Dark Matter Searches with AMS-02

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on behalf of AMS collaboration

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The Alpha Magnetic Spectrometer Experiment

AMS01: Precursor flight on space shuttle Discovery (June 1998) of detector prototype (Phys. Rept. Vol 366/6 (2002) 331)

AMS02: large acceptance (0.45 m^2 sr) cosmic-ray spectrometer to be installed on ISS (end of 2008) for three years data taking

- ✓ Spectrum and composition of charged cosmic rays and γ rays in the GeV to TeV range
- ✓ Antimatter/matter ratio
- ✓ Indirect search for dark matter

The AMS02 detector

Transition Radiation Detector (TRD):
Foam + Straw Drift Tubes (Xe/CO_2)
e/p separation, rejection power > 100 up to 300 GeV

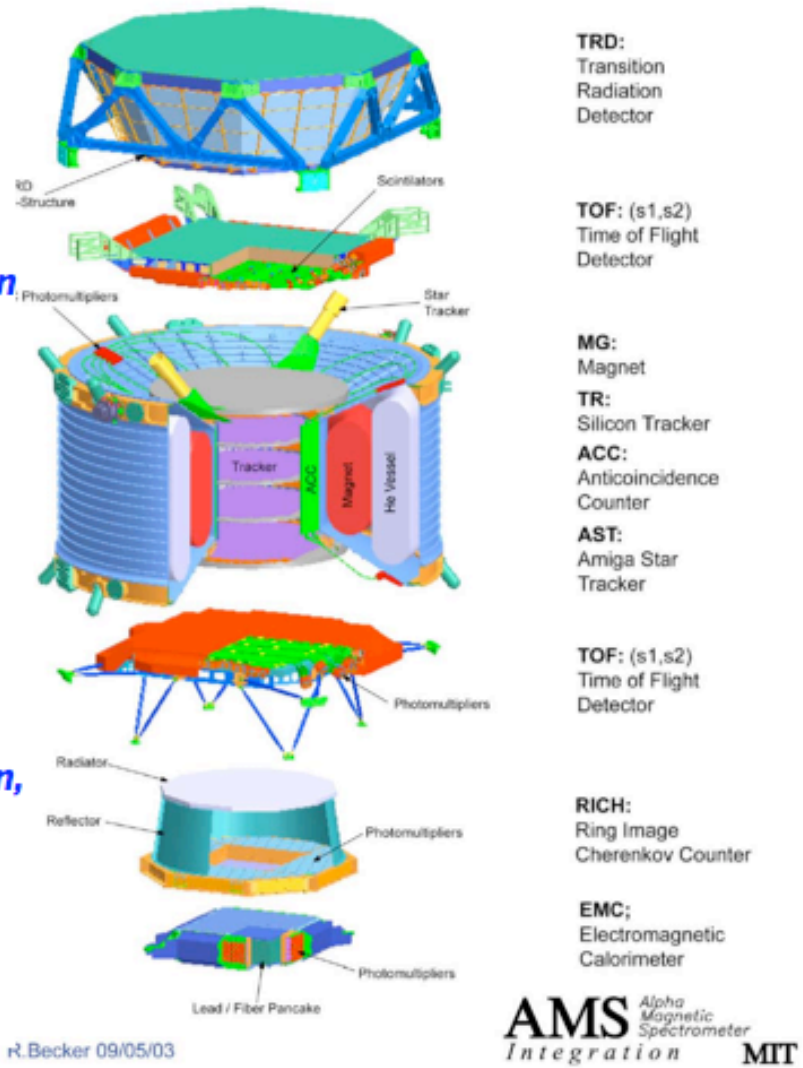
Time of Flight (TOF):
scintillators, Δt =~160ps
Main trigger, charge separation, β with few % precision

Superconducting Magnet :
BL^2 = 0.85 Tm^2

Tracker (8 layers) :
double sided silicon microstrip detector
<2% resolution below 10 GV, rigidity up to 2-3 TV, charge separation

RICH :
Radiator (Aerogel, NaF)
β measurement with 0.1% precision, charge separation, isotope separation (2% precision on mass below 10 GeV/n)

Electromagnetic Calorimeter (ECAL):
Lead+scint. Fibers
$e^{\pm}$,γ, detection, standalone trigger
<3% en. res. above 10 GeV, e/p separation >1000



New Physics Models providing Dark Matter candidates (WIMPs) accessible to AMS

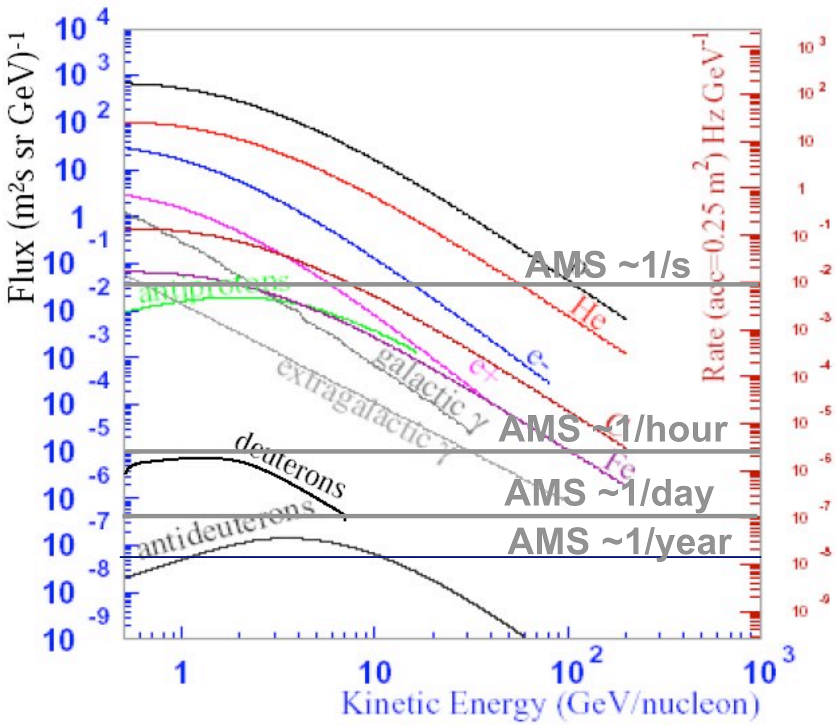
- Supersymmetric models:
  - mSUGRA
  - AMSB

  ⇒ Lightest SUSY Particle: Neutralino (χ)

- Extra-dimension models:

  ⇒ Lightest Kaluza-Klein Particle: first level of KK modes of Hypercharge gauge boson $B^{(1)}$

AMS02 fluxes



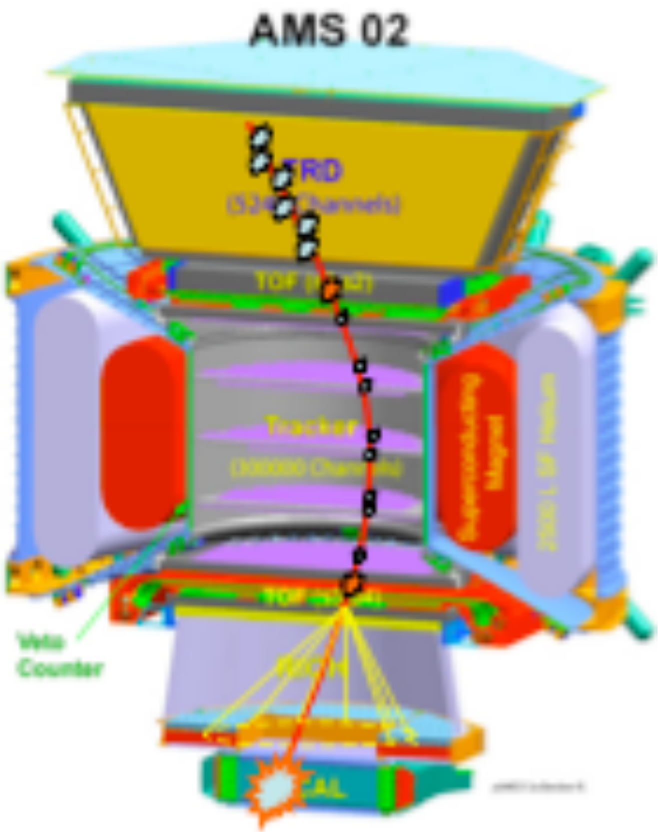
Particle	Energy range
p	0.1 up to several TeV
$\bar{p}$	0.5-300 GeV
e^-	0.1 up to O(TeV)
e^+	0.1-300 GeV
He	1 up to several TeV
anti – He…C	1 up to O(TeV)
Light Isotopes	1-10 GeV/nucleon
γ	1-1000 GeV

