# Gamma-ray source generation with ultra-high intensity lasers


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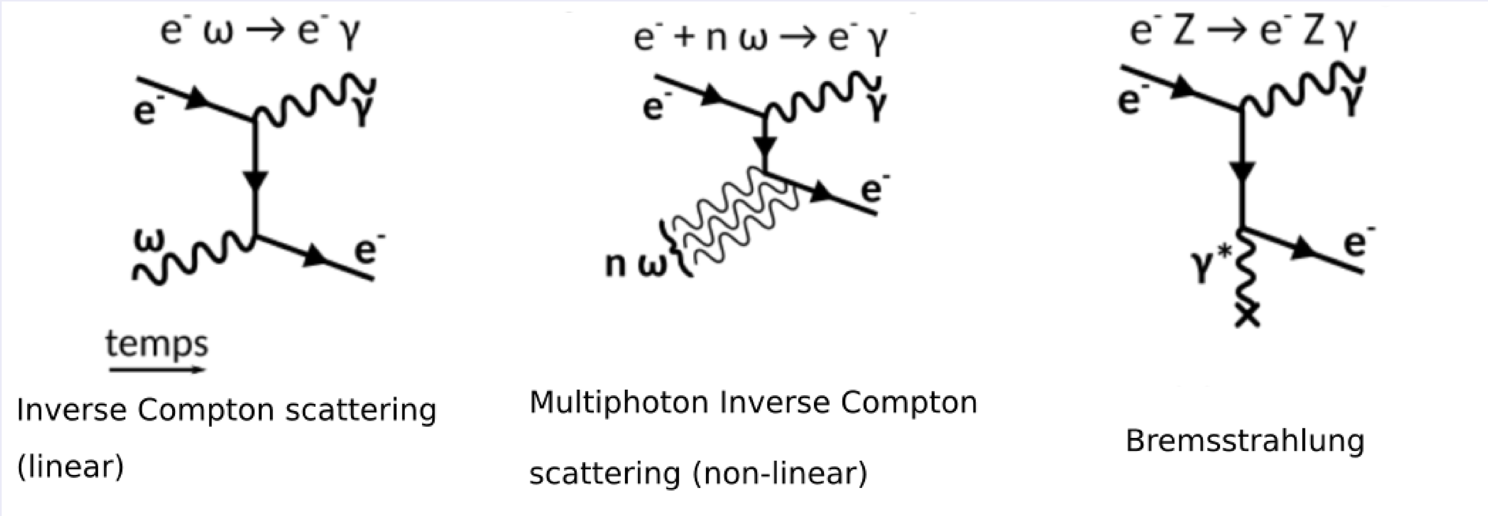
**Introduction :** $\gamma$ photons are omnipresent in the Universe. They are of great importance in nuclear physics because they can induce nuclear reactions and resonances. They also have a fundamental importance for imaging, detection, etc ... In particular, they allow to study exotic phenomena such as QED processes with, for example, creation of matter/antimatter. These phenomena require large densities of high energy photons. Such high densities are becoming reachable with new laser facilities.

