HIGH-D

Bundesministerium
für Bildung
und Forschung

-CheapCal-

Results with a first fibre-structured plastic scintillator prototype (Work package 2.4)

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High-D Consortium meeting
2nd - 5th September 2022

HUMBOLDT-UNIVERSITÄT ZU BERLIN

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

TUM

JG|U

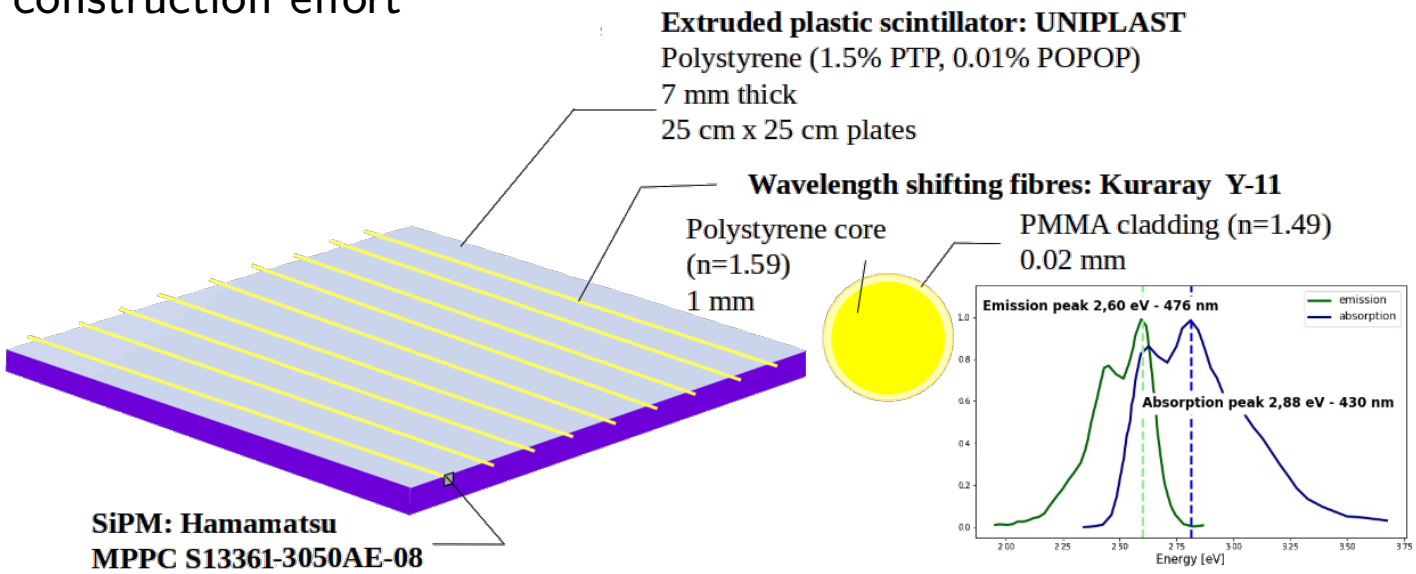
Overview

- Generic R&D: plastic-scintillator based tracker and/or calorimeter using plastic scintillator plates structured with wavelength shifting fibres

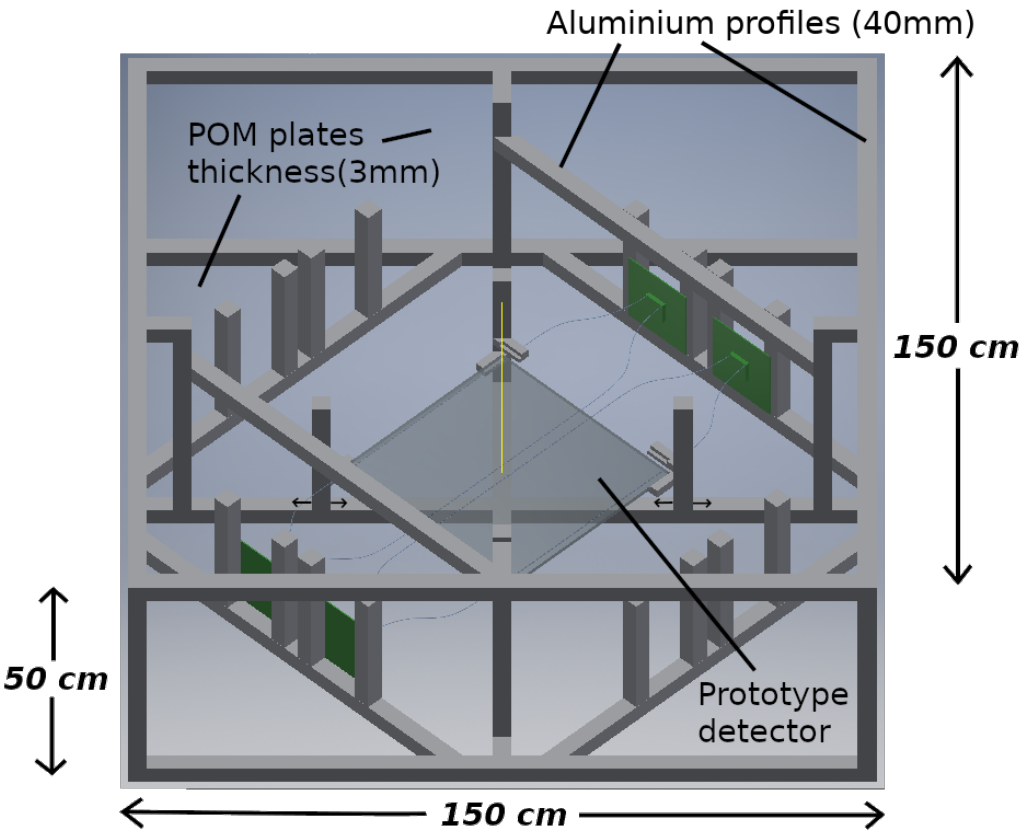
- Close collaboration between:
  - **Humboldt-Universität zu Berlin**: Darkbox, Prototype testing, photon transport simulations, data analysis
  - **Justus-Liebig Universität Gießen**: scintillator characterization, SiPM array, SiPM amplifier, general support
  - **Johannes Gutenberg-Universität Mainz**: Link to SplitCal, general support
  - **Technische Universität München**: prototype preparation (milling, gluing), teflon block for fiber coupling to SiPM array, general support

