LRO/CRaTER Data Products (Cosmic Ray Telescope for the Effects of Radiation)

Jody Wilson (UNH)

and the CRaTER Team

Jody.Wilson@unh.edu

Outline

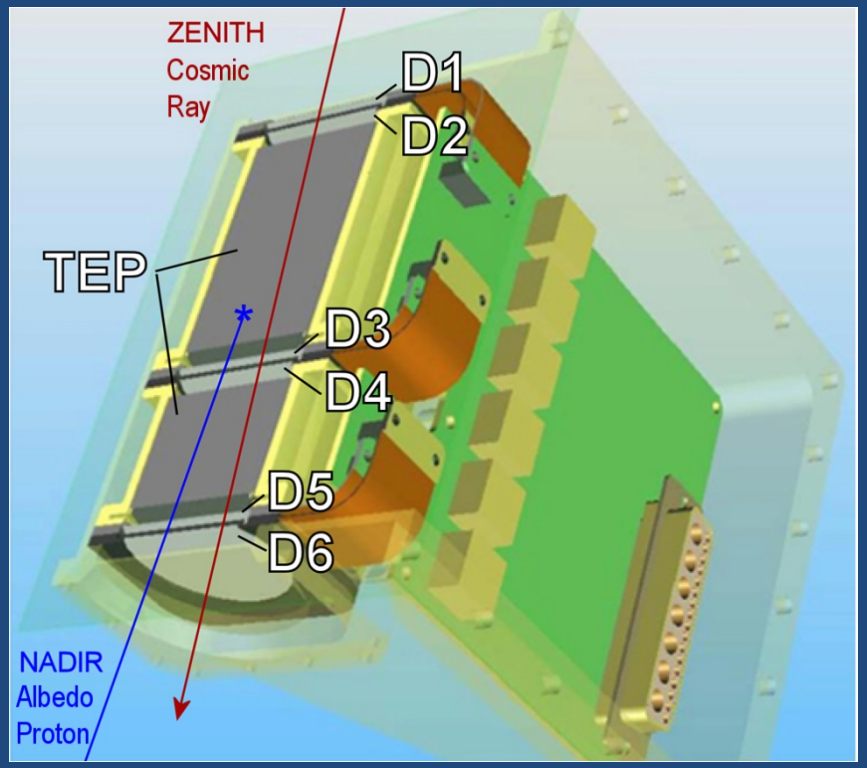
- How CRaTER works & purpose
- Derived Data at UNH

  http://prediccs.sr.unh.edu/craterweb/
- “Raw” Data at NASA PDS

  http://ppi.pds.nasa.gov/

CRaTER Instrument

- Six silicon detectors arranged in 3 pairs
- Thin (1,3,5)+ thick (2,4,6) detectors increase dynamic range
- Separated by Tissue Equivalent Plastic (TEP)
- Normally D1 faces zenith, D6 faces nadir (Moon)
- Records each time a cosmic ray passes through at least one detector



