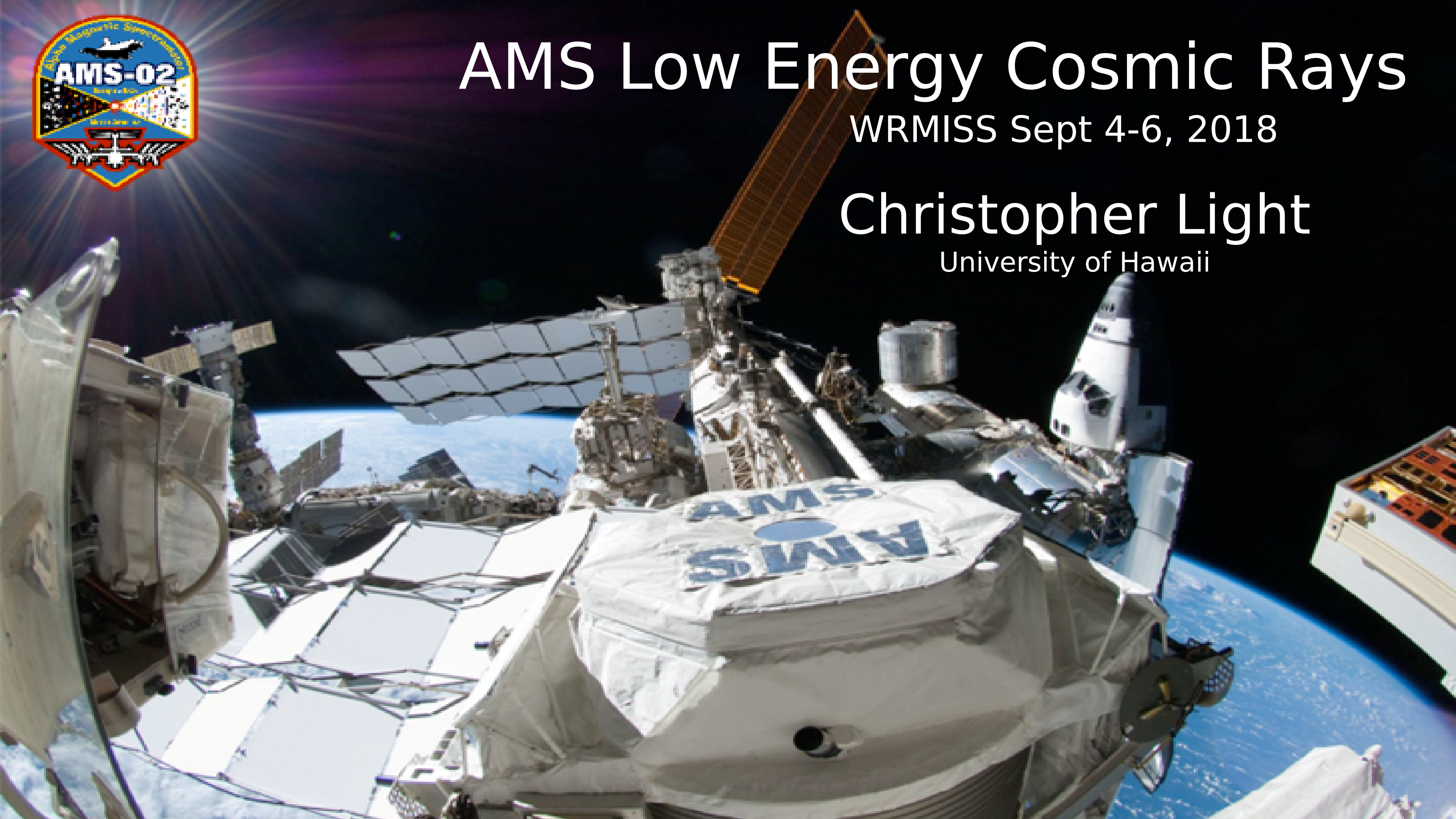
AMS Low Energy Cosmic Rays

WRMISS Sept 4-6, 2018

Christopher Light
University of Hawaii

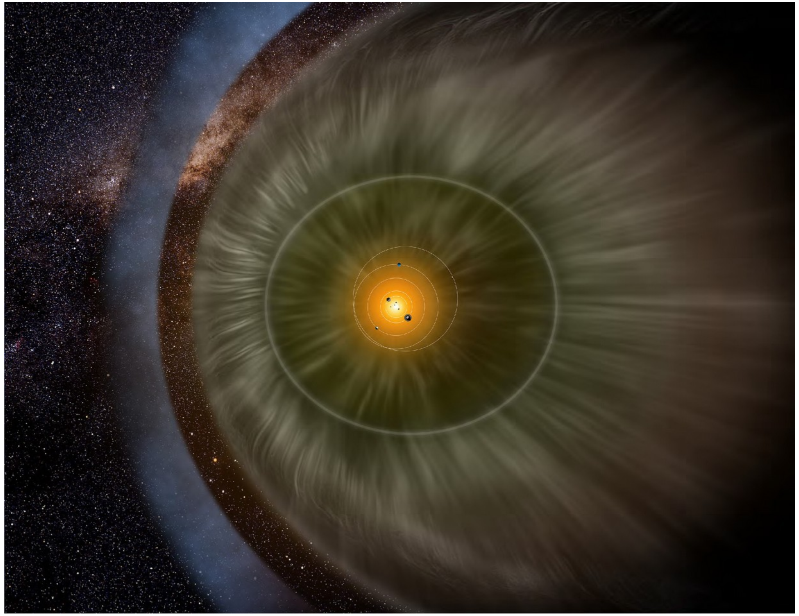


Solar Modulation of GCRs in the Heliosphere

Precise measurements of the time-dependent GCR spectra is important:

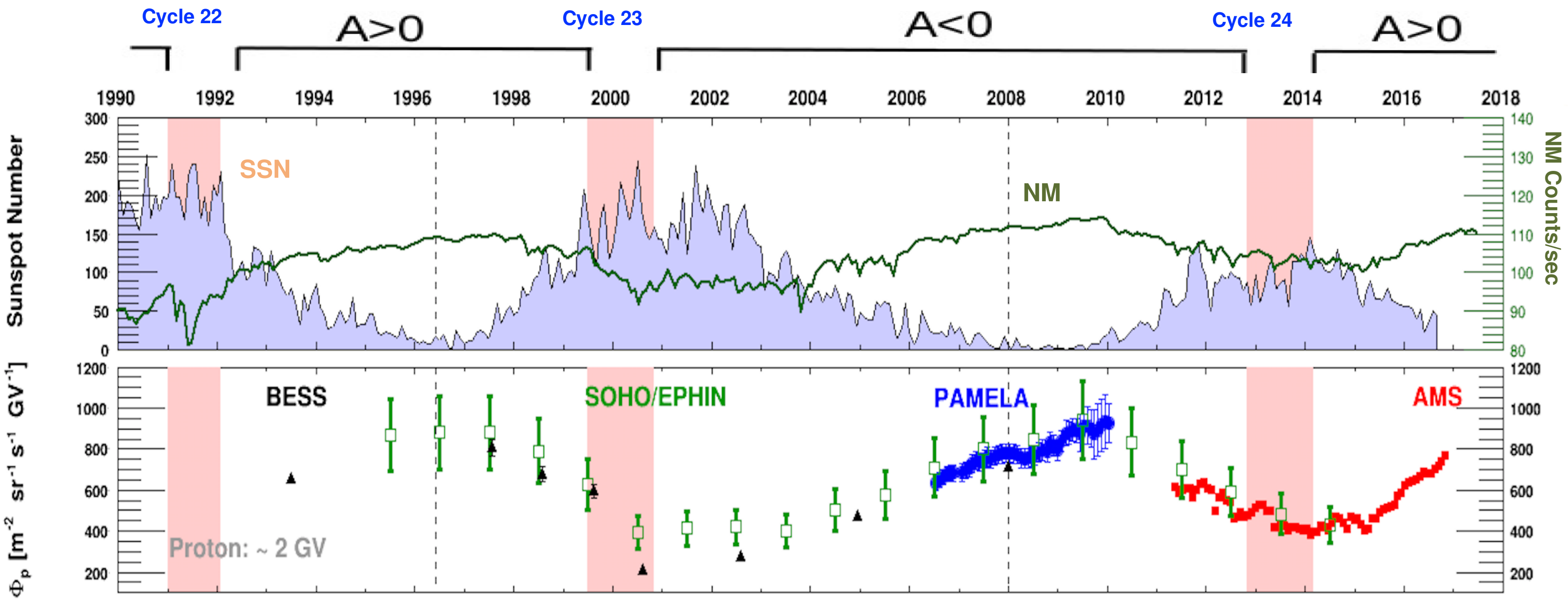
- to understand the propagation of GCRs in the heliosphere.
- to test solar modulation theories of particles diffusion and drift.
- to reduce the errors on theoretical models used for Dark Matter interpretation of the excess in the antimatter channels and in evaluation of the secondary background.