## $\gamma$ photon generation

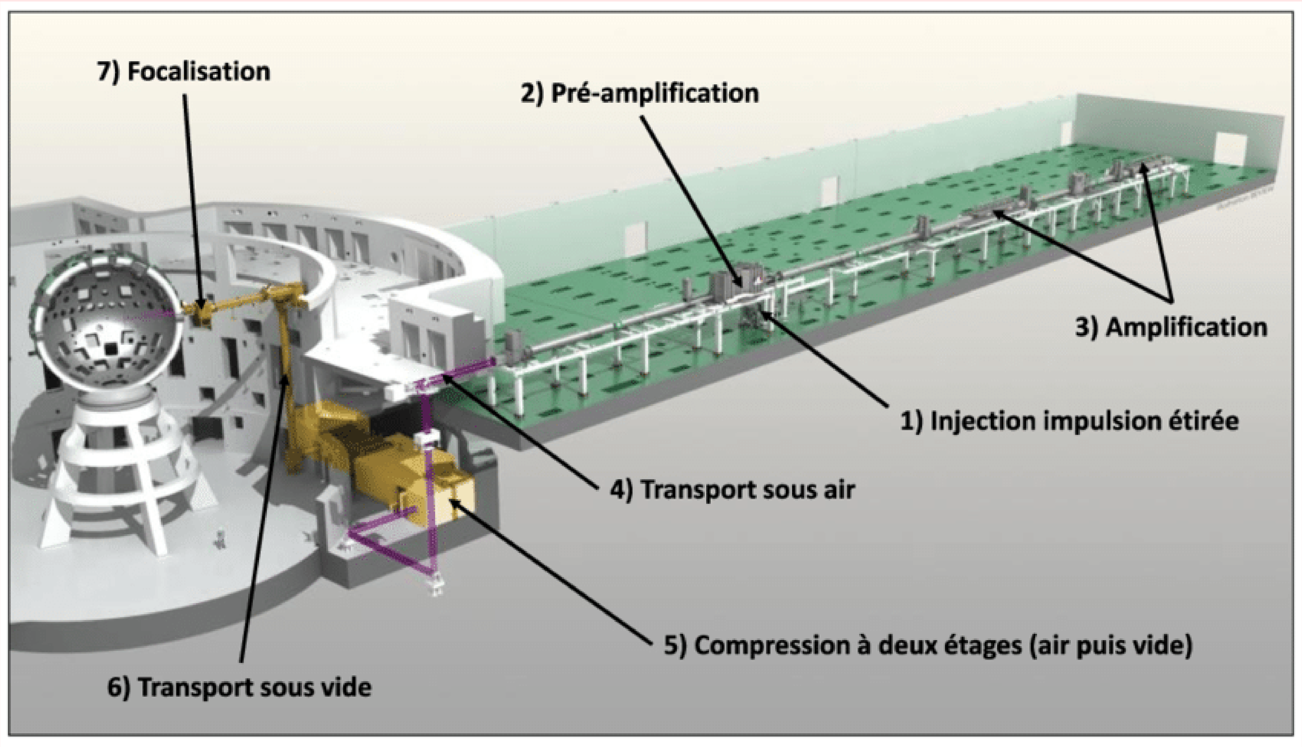
- $\gamma$ photon production come from radiations of energetic particles and nuclear desintegrations.
- Nuclear desintegrations are isotropic and do not allow to have luminous collimated sources.
- Radiation from particle deviations is therefore considered.



