Characterization of the RaD-X Mission Instruments

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Abstract

The NASA Radiation Dosimetry Experiment (RaD-X) stratospheric balloon flight mission, launched on 25 September 2015, provided dosimetric measurements above the Pfotzer maximum. The goal of taking these measurements is to improve aviation radiation models by providing a characterization of cosmic ray primaries, which are the source of radiation exposure at aviation altitudes. The RaD-X science payload consists of four instruments. The main science instrument is a tissue-equivalent proportional counter (TEPC). The other instruments consisted of three solid state silicon dosimeters: Liulin, Teledyne total ionizing dose (TID) and RaySure detectors. To properly interpret the measurements, it is necessary to evaluate how the payload affects the radiation environment of the detectors. In addition, it is necessary to evaluate how the detectors react to the different particles impacting them.
We present the results of the Geant-4 simulations of the interaction of the different radiations with the payload and the instruments. We show how it affect the measurements, and which instruments are better suited for future missions.

I -The RaD-X Mission

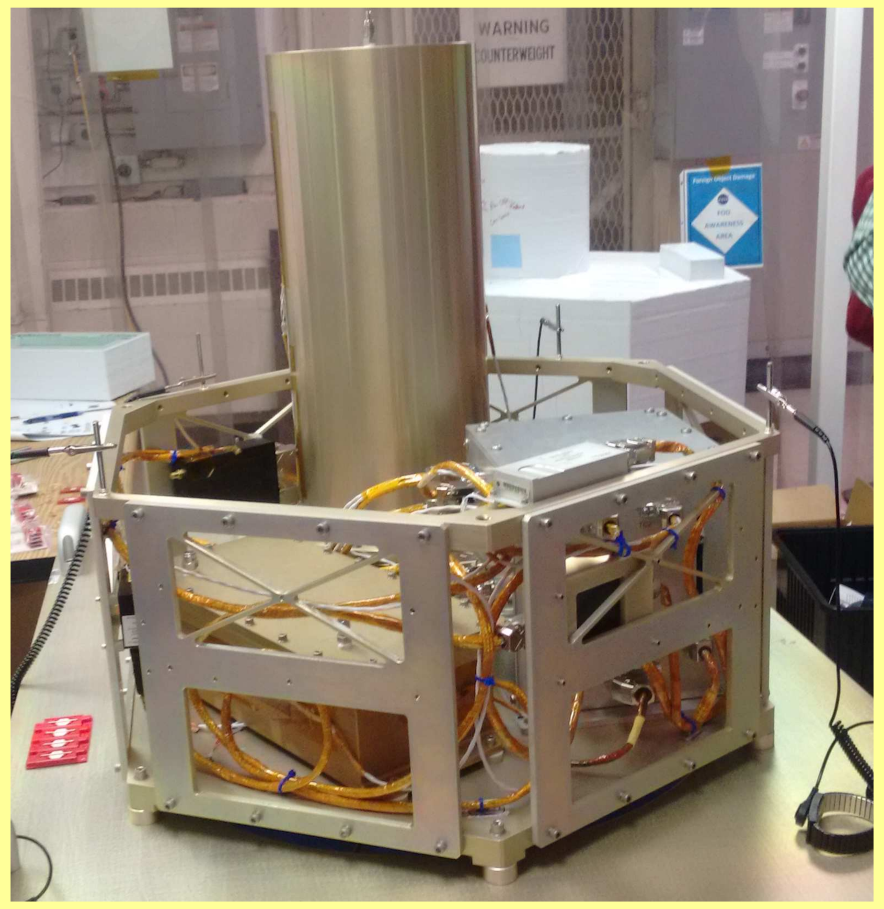
The RaD-X Mission

Objective: Provide measurements to improve aviation radiation models such as NAIRAS (Nowcast of Atmospheric Ionizing Radiation for Aviation Safety).

