

Solar Modulation, Forbush Decreases and Solar Energetic Particles Measured by AMS on the ISS



Claudio Corti

On behalf of the AMS Collaboration

24th Workshop on Radiation
Monitoring on the
International Space Station
Athens, 3 – 5 September 2019

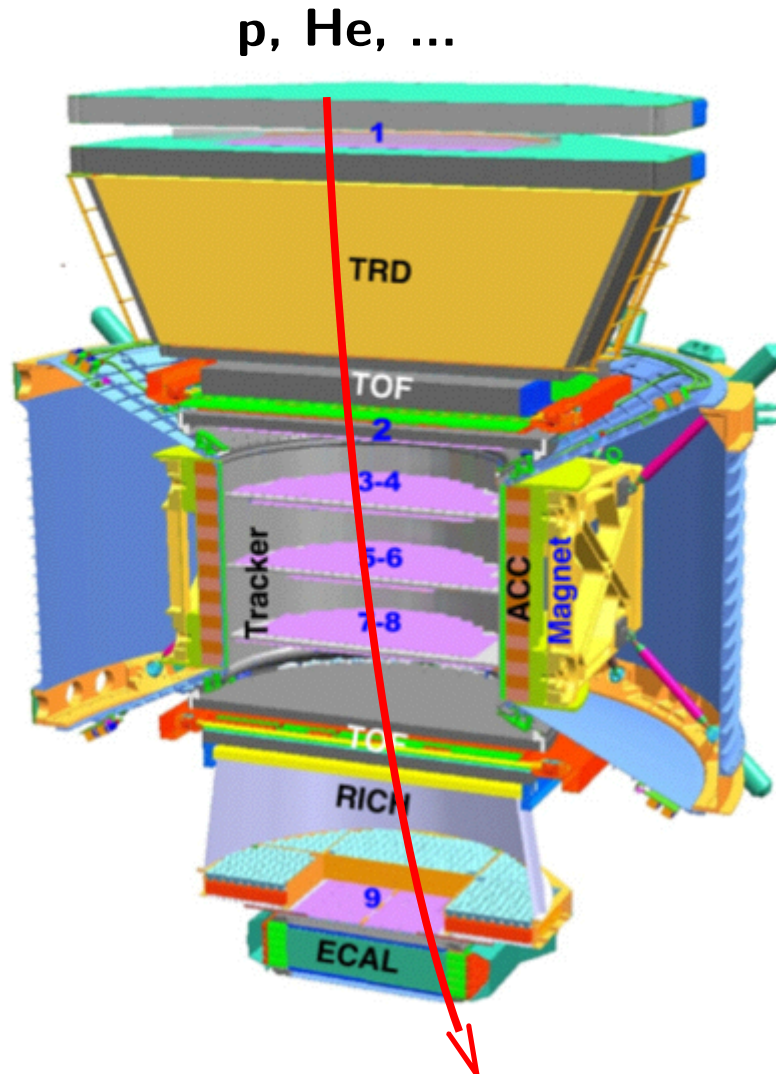
AMS Period of Observation

AMS is a GeV-TeV precision, multipurpose, magnetic spectrometer, on the ISS since May 2011.



Among the physics goals of AMS are measuring GCR fluxes and their time variation, to study solar modulation effect and short-term solar activity in the present and next solar cycle (24th-25th)

AMS Detector and Proton and Helium Identification



Transition Radiation Detector

- e^+ & e^- identification

Time-of-Flight counter

- Trigger
- Velocity
- Particle flight direction
- Charge

Silicon Tracker + Magnet

- Rigidity
- Charge & sign

Ring Imaging Cherenkov detector

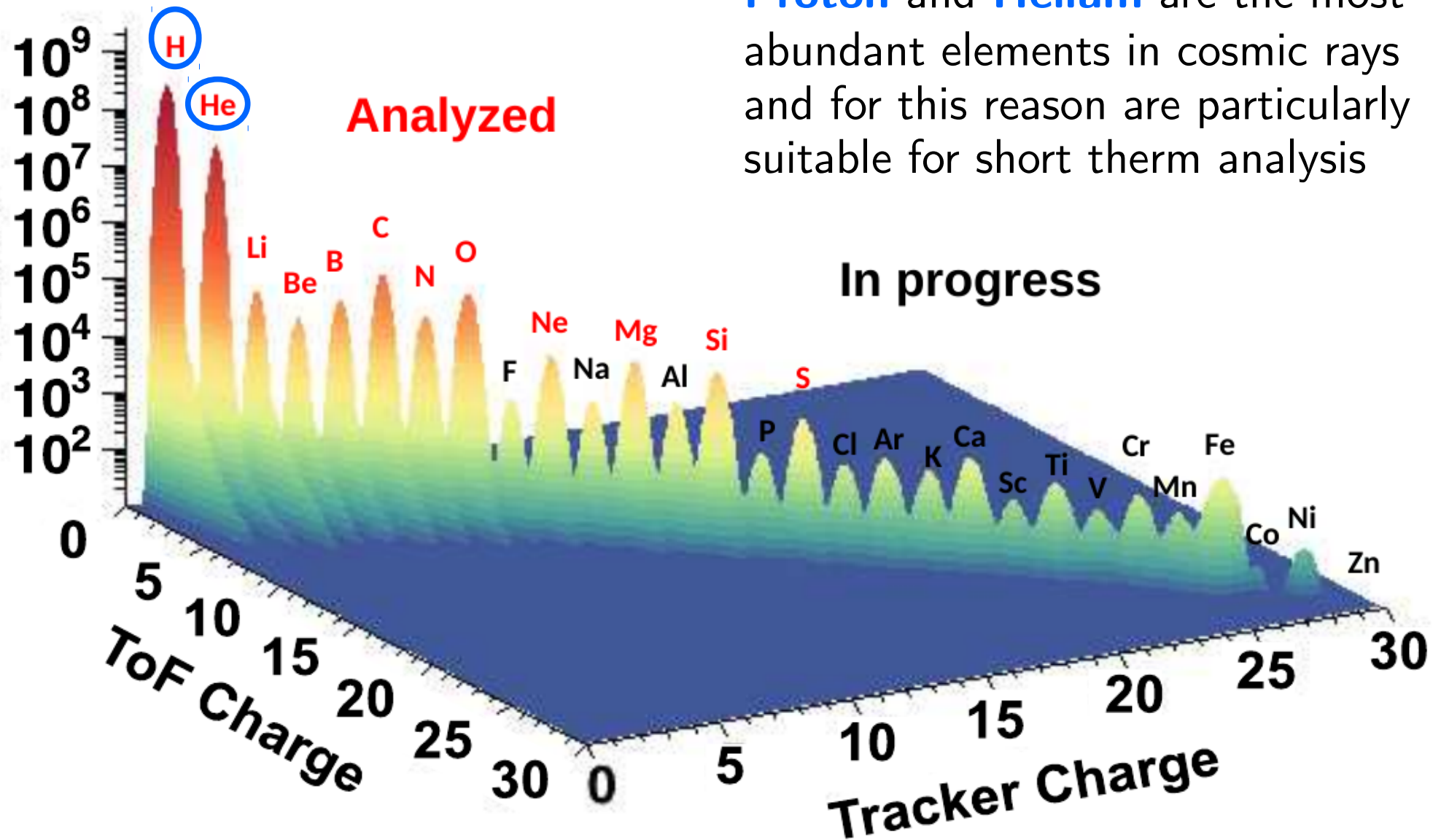
- Velocity
- Charge

Electromagnetic Calorimeter

- e^+ & e^- identification
- e^+ & e^- energy

AMS Proton, Helium & other Nuclei

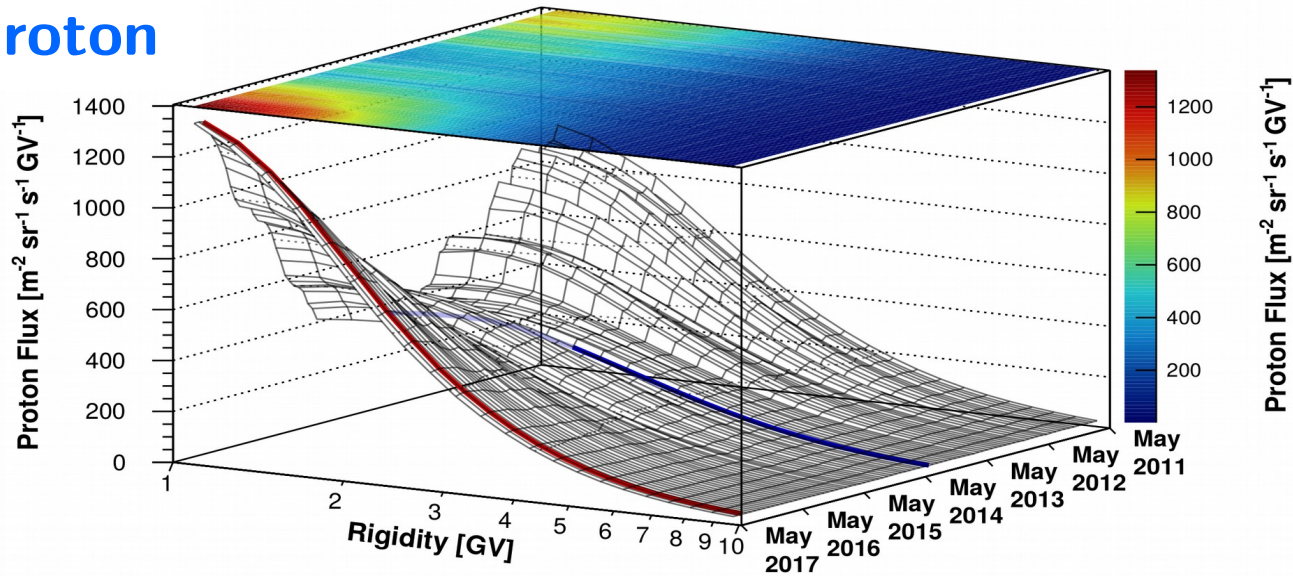
Proton and **Helium** are the most abundant elements in cosmic rays and for this reason are particularly suitable for short term analysis



AMS Proton and Helium Monthly Fluxes

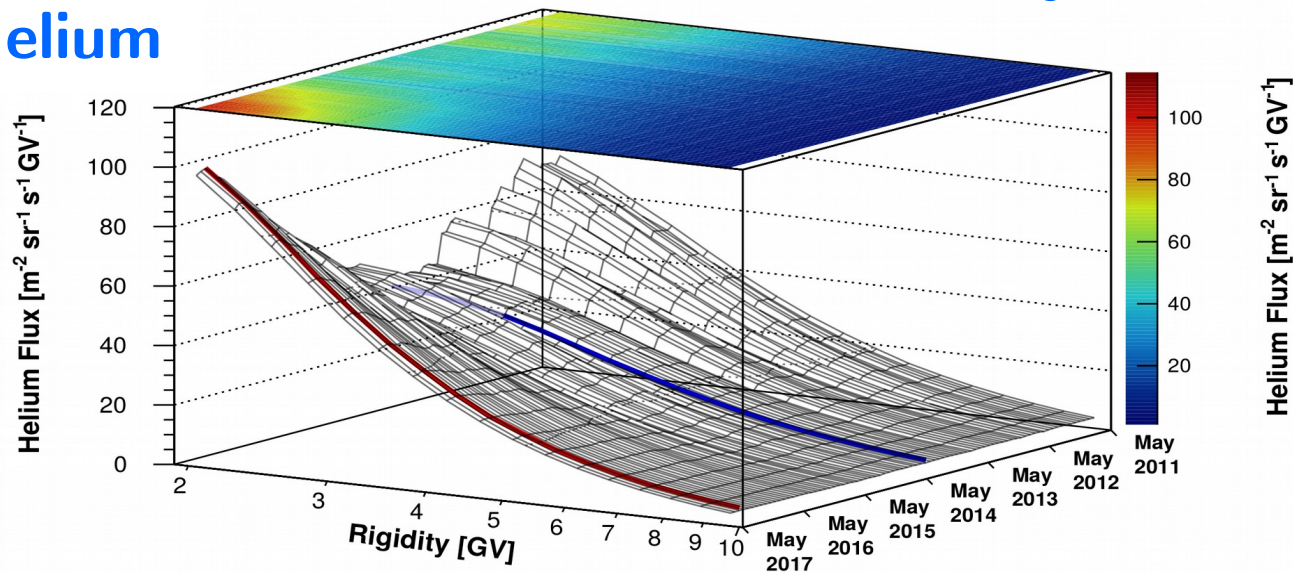
PHYSICAL REVIEW LETTERS **121**, 051101 (2018)

