The LEIA / Mini-FND Fast Neutron Detector

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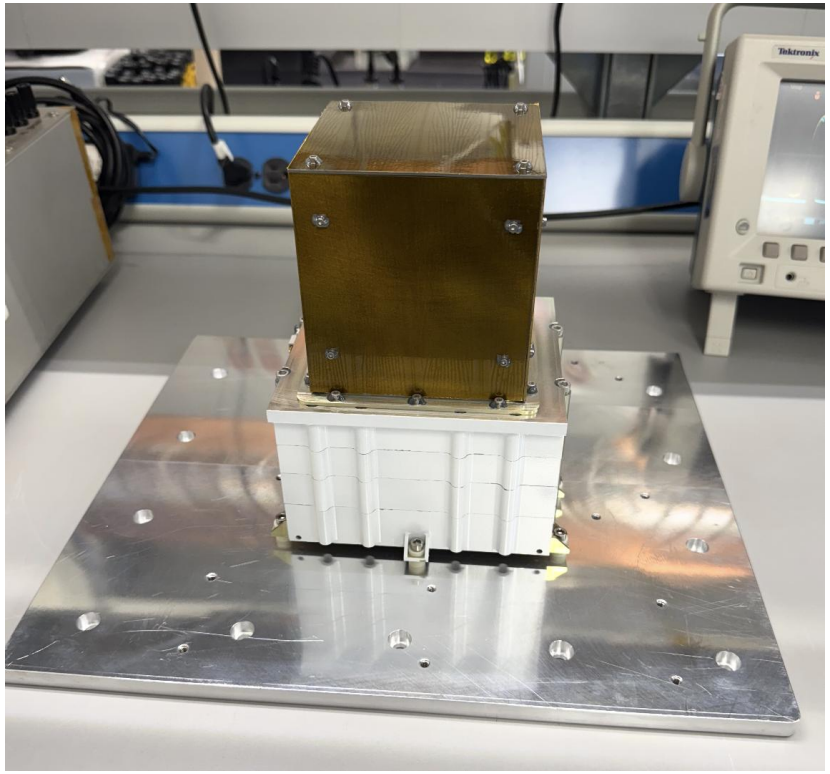
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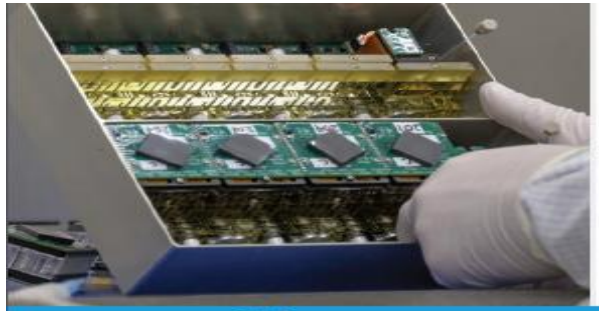
Mini-FND – The Miniaturized Fast Neutron Detector

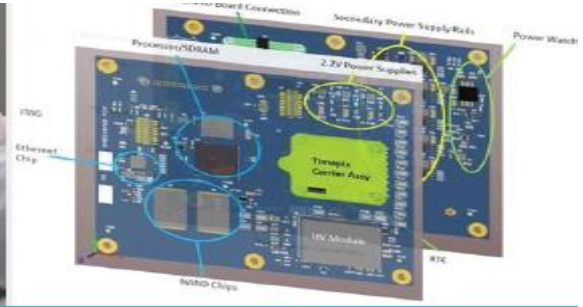
What is Mini-FND?

