X-Gamma, HP^3 Extended:

Heat Flow, Density, Composition and Habitability Below the Martian Surface

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- **Science**
- **Instrument**
- **Conclusion**

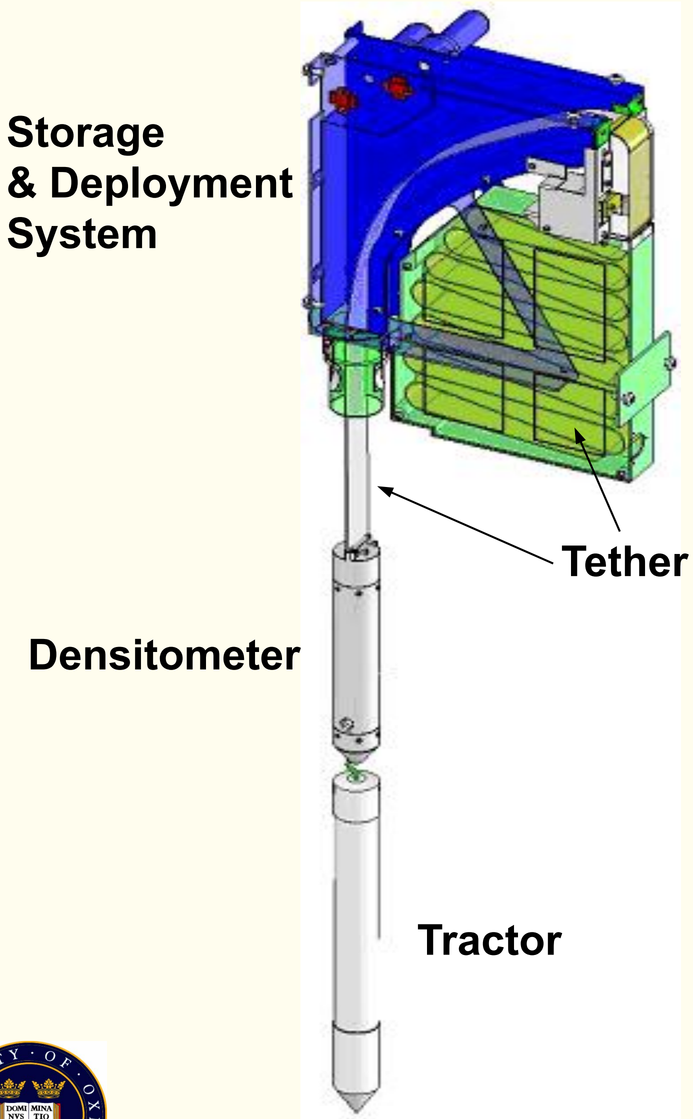
Density Profile

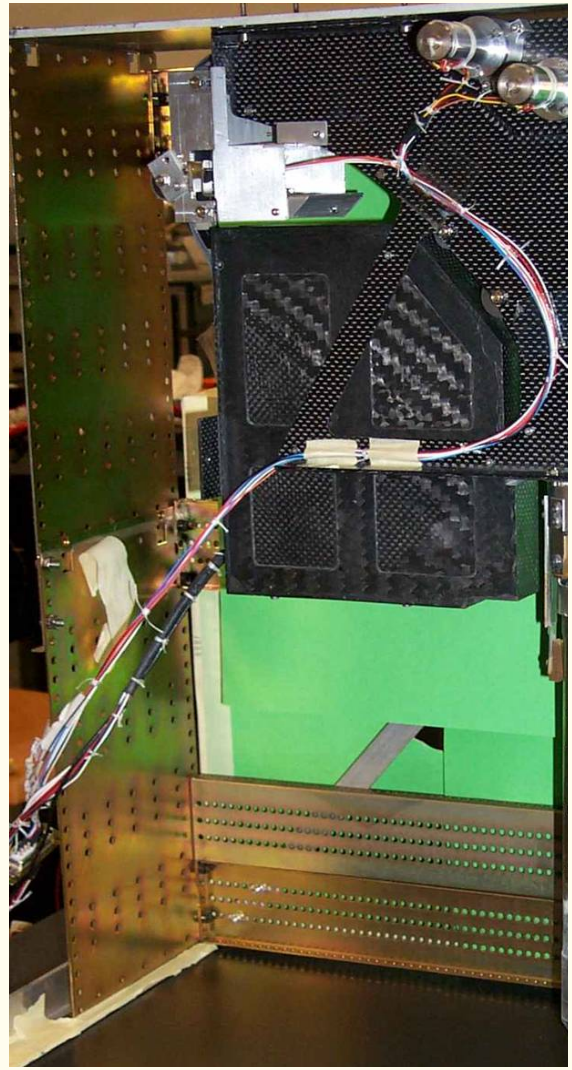
- Input to geophysical / geotechnical models of the Martian surface.
- Relate porosity to fluid flow.
- Ground truth for indirect estimates from orbit (e.g. thermal inertia).
- The soil density depends critically on consolidation and thus porosity. Even though we may *guess* a value, an actual measurement is preferable.

