The GanESS Project

Research and Development of Gaseous Detectors for Neutrino Physics

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1. Coherent Elastic Neutrino - Nucleus Scattering[1,2]

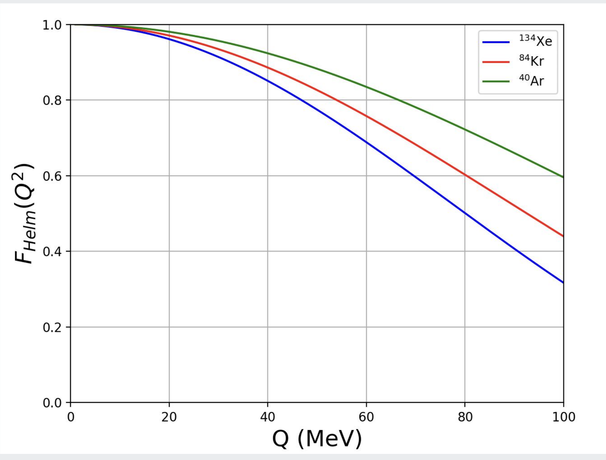
➔ What is the CEνNS process ?

- Predicted in the 70s and measured in 2017 by the COHERENT experiment
- Neutrinos scatter and see the nucleus as a whole instead of interacting with a single neutron
- Neutral current process that happens since the coherence condition |Q| < 1/R is respected

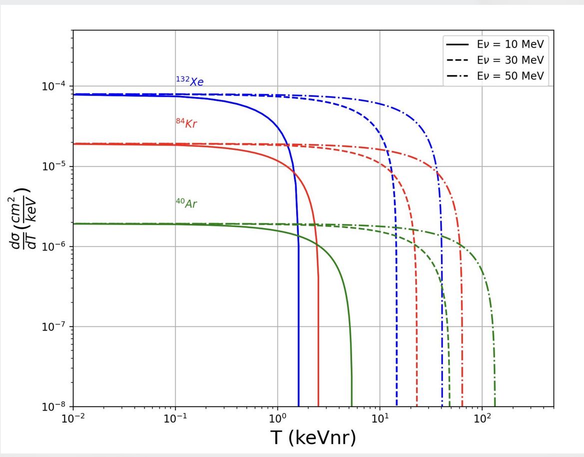
➔ What about the cross-section ?

$$\frac{d\sigma_{SM}(T,E_\nu)}{dT} = \frac{G_F^2}{2\pi}\frac{Q_W^2(Z,N)}{4}F^2(Q^2)M[2-\frac{2T}{E_\nu}+(\frac{T}{E_\nu})^2-\frac{MT}{E_\nu^2}]$$

$$Q_W = N - \underbrace{\boxed{(1-4sin^2(\theta_w))}}_{<<1}Z \longrightarrow \boxed{\sigma_{CE\nu NS} \propto N^2}$$



Helm form factor as a function of the transferred momentum for different gases.

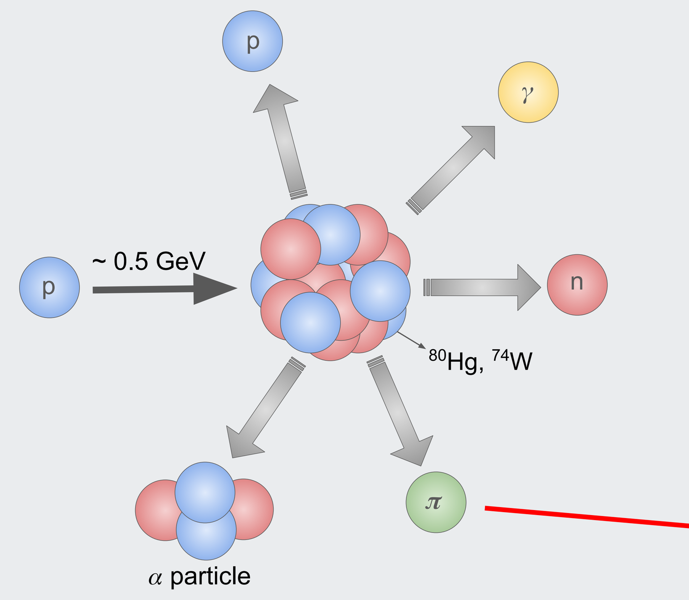


Evolution of the CEνNS differential cross-section as a function of the nuclear recoil for different gases and neutrino energy.

