Update on Scintillator studies @ MPP Munich

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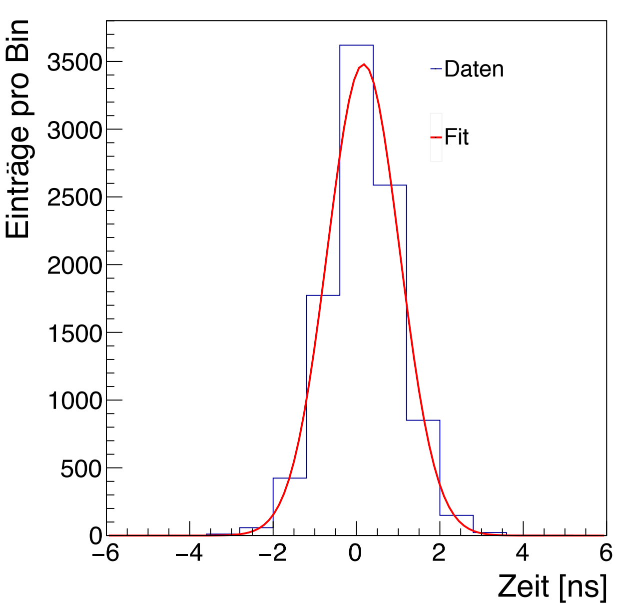
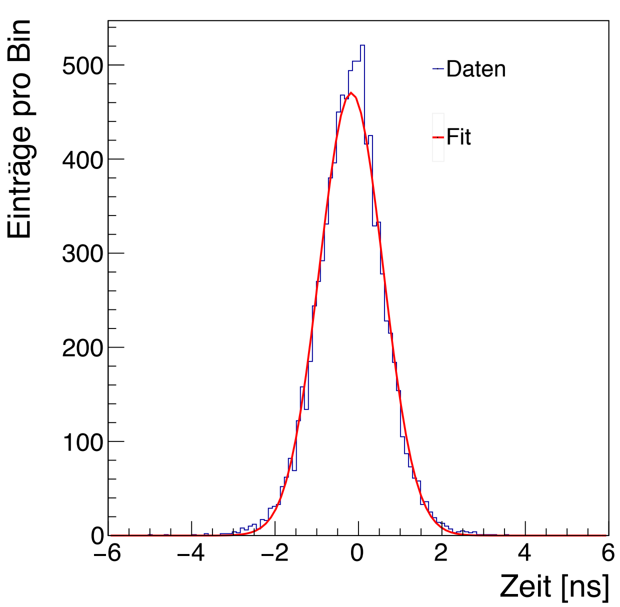
$\Delta p \cdot \Delta q \geq \frac{1}{2}\hbar$

Time resolution

- In the context of CLAWS (Belle II commissioning) measure the time resolution of our tile/MPPC system
- Setup: cosmic muons, stack of 4 PS tiles (as used in CLAWS) , coincidence trigger on the top and bottom tile
- Picoscope sampling rate 800 ps (with 4 channels operating)
- Determine the time difference between the signals in the two middle tiles
  - **Leading edge** (fixed threshold) - time walk effect
  - **Constant fraction** of peak value (with or without interpolation between bin centres that are 800 ps apart)





Time resolution

- Methods give similar results, **constant fraction** with interpolation gives the most stable fit
- Dependence on the cut value is small
- Time resolutions of < 1 ns can be achieved in CLAWS
  - Single tile resolution estimated **500 ps** (SuperKEKB bunch spacing is 4 ns)

Leading edge

$Schwelle\,[mV]$	$\sigma\,[ns]$	$RMS\,[ns]$	$\frac{\sigma}{RMS}$
5	0,74	0,78	0,91
10	0,74	0,89	0,83
15	0,81	1,01	0,80
20	0,87	1,15	0,76
25	0,97	1,34	0,72
30	1,05	1,48	0,71

Constant fraction

$Constant\ Fraction$	$\sigma\,[ns]$	$RMS\,[ns]$	$\frac{\sigma}{RMS}$
0,1	0,71	0,76	0,93
0,15	0,71	0,79	0,90
0,2	0,71	0,83	0,86
0,25	0,74	0,88	0,84
0,3	0,78	0,92	0,85
0,35	0,82	0,97	0,85
0,4	0,84	1,02	0,82
0,45	0,89	1,08	0,82
0,5	0,94	1,16	0,81

