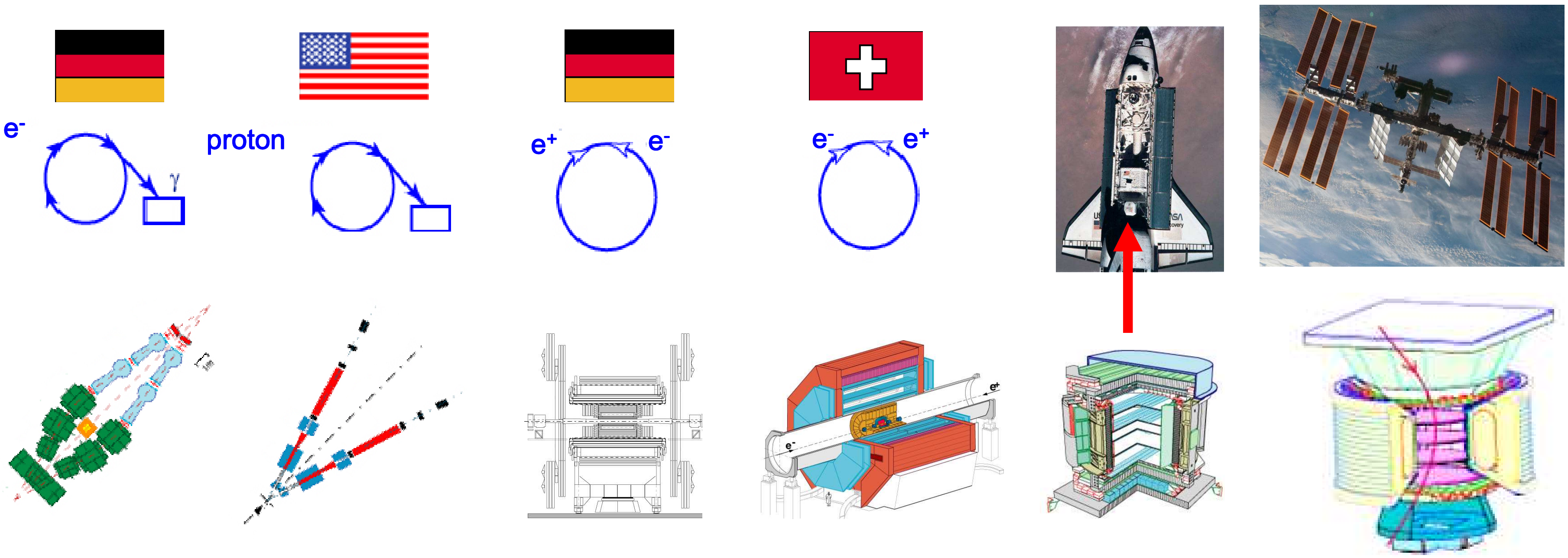
Precision Experiments on the Ground and in Space
The "J" Experiment at BNL
and the AMS Experiment on the Space Station"

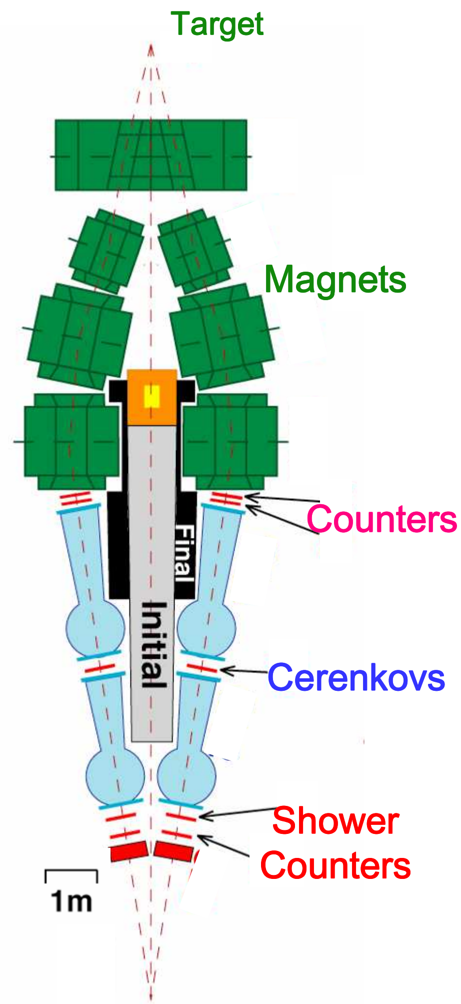
DESY	BNL	PETRA	LEP	Shuttle	ISS
1965-1972	1972-1974	1978-1983	1983-2003	1994-1998	1998-...

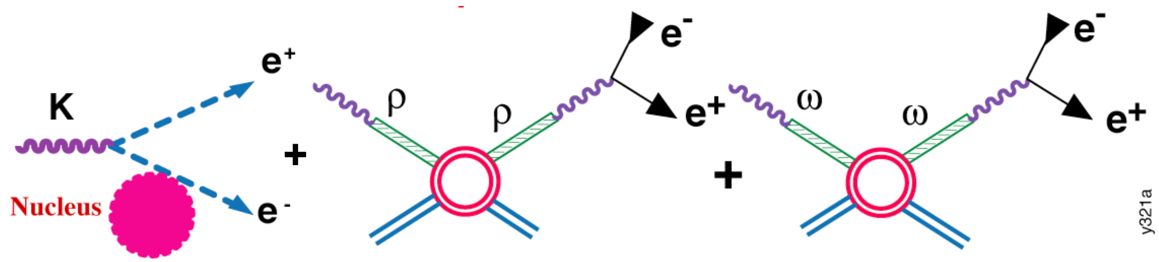


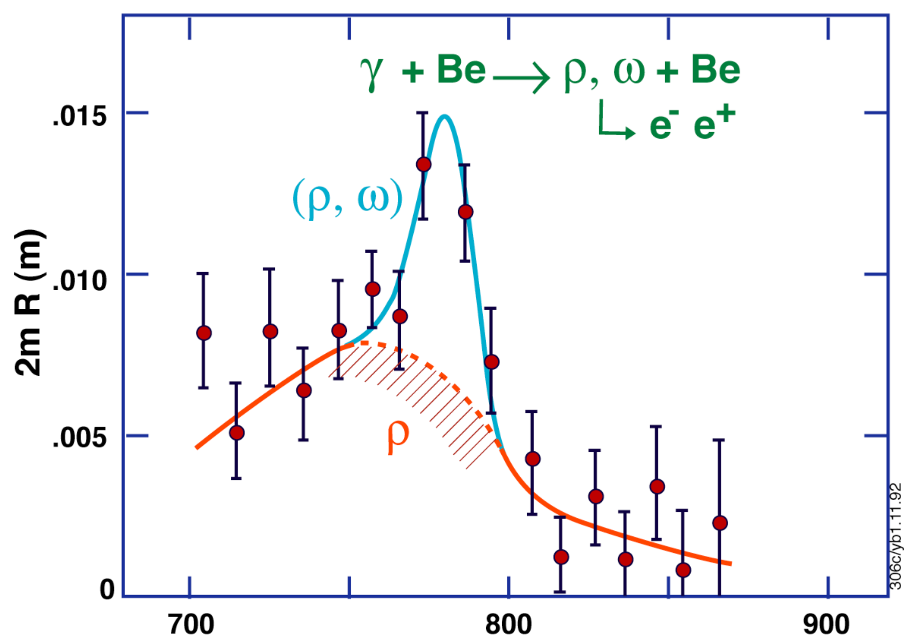
	DESY	BNL	PETRA	LEP	Shuttle	ISS
Physicists	10	20	60	600	400	600
Cost (M$)	0.01	0.1	15	~1,000	~500	>2,000

DESY 1965-1972

Observation of Coherent Interference Pattern between ⟩ and ⌉ Decays







P.R.L. 25 (1970) 1373

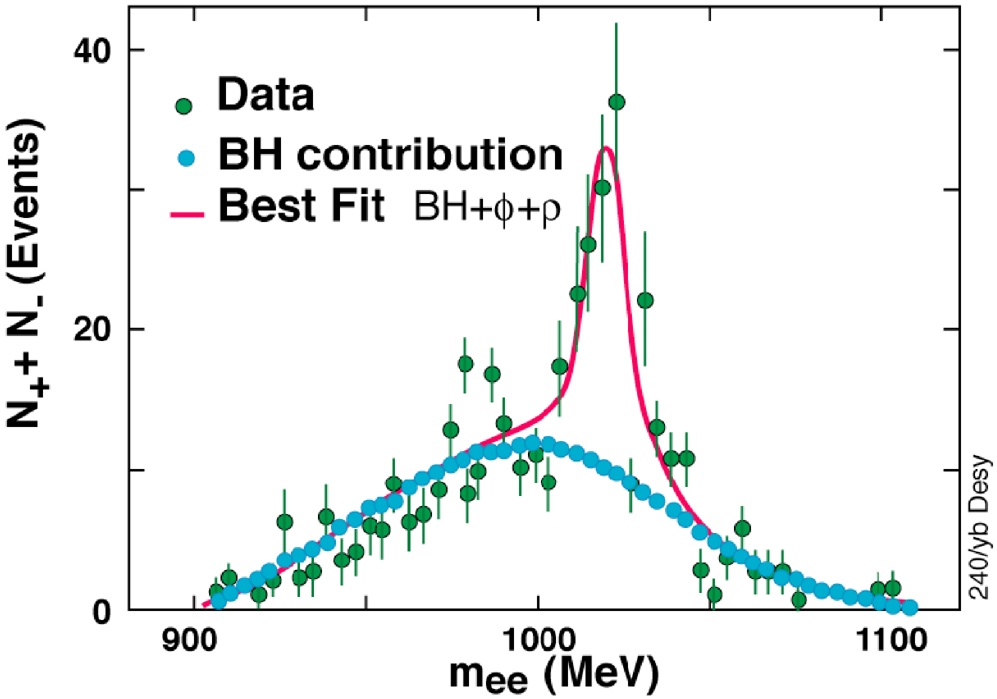
$$\frac{\Delta m}{m} = 0.5\ \%$$

$$\frac{\text{Background}}{\text{Signal}} =$$

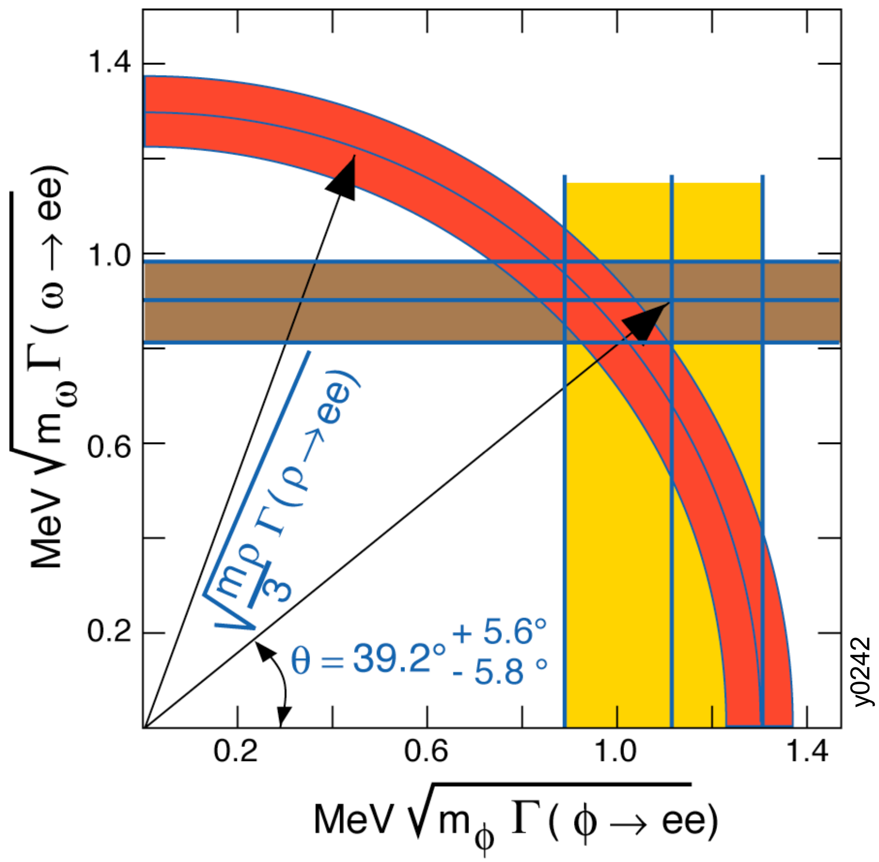
$$\frac{\square\,\square}{e\,e} > 10^8$$

3) Verification of Weinberg's first sum rule

Leptonic decays of ϕ



P. R. L., Vol 27, p.444, 1971



Weinberg's first sum rule:

$$\frac{1}{3} m_\rho \Gamma(\rho \to ee) = m_\omega \Gamma(\omega \to ee) + m_\phi \Gamma(\phi \to ee).$$

y97509

BNL

The best way to search for vector mesons is through production experiments of the type $p + p \rightarrow V^{o} + X$, $V^{o} \rightarrow e^{+}e^{-}$. The reasons are:

(a) The V^{o} are produced via strong interactions, thus a high production cross section.

(b) One can use a high intensity, high duty cycle extracted beam.

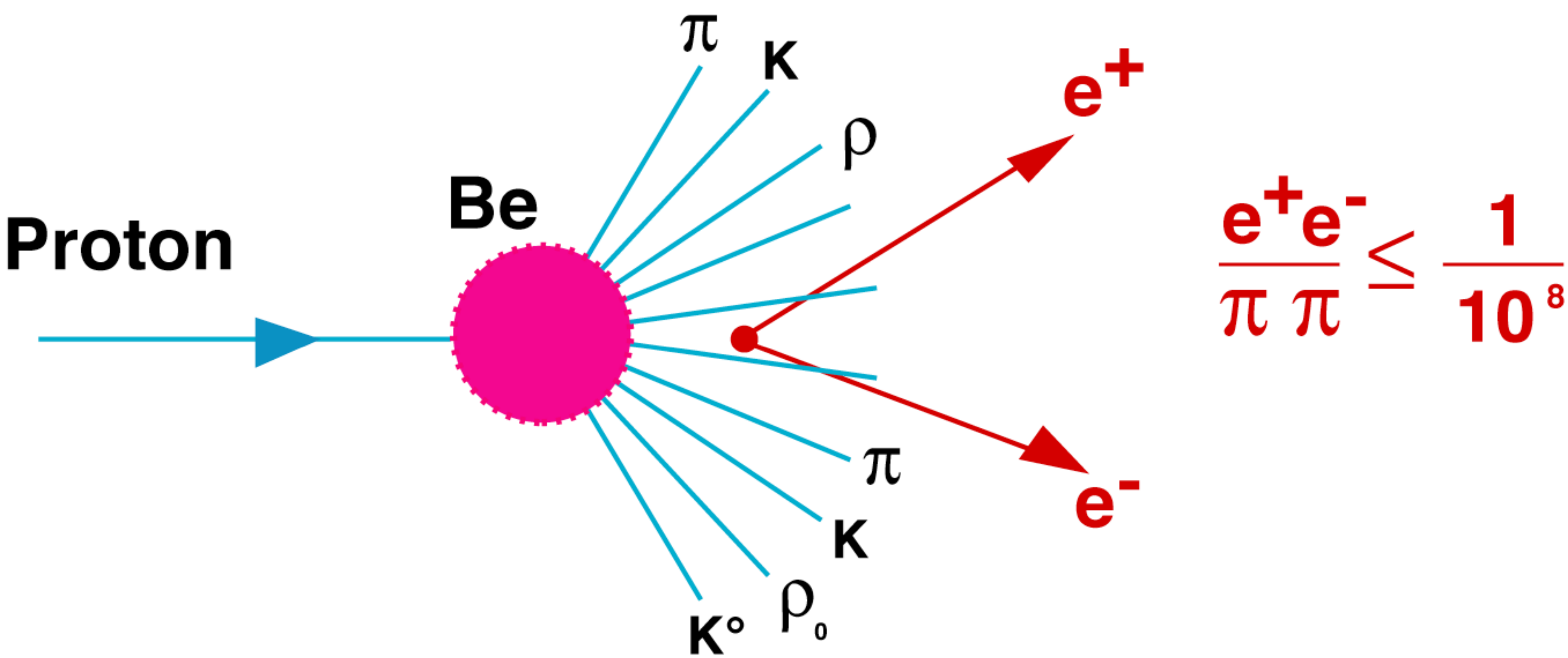
(c) An $e^{+}e^{-}$ enhancement limits the quantum number to 1^{-}, thus enabling us to avoid measurements of angular distribution of decay products.

Contrary to popular belief, the $e^{+}e^{-}$ storage ring is not the best place to look for vector mesons. In the $e^{+}e^{-}$ storage ring, the energy is well-defined. A systematic search for heavier mesons requires a continuous variation and monitoring of the energy of the two colliding beams—a difficult task requiring almost infinite machine time. Storage ring is best suited to perform detailed studies of vector meson parameters once they have been found.

Brookhaven BNL 598 Proposal

Becker 121P16

Discovery of new type of matter at BNL-AGS

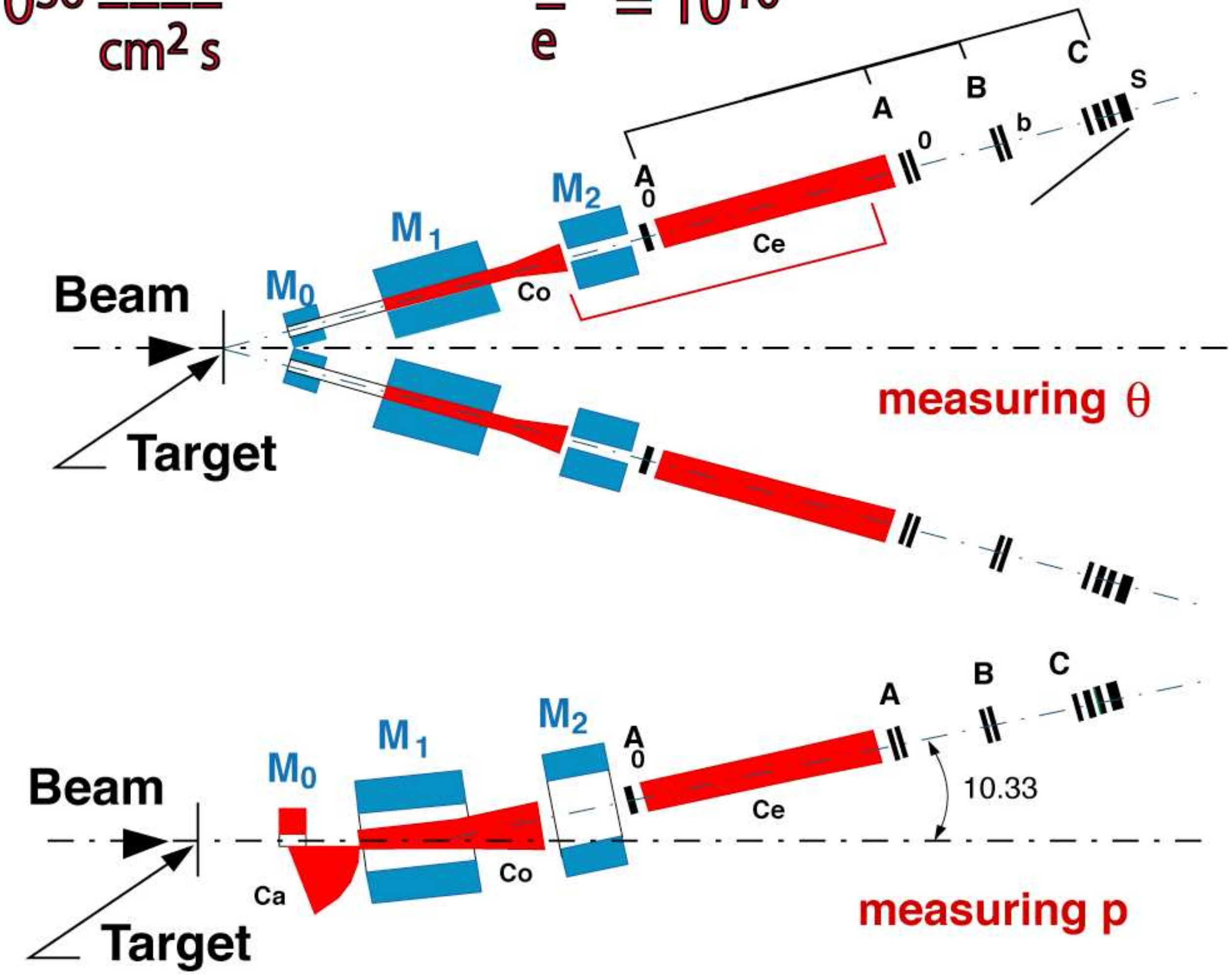


To obtain e^+e^- events we need 10^{12} protons/sec.

