AMS-02 Trigger System

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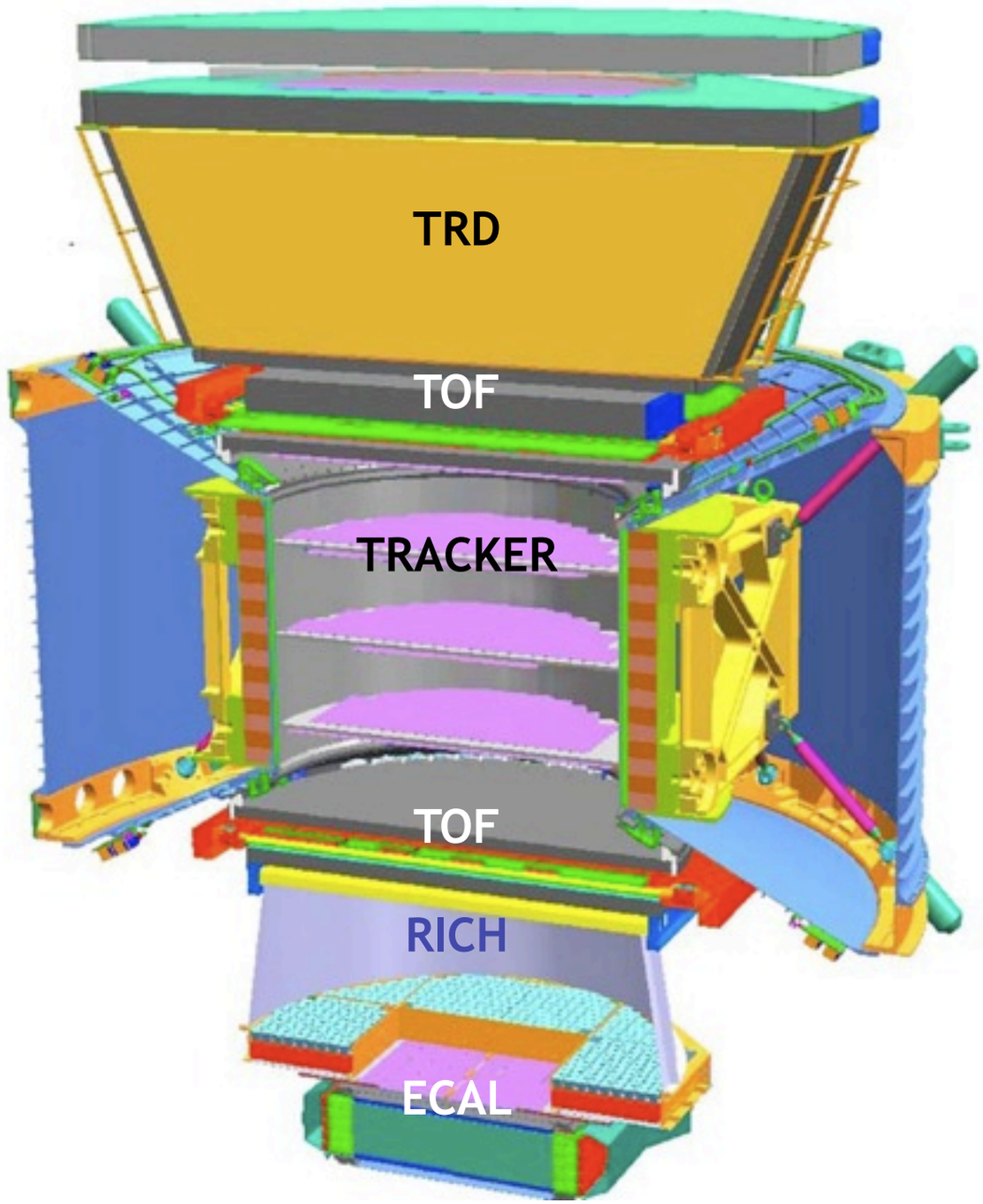
AMS-02 objectives

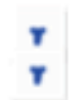
- Indirect search for Dark Matter signals
- Primordial anti-matter
- High statistic measurement of cosmic rays in GeV- TeV energy range up to the iron (Z=26) and behind
- Gamma ray astrophysics till TeV energies



