9th mini-school
on Particle and Astroparticle Physics

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R&D: Production and optical characterisation of PET and PEN scintillator samples

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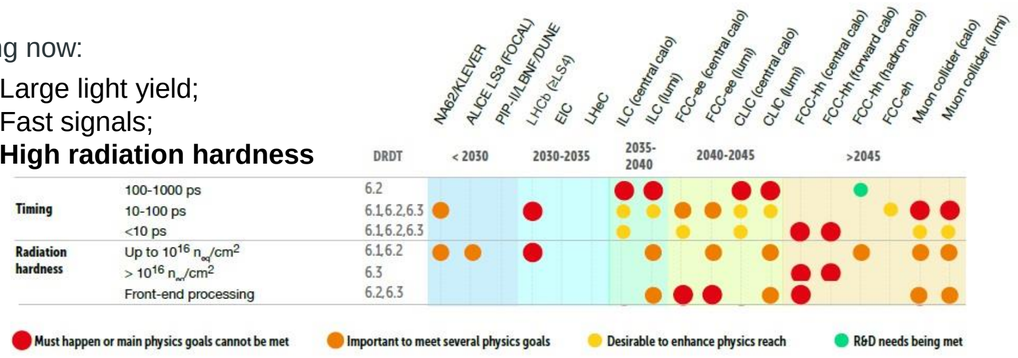
Challenges for future scintillator-based detectors in High-Energy Physics

- Future precision/high energy colliders will impose stringent requirements on next generation detectors
- R&D starting now:
  - * Large light yield;
  - * Fast signals;
  - * **High radiation hardness**



ECFA Detectors R&D Roadmap

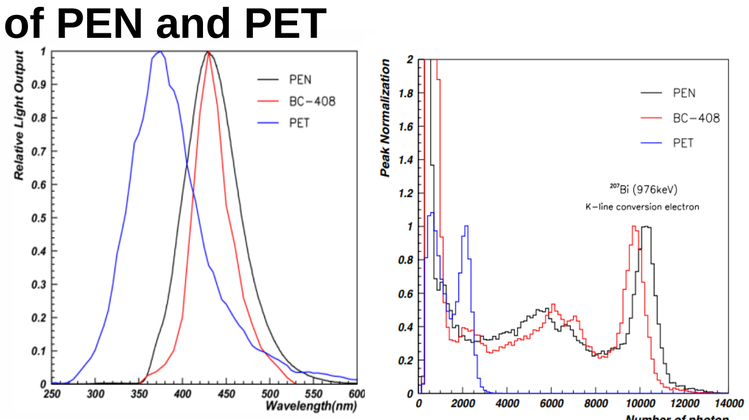
Objectives

Research new plastic scintillating materials, *PEN (Polyethylene Naphthalate)* and *PET (Polyethylene Terephthalate)*, with a specific focus on their optical and scintillation properties.

Scintillation properties of PEN and PET

- Competitive light yield
- Emits light ≅ in the same λ as BC-408 (commercial scintillator)
- Good radiation hardness

	PEN	BC-408	PET
Light Output photons/MeV	~ 10500	~ 10000	~ 2200
Max WL emission (nm)	425	425	370

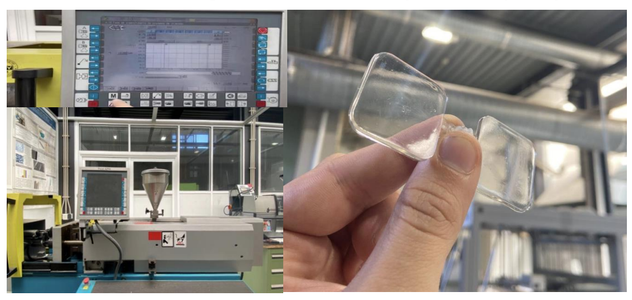


Spectra Emission and Number of photons for PEN, PET and BC-408

Sample production

PEN and *PET* produced in collaboration with the Institute for Polymers and Composites (IPC) of the University of Minho

- Injection Moulding:
- Samples currently measure 30 x 30 x 2 mm^3
- Some controlled parameters:
  - * Injection speed
  - * Cooling time
  - * Melting temperature
  - * Pressure
  - * Mold Polishing