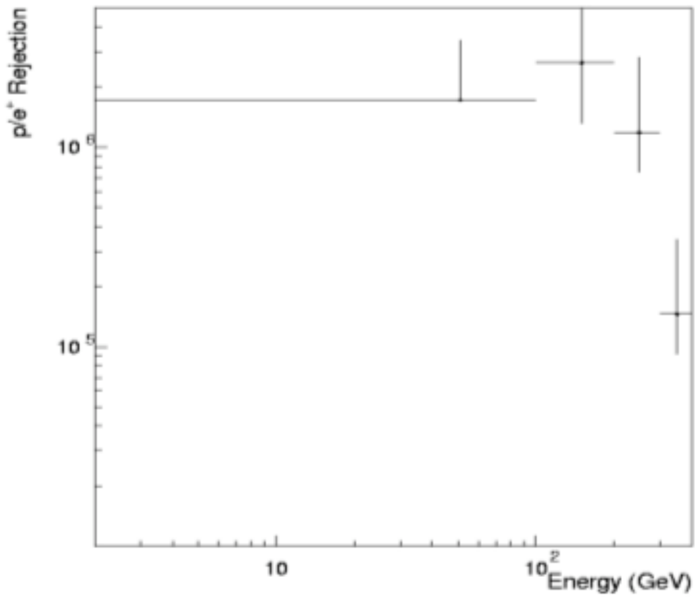
Antiprotons, positrons, and γ rays are optimal channels for the indirect detection of dark matter as they may originate from WIMPs annihilation processes, while standard CR background is low

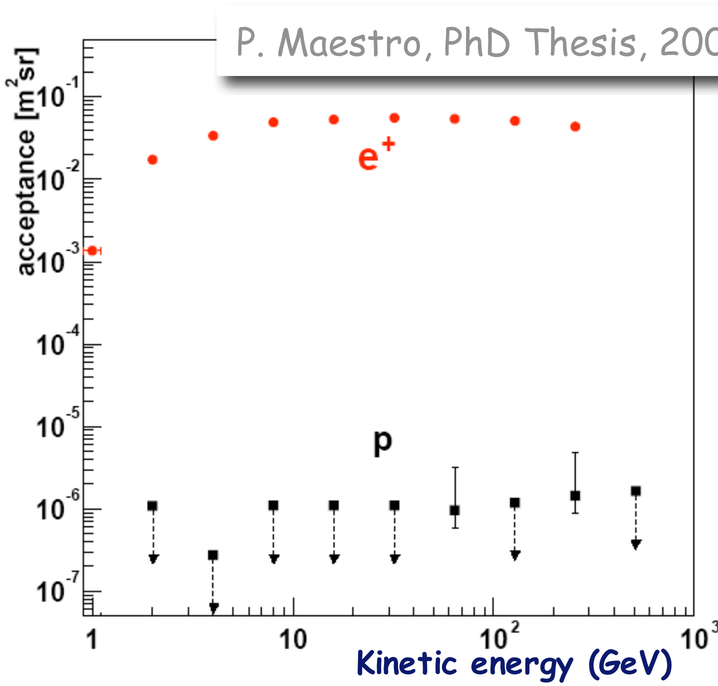
Positron detection: expected performance

- Overall proton rejection of $\sim 10^5$:
  ECAL e/p selection with shower shape and large Xray activity in TRD

- Acceptance $\sim 4.5 \cdot 10^{-2}\ m^2 \cdot sr$





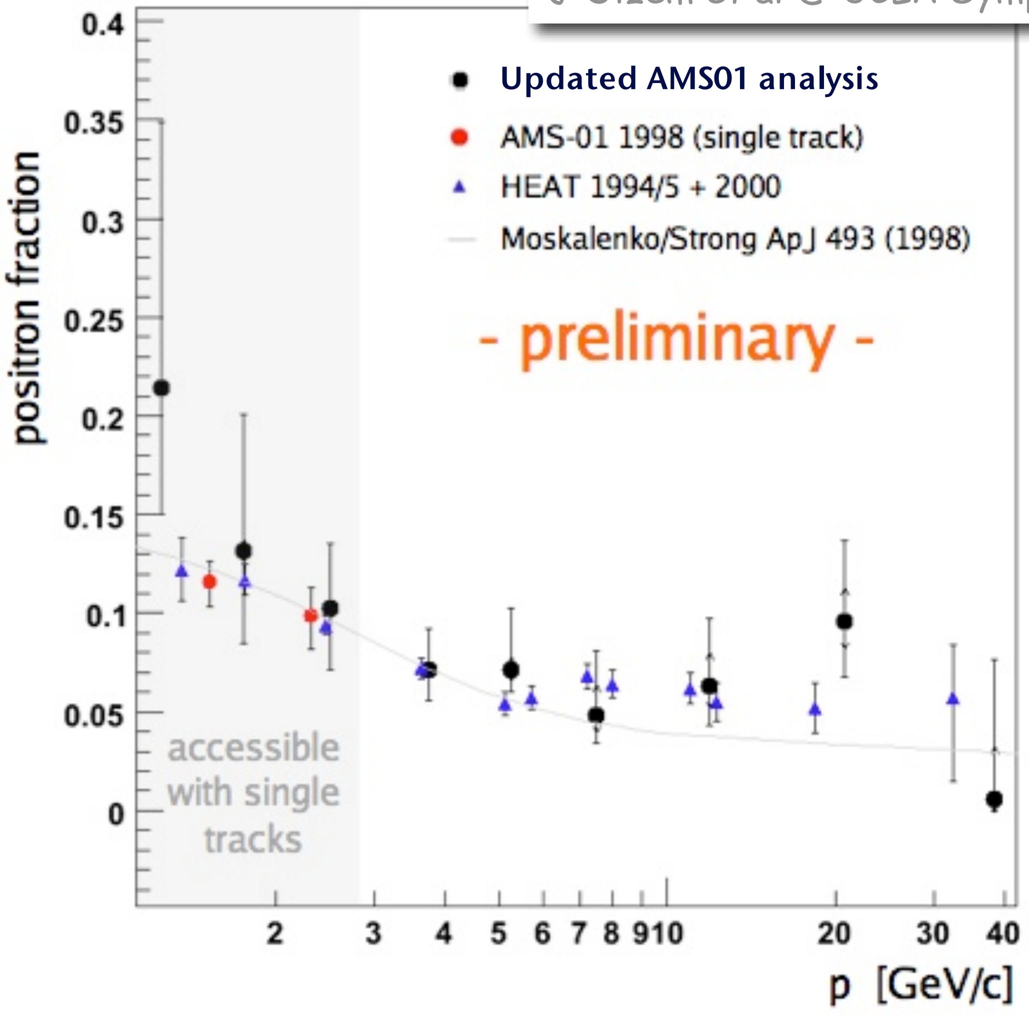


Current Positron flux measurement

•The relative fluxes of electrons and positrons are very uncertain at energies above 10 GeV.

•An excess of positron fraction is claimed by the HEAT balloon experiment, maybe hinting to WIMPs?

