Space Radiation Test Facility in Turkey: A CERN collaboration

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Astro-Particle Physics at METU

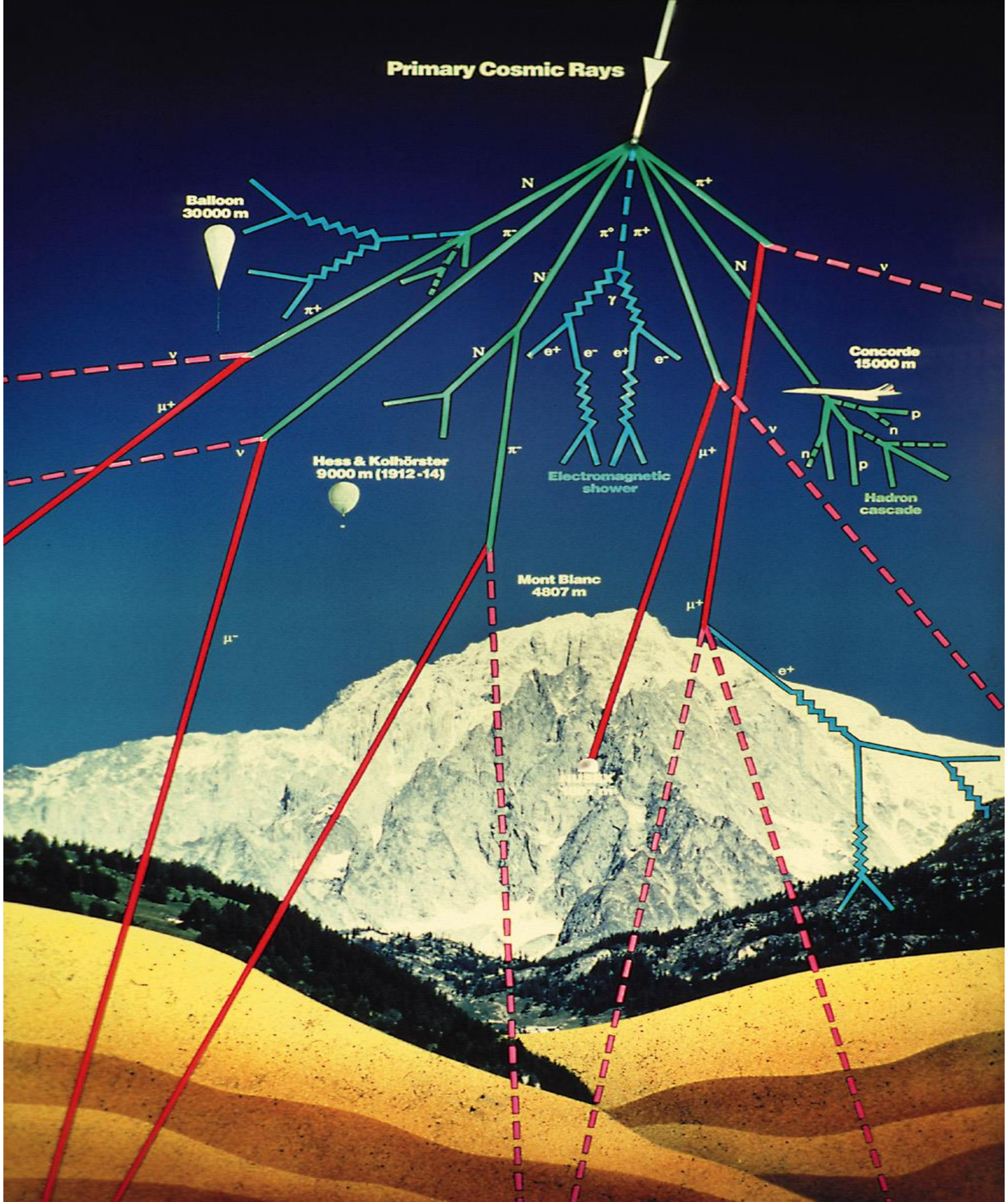
With the AMS-02 on the International Space Station:
- Measurement of cosmic-rays
- Search of a dark matter signal

→ ***Fundamental Science***

With the METU-DBL project:
- Radiation dose predictions for National satellites
- Radiation tests with 15-30MeV Protons according to ESA-ESCC-25100 standard

→ ***Applied Research***

The group consists of:
5 physicists, 5 engineers, 1 technicians
2 administrative staff, 4 PhD + 7 MS students.



- Cosmic Rays

- Primaries:
- Mostly protons close to the speed of light.

Alpha Magnetic Spectrometer (AMS-02)

AMS-02 is taking data on the ISS since May 2012


AMS
300,000 electronic channels
650 processors
15ft x 12ft x 9ft
7.5 tons

Dawn at the launch pad. AMS is ready for launch.

AMS is in Endeavour’s cargo bay

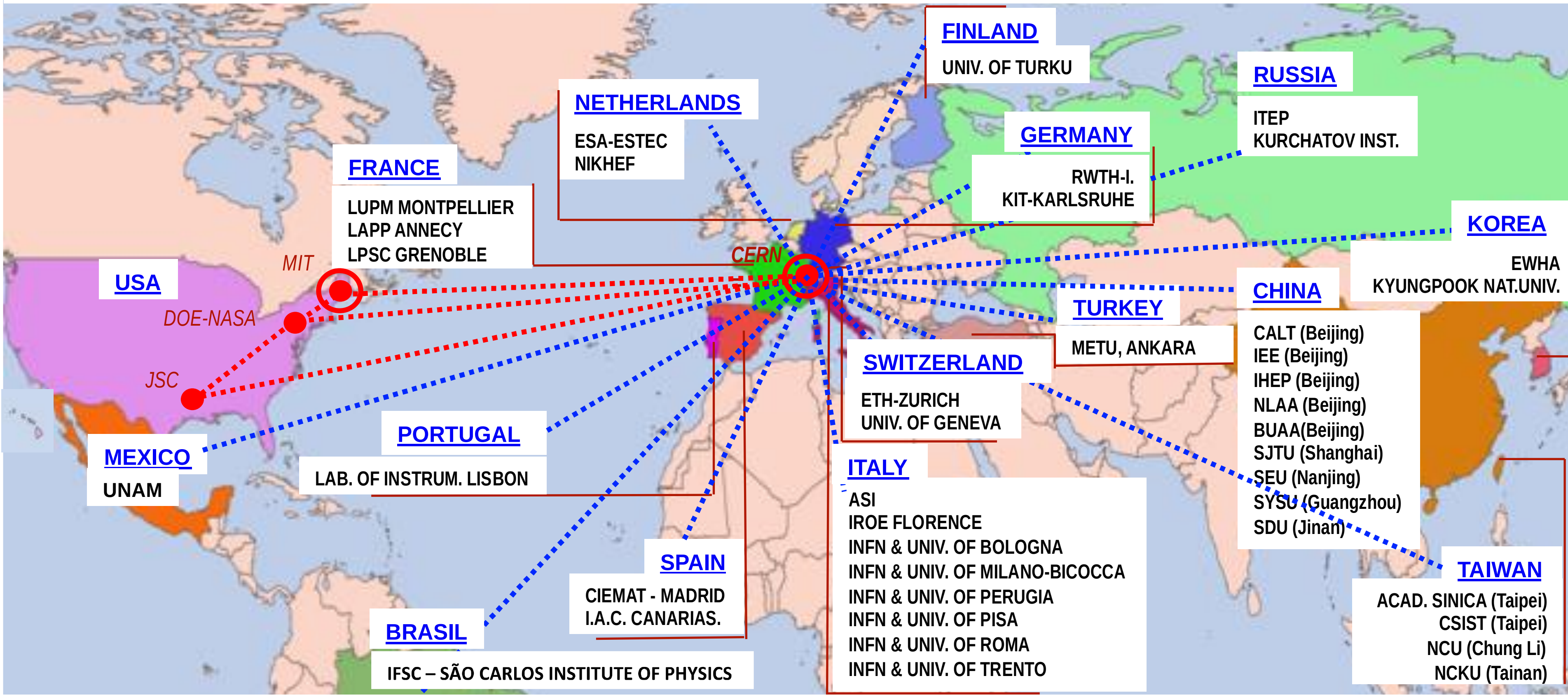
The STS-134 crew


Endeavour: 110 t
External tank: 756 t
2 SRB: 1142 t
(solid rocket boosters)
Total weight: 2008 t
AMS weight: 7.5 t


STS-134 launch May 16, 2011 @ 08:56 AM

May 19, 2011: AMS is installed on the International Space Station.

AMS is an international collaboration based at CERN



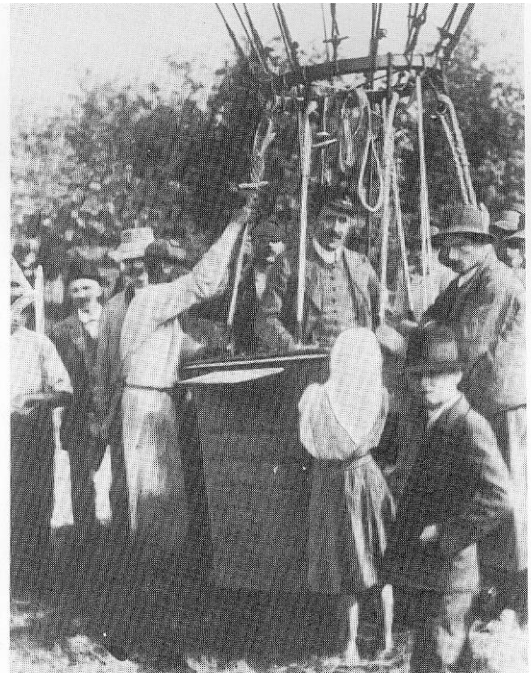
The METU group has worked on:

- Both Calorimetric and conversion-mode photon flux measurement
- Positron/electron ratio
- Proton flux and its variability
- Shadow of the moon in cosmic rays

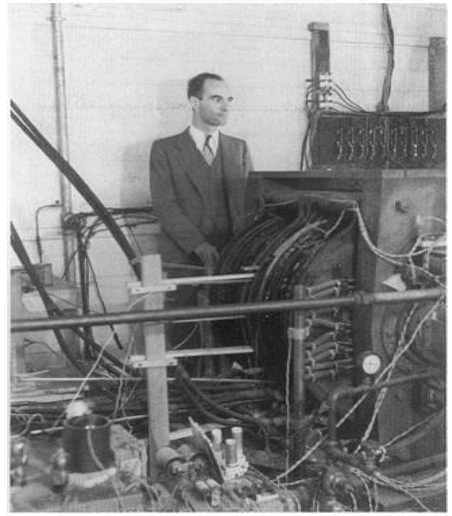
AMS is controlled from the CERN POCC since June 2011.

AMS and Science

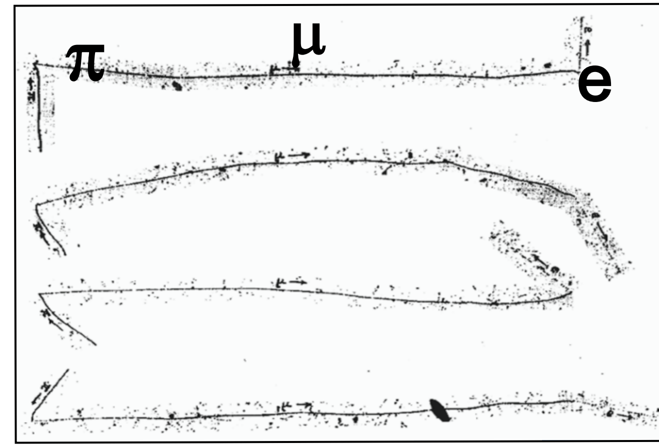
Important discoveries with cosmic rays



1912: Discovery of cosmic rays



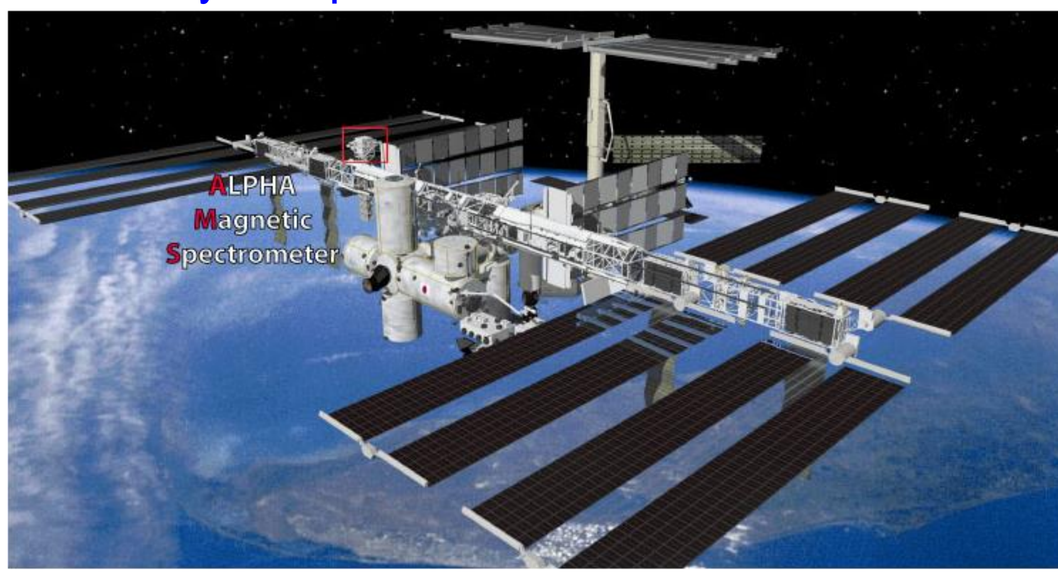
1932: Discovery of the positron



1947: Discovery of the pion

New particles

- 1936: Muon (μ)
- 1949: Kaon (K)
- 1949: Lambda (Λ)
- 1952: Xi (Ξ)
- 1953: Sigma (Σ)



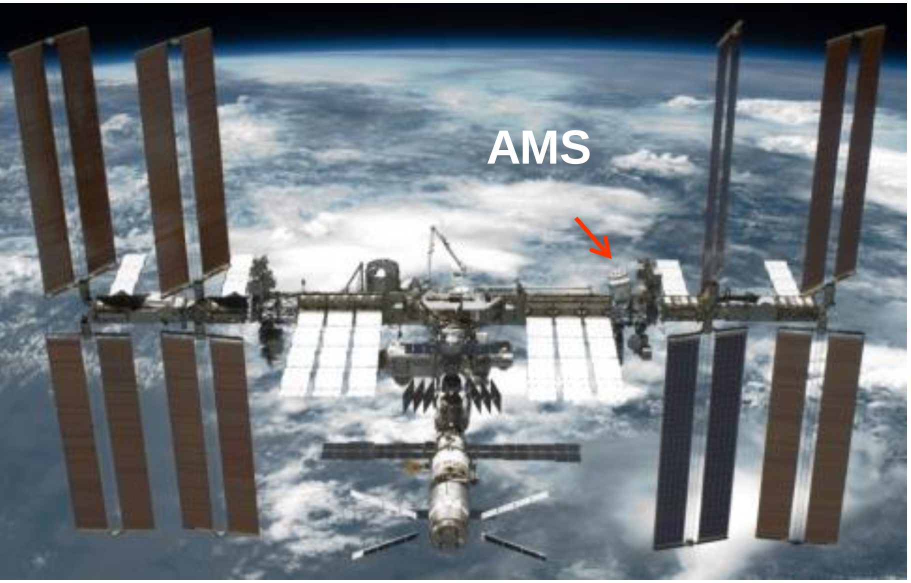
And now the ISS...

