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Joint ICTP-INFN-SISSA Conference: Topical Issues in LHC Physics

29 June - 2 July, 2009

Cosmic Antiparticles and Dark Matter Indirect Studies with the PAMELA Space Experiment

Mirko BOEZIO

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Italy

Cosmic Antiparticles and Dark Matter Indirect Studies with the PAMELA Space Experiment

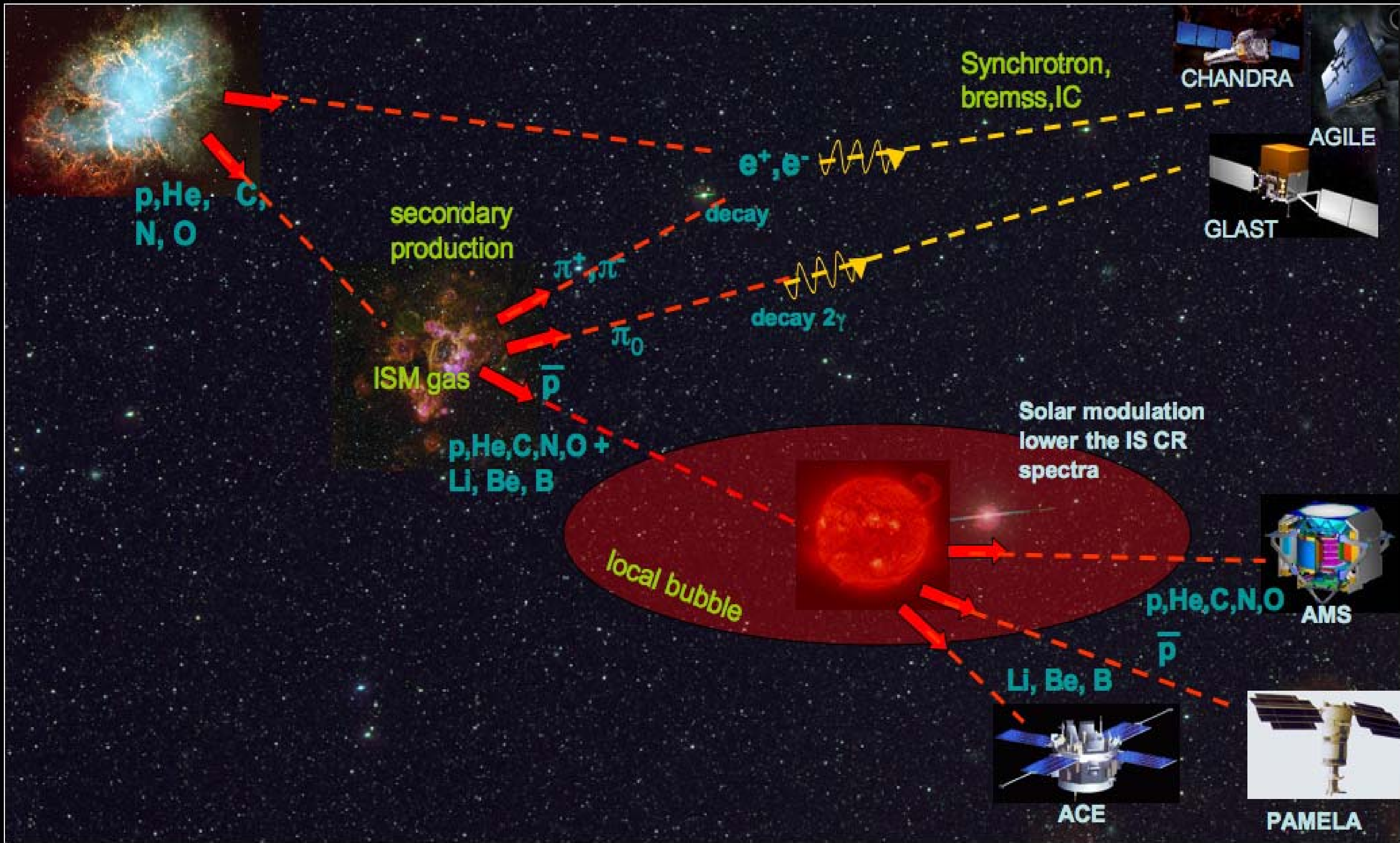
Mirko Boezio
INFN Trieste, Italy

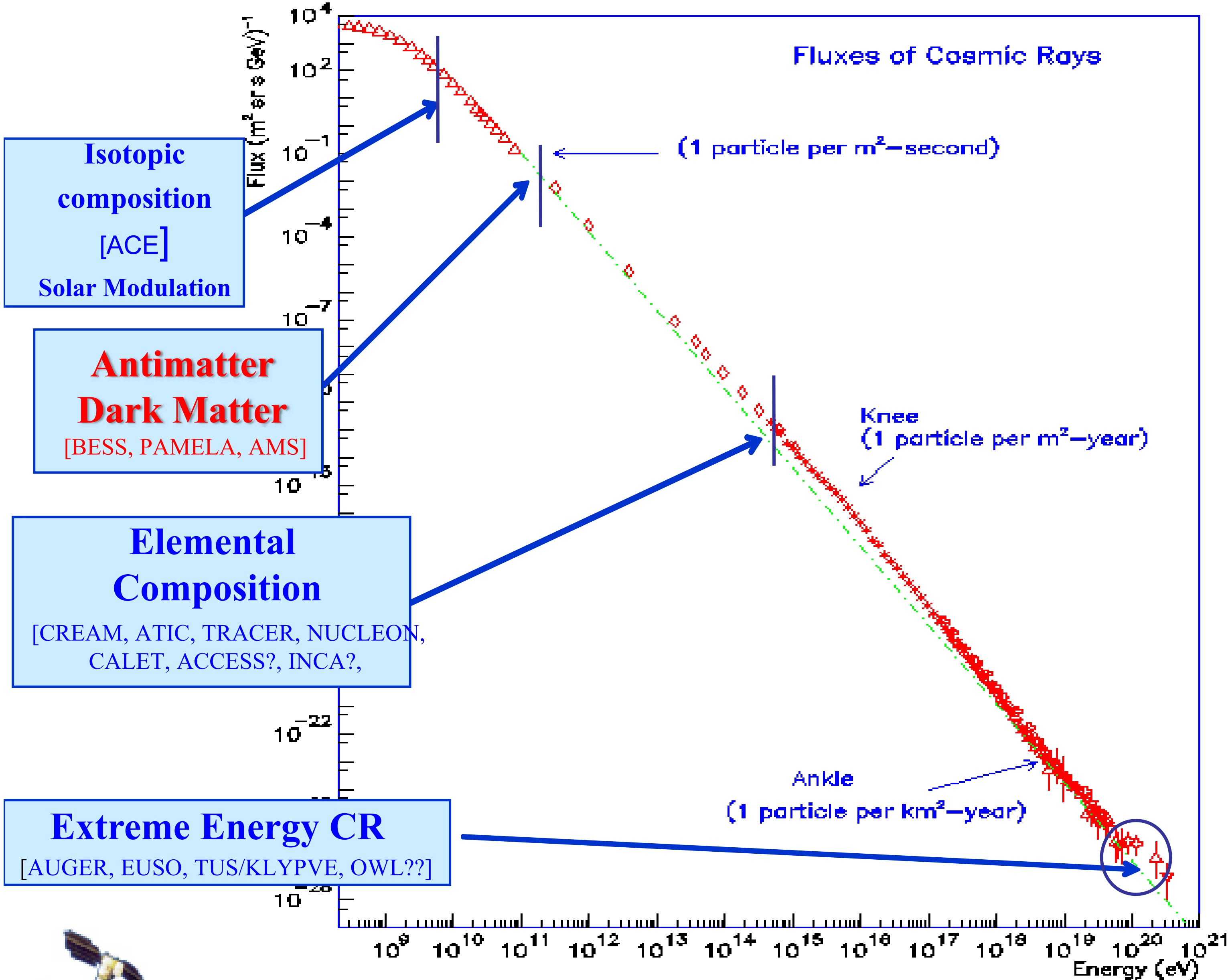
On behalf of the PAMELA collaboration

Joint ICTP-INFN-SISSA Conference

July 2nd 2009

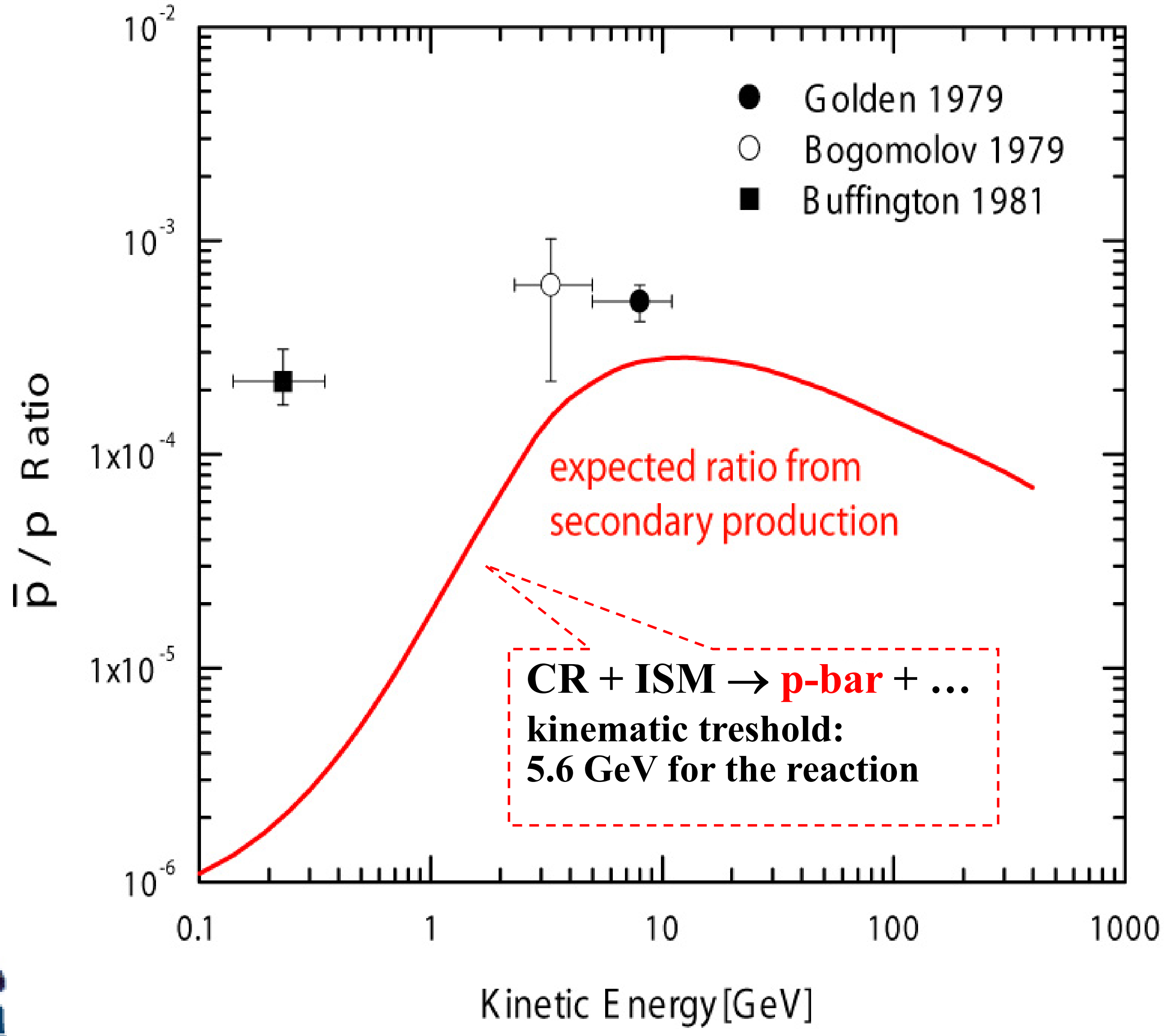
COSMIC RAYS PRODUCTION MECHANISMS



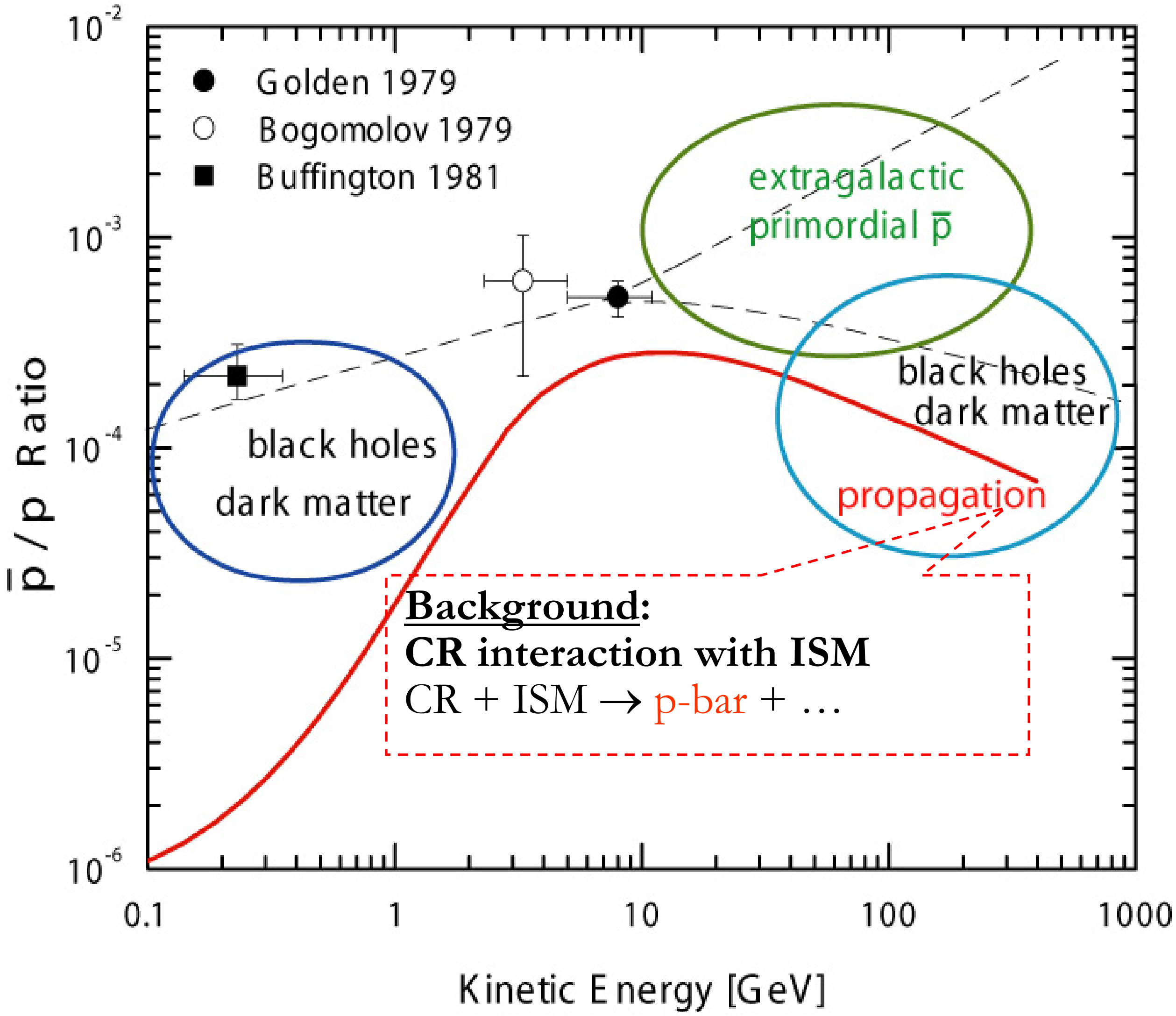


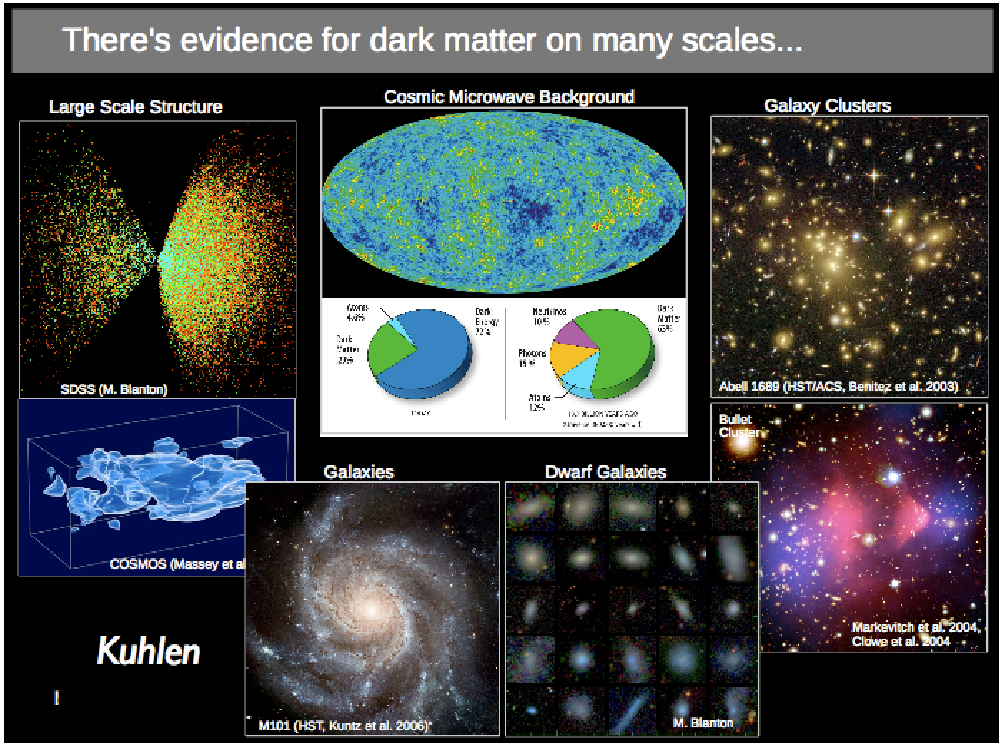
Fluxes of Cosmic Rays
(1 particle per m²–second)
Knee
(1 particle per m²–year)
Ankle
(1 particle per km²–year)
Flux (m² sr s GeV)⁻¹
Energy (eV)
Isotopic composition
[ACE]
Solar Modulation
Antimatter
Dark Matter
[BESS, PAMELA, AMS]
Elemental Composition
[CREAM, ATIC, TRACER, NUCLEON, CALET, ACCESS?, INCA?,
Extreme Energy CR
[AUGER, EUSO, TUS/KLYPVE, OWL??]

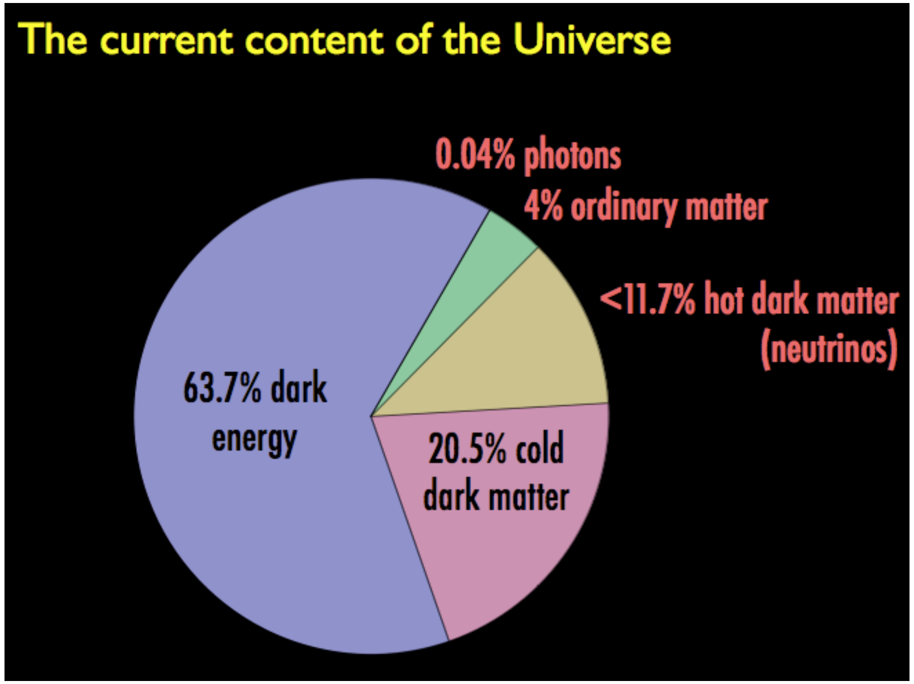
The first historical measurements on galactic antiprotons



The first historical measurements of the $\bar{p}/p$ - ratio and various Ideas of theoretical Interpretations





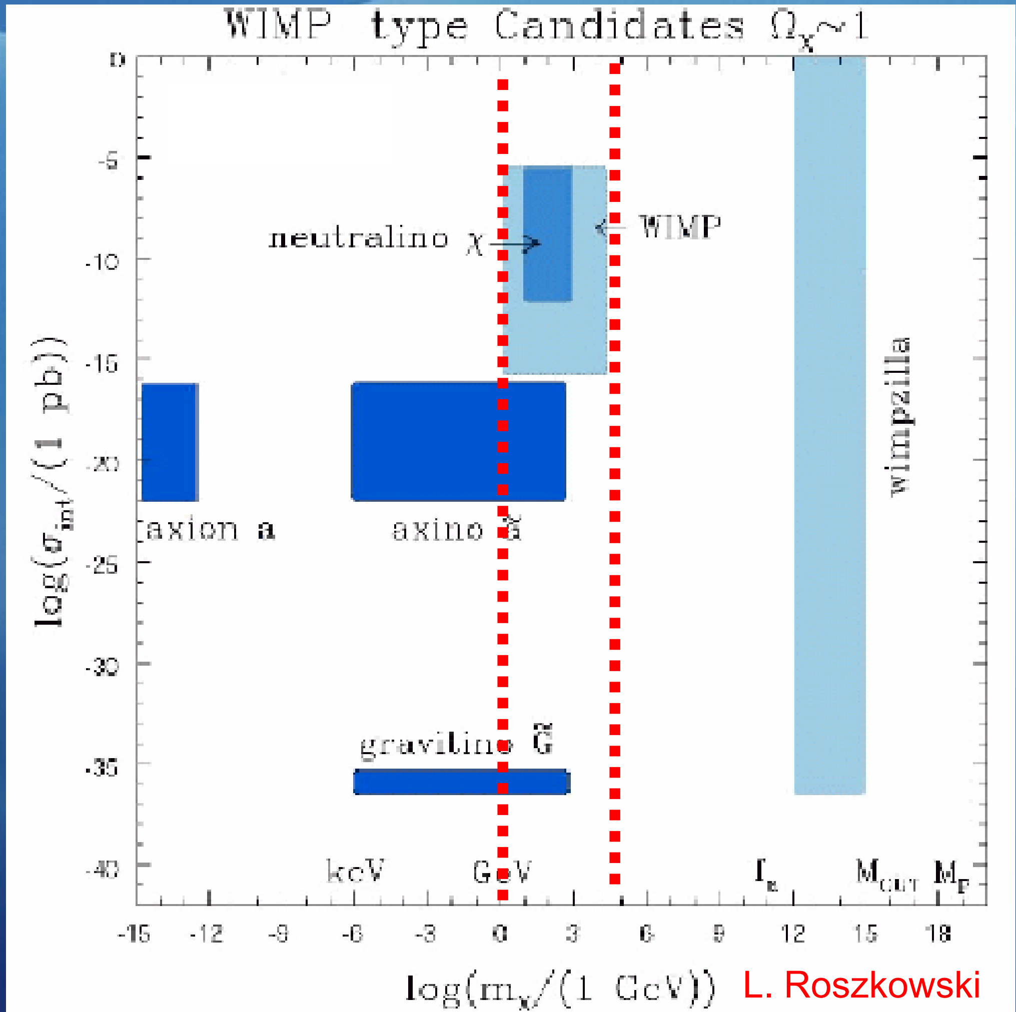


P. Gondolo, IDM 2008

Dark Matter Candidates

- •Kaluza-Klein DM in UED
- •Kaluza-Klein DM in RS
- •Axion
- •Axino
- •Gravitino
- •Photino
- •SM Neutrino
- •Sterile Neutrino
- •Sneutrino
- •Light DM
- •Little Higgs DM
- •Wimpzillas
- •Q-balls
- •Mirror Matter
- •Champs (charged DM)
- •D-matter
- •Cryptons
- •Self-interacting
- •Superweakly interacting
- •Braneworld DM
- •Heavy neutrino
- •NEUTRALINO
- •Messenger States in GMSB
- •Branons
- •Chaplygin Gas
- •Split SUSY
- •Primordial Black Holes

$$v(r) = \sqrt{\frac{GM(r)}{r}}$$

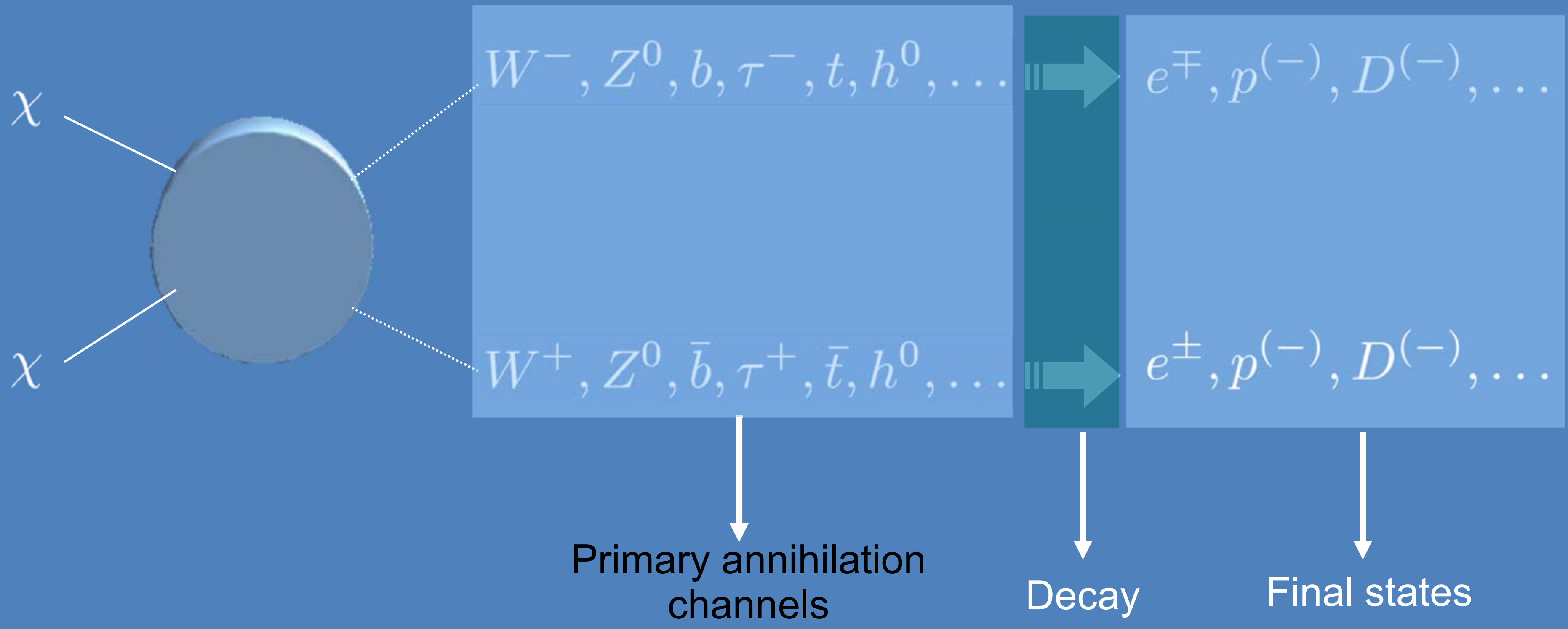


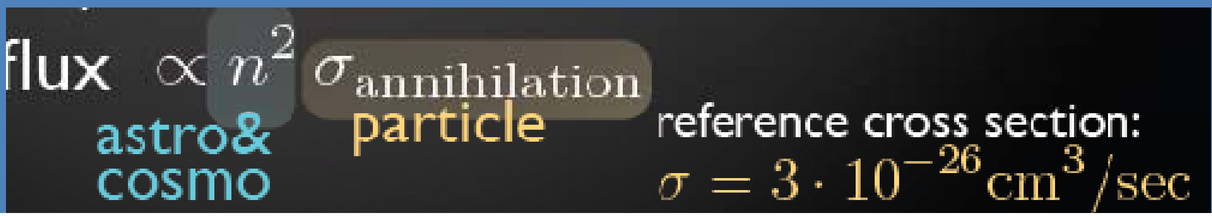
See talks by M. Cirelli and G. Kane

DM annihilations

See talks by M. Cirelli and G. Kane

DM particles are stable. They can annihilate in pairs.





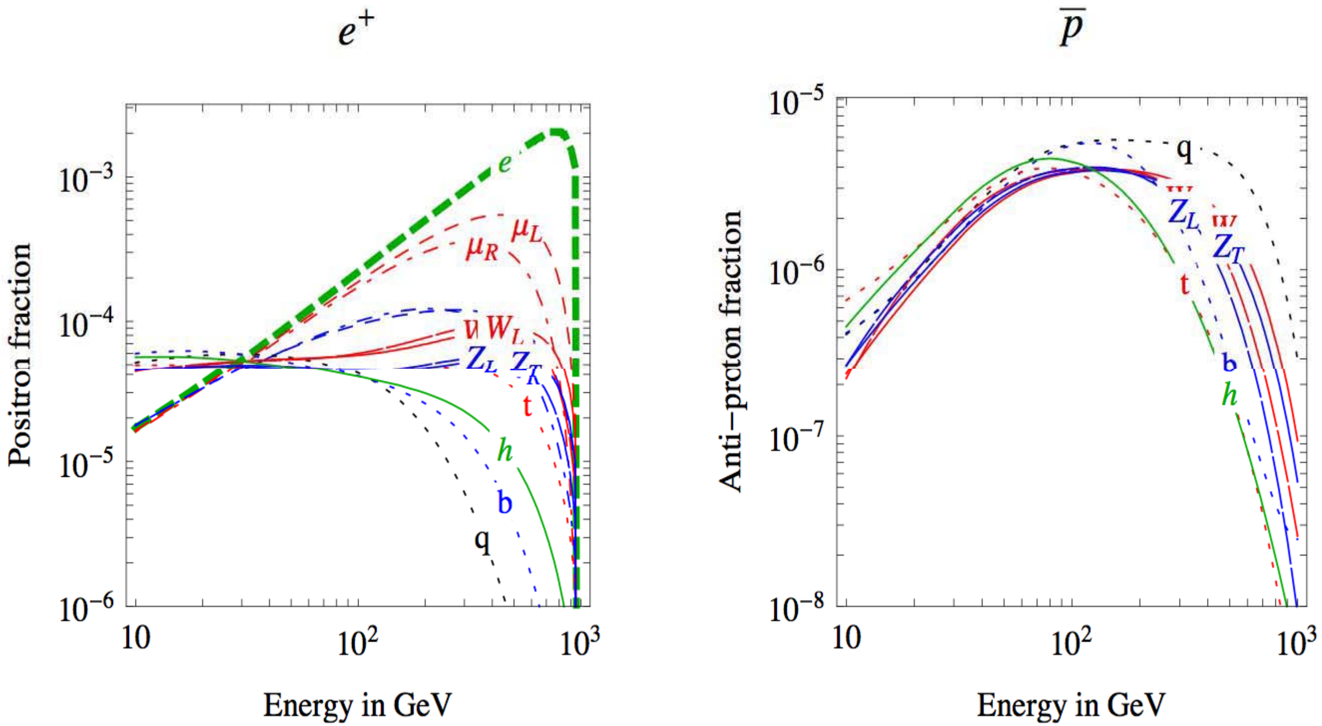
$\sigma_a = \langle \sigma v \rangle$

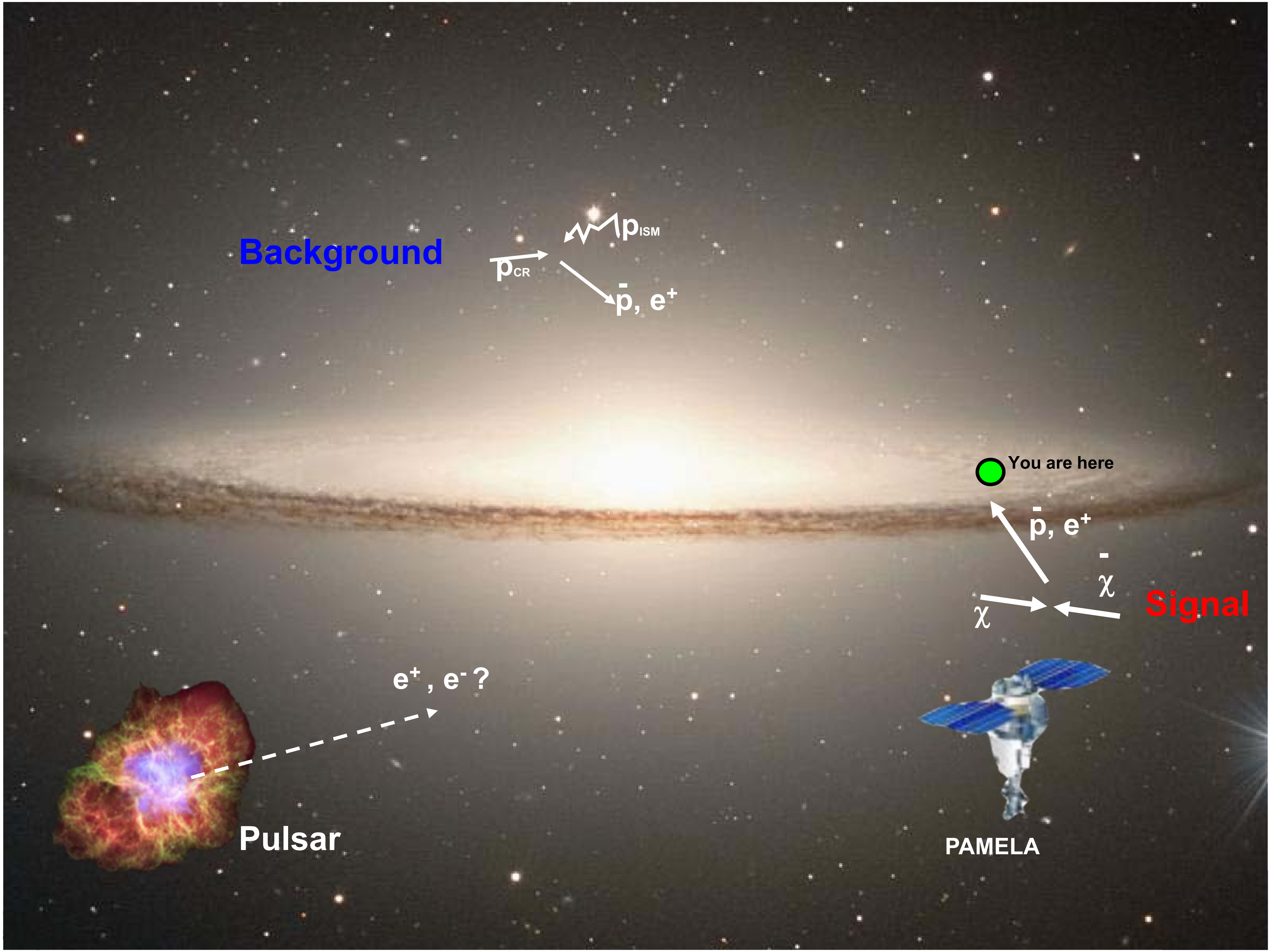
DM annihilations

Resulting spectrum for positrons and antiprotons
M_{WIMP}= 1 TeV

The flux shape is completely determined by:

