



Solar Energetic Particles measured by the Alpha Magnetic Spectrometer on the International Space Station during solar cycle 24

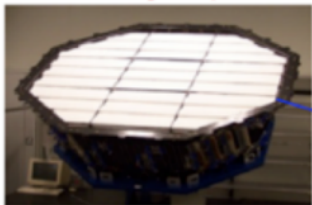


Christopher Light
On behalf of the AMS Collaboration

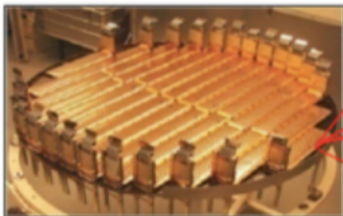
Alpha Magnetic Spectrometer

TRD

Identify e^+ , e^-



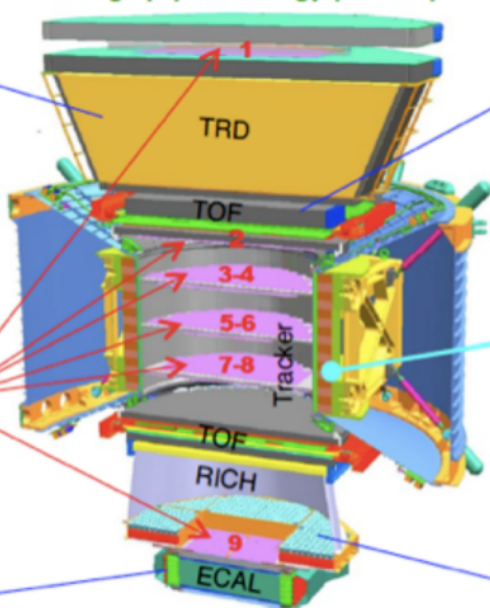
Silicon Tracker
 Z, P



ECAL
 E of e^+ , e^- , γ



Particles and nuclei are defined by their charge (Z) and energy ($E \sim P$)



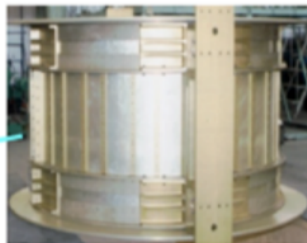
Z, P are measured independently by the Tracker, RICH, TOF and ECAL

TOF

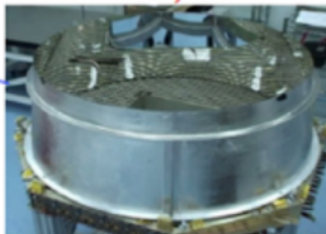
Z, E



Magnet
 $\pm Z$



RICH
 Z, E



Transition Radiation Detector

- $e^+ e^-$ identification

Time of Flight counter

- Trigger
- Velocity
- Particle flight direction
- Charge

Silicon Tracker & Magnet

- Rigidity
- Charge (with sign)

Ring Imaging Cherenkov Detector

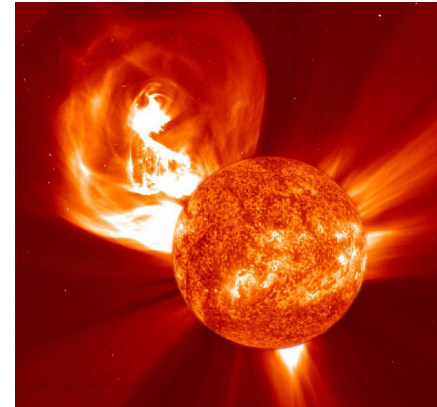
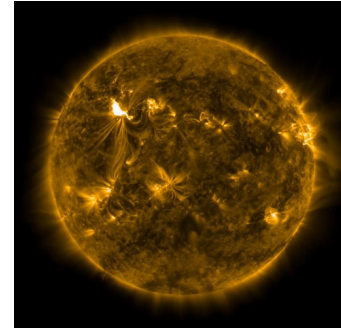
- Velocity
- Charge

Electromagnetic Calorimeter

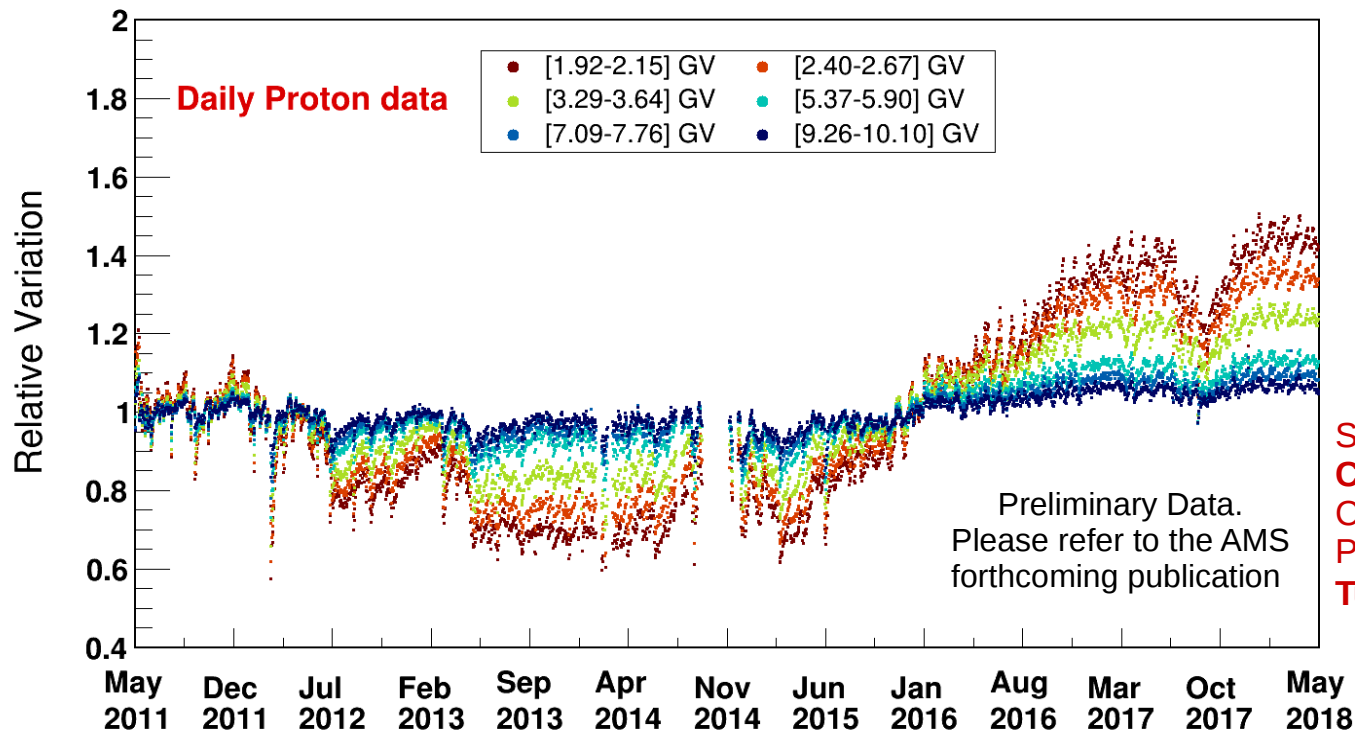
- $e^+ e^-$ identification
- $e^+ e^-$ energy