- Launched on September 25, 2015; 1 day mission.
- 4 radiation instruments Liulin, TID, TEPC, Raysure.
- Intercomparison of instrument response.
- Hours long measurements above the Pfotzer maximum.
- "High" altitude measurements (>32 km): dose mainly due to high-Z primary GCR particles.
- "Medium" altitude measurements (21-27 km): dose mainly due to proton and alpha primary GCR particles.

Outstanding questions: Are we able to correctly model the radiation effects of Solar Energetic Particle events at aircraft altitude? Are we able to correctly measure the dosimetry, and especially the impact of neutrons?

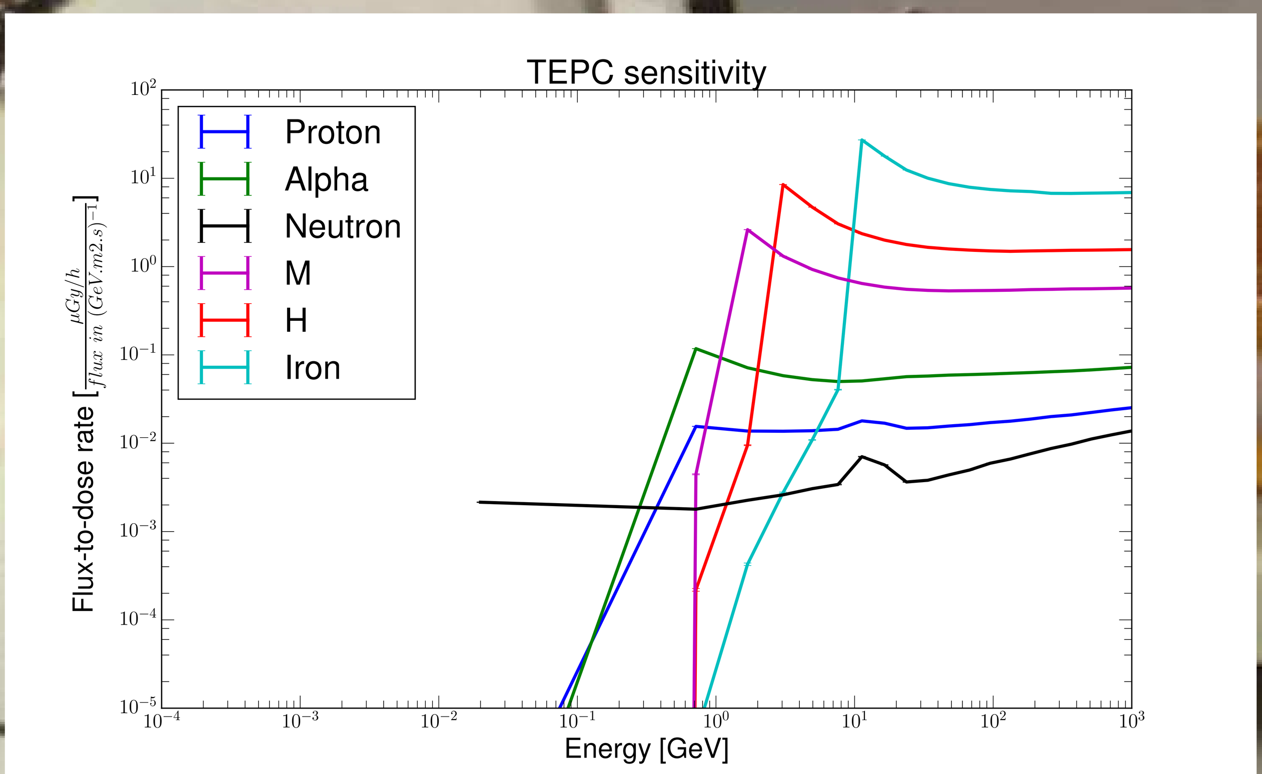
Relevance of this work: (1) Demonstrating the sensitivity of the different instruments to neutrons by modeling their response.
(2) Correcting the instruments' response from the effect of the payload.