To obtain $\pi^+\pi^-$ rejection to 1% we need rejection $1/10^{10}$.

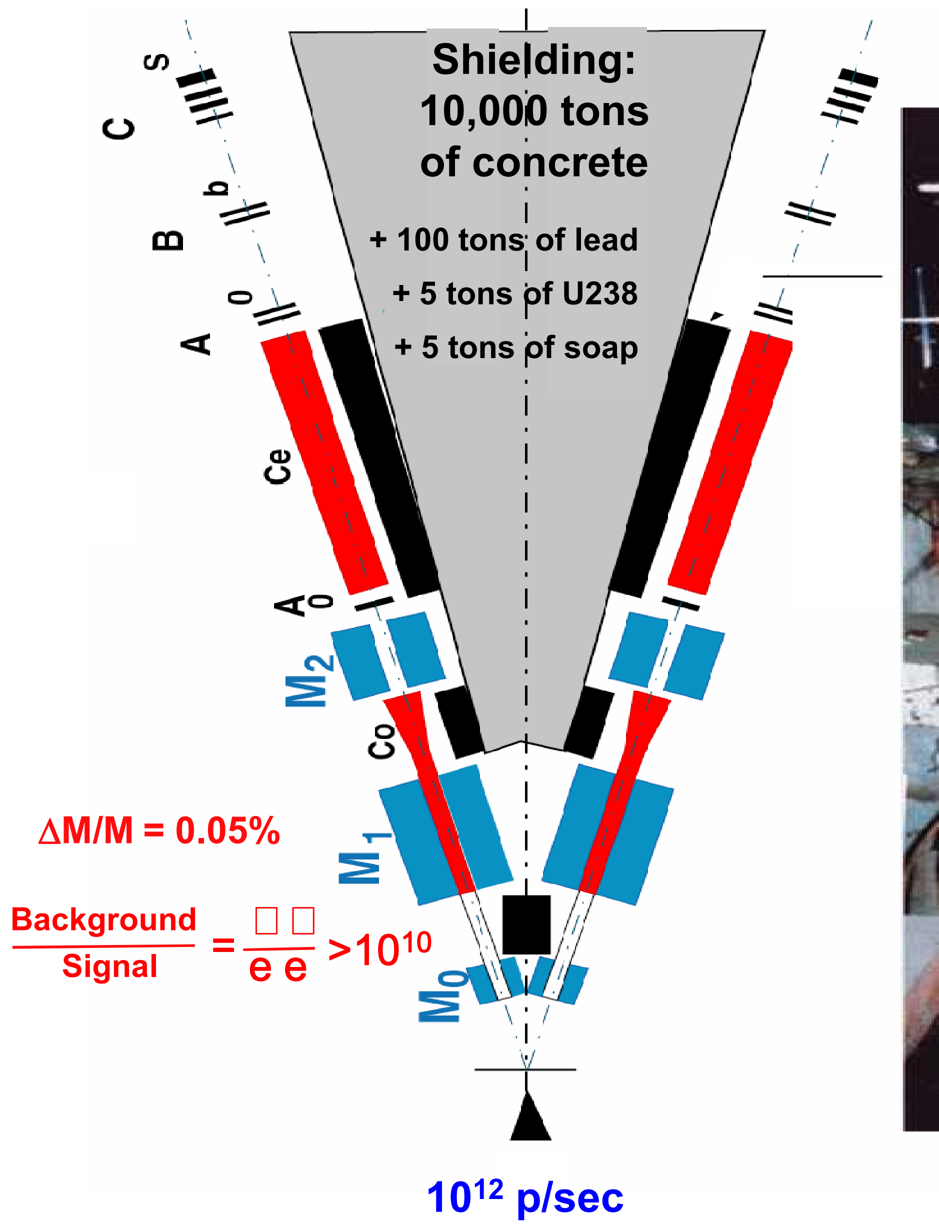
J particle Spectrometer

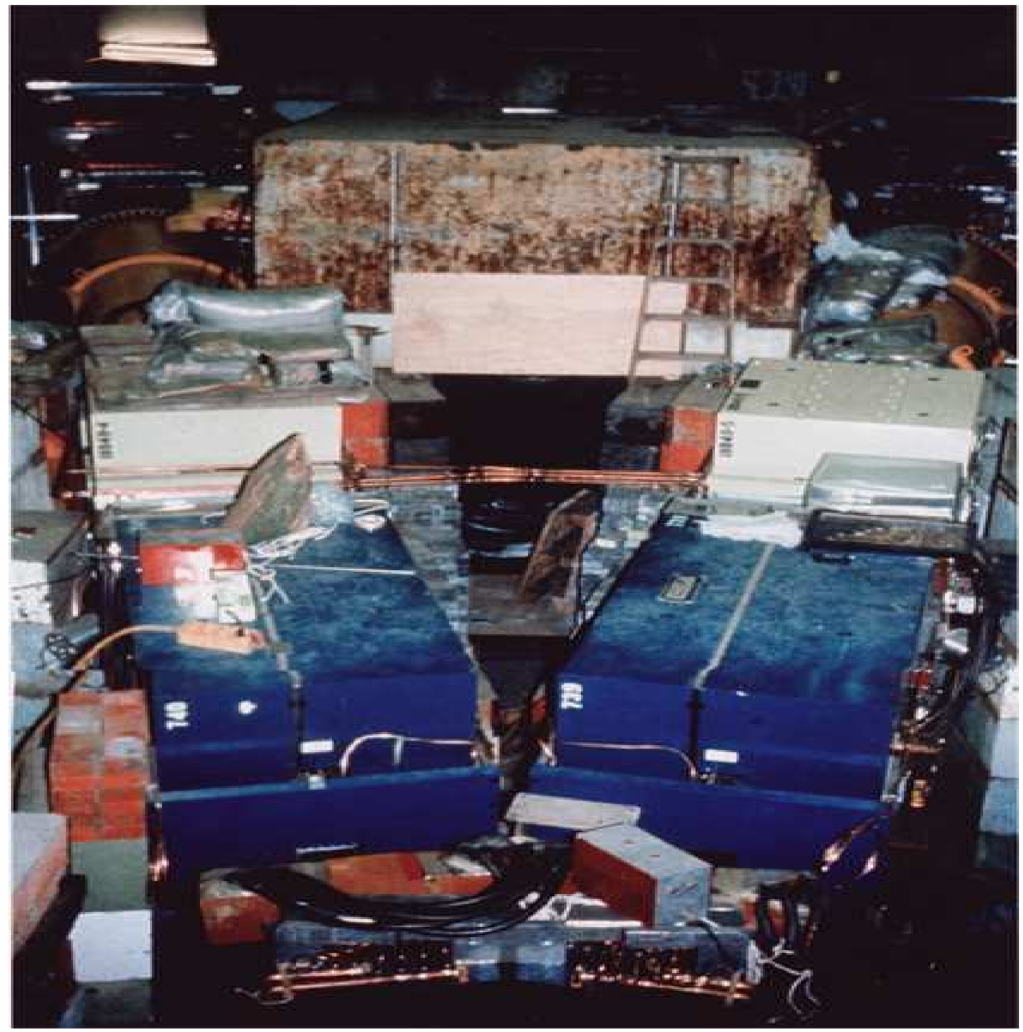
$L \cong 10^{36} \frac{1}{cm^2 s}$ $\qquad$ $\frac{p}{e} = 10^{10}$

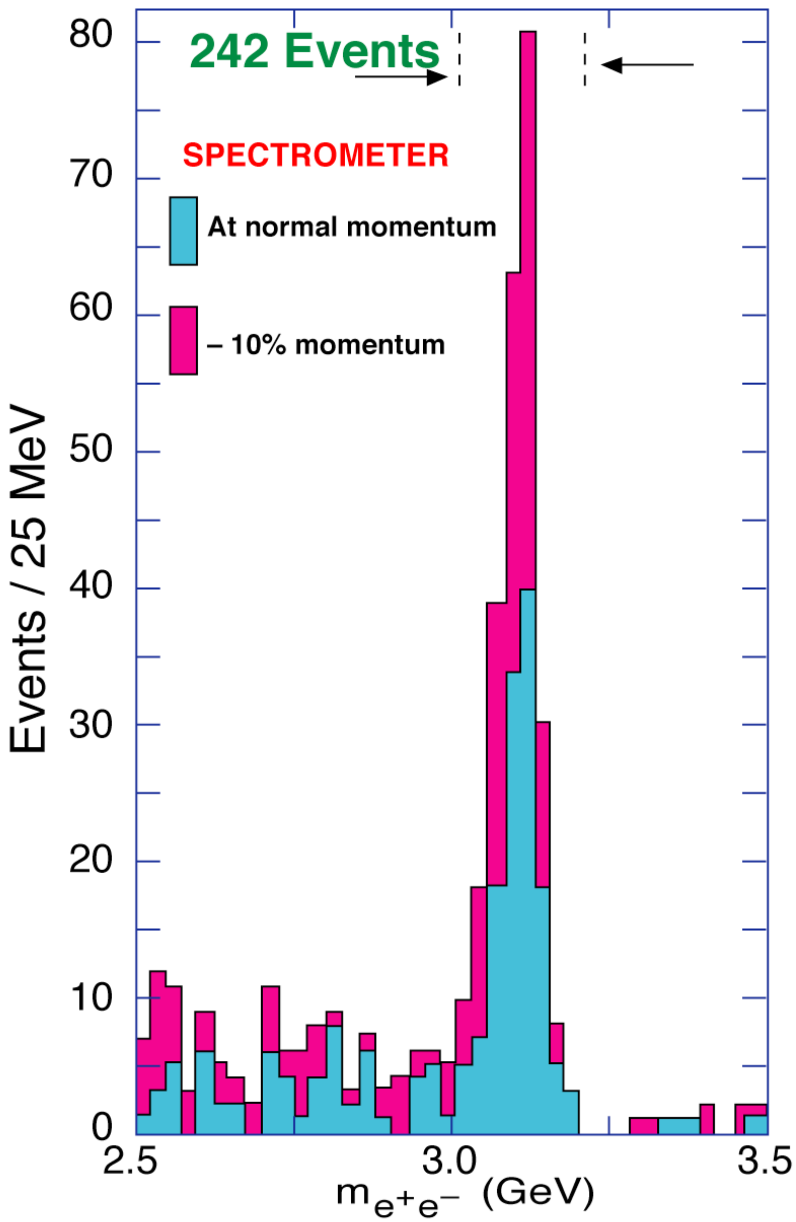


$$m^2_{ee} = p_+ p_- (1 - \cos\theta_{+-})$$

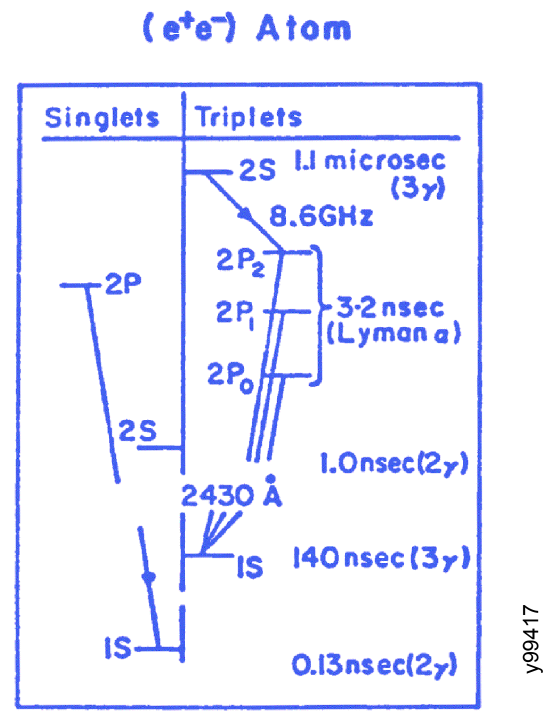
Experiment 598 at AGS

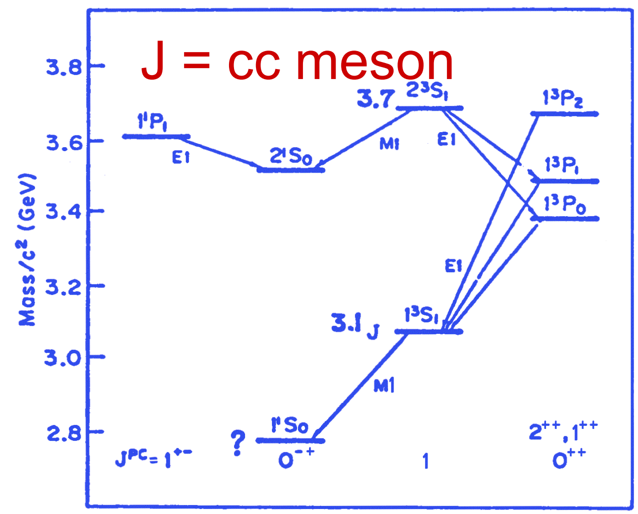






Discovery of "J"





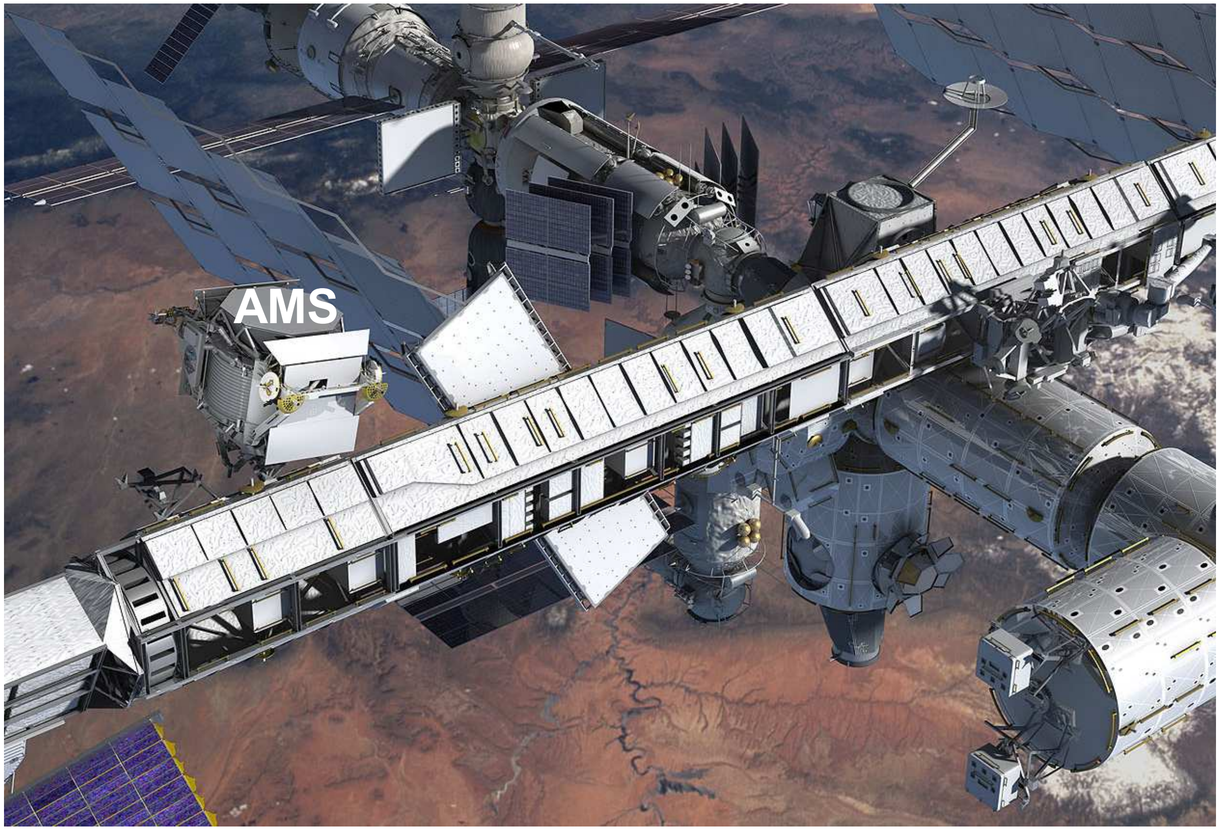
J(cc) meson has lifetime x10,000 longer than known mesons

Fundamental Science on the International Space Station (ISS)

There are two kinds of cosmic rays traveling through space

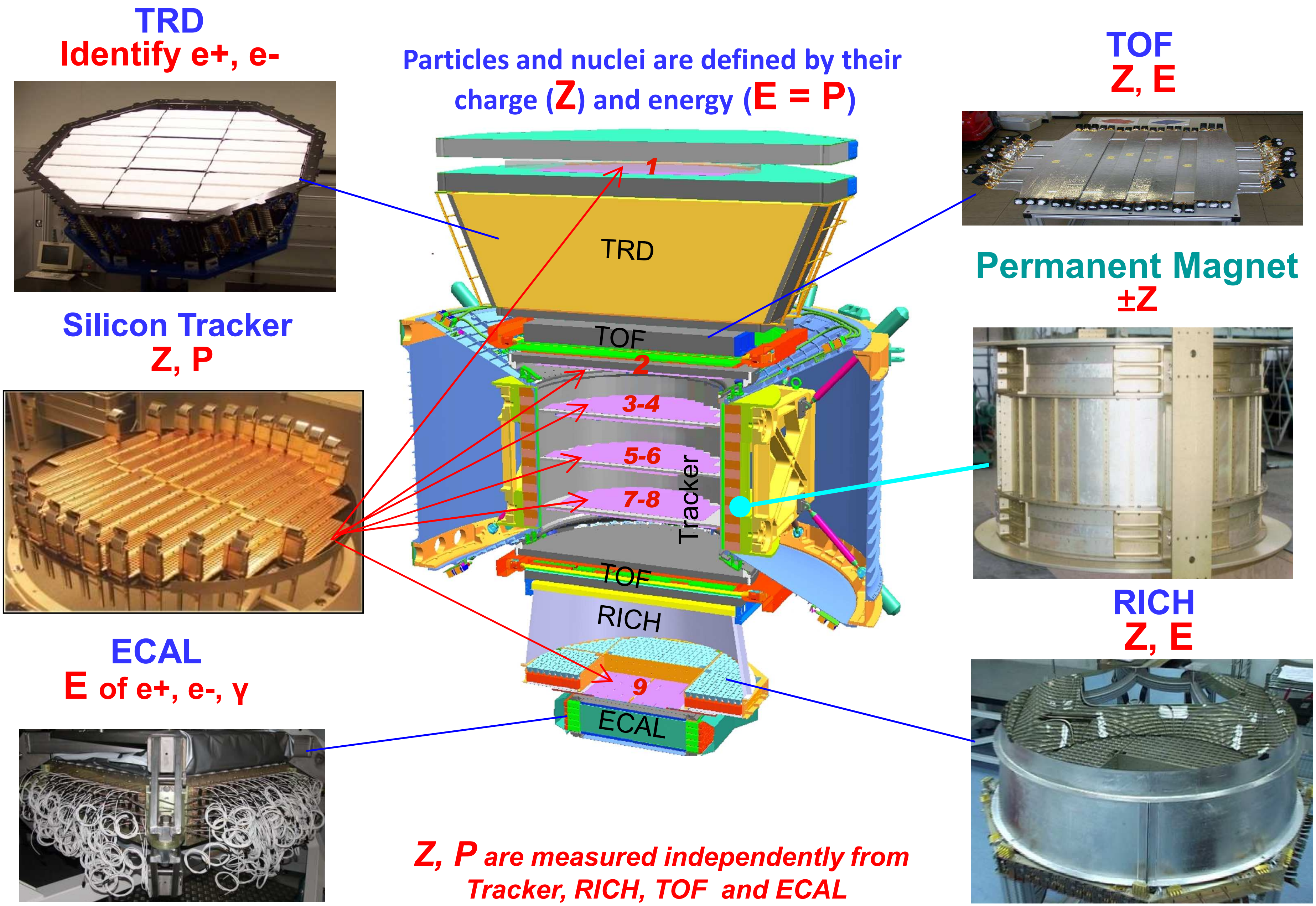
1- Light rays and neutrinos have been measured (e.g., Hubble) for over 50 years. Fundamental discoveries have been made .