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

- Part of the ***LEIA*** instrument suite (NASA/Ames) selected to fly on the CP22 mission to the lunar surface
- Consists of three instruments:
  - **BioSensor**; Charged particle detector (**ARES**); Fast neutron detector (**Mini-FND**)



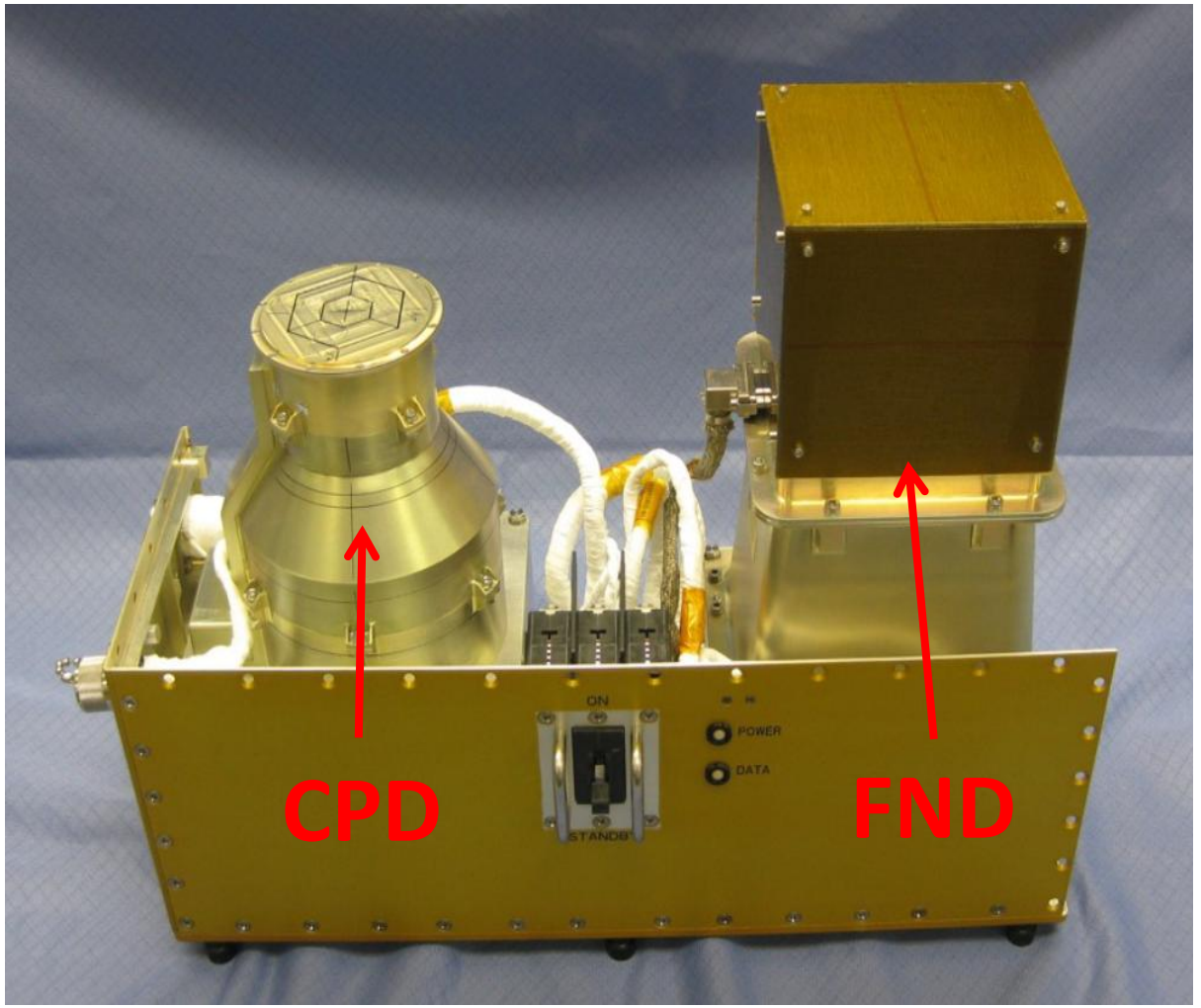




BioSensor	ARES
NTE Mass: 5.5 kg	**NTE Mass:** 0.4 kg
Dimensions: 20 x 19 x 8 cm	**Dimensions:** 13 x 10 x 3.3 cm
Power: 3.7W (+ heater)	**Power:** 3.6W

