Eyes on High-Energy Emissions: Ground- and Space-Based Perspectives in Gamma-Ray Research

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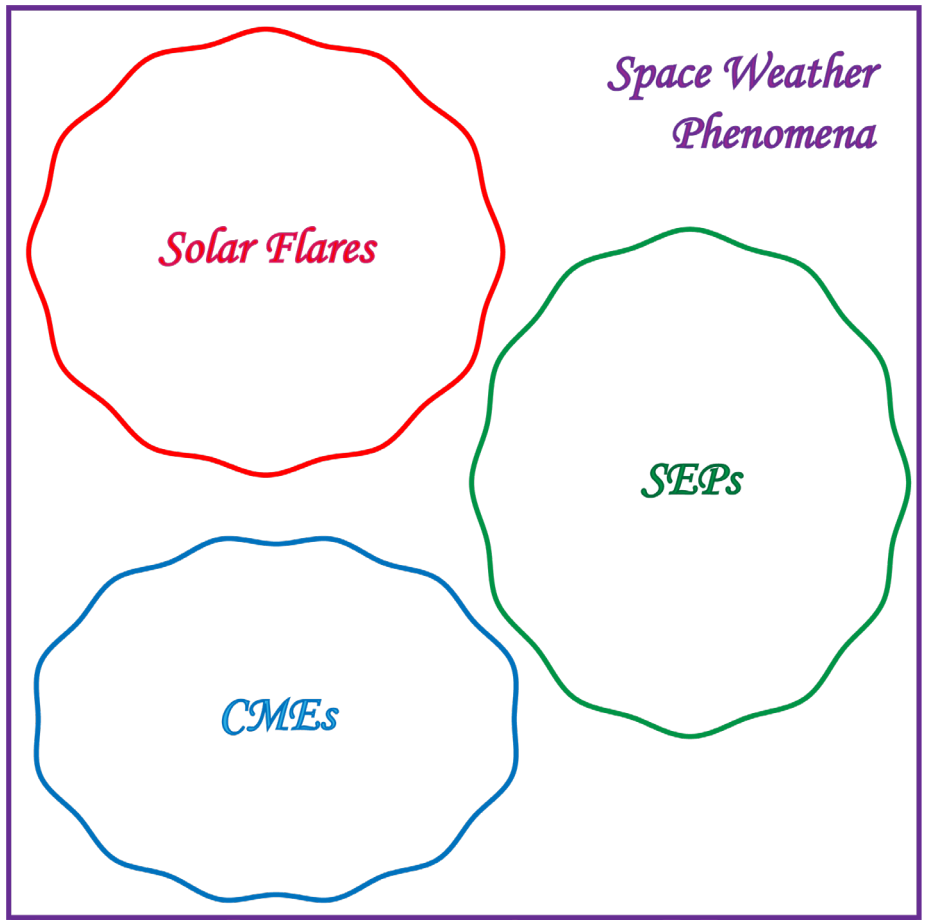
Advances in Modeling High-Energy Astrophysical Sources:
Insights from recent Multimessenger Discoveries

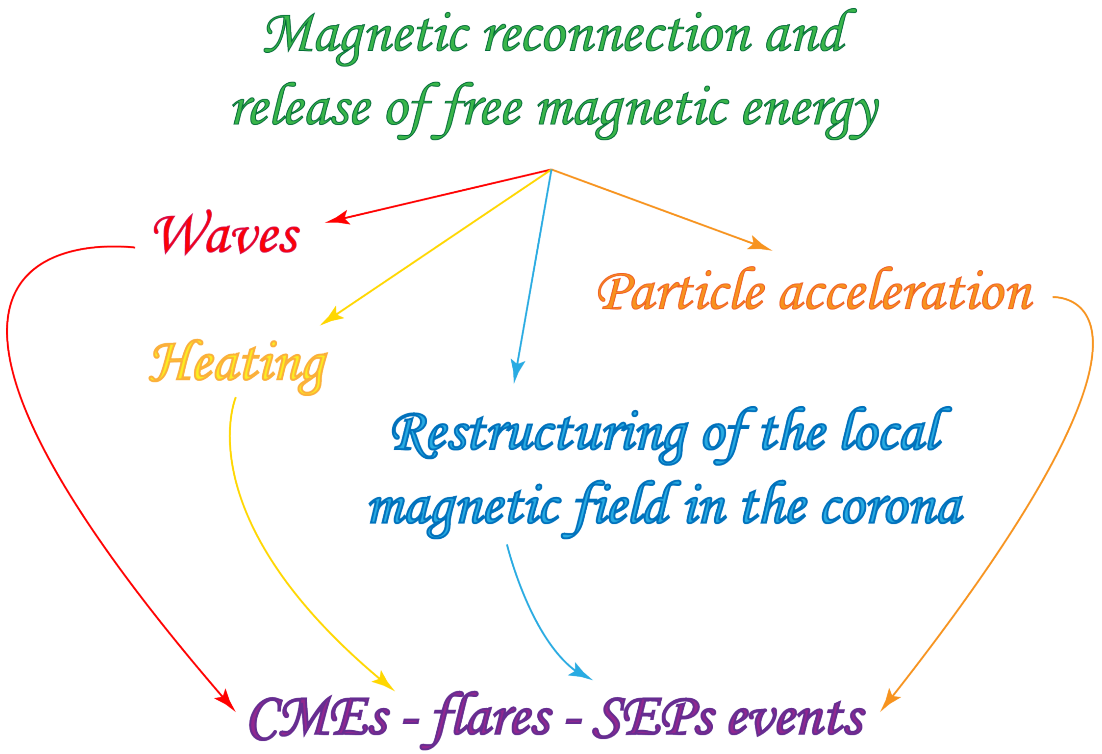
June 30, 2025 – July 4, 2025 ◦ Sexten (BZ), Italy