Signatures in AMS-02

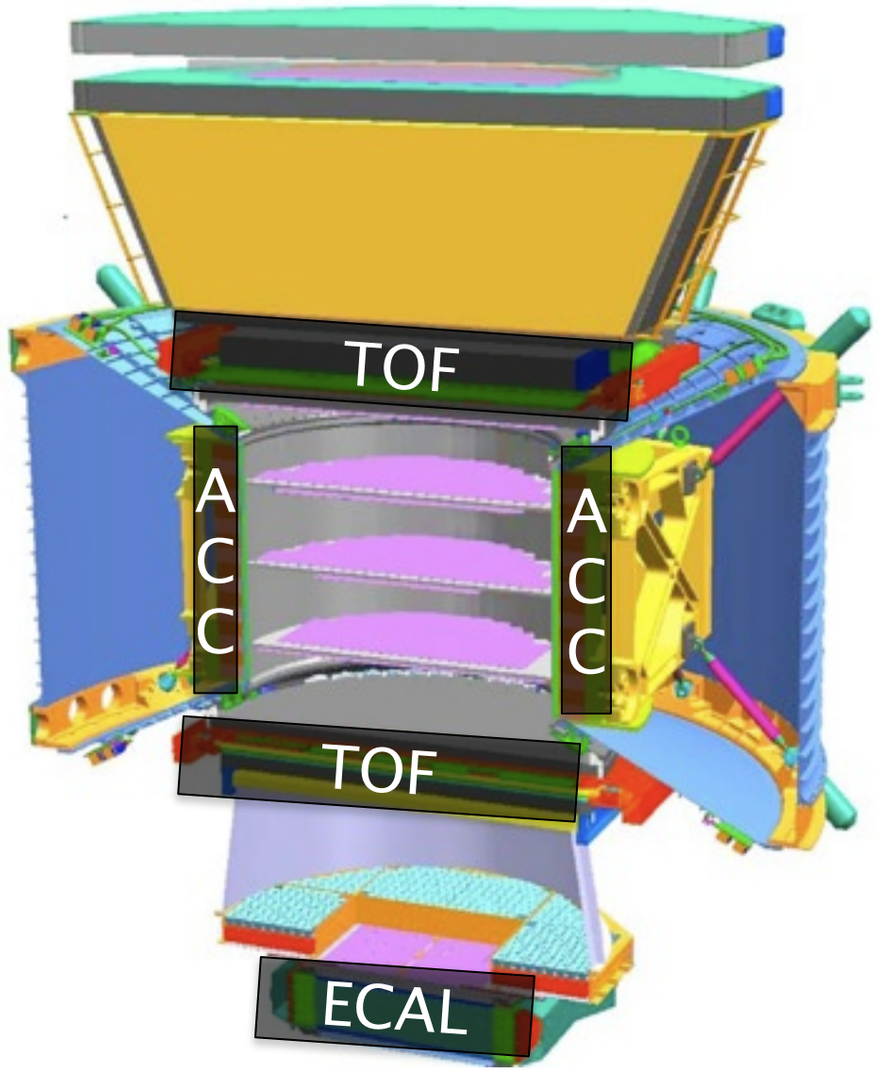
Charged particles

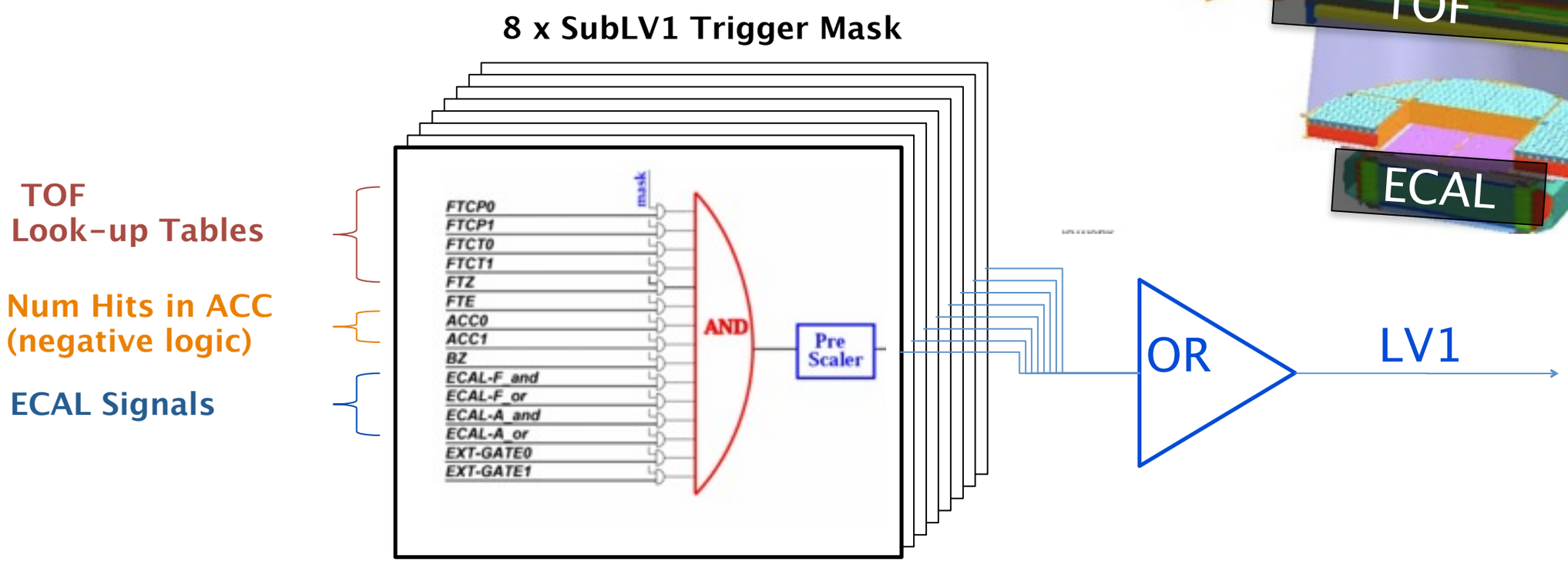
Photons

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

AMS-02 Trigger System

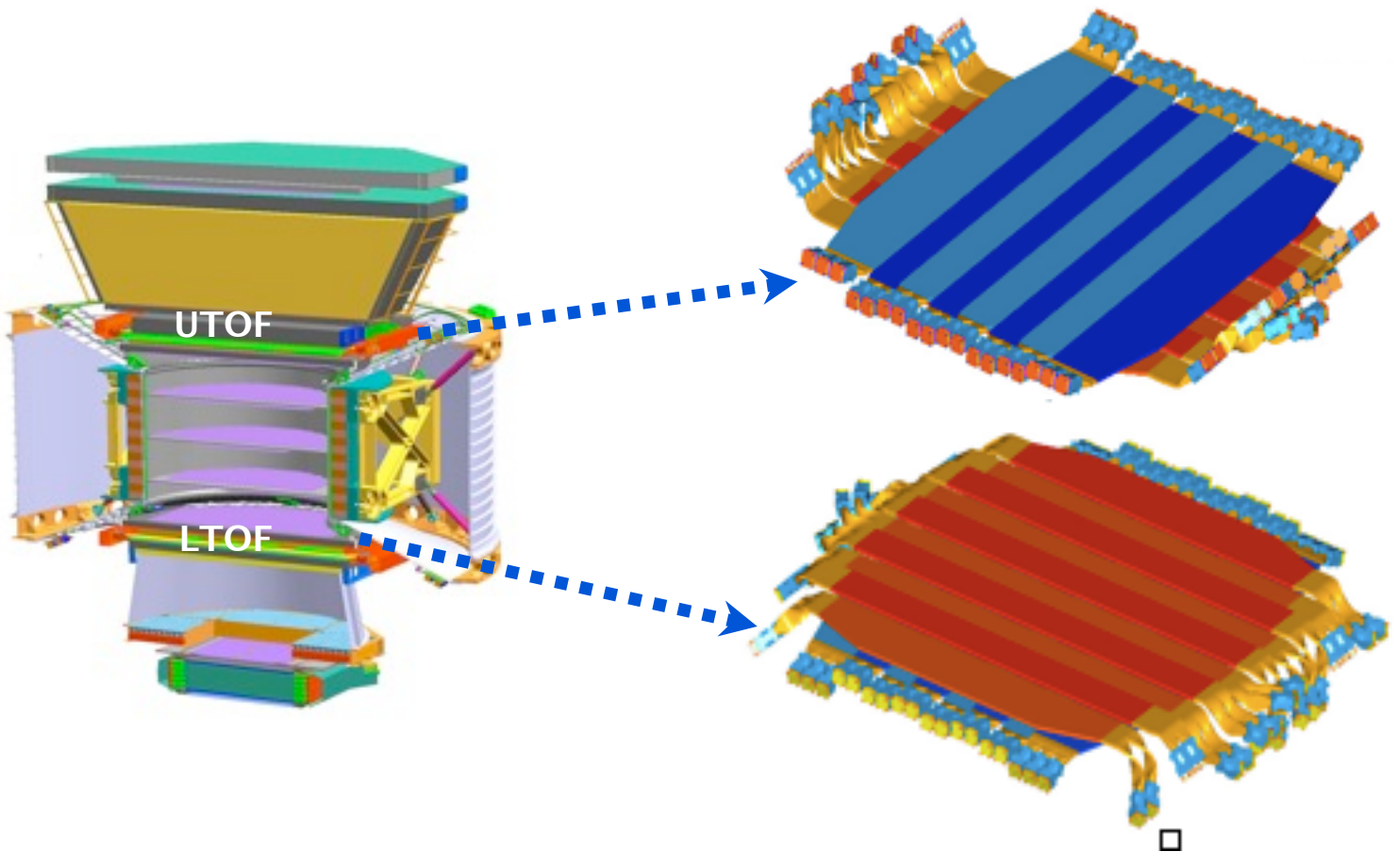
- ✓ **Fast Trigger** signal for charged particles generated by TOF.
- ✓ **Fast Trigger** signal for photons generated by ECAL.
- ✓ **Level-1 Trigger (LV1)** starts the event acquisition. Generated from the combination of TOF, ECAL and ACC information.
- ✓ **The DAQ system** is designed to operate at trigger rates up to 3 kHz, an average event size being about 2 KBytes.



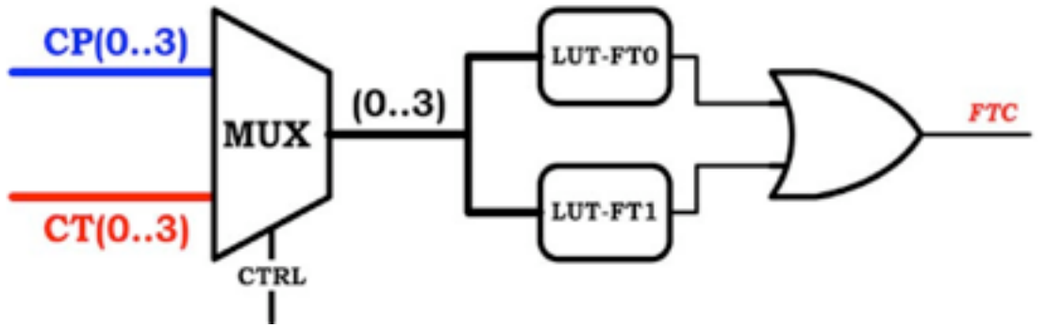


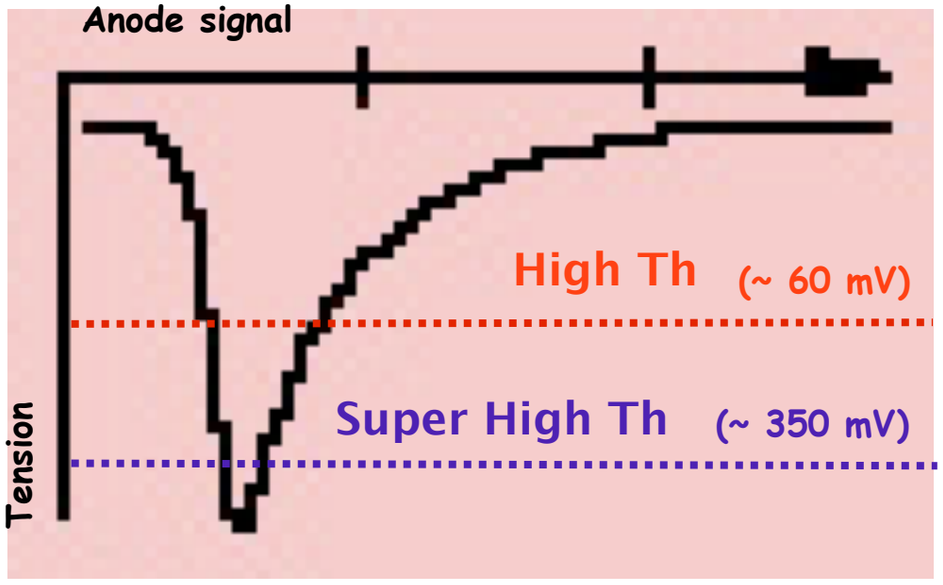
Alpha Magnetic Spectrometer

TOF fast triggers for charged particles



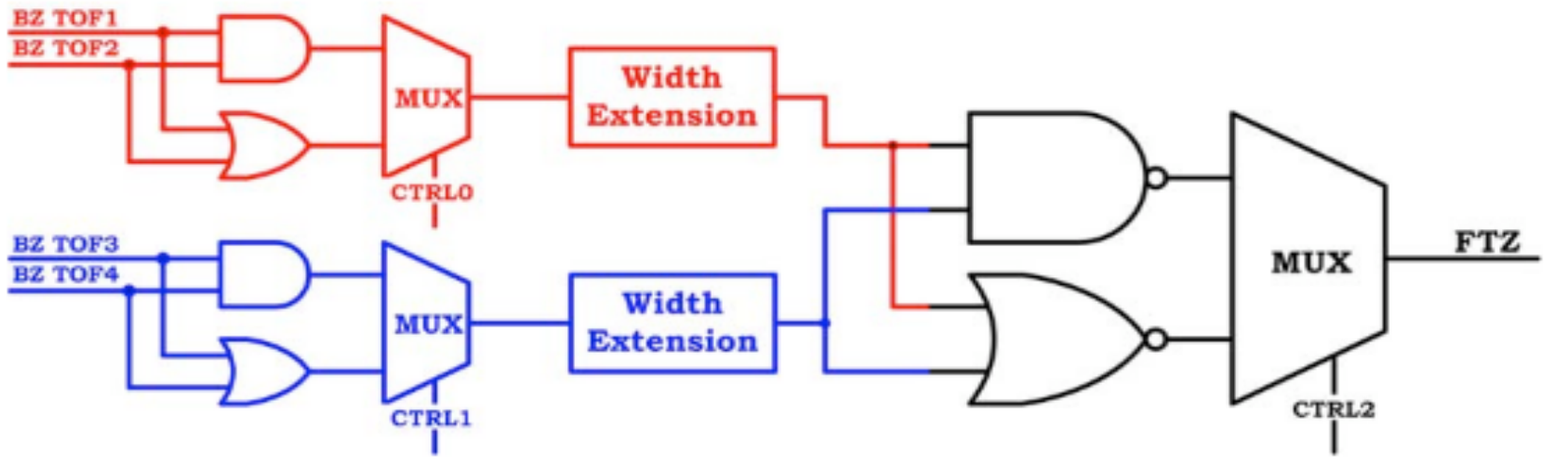
FTC (charged particle signal from TOF)



