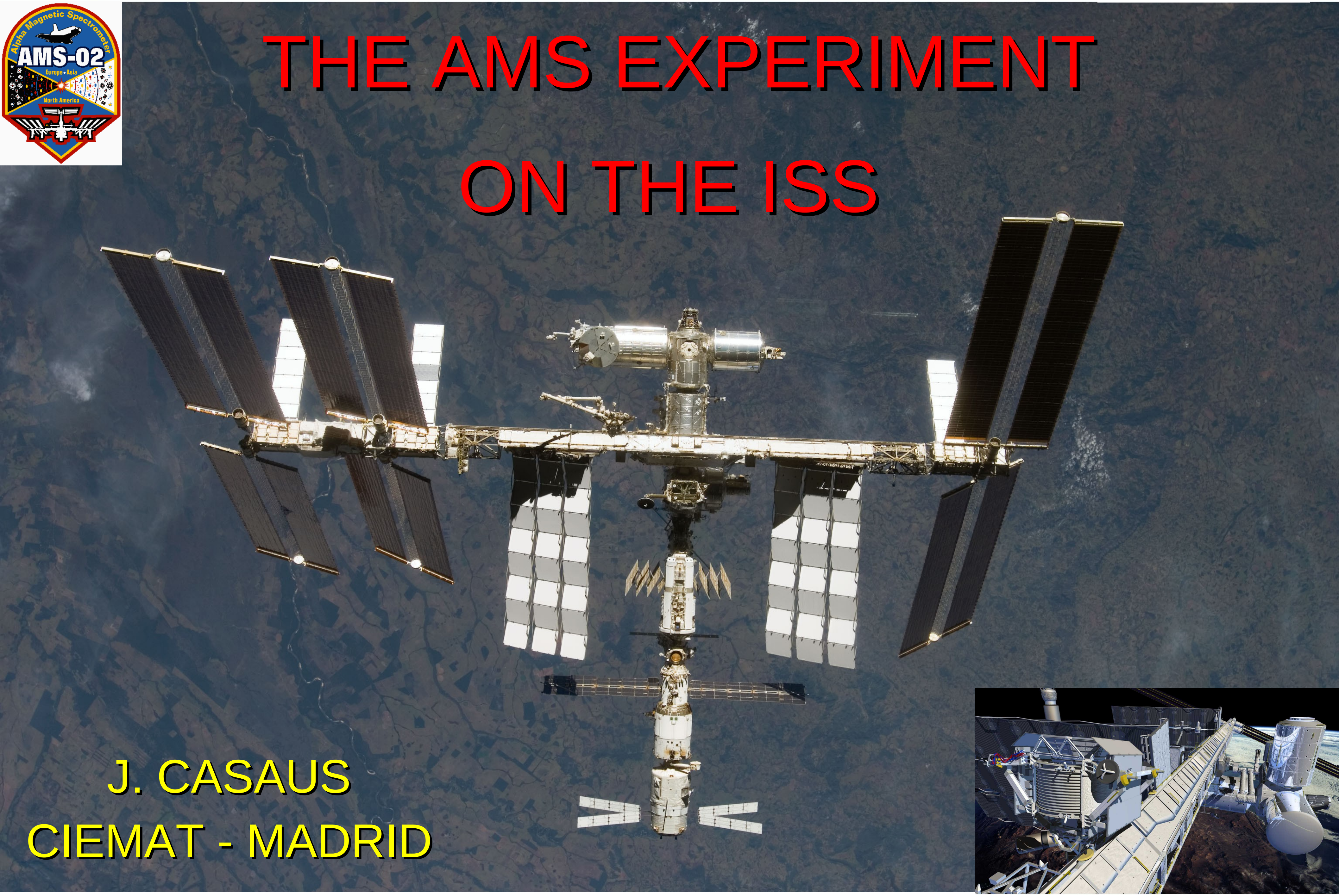
THE AMS EXPERIMENT ON THE ISS

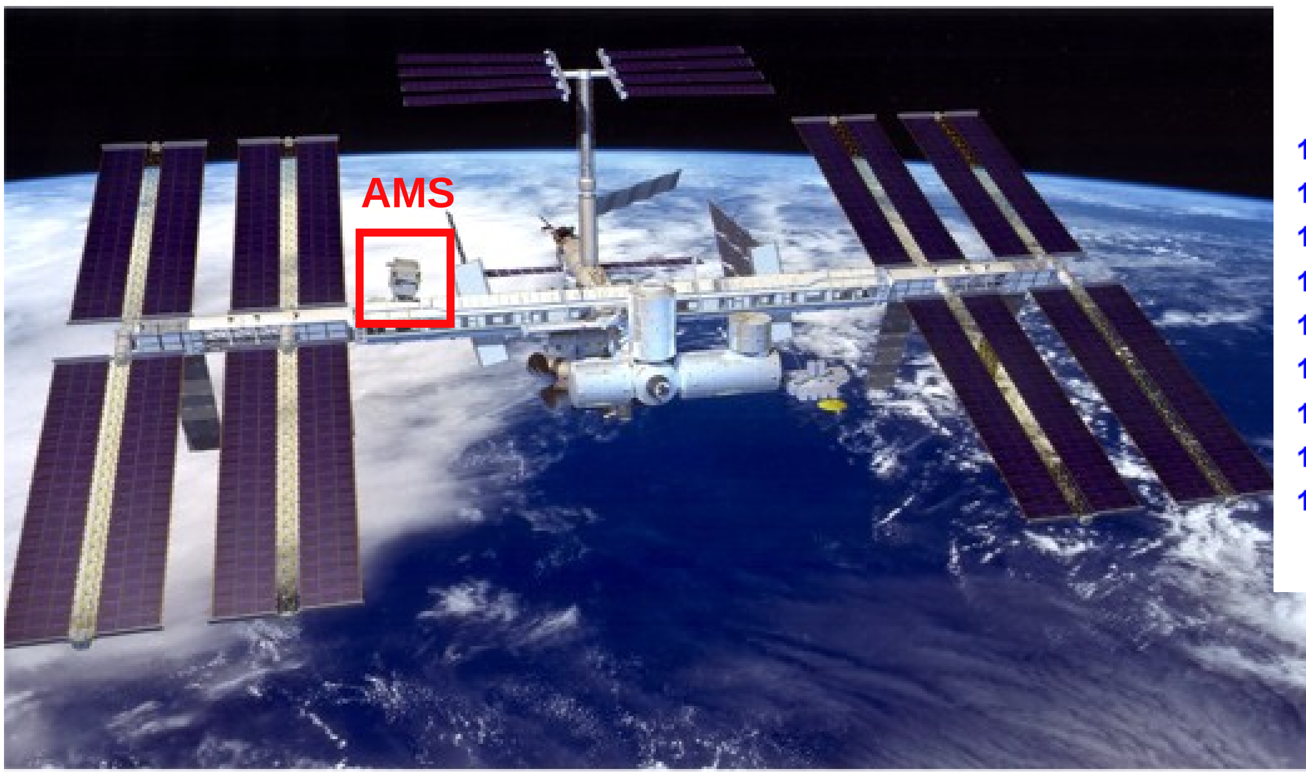


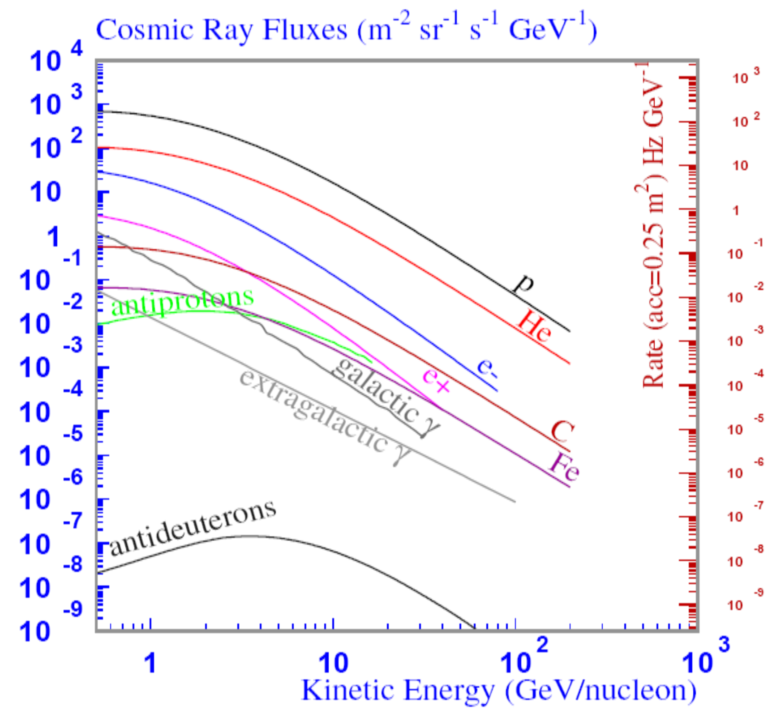
J. CASAUS
CIEMAT - MADRID

DISCRETE '08 – Valencia 11-16 Dec 2008

The AMS Experiment

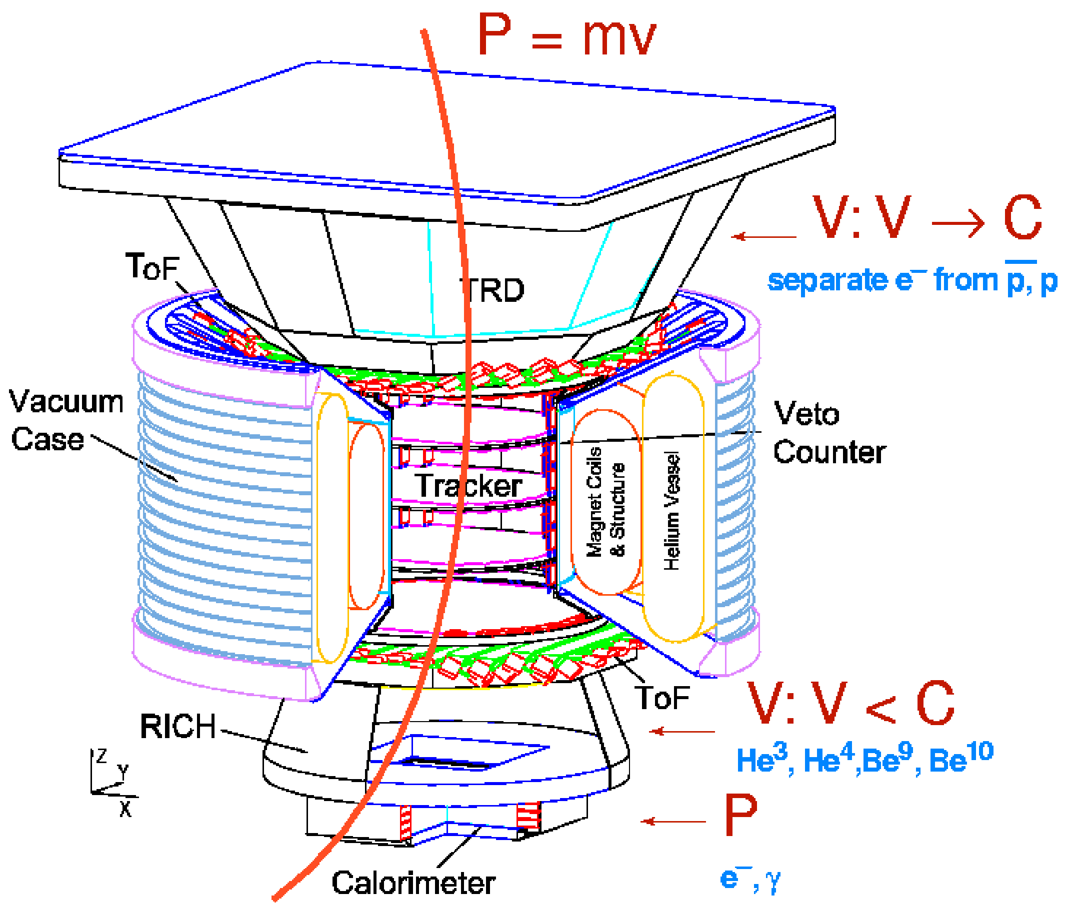
The aim of the AMS experiment is to install a particle detector on the ISS to perform a high precision study of the cosmic rays





AMS will perform accurate measurements of energetic cosmic rays (0.1 GeV to 2 TeV)

The AMS-02 detector



Subdetectors		Range/ Precision
Magnet	BL^2	0.78 Tm^2
Tracker	Planes	8
	$\sigma(p) / p$	1.5 %
TRD & EMC	e/p - γ	< 10^{-6}
RICH	$\sigma(\beta) / \beta$	0.1 %

Particle	Energy Range
p^+	1 TeV
He,....,Fe	1 TeV/n
Light Isotopes	10 GeV/n
p^-	350 GeV
e^+	350 GeV
Anti - He,C,...	1 TeV/n
e^-	1 TeV
γ	1 TeV

The AMS Experiment

Why on the ISS ?

Orbit Altitude	**350 km**
Power	**2 kW**
Weight	**7 T**
Exposure Time	**> 3 years**

The AMS Science Program

Accurate study of the nature and composition of the cosmic rays and the relative abundances of light isotopes

→ **CR Astrophysics**

Source abundances

Acceleration mechanisms

Propagation models

Precise measurement of the antiproton, positron and γ-ray fluxes

→ **Dark Matter**

Many candidates from Particle Physics (SUSY neutralinos, KK Bosons ...)

$\chi^{o} + \chi^{o} \rightarrow \bar{p} + \ldots$

$\rightarrow e^{+} + \ldots$

$\rightarrow \gamma + \ldots$

Antimatter ($\overline{He}$, $\overline{C}$) search 10^{3} - 10^{6} more sensitive than current limits

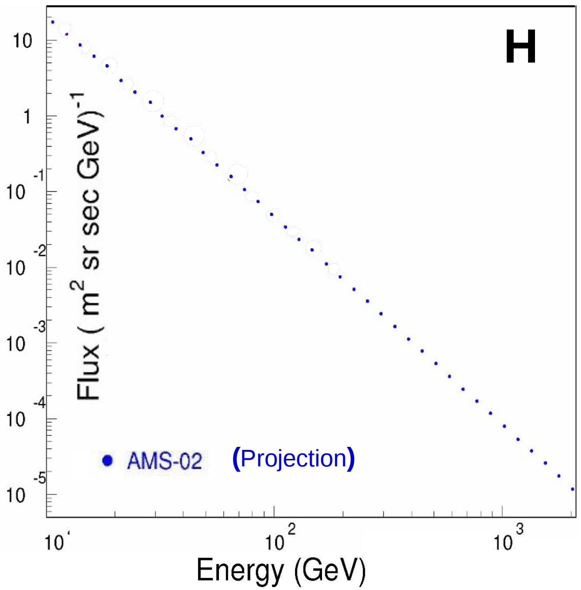
→ **Baryogenesis**

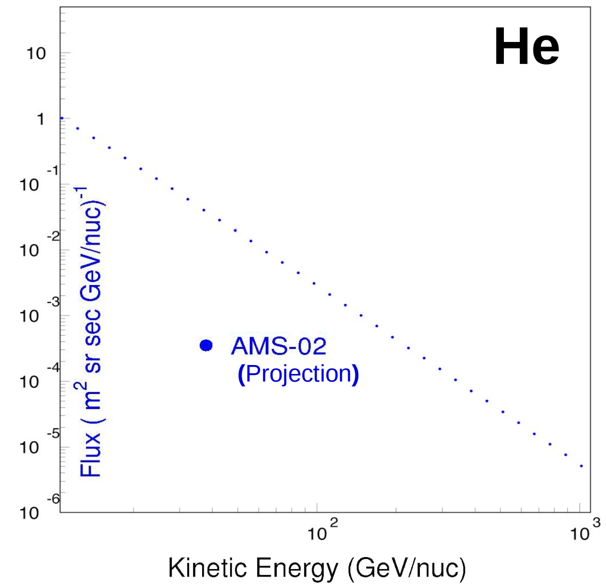
B non conservation

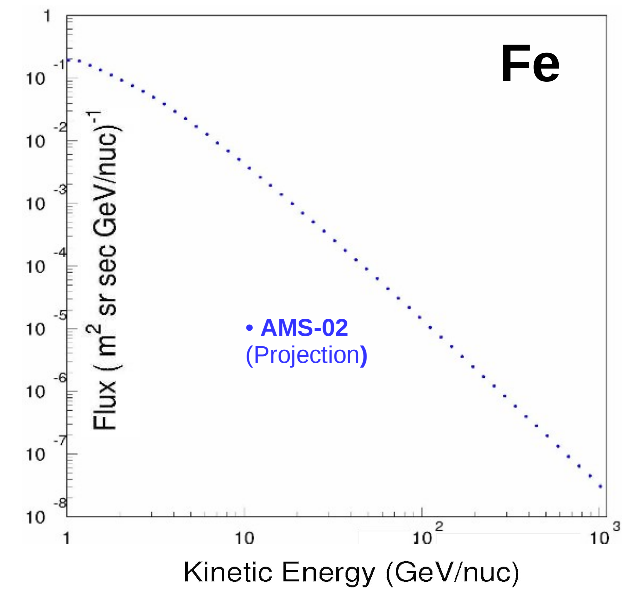
CP violation

Precision study of the properties of Cosmic Rays

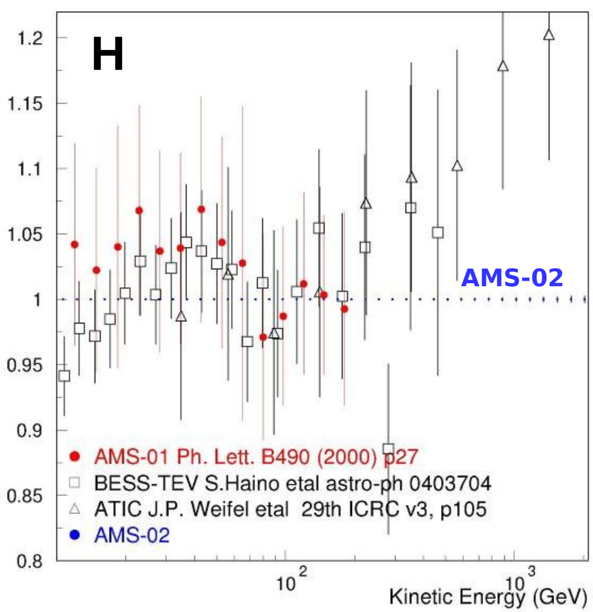
i. Fluxes of individual elements Z=1-26 (0.1 GeV/n - 1 TeV/n)

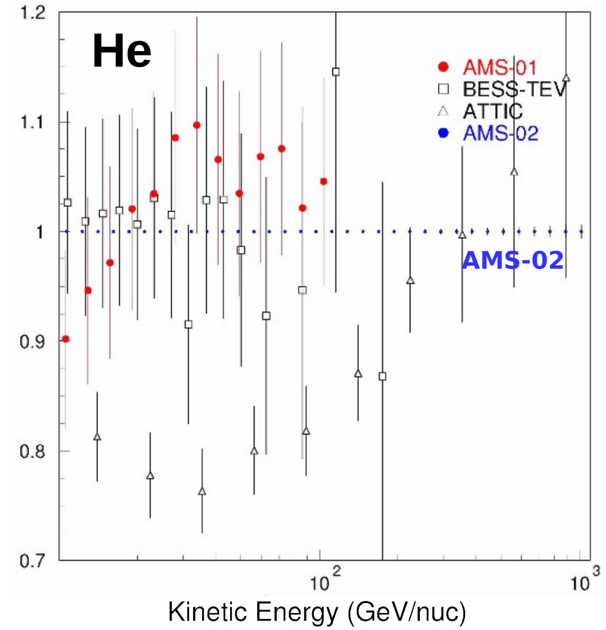


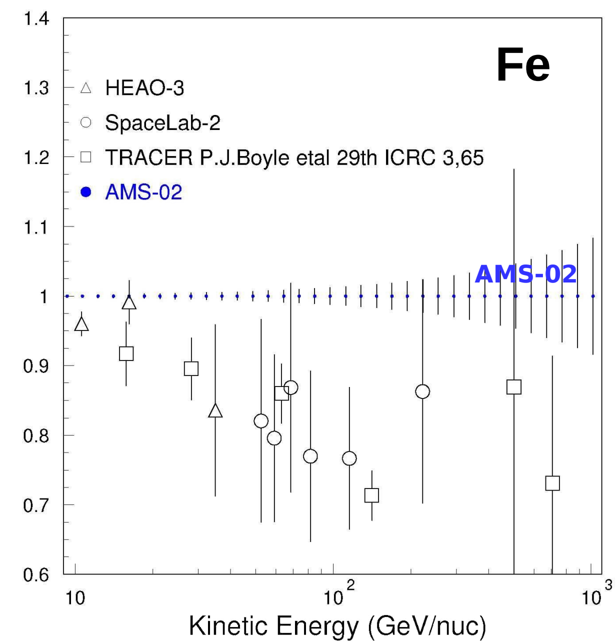




Relative Fluxes (normalized to AMS-02 projected value)



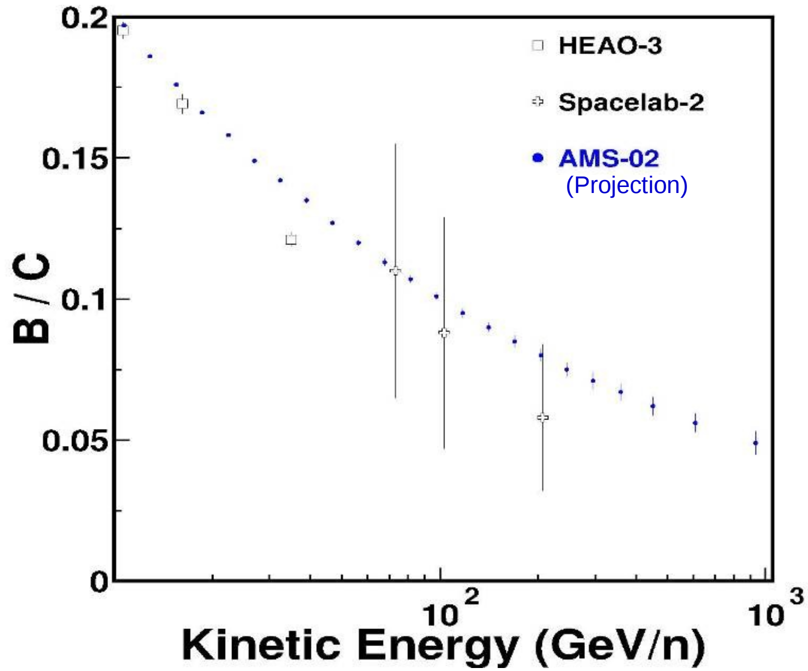


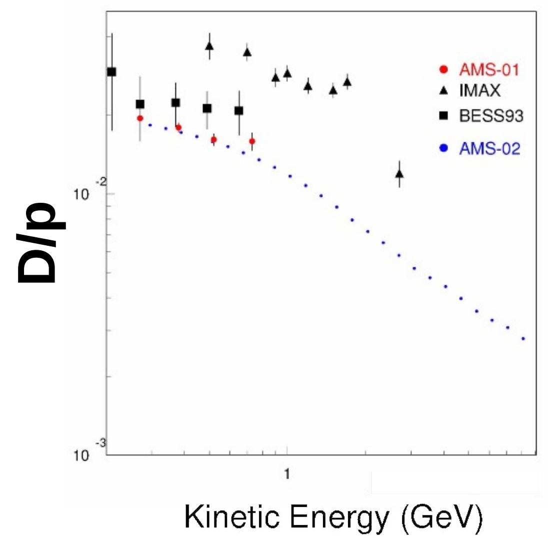


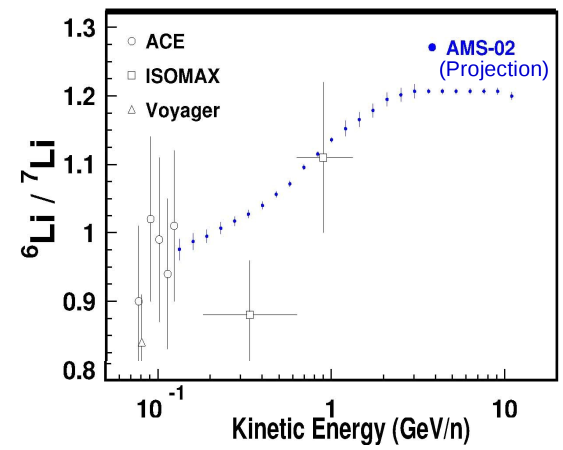
Precision study of the properties of Cosmic Rays

ii. Propagation Parameters (diffusion coefficient, galactic winds, ...)

Secondaries / Primaries, Isotopic ratios....