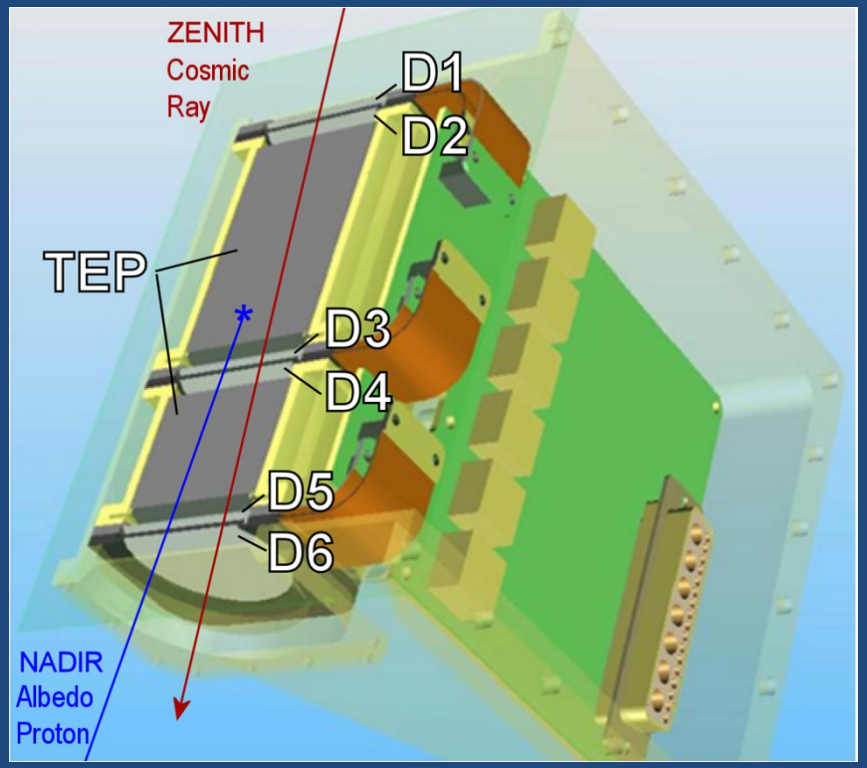
Measure Lunar radiation environment

Ever-present isotropic
Galactic Cosmic Rays

- Very high energy (relativistic) atomic nuclei from outside the solar system

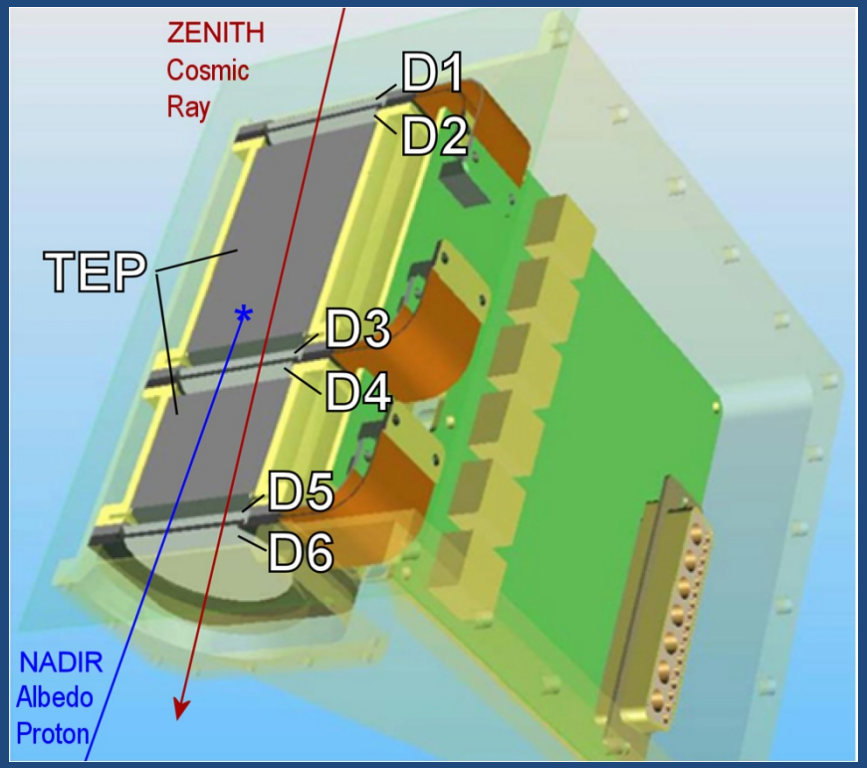
Intermittent storms of
Solar Energetic Particles

- Can have very high fluxes
- Less energy than cosmic rays, but still energetic



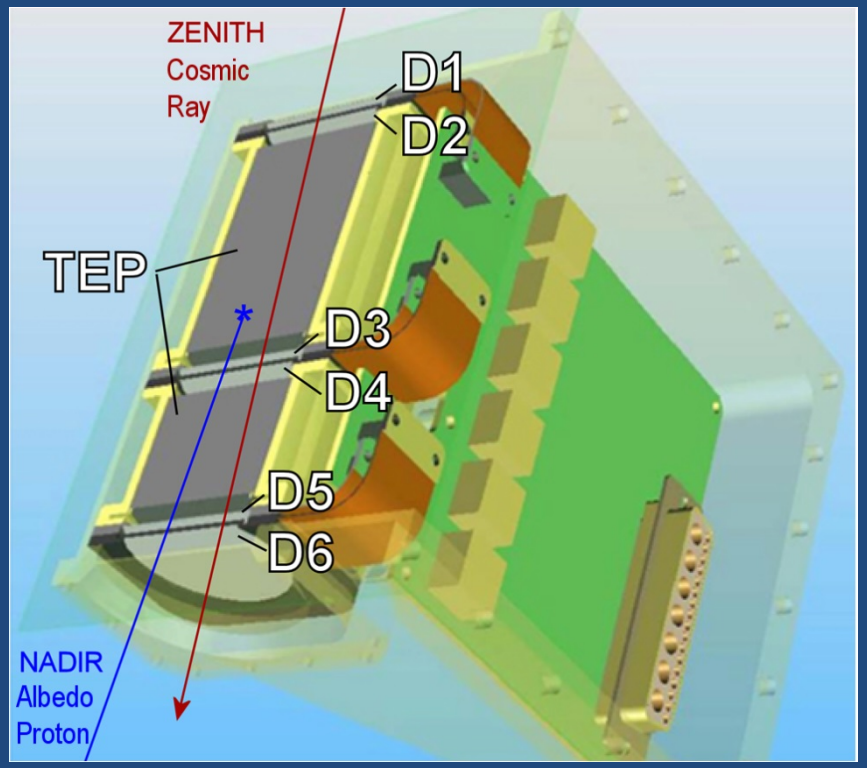
Exploration & science

- Radiation dose rates (and trends for future astronauts)
- Effects of shielding on radiation dose
- Quantifying radiation impacting lunar surface
- Long-term changes in cosmic ray background
- Details of solar particles (solar flares)



Shielding with Tissue Equivalent Plastic

- Top two detectors (D1/D2) = skin or eye lens behind thin spacecraft wall
- Middle two detectors (D3/D4) = blood-forming organs, shielded by 2” TEP
- Bottom two detectors (D5/D6) face the Moon … partly shielded from Cosmic Rays, also detect radiation from the Moon



Radiation Dose & Dose Equivalent

Dose = ionizing energy deposited per unit mass

1 gray = 1 J/kg

Dose Equivalent: like dose, but weighted by the effect of radiation type on **biological tissue**

- Non-linear function of LET

1 sievert ~ 1 gray

Dose limits for Astronauts*

Exposure Interval	30 days	1 year	Career[1]	10yr career, 3% mortlt.[2]	
Blood frmng. organs	**.25 Sv**	**.5 Sv**	**1-4**	**25yr woman**	**55yr man**
Eyes	1 Sv	2 Sv	4 Sv	**.40 Sv**	3 Sv
Skin	1.5 Sv	3 Sv	6 Sv		

Hypothetical mission doses for solar min.