1) WIMP mass
2) Annihilations channels

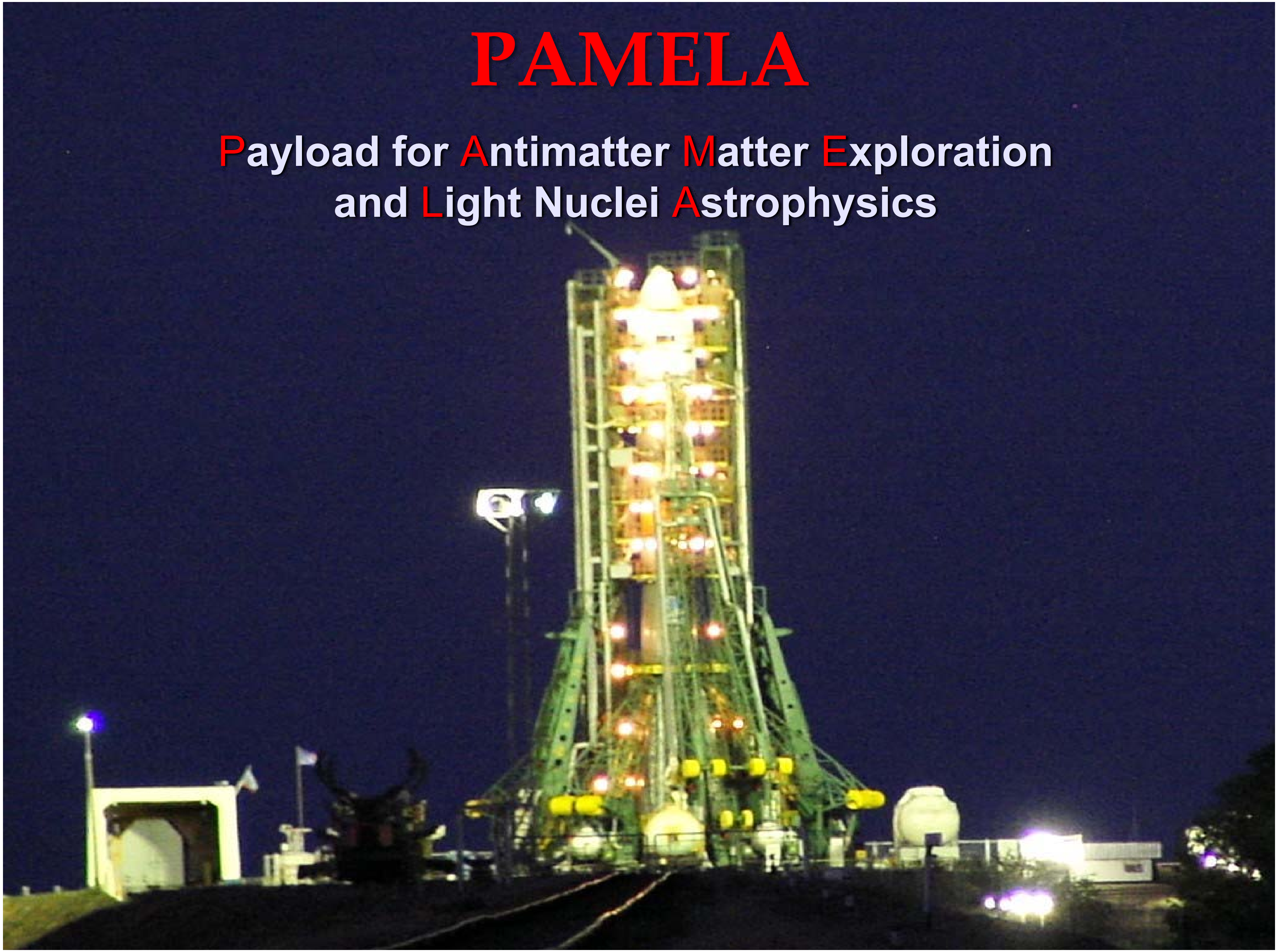




Background
p_{ISM}
p_{CR}
$\bar{p}$, e^+
You are here
$\bar{p}$, e^+
$\bar{\chi}$
χ
Signal
e^+ , e^- ?
Pulsar
PAMELA

PAMELA

Payload for Antimatter Matter Exploration and Light Nuclei Astrophysics



PAMELA Collaboration

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

Tor Vergata

Russia:

Ioffe Physico-Technical Institute

Moscow
St. Petersburg

Germany: Universität Gesamthochschule Siegen

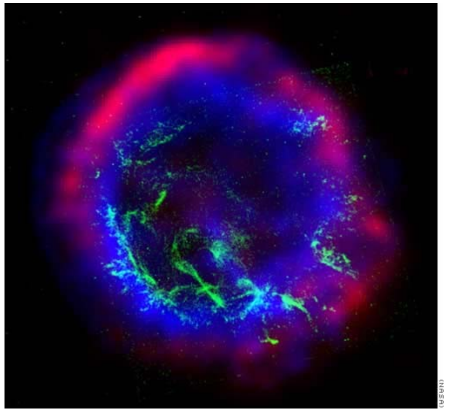
Siegen

Sweden: Kungl Tekniska Högskolan

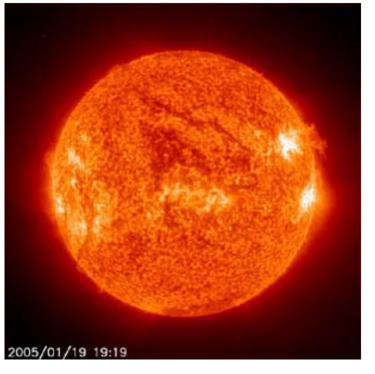
KTH, Stockholm

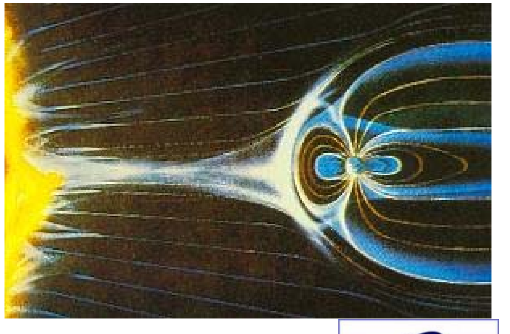
Scientific goals

- Search for dark matter annihilation
- Search for antihelium (primordial antimatter)



- Study of cosmic-ray propagation (light nuclei and isotopes)
- Study of electron spectrum (local sources?)
- Study solar physics and solar modulation
- Study terrestrial magnetosphere





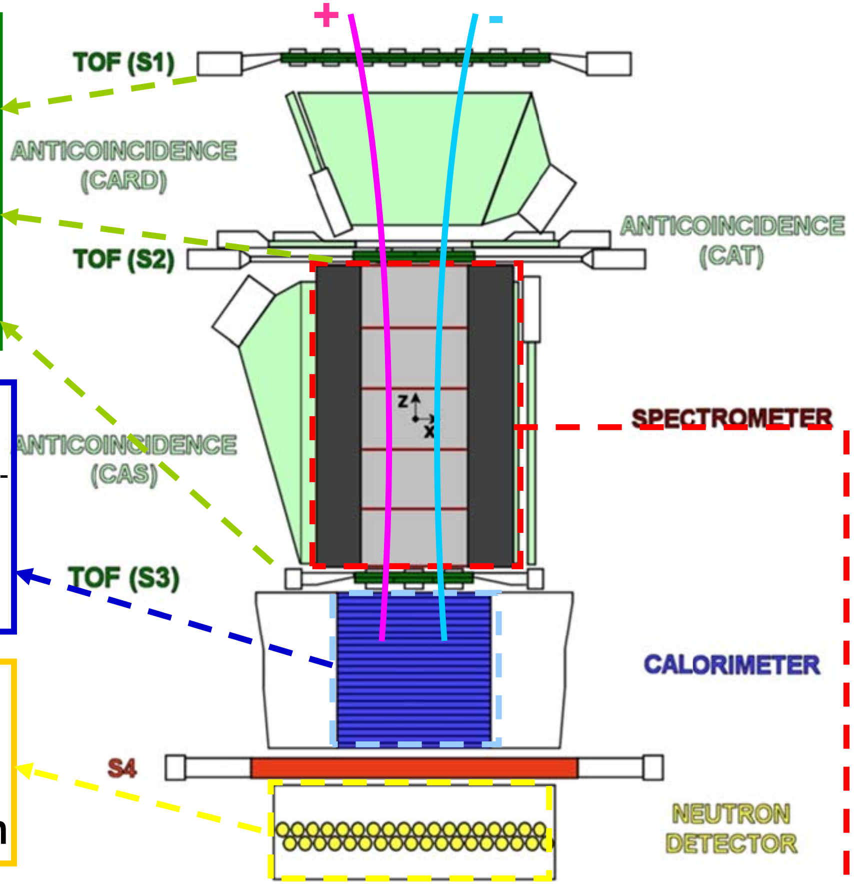
PAMELA detectors

Main requirements → high-sensitivity antiparticle identification and precise momentum measure

Time-Of-Flight
plastic scintillators + PMT:
- Trigger
- Albedo rejection;
- Mass identification up to 1 GeV;
- Charge identification from dE/dX.

Electromagnetic calorimeter
W/Si sampling (16.3 X_0, 0.6 λI)
- Discrimination e+ / p, anti-p / e^- (shower topology)
- Direct E measurement for e^-

Neutron detector
^{3}He tubes + polyethylene moderator:
- High-energy e/h discrimination



GF: 21.5 cm² sr
Mass: 470 kg
Size: 130x70x70 cm³
Power Budget: 360W

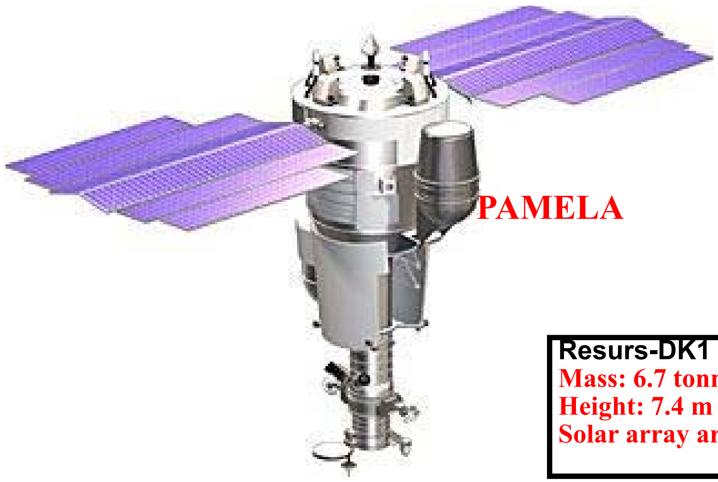
Spectrometer
microstrip silicon tracking system + permanent magnet
It provides:
- *Magnetic rigidity* → R = pc/Ze
- *Charge sign*
- *Charge value from dE/dx*

Design Performance

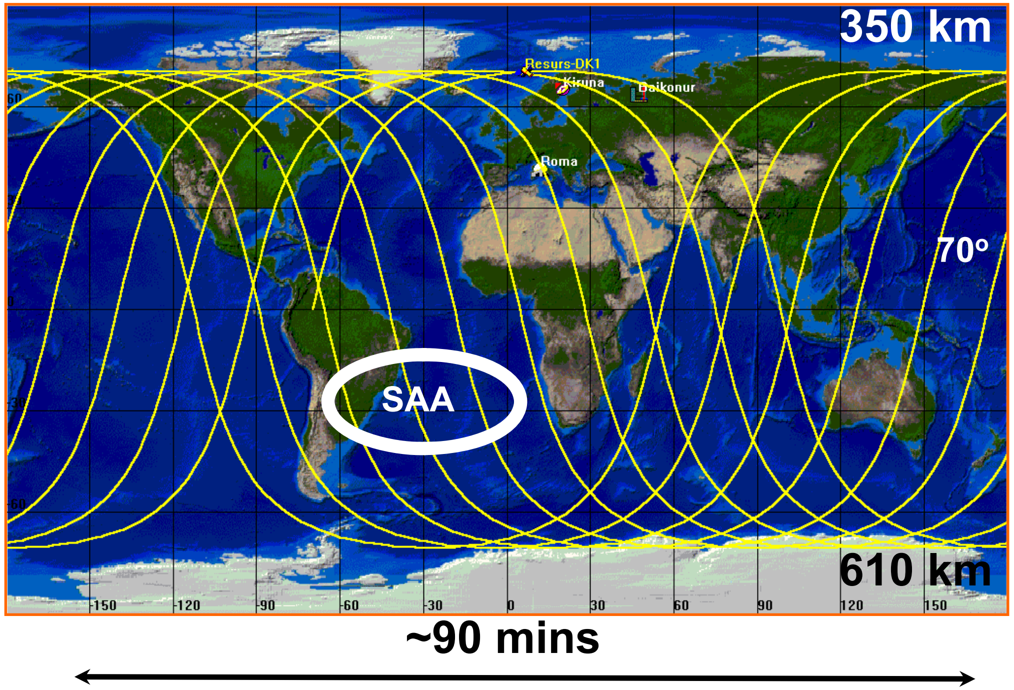
	energy range
• Antiprotons	80 MeV - 150 GeV
• Positrons	50 MeV – 300 GeV
• Electrons	up to 500 GeV
• Protons	up to 700 GeV
• Electrons+positrons	up to 2 TeV (from calorimeter)
• Light Nuclei (He/Be/C)	up to 200 GeV/n
• AntiNuclei search	sensitivity of $3\mathrm{x}10^{-8}$ in $\overline{\mathrm{He}}/\mathrm{He}$

→ Simultaneous measurement of many cosmic-ray species
→ New energy range
→ Unprecedented statistics

Resurs-DK1 satellite + orbit

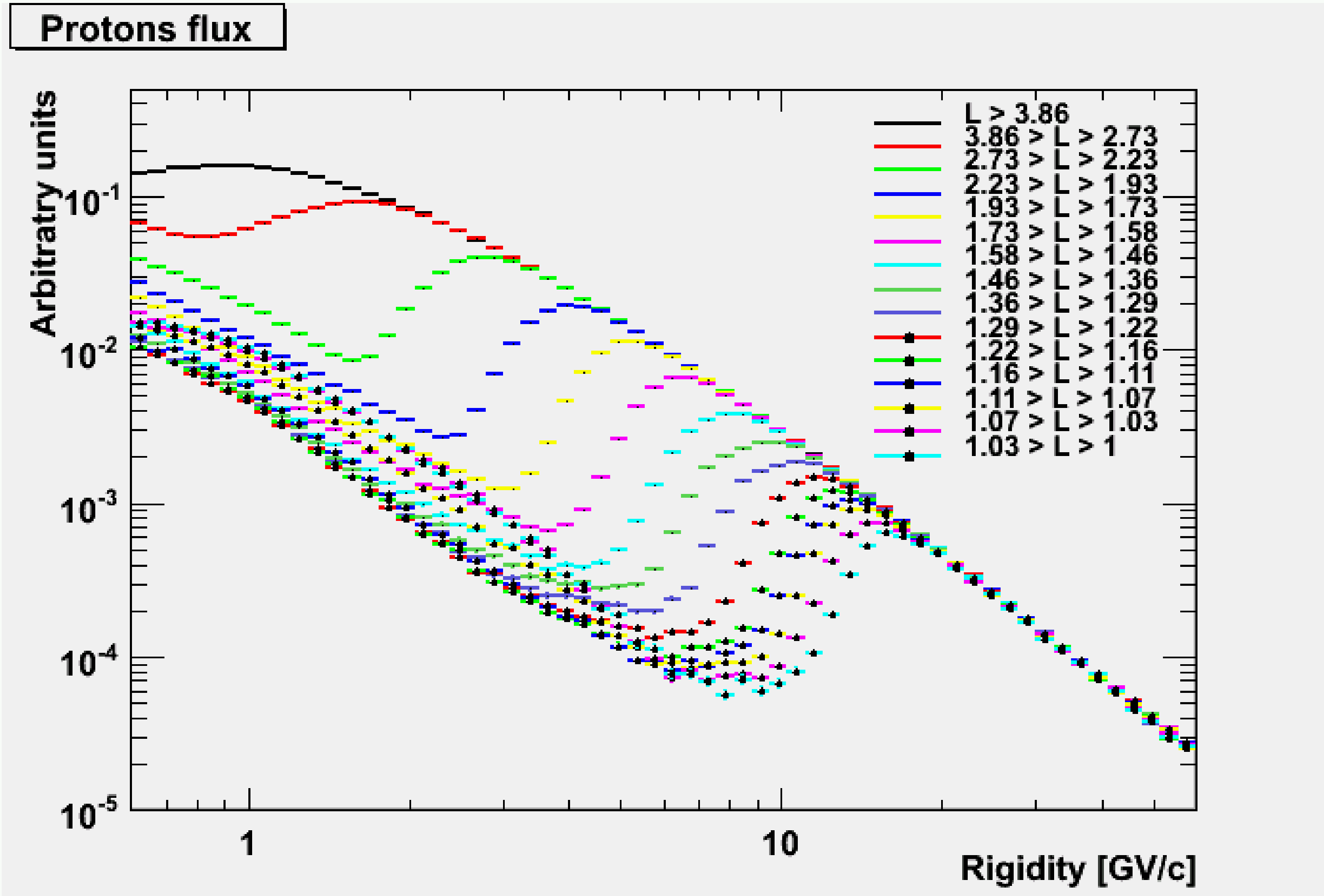


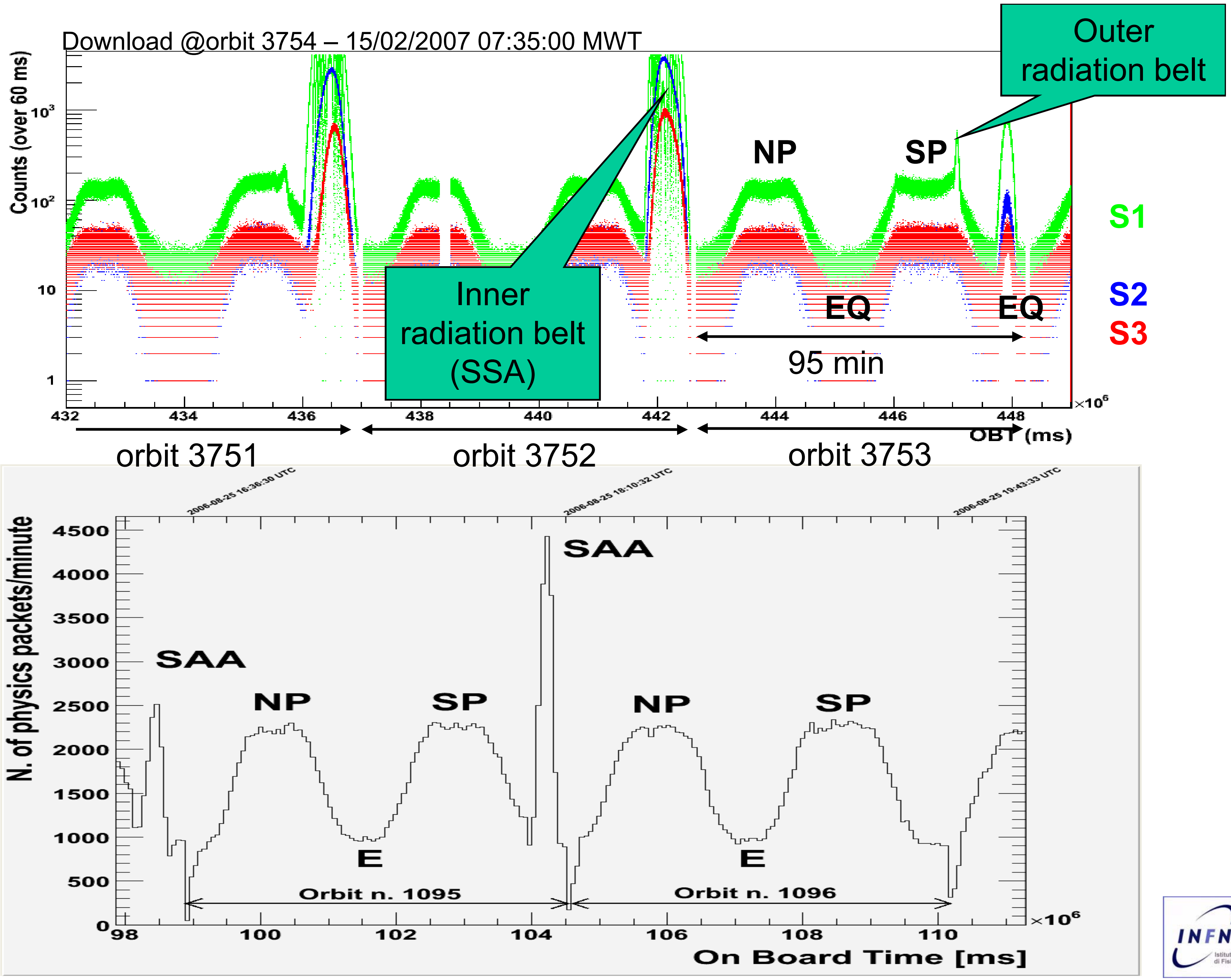
Resurs-DK1
Mass: 6.7 tonnes
Height: 7.4 m
Solar array area: 36 m^2



- Resurs-DK1: multi-spectral imaging of earth's surface
- PAMELA mounted inside a pressurized container
- Lifetime >3 years (assisted, first time last February)
- Data transmitted to NTsOMZ, Moscow via high-speed radio downlink. ~16 GB per day
- Quasi-polar and elliptical orbit (70.0°, 350 km - 600 km)
- Traverses the South Atlantic Anomaly
- Crosses the outer (electron) Van Allen belt at south pole

Subcutoff particles





Download @orbit 3754 – 15/02/2007 07:35:00 MWT
Outer radiation belt
Inner radiation belt (SSA)
Counts (over 60 ms)
NP
SP
EQ
EQ
95 min
S1
S2
S3
OBT (ms)
orbit 3751
orbit 3752
orbit 3753
SAA
SAA
NP
SP
NP
SP
E
E
Orbit n. 1095
Orbit n. 1096
N. of physics packets/minute
On Board Time [ms]
2006-08-25 16:36:30 UTC
2006-08-25 18:10:32 UTC
2006-08-25 19:43:33 UTC

PAMELA milestones

Launch from Baikonur → June 15th 2006, 0800 UTC.

‘First light’ → June 21st 2006, 0300 UTC.

- Detectors operated as expected after launch
- Different trigger and hardware configurations evaluated

→ PAMELA in continuous data-taking mode since commissioning phase ended on July 11th 2006

Main antenna in NTsOMZ

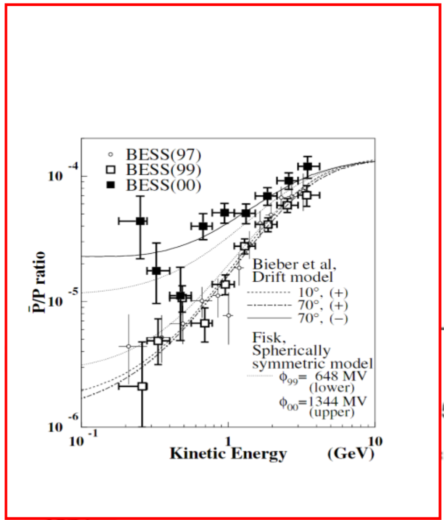
Trigger rate* ~25Hz
Fraction of live time* ~ 75%
Event size (compressed mode) ~5kB
25 Hz x 5 kB/ev → ~ 10 GB/day
(*outside radiation belts)

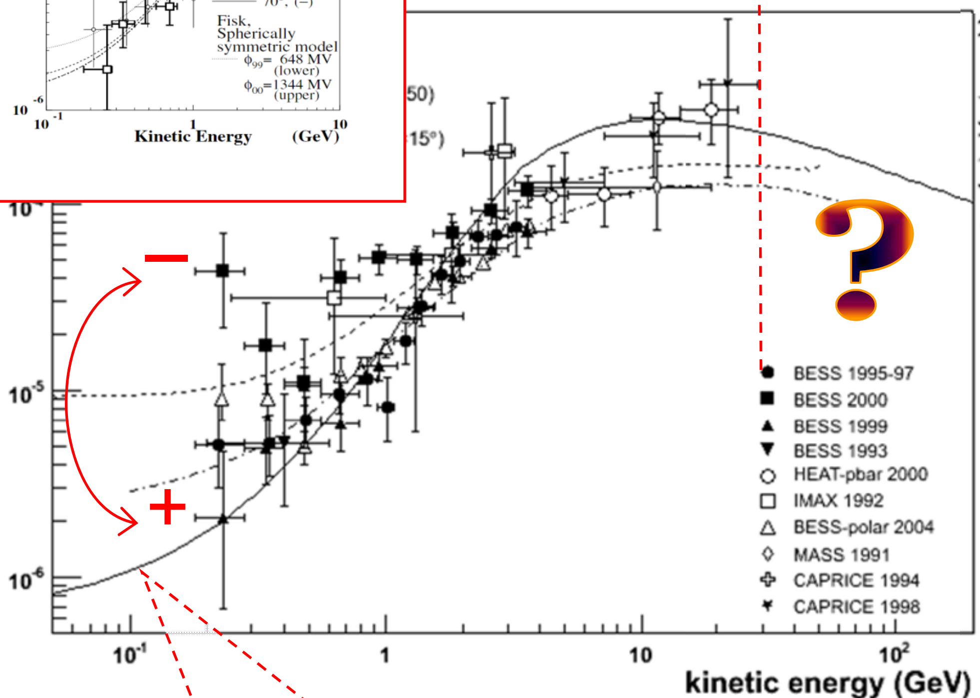
Till ~now:
~1100 days of data taking
~14 TByte of raw data downlinked
>10^9 triggers recorded and analyzed
(Data from April till December 2008 under analysis)

CR antimatter

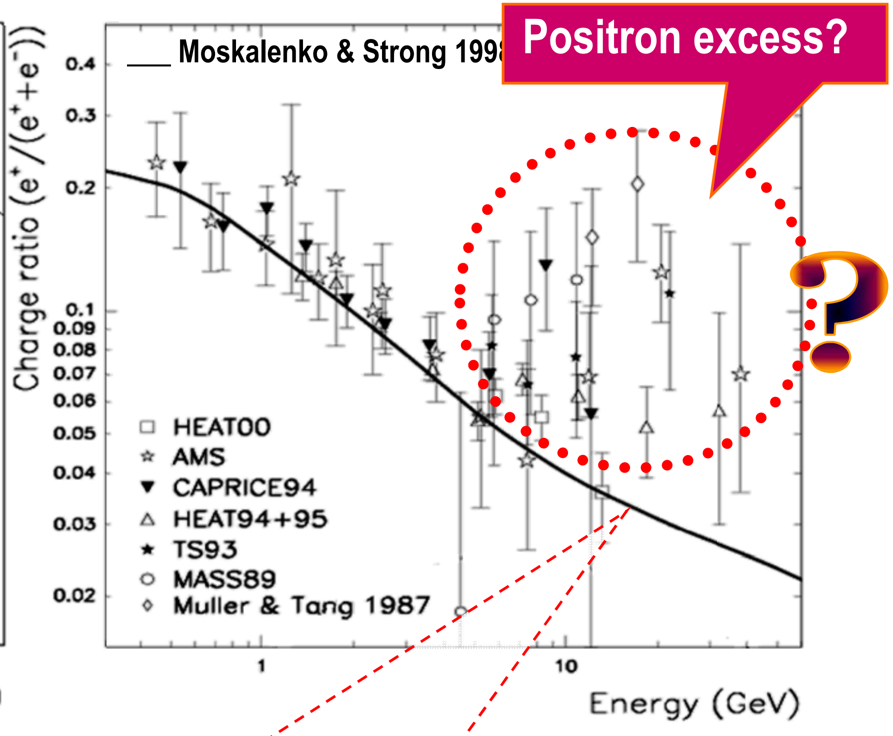
Present status

Antiprotons





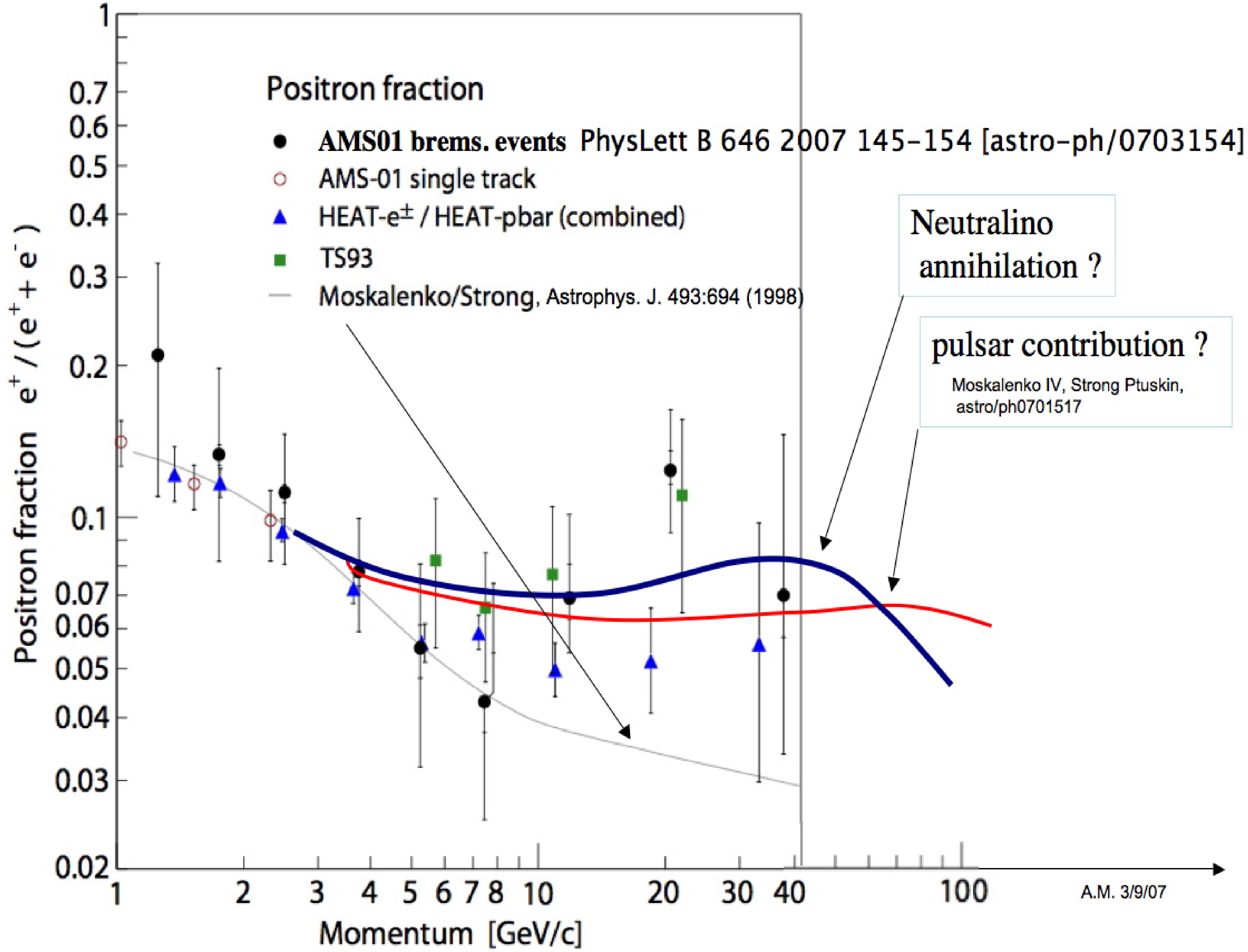
Positrons



CR + ISM → **p-bar** + …
kinematic treshold:
5.6 GeV for the reaction

$$pp \to \bar{p}ppp$$

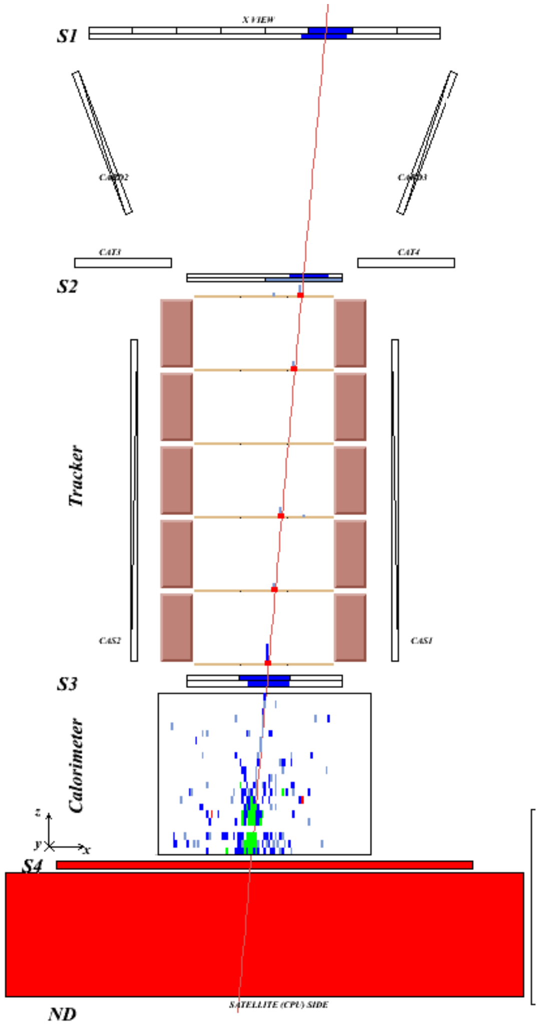
CR + ISM →$\pi^{\pm}$ + x → $\mu^{\pm}$ + x → **$e^{\pm}$** + x
CR + ISM → π^0 + x → $\gamma\gamma$ → **$e^{\pm}$**



Positron fraction
AMS01 brems. events PhysLett B 646 2007 145-154 [astro-ph/0703154]
AMS-01 single track
HEAT-e± / HEAT-pbar (combined)
TS93
Moskalenko/Strong, Astrophys. J. 493:694 (1998)
Neutralino annihilation ?
pulsar contribution ?
Moskalenko IV, Strong Ptuskin, astro/ph0701517
Positron fraction e+/(e+ + e-)
Momentum [GeV/c]
A.M. 3/9/07

