Characterization of plastic scintillators by cosmic rays

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Cosmic rays (CRs)

- Cosmic rays are high energetic charged particles hitting continuously the Earth at a rate about 10’000 particles by square meter by second at energies of 1 GeV.

- The number of particles quickly reduce as the energy increases, particles with energy above 10^{19} eV arrives at a rate about one particle by square kilometer by year.

Grieder, P., 2011. Extensive Air Showers: High Energy Phenomena and Astrophysical Aspects - A Tutorial, Reference Manual and Data Book. Springer Berlin Heidelberg.

CRs ENERGY SPECTRUM

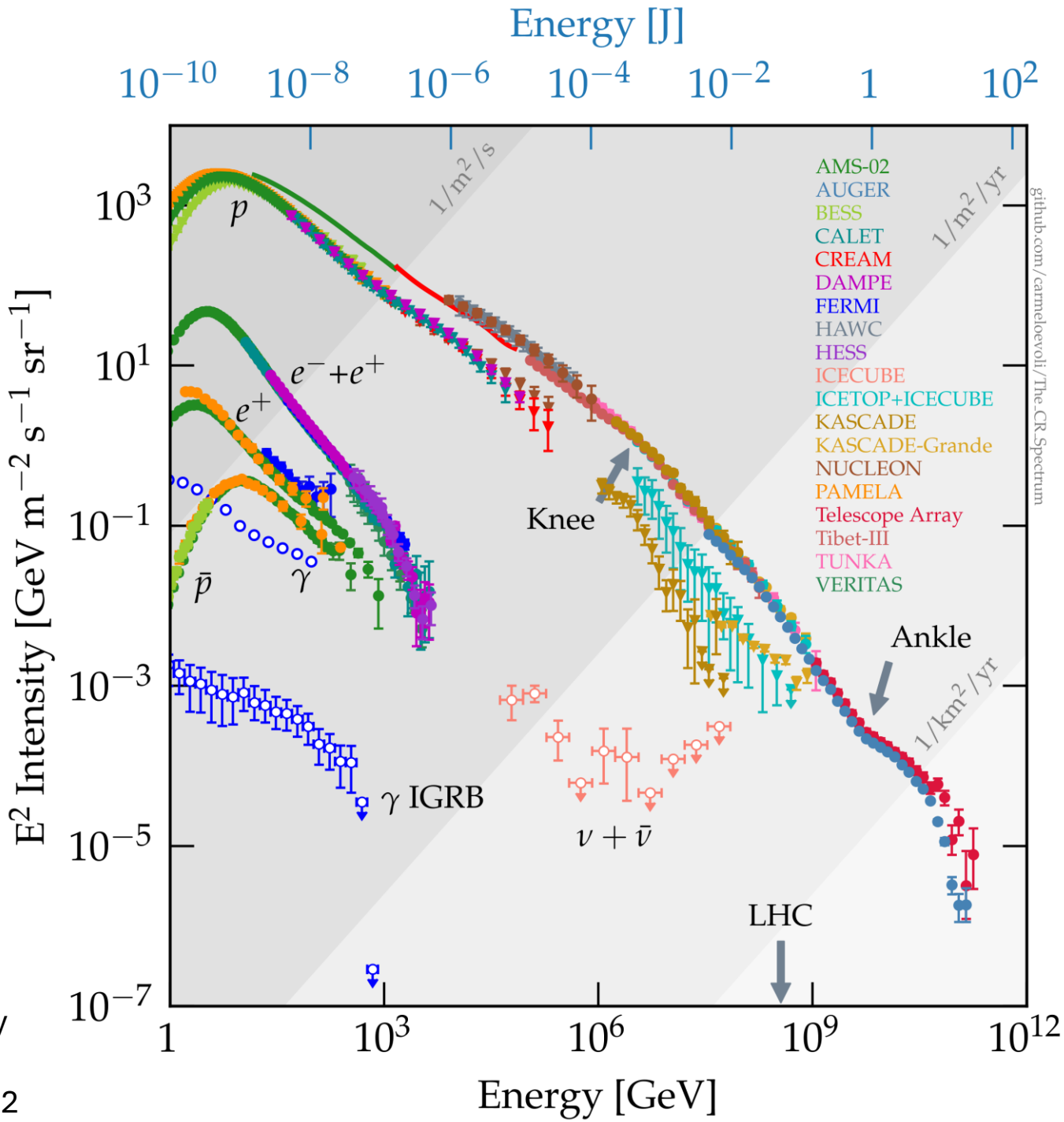


Figure 1. Global cosmic rays energy spectrum.

Evoli, C. (2020). The Cosmic-Ray Energy Spectrum. Zenodo. https://doi.org/10.5281/zenodo.7948212

EAS

An extensive air shower (EAS) takes place when a primary cosmic ray hit an air molecule on top of the atmosphere, generating a violent collision.
The fragments hit more air molecules since the energy of the original particle spread over millions of particles arriving the Earth's surface.

Studying EAS give us information about their development and energy of the primary particle.

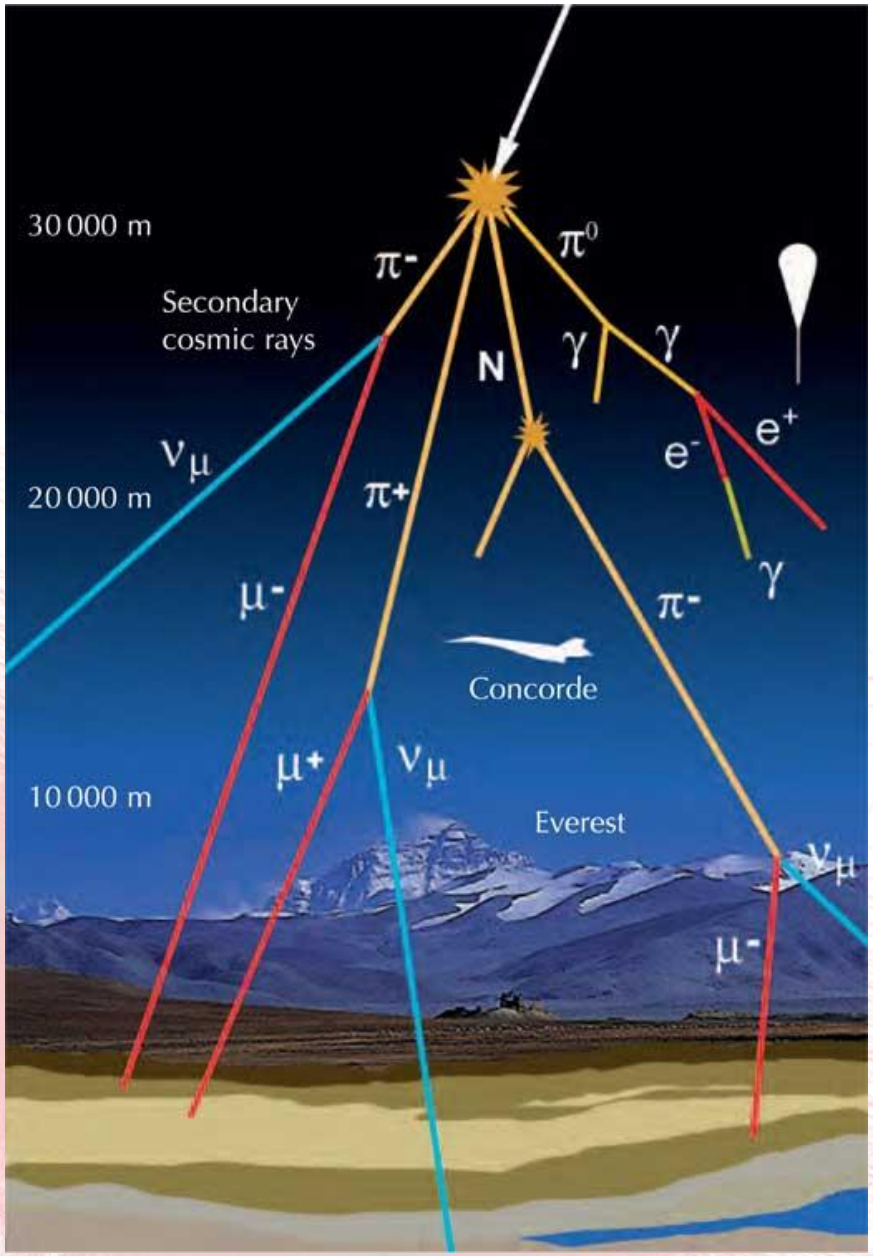
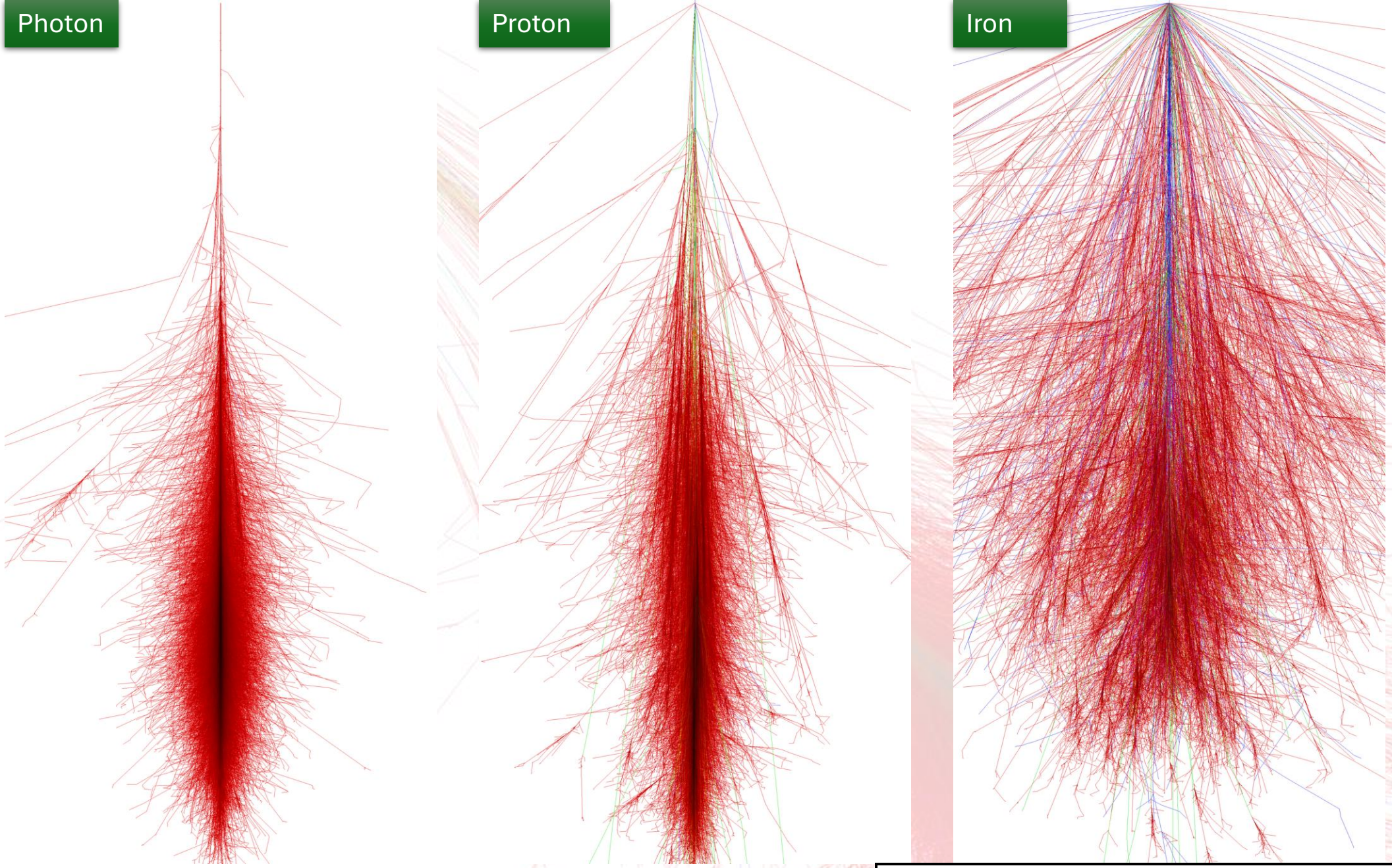