Proton



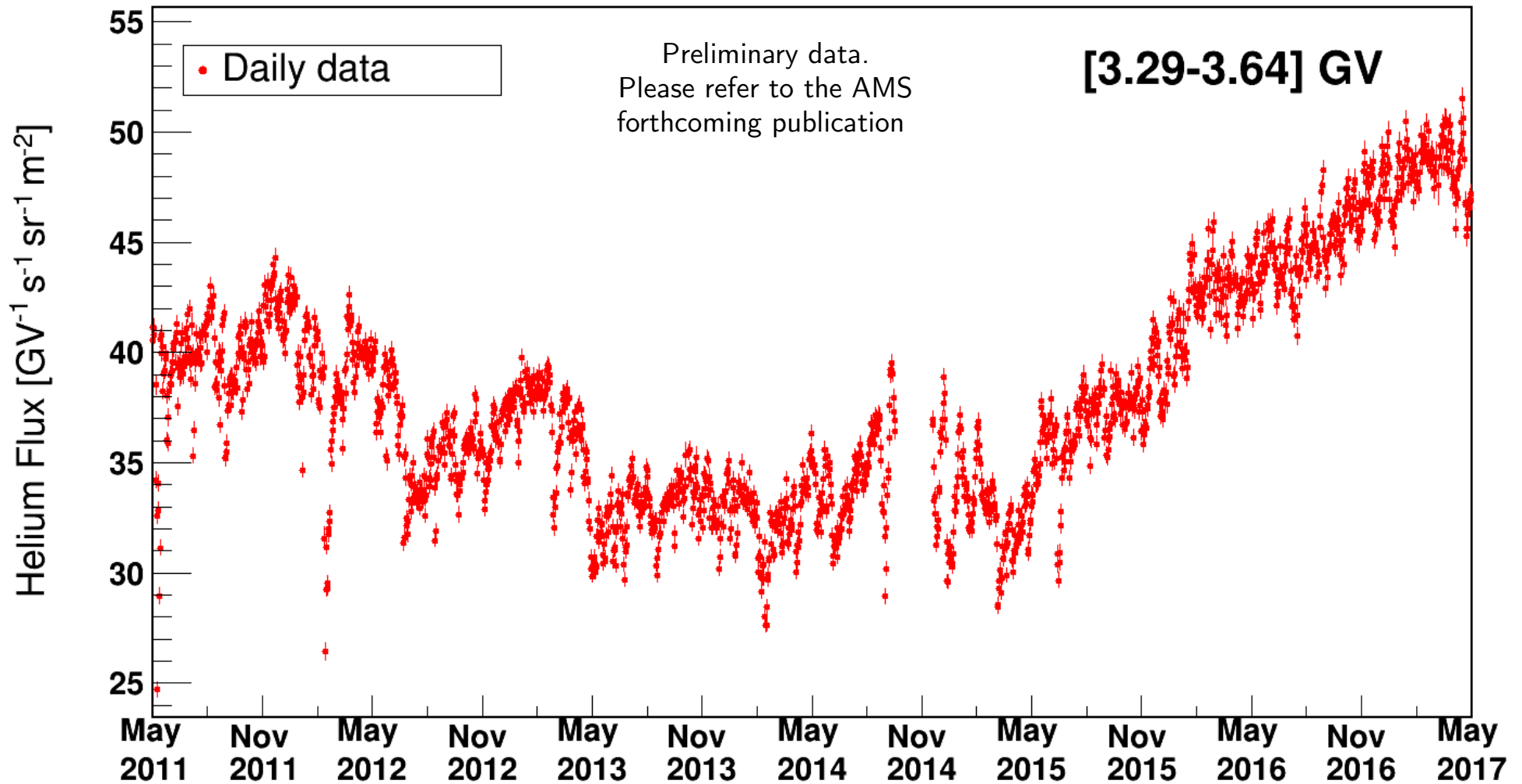
May 2011- May 2017

Helium



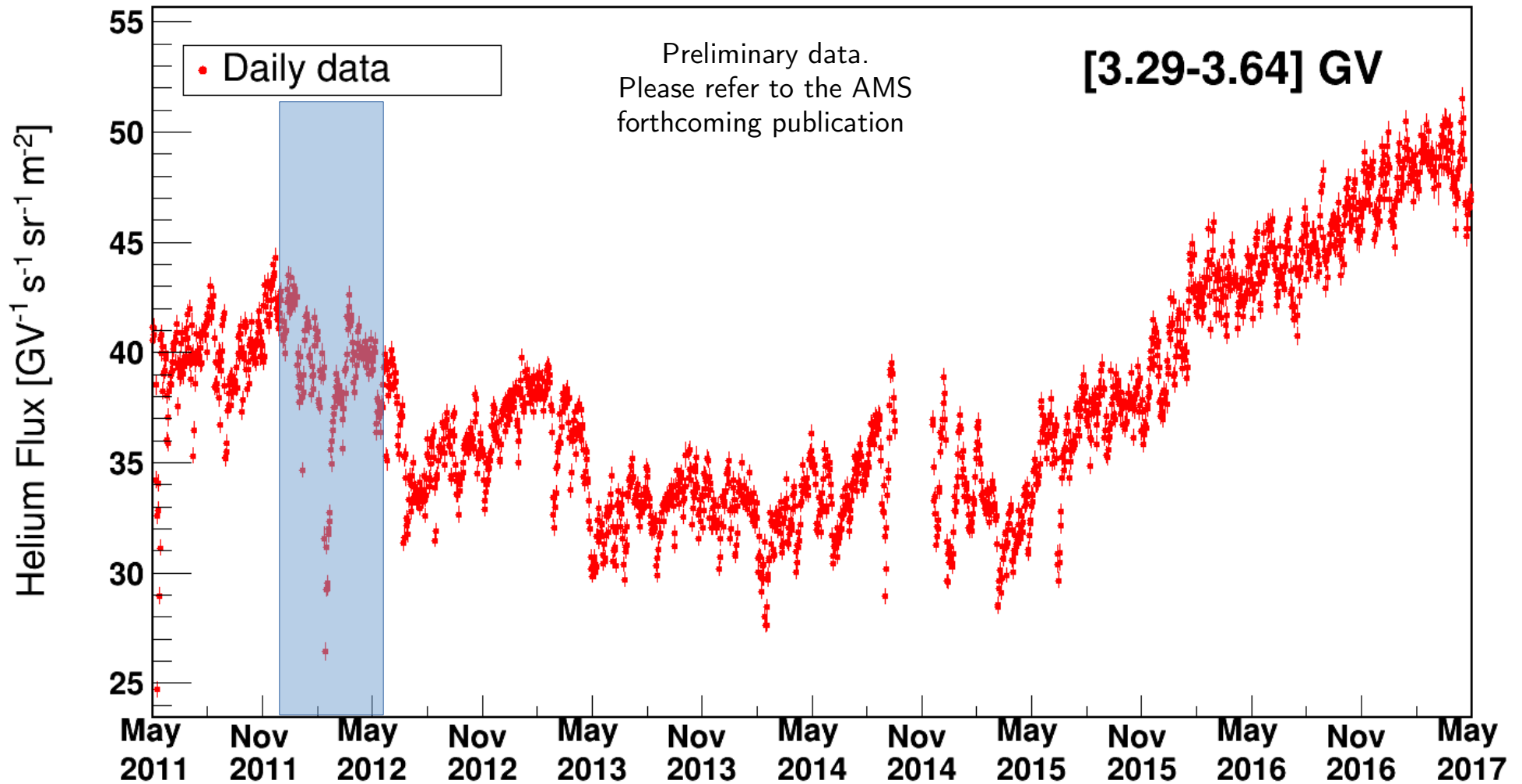
Helium Daily Fluxes

May 2011 – May 2018



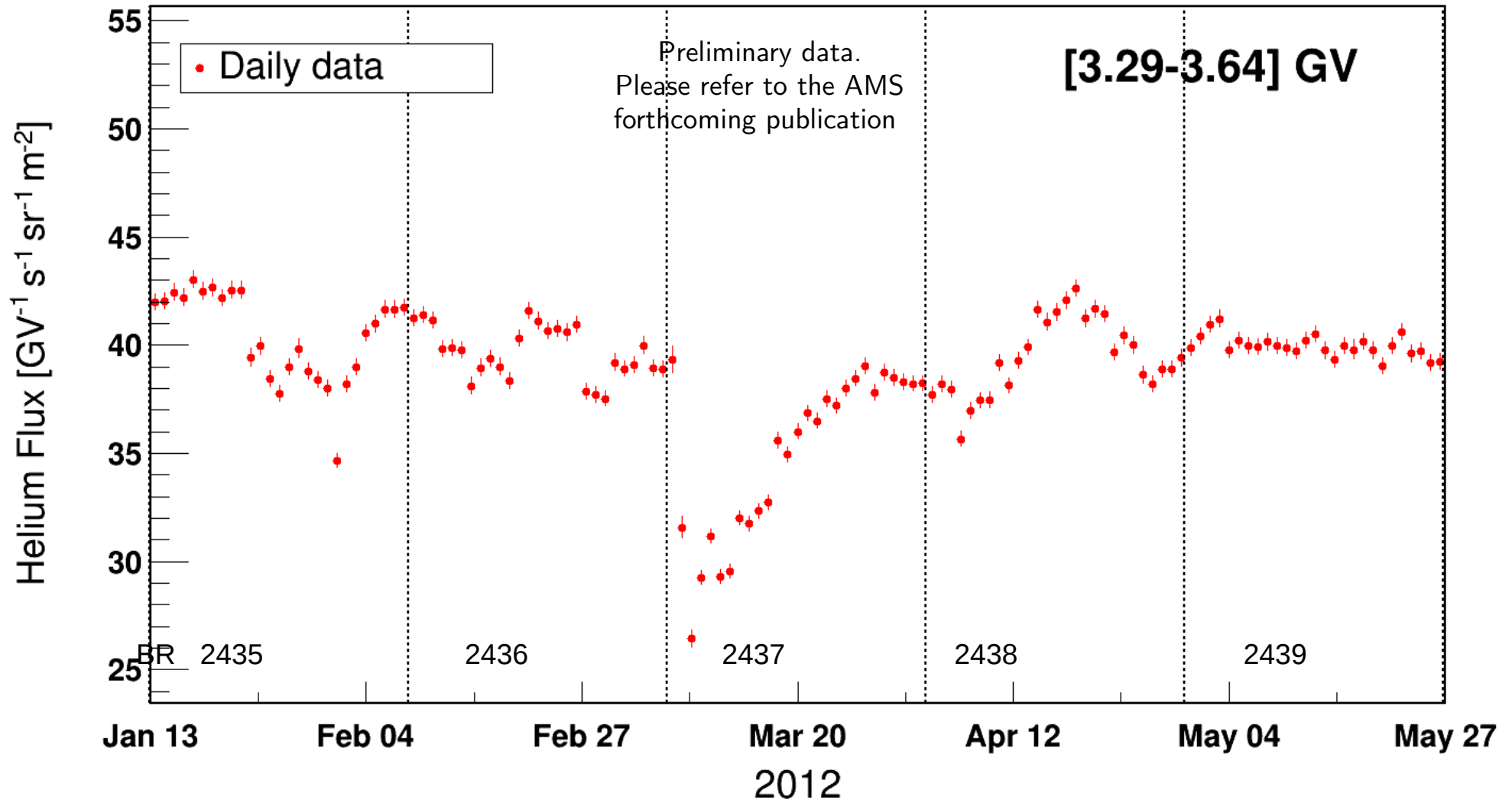
Helium Daily Fluxes

May 2011 – May 2018

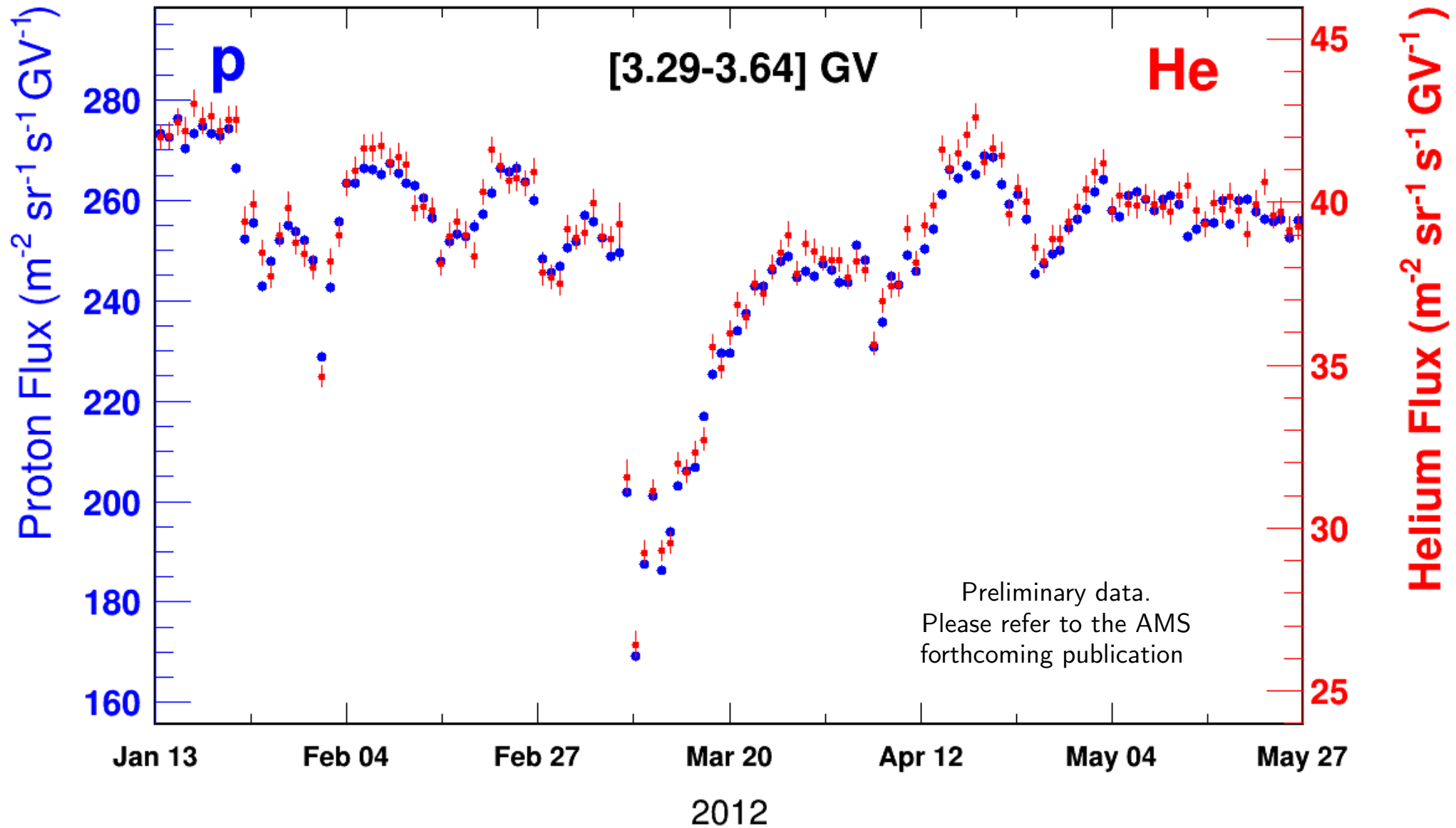


Helium Daily Fluxes