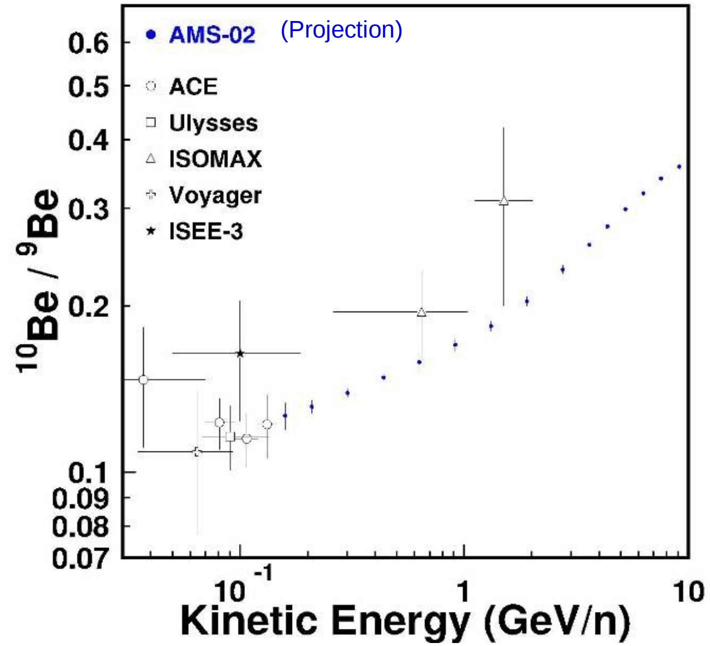






iii. Cosmic Ray confinement time

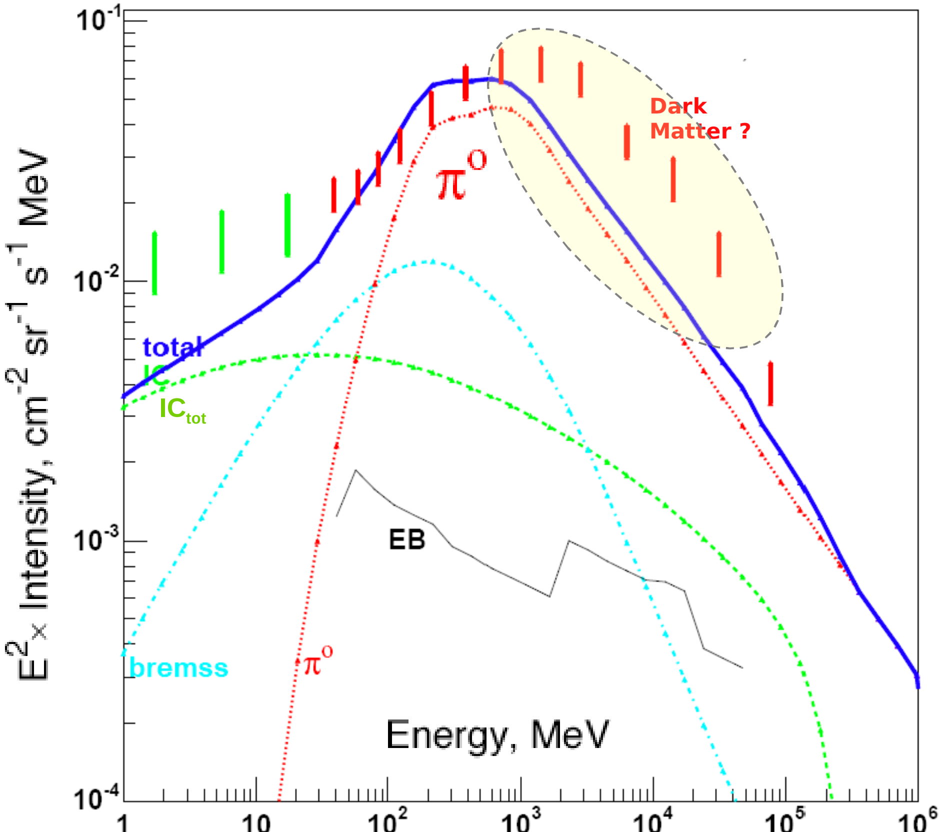
Radioactive clock (^{10}Be)



An application of AMS Cosmic Ray data:
Interpretation of the Egret Gamma-Ray “Excess”

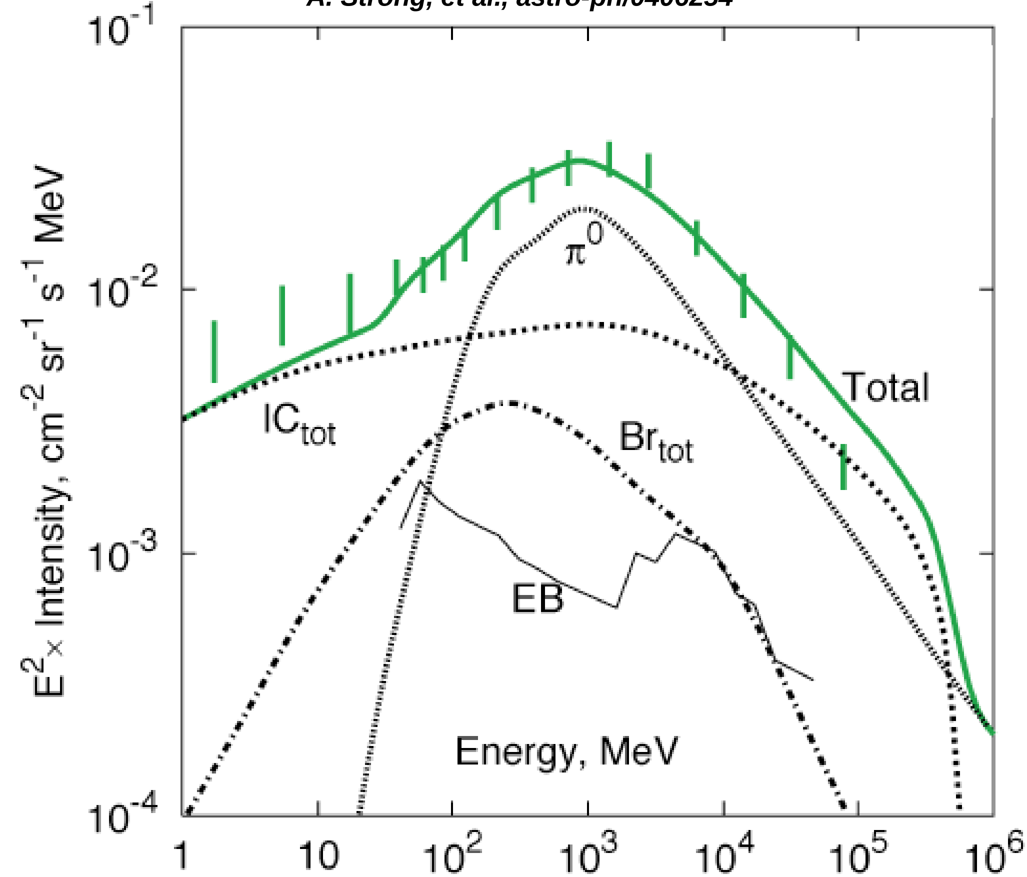
Strong & Moskalenko (1999) “Standard model” fails to explain EGRET observations: apparent excess above 1 GeV.

A. Strong, I. Moskalenko, astro-ph/9906228



Revised model (2004) does explain GeV gamma-ray excess.

A. Strong, et al., astro-ph/0406254



γ-ray origins

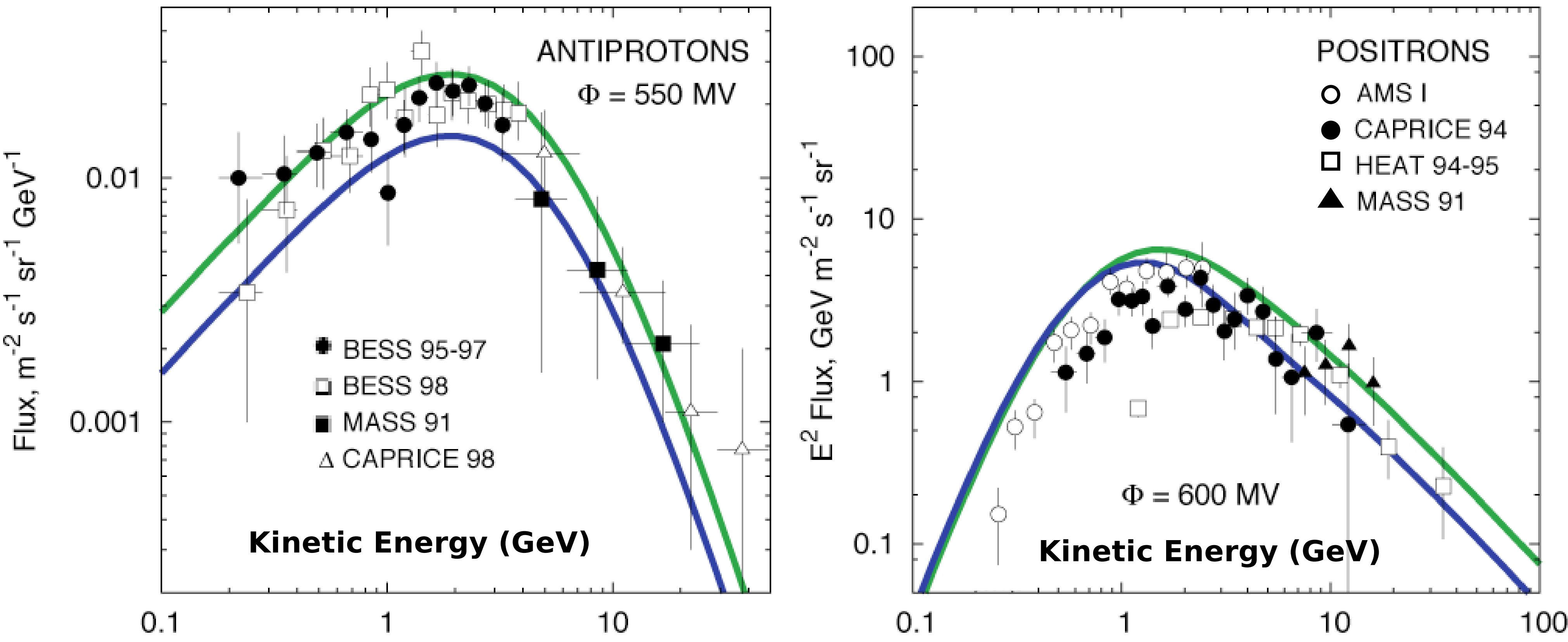
(1) N + N’ → $n\pi^0$ → γ + …

(2) IC_{tot}: Inverse Compton Scattering $\gamma_1 + e \rightarrow \gamma_2 + e$, $E_2 > E_1$

(3) Br_{tot}: Electron Bremsstrahlung

(4) EB: Extragalactic γ ray sources

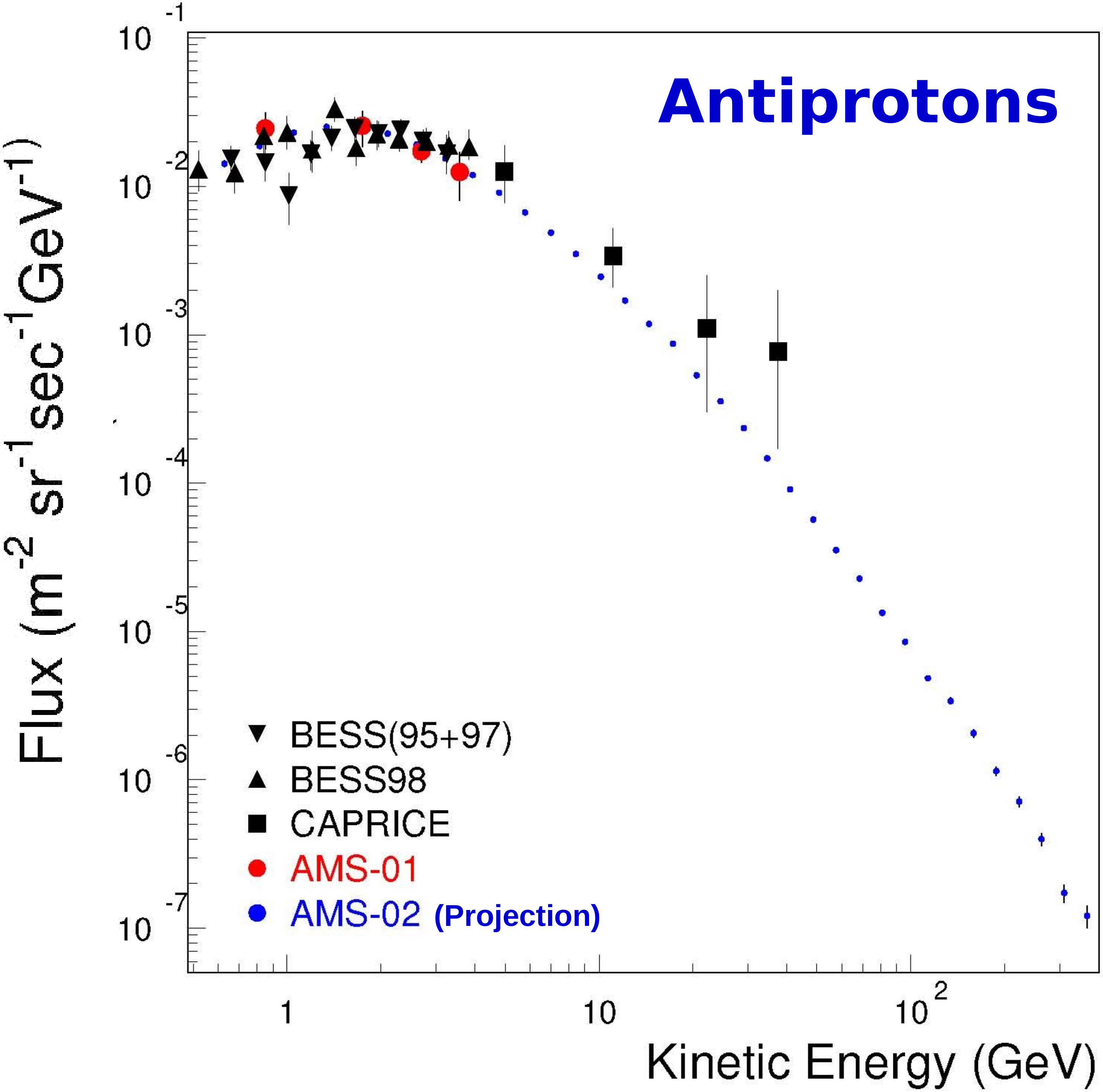
Antiprotons & Positrons



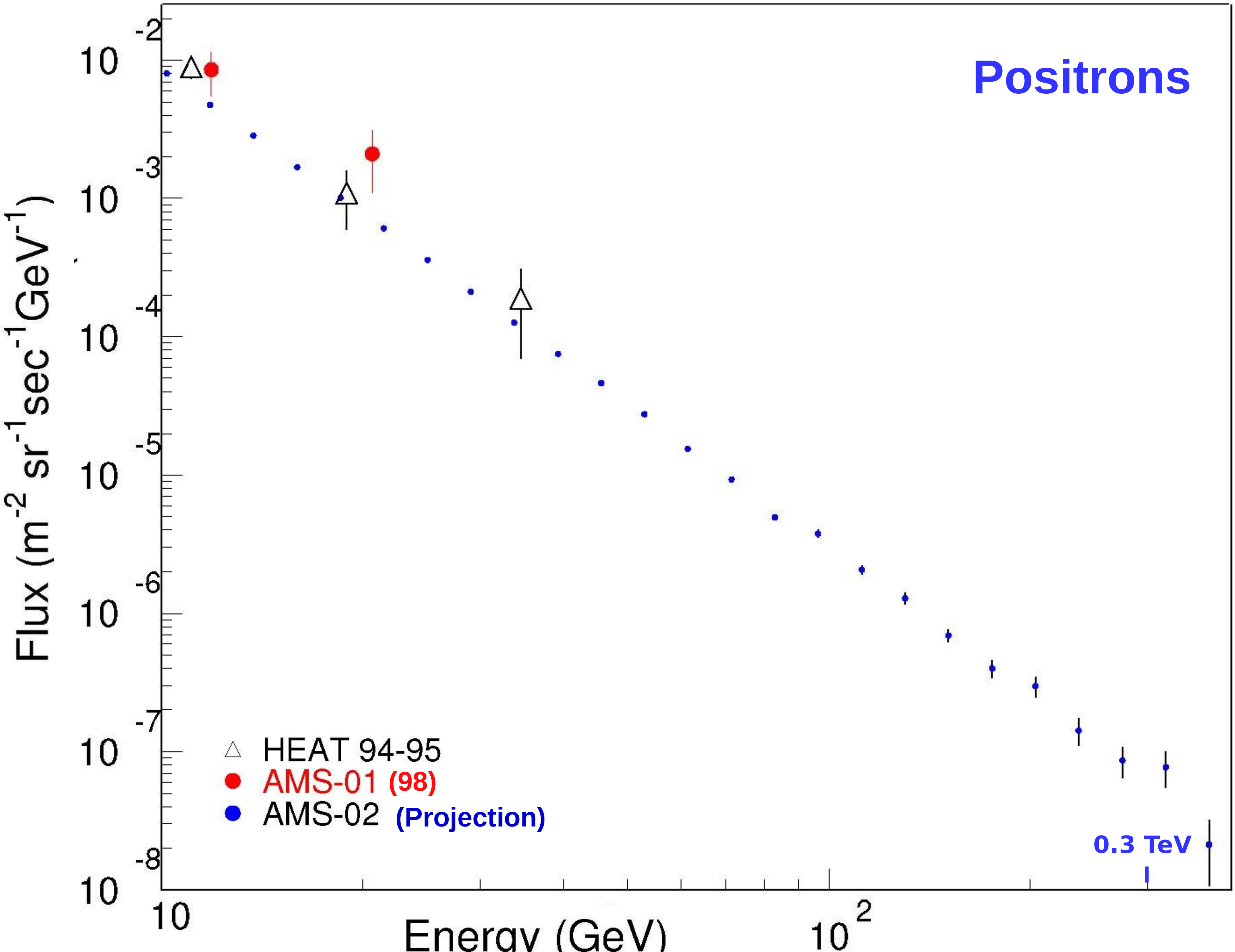
1999 Model – blue line, 2004 model - green line

The existing data cannot distinguish the two models

To calculate the correct γ -ray spectrum requires detailed knowledge of all the charged particles and nuclei flux as a function of energy.
AMS will provide this information.



Antiprotons
Flux (m^-2 sr^-1 sec^-1 GeV^-1)
Kinetic Energy (GeV)
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
1
10
10^2
BESS(95+97)
BESS98
CAPRICE
AMS-01
AMS-02 (Projection)



Positrons
Flux (m^-2 sr^-1 sec^-1 GeV^-1)
Energy (GeV)
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
10^-8
10
10^2
HEAT 94-95
AMS-01 (98)
AMS-02 (Projection)
0.3 TeV

Search for Cold Dark Matter

Many candidates from Particle Physics:

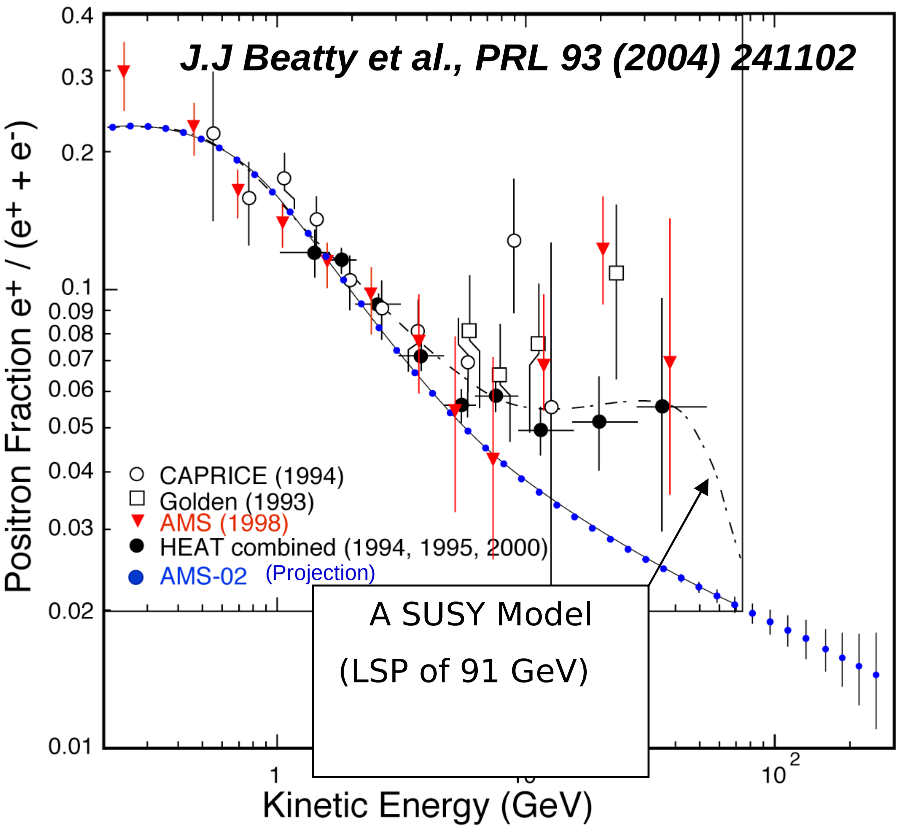
SUSY neutralinos (χ^0)

Kaluza-Klein bosons (B)

...

$\chi^0\chi^0 \rightarrow q\bar{q}$, WW, ZZ, $\gamma\gamma$, $l\bar{l}$ $\rightarrow$ structures in the spectra of

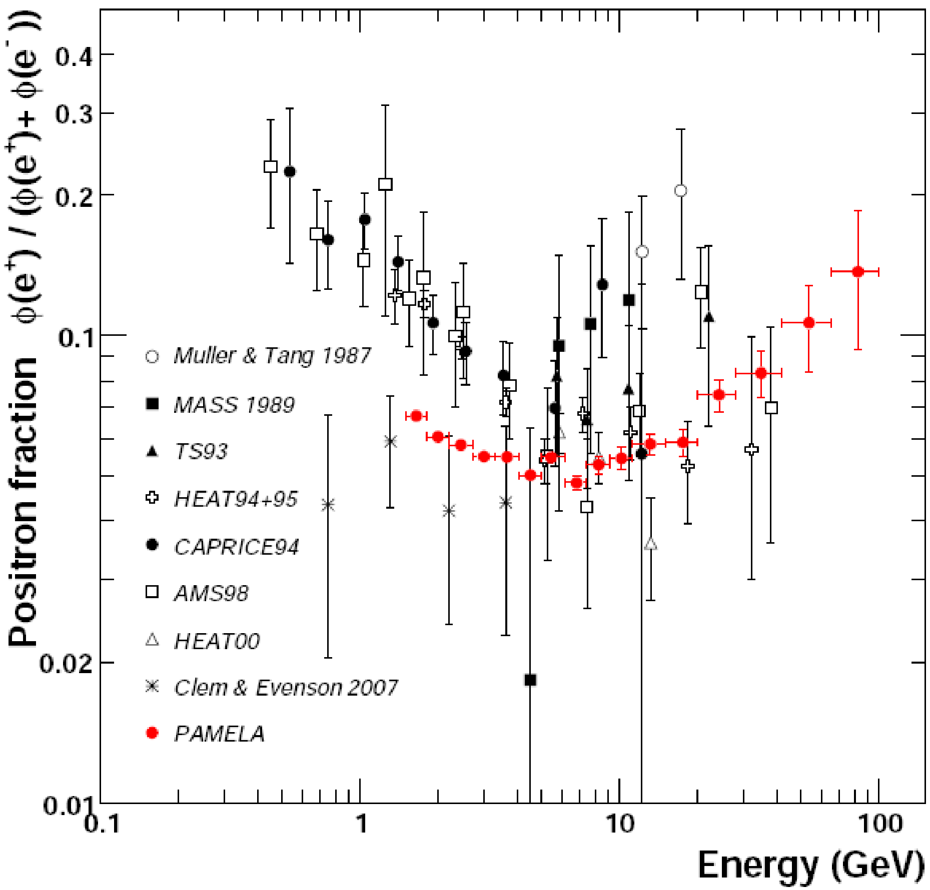
e^+, $\bar{p}$, $\bar{D}$, γ



PAMELA (A Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics)

arXiv:0810.4995v1 (28 October 2008)

Observation of an anomalous positron abundance in the cosmic radiation



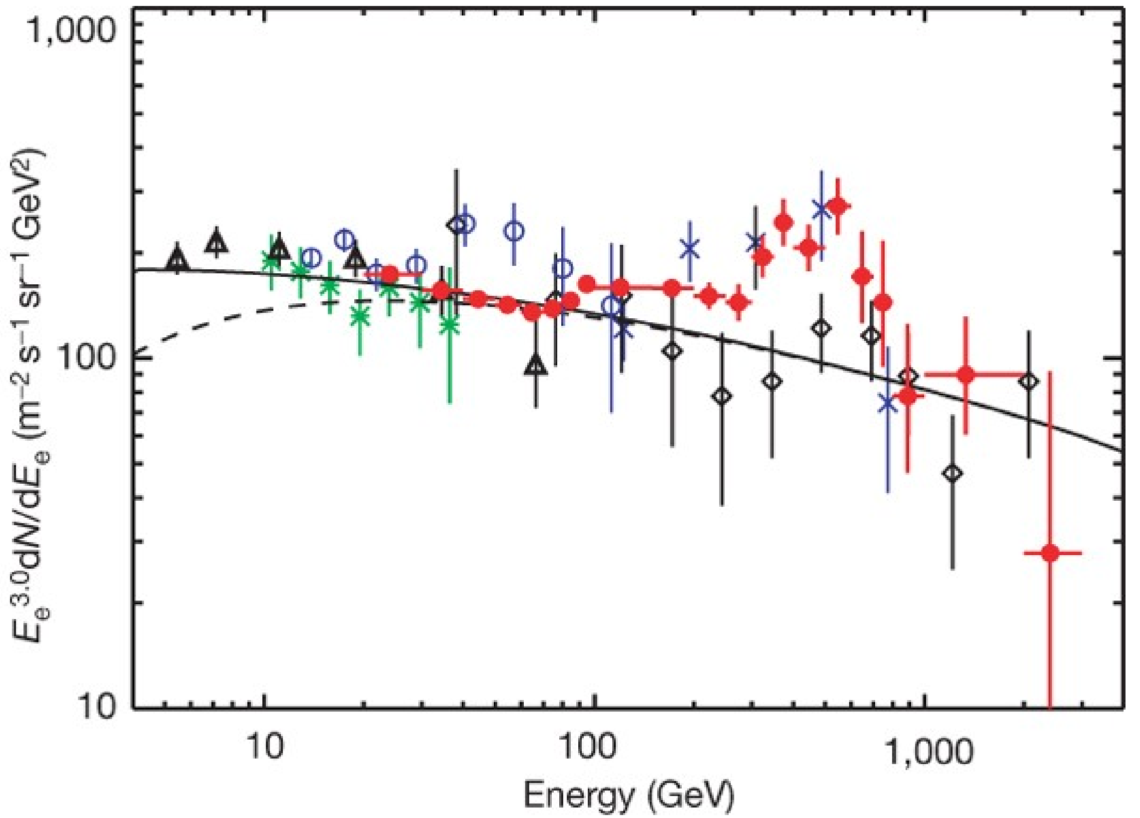
O. Adriani *et al.*, astro-ph/0810.4995

Positrons are known to be produced in interactions between cosmic-ray nuclei and interstellar matter ("secondary production"). Positrons may, however, also be created by dark matter particle annihilations in the galactic halo or in the magnetospheres of near-by pulsars. The nature of dark matter is one of the most prominent open questions in science today. An observation of positrons from pulsars would open a new observation window on these sources. Here we present results from the PAMELA satellite experiment on the positron abundance in the cosmic radiation for the energy range 1.5 - 100 GeV. Our high energy data deviate significantly from predictions of secondary production models, and may constitute the first indirect evidence of dark matter particle annihilations, or the first observation of positron production from near-by pulsars. We also present evidence that solar activity significantly affects the abundance of positrons at low energies.