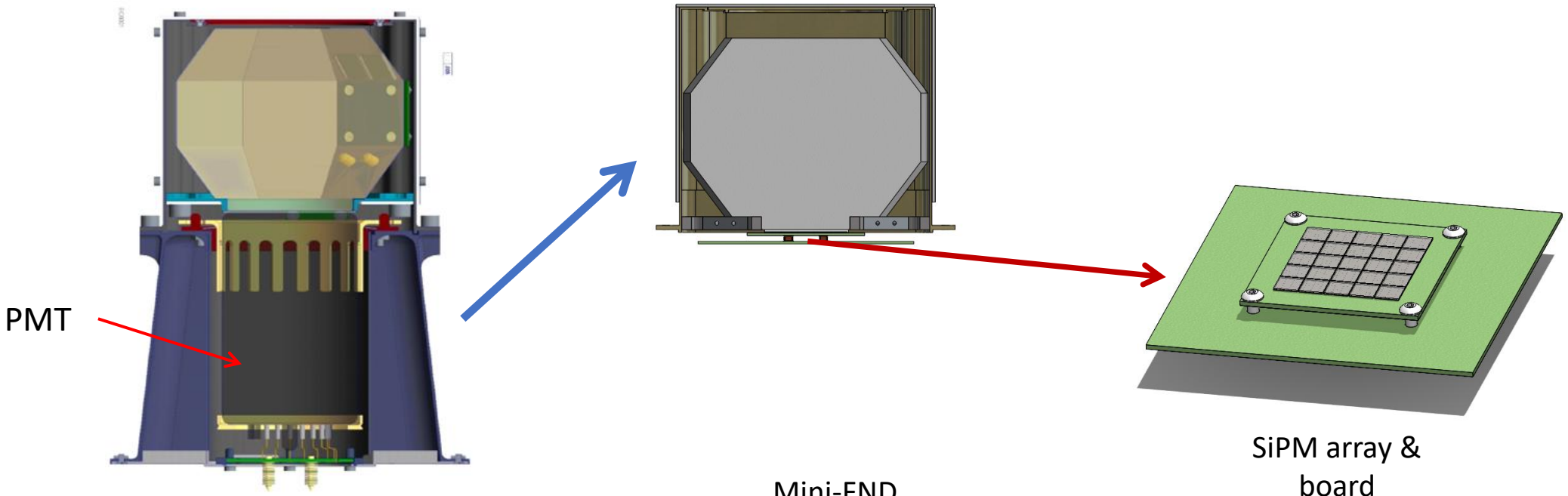
Mini-FND – Successor to ISS/RAD FND

- 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



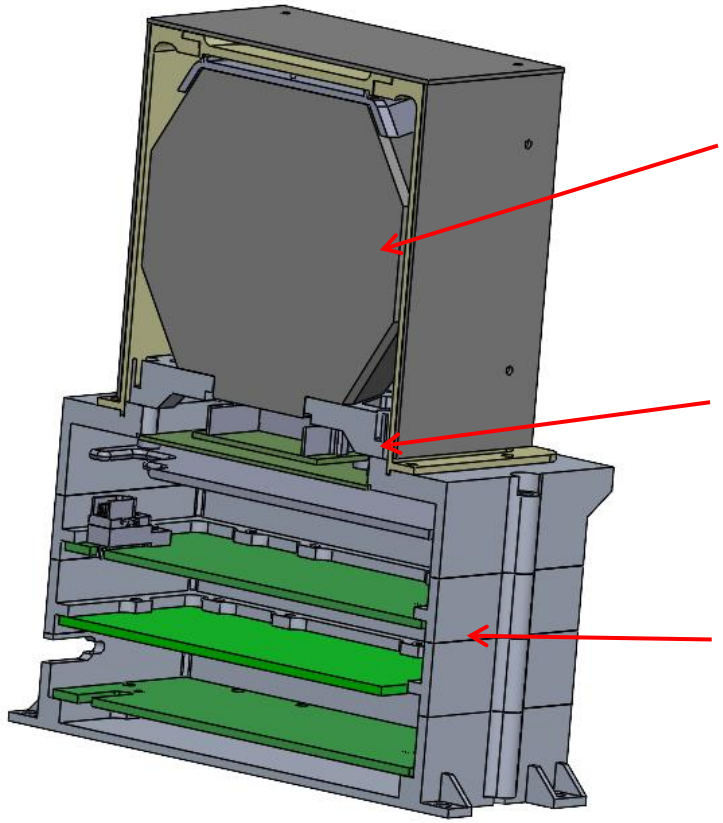
Miniaturizing FND

- 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)