Constant fraction with interpolation

$Constant\ Fraction$	$\sigma\,[ns]$	$RMS\,[ns]$	$\frac{\sigma}{RMS}$
0,1	0,66	0,68	0,97
0,15	0,69	0,71	0,97
0,2	0,72	0,75	0,96
0,25	0,76	0,79	0,96
0,3	0,80	0,83	0,96
0,35	0,84	0,88	0,95
0,4	0,89	0,94	0,95
0,45	0,94	1,00	0,94
0,5	1,01	1,08	0,94

New Scintillator Material: PEN

- PEN - Polyethylene naphthalete $(C_{14}H_{10}O_4)_n$
- Studies show that pure PEN scintillates comparably to BC408
  - H. Nakamura *et al.*, EPL, 95 (2011) 22001
  - E. Tiras for the CMS Collaboration, arXiv: 1510.08572

Wikipedia: *"It also has been found to show supreme scintillation properties and is expected to replace classic plastic scintillators."*

- Injection moulding being tested at the *Fraunhofer Institute for Chemical Technology ICT* and the *TU Dortmund*
- Collaboration with the GERDA group at MPP

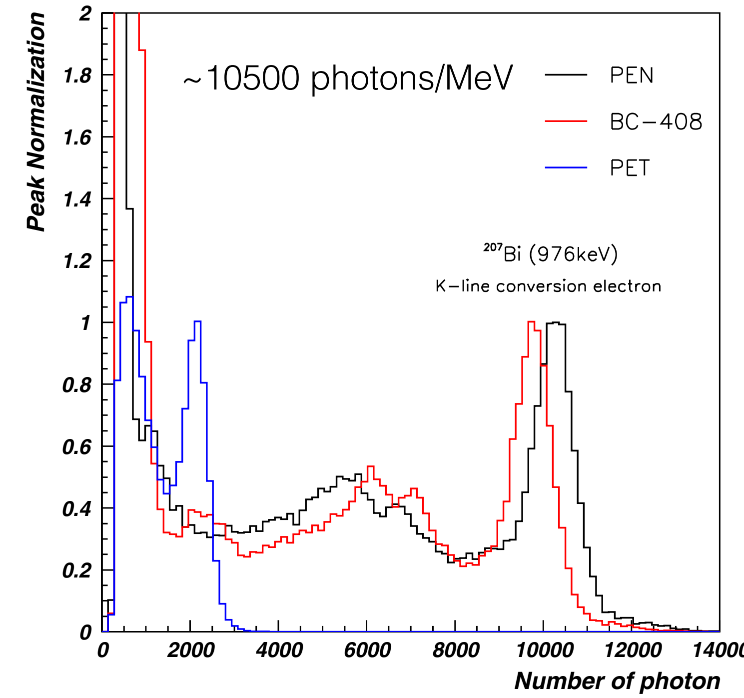


Fig. 2: Light output spectra of polyethylene naphthalate (PEN; black line), commercial organic scintillator (BC-408 (ref. [14]); red line) and a plastic bottle (PET; blue line).

