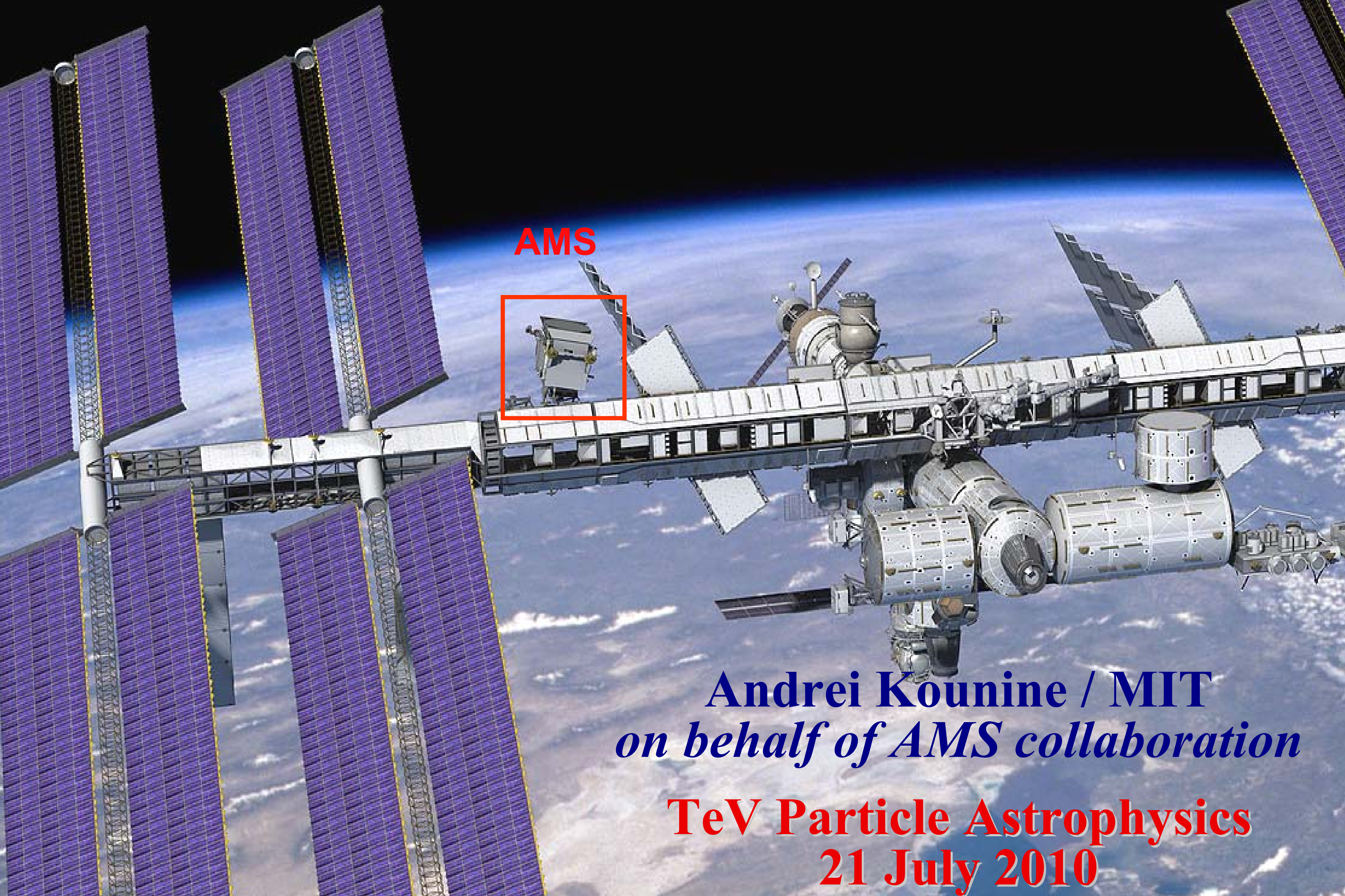
Status of the AMS Experiment

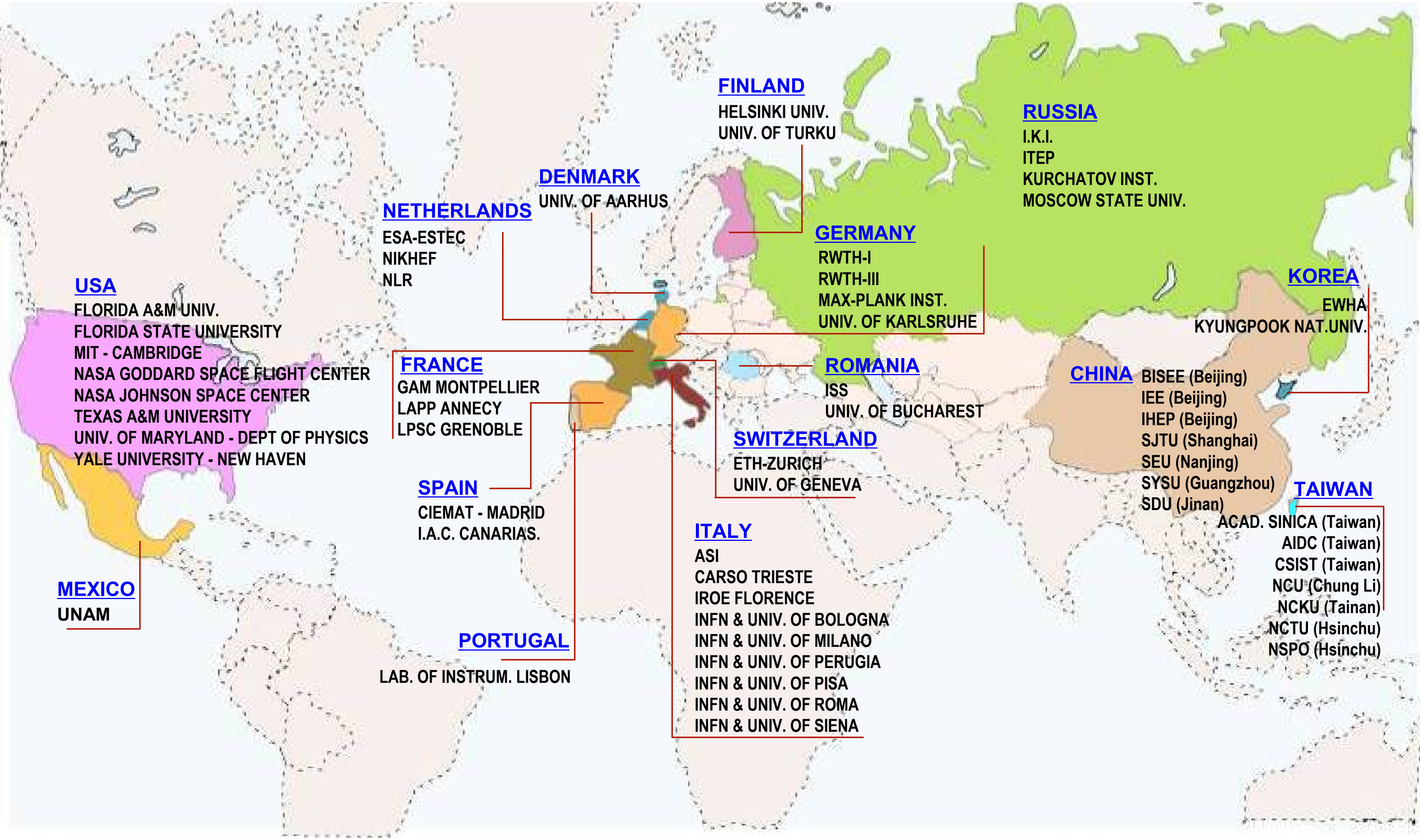


Andrei Kounine / MIT
on behalf of AMS collaboration

TeV Particle Astrophysics
21 July 2010

AMS International Collaboration

16 Countries, 60 Institutes and 600 Physicists

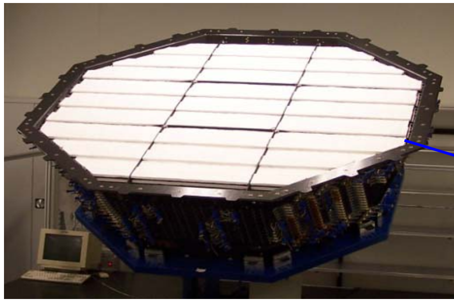


95% of the > $2.0B to build AMS has come from Europe and Asia .

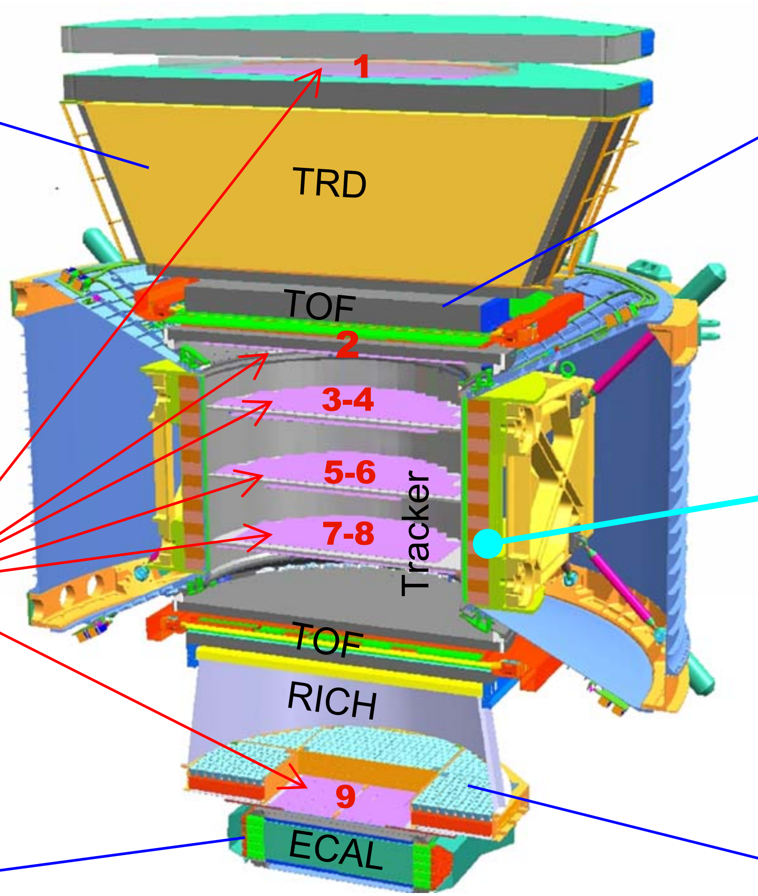
AMS: A TeV precision, multipurpose particle physics spectrometer in space.

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

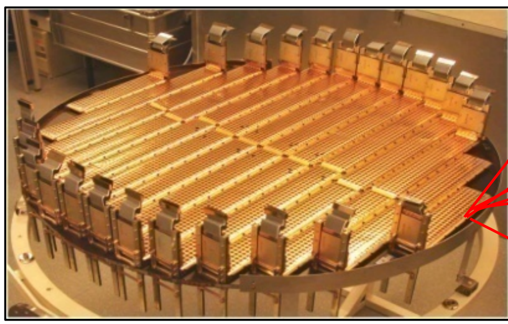
TRD
Identify e+, e-



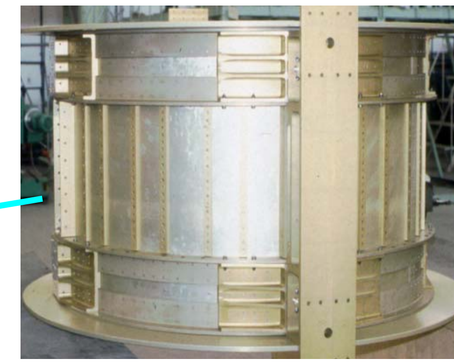
TOF
Z, E



Silicon Tracker
Z, P

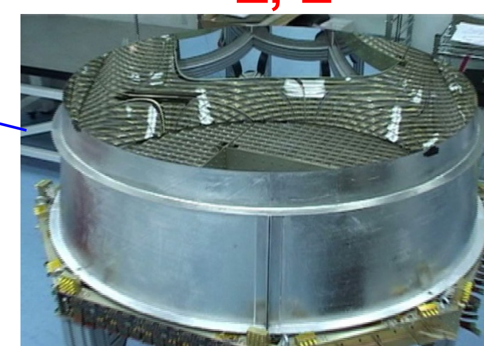


Magnet
±Z



ECAL
E of e+, e-, γ

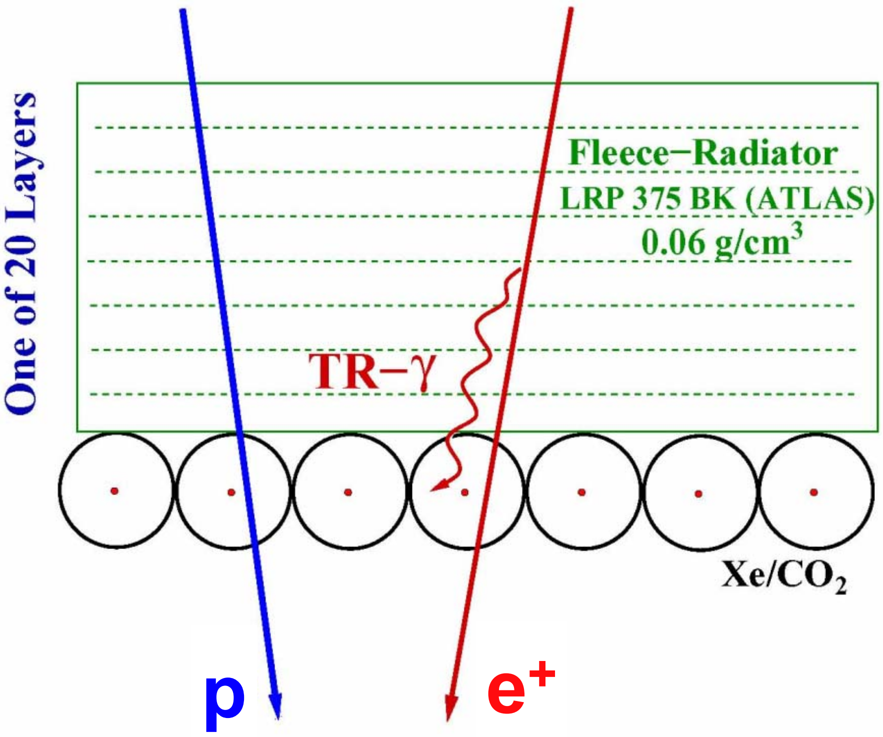
RICH
Z, E

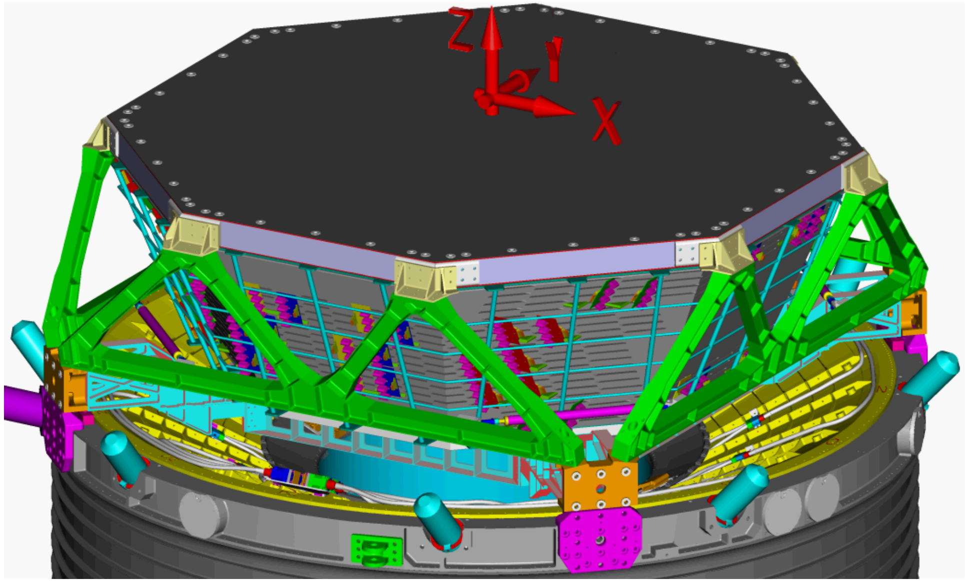


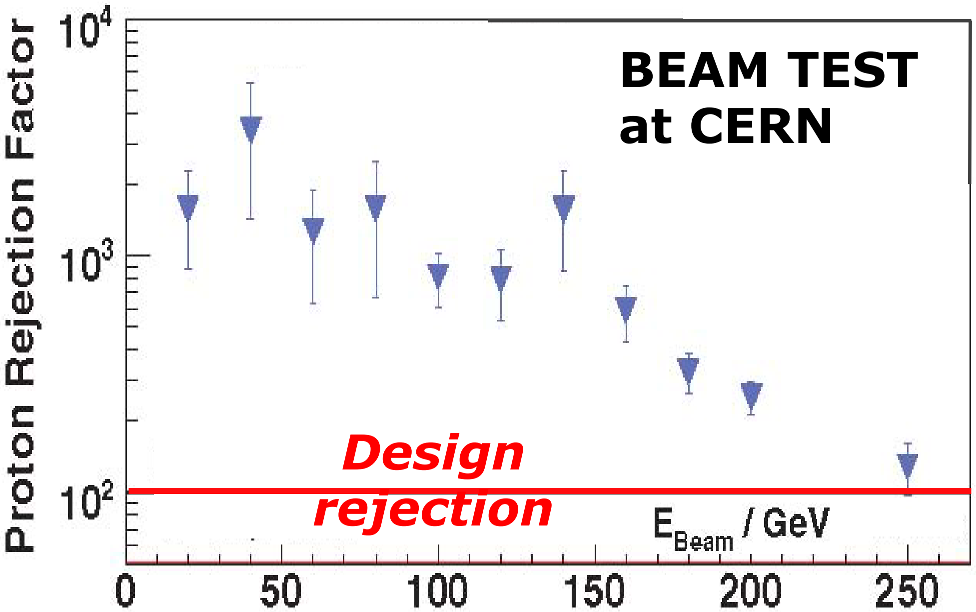
Z, P are measured independently from Tracker, RICH, TOF and ECAL

Transition Radiation Detector: TRD

Identify e⁺, reject P







Leakrate: $CO_2 \approx 6\ \mu g/s$

Storage: 5 kg – 24 years lifetime

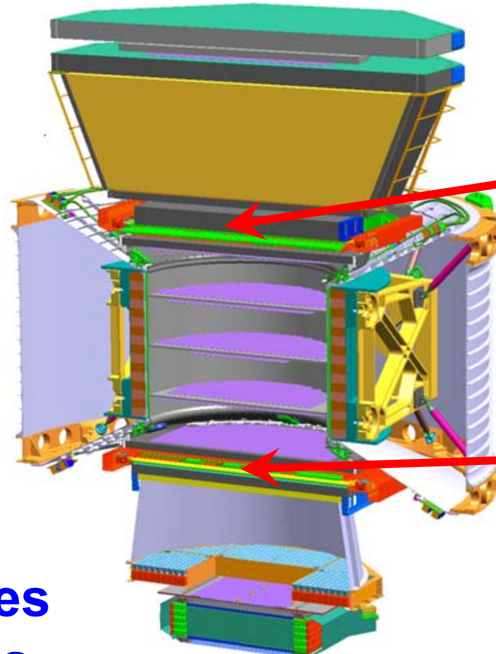
Time of Flight (TOF)

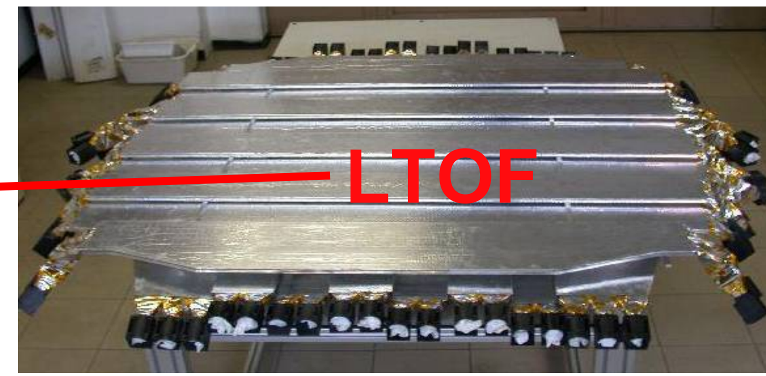
4 scintillator planes

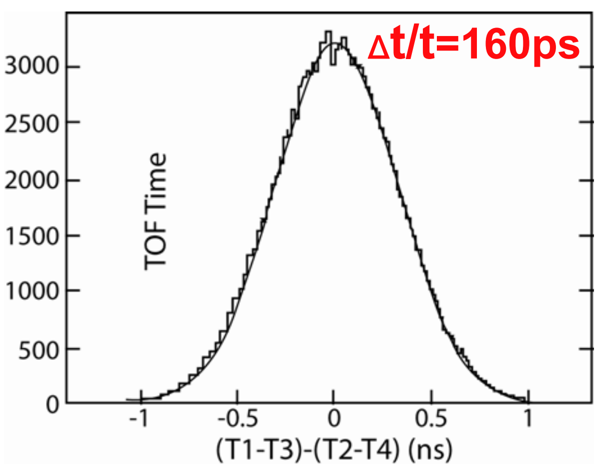
Provides trigger for charged particles

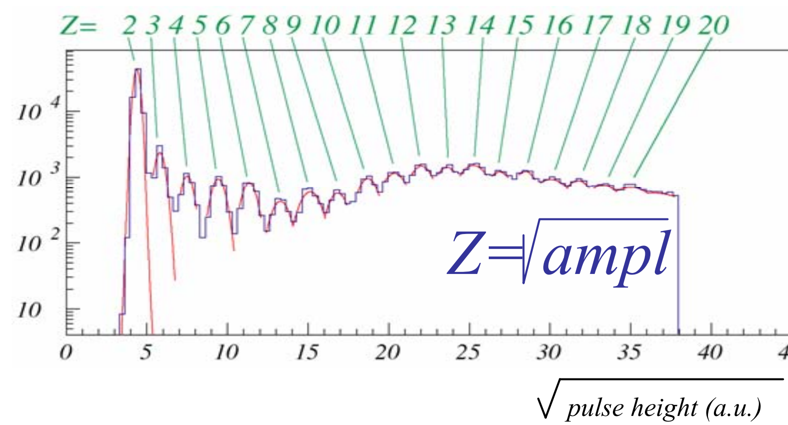
Trigger time is synchronized to UTC time to 1μs

