Simulation of a new photon detector design for neutrino detector

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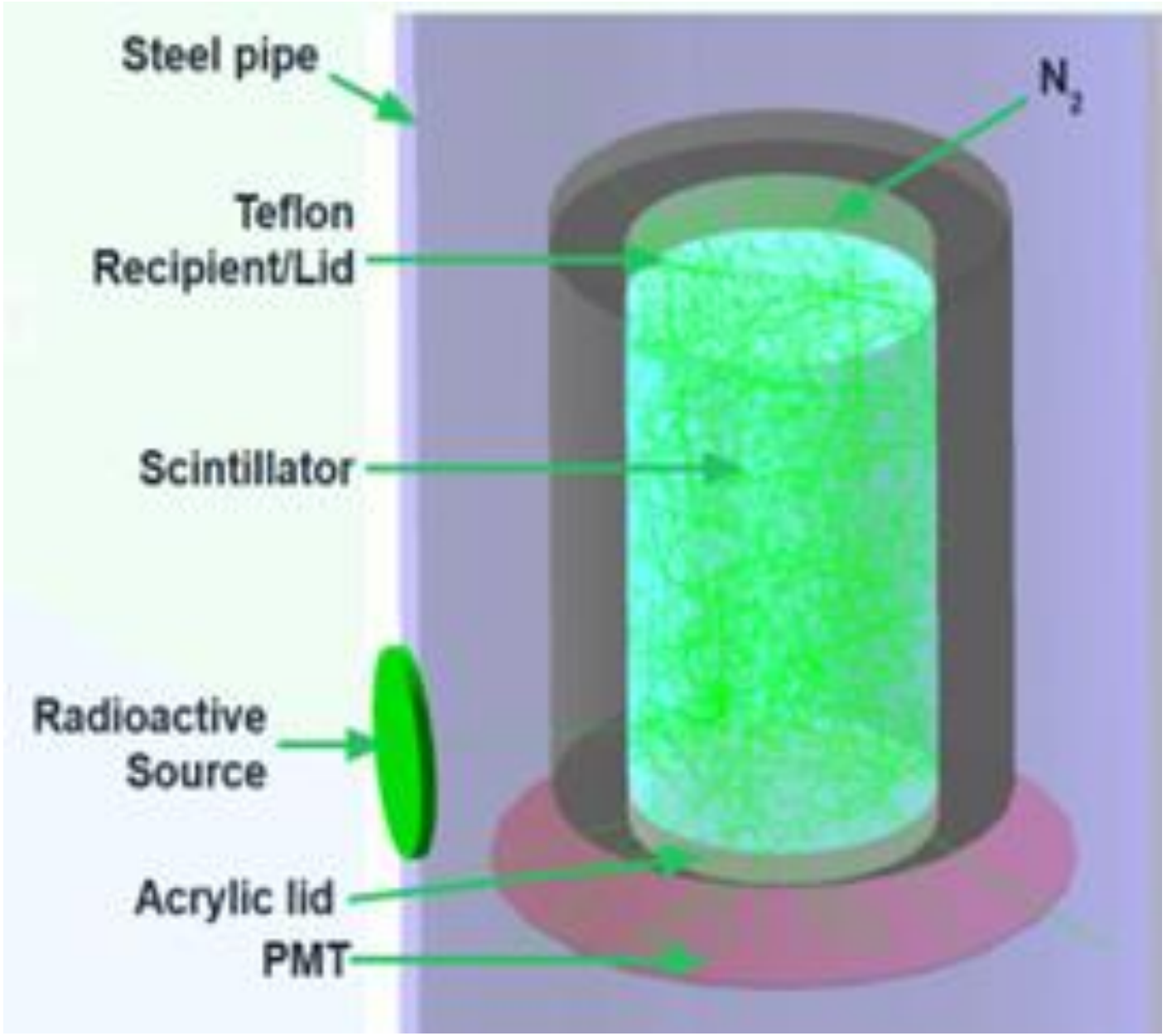
Introduction

- Simulation study of a new photon-detector design for neutrino-detector applications.
- Investigate the detector response to different radioactive gamma sources.
- Five sources .
  - Three different positions.
    - Three PPO concentrations: 0 g, 1 g and 2 g.
- Every simulation had 500 000 events at the source.
- Two quantities are studied for each position and concentration:
  - Wavelength of the photons detected at the SiPM
  - Number of photoelectrons (nPE) for each event

Structure

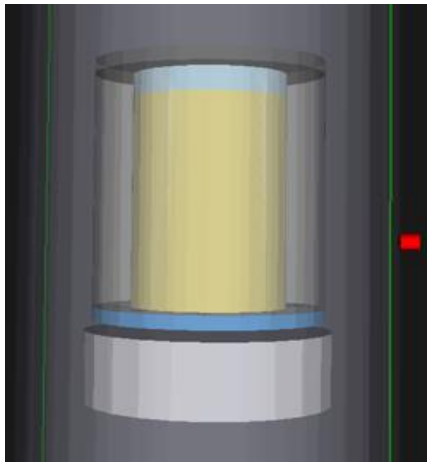

Steel pipe
N_2
Teflon
Recipient/Lid
Scintillator
Radioactive
Source
Acrylic lid
PMT

