Dark Matter Search Potentials with AMS

AMS: Alpha Magnetic Spectrometer

S. Rosier-Lees

on behalf of the AMS collaboration

LAPP, Annecy, IN2P3-CNRS

Rencontres de La Thuile, 1-6 March 2004

Outline

- Physics Motivations
- Detector requirements
- Prospects for Indirect Dark Matter searches
- Conclusions

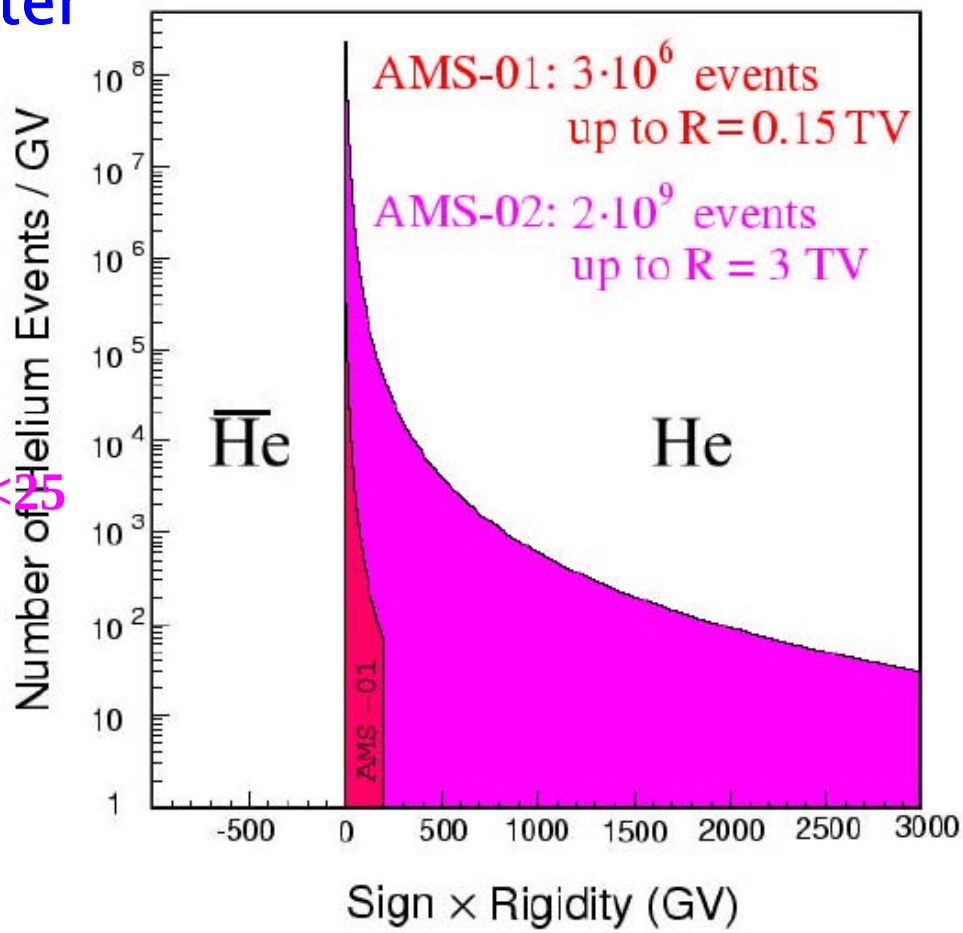
AMS Physics motivations

- Search for cosmic anti matter
- Search for Dark matter
- Precision measurement on

  $e^{\pm}$, γ , $p^{\pm}$, ^{3,4}He,B,C, ^{9,10}Be, elements Z<25

  GeV – TeV range

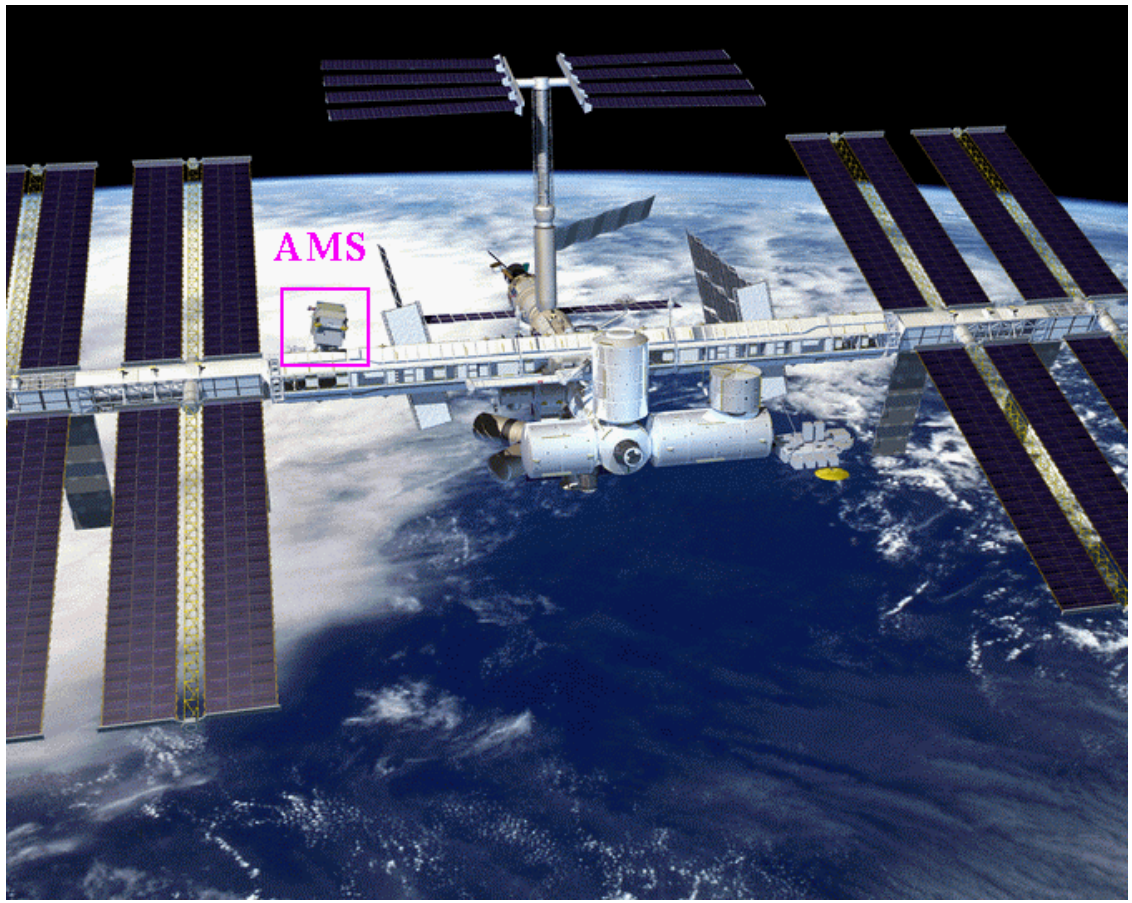
- Gamma ray astrophysics



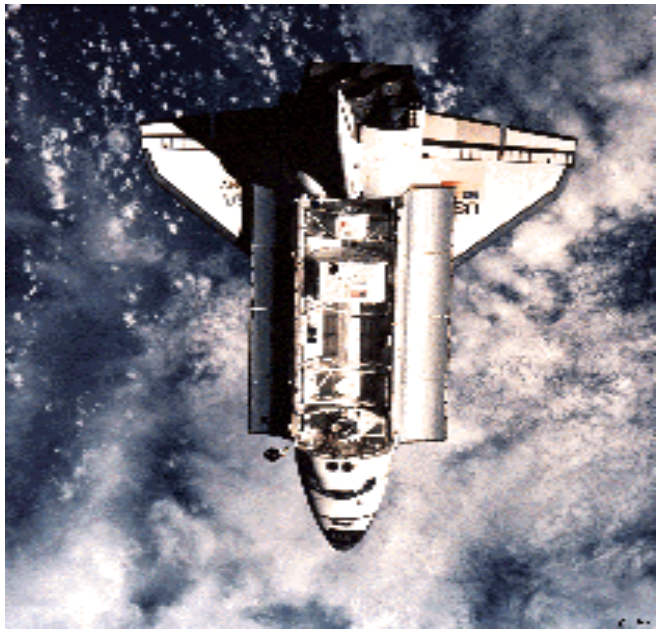
How to do it ?

A high energy physics detector in space for a long period is necessary

- **Very Large statistics of primary cosmic rays on a large energy/rigidity range**
- **Particle Identification including charge sign reconstruction and redundancy**



How to do it ?



