-CheapCal-

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

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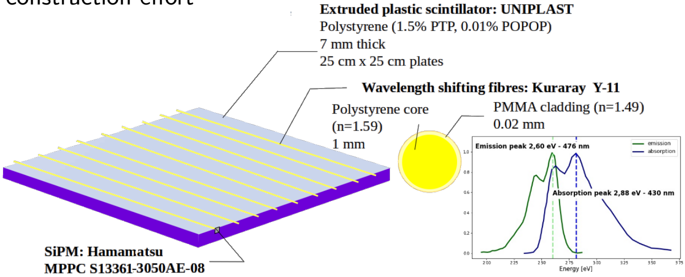
Overview

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

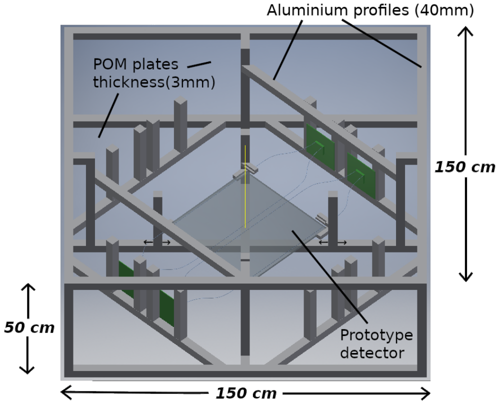
- Close collaboration between:
  - **Humboldt-Universität zu Berlin**: Darkbox, Prototype testing, photon transport simulations, data analysis
  - **Justus-Liebig Universität Gießen**: scintillator characterization, SiPM array, SiPM amplifier, general support
  - **Johannes Gutenberg-Universität Mainz**: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

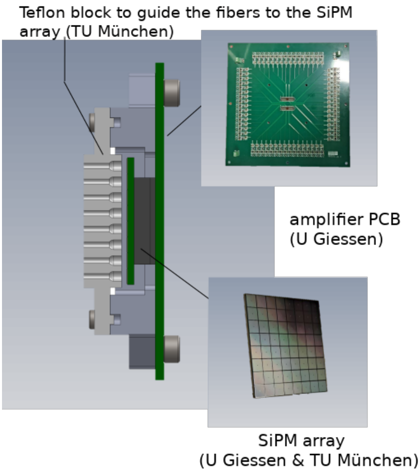
General Idea

- 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



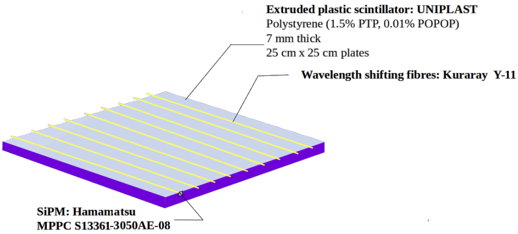
Darkbox setup

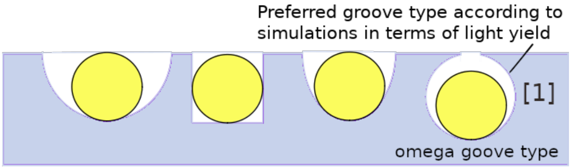




Detector setup[1]

- One-sided fibre readout
- 80 cm total fibre length
- 45 cm distance between detector and SiPM array
- SiPM bias voltage (used):
  - 58.0 V
- SiPM array readout:
  - via Wavecatcher





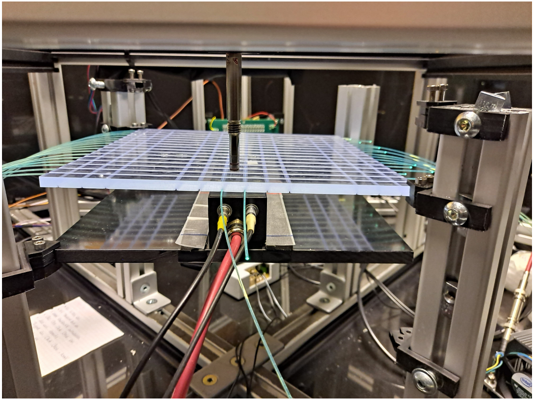
[1] The CMS Outer Hadron Calorimeter- Acharva, Bannaje Sripathi et al - CMS-NOTE-2006-127