➢ To understand significant sources of space radiation.

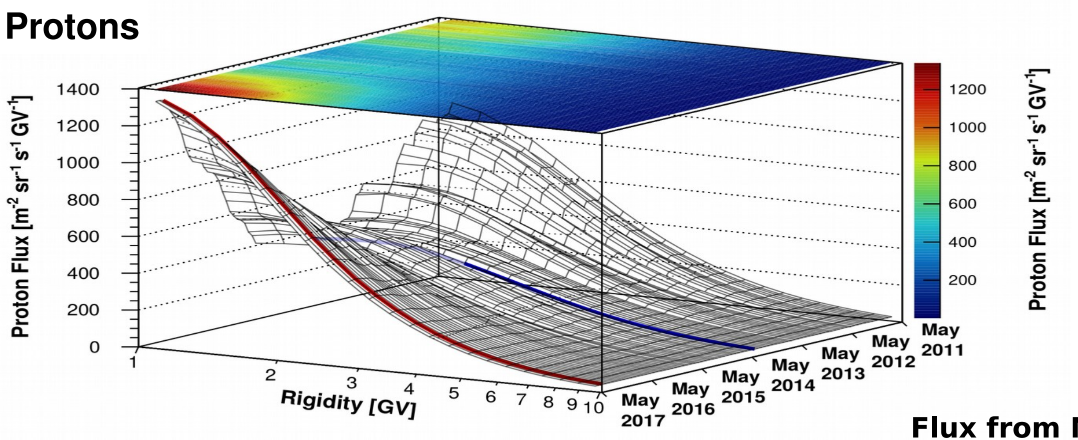


Solar activity measured by AMS

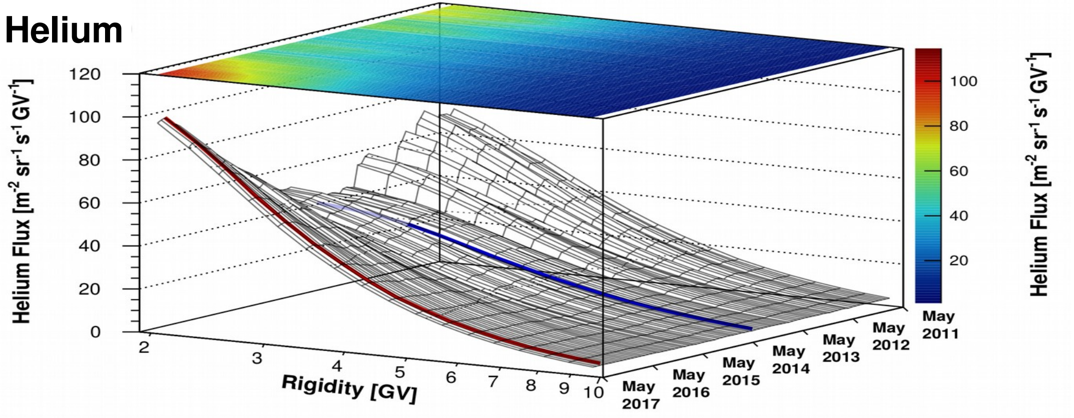
Cosmic rays entering the heliosphere are subject to diffusion, convection, adiabatic energy losses, and magnetic drift. Cosmic ray flux variation over time correlate with solar activity, which has several cycles.



AMS Proton and Helium time variation



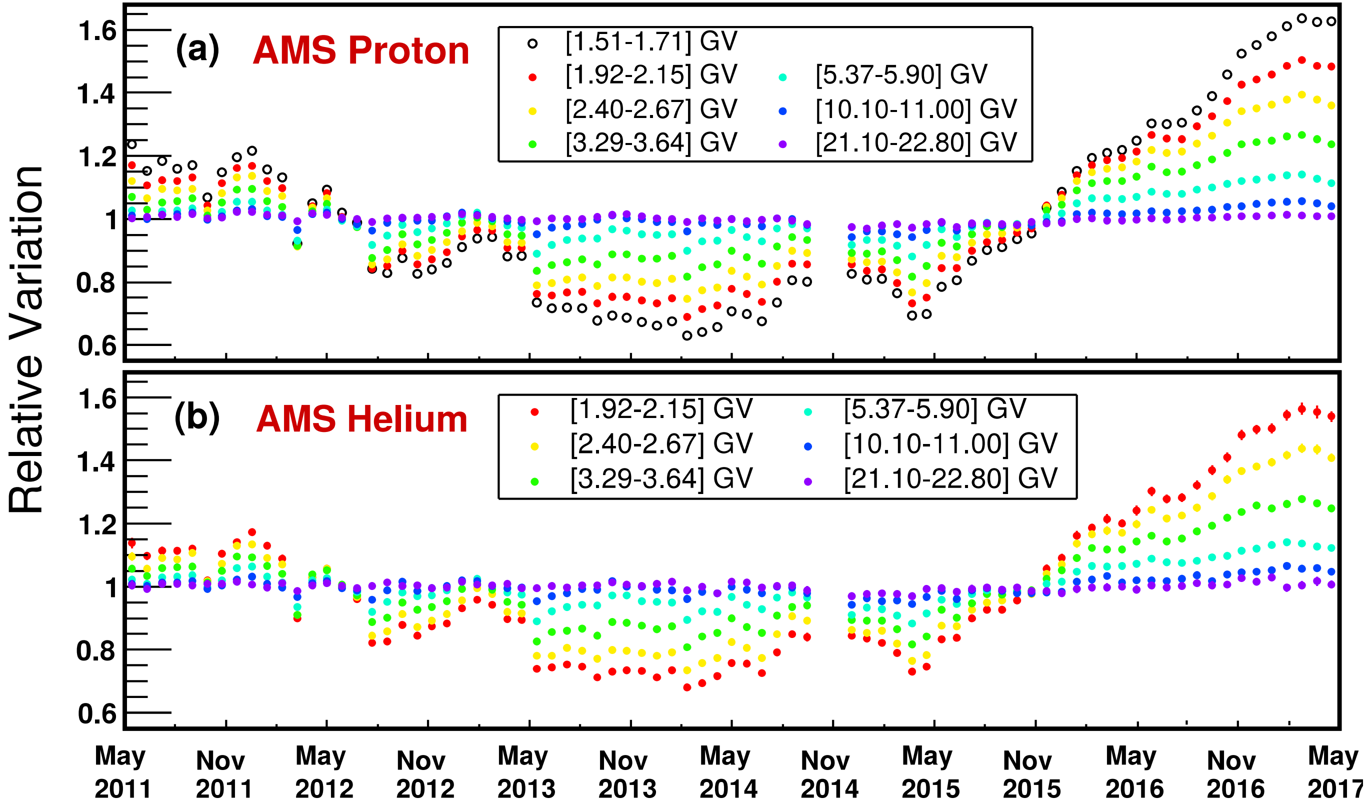
Flux from May 2011 to May 2017
Minimum Flux February 2014



Published in PRL
August 1, 2018

AMS Monthly Proton and Helium time variation (Bartels rotation 27 days)

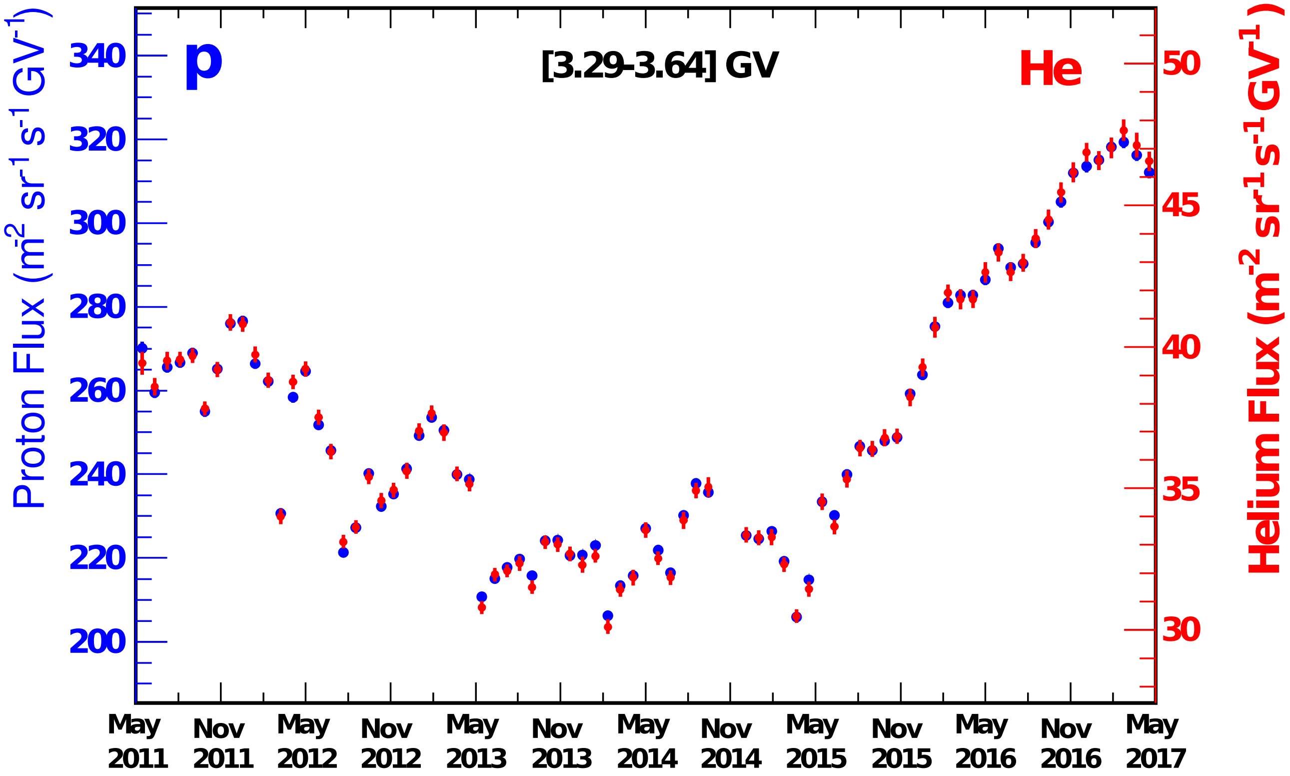
Minimum Flux
February 2014
Flux increases starting from March 2015



