Studies of poly(ethylene naphthalate) for use as a structural scintillator in low background experiments

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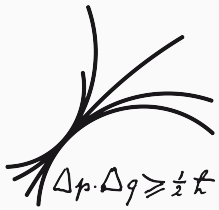
LRT Conference, Jaca



Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

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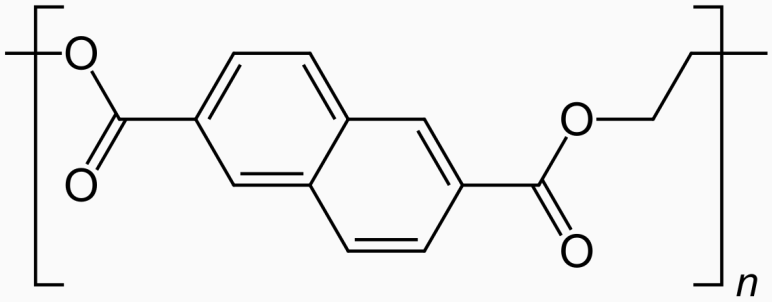
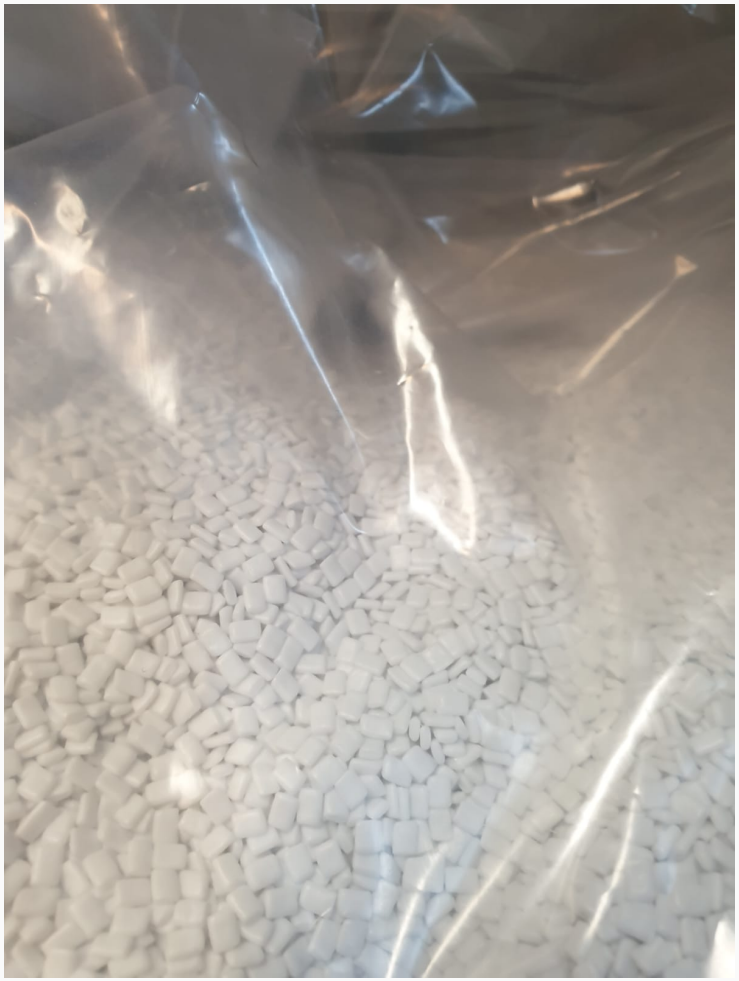
What is PEN?



Top: Structural formula of PEN.
Bottom: Custom molded PEN capsule parts

- Commercially available
- Brandnames: Teonex
- Relatively cheap
- Experience in manufacturing
- Transparent plastic
- Known to scintillate [arXiv:1903.10736]
  - Self-veto?
- PEN as low background material?

