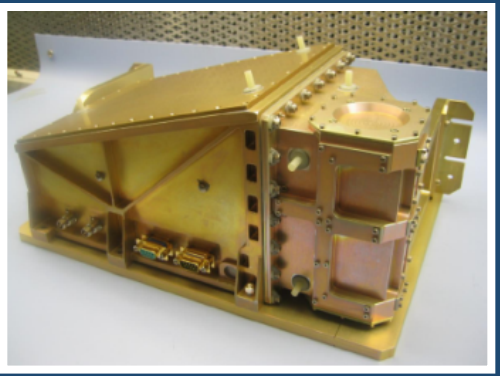


LRO/CRaTER Data Products (Cosmic Ray Telescope for the Effects of Radiation)

Jody Wilson (UNH)

and the CRaTER Team

Jody.Wilson@unh.edu

Outline

- How CRaTER works & purpose
- “Raw” Data
- Data Products (ADR)
- CRaTER Website

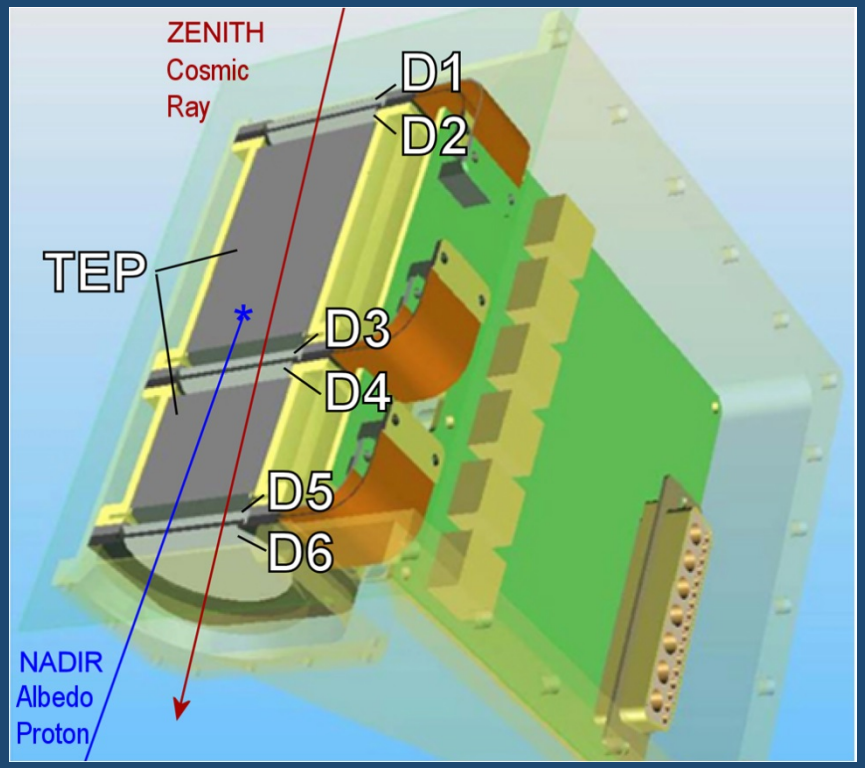
  http://crater-web.sr.unh.edu

- 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)
- Usually D1 faces zenith, D6 faces nadir (Moon)
- Records each time a particle passes through at least one detector