AMS-01

AMS01 Precursor flight (10 days in 1998)

on board of the Space Shuttle

Instrumental goal
(fulfil the constraints from space ?),

Background studies

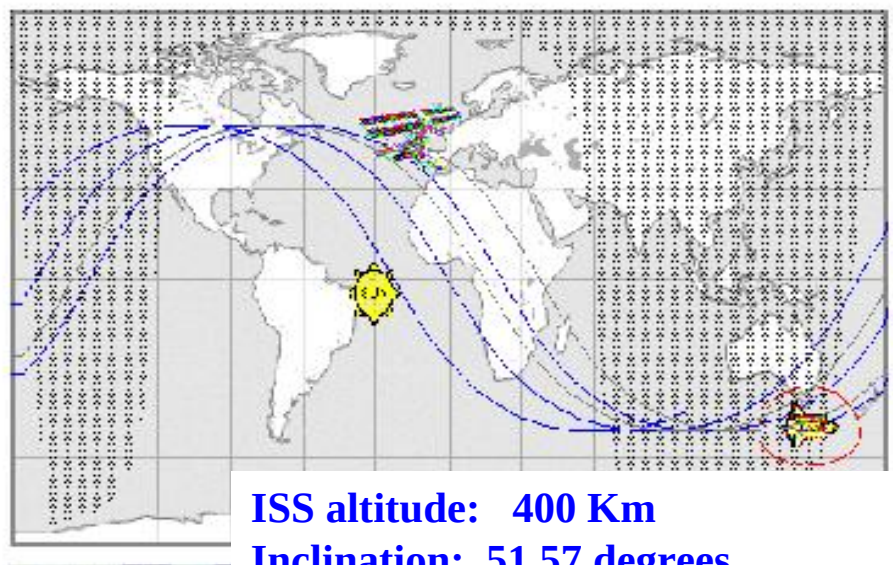
Physics PR 366/6, August 2002, p333-404

AMS-02 on ISS

Improved detector (acceptance,
Magnetic field, redundancy, particle ID)

Starting to operate in 2007 for at least 3 years on the International Space Station

International collaboration,
constructed mostly in Europe (90%)



ISS altitude: 400 Km
Inclination: 51.57 degrees
15.62 revolutions per days
Precession($d\Omega/dt$) -5.06 deg/day

The AMS-02 detector

Transition Radiation Detector : **separate e/p**
Foam + Straw Drift Tubes (Xe/CO_2) **to 300 GeV**

Time of Flight Upper : **trigger, β**
scintillators, Δt =~120ps

Superconducting Magnet :
$BL^2 = 0.85\ Tm^2$

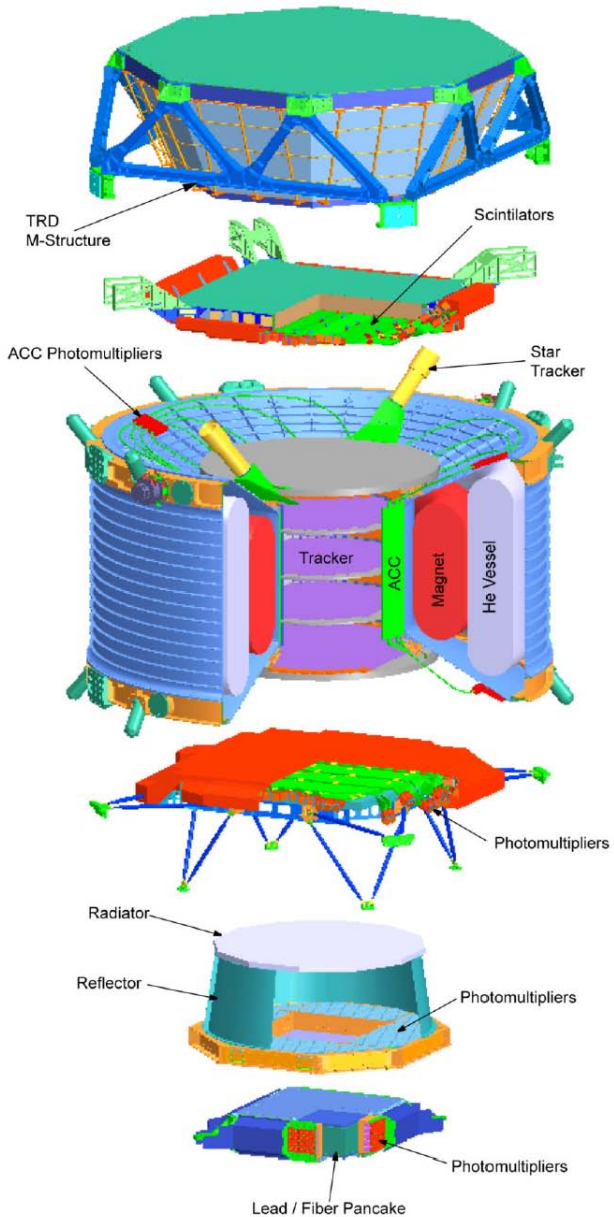
Rigidity up to 1 TeV
charge separation, β

Tracker (8 layers) :
double sided silicon strips, total of $6m^2$

Time of Flight Lower (+ trigger) :
scintillators,Δt =~120ps

RICH :
Radiator (Aerogel,NAF) **β,Z^2** **He^3,He^4,B,C**

Electromagnetic Calorimeter : **$e^{\pm}$,γ to 1 TeV**
Lead+scint. Fibers, 324 R7600 PMT's (4 pixels)



TRD: Transition Radiation Detector

TOF: (s1,s2) Time of Flight Detector

MG: Magnet

TR: Silicon Tracker

ACC: Anticoincidence Counter

AST: Amiga Star Tracker

TOF: (s1,s2) Time of Flight Detector

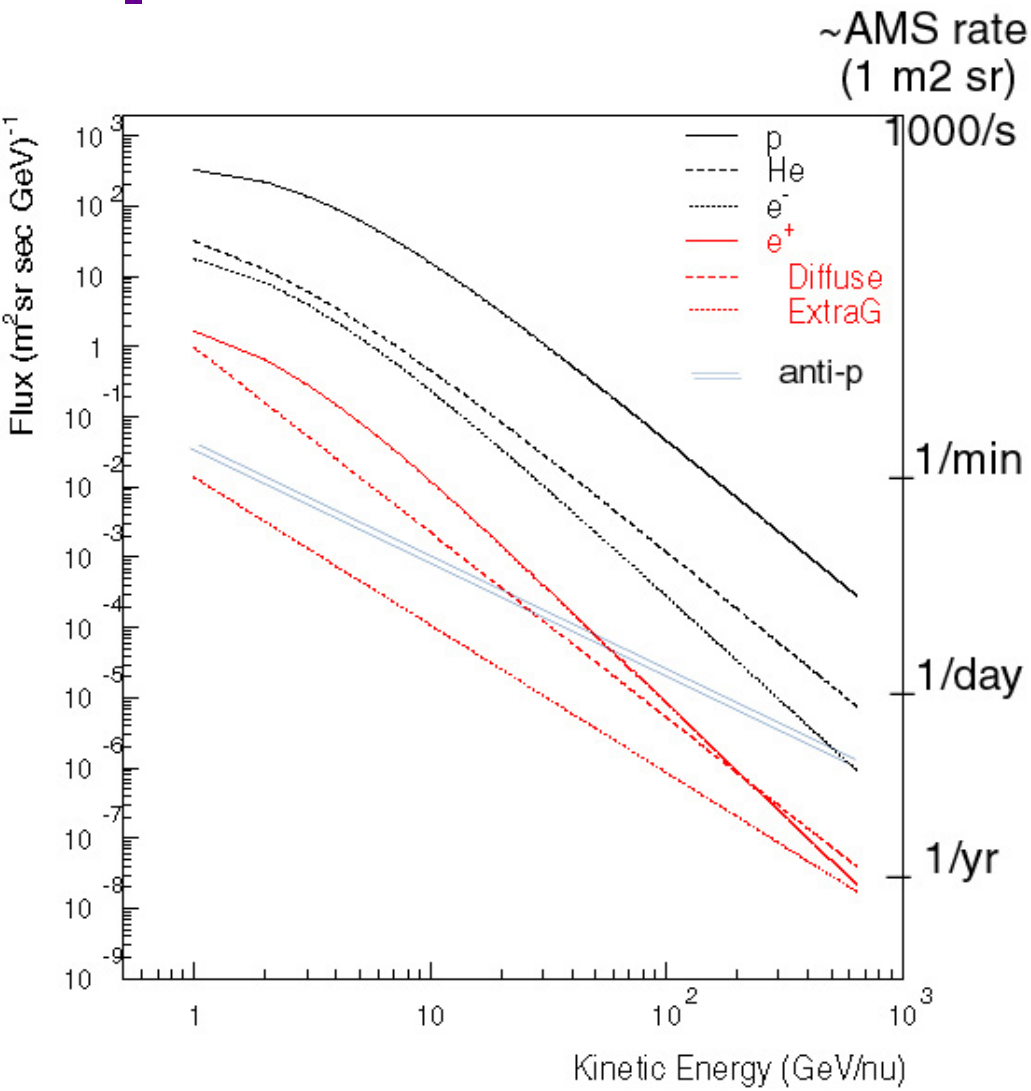
RICH: Ring Image Cherenkov Counter

EMC; Electromagnetic Calorimeter

R.Becker 09/05/03

AMS Alpha Magnetic Spectrometer Integration MIT

Cosmic Rays Fluxes



CR spectrum follows a « power law » $E^{-\gamma}$ γ [2-3]