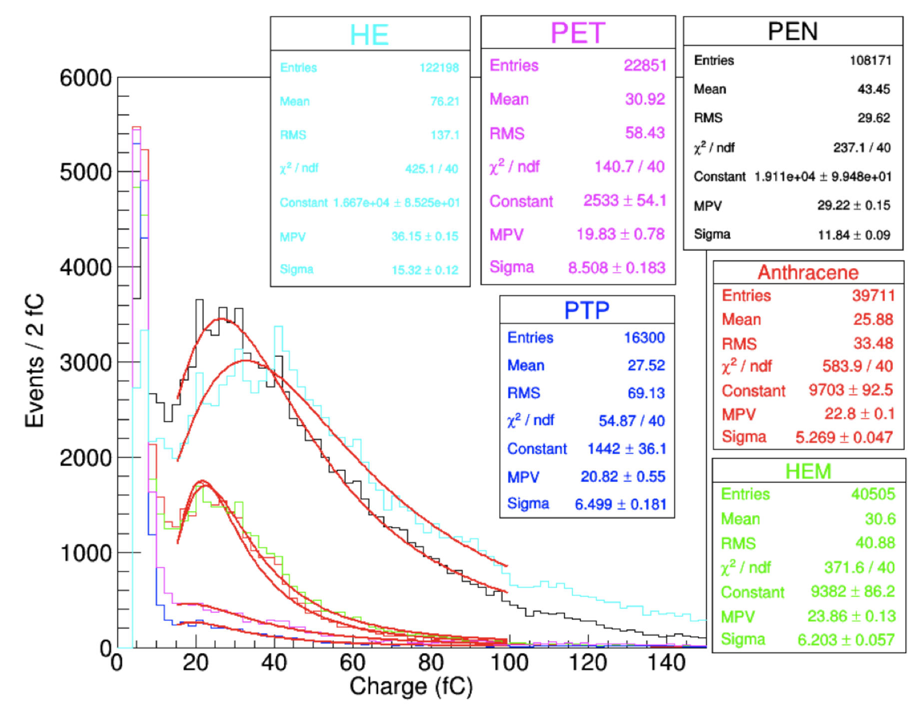
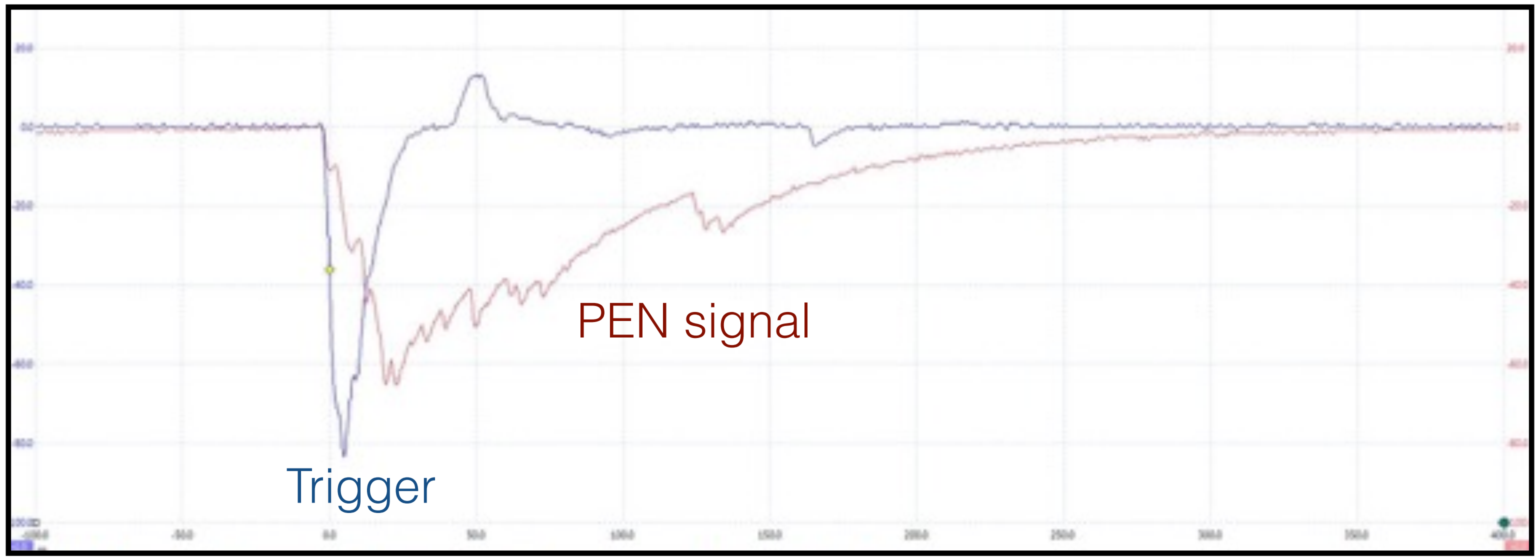
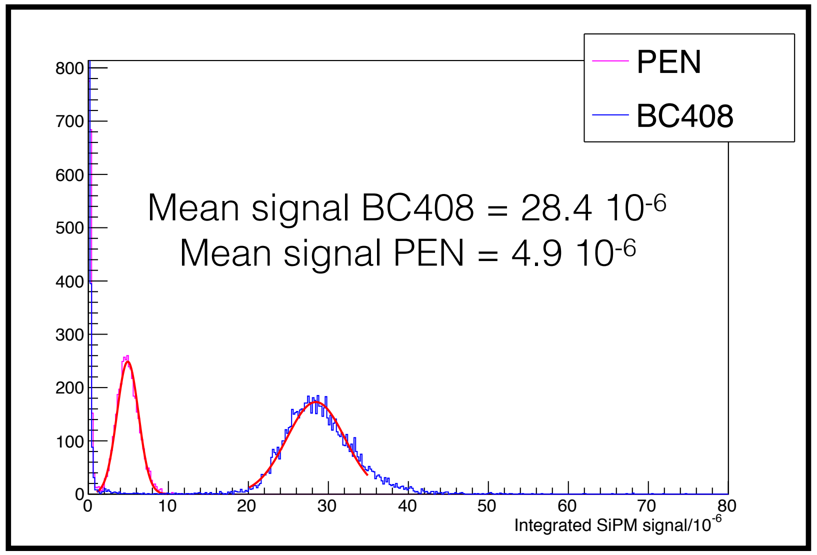