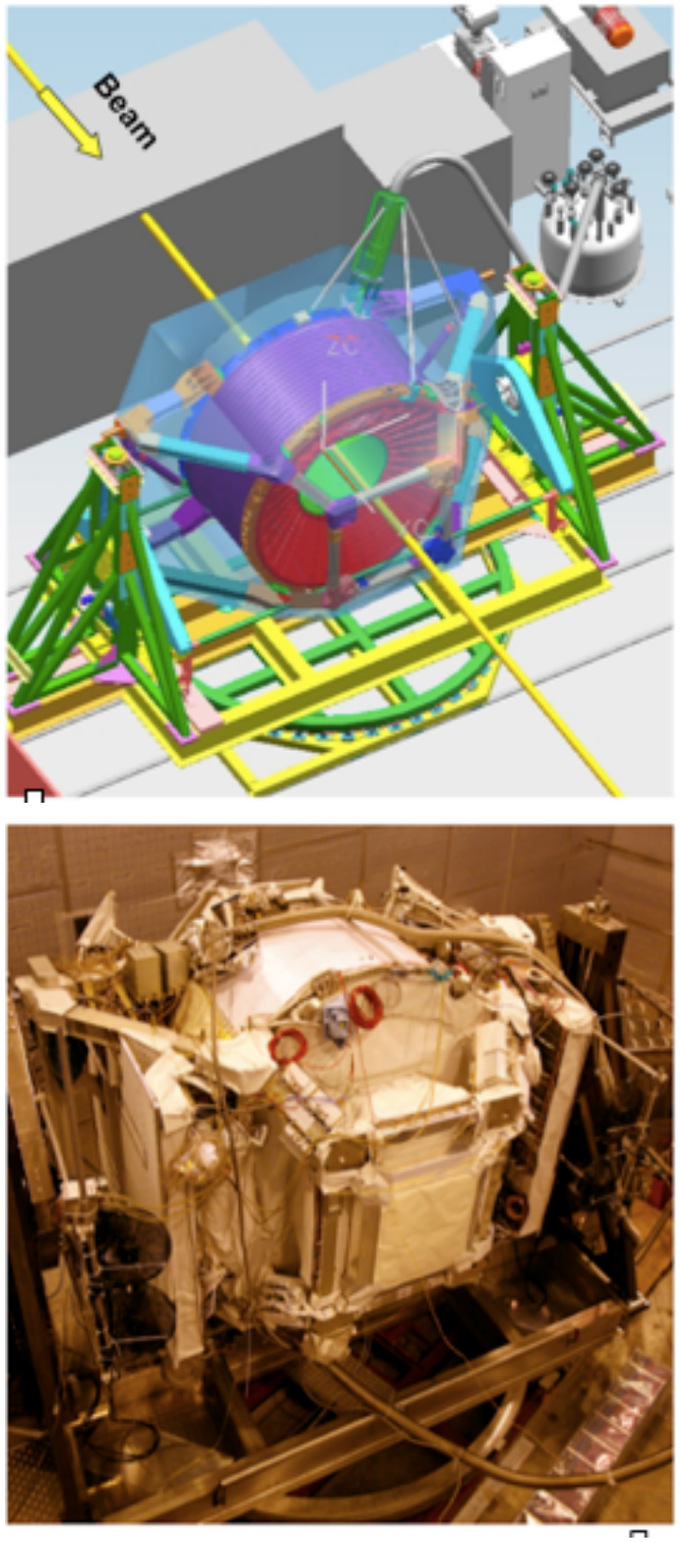


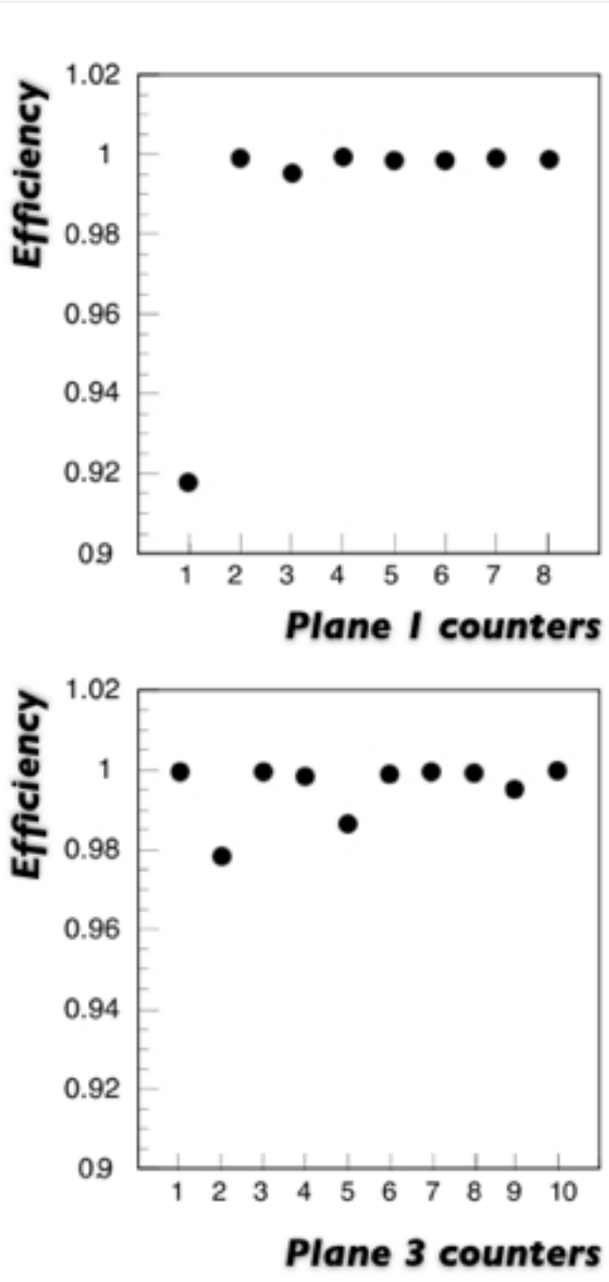
FTZ (using big Z particle signal from TOF)

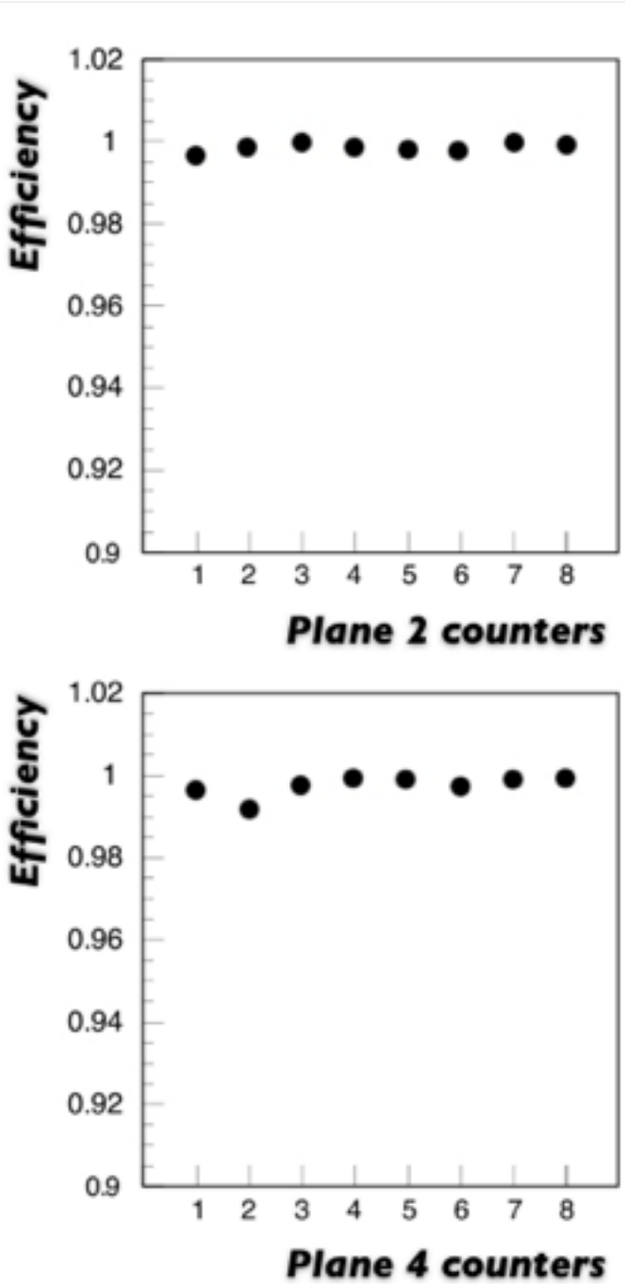
->1280 ns width extension for “slow” particles



TOF trigger efficiency during test beam 2010



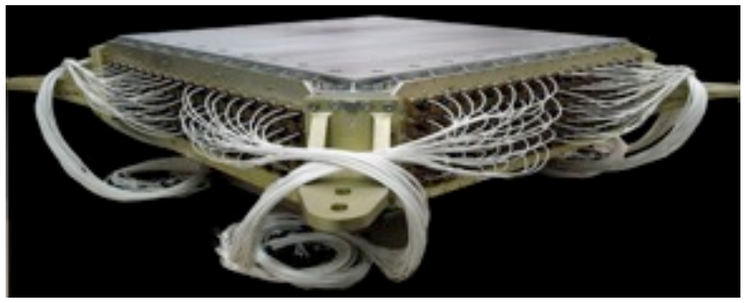




Assure Flat Trigger Efficiency

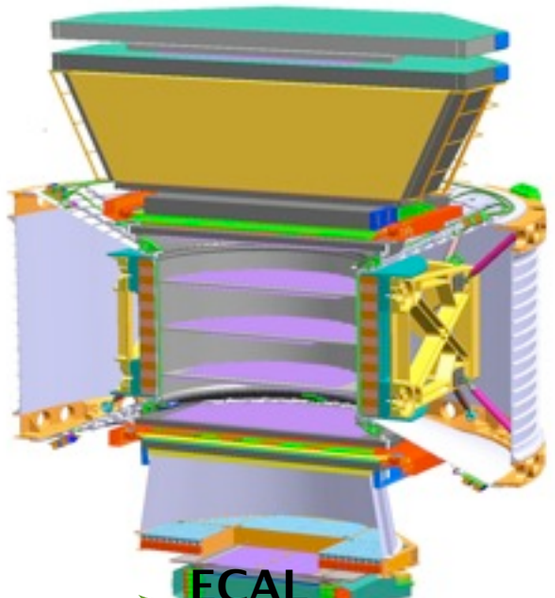
Alpha Magnetic Spectrometer

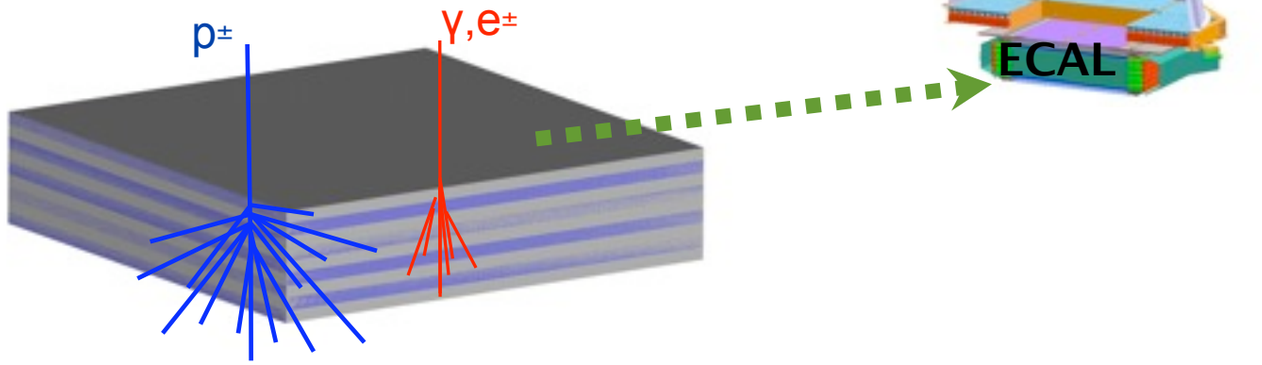
ECAL stand alone trigger for photons

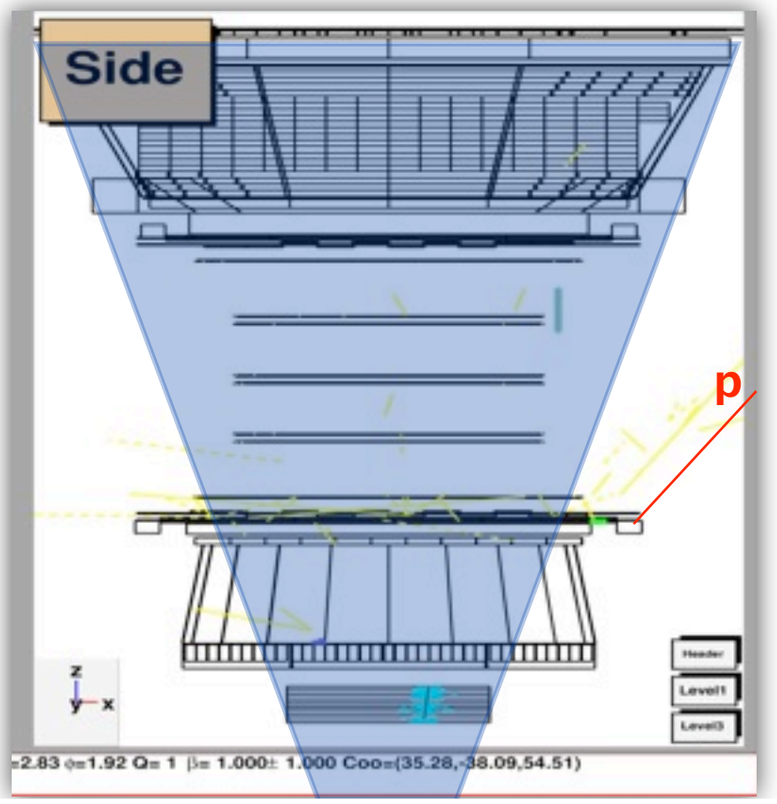


3D imaging profile

efficient trigger for gamma
with energies down to 2 GeV







The trigger for the gamma is made up of 2 steps:

* **Fast trigger** – to reveal any electromagnetic shower in the calorimeter

* **Angular Cut** – to obtain a fast reconstruction of the particle direction, to reject events outside the acceptance.