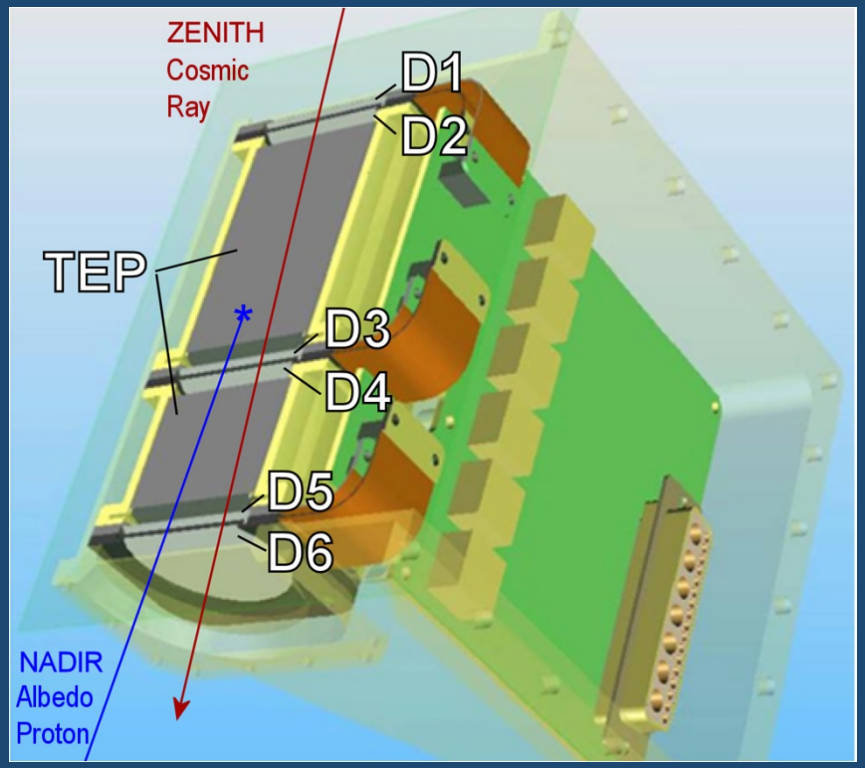
Measure Lunar radiation environment

Ever-present isotropic **Galactic Cosmic Rays**

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

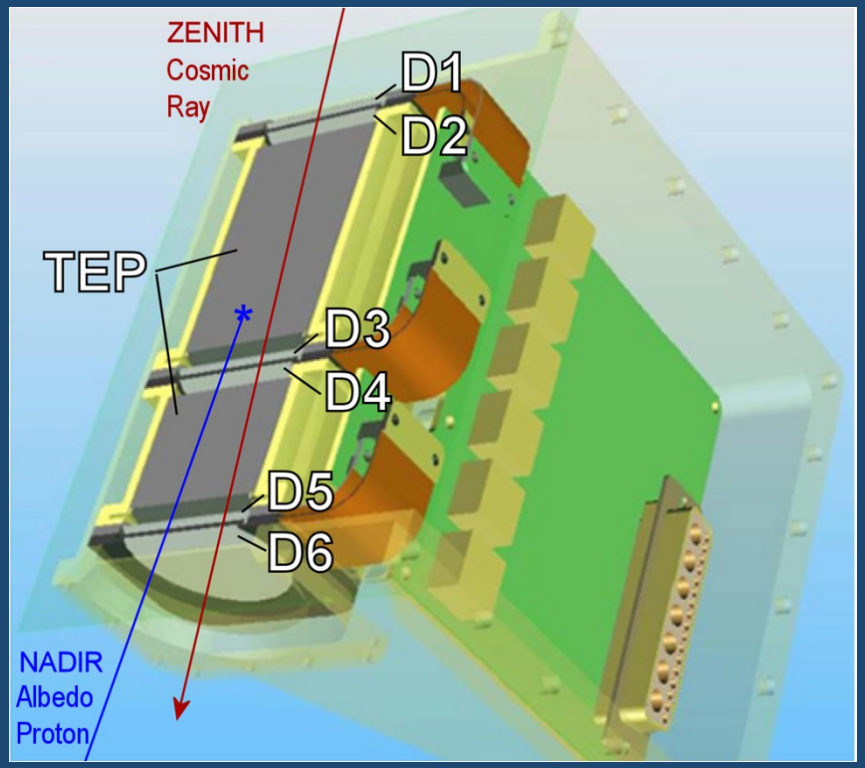
Intermittent storms of **Solar Energetic Particles**

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



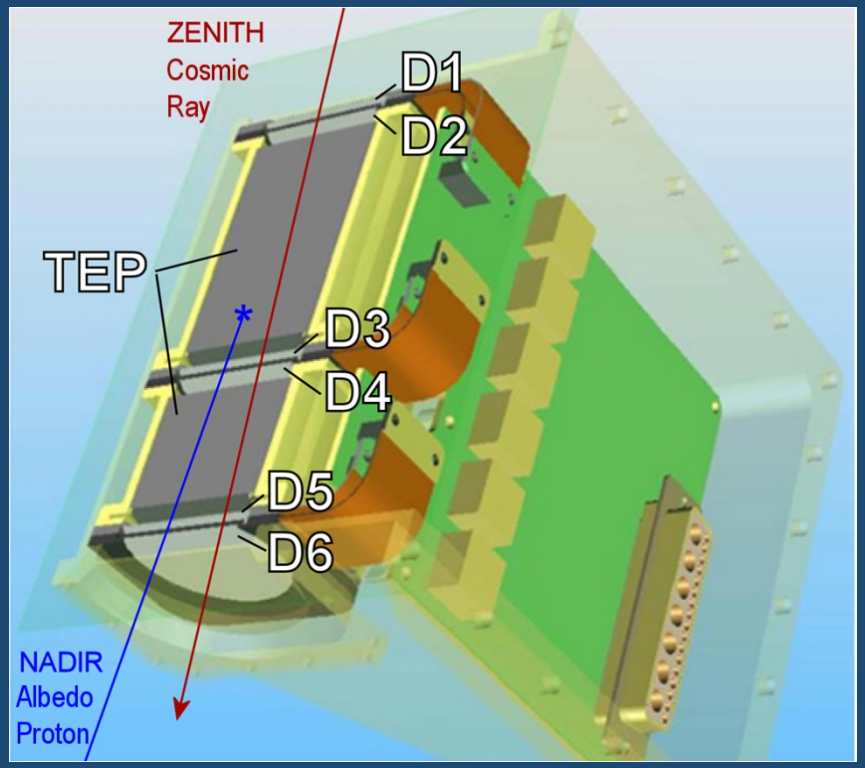
Exploration & Science

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



Shielding and Tissue Equivalent Plastic (TEP)

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



Linear Energy Transfer

- **LET**: Energy deposited per unit length by cosmic ray passing through matter
- LET higher for ions with higher charge
- LET increases as ion slows

“Raw” (L2) Data

- Large daily text files with one or more lines of data taken every second of the LRO mission
- SEC (secondary) 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” (L2) Data

PRI (primary) files: LET deposited in each detector for every particle detected by CRaTER

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

Primary L2 data file

(column headers in .FMT files)

