d19

2nd Cosmic-ray Antideuteron Workshop
University of California – Los Angeles

Antiproton Flux with the Alpha Magnetic Spectrometer on the ISS

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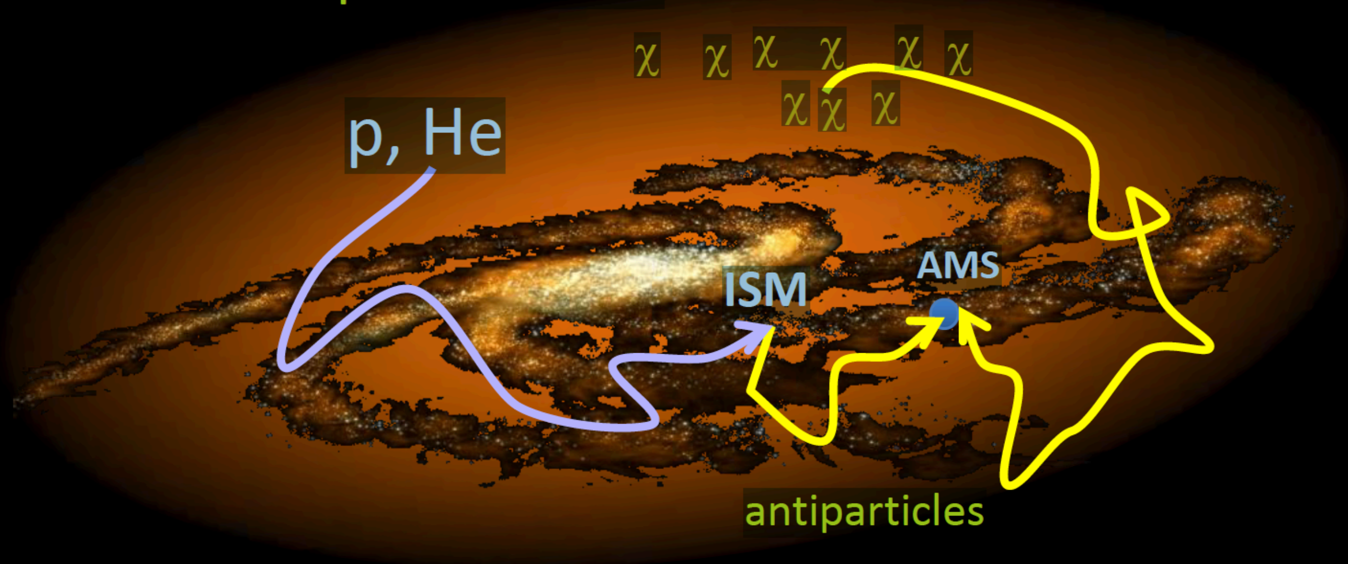
Antiparticles in Cosmic Rays and Dark Matter

The collision of cosmic rays with interstellar medium (ISM) produces antiparticles (e^+, $\bar{p}$, $\bar{D}$, ...)

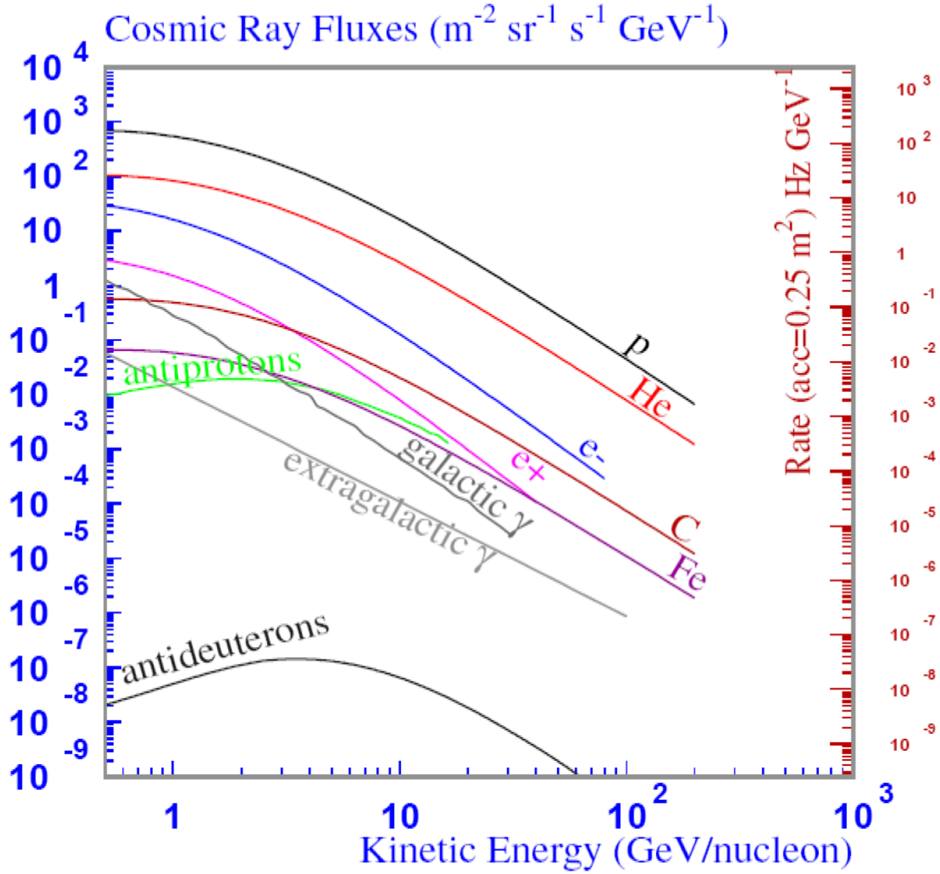
p, He + ISM $\rightarrow$ antiparticles + ...



The annihilation or decay of dark matter particles may produce additional antiparticles

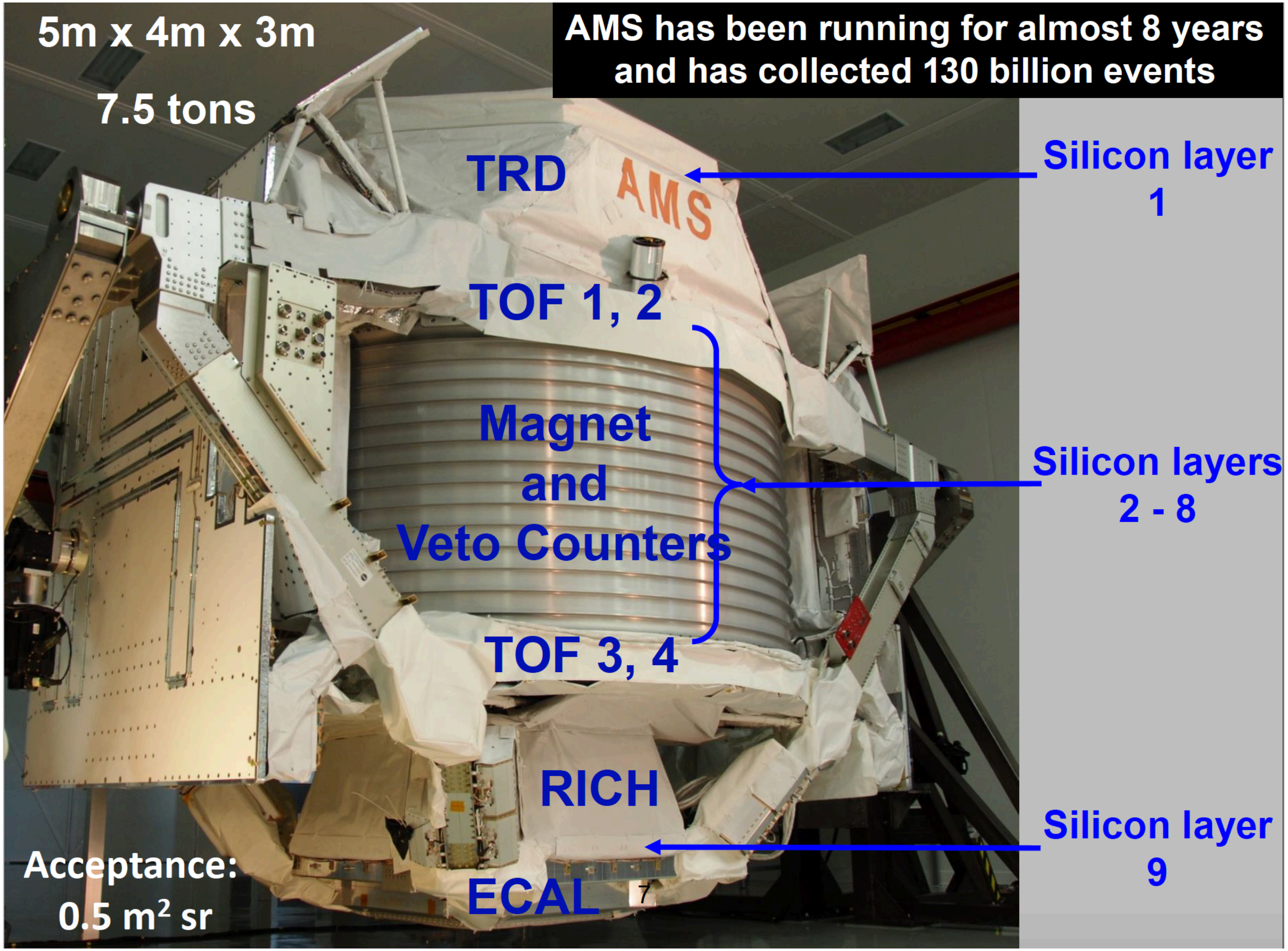
$\chi + \chi \rightarrow$ antiparticles + ...

Flux of antiparticles in Cosmic Rays



Precision measurements of antiparticles requires detectors with large acceptance, long exposure times and a percent level precision.