2- Charged cosmic rays: A large acceptance, multipurpose, magnetic spectrometer (AMS) on ISS is the only way to measure precisely high energy charged cosmic rays.



The major physical science experiment on the ISS .

AMS: A TeV precision, multipurpose spectrometer



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.

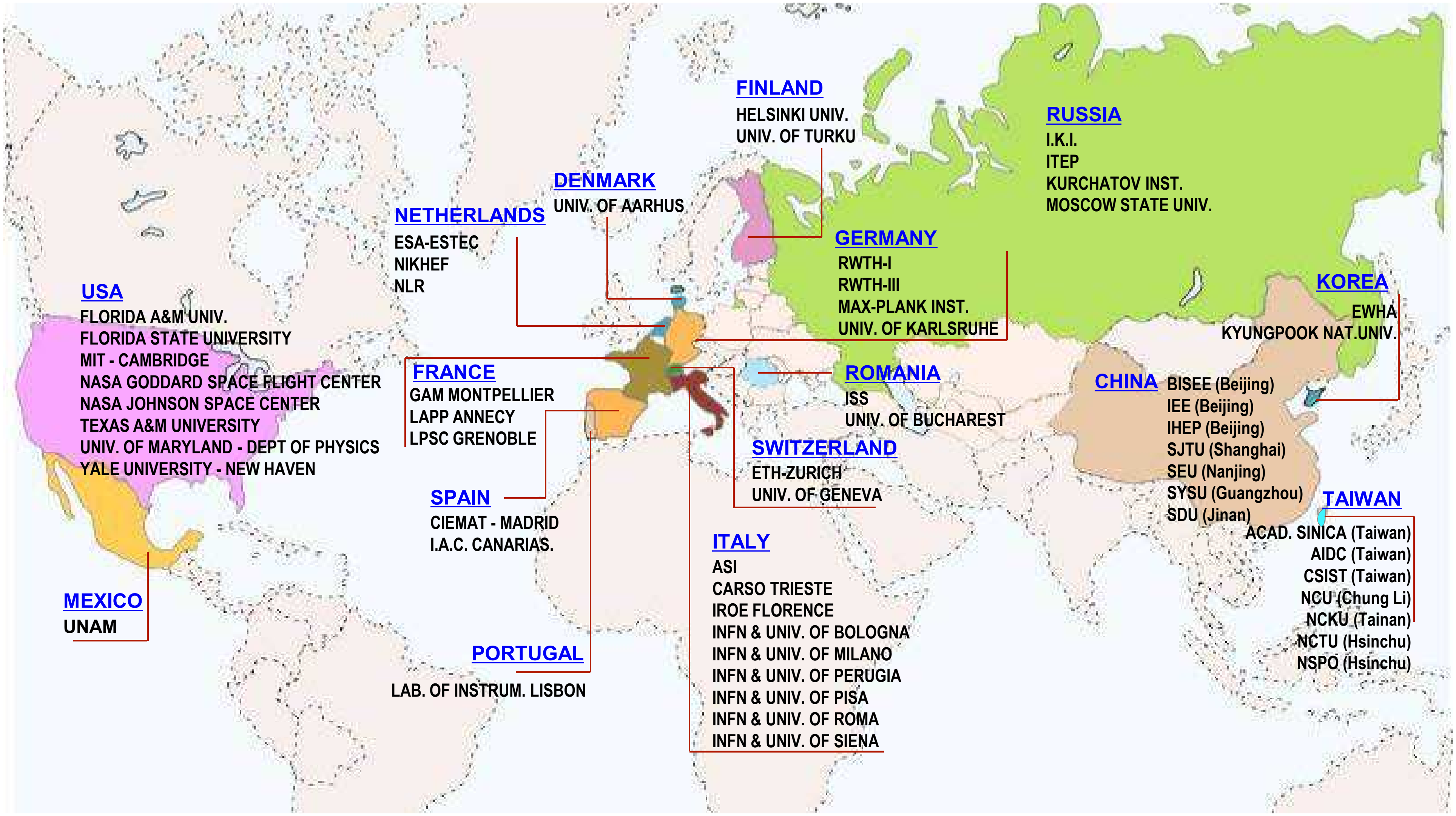
Endeavour will deliver spare parts including two S-band communications antennas, a high-pressure gas tank, additional spare parts for Dextre and micrometeoroid debris shields. This will be the 36th shuttle mission to the International Space Station.

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)

AMS is a DOE sponsored International Collaboration

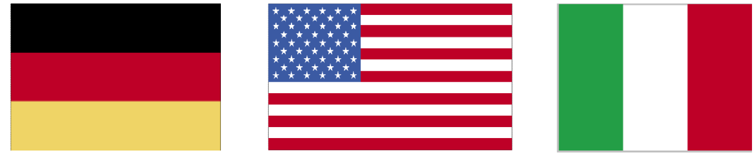
16 Countries, 60 Institutes and 600 Physicists



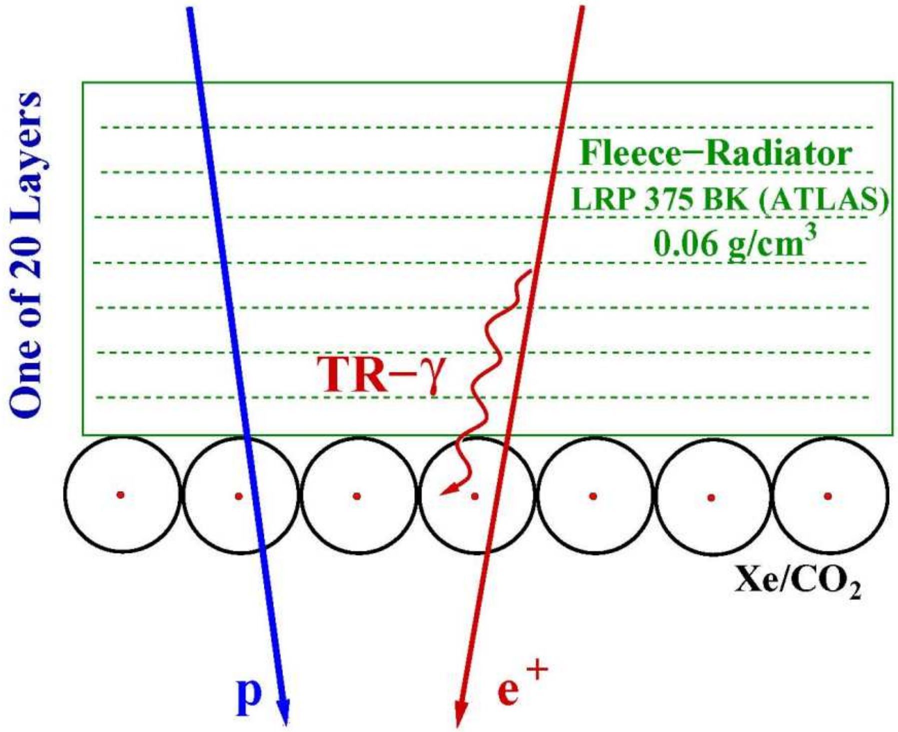
95% of the > $2.0B to build AMS has come from our international partners .

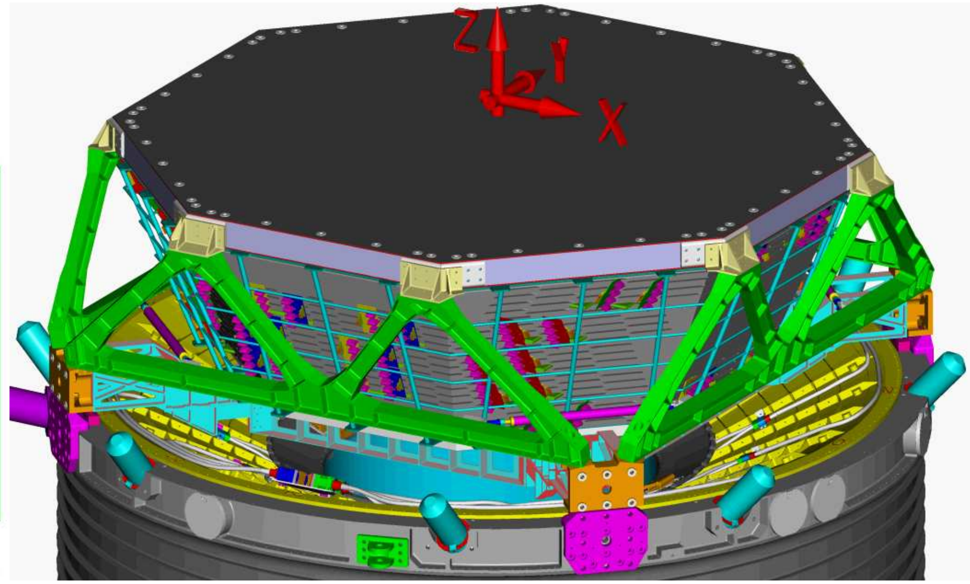
We acknowledge the continuous strong support from DOE (D. Kovar, S. Gonzalez)

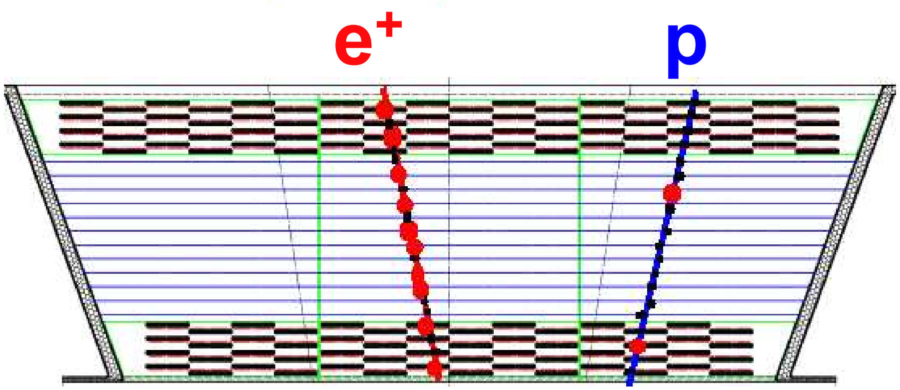
Transition Radiation Detector: TRD



Identify e^+, reject P

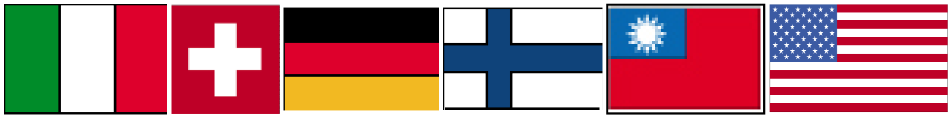




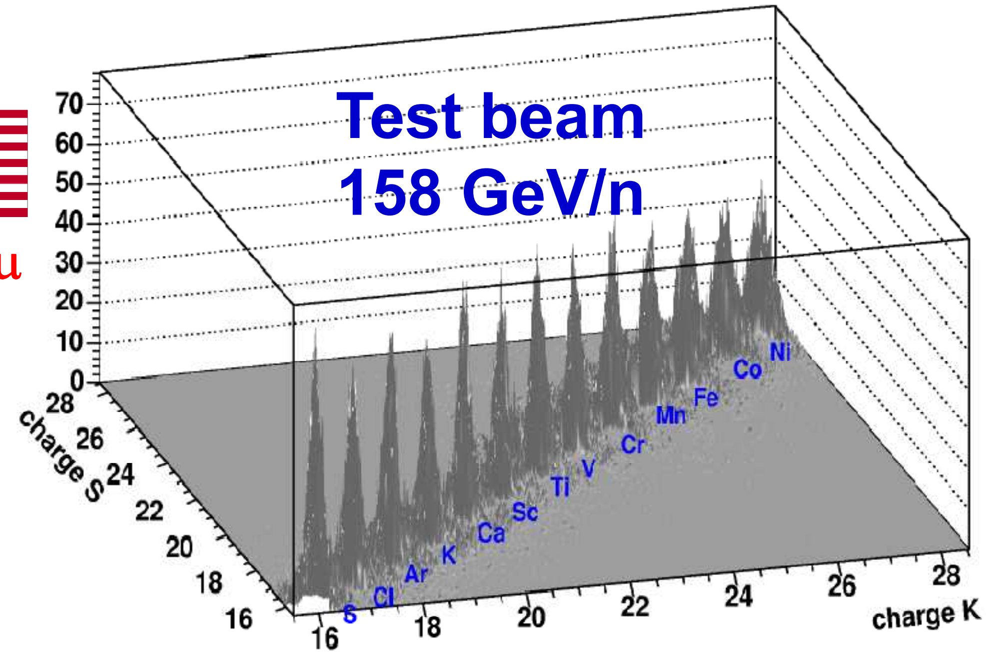


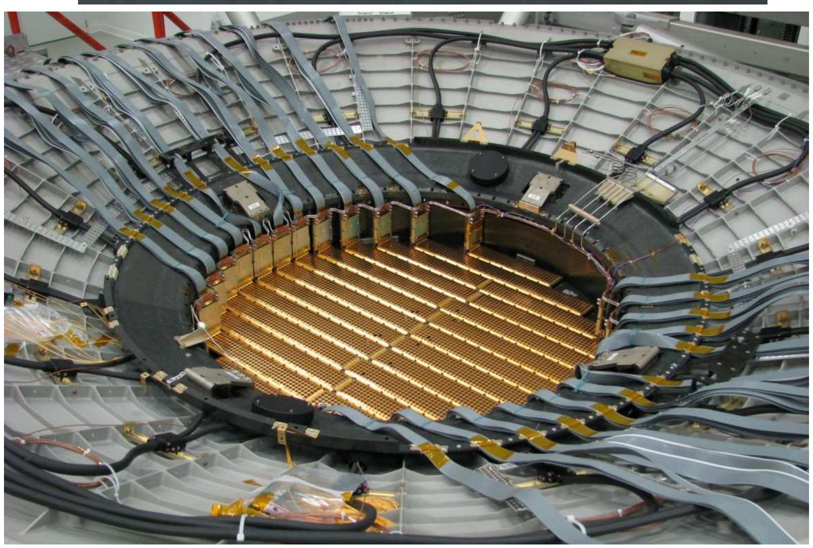
20 layers

Silicon Tracker

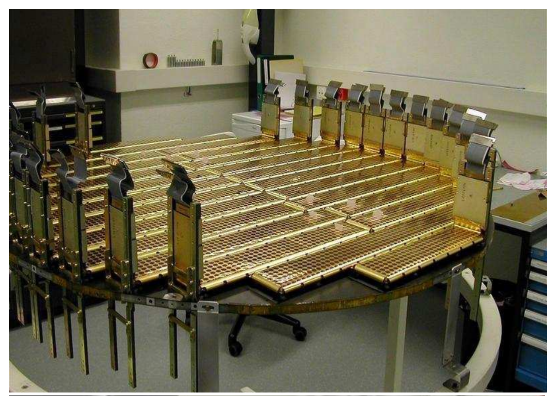


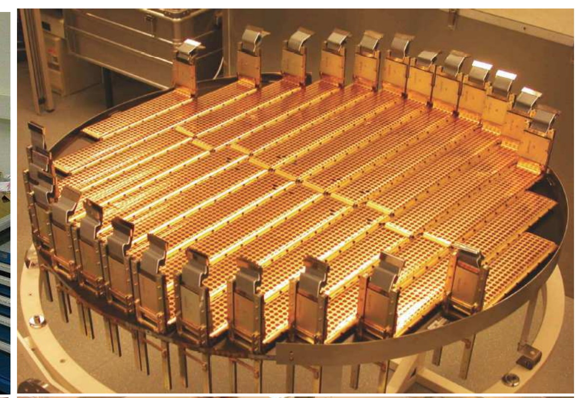
10 mil pitch; 200,000 channels; alignment 3 μ

