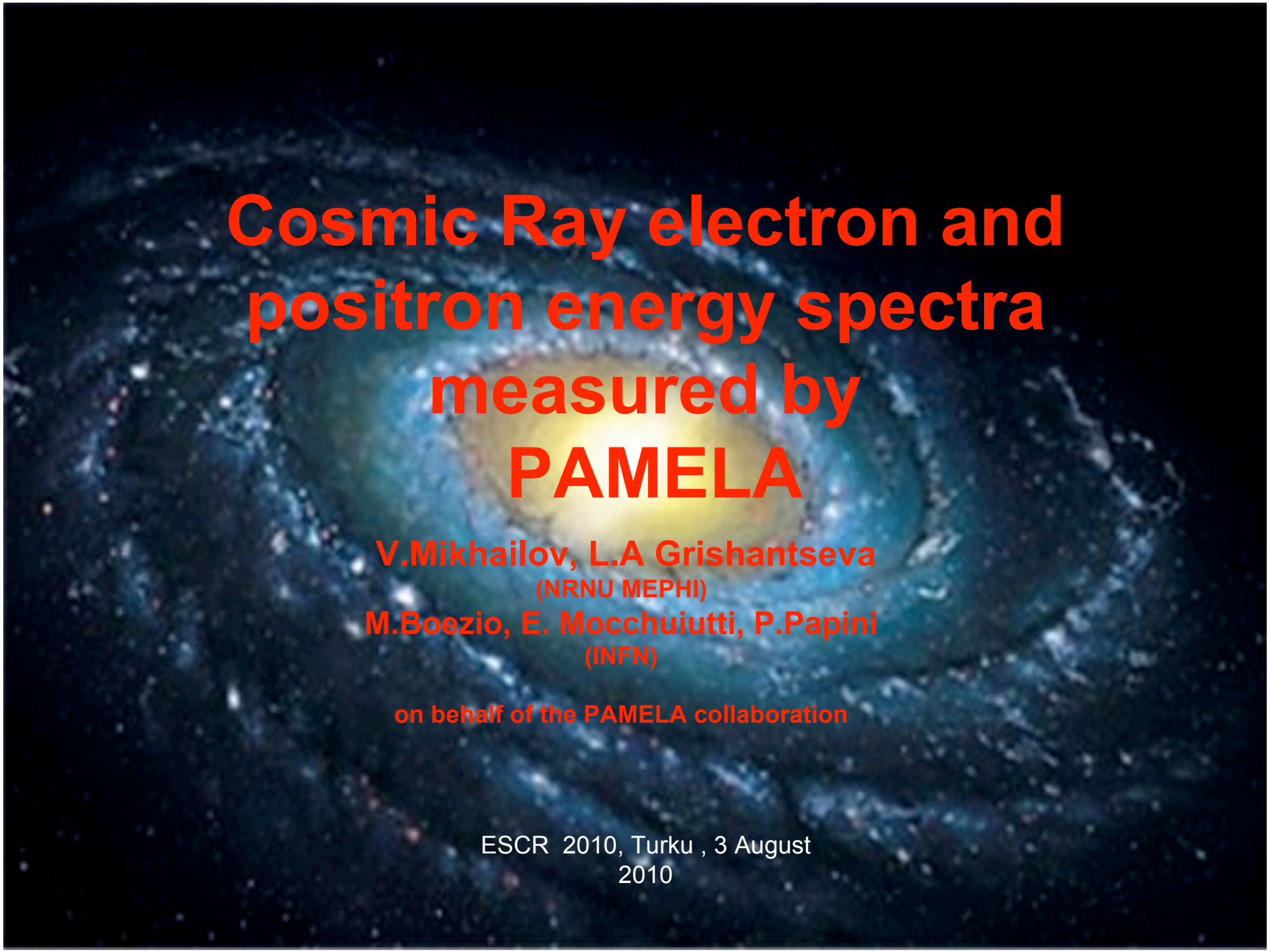


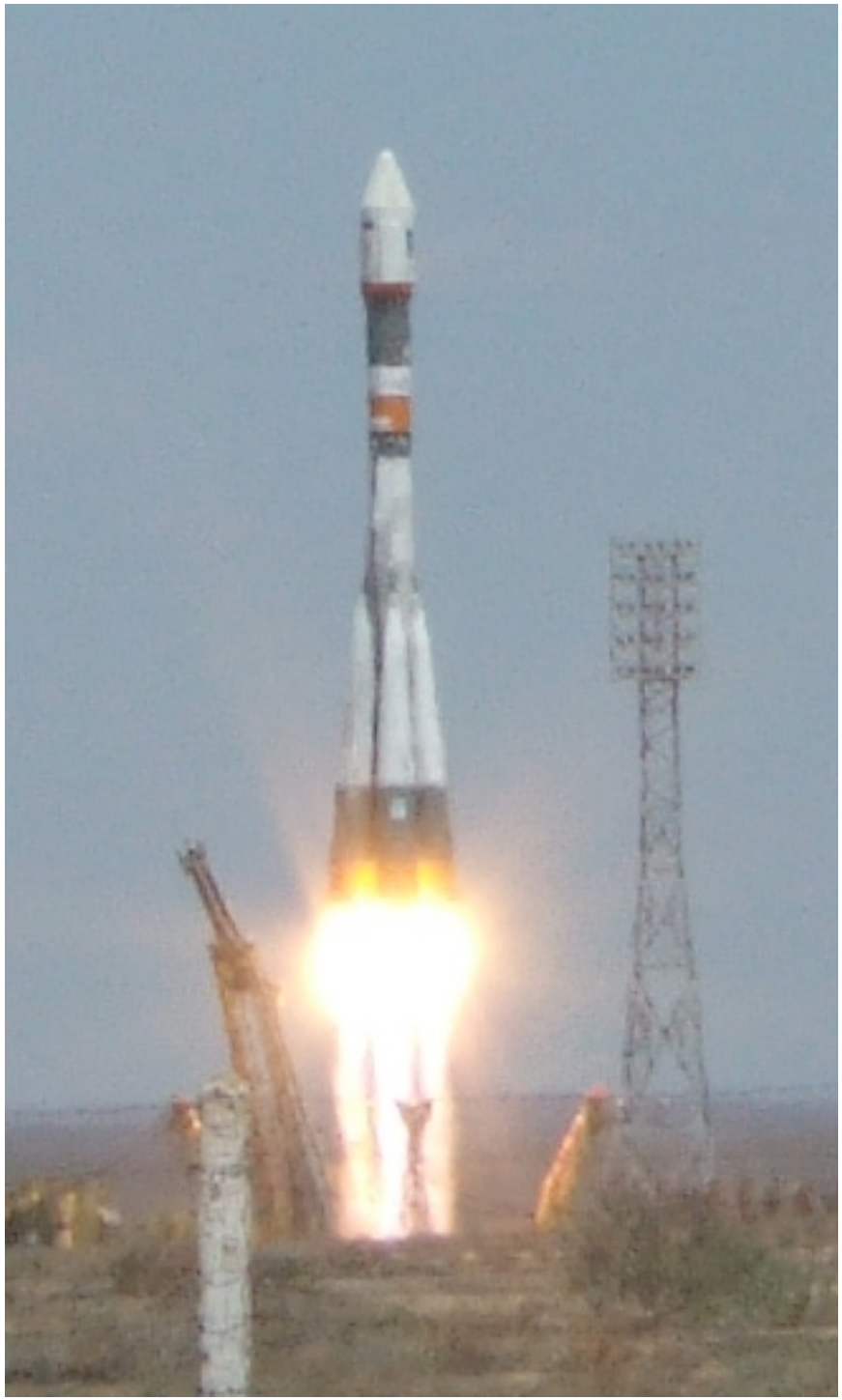
Cosmic Ray electron and positron energy spectra measured by PAMELA

V.Mikhailov, L.A Grishantseva
(NRNU MEPHI)
M.Boezio, E. Mocchiutti, P.Papini
(INFN)

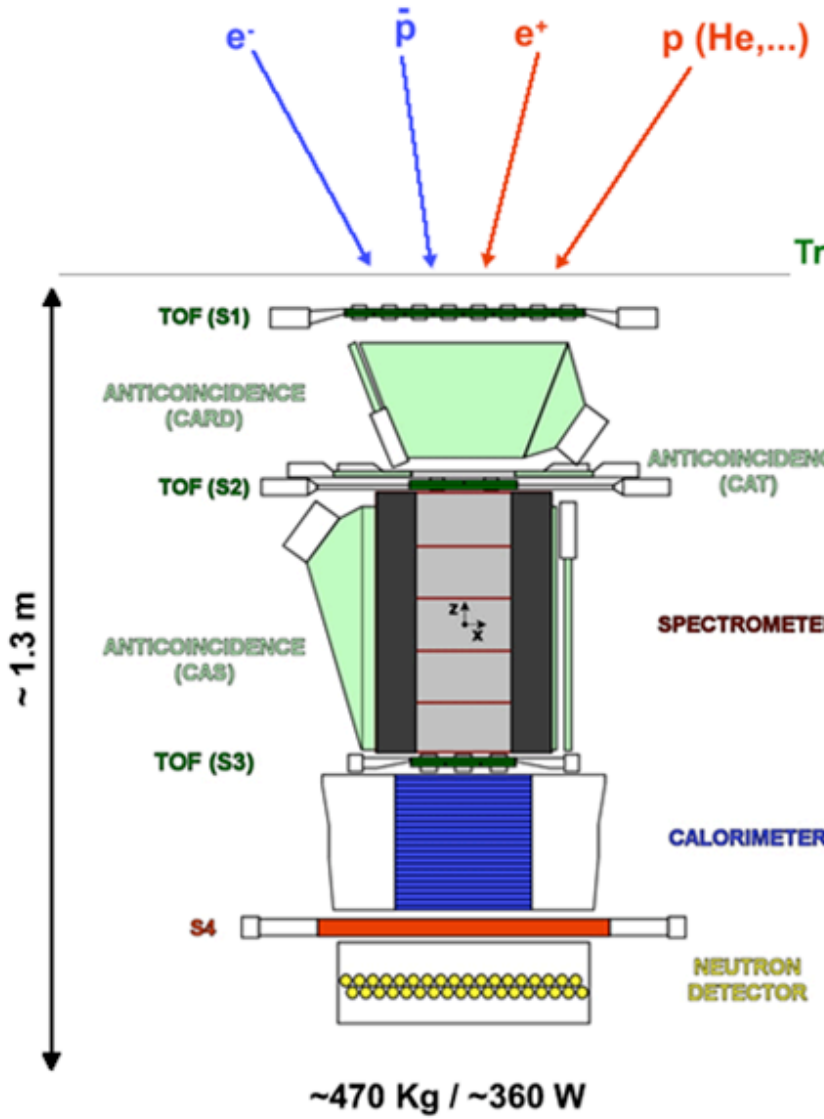
on behalf of the PAMELA collaboration

ESCR 2010, Turku , 3 August 2010

- PAMELA was launched 15.06.2006 on-board Resurs DK №1 satellite
- The instrument has been working in orbit ~1500 days till now
- 20 TB of data has been downlinked , >$3*10^9$ triggers were registered.



Scheme of the instrument



Trigger, ToF, dE/dx

- S1, S2, S3; double layers, x-y
- plastic scintillator (8mm)
- ToF resolution 300 ps (S1-3 ToF >3 ns)

SPECTROMETER

Sign of charge, rigidity, dE/dx

- Permanent magnet, 0.43 T
- 21.5 cm^2 sr
- 6 planes double-sided silicon strip detectors (300 μm)
- 3 μm resolution in bending view

