The LEIA / MiniFND Fast Neutron Detector

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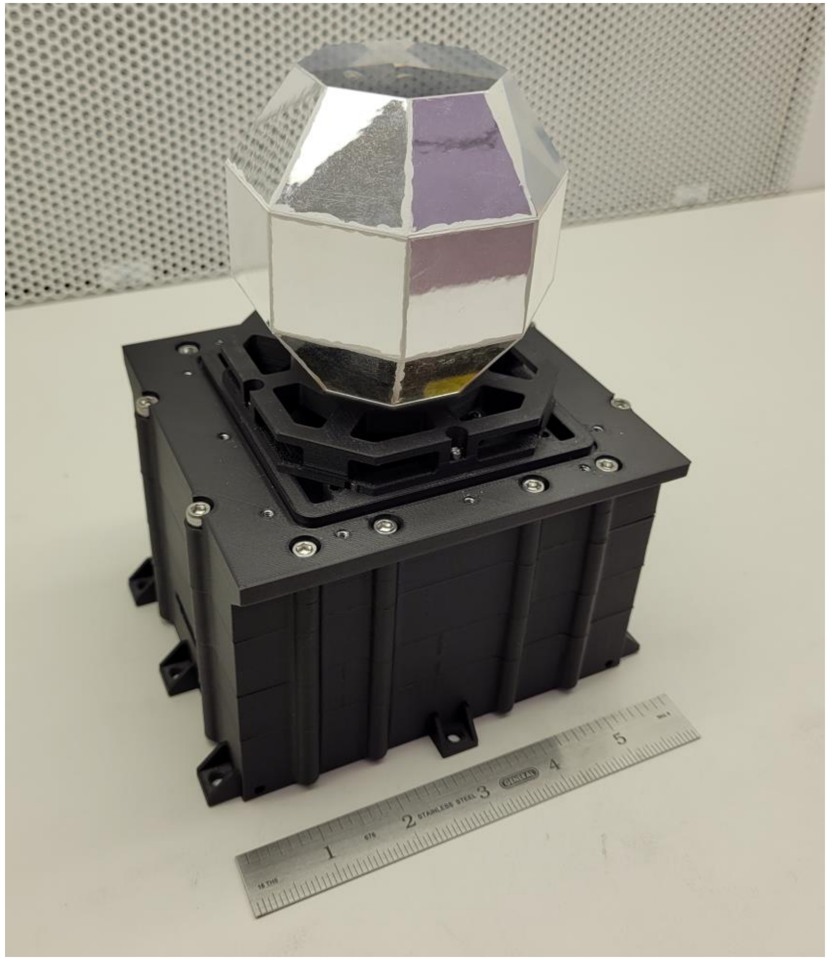
Mini-FND –
The Miniaturized Fast Neutron Detector

What is Mini-FND?

- Detector designed to measure fast neutrons
- “Fast” neutrons are neutrons with energies > 0.3 MeV