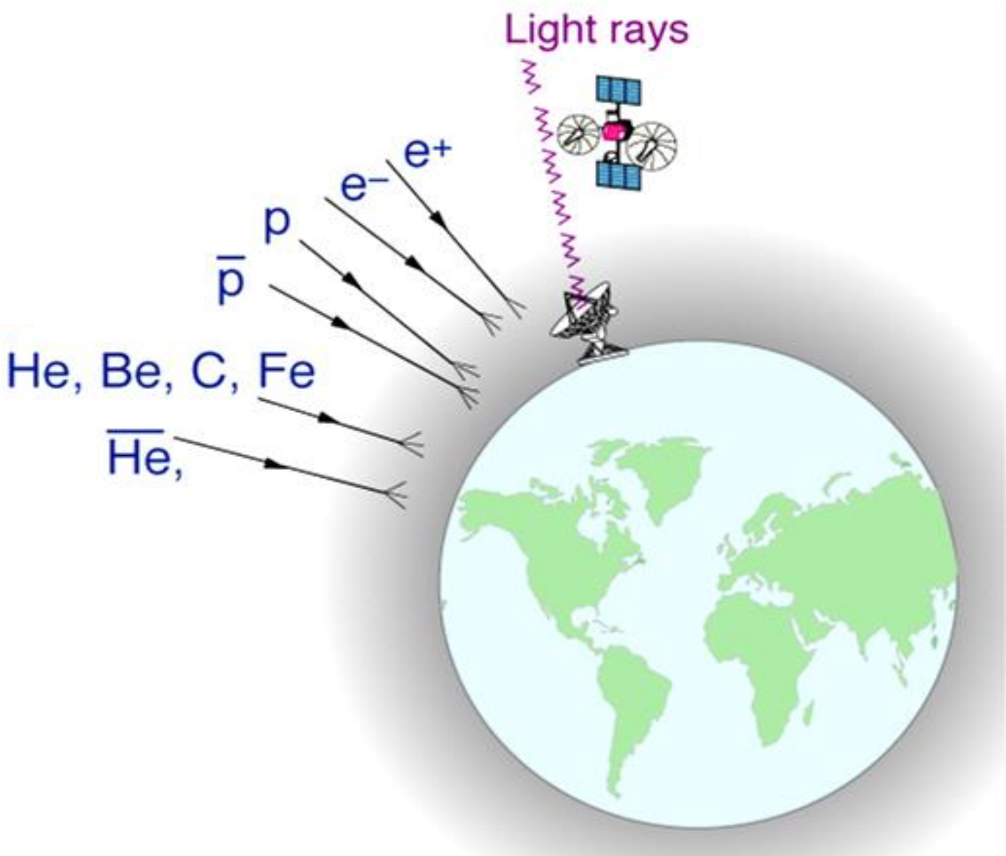
Fundamental Science on the International Space Station (ISS)

There are two kinds of cosmic rays traveling through space

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

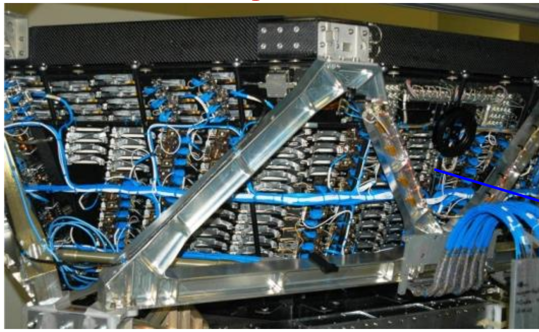
2- Charged cosmic rays: Following the pioneering experiments with balloons and small satellites, using a magnetic spectrometer (AMS) on ISS is a unique way to provide precision long term (10-20 years) measurements of high energy charged cosmic rays.





AMS: A TeV precision, multipurpose spectrometer

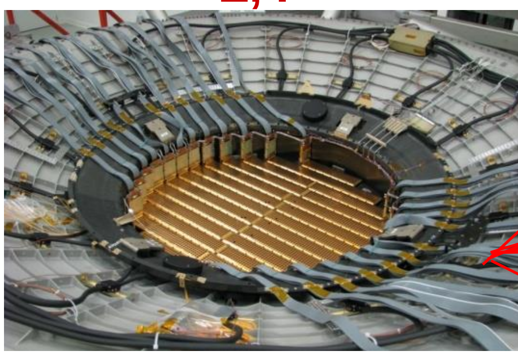
TRD
Identify e^+, e^-

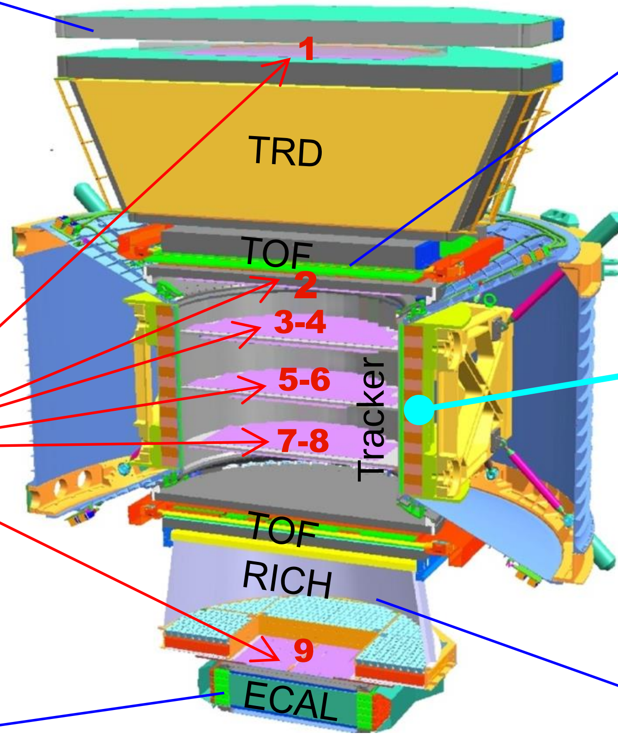


Particles and nuclei are defined by their charge (**Z**) and energy (**E ~ P**)