- Need of heavy gases
- Partial coherence after ~ 50 MeV
- Good $\sigma_{CE\nu NS}$ but low nuclear recoils so the detection is difficult

2. Why Spallation Sources ?[1]

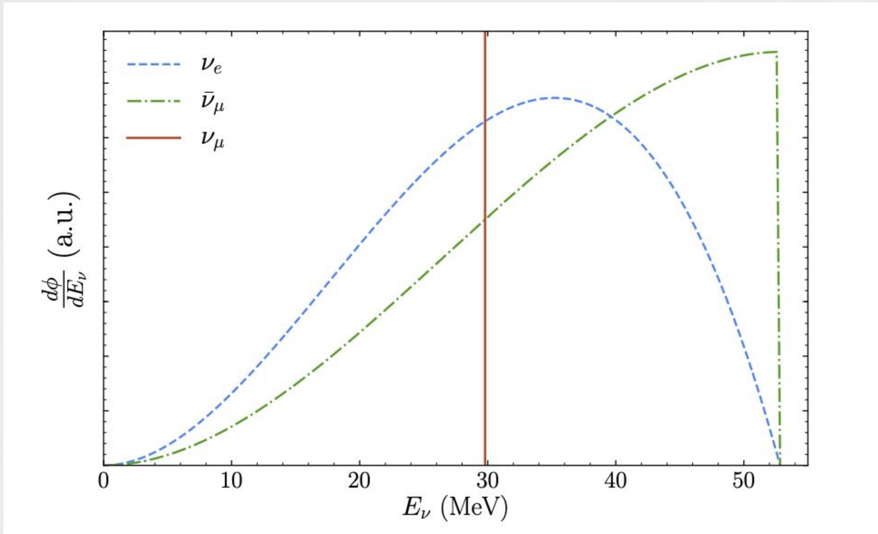
➔ What are spallation sources ?



- Production of neutrons by colliding accelerated protons into a heavy metal target
- Production of secondaries. Among them :
  - π- will be absorbed by the nucleus before its disintegration
  - π+ will decay at rest (DAR) and produce a neutrino source

$$\pi^+ \to \mu^+\nu_\mu \longrightarrow \mu^+ \to e^+\nu_e\bar{\nu}_\mu$$

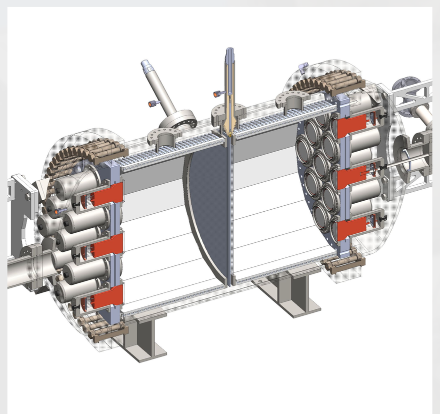
➔ What do we need ?



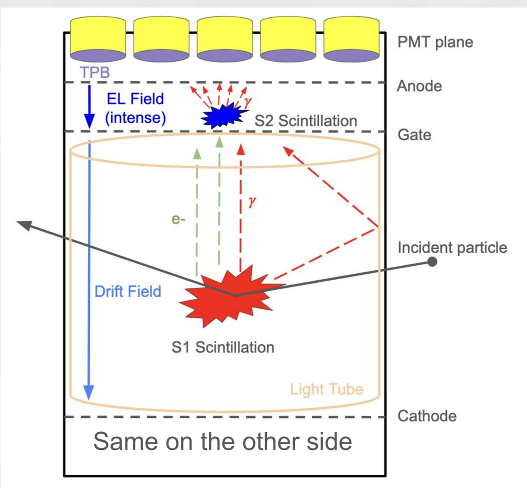
Neutrino flux spectra expected from pion DAR, in arbitrary units (a.u.), as a function of the neutrino energy in MeV.

- Neutrino sources intense enough and low in energy. The DAR of the π+ represents one of the best ways to respect the conditions
- Several interesting spallation sources such as :
  - European Spallation Source (ESS) located in Lund (Sweden). 2,53x10^{23} ν/year, almost 10 times better than the Spallation Neutron Source (SNS)
  - Japan Proton Accelerator Research Complex (J-PARC) can also be one of the possibilities.