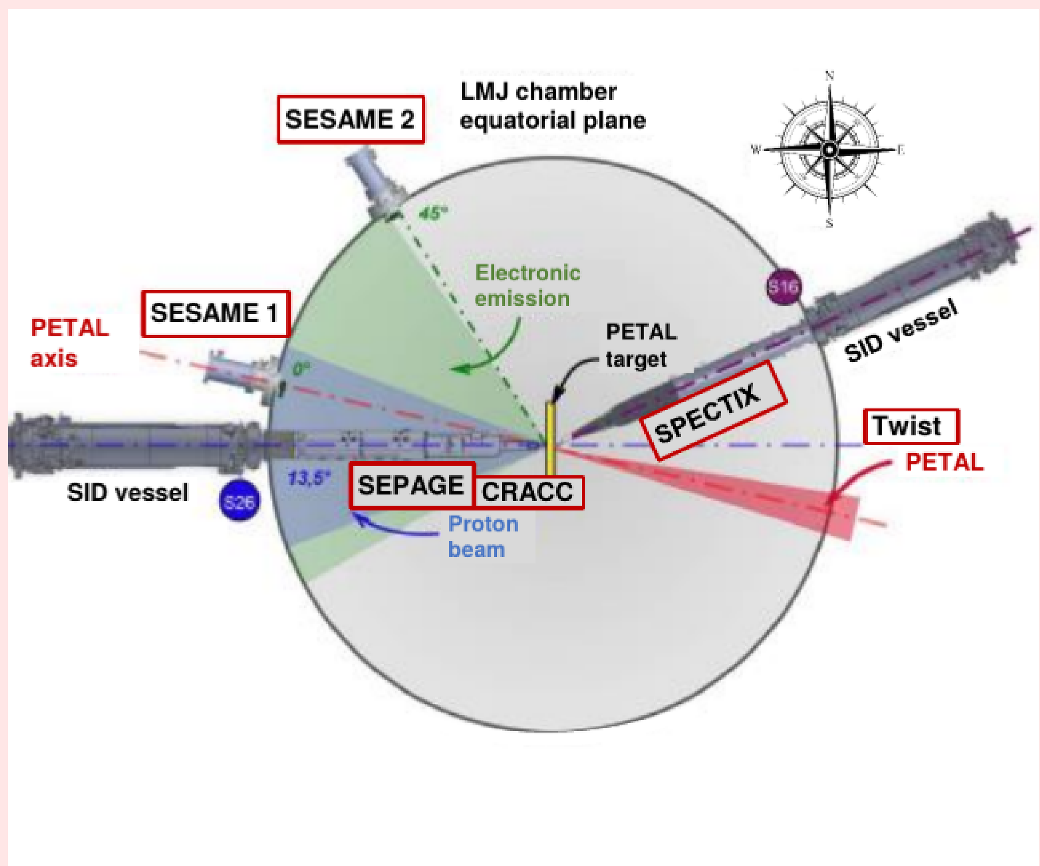

- For these phenomena, we need high energy electrons (MeV).
- Actual lasers facilities allow to generate very strong electromagnetic fields ⇒ we can accelerate electron to high energies with Laser Wake Field Acceleration or direct acceleration.

## Petal laser facility and experiment

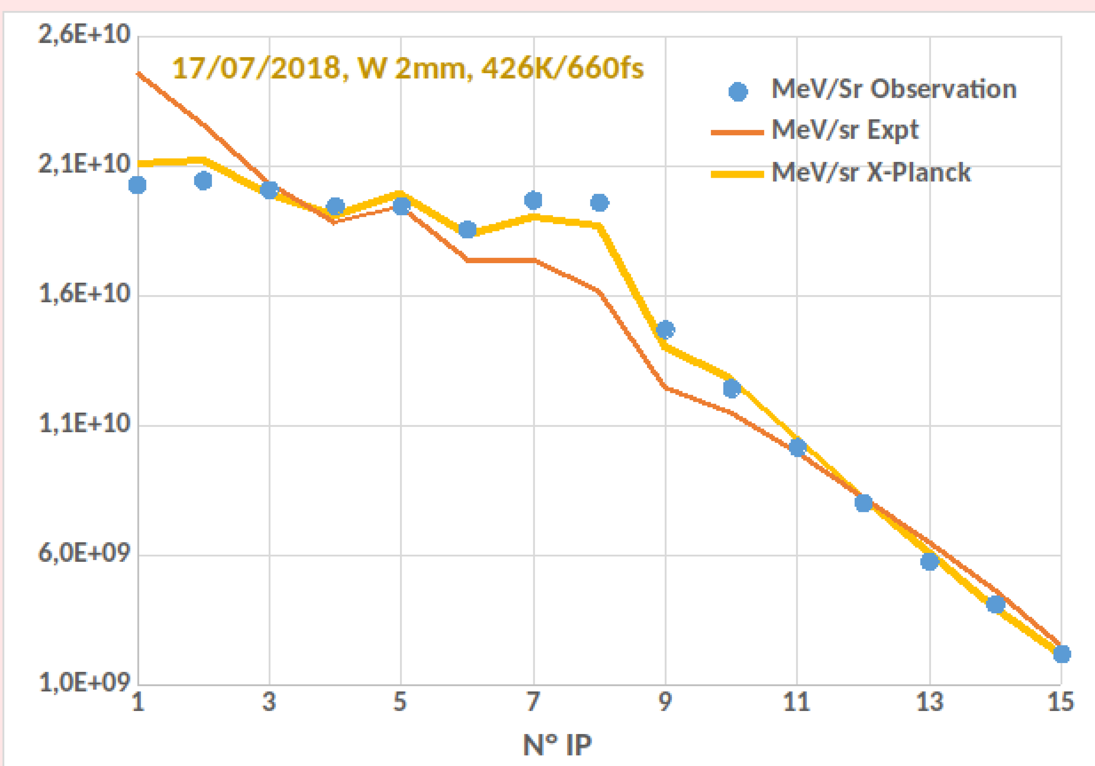
The PETAL laser is a Petawatt laser with $t_{FWHM} \in$ [500 fs-10 ps] $E_{laser} \in$ (100 J – 1 kJ). It is developped at Laser Mega Joule (LMJ) in CEA-CESTA).