CALORIMETER

Electron energy, dE/dx, lepton-hadron separation

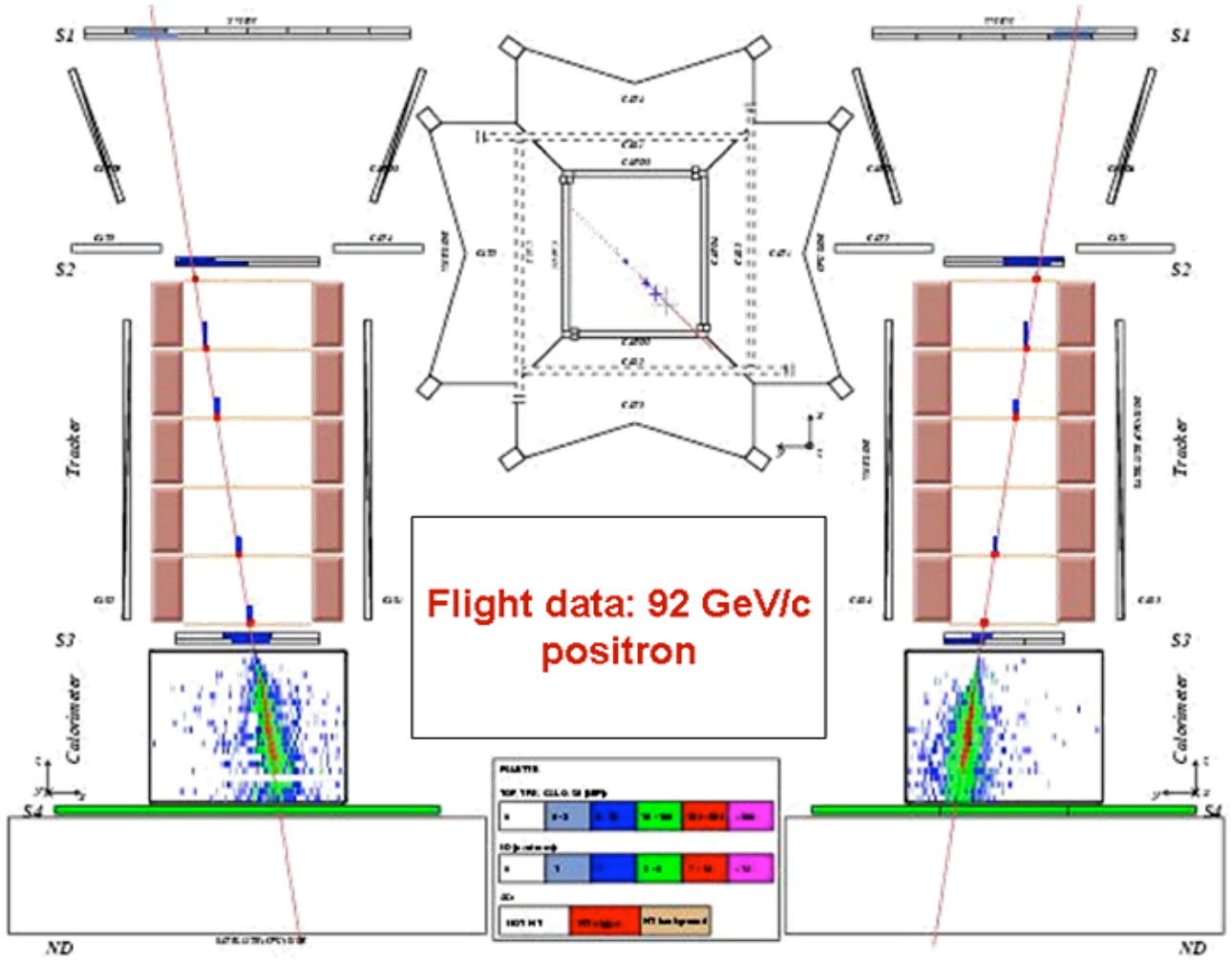
- 44 Si-x / W / Si-y planes (380)
- 16.3 X0 / 0.6 L
- dE/E ~5.5 % (10 - 300 GeV)

- 36 ^{3}He counters
- ^{3}He(n,p)T; E_p = 780 keV
- polyethilen moderator

Positron with energy 92 GeV

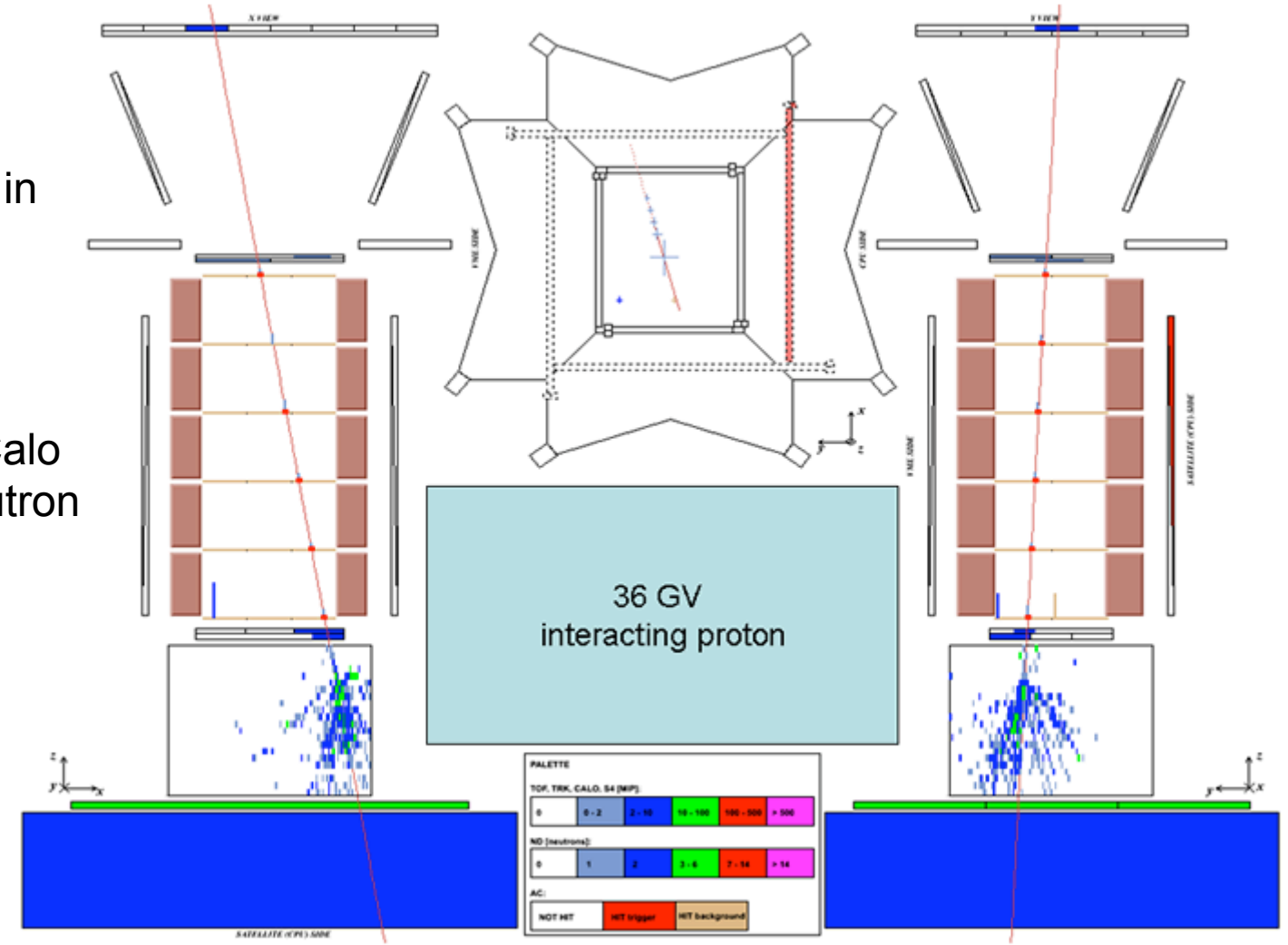
Particle identification :

•| Z|=1 (dE/dx= 1 MIP in ToF and SPE)
• β=1 → ToF
•rigidity (R) ~ Ecalo
• charge sign =+1
• electromagnetic shower in Calo
•No neutrons

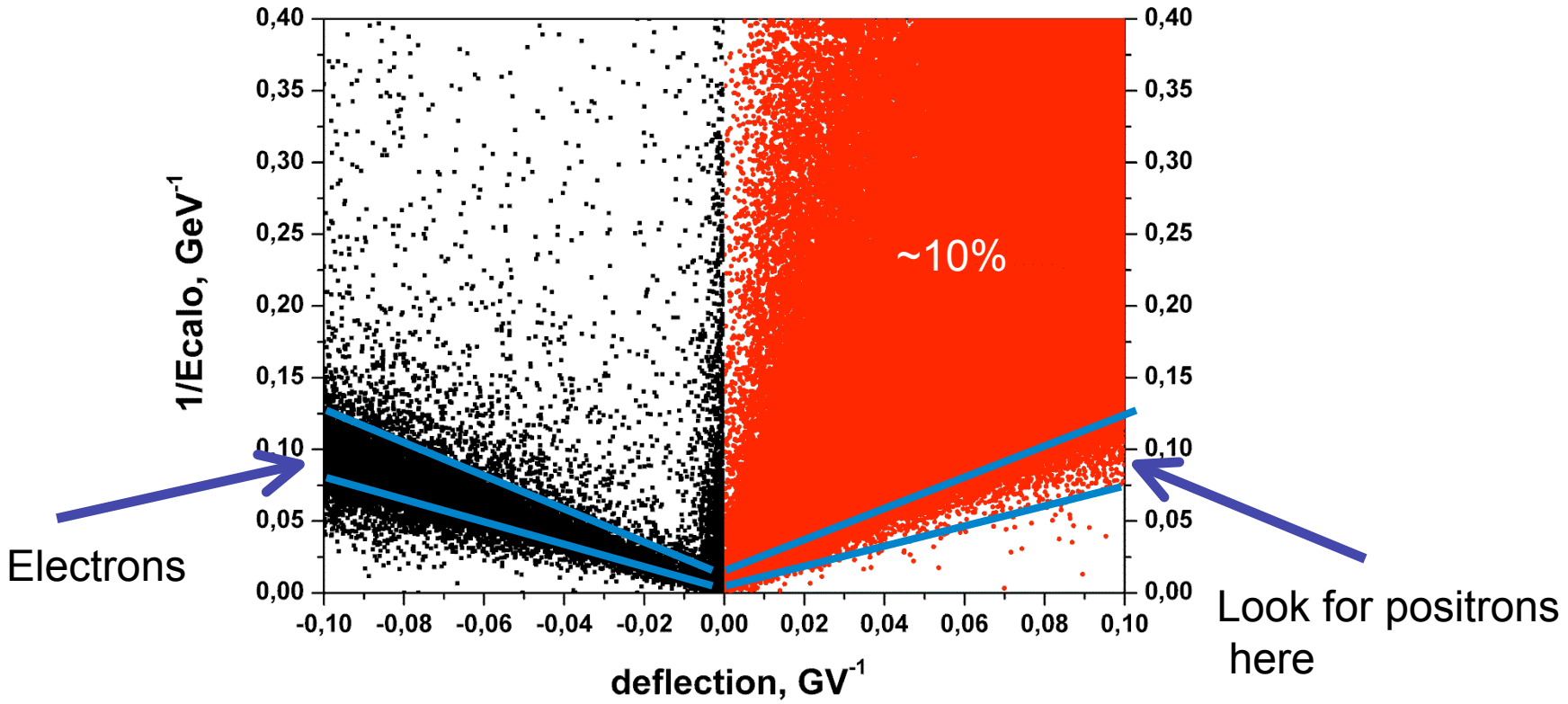


Proton with energy 36 GeV

Particle identification :
• |Z|=1 (dE/dx= 1 MIP in ToF and SPE)
• β=1 → ToF
•rigidity (R) >> Ecalo
• charge sign =+1
• hadrons shower in Calo
•There is signal in neutron detector



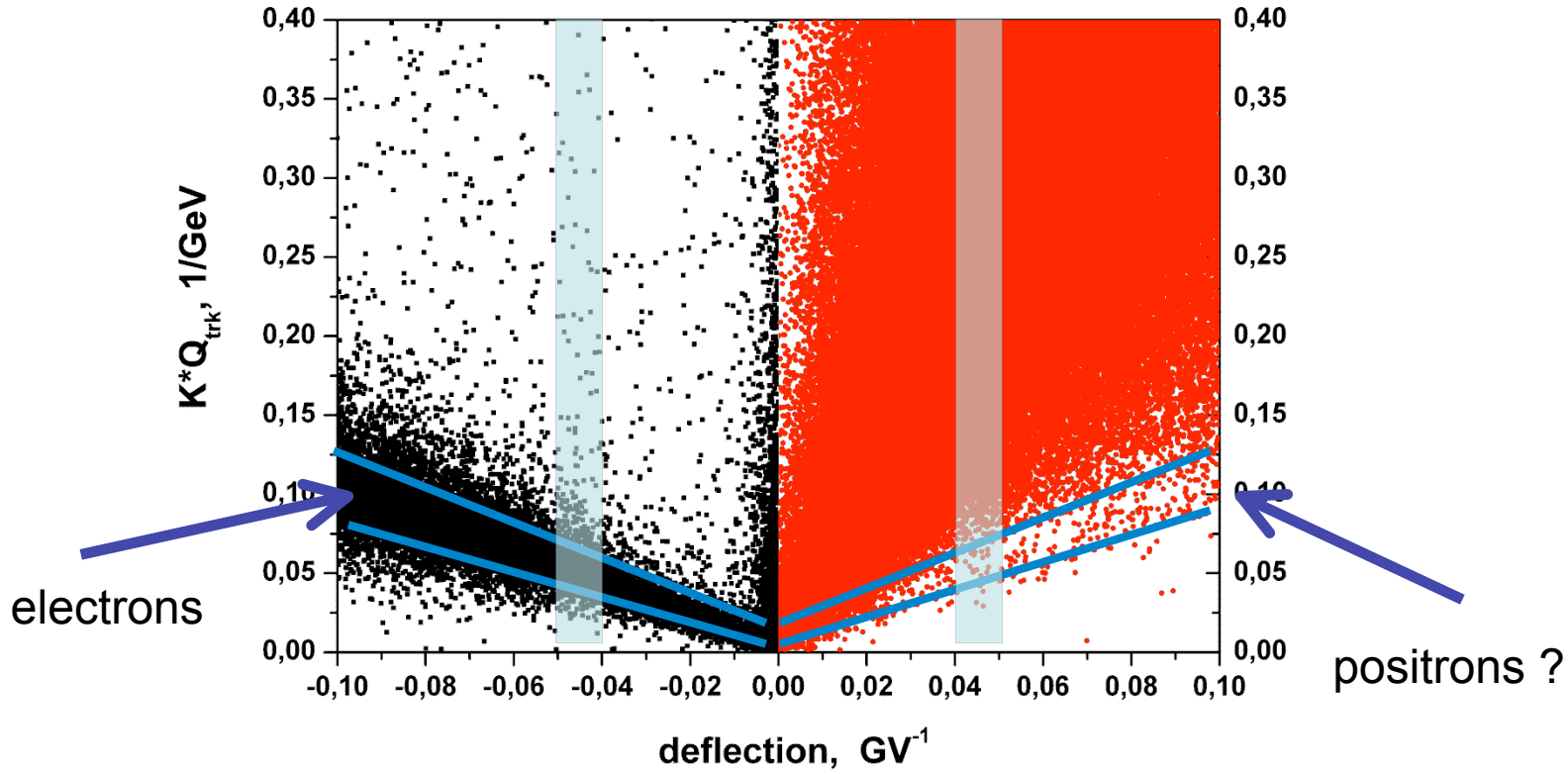
$1/E_{calo}$ vs deflection in tracker



~10% events are shown for positive (red points)