Gamma sources

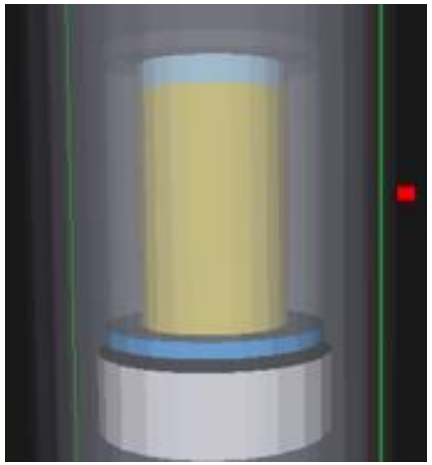
- Cs137
- Co60
- Na22
- Ba133
- Co57

Positions

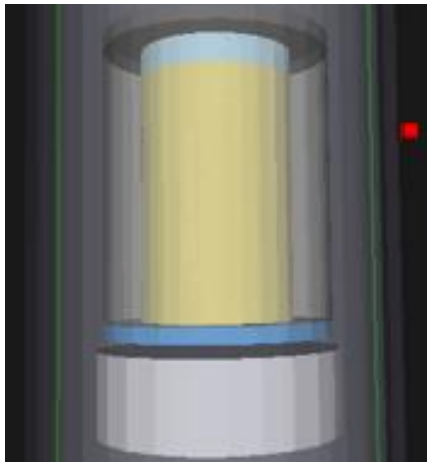
PMT(z=-207)



Position 1
(z=-185)

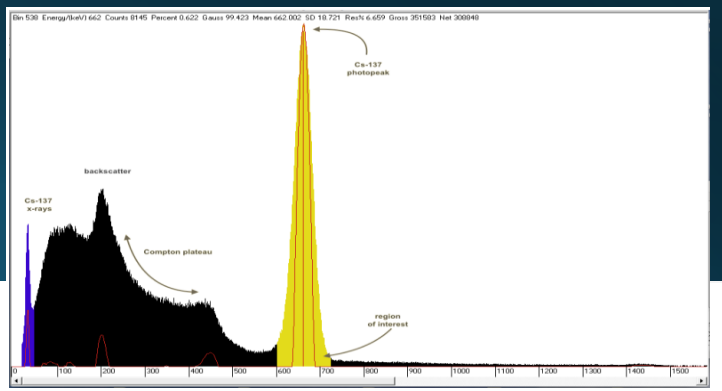


Position 2
(z=-170)

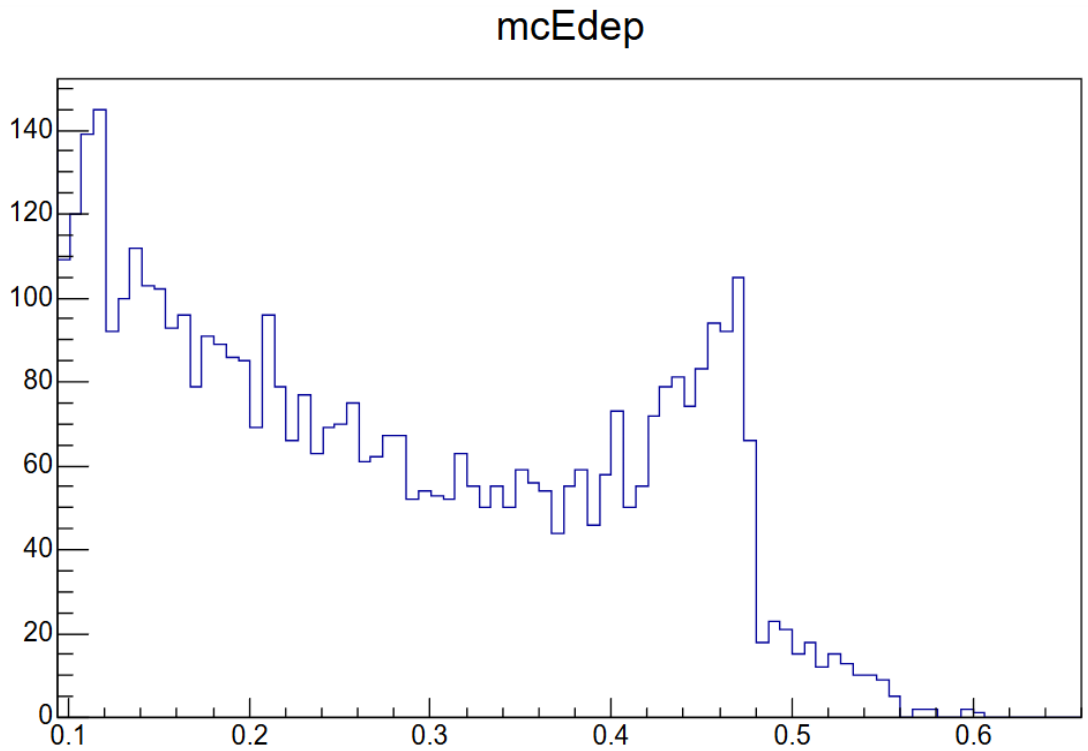


Position 3
(z=-155)