Commissioning of the PETAL laser (QPETAL1 and QPETAL2) was performed between 2017 and 2018. T10 shots were carried out on different targets.




These shots allowed to measure and study acceleration of electrons and ions, generation of electromagnetic pulses, $\gamma$ photons generation etc ...



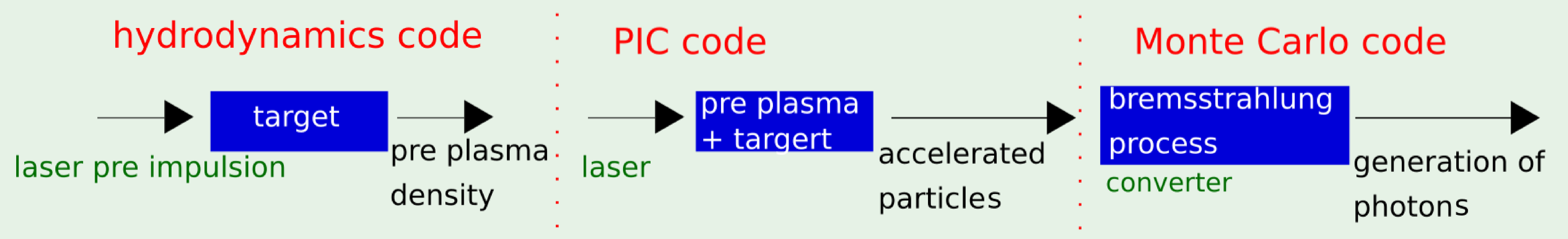

From the gamma photons deposited in the image plates, we can find the gamma photon spectrum.

Preliminary simulations were performed to estimate all the different processes. These simulations were below experimental data. New study are therefore realised to describe the experimental results.

