

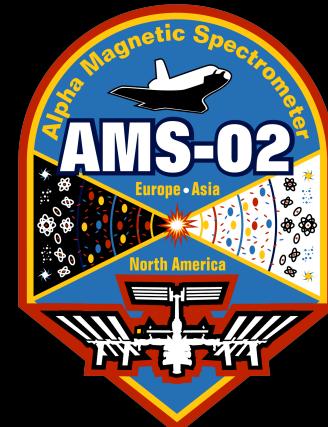


AMS-02: cosmic electron and positron ($e^+ + e^-$) spectrum up to 1 TeV

J. Bazo, ASDC & INFN

For the AMS-02 Collab.

RICAP-2014, 2 Oct, Noto, Italy



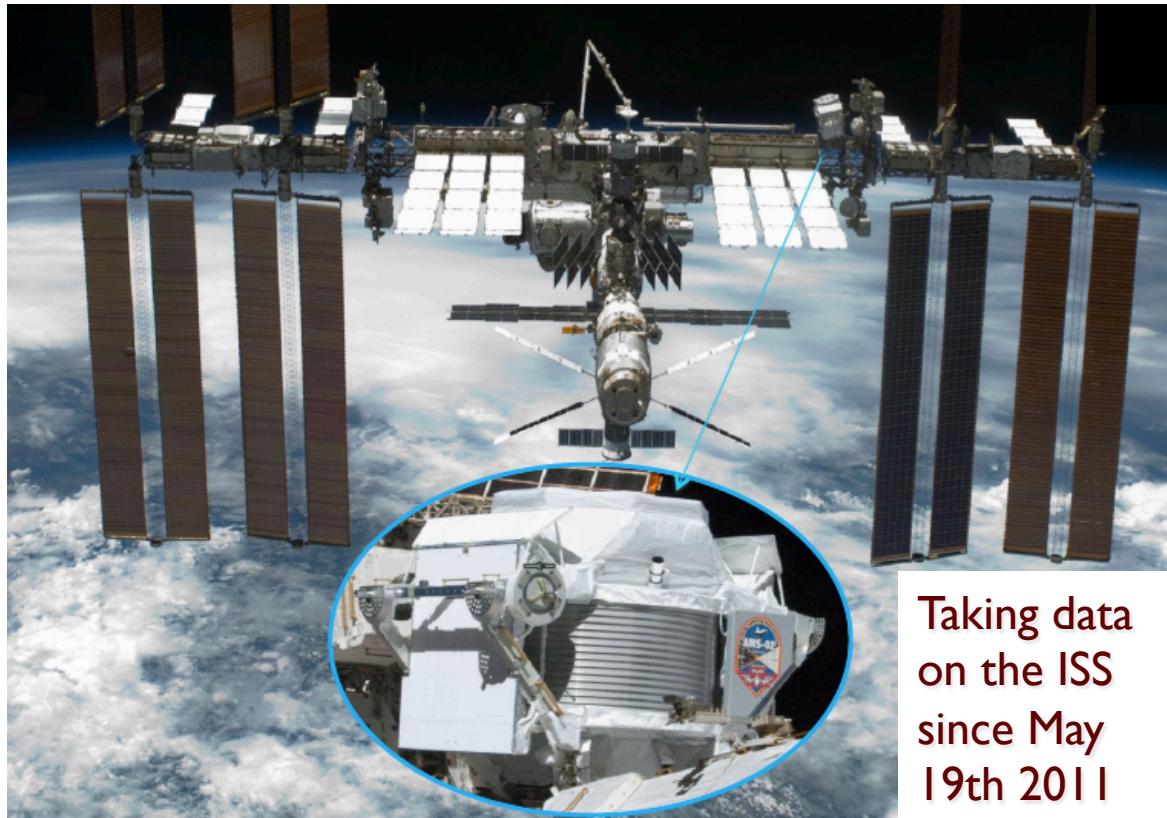
Alpha Magnetic Spectrometer AMS-02

AMS-02 Collaboration:
16 countries, 60 institutes,
600 people

Space Shuttle Endeavour
lifts off on May 16th 2011
taking AMS to the ISS

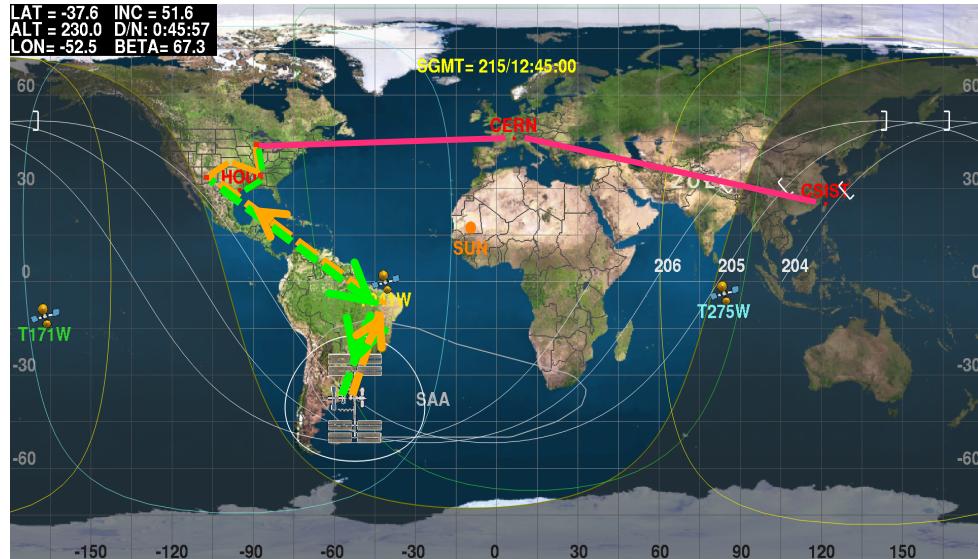


Performs accurate, high statistics, long period
measurements of charged cosmic rays (GeV-TeV)



Taking data
on the ISS
since May
19th 2011

Detector operations



- ❖ Flying @ ~400 km
- ❖ Each orbit ~93min
- ❖ Calibration every 46min @equator

Data rate: 16 billion events/year

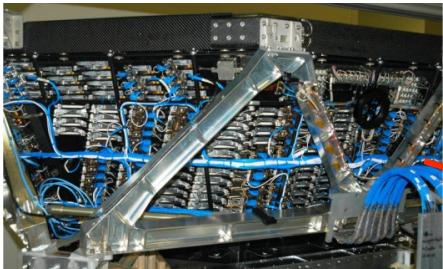
So far: 3.4 years of data taking
→ ~54 billion events collected

Payload and Operations Control Center (POCC) at CERN
24/7 monitoring and communication with NASA

