Solar and Heliospheric Physics

Rapporteur Talk

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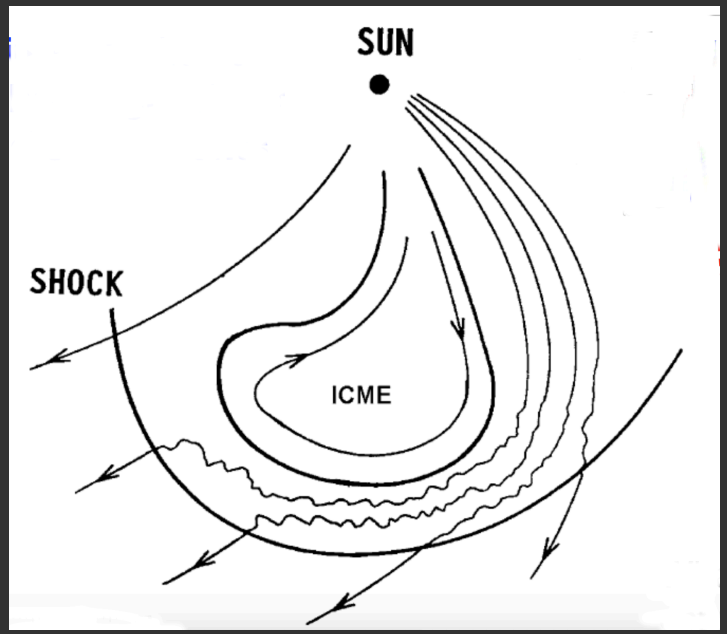
Key questions

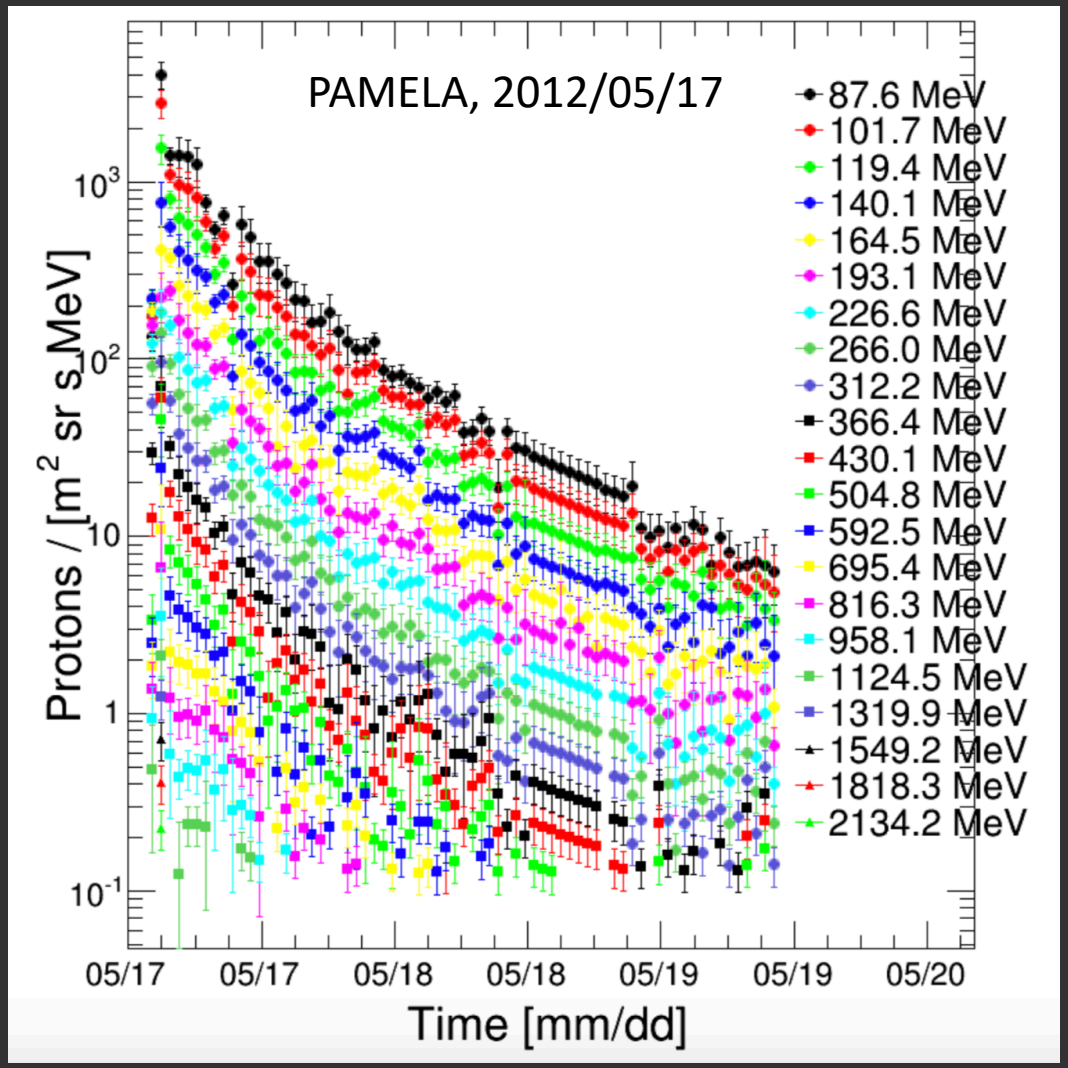
1. Where and how is particle acceleration taking place?
2. How is propagation processing particle fluxes, spectra, etc?
3. How have conditions in the heliosphere evolved over time?

1. Where and how is particle acceleration taking place?

Solar Energetic Particles

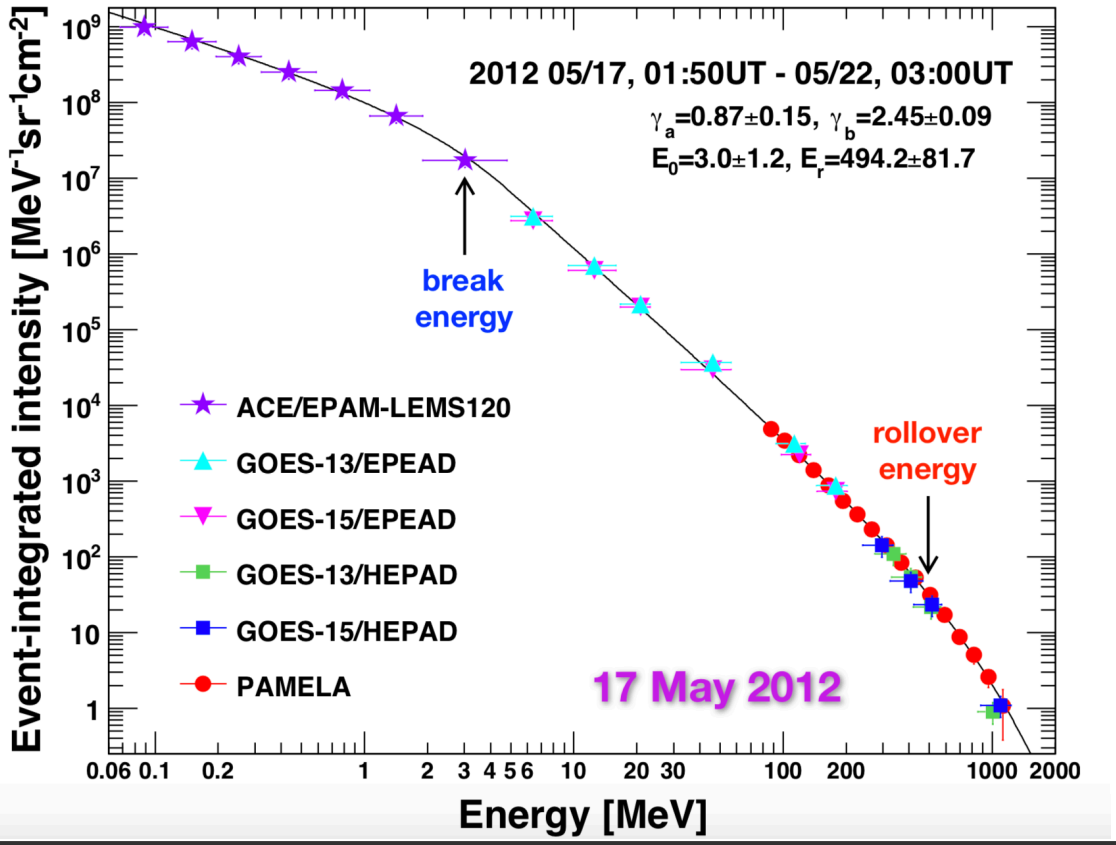
- Accelerated during Coronal Mass Ejections (CMEs) and flares