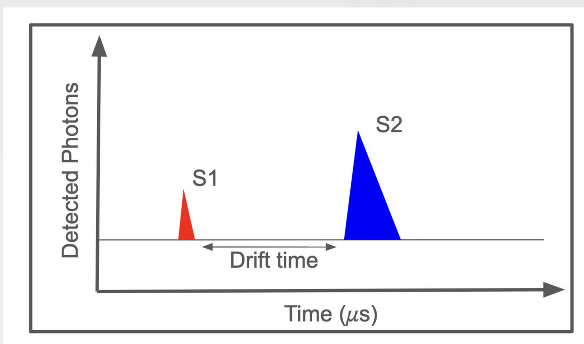
3. What is the GanESS detector?[3,4]



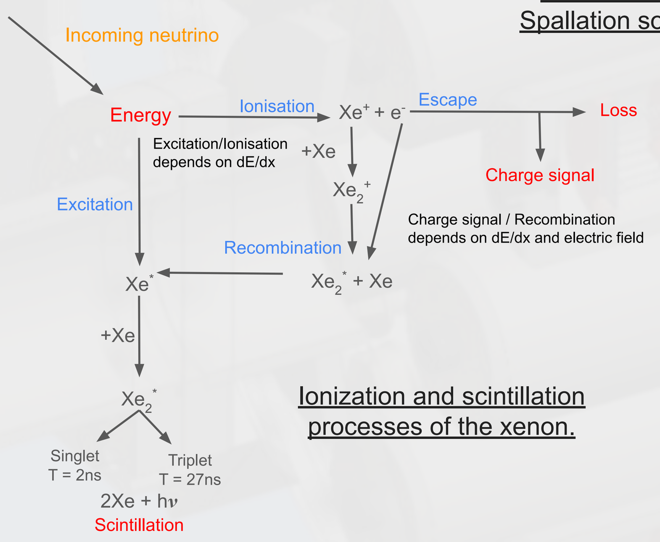
Representation of the GanESS detector, a high-pressure noble gas TPC.



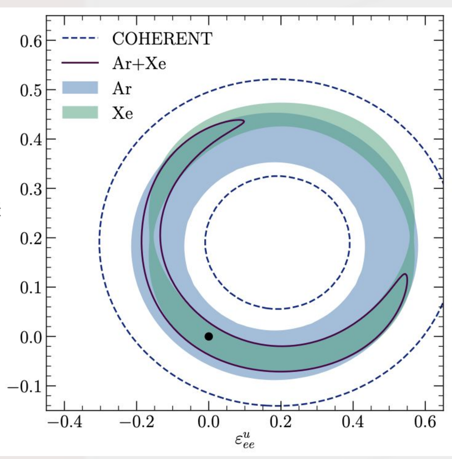
Representation of a gaseous single-phase TPC. No interface so no charges trapped. Spallation source covers the statistical deficit.



S1 and S2 scintillation detections : Good background discrimination and optimal energy resolution. Detection threshold as low as the energy needed to form an electron-ion pair (22.1 eV in gaseous xenon)