Figure 2. Schematic illustration of EAS development.



F. Schmidt, J. Knapp, "CORSIKA Shower Images", 2005, https://www-zeuthen.desy.de/~jknapp/fs/showerimages.html

Figure 3. Illustration of EAS simulations for different primaries CRs.

Scintillator plastics

- Transparent materials able to generate light by their interaction with ionizing radiation.
- Generate approximately 10’000 photons by the incident radiation.
- The color emission depends on the composition (typically blue emission).

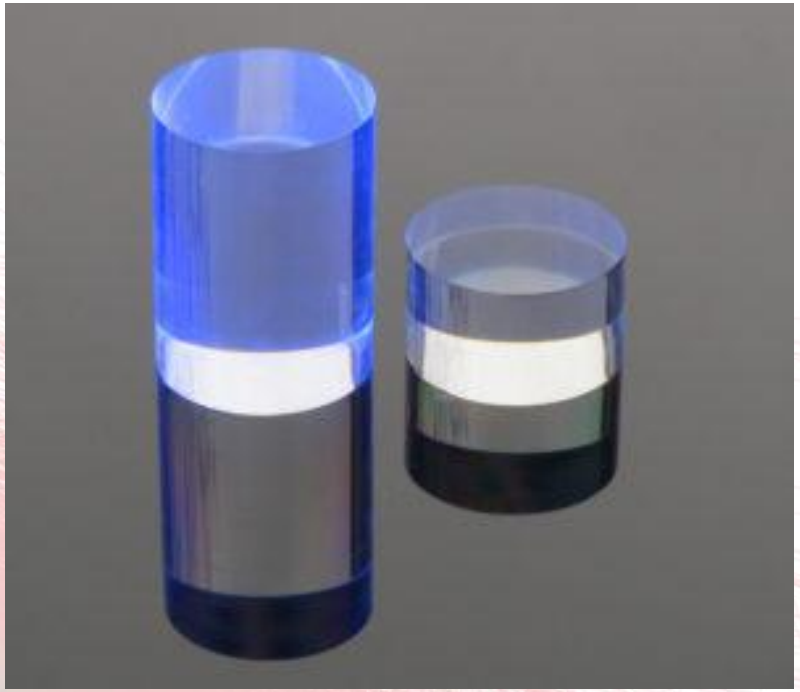


Figure 4. plastic scintillator emitting light (left) and without emitting light.

https://www.rmdinc.com/development/tin-loaded-plastic-scintillators/

Scintillator plastics and PMTs

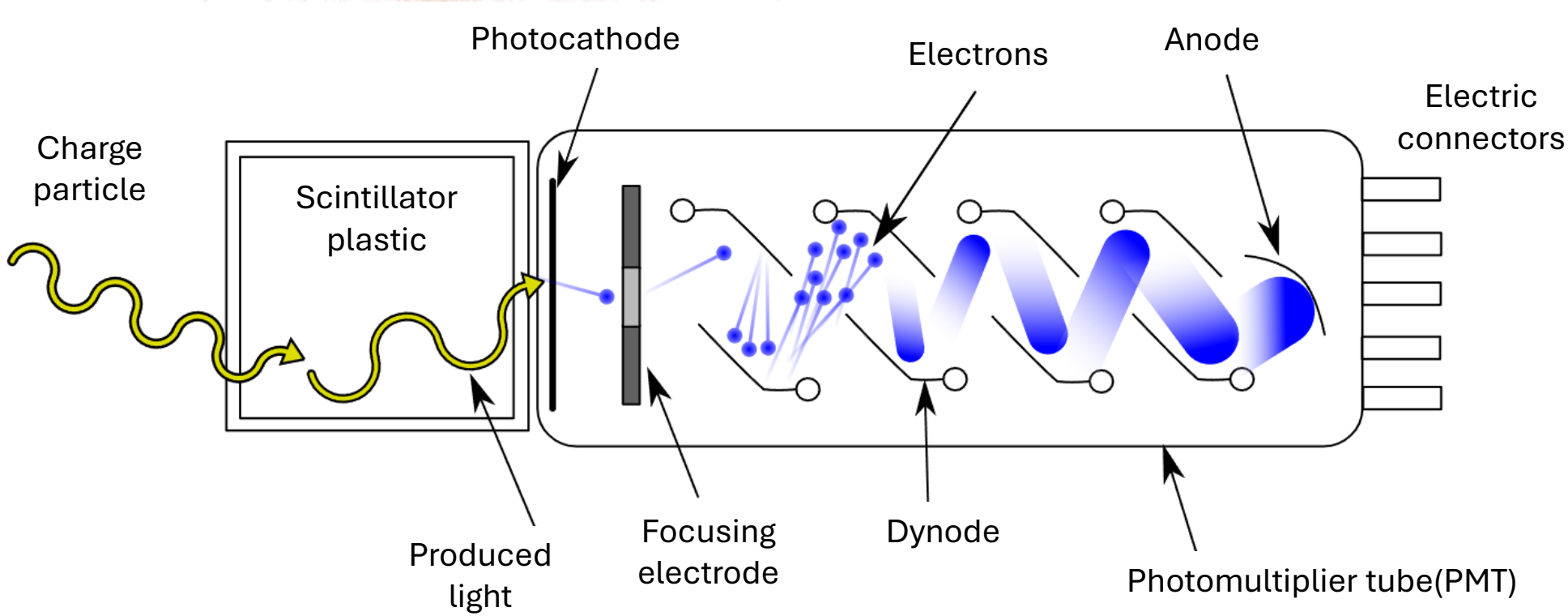
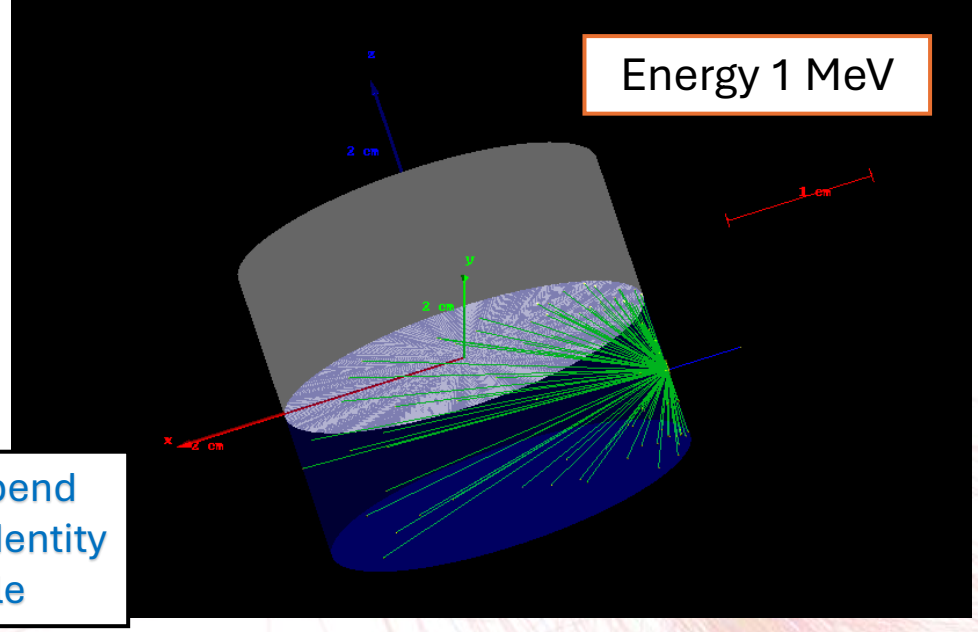