Published in PRL
August 1, 2018

Monthly Proton and Helium fluxes

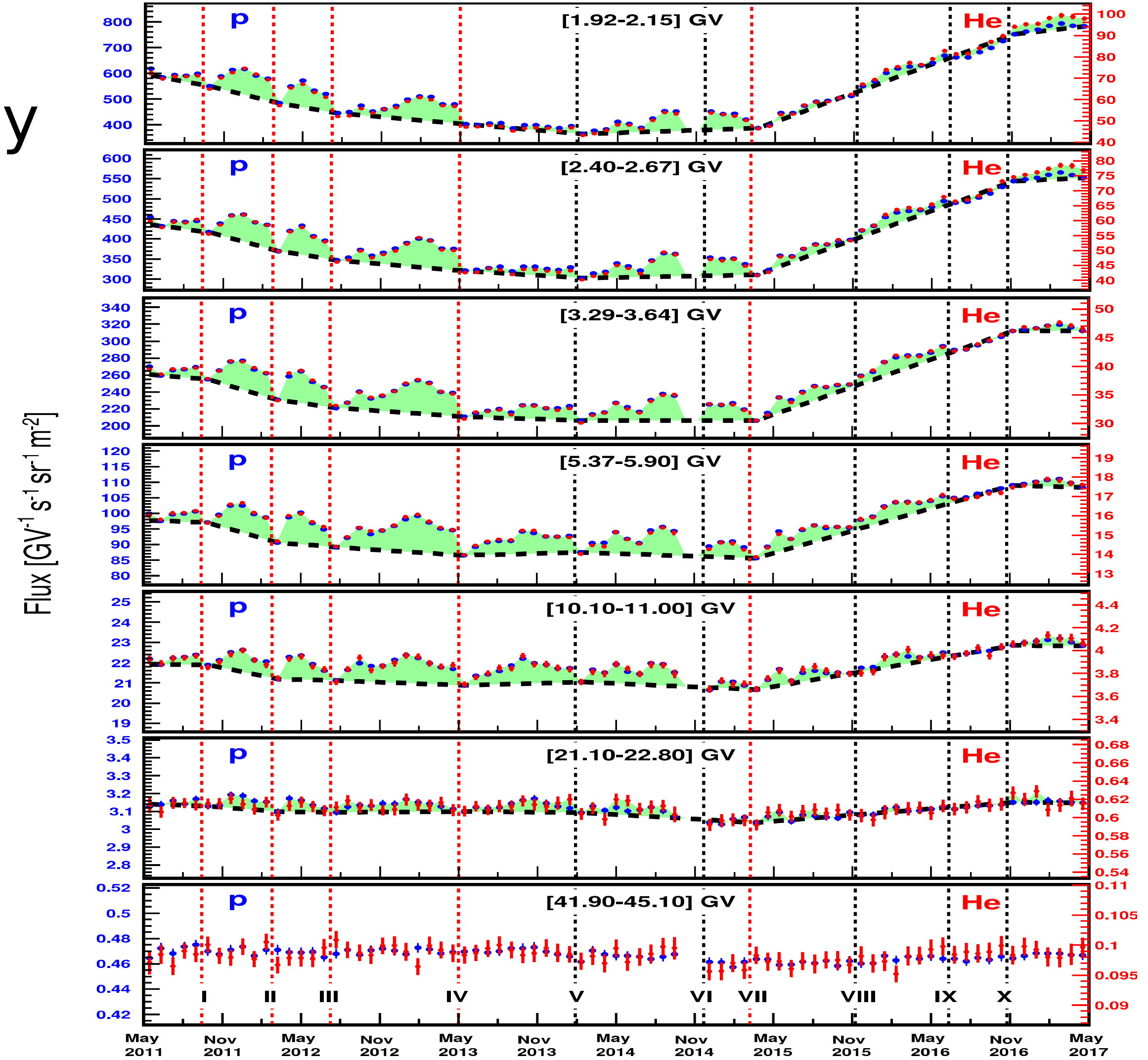
The proton flux and the helium flux have time structures nearly identical in time and relative amplitude.



Published in PRL
August 1, 2018

AMS Proton and Helium low energy structures

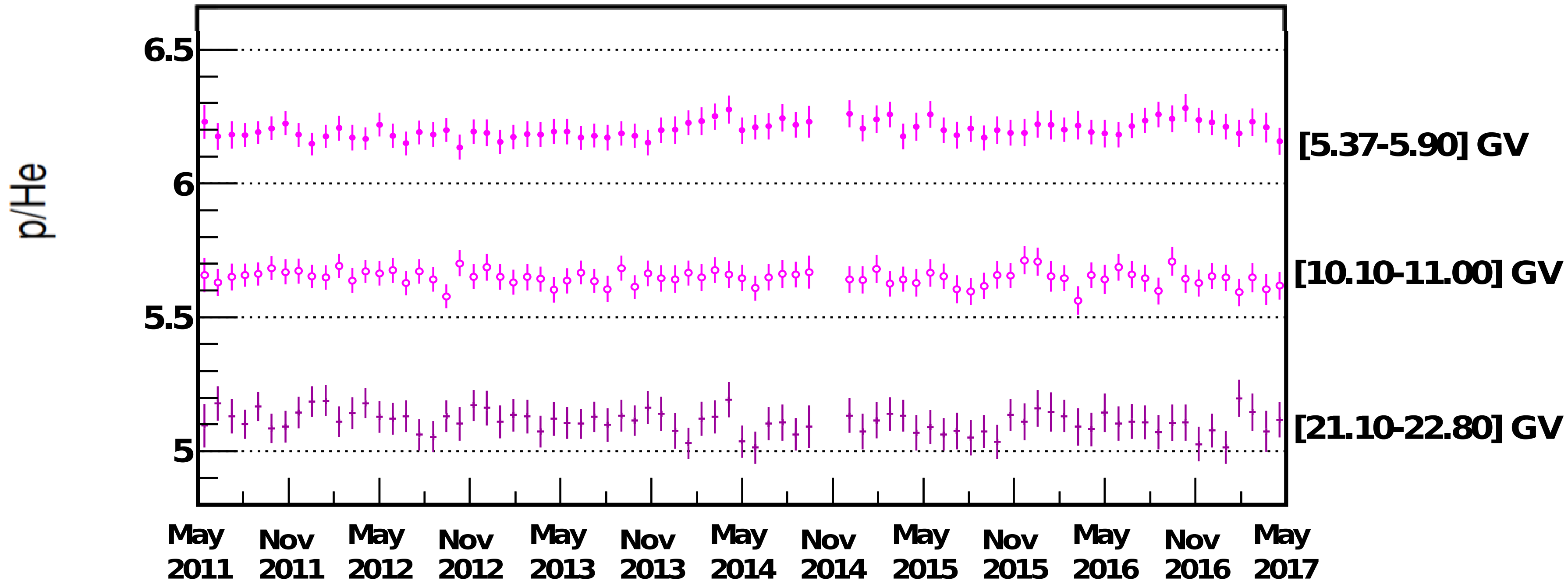
- For P and He structures are clearly present below 40 GV.