Date & Time # 1 2 3 4 5 6 Energy LET→

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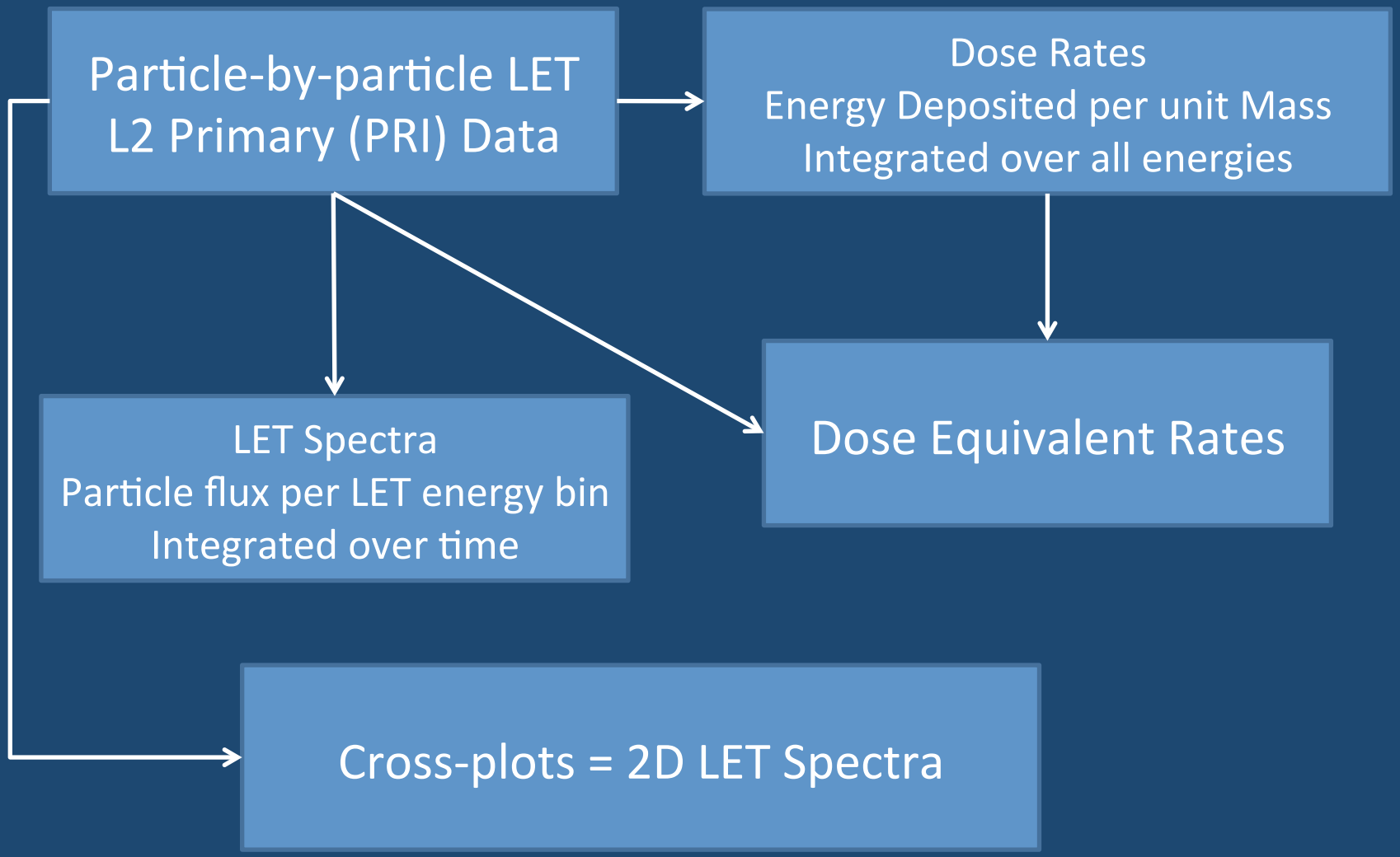
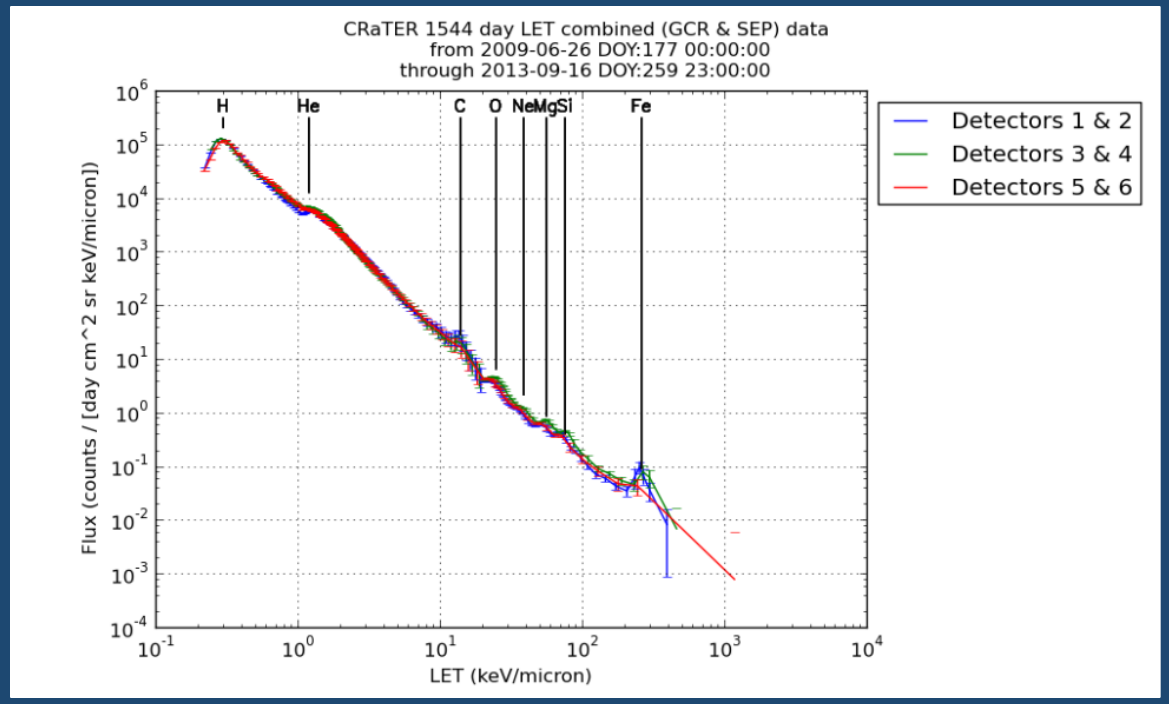
Data Products Flow Chart



Linear Energy Transfer Spectra (LET)

- **LET**: Energy deposited per unit length by cosmic ray passing through matter

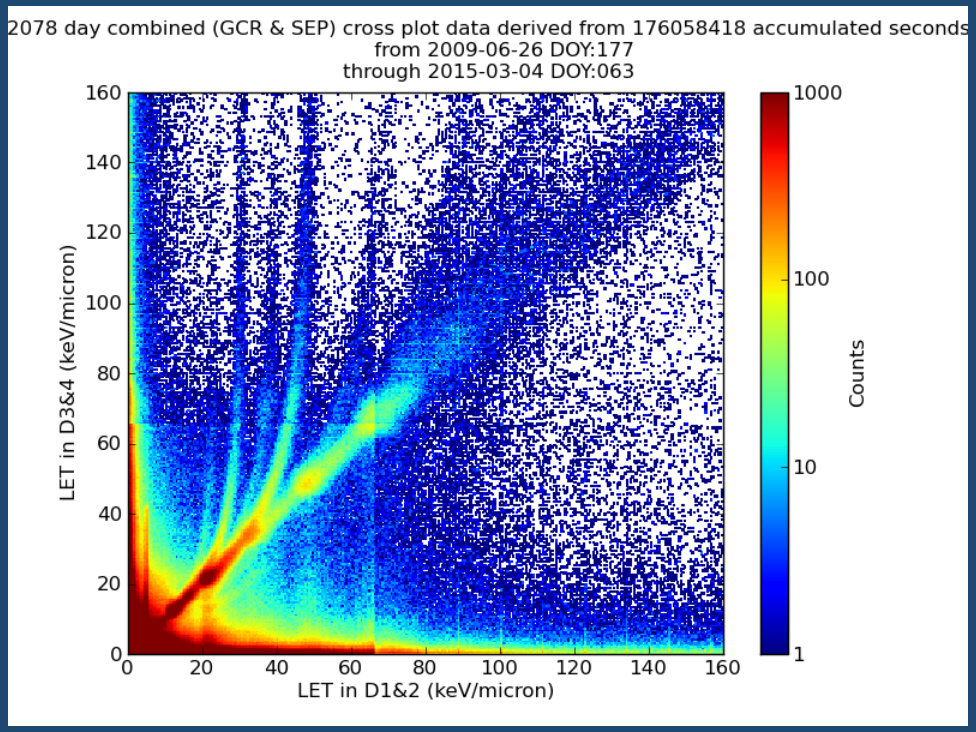
- **LET spectrum**: particle flux per LET energy bin
  - Integrated over time
  - Shows peaks (MIPs) from different elements in cosmic ray population



