Balloon-borne and Space-based Particle Measurements with Magnetic Spectrometers

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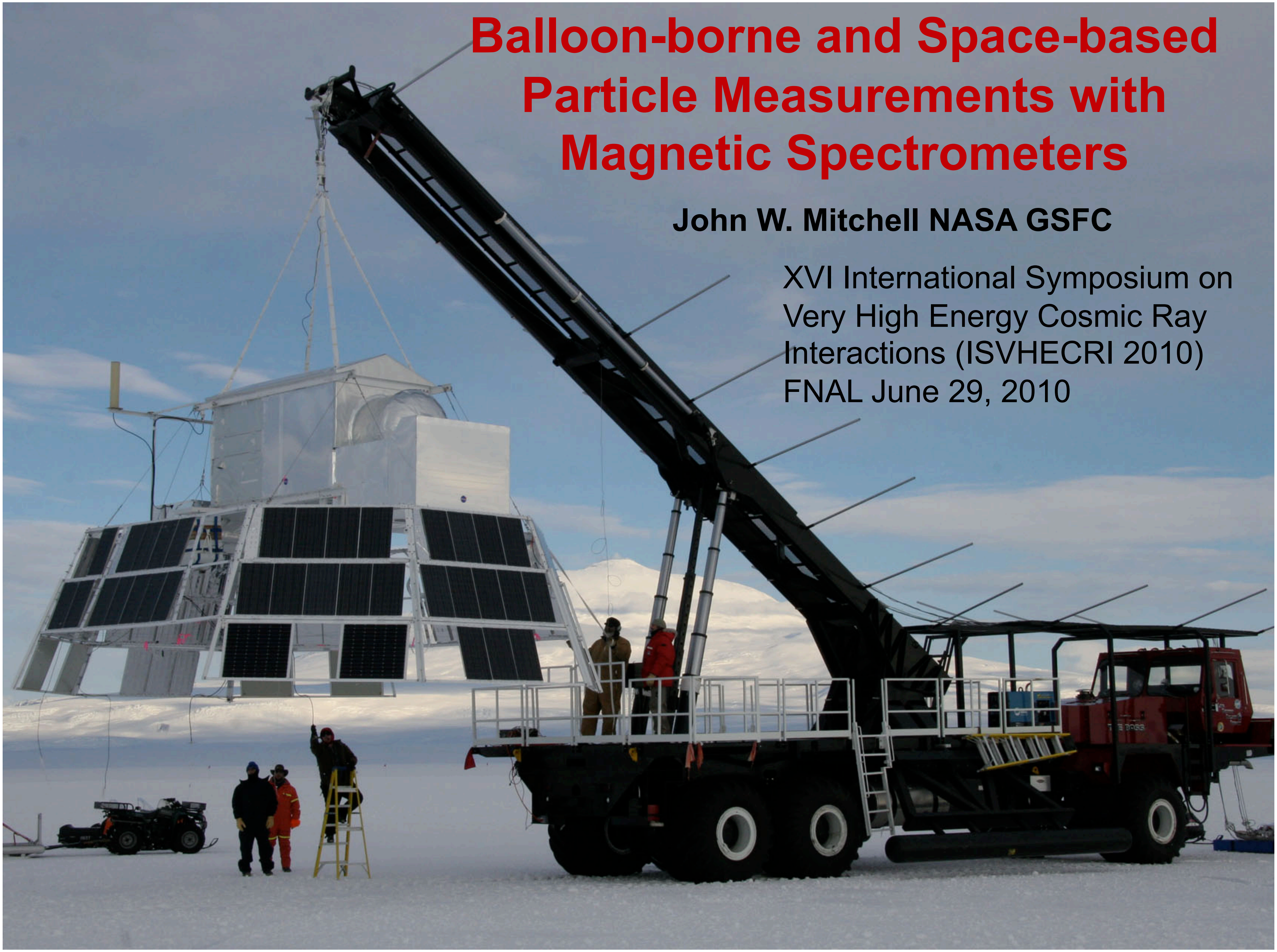
XVI International Symposium on Very High Energy Cosmic Ray Interactions (ISVHECRI 2010)
FNAL June 29, 2010



Magnetic-Rigidity Spectrometers

Measure magnetic rigidity – R = pc/Ze

Instrument Components

- **Magnetic field**
  - Superconducting magnet; permanent magnet; Earth's magnetic field
- **Particle tracking /** momentum measurement
  - Gas chambers; spark chambers; emulsion
- **Charge measurement**
  - Scintillator; Emulsion (early work)
- **Auxiliary detector(s)**
  - Velocity - Lorentz factor - energy deposit
  - TOF, Cherenkov, TRD, shower counter, calorimeter

Unique Measurement Capabilities

- Charge sign
- Mass at energies above dE/dx-total E, dE/dx-Cherenkov
- Energy measurement with minimal mass in beam

Space: No Atmosphere, Long Duration

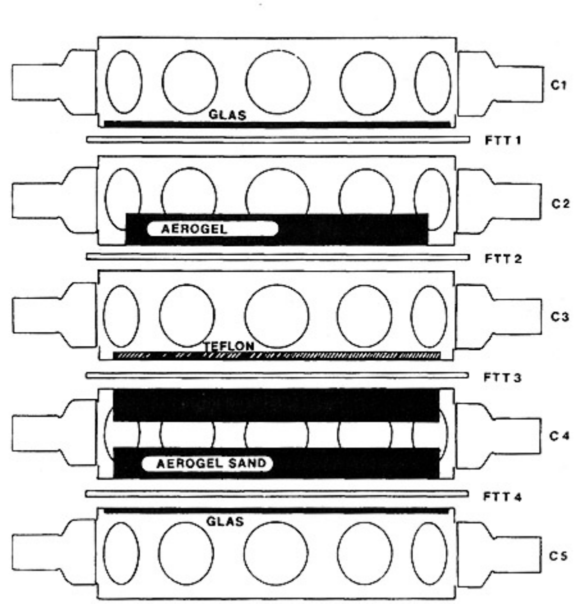
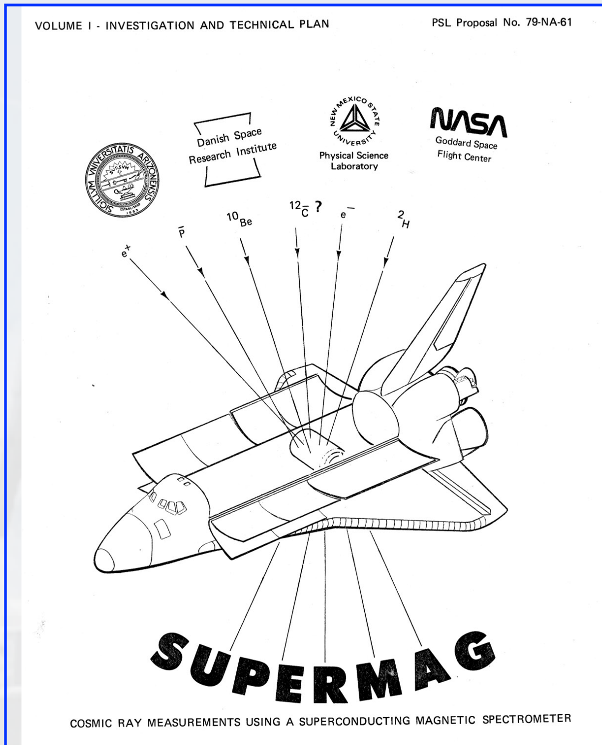


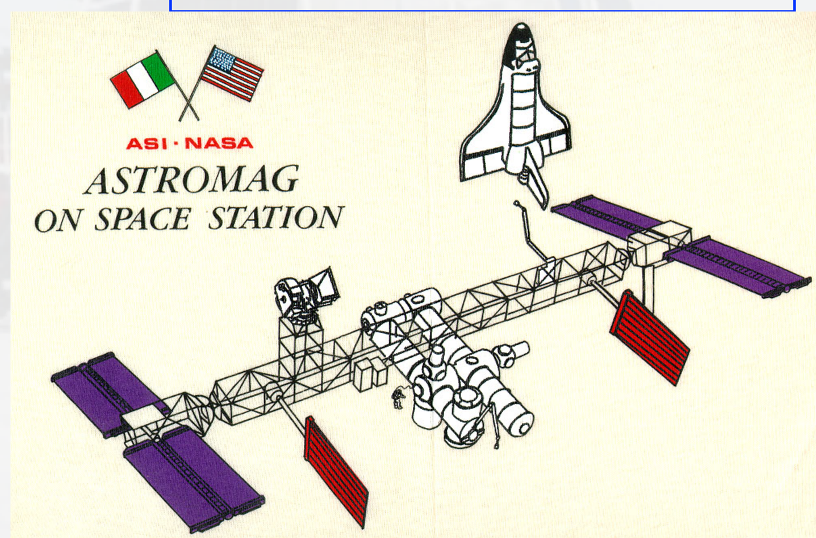
Fig. 1. The detector configuration of the danish-french cosmic ray spectrometer on HEAO-3. Four neon flash-tube hodoscope elements (FTT 1 – FTT 4) are interspersed between five Cerenkov counters (C1 – C5). A time-of-flight system between C1 and C5 determines the travel direction for each detected particle

HEAO: used geomagnetic cutoff

F_{AN} Z > 9, 1.5 10^{-4}, ≈ 2 - 11 GeV/n

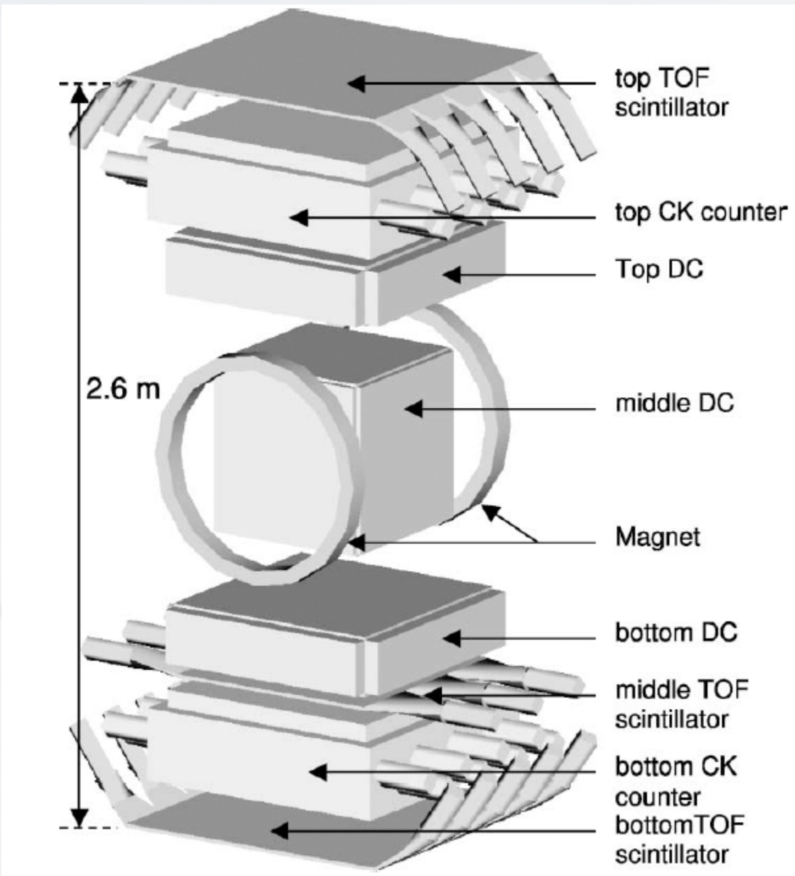
Lund and Rothenberg Astron. Astrophys. 164 (1986) 231

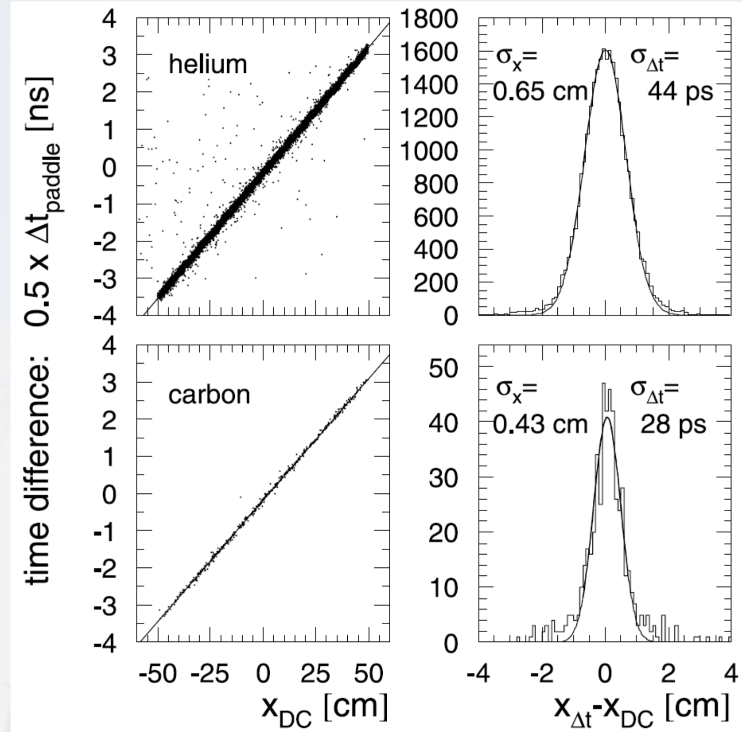




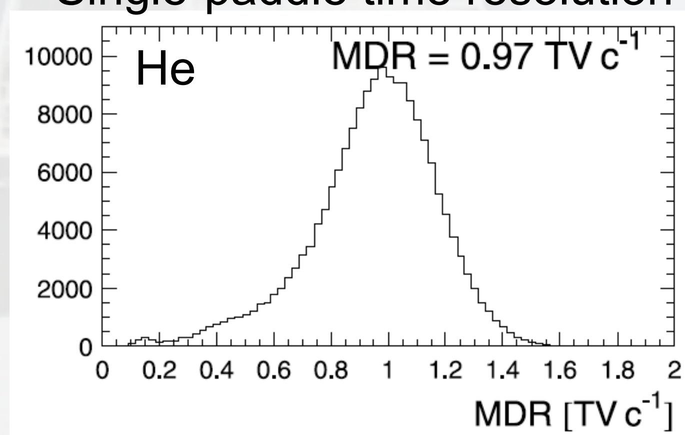
Isotopes: Isotope Magnet Experiment (ISOMAX)

- Clock isotope ^{10}Be probes storage of GCR in Galaxy
- ^{10}Be to ^{9}Be ratio to relativistic energies provides test of diffusive halo model
- Flight 1998, Destroyed 2000



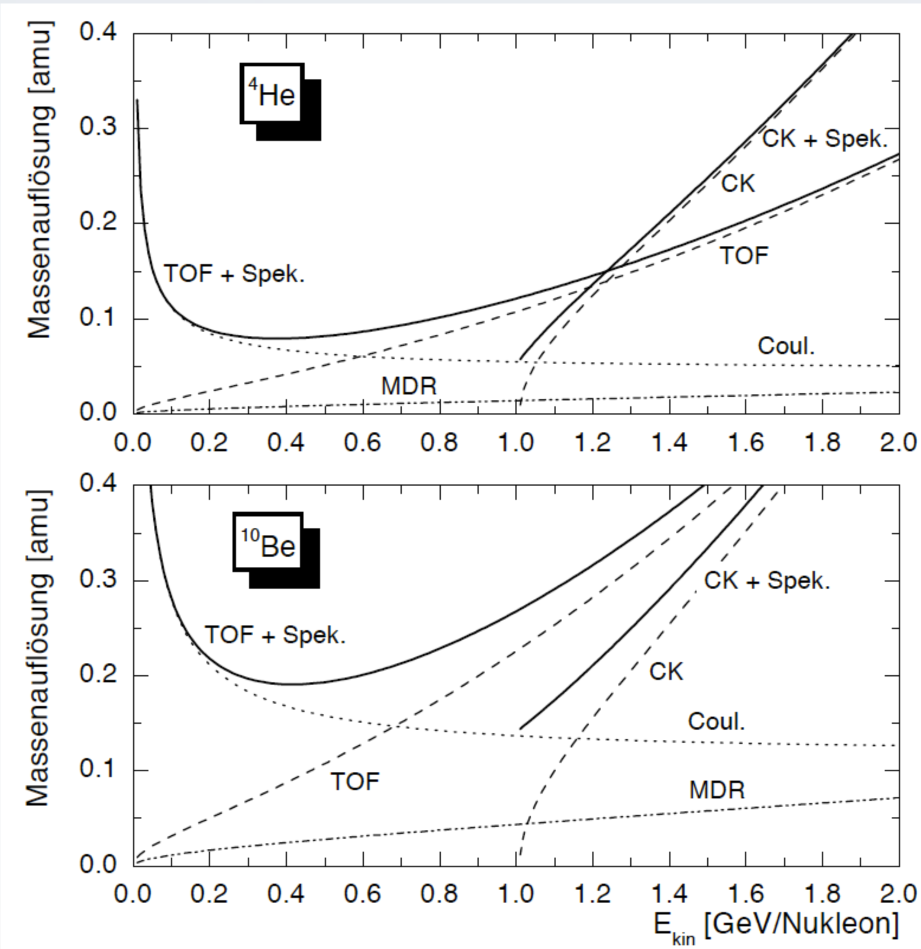


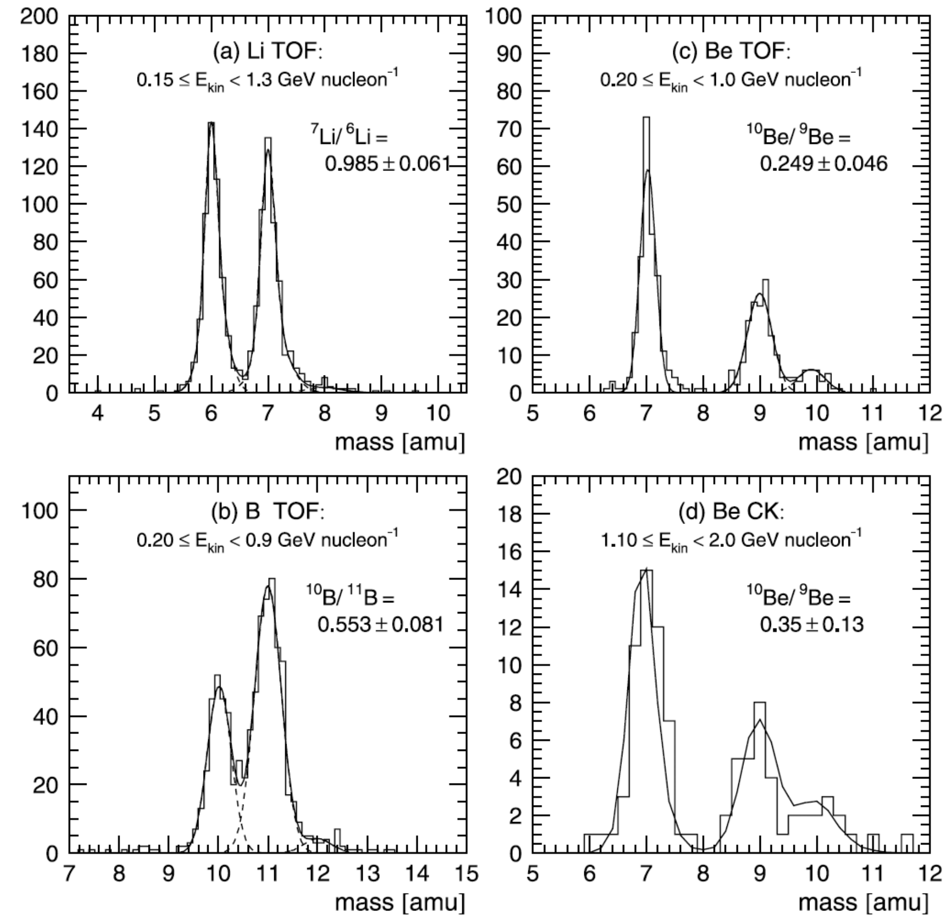
Single-paddle time resolution



B=0.8 T, MDR=1.2 TV (Be)

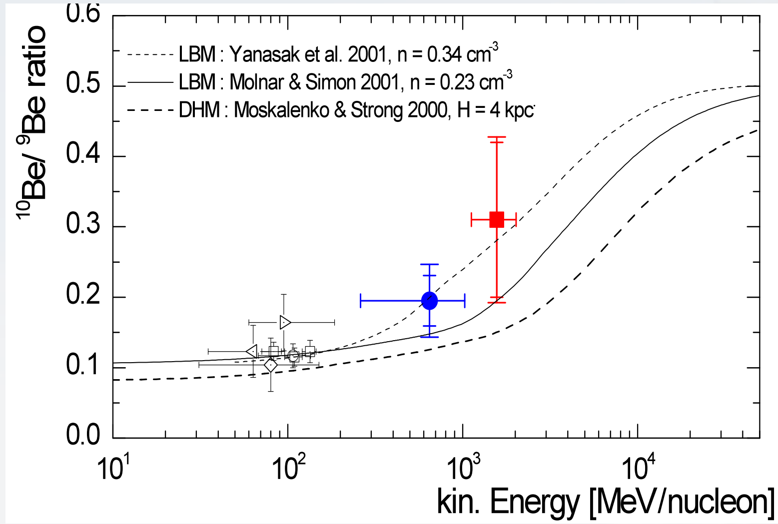
Isotope Magnet Experiment (ISOMAX)



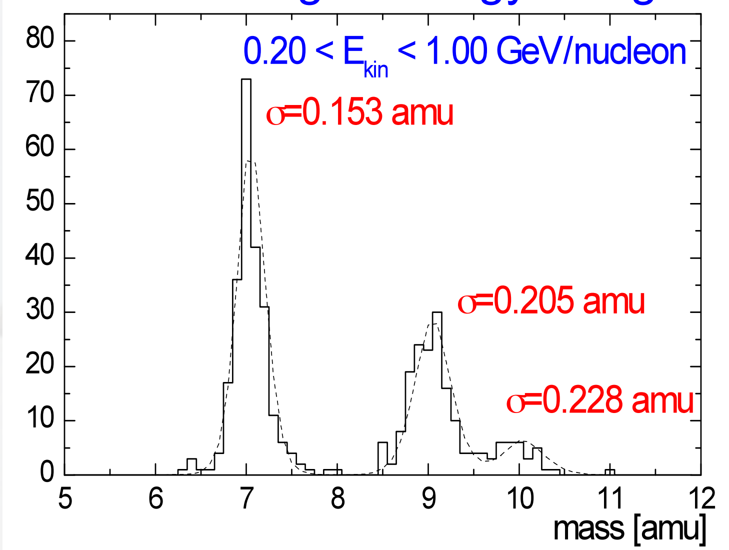


ISOtope MAgnet eXperiment

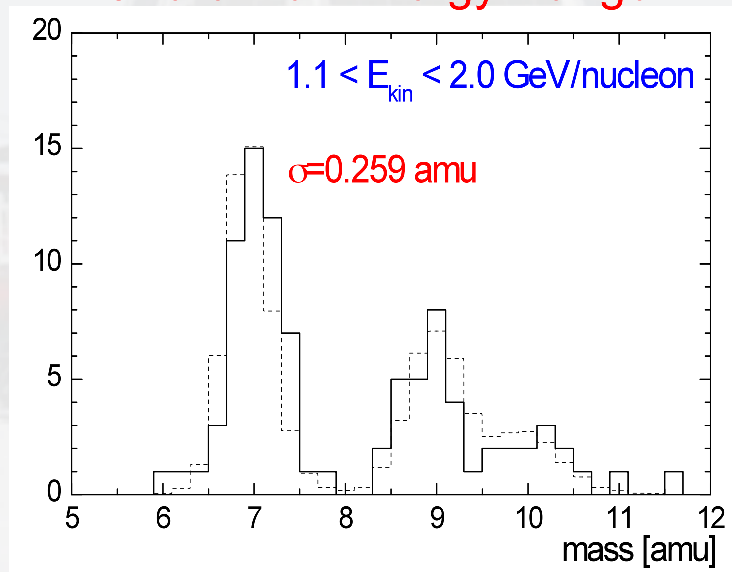
Beryllium Results



Time-of-Flight Energy Range

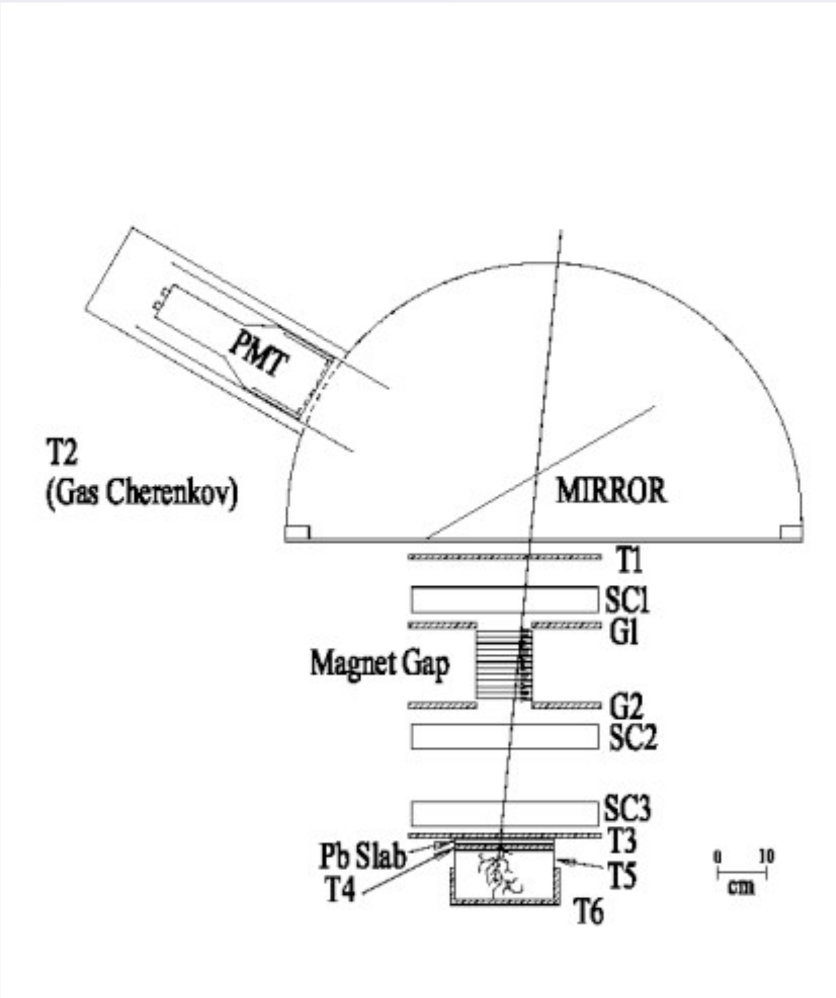


Cherenkov Energy Range

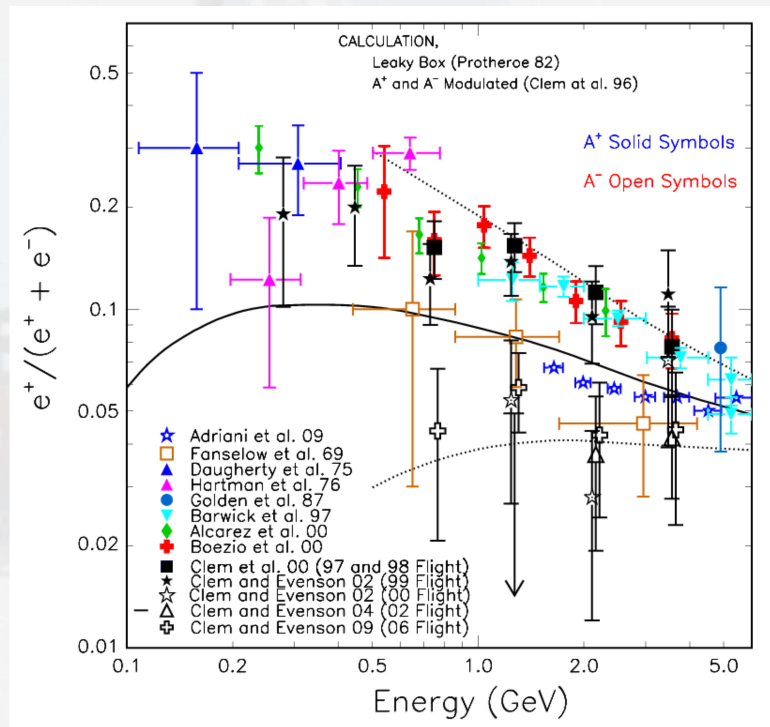


AESOP – positron/electron

Anti-Electron Sub Orbital Payload
University of Delaware/Bartol Research Institute



- Charge-sign dependent solar modulation.
- Permanent magnet and digital optical spark chambers
- ~6GV MDR
- Frequent flights 1995-2009



BESS Collaboration

Balloon-borne Experiment with a Superconducting Spectrometer

National Aeronautics and Space Administration Goddard Space Flight Center

High Energy Accelerator Research Organization(KEK)

The University of Tokyo

University of Maryland

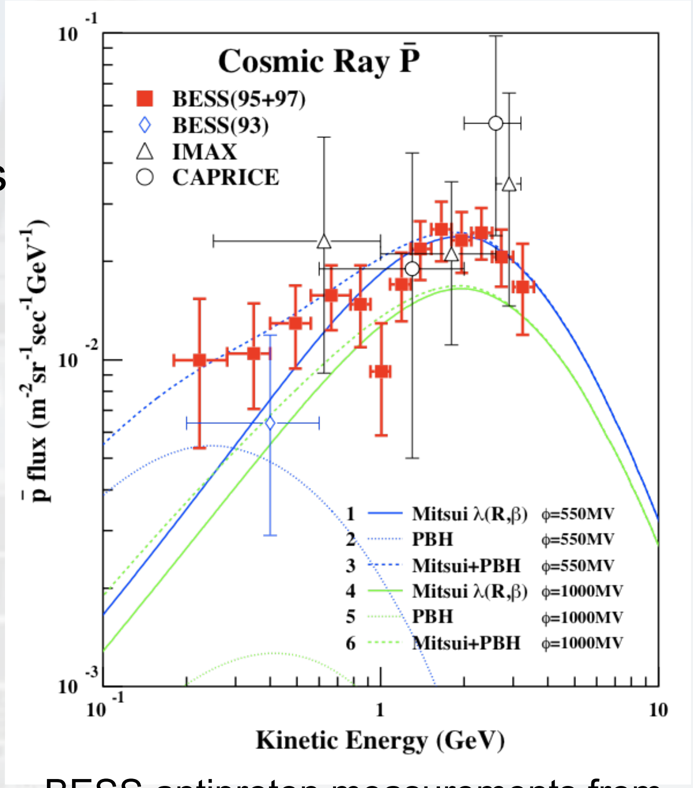
Kobe University

Institute of Space and Astronautical Science/JAXA

University of Denver

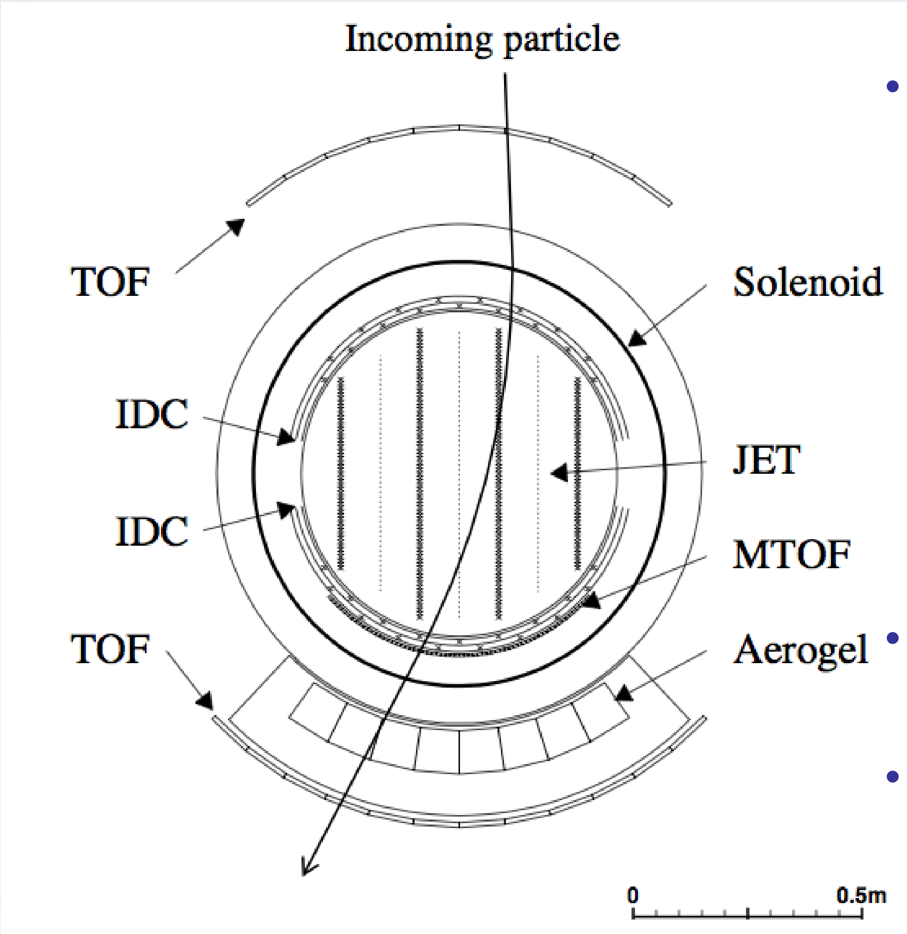
BESS/BESS-Polar Science Reach

- Cosmic-ray particles and antiparticles probe the early Universe
  - Antinuclei test symmetry of matter and antimatter
  - Antiprotons:
    - Mainly secondary origin - cosmic ray interactions
    - Possible small primary component;
      - -Evaporation of primordial black holes (PBH) initially near ~5×10^{14}g?
      - -Decay of super-symmetric particles?
- Cosmic ray spectra and composition
  - p, He, Li, Be isotopic and elemental spectra
  - B, C, N, O elemental spectra
  - Atmospheric muons
- Heliospheric influence on Galactic cosmic rays
  - Charge-sign dependent Solar modulation
  - Short-term transients and diurnal variation
- Future program
  - High-energy positrons
  - Radioactive ^{10}Be to high velocity (time dilation)



BESS antiproton measurements from 1995-1997 Solar minimum suggest possible excess at low energy.

