Detection and measurement of γ rays with the AMS02 detector

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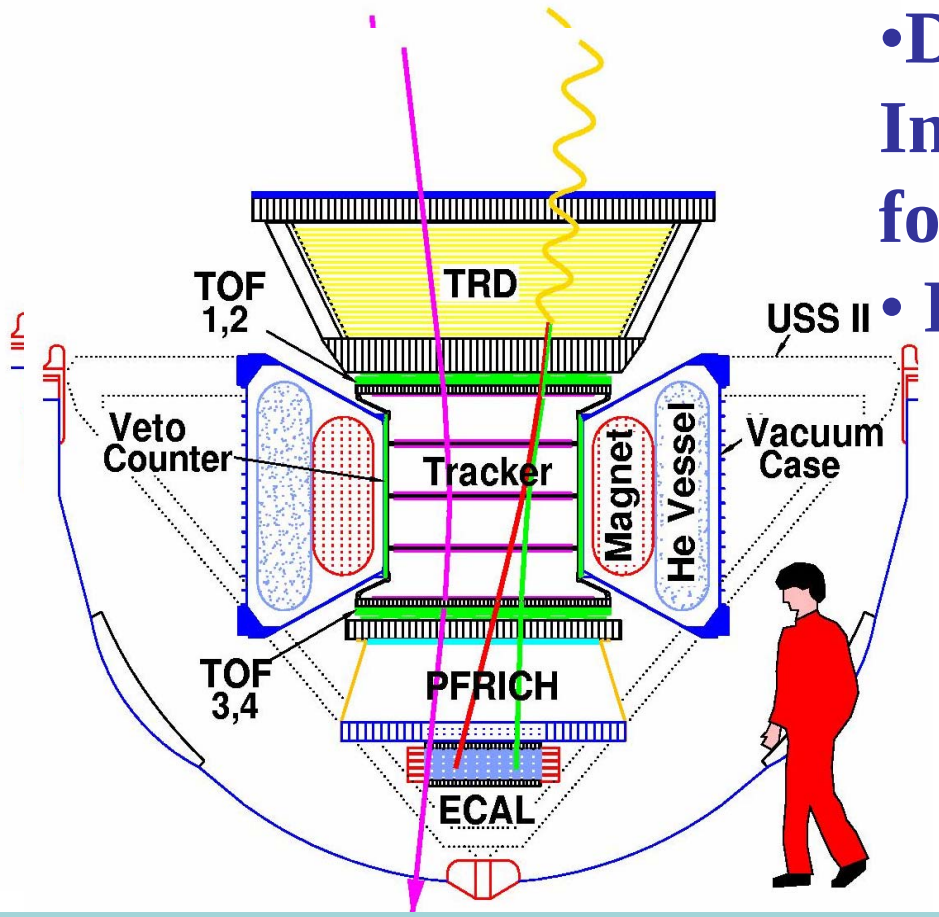
on behalf of AMS Collaboration

Outline

- AMS detector
- γ detection performances:
  - Energy resolution
  - Angular resolution
- Physics: Dark matter γ
  - Minimal Supersymmetric Standard Model
- Conclusions

The Alpha Magnetic Spectrometer

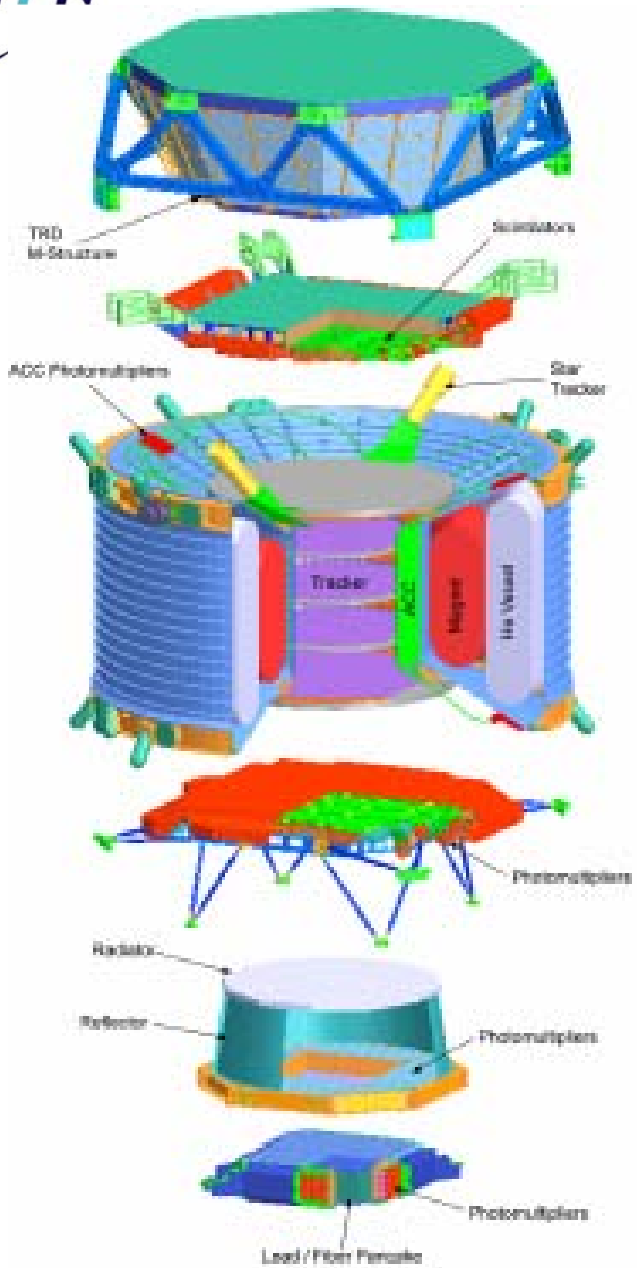


- **Designed to take data on International Space Station for more than 3 years.**
- **Full assembled in 2008**
  - Study of charged particles and nuclei with rigidity 0.5 GV– few TV
  - Direct search for antimatter (antihelium)

Total statistics expected above 10^{10} events

➢ **Indirect search for Dark Matter .**

Dimensions 3m x 3mx3m,7 t Large acceptance ~ 0.5m^{2}sr.



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

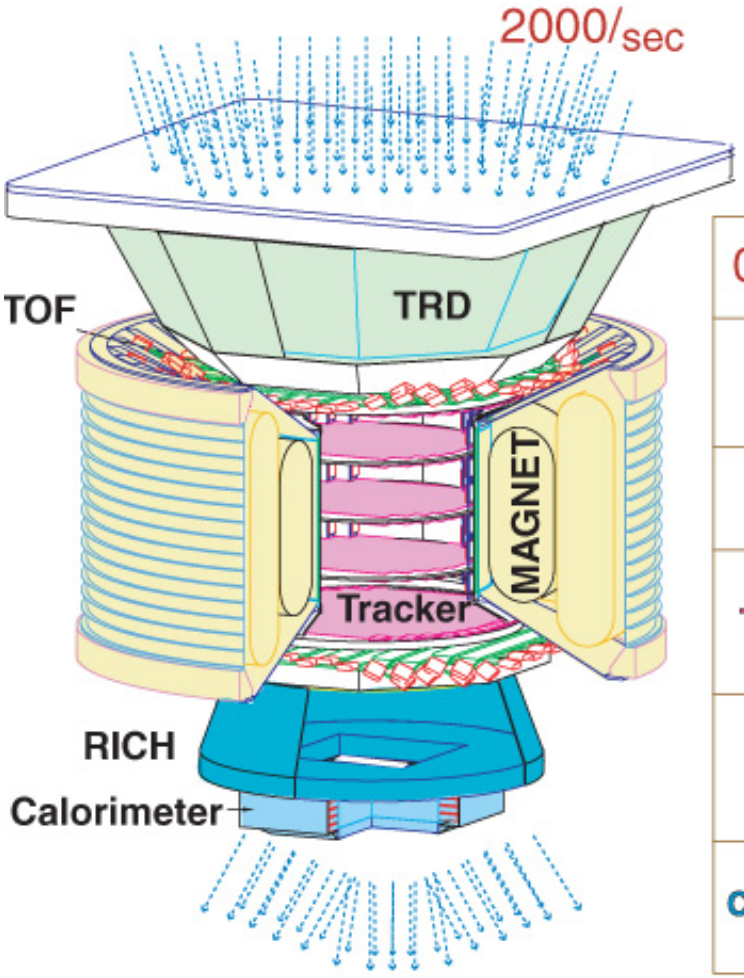
RICH: Ring Image Cherenkov Counter

EMC; Electromagnetic Calorimeter

- **Transition Radiation Detector**
- **Time of Flight scintillator counters**
- **8 layers of Si strips on 5 supporting planes in superconducting magnet**
- **Rich Imaging Cerenkov detector**
- **Electromagnetic calorimeter**

