Ultrafast Inorganic Scintillator
HEPCAT Summer School 2024

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August 19, 2024

Caltech

Goal

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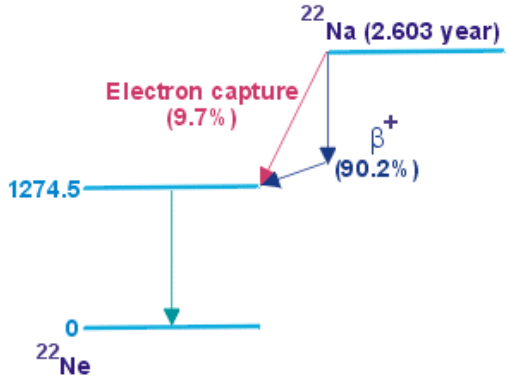
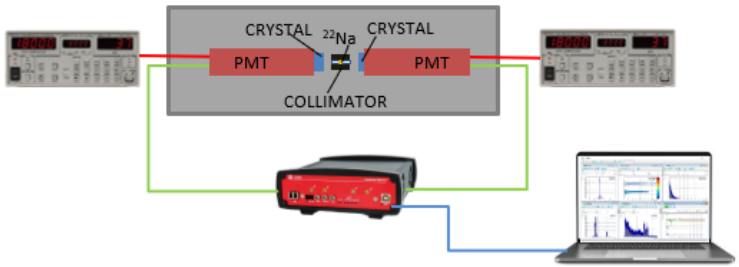
The goal of this module is to measure the characteristics of 2 different inorganic crystal scintillator: Cesium Iodide (CsI) and Barium Fluoride (BaF_2).

- We will use a ^{22}Na positron source
- 2 back-to-back 511 keV gamma rays are produced from electron-positron annihilation
- We will use the coincidence spectrum to measure timing characteristic of CsI and BaF_2



Apparatus



- 1 collimated ^{22}Na positron source ($\approx 4\,\mu\mathrm{Ci} \approx 10^5\mathrm{Bq}$)
- 2 scintillator crystals (CsI, BaF_2)
- 2 photomultiplier tubes (PMT)
- 2 power supplies for the PMTs
- 1 CAEN DT5751 digitizer
- 1 laptop with CoMPASS software

