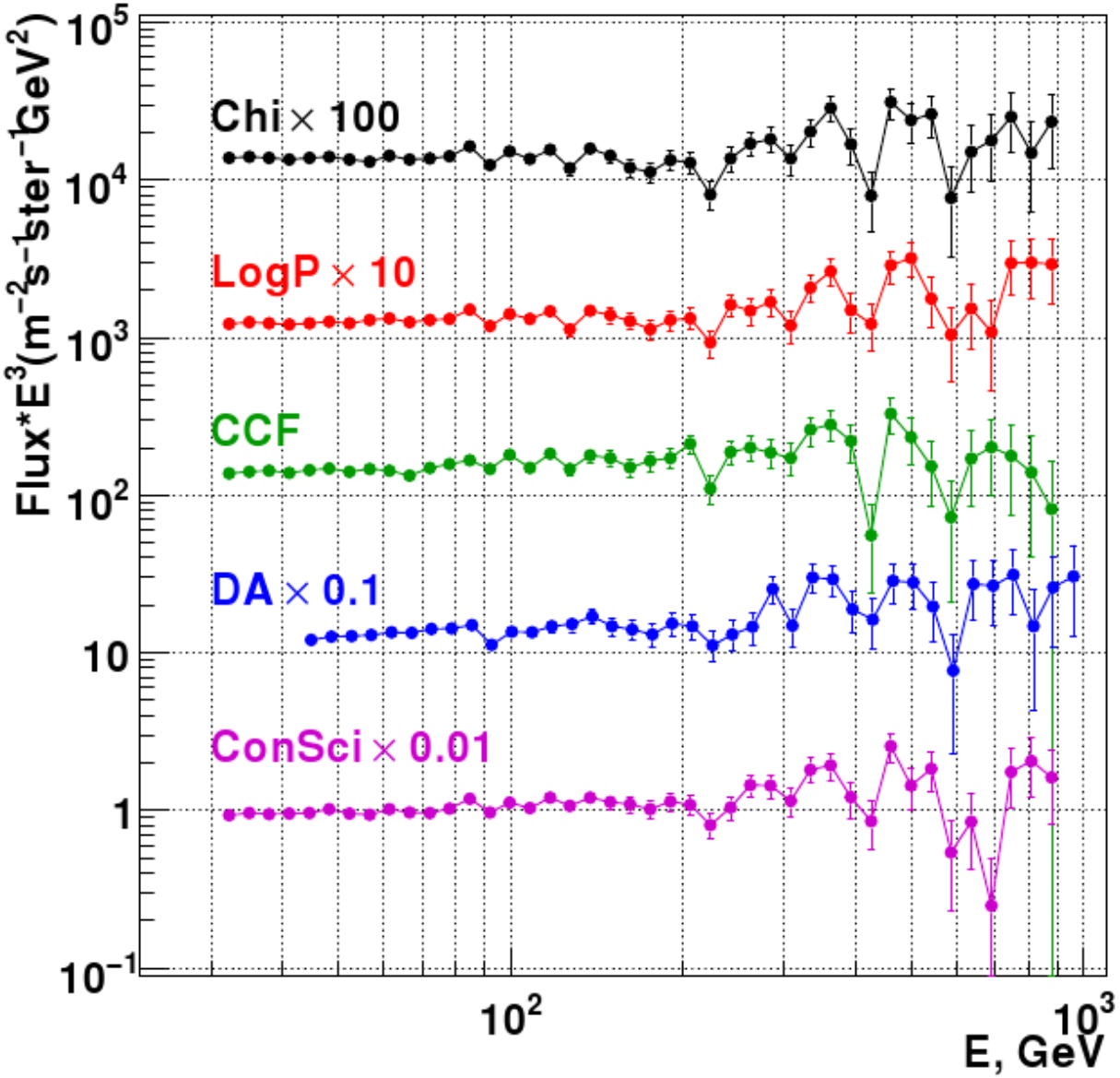
$$(99.69^{+0.10}_{-0.07})\%$$

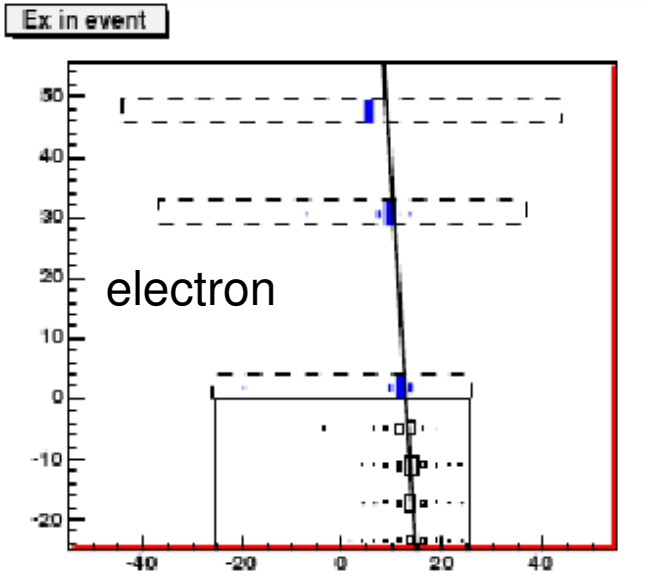
$\approx 99.7\%$

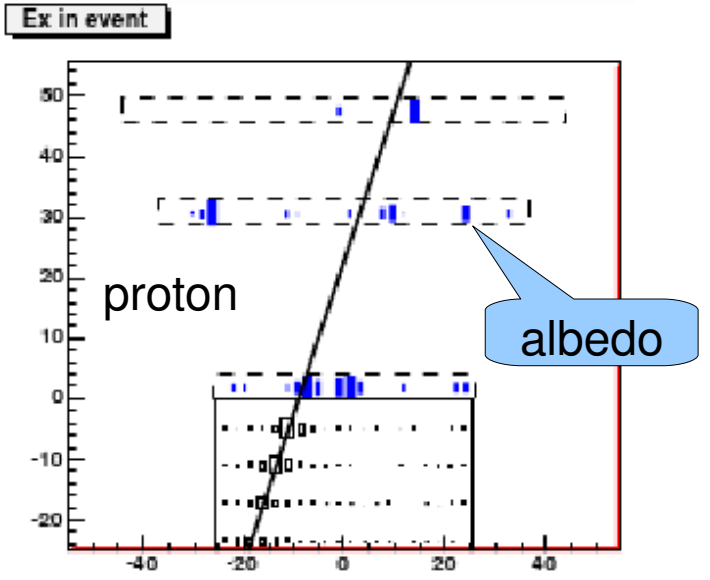
χ^2-statistical significance of the structure in ATIC-2 + ATIC-4:

$$(99.68^{+0.07}_{-0.05})\%$$

Excluding systematics. 1. The same structure with different filters

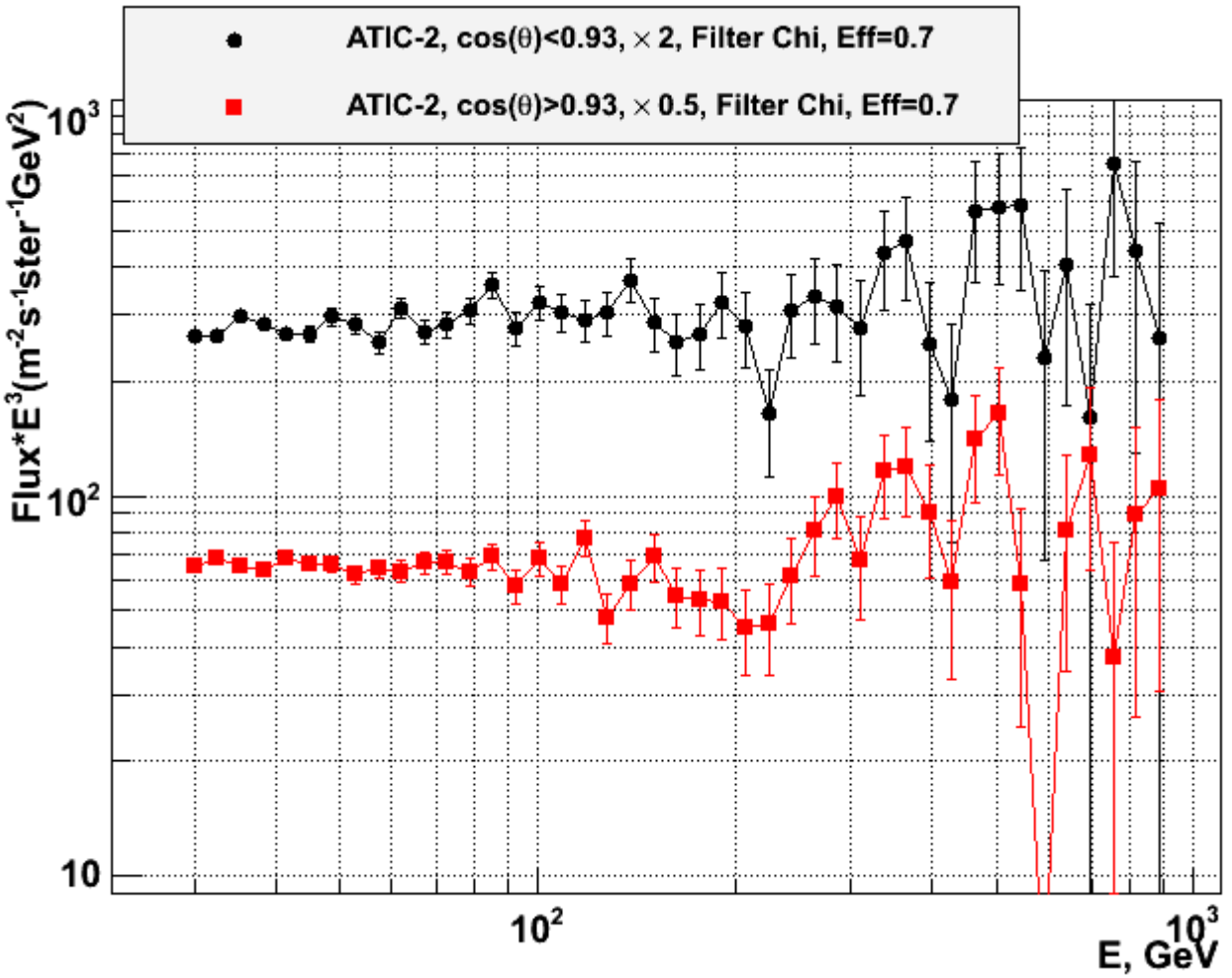




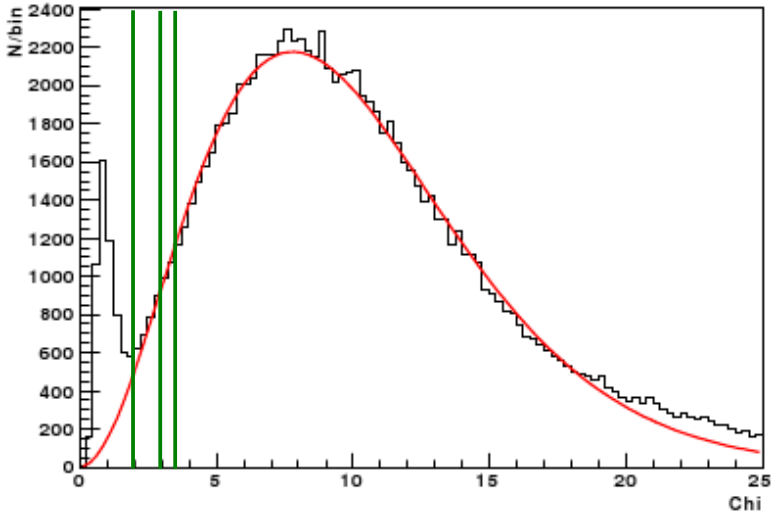


Excluding systematics.

2. The same structure for different zenith angles



Excluding systematics. 3. No structures in proton background



2.0<Chi<3.0:

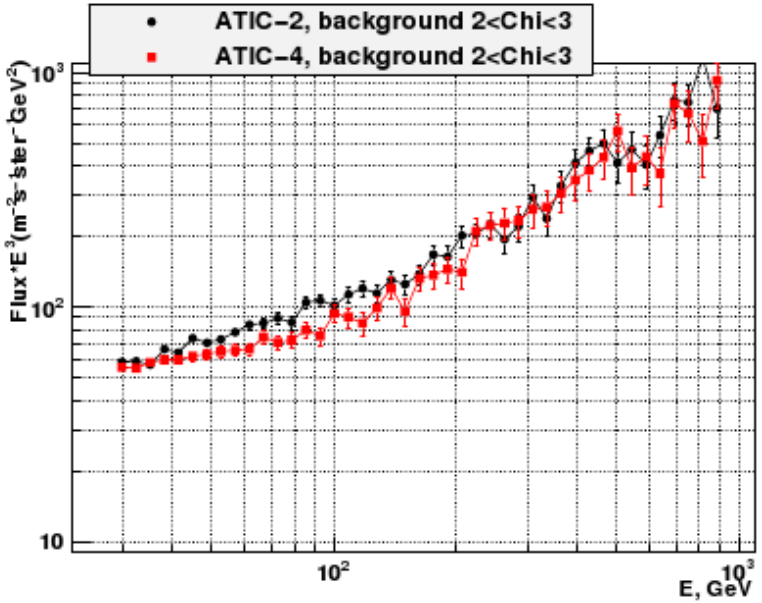
MeanCorrelation = 0.089 ± 0.099

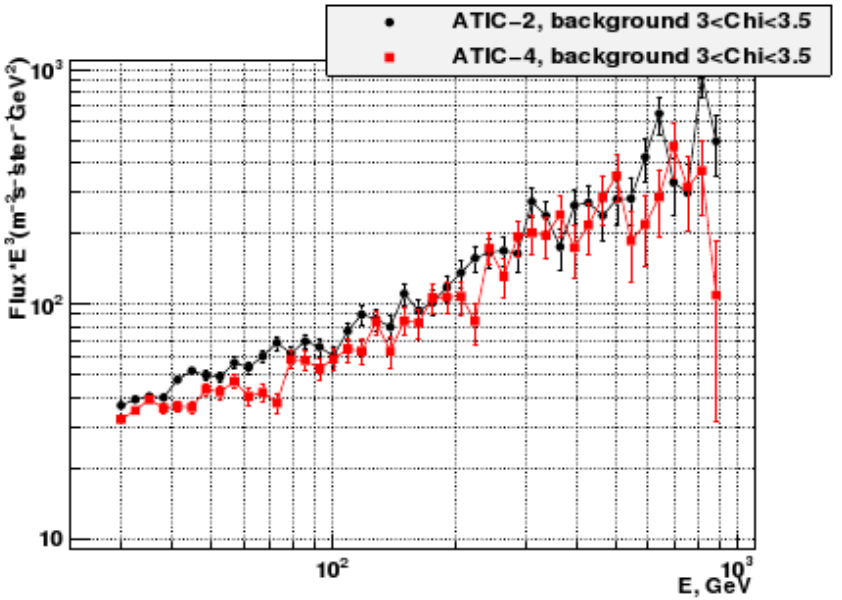
No correlations within 1-σ corridor

3.0<Chi<3.5:

MeanCorrelation = -0.099 ± 0.118

No correlations within 1-σ corridor





We must conlude:

ATIC definitely sees fine structure

in the electron spectrum,

this structure is statistically significant

and there are no signs of methodical

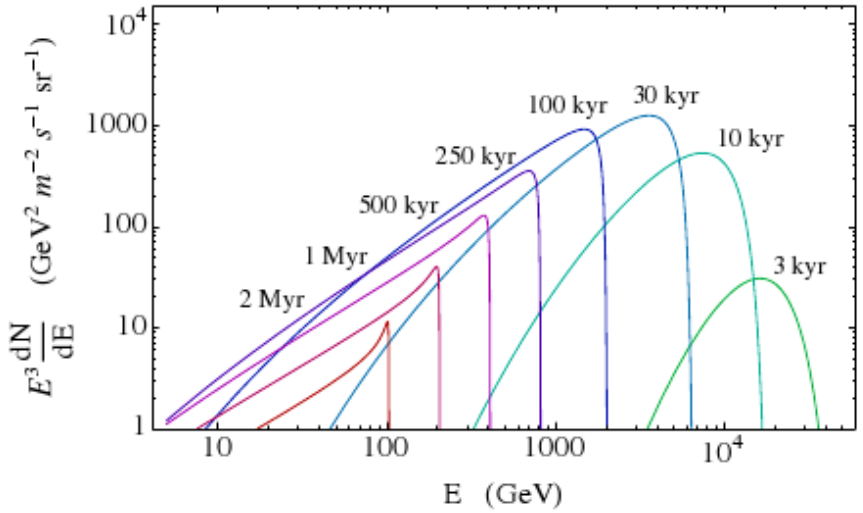
origin of the structure.

Pulsars, cooling of electrons, and fine structure

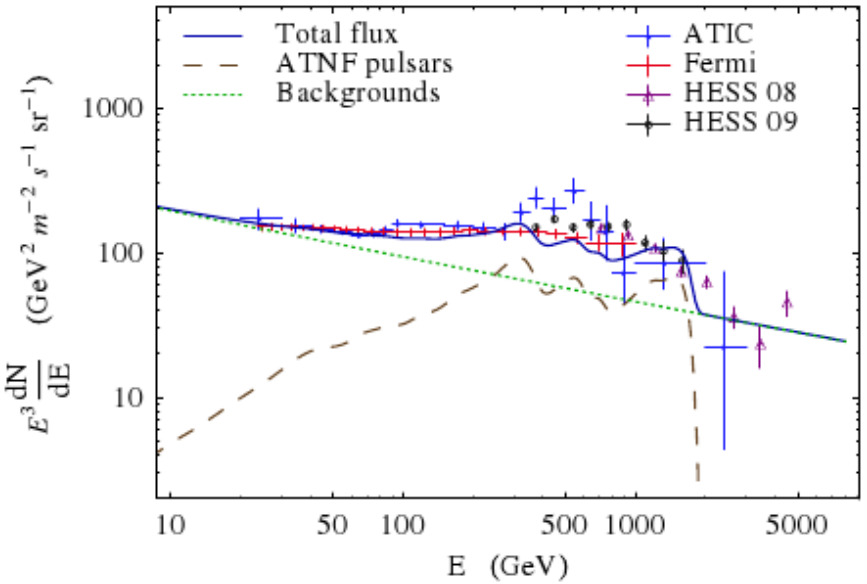
D. Malyshev, I. Cholis, J. Gelfand.

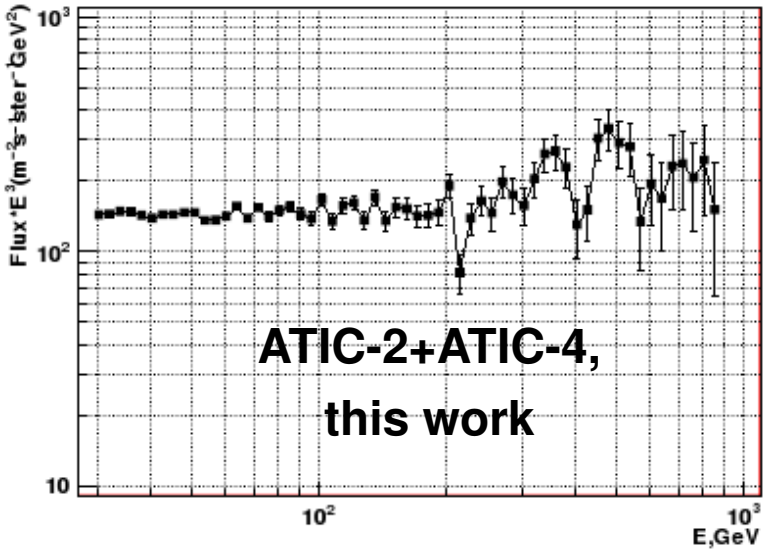
Pulsars versus dark matter interpretation of ATIC/PAMELA. Phys. Rev. D 80, 063005 (2009)

