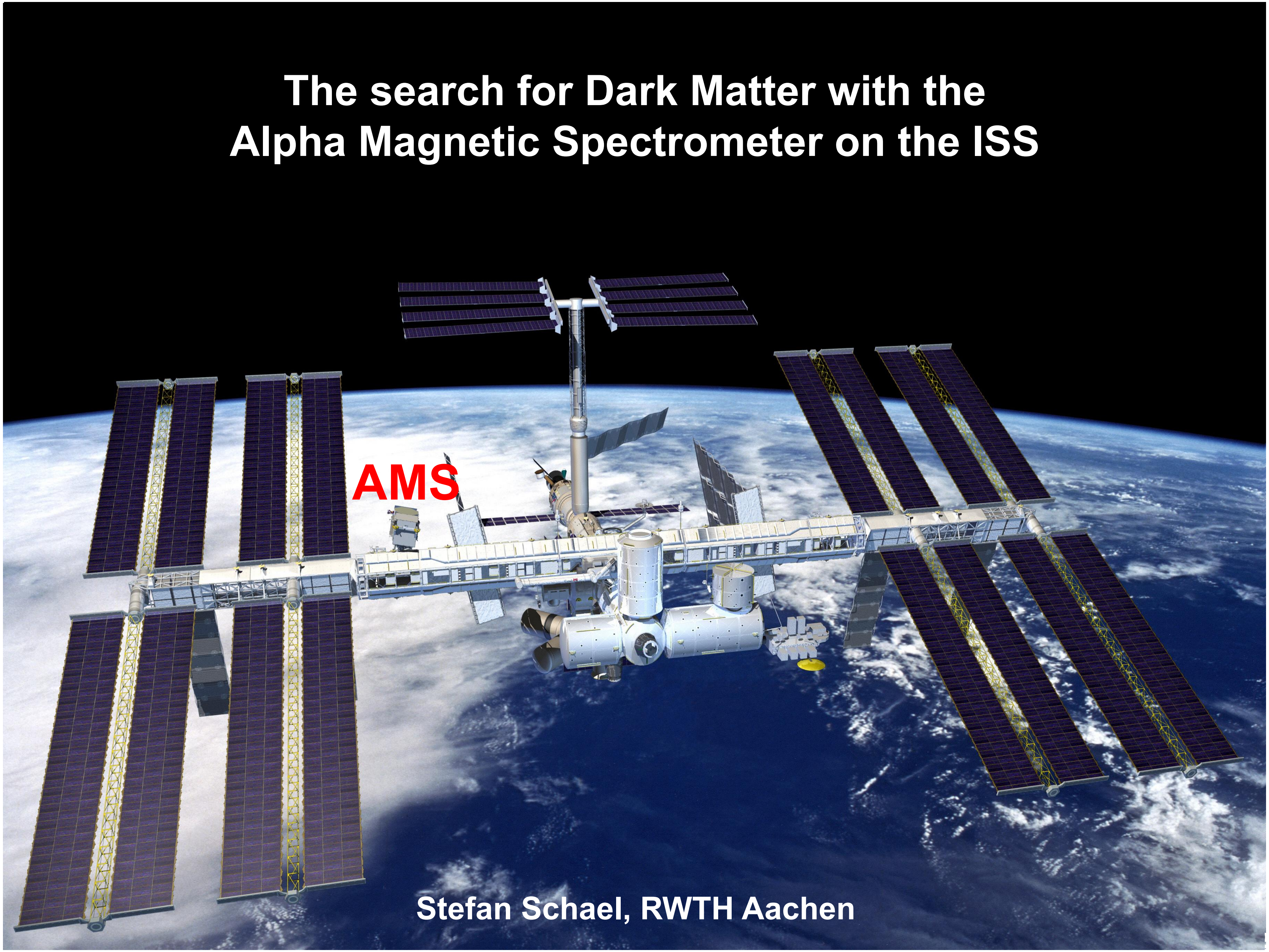
The search for Dark Matter with the Alpha Magnetic Spectrometer on the ISS



Stefan Schael, RWTH Aachen

AMS-02 will not be launched July 29, 2010 !

Alpha Magnetic Spectrometer

JSC NASA AMS

Time until launch: T-

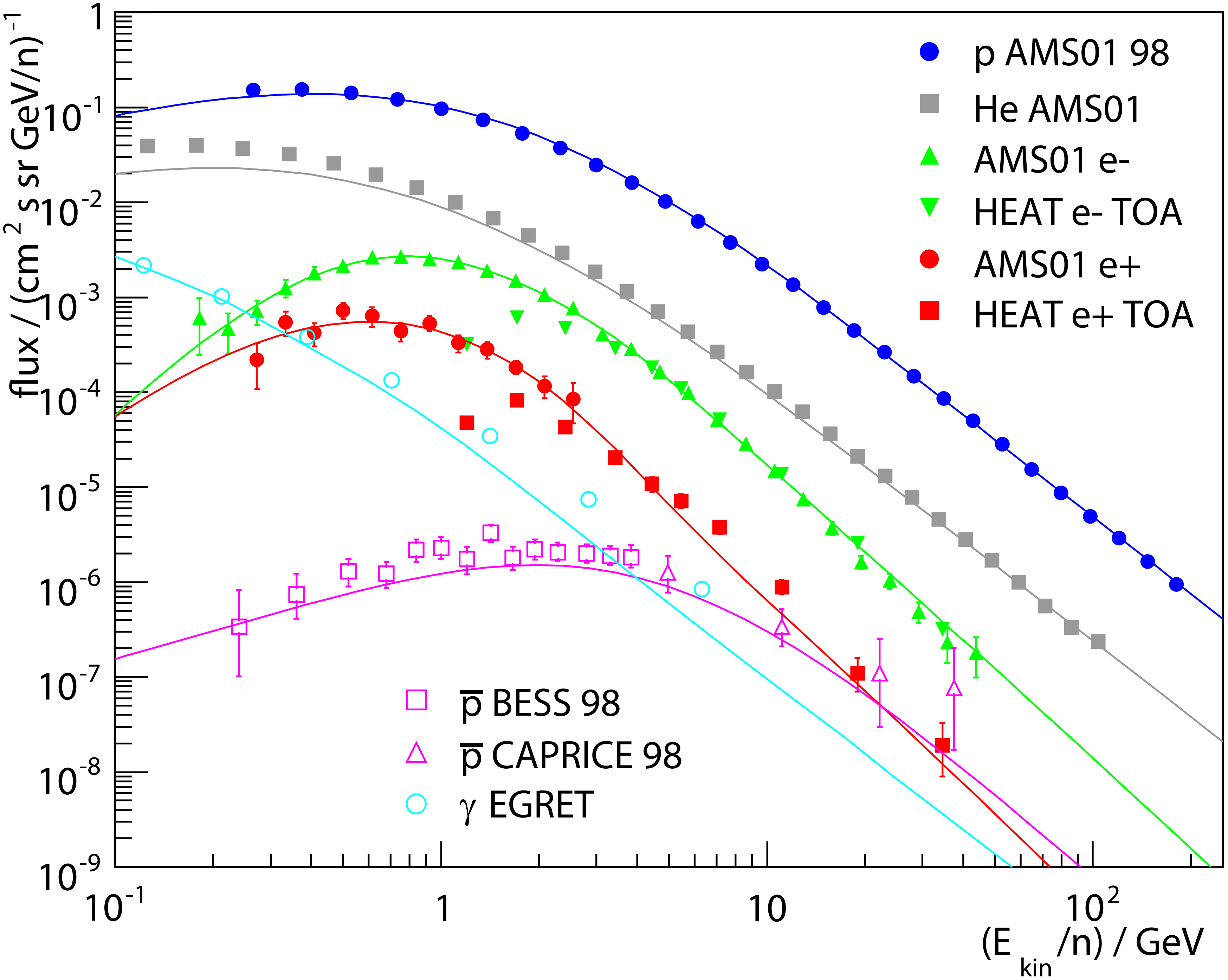
Days	Hours	Mins	Secs
100:	08:	41:	06

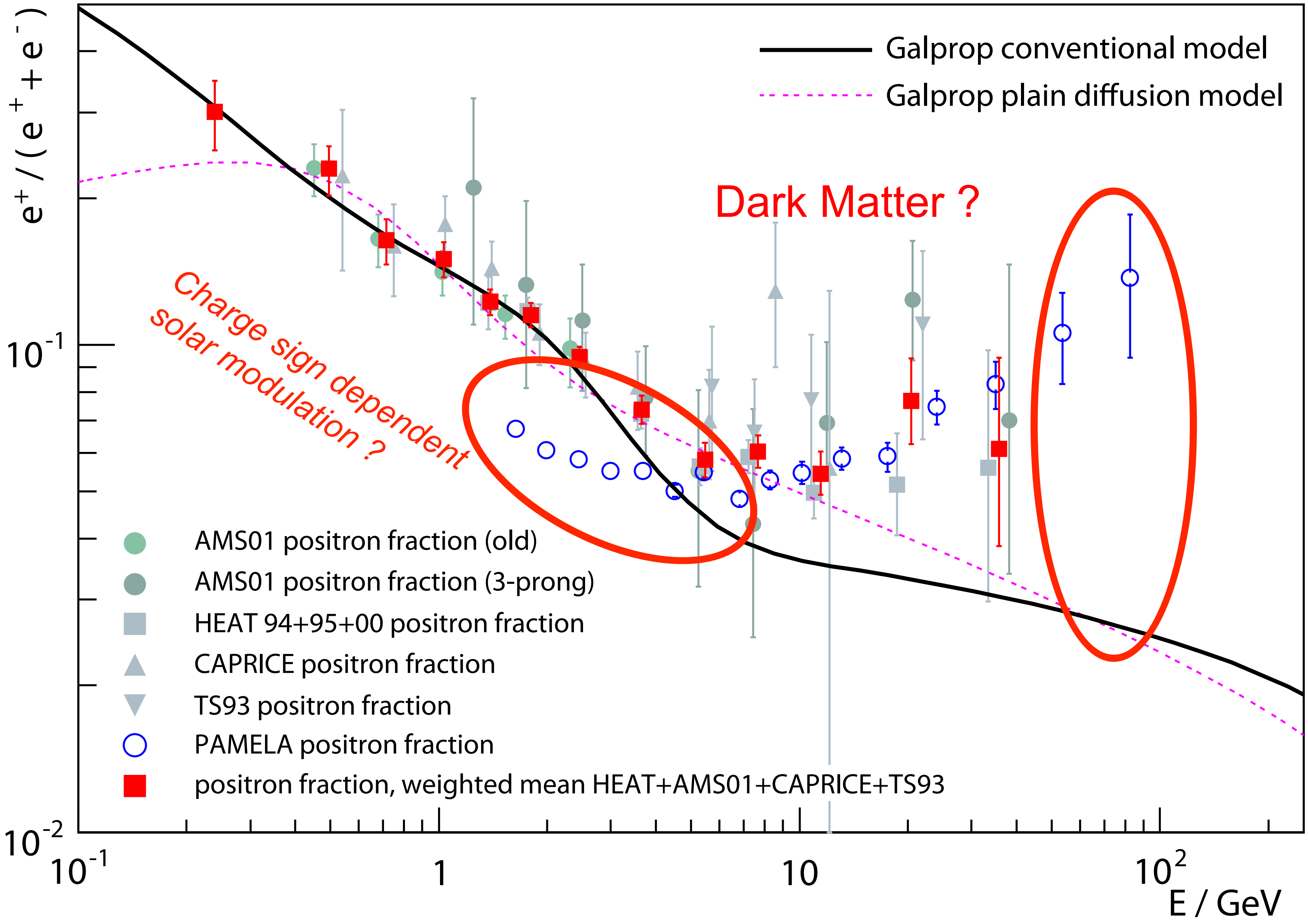
STS-134 / ULF6
AMS scheduled launch: July 29, 2010

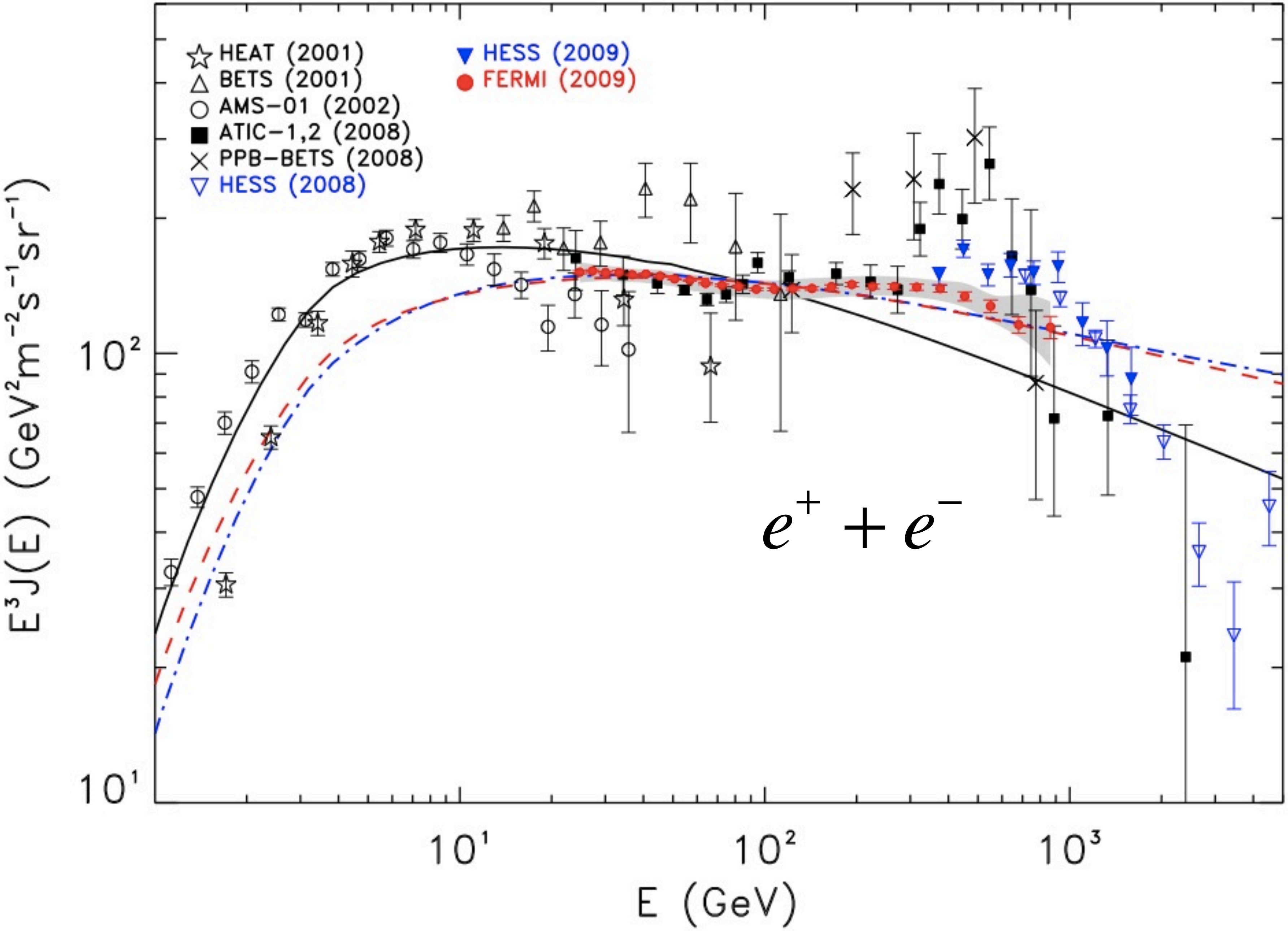
…ion Activities
Life Cycle Reviews
Drawings
Documentation
Correspondence

Video

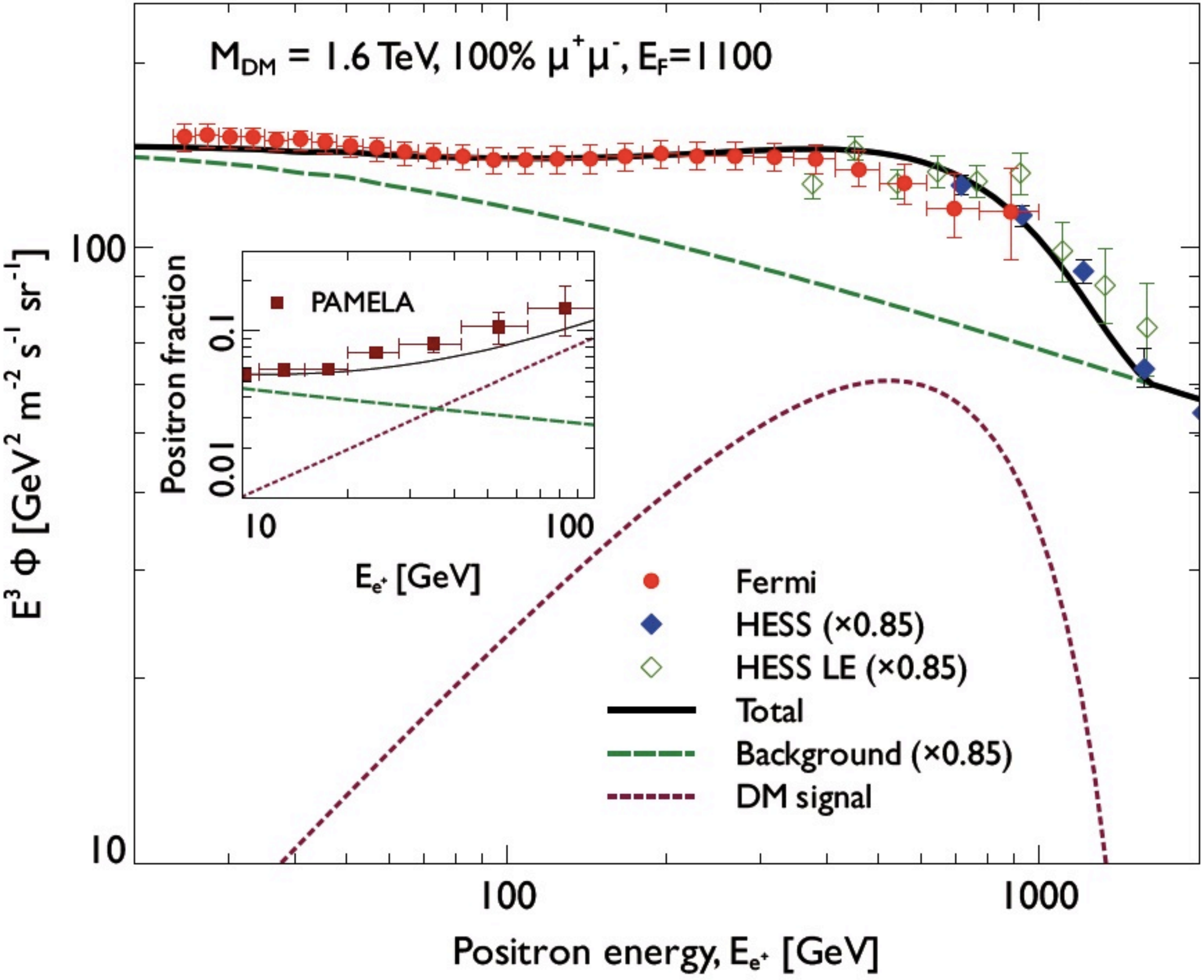
AMS Public Site · CCB · Contact Us · Other Projects

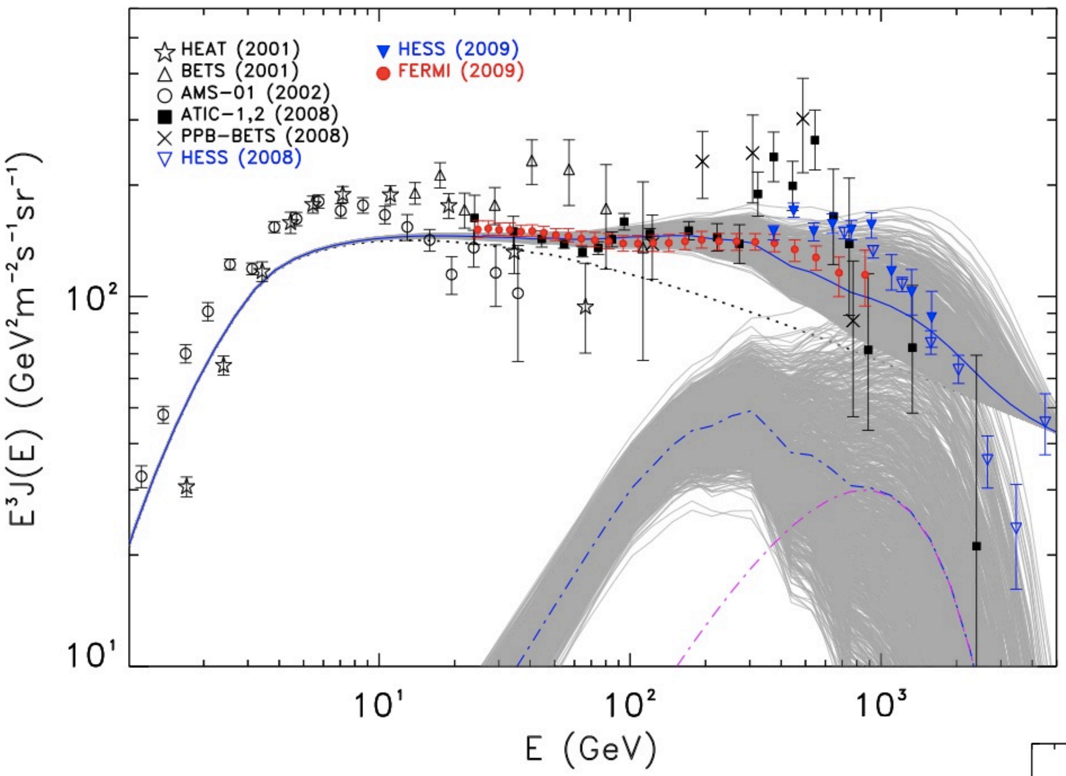

flux / (cm^2 s sr GeV/n)$^{-1}$
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-1}
1
10
10^2
(E_{kin}/n) / GeV
p AMS01 98
He AMS01
AMS01 e-
HEAT e- TOA
AMS01 e+
HEAT e+ TOA
$\bar{p}$ BESS 98
$\bar{p}$ CAPRICE 98
γ EGRET