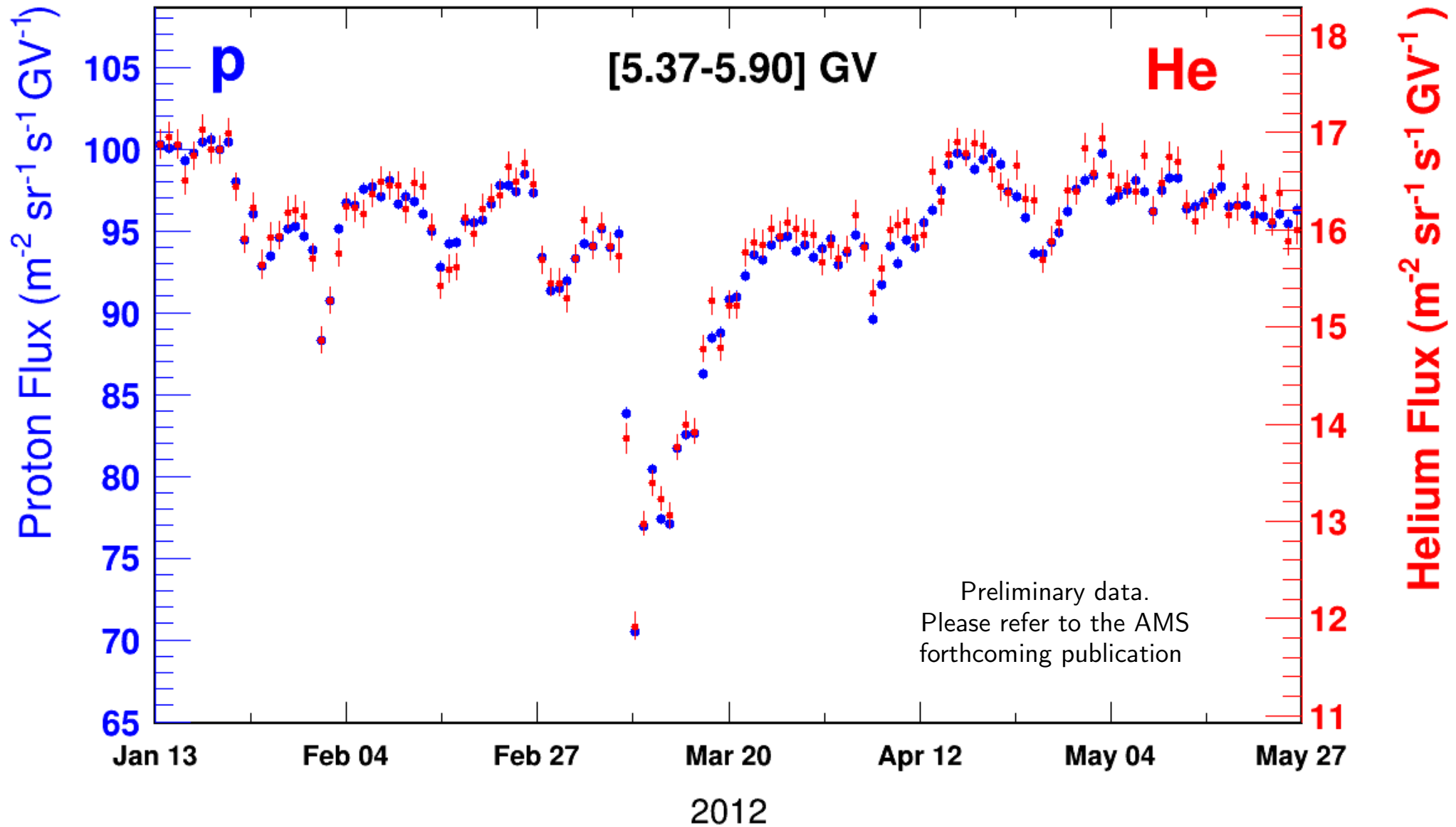
Forbush Decrease



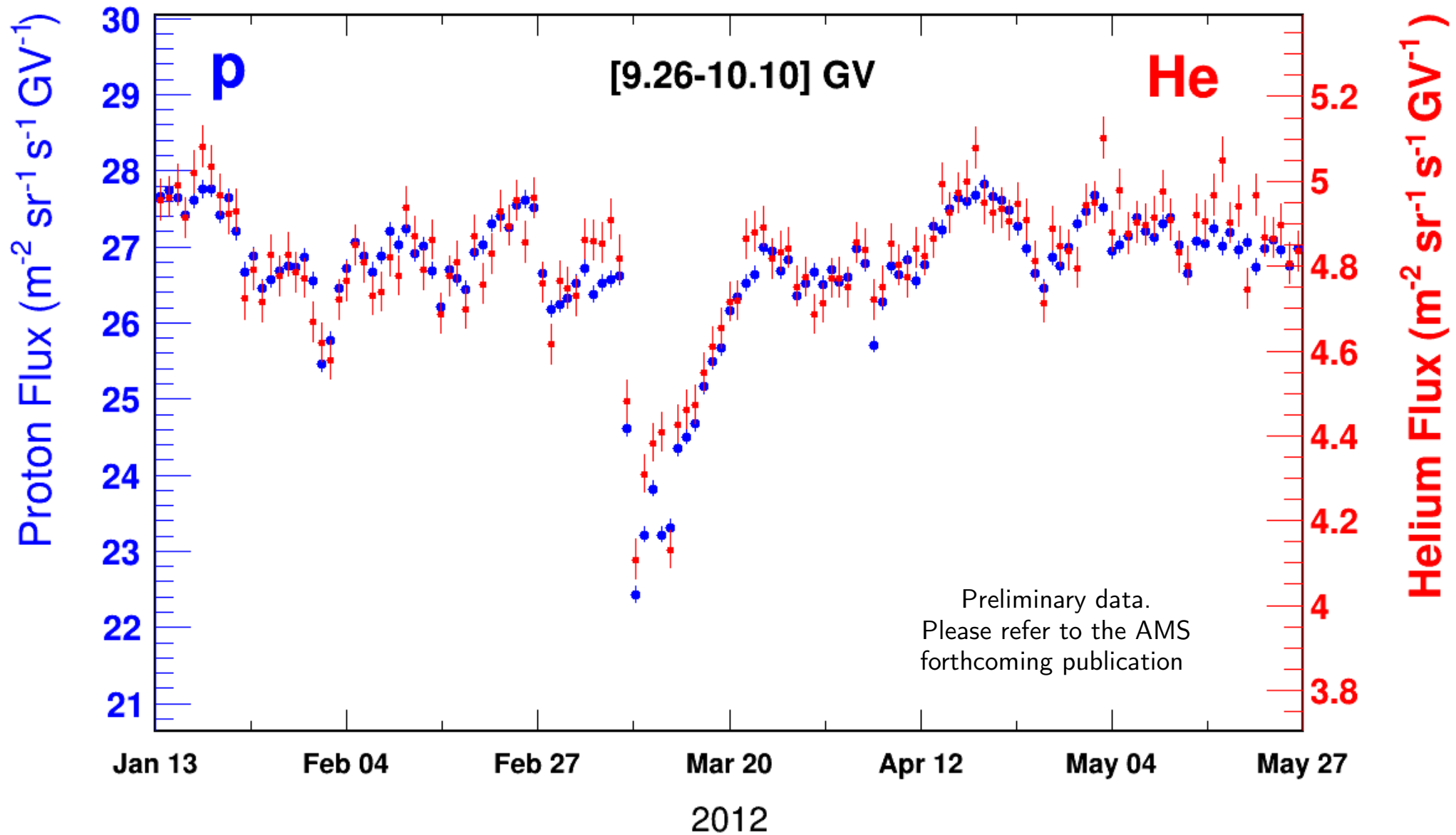
Proton & Helium Daily Fluxes



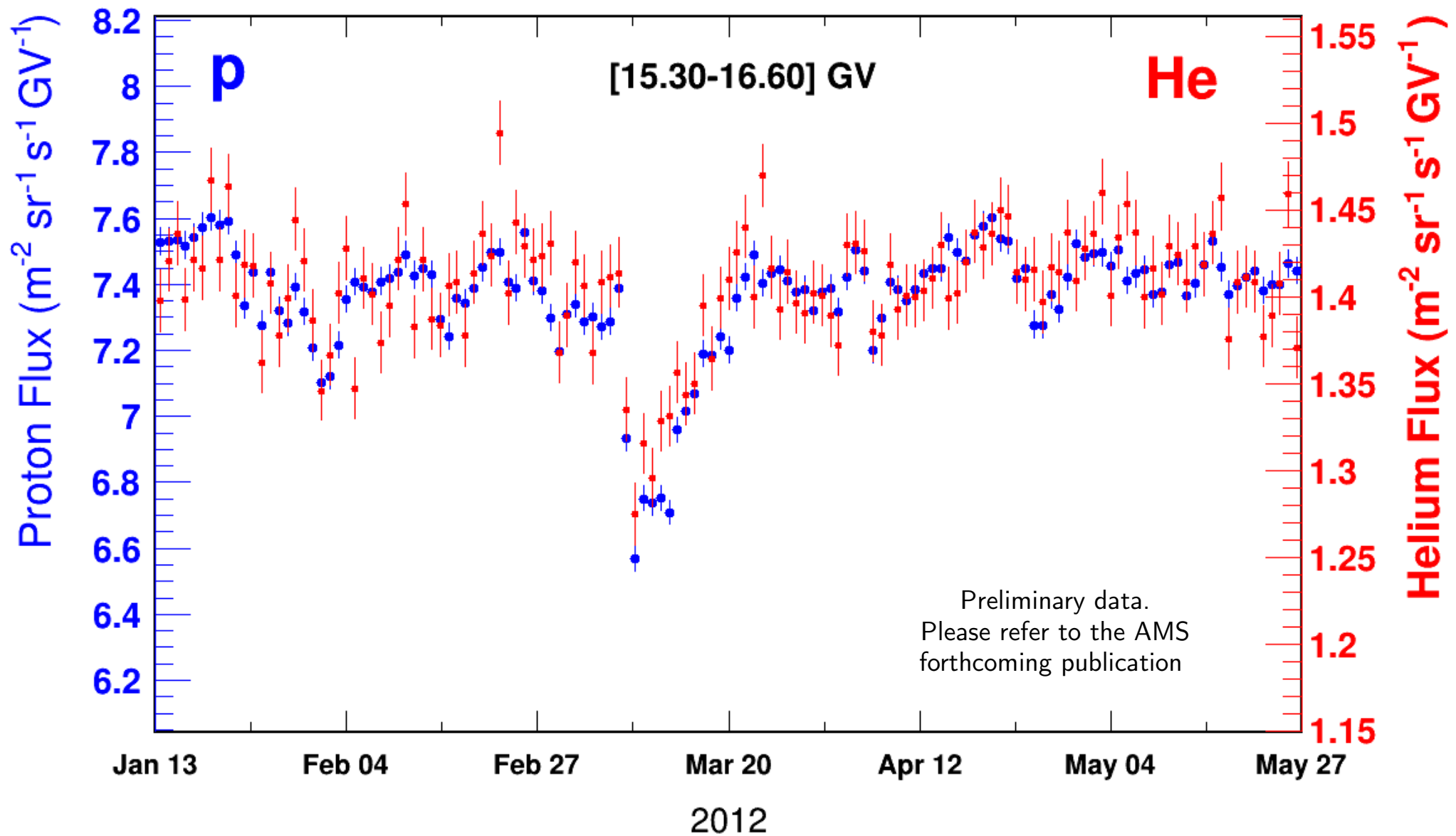
Proton & Helium Daily Fluxes



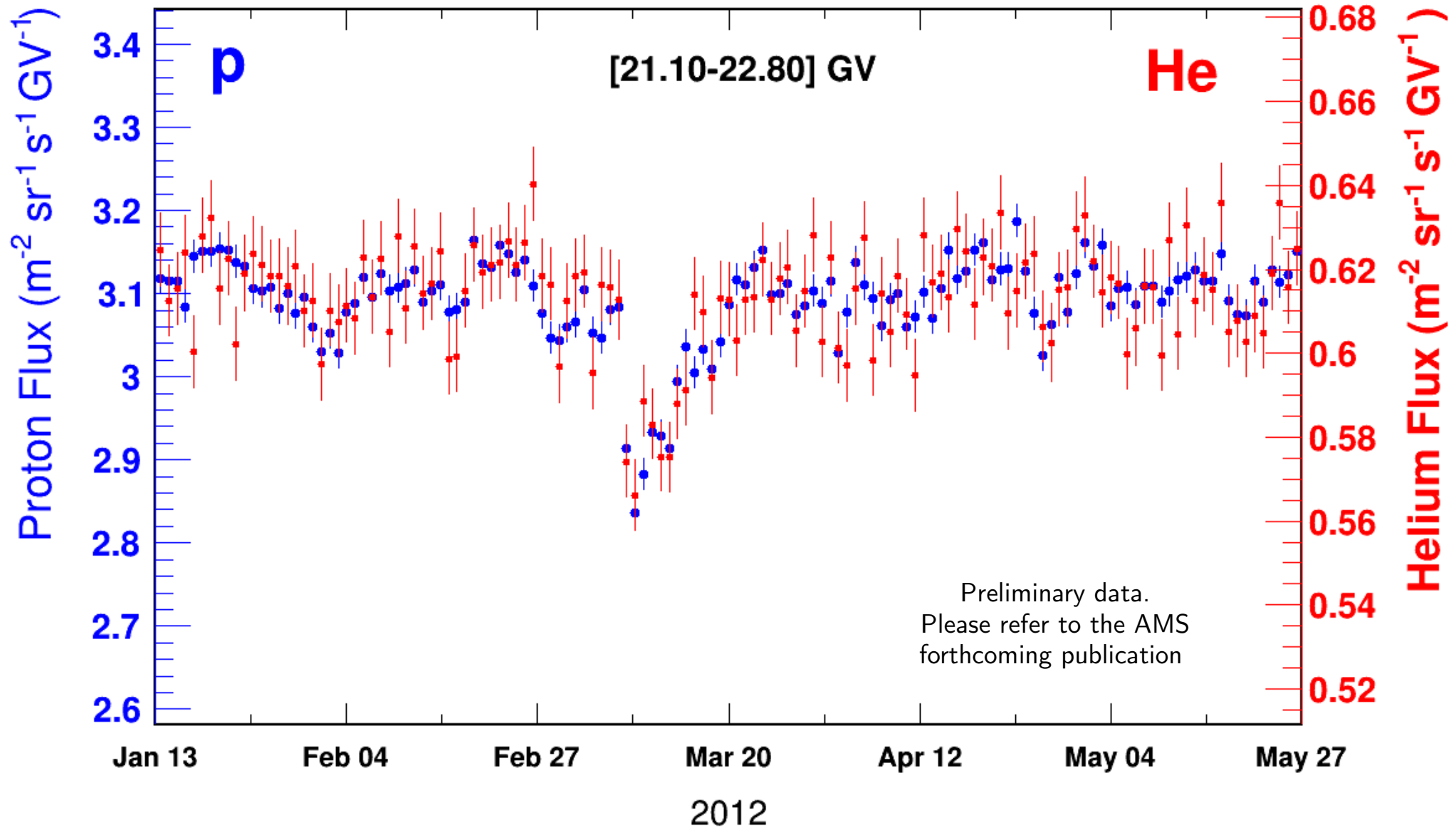
Proton & Helium Daily Fluxes



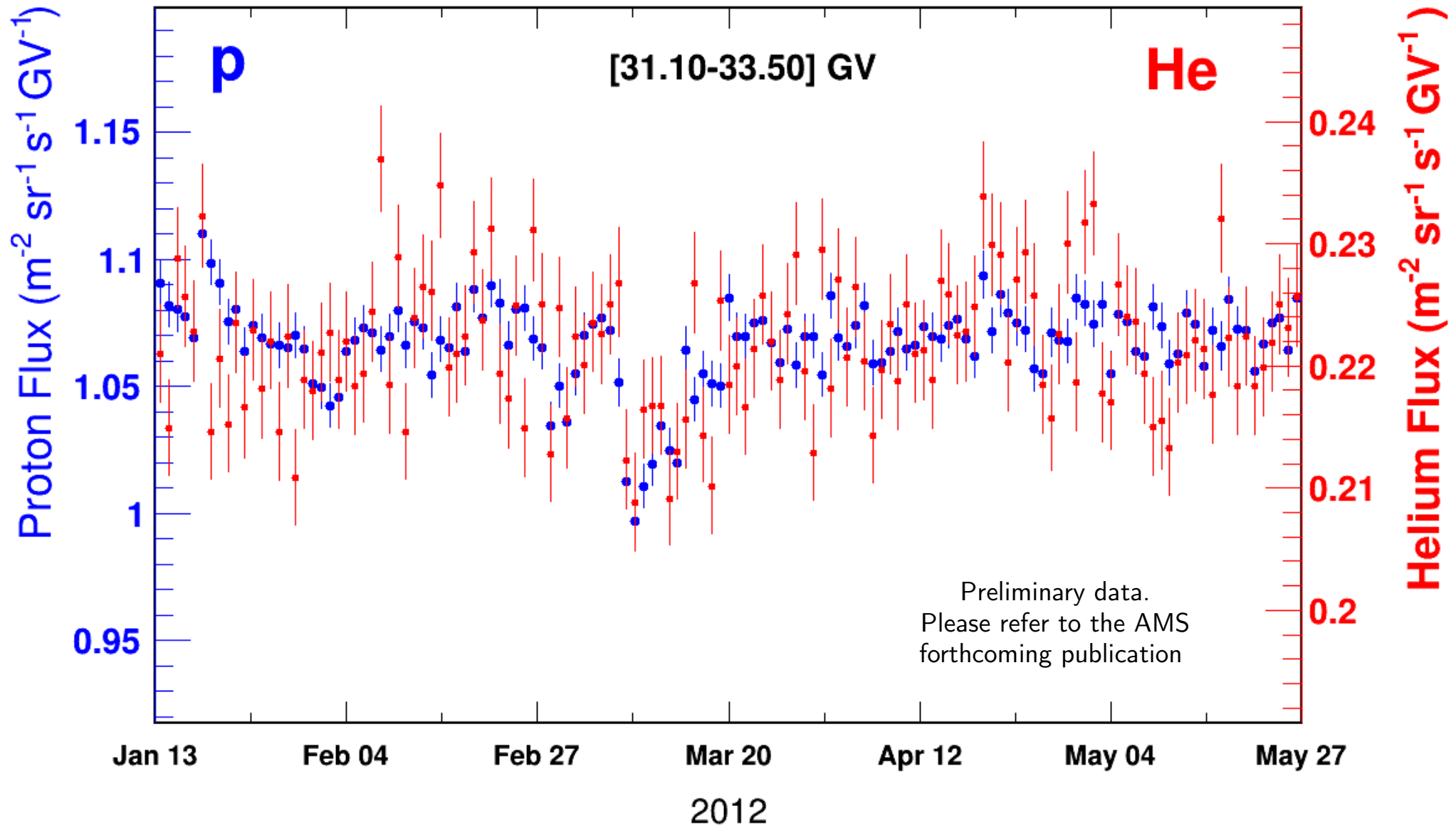
Proton & Helium Daily Fluxes