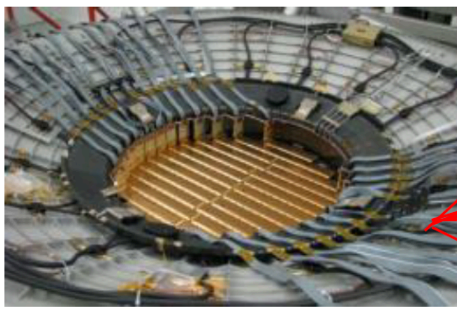
AMS a particle detector in near Earth orbit



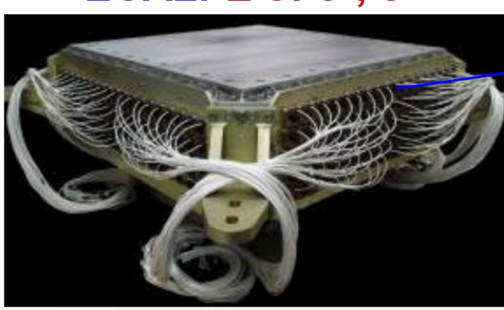
AMS: a TeV precision spectrometer

TRD: Identify e^+, e^-, Z

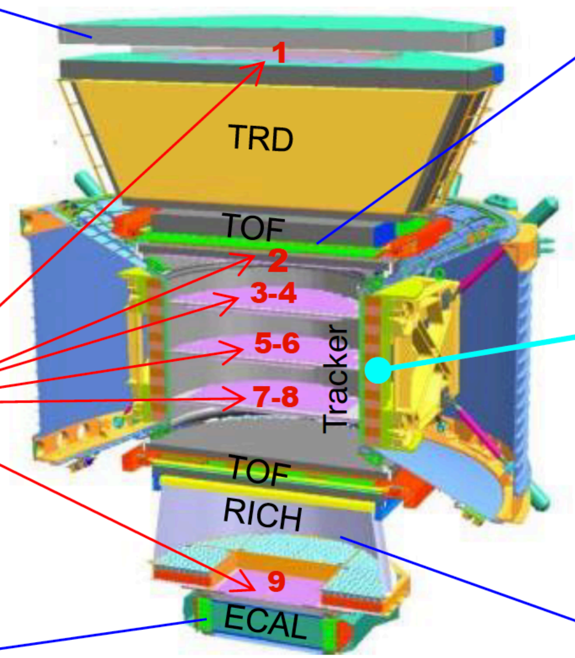
Silicon Tracker: Z, P



ECAL: E of e^+, e^-



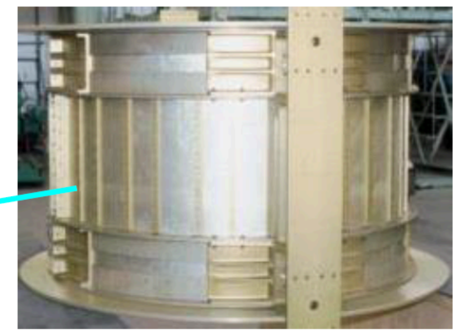
Particles and nuclei are defined by their charge (Z) and energy (E ~ P)



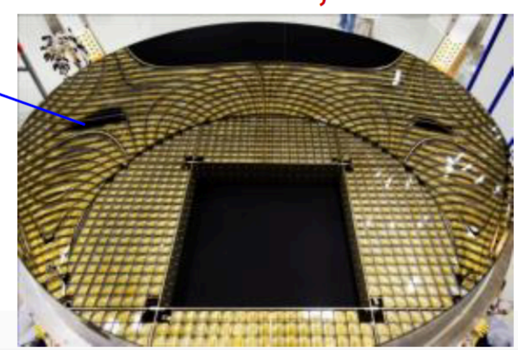
Z and P
are measured independently by the Tracker, RICH, TOF and ECAL

TOF: Z, E

Magnet: ±Z

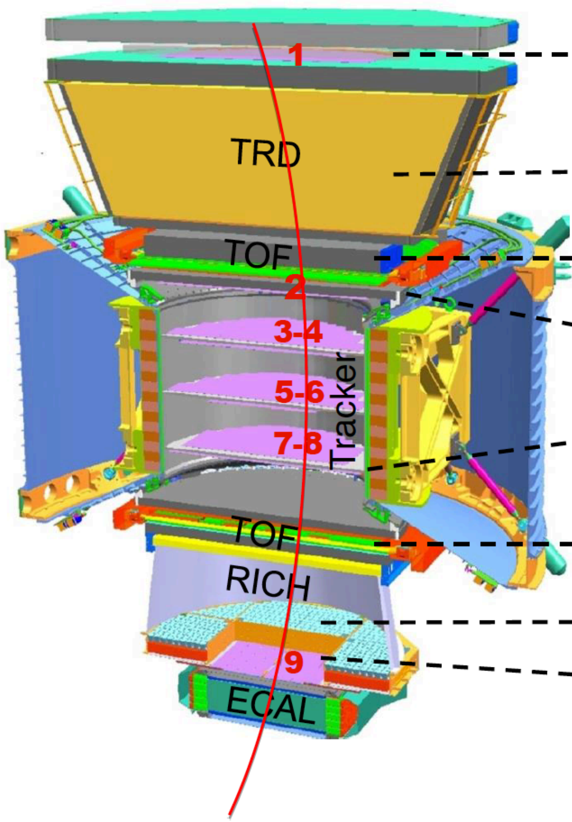


RICH: Z, E



Charge identification with AMS

Multiple Independent Measurements of the Charge (|Z|)

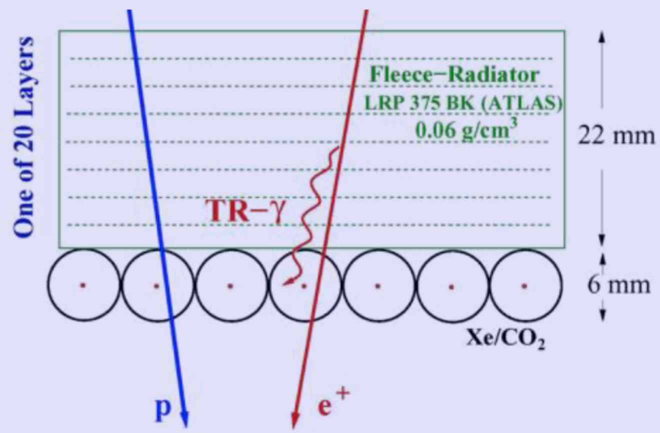


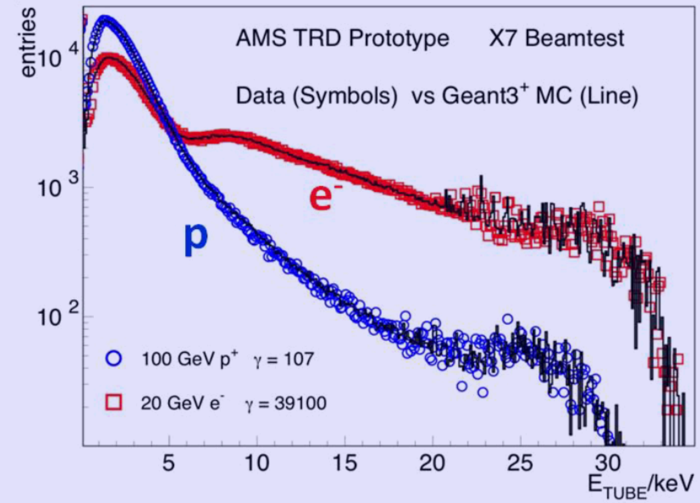
	ΔZ (cu)
1. Tracker Plane 1	0.17
2. TRD	0.10
3. Upper TOF	0.08
4. Tracker Planes 2-8	0.05
5. Lower TOF	0.08
6. RICH	0.30
7. Tracker Plane 9	0.17