LET Cross-Plots

Cross-plots: Two-dimensional LET spectra

- Particle-by-particle LET in two separate detectors
- Nuclei lose energy in TEP, so they deposit unequal energies in detectors



Location on plot tells

- Direction of arrival
- Element/species

Critical component of lunar proton mapping

Radiation Dose & Dose Equivalent

Dose = total 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.

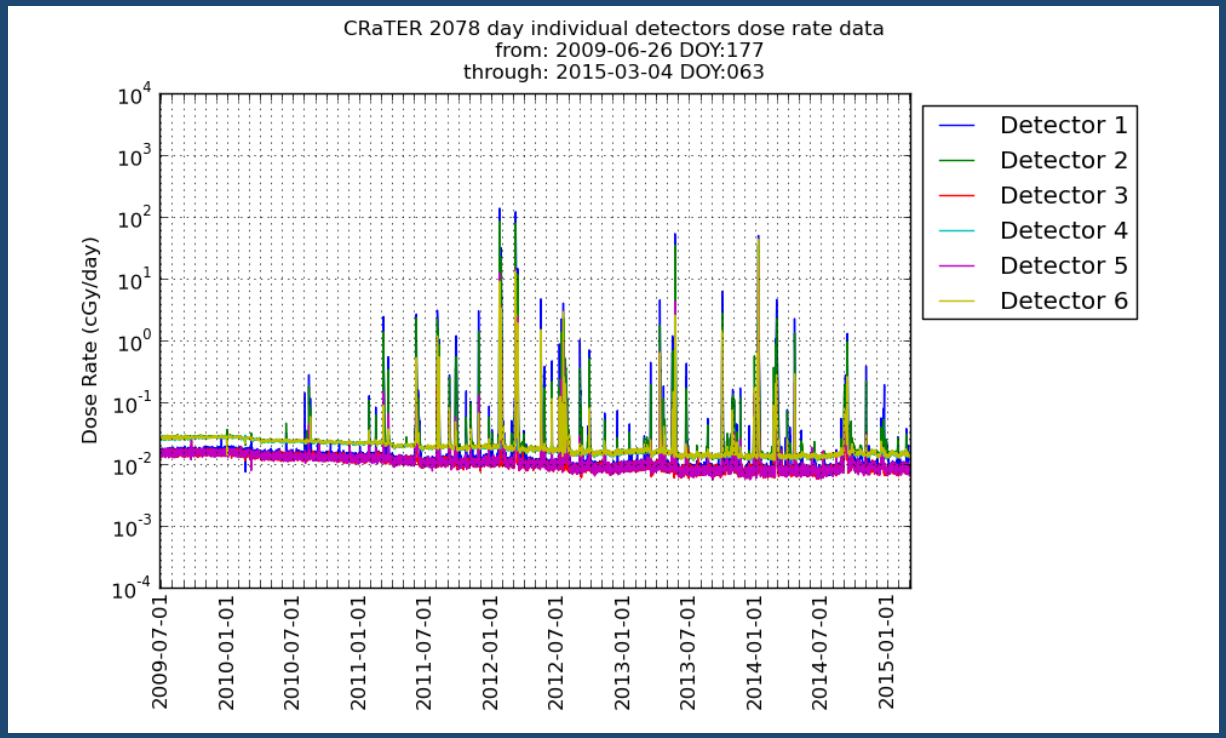
Apollo-like	Moon base	Mars round-trip
1 week	6 months	2 years
.007 Sv	.13 Sv	1 Sv
✓**Manageable**	✓**Manageable**	○**Reaching/exceeding some limits** ○**Avoid high dose events**

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



CRaTER Data Products

http://crater-web.sr.unh.edu/

Documentation

Instrument Description
Data Product Description

Publications, News and Media

The CRaTER Special Issue of Space Weather Publications
CRaTER Live Radio

Links

PREDICCS
UNH EOS
NASA PDS PPI Node CRaTER Data Archive

Contact Us

CRaTER PI: Nathan Schwadron
Legacy Data Product Website
Webmaster for CRaTER Data Products

Data

- Level 2 Data
  - Daily: Full (data files)
- Event Periods
  - SEP Events Visualization

Products

- Dose Rates
- Dose Equivalent
- Micro Dosimeter
- Lineal Energy Spectra (LET)
- Cross Plots
- Lunar Albedo Maps
- Dielectric Charging (coming soon)
- Dose vs Depth (coming soon)