Heat Flow, Thermal Evolution & Climate

- Constrains models of thermal evolution of Martian interior and climate effects on the top ~10 m
  - A first: not planned for any other approved mission.
  - Determined using temperature gradient and thermal conductivity; real case requires bulk density and specific heat capacity for a robust determination.
  - To determine the existence of the physical conditions (*T*, porosity) necessary for the existence of sub-surface ices.

HP^3 and the Densitometer



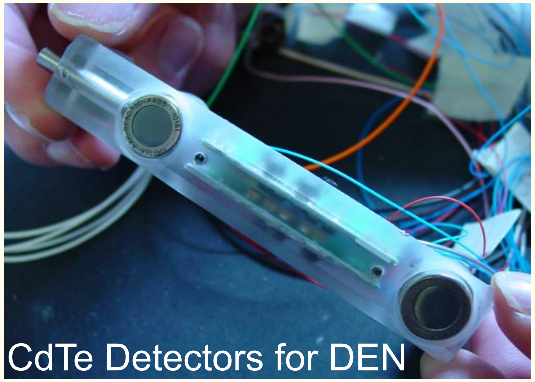


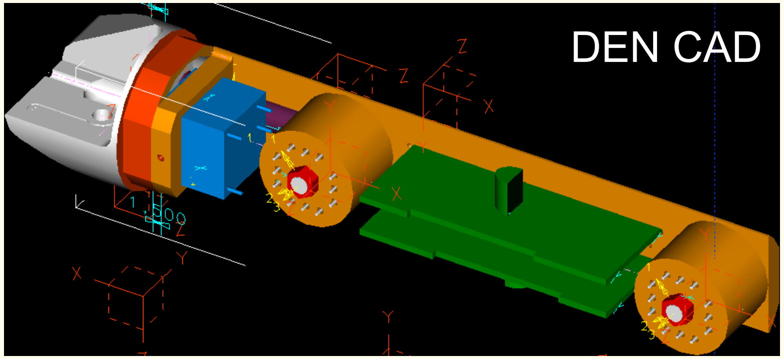
HP^3 and the Densitometer

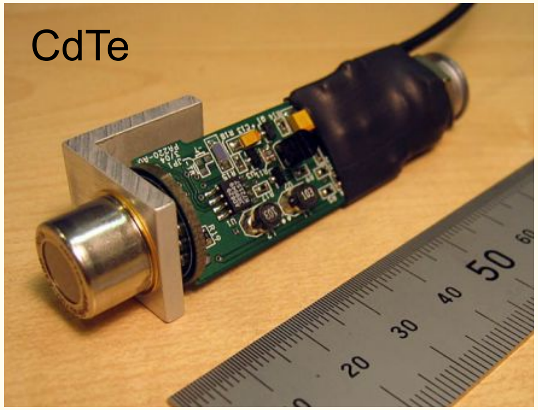