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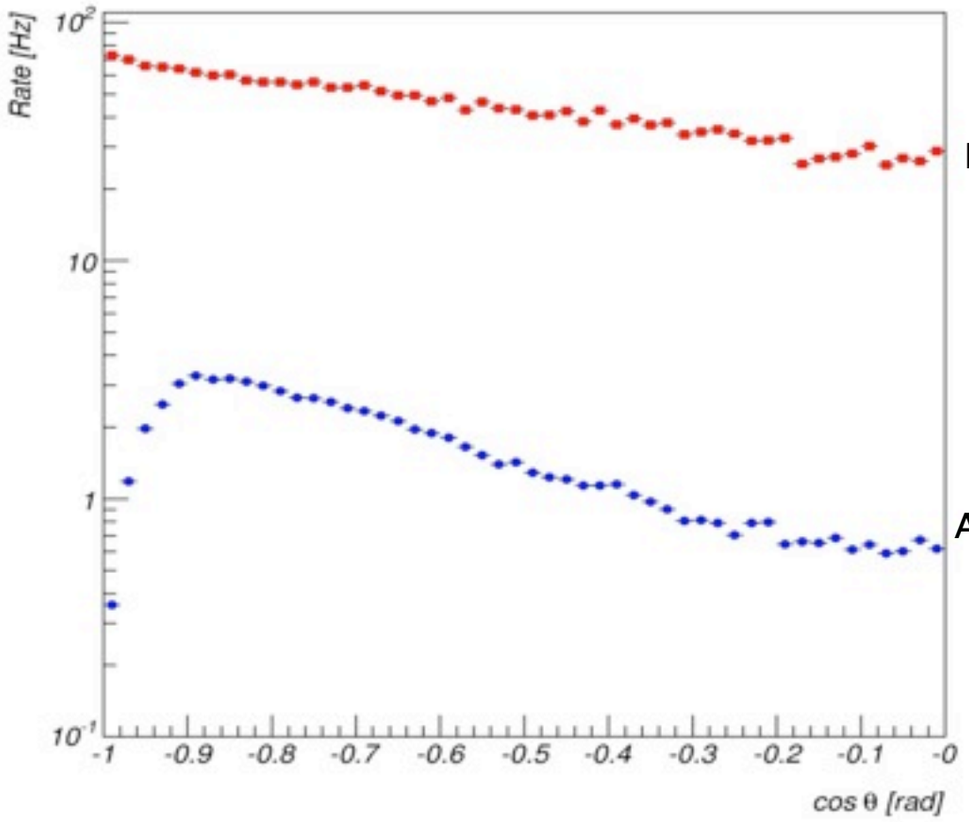
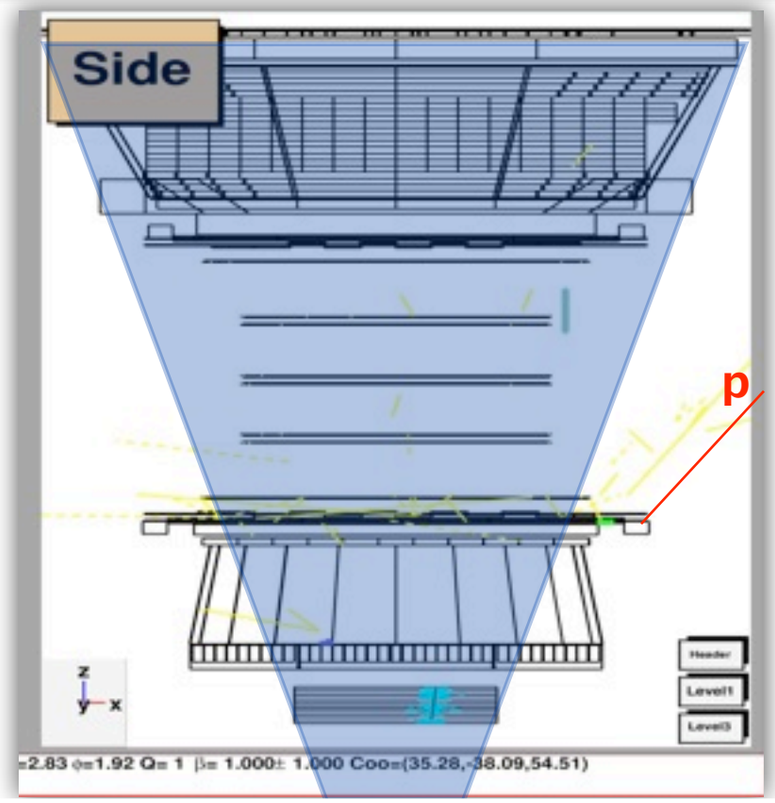
ECAL stand alone trigger



Ecal
Fast trigger

Angular cut



- Background Rates:
  - downward going protons: 70 Hz
  - down. He: 39 Hz
  - down. e^-: 9 Hz

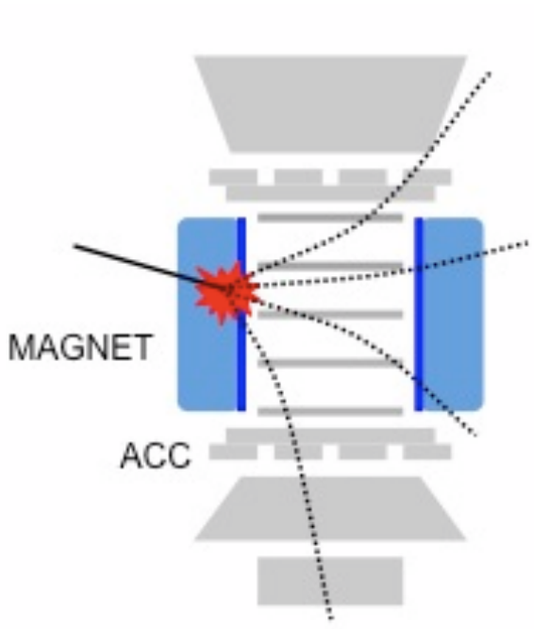
  (upward going in eq. orbit 0.6 Hz)

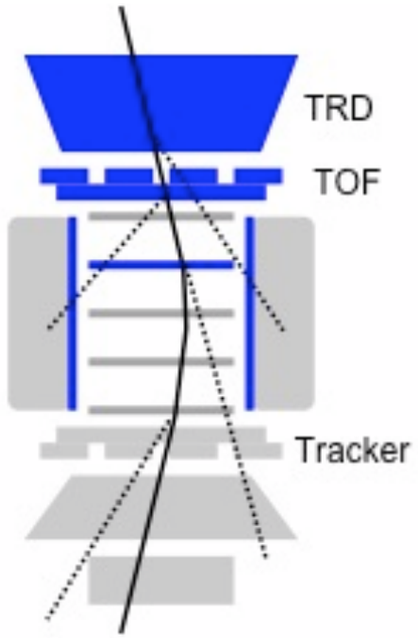
- Efficiency

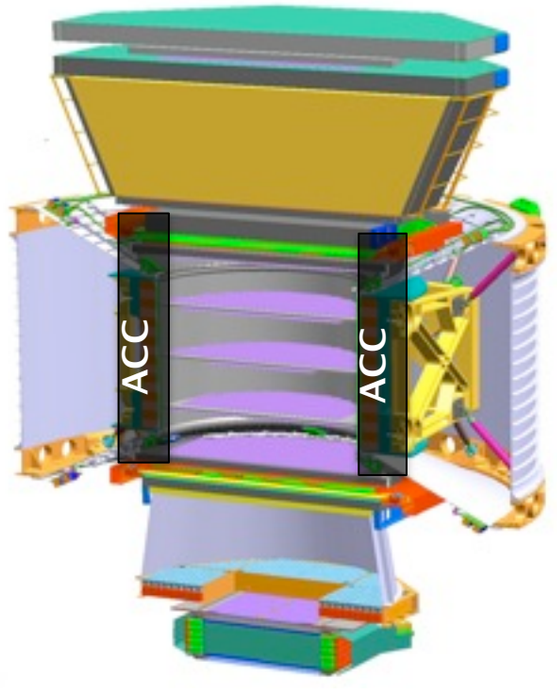
E^g [GeV]	1	1.5	2	3	4	5	10	20	50	100	300
170°-180°	20	66	90	97	98	98	99	99.3	99.0	99.7	99.7
160°-170°	18	65	89	97	98	98	99	99.3	99.5	99.5	99.2

Anti Coincidence Counters - ACC

- Surrounds the silicon tracker.
- Rejects events with particles entering the detector from the side or with particles interacting inside the detector which could distort the charge measurement.

