# Cosmic Ray and Gamma Astrophysics with AMS-02 Experiment


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on behalf of the AMS Collaboration


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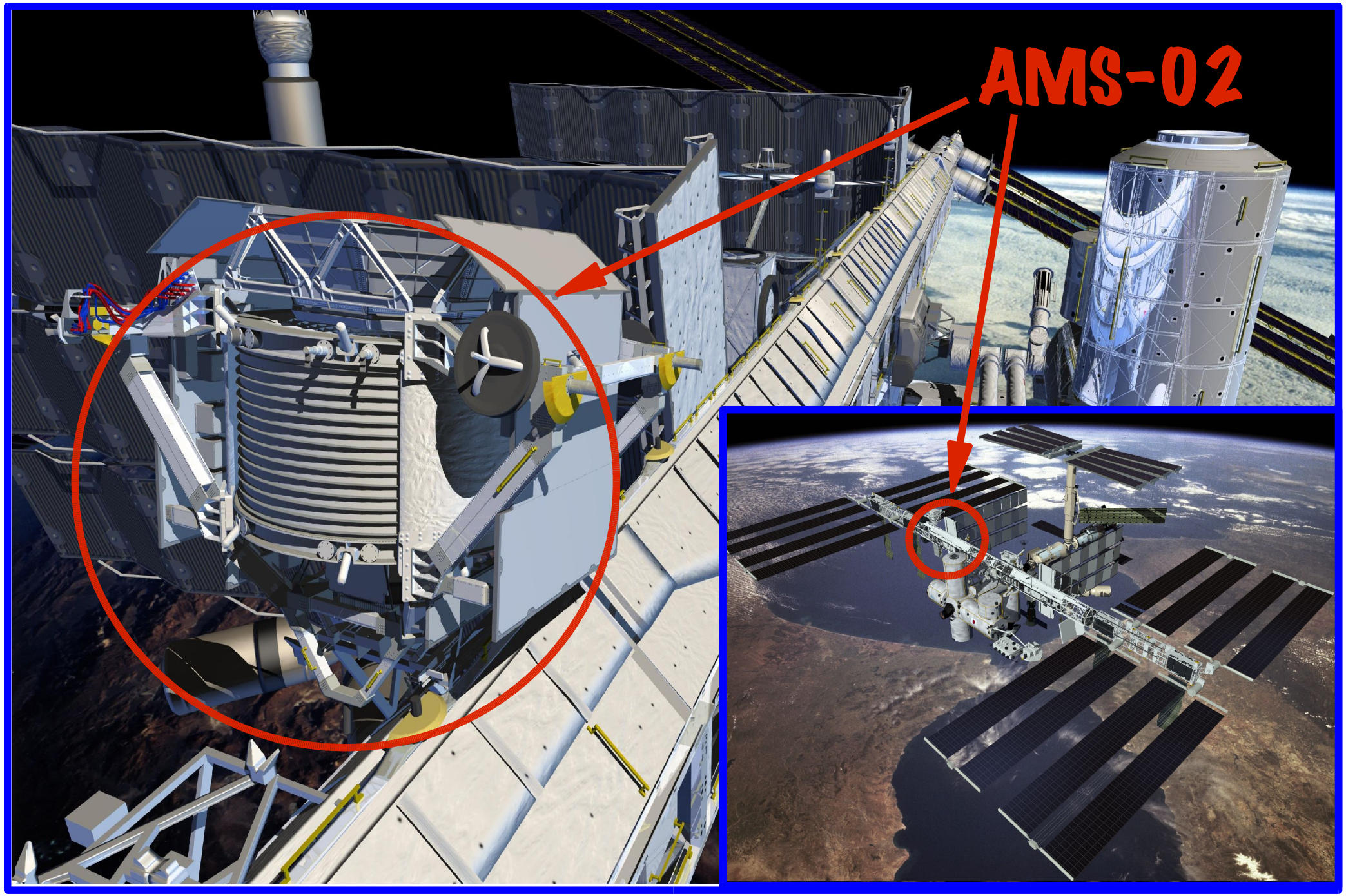
**Outline:**

- ✔ ISS and AMS-02
- ✔ Physics Goals
- ✔ The Detector
- ✔ AMS-02 Expected Performances
- ✔ Conclusions

UNIVERSITÉ DE GENÈVE

# AMS-02 on the International Space Station (ISS)





# The Alpha Magnetic Spectrometer (AMS)

*A large acceptance and high precision magnetic spectrometer on the ISS*

✔ *Orbital parameters of ISS:*

*Orbital period ~ 92 min*

*Mean altitude ~ 382 km*

*Inclination ~ 51.6°*

✔ *Main Physics topics:*

*Origin and transport of cosmic rays (from 1GeV to 1TeV)*

*Antimatter ($e^+$, $\bar{p}$, $\bar{N}$)*

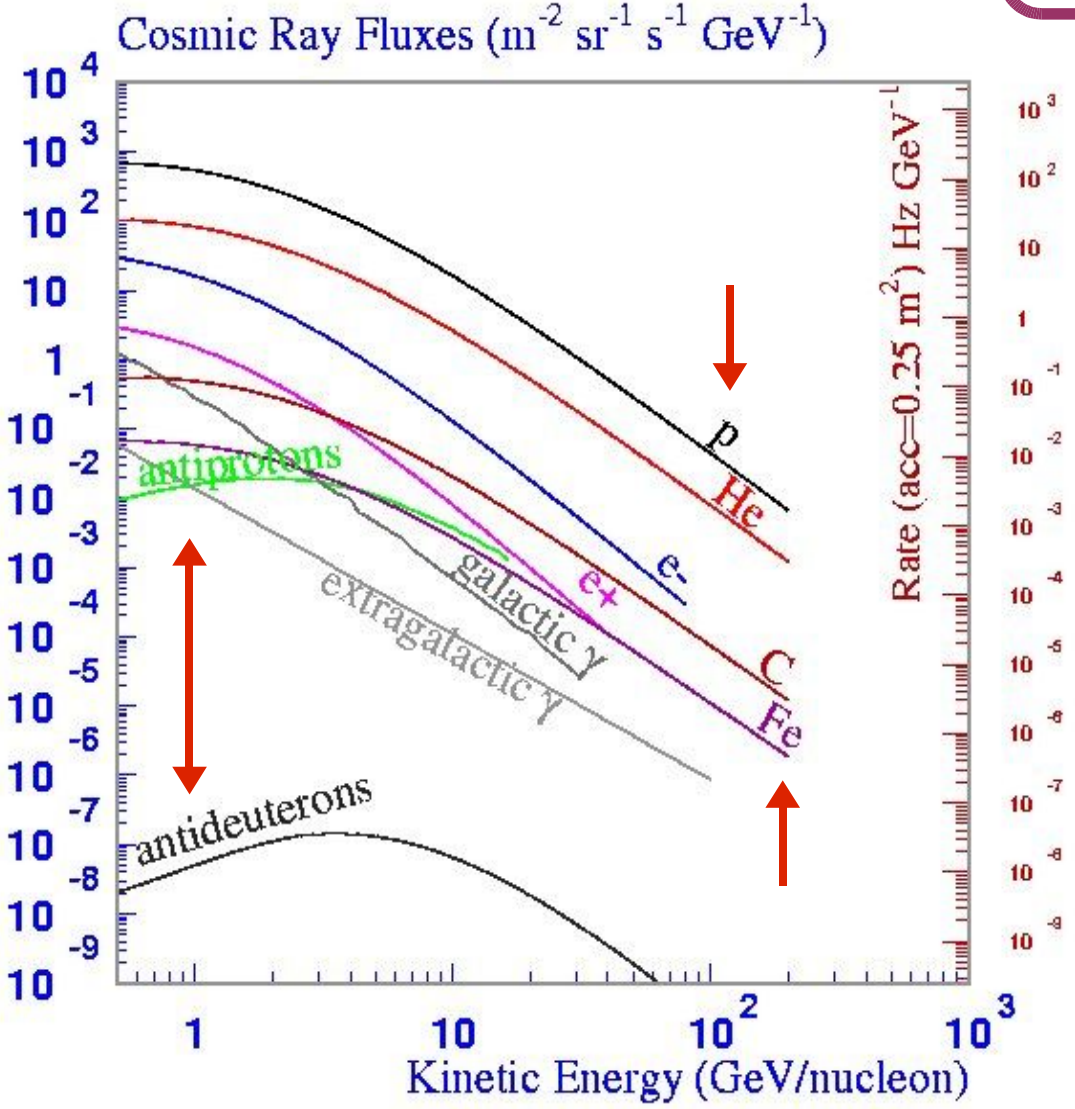
*Dark matter ($e^+$, $\bar{p}$, $\gamma$, $\bar{D}$)*

*Study of galactic and extragalactic $\gamma$-rays*

# Cosmic Rays

**AMS-02 will collect in 3 years:**

- *p: dominant component ($2x10^{10}$)*
- *He: 5% of p flux @ 10GeV*
- *D, Li, Be, B and C*
- *Anti-proton: ~ $10^{-4}$ of p flux*



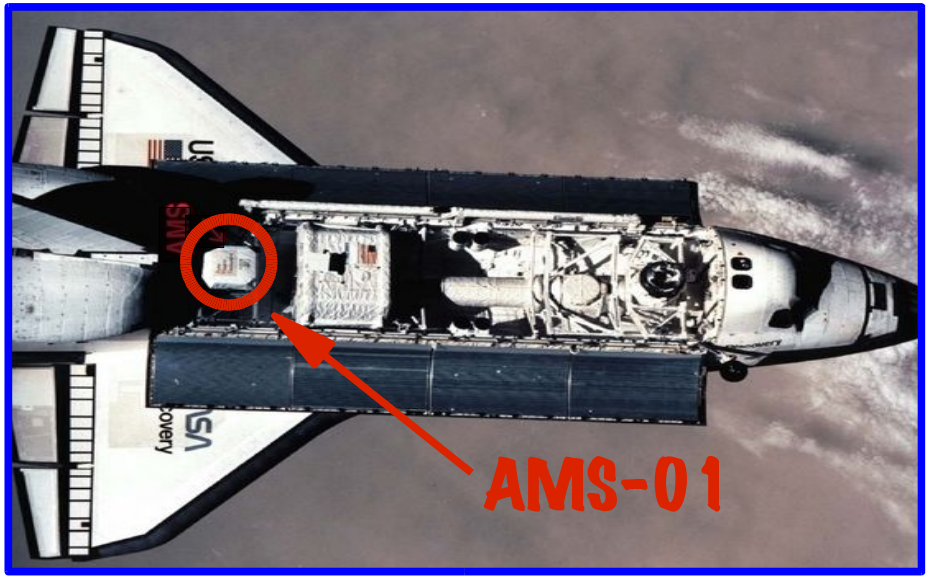

***Protons:*** *a way to measure the solar activity.*

***Isotopes:*** *information on the propagation of Cosmic Rays in the Galaxy.*

***$^{10}$Be/$^{9}$Be ratio ($^{10}$Be → 1.6x10$^6$yrs):***

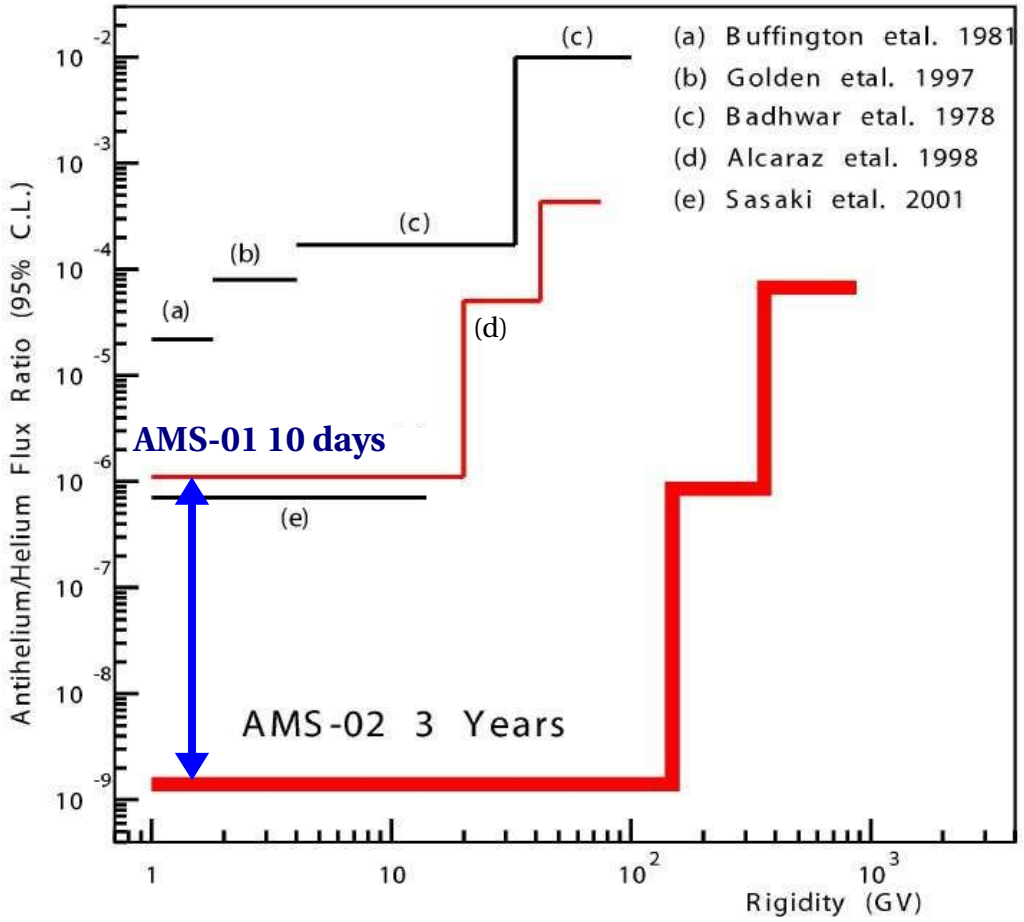
- *Cosmic Rays confinement time in the Galaxy*
- *Mean density of interstellar material traversed.*

# Antimatter




*The Big Bang Theory requires* matter and antimatter *equally abundant*.

