AGILE: CubeSat instrument for ion identification and energy measurement

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on behalf of AGILE collaboration

University of Kansas

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AGILE Collaboration

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Overview

AGILE (Advanced enerGetic Ion eLectron tElescope) Objectives

AGILE is an instrument developed between the University of Kansas and NASA. AGILE will:

- be a compact low power and low-cost instrument for characterization of solar energetic (SEP) and anomalous cosmic ray (ACR) particles;
- focus on:
  - **Ions (H-Fe), E=(1-100)MeV/nucl;**
  - Electrons, E=(1-10)MeV;
- be upgradable to higher energy ranges.

AGILE will perform robust real-time particle identification and energy measurement in space.

Solar Energetic Particles (SEPs)

Characterization of:

- Impulsive (He-3-rich) events;
- Gradual (proton-rich) events;

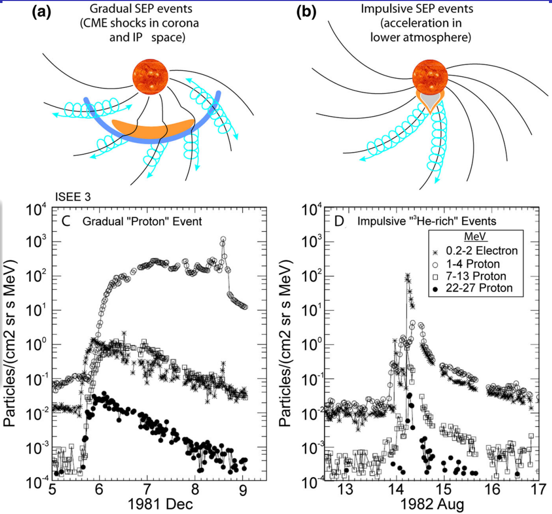
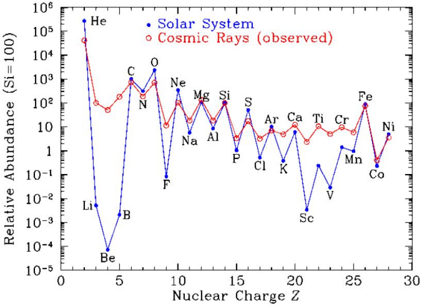
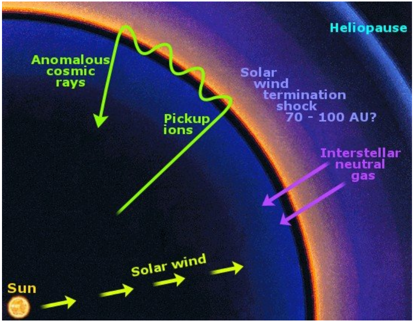


Figure 1: Gradual and impulsive SEP events, adapted from [1] and [2].

Anomalous Cosmic Rays (ACRs)



(a) Elemental mean abundances from ACE/CRIS instruments [3, 4].



(b) Anomalous cosmic rays production[5].

ACRs studies help to:

- Understand dynamics of energetic particles within the solar system;
- Improve characterization of the heliosphere;
- Probe the interstellar medium.

Future science return

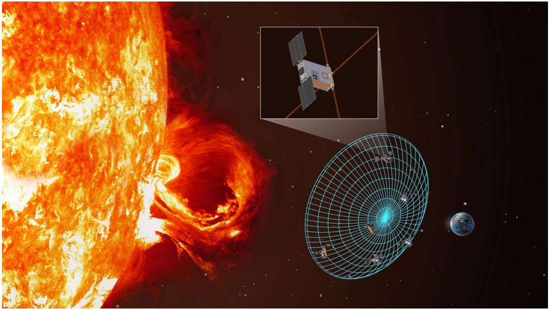



Figure 3: Illustration of CubeSats constellations in Solar system missions.

Science CubeSat constellation used for

- Solar system space exploration (Moon, Mars, Jovian system);
- Human exploration radiation monitoring;
- Global 3d source mapping.