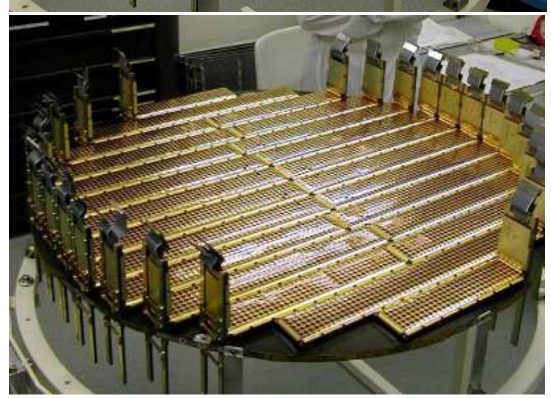




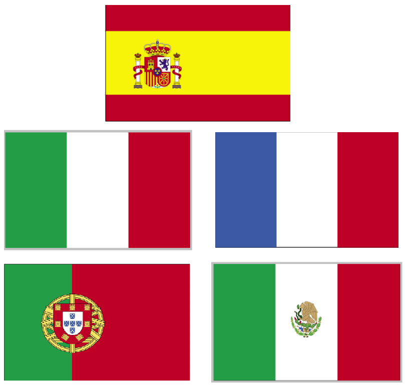
8 planes

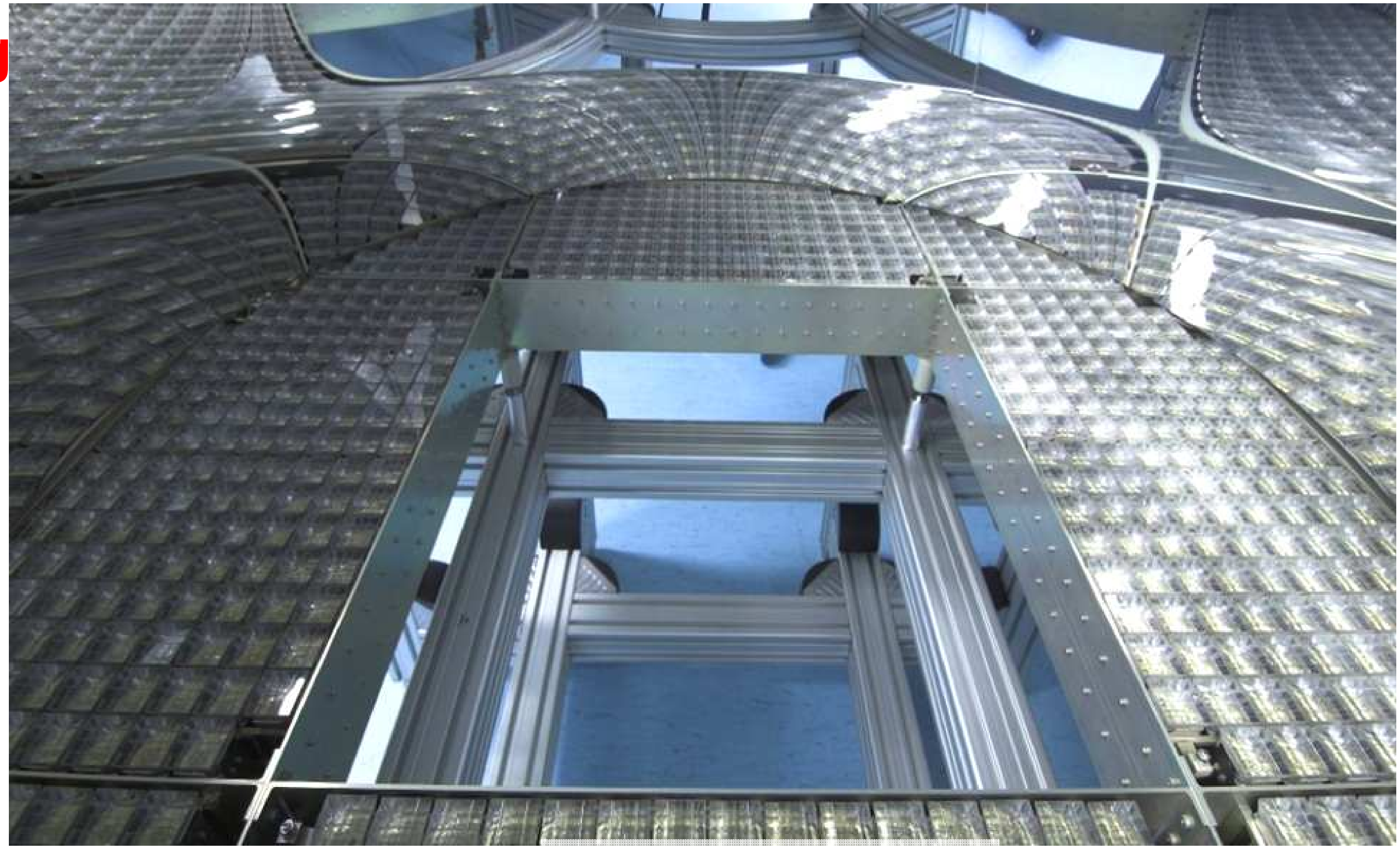




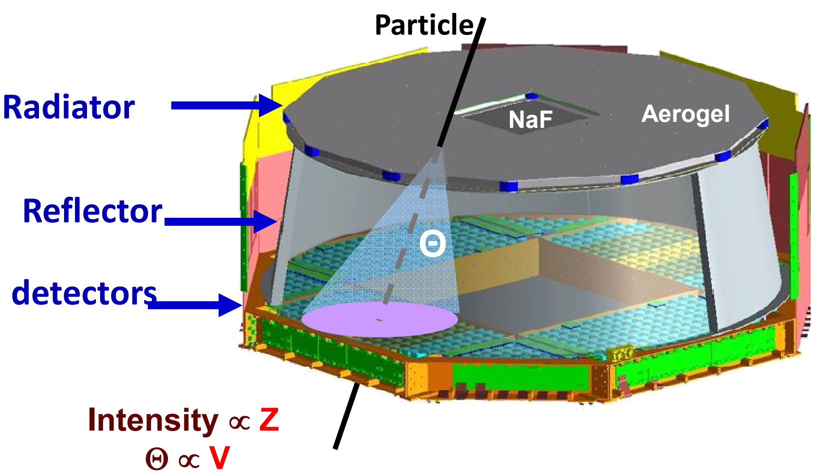


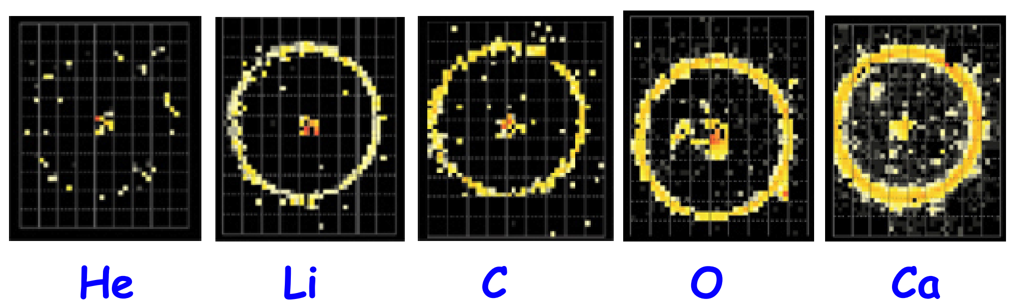
Ring Imaging CHerenkov (RICH)





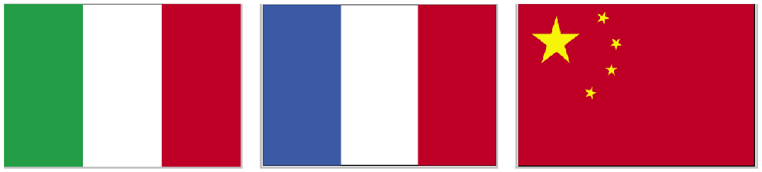
10,880 photosensors





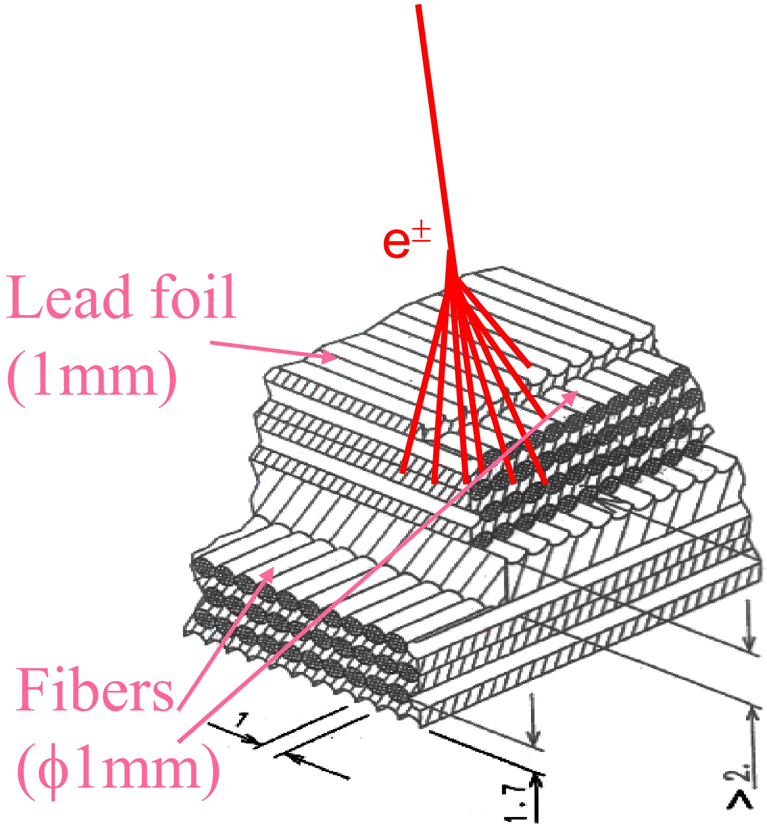
Single Event Displays

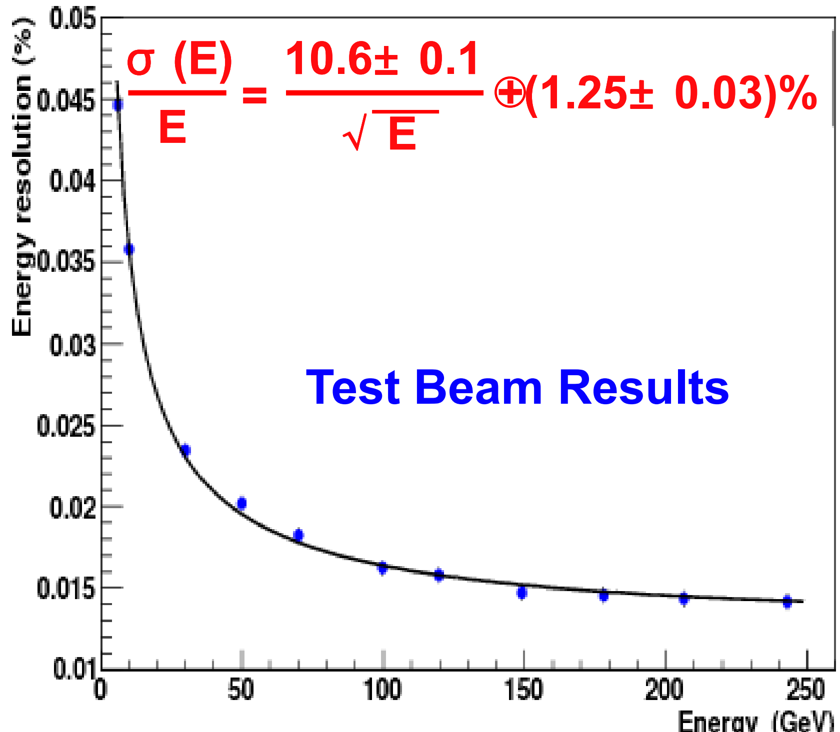
RICH test beam E=158 GeV/n

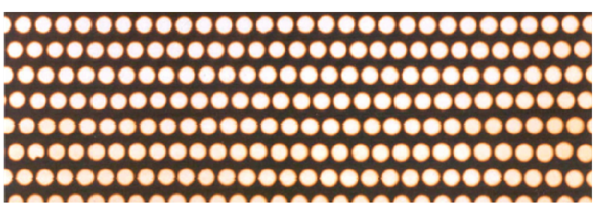


Calorimeter (ECAL)

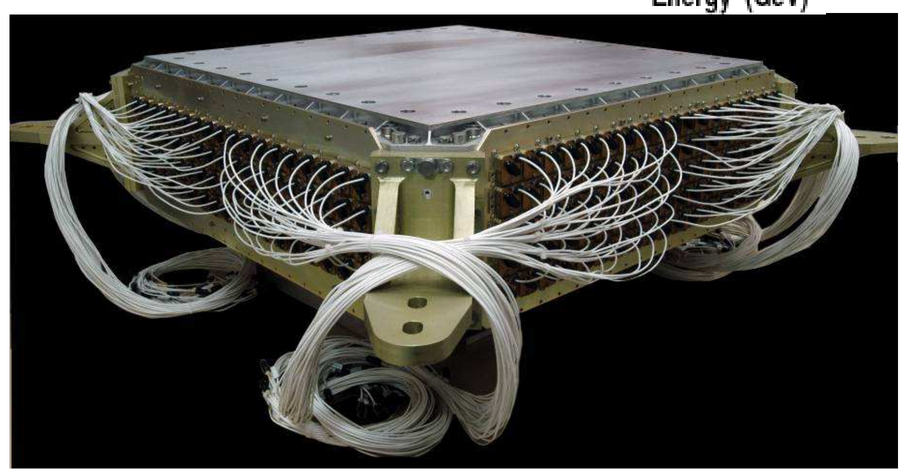
A precision, 17 X_0, 3-dimensional measurement of the directions and energies of light rays and electrons







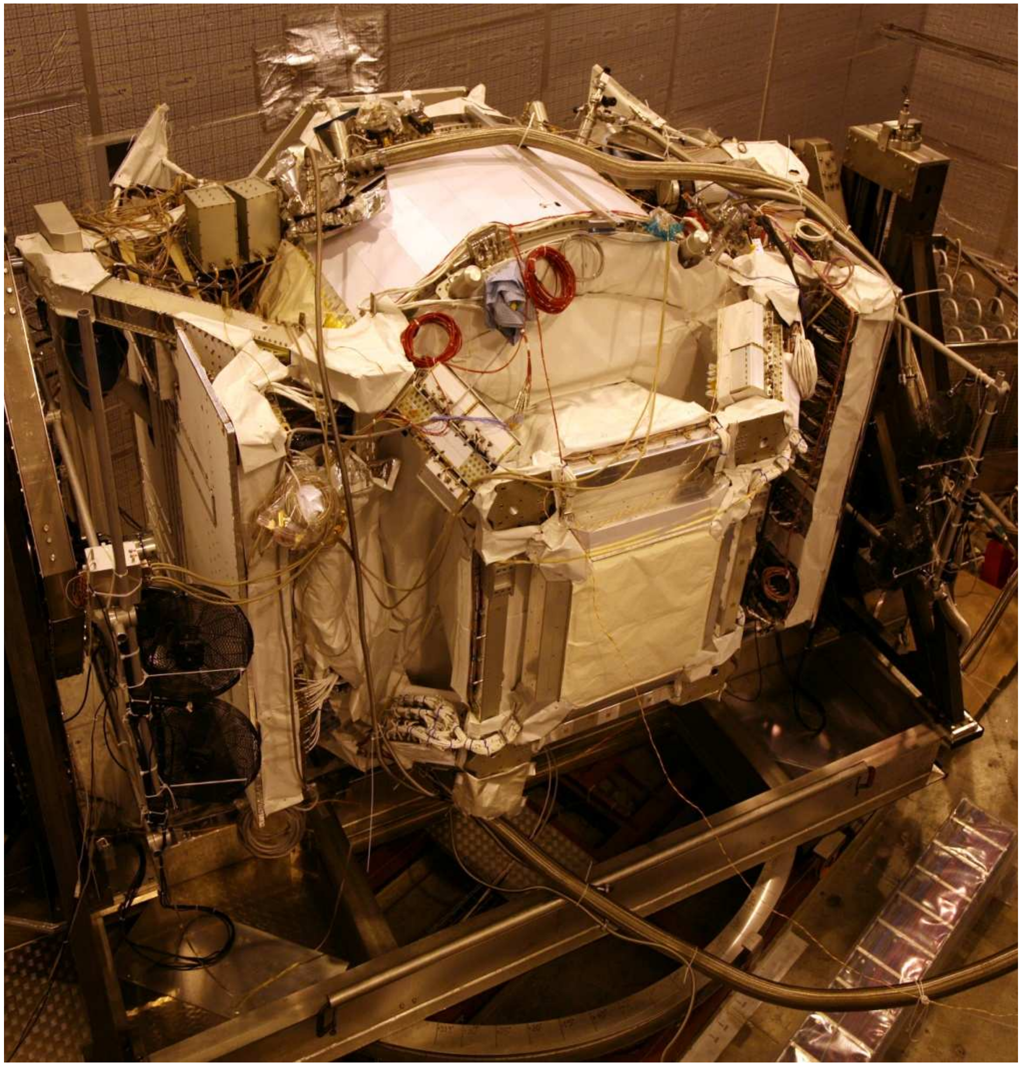
10 000 fibers, $\phi = 1$ mm
distributed uniformly
Inside 1,200 lb of lead

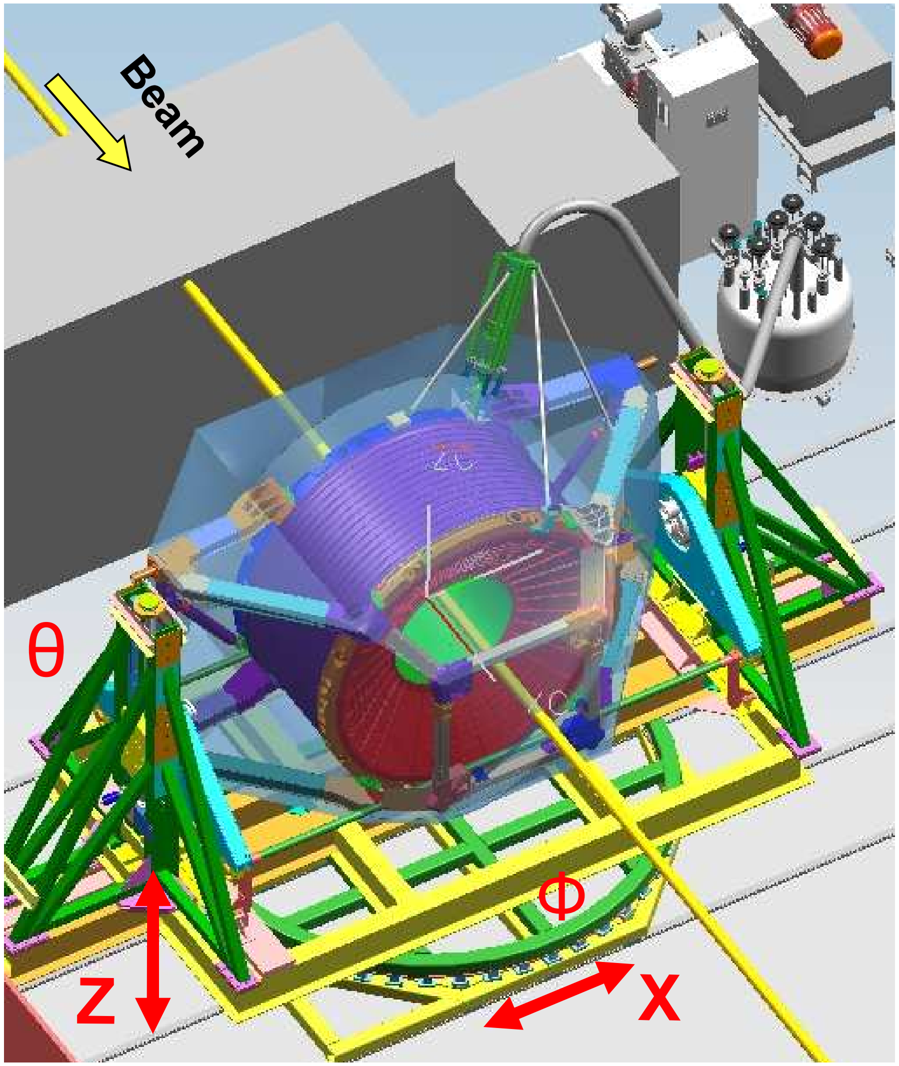


AMS in Test Beam, Feb 4-8, 2010

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.