Antiparticles with PAMELA

Antiproton / positron identification



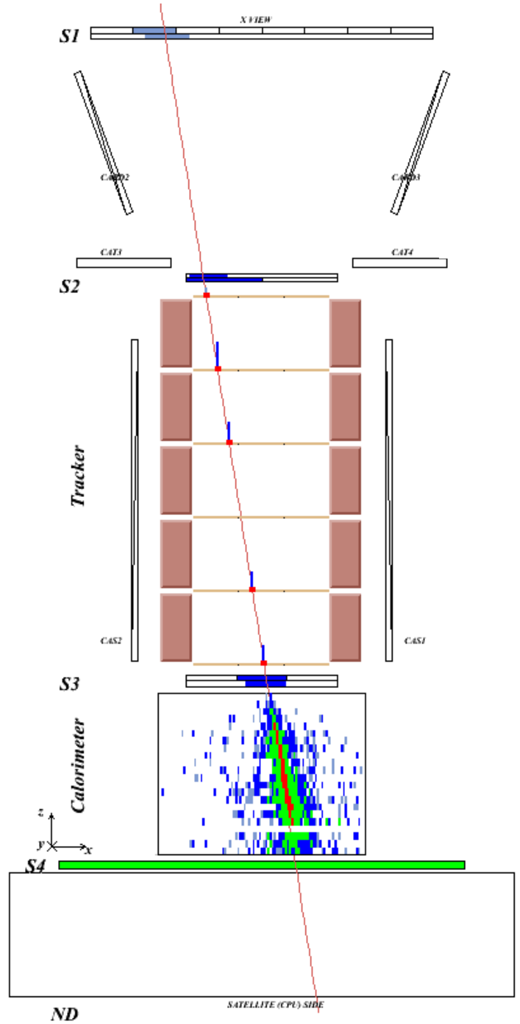
Antiproton
(NB: $e^-/\bar{p} \sim 10^2$)

Time-of-flight:
trigger, albedo rejection, mass determination (up to 1 GeV)

Bending in spectrometer:
sign of charge

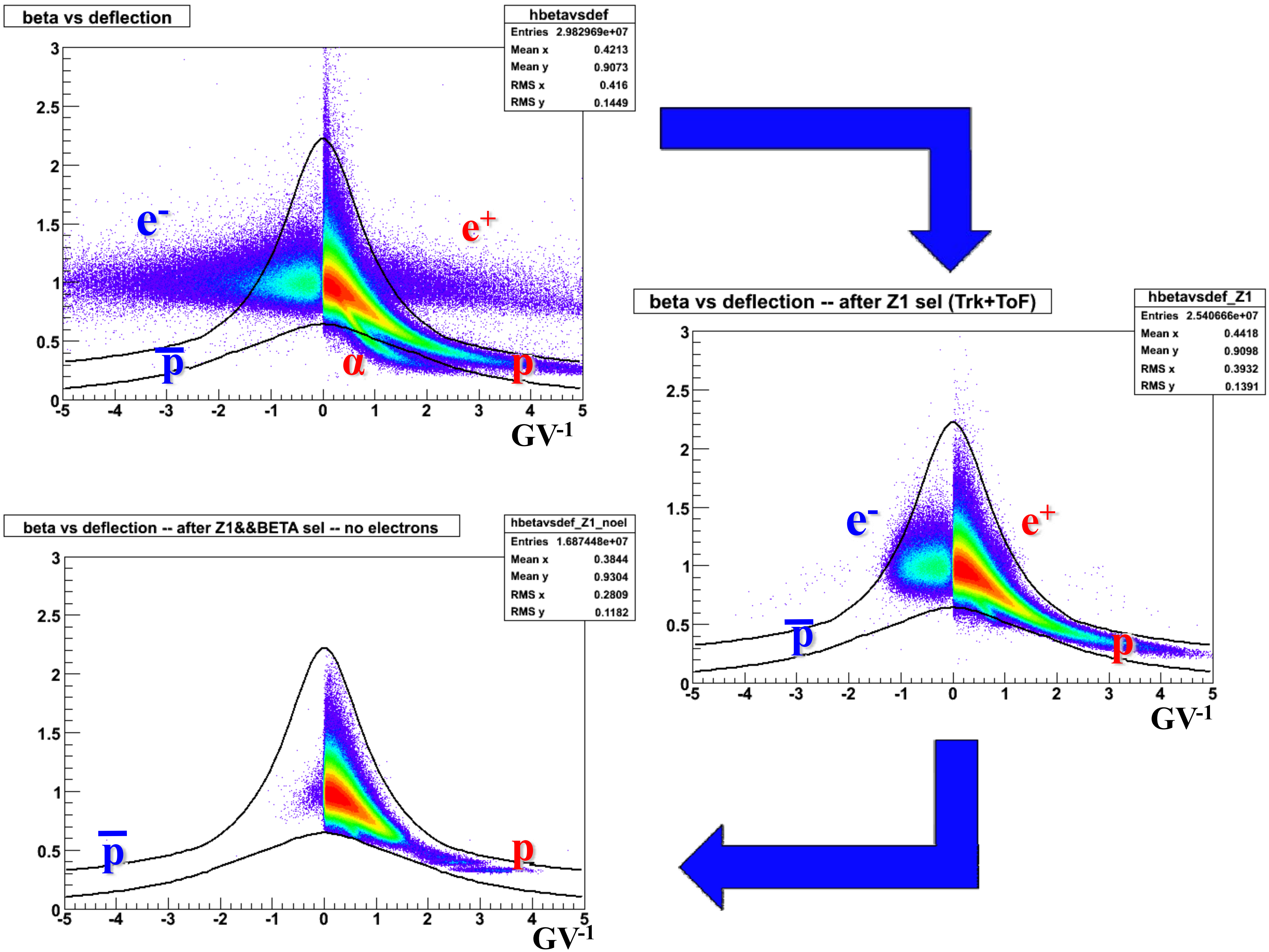
Ionisation energy loss (dE/dx):
magnitude of charge

Interaction pattern in calorimeter:
electron-like or proton-like, electron energy

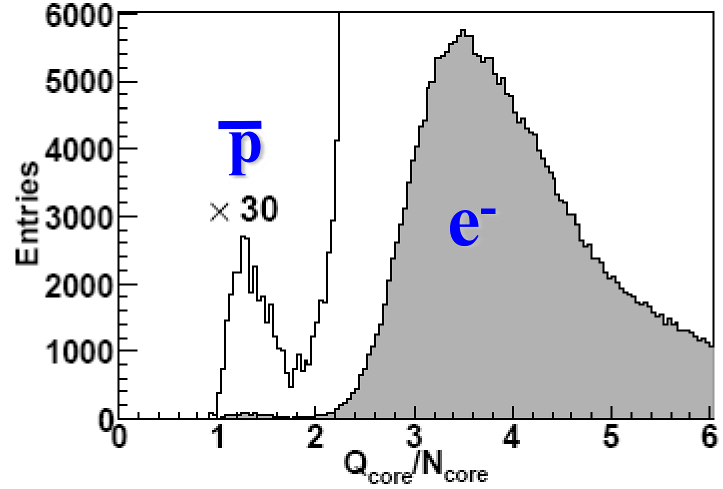


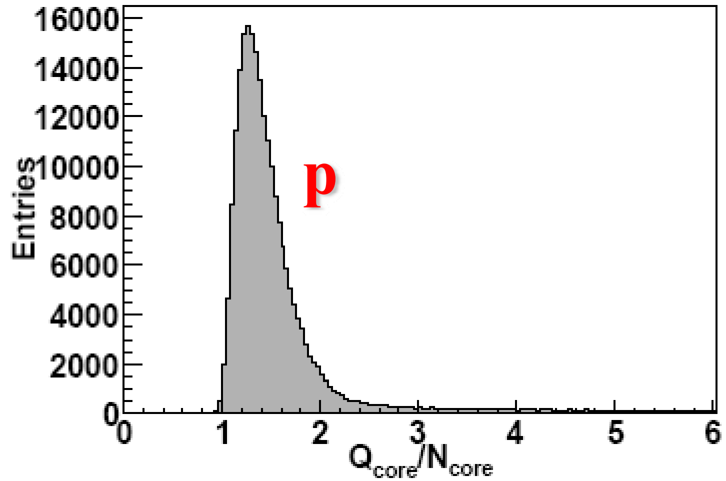
Positron
(NB: $p/e^+ \sim 10^{3-4}$)

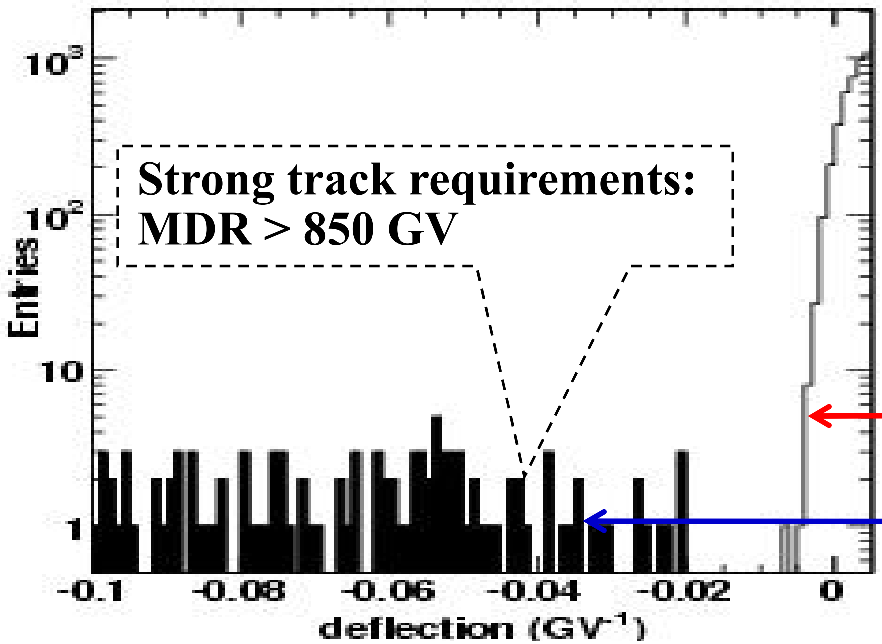
ANTIPROTONS


beta vs deflection
hbetavsdef
Entries 2.982969e+07
Mean x 0.4213
Mean y 0.9073
RMS x 0.416
RMS y 0.1449
e-
e+
p̄
α
p
GV-1
beta vs deflection -- after Z1 sel (Trk+ToF)
hbetavsdef_Z1
Entries 2.540666e+07
Mean x 0.4418
Mean y 0.9098
RMS x 0.3932
RMS y 0.1391
e-
e+
p̄
p
GV-1
beta vs deflection -- after Z1&&BETA sel -- no electrons
hbetavsdef_Z1_noel
Entries 1.687448e+07
Mean x 0.3844
Mean y 0.9304
RMS x 0.2809
RMS y 0.1182
p̄
p
GV-1

Calorimeter selection







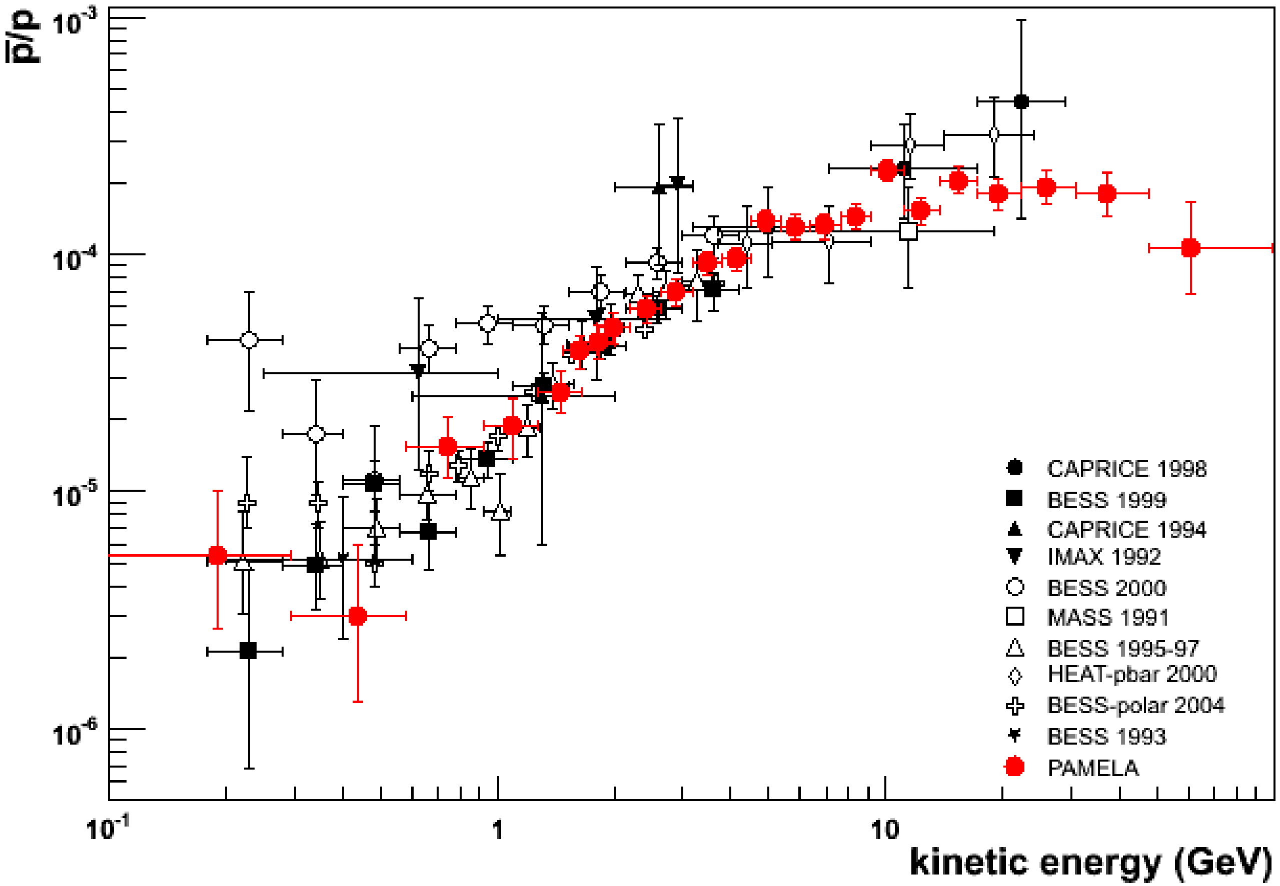
Tracker Identification

Protons (& spillover)

Antiprotons

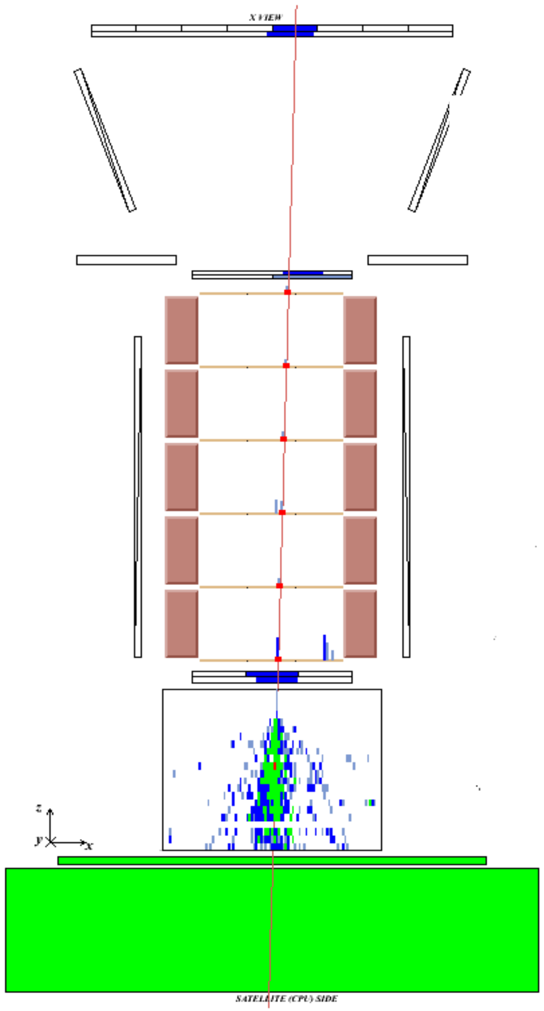
Antiproton to proton flux ratio

PRL 102, (2009) 051101, Astro-ph 0810.4994



POSITRONS

Proton / positron discrimination

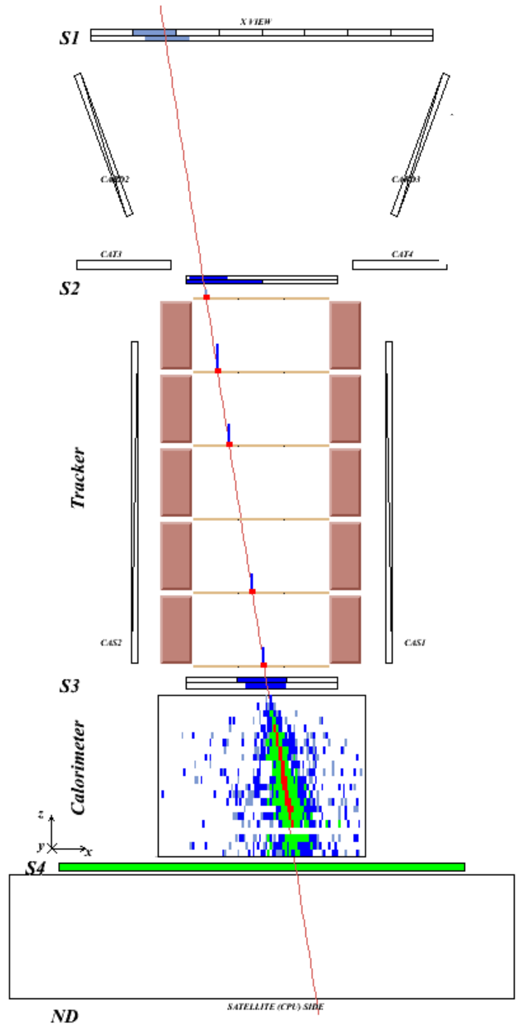


Time-of-flight:
trigger, albedo rejection, mass determination (up to 1 GeV)

Bending in spectrometer:
sign of charge

Ionisation energy loss (dE/dx):
magnitude of charge

Interaction pattern in calorimeter:
electron-like or proton-like, electron energy

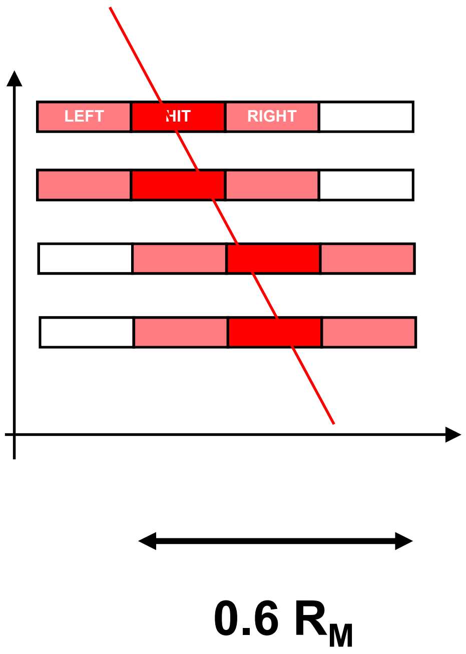


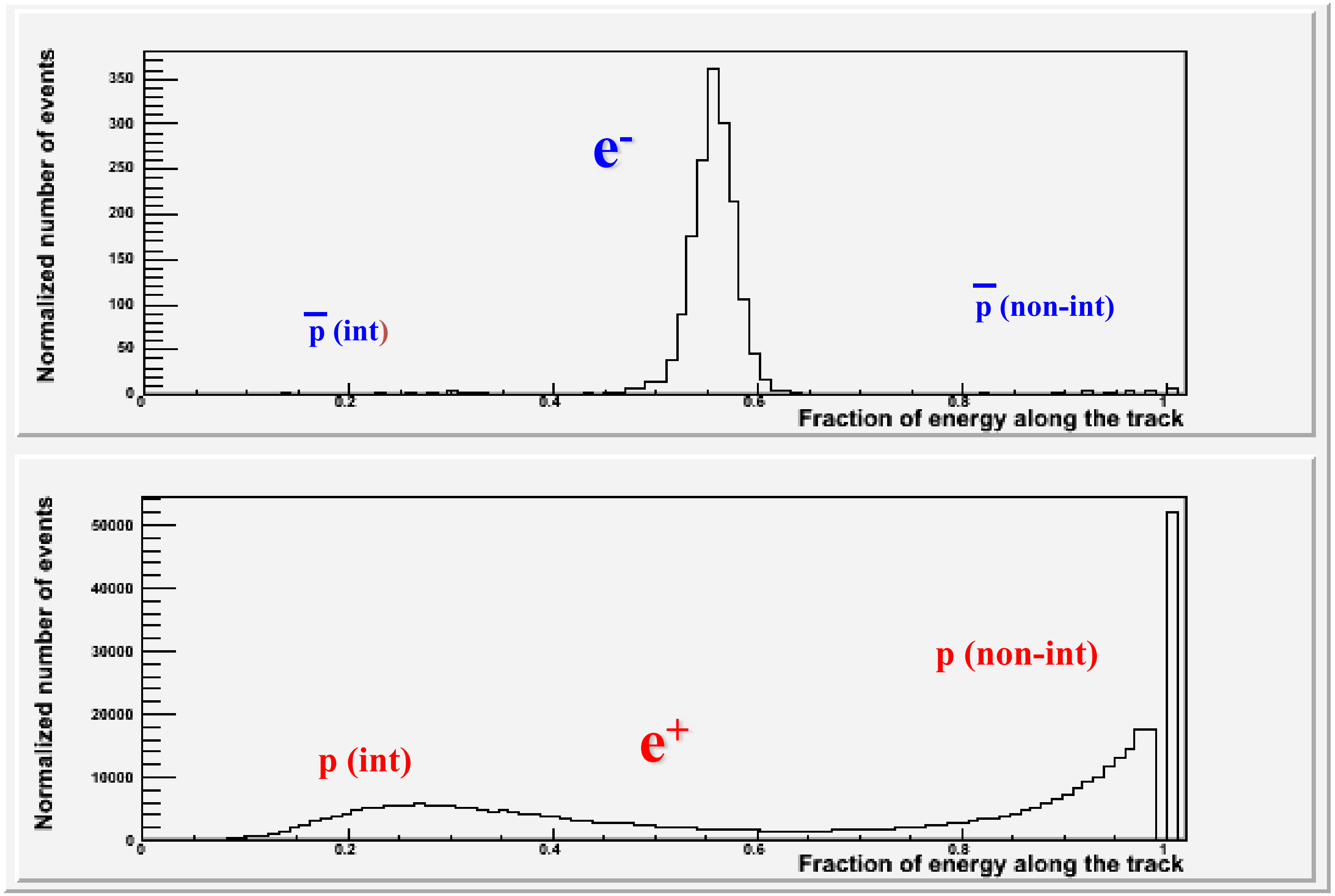
Proton

Positron

Positron selection with calorimeter

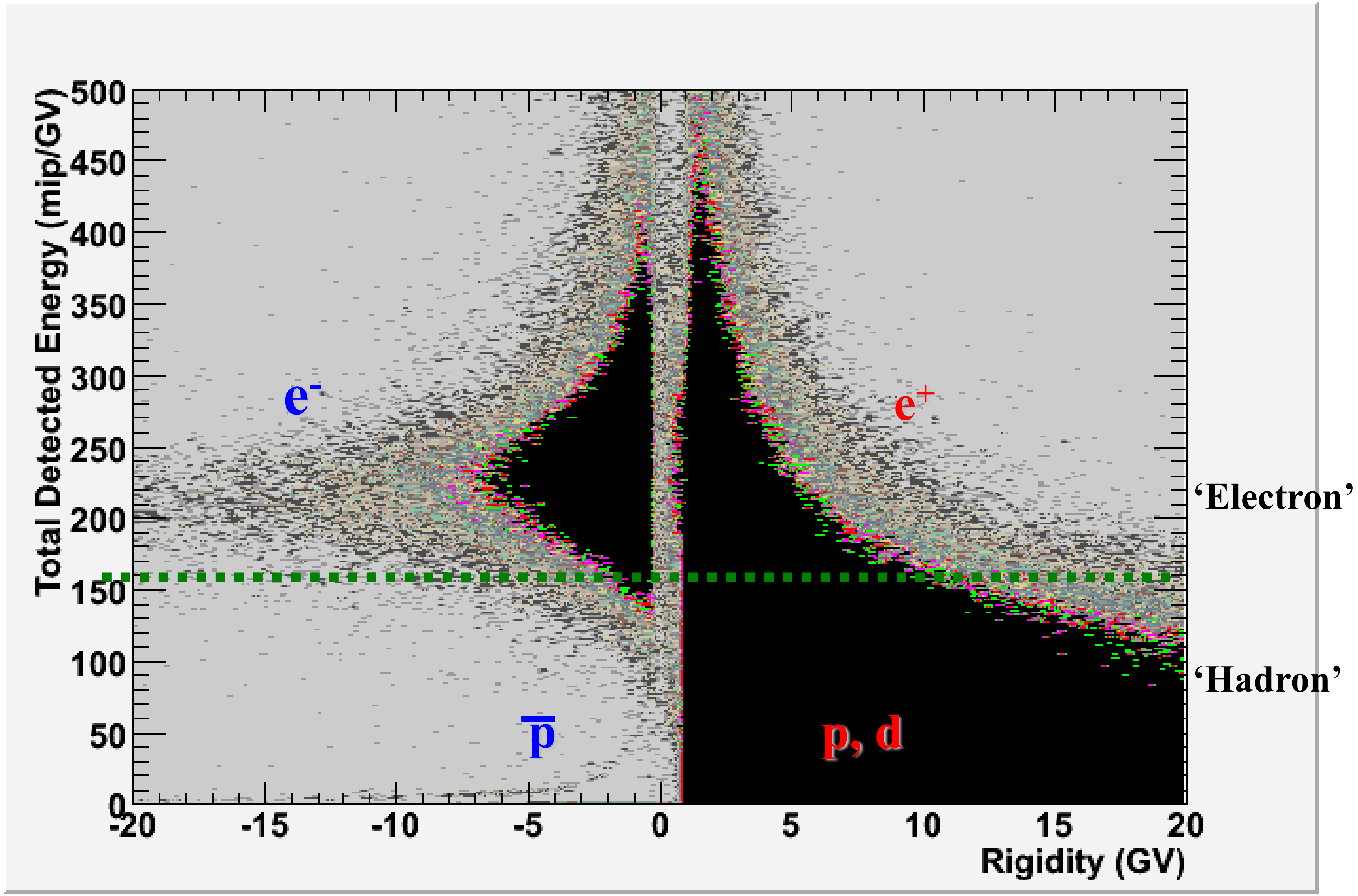
Fraction of energy released along the calorimeter track (left, hit, right)





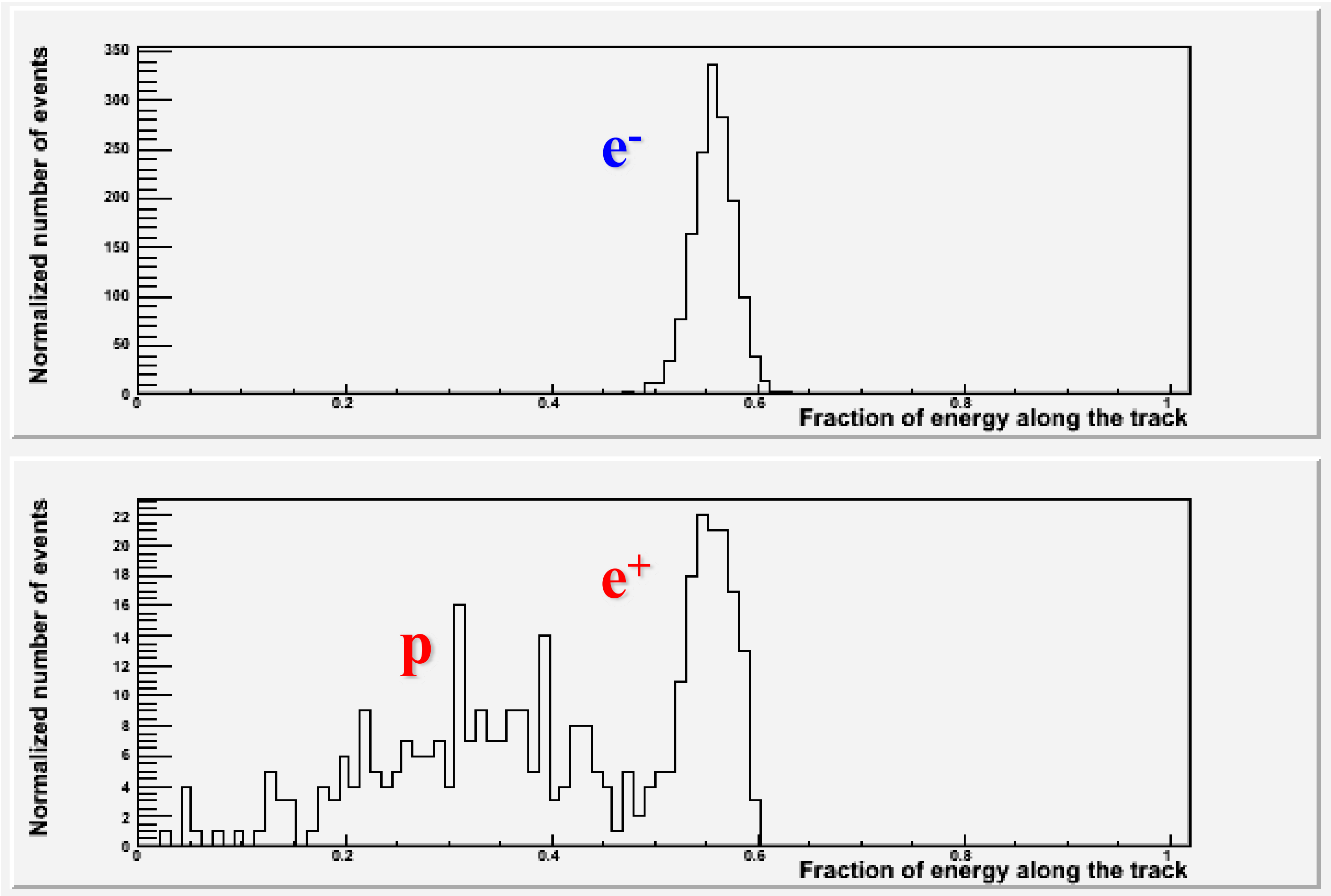
Rigidity: 20-30 GV

Antiparticle selection



Positron selection with calorimeter

Rigidity: 20-30 GV

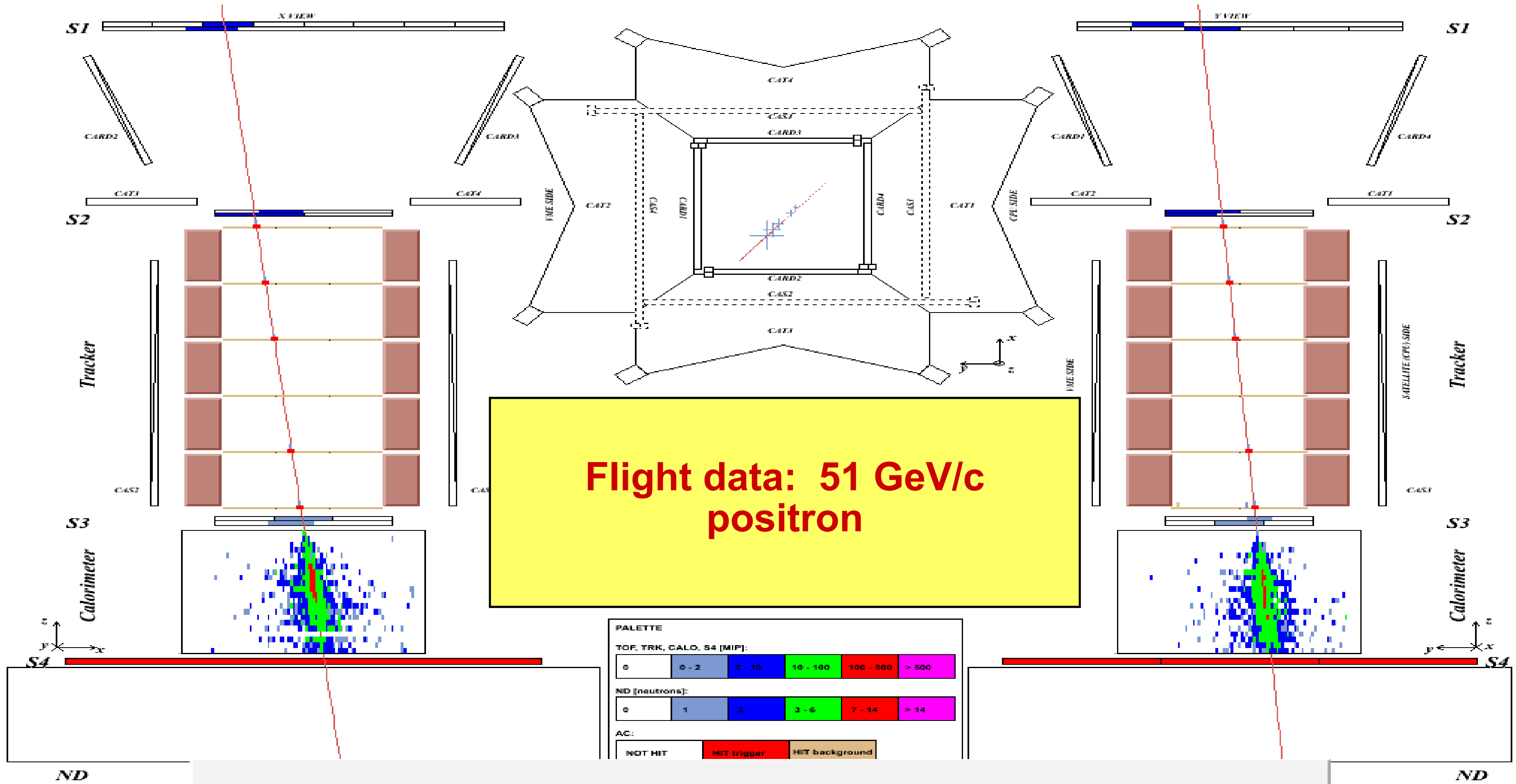


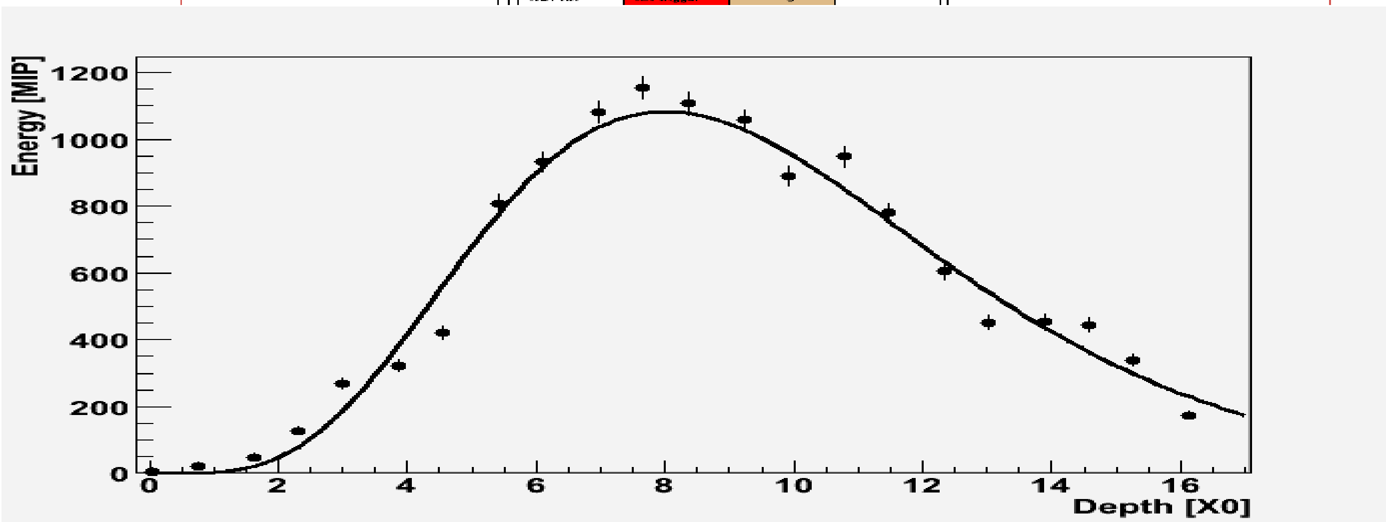
Fraction of charge released along the calorimeter track (left, hit, right)