Outline

- Space Weather Studies
  - Introduction
  - Detector Design using Geant4
  - Simulation Results
  - Upcoming: Solar Flares Monitoring using Fermi-LAT data
- Environmental Radioactivity Studies
  - Introduction
  - Environmental Monitoring
  - Spectral Analysis – Heat Maps and PCA

Space Weather – Introduction





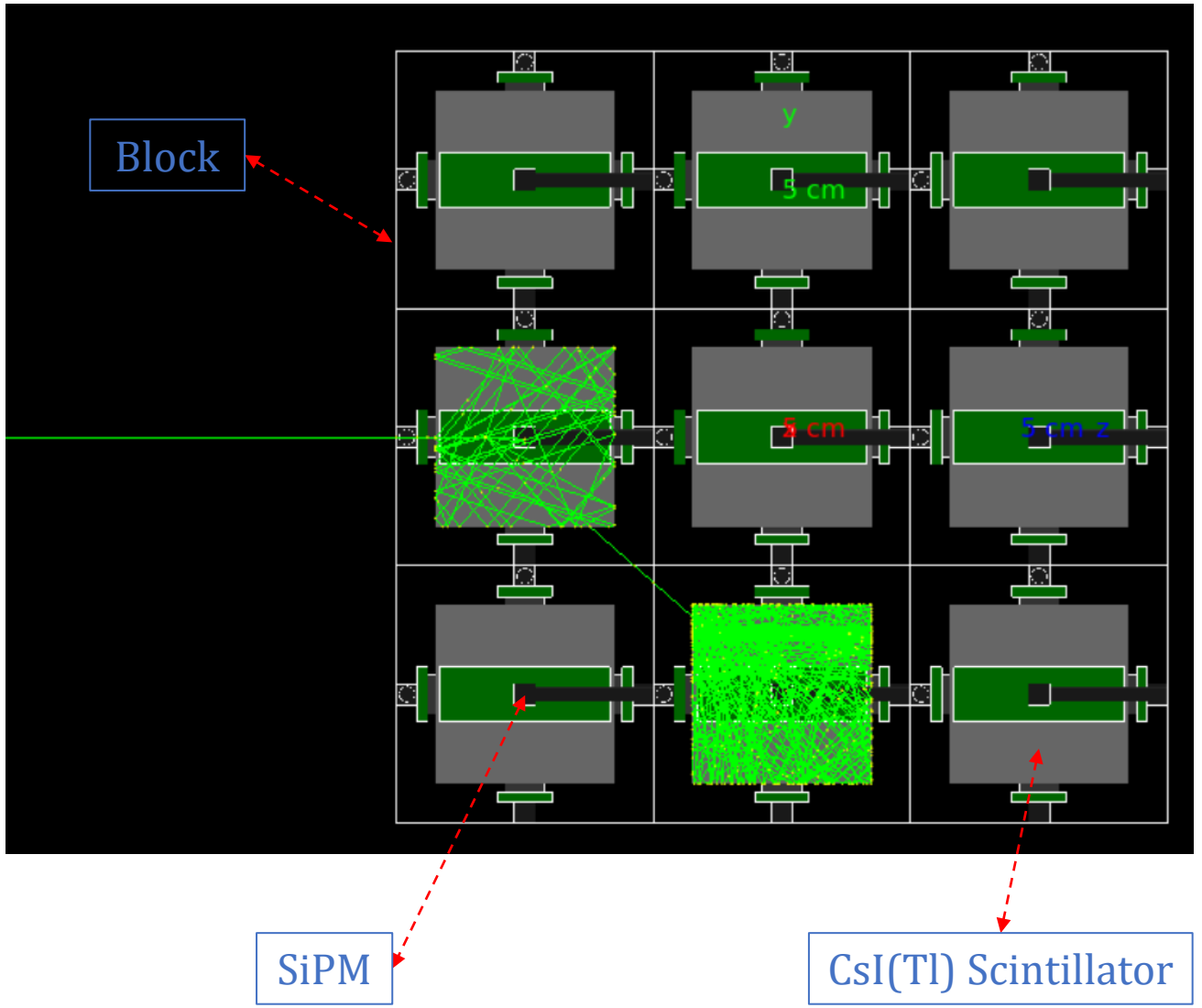
Detector Design using Geant4

Optimization of structural geometry and physical response of detectors using Geant4 Monte Carlo simulations.

Current configuration:

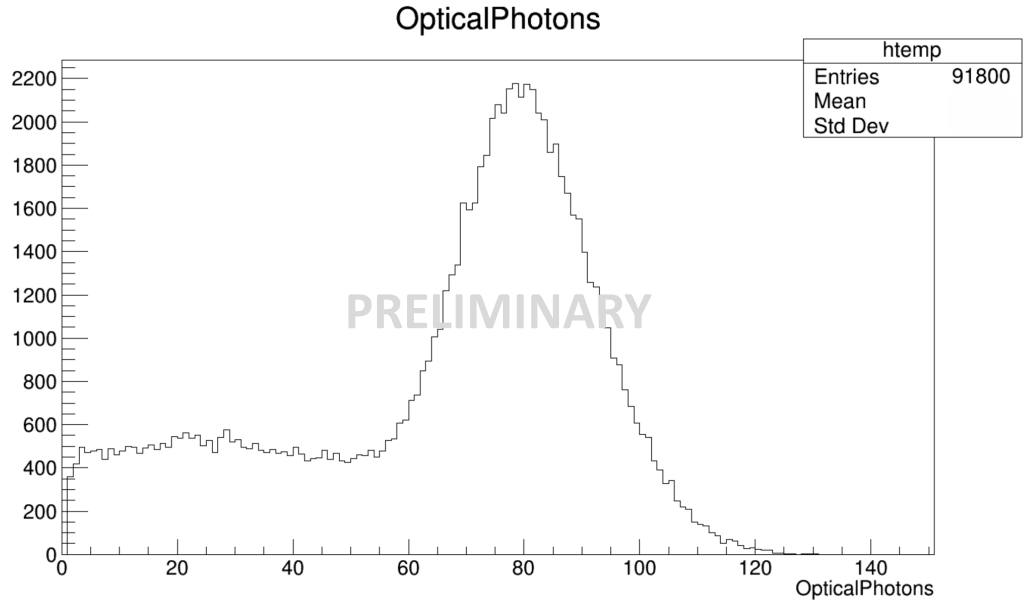
- 27 blocks
  - 1 CsI(Tl) scintillator
  - 6 SiPMs

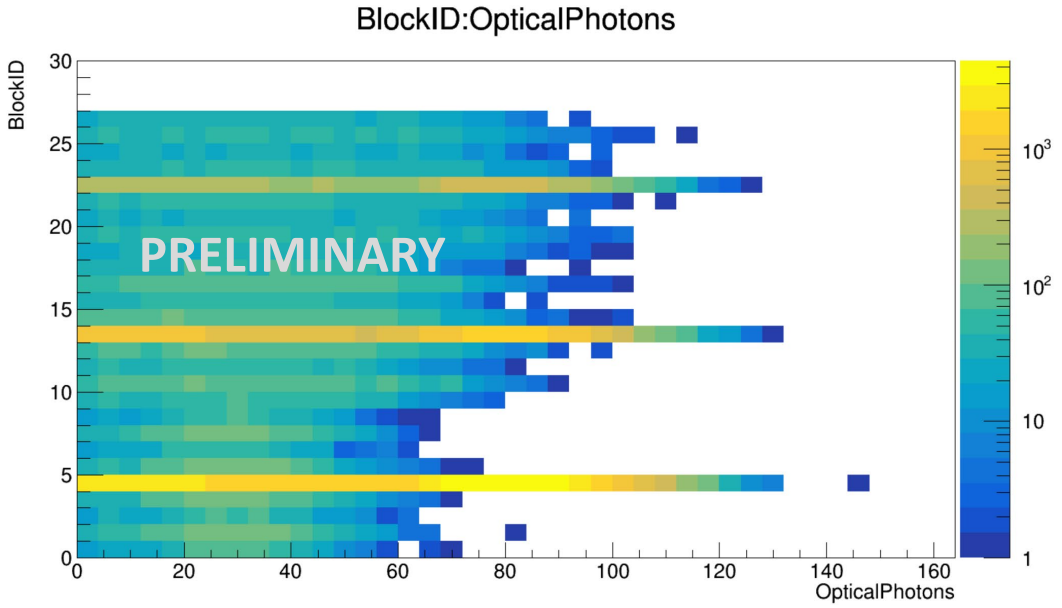
The blocks are arranged in a Rubik's-like structure.



Simulation Results – Optical Photons

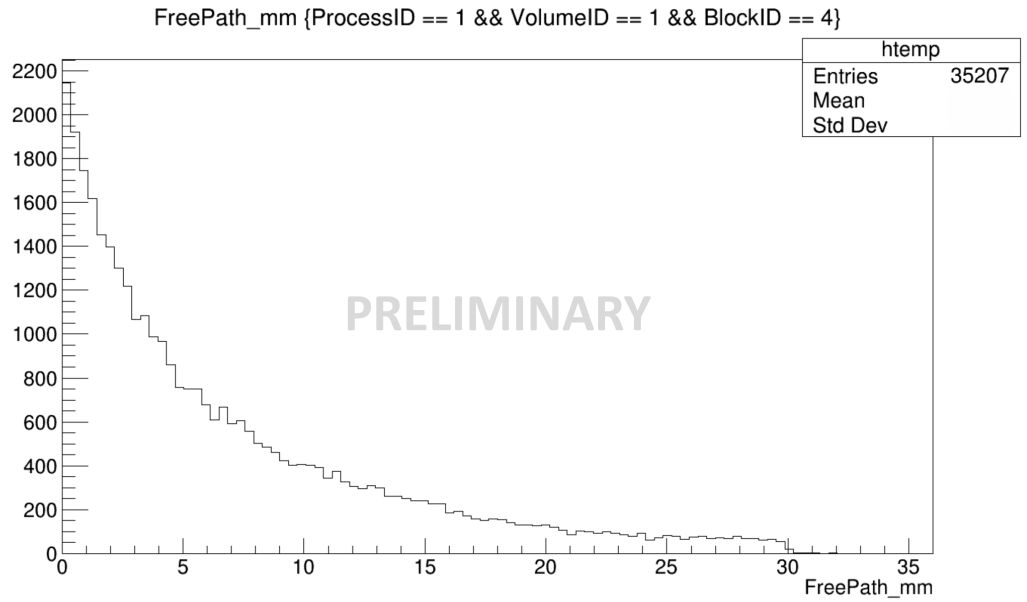
Total and "block by block" SiPM absorption of optical photons for 662 keV gammas sent along the x direction towards the center of the side of the cube.