anti-p Z=1

Antiproton/electron separation with TRD

Identifies nuclei by dE/dX and $e^{\pm}$ by transition radiation

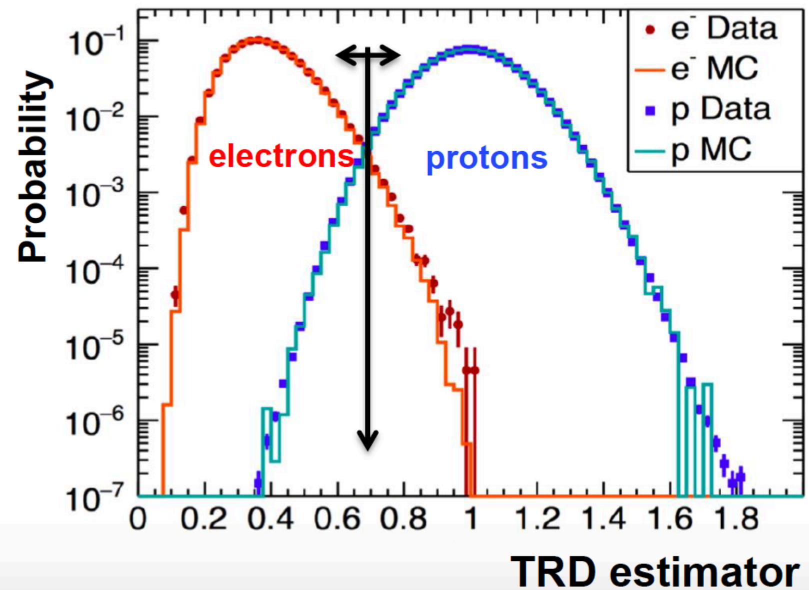




N = 20 layers

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

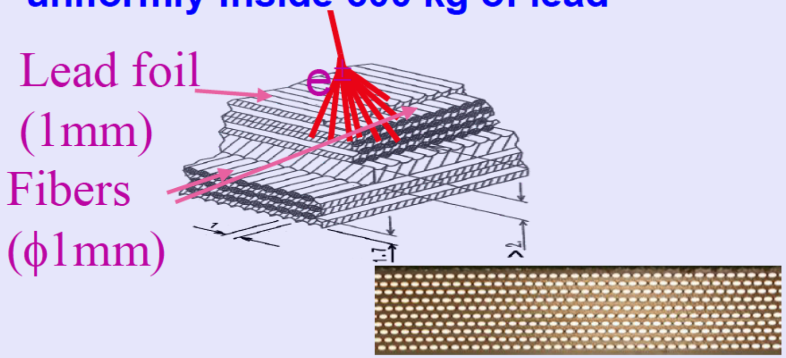
TRD estimator = $-\ln(P_e/(P_e+P_p))$

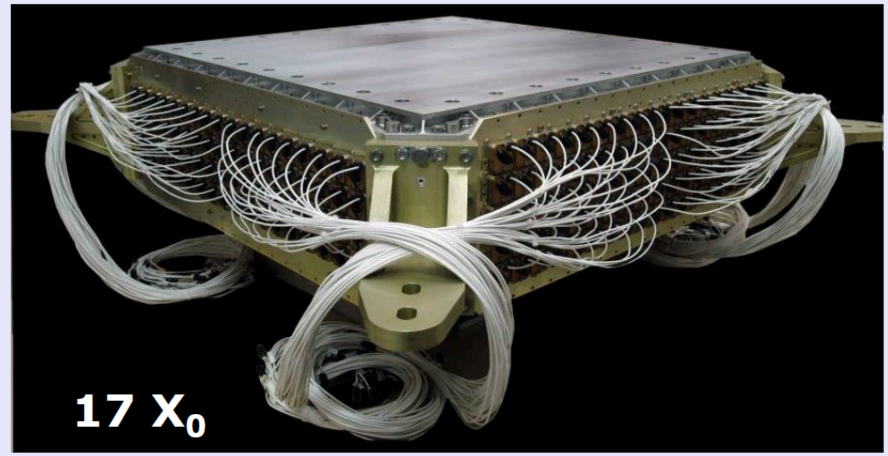


Antiproton/electron separation with ECAL

3-dimensional measurement of the shower

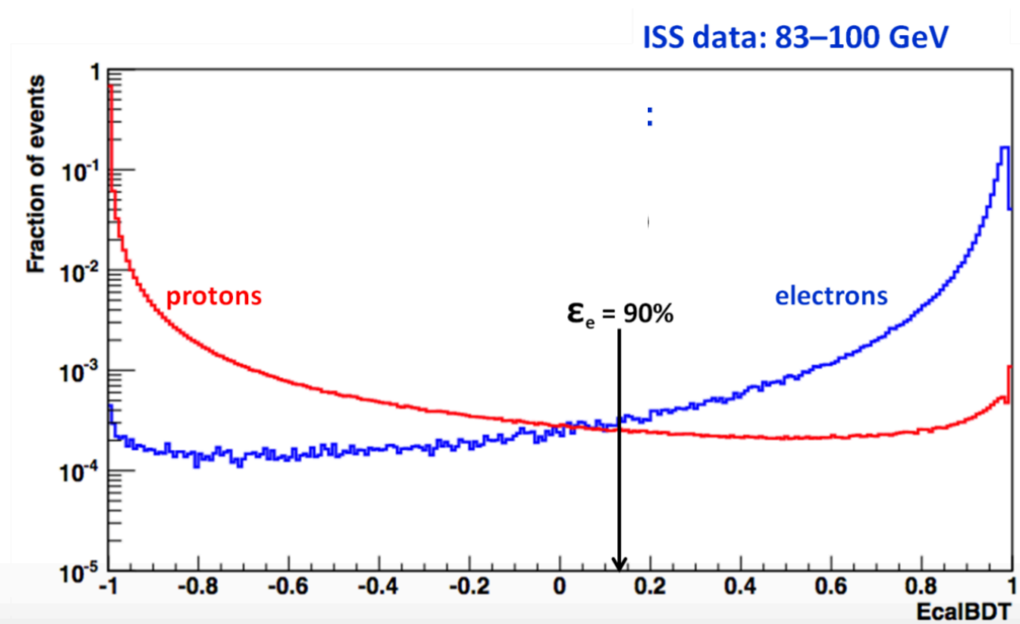
50 000 fibers, $\phi = 1$ mm distributed uniformly Inside 600 kg of lead



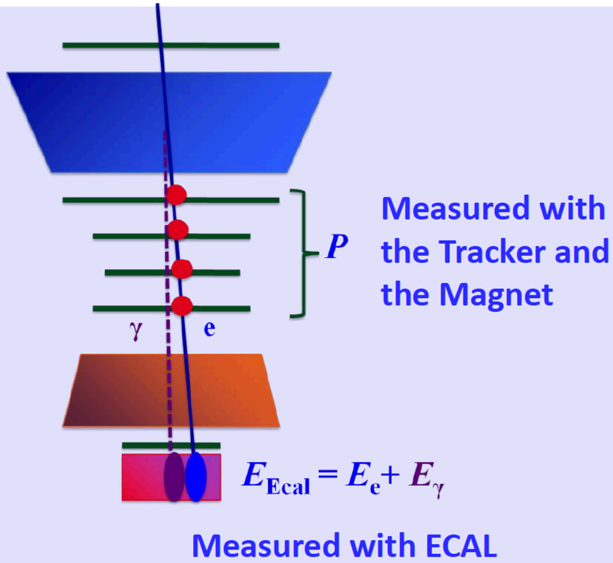


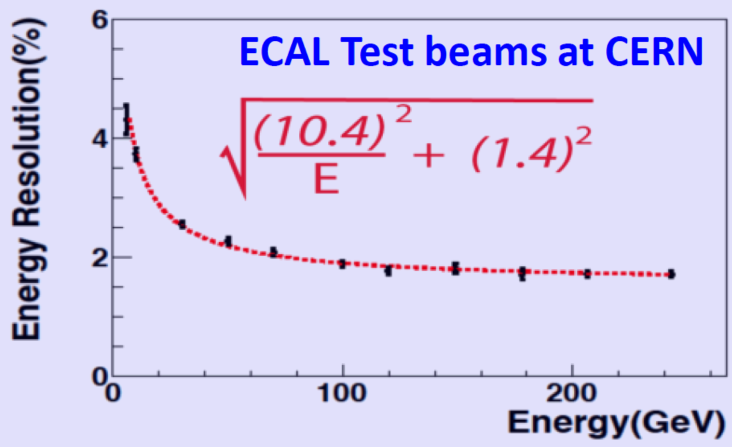
Boosted Decision Tree: EcalBDT

Combines
19 variables describing
3D shower shape



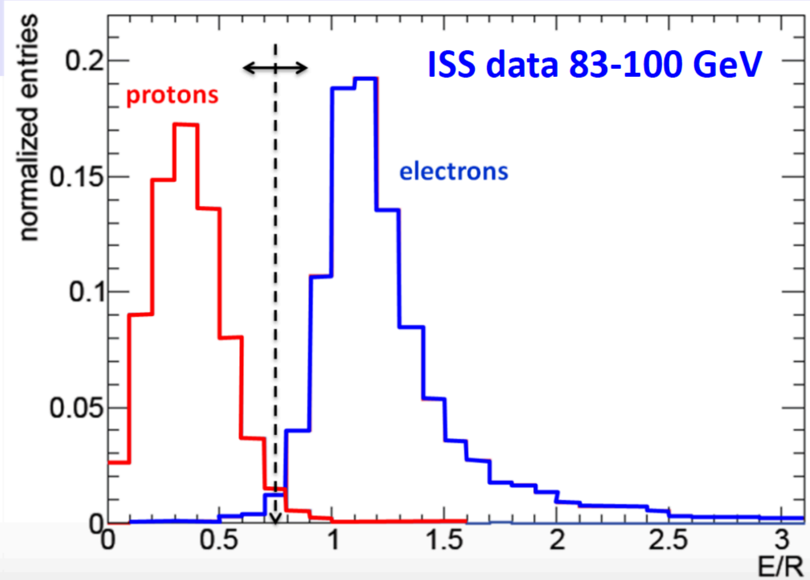
Antiproton/electron separation with ECAL+ Tracker