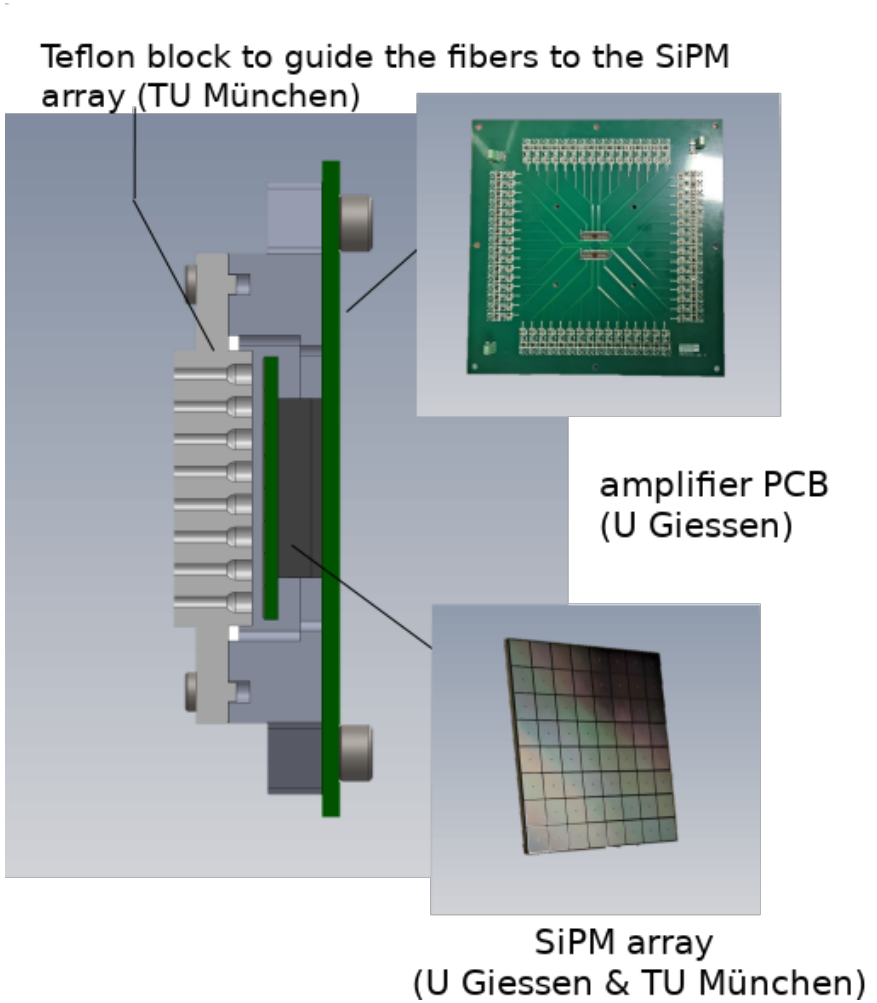
General Idea

- Explore if a fibre-structured scintillator detector can be built with:
  - 3D spatial information
  - sufficient light yield in the individual fibres to obtain spatial and/or energy information
  - affordable costs
  - acceptable construction effort

