Lunar Reconnaissance Orbiter: CRaTER Instrument

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Nuclear Engineering

CRaTER Science Team

- **Harlan Spence (Boston Univ.) – PI**
- **Justin Kasper (Harvard Smithsonian) – Project Scientist**
- **Mike Golightly (BU) – Dep. Project Scientist/SOC lead**
- **J. B. Blake (Aerospace Corp.) – Co-I Radiation Physics**
- **Joe Mazur (Aerospace Corp.) – Co-I SEP/GCR Physics**
- **Larry Townsend (Univ. Tennessee) – Co-I Radiation Transport Modeling**
- **Terry Onsager (NOAA/SWPC) – Co-I Space Weather Effects**

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Outline

- LRO Mission and Spacecraft Overview
- CRaTER Description and Calibration
- Data Products
- LET Spectrum Examples
- Concluding Remarks

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LRO Mission Overview

- LRO's launch date is scheduled for no earlier than June 2, 2009
- LRO's objectives are to find safe landing sites, locate potential resources, characterize the radiation environment and test new technology
- After launch, LRO will take approximately four days to reach the moon.
- At the moon LRO will enter an elliptical orbit (30 x 216 km) for ~ 60 days for spacecraft check out scientific instrumentation suite activation and testing
- LRO will then enter its operational circular polar orbit, 50 km (about 30 mi) above the Moon’s surface for a nominal 1 year mission

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LRO Spacecraft Overview

- LRO payload consists of seven instruments
  - **CRaTER:** goal is to characterize the lunar radiation environment
  - **Diviner Lunar Radiometer Experiment (DLRE):** measure lunar surface temperatures at scales that provide information for future surface operations
  - **Lyman Alpha Mapping Project (LAMP):** map the entire lunar surface in the far UV; search for surface ice and frost in the polar regions; and provide images of permanently shadowed regions
  - **Lunar Exploration Neutron Detector (LEND):** map hydrogen by measuring spatial distribution of neutron energies between thermal and 15 MeV