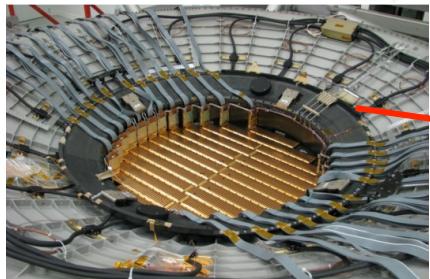


The sub-detectors

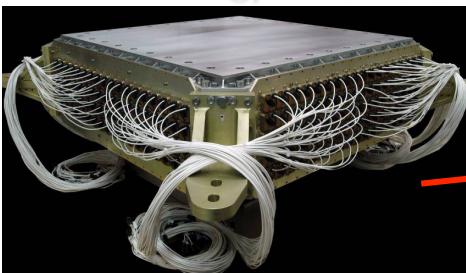
TRD: Identifies e^+ , e^-



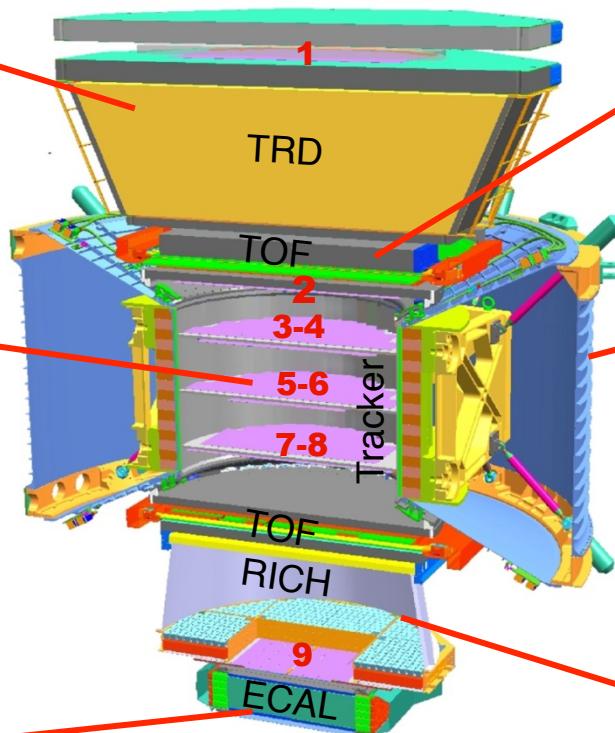
Silicon Tracker: Z, P



ECAL: energy: e^+ , e^- , γ



AMS-02



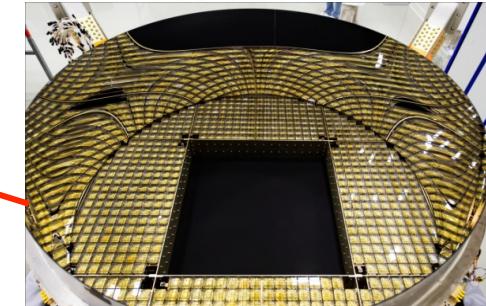
TOF: Z, E



Magnet: $\pm Z$



RICH: Z, E



(e⁺+e⁻) flux measurement

Why? Φe^- (700 GeV),
 Φe^+ (500 GeV),
positron fraction (500 GeV)

but $\Phi(e^++e^-)$ upto 1 TeV

Next talk by C.
Pizzolotto

Because Experimental advantage:

- Higher efficiency in sample selection
- Insensitive to charge confusion

Thus the combined flux measurement is more accurate than the sum of the individual fluxes and can be extended at higher energies.

Flux measurement

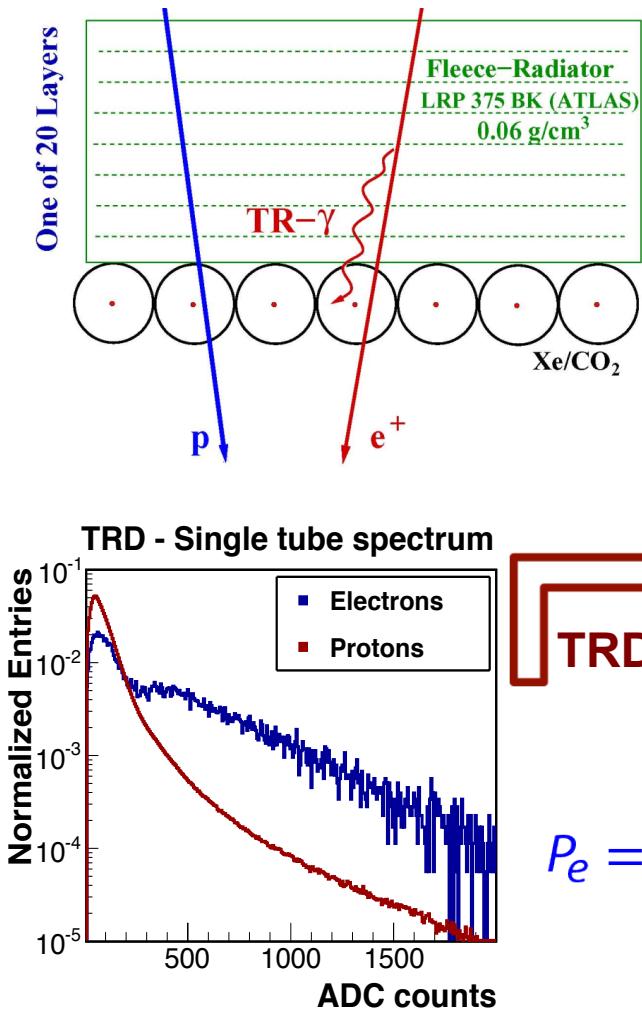
$$\Phi(e^+ + e^-) = \frac{N(E)}{A_{\text{eff}}(E) \cdot \epsilon_{\text{trig}}(E) \cdot \epsilon_{\text{ECAL}}(E) \cdot T(E) \cdot \Delta E}$$

- Φ = isotropic flux
- N = number of observed ($e^+ + e^-$) events
- A_{eff} = effective detector acceptance
- ϵ_{trig} = trigger efficiency
- ϵ_{ECAL} = signal selection efficiency based on the ECAL estimator
- T = exposure time
- ΔE = energy bin width

Event selection

- ✓ **Geomagnetic effects:** $E > 1.2$ max geomagnetic cutoff
- ✓ **TRD :** hits in at least 8/20 TRD layers, used for e/p identification
- ✓ **TOF :** relativistic down-going particle
- ✓ **ECAL:**
 - ✓ shower axis within the fiducial volume
 - ✓ reject events with energy deposition compatible with a MIP in the first 5 layers of ECAL.
- ✓ **TRACKER:**
 - ✓ $Z < 1.5$
 - ✓ single track passing through ECAL and matching shower

Particle separation with TRD

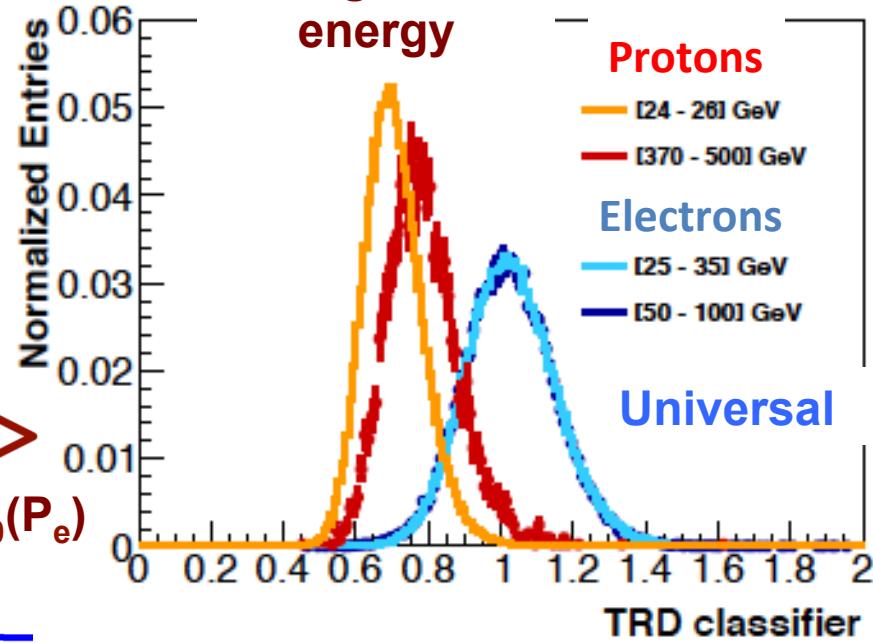


TRD

Changes with
energy

- Protons**
 - [24 - 26] GeV
 - [370 - 500] GeV
- Electrons**
 - [25 - 35] GeV
 - [50 - 100] GeV