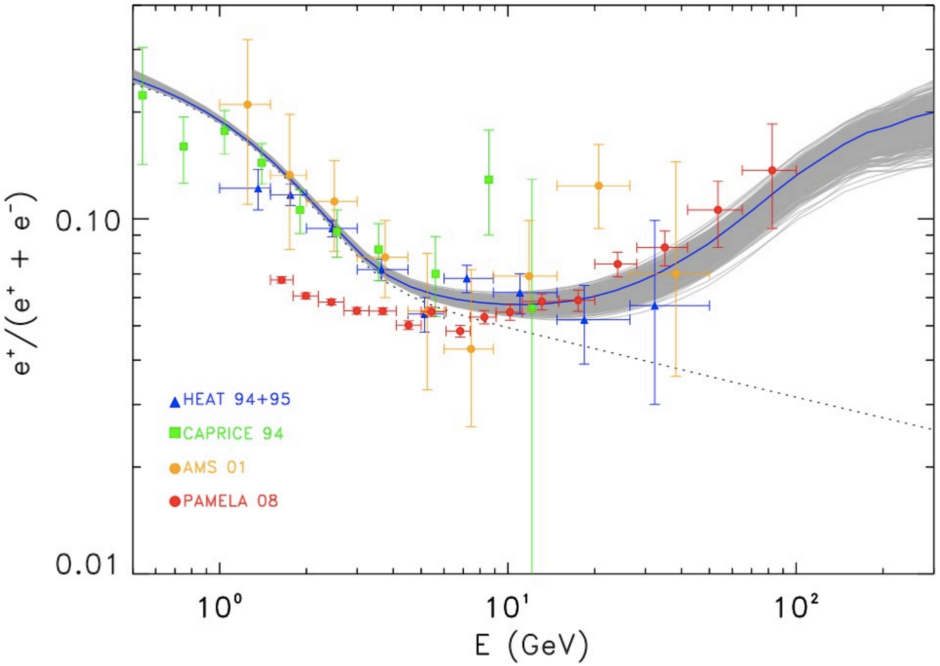

e+ / (e+ + e-)
10^-1
10^-2
10^-1
1
10
10^2
E / GeV
Galprop conventional model
Galprop plain diffusion model
Dark Matter ?
Charge sign dependent solar modulation ?
AMS01 positron fraction (old)
AMS01 positron fraction (3-prong)
HEAT 94+95+00 positron fraction
CAPRICE positron fraction
TS93 positron fraction
PAMELA positron fraction
positron fraction, weighted mean HEAT+AMS01+CAPRICE+TS93


HEAT (2001)
BETS (2001)
AMS-01 (2002)
ATIC-1,2 (2008)
PPB-BETS (2008)
HESS (2008)
HESS (2009)
FERMI (2009)
$E^3J(E)$ $(GeV^2m^{-2}s^{-1}sr^{-1})$
10^2
10^1
10^1
10^2
10^3
E (GeV)
$e^+ + e^-$

Bergström, Edsjö & Zaharijas 2009

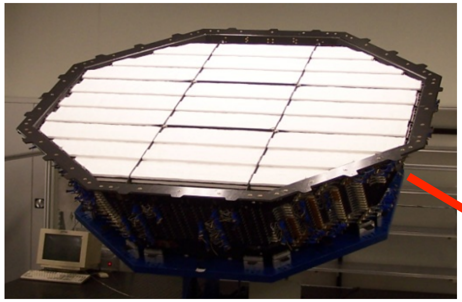



HEAT (2001)
BETS (2001)
AMS-01 (2002)
ATIC-1,2 (2008)
PPB-BETS (2008)
HESS (2008)
HESS (2009)
FERMI (2009)
$E^3J(E)$ $(GeV^2m^{-2}s^{-1}sr^{-1})$
10^2
10^1
10^1
10^2
10^3
E (GeV)

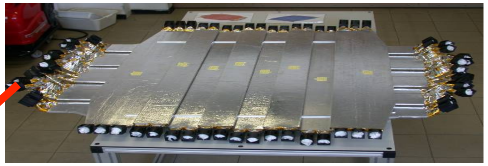

$e^+/(e^+ + e^-)$
0.10
0.01
HEAT 94+95
CAPRICE 94
AMS 01
PAMELA 08
10^0
10^1
10^2
E (GeV)

Particles are defined by their mass (m), charge (Q) and energy (E = P)

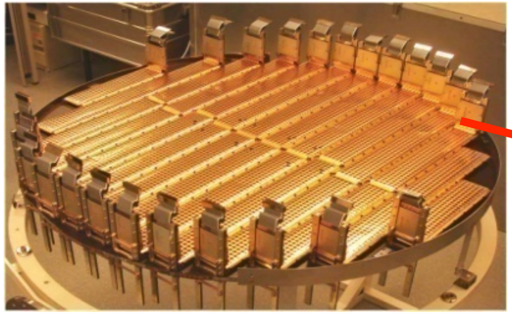
TRD
Identify e+, e-



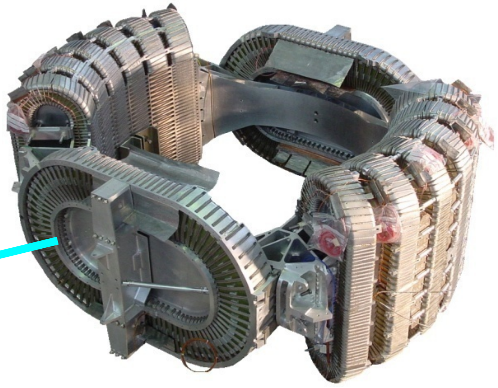
TOF
m, Q, E

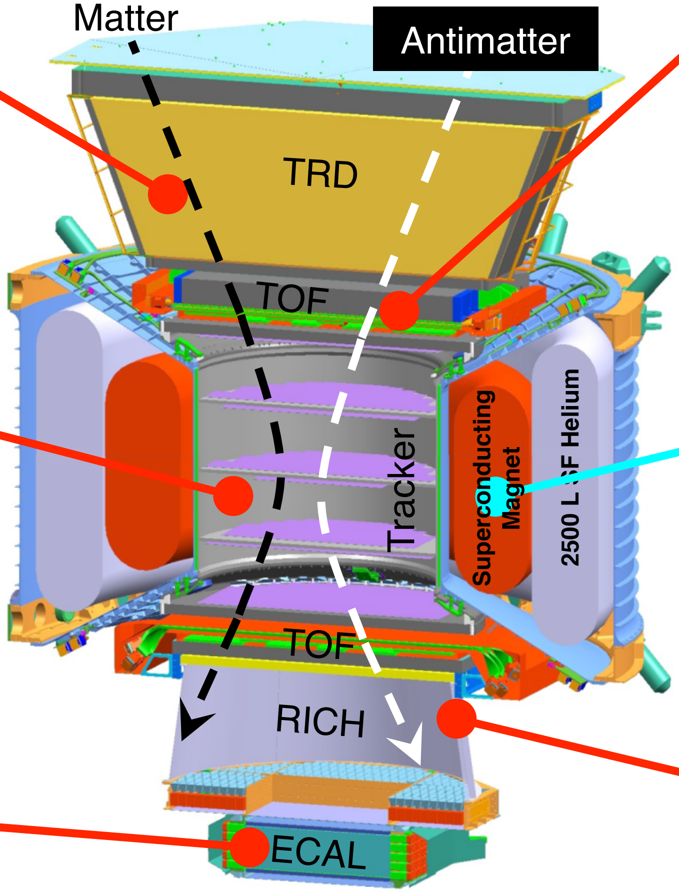


Silicon Tracker
m, Q, E



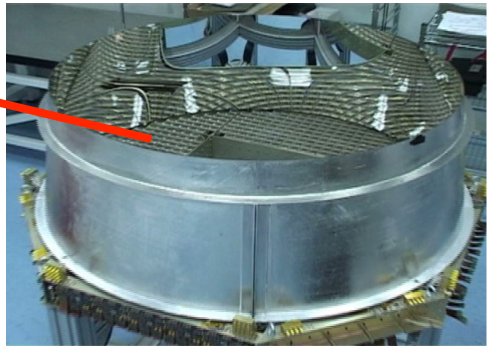
Magnet
± Q



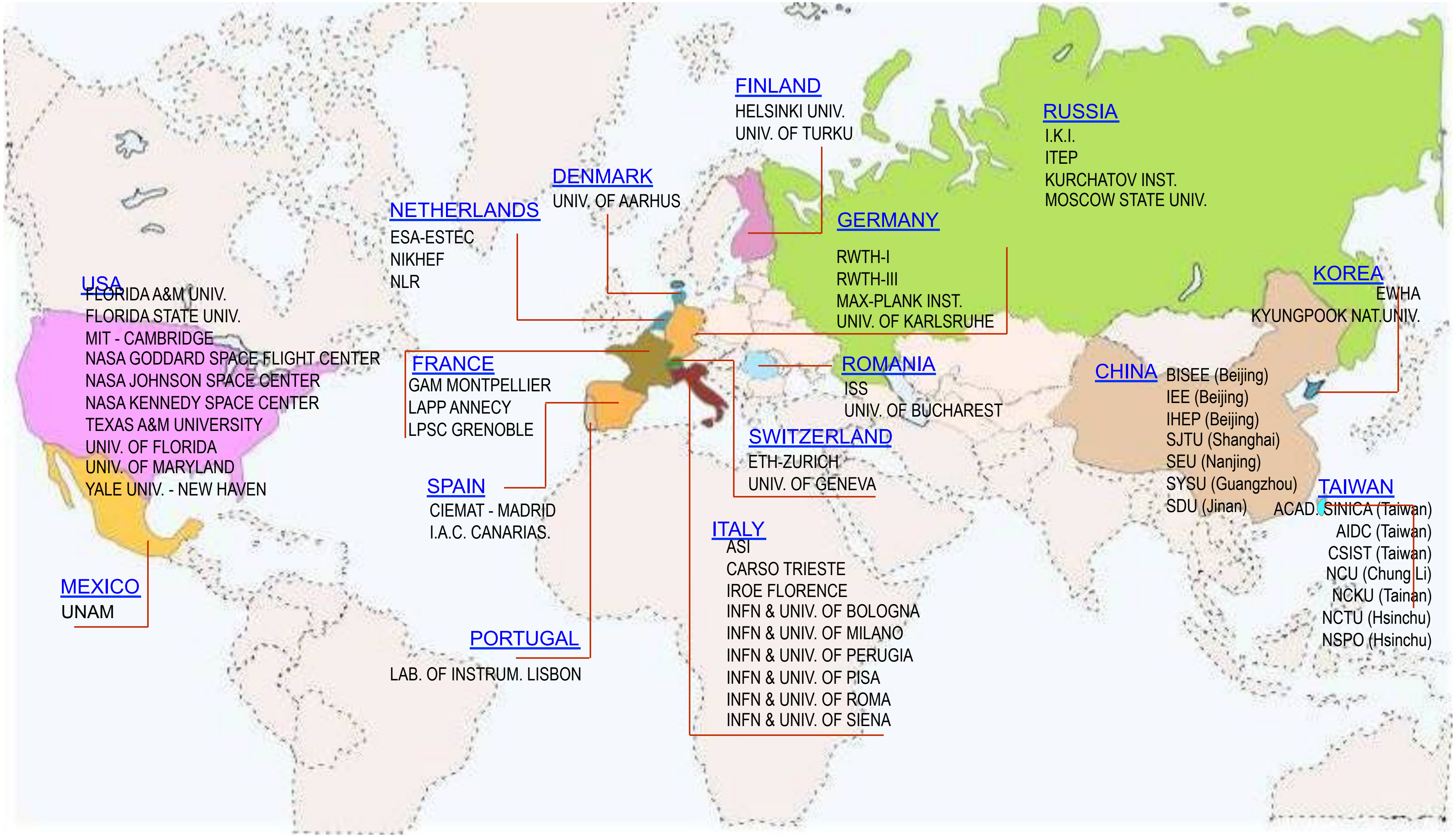


ECAL
E of e+, e-

RICH
m, Q, E



AMS is an international collaboration of 16 countries, 60 institutes (10 U.S.) and 600 physicists.



USA
FLORIDA A&M UNIV.
FLORIDA STATE UNIV.
MIT - CAMBRIDGE
NASA GODDARD SPACE FLIGHT CENTER
NASA JOHNSON SPACE CENTER
NASA KENNEDY SPACE CENTER
TEXAS A&M UNIVERSITY
UNIV. OF FLORIDA
UNIV. OF MARYLAND
YALE UNIV. - NEW HAVEN

MEXICO
UNAM

NETHERLANDS
ESA-ESTEC
NIKHEF
NLR

DENMARK
UNIV. OF AARHUS

FINLAND
HELSINKI UNIV.
UNIV. OF TURKU

RUSSIA
I.K.I.
ITEP
KURCHATOV INST.
MOSCOW STATE UNIV.

GERMANY
RWTH-I
RWTH-III
MAX-PLANK INST.
UNIV. OF KARLSRUHE

FRANCE
GAM MONTPELLIER
LAPP ANNECY
LPSC GRENOBLE

SPAIN
CIEMAT - MADRID
I.A.C. CANARIAS.

PORTUGAL
LAB. OF INSTRUM. LISBON

ITALY
ASI
CARSO TRIESTE
IROE FLORENCE
INFN & UNIV. OF BOLOGNA
INFN & UNIV. OF MILANO
INFN & UNIV. OF PERUGIA
INFN & UNIV. OF PISA
INFN & UNIV. OF ROMA
INFN & UNIV. OF SIENA

SWITZERLAND
ETH-ZURICH
UNIV. OF GENEVA

ROMANIA
ISS
UNIV. OF BUCHAREST

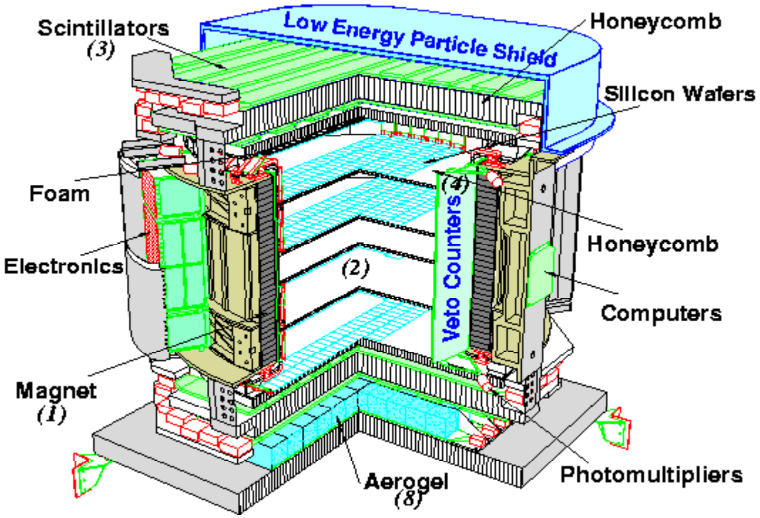
CHINA
BISEE (Beijing)
IEE (Beijing)
IHEP (Beijing)
SJTU (Shanghai)
SEU (Nanjing)
SYSU (Guangzhou)
SDU (Jinan)

KOREA
EWHA
KYUNGPOOK NAT.UNIV.

TAIWAN
ACAD. SINICA (Taiwan)
AIDC (Taiwan)
CSIST (Taiwan)
NCU (Chung Li)
NCKU (Tainan)
NCTU (Hsinchu)
NSPO (Hsinchu)

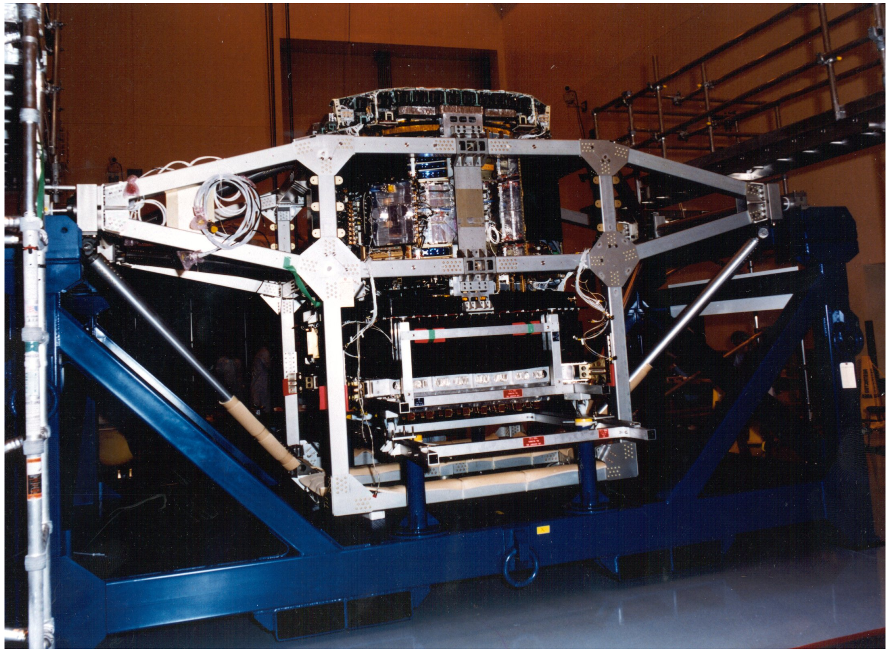
In den letzten 15 Jahren, sind 95% der $2Mrd um AMS zu bauen von Europa und Asien aufgebracht worden. Die Grundlage dafür war die Zusage der NASA AMS auf die ISS zu bringen.

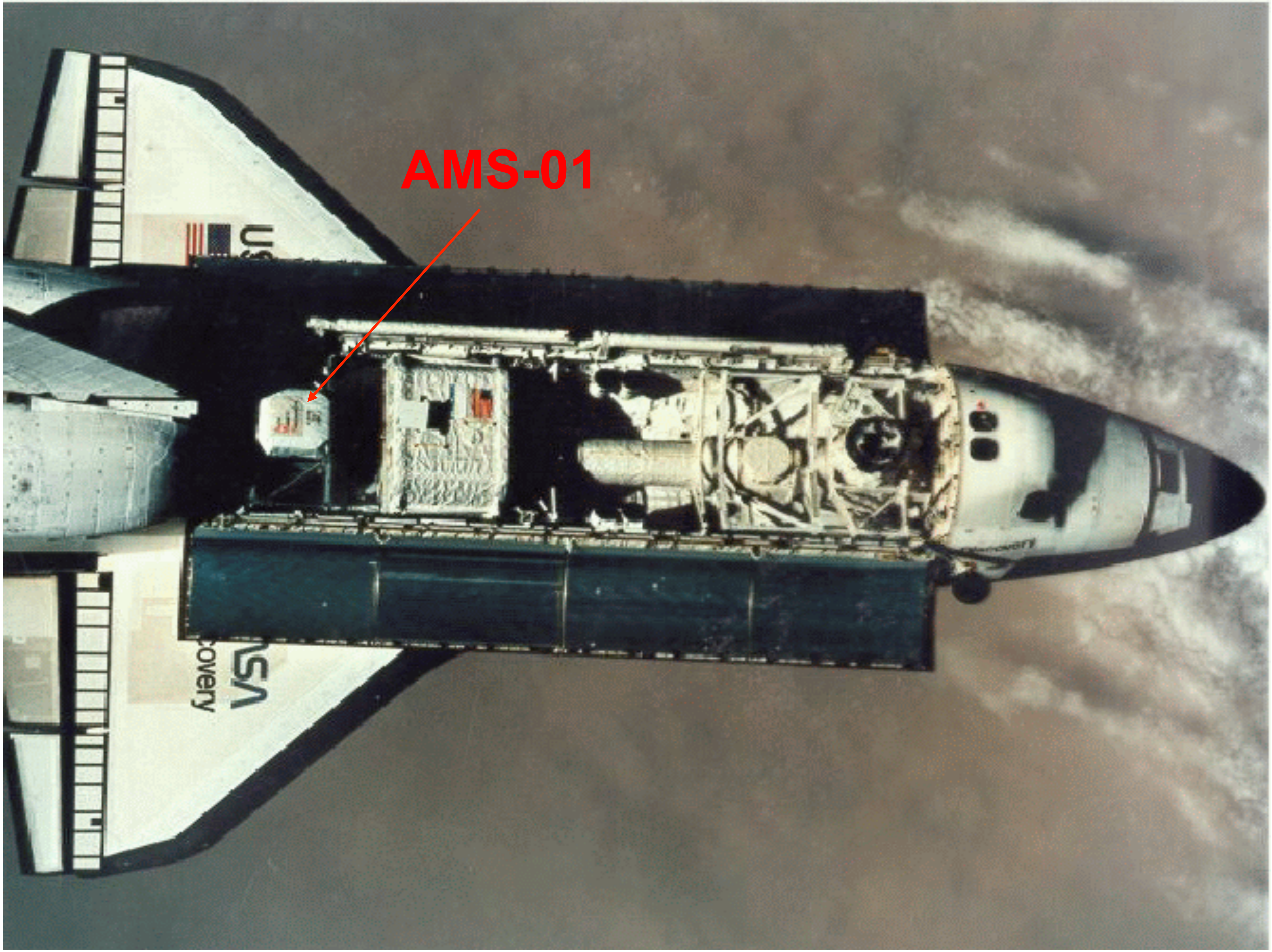
AMS-01: STS-91 1998 Flight Results



- Data taking 135 hours
- Shuttle altitude 370 km
- Trigger rate 100 – 700 Hz
- 100 million events recorded