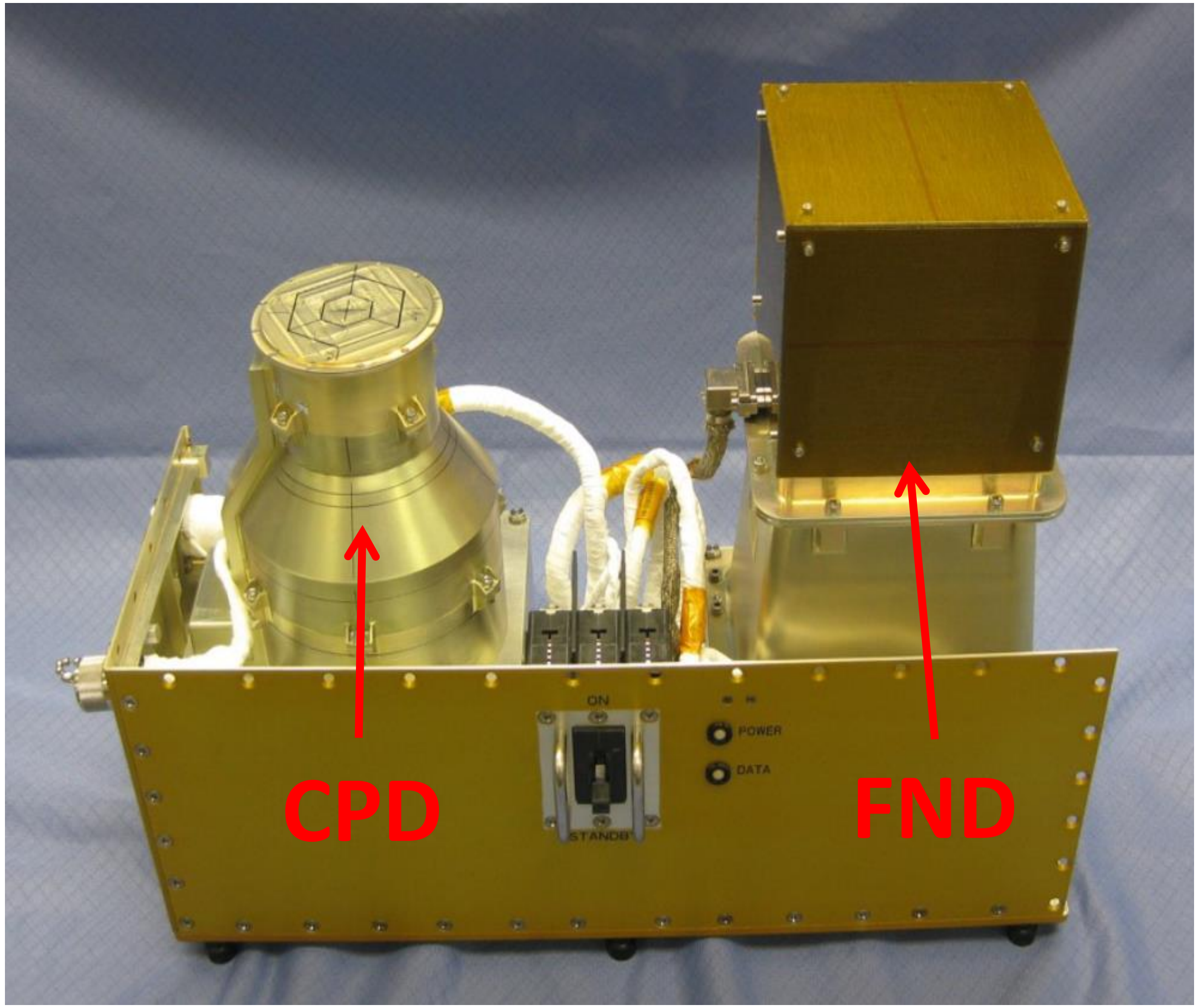
Why “Mini”-FND?

- Based on the ISS/RAD Fast Neutron Detector (FND) that is operating on the Space Station since 2016
- Design changes to reduce volume & mass