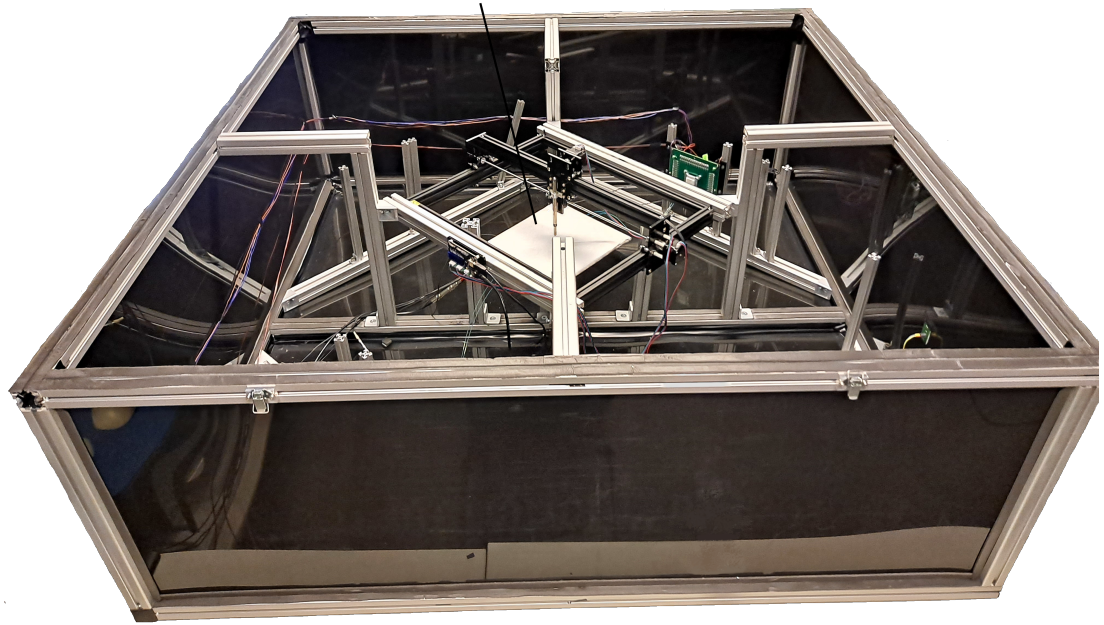


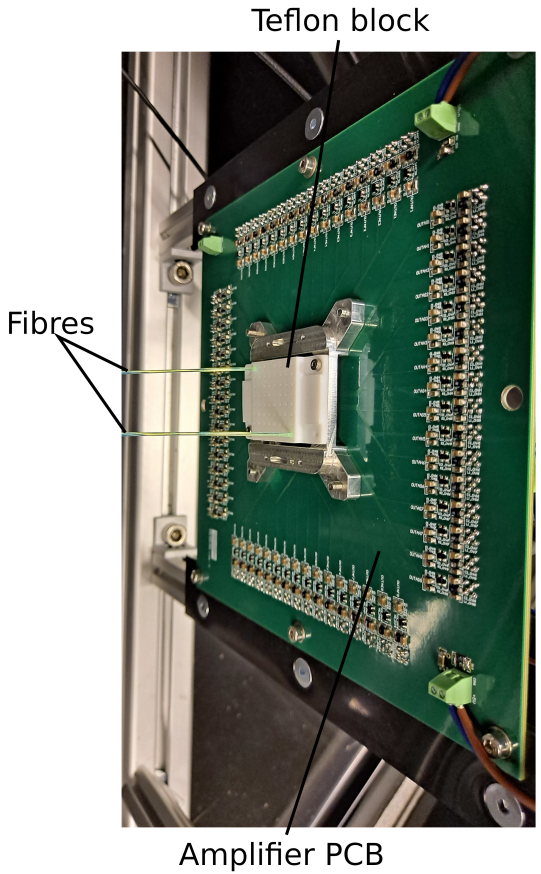
Darkbox setup





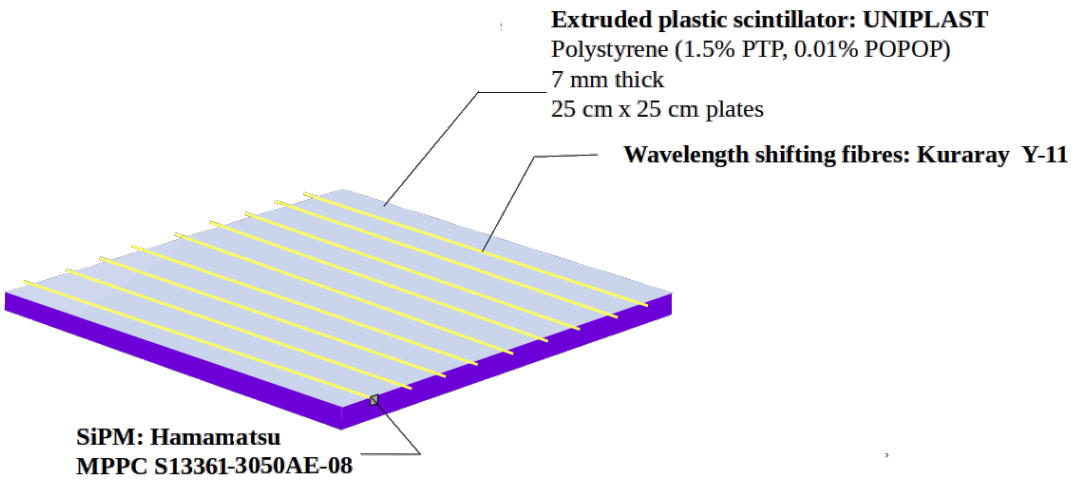
Darkbox setup (current status)

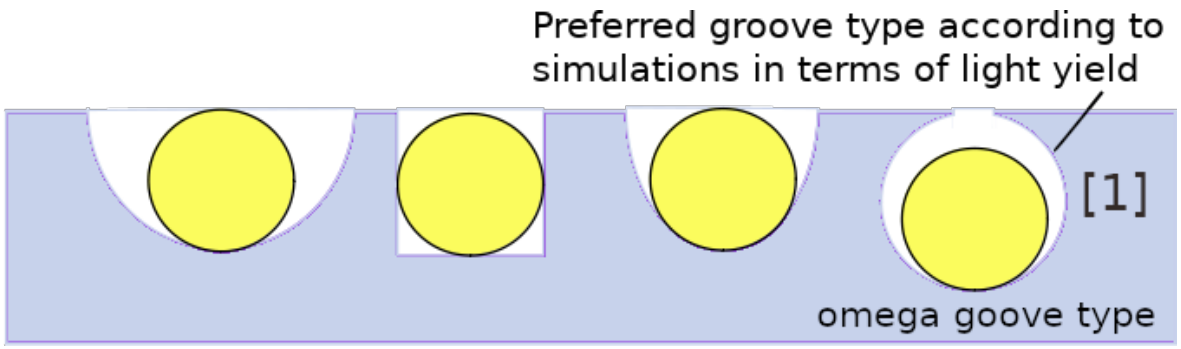




Detector setup

- One-sided fibre readout
- Other end closed with reflective foil
- 120 cm total fibre length
- 45 cm distance between detector and SiPM array
- Detector wrapped with Tyvek foil to increase light yield through diffuse reflection of scintillation light