^{137}Cs

Shield

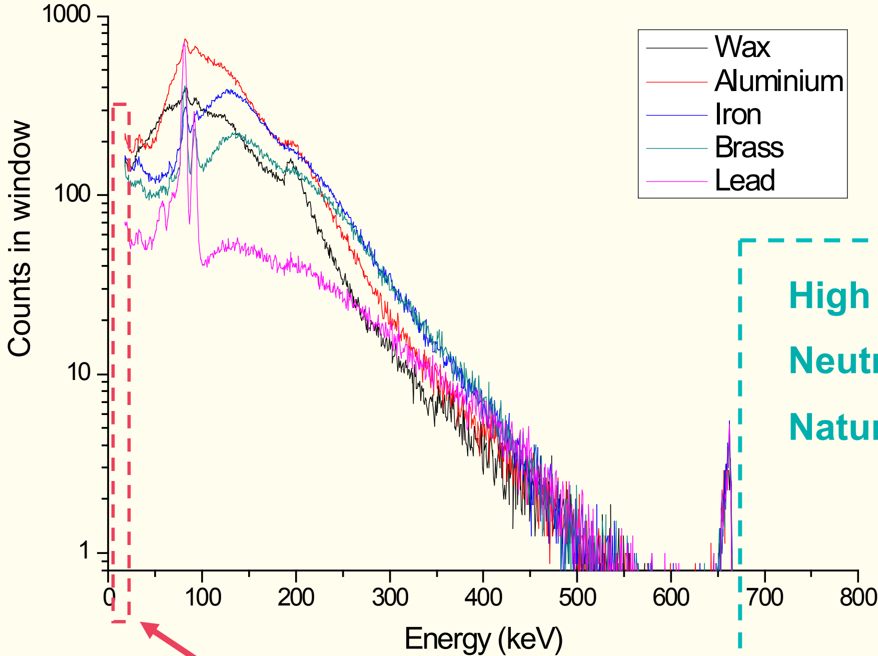
25 mm







Model and Measurements



High energy γs

Neutron activation

Natural radioactivity

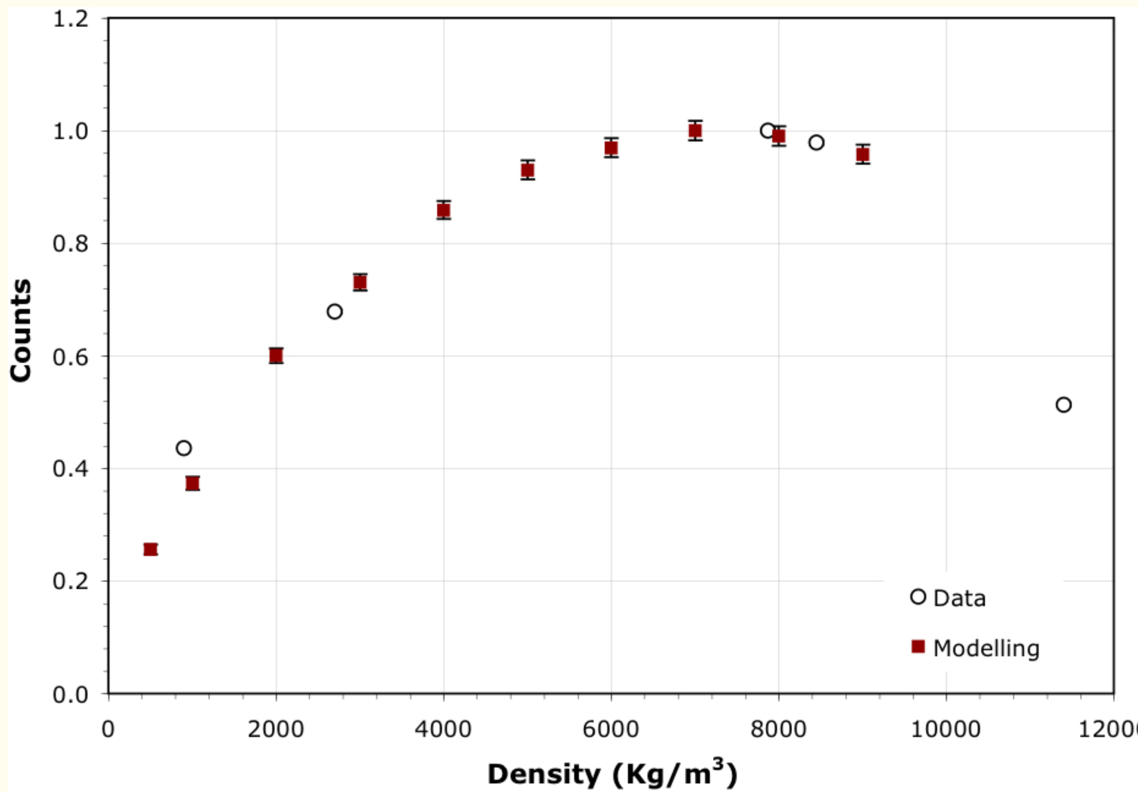
Soft X-rays

X-ray

fluorescence

X-Gamma

Extension



Sub-surface Geology & Past Climate

- Essential chemical analyses for any landing site, complementary to rover
  - Accesses depths below oxidised layer (2-5 m; Lammer *et al.*, 2003) and sulphate overprint in top few metres.
  - Extended integration time at a single location (precision, time variation).
  - Stratigraphy with fine depth resolution, nominally ~few cm.