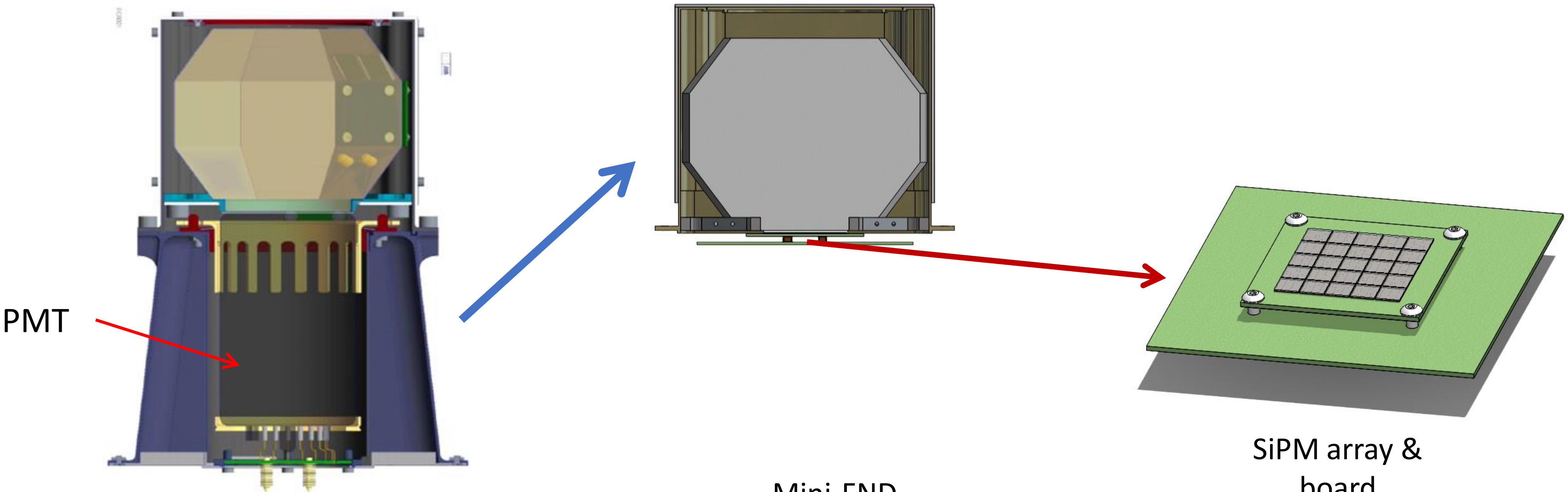
ISS/RAD FND

- ISS/RAD consists of a Charged Particle Detector (CPD) & a Fast Neutron Detector (FND) with accompanying electronics
- CPD heritage design from MSL/RAD; FND was new development
- On ISS, requirements for mass, volume & power are less restrictive
- ISS/RAD FND is relatively large & heavy
- Not ideally suited for planetary or deep space missions with tight constraints on mass, volume & power



Miniaturizing FND

- ISS/RAD FND has a large Photomultiplier Tube (PMT) as read-out detector and requires high voltage power supply