Published in PRL
August 1, 2018

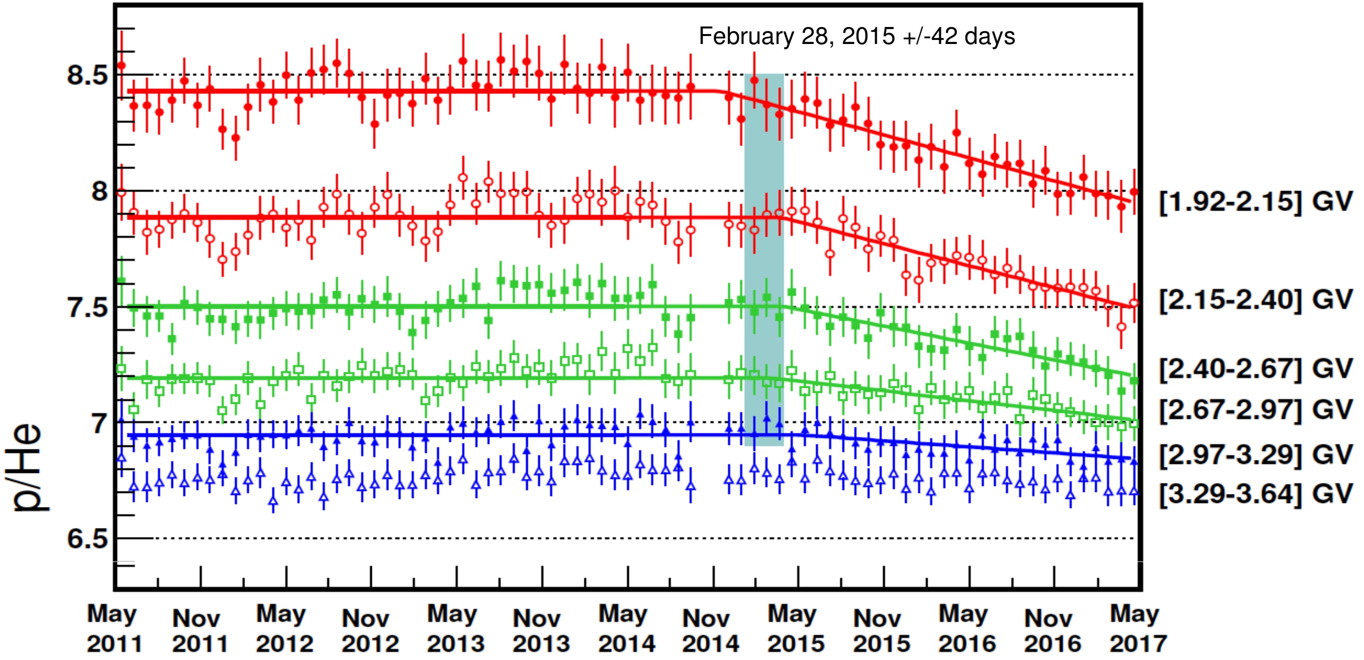
AMS Proton /Helium ratio time dependence

The p/He flux ratio above 3 GV is time independent.



AMS Proton /Helium ratio time variation

Below 3 GV the ratio has a long-term decrease coinciding with the period during which the fluxes start to rise.

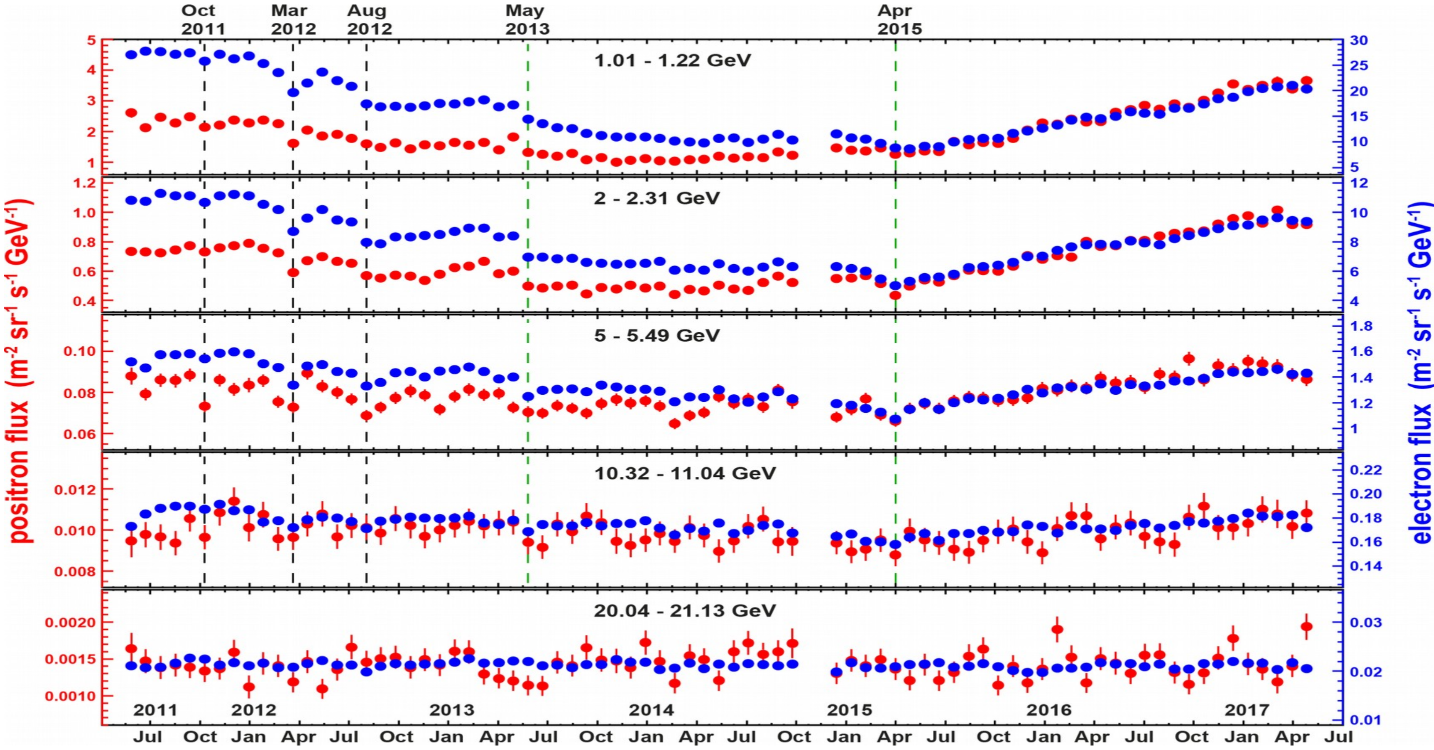


Carbon analysis vs time is ongoing.

AMS electron and positron monthly time variation

Probe the drift process in the heliosphere

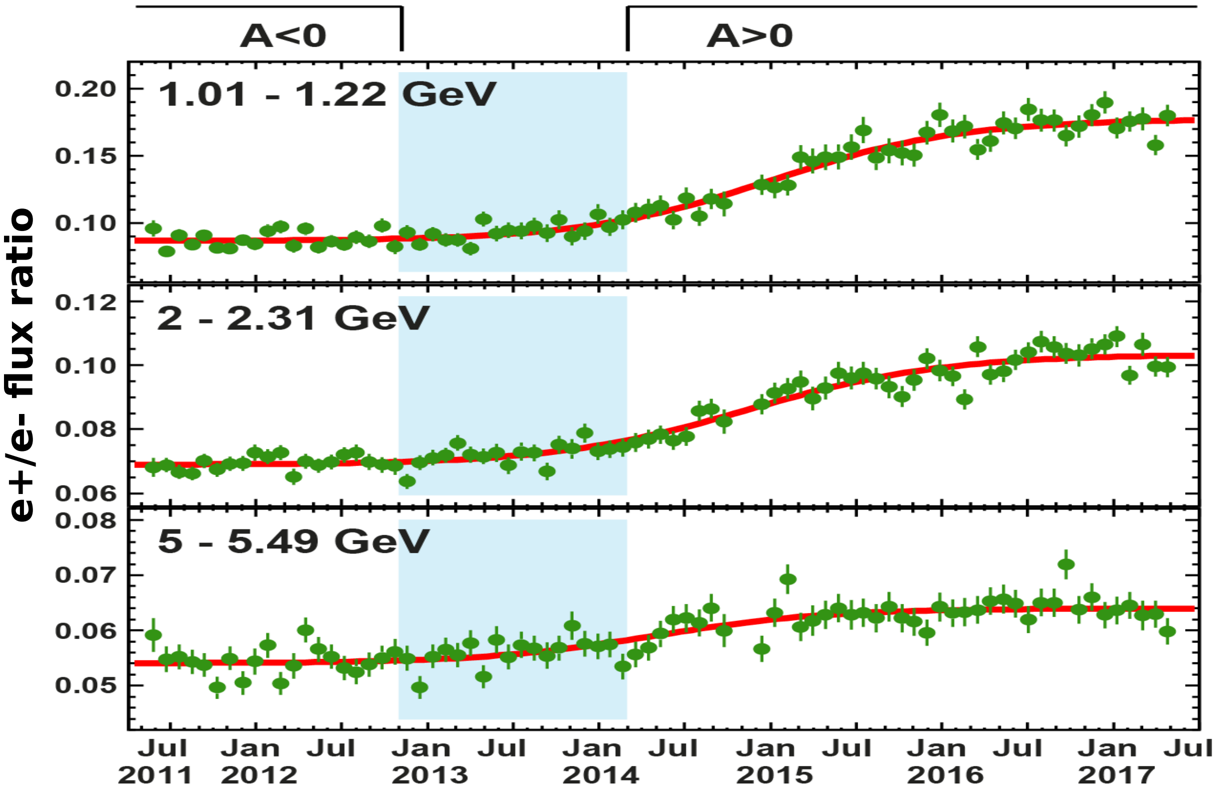
- At energies above 20 GeV, no time dependence.
- Prominent, distinct structures in both fluxes.
- Spectral indices soften with identical slope after April 2015.