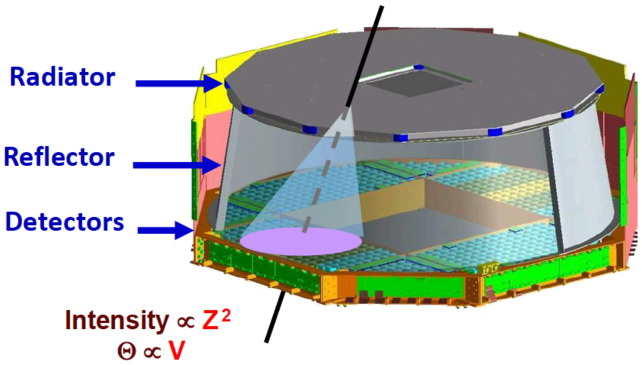


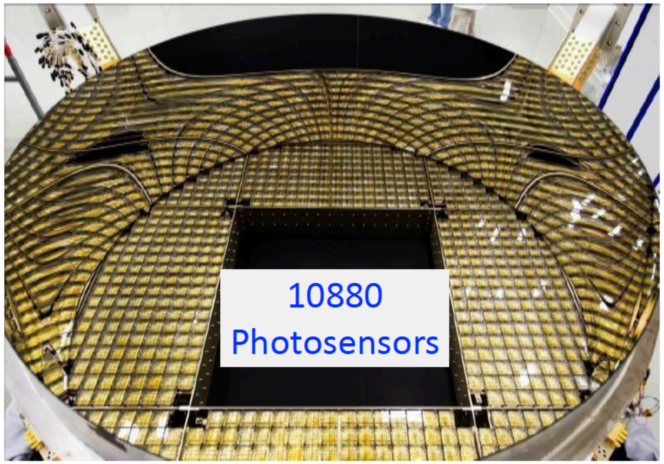
ECAL/Tracker

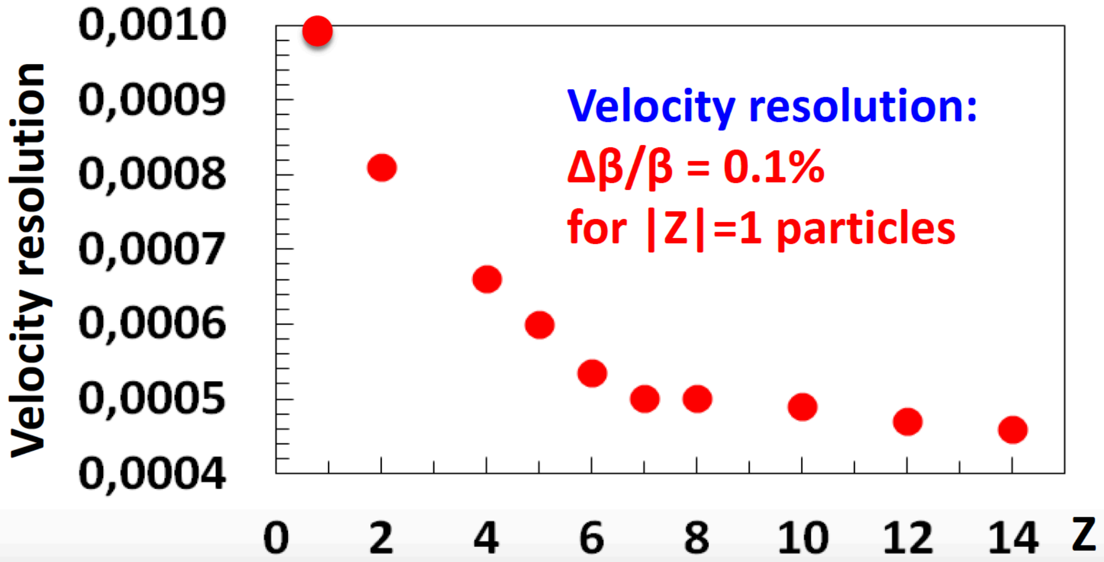
(E/p matching)