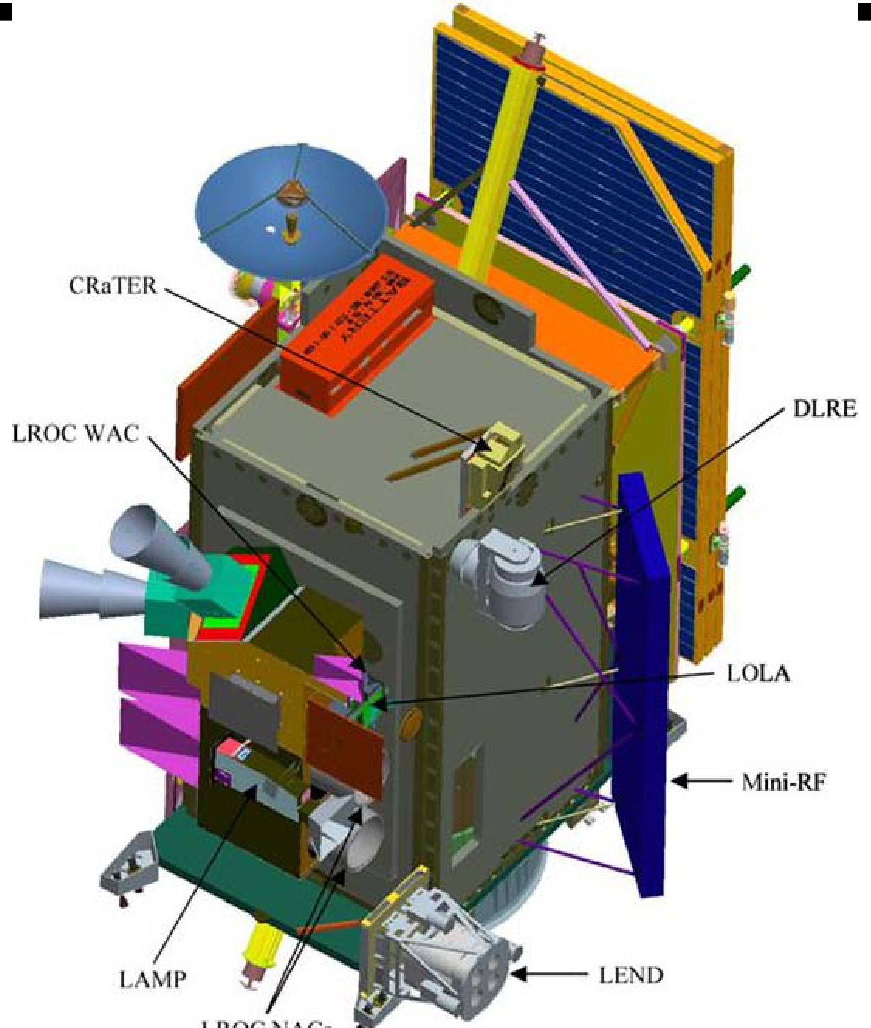
LRO Spacecraft Overview

- LRO payload (cont.)
  - **Lunar Orbiter Laser Altimeter (LOLA):** provide a precise global lunar topographic model and geodetic grid for precise target location, safe landing, and surface mobility for exploration activities
  - **Lunar Reconnaissance Orbiter Camera (LROC):** high-resolution (~ 50 cm) B&W images of the lunar surface; also UV and visible color images (~100 m resolution) over the complete lunar surface ⇒
    show polar lighting conditions, identify potential resources and hazards, and aid selection of safe landing sites.

LRO Spacecraft Overview