Measures the time of relativistic particles to 160 picoseconds

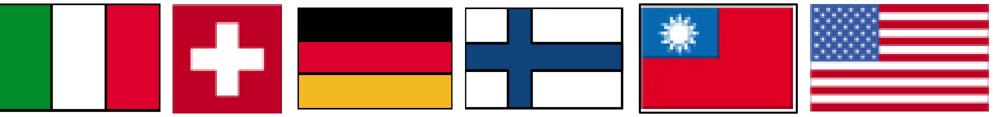




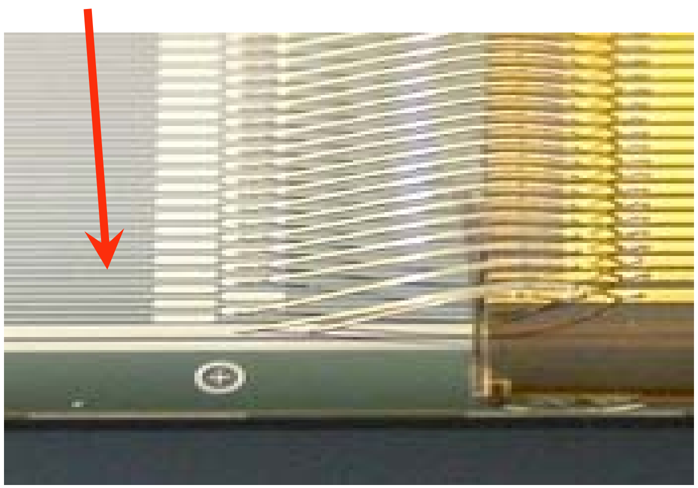


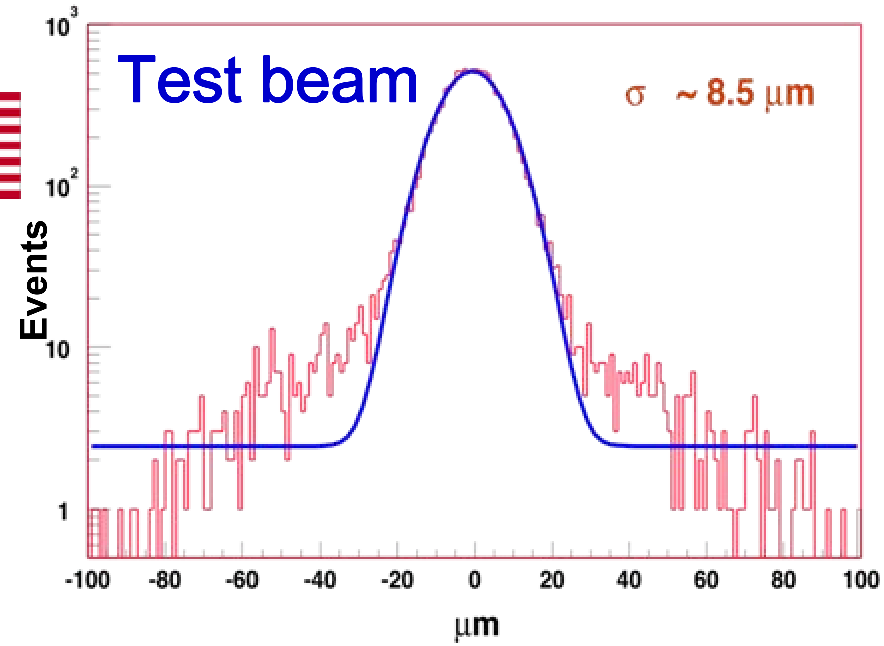


Silicon Tracker

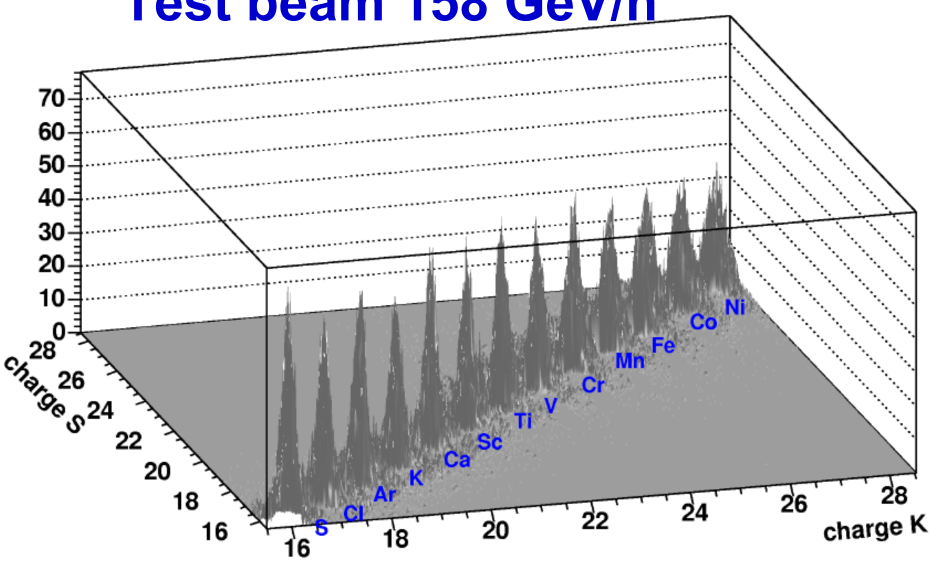


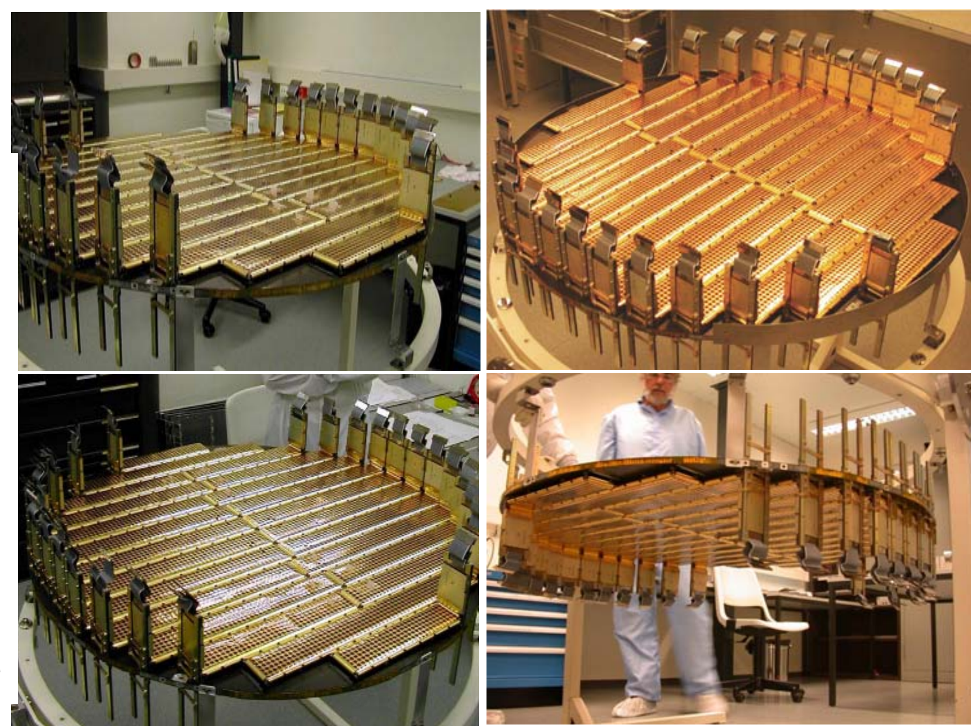
10 mil pitch; 200,000 channels; alignment 3 μm



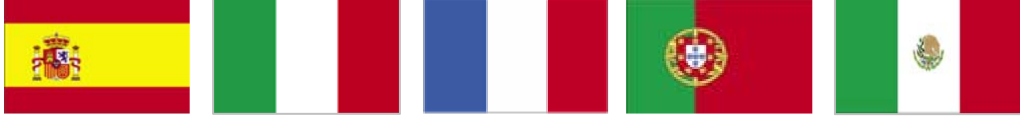


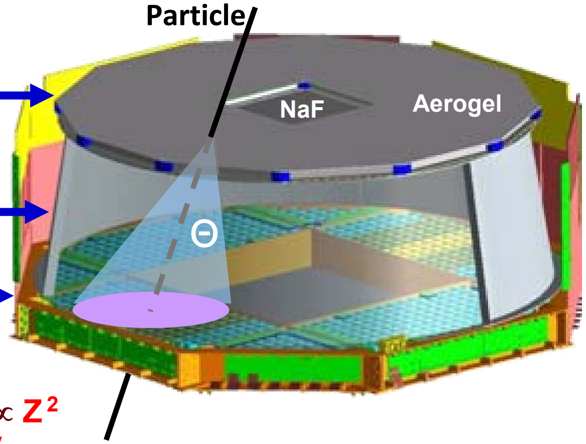
Test beam 158 GeV/n

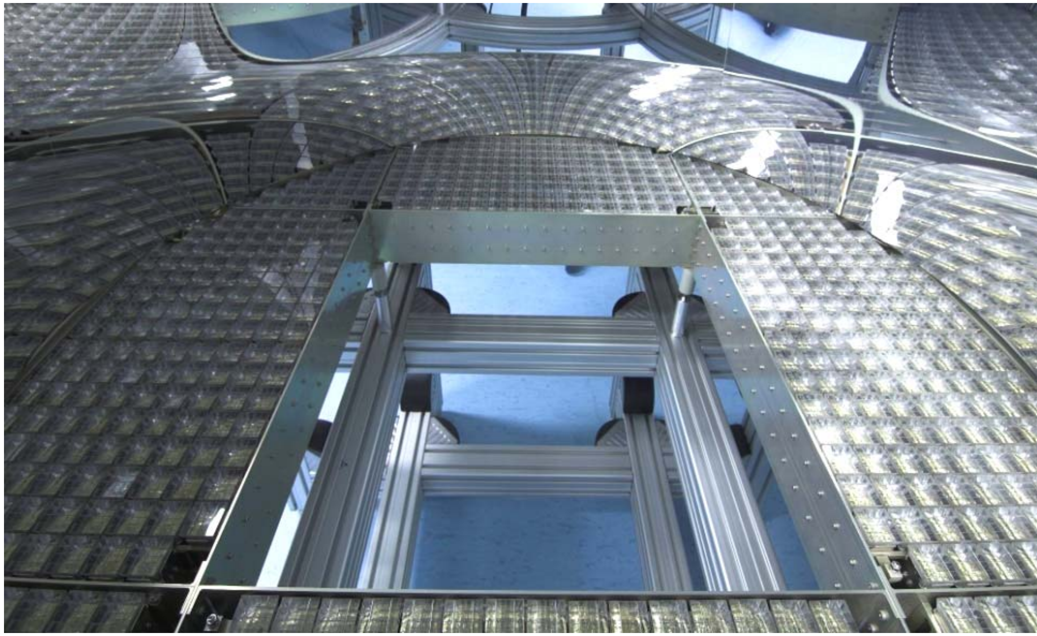




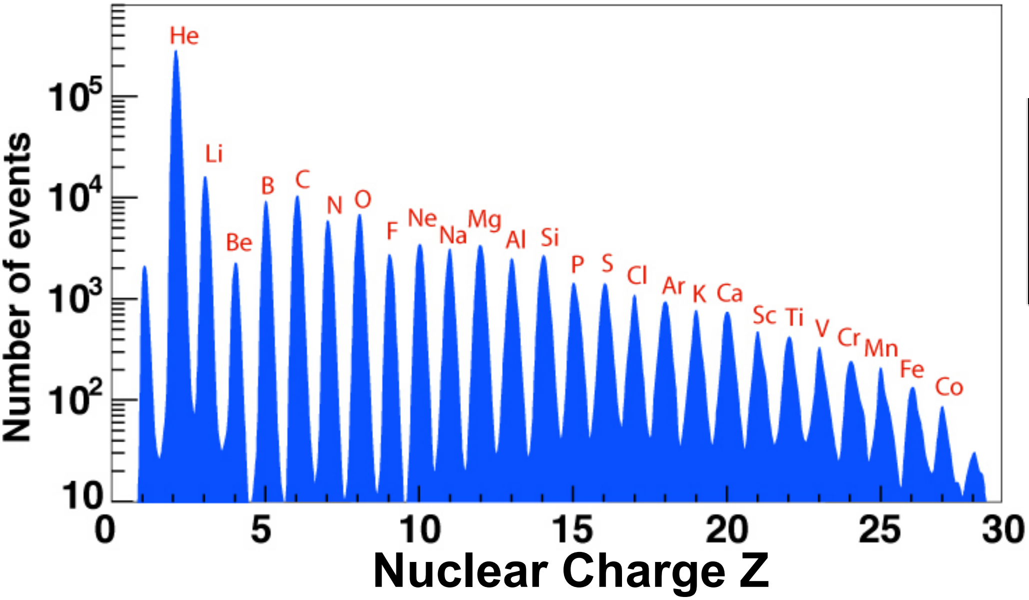
Ring Imaging Cherenkov Detector (RICH)

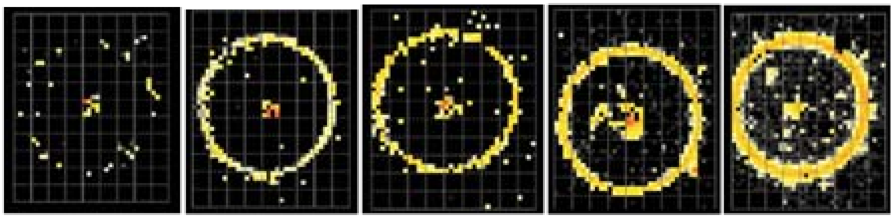






10,880 photosensors

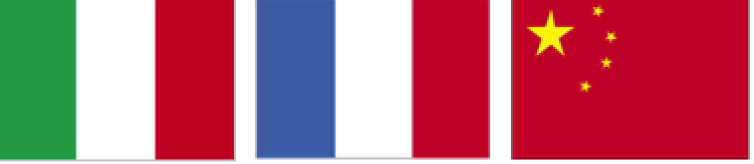




He Li C O Ca

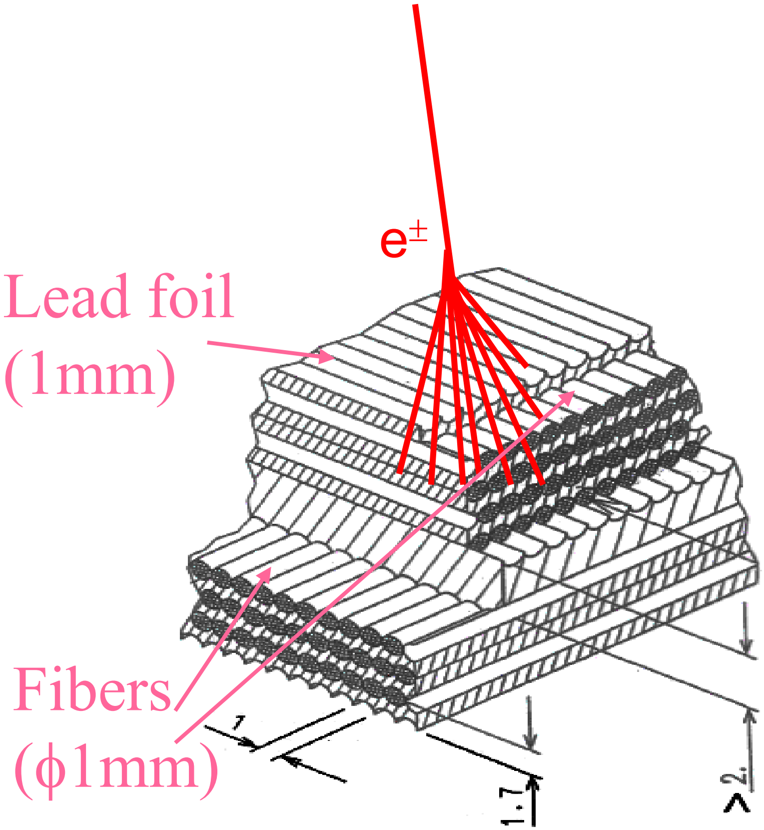
Single Event Displays

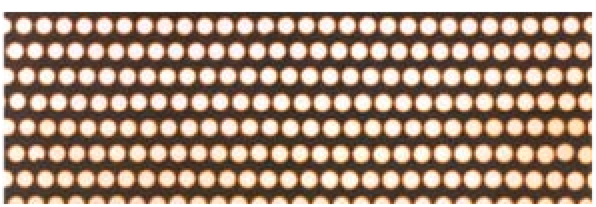
RICH test beam E=158 GeV/n



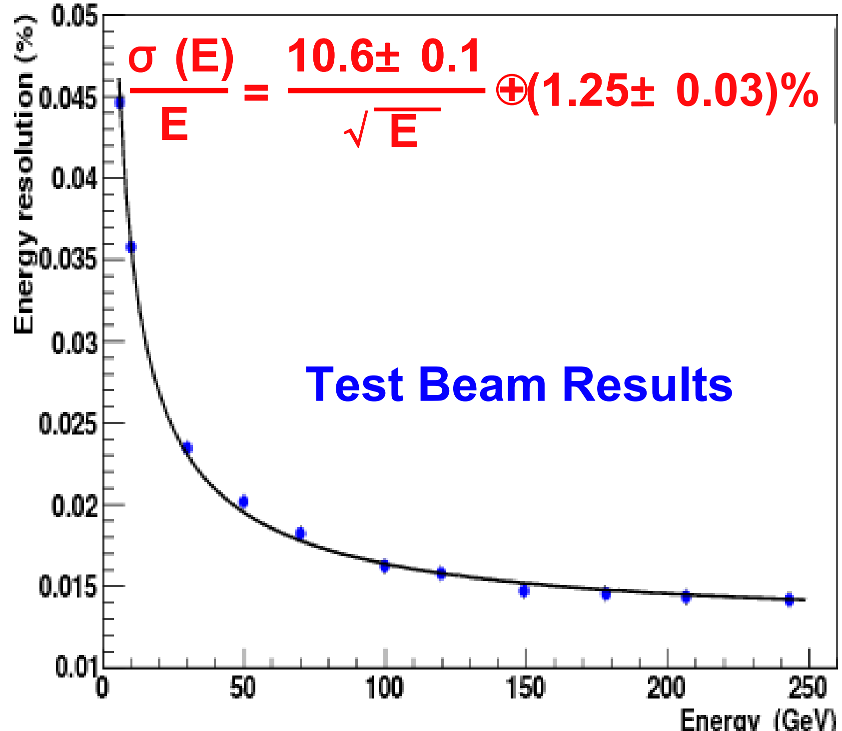
Calorimeter (ECAL)

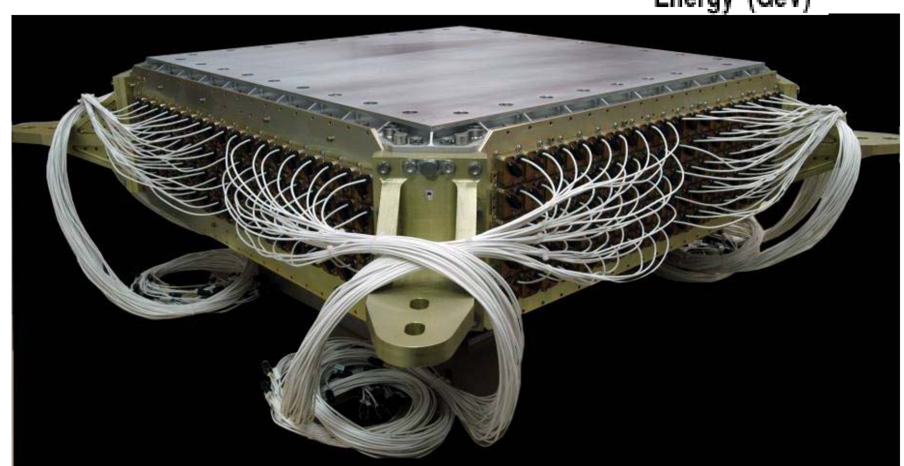
A precision, 17 X_0, 3-dimensional measurement of the directions and energies of light rays and electrons