Detector performance was not affected by the change of magnetic field





From: Steve Myers Sent: Mon 2/8/2010 7:58 AM **To: Dimitri Delikaris; Dietrich Schinzel**

Dear Dimitri,

There is a decision from the Directorate level to give the maximum possible amount of help to AMS.

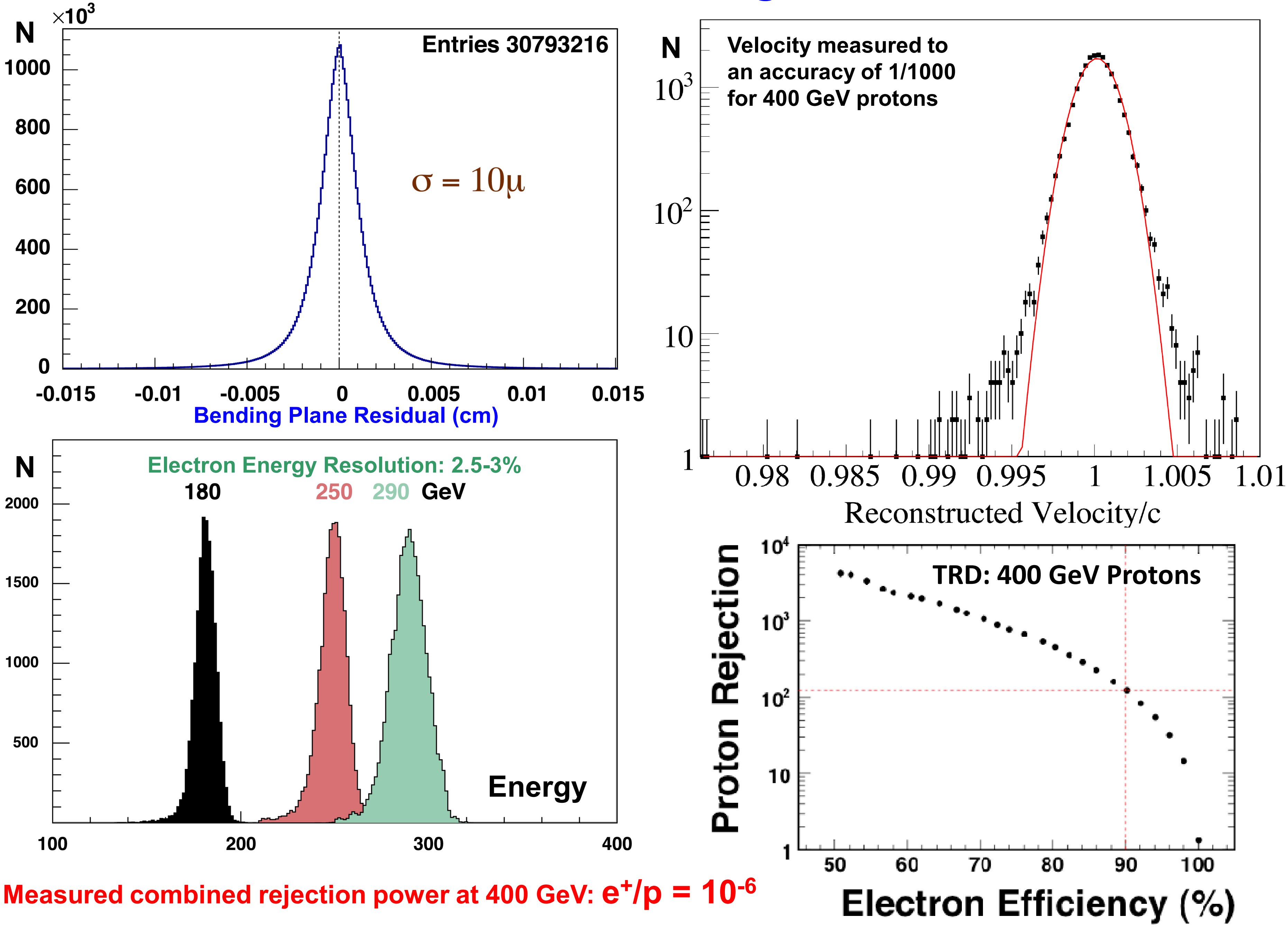
I really appreciate your aid. If there are any "legal" problems please let me know right away.

Regards,

Steve

Steve Myers
Director of Accelerators and Technology
European Organisation for Nuclear Research (CERN)
CH-1211 Geneva 23
Switzerland

Test Beam Results of integrated detector



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

THE DIRECTOR GENERAL

DG/146

Paris, 3 February 2010

Samuel C.C. Ting
CERN, Physics Department
CH-1211 GENEVA 23

Ref. My letter DG/137 dated 29 January 2010

Dear Professor Ting,

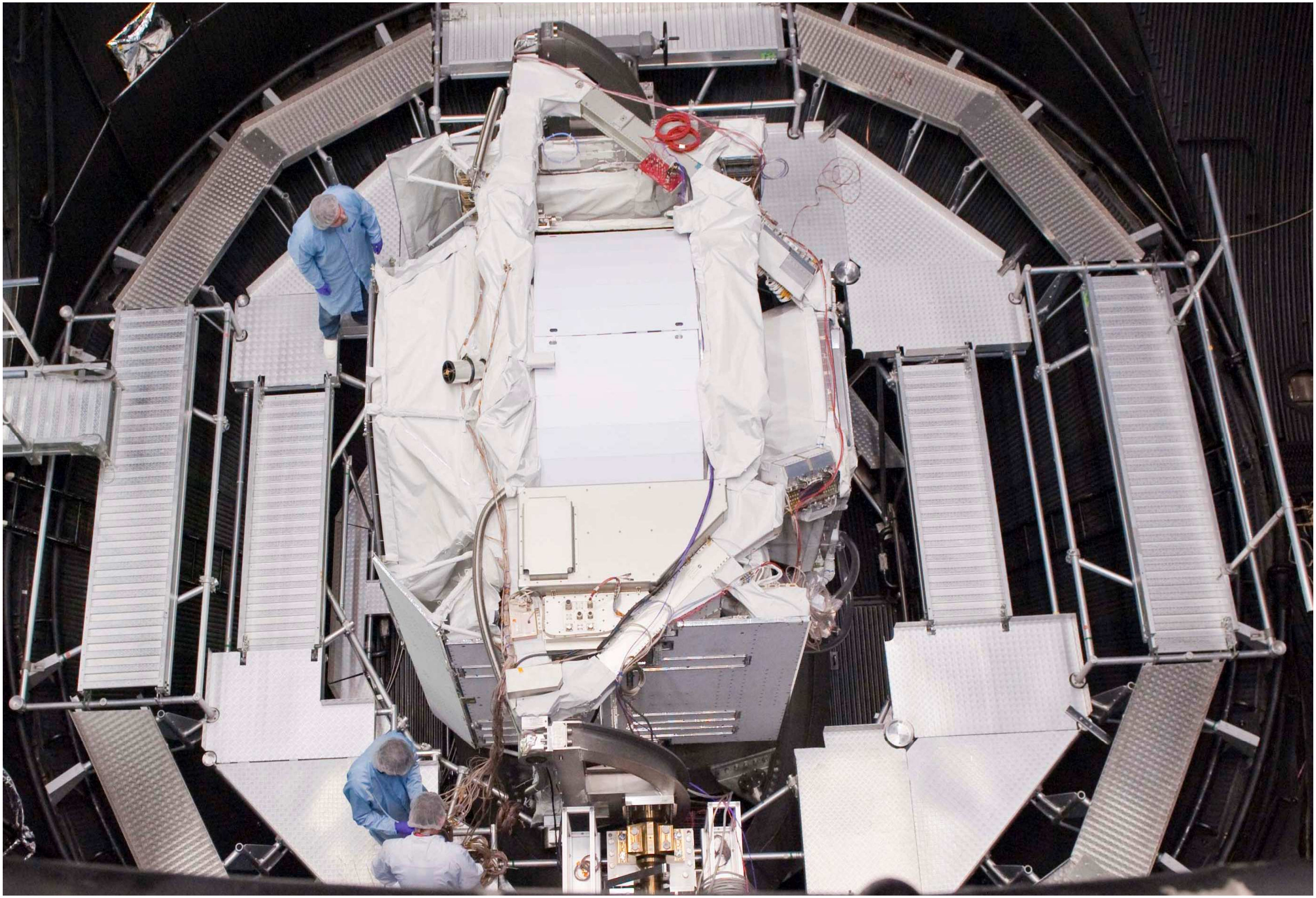
A I wrote to you in my referenced letter, and following the positive outcome from the visit of the ESA team at CERN to evaluate the readiness of AMS-02, I confirm that I grant the highest priority to AMS-02 in providing it access to the ESTEC Test Centre as soon as possible in order that you meet your targeted launch date.

....

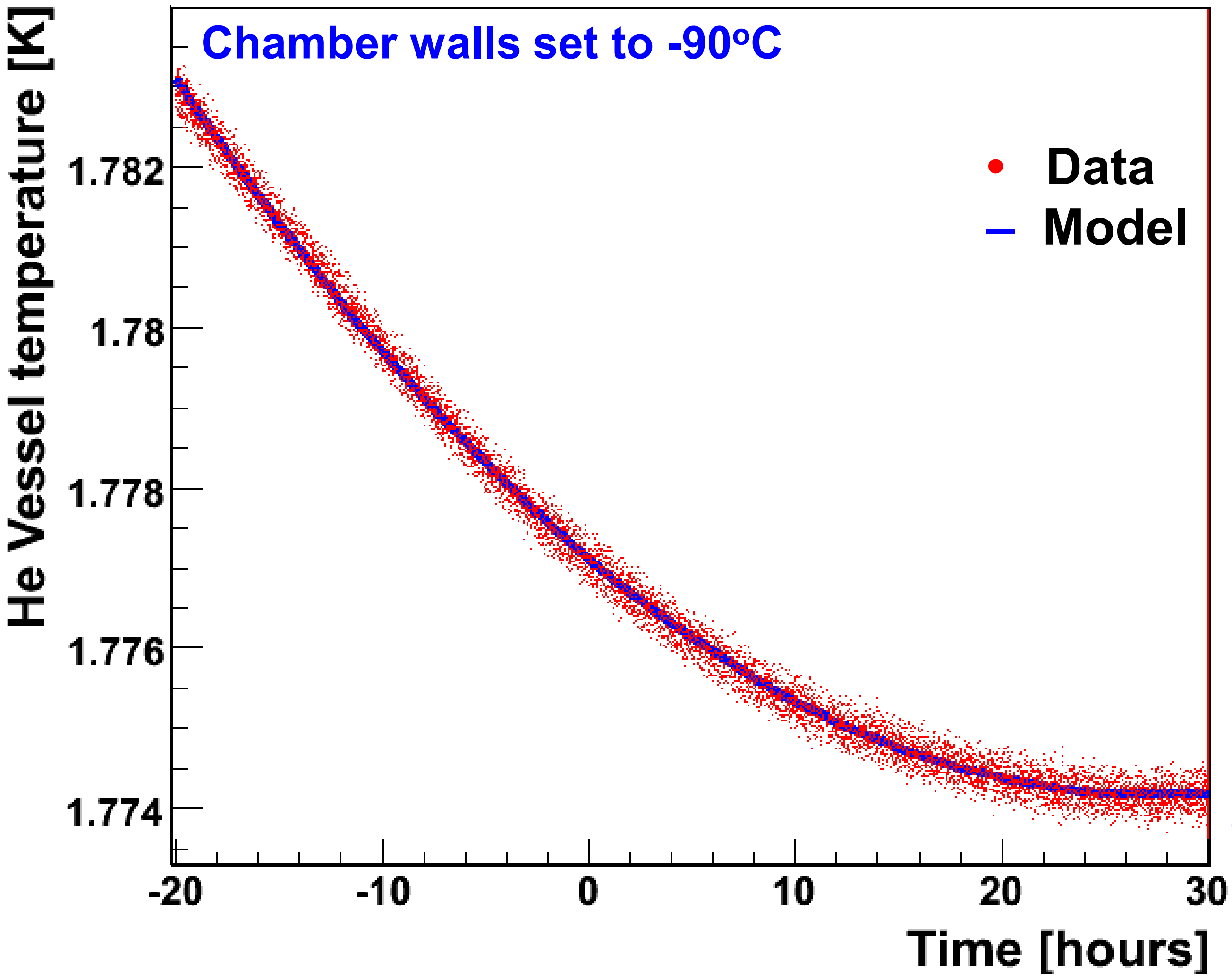
Yours sincerely,

Jean-Jacques Dordain

AMS in the ESA TVT Chamber



Stabilization of the He Vessel



Stability criteria:
dT/dt < 0.0001K/h

Expected life time of the AMS Cryostat on ISS:

20±4 months with M87 cryocoolers (1999)

28±6 months with GT cryocoolers (2010)

IMPLEMENTING ARRANGEMENT
BETWEEN
THE DEPARTMENT OF ENERGY
AND
THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
REGARDING THE
ALPHA MAGNETIC SPECTROMETER IN SPACE PROGRAM

…

I. PROGRAM DESCRIPTION

The AMS is a state-of-the-art particle physics detector containing a large permanent magnet that will be designed constructed and tested by an international team organized under DOE sponsorship and that will use the unique environment of space to advance knowledge of the universe and lead potentially to a clearer understanding of the origin of the universe. Specifically, the science objectives of the AMS are to search for cosmic sources of anti-matter (i.e., anti-helium or heavier elements) and dark matter.

… On the second flight, NASA will launch the AMS on the Shuttle and transfer and install it onto the International Space Station (ISS). The AMS then will be operated as an externally attached payload on the ISS for a nominal three-year period, after which NASA will detach the AMS from the ISS, transfer it to a Space Shuttle, and return it to Earth. …

By Harry C. Holloway
Associate Administrator
for Life and Microgravity
Sciences and Applications
National Aeronautics and
Space Administration

Date: 20 Sept 95

By Martha Krebs
Director
Office of Energy Research
Department of Energy

Date: Sept 20, 1995

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.

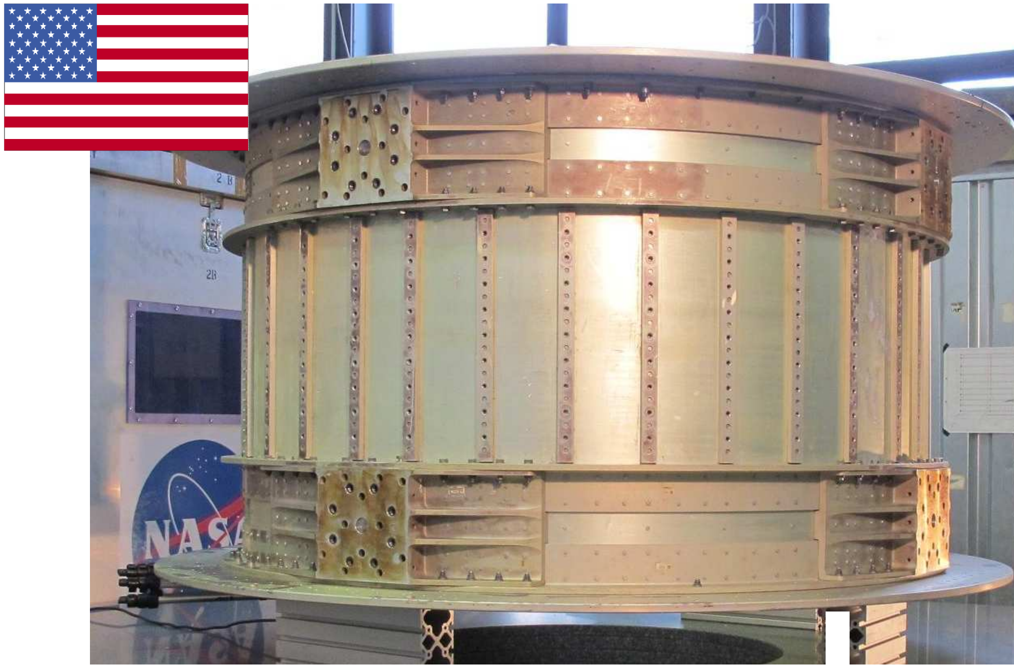
For the latest about the International Space Station, visit the Internet at: http://www.nasa.gov/station

- end -

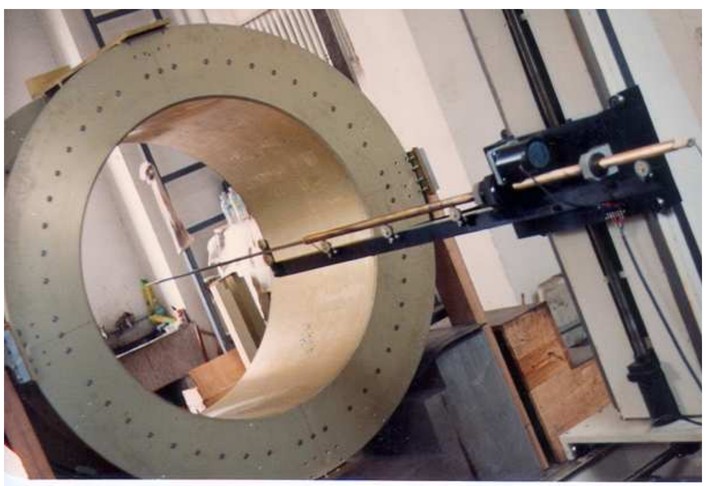
A superconducting magnet was ideal for a three year stay on ISS as originally planned for AMS.