Fine structure may be a signature to distinguish pulsars and SR from DM



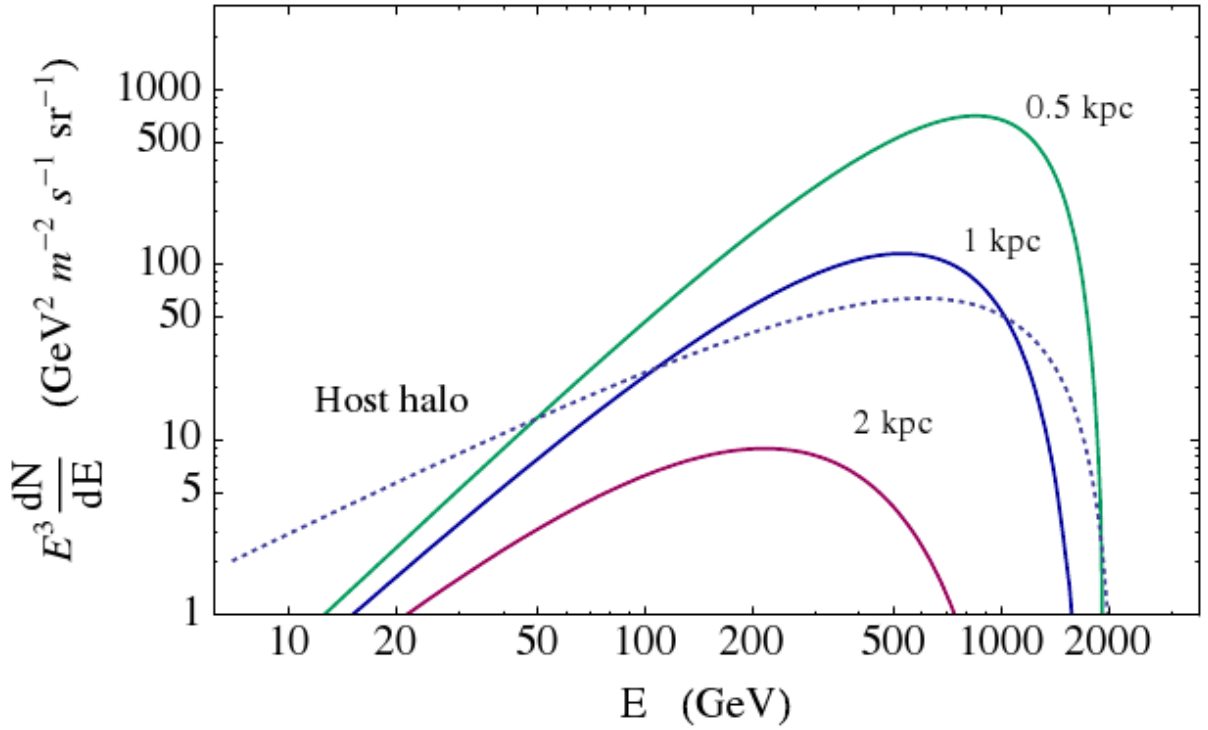
Cooling of electrons from point-like in space and instantaneous in time source -> sharp peaks





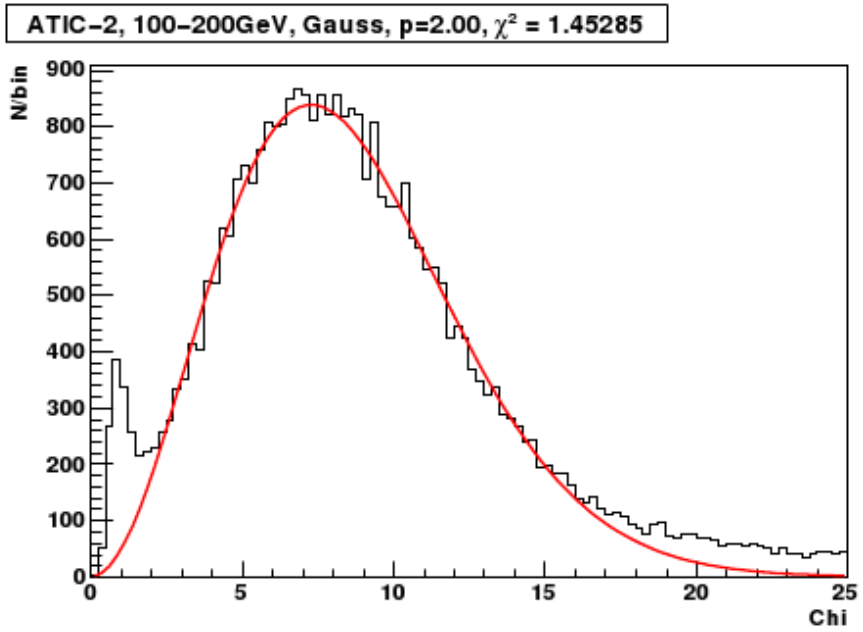
Dark matter halo and local dark matter clumps can not produce a structure with sharp peaks

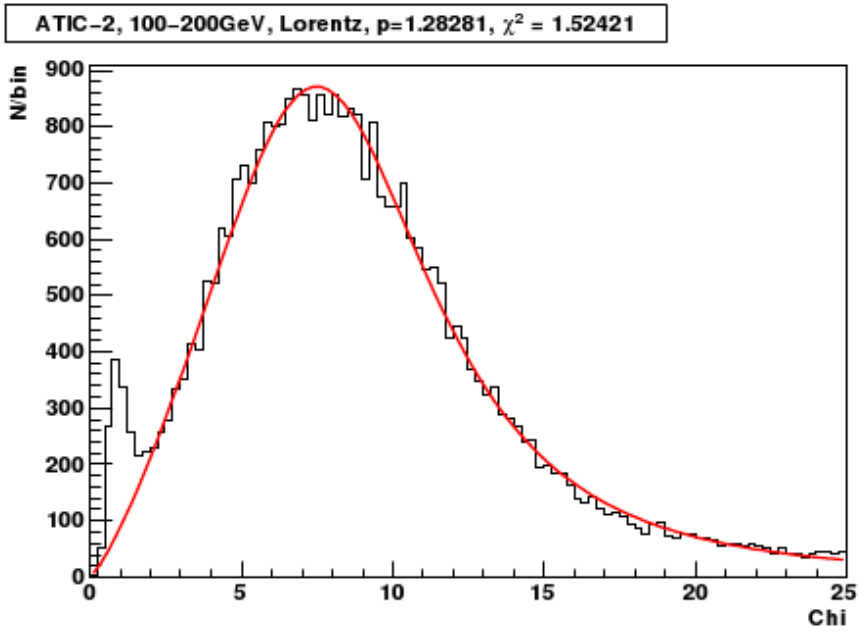
M. Kuhlen, D. Malyshev. ATIC, PAMELA, HESS, and Fermi data and nearby dark matter subhalos. Phys. Rev. D 79, 123517 (2009)

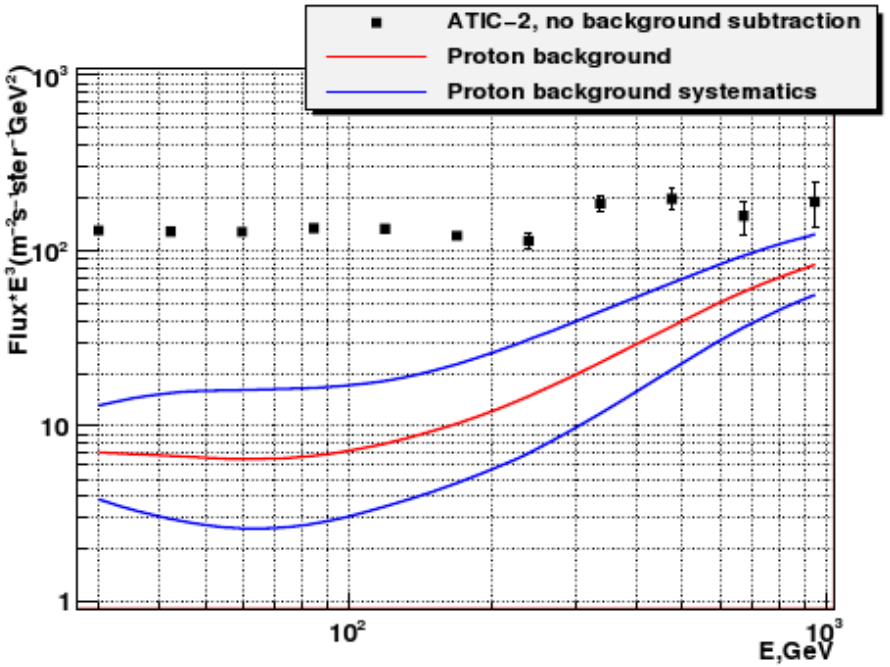


Any dark matter source must be continuous in time. Electrons of all ages present in the spectrum, all peaks spreaded and sharp peaks in the electron spectrum can not be produced.