*Antimatter within our cluster of galaxies excluded: no photon annihilation signal.*




- *Single anti-He Cosmic Rays nucleus:* → *Antimatter Domains*
- *Single anti-C Cosmic Rays nucleus:* → *Antimatter Stars*

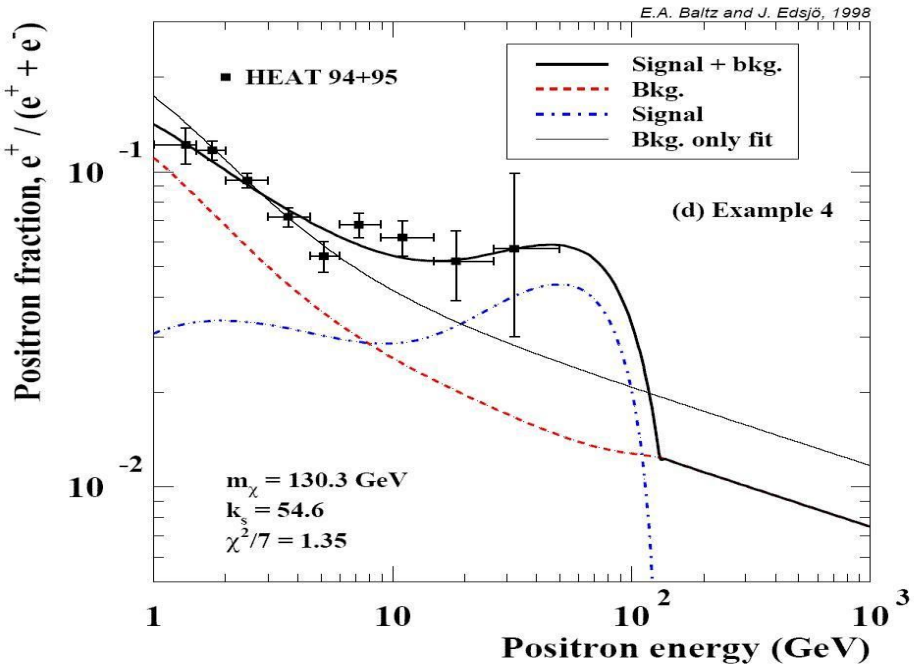
# Dark Matter

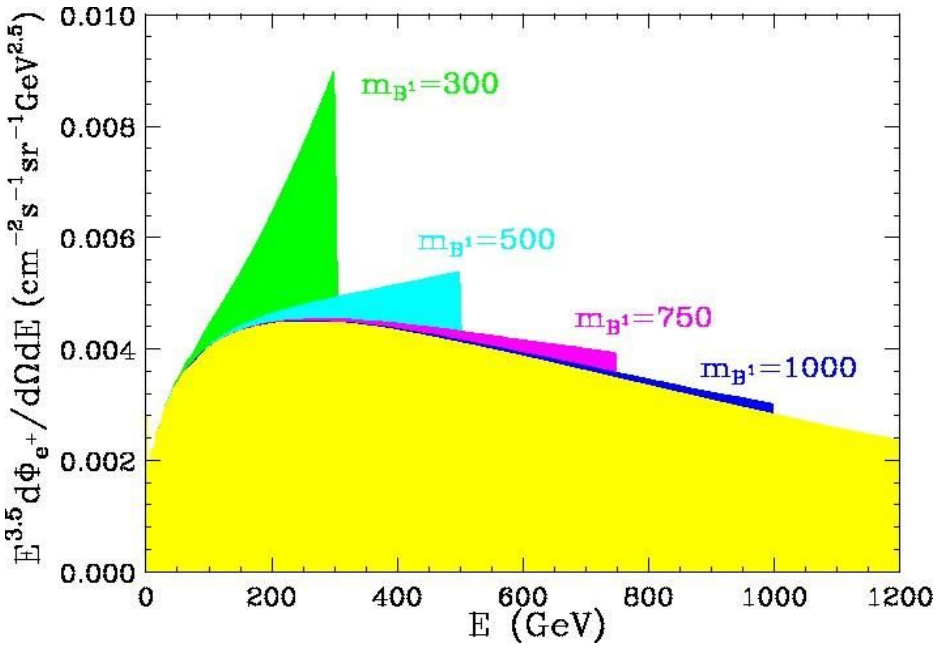
*Annihilation of neutralinos in the galactic halo might produce a visible contribution to the anti-particle and photon spectra :*

$\tilde{\chi}^0 \tilde{\chi}^0 \rightarrow q\bar{q} \rightarrow \bar{p} + \ldots.$

$\rightarrow W^+W^-, ZZ \rightarrow e^+ + \ldots.$

$\rightarrow W^+W^-, ZZ \rightarrow \gamma + \ldots.$



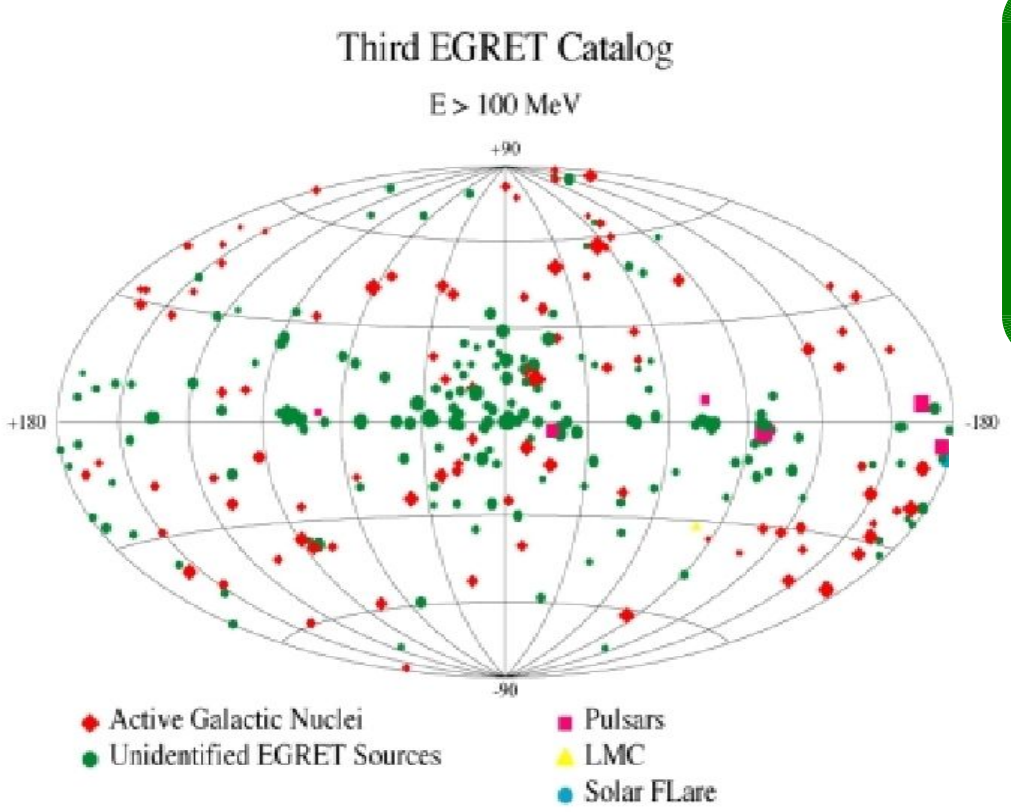




*AMS-02 is conceived to measure:*

- *$\bar{p}$ spectrum (~ 1GV< R < 200 GV, R=pc/Ze)*
- *$e^+$ structure in spectra above few GeV*