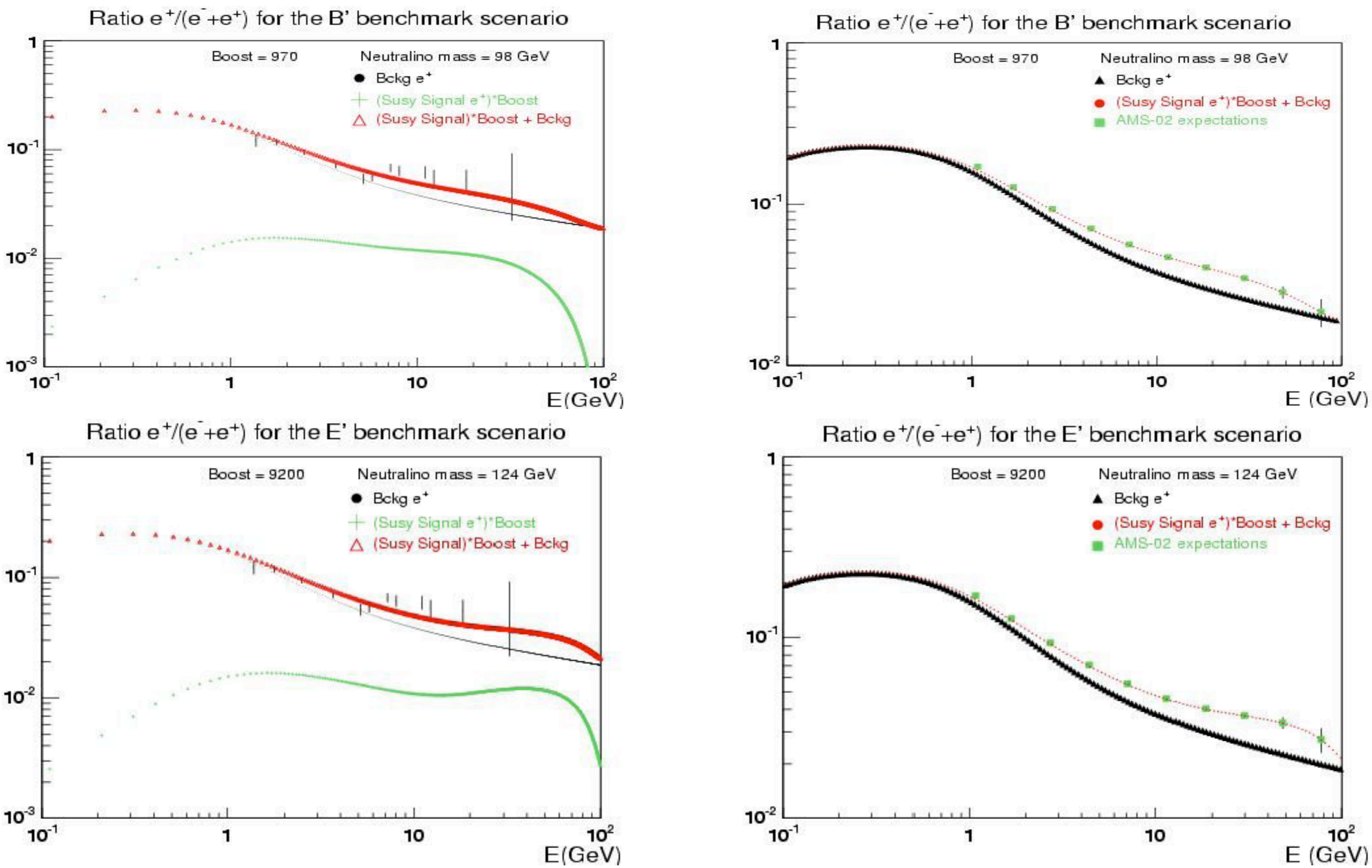
J Olzem et al @ UCLA Symposium 2006



SUSY DM Searches in the positron channel

- B'(bulk) and E'(focus point, $\chi\chi \rightarrow W^+W^-$ dominated) benchmark mSUGRA scenarios (Battaglia et al. hep-ph/0306219)

- Boost factors tuned in order to match HEAT excess



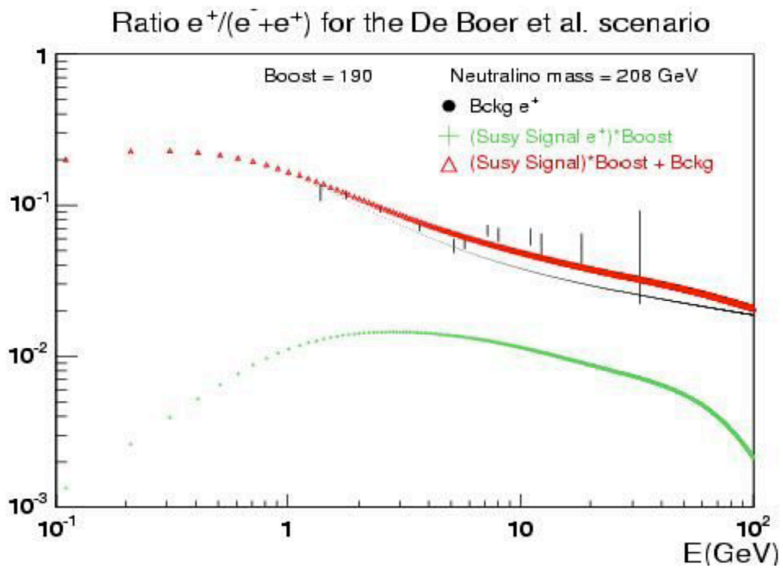
J Pochon (2005)

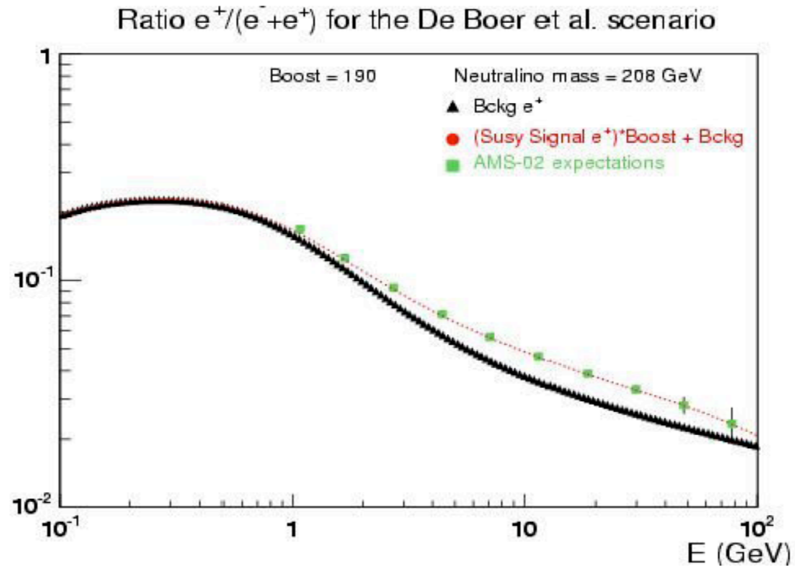
SUSY DM Searches in the positron channel

•De Boer et al. scenario (simultaneous fit to $\bar{p}$ spectrum + HEAT + EGRET excesses 2003) with dominant annihilation: $\chi\chi \rightarrow b\bar{b}$ (tanβ = 50)

•Boost factors tuned in order to match HEAT excess

J Pochon (2005)