Figure 5. Scheme of a scintillator plastic coupled to a PMT and its operation

Adapted from: https://commons.wikimedia.org/w/index.php?curid=1222641

Energy loss depend strongly on the identity of the particle

$$\frac{dE}{dx} \propto \frac{1}{m^2}$$



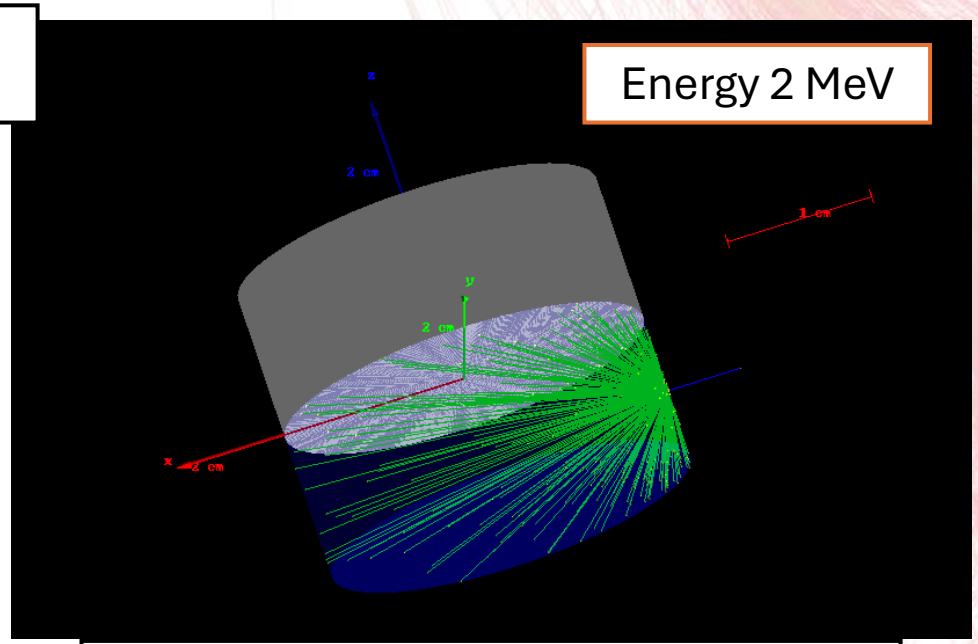
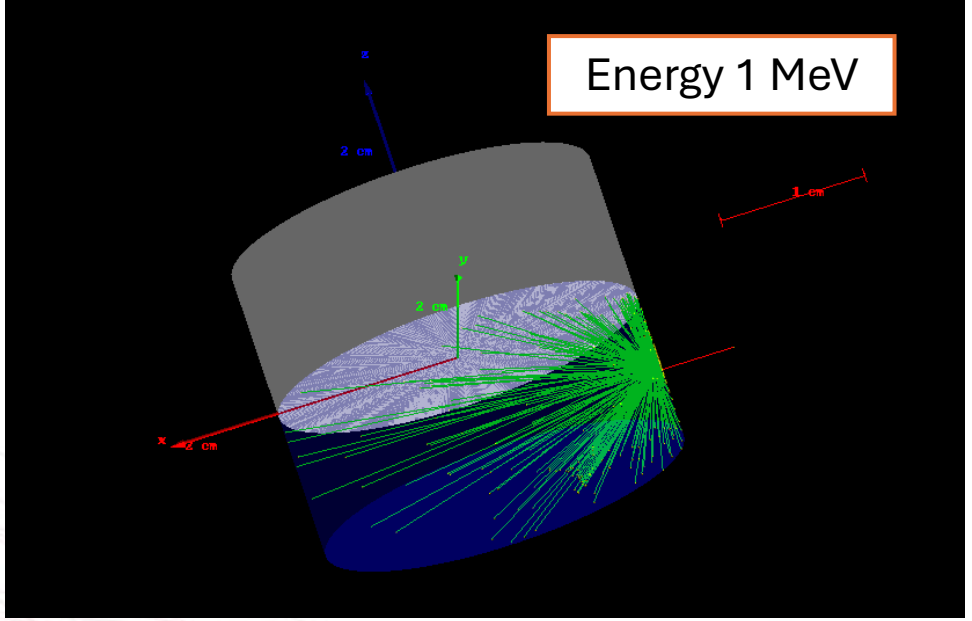


Figure 6. GEANT4 simulation of incident proton



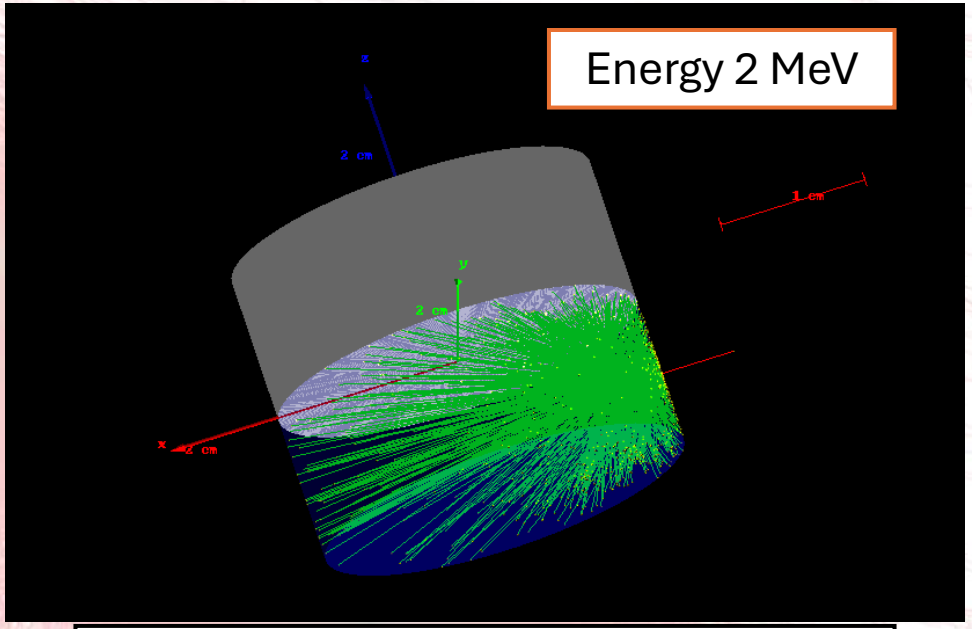


Figure 7. GEANT4 simulation of incident electron

Vertical Equivalent Muon (VEM)