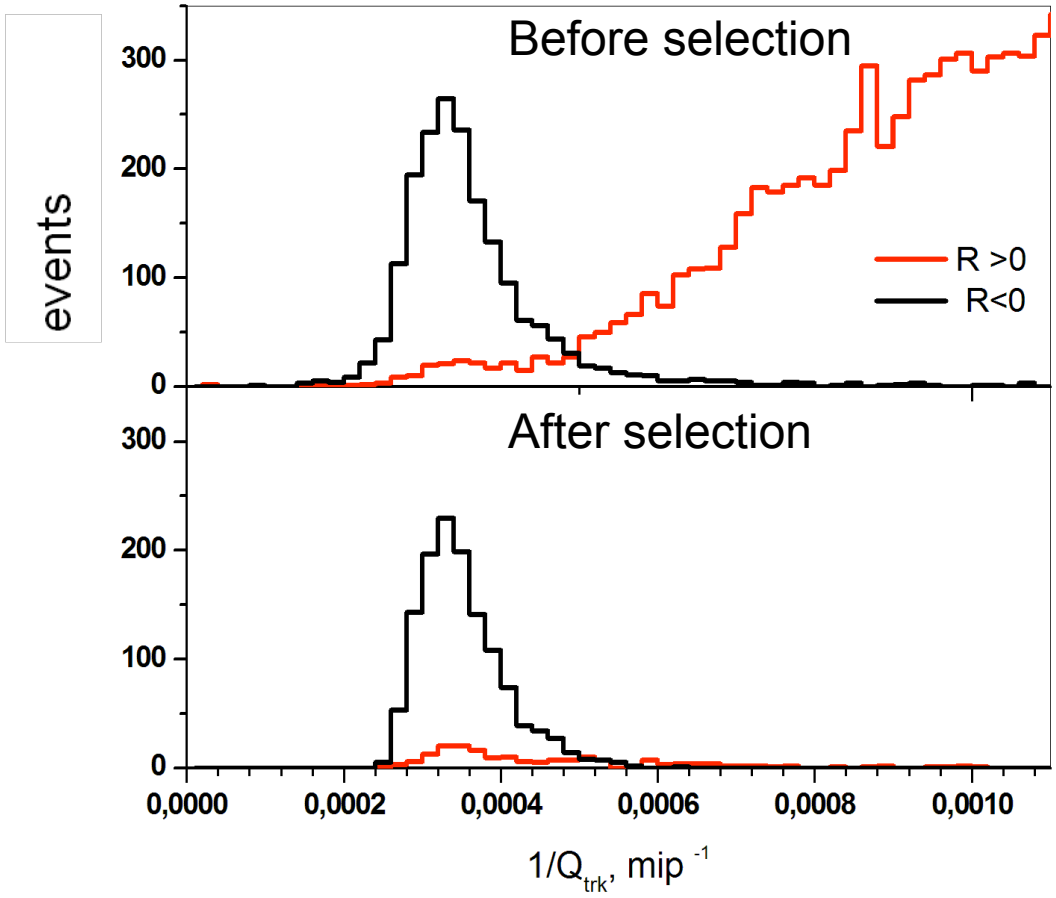
E_{calo} – released energy in calorimeter

$1/Q_{calotrk}$ vs deflection



$Q_{calotrk}$ is energy deposit in ~0.6 Molier radii (~4 mm) along shower axis

Distribution $1/Q_{calotrk}$ for R=20-25GV

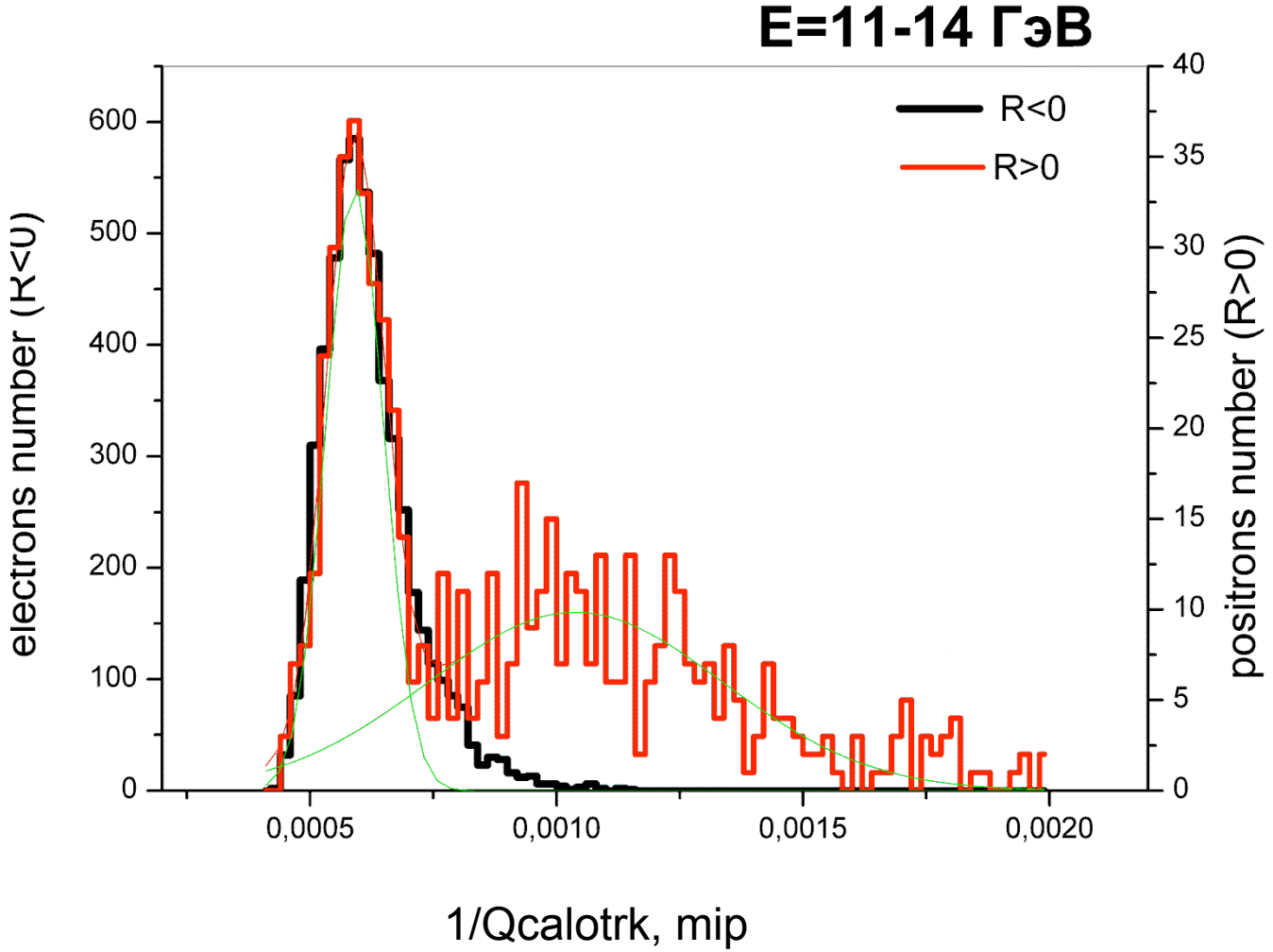


Calorimeter selection :
1)Interaction point in first
4 layers of W
2) Longitudinal profile of shower

Energy – rigidity match

No signal in Neuron detector

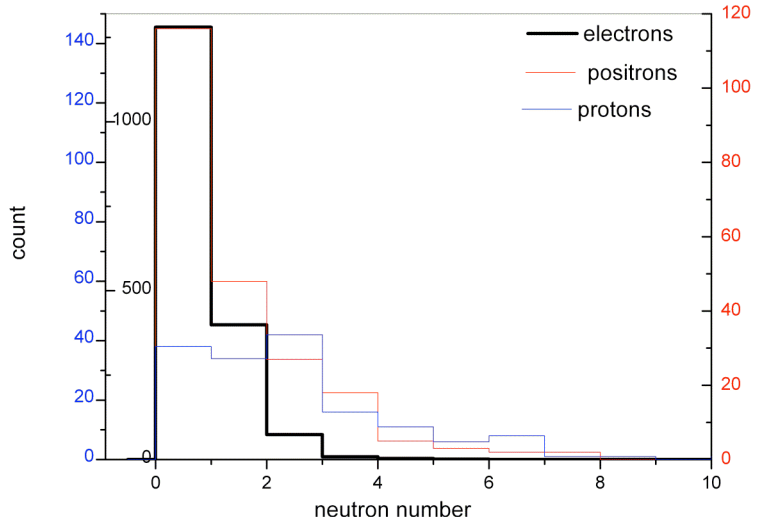
Positron signal



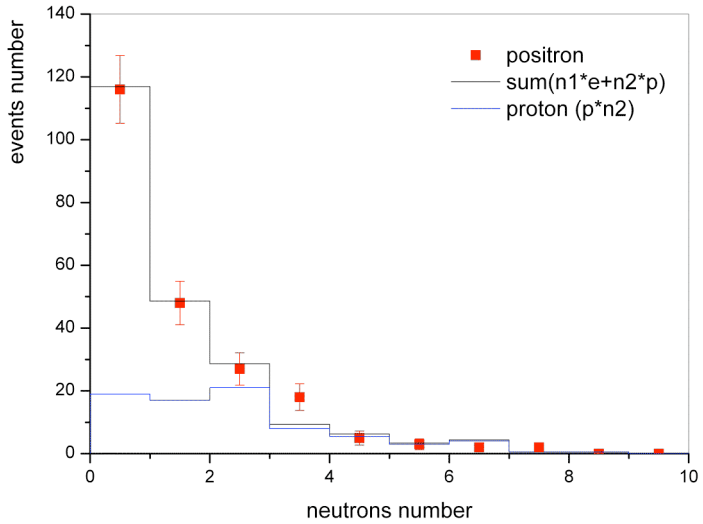
Discussion of systematic is in Astropart. Phys., 34, (2010), 1-11

Background estimation with neutron detector

E=22-35ГэВ

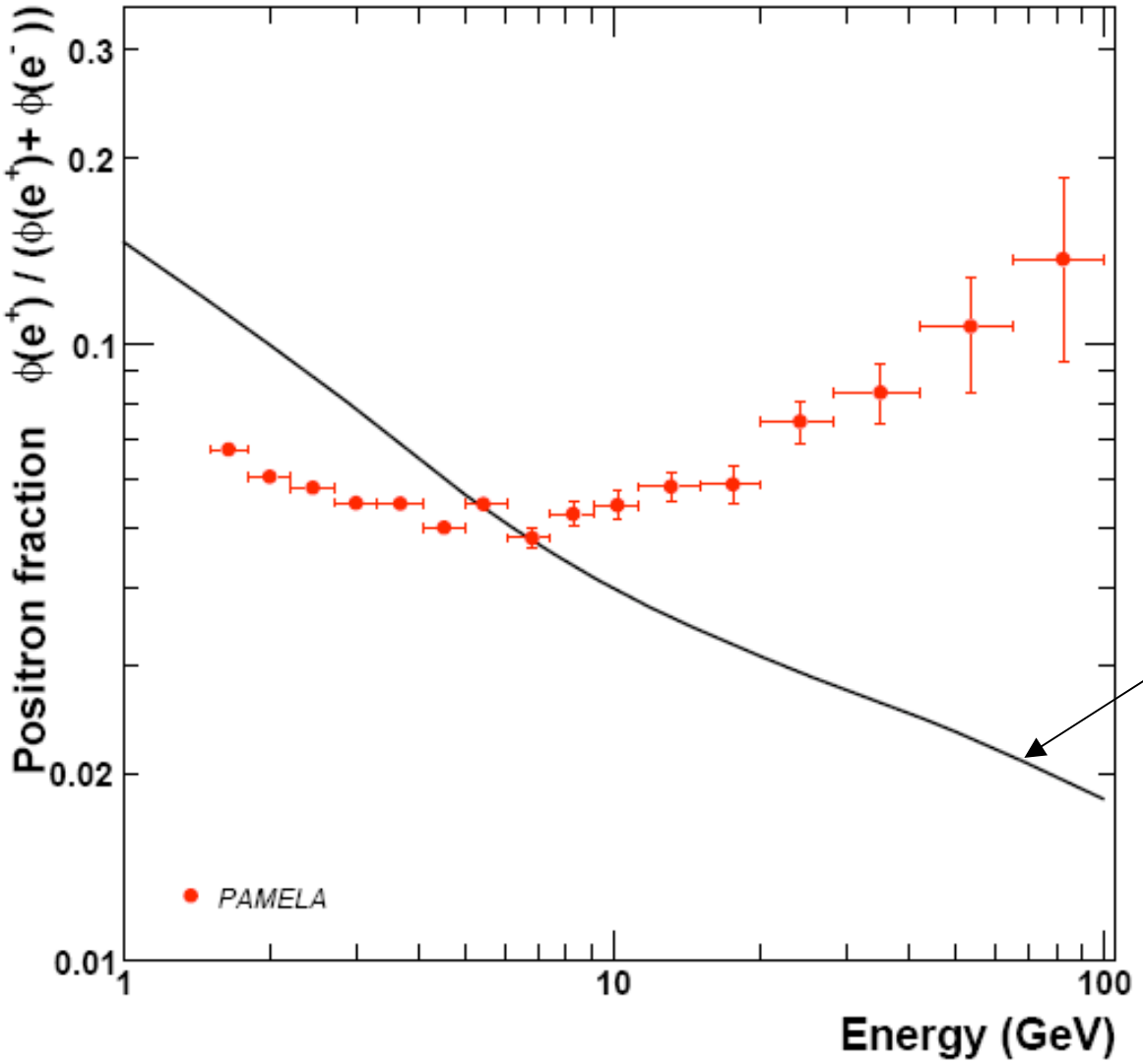


neutron distributions for electrons, positrons and protons



Fit of positrons with “electron” and “proton” functions

Positron fraction



Secondary production, Moskalenko & Strong (1998)