Figure 6: The MIP (muon) response of various tiles, tested at CERN H2 Test Beam Area.

PEN TEST SAMPLES

- Fraunhofer institute: injection moulded plates, machine tiles out of these
- TU Dortmund: injection moulded tiles (including dimple)
- Shown in the last CALICE meeting that the light yield is very low (a few p.e. only), and the signal is very spread out in time (MPPC S13360-25PE)
- Using a large SiPM (3x3mm^2) the signal size is better, but still 6 times lower than BC408



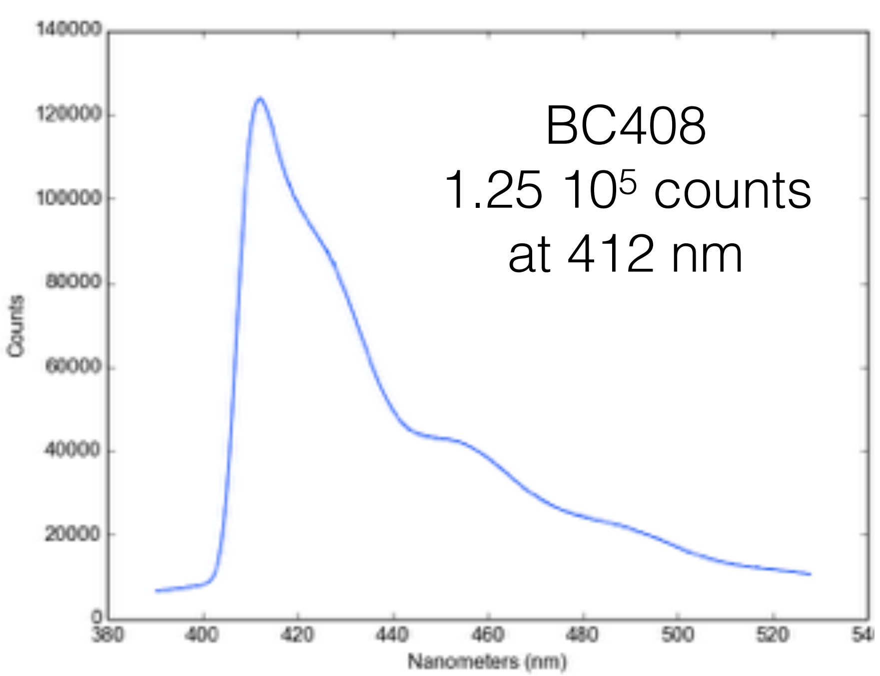


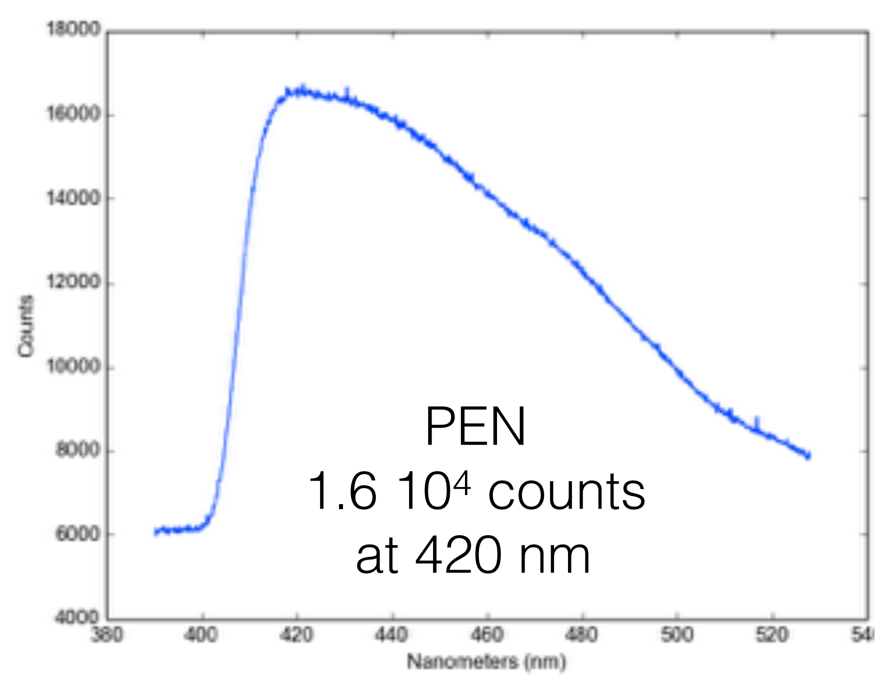
Optical grease

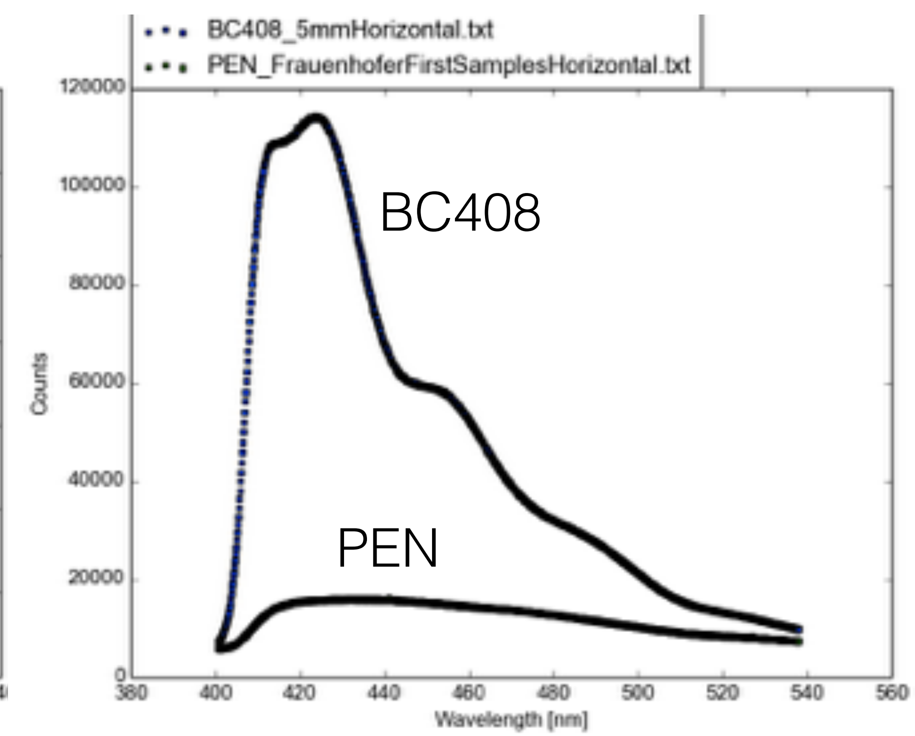
- Investigated if the low yield is caused by an inefficiency of the light to reach the SiPM (PEN has a different refraction index as BC408 (1.65 vs1.58))
- Fill the dimple of the tile with optical grease (BC-630)
- For both BC408 and PEN grease gives a 1/3 higher signal