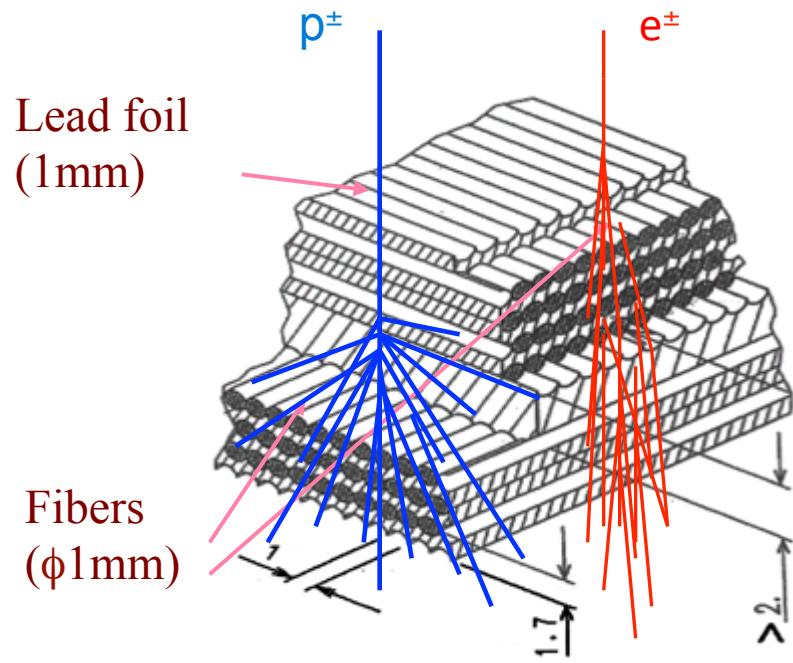
Universal



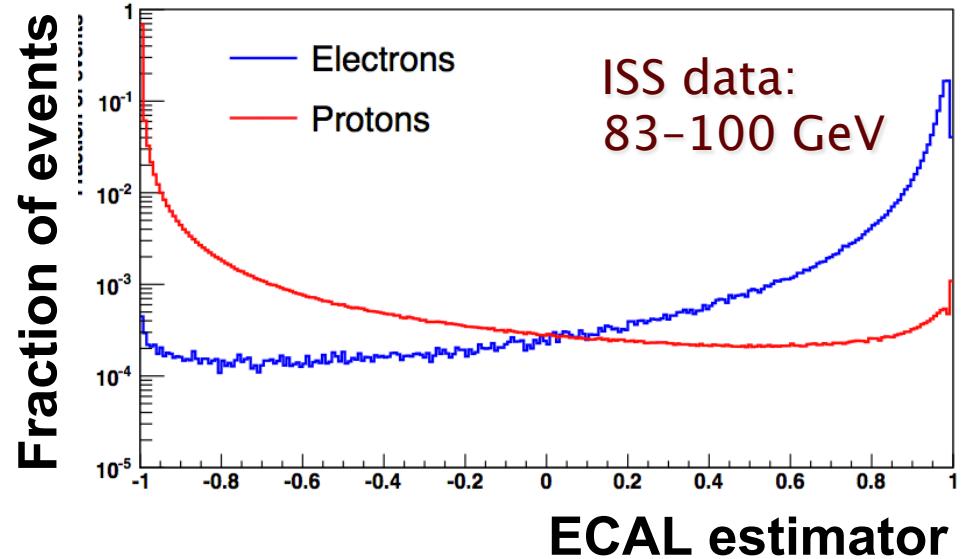
$$\text{TRD-LLe} = \log_{10}(P_e)$$

$$P_e = \sqrt[n]{\prod_i^n P_e^{(i)}(A)}$$

Particle separation with ECAL

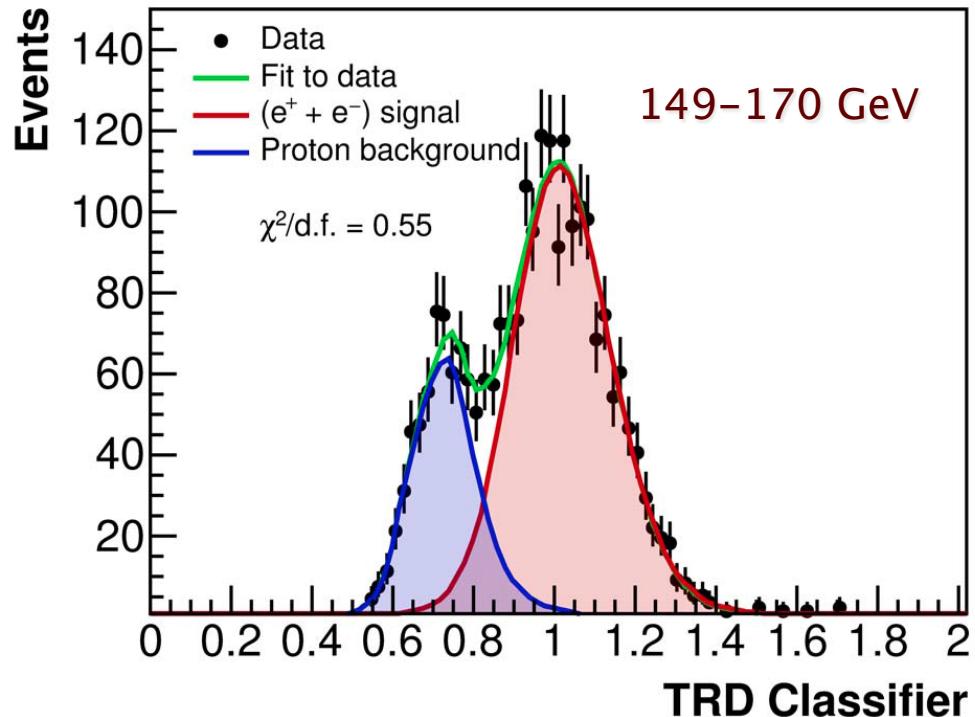


Boosted Decision Tree, BDT:
19 variables describing 3D shower shape



Template fit to measure N_e and N_p

- Reference spectra based on the TRD estimator for signal ($e^+ + e^-$) and background (protons) are constructed using the ECAL estimator, E/p matching and charge-sign.
- Sum of templates is fit to data varying their normalizations, for different cuts on the ECAL BDT estimator.
- Measurement is performed for BDT cut that minimizes the overall statistical and systematic uncertainty.



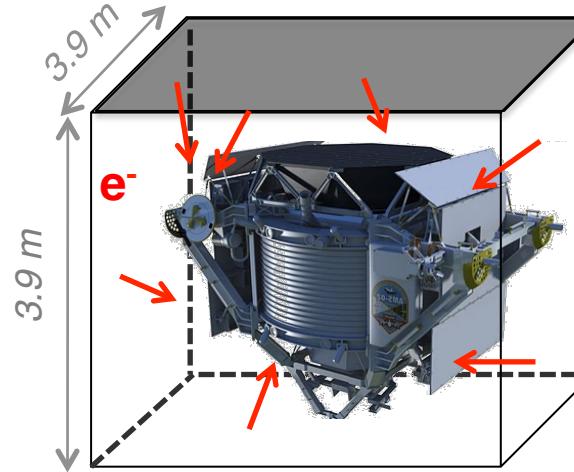
Out of 41 billion events, 10.6 million have been identified as $(e^+ + e^-)$

Acceptance

$$A_{\text{eff}} = A_{\text{geom}} \cdot \epsilon_{\text{sel}} \cdot (1 + \delta)$$

A_{geom} = geometric acceptance $\sim 550 \text{cm}^2\text{sr}$
 in active volume of Tracker, TRD, TOF, ECAL
 ϵ_{sel} = event selection efficiency: 70%@1TeV
 δ = data derived correction: -2% for HE