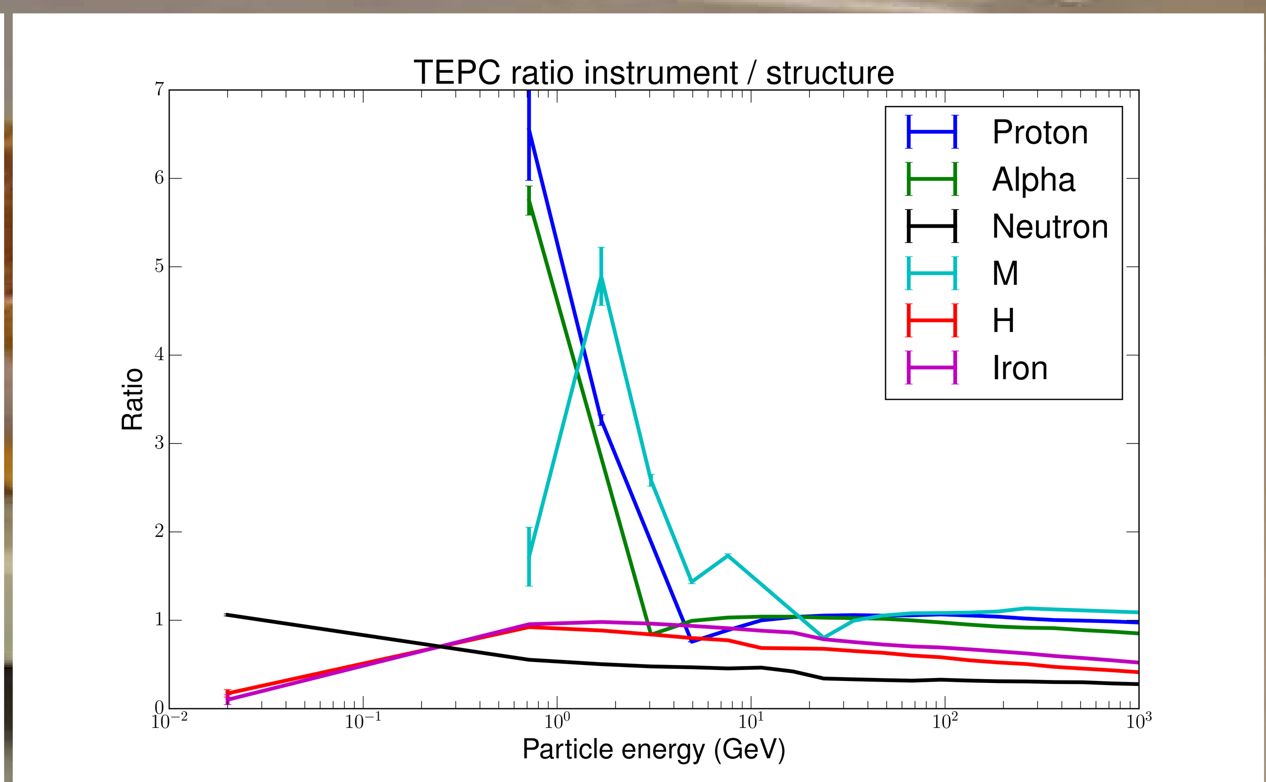


II- The Geant-4 RaD-X Payload Simulations

The simulations of the particle impact on the payload have been made using the Geant-4 toolkit along with the physics library QGSP_BERT_HP, recommended for radiation shielding applications. The different instruments were modeled so that the energy deposition in their detector were recorded. For each instrument, the sensitivity was computed by simulating the energy deposition for a range of discrete energies (between 0.02 GeV and 1 TeV) and several primary particles.
The energy deposition, while the instruments were located in the payload, was then computed to show the influence of the payload on the instruments' response. When these results are integrated with the particle fluxes, a correction factor can be computed for the instrument during the flight: multiplying the instrument response by this factor gives the dose at that altitude.
The model was validated by laboratory measurements at Lawrence Livermore National Laboratory(Straume et al. 2016, Gronoff et al. 2016).

