CCMC Workshop
Key Largo, FL

Relativistic Electron Alert System for Exploration (REleASE): Performance and Challenges

Arik Posner[1,2], Oliver Rother[3], Bernd Heber[4], Reinhold Müller-Mellin[4], and Jason Lee[5]

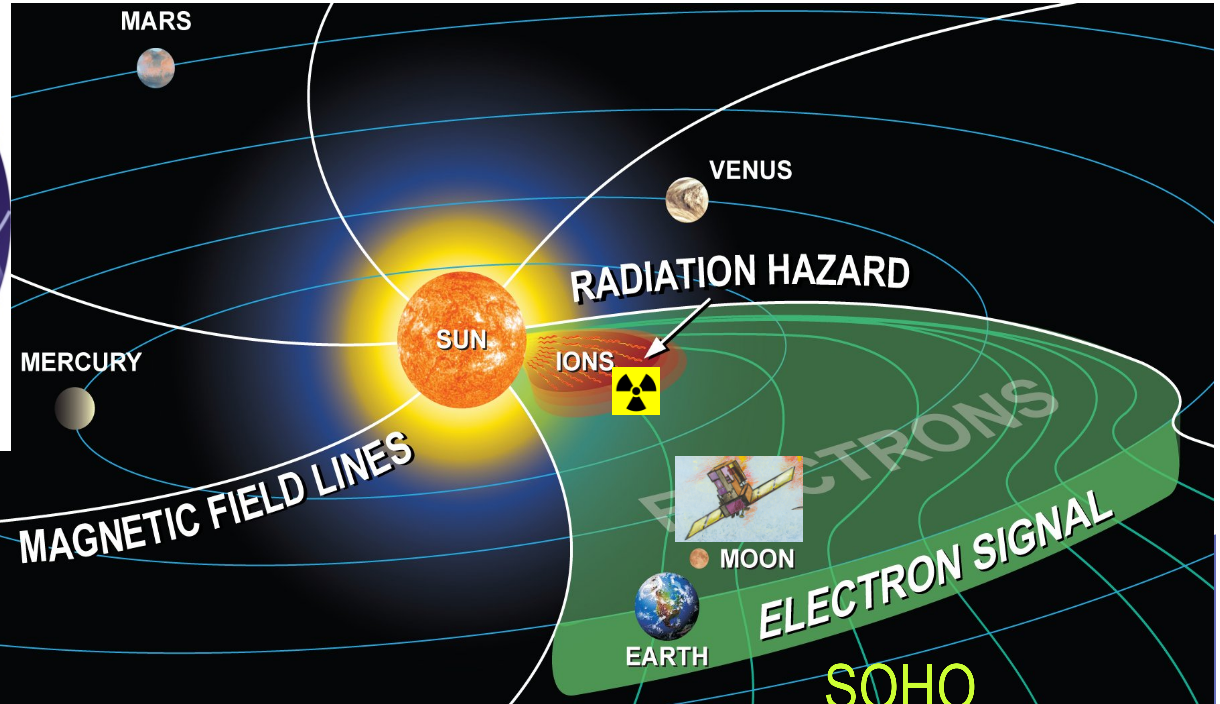
(1) NASA Goddard Space Flight Center, Greenbelt, MD
(2) also at NASA/HQ, SMD, Washington, DC
(3) omrother Scientific Data Processing, Kiel, Germany
(4) IEAP, Universität Kiel, Germany
(5) Thomas Jefferson High School for Science and Technology, Alexandria, VA

Outline

- Introduction
- Long-Term Performance
- SEP Instrumentation Limitations
- Comparison with other Methods
- Performance of Live Forecasting 2008-2011
- Summary

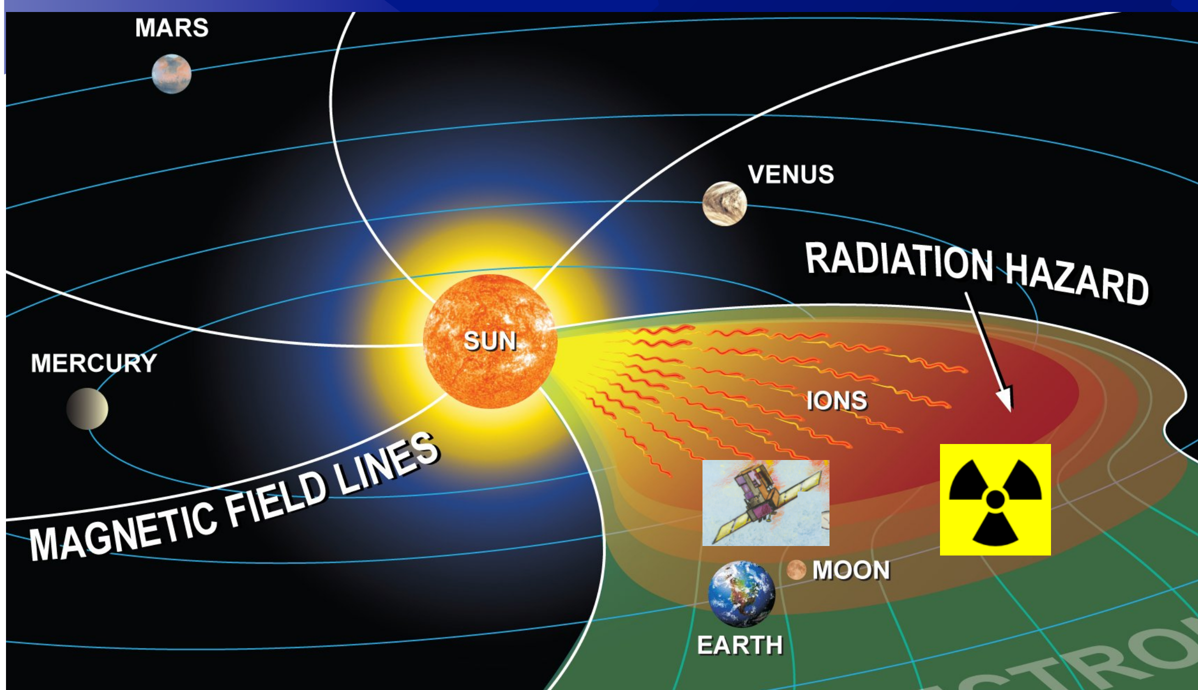
REleASE

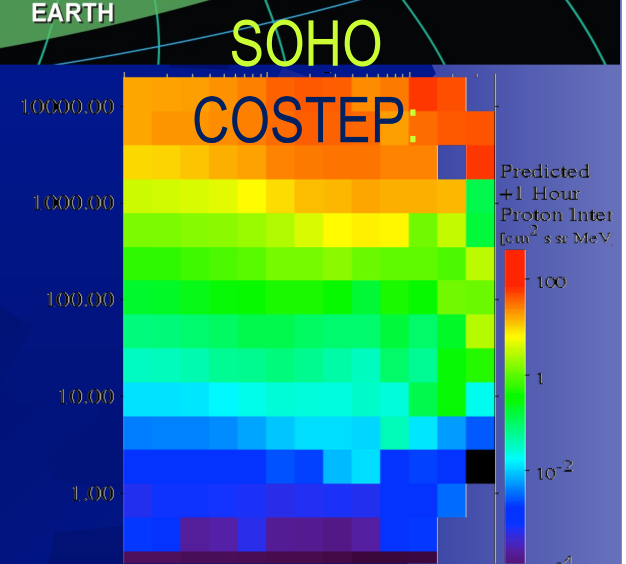
Relativistic Electron Alert System for Exploration



Empirical Method:

- e vs p Speed Difference
- 1+ AU Distance



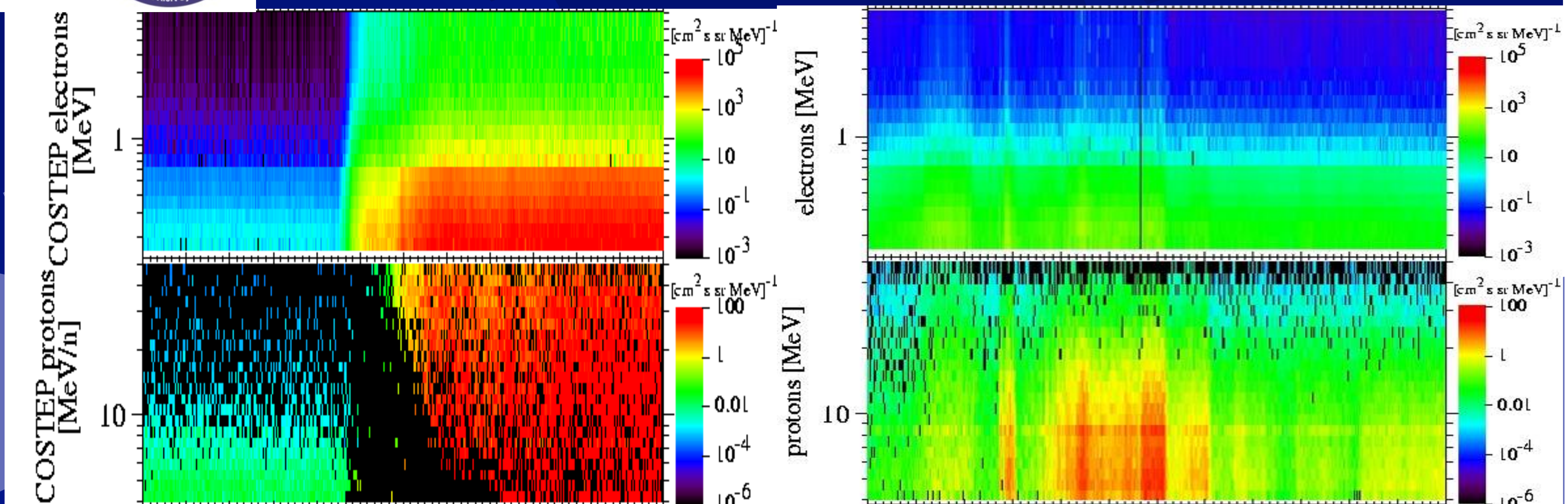


Electron Rise Parameter

Empirical Forecasting Matrix Translates Solar Electron Data into +1h Proton Hazard Forecast

(Posner, *Space Weather*, 2007)

Classification: Prompt or Delayed?