10 000 fibers, $\phi = 1$ mm distributed uniformly Inside 1,200 lb of lead

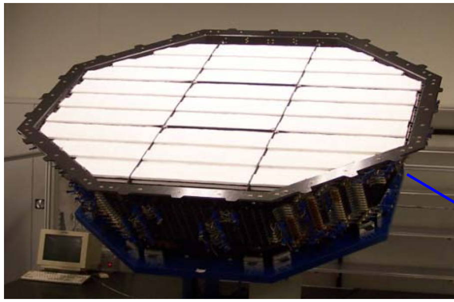




2009: AFTER 9000 hrs of TVT…THE END OF SUB-SYSTEM TESTS

AMS assembly for 3-year mission on ISS

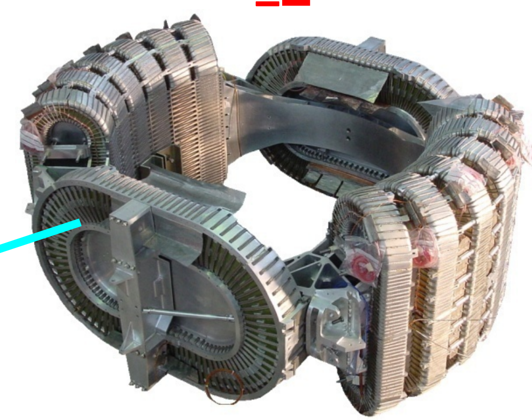
TRD
Identify e+, e-



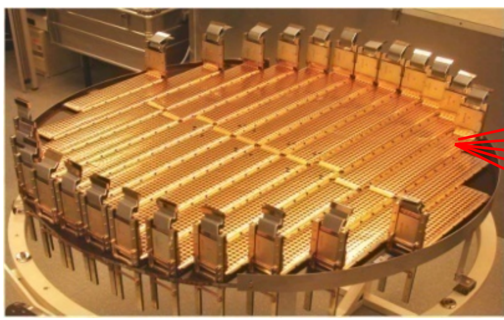
Particles and nuclei are defined by their charge (**Z**) and energy (**E ~ P**)

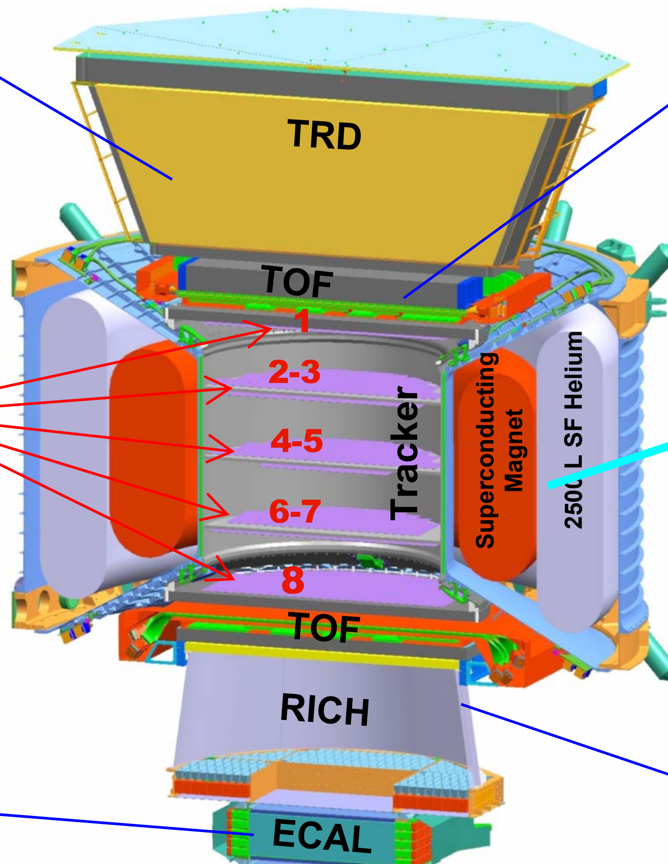
TOF
Z , E

Magnet
±Z



Silicon Tracker
Z , P





ECAL
E of e+, e-, γ

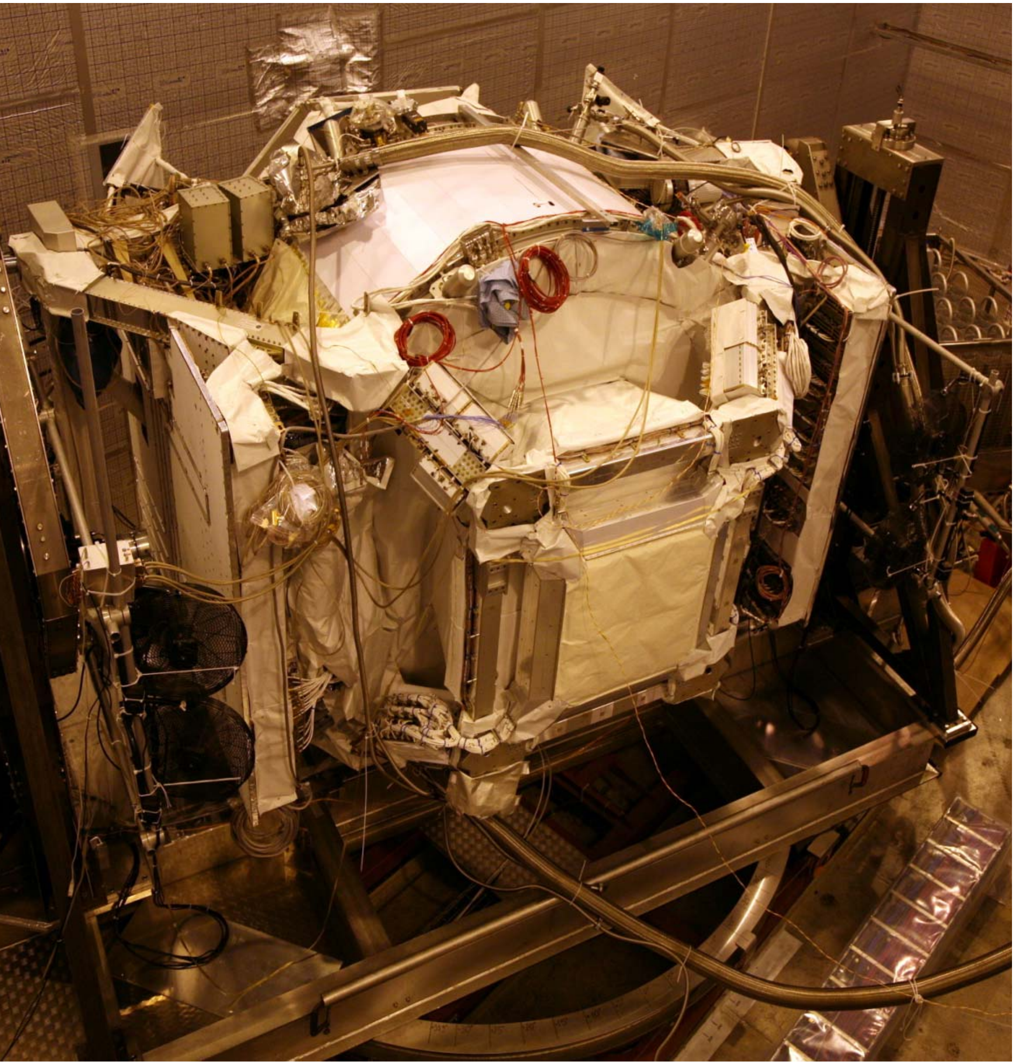
RICH
Z , E

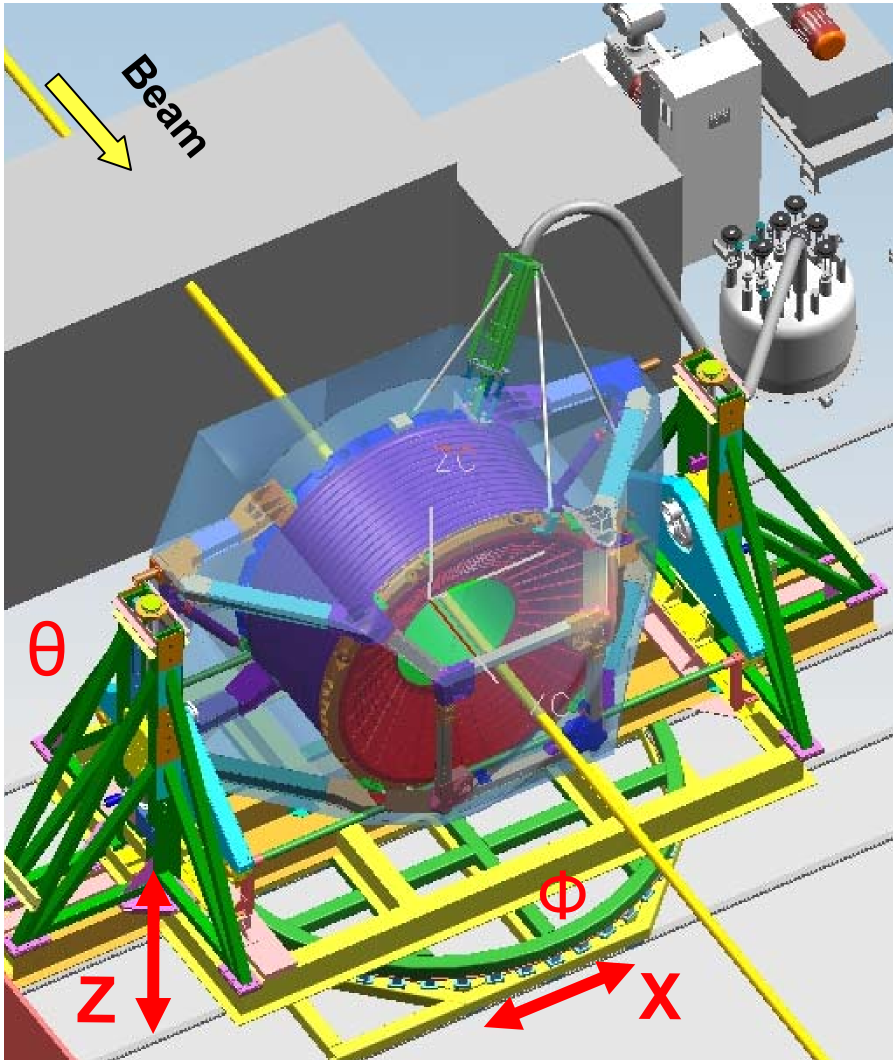
Z, E are measured independently from Tracker, RICH, TOF and ECAL

AMS in Test Beam, Feb 4-8, 2010

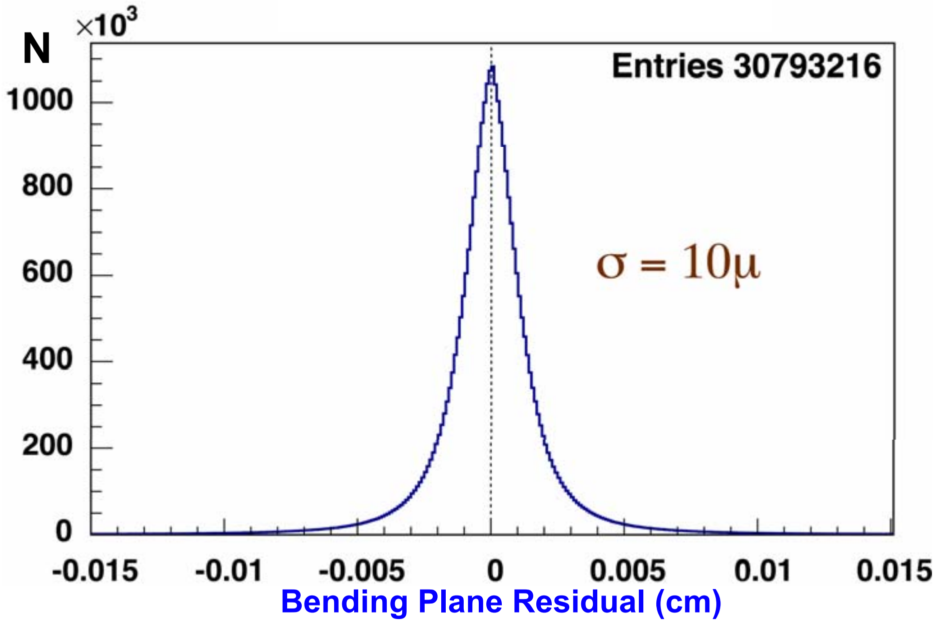
Tests were performed with the superconducting magnet charged to its design current of 400A and to 80A corresponding to the field of the AMS-01 permanent magnet.

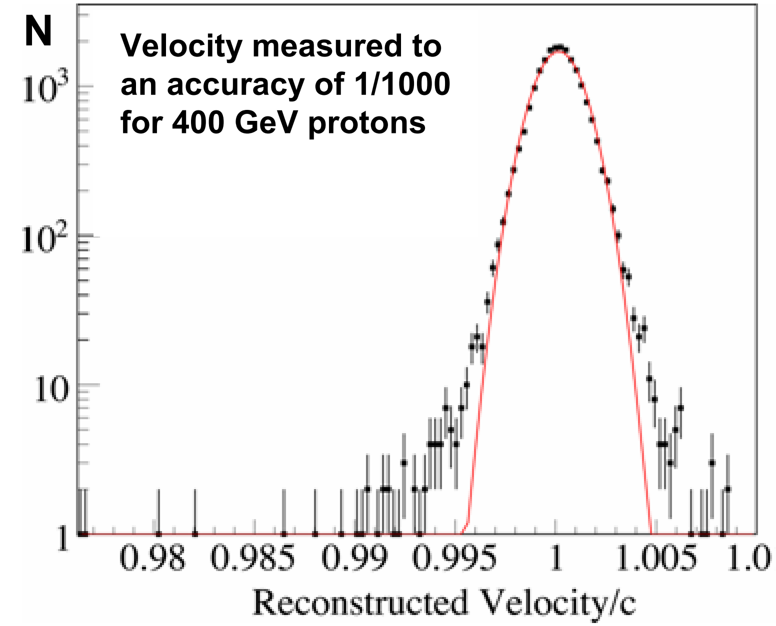
TRD, Tracker, RICH, TOF and ECAL performance was not affected by the change of magnetic field