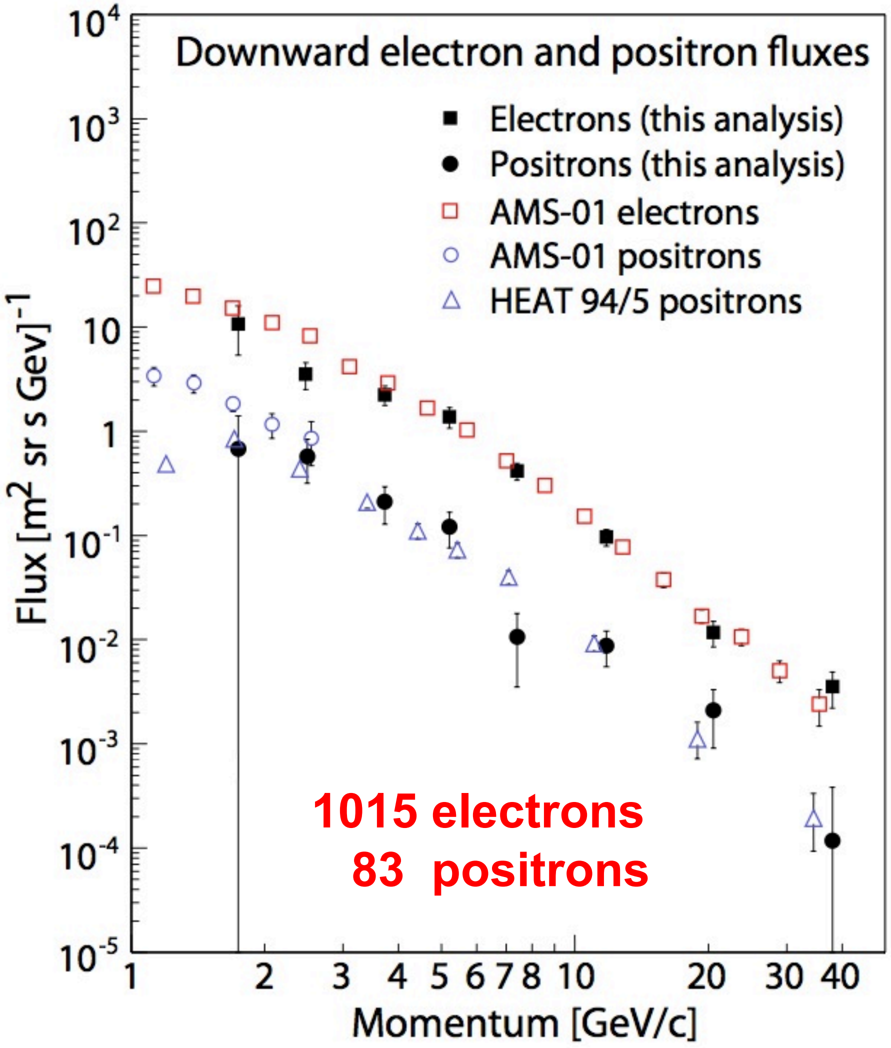
- Energy Range:
  100 MeV/n$<E_k<$ 300 GeV/n
- Electronics channels: 70000
- Power: 1 kW
- Weight: 3 t



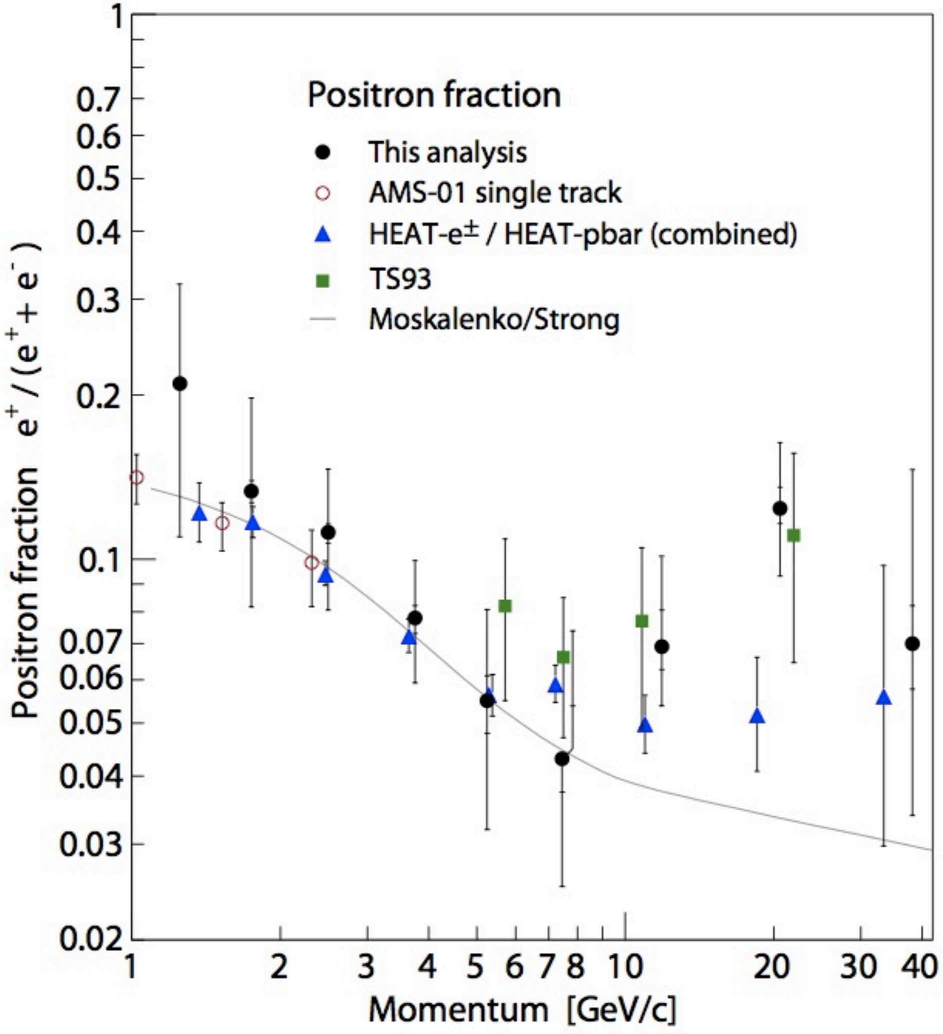


AMS-01

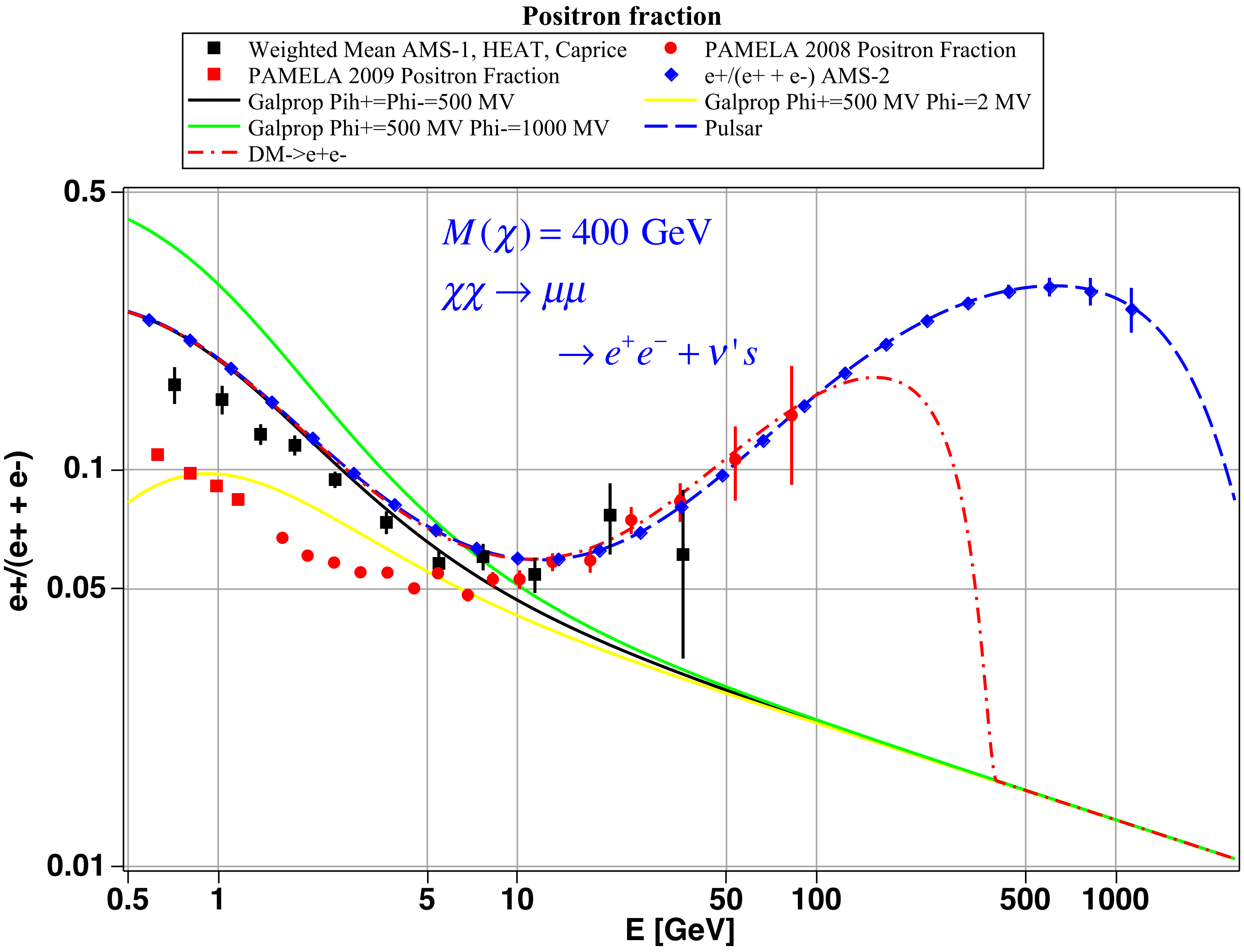
Using a purely geometric method (Bremstrahlung + Conversion)
we identified in the AMS-01 data sample clean electrons & positrons
Physics Letters B 646 (2007) 145–154



1015 electrons
83 positrons



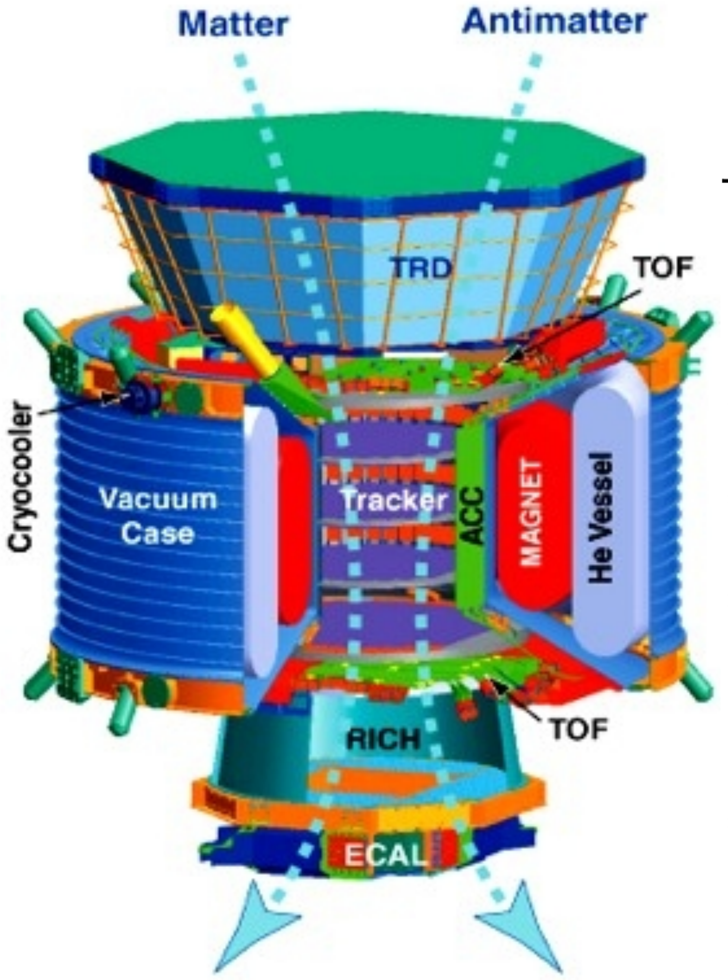
Signatures of dark matter annihilation in charged cosmic rays ?



Positron fraction

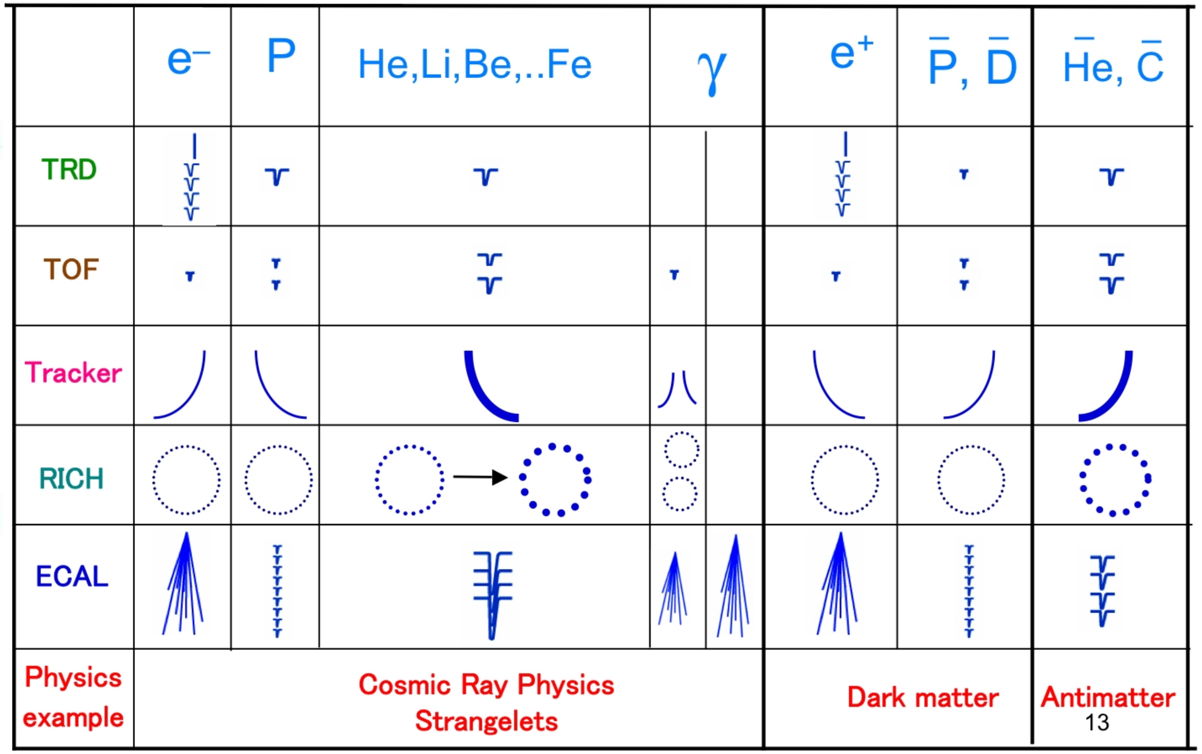
B.Beischer et al. *NewJournal ofPhysics***11(2009)105021**

Das Alpha Magnetic Spectrometer Experiment



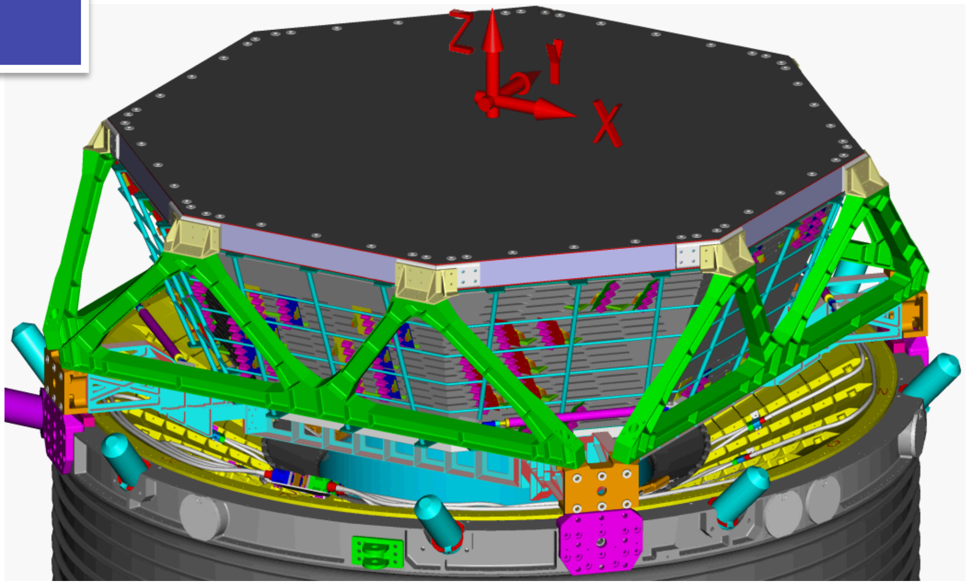
Characteristics of AMS–02

$\Delta t = 100$ ps, $\Delta x = 10$ μm, $\Delta v/v = 0.001$



	e^-	P	He,Li,Be,..Fe	γ	e^+	$\bar{P}$, $\bar{D}$	$\overline{He}$, $\bar{C}$
TRD							
TOF							
Tracker							
RICH							
ECAL							
Physics example	Cosmic Ray Physics Strangelets				Dark matter		Antimatter

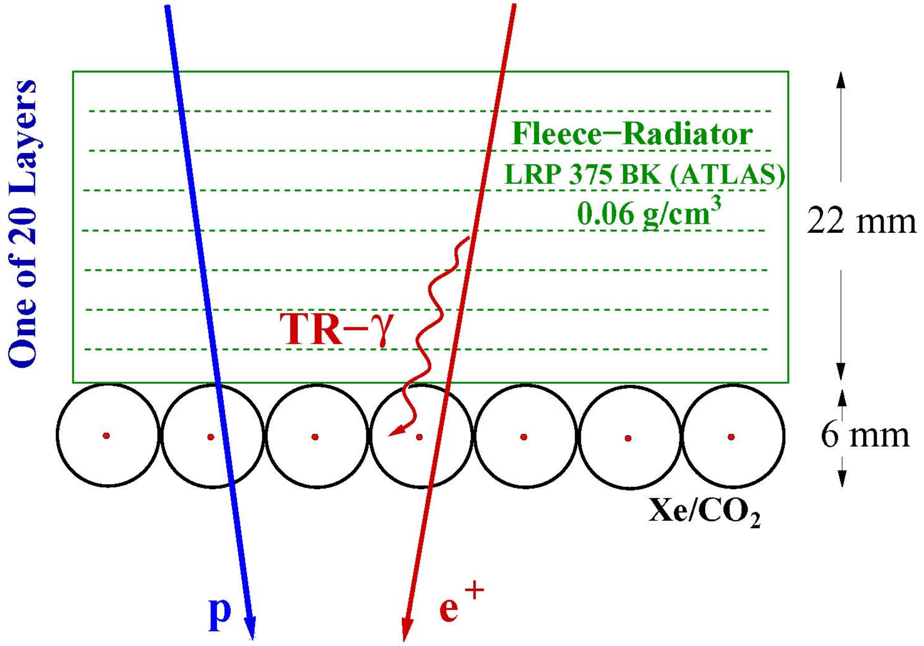
Transition Radiation Detector



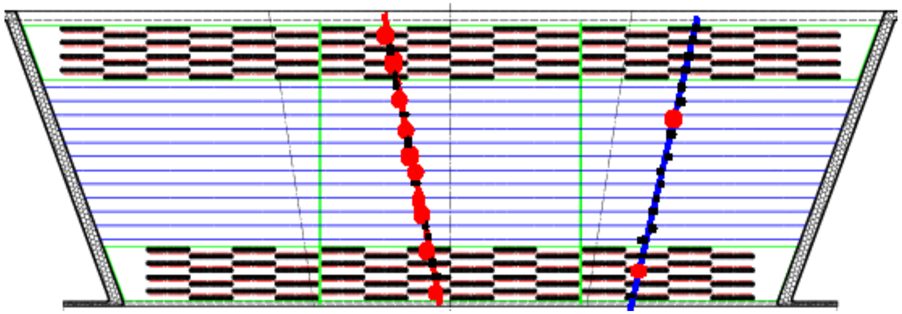
p^+ rejection $>10^2$ 1-300 GeV
acceptance: $0.5m^2sr$

Choosen configuration for 60 cm height:
20 Layers each existing of:

- **22 mm fibre fleece**
- **Ø 6 mm straw tubes**
  filled with Xe/CO_2 80%/20%



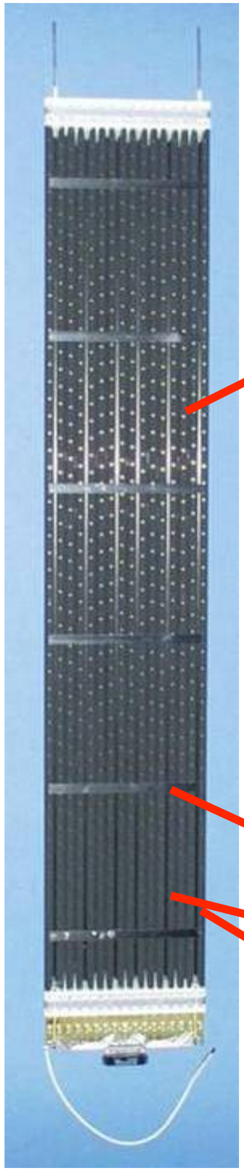
12 layers in the bending plane
2 x 4 layers in the non-bending plane