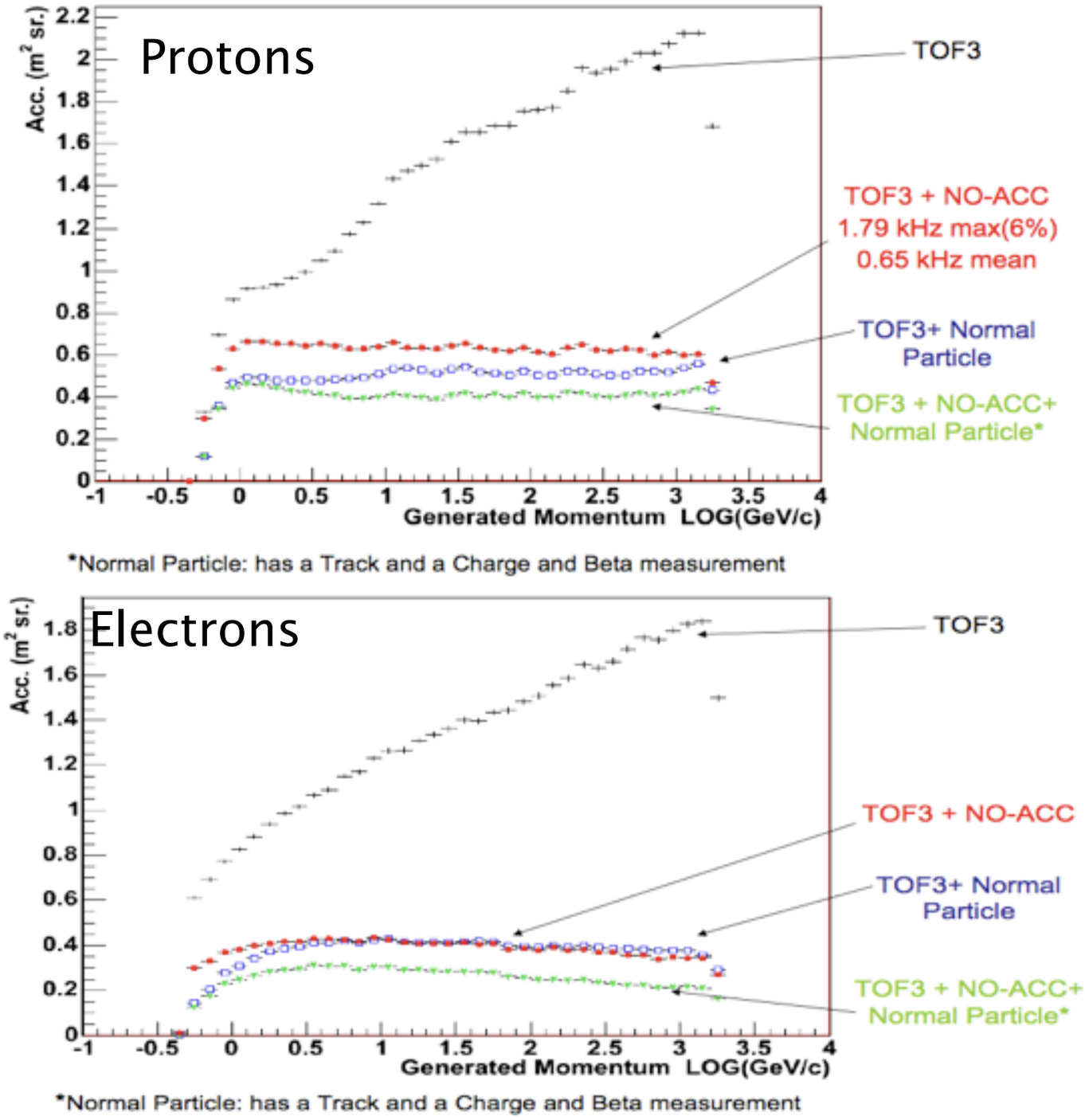


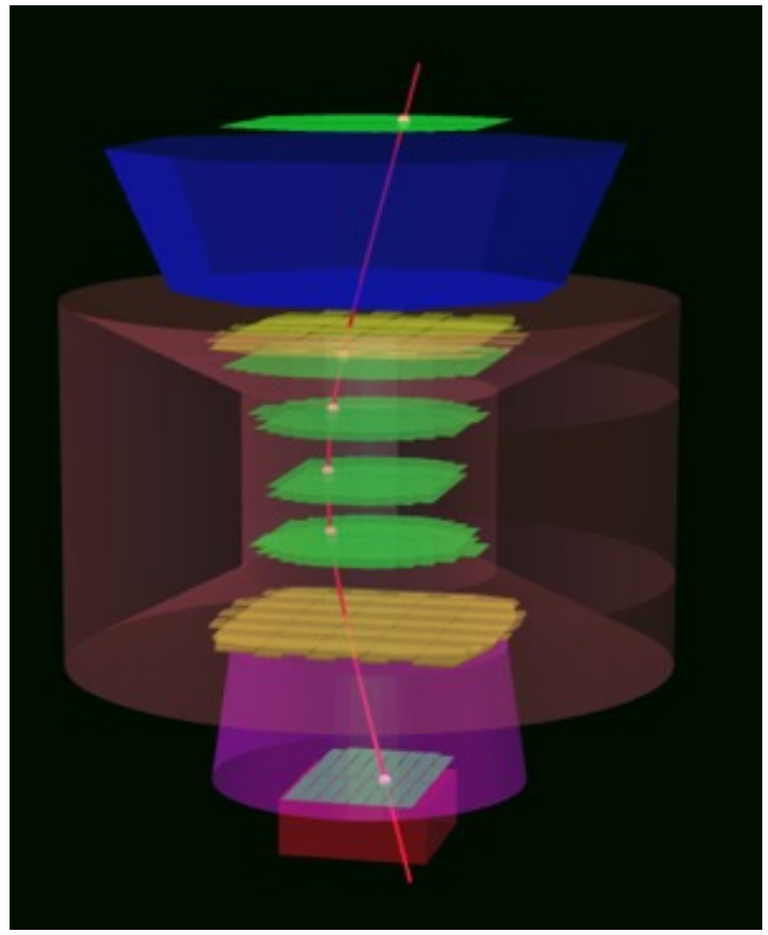




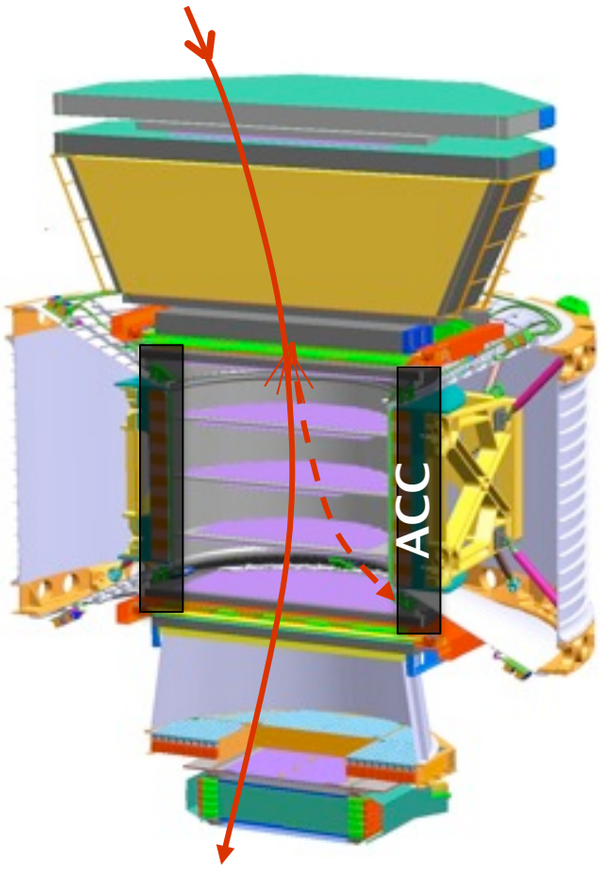
- Reduces the trigger rate during periods of very large flux.
- The inefficiency is the ratio of missed to the total number of particle tracks crossing the ACC.
- **Measured during 2010 test beam: Inefficiency ~10^{-5}**