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

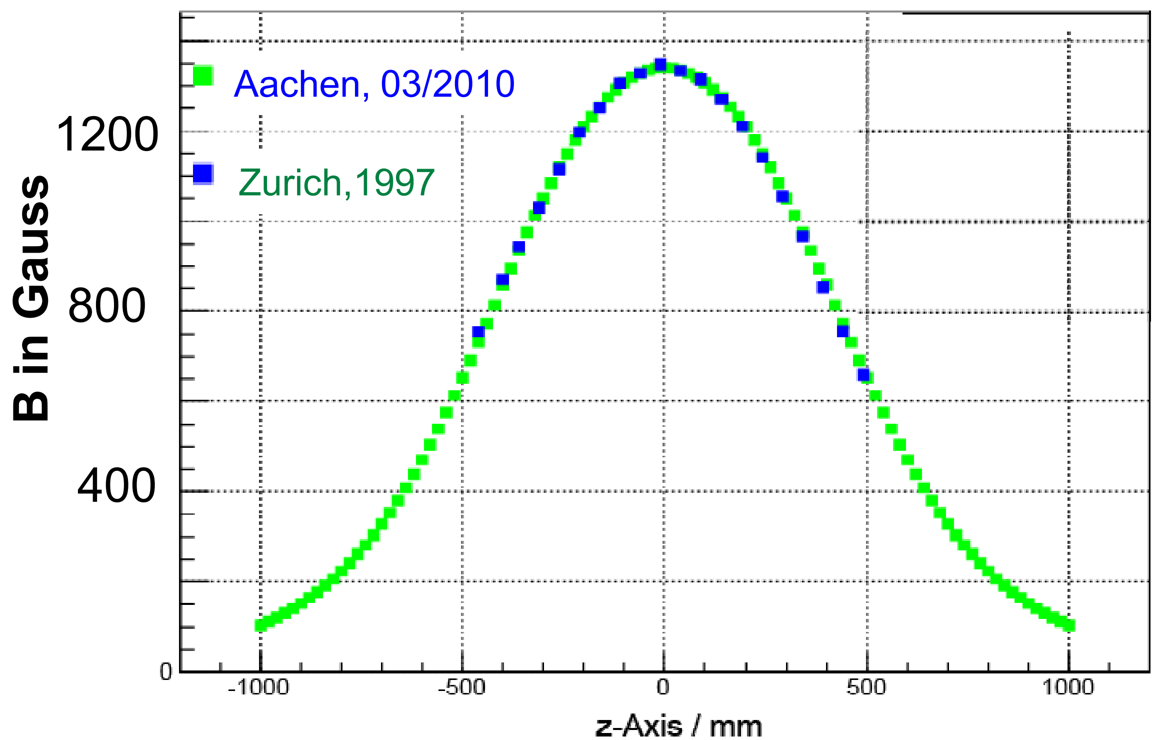
A superconducting magnet is no longer the ideal choice.



AMS-01 Permanent Magnet in Aachen Germany, 10 April 2010.



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

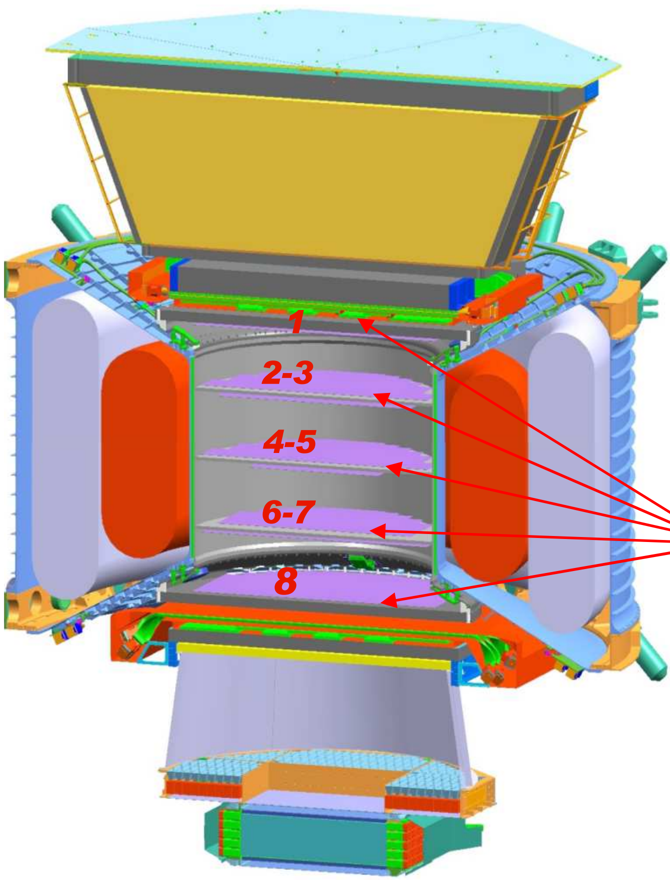


AMS-02

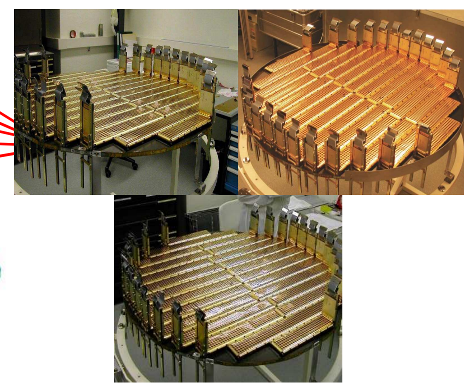
(3 yrs)
with SC Magnet

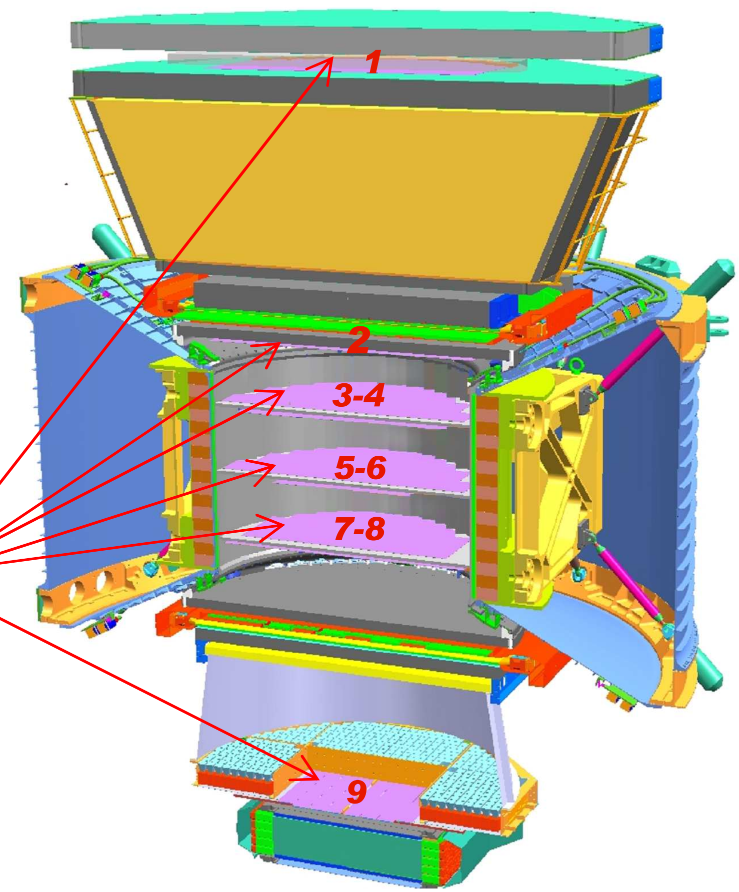
AMS-02

(10 Yrs to 18 yrs)
with Permanent Magnet
9 layers of Silicon

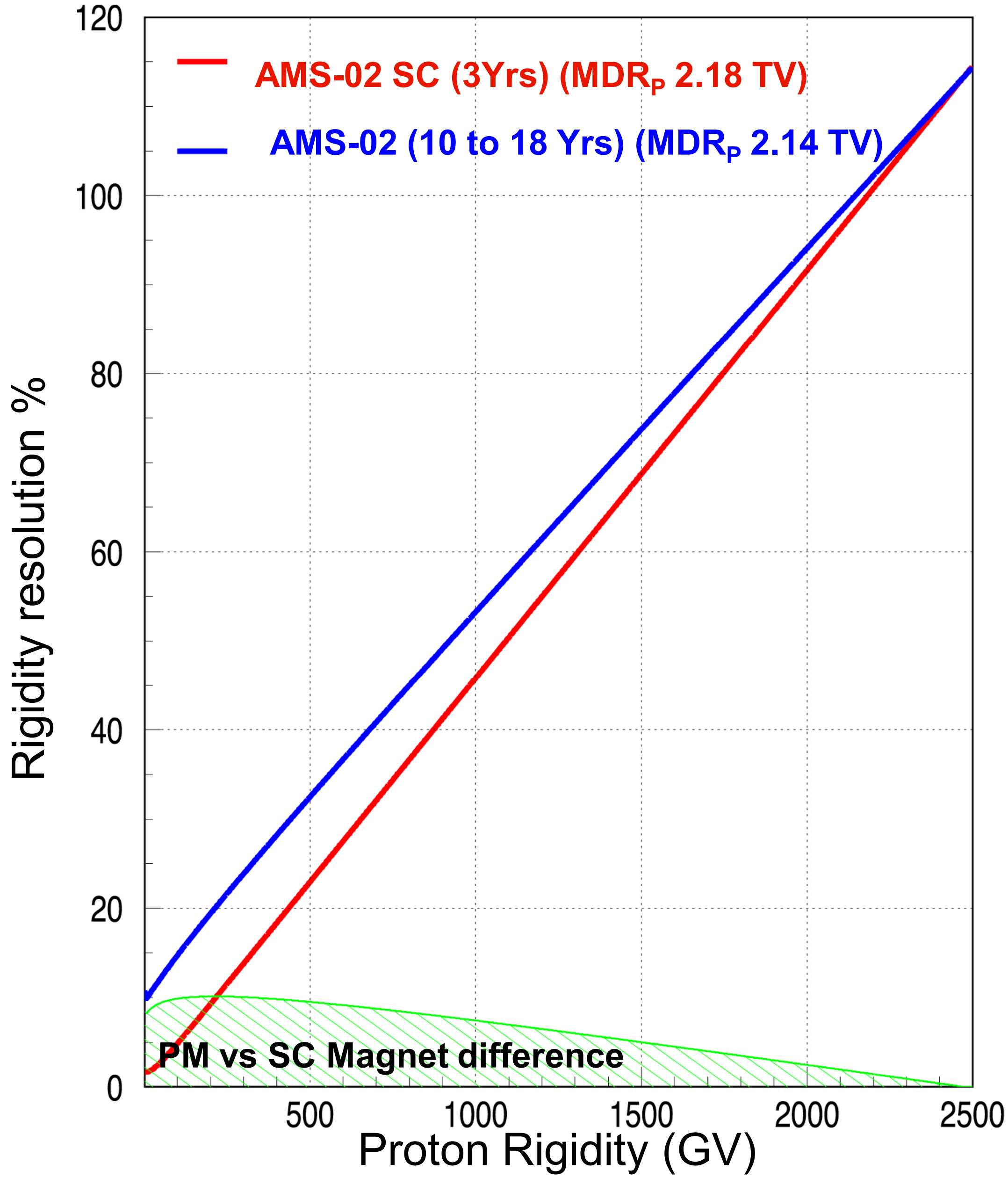


Silicon layers



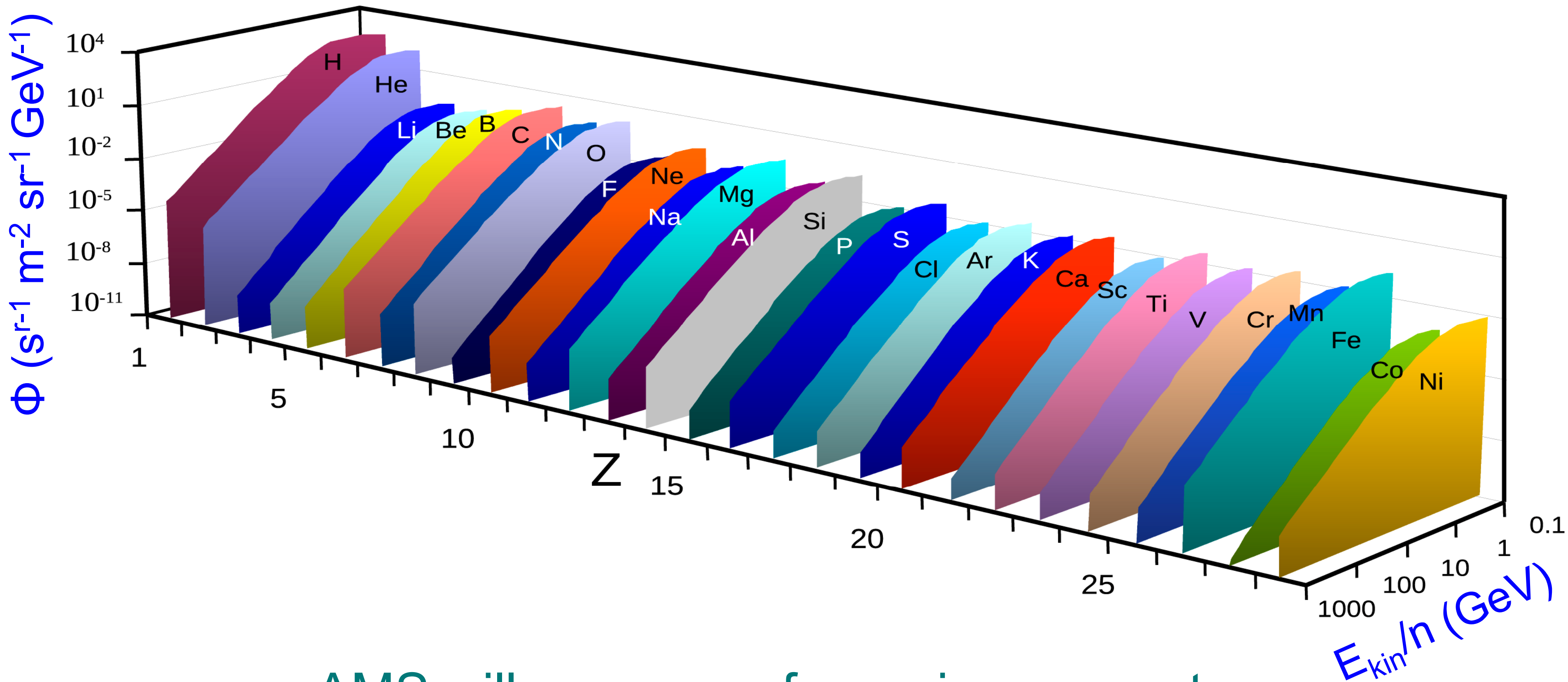


Layers 1 and 9 are far away from the magnet.



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.

Physics of AMS: Nuclear Abundances Measurements

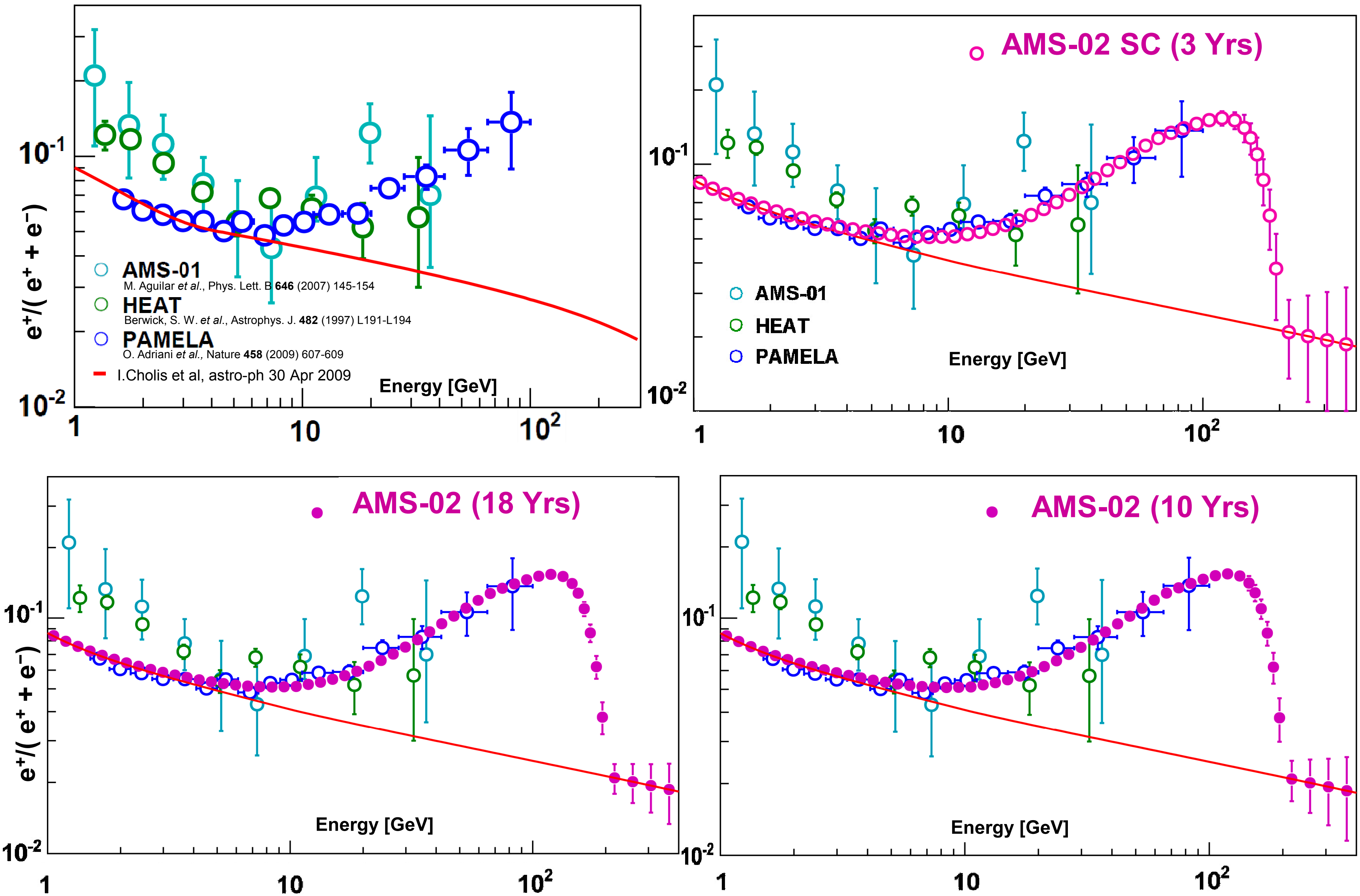


AMS will measure of cosmic ray spectra
for nuclei, for energies from 100 MeV to 2 TeV
with 1% accuracy over the 11-year solar cycle.