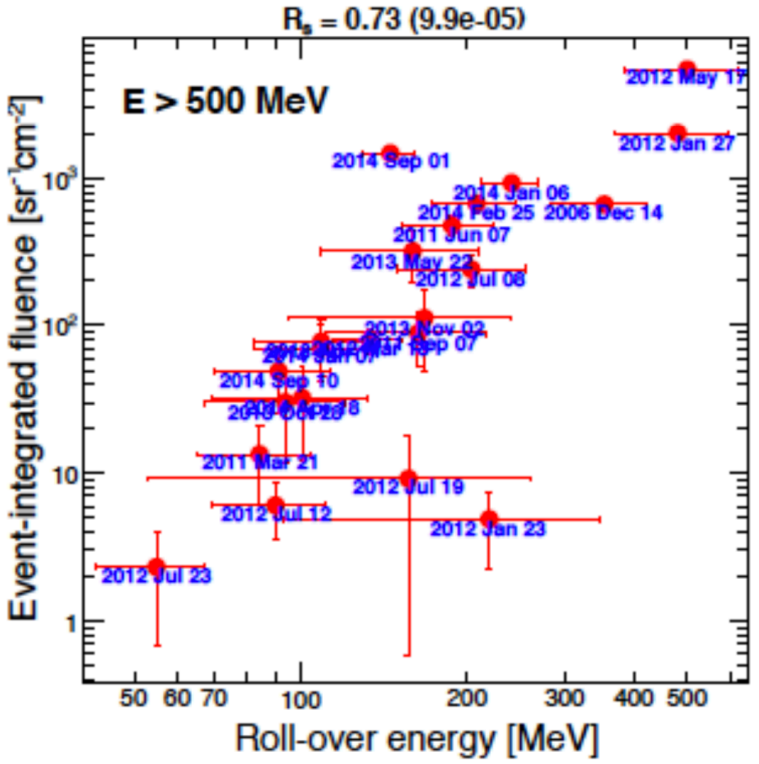




Bruno et al SH7a

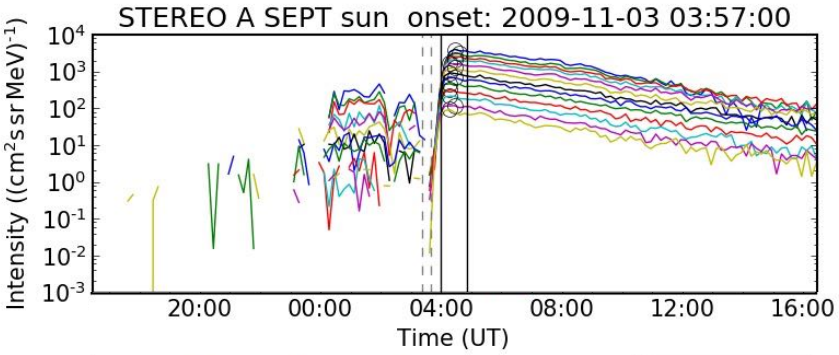
SEP proton spectra



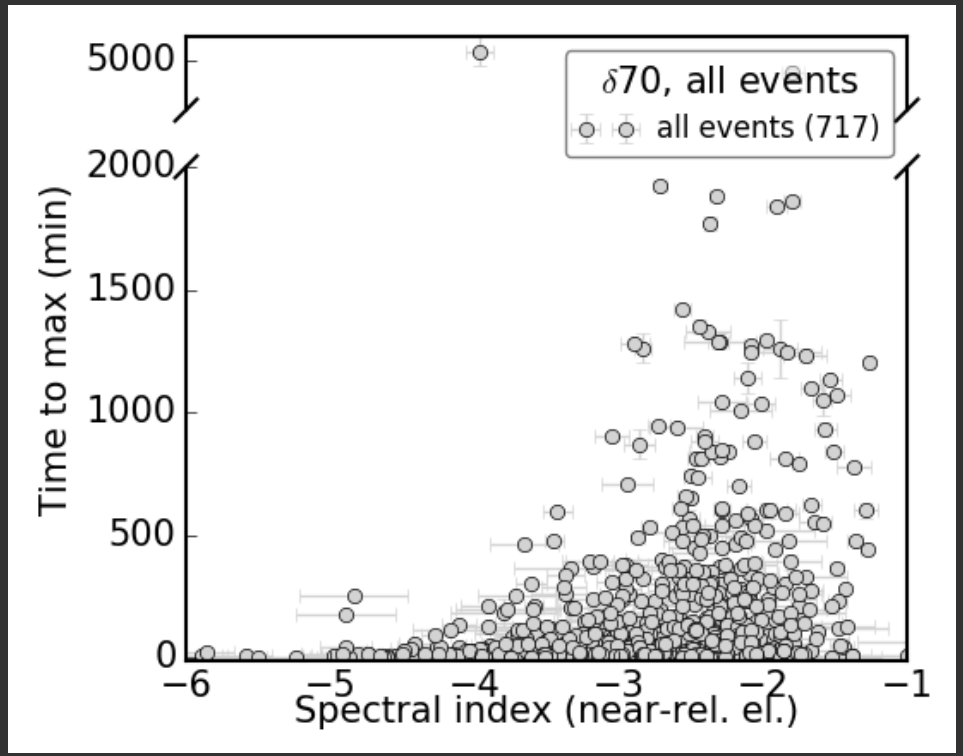


Bruno et al SH7a

SEP electron spectra

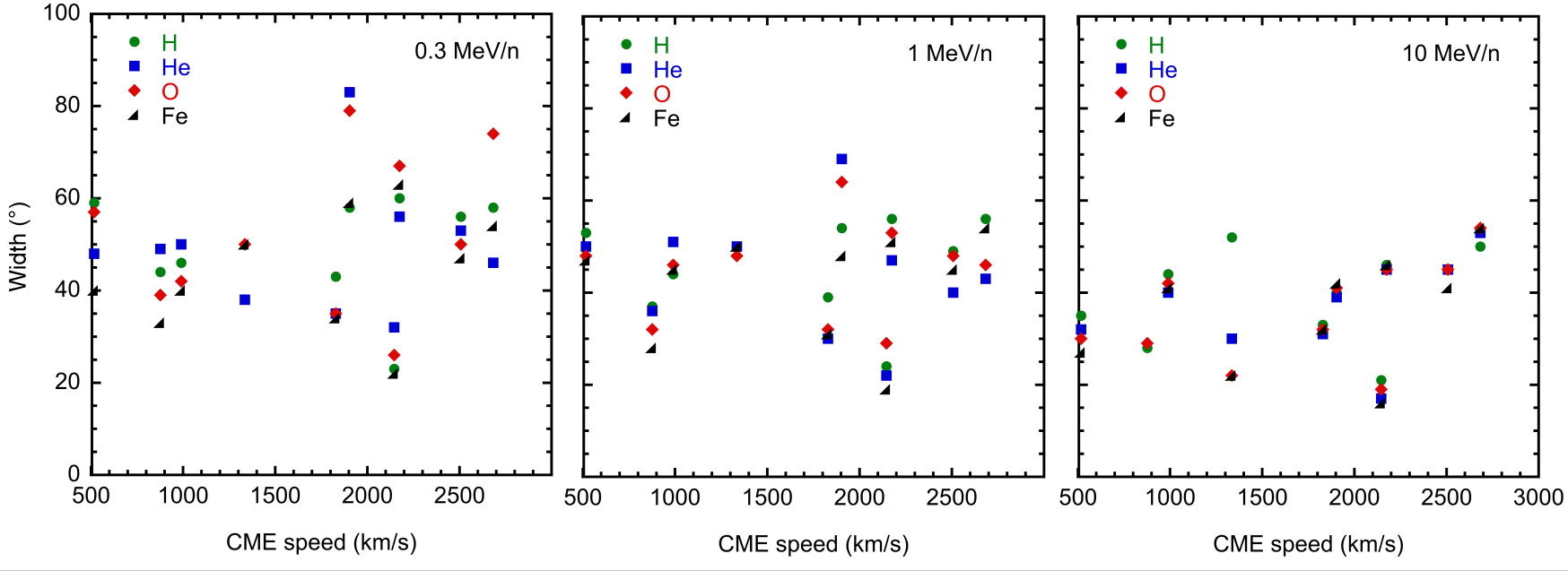


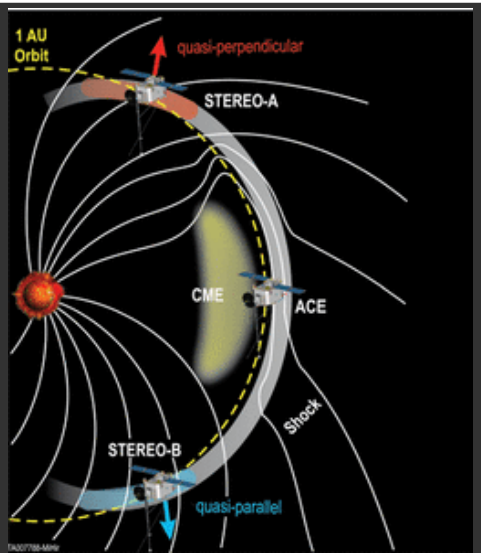
- 717 solar electron events (45-450 keV STEREO/SEPT)



Dresing, Kuhl, SH3g

Multi-spacecraft SEP observations

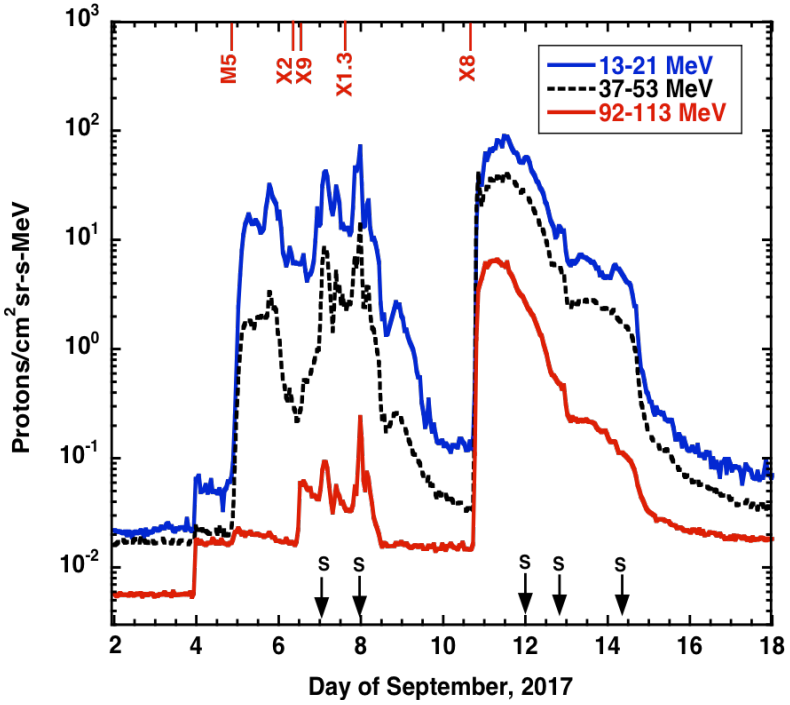


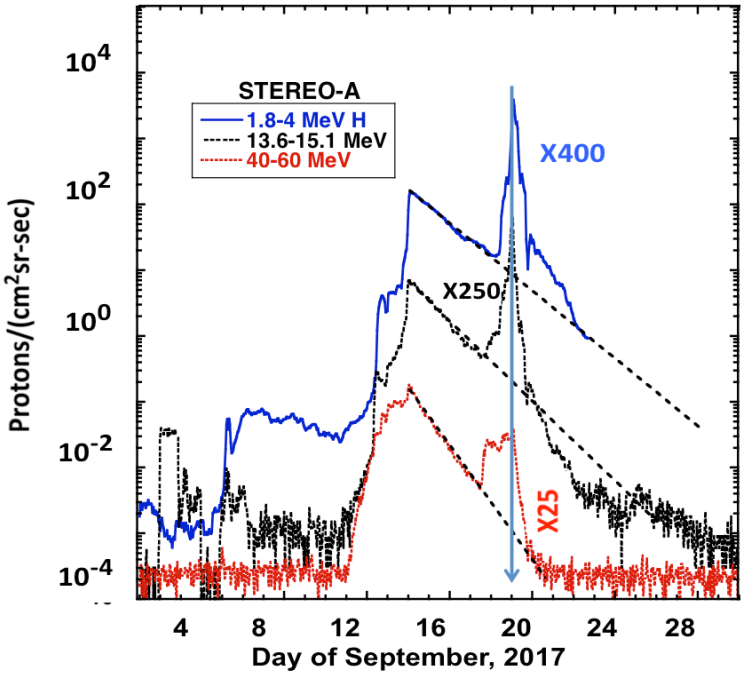


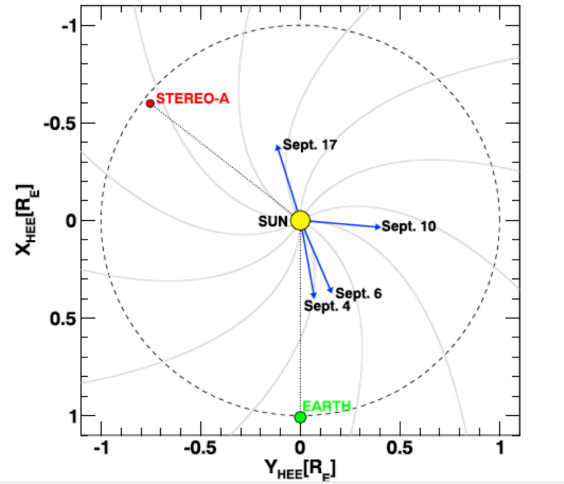
Cohen et al SH3f

- STEREO H, He, O, Fe (0.3-10 Mev/nuc)
- Width of SEP event in interplanetary space does not correlate with Coronal Mass Ejection (CME) properties