ATIC **(Advanced Thin Ionizaton Calorimeter)**

Nature 456, 362-365 (20 November 2008)

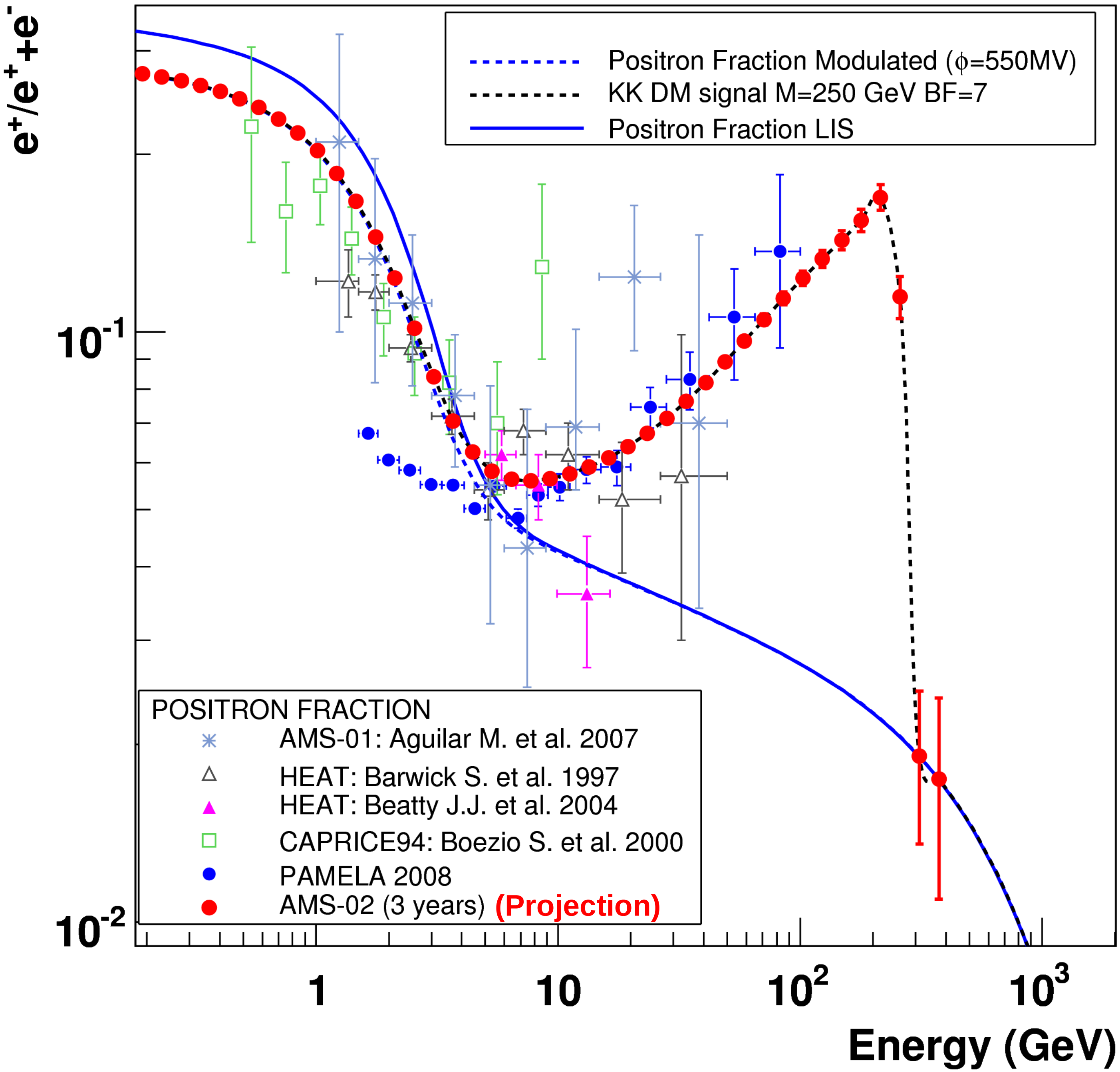
An excess of cosmic ray electrons at energies of 300–800 GeV



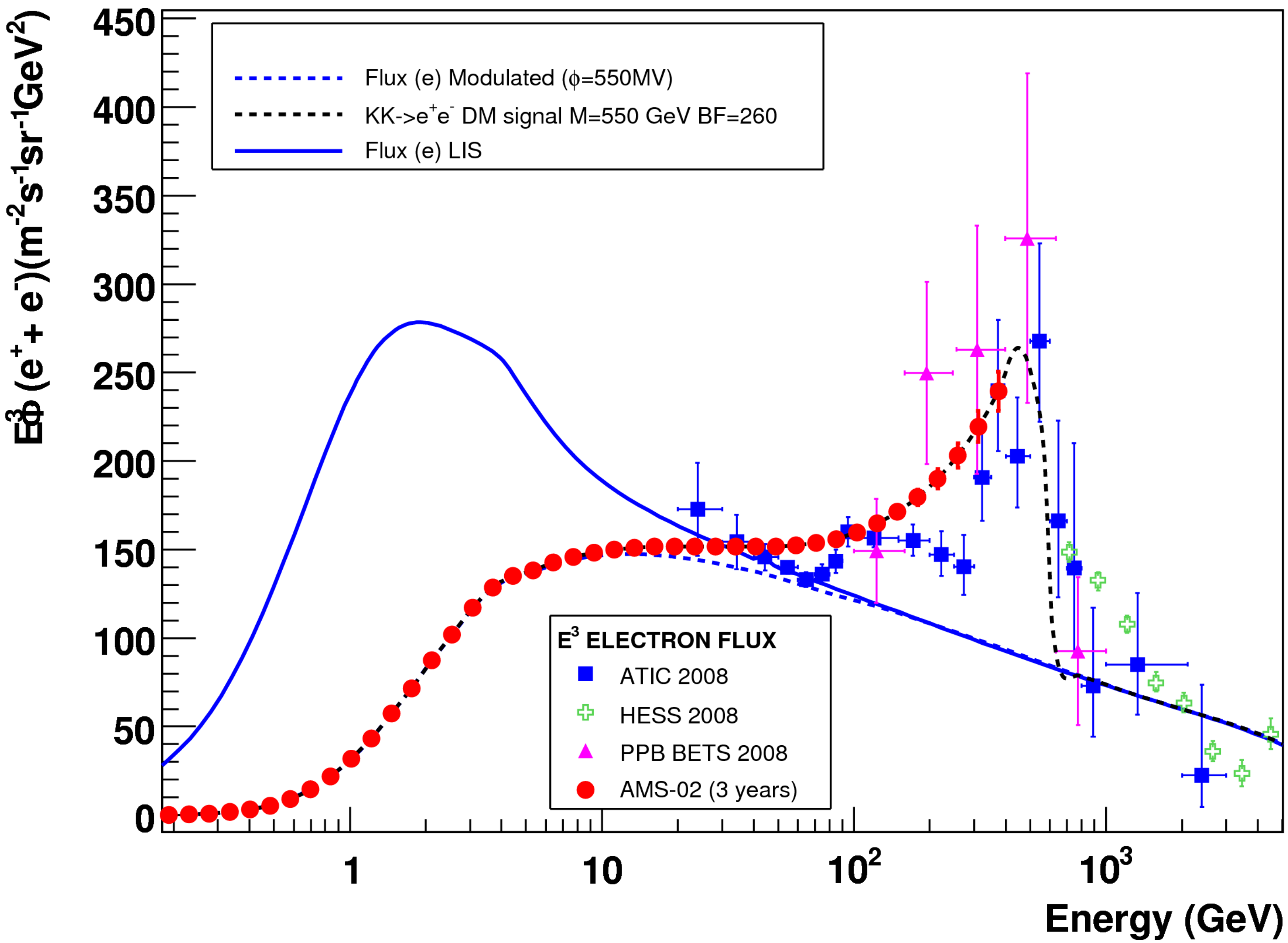
J Chang *et al. Nature* **456**, 362-365 (2008) doi:10.1038/nature07477

Galactic cosmic rays consist of protons, electrons and ions, most of which are believed to be accelerated to relativistic speeds in supernova remnants[1, 2, 3]. All components of the cosmic rays show an intensity that decreases as a power law with increasing energy (for example as E-2.7). Electrons in particular lose energy rapidly through synchrotron and inverse Compton processes, resulting in a relatively short lifetime (about 105 years) and a rapidly falling intensity, which raises the possibility of seeing the contribution from individual nearby sources (less than one kiloparsec away)[4]. Here we report an excess of galactic cosmic-ray electrons at energies of 300–800 GeV, which indicates a nearby source of energetic electrons. Such a source could be an unseen astrophysical object (such as a pulsar[5] or micro-quasar[6]) that accelerates electrons to those energies, or the electrons could arise from the annihilation of dark matter particles (such as a Kaluza–Klein particle[7] with a mass of about 620 GeV).

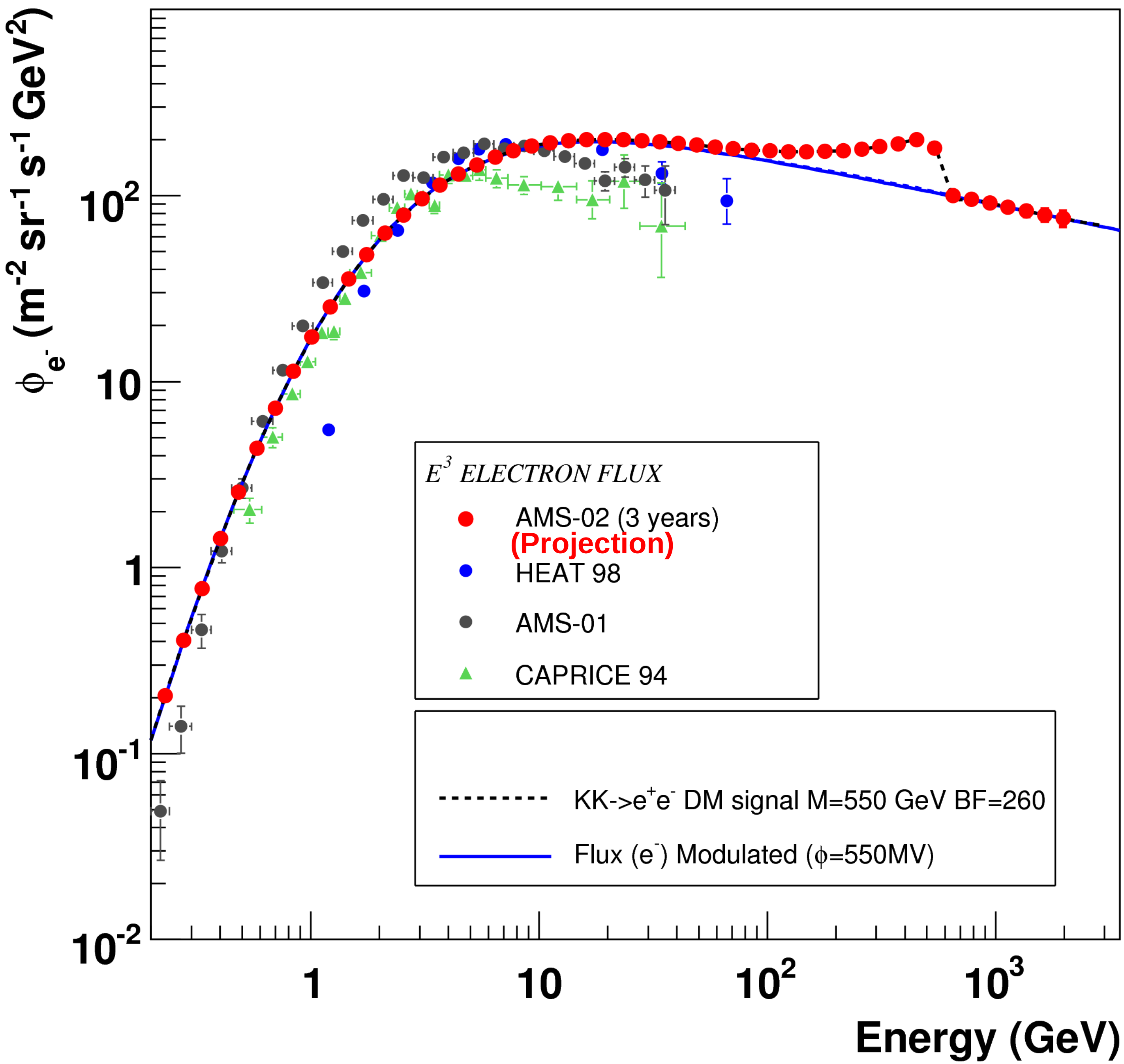
Positron Ratio



Electrons & Positrons

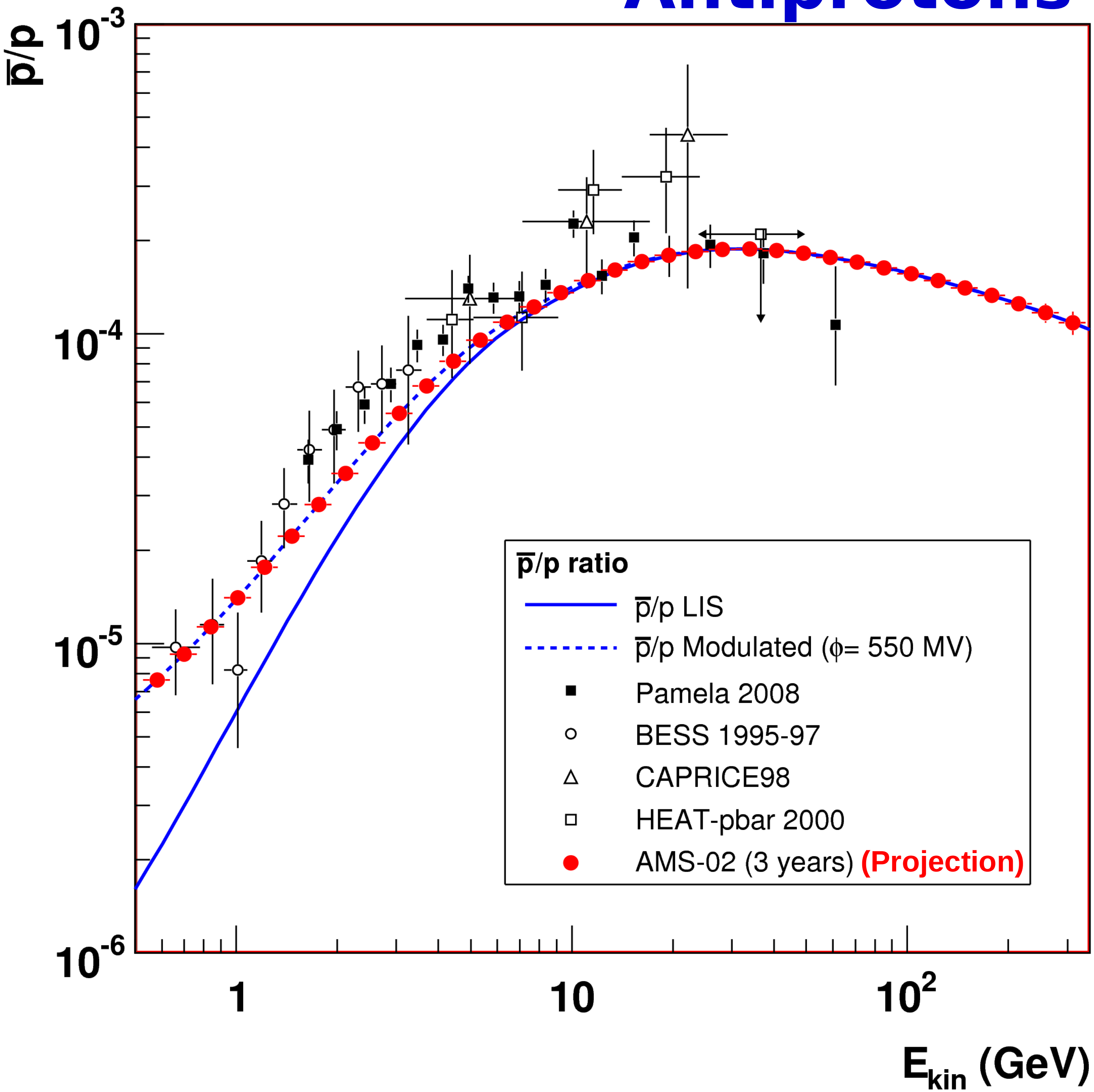


Electrons



ϕ_{e^-} (m^{-2} sr^{-1} s^{-1} GeV^2)
10^{-2}
10^{-1}
1
10
10^2
1
10
10^2
10^3
Energy (GeV)
E^3 ELECTRON FLUX
AMS-02 (3 years)
(Projection)
HEAT 98
AMS-01
CAPRICE 94
KK->e$^+$e$^-$ DM signal M=550 GeV BF=260
Flux (e$^-$) Modulated (ϕ=550MV)

Antiprotons

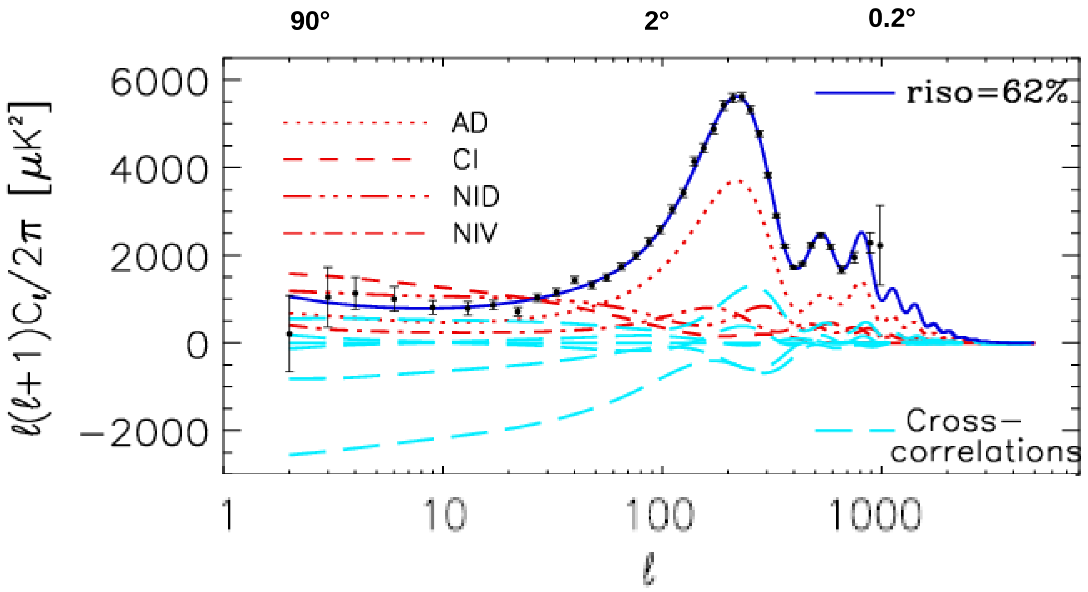


Could our universe be matter-antimatter symmetric ?

If so, regions of matter and antimatter are either close to each other and annihilate or far away from each other, which contradicts the isotropy of the CMB (Cohen et al., ApJ 495 (1998) 539). This assumes adiabatic fluctuations (i.e. matter and radiation fluctuate together).

But there could be isocurvature fluctuations (i.e. radiation fluctuates independently (differently) from matter and antimatter). Matter and antimatter could be separated by regions of low baryon density and uniform photon background.

In this case annihilation would be weak. The universe could consist of large matter and antimatter domains with small voids - the isotropy of the CMB radiation would not be affected.