O.Adriani et al. //
Nature 2009, V.458, P.607

Electron spectrum reconstruction

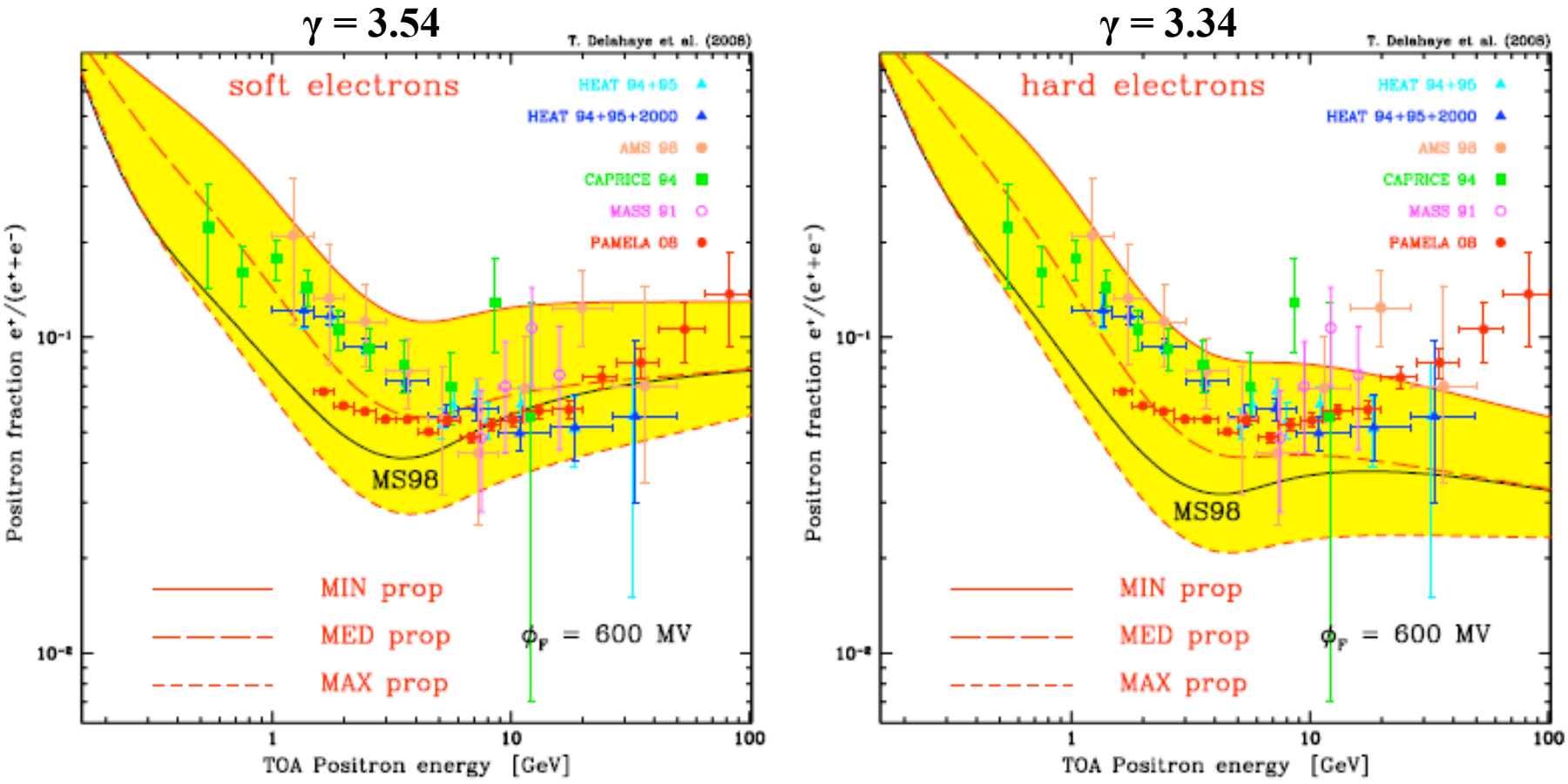
different approaches:

Tracker-based selection (strong track quality requirements, loose calorimeter selection, energy measured by the tracker)

Tracker&Calorimeter-based selection (loose track quality requirements, calorimeter selection, energy-rigidity match)

Calorimeter-based selection (loose/no track quality requirements, strong calorimeter selection, energy measured by calorimeter)

«Secondary production » positron to electron ratio in diffusion model



T. Delahaye et al., arXiv: 0809.5268v3

There were processed data for 07.2006- 12.2008

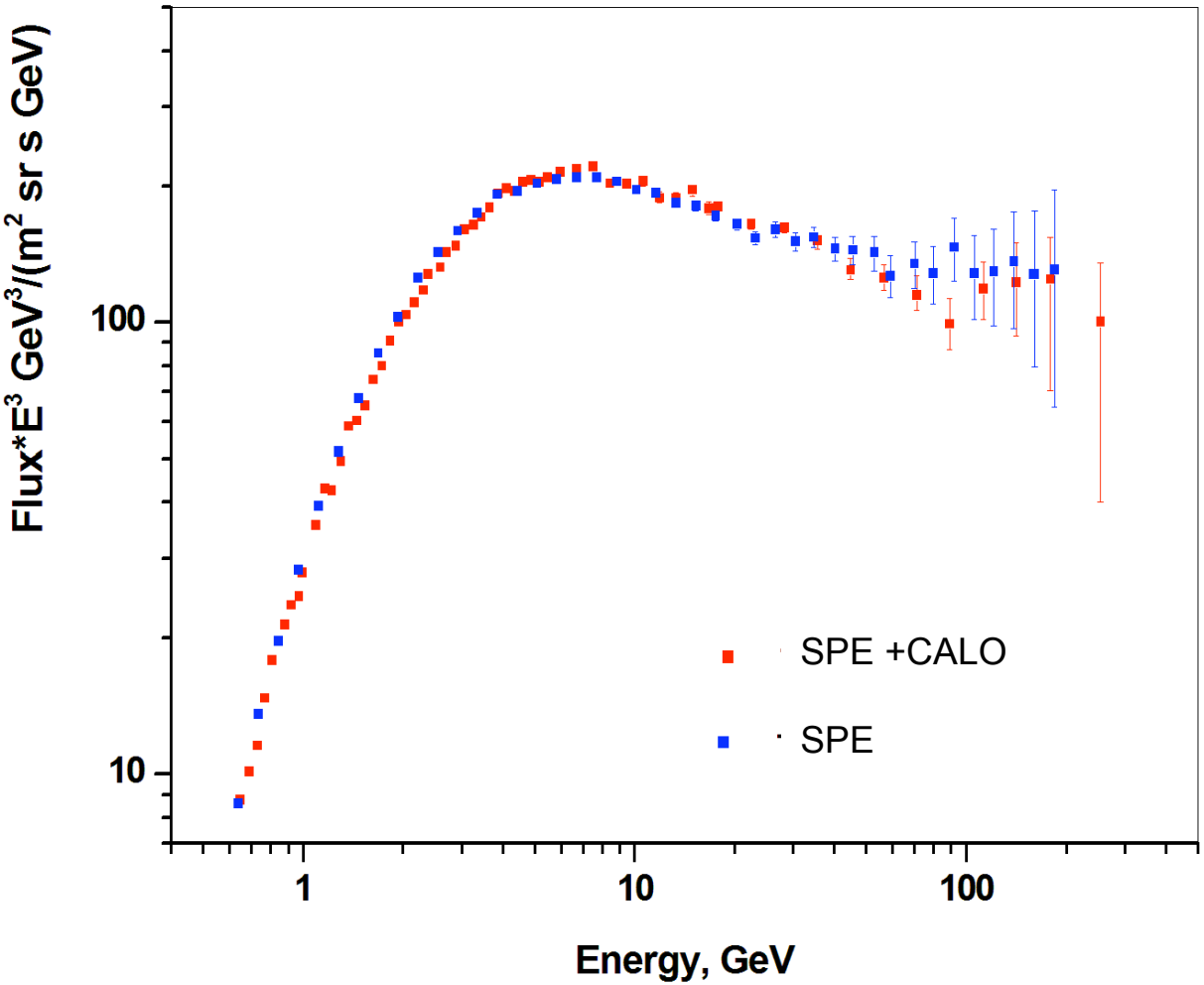
$R_{particle} > 1.3\ R_{geomagnetic\ cut\text{-}off}$

Tracker-based selection ~650000 electrons E>1ГэВ

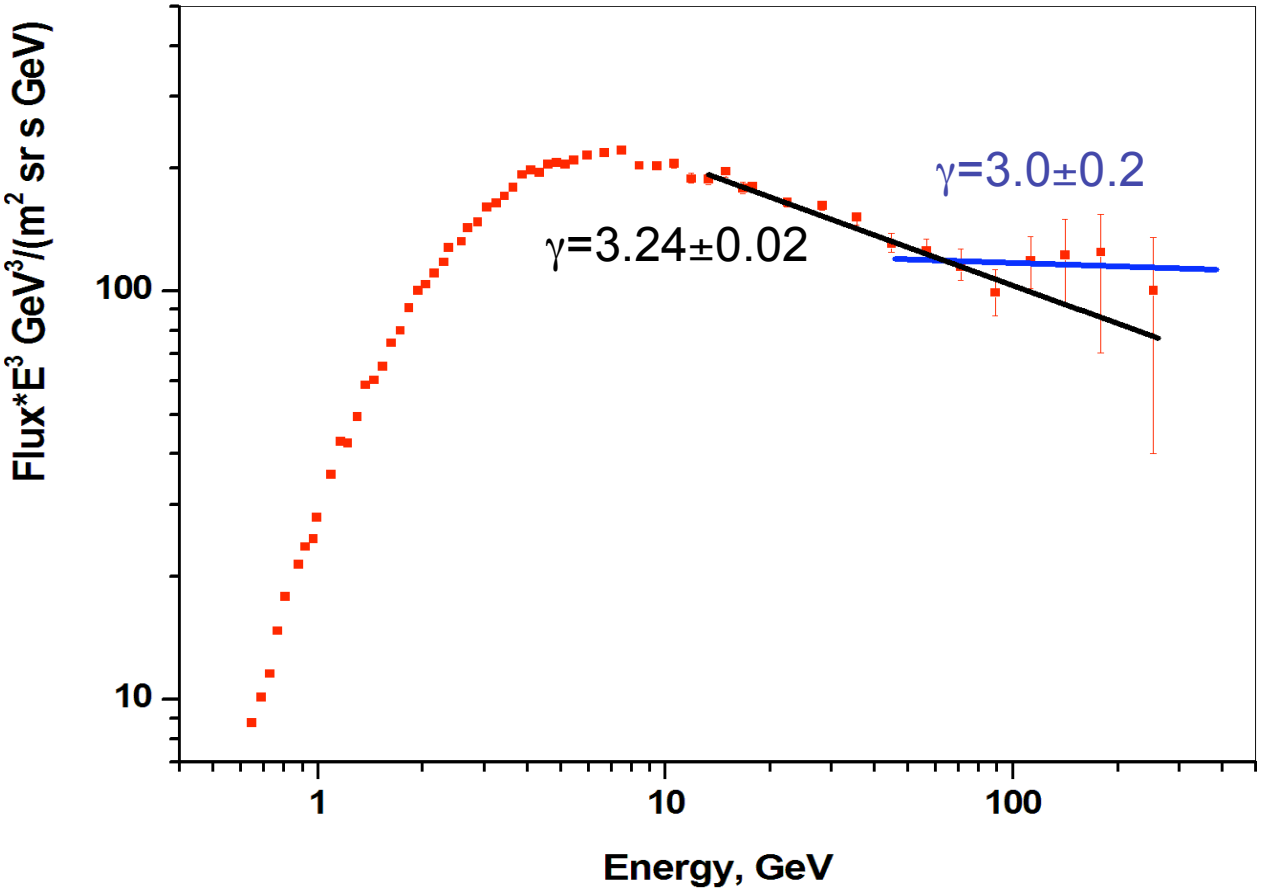
Tracker&calorimeter- based selection ~950000 electrons , ~90000 positrons

- Exposure time was measured with accuracy better 0.1%
- Efficiency was calculated by MC with GEANT3 and compared with experimental estimations (~3% error)
- Unfolding procedure takes into account resolution of the tracker and energy release before spectrometer