Published in PRL
August 1, 2018

AMS positron/electron ratio time variation

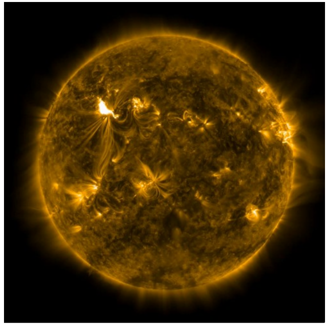
- Short-term variations largely cancel and clear overall trend revealed.
- Below 6GeV, smooth, long-term transition in e+/e- flux ratio after polarity reversal of solar magnetic field in 2013.
- Above 6GeV, e+/e- flux ratio is time independent.



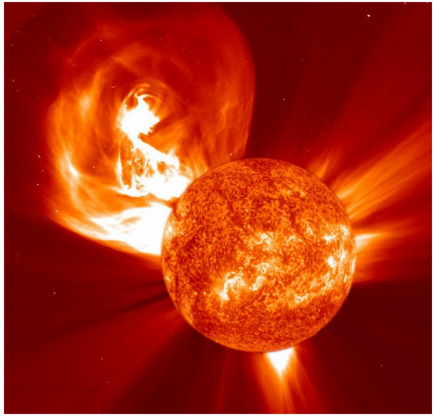
Short term solar activity

Solar Energetic Particles

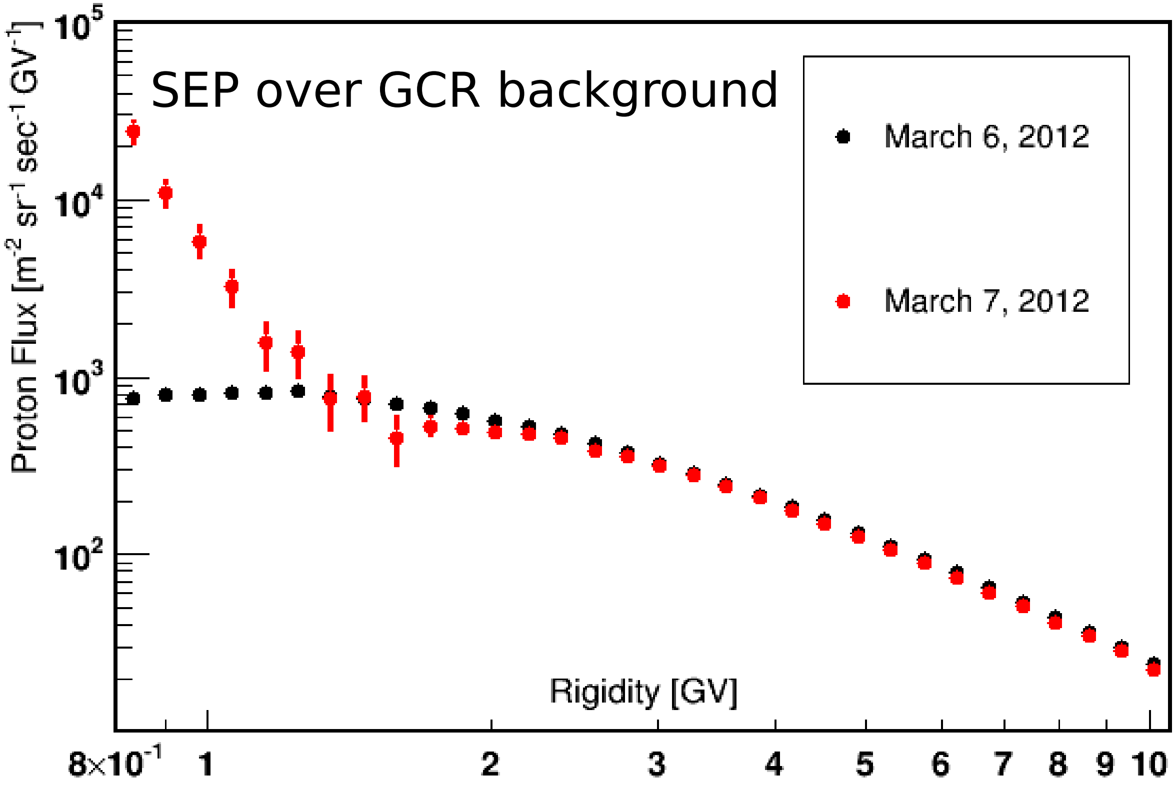
- Related to **flares** and **coronal mass ejections** (CME) at the Sun
- Solar Energetic Particles (SEP)
  - Temporary increase in particle flux
  - M- and X-class flares and high speed CMEs generate SEP events measured by AMS



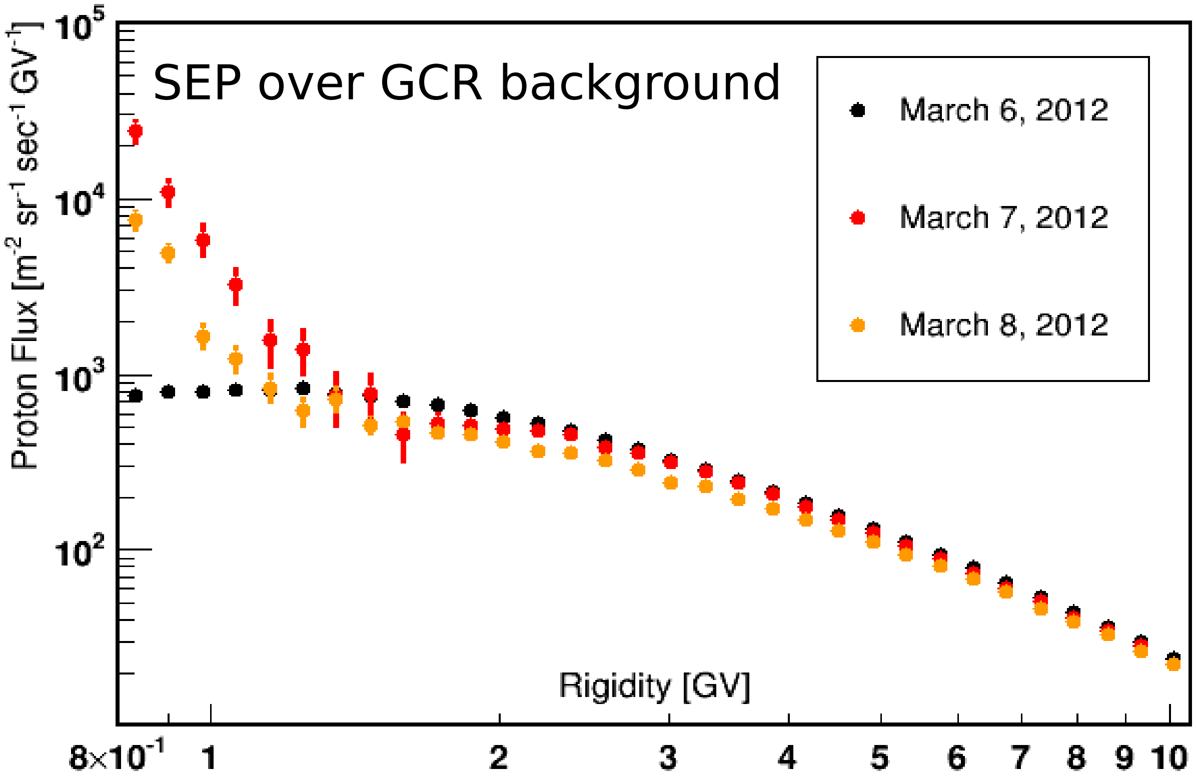
March 7, 2012
Two Solar Flares of class X5.4 and X1.3 (XRT Flare catalog SDO UV light).
Two Coronal Mass Ejections with speeds of 2684 km/s and 1825 km/s (SOHO LASCO CME catalog).