Ancillary Information

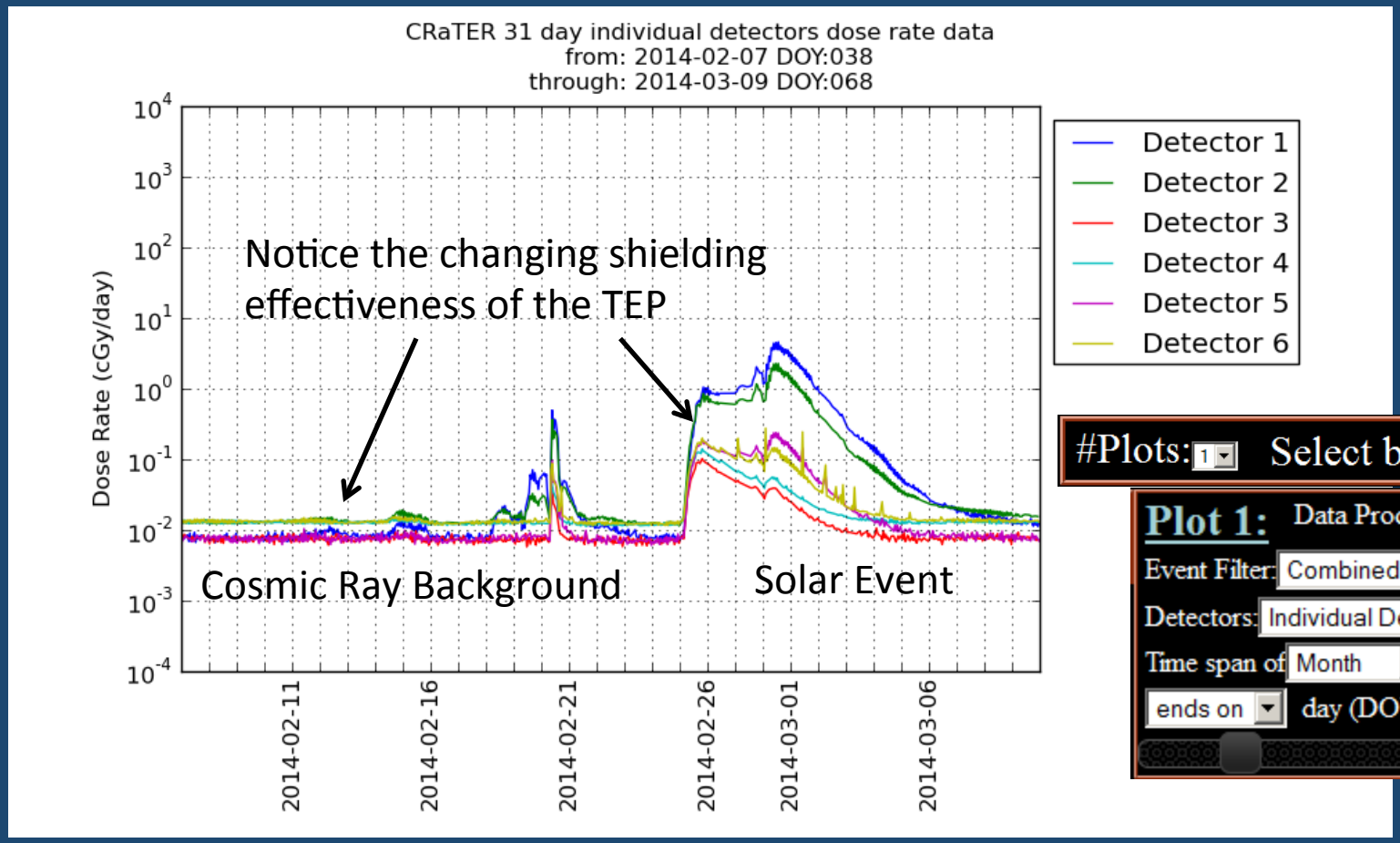
- Instrument
  - Housekeeping Data
    - HK Daily
- Ephemeris and Pointing
  - Daily: LRO Ephemeris/CRaTER Telescope Pointing Vectors (data files)

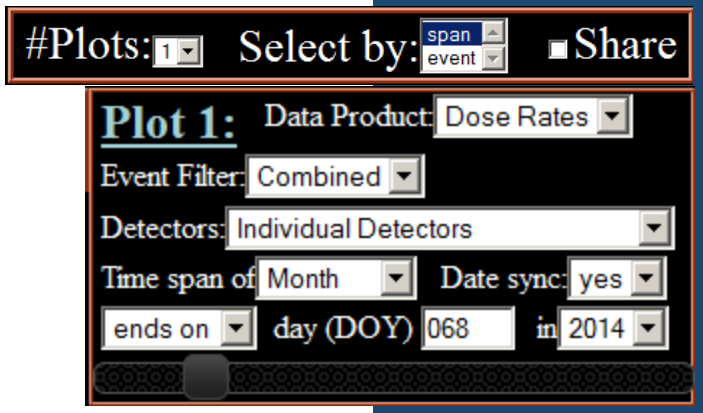
CRaTER Data Products
http://crater-web.sr.unh.edu/

- L2 Data, Dose rates, Equivalent Dose, Micro-dosimeter, LET spectra, and Cross-plots
- Image plots and ASCII text files
- Time ranges from 1 week to whole mission
  - Option to include only solar particle events (SEPs) or times with only galactic cosmic rays (GCRs)
- Event List Visualization Page allows for quick navigation to a particular solar particle event

Dose rate plot customizations

For Dose (energy in D1-D6), Dose Equivalent (biological), or Micro Dosimeter (simple single detector) rates