Spectroscopy

- Compared the output spectrum of PEN to that of BC408
- Used a UV lamp to illuminate the tile and measured the output spectrum
- PEN shows much less intensity (~1/10) and a less peaked distribution

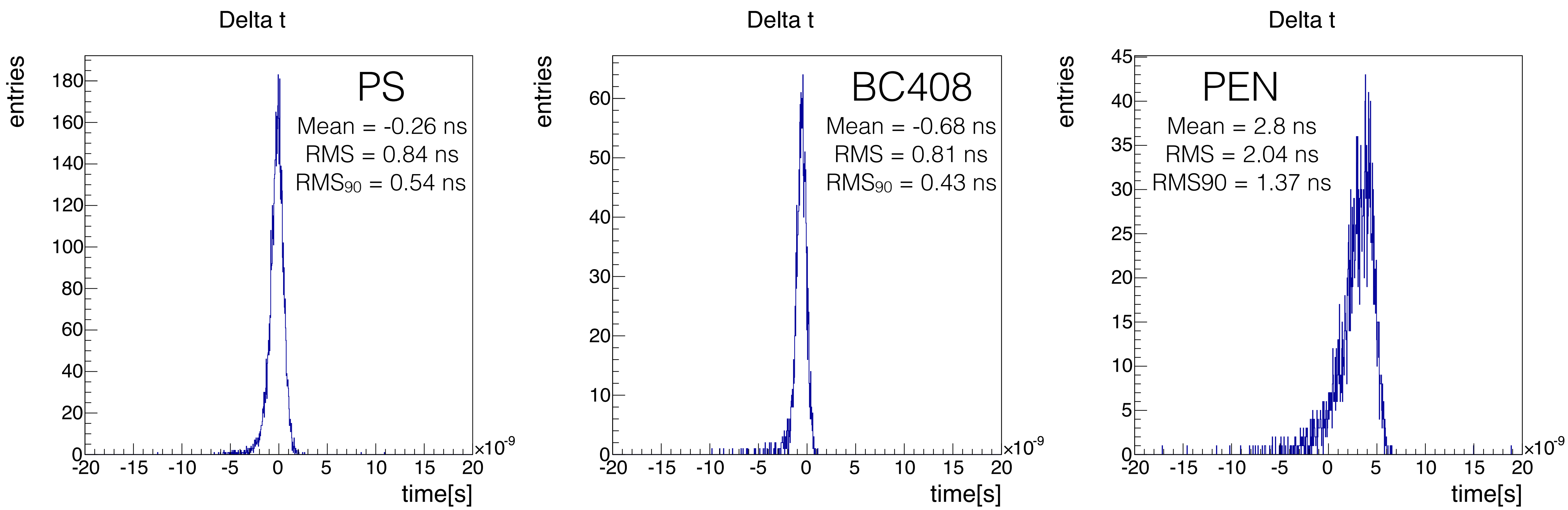






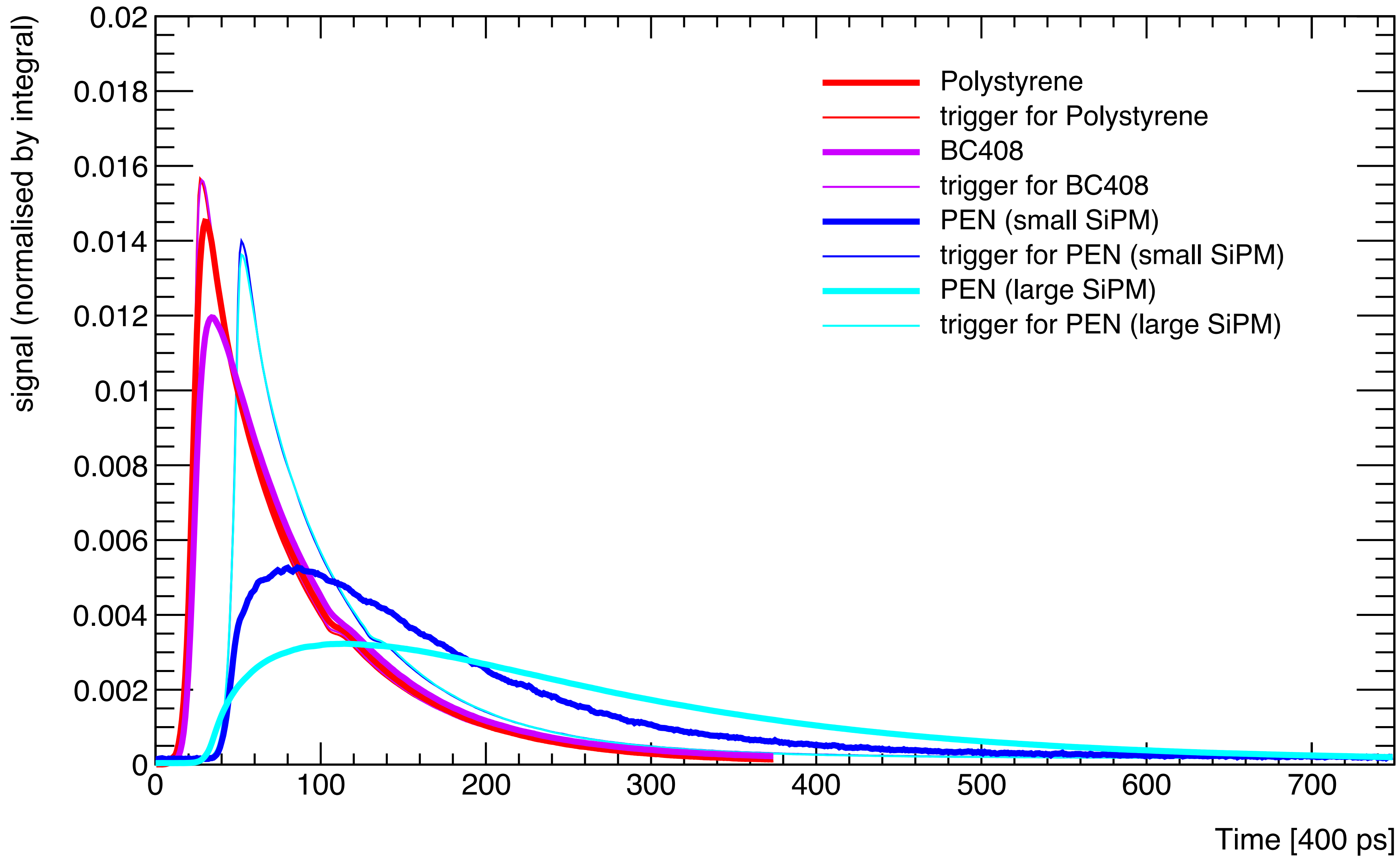
Timing in different scintillators

- Comparison of time resolution with different scintillators
  - setup: cosmic muons, two tiles on top of each other, trigger on the bottom tile only, Picoscope sampling rate 400 ps
    - introduces asymmetric time distribution - harder to interpret
  - always the same PS trigger tile, different “signal” tiles
  - time-of-first hit determined with the Constant Fraction (25%) with interpolation method