Multi-spacecraft SEP observations



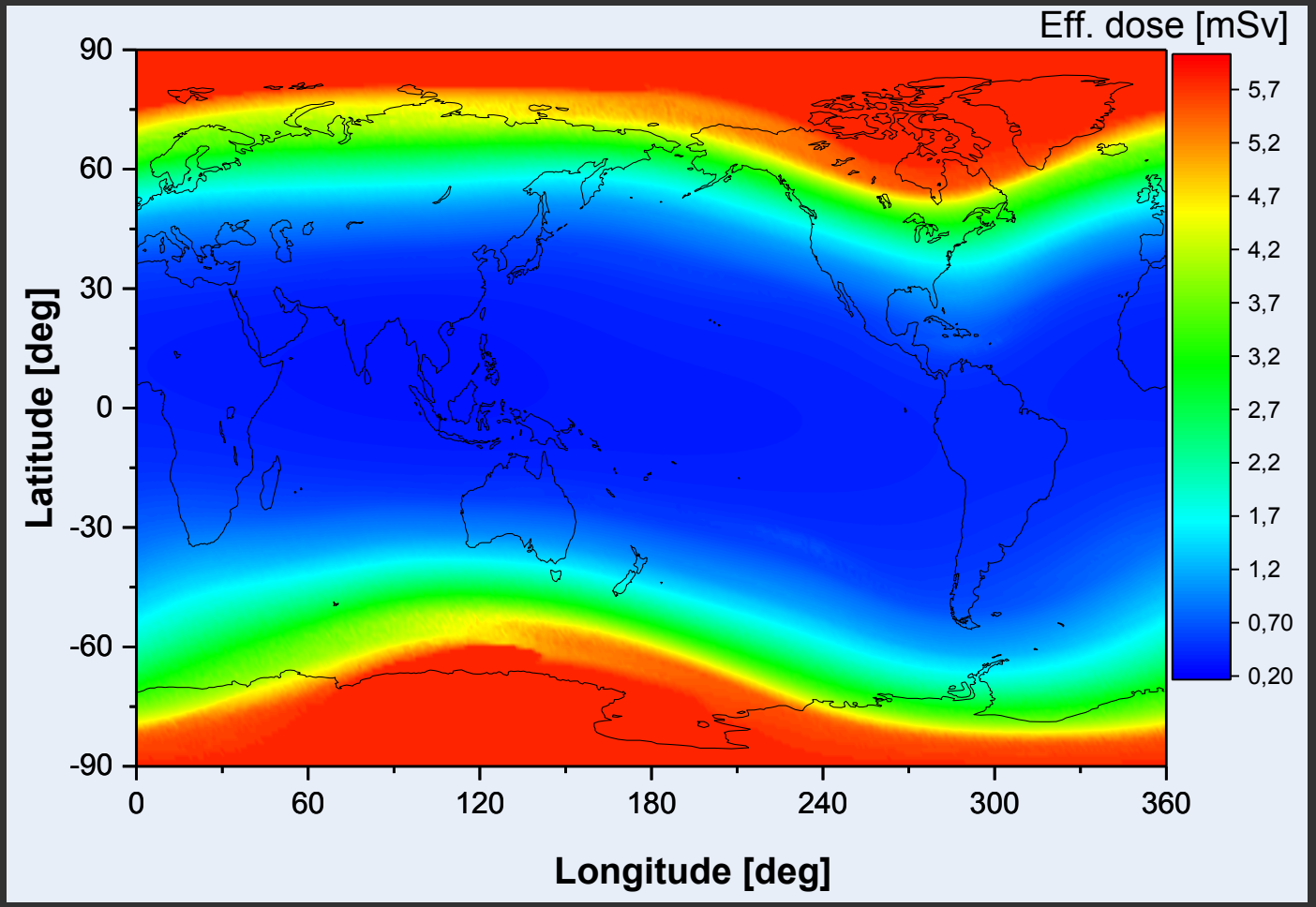




Mewaldt et al SH3d

- September 2017 events at Earth and STEREO A

Radiation dose associated with GLEs

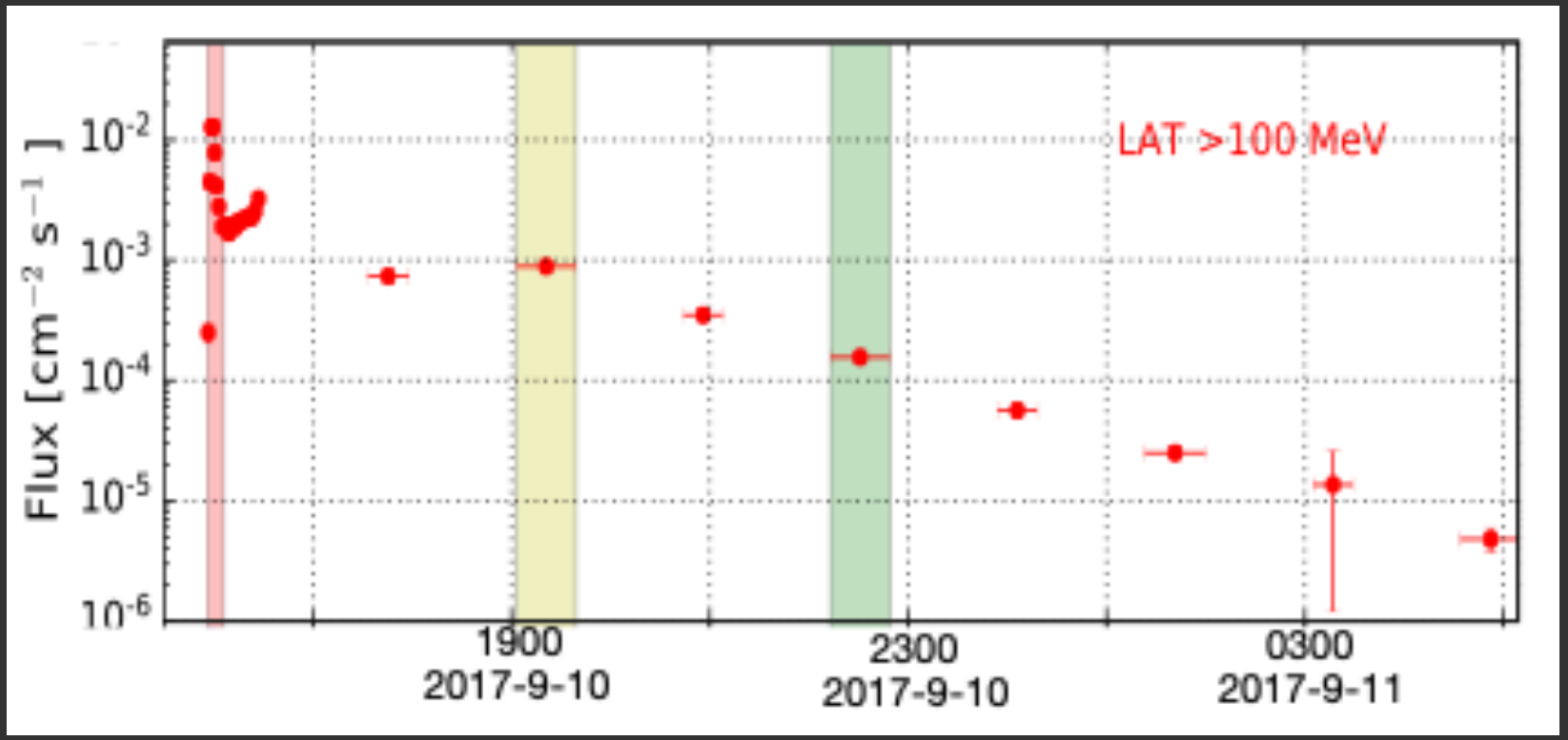


Mishev et al, SH7f

- Effective dose at 35 kft over first 3 hr of GLE 5, from neutron monitor data

Long duration solar γ-ray emission

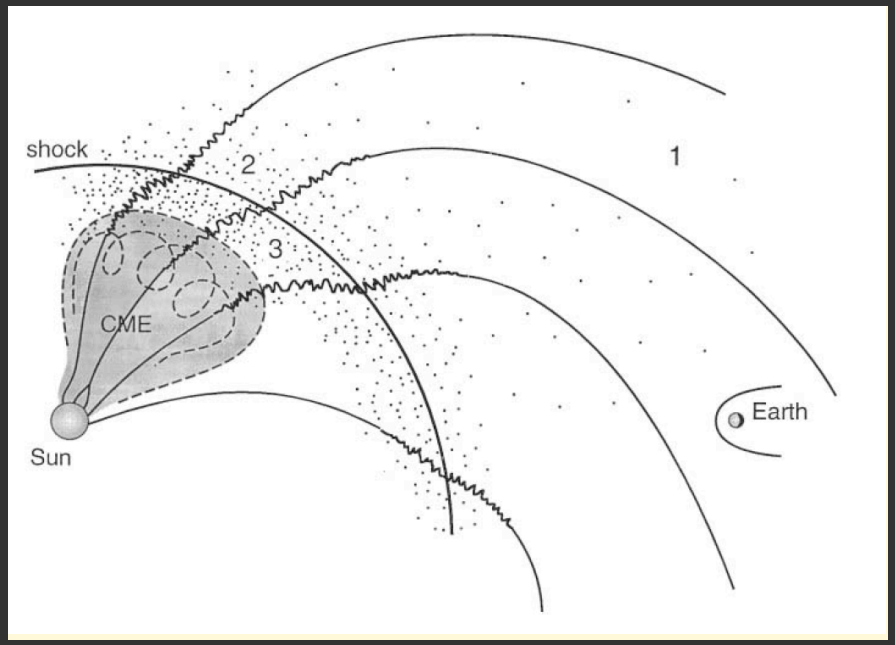
- 2017 September 10 event, FERMI/LAT >100 MeV

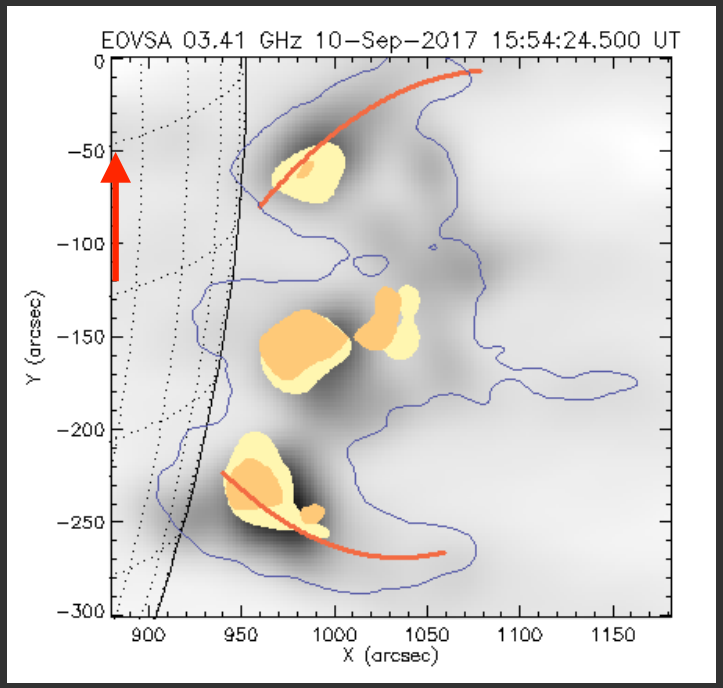


Ryan et al, SH5d

Mechanisms for extended γ-ray emission

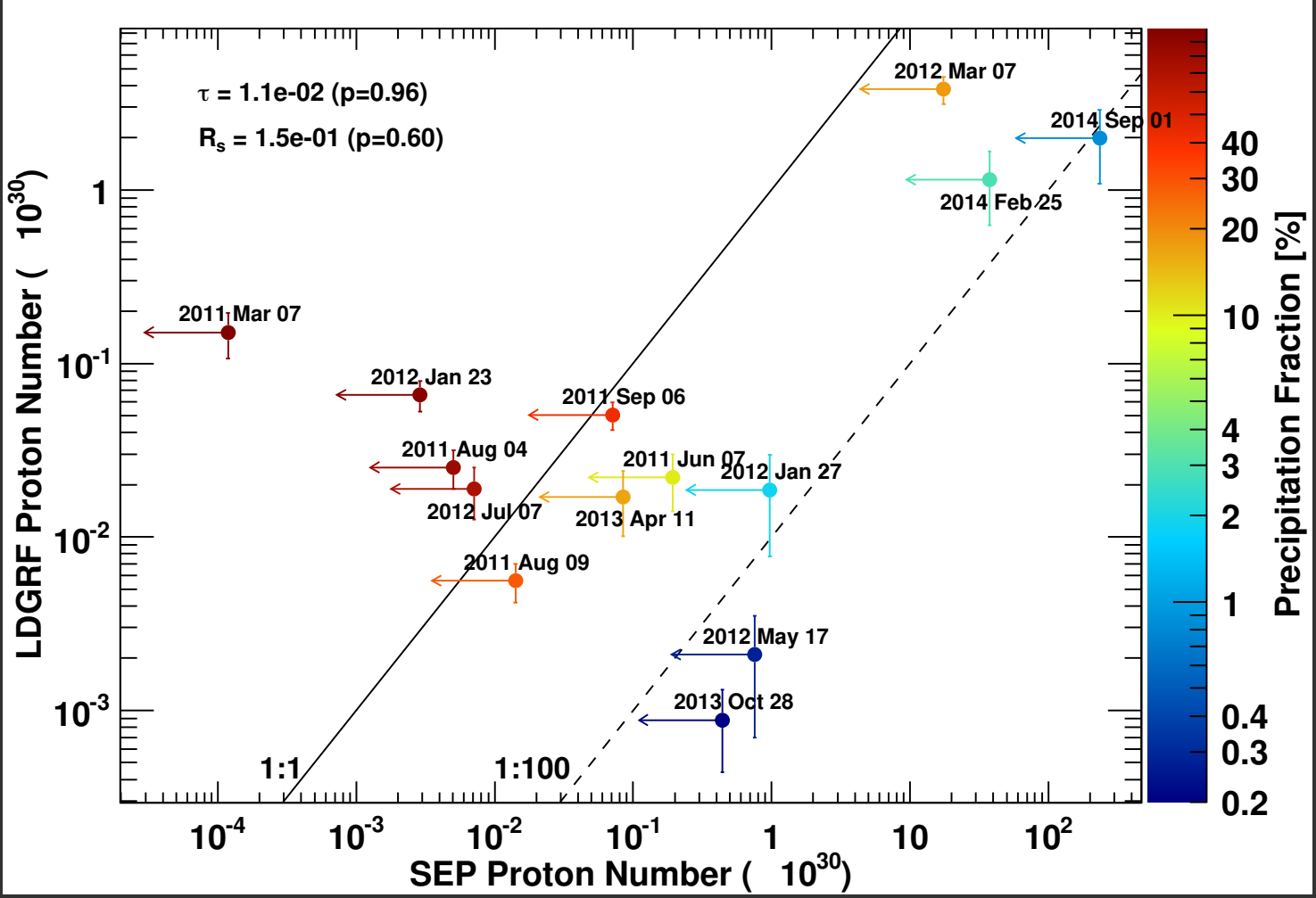
- Acceleration at CME driven shock + back-precipitation
- Trapping and acceleration (2nd order Fermi) in large coronal loops