M.L. Arruda Poster

AMS: A TeV Magnetic Spectrometer in Space



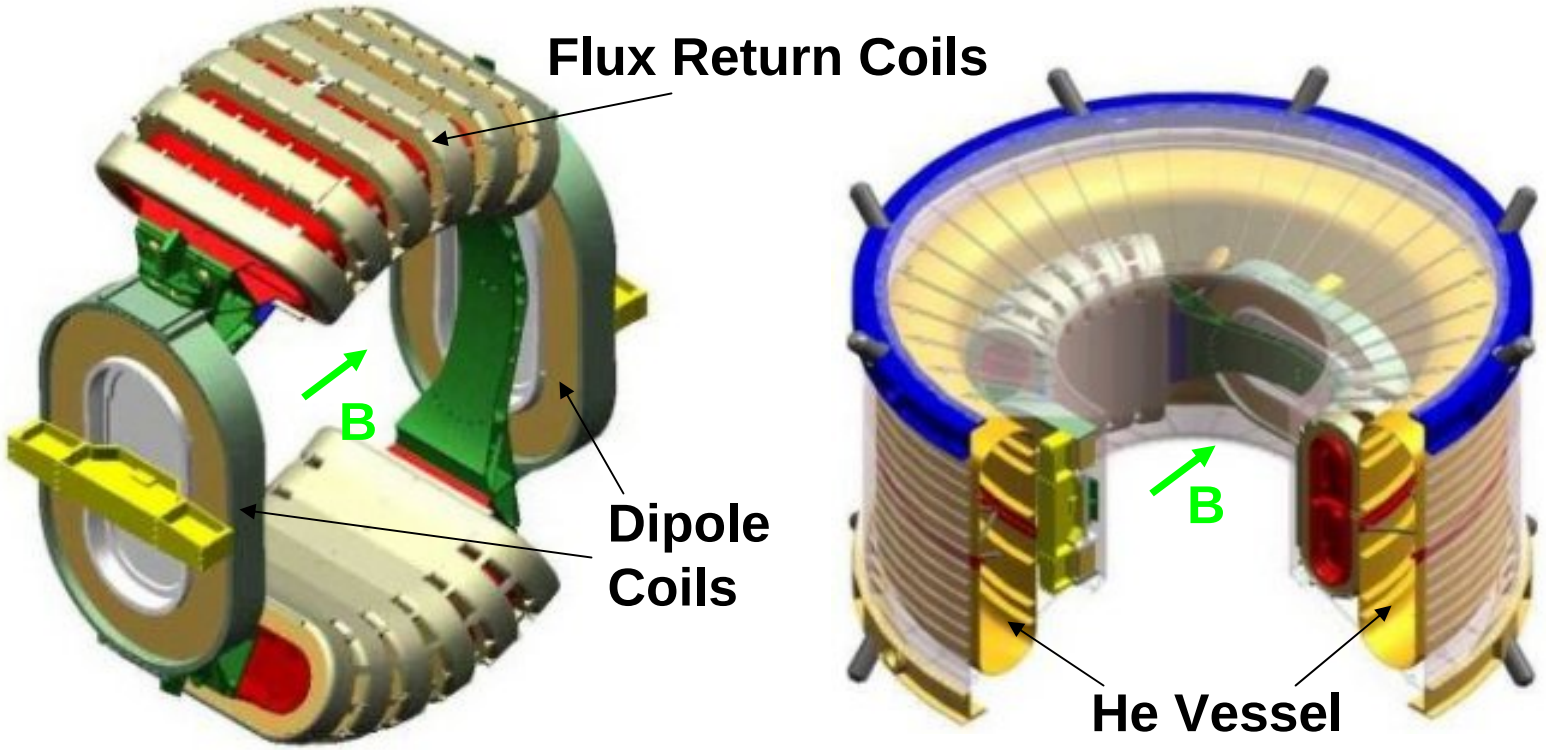
0.3 TeV	e⁻	e+	P	$\bar{He}$	γ
TRD					
TOF					
Tracker					
RICH					
Calorimeter					