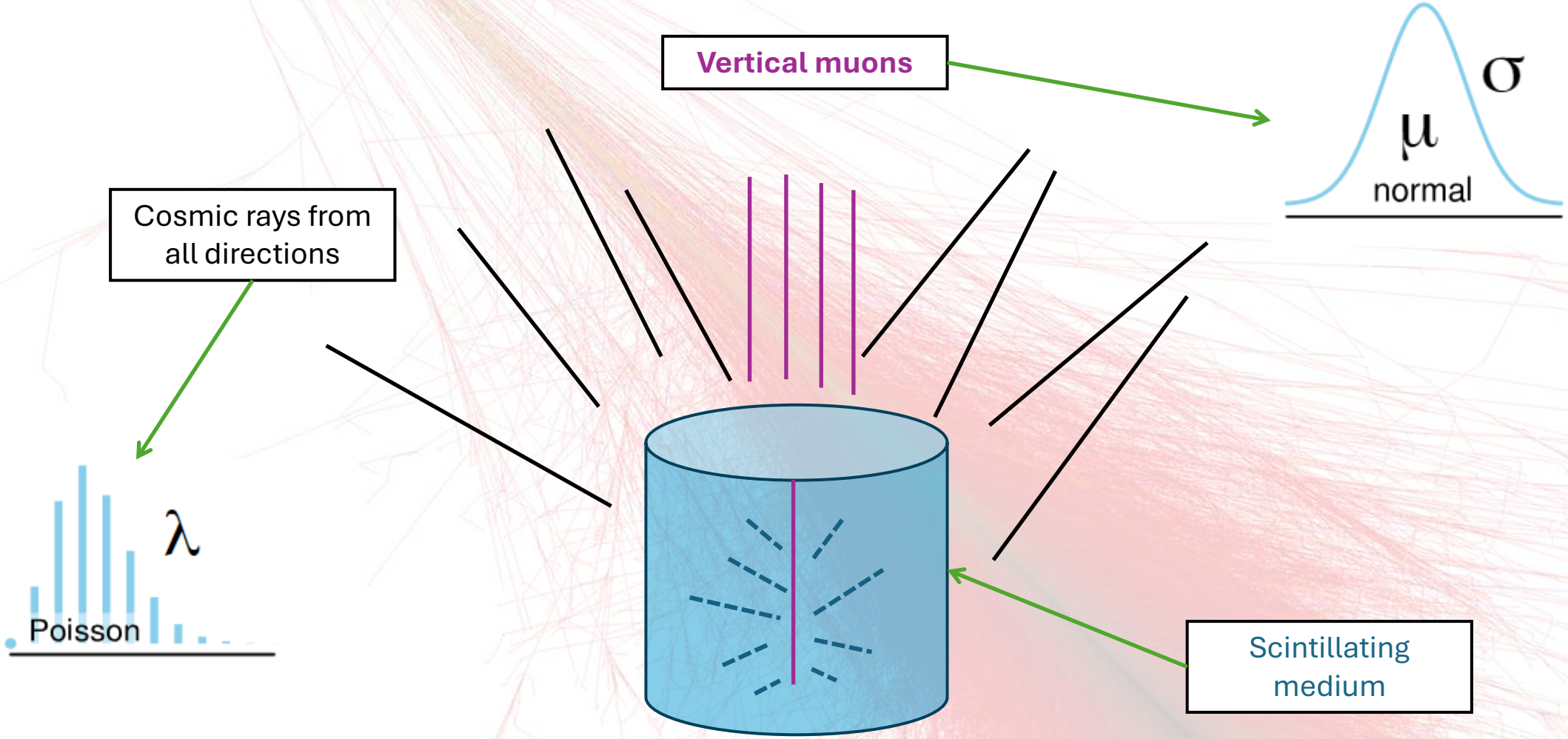
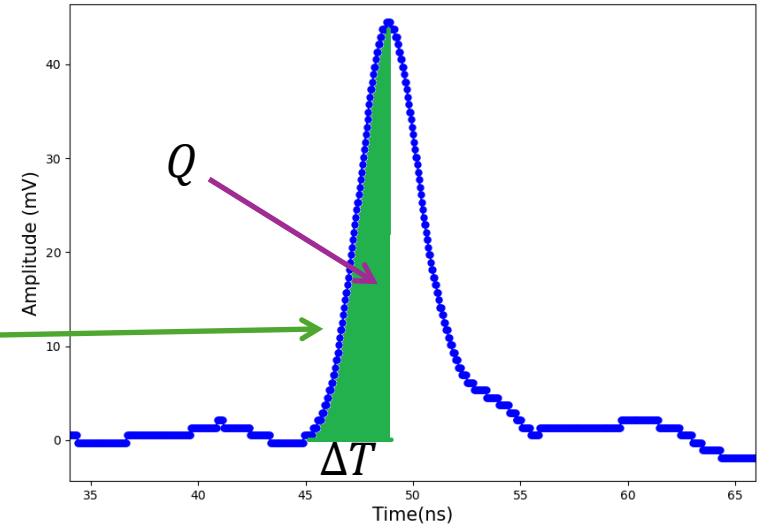


Figure 8. Illustration of interactions of secondary cosmic rays with a scintillator

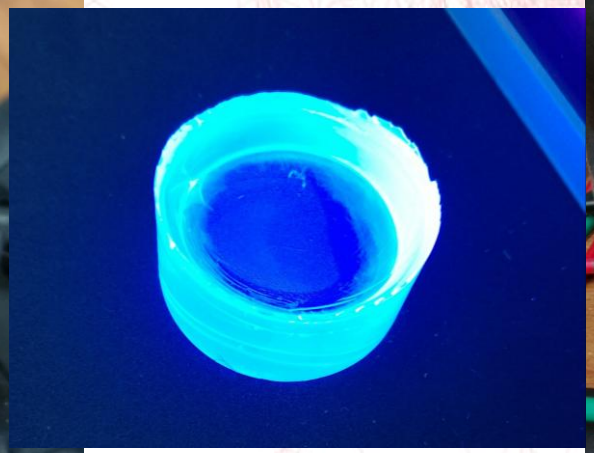


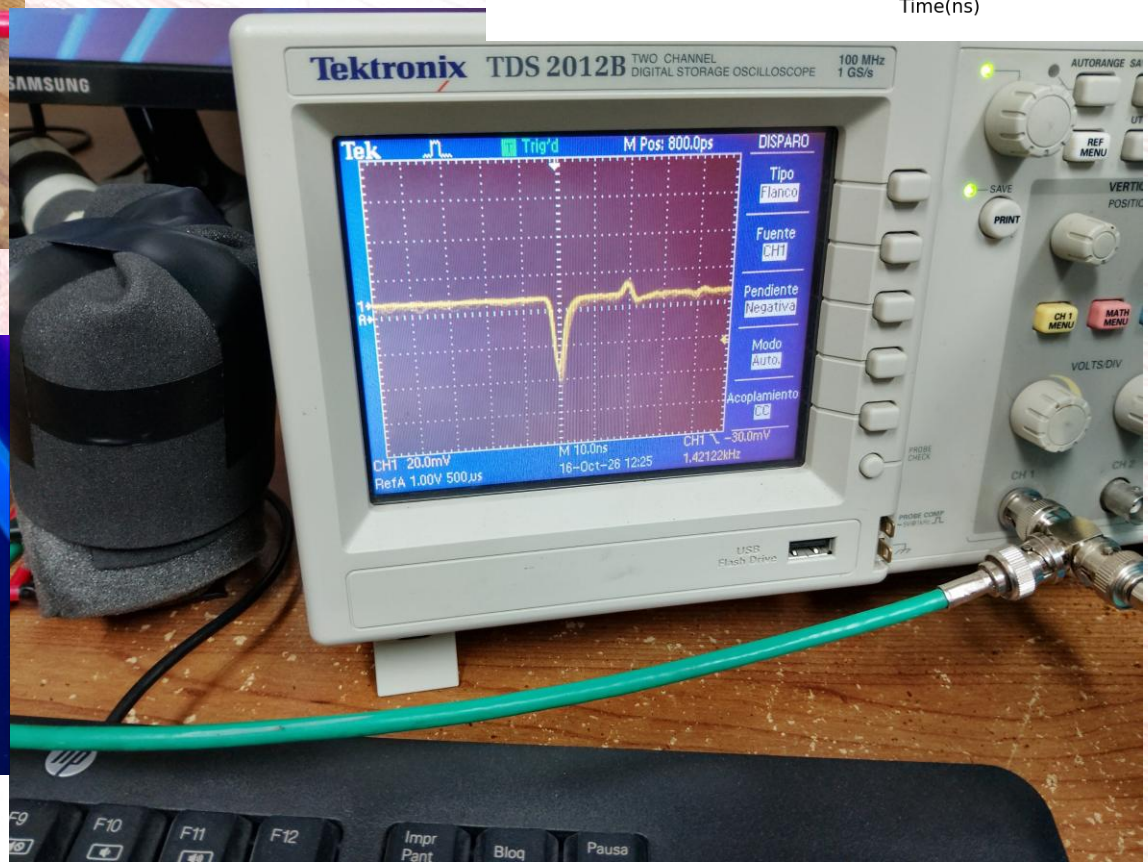
Analysis of 78’000 waveforms.