**See Corinne Goy's talk in Dark Energy IV Session**

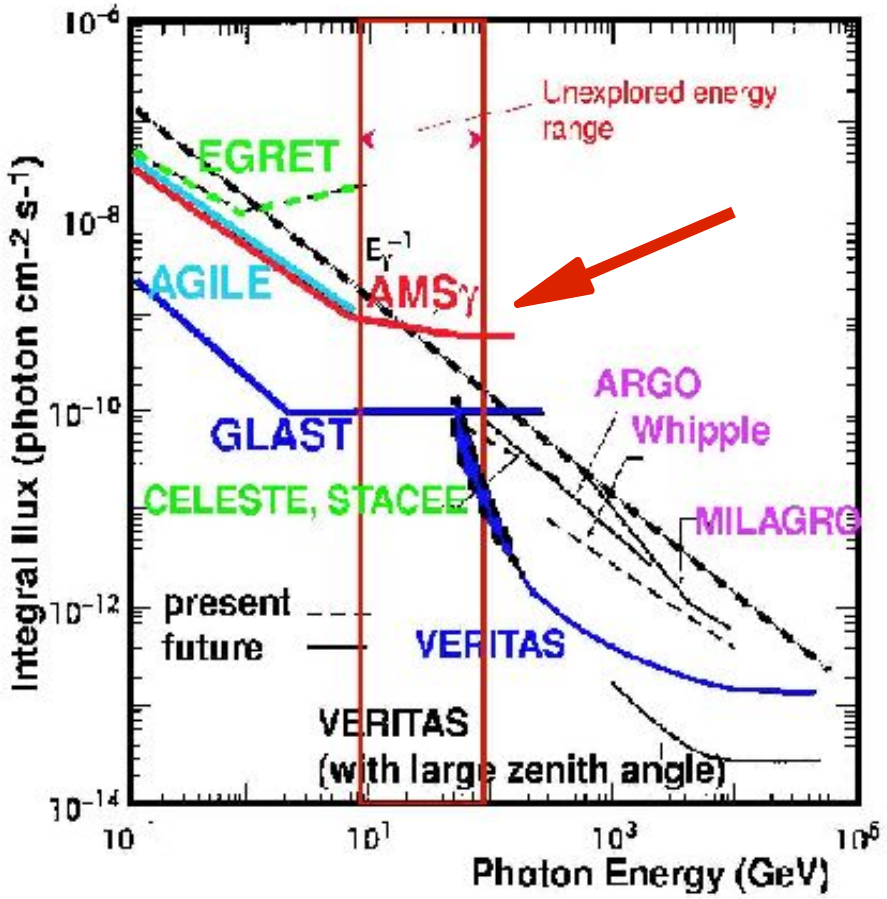
# High Energy γ-Rays



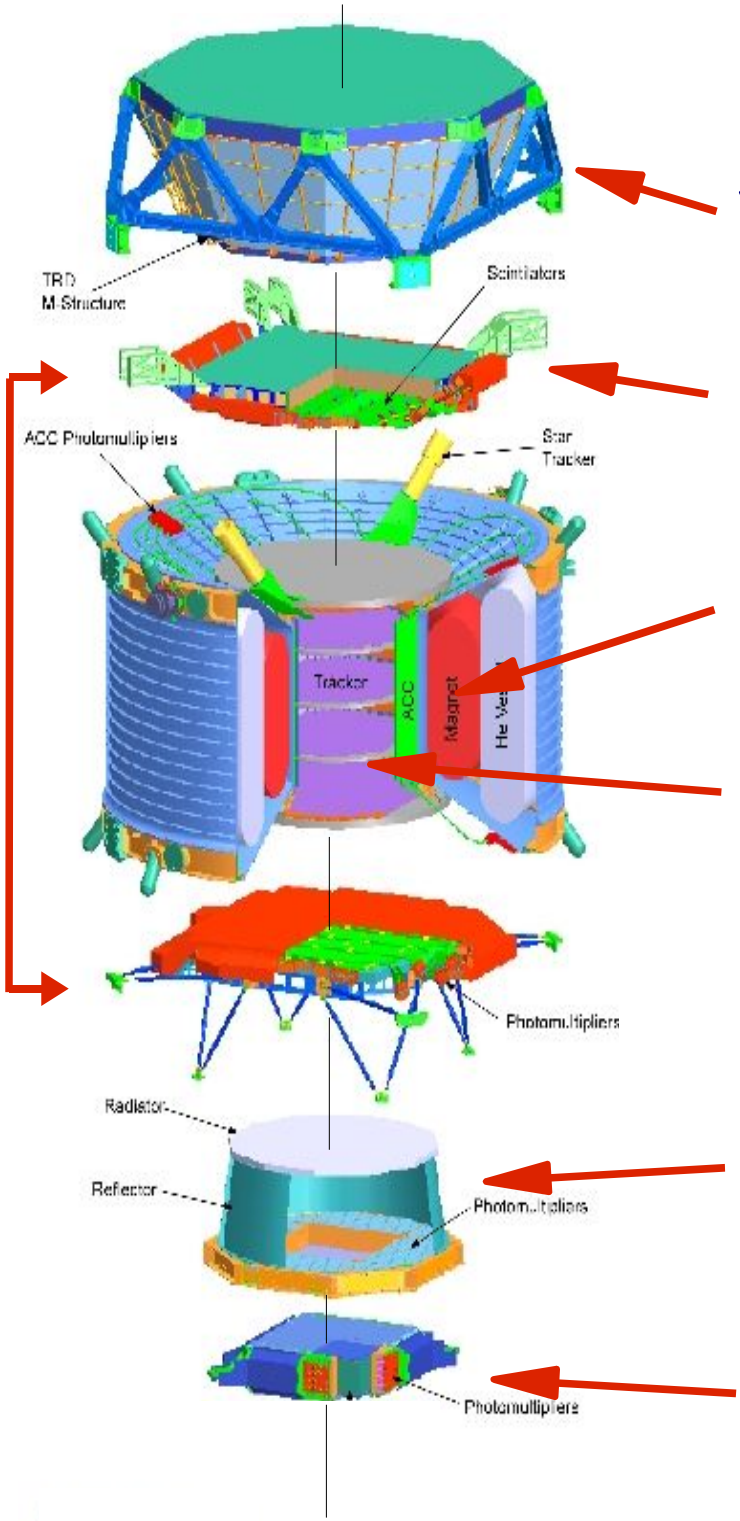

***AMS-02 will constantly monitor the γ-ray sky to complement the observations in other wavelength bands.***

***~ 280 pointlike γ-ray sources detected by EGRET:***

***~ 70 Active Galactic Nuclei (AGNs)***
***~ 7 Pulsars***
***~ 200 sources not identified yet***



# AMS-02 Detector




**Transition radiation :** *allows hadron/electron separation*

**Time of Flight :** *measures time of flight, velocity β, direction and dE/dx*

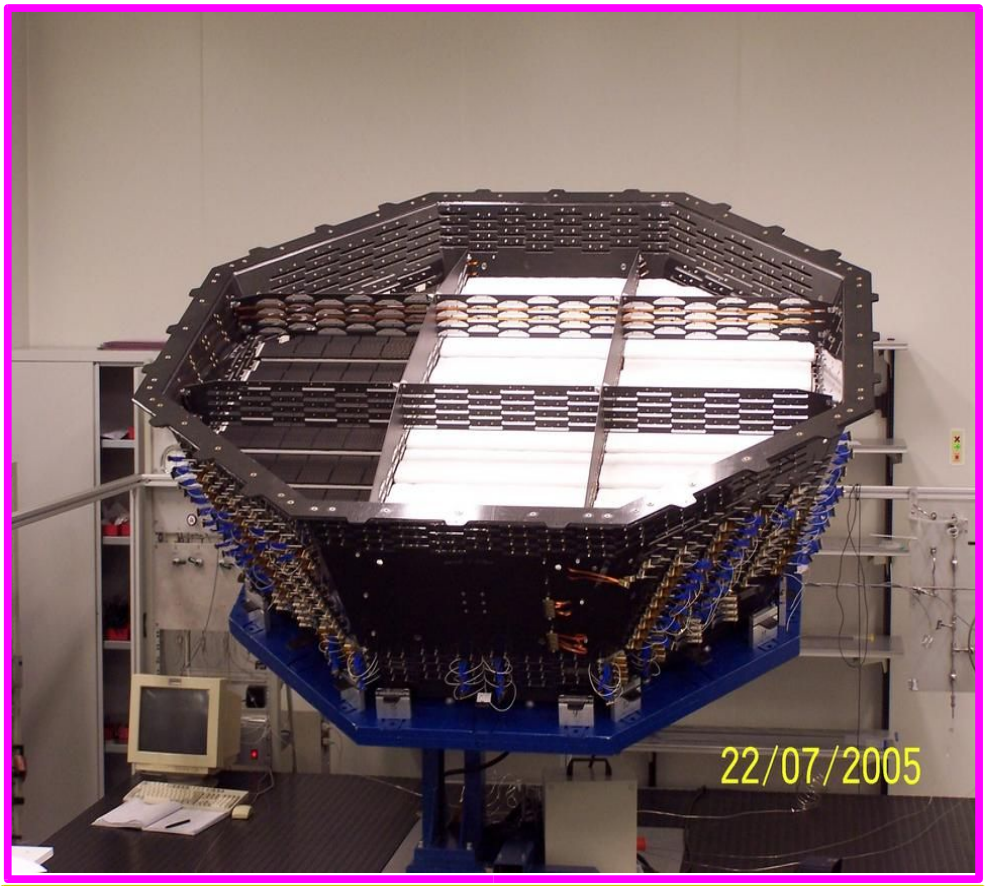
**Magnet :** *superconducting magnet (B=0.8T)*

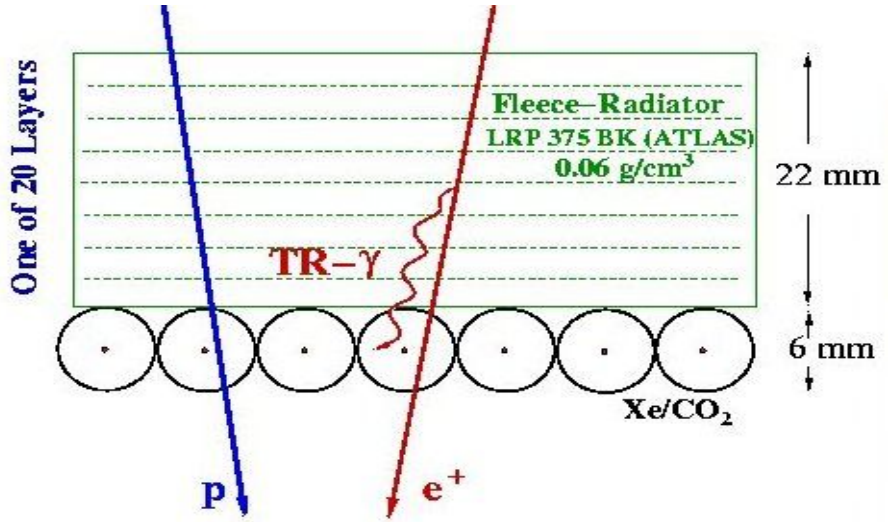
**Tracker :** *charged particle localization, rigidity with magnet, specific energy loss ($dE/dx \sim |Z|^2$), direction and energy of converted photons*

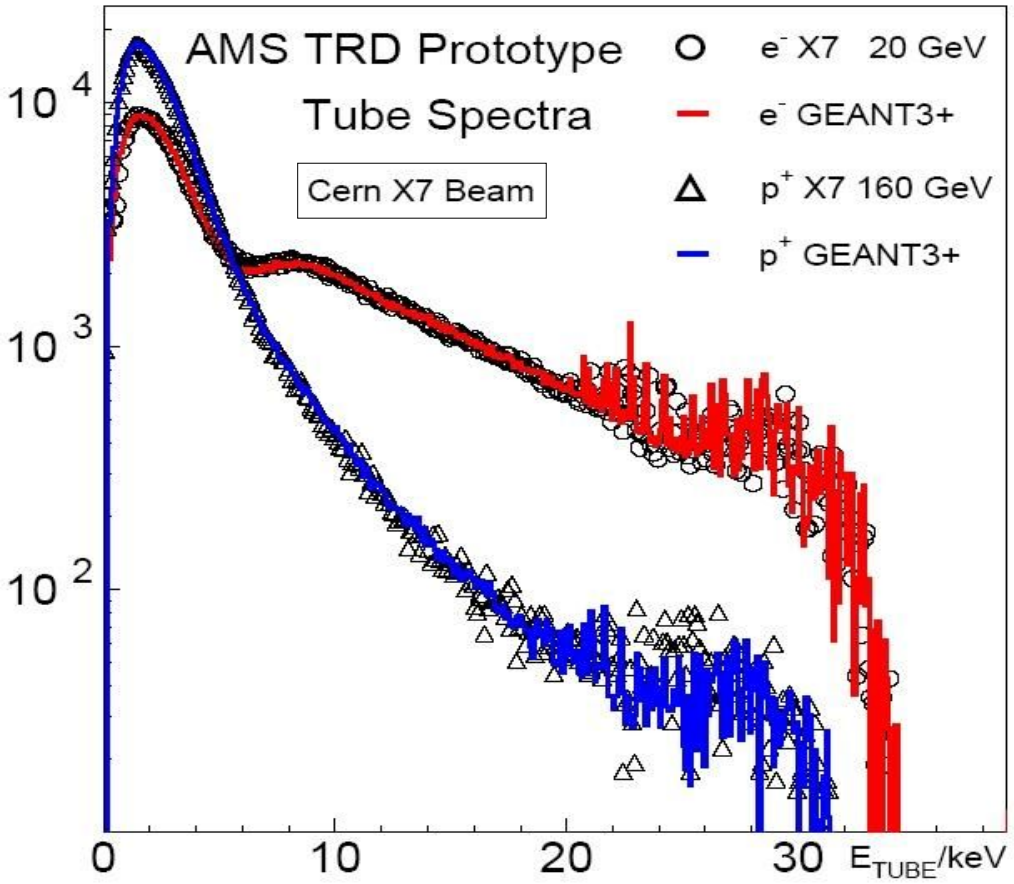
**Cerenkov :** *velocity β, energy loss dE/dx and mass measurements*

**E.m. Calorimeter :** *lepton/photon energy and lepton/hadron separation*

# AMS-02 Transition Radiation Detector



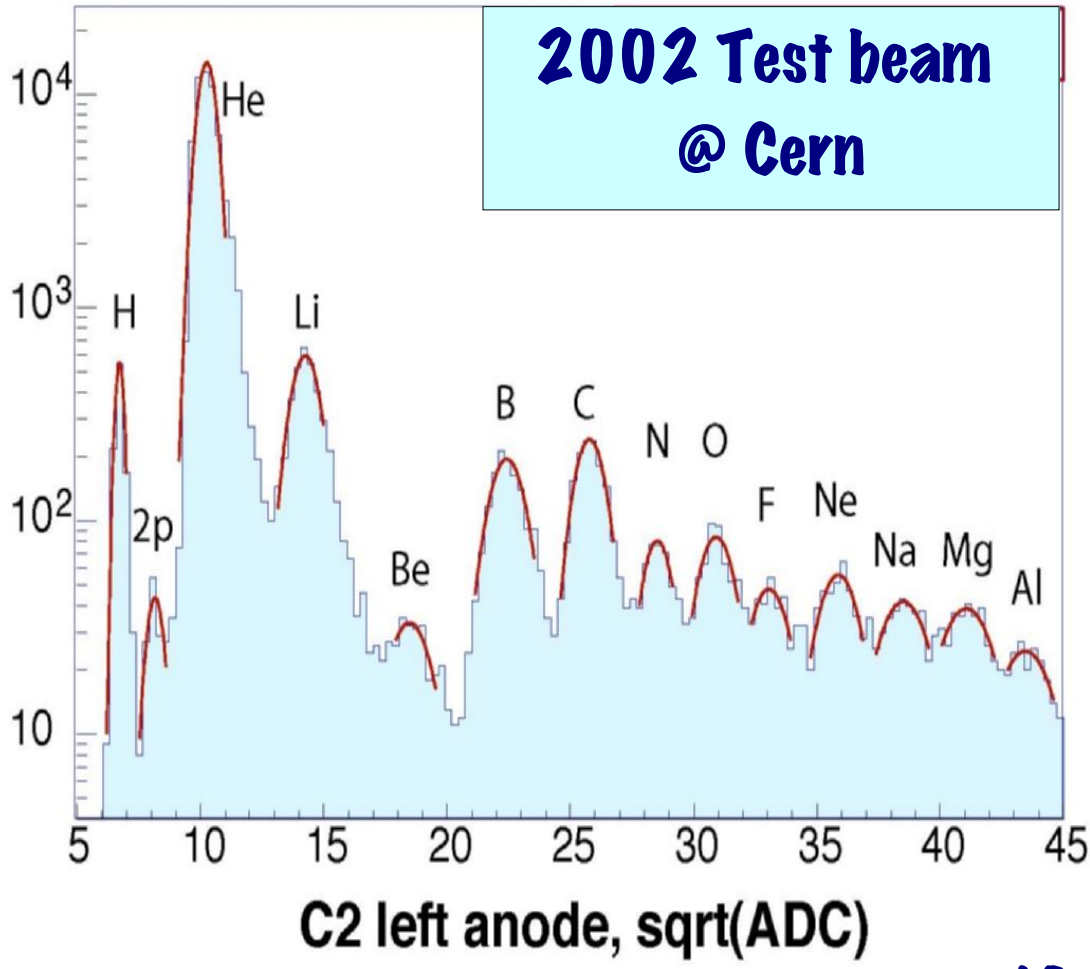

- *20 layers assembled in octagonal structure.*
- *328 modules of fleece and straw tubes.*