Protons background subtraction without protons simulation





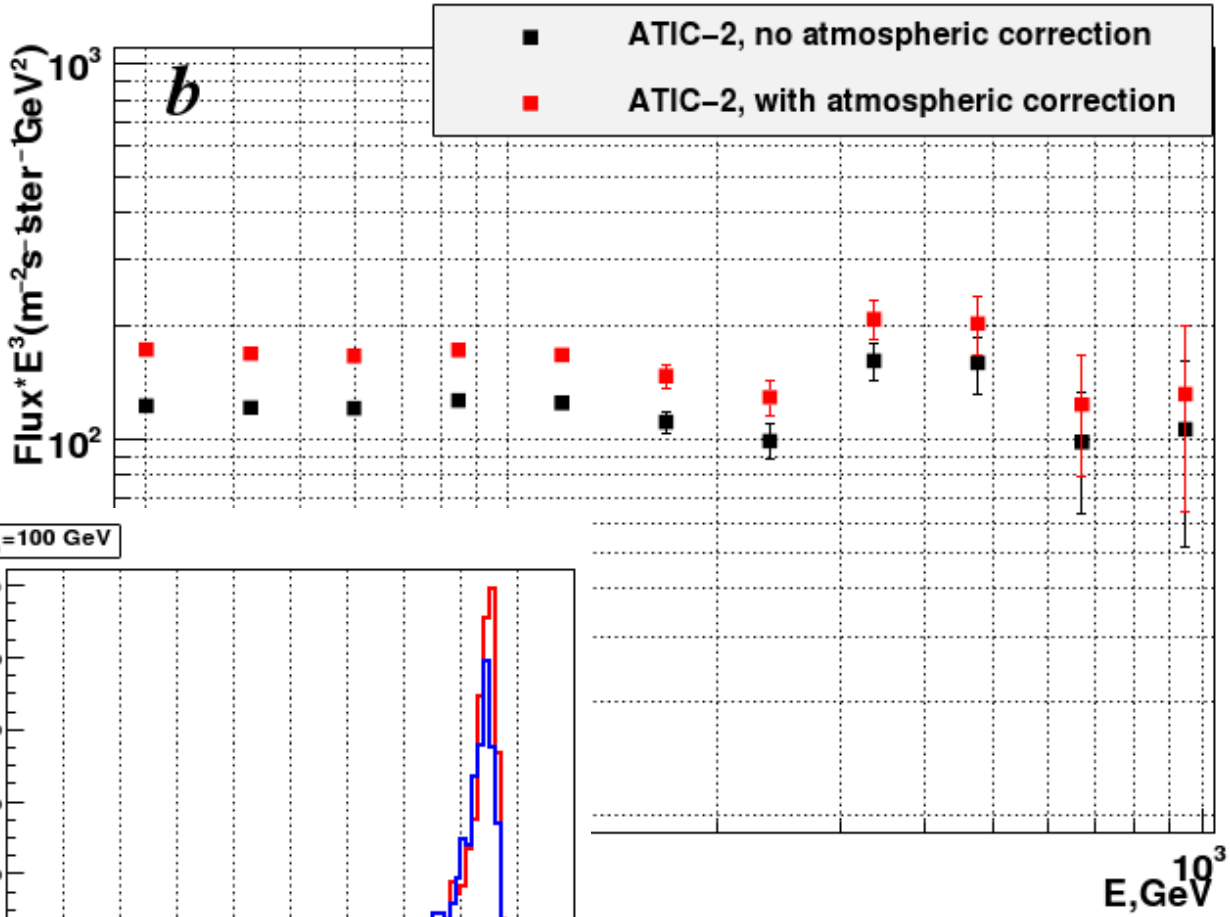


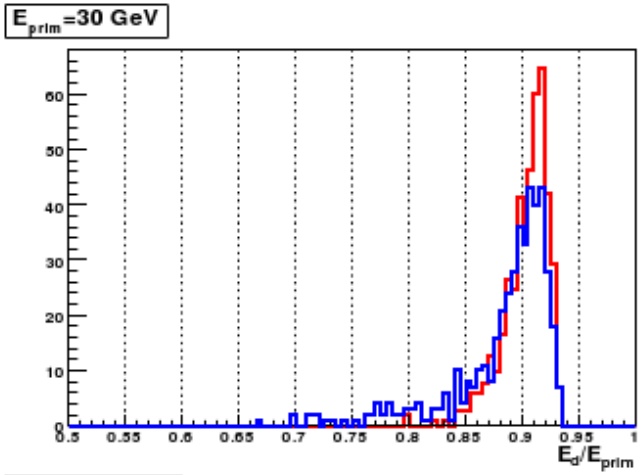
Large energy step:

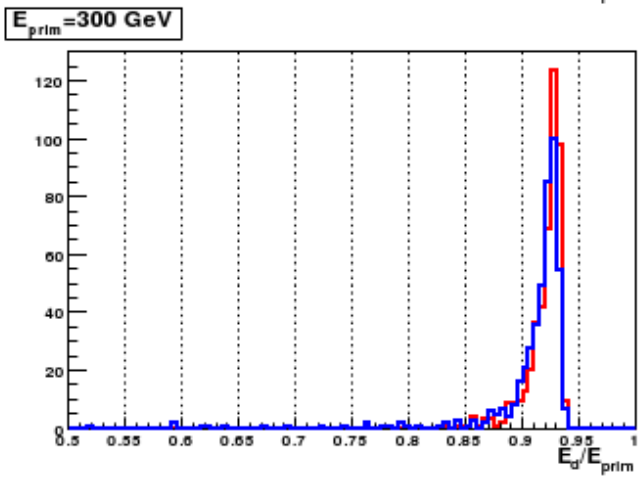
0.15 decade of energy.