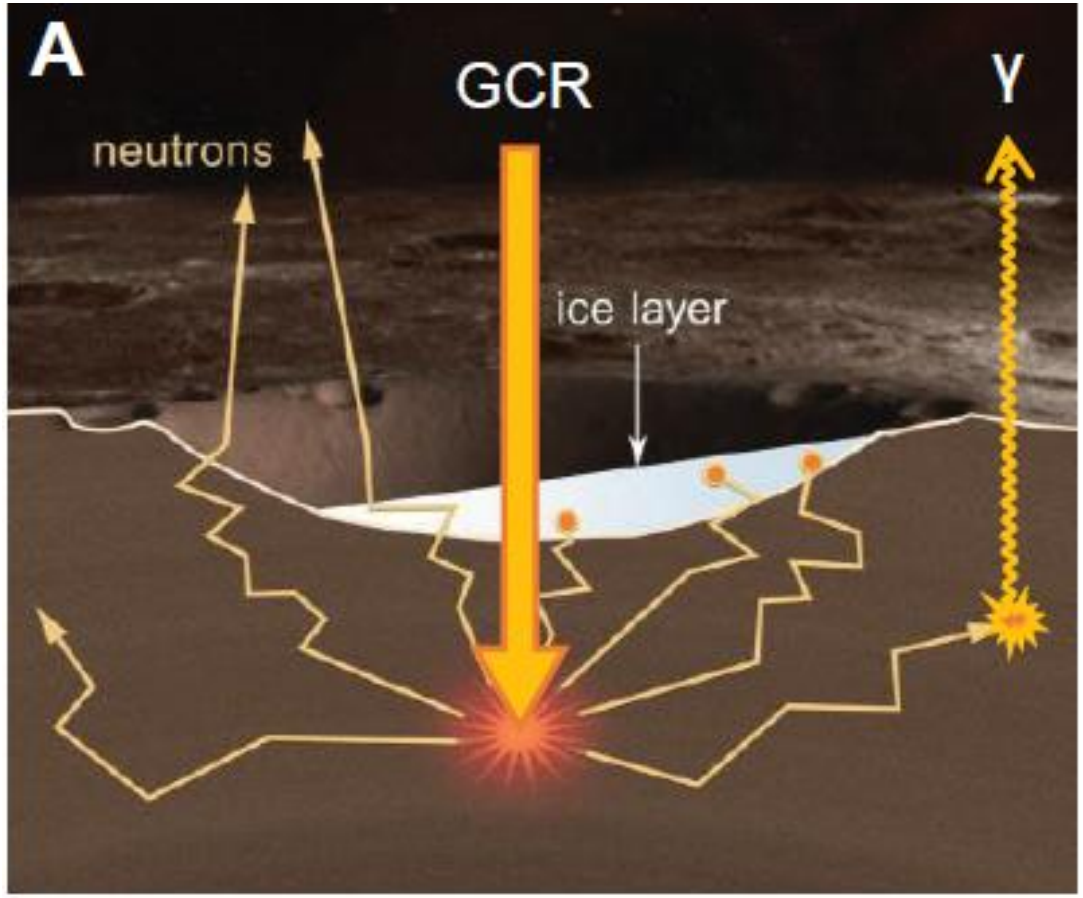
Mini-FND Overview

- 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 ground-truth measurements of the fast neutron albedo provide important information about potential health risks for future human explorers