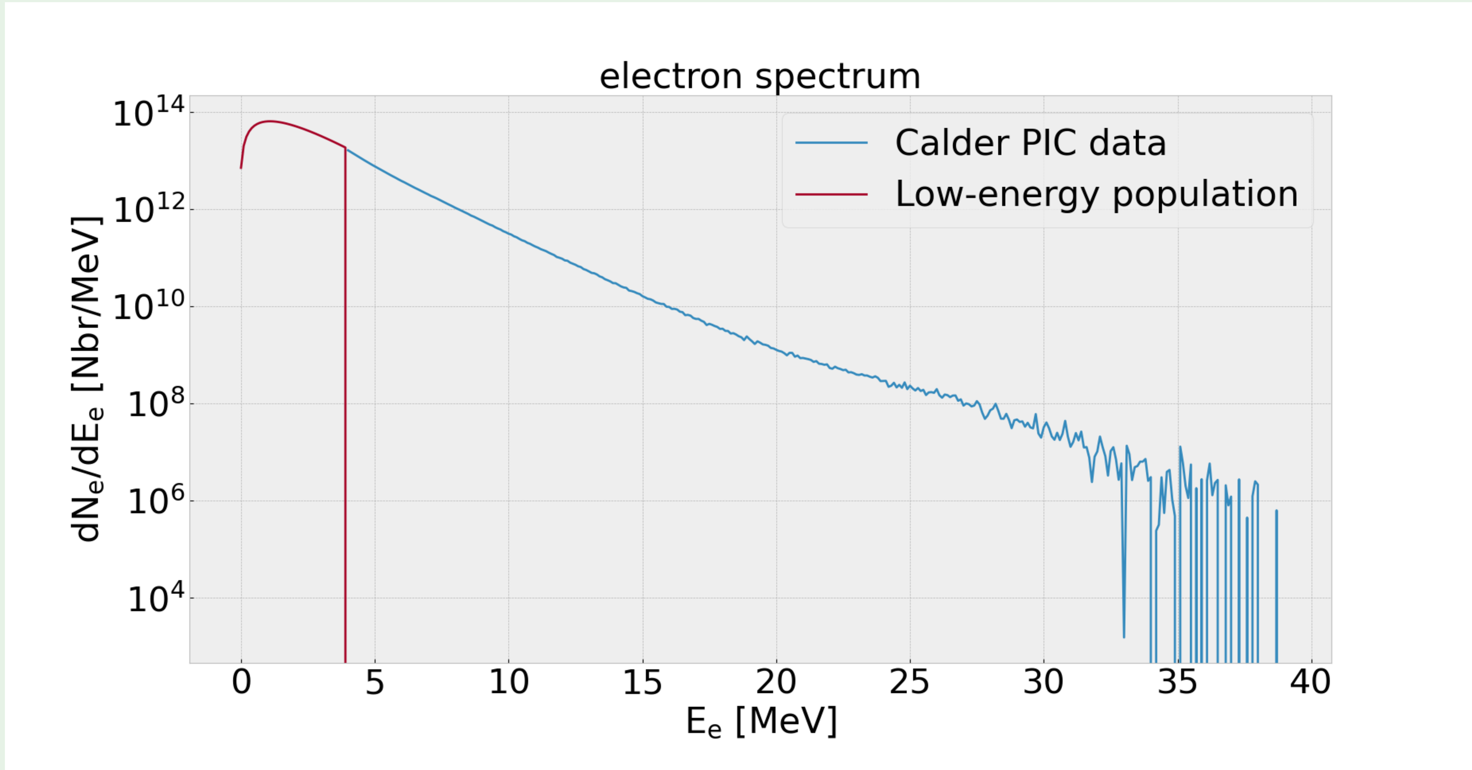
## Simulation chain

The laser pulse was made from a long prepulse and a short main peak with intensity of $I \approx (8.10^{18} W.cm^{-2})$ .

We cannot simulate all the physics involved with just one code.