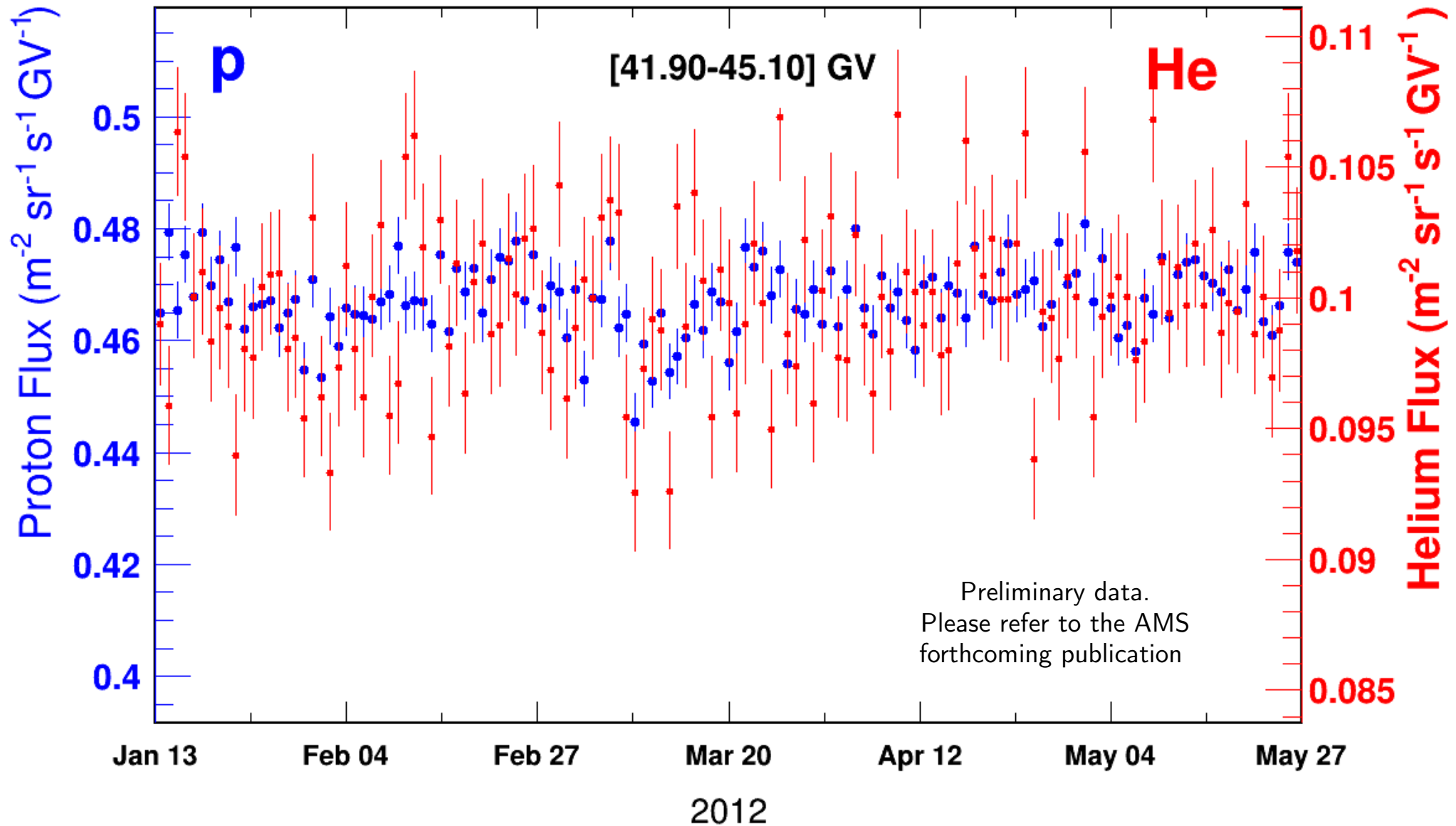
Proton & Helium Daily Fluxes



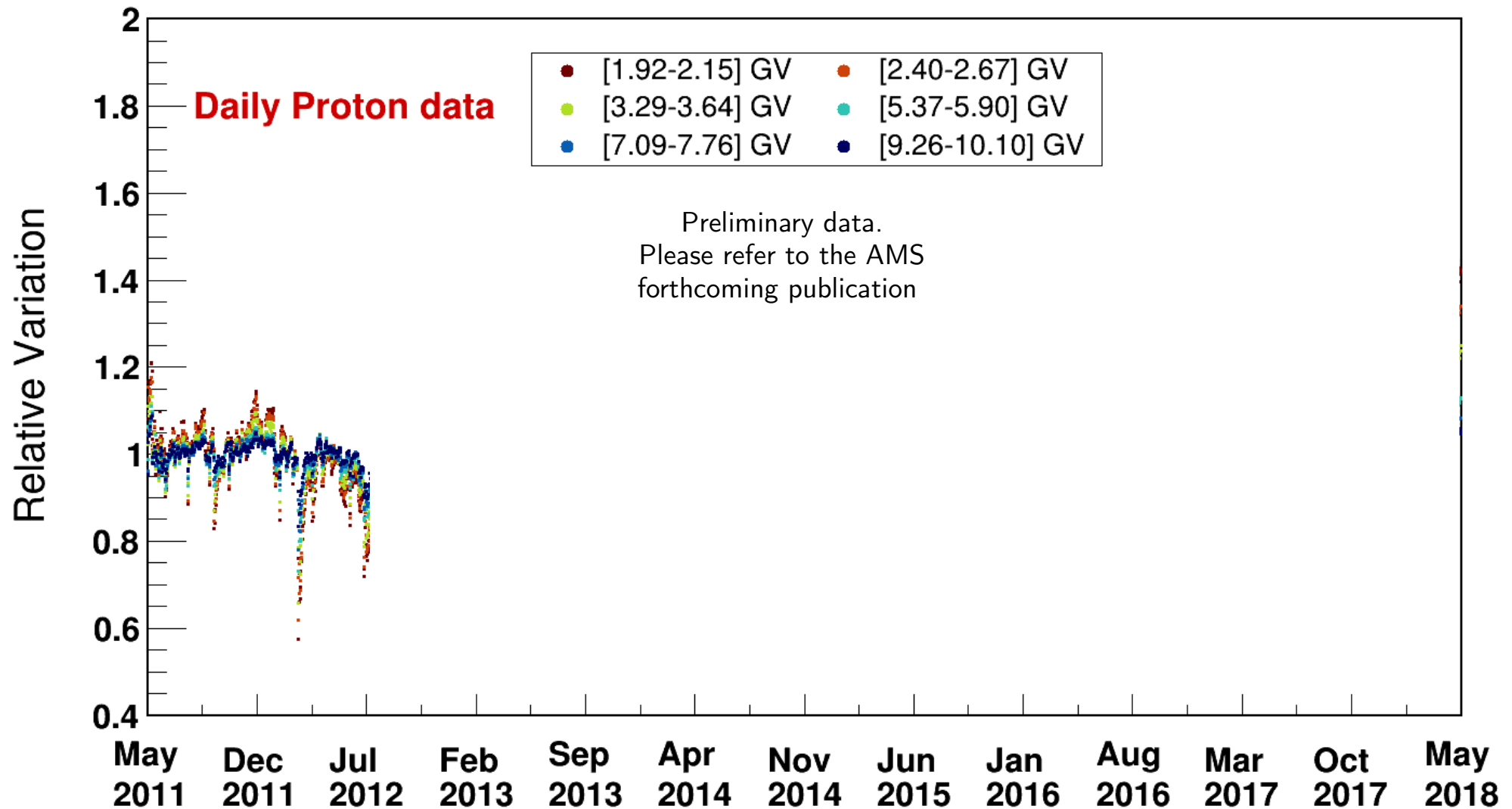
Proton & Helium Daily Fluxes



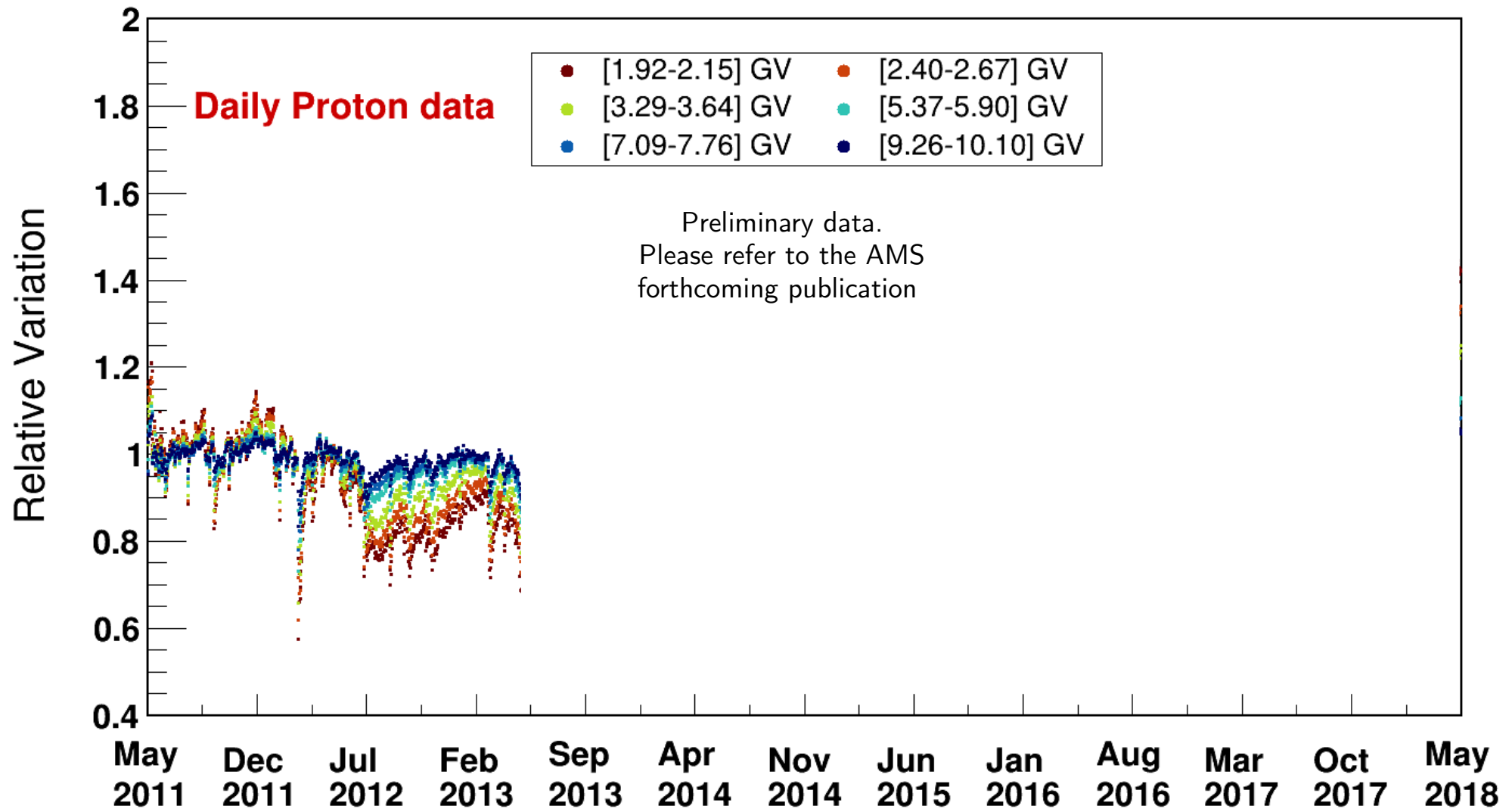
Proton & Helium Daily Fluxes



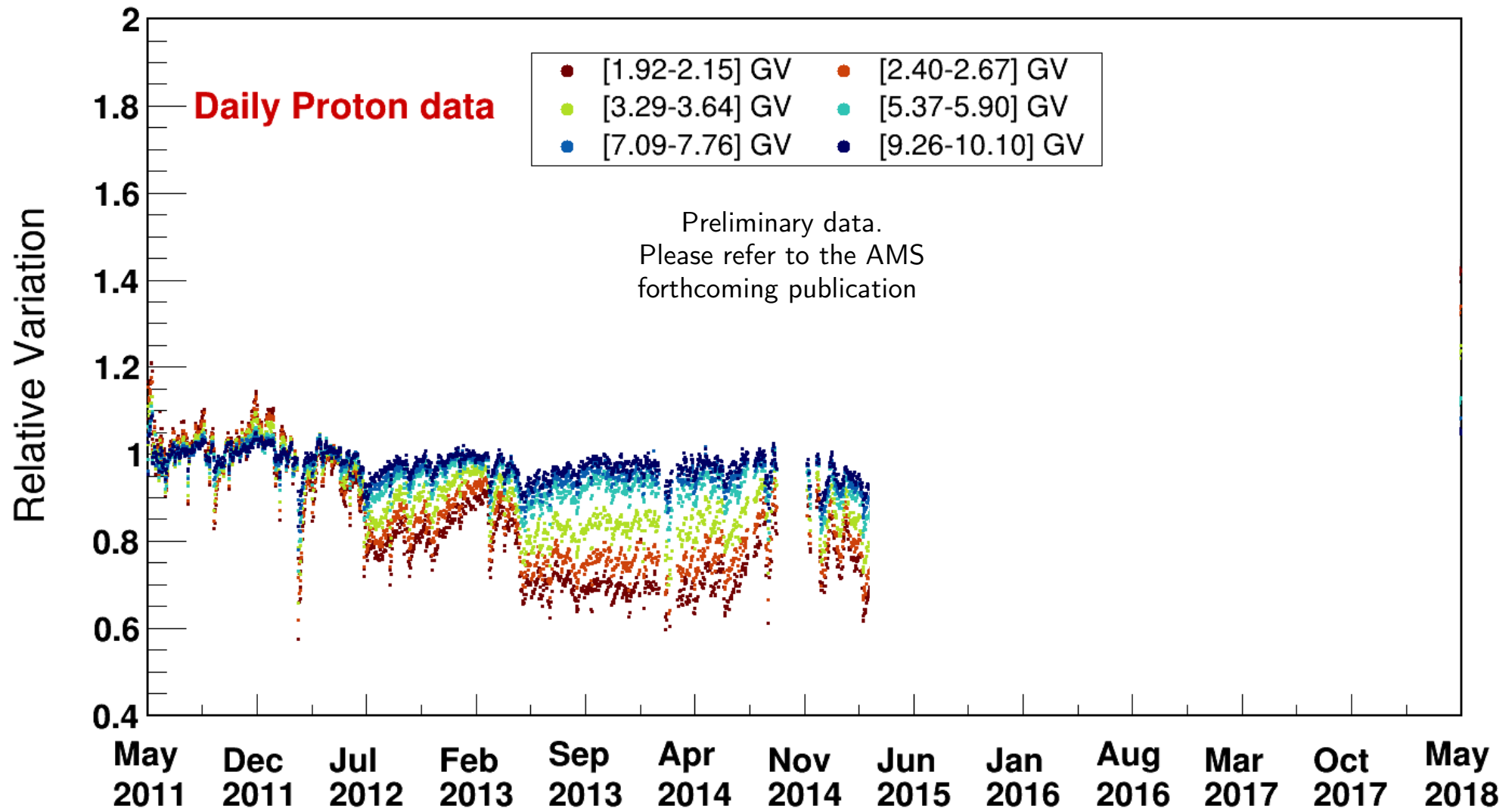
Proton Daily Fluxes Relative Variation May 2011 – May 2018