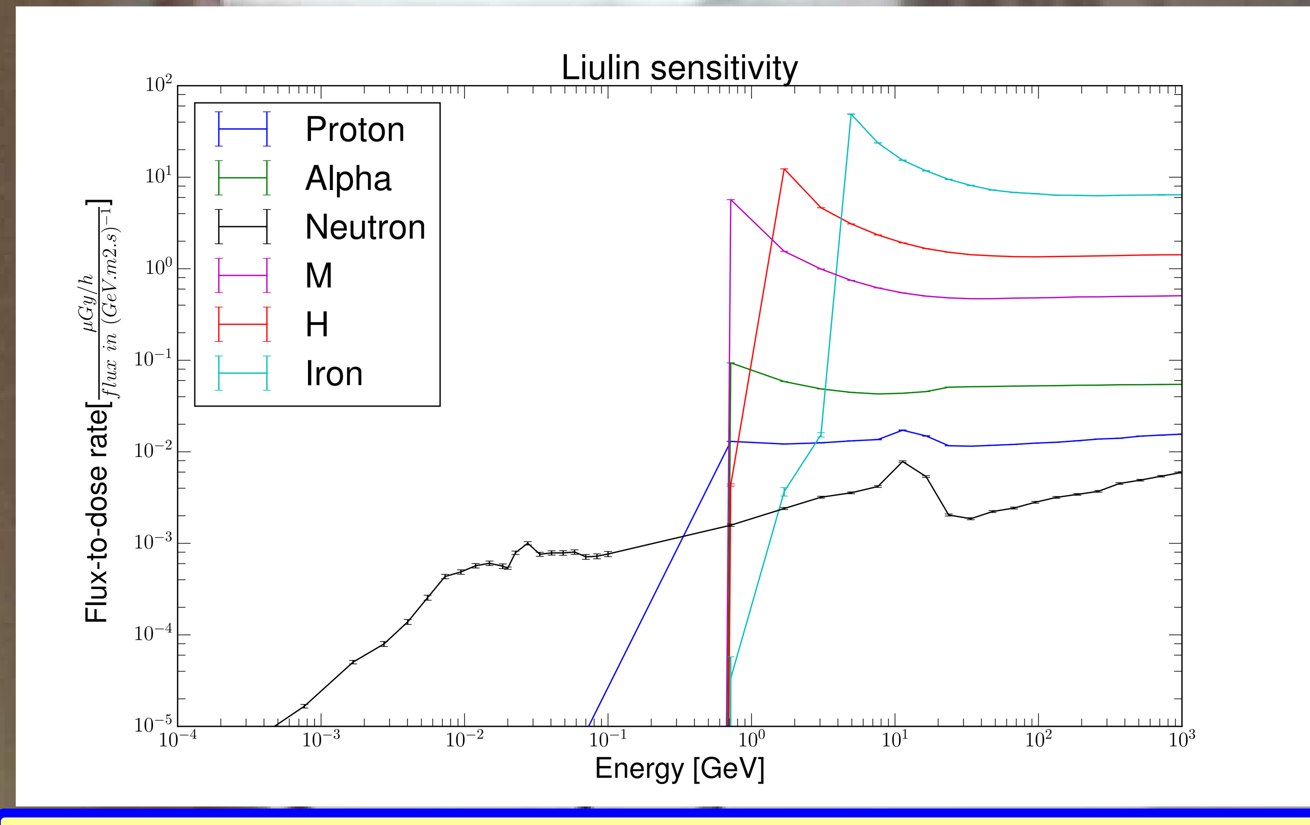
III- The Tissue-Equivalent Proportional Counter (TEPC)