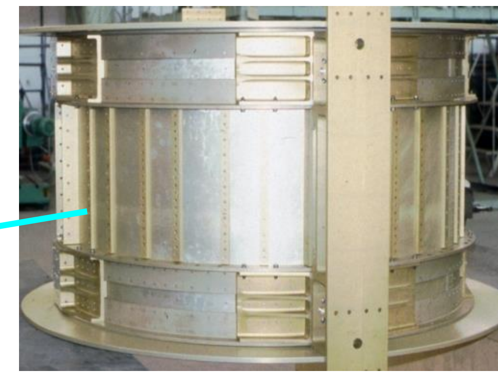
TOF
Z, E

Silicon Tracker
Z, P

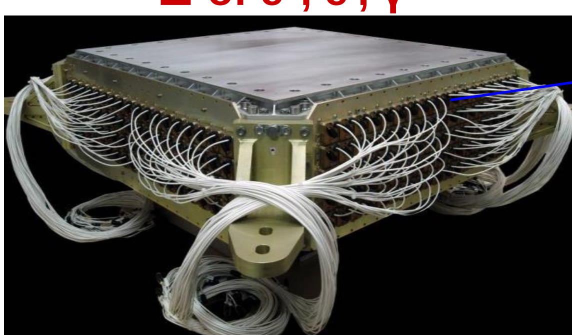




Magnet
±Z

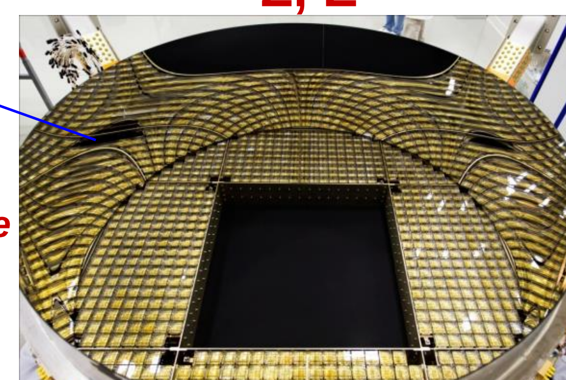


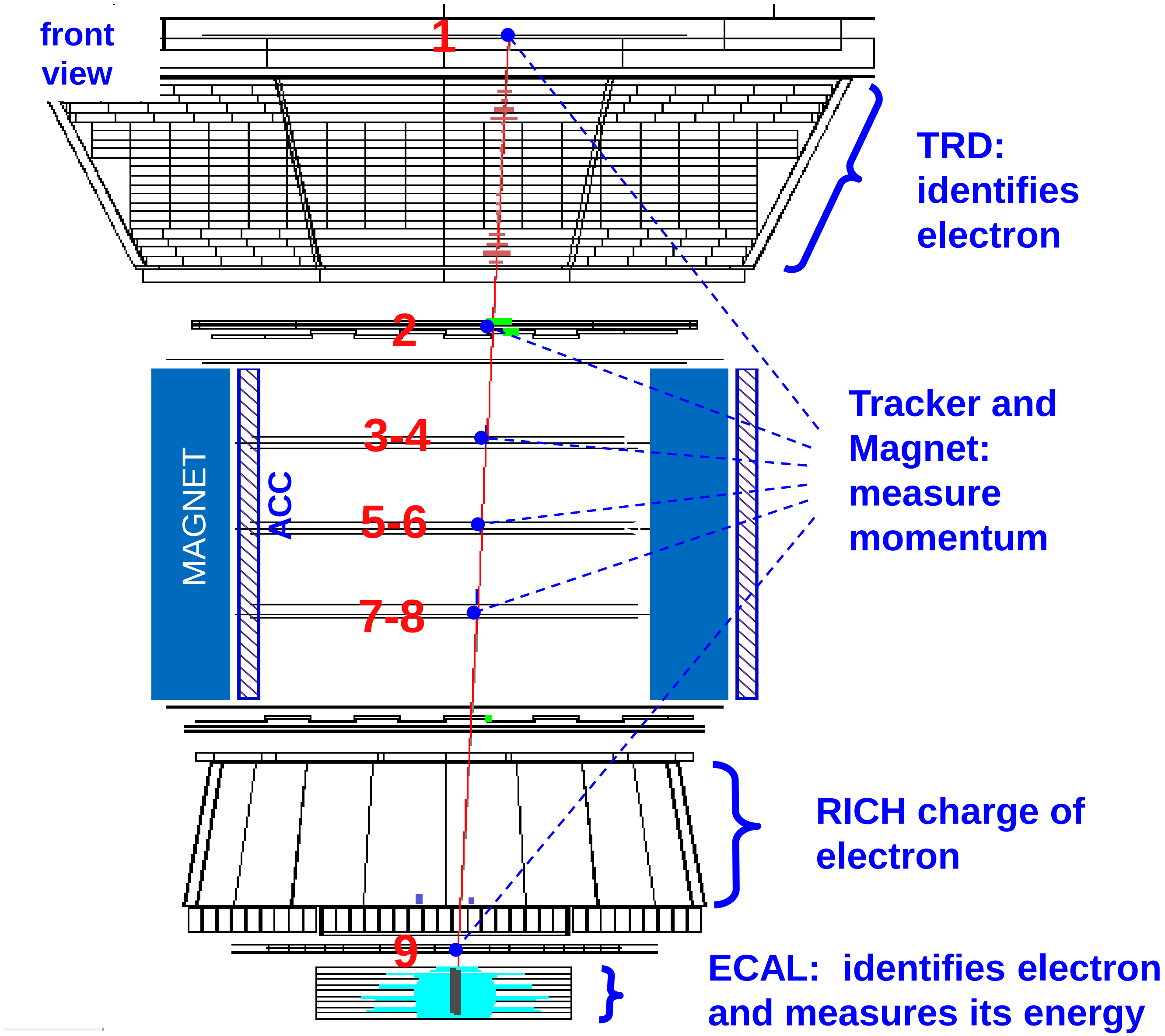
ECAL
E of e^+, e^-, γ



Z, P *are measured independently by the Tracker, RICH, TOF and ECAL*

RICH
Z, E

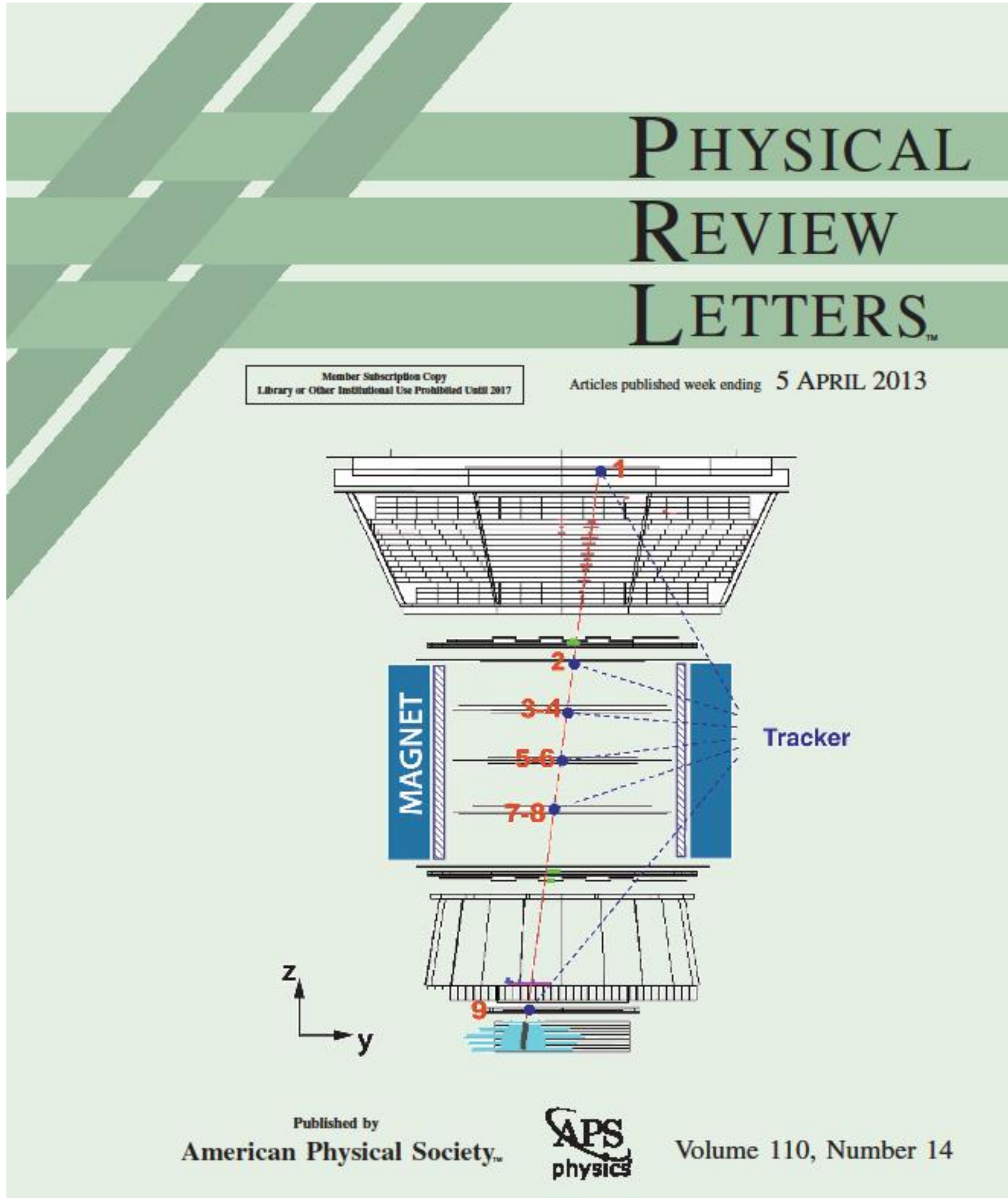


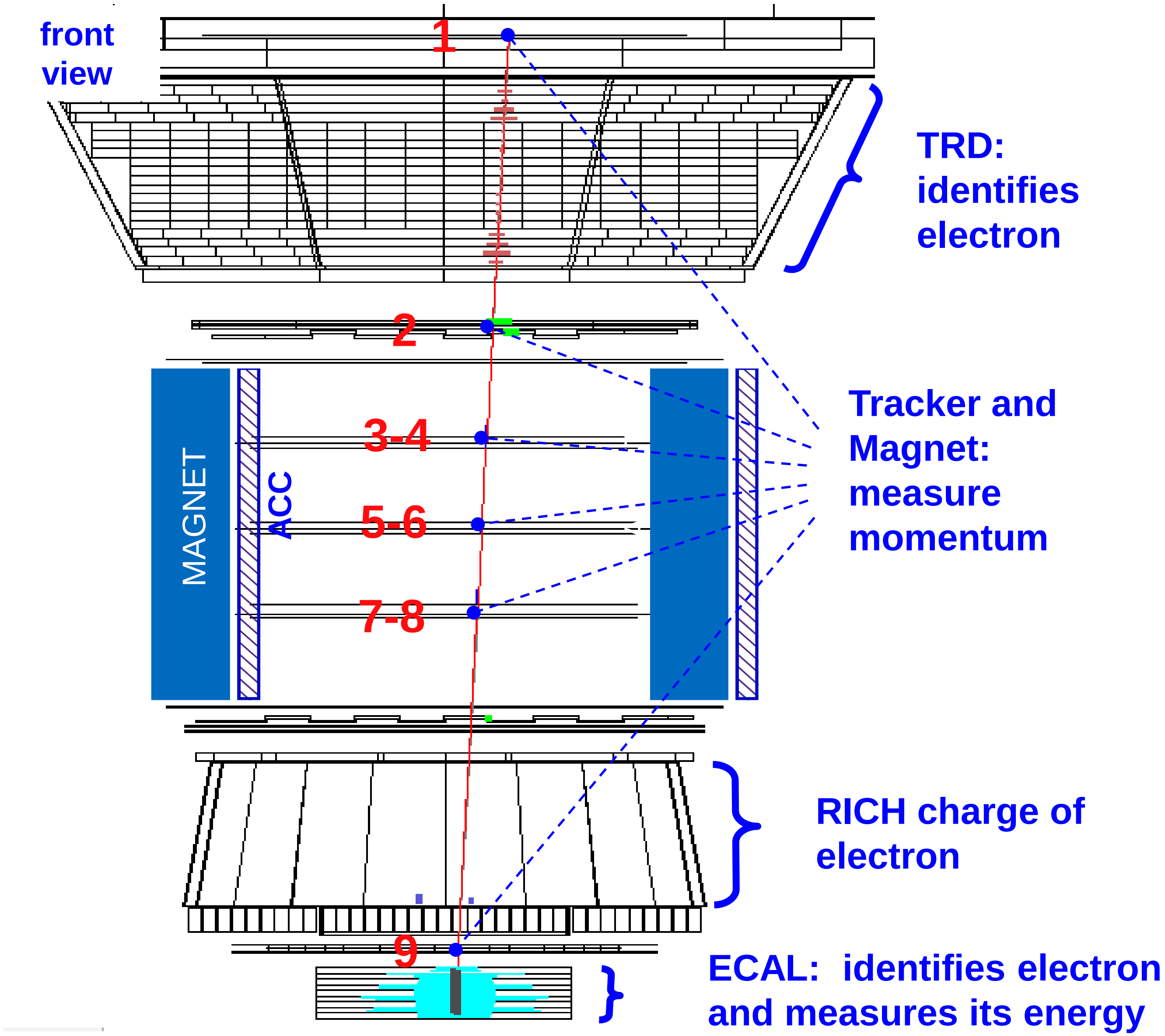


AMS data on ISS: 424 GeV positron

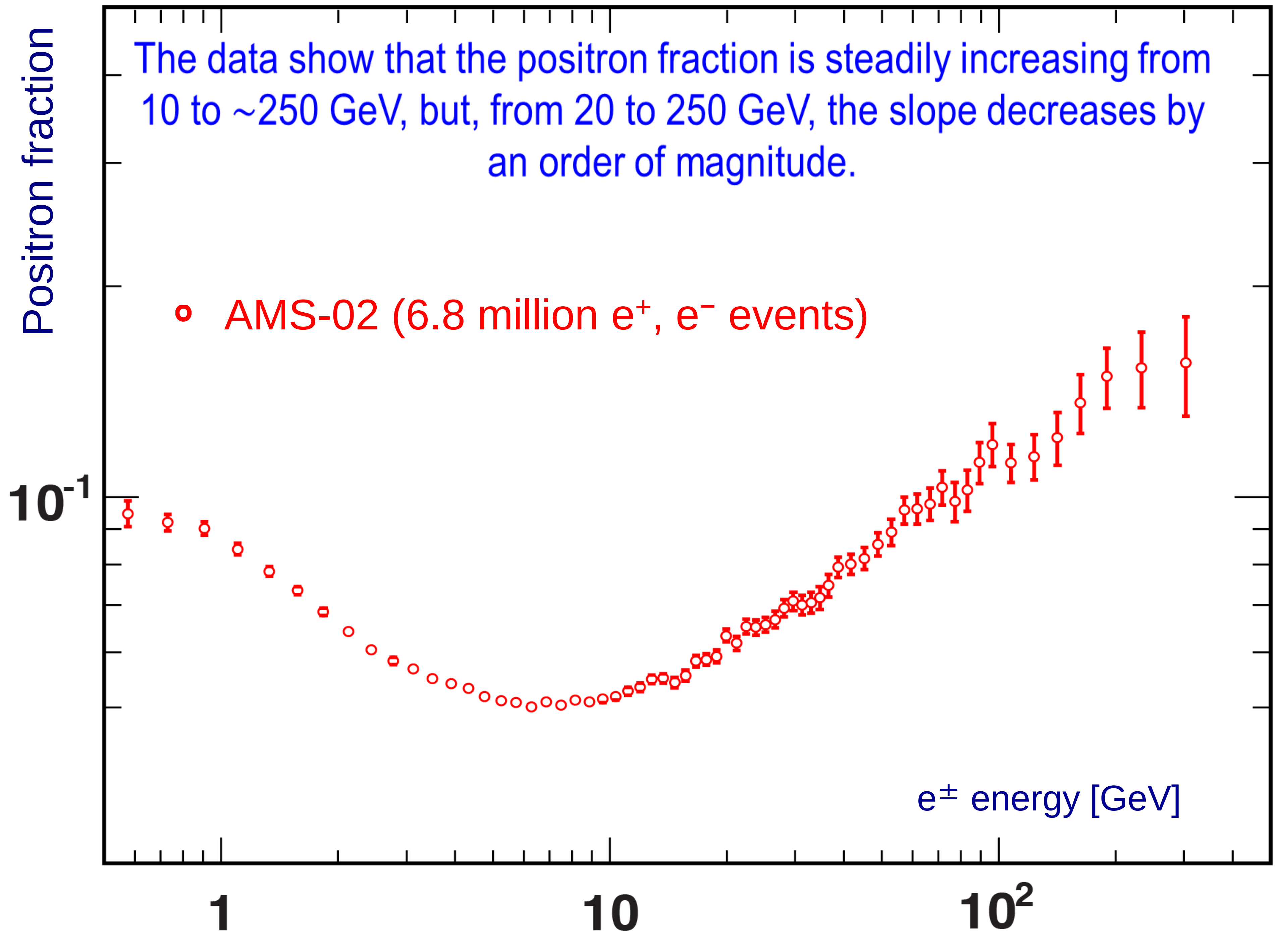
"First Result from the AMS on the ISS: Precision Measurement of the Positron Fraction in Primary Cosmic Rays of 0.5-350 GeV"

Selected for a Viewpoint in Physics and an Editors' Suggestion [Aguilar,M. et al (AMS Collaboration) Phys. Rev. Lett. 110, 141102 (2013)]