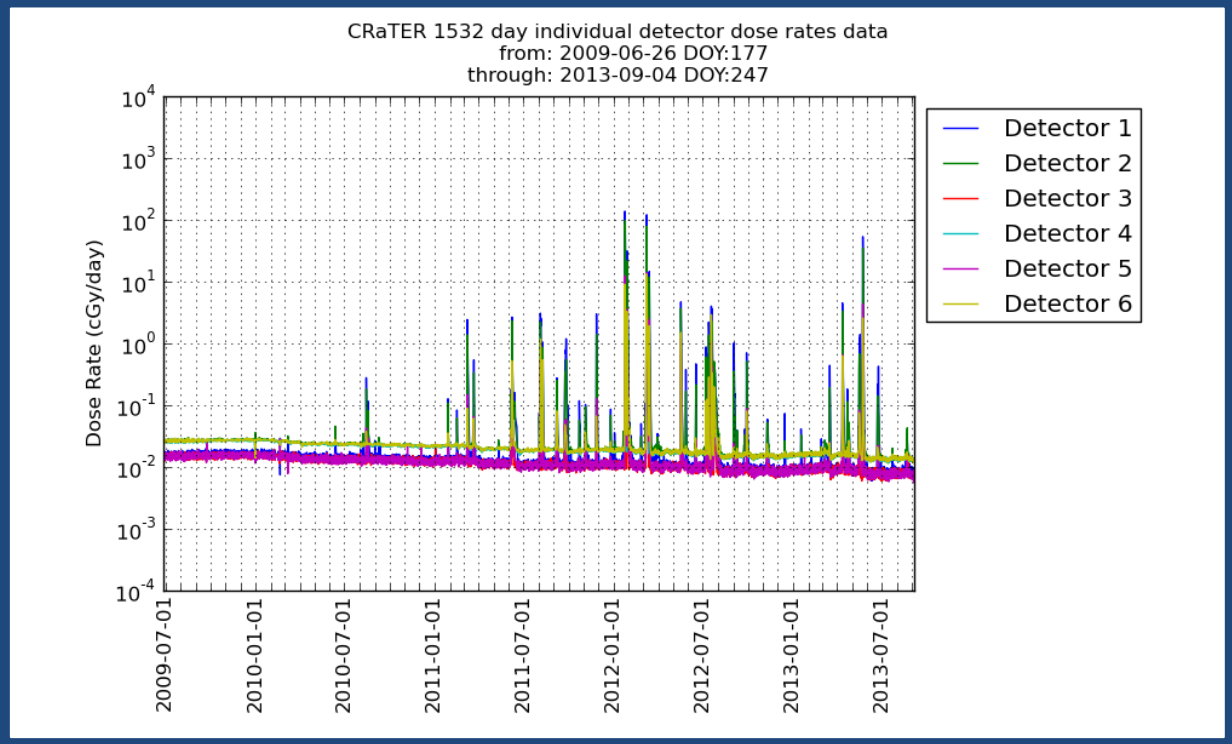
Apollo-like	Moon base	Mars round-trip
1 week	6 months	2 years
.007 Sv	.13 Sv	1 Sv
✓**Manageable**	✓**Manageable**	o**Reaching/exceeding some limits** o**Avoid high dose events**

1. NCRP Report No. 98 (1989)
2. NCRP Report No. 132 (2000)

Dose Rates during LRO Mission

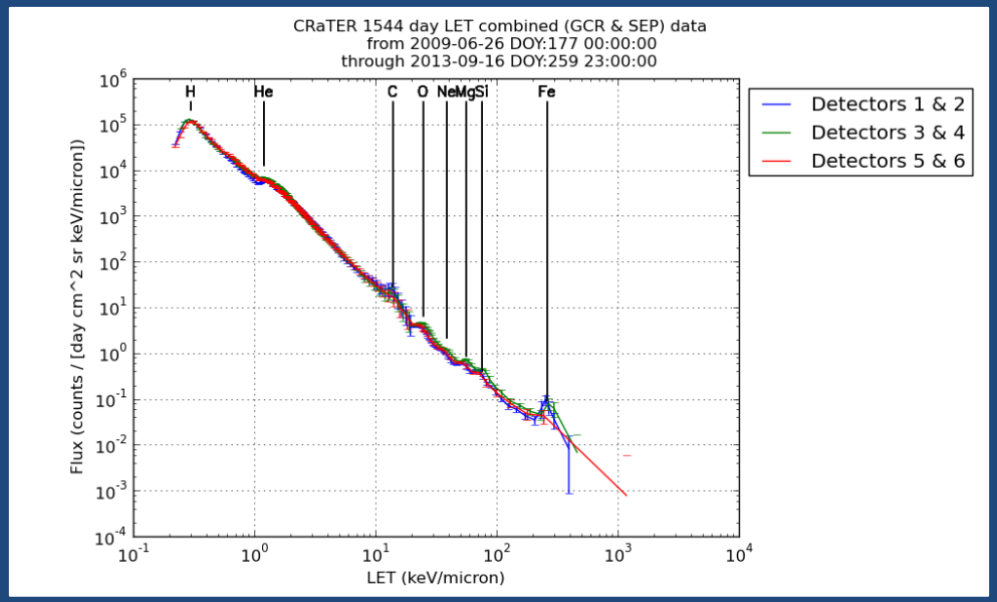
- Variety of solar particle events – some of them dangerous to deep-space astronauts

- Declining cosmic ray background dose rate due to increasing solar activity, interplanetary B field



Linear Energy Transfer Spectra (LET)