Calculate integrated signal and risetime in $(T_{10} - T_{90})$



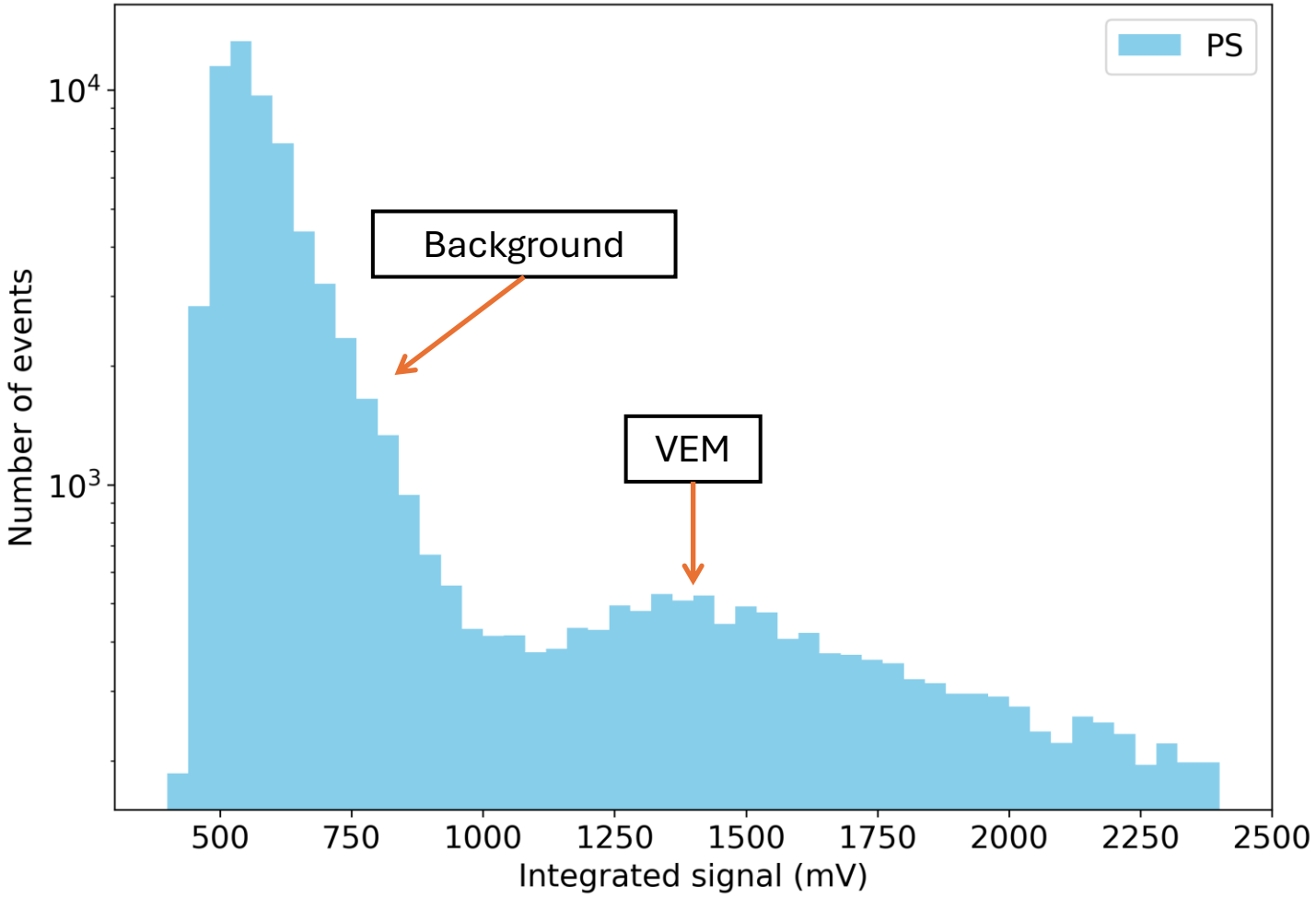


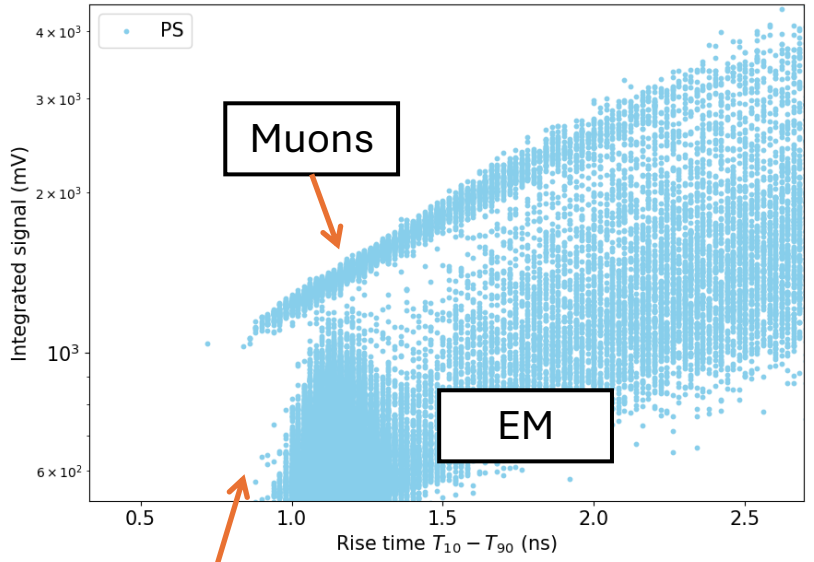


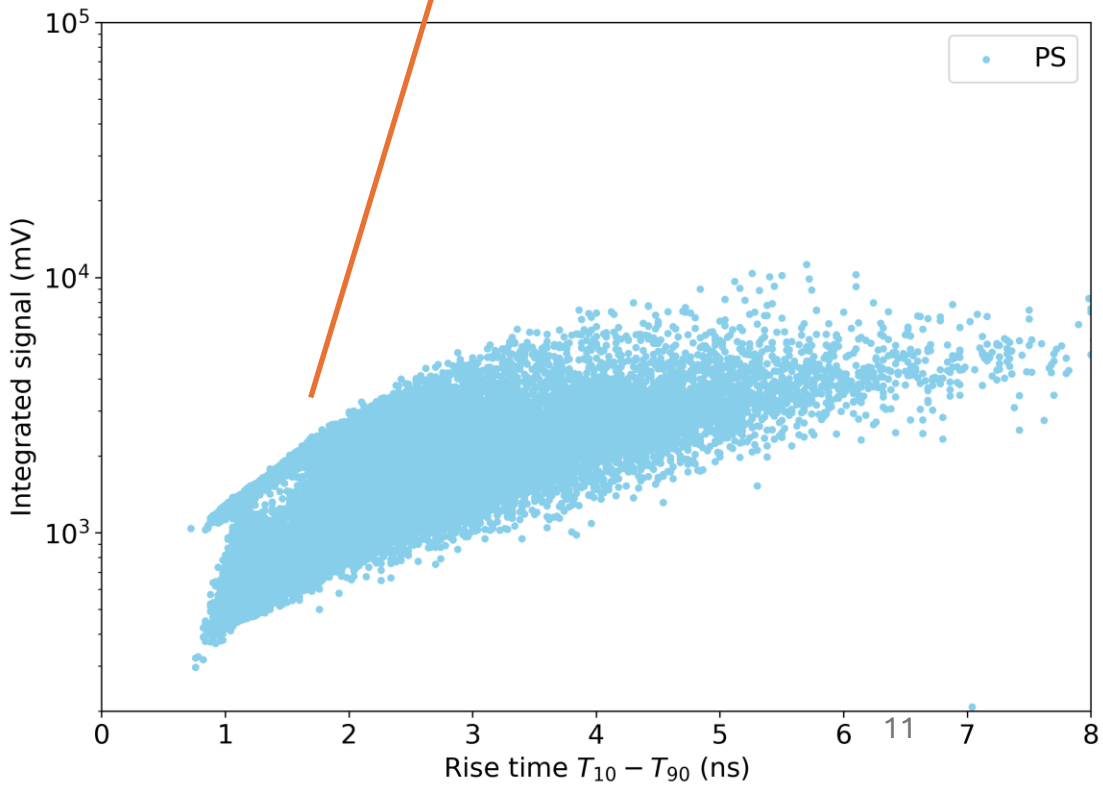




PS-PPO-POPOP

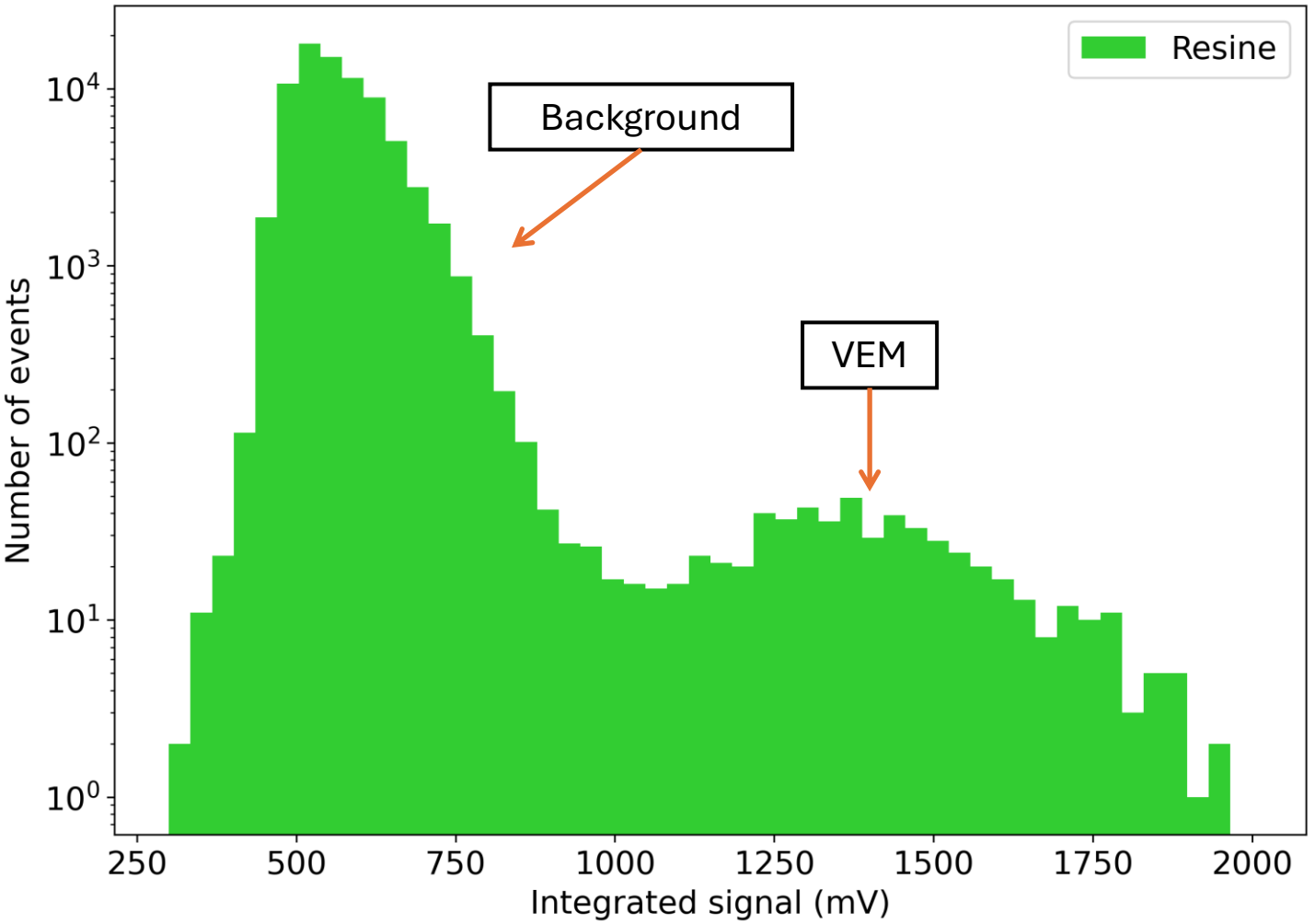

PS
Background