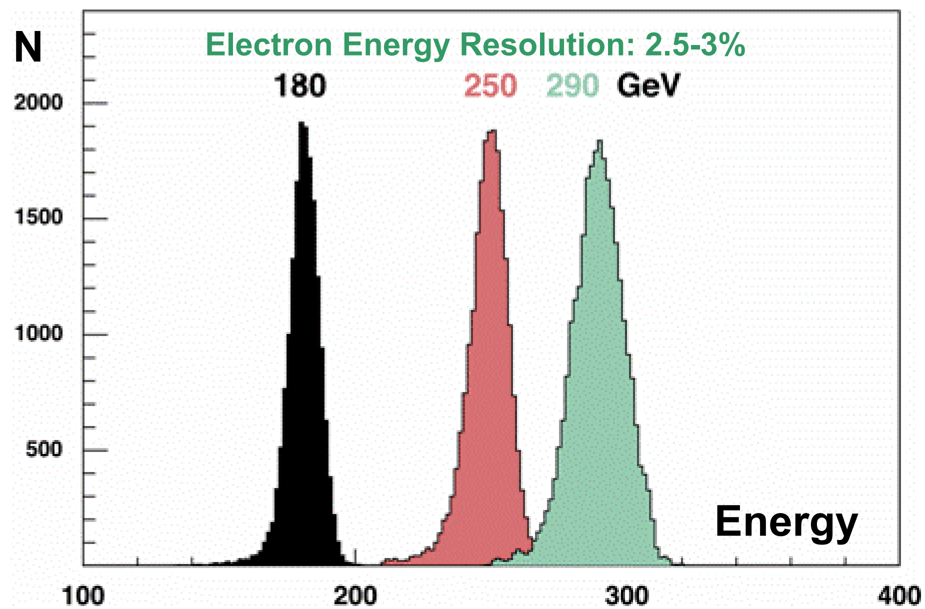


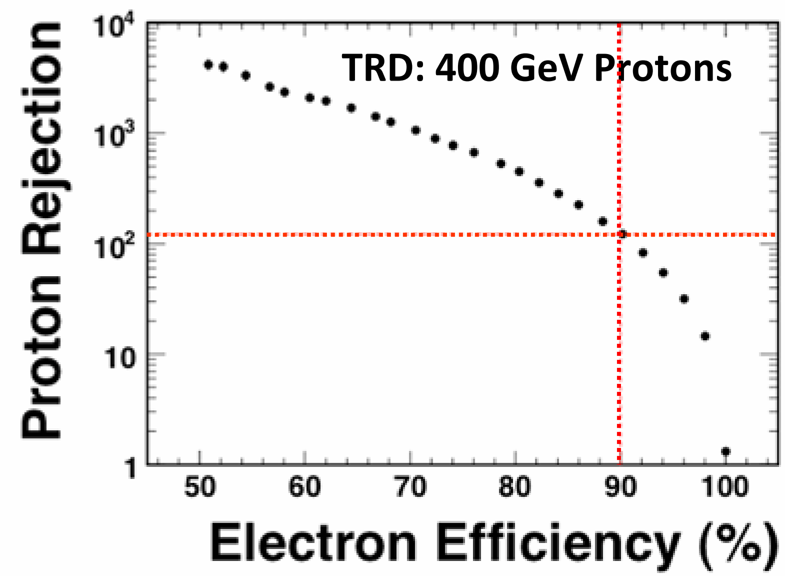


Test Beam Results of integrated detector



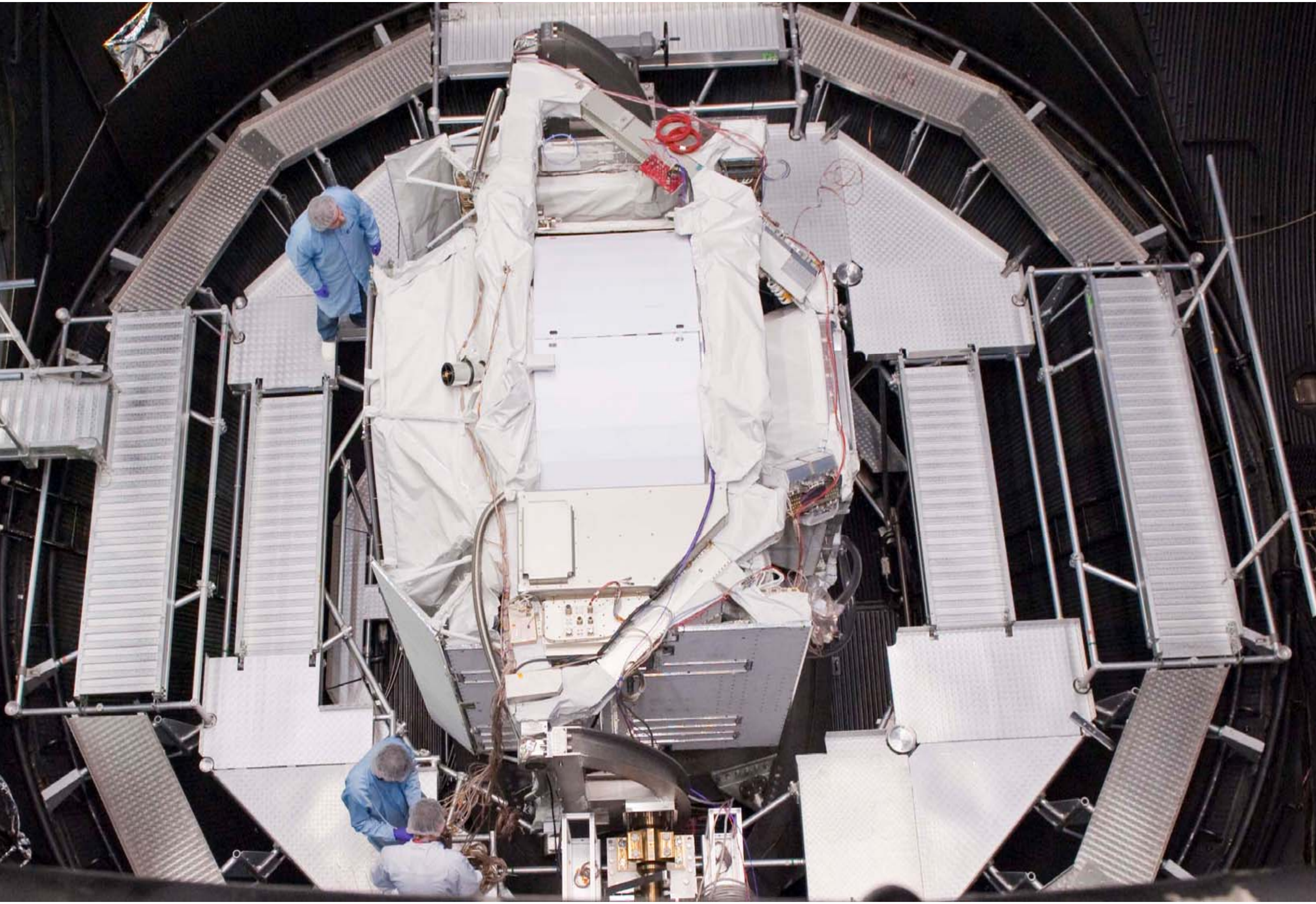




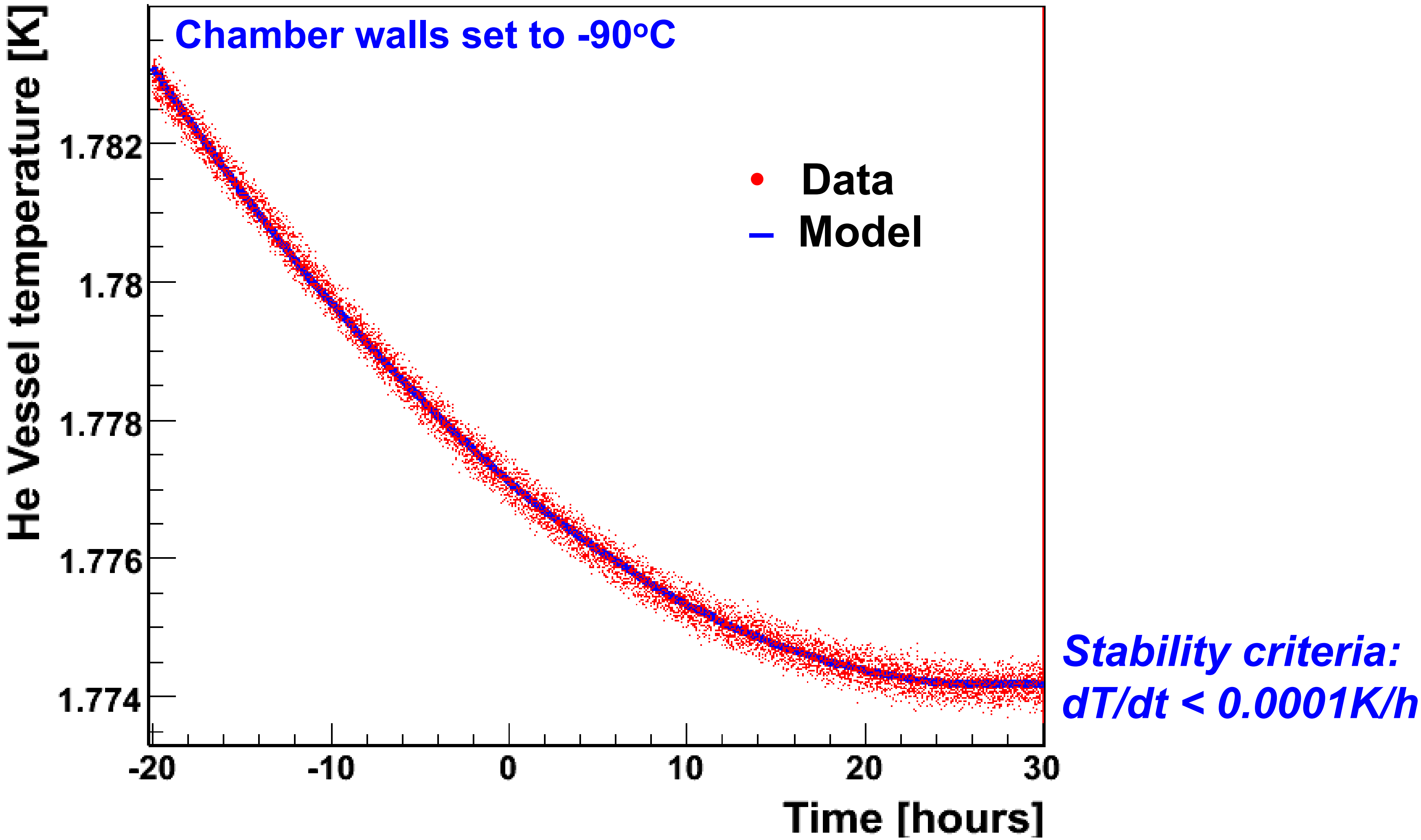


Measured combined rejection power at 400 GeV: $e^+/p = 10^{-6}$

AMS in the ESA TVT Chamber



Stabilization of the He Vessel

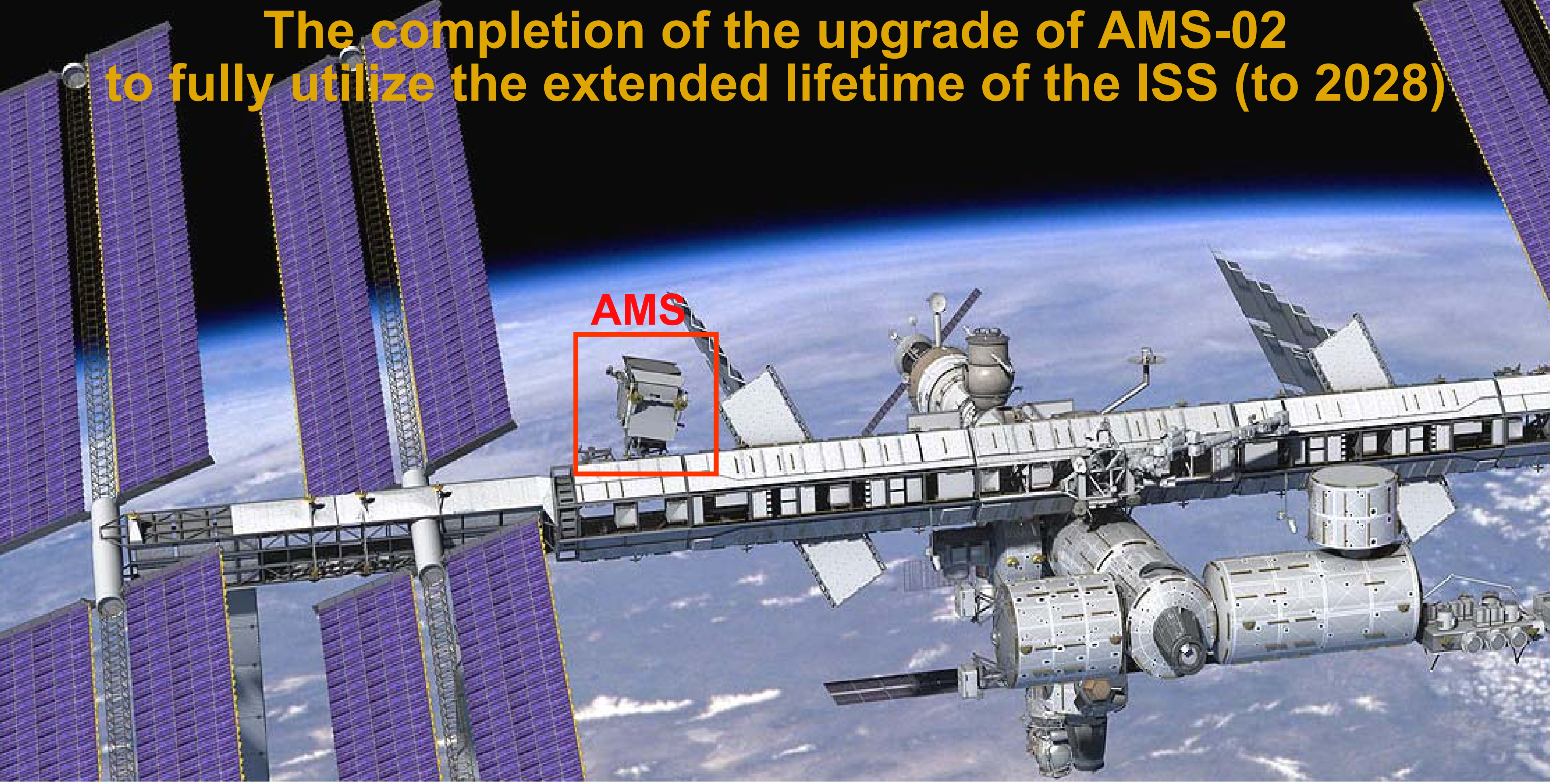


Expected life time of the AMS Cryostat on ISS:

20±4 months with M87 cryocoolers (1999)

28±6 months with GT cryocoolers (2010)

The completion of the upgrade of AMS-02 to fully utilize the extended lifetime of the ISS (to 2028)



This upgrade has been supported by agencies from
Italy, Germany, Switzerland, Spain, the Netherlands and the U.S.A.

The European science community realizes the importance of full exploitation of the potential of ISS, to which they have contributed greatly.

Michael Braukus
Headquarters, Washington
202-358-1979
michael.j.braukus@nasa.gov

March 11, 2010

RELEASE : 10-063

Heads of Agency International Space Station Joint Statement

TOKYO -- The heads of the International Space Station (ISS) agencies from Canada, Europe, Japan, Russia, and the United States met in Tokyo, Japan, on March 11, 2010, to review ISS cooperation.

With the assembly of the ISS nearing completion and the capability to support a full-time crew of six established, they noted the outstanding opportunities now offered by the ISS for on-orbit research and for discovery including the operation and management of the world's largest international space complex. In particular, they noted the unprecedented opportunities that enhanced use of this unique facility provides to drive advanced science and technology. This research will deliver benefits to humanity on Earth while preparing the way for future exploration activities beyond low-Earth orbit. The ISS will also allow the partnership to experiment with more integrated international operations and research, paving the way for enhanced collaboration on future international missions.

The heads of agency reaffirmed the importance of full exploitation of the station's scientific, engineering, utilization, and education potential. They noted that there are no identified technical constraints to continuing ISS operations beyond the current planning horizon of 2015 to at least 2020, and that the partnership is currently working to certify on-orbit elements through 2028. The heads of agency expressed their strong mutual interest in continuing operations and utilization for as long as the benefits of ISS exploitation are demonstrated. They acknowledged that a U.S. fiscal year 2011 budget consistent with the U.S. administration's budget request would allow the United States to support the continuation of ISS operations and utilization activities to at least 2020. They emphasized their common intent to undertake the necessary procedures within their respective governments to reach consensus later this year on the continuation of the ISS to the next decade.

In looking ahead, the heads of agency discussed the importance of increasing ISS utilization and operational efficiency by all possible means, including finding and coordinating efficiencies across the ISS Program and assuring the most effective use of essential capabilities, such as space transportation for crew and cargo, for the life of the program.

For the latest about the International Space Station, visit the Internet at: http://www.nasa.gov/station

- end -

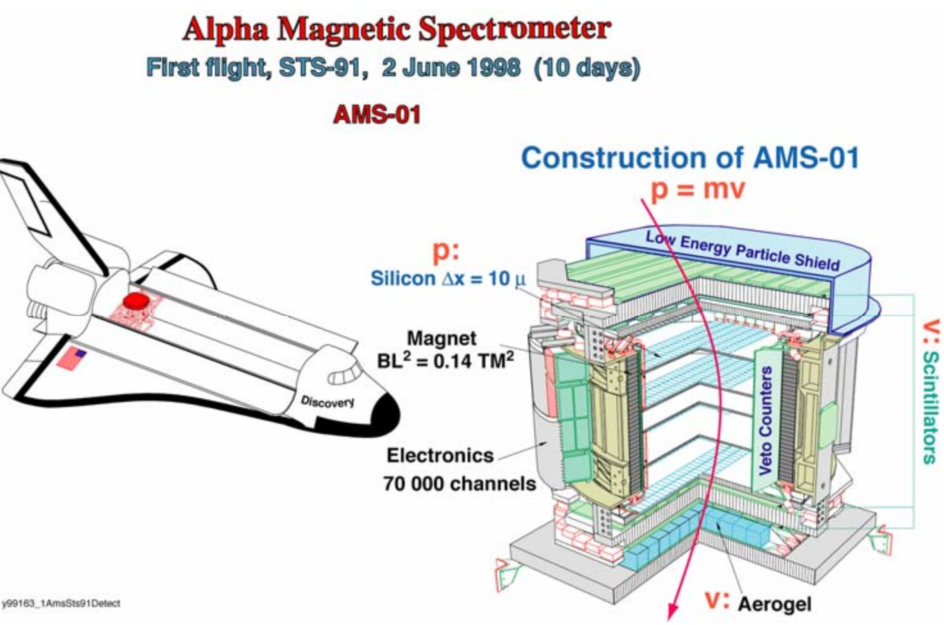
A superconducting magnet was ideal for a three year stay on ISS as originally planned for AMS.

The ISS lifetime has been extended to 2020 (2028), the Shuttle program will be terminated, thus eliminating any possibility of returning and refilling AMS.

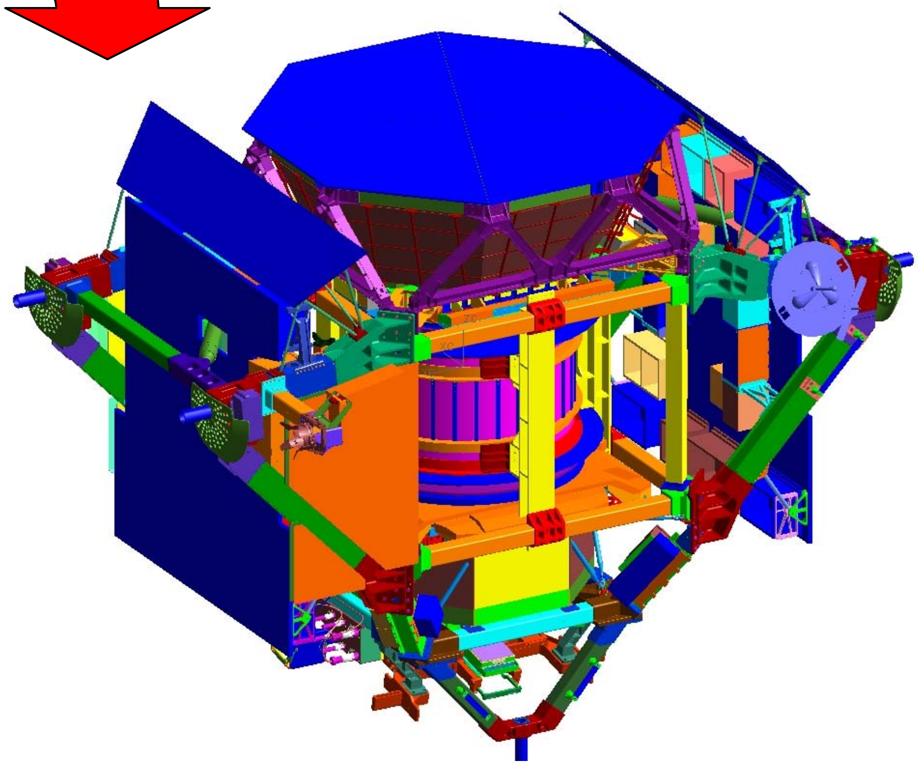
A superconducting magnet is no longer the ideal choice.

Most importantly, the permanent magnet option will have 10-18 years time to collect data, providing much more sensitivity to search for new phenomena.

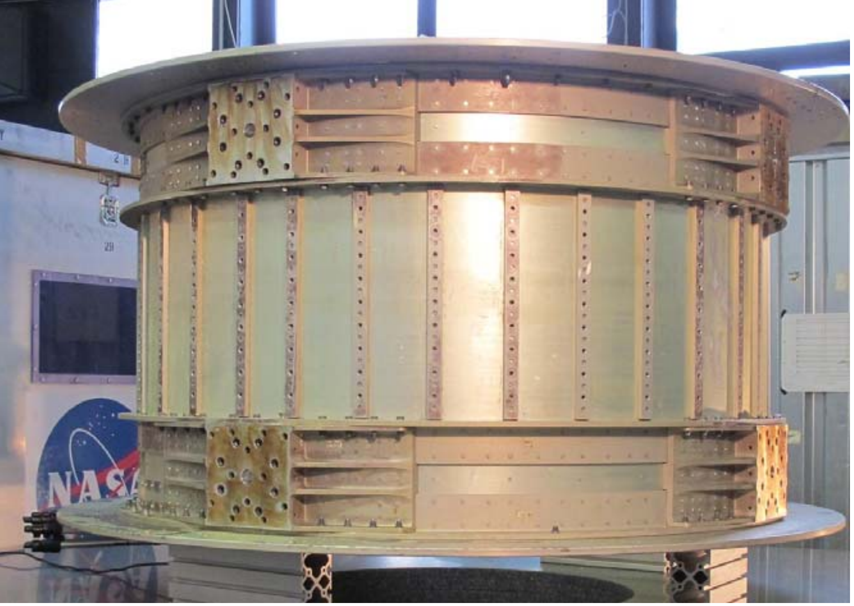
During the past ten years the AMS-01 Permanent Magnet has been kept as an alternative for AMS-02, and has been reviewed regularly by the Collaboration.



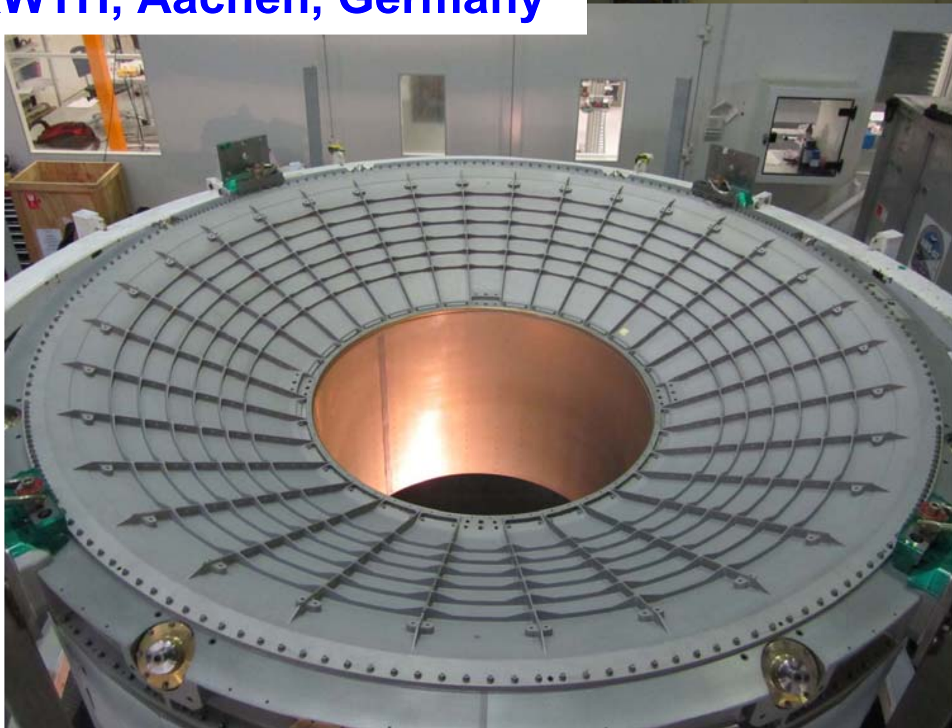
AMS Group Meeting,
CERN - 30Jan.-3 Feb. 2006