CR composition

P: 88 % He nuclei 9 % e^- 2 %

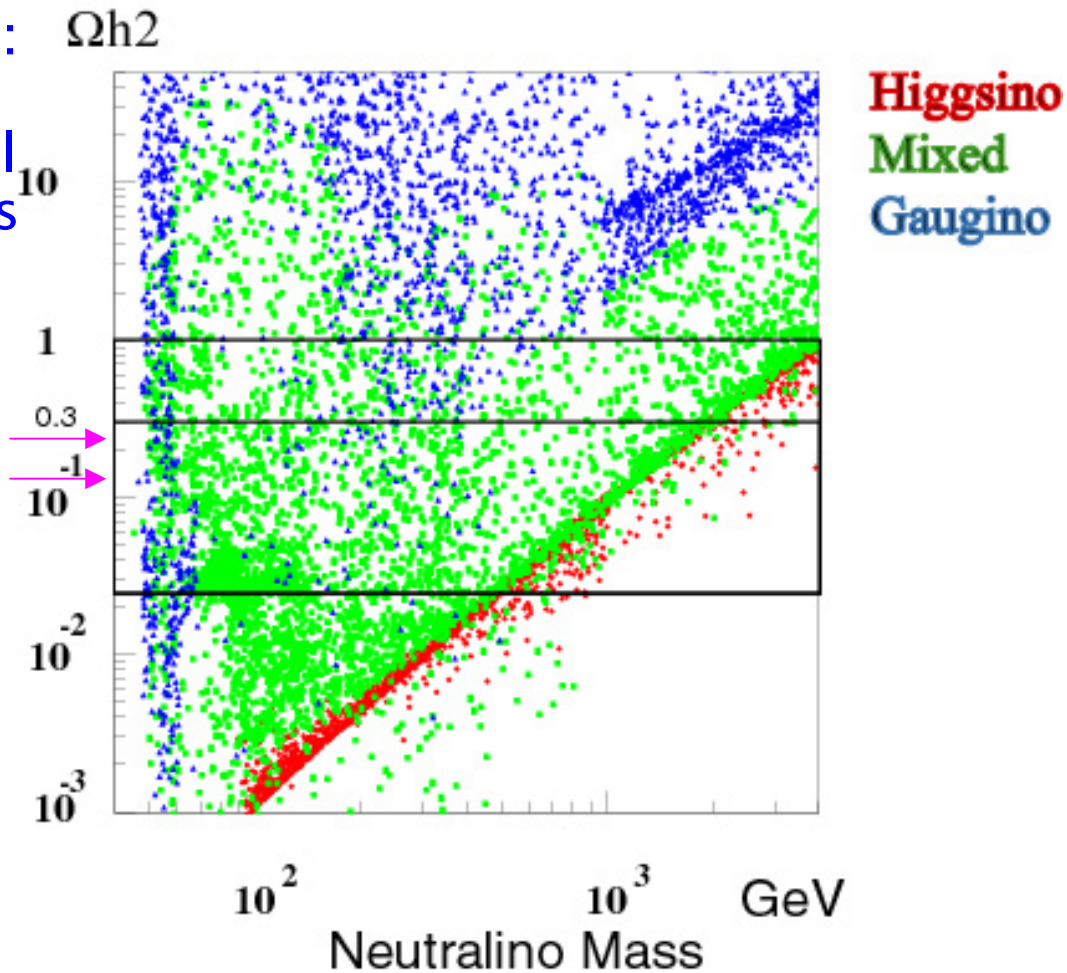
- Signal: look for anti-particle spectrum
- Background:p,He, e^- will be well measured

Dark Matter quest

large quantity of non-baryonic darkmatter $\Omega_m \approx 0.3$

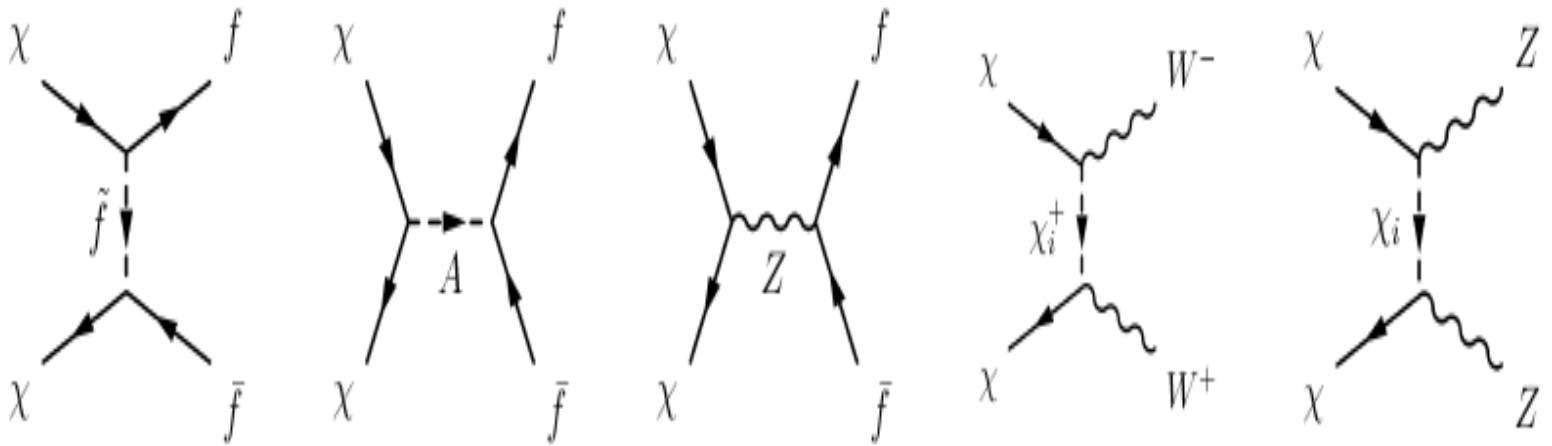
The lightest SUSY particle χ: mixture of the superpartners of the neutral Higgs and EW gauge bosons is a good DM candidate

- Constraints from the relic density Ωh^2, stronger with WMAP
- Indirect limits from LEP: M χ > 40 GeV



Indirect χ detection

χ annihilation products in the galactic halo.



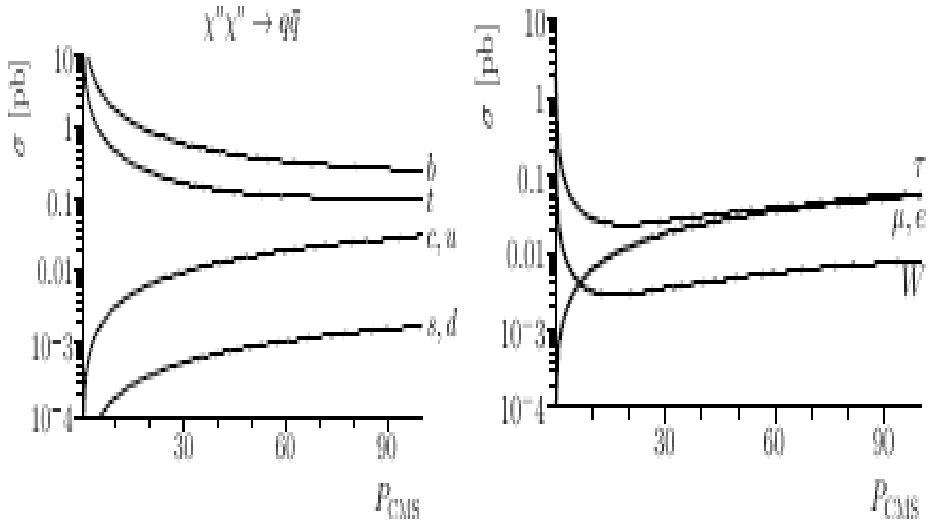
+ $\chi\,\chi \rightarrow Z\gamma,\ \gamma\gamma$ **(1st loop)**

$\chi\,\chi \rightarrow q\,\bar{q}$
b b̄ dominant mode

$\chi\,\chi \rightarrow l^-l^+,\ WW^+$

Identified particle in the final state:

$e^+,\ \bar{p},\ \gamma,\ \bar{D}$

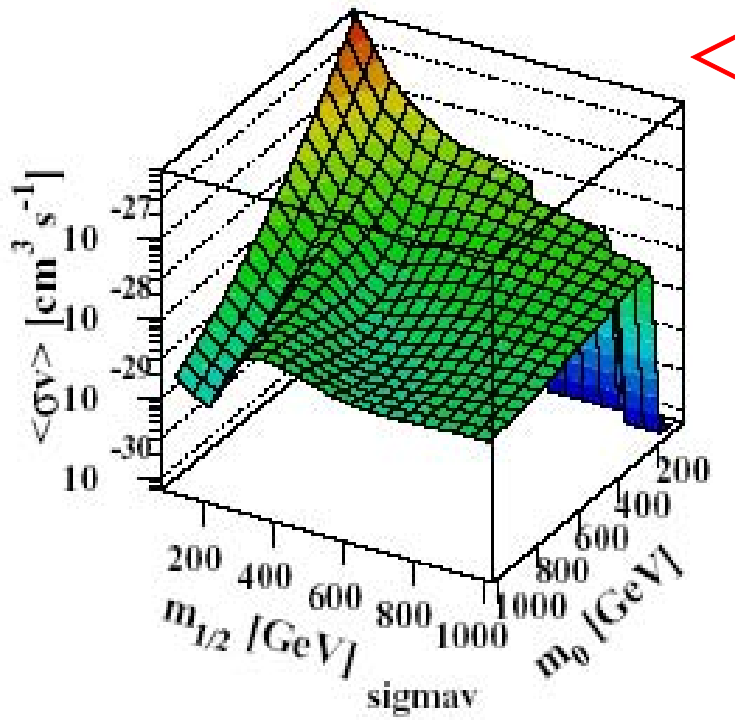


Indirect χ detection

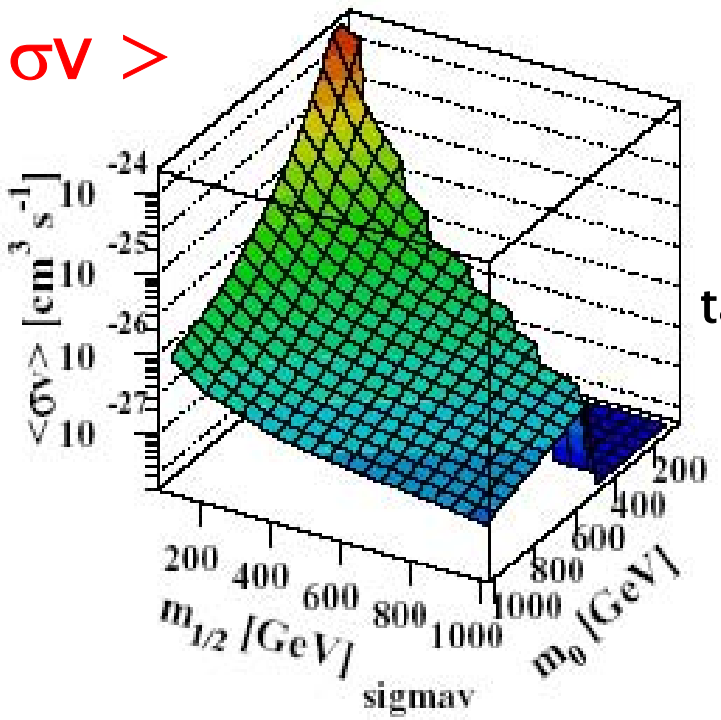
$\phi_{prod} \propto \langle \sigma v \rangle \rho_\chi^2 / m_\chi^2 \times g(\text{propagation})$