- LRO payload (cont.)
  - **Mini-RF:** provide observations of the permanently shadowed areas using radar illumination of the surface to determine if ice is present in significant quantities
- The LRO launch will also carry another spacecraft – Lunar Crater Observation and Sensing Satellite (LCROSS) which will attempt to determine if water ice occurs in areas of permanent shadow near the lunar poles

LRO Spacecraft Overview



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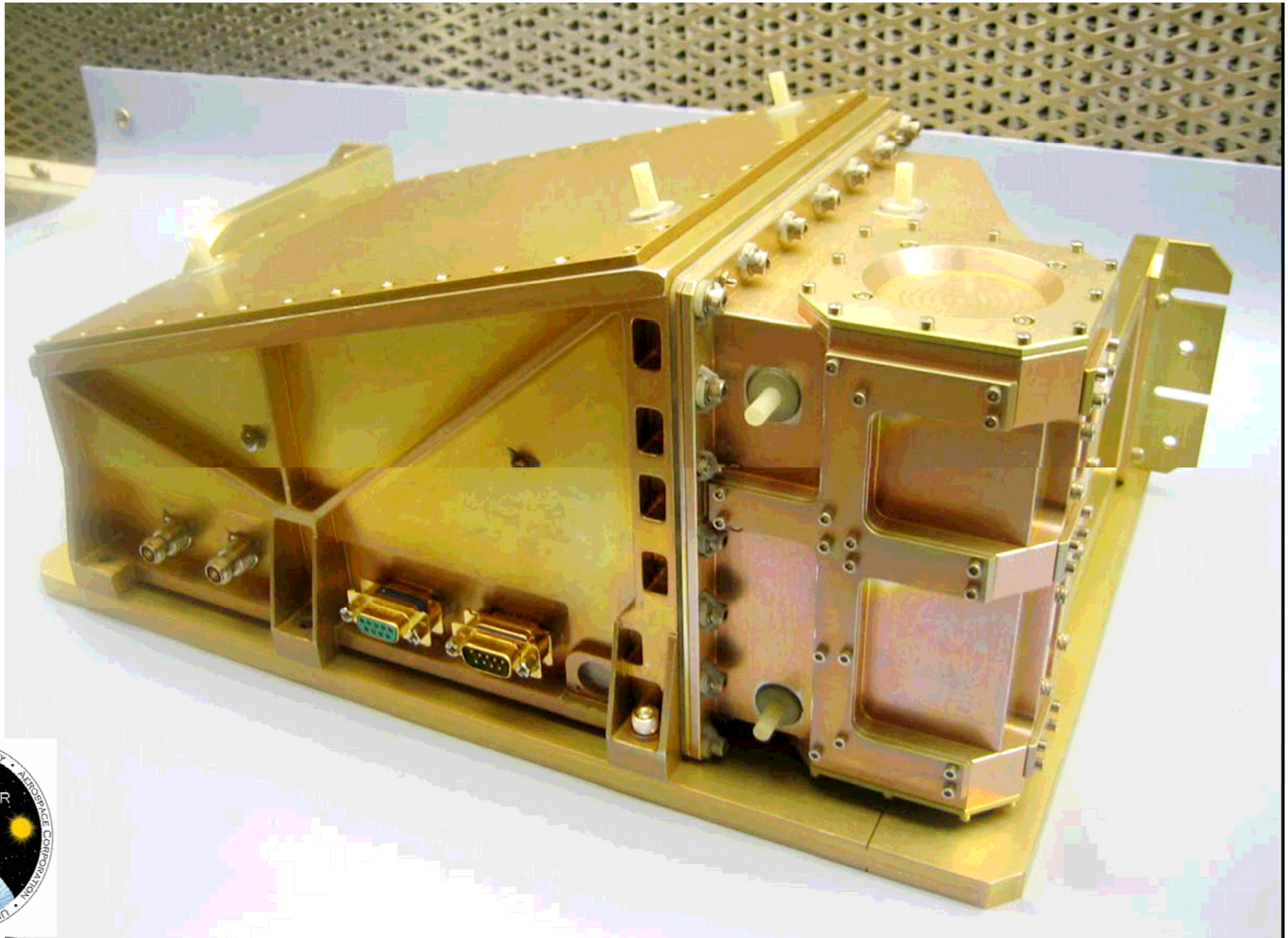
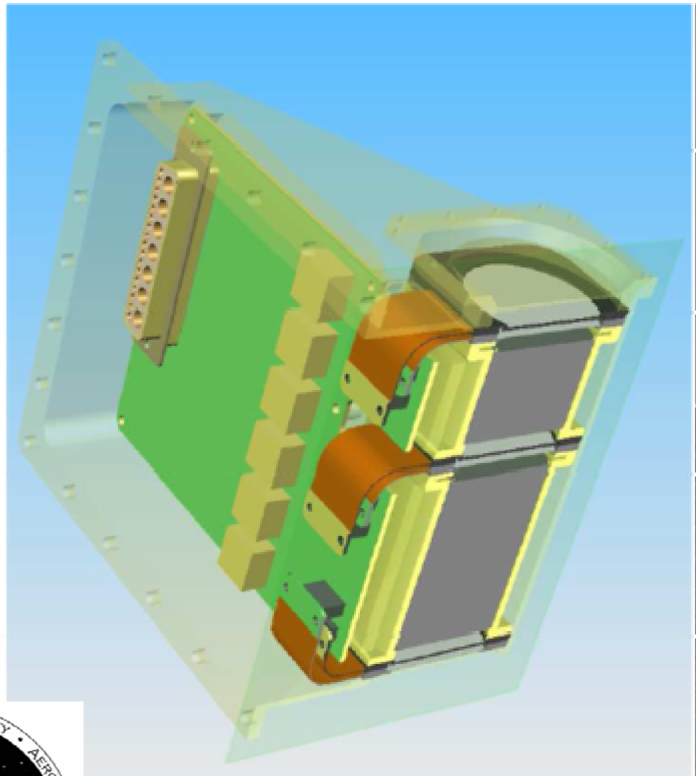
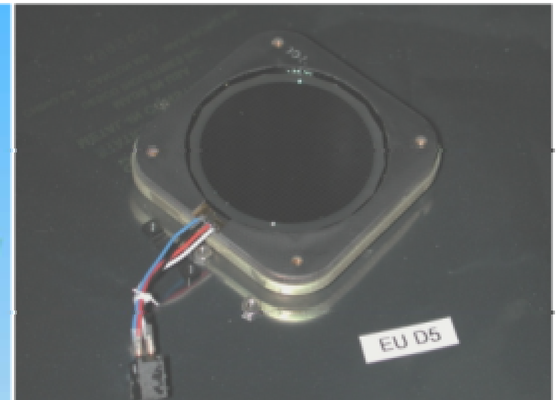
CRaTER Description