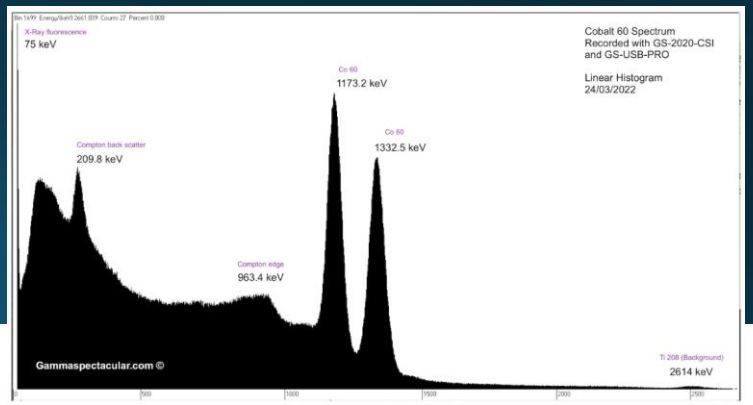
Cs 137 - Characteristics



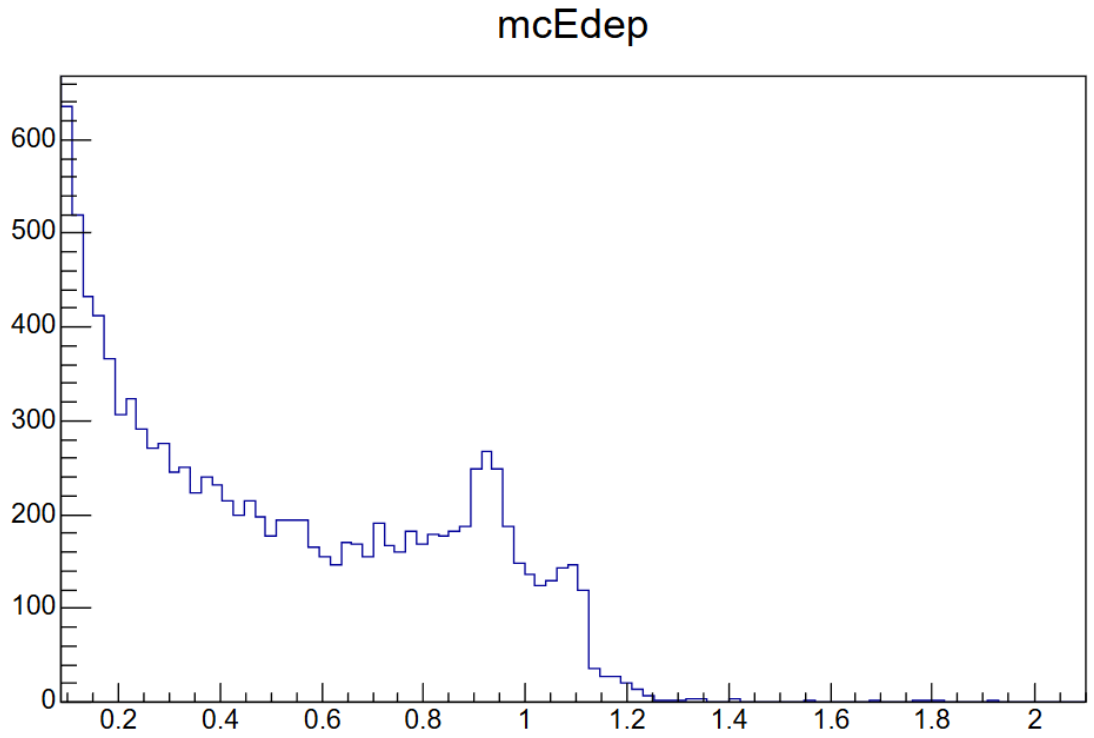
- **Isotope:** ^{137}Cs
- **Half-life:** ≈ 30.0 years
- **Decay mode:** β^- decay to stable ^{137}Ba
- **Gamma emission:** Principal line at **661.7 keV** (emission probability ≈ 85%)
- Used as the reference for comparison