SUSY Parameters dependence

tanβ=5



$\langle \sigma v \rangle$



tanβ=50

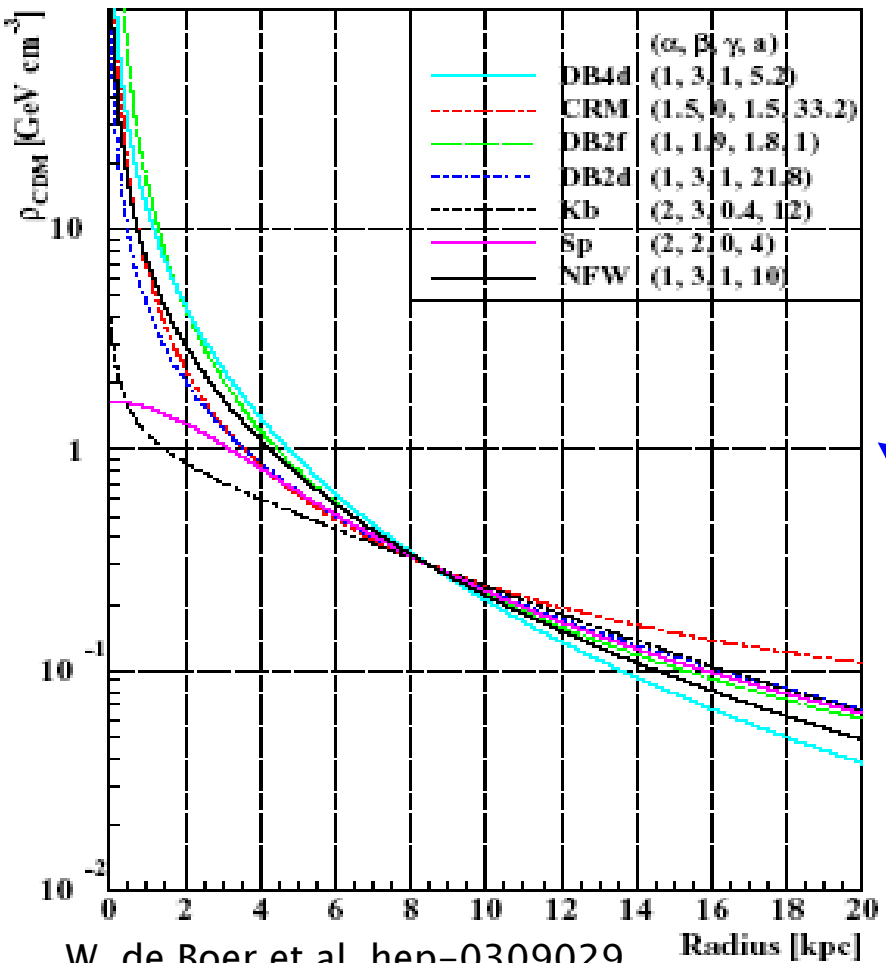
- Coupling and mass spectrum
- Lower sensitivity for larger χ masses

W. de Boer et al, hep-0309029

Indirect χ detection

$\phi_{prod} \propto \langle\sigma v\rangle \rho_\chi^2 / m_\chi^2 \times g(\text{propagation})$

Astrophysics/Cosmology dependence:



W. de Boer et al, hep-0309029

- Clumpiness
- " Dark" halo profile (NWF, CR&M,etc)

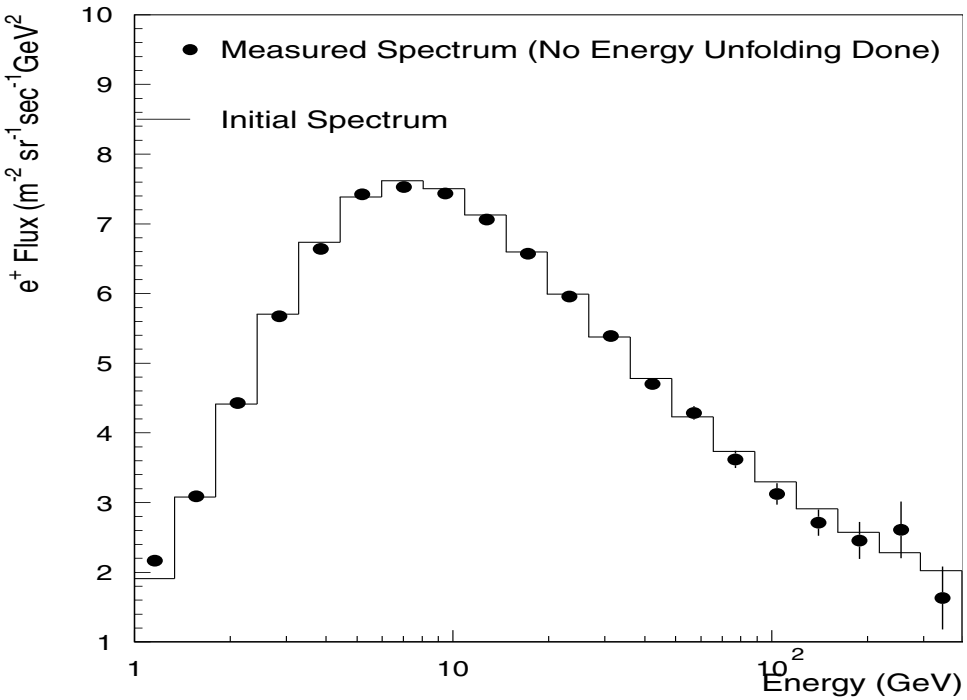
$$\rho(r) = \rho_0 \cdot (\frac{r}{a})^{-\gamma} \left[1 + (\frac{r}{a})^{\alpha}\right]^{\frac{\gamma-\beta}{\alpha}}$$

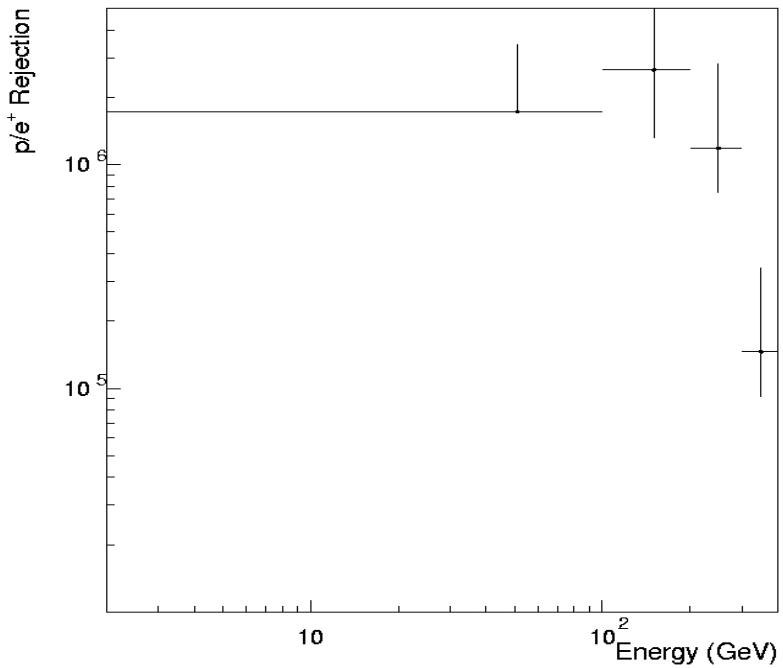
- Propagation parameters

DM searches with positons

e^+

Sensitivity to exotic flux greater than 10^{-7} E^2(cm.s.sr.GeV)$^{-1}$





Precise measurement of the energy spectrum after 3 years

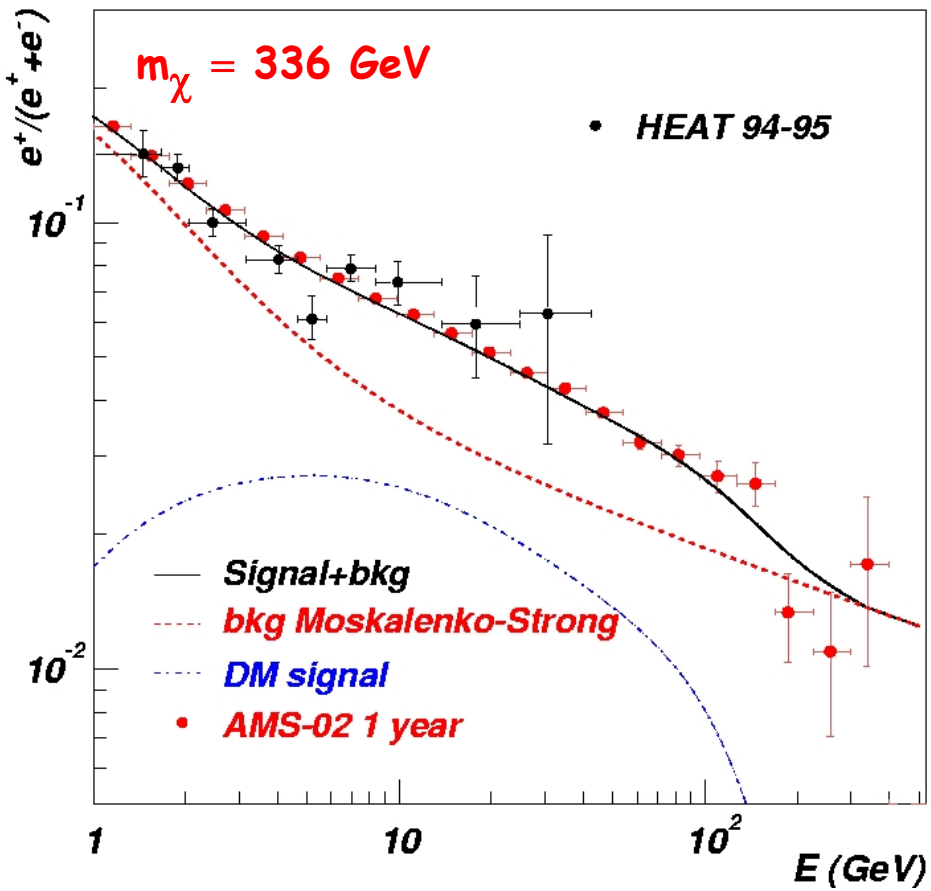
~1% stat error at 50 GeV.