Method

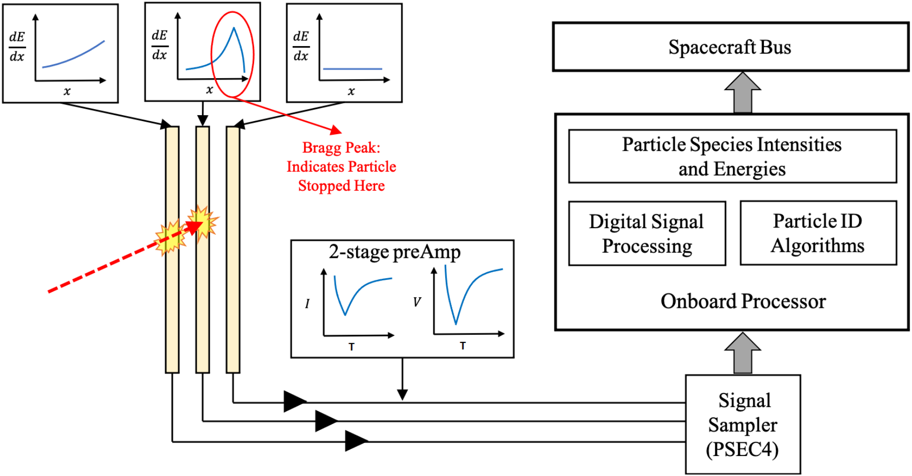


Figure 4: Schematics of AGILE discrimination process.

Stopping Layer signal

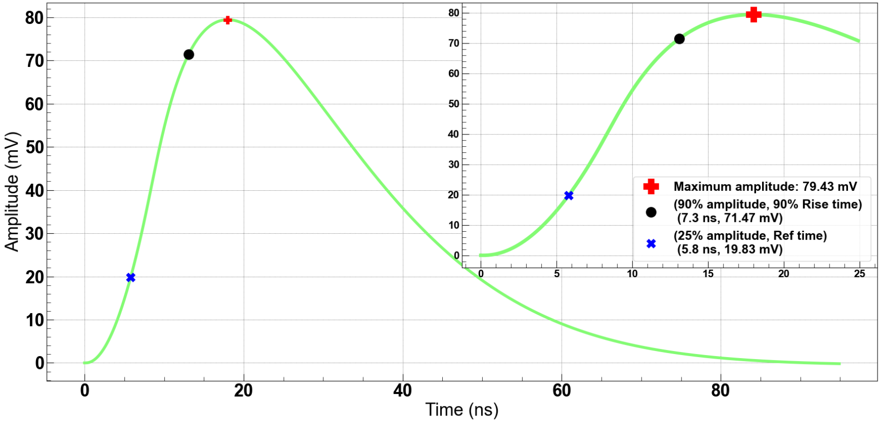


Figure 5: Simulated signals of a 14 MeV/n oxygen ion that stopped in AGILE second layer. The key characteristics of the pulse (Maximum Amplitude, 90% Rise Time) are zoomed-in in the inset.

Amplitude vs Time

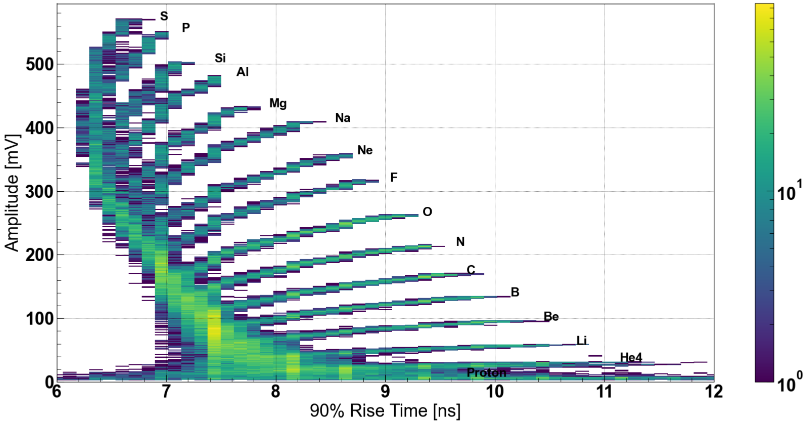


Figure 6: Maximum amplitude vs 90% Rise time for p-Fe ions stopping in the detector. The color bar shows the number of events in each bin of this 2D histogram.