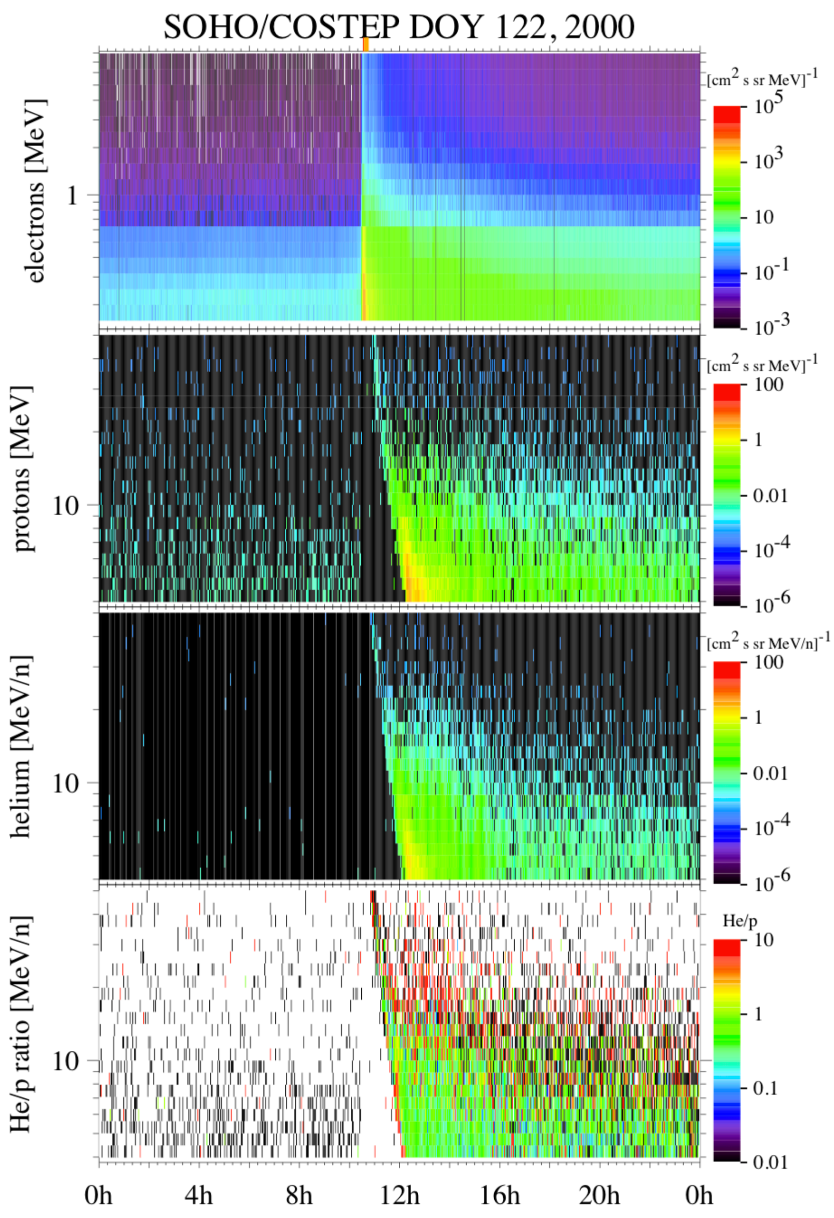


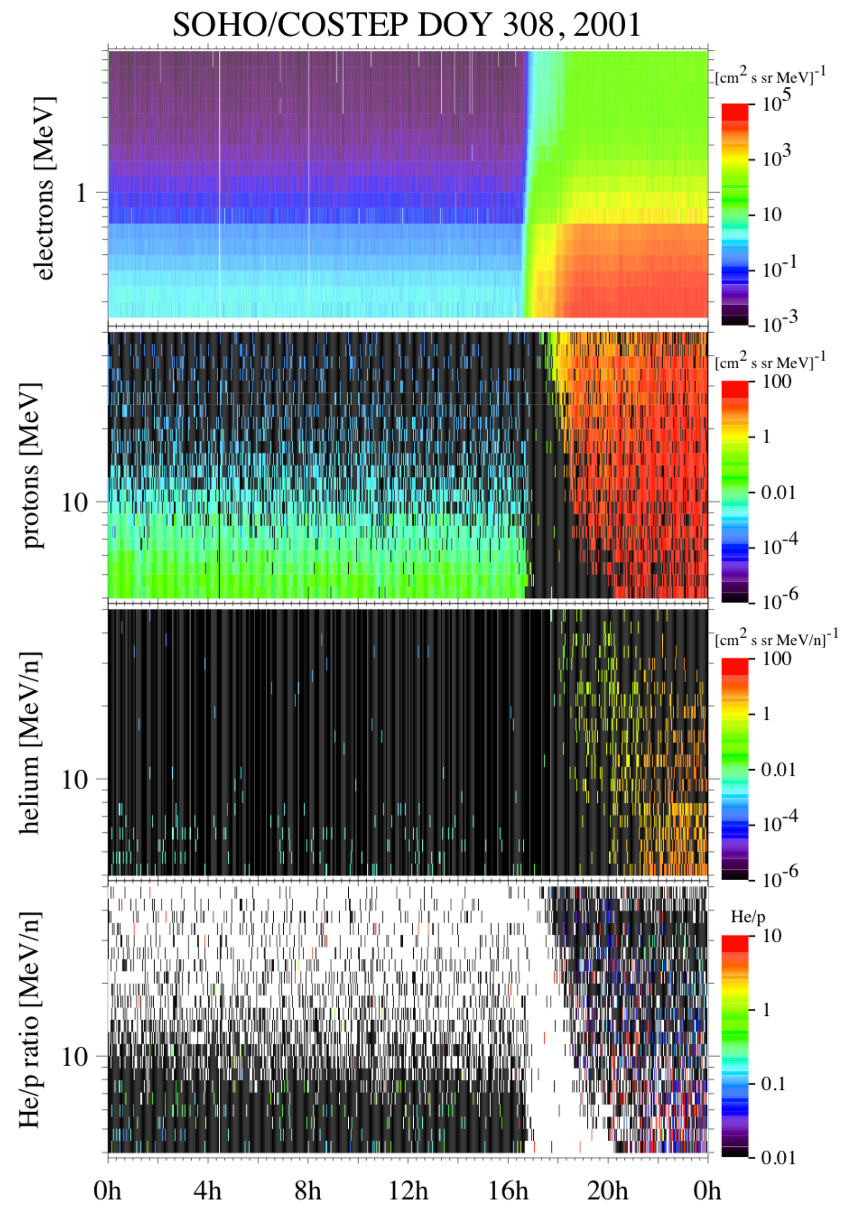
“Prompt” (left, November 04, 2001, 12 hours shown) and “Delayed” (right, July 28, 2000, full day) particle enhancements at 1 AU. A simple classification distinguishes events on whether they reveal proton velocity dispersion at onset (left, meaning that low-energy protons arrive later than fast, high-energy protons) or not (right side).

The forecasting technique introduced here is intended only to warn against Prompt SEP events.

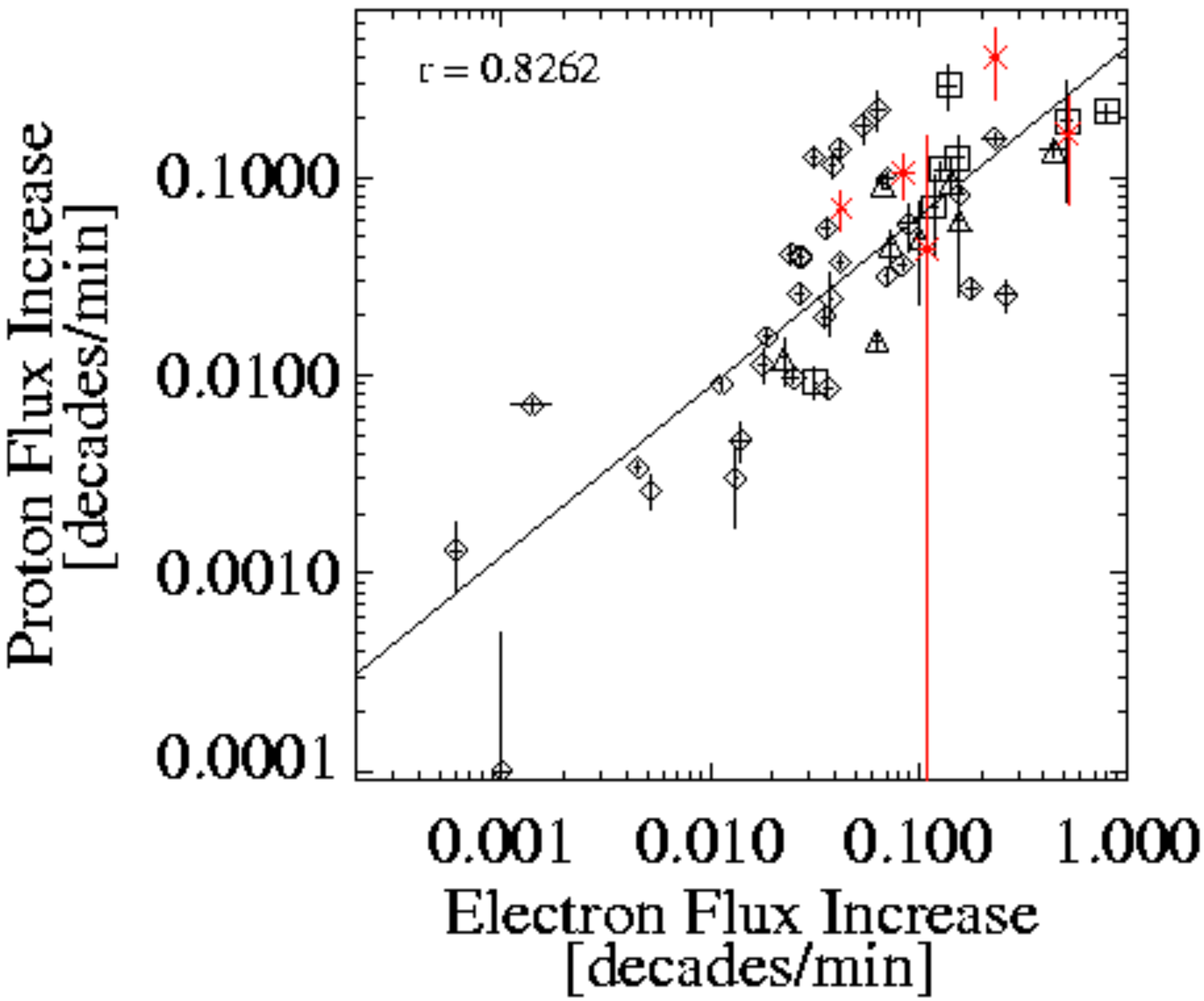
Note the apparent disappearance of pre-event proton background in the Nov. 04, 2001 event. Rather large statistical uncertainties for protons intensities incur as long as extreme electron-to-proton ratios persist.

Not to be confused with "Impulsive" / "Gradual" Events





Comparison of SEP Rise Times



Diamonds: Regular Observing Mode
Triangles: Low Geometric Factor Mode
Squares: Extreme Fluxes, Not Used for Fit

Impulsive Events (red symbols) from List of Reames and Ng, *ApJ*, 2004

Posner, *Space Weather J.*, 2007

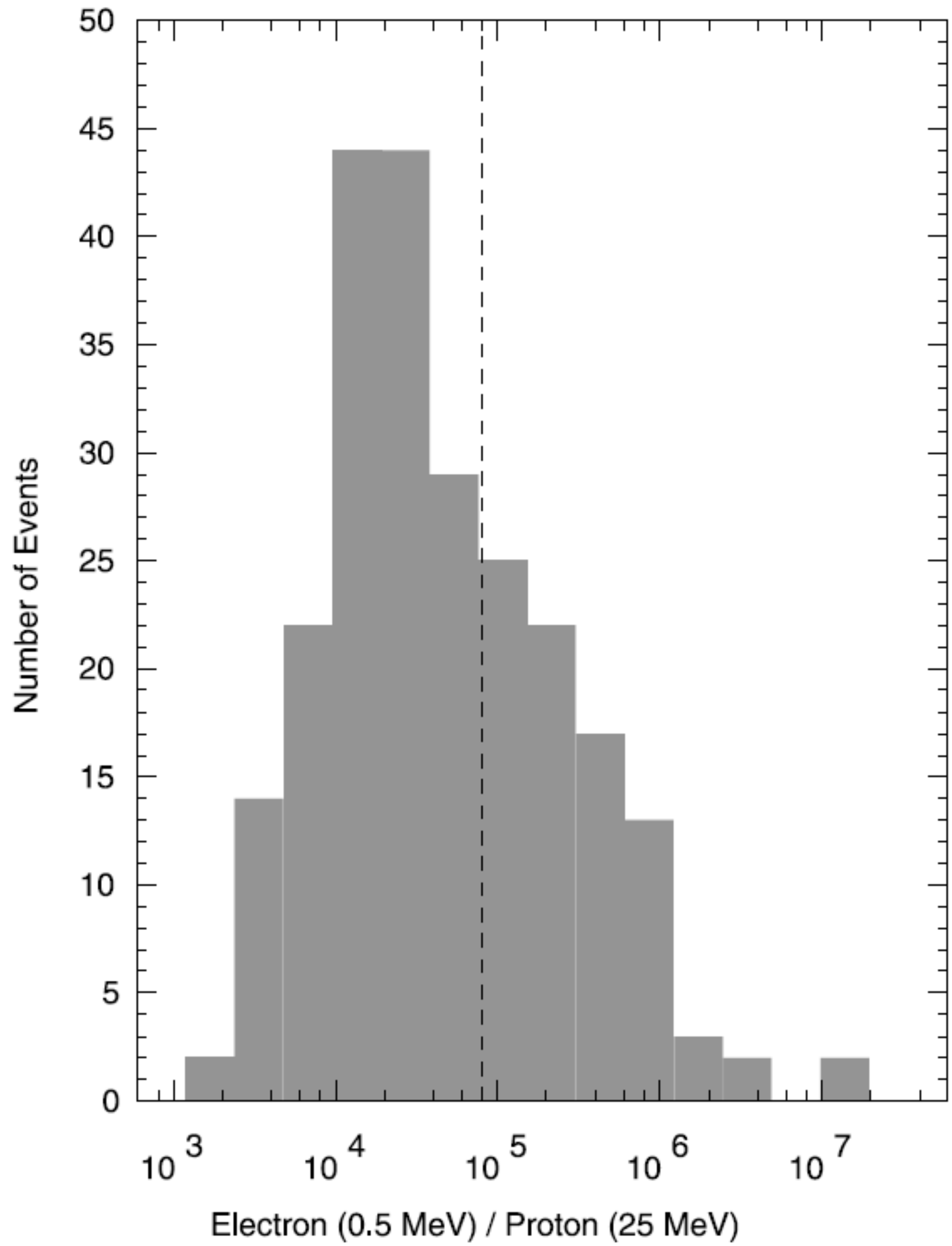
REleASE
Relativistic Electron Alert System for Exploration