- Investigation of processes responsible for the formation and evolution of the regolith (impacts, fluvial, glacial, aeolian…).

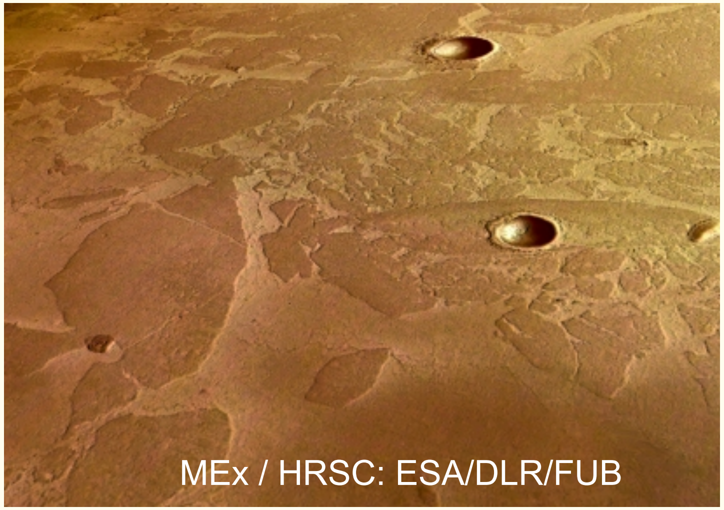
- Characterise alteration geochemistry (carbonates, sulphates, clays, halides such as Br) below top few metres and thus constrain past environmental conditions

- Determine specific heat capacity and concentration of naturally-occurring radioactive elements K, U, Th, and daughters (synergy with heat flow).

- Constrain contribution of meteoritic material to the Martian soil (Ni).

Search for Ice

- Increased recognition of glacial action on Mars
- Relevant to possible *ExoMars* landing sites
  - e.g. dust-covered Frozen Sea theory in Elysium (Murray *et al.*, 2004)
- Detect H_2O, CO_2 ices within top 0-10 m (vs. 1 m for H from *Odyssey* NS) and help characterise sediments associated with glaciations



Esker (water channel) deposited under ice sheet in SW Isidis Planitia.
Seabrook et al., 2005, LPSC