Setup for Measuring Light Response (LR)

- ^{90}Sr source scans the scintillators
- Wave-Length Shifiting (WLS) fibers collect light from the scintillator and guide it to the PMT
- Digital Multimeter: integrated signal over 400 ms
- Control and data acquisition software (Labview)

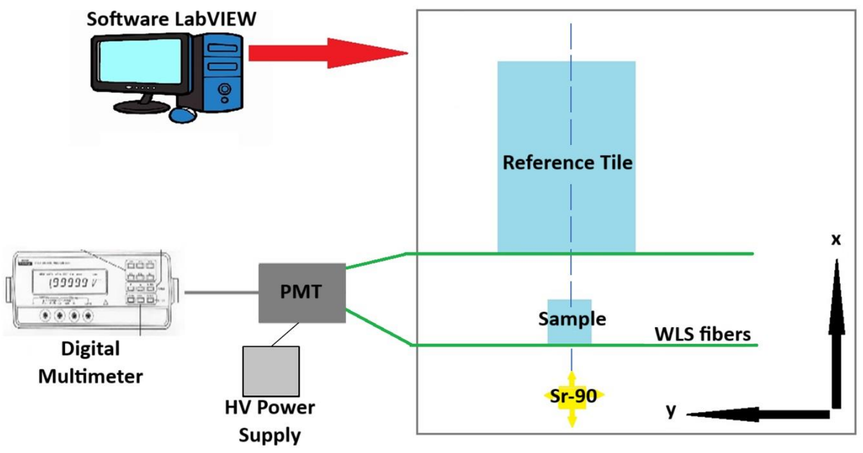
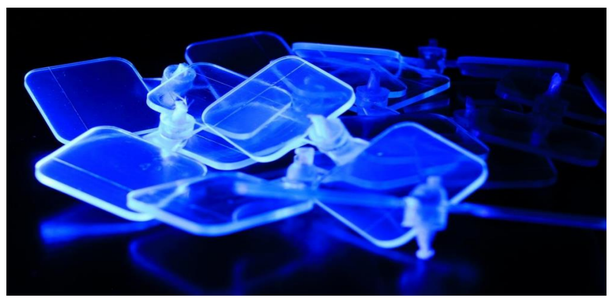


Diagram of how the "tilemeter" works, where the light response is measured

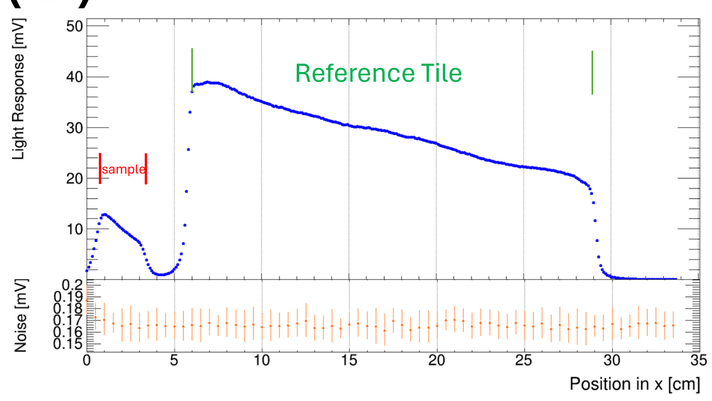
Light response of PEN sample to UV source



Picture by Agostinho Gomes

Sample Light Response (LR)

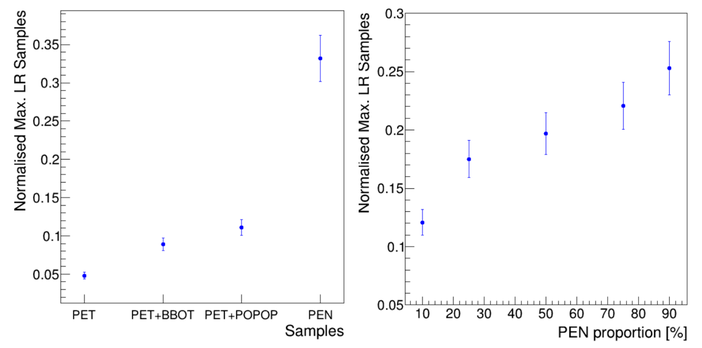
- Both scintillators are wrapped in a Tyvek® envelope to improve light collection by the fibres
- Scintillator signal: each point is the average of 30 measurements.
- Noise value is updated at each 5 scan points
- LR = scintillator signal – noise value
- It is not trivial to compare the LR_{sample} with $LR_{Ref\ Tile}$
  - Different materials
  - different dimensions
  - fiber-scintillator contact area