Cane, Richardson and von Rosenvinge (JGR, 2010):

•Electron-to-proton ratio of 1997-2006 SEPs

•Most SEPs within factor of 10 of a median e/p ratio

•Continuum of event properties that does not support the simplest “two class” picture of SEP events



Posner, Rother, Heber,
Müller-Mellin & Lee

Fast Rise of Solar Energetic Particle Events

Acute Radiation Sickness Lower Threshold

Equivalent Dose Rate from SEP Protons Rises Rapidly

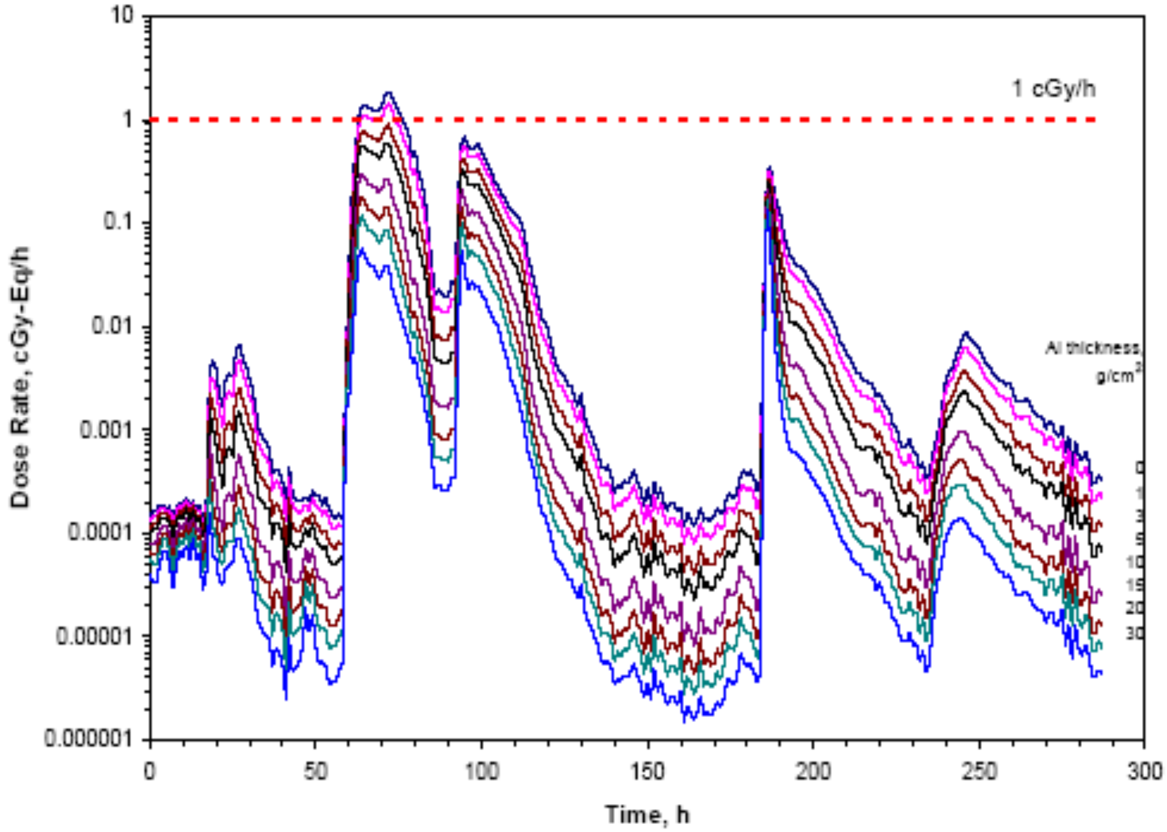
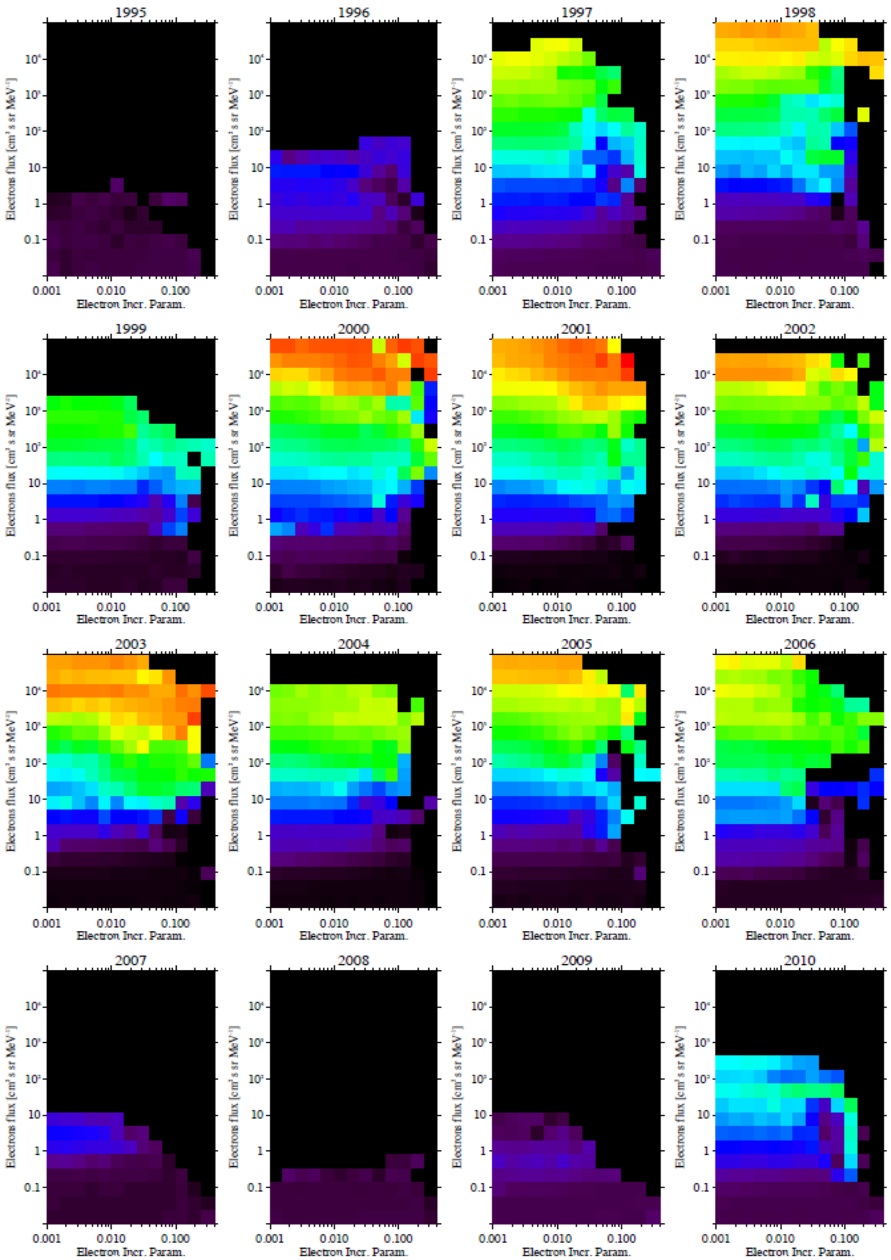
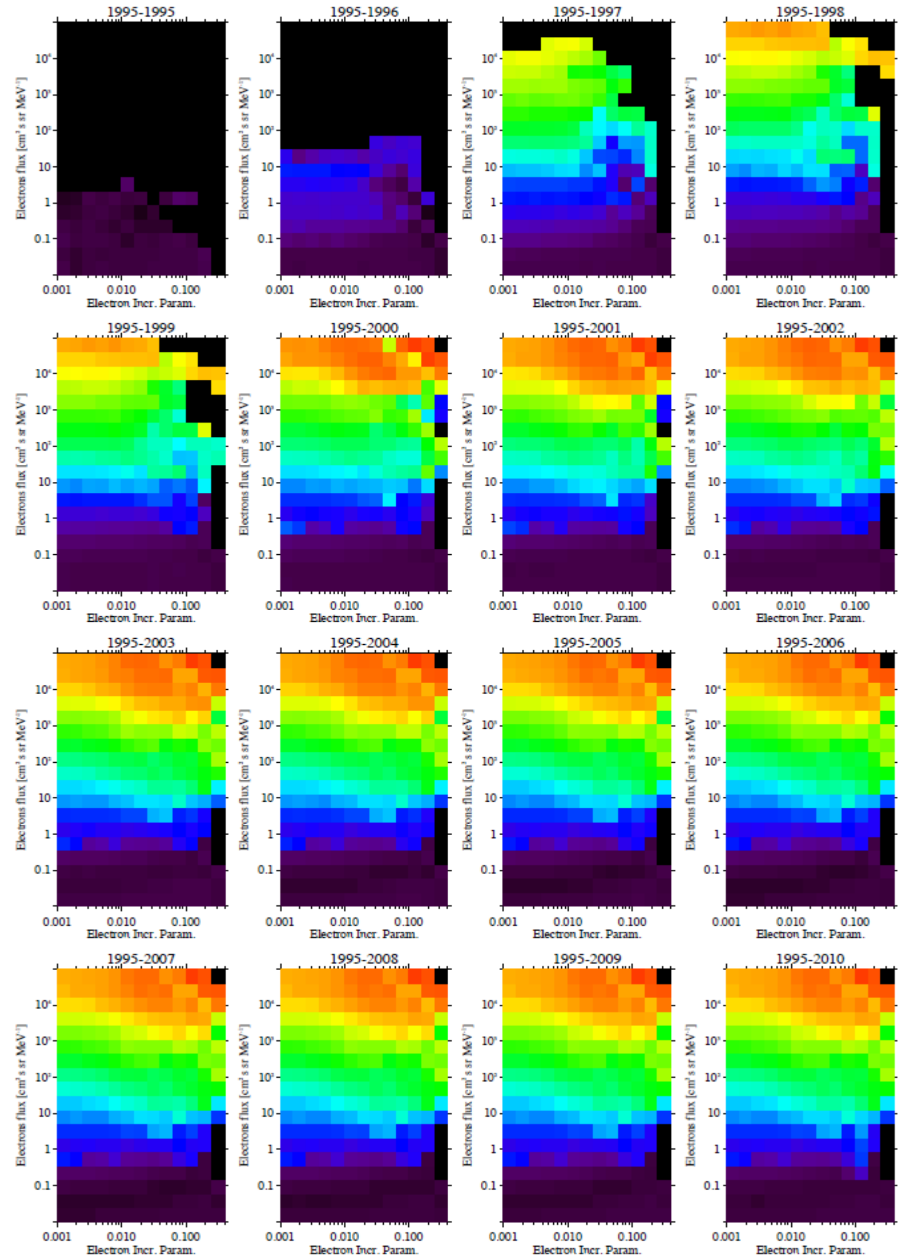