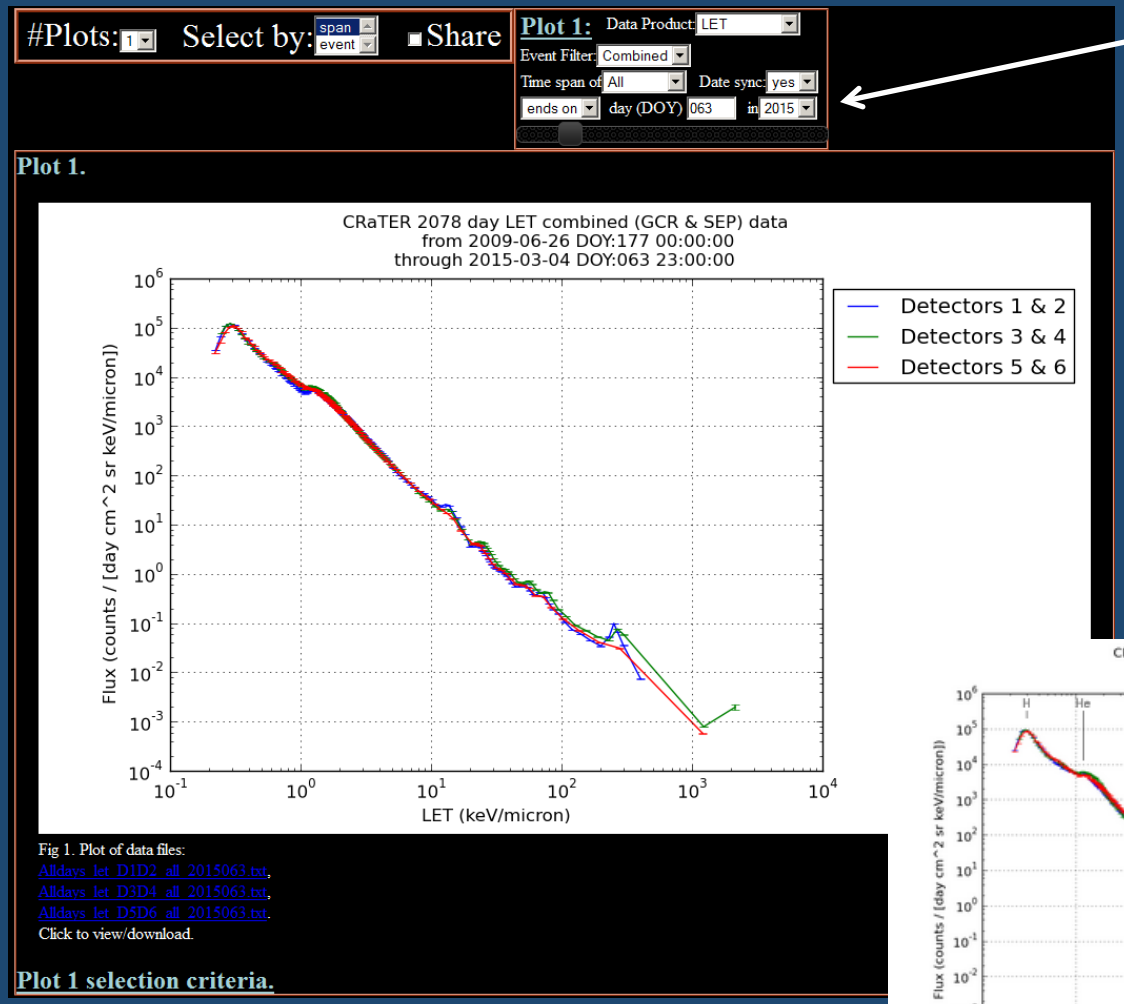




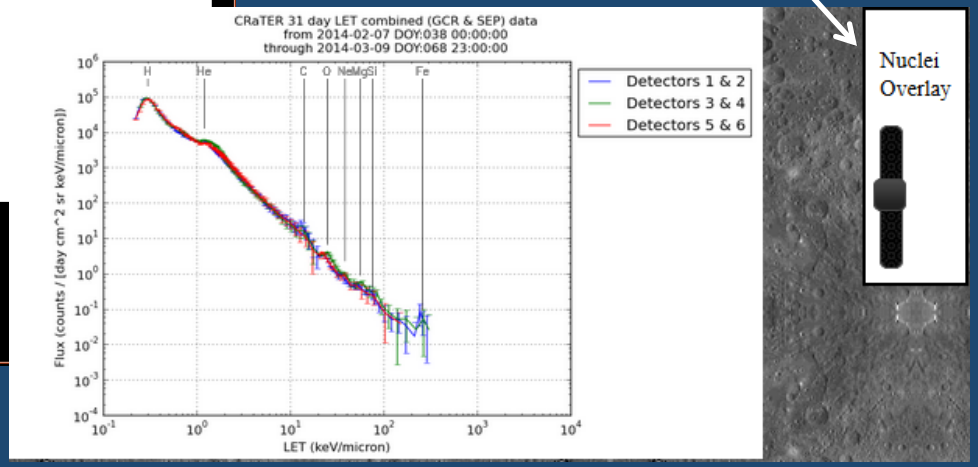
Dose Equivalent Rate text file

# Julian Date	Year	DOY	Year Fraction	H2O	Alt.	GE	D1&2 dose rate	D3&4 dose rate	D5&6 dose rate	D1 dose rate
2457084.520833	2015	62	2015.1671804	1.333	0.711	1.000	8.5048e-02	7.6991e-02	6.6342e-02	7.7988e-02
2457084.562500	2015	62	2015.1672945	1.333	0.811	1.000	8.4554e-02	9.2122e-02	1.0877e-01	7.6912e-02
2457084.604166	2015	62	2015.1674087	1.333	0.711	1.000	7.6447e-02	7.8311e-02	7.4558e-02	6.9332e-02
2457084.645833	2015	62	2015.1675228	1.333	0.812	1.000	1.1005e-01	9.8251e-02	8.9516e-02	1.0241e-01