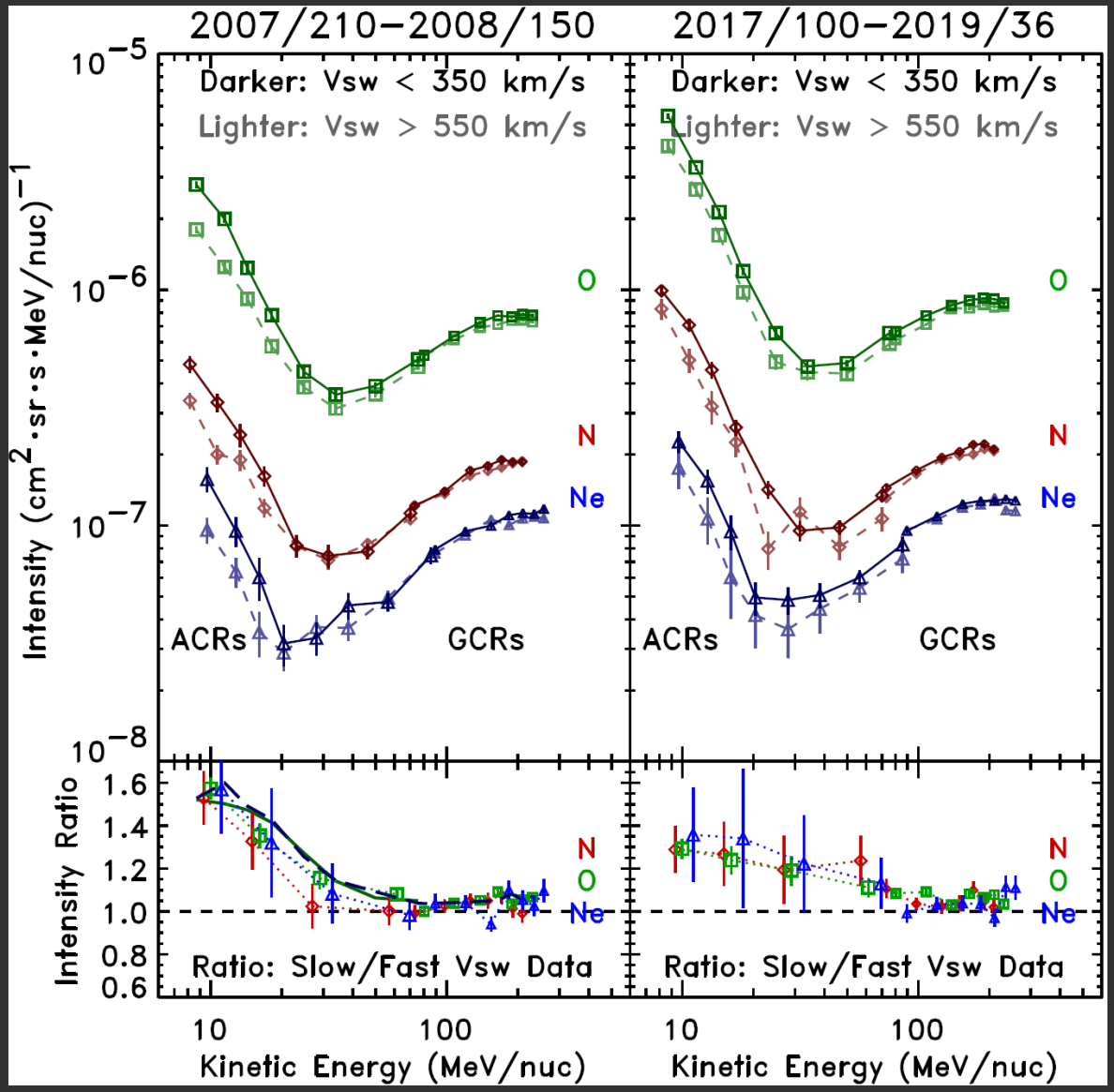
Ryan et al, SH5d

Comparing interacting particle and SEP numbers



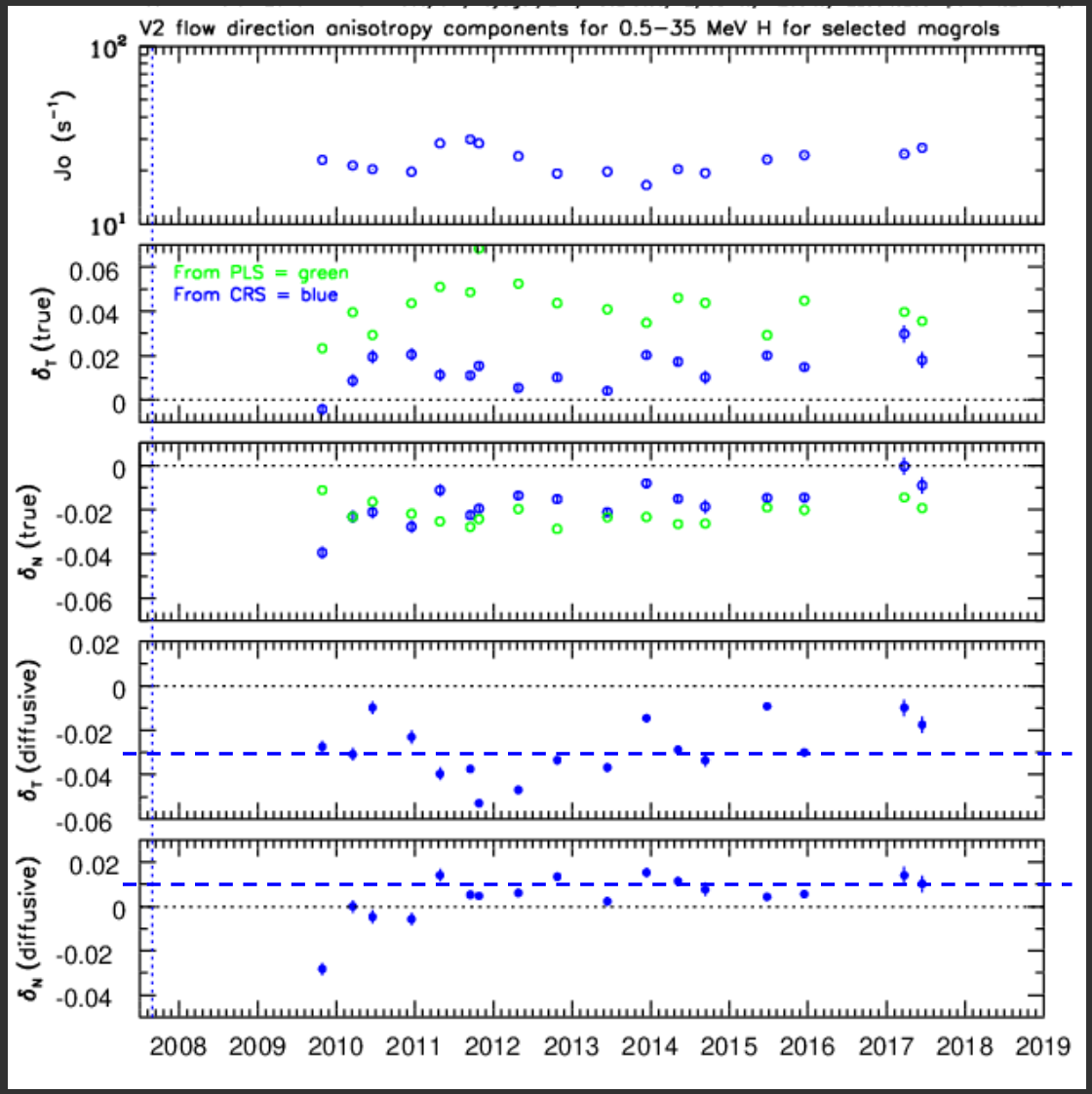
de Nolfo et al, SH5c

Anomalous Cosmic Rays



Leske et al, SH4e

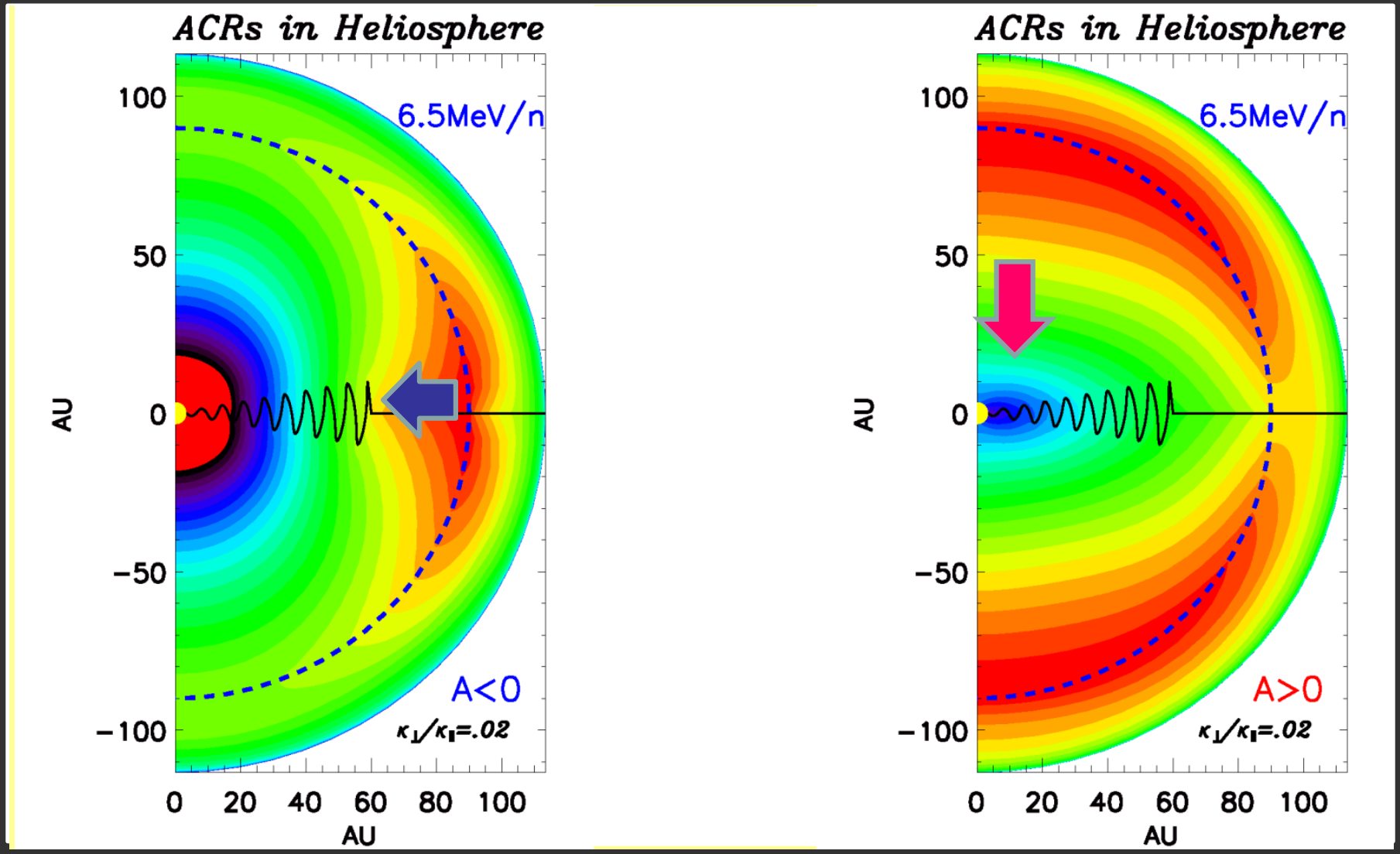
Anisotropy of ACRs



- Anisotropy measurements at Voyager 2
- Diffusive flow is equatorward and towards nose of termination shock, from flank or tail
- Supports flank or tail as main acceleration site

Cummings et al, SH1a

Modelling ACRs



Kota et al SH1b

2. How is propagation processing particle intensities, spectra, etc?

Heliospheric modulation of GCRs

- 3D steady state modulation model based on Parker equation:

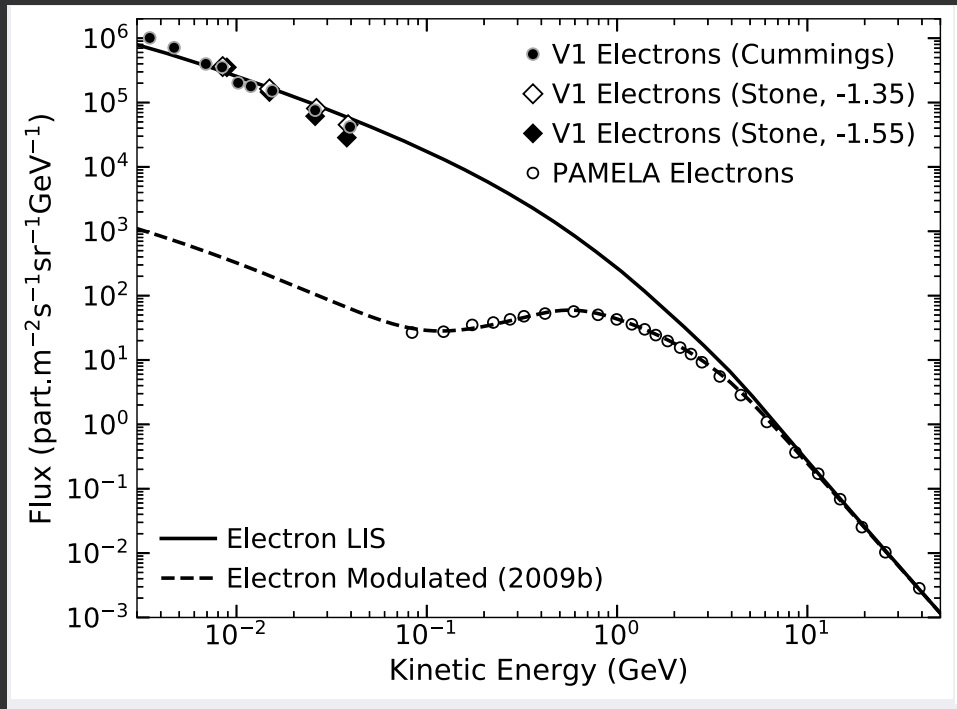
$$\frac{\partial f}{\partial t} = \underbrace{-\vec{V}_{SW}\cdot\vec{\nabla} f}_{\text{Solar wind plasma convection}} \underbrace{-\vec{V}_{D}\cdot\vec{\nabla} f}_{\text{Particle drift}} + \underbrace{\vec{\nabla}\cdot\left(K\cdot\vec{\nabla} f\right)}_{\text{Particle diffusion}} + \underbrace{\frac{1}{3}\vec{\nabla}\cdot\vec{V}_{SW}\frac{\partial f}{\partial \ln R}}_{\text{Energy losses}} + \underbrace{Q}_{\text{Sources/ sinks}}$$