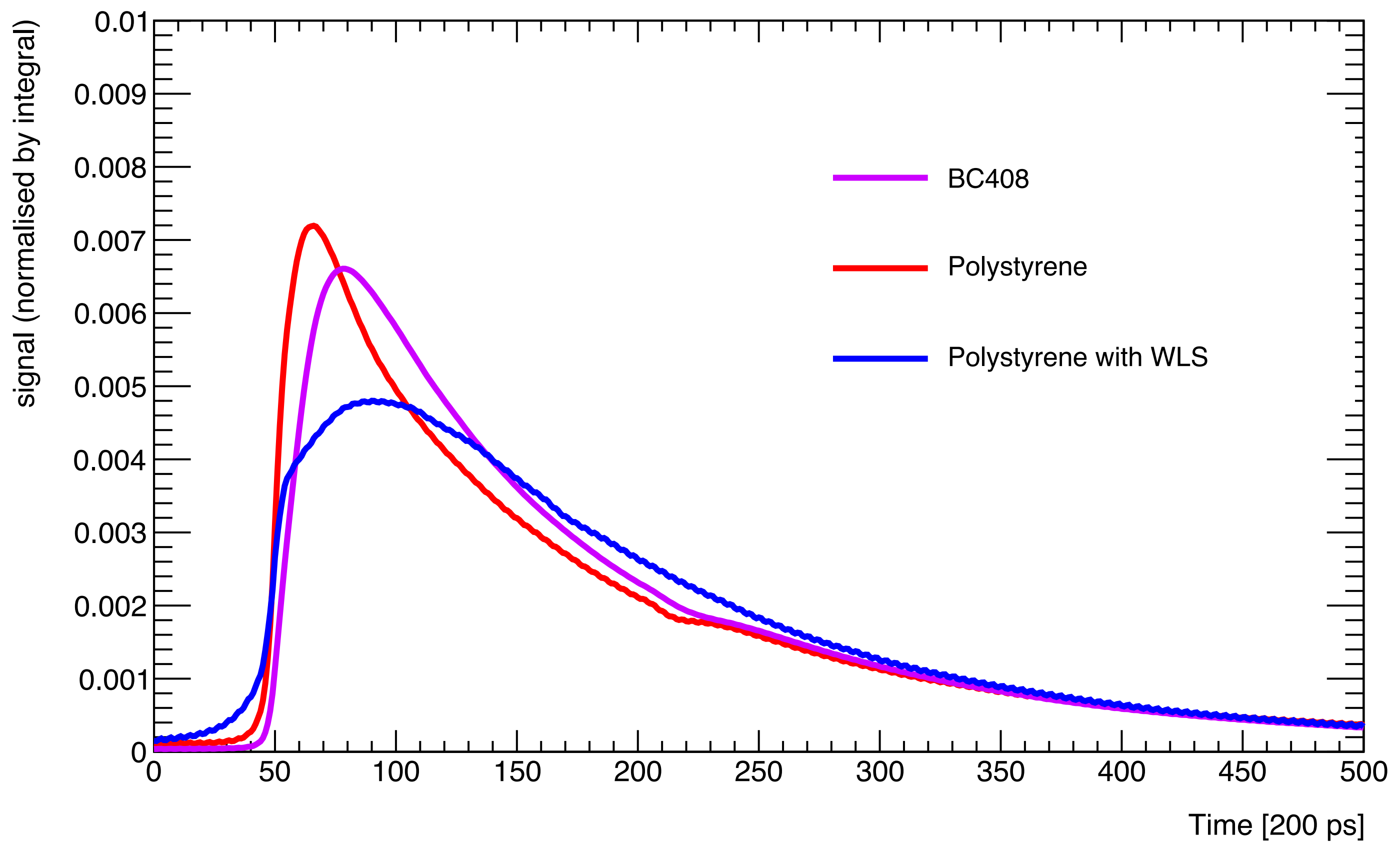
Average waveform

- Average MIP waveform by adding all waveforms and then normalising with the integral
- PS and BC408 are similar, PEN much broader
- Large (3x3 mm^2) SiPM broader than small (1.3x1.3mm^2) SiPM



Average waveform

- When using only one channel of the Picoscope, a sampling rate of **200 ps** is possible
- compare waveforms of different tiles (trigger on ~3 p.e.)
- PS is a little steeper than BC408
- PS with WLF fibre is not as fast as PS
  (the coupling of the WLF fibre to the SiPM might not yet be optimal in the current setup)



Next...

- PEN
  - It seems likely that the production process for PEN is extremely important for the scintillation properties
  - Test the light yield with a WLS fibre (a WLS fibre was use by CMS)
  - Produce a sample of PS tiles from the same mould as the PEN in Dortmund to see if those give a good light yield (ongoing)
- WLS fibre
  - a better coupling of the SiPM to the WLS fibre using e.g. optical glue (also relevant for PEN tests)
- Time resolution
  - Investigate other methods to determine the time-of-first hit