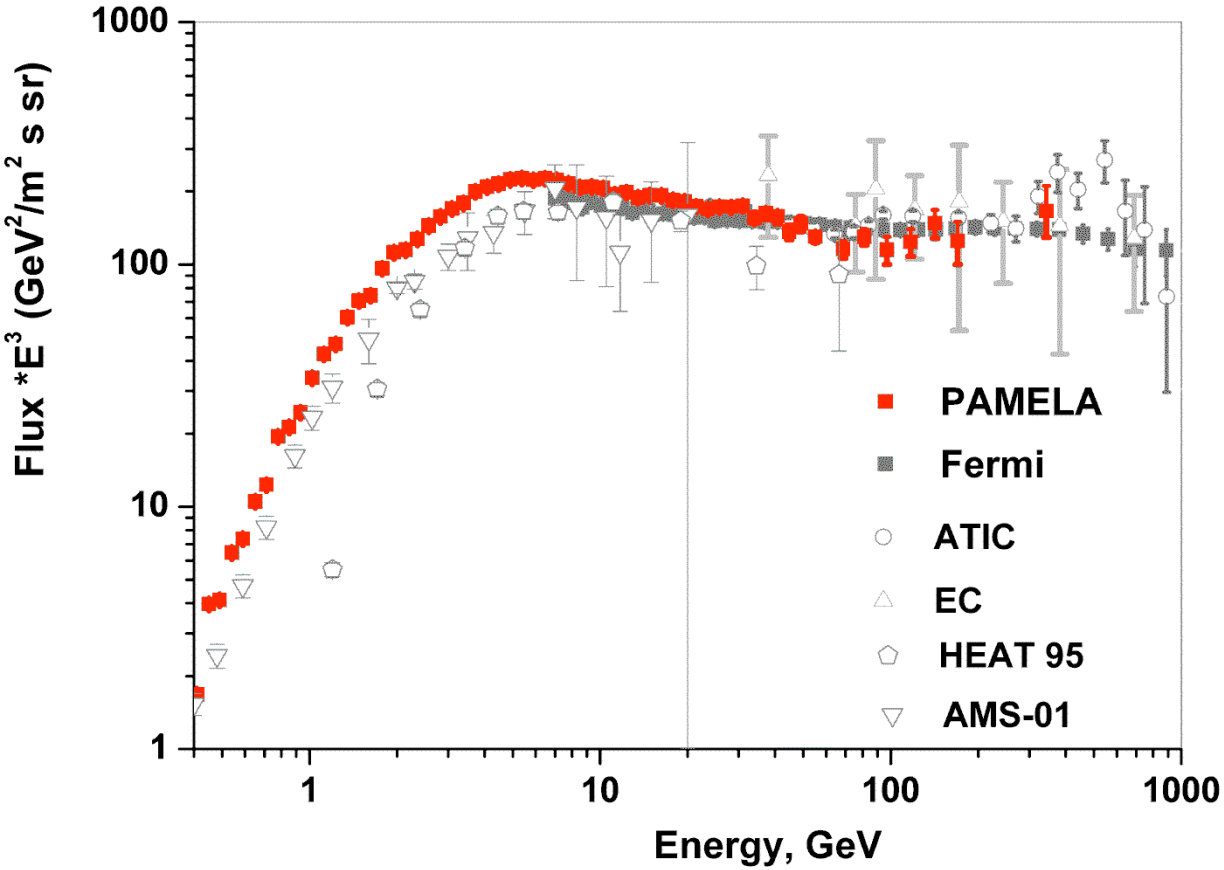
Electron spectrum



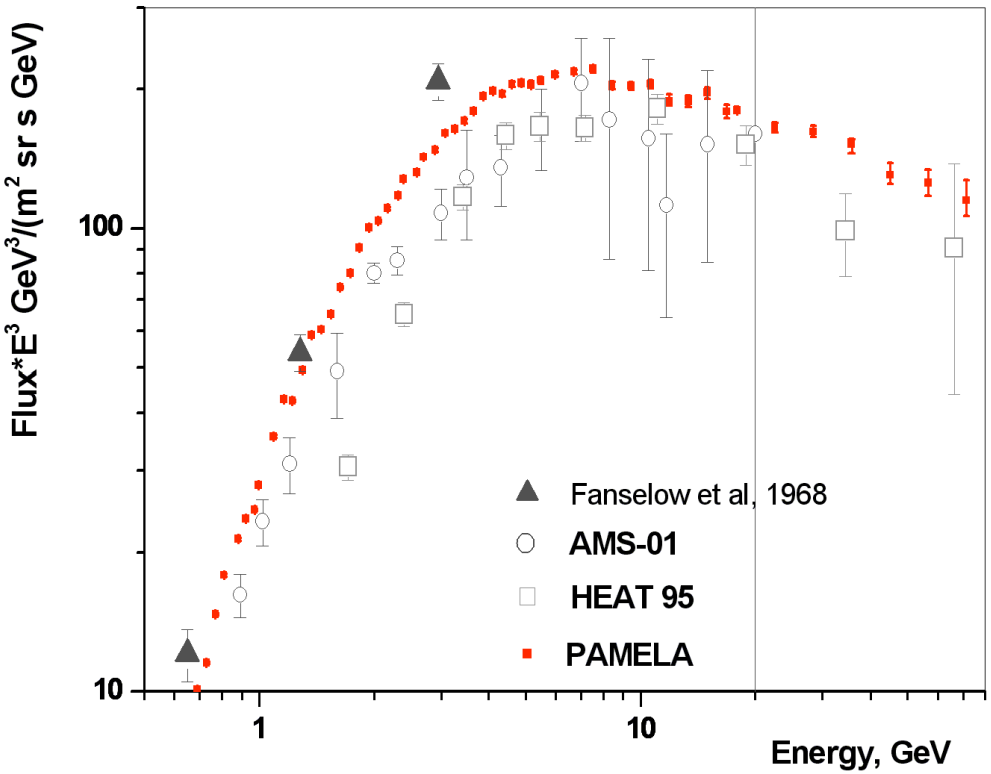
Electron spectrum



Total electron + positron flux

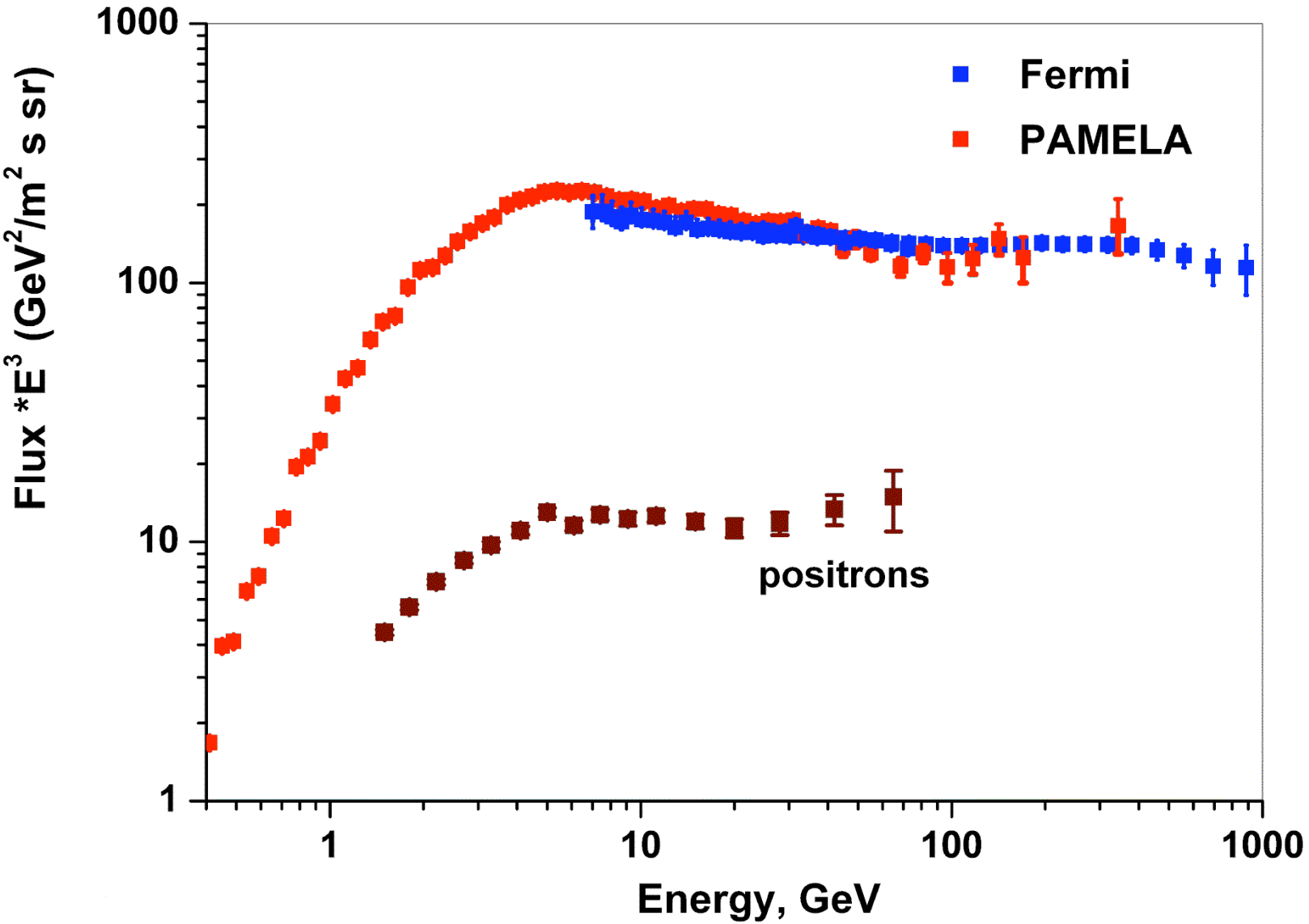


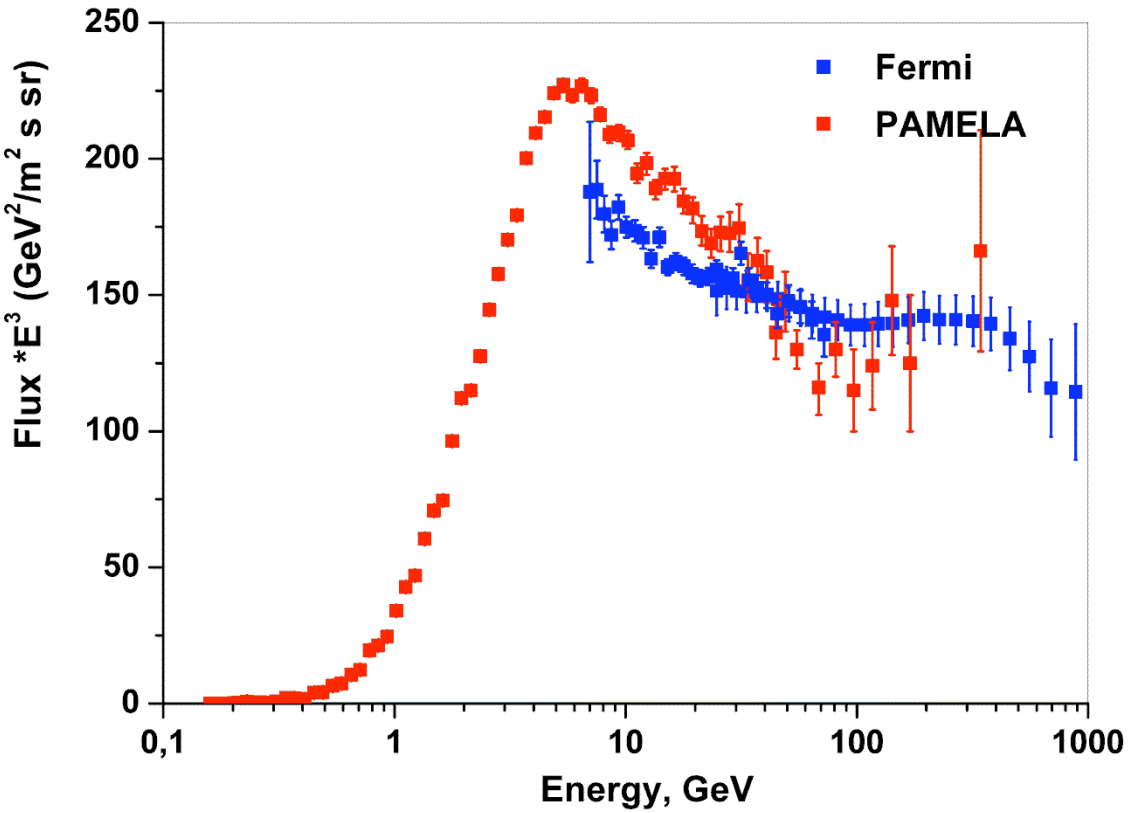
Low energy part of electron spectrum



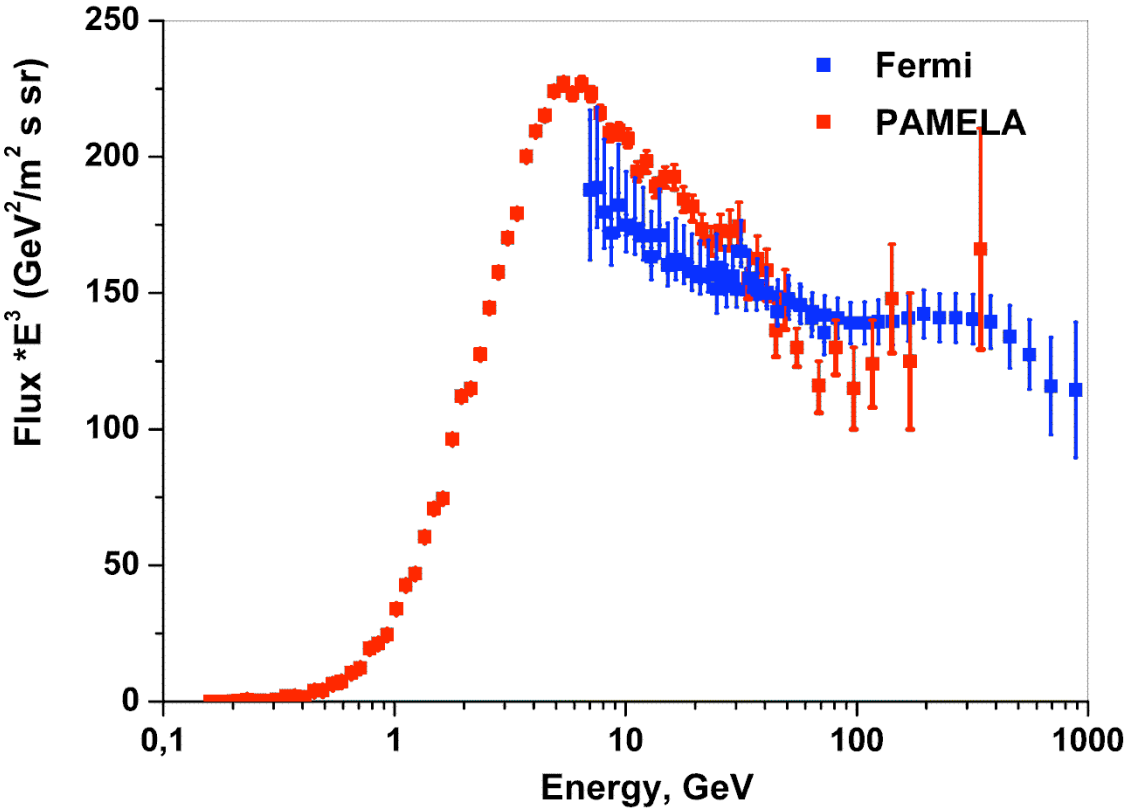
Balloon experiment
ApJ 1969 , 158,771
Flight was in 1965-1966
during minimum of solar activity
A<0
Φ~500MV

PAMELA in 2006-2008:
A<0
Φ~550-400MV


Flux *E^3 (GeV^2/m^2 s sr)
1000
100
10
1
1
10
100
1000
Energy, GeV
Fermi
PAMELA
positrons



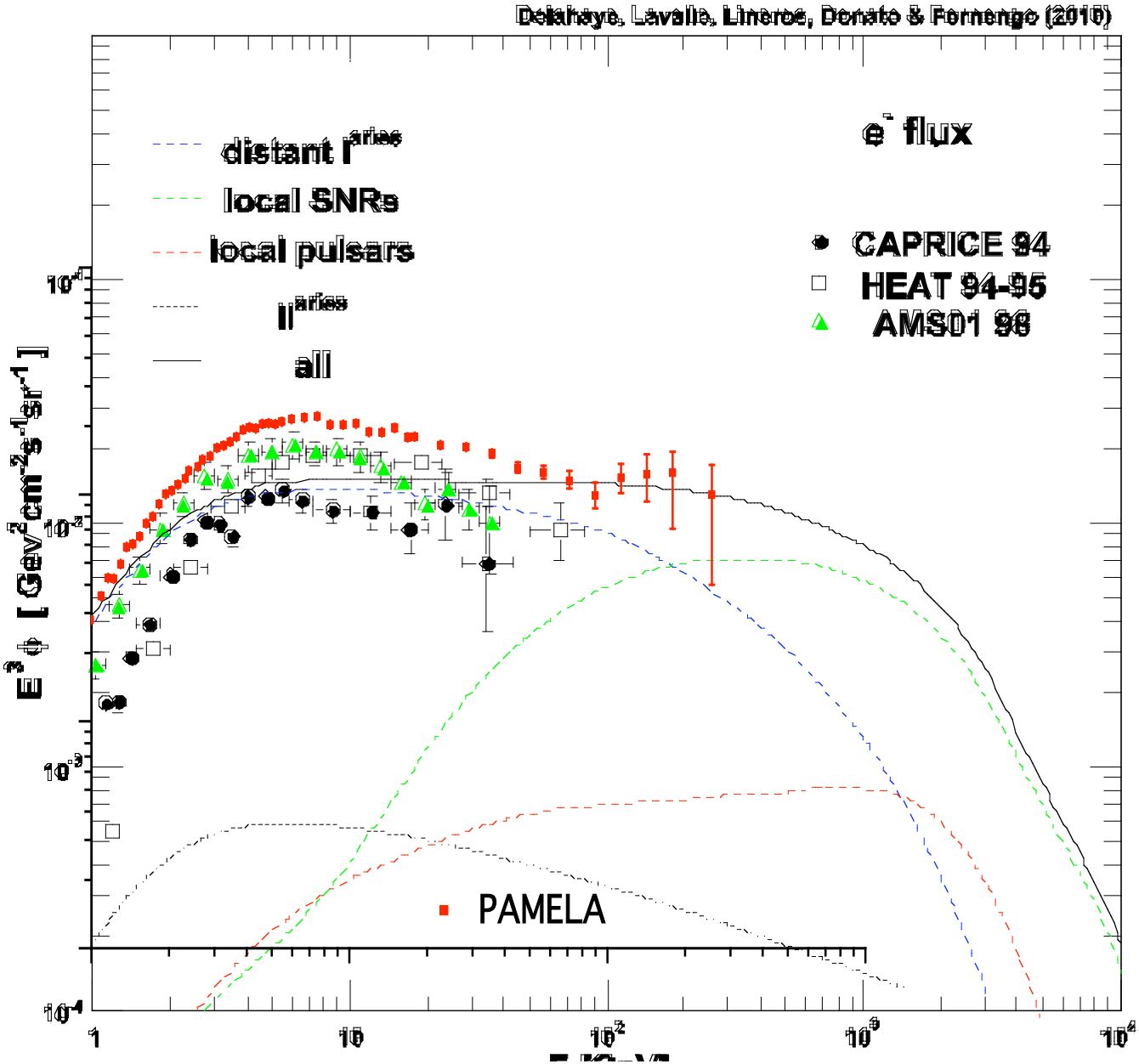
Low energy Fermi points from “Fermi symposium, Washington, Nov. 2-5, 2009”


Fermi
PAMELA
Flux *E^3 (GeV^2/m^2 s sr)
Energy, GeV
250
200
150
100
50
0
0,1
1
10
100
1000

Comparison of methods

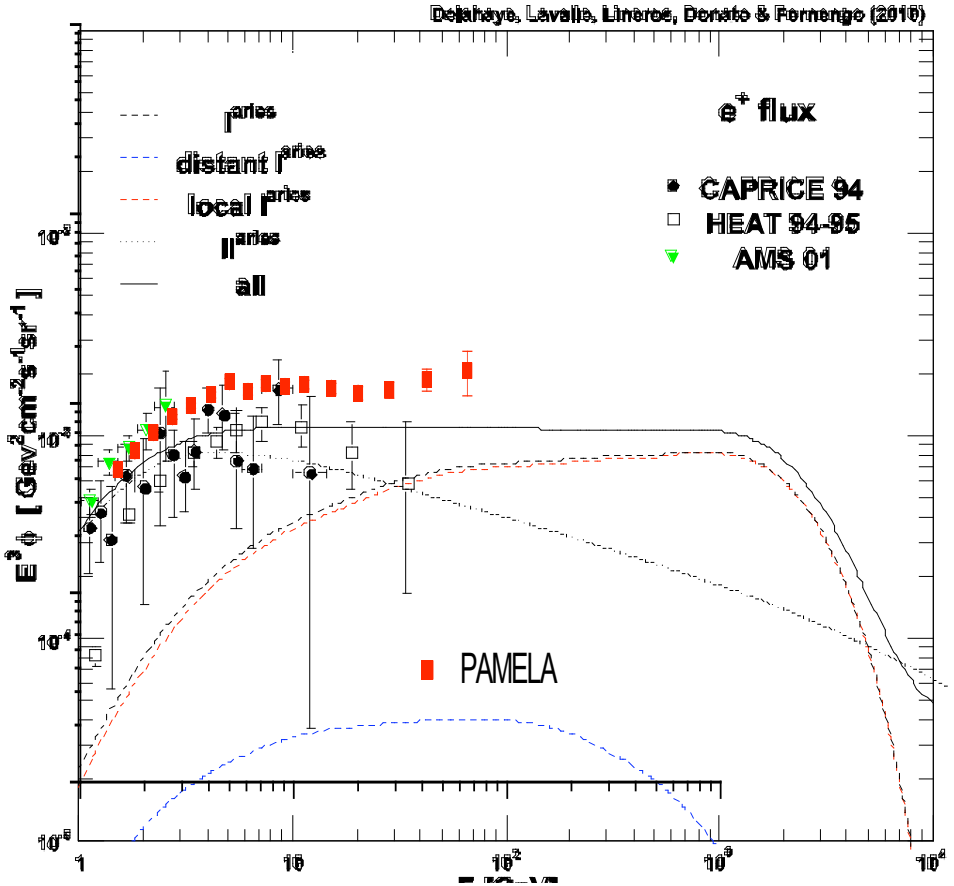
method	Energy, GeV	particles	comments