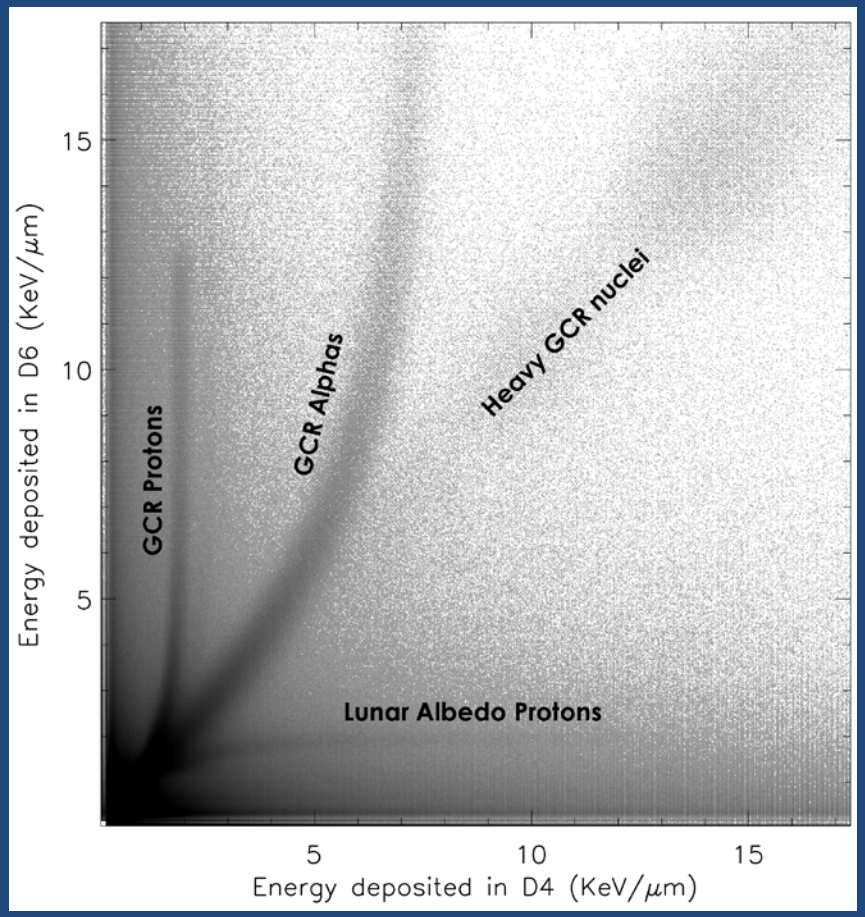
- LET = Energy deposited per unit length by cosmic ray passing through matter
- LET spectrum: particle-by-particle histogram of LET
  - Shows peaks from different elements in cosmic ray population
  - **Used to derive dose and dose equivalent**



LET Cross-Plots

Cross plots = two-dimensional LET spectra

- Particle-by-particle LET in two separate detectors
- Nuclei lose energy in TEP → deposit unequal energies in detectors
- Only show particles arriving in cone-shaped zones from top or bottom -> Telescope!
- Better discrimination of different species
- Contain DIRECTIONAL information – can distinguish protons coming from lunar surface

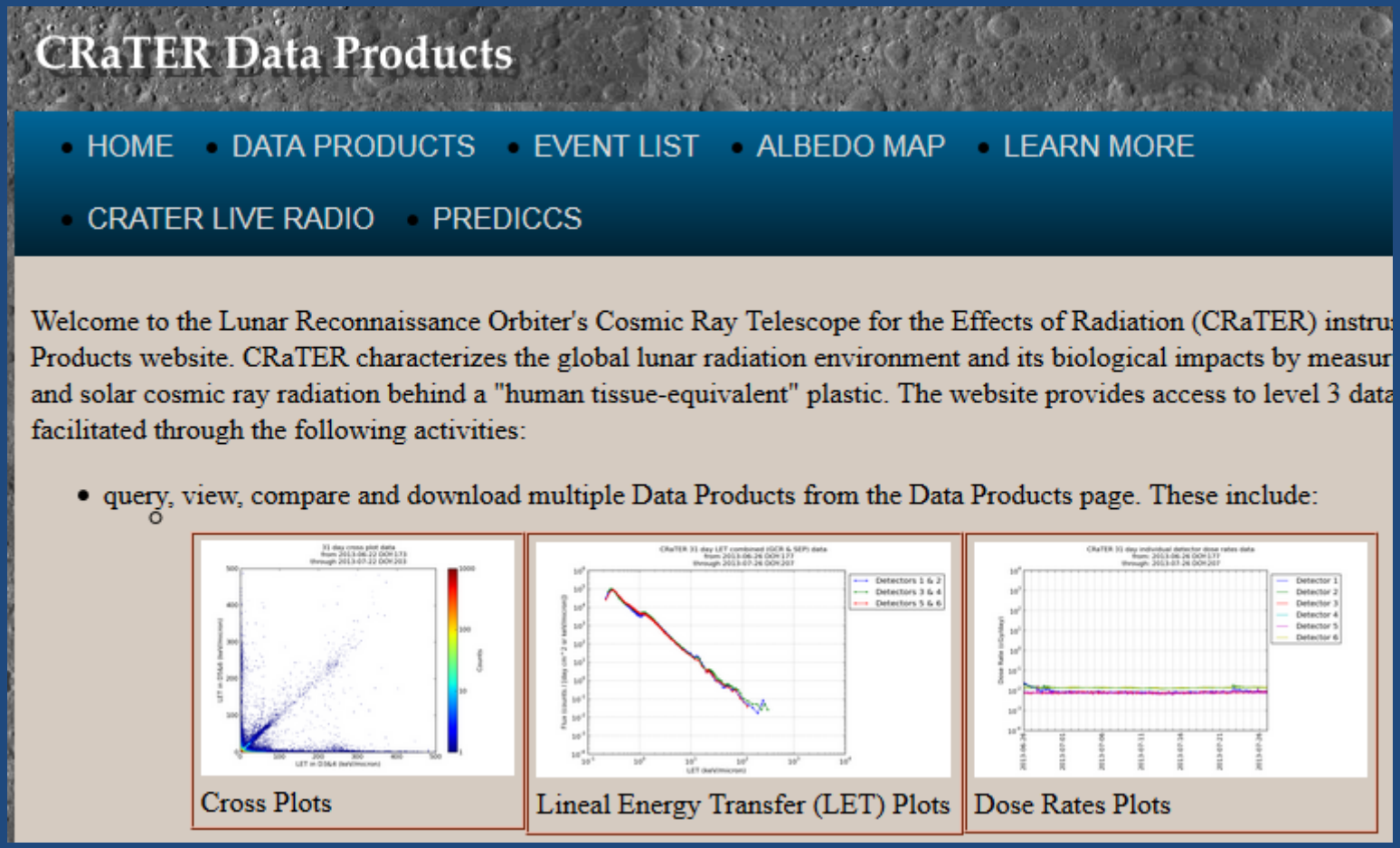


Derived Data Products Page
http://prediccs.sr.unh.edu/craterweb/

- Dose rates, LET spectra, and cross-plots
- All data available in both image plots and simple ASCII text files
- Customizable date ranges (1 week to mission)
  - Option to include only solar particle events OR times with only galactic cosmic rays
- Event List Visualization Page allows for quick navigation to a particular solar particle event