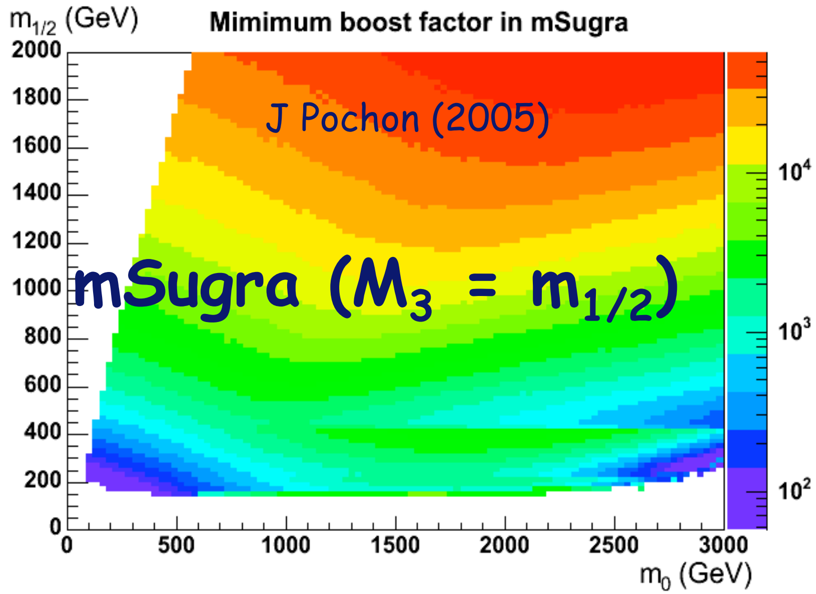


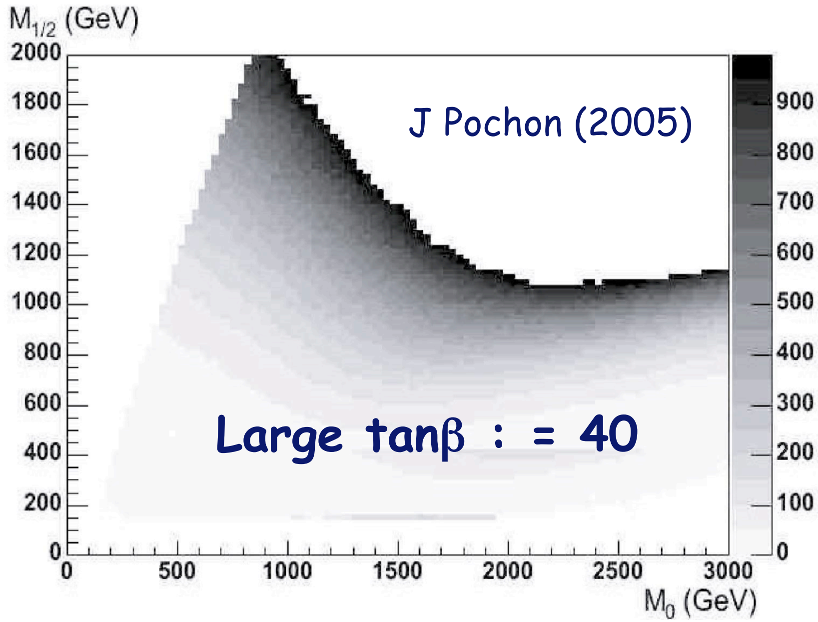


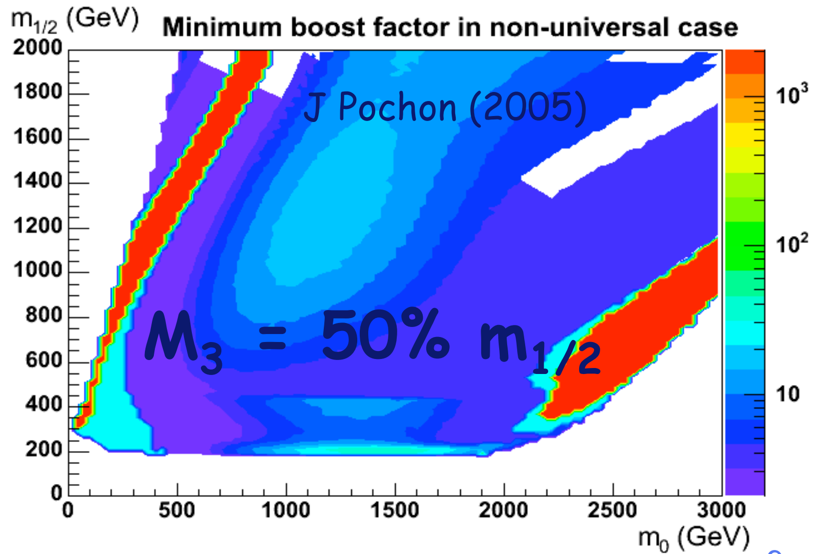
Boost factors and general MSSM scans

•Signal must be enhanced by a boost factor to be observable in AMS-02 in three years

•Minimum boost factors are deduced for each set parameter in (m_0, $m_{1/2}$) plane for AMS-02 limit sensitivity.





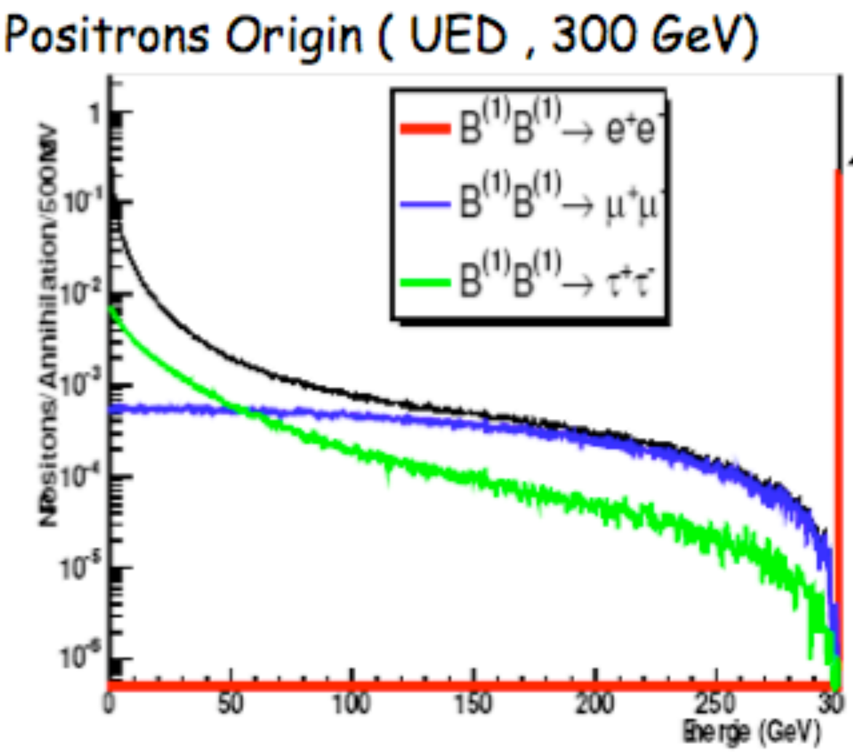


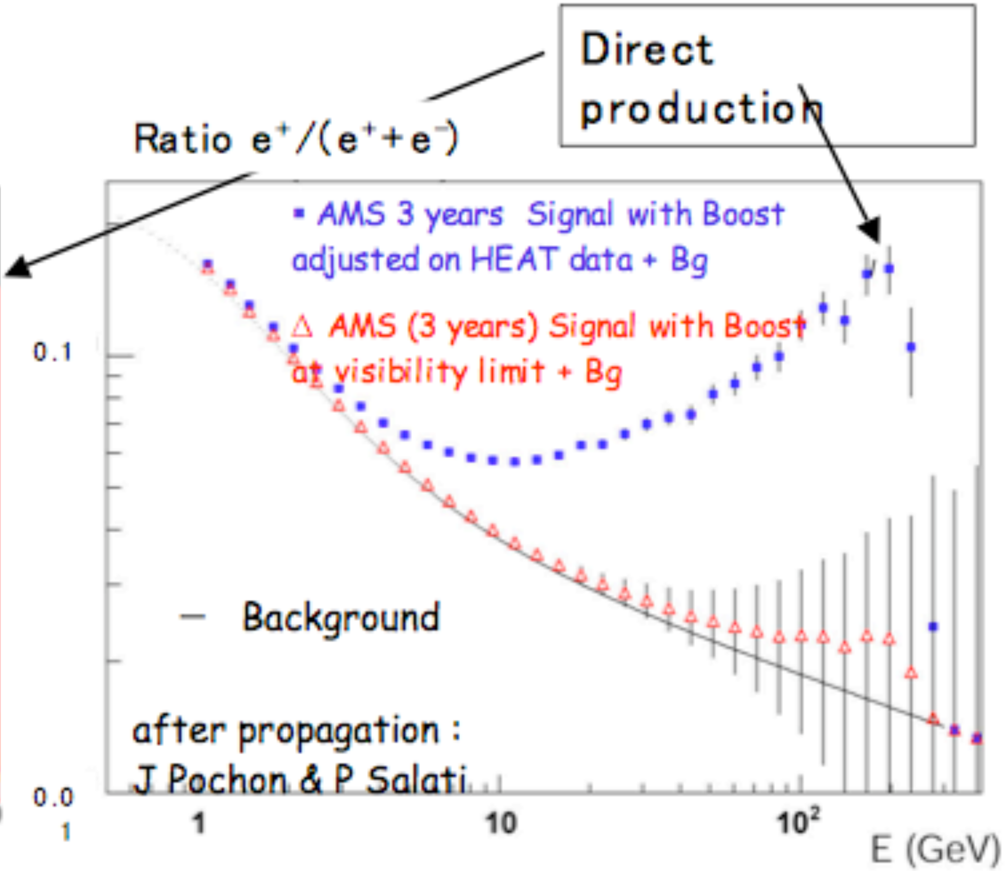
Models with Extra Dimensions
Searches in the positron channel