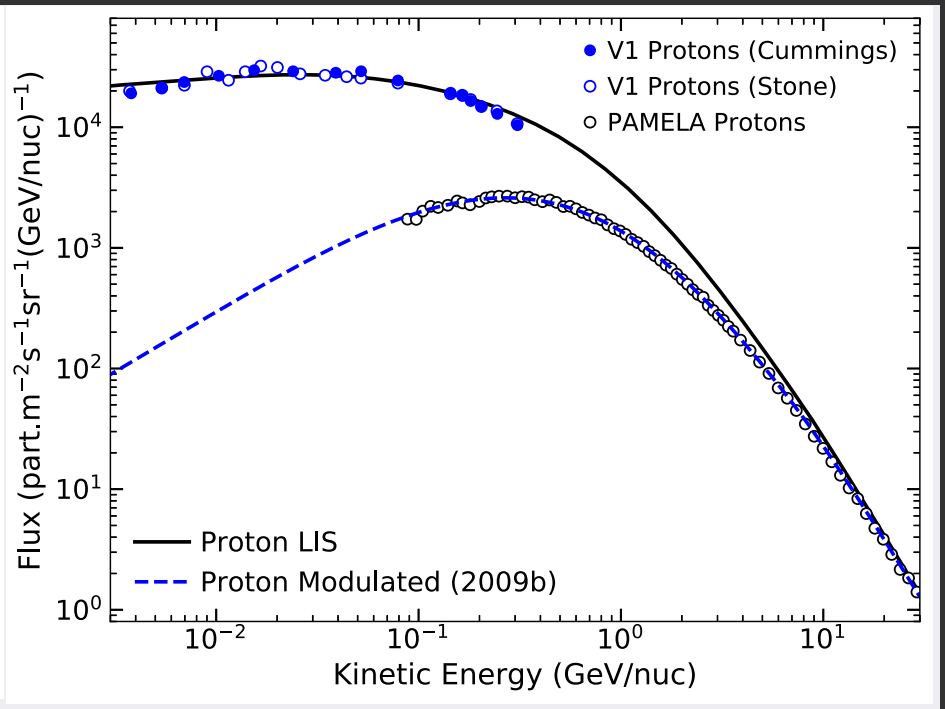
K = diffusion tensor
f = omnidirectional distribution function of GCRs

Eg: Corti et al, SH2b, Bischhoff et al SH1c

Heliospheric modulation of GCRs (1)

- Tune modulation model using proton and electron data at Voyager 1 and PAMELA
- Use GALPROP to derive LISs for a variety of species

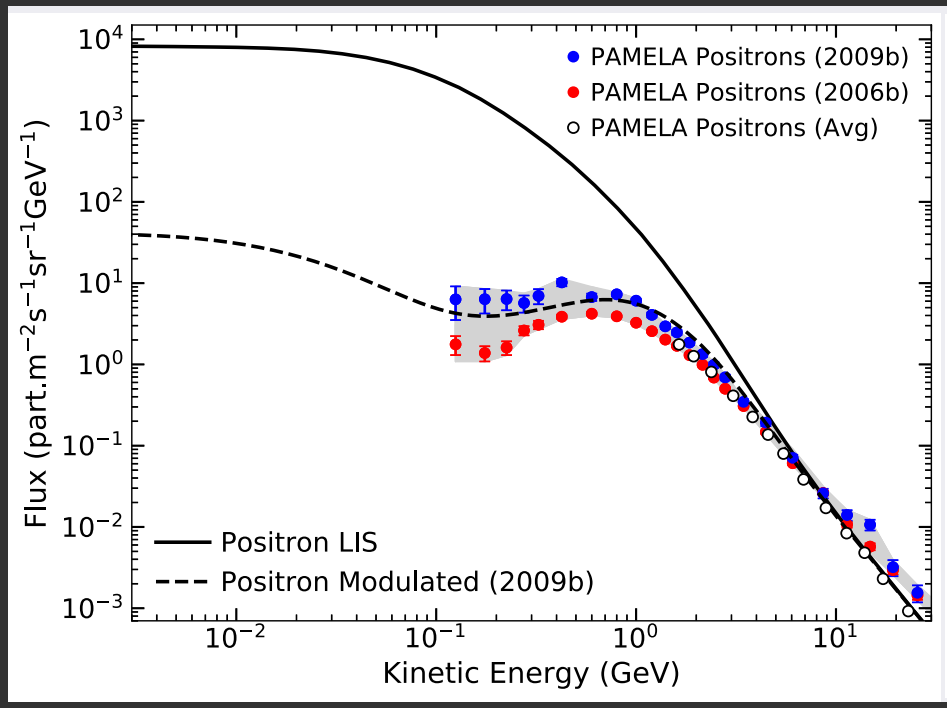


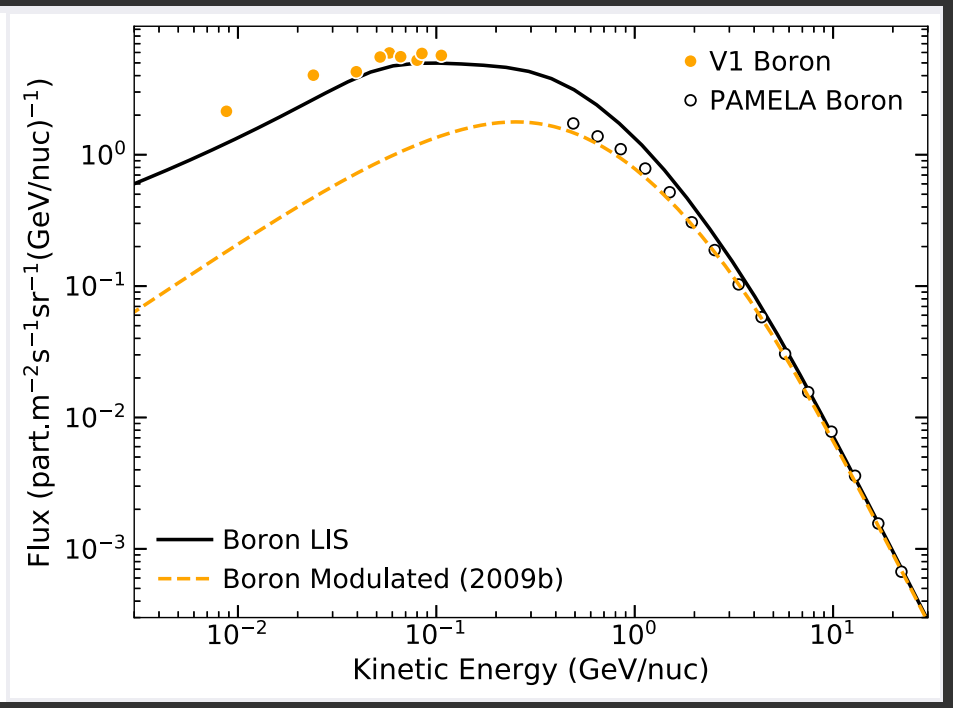


Bischhoff et al SH1c

Heliospheric modulation of GCRs (1)

- Model predicts eg positron and boron spectra

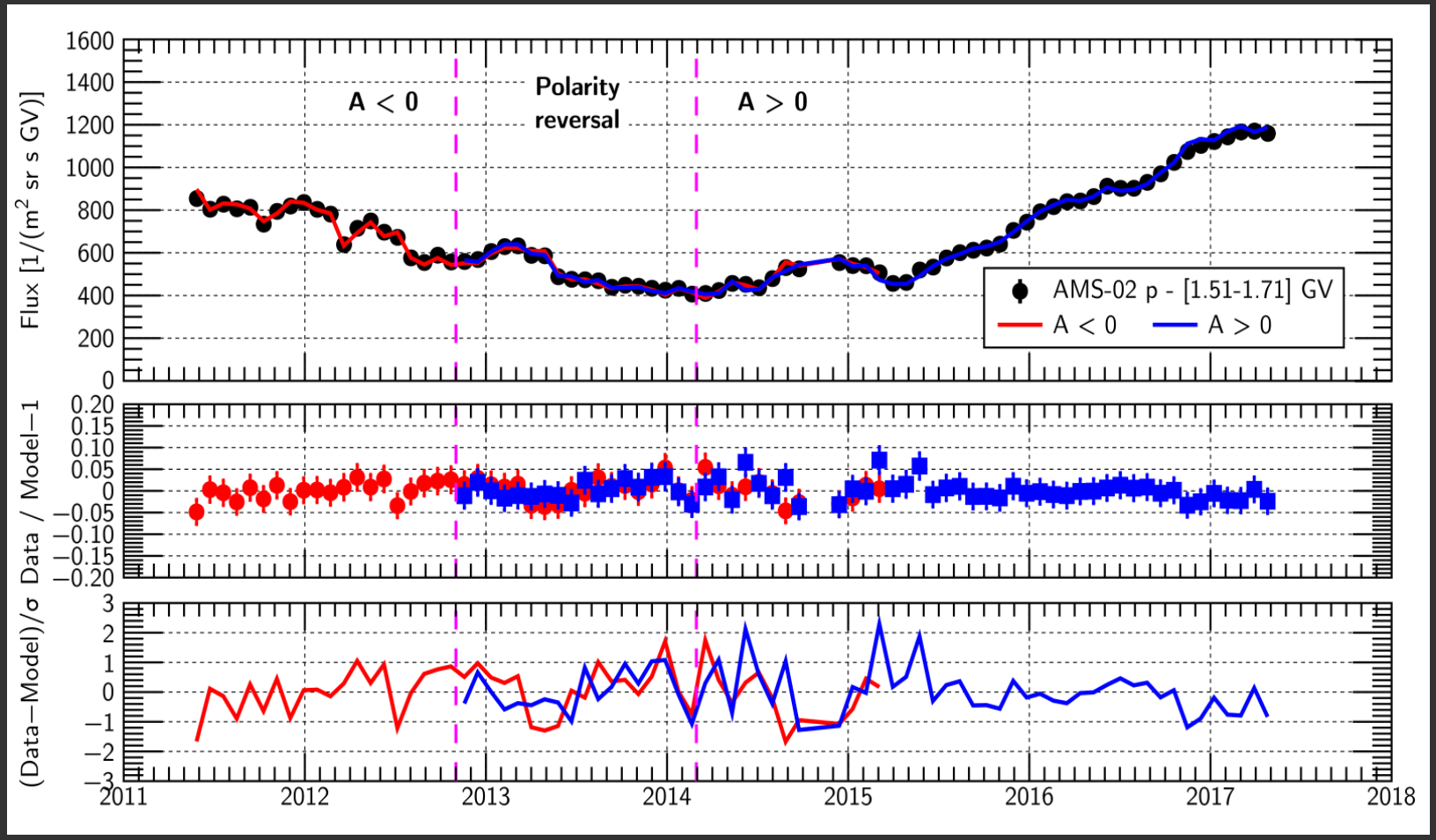




Bischhoff et al, SH1c

Heliospheric modulation of GCRs (2)