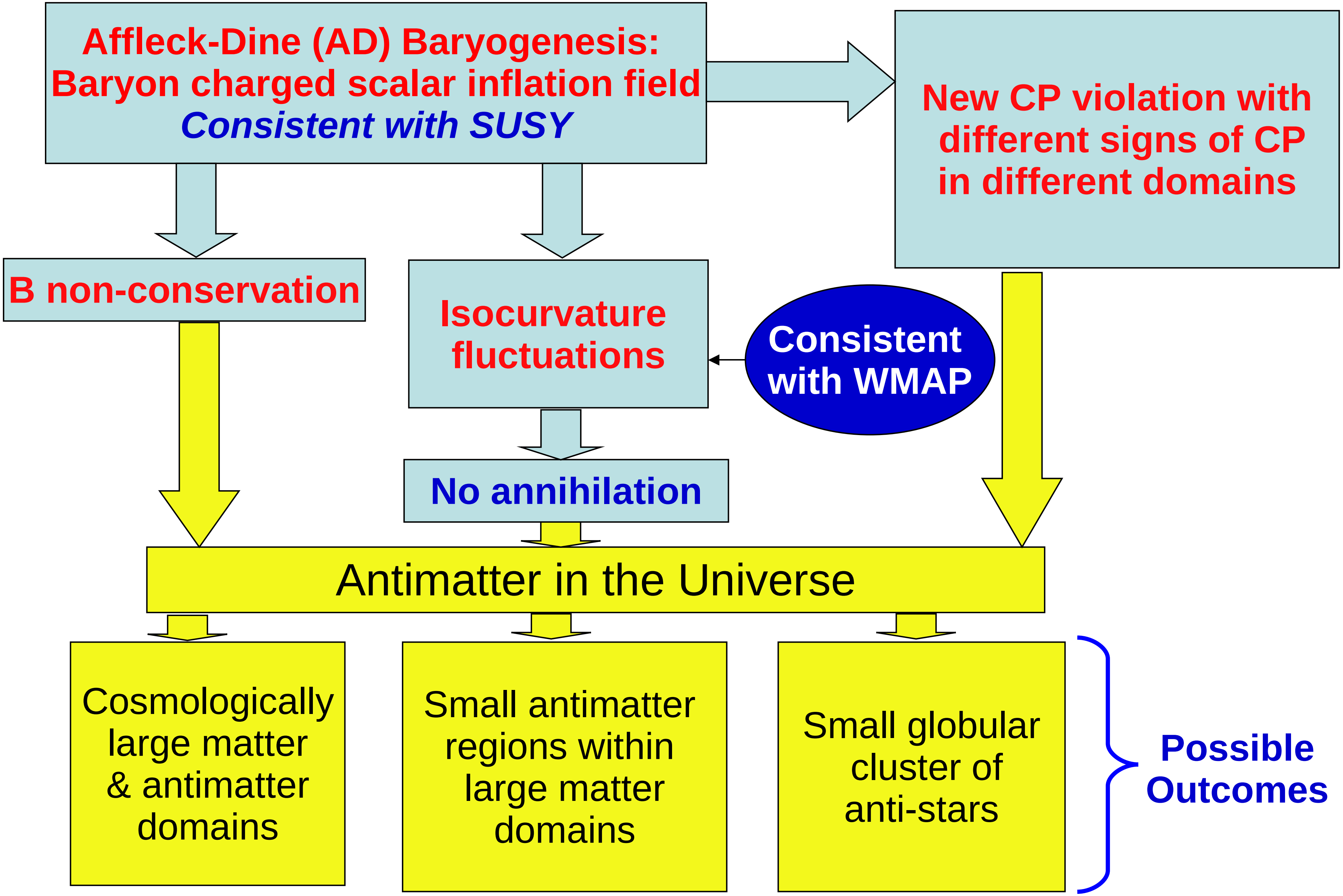
Constraining Isocurvature Initial conditions with WMAP 3-year data

R. Bean, J. Dunkley, E.Pierpaoli,
astro-ph/0606685 v2 ***17 Aug 2006***

AD: Adiabatic Fluctuations
CI: Cold Dark Matter Isocurvature
NID: Neutrino Isocurvature Density
NIV: Neutrino Isocurvature Velocity
riso: Isocurvature fraction = 62%

($\Omega_b h^2$= 0.037, $\Omega_c h^2$= 0.13, $\Omega_\Lambda h^2$= 0.75, …)

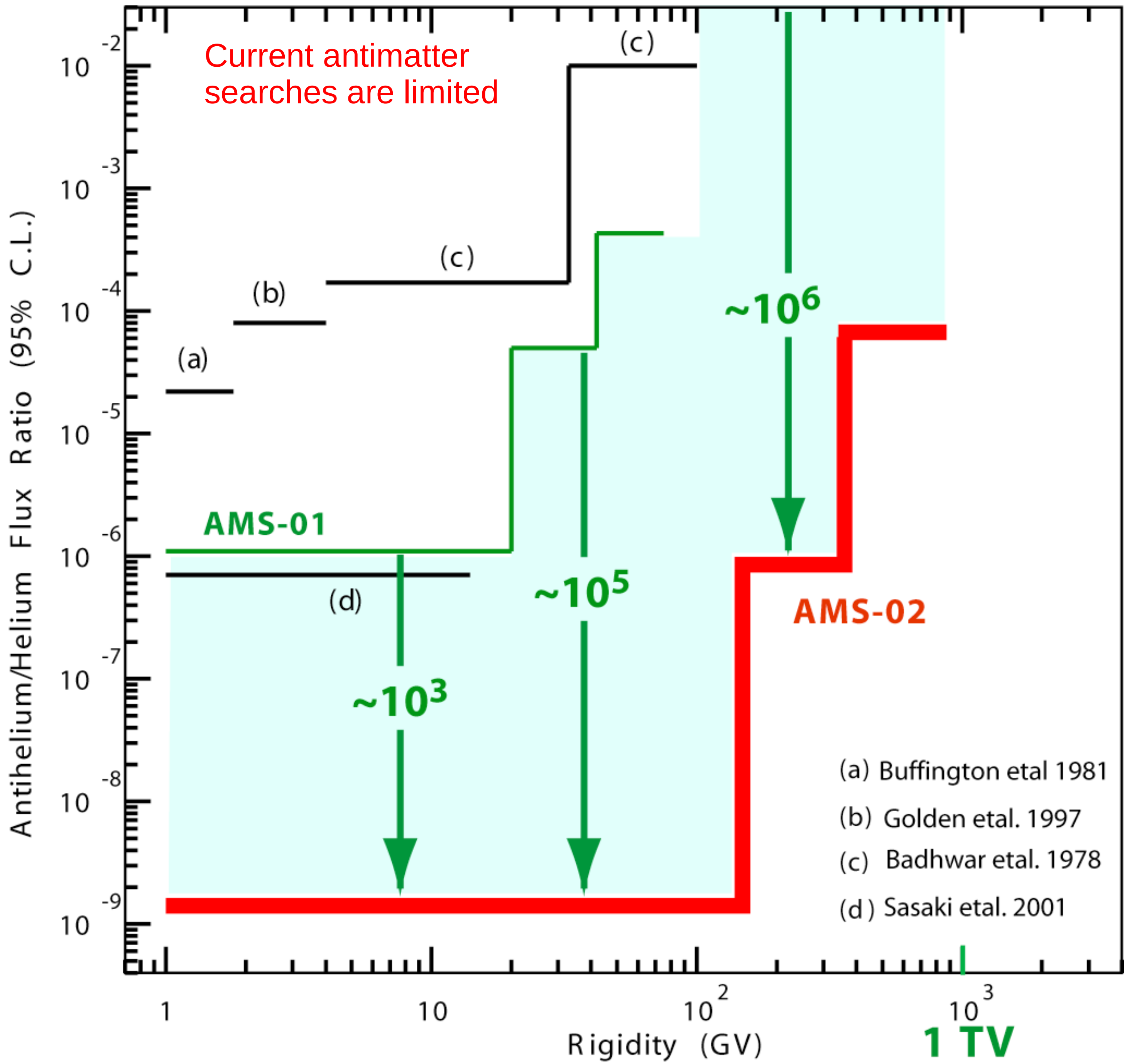
Our Universe can have some fraction of antimatter:



These predictions are consistent with current limits (γ's, AMS-01)

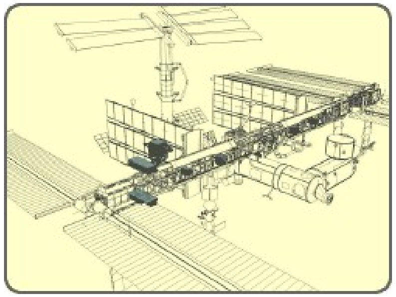
AMS-02 will provide 10^3 to 10^6 more sensitivity

AMS-02 Antihelium Limits



y06K301

The AMS Experimental Program



Approved (NASA - DOE MOU)
1995

- The AMS international collaboration (DOE partners) is responsible science management and detector construction.

- NASA provides project management and three shuttle flights:
  1. STS-91 for Engineering test
  2. a flight to install AMS on ISS S3 truss for 3 years
  3. a flight to return AMS

AMS-01: Engineering Fight

- Proof of principle
- Background studies in real conditions

STS-91 Jun 98 (10-day mission)

AMS-02: Science Flight

- 3 years on the ISS to accomplish the AMS science program

UF4.1 Flight (before end 2005)

Columbia failure in Jan 03 stopped NASA ISS assembly

Return to flight 1 (Jul 05) and 2 (Jul 06)

NASA resumed ISS assembly activities in Sep 06

NATURE|Vol 455|16 October 2008

Sam Ting's last fling

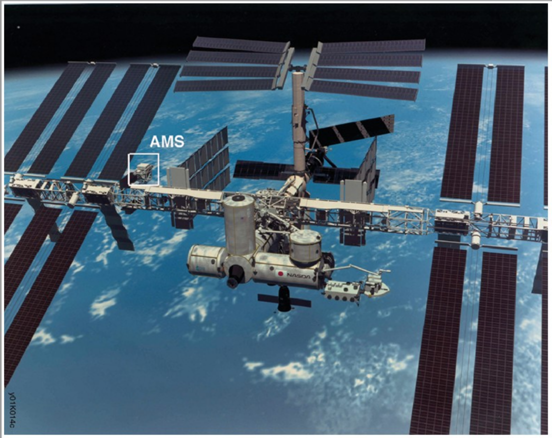
The International Space Station's one chance of scientific greatness rests on a high-profile refugee from the world of the particle accelerator — but is it too long a shot to be worth taking? **Eric Hand** reports.

Issue No. 49-50/2008 - Monday 01 December 2008

The Bulletin

AMS is 'go' for launch!

President Bush has approved extra funding for one more Space Shuttle launch to take the AMS experiment to the International Space Station.



Artist's impression of the AMS experiment on the International Space Station.

On 15 October President Bush signed the NASA authorization act which will allow an extra Space Shuttle flight to deliver the Alpha Magnetic Spectrometer (AMS) to the International Space Station (ISS) in 2010.

AMS is a CERN recognised experiment designed to search for antimatter and dark matter by measuring cosmic rays. It is being assembled in clean rooms here at CERN (see Bulletin No. 40/2007).

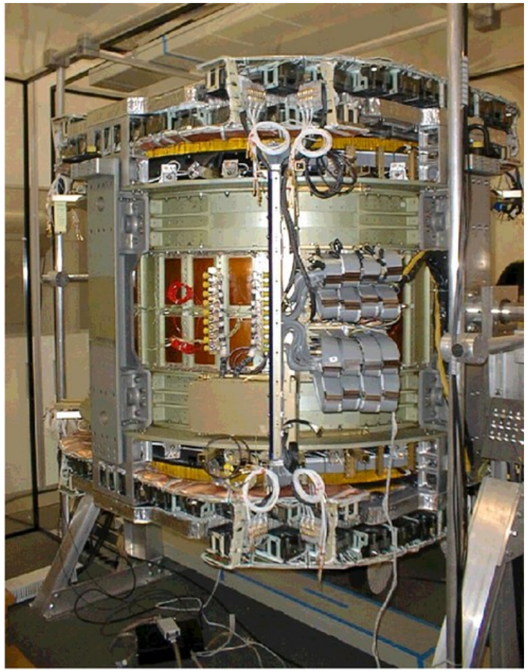
In 1995 NASA agreed to launch AMS on a shuttle flight to the ISS, but constraints resulting from the Columbia accident in 2003, including a two-and-a-half year suspension of flights, pushed AMS off the NASA manifest.

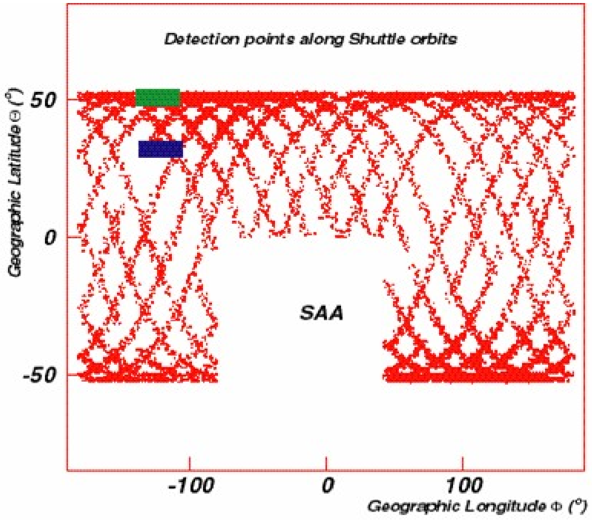
It was uncertain if AMS would ever be launched, but after years of speculation and a considerable amount of effort from the AMS team, one extra shuttle flight has been added to NASA's manifest before the fleet's scheduled retirement.

The experiment has wide support from members of Congress, who have frequently asked NASA to try and find a way to fit AMS in. It was finally passed unanimously by the full Senate on 25 September 2008, and was passed by the House on 27 September 2008.

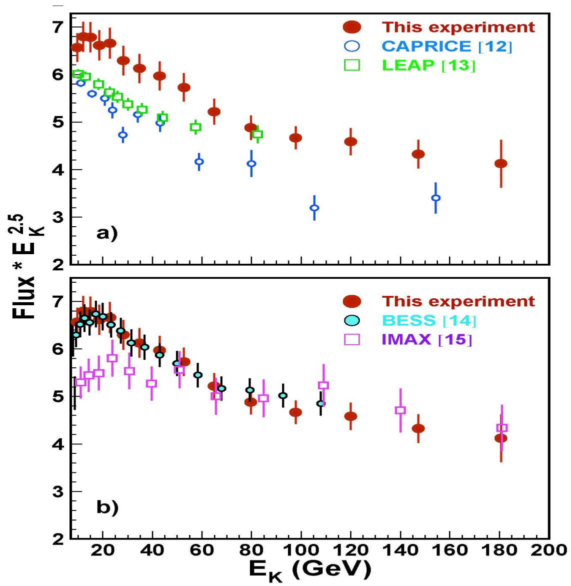
President elect Barack Obama has also issued a statement in favour of the increase in resources to NASA for the extra shuttle flight for AMS.

AMS-01 Results

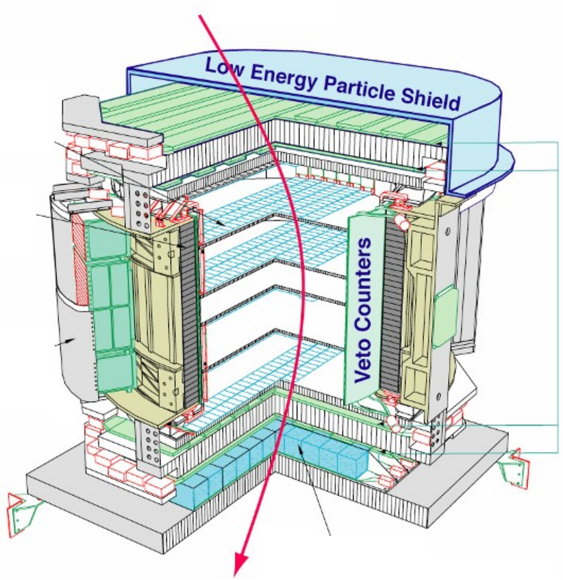


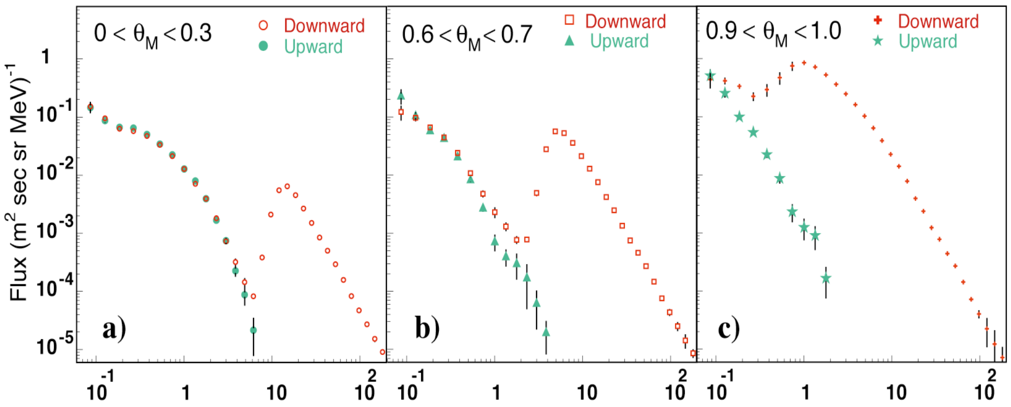


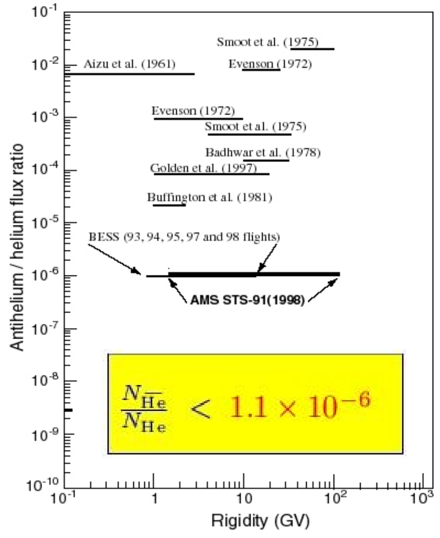
	Cutoffs(GV)	Latitudes	Longitudes
AMS		+/- 51.7	all (SAA excluded)
BESS98	<0.5		(Lynn Lake - Canada)
CAPRICE94		+56.5 N	101-117 W (Lynn Lake - Canada)
MASS91	4.3	+34 N	104 W (Forth Sumner)
IMAX92	0.37-0.63	+56.5 N	101-118 W (Lynn Lake - Canada)
LEAP87	0.6-1.1	n.a.	n.a. (Prince Albert - Canada)



Science Publications (p,$\bar{p}$,e^+,e^-,He,D, $\overline{He}$ limit...)







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Physics Letters B 646 (2007) 145–154

PHYSICS LETTERS B

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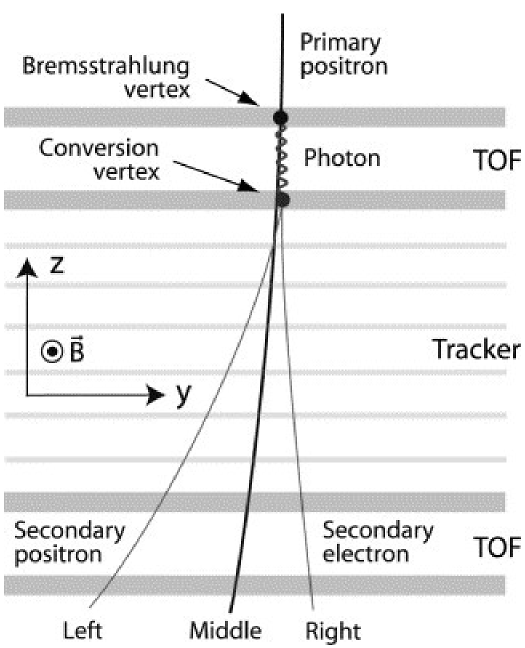
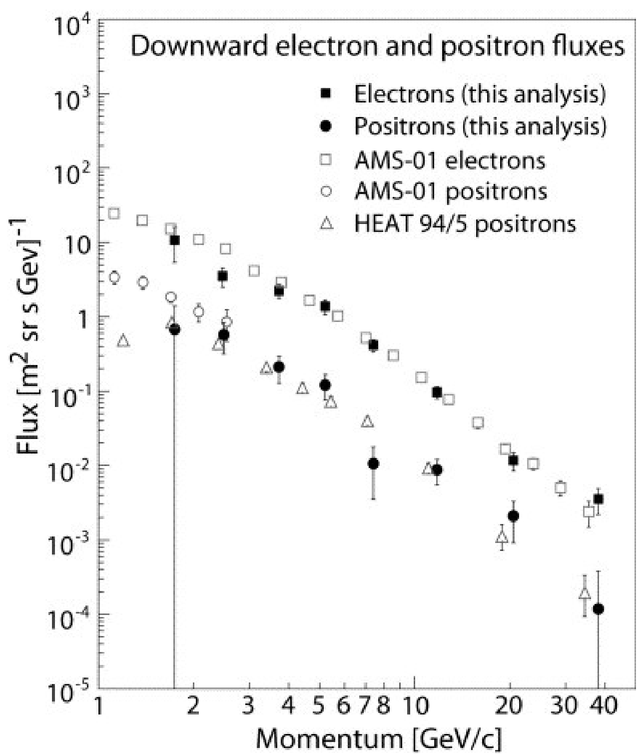
Cosmic-ray positron fraction measurement from 1 to 30 GeV with AMS-01

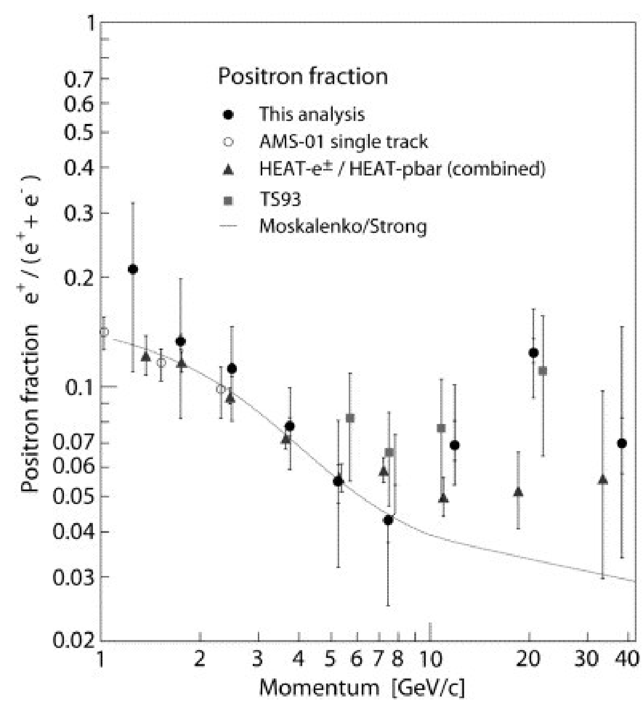
AMS-01 Collaboration

Abstract

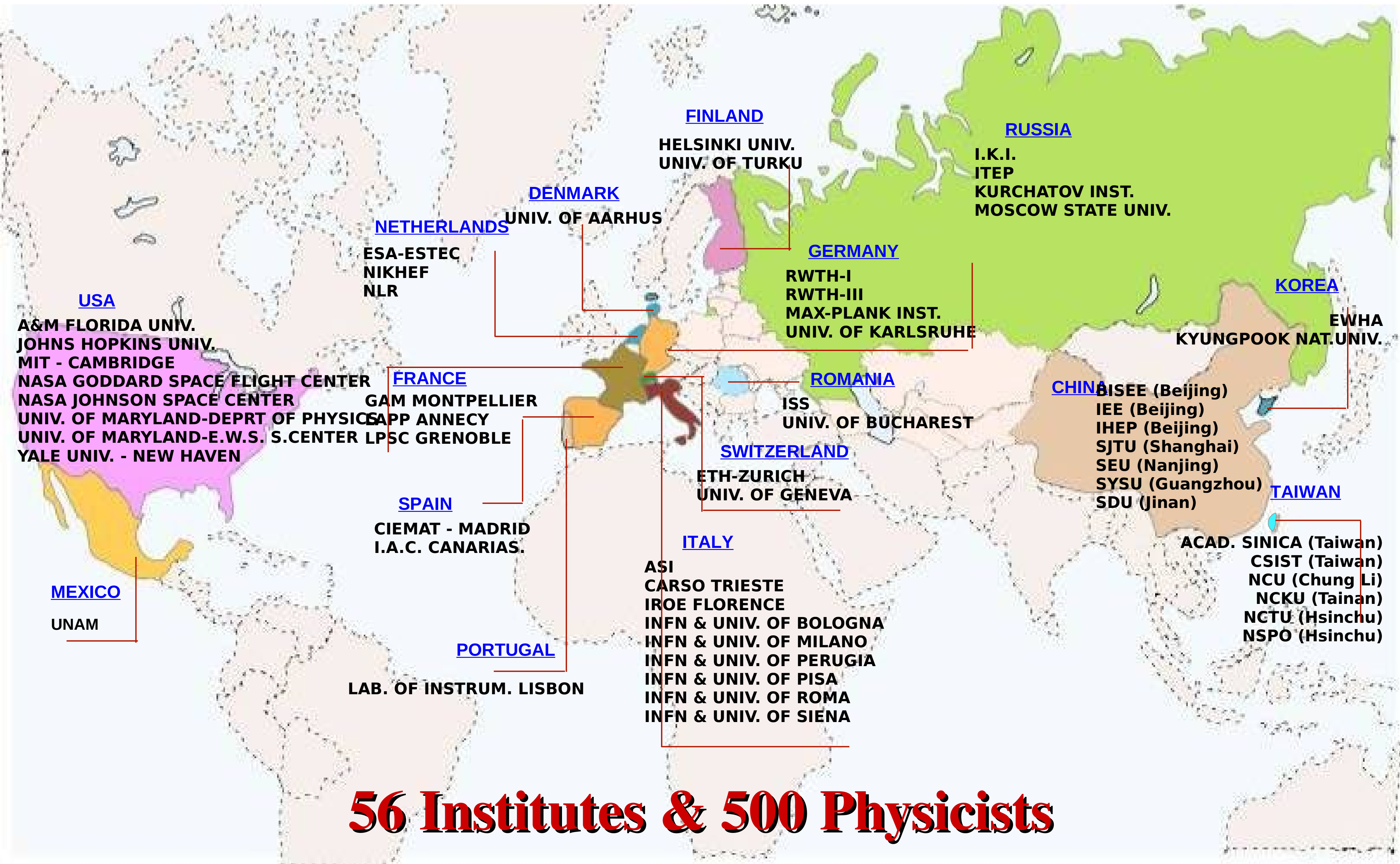
A measurement of the cosmic ray positron fraction $e^+/(e^+ + e^-)$ in the energy range of 1–30 GeV is presented. The measurement is based on data taken by the AMS-01 experiment during its 10 day Space Shuttle flight in June 1998. A proton background suppression on the order of 10^6 is reached by identifying converted bremsstrahlung photons emitted from positrons.