Amplitude vs Rise time

Not only ion charge is determined but also the mass, allowing isotopes discrimination such as ^{3}He and ^{4}He for SEPs event characterisation.

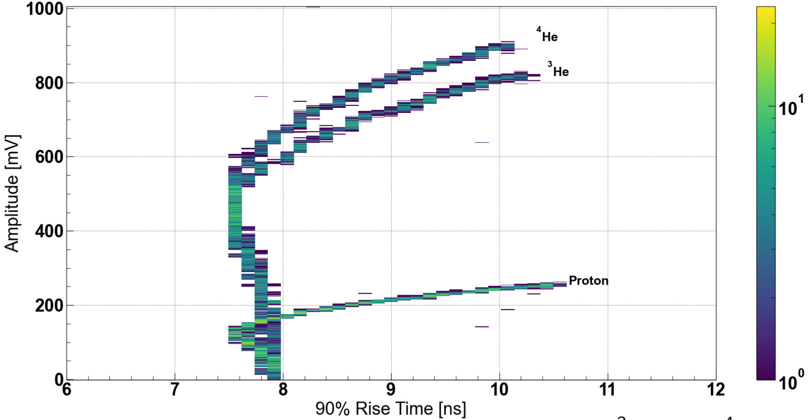
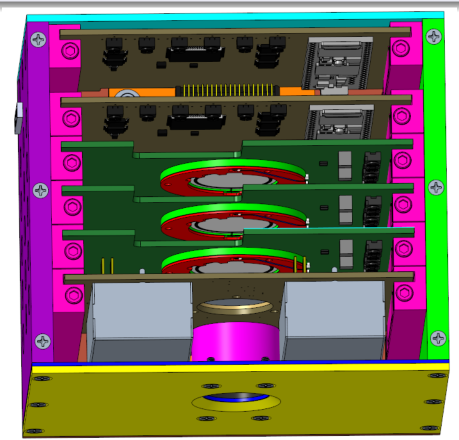


Figure 7: Maximum amplitude vs Rise time for Protons, ^{3}He, and ^{4}He ions stopping in the detector. The color bar shows the number of events in each bin of this 2D histogram.

First prototype

- 3 layers of 300 μm Si-detectors
- Dimensioned to fit a CubeSat
- Flying in fall 2023 for a 1 year mission
- Focus on ions and lower energy range (40 MeV/n)



First prototype

- Tested in lab with Americium 241
- Full beam test for H-Fe ions range in 2023

Figure 8: Integrated AGILE.

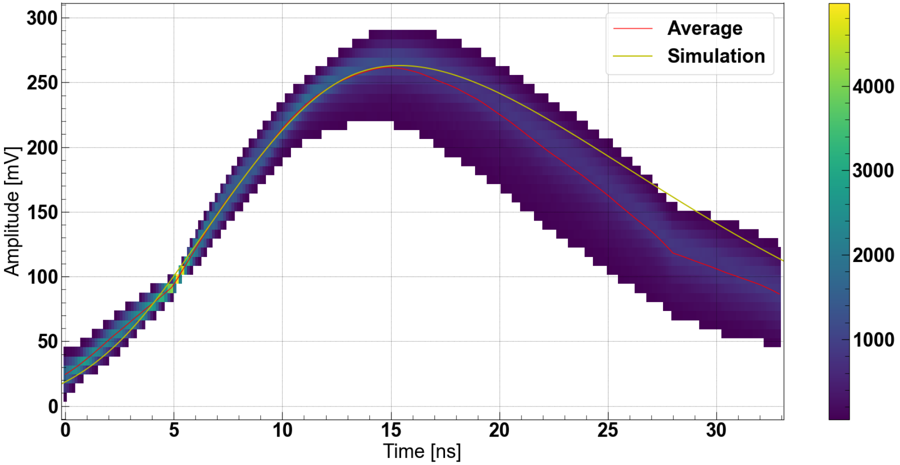


Figure 9: AGILE acquisition of alpha particles (Americium 241 source) compared to expected simulated signal.