AMS Measurements of Solar Energetic Particles

- Solar Energetic Particles (SEPs)
 - SEPs are charged particles that are accelerated in large eruptions that occur in the solar corona.
 - These eruptions generally produce a flare and a coronal mass ejection, along with SEPs
 - SEPs have a wide spectrum of energies from keV to GeV
- SEP Events in AMS
 - AMS measures the highest energy SEPs, up to the high energy limit of the SEP spectrum
 - AMS SEP events are generally associated with M and X class flares, and fast moving coronal mass ejections (CMEs)
 - AMS measures SEPs as an excess of particles above the galactic cosmic ray background



Alpha Magnetic Spectrometer

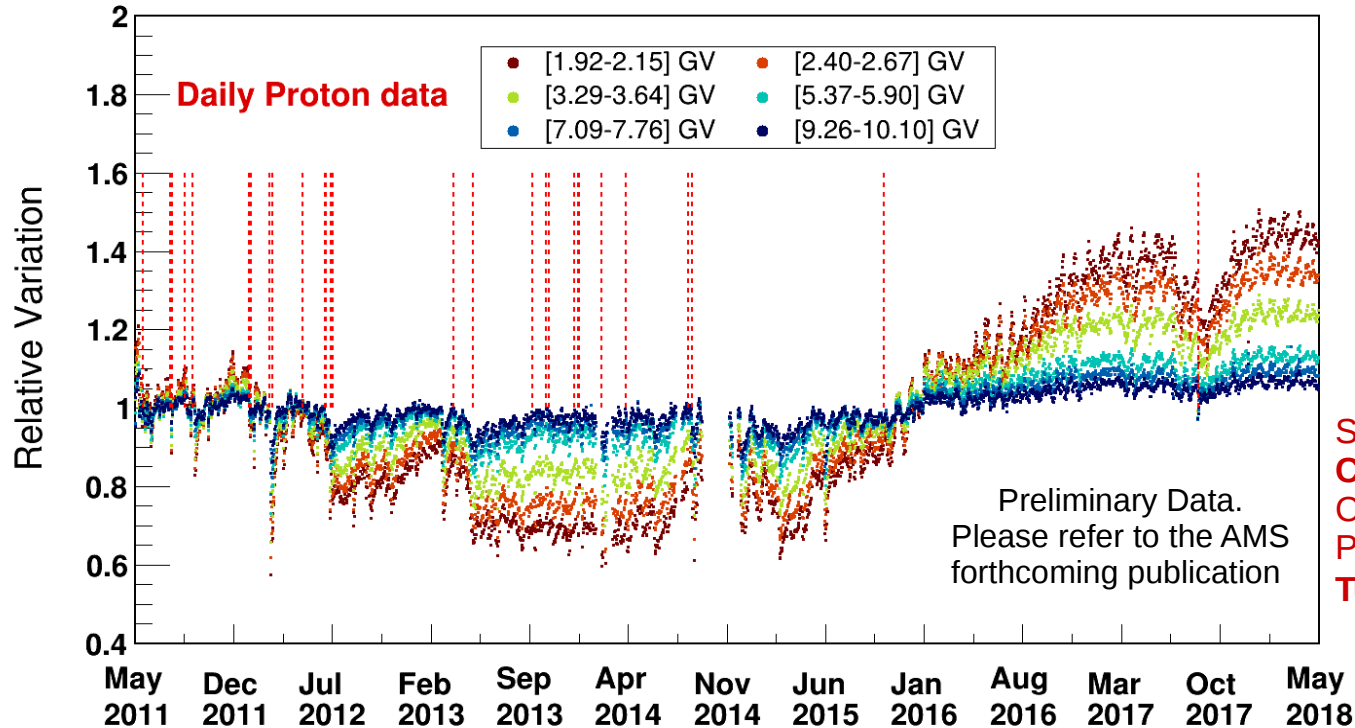


See Presentation by
Cristina Consolandi:
Cosmic Ray Direct
Parallel Session
Tuesday, July 30th

AMS began taking measurements in May 2011 and will continue until the decommission of the International Space Station.

Over 140 billion particle events have been collected.

Alpha Magnetic Spectrometer



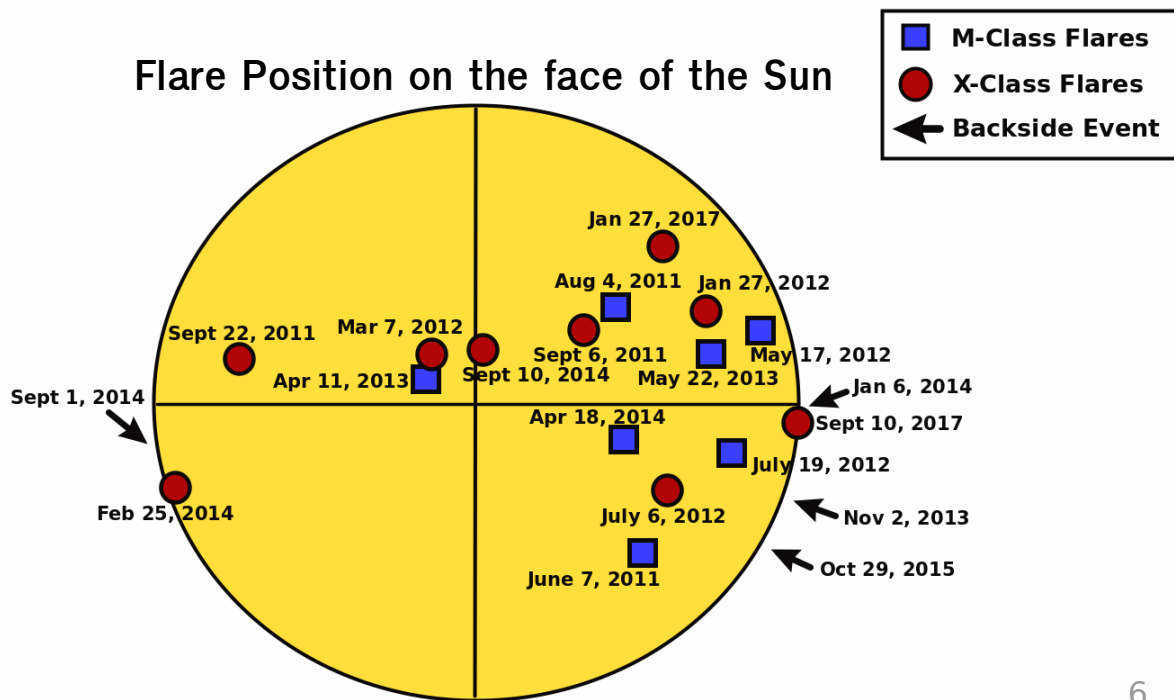
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Parallel Session
Tuesday, July 30th

Through May 2018, AMS has detected 28 SEP events.