+

- **Energy-momentum match**
- **Starting point of shower**

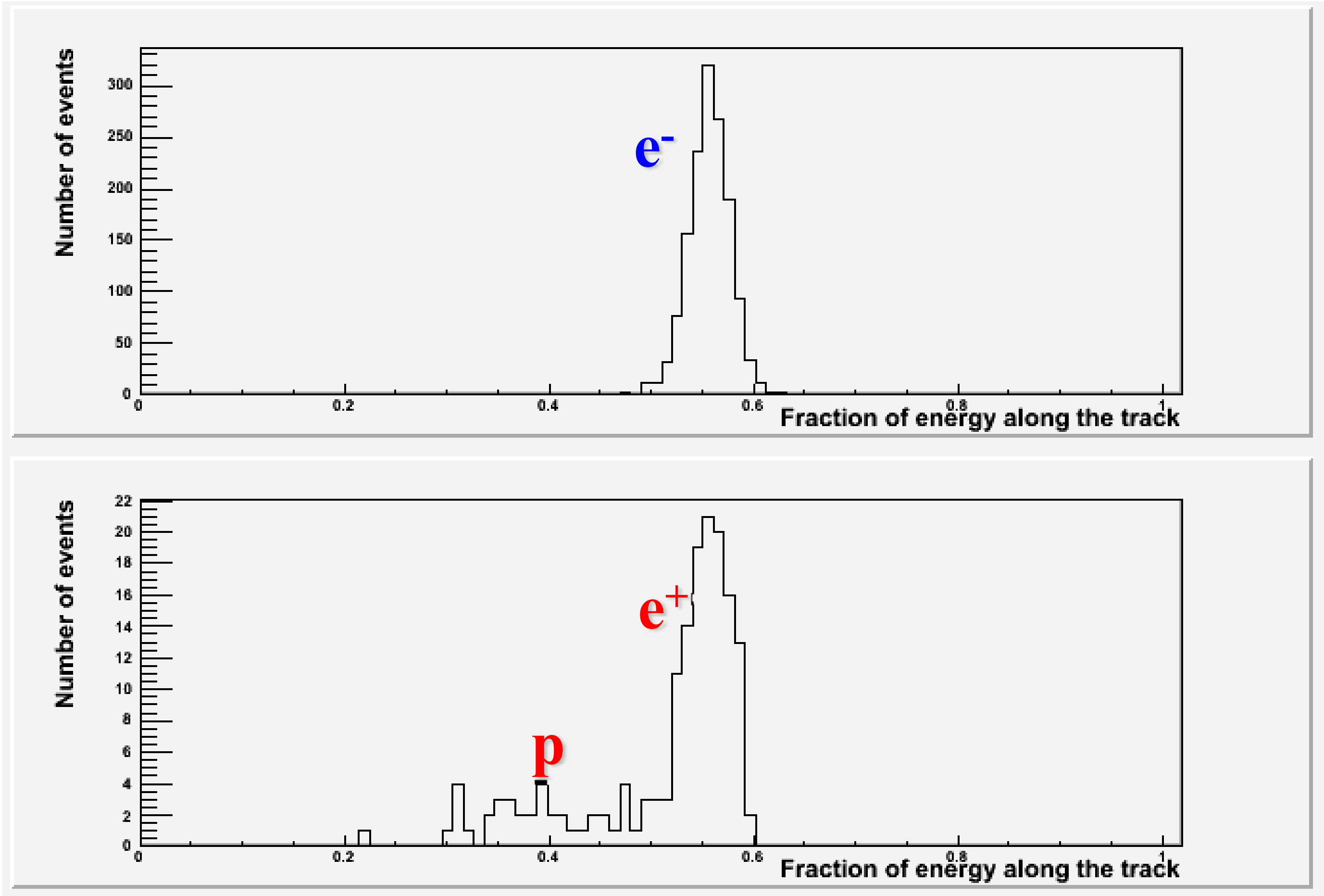
Flight data: 51 GeV/c positron





Positron selection with calorimeter

Rigidity: 20-30 GV

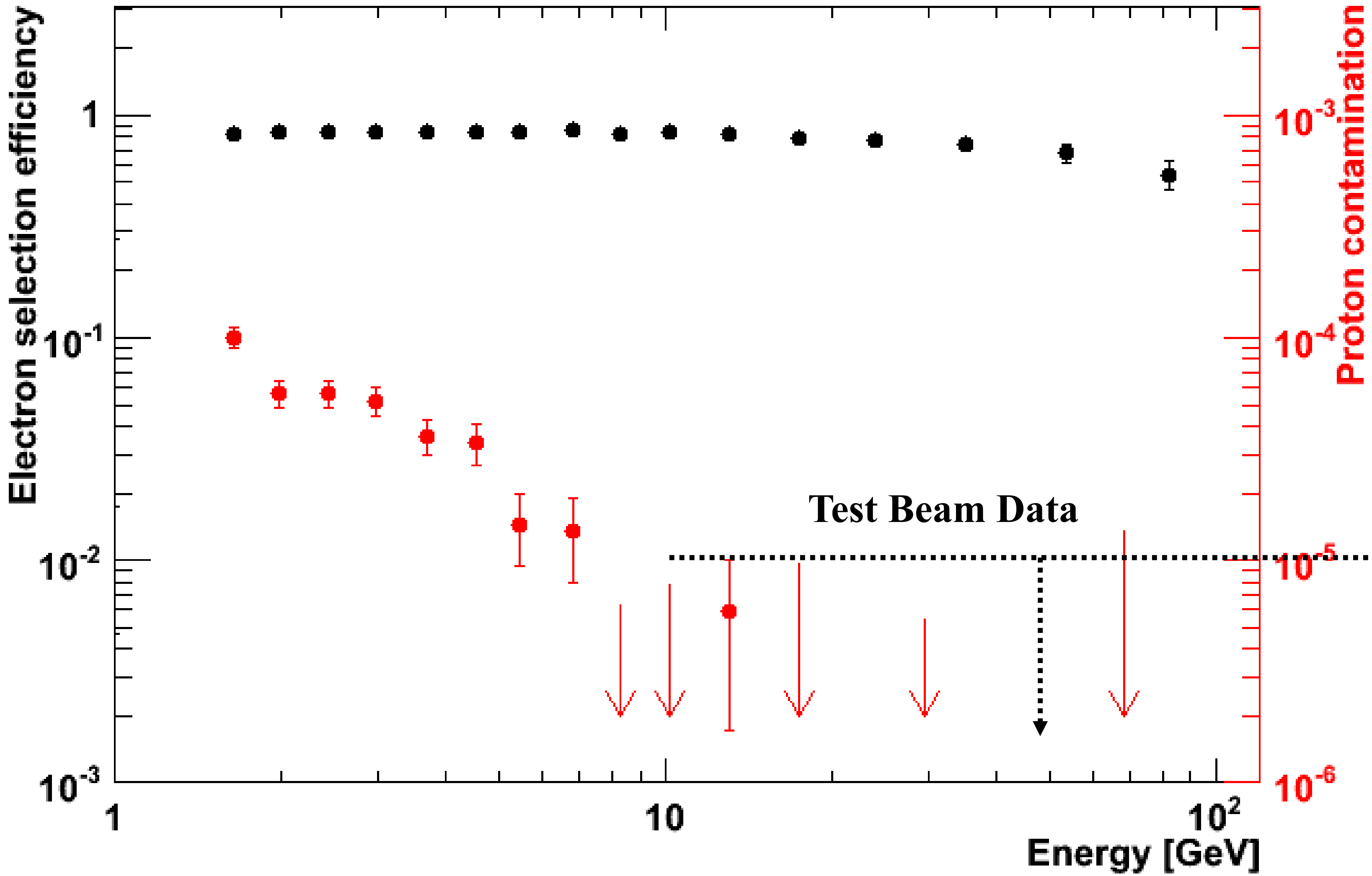


Fraction of charge released along the calorimeter track (left, hit, right)

+

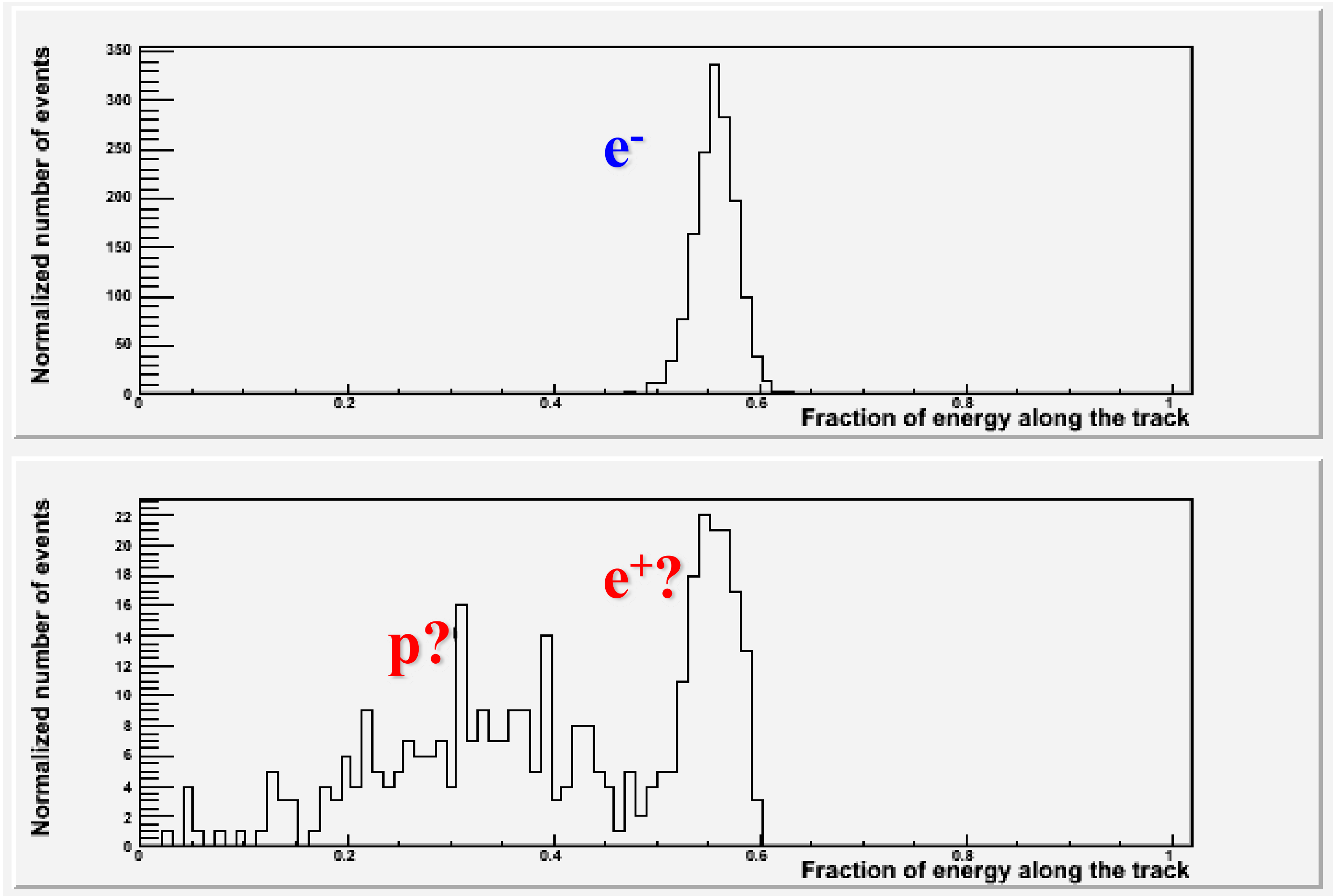
- **Energy-momentum match**
- **Starting point of shower**
- **Longitudinal profile**

Positron selection with calorimeter



Positron selection with calorimeter

Rigidity: 20-30 GV



Fraction of charge released along the calorimeter track (left, hit, right)

+

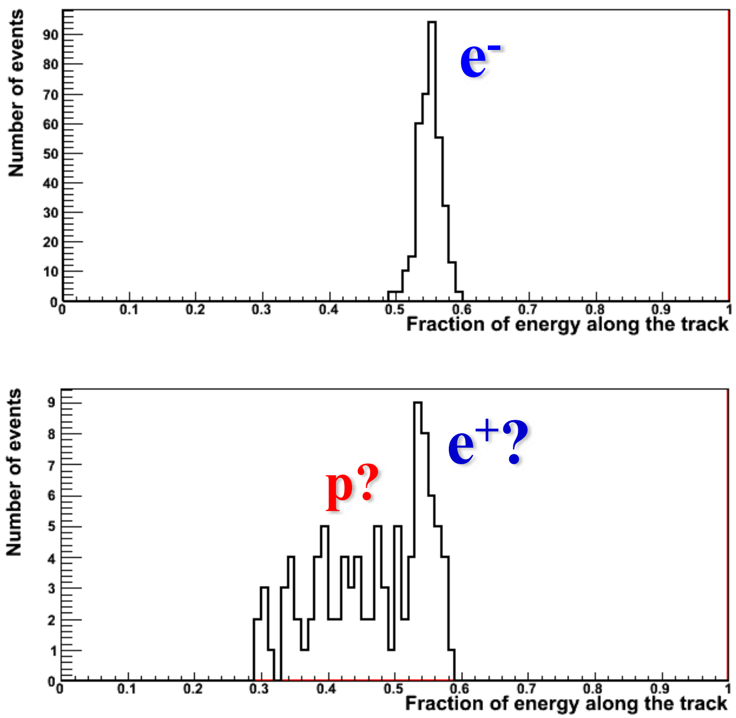
- Energy-momentum match
- Starting point of shower

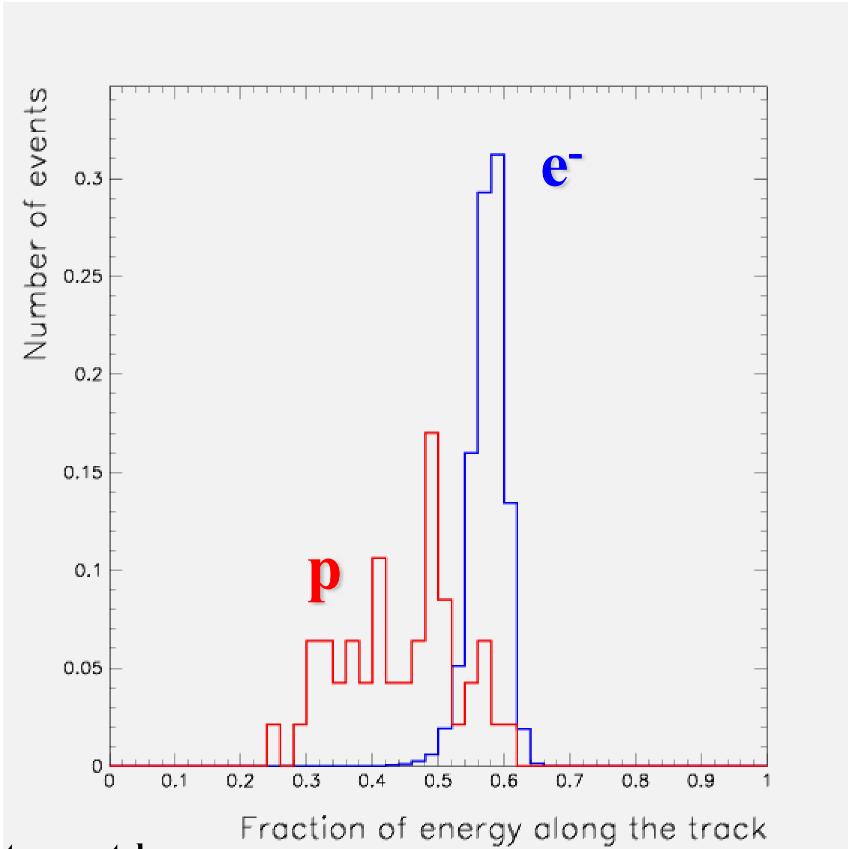
Positron selection with calorimeter

Fraction of charge released along the calorimeter track (left, hit, right)

Flight data: rigidity: 42-65 GV

Test beam data: momentum: 50GeV/c



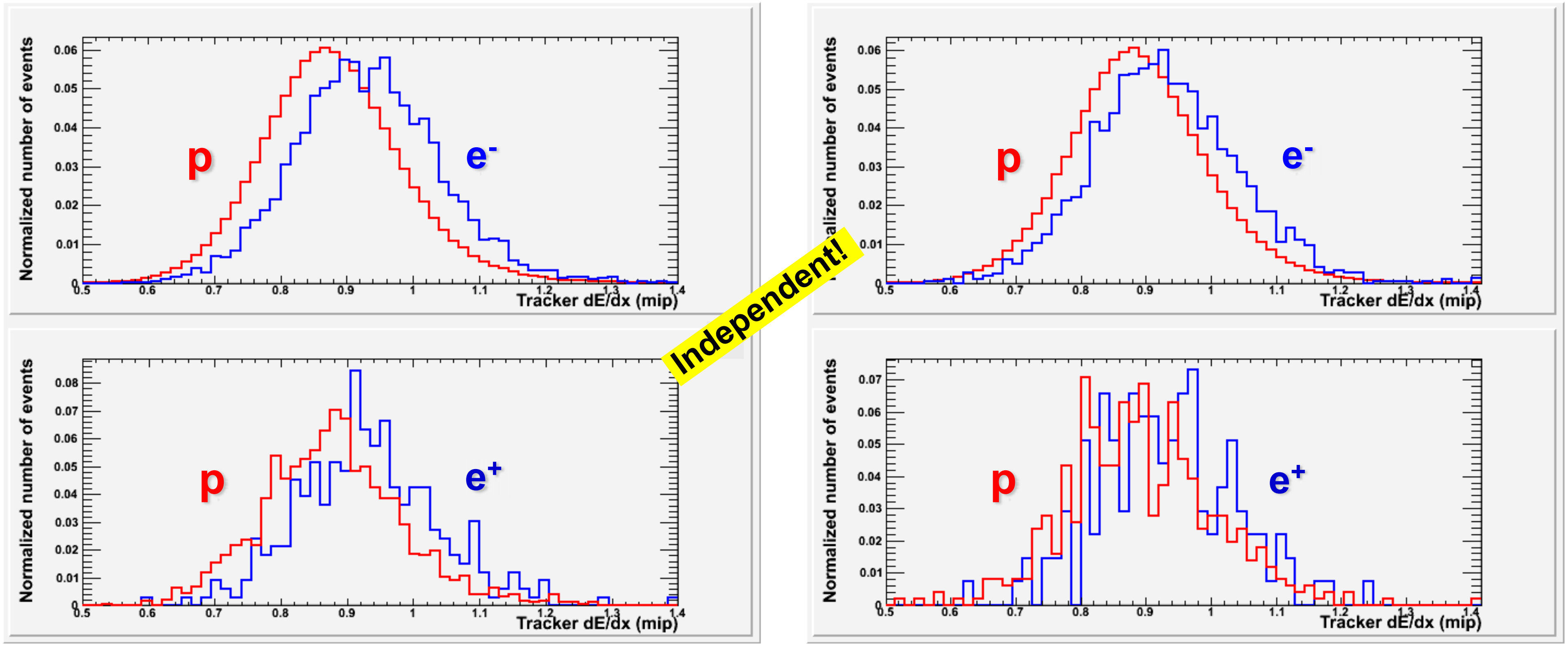


- Energy-momentum match
- Starting point of shower

Positron selection with dE/dX

Energy loss in silicon tracker detectors: $-\frac{dE}{dx} = Kz^2\frac{Z}{A}\frac{1}{\beta^2}\left[\frac{1}{2}\ln\frac{2m_ec^2\beta^2\gamma^2T_{\max}}{I^2} - \beta^2 - \frac{\delta(\beta\gamma)}{2}\right]$

TOP: positive (mostly p) and negative events (mostly e^-)



BOTTOM: positive events identified as p and e^+ by transverse profile method

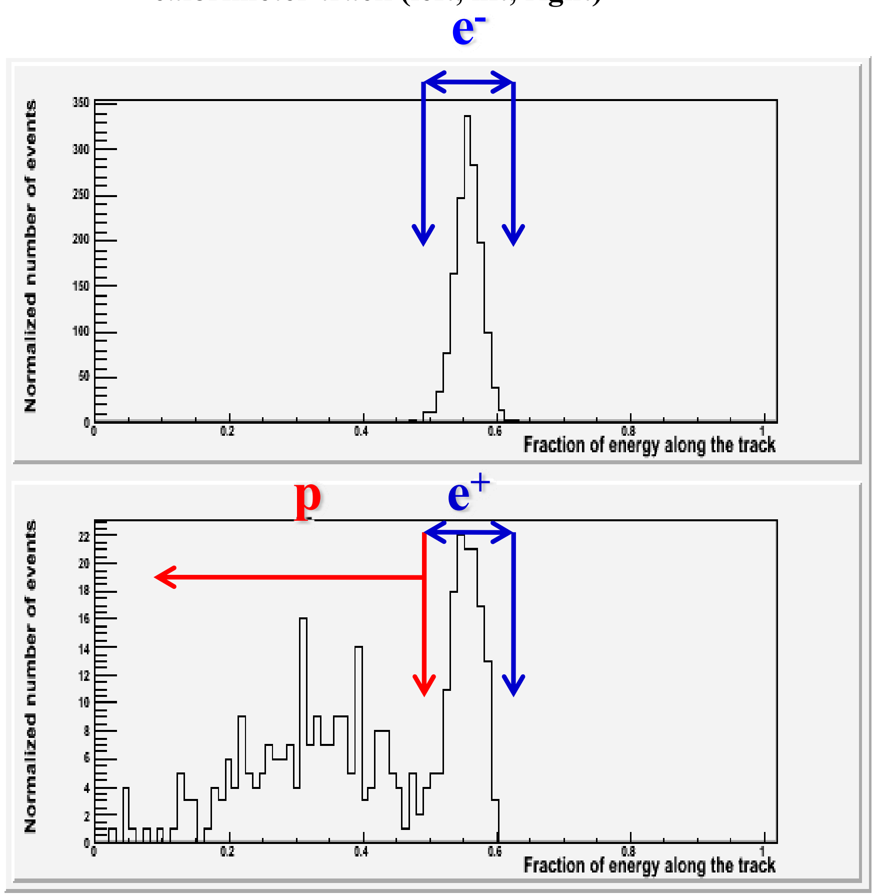
Rigidity: 10-15 GV

Rigidity: 15-20 GV

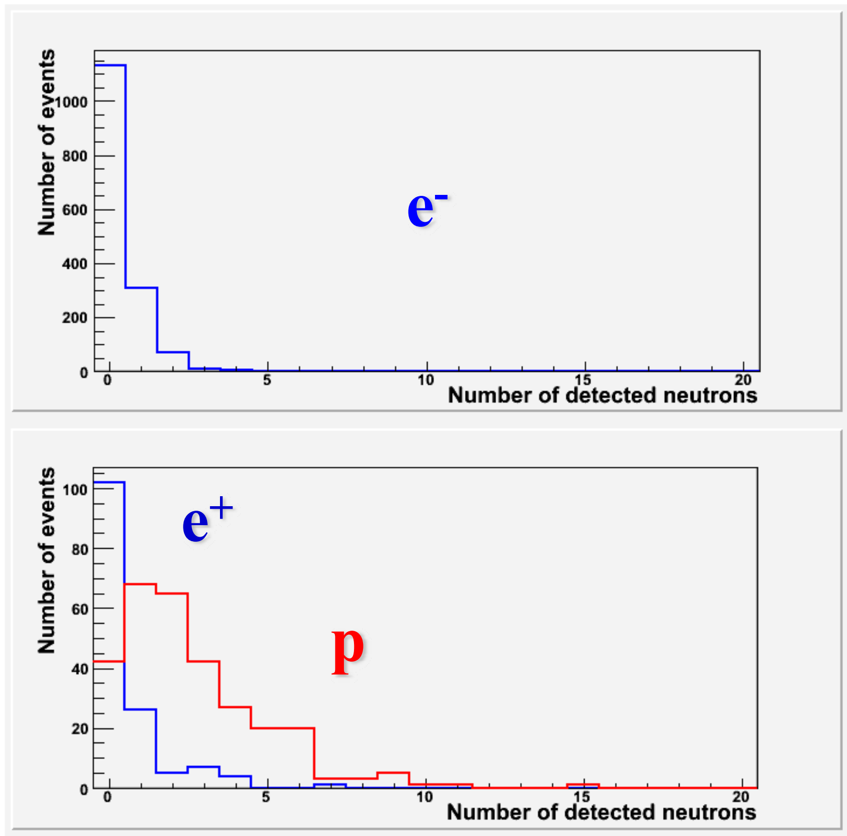
Positron selection with calorimeter

Rigidity: 20-30 GV

Fraction of charge released along the calorimeter track (left, hit, right)

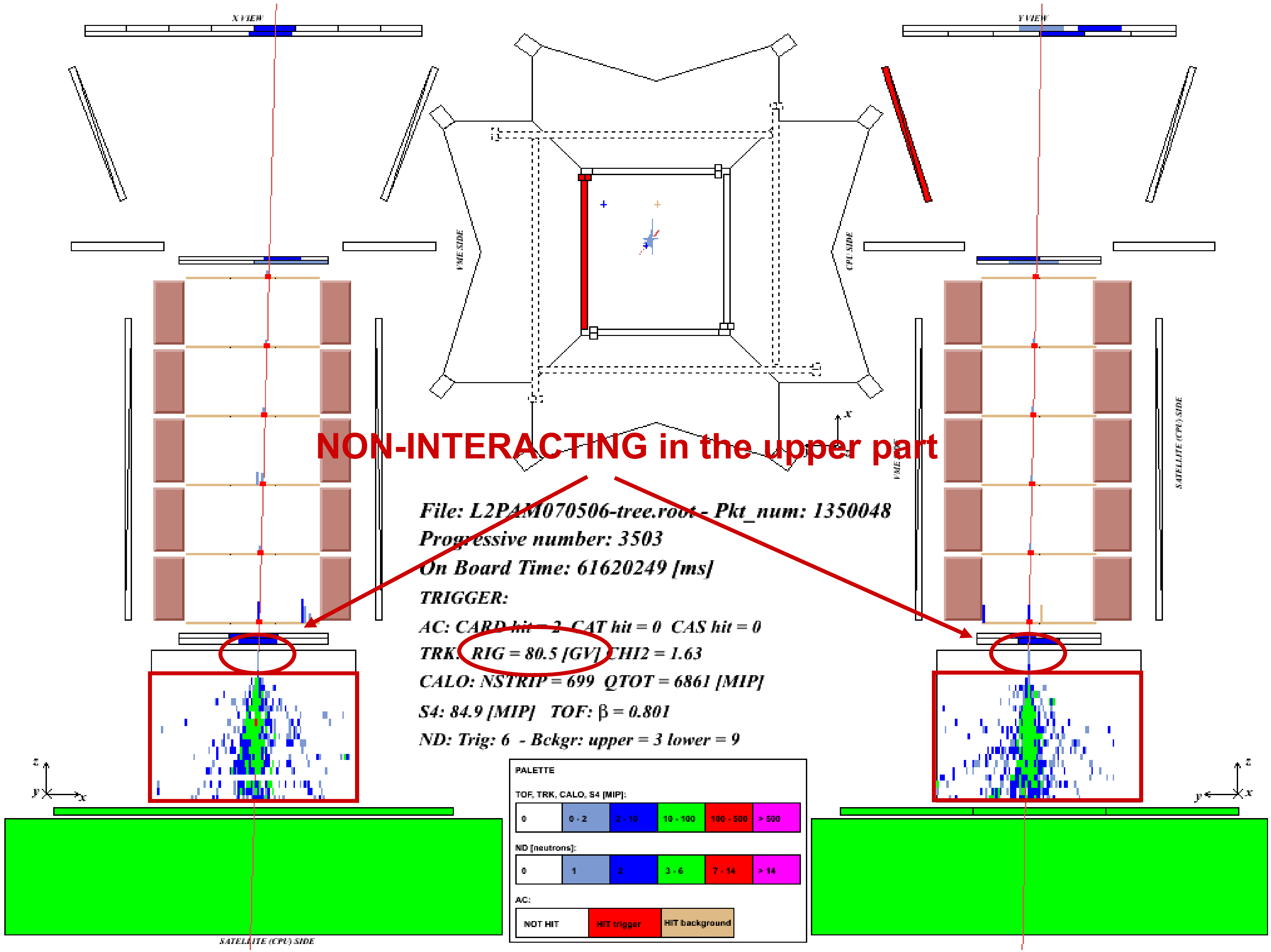


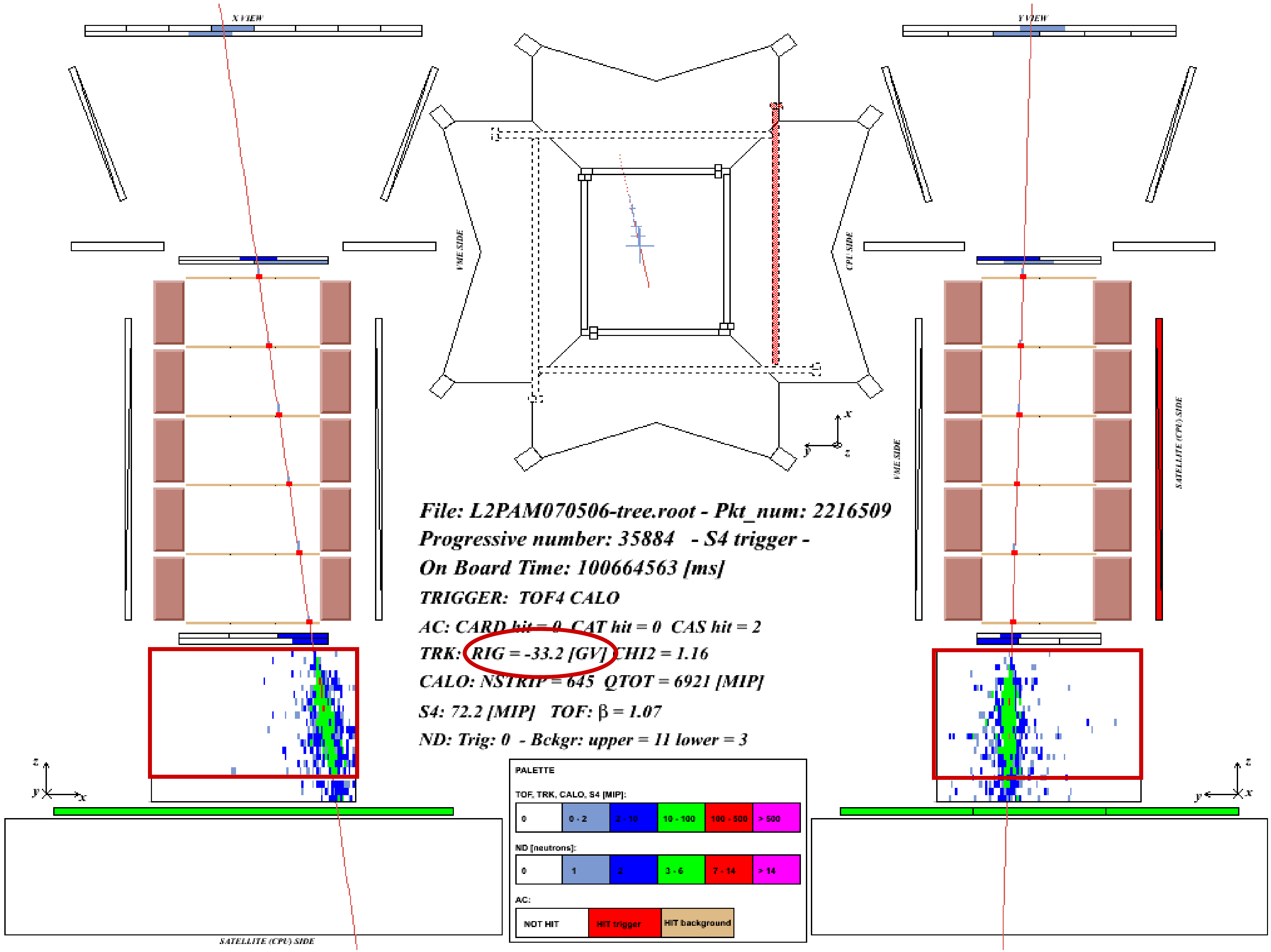
Neutrons detected by ND



- Energy-momentum match
- Starting point of shower

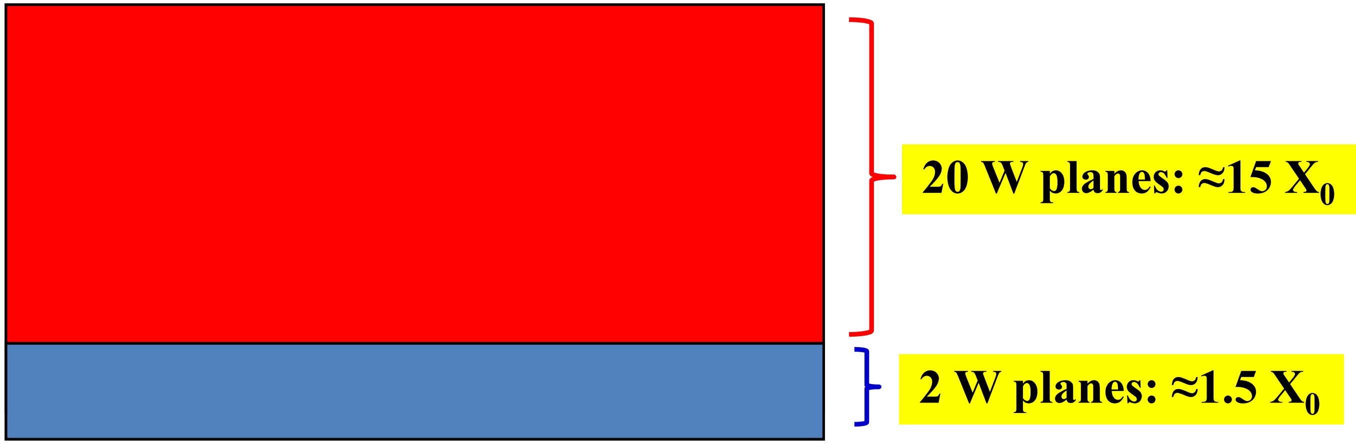
Can we create a sample of protons from the flight data themselves?
Yes with the “pre-sampler” method!