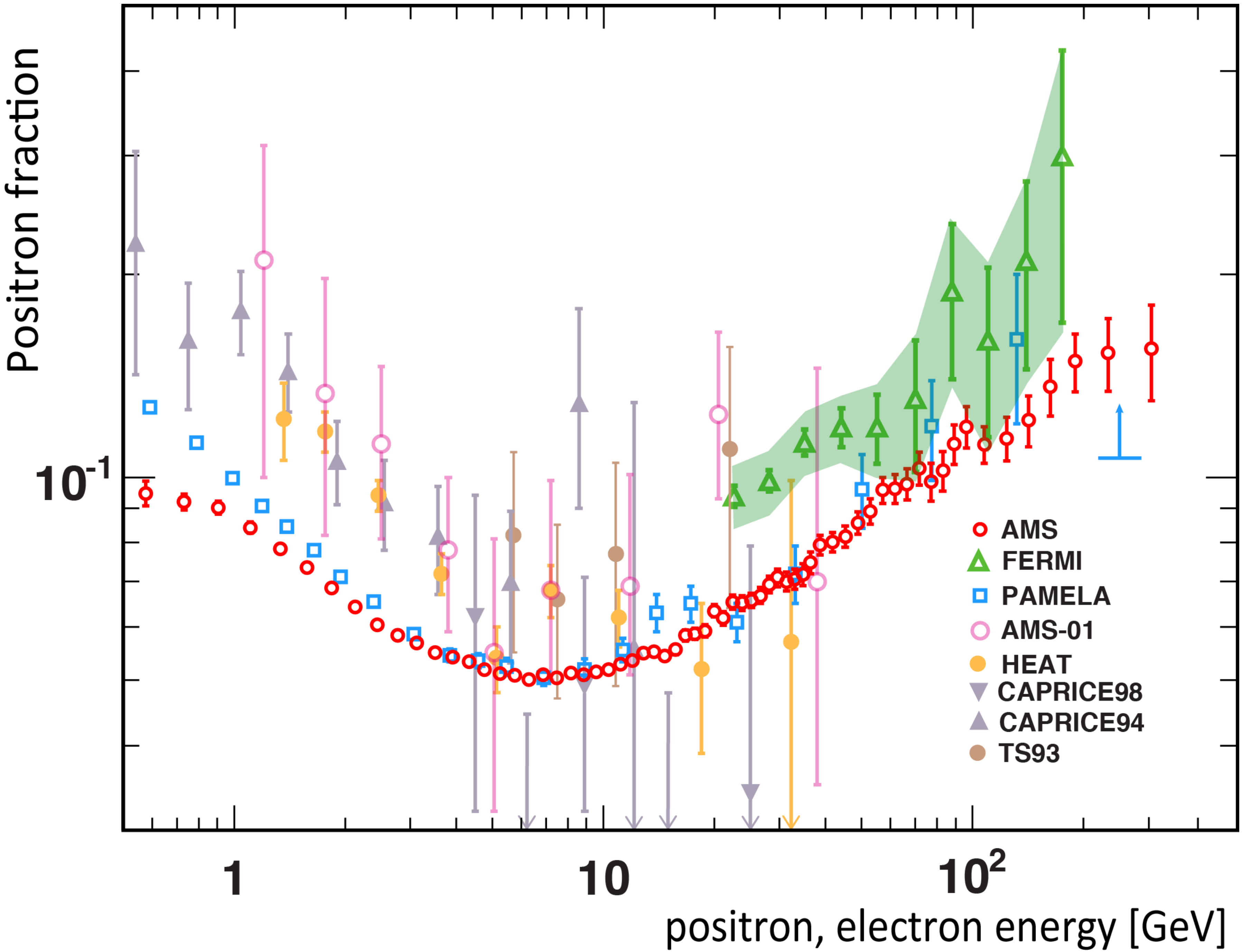




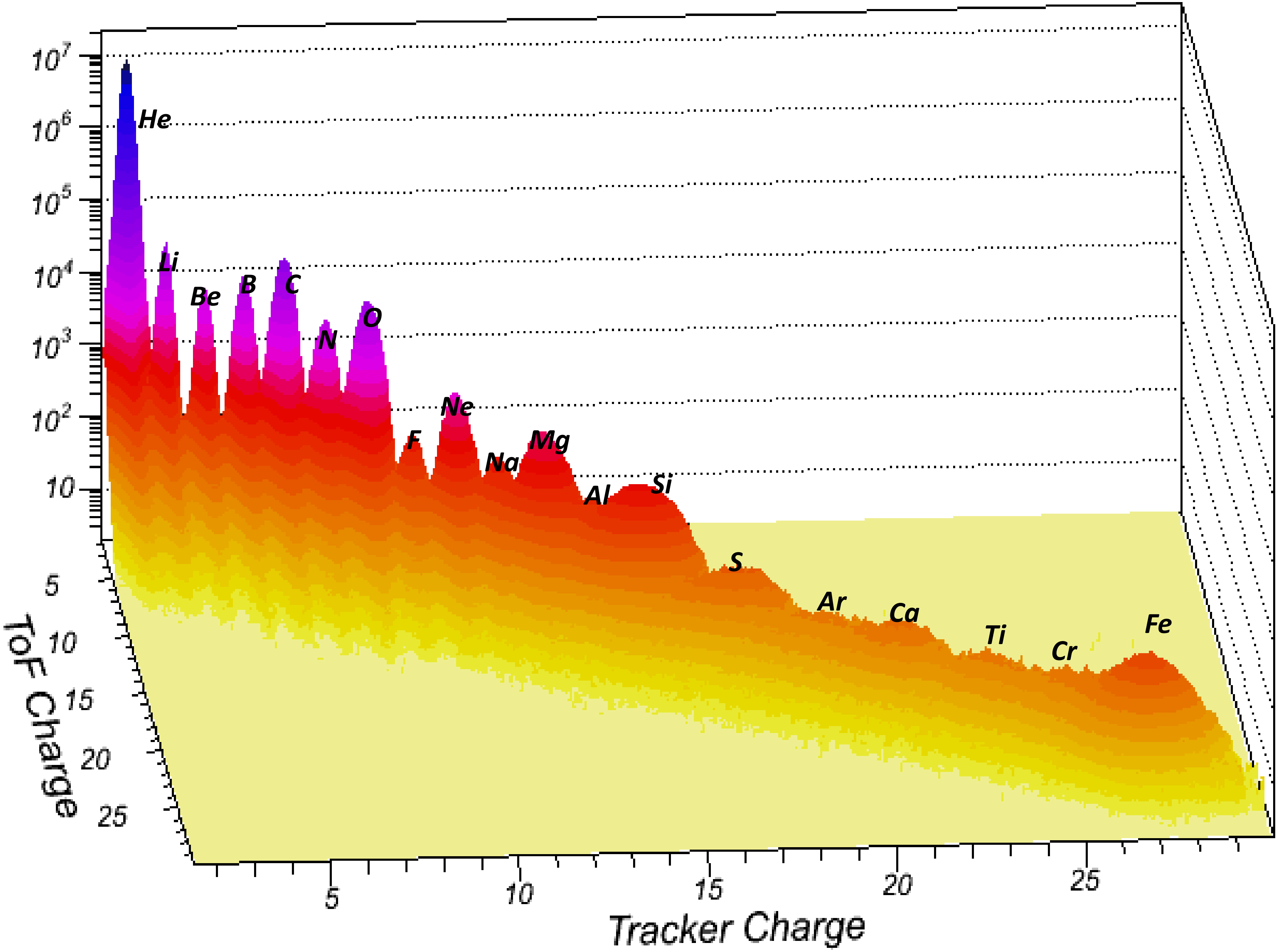
AMS data on ISS: 424 GeV positron



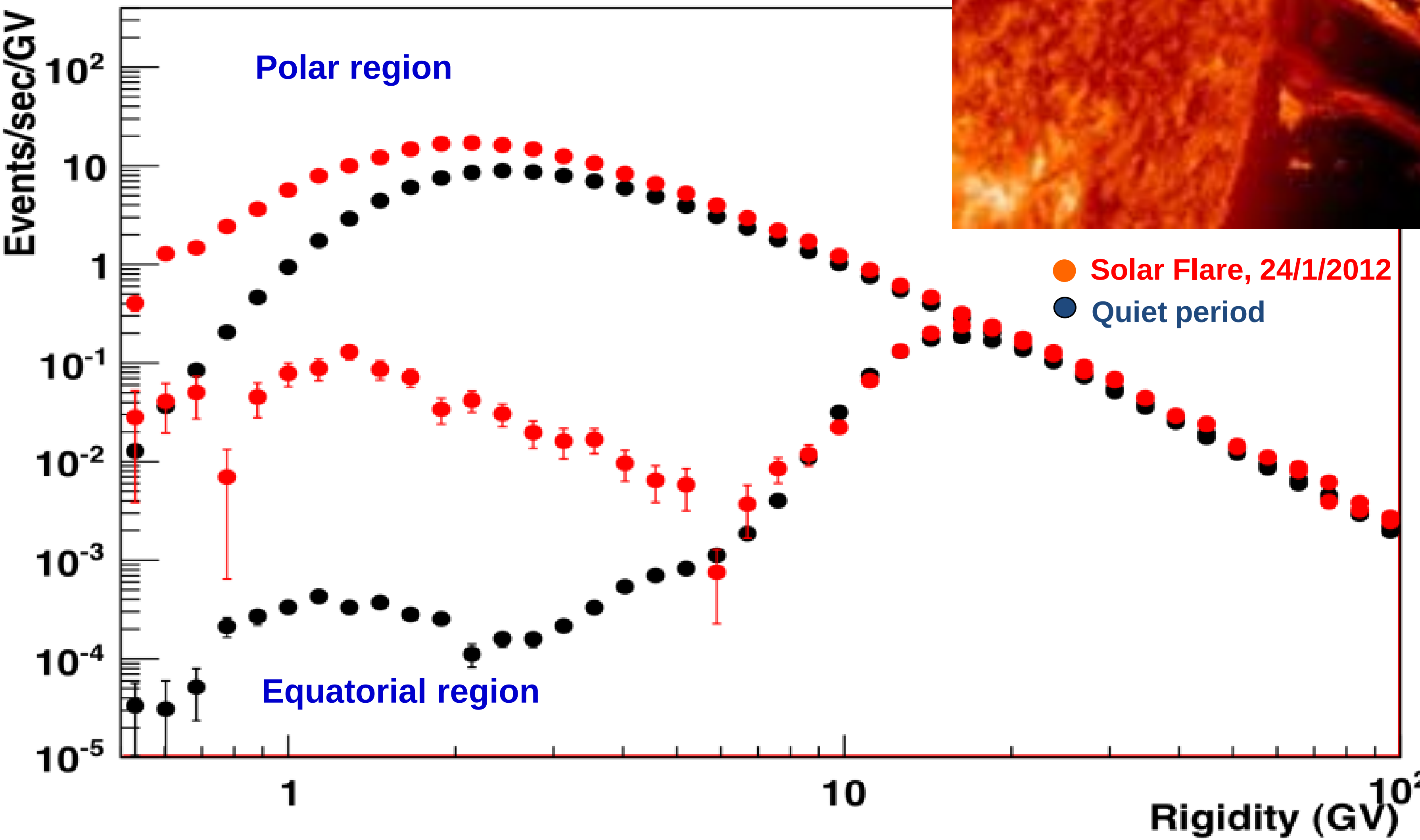
Positron fraction
The data show that the positron fraction is steadily increasing from 10 to ~250 GeV, but, from 20 to 250 GeV, the slope decreases by an order of magnitude.
AMS-02 (6.8 million e+, e− events)
10-1
e± energy [GeV]
1
10
102



Positron fraction
10^-1
1
10
10^2
positron, electron energy [GeV]
AMS
FERMI
PAMELA
AMS-01
HEAT
CAPRICE98
CAPRICE94
TS93


He
Li
Be
B
C
N
O
Ne
F
Na
Mg
Al
Si
S
Ar
Ca
Ti
Cr
Fe
10^7
10^6
10^5
10^4
10^3
10^2
10
ToF Charge
5
10
15
20
25
Tracker Charge
5
10
15
20
25

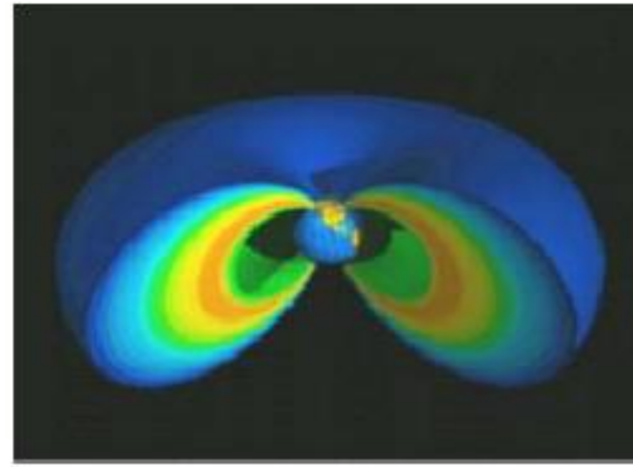
AMS data: He rate and Solar Flare

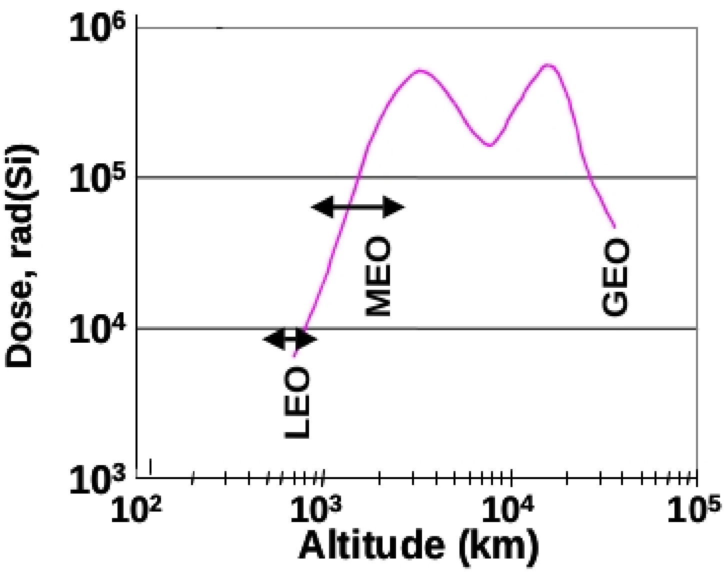


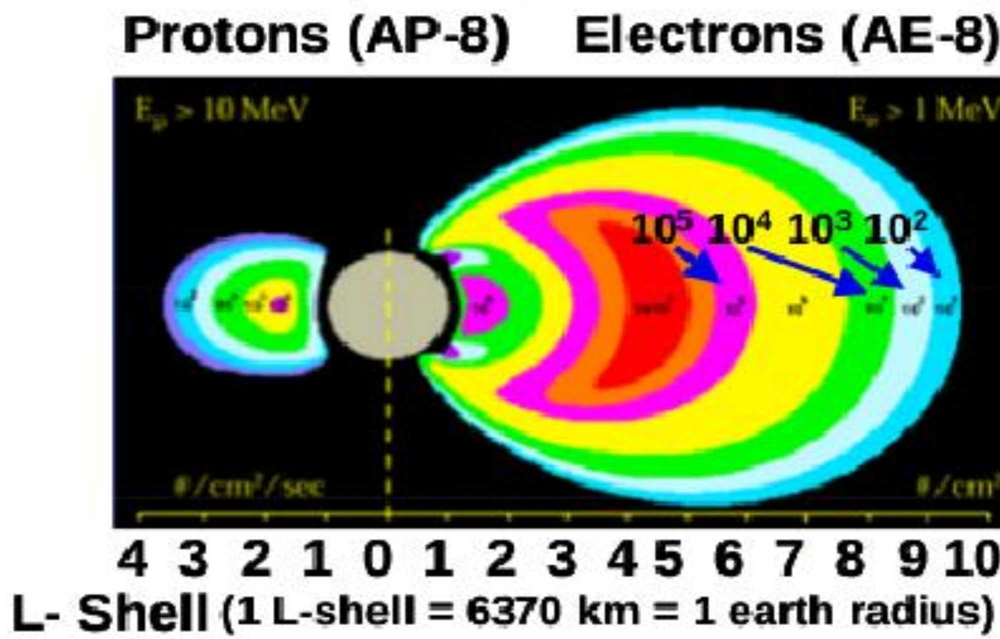
LEO (550 – 1000 km) ~ 1-10 krad (Si) / yıl

MEO (1000 – 3000 km) ~ 100-1000 krad (Si) / yıl

GEO (36,000 km) ~ 10-100 krad (Si) / yıl





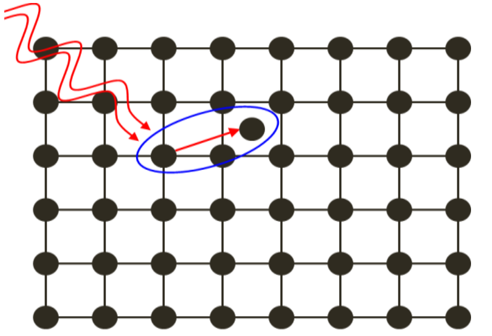


1) Ionising Effects

Total Ionisation Dose (TID)

LET: Lineer Energy Transfer $LET = -\frac{1}{\rho}\frac{dE}{dx'}$

2) Non-ionising Effects(DD)



3) Single Event Effects (SEE)

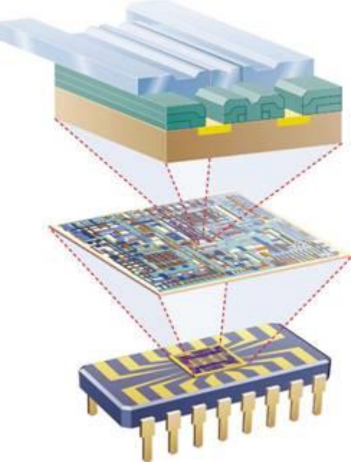
Single Event Latchup (SEL)

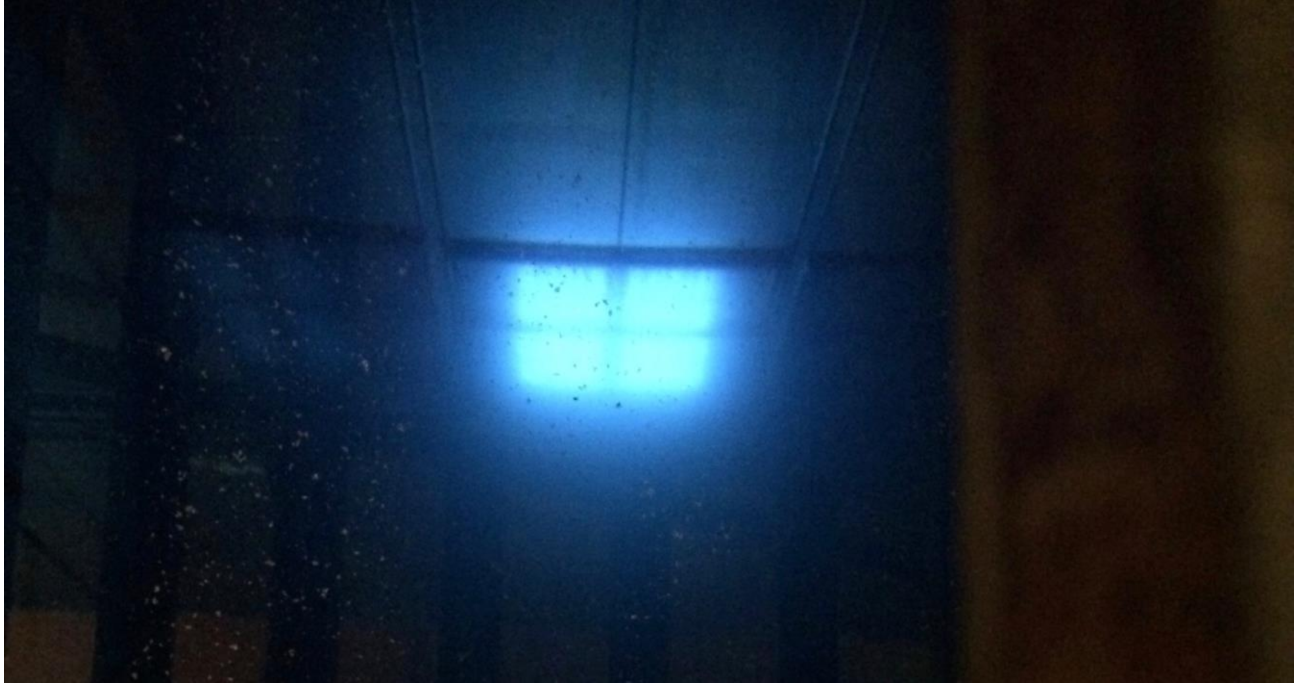
Single Event Burnout (SEB)

Single Event Upset (SEU)

Single Event Transient (SET)

Single Event Gate Rupture (SEGR)





300 microCu
Cobalt60 source
→ TID tests can be performed

METU ve Aselsan Teams
During successful testing of SSPAs developed by Aselsan for space.