•Interesting on the phenomenological point of view because of direct production of e+e- pairs in LKP (B^1) annihilations

•Boost factors needed:
~O(10^2) to fit HEAT data
~1÷10 for discovery

Example:





Antiproton detection:expected performance

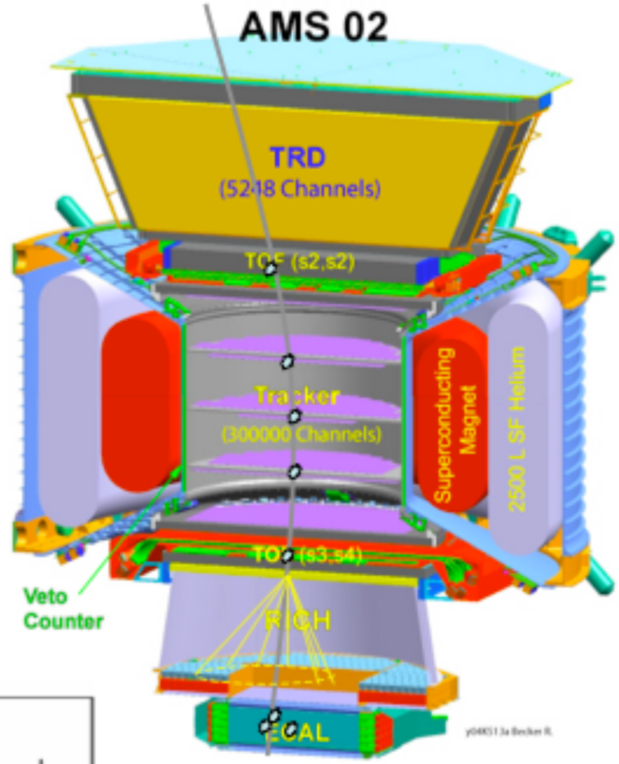
- Electron rejection > 10^4 :

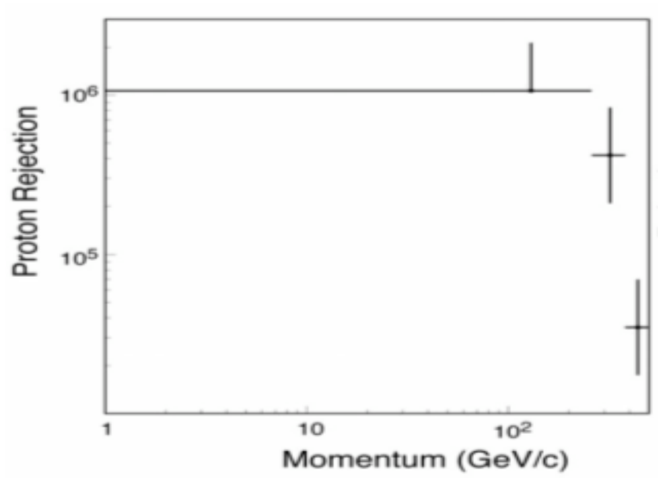
  use TOF + RICH β measurement at low energies; TRD and ECAL rejection capabilities at high energies

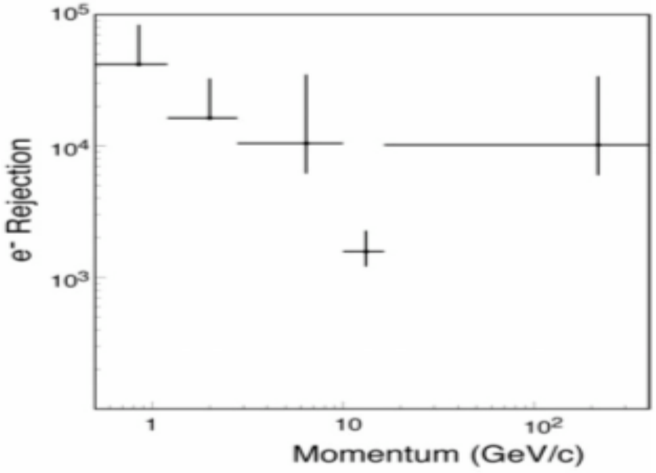
- Proton rejection ~10^6:

  good control of charge confusion, interactions with the detector and misreconstructed tracks