Trigger setup

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

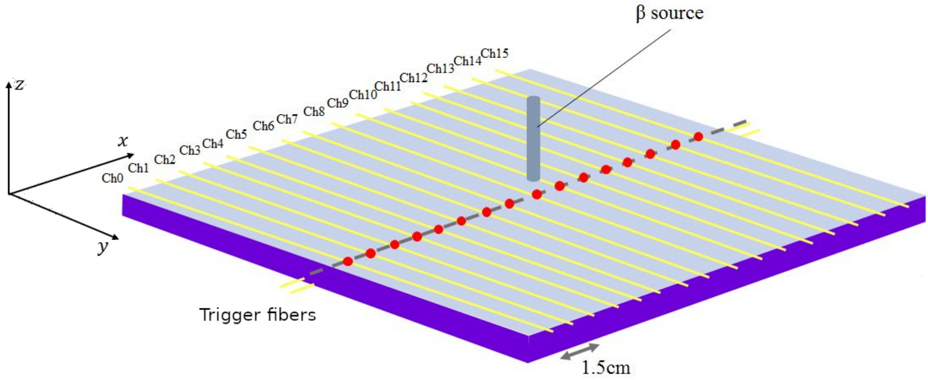
- Trigger box power supply:
  - 780 V
  - 287 mA

- Trigger with one PE threshold on both triggerbox channels and two additional fibres



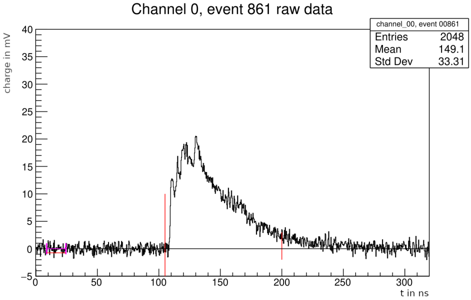
[2] https://indico.cern.ch/event/198640/contributions/1480489/attachments/294406/411441/Sr_setup_FCAL.pdf

Measurement setup

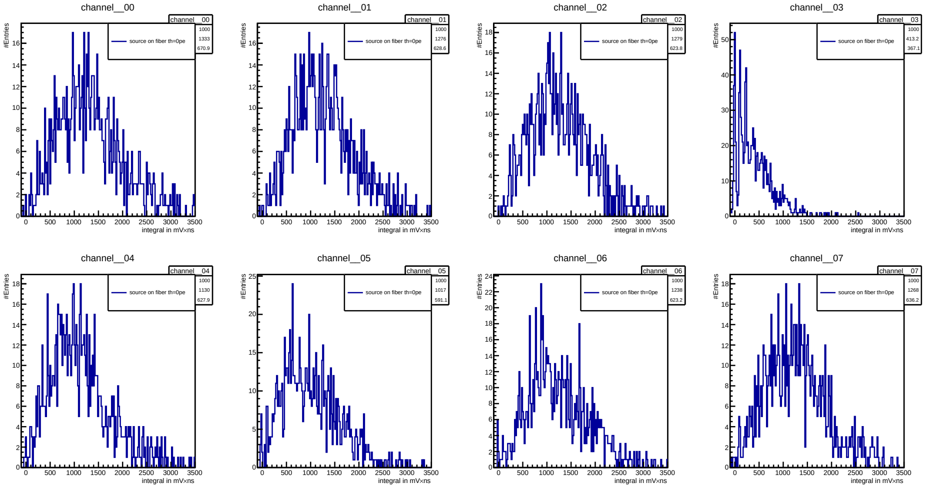


Integration of charge signal

- Integration of the signal within the integration window (95 ns)
- Window is determined starting from the maximum
- Start of window:
  - 25 ns before maximum
- End of window:
  - 70 ns after maximum



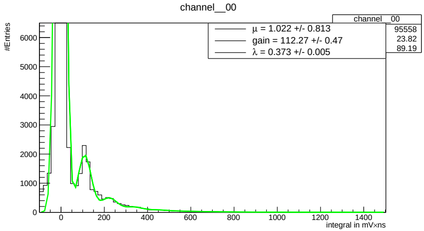
Charge histograms for source above corresponding channel