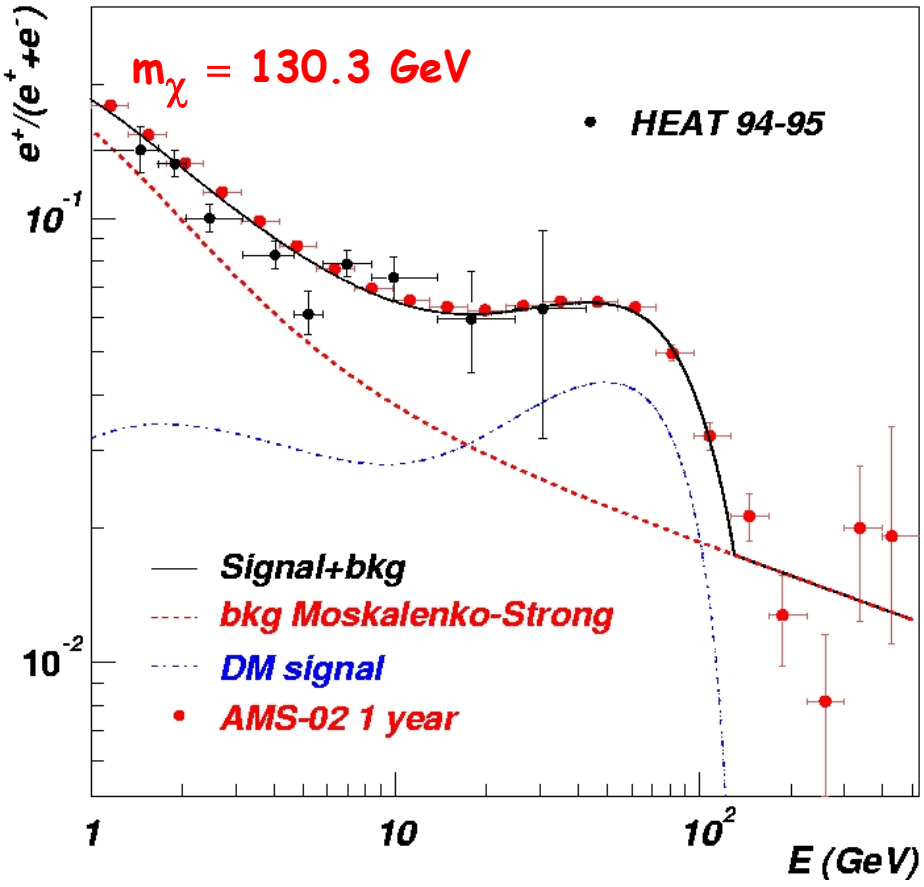
~30% stat error at 300 GeV

rejection $e^+/p > 10^5$

DM searches in positons

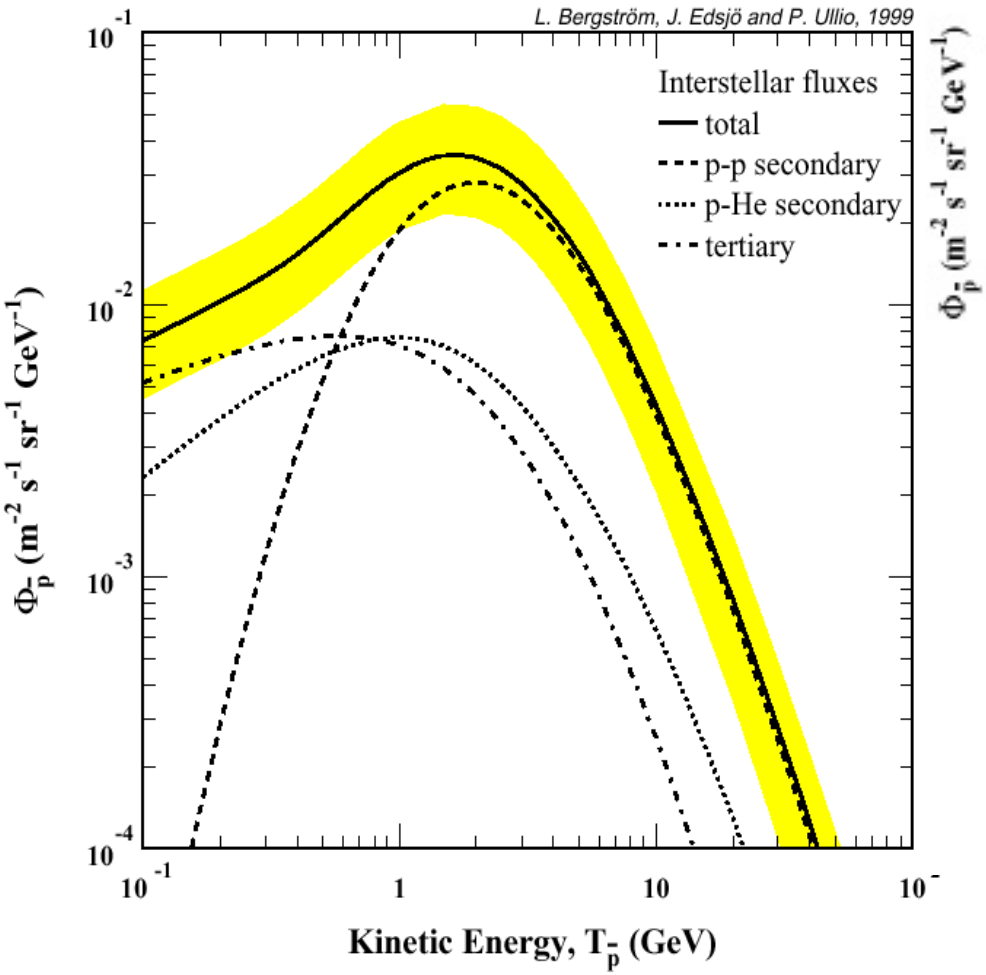
Sensitivity after one year data taking: Precise data extended to higher energies will be provided by AMS