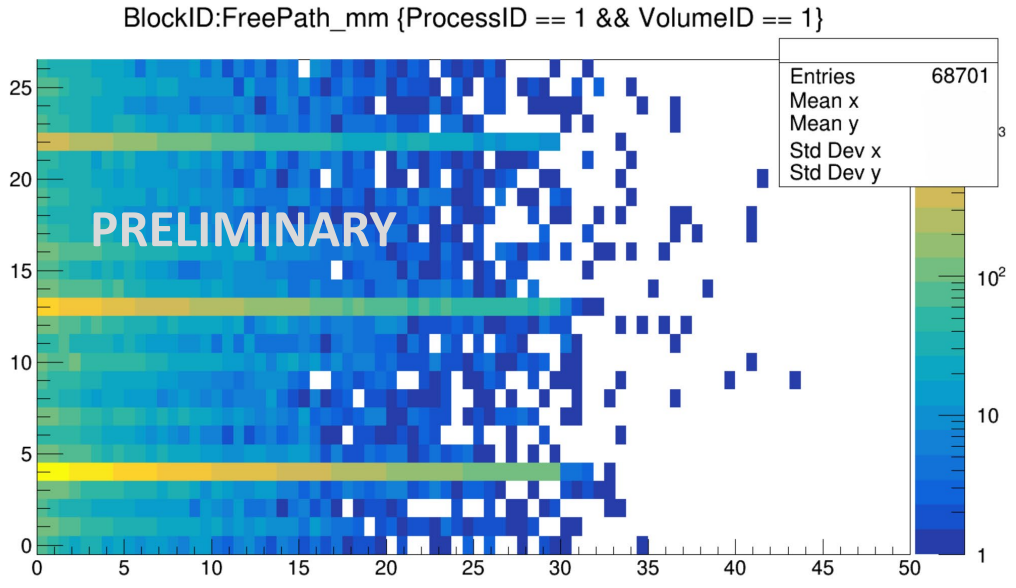




Simulation Results – Mean Free Path

Single and “block by block” mean free path of photoelectric effect for 662 keV gammas sent along the x direction towards the center of the side of the cube.



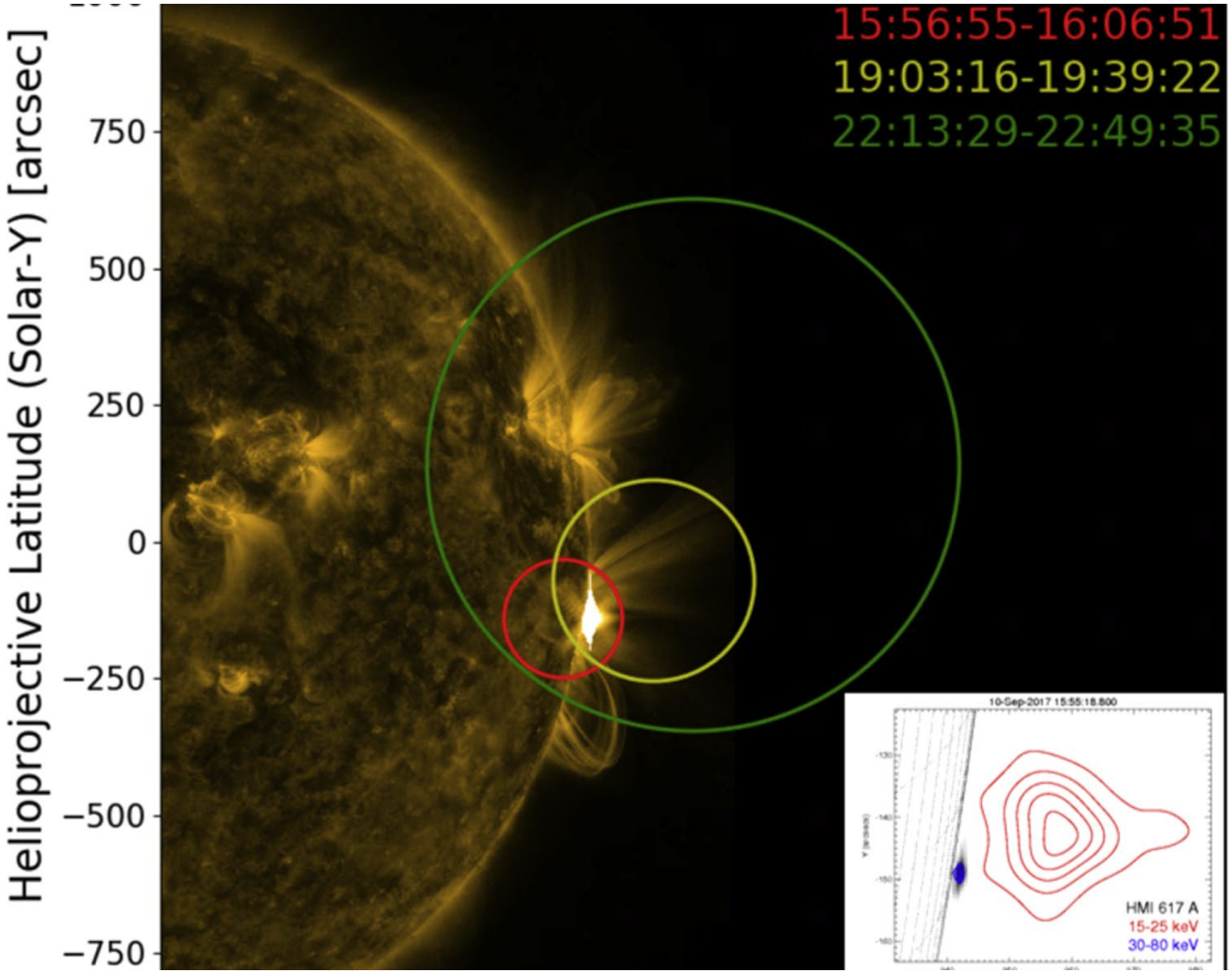


Upcoming - Solar Flares Monitoring using Fermi-LAT data

Fermi-LAT data enable detailed investigations of:

- ❑ *temporal profiles*
- ❑ *photon energy spectra*
- ❑ the *proton spectral index* from hadronic interactions
- ❑ potential *localization* of the flare site

This line of work has only recently been initiated.