Light response (in mV) as a functionof ^{90}Sr source position of the PEN sample and the reference scintillator tile

Light Response: blends and PET+dopants

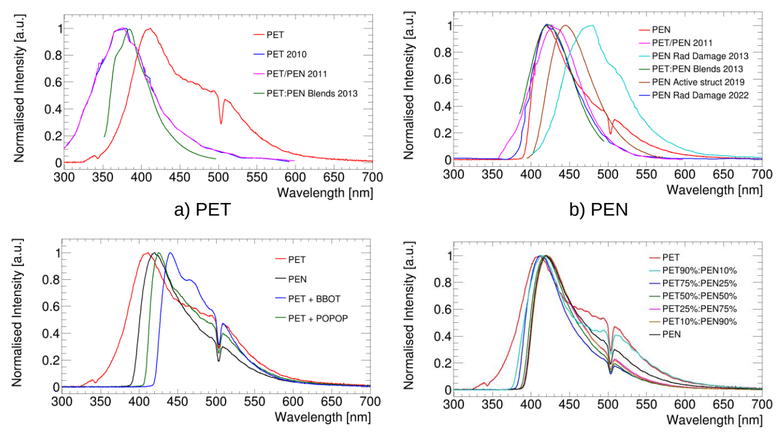
- Dopant addition: +80% (BBOT) and +120% (POPOP) in Norm Max LR
- Linear dependence as a function of the percentage of PEN
- Blend production
  - Material is initially mixed (granule form)
  - Mixture is left at melting temperature for 5 minutes in the machine before injection



Left: Norm Max LR for samples + dopants (0.022%). Right: Norm Max LR for blends with different proportions of PEN

Emission Spectra

- Peak PEN ~ 420 nm compatible with literature
- Peak PET ~ 410 nm, higher than literature
- Differences in PET peaks could be attributed to the varied material sources
- Add POPOP and BBOT to the PET causes the WLS of the original scintillation light
- Results peaks:
  - POPOP ~ 425 nm
  - BBOT ~ 440 nm
- PET:PEN blends
  - 10:90, 25:75 and 50:50 near PEN
  - 90:10 and 75:25 near PET



Emission spectra of the (a) PET, (b) PEN, (c) PET+dopants and (d) PEN:PET mixtures samples. Data from the literature is displayed for comparison

PET 2010 [1], PET/PEN 2011 [2], PET:PEN Blends 2013 [3], PEN Rad Damage 2013 [4], PEN active struct 2019 [5], PEN Rad Damage 2022 [6]

Conclusions

- Future HEP experiments with scintillator detectors will need cheap materials with high scintillation efficiency and radiation hardness.
- Manufacture of pure PEN and PET scintillators, PET+dopants, and PET:PEN mixtures in different proportions
- Emission spectra of PET and PEN are consistent with the literature; PET with dopants exhibits wavelength-shifting (WLS) in light emission, and in blends, PEN demonstrates predominant spectral
- LR of PEN is about 7 times higher than PET. Additionally, the addition of dopants to PET doubles its light yield. As expected, there is a correlation between LR and the proportion of PEN in blends

Acknowledgement: Exploratory project **"**DLight: Novos Materiais Cintilantes para Futuros Detectores de Luz", EXPL/EME-NUC/1311/2021, DOI 10.54499/EXPL/EME-NUC/1311/2021. OE, FCT-Portugal, LA/P/0016/2020. R. Machado was supported by the PhD fellow ship SFRH/PRT/BD/151543/2021 from PT-CERN/IDPASC. B. Pereira was supported by the PhD fellow ship SFRH/PRT/BD/152223/2021 from PT-CERN/IDPASC and by the CERN Doctoral Student Programme. R. Pedro was supported by the Junior Researcher fellow ship 2021.01023.CEECIND from the Individual Call to Scientific Employment Stimulus by FCT Portugal.