y2K025 _5 Gamma

Simonetta Gentile

XX ECRS ,Lisbon, 5th September, 2006

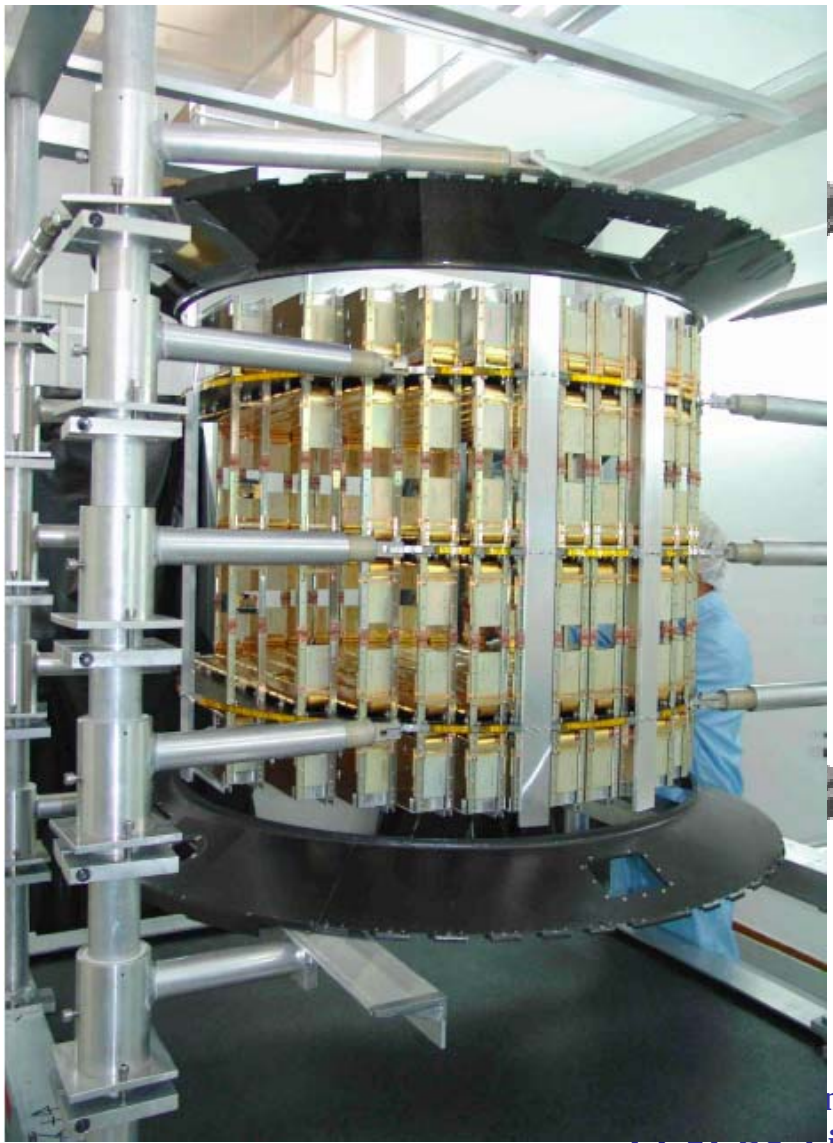
Superconducting Magnet



2500 Liters Superfluid He

$BL^2 = 0.9\ Tm^2$

Silicon Tracker

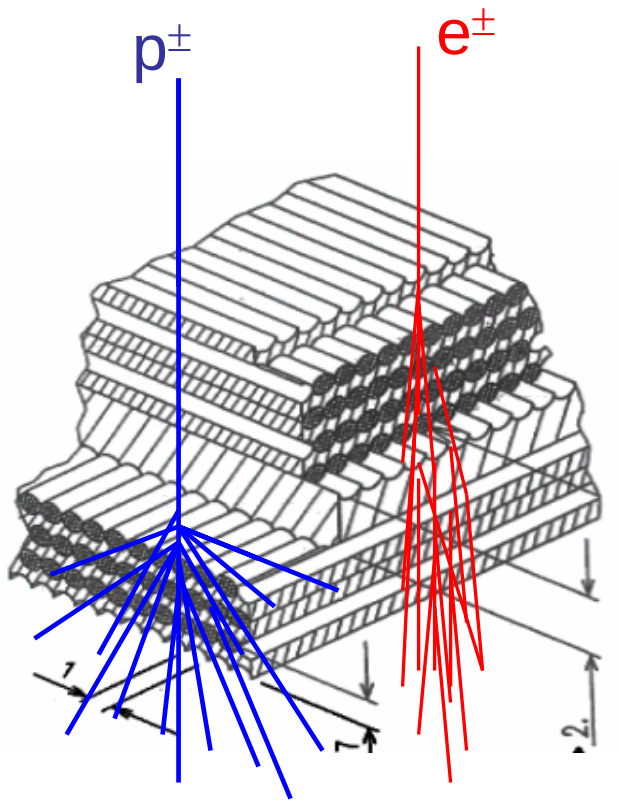


- Rigidity ($\Delta R/R < 2\%$ up 20 GeV Protons) with Magnet
- Signed Charge (dE/dx)
- 8 Layers in 5 planes, ~6.7m^2
- Pitch (Bending): 110 μm (coord. res. 10 μm)
- Pitch (Non-Bending): 208μm (coord. res. 30 μm)
- Charge magnitude up Z ~ 26

Electromagnetic Calorimeter

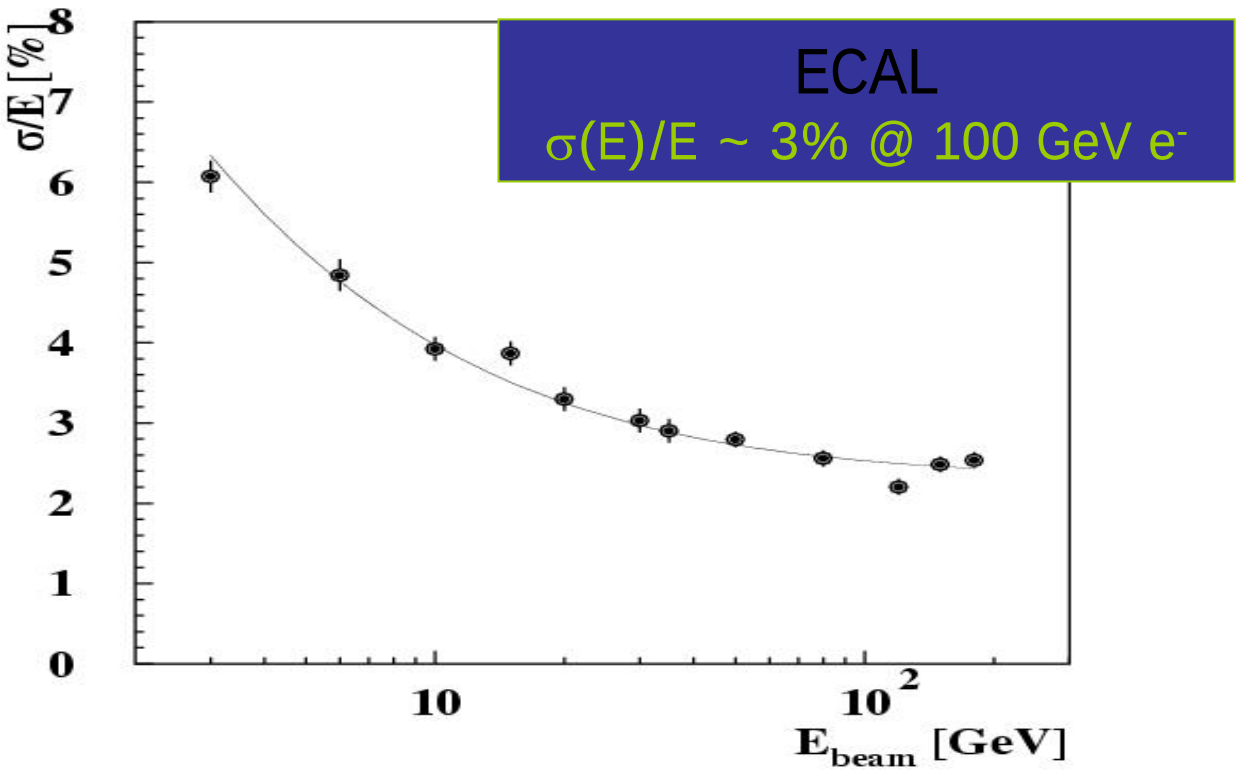
3D sampling calorimeter

- 9 superlayers of 10 fiber/lead planes each alternate in x and y scintillating fibers viewed by PMT
- 16.4 X_0 radiation length
- **Measure energy** (few % resolution) and angle (1° - 0.5° angular resolution) of γ, e^+,e^-

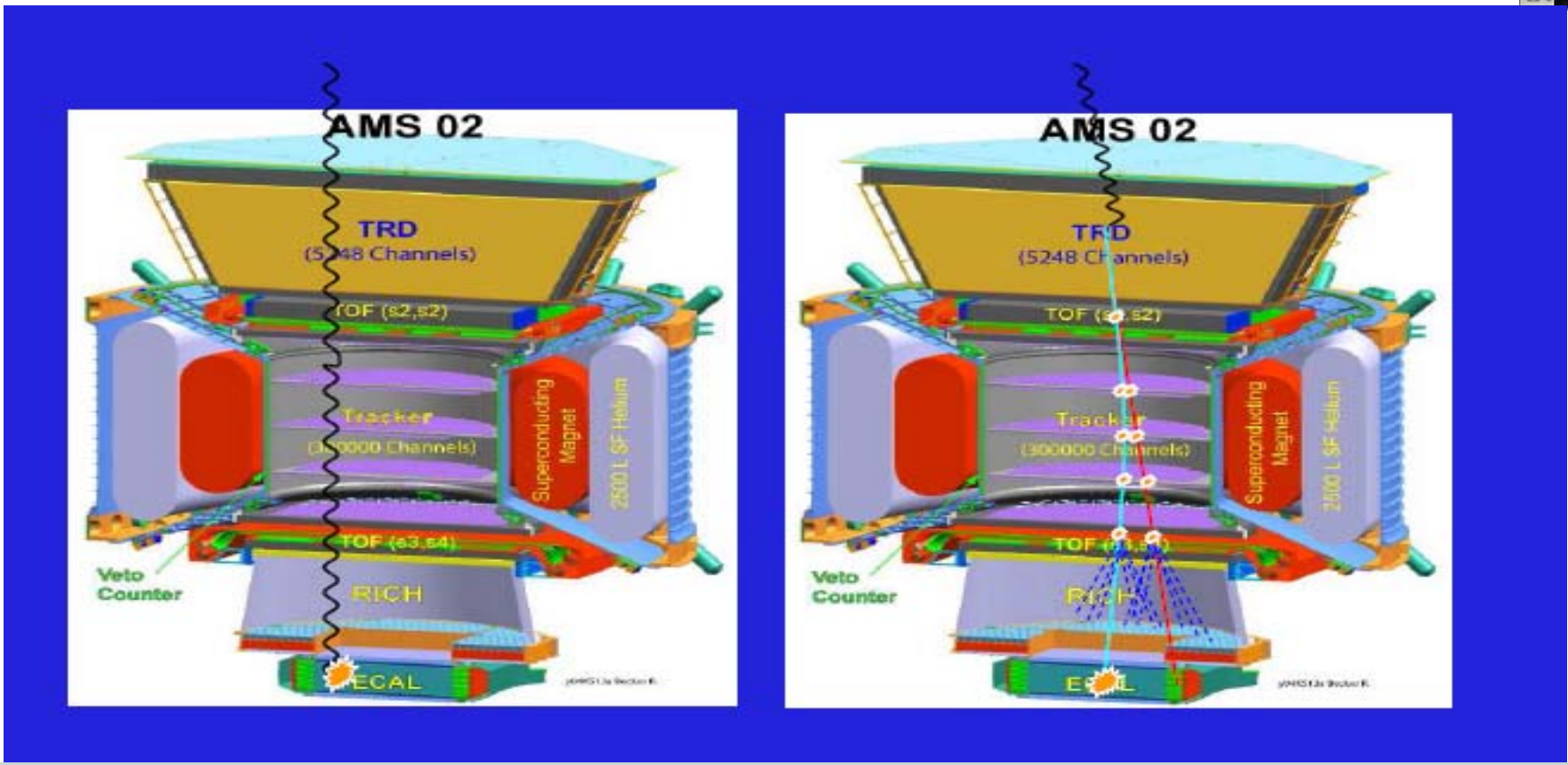


10^{-3} $p^{\pm}$ Rejection with 95% $e^{\pm}$ Efficiency Via Shower Profile
1 GeV - 1 TeV