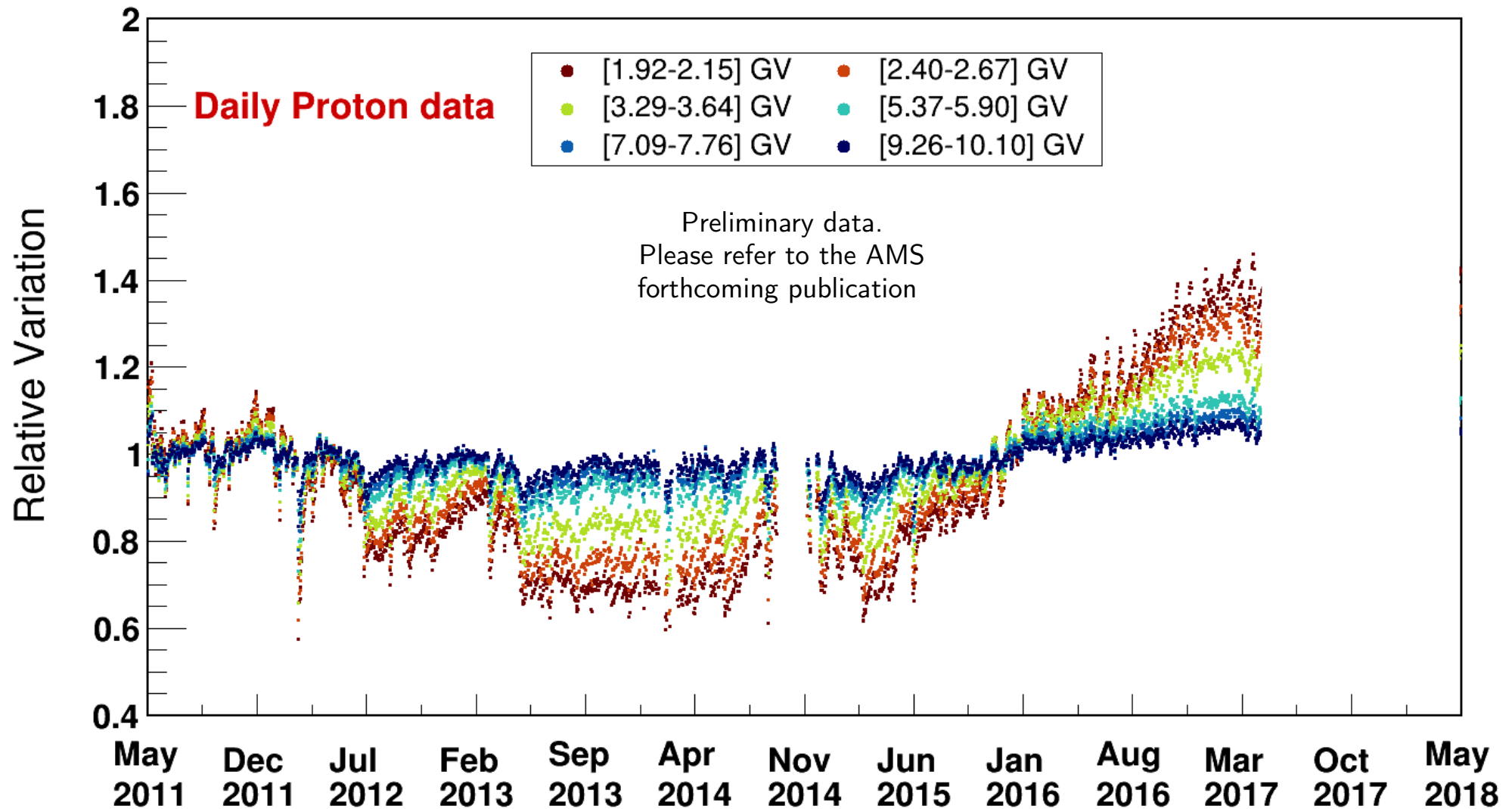
Proton Daily Fluxes Relative Variation May 2011 – May 2018



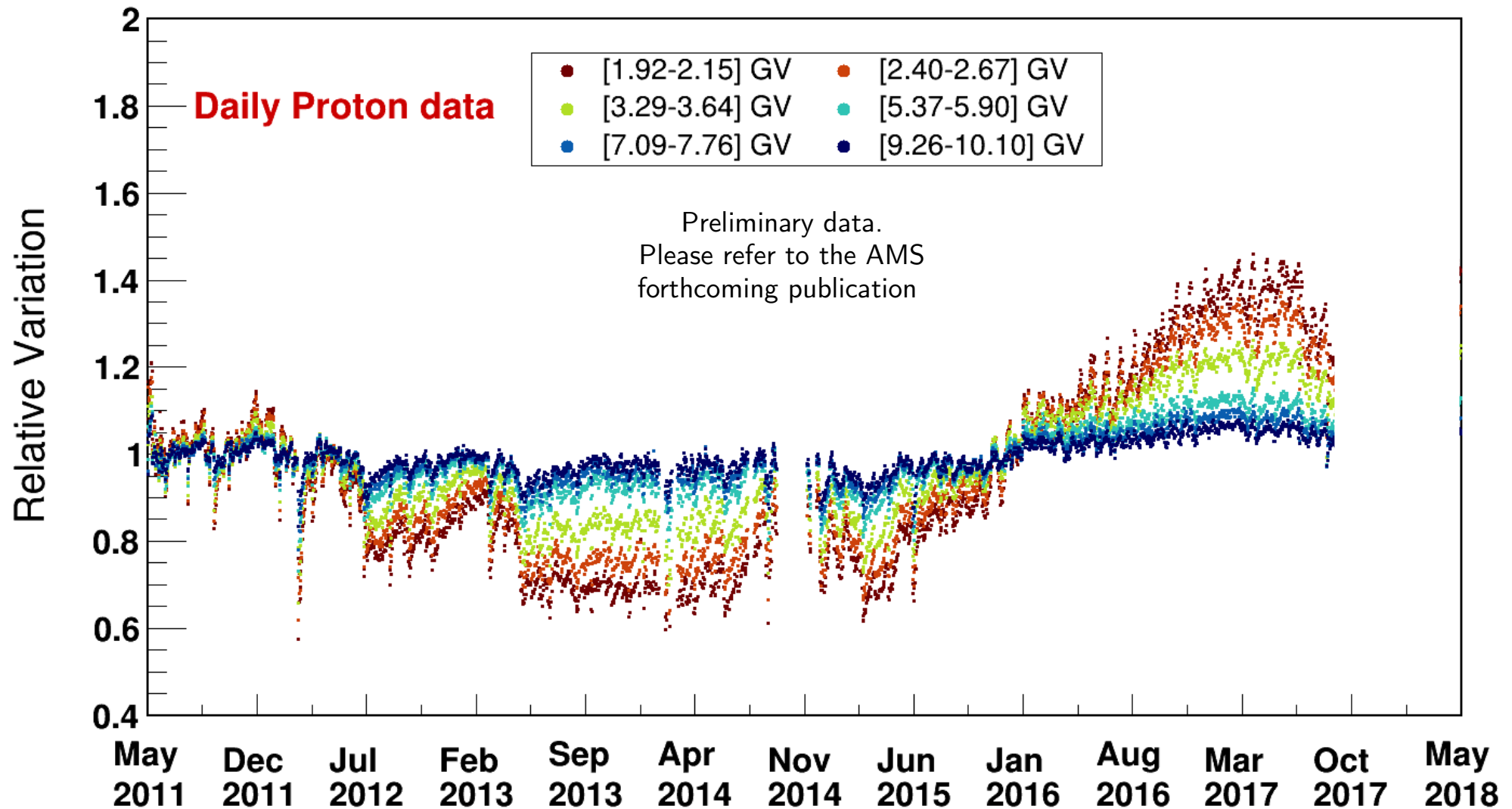
Proton Daily Fluxes Relative Variation May 2011 – May 2018



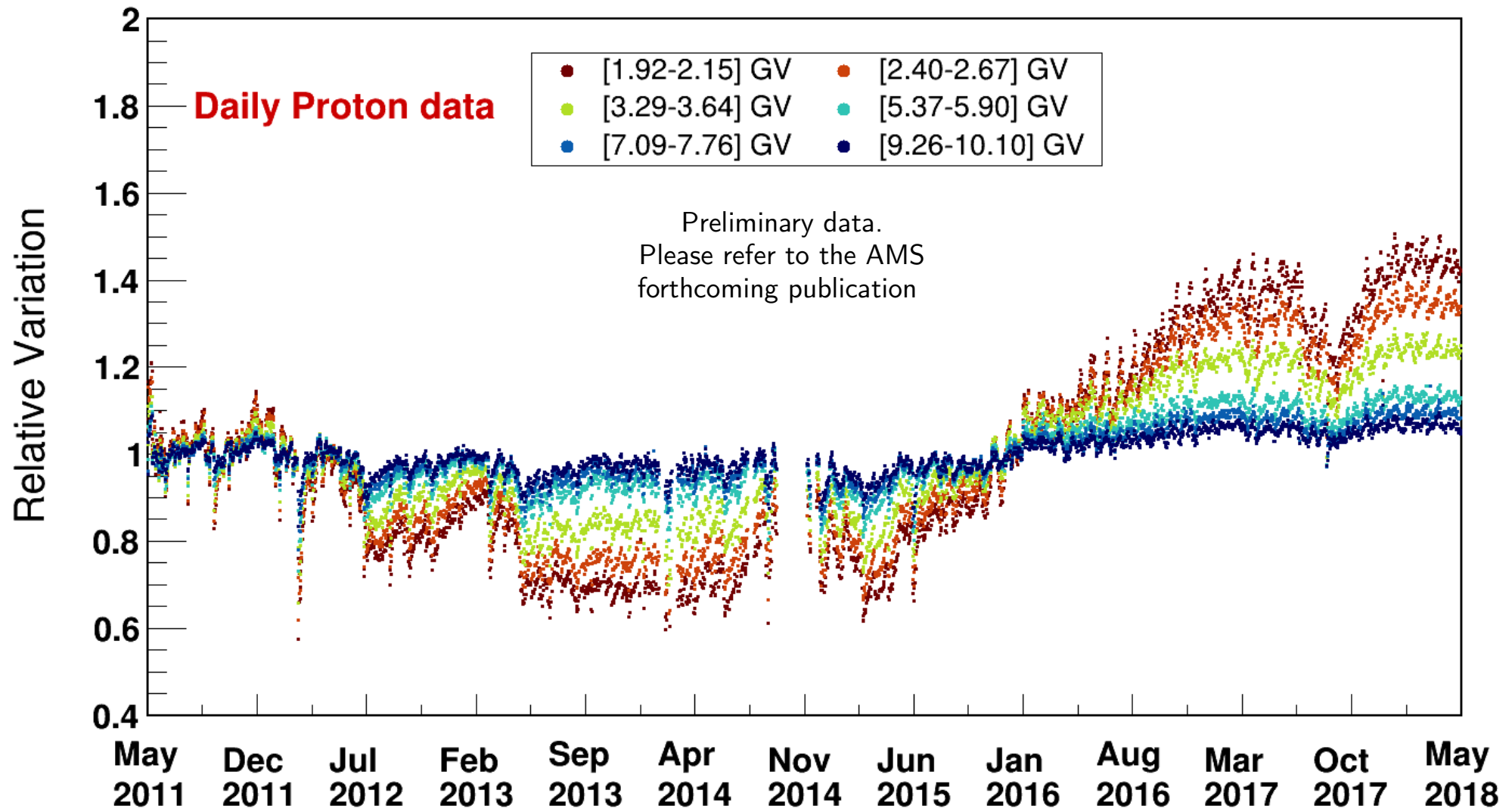
Proton Daily Fluxes Relative Variation May 2011 – May 2018



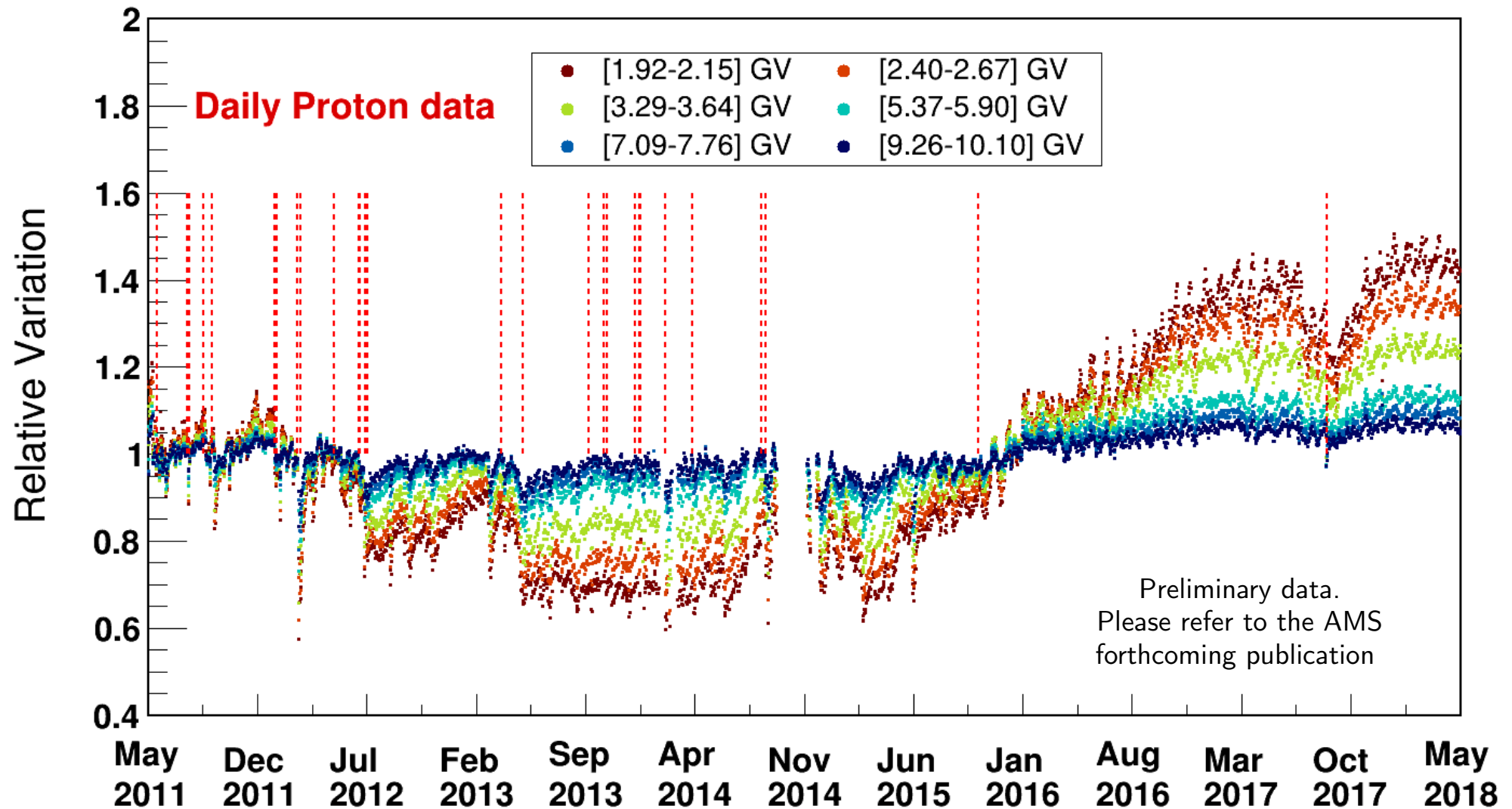
Proton Daily Fluxes Relative Variation May 2011 – May 2018