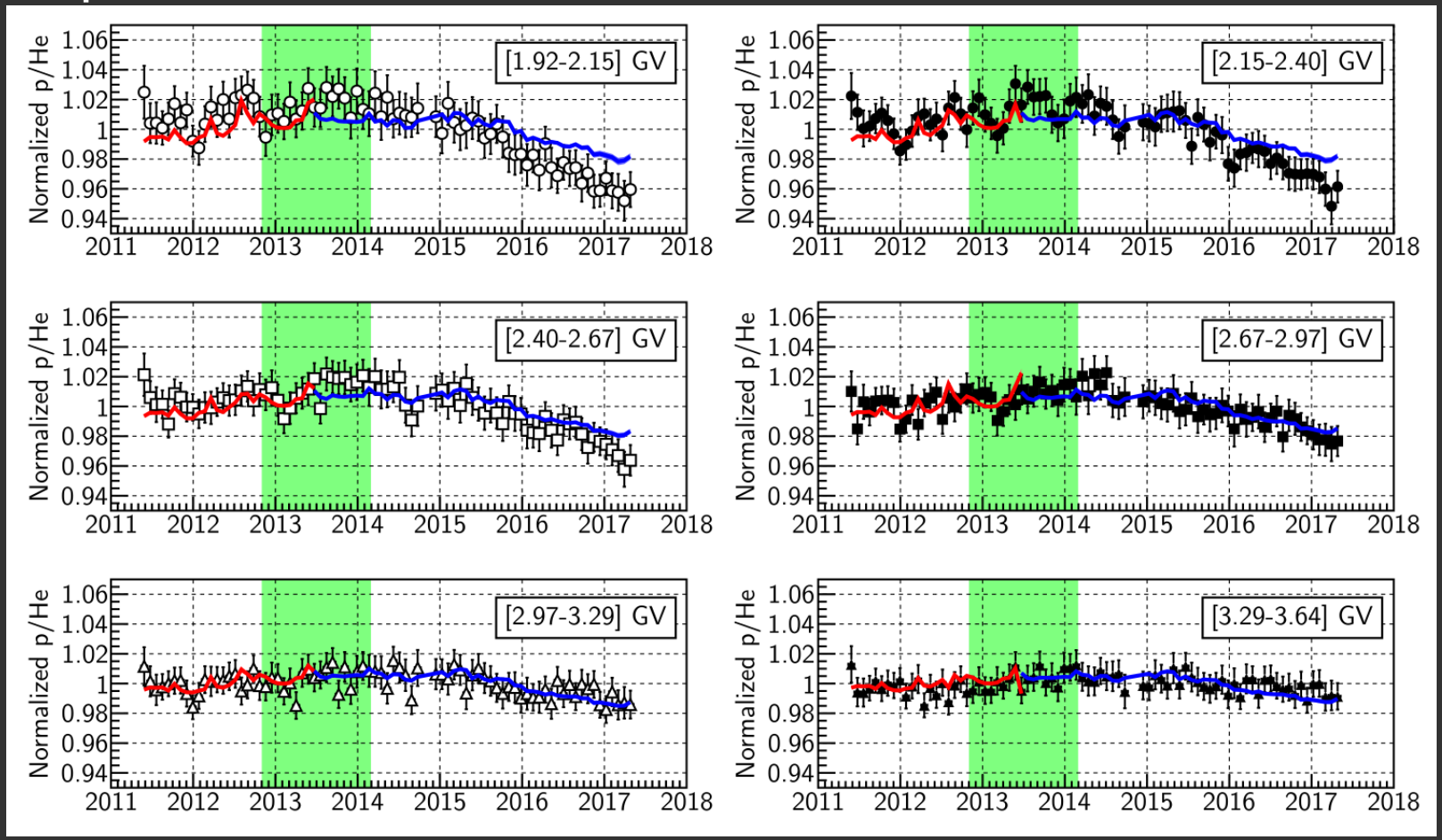
- Modulation model tuned to fit AMS ~1.5 GeV proton flux



Corti et al SH2b

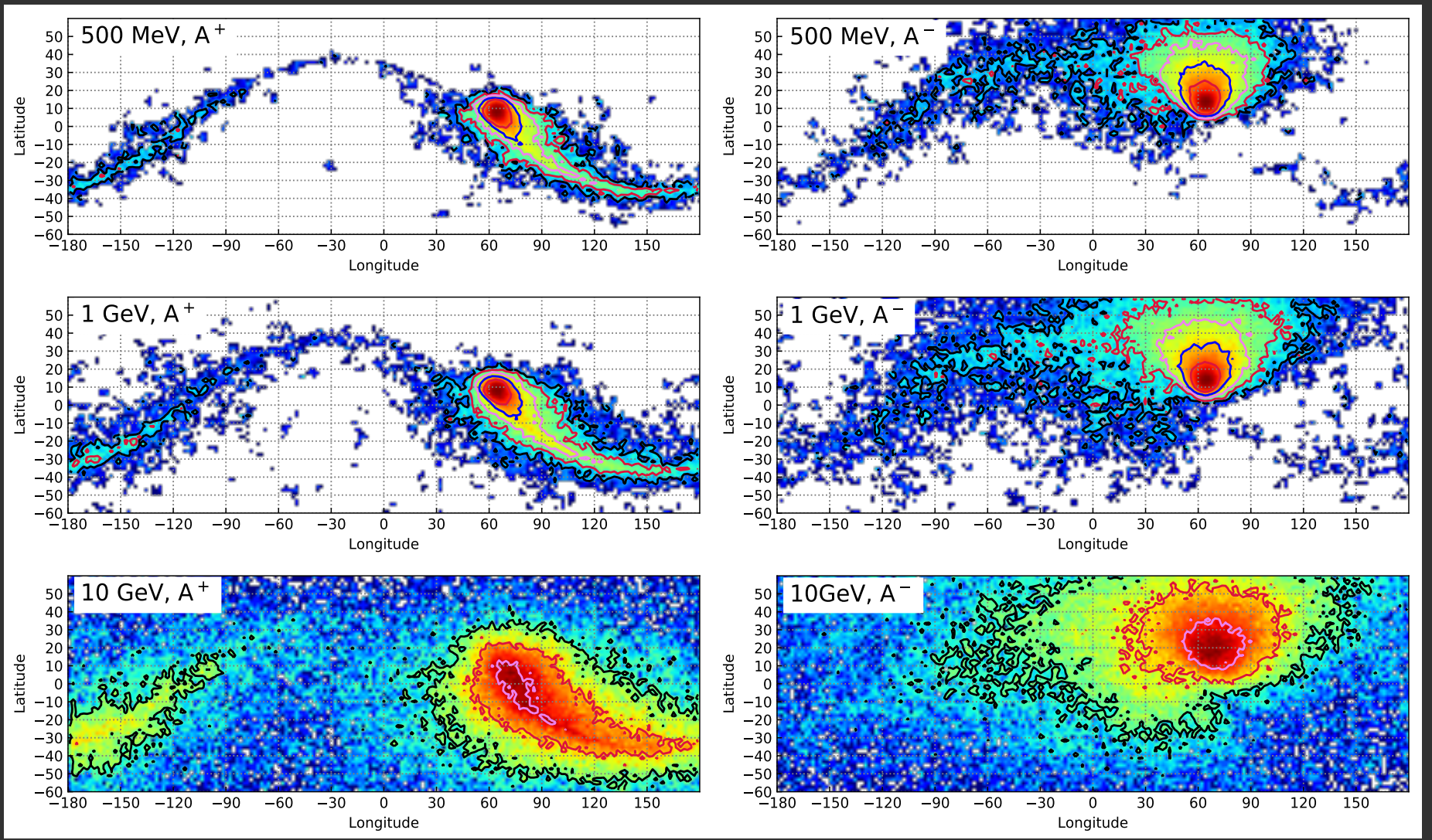
Heliospheric modulation of GCRs (2)

- Decrease of p/He ratio reproduced and attributed to A/Z dependence of diffusion



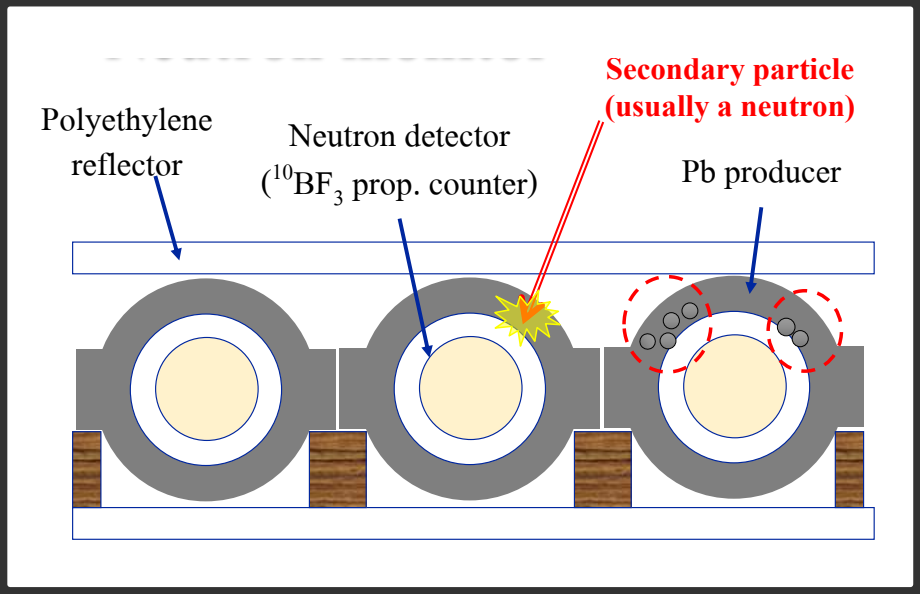
Corti et al, SH2b

Solar relativistic proton propagation



Dalla et al, SH7e

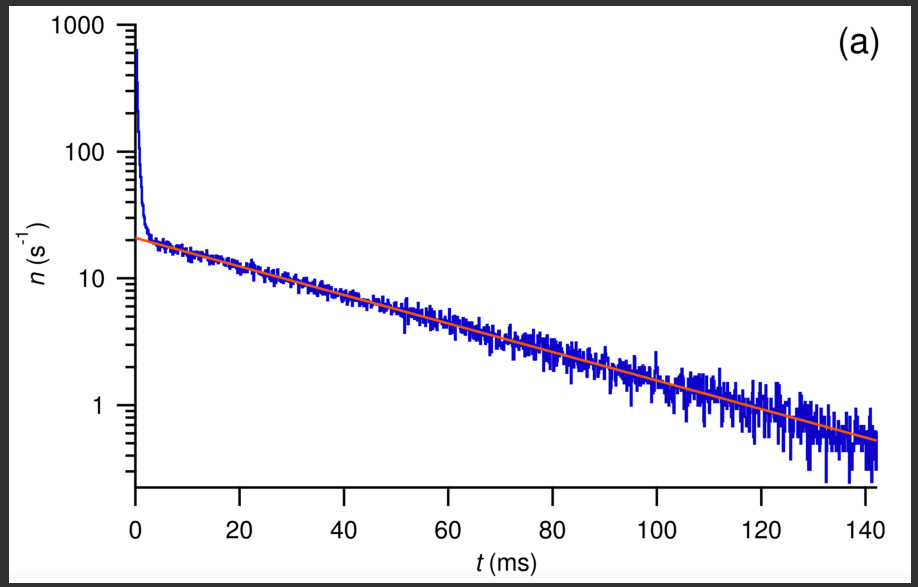
Energy information from neutron monitors



