Polyethylene naphthalate (PEN) as a wavelength shifter in ProtoDUNE-DP

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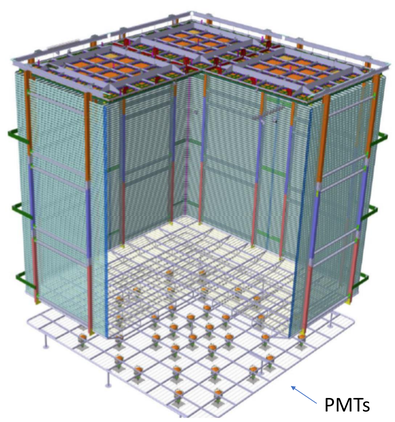
What is ProtoDUNE Dual-Phase?

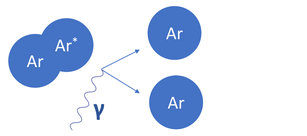


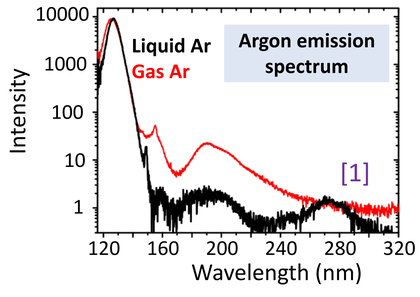
- It is a 6x6x6m^3 active volume **double-phase liquid argon TPC** being operated at CERN since summer 2019.
- It has 300ton of fiducial mass and 6 meters drift distance.
- It is a prototype of the Dual Phase Far Detector of **DUNE.**
- It uses **36 cryogenic photomultiplier tubes,** placed below the active volume**,** to detect scintillation light.
- See first results in poster done by A. Gallego-Ros.

Scintillation in liquid argon

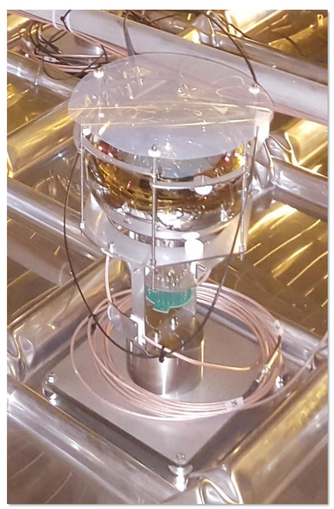
Scintillation light in liquid argon is emitted by radiative decay of molecular argon excimers.

- Emission peak at **128nm** where most photosensors are not sensitive.
- **Fluorescent materials** are needed to shift the wavelength of the emitted photons towards the visible light range.





Wavelenght shifting in ProtoDUNE Dual-Phase

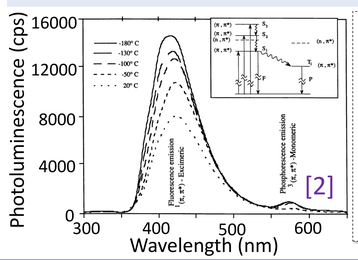


Polyethylene naphthalate (PEN)

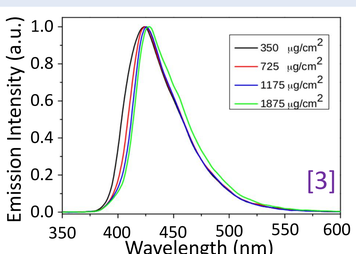
- 30 PMTs are covered with a **PEN** foil.
- Circular foils of 24cm diameter and 125um thickness, placed tangent to the PMT surface.
- Thermoplastic **very easy to install**.
- Novel and promising material, but re-emission efficiency is not well known.

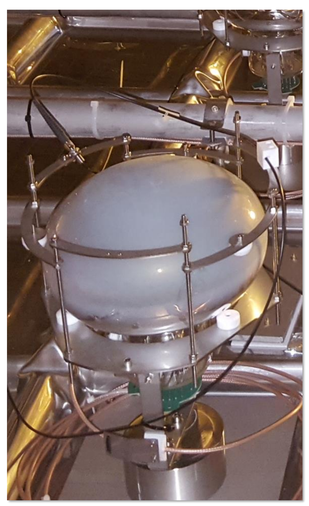
Tetraphenyl butadiene (TPB)

- 6 PMTs are coated with **TPB.**
- Directly deposited over the PMT glass surface with a **dedicated evaporation set-up**.
- Coating density of 0.2mg/cm2
- Very efficient and widely used in many experiments.