- Mini-FND is read-out by an array of small Silicon Photomultipliers (SiPMs) (no high voltage required)



ISS/RAD FND
Sensor Head
with PMT

Mini-FND
Sensor Head
with SiPM readout

SiPM array &
board

The LEIA Instrument Suite

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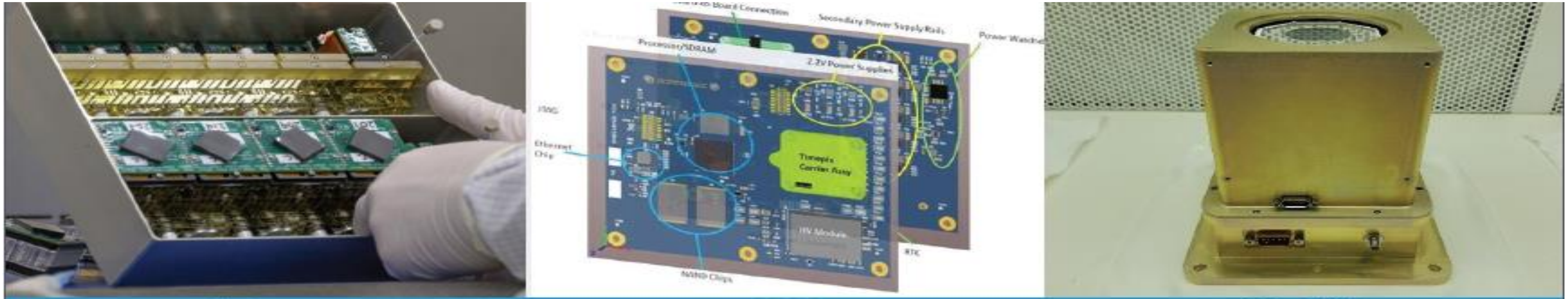
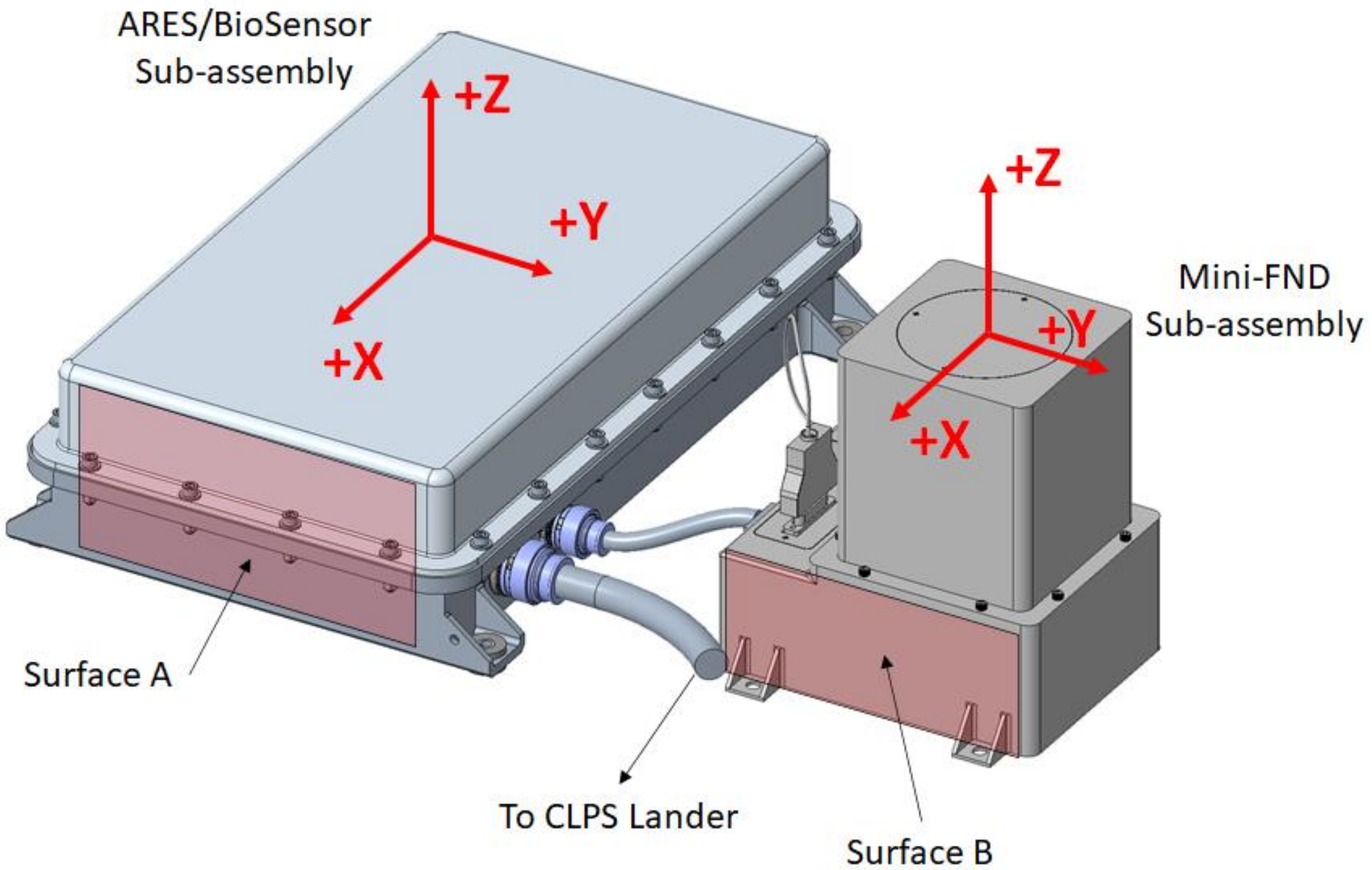
- LEIA = Lunar Explorer Instrument for space biology Applications
- Consists of three instruments:
  - **BioSensor**; Charged particle detector (**ARES**); Fast neutron detector (**MiniFND**)
- Selected for NASA's Commercial Lunar Payload Services (CLPS) CP-22 mission to land at south polar region of the moon in 2027