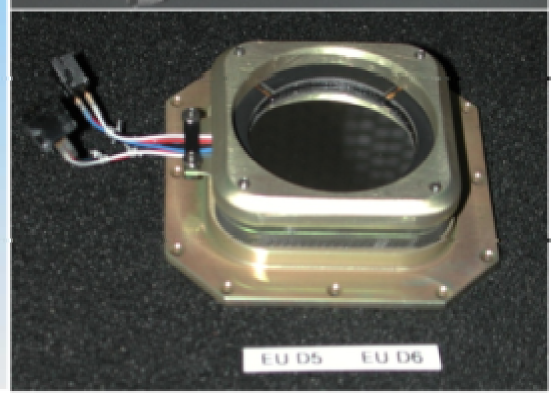
CRaTER Description

Telescope in cross-section



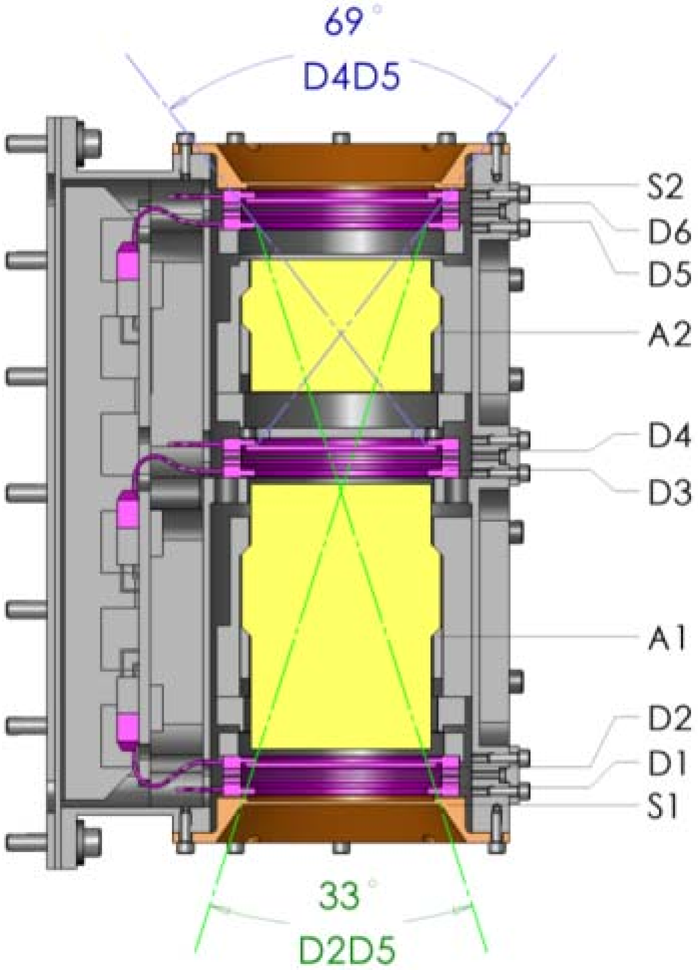


A single detector (D5 for EM)



A pair of thin and thick detectors (D5 and D6 for EM)