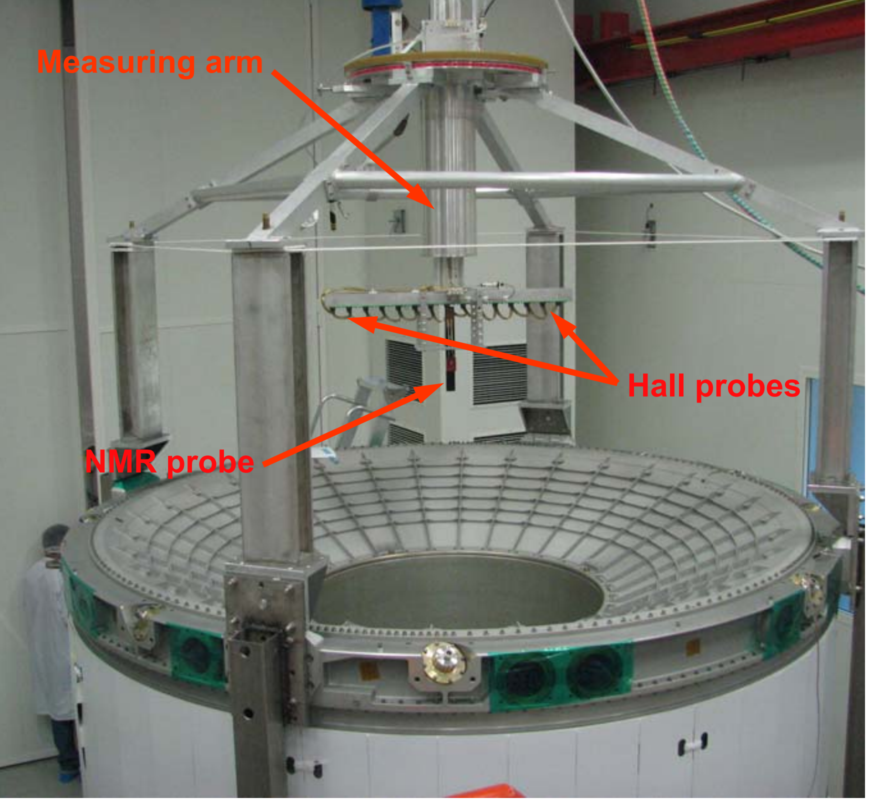
AMS-02 with a permanent magnet

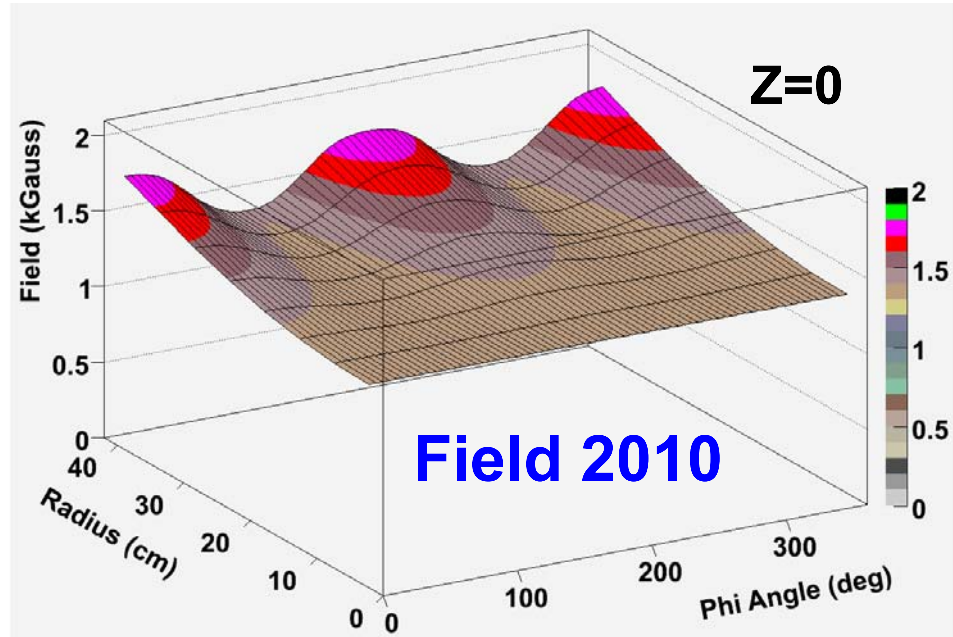


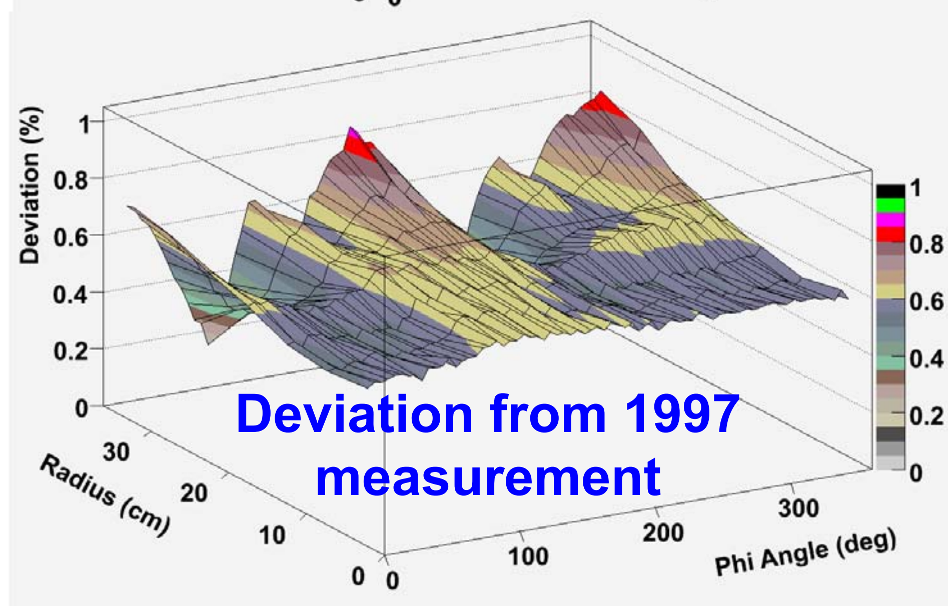
Permanent Magnet installation,
12 May 2010, RWTH, Aachen, Germany



In 12 years the field has remained the same to <1%

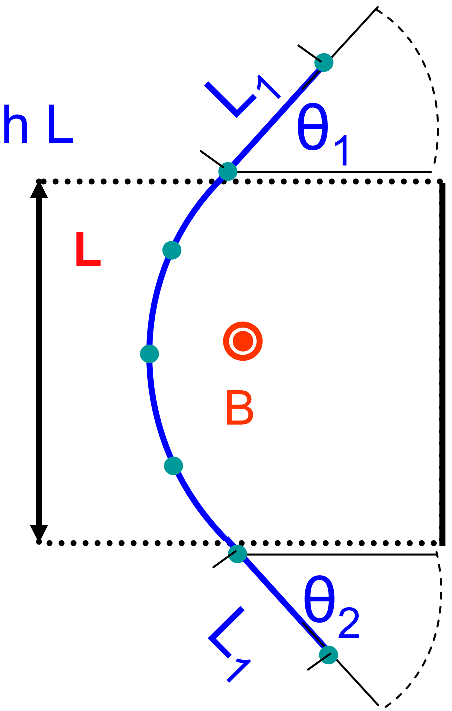






The detailed 3D field map (120000 locations) was measured at CERN on 25-27 May 2010

The momentum resolution ($\Delta p/p$) is the sum of two contributions:



1. Measurement inside the magnet with an effective length L

$$(Z/p)\cdot(\Delta p/p) \propto 1/BL^2$$

2. Measurement of the incident (θ_1) and exit (θ_2) angles which depend on the length L_1

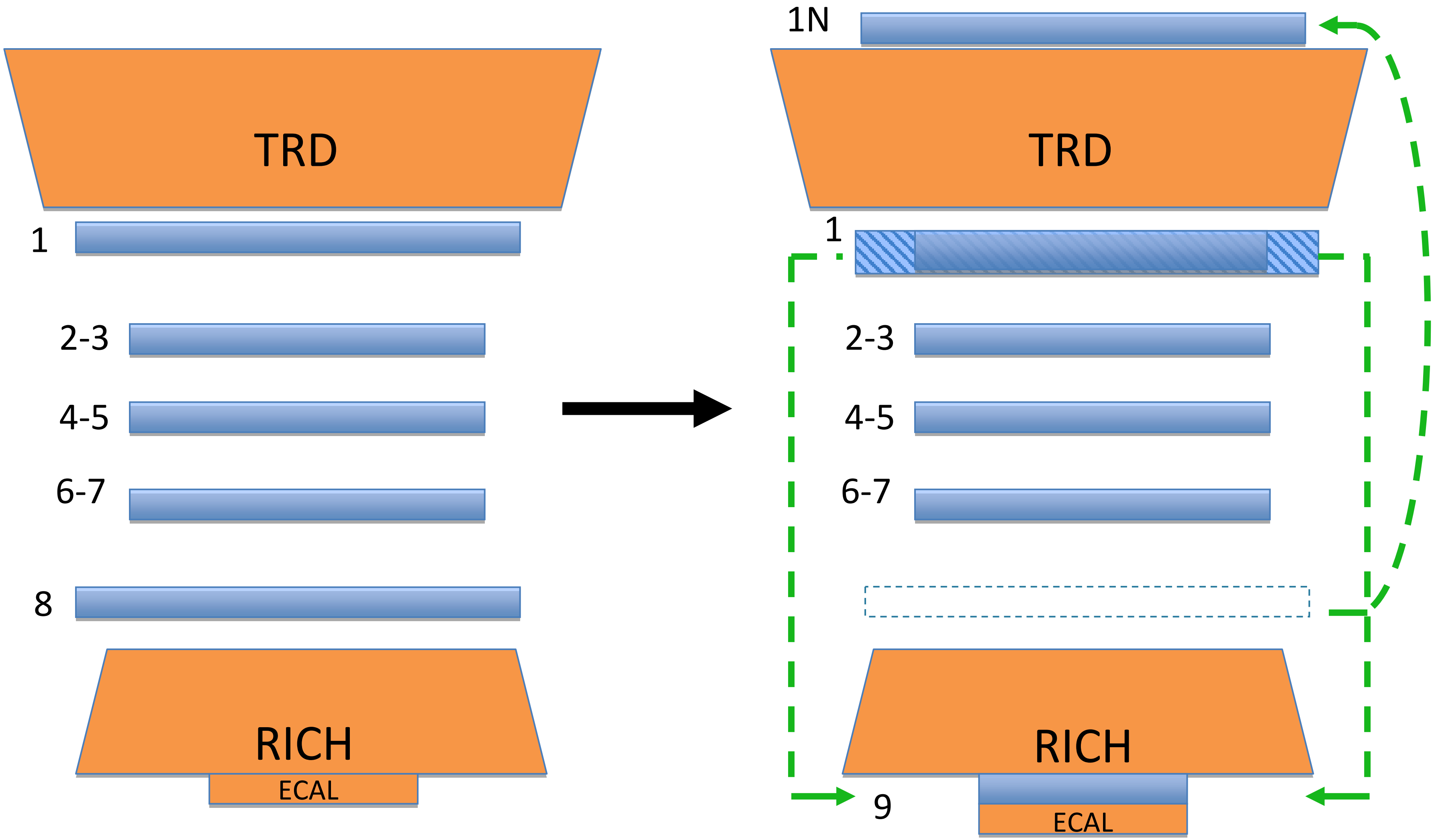
$$(Z/p)\cdot(\Delta p/p) \propto 1/BLL_1$$

For both magnets, L ~ 80 cm,
but in the permanent magnet B is 5 times smaller

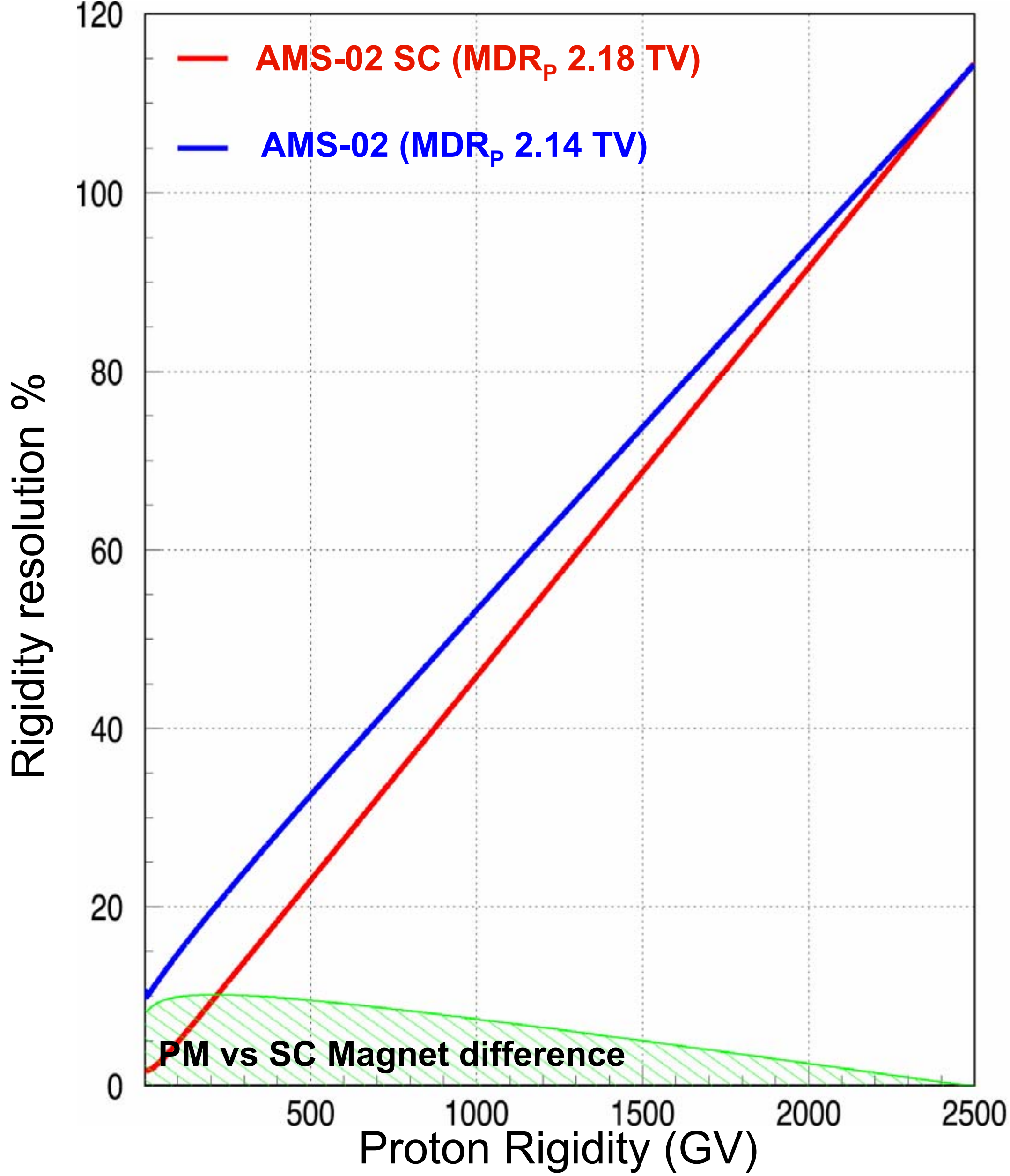
to maintain the same $\Delta p/p$ we increase L1 from ~15 cm (Superconducting Magnet) to ~125 cm (permanent magnet)

AMS-02 SC (3Yrs)
Silicon Tracker Layers

AMS-02 (10 - 18 Yrs)
Silicon Tracker Layers

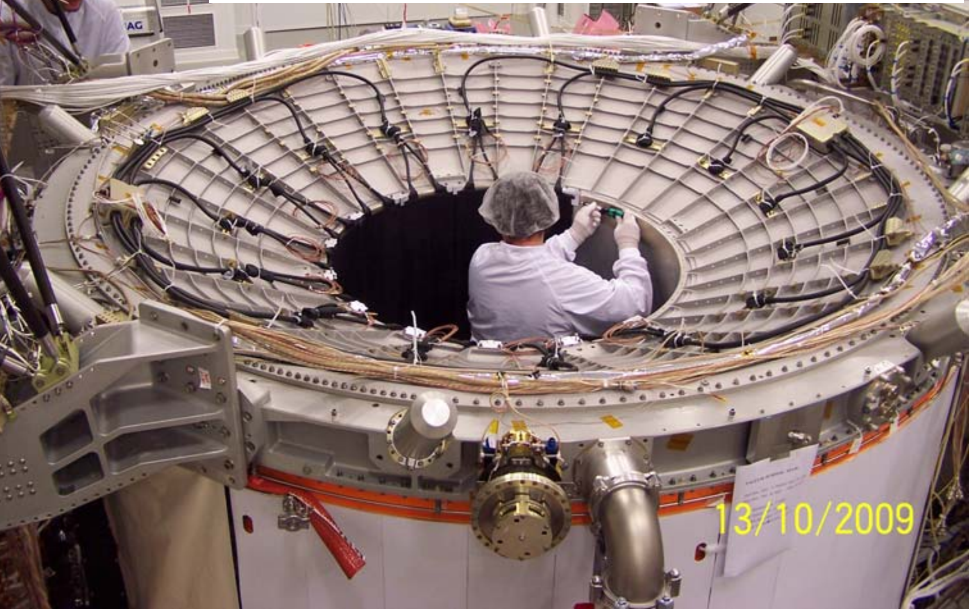


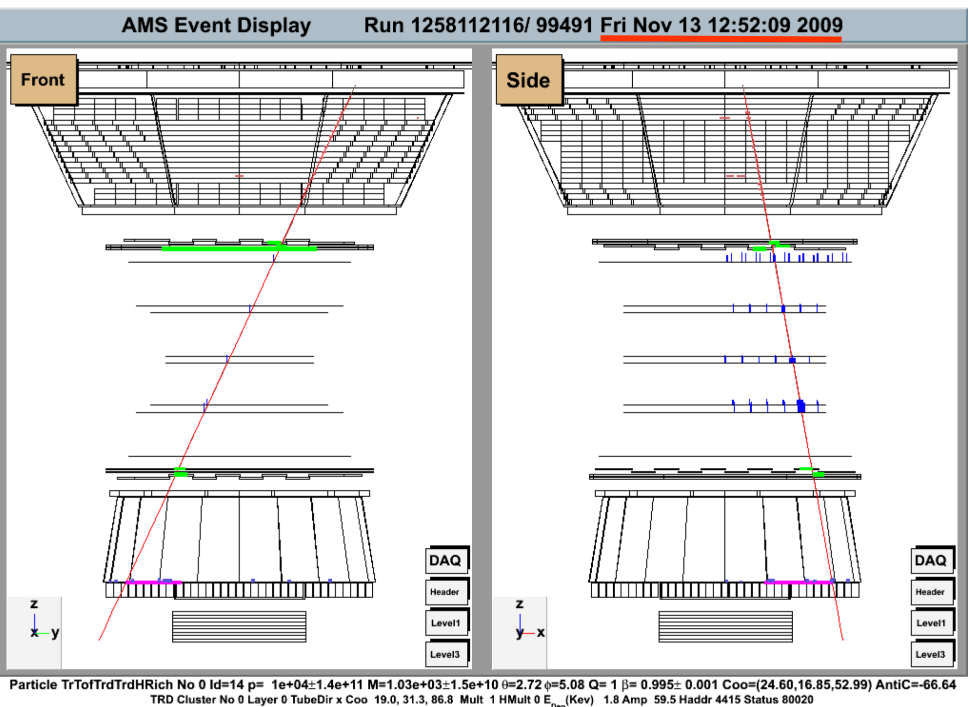
Layer 9 comes from moving the ladders at the edge of the acceptance from layer 1. The layer 8 is moved on top of the TRD to become 1N.
No new silicon and no new electronics are required.



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.

2nd integration of AMS,2009
installation of the Veto system





Flight integration, 2010:

begins 7 June,
with installation of veto system

Completion – 7 August

Test beam: 7-14 August
Transport to KSC: 24 August

Launch Ready: Nov 2010

Mr. Gerstenmaier spent June 19th examining all the engineering details of the integration

It's not often that you're doing something like this with the NASA Associate Administrator for Space Operations looking on…

12 July 2010

from CERN

…to KENNEDY

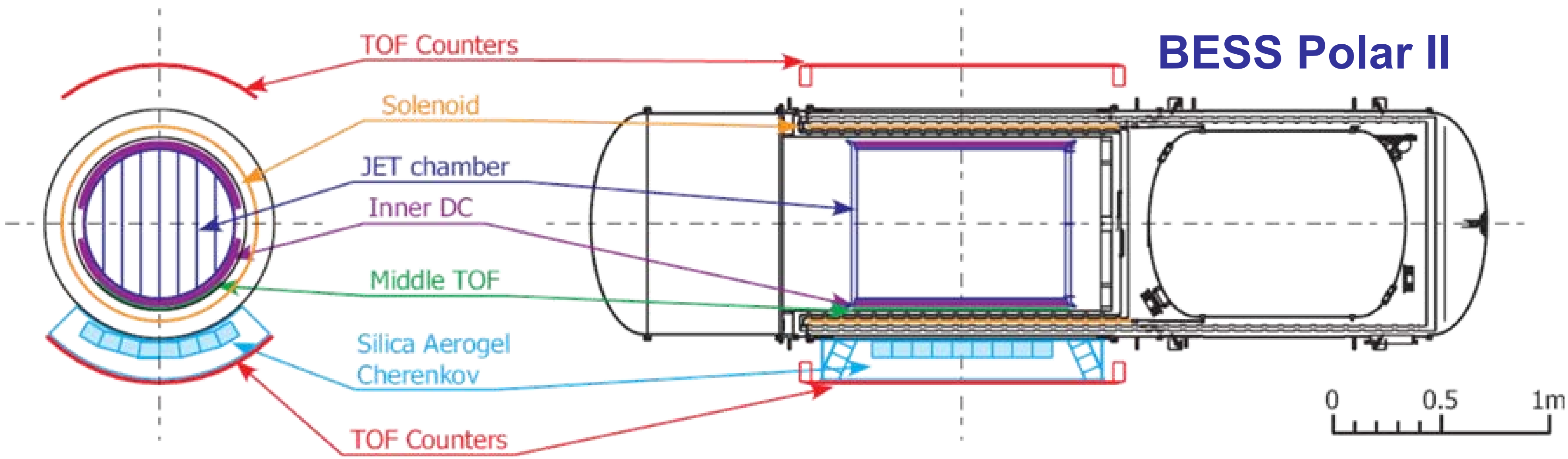
		Apr 25	AMS AT CERN BACK FROM TVT ESTEC
Apr 26	–	May 31	AMS DE-INTEGRATION
June 1	–	June 6	**MAGNET CHANGE**
June 7	–	Aug 7	AMS INTEGRATION & Test with cosmic rays
Aug 8	–	Aug 14	**TEST BEAM**
Aug 15	–	Aug 24	AMS READY ON USAF C5
Aug 25			AMS AT KSC

Magnetic spectrometers for cosmic ray studies

Goals:

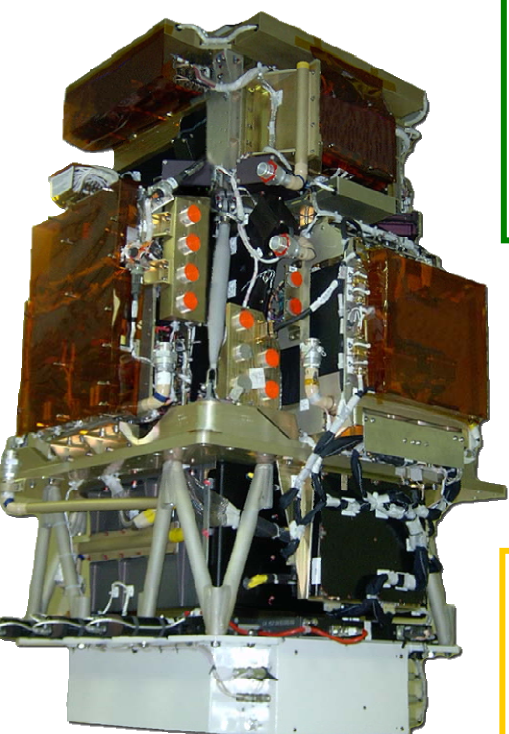
- **Searches for primordial antimatter:**
  - Light anti-nuclei: $\bar{D}$, $\overline{He}$, …
  - $\bar{p}$ / p ratio
- **Dark Matter searches:**
  - e^+, $e^\pm$, $\bar{p}$, …
  - simultaneous observation of several signal channels.
- **Searches for new forms of matter:**
  - **stranglets, …**
- **Measuring CR spectra – refining propagation models;**
- **Identification of local sources of high energy CR (~TeV):**
  - **SNR, Pulsars, PBH, …**
- **Study effects of solar modulation on CR spectra**
- **…**