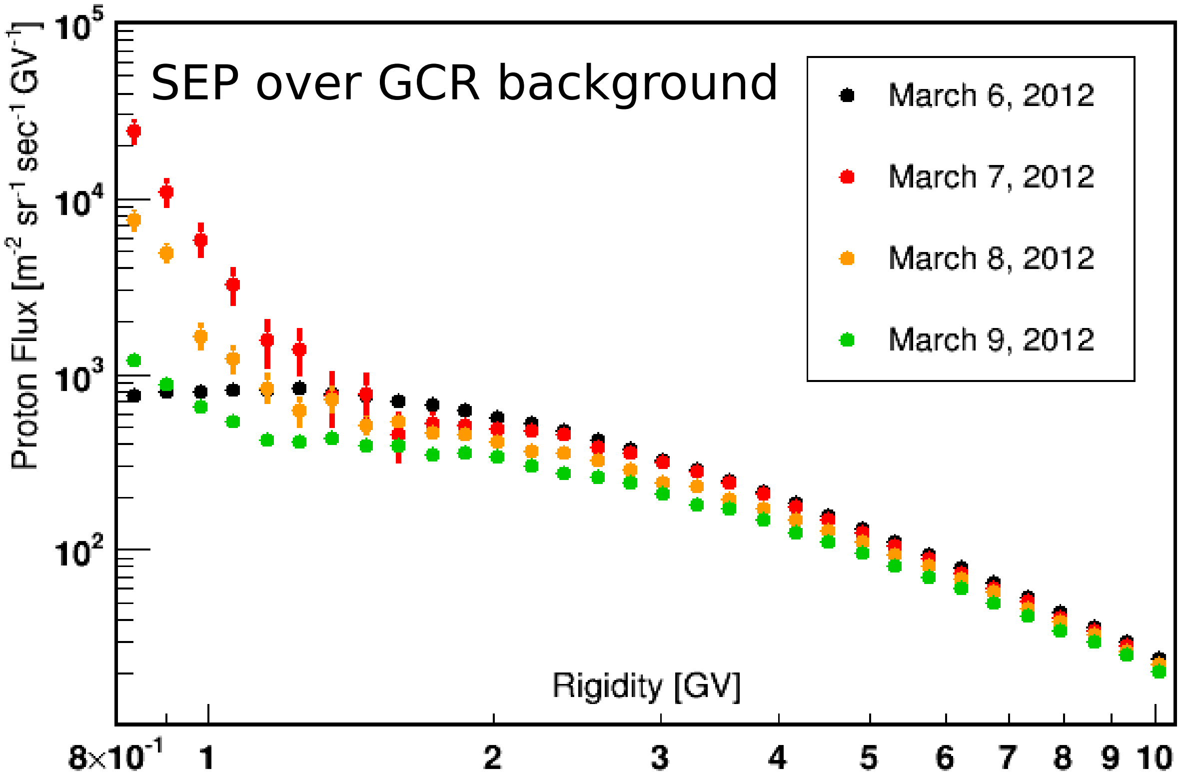
Solar Energetic Particles Observed as an Excess above the GCR Background



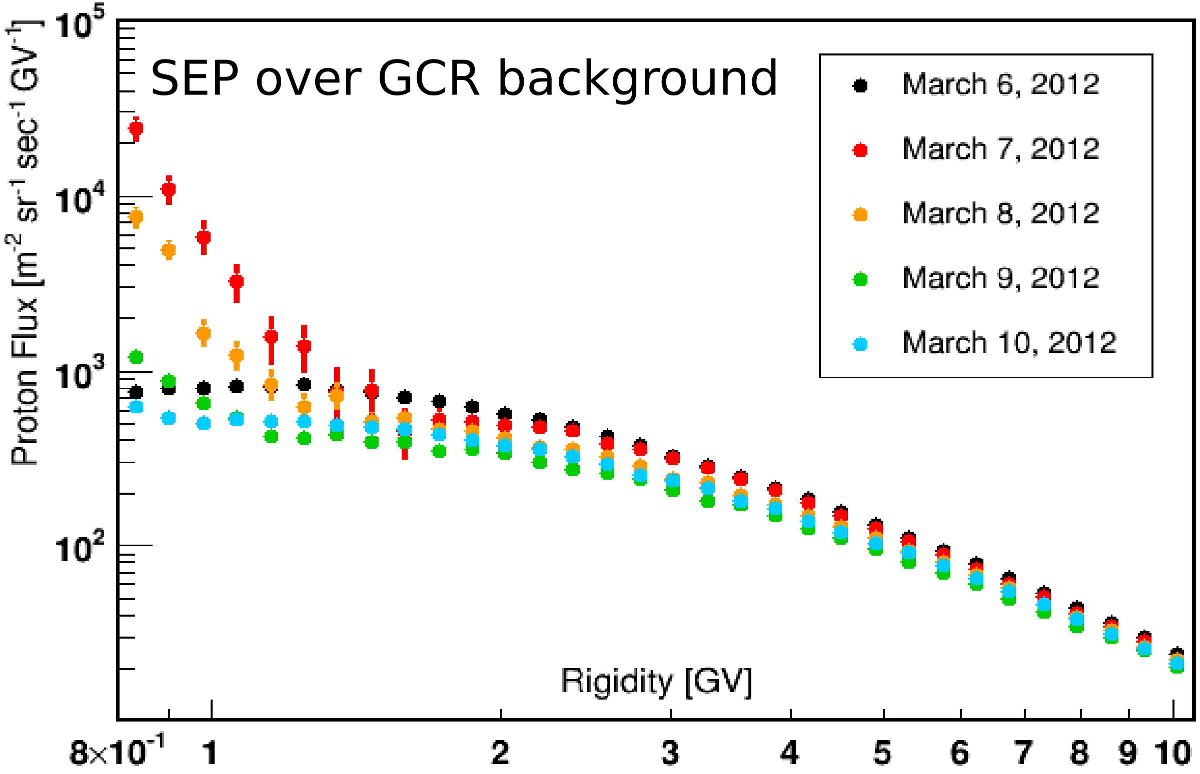
Solar Energetic Particles Observed as an Excess above the GCR Background



Solar Energetic Particles Observed as an Excess above the GCR Background



Solar Energetic Particles Observed as an Excess above the GCR Background



Solar Energetic Particles Observed by AMS

AMS SEP events from May 2011 to May 2016.

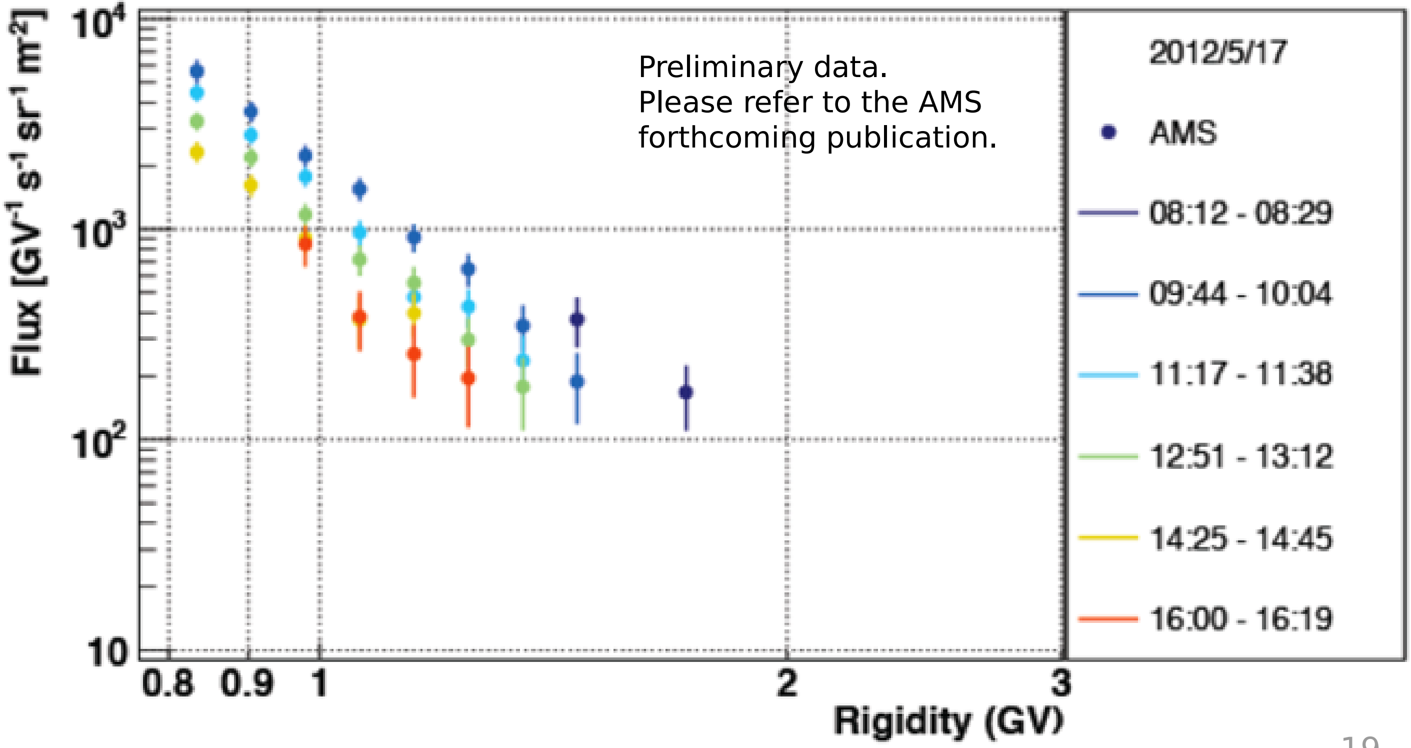
SEPs are typically associated with M- and X-class flares and fast CMEs.