LET Spectra



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

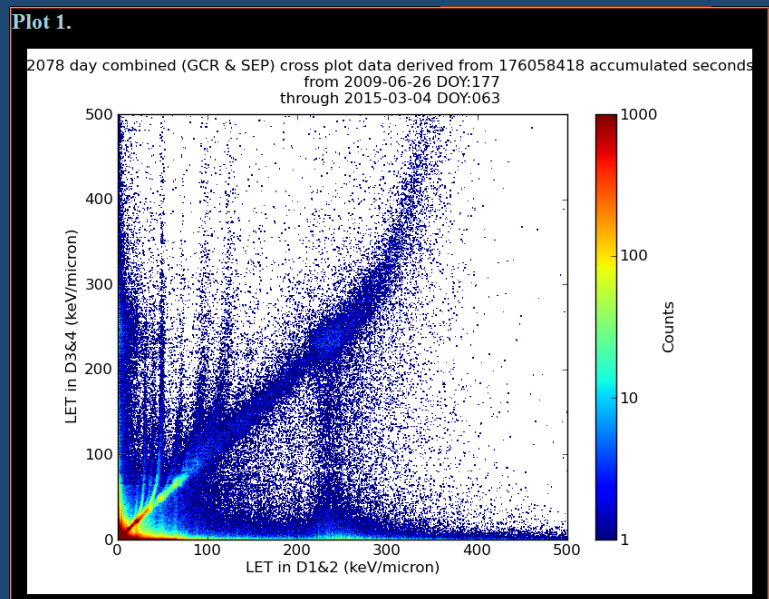


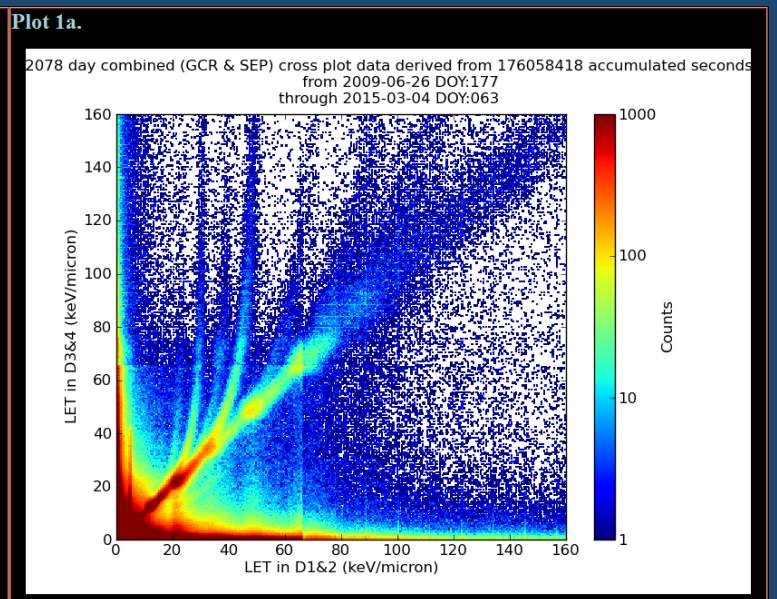
LET Spectra text file

# LET	Flux	Flux Error
2.231900e-01	2.674200e+04	2.568700e+02
2.448700e-01	5.646900e+04	3.732700e+02
2.665500e-01	9.247100e+04	4.776700e+02
2.882300e-01	1.032600e+05	5.047500e+02
3.099100e-01	9.670800e+04	4.884800e+02
3.315900e-01	7.761500e+04	4.376200e+02
3.532700e-01	6.437200e+04	3.985400e+02
3.749500e-01	4.937800e+04	3.490500e+02
3.966300e-01	4.297700e+04	3.256400e+02
4.183100e-01	3.457100e+04	2.920600e+02
4.399900e-01	3.058100e+04	2.746900e+02
4.616700e-01	2.594500e+04	2.530100e+02

LET Cross-Plots

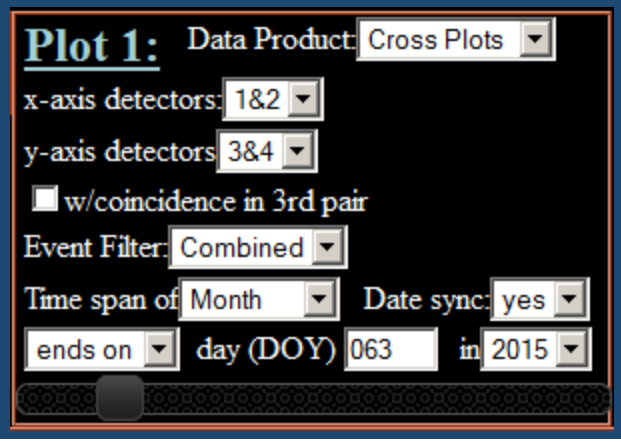
- Cross-plot images are down-sampled to fit on a computer screen – 2 zoom levels
- Use text files (2-D tables) for quantitative analysis