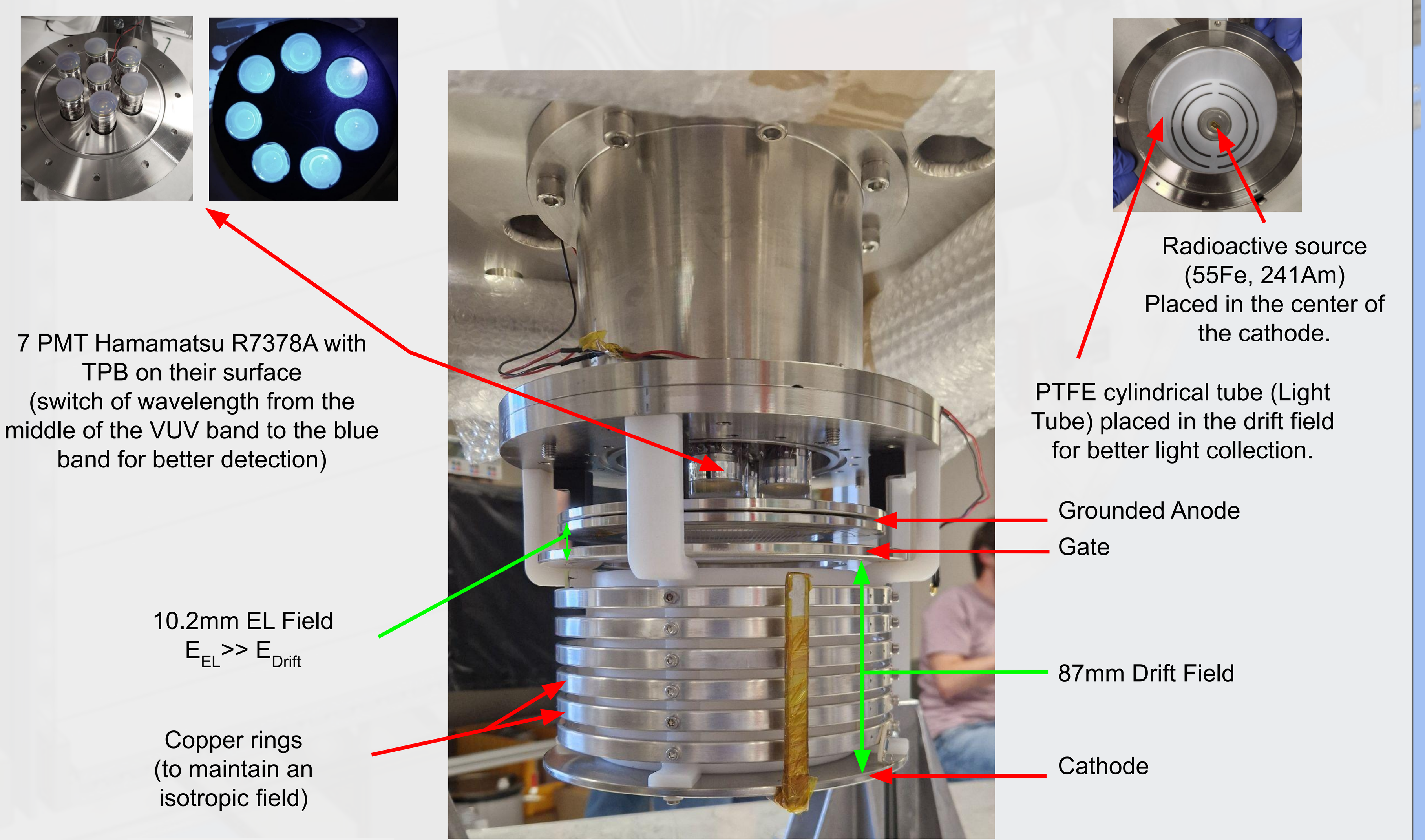
Ionization and scintillation processes of the xenon.



Operation with different gases (xenon, argon,krypton) with few modifications of the configuration of the detector : (~20kg of xenon at ~20bar in the GanESS detector).

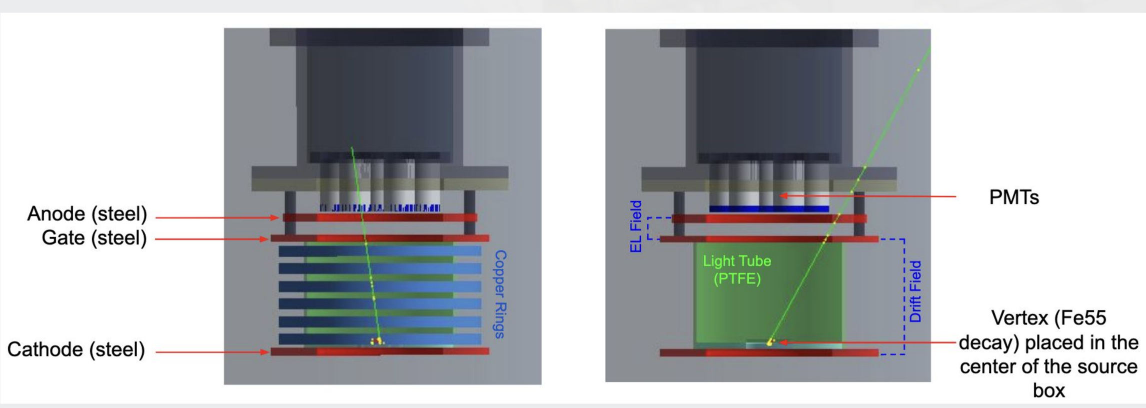
Expected allowed regions in the (ε^{uV}_{ee}, $\varepsilon^{uV}_{\mu\mu}$) plane at the 90% confidence level for 2 degrees of freedom for the gas TPC detector operating with two different nuclei.