BESS Instrumentation

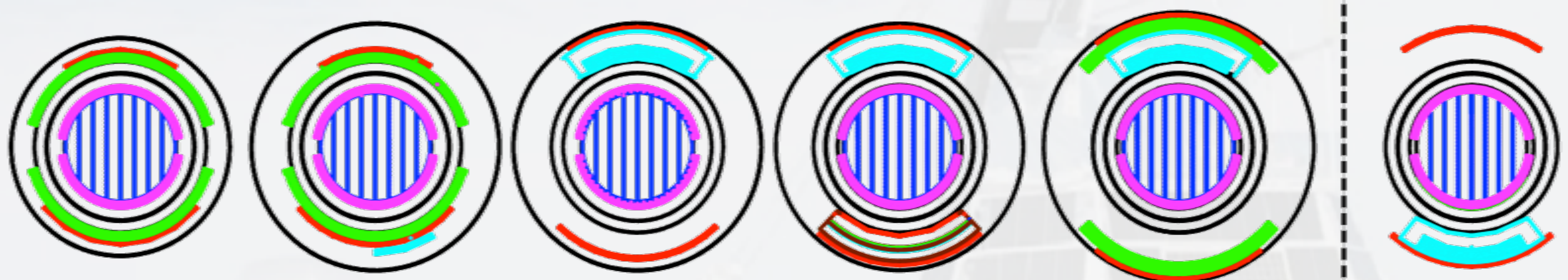


- Measures charge, charge-sign, mass, and energy
- Superconducting magnetic spectrometer: momentum from magnetic rigidity
  - Thin solenoidal superconducting magnet
  - Fully active "JET" and "IDC" drift chambers with 54 points on trace, σ <130 μm
  - MDR: 200 GV BESS; 1400 GV BESS-TeV; 280 GV BESS-Polar
- Time-of-flight system (TOF): velocity and charge
- Silica-aerogel Cherenkov detector (ACC, n=1.02/1.03): background rejection

$$m = \frac{RZe}{\gamma\beta c}$$

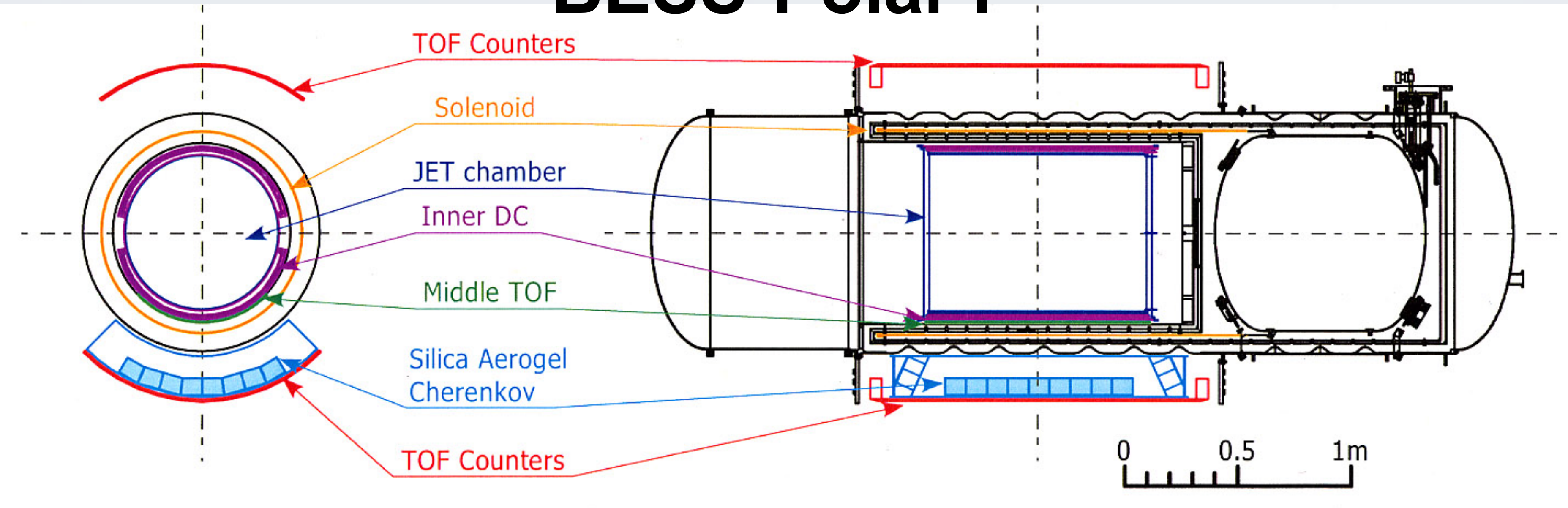
Evolution of BESS

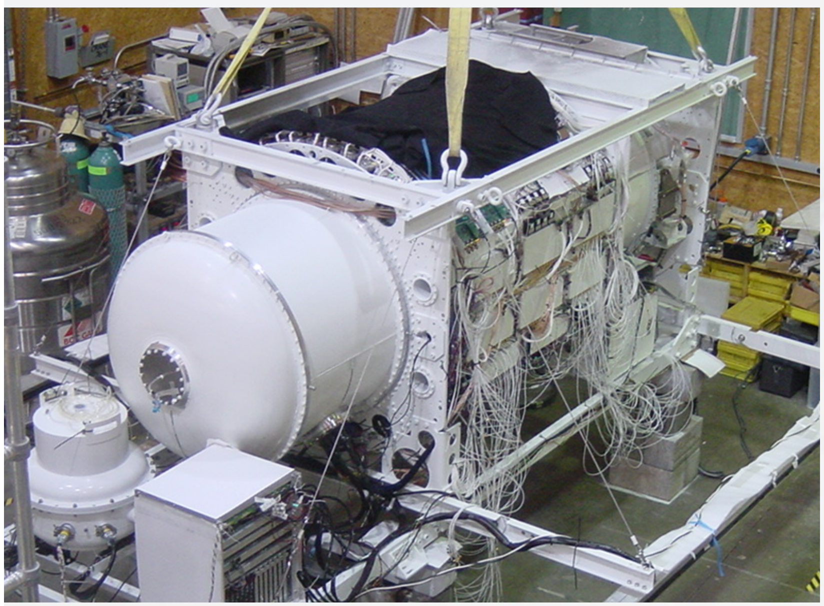
- Nine northern latitude flights (1+ days) 1993-2002 and two Antarctic flights in 2004 (8.5 days) and 2007 (24.5 days)
- **Including BESS-Polar I 3757 antiprotons reported 0.2 - 4.2 GeV**



BESS-93,94	BESS-95	BESS-97,98	BESS-99,00	**2001-2002** BESS-TeV	**2004, 2007** BESS-Polar
	Larger Vessel			Larger Vessel	No Vessel
σ_{TOF} =300 ps	σ_{TOF} =110 ps	σ_{TOF} =70 ps Aerogel C 97 n=1.03 $\bar{p}$ 0.2-3.5 GeV 98 n=1.02	Shower Counter $2X_0$ Lead e/μ sep.	New ODC's New JET/IDC's p/He up to 1 TeV	New Mag (ultra thin)
$\bar{p}$ 0.2-0.6 GeV	$\bar{p}$ 0.2-1.4 GeV	$\bar{p}$ 0.2-4.2 GeV	$\bar{p}$ 0.2-4.2 GeV	$\bar{p}$ 0.2-4.2 GeV	$\bar{p}$ 0.1-4.2 GeV
6,2	**43**	**415, 398**	**668, 558**	**147**	**1,512, ~8,000**

BESS-Polar I

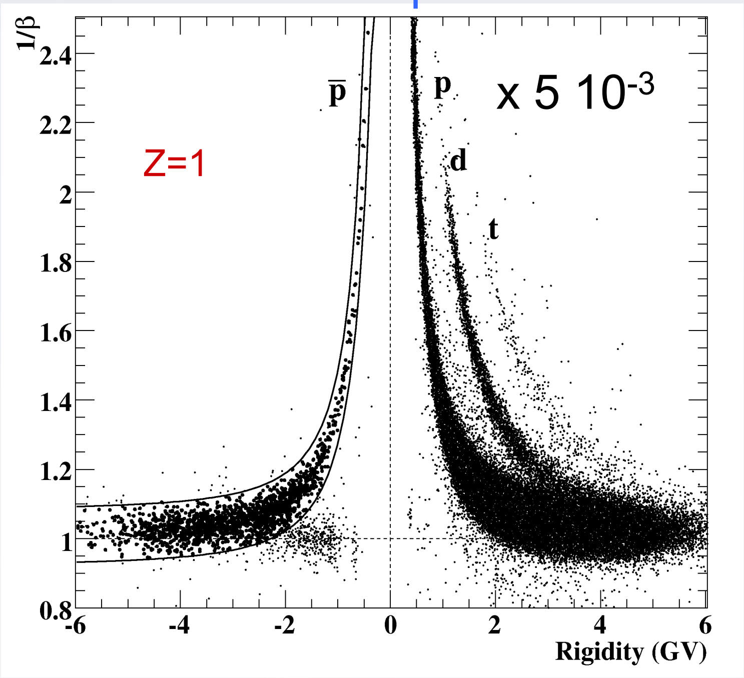


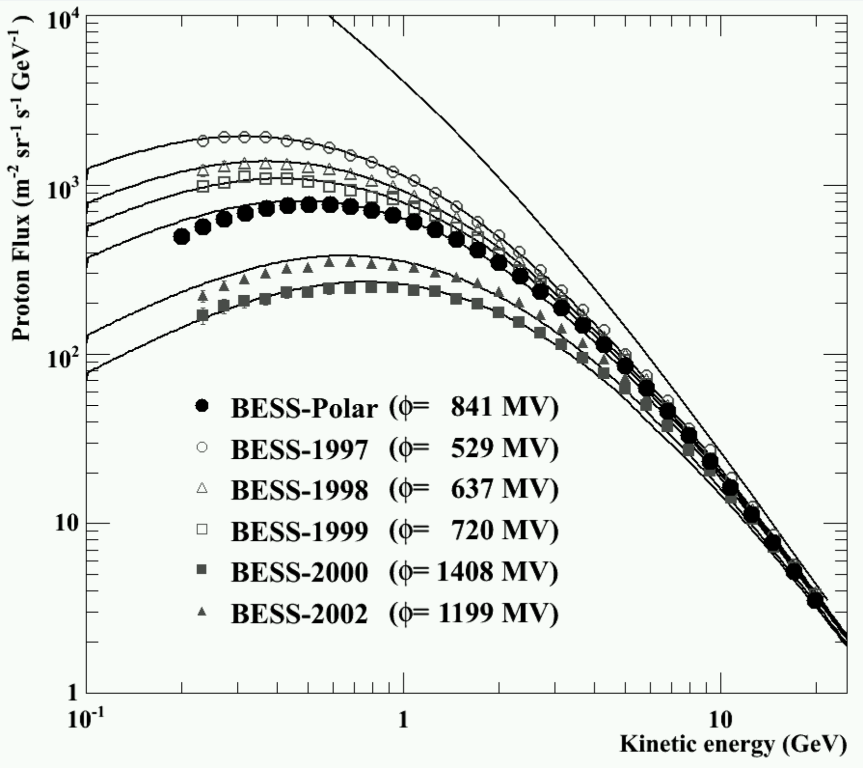


- Minimum material in path of particle (4.5 g/cm^2)
  - Thinner magnet (2.2 g/cm^2 with cryostat ~1/2 BESS)
  - Middle TOF (MTOF) - low energy TOF/trigger
  - No pressure vessel - TOF, ACC in near-vacuum
  - Total material in path 1/4 of BESS
- No in-flight data selection
- 3.6 TB hard disk array
- High speed data acquisition - 2.5 kHz event rate
- Cryogen lifetime ~11.5 days - 400 liters Lhe
- 8.5 day flight

Protons

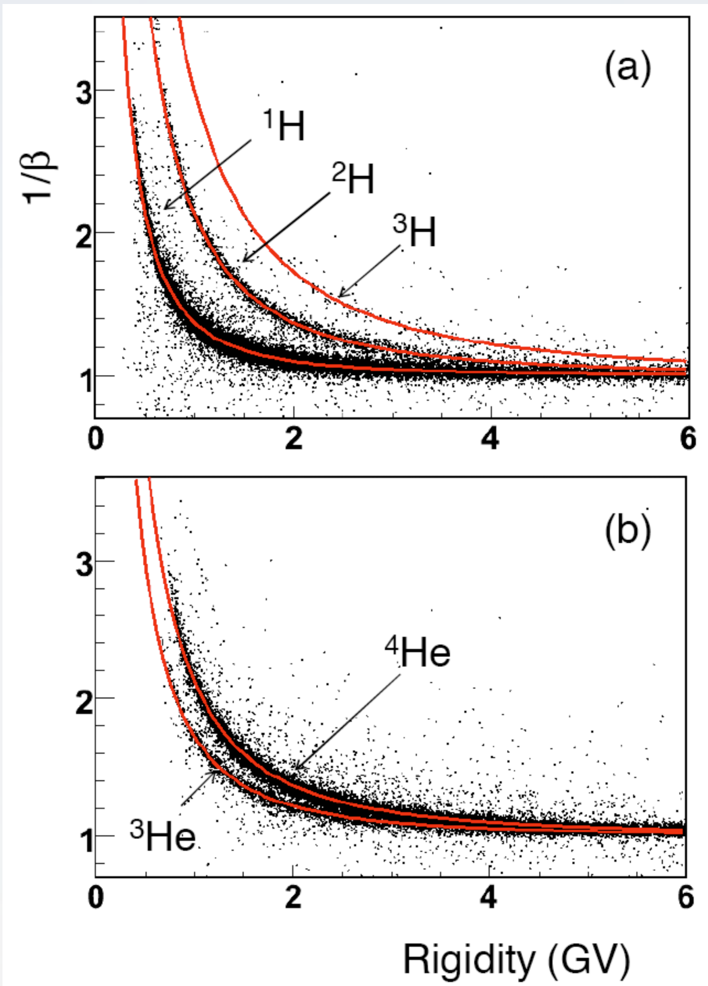
BESS-Polar I particle ID





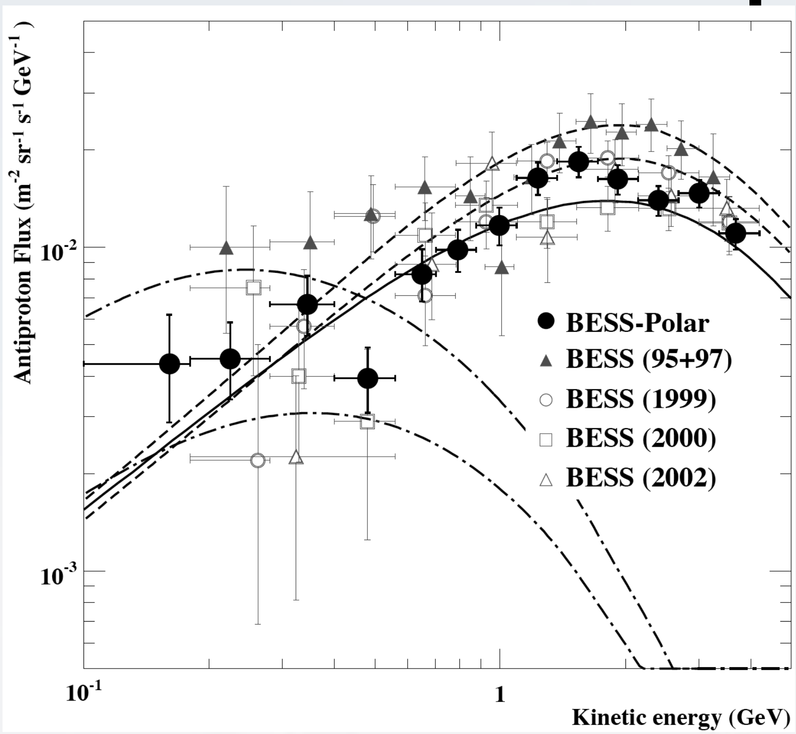
- Proton spectra measured to ~500 GeV
- Proton spectra to 100 GeV measured for full solar cycle
- Upper solid line shows local interstellar (LIS) proton spectrum from best fit to BESS data (spectral index 2.76)
- Lower curves show the variation with time (Solar modulation) of the measured proton spectra extrapolated to the top of the atmosphere

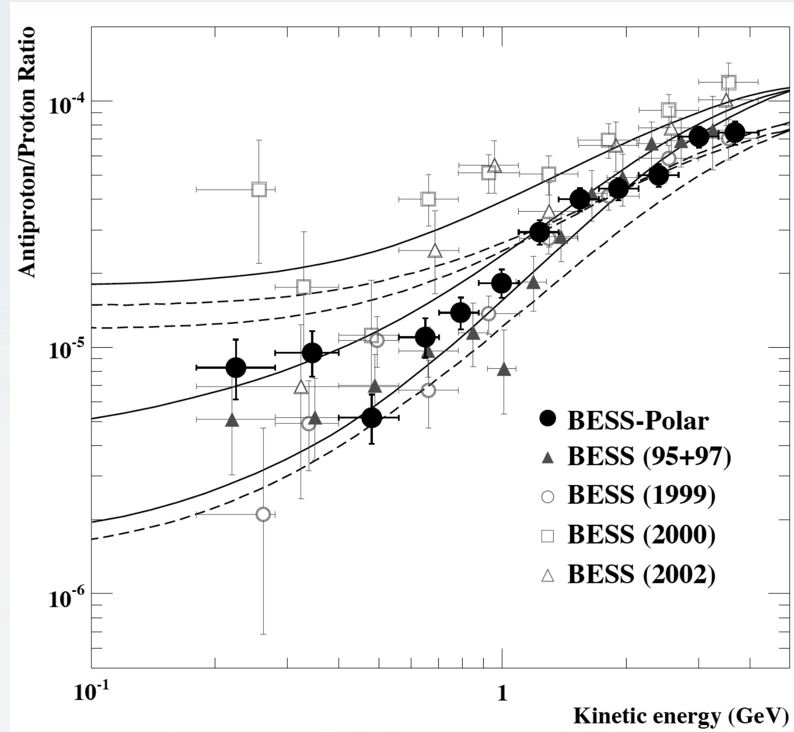
Light Isotopes



- dE/dx vs rigidity gives charge
- 1/β vs rigidity gives mass
- Isotopes of hydrogen and helium isotopes are well separated to >0.5 GeV/nucleon with TOF

Antiprotons

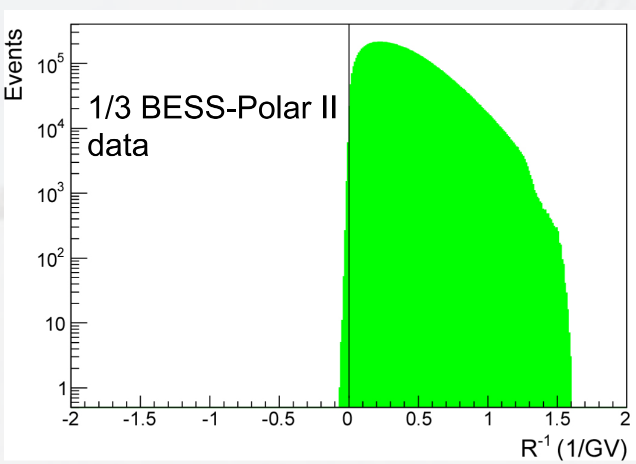


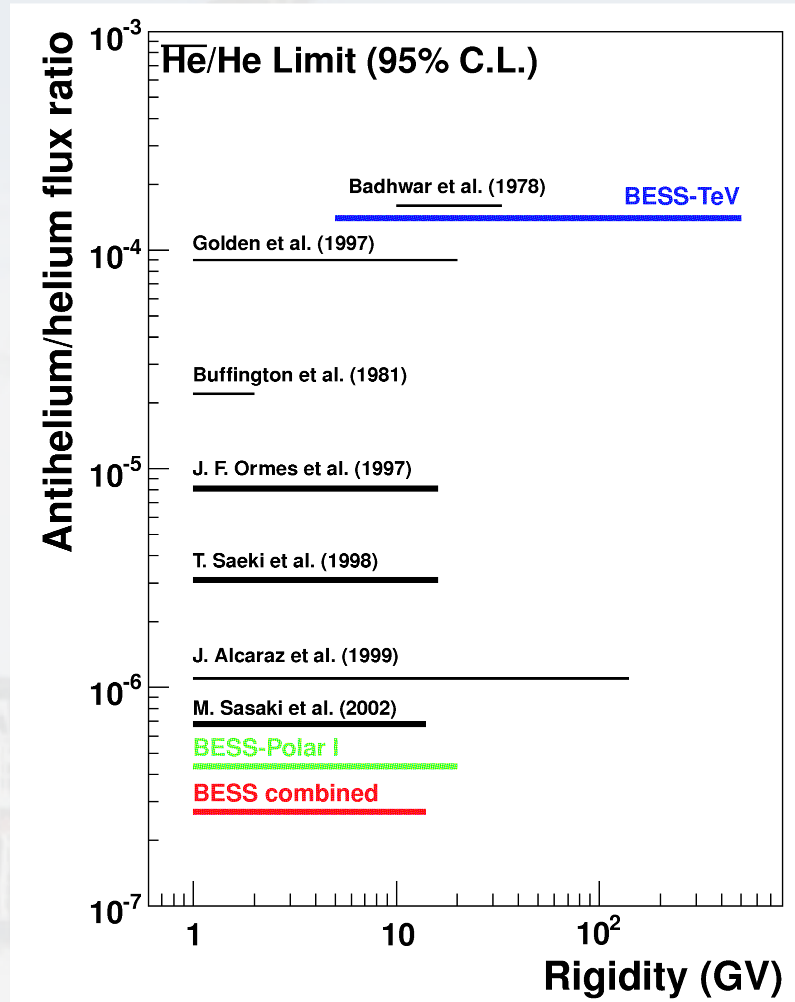


- BESS (95+97) Solar min data show a possible *flattening of the antiproton spectrum at lower energies* compared to secondary production. (Upper dash curve leaky box with spherically symmetric modulation @ 550 MV.)
- BESS-Polar I data at higher solar activity (851 MV - lower dashed curve) are consistent with secondary production, as expected.
- Primary source suppressed at higher modulation levels.
- Solid curve diffusive reacceleration with break at 30° Solar tilt angle

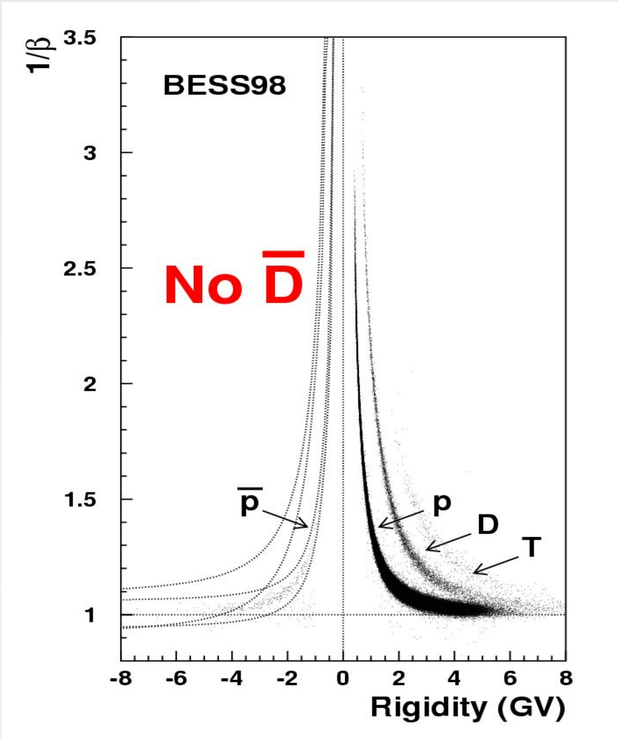
Antihelium Search

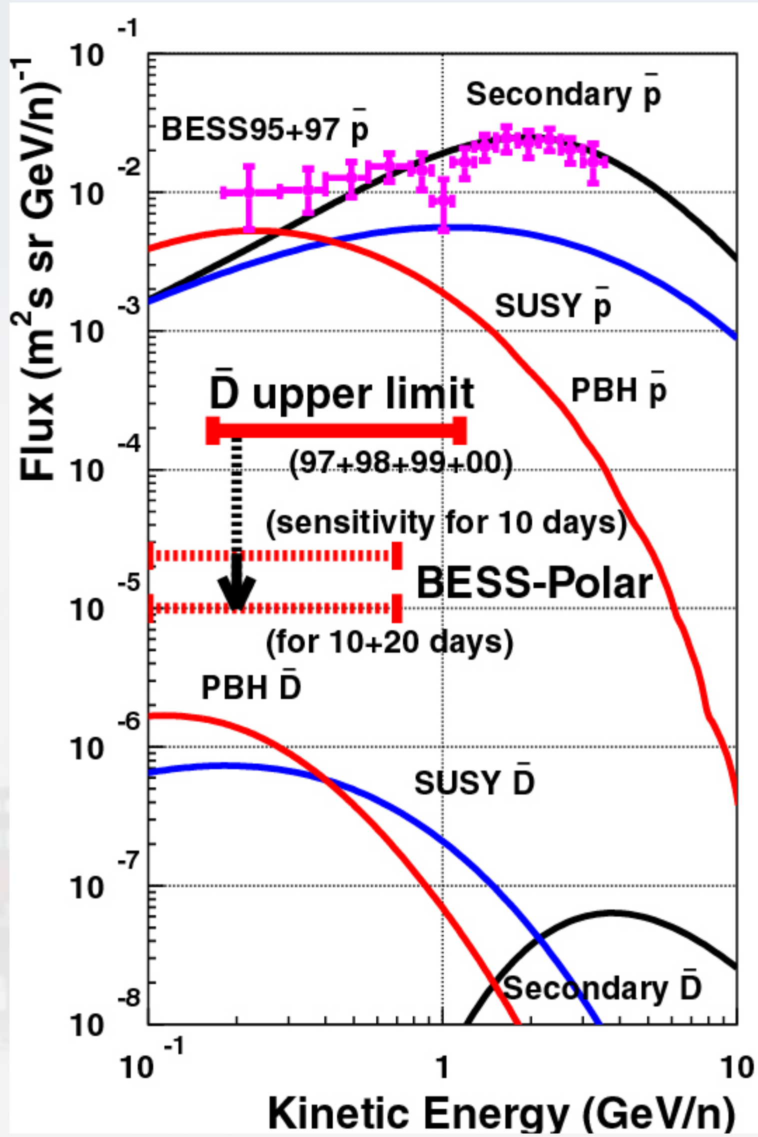
- **No antihelium candidate found by any investigation**
- **95% confidence level $\overline{\text{He}}$/He upper limits set, assuming $\overline{\text{He}}$ spectrum same as He**
- BESS-TeV - 1.4 x 10^{-4}
  1 - 500 GV, 7 x 10^{4} He events
- BESS-Polar I - 4.4 x 10^{-7}
  0.6 - 20 GV, 10^{6} He events
- BESS combined - 2.7 x 10^{-7}
  1 - 14 GV





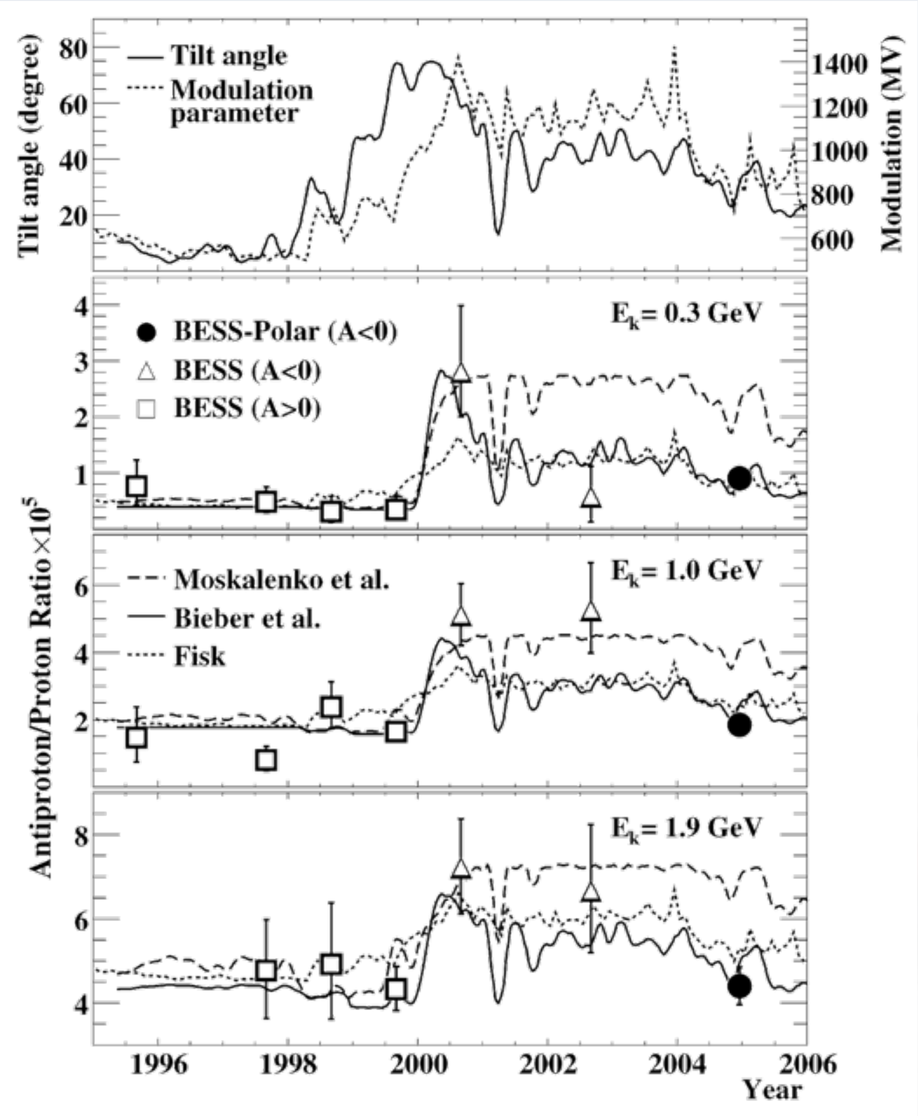
Antideuteron Search



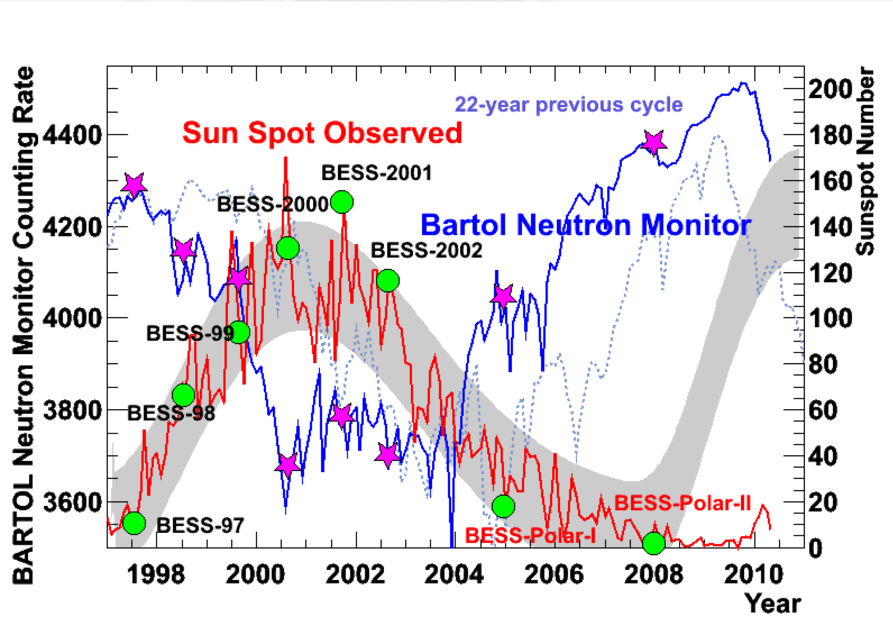


- Secondary $\bar{D}$ probability is negligible at low energies due to kinematics
- Any observed $\bar{D}$ almost certainly has a primary origin!
- $\bar{D}$ 95% upper limit (first reported) 1.92×10^{-4} $(m^2\ s\ sr\ GeV/n)^{-1}$

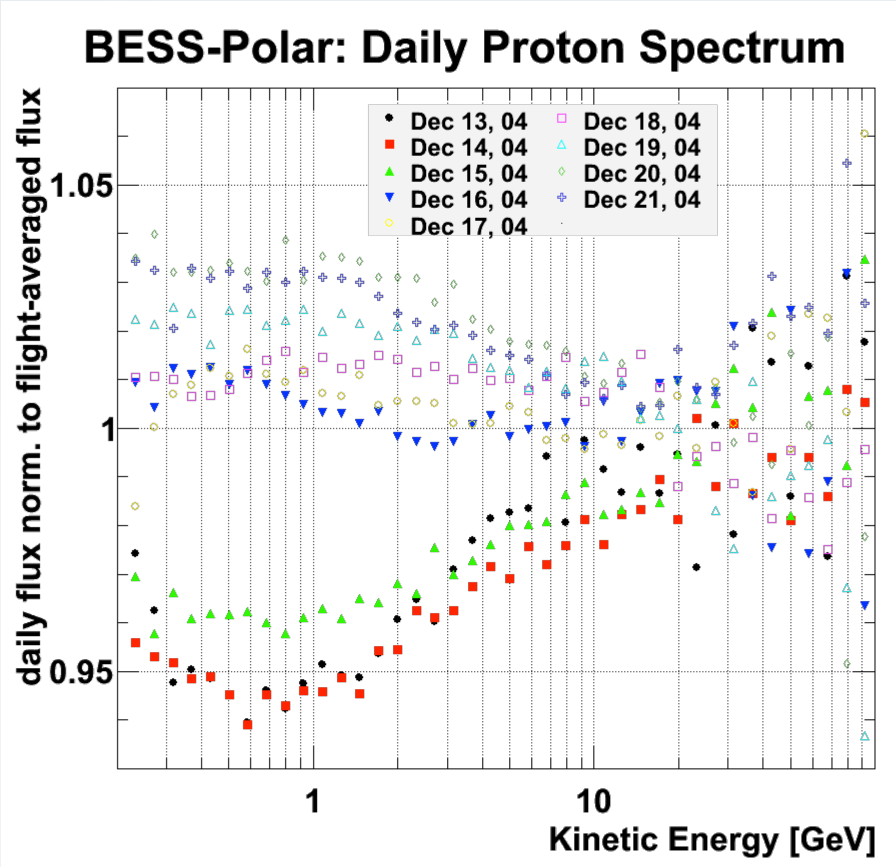
Antiproton/Proton Ratio - Solar Modulation