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

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

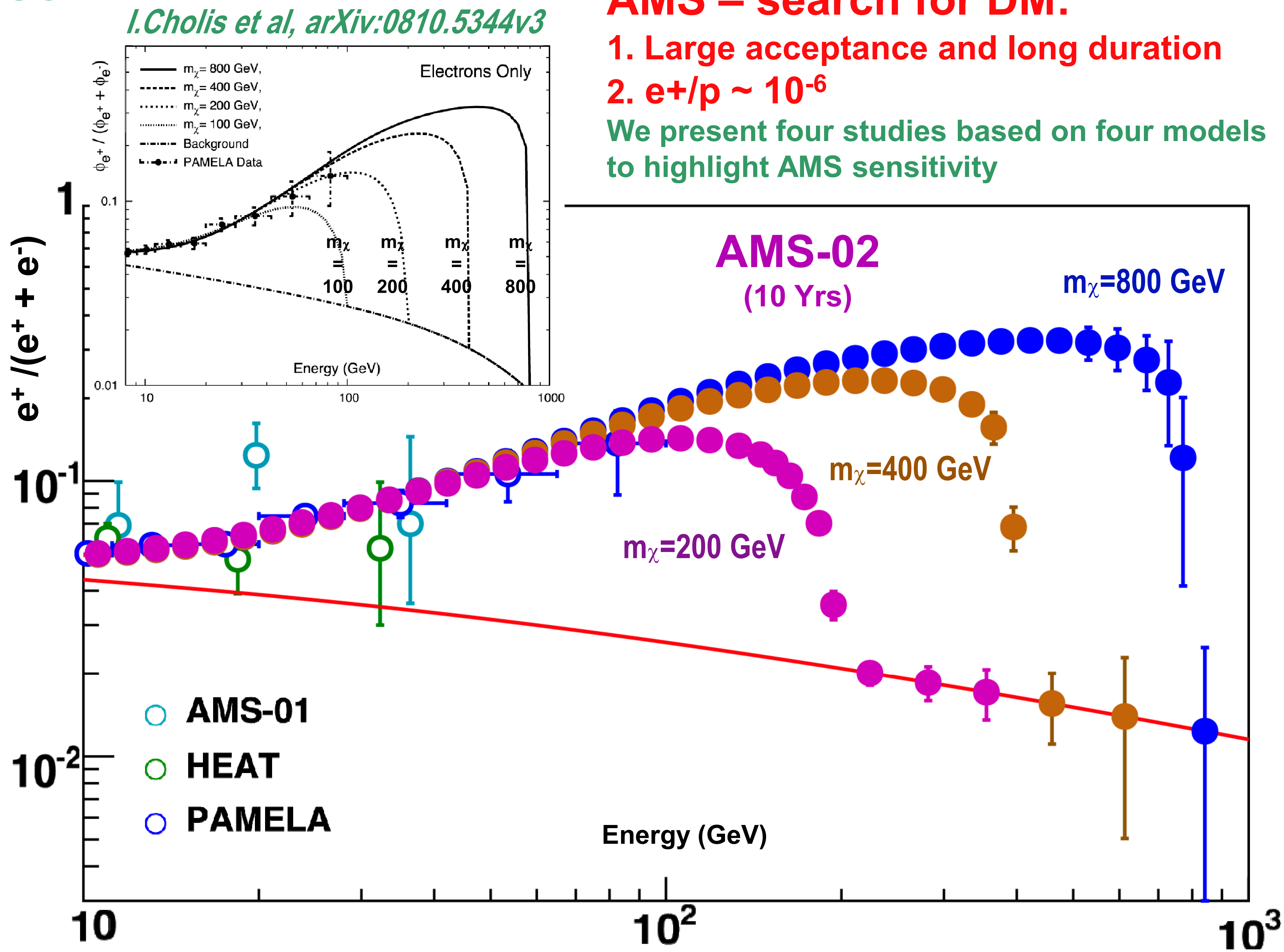


case 1

AMS – search for DM:

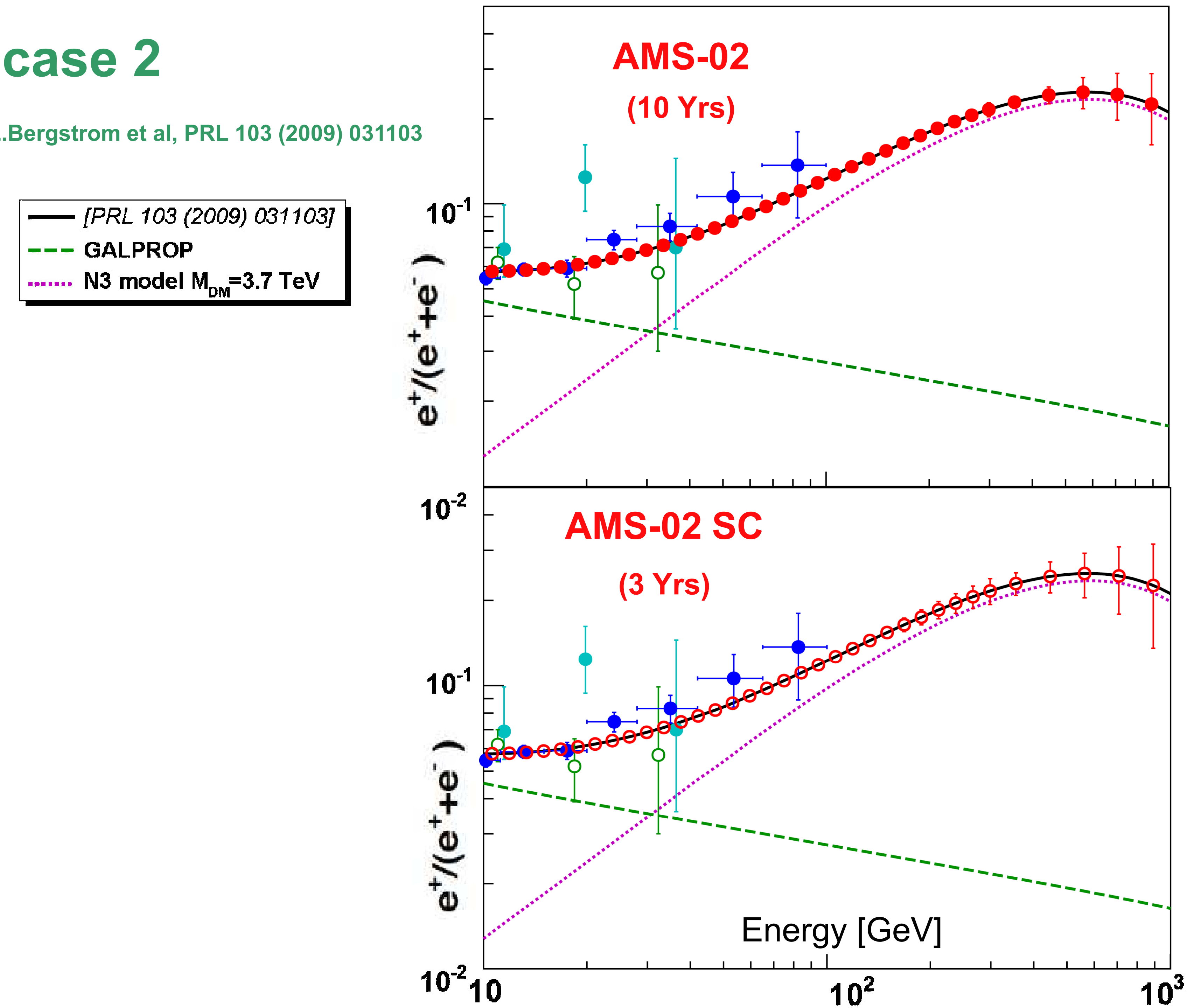
1. Large acceptance and long duration
2. e+/p ~ 10^{-6}

We present four studies based on four models to highlight AMS sensitivity



case 2

L.Bergstrom et al, PRL 103 (2009) 031103

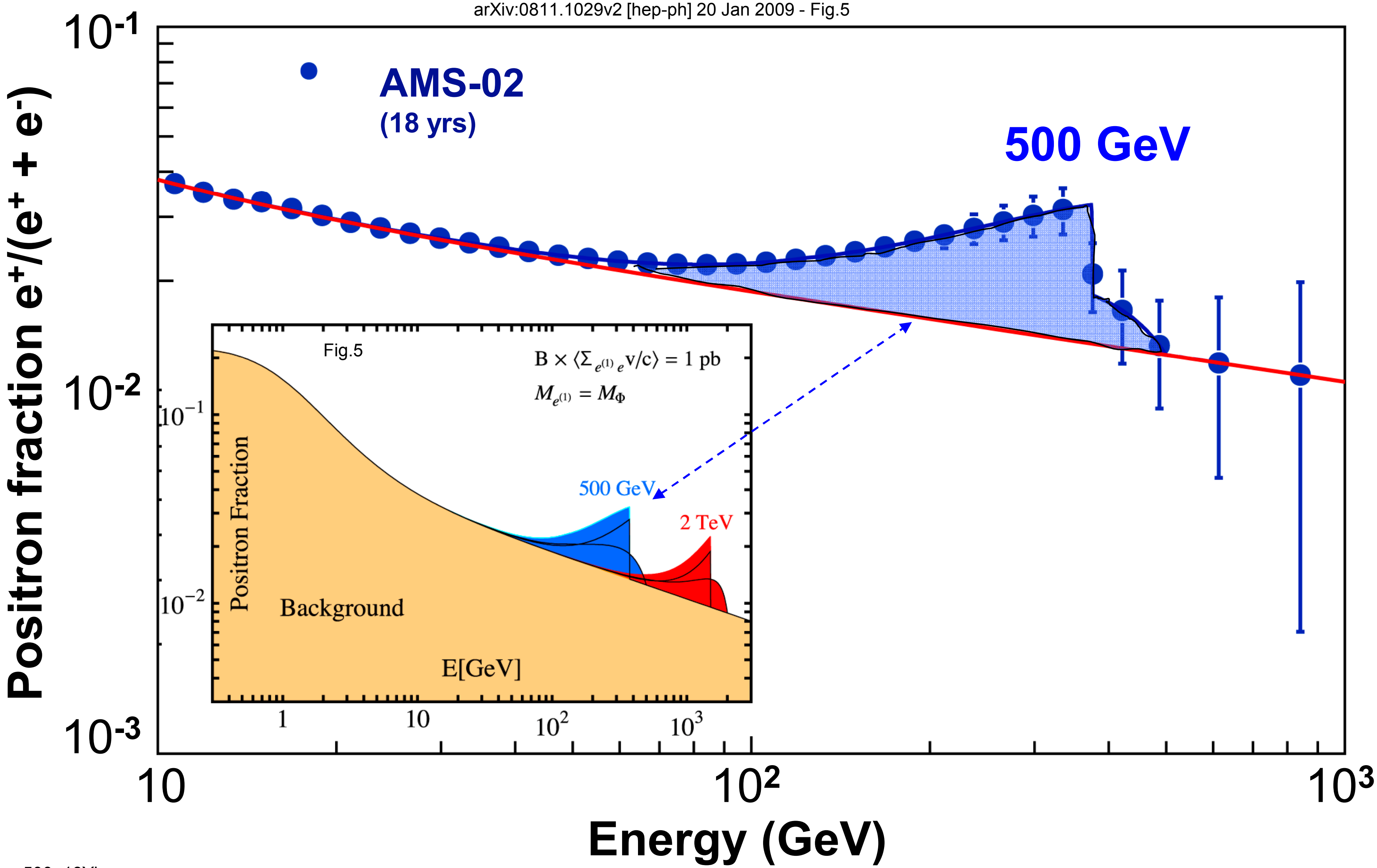


Kaluza-Klein Bosons are also Dark Matter candidates

case 3 TeV Scale Singlet Dark Matter

Eduardo Pontón and Lisa Randall

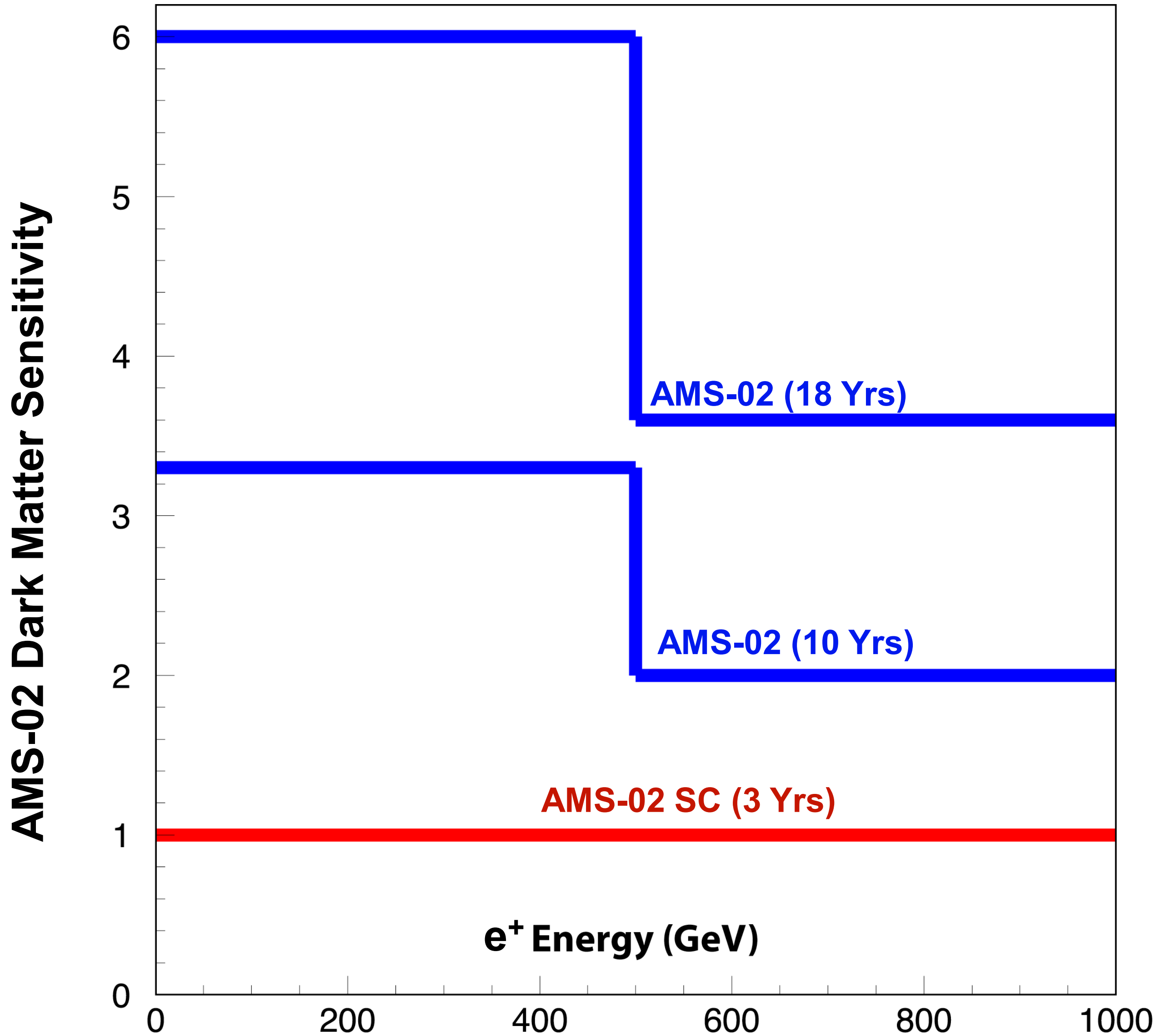
arXiv:0811.1029v2 [hep-ph] 20 Jan 2009 - Fig.5



sdm_500_18Yb

Dark Matter Searches

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

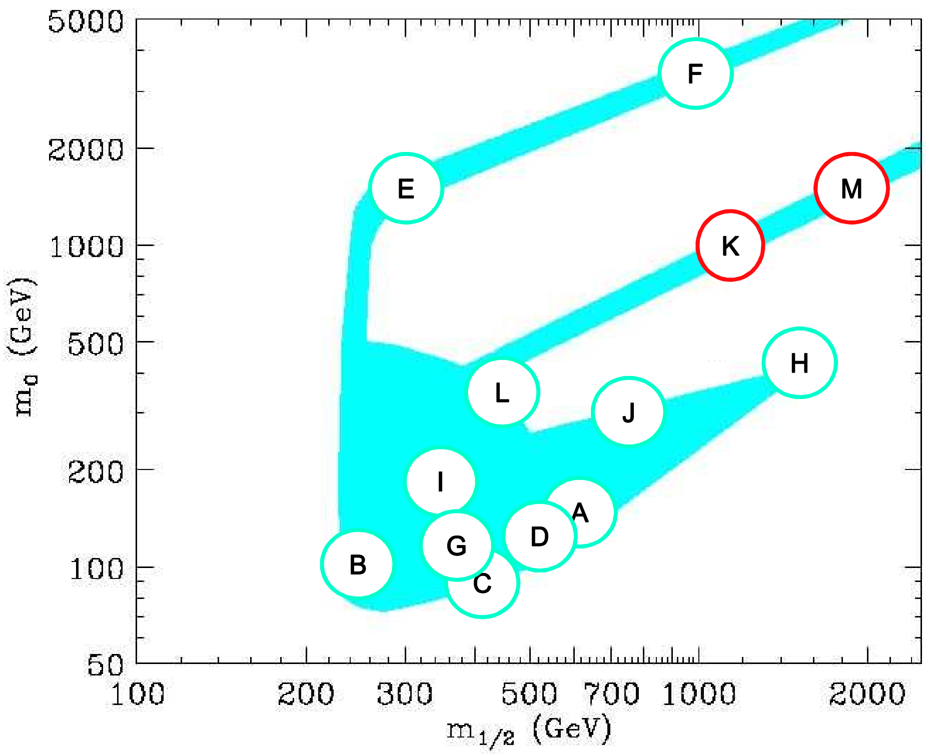


As seen, the permanent magnet upgrade of AMS has a 600-200% improvement in sensitivity in the search for Dark Matter.

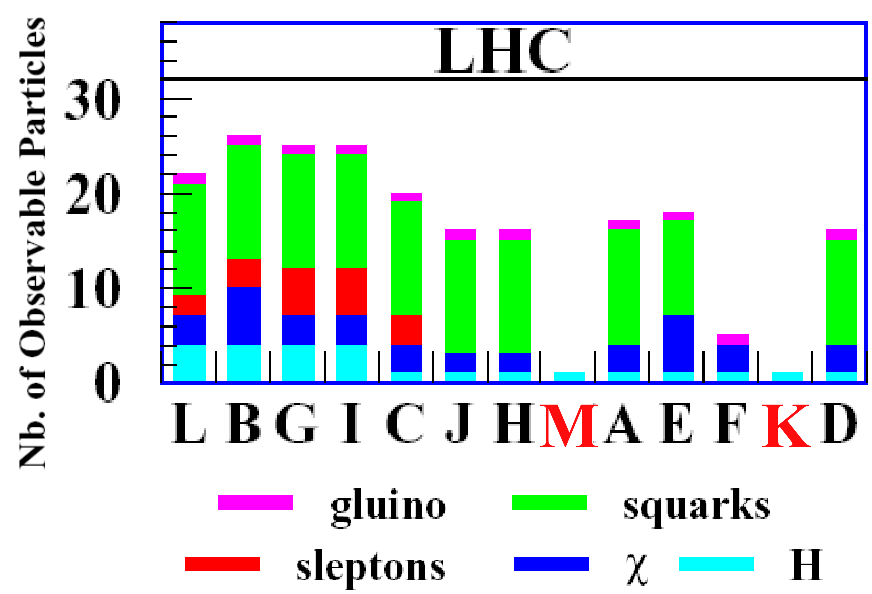
AMS is sensitive to SUSY parameter space that is difficult to study at LHC (large m_0, $m_{1/2}$ values)

J.Ellis, private communication

Shaded region allowed by WMAP, etc.