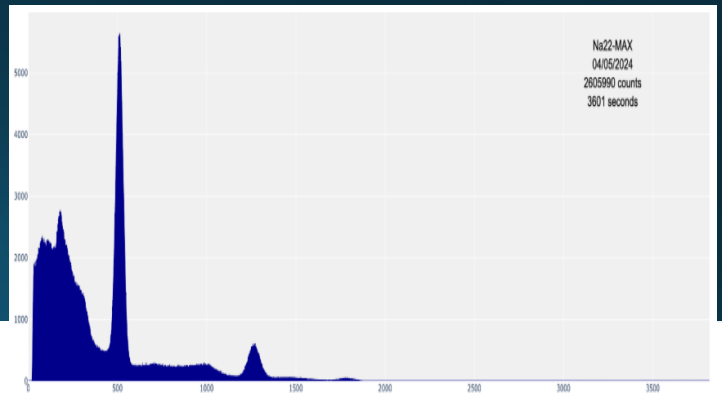
Co 60 - Characteristics



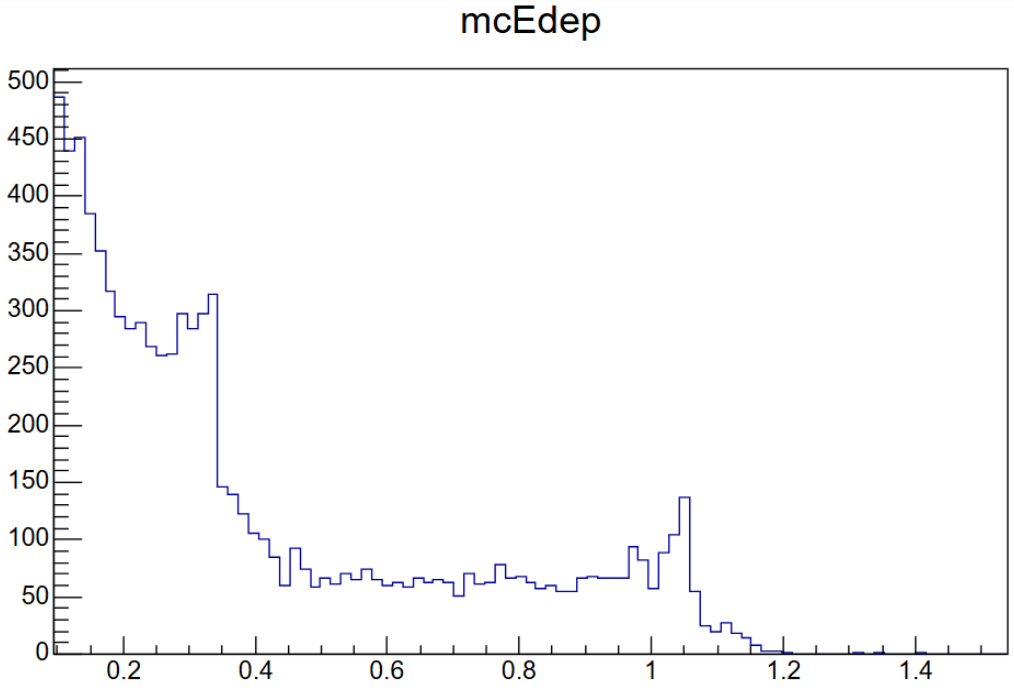
- **Isotope:** ^{60}Co
- **Half-life:** ≈ 5.27 years
- **Decay mode:** β^- decay to stable ^{60}Ni
- **Gamma emission:** Two prominent cascade lines at **1173.2 keV** and **1332.5 keV** (both emitted with very high intensity)



Na 22 - Characteristics



- **Isotope:** ^{22}Na
- **Half-life:** ≈ 2.60 years
- **Decay mode:** Predominantly β^+ (positron) emission, with a smaller electron-capture branch
- **Gamma features:** Two main components – **511.0 keV** annihilation photons (from positron–electron annihilation) and a **1274.5 keV** gamma ray



Ba 133 & Co 57 - Characteristics

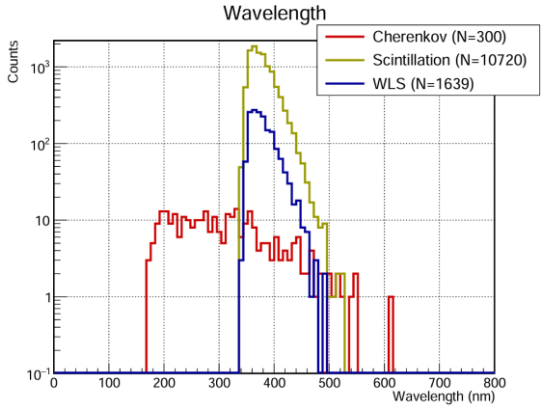
- **Isotope:** ^{133}Ba
- **Half-life:** ≈ 10.55 years
- **Decay mode:** Electron capture to stable ^{133}Cs
- **Gamma emission:** Multiple useful lines at **81.0, 276.4, 302.9, and 356.0 keV** – the 356.0 keV line is the strongest (intensity ≈ 62%)

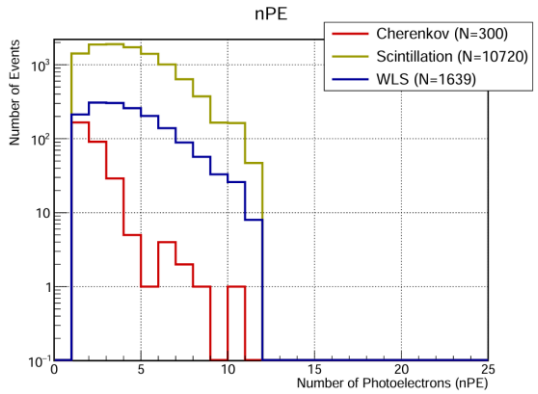
- **Isotope:** ^{57}Co
- **Half-life:** ≈ 271.8 days
- **Decay mode:** Electron capture to stable ^{57}Fe
- **Gamma emission:** Main lines at **122.1 keV** (dominant) and **136.5 keV**; widely used as a gamma/X-ray spectrometer reference source

- **Application in this study:** Tests the detector response at relatively low gamma energies
- No data was gathered