BioSensor	ARES	Mini-FND
NTE Mass: 5.5 kg	**NTE Mass:** 0.4 kg	**NTE Mass:** 2.8 kg
Dimensions: 20 x 19 x 8 cm	**Dimensions:** 13 x 10 x 3.3 cm	**Dimensions:** 15.8 x 14.5 x 16.6 cm
Power: 3.7W (+ heater)	**Power:** 3.6W	**Power:** 4.0W (+ heater)

The LEIA Instrument Suite

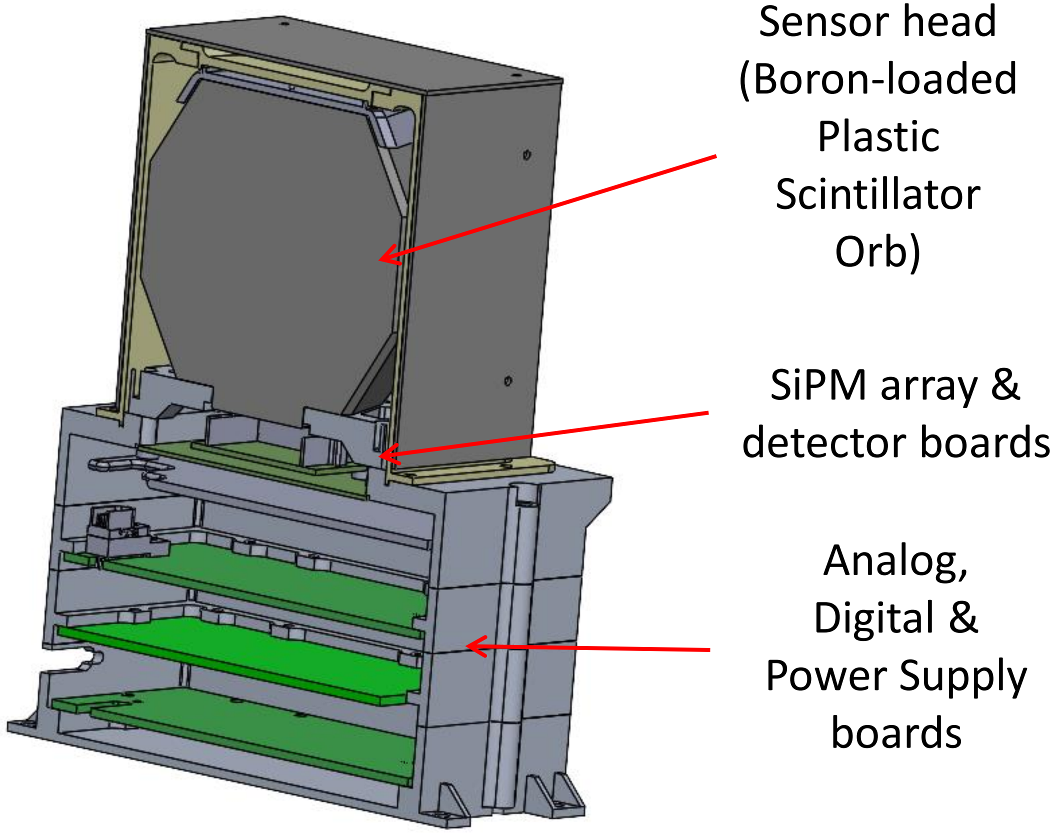


LEIA / BioSensor

- Based on heritage BioSentinel deployed during Artemis-I launch
- LED-based spectrophotometer with microfluidics cards containing yeast strains
- BioSensor will perform two experiments by activating the yeast and monitoring metabolic activity and protein production
- Yeast is widely used as an analog for human cells & the chosen strain is edible yeast used to make fermented foods
- The first experiment will be conducted early after landing, the second late in the mission phase
- To correctly interpret the biological response of the yeast strains, need to understand the radiation environment during both experiments