Safety

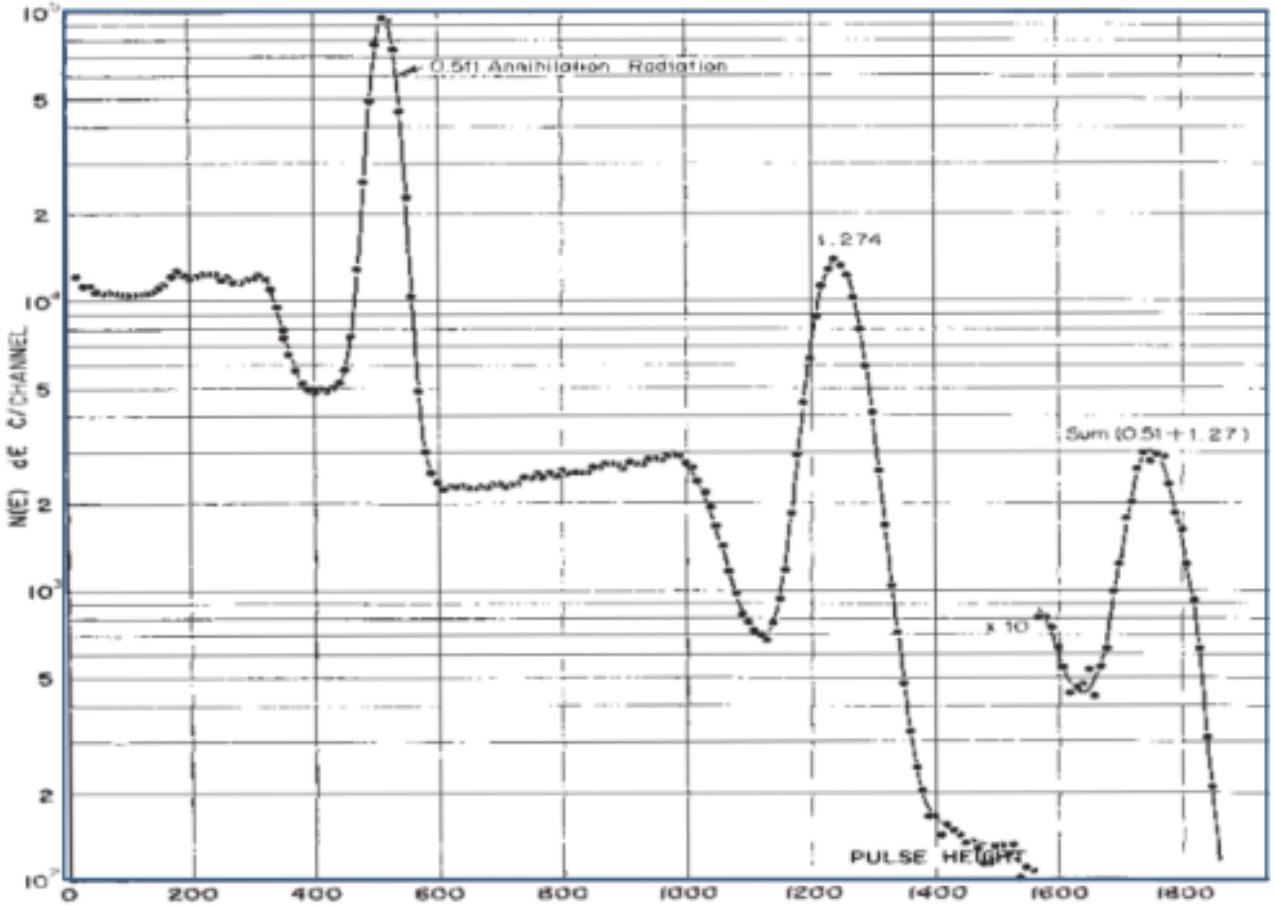
- 4 μCi positron source is sealed and inside a collimator: it is safe as long as it is not dropped on the floor or thrown at the wall
- DO NOT OPEN THE DARK BOX WHEN THE HIGH VOLTAGE IS ON: it will damage the PMT

Procedure

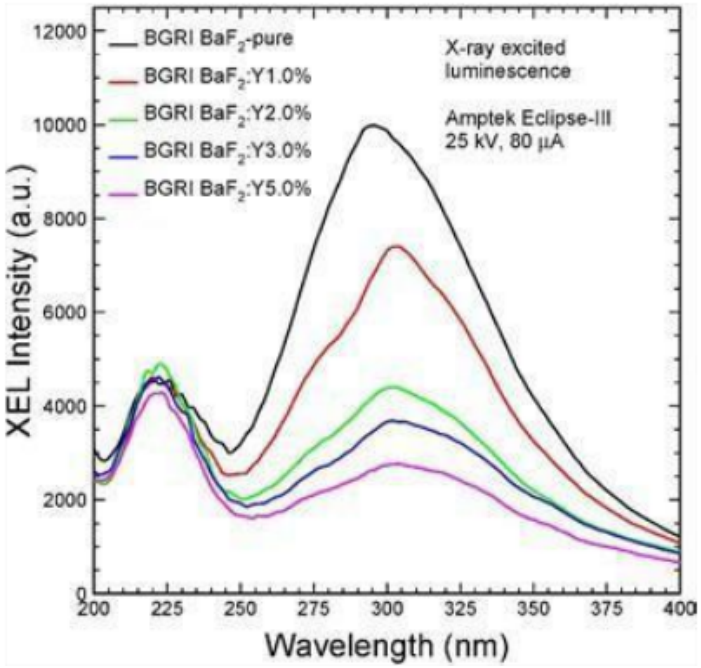
1. Place a scintillator crystal and a PMT in the dark box
   - 3 scintillator crystals: pure CsI, pure BaF_2, Y-doped BaF_2
   - 2 types of Photomultiplier Tubes (PMT): "classic" and solar-blind
2. Close the dark box before turning on the high voltage for the PMTs
3. Take data using the CoMPASS software connected to the digitizer
   - waveform
   - energy spectrum
   - coincidence spectrum

22Na energy spectrum

This is what the energy spectrum of ^{22}Na looks like:



BaF2 emission spectrum



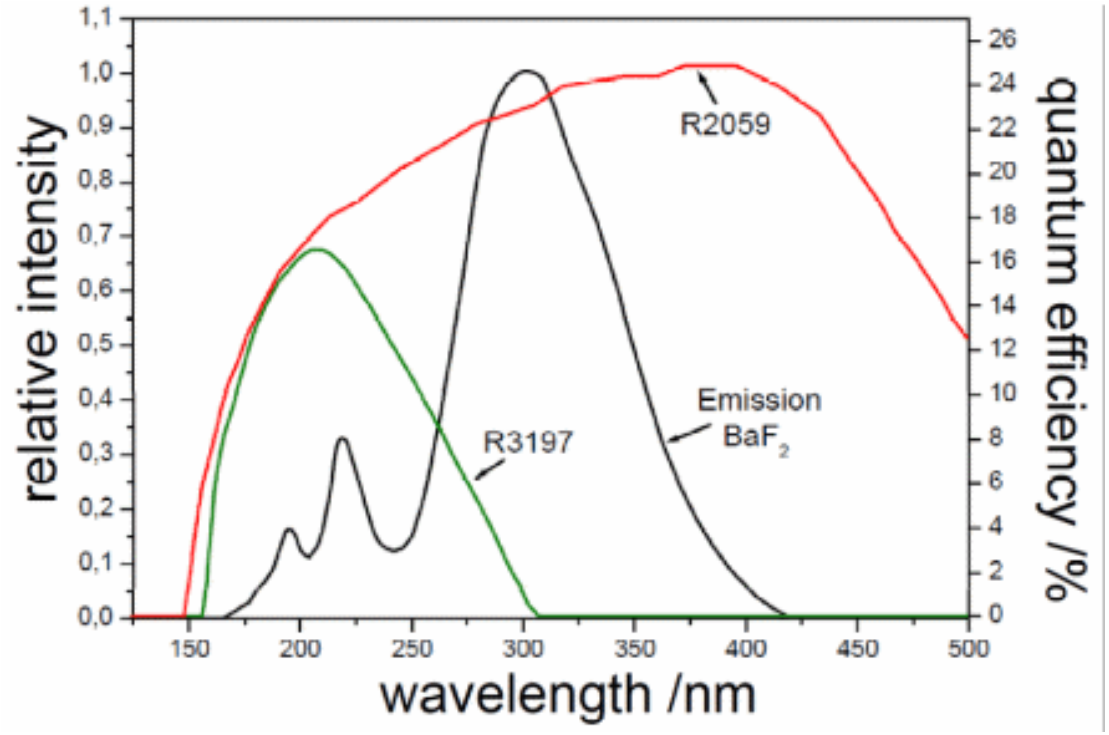
2 peaks:

- Fast component (0.9 ns) at 220 nm
- Slow component (630 ns) at 300 nm

Y-doping reduces the intensity of the slow component

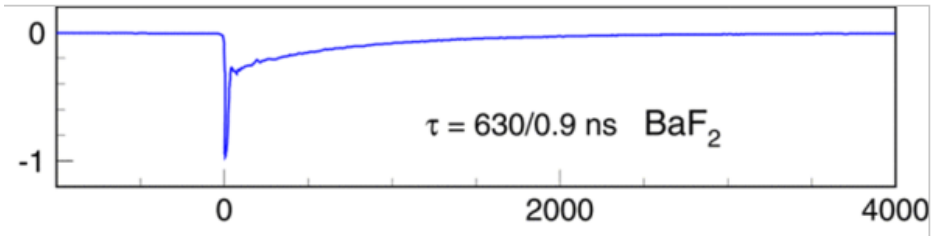
solar-blind PMT

Hamamatsu R2059 PMT characteristics compared to Hamamatsu R3197 solar-blind PMT:



BaF2 waveform

This is what you should see on the oscilloscope:

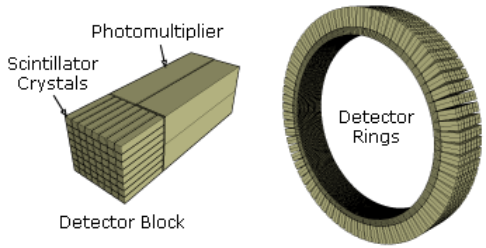


Application: PET scan

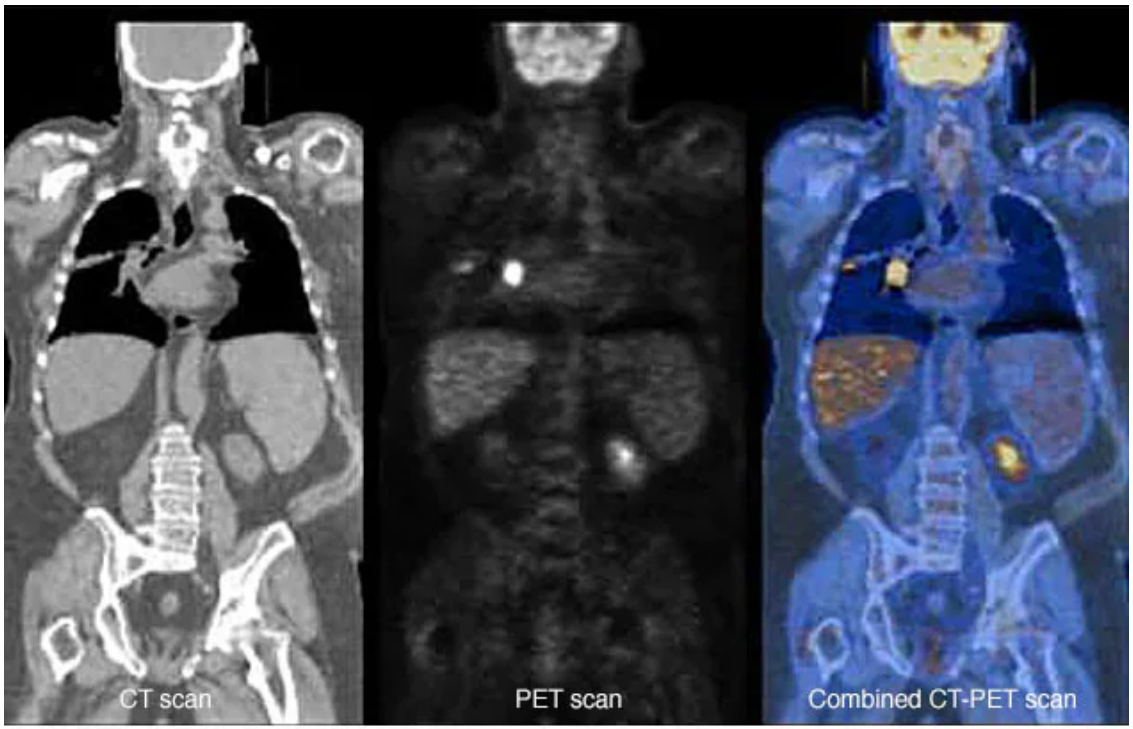
PET: Positron Emission Tomography

PET scanner are state-of-the-art imaging devices used in nuclear medicine:

- Patient ingest a positron-emitting radiotracer
  - detect and image tumors using fluorodeoxyglucose (FDG) tracer
  - detect some brain diseases such as Alzheimer's disease or seizures using ^{15}O or FDG



PET scan image

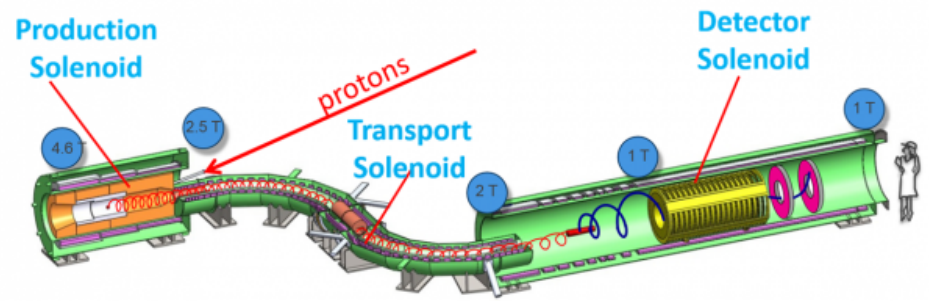


For tumor imaging, FDG tracer is some kind of sugar, and tumor cells consume a lot of sugar, so it appears highlighted on the picture