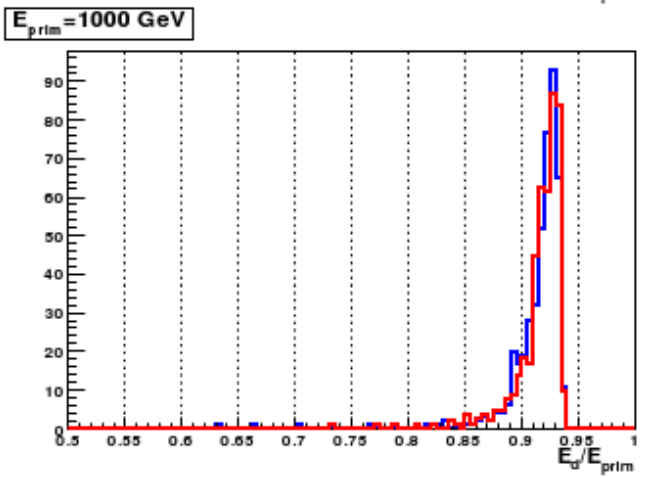
No fine structure is visible

Correction of scattering in the atmosphere







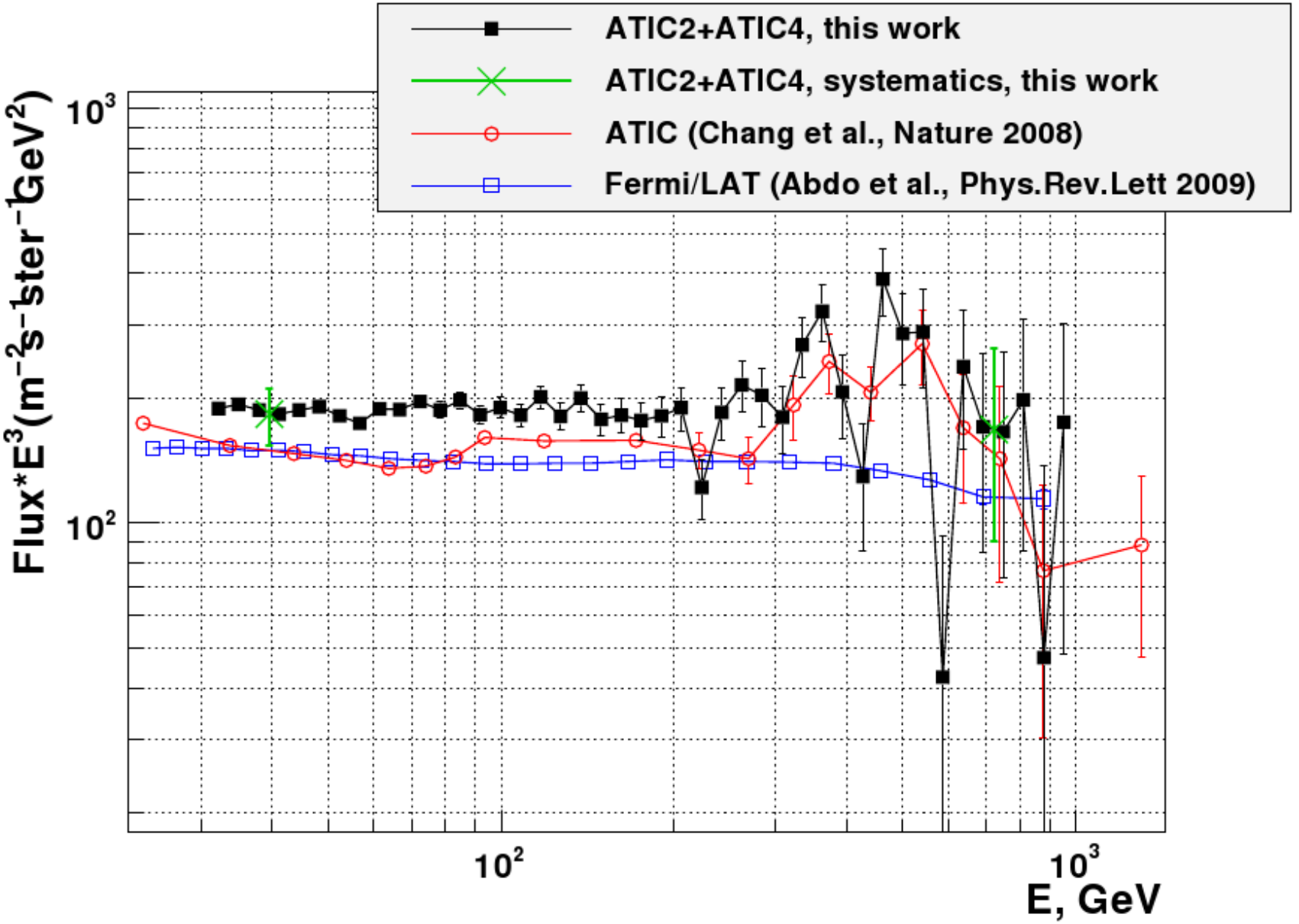


No energy shift!