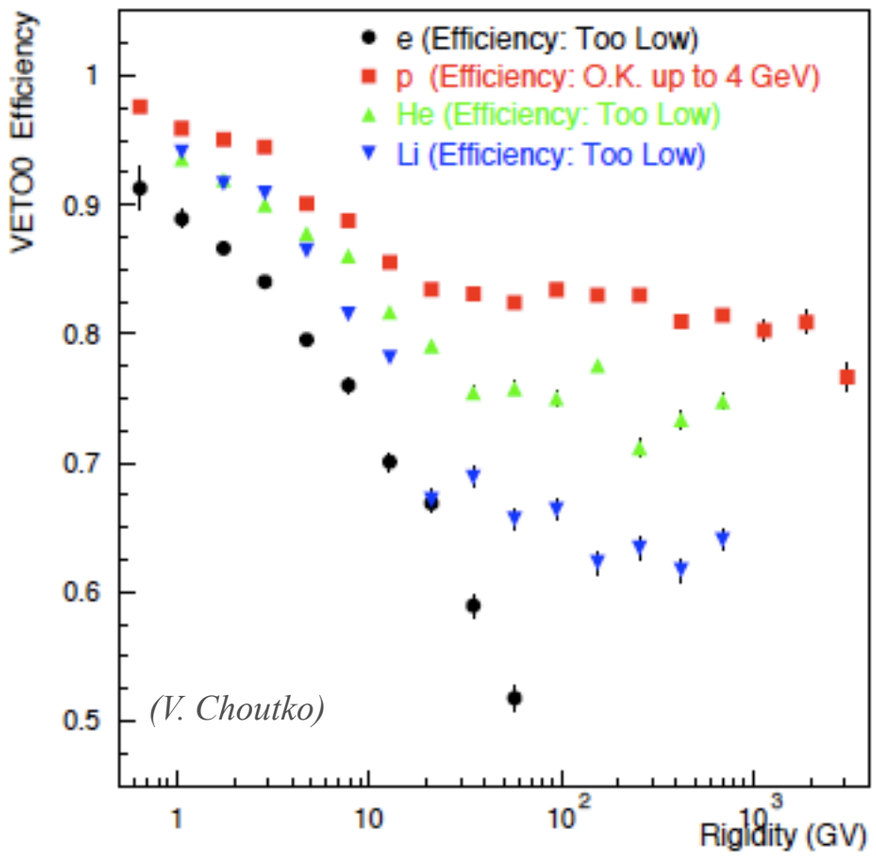
AMS-02 acceptance vs momentum



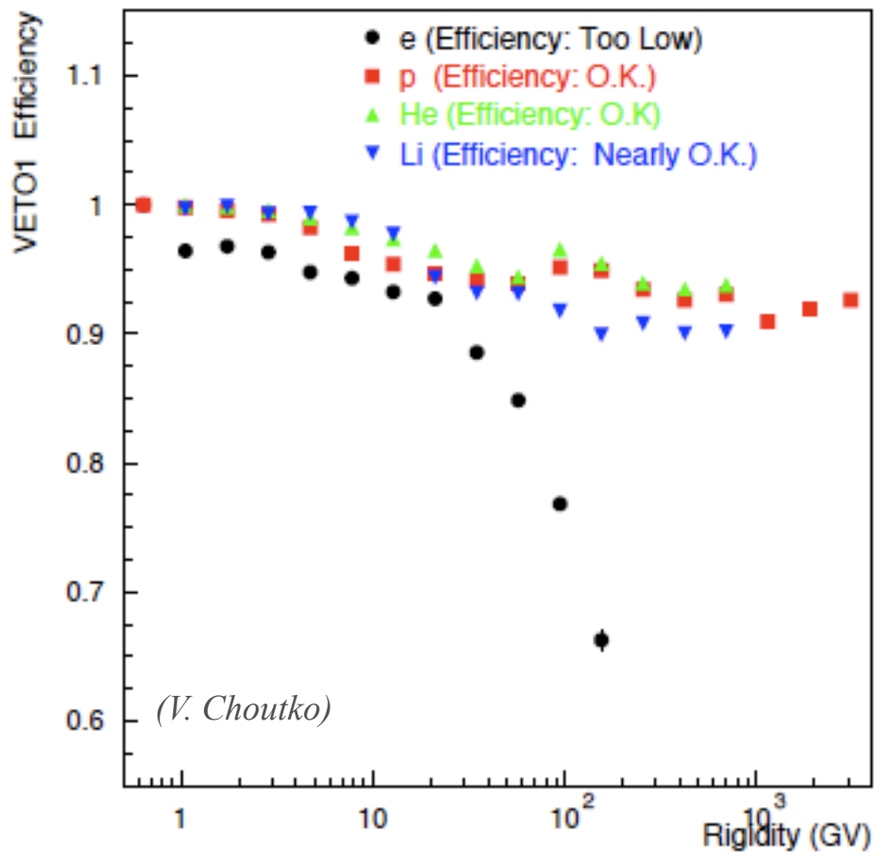


Adding ACC VETO





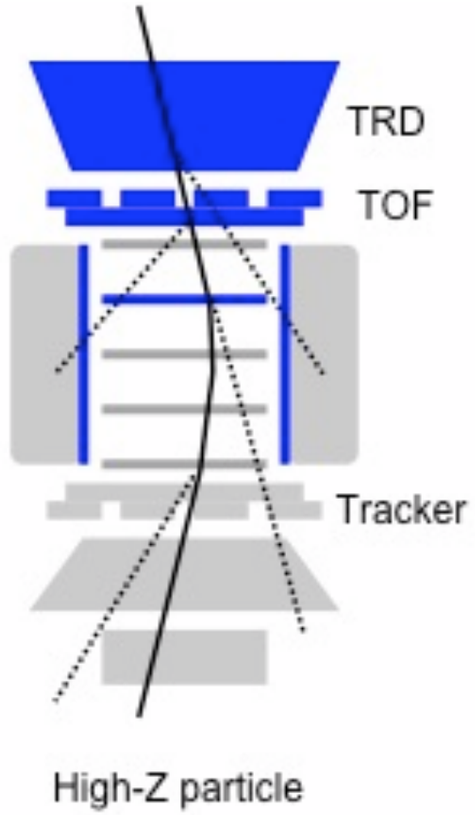
No Veto counters fired

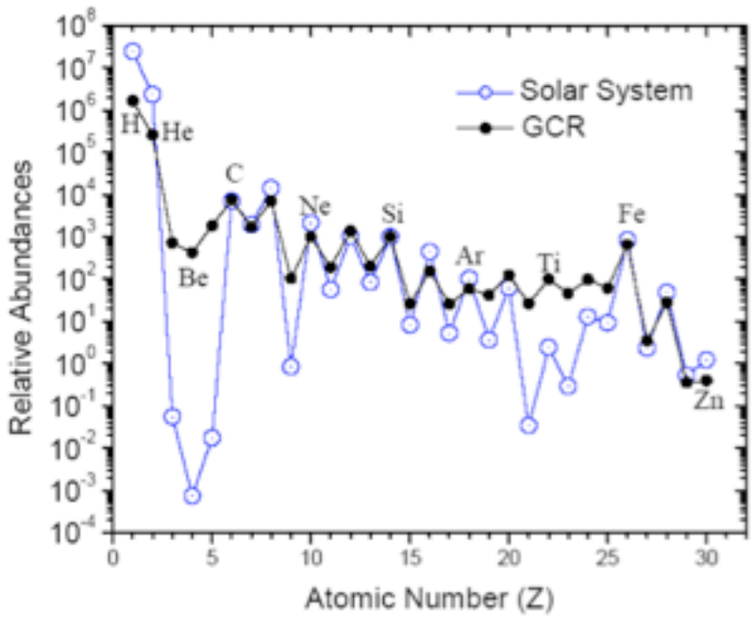


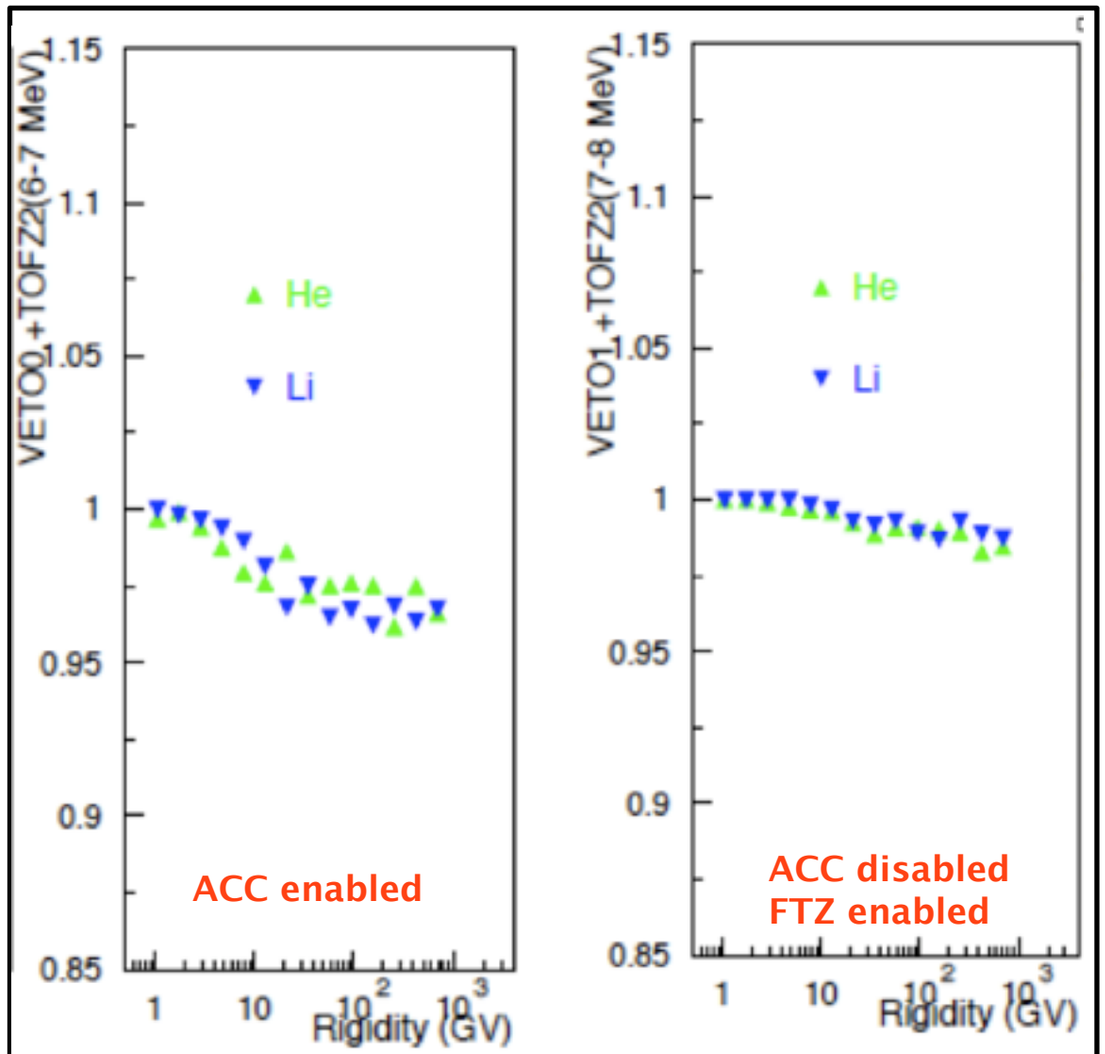
At Most one Veto counter fired

Trigger strategies: ions

When an ion traverse matter is accompanied by electron production that can easily fire the ACC.

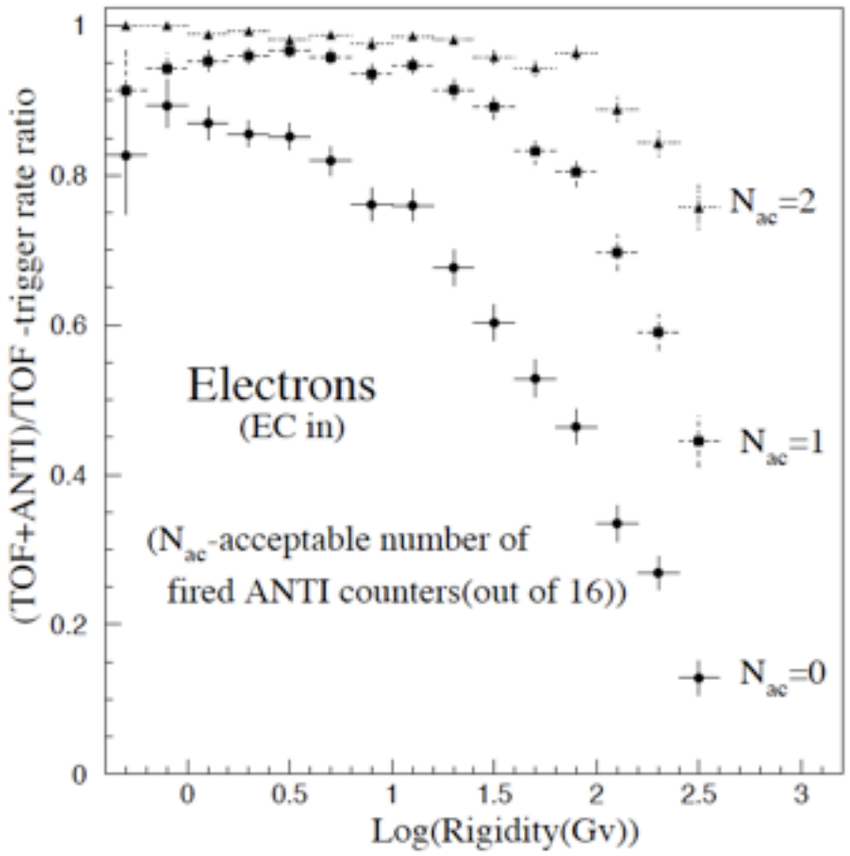


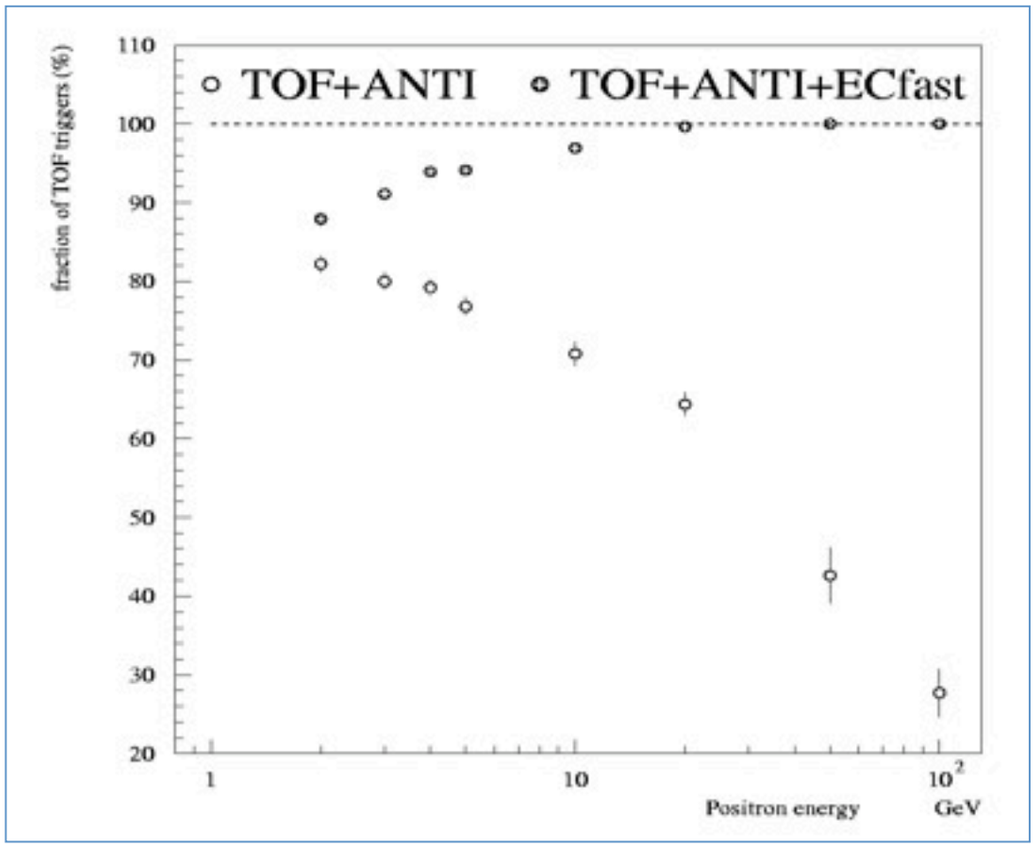




Ion events require the ACC veto disabled and Super high TOF threshold FTZ used to identify ions enabled.

Trigger strategies: ECAL backsplash recovering





When a particle releases its energy in the ECAL, backsplash particles are produced. These particles may exit from the calorimeter surface and hit the ACC.