- Acceptance ~$3 \cdot 10^{-2}$ $m^2 \cdot sr$ up to 20 GeV

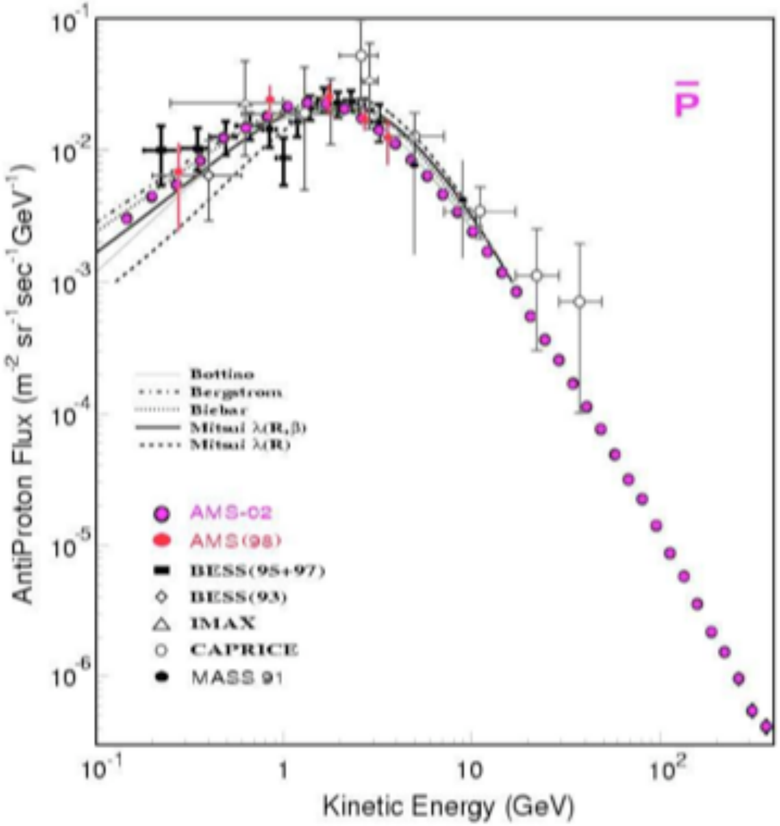


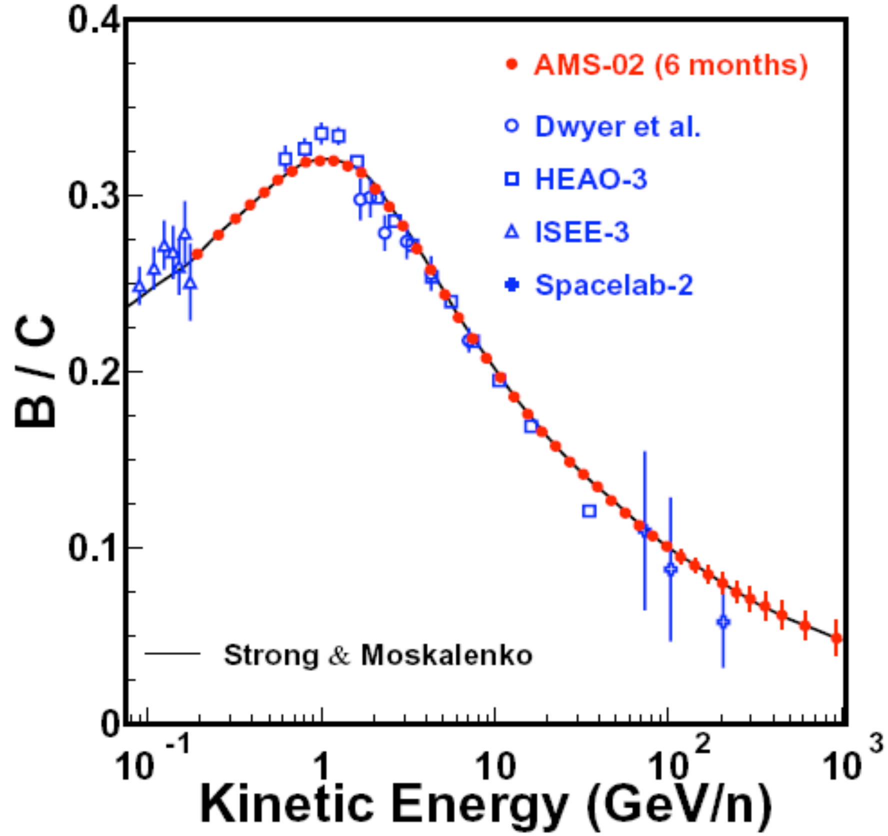




Antiproton flux measurement

- Current measurements large errors below 35 GeV
- Particularly sensitive to the physics details of cosmic ray propagation, particularly at low momentum. Controlled by secondary/primary ratios, like B/C
- AMS will measure the B/C ratio with high precision





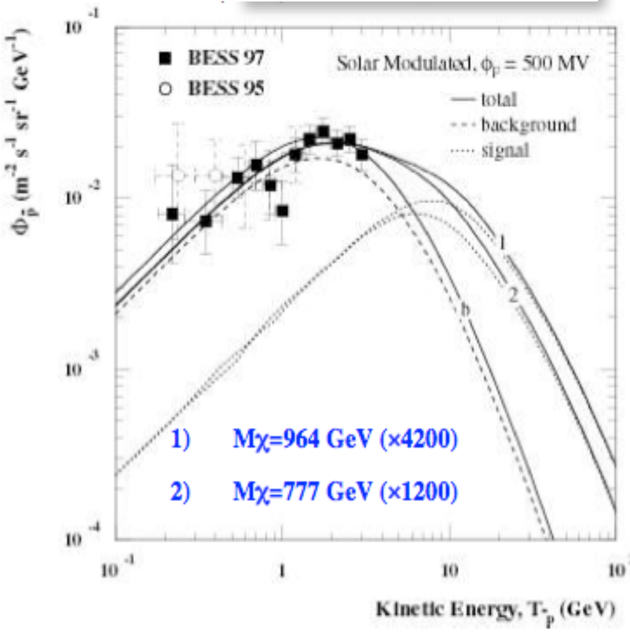
AMS02 expected measurement:

Conventional p flux with Statistical Errors (3 years);
Range 0.1 to ~ 500 GeV

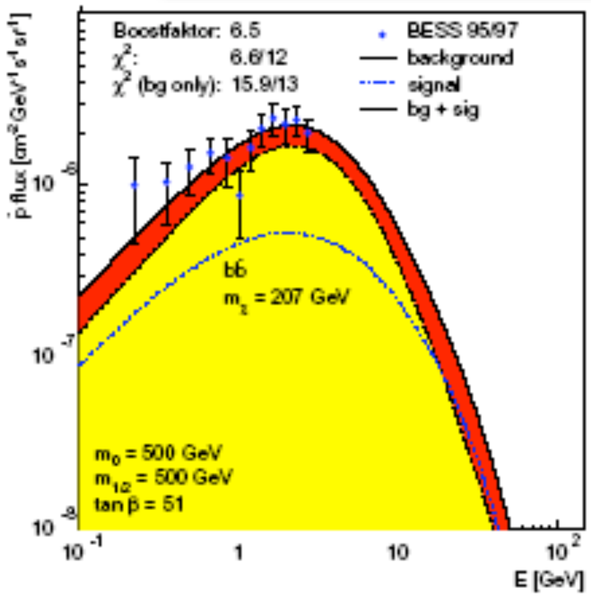
Antiproton signals from DM

- Focus on dark matter signals at high momentum
- Sensitivity to wide range of cases:
  1. Very favorable: flat spectrum (Ullio astro-ph/9904086) high mass ~1.4 TeV; high boost factor ~7·10³
  2. De Boer et al. (hep-ph/0309029) data-fitted model would be detectable (boost factor required of 6.5)
  3. Conservative (no boost factor): detection/exclusion of AMSB scenarios (Profumo et al. hep-ph/0406018).

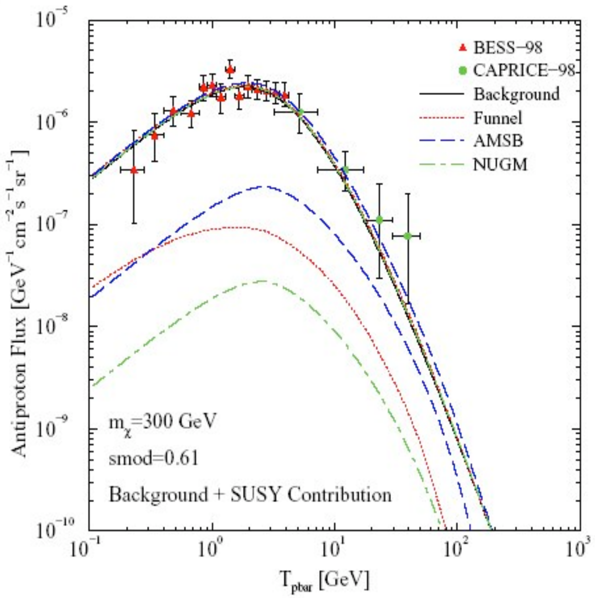
Ullio (astro-ph/9904086)



De Boer et al. (hep-ph/0309029)



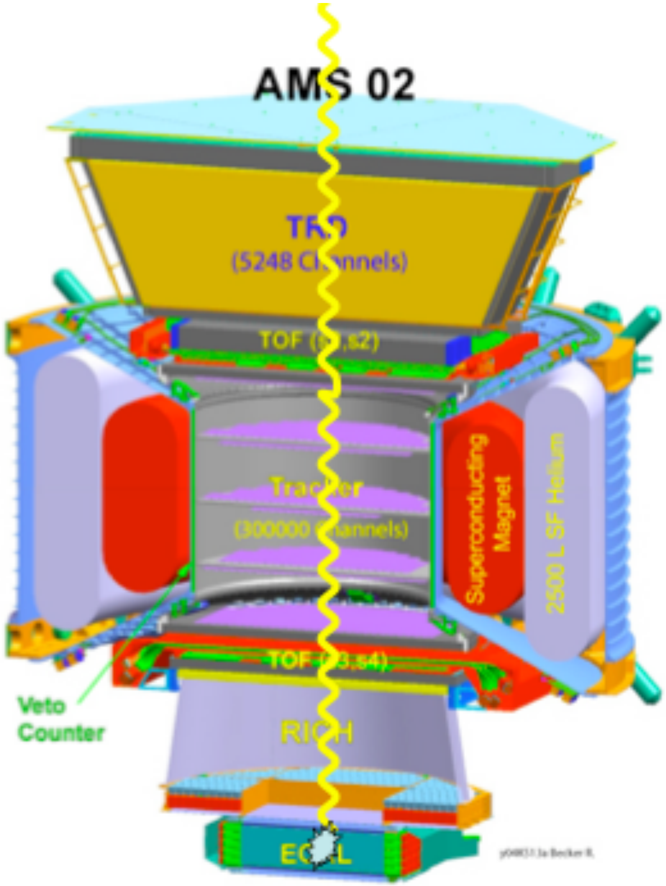
Profumo et al. (hep-ph/0406018)