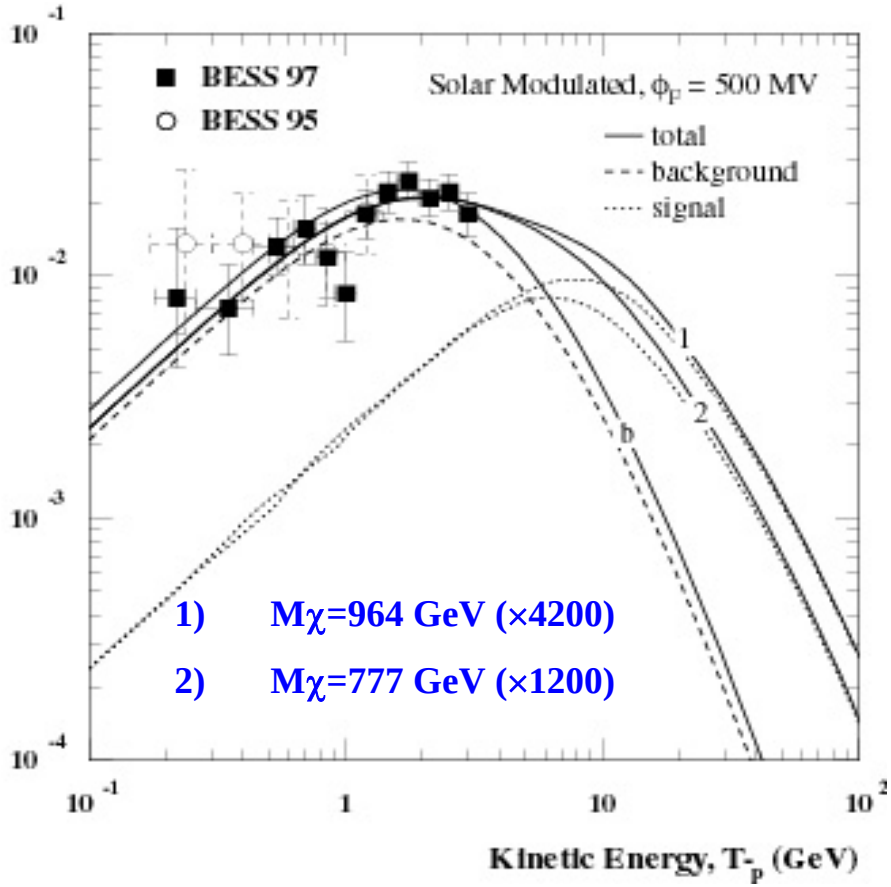




Based on the work of E.A. Balts et al. 99 large boost factor needed

DM searches in anti-protons





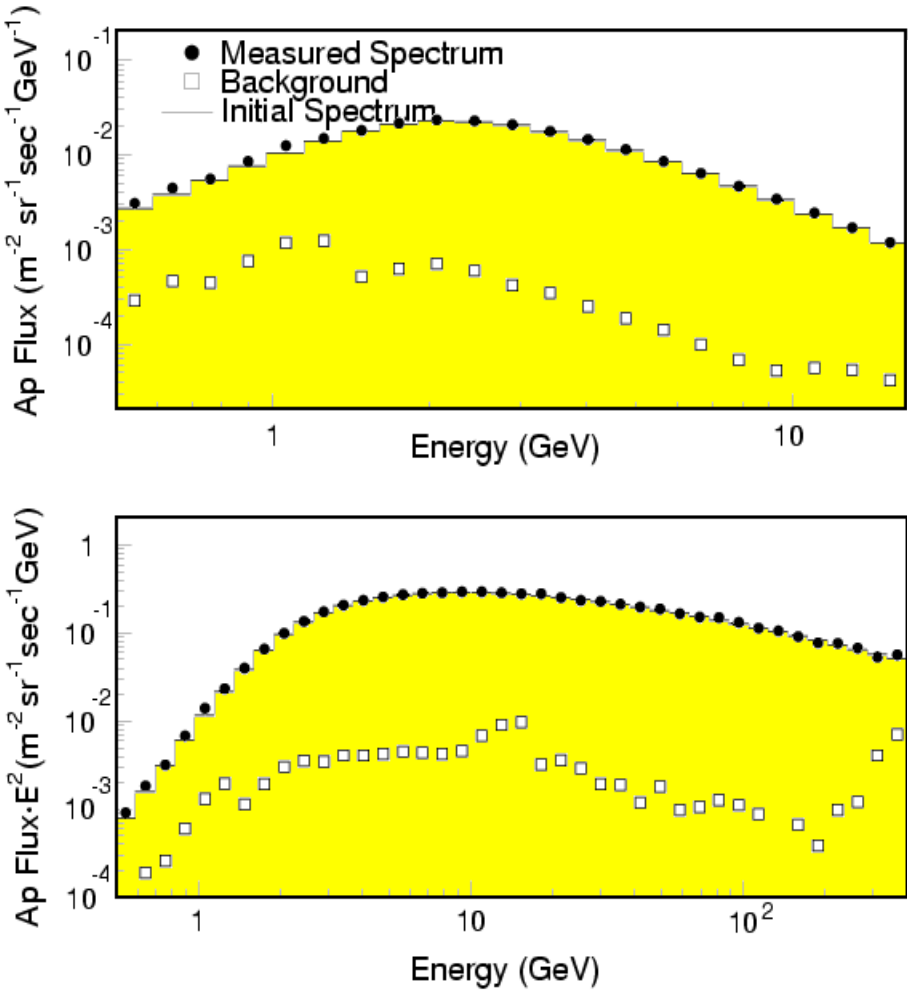
Background secondary $\bar{p}$

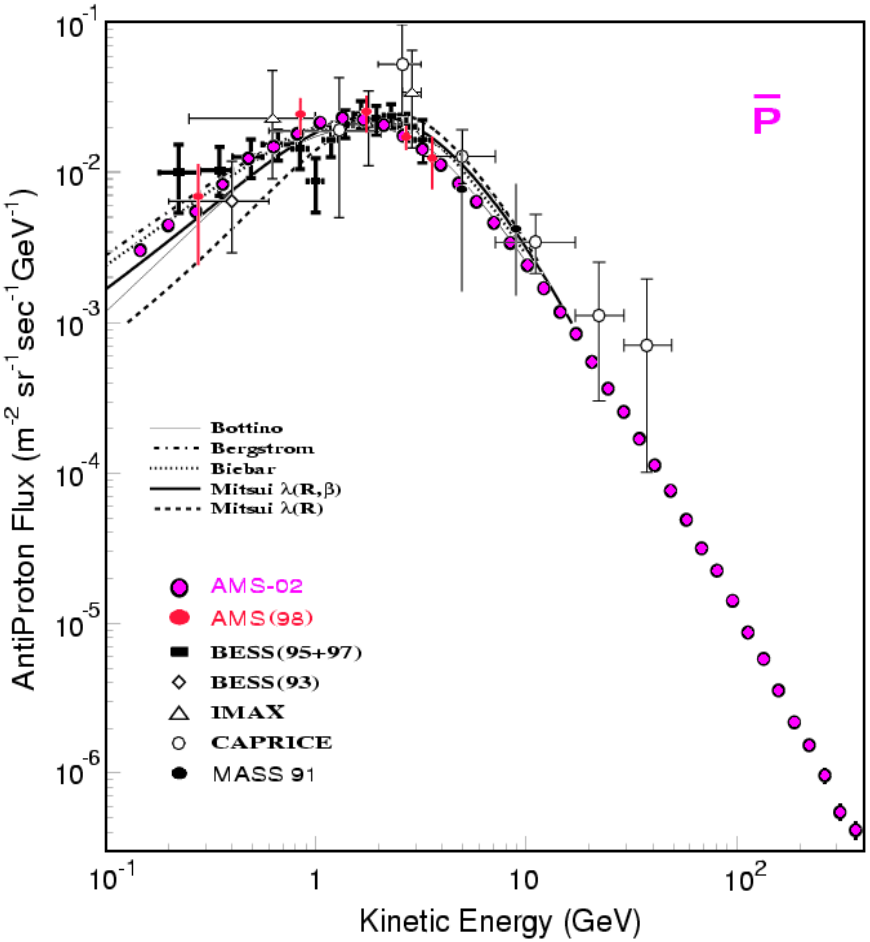
Sizable effects

Primary $\bar{p}$,from χ annihilations

DM searches in anti-protons

Prospects with AMS-02 after 3 years





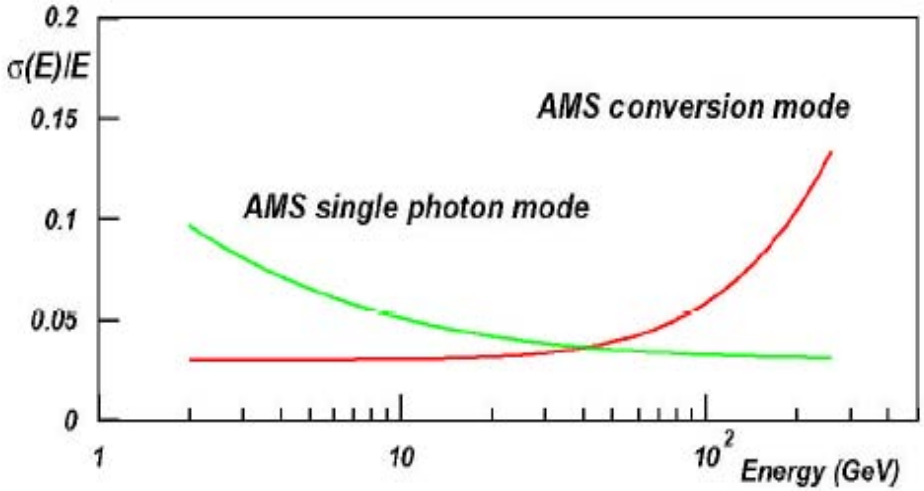
Background rejection :

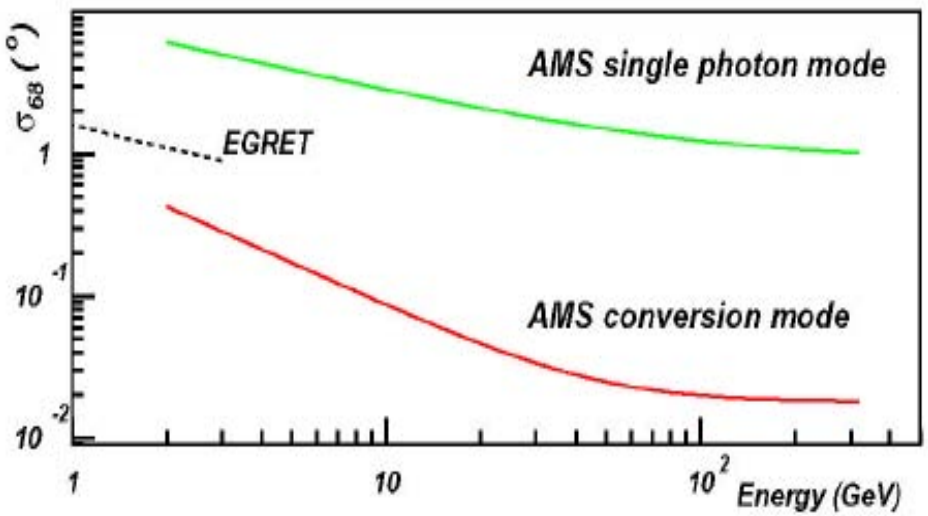
$p / \bar{p} > 10^6$, $e^- / \bar{p}$ 10^3-10^4