BESS



- 25 days of Data Acquisition Time (BESS Polar II)
- Time resolution 70-130ps
- Coordinate resolution 130μm
- MDR – 280GV
- e/p separation – factor 6000
- Average altitude – 36 km

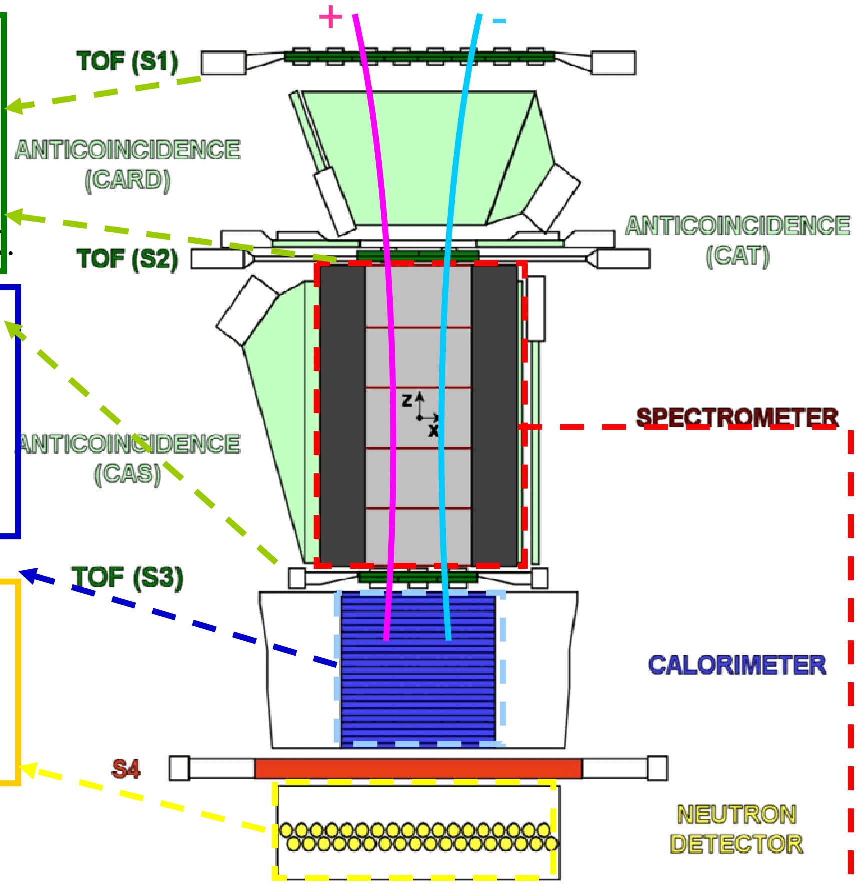
PAMELA



Time-Of-Flight (~300ps)
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 (factor ~1000-10000)

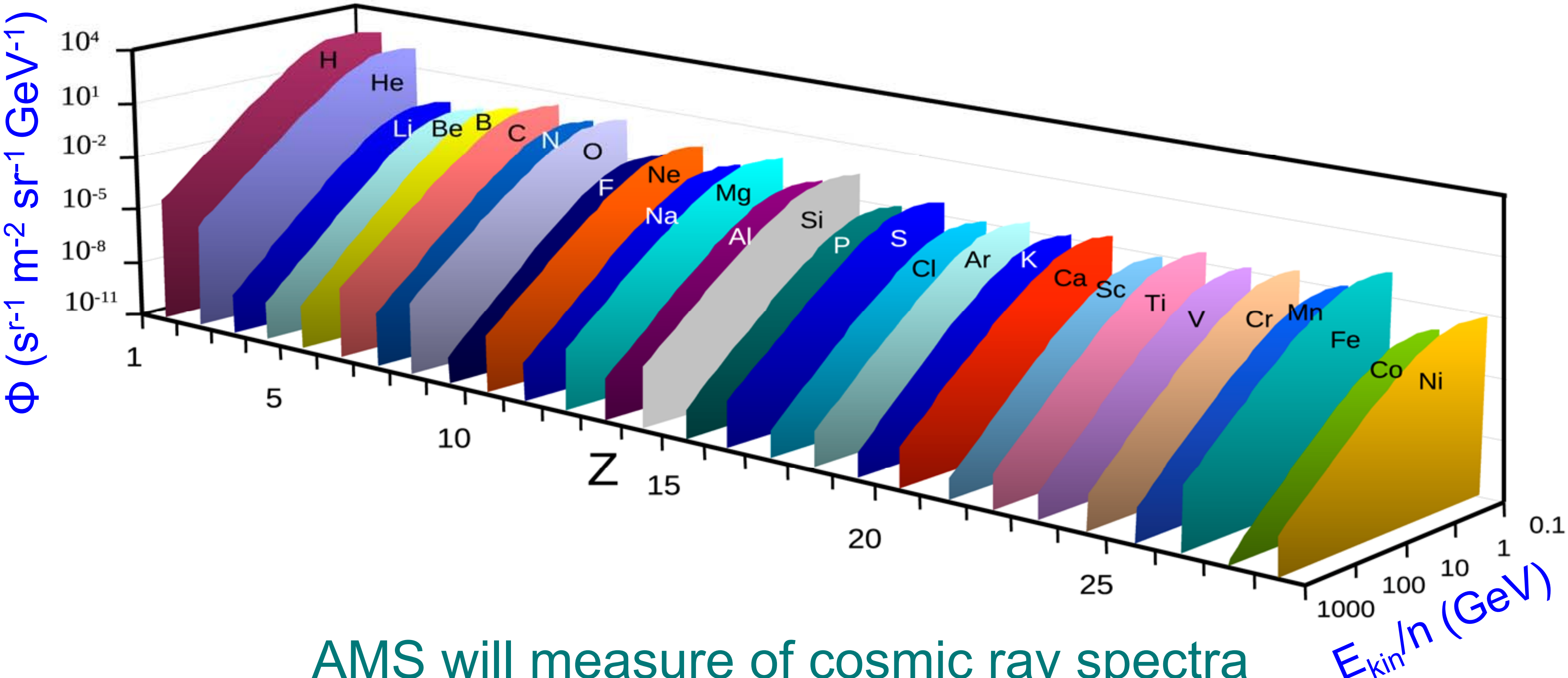


GF: 21.5 cm² sr
Magnetic Field: 0.43 T
MDR: ~1 TV
Mass: 470 kg
Size: 130x70x70 cm³
Power Budget: 360W

Spectrometer
microstrip silicon tracking system (4µm) + permanent magnet
It provides:
- *Magnetic rigidity* → R = pc/Ze
- *Charge sign*
- *Charge value from dE/dx*

Physics of AMS

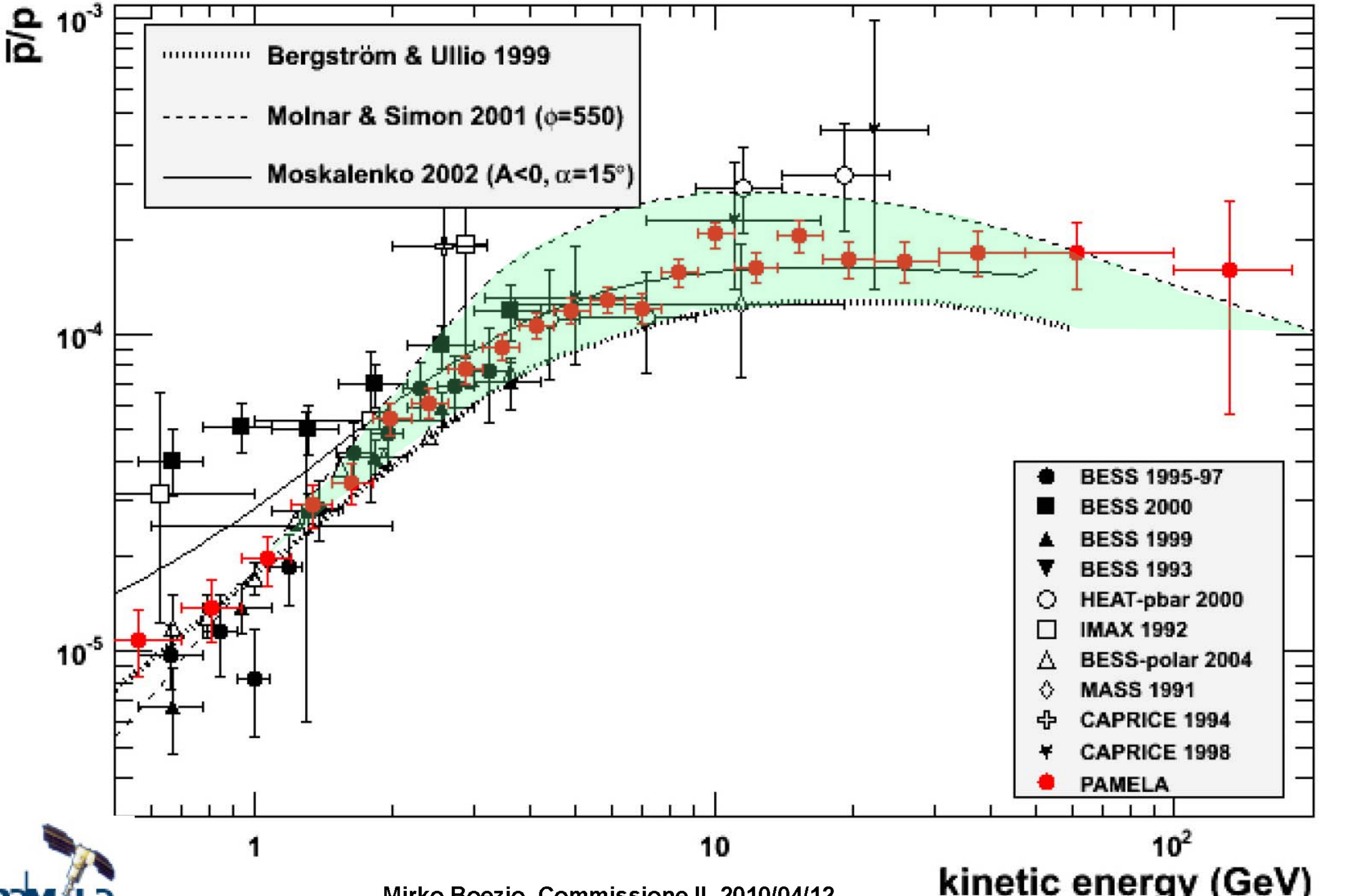
Nuclear Abundances Measurements



AMS will measure of cosmic ray spectra
for nuclei, for energies from 100 MeV to 2 TeV
with 1% accuracy over the 11-year solar cycle.

These spectra will provide experimental measurements to refine the assumptions that go into calculating the background in searching for Dark Matter, i.e., $p + C \rightarrow e^{+}, \bar{p}, \ldots$

Rapporto Antiprotoni



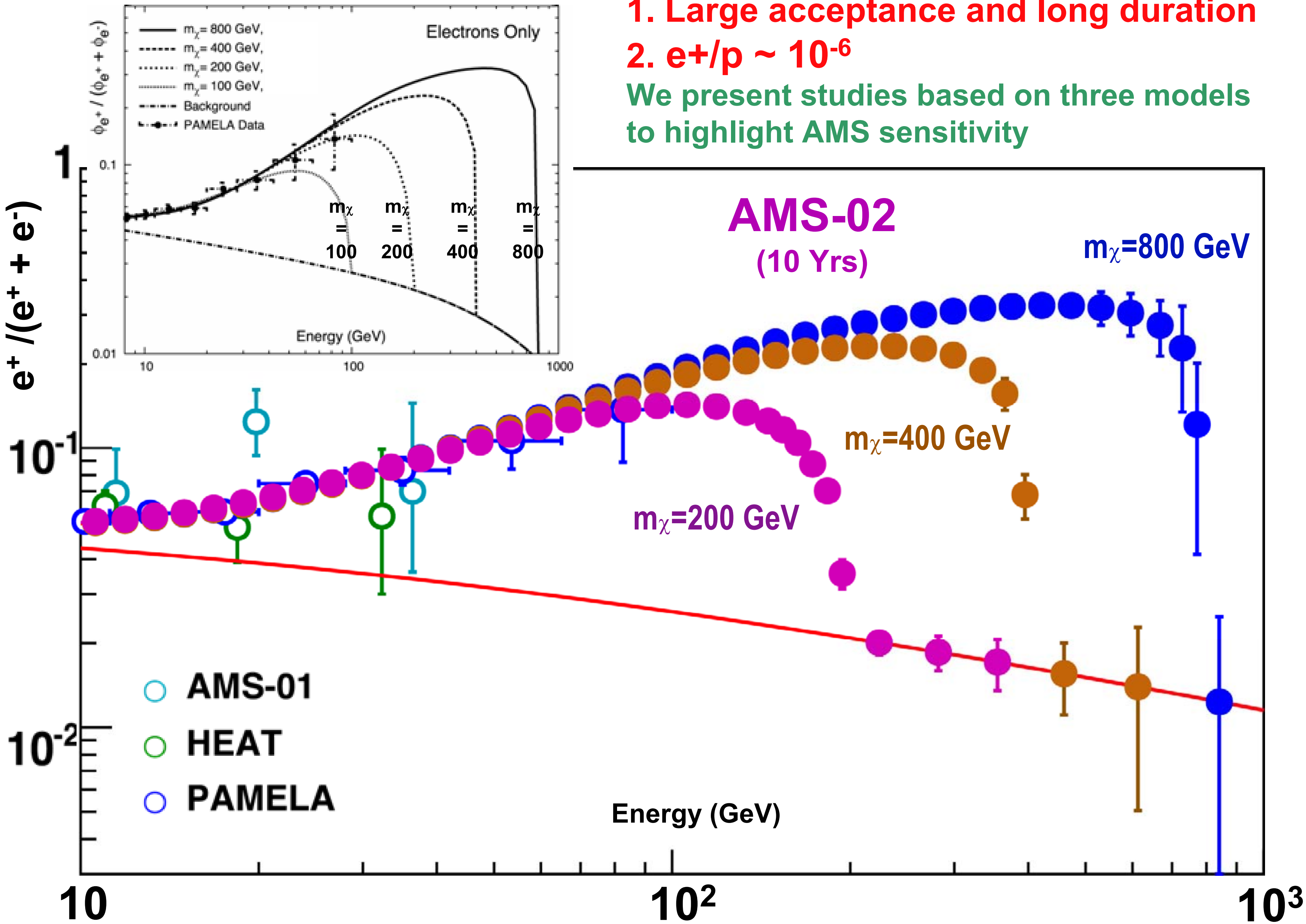
Mirko Boezio, Commissione II, 2010/04/12 case 1

I.Cholis et al, arXiv:0810.5344v3

AMS – search for DM:

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

We present studies based on three models to highlight AMS sensitivity

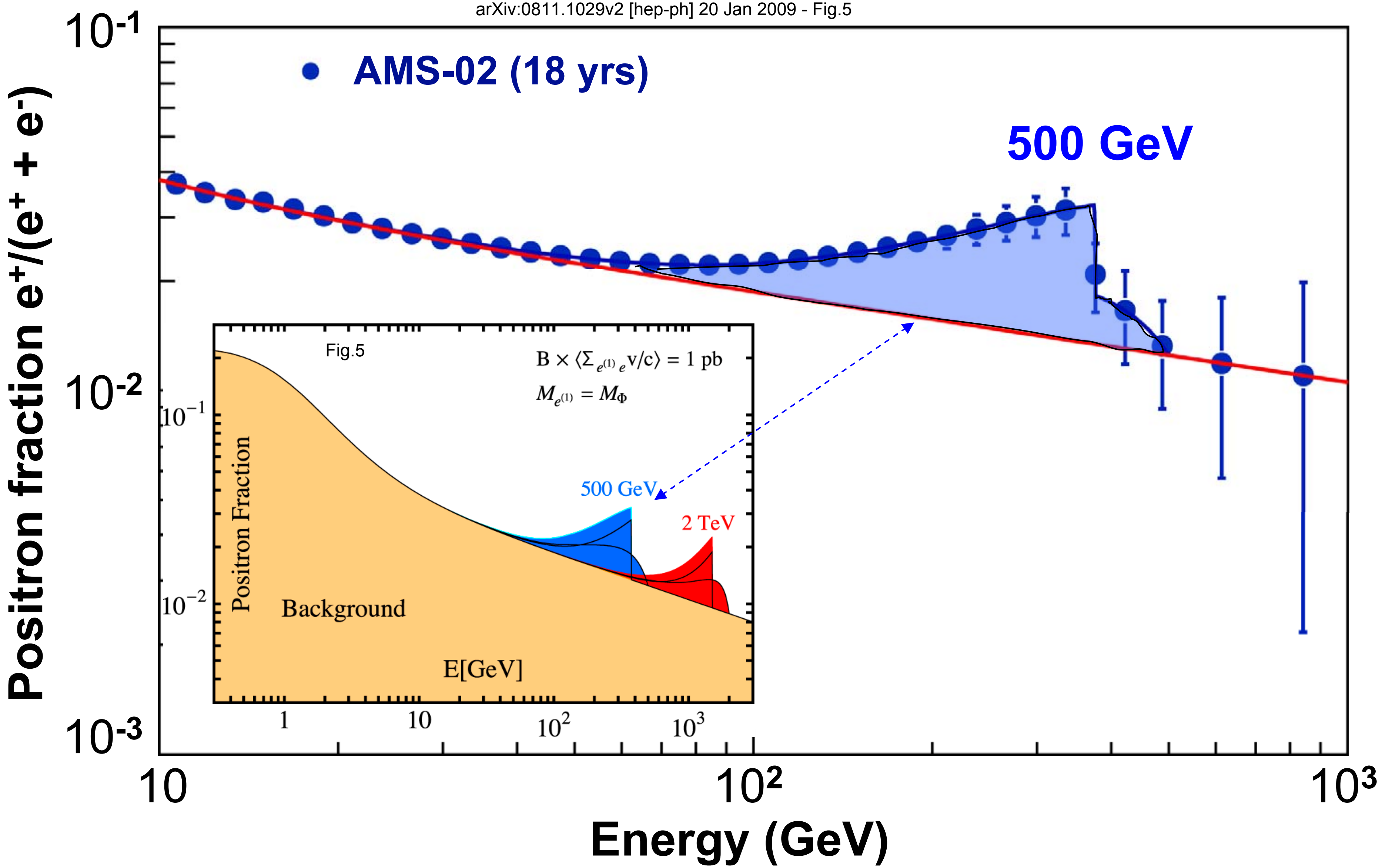


Kaluza-Klein Bosons are also Dark Matter candidates

case 2 TeV Scale Singlet Dark Matter

Eduardo Pontón and Lisa Randall

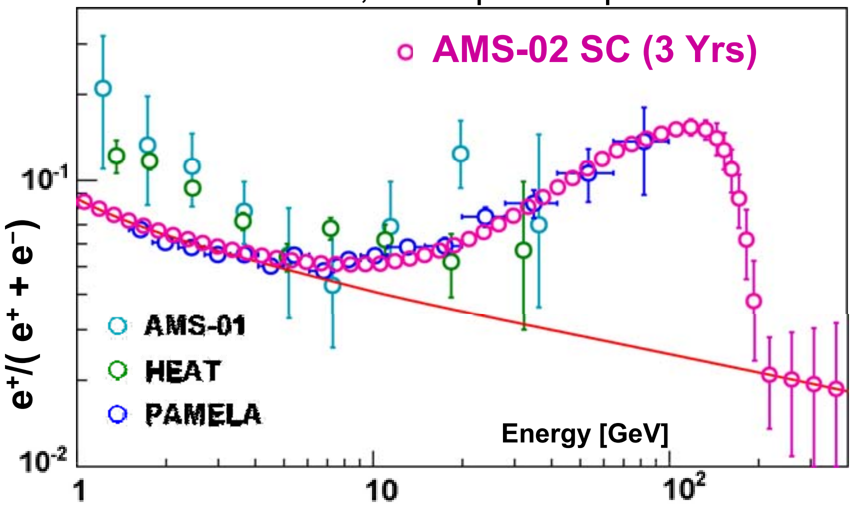
arXiv:0811.1029v2 [hep-ph] 20 Jan 2009 - Fig.5