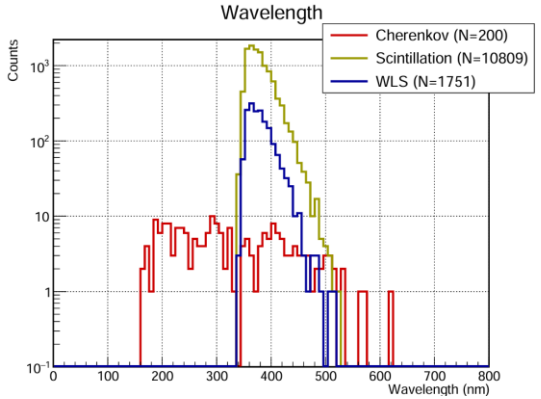
Results

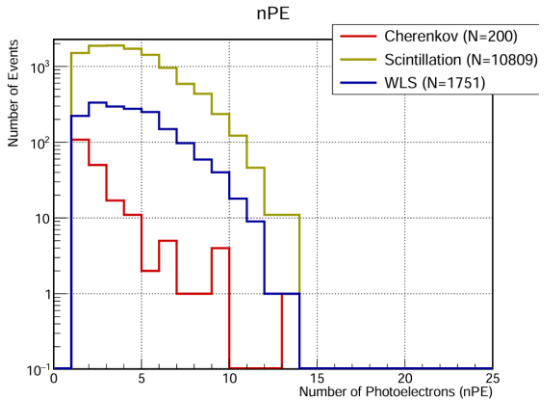
Position 1





Position 2



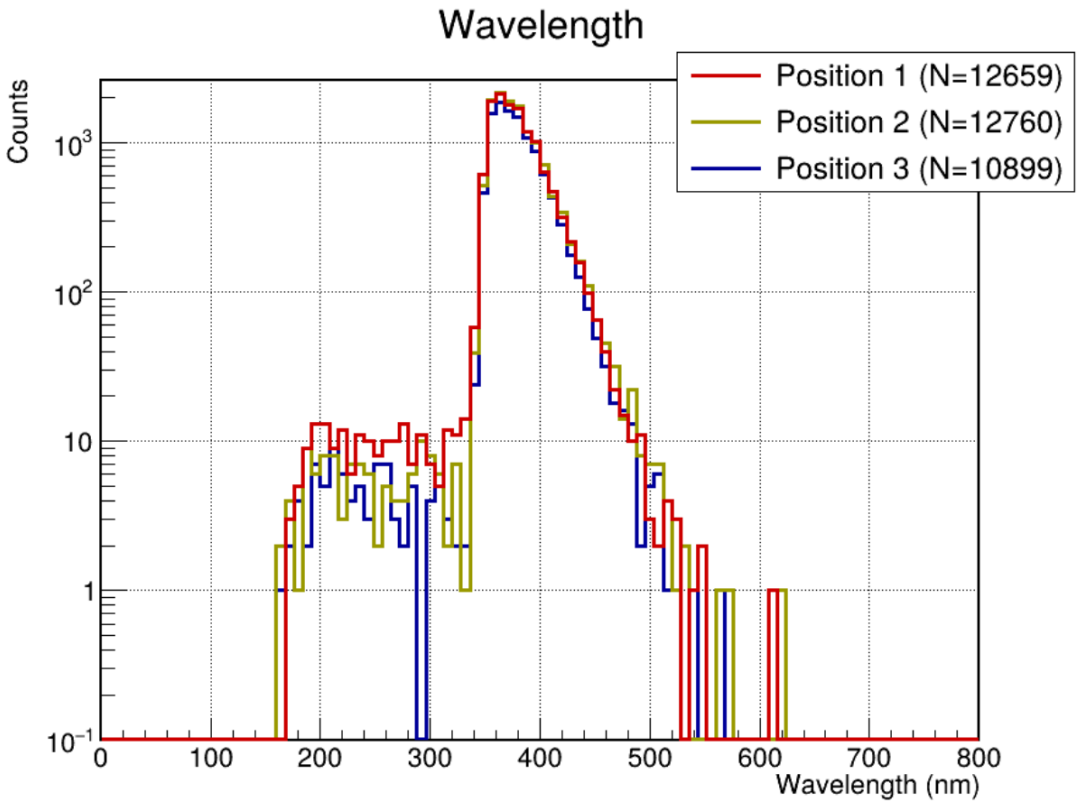


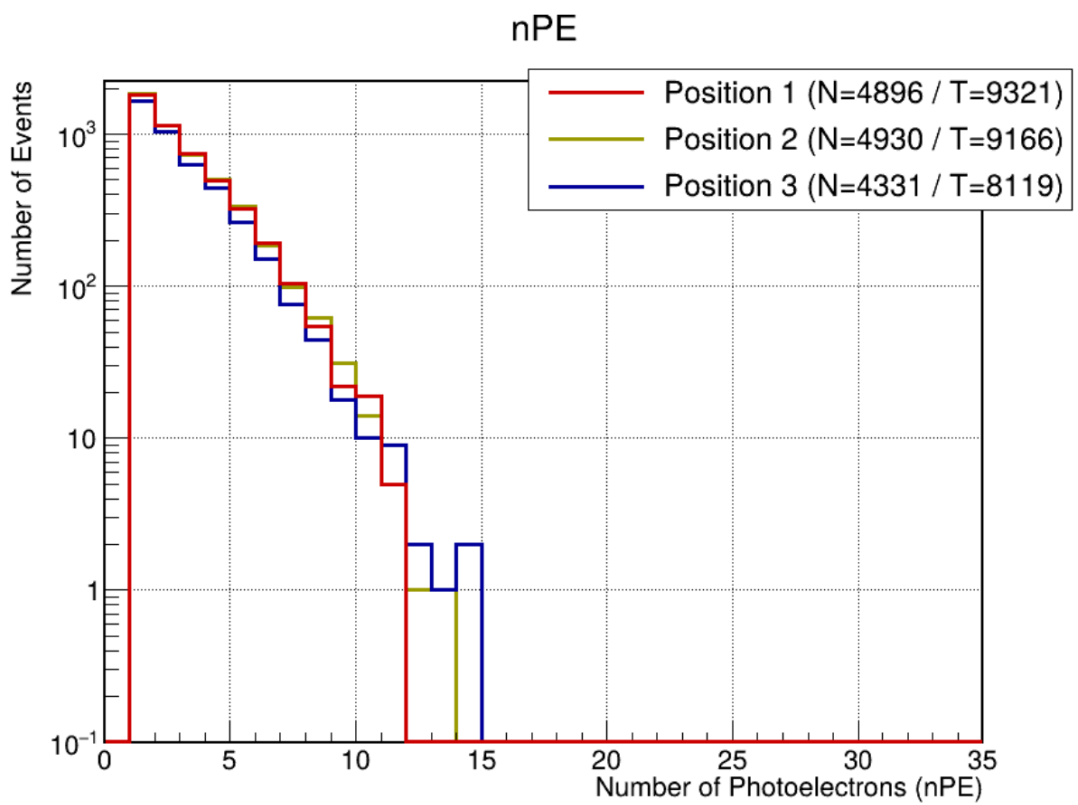
The Cs137 appears to bring the most “interesting” results because the event rate in the scintillator is high, and the event energies are high enough for both Cherenkov and scintillation to occur.