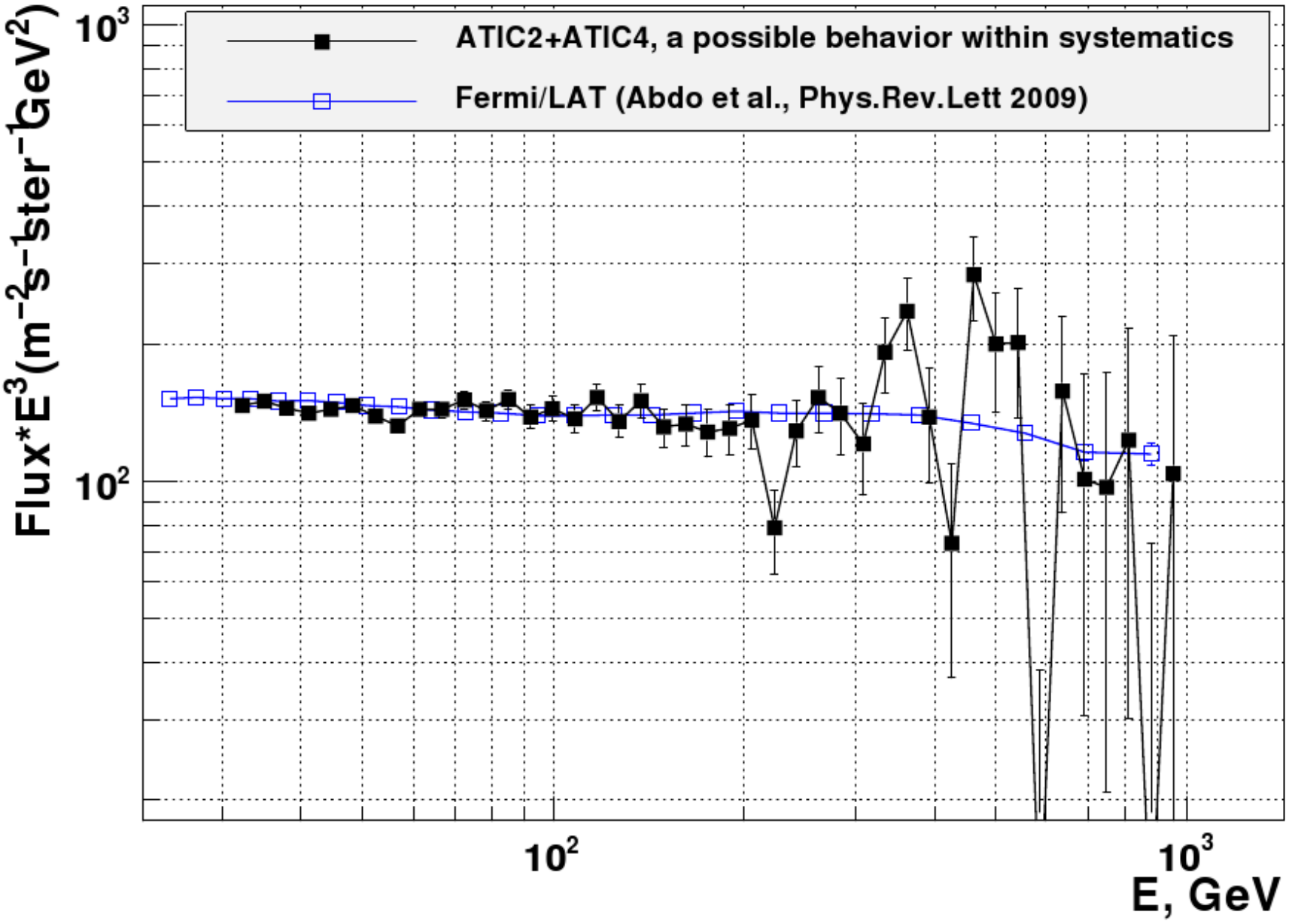
without atmosphere

with atmosphere

ATIC this work, ATIC (2008) and Fermi/LAT (2009)



ATIC and Fermi/LAT — a possible behavior within systematic error corridor of ATIC



Conclusions

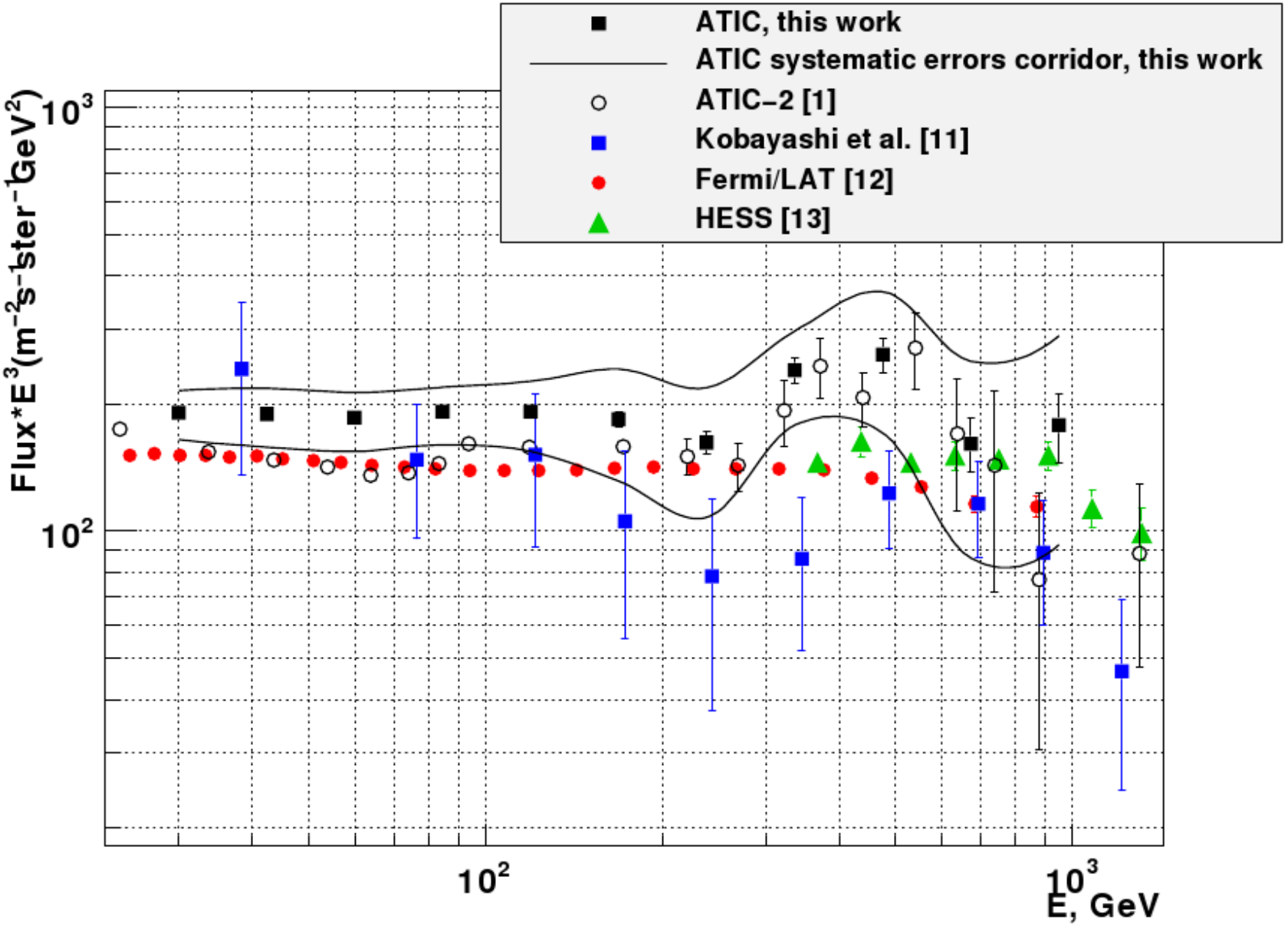
1. We definitely observe fine structure of the ATIC's excess.

2. It is very important, because such a structure may be explained by nearby sources like pulsars but could not be explained by dark matter.

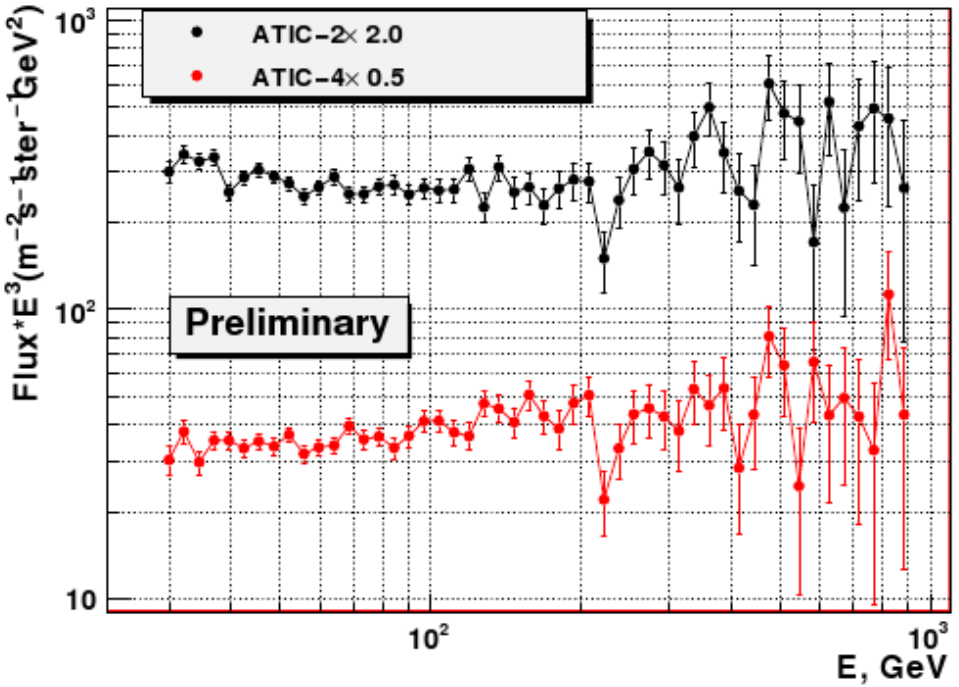
3. There is agreement of ATIC spectrum with Fermi/LAT data within systematic errors corridor up to 200 GeV. There is a structure in the ATIC spectrum behind 200 GeV but there is no structure in the Fermi/LAT spectrum

Thank you for attention!