VEM
Number of events
Integrated signal (mV)

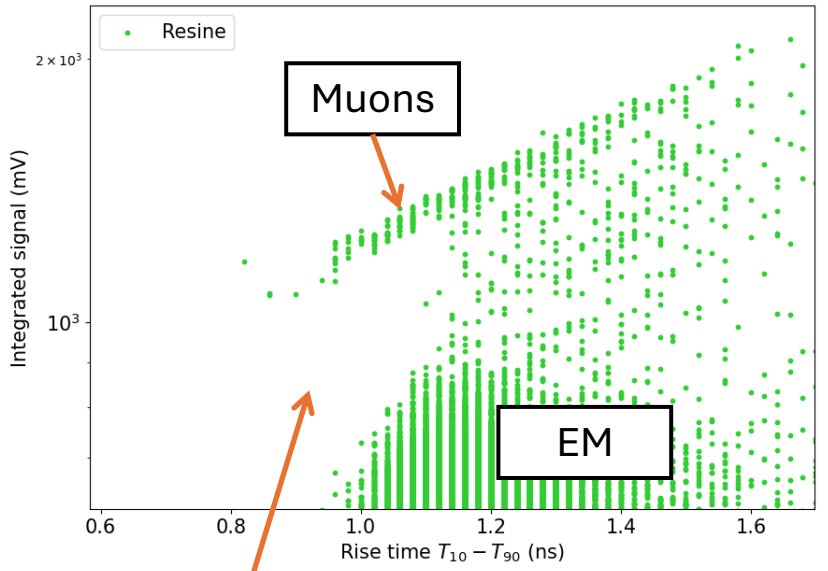

PS
Muons
EM
Integrated signal (mV)
Rise time $T_{10} - T_{90}$ (ns)

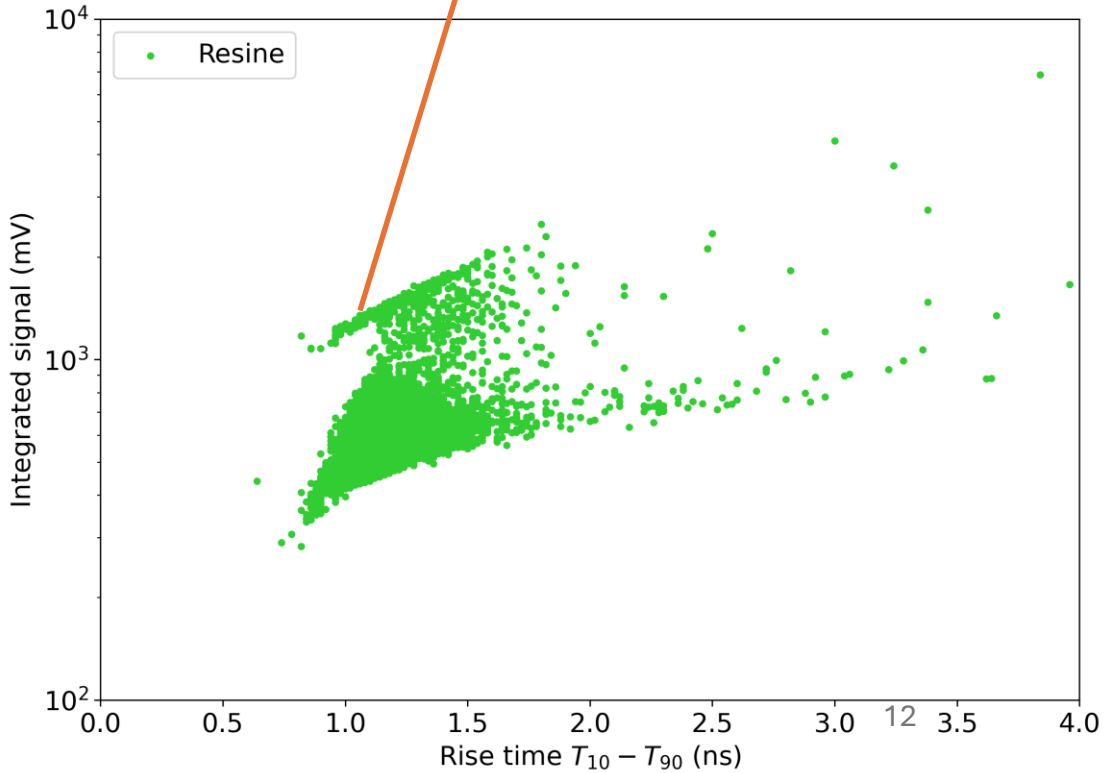

PS
Integrated signal (mV)
Rise time $T_{10} - T_{90}$ (ns)