***h/e rejection of $10^2$-$10^3$***
***(in the range 300 → 3 GeV)***

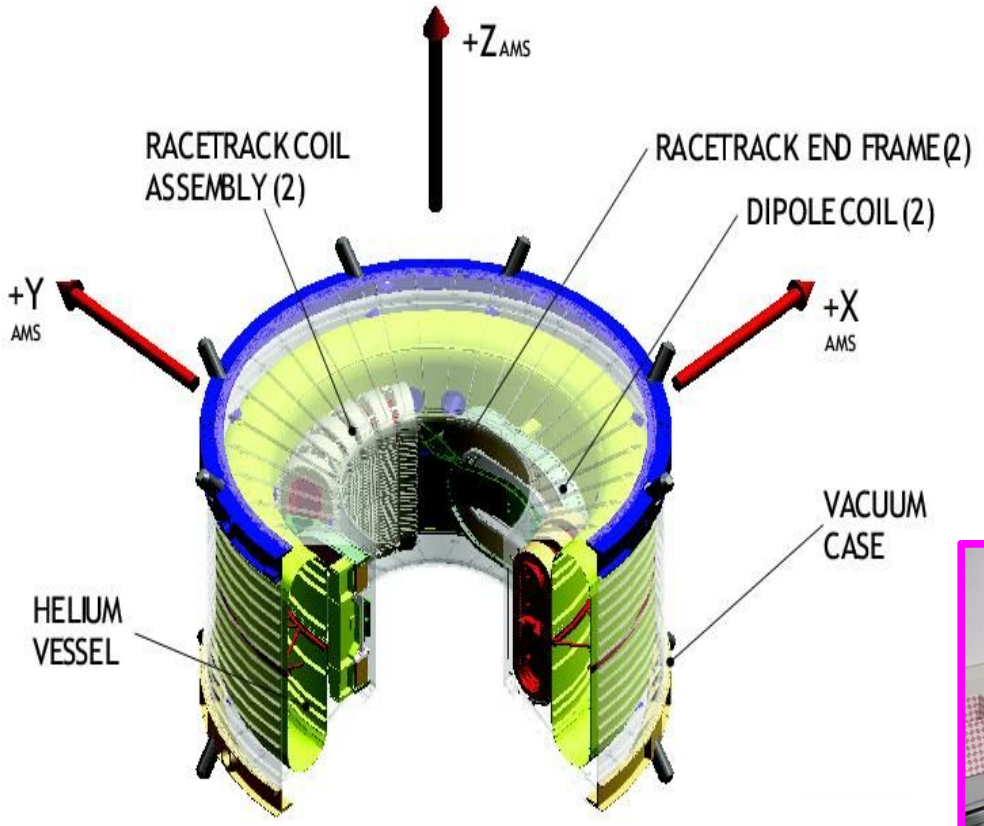
# AMS-02 Time of Flight System

*2x2 planes + total of 34 scintillator paddles*
*(seen by 2 (or 3) PMTs on each side)*

*Time resolution: $\Delta t$ ~ 180 ps (Z=1), 100 ps (Z>1)*

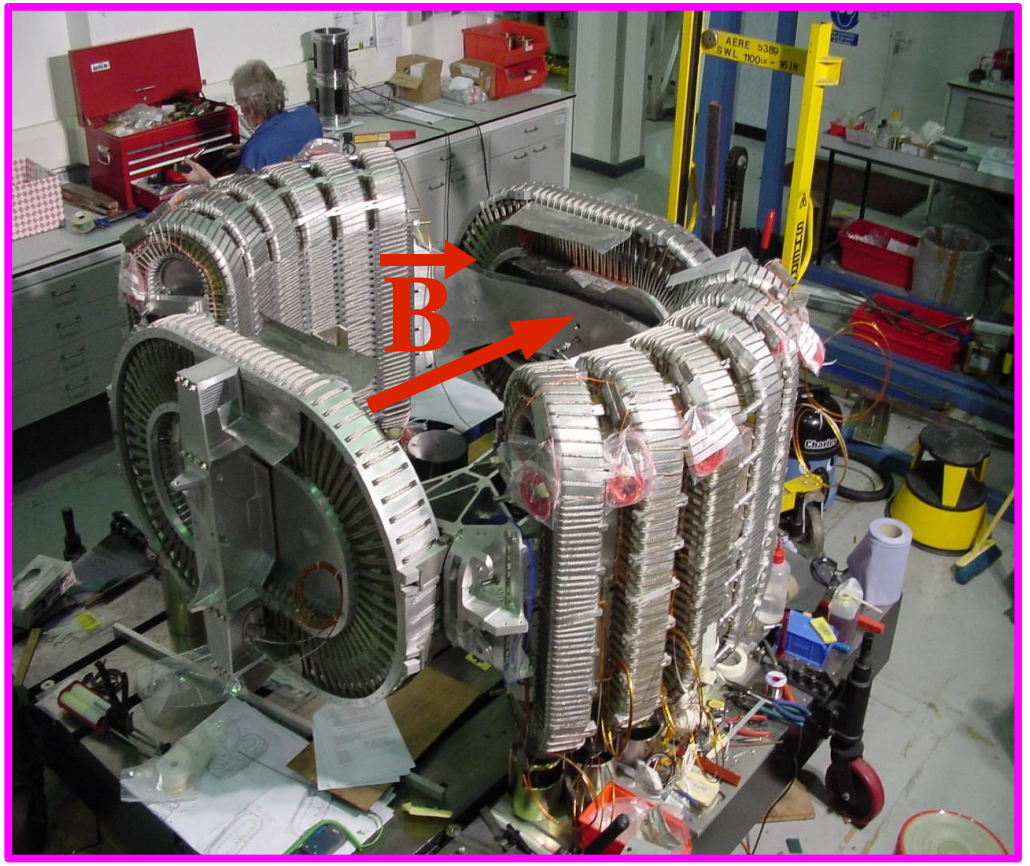


# AMS-02 Superconducting Magnet




AMS-02 SUPERCONDUCTING MAGNET

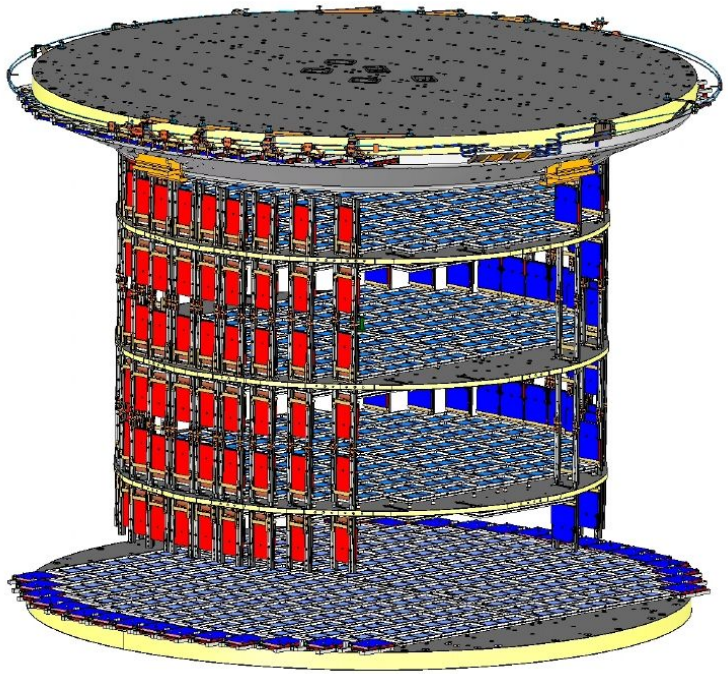
***AMS-02 is still the only experiment in space which will use a*** superconducting ***magnet***




- ***12 racetrack coils + 2 dipoles coils***
- ***2500 liters of superfluid helium***

***Bending power : $BL=0.86Tm^2$***

# AMS-02 Silicon Tracker

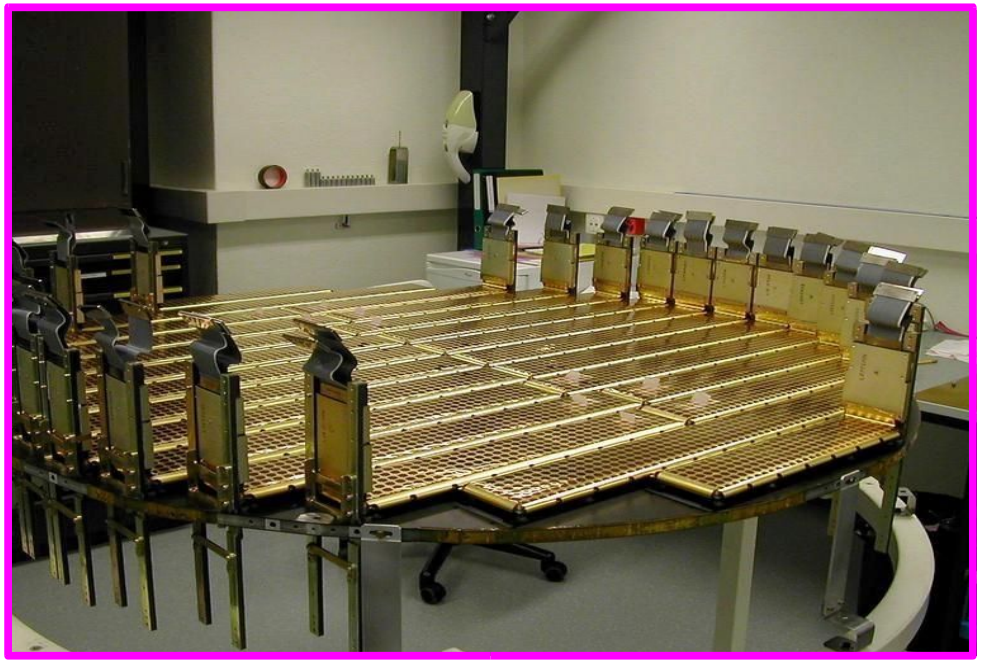


- *8 layers of double sided silicon sensors*
- *6.6m² → 192 Ladders → 196k channels*