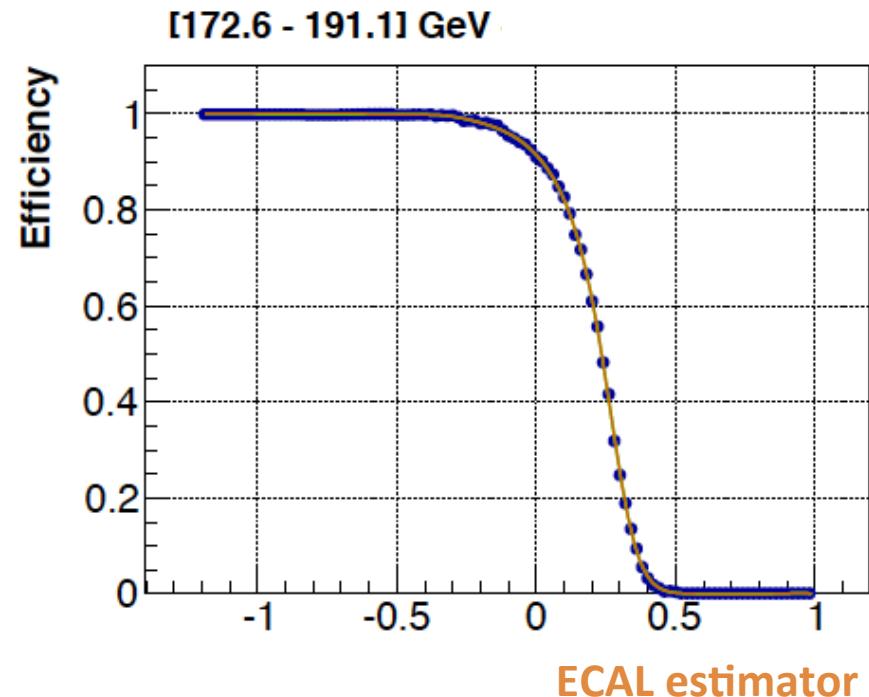
Estimated with
MC (Geant 4)



Efficiencies

ϵ_{ECAL} is measured from data using negative rigidity samples and different selection cuts.

S/N in sample is naturally enhanced and the evaluation is possible up to highest energies



Trigger efficiency (ϵ_{trig}) is determined from flight data using a pre-scaled sample with looser trigger conditions. It is 100% above 3GeV decreasing to 75% at 1GeV.

← Close to ECAL trigger threshold

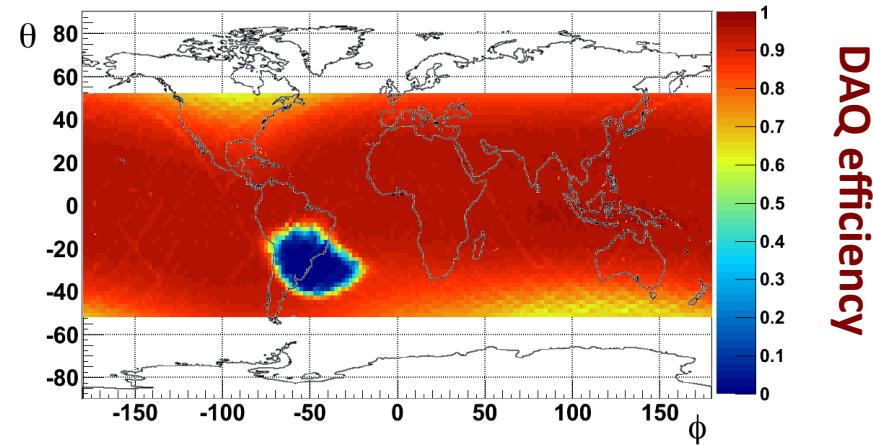
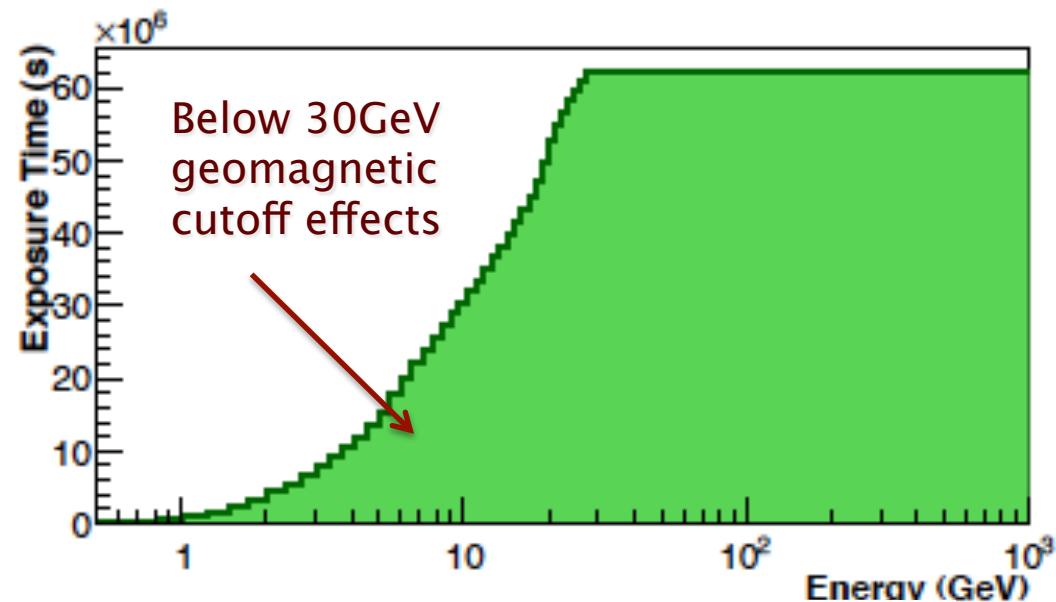
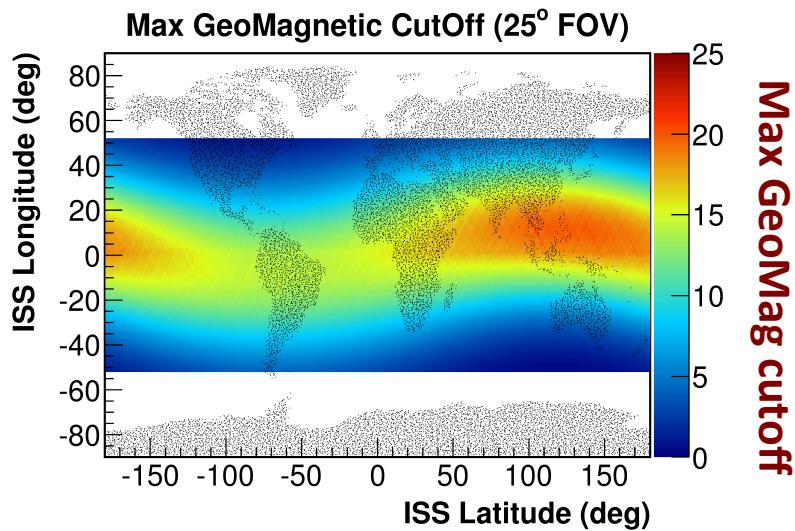
Exposure time

Data taking period:

19 May 2011 - 26 Nov 2013

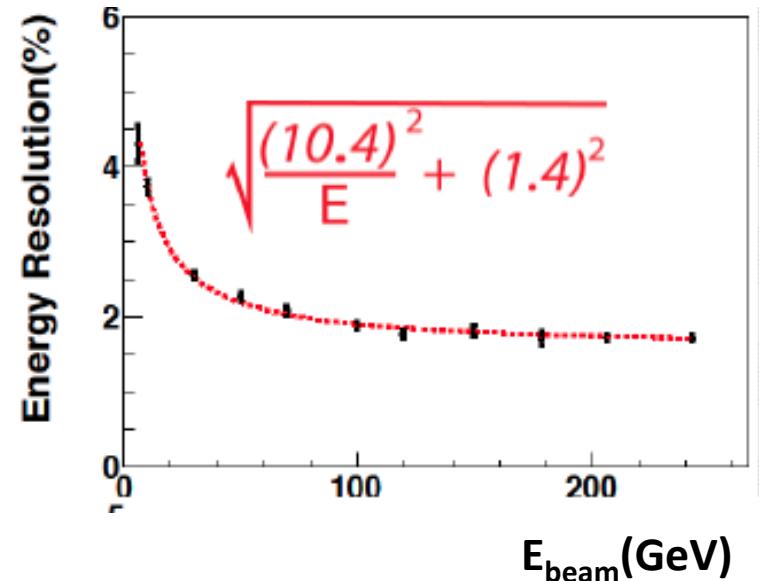
Total exposure time above 30 GeV: 6.2×10^7 s (~80 % uptime)

Downtime: South Atlantic Anomaly, TRD gas refills, AMS not pointing towards zenith ($>40^\circ$), detector dead time, ...