Radiopurity Screening



Raw PEN Granulate

- Low-background experiments need low-background material
- Commercially available PEN granulate gamma screened at LNGS
- Two types: TN8050, TN8065
- Reference measurement: GERDA HV-capacitor [arXiv:1903.10736]

Radiopurity Results

	TN-8065S	TN-8050SC	Teonex Q51 [Eur. Phys. J. C (2013) 73:2445]
	[mBq/kg]		
Ra-228	< 0.15	< 0.15	
Th-228	(0.23 ± 0.05)	< 0.13	< 1.4
Ra-226	(0.25 ± 0.05)	< 0.11	< 2.0
Th-234	< 11	< 15	
Pa-234m	< 3.4	<3.0	
U-235	< 0.066	< 0.054	
K-40:	1600 ± 400	1000 ± 400	< 3.6
Cs-137	< 0.057	< 0.064	

Measurement by M. Laubenstein (68 % C.L.)

- Commercially available pellets have comparable counts to materials in use
- Surface contamination
- Reduce levels in PEN by synthesis

Material Properties

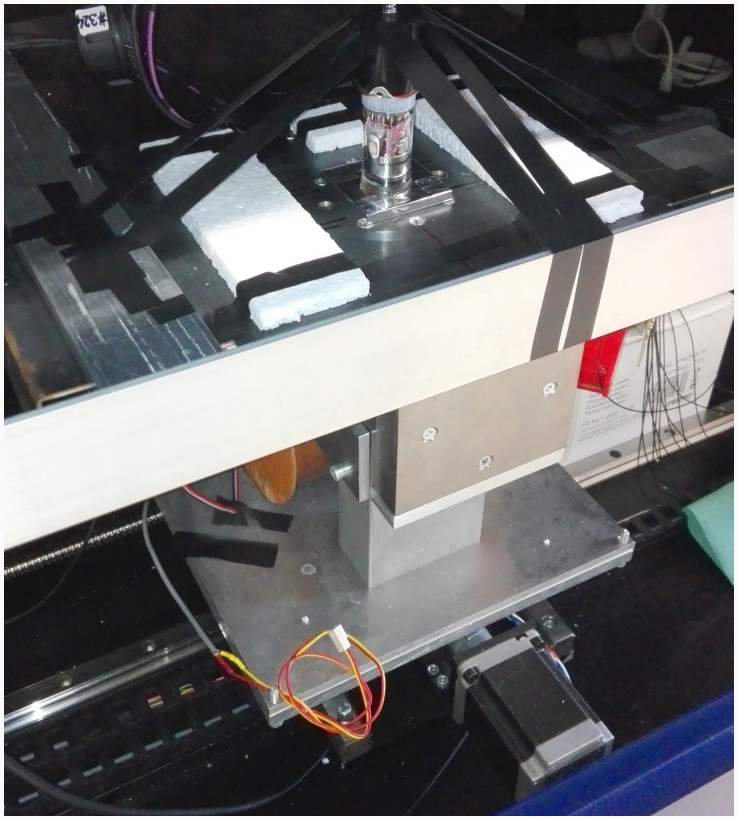
- Very resistant to most acids and alcohols
  - Can be cleaned aggressively
- 3 point bending test of material at room temperature and in LN2
- High structural stability
- Structural, transparent material ✓

Three-point bending flexural test results with PEN samples ($15 \times 30 \times 3$ mm^3)

Temperature	PEN at 296 K	PEN at 77 K	Copper at 296 K [www.memsnet.org/material/coppercubulk/]
σ_{el} [MPa]	108.6 ± 2.6	209.4 ± 2.8	100
E-Modulus [GPa]	1.855 ± 0.011	$3.708.1 \pm 0.084$	128