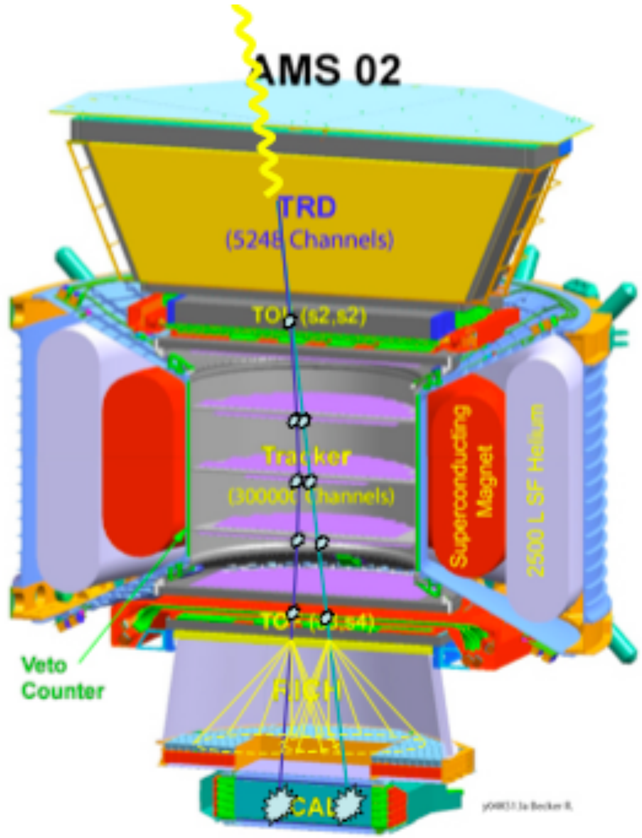


AMS02 γ-ray detection: two complementary methods

- Single photon mode:
  detection in ECAL

- Conversion mode:
  TRACKER recostruction of e^+e^- pairs produced by photon conversion in upstream layers of the detector (TRD ~0.25 X_0)



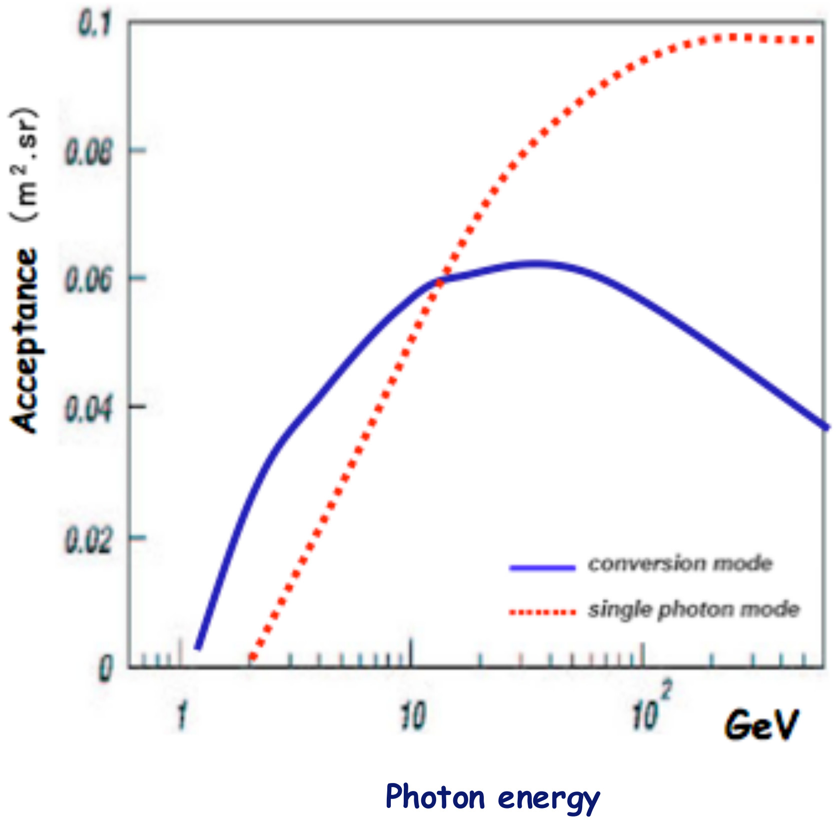


AMS02 γ-ray detection: expected performances

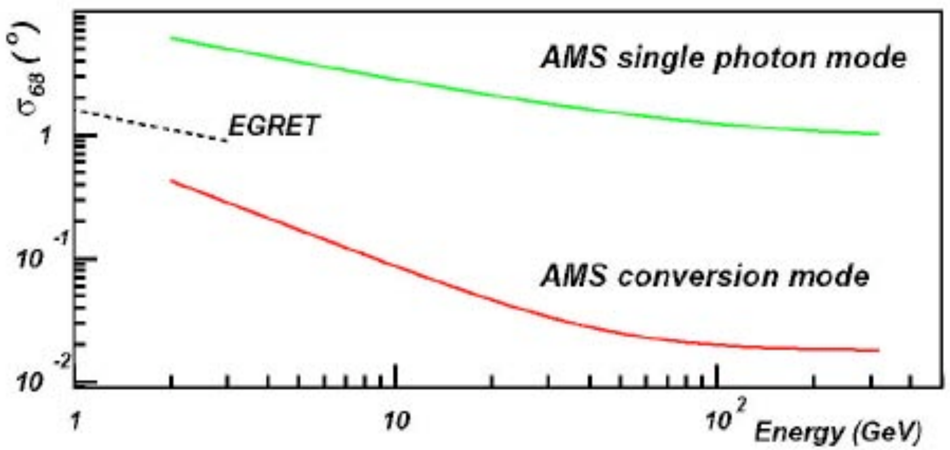
- Excellent angular resolution for the conversion mode
- Acceptance:
  - Lower energy threshold for the conversion mode
  - Larger acceptance in single photon mode at high energies
- Background rejection:

  conversion mode: p 10^5 ; $e^- \sim 10^4$

  single photon mode: $5 \cdot 10^6$



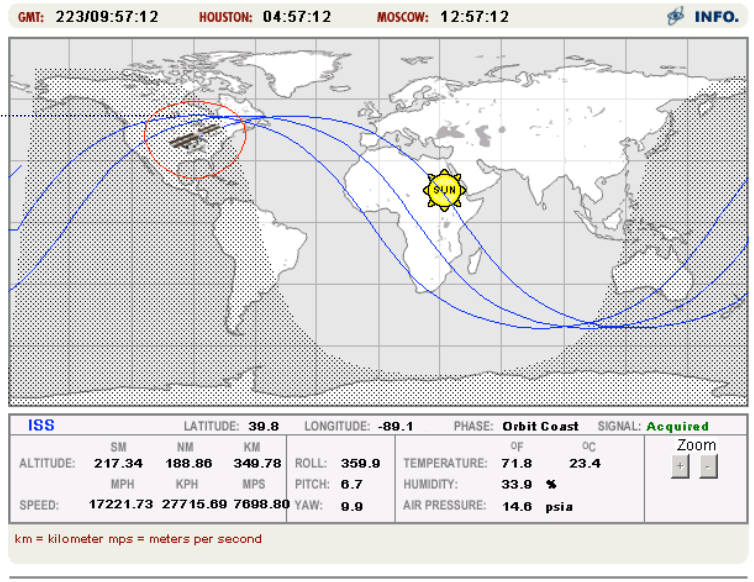
Jacholkowska et al.,
Phys. Rev. D74, 023518 (2006)