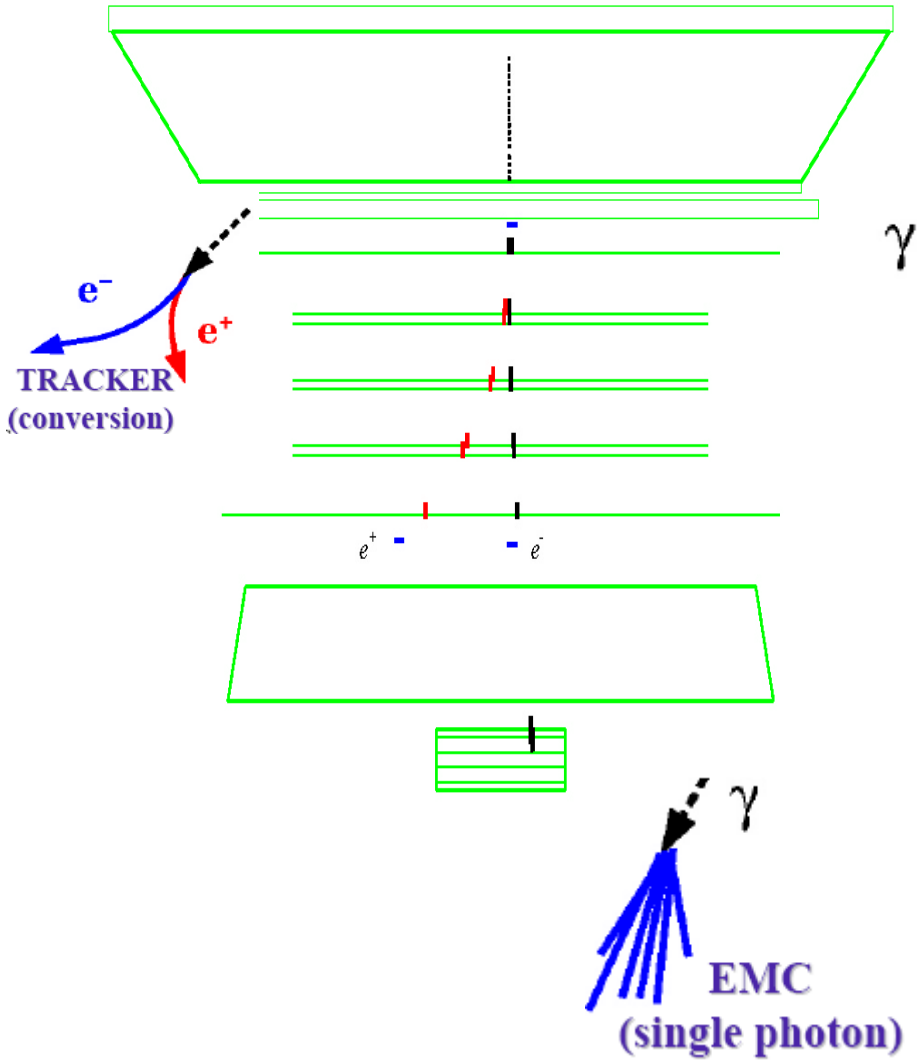
Up to 300 GeV

AMS-02 γ

Two complementary detection modes

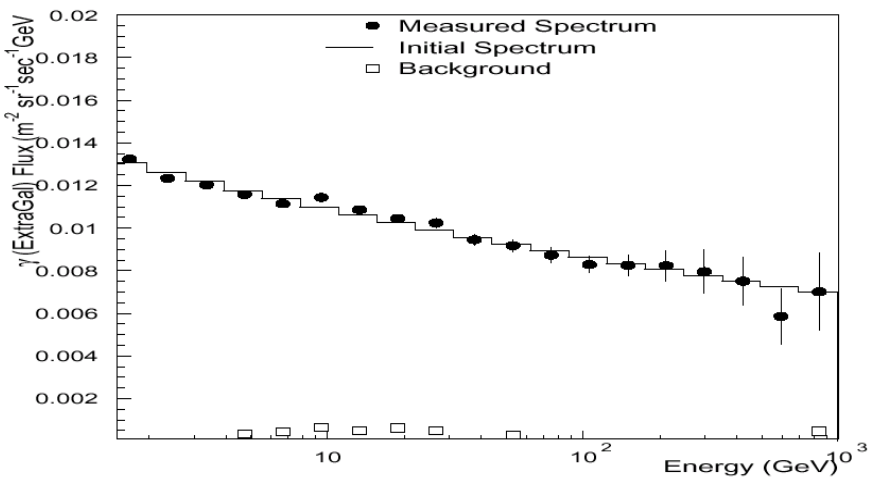




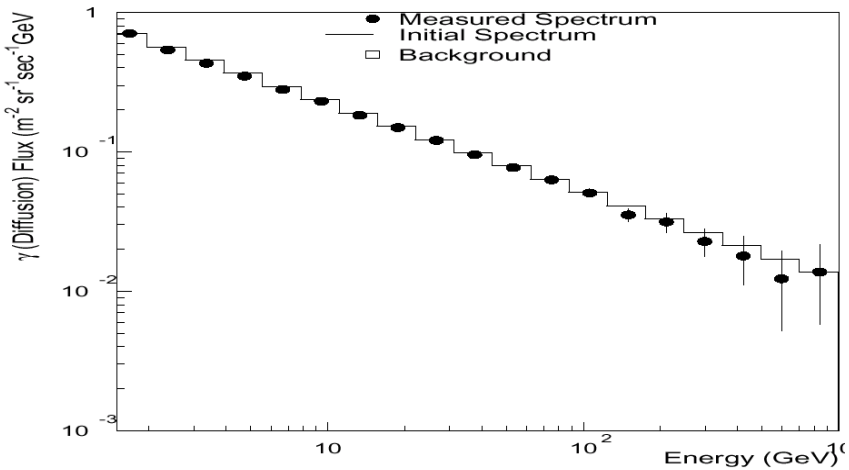


AMS-02 γ

ExtraGalactic γ spectrum



Galactic diffuse γ spectrum

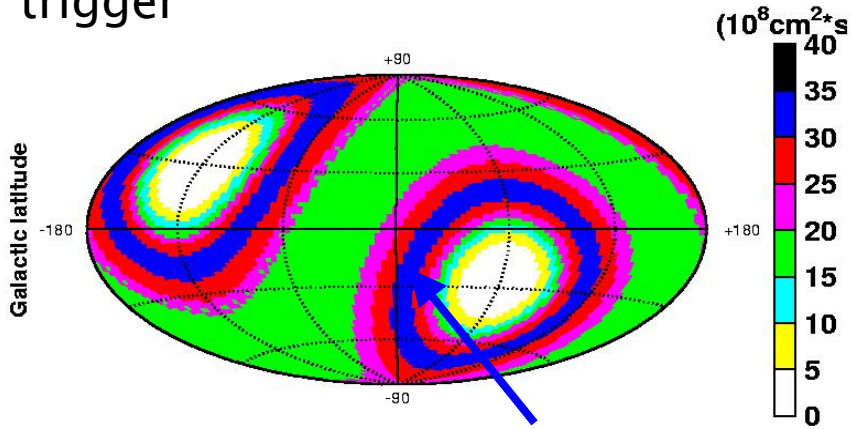


AMS-02 3 Y measurements

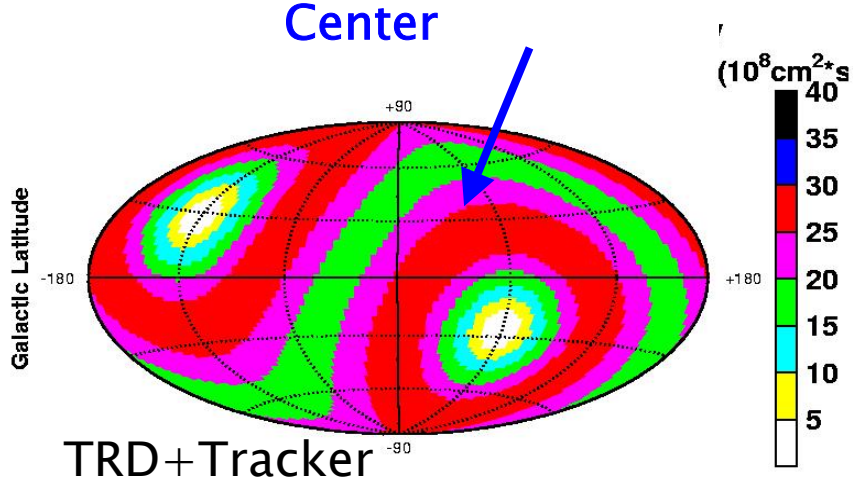
One year sky coverage

ECAL + γ stand-alone trigger

10^8 cm^{2}s



Exposure of the Galactic Center

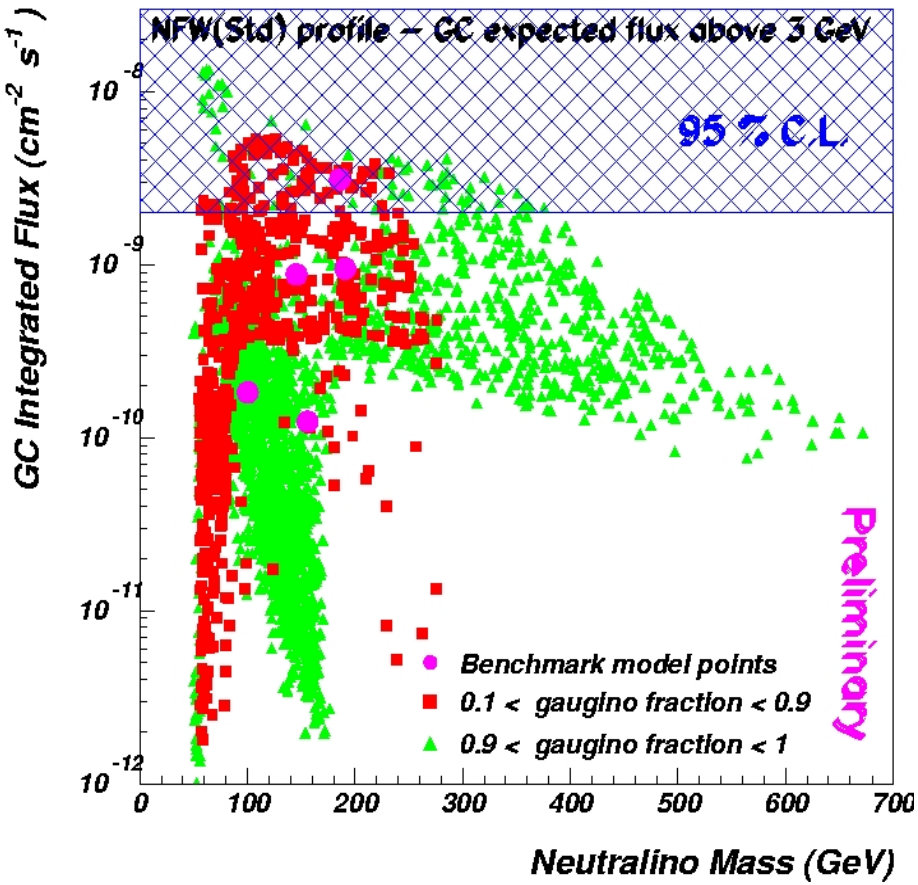


TRD+Tracker

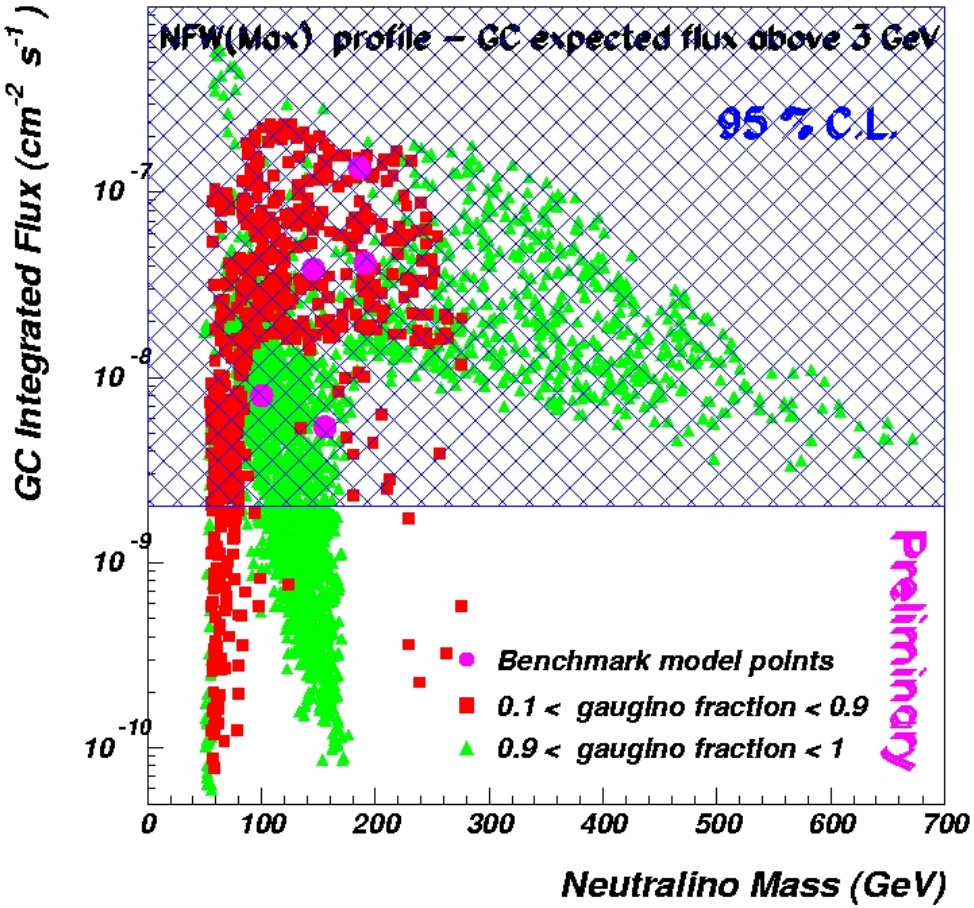
Galactic Longitude (degrees)

AMS-02 γ

Msugra results: Integrated flux from the Galactic Center in the focus point, region for two NFW profile parametrizations

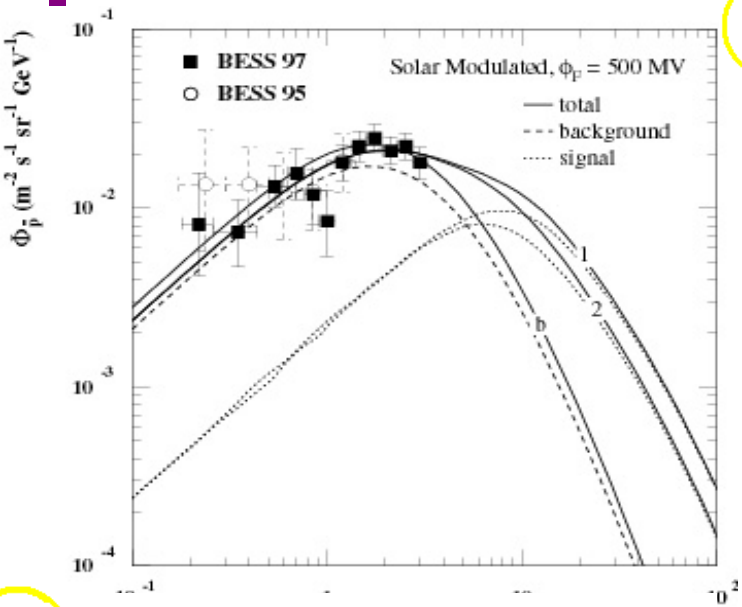