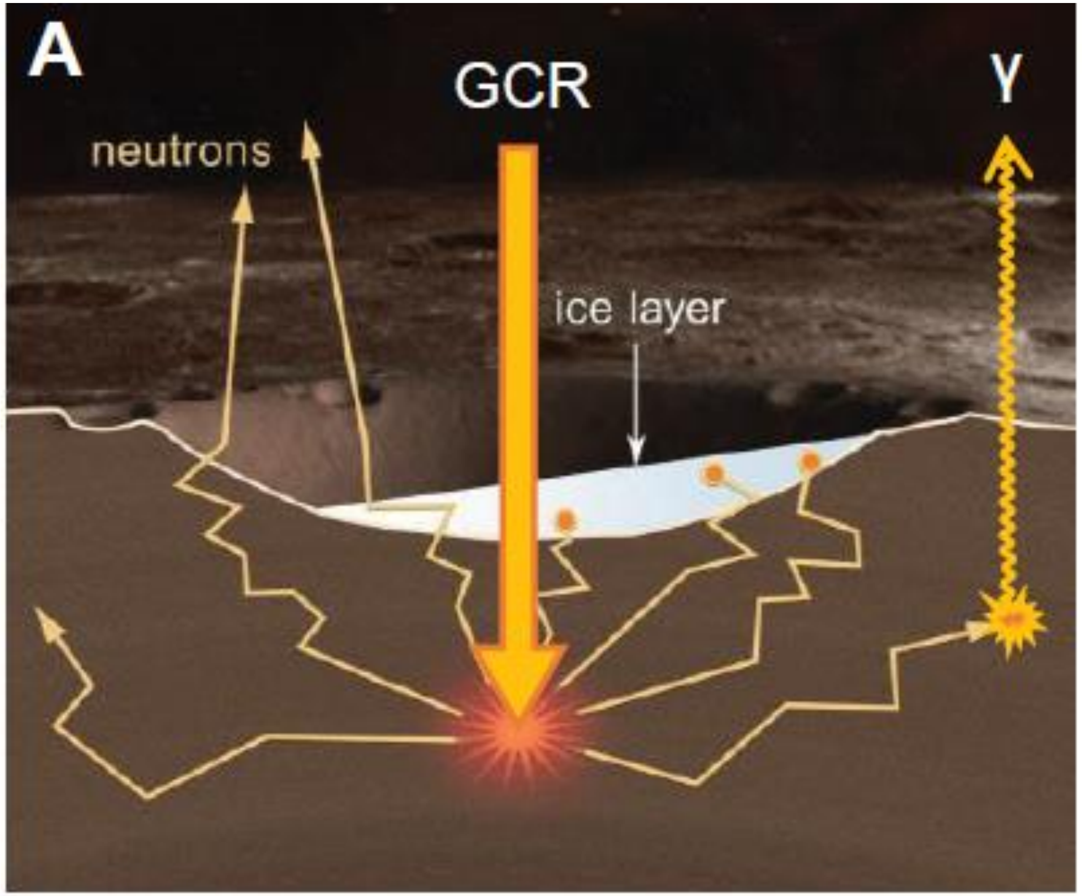
Mini-FND Overview

- Mini-FND measures neutrons in the energy range of 0.7 – 5 MeV providing integrated flux and energy spectra information
- Mini-FND measurements are crucial to assess the influence of the radiation field on the LEIA biological samples…
- … and first-ever ground-truth measurements of the fast neutron spectrum provide important information about potential health risks for future human explorers



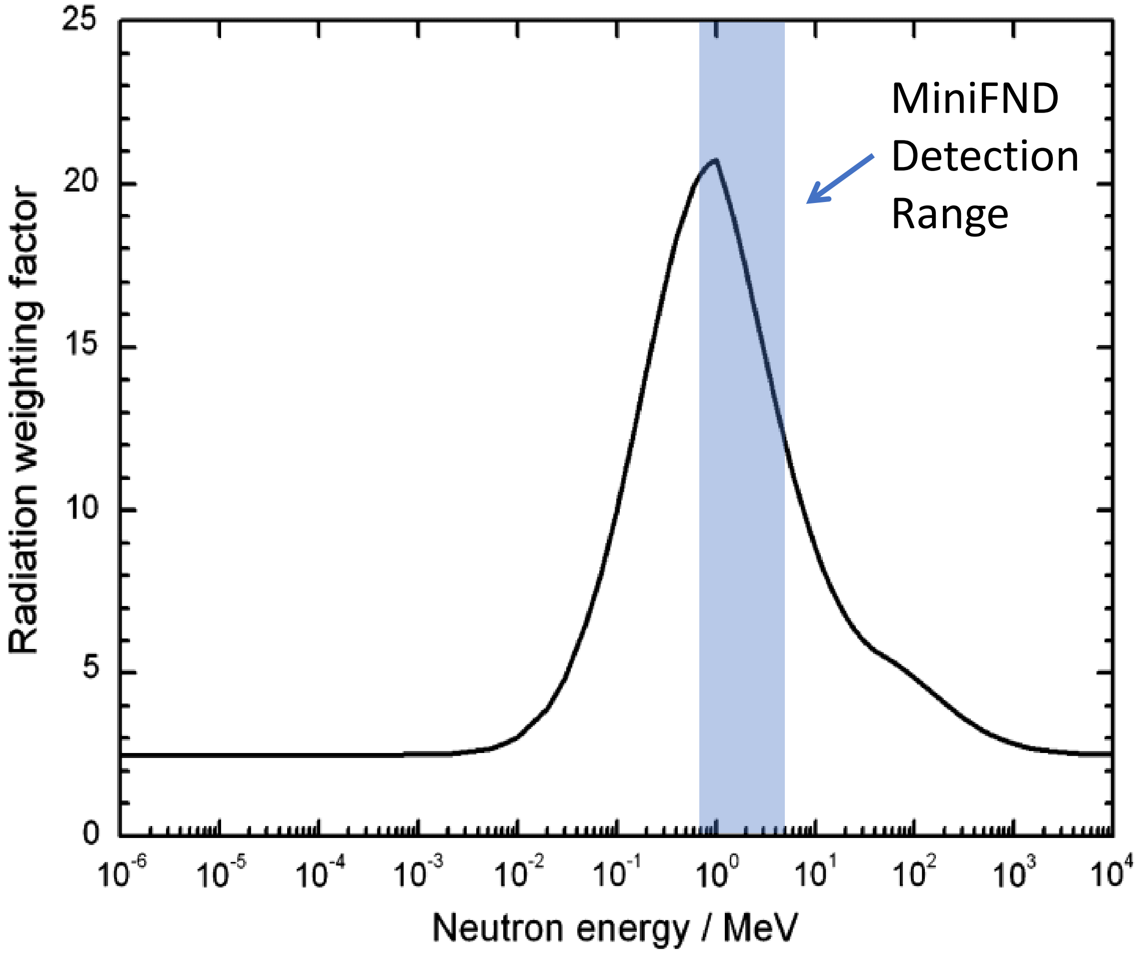
The Radiation Environment on the Lunar Surface