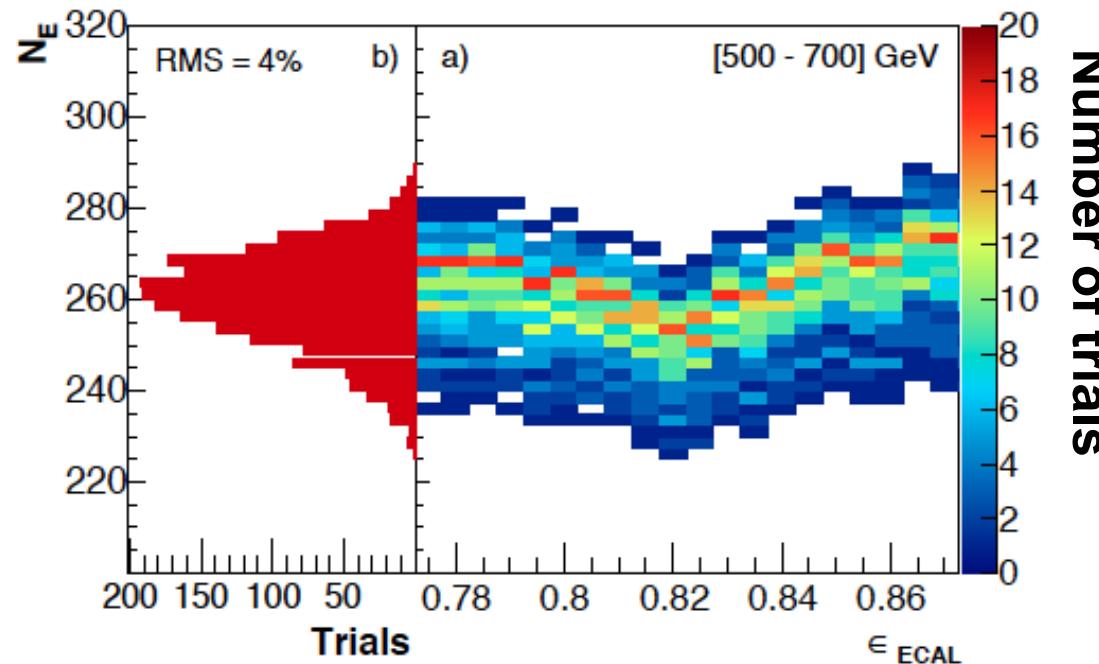


Energy, binning and systematics

- Flux is evaluated in 74 energy bins of width $\geq 2 \times$ energy resolution
- **Systematics:** Bin-to-bin migration error: 1%@1GeV down to 0.2%@10GeV
- The absolute energy scale uncertainty is 2% (10–290 GeV)



Systematics due to event selection



Stability of events measured

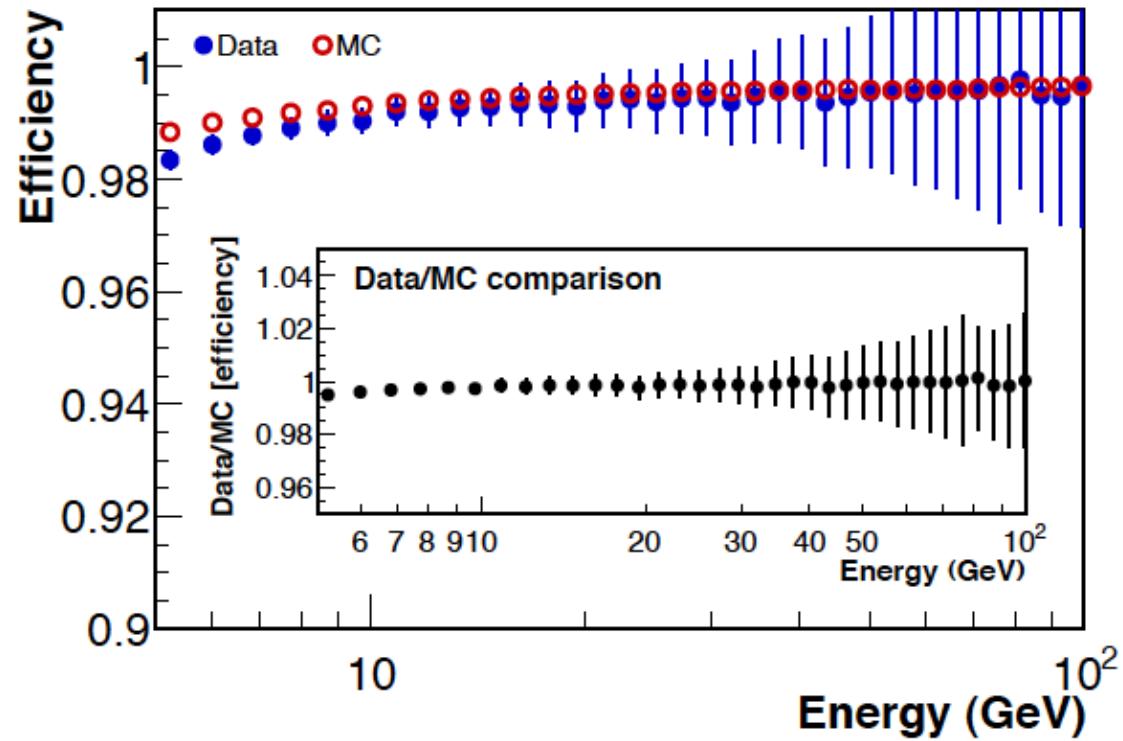
2000 trials show that the result ($N_E = N/\epsilon_{ECAL}$) is stable over a $\pm 5\%$ range of ϵ_{ECAL} around the ECAL estimator cut and changing the templates.

Systematics= RMS of estimated N_E over a large range of BDT cut efficiencies= 4%@[500-700]GeV