1.Strong track, loose calorimeter selection	0.1-200	electrons	Proton background limits max energy of electrons ~200GeV. Constant efficiency from ~2 до ~70GeV
Track & Calorimeter selection , Energy –rigidity match	0.1-400	Electrons and positrons separately	Minimal background, rejection of protons ~10^5 · Efficiency decreases with energy due to tracker resolution
3.Strong calorimeter selection + Sign from track	20-800 ~1- 400	Electrons-positrons sum electrons	Maximal energy, no electron/positron separation, possible residual background. Rejection of protons 10^3 -10^4

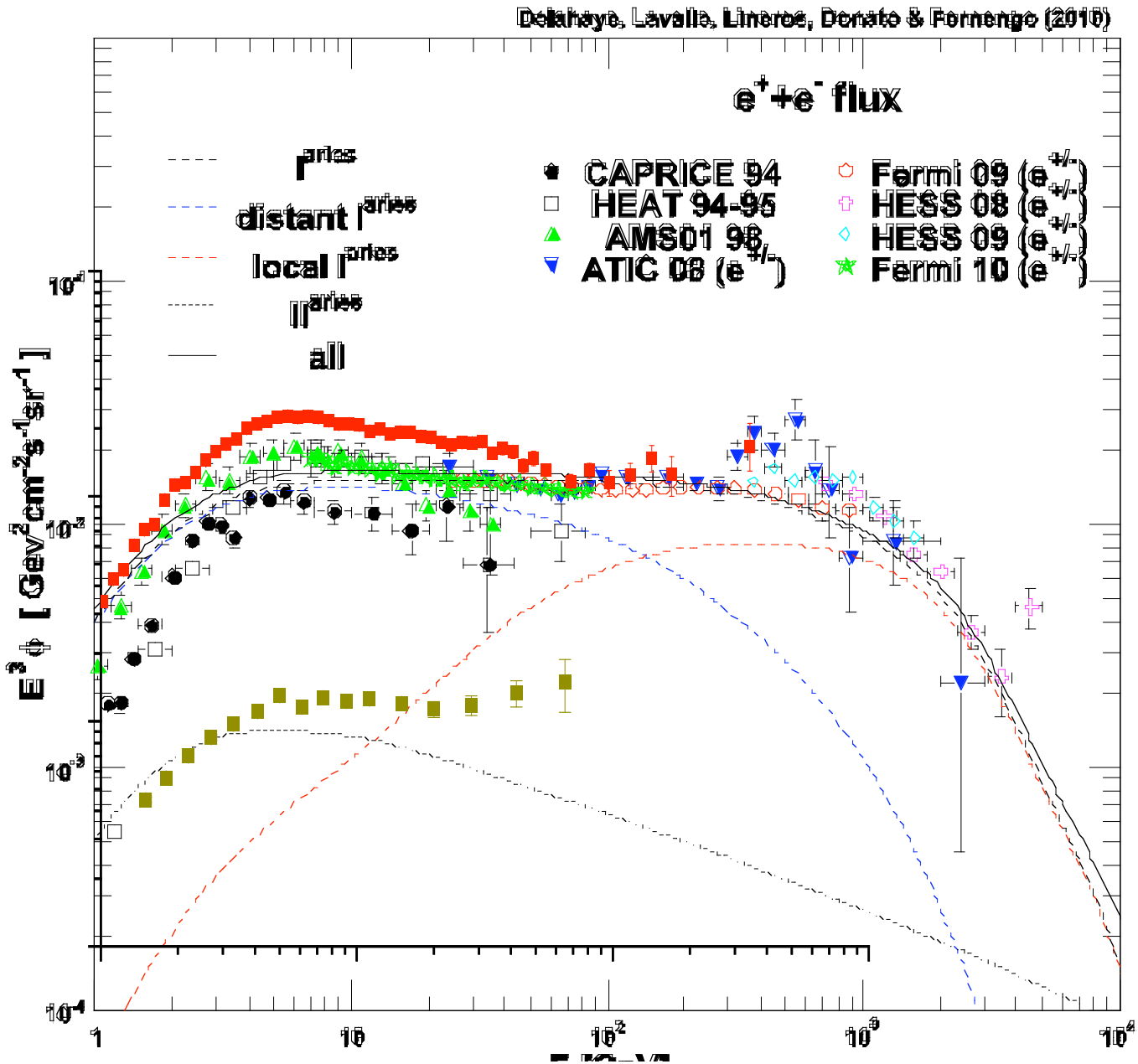
e^- flux



Galactic electrons and positrons at the Earth: new estimate of the primary and secondary fluxes
T. Delahaye, J. Lavall, R. Lineros, F. Donato, and N. Fornengo
ArXiv:1002.1910

e^+ flux


Delahaye, Lavalle, Lineros, Donato & Fornengo (2010)
e^+ flux
CAPRICE 94
HEAT 94-95
AMS 01
PAMELA
all
$E^3\,\Phi$ [GeV^{2}cm^{-2}s^{-1}sr^{-1}]