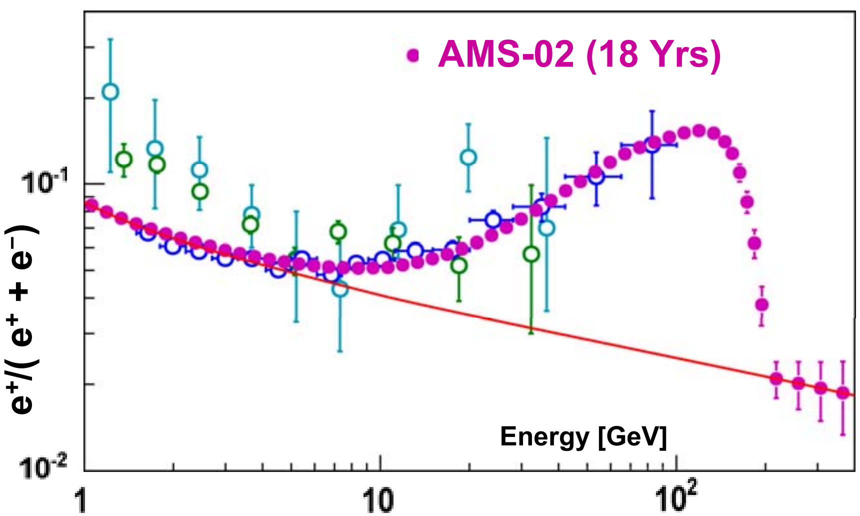


Sensitivity in Dark Matter Searches – large acceptance, long duration

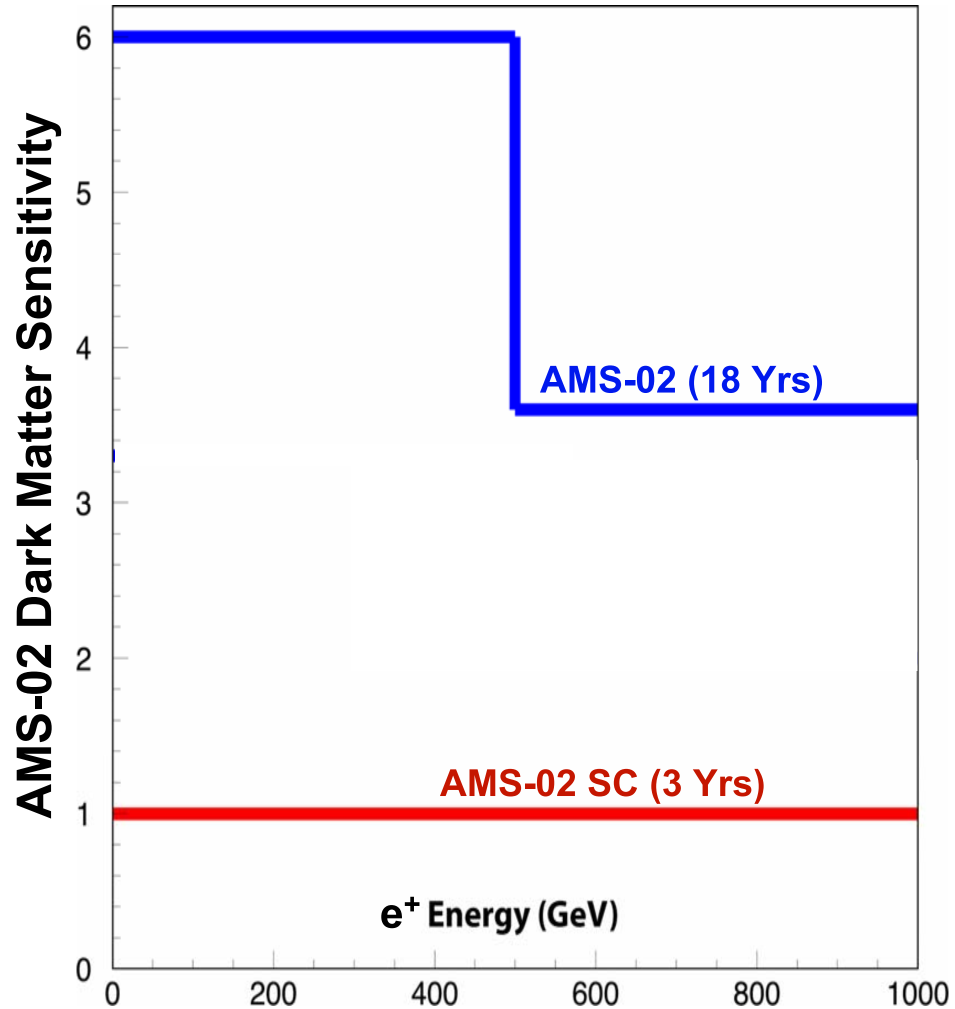
$\chi^0 \chi^0 \rightarrow e^+, e^-$ for $m\chi^0$ = 200 GeV

I.Cholis et al, astro-ph 30 Apr 2009





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

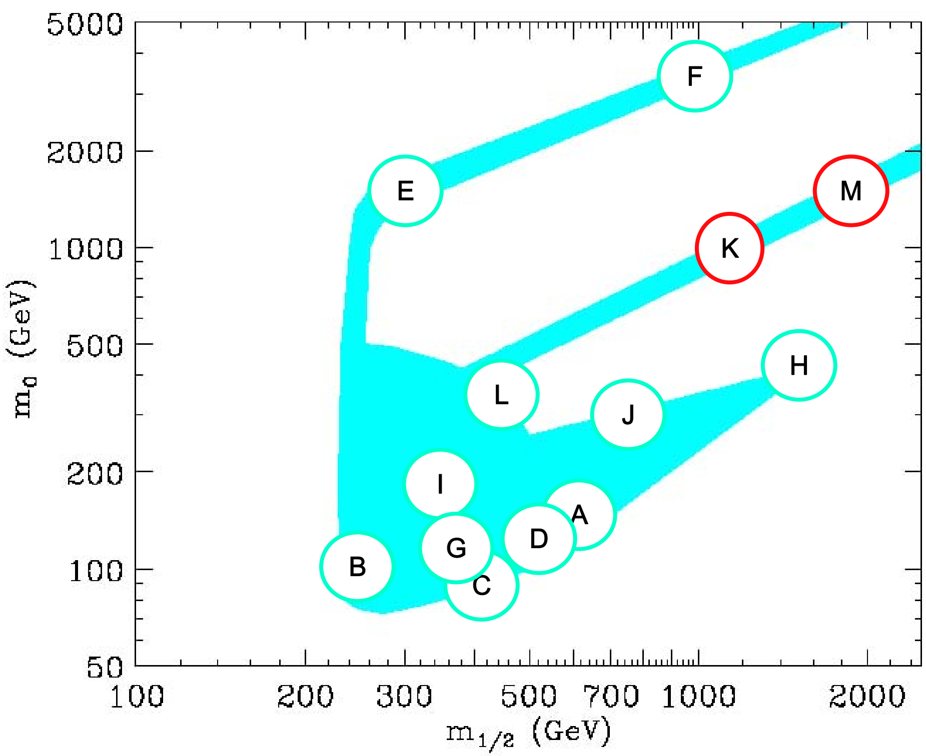


As seen, the permanent magnet upgrade of AMS has a 600-400% improvement in sensitivity in the search for Dark Matter.

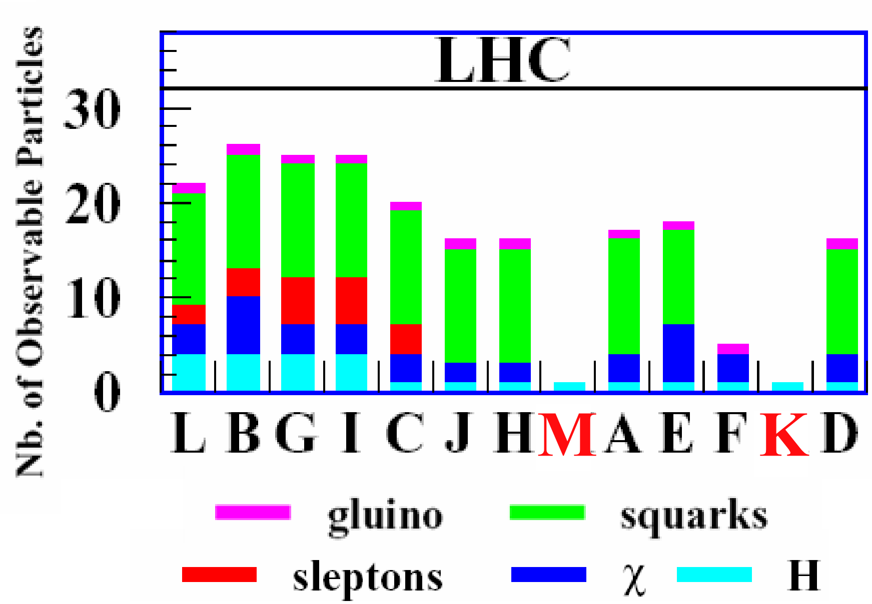
AMS is sensitive to SUSY parameter space that is difficult to study at LHC (large m_0, $m_{1/2}$ values)

J.Ellis, private communication

Shaded region allowed by WMAP, etc.



Post-WMAP Benchmarks

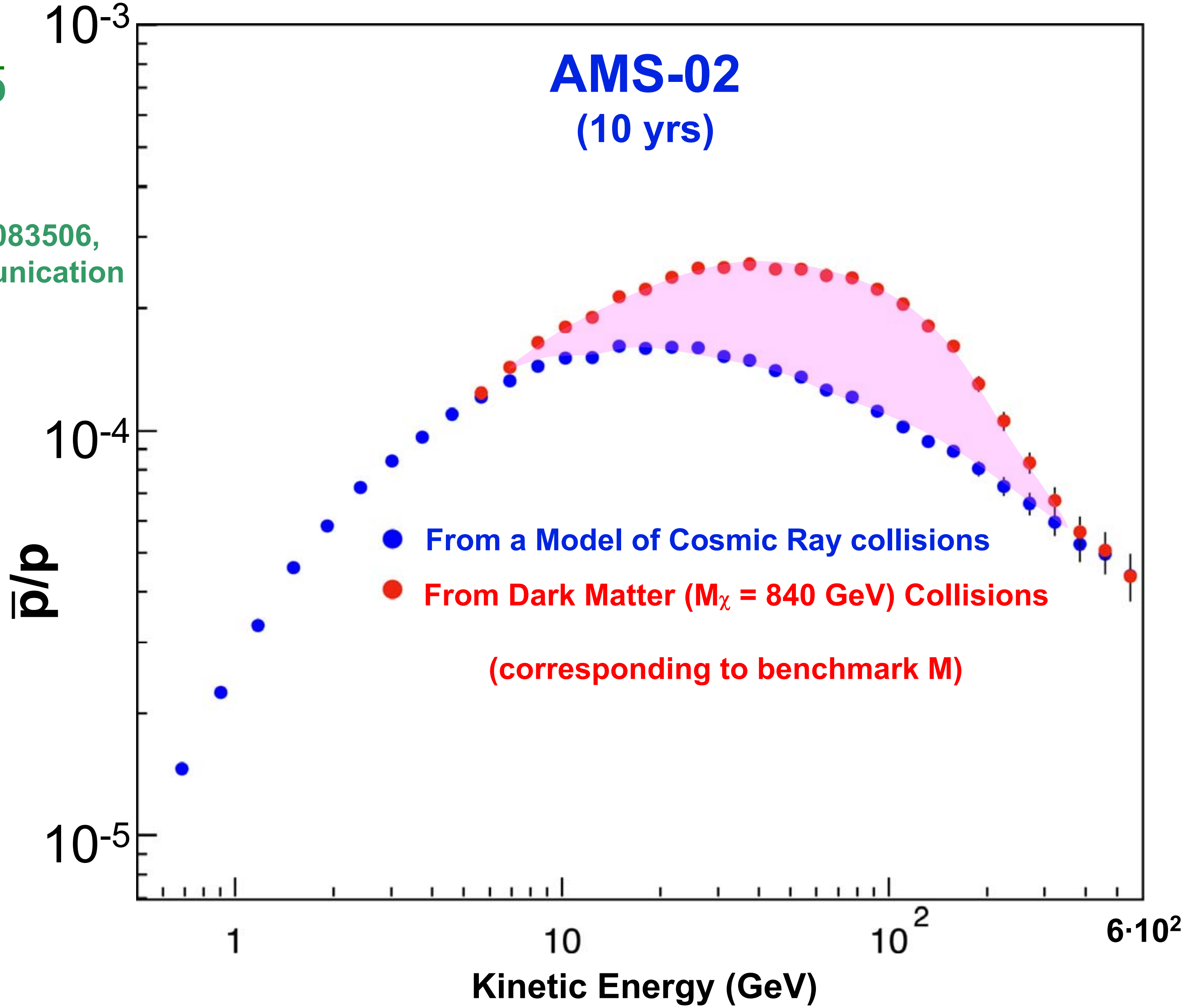


At benchmarks "K" & "M" Supersymmetric particles are not visible at the LHC.

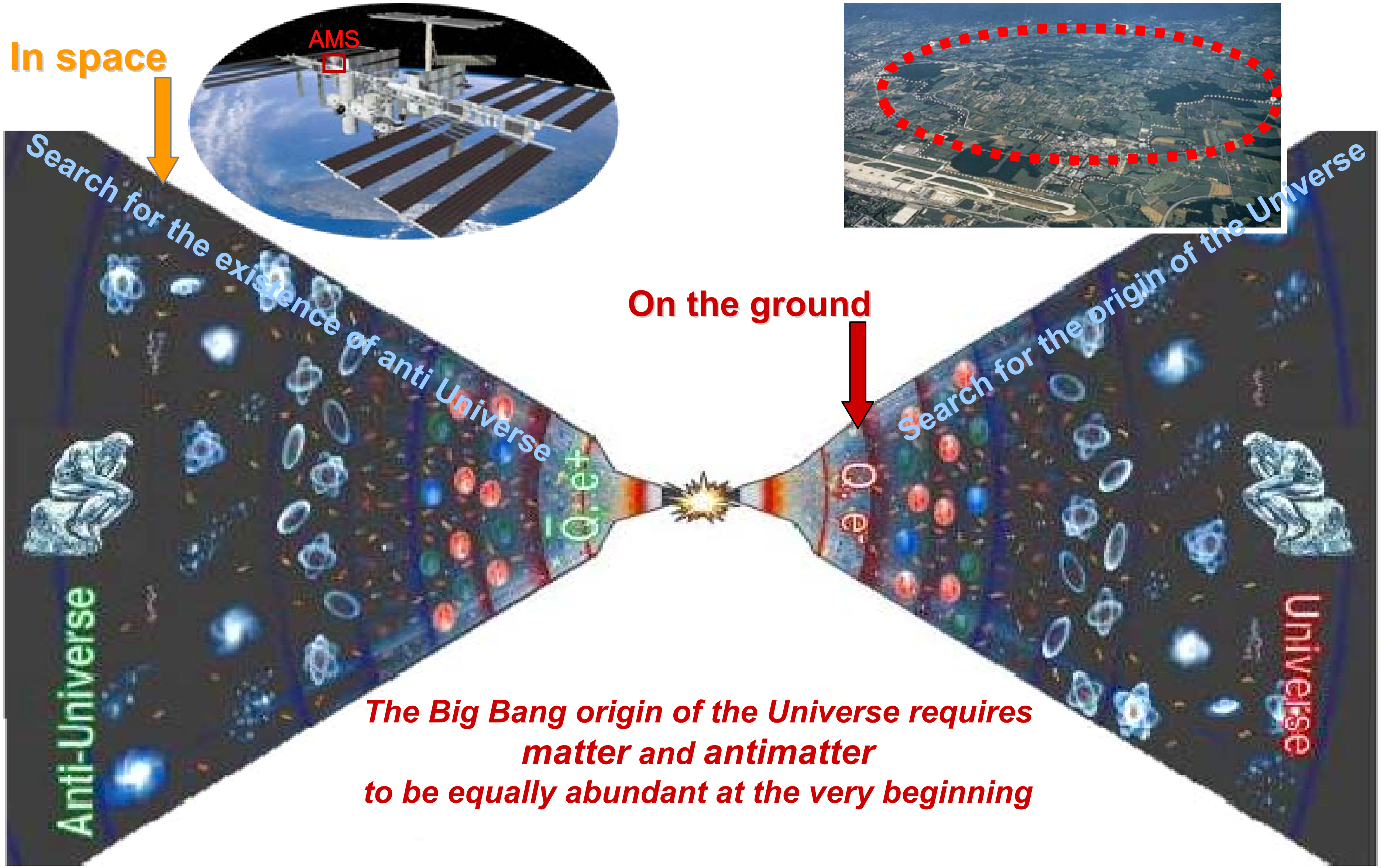
M. Battaglia et al., hep-ph/0112013
M. Battaglia et al., hep-ex/0106207
M. Battaglia et al., hep-ph/0306219
D.N. Spergel et al., astro-ph/0603449

case 3:
DM signal from $\bar{p}$

P. Brun, Phys.Rev.D76:083506, 2007 and private communication



Search primordial Antimatter in the Universe



The Big Bang origin of the Universe requires
matter *and* ***antimatter***
to be equally abundant at the very beginning

Experimental work on Antimatter in the Universe

Direct search

AMS

Increase in sensitivity: x $10^3 – 10^6$

Increase in energy to ~TeV

Search for Baryogenesis

New CP

BELLE

BaBar

(sin 2β= 0.672±0.023 consistent with SM)

FNAL KTeV

($Re(\varepsilon'/\varepsilon) = (19.2\pm2.1)*10^{-4}$)

CERN NA-48

CDF, D0

LHC-b

ATLAS

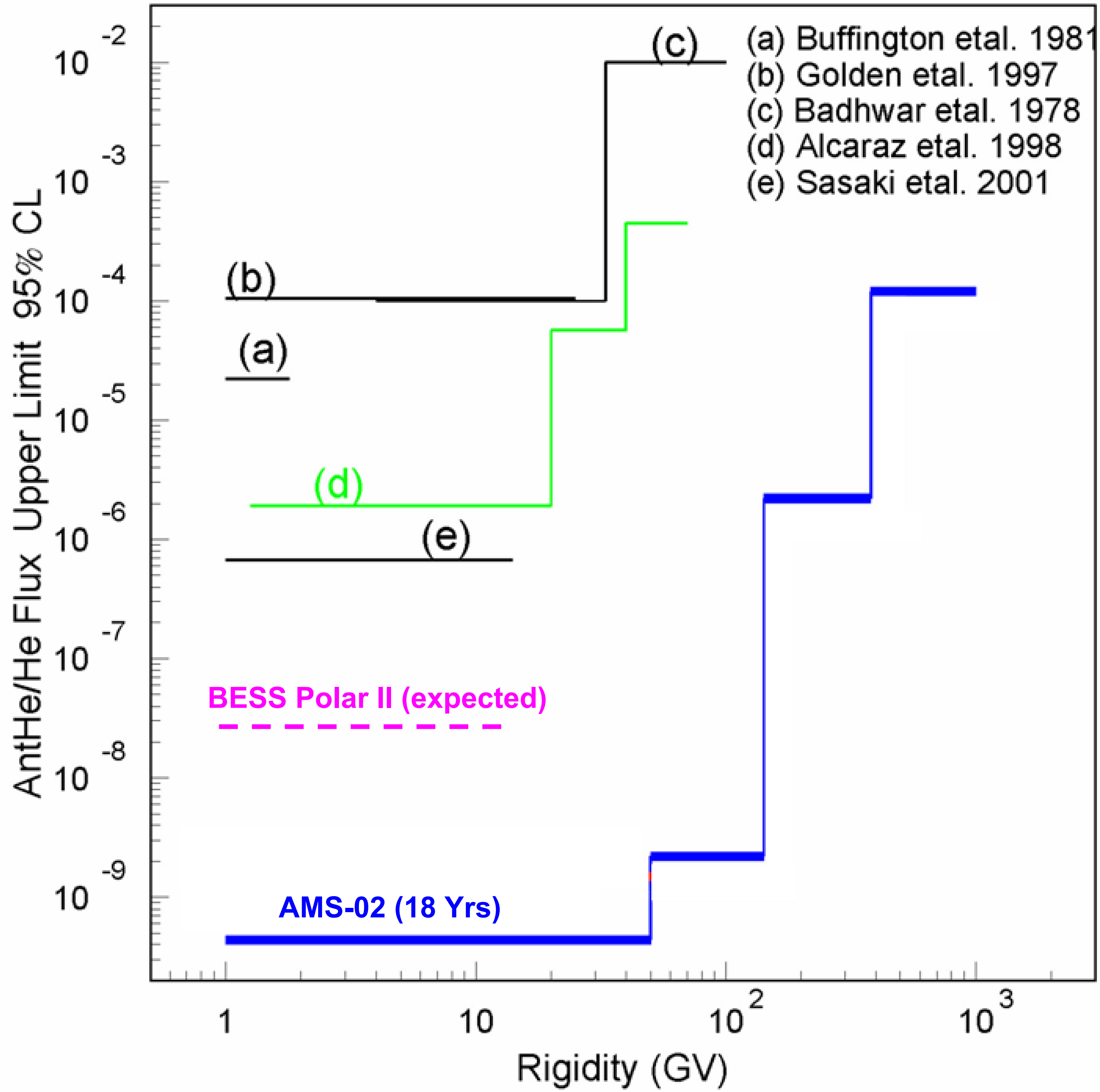
CMS

Proton decay

Super K

($\tau_p > 6.6 * 10^{33}$ years)

y06K299a



(a) Buffington etal. 1981
(b) Golden etal. 1997
(c) Badhwar etal. 1978
(d) Alcaraz etal. 1998
(e) Sasaki etal. 2001
(c)
(b)
(a)
(d)
(e)
BESS Polar II (expected)
AMS-02 (18 Yrs)
AntHe/He Flux Upper Limit 95% CL
Rigidity (GV)