- Particle backsplash from ECAL reduce electron/positron trigger efficiency:
- Preferred triggers:
  - TOF3/4 **AND** ECAL FT-proj OR **AND** NACC<6
  - TOF3/4 **AND** NOECAL **AND** NACC<2

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Trigger summary

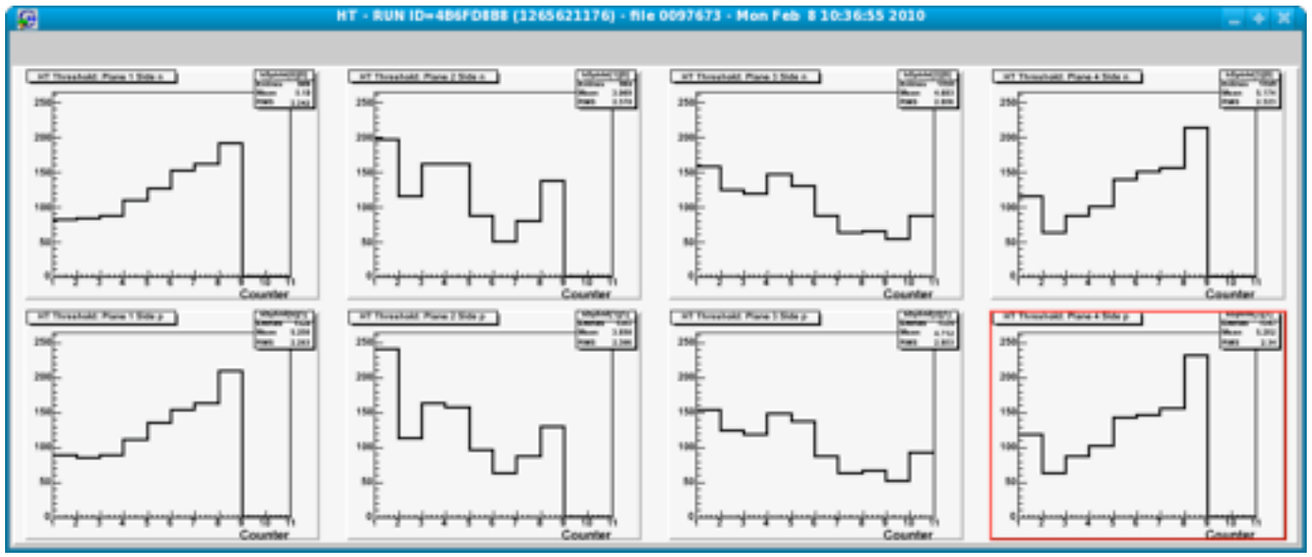
- Level 1 Trigger goals:
  - Keep the mean event rate below ~2.4 kHz (live-time >~ 75%)
  - Maximize the acceptance for the different CR species (p, e, He, nuclei, photons)
  - No rigidity dependences in the acceptance

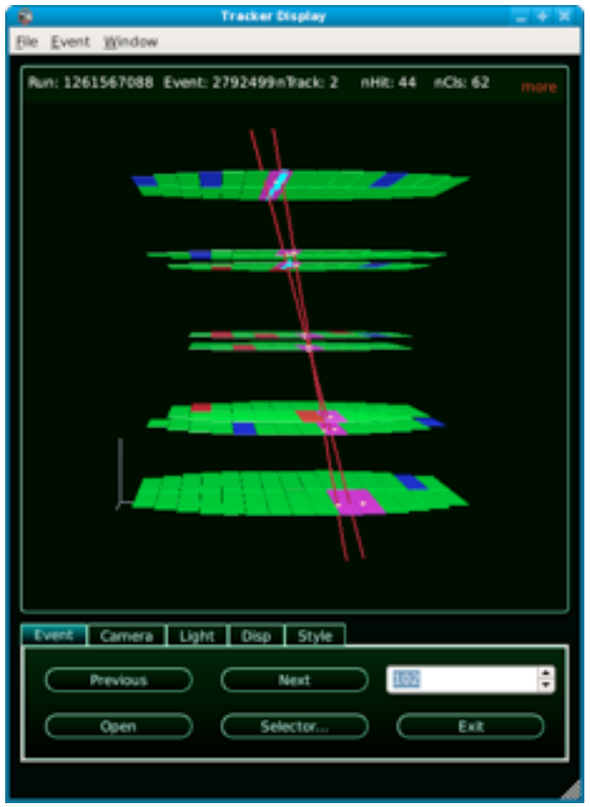
- Trigger Strategies:

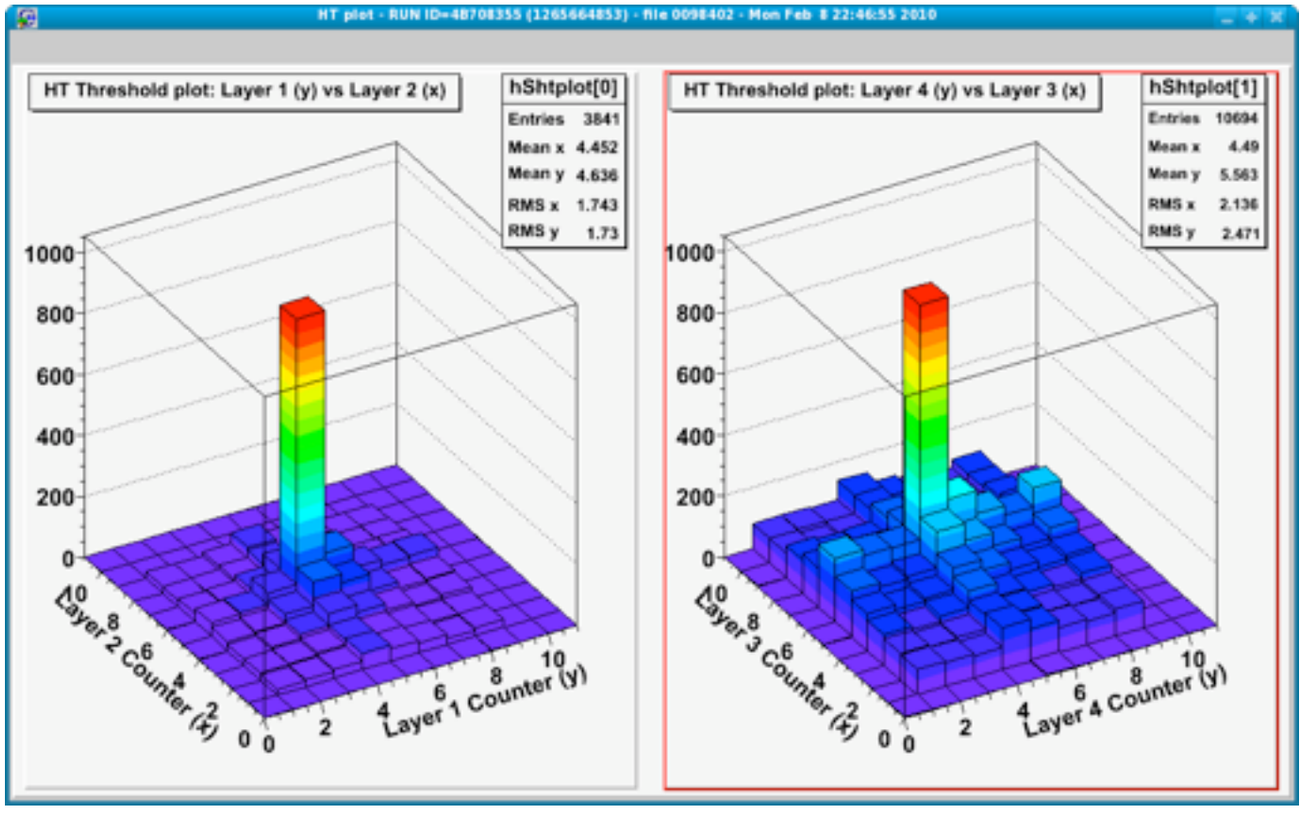
Trigger ID	Signal Configuration	
Single charged not EM	TOF=4of4 with Low Thrs, 0 hit in ACC	OR
Electrons	TOF=4of4 with Low Thrs, ECAL FT-proj AND	
Normal Ions	TOF>=3of4 with BigZ Thrs	LV1 Science Trigger
Strange Ions	BigZ Thrs, special FTZ “slow particle”	
Photons	FT-projAND, EC Angle-projAND	
Unbiased charged	TOF=4of4 with Low Thrs, presc.factor~1000	Unbiased to check acceptance
Unbiased EM	ECAL FT-proj OR, presc.factor~1000	

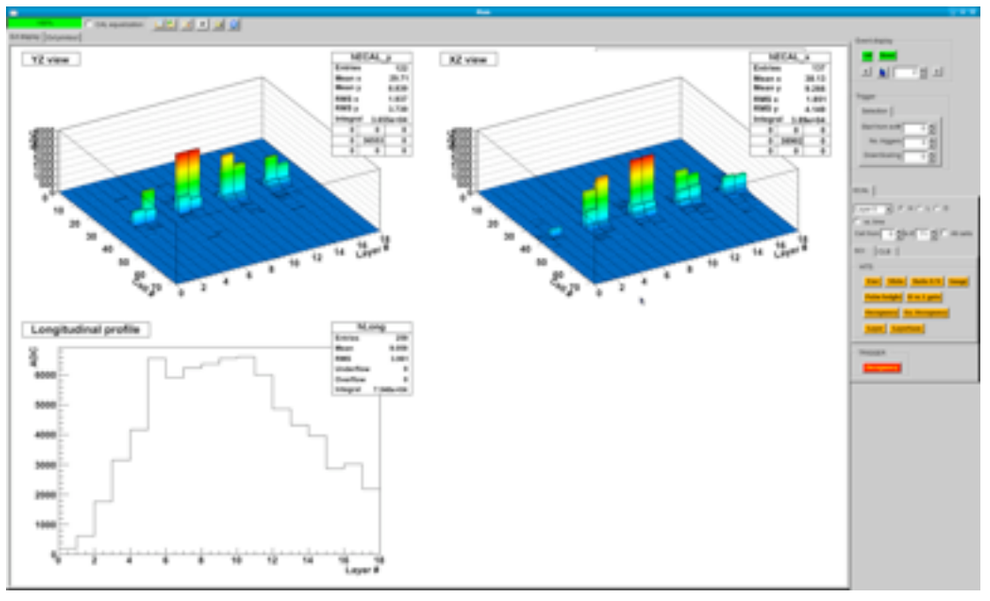
Alpha Magnetic Spectrometer

Data center at MIT for POCC and SOC









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Conclusions

- Fast trigger signals from TOF (charged particles and ions) and from ECAL (photons).
- Level 1 Trigger generated by the combination of TOF, ECAL and ACC signals
- Trigger strategies are necessary to efficiently reveal the different species of cosmic rays.
- During the last test beam in February 2010 the trigger system and its efficiency was tested.
- The trigger will be tested again during the next test beam mid of August 2010.
- Next years a SOC and POCC data center will be built at MIT:
  - to monitor AMS-02 detector status and performance giving a fast feedback on the data quality,
  - to provide a analysis center for unique physics studies at MIT.