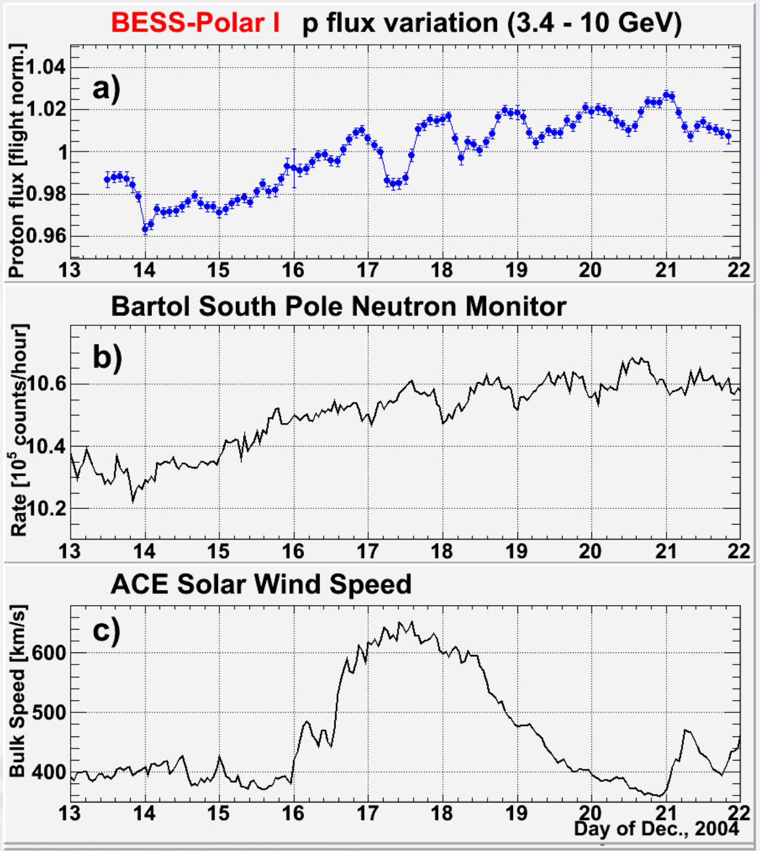


- Antiprotons and protons differ only in charge-sign
- Simultaneous measurements of proton and antiproton spectra provide a powerful test of models of charge-dependent Solar modulation of cosmic-rays (protons are most sensitive)



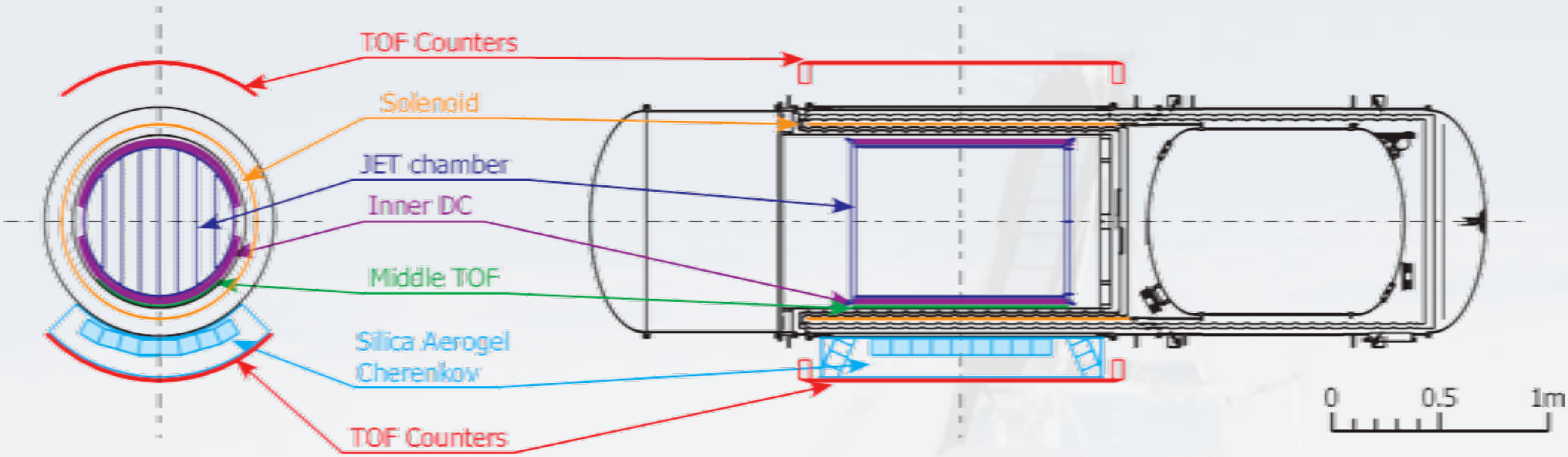
BESS-Polar I Proton Spectrum - Solar Effects





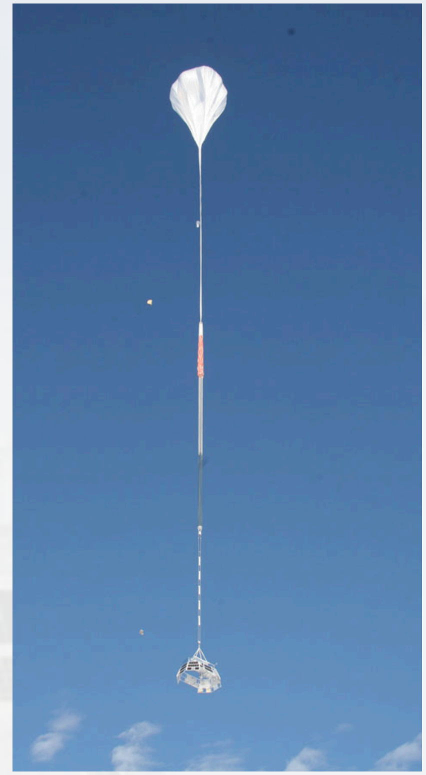
- General trend of BESS-Polar I proton flux tracks the neutron monitor
- BESS-Polar I observes diurnal variation in the proton flux (work in progress)
  - First direct measurement of this effect (requires large collecting area)
- Transient and diurnal variation investigation continues with BESS-Polar II

BESS-Polar II

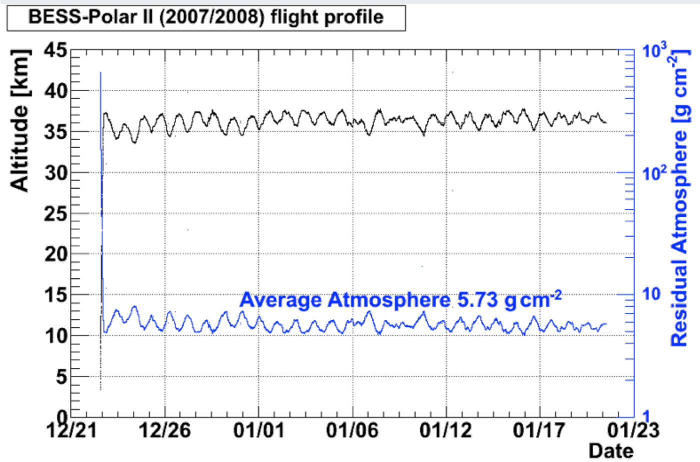


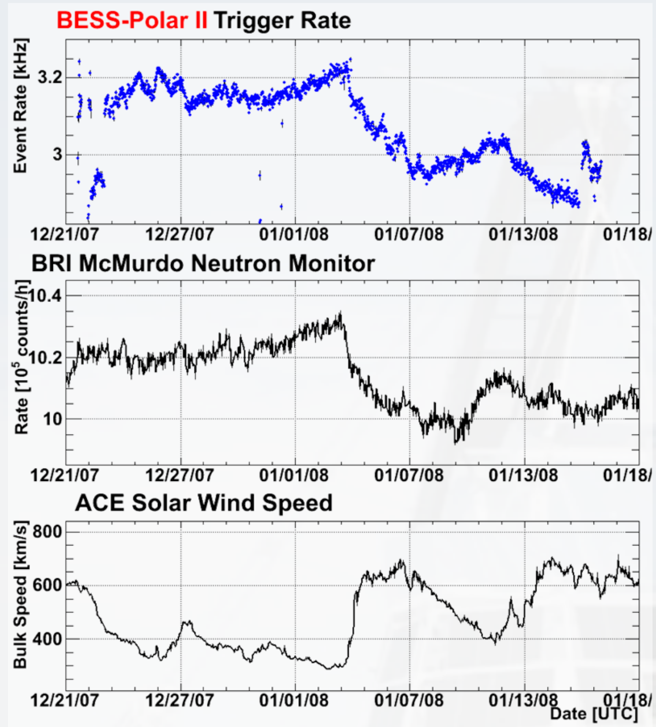
- Longer Observing Time
  - Magnet cryogen life: >25 days
    - 520 liters LHe
  - 16 TB data storage
- Improved Reliability
  - Pressurized TOF PMT units
  - Improved electronics efficiency
- Improved Performance
  - ACC rejection power
  - Middle TOF resolution
  - Outer TOF resolution

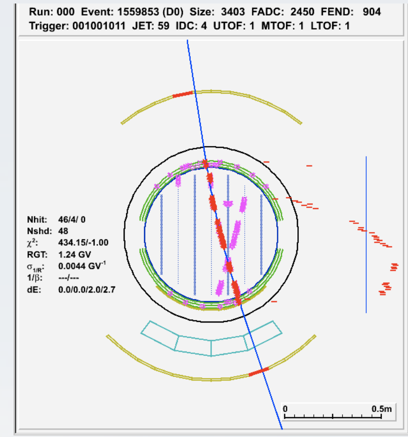
BESS-Polar II Launch - December 22, 2007



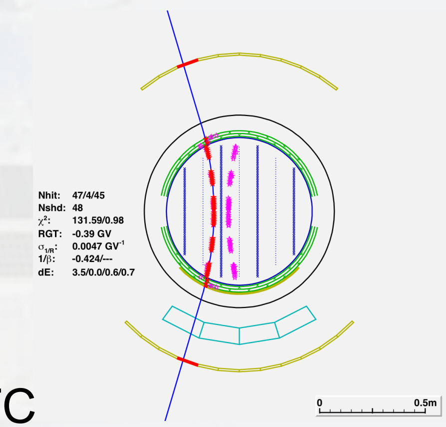
BESS-Polar II Flight



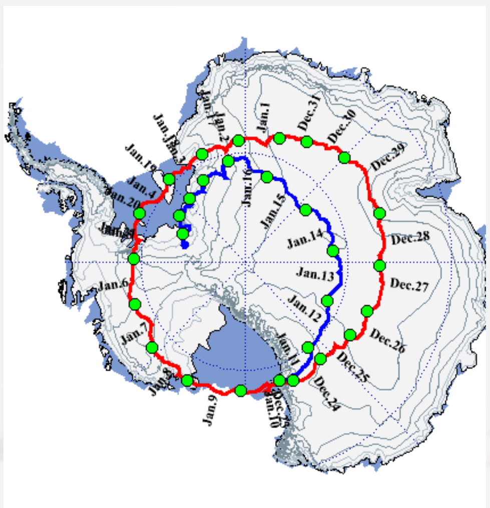




Positive Event

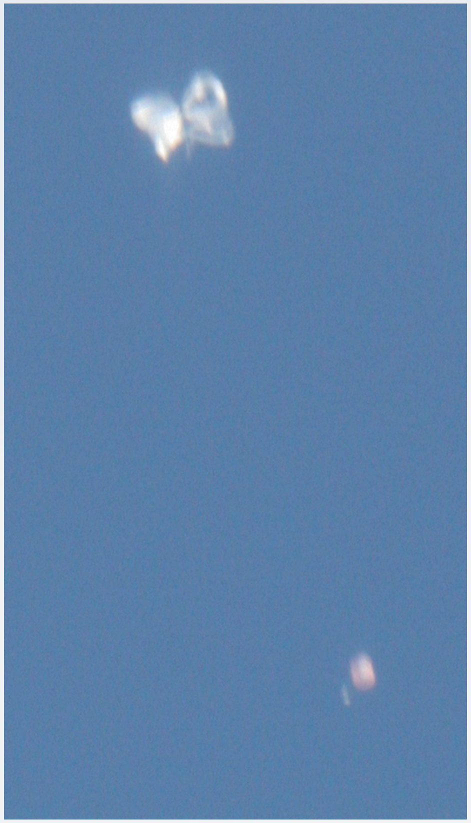


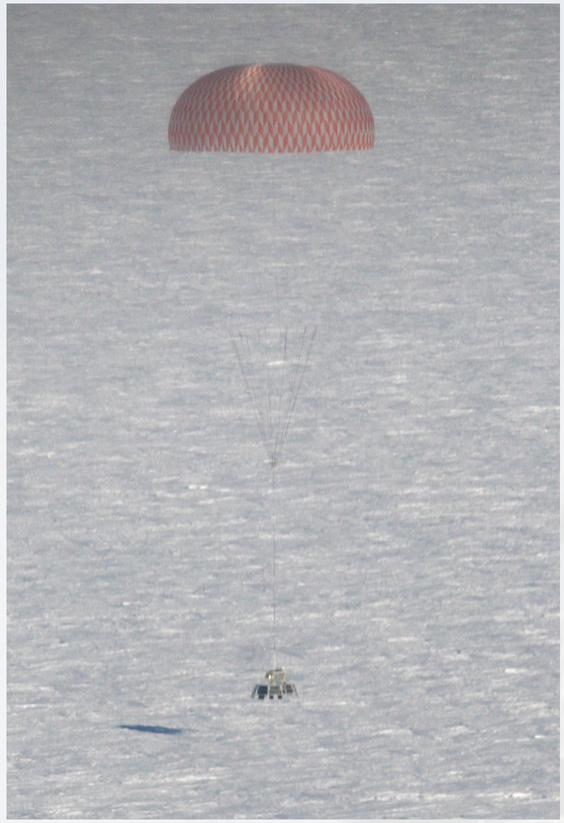
Negative Event



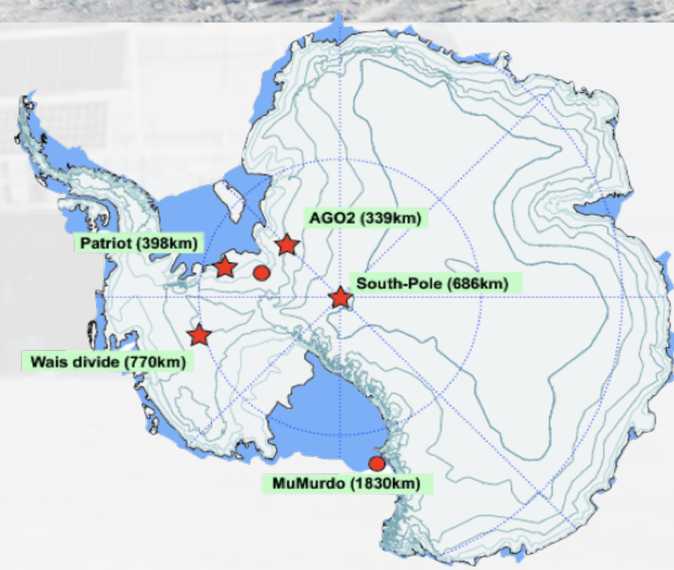
- Launch 12/22/07 17:30 UTC
- Science Termination 1/16/08 2:00 UTC
- Magnet-on at float - 24 days 10 hours
- Average altitude ~36 km (118,000 ft)
- Latitude 77.9° - 83° South

End of BESS-Polar II Flight



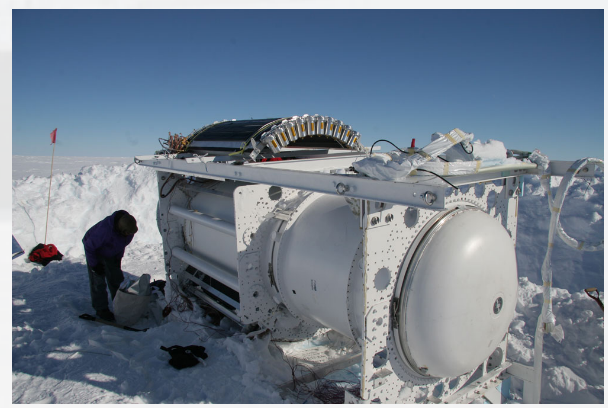


- Flight termination January 20, 2008 ~30 days
- Location 83 ° 51.23' S, 73° 5.47' W
- On West Antarctic ice sheet - 225 nm from Patriot Hills Camp, 185 nm from AGO-2, 357 nm from South Pole
- Data successfully recovered February 3, 2008!



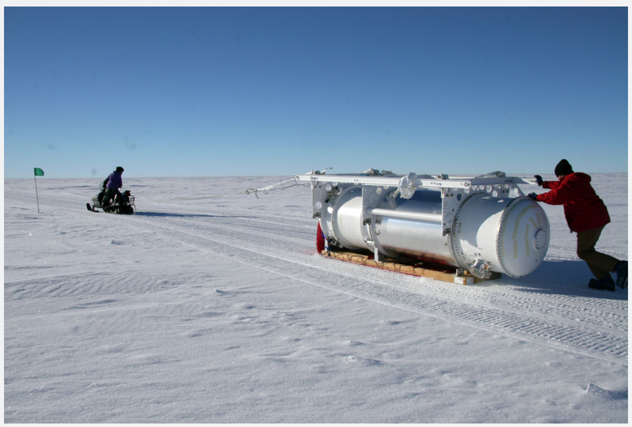
BESS-Polar II Recovery 2009-2010

- Staged from WAIS Divide/Byrd Surface Camp
- Camped on site 13 days for disassembly
- Basler (turboprop DC-3) used due to range and instrument size



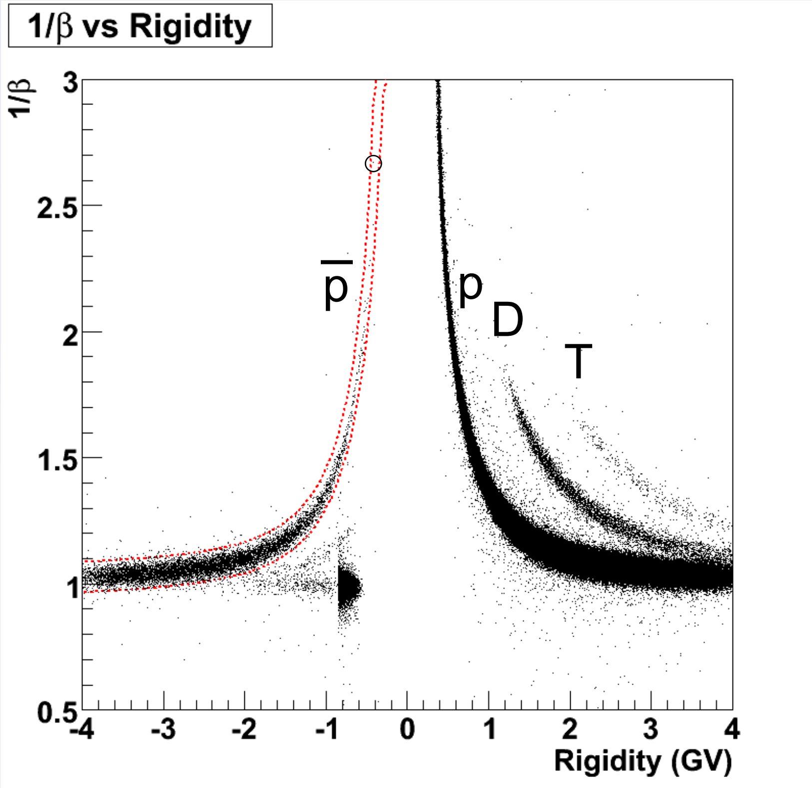
BESS-Polar II Recovery

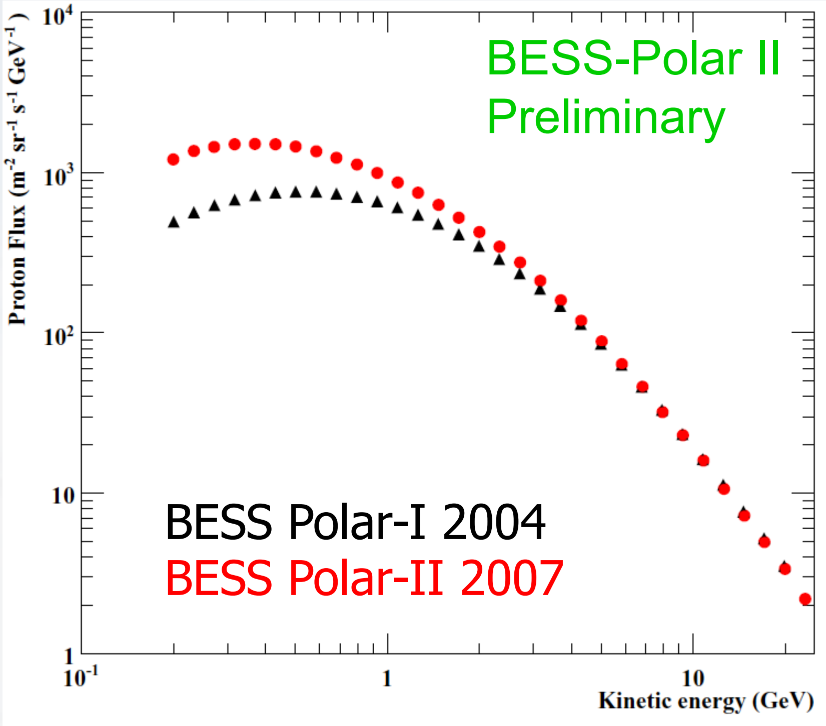




BESS-Polar II Performance

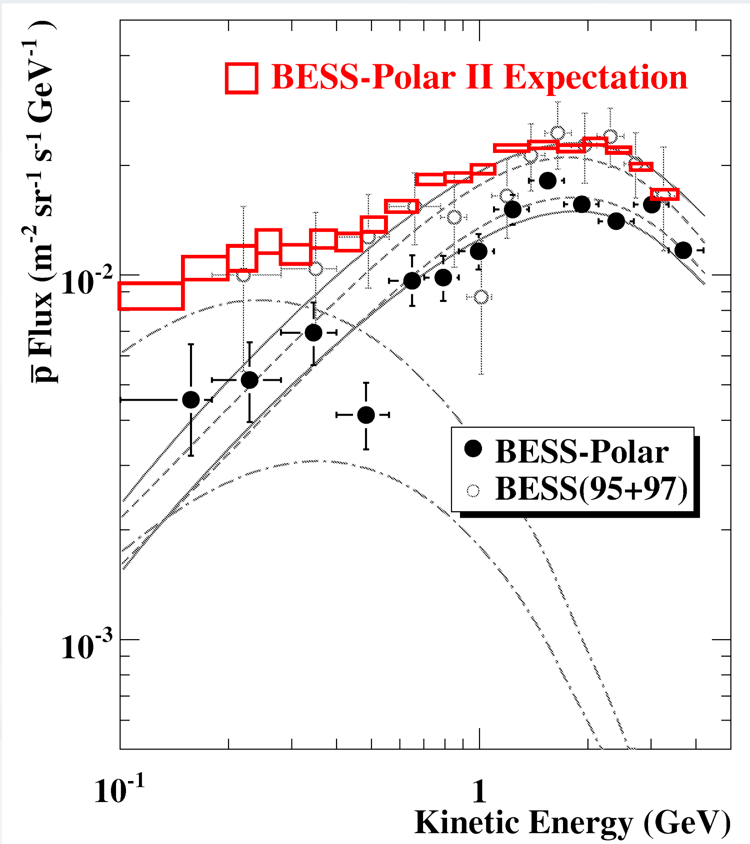




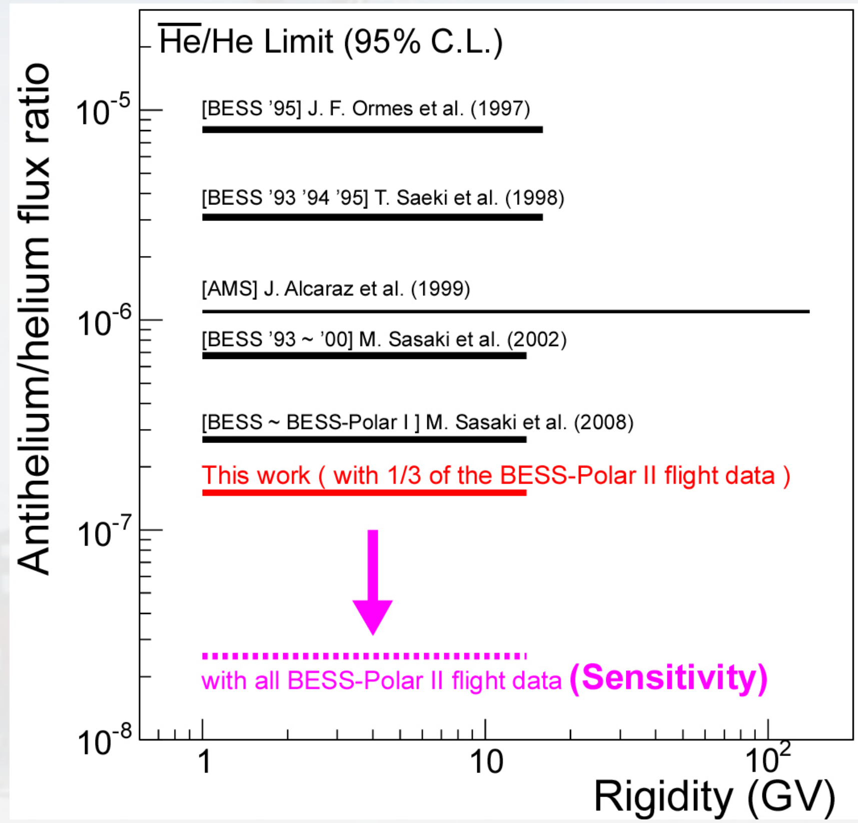
- Spectrometer - <130 μm resolution, B=0.8 T, MDR 266 - 281 GV
- Outer TOF - 120 ps
- Middle TOF - 280-380 ps
- Aerogel Cherenkov - 11.3 pe, ~6000 background rejection factor
- Data Acquisition - 2.5 kHz event rate, no onboard event selection, 82% live

BESS Polar II Observations/Expectations

- Total events ~4.7 x 10^9
- Total data volume 13.5 TB (3.07 kB/event)
- Antiprotons 8,000 - 10,000 10-20 times previous Solar minimum dataset



Antiproton



Antihelium

PAMELA Collaboration

LNF

Bari Florence Frascati Naples Rome Trieste CNR, Florence

Tor Vergata

Russia:

Физический Институт

Ioffe Physico-Technical Institute

Moscow
St. Petersburg

Germany: Universität Gesamthochschule Siegen

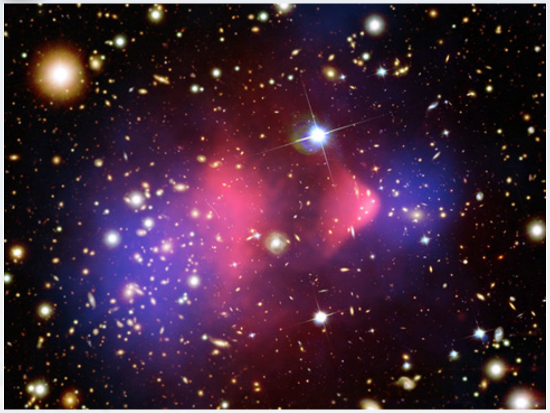
Siegen

Sweden: Kungl Tekniska Högskolan

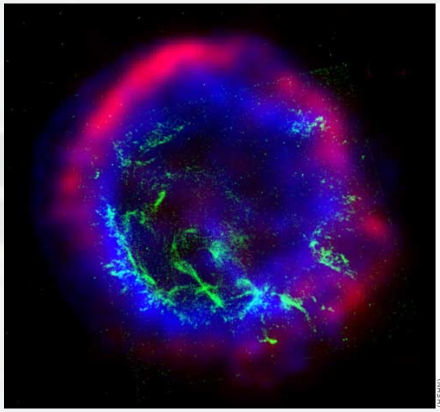
KTH, Stockholm

PAMELA Scientific goals

- Search for dark matter annihilation

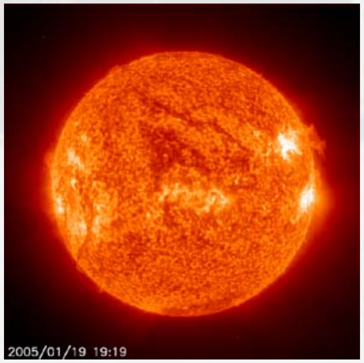


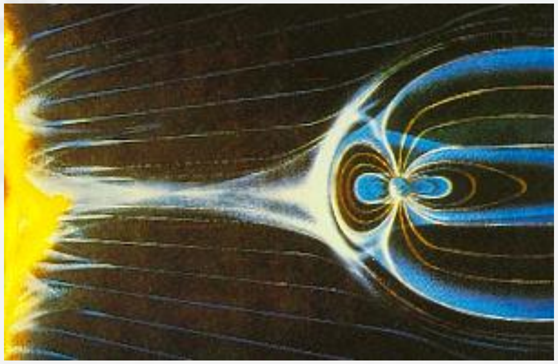
- Search for antihelium (primordial antimatter)
- Search for new Matter in the Universe (Strangelets?)



- Study of cosmic-ray propagation (light nuclei and isotopes)
- Study of electron spectrum (local sources?)

- Study solar physics and solar modulation
- Study terrestrial magnetosphere





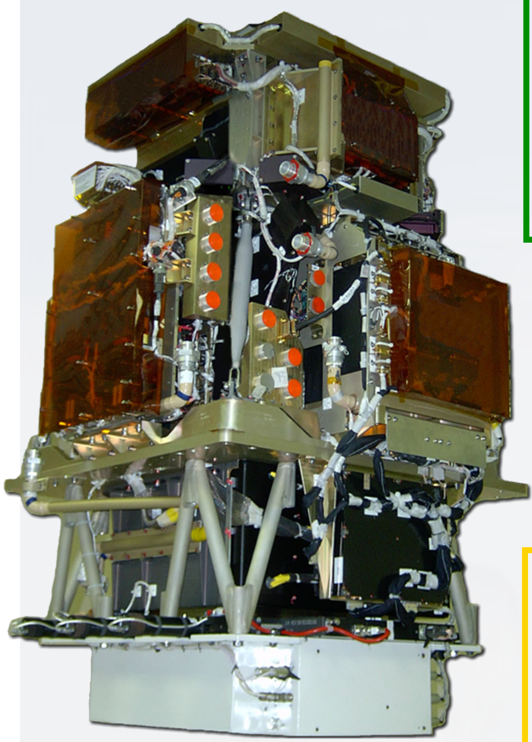
Design Performance

	energy range
• Antiprotons	80 MeV - 190 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 3×10^{-8} in $\overline{\text{He}}$/He

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

PAMELA detectors

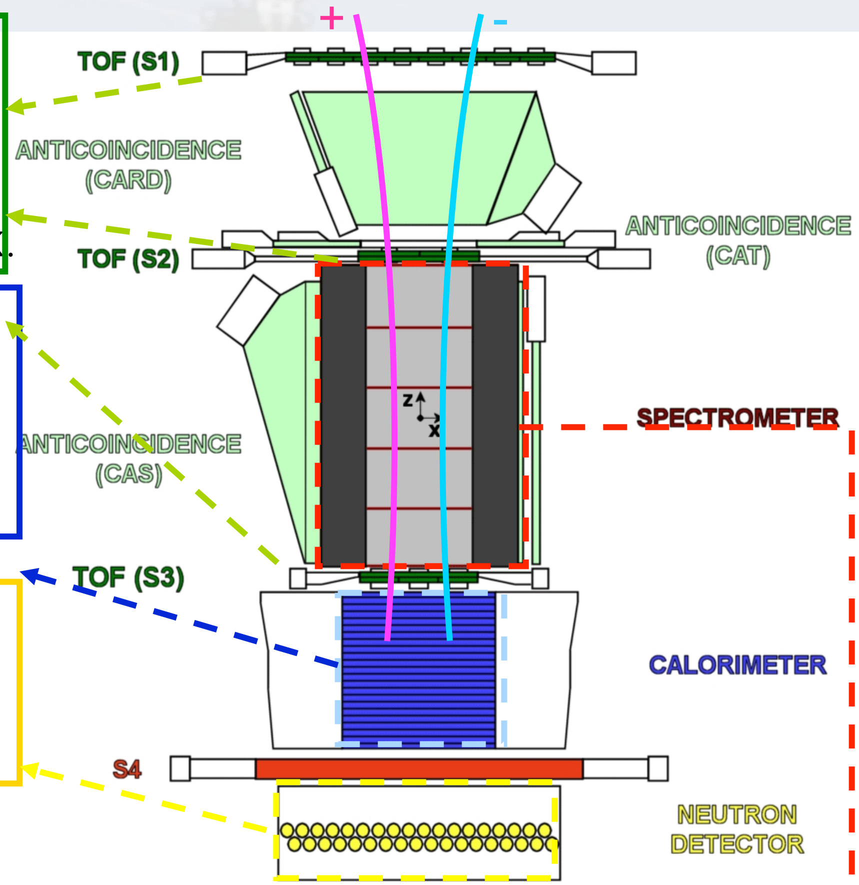
Main requirements → high-sensitivity antiparticle identification and precise momentum measure



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
plastic scintillators + PMT:
- High-energy e/h discrimination

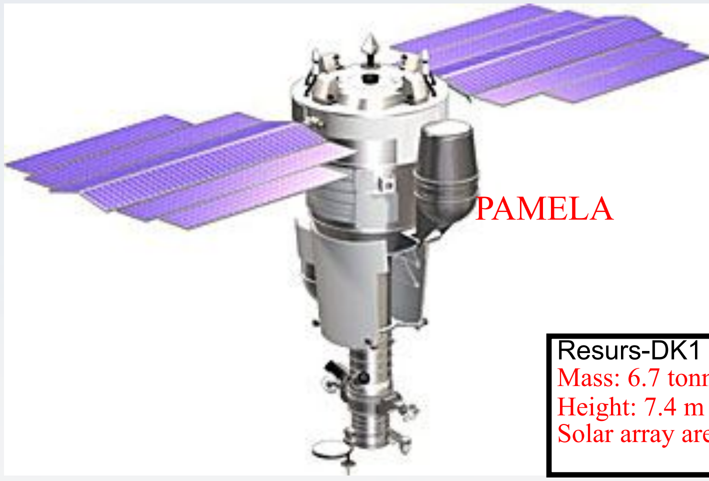


GF: 21.5 cm^2 sr
Magnetic Field: 0.43 T
MDR: ~1 TV
Mass: 470 kg
Size: 130x70x70 cm^3
Power Budget: 360W

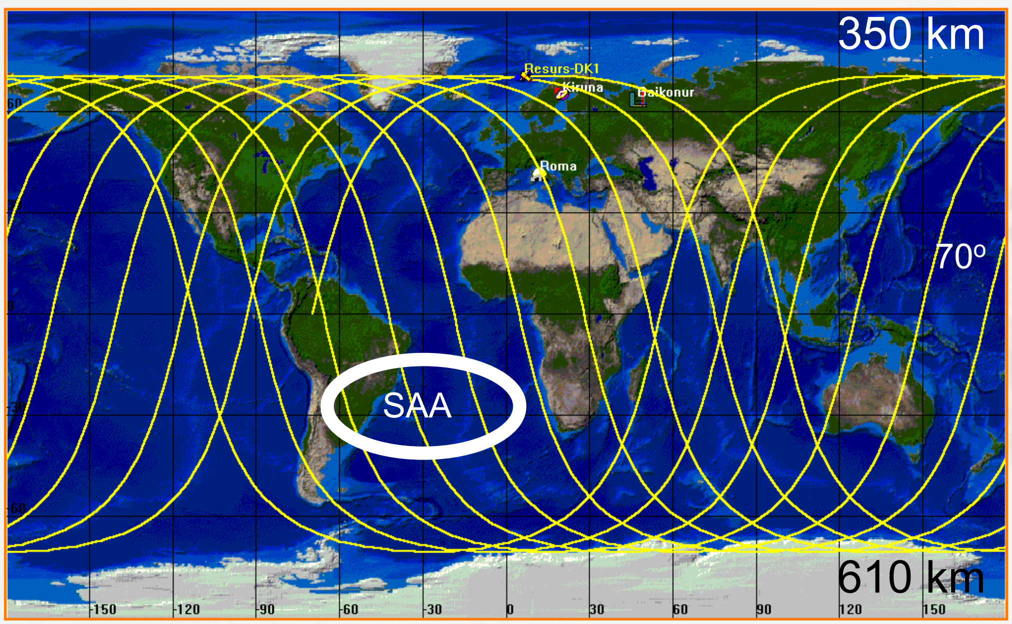
Spectrometer
microstrip silicon tracking system + permanent magnet
It provides:
- *Magnetic rigidity* → R = pc/Ze
- *Charge sign*
- *Charge value from dE/dx*