Molding PEN Parts

Light Yield Measurements

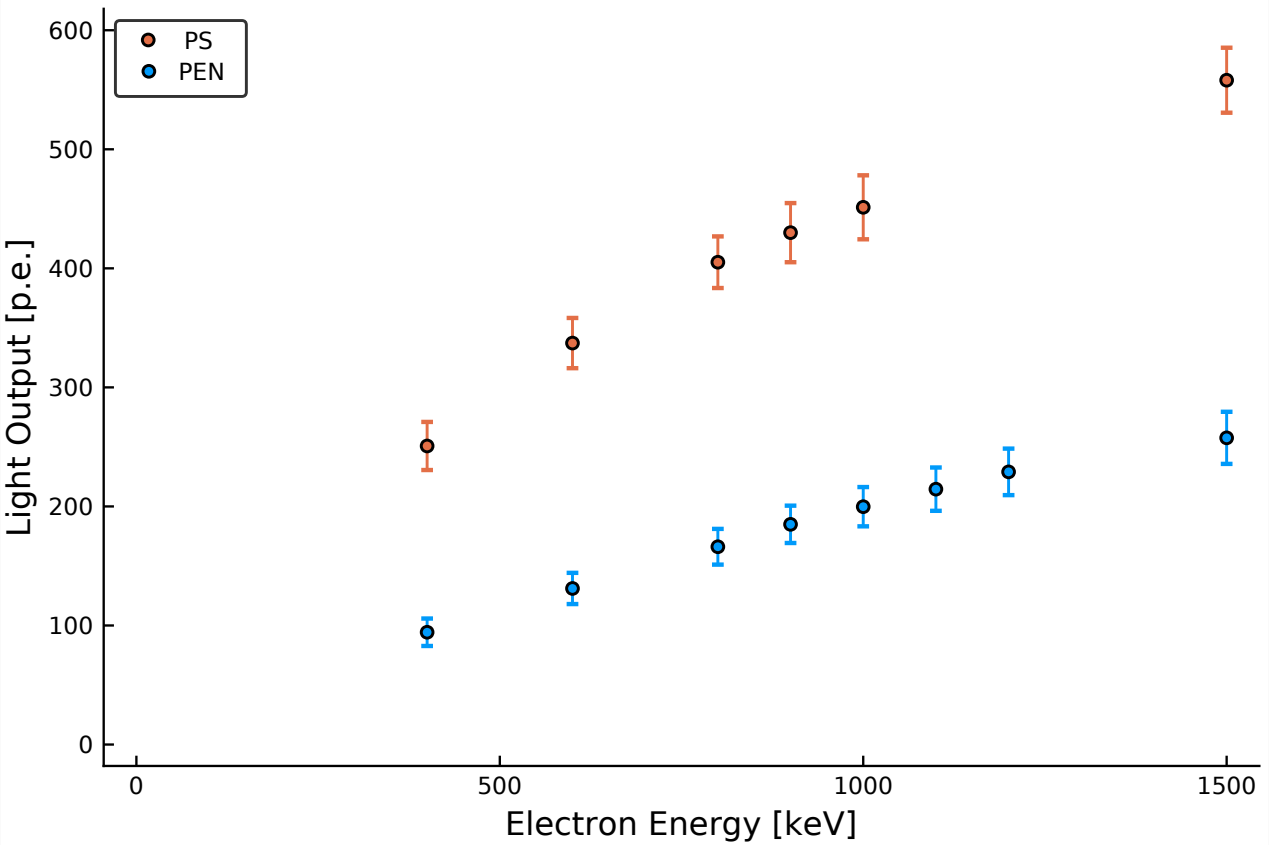


Set up used for light yield measurements

- Scintillation yield measured in electron spectrometer

  [doi:10.1088/1748-0221/10/09/P09008]
- Electron energies between 0.4 - 1.6 MeV used
- Compared to a PS, SuperNEMO