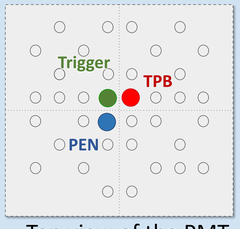
- Both materials show a similar re-emission spectrum, with a peak around 430nm.
- Our goal is to meaure the PEN re-emission efficiency (ε), i.e. the ratio of photons converted to visible light.





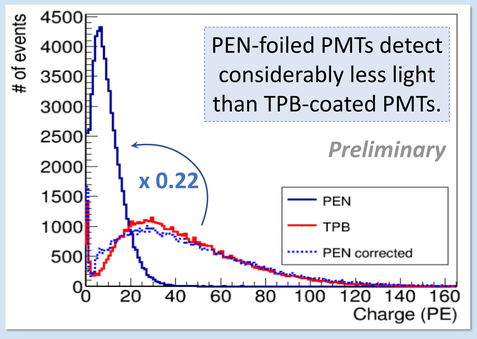
Polyethylene naphtalate performance measurement in ProtoDUNE Dual-Phase

Direct experimental result



Top view of the PMT layout

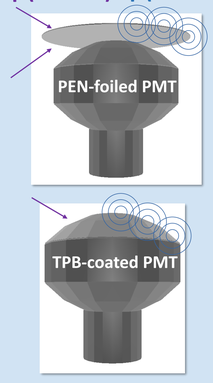
- Triggering on cosmic muons.
- Comparing two PMTs symmetrically placed w.r.t the detector axis and the trigger channel.



The ratio of photo-electrons detected on PEN-foiled PMTs w.r.t TPB-coated PMTs is:

$NPE_{PEN}/NPE_{TPB} = 0.22 \pm 0.01$ considering signals of ~30PE on average.

Geometrical considerations (from simulations)



- The TPB coated surface receives 30% less photons than PEN foil:

  $\gamma_{coat}/\gamma_{foil}=0.7$

- Assuming **isotropic re-emission** on the TPB/PEN, only 25% of the photons re-emitted by the PEN will arrive to the photocathode ($\Delta_{foil}=0.25$), for the 50% in the TPB coating ($\Delta_{coat}=0.5$).

Results and discussion

- Correcting the geometrical differences, a value for the relative PEN/TPB re-emission efficiency at **128nm** and **87K/cryogenic temperature** based on protoDUNE-DP measurements is obtained:

$$\frac{\varepsilon_{PEN}}{\varepsilon_{TPB}} = \frac{NPE_{PEN}\,\gamma_{coat}\,\Delta_{Coat}}{NPE_{TPB}\,\gamma_{foil}\,\Delta_{Foil}} = 0.30 \pm 0.08$$

Preliminary

- Taking into account the effective QE of the TPB coated PMT at room temperature of 0.14±0.02 (ratio of detected photo-electrons per incident 128nm photon, measured in the lab), and correcting to cryogenic temperature [3], we obtain an absolute value for the PEN re-emission efficiency of:

$$\varepsilon_{PEN} = \frac{NPE_{PEN}\,\gamma_{coat}}{NPE_{TPB}\,\gamma_{foil}}\frac{QE_{eff,TPB}}{\Delta_{Foil}QE} = 0.52 \pm 0.15$$

Preliminary

(being QE=0.18±0.02, the PMT quantum efficiency)

- Similar values have been reported in the literature [4]: $\varepsilon_{PEN}/\varepsilon_{TPB}$ ~ 0.38 and ε_{PEN} ~ 0.42, but they used different PEN/TPB configurations, which makes the measurements not totally comparable.
- **Polyethylene naphthalate is not as efficient as TPB, but its mechanical advantages make it a good candidate for future experiments.**

REFERENCES

[1] T. Heidi et al., EPL **91** (2010) 62002

[2] D. Mary et al., J. Phys. D Appl. Phys. **30**, 171 (1997)

[3] R. Francini et al., JINST **8**, P09006 (2013)

[4] M. Kuzniak, Eur. Phys. J. C. (2019) 79:291

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