CRaTER Description



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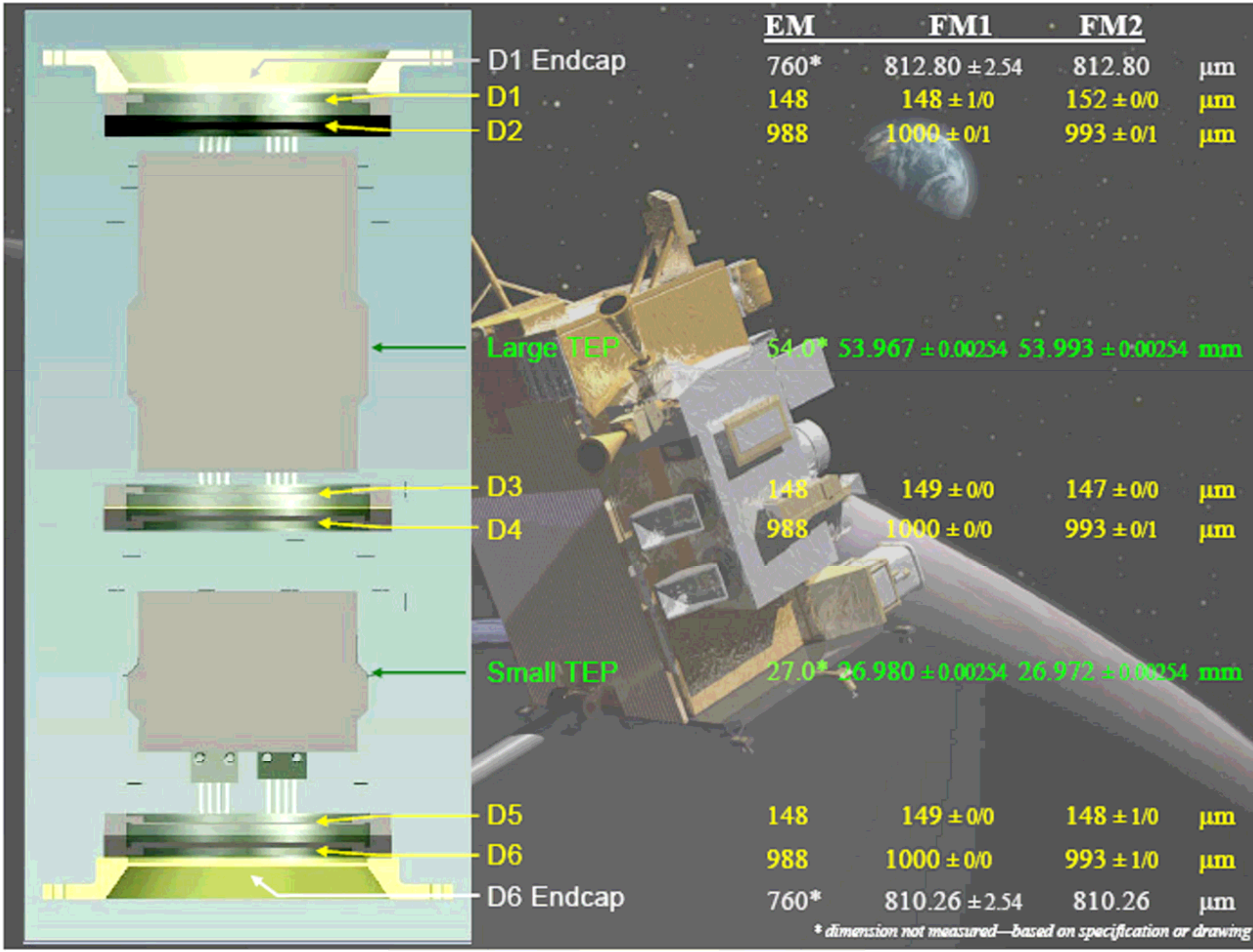
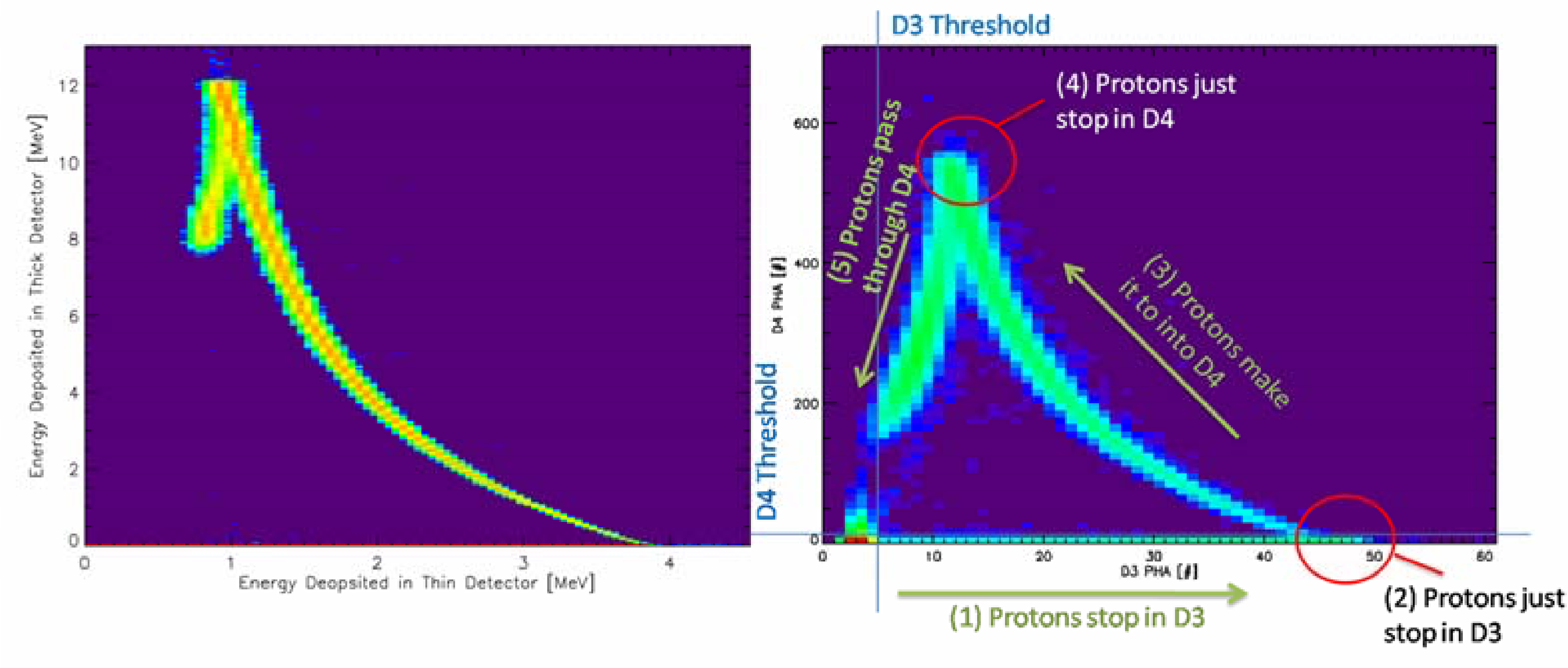


EM FM1 FM2
D1 Endcap 760* 812.80 ± 2.54 812.80 µm
D1 148 148 ± 1/0 152 ± 0/0 µm
D2 988 1000 ± 0/1 993 ± 0/1 µm
Large TEP 54.0* 53.967 ± 0.00254 53.993 ± 0.00254 mm
D3 148 149 ± 0/0 147 ± 0/0 µm
D4 988 1000 ± 0/0 993 ± 0/1 µm
Small TEP 27.0* 26.980 ± 0.00254 26.972 ± 0.00254 mm
D5 148 149 ± 0/0 148 ± 1/0 µm
D6 988 1000 ± 0/0 993 ± 1/0 µm
D6 Endcap 760* 810.26 ± 2.54 810.26 µm
* dimension not measured—based on specification or drawing