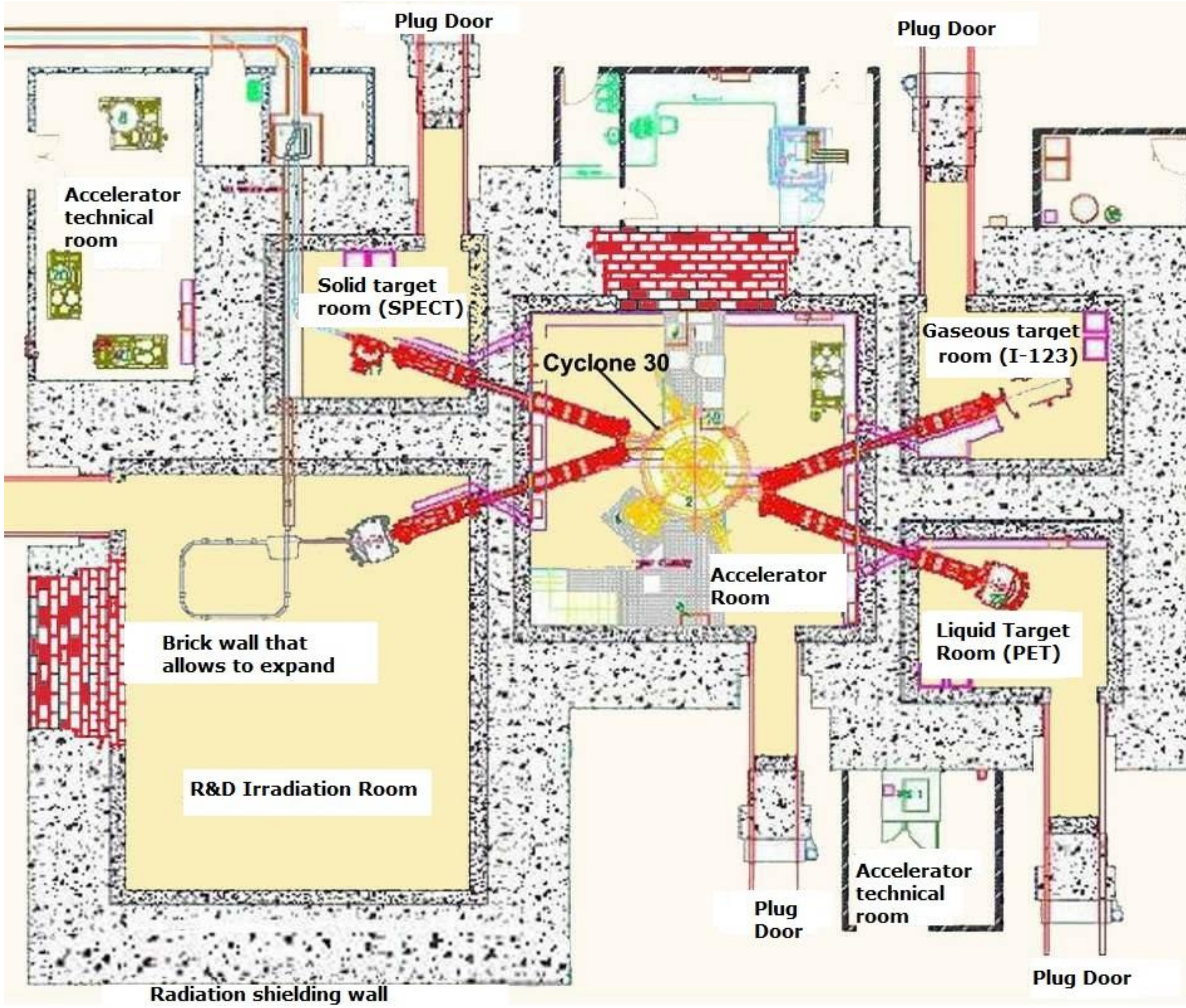
TAI SPACE SYSTEMS INTEGRATION AND TEST CENTER (USET)

- Integration
- MLI preparation
- Enviromental tests
- EMI tests
- Acoustic tests
- Vibration and shock tests
- Thermal vacuum tests
- Solar array deployment tests
- And others…

The only test that can not be performed here : Radiation tests

TAEA SANAEM
Proton Accelerator Facility

Energy Range	30MeV
Current Range	>0.1µA <1.2mA
Beam size at R&D room	Circle with a diameter of 1cm



*TAEK SANAEM, Proton Accelerator Facility Booklet, Ankara, 2012.

TAEA SANAEM
Proton Accelerator Facility

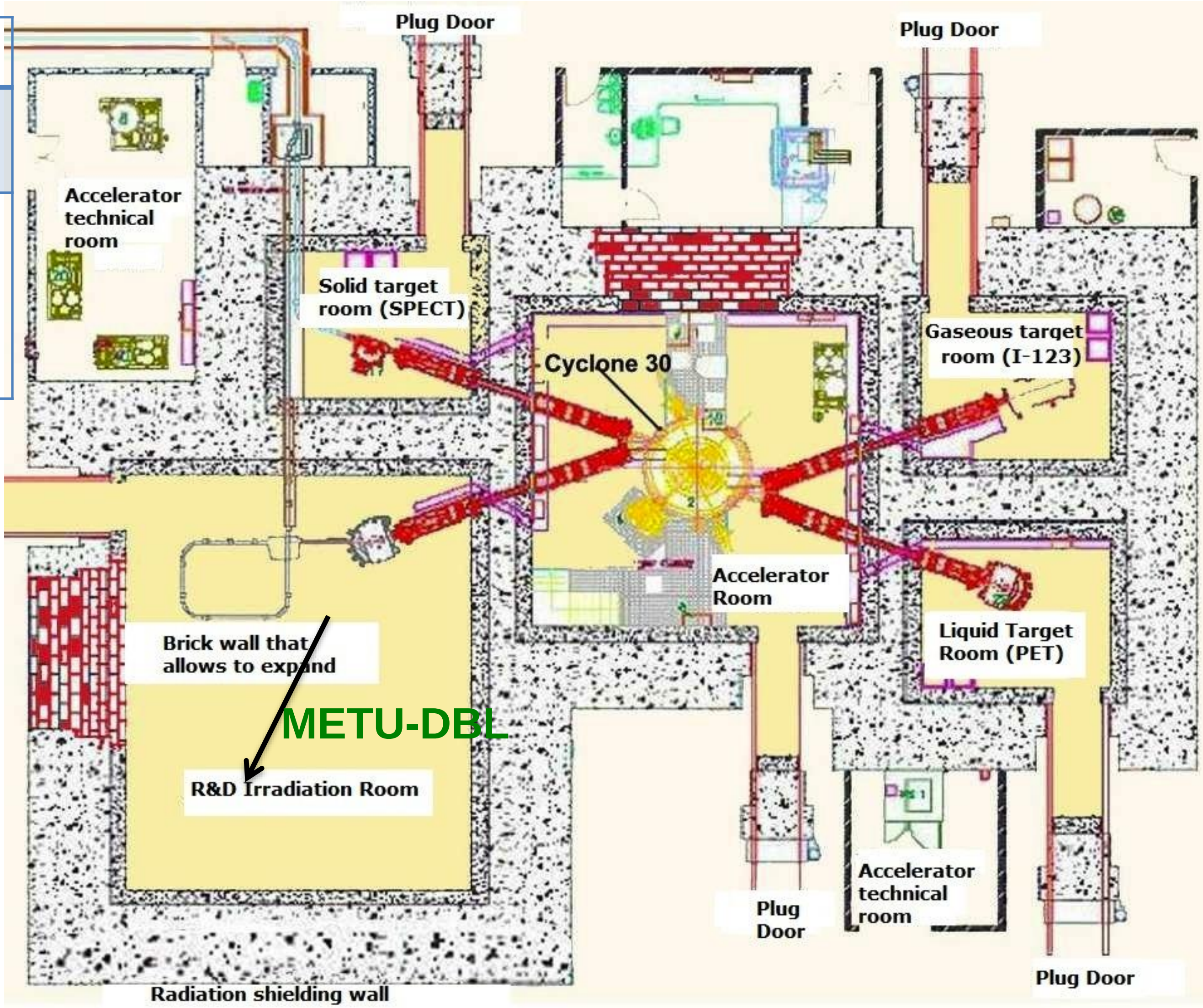
Energy Range	30MeV
Current Range	>0.1µA <1.2mA
Beam size at R&D room	Circle with a diameter of 1cm

METU-Defocusing Beamline METU-DBL:

- Enlarge the beam
- Reduce the flux
- Measure the beam

To perform proton irradiation tests for

- Hi-Lumi LHC
- Space applications
- Nuclear applications



from TAEA SANAEM PAF Booklet

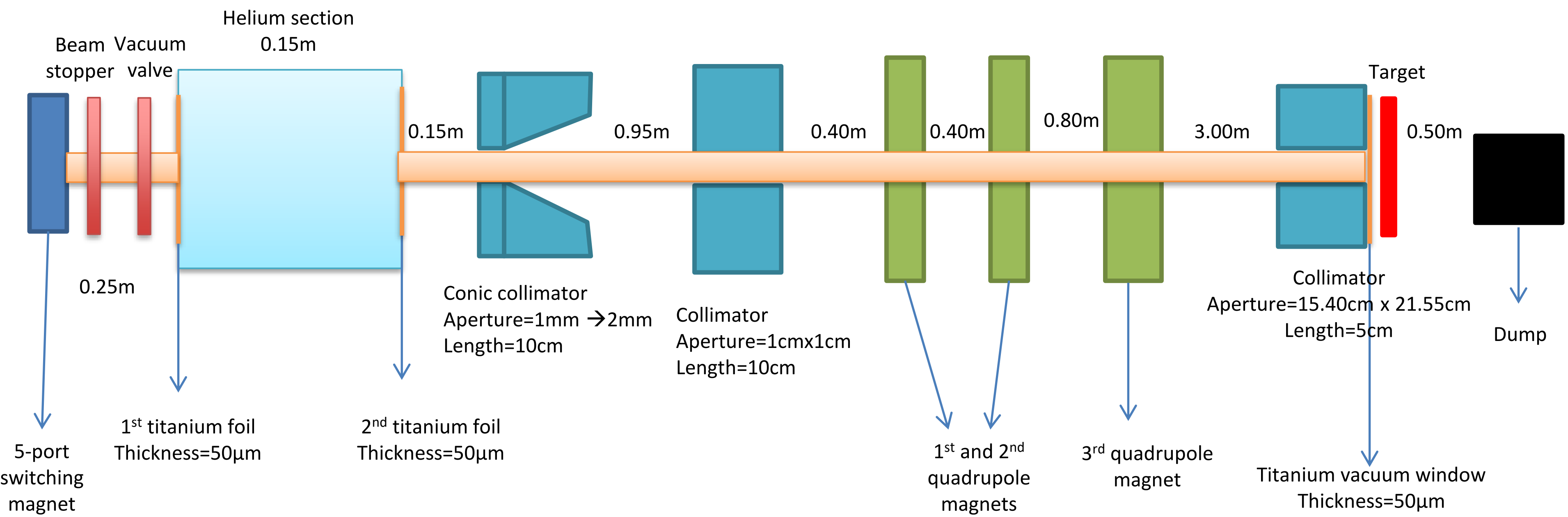
ESA ESCC No. 25100
Single Event Effects Test Method and Guidelines

Requirement	Range	METU-DBL can satisfy
Proton Kinetic Energy	20 – 200 MeV	✓
Irradiation Area	15.40cm x 21.55cm	✓
Proton Flux	10^5 p/cm^2/s at least 10^8 p/cm^2/s	✓
Flux uniformity	±%10	✓
Fluence for One Irradiation	10^{11} p/cm^2	✓
Response Curve	5 different energies between 20 and 200 MeV	✗ Only at one energy✓

METU Defocusing Beam Line
METU DBL

- Beam size enlargements → three quadrupole magnets
- Beam flux reduction → scattering foils and collimators
- Simulation programs
  - Beam optics → MAD-X and Transport
  - Particle tracking→ Turtle and G4beamline