| AMS Event | Event Date | Flare Class | CME Vel. (km/s) |
|-----------|---------------------|------------------|-----------------|
| 1 | 2011/06/07 | M2.5 | 1255 |
| 2 | FD 2011/08/04 | M9.3 | 1315 |
| 3 | 2011/08/09 | X6.9 | 1610 |
| 4 | 2011/09/06 | X2.1 | 575 |
| 5 | 2011/09/22 | X1.4 | 1905 |
| 6 | FD 2012/01/23 | M8.7 | 2175 |
| 7 | FD 2012/01/27 | X1.7 | 2508 |
| 8 | FD 2012/03/07 | X5.4, X1.3 | 2684, 1825 |
| 9 | FD 2012/03/13 | M7.9 | 1884 |
| 10 | 2012/05/17 | M5.1 | 1582 |
| 11 | 2012 /07/06 | X1.1 | 1854 |
| 12 | 2012/07/08 | M6.9 | 1495 |
| 13 | FD 2012/07/19 | M7.7 | 1631 |
| 14 | FD 2012/07/23 | backside | 2003 |
| 15 | 2013/04/11 | M6.5 | 861 |
| 16 | FD 2013/05/22 | M5.0 | 1466 |
| 17 | filament 2013/09/29 | C1.2 | 1179 |
| 18 | 2013/10/28 | M5.1, M2.8, M4.4 | 1201, 1073, 812 |
| 19 | FD 2013/11/02 | backside | 828 |
| 20 | 2013/12/28 | backside | 1118 |
| 21 | FD 2014/01/06 | backside | 1118 |
| 22 | FD 2014/01/07 | X1.2 | 1830 |
| 23 | FD 2014/02/25 | X4.9 | 2147 |
| 24 | FD 2014/04/18 | M7.3 | 1203 |
| 25 | 2014/09/01 | backside | 1404 |
| 26 | FD 2014/09/10 | X1.6 | 1267 |
| 27 | 2015/10/29 | backside | 530 |
| 28 | 2017/9/11 | X8.2 | 2868 |

Solar Energetic Particle Events Observed by AMS

SEP events detected by AMS are a subset of events with a very hard spectrum, they are typically associated with M- and X-class flares and fast CMEs.

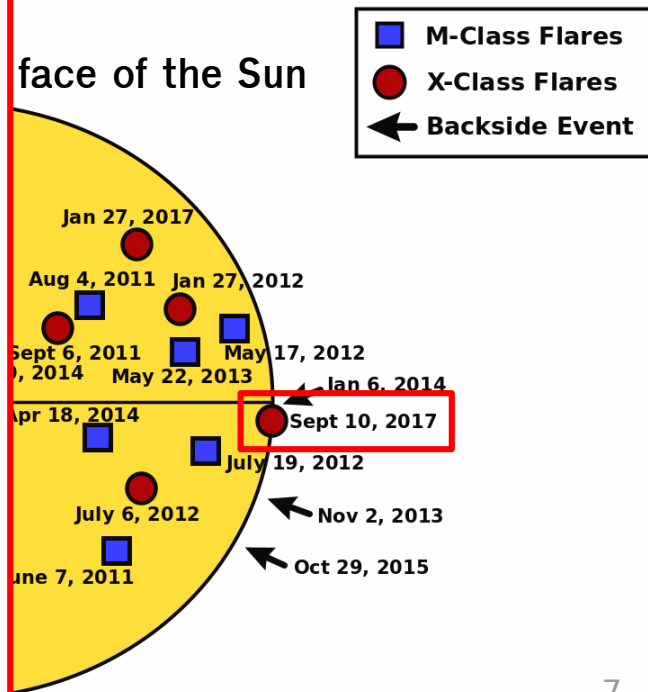


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Solar Energetic Particle Events Observed by AMS

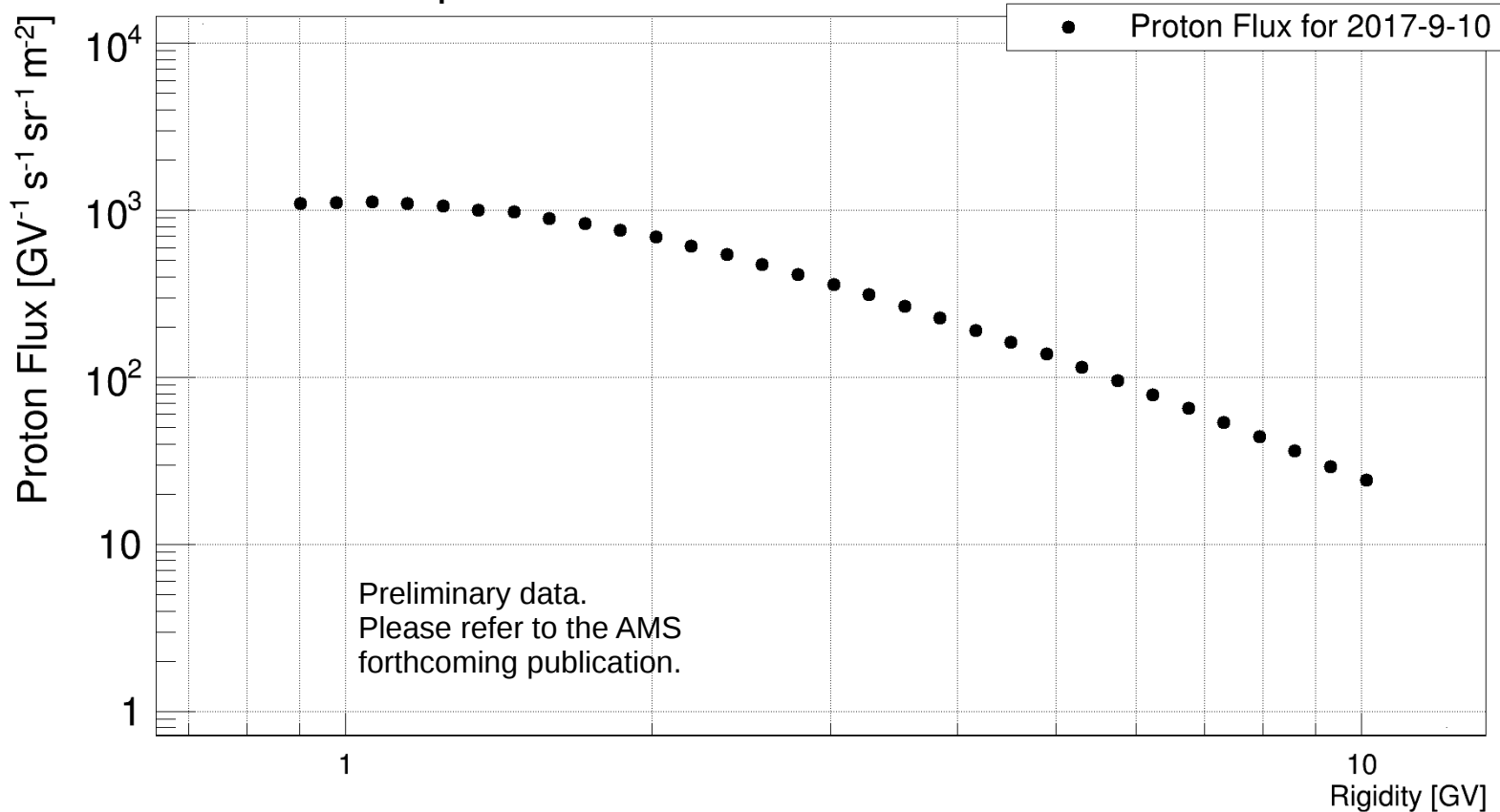
September 2017

- Most recent Ground Level Enhancement (GLE) SEP event.
- X8.2 Flare at 16:06 on the 10th of Sept.
- Fast (2868 km/s) Halo CME associated with this event
- Interesting event because this was a GLE that occurred deep into the descending phase of solar activity.