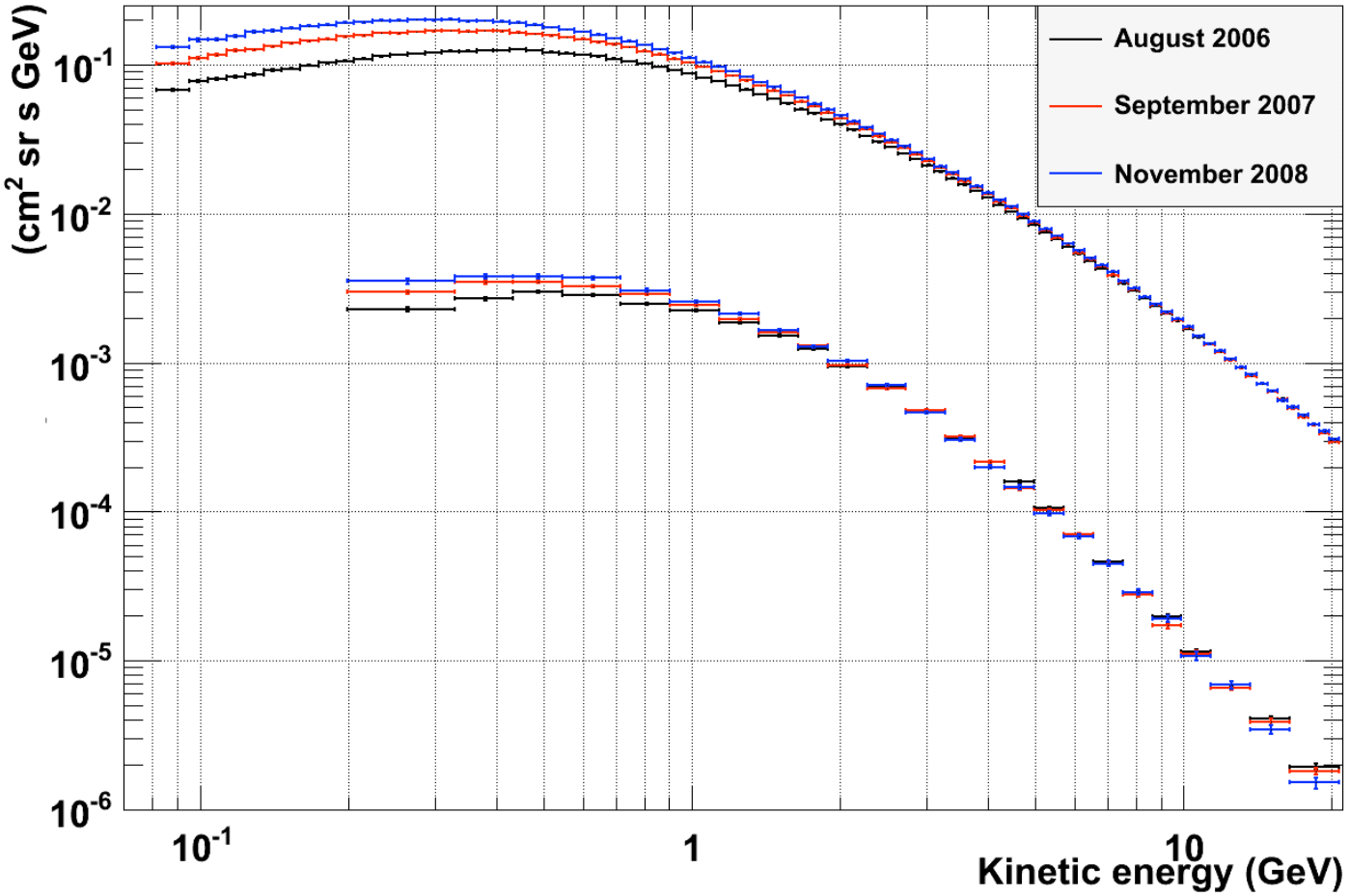

Delahaye, Lavalle, Lineros, Donato & Fornengo (2010)
e+ +e- flux
CAPRICE 94
HEAT 94-95
AMS01 98
ATIC 08 (e+/-)
Fermi 09 (e+/-)
HESS 08 (e+/-)
HESS 09 (e+/-)
Fermi 10 (e+/-)
all
E³ Φ [GeV² cm⁻² s⁻¹ sr⁻¹]

Conclusion

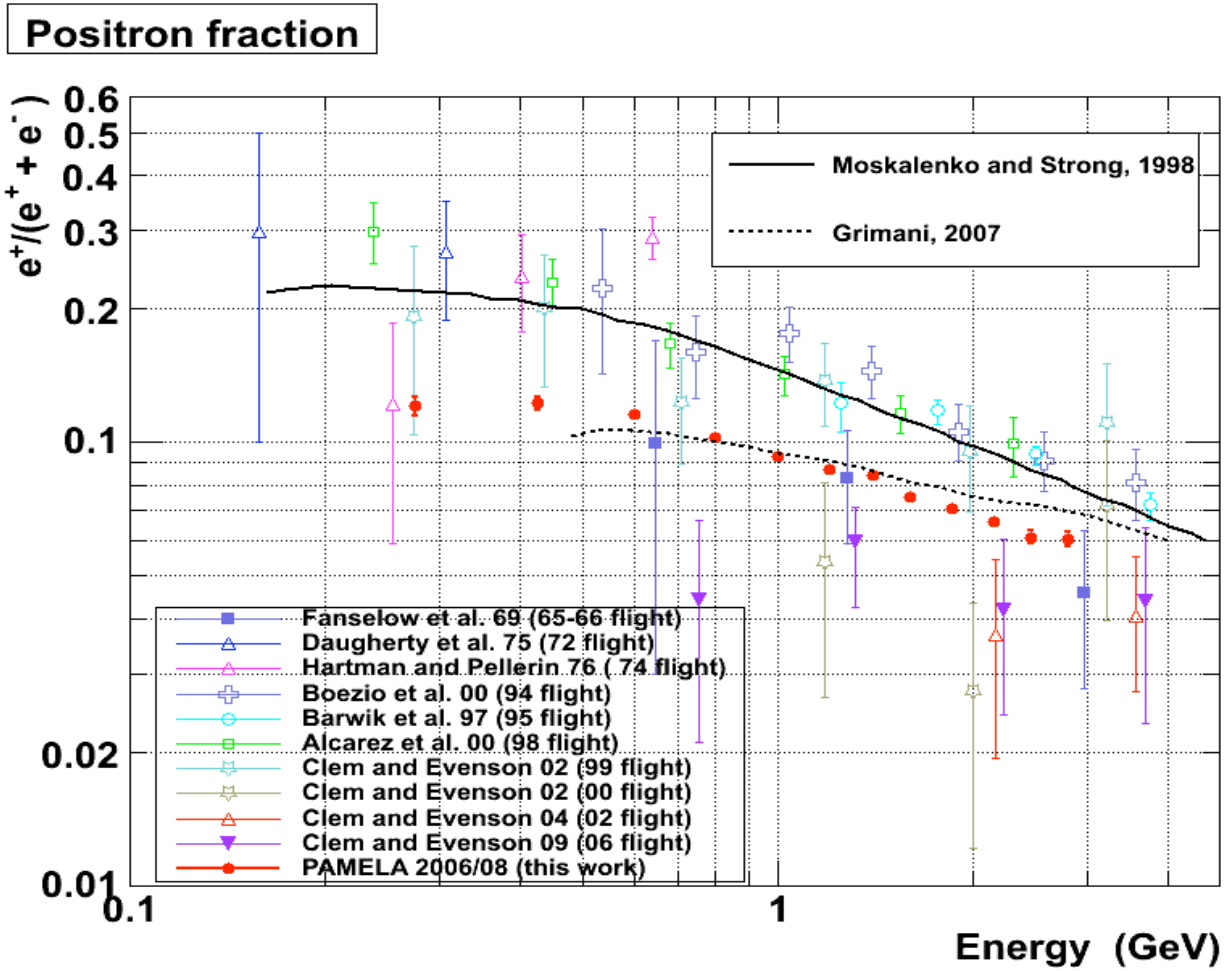
- PAMELA has been in orbit and collected data for ~1500 days. >3 10^9 triggers registered, and >20 TB of data has been down-linked.
- The instrument provides good electron and positron separation with rejection of protons about 10^5
- Electron /positron spectrum obtained by different methods are in good agreement
- Preliminary estimations shows that positron spectrum appears to be more harder than “conventional ” diffusive model predicted.
- Analysis ongoing to finalize the electron & positron spectra