Electromagnetic Calorimeter



Photons in AMS: Two complementary modes

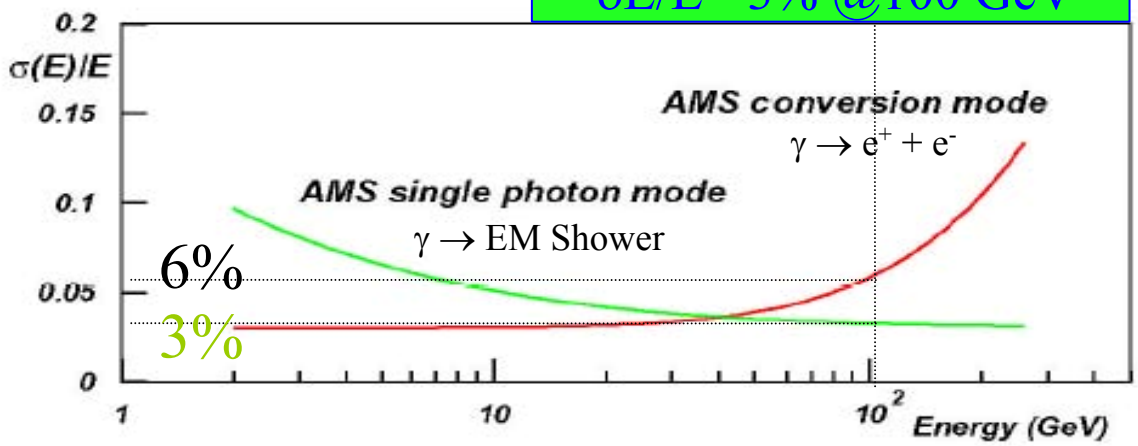


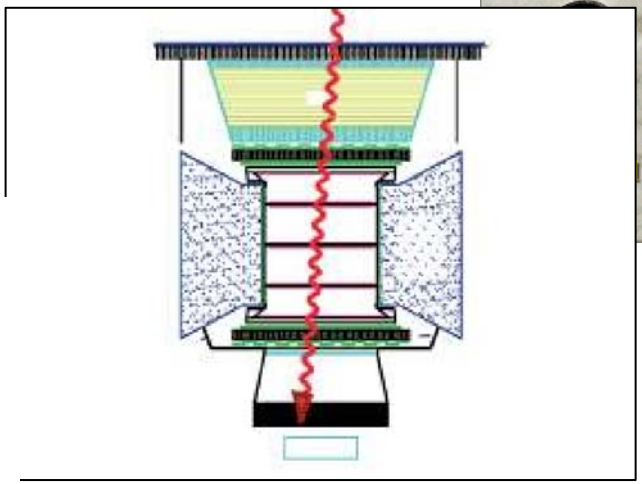
Single photon mode: detection
In the electromagnetic calorimeter.
Criteria: "electromagnetic shape"
No activity in the rest of detector

Conversion mode: γ conversion
In upstream layers of the detector
Criteria:very small invariant mass, no TRD
Activity in top layer, no particle activity
in the rest of detector