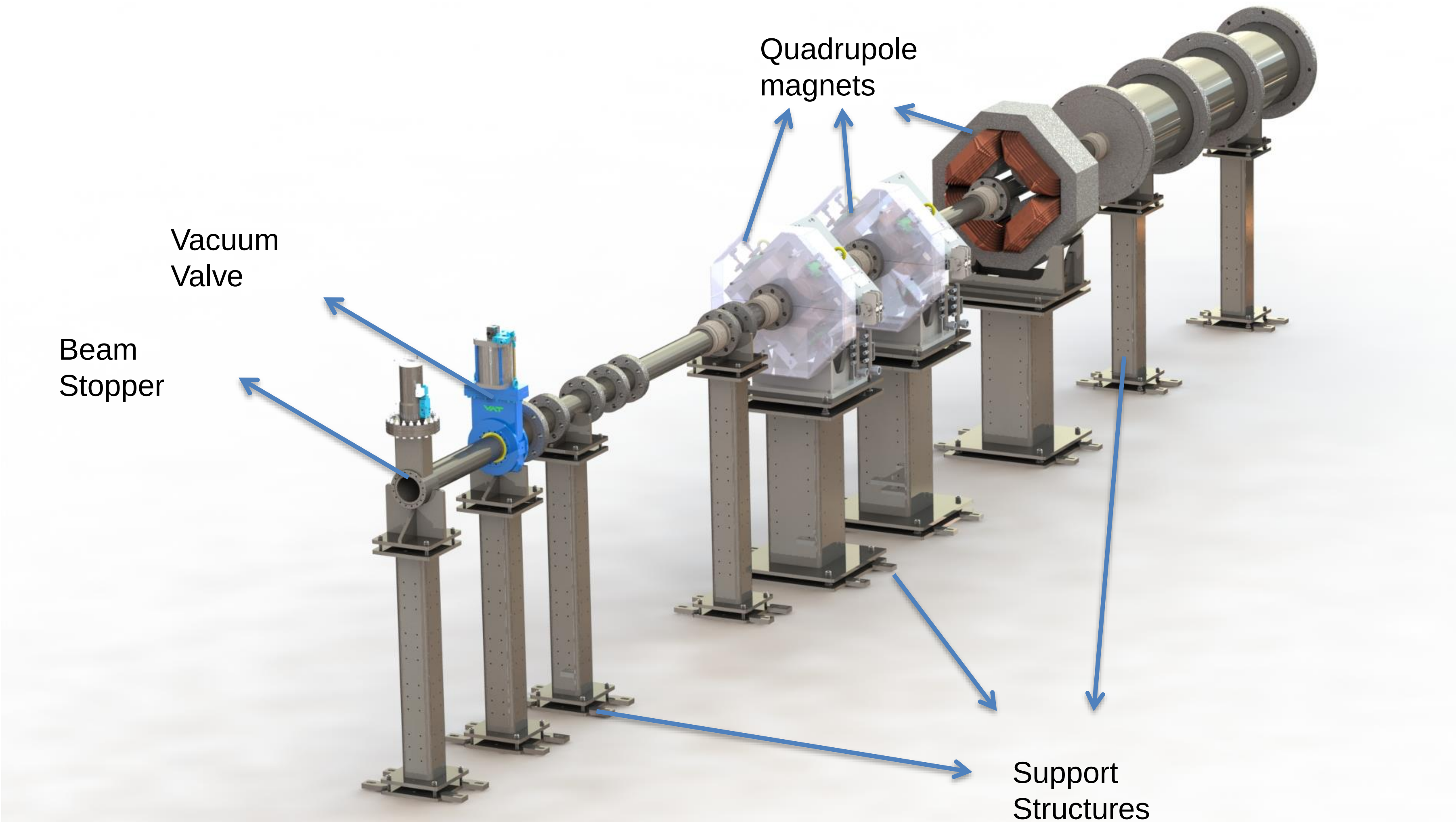
Defocusing BeamLine Layout



Quadrupole magnets → Enlarge the beam size

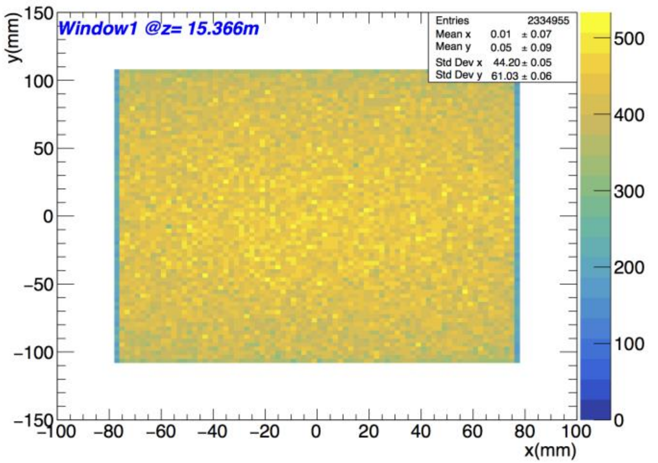
Scattering foils and collimators → Reduce the proton flux

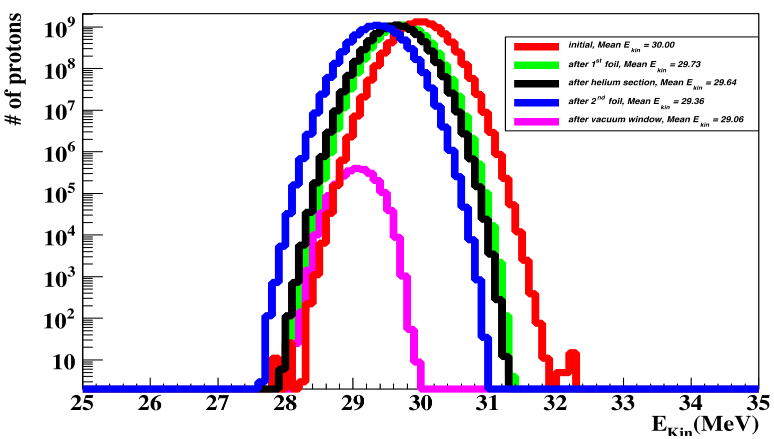
METU-DBL Technical Design



Vacuum < 10^{-6} mbar
Cooling system design to withstand: 100μA

Beam Size, Kinetic Energy and Flux at the Target





Mean KE= 29.1 MeV

Conic collimator Aperture(mm)	Flux (p/cm²/s)
1 → 2	1.5×10^6
2 → 3	6.0×10^6
3 → 4	1.3×10^7
4 → 5	2.2×10^7
5 → 6	3.2×10^7
6 → 7	4.3×10^7
7 → 8	5.3×10^7
8 → 9	6.3×10^7
9 → 10	7.3×10^7

X 50
***for 1μA input beam current**

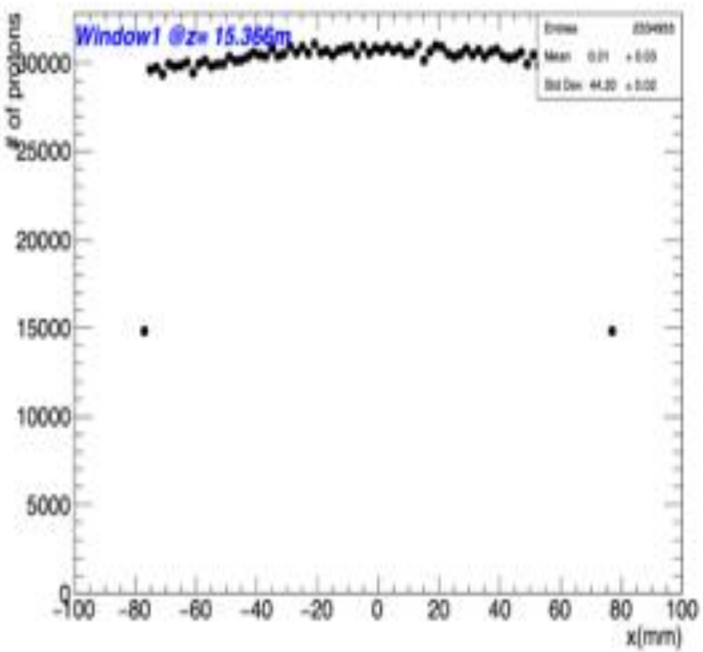
For input beam current
Minimum → 0.1 μA
Maximum* → 100 μA

X 50000

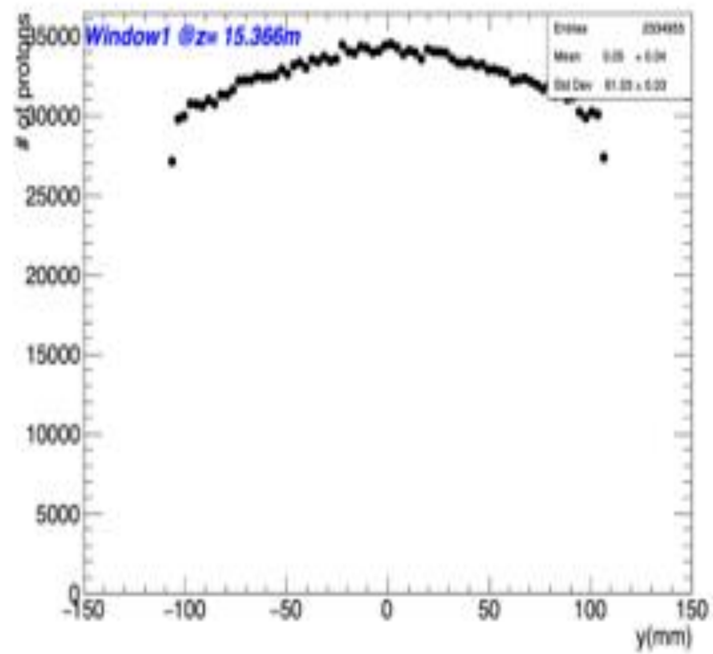
* This is the maximum current that the cooling system can cool down

*Calculated using TURTLE simulation program

Uniformity at the target position

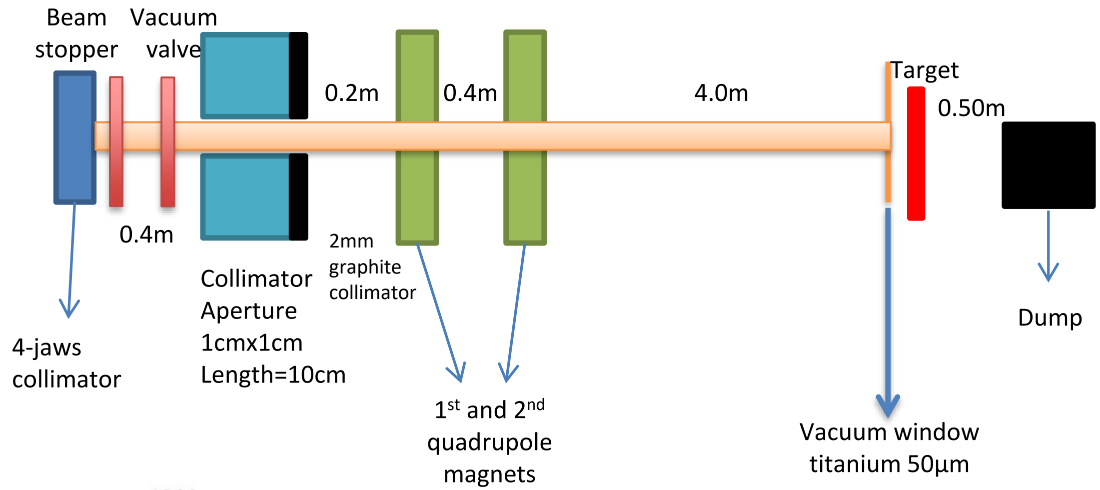


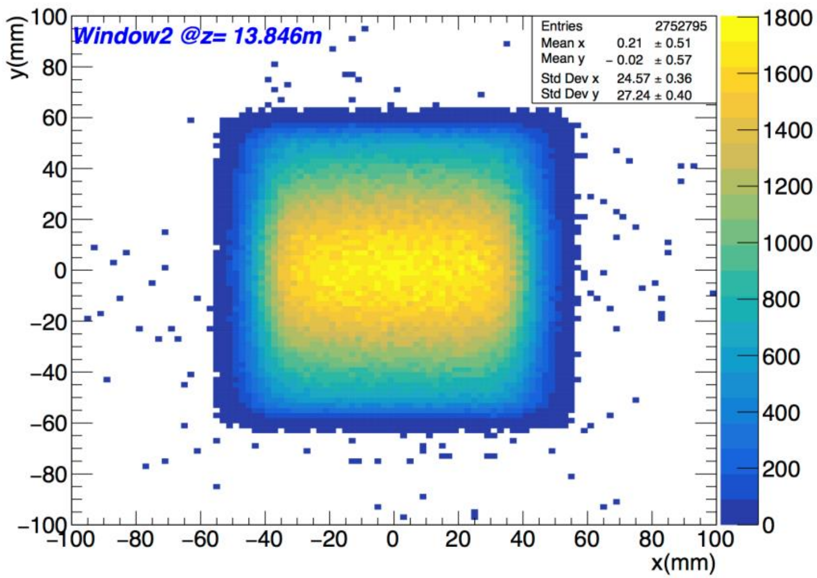
Uniformity in x axis→ %2.8



Uniformity in y axis→ %7.3

METU-DBL Preliminary Test Setup





Flux = 1.7 x 10^9 p/cm^2/s
(6 cm x 4 cm at the centre)

*Calculated using TURTLE simulation program

Preliminary Test Setup Construction

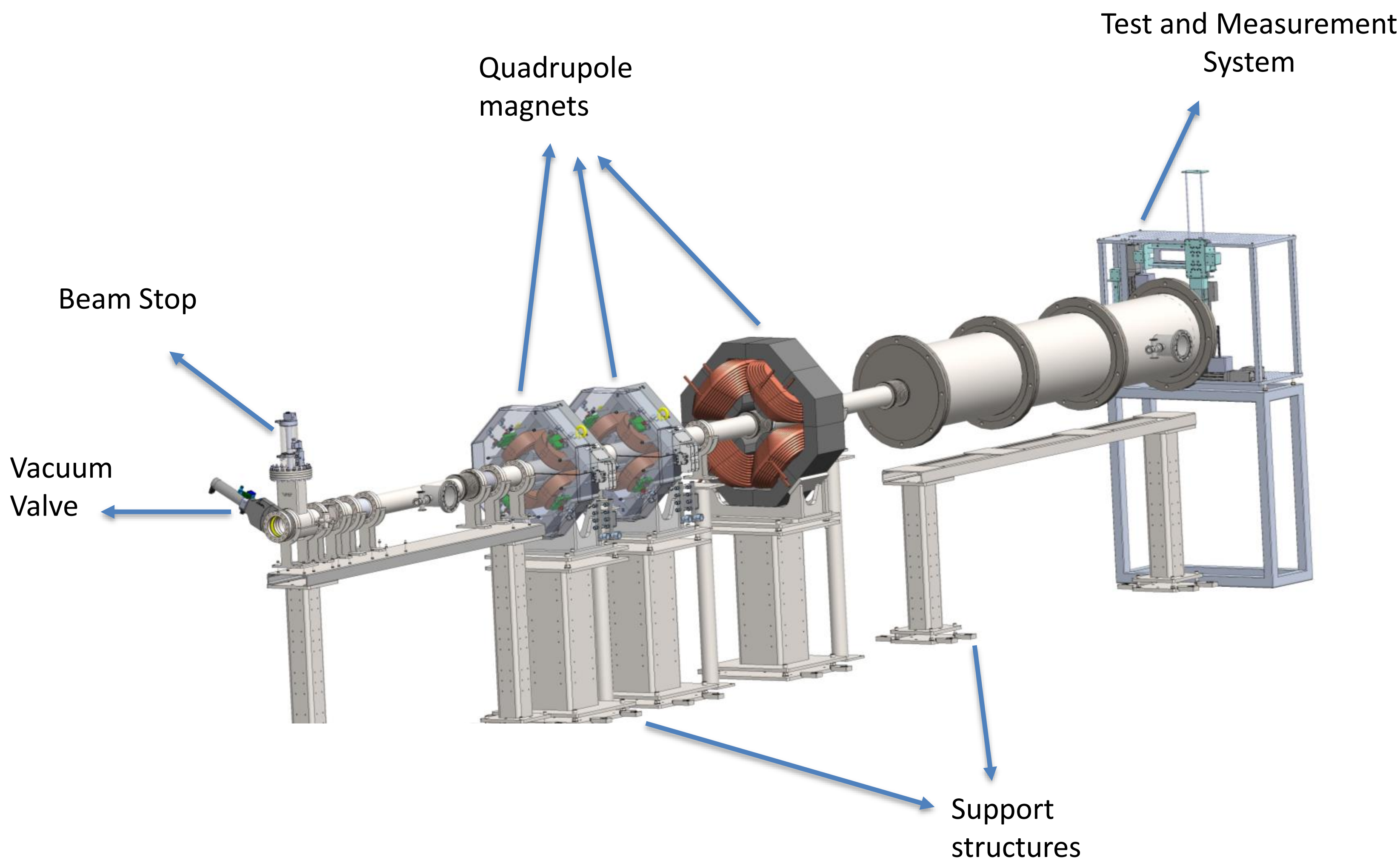
Cooling system → To cool down magnets and collimators

Target table → for mounting and moving detectors and target

Power supplies and cabling → For powering up, communicating with electronics of the beamline