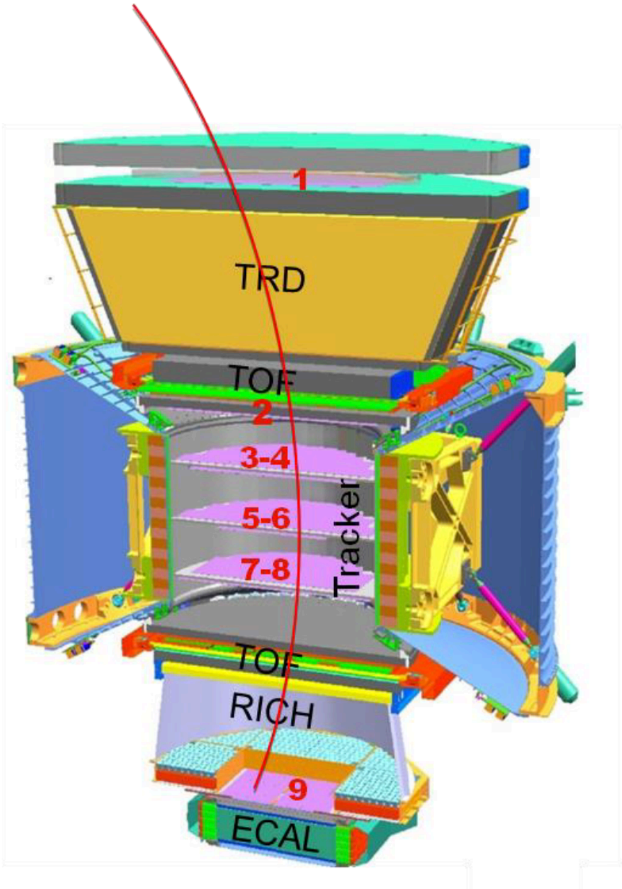
electrons rejection with RICH

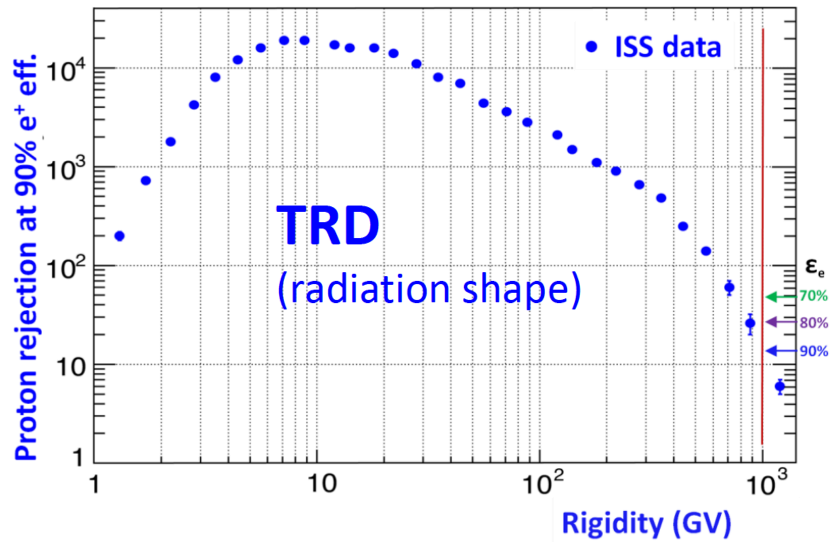


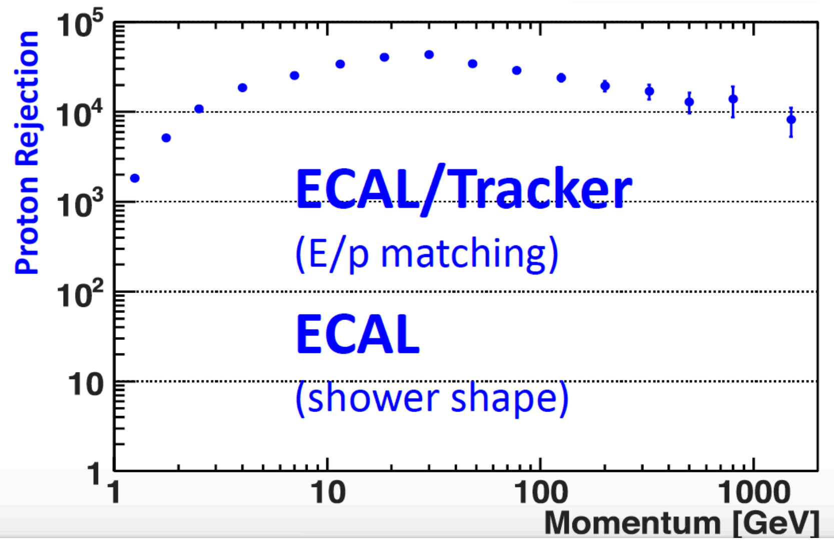




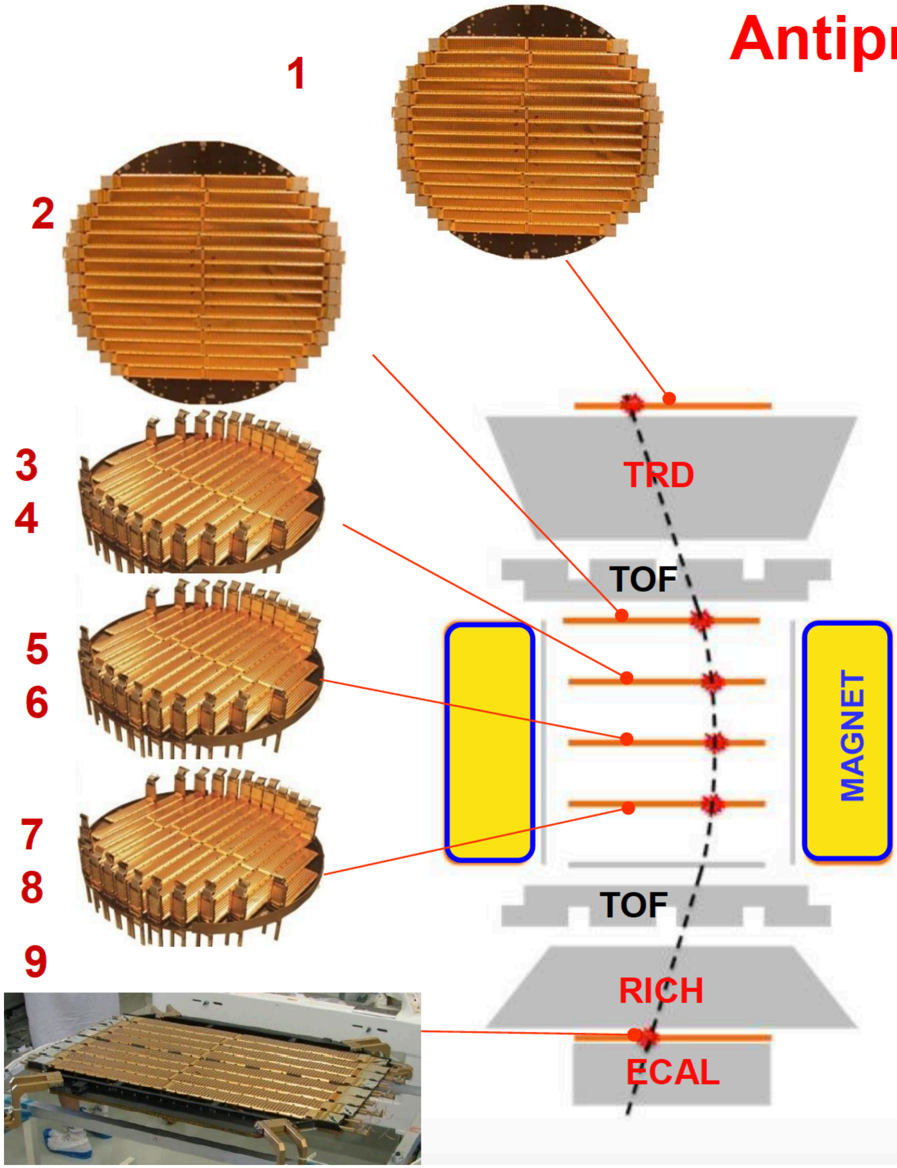
electron rejection efficiency

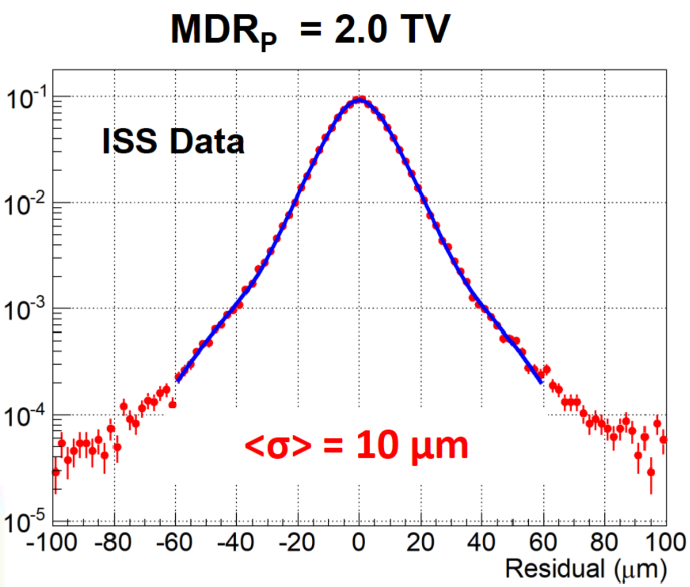






Antiproton Selection (Q < 0)





Charge confusion:

< 1% up to 300 GeV

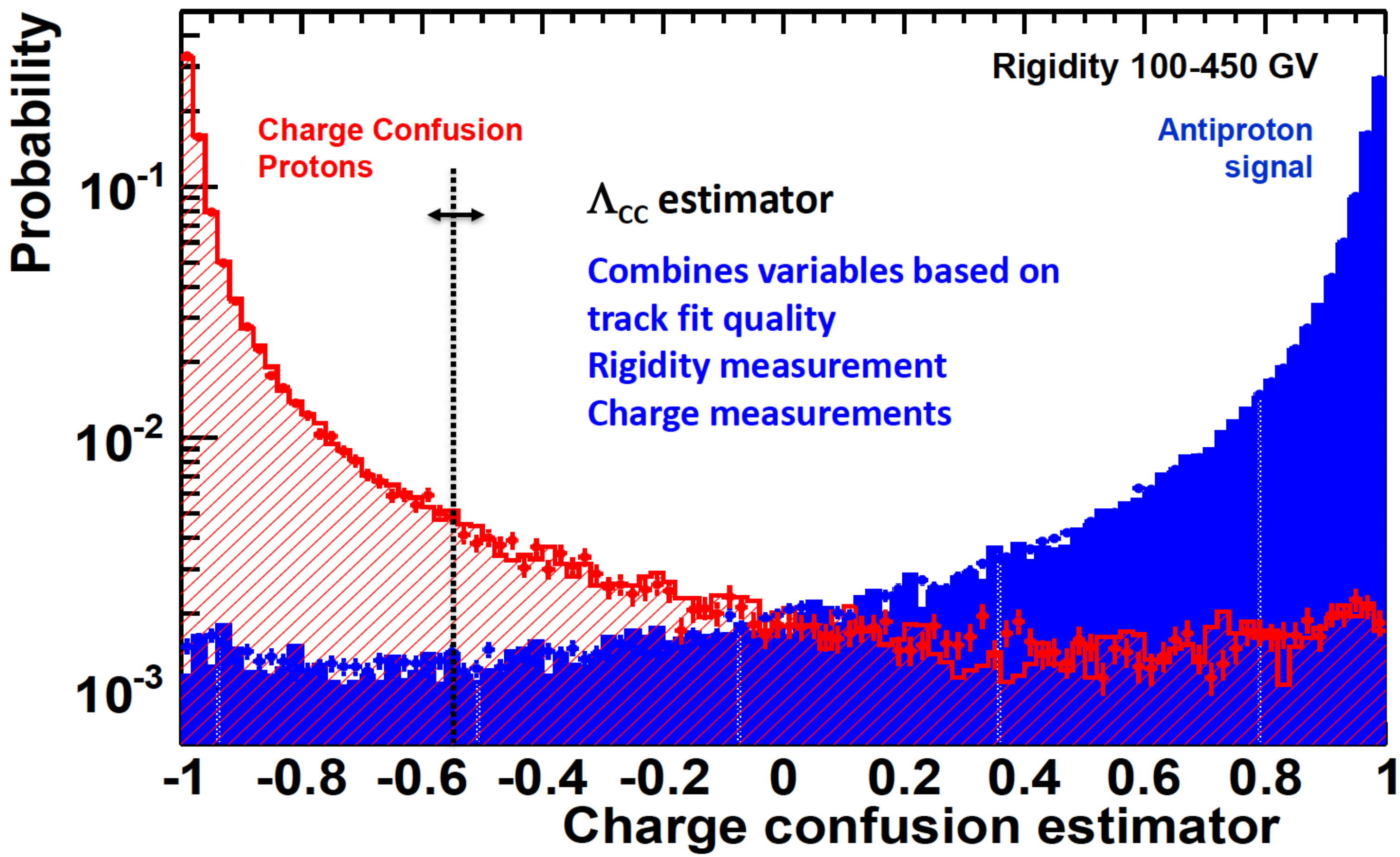
< 10% up to 1 TeV

Maximum Detectable Rigidity(MDR)

2.0 TV for Z=1 particles

Charge confusion

A Charge Confusion estimator Λ_{CC} is defined from MC using the boosted decision tree technique.



Antiproton Flux

$$\Phi_i^{\bar{p}} = \frac{N_i^{\bar{p}}}{A_i^{\bar{p}} T_i \Delta R_i}$$

i: 57 Rigidity bins [1 GV – 450 GV]

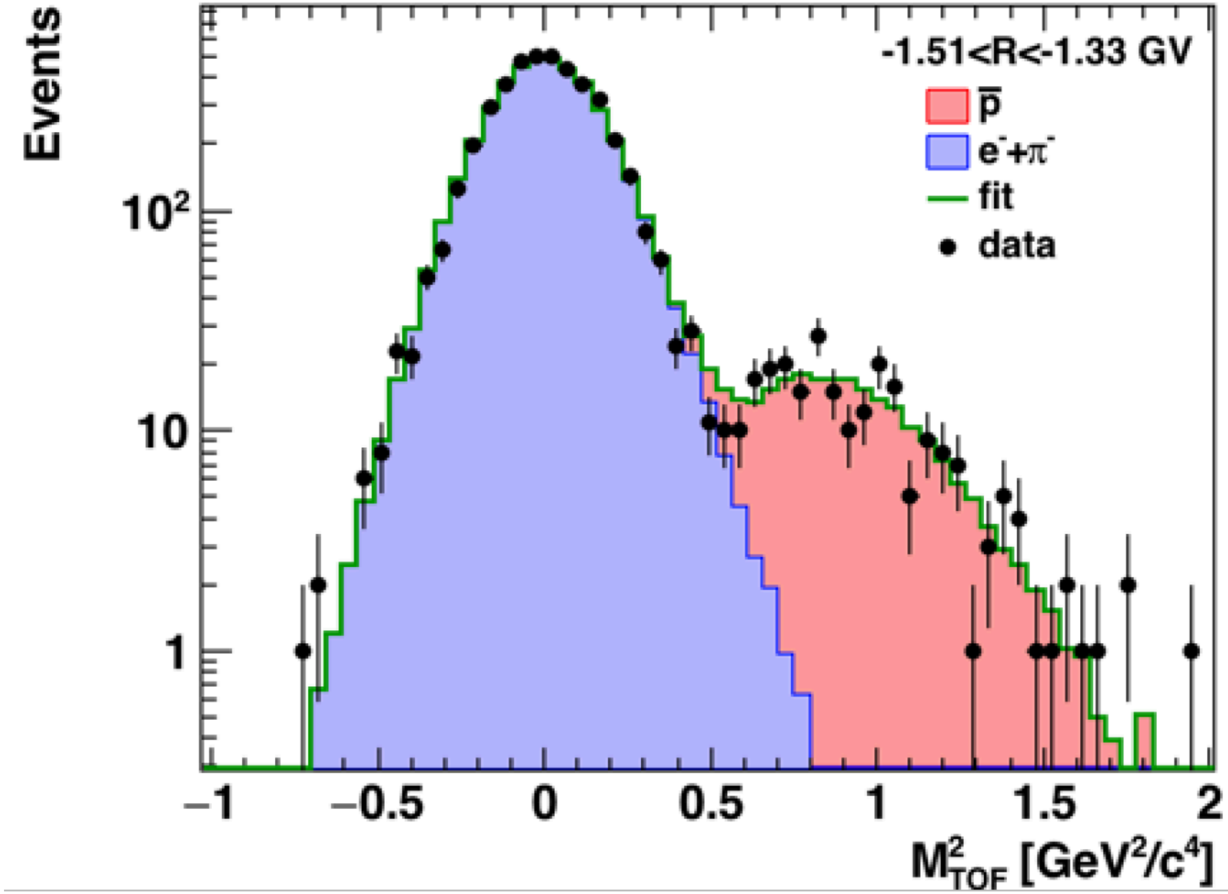
The number of antiprotons is determined from template fits