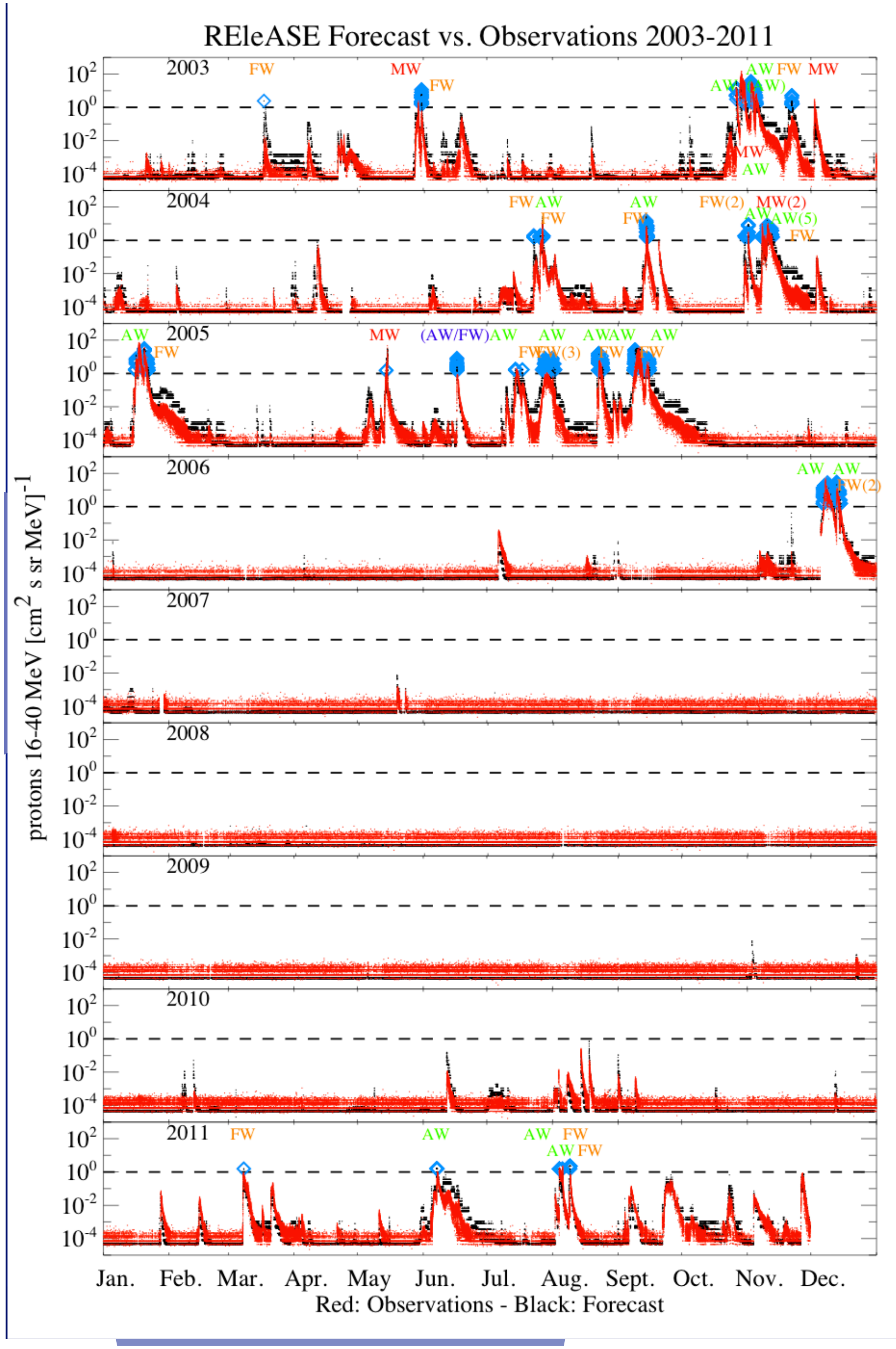
Figure 5. BFO dose rate behind various aluminum thicknesses during Oct 26-Nov 6, 2003 SPE.

Kim, Hu, and Cucinotta [*Proc. AIAA*, 2005]

REleASE Forecasting Matrix Evolves: 1995-2010





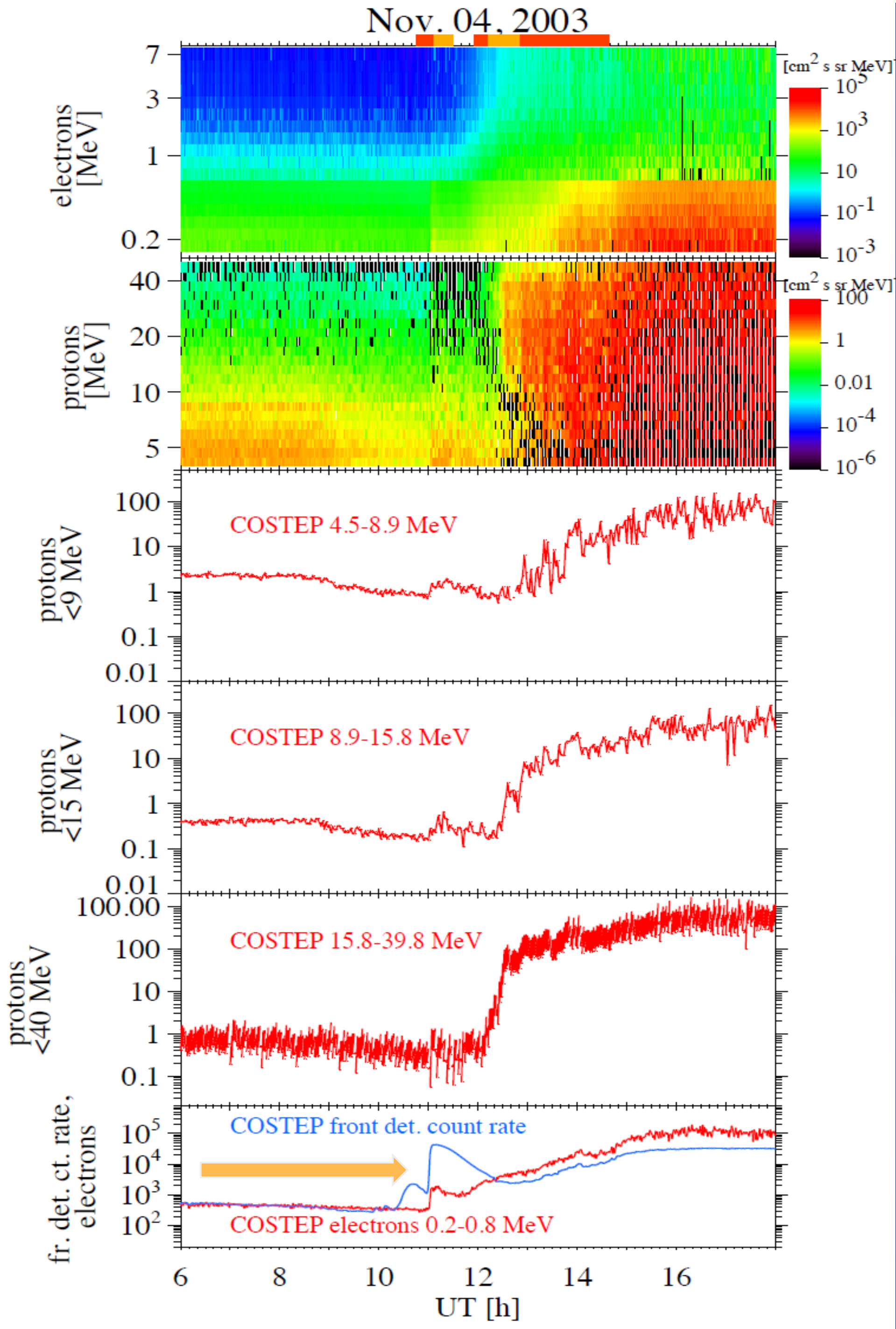


REleASE

Relativistic Electron Alert System for Exploration

- Threshold is 24pfu for 16-40 MeV protons (others: 10pfu for >10 MeV protons).
- Same methodology as 2007 paper.
- Matrix updated every year.
- Not corrected for instrumental deficiencies.

Method	POD	FAR
REleASE/COSTEP (Posner, 2007)	0.79 23/29	0.48 21/44
UMASEP (Nunez, 2011)	0.81 134/166	0.34 69/203
Balch (2008) auto forecaster-in-loop	0.57 0.88	0.55 0.18
Laurenza (2009)	0.63	0.42

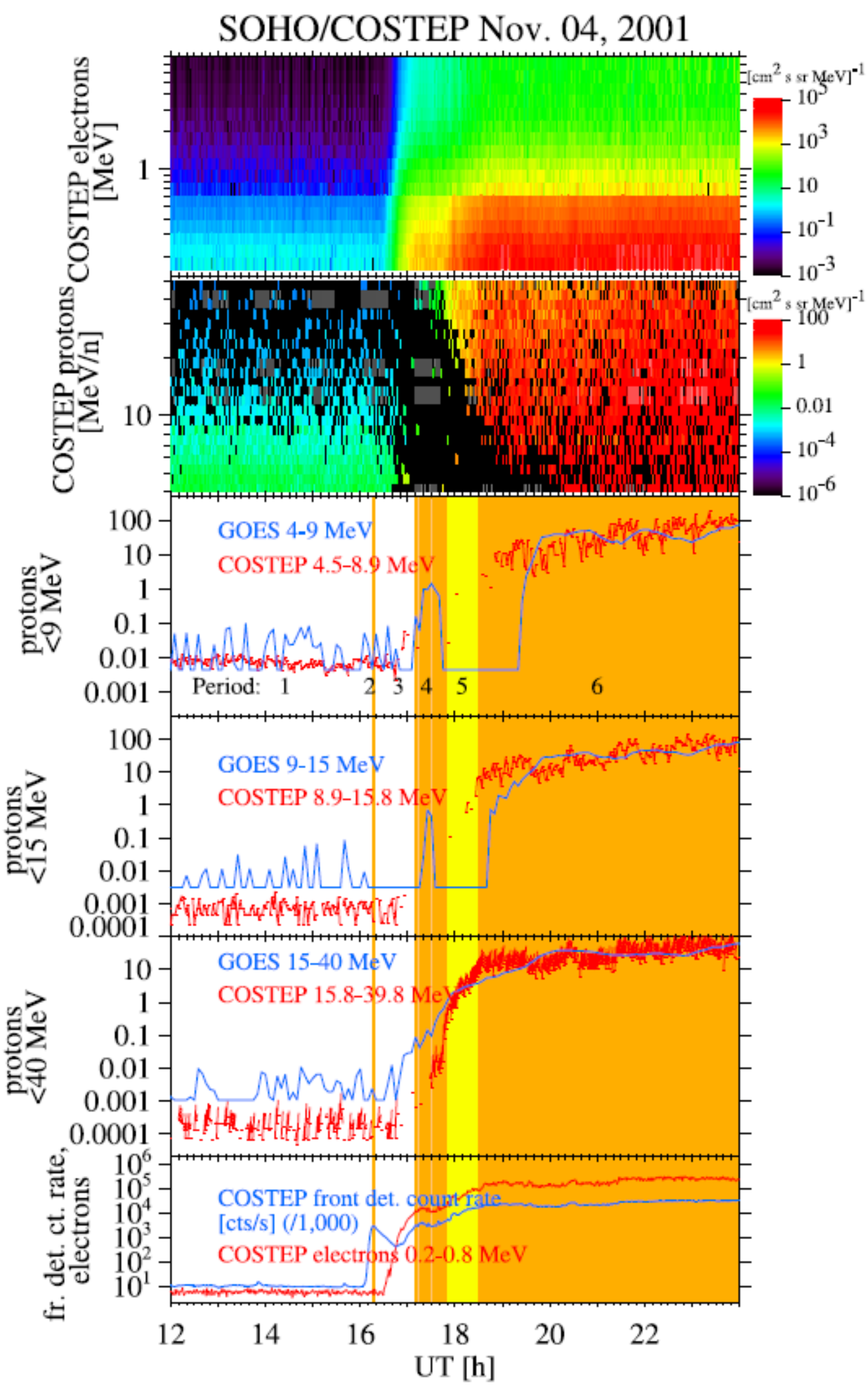


Examples of Instrumental and System Deficiencies

1: COSTEP X-Ray Contamination

Effect: Front Detector Vetoes SEP Electrons Due to High Rate of X-Ray Conversion Electrons