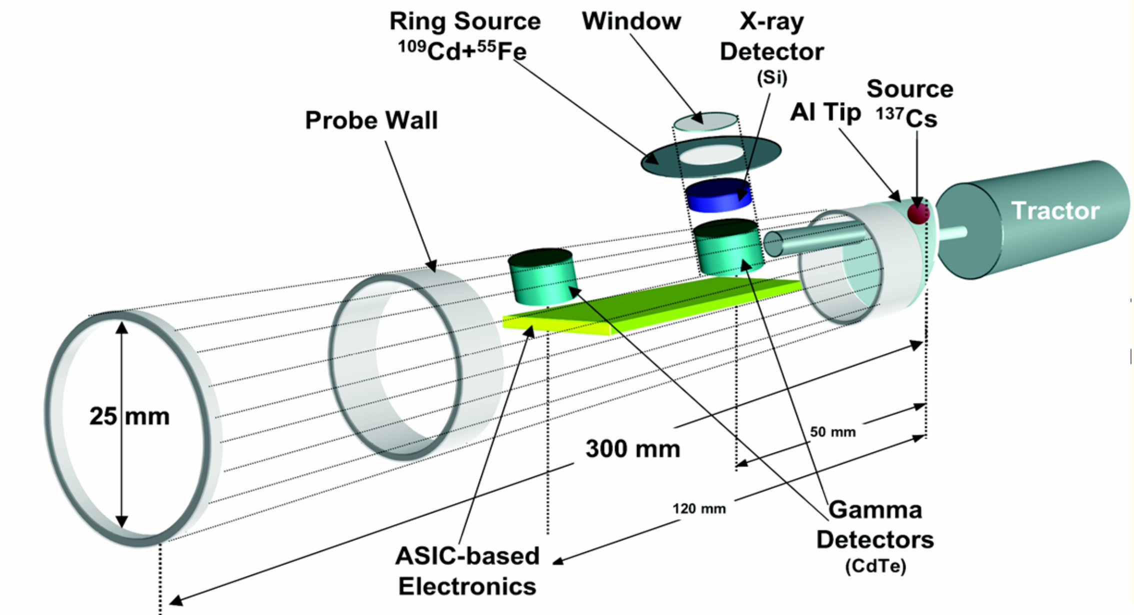
Determining Habitability

- Address directly the stated *ExoMars* goal of "characterising vertical distribution profiles for water and geochemical composition"
- Determination of composition to assess the presence of energy sources, nutrients and environment for life, e.g. C, N
- To assess preservation potential of biomarkers from past life by characterising the sub-surface environment
- May thus have the best access of any existing or planned instrument to a potentially habitable zone.

What is the Enabling Technology?

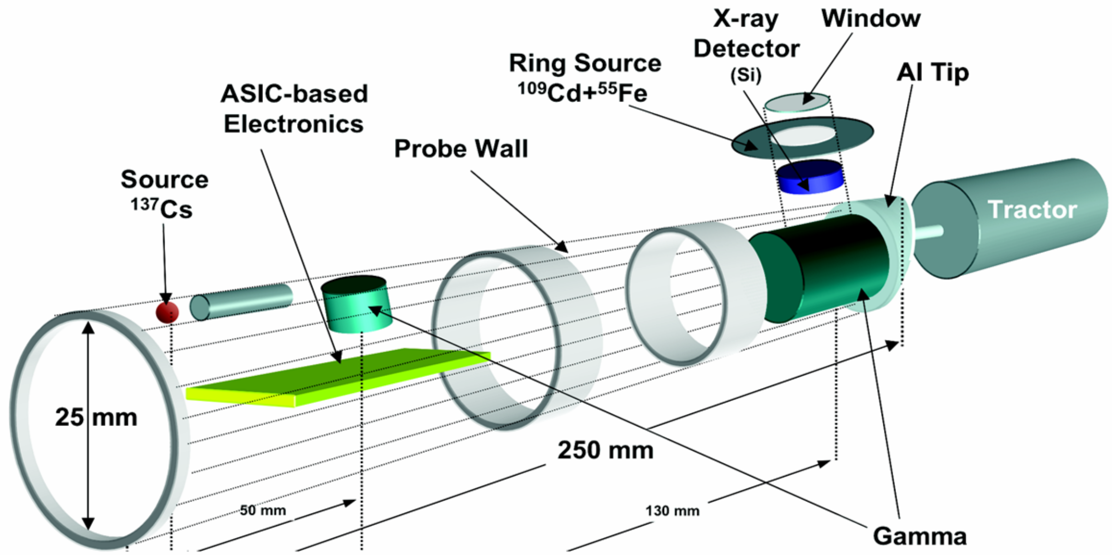
- Hybrid detector providing complementary X & Gamma spectroscopy.
- Gammas from neutron activation and natural radioactivity, X-rays from XRF.
- CdTe and Si detectors.
- Upgraded HP^3 with better energy resolution at lower energies (XRFS mode) and extended high energy coverage (gamma mode).
- X-Gamma thus measures a broader range of elements (low Z as well as high Z) and natural radioactivity.
- Trade-offs between a number of possible configurations.
- For the XRF mode detection limits of 5-10 ppm for elements like Br, Rb, Sr, Zr; precision of ~3% for Si and 5-10% for the major elements and 10-15% for the trace elements.
- For the Gamma mode we need to investigate the limits of detectability. These measurements will form part of our current experimental programme.

Candidate Configurations



Current DEN design with one additional component X-Gamma hybrid sensor, sensitive up to 2.5 MeV

Evolved design with a large volume detector, sensitive to energies higher that 2.5 MeV; requires experimental evaluation