More energetic primary
More energetic secondary

More neutrons in monitor

Higher multiplicity

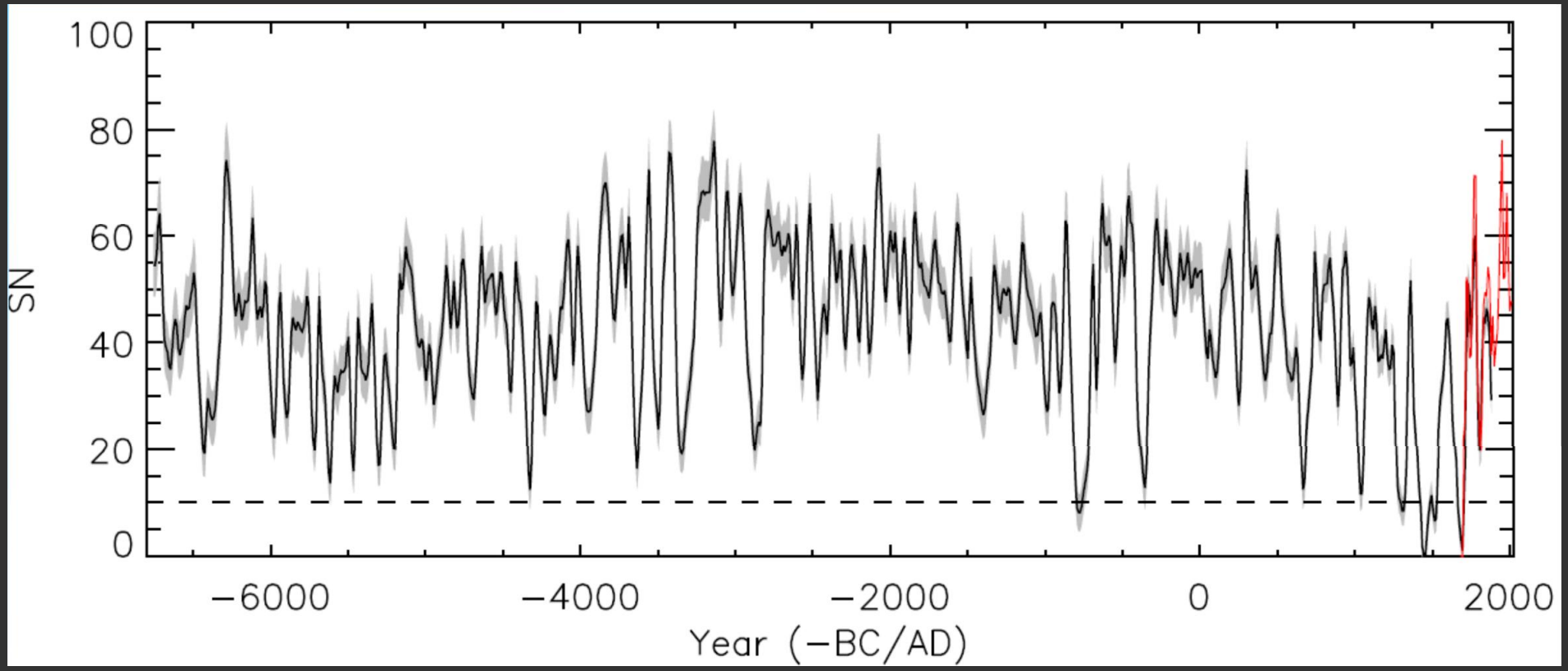


- Time delay <4 ms: correlated arrival of neutrons

Banglieng et al, SH2f

3. How have conditions in the heliosphere evolved over time?

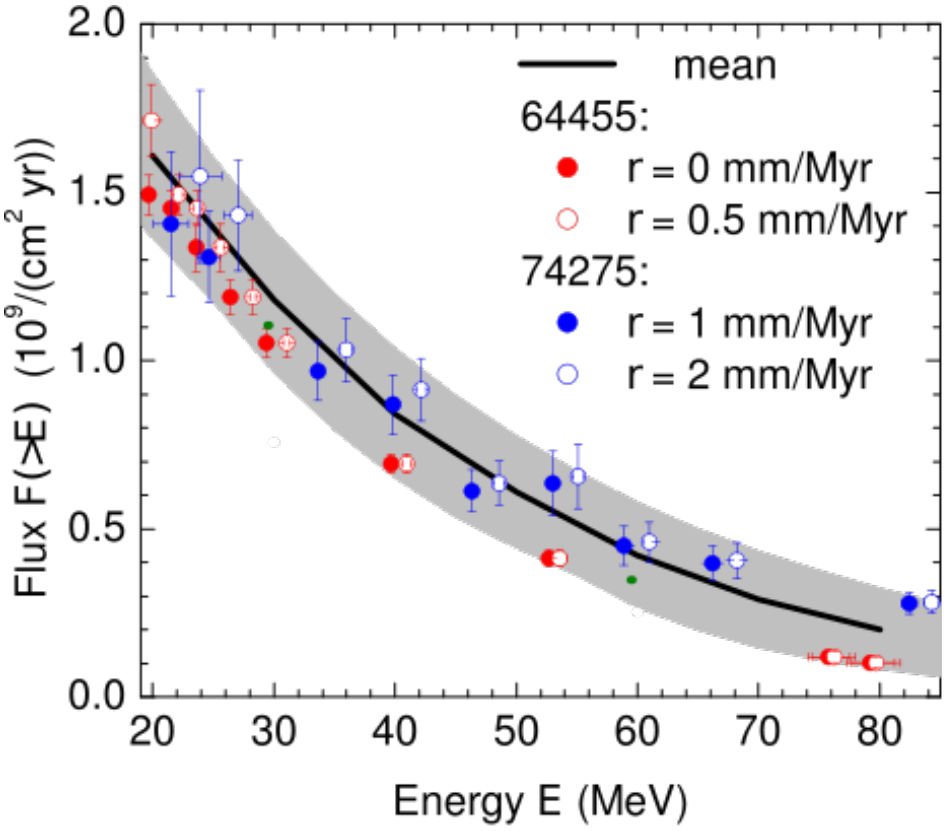
Sunspot number reconstruction

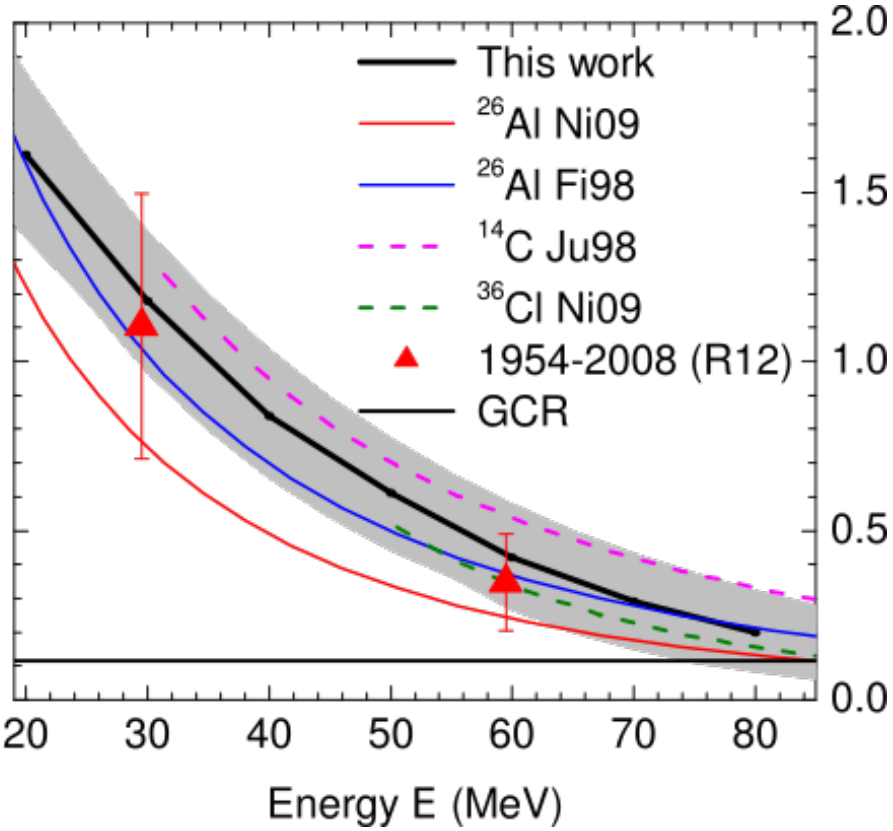


Usoskin et al SH4a

- multi-proxi Bayesian approach, using multiple ^{14}C and ^{10}Be datasets

SEP spectra over Myrs





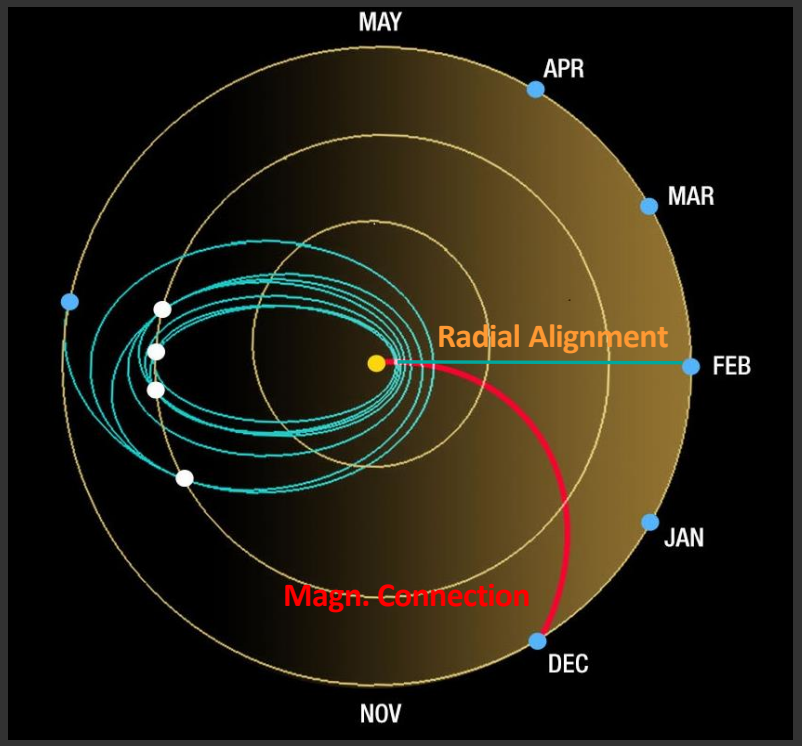
- Analysis of ^{26}Al in lunar samples

Poluianov et al SH4c

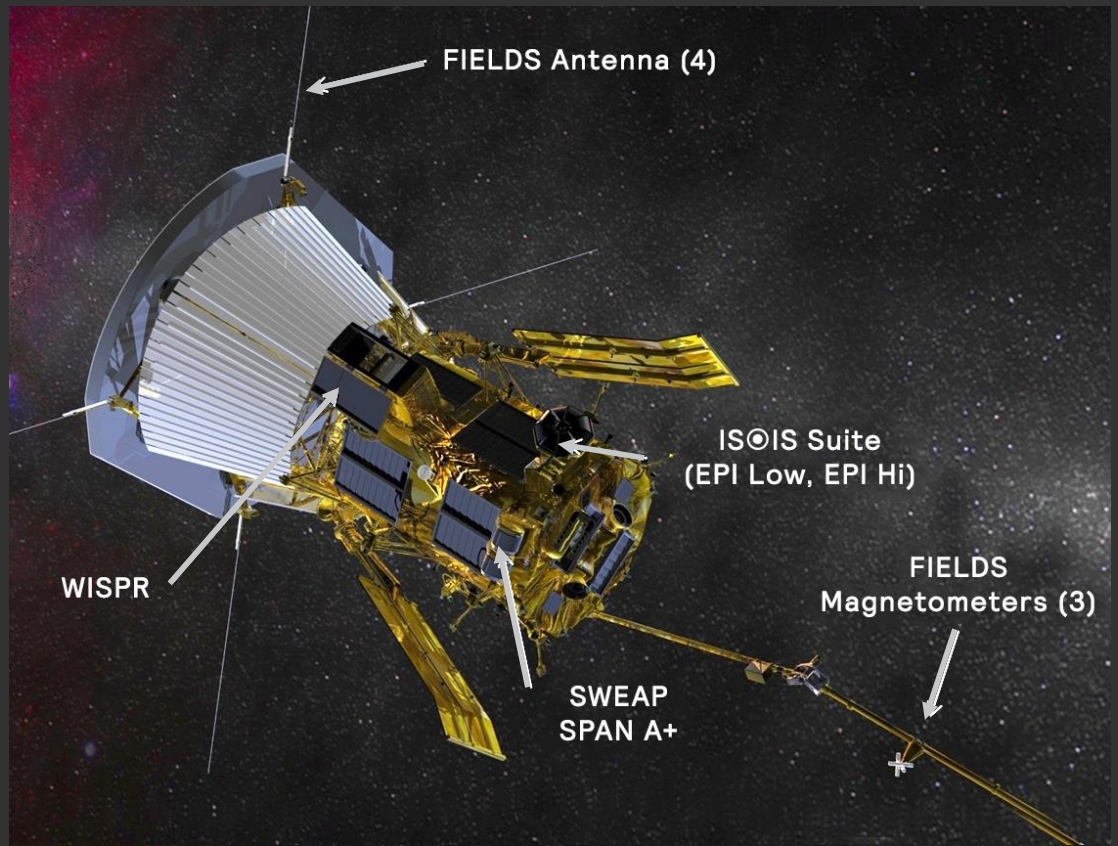
- SEP flux on Myr scale comparable with recent decades