Features discrimination

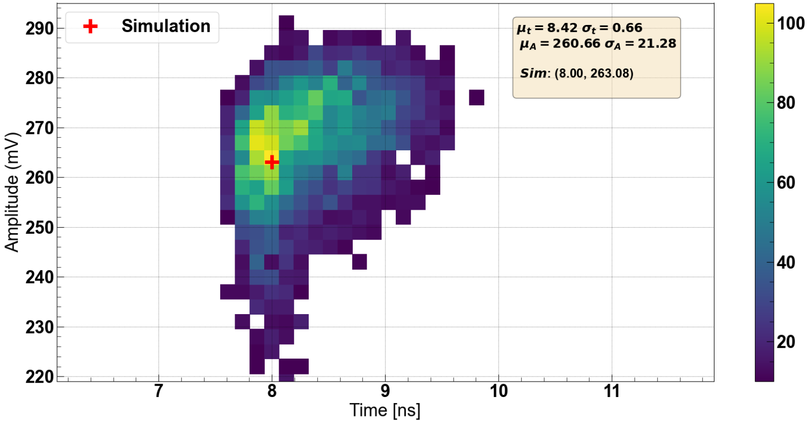


Figure 10: Maximum Amplitude vs 90% Rise time of alpha particles measured by AGILE compared to simulated value.

Energy Acceptance

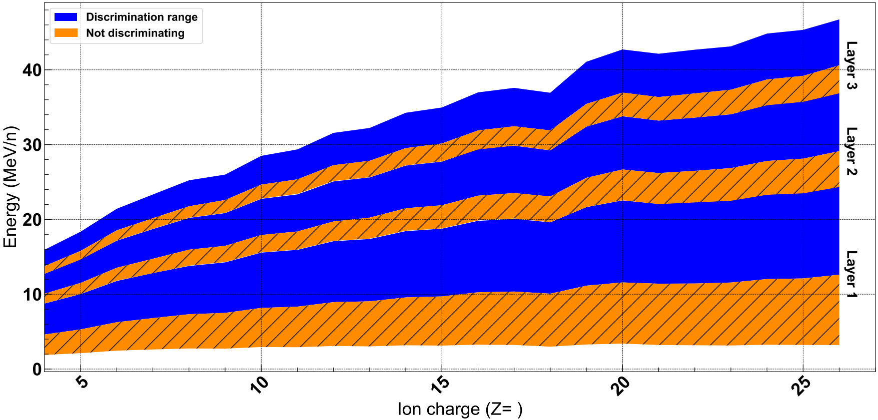


Figure 11: Energy vs Charge (Z). Plain blue regions are the domain where the method can identify the particles. The hatched orange regions are the domain where the discrimination is not possible.