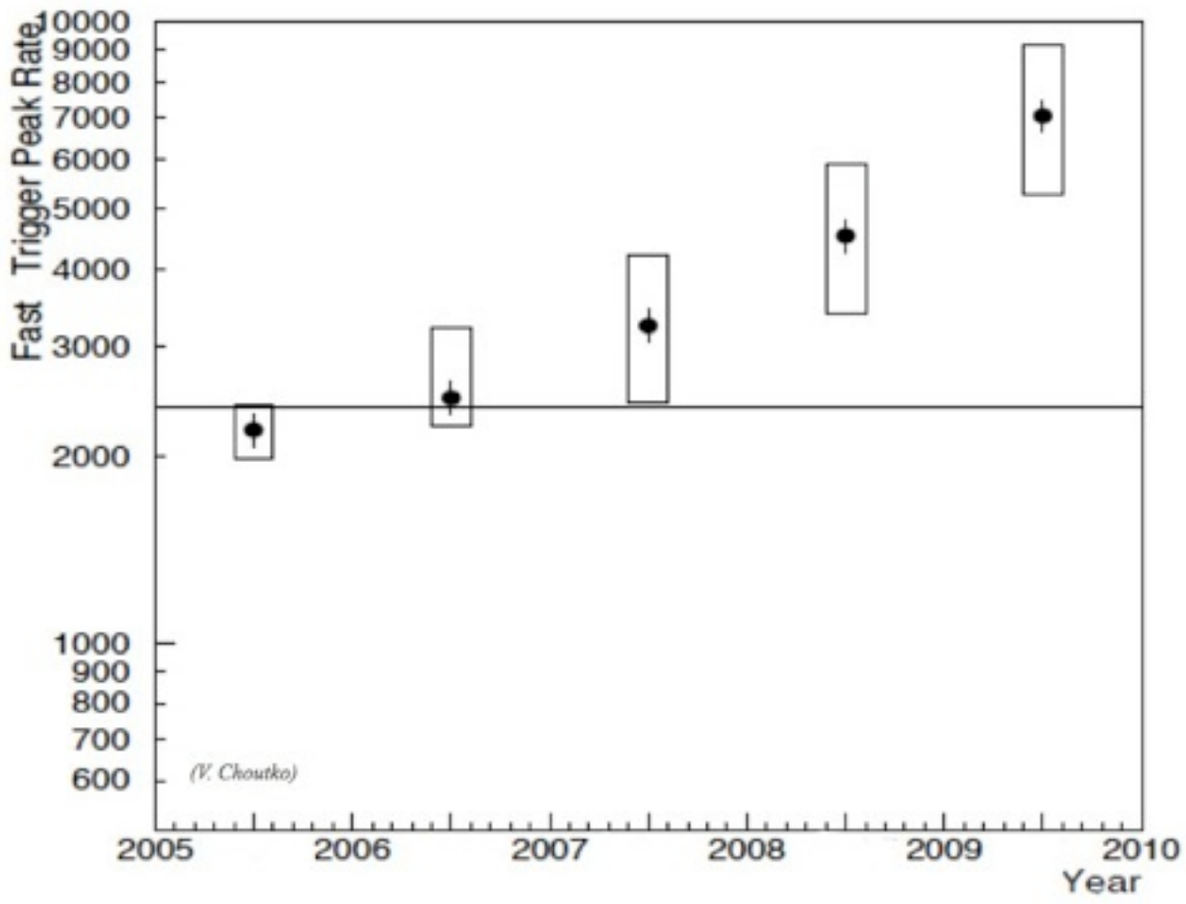
Back-up slides

Why the Level 1 Trigger?

* The DAQ system is designed to operate at trigger rates up to 2 kHz, an average event size being about 2 KBytes

* The maximal Front-End readout time is 120 us, which corresponds to a dead time of 20% at 2 kHz

Keep Input Rate Under 2400-2500 Hz (75% Live Time)



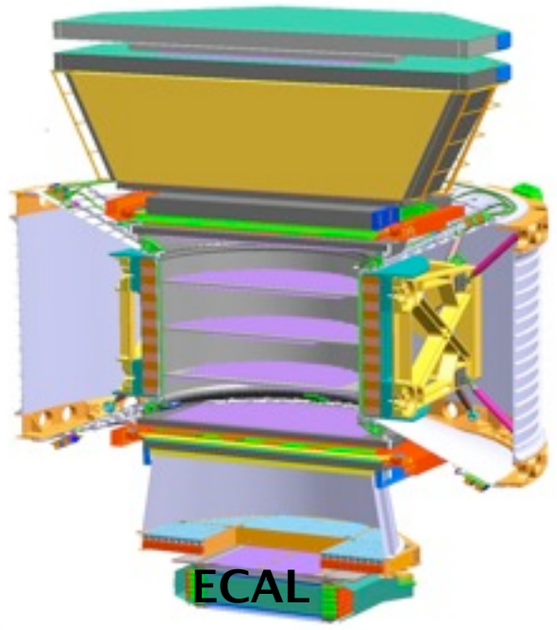
Alpha Magnetic Spectrometer

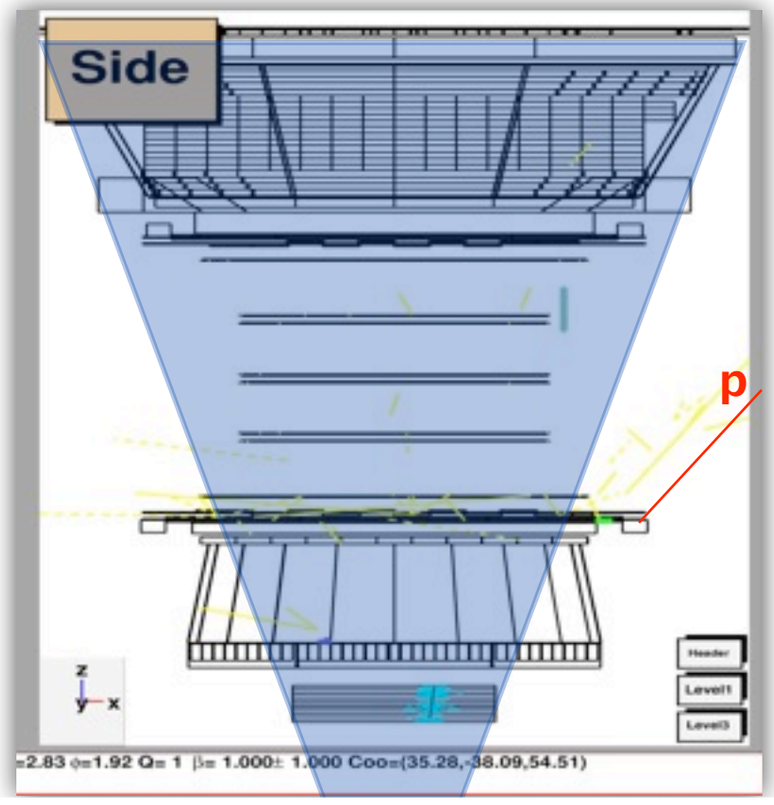
ECAL stand alone triggers

A precision, 17 X_0, 3-dimensional measurement of the directions and energies of light rays and electrons

9 super-layers of Lead + Scintillator Fibers
Standalone Trigger
e±, γ detection
e/p separation > 10^3
3D imaging UN GRADO

- High e/h rejection factor: ~ 10^4
  - high λ_I/X_0 ratio
  - 3D imaging of the longitudinal and the lateral shower development
- Good energy resolution over large interval (from 1 GeV up to ~ 1 TeV)
- Self-triggering (Gamma Ray Physics)





Basic Idea: to reject events outside the sensitive volume (TOF)

The trigger is made up of 2 steps:

1. Fast trigger logic:
   - super-layer thresholds follow EM Shower profile
   - Trigger Granularity: 1 PMT (Last Dynode signal), good EM shower image reconstruction (1 PMT ≅ 1 Moliere Radius)
   - 2 (out of 3) super-layers for each view (X,Y) with at least one PMT above Threshold
2. Angular Cut:
   - For each super-layers the center of gravity of the PMT's above threshold is computed to obtain a fast reconstruction of the particle direction.

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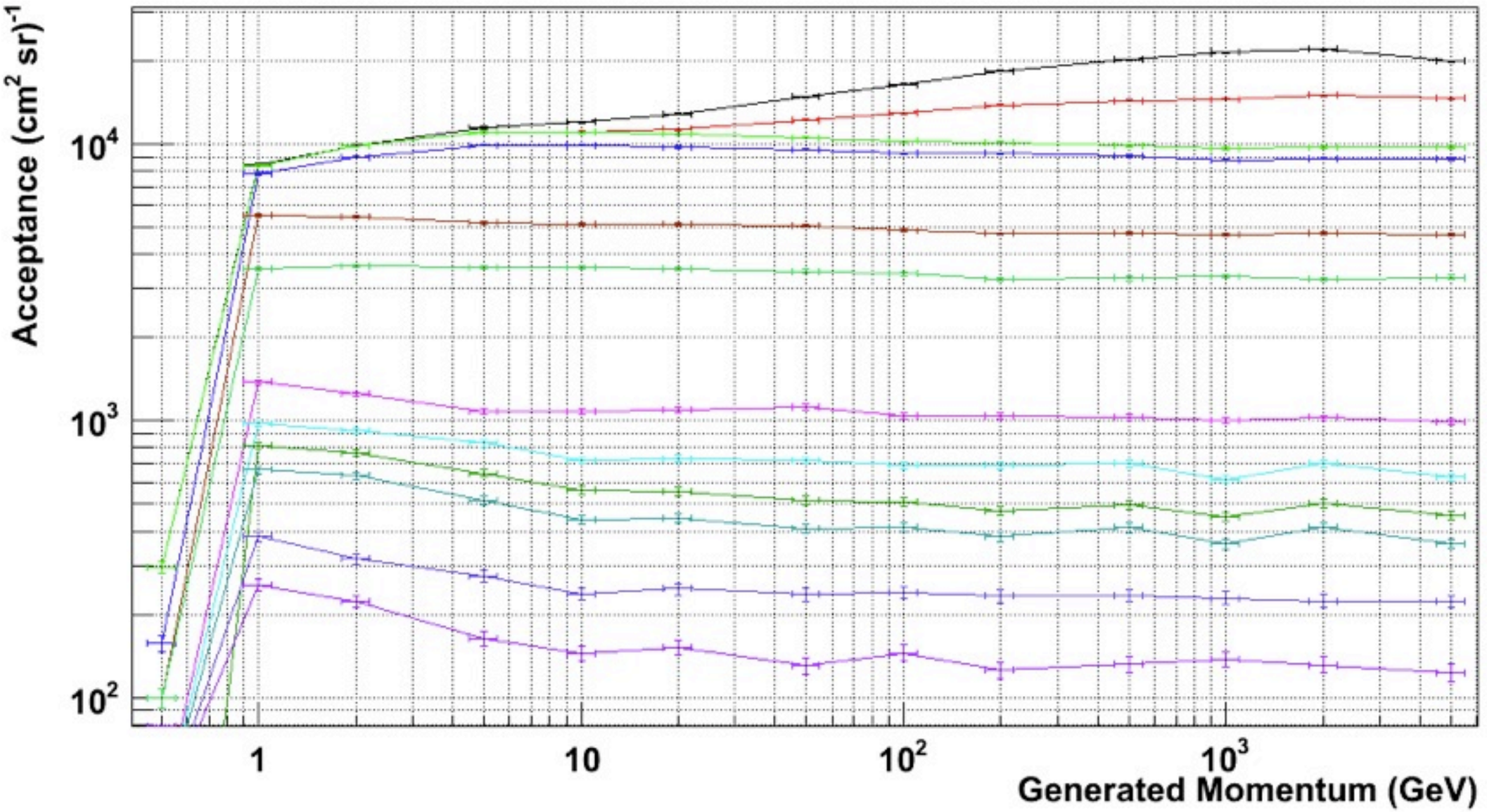
AMS-02 acceptances



Onboard Data Processing – Level3 Trigger

- Goal – keep average data downlink bandwidth around 4-5 Mbit/s

- Performs fast (~2ms) event classification based on

•Sub-detector data quality;
•Presence of a track in the tracker;
•Particle direction;
•Presence of an electromagnetic shower in ECAL
•Magnitude of the particle charge.

- Performs fast lossless data compression based on Huffman encoding