4. The Gaseous Prototype (GaP)[5]

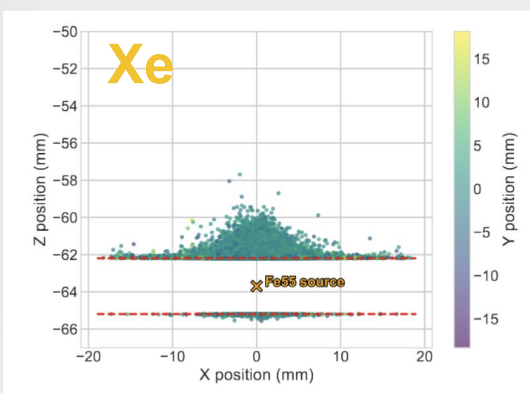


Picture of the GaP TPC.

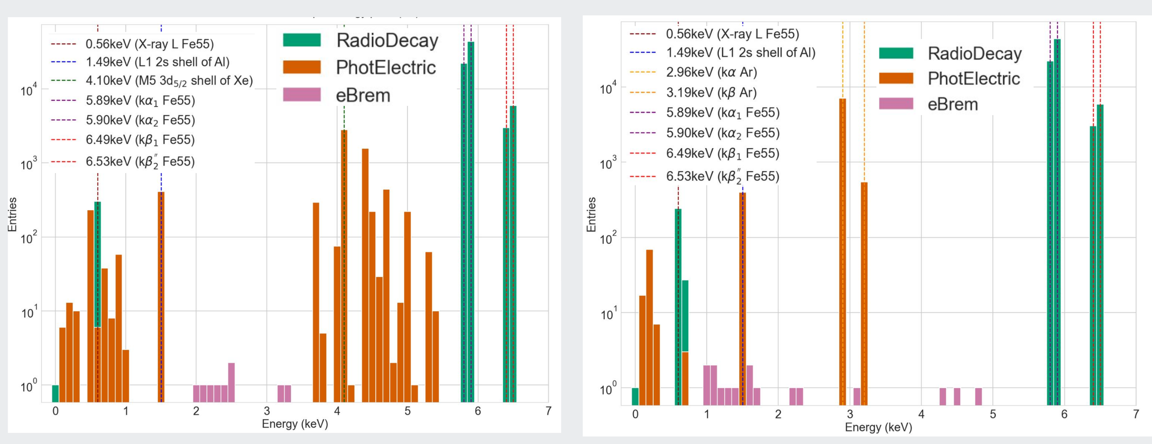
5. GaP Geant4 simulation[5]



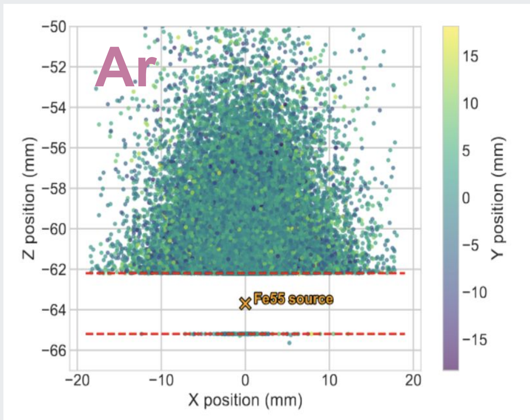
Geometry of the Geant4 simulation of GaP.



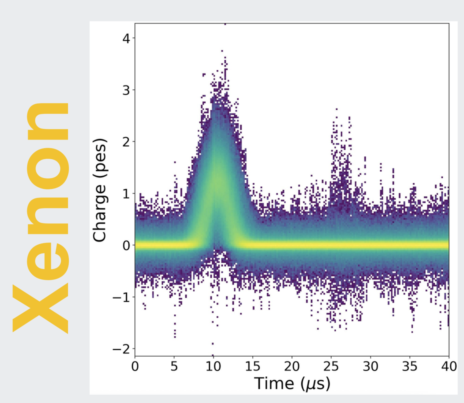
Scatter plot of the final position of the primary gammas (just after decay of Fe55).