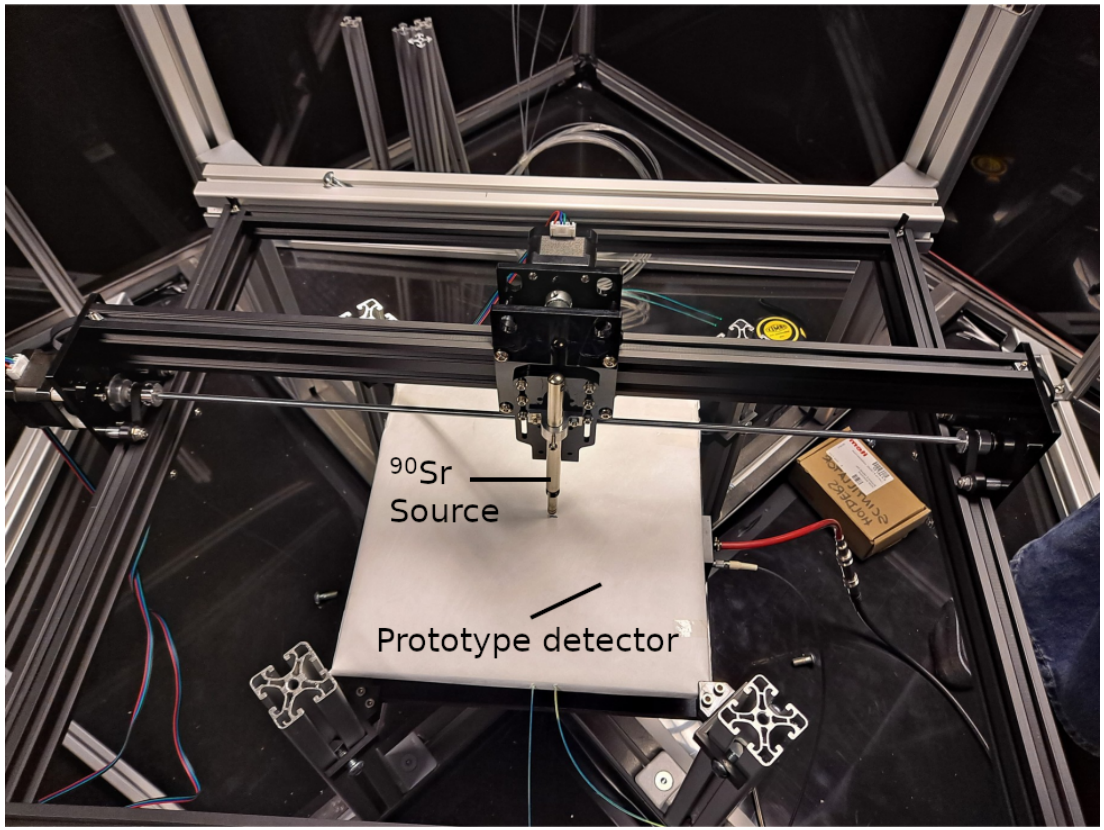




[1] The CMS Outer Hadron Calorimeter- Acharva, Bannaje Sripathi et al - CMS-NOTE-2006-127

Detector setup (current status)

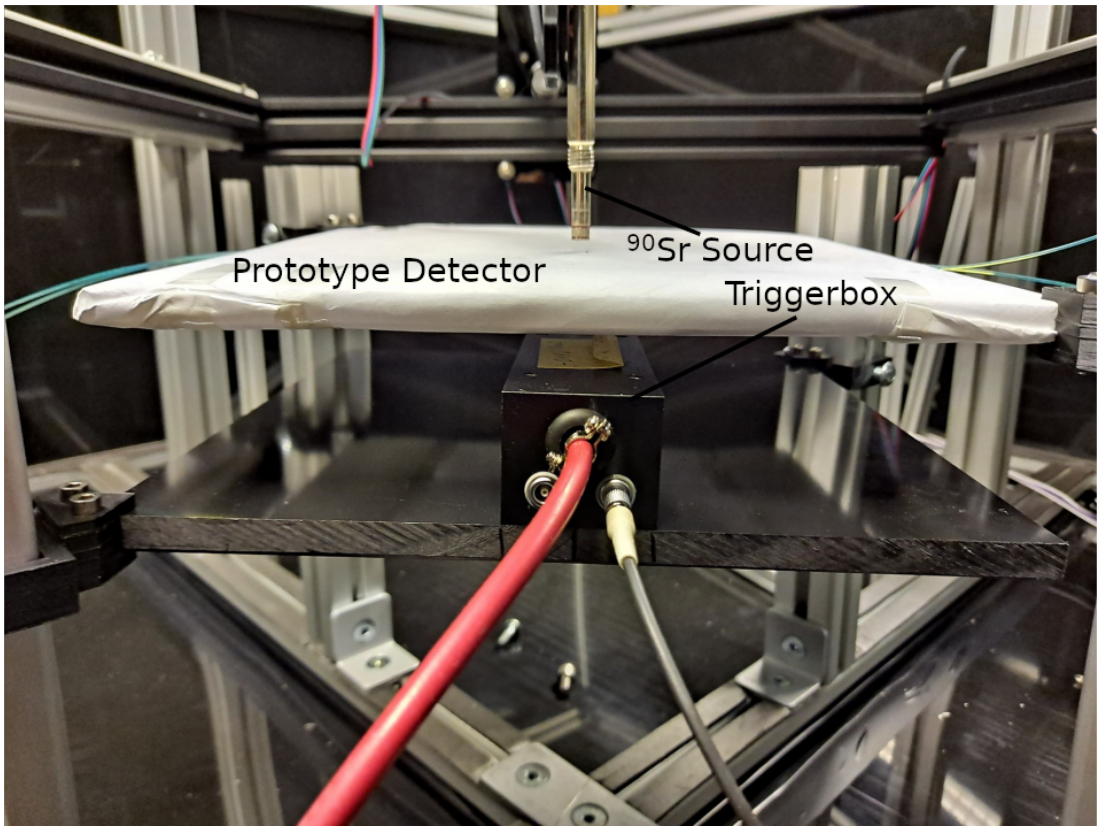
- SiPM array power supply:
  - 6 V
  - 2.65 A
- SiPM breakdown voltage:
  - 53.8 V
- SiPM bias voltage (used):
  - 55.0 V (1.2 V over voltage)
- SiPM array readout:
  - via Wavecatcher