- The source in position 1 with 2g of PPO
  Good results in Cherenkov
- The source in position 2 with 2g of PPO
  Good results in nPE

Comparison between positions

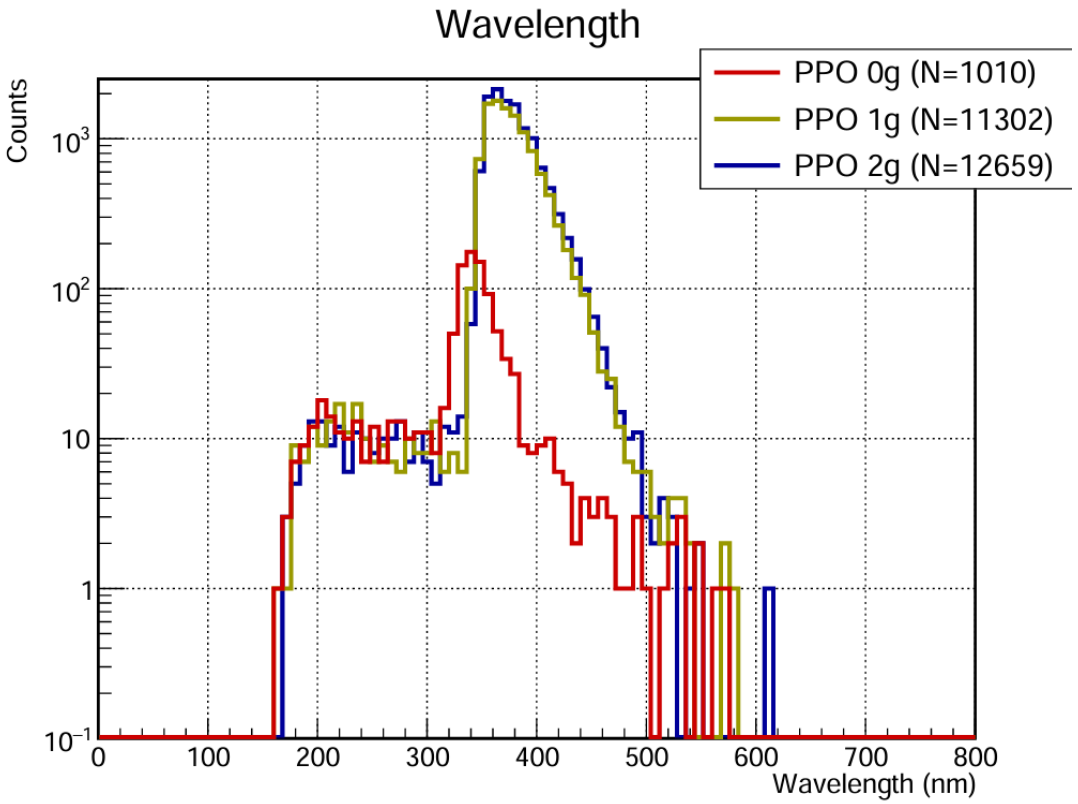
PPO 2g

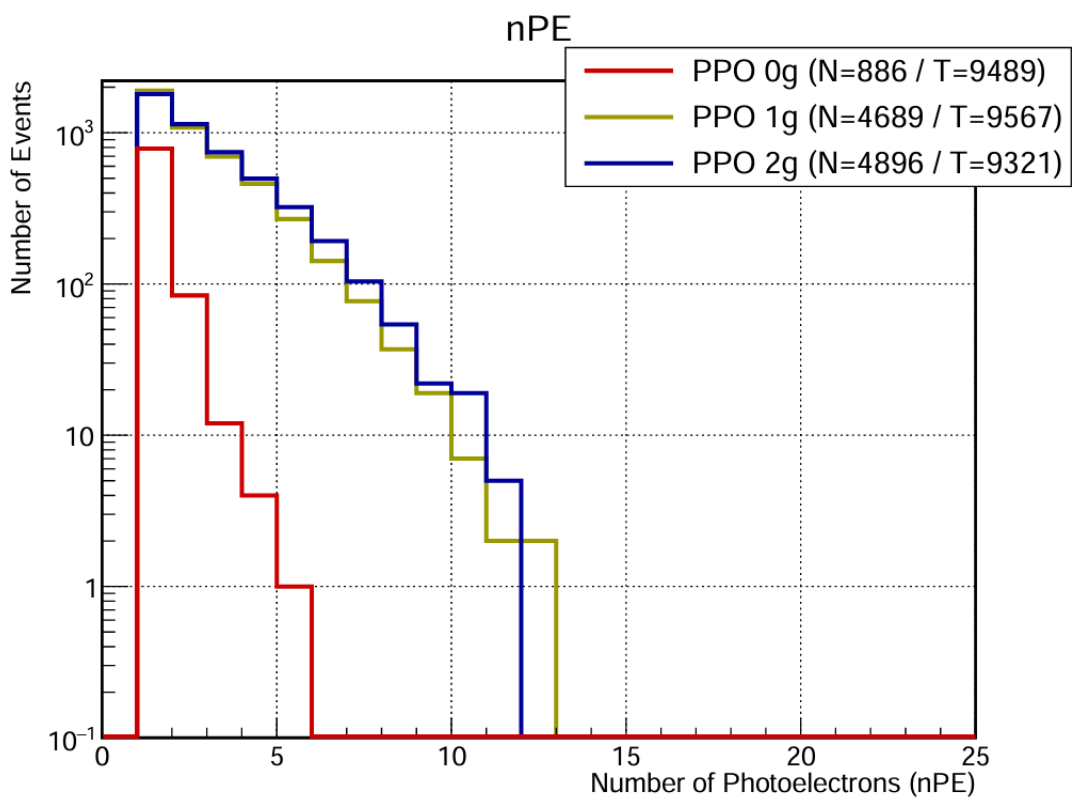




Comparison with other PPO concentration