The Launch: 15th June 2006

Resurs-DK1 satellite + orbit

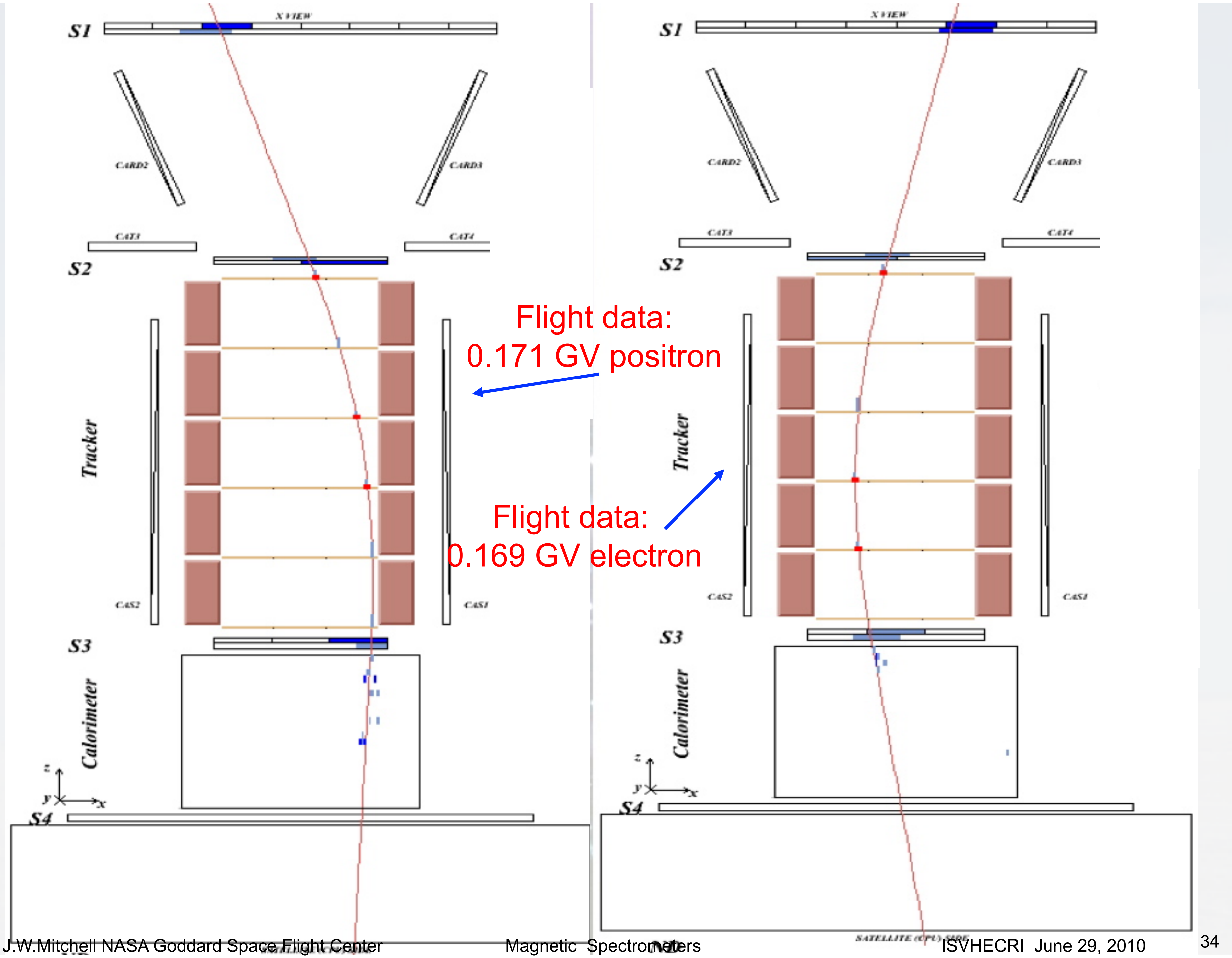


Resurs-DK1
Mass: 6.7 tonnes
Height: 7.4 m
Solar array area: 36 m^2

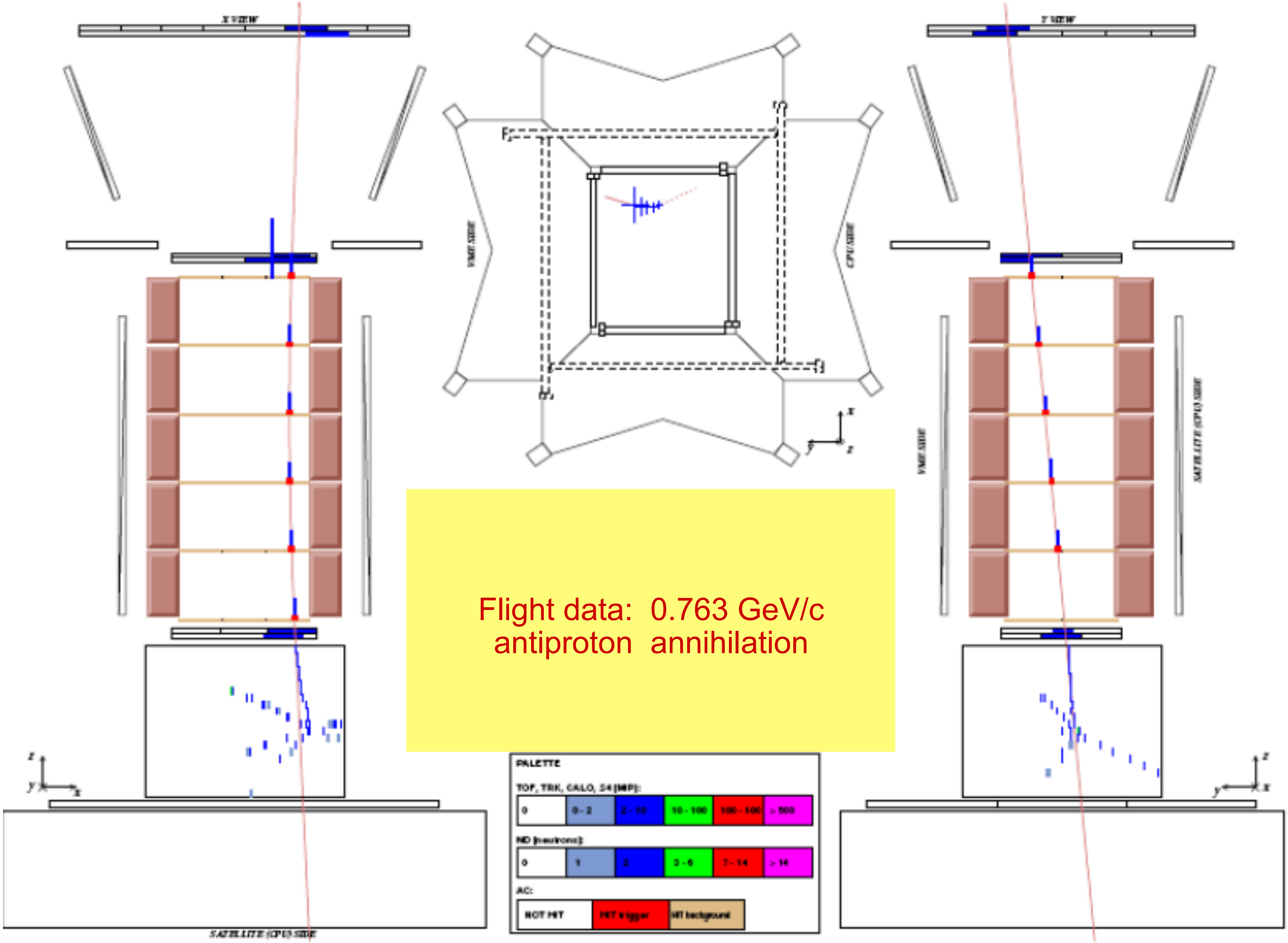


~90 mins

- Resurs-DK1: multi-spectral imaging of earth's surface
- PAMELA mounted inside a pressurized container
- Lifetime > 4 years
- 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

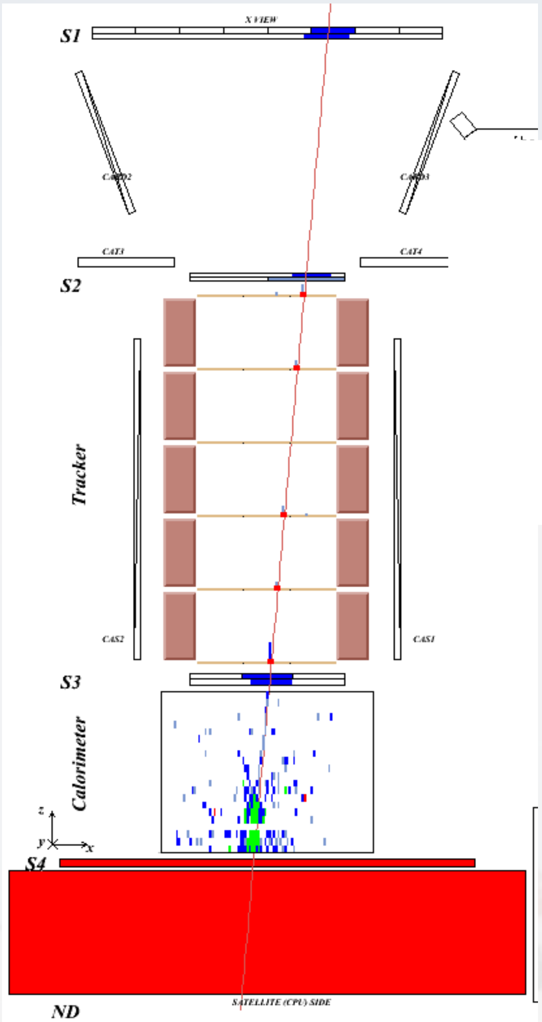


S1
X VIEW
CARD2
CARD3
CAT3
CAT4
S2
Tracker
CAS2
CAS1
S3
Calorimeter
S4
Flight data:
0.171 GV positron
Flight data:
0.169 GV electron



Flight data: 0.763 GeV/c
antiproton annihilation
X VIEW
Y VIEW
VME SIDE
CPU SIDE
SATELLITE (CPU) SIDE
PALETTE
AC:
NOT HIT

Antiproton / positron identification



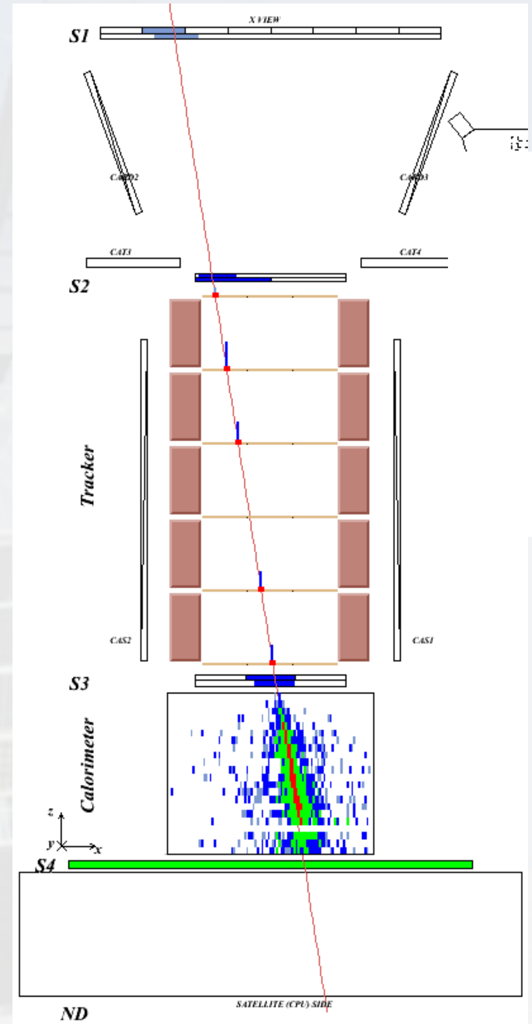
Antiproton
$(\text{NB: } e^- / \bar{p} \sim 10^2)$

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

Bending in spectrometer:
sign of charge

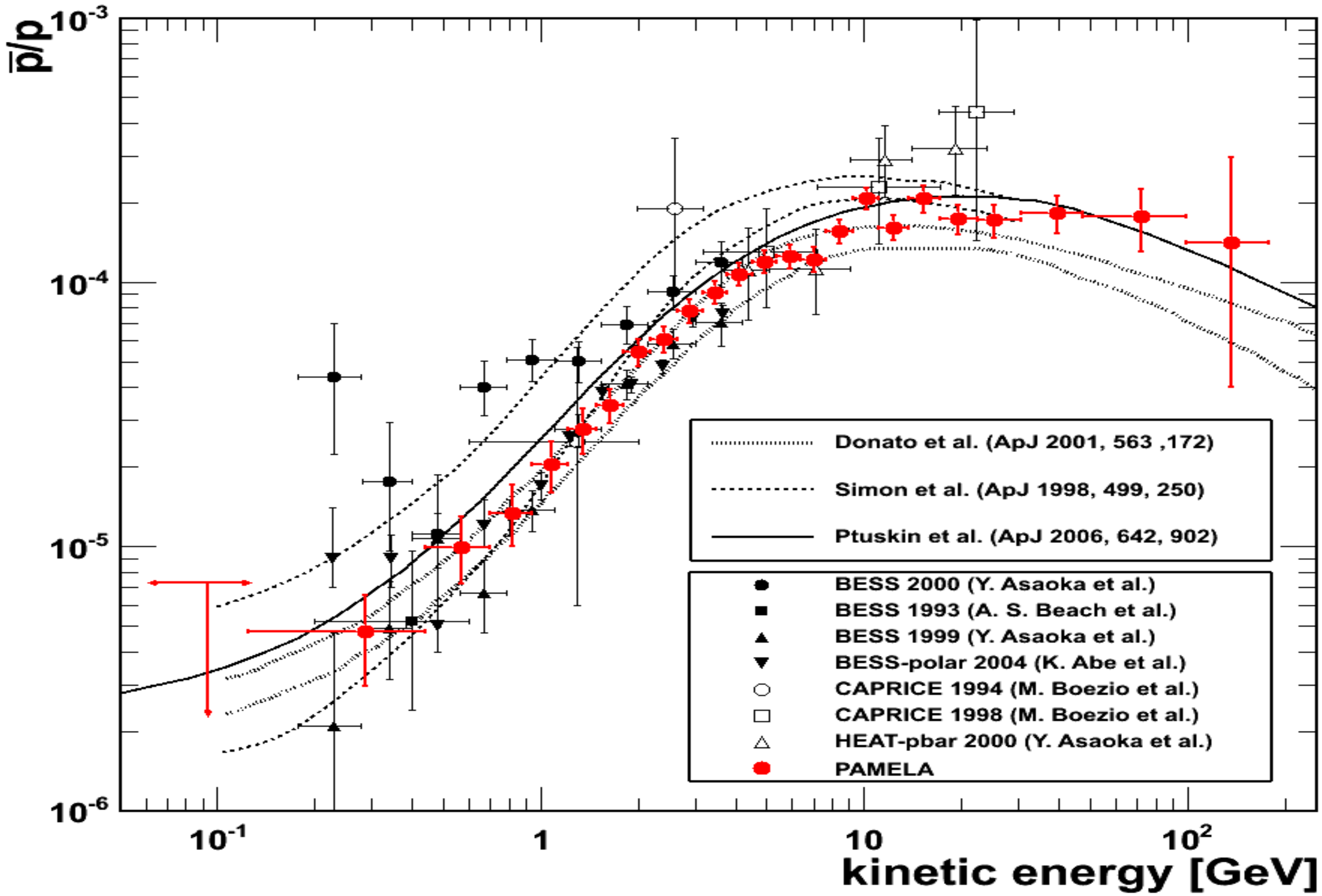
Ionisation energy loss (dE/dx):
magnitude of charge

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

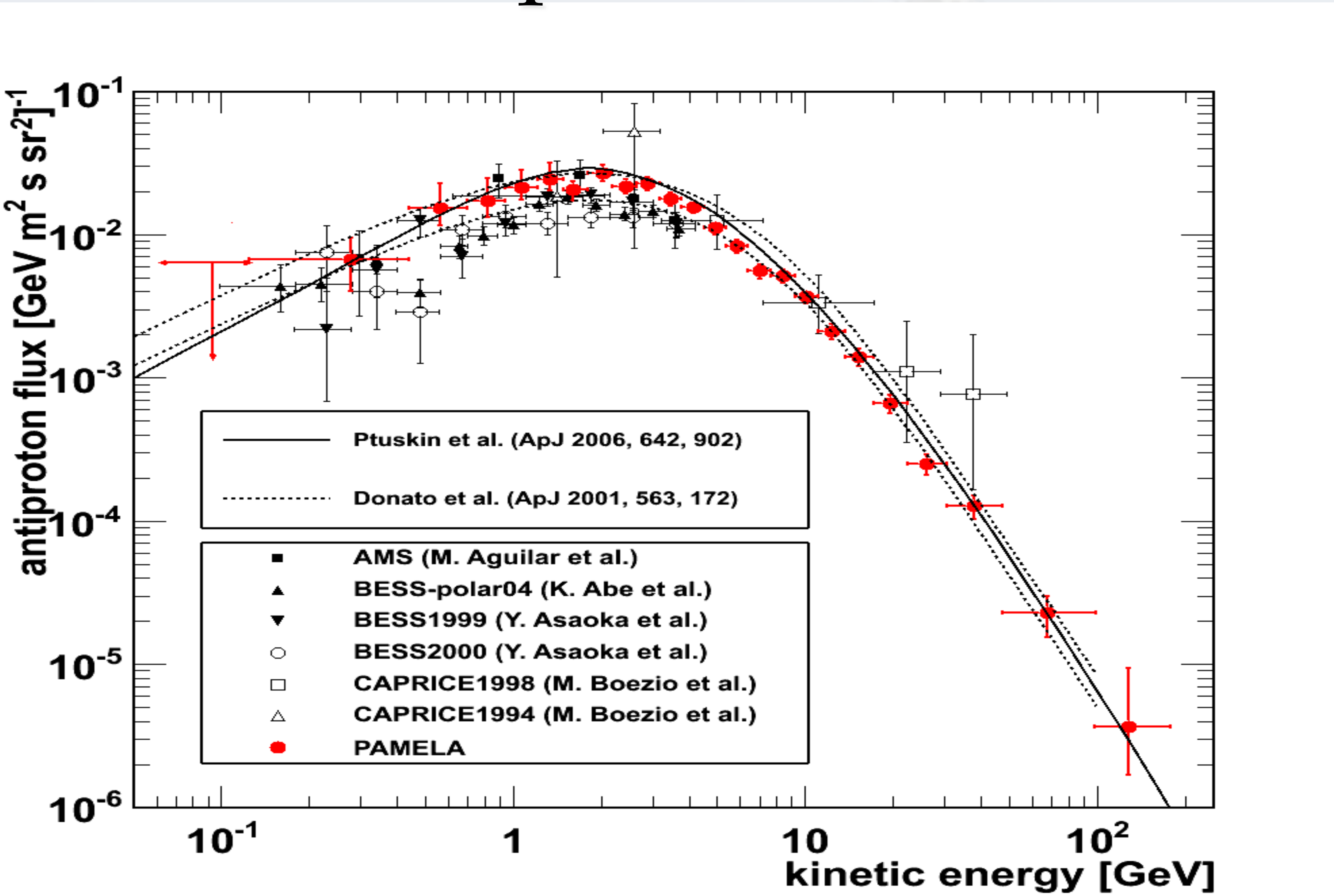


Positron
$(\text{NB: } p/e^+ \sim 10^{3\text{-}4})$

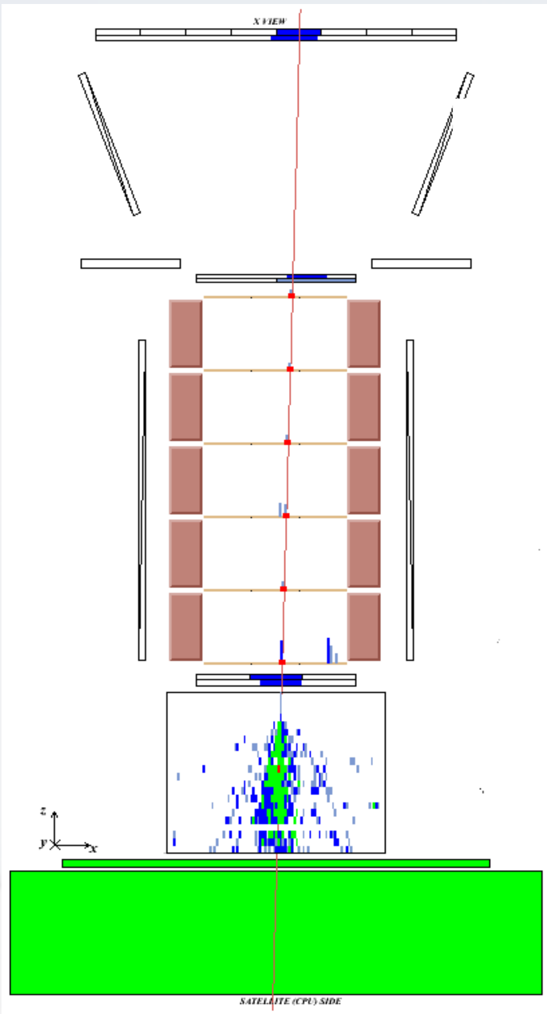
Antiproton to proton flux ratio



Antiproton Flux



Proton / positron discrimination

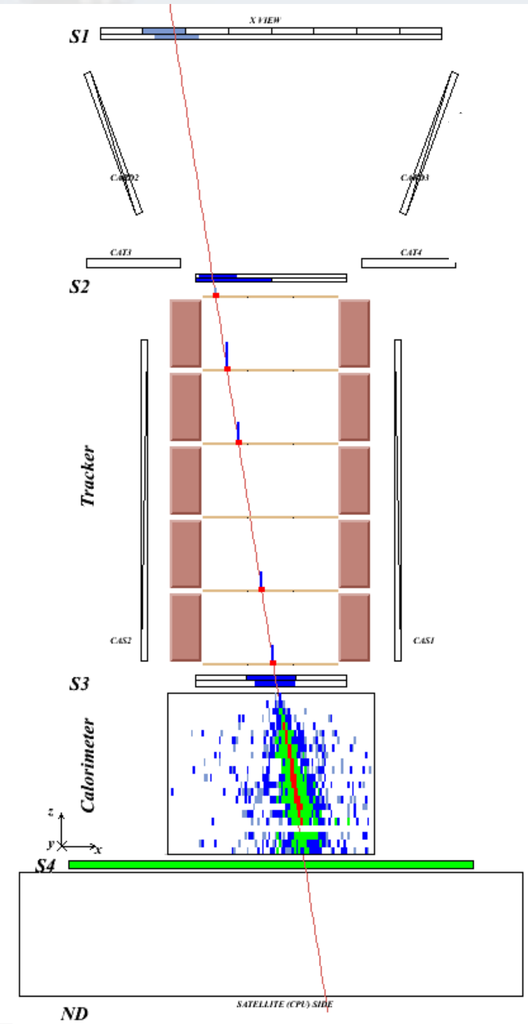


Time-of-flight: trigger, albedo rejection, mass determination (up to 1 GeV)

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

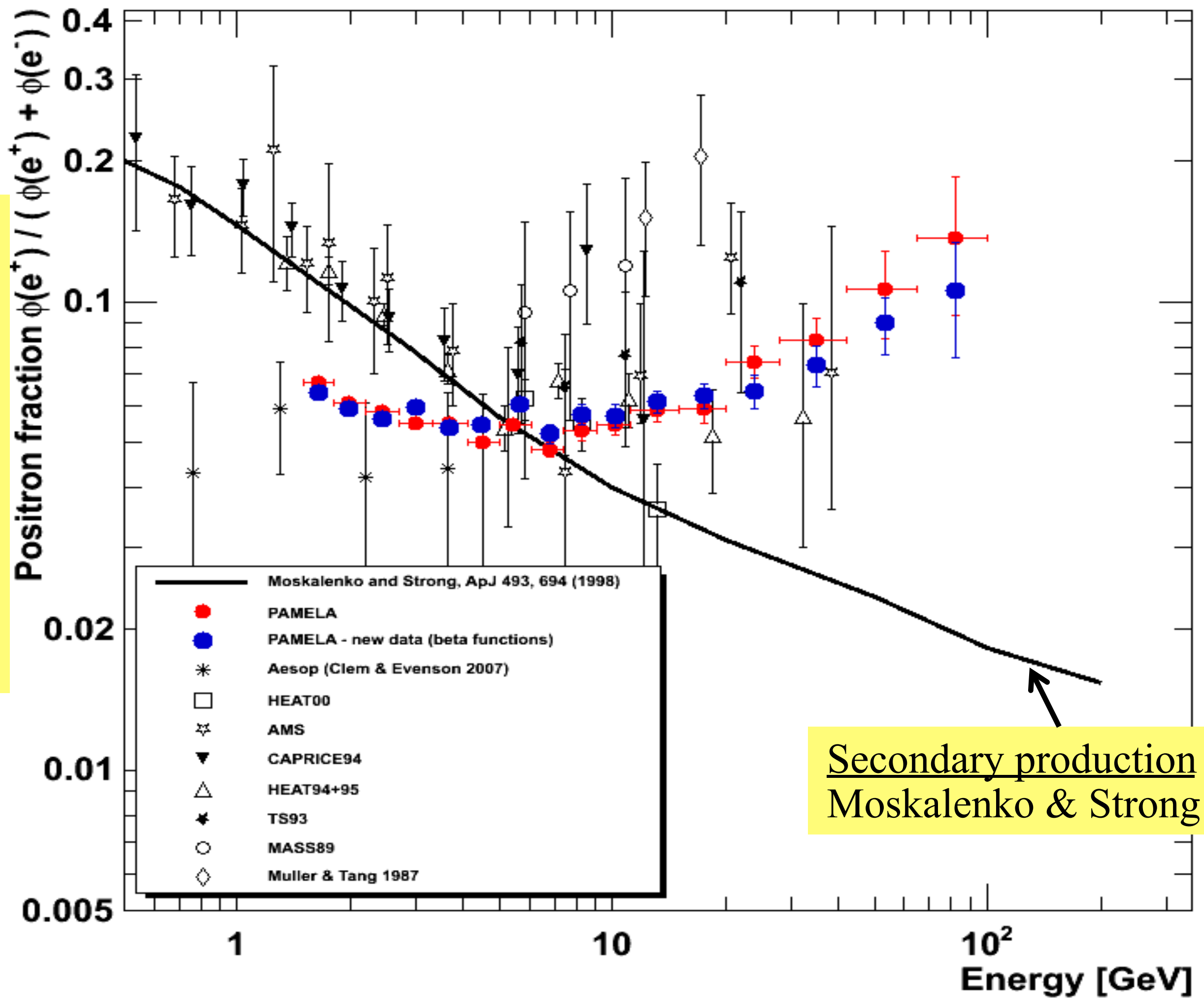


Proton **Positron**

Positron to Electron Fraction

In Nature article published data acquired till February 2008

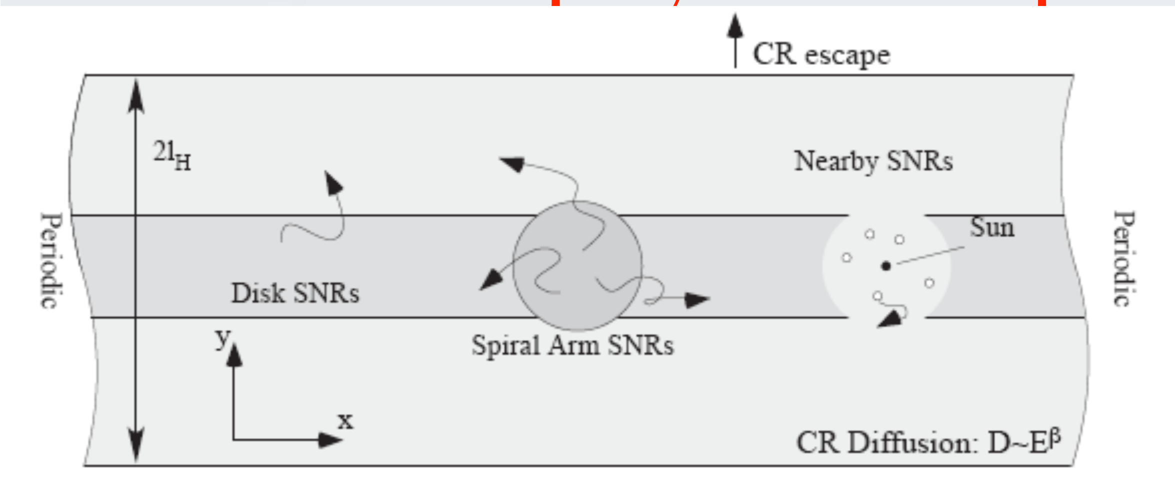
New data reduction: data till end of 2008. With same approach of Nature paper ~30% increase in statistics better understanding of systematics.

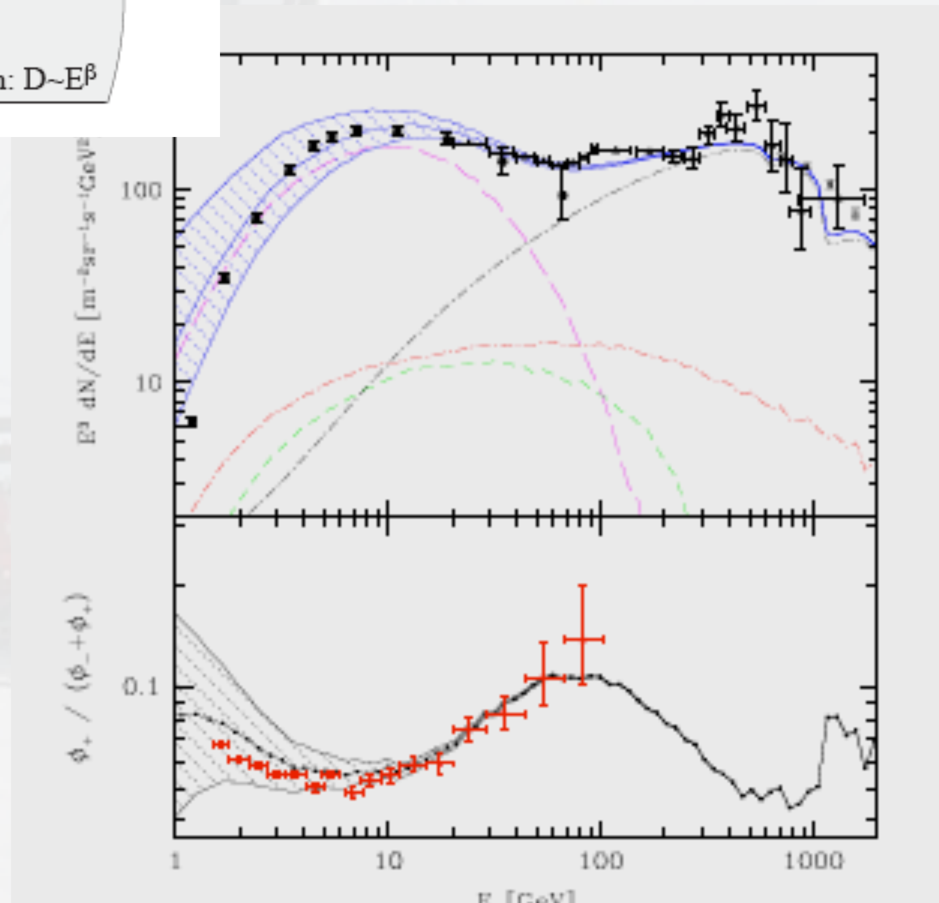


Secondary production
Moskalenko & Strong 98

Adriani et al, arXiv:1001.3522 [astro-ph.HE]