- Radiation environment mainly stems from Galactic Cosmic Radiation (GCR) impinging on the lunar surface
- Occasionally, highly intense Solar Energetic Particles (SEPs) emitted from the sun during solar storms
- GCR interacting with the ground produce backscattering neutrons
- Exposure to this radiation can lead to severe health effects (e.g., DNA damage or strand breaks, cataracts, cancer…



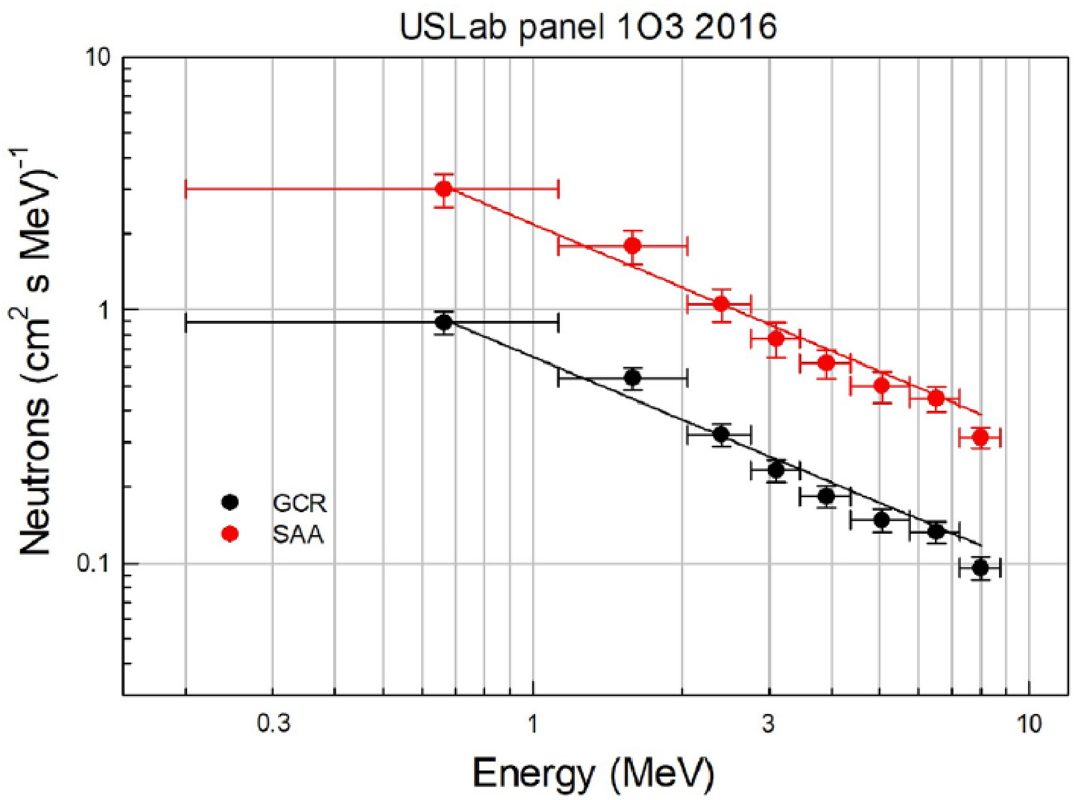
Why are neutron measurements important?

- Shielding against neutrons is highly difficult (low interaction cross section with most materials)
- Neutrons have a high interaction cross section with hydrogen
- Thus, neutrons have a high biological relevance as expressed in the neutron radiation weighting factor
- The required Mini-FND energy detection range (0.7 – 5 MeV) is sufficient to cover the peak of the weighting factor curve