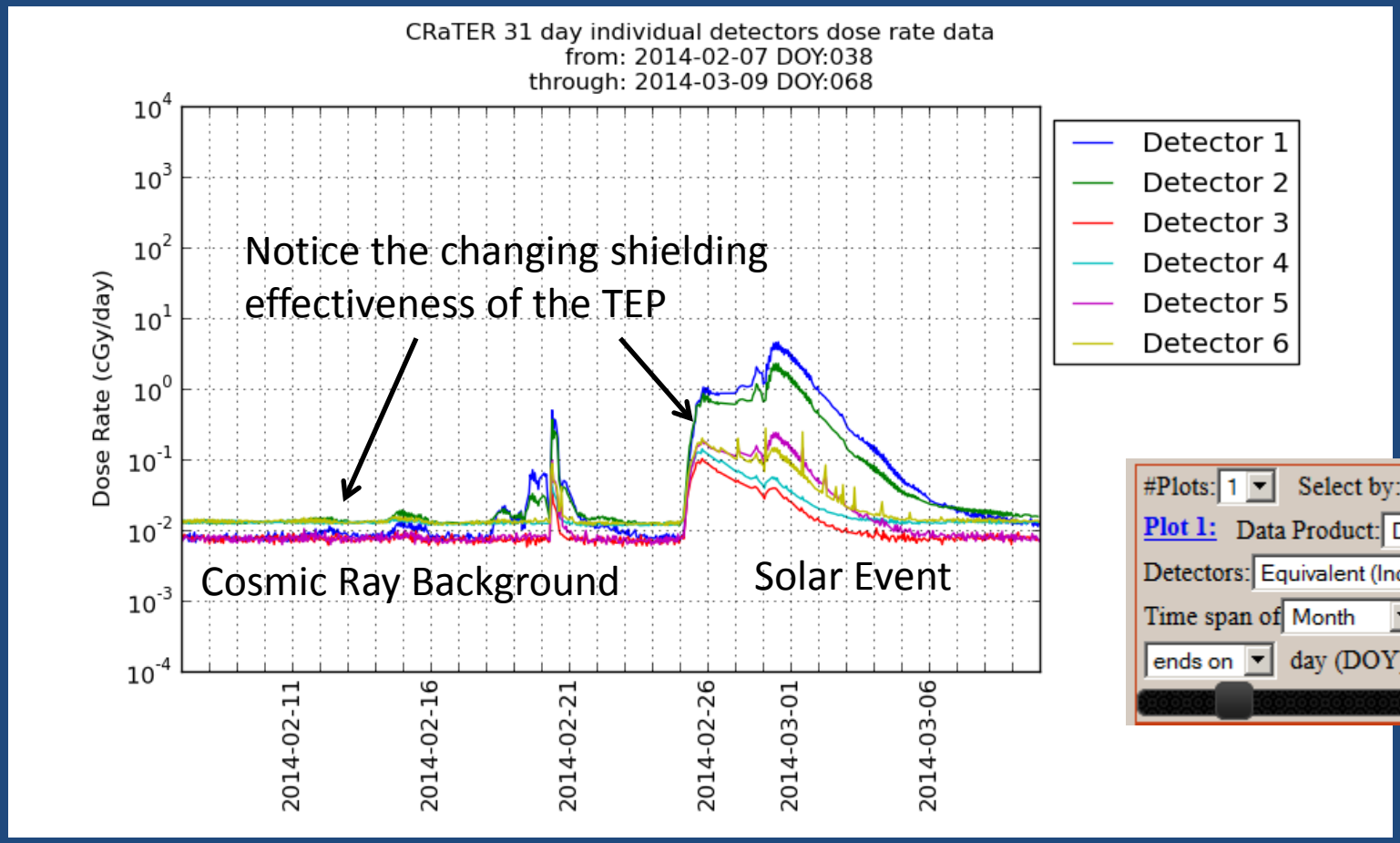
Derived Data Products Page

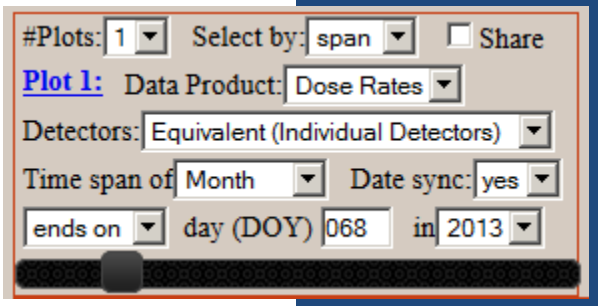
http://prediccs.sr.unh.edu/craterweb/



Dose rate plot customizations

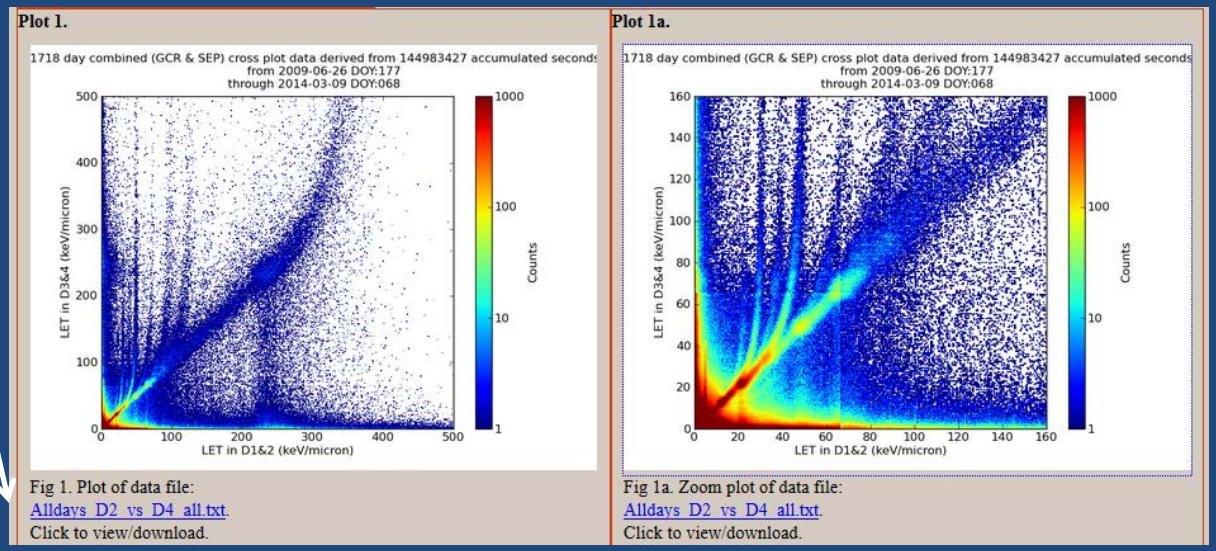
- Choose dose (energy) or dose equivalent (bio)