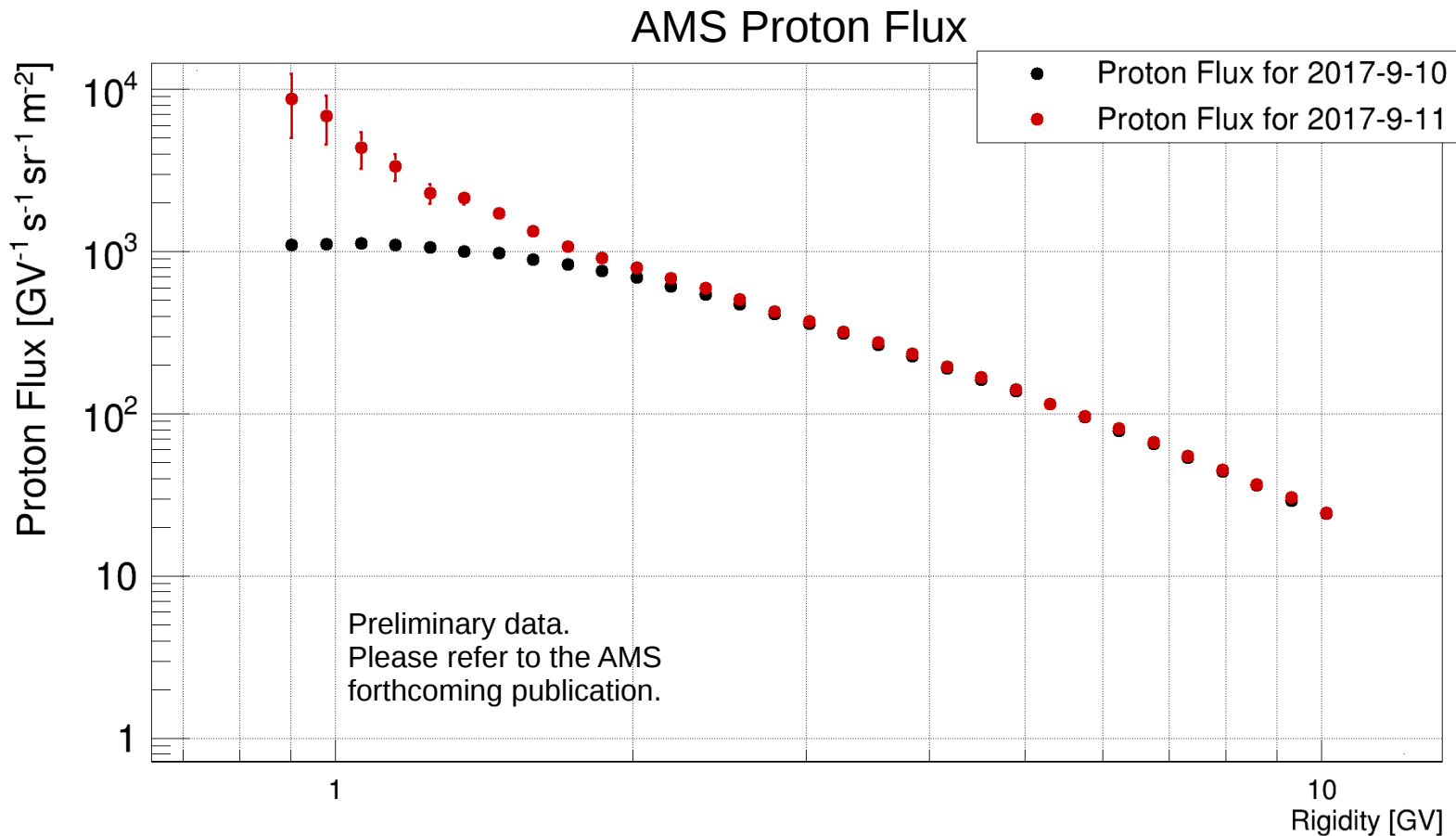


September 2017 Solar Energetic Particle Event

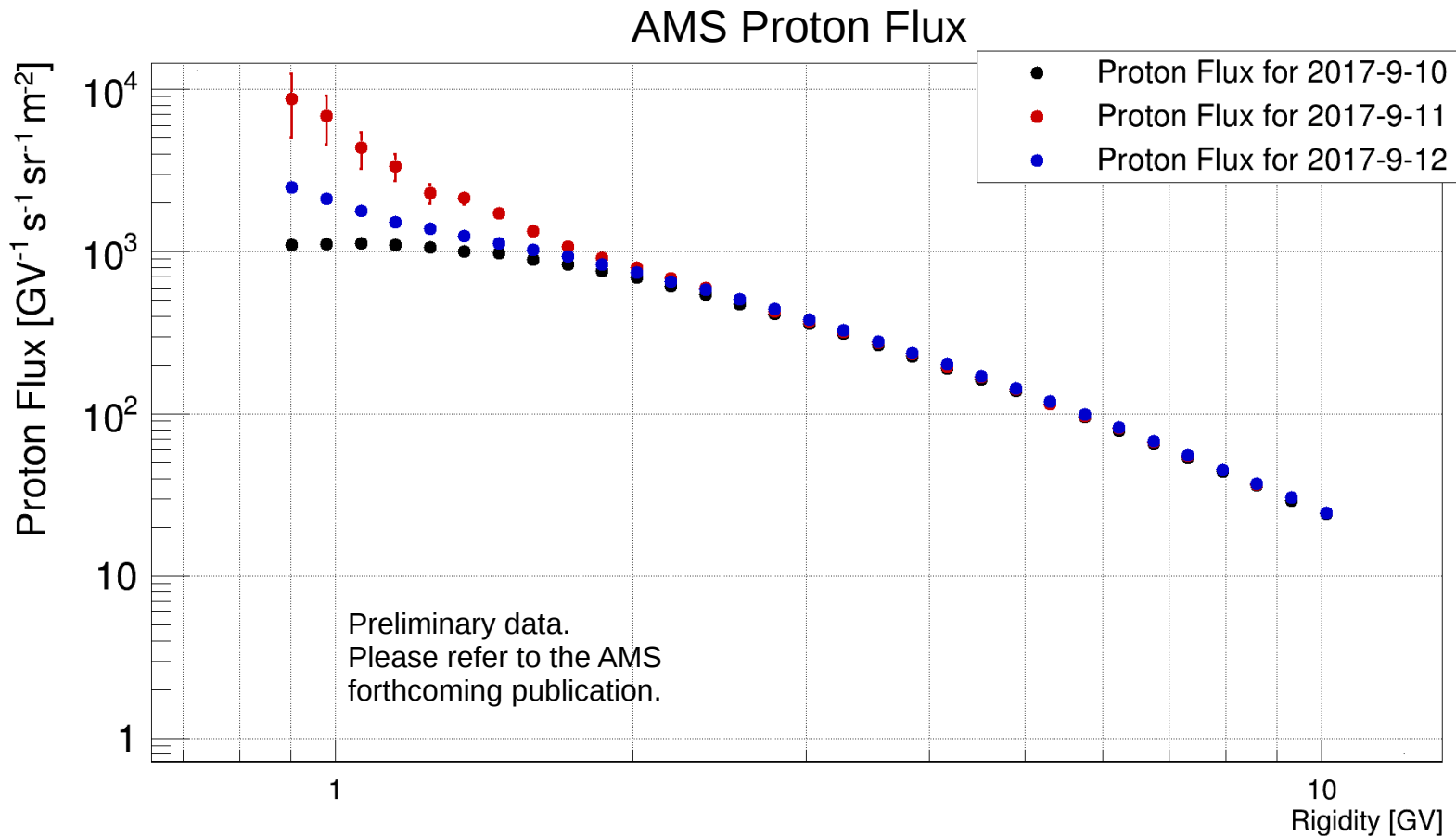
September 10, 2017 AMS GCR Proton Flux