NON-INTERACTING in the upper part
File: L2PAM070506-tree.root - Pkt_num: 1350048
Progressive number: 3503
On Board Time: 61620249 [ms]
TRIGGER:
AC: CARD hit = 2 CAT hit = 0 CAS hit = 0
TRK: RIG = 80.5 [GV] CHI2 = 1.63
CALO: NSTRIP = 699 QTOT = 6861 [MIP]
S4: 84.9 [MIP] TOF: β = 0.801
ND: Trig: 6 - Bckgr: upper = 3 lower = 9
PALETTE
TOF, TRK, CALO, S4 [MIP]:
0
0 - 2
2 - 10
10 - 100
100 - 500
> 500
ND [neutrons]:
0
1
2
3 - 6
7 - 14
> 14
AC:
NOT HIT
HIT trigger
HIT background
X VIEW
Y VIEW
VME SIDE
CPU SIDE
SATELLITE (CPU) SIDE

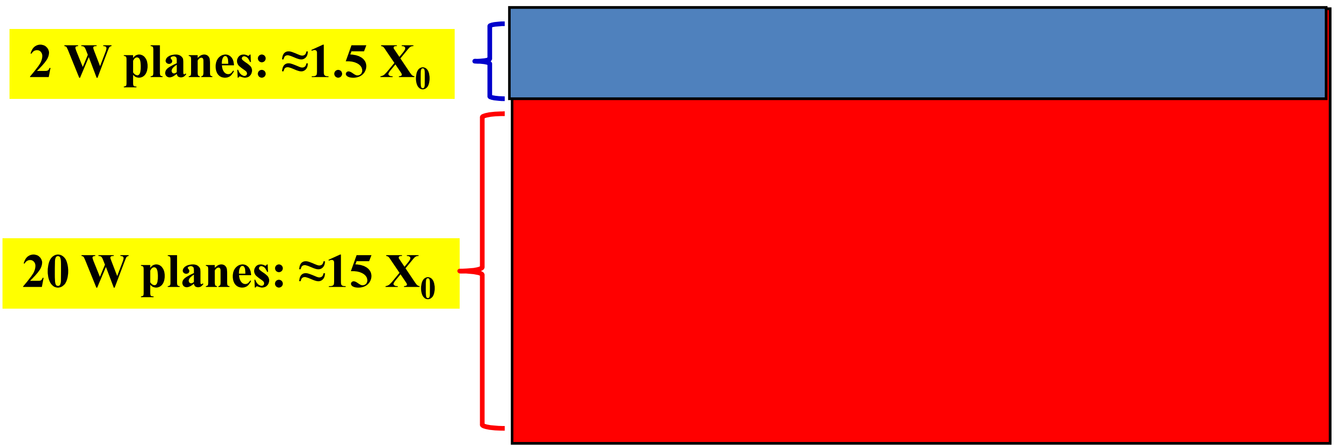

X VIEW
Y VIEW
VME SIDE
CPU SIDE
SATELLITE (CPU) SIDE
File: L2PAM070506-tree.root - Pkt_num: 2216509
Progressive number: 35884 - S4 trigger -
On Board Time: 100664563 [ms]
TRIGGER: TOF4 CALO
AC: CARD hit = 0 CAT hit = 0 CAS hit = 2
TRK: RIG = -33.2 [GV] CHI2 = 1.16
CALO: NSTRIP = 645 QTOT = 6921 [MIP]
S4: 72.2 [MIP] TOF: β = 1.07
ND: Trig: 0 - Bckgr: upper = 11 lower = 3
PALETTE
TOF, TRK, CALO, S4 [MIP]:
0
0 - 2
2 - 10
10 - 100
100 - 500
> 500
ND [neutrons]:
0
1
2
3 - 6
7 - 14
> 14
AC:
NOT HIT
HIT trigger
HIT background
SATELLITE (CPU) SIDE

The "pre-sampler" method

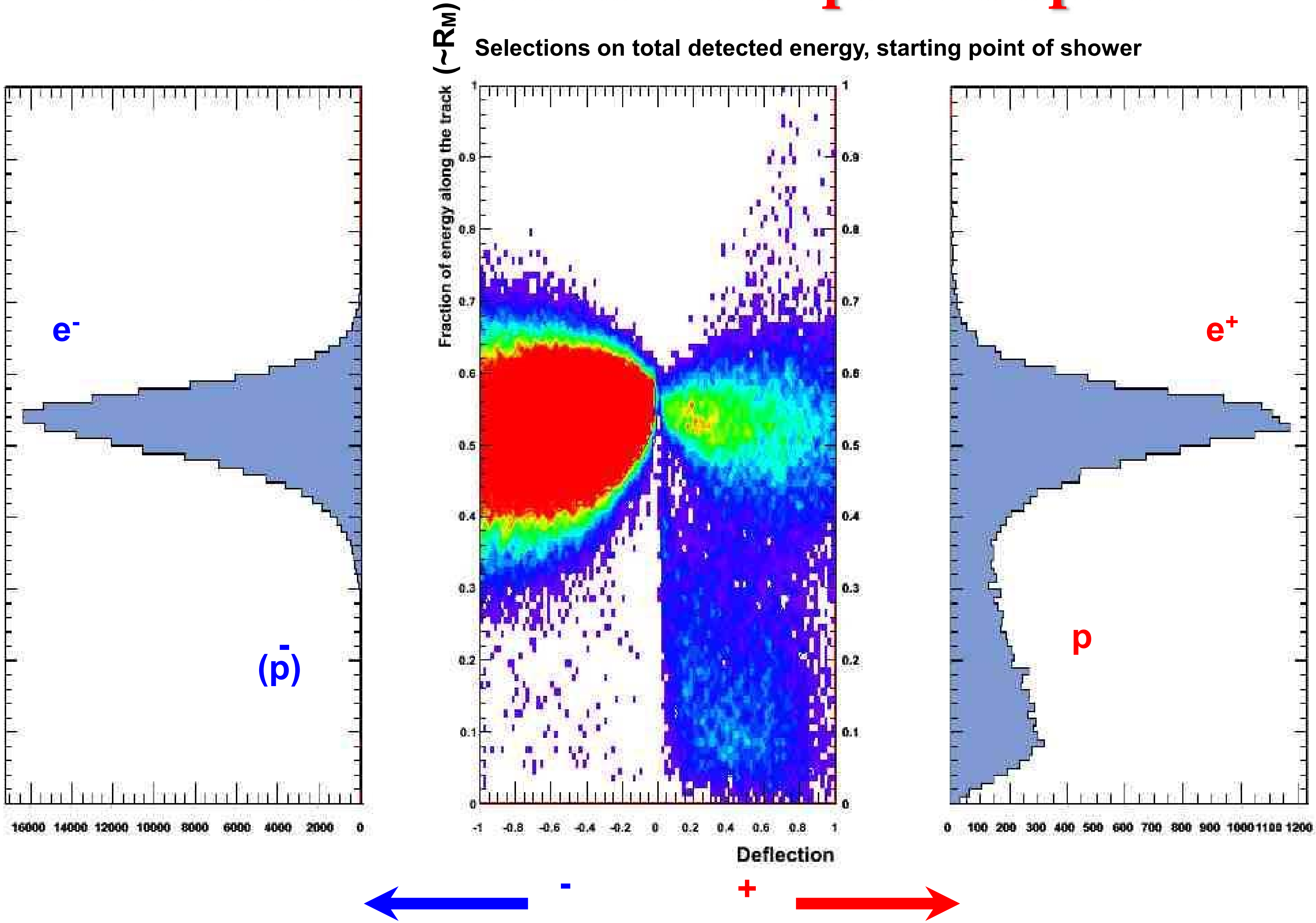
POSITRON SELECTION



PROTON SELECTION

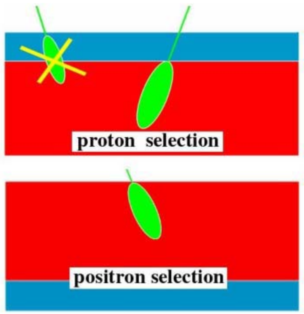


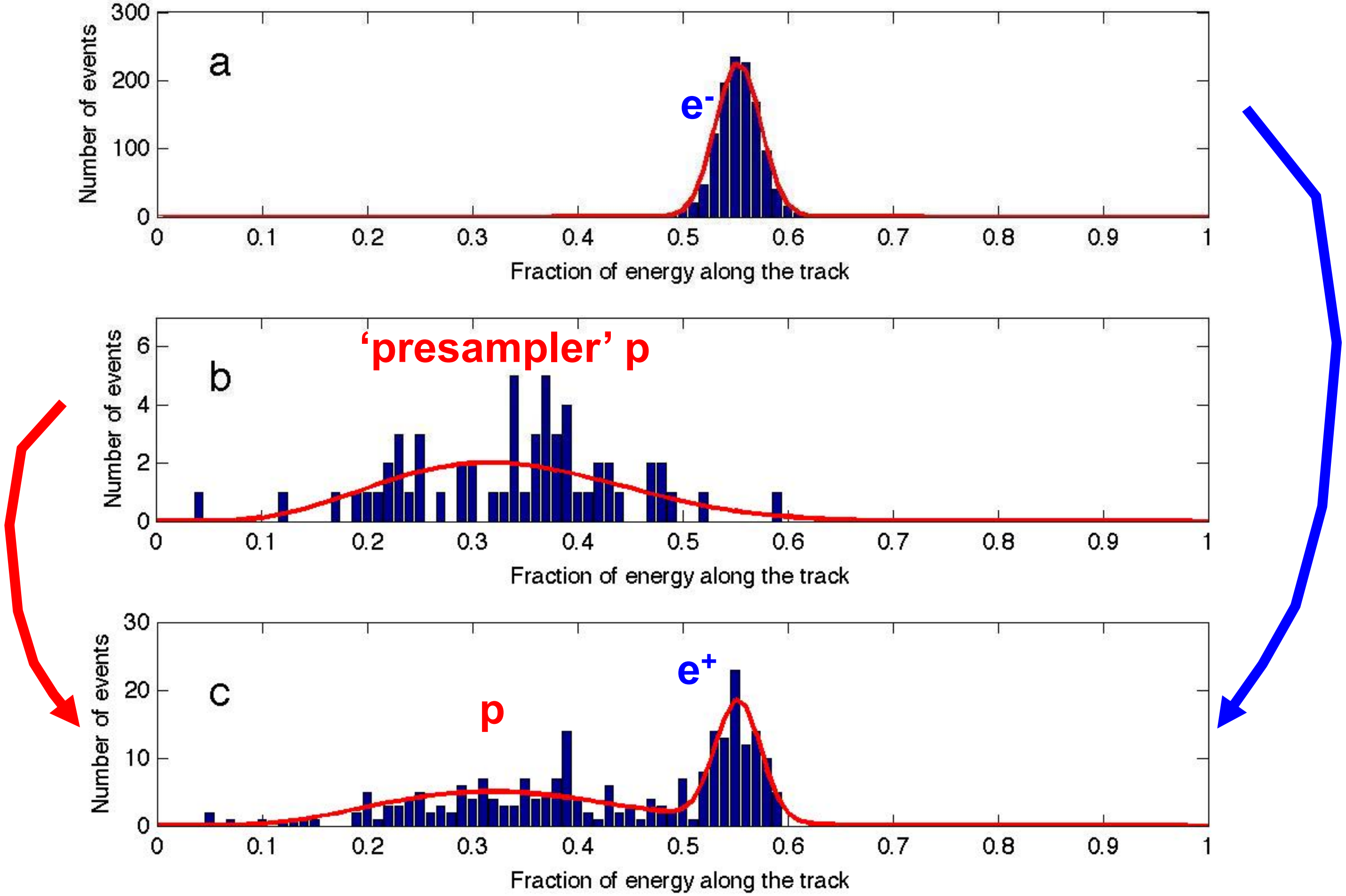
Positron selection with “pre-sampler”



e$^+$ background estimation from data

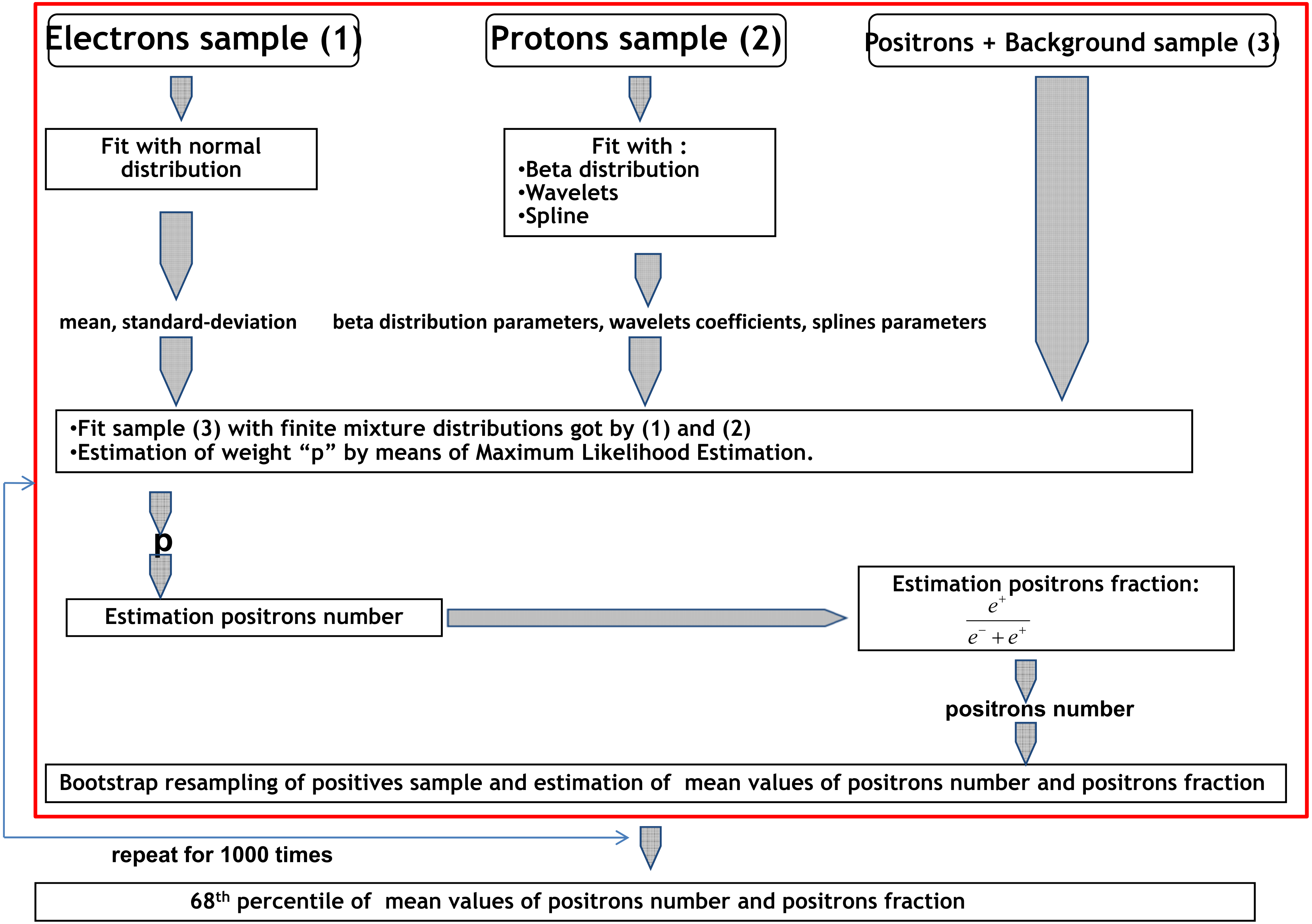
Rigidity: 20-28 GV



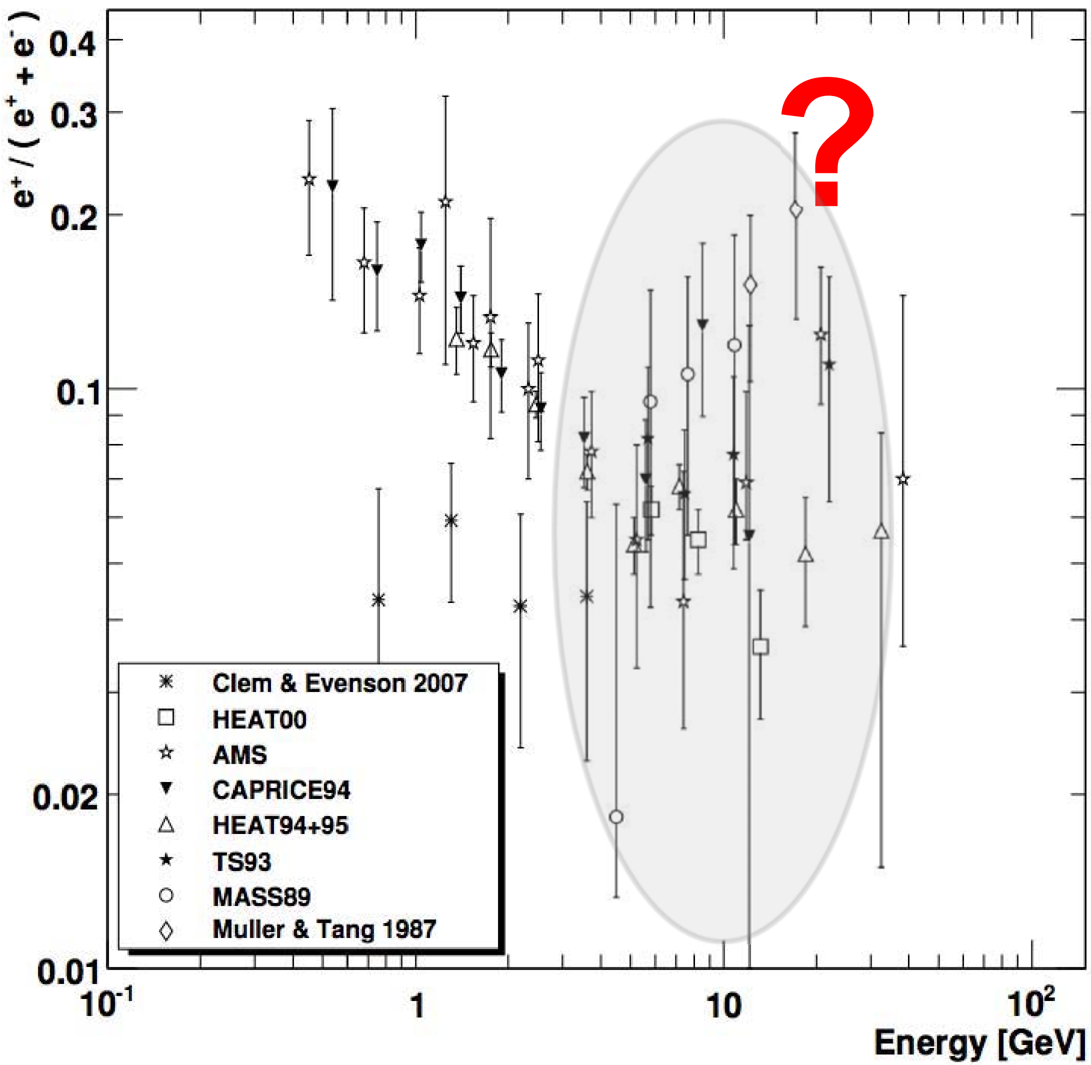


+ • Energy-momentum match
• Starting point of shower

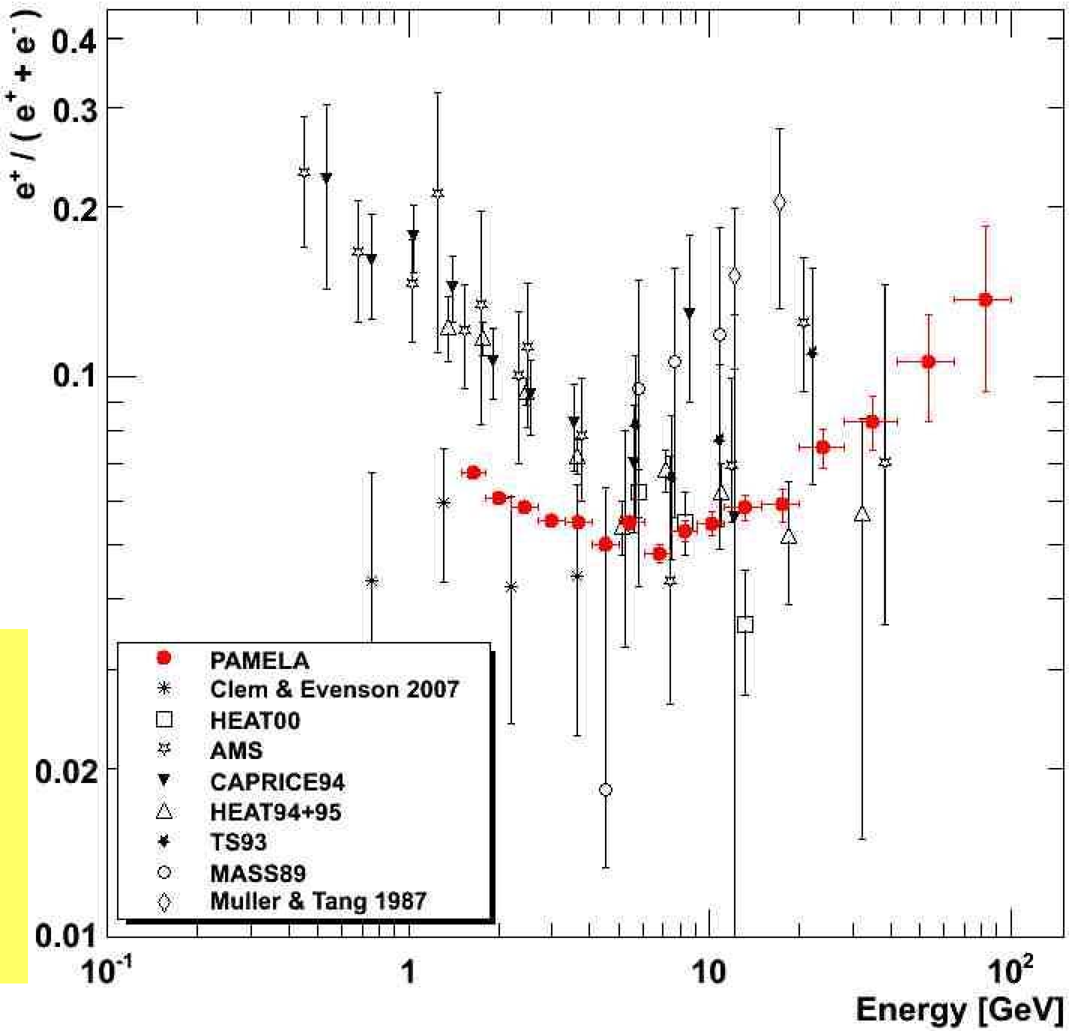
Procedure e^{+} background estimation from data



Pre-PAMELA positron fraction



Positron to Electron Fraction

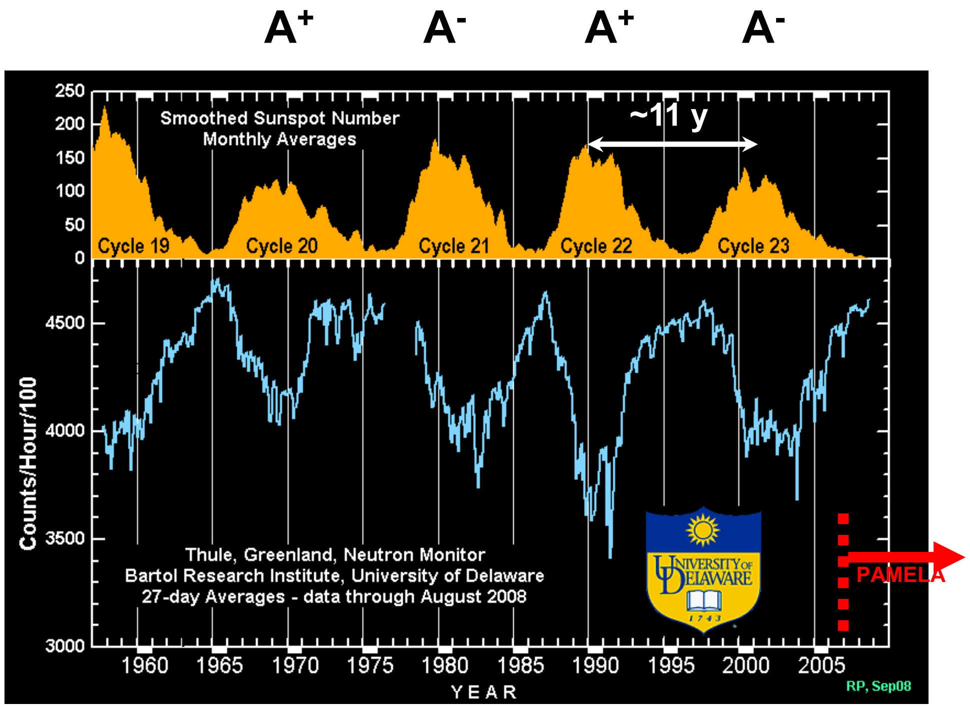


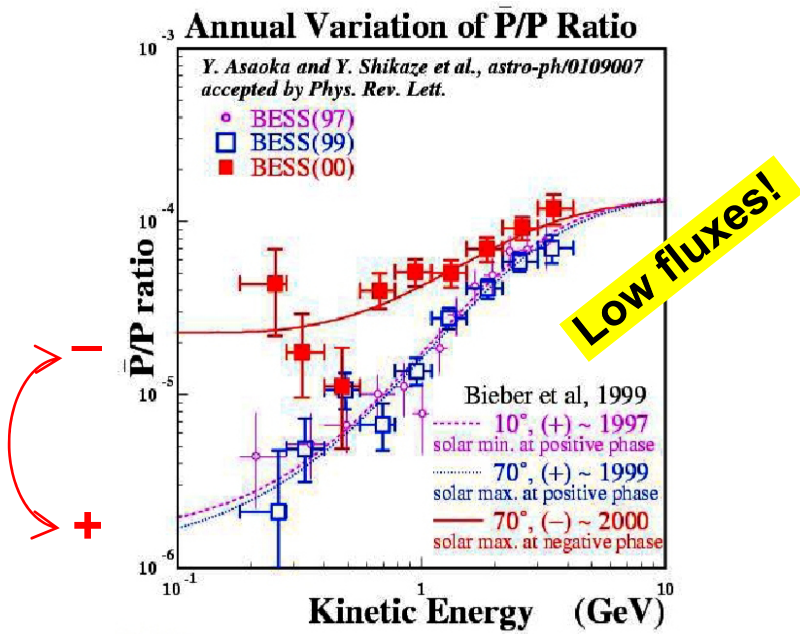
End 2007:
~10 000 e^+ > 1.5 GeV

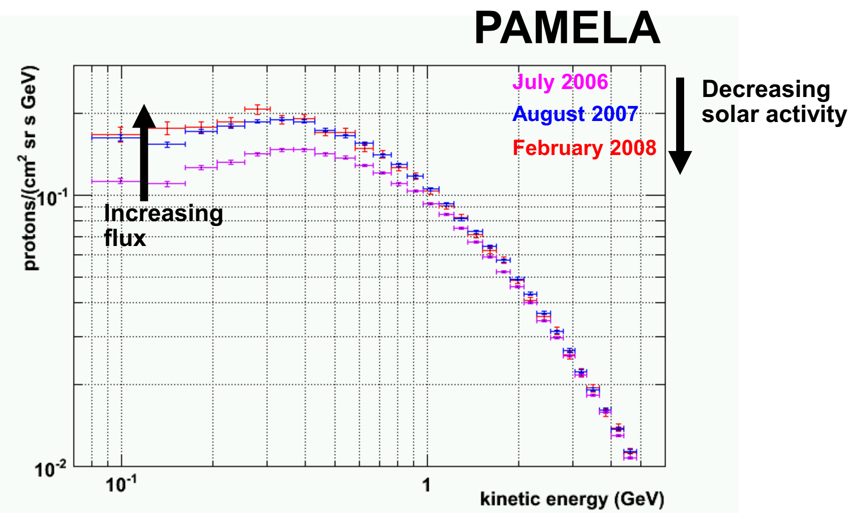
~2000 > 5 GeV

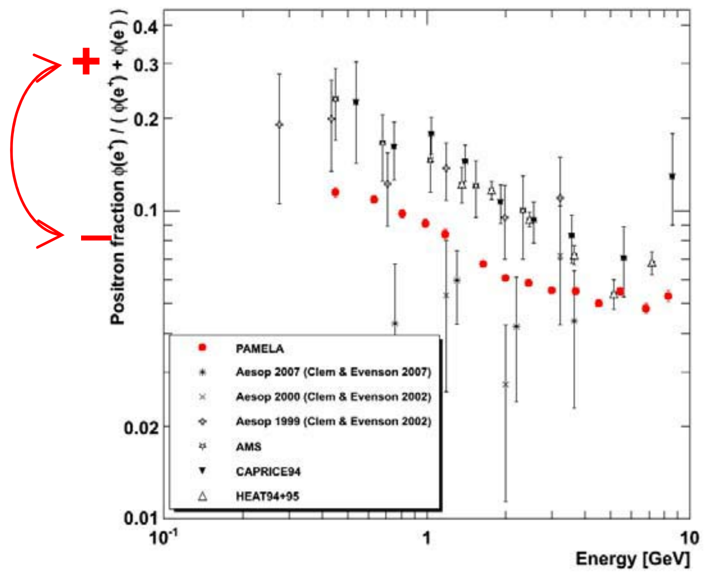
Nature 458 (2009) 607,
Astro-ph 0810.4995