Proton Daily Fluxes Relative Variation May 2011 – May 2018



Solar energetic particles events observed by AMS

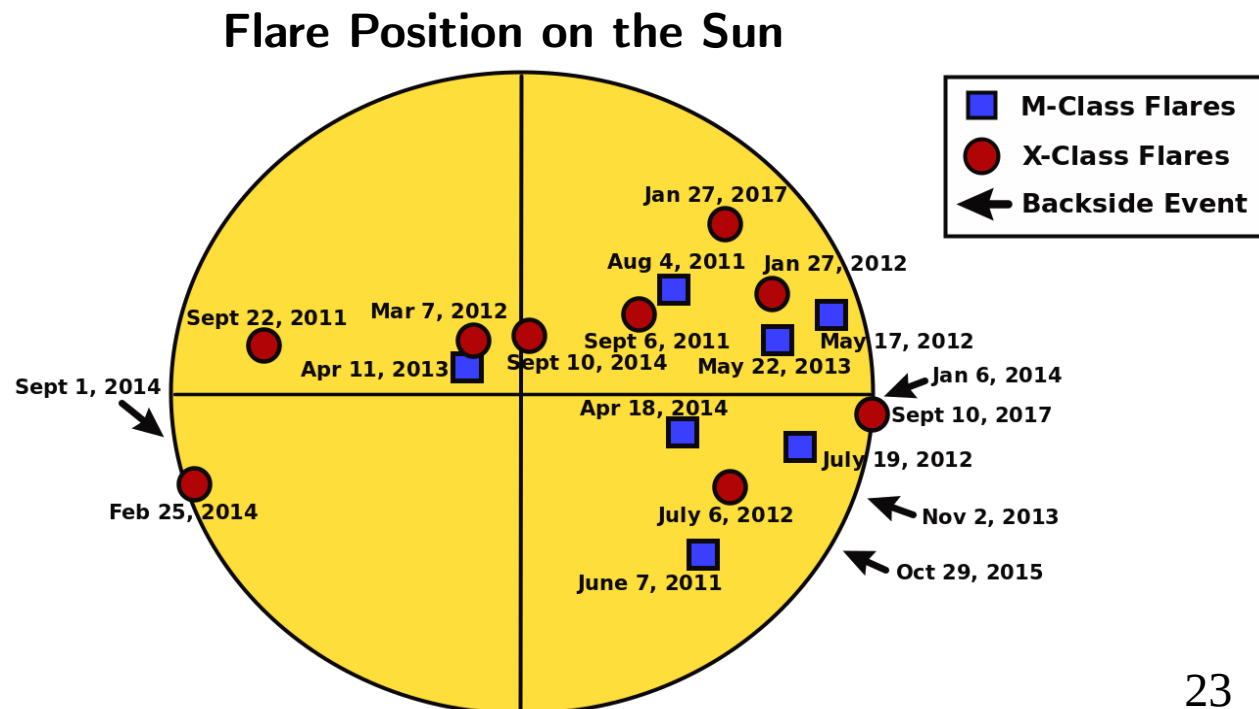


Through May 2018, AMS has detected 28 SEP events.

Solar Energetic Particles Events Observed by AMS

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

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



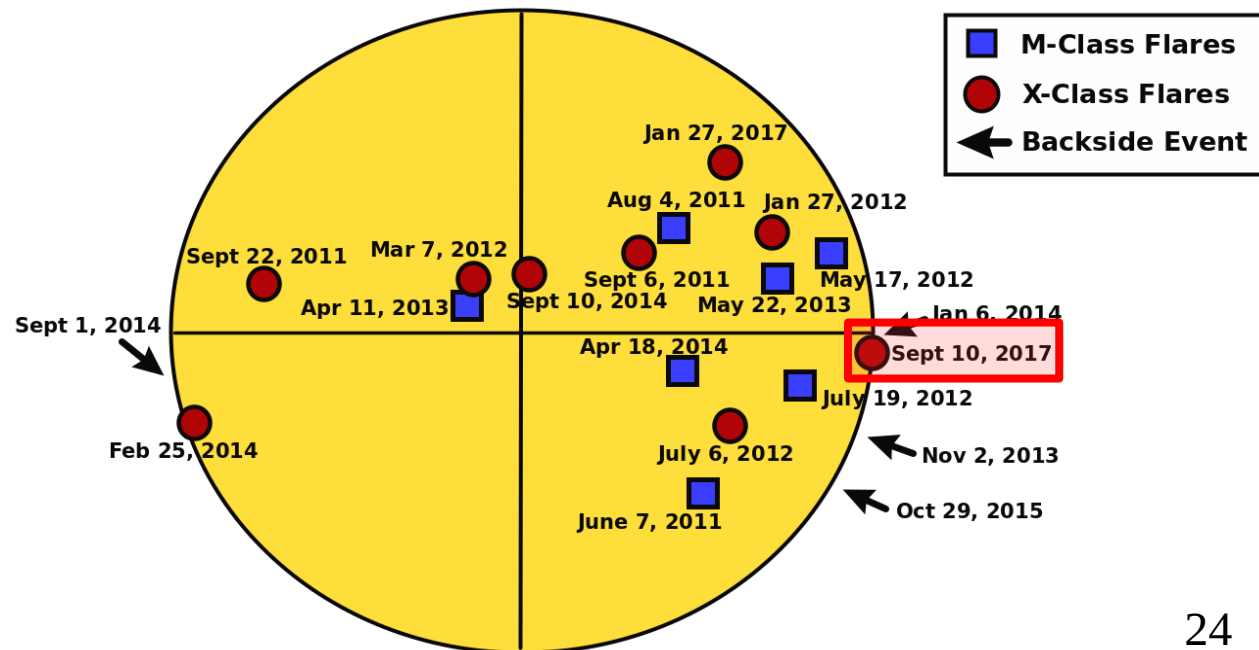
Solar Energetic Particles Events Observed by AMS

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

September 2017

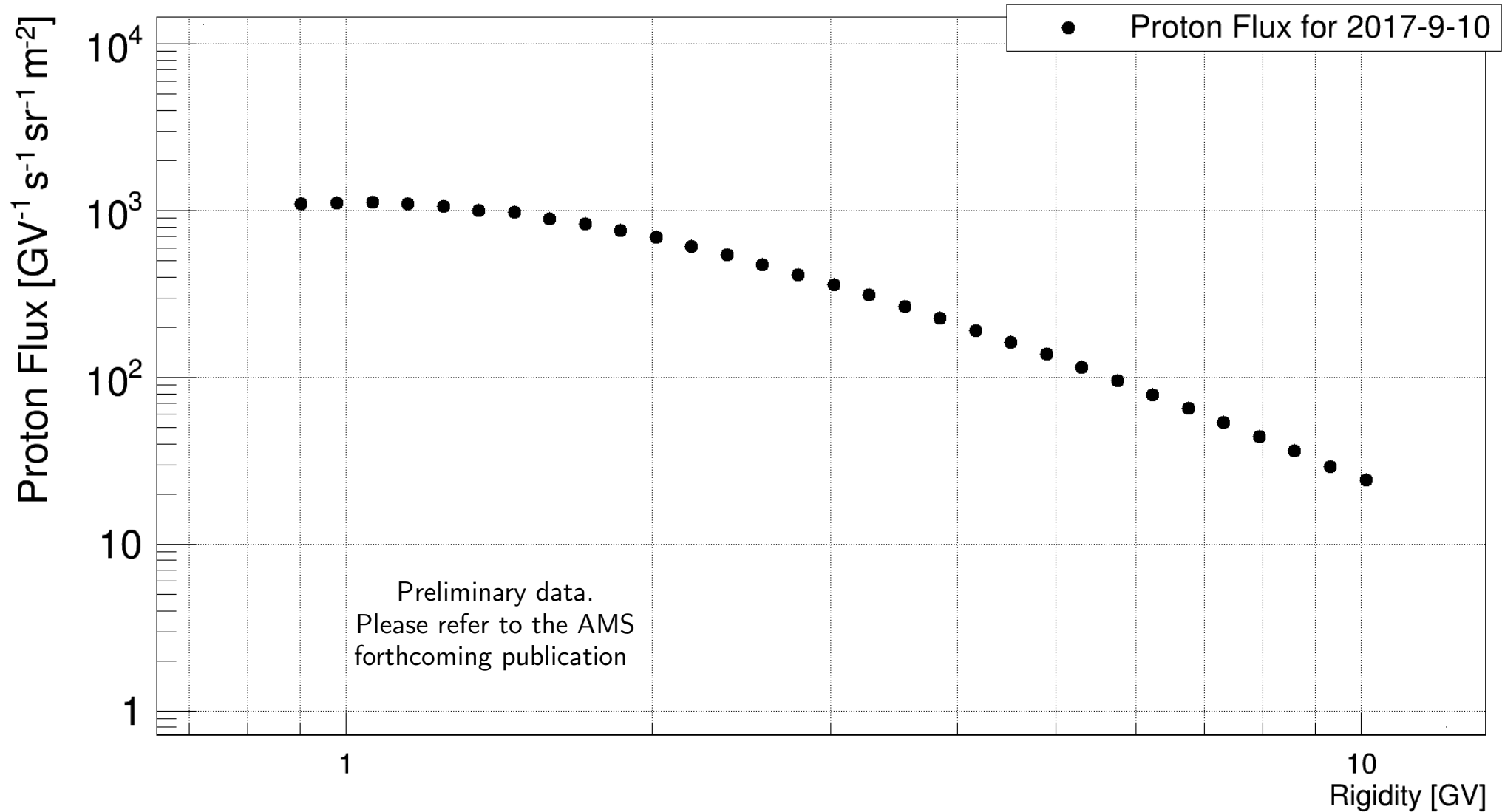
- Most recent Ground Level Enhancement (GLE) SEP event.
- X8.2 flare at 16:06 on the 10th of Sept.
- Fast (2868 km/s) Halo CME associated with this event.
- Interesting event because it occurred deep into the descending phase of solar activity.