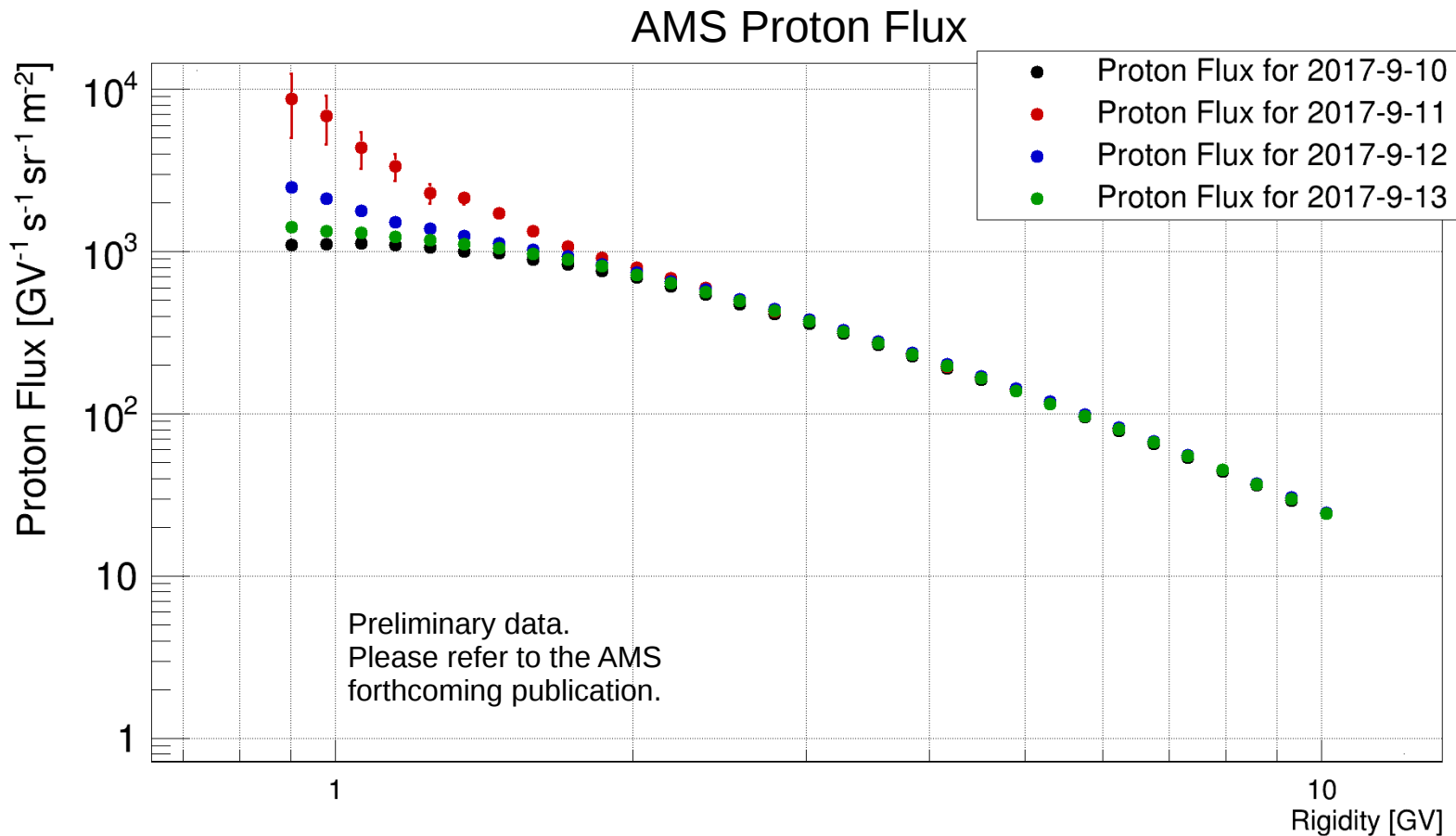
September 2017 Solar Energetic Particle Event



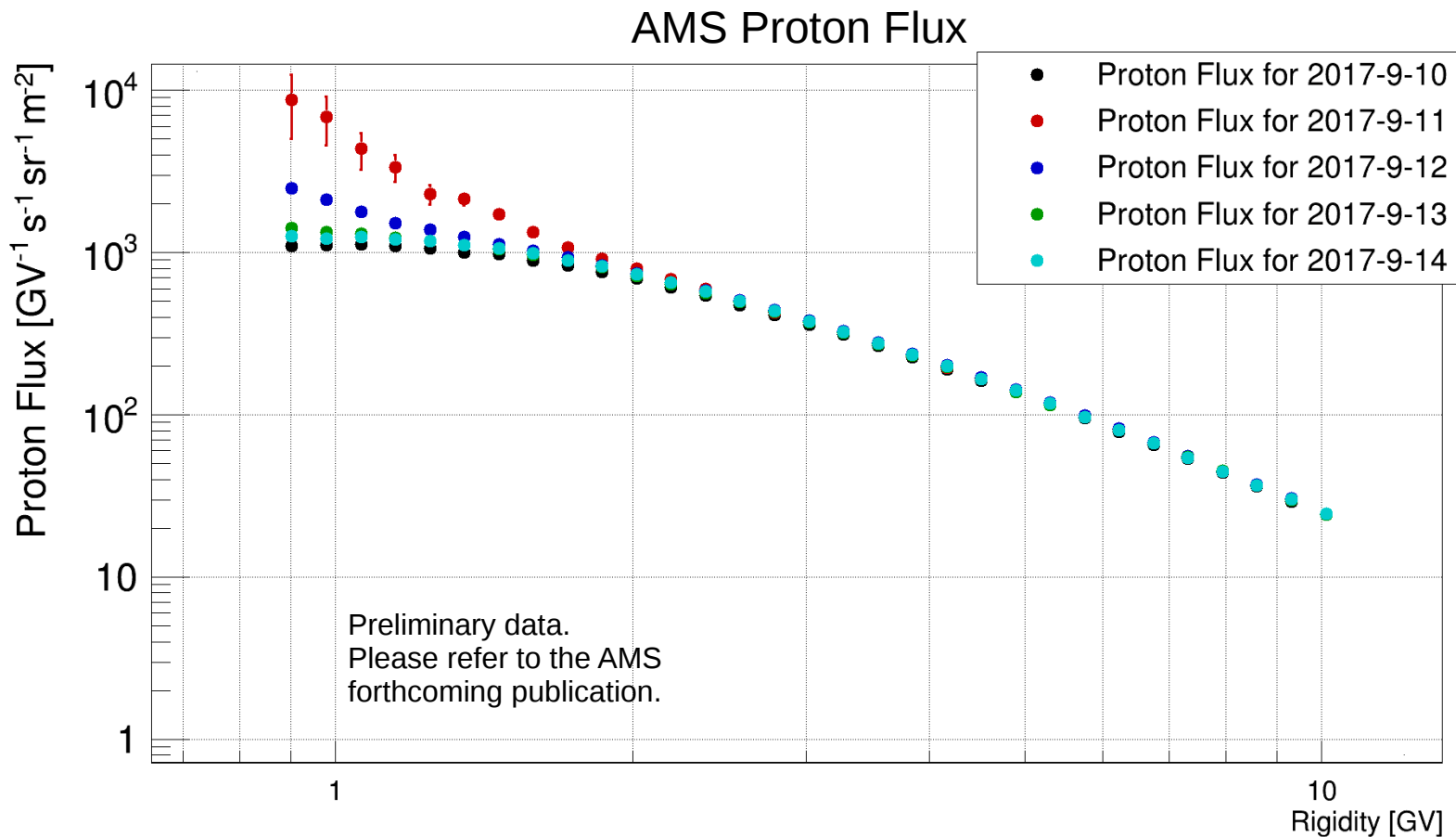
September 2017 Solar Energetic Particle Event