Energy precision

AGILE requirement is to achieve a precision of $\Delta E/E < 30\%$

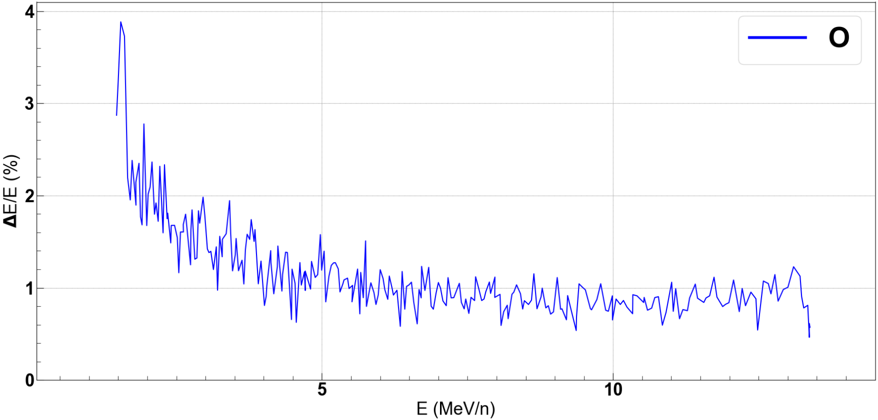
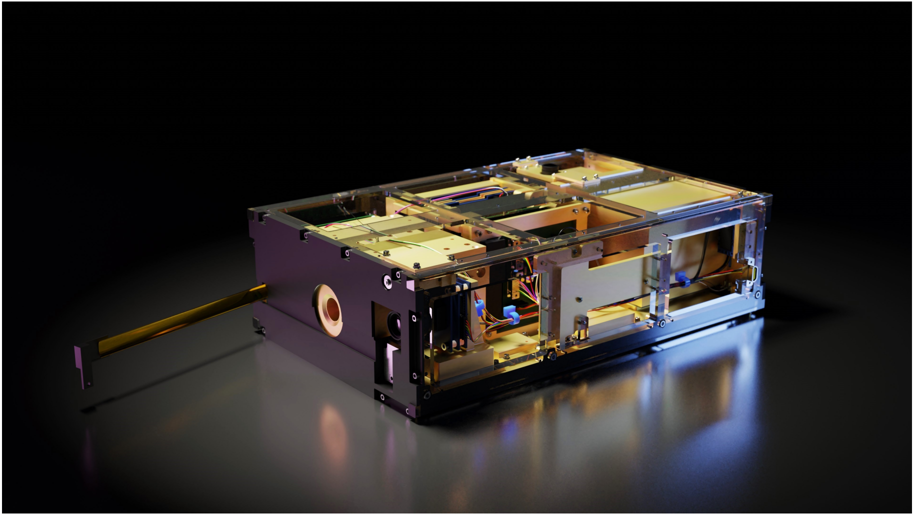


Figure 12: Energy resolution due to statistical fluctuations of the energy deposition and the number of charge carriers and electronics noise.

GenSat: AGILE carrier



Thank You!

[1] M. Desai and J. Giacalone. "Large gradual solar energetic particle events". In: *Living Reviews in Solar Physics* 13.1 (Dec. 2016).

[2] D. Reames. "Particle Acceleration At The Sun And In The Heliosphere". In: *Space Science Reviews* 90 (1999), pp. 413–491.

[3] T. K. Gaisser, R. Engel, and E. Resconi. *Cosmic rays and particle physics*. Cambridge University Press, 2016.

[4] K. Lodders. "Solar system abundances and condensation temperatures of the elements". In: *The Astrophysical Journal* 591.2 (2003), p. 1220.

[5] E. C. Stone et al. "The Solar Isotope Spectrometer for the Advanced Composition Explorer". In: *Space Science Reviews* 86.1 (1998), pp. 357–408.

Back up

Space particle detector

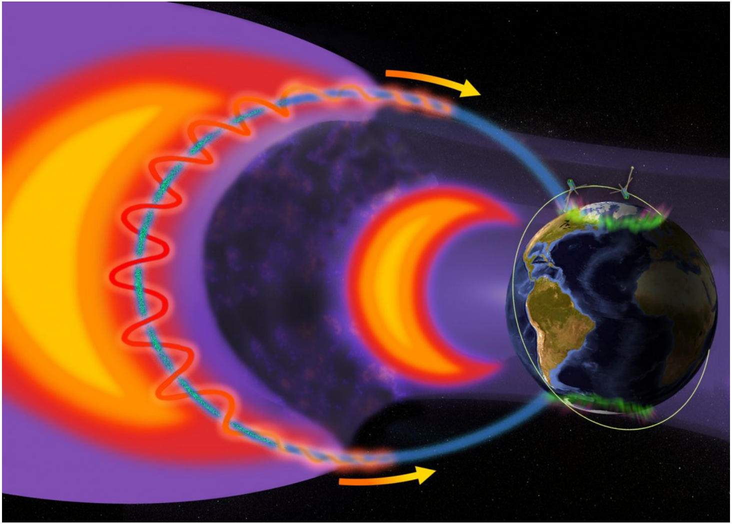


Figure 13: Artist rendering of a CubeSat probe in Earth Radiation belts. Credit NASA.