To maximize the measurement accuracy, different templates are used in three rigidity regions

1. **Low rigidity region:** 1.00-4.02 GV
2. **Intermediate region:** 3.67-18.0 GV
3. **High rigidity region:** 16.6-450 GV

Counting anti-p at low rigidity (|R| = [1-4] GV))

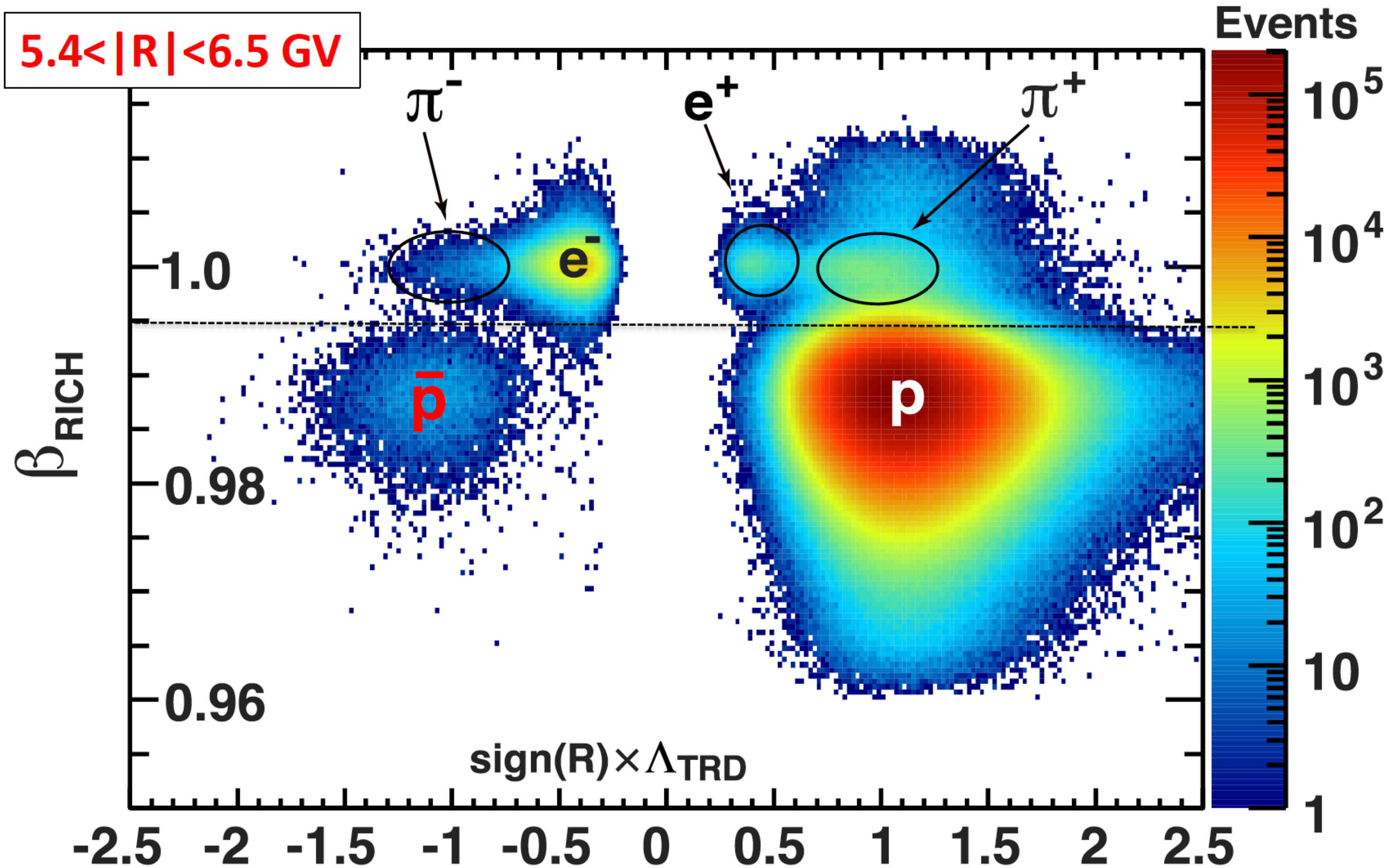
Signal identification by using the TRD estimator and the mass calculated from TOF and Tracker



Counting anti-p at intermediate rigidity (|R| = [3-18] GV))

Main background: Electrons and pions

Signal identification by using the RICH and the TRD estimator

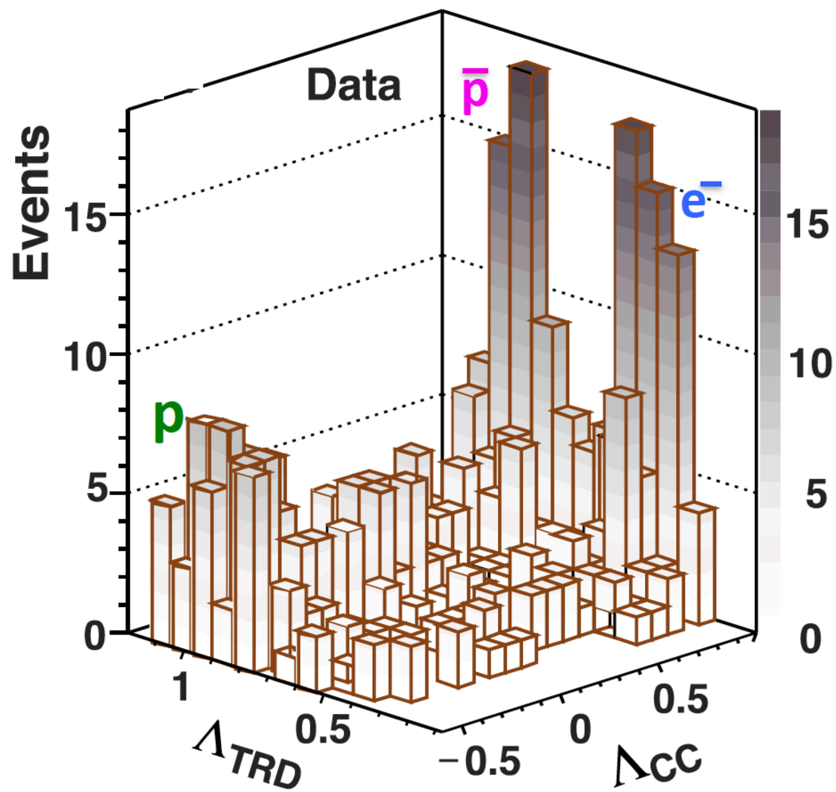


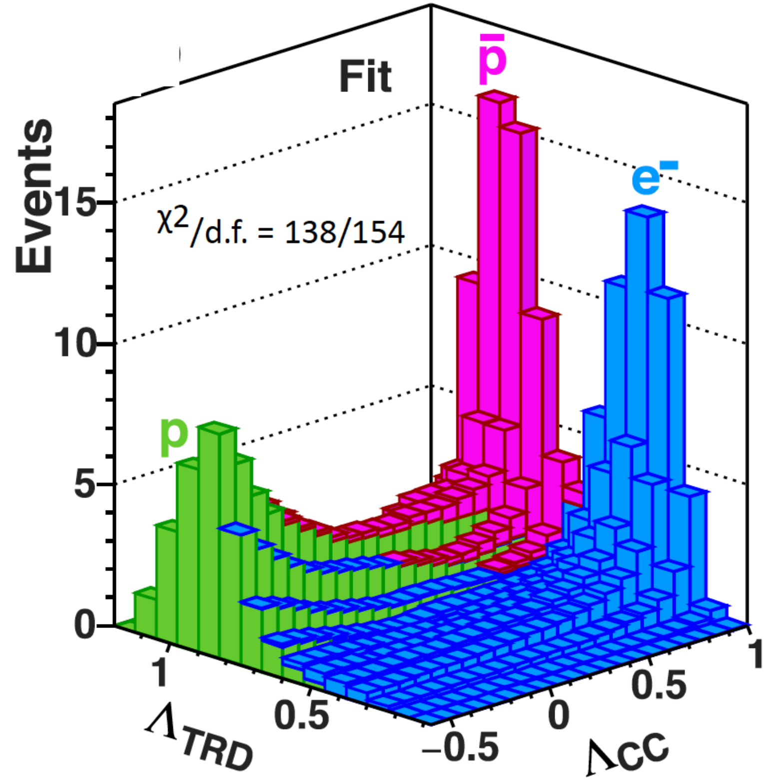
Counting anti-p at high rigidity (|R| = [17-450] GV)