The AMS Collaboration

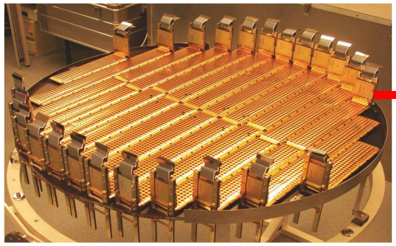


56 Institutes & 500 Physicists

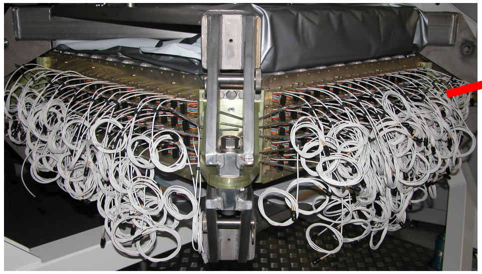
AMS-02 Subsystems

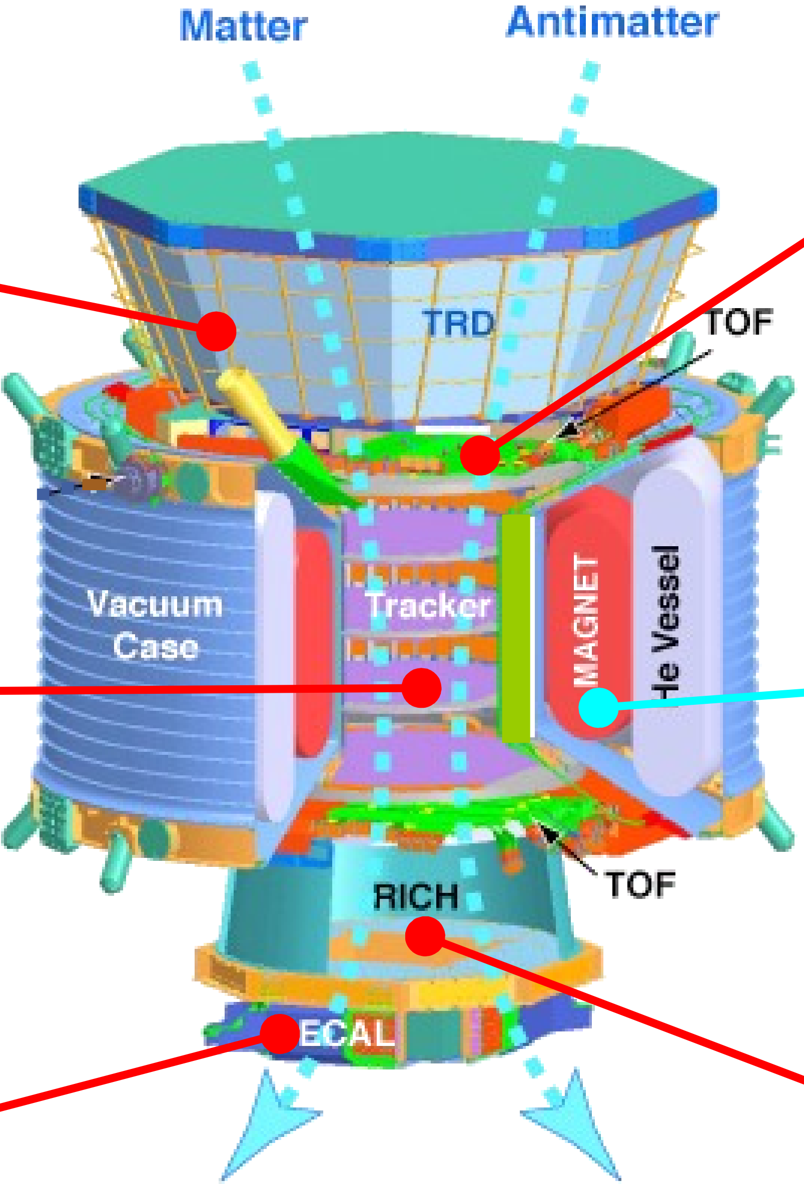
TRD
e

Silicon Tracker
Z, P



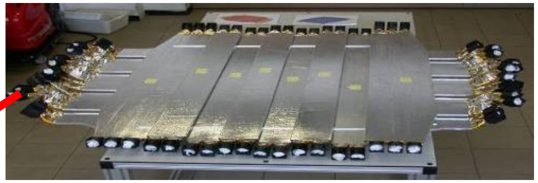
Calorimeter
e, γ



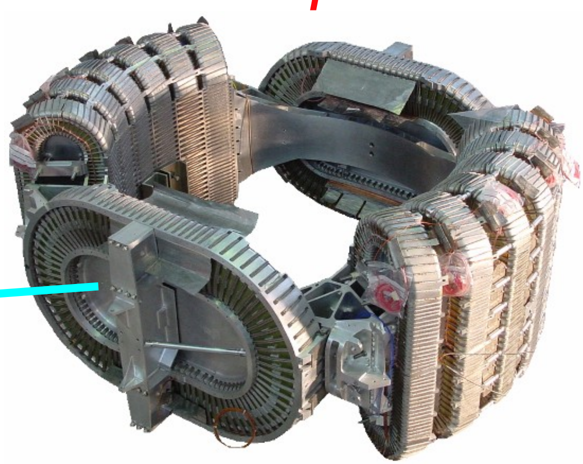


Size: 3m x 3m x 3m
Weight: 7 tons

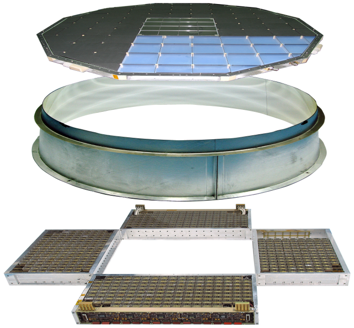
Time of Flight
v, Z



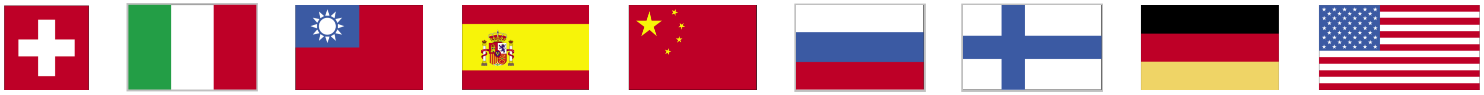
Magnet
P

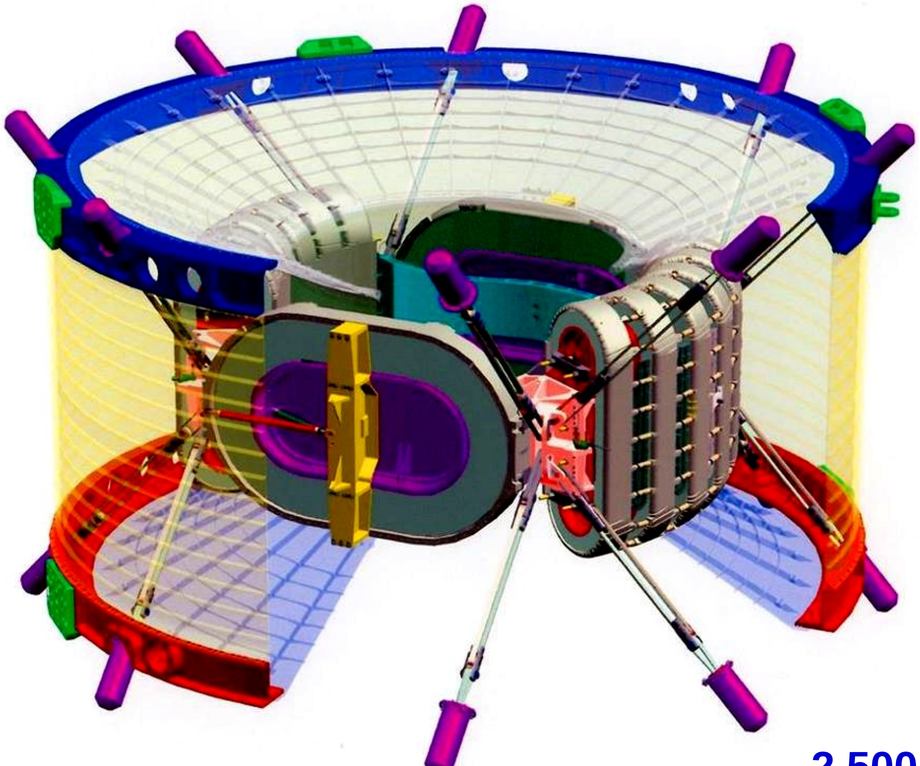


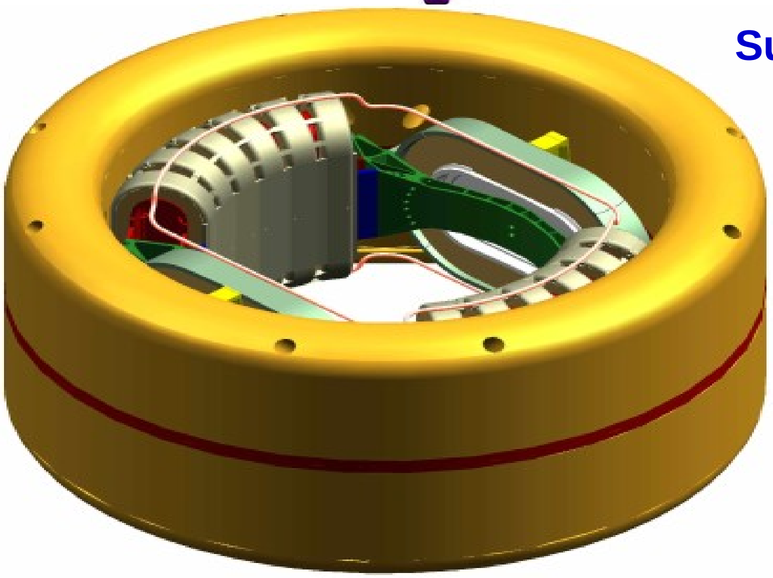
RICH
v, Z



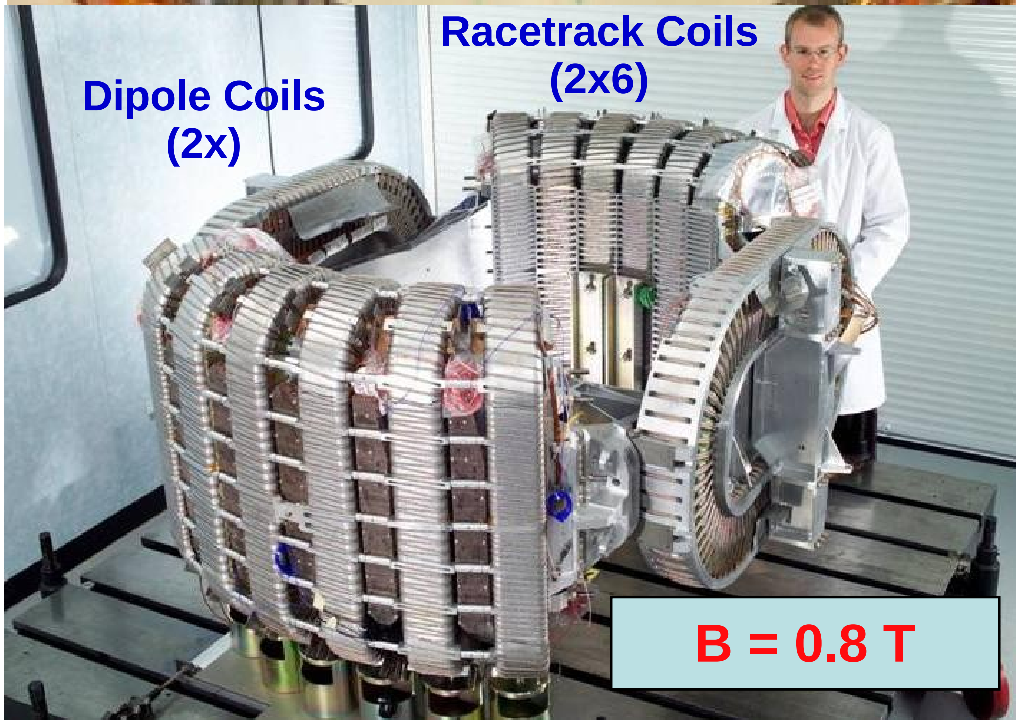
Construction of the AMS-02 Superconducting magnet





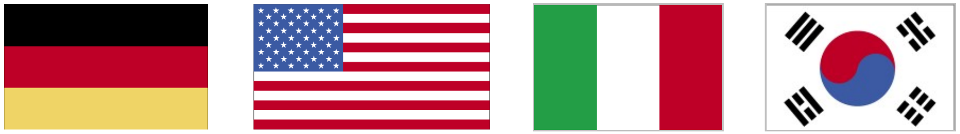


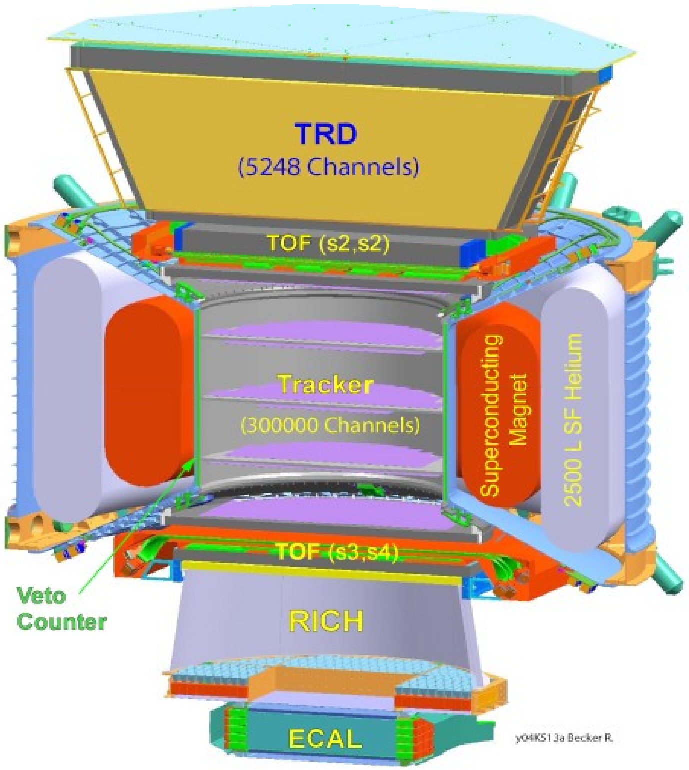
2,500 l
Superfluid He
Duration:
3 years

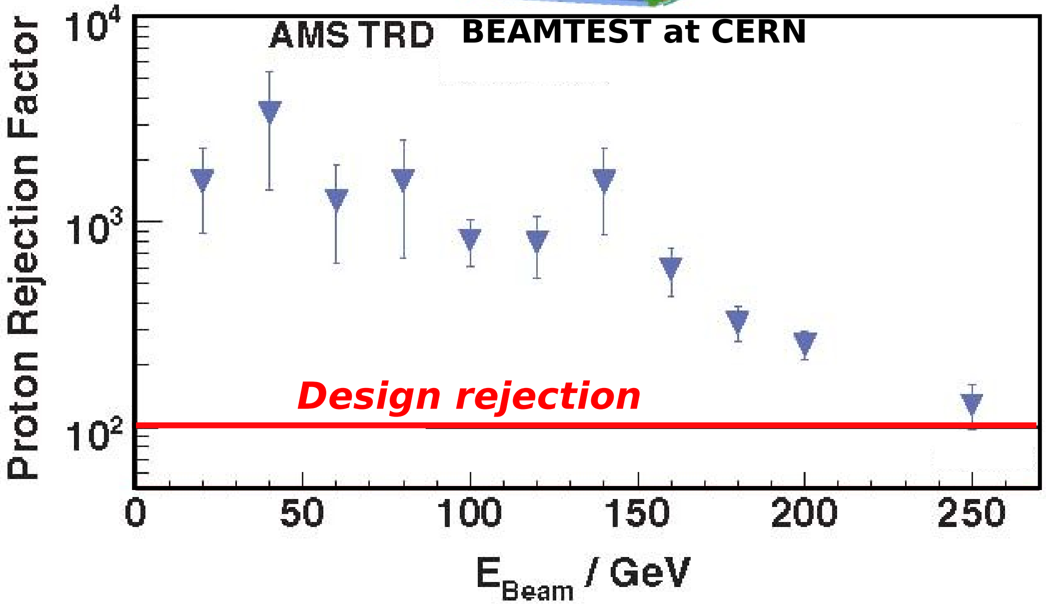


Transition Radiation Detector: TRD

p/e$^+$ Rejection



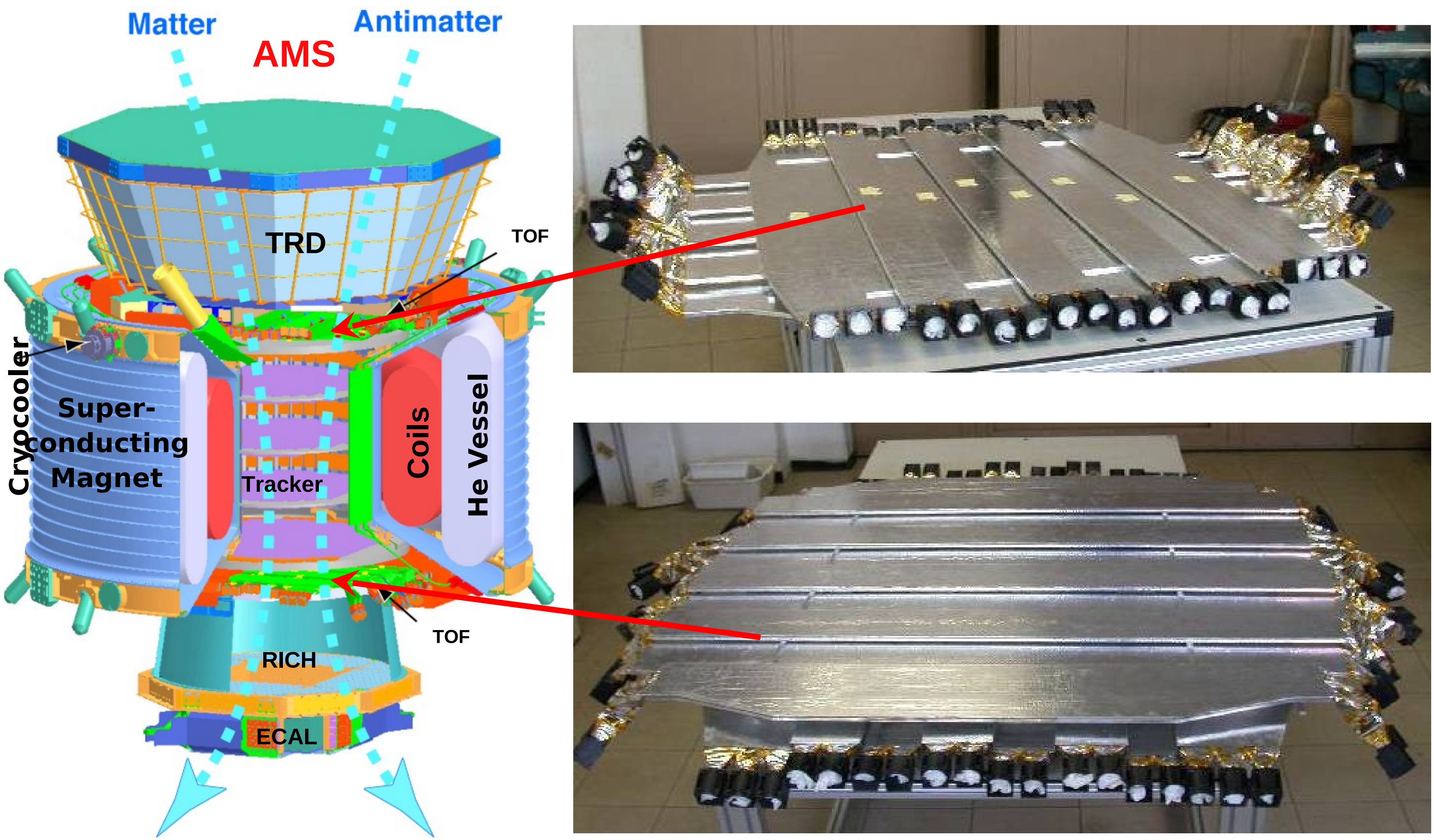




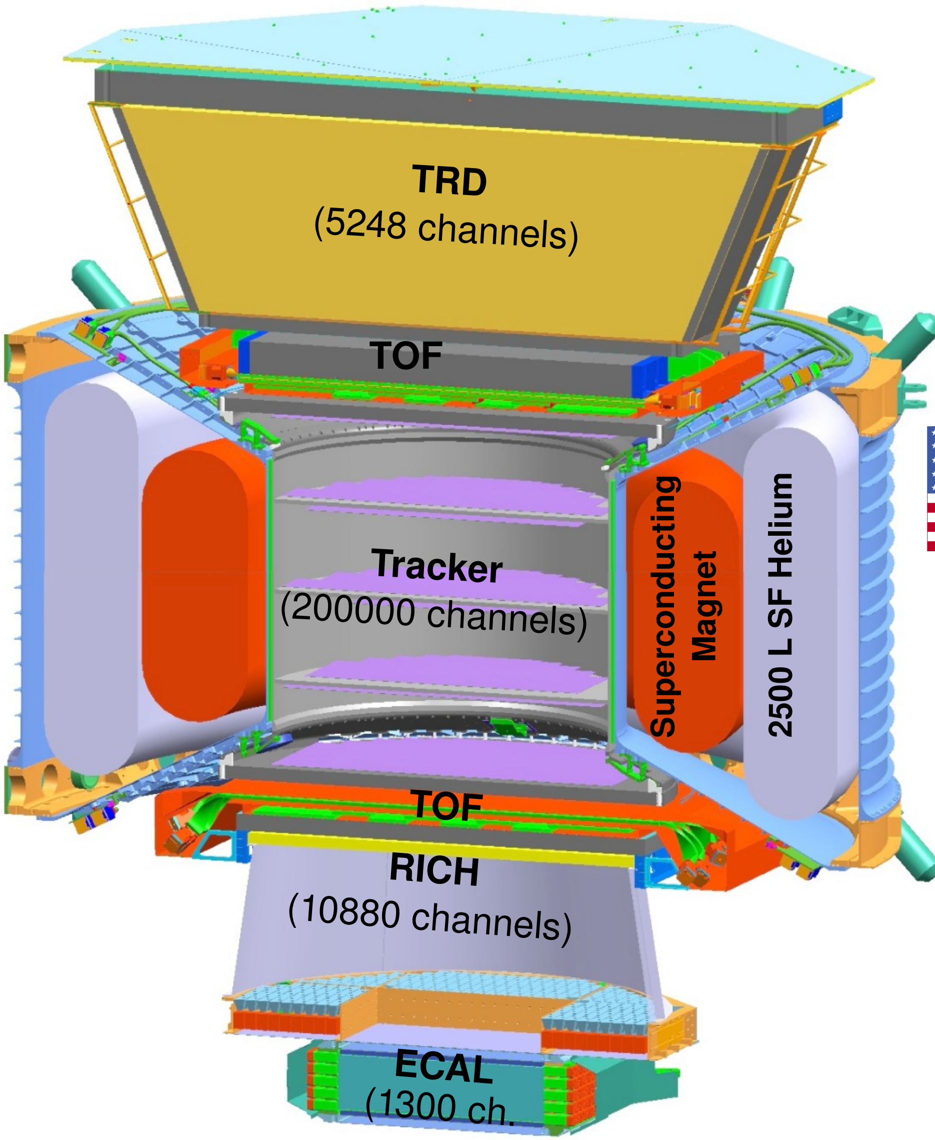
p$^+$ rejection >10^2 1-300 GeV
acceptance: 0.5m^{2}sr

Time of Flight (TOF)

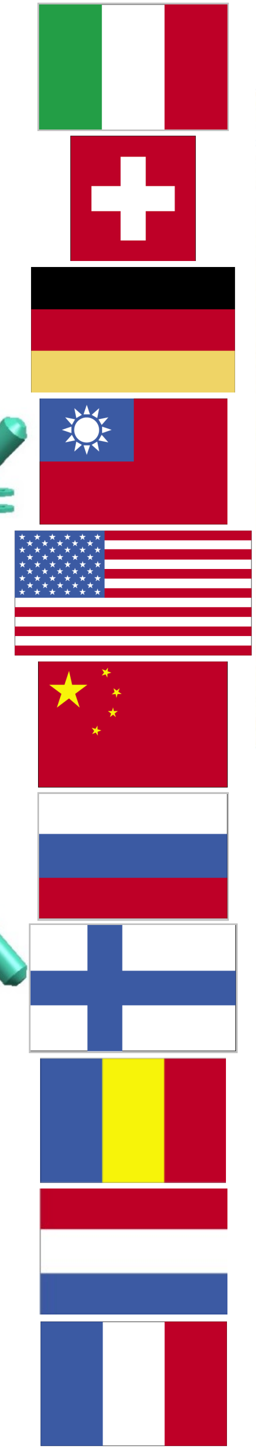
Measures the time of relativistic particles to ~ 100 picoseconds