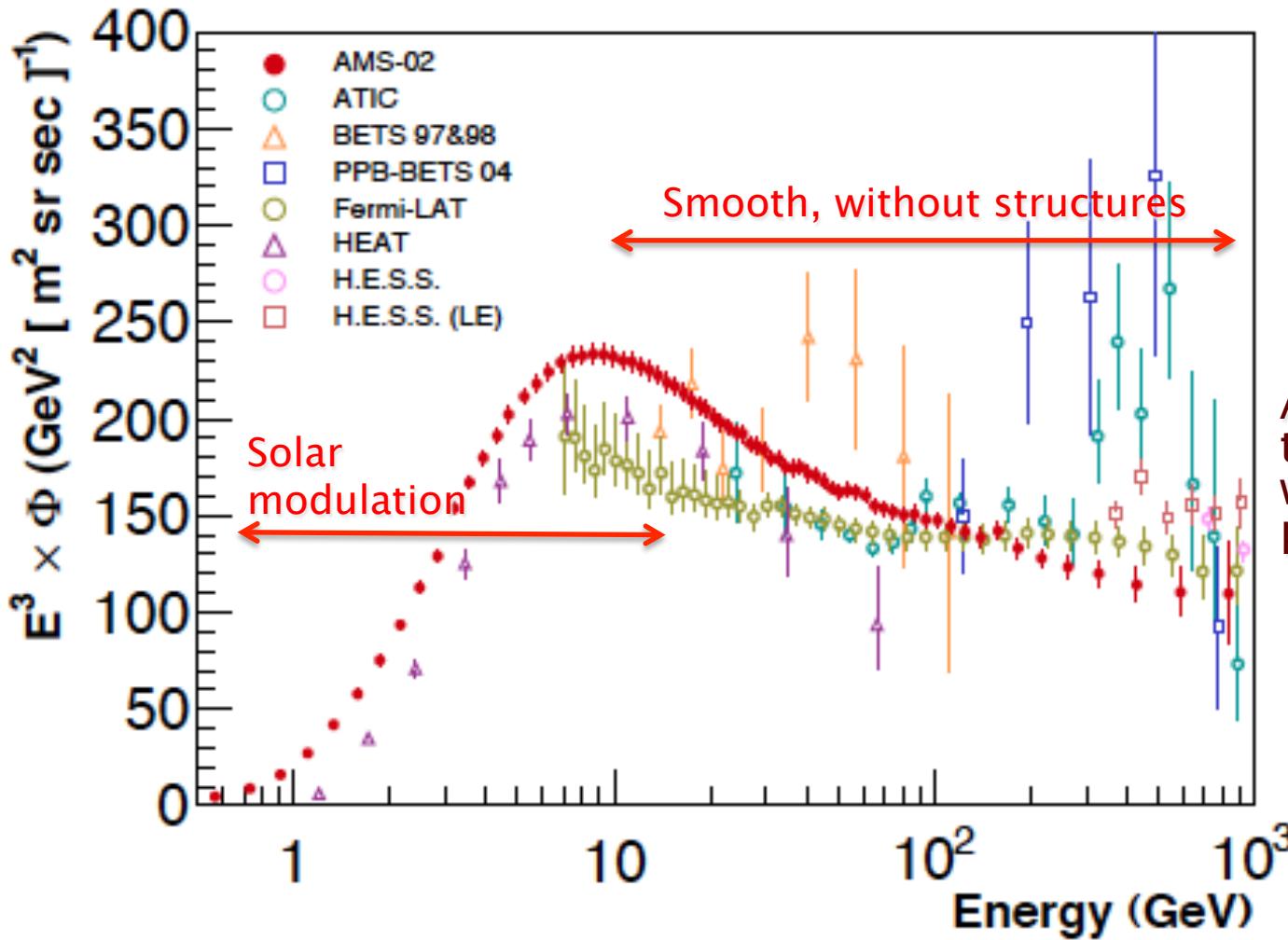
Systematics due to acceptance

Systematic: Uncertainty
 on MC/Data agreement
 from all cuts:
 6%@1GeV, 2%@>3GeV

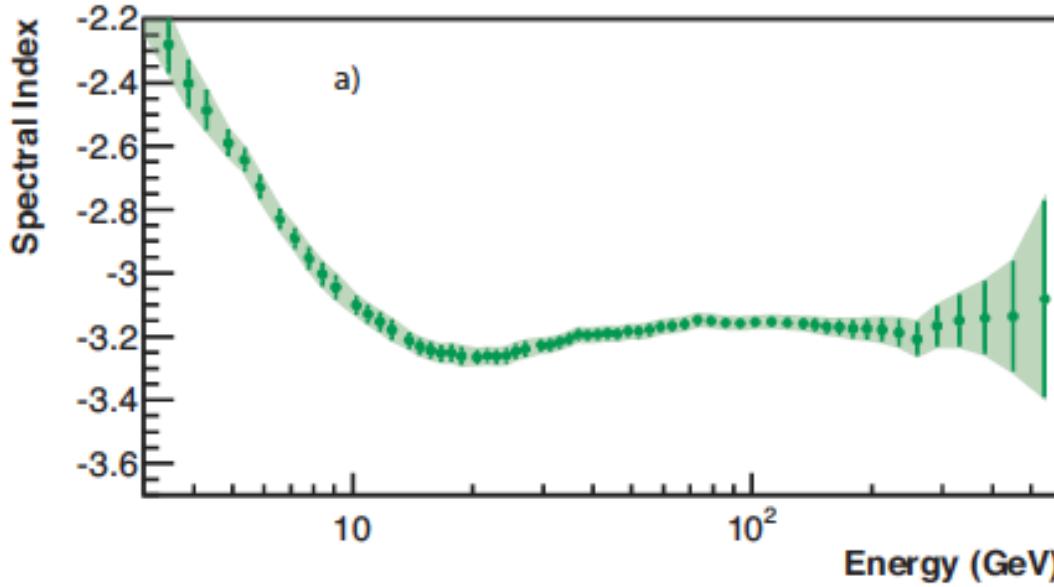
An example: *TRD quality criteria*.
 Discrepancies: hint of systematic effects in MC.



Measured e^+e^- flux



Spectral power law fit

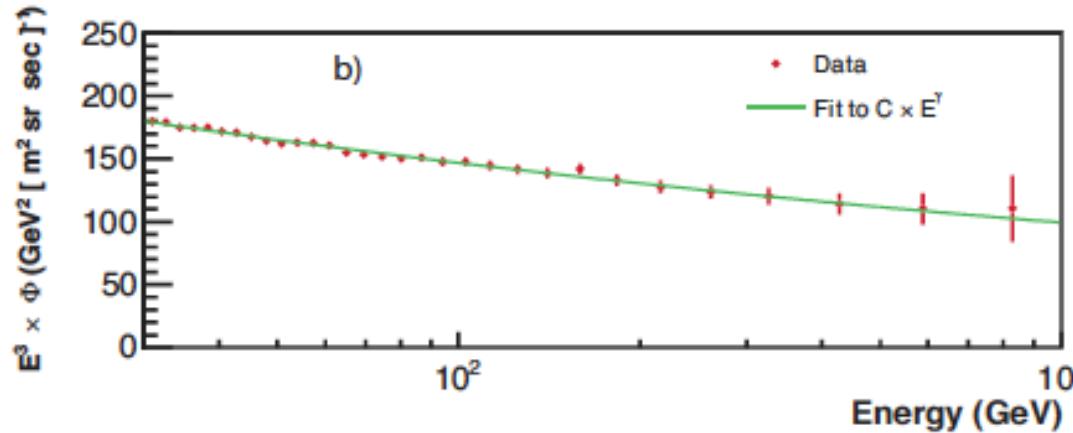


Single power law fit

$$\Phi(e^+ + e^-) = CE^\gamma$$

(30.2GeV – 1TeV):

$$\gamma = -3.17 \pm 0.008 \text{ (stat+sys)} \\ \pm 0.008 \text{ (energy scale)}$$



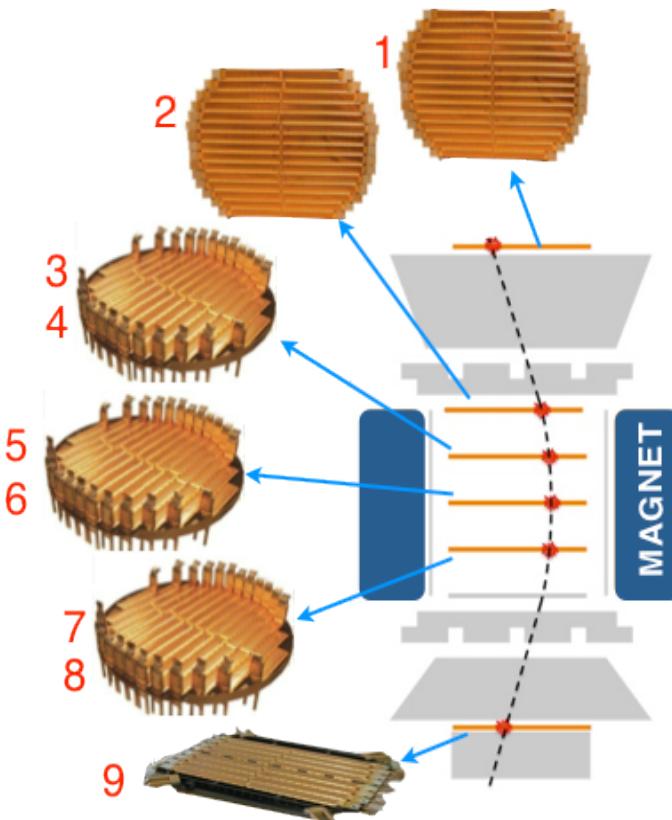
Conclusions

- ✧ Analysis based on 41 billion events collected by AMS-02.
- ✧ e^+e^- flux measured between 0.5 GeV to 1 TeV.
- ✧ Flux is smooth and without structures.
- ✧ From ~30 GeV to 1 TeV the flux can be described by a single power law with $\gamma = -3.17 \pm 0.008$ (stat+sys) ± 0.008 (energy scale)
- ✧ The analysis has been submitted for publication to Physical Review Letters.