The future: New missions and instrumentation

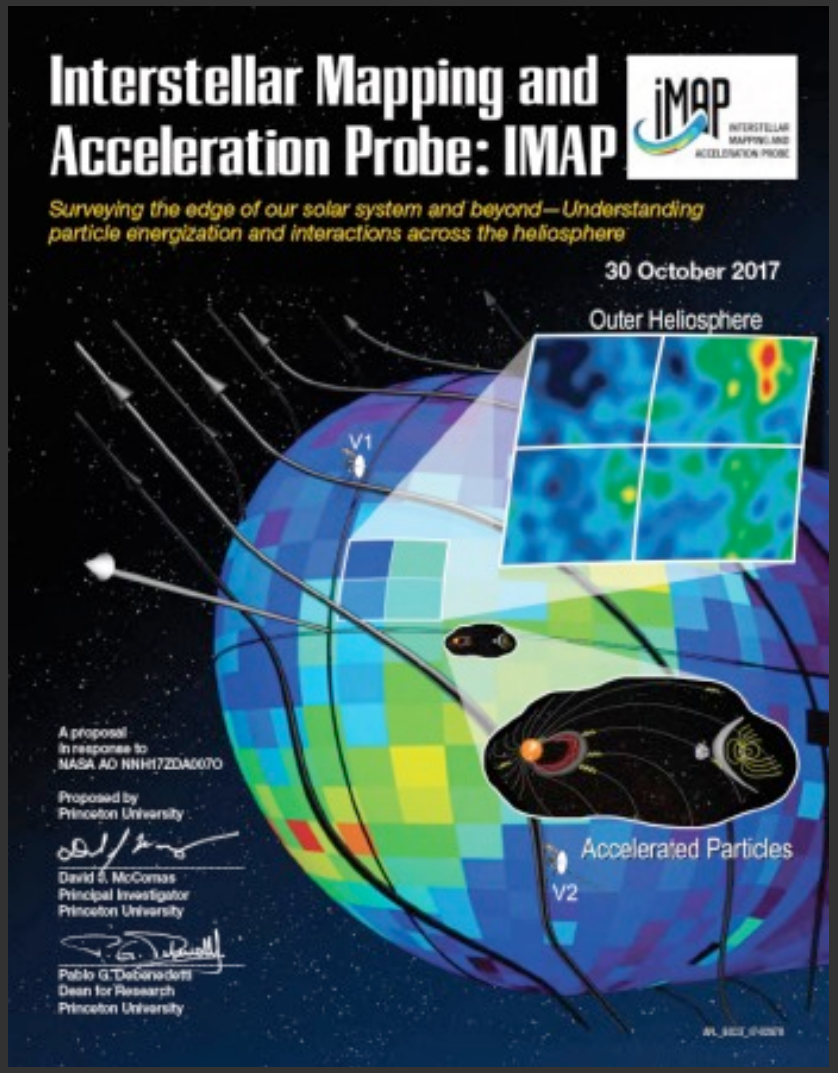
New missions: Parker Solar Probe

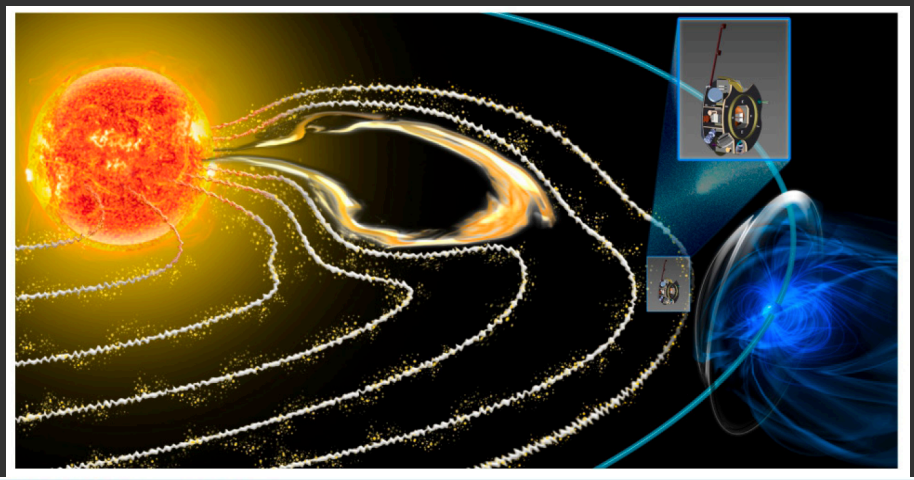


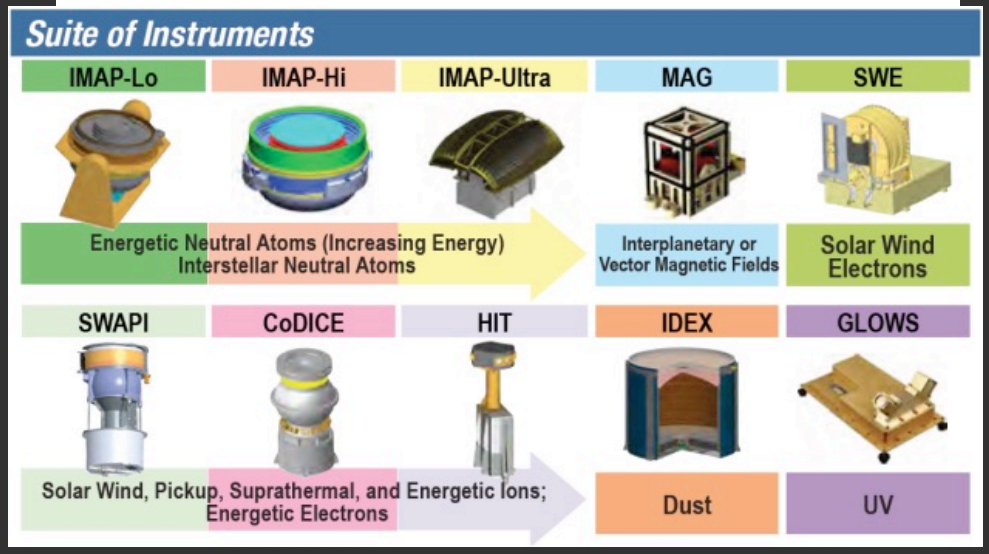
Posner,
Christian et al
- Review Talk



New missions: IMAP

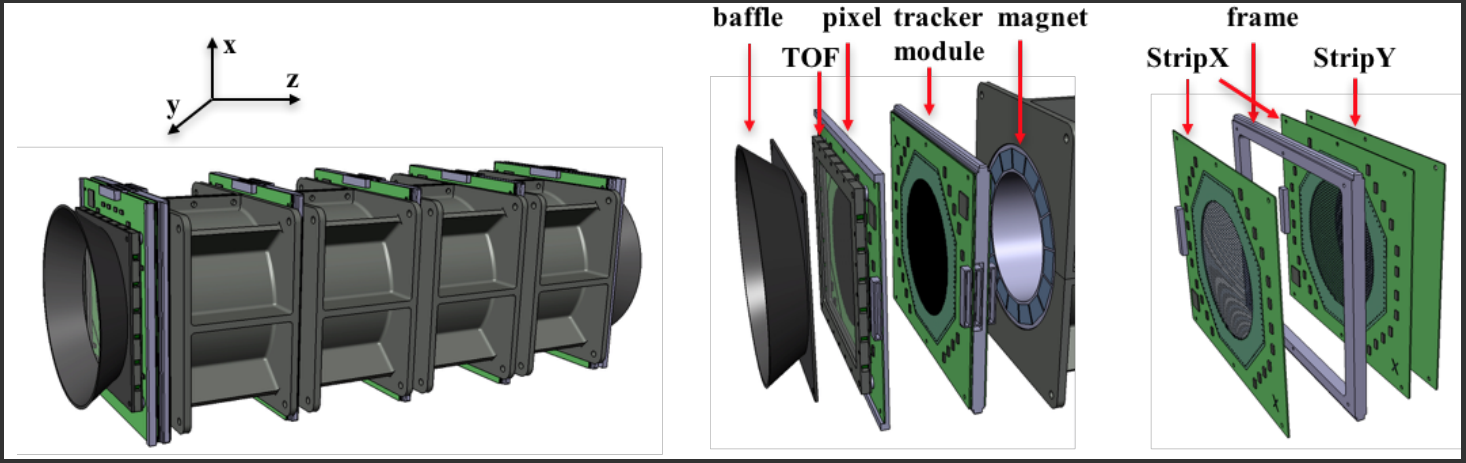




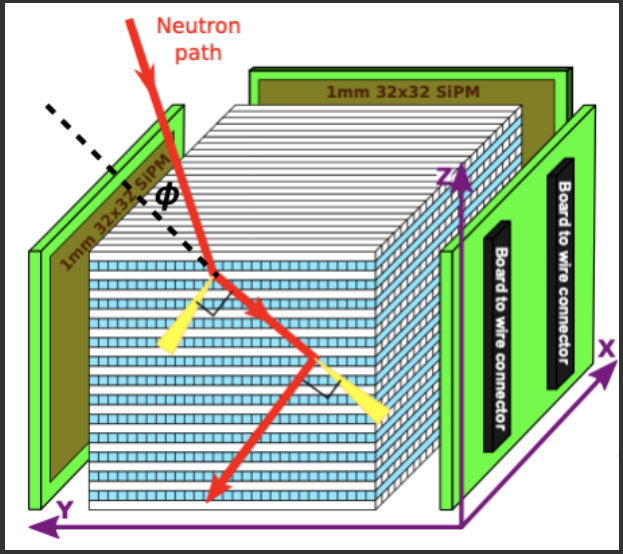


Christian et al SH6d

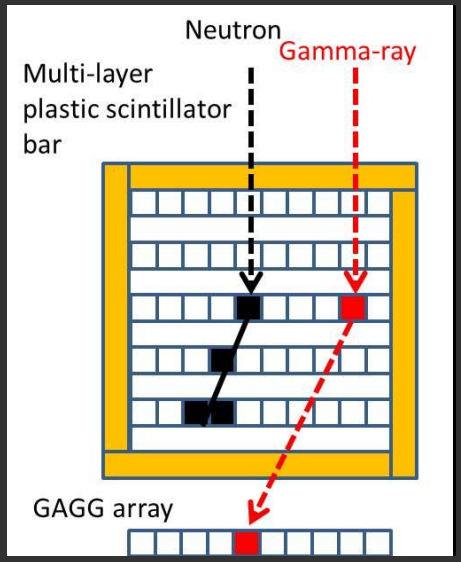
New instrumentation



Ambrosi et al SH6a



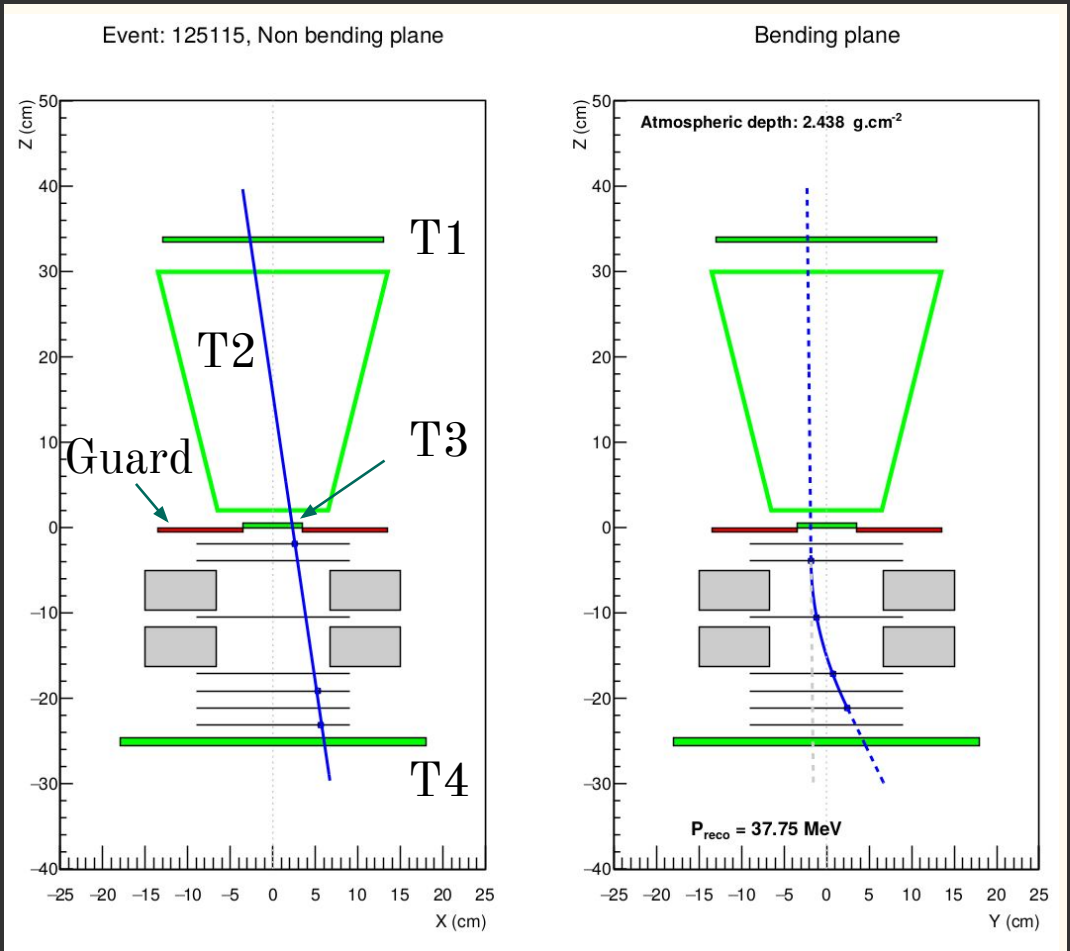
de Nolfo et al PS1-267



Matsushita et al SH6f

New instrumentation

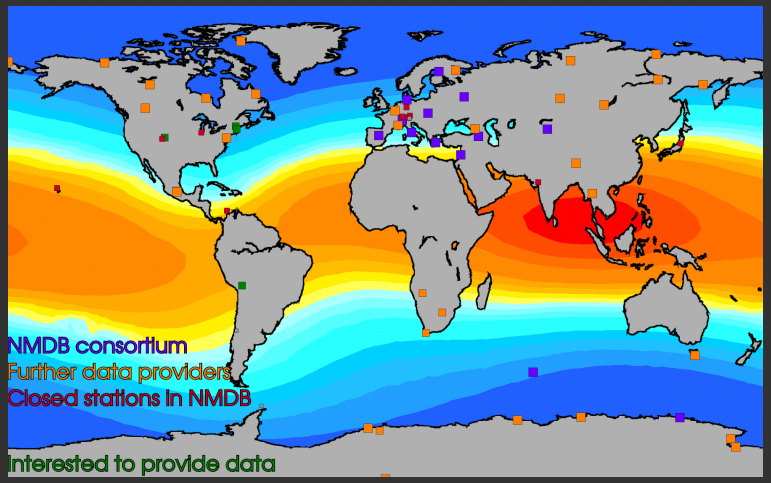
- AESOP -Lite



Mangeard et al, SH6b;
Mechbal et al SH6c

New neutron monitors

Blanco et al, PS-265



Strauss et al, SH6h

Conclusion

- New high energy and multi-spacecraft SEP data, and γ-ray data key to unsolved questions on solar particle acceleration
- Modulation models of increased sophistication – work in progress on links to microphysics and predictive capability
- Significant progress on understanding past behaviour over Myrs
- Parker Solar Probe and IMAP will provide key new data

Looking forward to hearing about the results in Berlin!!!

Thank you!