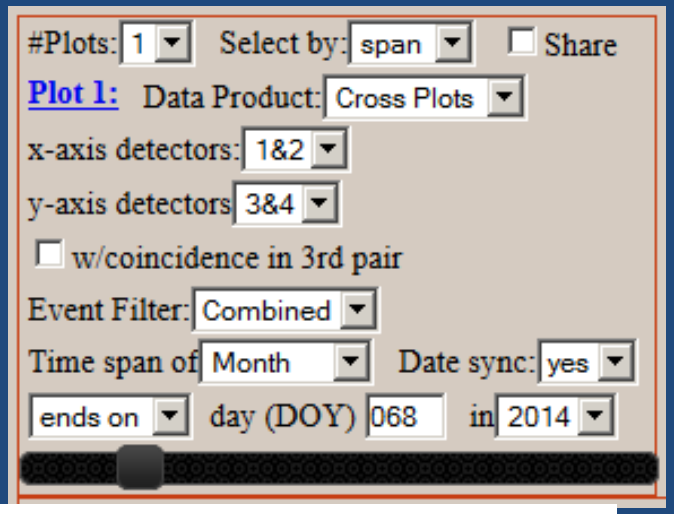
LET Cross-Plots

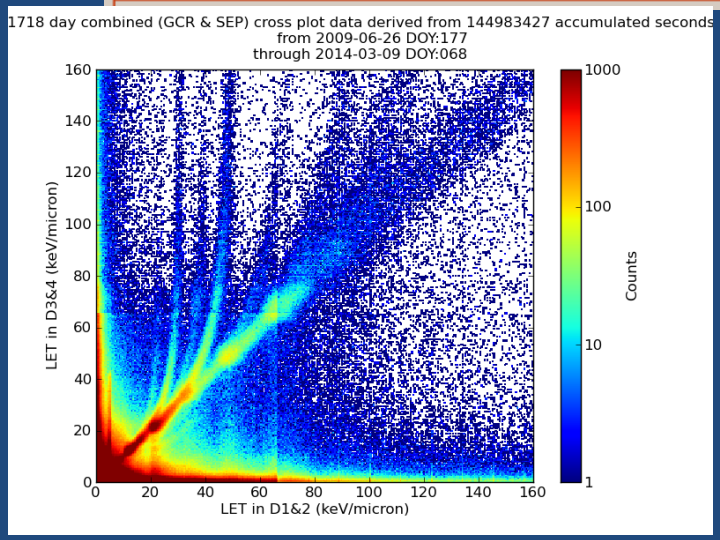
- Cross-plot images are downsampled to fit on a computer screen
- Use corresponding text files (large 2-D tables) for quantitative analysis