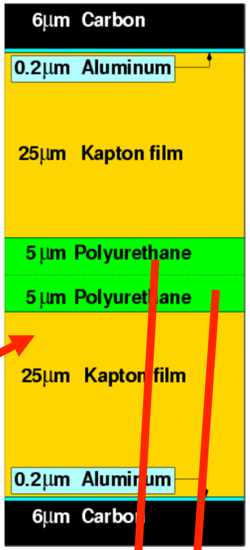


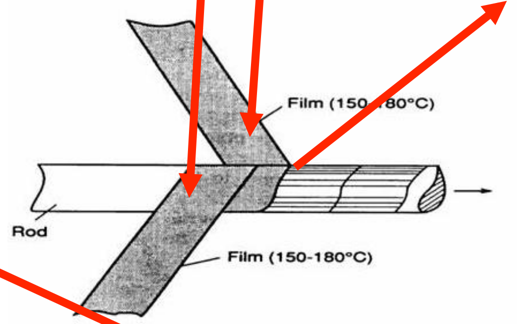
Straw Module

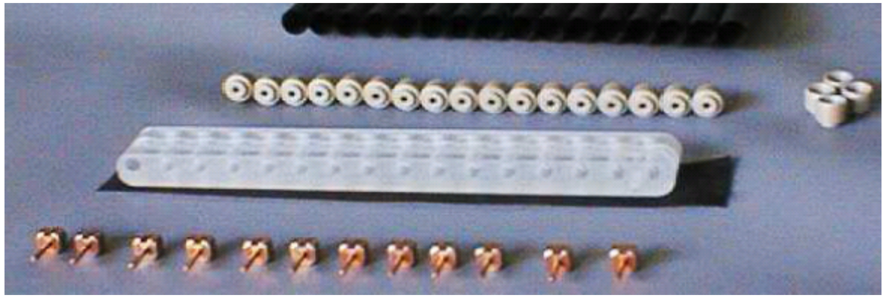
Straw tube proportional counter modules:

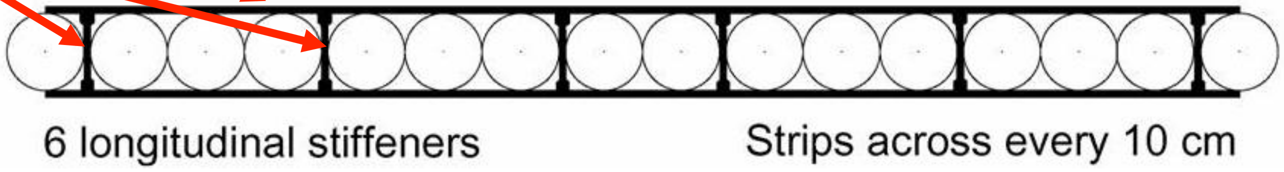
- Straw tubes: 72 µm multilayer aluminium kapton foil,
  Ø 6 mm , 0.8 ÷ 2.0 m length
- Wire: tungsten anode wire, 30 µm Ø, tension ≈ 100 g
- Gas mixture: Xe / CO_2 (80% / 20%)
- Operating HV ~ 1380 V → Gasgain of ~ 3000
- 1 Module → 16 Straws, 100 µm mechanical accuracy
- 328 Modules → 5248 Straws



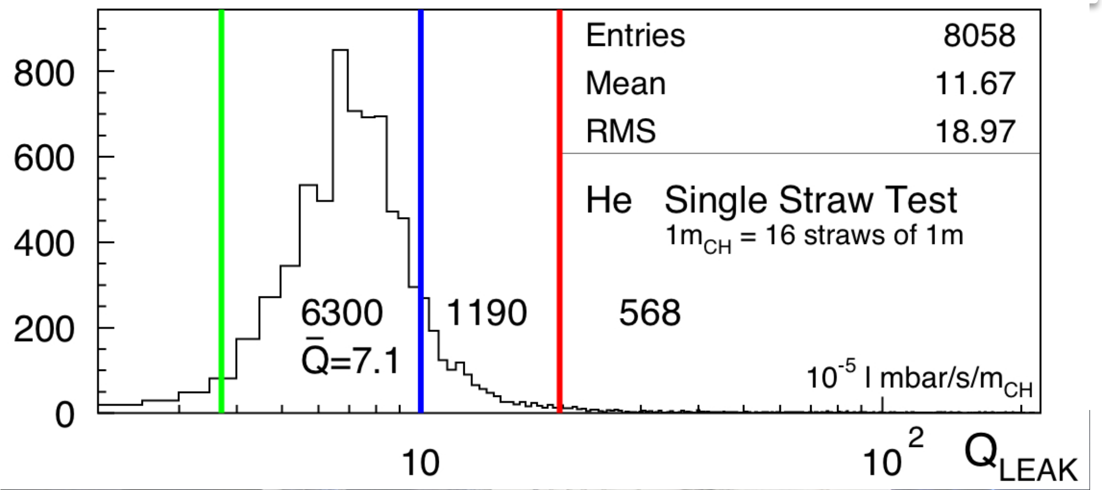


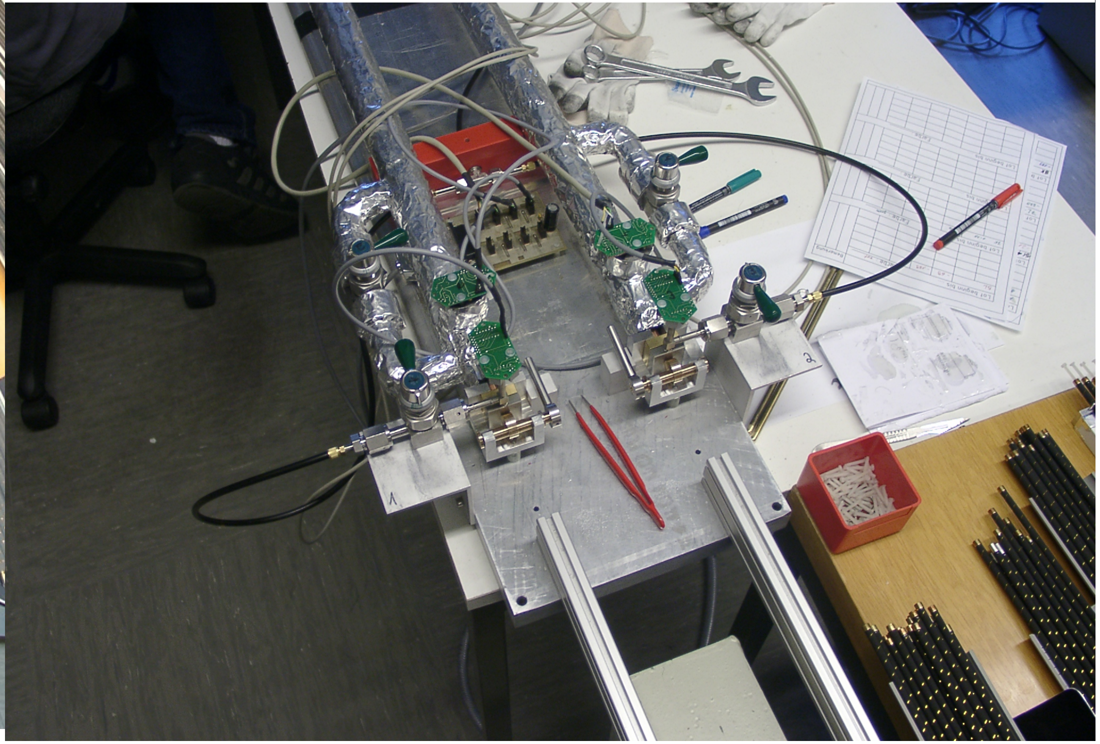




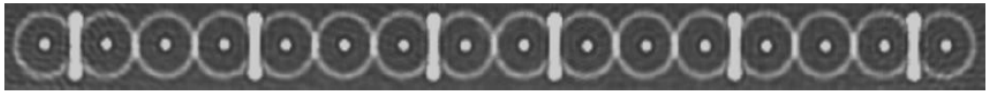


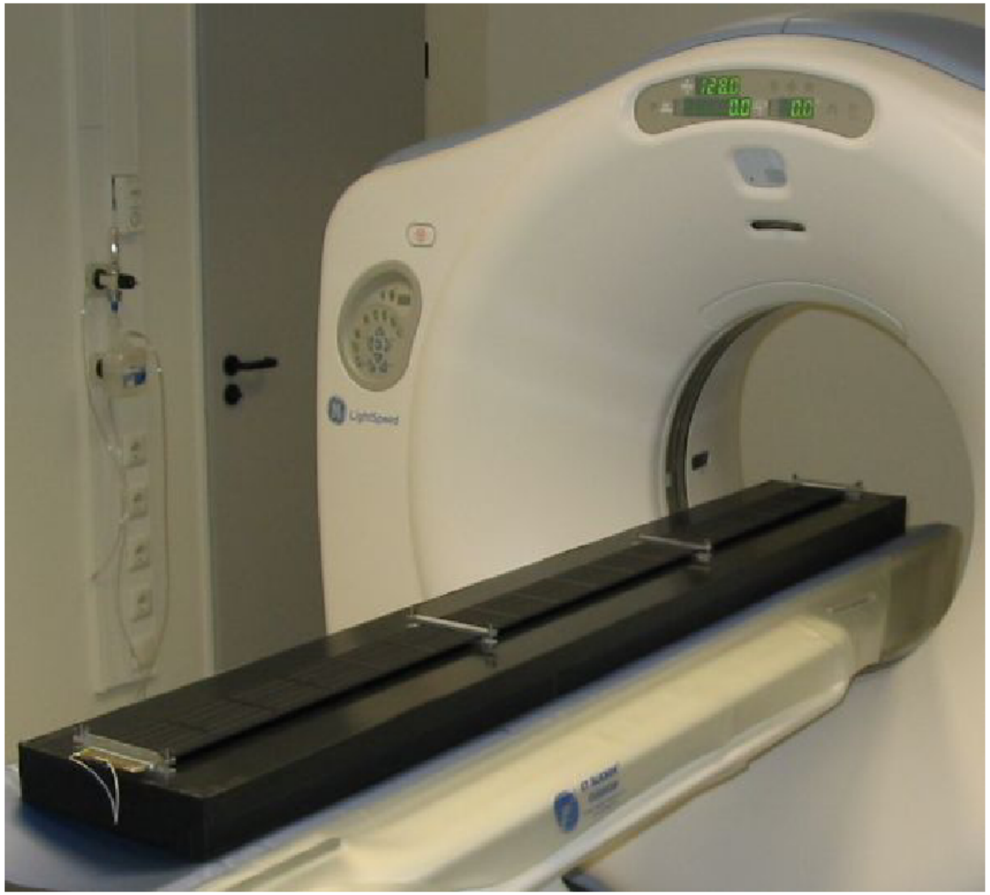
TRD single Straw Test to select 5248 good straws



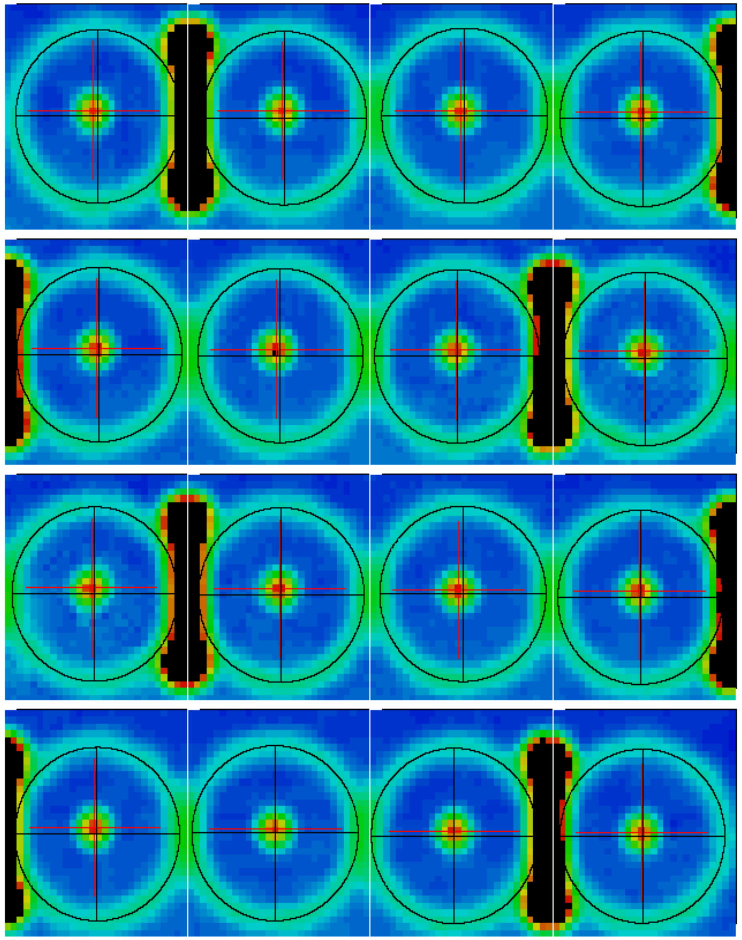


TRD Module Computer-Tomography X-Ray Scan

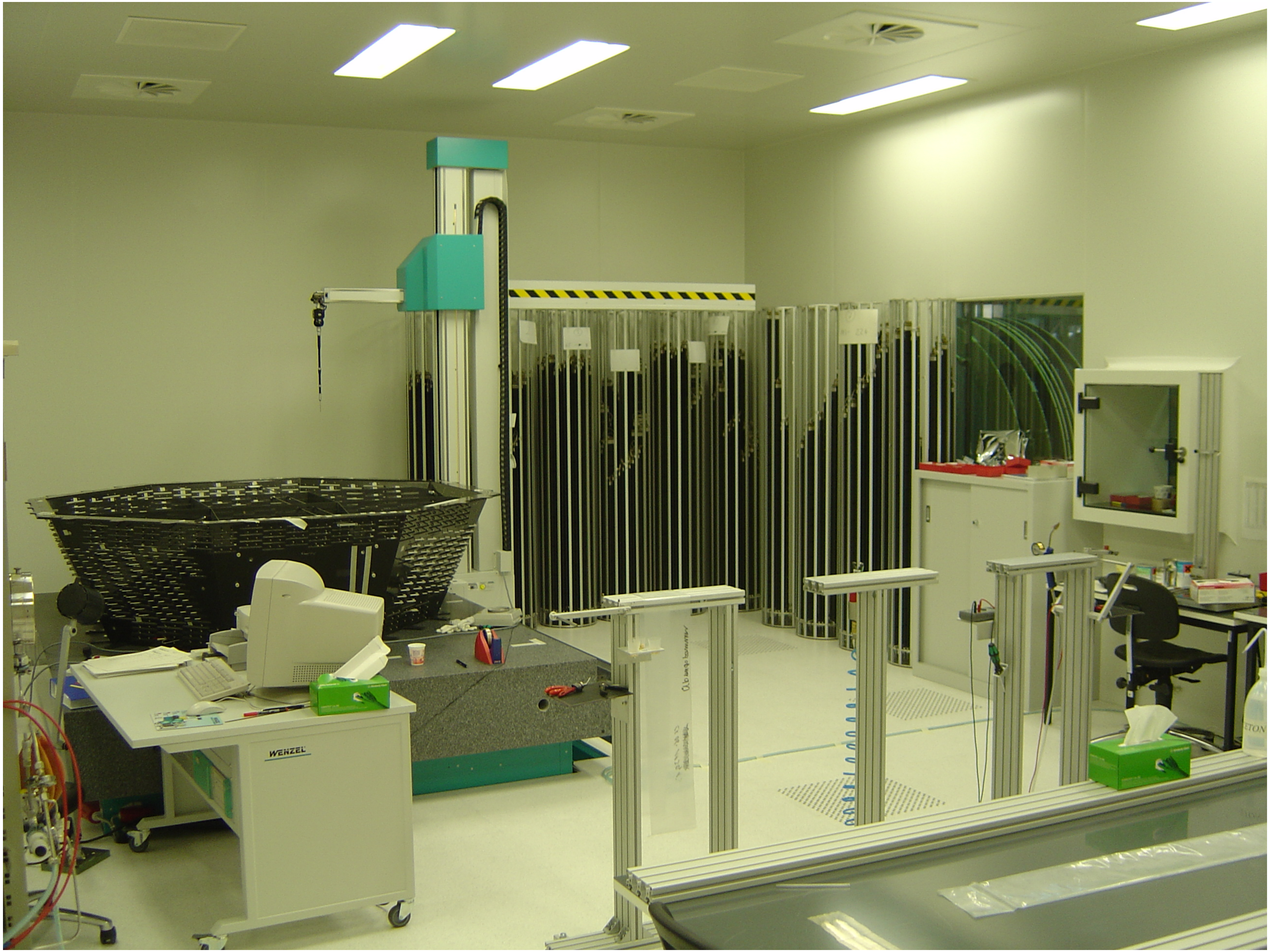




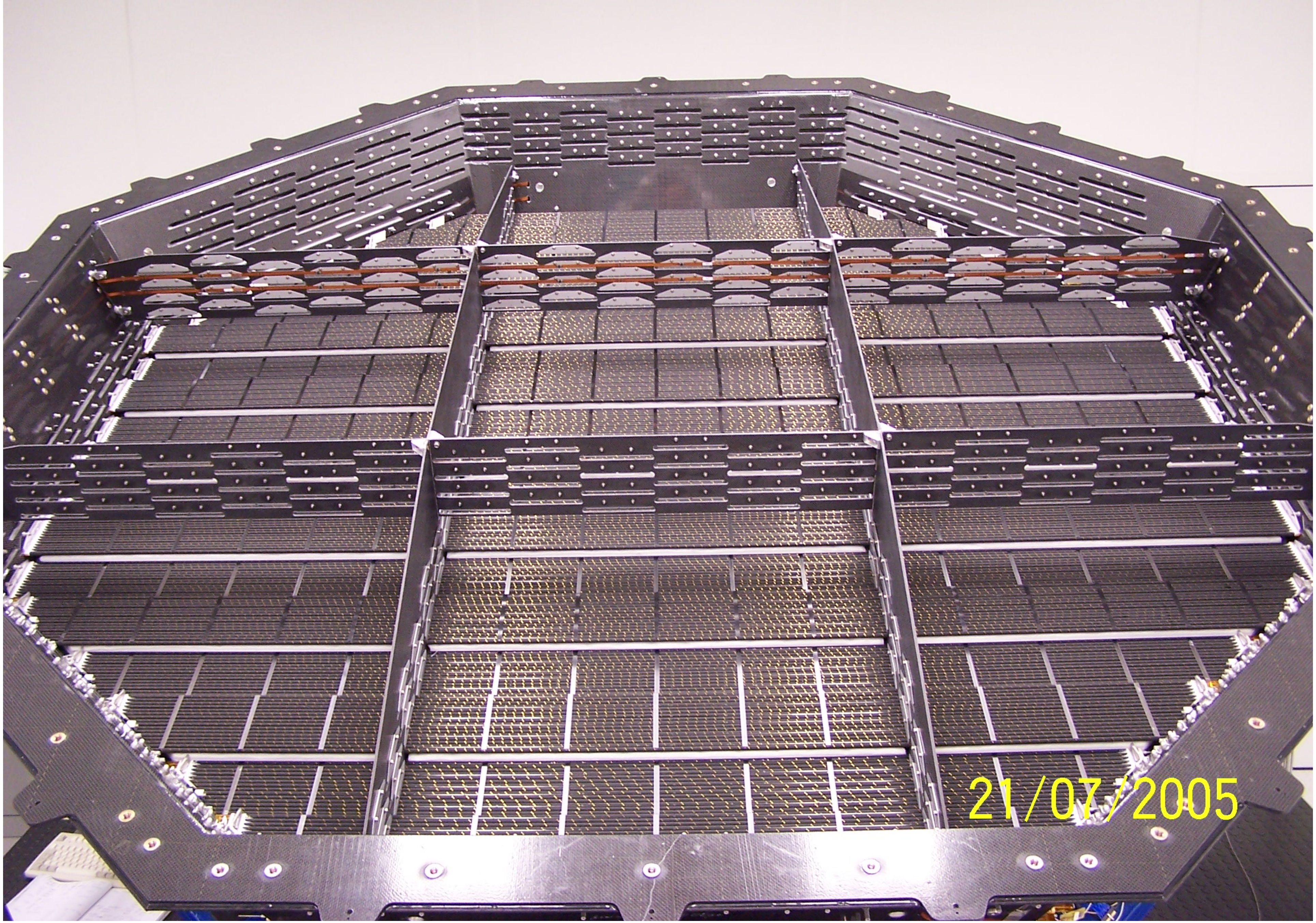
Luisenhospital Aachen (GE 16-Channel CT)



Wire- and Tube-xy-Fit ($\sigma \approx 10\mu m$)