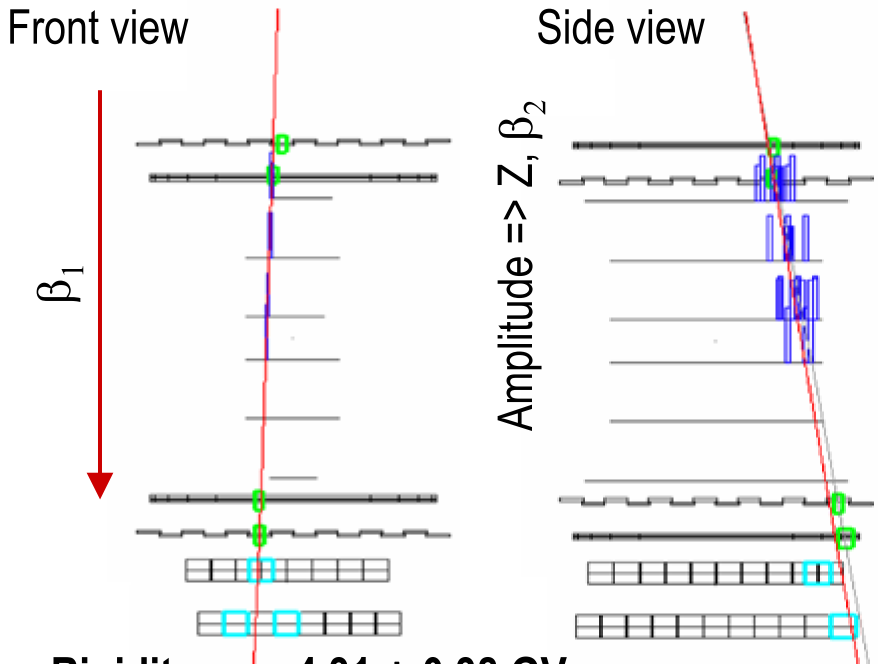
Strangelets

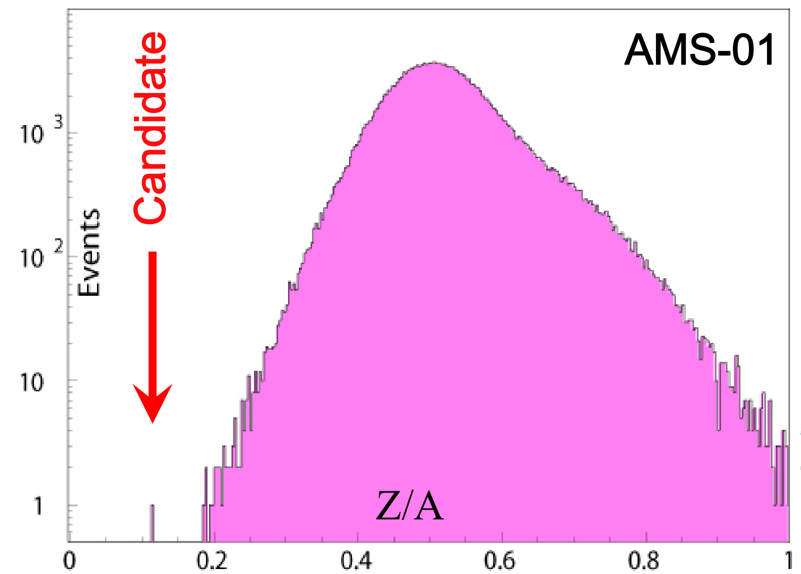
E. Witten, Phys. Rev. D,272-285 (1984)
Jack Sandweiss (Yale) is leading the AMS search.

All the known material on Earth is made out of u and d quarks.
Is there material in the universe made up of u, d, & s quarks?

Z/A~0.1

Candidate observed with AMS-01 5 June 1998 11:13:16 UTC

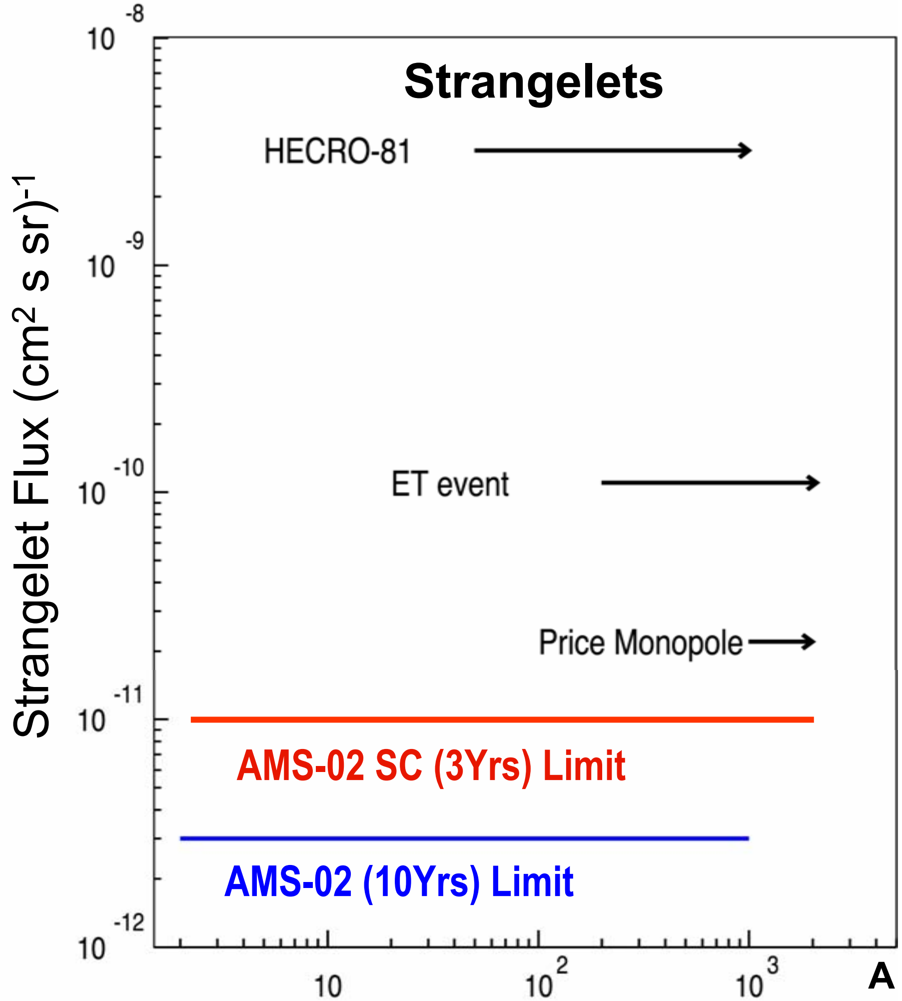




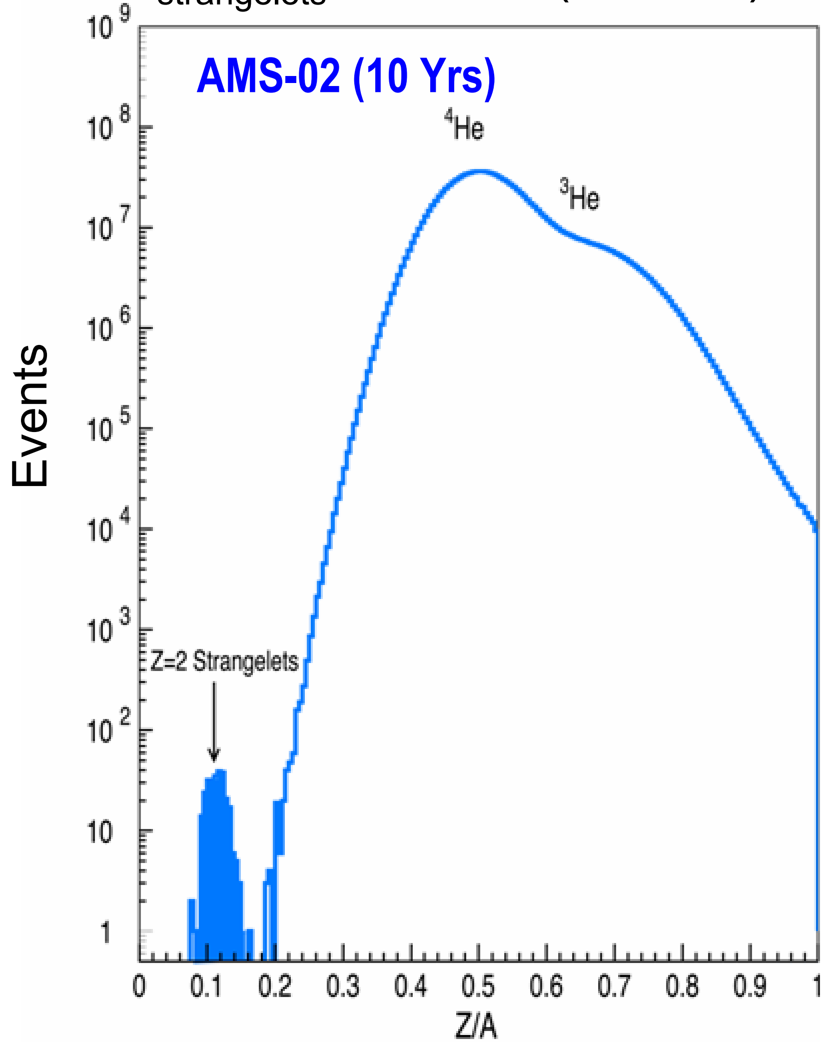
Rigidity $= 4.31 \pm 0.38$ **GV**
Charge Z $= 2$
$\beta_1 = \beta_2$ $= 0.462 \pm 0.005$
Mass $= 16.45 \pm 0.15$ **GeV/**c^2
Z/A $= 0.114 \pm 0.01$
Flux $(1.5 < E_K < 10$ **GeV**$) = 5\times10^{-5}$ $(m^2$ **sr sec**$)^{-1}$

Background probability $< 10^{-3}$

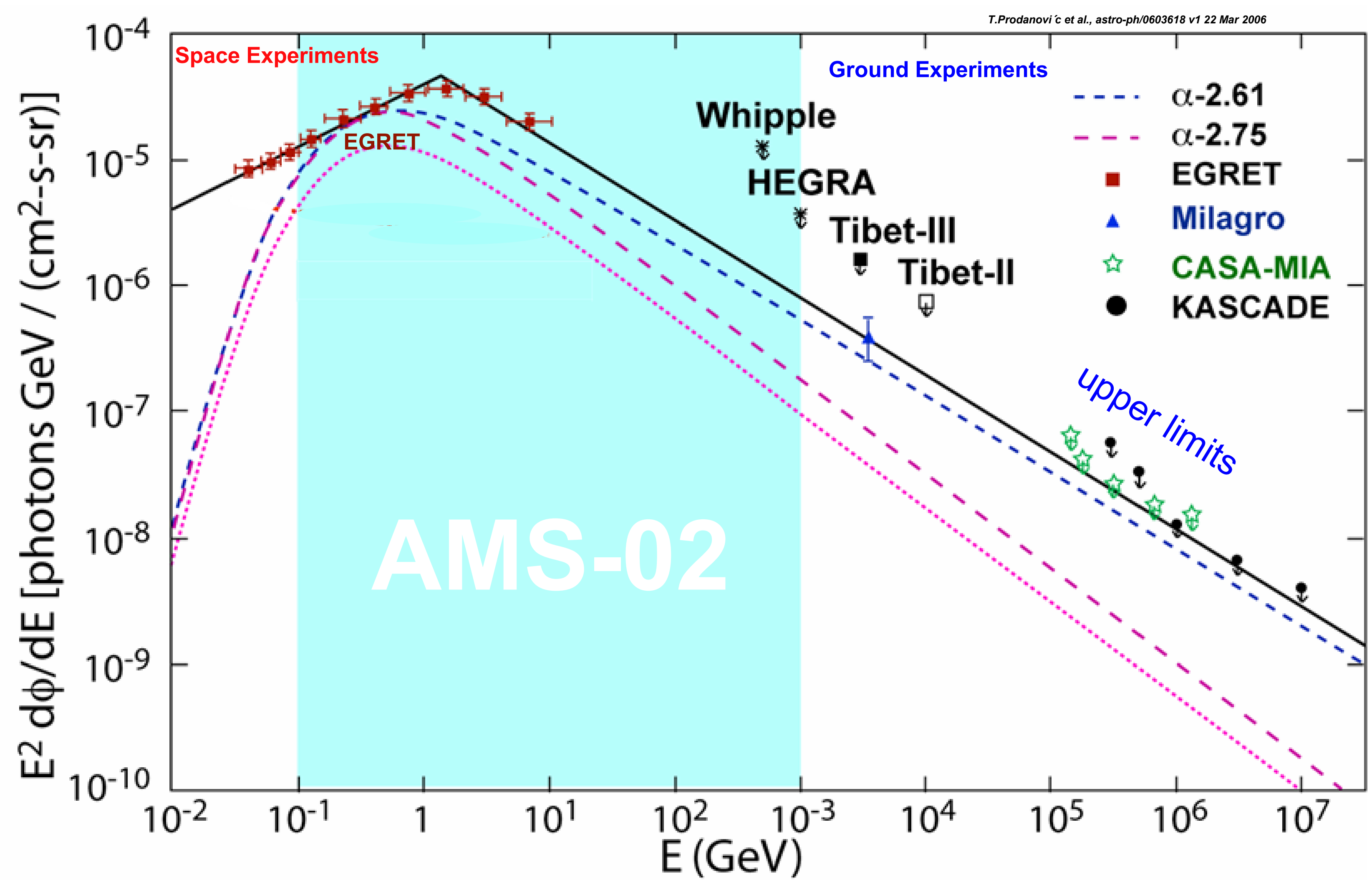
Strangelets with AMS-02



$\Phi_{strangelets} = 5x10^{-10}(cm^2 s\ sr)^{-1}$



Study of high energy (0.1 GeV – 1 TeV) diffuse gammas



The diffuse gamma-ray spectrum of the Galactic plane

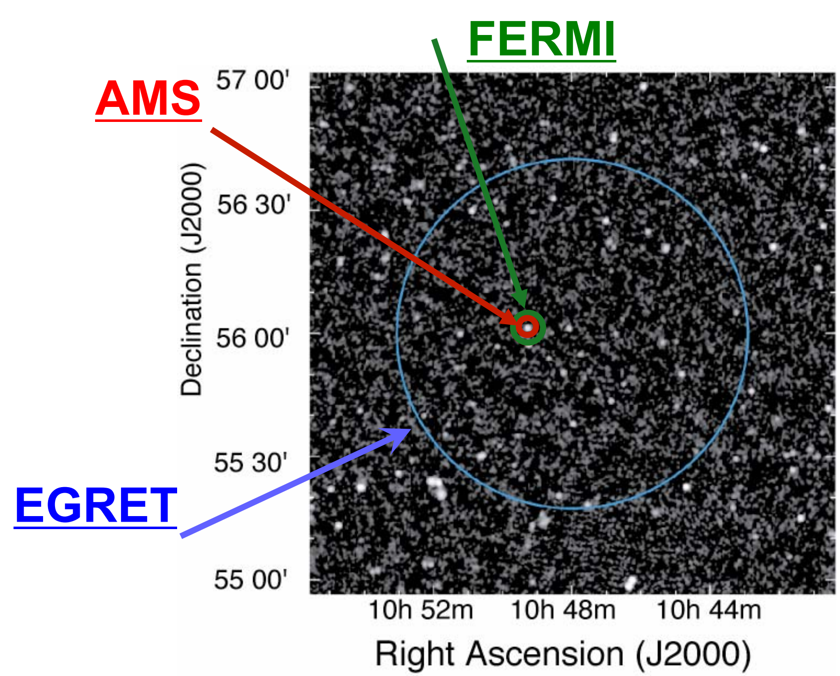
$40^o < 1 < 100^o$, $|b| < 5^o$

AMS Photon Detection
Magnetic Spectrometer

FERMI
Non magnetic detector

	A. Identify gamma rays from → e^+e^- with magnetic pair spectrometer	**Identify γ with 8 X_0 calorimeter only**
Energy resolution	$\Delta E\gamma$(10 GeV)=1.5%	$\Delta E\gamma$(10 GeV)=6%
Angular resolution	$\Delta\theta\gamma$ < 2 arc-sec	$\Delta\theta\gamma$ ~ 5 arc-sec
Energy Range	0.1 Gev – 1 TeV	0.01 GeV – 300 GeV

B. Redundant energy measurement with 17 X_0 calorimeter

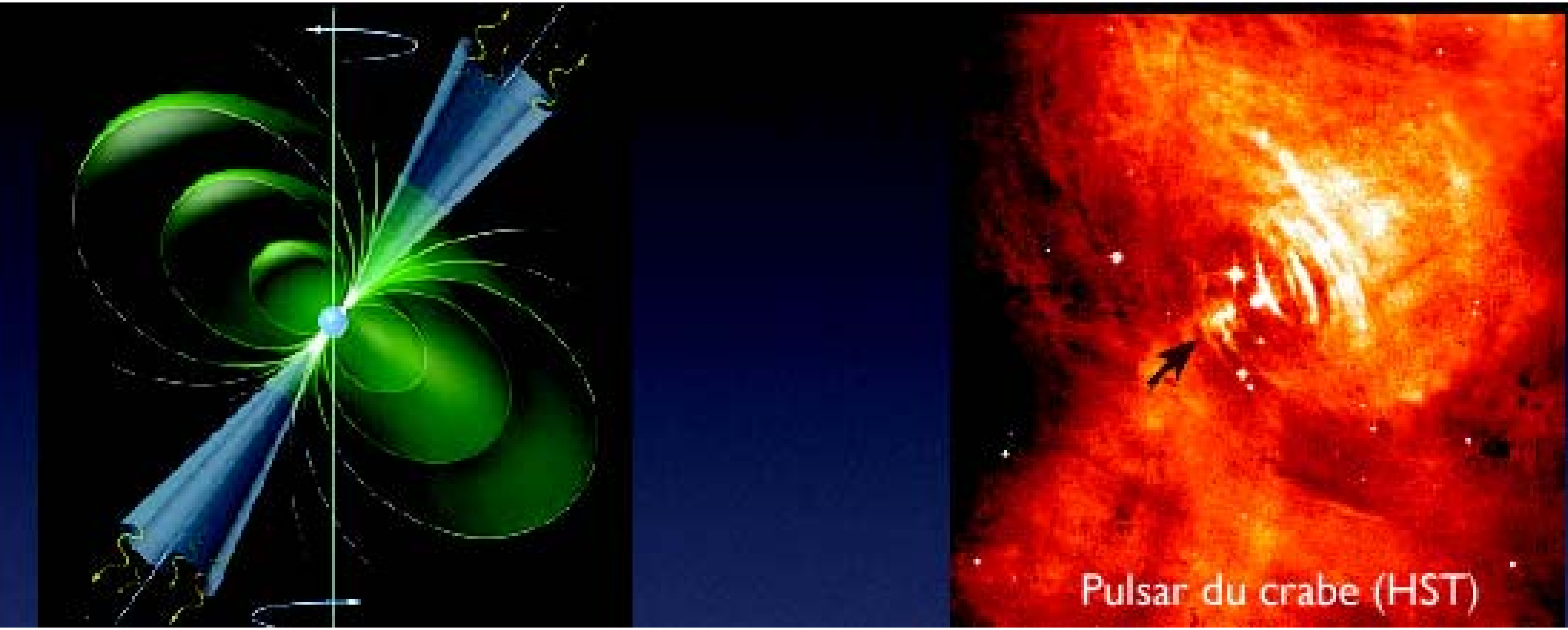


<u>Pulsars in the Milky Way:</u>

Pulsar: neutron star sending radiation in a periodic way.
Emission in radio, visible, X and gamma

(currently measured to millisec precision with energy ~ GeV)

<u>AMS:</u> energy spectrum for pulsars in the 100 MeV – 1 TeV and pulsar periods measured with μsec time precision



Similar studies can be made for Blazers and Gamma Ray Bursters

AMS will be launch ready at KSC by November 2010

STS-134 Mission Information

Image above: Pictured clockwise in the STS-134 crew portrait are NASA astronauts Mark Kelly (bottom center), commander; Gregory H. Johnson, pilot; Michael Fincke, Greg Chamitoff, Andrew Feustel and European Space Agency's Roberto Vittori, all mission specialists. Image credit: NASA

The STS-134 crew members are Commander Mark Kelly, Pilot Gregory H. Johnson and Mission Specialists Michael Fincke, Greg Chamitoff, Andrew Feustel and European Space Agency astronaut Roberto Vittori.

Endeavour will deliver spare parts including two S-band communications antennas, a high-pressure gas tank, additional spare parts for Dextre and micrometeoroid debris shields. This will be the 36th shuttle mission to the International Space Station.

Overview

Launch Target:
Nov. 2010
Orbiter:
Endeavour
Mission Number:
STS-134
(134th space shuttle flight)
Launch Window:
10 minutes
Launch Pad:
39A
Mission Duration:
10 days
Landing Site:
KSC
Inclination/Altitude:
51.6 degrees/122 nautical miles
Primary Payload:
36th station flight (ULF6), EXPRESS Logistics Carrier 3 (ELC3), Alpha Magnetic Spectrometer (AMS)