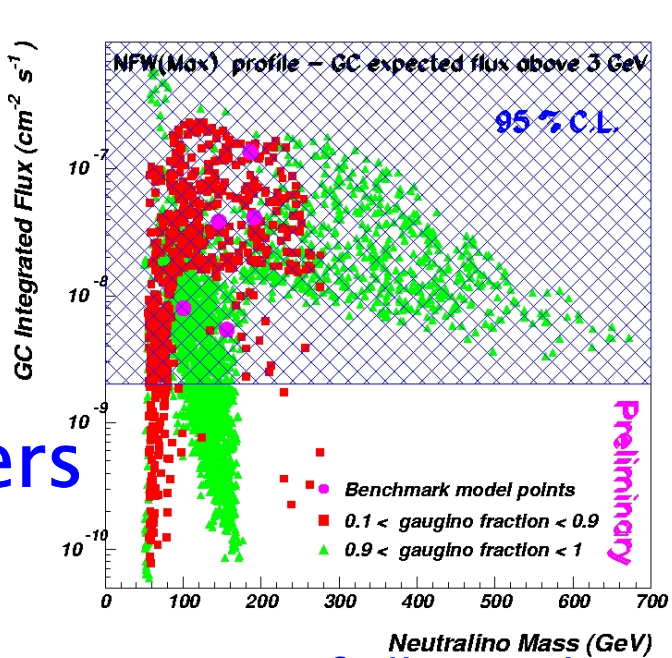
$R_0 = 8.0\ kpc$, $r_0 = 0.3\ GeV/cm^3$, $a = 20\ kpc$

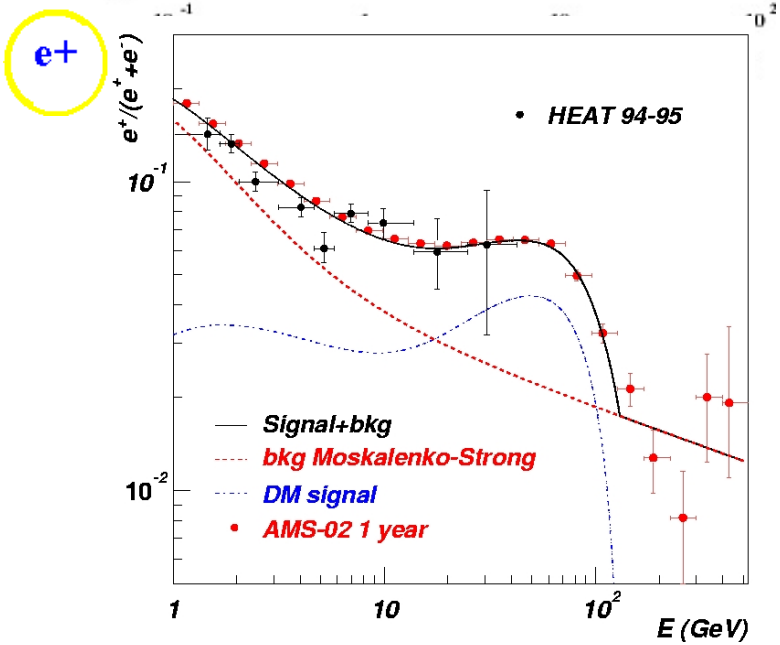


$R_0 = 8.5\ kpc$, $r_0 = 0.4\ GeV/cm^3$, $a = 4\ kpc$

Susy DM: summary







AMS offers

Precise measurements of all particle spectra

Measurements of Nuclei fluxes for propagation model

Wide range of SUSY annihilation products.

Potential gain in sensitivity by combining them

Alternative scenarios (Extra Dim, AMSB) could be also promising

Conclusions

- AMS is a High Energy Physics detector in space foreseen to operate on the ISS for 3 years

- Complete detector in 2005

- The cosmic rays, including gamma, will be measured with a high accuracy from the GeV to the TeV range

- Unique opportunity to perform Dark Matter searches