Performances γ-rays detection

δE/E~ 3% @100 GeV

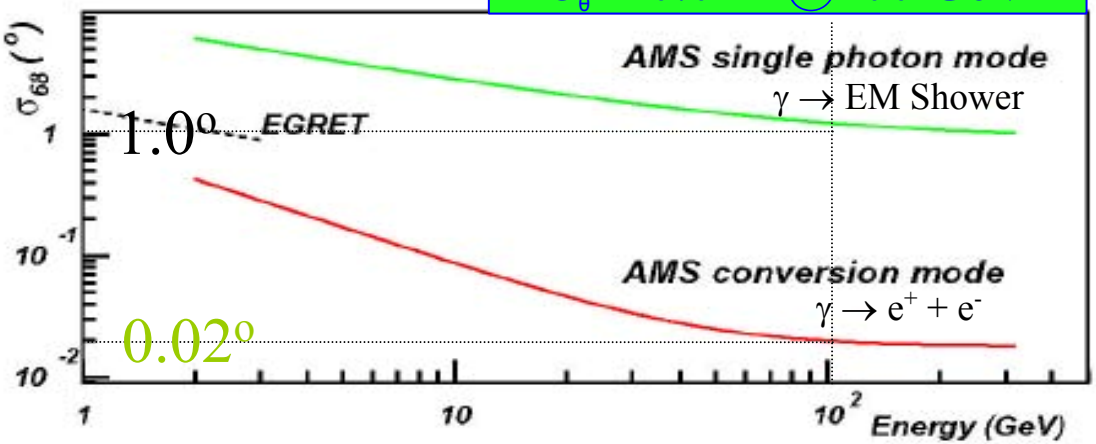


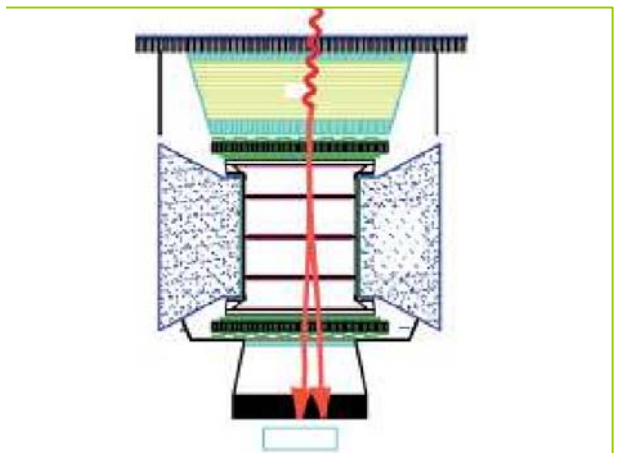


Single Photon Mode

γ → EM Shower

σ_θ ~ 0.02 º @100 GeV



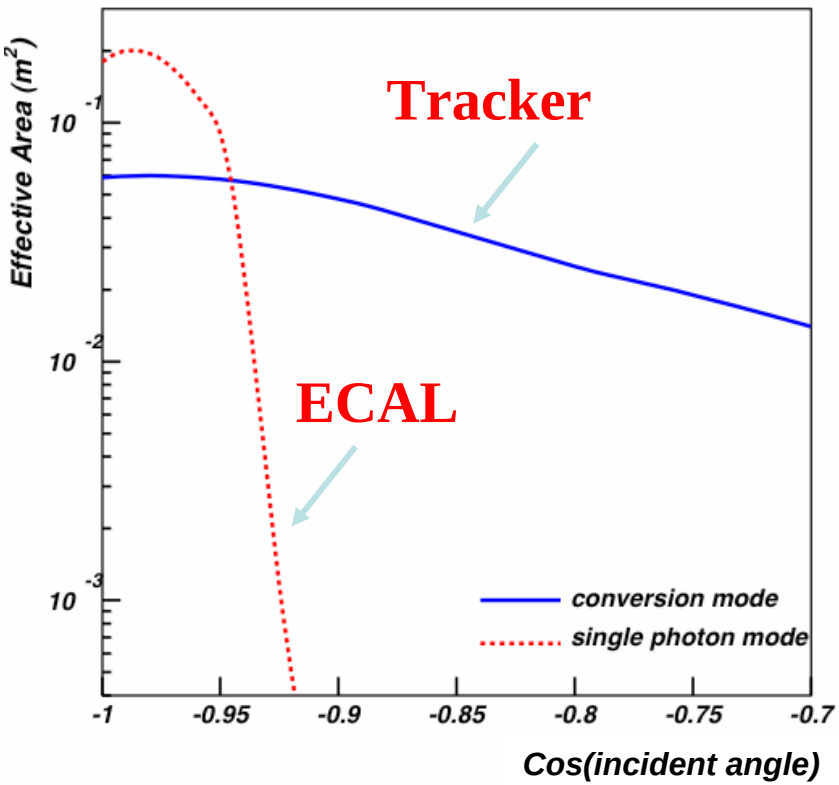


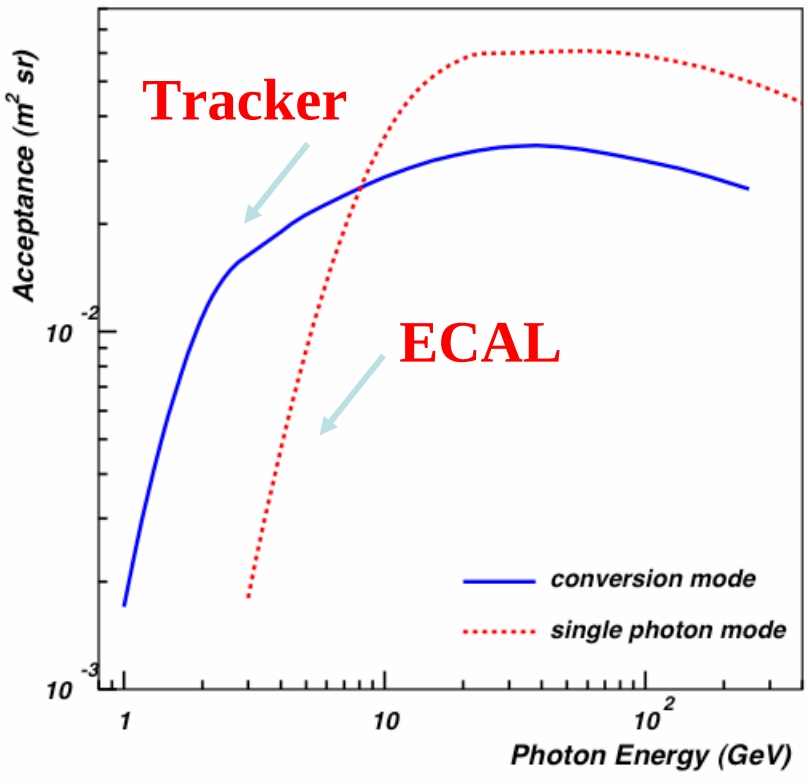
Conversion Mode

γ → e+ + e-

Performances γ-rays detection

Effective Area of Tracker and ECAL

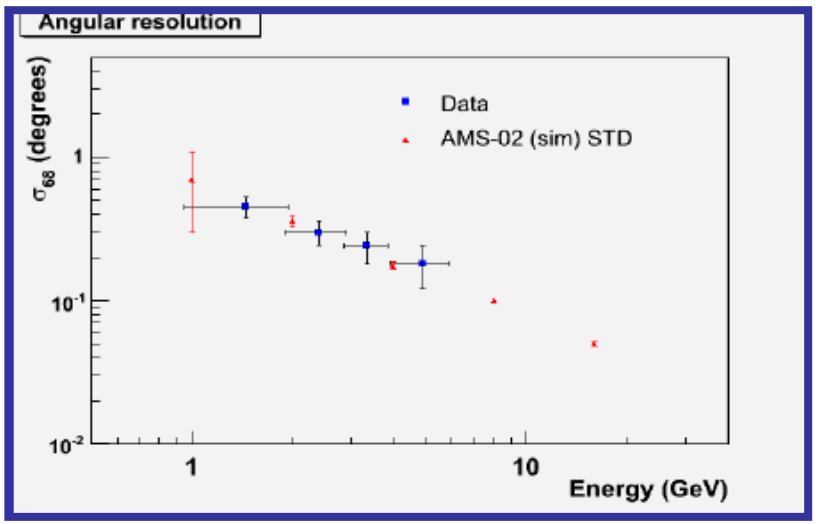


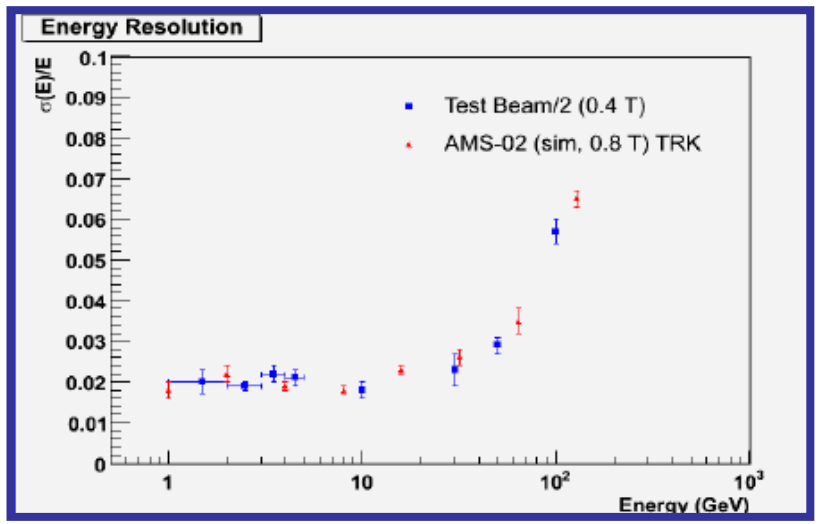


- **Acceptance ECAL (TRK)** ~ 5 (3)·10^{-2} m^2·sr from 10 GeV.
- **Proton rejection 10^5 ; e^- ~ 10^4**

Test beam (conversion mode)

- Test beam with electrons (producing γ up to 7 GeV).
- Dominant systematic multiple scattering of electrons



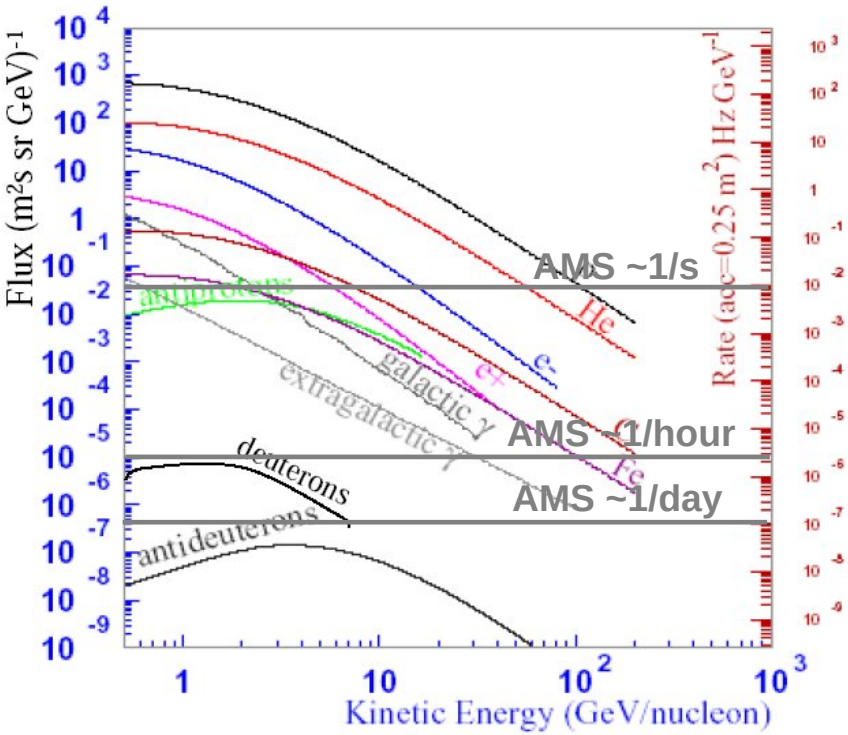


γ Origin

- Energy range : 1-300 GeV
- Sources in scope of AMS:
  - Galactic : pulsars, nebulas (VELA, CRAB,…)
  - Extra-Galactic : GRBs
- Diffuse γ emission : interaction of Charged rays with galactic medium produce γ (π^0)
- Dark Matter