Trigger setup

- Triggerbox [2]built by:
  - U Hamburg
  - DESY Zeuthen

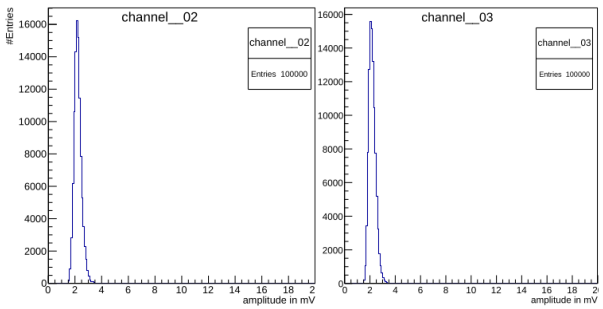
- Trigger box power supply:
  - 780 V
  - 287 mA



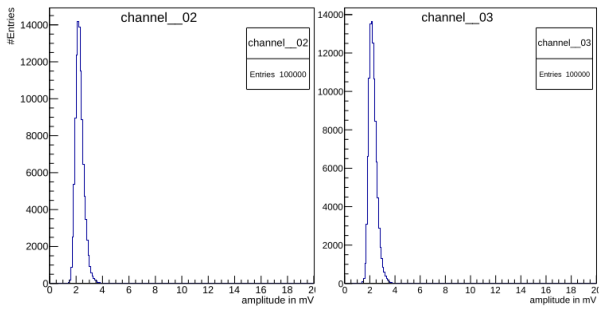
[2] https://indico.cern.ch/event/198640/contributions/1480489/attachments/294406/411441/Sr_setup_FCAL.pdf