Remedy:
More Massive Shielding of Front Detector from Direct Sunlight



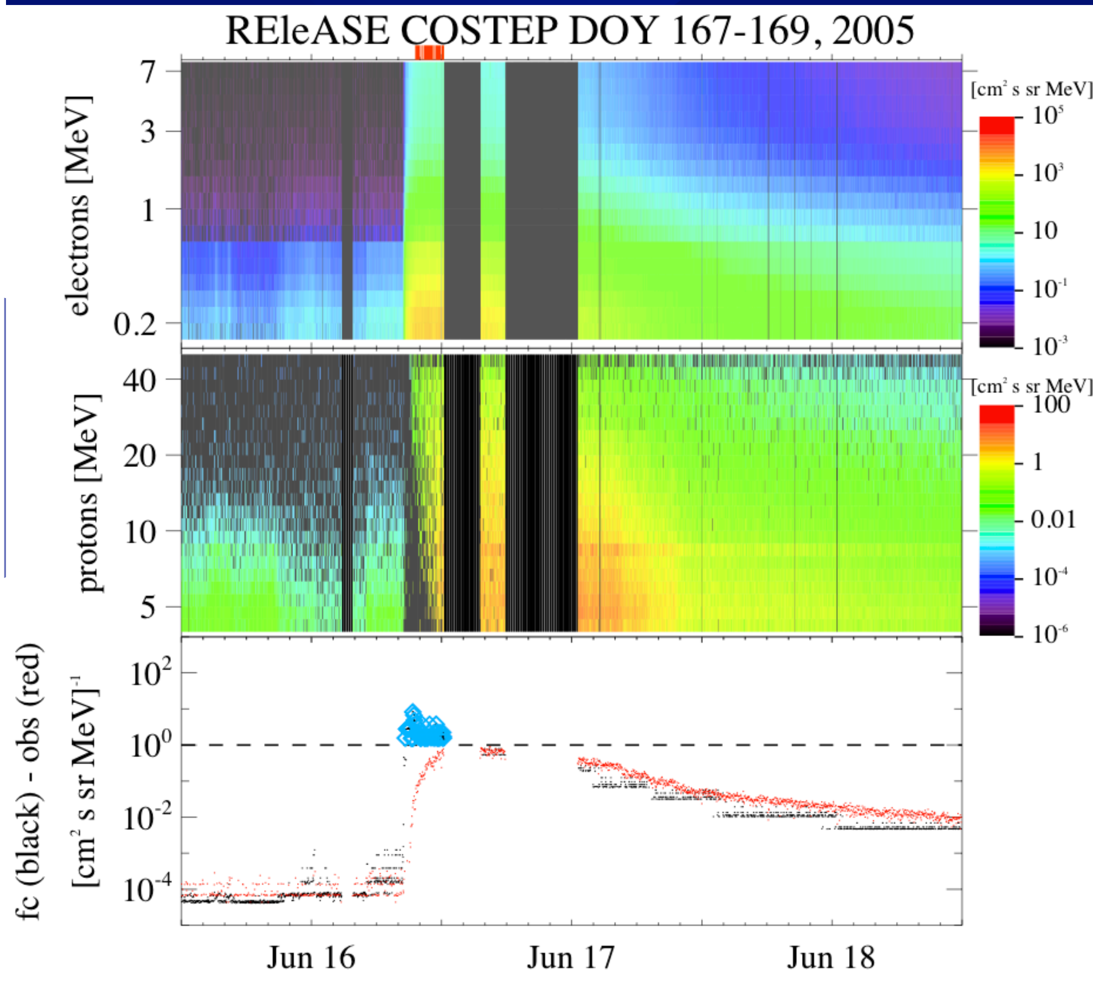
Examples of Instrumental and System Deficiencies

2: GOES/SEM (SEISS?)
Passive Shielding Use

Effect: High-Energy Particles Penetrate Passive Shielding, Artificially Increase High-E Count Rates

Remedy:
Veto Through Use of Active Anti-Coincidence Shielding, Pulse-Height Analysis

Examples of Instrumental and System Deficiencies



3: SOHO Data Coverage Gaps

Effect: Loss of Data, Lower Fidelity (in SOHO Key-Hole Periods)

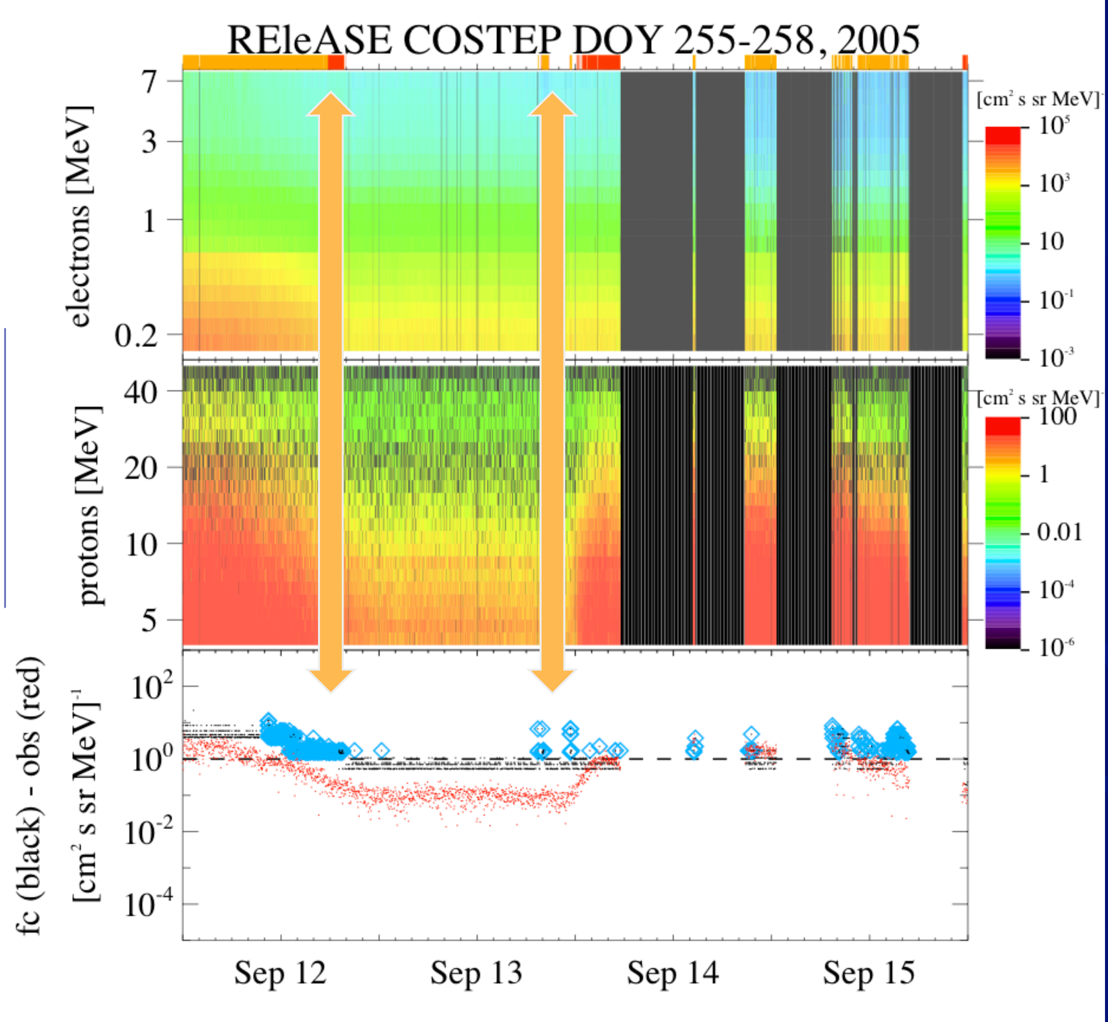
Remedy: Beacon Mode, Transmission Redundancy (small data set)

4: COSTEP e/p Particle Discrimination Threshold

Effect: Proton Channel Buffer Filled with Electrons, Statistical Uncertainty Increased

Remedy: Optimize e/p Particle Discrimination Thresholds

Examples of Instrumental and System Deficiencies



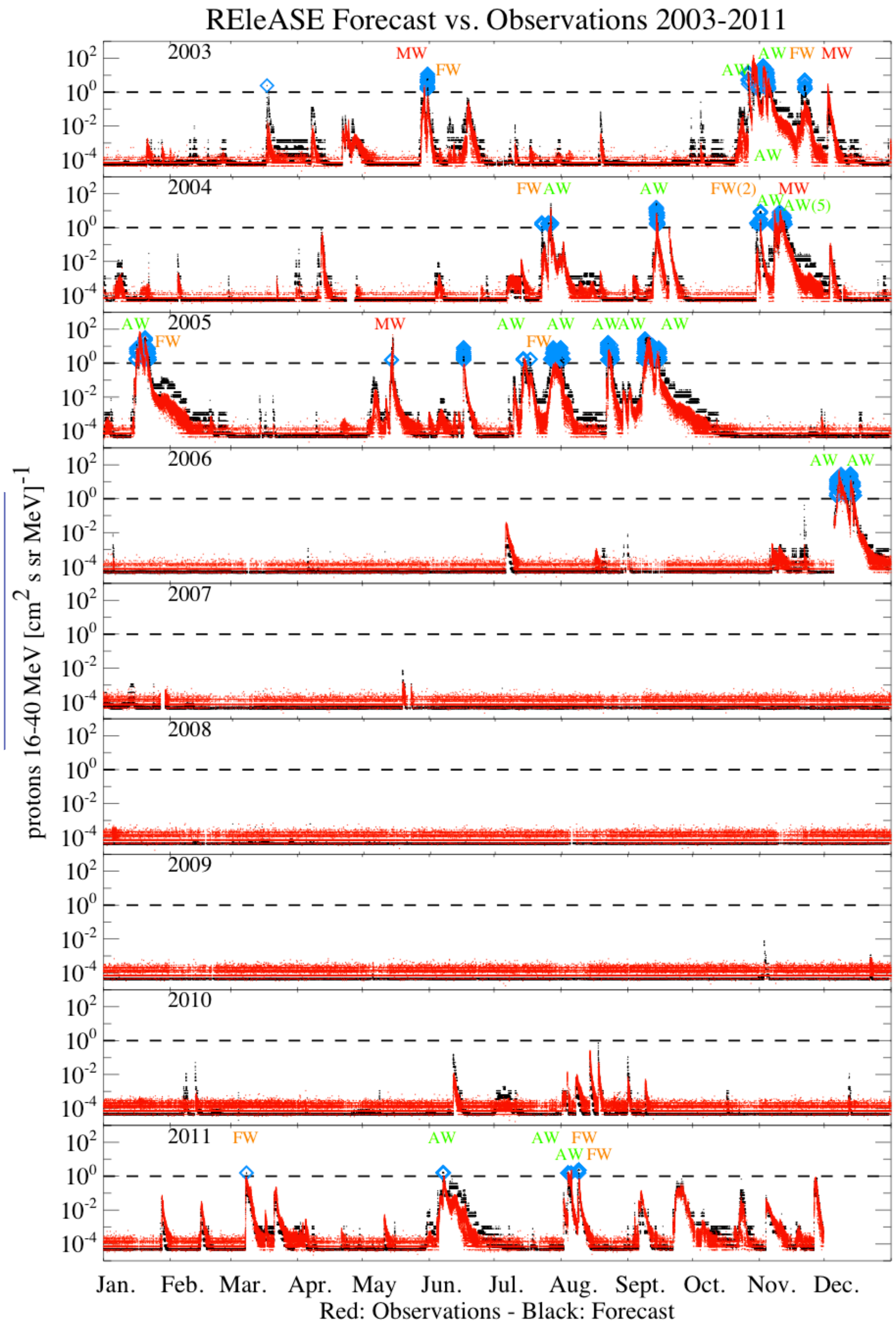
5: COSTEP Anti-Coincidence Techniques Inadequate