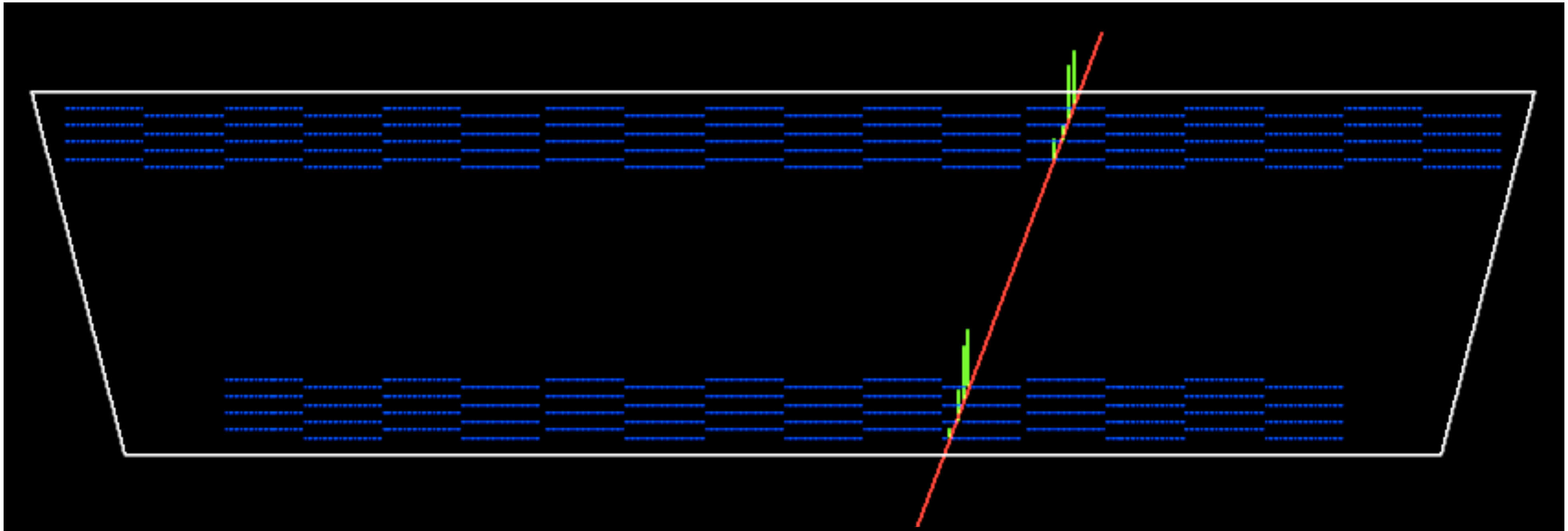

WENZEL

AMS-02 Transition Radiation Detector



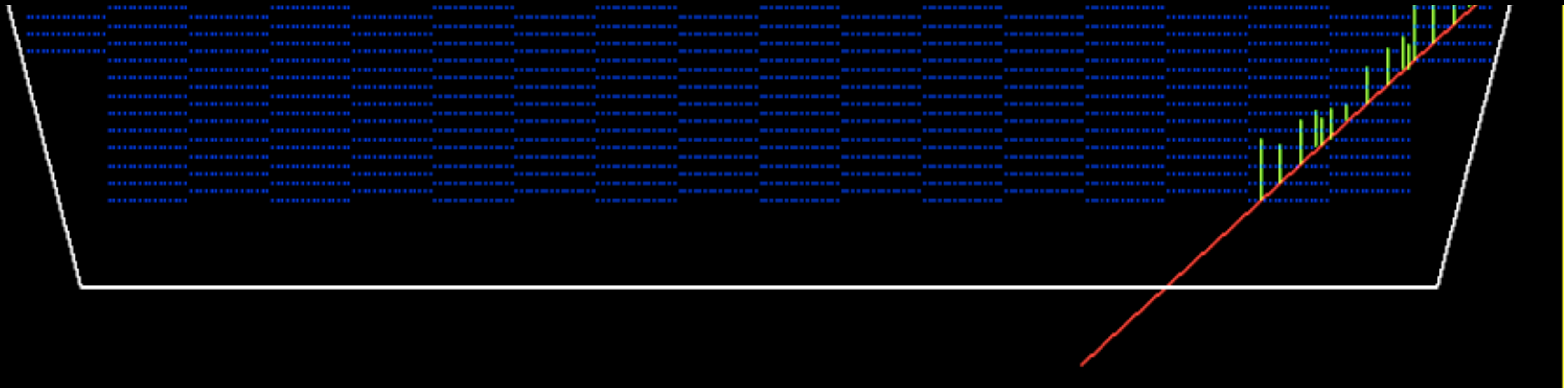
21/07/2005

Fertiggestellt nach einer Bauzeit von 10 Jahren

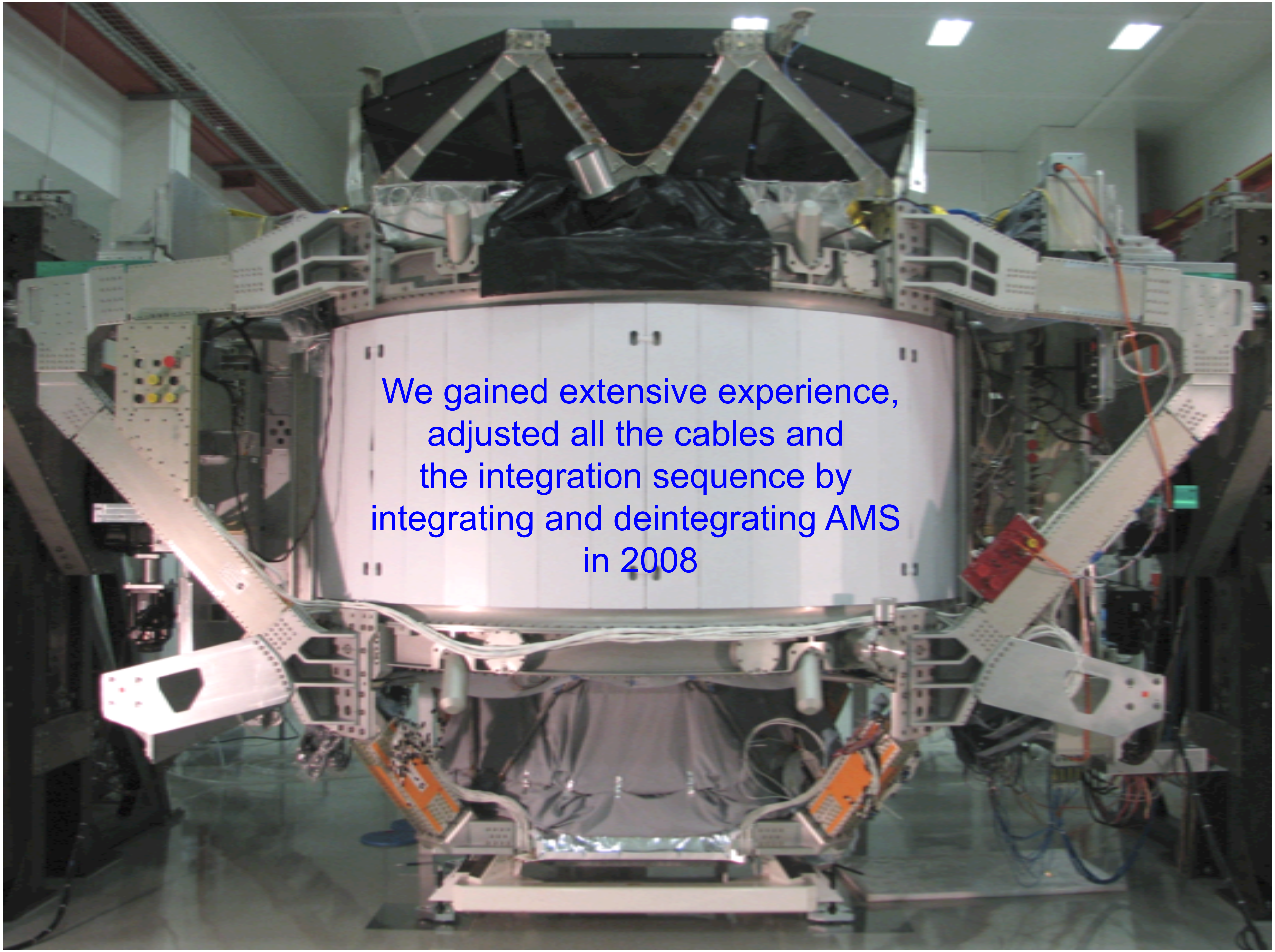


Der AMS-2 TRD wurde 1 Monat lang intensiv in Aachen mit Muonen aus der kosmischen Höhenstrahlung getestet, bevor er zum CERN transportiert wurde.

Alle 5248 Einzelröhrchen arbeiten einwandfrei!

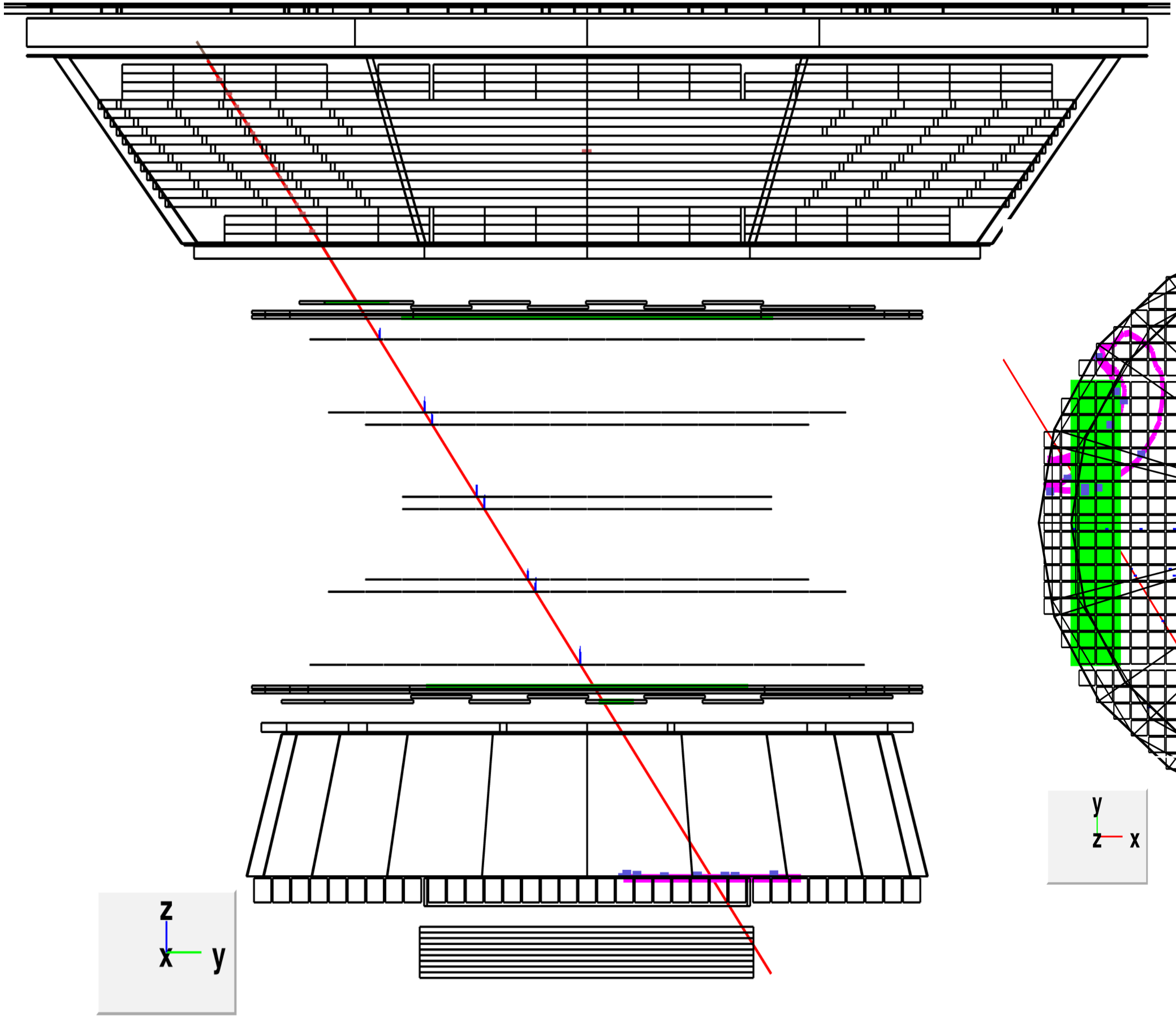



1000 KG
WLL 100

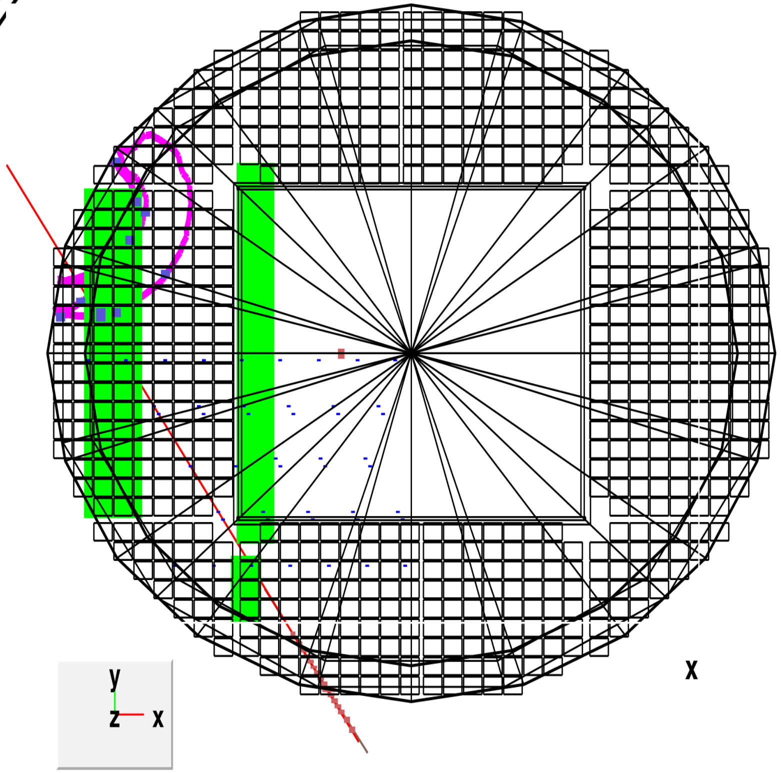


We gained extensive experience,
adjusted all the cables and
the integration sequence by
integrating and deintegrating AMS
in 2008

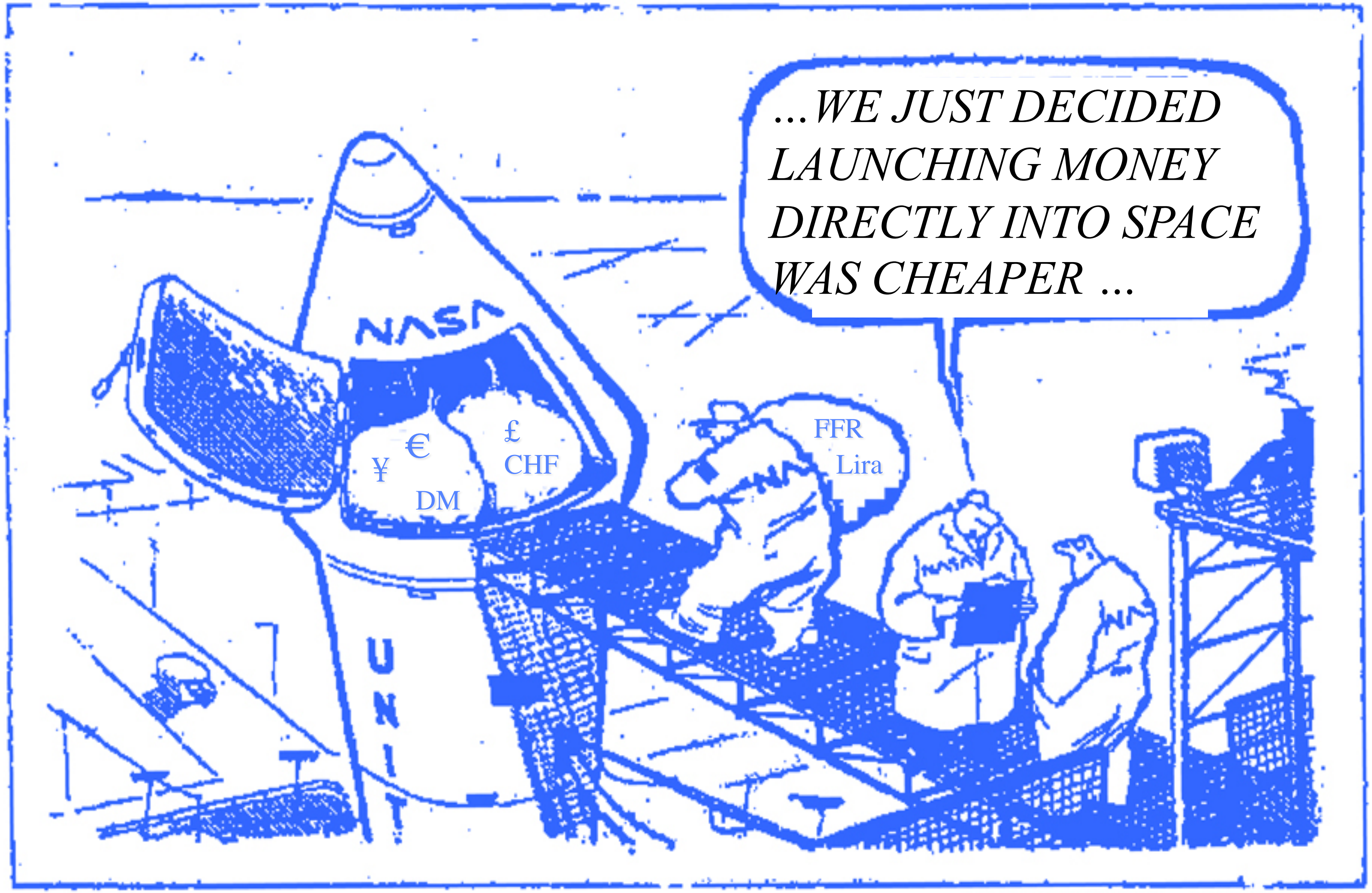
A cosmic ray event seen by all AMS detectors



Side view



Top view



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Visit of Senator Bill Nelson - March 16, 2008

Dr. B. Accoyer, M.D. , *President, French National Assembly*

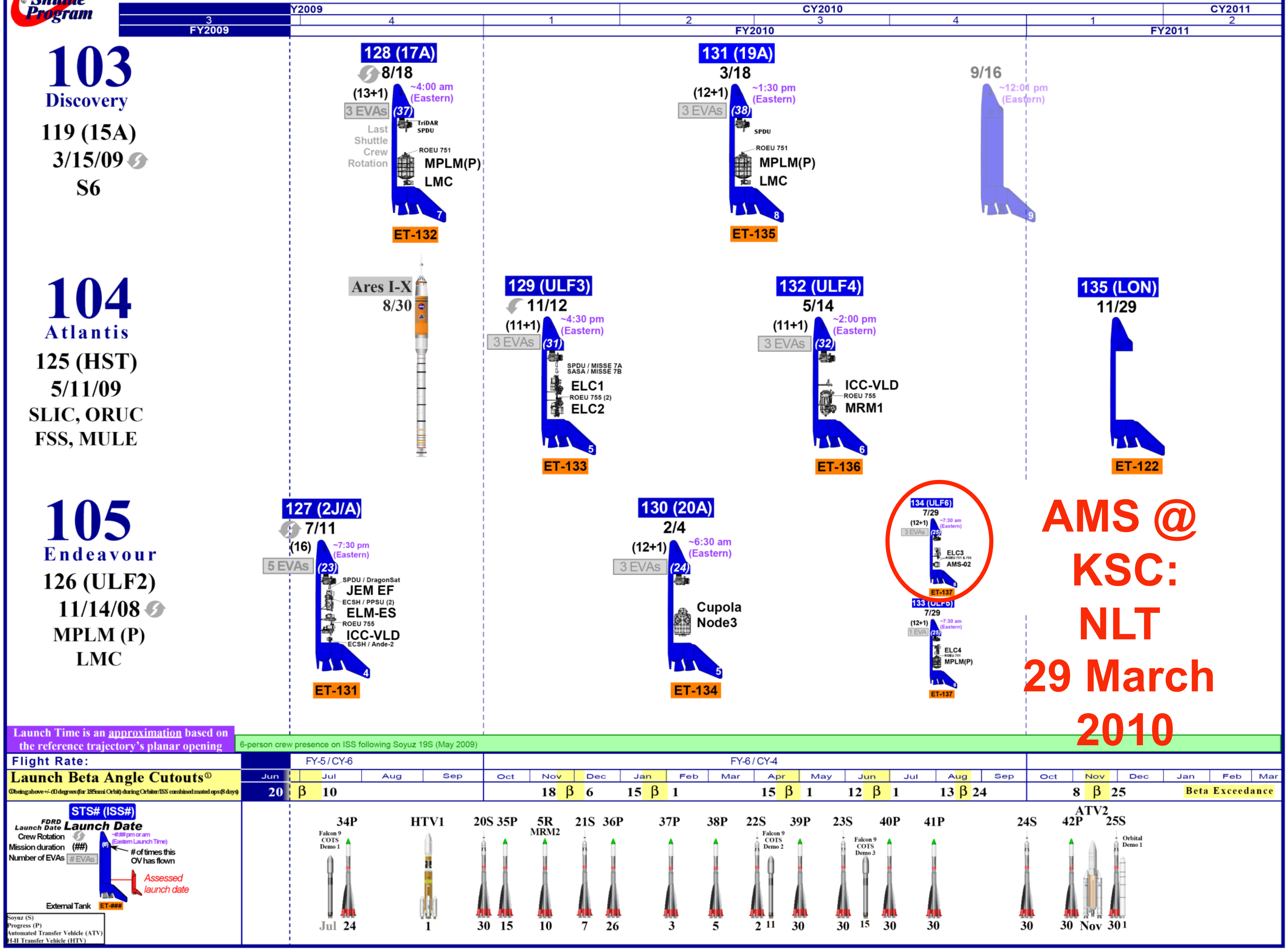
Professor G. Bignami, *President, Italian Space Agency (ASI)*

Prof. Dr.-Ing. J-D Woerner, *President, German Space Agency (DLR)*

Dr. M. Serrano, *Head, Spanish Space Program (CDTI)*

Space Shuttle Program (SSP) Manifest

NASA Official: *John Coggeshall*
USA Project Lead: *Barton K. Gibson*
Chart updated: 25-Jun-2009



CY2009 | CY2010 | CY2011
FY2009: 3 | FY2010: 4, 1, 2, 3 | FY2011: 4, 1, 2

103 Discovery
119 (15A)
3/15/09
S6

- **128 (17A)** 8/18 (13+1) ~4:00 am (Eastern) 3 EVAs (37) Last Shuttle Crew Rotation; TriDAR SPDU; ROEU 751; MPLM(P); LMC; 7; ET-132
- **131 (19A)** 3/18 (12+1) ~1:30 pm (Eastern) 3 EVAs (38) SPDU; ROEU 751; MPLM(P); LMC; 8; ET-135
- 9/16 ~12:01 pm (Eastern) 9