Solar modulation

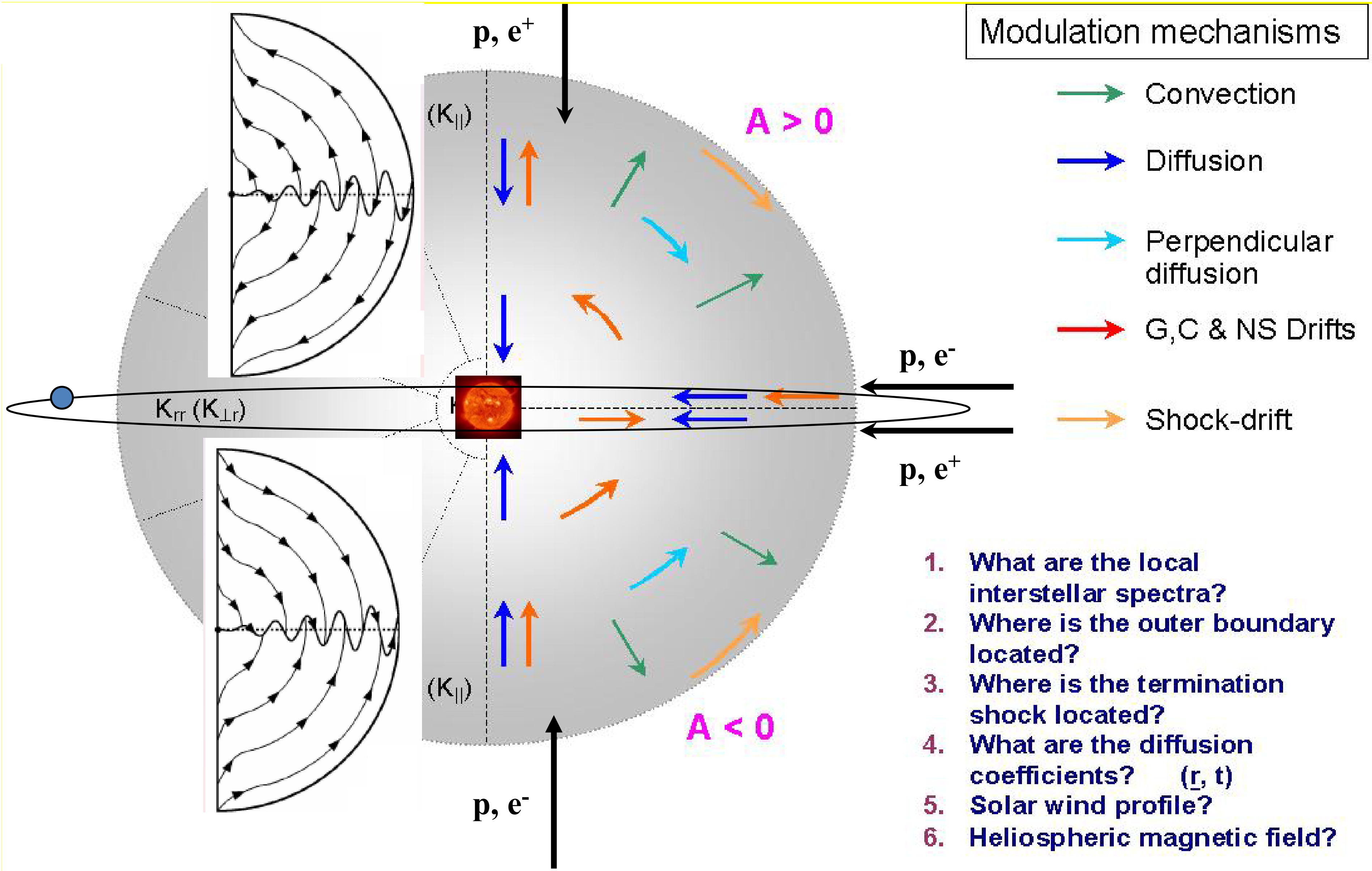






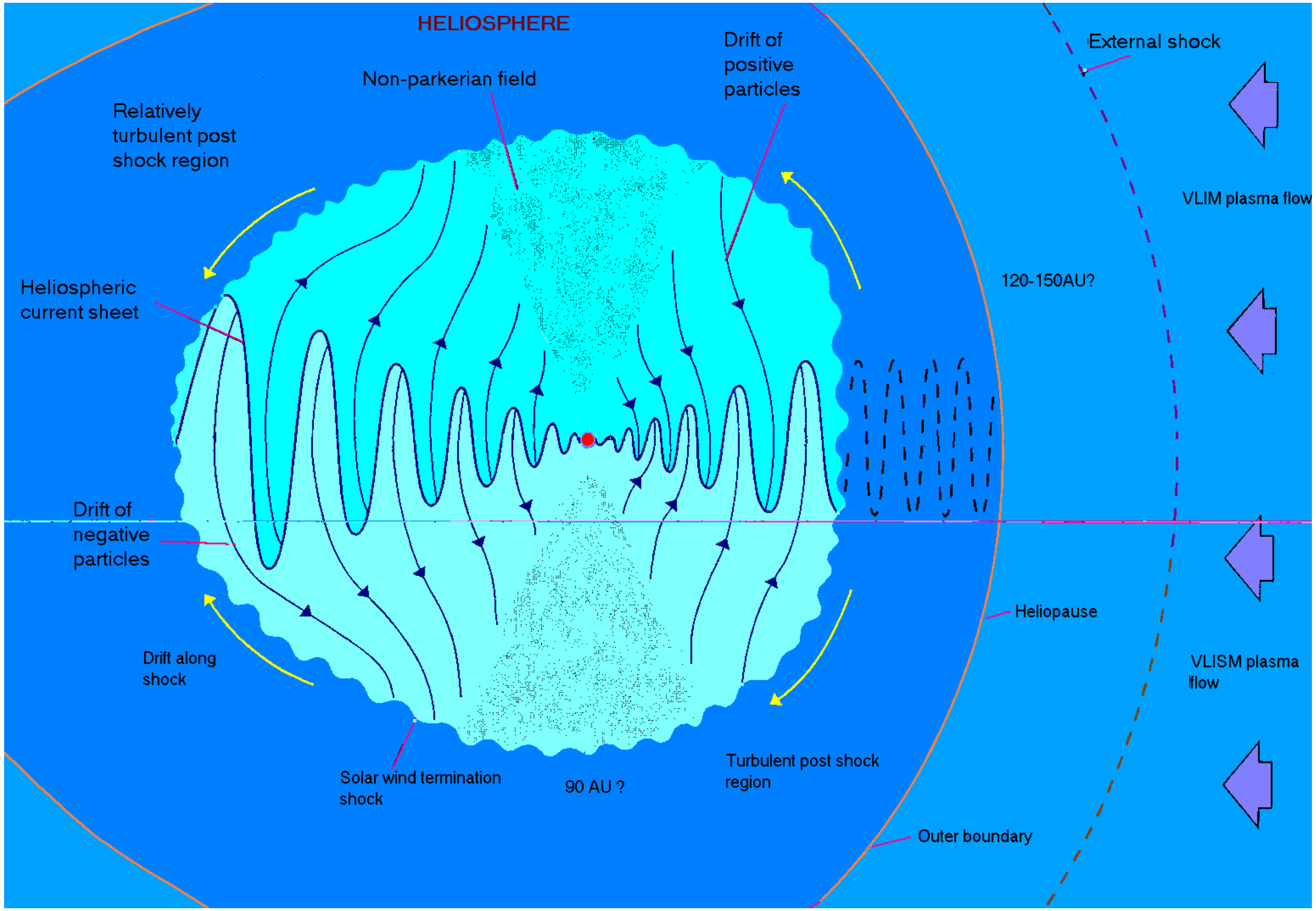


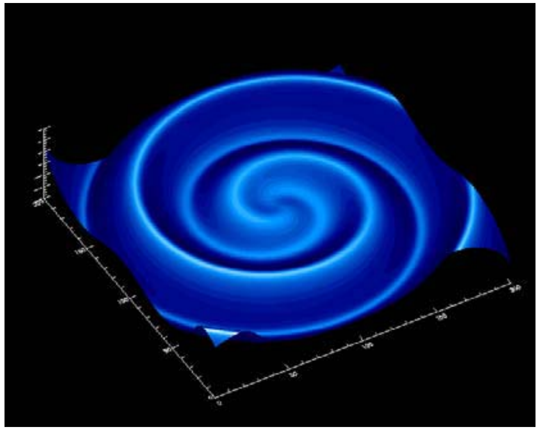
Charge dependent solar modulation



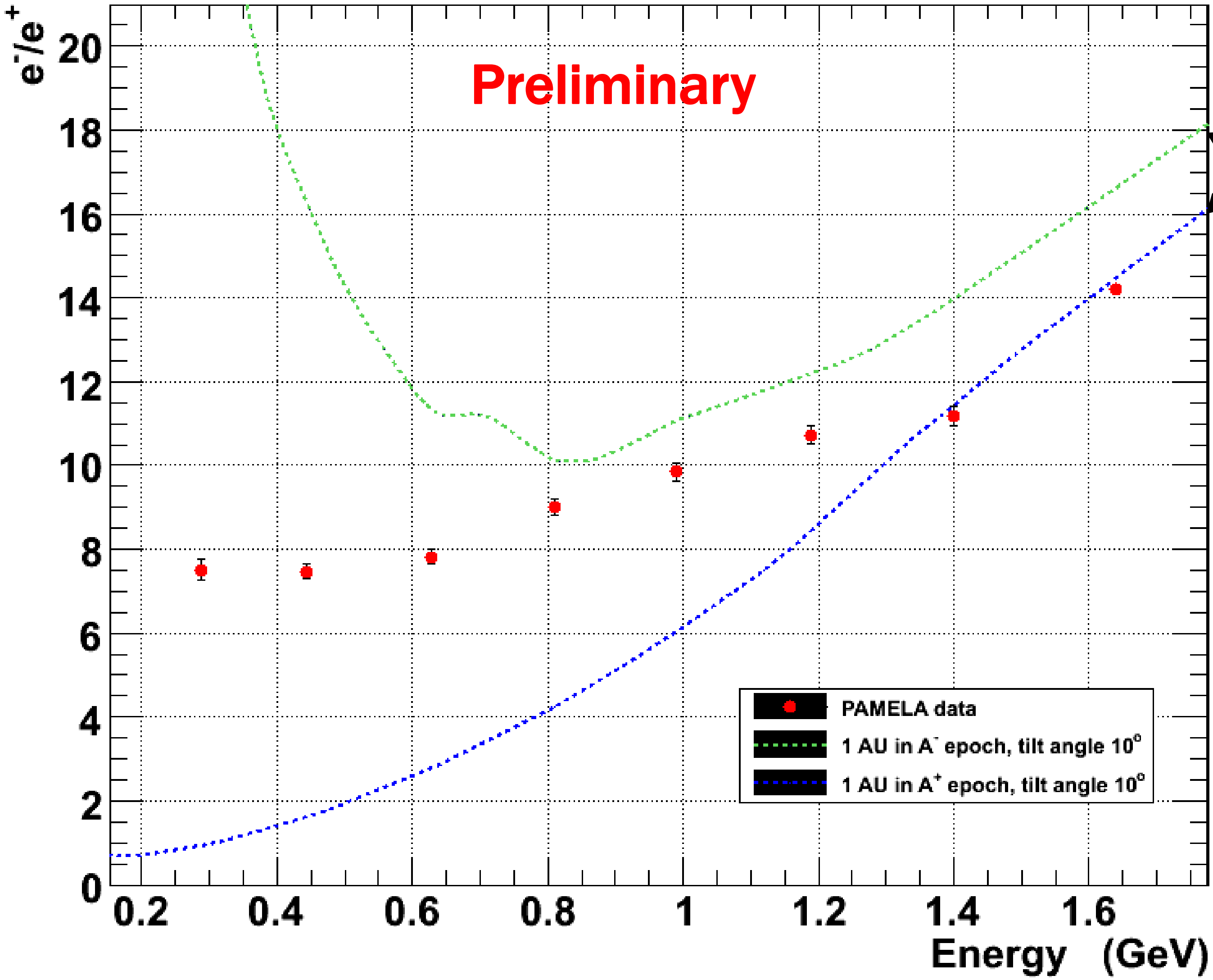
1. What are the local interstellar spectra?
2. Where is the outer boundary located?
3. Where is the termination shock located?
4. What are the diffusion coefficients? (r, t)
5. Solar wind profile?
6. Heliospheric magnetic field?

Heliosphere & Cosmic Ray Modulation Mechanisms



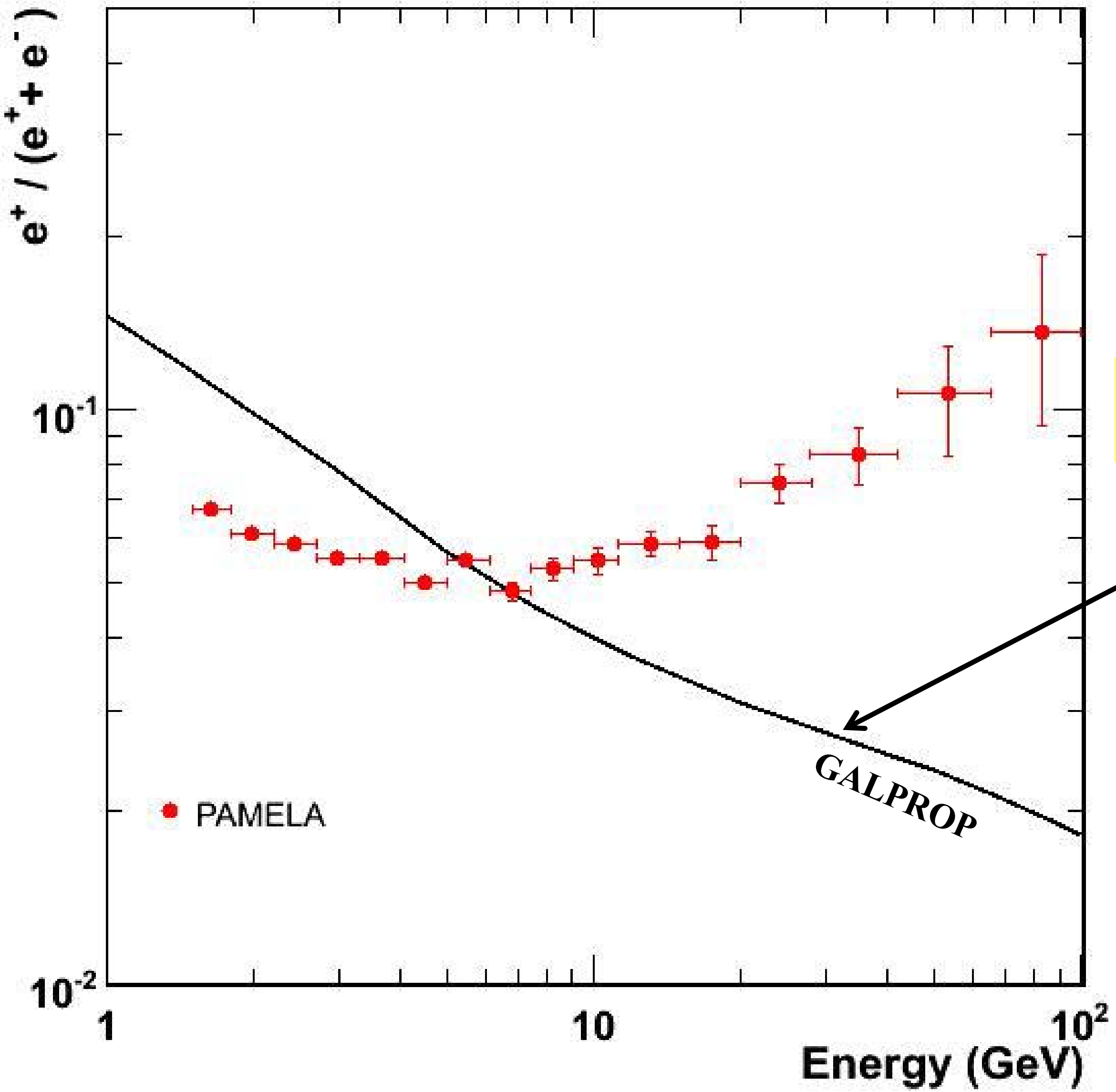


PAMELA electron to positron ratio and theoretical models



U.W. Langner, M.S. Potgieter, Advances in Space Research 34 (2004)

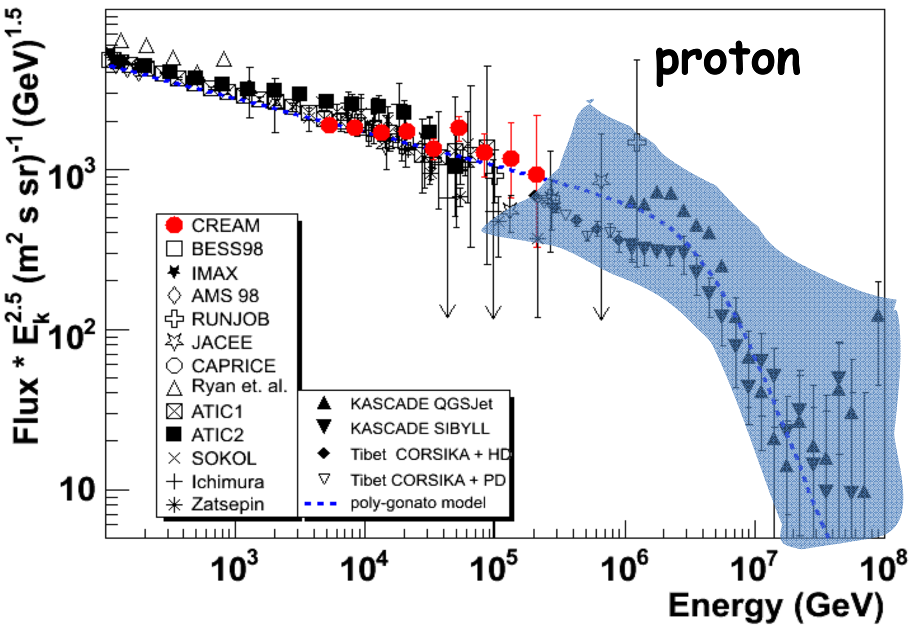
PAMELA Positron Fraction

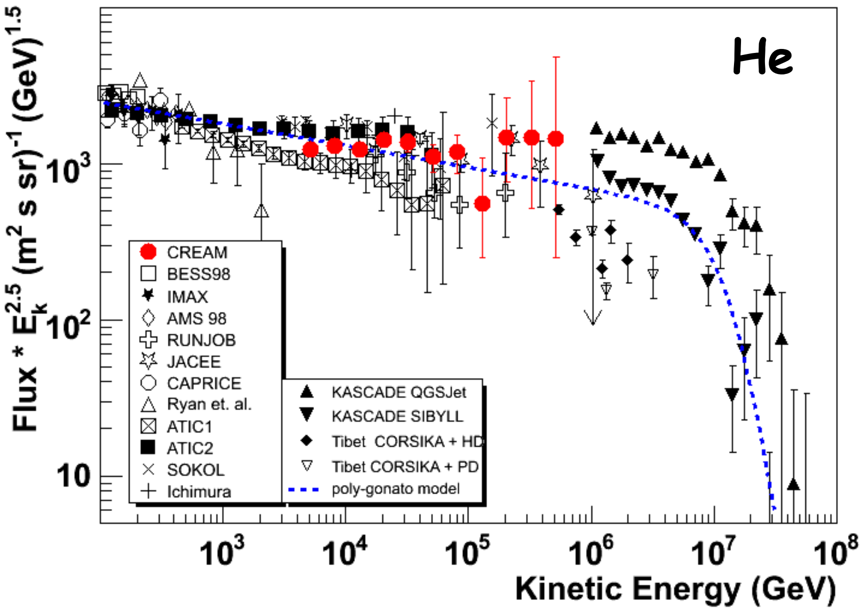


Secondary production
Moskalenko & Strong 98

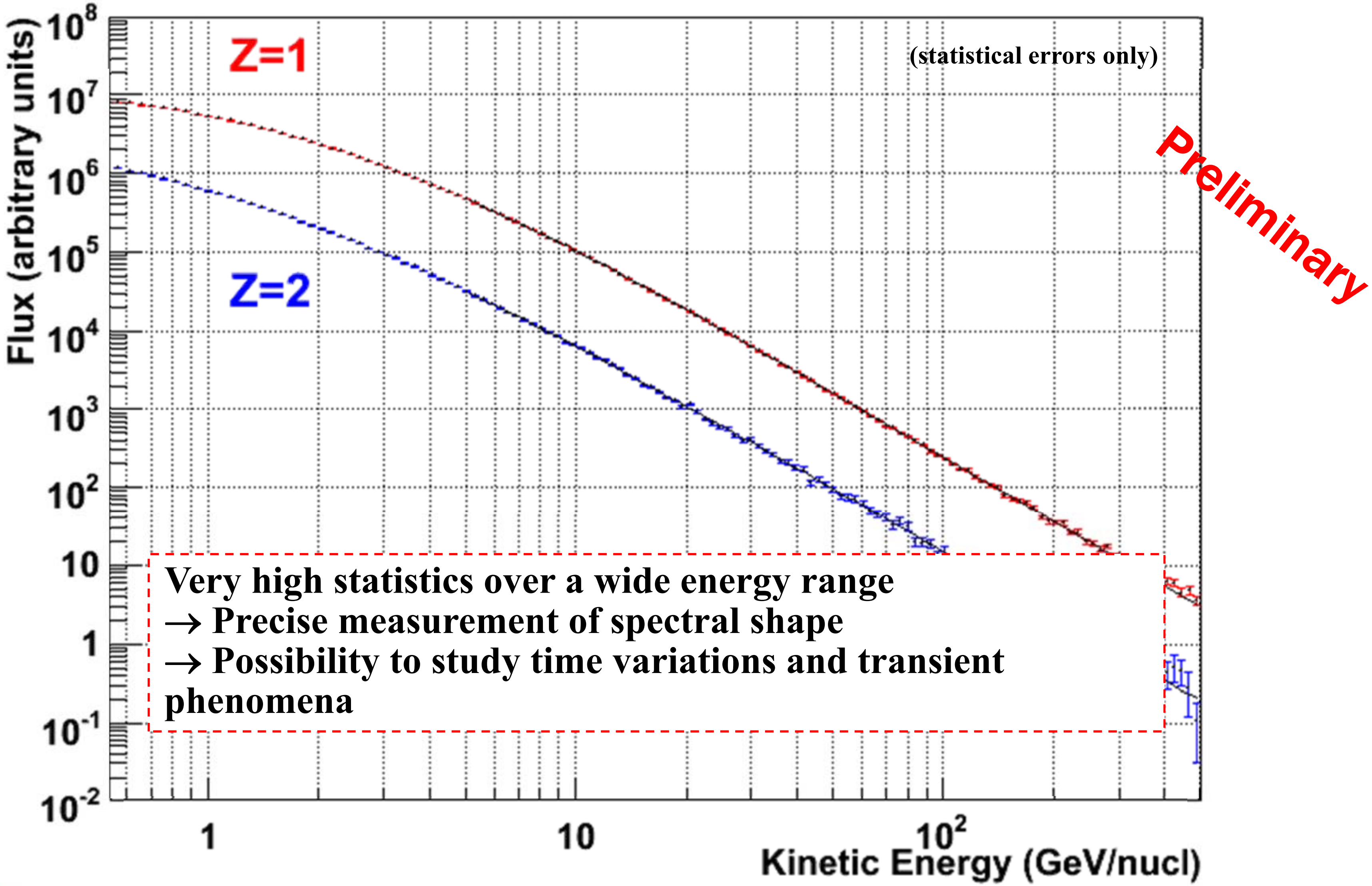
But uncertainties on:
- **Secondary production (primary fluxes, cross section)**

Galactic H and He spectra



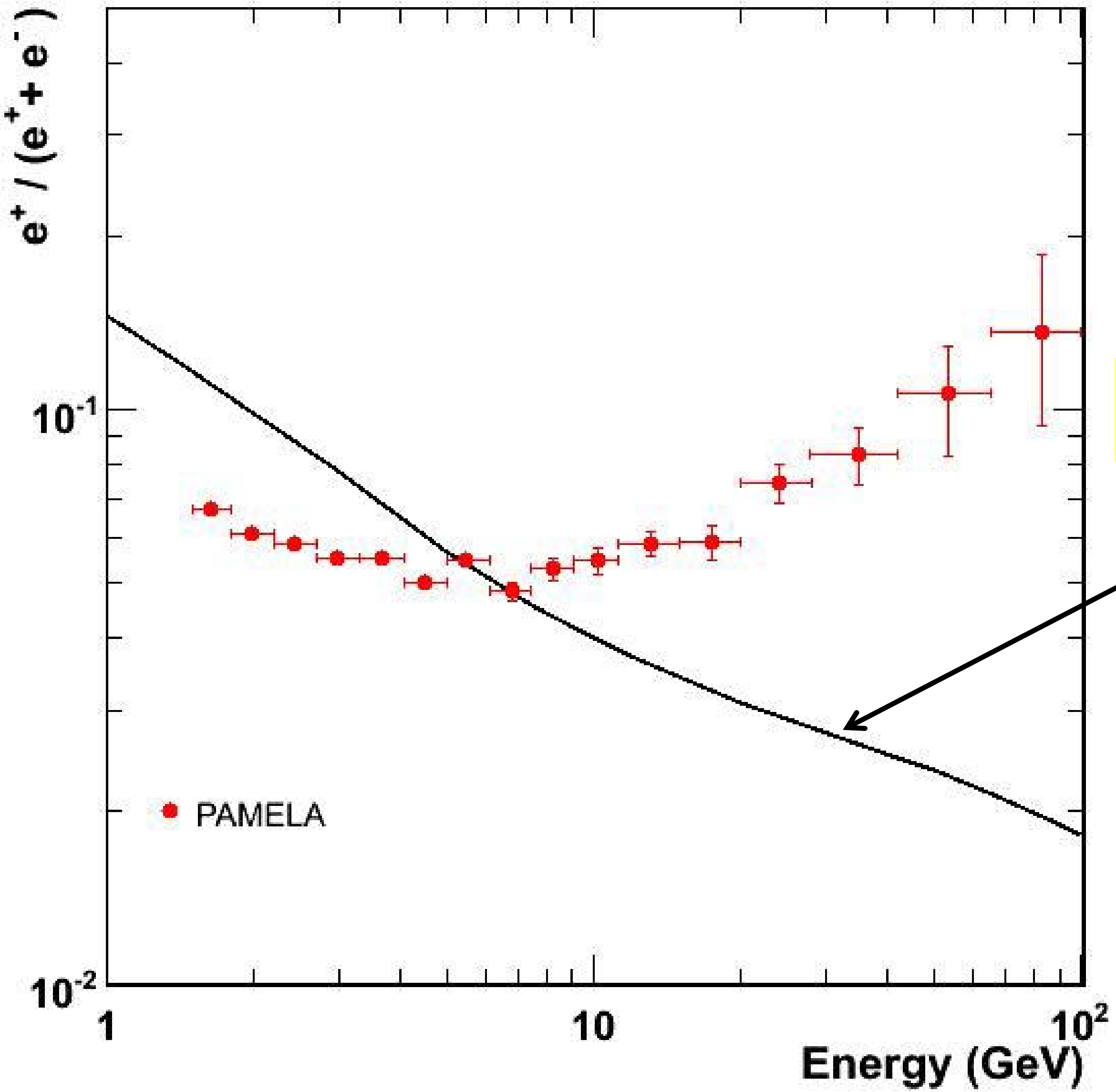


Galactic H and He spectra



Very high statistics over a wide energy range
→ Precise measurement of spectral shape
→ Possibility to study time variations and transient phenomena

PAMELA Positron Fraction

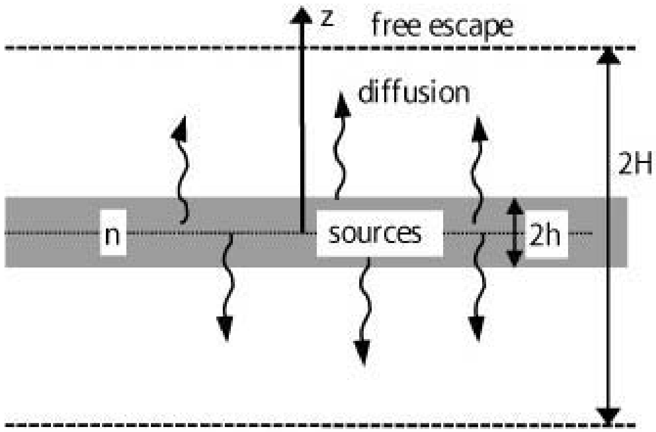


<u>Secondary production</u>
Moskalenko & Strong 98

But uncertainties on:

- **Secondary production (primary fluxes, cross section)**
- **Propagation models**

Diffusion Halo Model



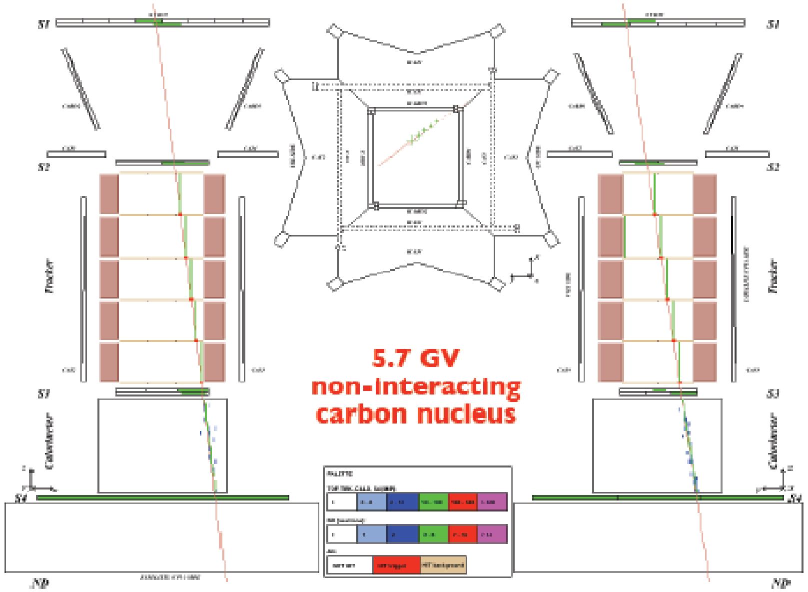
$$\frac{\partial N_i(E,z,t)}{\partial t} = \underbrace{D(E)\cdot\frac{\partial^2}{\partial z^2}N_i(E,z,t)}_{\text{diffusion}} \underbrace{- N_i(E,z,t)\left\{\frac{1}{\tau_i^{\text{int}}(E,z)}+\frac{1}{\gamma(E)\tau_i^{dec}}\right\}}_{\text{interaction and decay}}$$

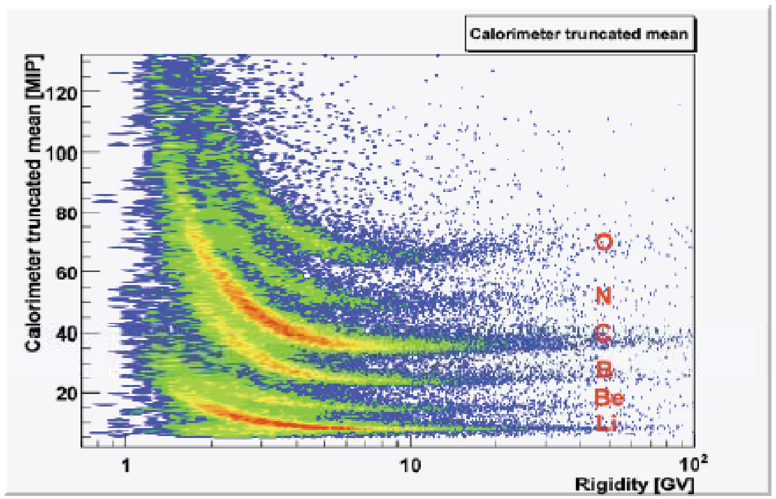
$$+ \underbrace{\sum_{k>i}\frac{N_k(E,z,t)}{\tau_{\text{int}}^{k\to i}(E,z)}}_{\text{secondary production}} + \underbrace{Q_i(E,z)}_{\text{primary sources}}$$

$$\underbrace{-\frac{\partial}{\partial E}\left\{\left\langle\frac{\partial E}{\partial t}\right\rangle\cdot N_i(E,z,t)\right\}+\frac{1}{2}\frac{\partial^2}{\partial E^2}\left\{\left\langle\frac{\Delta E^2}{\Delta t}\right\rangle\cdot N_i(E,z,t)\right\}}_{\text{energy changing processes (ionisation, reacceleration)}}$$

Nuclei identification

- **Important input to secondary production + propagation models**
  - Secondary to primary ratios:
    - B / C
    - Be / C
    - Li / C
  - Helium and hydrogen isotopes:
    - ^{3}He / ^{4}He
    - d / He

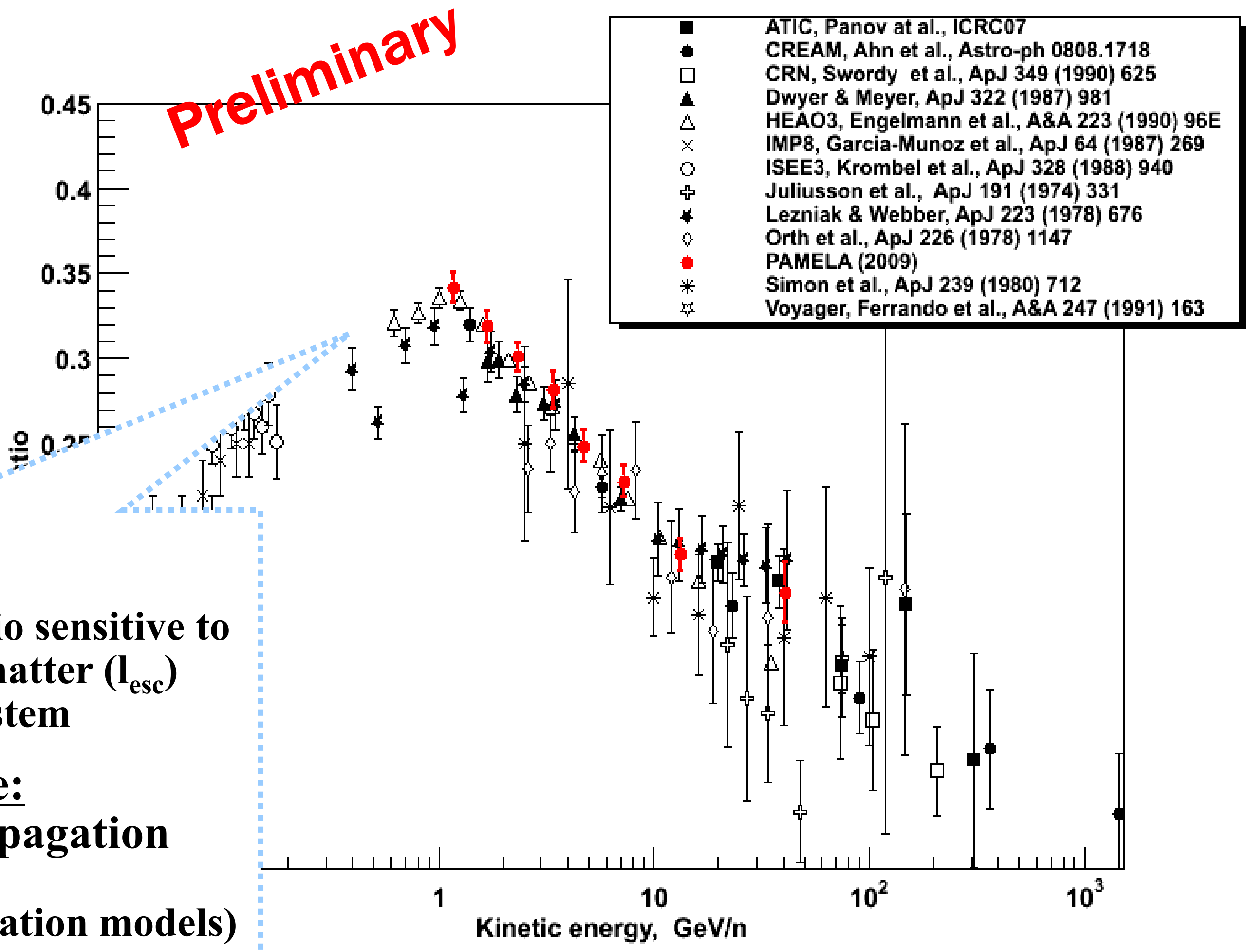




Truncated mean of multiple dE/dx measurements in different silicon planes

Secondary nuclei

$$\frac{N_S}{N_P} \propto \lambda_{esc} \cdot \sigma_{P \to S}$$



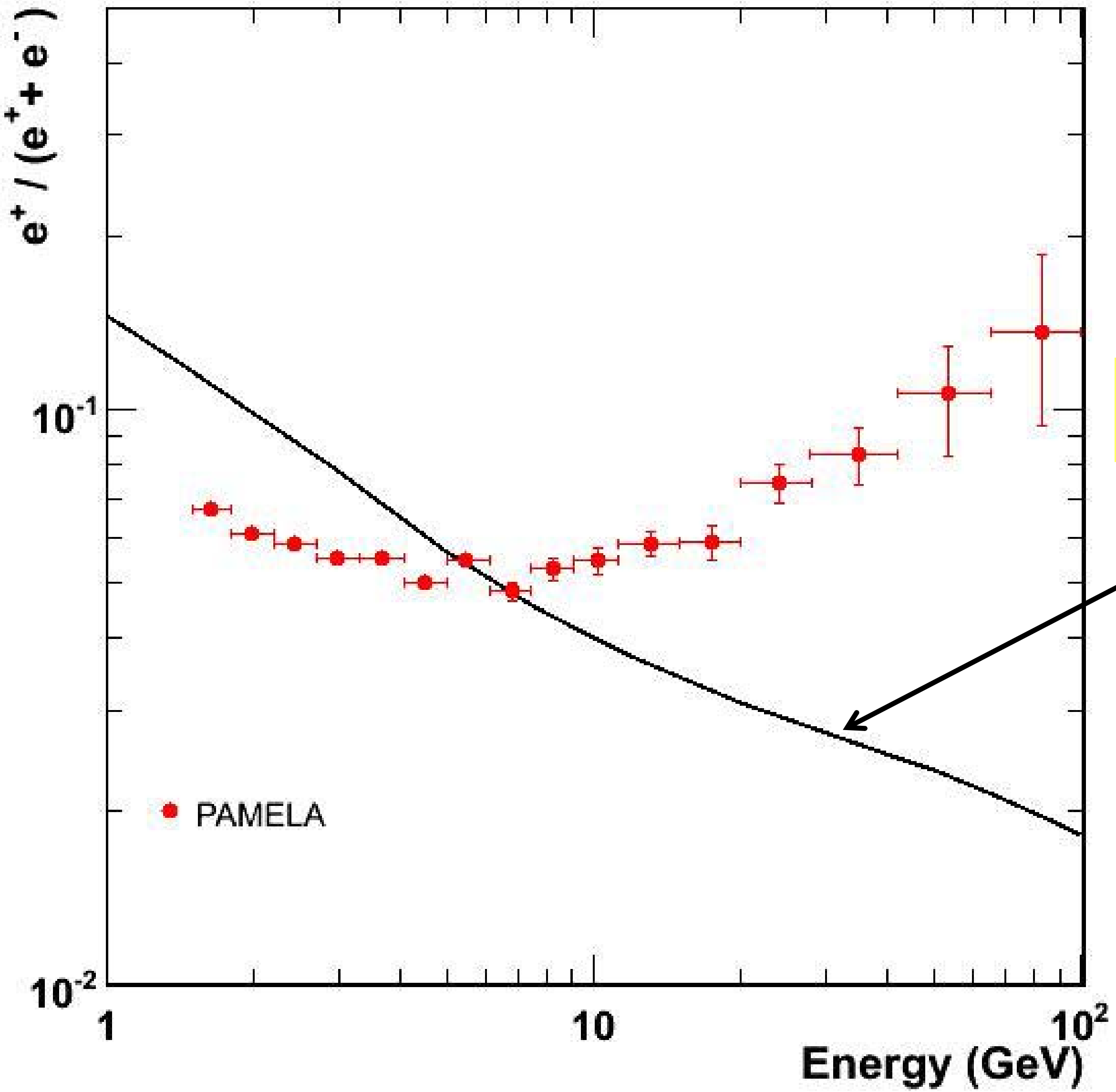
- B nuclei of secondary origin:
  CNO + ISM → B + …
- Local secondary/primary ratio sensitive to average amount of traversed matter (l_{esc}) from the source to the solar system