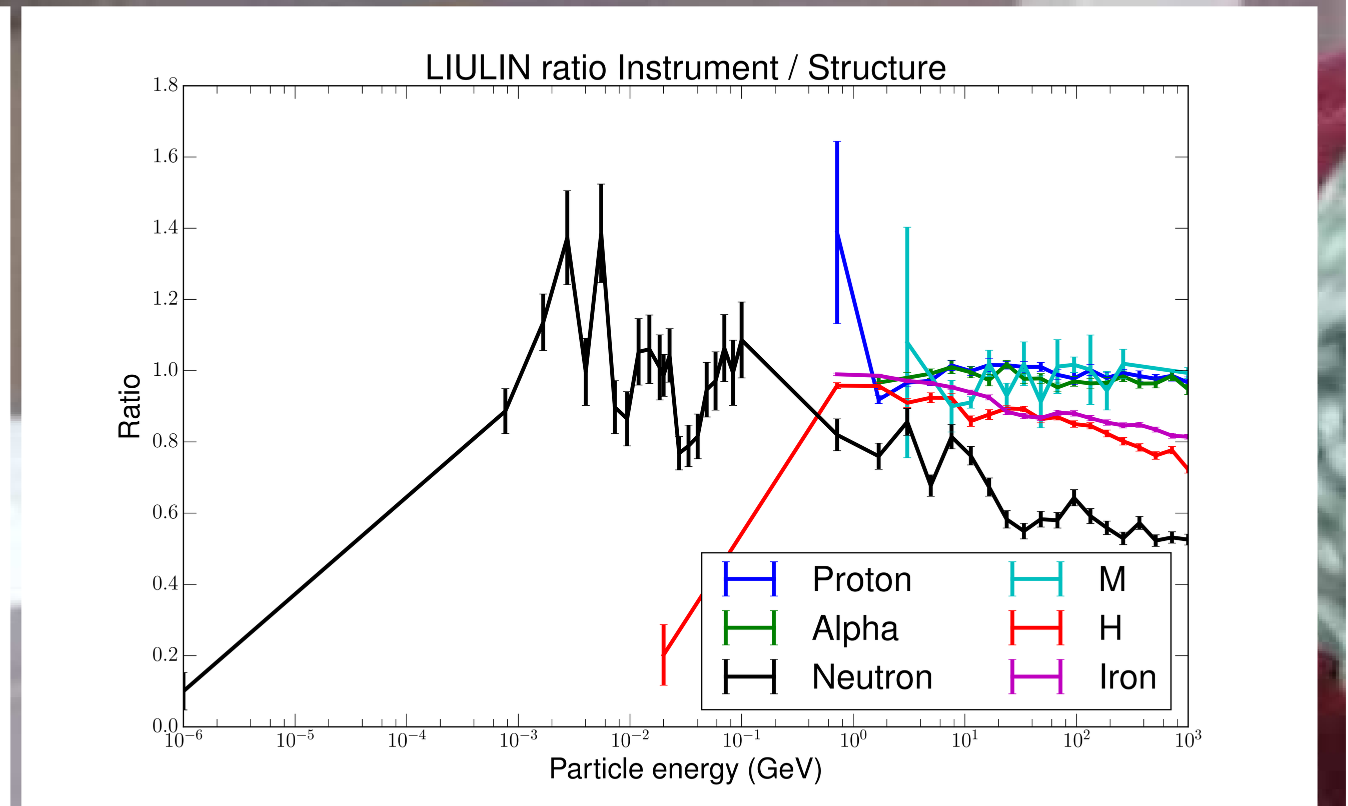




The TEPC (a Hawk Version 3 manufactured by Far West Technology Inc.) is the "gold standard" of microdosimetry. The detector is made of an A-150 tissue equivalent plastic shell filled with propane at 933 Pa. Its inclusion in the RaD-X mission allows for the validation of all the other instruments.