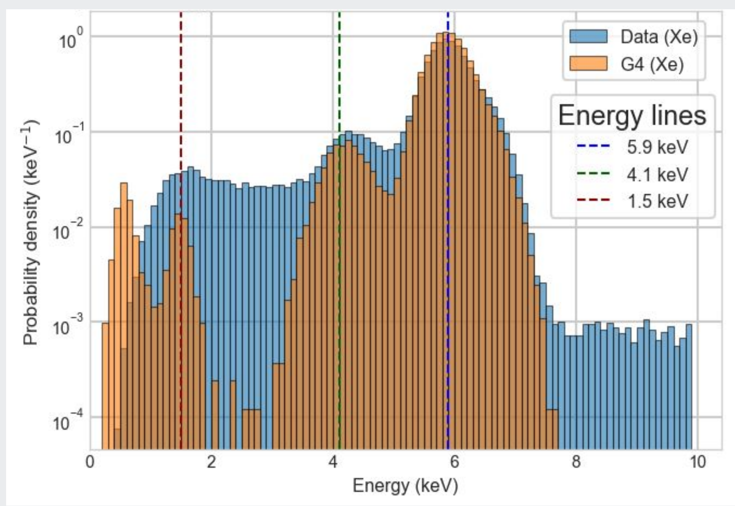
Contribution of creator processes per energy peak for xenon (left) and argon (right).



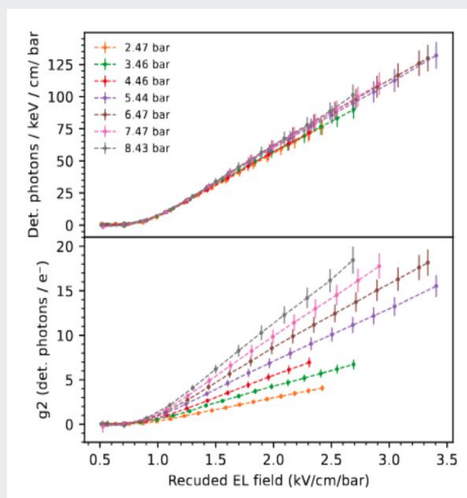
6. Last important results[5]



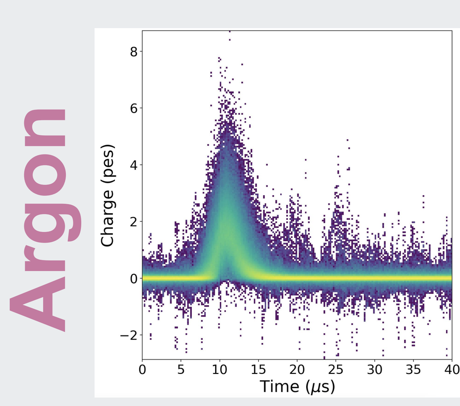
Superimposed waveforms between 1.3 and 1.6keV (after denoising).

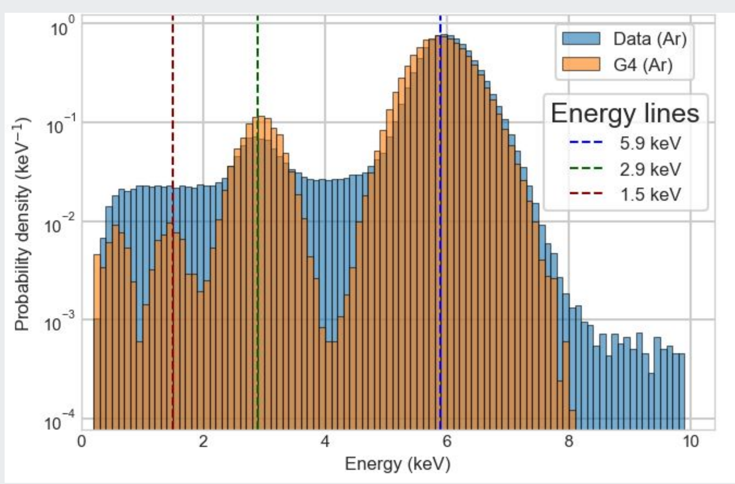


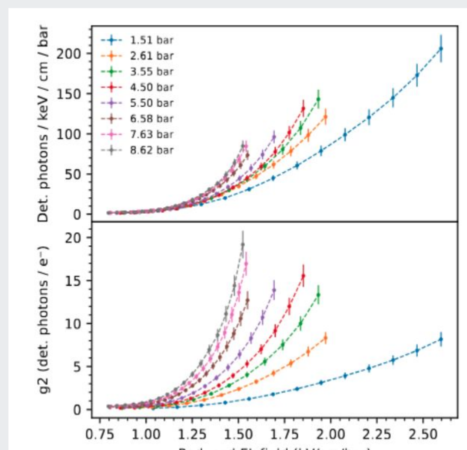
Comparison between data (after denoising) and G4 GaP simulation.



Detected photons per keV and g2 as a function of the electroluminescence field for different operating pressures.







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