Credits: https://doi.org/10.3847/2041-8213/aae077

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Environmental Radioactivity

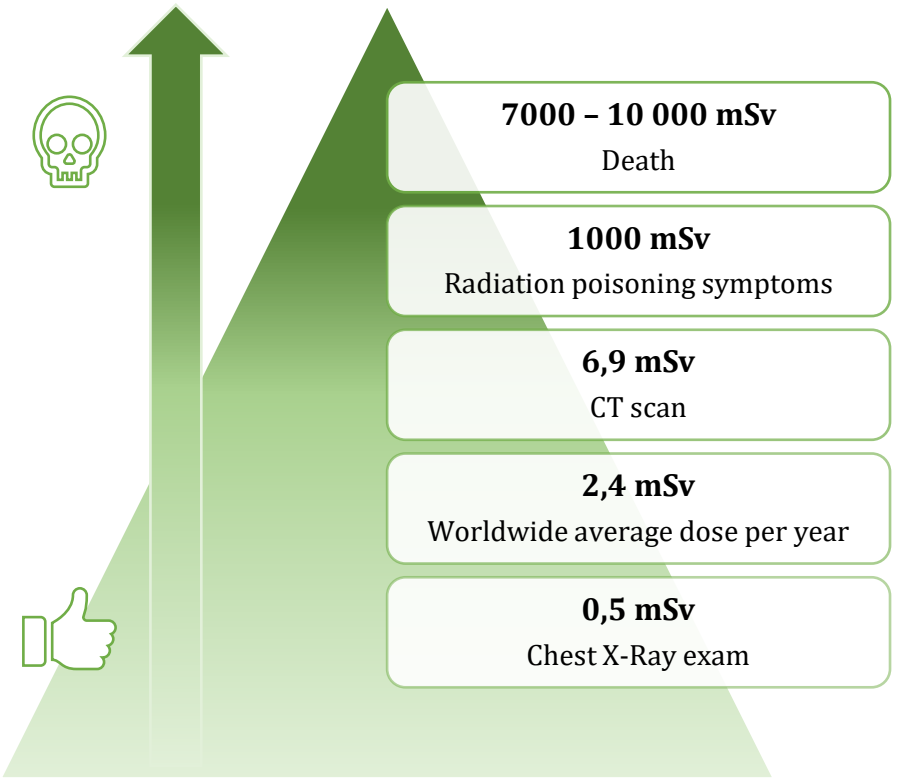
What is its origin?

Decay of Natural Radionuclides

Civil or Military activities

Incidents

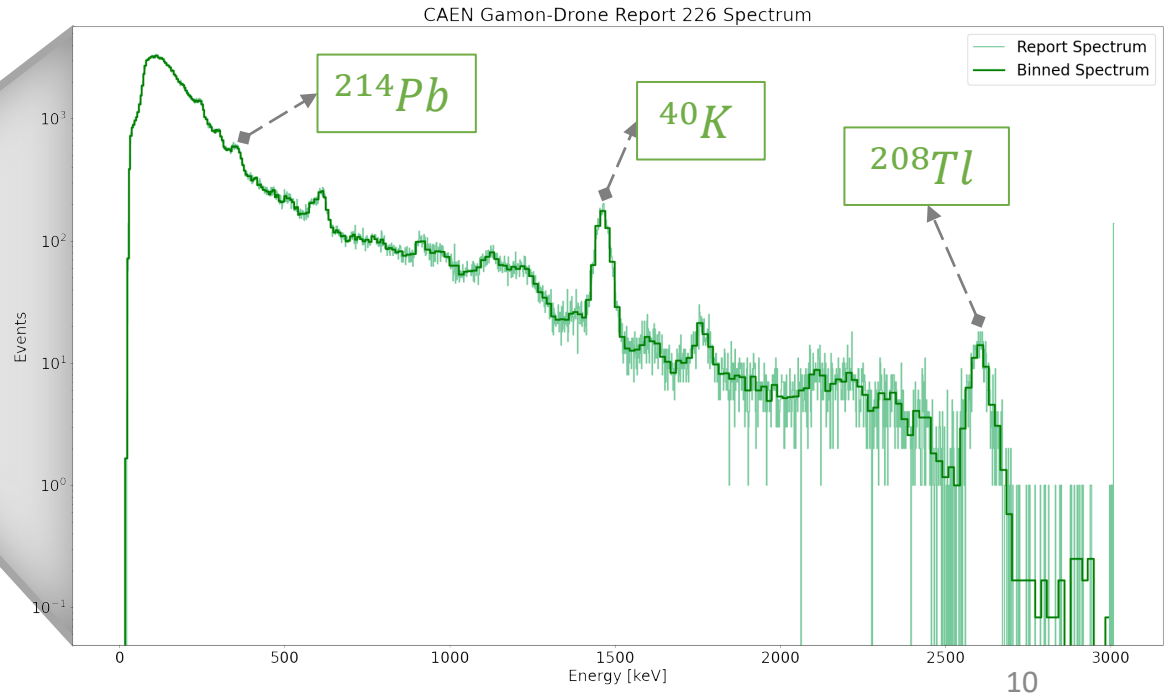
Is it life-threatening?