<u>Local secondary abundance:</u>

⇒ study of galactic CR propagation

(B/C used for tuning of propagation models)

PAMELA Positron Fraction

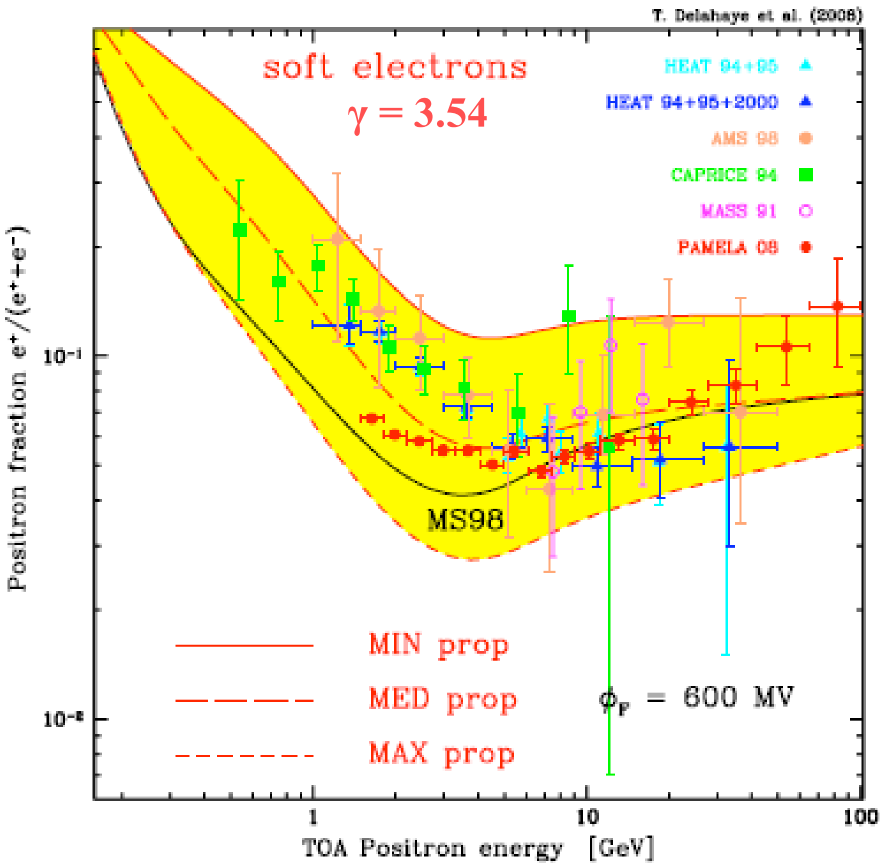


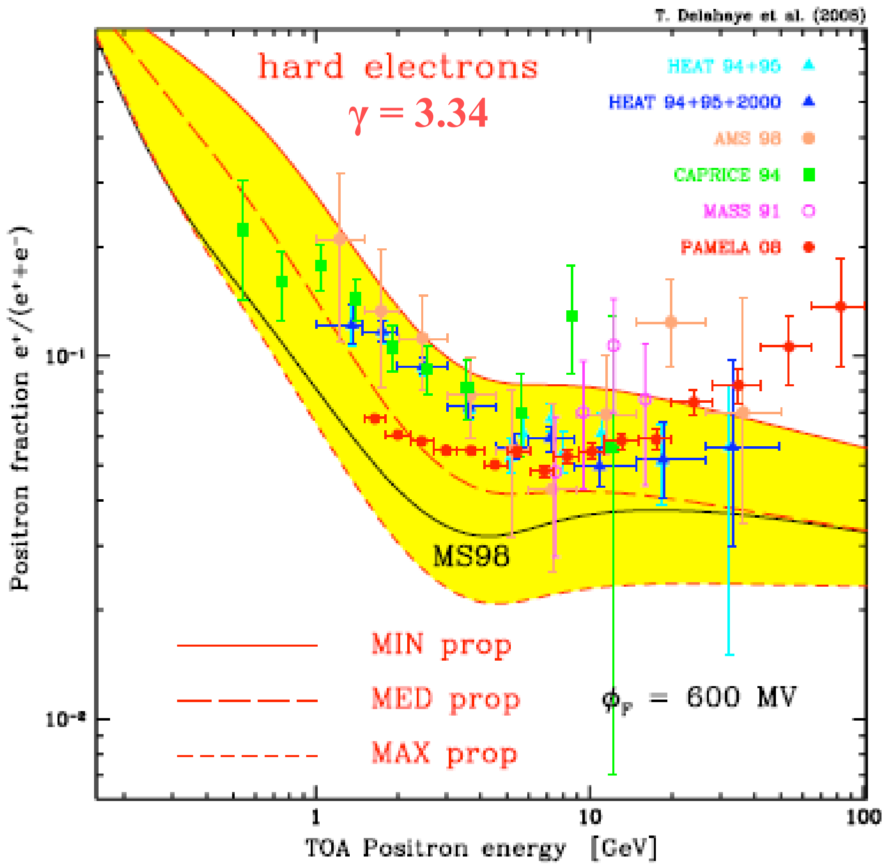
Secondary production
Moskalenko & Strong 98

But uncertainties on:

- **Secondary production (primary fluxes, cross section)**
- **Propagation models**
- **Electron spectrum**

Theoretical uncertainties on "standard" positron fraction





T. Delahaye et al., arXiv: 0809.5268v3

Reasons for the positron fraction to rise

(slide by I. Moskalenko)

- ❑ Main reason – primary positrons are perhaps unavoidable
- ❑ There is no deficit in papers explaining the PAMELA positron excess

  (>200 papers since Oct 2008!):
  - Various species of the dark matter (~170)
  - Pulsars
  - SNRs
  - Microquasar
  - a GRB nearby
  - …

- ❑ Perhaps we have to discuss a deficit of positrons, not their excess!

<u>Unfortunately, they are all wrong!</u>

Reason – we do not know the electron spectrum and thus can't get an idea of the spectrum of the primary positron component (*I. Moskalenko)*

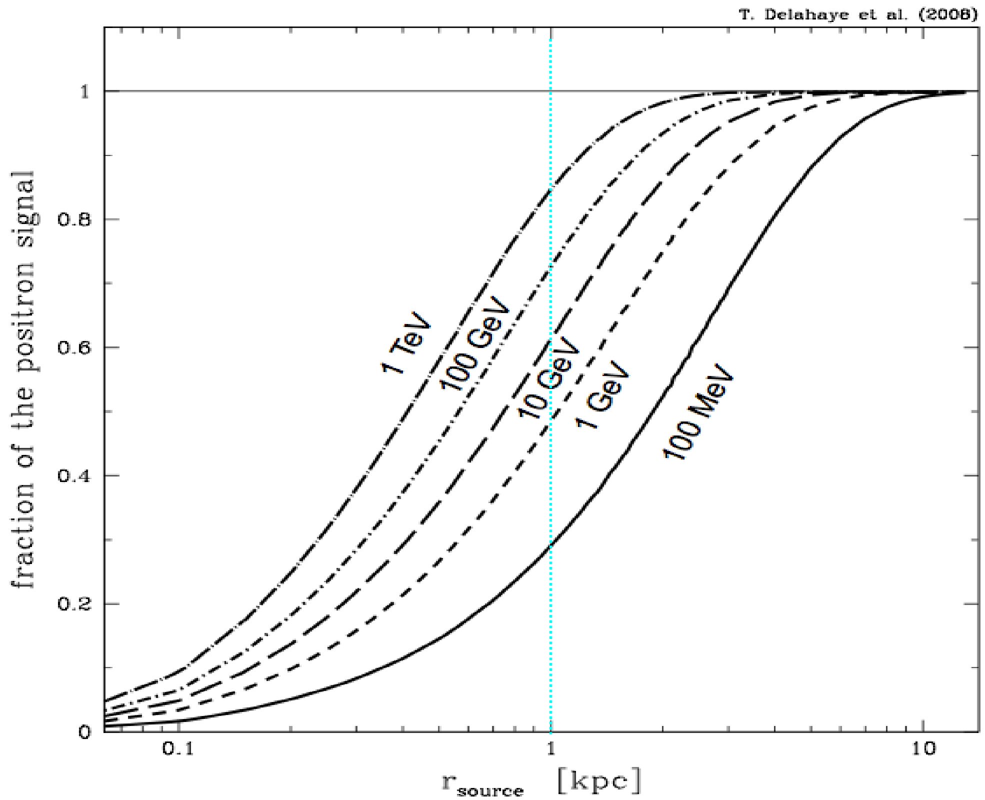
Positrons detection

Where do positrons come from?

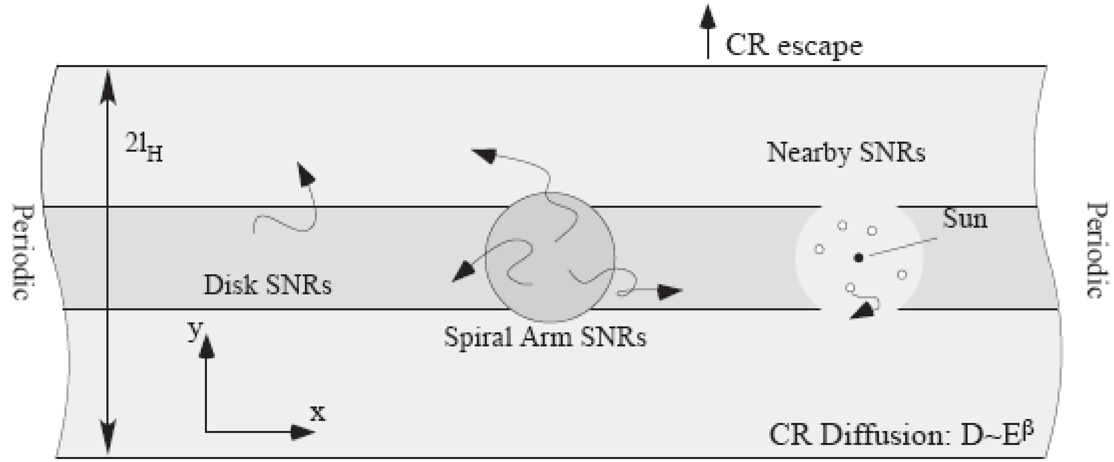
Mostly locally within 1 Kpc, due to the energy losses by Synchrotron Radiation and Inverse Compton

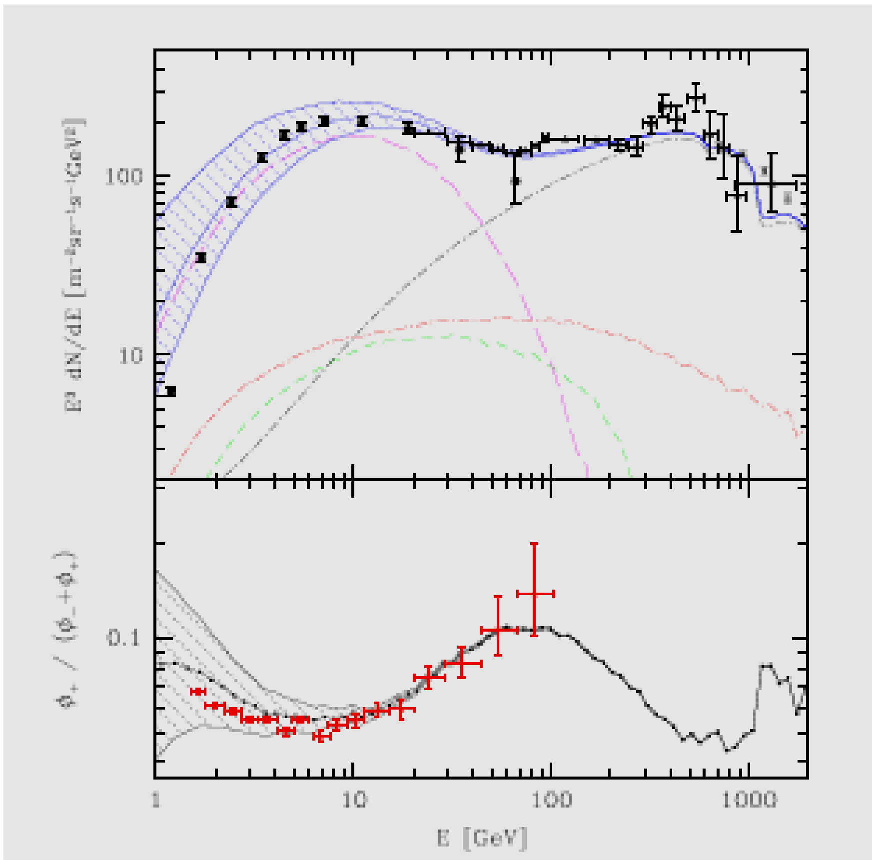
Typical lifetime

$$\tau \simeq 5 \cdot 10^5 \mathrm{yr} \left(\frac{1\,\mathrm{TeV}}{E} \right)$$



Astrophysical Explanation: SNR

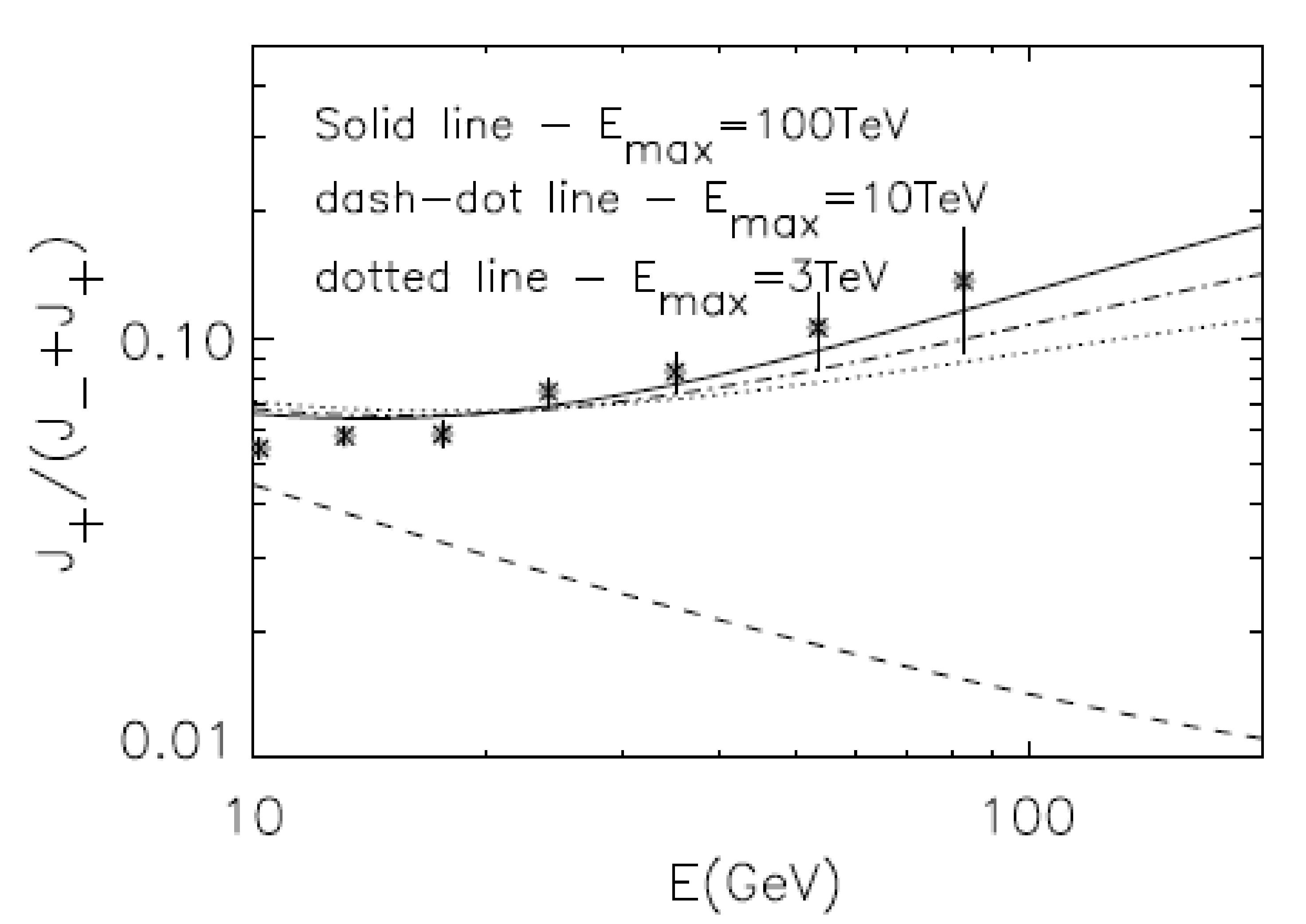




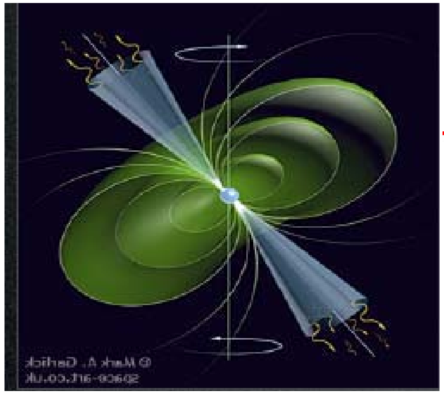
N.J. Shaviv et al., arXiv:0902.0376v1

Astrophysical Explanation: SNR

Positrons (and electrons) produced as secondaries in the sources (e.g. SNR) where CRs are accelerated



P.Blasi, arXiv:0903.2794 [astro-ph]



Astrophysical Explanation: Pulsars

- Mechanism: the spinning $\overrightarrow{B}$ of the pulsar strips e^- that accelerated at the polar cap or at the outer gap emit γ that make production of $e^\pm$ that are trapped in the cloud, further accelerated and later released at $\tau \sim 10^5$ years.

- Young ($T < 10^5$ years) and nearby (< 1kpc)
- If not: too much diffusion, low energy, too low flux.

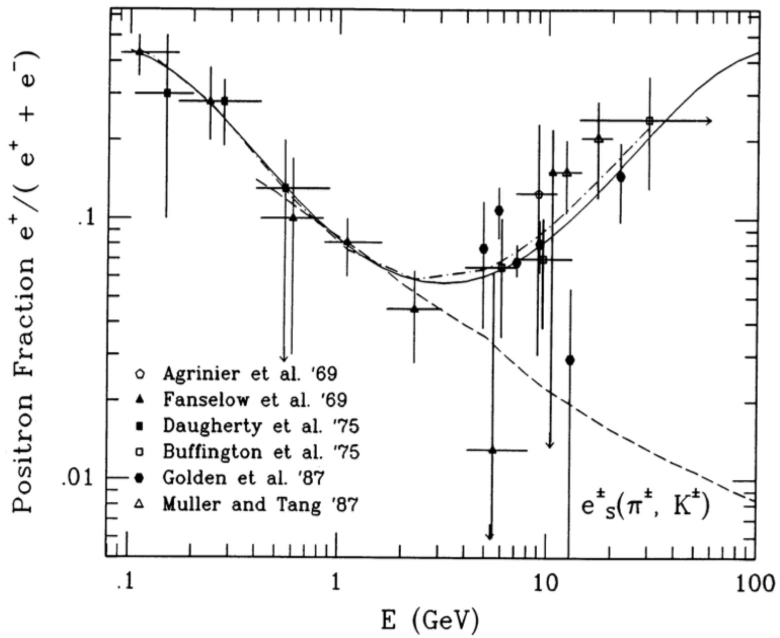
- Geminga: 157 parsecs from Earth and 370,000 years old
- B0656+14: 290 parsecs from Earth and 110,000 years old.

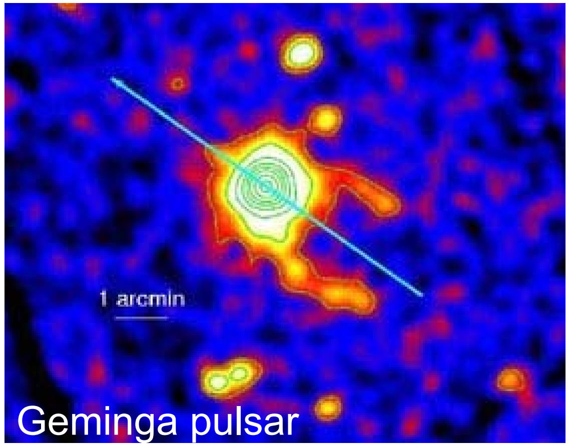
- Diffuse mature pulsars

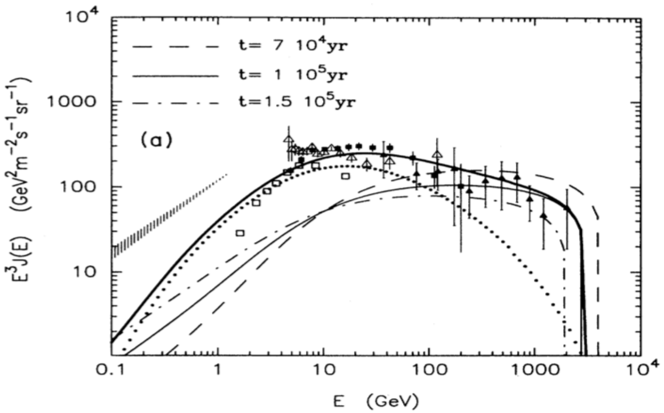
Astrophysical Explanation: Pulsars

Are there "standard" astrophysical explanations of the PAMELA data?

Young, nearby pulsars

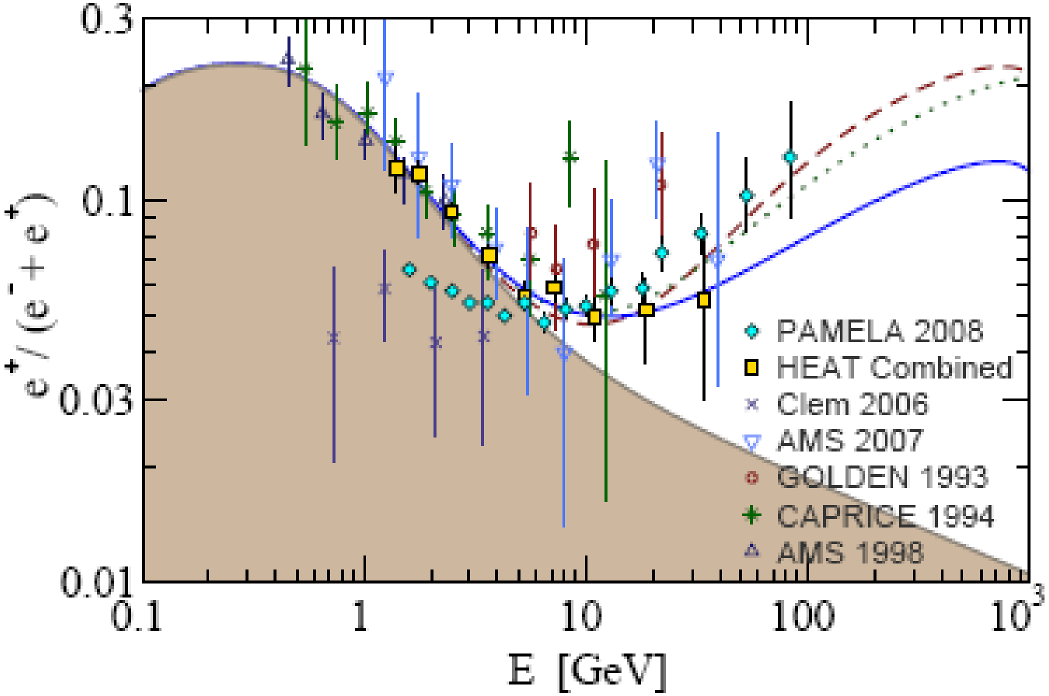




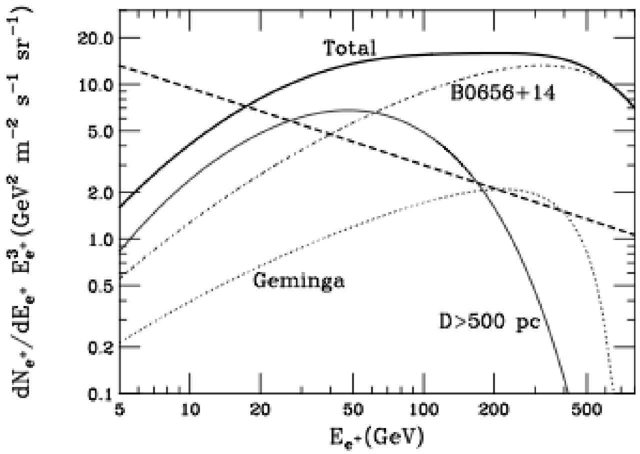


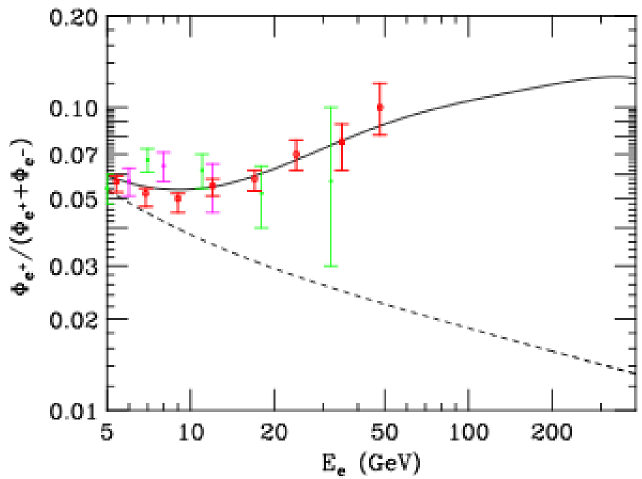
Not a new idea: Boulares, ApJ 342 (1989), Atoyan et al (1995)

Astrophysical Explanation: Pulsars



H. Yüksak et al., arXiv:0810.2784v2
Contributions of e- & e+ from Geminga assuming different distance, age and energetic of the pulsar





diffuse mature &nearby young pulsars
Hooper, Blasi, and Serpico
arXiv:0810.1527

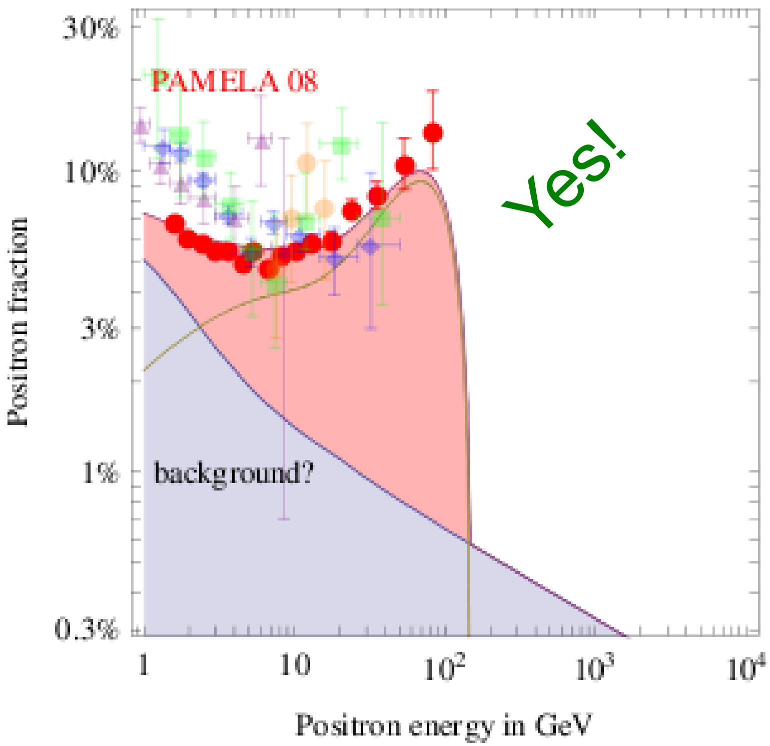
M. Cirelli et al., arXiv: 0809.2409v3

Interpretation: DM

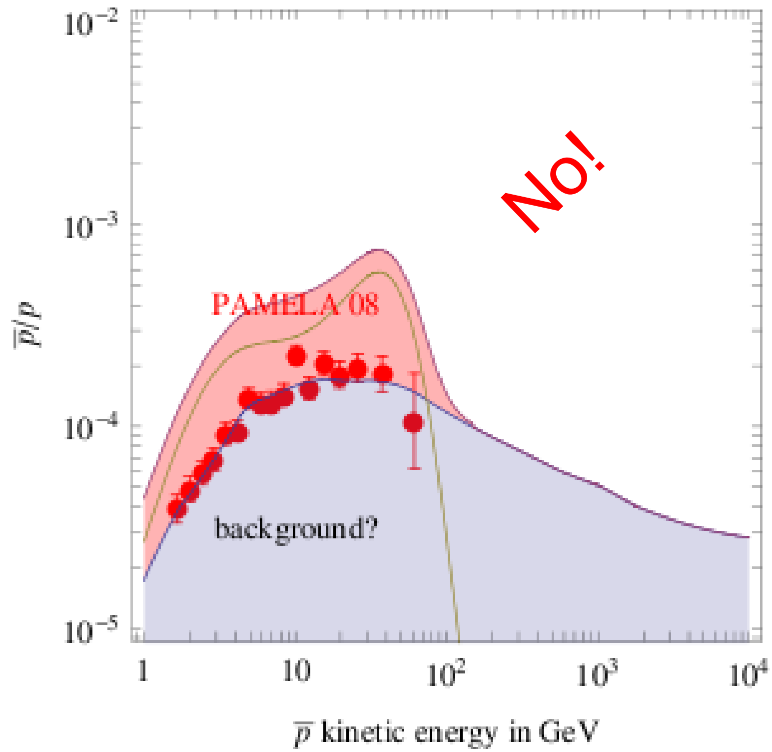
Which DM spectra can fit the data?

DM with $m_\chi \simeq 150\,\mathrm{GeV}$ and W^+W^- dominant annihilation channel (possible candidate: Wino)

positrons



antiprotons



M. Cirelli et al., arXiv: 0809.2409v3

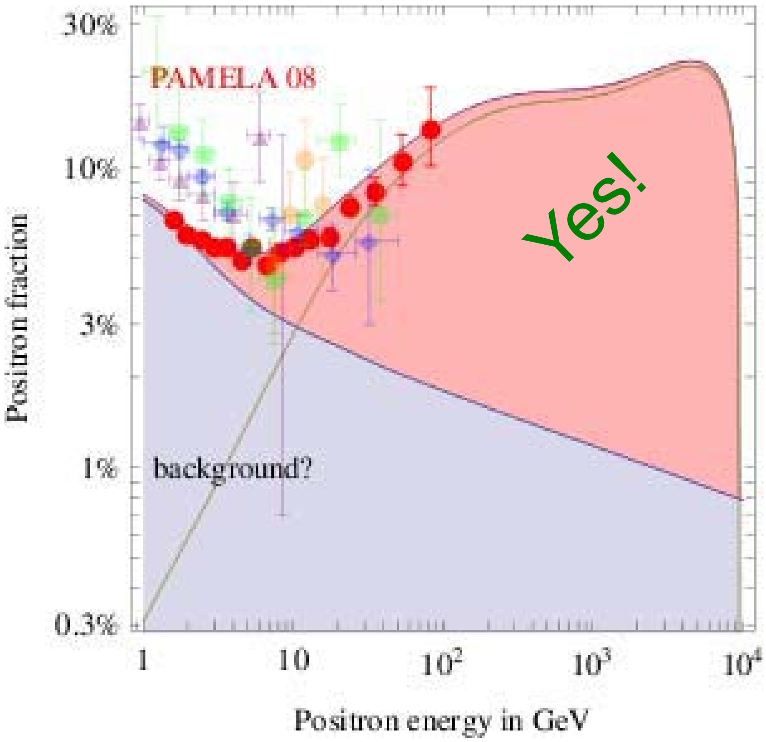
Interpretation: DM

Which DM spectra can fit the data?