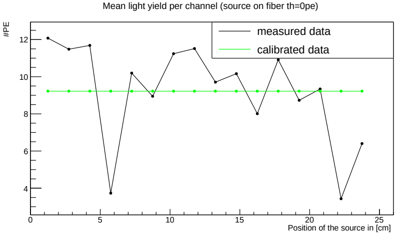


Conversion to photoelecton number (#PE)

- Darkcount measurement to estimate the gain of each channel
- Darkcount fit: Convolution of a Poisson distribution with a Gaussian distribution
- PE number = integral / gain
- Calibration of the light yield per fibre so that each fibre has the same mean light yield

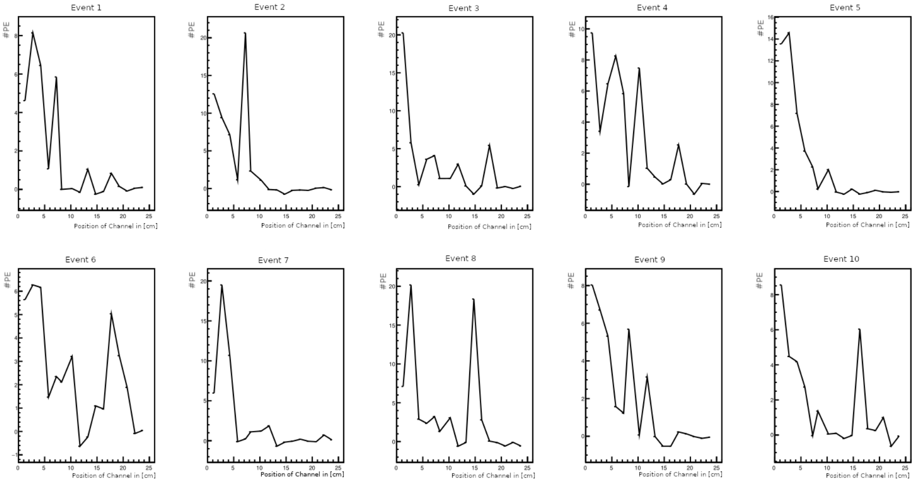
$$meas_{i,cali} = meas_i \cdot \frac{total\ pe\ mean}{light\ yield_i}$$





$meas_i \mathrel{\widehat{=}}$ measured light yield in channel i $light\ yield_i \mathrel{\widehat{=}}$ mean light yield of channel i

How single events can look like (Source position 1.25 cm)



Position reconstruction algorithm

Method 1:

- Weighted mean
  - over all channels (16)

$$pos_{mean} = \frac{\sum_{i=0}^{chmax} weight_i \cdot pos_i}{\sum_{i=0}^{chmax} weight_i}$$

Method 2:

- Truncated weighted mean
  - weighted mean over 3 adjacent channels
  - selection via highest weight

$$pos_{trunc} = \frac{\sum_{i=i_{max}-1}^{i_{max}+1} weight_i \cdot pos_i}{\sum_{i=i_{max}-1}^{i_{max}+1} weight_i}$$

$$i_{max} = \text{argmax}_i \sum_{i-1}^{i+1} weight_i$$

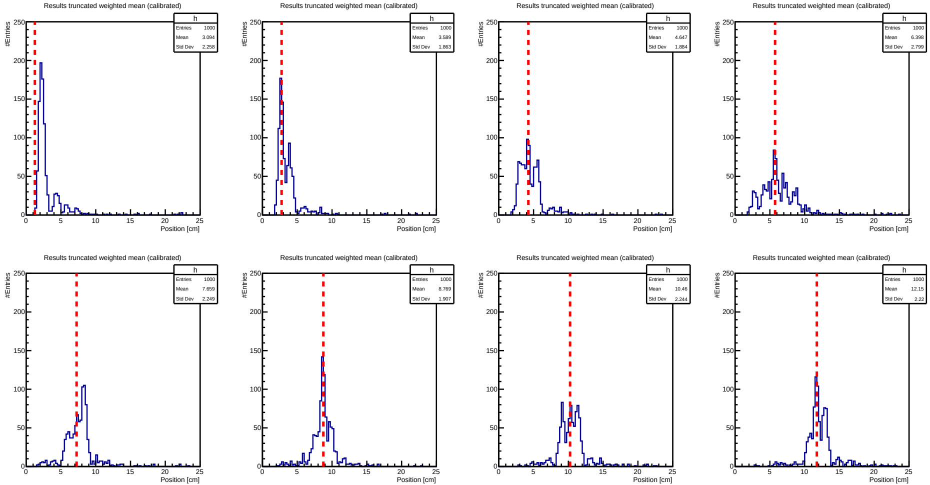
Weight:

- $weight_i = meas_i \cdot f_{cali} \cdot \sqrt{meas_i}$

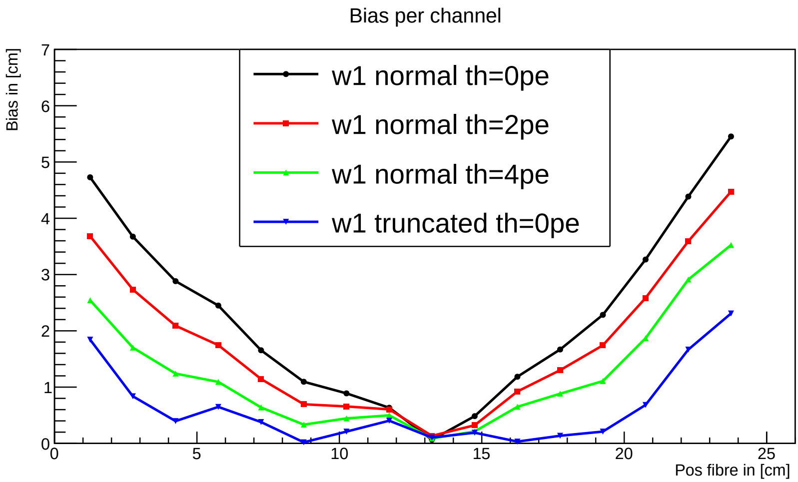
$$f_{cali} = \frac{total\ pe\ mean}{light\ yield_i}$$

$f_{cali} \mathrel{\widehat{=}}$ calibration function

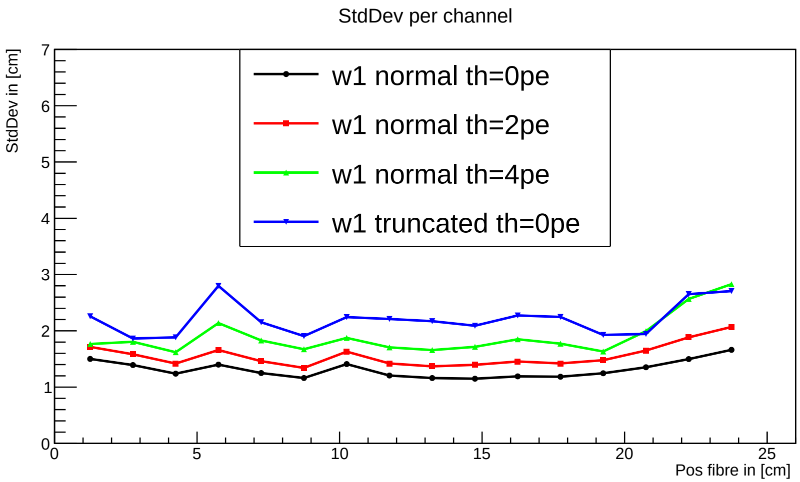
Results for the truncated mean



Results


Bias per channel
w1 normal th=0pe
w1 normal th=2pe
w1 normal th=4pe
w1 truncated th=0pe
Bias in [cm]
Pos fibre in [cm]
0
1
2
3
4
5
6
7
0
5
10
15
20
25

Results


StdDev per channel
w1 normal th=0pe
w1 normal th=2pe
w1 normal th=4pe
w1 truncated th=0pe
StdDev in [cm]
0
1
2
3
4
5
6
7
0
5
10
15
20
25
Pos fibre in [cm]

Conclusion

- For a good spatial resolution, the absolute light yield needs to be increased
- Light yield will automatically increase by reading out both fibre sides and shortening the fibre length to the scintillator plate dimension
- Further studies on best configuration of reflectivity foil with respect to overalll light yield and spatial resolution will be performed
- A first, very preliminary attempt with a neural net (not shown here), provides a significantly smaller bias and also better resolution than the mean and truncated mean estimators over the whole detector using only the raw calibration data!