Monitoring Space Weather

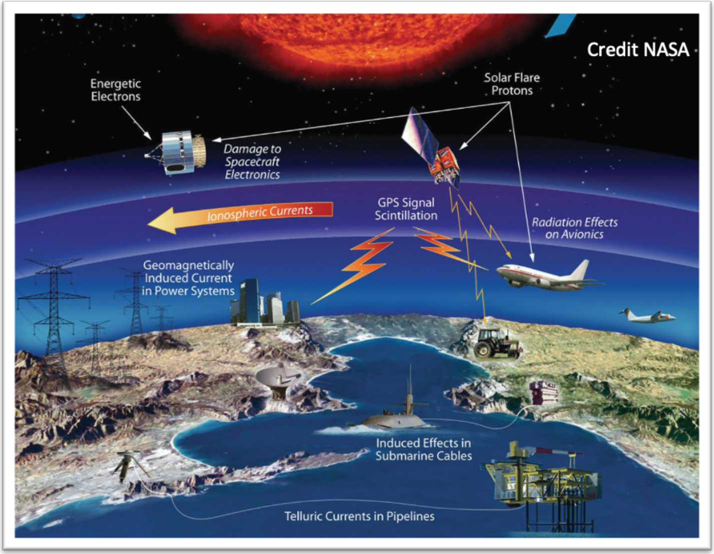
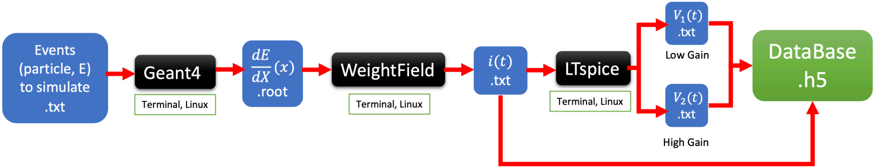
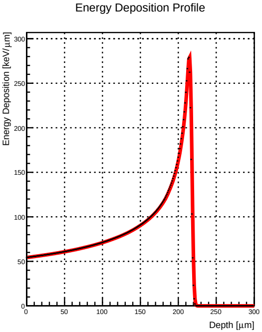
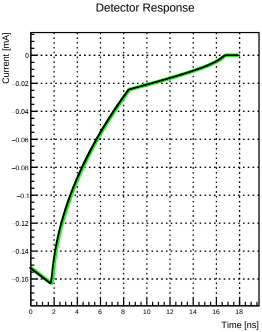


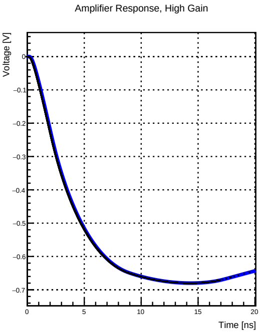
Figure 14: Illustration of Solar activity interaction with Earth and human activities