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**

AMS Multi-orbit Observations
SEP Time evolution

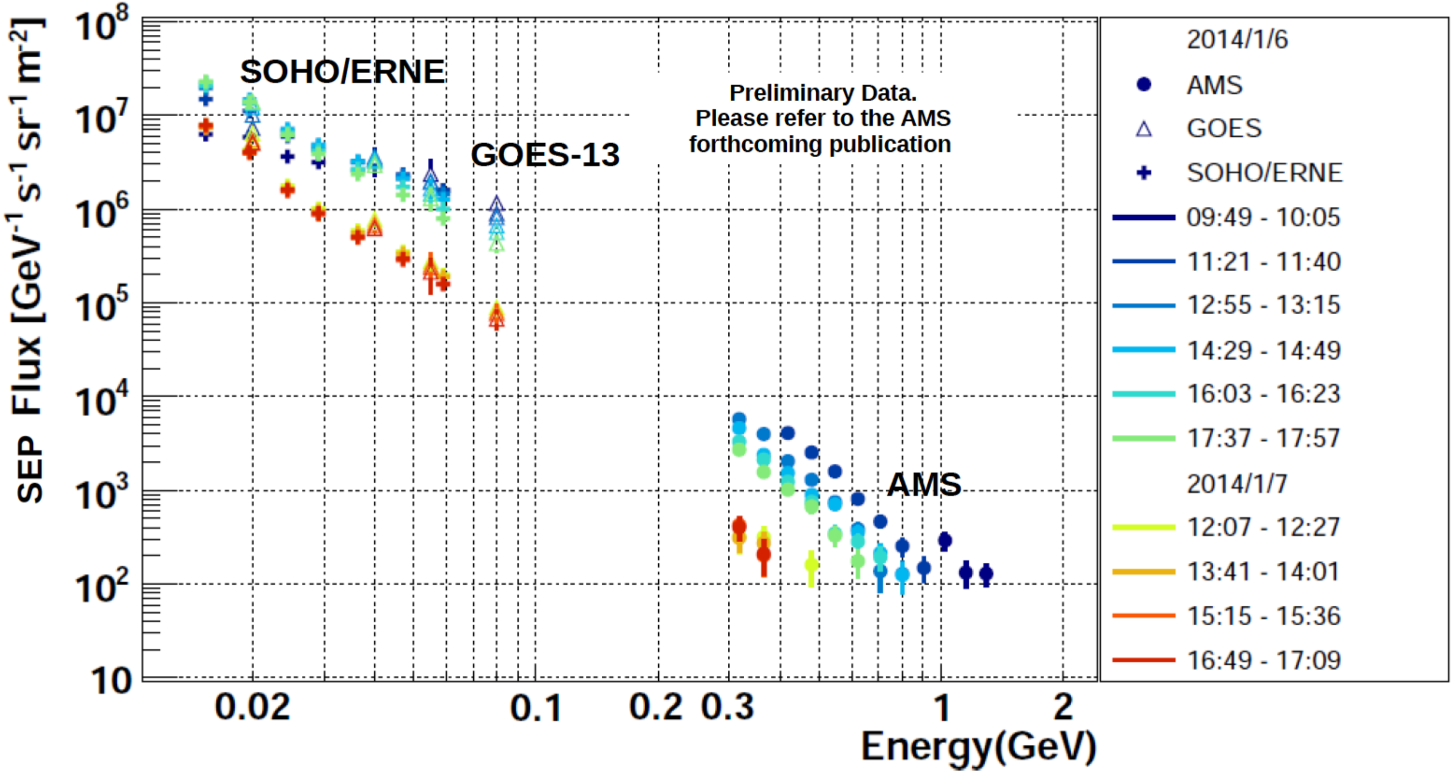
Average integration time about 20 minutes

May 17, 2012



Multi-spacecraft Observation

AMS data, combined with other instruments at lower energy, provide a baseline for the modeling of SEP production.