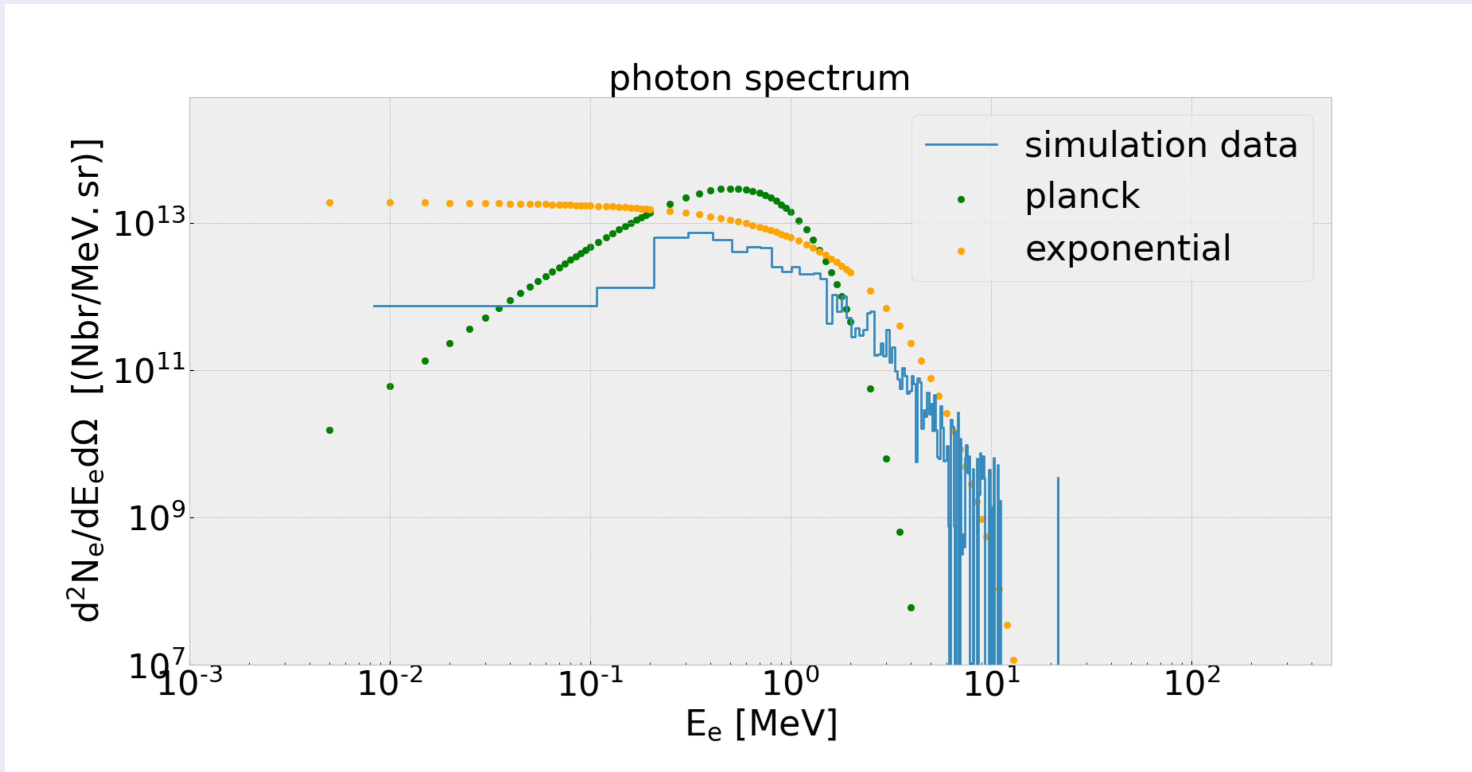

- Hydrodynamics simulation are performed with the code TROLL to simulate of the interaction between the prepulse and the target.
- We use the Particle In Cell (PIC) code Calder. This code solves the kinetic motion equations of particles. We can simulate acceleration of particles and in particular electrons.