Flare Position on the Sun



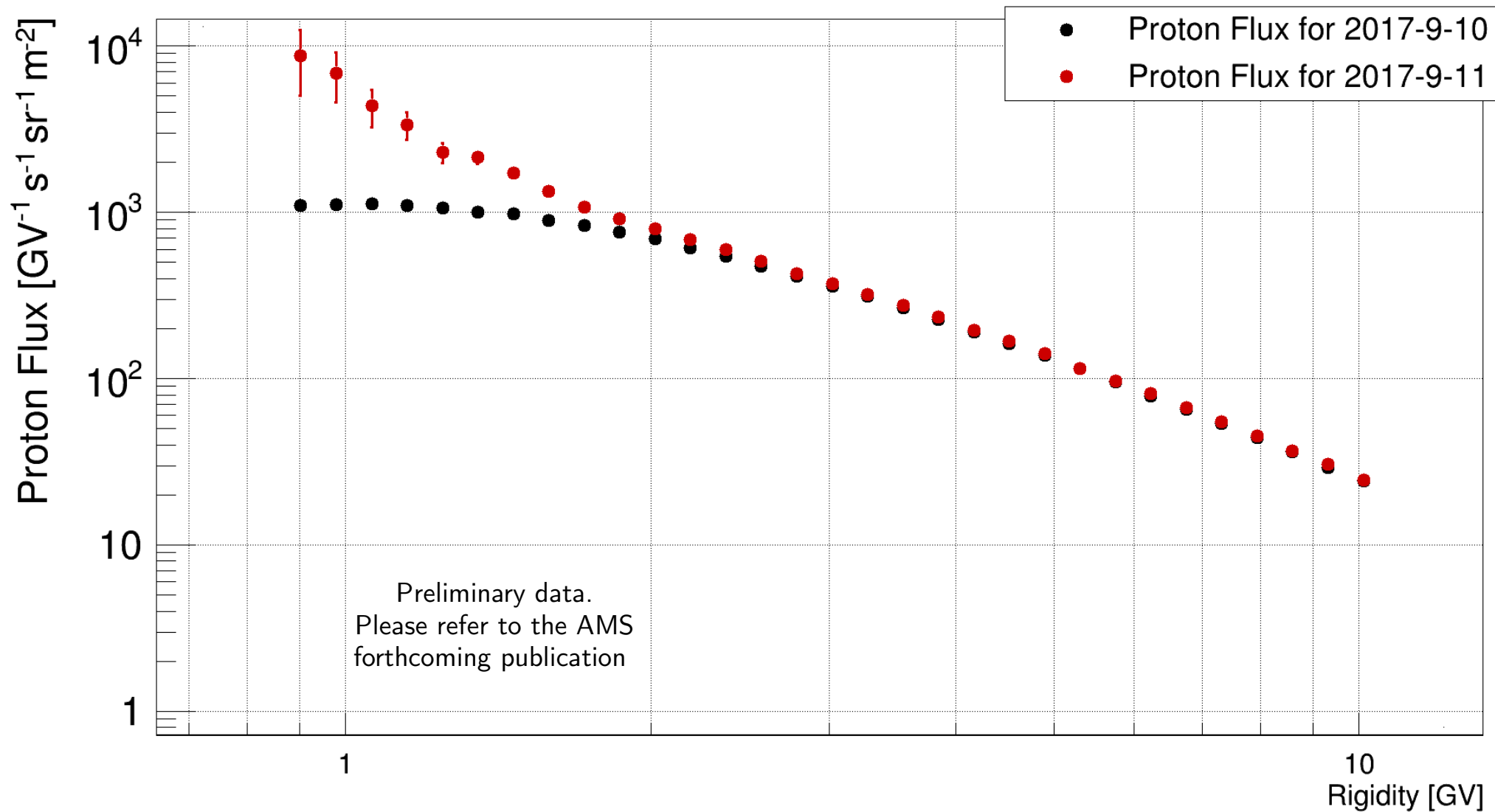
September 2017 SEP Event

AMS proton flux, September 10th, GCR background



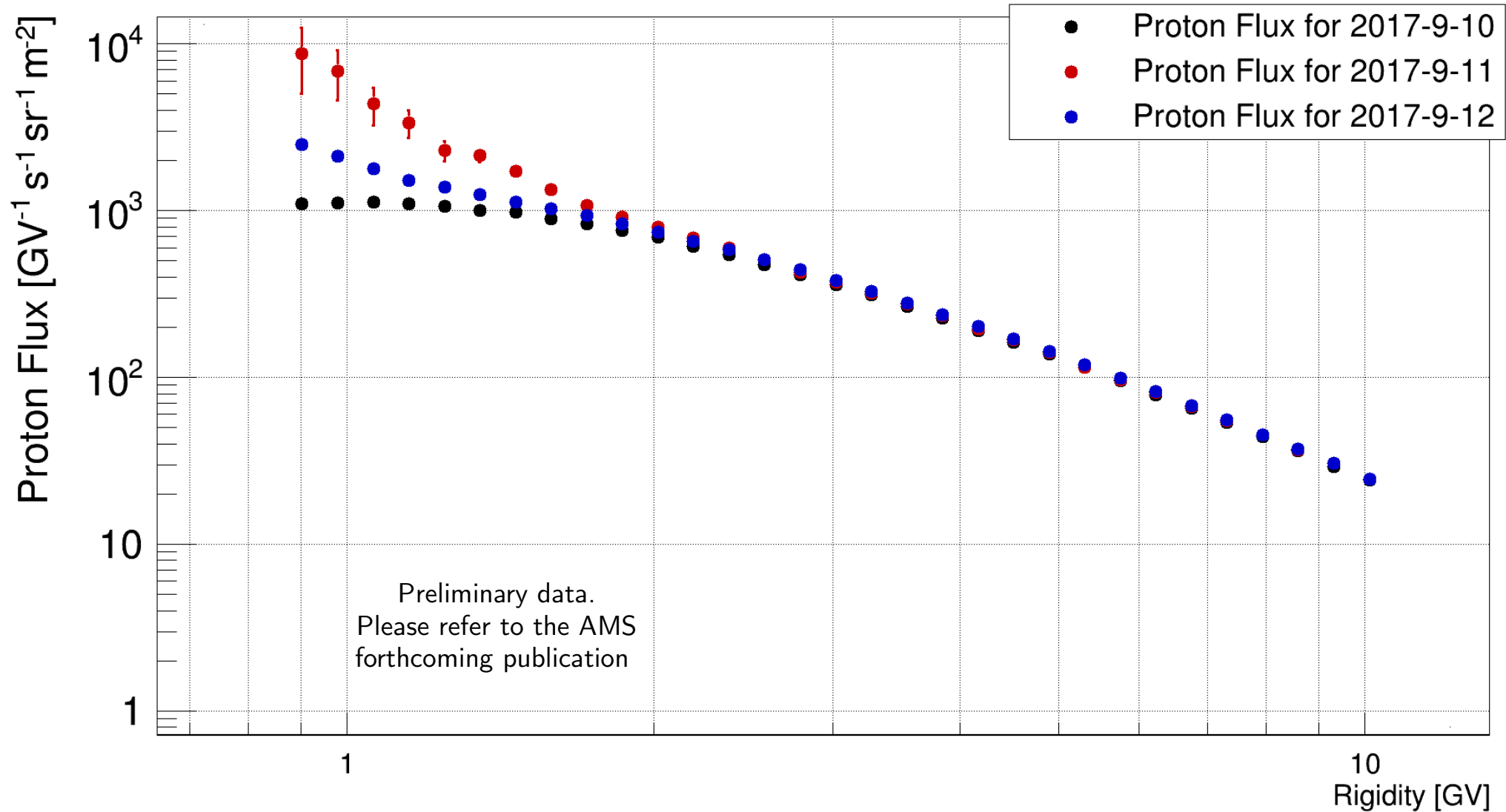
September 2017 SEP Event

AMS proton flux, September 11th, GCRs + SEPs



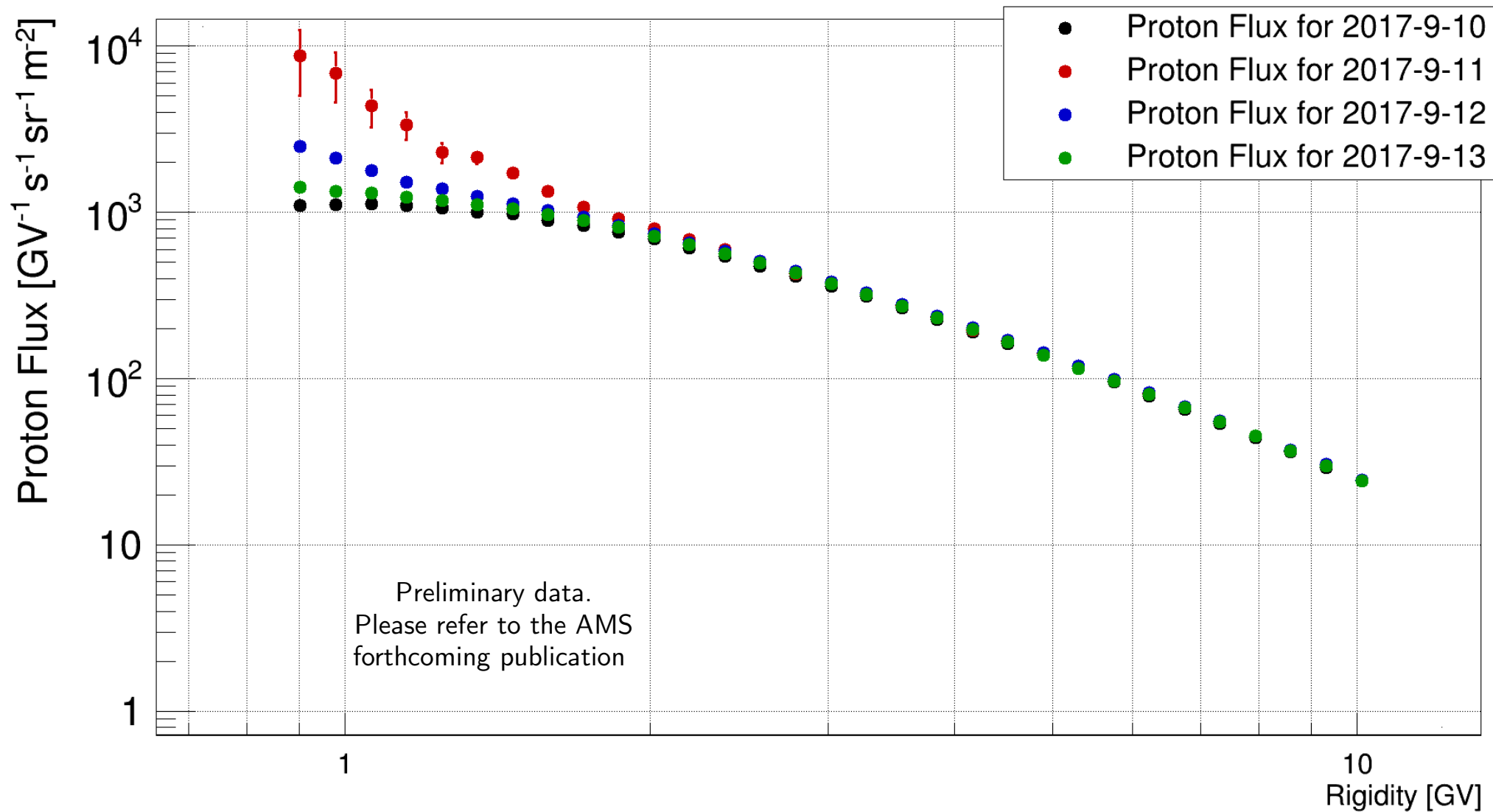
September 2017 SEP Event

AMS proton flux, September 12th, GCRs + SEPs



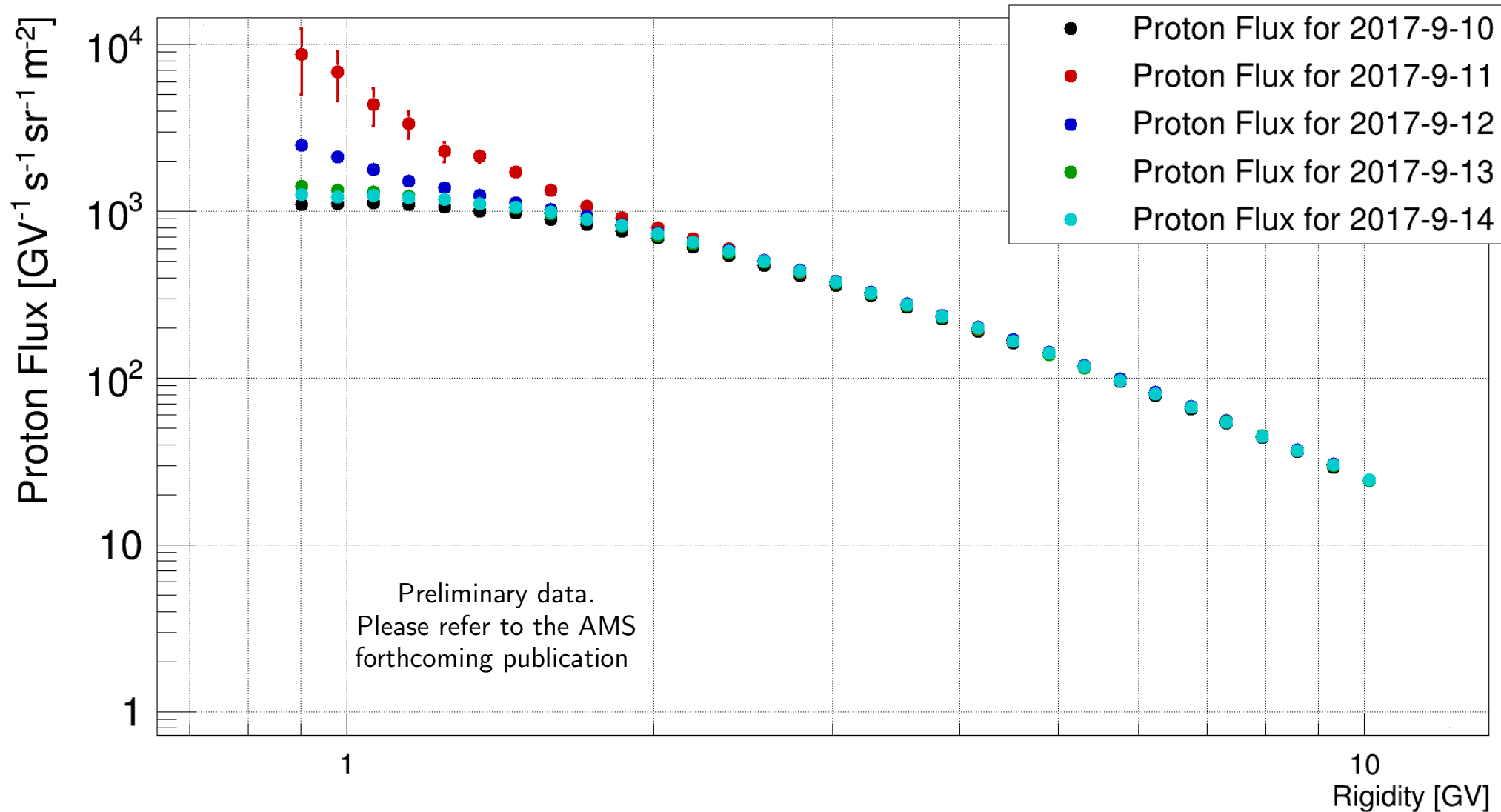
September 2017 SEP Event

AMS proton flux, September 13th, GCRs + SEPs



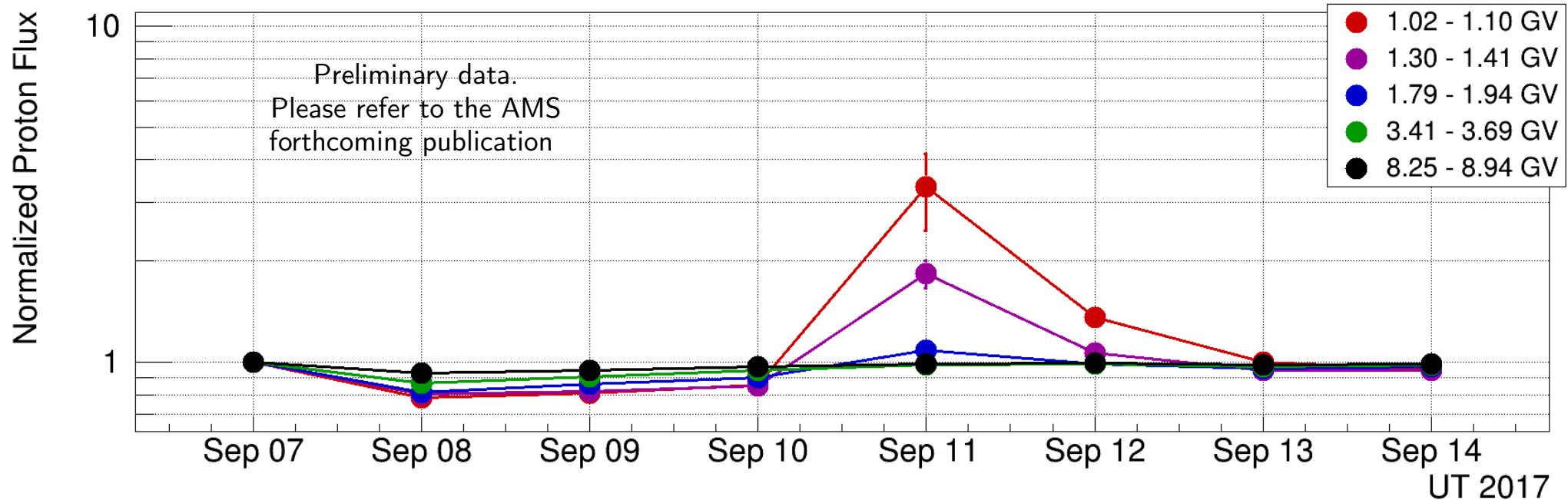
September 2017 SEP Event

AMS proton flux, September 14th, GCRs + SEPs



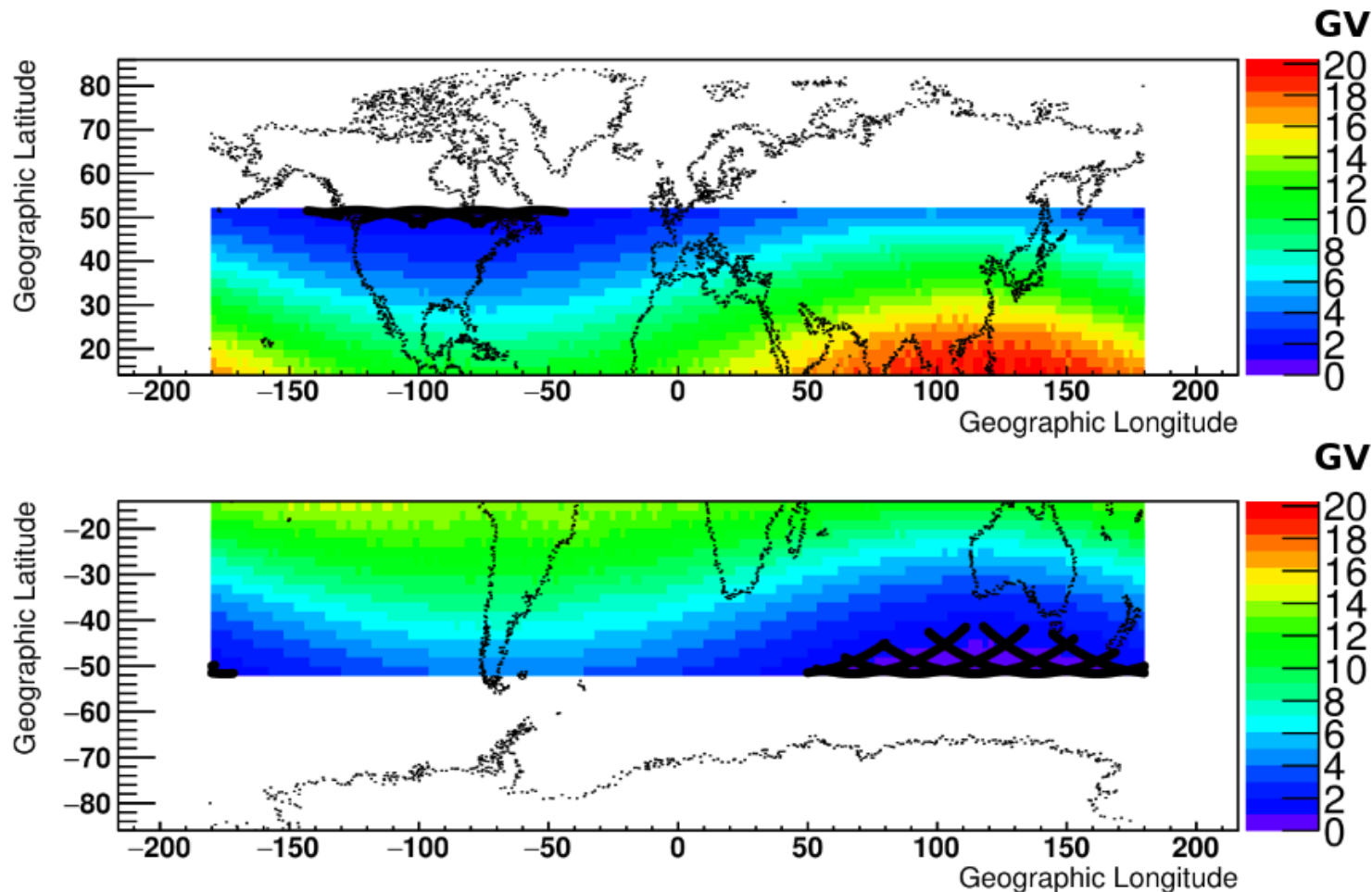
September 2017 SEP Event

AMS proton flux on September 7 – 14, 2017, normalized to September 7th.



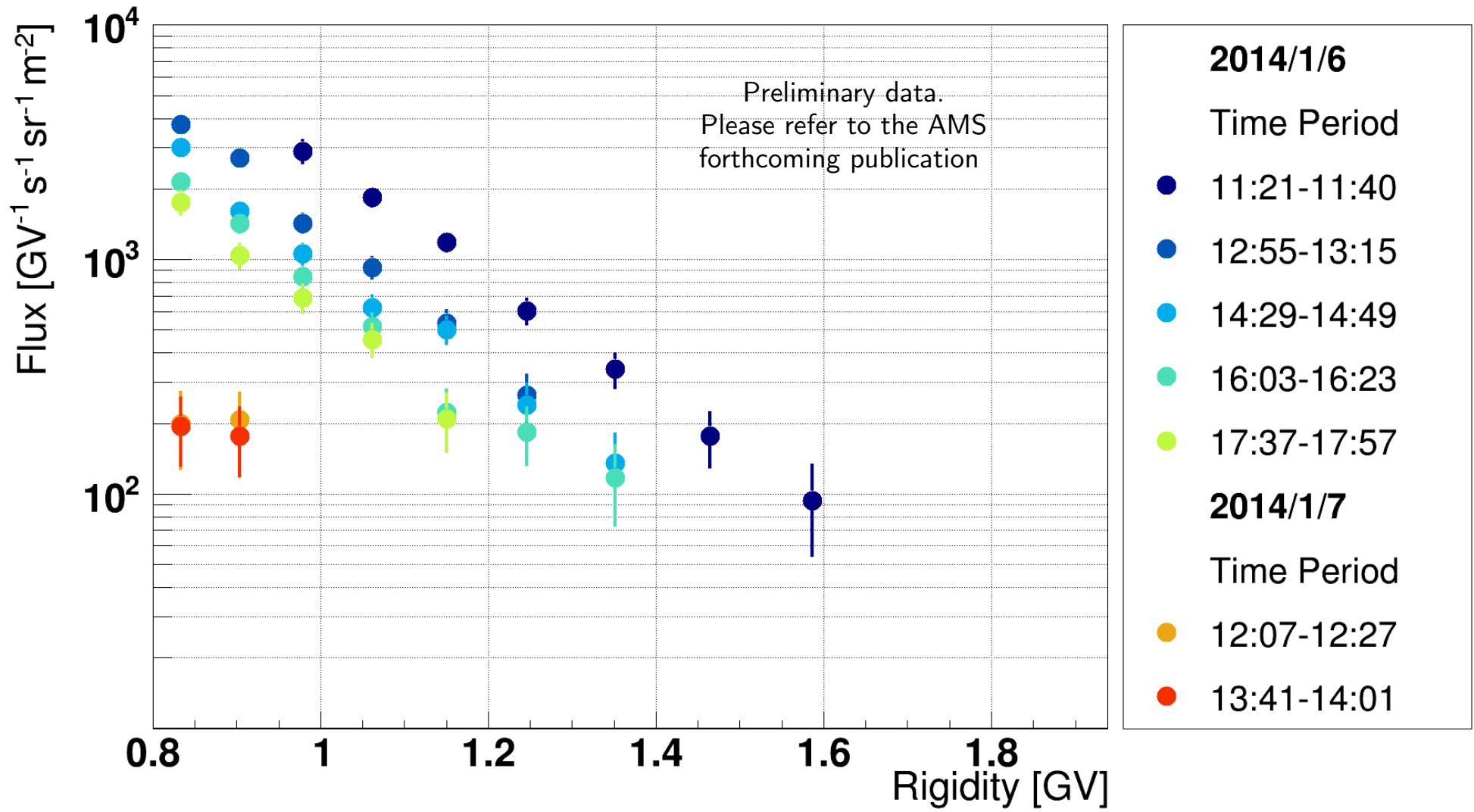
AMS Exposure to SEPs

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