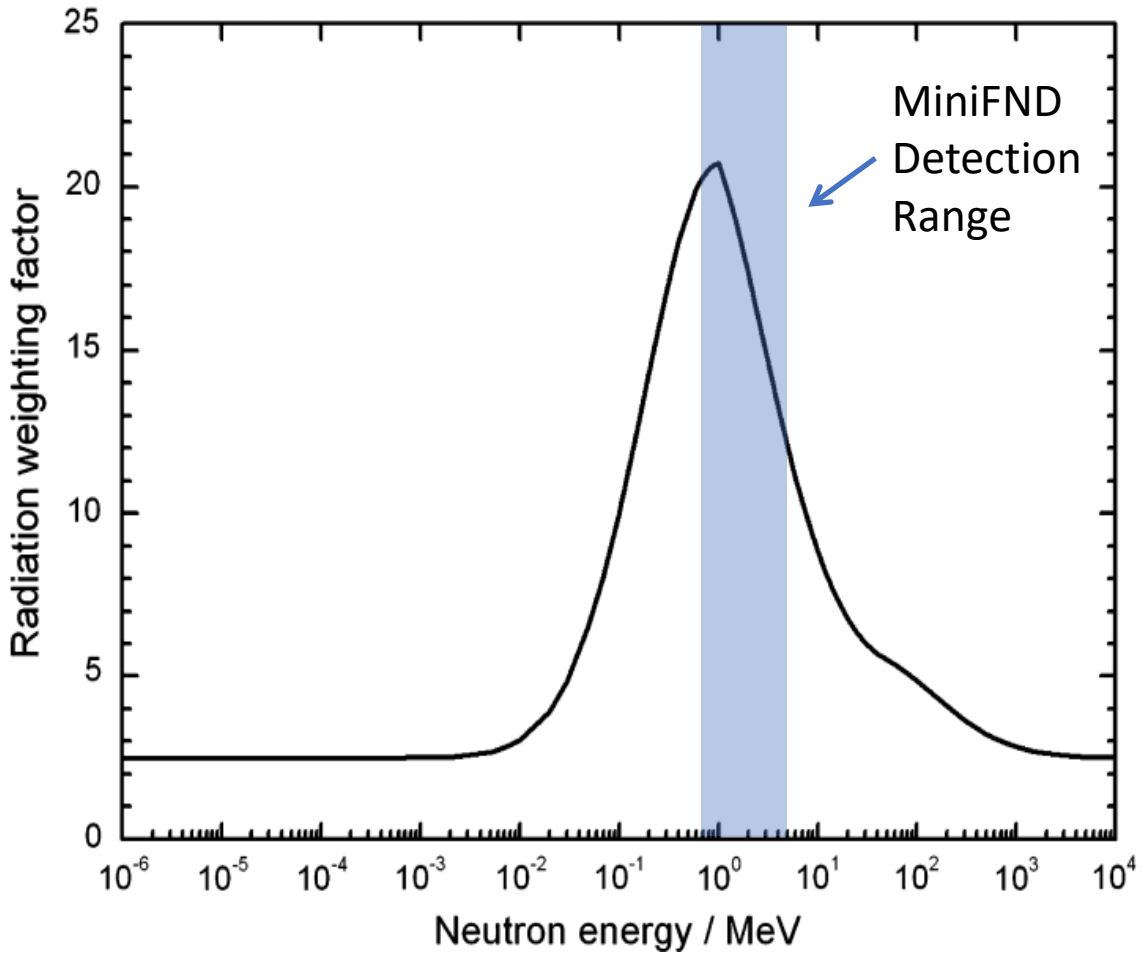
The Radiation Environment on the Lunar Surface