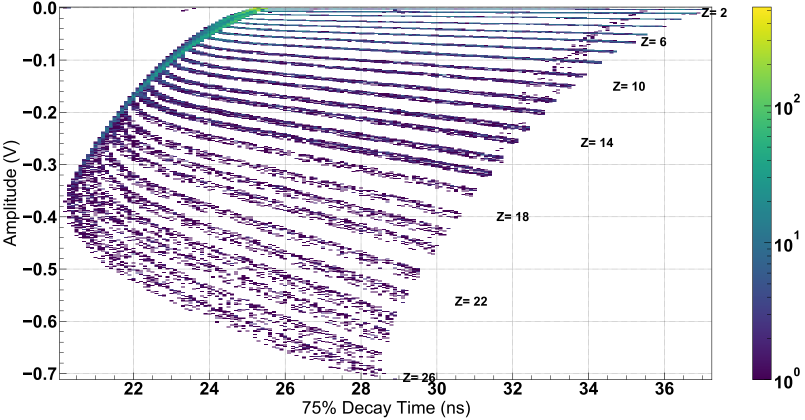
Simulation Chain







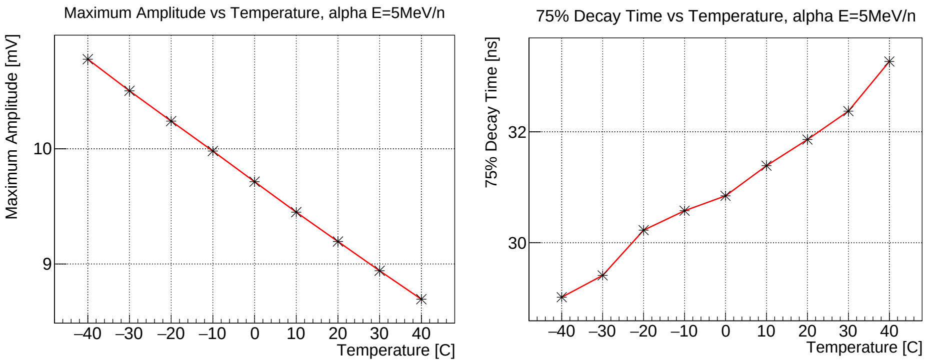




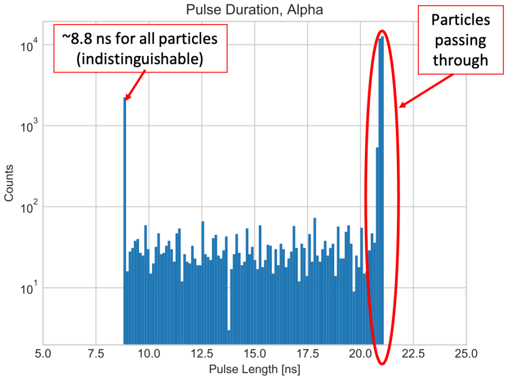
A field of view of 40° (20° of half angle) is manageable for all ions. A wider angle makes discrimination more challenging for heavy ions.

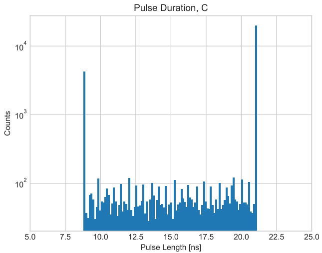
Temperature Effects

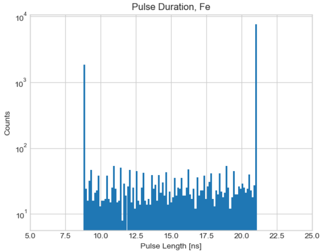
The key signal characteristics are proportional to temperature and thus can be "corrected" on-board if the ambient temperature is known.



Energy Acceptance

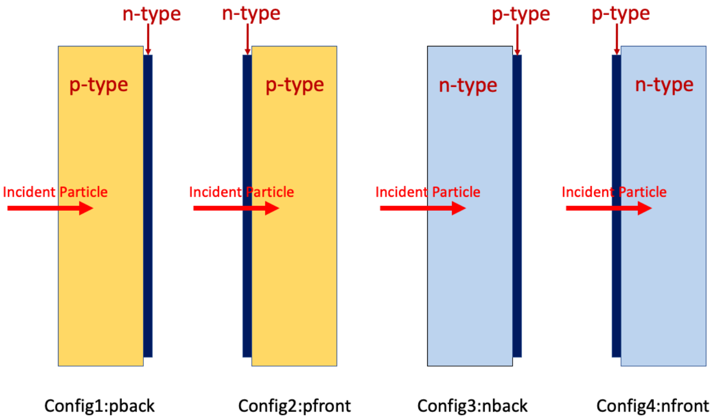






Detector orientation

Potential ways of improvement



Detector orientation

Potential ways of improvement