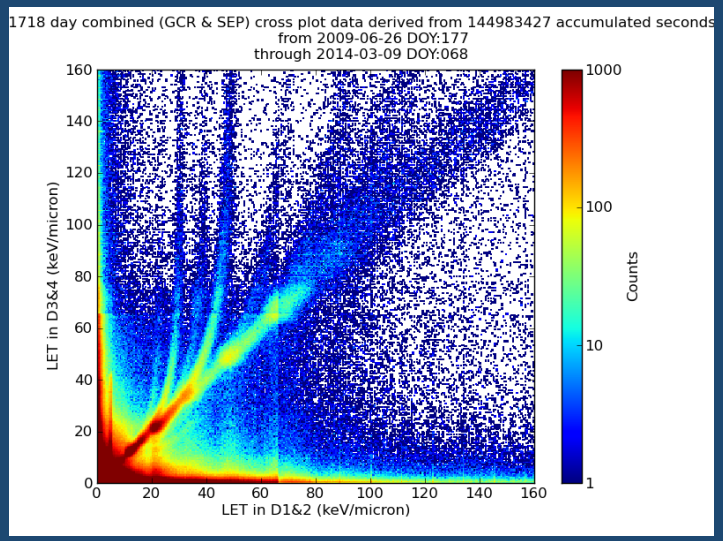




Cross-plot customizations

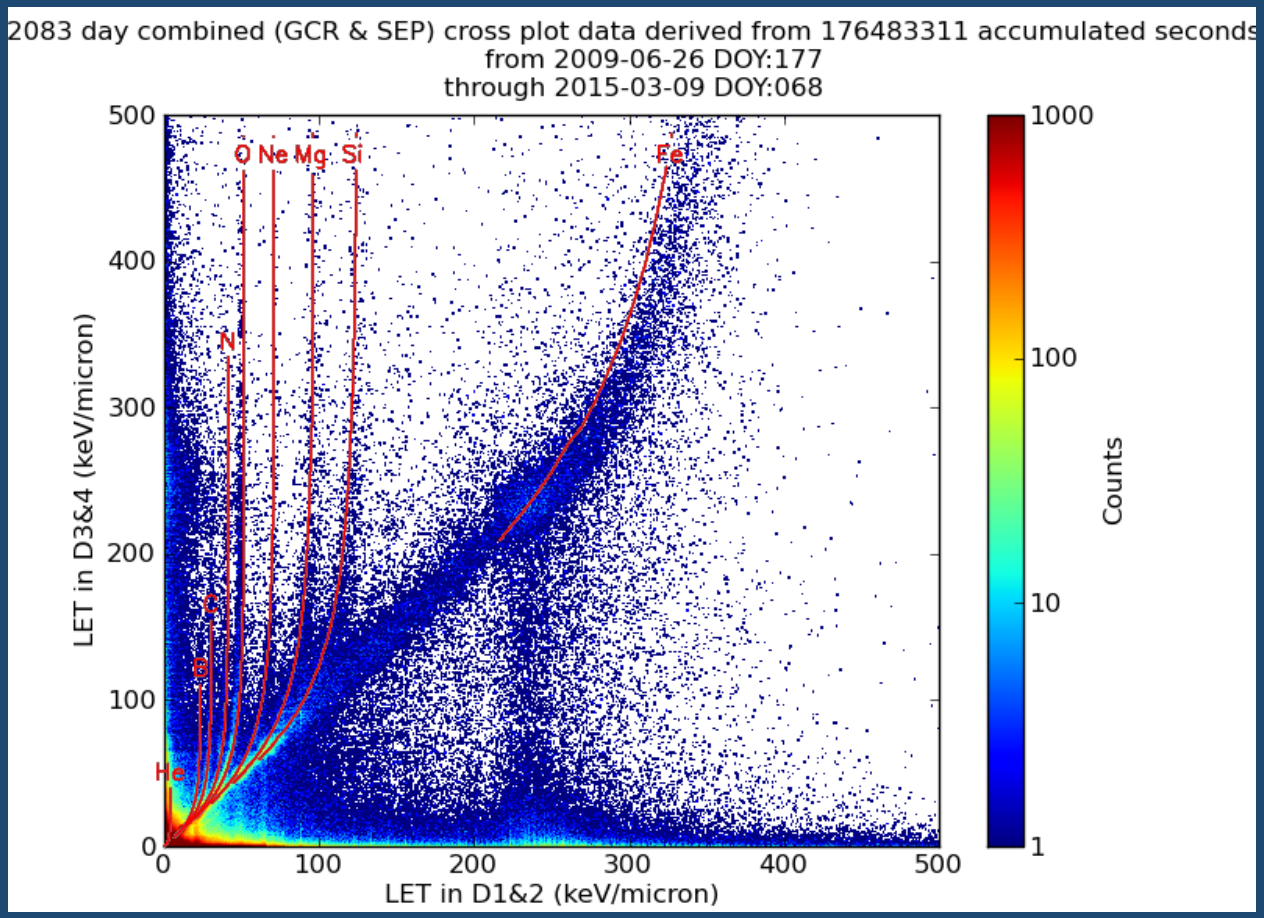
- Choose which detector pairs to plot
- Further option to require or exclude detection in 3rd detector pair
  - "Triple coincidence" particles are less numerous, but can be more confidently identified





Cross-plot customizations

- Clicking on plot brings up element overlay

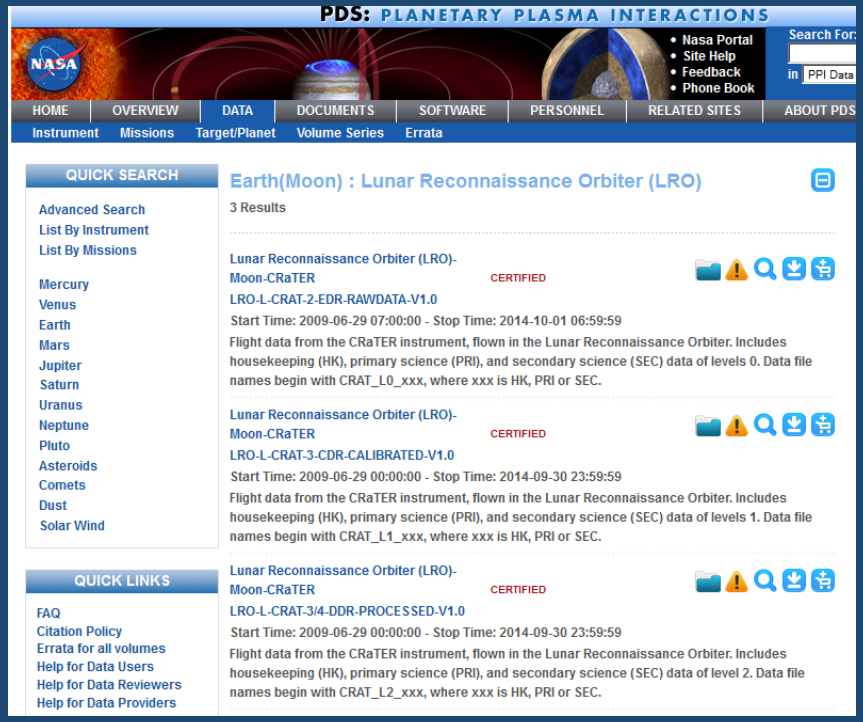


Additional webpage info

- Plots, tables updated daily (M-F)
- Select from 1 to 4 plots (LET, cross-plot, dose) to show at one time
- General descriptions of plots and calibration notes in the “Learn More” tab
- Clicking on LET spectrum or cross-plot brings up element-identification slider

Data in NASA PDS

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



- Data organized by year (2009-) then by Day-of-year (1-366)
- Directory for each day contains .FMT files with column names
- HK (housekeeping) files: instrument voltages, temperatures, crude pointing information
- Updated quarterly

Uses for Raw Data Files

- Plotting particles per second from SEC files using any plotting program: MS Excel, autoplot… (will be similar to dose rate plots)
- High resolution (time, energy) analysis of cosmic ray background or solar particle events (PRI files)

Notes on using raw data

- Don't use data during "pulser sweeps"
- Check LRO/CRaTER's orientation (HK files)
  - Usually oriented with D1-zenith, D6-nadir
- CRaTER changes to lower-sensitivity modes during high-flux solar particle events

Coming Soon

- Dose, LET and Cross-plot data products (LRO launch through 2014) about to be released on NASA PDS (in addition to UNH site)
- Updated maps of albedo protons from Moon
- New Data products
  - Electric charging of lunar surface vs. location & time (Talk on Thursday by Andrew Jordan)
  - Dose rates vs. depth in lunar soil