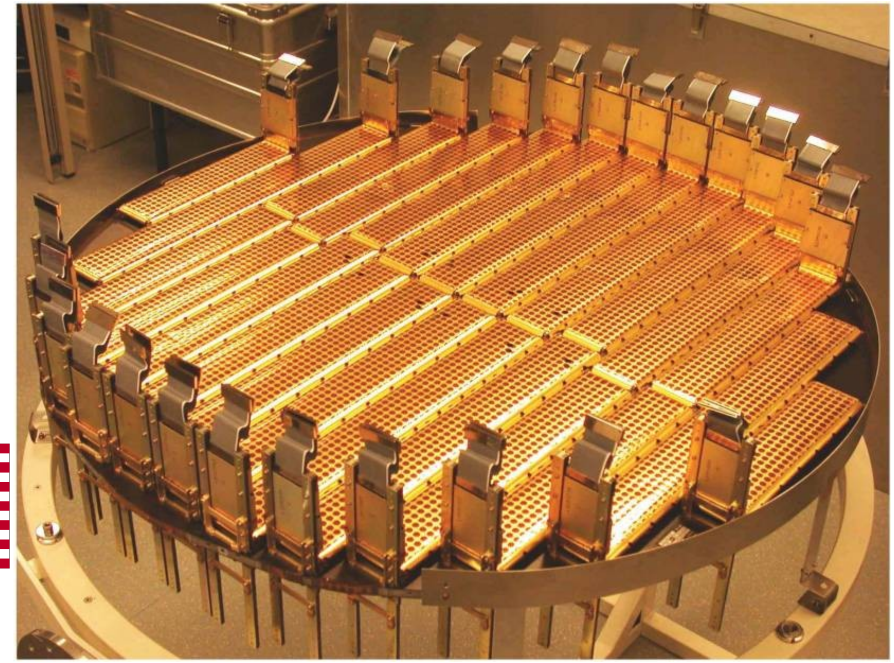
Silicon Tracker

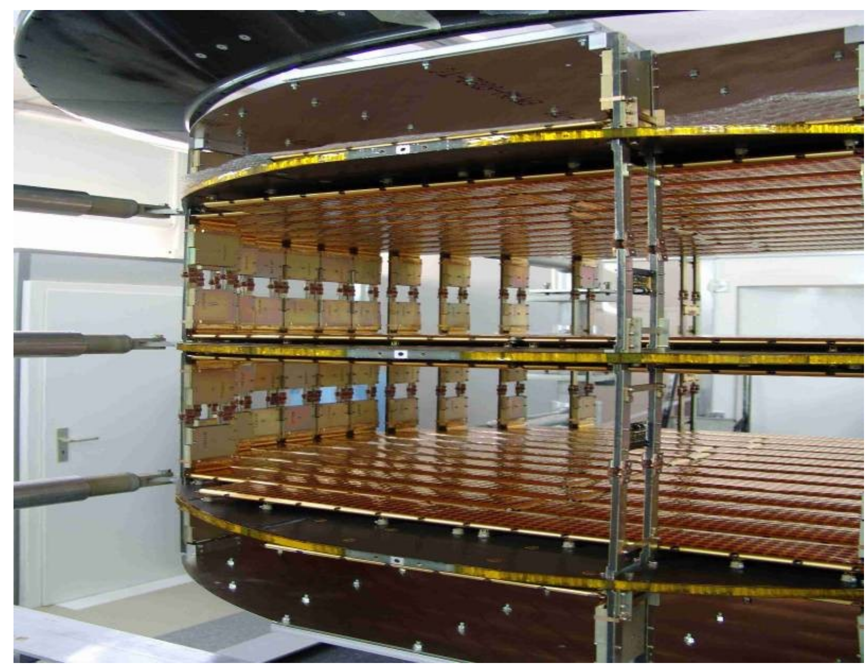


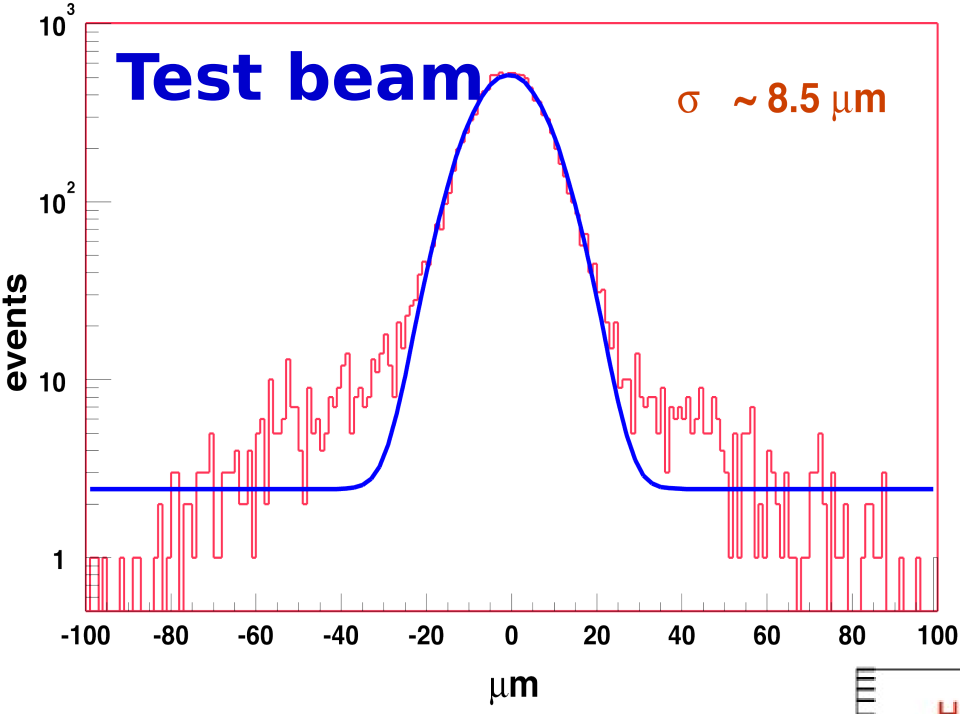
8 planes, 6.6 m^2



Resolution < 10 µm

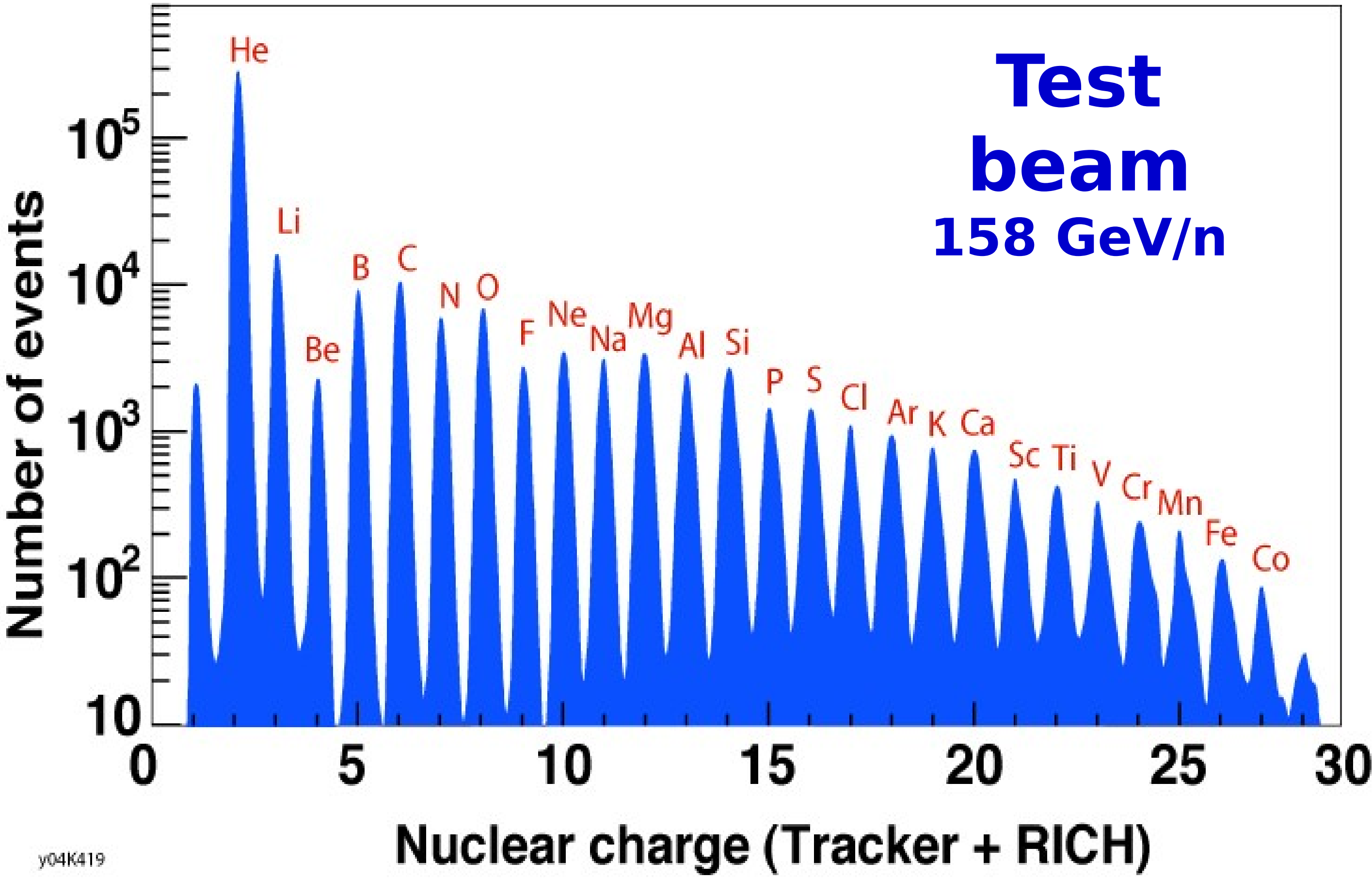






Sensor positioning (Geneva)

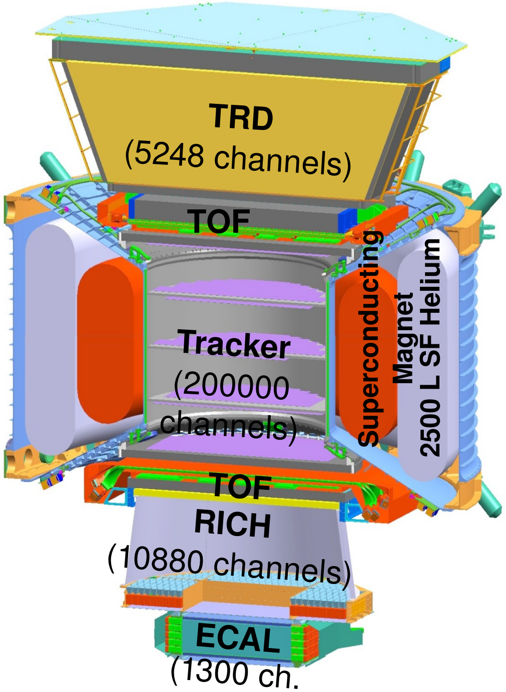
Ultrasonic wire bonding (ETH-Z)

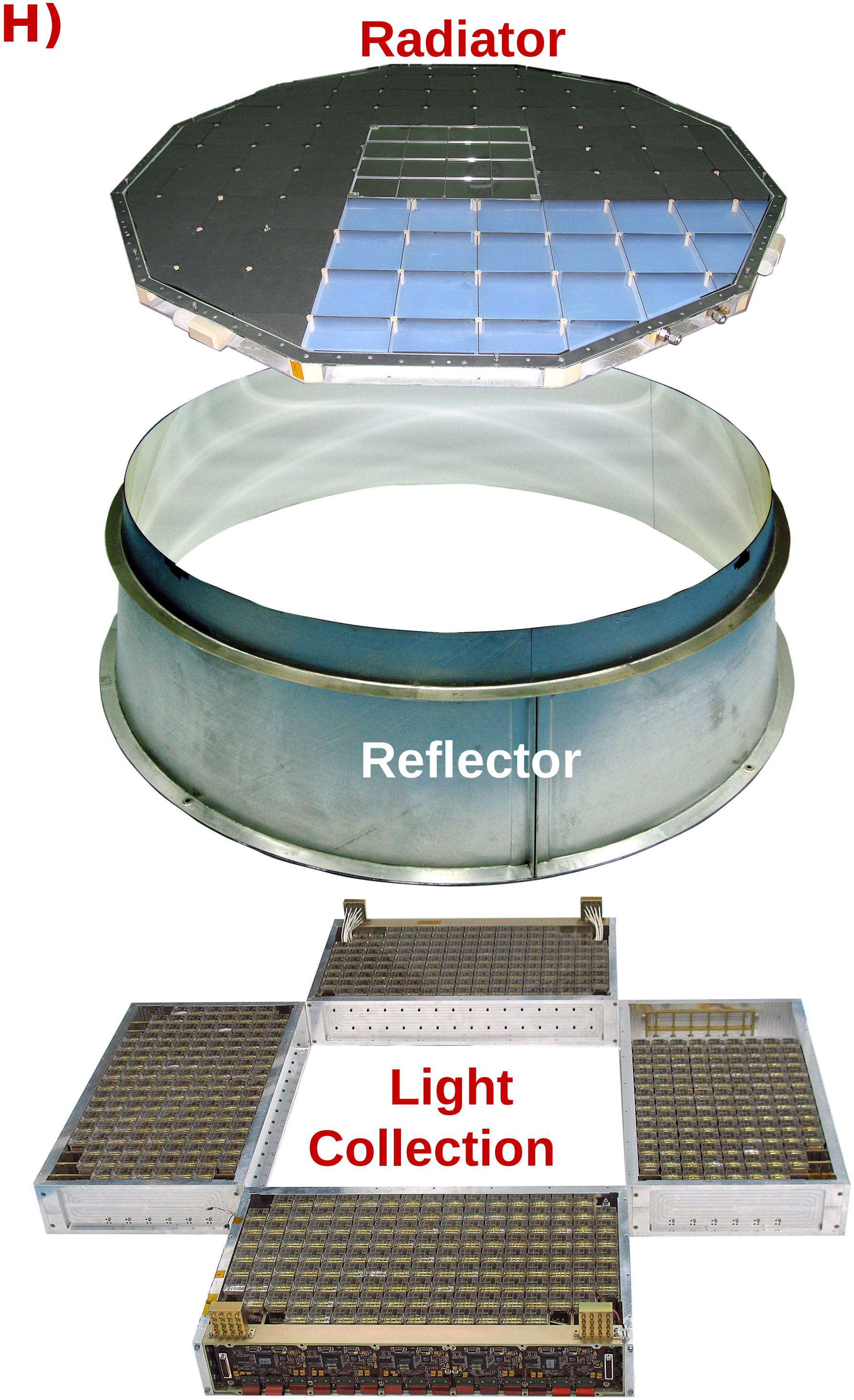


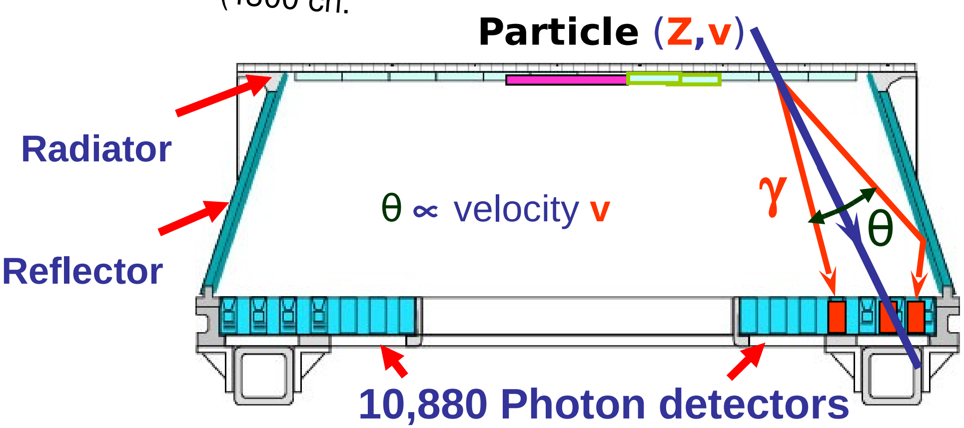
y04K513_05

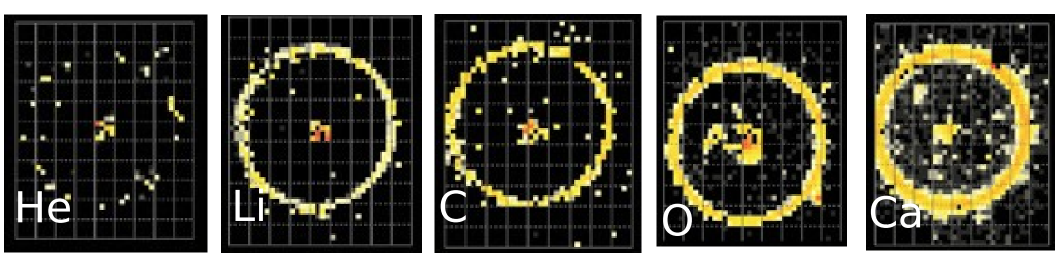
y04K419

Ring Imaging Cerenkov Counter (RICH)





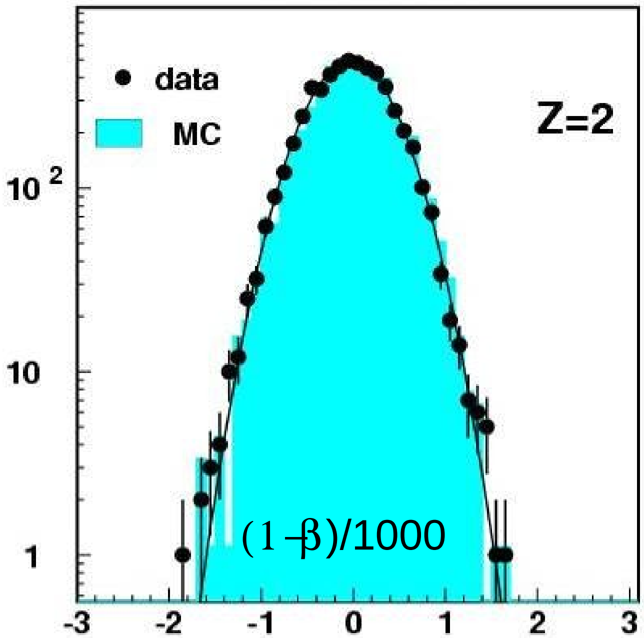


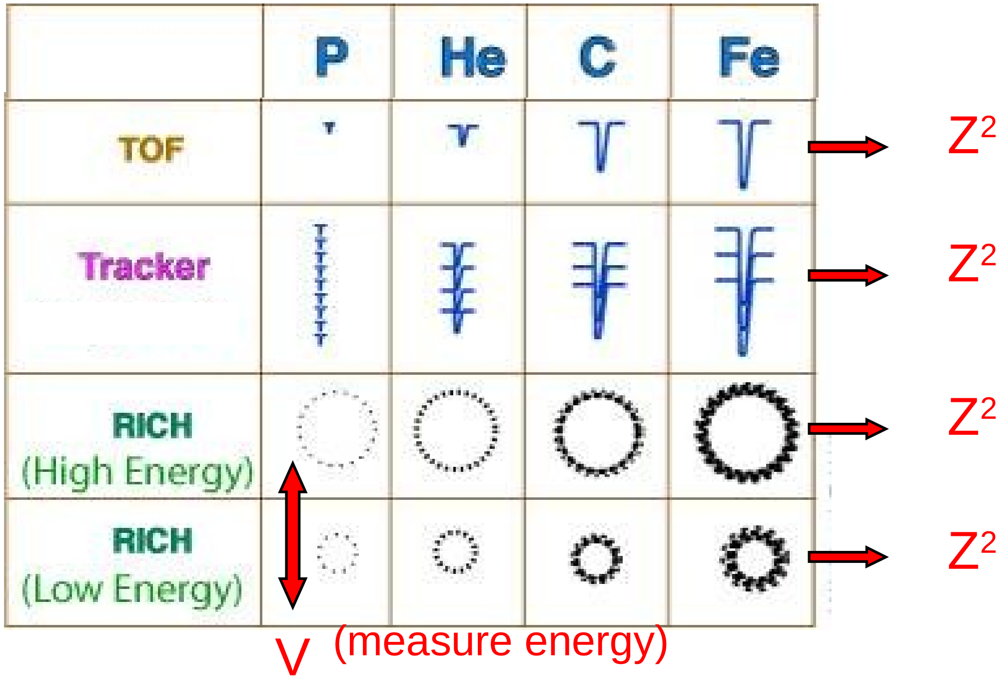


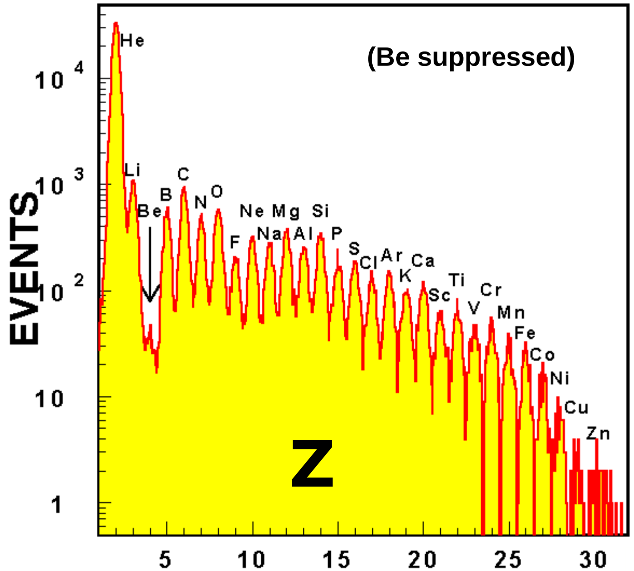
Single Event Displays (158 GeV/n)

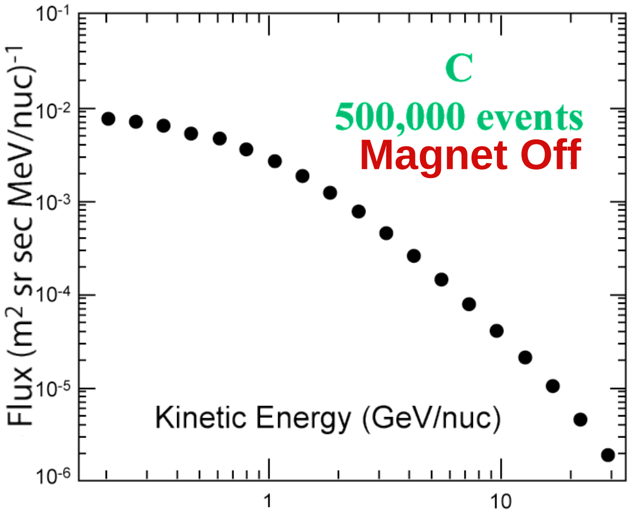
AMS Physics: 3 years with the magnet operating then 10+ years without

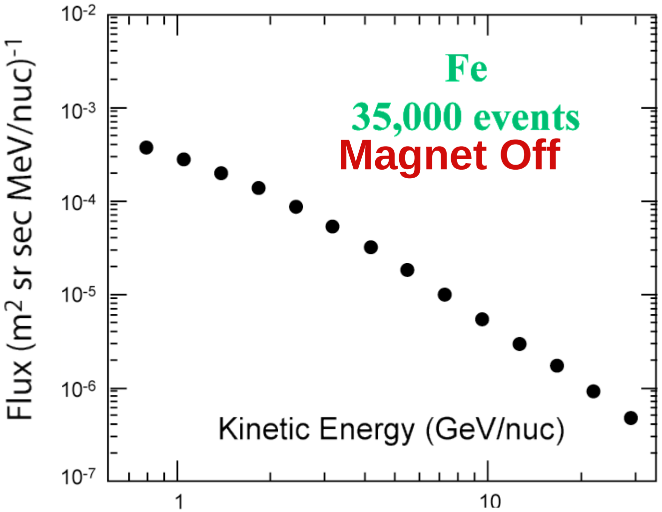
RICH test beam E=158 GeV/n





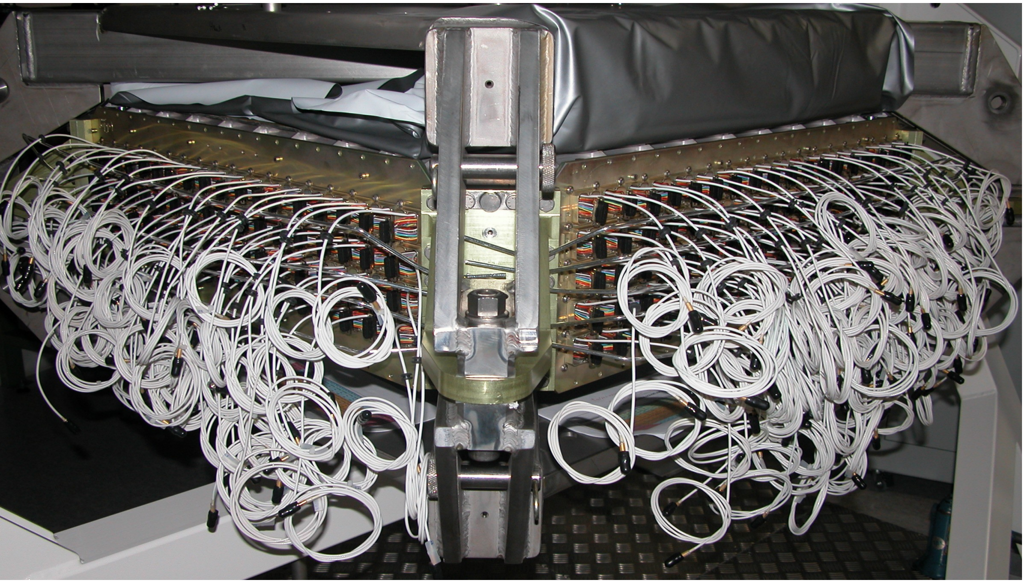


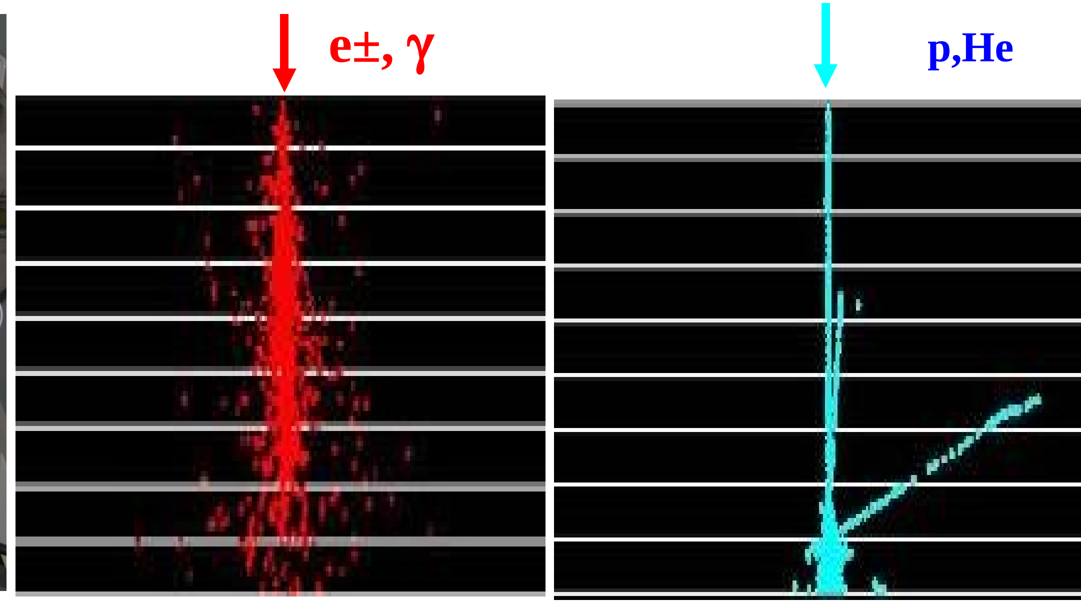


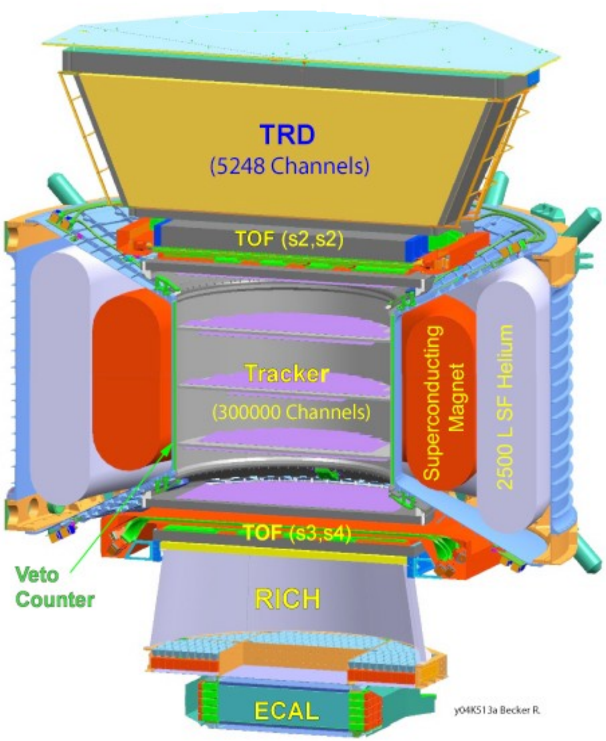


Spectra from 0.1 GeV/n to 30 GeV/n in one week.