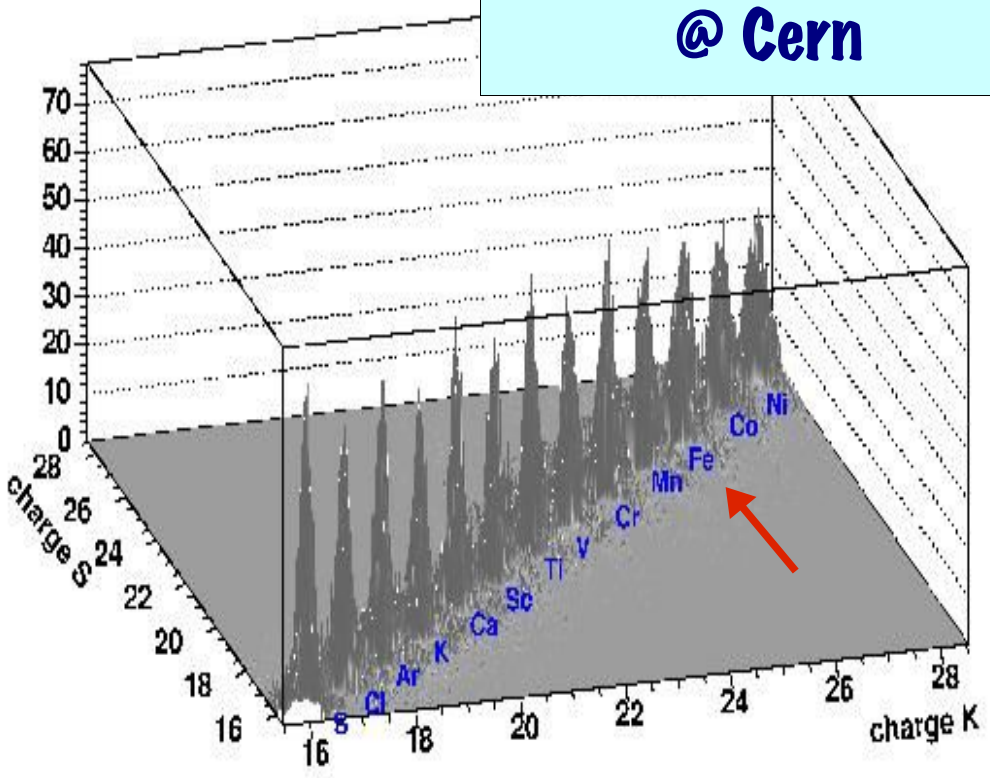
$\sigma(p)/p = 1.5\%$ *@ 10GeV*

$MDR^{(*)} \sim 2.5TV$

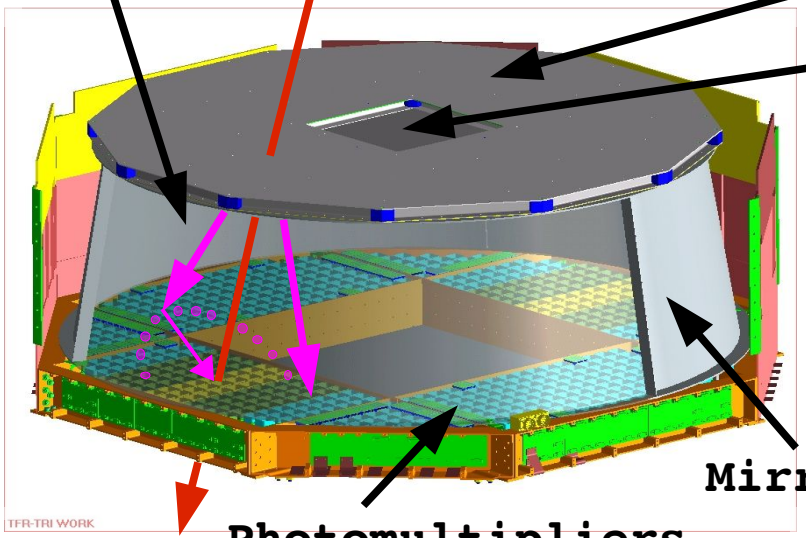
*(*) max detec. rigidity*



**2002 Test beam @ Cern**



# AMS-02 Ring Imaging Cerenkov Counter

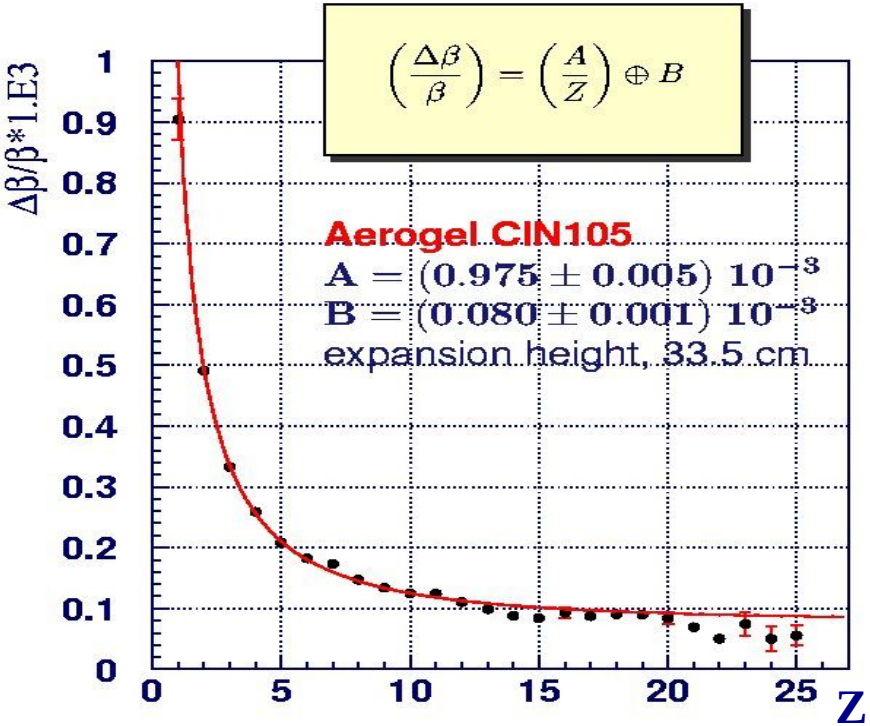


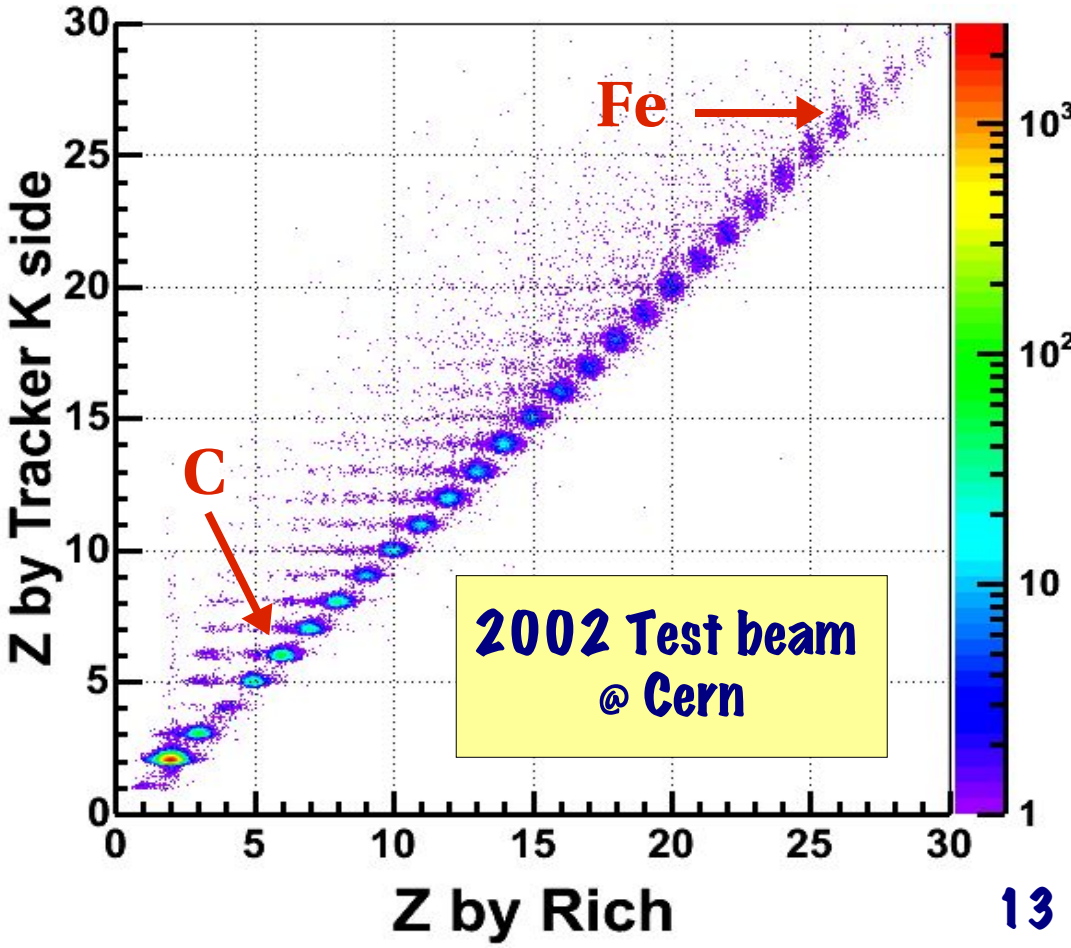

*3 cm silica aerogel (n=1.05) + NaF (n=1.33) radiator*

*680 multianode PMTs*

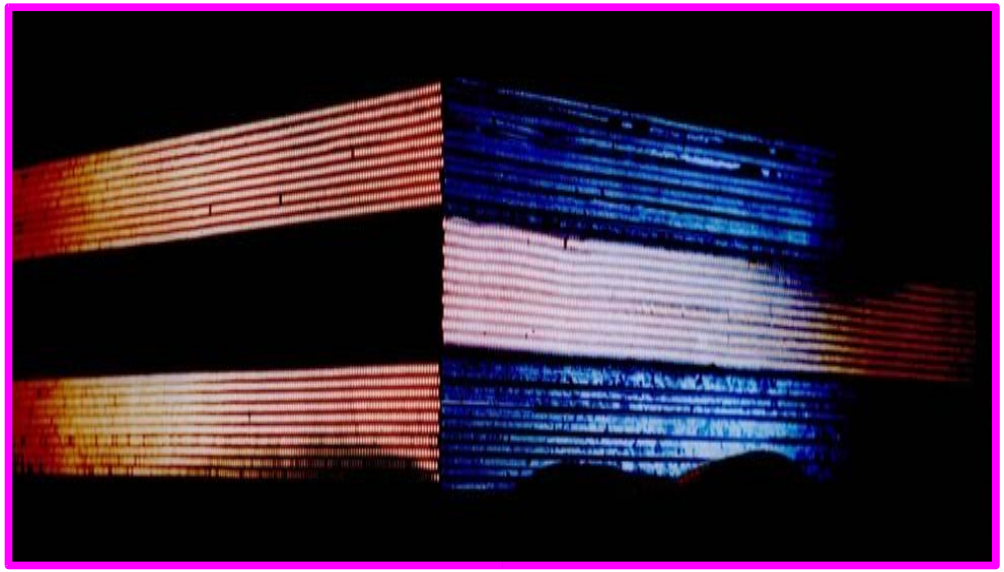
$\sigma(\beta)/\beta = 0.1\%$ @ $\beta = 1$ *(protons)*