Effect:

Outer Ring of Front Detector Switches Off (Lower # Particles Analyzed), Opens Active Anti-Coincidence Shield

Remedy:

Optimized Mode Changes or Distinct Detectors would Leave Anti-Coincidence Shield(s) Intact, Clean Electron and Proton Spectra



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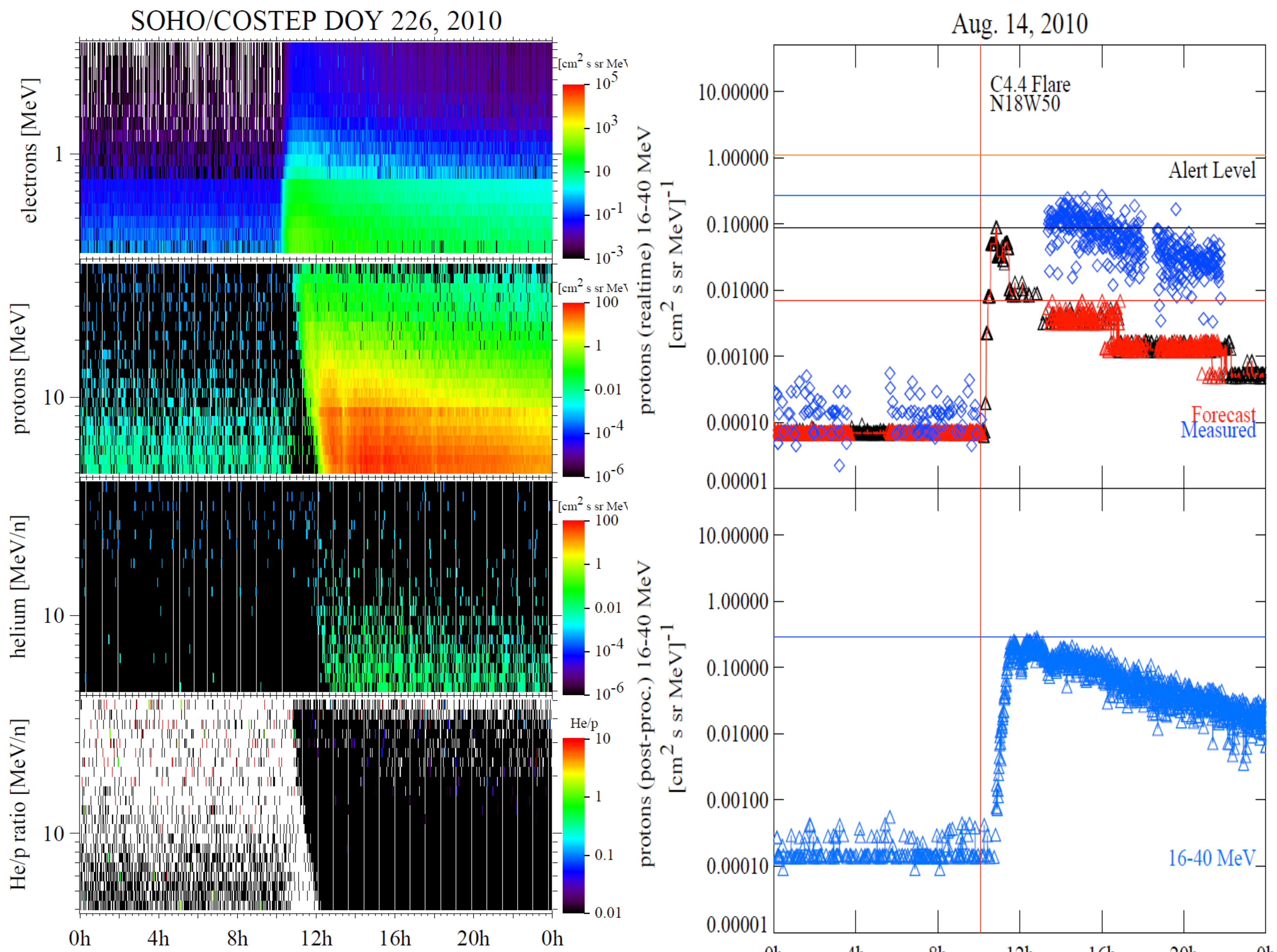
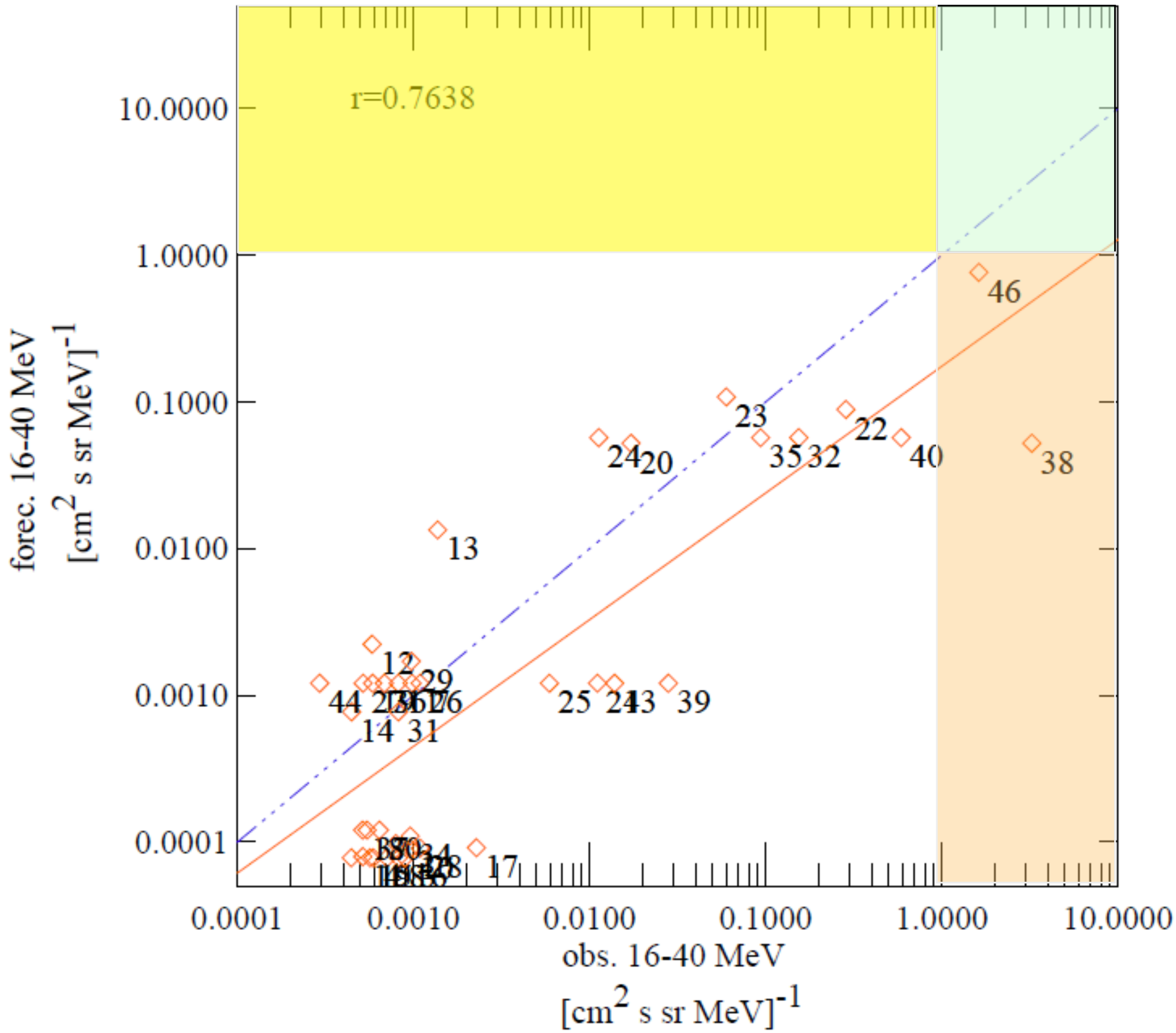
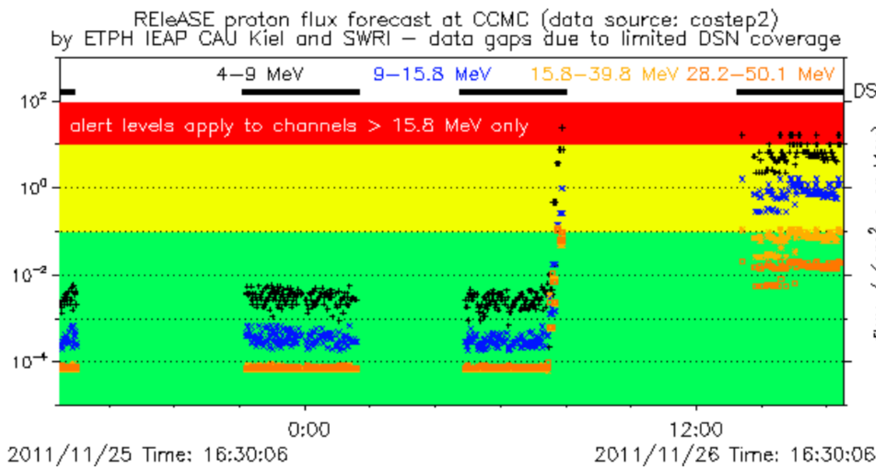
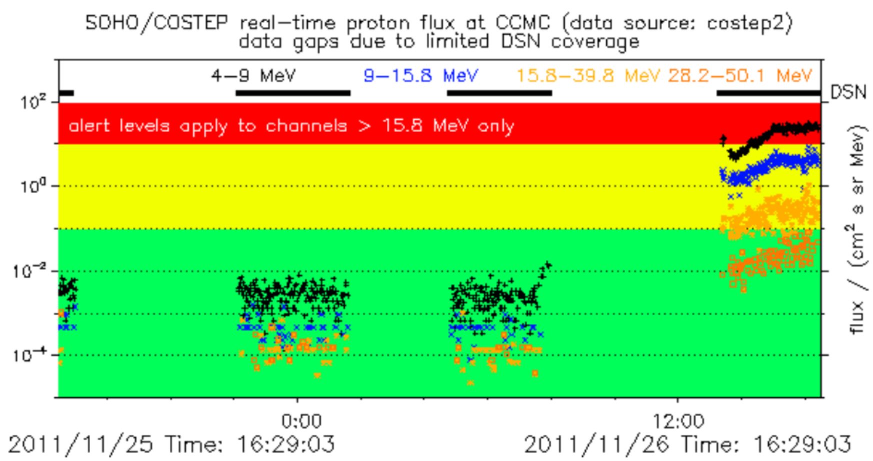