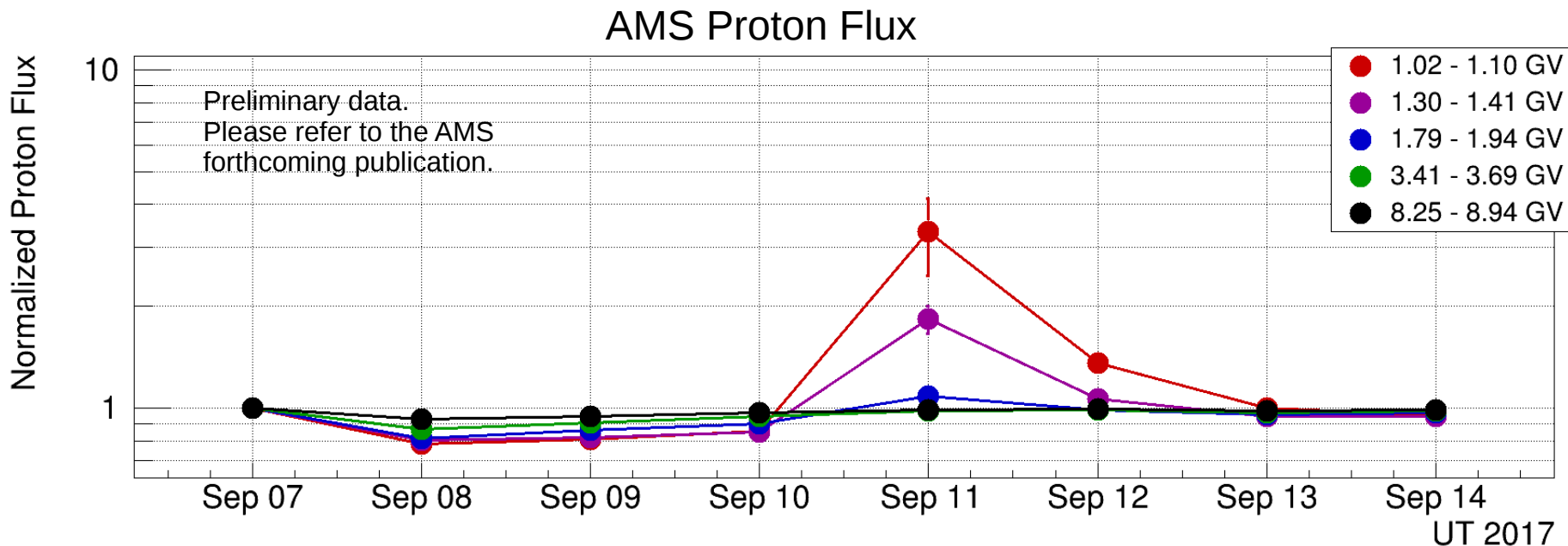
September 2017 Solar Energetic Particle Event



September 2017 Solar Energetic Particle Event



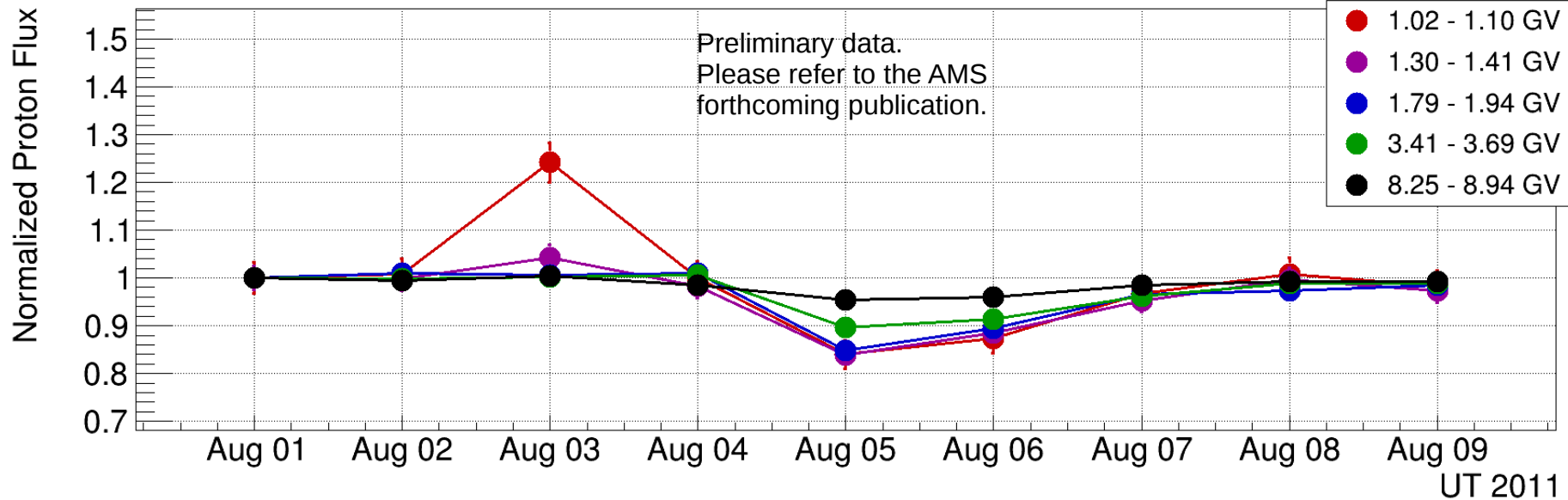
September 2017



AMS proton flux from September 2017, normalized using the flux of the first day in the plot. The eruption in the solar corona on September 10th caused the SEP event visible here starting on the 11th.