Cross-plot customizations

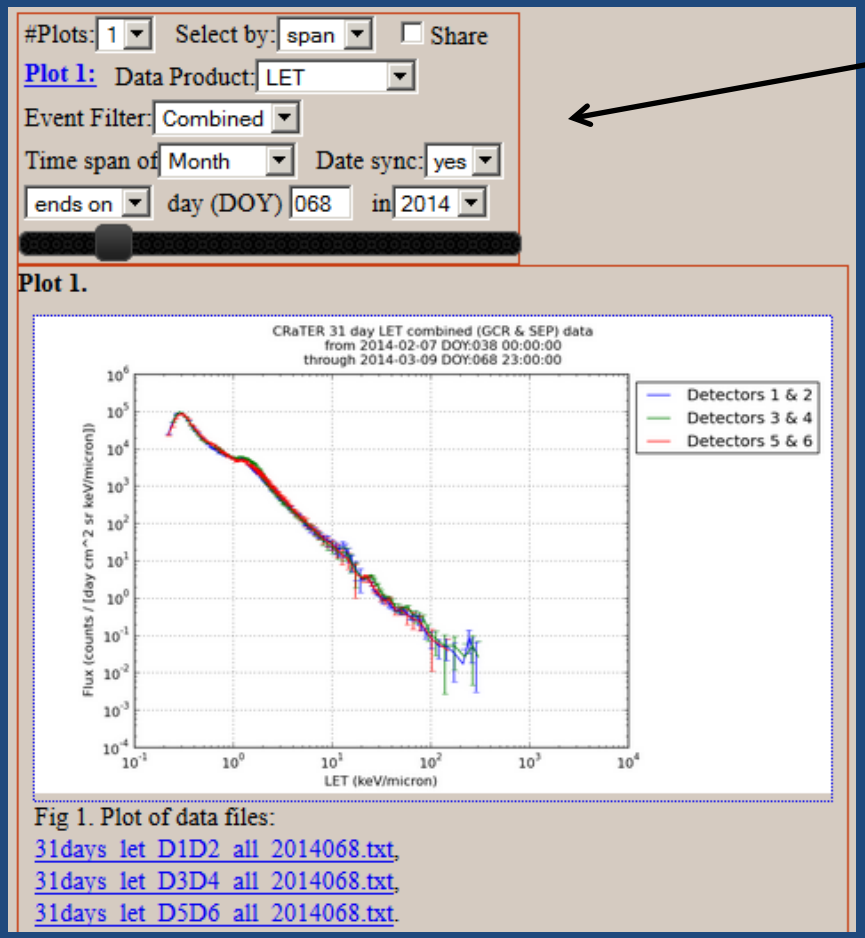
- Choose which detector pairs to plot
- Further option to require or exclude detection in 3rd detector pair
  - "Triple coincidence" particles are less numerous, but are confined to a narrower directional cone, and can be more confidently identified



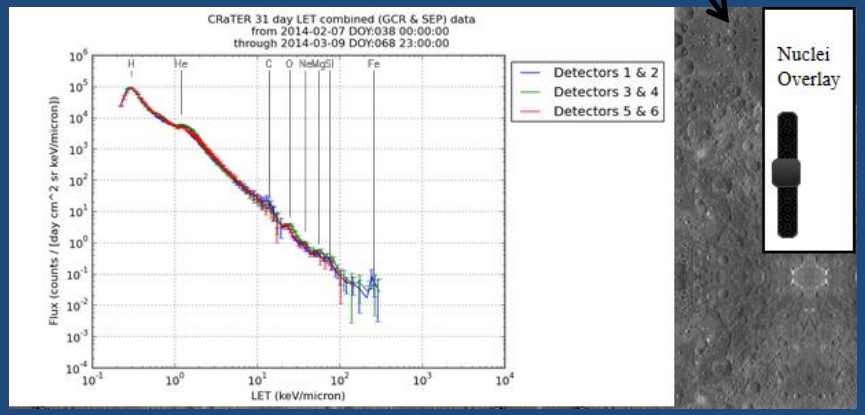


http://prediccs.sr.unh.edu/craterweb/
Jody.Wilson@unh.edu
http://ppi.pds.nasa.gov/

LET Spectra



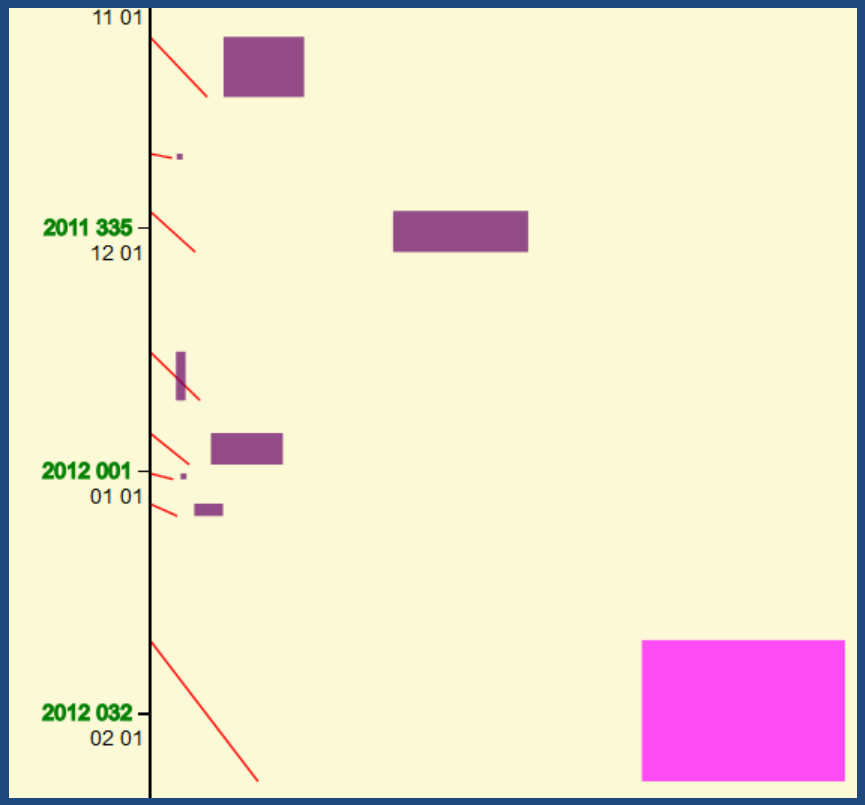
Customize time frame, then click on image to get to element identification slider



Solar Particle Event Visualization Page

- Height → length of particle event
- Left and Right edges → avg. and max dose rates
- Color → Total dose

- Clicking on event brings up LET spectra and cross-plots for the event



Additional webpage info

- Select from 1 to 4 plots (LET, cross-plot, dose) to show at one time
- Synchronize all plots to the same time frame, or select separate times for each plot
- General descriptions of plots and calibration notes in the “Learn More” tab
- Clicking on LET spectrum or cross-plot brings up element-identification slider