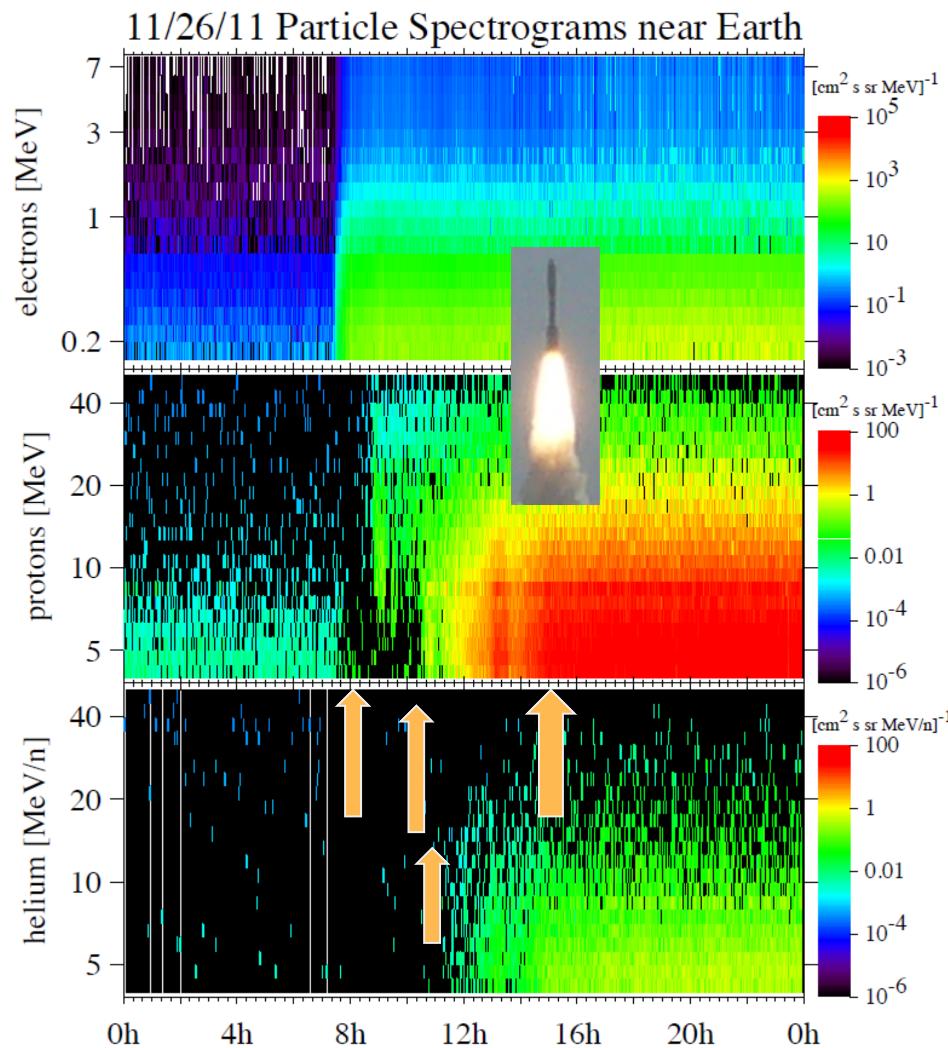
SOHO/COSTEP DOY 226, 2010
electrons [MeV]
protons [MeV]
helium [MeV/n]
He/p ratio [MeV/n]
[cm2 s sr MeV
He/p
0h
4h
8h
12h
16h
20h
Aug. 14, 2010
C4.4 Flare
N18W50
Alert Level
Forecast
Measured
protons (realtime) 16-40 MeV [cm2 s sr MeV]-1
protons (post-proc.) 16-40 MeV [cm2 s sr MeV]-1
16-40 MeV
10.00000
1.00000
0.10000
0.01000
0.00100
0.00010
0.00001

This slide only shows events forecast and/or observed in the energy range 16-40 MeV. Statistics of low numbers of events observed at high intensities.









0800UT REleASE FC Crosses 10 pfu

1113UT SWD Alert Based on REleASE

1125UT GOES >10pfu Event Detected

(~1300UT A Well-Informed MSL/RAD Team)

1502UT MSL Launch

Summary

Archival V&V:

UMASEP and REleASE Methods Lead Automated SEP Forecasting (followed by Laurenza, Balch Methods)

However, Higher Skills Through Forecasters in Loop

Falconer Method only one to provide SEP All-Clear for On-Disk ARs

REleASE/COSTEP, V&V of all Methods Hampered by System Deficiencies (Instruments SOHO/COSTEP, GOES/SEM, + Downlink)

Improved SEP Forecasting Instruments Needed to Push the Envelope

Live V&V:

Live REleASE/COSTEP: Lower Forecast Fluxes than Archival Performance

Limited Analyzed Event Statistics (2)

Hampered by Limited Downlink

Successful Practical Application at MSL Launch

Acknowledgments

•Univ. Kiel Team: COSTEP-EPH Instrument

•SOHO Team at GSFC (Amy Forinash, Joe Gurman, Bernhard Fleck etc.)

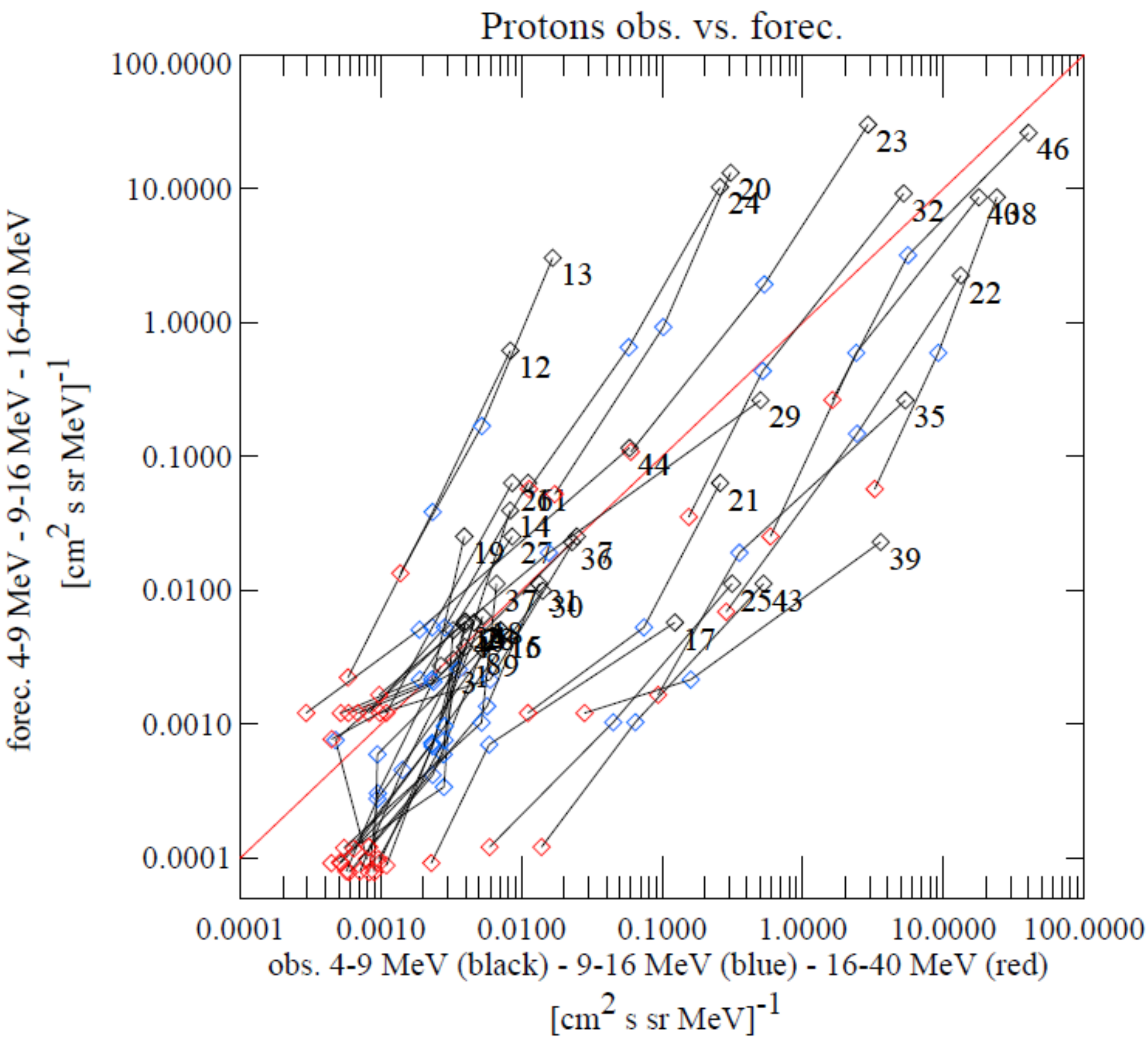
•CCMC Team (L. Rastaetter, M. Hesse, M. Maddox, D. Berrios etc.) for hosting and maintaining REIeASE real-time data stream on iSWA

•CCMC Space Weather Alerts (Y. Zheng, A. Chulaki, A. Pulkkinen)

Backup Slides

Observed Peak Intensities for 47 SEP Events

This list includes all useful SEPs, i.e. SEPs of which sufficient observations exist to provide peak intensities. Some events did not cover peak intensities in realtime data, e.g. #22, #25, #43.