Astrophysical Explanation: SNR



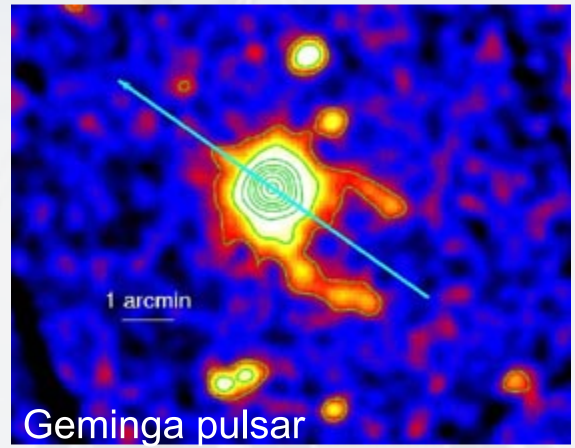


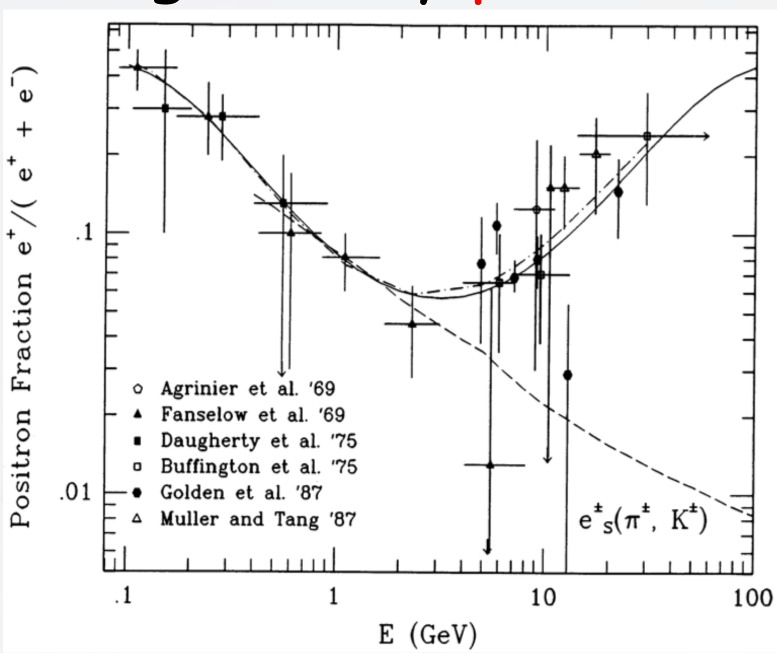
N.J. Shaviv et al., arXiv: 0902.0376v1

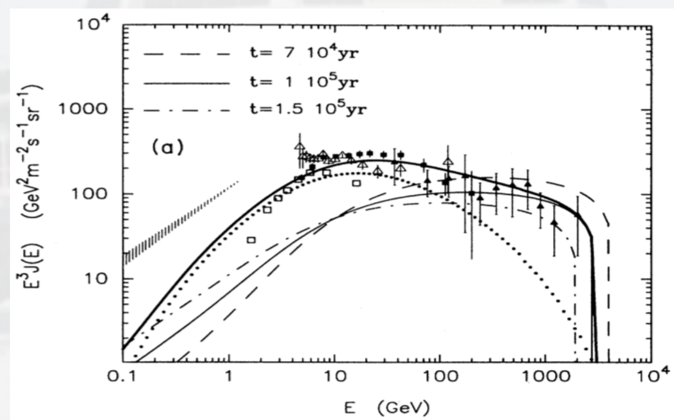
Astrophysical Explanation: Pulsars

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

Young, nearby pulsars







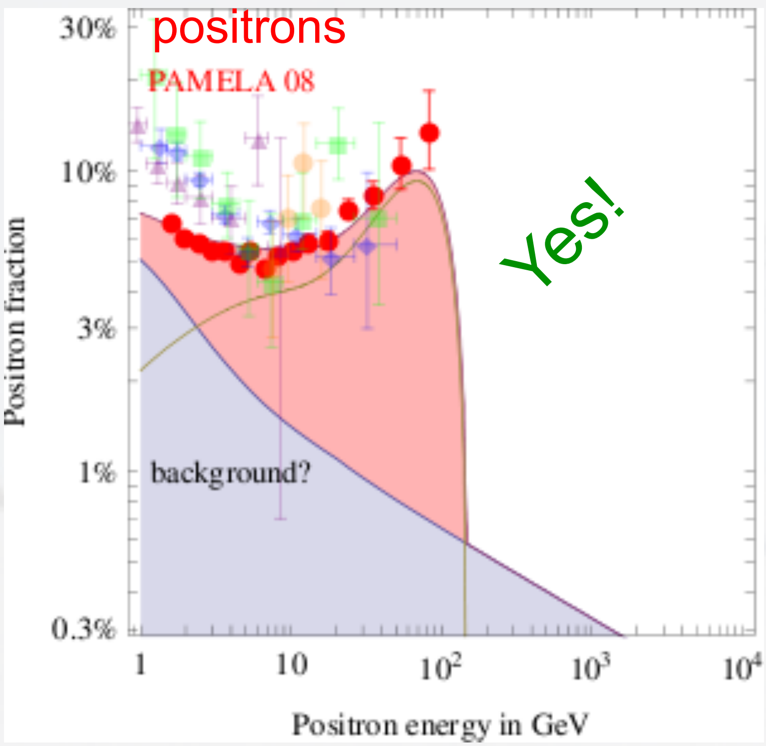
Not a new idea: Boulares, ApJ 342 (1989), Atoyan et al (1995)

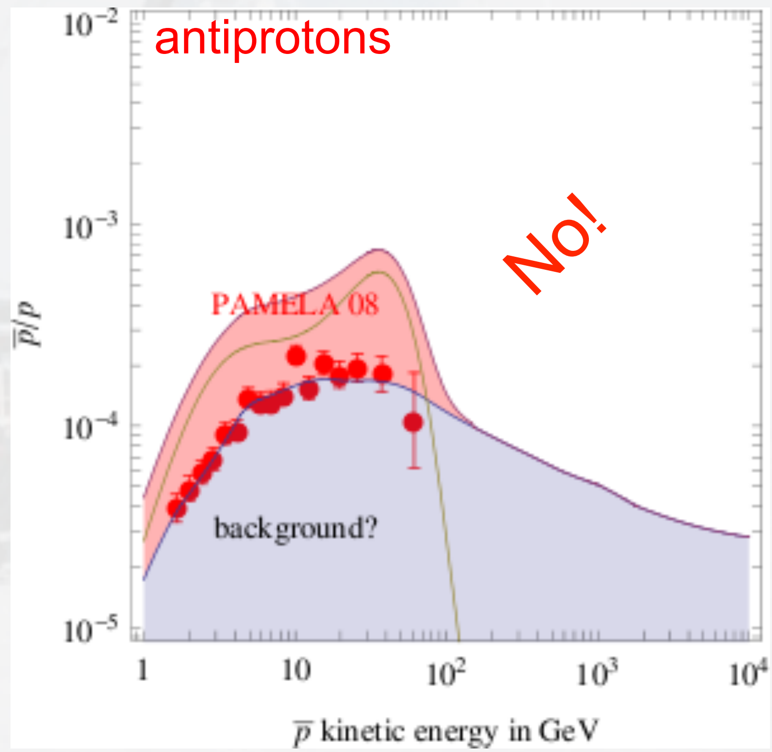
M. Cirelli et al., Nucl. Phys. B 813 (2009) 1; arXiv: 0809.2409v3

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)





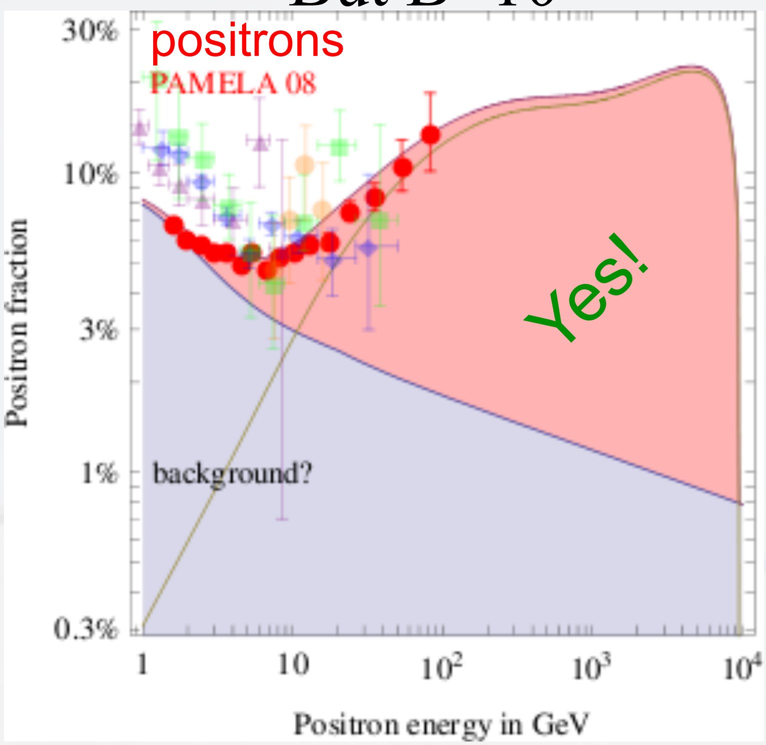
Interpretation: DM

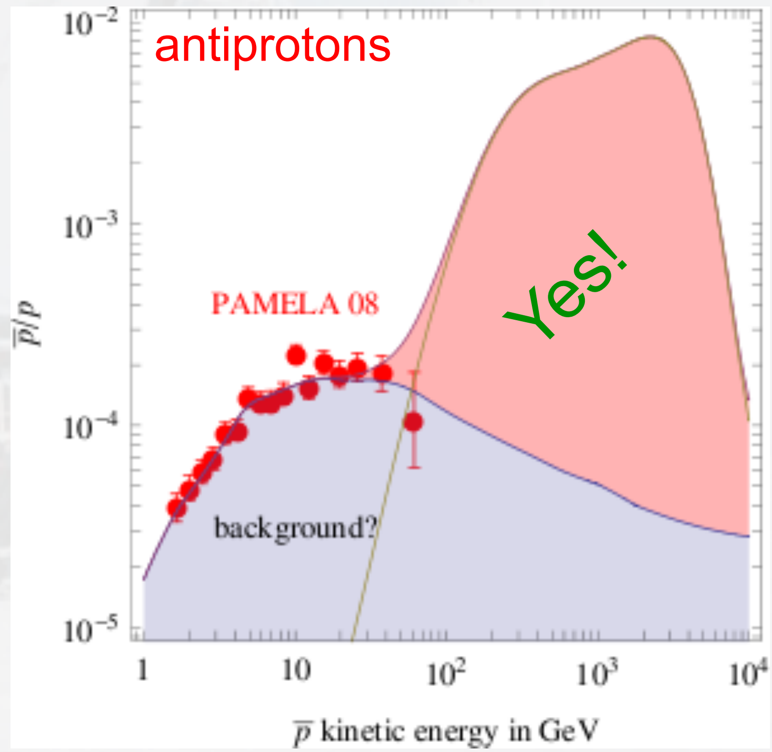
M. Cirelli et al., Nucl. Phys. B 813 (2009) 1; arXiv: 0809.2409v3

Which DM spectra can fit the data?

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

But B≈10^4

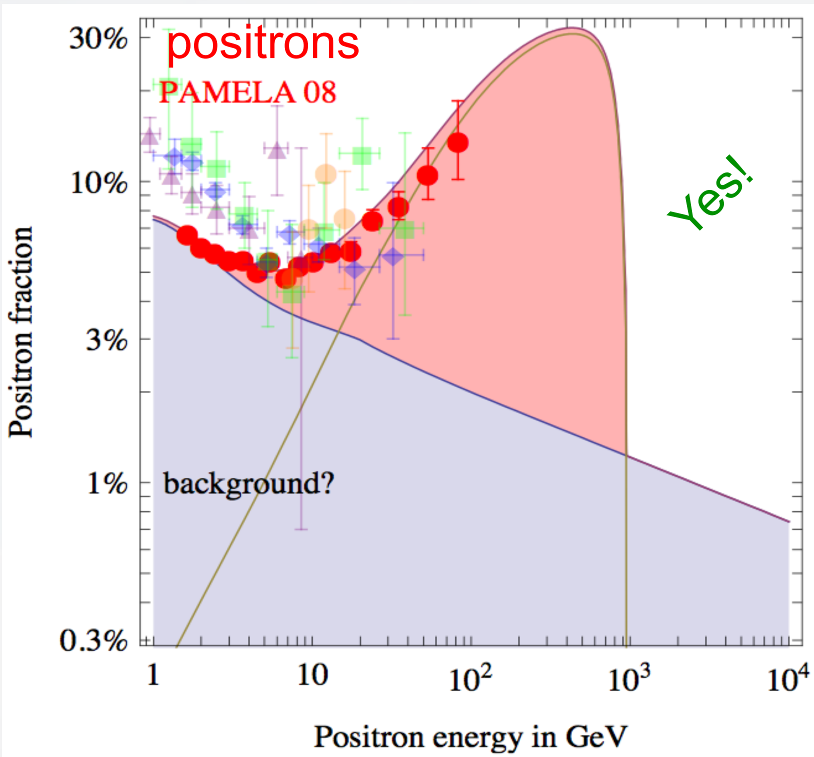


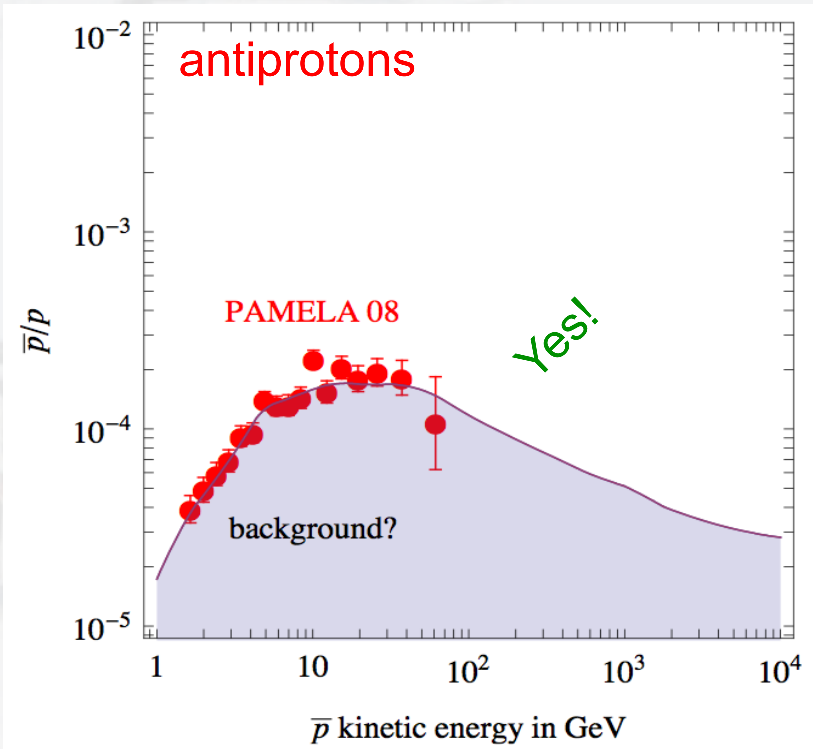


M. Cirelli et al., Nucl. Phys. B 813 (2009) 1; arXiv: 0809.2409v3

Interpretation: DM

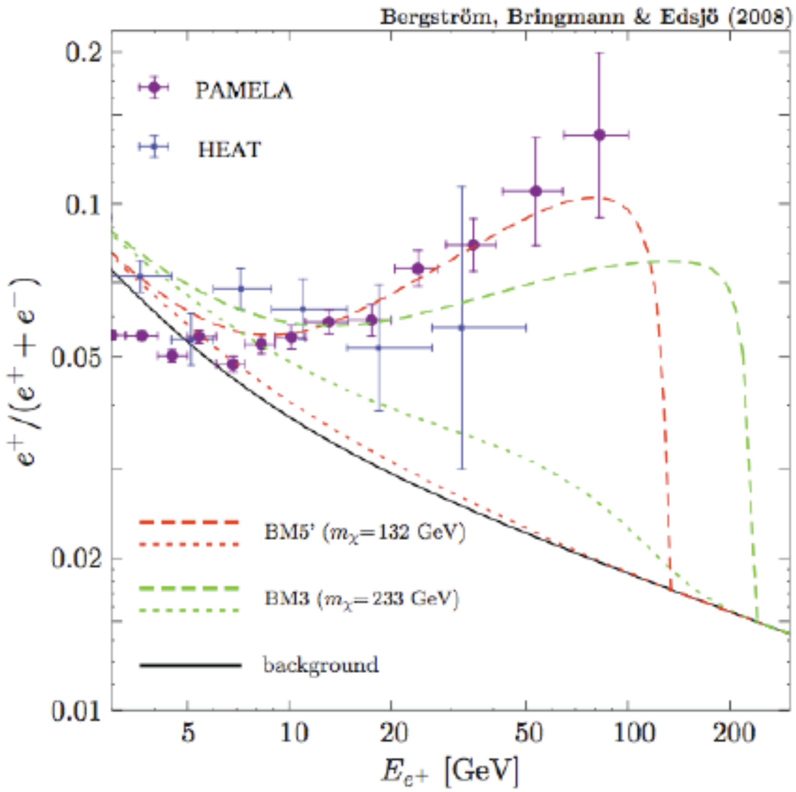
DM with $m_\chi \simeq 1\,\mathrm{TeV}$ and $\mu^+\mu^-$ dominant annihilation channel





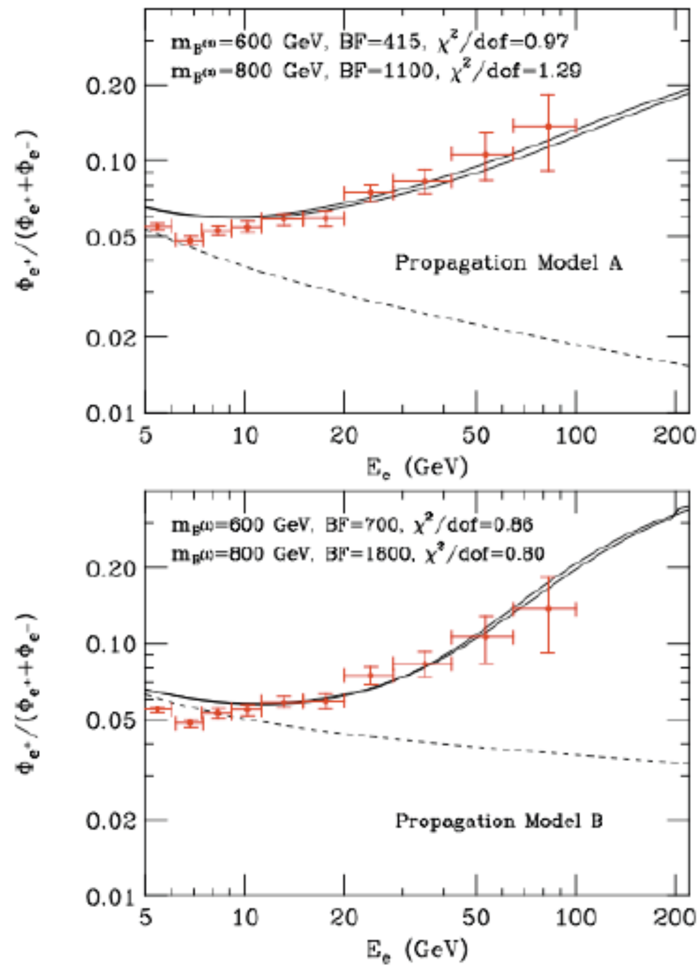
Example: Dark Matter

arXiv:0808.3725



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

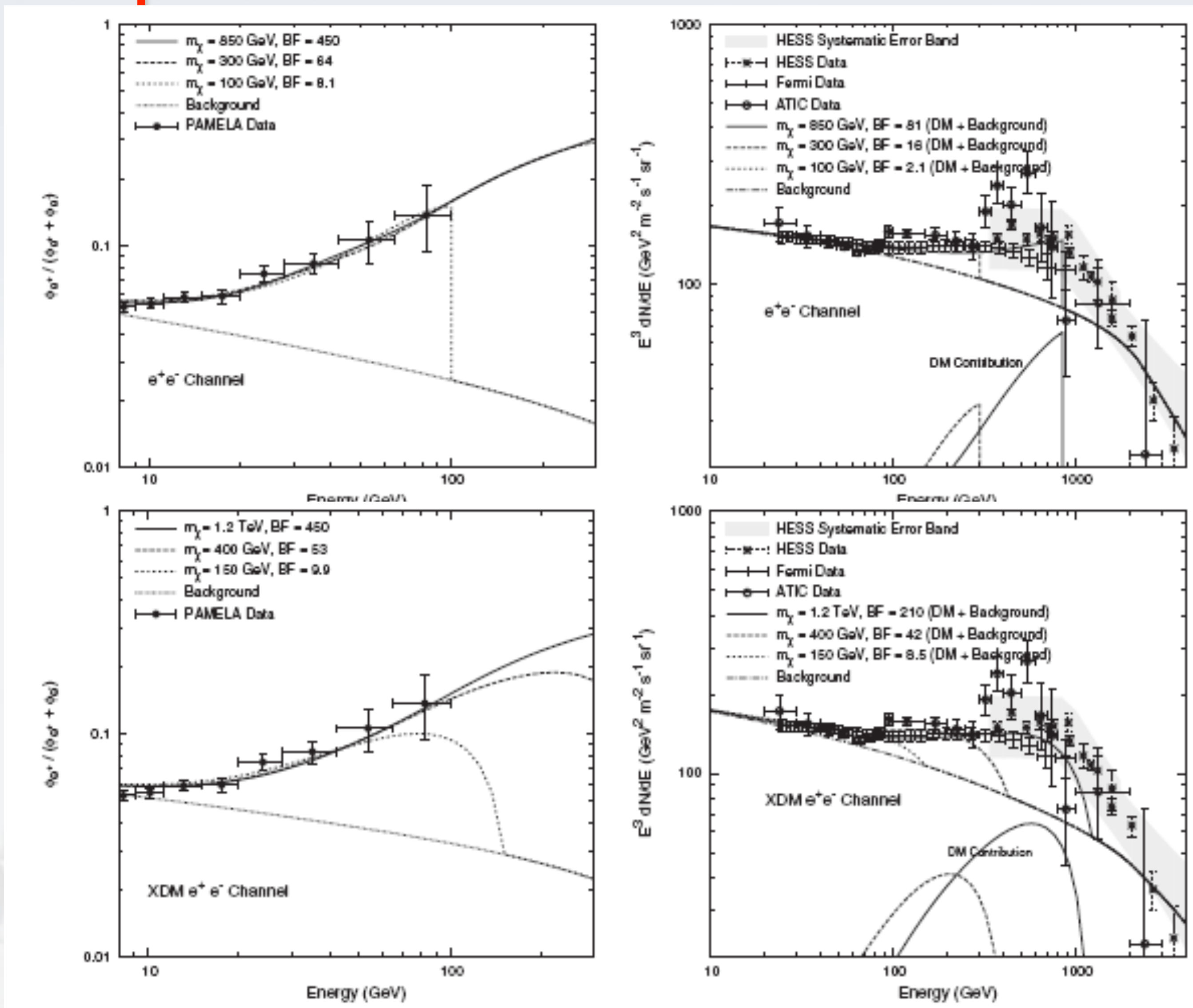
Hooper and Zurek
arXiv:0902.0593v1



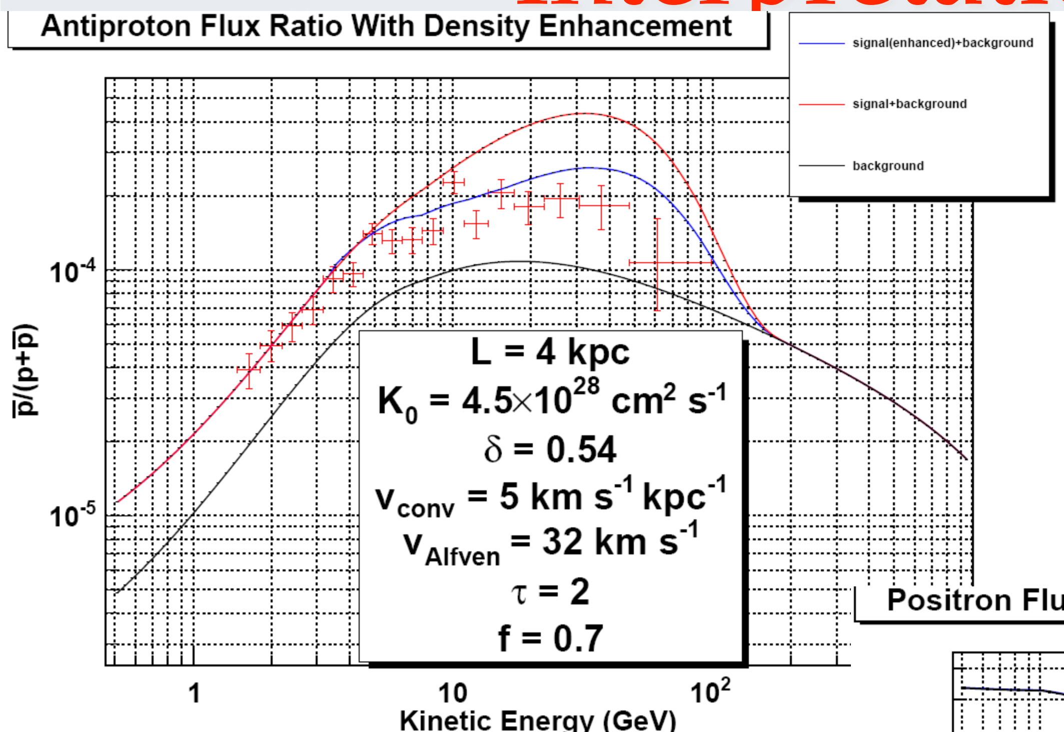
Kaluza-Klein dark matter

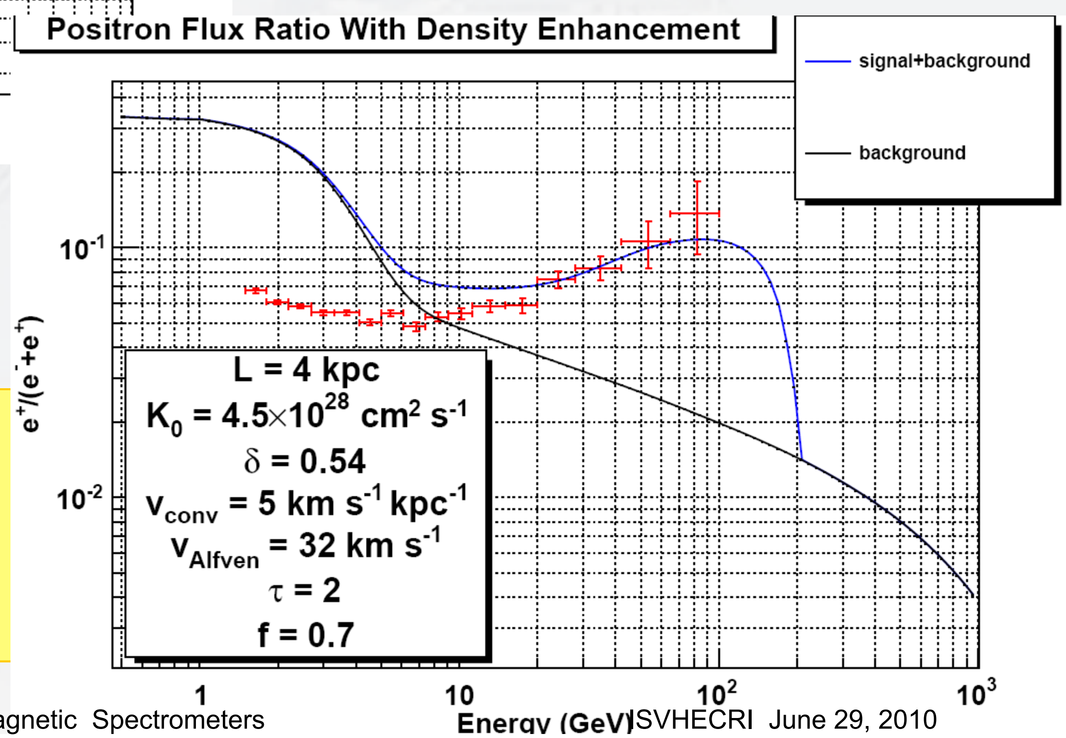
Interpretation: DM

I. Cholis et al. Phys. Rev. D 80 (2009) 123518; arXiv:0811.3641v1



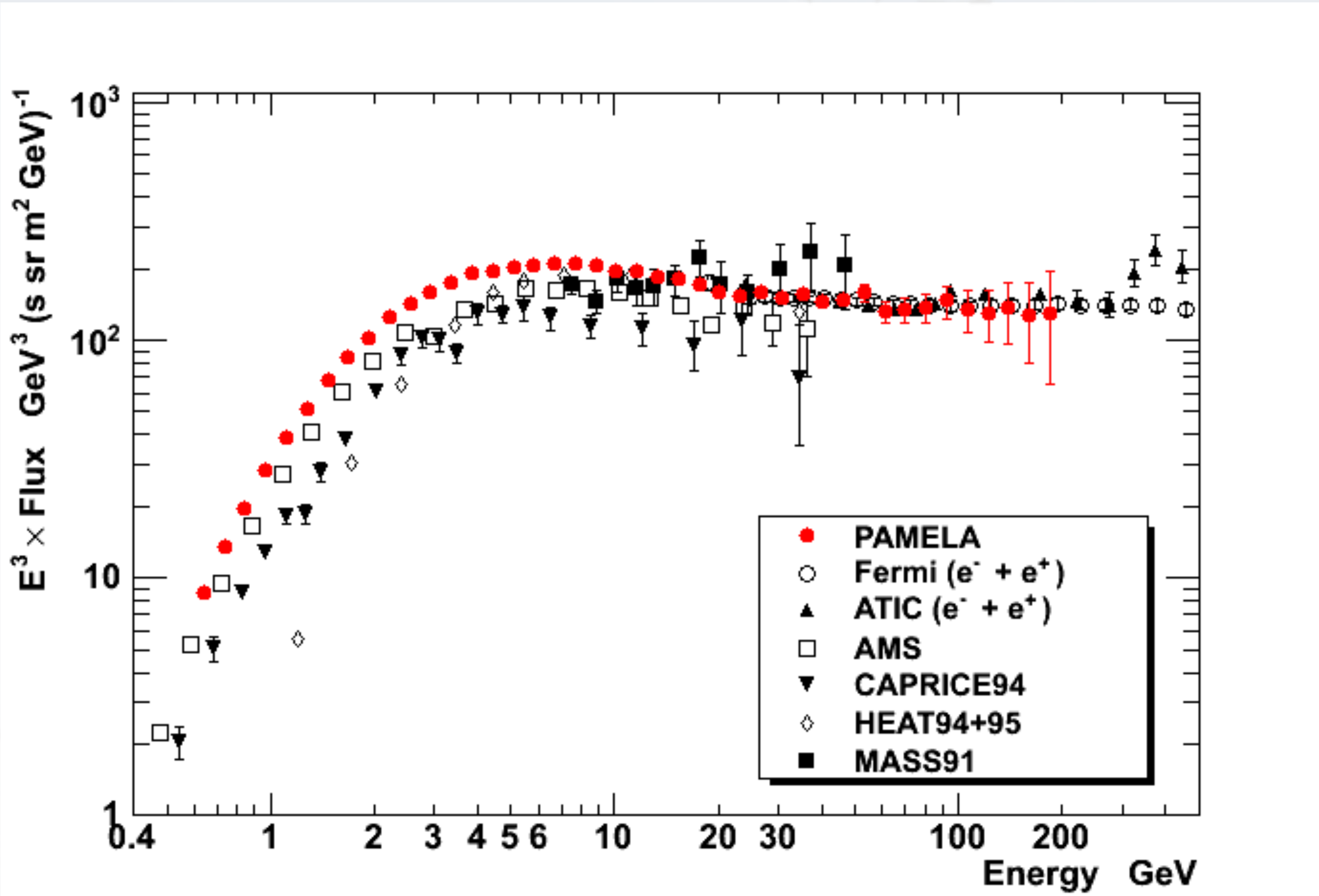
Interpretation: DM



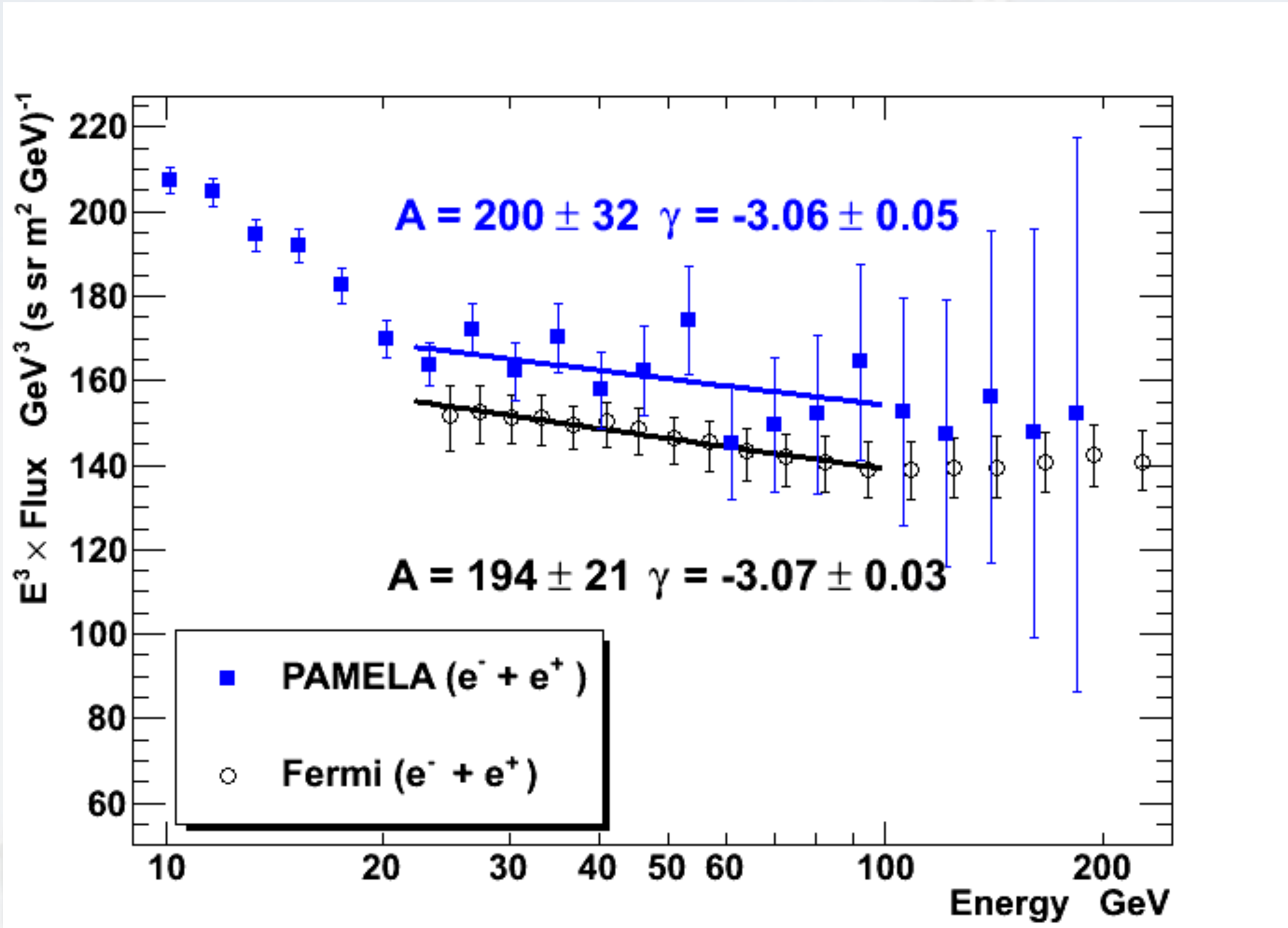


P. Grajek et al., Phys. Rev. D 79 (2009) 043506; arXiv: 0812.4555v1
Non-thermal wino-like neutralino
Varying propagation model, no boost factor