CRaTER Calibration

Proton Beam @ MGH



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CRaTER Calibration
650 MeV/nucleon Fe Beam @ NSRL

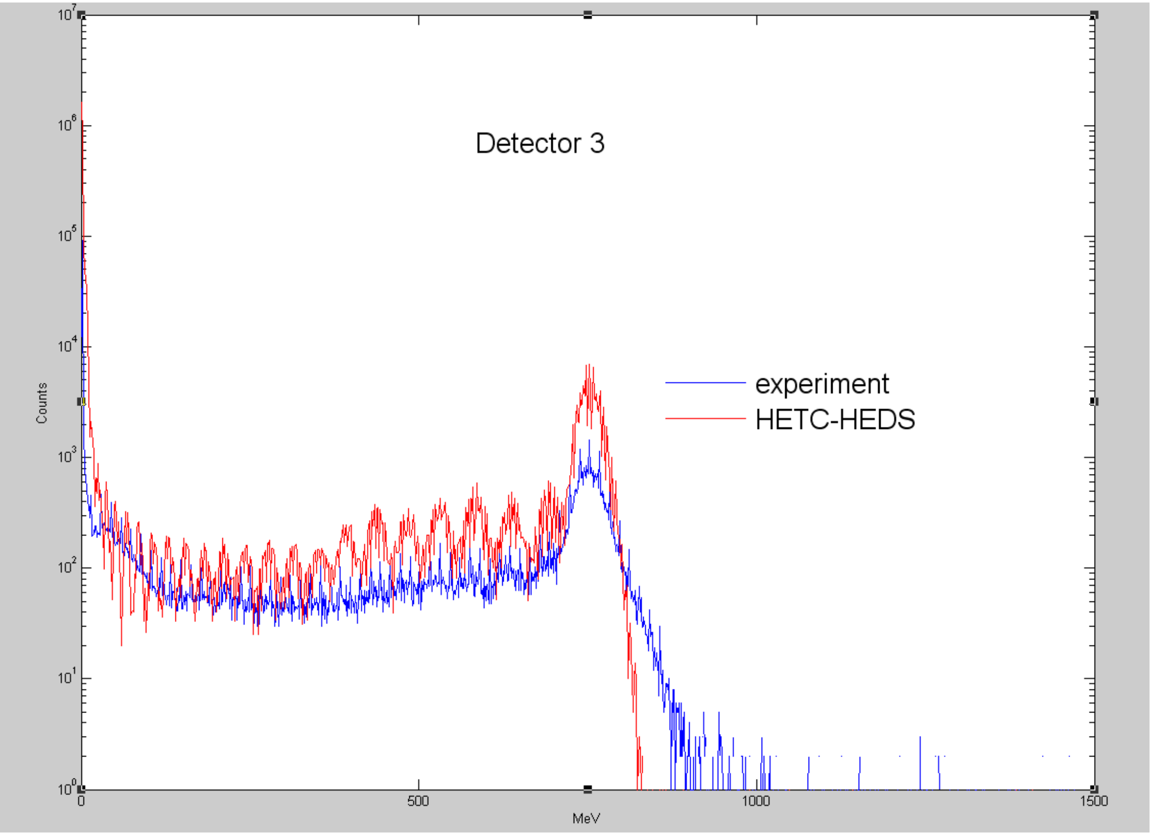

Figure 42. Detector 3 Response for 650 MeV/nucleon Fe Beam

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Data Products

- LET spectra of cosmic rays (esp. > 10 MeV) in tissue equivalent plastic
  - Minimum LET: < 0.25 keV/micron
  - Maximum LET: >2 MeV/micron
- Change in LET spectrum through TEP
- High time resolution fluxes of GCR and solar proton variability
- Nadir and limb sounding time profiles of secondary particles from lunar surface
- Continuous radiation measurements in lunar orbit to explore solar cycle dependence of GCR and solar cycle dependence of impulsive solar particle events

Data Products

- By combining signals from different detectors CRaTER can be used to understand how radiation loss evolves in human tissue and how dose rates change during periods of heightened solar activity and ultimately over the course of the solar cycle
- CRaTER telemetry rate is sufficient to capture high resolution LET values for up to 1,200 events per second
- CRaTER will be able to produce spectra with high resolution in both LET and time.