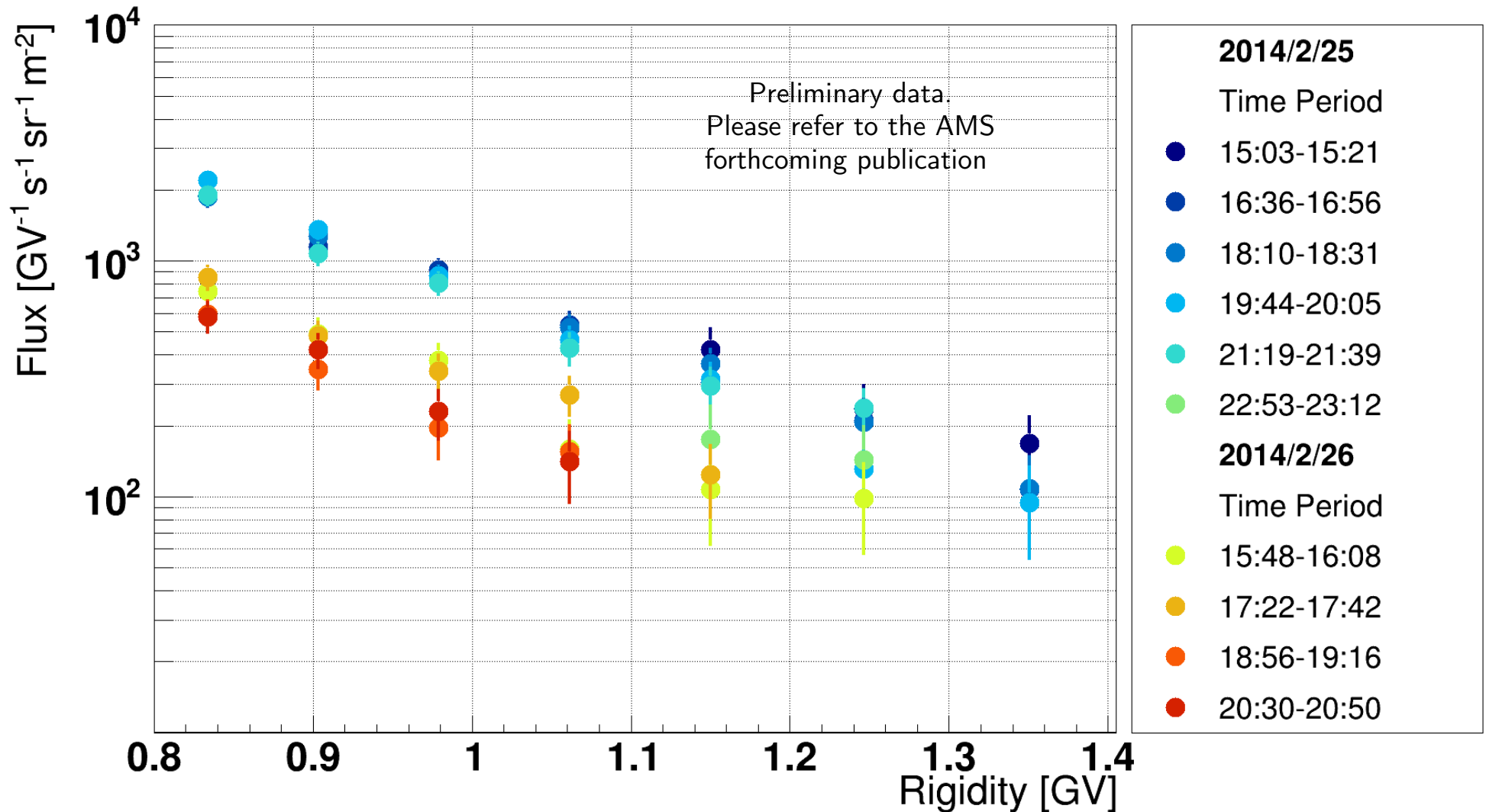
AMS Orbit-by-orbit SEP Proton Fluxes

AMS proton flux after subtracting GCR background, January 2014



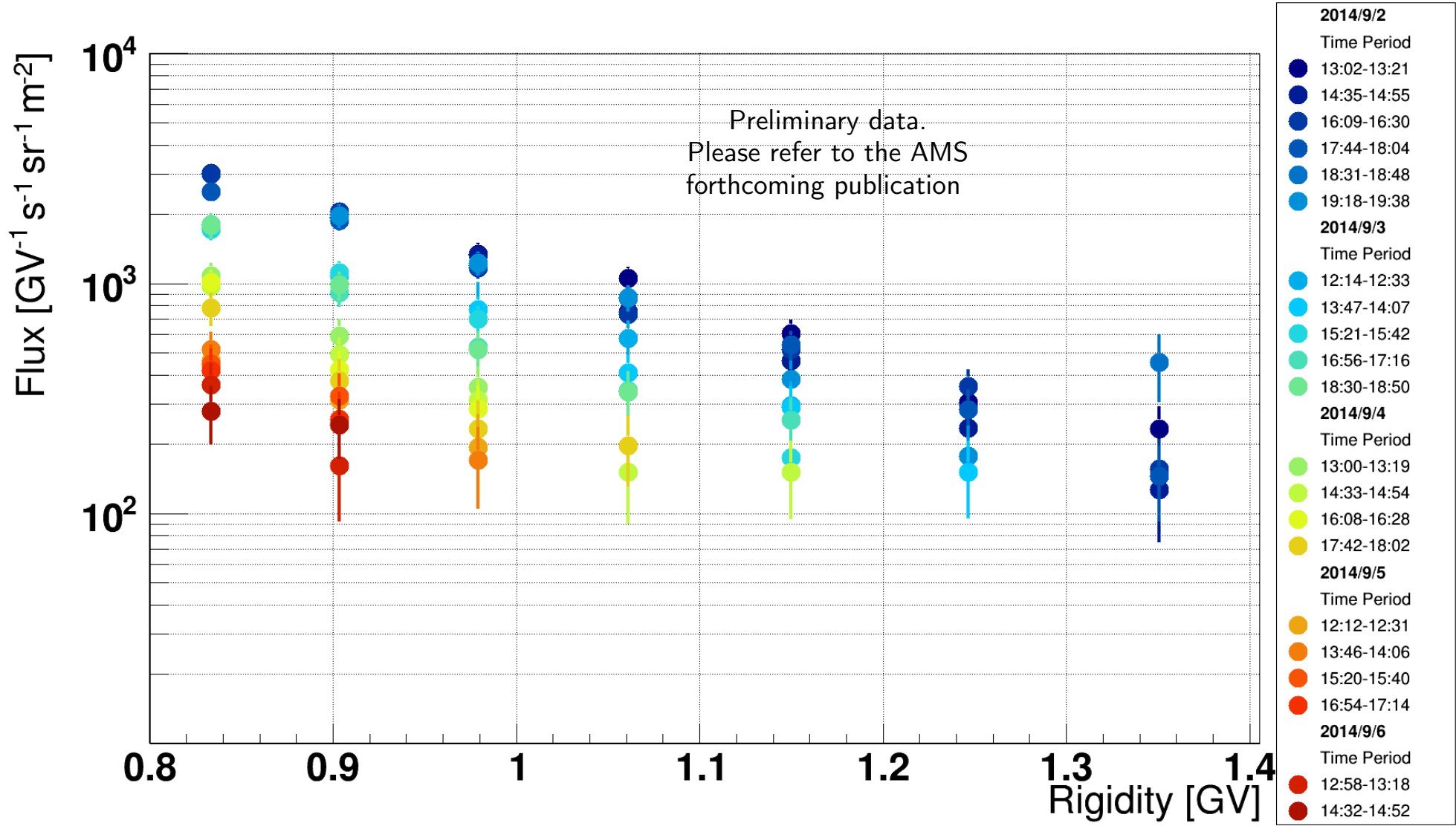
AMS Orbit-by-orbit SEP Proton Fluxes

AMS proton flux after subtracting GCR background, February 2014



AMS Orbit-by-orbit SEP Proton Fluxes

AMS proton flux after subtracting GCR background, September 2014



Summary

- Seven years of AMS data were analyzed.
- Proton and Helium daily fluxes were measured during solar cycle 24.
- Proton and Helium daily fluxes show nearly identical substructures up to 40 GV.
- The comparison of multiple rigidity ranges shows different behaviors depending on the solar cycle phase.
- 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.
- Between May 2011 and 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.