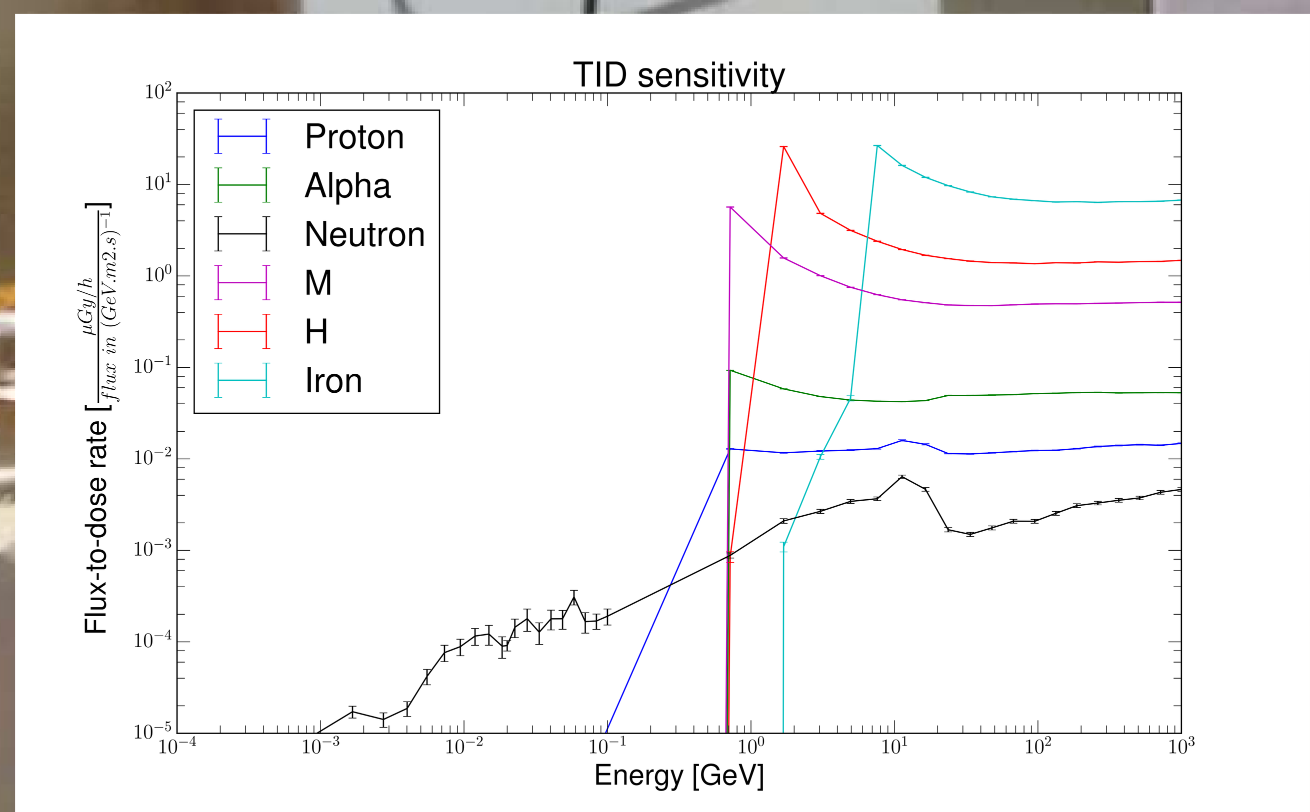
IV- The Liulin

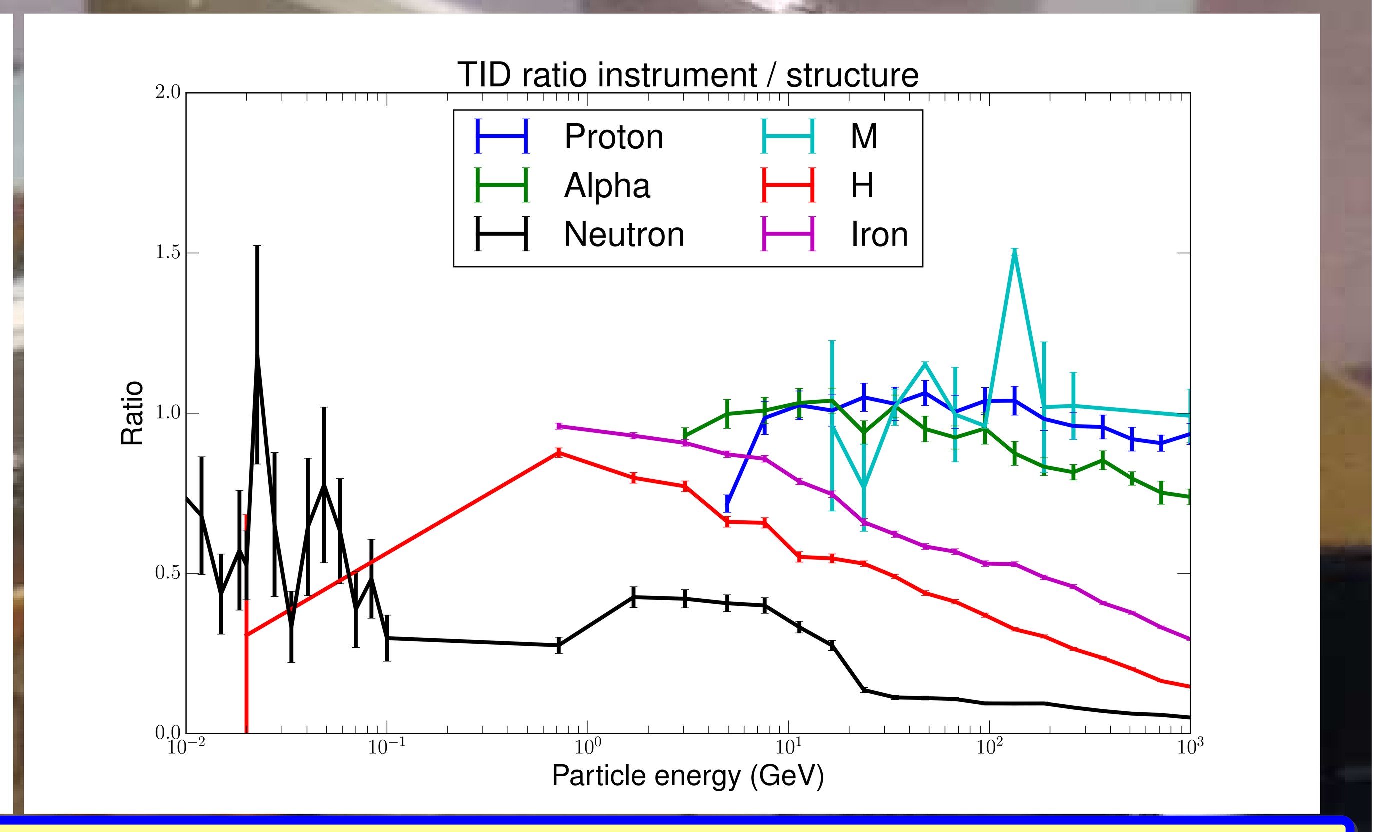




The Liulin dosimeter/spectrometer (Dachev et al. 2016) measures dose in a silicon detector, it has several channels of different linear energy transfers (LET).