All systems will be controlled by the Control System designed in LabVIEW

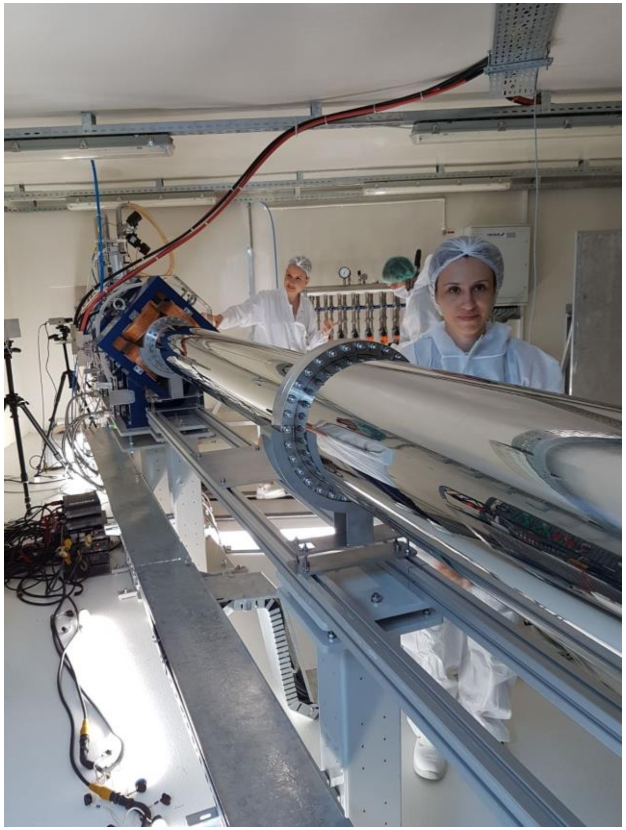
METU-DBL drawing



Vacuum level < 10^{-6} mbar
Cooling system designed to: 100μA

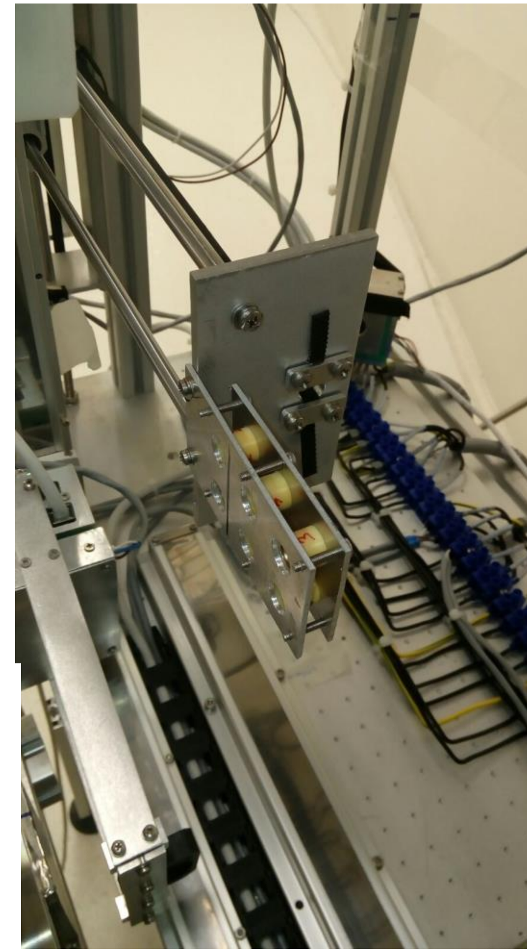
Preliminary Test Setup Construction

Construction of METU-DBL Preliminary Test



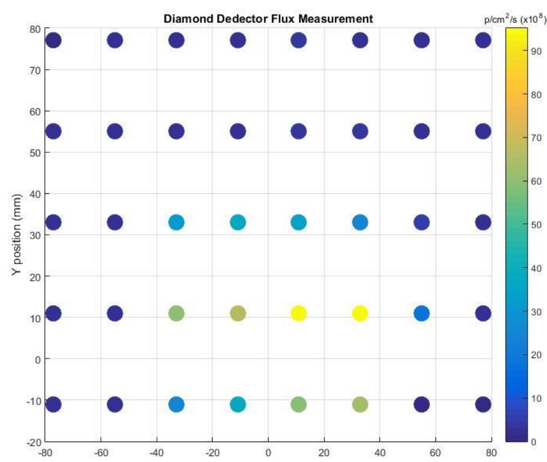
TAEA SANAEM PAF at R&D Room

First Test with Protons



With Prof. Selahattin Özdemir
Tests of 6 pin-diodes.

Since then: Solar cells, glass covers, metallic glass, composites, Buffers, GaN transistors, batteries...



“IMECE Project
National Earth Observation Satellite”

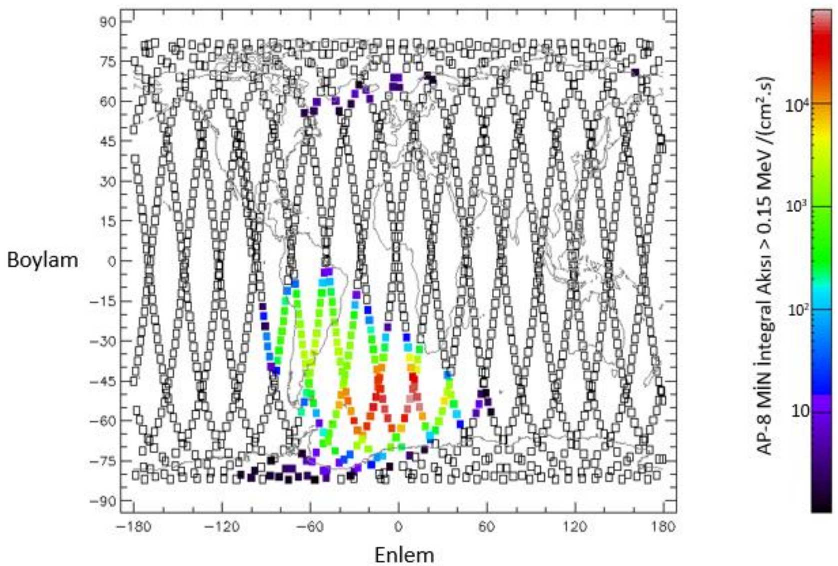
Components that will be developed
for IMECE project

- Li-Ion battery and control card
  - Developed by TUBITAK Energy Institute
- Solar panels
  - Developed by TUBITAK MAM Institute and Gazi University
- Multi layer insulation

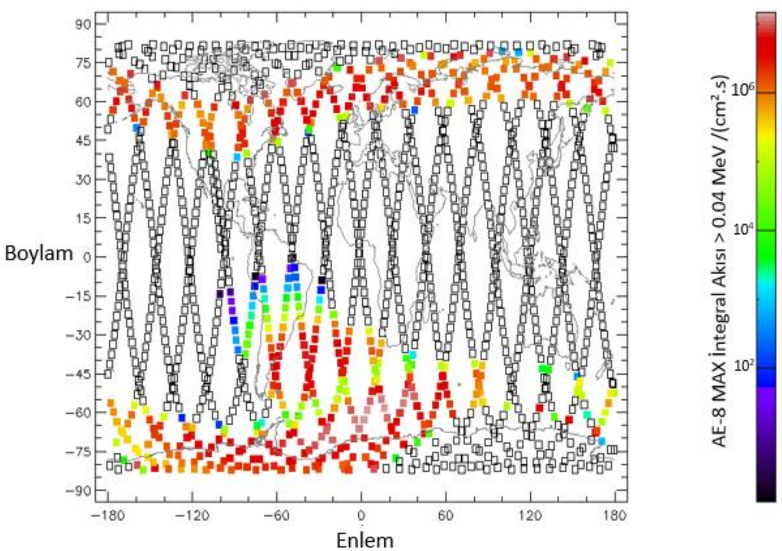
Will be tested and radiation analysis will be performed
With the METU Defocusing Beamline (DBL) Project.
Funding: 7 million TL

Radiation Dose predictions for Turkish satellites:

Captured proton and electron integral fluxes for the IMECE satellite



Integral Flux for Protons

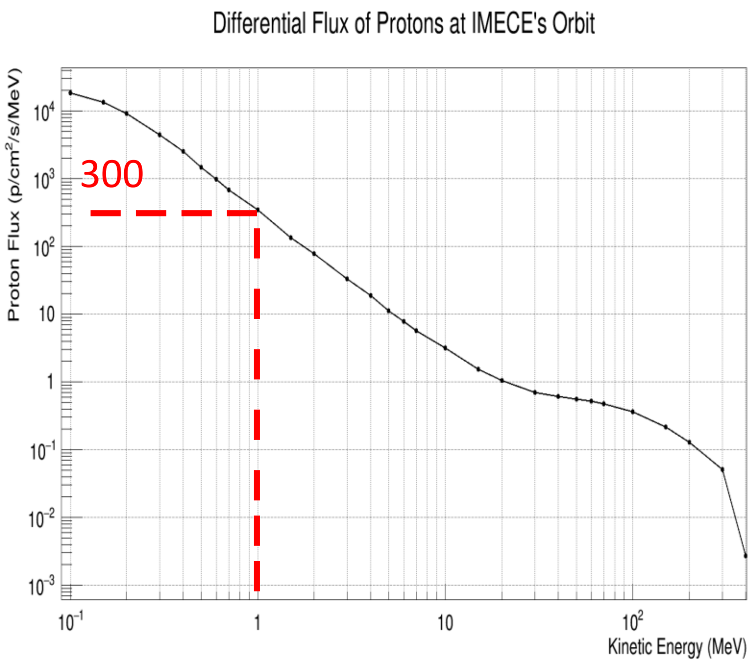


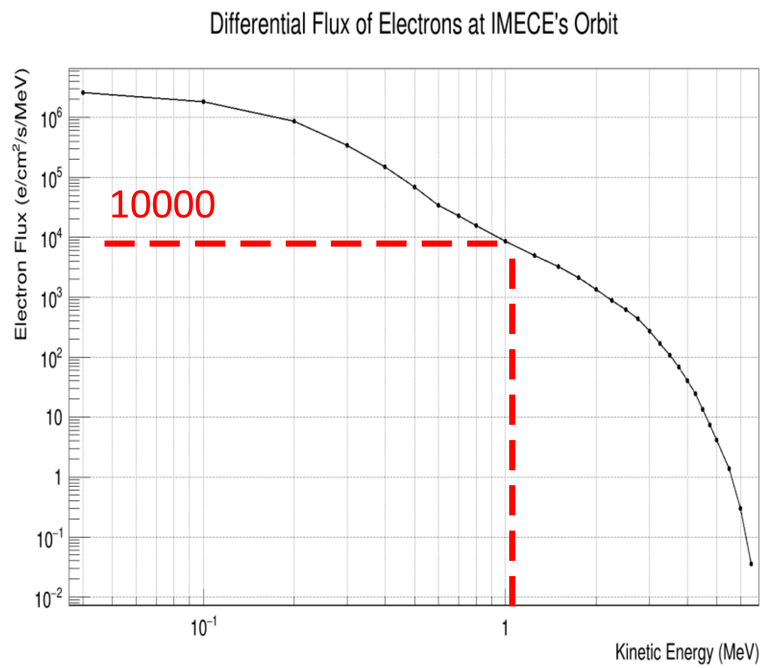
Integral Flux for Electrons

Space Radiation Simulations for IMECE Satellite

Spenvis Simulations for IMECE Satellite:

- Experimental Satellite
- Launch after 2020
- Low Earth Orbit Satellite
- 5 years mission duration

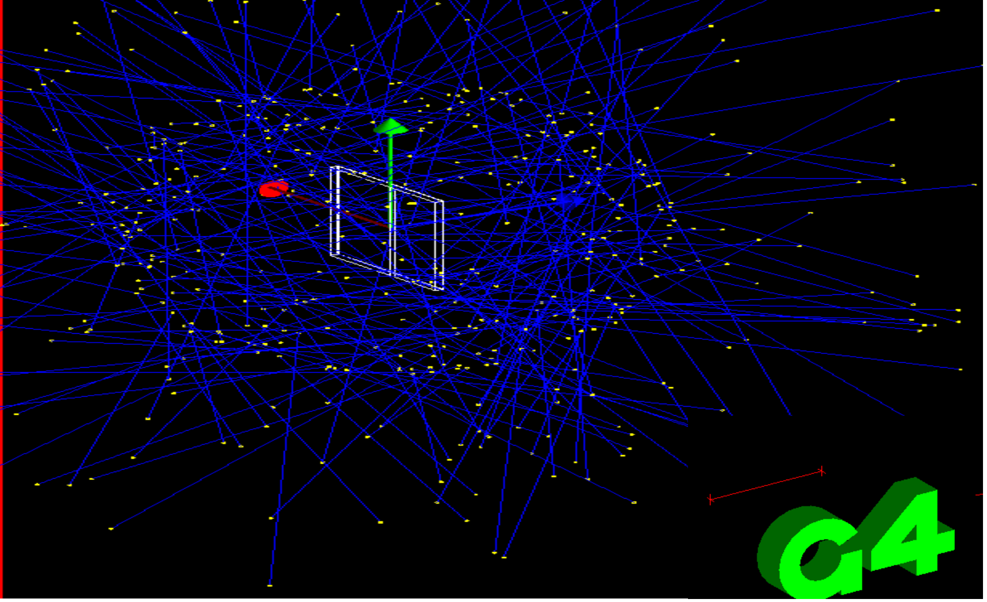


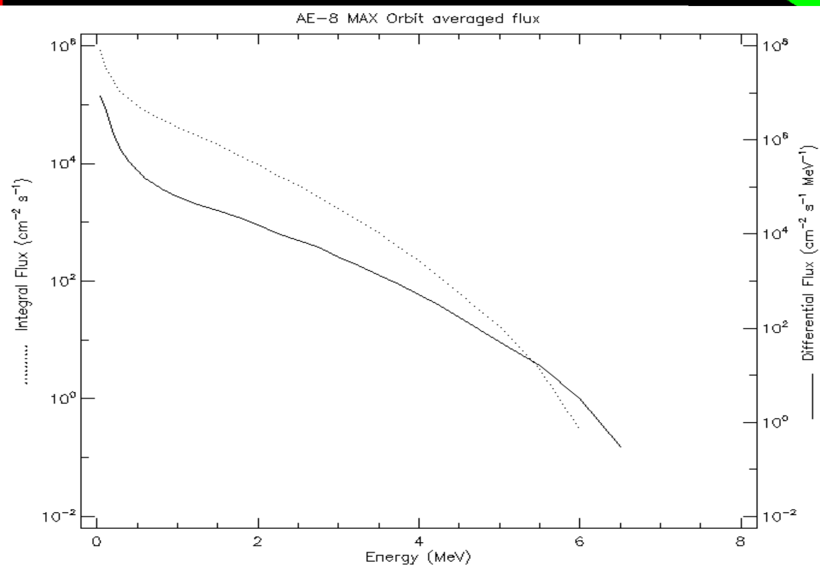


Electron flux dominates over proton flux

* M. Yiğitoğlu, Radiation Environment Predictions For The IMECE Satellite And G4beamline Simulations For The METU-DBL Project. Master's Thesis, Middle East Technical University, 2017.