104 Atlantis
125 (HST)
5/11/09
SLIC, ORUC
FSS, MULE

- **Ares I-X** 8/30
- **129 (ULF3)** 11/12 (11+1) ~4:30 pm (Eastern) 3 EVAs (31) SPDU / MISSE 7A; SASA / MISSE 7B; ELC1; ROEU 755 (2); ELC2; 5; ET-133
- **132 (ULF4)** 5/14 (11+1) ~2:00 pm (Eastern) 3 EVAs (32) ICC-VLD; ROEU 755; MRM1; 6; ET-136
- **135 (LON)** 11/29; ET-122

105 Endeavour
126 (ULF2)
11/14/08
MPLM (P)
LMC

- **127 (2J/A)** 7/11 (16) ~7:30 pm (Eastern) 5 EVAs (23) SPDU / DragonSat; JEM EF; ECSH / PPSU (2); ELM-ES; ROEU 755; ICC-VLD; ECSH / Ande-2; 4; ET-131
- **130 (20A)** 2/4 (12+1) ~6:30 am (Eastern) 3 EVAs (24) Cupola; Node3; 5; ET-134
- **134 (ULF6)** 7/29 (12+1) ~7:30 am (Eastern) 3 EVAs (25) ELC3; ROEU 751 & 755; AMS-02; 6; ET-137
- **133 (ULF5)** 7/29 (12+1) ~7:30 am (Eastern) 1 EVA (25) ELC4; ROEU 751; MPLM(P); 6; ET-137

AMS @ KSC: NLT 29 March 2010

Launch Time is an approximation based on the reference trajectory's planar opening

6-person crew presence on ISS following Soyuz 19S (May 2009)

Flight Rate: FY-5 / CY-6 | FY-6 / CY-4

Launch Beta Angle Cutouts①
①being above +/- 60 degrees (for 185nmi Orbit) during Orbiter/ISS combined mated ops (8 days)

Jun 20 β Jul 10 | Nov 18 β Dec 6 | Jan 15 β Feb 1 | Apr 15 β May 1 | Jun 12 β Jul 1 | Aug 13 β 24 | Nov 8 β 25 | Beta Exceedance

STS# (ISS#)
FDRD Launch Date **Launch Date**
Crew Rotation
Mission duration (##)
Number of EVAs # EVAs
~#:## pm or am (Eastern Launch Time)
(#) # of times this OV has flown
Assessed launch date
External Tank ET-###

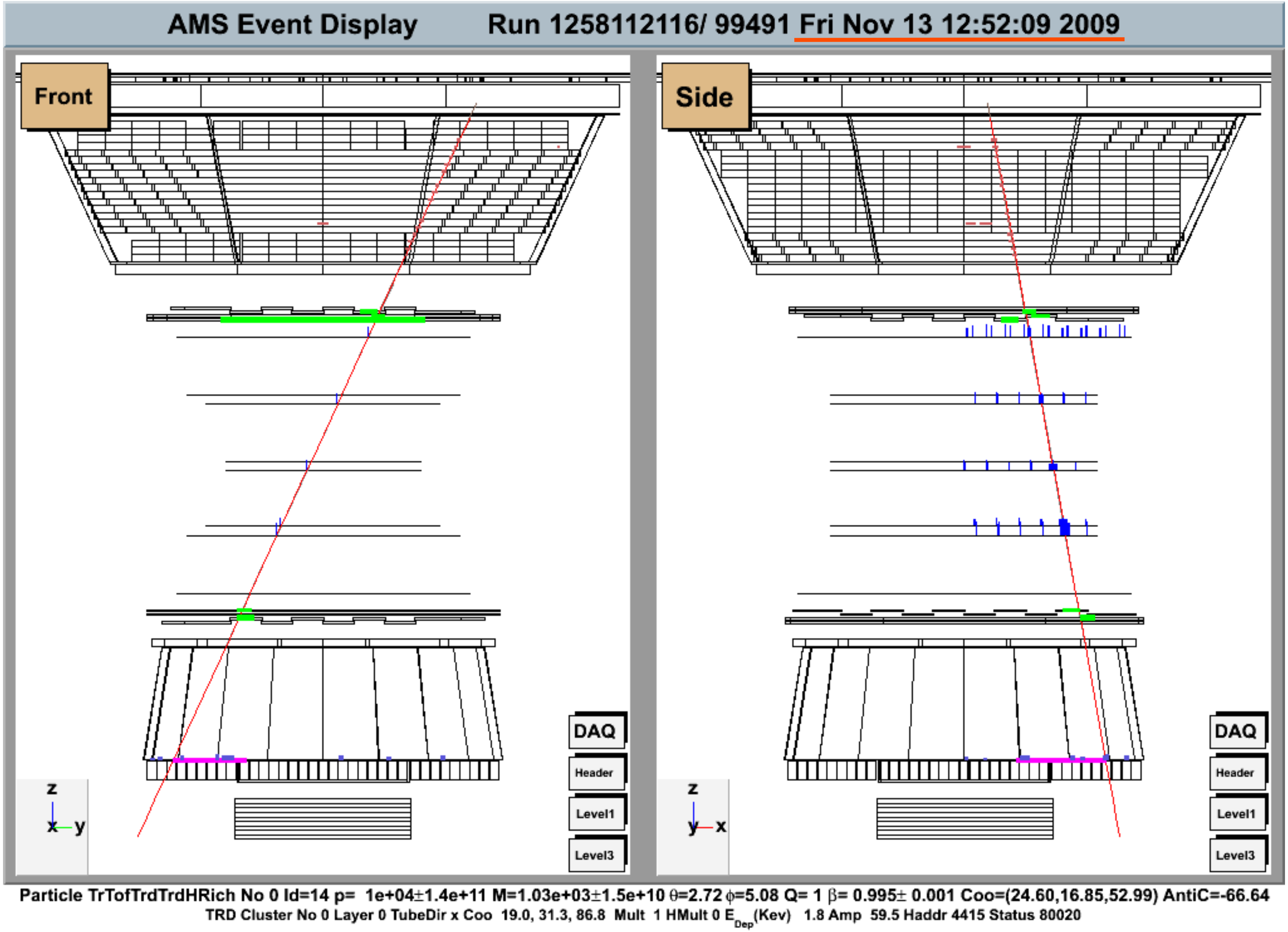
Soyuz (S)
Progress (P)
Automated Transfer Vehicle (ATV)
H-II Transfer Vehicle (HTV)

34P Jul 24; Falcon 9 COTS Demo 1 Jul; HTV1 1; 20S 30; 35P 15; 5R MRM2 10; 21S 7; 36P 26; 37P 3; 38P 5; 22S 2; Falcon 9 COTS Demo 2 11; 39P 30; 23S 30; Falcon 9 COTS Demo 3 15; 40P 30; 41P 30; 24S 30; 42P 30; ATV2 Nov; 25S 30; Orbital Demo 1 1

October 2009

18.11.2009

Video format: Motion JPEG

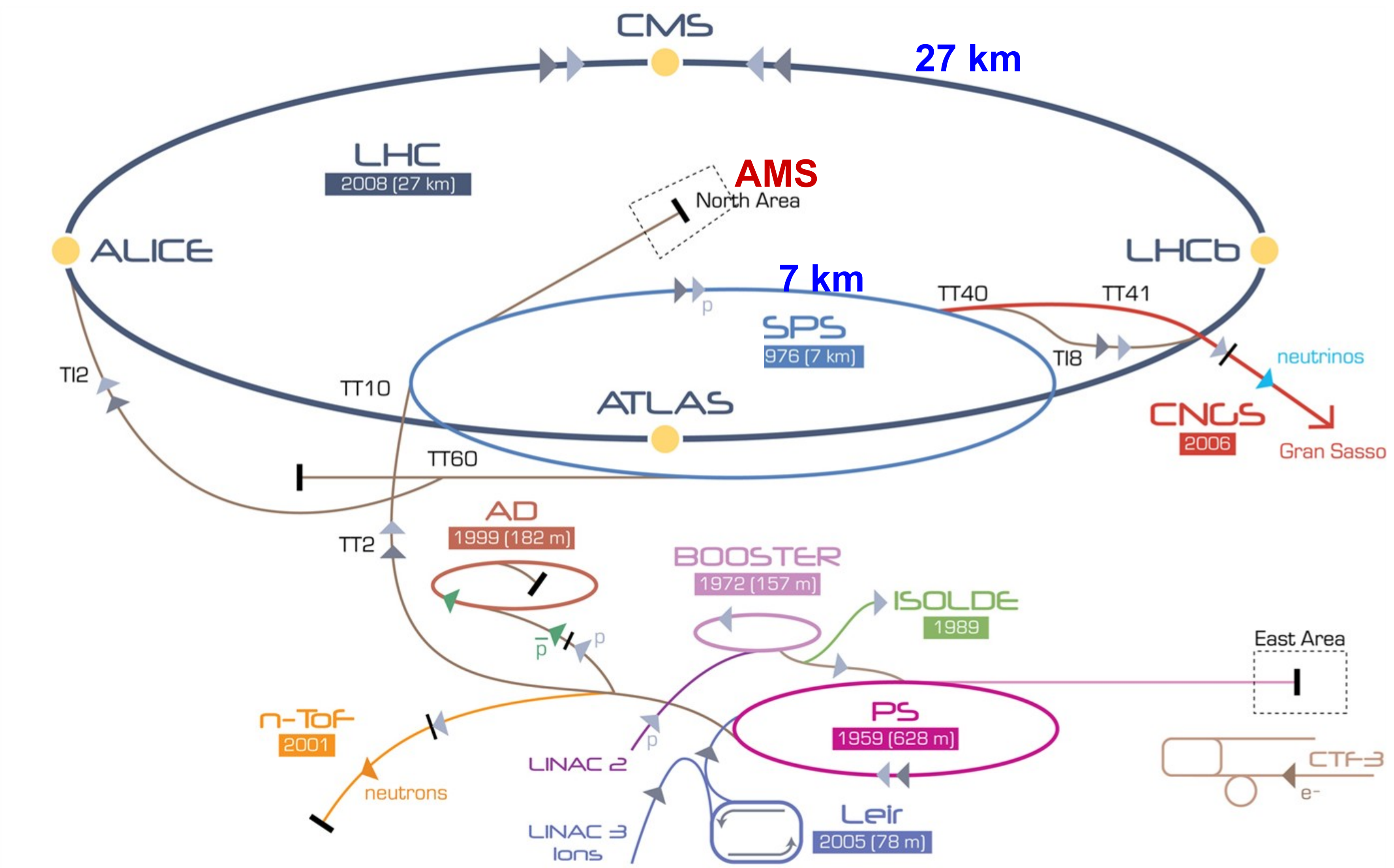


AMS Event Display Run 1258112116/ 99491 Fri Nov 13 12:52:09 2009

Particle TrTofTrdTrdHRich No 0 Id=14 p= 1e+04±1.4e+11 M=1.03e+03±1.5e+10 θ=2.72 ϕ=5.08 Q= 1 β= 0.995± 0.001 Coo=(24.60,16.85,52.99) AntiC=-66.64

TRD Cluster No 0 Layer 0 TubeDir x Coo 19.0, 31.3, 86.8 Mult 1 HMult 0 E_{Dep}(Kev) 1.8 Amp 59.5 Haddr 4415 Status 80020

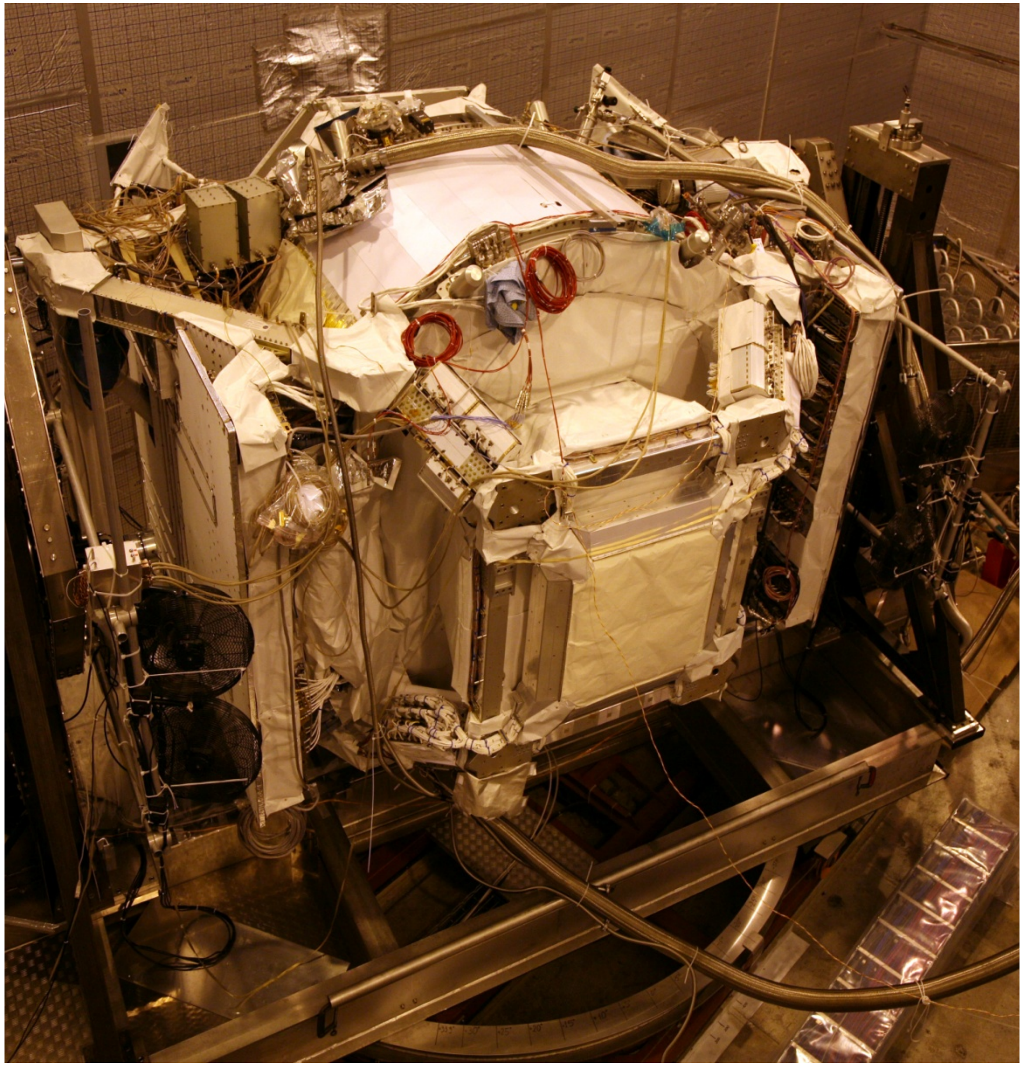
Test at CERN
AMS in accelerator test beam Feb 4-8, 2010