Credits: https://www.nea.gov.sg/our-services/radiation-safety/understanding-radiation/health-effects-of-ionising-radiation-on-people

Environmental Monitoring

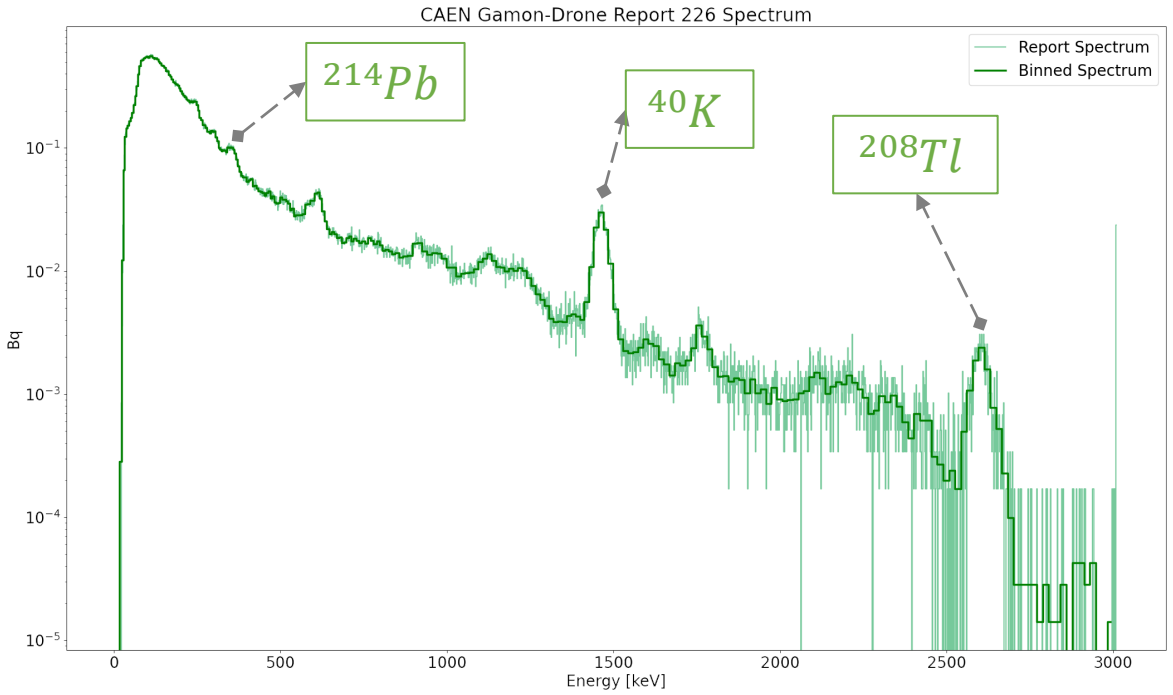
Environmental spectra are acquired using gamma detectors, generally made of $CeBr_3$ or $NaI(Tl)$ crystals.
Handly and portable, they can be easily installed on a drone.



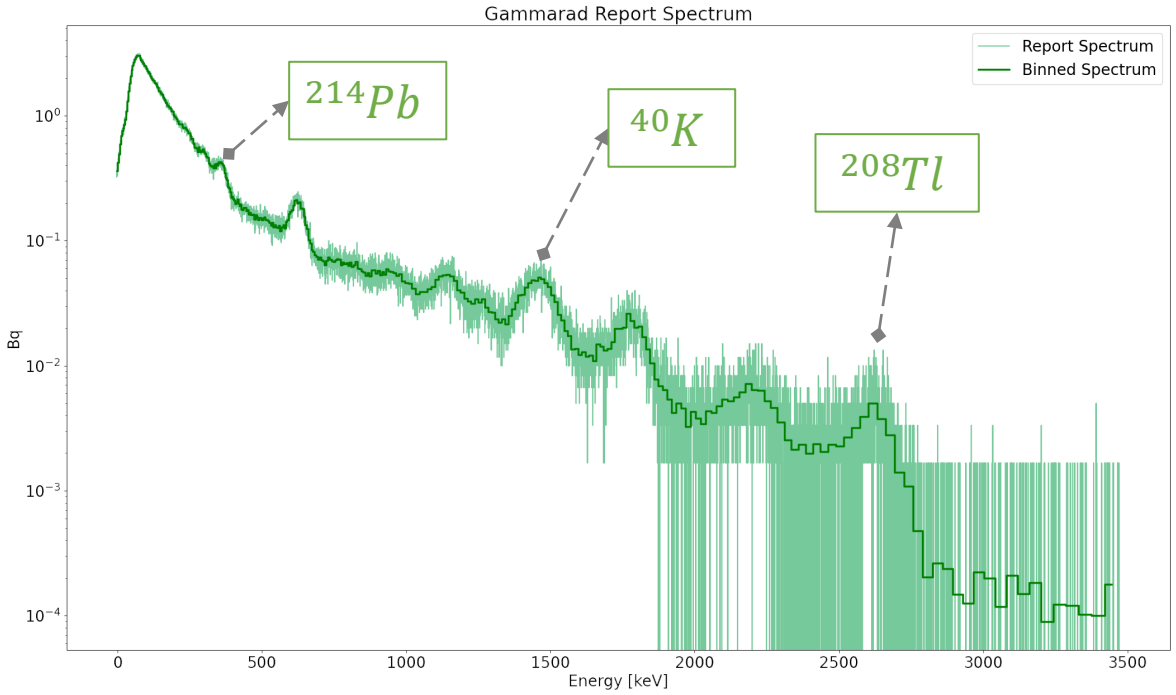
Credits: https://www.caen.it/products/gamon-drone/