AMS02 exposure to γ rays from galactic center

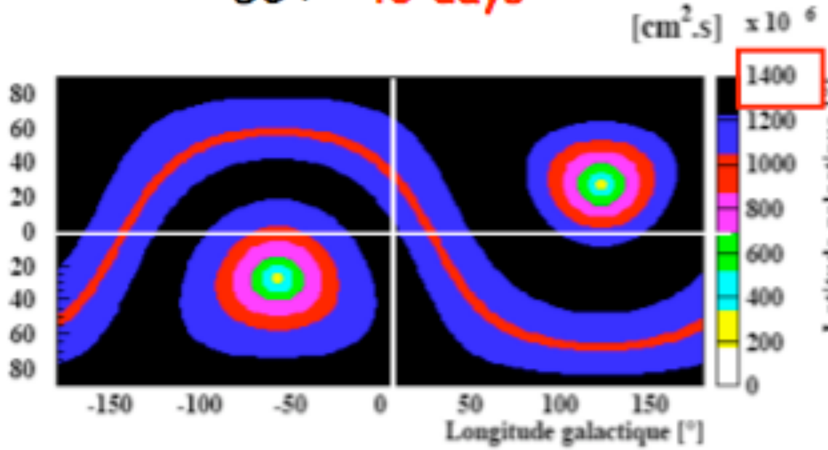
51° latitude

Revolution : 90'



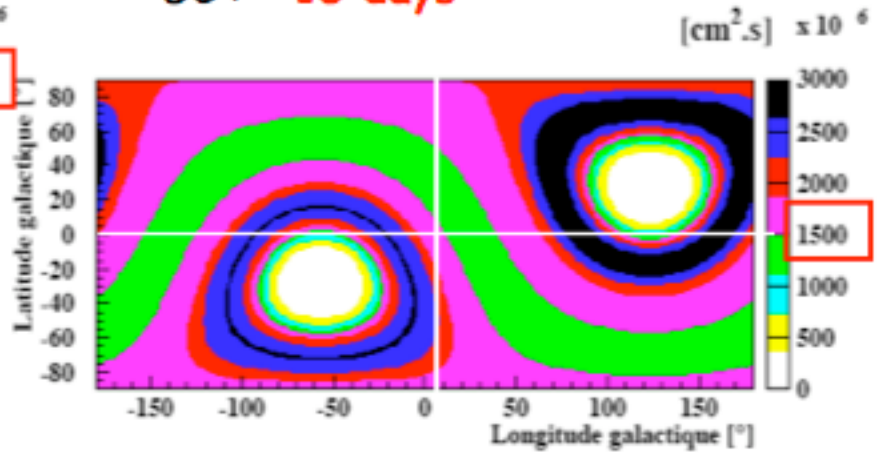
Conversion mode (sel. acc.)

GC : ~ 40 days



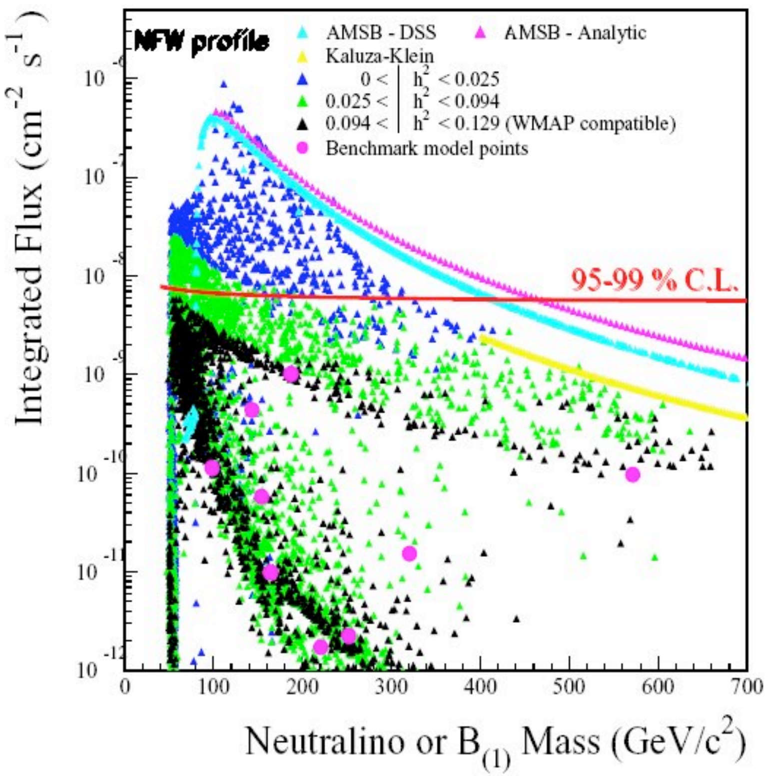
Single photon mode (geom. acc.)

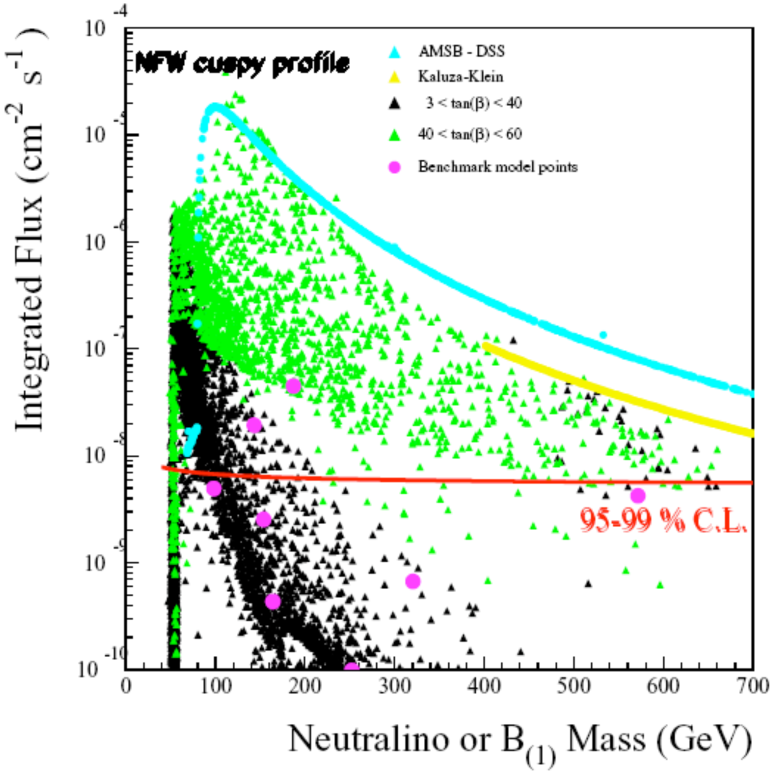
GC : ~ 15 days



SUSY and Kaluza-Klein DM Searches with AMS02 in the γ-ray channel

- Galactic center treated as point source.
- NFW halo profiles (Navarro, Frenk & White, ApJ 490 (1997) 493)
- Benchmark points of parameter space accessible in case of cuspy profile as well as several KK candidates
- Large exclusion potential for AMSB models and cuspy halos





Jacholkowska et al.,
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Conclusions

- In three years of data taking the AMS02 detector will be able to measure simultaneously and with high precision the rates and spectra of antiprotons, positrons, γ-rays and heavy ions in the GeV-TeV range

- AMS will perform very accurate measurement of the high energy tail of the antiproton spectrum

- AMS will be able to confirm or disprove with high accuracy the excess in HEAT positron data in the few GeV region

- A γ DM signal from the galactic center will be visible in AMS in the case of cuspy halo profile or extra enhancements

- Furthermore AMS will provide a simultaneous measurement of cosmic rays spectra, which will help to disentangle purely astrophysical effects from true dark matter signals.