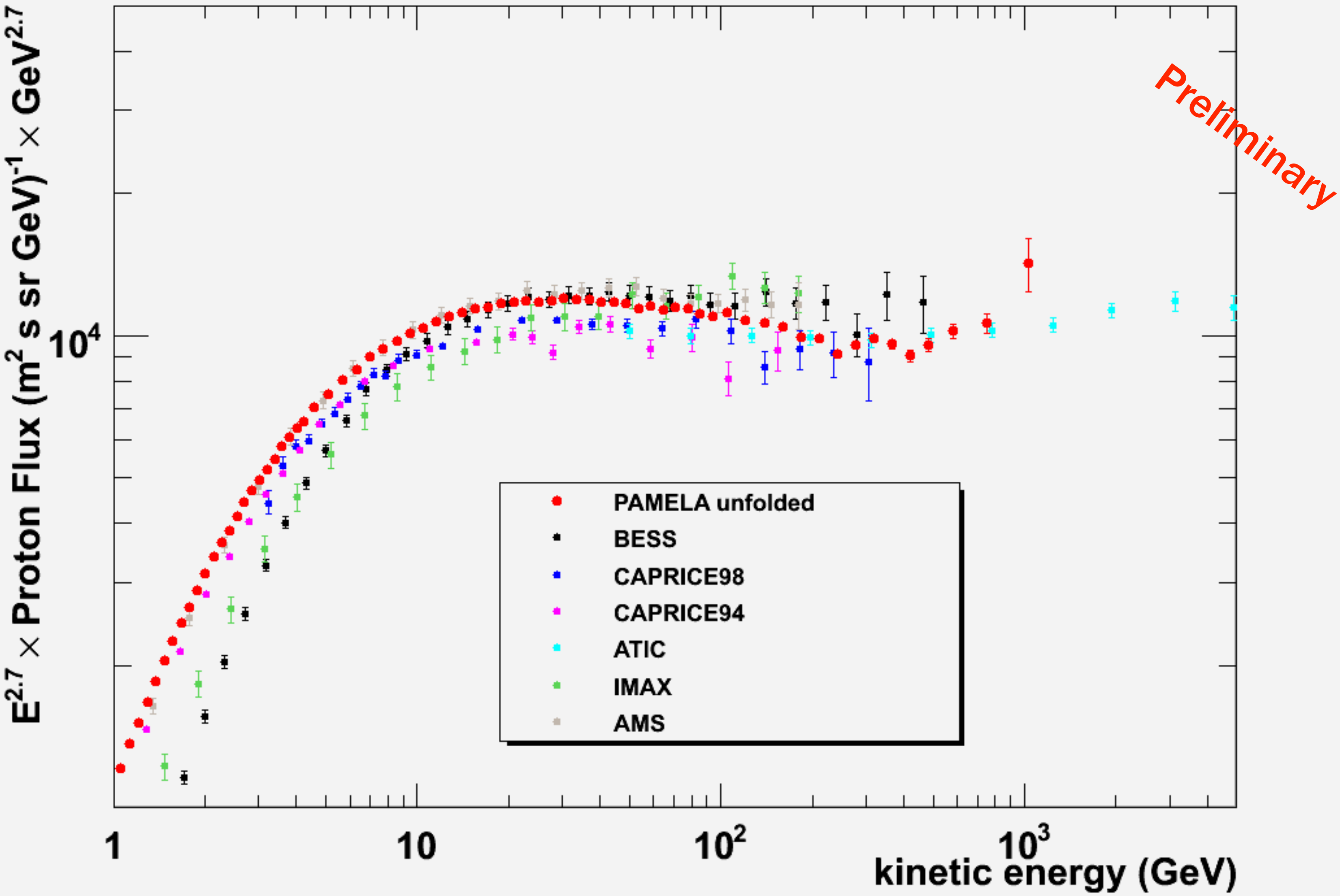
PAMELA Electron (e^-) Spectrum



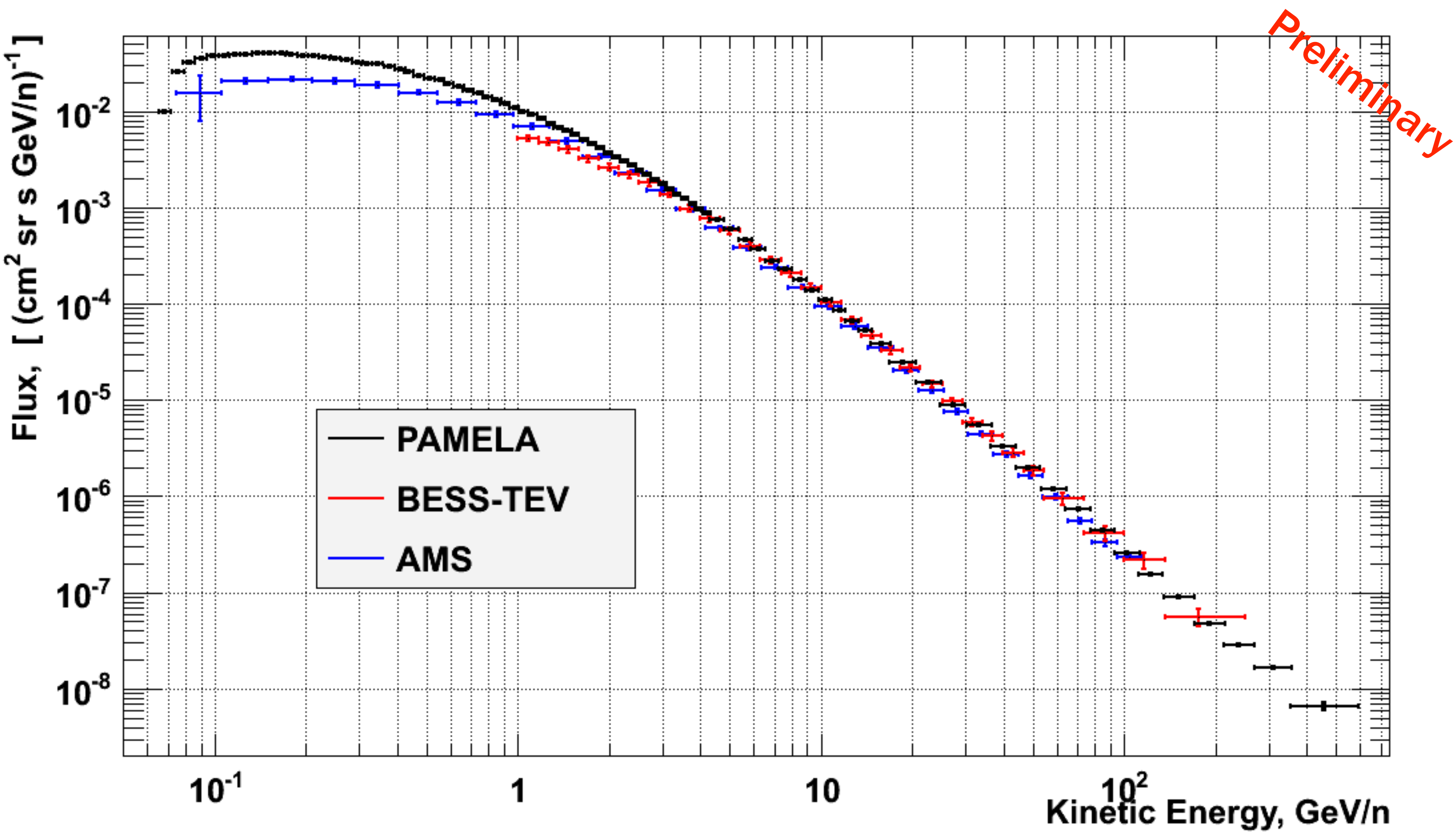
PAMELA Electron (e^- + e^+) Spectrum



Proton Spectrum



Helium Nuclei Spectrum



Preliminary!!

Secondary nuclei

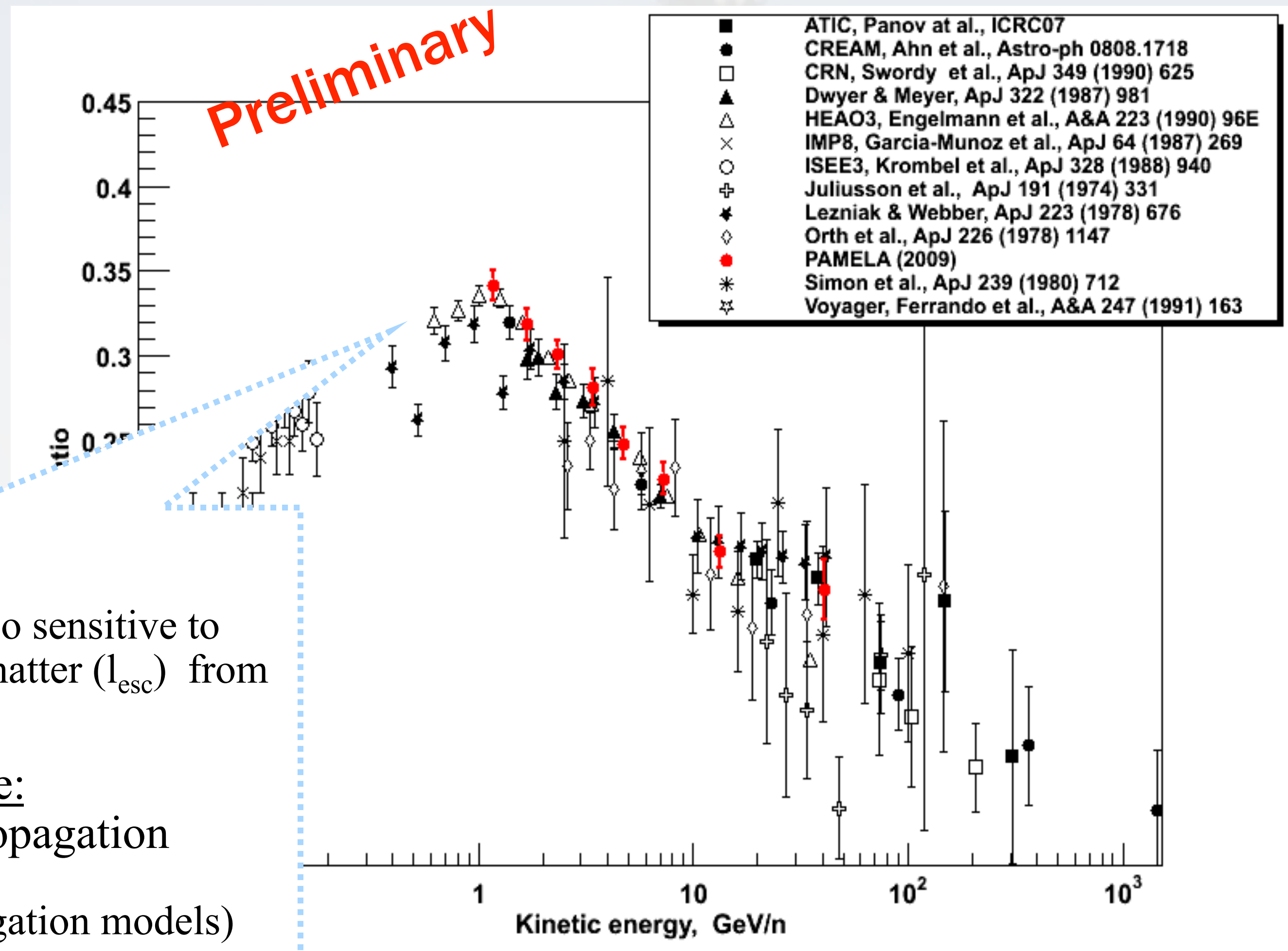
LBM

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

- 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

Local secondary abundance:
⇒ study of galactic CR propagation

(B/C used for tuning of propagation models)



Solar Modulation of galactic cosmic rays

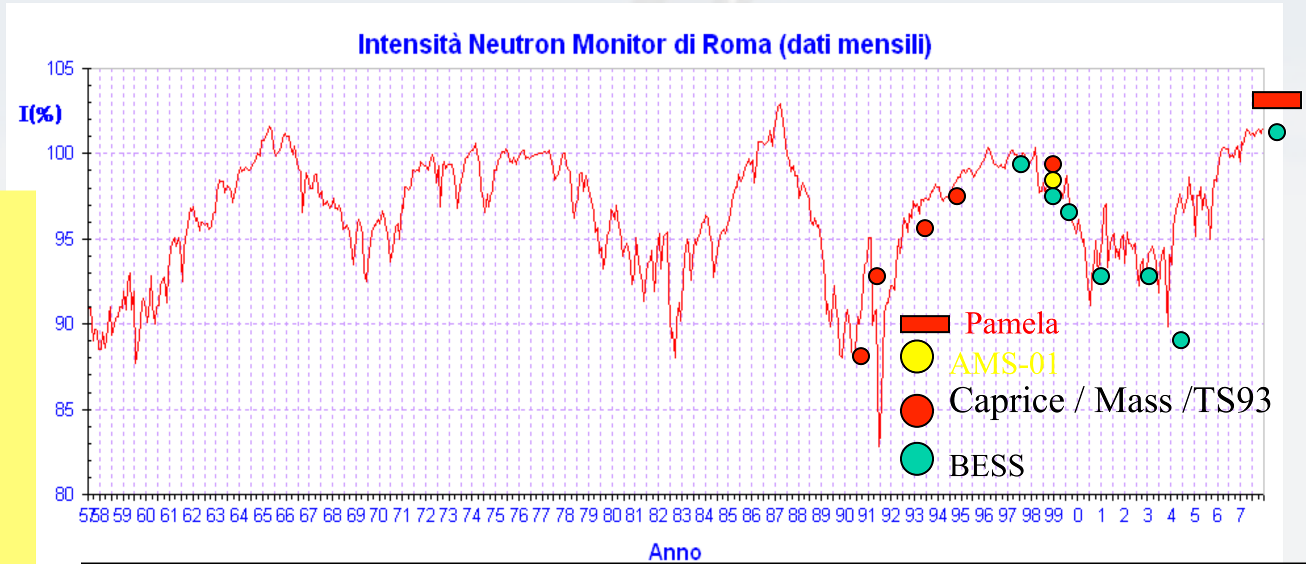
- **Study of charge sign dependent effects**

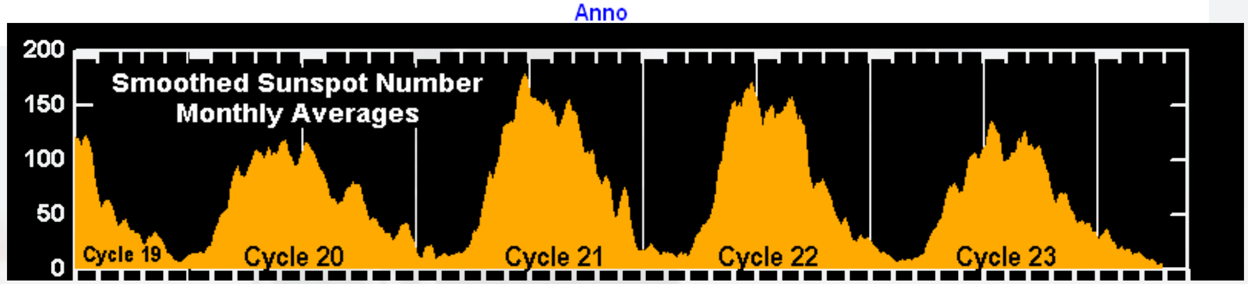
Asaoka Y. et al. 2002, Phys. Rev. Lett. 88, 051101),

Bieber, J.W., et al. Physi-cal Review Letters, 84, 674, 1999.

J. Clem et al. 30th ICRC 2007

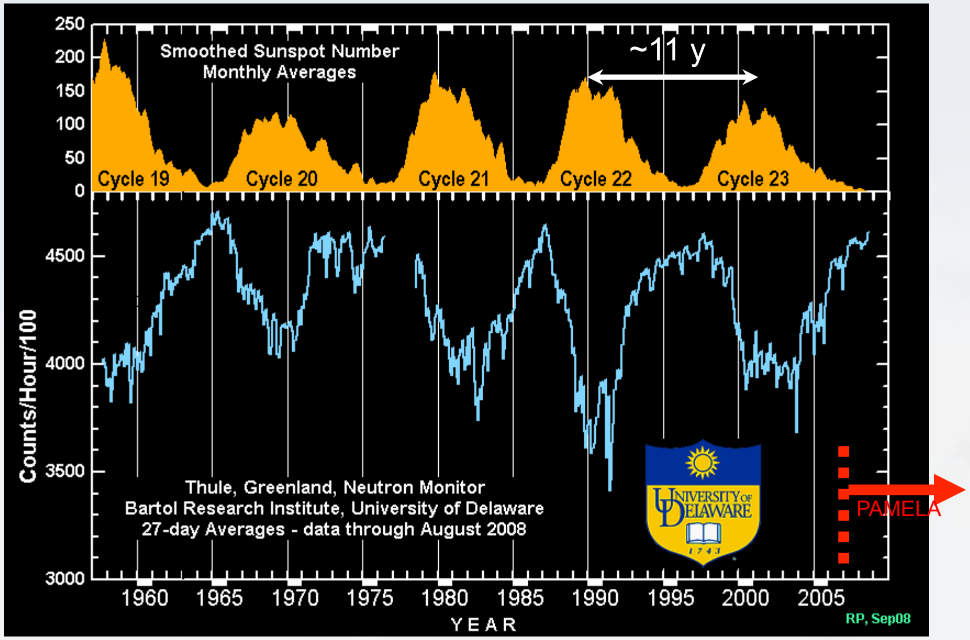
U.W. Langner, M.S. Potgieter, Advances in Space Research 34 (2004)

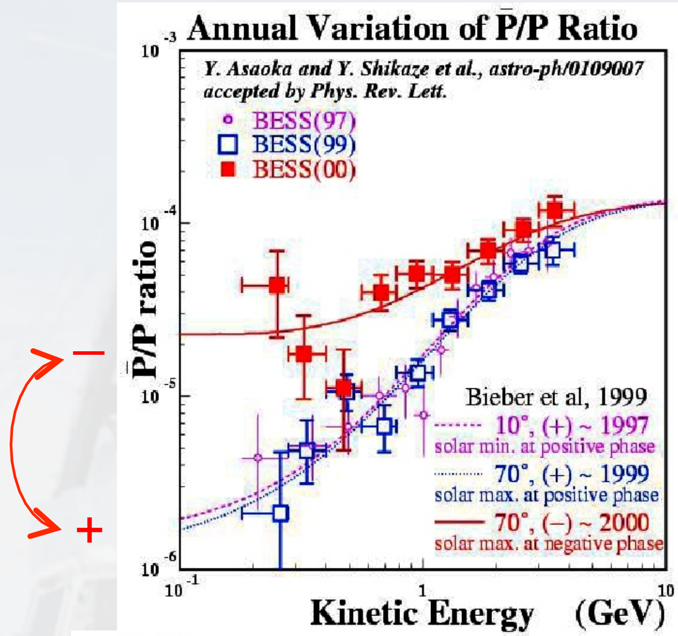


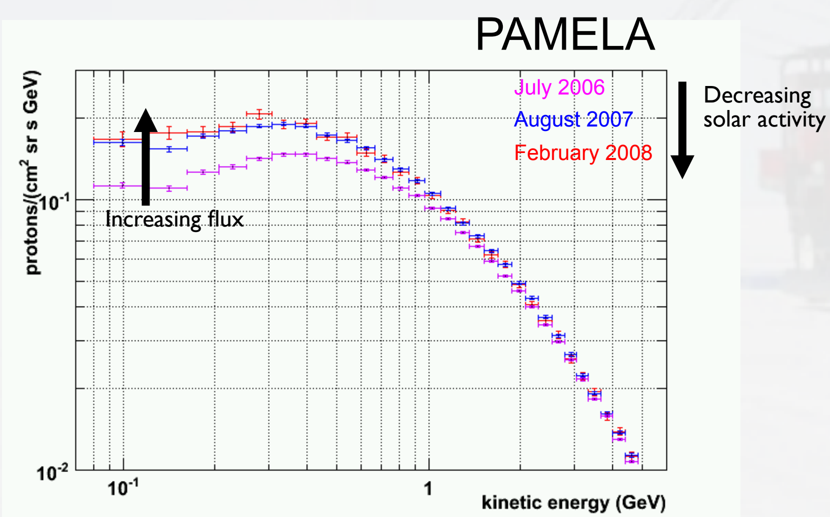


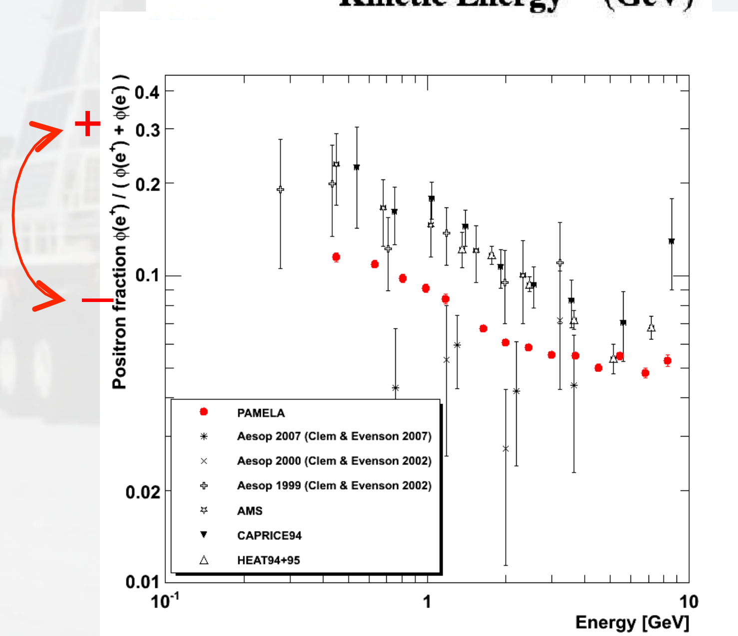
Solar modulation

A^+ A^- A^+ A^-



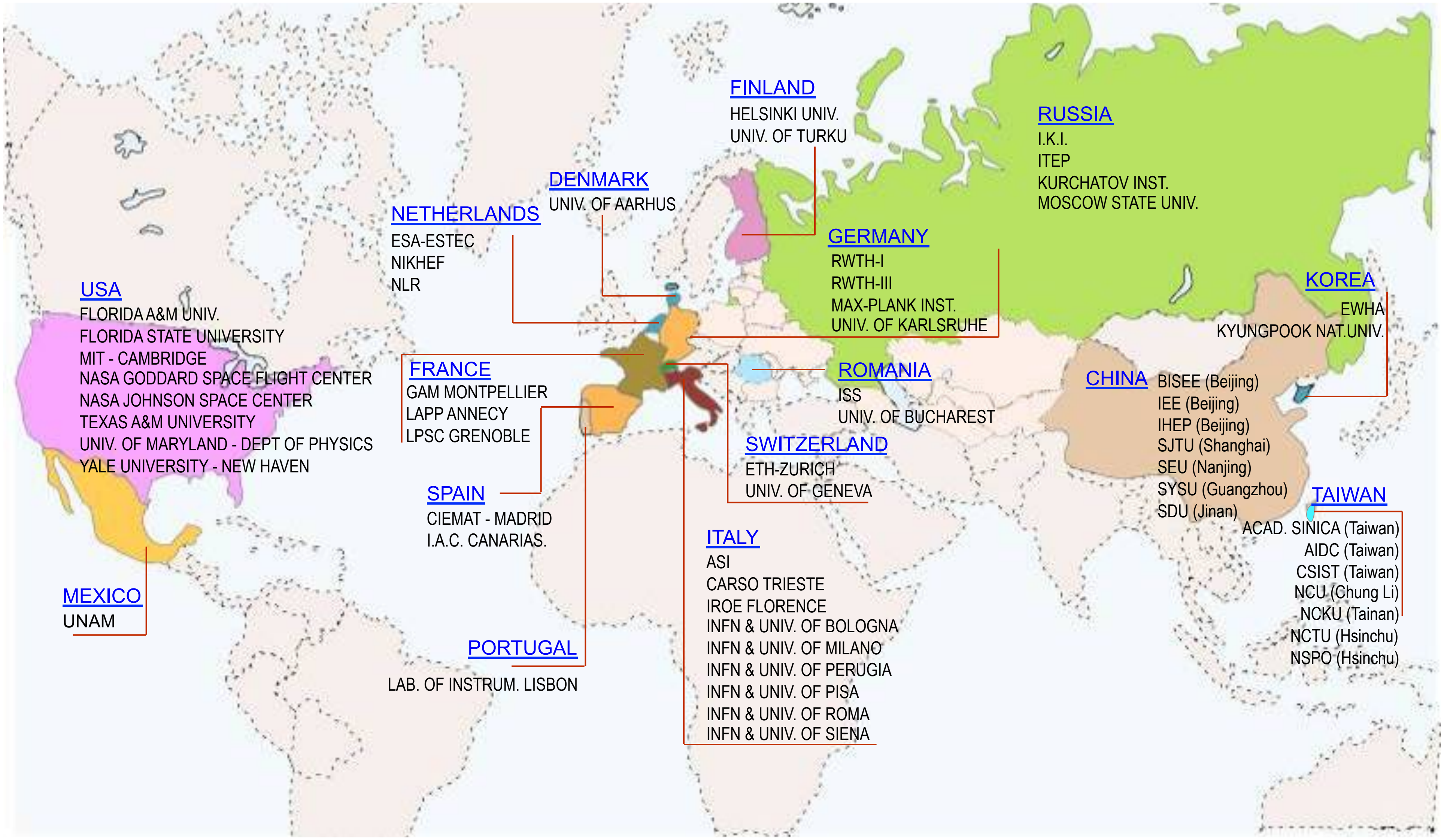






AMS International Collaboration

16 Countries, 60 Institutes and 600 Physicists

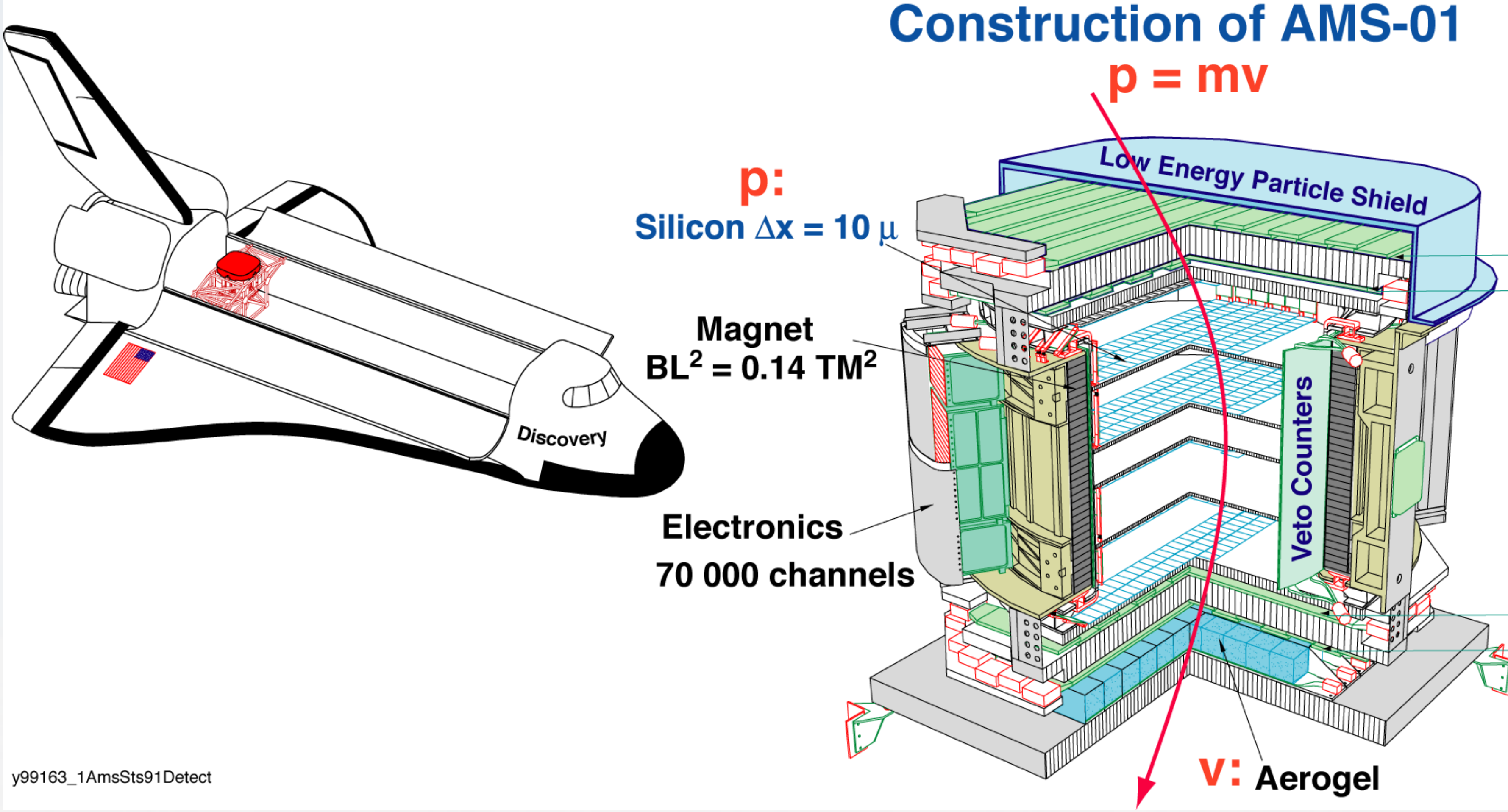


95% of the ~$2.0B to build AMS has come from international partners.

Alpha Magnetic Spectrometer

First flight, STS-91, 2 June 1998 (10 days)

AMS-01

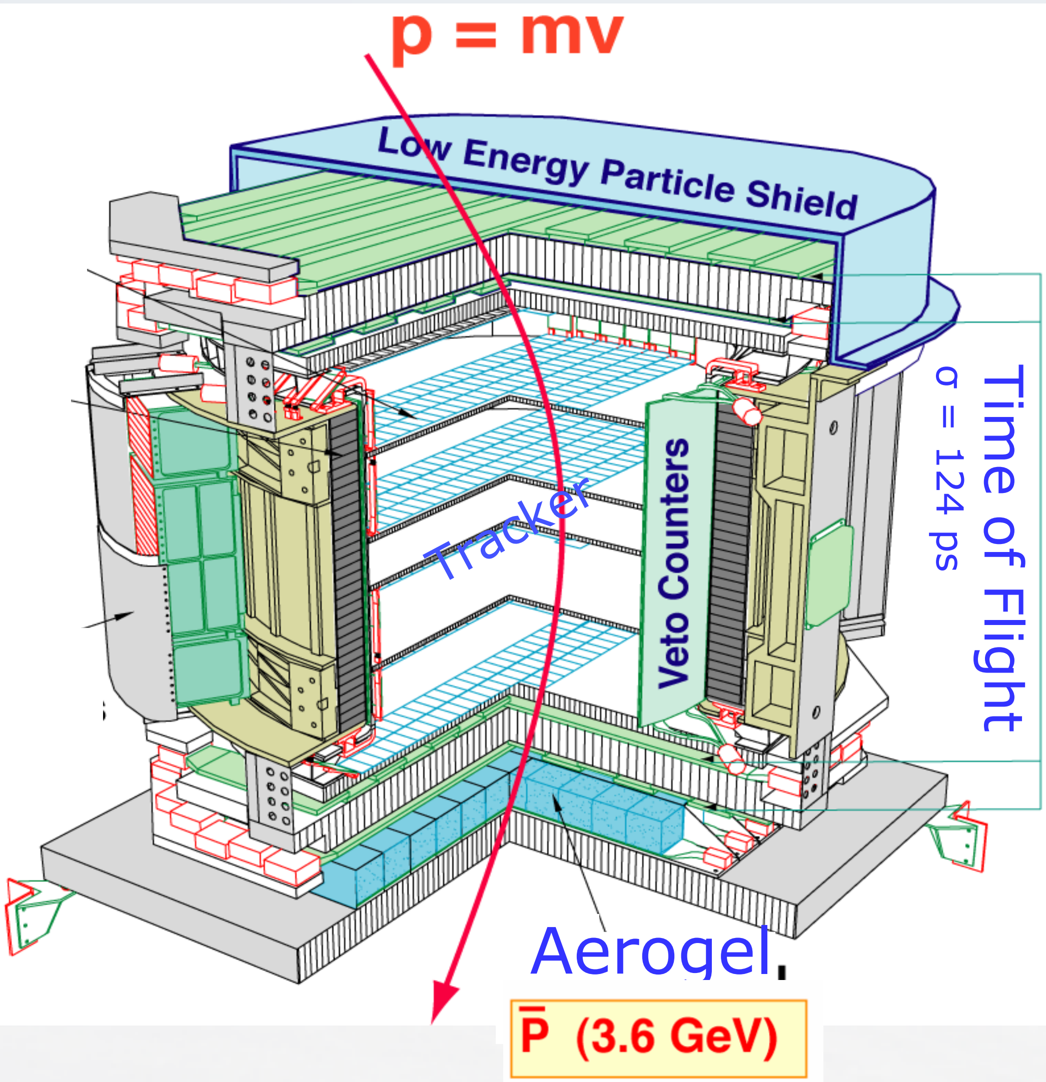


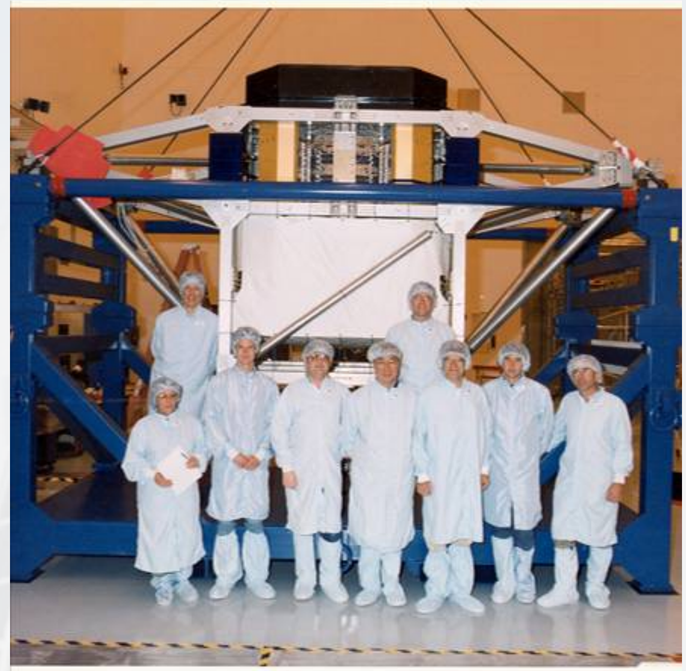
y99163_1AmsSts91Detect

The AMS-01 Detector

Flew 10 days on STS-91 June 1998

6 planes of Silicon Tracker: 3.2 % X_0, 10 μm.
BL^2 = 0.14 Tm^2, $\Delta P/P$ = 7% at 10 GeV





AMS-01 Publication: *Physics Reports 366 (2002) 331-405*

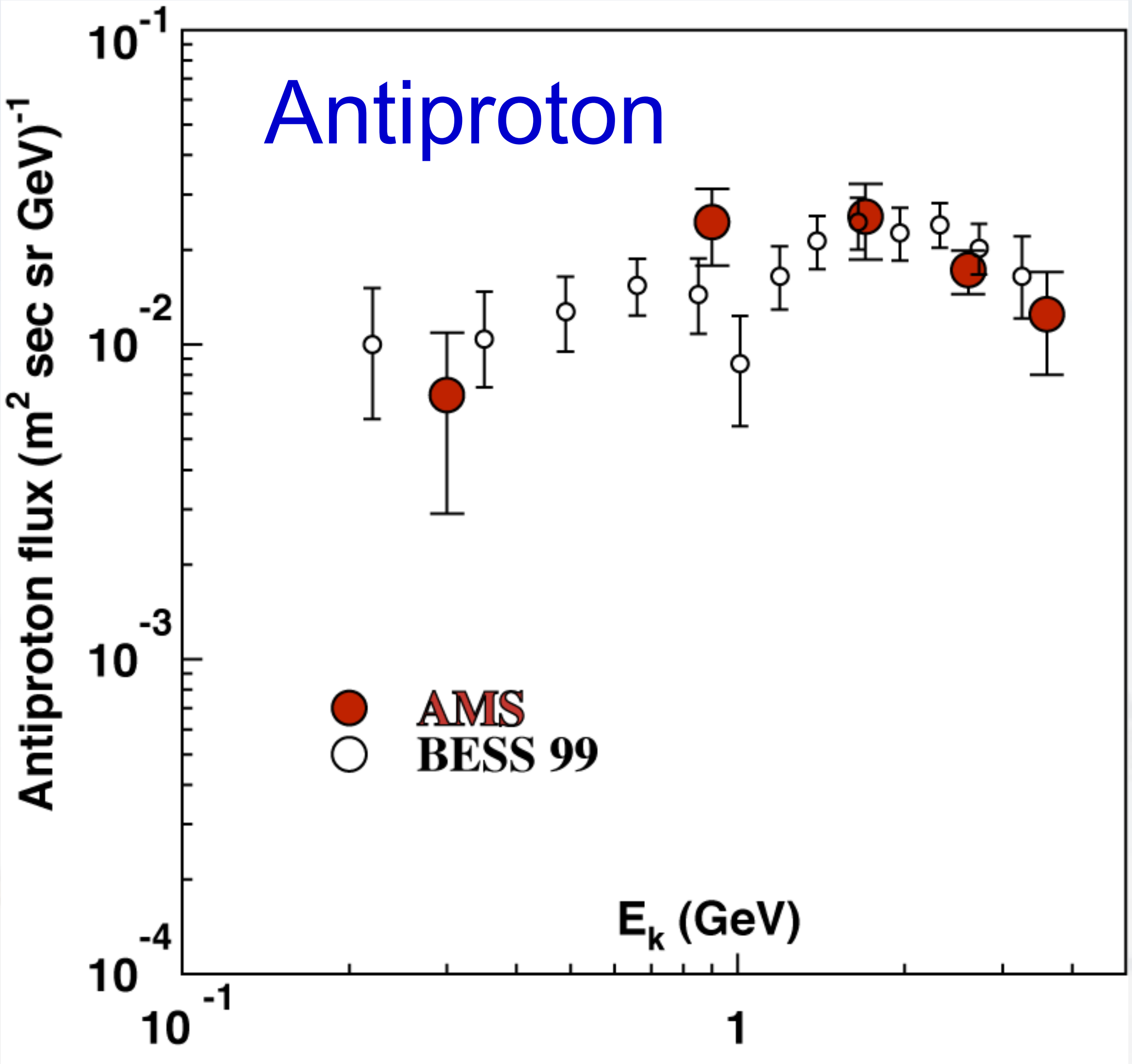
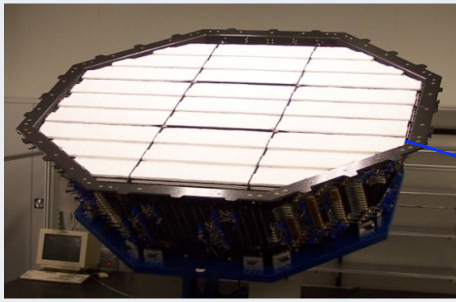


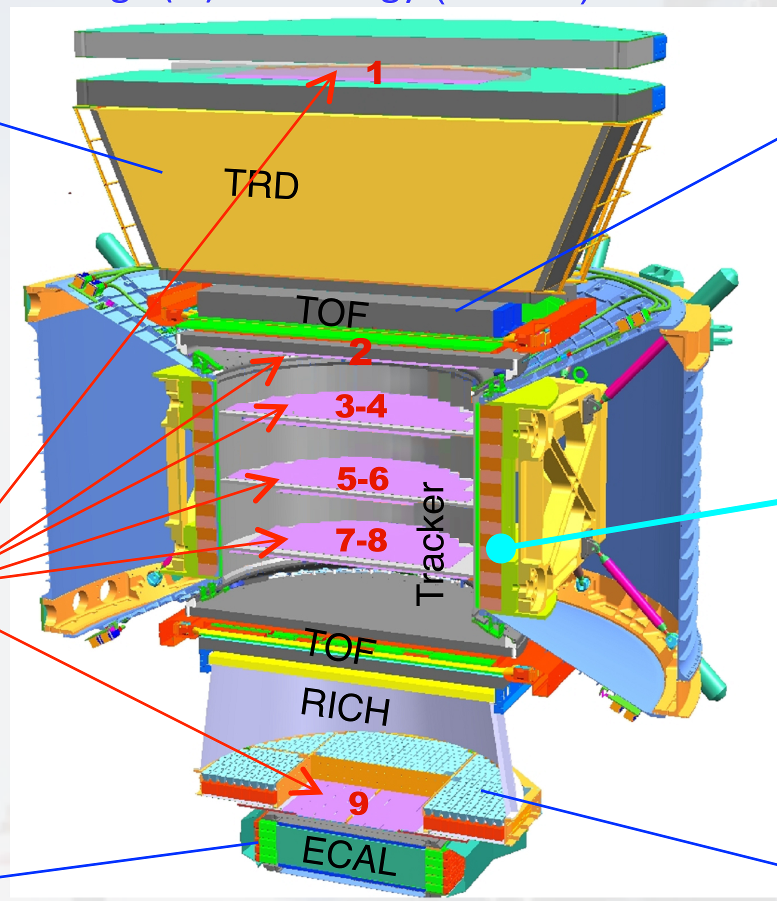
Fig. 4.40. The AMS antiproton flux measurement in comparison with BESS [70] data.