Post-WMAP Benchmarks

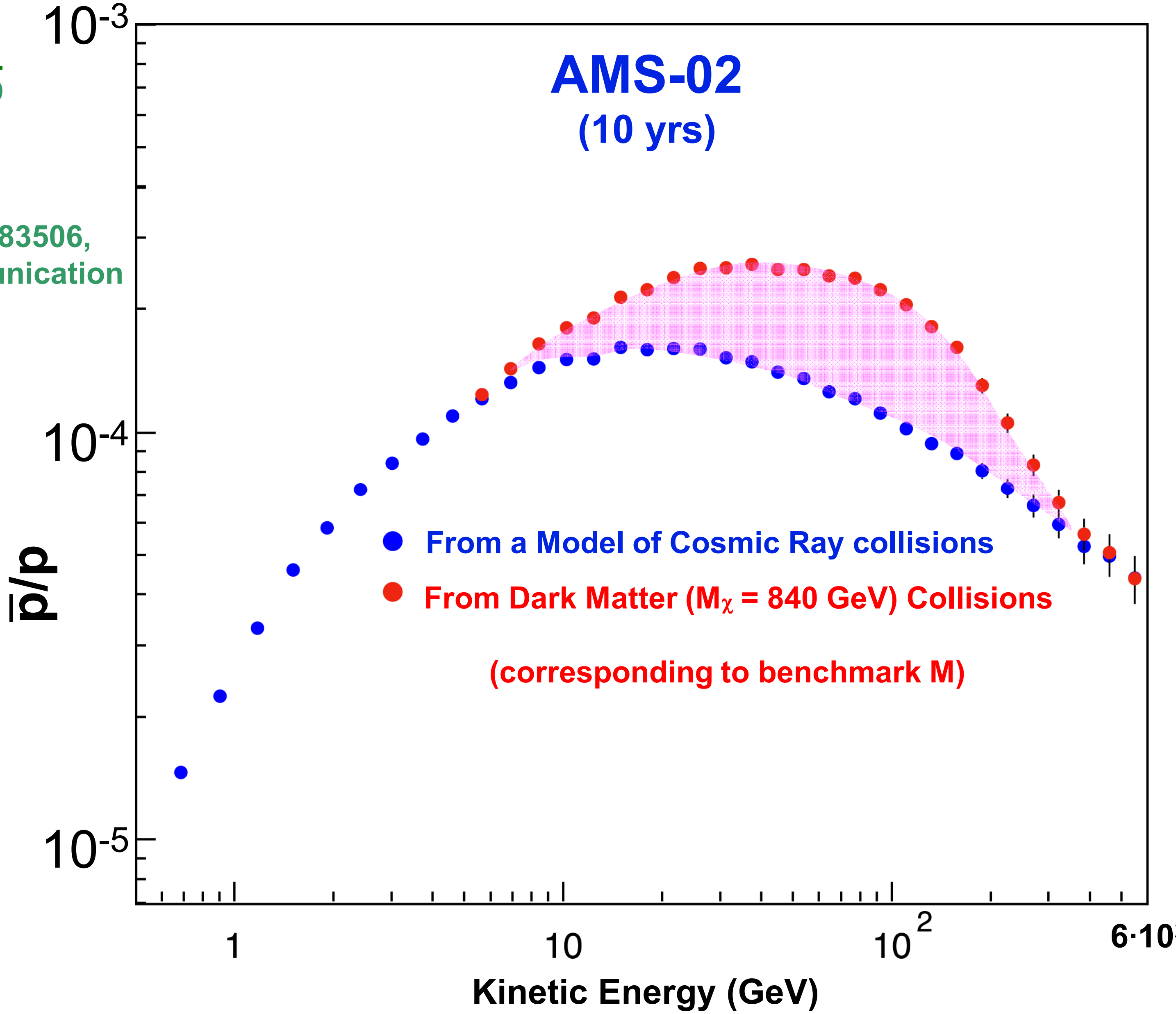


At benchmarks "K" & "M" Supersymmetric particles are not visible at the LHC.

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 4:
DM signal from $\bar{p}$

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



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

($Re(\varepsilon'/\varepsilon) = (19.2 \pm 2.1) * 10^{-4}$)

CERN NA-48

CDF, D0

LHC-b

ATLAS

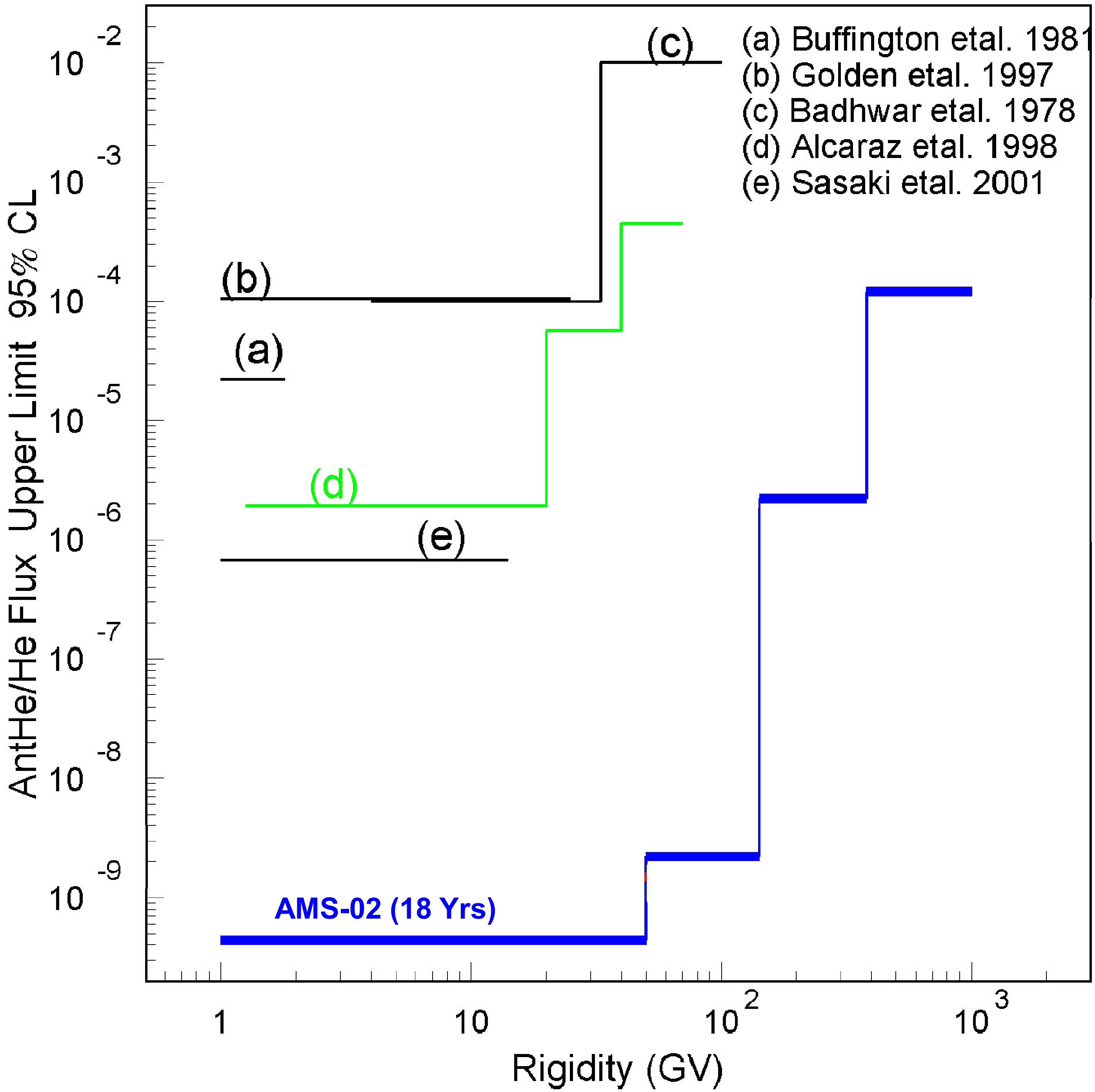
CMS

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
(a)
(b)
(c)
(d)
(e)
AMS-02 (18 Yrs)
AntHe/He Flux Upper Limit 95% CL
Rigidity (GV)
10 -2
10 -3
10 -4
10 -5
10 -6
10 -7
10 -8
10 -9
1
10
10 2
10 3

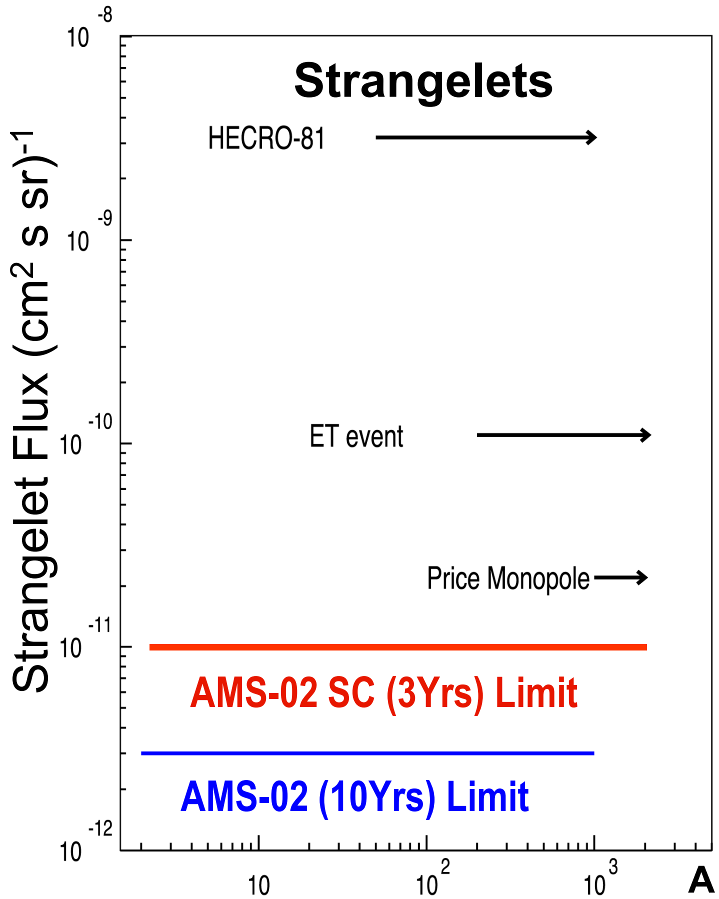
Strangelets

E. Witten, Phys. Rev. D,272-285 (1984)

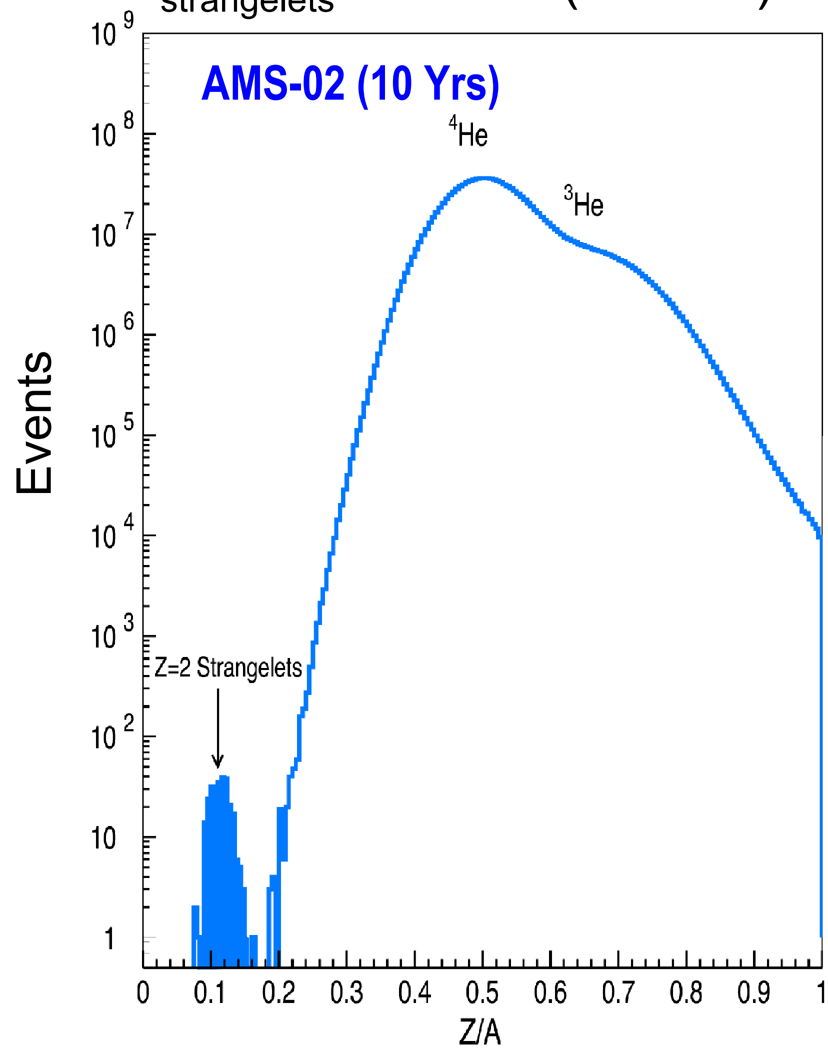
All the known material on Earth is made out of u and d quarks

Is there material in the universe made up of u, d, & s quarks?

Z/A~0.1

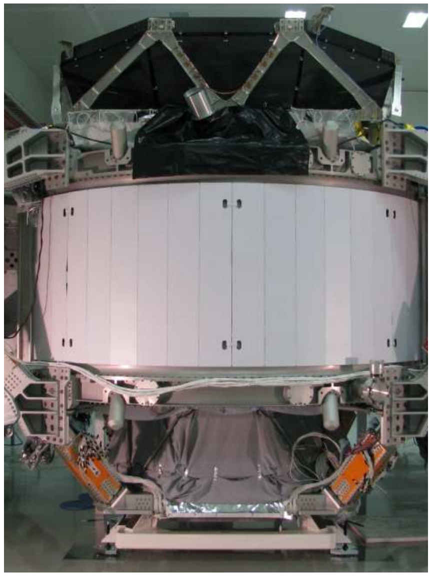


$\Phi_{strangelets} = 5x10^{-10}(cm^2 s\ sr)^{-1}$

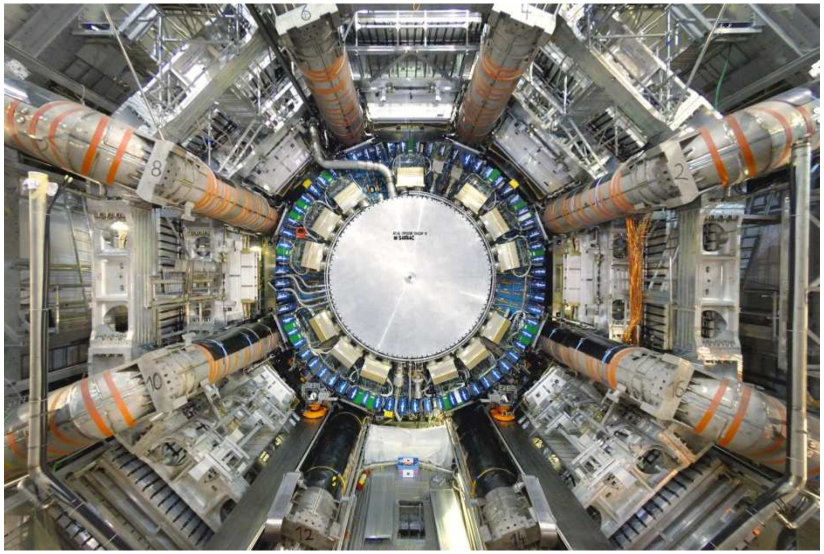


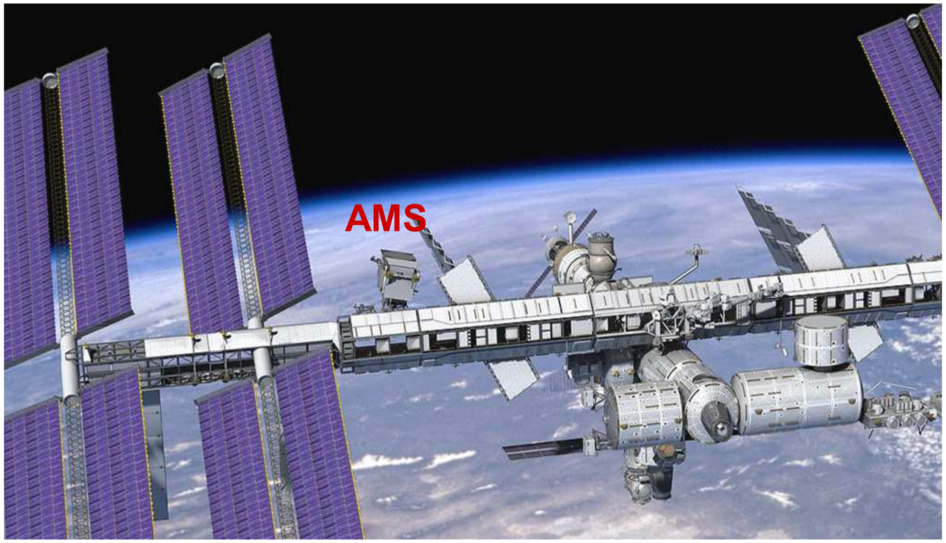
This can be answered definitively by AMS.

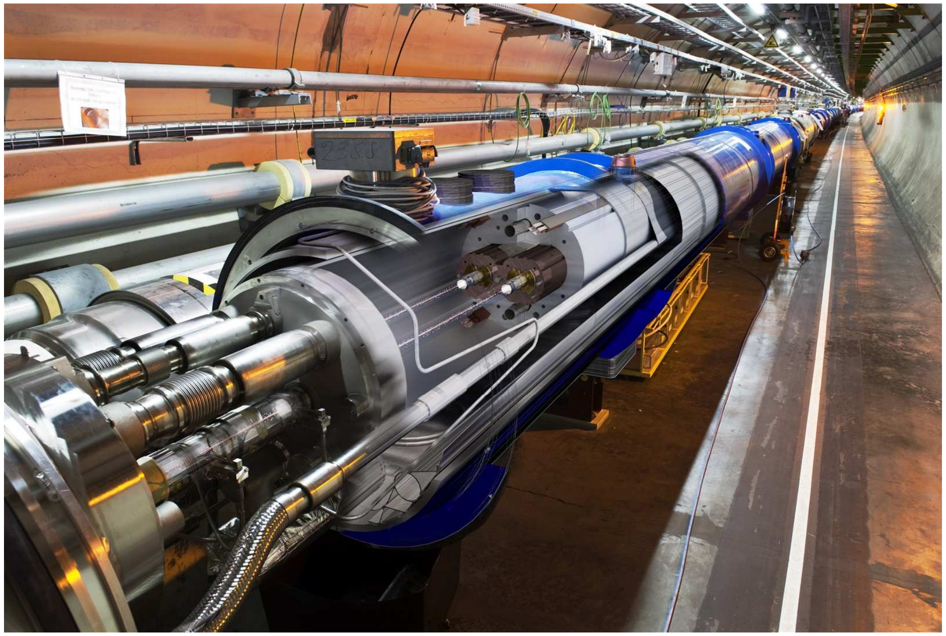
AMS



ATLAS, CMS,
ALICE & LHCb







ISS cost = ~10 LHC.
LHC has 4 big experiments.
ISS only has AMS.