Darkcount SiPM scan searching for breakdown voltage

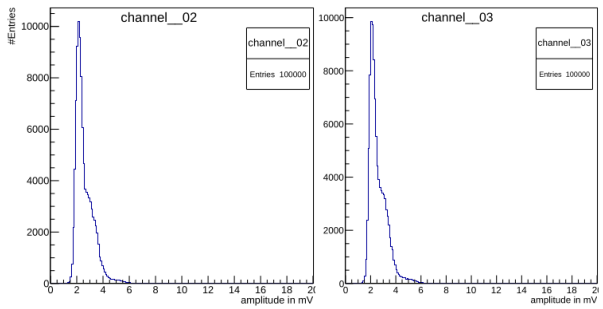
52 V



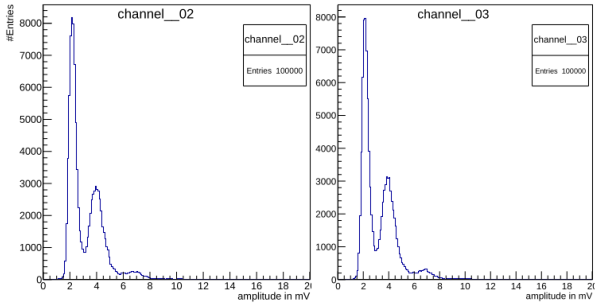
53 V



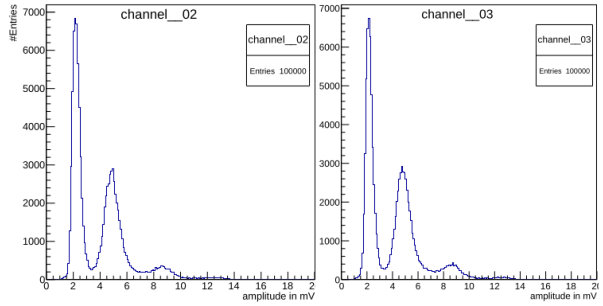
54 V



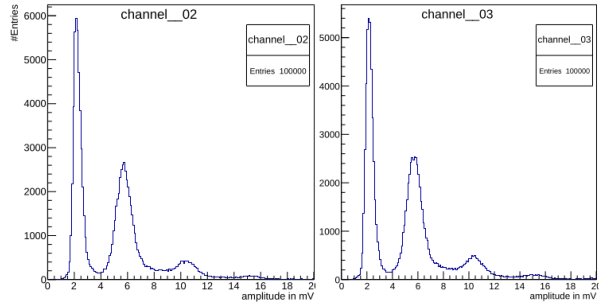
55 V



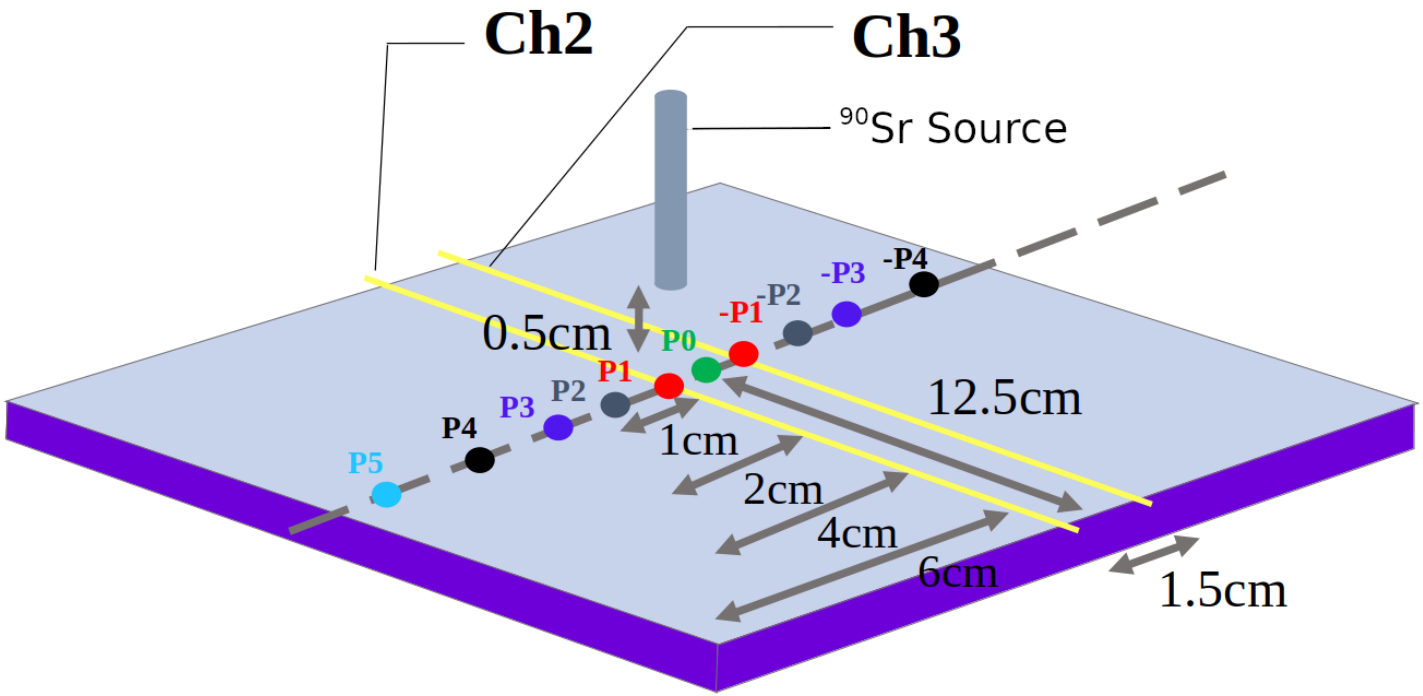
56 V



57 V

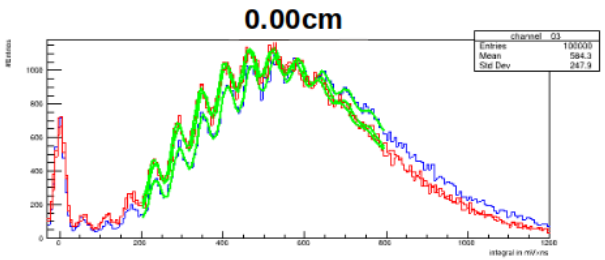


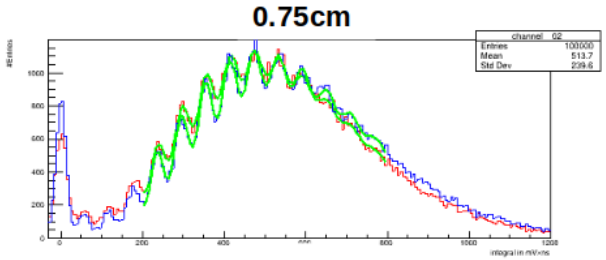
Spatial scan with a β^- source

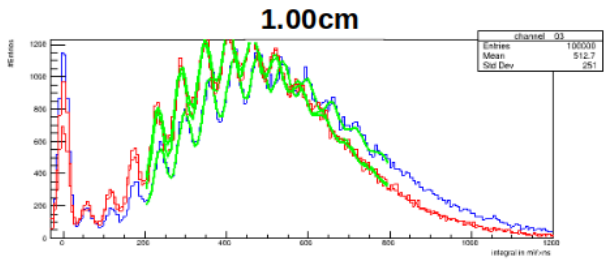


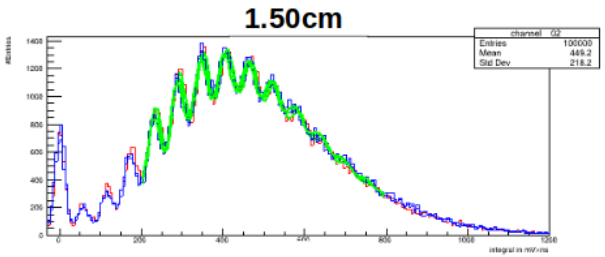
Spatial scan with a β^- source