Radiation Analysis for The Solar Panels of IMECE satellite



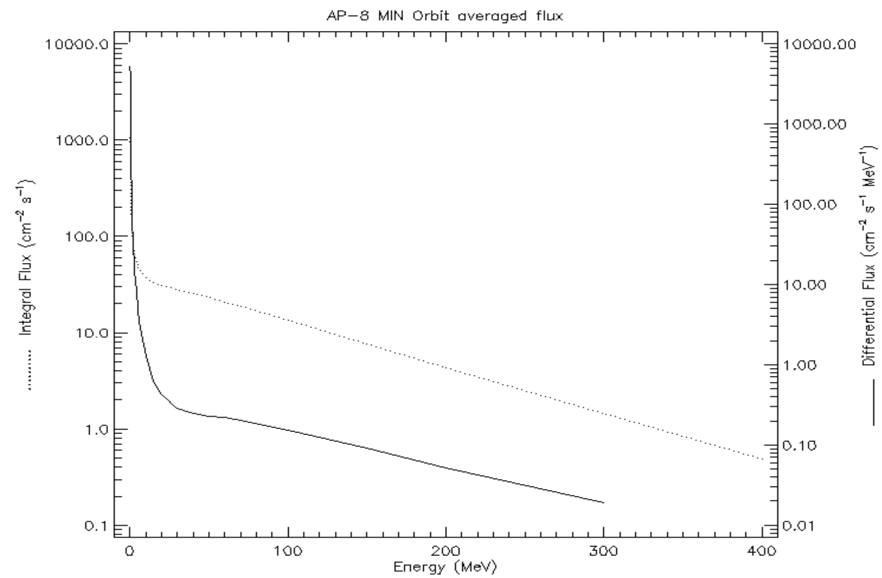


Electron E>0.5

5 year total dose: 309 krad

Effect of Secondaries: %1.28

All ionizing dose



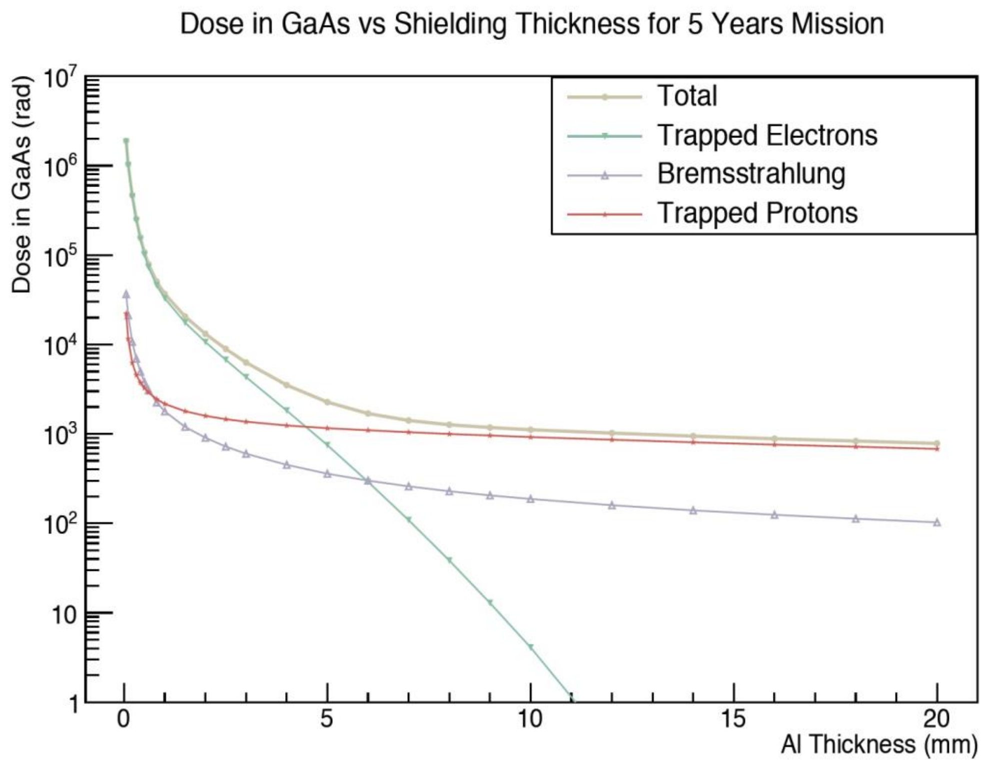
Proton E> 1 MeV

5 year total dose: 2.28 krad

Effect of Secondaries: %0.68

Non-ionizing dose : 38.7 mrad

Radiation Dose for IMECE Satellite



Electron flux → decreases with increasing thickness
Proton flux → nearly constant after 2mm of shielding

* M. Yiğitoğlu, Radiation Environment Predictions For The IMECE Satellite And G4beamline Simulations For The METU-DBL Project. Master's Thesis, Middle East Technical University, 2017.

Associate Membership of Turkey to CERN

12th of May 2014, CERN

28 Nisan 2015 SALI — Resmî Gazete — Sayı : 29340

MİLLETLERARASI ANDLAŞMA

Karar Sayısı : 2015/7421

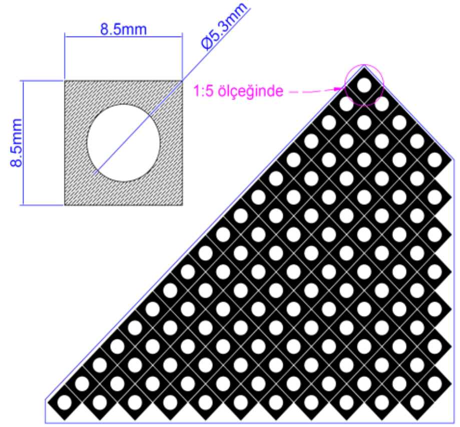
12 Mayıs 2014 tarihinde Cenevre'de imzalanan ve 22/1/2015 tarihli ve 6587 sayılı Kanunla onaylanması uygun bulunan ekli "Türkiye Cumhuriyeti ile Avrupa Nükleer Araştırma Örgütü (CERN) Arasında CERN'de Ortak Üye Statüsü Verilmesi Hakkında Anlaşma" ve Anlaşma'ya dair beyanımızı içeren Mektup'un onaylanması; Dışişleri Bakanlığının 27/2/2015 tarihli ve 7476372 sayılı yazısı üzerine, 31/5/1963 tarihli ve 244 sayılı Kanunun 3 üncü maddesine göre, Bakanlar Kurulu'nca 16/3/2015 tarihinde kararlaştırılmıştır.

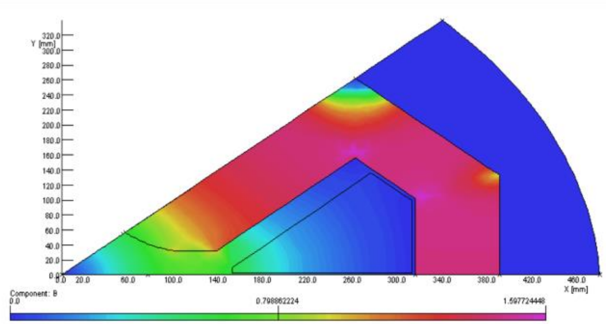
Recep Tayyip ERDOĞAN
CUMHURBAŞKANI

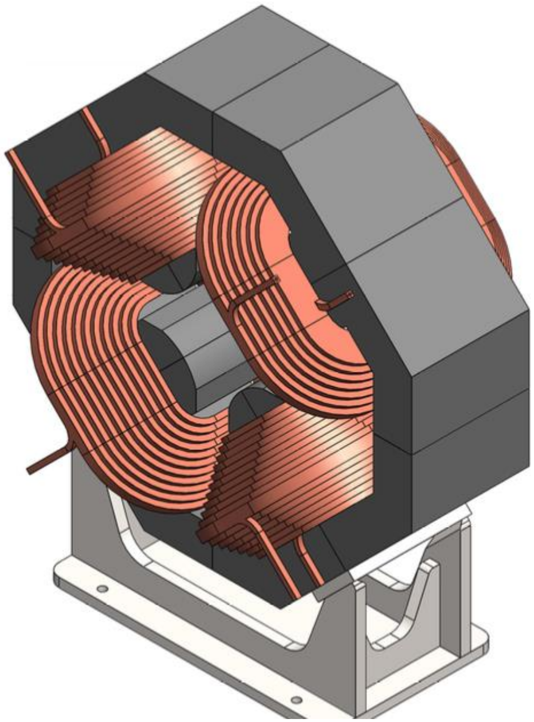
Ahmet DAVUTOĞLU
Başbakan

B. ARINÇ Başbakan Yardımcısı	A. BABACAN Başbakan Yardımcısı	Y. AKDOĞAN Başbakan Yardımcısı	N. AVCI Başbakan Yardımcısı V.
K. İPEK Adalet Bakanı	A. İSLAM Aile ve Sosyal Politikalar Bakanı	V. BOZKIR Avrupa Birliği Bakanı	F. IŞIK Bilim, Sanayi ve Teknoloji Bakanı
F. ÇELİK Çalışma ve Sosyal Güvenlik Bakanı	İ. GÜLLÜCE Çevre ve Şehircilik Bakanı	A. Ç. KILIÇ Dışişleri Bakanı V.	N. ZEYBEKCİ Ekonomi Bakanı
T. YILDIZ Enerji ve Tabii Kaynaklar Bakanı	A. Ç. KILIÇ Gençlik ve Spor Bakanı	M. M. EKER Gıda, Tarım ve Hayvancılık Bakanı	N. CANİKLİ Gümrük ve Ticaret Bakanı

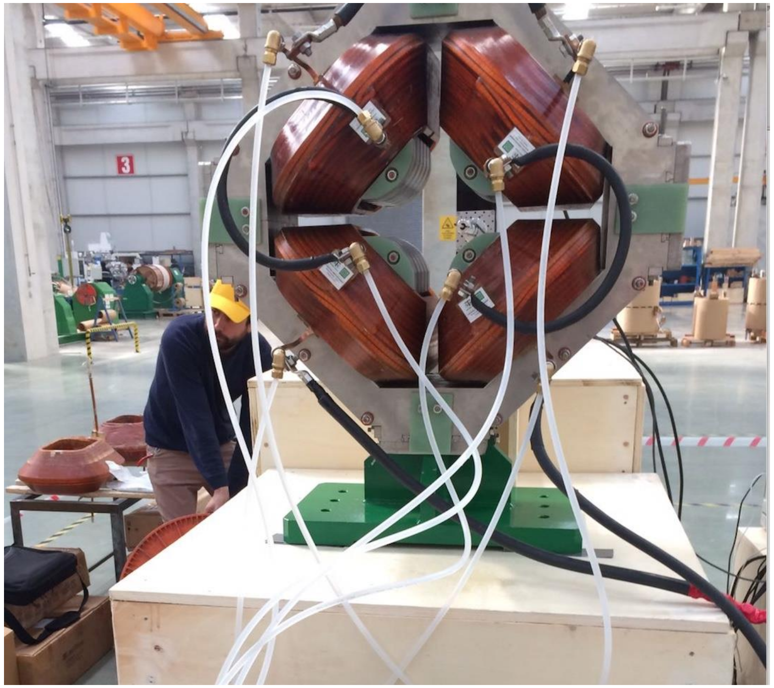
A first in Turkey:
Design of an industrial size quadrupole magnet and production





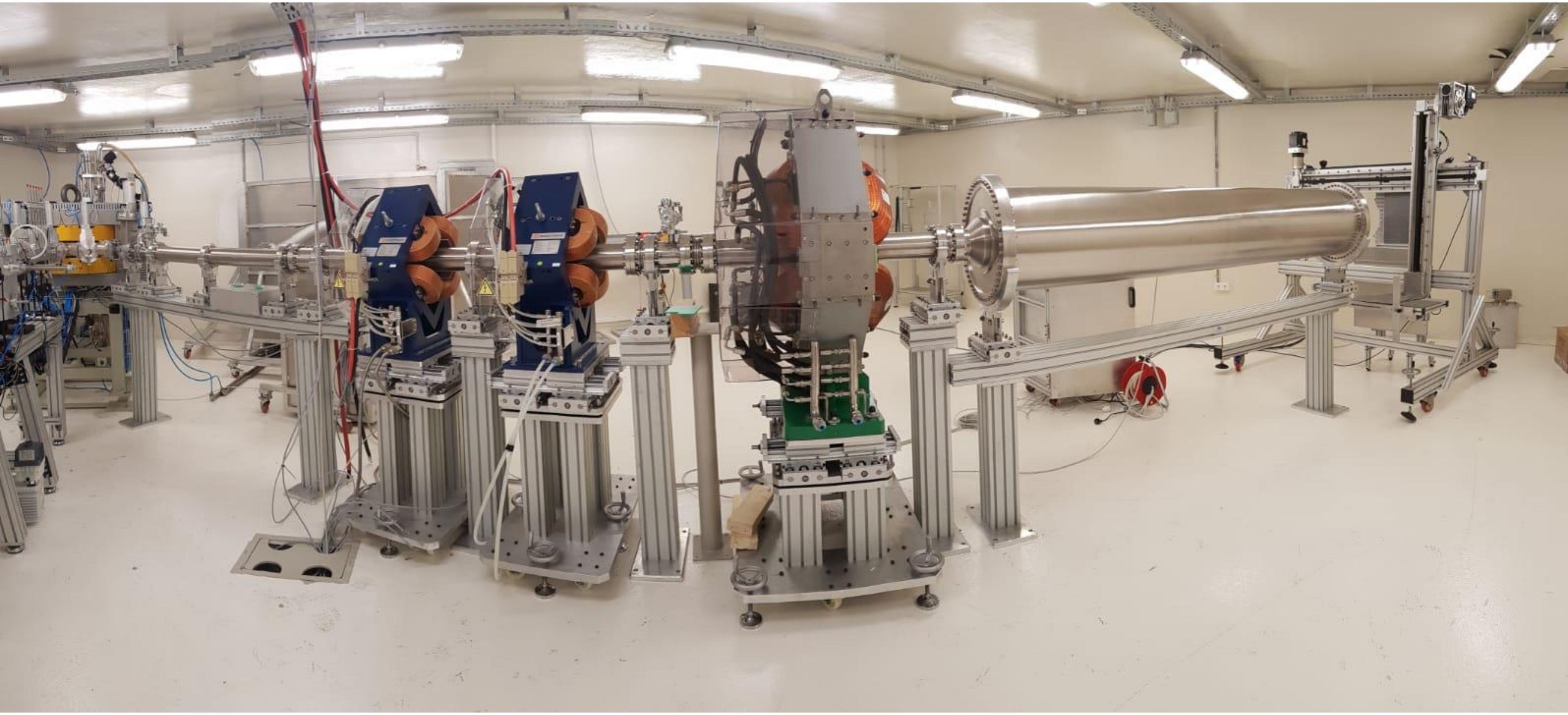


METU and Sönmez Transformator San. ve Tic. Aş.
collaboration



Tested at CERN
April 2018

Final Construction



Thank you for listening

Also thanks to:

- Presidency of Budget and Strategy
- TAEA SANAEM personnel