“Raw” Data in NASA PDS

http://ppi.pds.nasa.gov/

- Large daily text files with one or more lines of data taken every second of the LRO mission
- SEC files: second-by-second number of particle detections in each detector (D1-D6)
  - Also contain instrument settings (not shown here)

```
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```

“Raw” Data in NASA PDS

http://ppi.pds.nasa.gov/

PRI files: LET deposited in all 6 detectors for **each particle** detected by CRaTER!

- 20 to 40 particles per second during quiet times
- Large files with 1000’s of particles per second during solar events
- Used to produce LET spectra and cross-plots

PRI data file

(column headers in .FMT files)

Date & Time # 1 2 3 4 5 6 Energy LET→

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“Raw” Data in NASA PDS

http://ppi.pds.nasa.gov/

- Earth (Moon) → LRO → Cosmic Ray Telescope
- Data organized by year (2009-2014) then by Day-of-year (1-366)
- Directory for each day contains .FMT files that identify the columns in the data files
- HK (housekeeping) files: instrument voltages, temperatures, crude pointing information

Simple Uses of Raw Data Files

- Plotting particles per second from secondary files using any plotting program: MS Excel, autoplot, your favorite programming language… (will look a lot like the dose rate plots already available in the Derived Data page!)

Issues

- Occasional noise in detector D2
- Occasional data gaps due to spacecraft glitches, file transmission errors
- Don’t use data during “pulser sweeps”
- Check LRO/CRaTER’s orientation (HK files)
  - Usually oriented with D1-zenith, D6-nadir
- Multiple/changing particles evident in cross-plots as “diffuse” signal

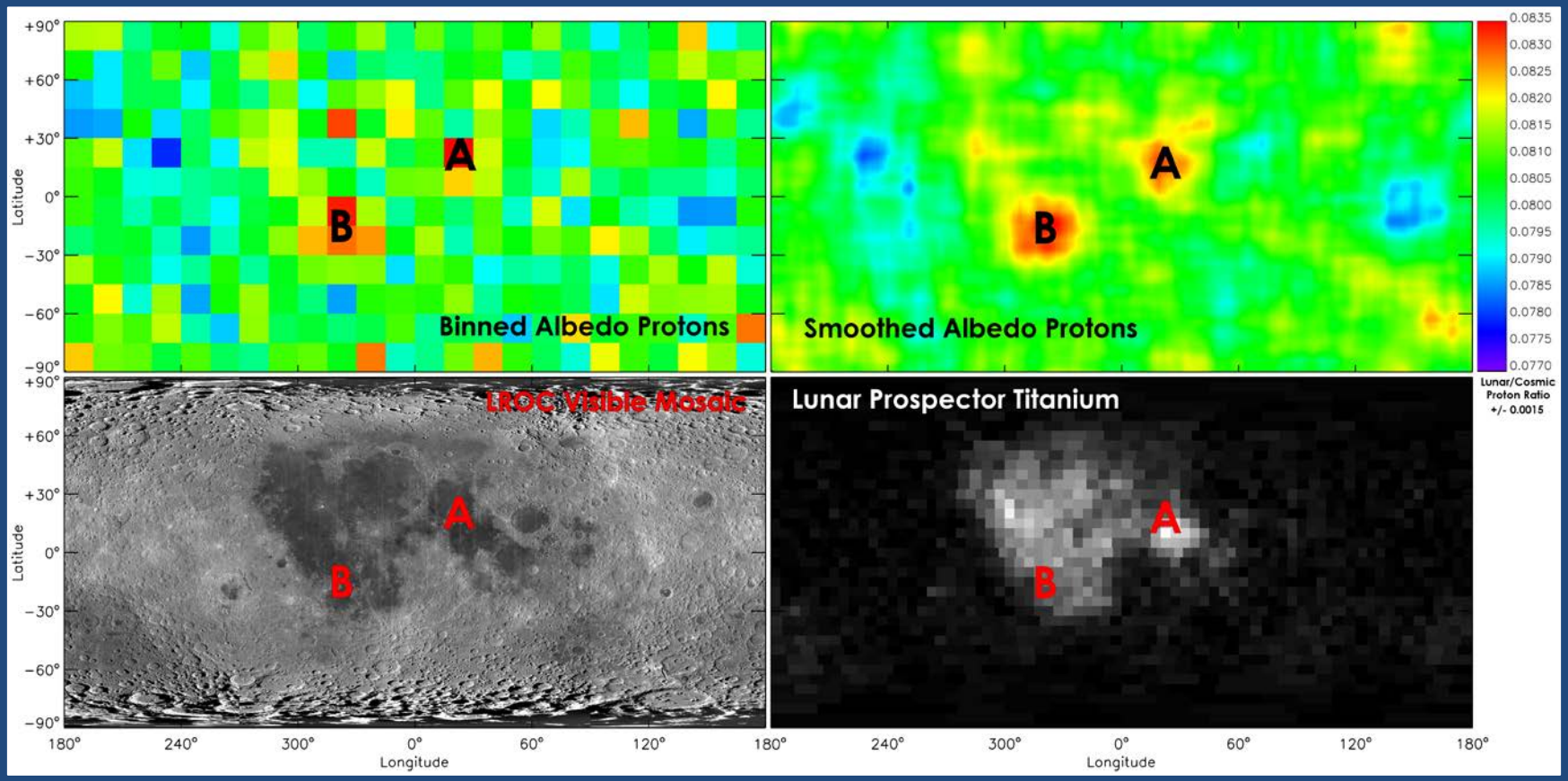
LRO/CRaTER Data Products (Cosmic Ray Telescope for the Effects of Radiation)

Jody Wilson (UNH) and the

CRaTER Team

Jody.Wilson@unh.edu

Albedo Proton Map



Computational sequence

- LET of individual particles in 6 detectors (Raw)
- LET spectra
- Dose rates
- Equivalent dose rates

- Cross-plot = 2-Dimensional LET spectrum