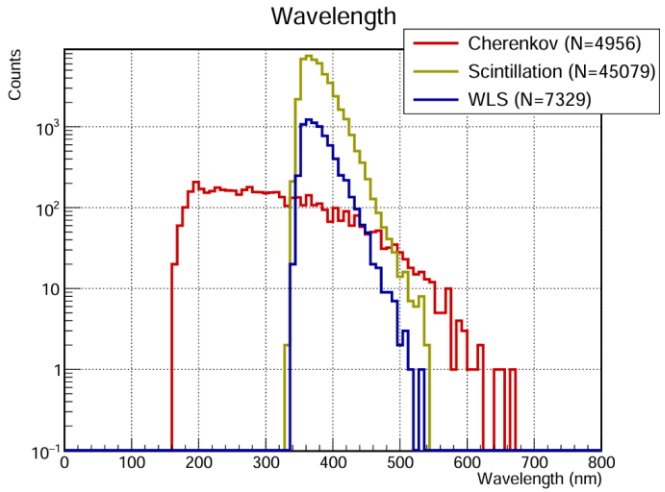
Position 1

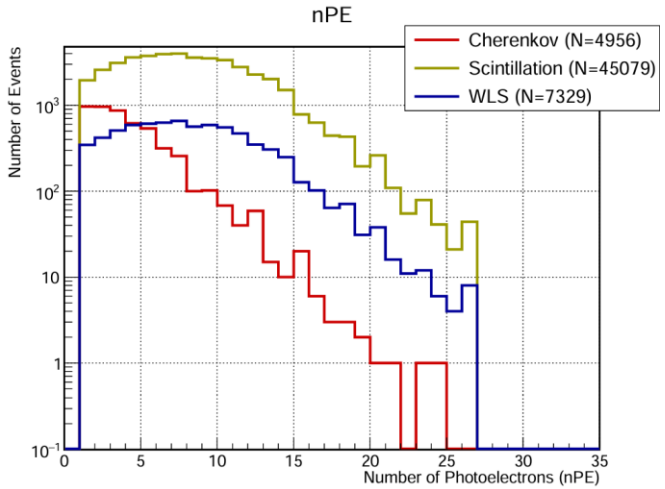




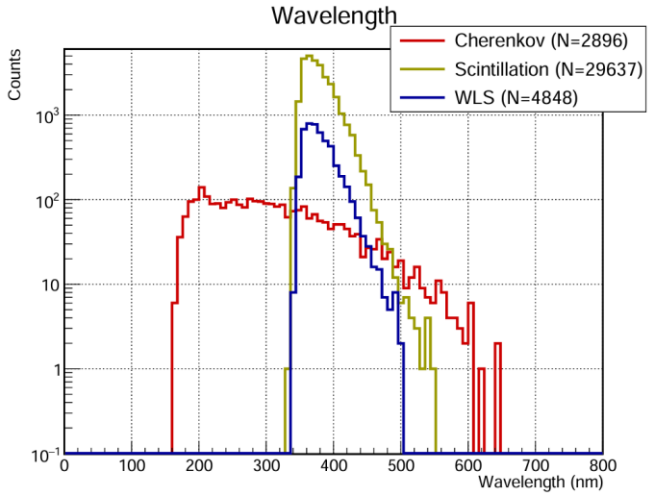
Other interesting results

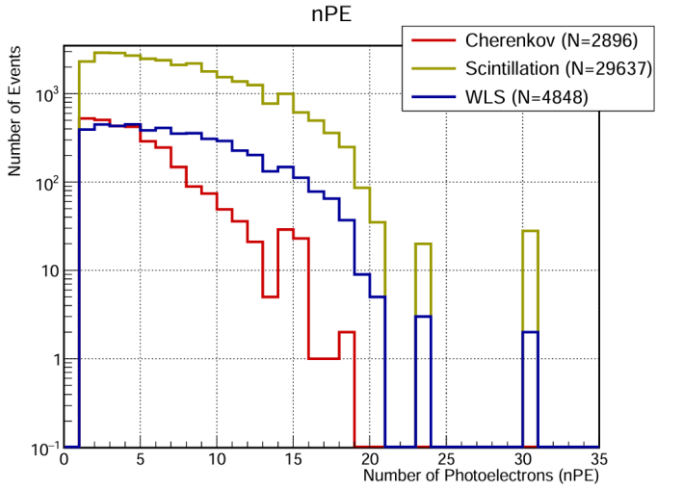
The Co60 and the Na22 sources also have interesting results