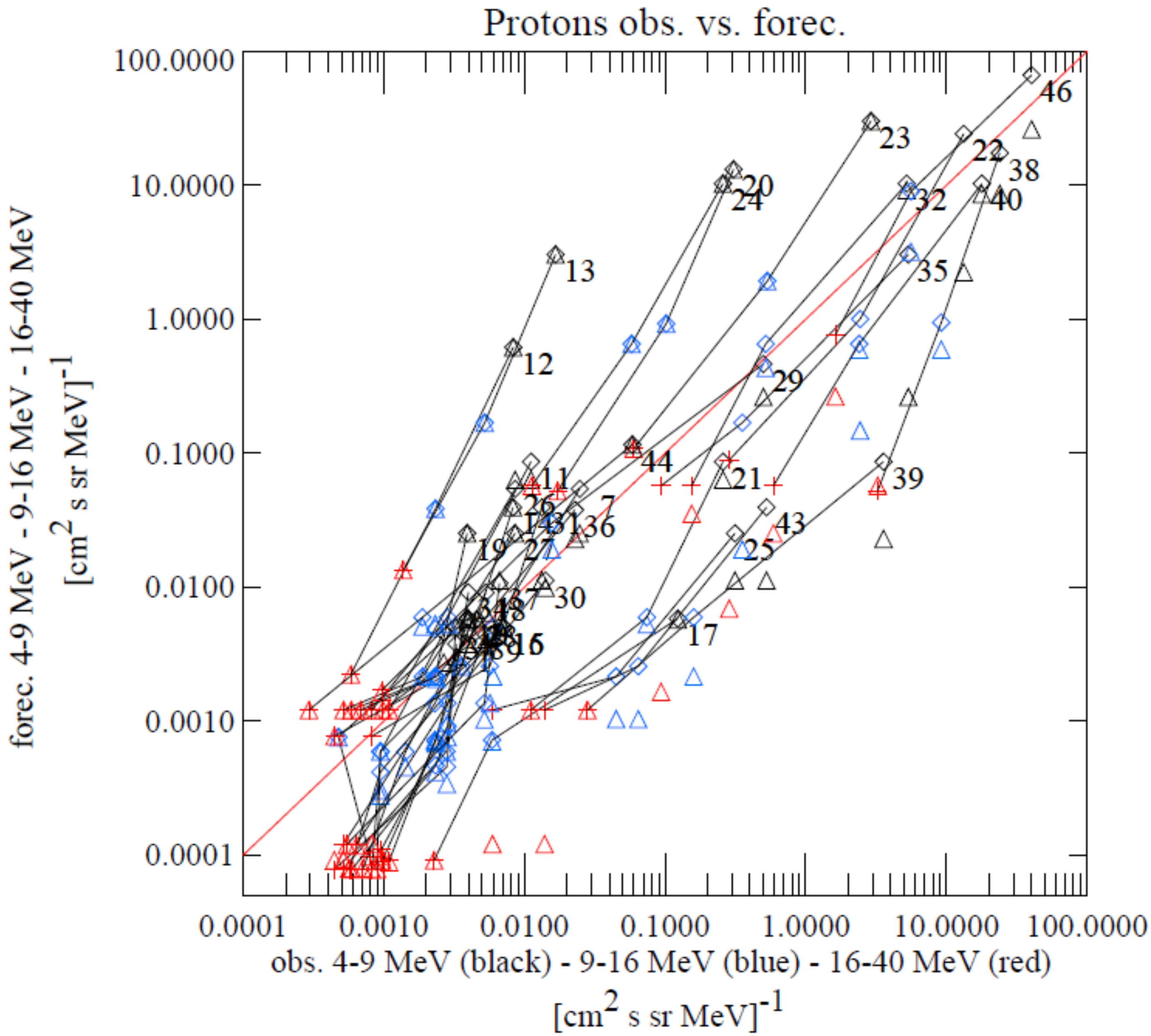


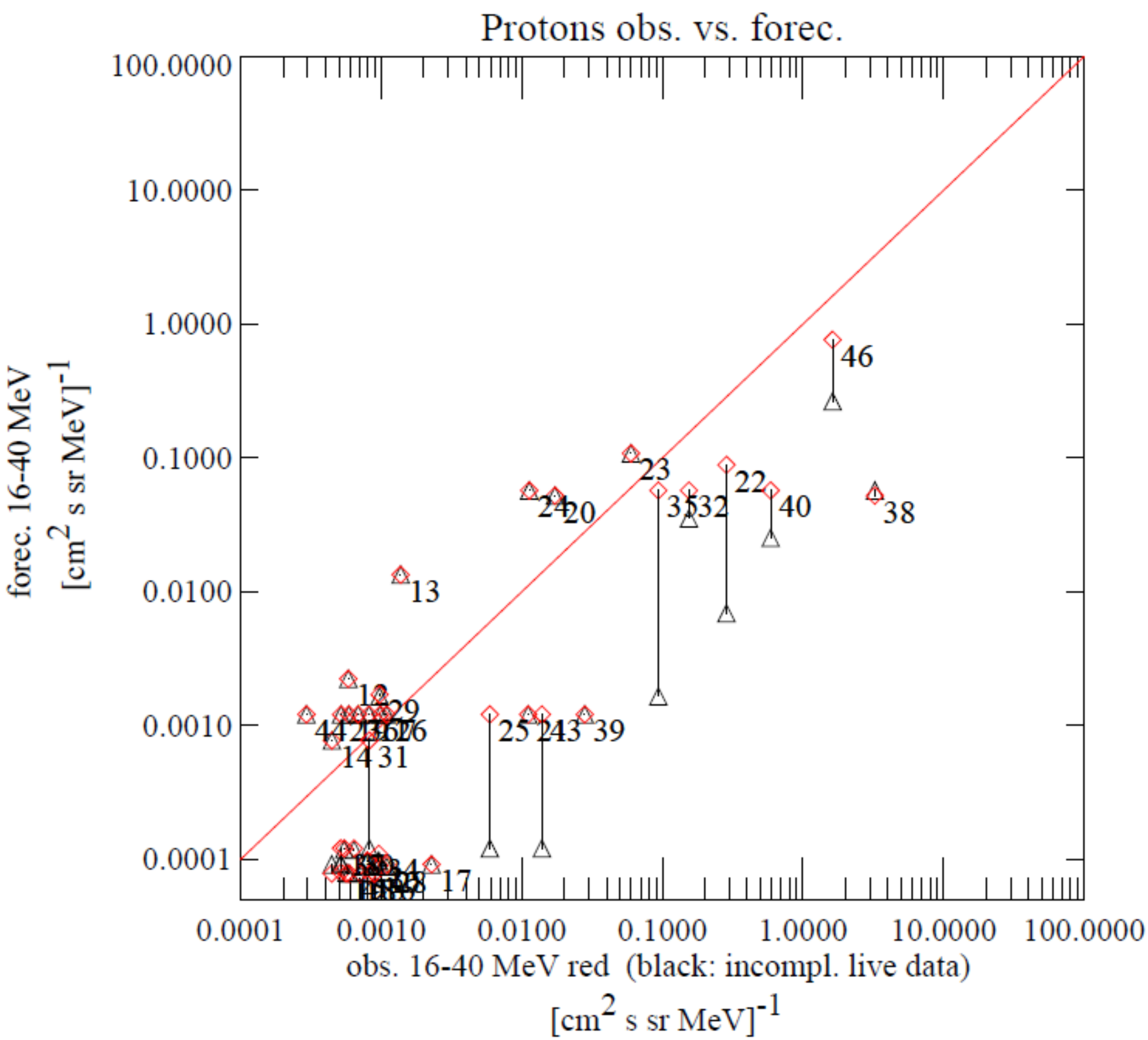
REleASE

Relativistic Electron Alert System for Exploration

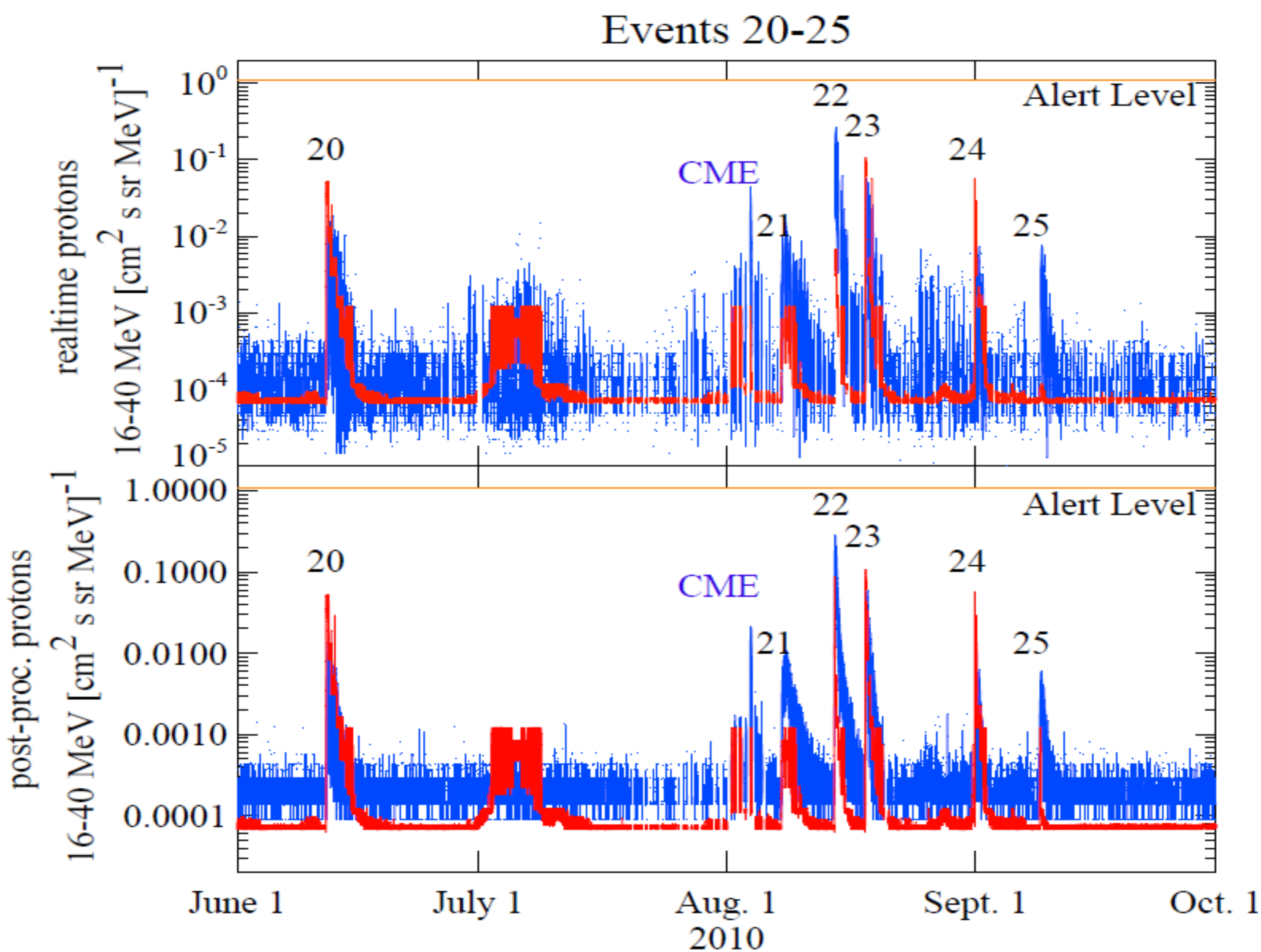
This slide fills real-time data gaps with (meanwhile) archived data.

“Gap effect” mostly impacts forecast flux, sets minimum coverage, cadence requirements for SWx method.



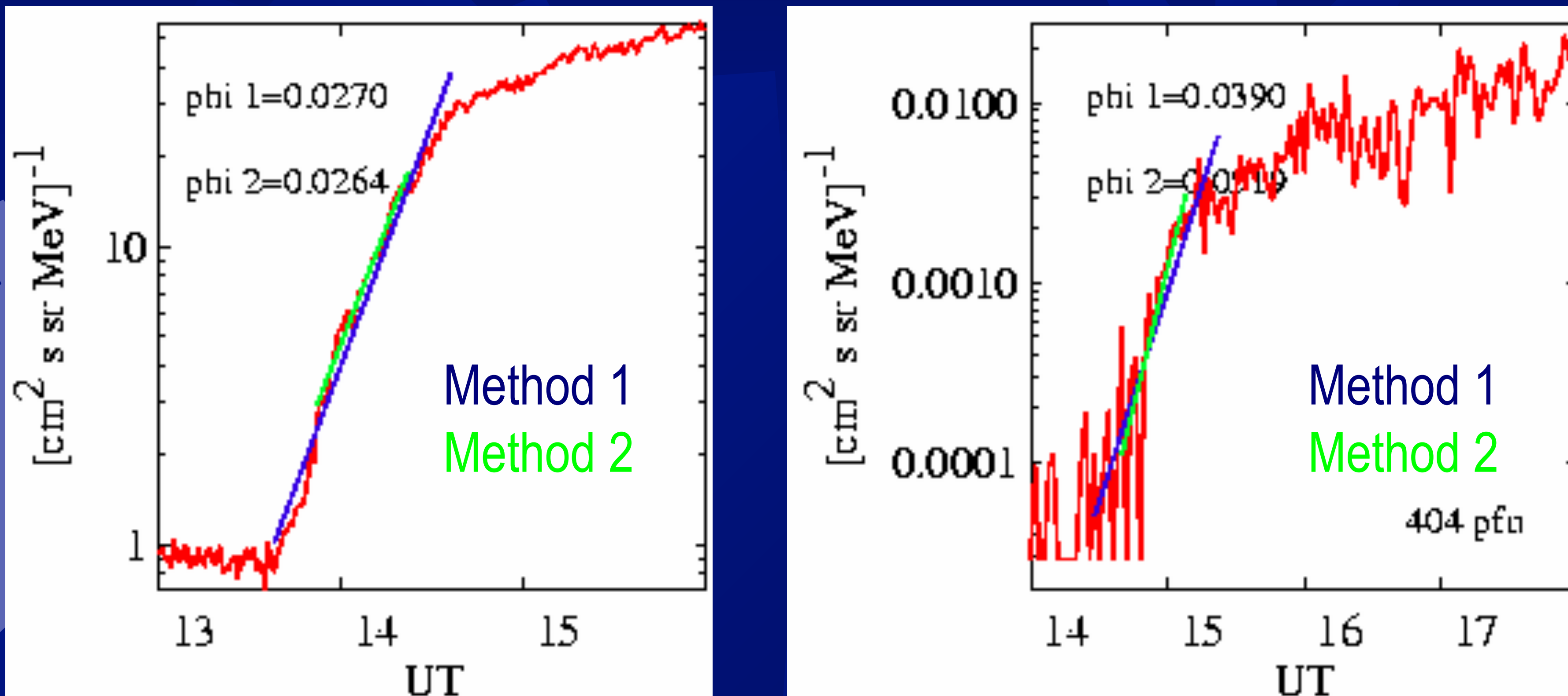


This slide only shows data for the energy range 16-40 MeV, which is relevant for astronaut safety.



Events 20-25
realtime protons
16-40 MeV [cm2 s sr MeV]-1
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
Alert Level
20
21
22
23
24
25
CME
post-proc. protons
16-40 MeV [cm2 s sr MeV]-1
1.0000
0.1000
0.0100
0.0010
0.0001
Alert Level
20
21
22
23
24
25
CME
June 1
July 1
Aug. 1
Sept. 1
Oct. 1
2010

Rise Times for Electrons and Protons in Prompt SEPs



Onset phases of the Nov. 09, 2002 prompt SPE electrons (left) and protons (right). The rates of intensity increase are being determined independently with exponential fits of full (method-1) and center-interval (method-2) periods. The fits are largely independent of the method.

In general, the rise times of electrons and protons are closely correlated.

Cane et al. cont'd:

Group 5: slow-rising, ions peak at shock

Group 4: Fe-poor, e-poor, sign. shock

Group 3:Fe-poor, e-poor, no sign. shock

Group 2: Fe-rich, not e-rich

Group 1: Electron-rich events

Group Linkage to relative timing of metric Type-III emission H-α flare

Group 1: Type-III early