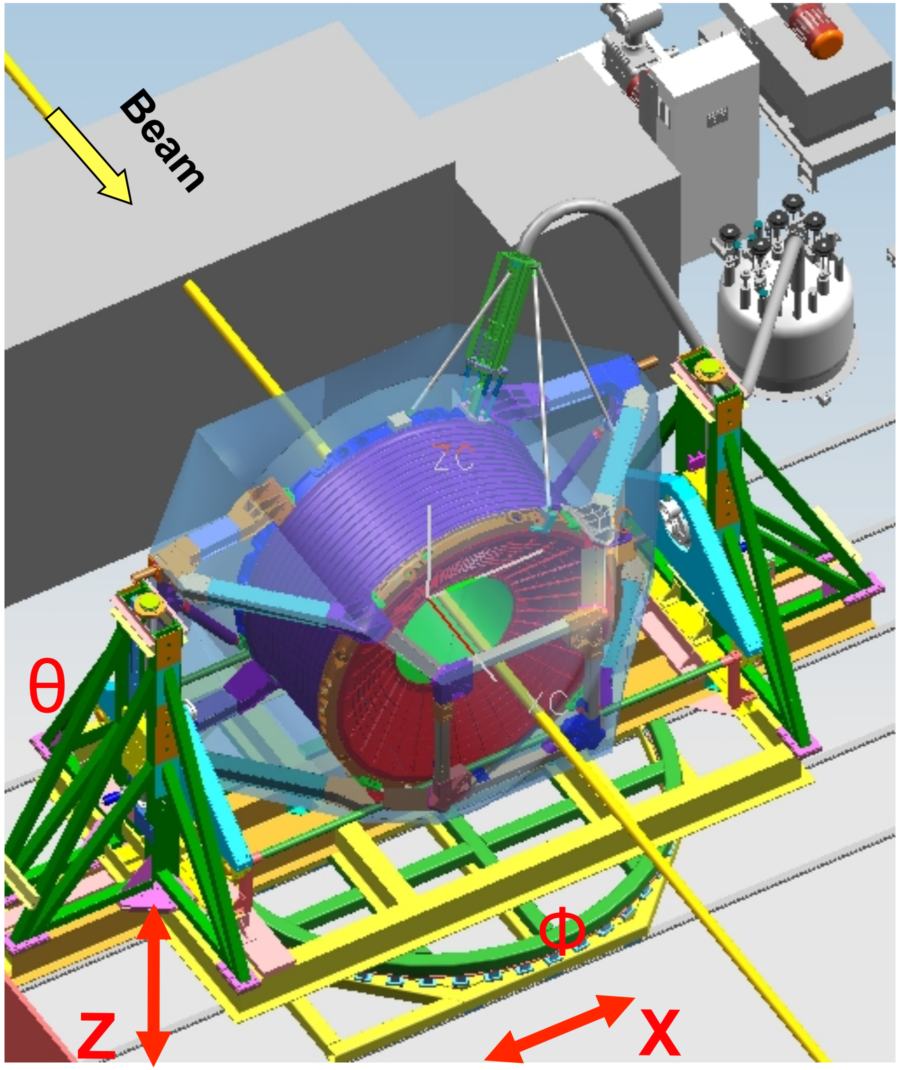


CERN Accelerator Complex

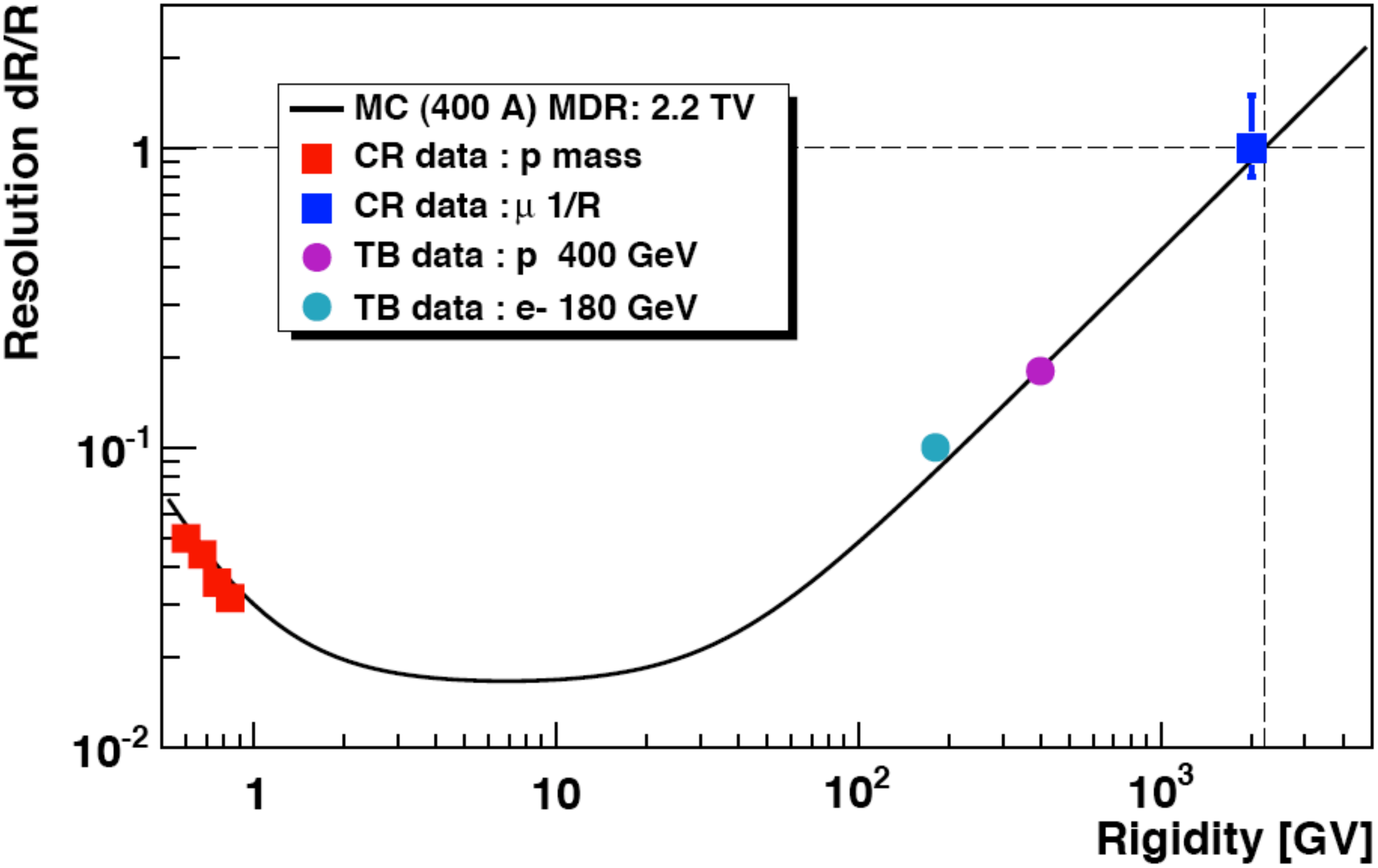
AMS in Test Beam

Feb 4-8, 2010

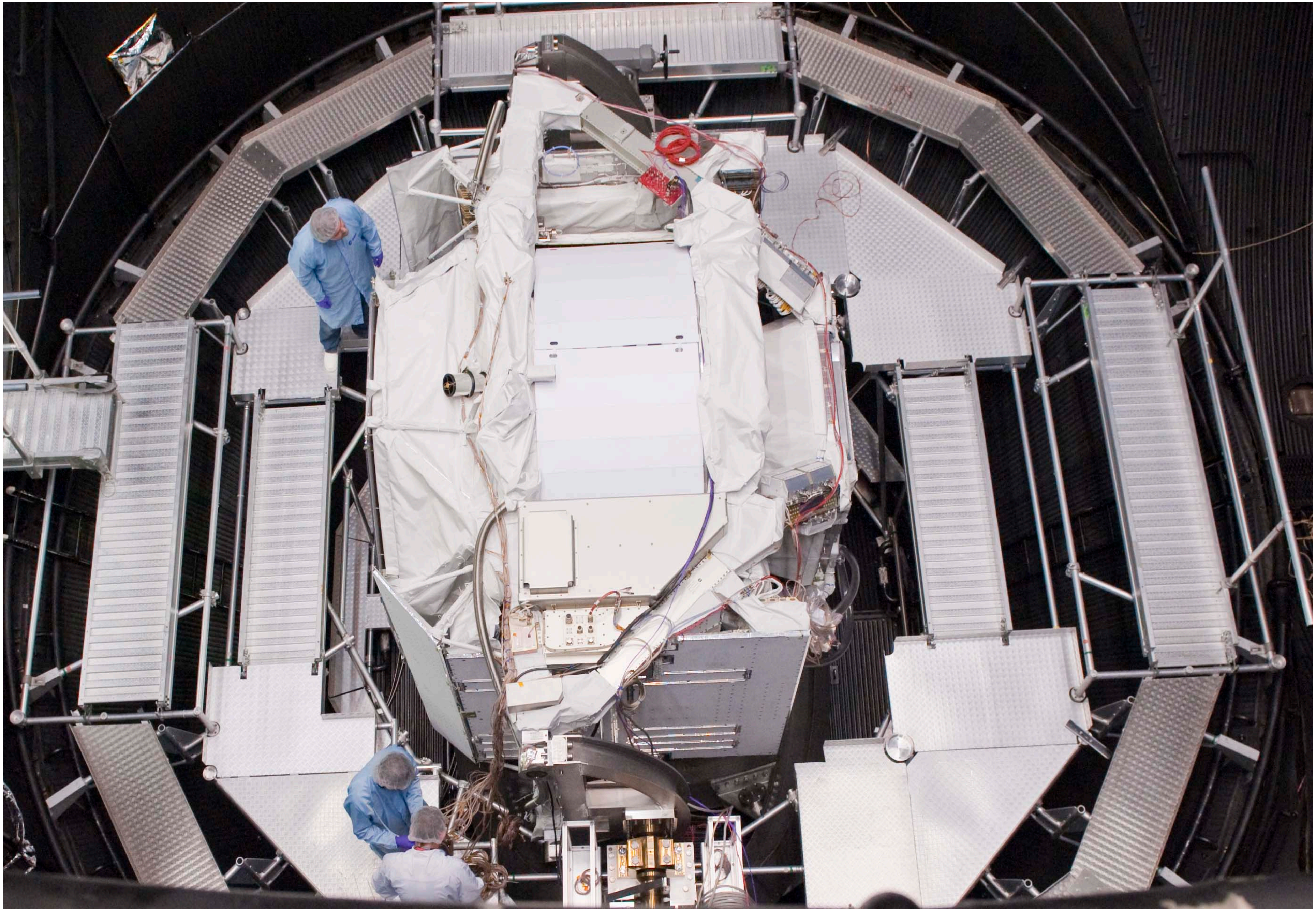




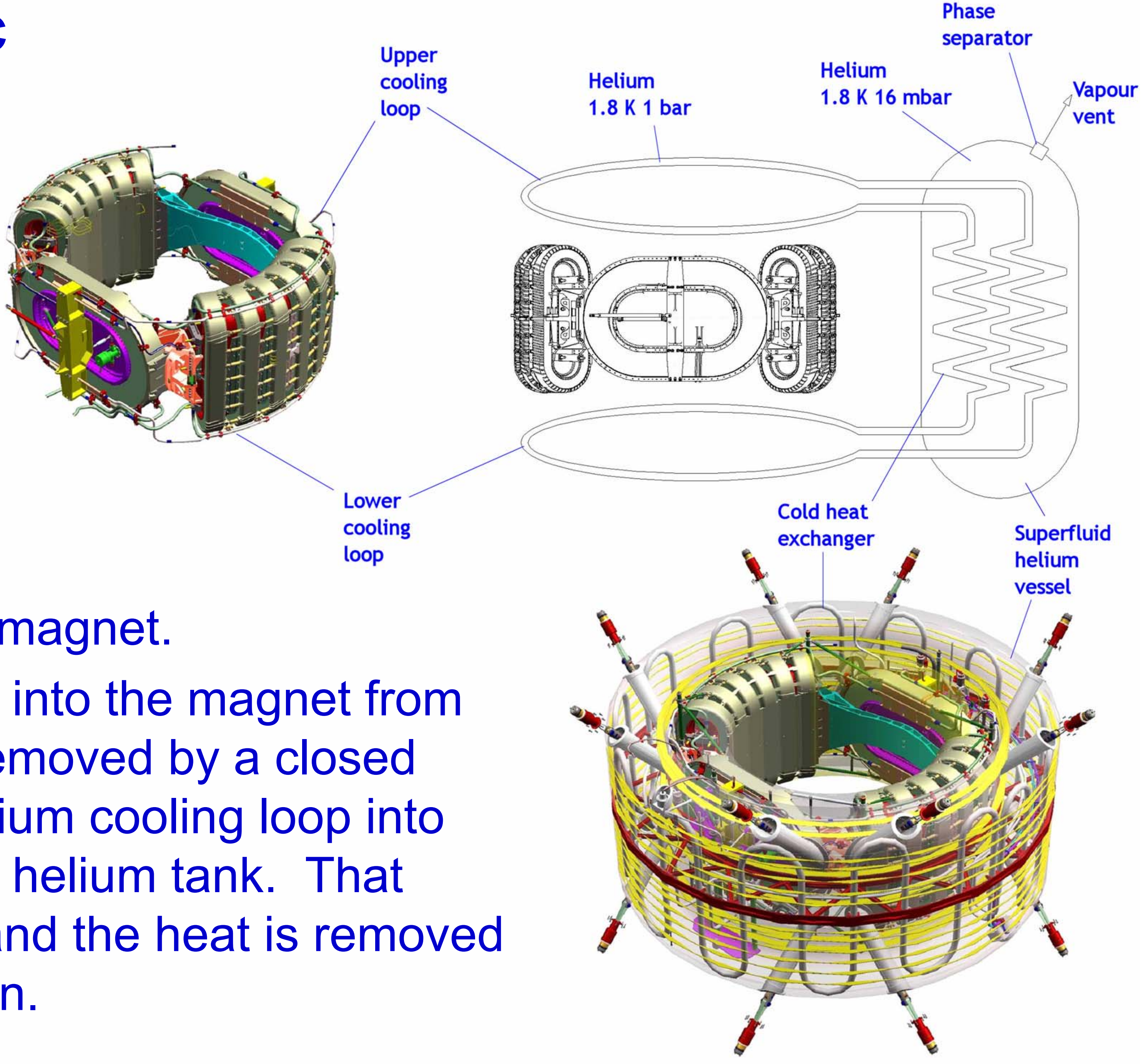
Test Beam 2010 : momentum resolution of the spectrometer



12.February 2010 - 16. Febrauary 2010:
AMS-02 Transport from CERN, Geneva to ESTEC, Noordwijk



Cryogenic thermal design for AMS



AMS is a dry magnet.

As heat leaks into the magnet from outside it is removed by a closed superfluid helium cooling loop into the superfluid helium tank. That helium boils and the heat is removed by evaporation.

130 layers of Multi-Layer Insulation

with instrumentation and plumbing heat stationed to it.

Heat load Breakdown

	Room	TVT(242K)	ISS(250K)
• Radiation	120mW	20mW	(20mW)
• Straps (+ …)	260mW	130mW	(130mW)
• Cryocoolers (eff)	0mW	70mW	(0mW)
• Current Leads	240mW	160mW	(10mW)
• Actuation lines	100mW	100mW	(0mW)
• Instrumentation	20mW	10mW	(2mW)
• **Total**	**720mW**	**490mW**	**(160mW)**

Expected life time of the AMS Cryostat on ISS

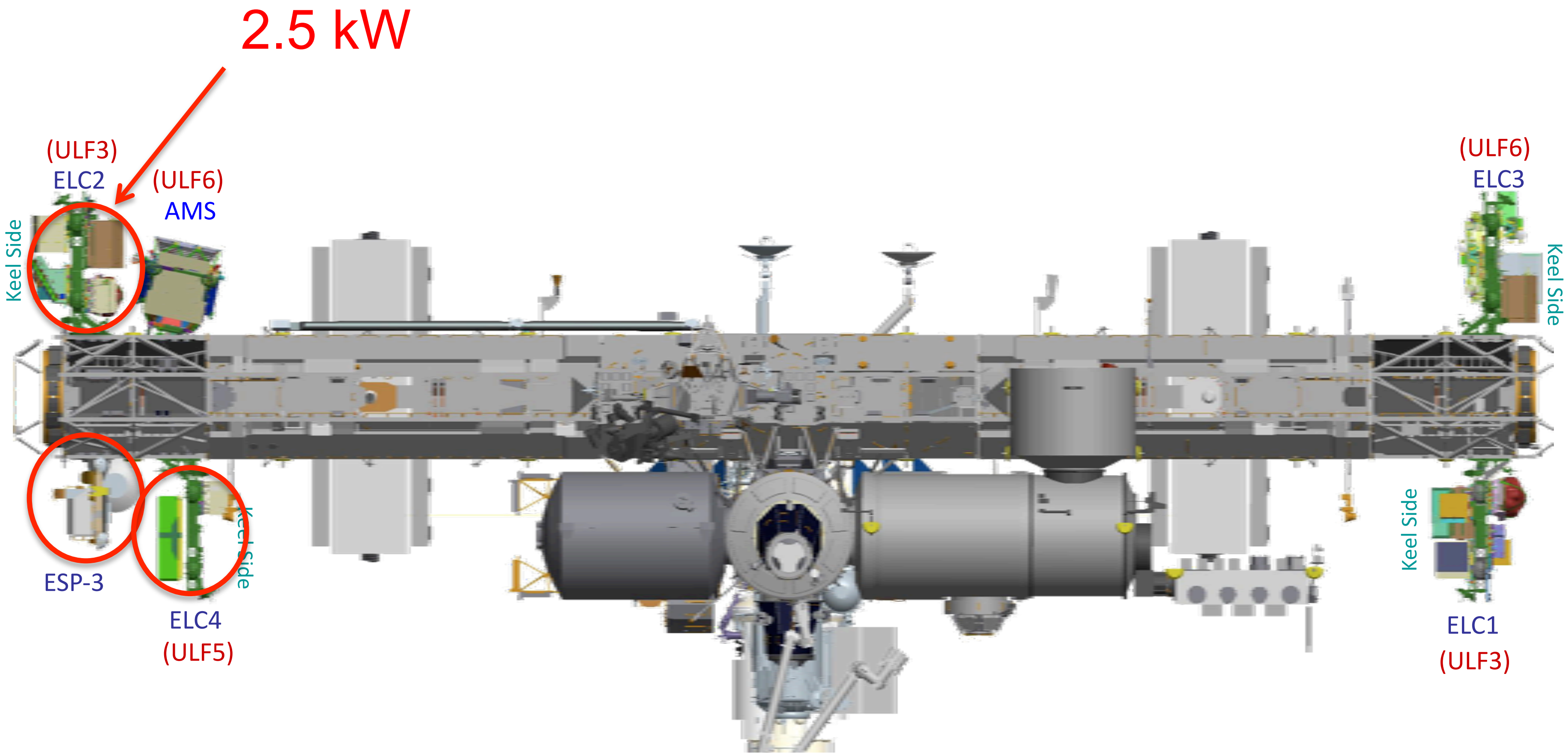
20±4 months

(28±6 months with GT cryocoolers)

Uncertainties:

Accuracy of Heat Load estimates	**– 15%**
Nearby Payloads on ISS	**– 9%**
Waiting time on the launch pad	**– 8%**
ISS attitude control	**– 6%**

Truss Attach Site Usage



2.5 kW

<u>Notes</u>: 1. MISSE-7 PECs are returned on ULF6 and MISSE-8 PEC is launched on ULF6
2. ESP-3 relocation to S3LO planned for 21S Stage (see CR 11648).

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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.

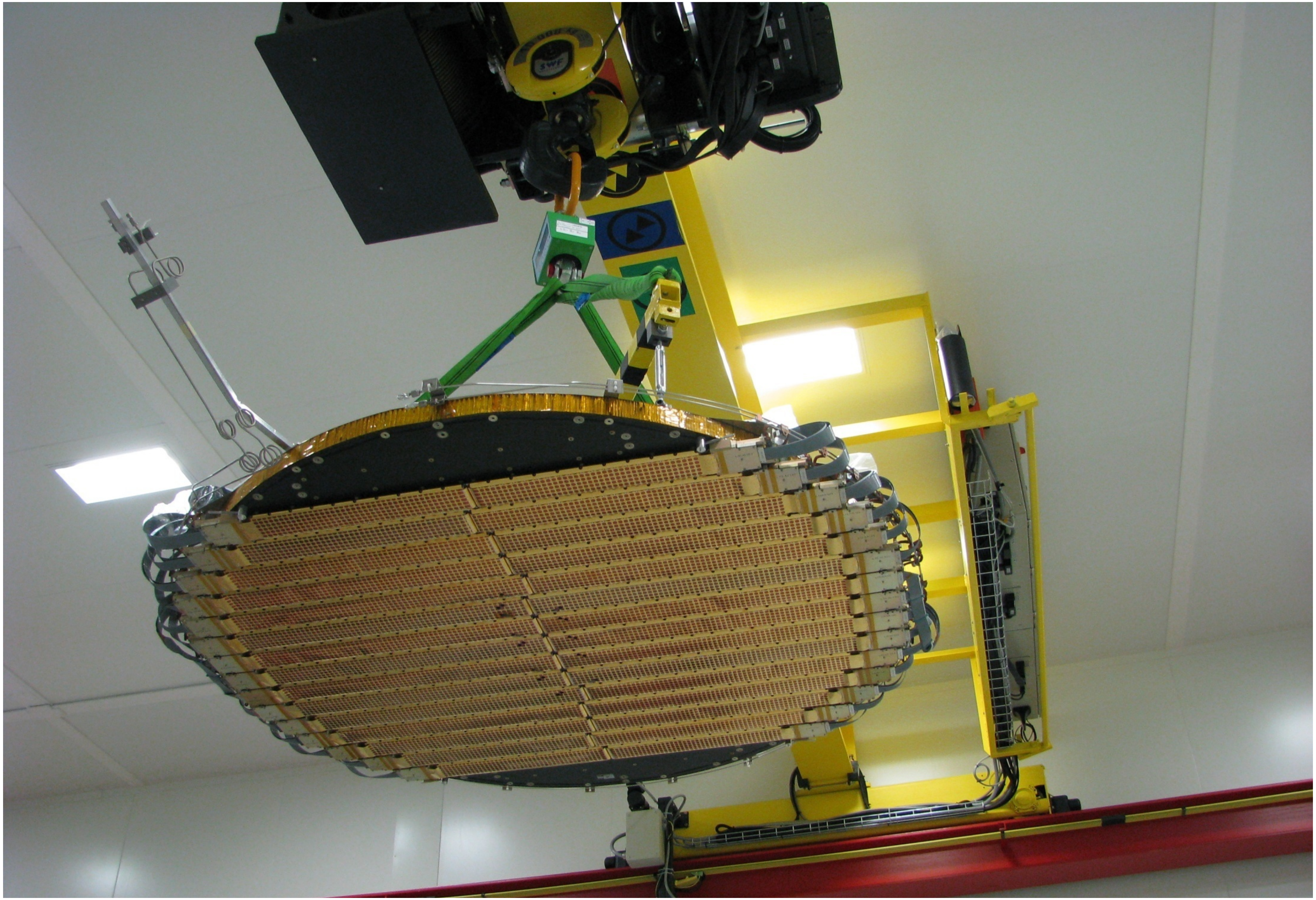
The heads of agency reaffirmed the importance of full exploitation of the station's scientific, engineering, utilization, and education potential. They noted that there are no identified technical constraints to continuing ISS operations beyond the current planning horizon of 2015 to at least 2020, and 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 -

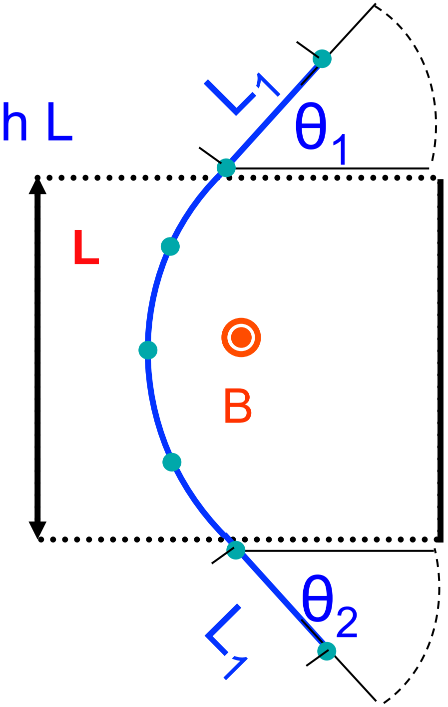
Silicon Tracker planes are movable



The function of the magnet is to measure the sign of the charge (±) and the momentum (P) of charged particles.

A charged particle passing through a magnetic field (B) experiences a bending. The amount of the bending depends on the value of the charge, Q, and momentum, p. The direction of the bending depends on the sign of the charge (±) .

The momentum resolution (Δp/p) is a measure the detectors ability to distinguish the sign of the charge and the accuracy of the momentum. It is the sum of two contributions:



1. Measurement inside the magnet with an effective length L

$$\sigma_p / p \propto 1 / B \cdot L^2$$

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

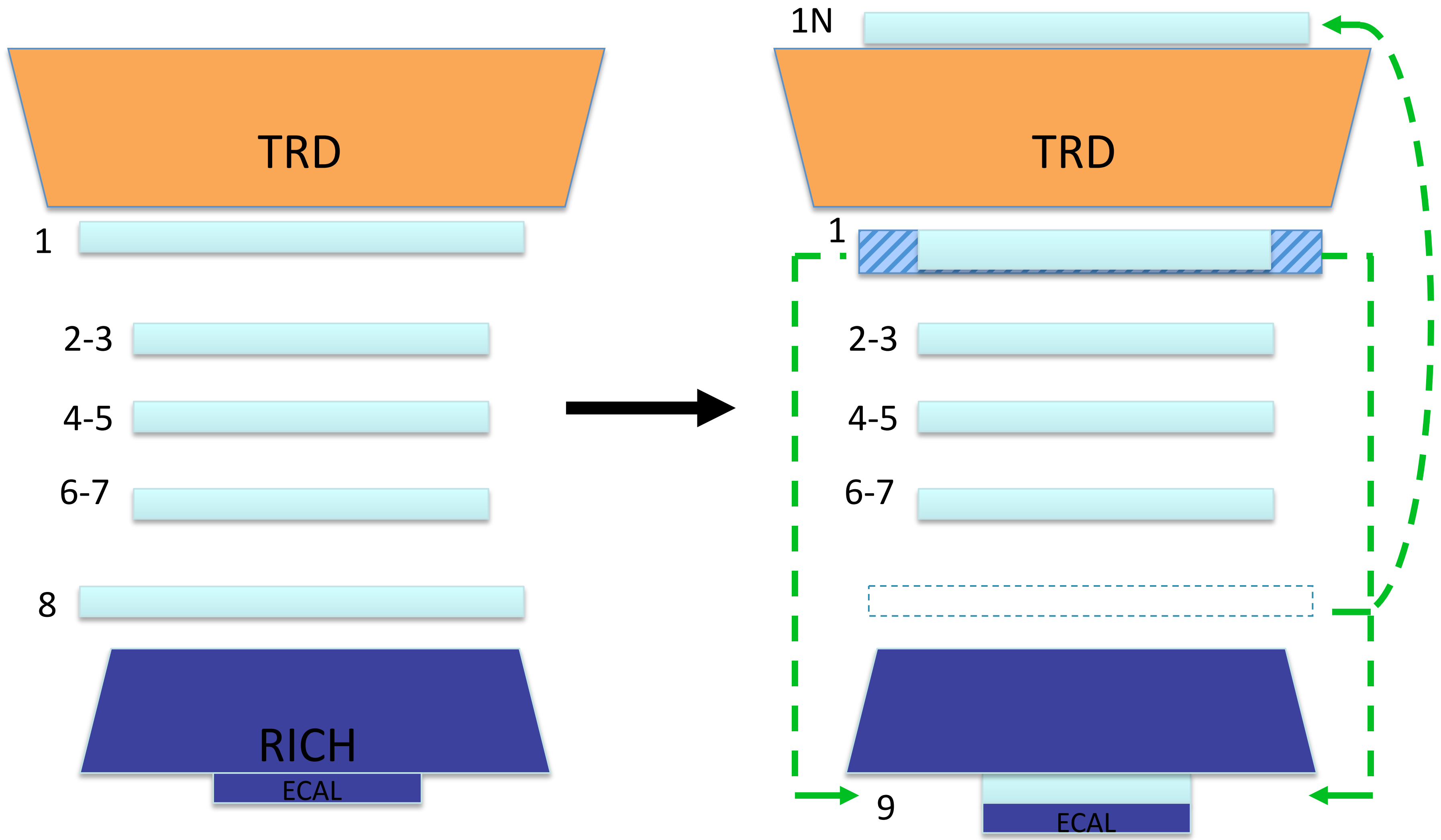
$$\sigma_p / p \propto 1 / B \cdot L \cdot L_1$$