August 2011

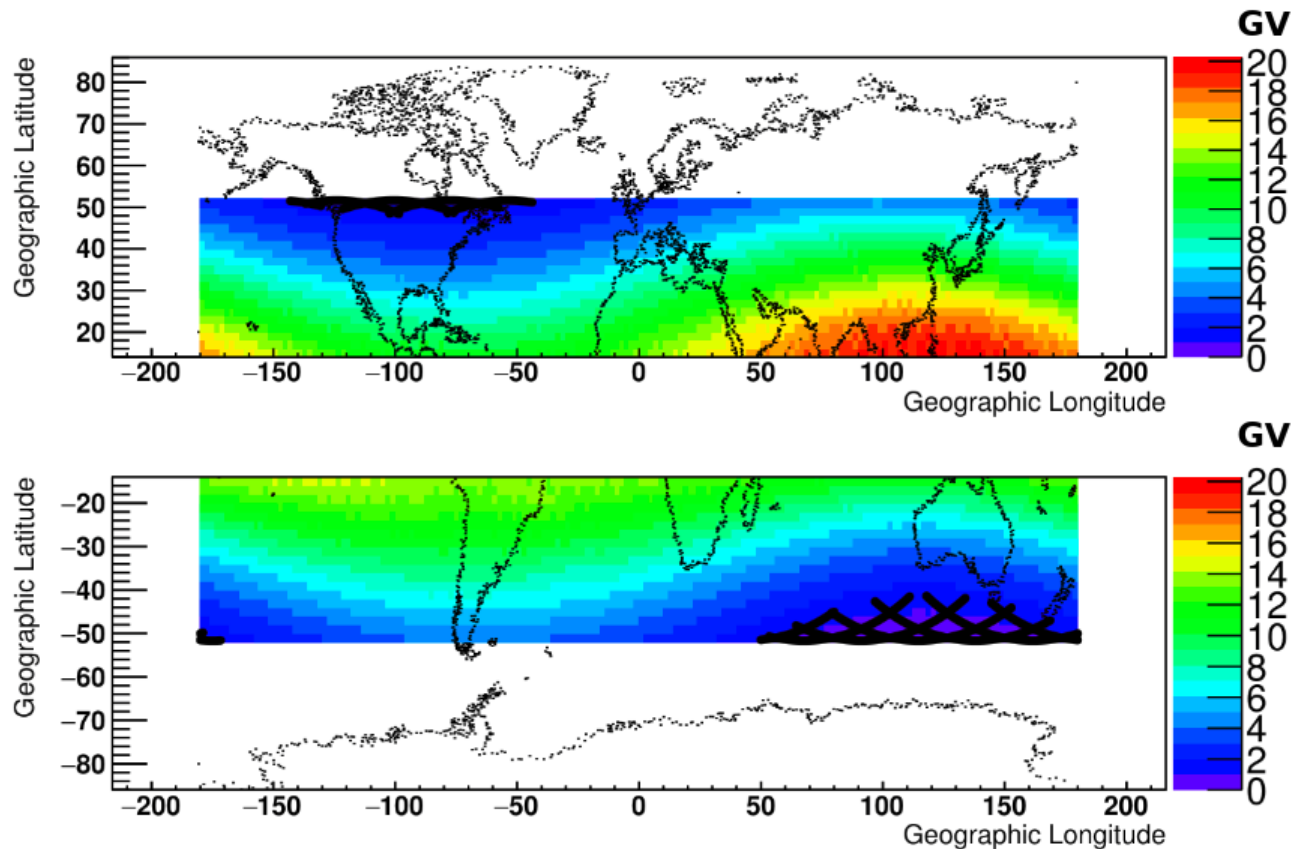
AMS Proton Flux



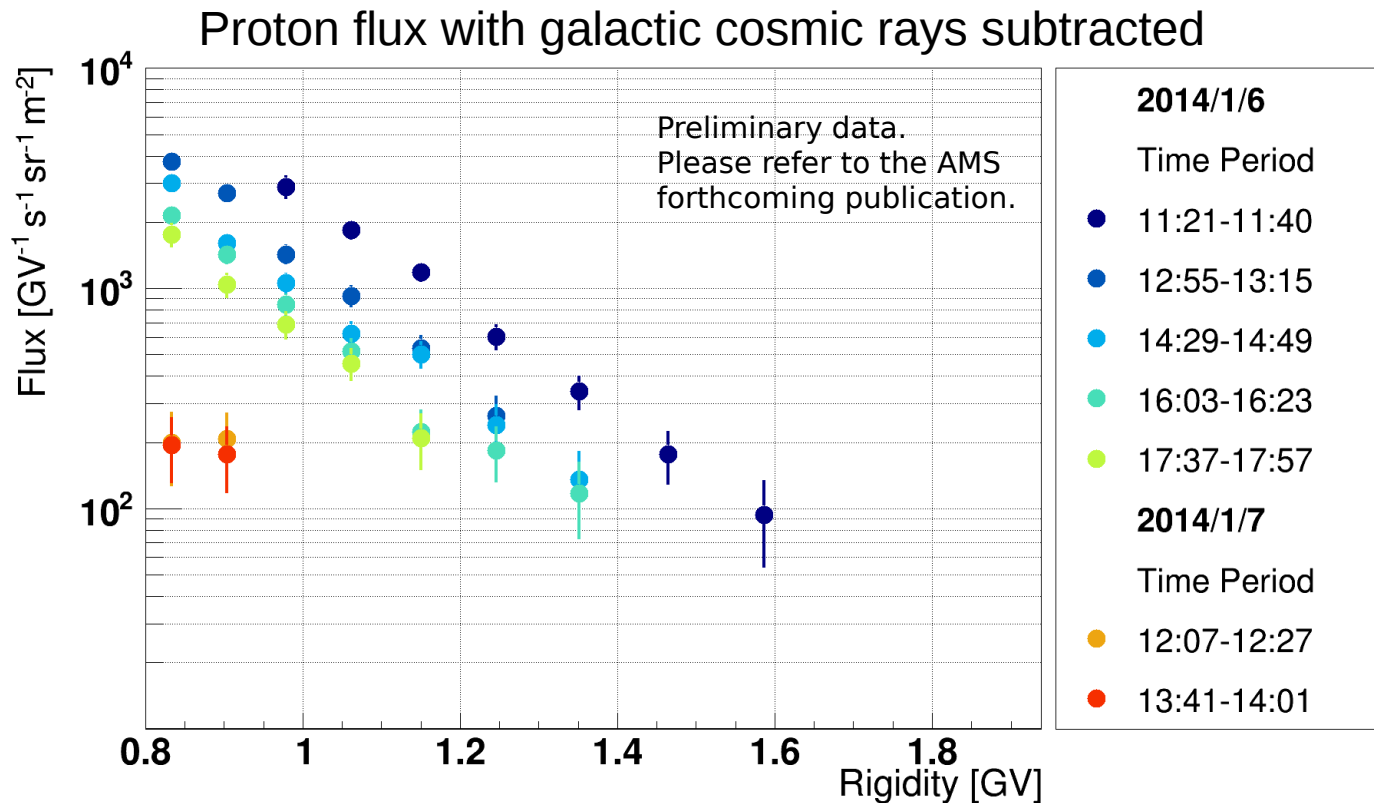
AMS proton flux from August 2011, normalized using the first day in the plot. This SEP event is accompanied by a Forbush decrease. The occurrence of a Forbush decrease around the same time as an SEP event is common.

Exposure to SEPs

AMS is exposed to SEPs only when the geomagnetic cutoff is low (SEPs typically have rigidities below 2 GV), which occurs when the ISS is at high latitudes.