Data Products

CRaTER Data Level Definitions

Data Level	Description
Level 0	Unprocessed instrument data (pulse height at each detector, plus secondary science) and housekeeping data.
Level 1	Depacketed science data, at 1-s resolution. Ancillary data pulled in (spacecraft attitude, calibration files, etc.)
Level 2	Pulse heights converted into energy deposited in each detector. Calculation of Si LET
Level 3	Data organized by particle environment (GCR, foreshock, magnetotail). SEP-associated events identified and extracted.
Level 4	Calculation of incident energies from modeling/calibration curves and TEP LET spectra

LET Spectra Calculations

- Used the HETC-HEDS code to calculate energy losses and estimate LET in each detector component for the flight model for all elements from hydrogen through iron at 44 different energies from

  20 MeV/nucleon to 3 GeV/nucleon
- Data are tabulated in PhD dissertation of Y. Charara (UT, 2009) and the LET calculations are being parameterized for ease of use by the space radiation community

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LET Spectra Examples

E	D1	D2	TEP1	D3	D4	TEP2	D5	D6
900	3.0E-06	3.0E-06	1.5E-06	2.3E-06	2.3E-06	1.3E-06	2.0E-06	2.0E-06
1000	2.7E-06	2.7E-06	1.4E-06	2.0E-06	2.0E-06	1.1E-06	1.7E-06	1.7E-06

1. Badhwar-O'Neill GCR model for solar minimum Fe spectrum used
2. Energy units are MeV/nucleon
3. LET units are keV/micron/second

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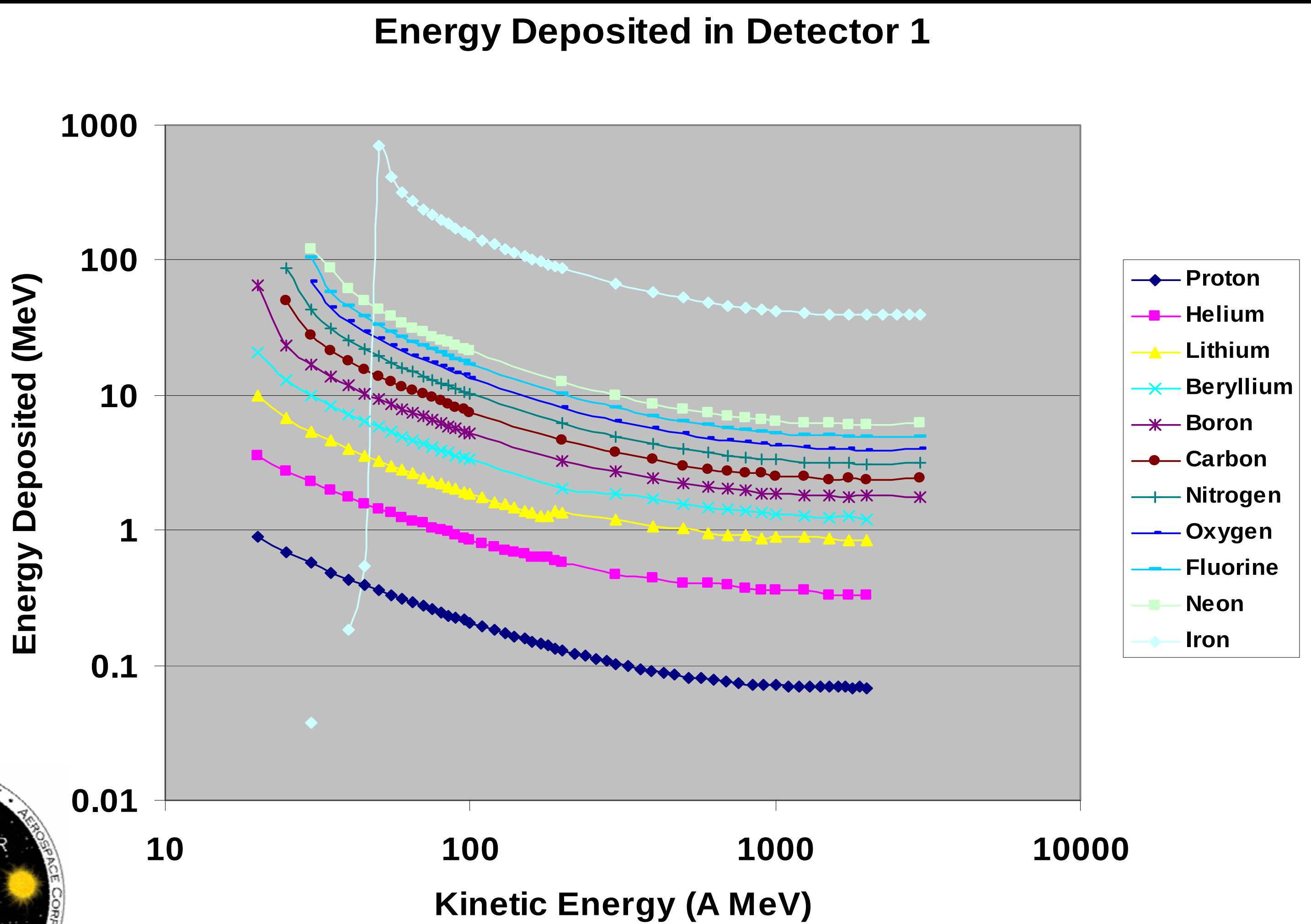
LET Spectra Examples