Back-up Slides

The Silicon Tracker

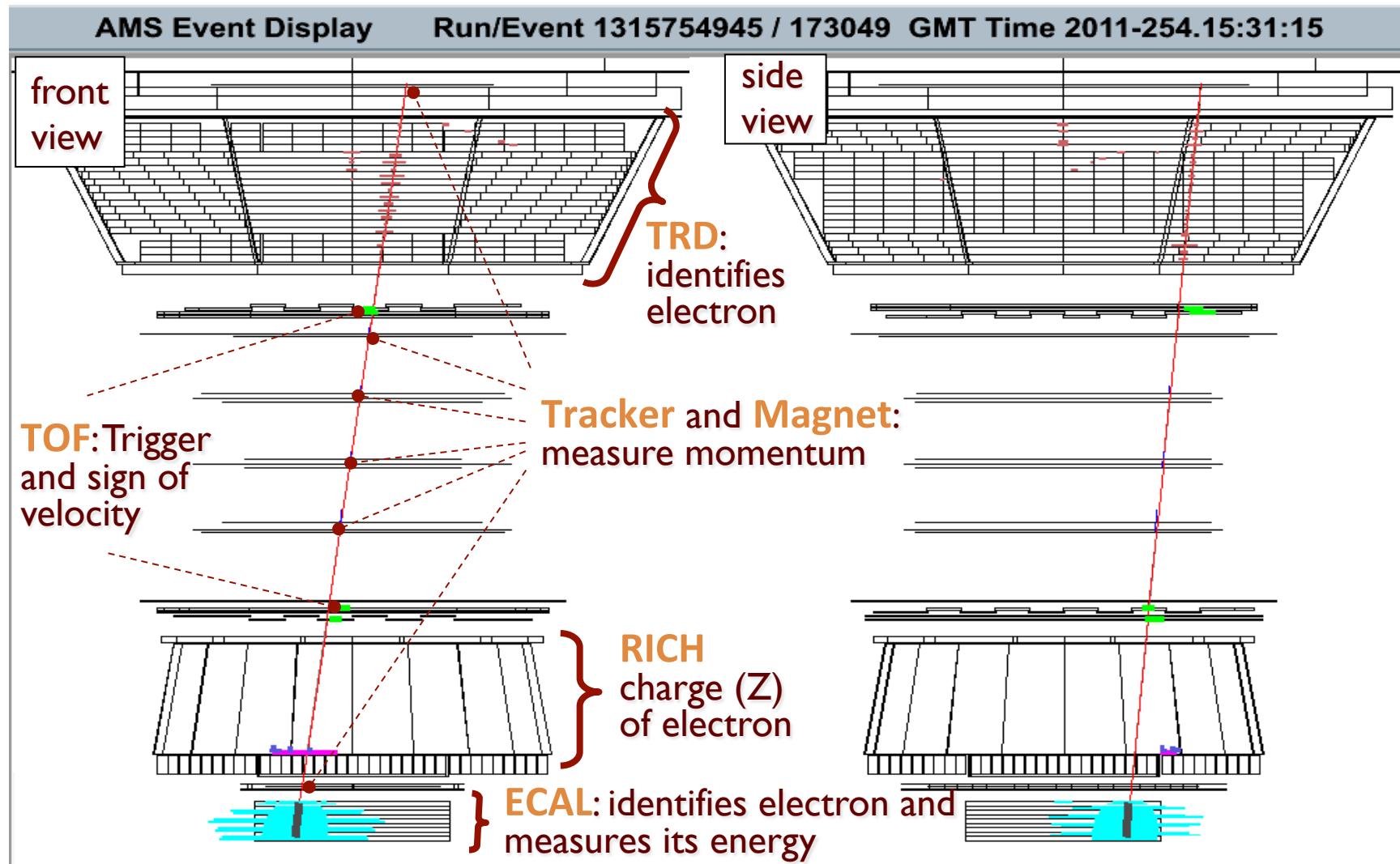
Particle track reconstruction



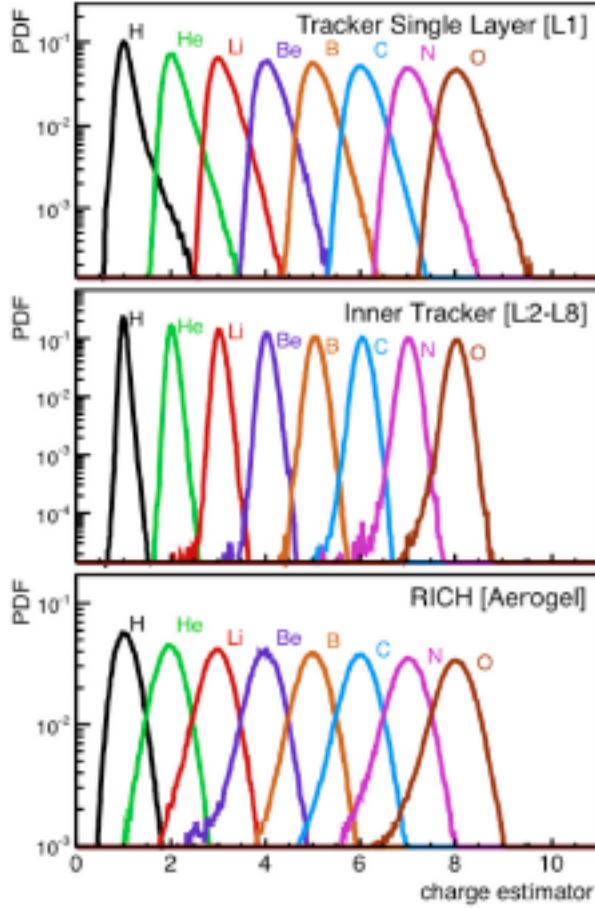
The silicon tracker is the most precise tracker ever built to work in space:

- Measures the coordinates of the particle in 9 layers along its path.
 - Separates directly matter from anti-matter, from the sign of the charge.
 - Measures the particle's arrival direction and its momentum.
-
- 9 layers of double-sided silicon sensors
 - 6.4m² active area, ~200k channels
 - Permanent magnet: 0.14 T
 - Max detectable rigidity ~2TV
 - Spatial accuracy in bending direction: ~10μm

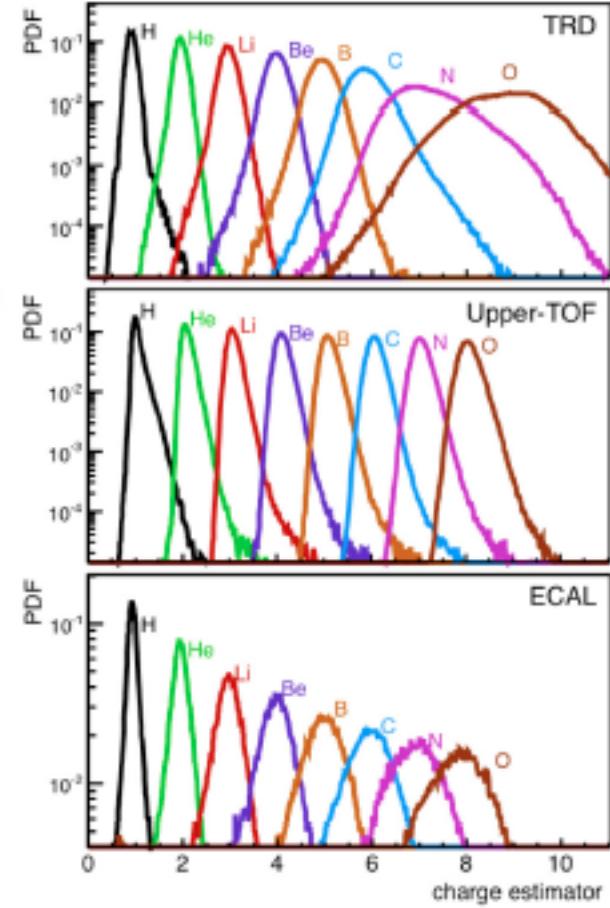
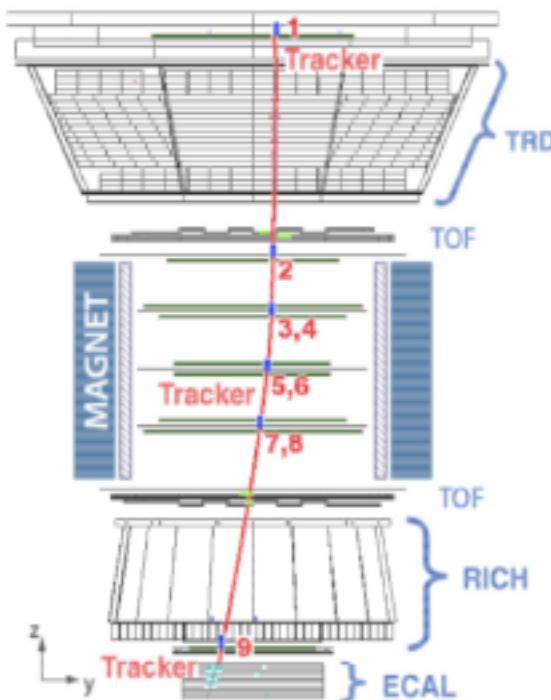
A 1.03 TeV electron from data