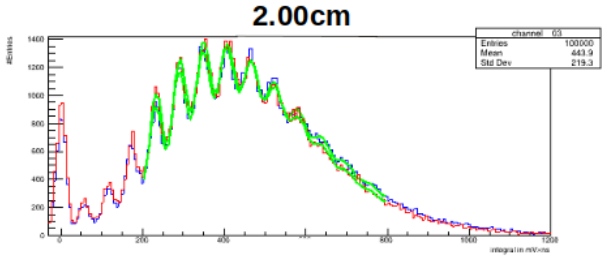
Ch2 Ch3

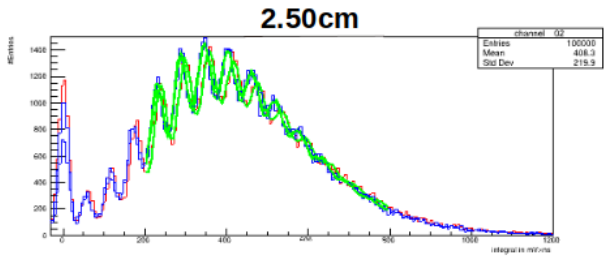


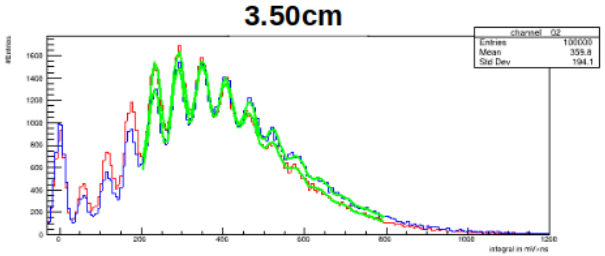


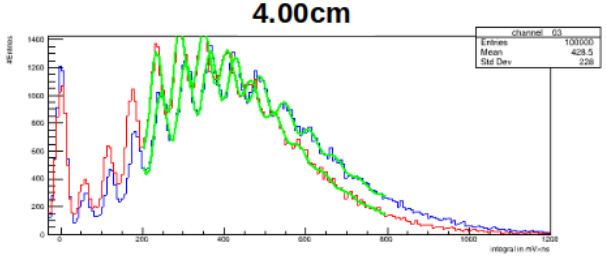


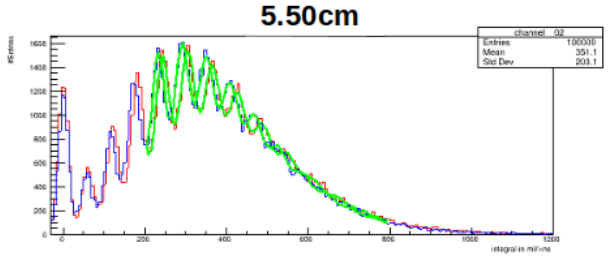












Fit function[3] for SiPM photo-electron spectrum

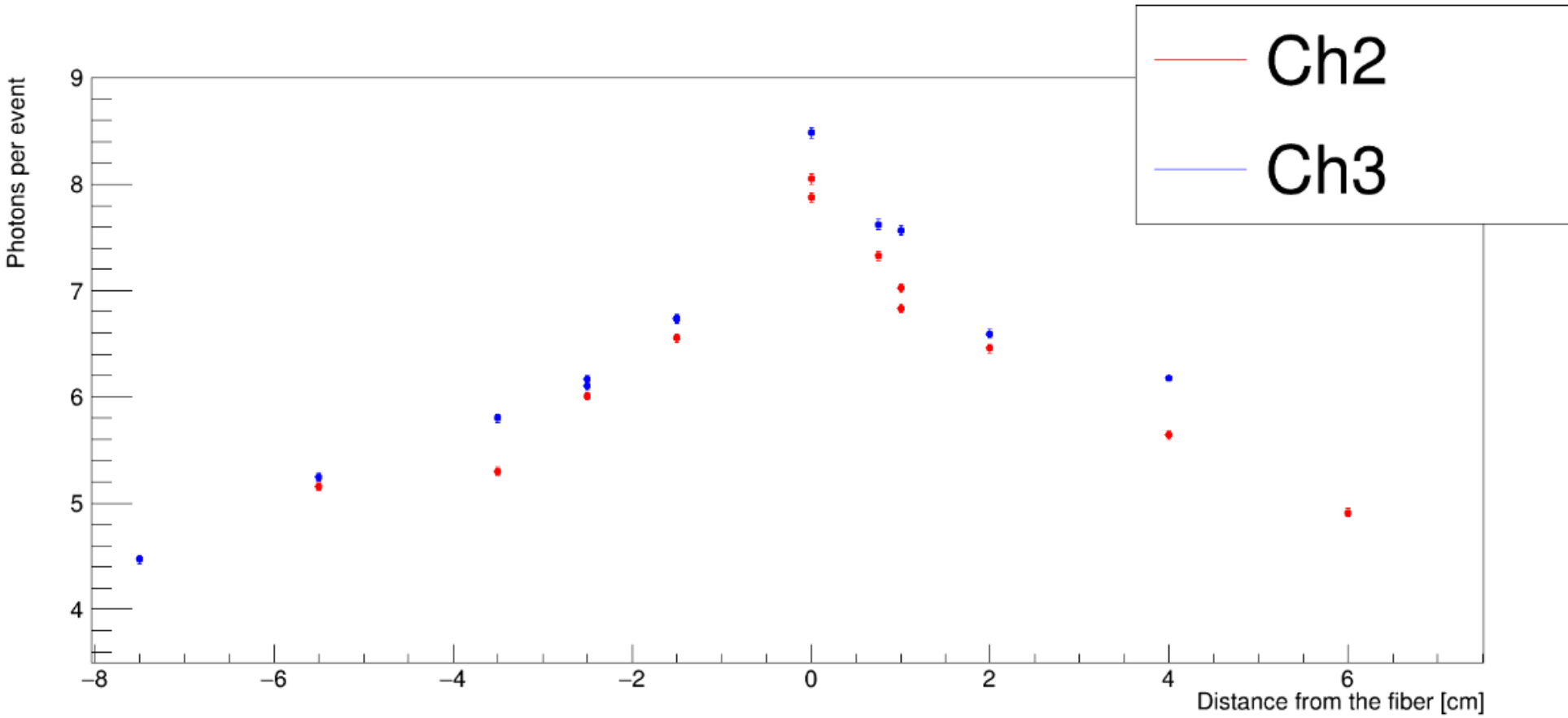
$$\sum_k N_0 \cdot \frac{\mu(\mu + k \cdot \lambda)^{k-1} \cdot e^{-\mu + k \cdot \lambda}}{k!} \left(\frac{1}{\sqrt{2\pi} \cdot \sigma_k} e^{\frac{(x_i (k \cdot G + B))^2}{2\sigma_k^2}} \right)$$