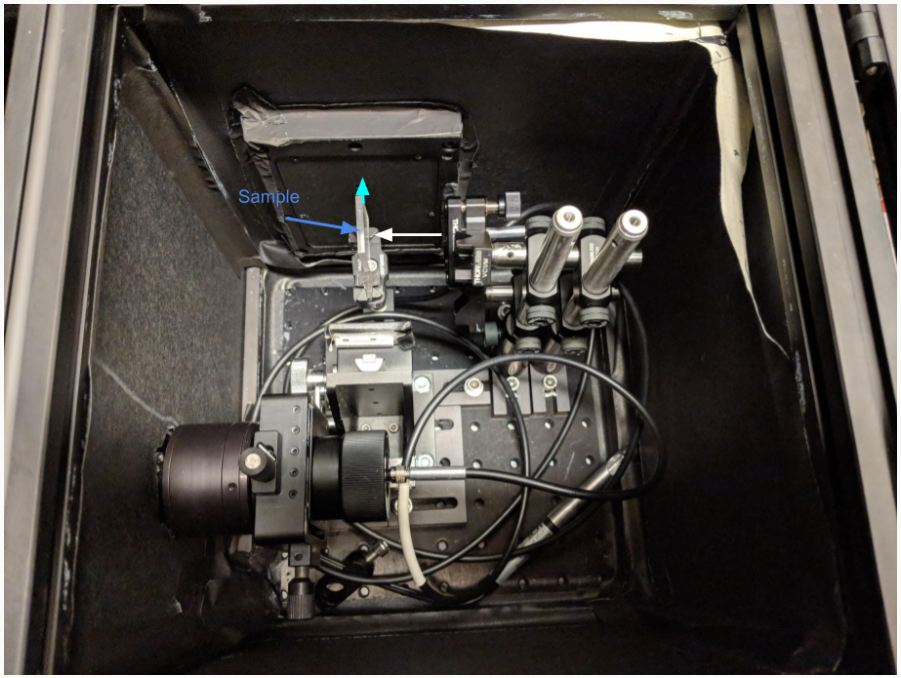
Light Yield Results



PS and PEN light output when excited with mono-energetic electrons (FWHM = 1.0 ± 0.2 % at 1 MeV)

- Light yield for PEN around 2/3s of PS
- Lower yield then literature, self produced tiles
- Trade off: cleanliness vs light yield