R. Pereira
Poster

Cosmic Ray Fluxes

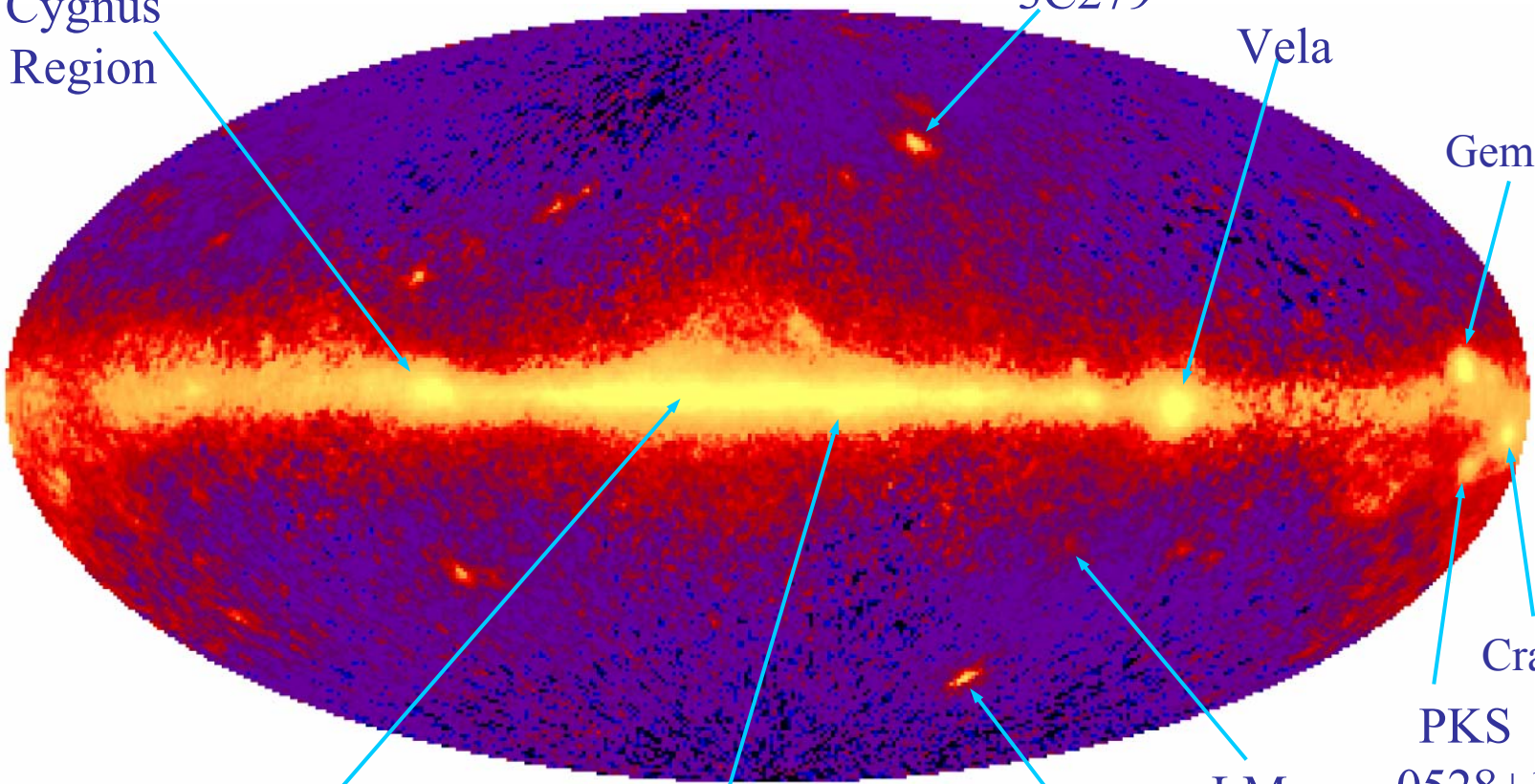


Number of particles inside geometrical acceptance
(assuming 0.45 m^2sr)

- Cosmic Rays Composition :
  - p : 88 %
  - He nuclei : 9 %
  - e^- : 2 %
  - γ : < 1%
- Standard CR spectra follows a "power law"
  $E^{-\beta}$ with $\beta = 2\text{-}3$
- DM signal : exponential cut-off in the spectra

γ rays

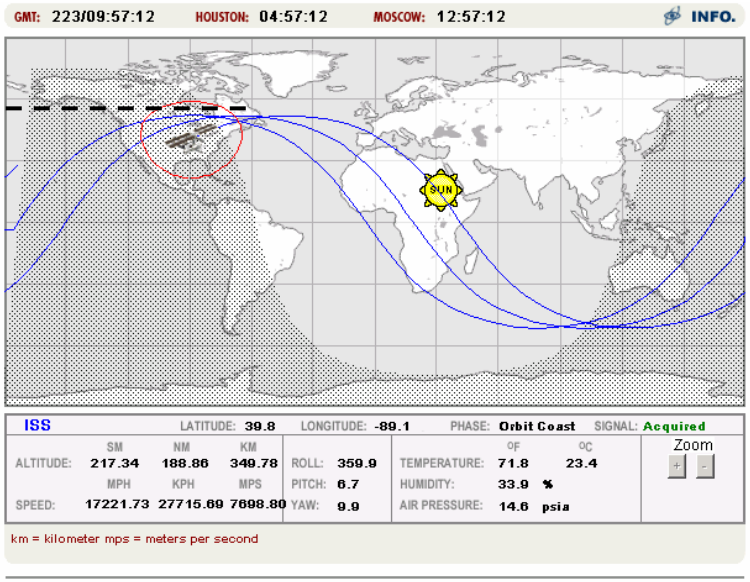
EGRET map Eγ>100 MeV



AMS exposure to galactic γ

51° latitude

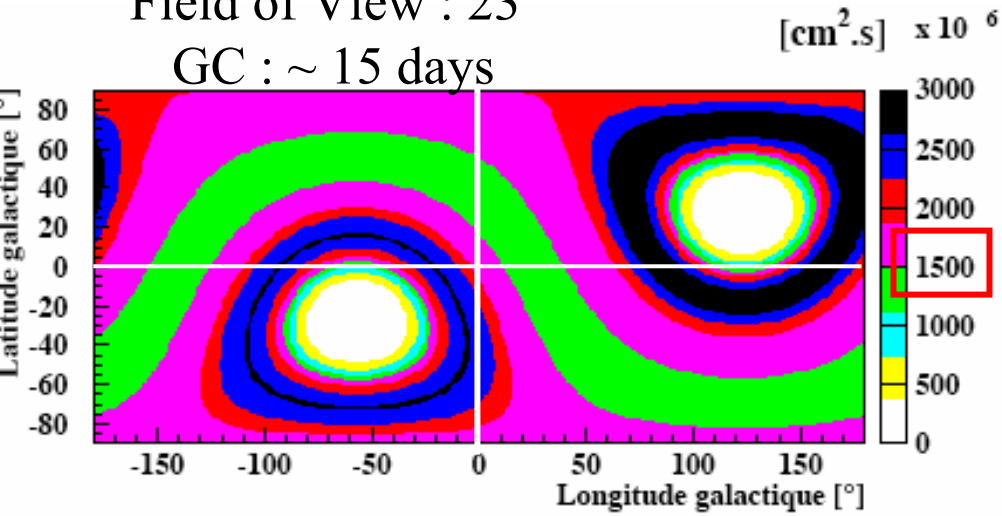
Revolution : 90



Calorimeter mode (geom. acc.= area x t_{obs})

Field of View : 23°

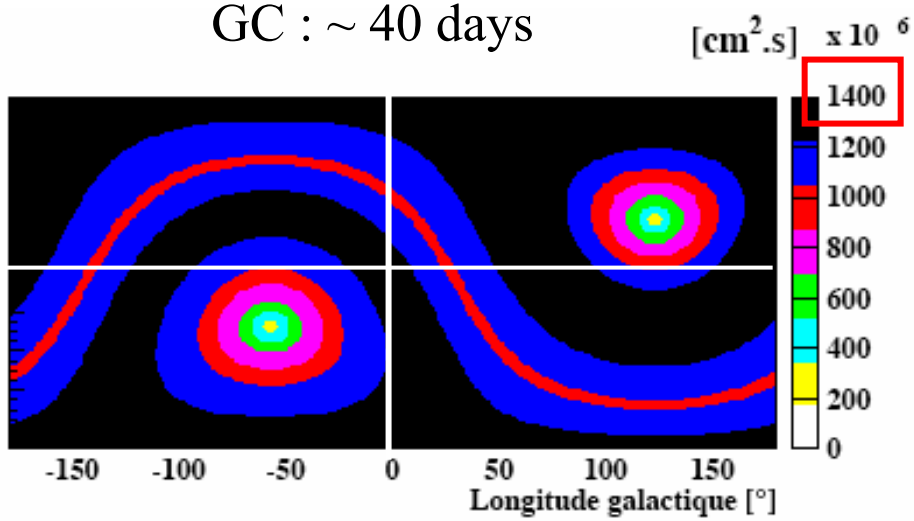
GC : ~ 15 days



Conversion mode (sel. acc.)