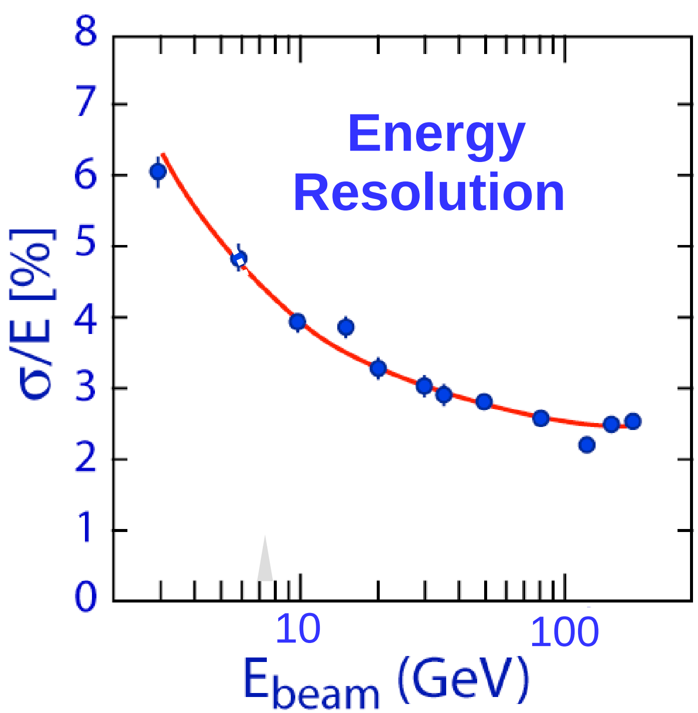
ECAL: A 3 dimensional, 16 X_0 measurement of the direction & energy of gamma rays and electrons

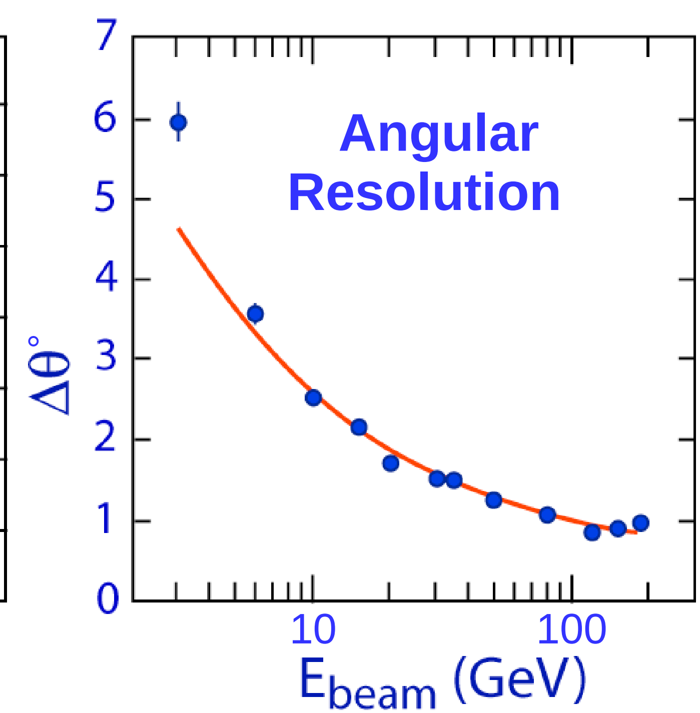




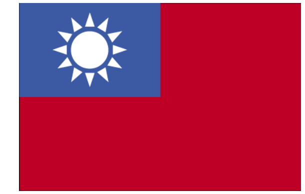


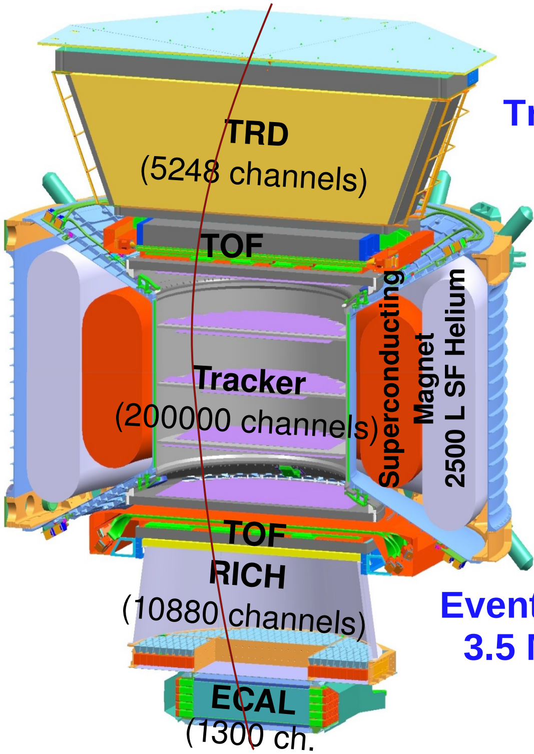
Verified by accelerator calibration





AMS-02 Electronics

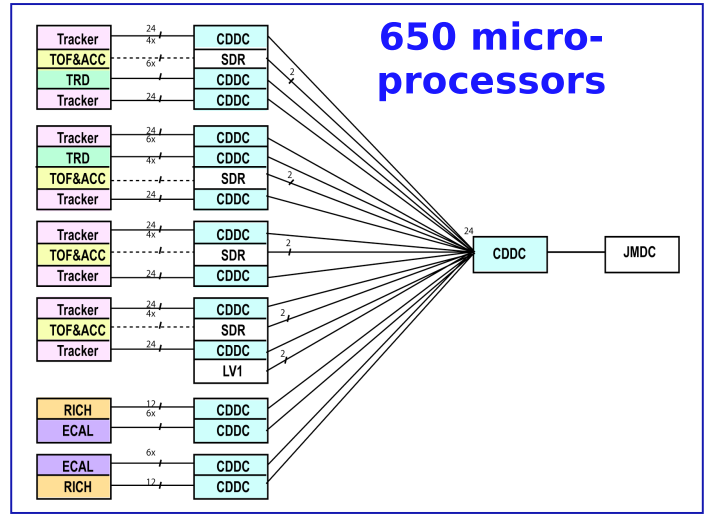




Trigger Rate
2000 Hz

Event Size
3.5 Mbit

~ 7 Gbit/sec



4 Mbit/sec

The AMS electronics is based on Accelerator physics technologies.
It is ~ 10 times faster than commercial space electronics.