- 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…



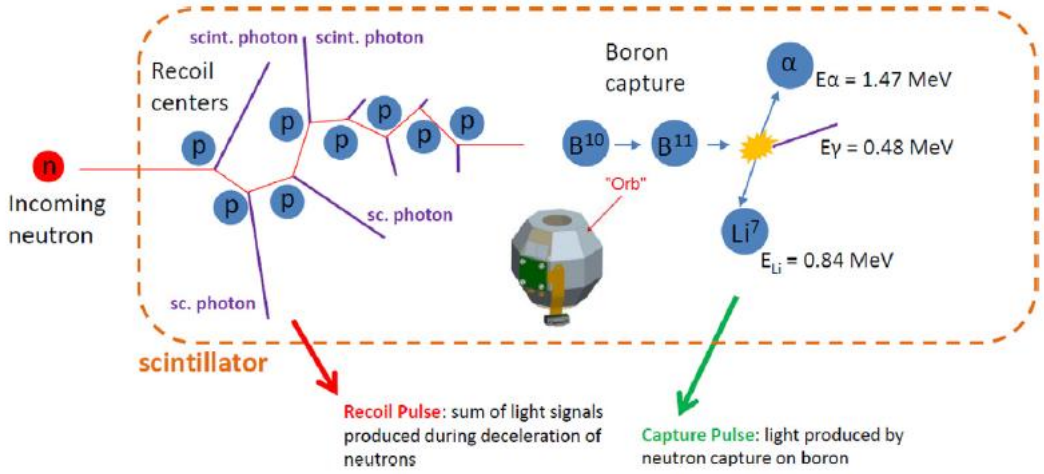
Why are neutron measurements important?

- 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 neutron detection scheme – Capture gating method

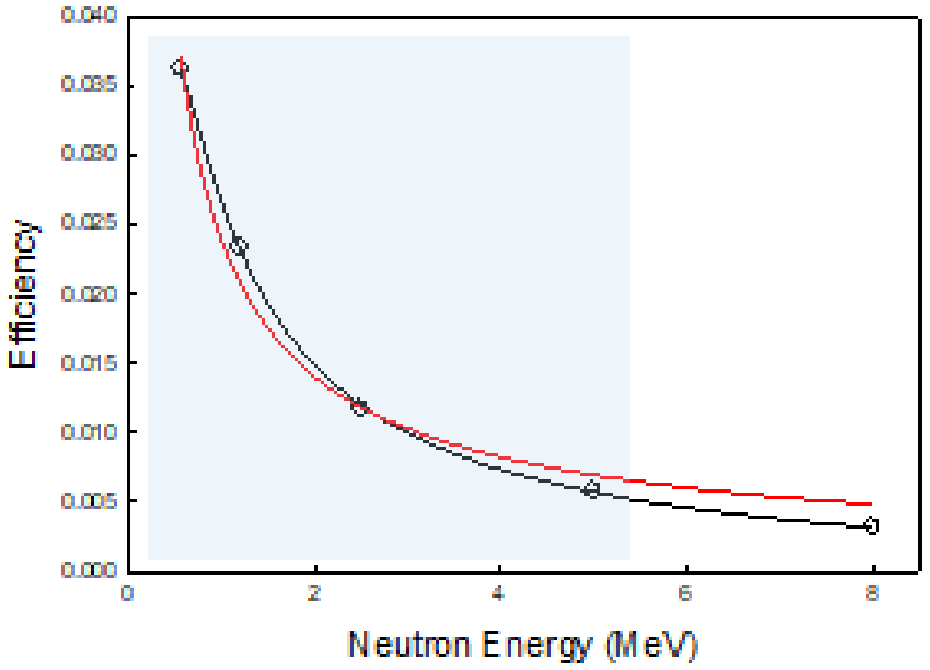
- The Mini-FND neutron sensor consists of a boron-loaded plastic (BLP) scintillator orb
- Neutrons lose energy in the BLP and create a scintillation light pulse
- If the neutrons reach low enough (thermal) energies, the neutrons can be captured by boron atoms in the BLP…
- … producing a second characteristic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