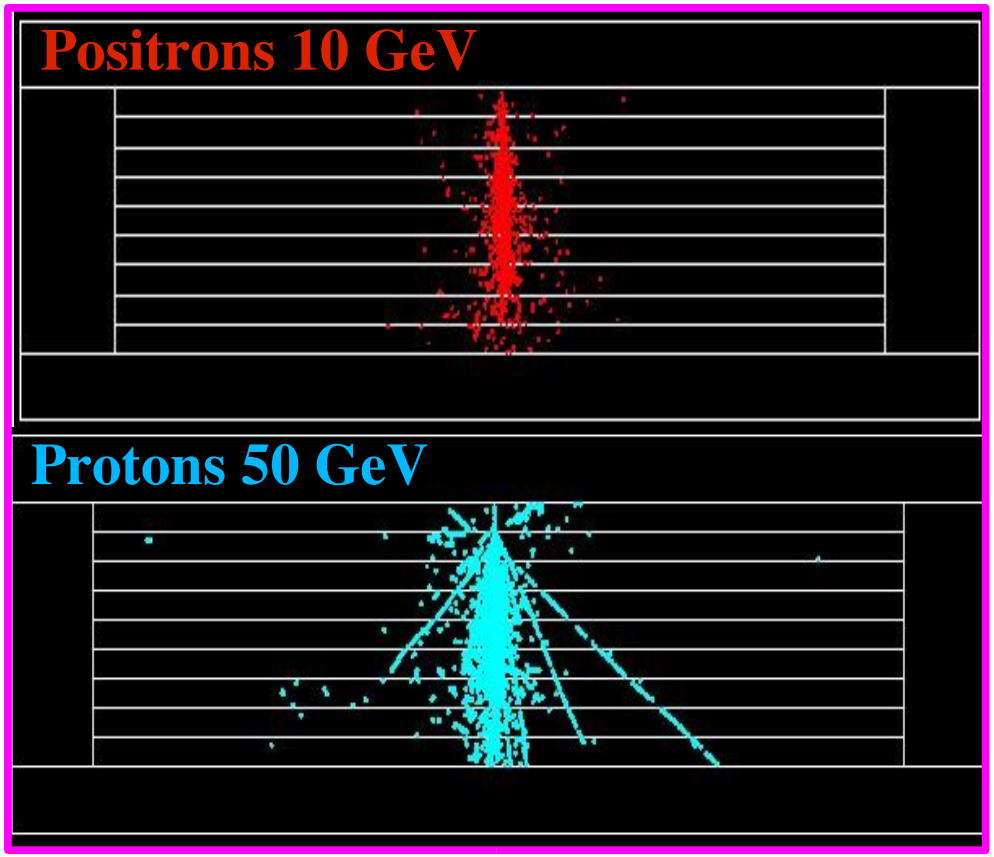
$\Delta Z \sim 0.2$ *up to Fe*



# AMS-02 Electromagnetic Calorimeter



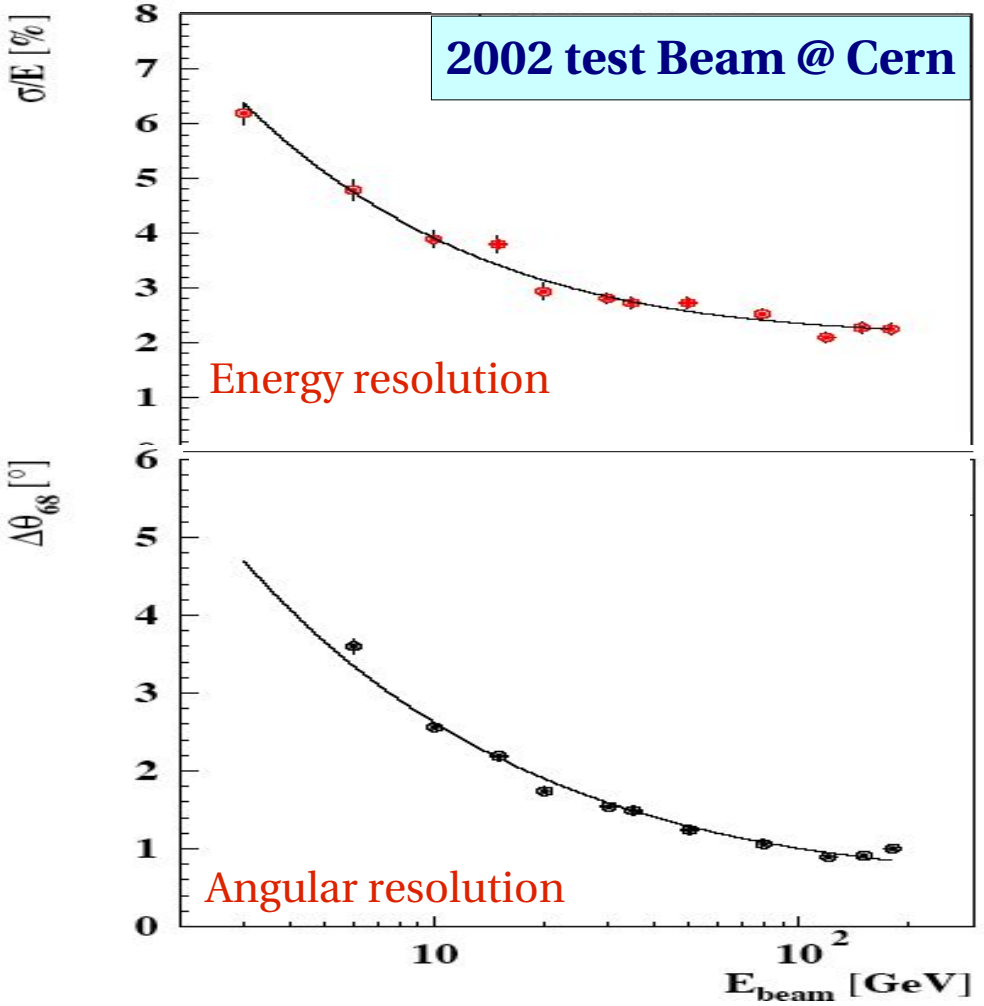



***9 super layers of Sci-Fi/Lead ($16X_o$)***

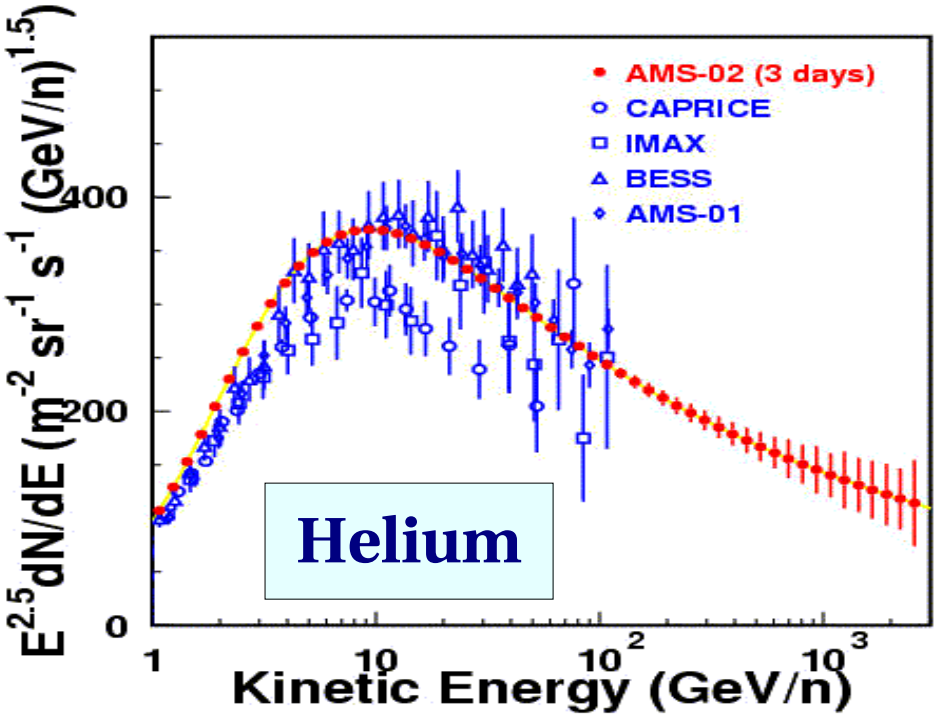
***(324 multianode PMTs)***

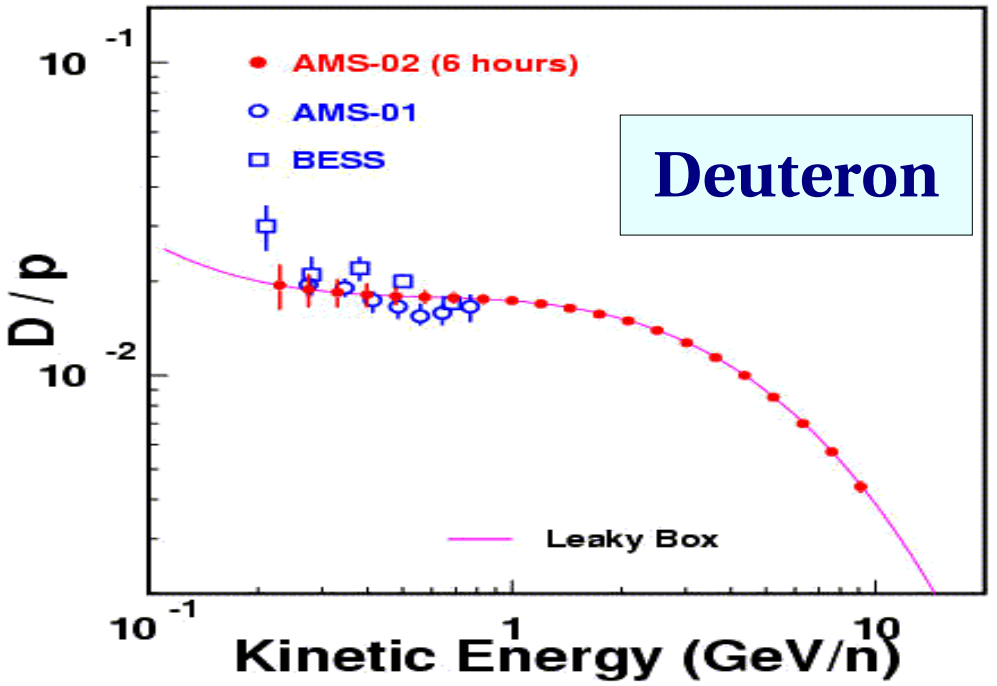
***$\sigma(E)/E$ =3% @ 100GeV***

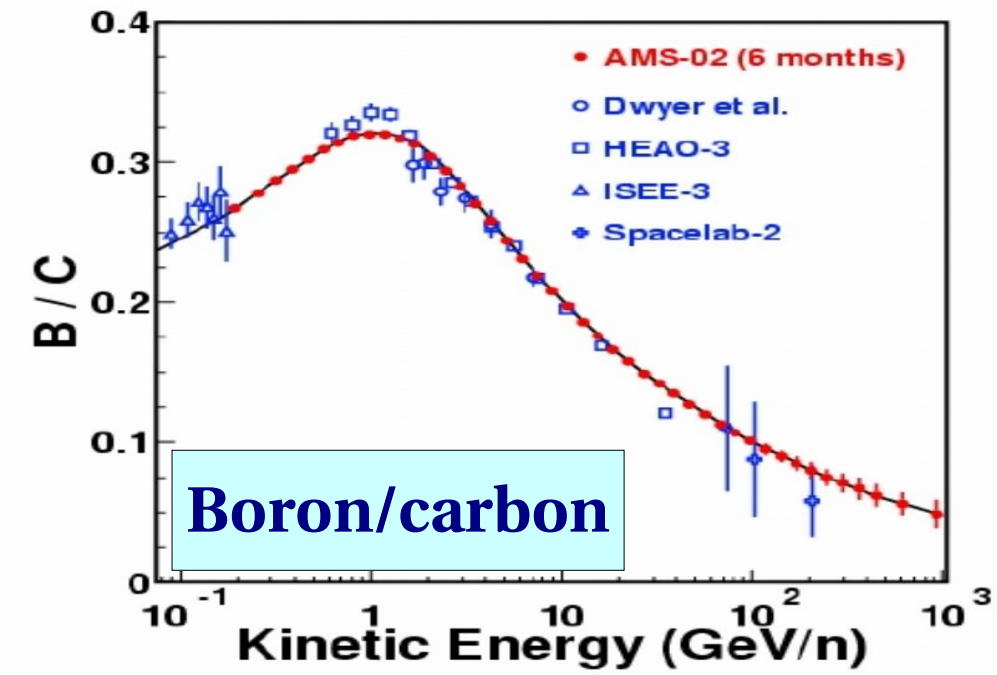