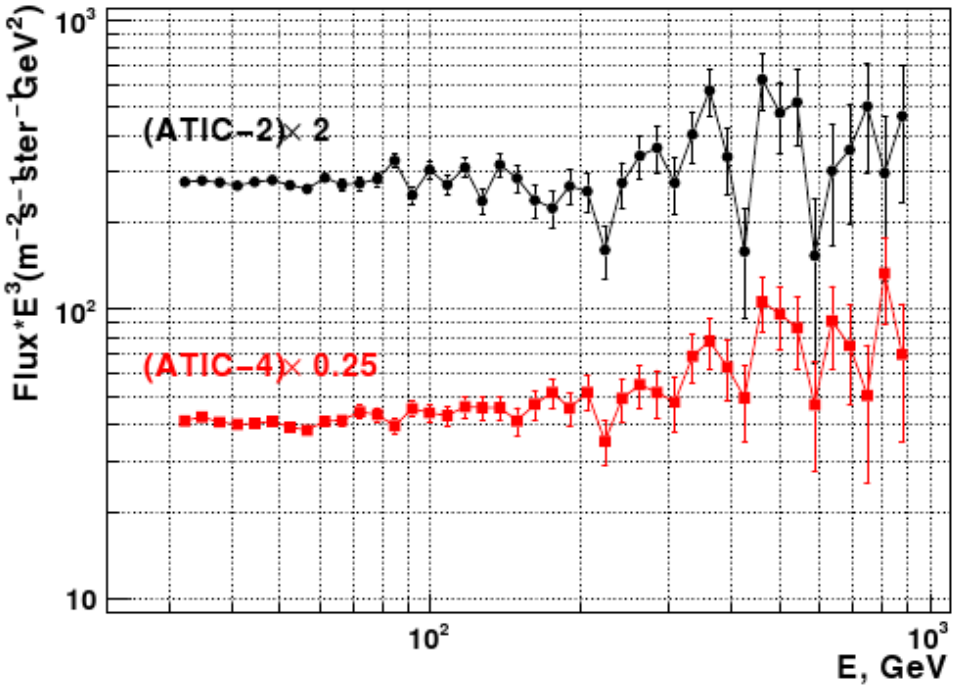
ATIC and some other experiments



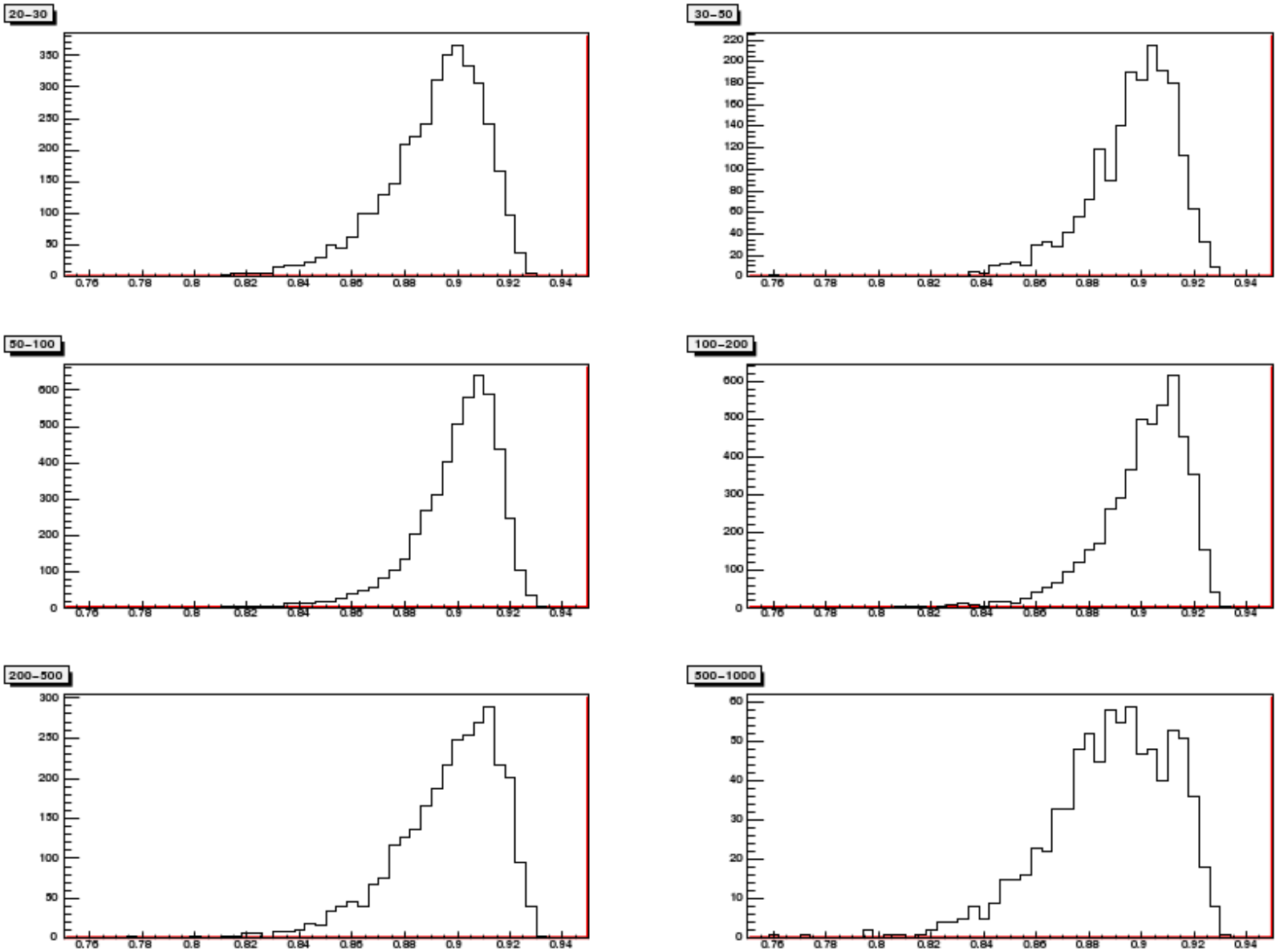
2009, 31ICRC, preliminary



2010, this work



Energy resolution of ATIC - simulation



Simulation: better than **3%** (half of width at the half of height),
energy dependence is not strong