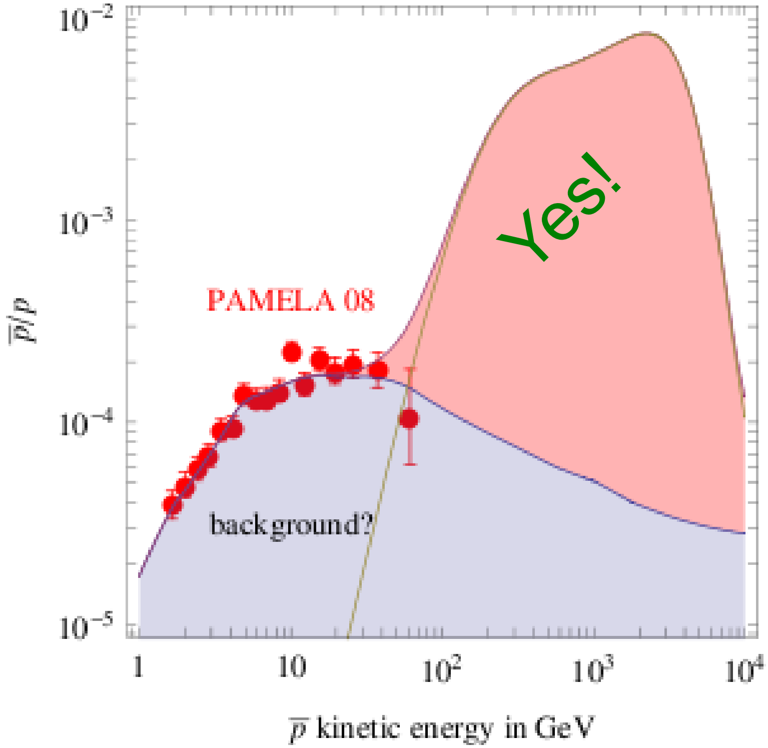
DM with $m_\chi \simeq 10\,\mathrm{TeV}$ and W^+W^- dominant annihilation channel (no "natural" SUSY candidate)

But B≈10^4

positrons



antiprotons

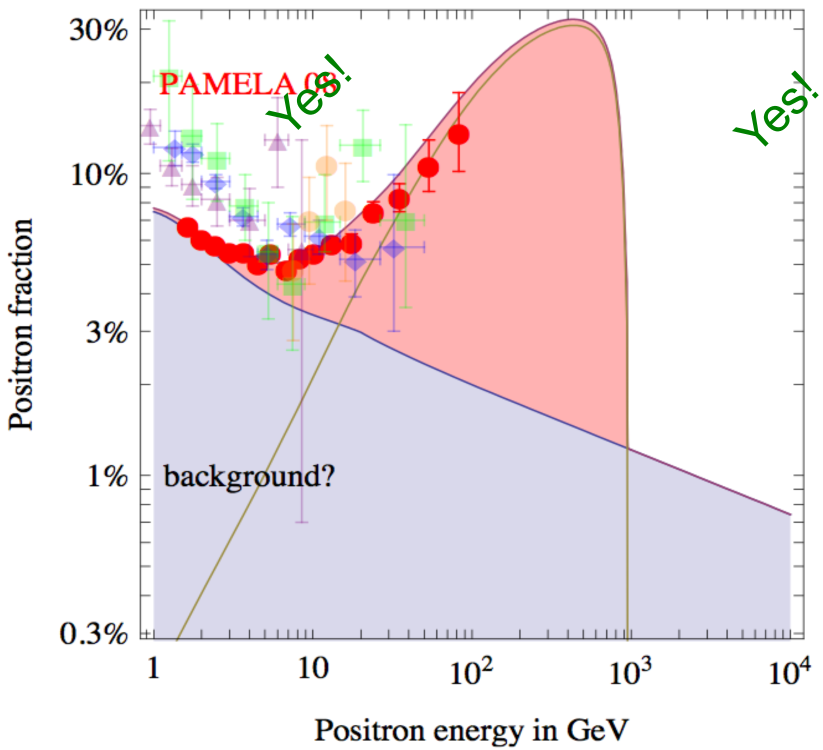


M. Cirelli et al., arXiv: 0809.2409v3

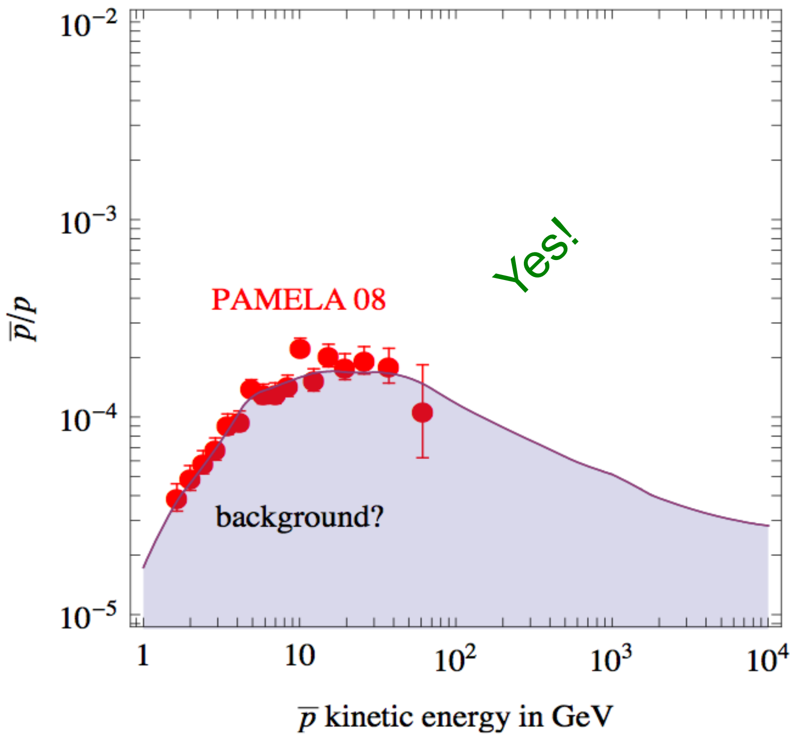
Interpretation: DM

DM with $m_\chi \simeq 1\,\mathrm{TeV}$ and $\mu^+\mu^-$ dominant annihilation channel

positrons

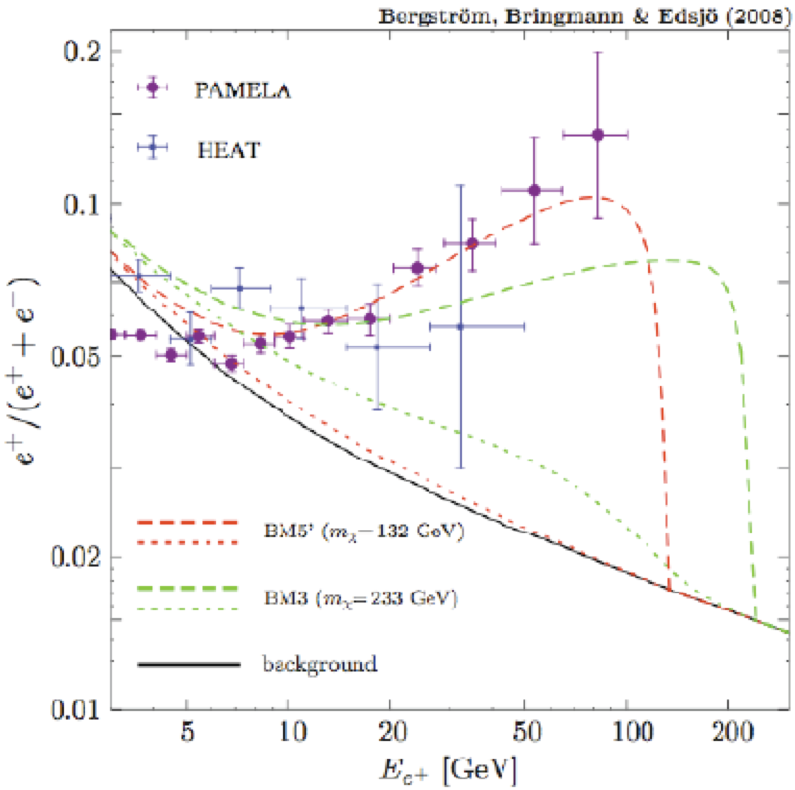


antiprotons



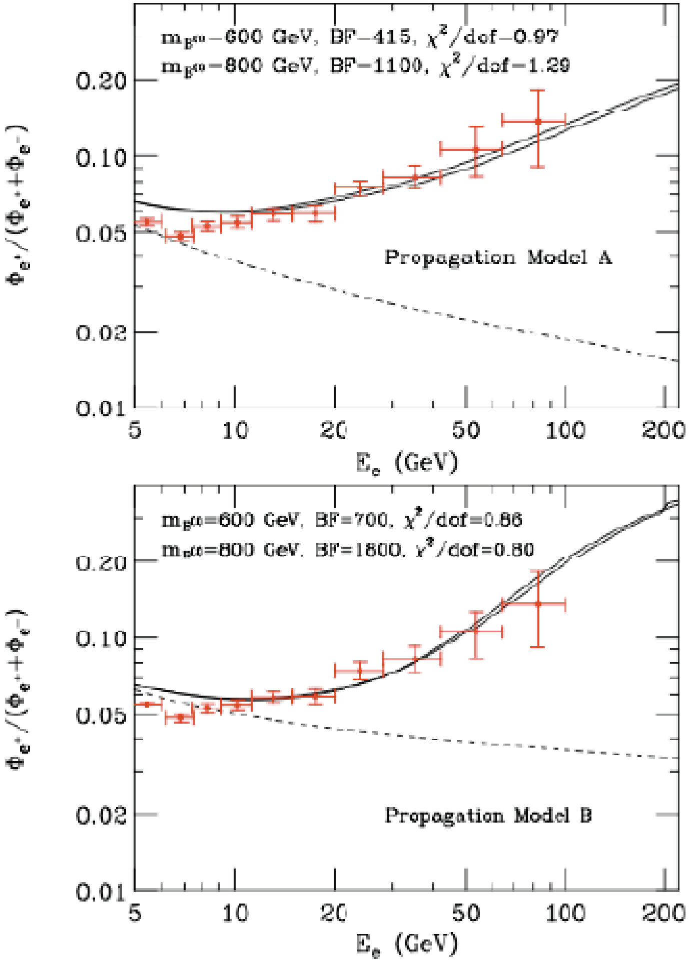
Example: Dark Matter

arXiv:0808.3725



Majorana DM with **new** internal bremsstrahlung correction. NB: requires annihilation cross-section to be 'boosted' by >1000.

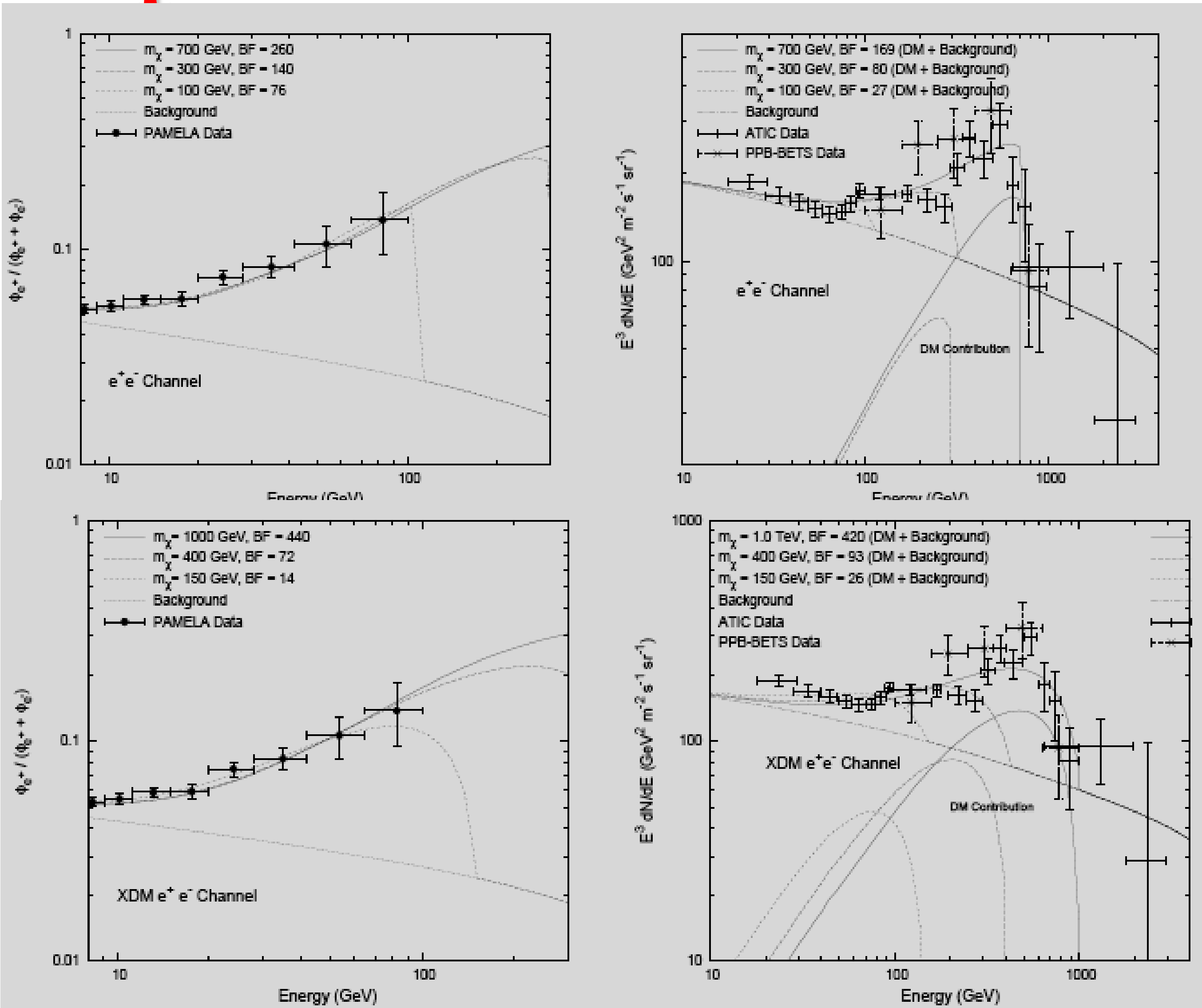
Hooper and Zurek
arXiv:0902.0593v1



Kaluza-Klein dark matter

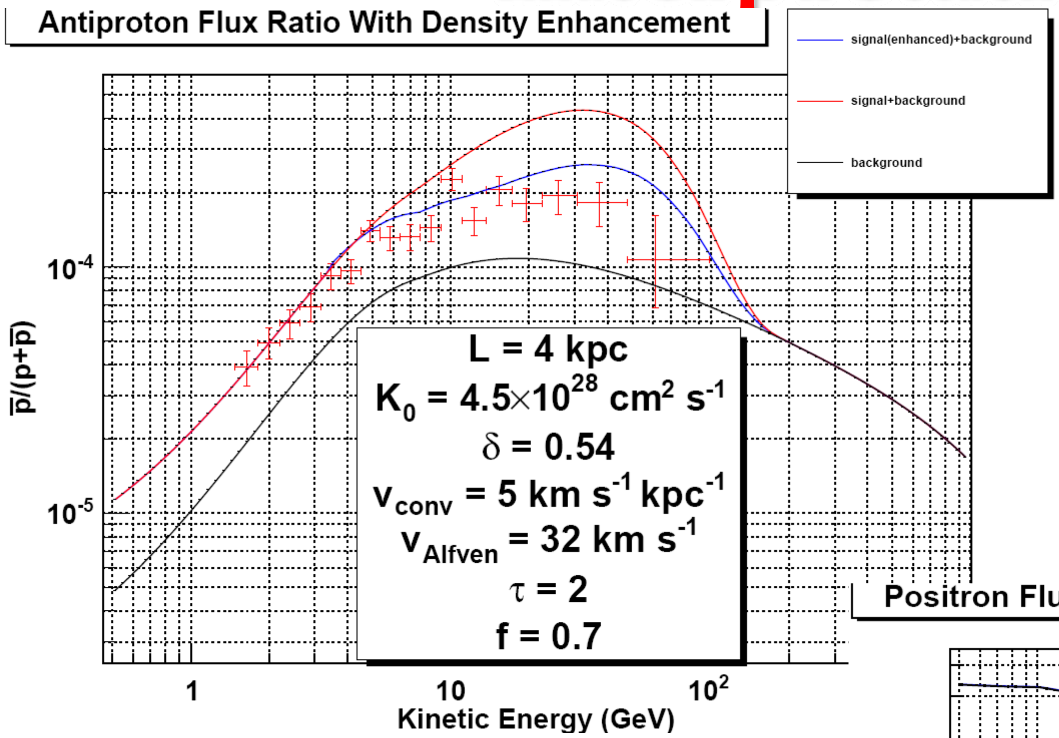
Interpretation: DM

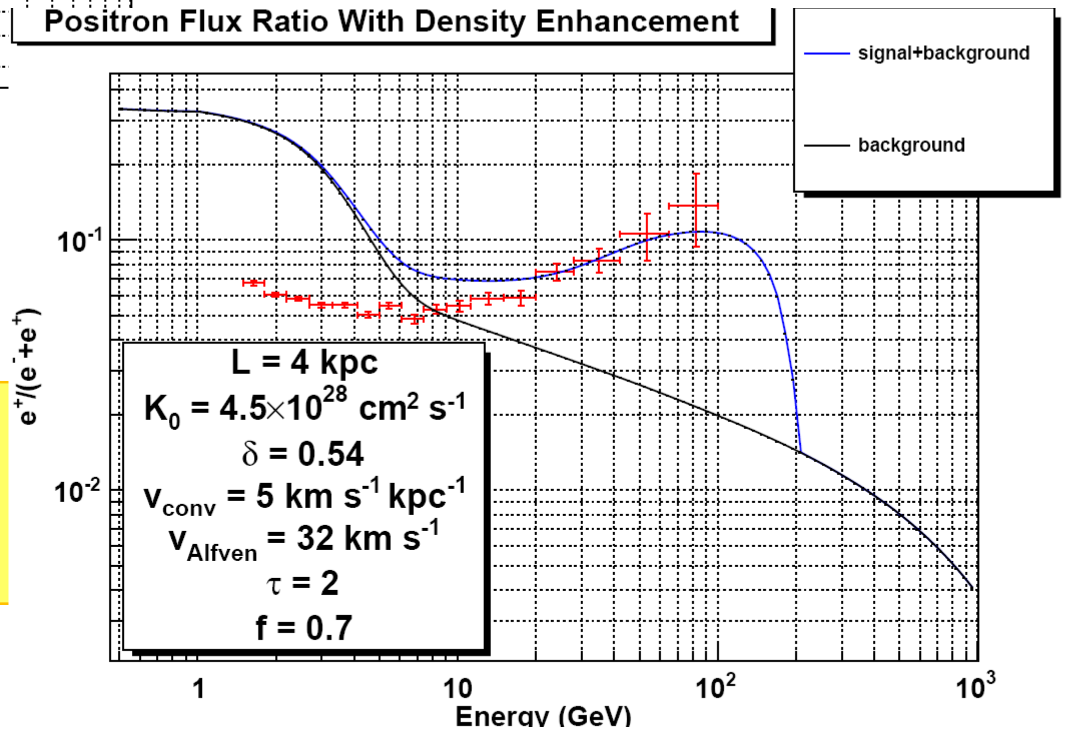
I. Cholis et al. arXiv:0811.3641v1



- Propose a new light boson ($m_\Phi \leq$ GeV), such that $\chi\chi \rightarrow \Phi\Phi$; $\Phi \rightarrow e^+e^-$, $\mu^+\mu^-$, ...
- Light boson, so decays to antiprotons are kinematically suppressed

Interpretation: DM





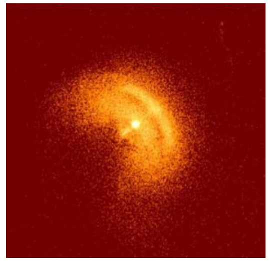
P. Grajek et al., arXiv: 0812.4555v1
Non-thermal wino-like neutralino
Varying propagation model, no boost factor

What about Electrons?

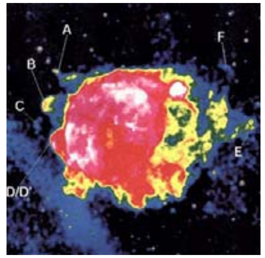
All Electron (e^- + e^+) spectra

Possible Nearby Sources
- $T < 10^5$ years
- $L < 1$ kpc

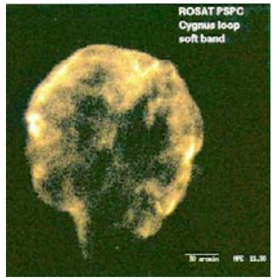
Observation of electron spectrum in 1~10 GeV for study of solar modulation

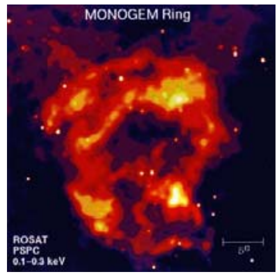


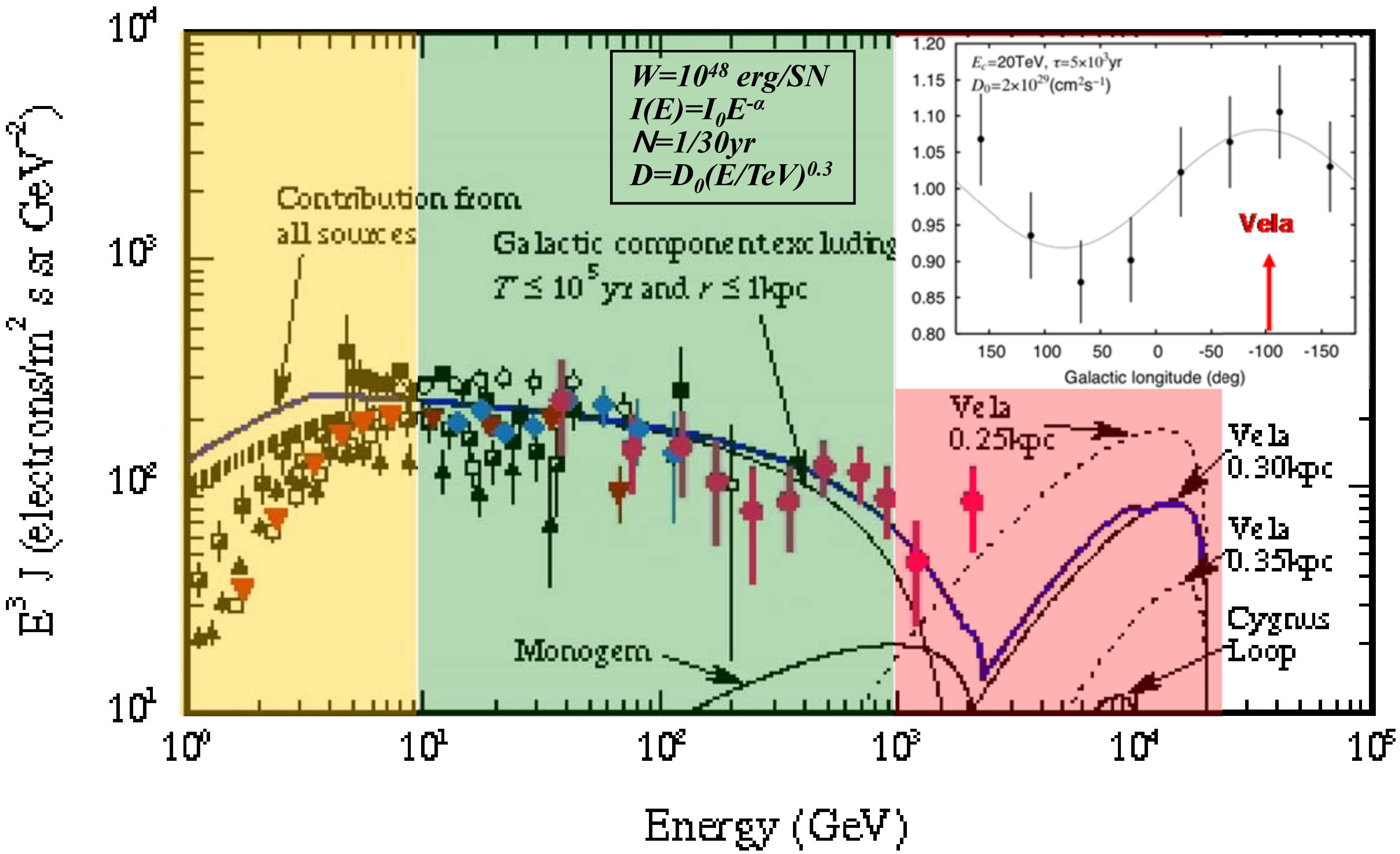
Chandra



ROSAT







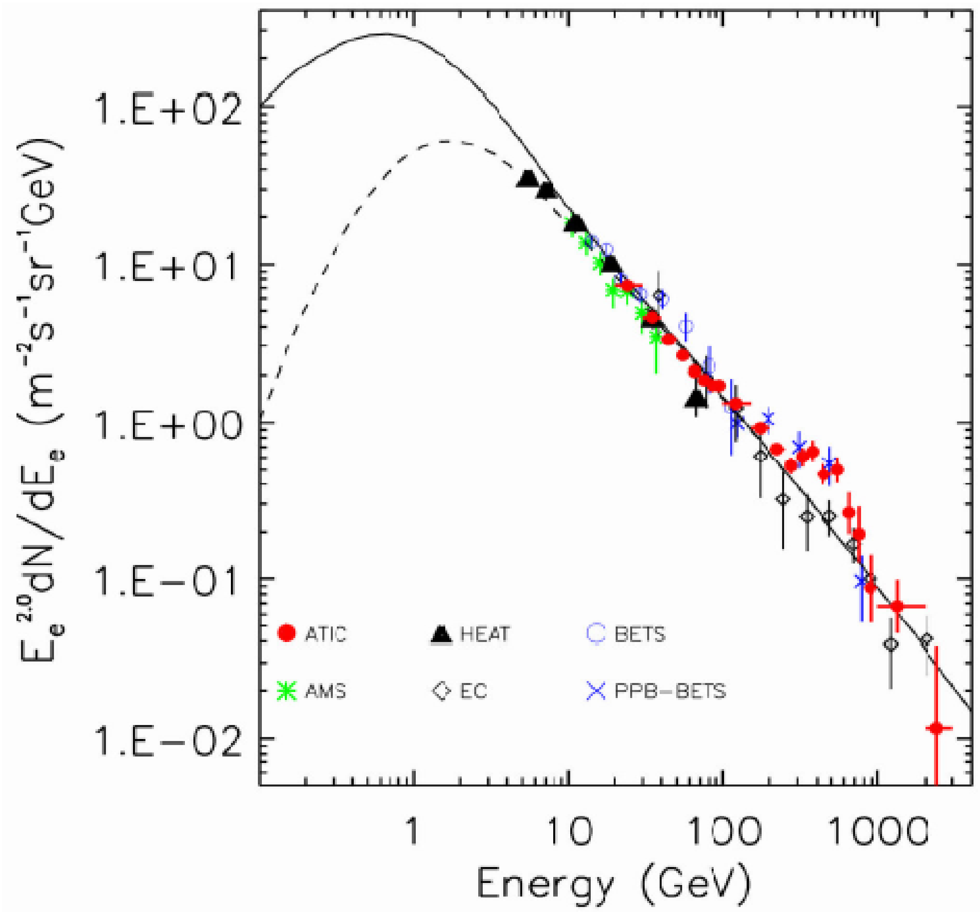
The ATIC electron results exhibits a feature

Curves are from GALPROP diffusion propagation simulation code

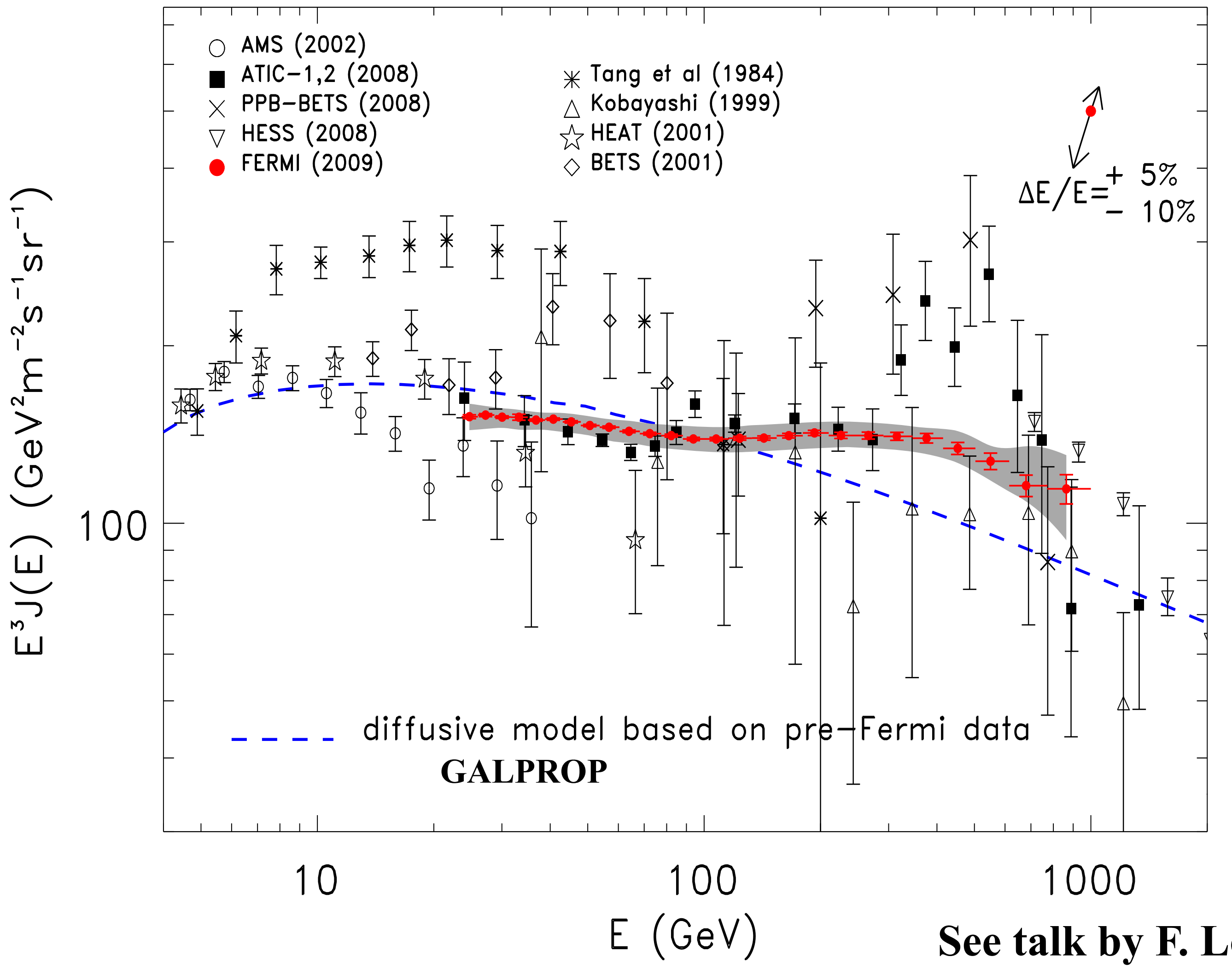
- Solid curve is local interstellar space
- Dashed curve is with solar modulation (500 MV)

“Excess” at about 300 – 600 GeV

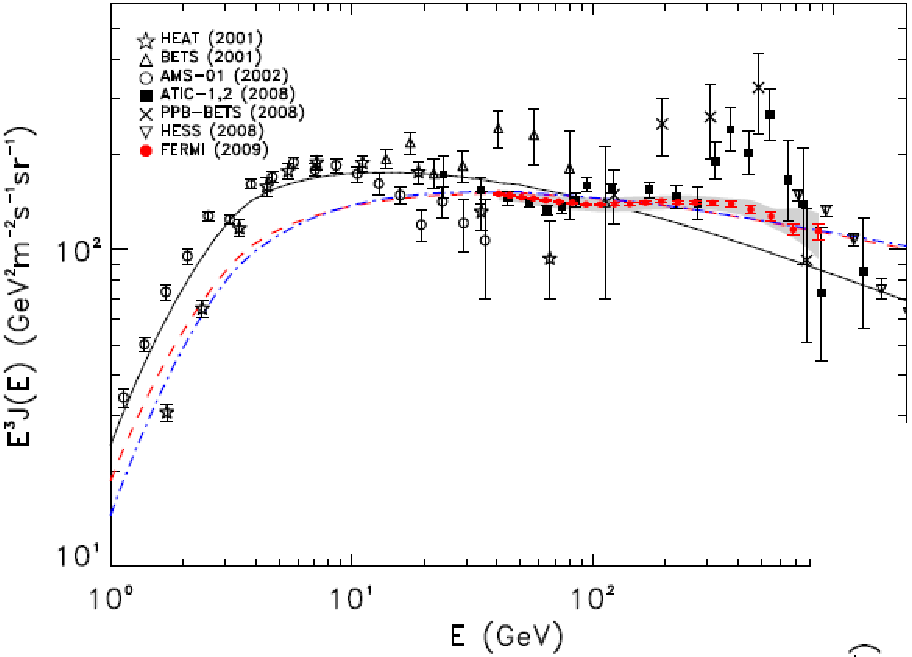
Also seen by recent PPB-BETS



FERMI all Electron Spectrum



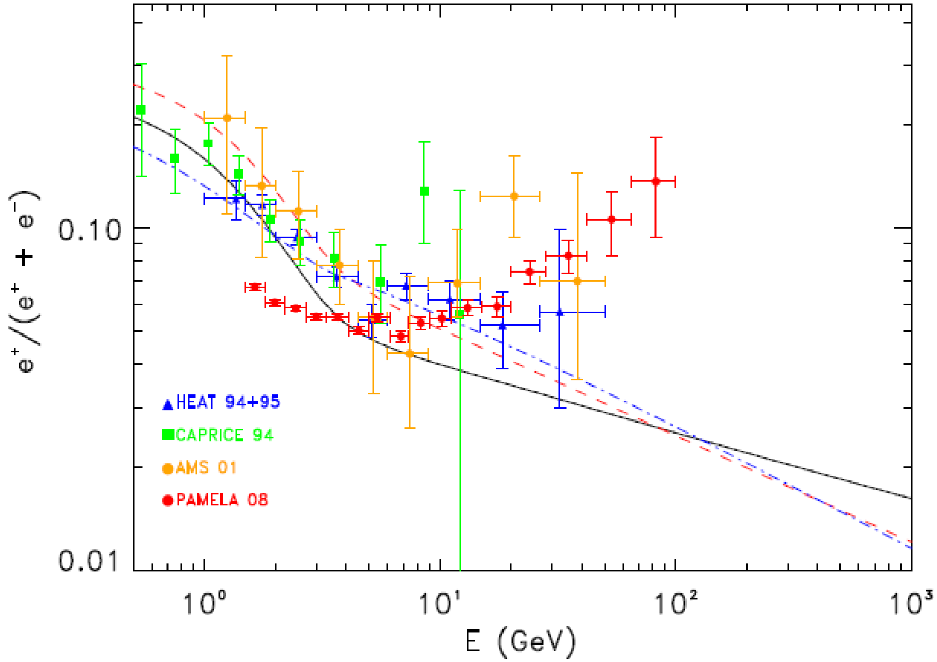
See talk by F. Longo



Modify the injection indices of GALPROP?

D. Grasso et al., arXiv:0905.0636

Does not fit at all the PAMELA ratio:



Summary

- PAMELA has been in orbit and studying cosmic rays for ~36 months. >10^9 triggers registered and >14 TB of data has been down-linked.

- Antiproton-to-proton flux ratio (~100 MeV - ~100 GeV) shows no significant deviations from secondary production expectations. Preliminary data presented up to ~180 GeV.

- High energy positron fraction (>10 GeV) increases significantly (and unexpectedly!) with energy.
Data at higher energies will help to resolve origin of rise (spillover limit ~300 GeV).

- Analysis ongoing to measure the e^- spectrum up to ~500 GeV, e^+ spectrum up to ~300 GeV and all electrum ($e^- + e^+$) spectrum up to ~1 TV.

http://pamela.roma2.infn.it

Thanks!

PaMeLa

INFN Istituto Nazionale di Fisica Nucleare