$$\sigma_k = \sqrt{(\sigma_0)^2 + (k \cdot \sigma_1)^2}$$

- μ = mean for generalized poisson distribution
- N_0 = normalization
- λ = Borel-branching parameter for prompt crosstalk probability
- σ_0 = width of the pedestal peak
- σ_1 = width of the first photoelectron peak
- G = gain
- B = pedestal value

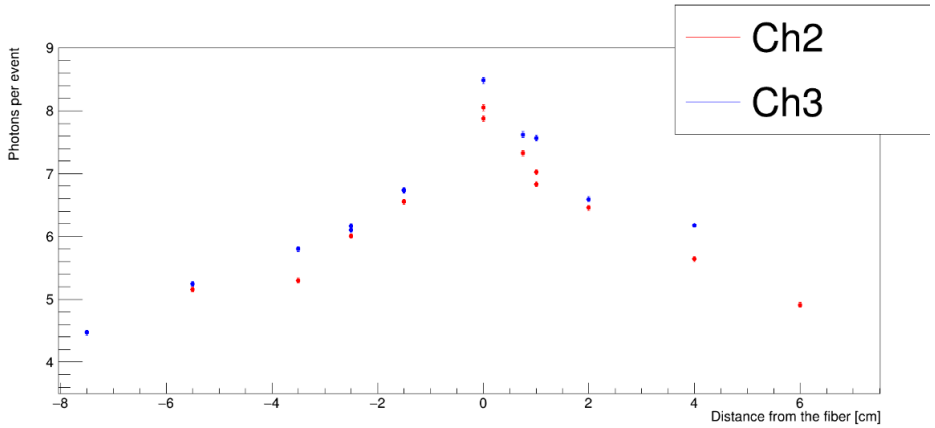
[3] https://doi.org/10.1016/j.nima.2017.02.049

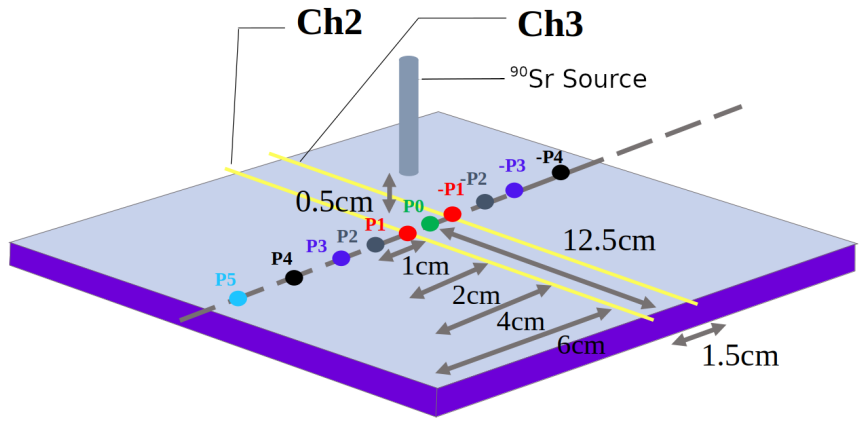
Results


Ch2
Ch3
Photons per event
9
8
7
6
5
4
−8
−6
−4
−2
0
2
4
6
Distance from the fiber [cm]

Results

- First measurements showed a clear dependence of light yield as function of distance to the β^- source
- For a good spatial resolution the absolute light yield needs to be increased
- Further studies on best configuration of reflectivity foil with respect to light yield and spatial resolution are needed





Next steps

- Reading out both ends of the fibre simultaneously to increase the amount of collected photons per fibre (already in progress)
- Produce prototypes with only omega groove geometry and fully equipped with fibres on front and back side
- Installation of an additional water-to-air heat exchanger to further reduce darkcount generated by the SiPMs
- Optimize the used bias voltage in terms of efficiency
- Optimize fibre-SiPM optical coupling
- Increase light yield by mounting the SiPMs directly at the end of the scintillator

Thank you for your attention