Application: Mu2e calorimeter

Mu2e

Muon-to-Electron Experiment, located at Fermilab

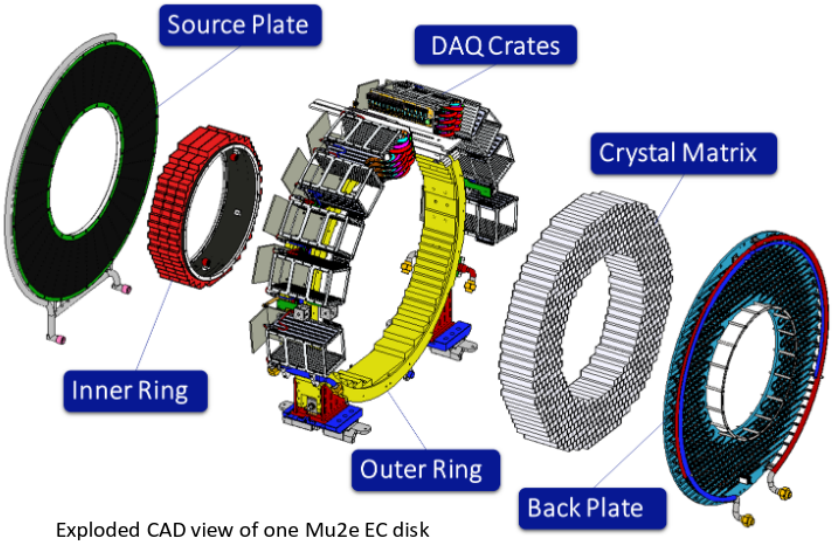


Goal: detect neutrinoless muon conversion into electron

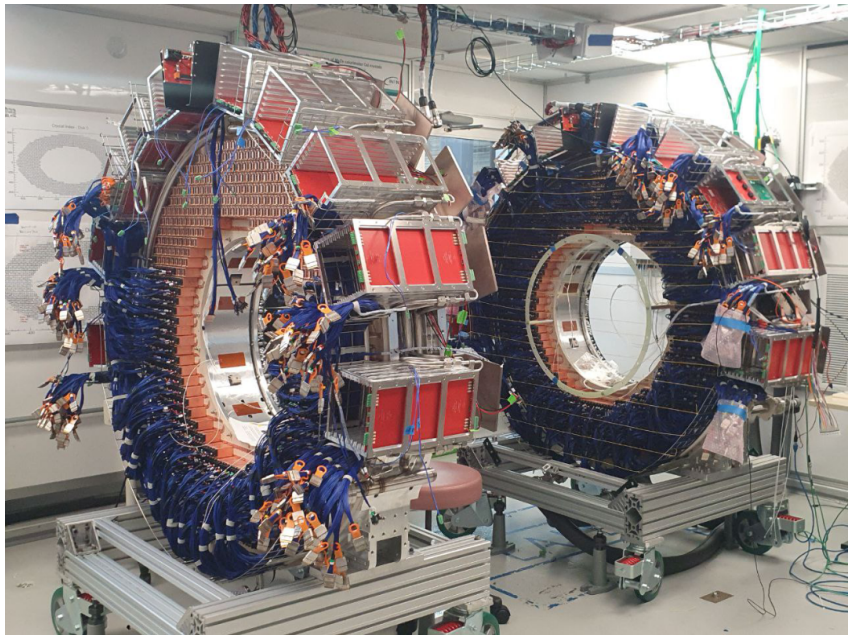
2 detectors:

- Straw tube tracker: measure momentum
- Electromagnetic calorimeter: fast trigger and Particle Identification (PID)

Application: Mu2e calorimeter



Exploded CAD view of one Mu2e EC disk



- 2 annular disks, each made of 674 pure CsI crystals
- each crystal is read out by 2 UV-extended SiPM
- energy resolution < 10 % (at 100 MeV)
- time resolution < 0.5 ns
- position resolution ≈ 1 cm

Conclusion

- Ultrafast inorganic scintillator have a wide range of application in nuclear medecine or particle physics
- Do not open the dark box when the high voltage is on