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

to maintain the same Δp/p we increase L1 from ≈15 cm (Superconducting Magnet) to ≈125 cm (permanent magnet)

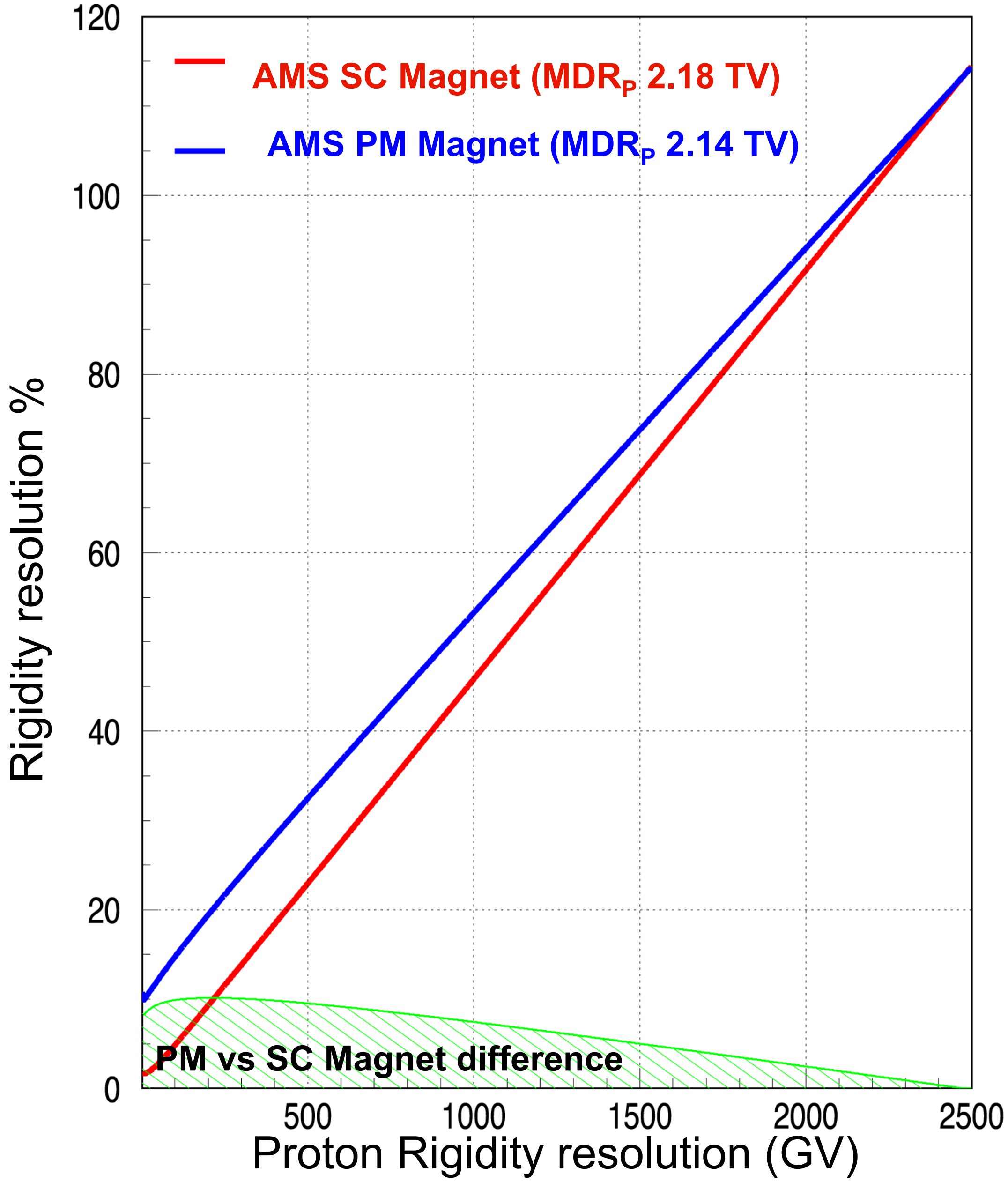
AMS-02 Superconducting Magnet Silicon Tracker Layers

AMS-02 Permanent Magnet Silicon Tracker Layers

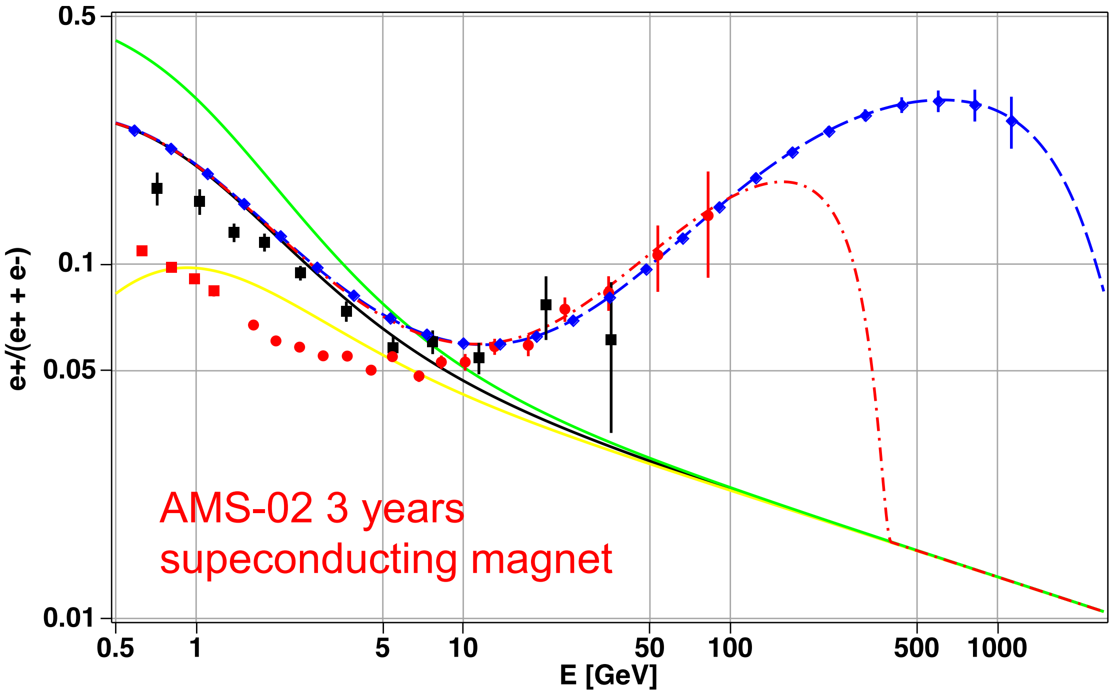


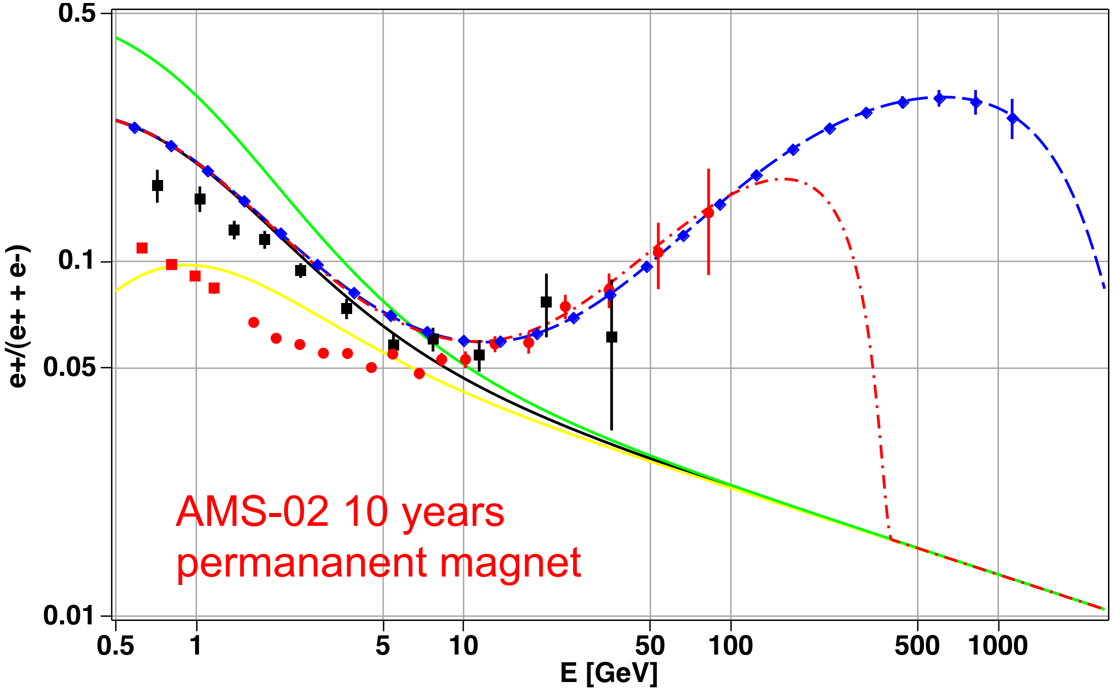
Layer 9 comes from moving the ladders at the edge of the acceptance from layer 1. The layer 8 is moved on top of the TRD to become 1N.

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, but with the permanent magnet AMS will be active for the duration of the ISS.

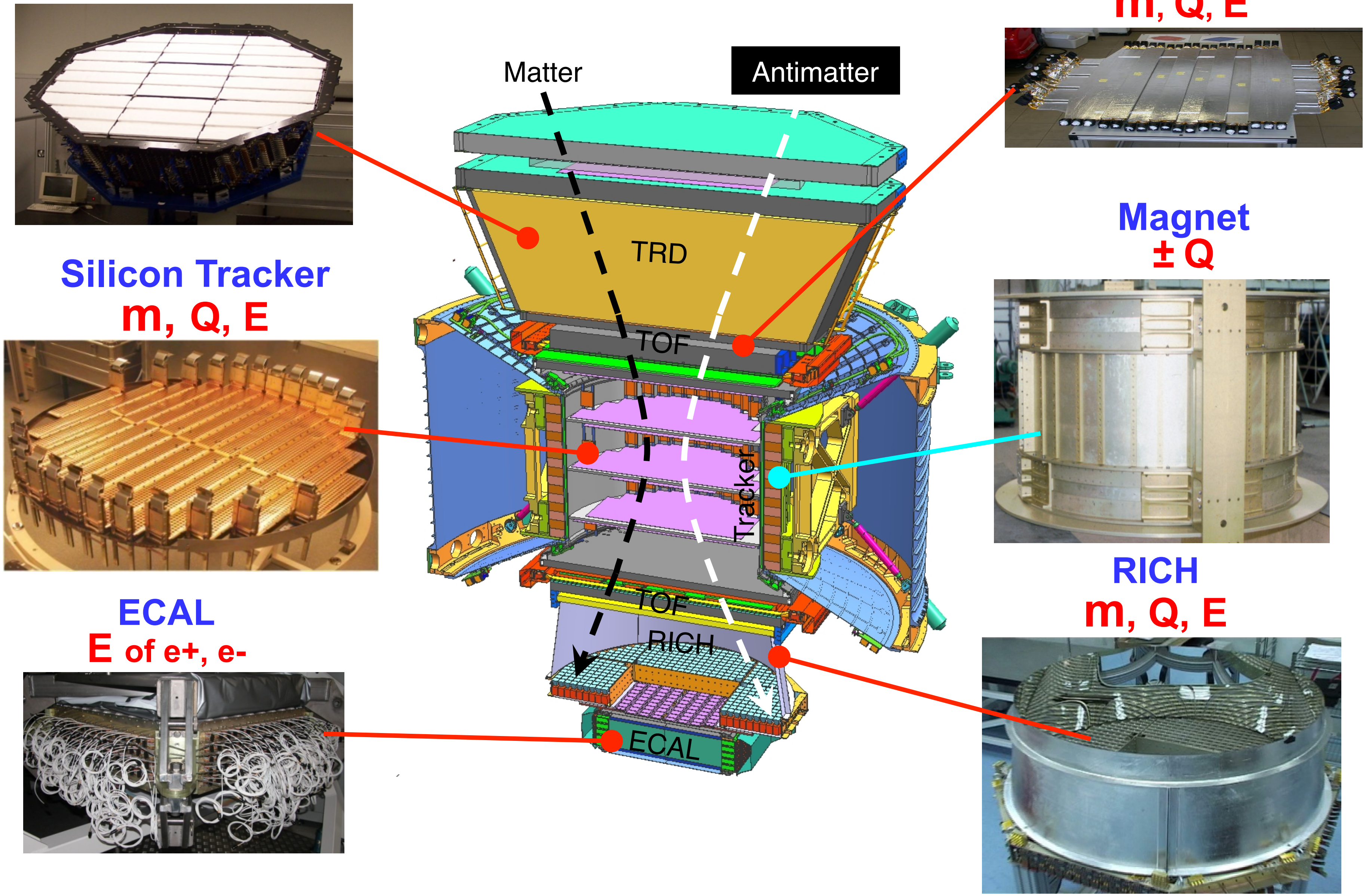




	Energy [GeV]	e^-	e^+
3 years, SC-Magnet	963-1320	78±9	27±5
10 years, PM-Magnet	963-1320	130±11	44±7

Particles are defined by their

mass (m), charge (Q) and energy (E = P)



TRD
Identify e+, e-

TOF
m, Q, E

Silicon Tracker
m, Q, E

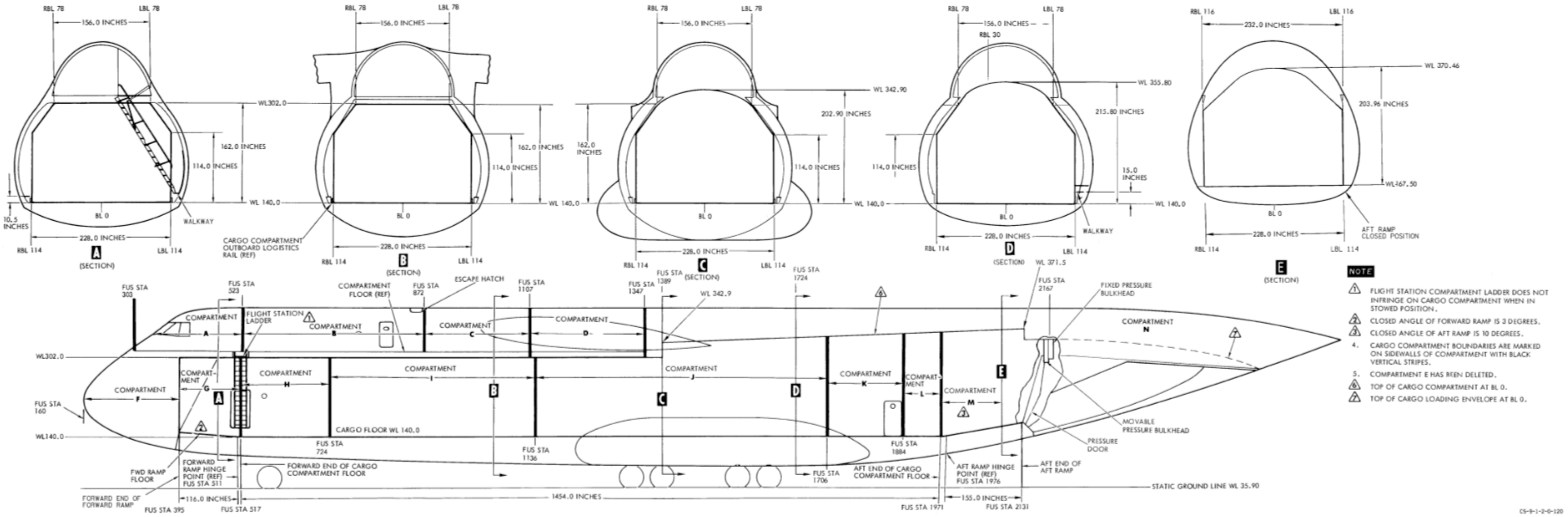
Magnet
± Q

ECAL
E of e+, e-

RICH
m, Q, E

A US Air Force C-5 Galaxy will be used for transport from Geneva to KSC September 2010

NASA Shuttle Landing Facility



NOTE

△1 FLIGHT STATION COMPARTMENT LADDER DOES NOT INFRINGE ON CARGO COMPARTMENT WHEN IN STOWED POSITION.

△2 CLOSED ANGLE OF FORWARD RAMP IS 3 DEGREES.

△3 CLOSED ANGLE OF AFT RAMP IS 10 DEGREES.

4. CARGO COMPARTMENT BOUNDARIES ARE MARKED ON SIDEWALLS OF COMPARTMENT WITH BLACK VERTICAL STRIPES.

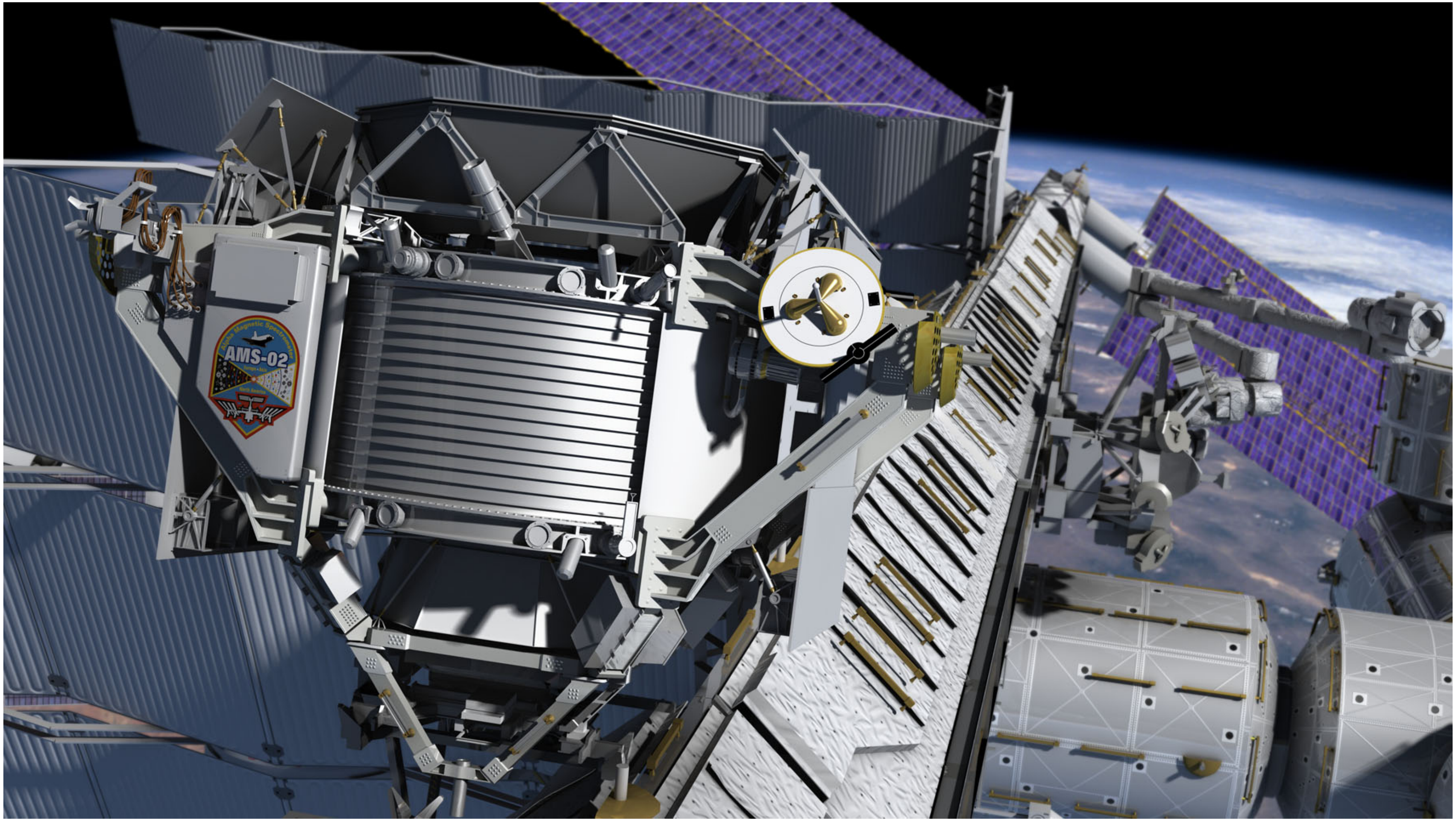
5. COMPARTMENT E HAS BEEN DELETED.

△6 TOP OF CARGO COMPARTMENT AT BL 0.

△7 TOP OF CARGO LOADING ENVELOPE AT BL 0.

As soon as possible,
we want to see this…

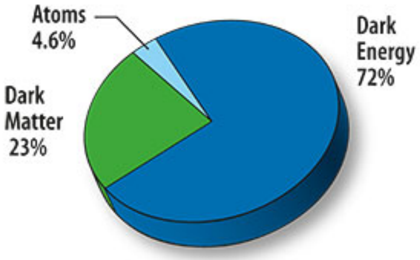
…and a few days later, this...



…and for the next ~10+ years...

Summary

- **We know that dark matter exists.**
  We don‘t know what it is.



- **We observe anomalies in the spectra of charged cosmic rays which could be explained by dark matter annihilation.**

- **Within the next five years we expect answers from:**
  - **Collider Experiments:**
    Tevatron (<=2010), LHC (>=2010)
  - **Direct dark matter searches:**
    CMDS, Edelweis, CRESST, XENON, ...
  - **Indirect dark matter searches:**
    - **in space: PAMELA, FERMI, AMS-02**
    - **Neutrino-Exp.: IceCube, ANTARES**
    - **Cherenkov-Telescopes: HESS, MAGIC**