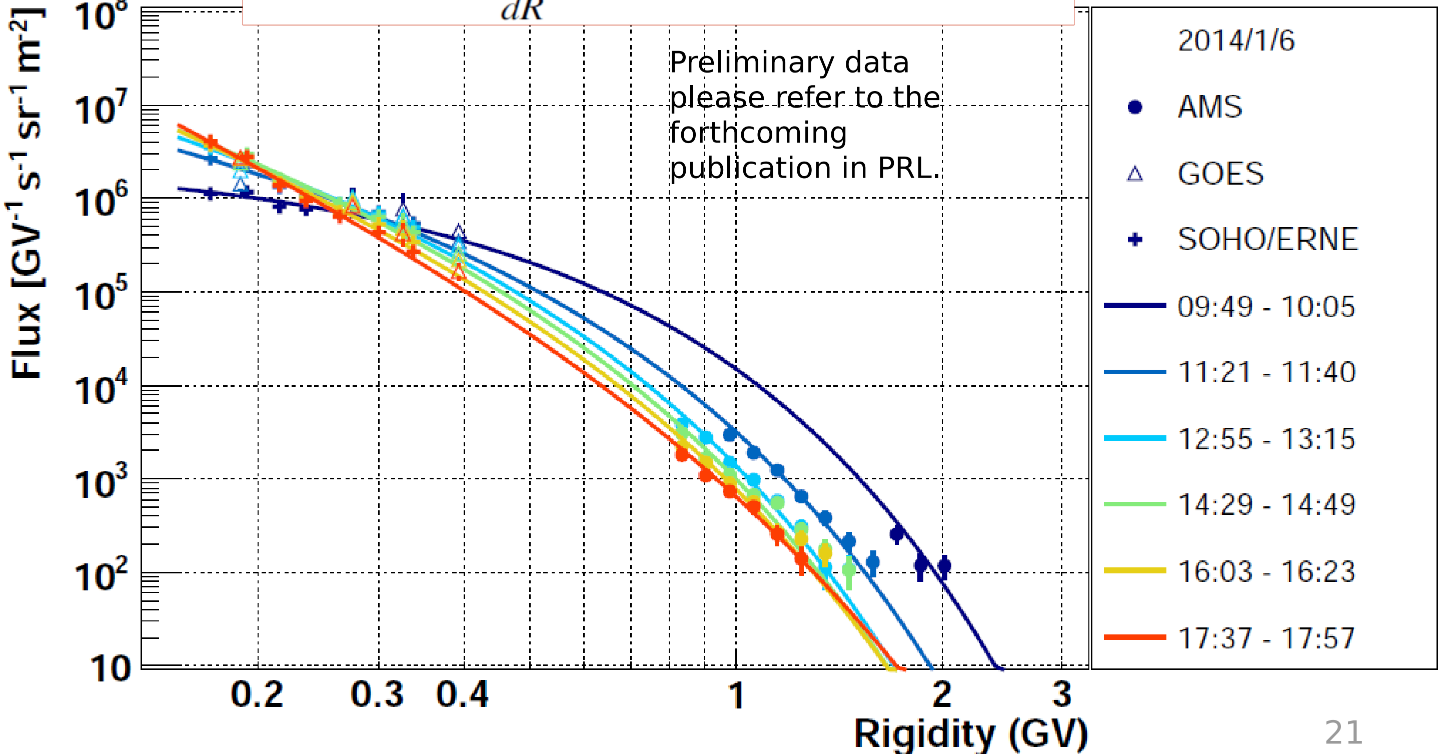


January 6, 2014 Event - time evolution

Ellison-Ramatay PL*Exponential in Rigidity

Diffusive Shock Acceleration by CMEs

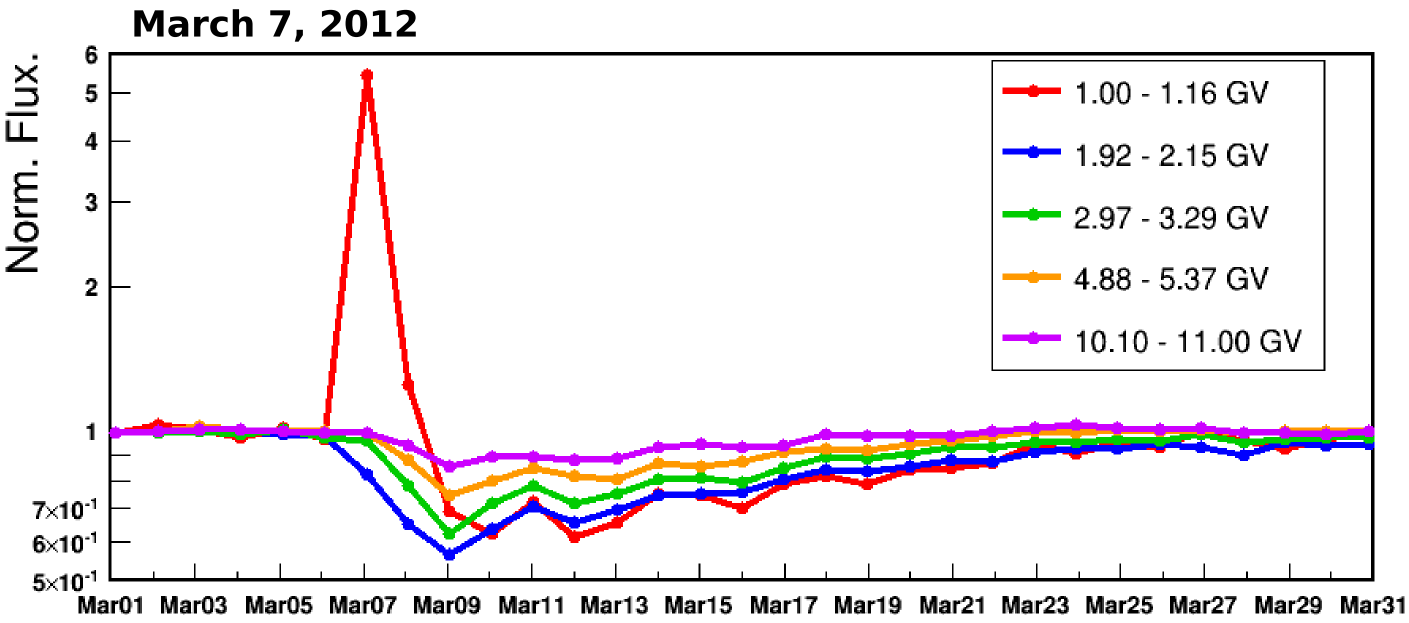
$$\frac{dJ}{dR} = AR^{-\gamma}e^{-R/R_0}$$



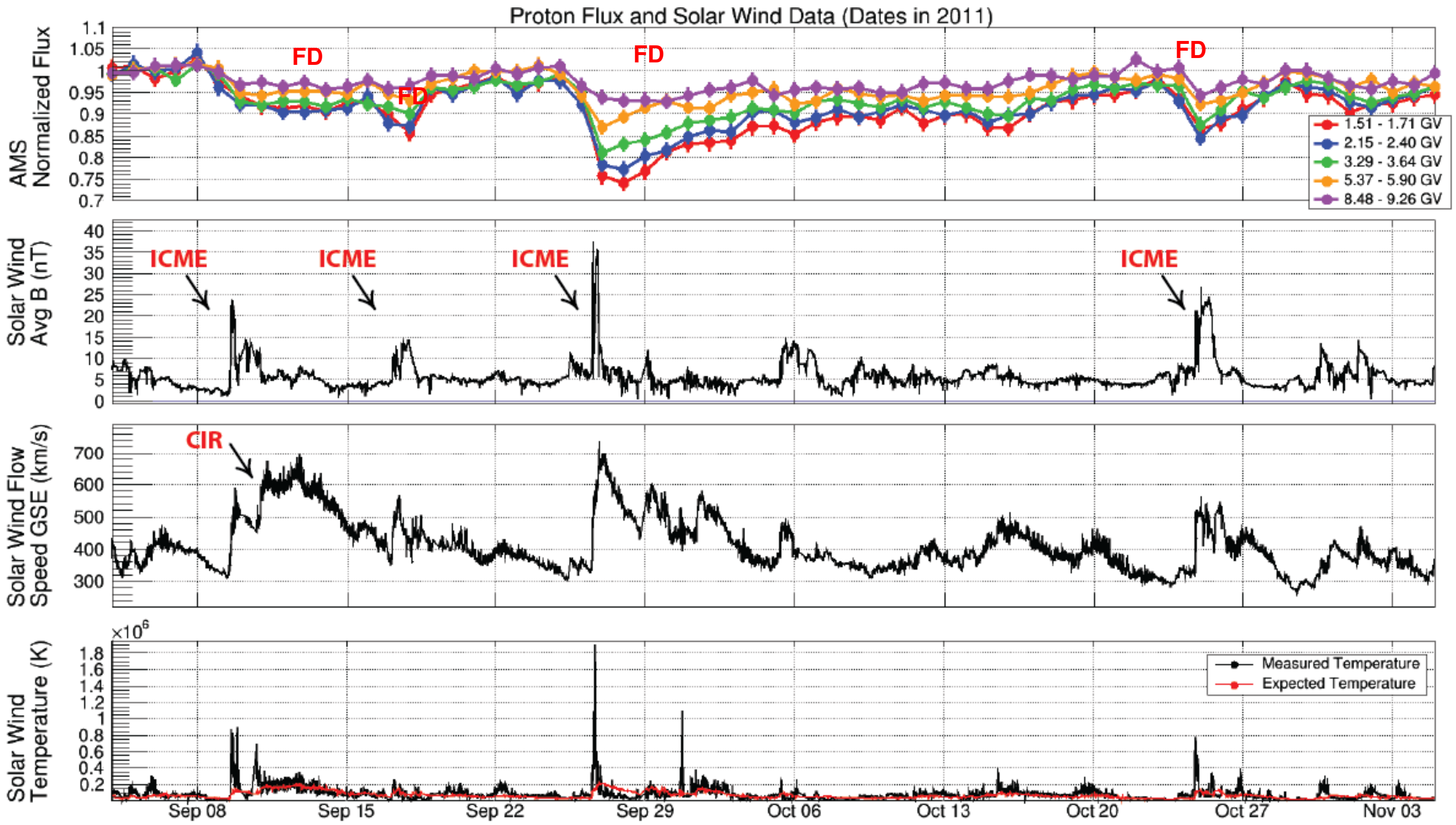
Forbush Decreases

Temporary decrease in the galactic cosmic ray flux

Caused by a passing Interplanetary Coronal Mass Ejection or Corotating Interacting Regions



FD Relationship with Solar Wind



Identified 69 Forbush Decreases in AMS

FD Characteristics for Selected Events

AMS-02 FD	Start Date	Date of Minimum	Duration (Days)	Max Rigidity (GV)	Amplitude 1.92 - 2.15 GV (%)
1	2011/06/23	2011/06/24	6	19.5 - 21.1	8.5 ± 2.2
2	2011/08/06	2011/08/06	4	14.1 - 15.3	16.6 ± 2.0
3	2011/09/26	2011/09/27	23	15.3 - 16.6	20.6 ± 1.9
4	2011/10/25	2011/10/25	3	16.6 - 18.0	9.9 ± 2.1
5	2012/01/22	2012/02/01	13	28.8 - 31.1	21.3 ± 1.9
6	2012/02/27	2012/02/27	4	14.1 - 15.3	8.8 ± 2.2
7	2012/03/08	2012/03/09	20	28.8 - 31.1	41.5 ± 2.8
8	2012/04/06	2012/04/06	4	8.48 - 9.26	7.9 ± 2.2
9	2012/06/17	2012/06/18	5	18.0 - 19.5	10.3 ± 2.4
10	2012/07/15	2012/07/16	9	14.1 - 15.3	20.1 ± 2.0
11	2012/09/04	2012/09/05	4	22.8 - 24.7	14.7 ± 2.1
12	2012/11/24	2012/11/25	5	14.1 - 15.3	8.2 ± 2.2
13	2013/03/17	2013/03/19	16	21.1 - 22.8	17.9 ± 2.0
14	2013/04/15	2013/04/15	3	13.0 - 14.1	10.5 ± 2.2
15	2013/06/23	2013/06/28	9	12.0 - 13.0	12.1 ± 2.2
16	2013/12/15	2013/12/15	4	7.09 - 7.76	6 ± 1.8

- Precise time variation measurements of GCRs provide unique information to probe **the dynamics of solar modulation diffusion and drift**, and to improve the processes of **galactic cosmic ray propagation in the heliosphere.**

- The AMS experiment is measuring **SEPs** with high statistics **at energies not accessible to current satellites** attianing valuable information for the heliophysics and space radiation communities.

- 69 **Forbush decreases** were measured in space with very high accuracy.

- AMS can help to better understand and predict **space radiation** for future **manned missions** to the Moon and Mars.