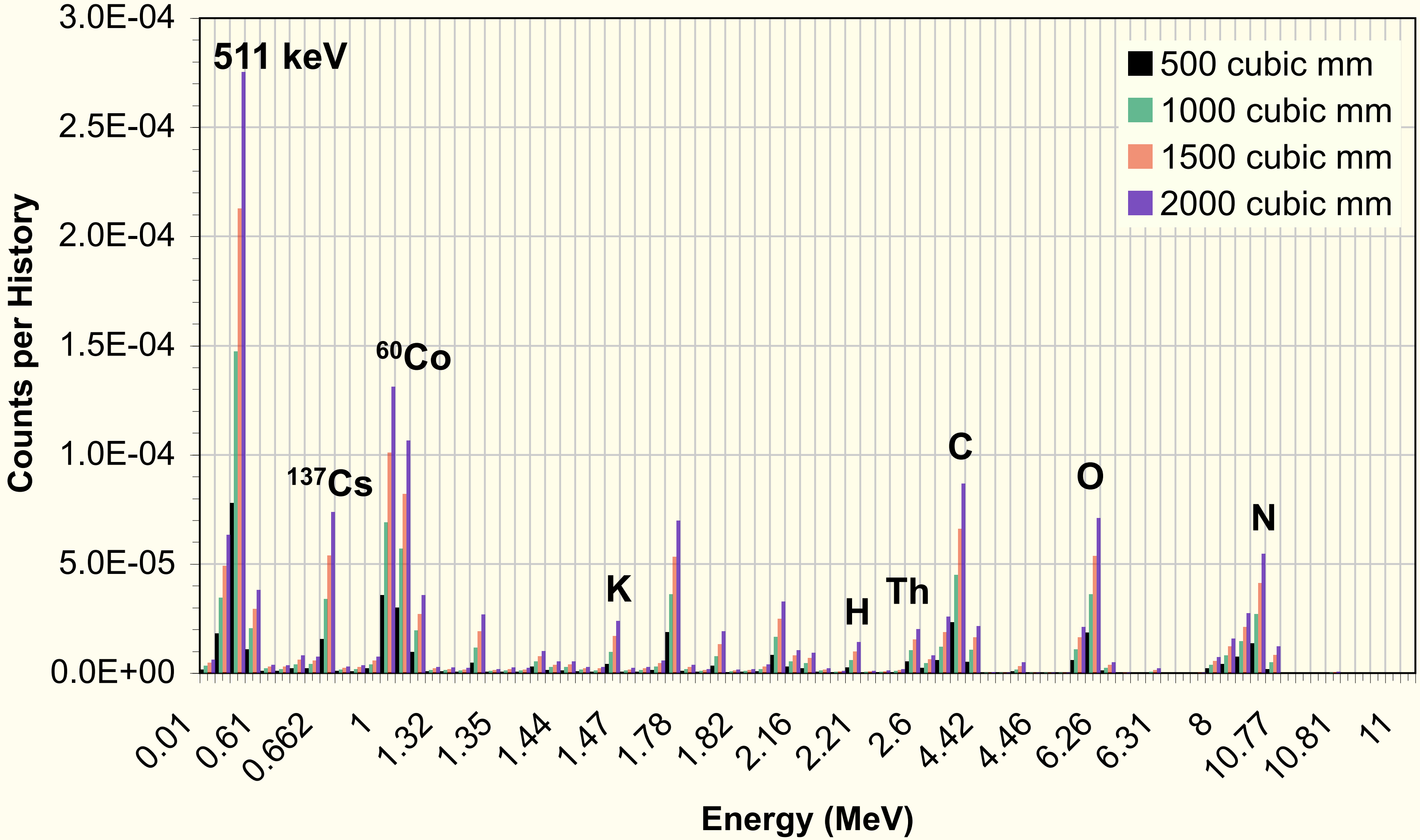


Recent Developments

- Funded by EPSRC Sensors for Extreme Environments.
- Develop a breadboard X-Gamma as part of Ph.D. student project.
- In collaboration with EURORAD.
- Testing 3 large volume CdTe detector, charge loss correction and pulse processing electronics for testing.
- Testing 2 types of scintillators coupled to photodiodes and associated electronics to test.
- The aim is to determine whether we can extend the capabilities of X-Gamma beyond 6 MeV and ultimately beyond 10 MeV.
- Planned neutron activation studies at the FRMII reactor facility in Garching, Munich, EU funded access.

Recent Developments

- Developing MCNP model for detection efficiency.



Conclusions

- Unique opportunity to characterise Martian sub-surface to study habitability, geology, past climate and thermal evolution.
- Versatile, low-resource instrument caters for all potential landing sites: Mars, Moon, Asteroids, Comets.
- Breadboard HP^3, breadboard X-Gamma and knowledge of response of large volume CdTe to high energy gamma rays.
- Links existing heritage to future missions.