AMS: A TeV precision, multipurpose spectrometer

TRD
Identify e+, e-

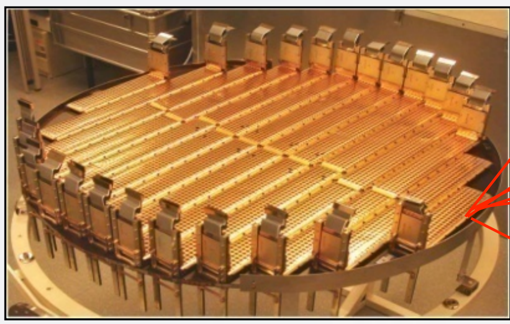


Particles and nuclei are defined by their charge (Z) and energy (E ~ P)

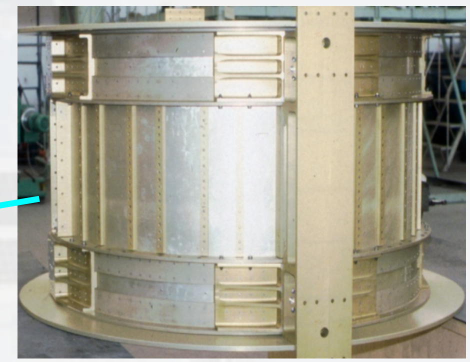


TOF
Z, E

Silicon Tracker
Z, P

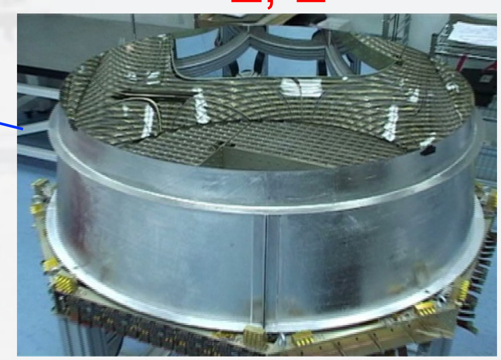


Magnet
±Z



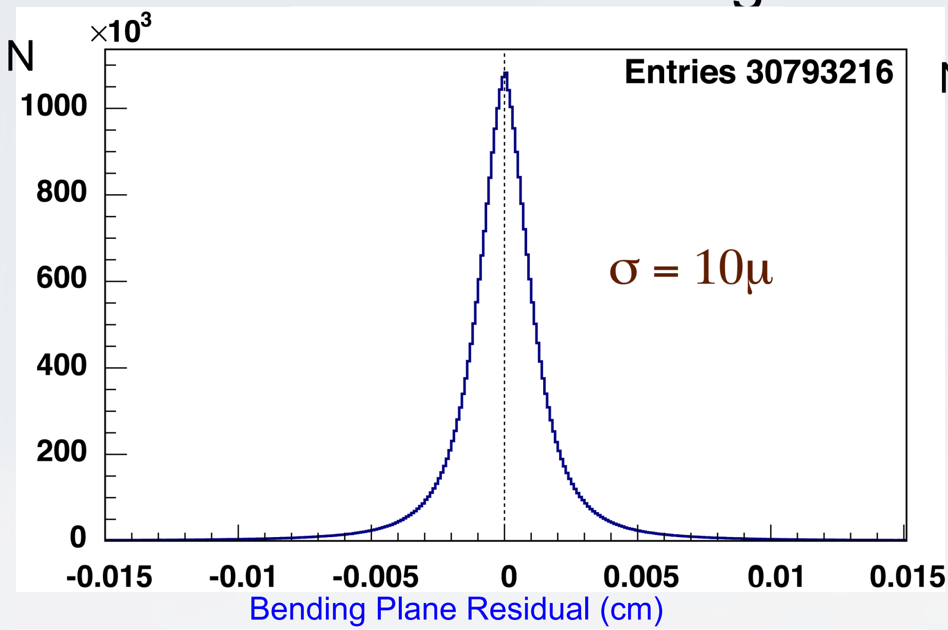
ECAL
E of e+, e-, γ

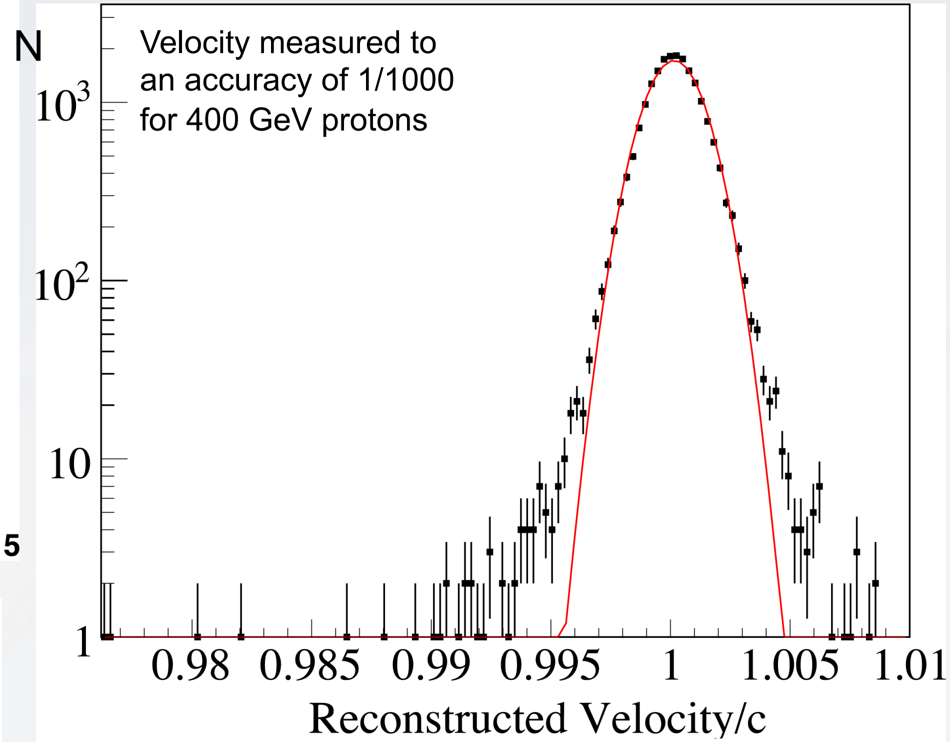
RICH
Z, E

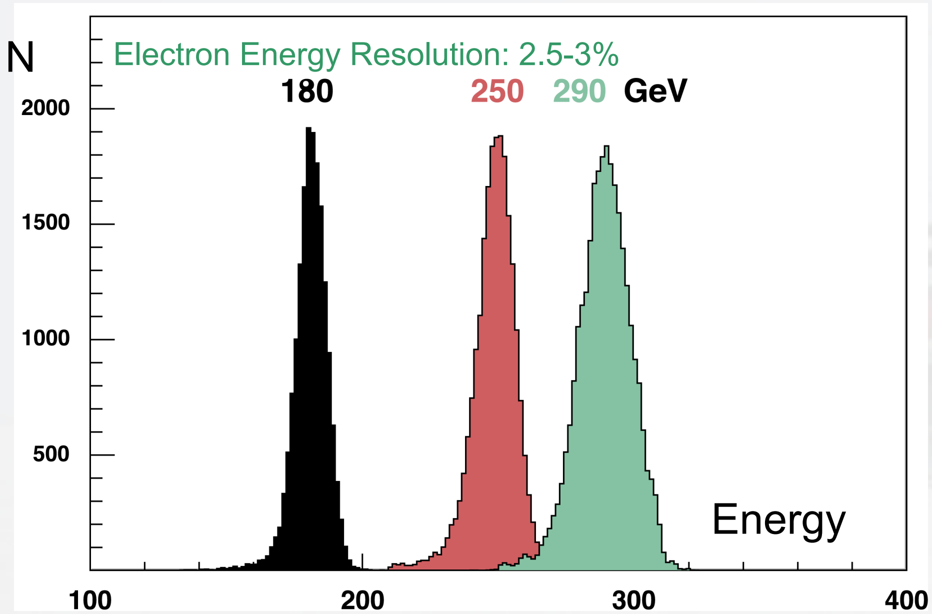


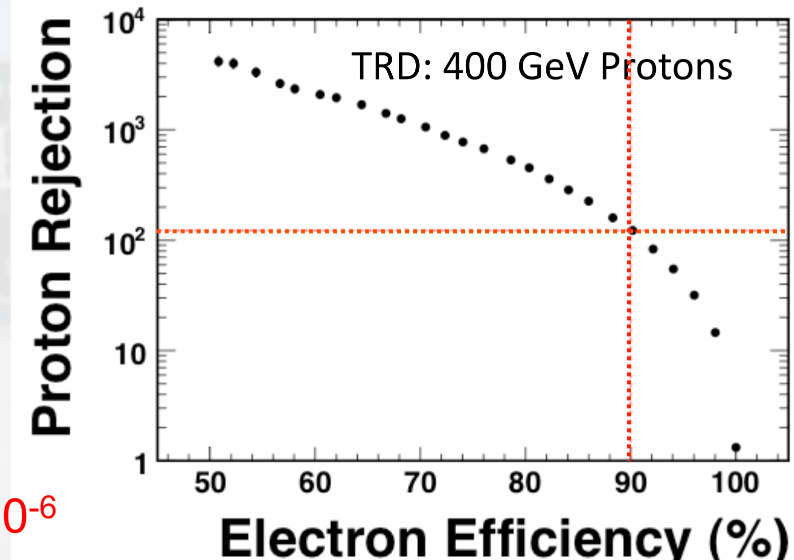
Z, P are measured independently from Tracker, RICH, TOF and ECAL

Test Beam Results of integrated detector









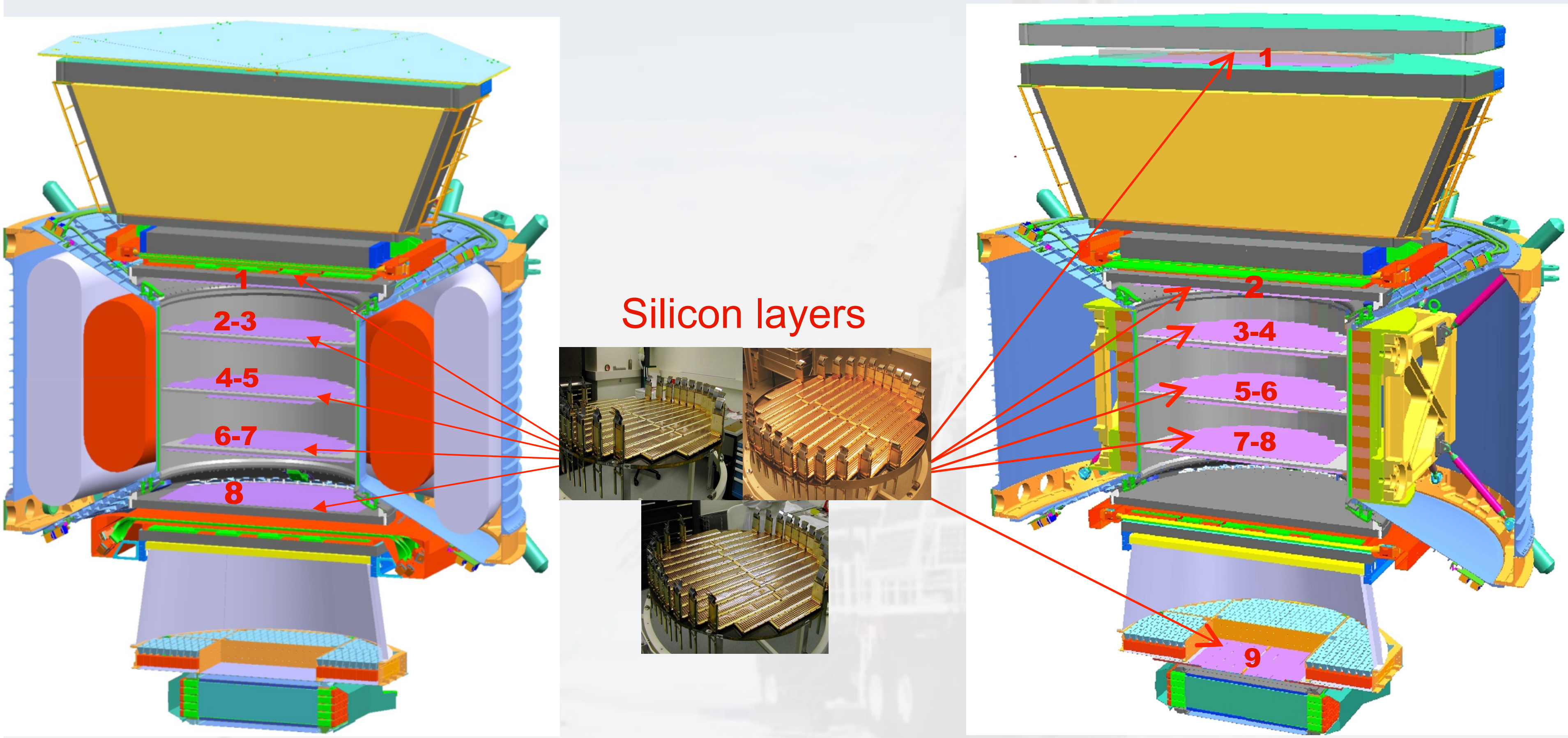
Measured combined rejection power at 400 GeV: $e^{+}/p = 10^{-6}$

AMS-02

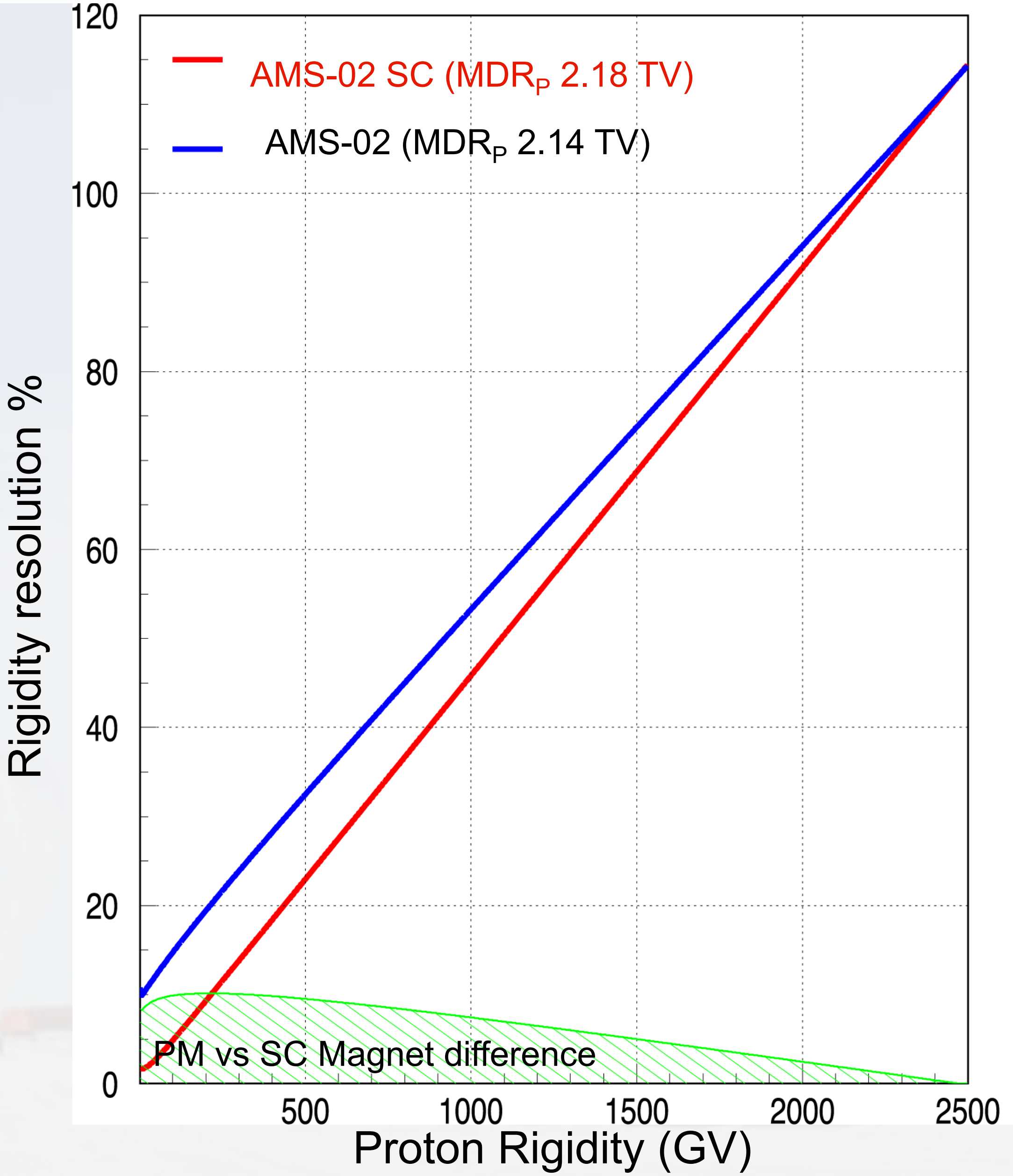
(3 yrs)
with SC Magnet

AMS-02

(10 Yrs to 18 yrs)
with Permanent Magnet
9 layers of Silicon



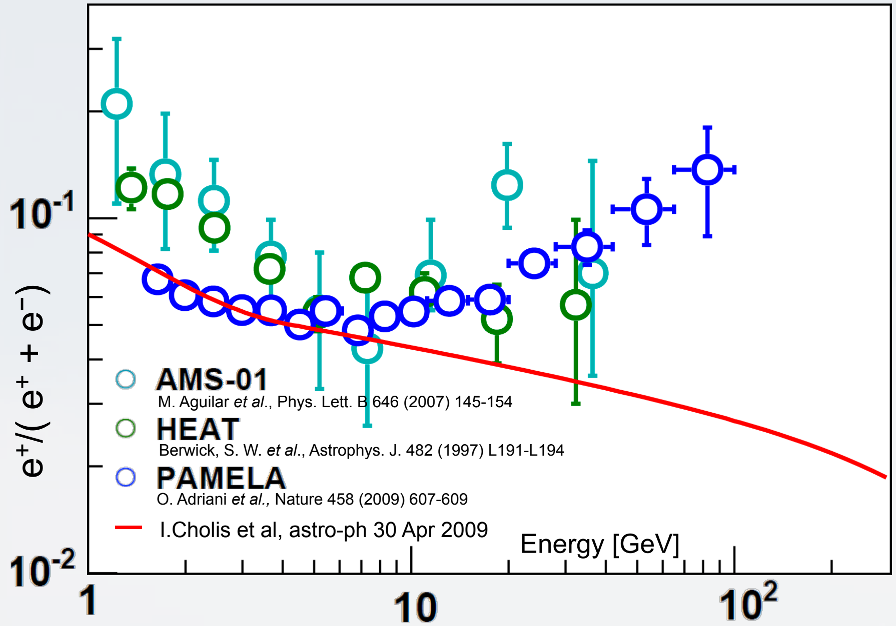
Layers 1 and 9 are far away from the magnet.

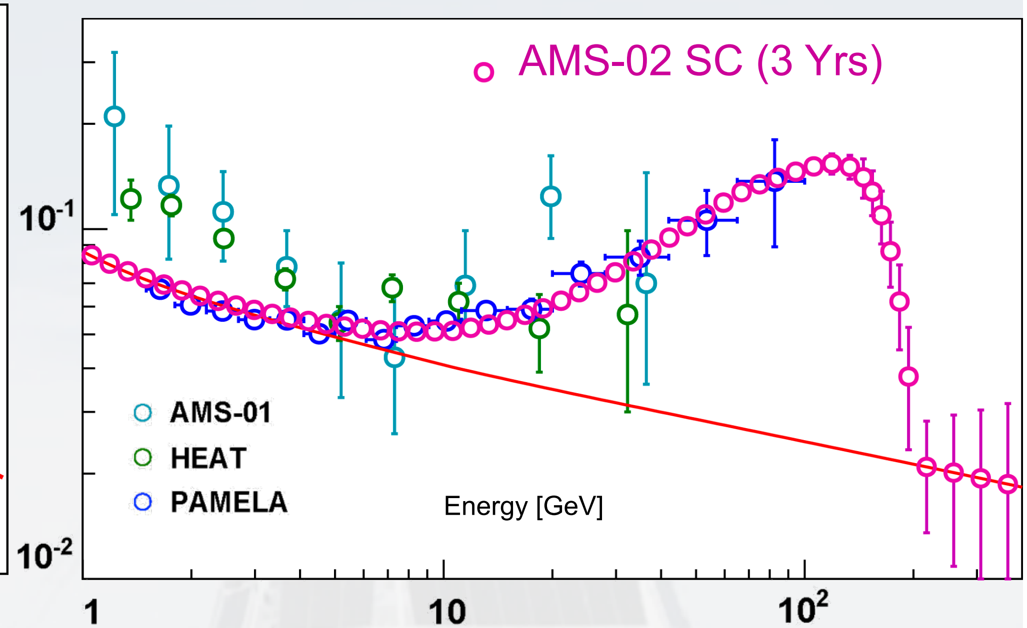


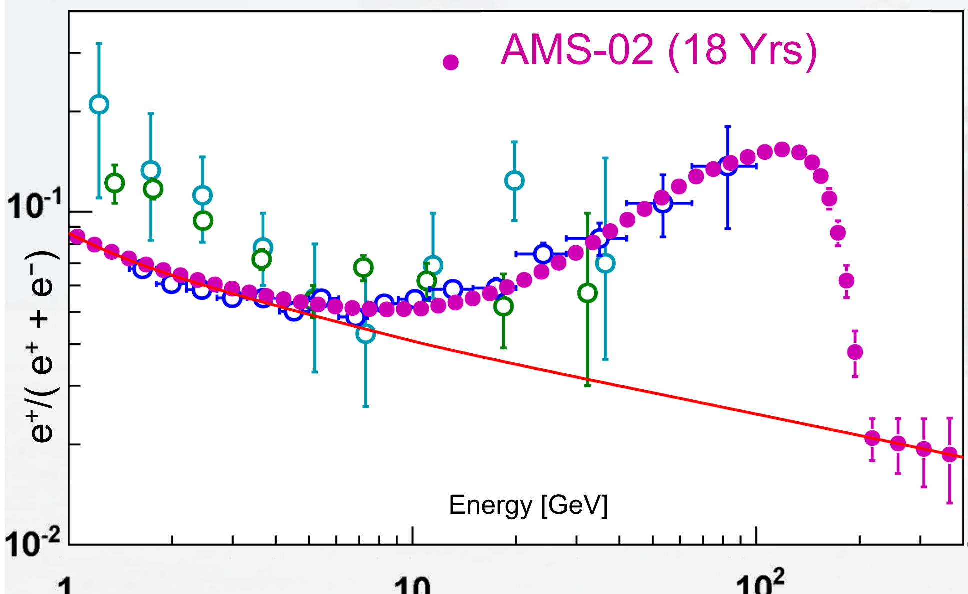
With 9 tracker planes, the resolution of AMS with the permanent magnet is equal (to 10%) to that of the superconducting magnet. For helium, the MDR for the permanent magnet is 3.75 TV.

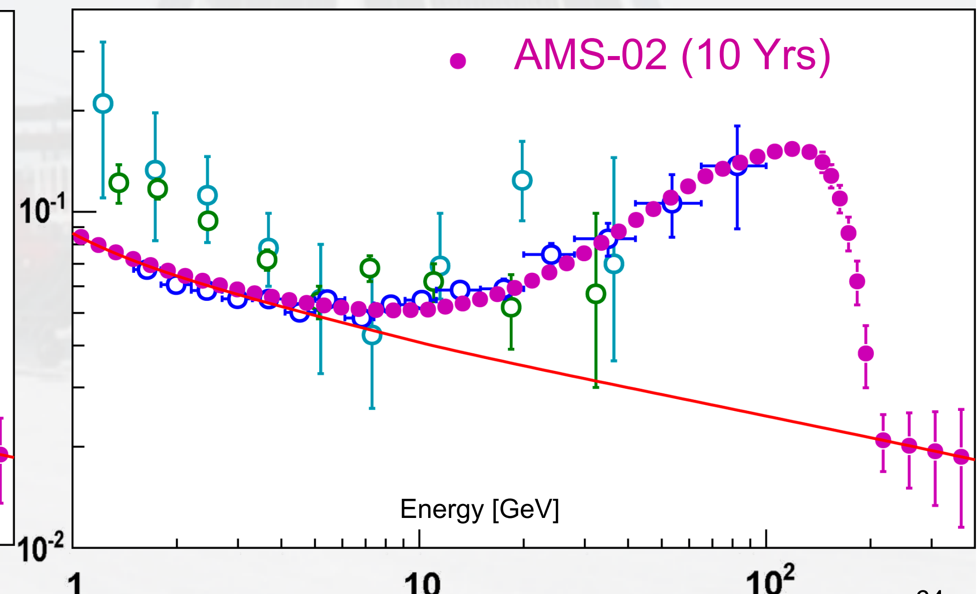
Sensitivity in Dark Matter searches: large acceptance, long duration

$\chi^0 \chi^0 \rightarrow e^+, e^-$ for $m\chi^0$ = 200 GeV   I.Cholis et al, astro-ph 30 Apr 2009







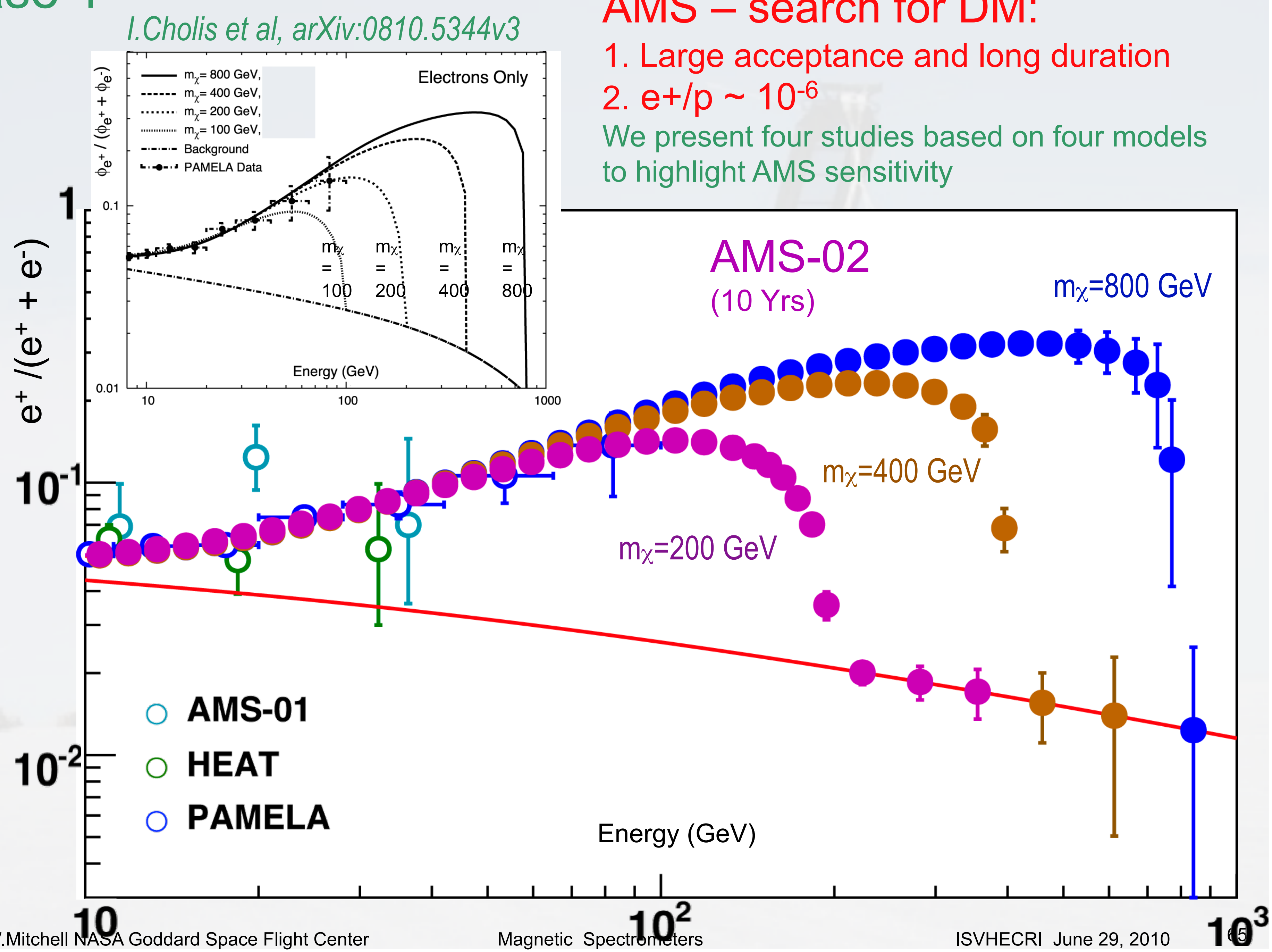


case 1

AMS – search for DM:

1. Large acceptance and long duration
2. e+/p ~ 10^{-6}

We present four studies based on four models to highlight AMS sensitivity

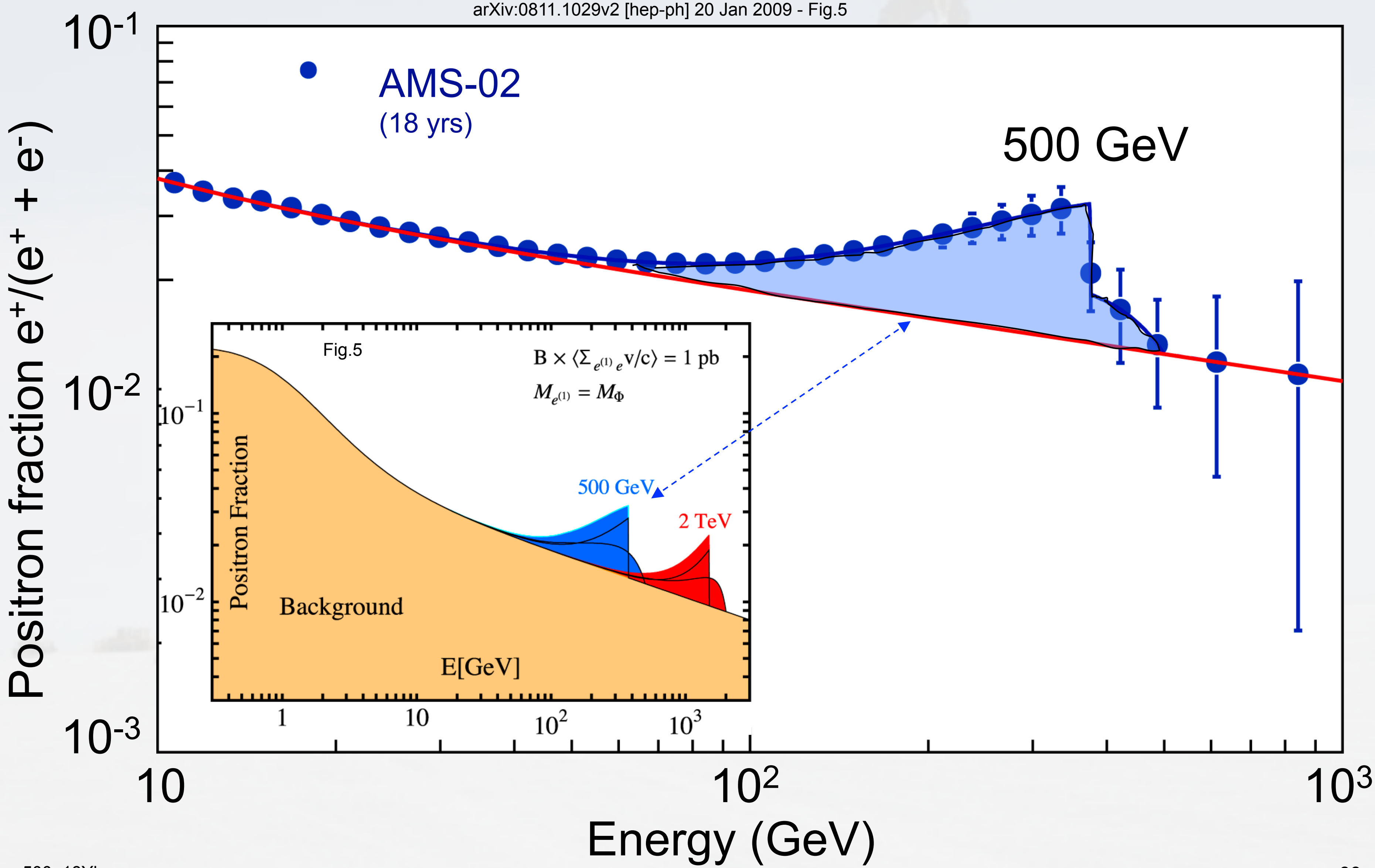


Kaluza-Klein Bosons are also Dark Matter candidates

case 3 TeV Scale Singlet Dark Matter

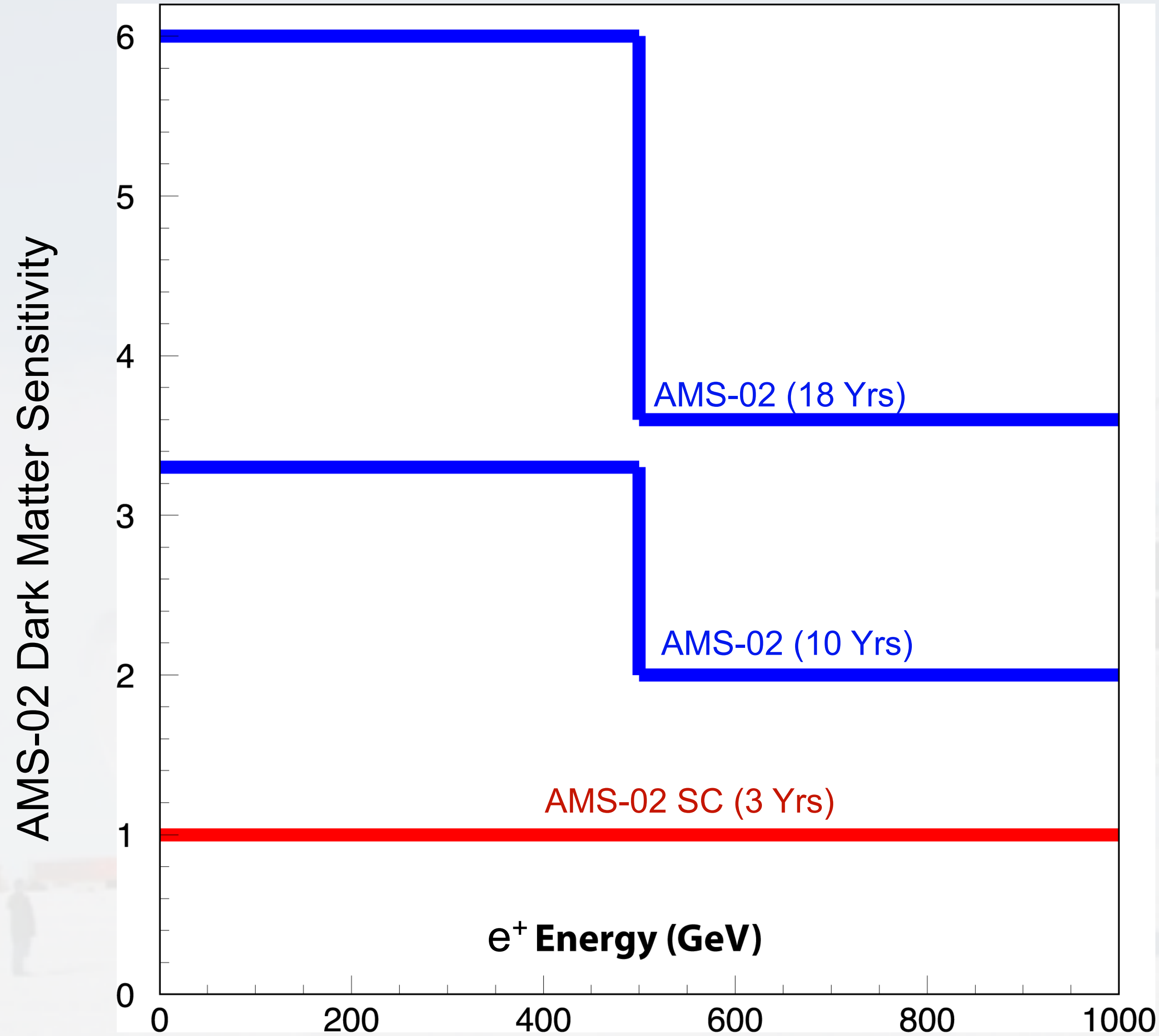
Eduardo Pontón and Lisa Randall

arXiv:0811.1029v2 [hep-ph] 20 Jan 2009 - Fig.5

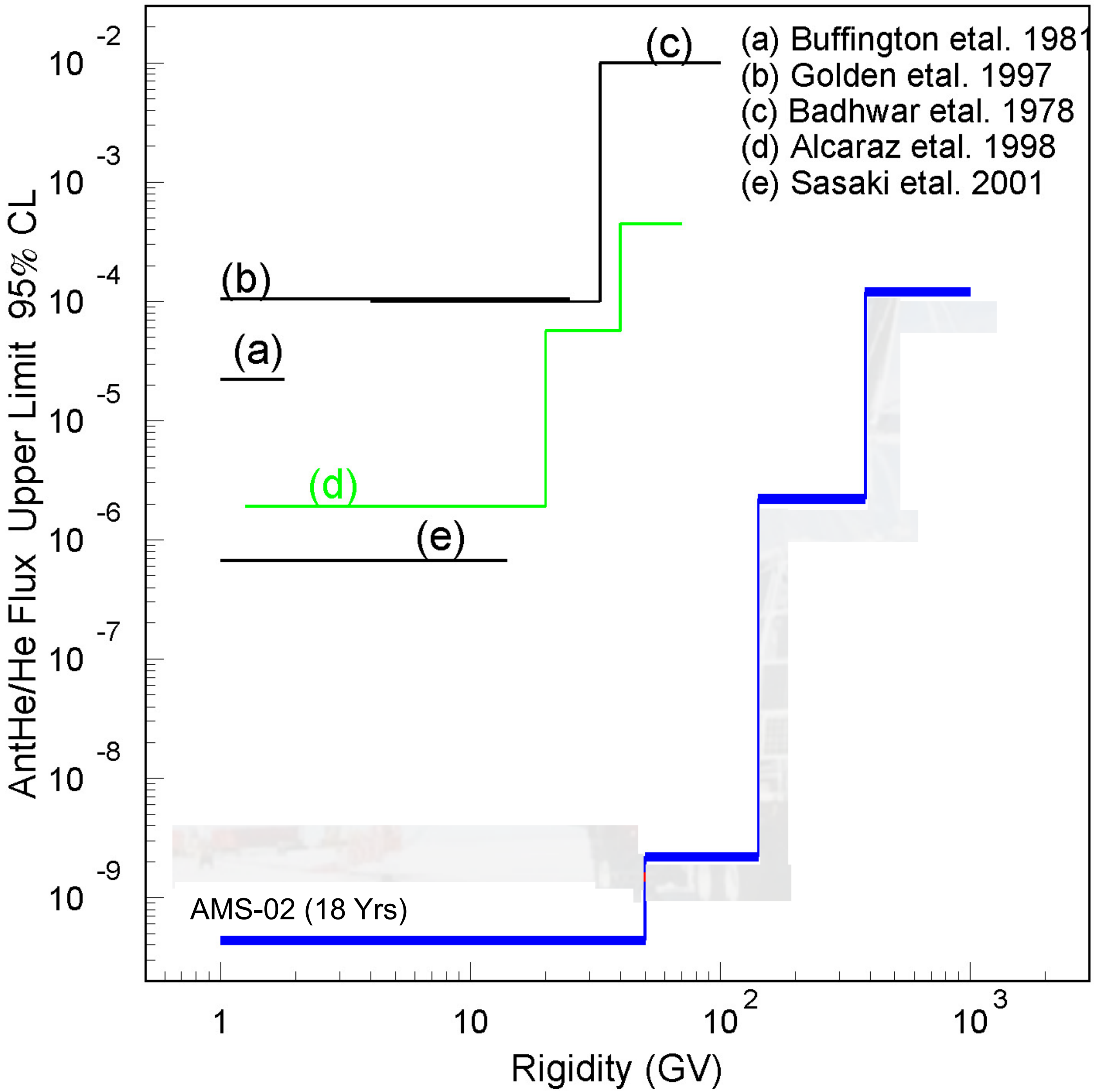


Dark Matter Searches

normalized to the sensitivity of AMS with superconducting magnet on ISS for 3 years



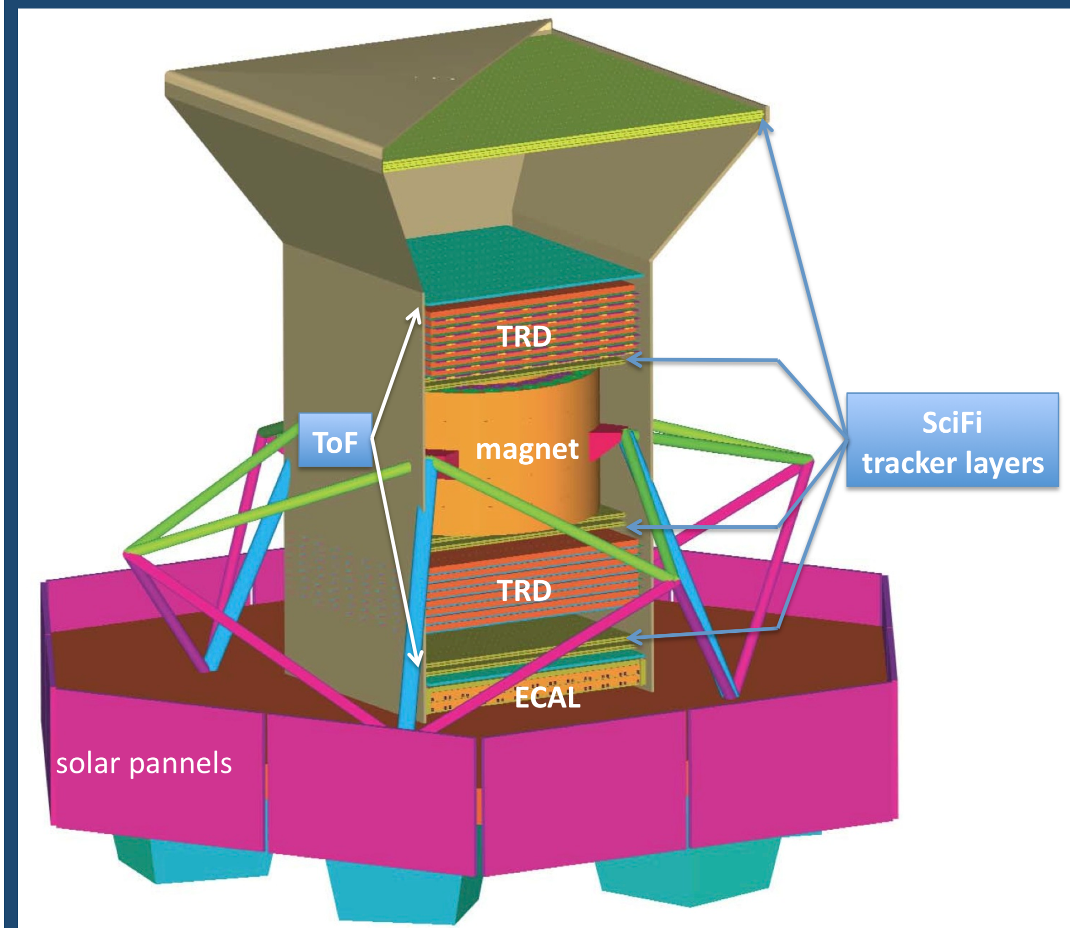
As seen, the permanent magnet upgrade of AMS has a 600-200% improvement in sensitivity in the search for Dark Matter.

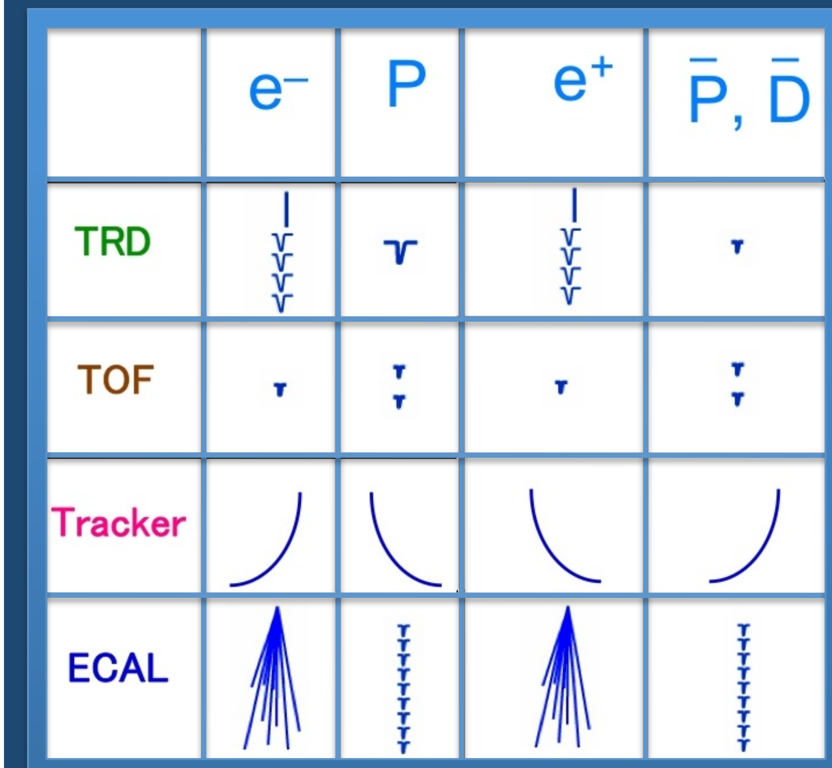

(a) Buffington etal. 1981
(b) Golden etal. 1997
(c) Badhwar etal. 1978
(d) Alcaraz etal. 1998
(e) Sasaki etal. 2001
(a)
(b)
(c)
(d)
(e)
AMS-02 (18 Yrs)
AntHe/He Flux Upper Limit 95% CL
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
1
10
10^{2}
10^{3}
Rigidity (GV)

PEBS
(Positron Electron Balloon Spectrometer)

Ohio State University, ETH Zurich, EPF Lausanne, Switzerland, RWTH Aachen, Germany, University of Chicago

The overall height, including the lower crush pads, is 2.7 m and the overall width is 3.3 m. The total weight of the instrument is 2000 kg.

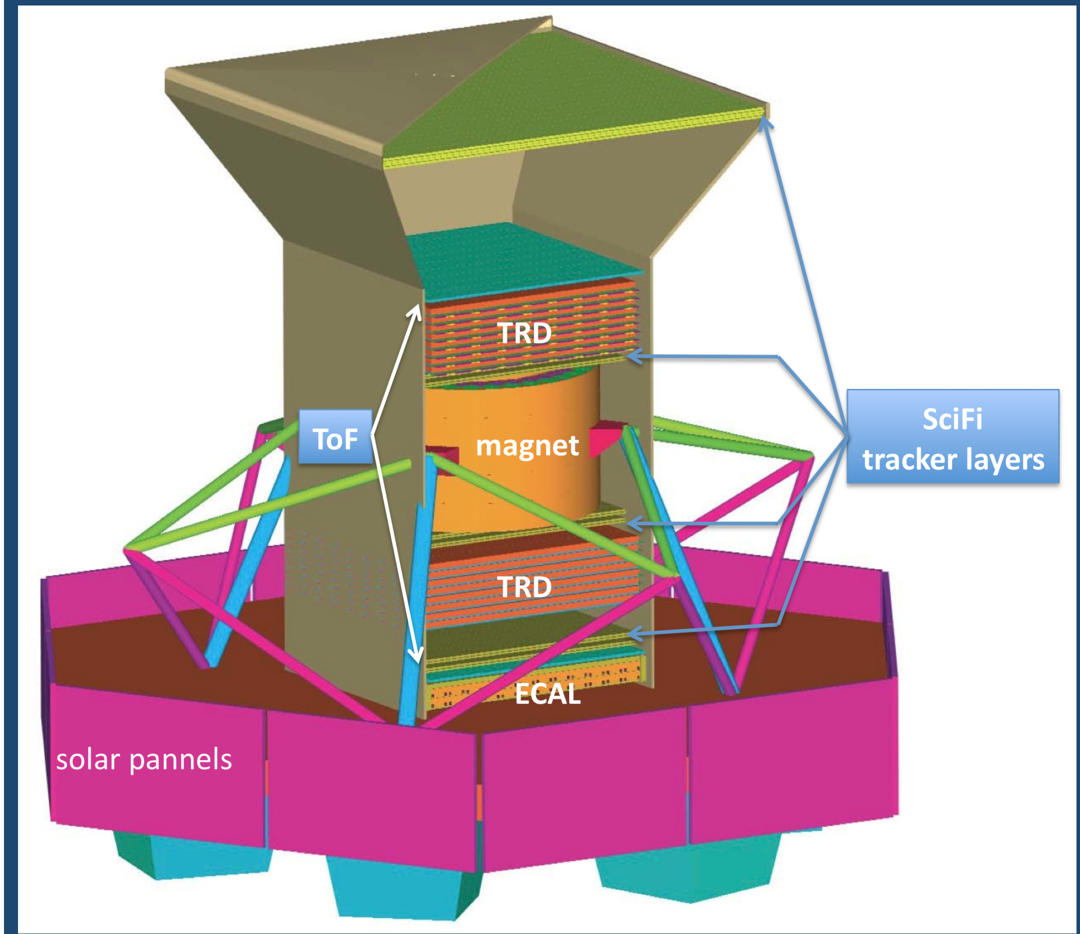




$$\frac{\sigma_p}{p} = 0.0010 \cdot p \oplus 0.038$$

PEBS Experiment

2014



The magnetic spectrometer has a geometrical acceptance of 1300 cm^2 sr for electrons.

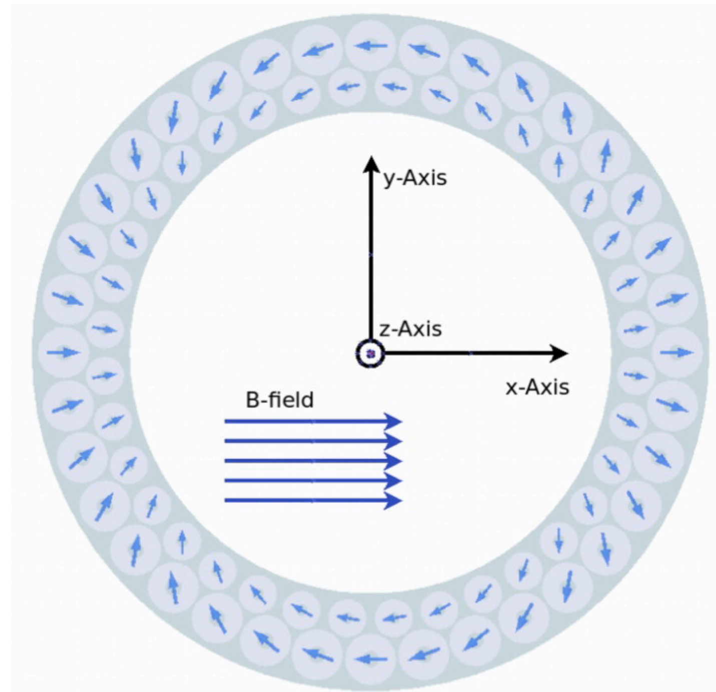
The most important contributions to the overall weight are the magnet weight and the weight of the calorimeter with 890 kg and 650 kg, respectively.

The power consumption is dominated by the 250 W needed for the tracker which has roughly 60,000 individual readout channels.

The lower detector combination of TRD and ECAL, which is used for the measurement of the combined electron positron spectrum at high energies, has an acceptance of 6000 cm^2 sr.

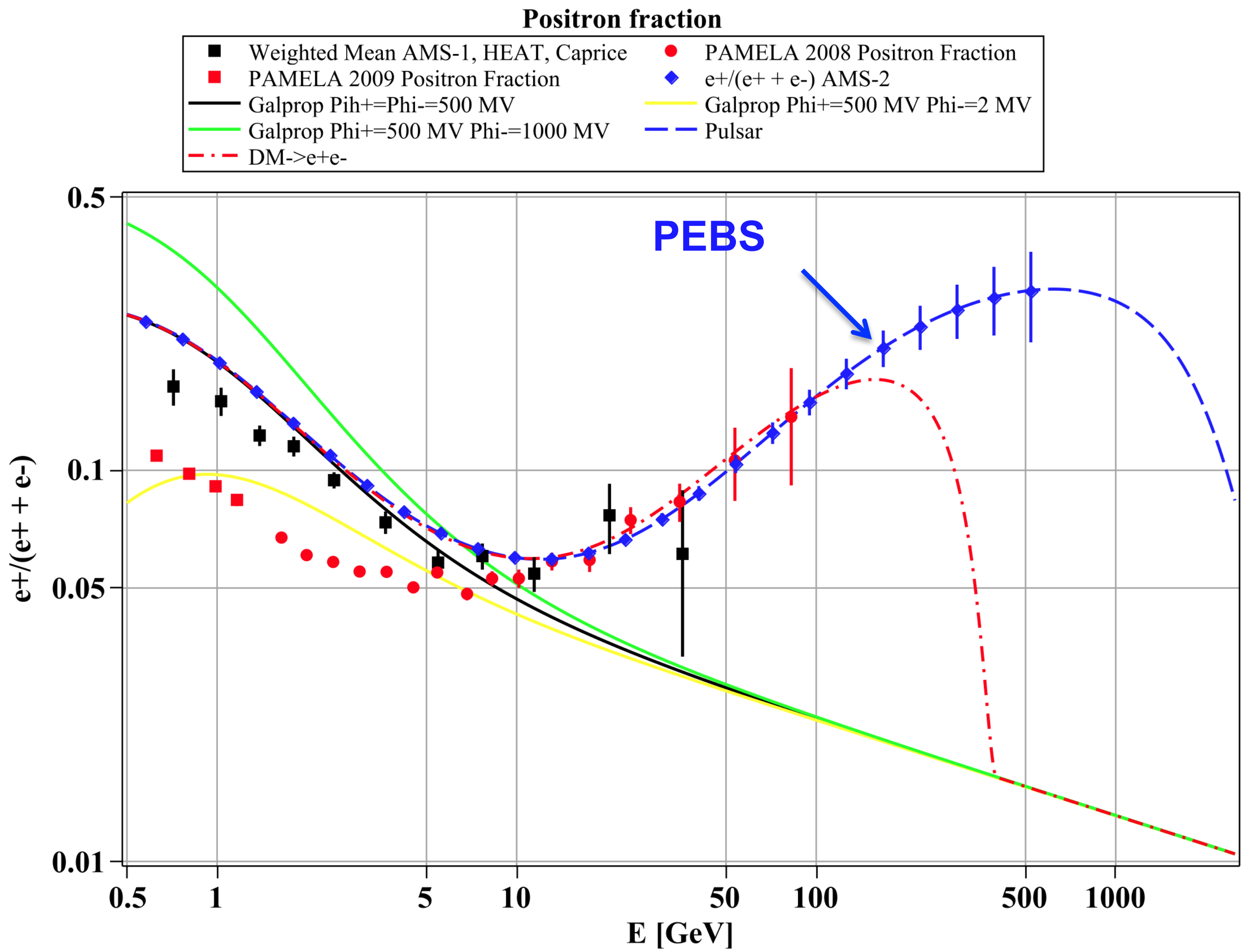
PEBS Permanent Magnet

Final polishing of the PERDAIX permanent magnet which is constructed in the same way as the PEBS magnet. An aluminum matrix is used to supports the 72 NdFeB cylinders form the permanent magnet.

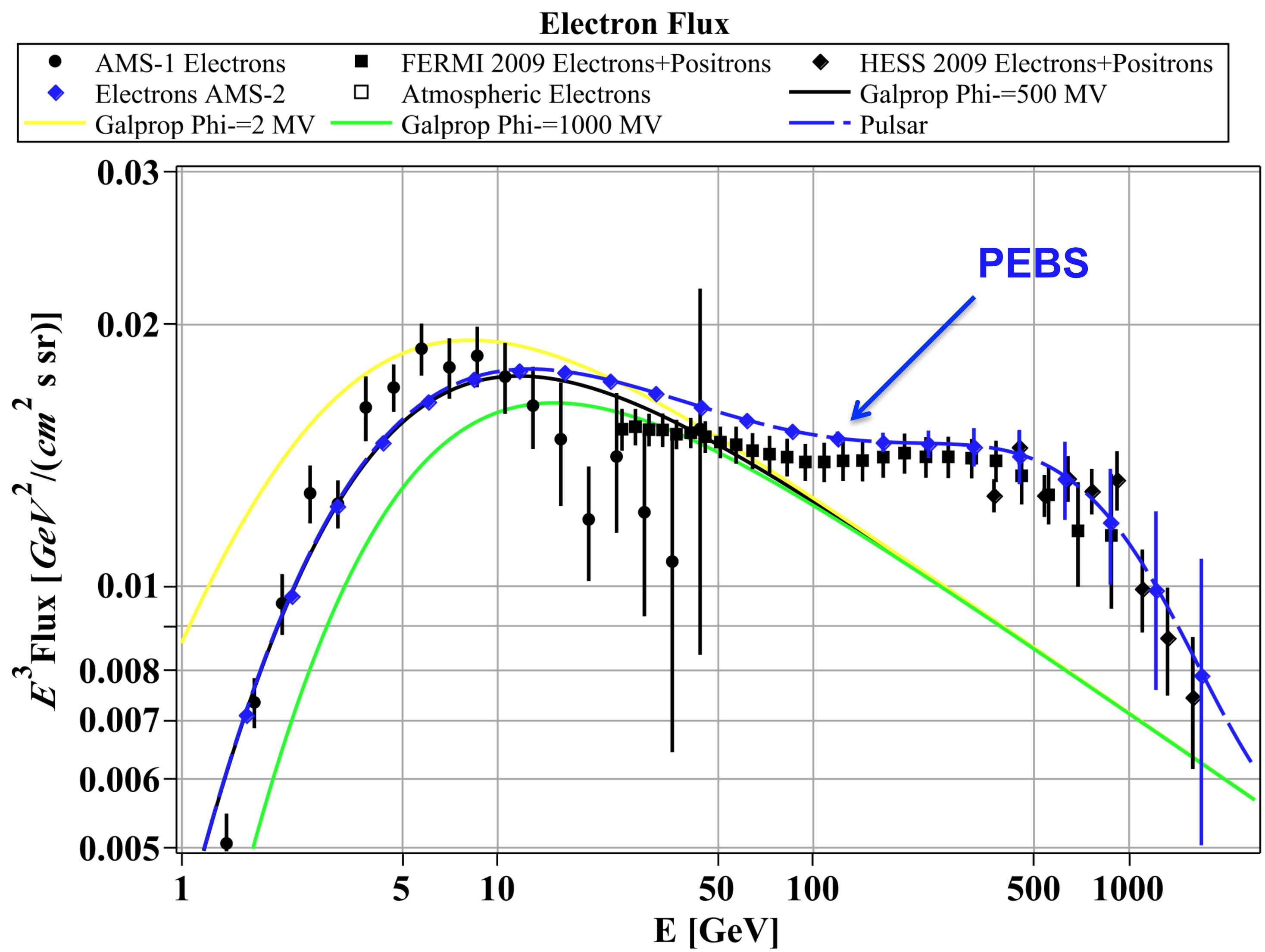


Weight 892 kg, B-Field 0.34 Tesla,

rInner=0.32 m, rOuter = 0.44 m,
Height = 50.0 cm



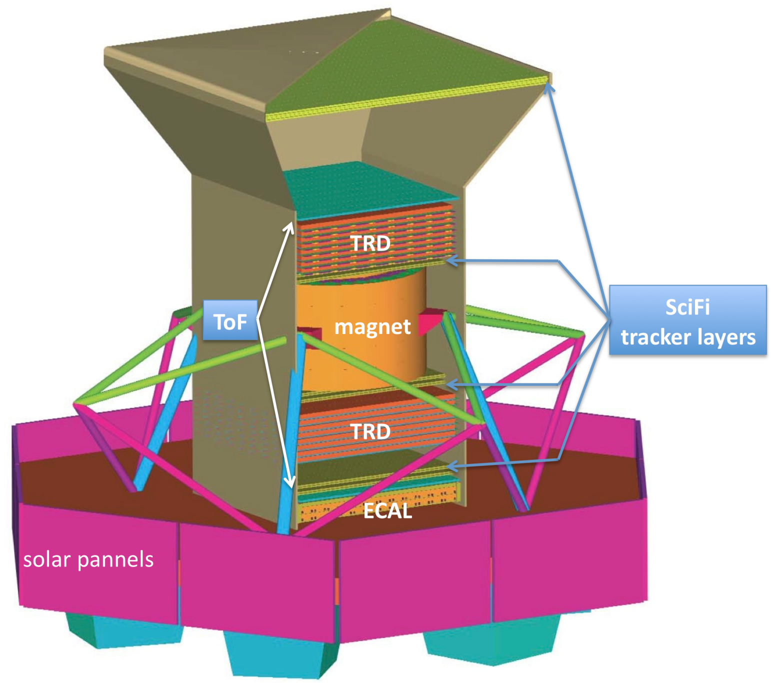
The expected statistics from a single 20 day flight of PEBS shown as blue circles assumed to conform to Galprop model plus a nearby pulsar (blue dashed line) or dark matter annihilation (red dashed line) as an additional electron and positron source.

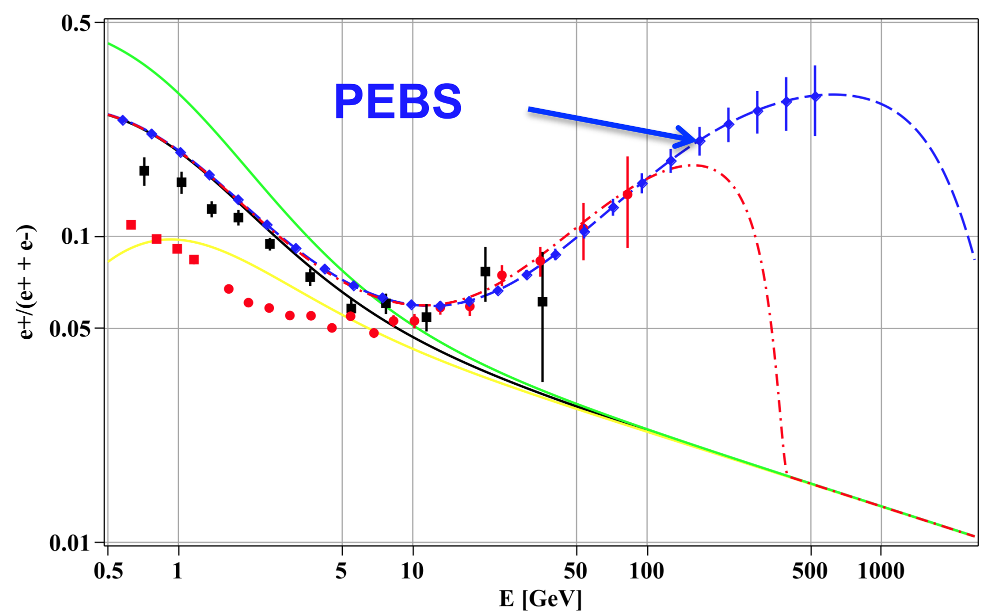


The expected statistics for the combined electron+positron spectrum from a single 20 day flight of PEBS shown as blue circles assumed to conform to Galprop model plus a nearby pulsar (blue line) as an additional electron and positron source.

PEBS Summary

- A dedicated balloon experiment could provide a competitive measurement of the cosmic ray electron & positron flux.
- The spectrometer is based on a scintillating fiber tracker with SiPM readout in a permanent magnet.
- The proton rejection of ~10^6 can be achieved by a combination of ToF, TRD, ECAL and Tracker.
- Key parameters:
  Acceptance: ~1300 cm^2 sr
  Weight: ~2000 kg
  Power: ~900 Watt
- R&D Phase:
  2006 – 2010, first test flight of a small prototype (PERDAIX) in October 2010
- Construction Phase: 2010 - 2013
- First PEBS Flight: 2014





Summary

- Magnetic-rigidity spectrometer techniques have been applied with great success to positron, antiproton, and isotope measurements as well as to the search for cosmic antimatter.
- The current generation of instruments, BESS-Polar II and PAMELA, have achieved exceptional sensitivity.
- The upcoming flight of AMS-02 will greatly improve statistical sensitivity in the measurement of positrons and antiprotons and in the search for cosmic antihelium and heavier antinuclei.
- Future magnetic-spectrometer balloon experiments include PEBS and future flights of BESS-Polar. PEBS will measure positrons and antiprotons. BESS-Polar will be configured to measure positrons and antiprotons or light isotopes.