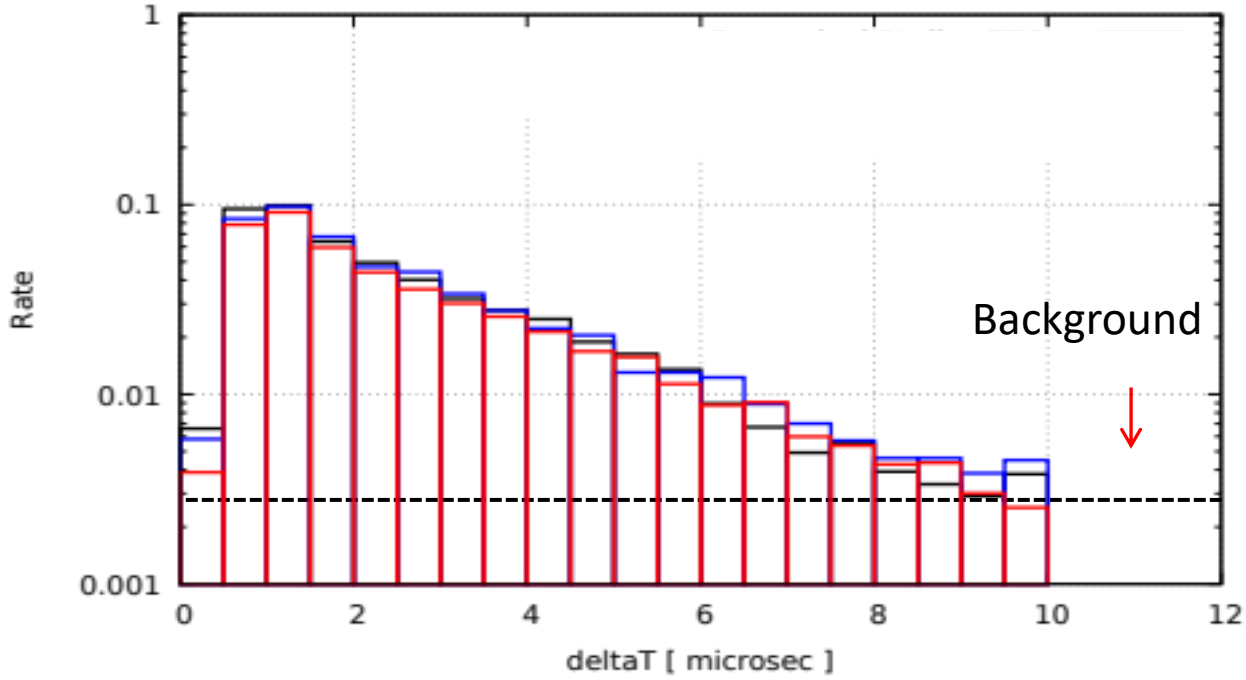


From Zeitlin et al., Life Sciences in Space Research (2023).

Mini-FND Fast Neutron Detection Scheme & Detection Efficiency

- Timing of the two pulses is used to identify the particle as a neutron (capture gating method)
- High-Δt tail can be used for background correction
- ***Measurements with Cf255 source show neutron identification works as designed***





In the Mini-FND energy detection range, ***fast neutron detection efficiency is on the order of ~1 – 3.5 %***

Status of Mini-FND Development

- Mini-FND successfully went through thermal characterization and thermal vacuum test…
- … and EMI & IT test with LEIA at NASA Ames
- Calibration completed with gamma-ray sources
- Potential irradiation campaign at PTB in late 2026, early 2027? (once PTB re-opens)
- Delivery to lander (IM) scheduled for March 2027
- Launch scheduled for October 2027
- Plan to develop new Mini-FND version employing MicroPMTs