Multiple charge measurements



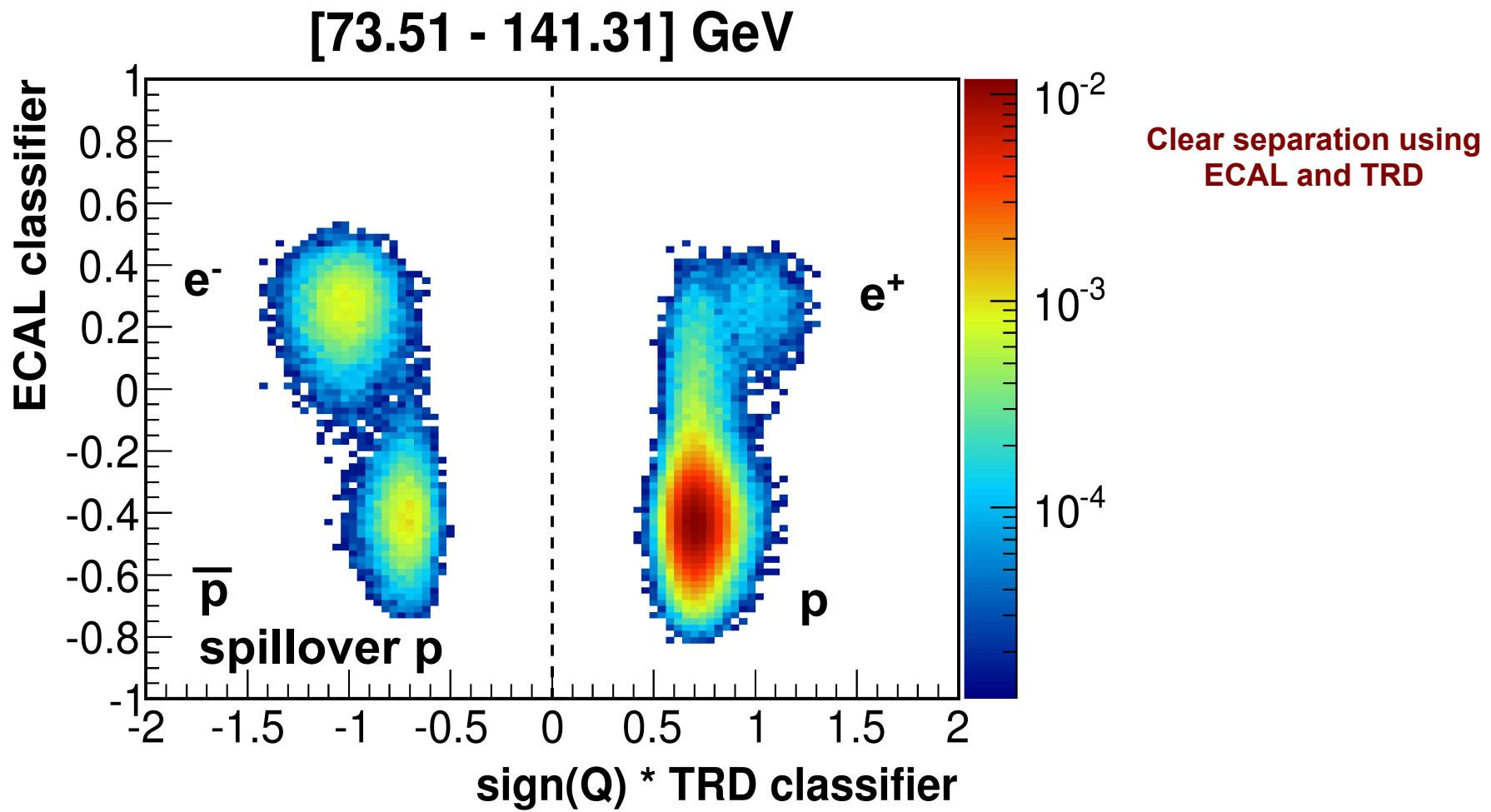
AMS-02 Charge Measurements
of Light Cosmic-Ray Nuclei



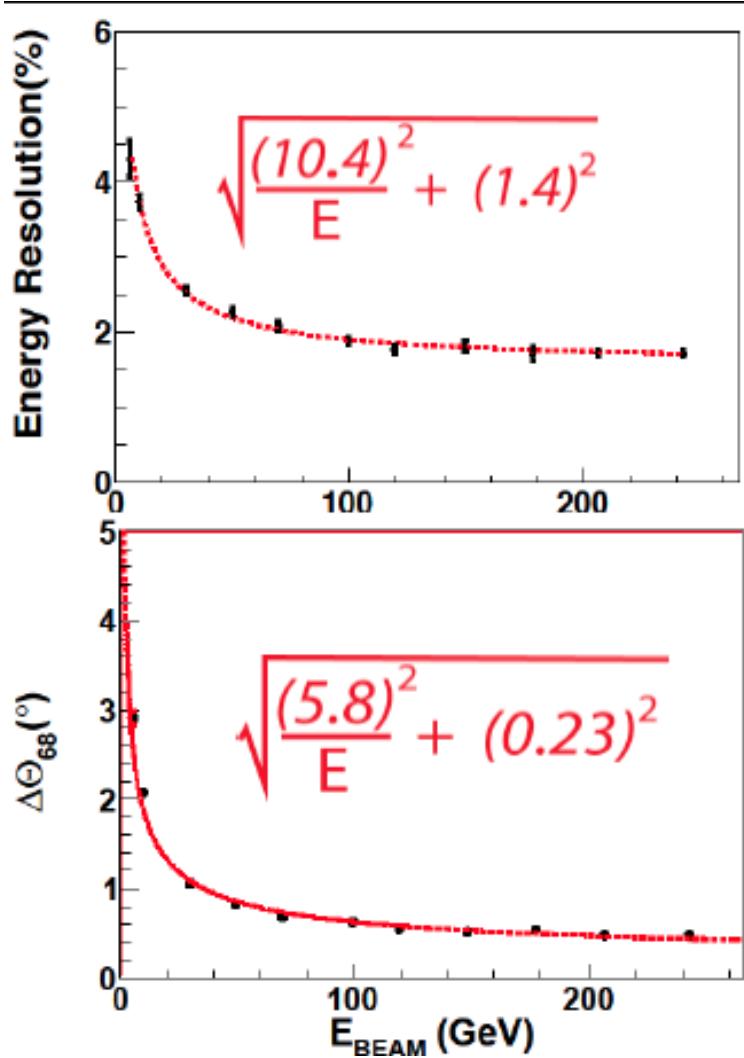
Particle identification

	e^-	e^+	p
TRD			
TRK + magnet			
ECAL			 MIP

Particle identification



Energy resolution



- 17 Xo calorimeter
- Energy resolution – better than 2% at $E > 100$ GeV
- Energy scale 5% @ TeV
- Angular resolution – better than 1 degree at $E > 30$ GeV

Minimal model fit