***p/e rejection of $10^3$***

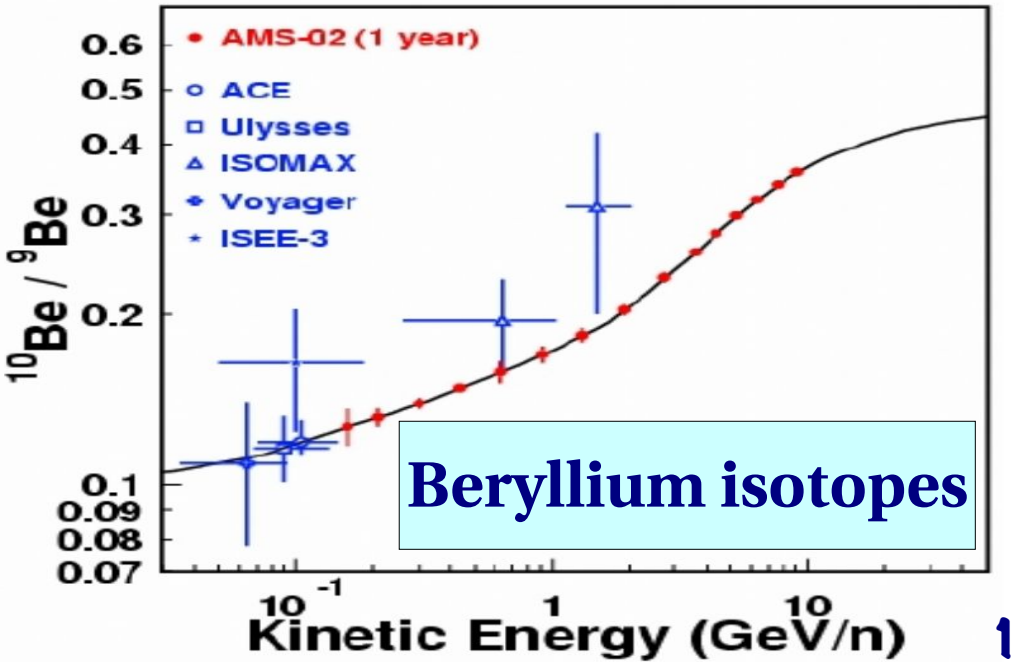


# Cosmic Ray Detection



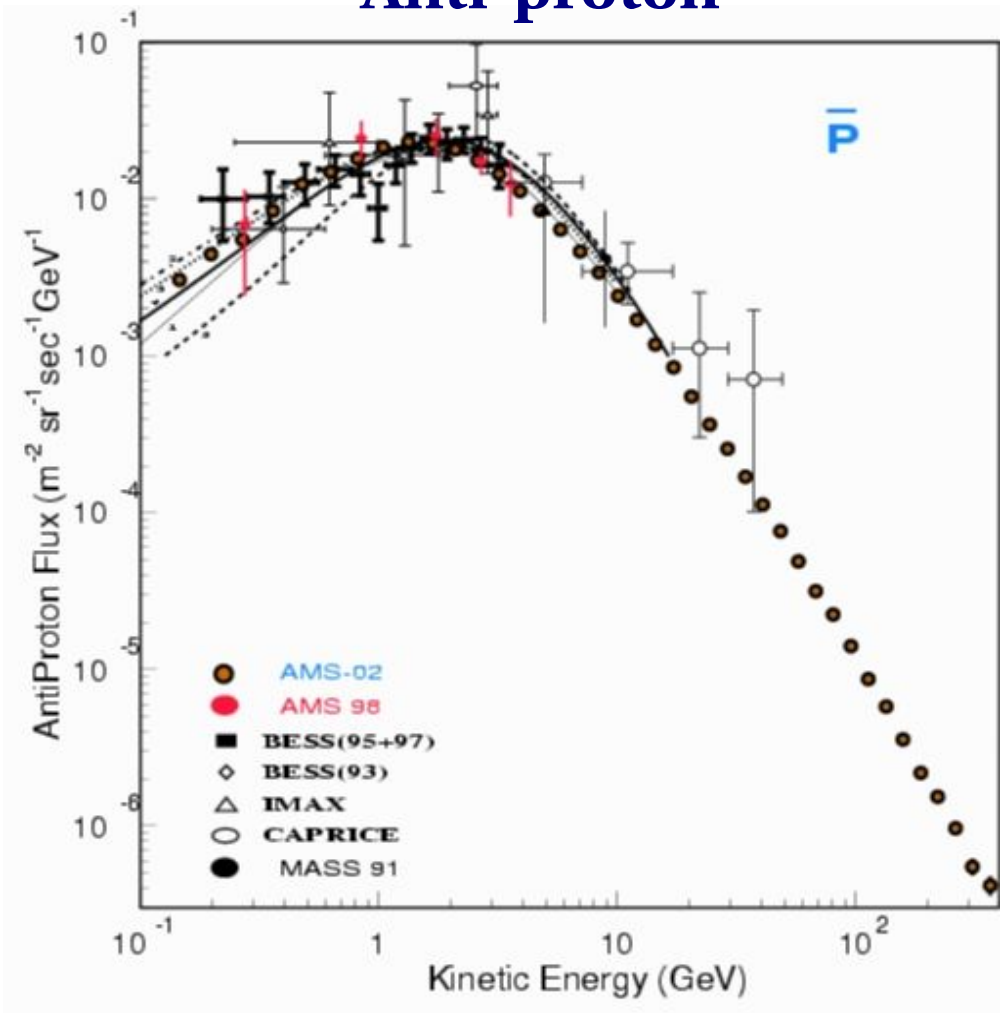



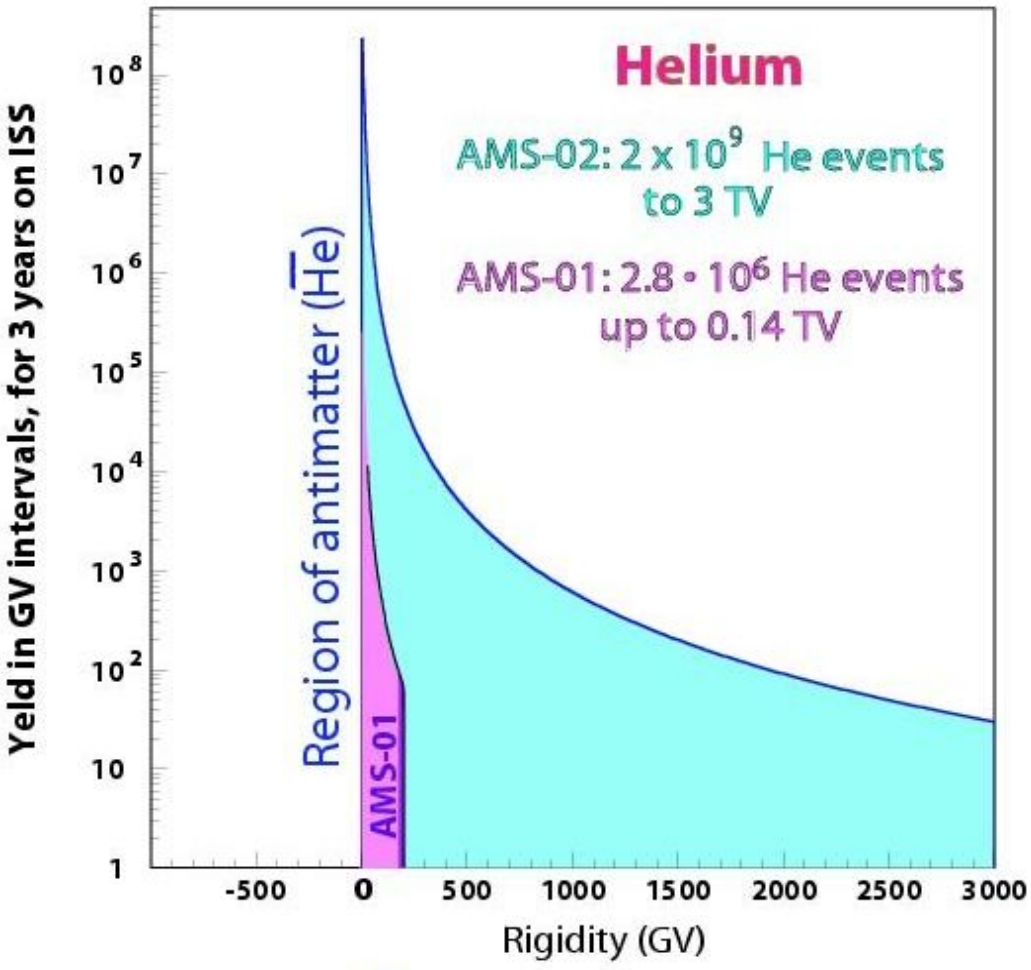



# Search for Antimatter

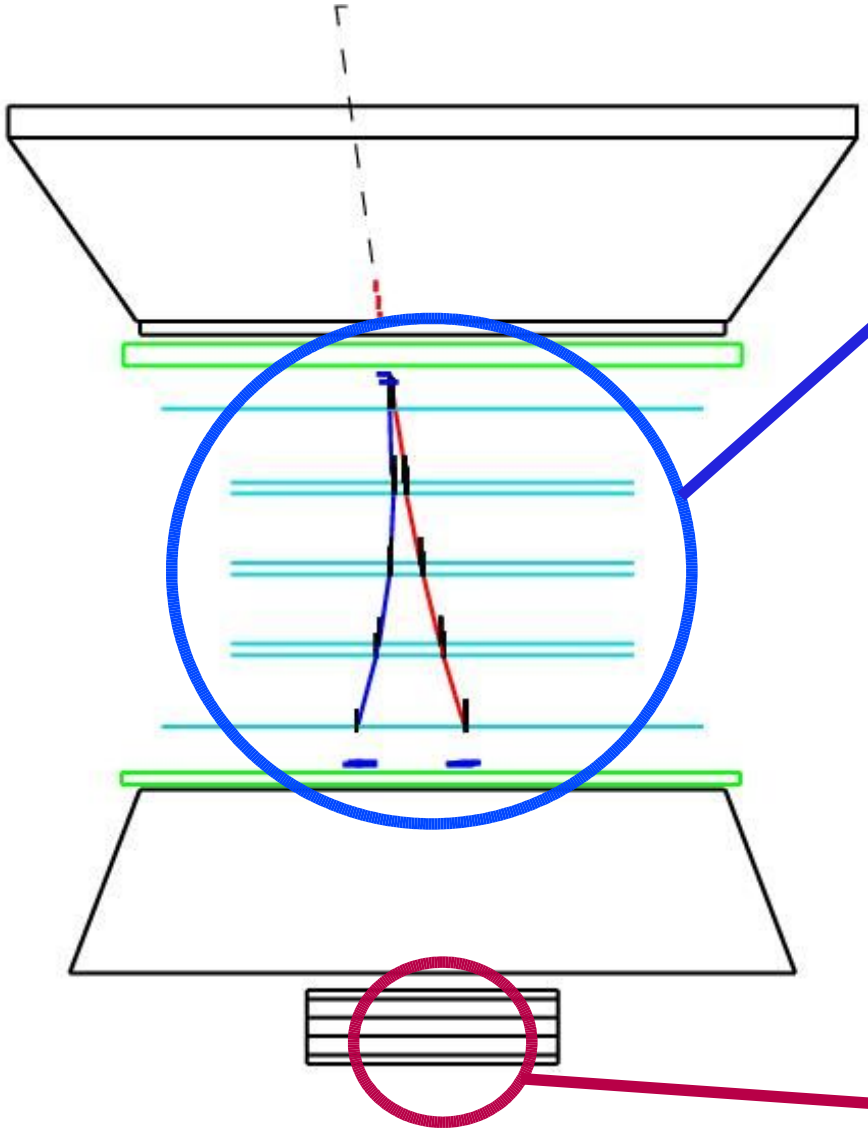
## Anti-proton




## Anti-Helium

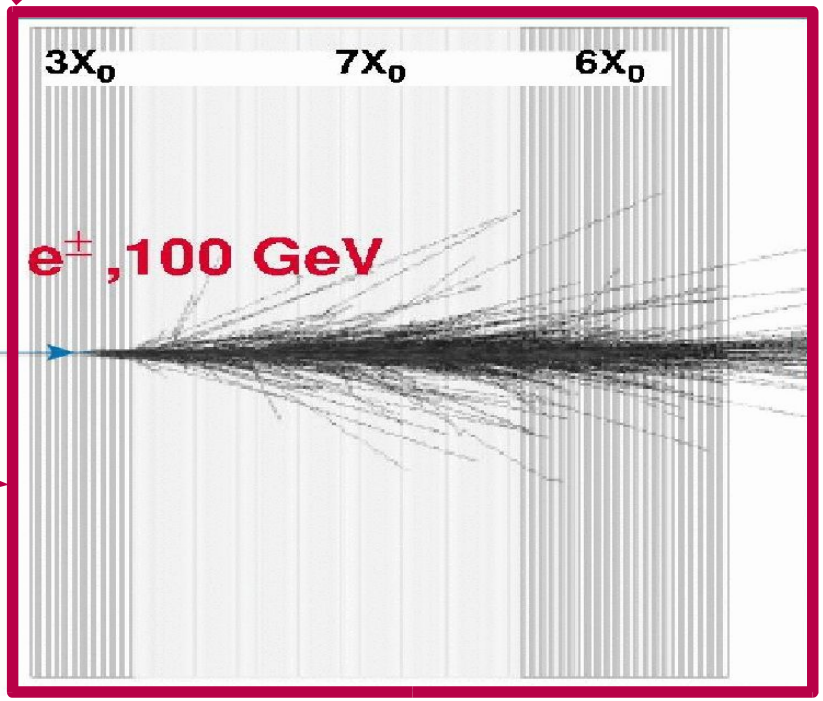


# γ-Ray Detection with AMS-02



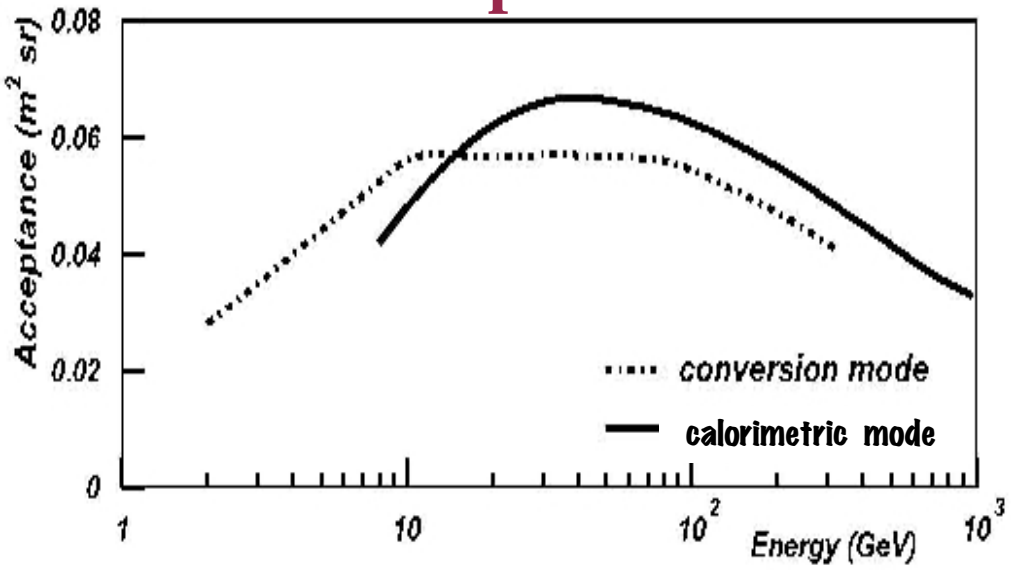
***Conversion Mode:***
***e+e- pair in the TR***