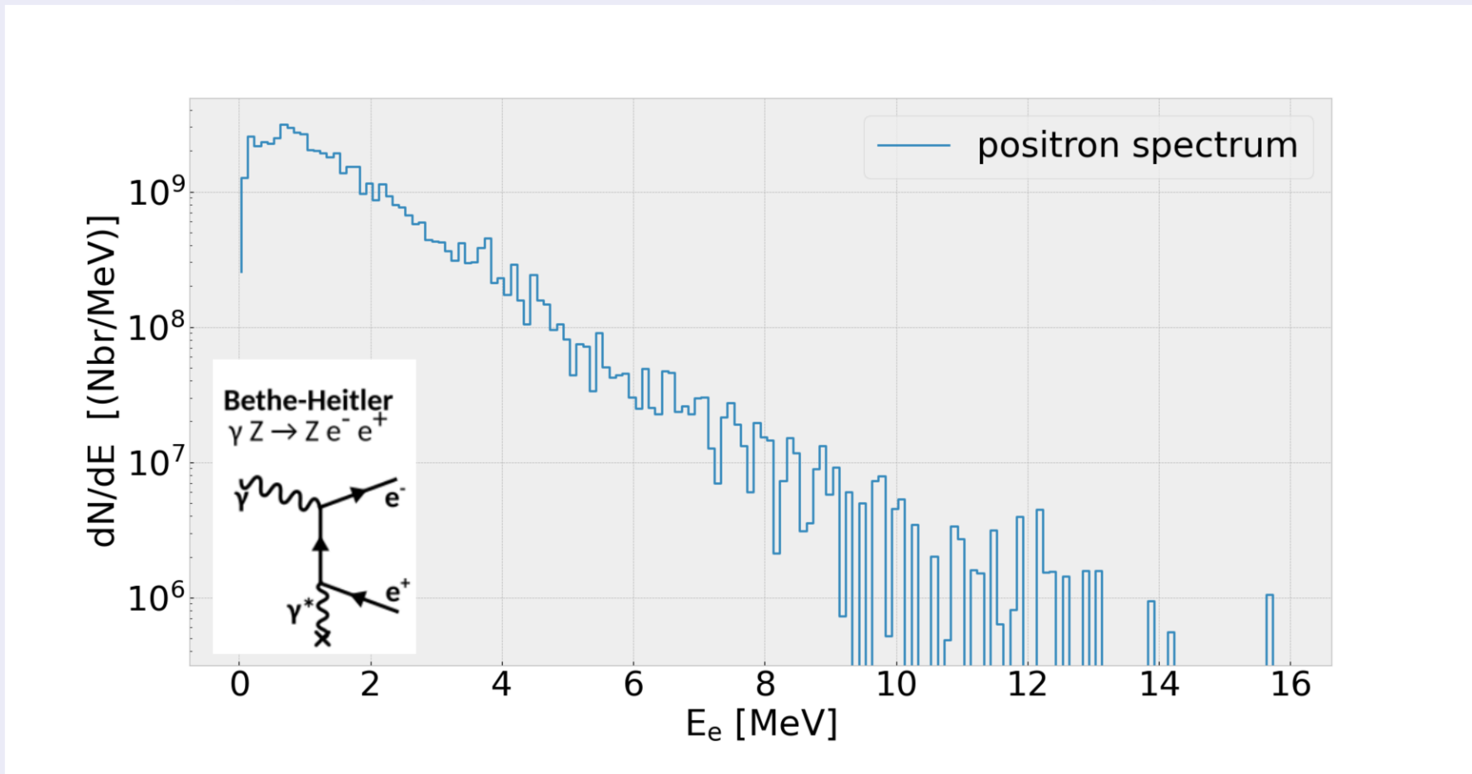

- We then use a Monte Carlo code named gp3m2 based on the toolkit Geant4 to simulate the interaction between accelerated electrons and solid target. We get, from bremsstrahlung process, the electron's radiation.

## Simulation results compare to the experimental measurements

- We get a good agreement between one of the two theoretical photons spectrums and our data from gp3m2 simulation.




- We also look at positron production from the Bethe-Heitler process.




## Conclusion/Outlook

- Addition of the low energy electron population.
- Injection of PIC data in the Monte Carlo simulation.
- Production of $\gamma$ photons in agreement with experimental data.

In the future we will better characterize (energy, number, angle of emission) the photon emission and the positron production from the Bethe-Heitler process. We will also estimate positron production from the Breit–Wheeler process if we split the laser and the target.


- D. Raffestin *and al.*, *Enhanced ion acceleration using the high-energy petawatt PETAL laser*, Matter and Radiation at Extremes, (2021)
- D. Raffestin *and al.*, *Modeling of High-Energy Particles and Radiation Production for Multipetawatt Laser Facilities*, Laser and Particle Beams, (2021)