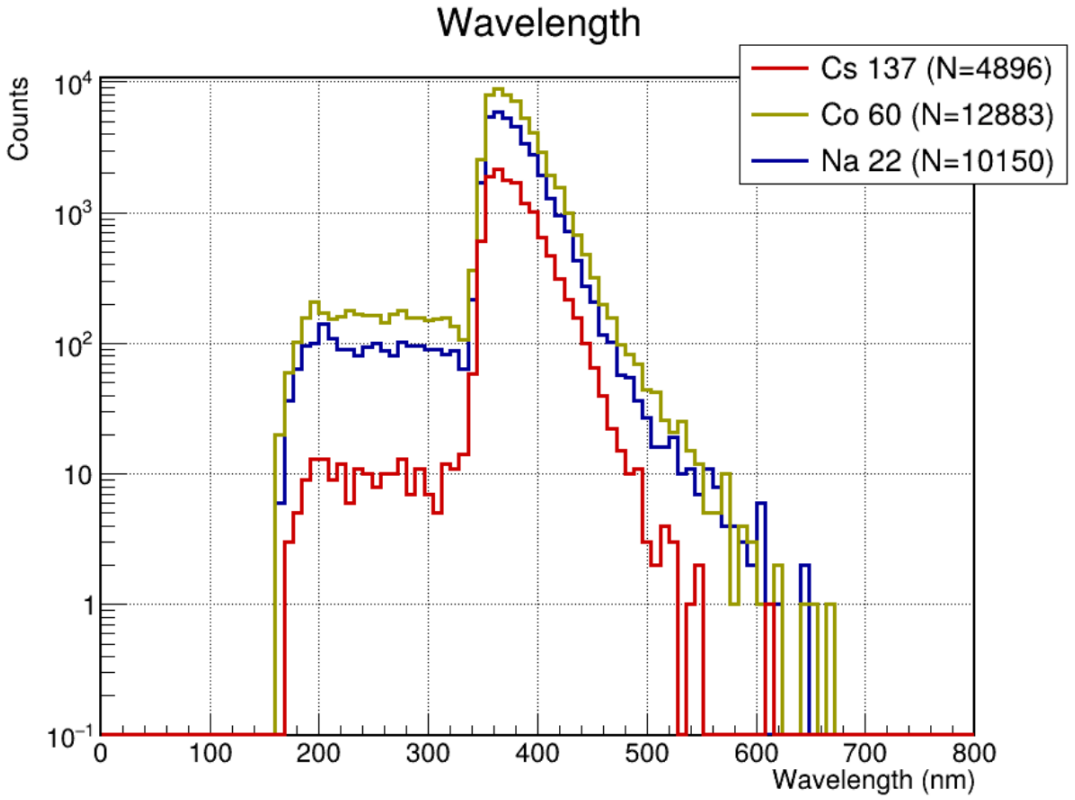
Co 60

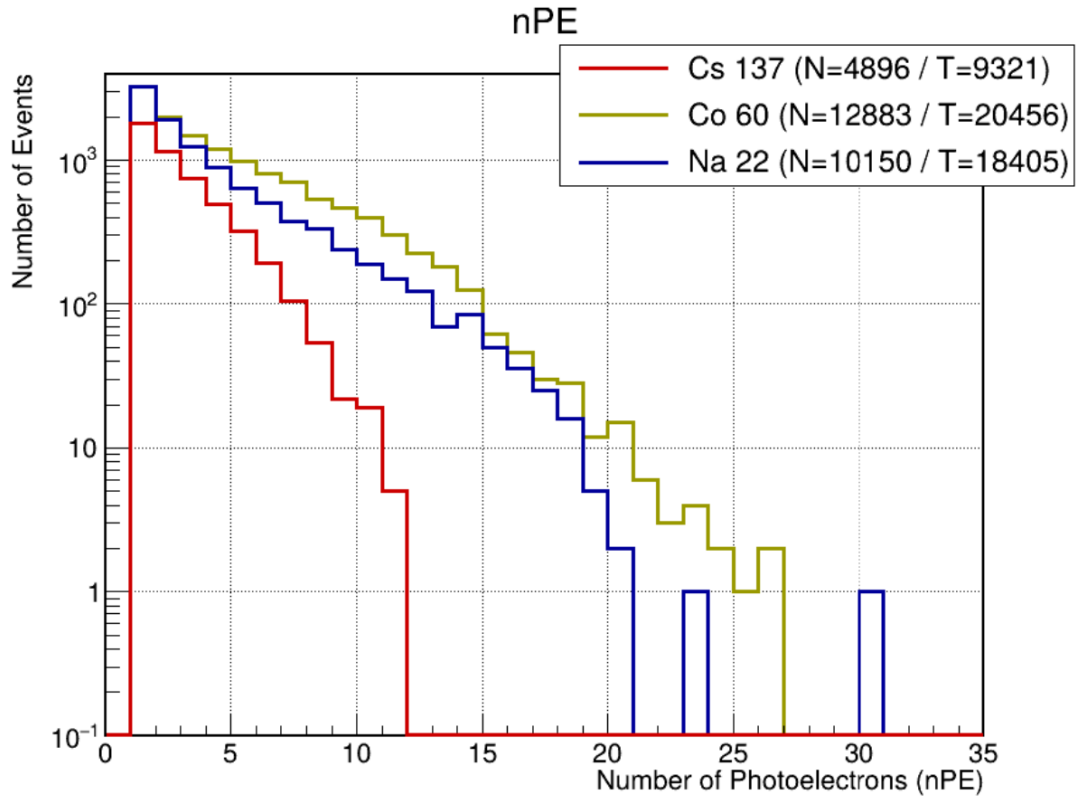




Na 22

Comparison between sources





Conclusion

Study still at a preliminary stage:

- The simulation was implemented with a realistic setup.
- Typical sources with existing results were used.

Initial study for setup optimization:

- Position 1 is the best to maximize the presence of Cherenkov and scintillation light.

Next steps:

- Optimization of the setup geometry.
- Assembly of the test setup.
- Comparison of simulation results with acquired data (locally and with collaborators from Campinas).

Questions?