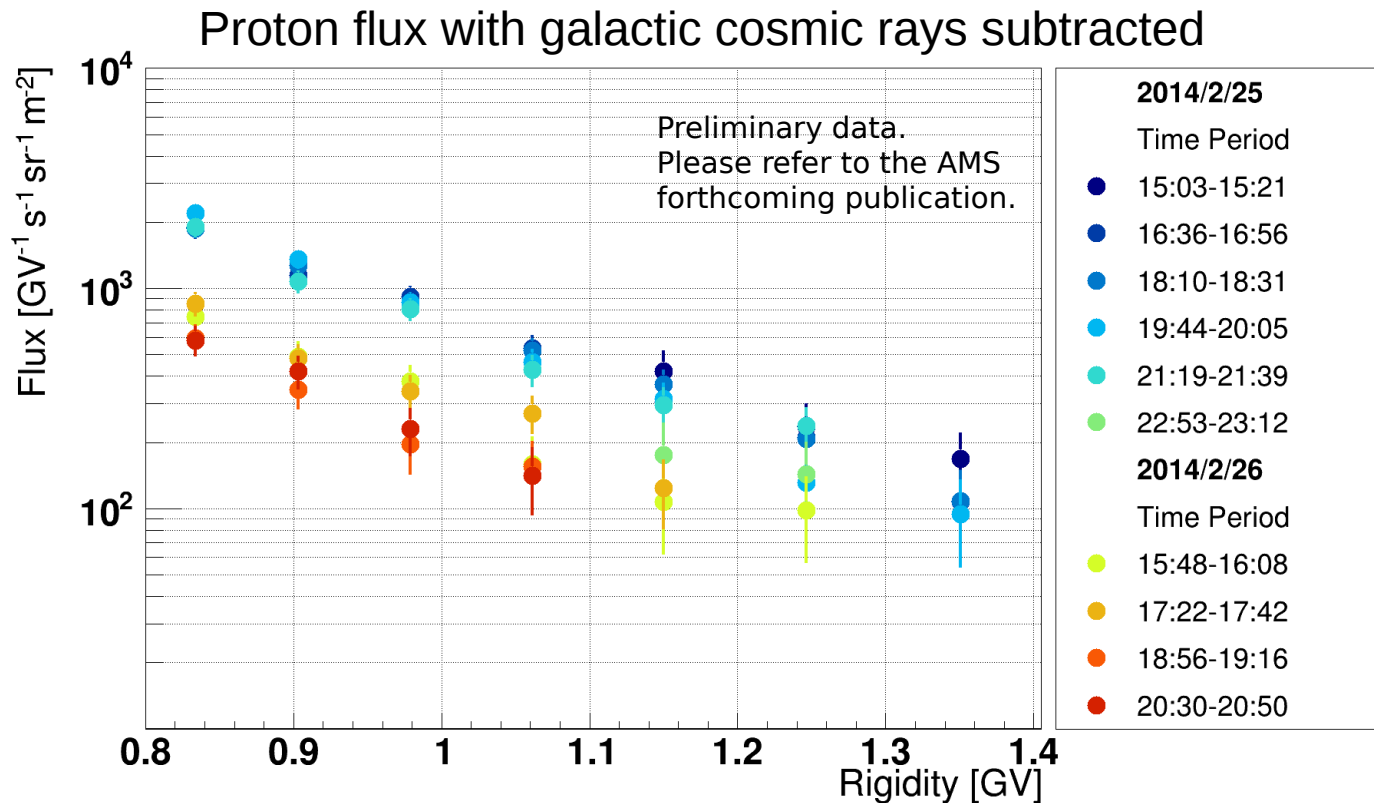
AMS Orbit-by-Orbit SEP proton fluxes



AMS Published GCR Flux:

M. Aguilar *et al.* (AMS Collaboration), Observation of Fine Time Structures in the Cosmic Proton and Helium Fluxes with the Alpha Magnetic Spectrometer on the International Space Station, *Phys. Rev. Lett.* **121**, 051101, 2018.

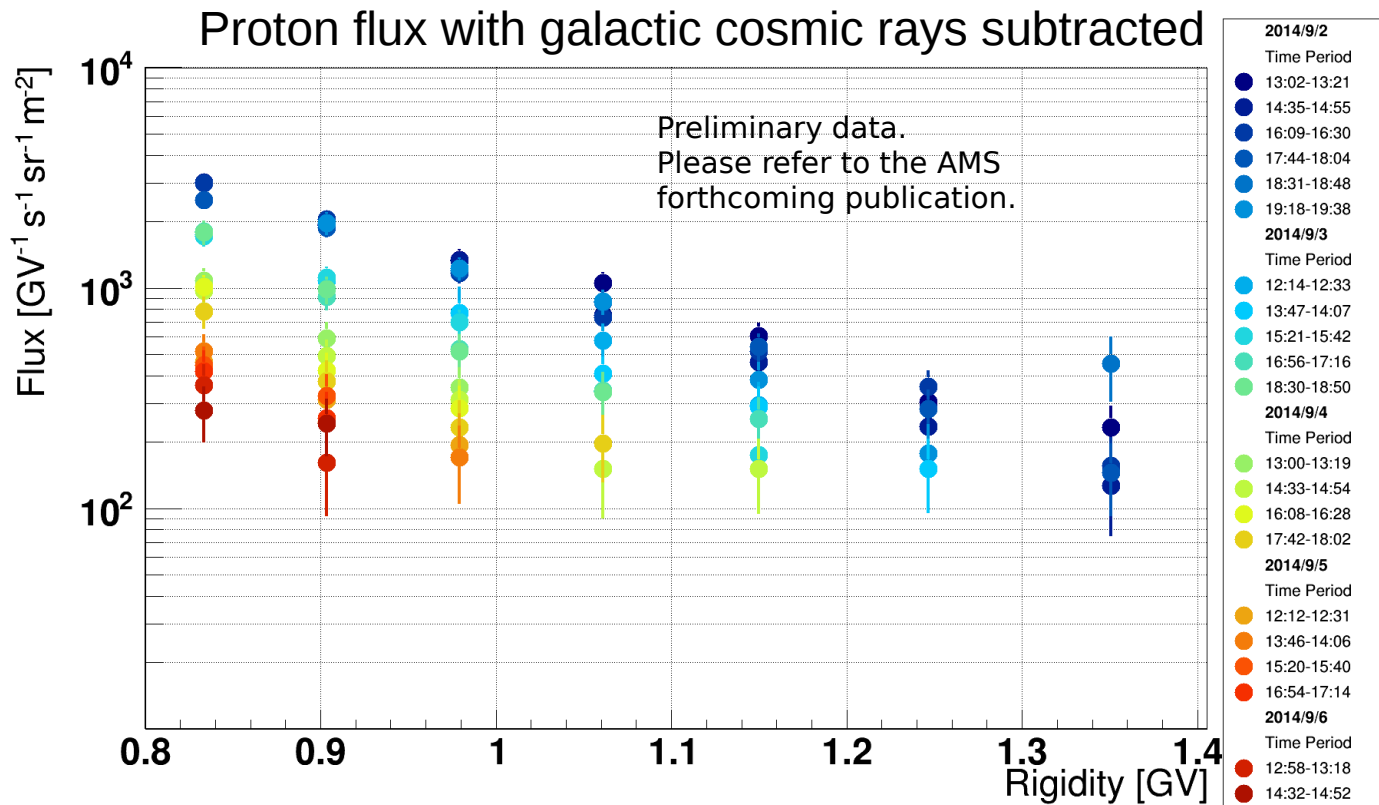
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Summary

- AMS is a uniquely capable instrument for the study of Solar Energetic Particle (SEP) Events.
- AMS can measure high energy SEPs up to the high energy limit of the SEP spectrum.
- From May 2011 through May 2018 AMS measured 28 SEP events.
- AMS is making precise measurements of SEPs on short time scales, enabling the study of the time evolution of SEP events.

Backup

Example of GCR Subtraction Process