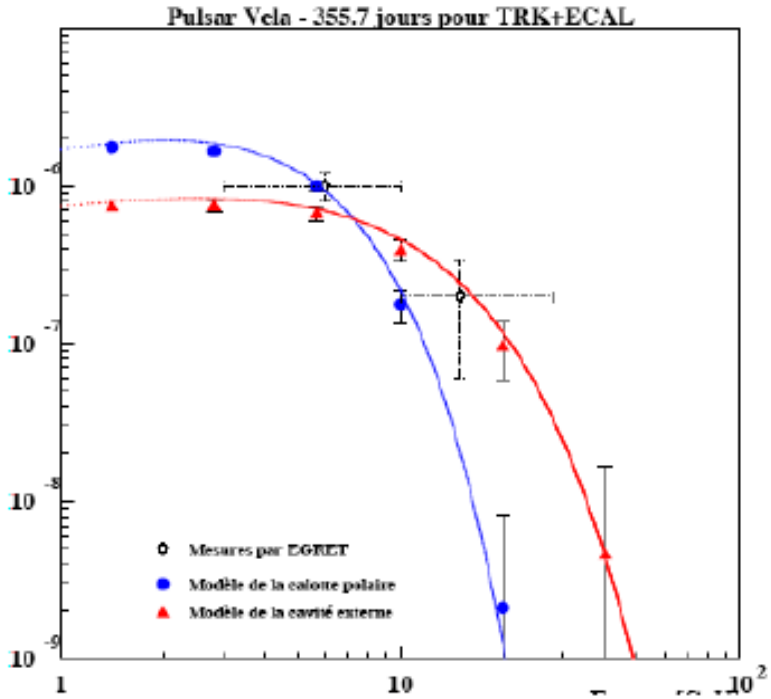
Larger Field of view: 43°

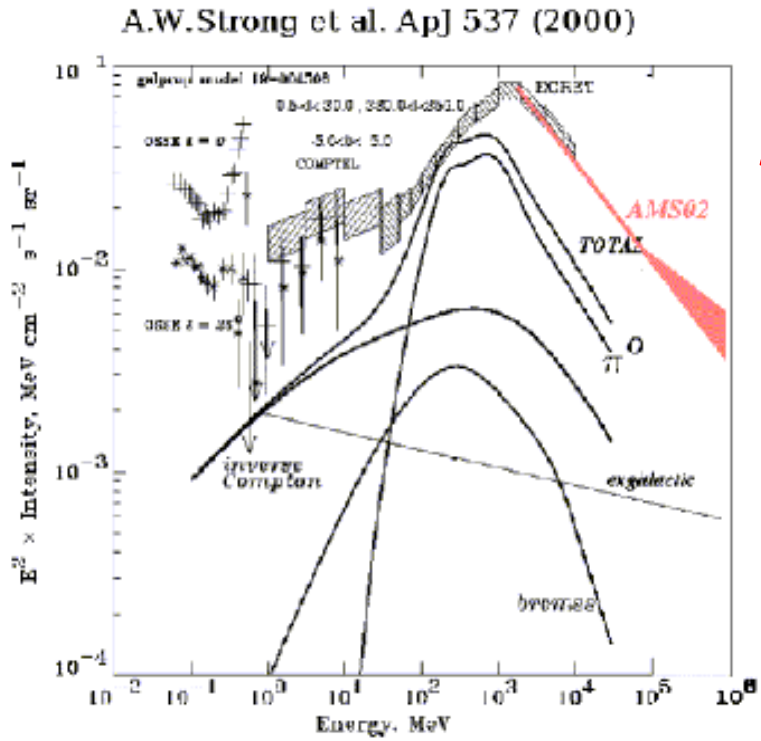
GC : ~ 40 days



Astrophysical γ sources

AMS expectations





γ rays emission from Vela Pulsar

Measurements and model prediction for diffuse γ rays from central part of galaxy

Dark Matter

- One of the most popular candidates for Dark matter is the **neutralino χ^0, the Lightest Supersymmetric Particle (LSP),** neutral, weak-interacting and stable in R-parity conserving SUSY models.

NOT YET OBSERVED!

$$\tilde{\chi}_1^0 = a_0\tilde{B} + b_0\tilde{W} + c_0\tilde{H}_1^0 + d_0\tilde{H}_2^0 + \Rightarrow$$

Mixture of superpartners of Higgs boson and W-boson and Z/γ bosons (B)

- Direct detection – elastic interaction on nucleus (CDMS, DAMA, EDELWEISS)

Indirect detection - Neutralino annihilation

$$\chi^0_1\chi^0_1 \rightarrow q\,\bar{q},\ W^+W^-,\ ZZ,\ \ldots$$

$$\rightarrow\ \bar{p},\ \bar{D},\ \gamma\ \text{(continuum)},\ e^+$$

Indirect searches with AMS: detection channels

Possible detectable products from: $\chi\chi \rightarrow xx$ with **small physical backgrounds**

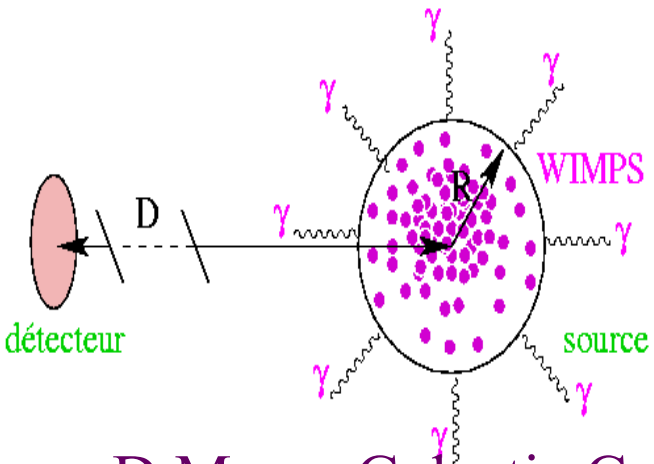
- **Gamma rays:**
  - They are originated either from annihilation into a final state containing $Z\gamma$ or $\gamma\gamma$ (line signal) or from the decay of other primary annihilation products (continuum signal).
- **Positrons:**
  - Primarily from the decay of gauge bosons (e.g.,W^+W^-) as primary annihilation products; or from heavy quark/lepton decay
- **Antiprotons and antideuterons**:
  - Production in WIMP annihilations by hadronization of quark and gluon subproducts.