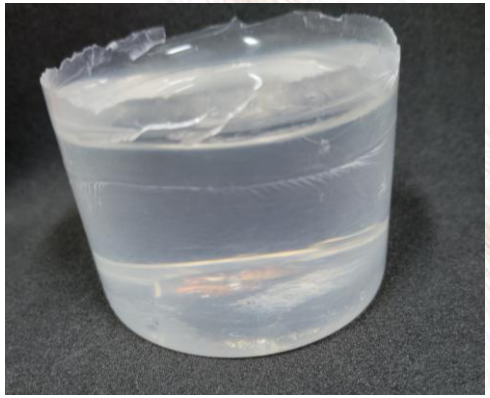


PS-PPO-POPOP-crystal resine

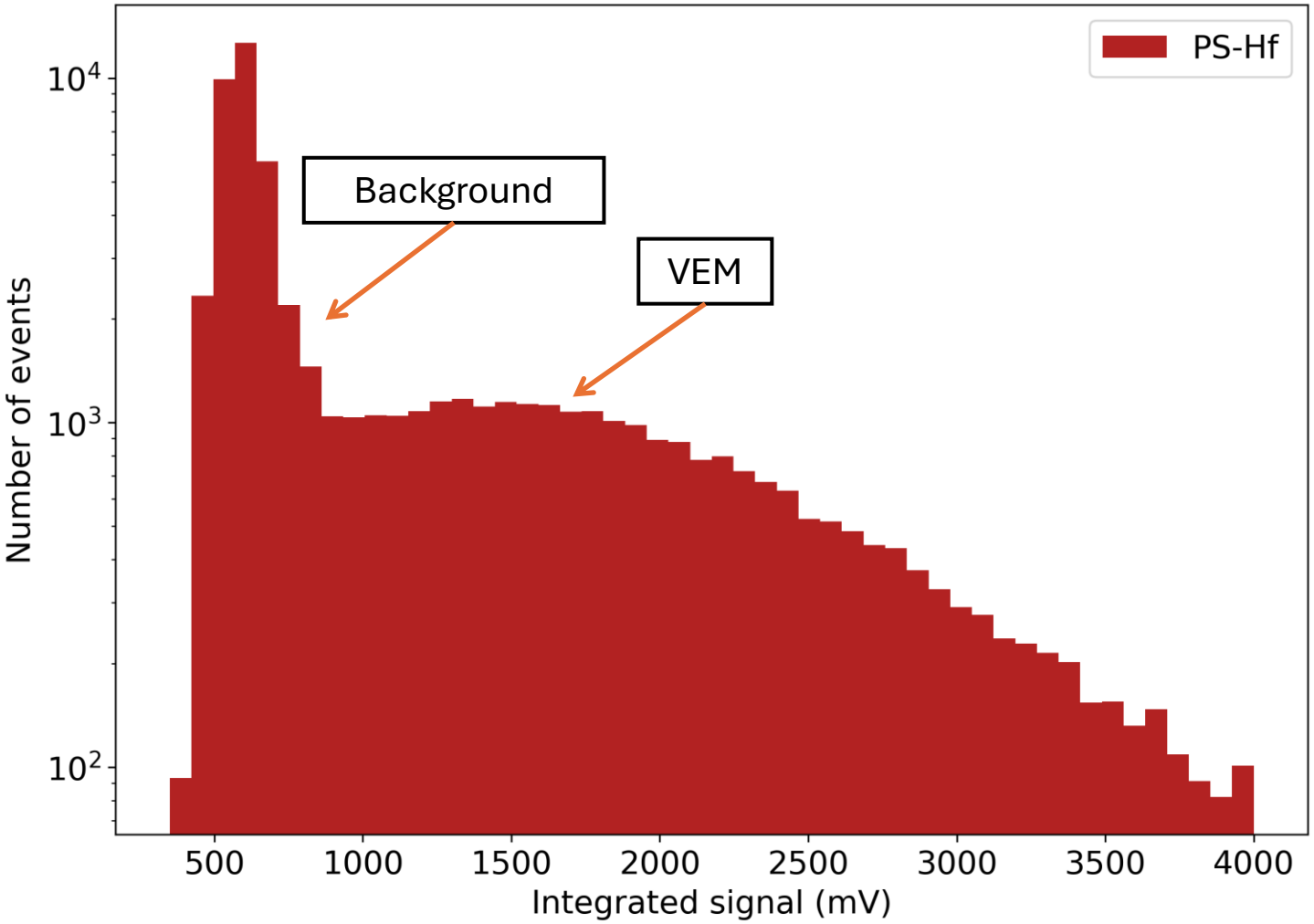


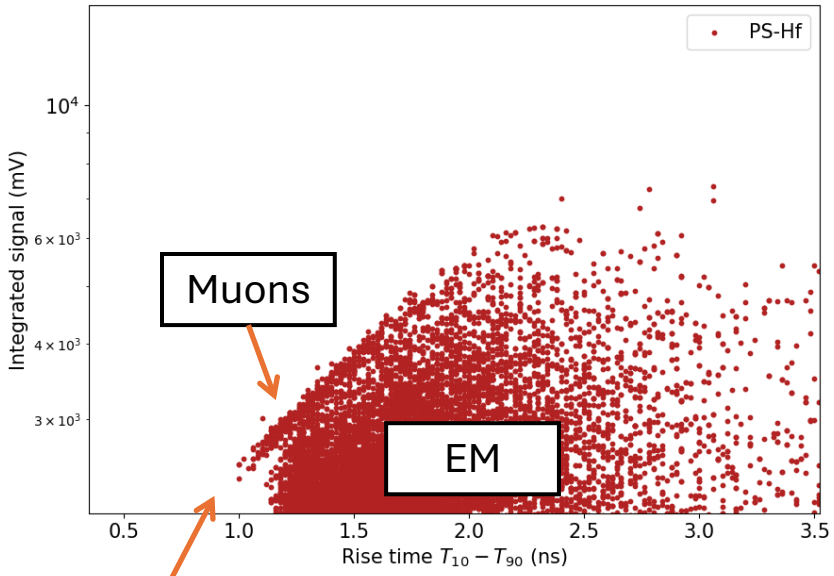


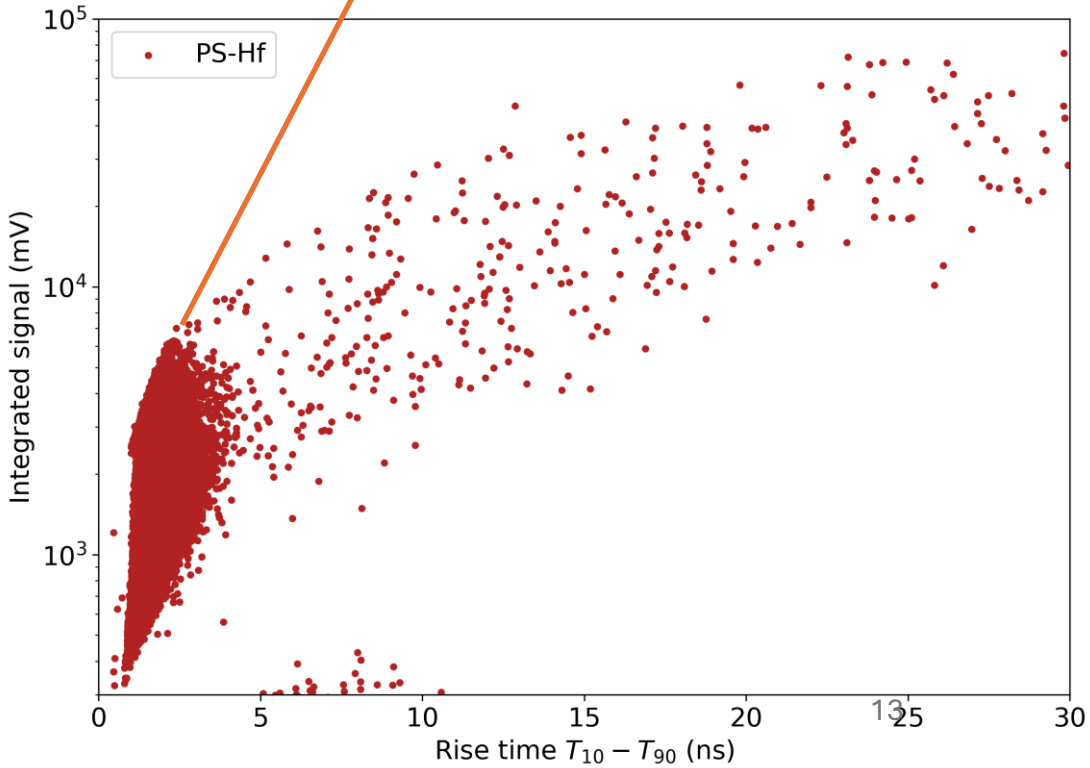


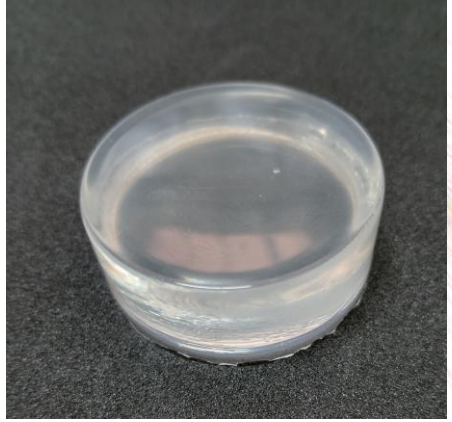


PS-PPO-POPOP-Hf-1

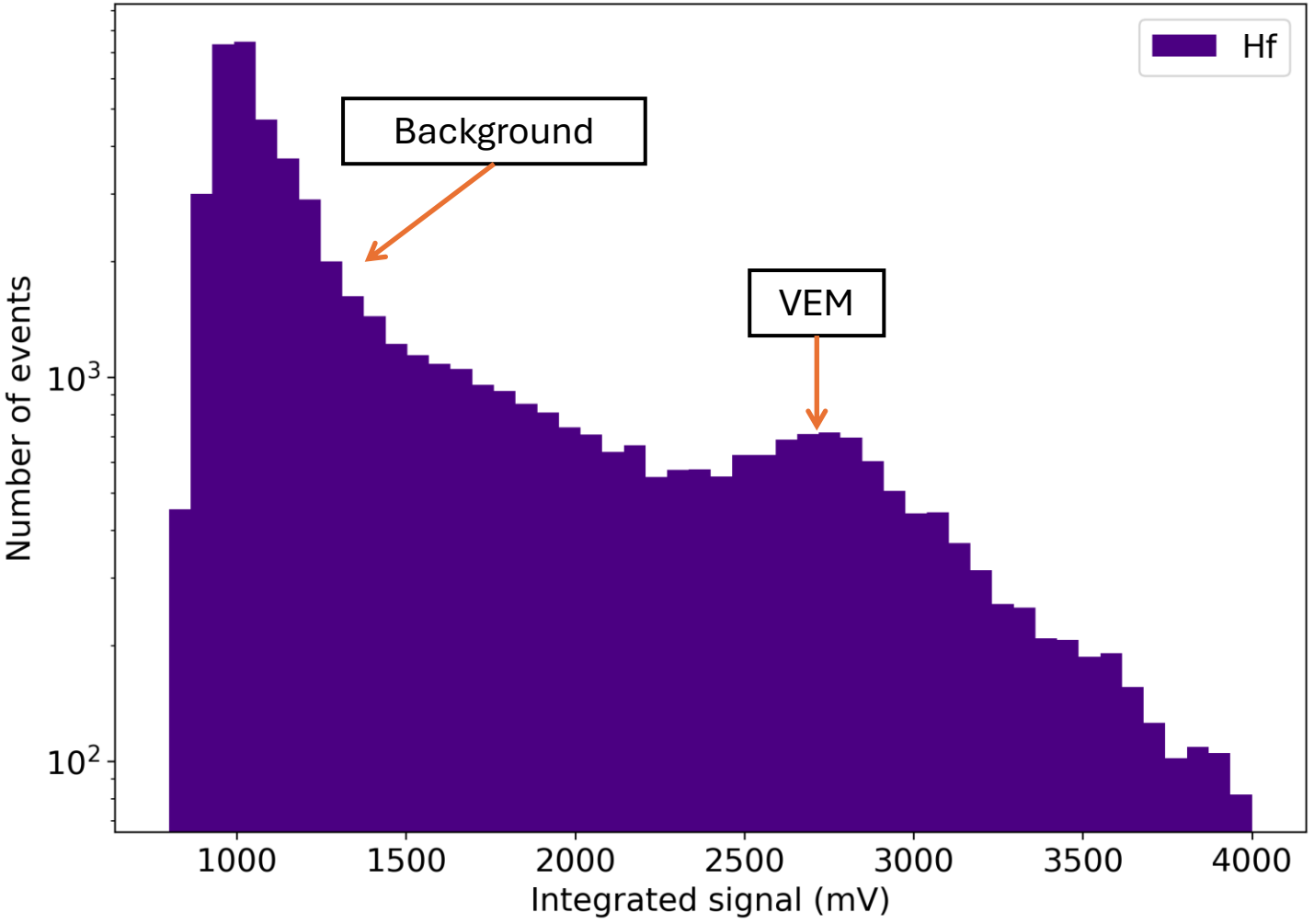


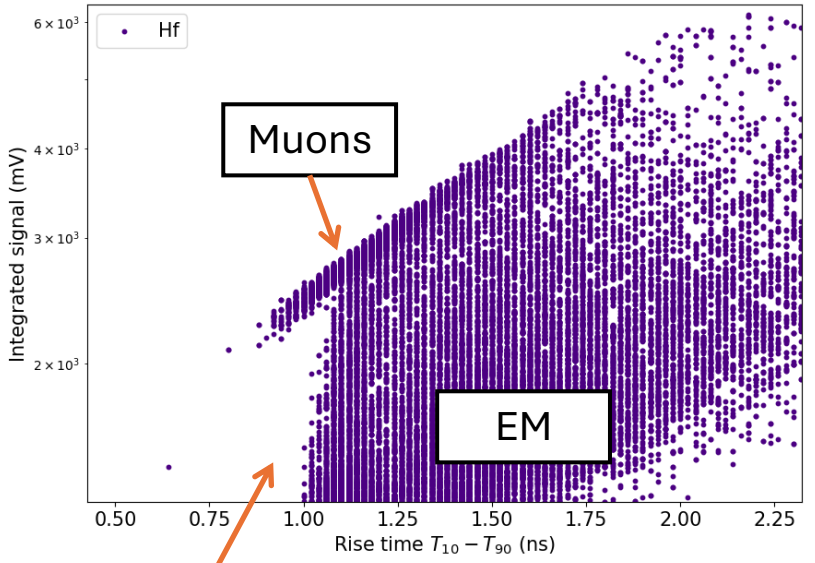


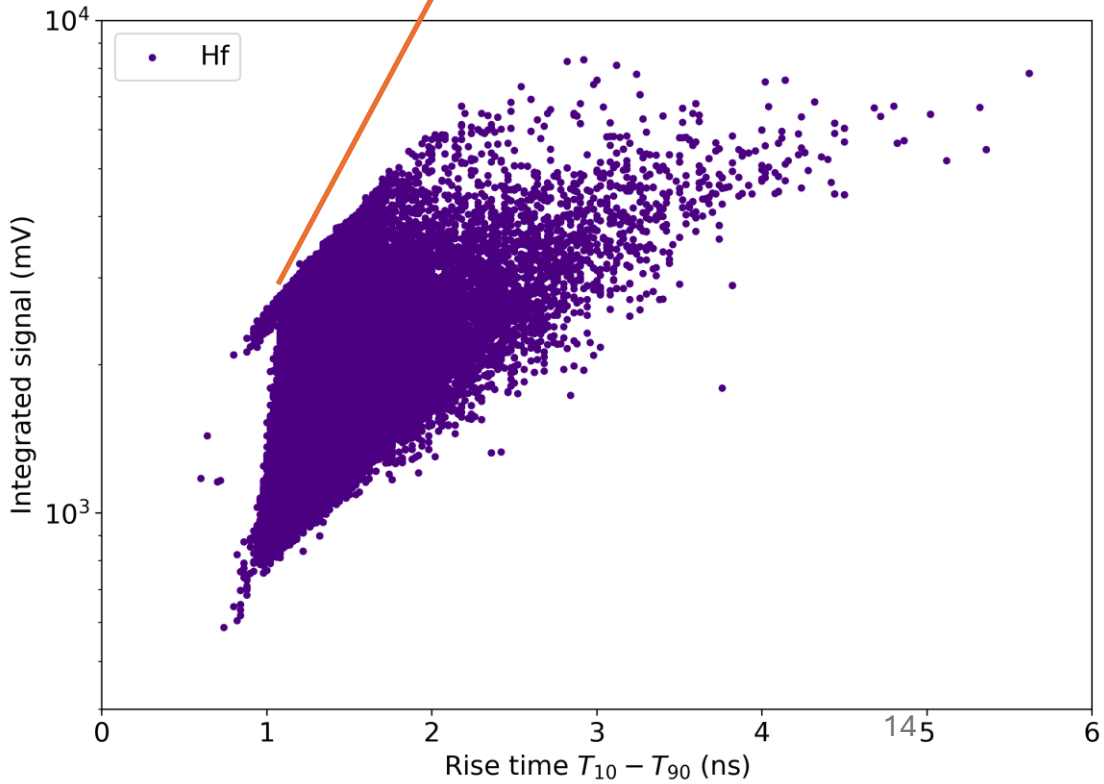




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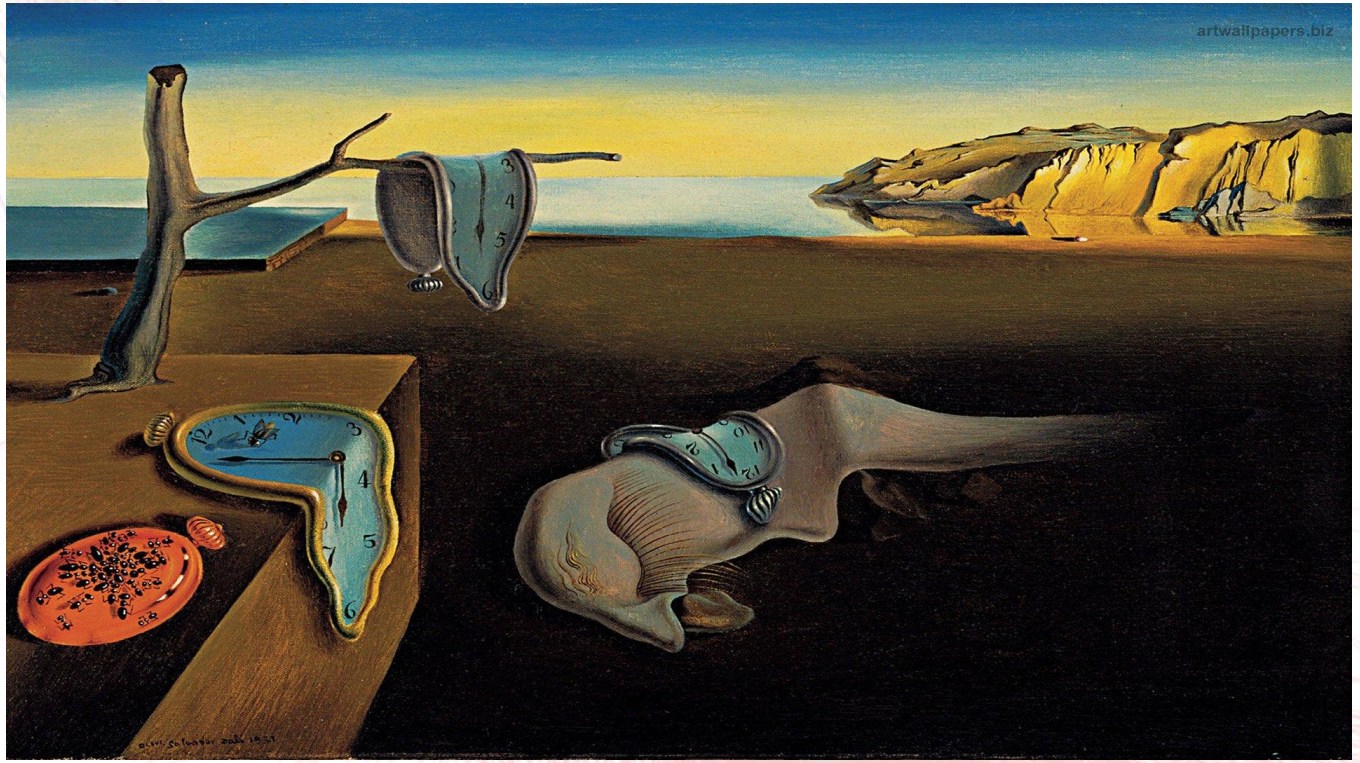






Summary

- The study materials showed the properties of plastic scintillators.
- The region of the VEM was found for all samples.
- The composition of the material change the light production and its tunability helps to implement them in different radiation environments.
- The load of high Z elements such as Hf, strongly enhance the capabilities of detection.



Thanks for your time

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