Dedicated facilities in Taiwan

AMS pre-integration @CERN

16/08/2007

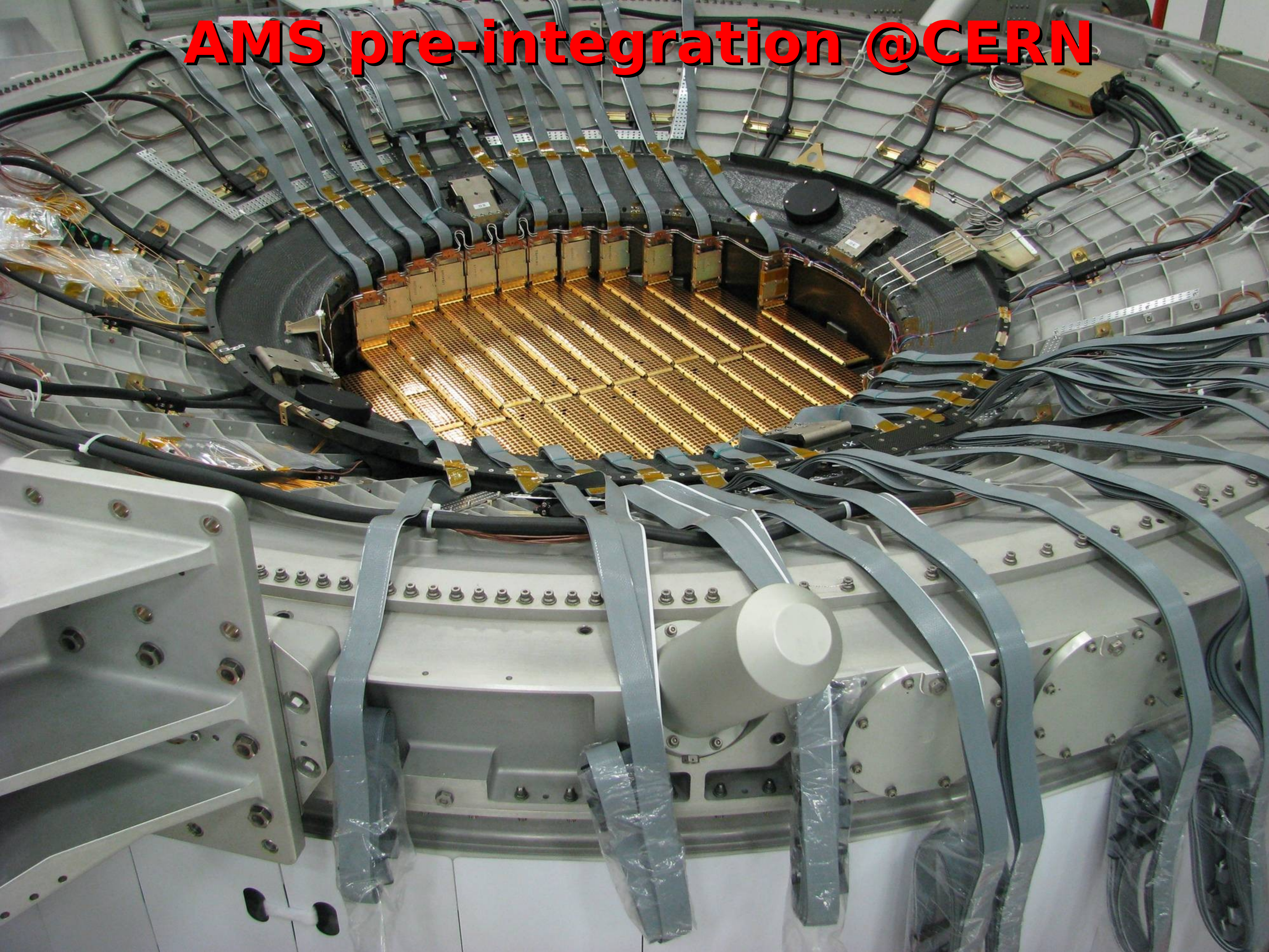
AMS pre-integration @CERN

23/08/2007

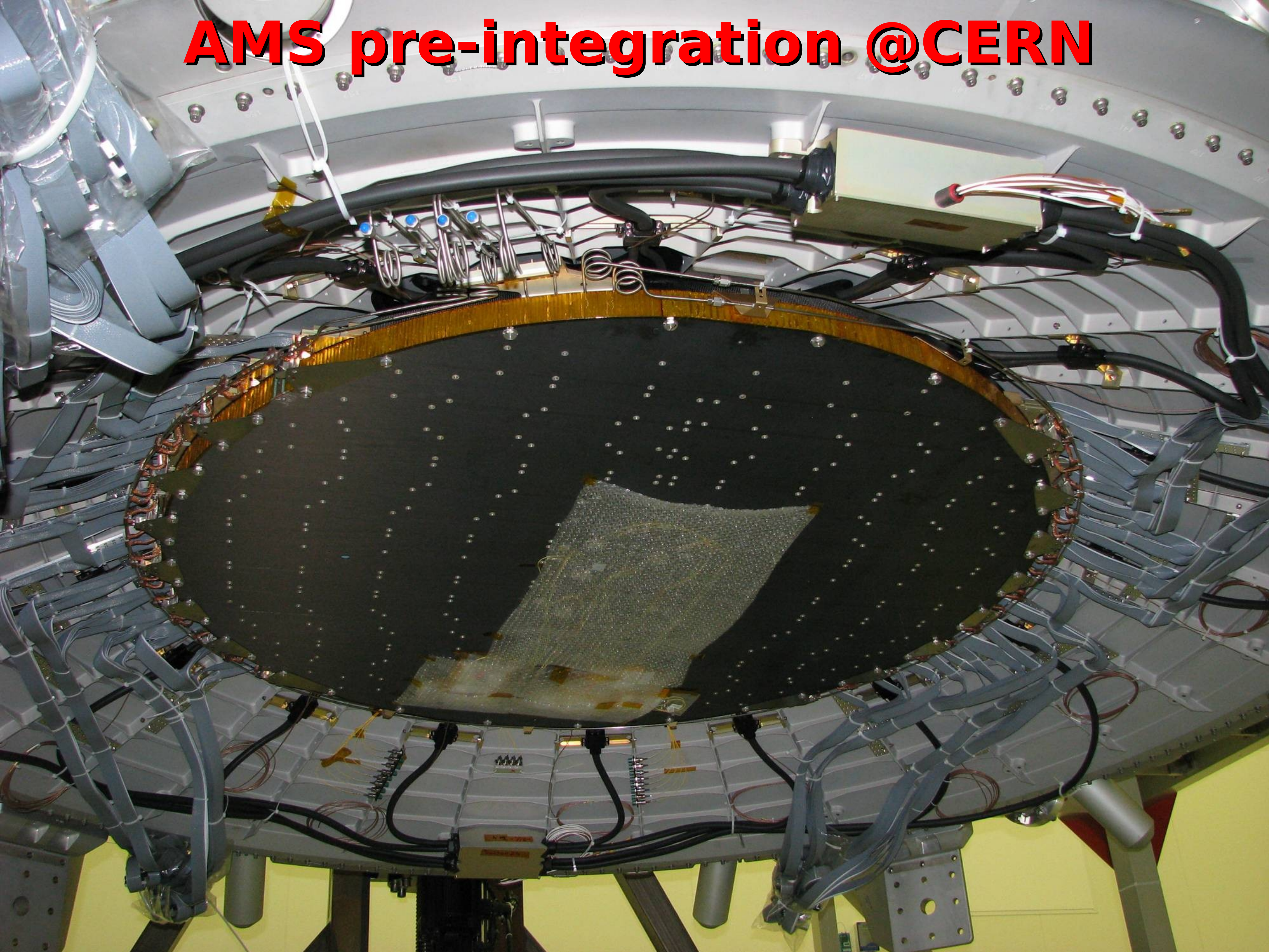
AMS pre-integration @CERN

08/10/2007

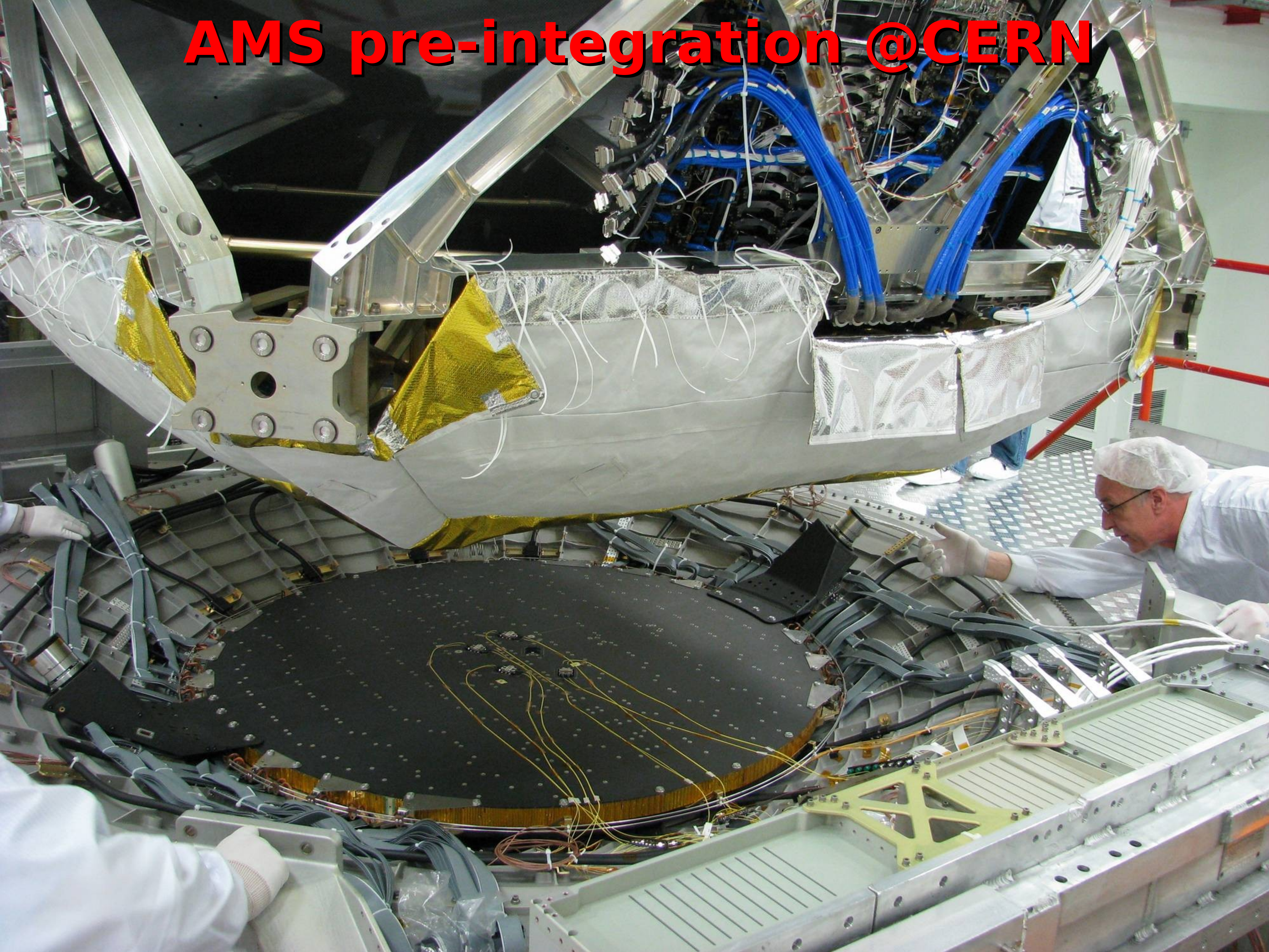
AMS pre-integration @CERN



AMS pre-integration @CERN



AMS pre-integration @CERN



AMS pre-integration @CERN

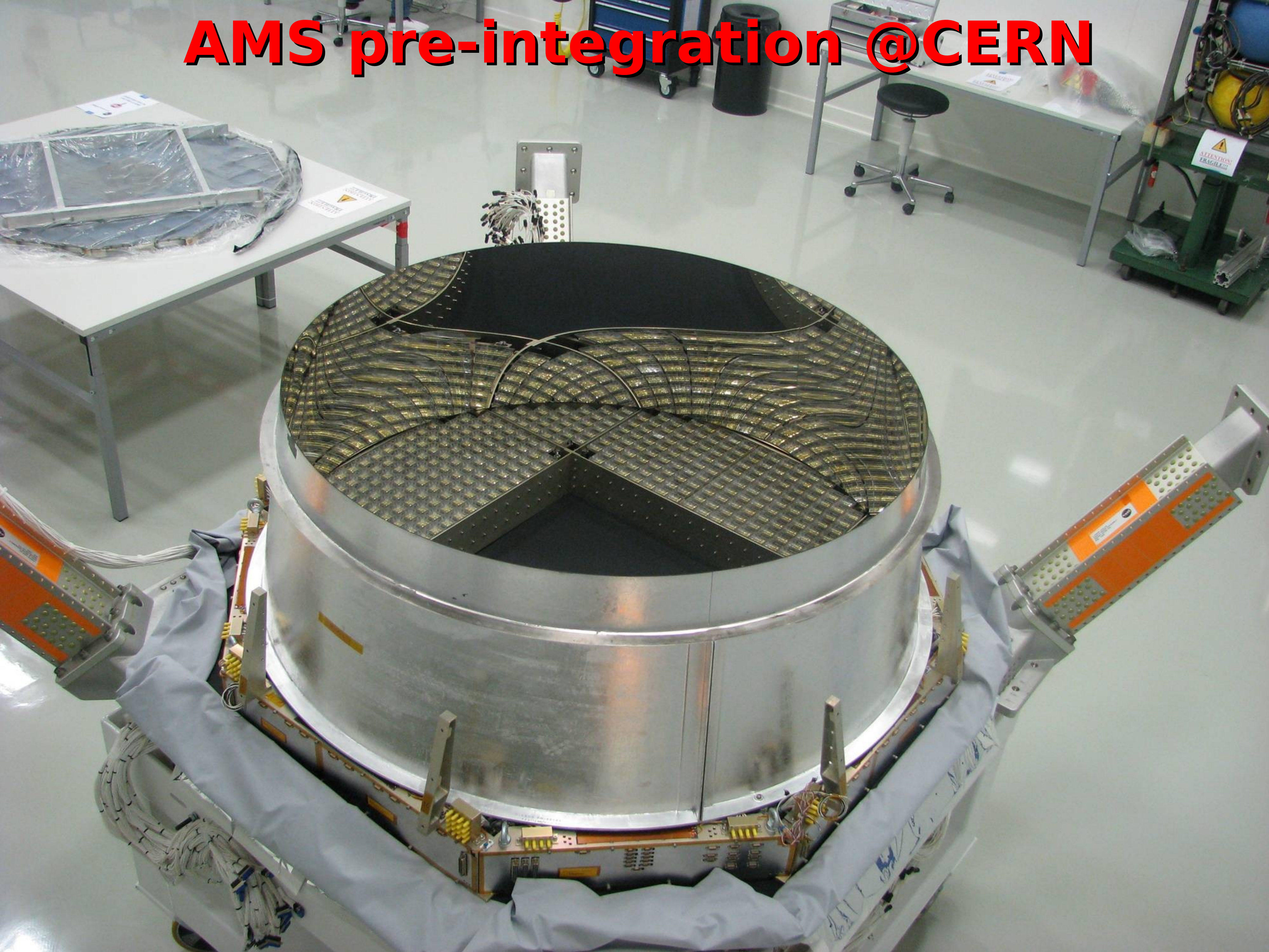
22/11/2007

AMS pre-integration @CERN

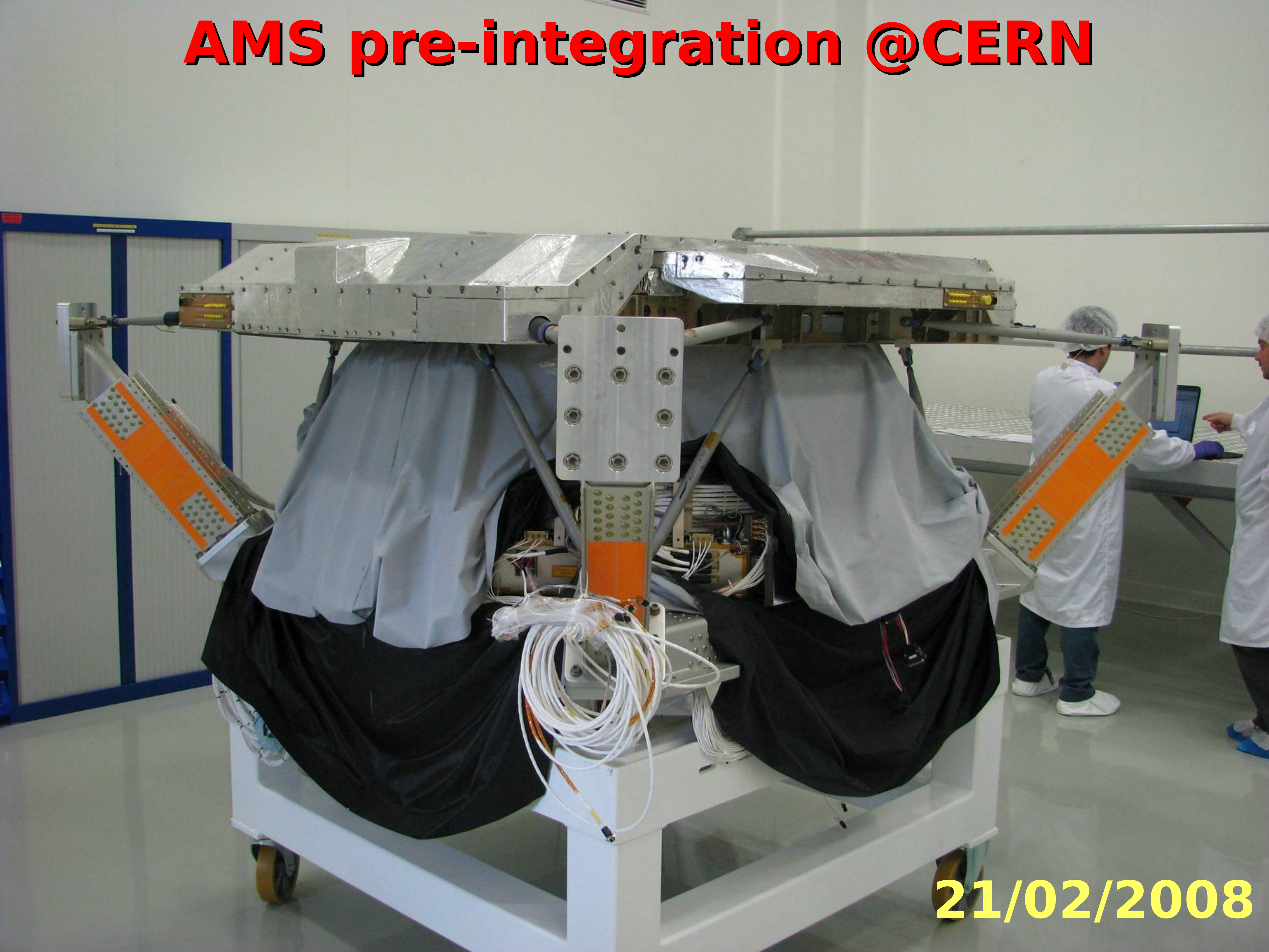
11/09/2007

AMS pre-integration @CERN

AMS pre-integration @CERN

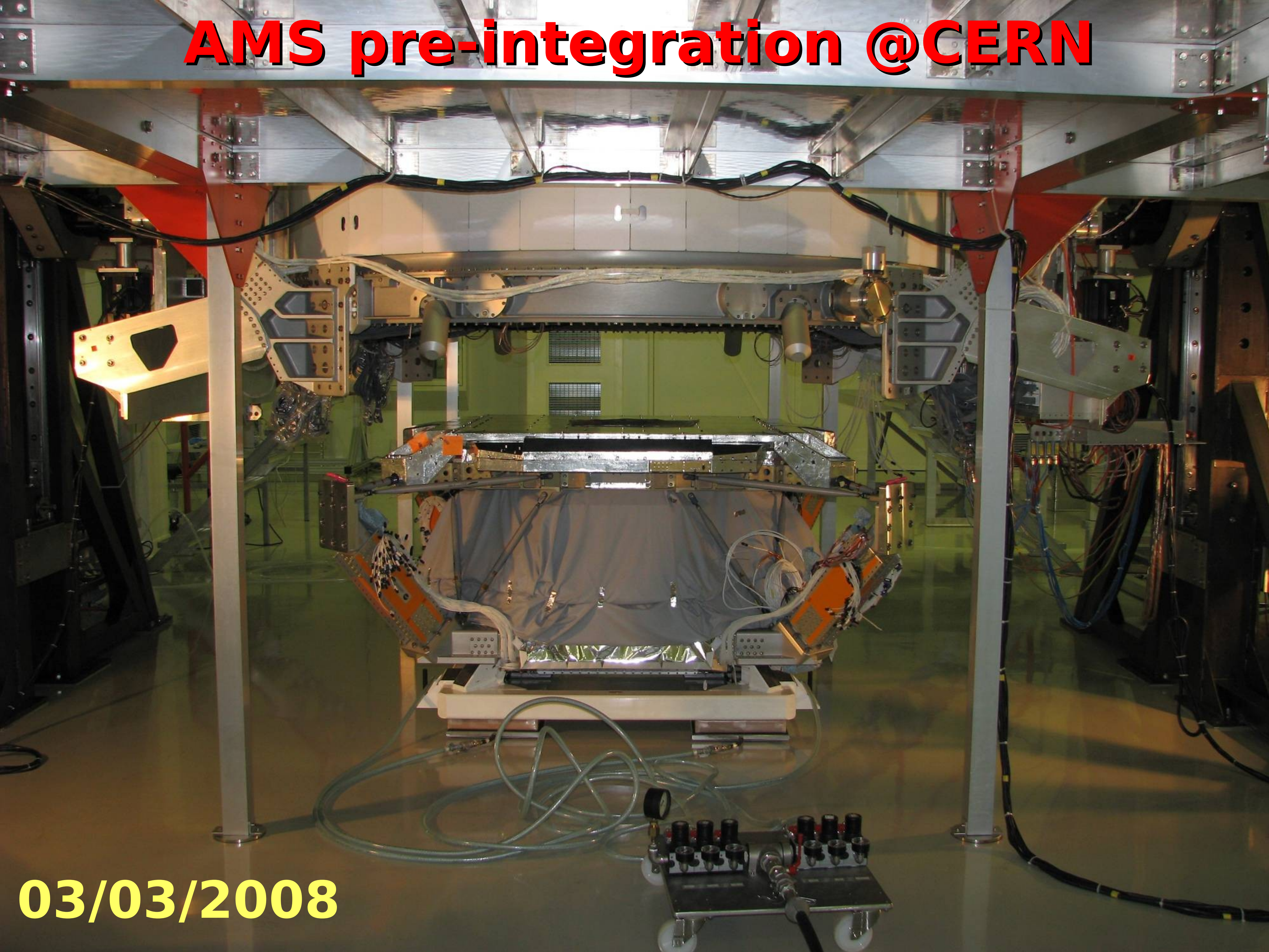


AMS pre-integration @CERN



21/02/2008

AMS pre-integration @CERN

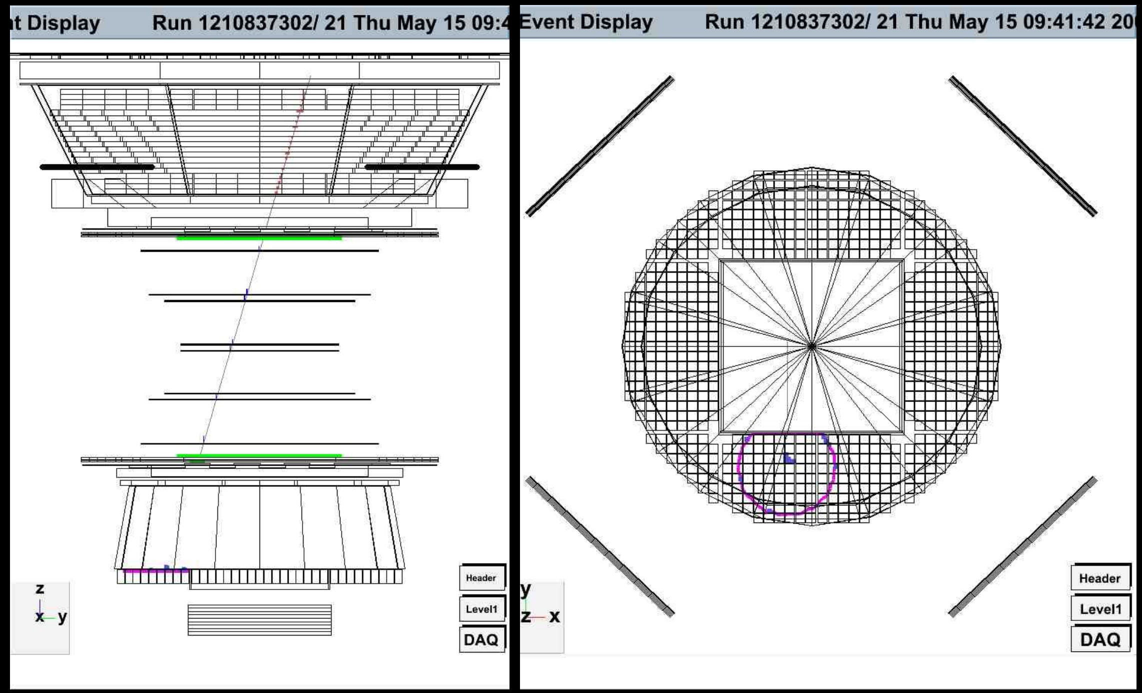


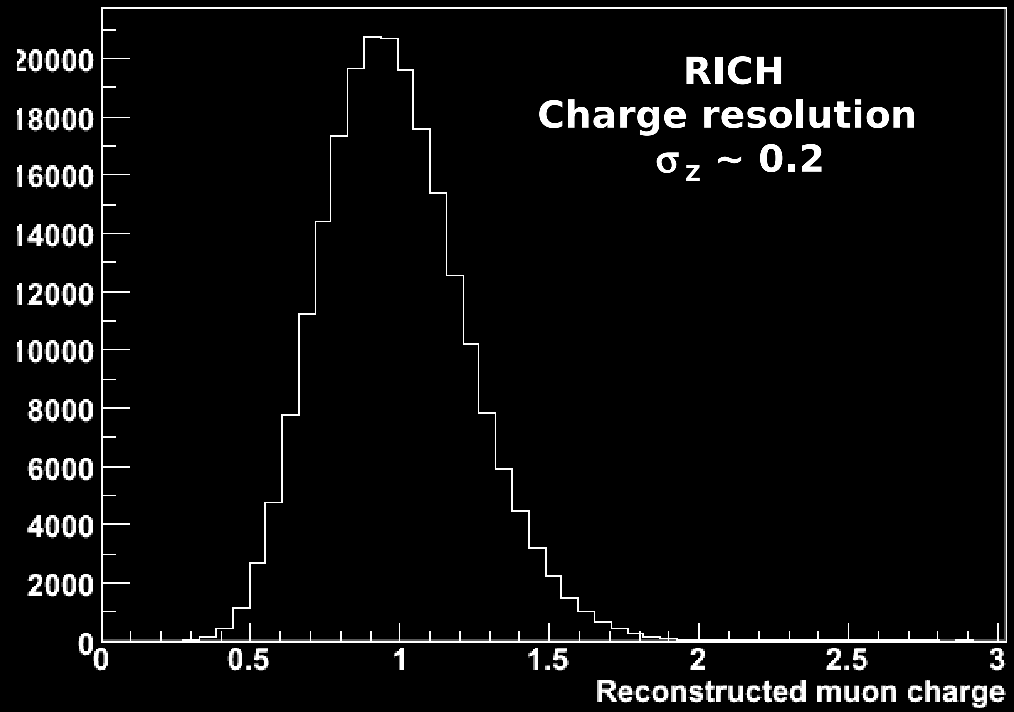
03/03/2008

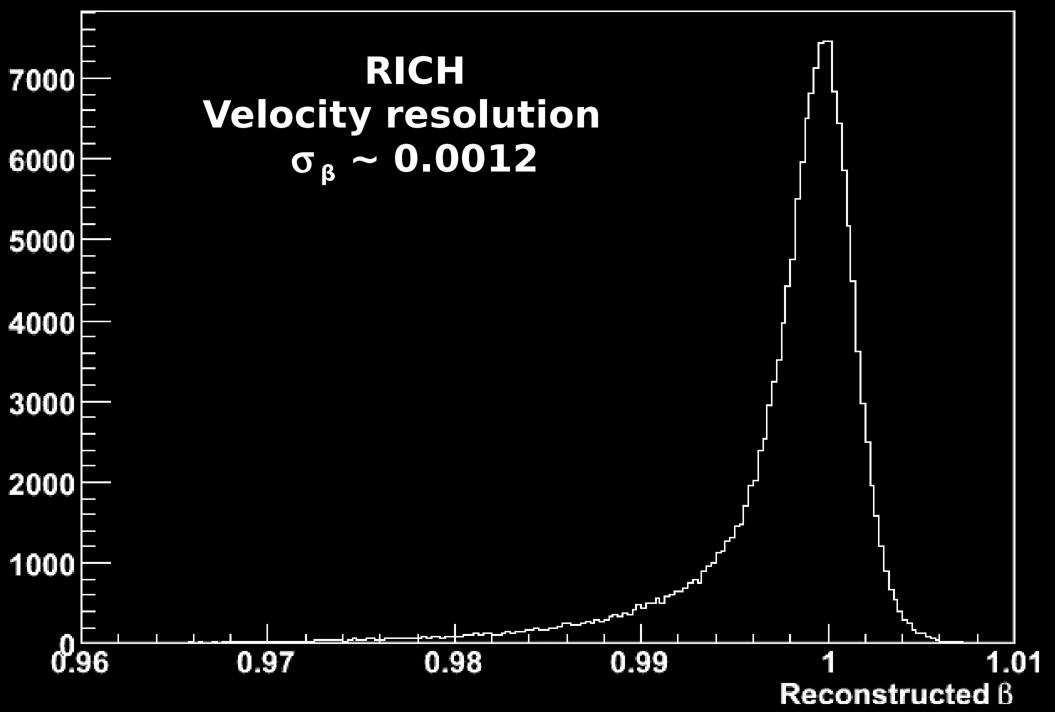
AMS pre-integration @CERN

04/03/2008

DAQ Test at CERN (May-June 2008)

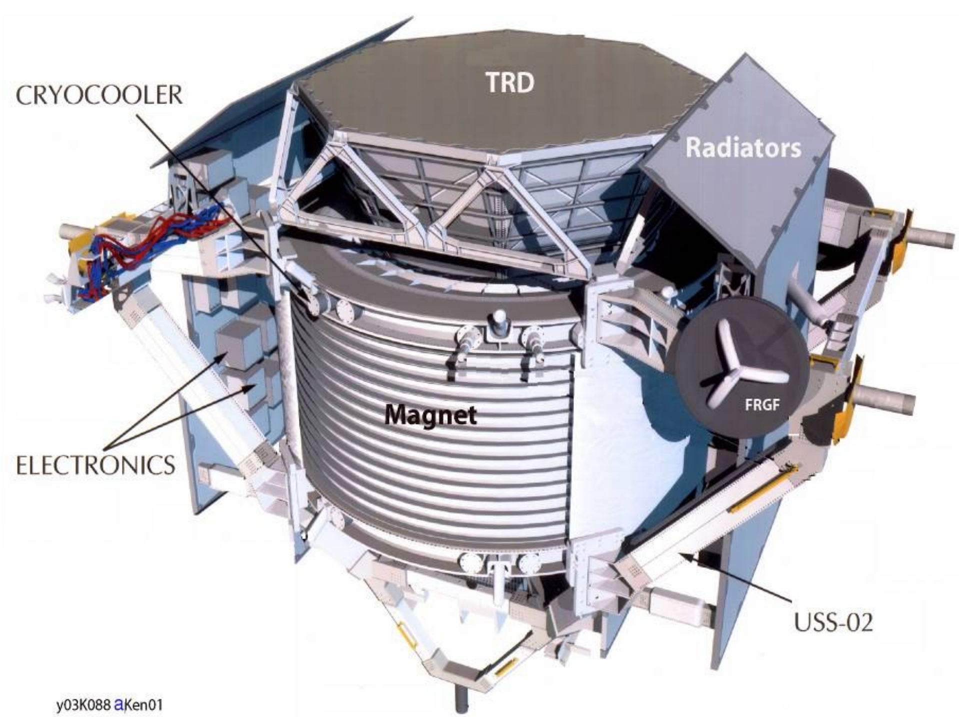




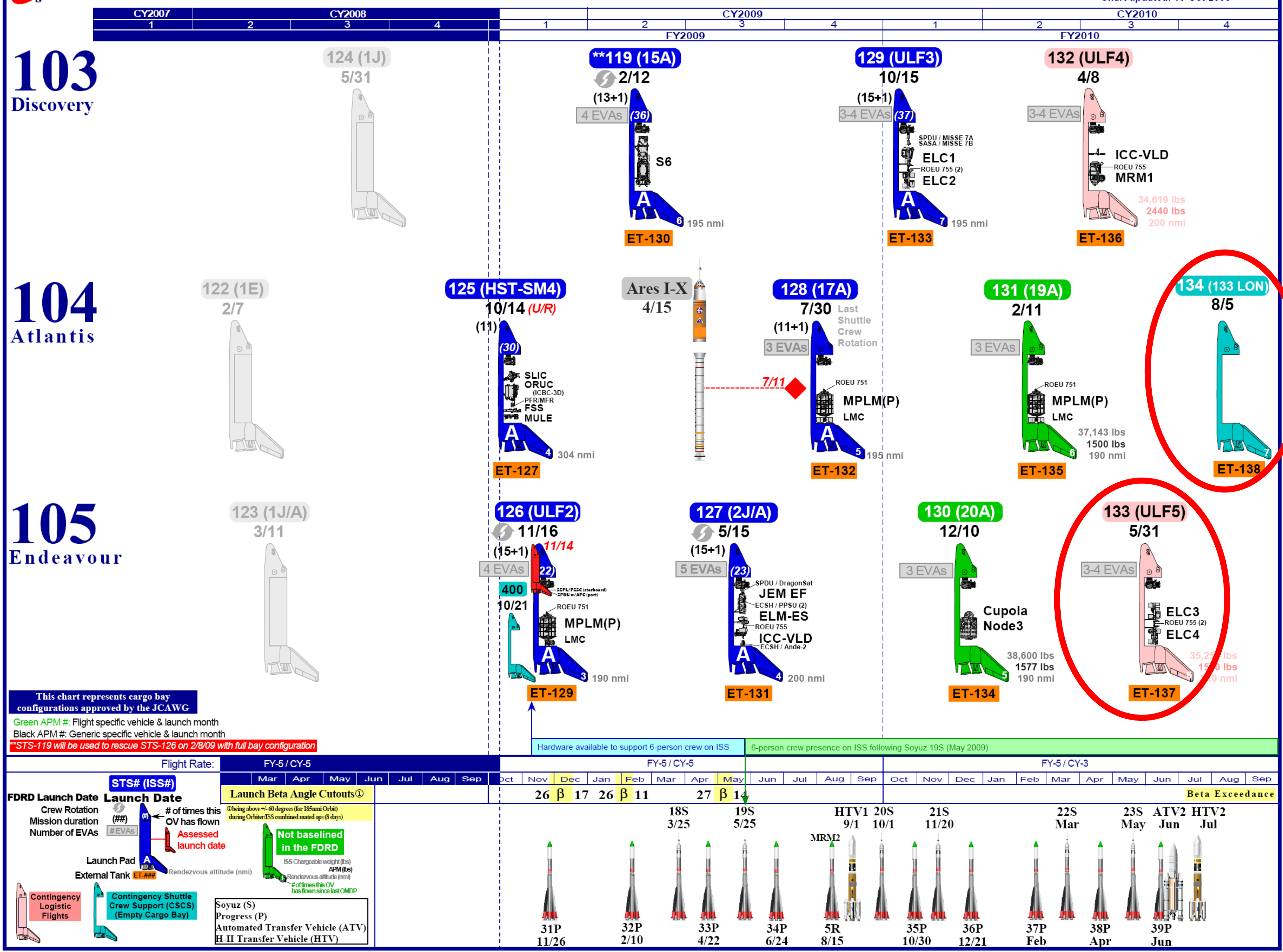


AMS-02 Current Status

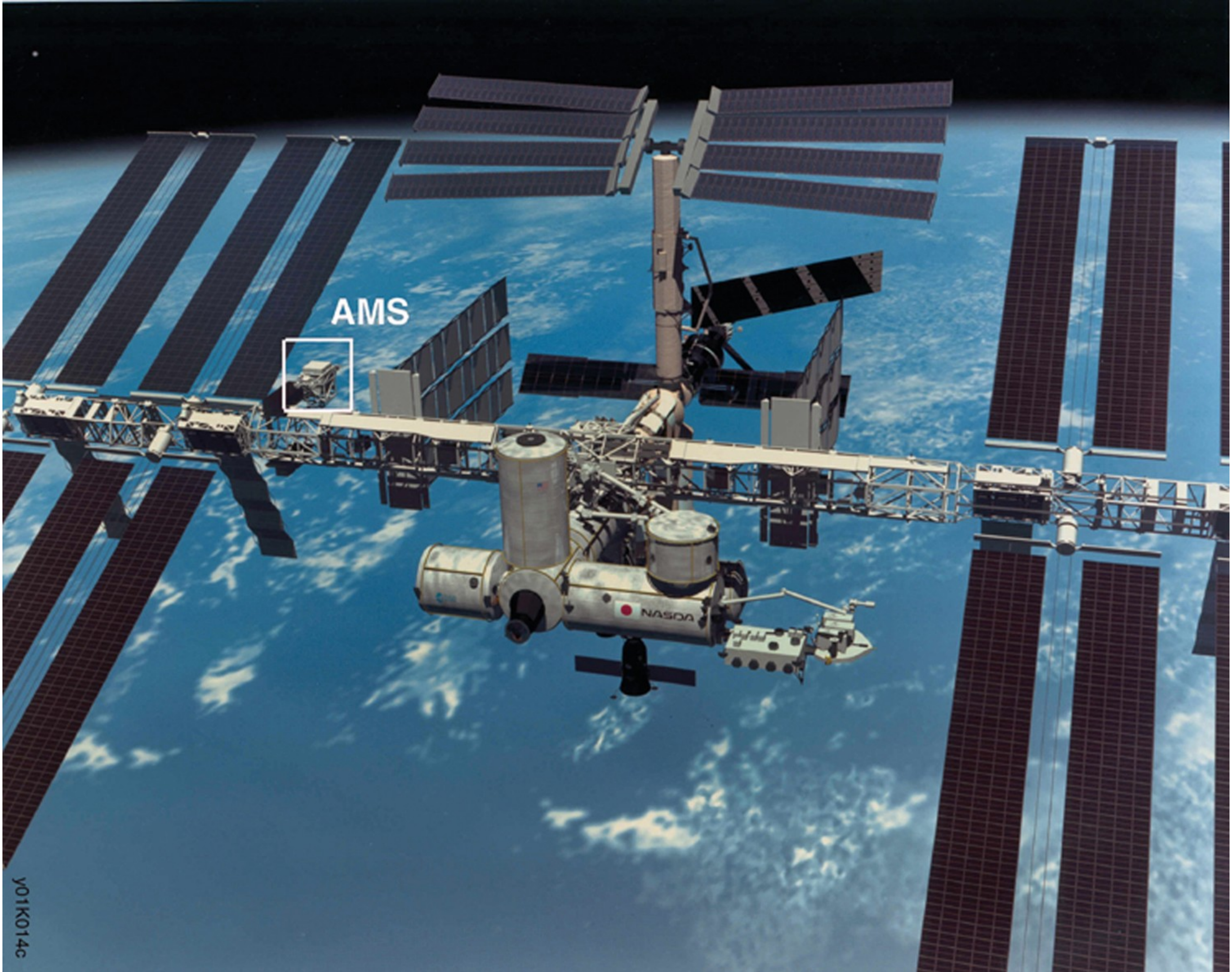
- **Magnet@CERN (Dec.2008)**
- **Final Integration & calibration with beam @CERN (Oct.2009)**
- **TVT and EMI @ESA facilities (Noordwijk) in (Jan.2010)**
- **Pre-fligth ops @KSC complete (May.2010)**



Flight Assignment Working Group (FAWG) Planning Manifest



The Space Shuttle Discovery lifts off from Launch Pad 39A at 6:06:24 p.m. EDT June 2 on its way to the Mir space station. On board Discovery the first on-orbit test of the Alpha Magnetic Spectrometer (AMS) ...


AMS
NASDA
y01K014c