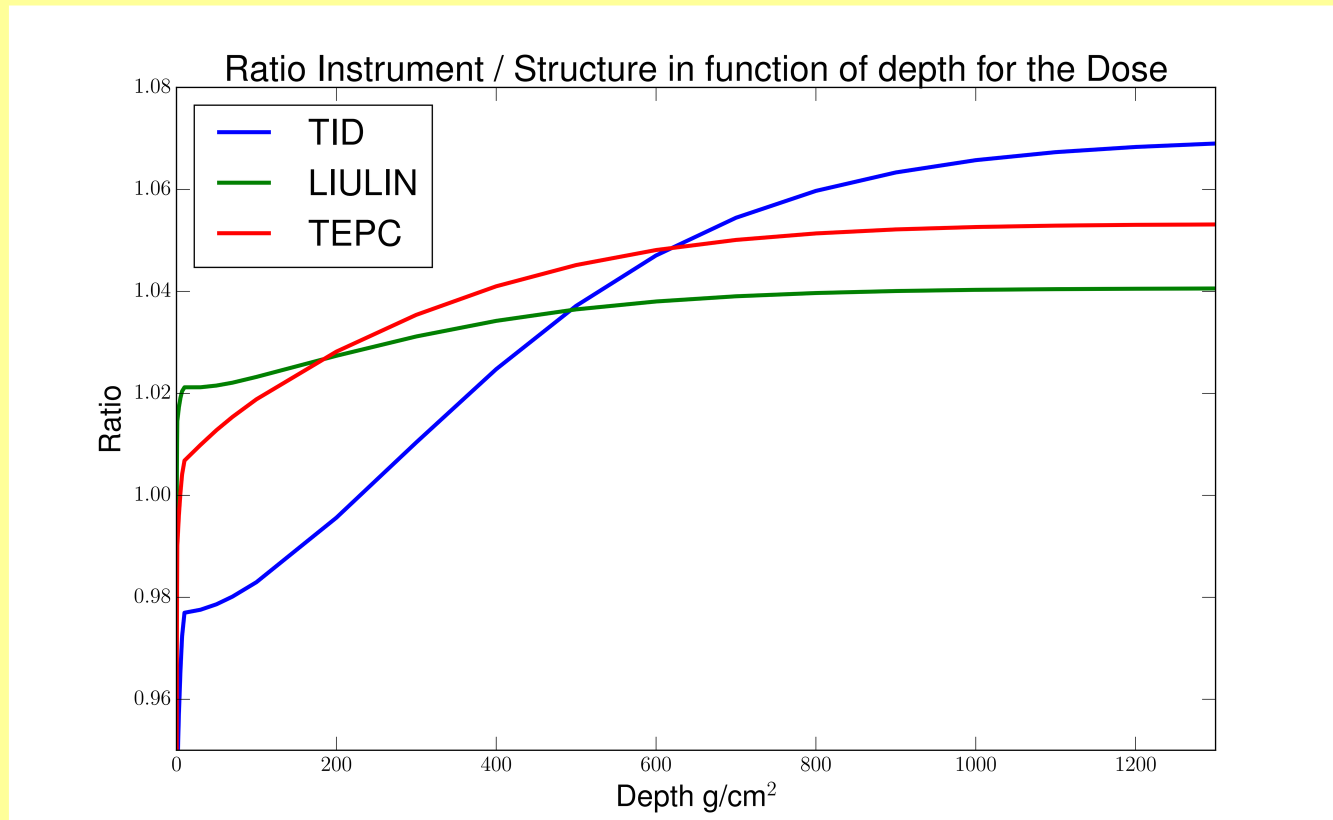
V- The Teledyne Total Ionizing Dose (TID)





The Teledyne TID is a silicon detector that reports the total ionizing dose (Lindstrom et al. 2011). TIDs have been flying, notably in Lunar Reconnaissance Orbiter.

Discussion / Conclusion



The simulation allowed the computation of the correction factors (left). The biggest uncertainty in our understanding of GCR is neutron fluxes, therefore a sensitivity computation was performed. These results show that the corrections are less than 7% and that intercomparison is feasible.
The RaD-X mission allowed us to measure dose at aircraft altitude and above, highlighting the needed improvements in the simulation of dose at aircraft altitude. It compared the performance of the standard dosimetric instrument, the TEPC, with lighter, cheaper, and more energy efficient Si detectors (TID, Liulin).
Additional missions are required to better address the effect of Solar Energetic Particle events (SEP) on the dosimetry at radiation altitude. The NASA/Living With a Star SAFESKY group is currently working on white papers for future mission/research recommendations.

References

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