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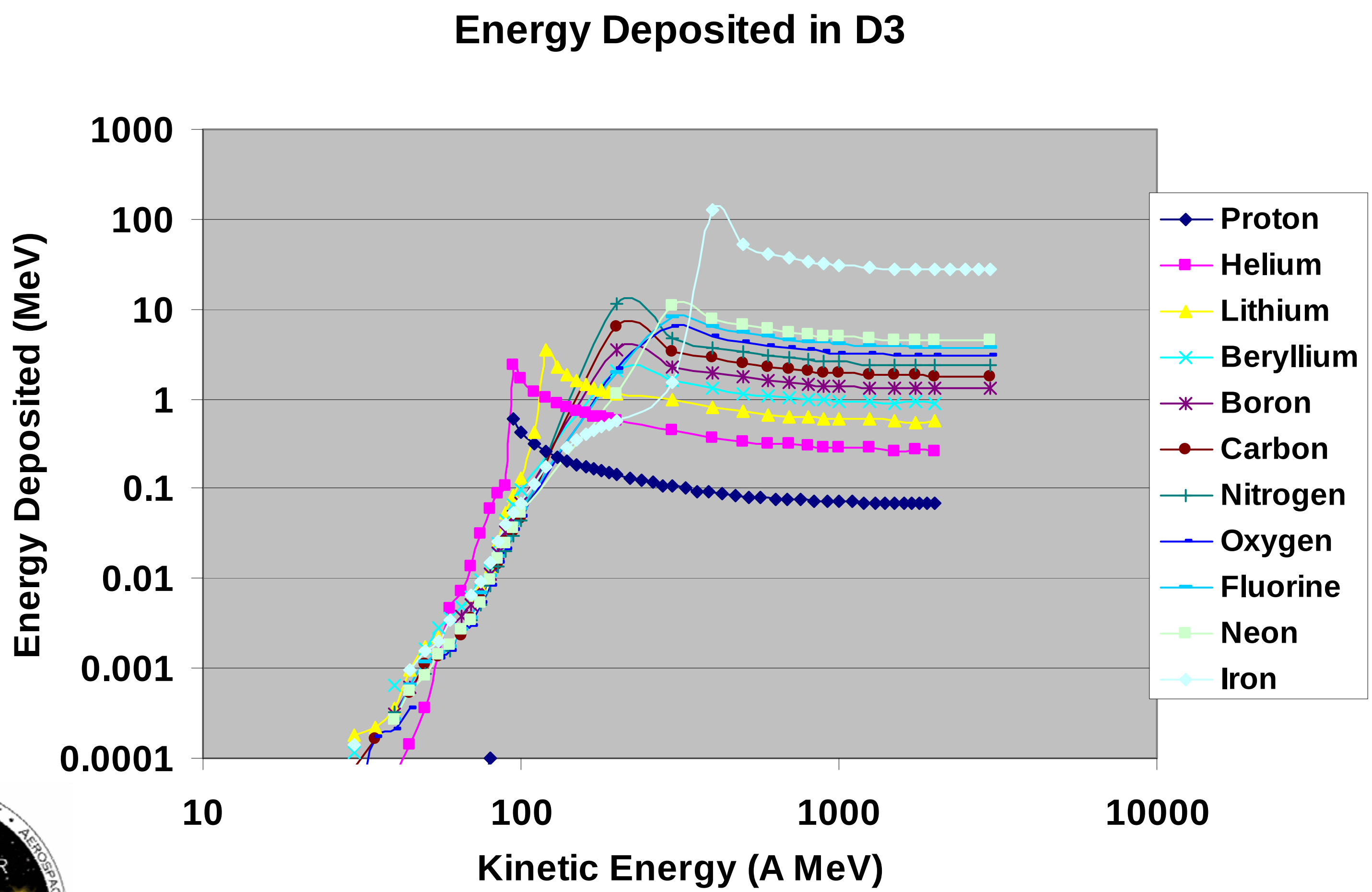
LET Spectra Examples



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Concluding Remarks

- LRO/CRaTER at the Cape and ready to fly (June 2?)
- Brief overview of LRO mission presented
- CRaTER instrument described
- Data products discussed
- Calculations of example LET spectra presented
- **Questions?**