γ ray telescopes and satellites

Balloons

AMS

Dark Matter - γ ray case



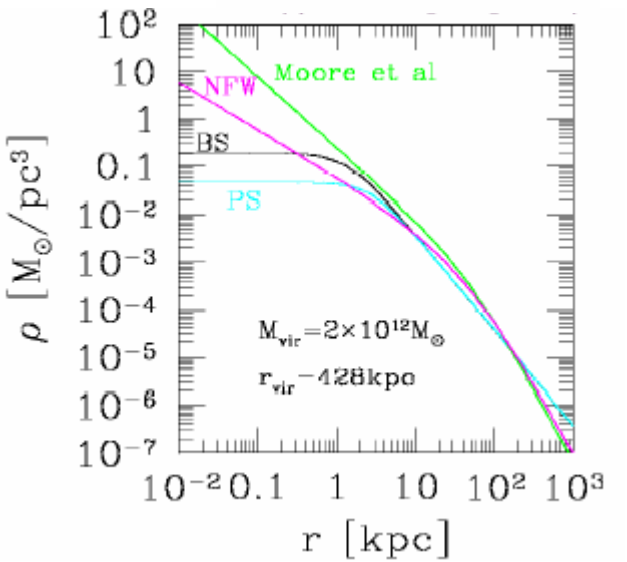
Detection rate (source) :

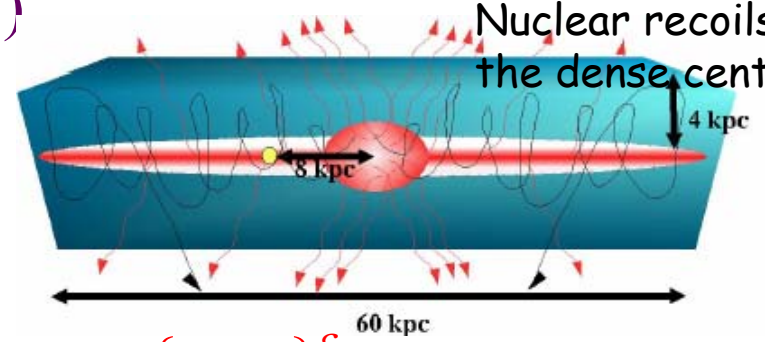
$$\Phi\gamma \sim \frac{N\gamma \langle\sigma v\rangle}{m^2_\chi} \int\int \rho^2(r)\, dl(\theta)\, d\Omega$$

LoS

SUSY — Astrophysics

• source D M : γ Galactic Centre (G. C.)





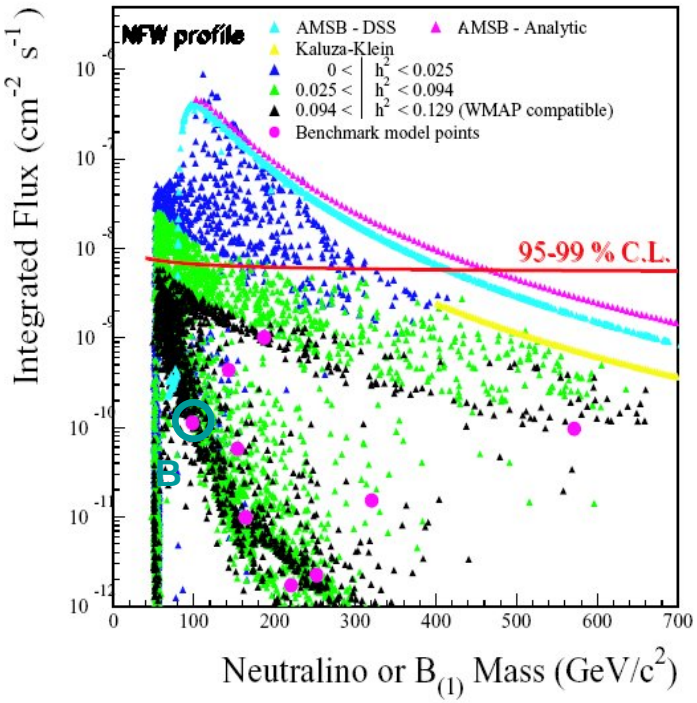
$$\rho_{\tilde{\chi}}(r) = \rho_{\tilde{\chi}}(r_0)\left(\frac{r_0}{r}\right)^{\gamma}\left\{\frac{r_0^{\alpha}+a^{\alpha}}{r^{\alpha}+a^{\alpha}}\right\}^{\varepsilon}$$

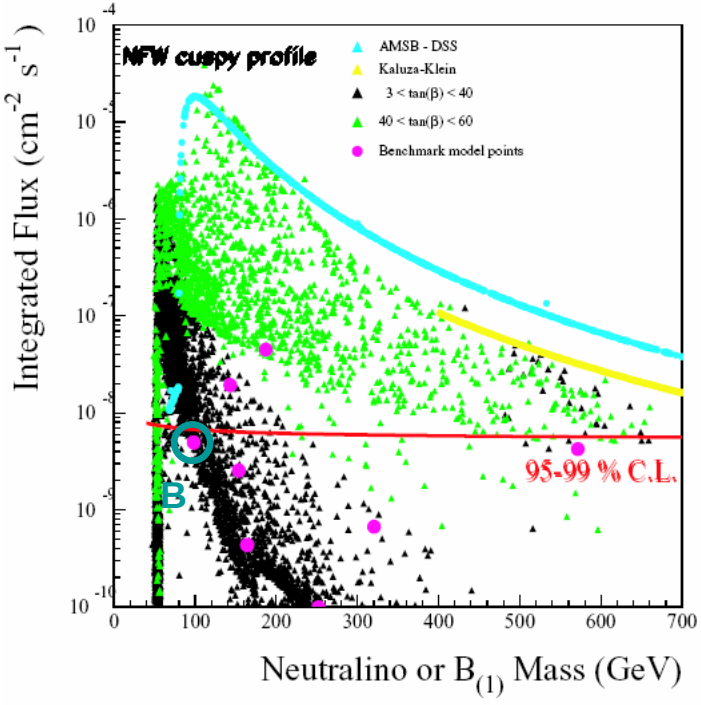
Mass density Profile in our Galaxy

NFW : Navarro-Frenk-White $(\alpha, \varepsilon, \gamma) = (1, 2, 1)$

Moore et al. : $(\alpha, \varepsilon, \gamma) = (1, 1.5, 1.5)$

Gamma sensitivity to different DM halo profiles





Gamma rays

- Many experiments will be covering the little known 1-300 GeV range in the next decade.
- Case considered: Galactic center treated as point source. Favorable conditions to detect or exclude AMSB scenarios; benchmark points of parameter space accesible in case of cuspy profile as well as several KK candidates.

A.Jacholkwska et al. Astro-ph/0508349, Phys. Rev D.74 vol 2

MSSM = Minimal SuperSymetric Model

mSUGRA = Minimal SUGRA model

SUGRA = SuperGravity grand unified models

AMSB = Anomaly Mediated SUSY Breaking

Predictions for benchmark fluxes Galactic Centre

- mSUGRA models MC simulation
- Accelerators & WMAP constraints
- Various DM halo profiles

J. Ellis *et al.* Eur. Phys. J. C24 (2002) 311

Model	B	G	I	K	L
m_χ	98.3	153.6	143.0	571.5	187.2
m_0	59.0	116.0	178.0	999.0	299.0
tan β	10.	20.	35.	38.2	47
Ω_{relic}	0.12	0.13	0.13	0.09	0.10
n_γ (NFW)	0.2	0.1	0.8	0.3	2.1
n_γ (NFW cuspy)	5.5	3.5	24.5	9.1	64.7
n_γ (Moore)	15.8	10.2	70.4	26.2	185.4

A.Jacholkwska et al. Astro-ph/0508349, Phys. Rev D. 74 vol2

3 years of operation

CONCLUSIONS

AMS02 is magnetic spectrometer on International Space Station, ready in 2008:

- **Large Acceptance**
- **Long term operation**

AMS02 will provide:

- **Precise Cosmic Ray elemental and isotopic fluxes in a wide energy range**
- **Direct search for antimatter (antihelium)**
- **Indirect search for Dark Matter (positrons, antiprotrons, gamma).**
- **Good γ performance detection through conversion and and calorimetric mode:**
  - **Angular resolution** under **~3º** (~**0.1º**) over 10 GeV.
  - **Energy resolution** ~**3** % over 10 GeV

CONCLUSIONS

- **Using Si-Tracker and EM Calorimeter, AMS-02 will provide new γ measurements in the range 1-300 GeV .**
- **AMS-02 will study several galactic and extragalactic γ sources as Pulsars, GRBs…**
- **(At least) constraints in various Cold Dark Models will be provided.**

γ-rays - AMS vs.

- Similarities: Silicon for Tracker, Coverage 1-100 GeV
- GLAST: quasi-independent detector operation, charged particle vetoing, conversion-optimized