$CeBr_3 - NaI(Tl)$ Spectral Comparison

$CeBr_3$

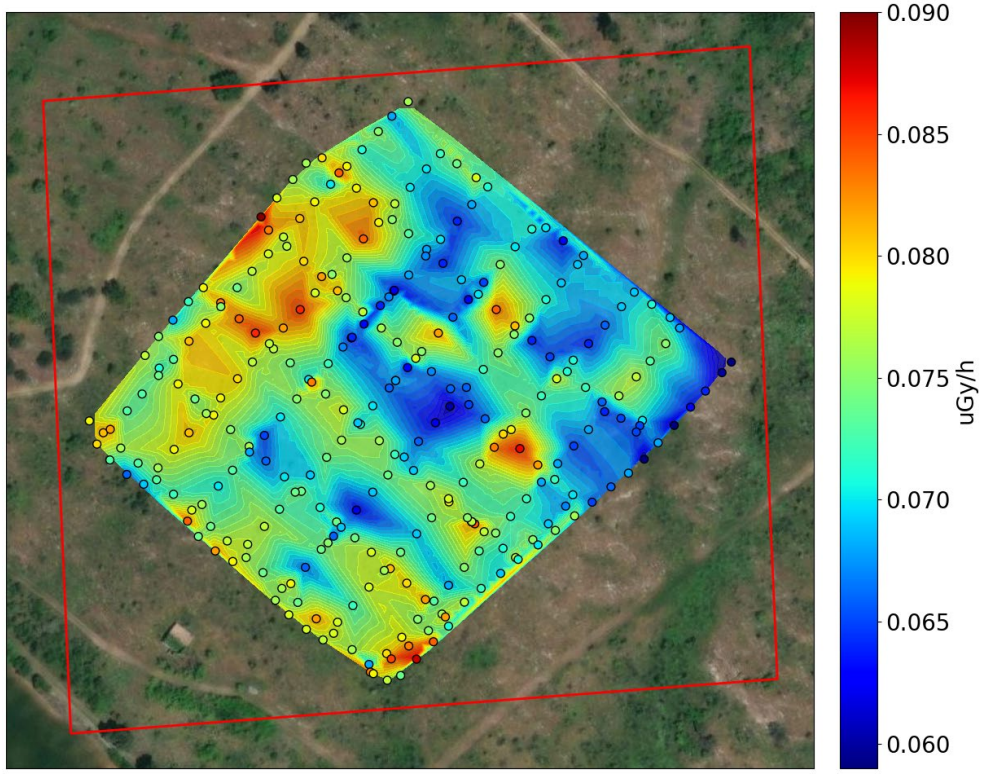


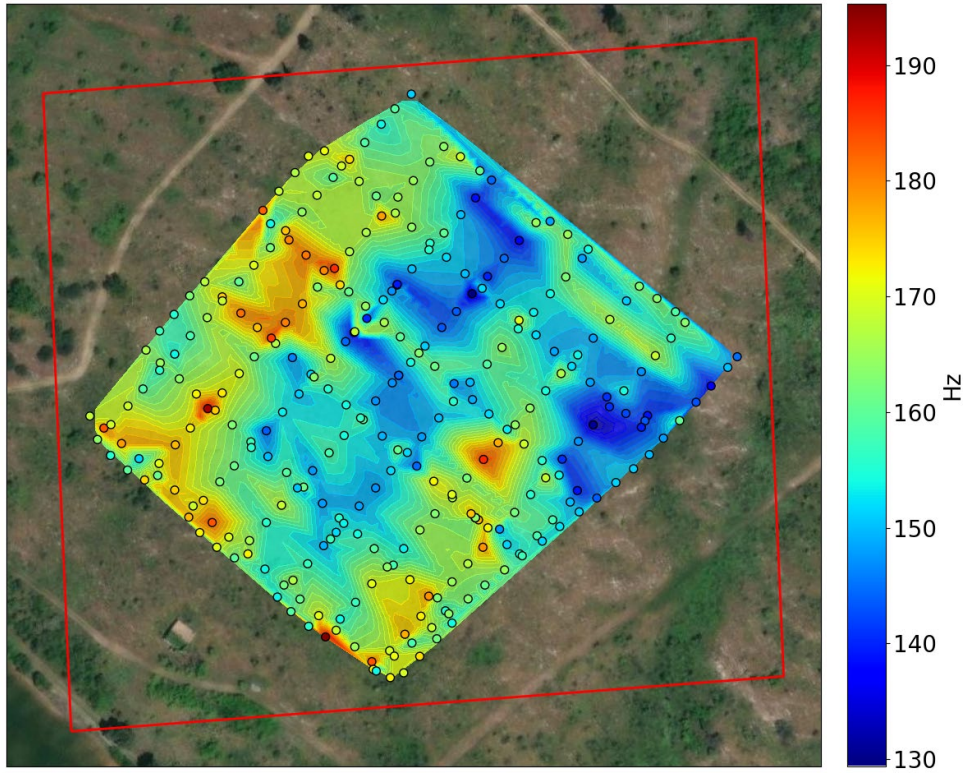
$NaI(Tl)$



Spectral Analysis – Radiation Risk

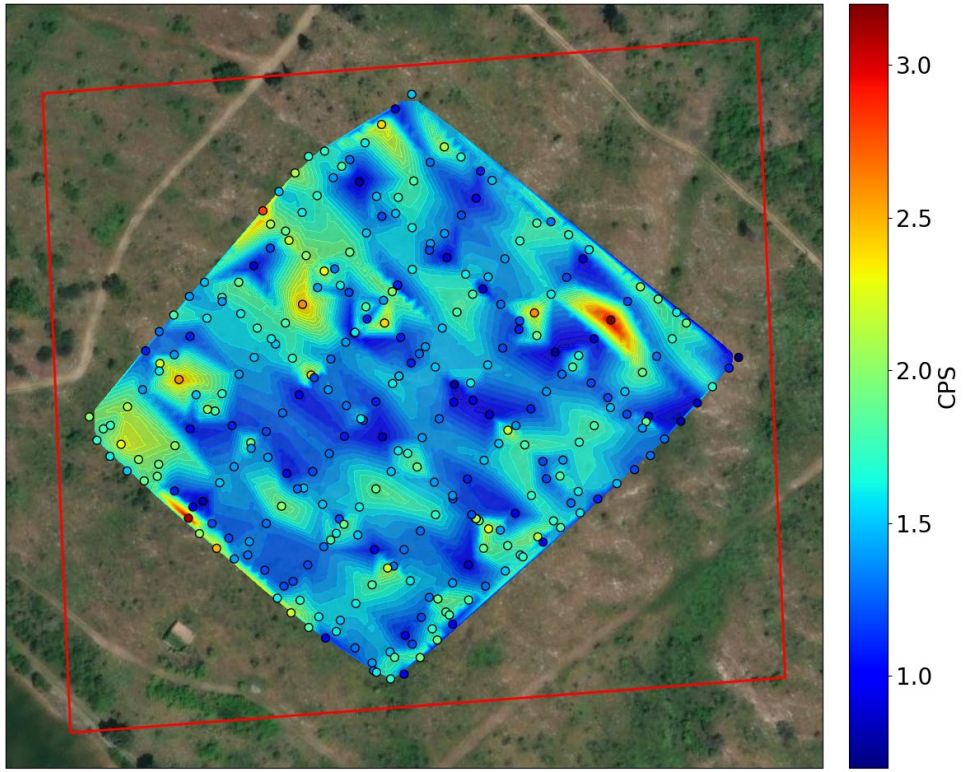
Drone-enabled ground scans provide spatial heat maps of gamma dose $[\mu Gy/h]$ and rate $[Hz]$, offering a clearer understanding of ground-level radiation risks.



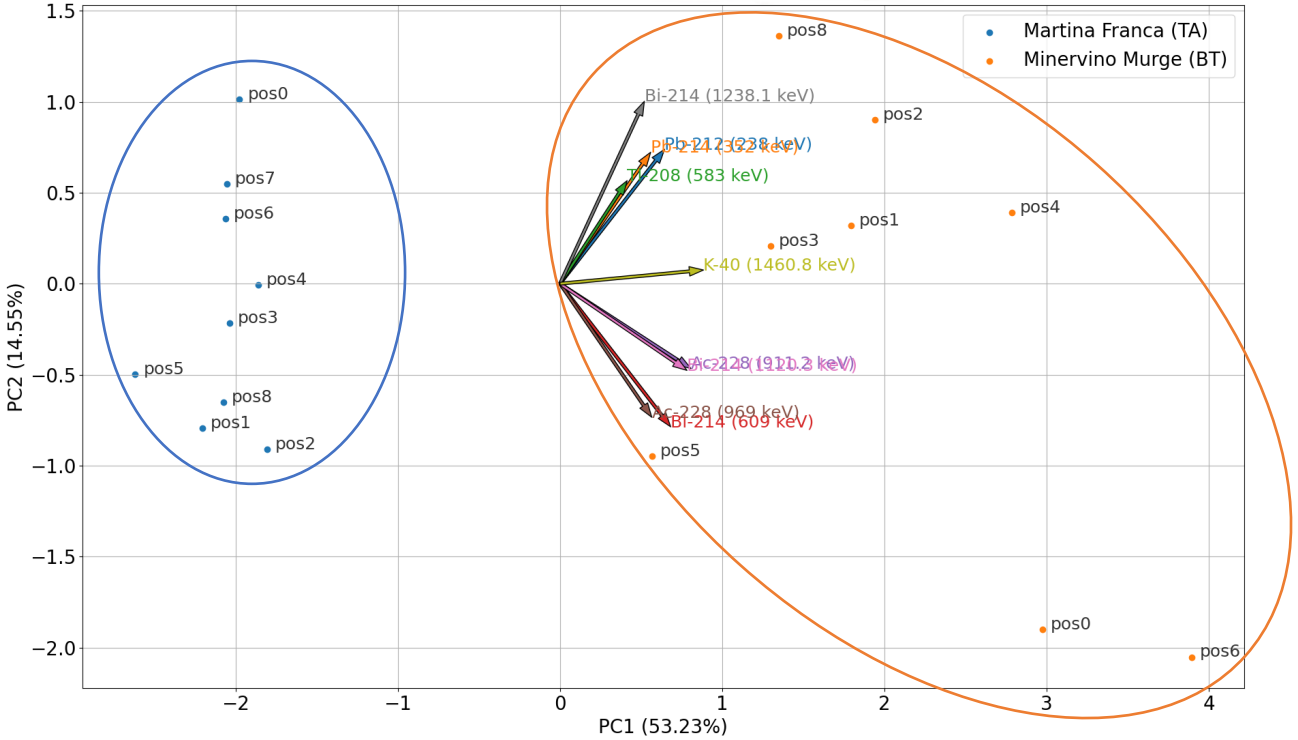


Spectral Analysis – Soil Characterization

^{40}K heat map to assess soil fertility



PCA to distinguish regions
with different soil constitutions



Thank you for your attention