Thank you

Proton and electron spectra

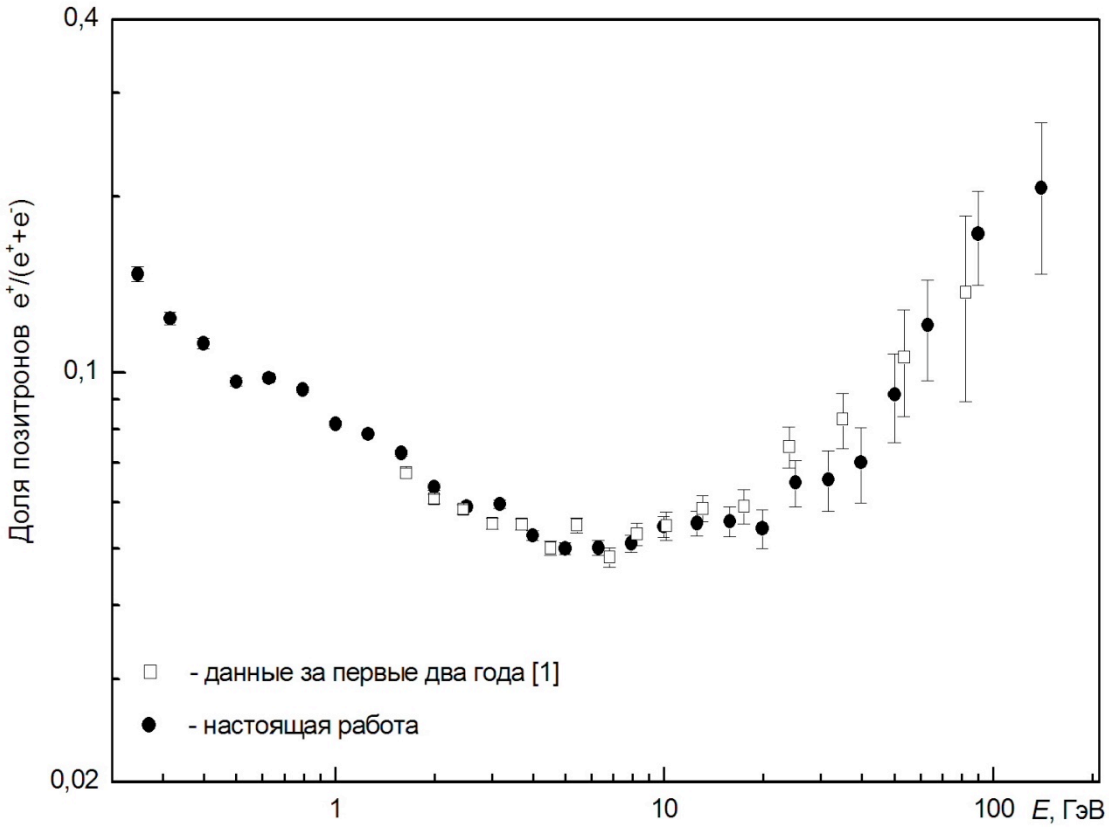


PAMELA positron fraction at low energy



Filled markers: A- polarity epoch
Open markers: A+ polarity epoch

Positron ratio

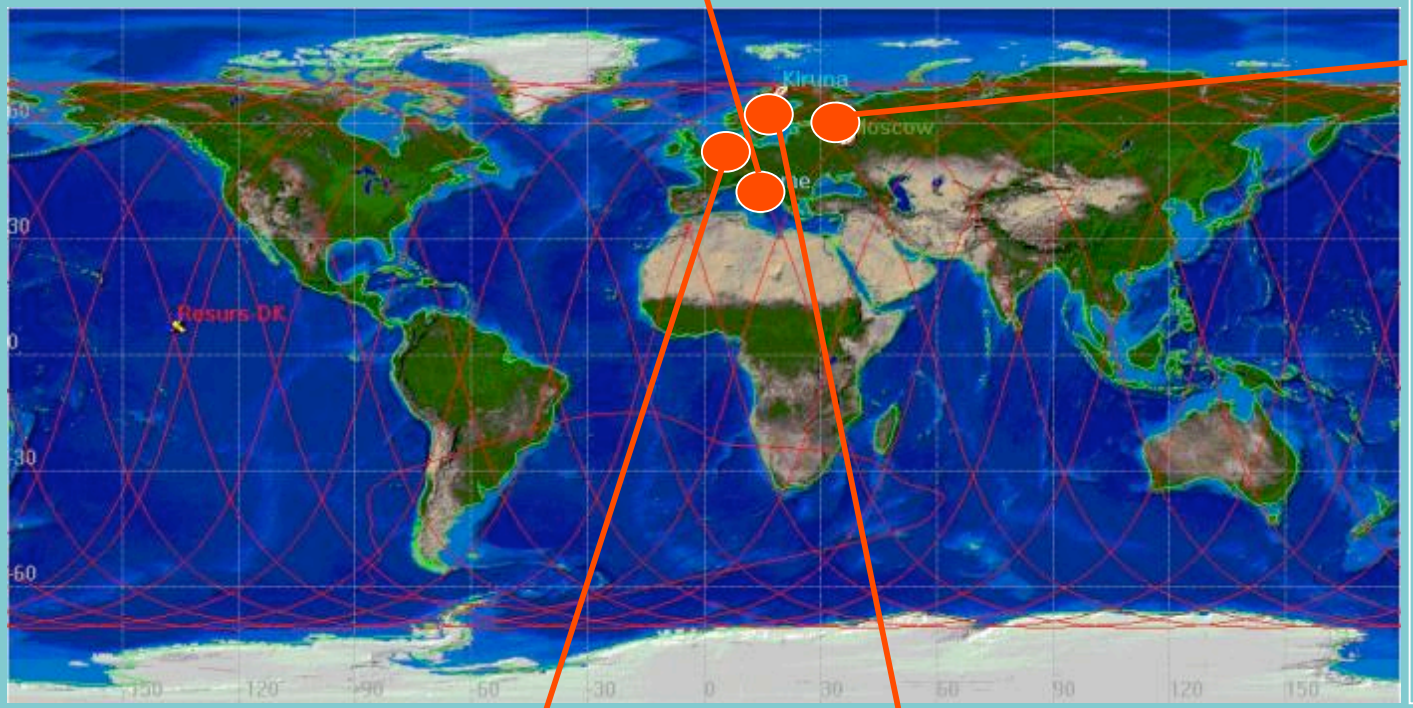


[1] O.Adriani et al. // Nature 2009, V.458,P.607

PAMELA collaboration

Italy:

Bari, Florence, Frascati, Naples, Rome, Trieste, CNR, Florence



Russia:

Moscow

Moscow

St. Petersburg

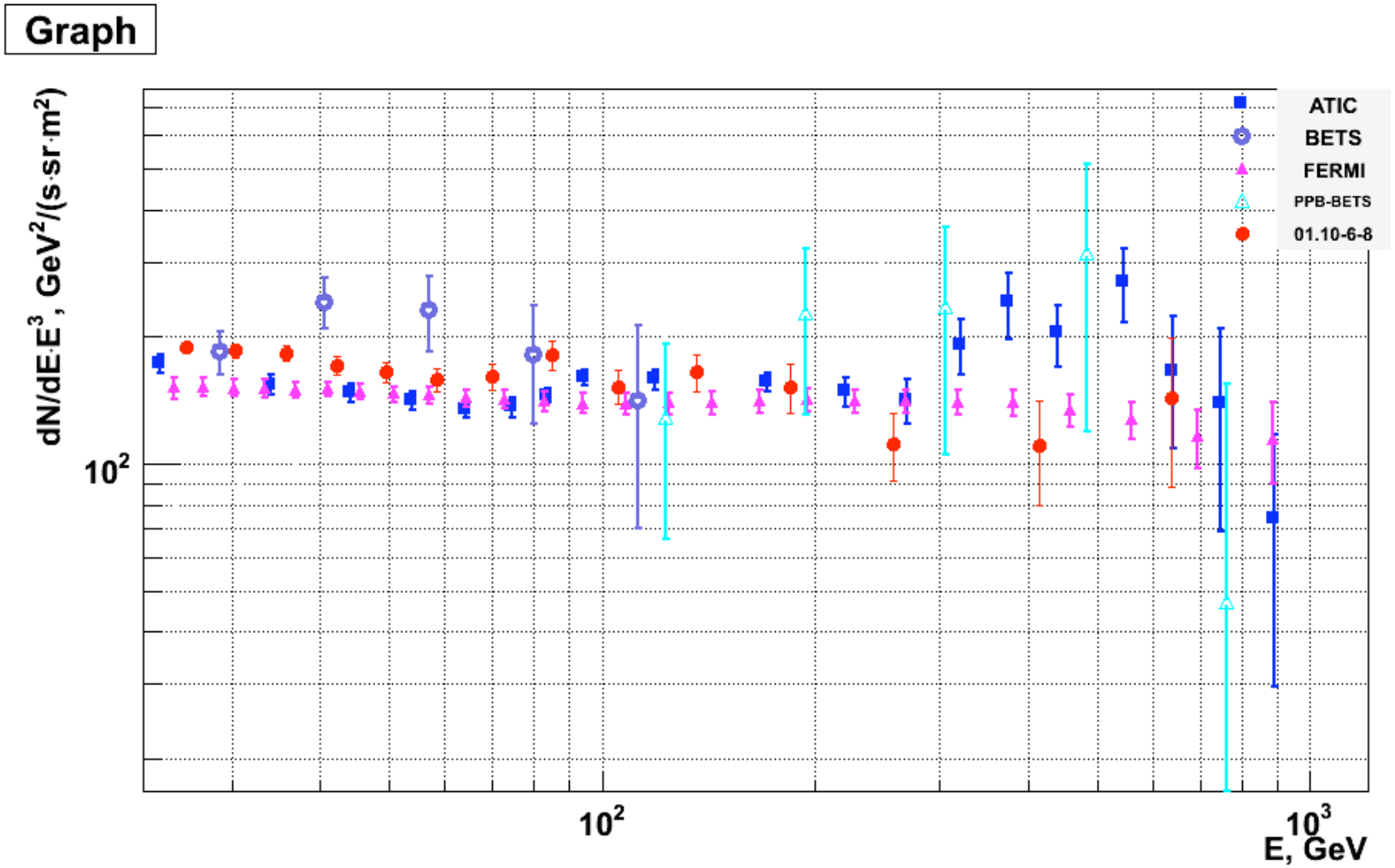
Germany:

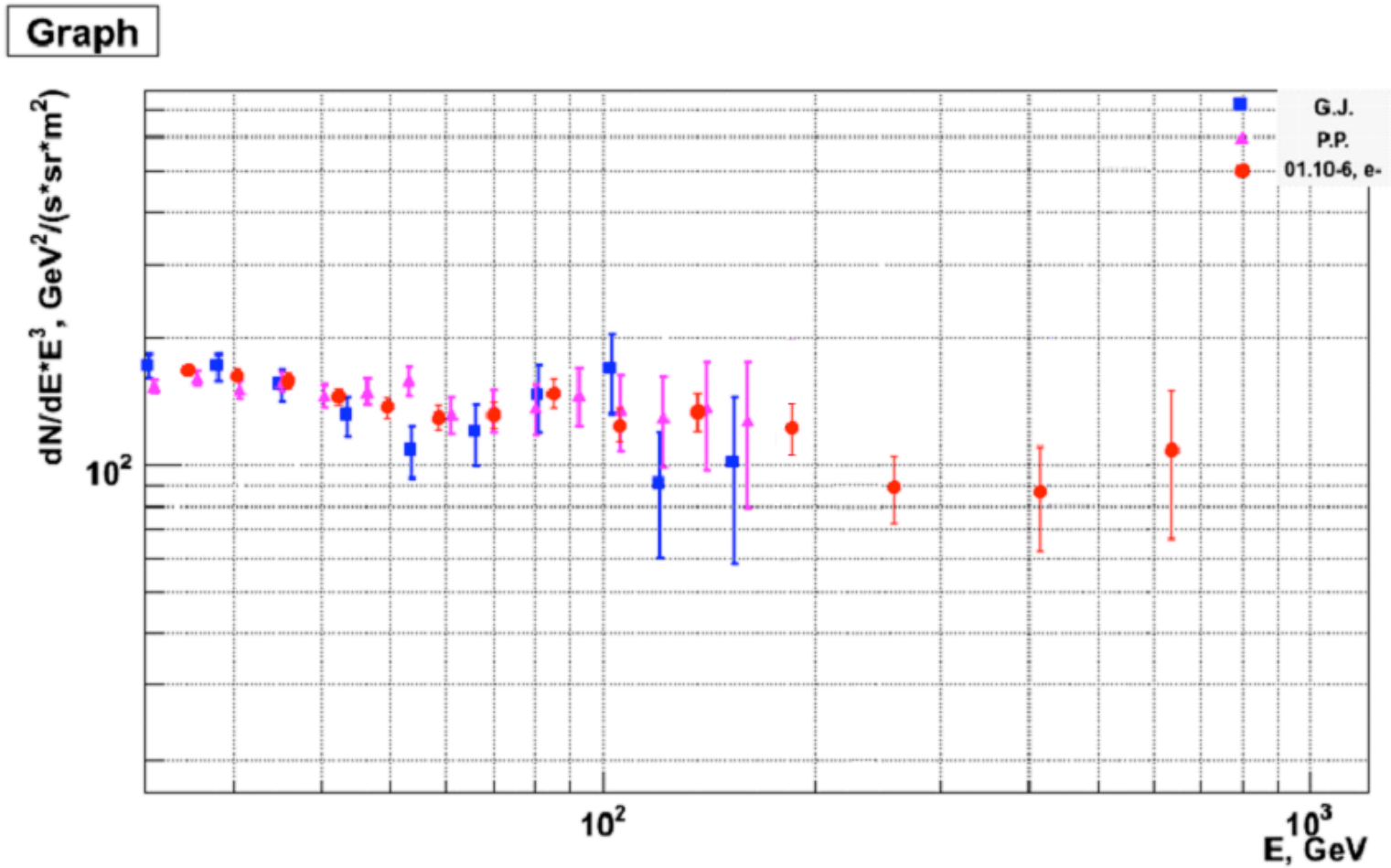
Siegen

Sweden:

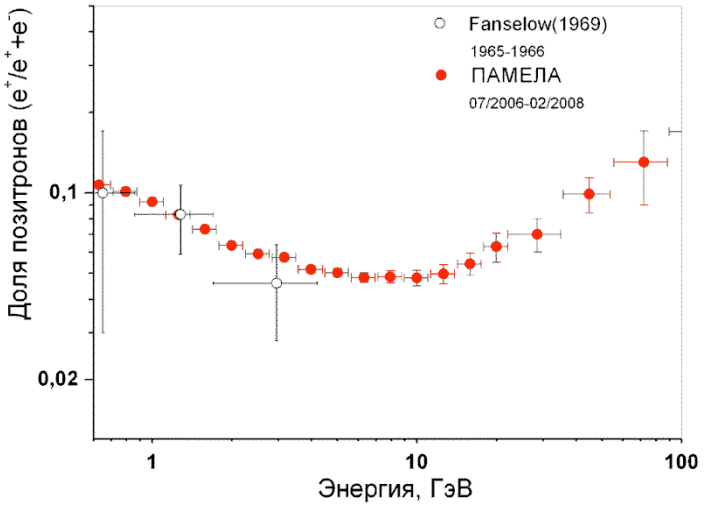
KTH, Stockholm

electron+positron spectrum with calorimeter



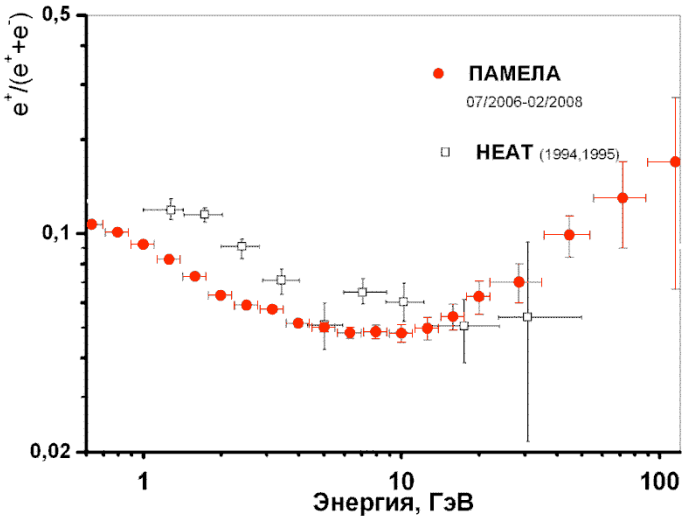

Graph
dN/dE*E^3, GeV^2/(s*sr*m^2)
10^2
10^2
10^3
E, GeV
G.J.
P.P.
01.10-6, e-

Отношение $e^+/(e^-+e^+)$



Сравнение результатов с данными баллонного эксперимента чикагской группы. ApJ 1969 , 158,771
Полеты проводились в 1965-1966г во время солнечного минимума A<0 Ф~500МВ

PAMELA A<0 Ф~550-450МВ



Сравнение результатов с данными баллонного эксперимента HEAT A>0 Ф~600МВ