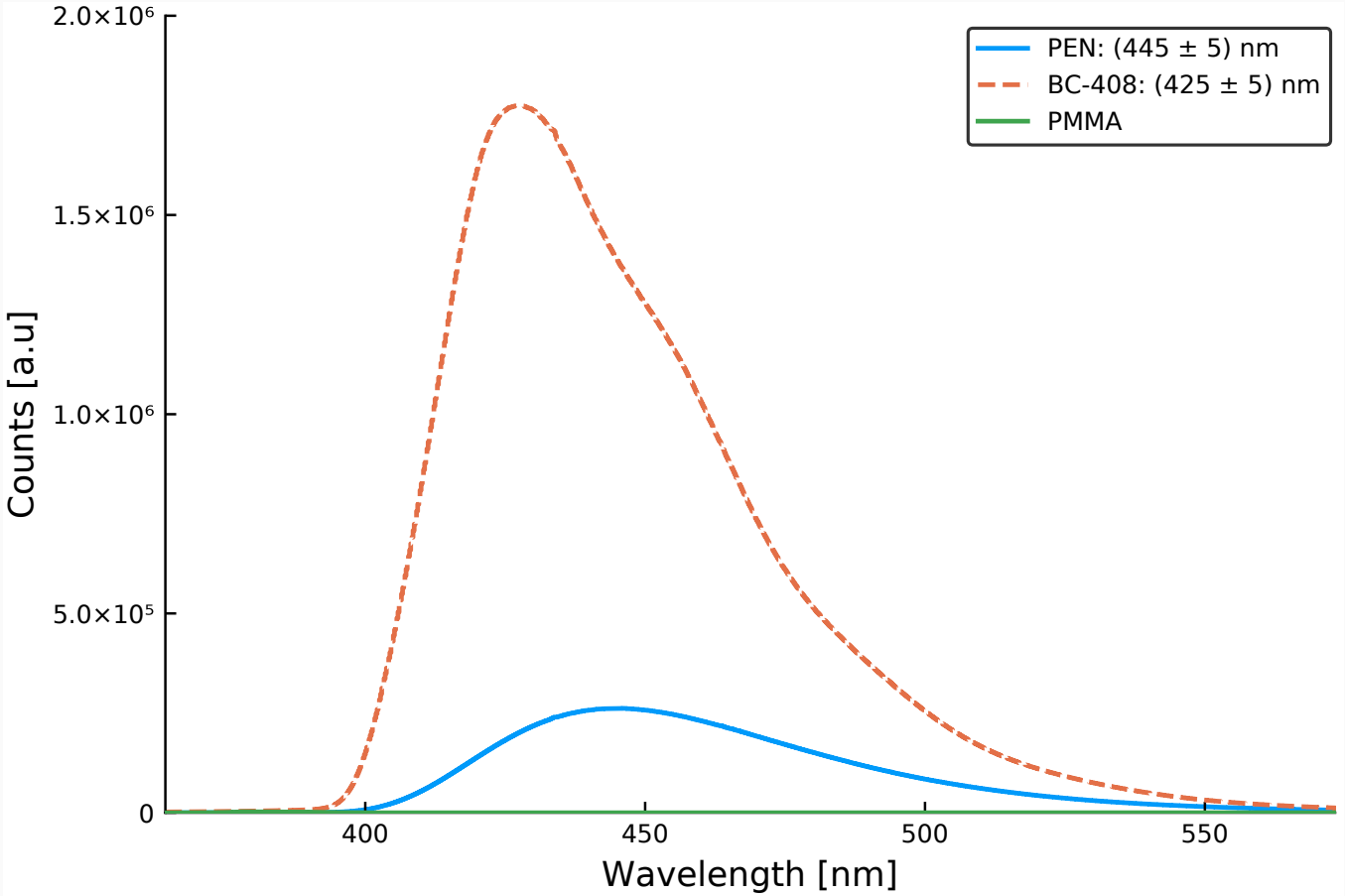
Emission Spectra



Set up for emission spectrum

- PEN emits blue light, no extra fluors
- Good match to commercial PMTs and SiPMs
- Emission spectrum measured with spectrograph
- BC-408 and PS similar yields, use BC-408 as reference
- Excited by monochromatic 380 nm light
- Drawback: limited absorption length

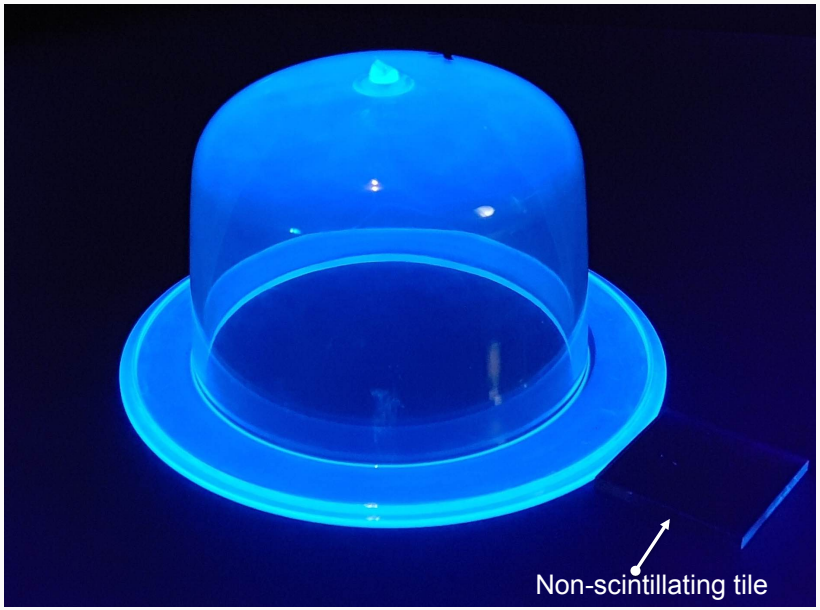
Emission Spectra Results



Emission Spectra of PEN, BC-408 and PMMA tiles (30 x 30 x 3 mm^3)