Mini-FND Science Data Products

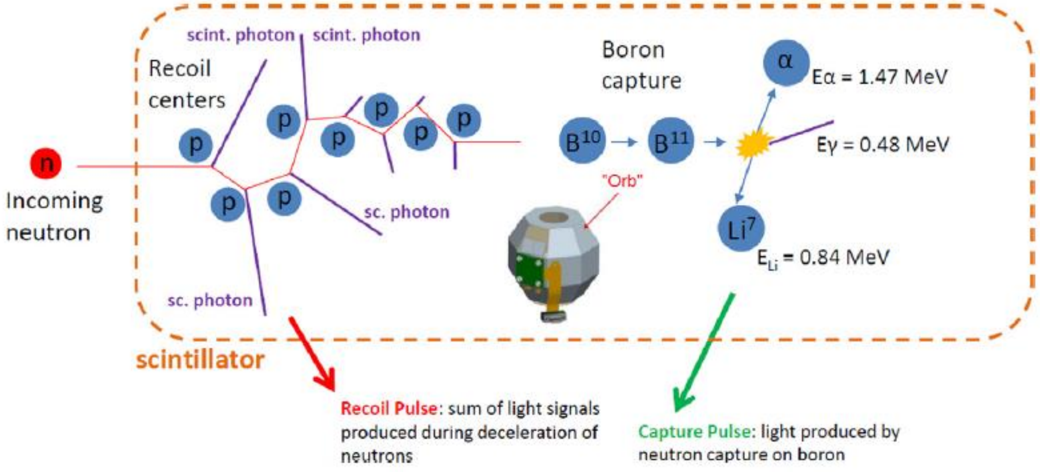
- From the Mini-FND neutron measurements, we can derive:
- Integrated fast neutron flux over time
- Fast neutron energy spectra over time
- Both quantities can be calculated with known methods from ISS/RAD FND data analysis



Unfolded ISS/RAD FND energy spectra, separated for GCR and South Atlantic Anomaly (SAA) contributions. *From Zeitlin et al., Life Sciences in Space Research (2023)*.

Mini-FND neutron detection scheme – Capture gating method

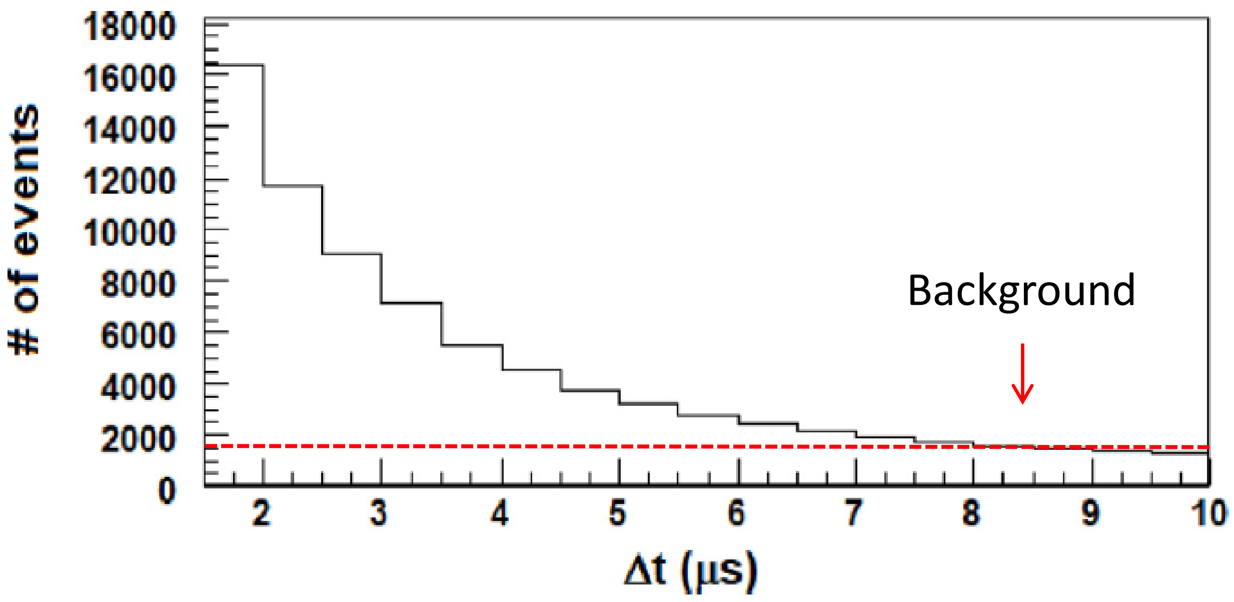
- The Mini-FND neutron sensor consists of a boron-loaded plastic (BLP) scintillator orb
- Neutrons lose energy in the BLP and create a scintillation light pulse
- If the neutrons reach low enough (thermal) energies, the neutrons can be captured by boron atoms in the BLP…
- … producing a second characteristic light pulse (capture pulse)



From Zeitlin et al., Life Sciences in Space Research (2023).

Mini-FND neutron detection scheme – Capture gating method II

- Timing of the two pulses is used to identify the particle as a neutron (capture gating method)
- The average Δt between the two pulses is 1.7 μs
- At high Δt, distribution dominated by chance double pulses
- This high Δt tail can be used for background correction



Δt (recoil to capture pulse) histogram of candidate neutron events (ISS/RAD FND data). *From Zeitlin et al., Life Sciences in Space Research (2023)*.