***Calorimetric Mode:***
***e.m. shower in ECAL***

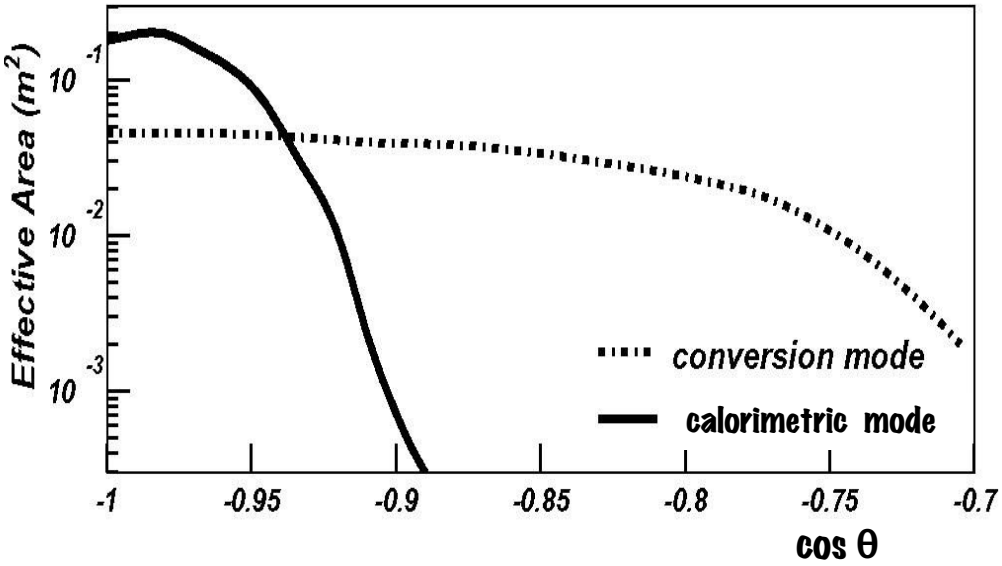


# Tracker and Ecal Performances

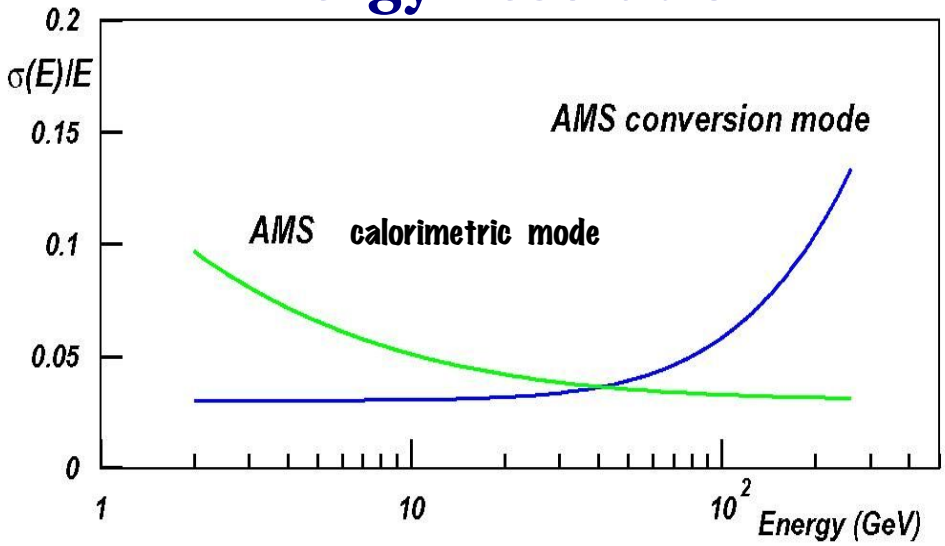
## Acceptance



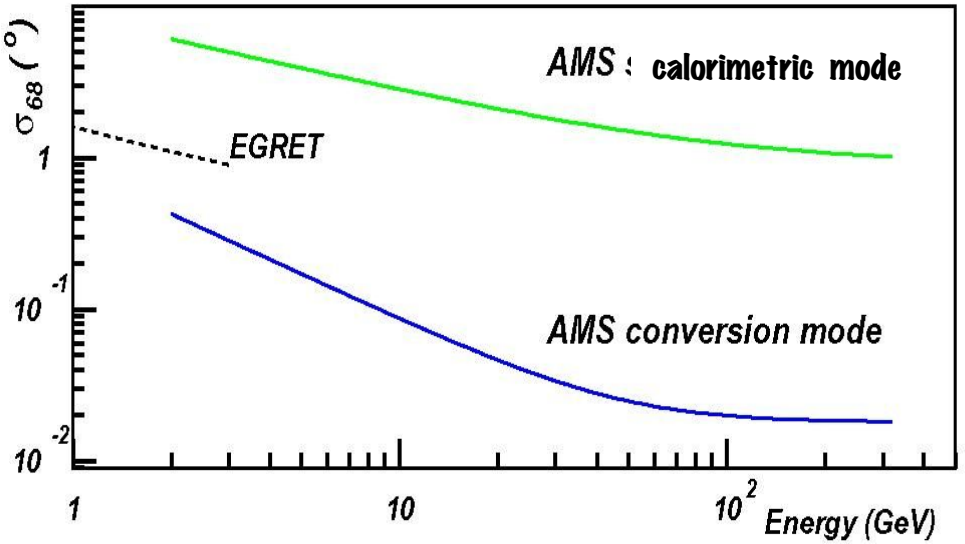

## Effective Area




## Energy Resolution

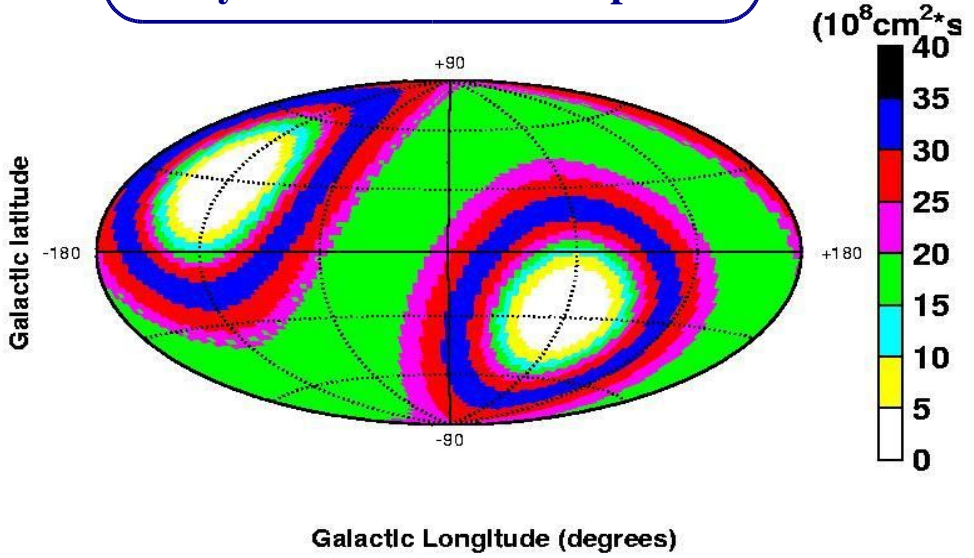



## Angular resolution

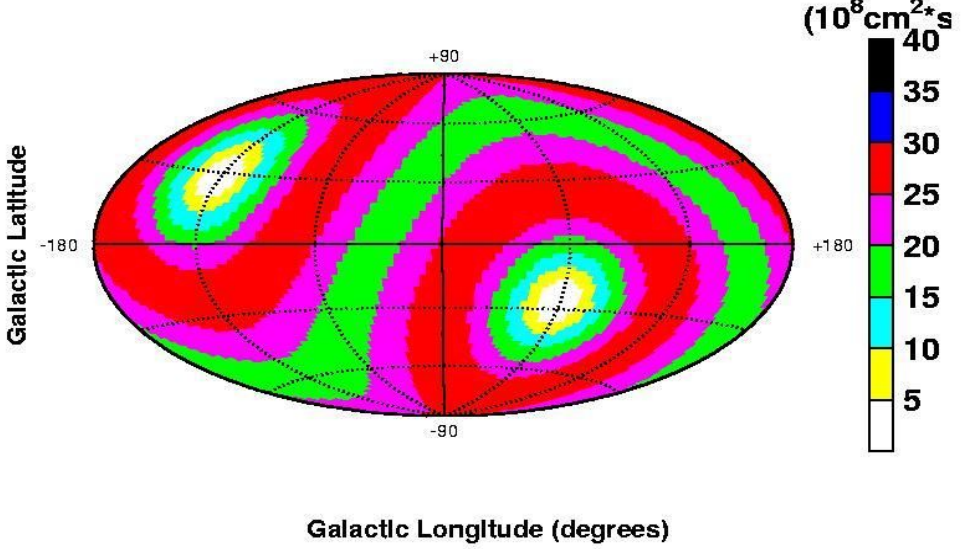


# AMS-02 high energy Gamma Rays Exposure

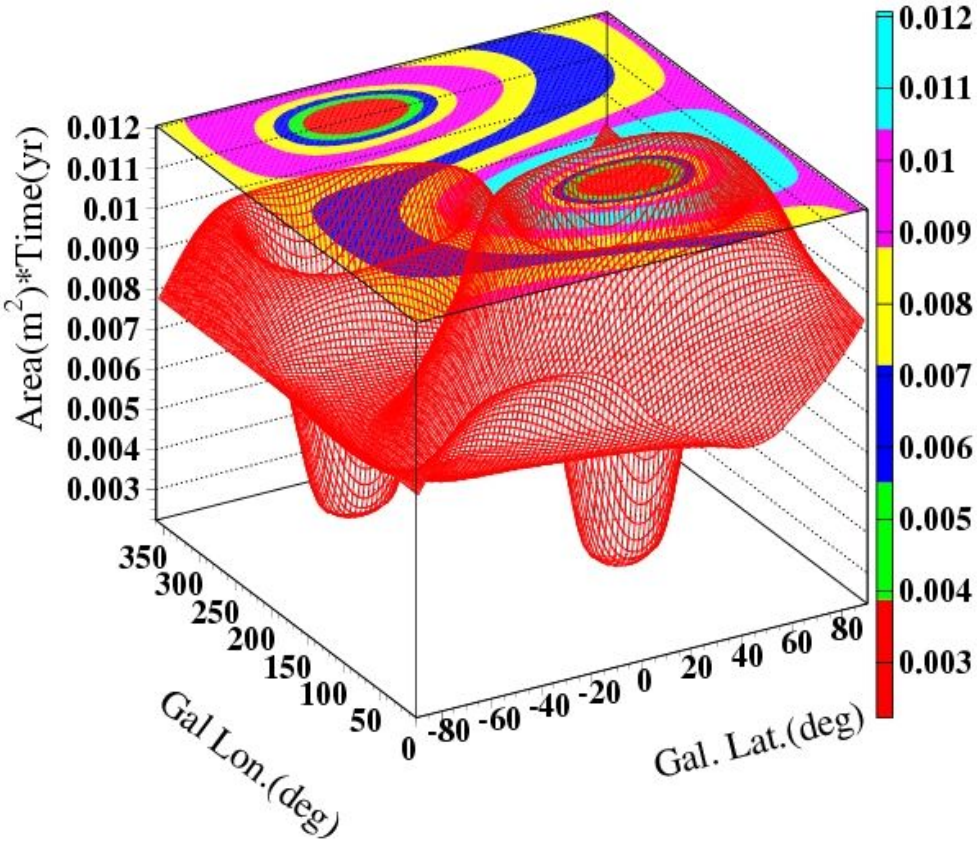
**One year AMS-02 Ecal Exposure**




**One year AMS-02 Tracker Exposure**




**One year AMS-02 Tracker+ Ecal Exposure**




***Tracker + Calorimeter give the whole sky coverage***

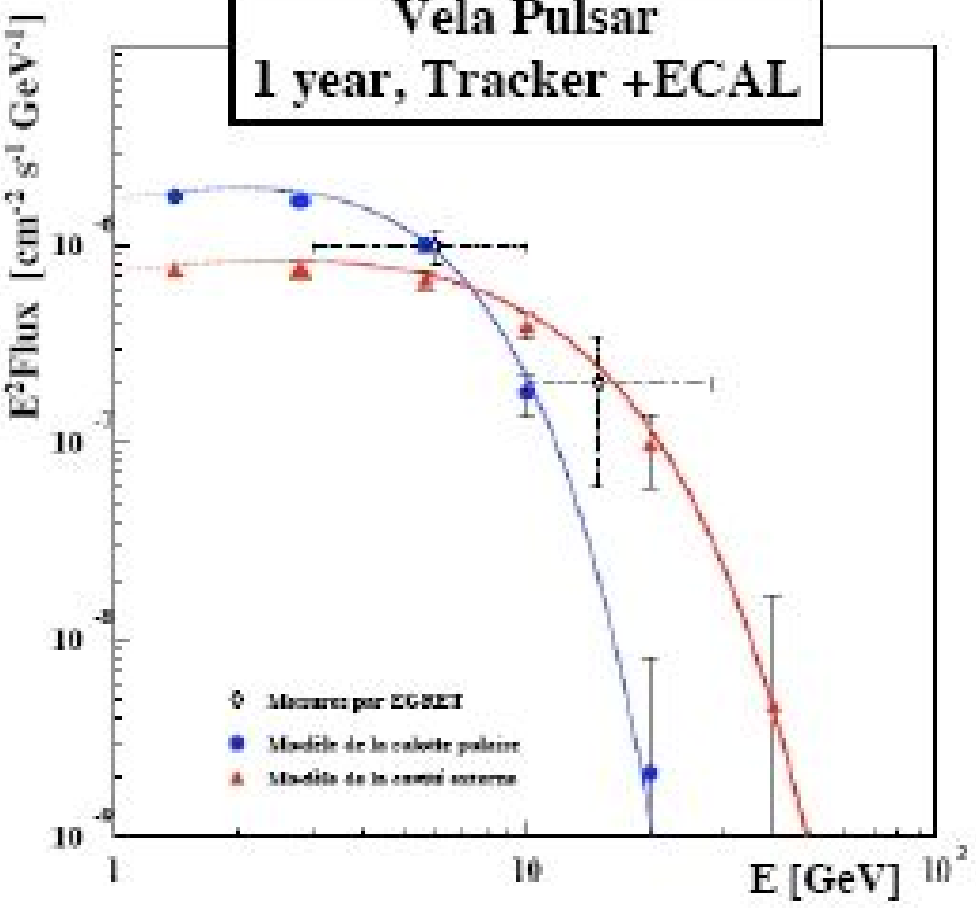
# One example : estimates for γ-sources

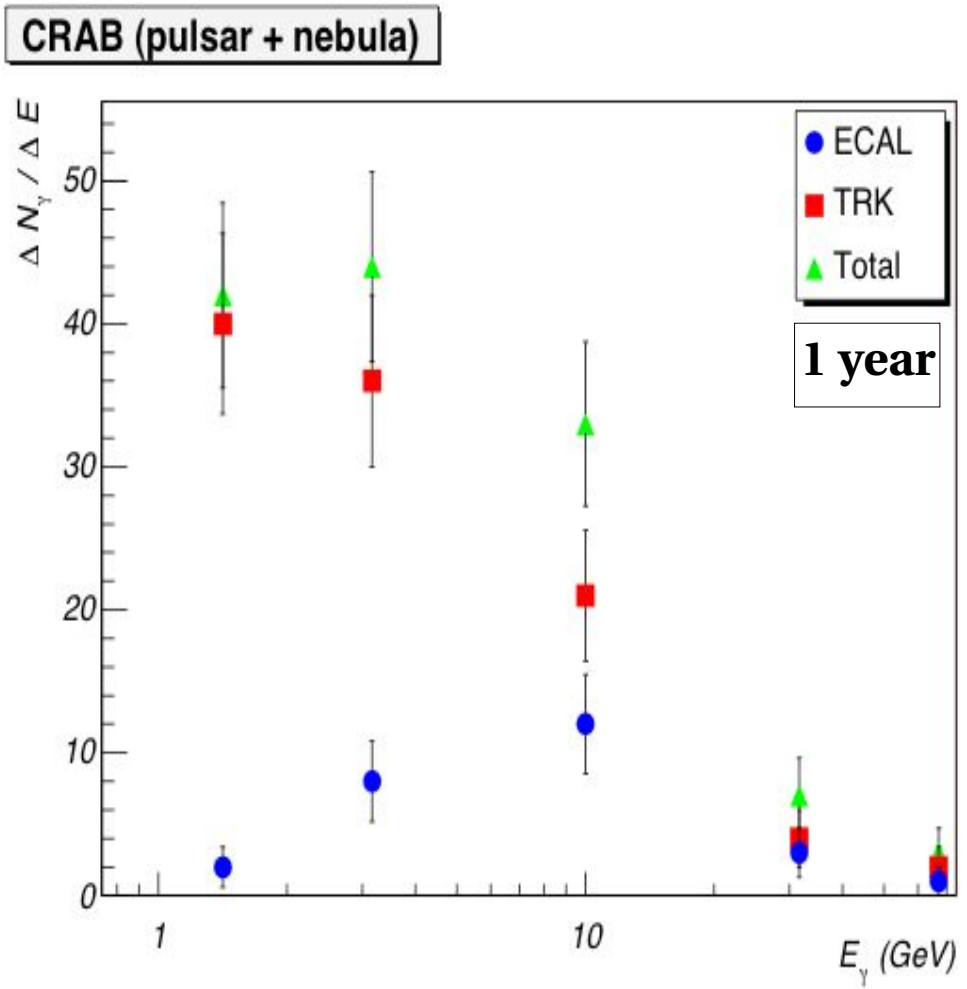
***Using a*** fast simulation ***tool with*** parametrization ***of AMS-02 ECAL and Tracker acceptances and resolutions***

**1 year data taking**

| 3EG Catalog | Other Name | Nγ (Tracker) | Nγ (ECAL) | Nγ (total) |
|---|---|---|---|---|
| J0210-5055 | 0208-512 | 47.0 | 13.4 | 60.4 |
| J0530+1323 | 0528+134 | 18.7 | 4.0 | 22.7 |
| J0534+2200 | **Crab** | **102.2** | **26.6** | **128.8** |
| J0834-4511* | Vela | 491.4 | 203.8 | 695.2 |
| J1255-0549 | 3C279 | 138.6 | 35.8 | 138.6 |
| J1409-0745 | 1406-076 | 31.7 | 5.9 | 37.6 |
| J1635+3813 | 1633+382 | 65.5 | 18.3 | 83.8 |

# One example : estimates for γ-sources



# Conclusions

- *AMS-02 is approved by NASA to operate on t he ISS for* 3 years at least.
- *AMS-02 will be* fully assembled *end 2007.*
- *AMS-02* large acceptance *and* long exposure time *outside the Earth's atmosphere, will allow an unprecedented sensitive search for Antimatter, Dark Matter and studies of Cosmic Rays.*
- *Interesting* Galactic and Extragalactic Gamma Ray *measurements can be made.*