- Blue emission from PEN
- Lower yield than BC-408

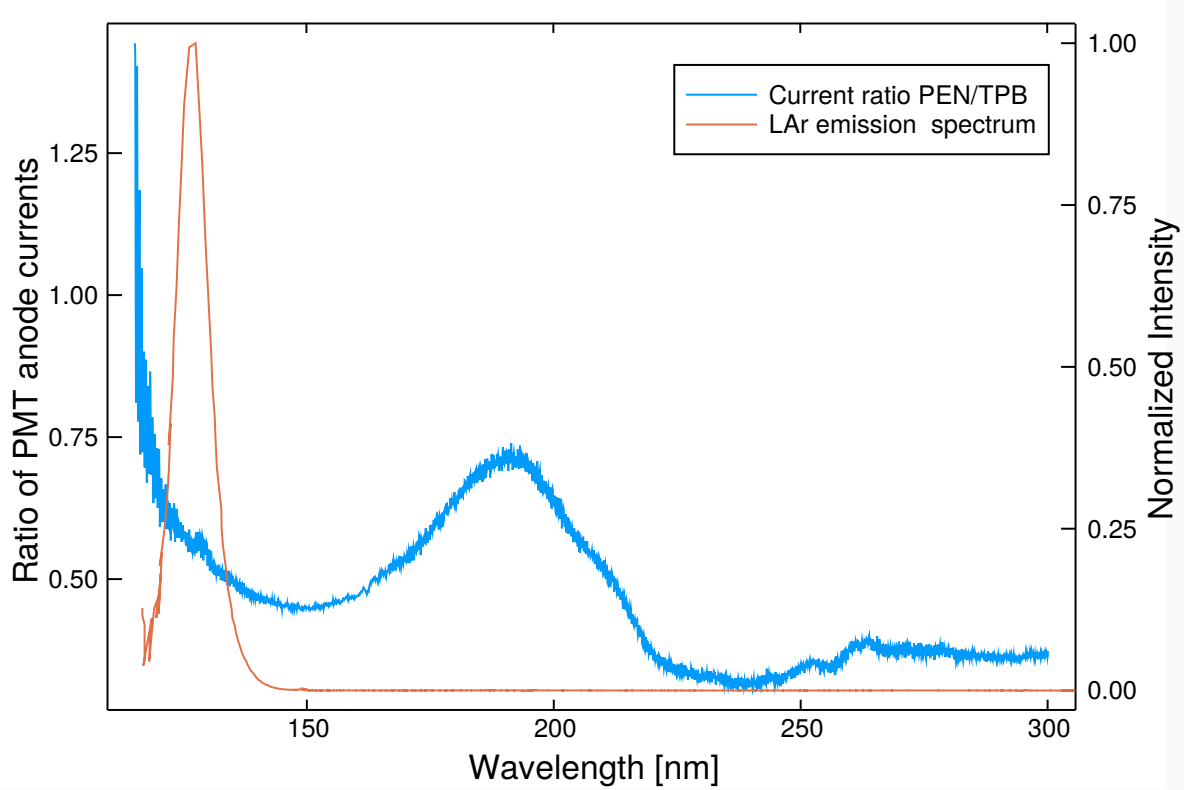
Wavelength Shifting



PEN exposed to UV

- Measured emission spectrum from wavelength shifting, not scintillation
- Can PEN shift VUV?
- 126 nm light from LAr source
- Compare efficiency of tile coated with TPB and PEN

Wavelength Shifting Results



Left: Ratio of PMT anode currents (blue line) PEN/TPB Right: VUV/UV emission spectrum of liquid argon [arXiv:1511.07718]

- Efficiency of wavelength shift around 50% of TPB at 126 nm
- Optically active without scintillation
- Enhanced efficiency of liquid argon vetoes
- Consistent with DEAP: arXiv:1806.04020

Summary

- PEN is a commercially available plastic, relatively radiopure
- Good structural properties, suitable as a support material
- Both scintillates and wavelength shifts
- Emission peak suitable for many photo-detectors
- Scintillation yield lower than other plastics,
  attenuation limits part size
- Demonstrated to wavelength shift liquid argon peak emission to blue
- PEN is already in consideration for future low-background experiments, such as DarkSide, DUNE, LEGEND, KAMLAND-ZEN