Main background: Electrons and charge confusion events

Signal identification from 2D template fit in (Λ_{TRD} - Λ_{CC}) plane

175<|R|<211 GV

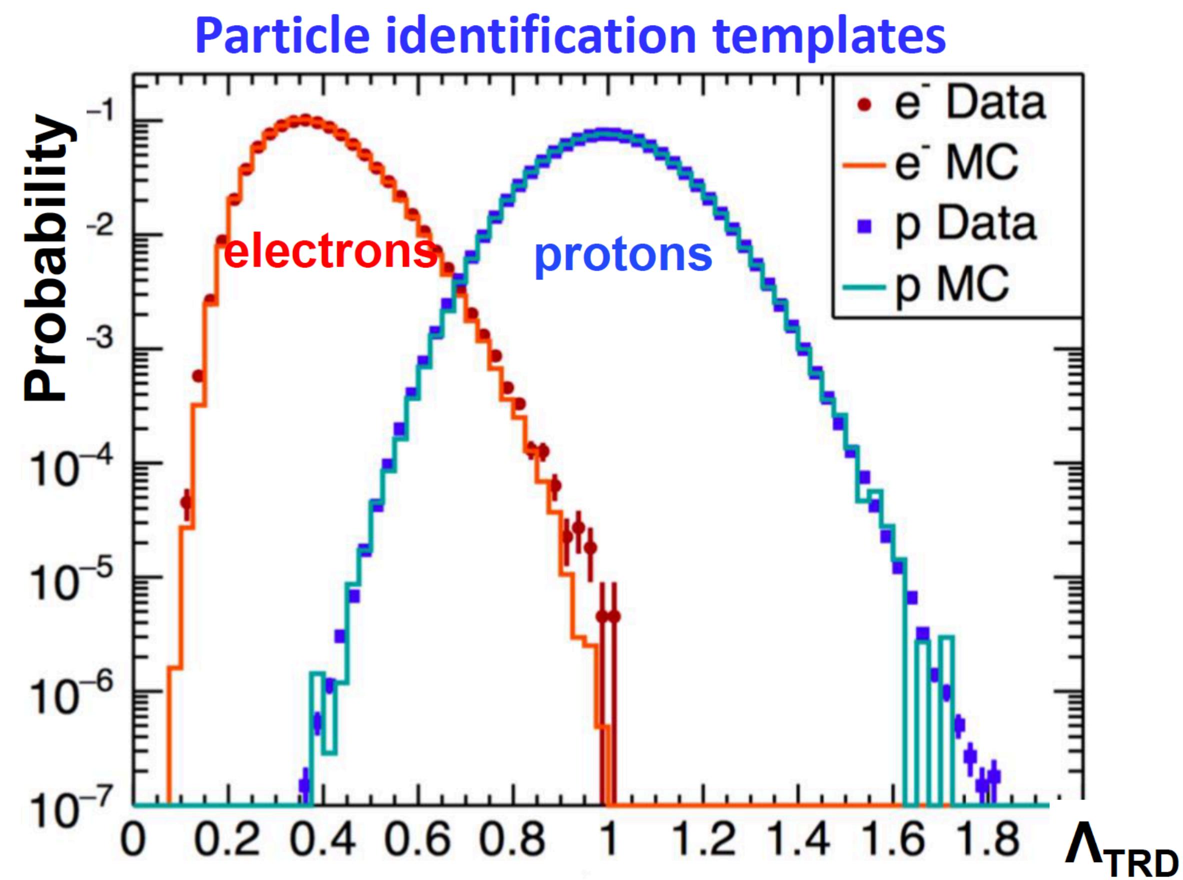




Study of the systematic errors

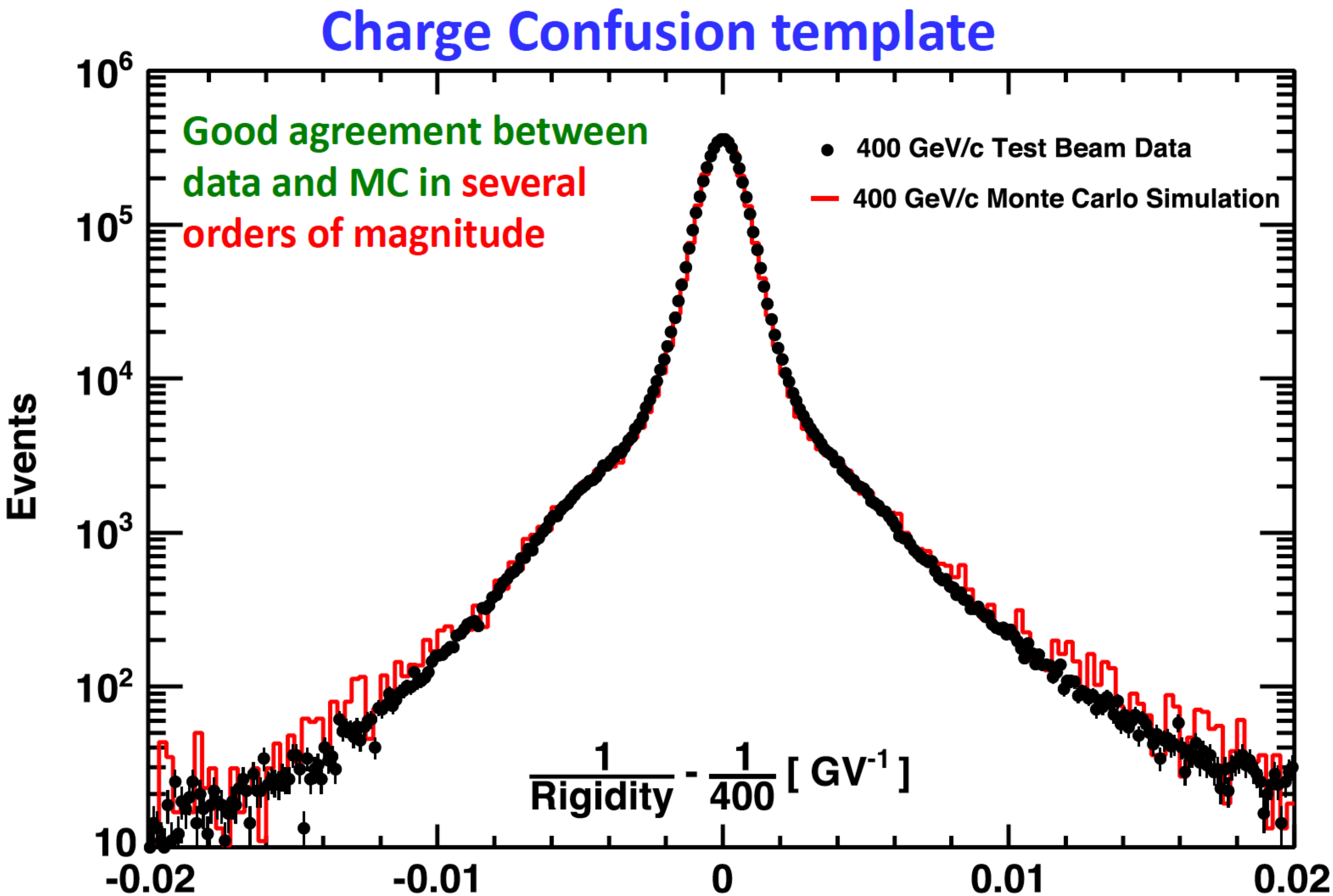
- **Affect the antiproton counting σ_N**
  - Cutoff
  - Selection
  - **Charge confusion templates**
- **Affect the acceptance, σ_A**
  - **Inelastic cross sections**
  - MC statistic fluctuation
  - Migration matrix
- **Rigidity scale, σ_R**

Systematic error from templates definition



Definition of the reference spectra is based on pure samples of electrons and protons of finite statistics.

Systematics from charge confusion

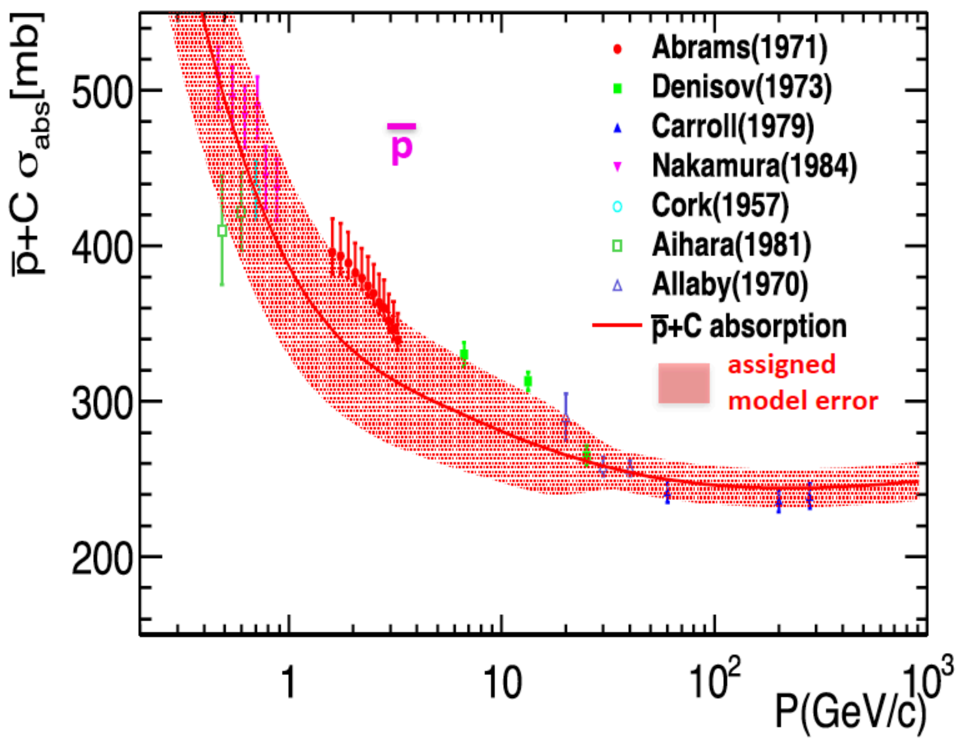


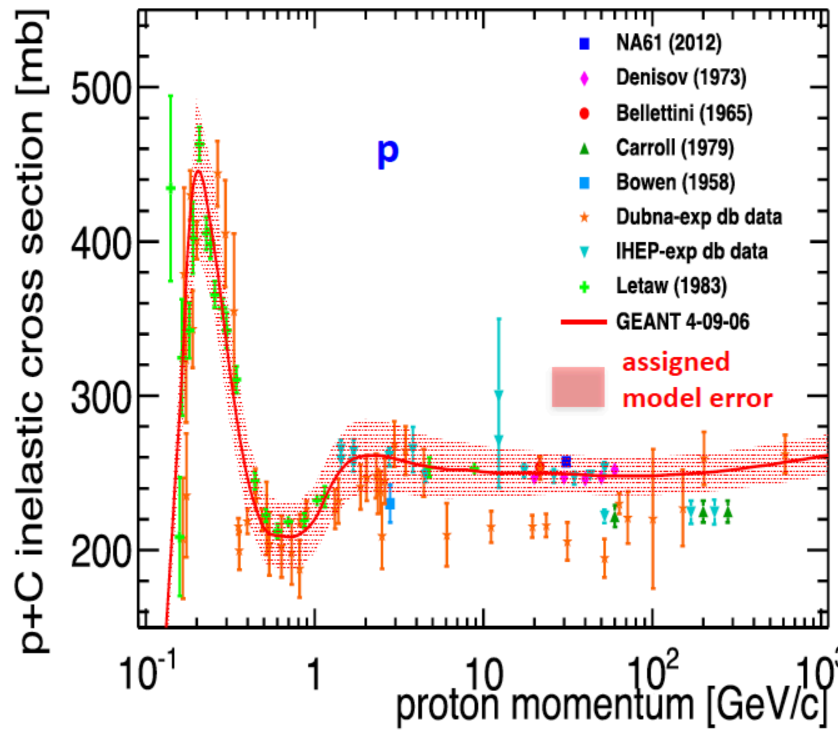
Systematic Error due to templates definition:

< 1% below 30 GV and 12 % at 450 GV

Systematic error from the cross sections uncertainty

The inelastic cross section are used in MC simulation to calculate the effective acceptance

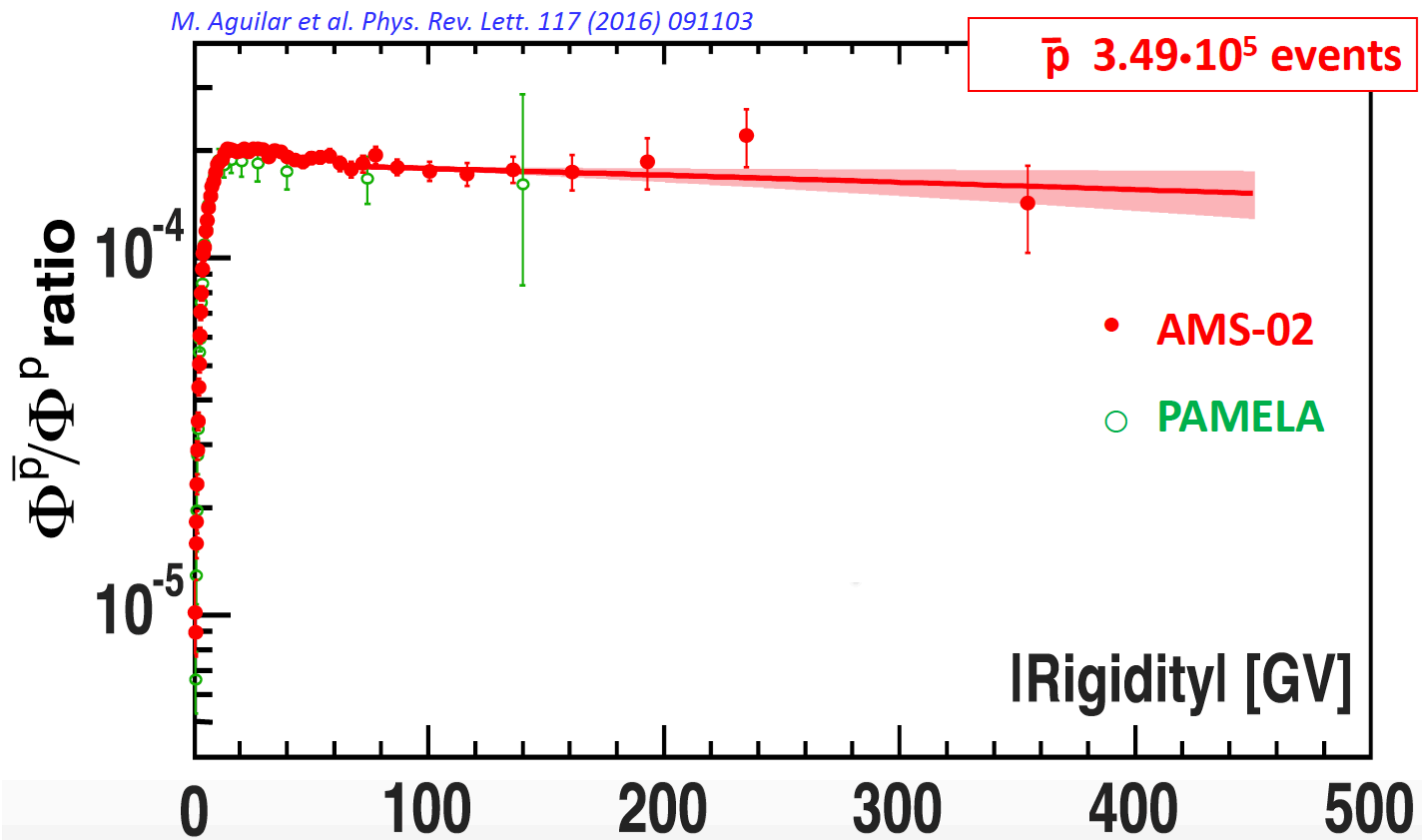




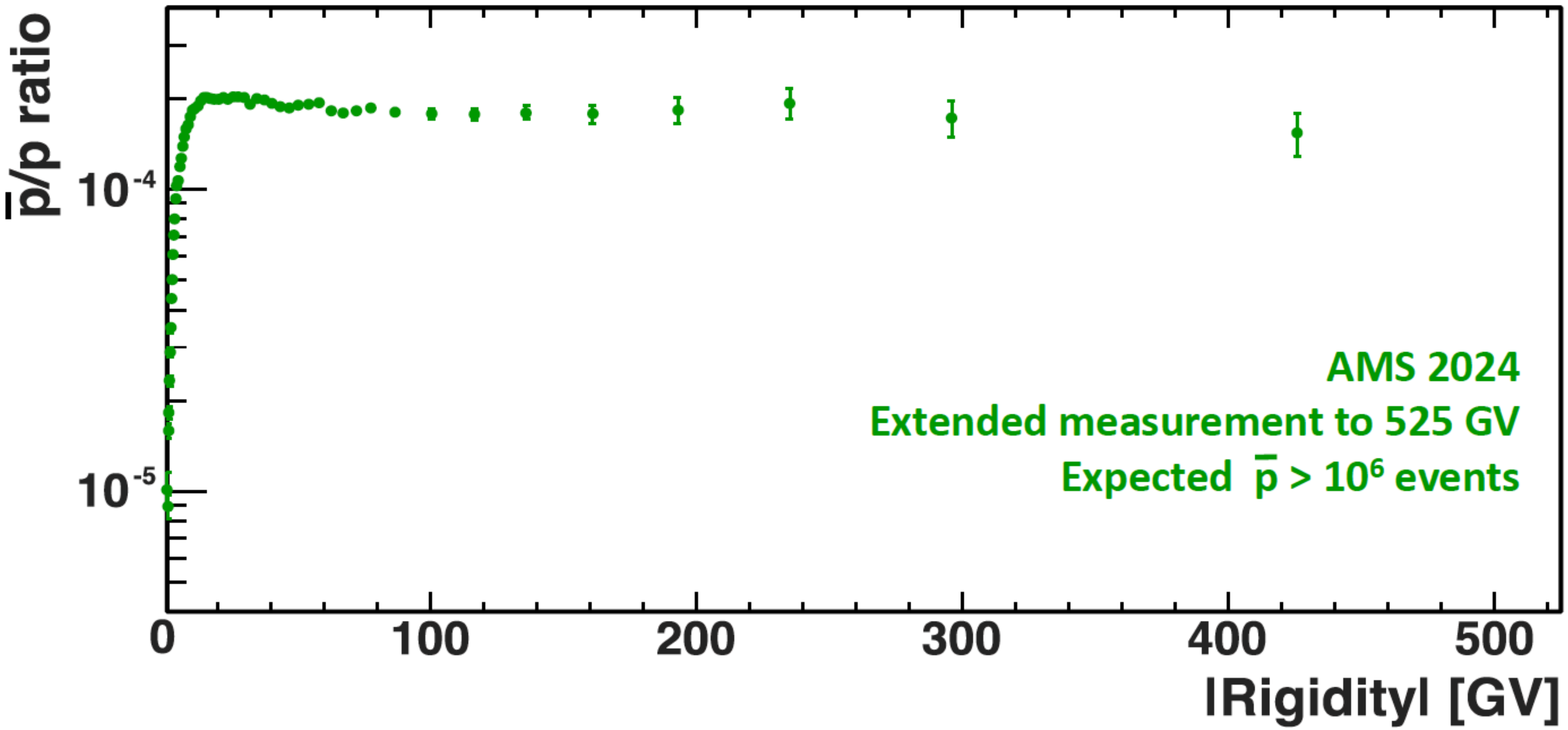
The corresponding systematic error for $\bar{p}$ is

4% at 1 GV and ~1% above 50 GV

Final result



Projection to 2024



Summary

- AMS data on anti-proton provide a high statistic accurate measurement
- The apparent flatness of the anti-p/p ratio above 60 GeV, might be related to a new source of anti-p
- The steady data collection of AMS promises some extension on the measurement range and a reduction of the statistical errors
- The constant efforts of the AMS collaboration to provide the best possible measurement will likely provide smaller systematic errors

- Two key issues need to be addressed to unlock the discovery potential of AMS anti-p data
  - Cosmic Rays propagation through the galaxy
  - anti-p production cross sections in p-p, p-He and He-He interactions