Thank you for your attention

Fit function[3]for SiPM photo-electron spectrum

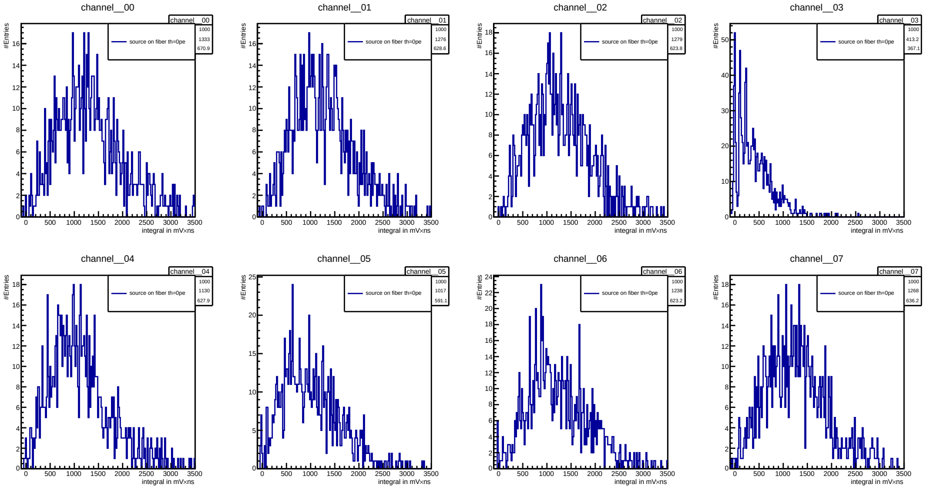
$$\sum_k N_0 \cdot \frac{\mu(\mu + k \cdot \lambda)^{k-1} \cdot e^{-\mu + k \cdot \lambda}}{k!} \left(\frac{1}{\sqrt{2\pi \cdot \sigma_k}} e^{\frac{\left(x_i(k \cdot G + B)\right)^2}{2\sigma_k^2}} \right)$$

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

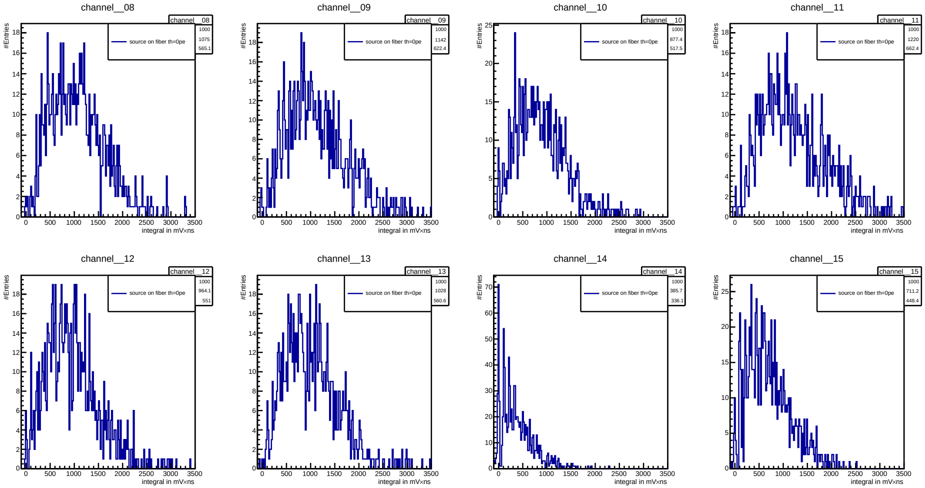
- μ = mean for generalized poisson distribution
- N_0 = normalization
- λ = Borel-branching parameter for prompt crosstalk probability
- σ_0 = width of the pedestal peak
- σ_1 = width of the first photoelectron peak
- G = gain
- B = pedestal value

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

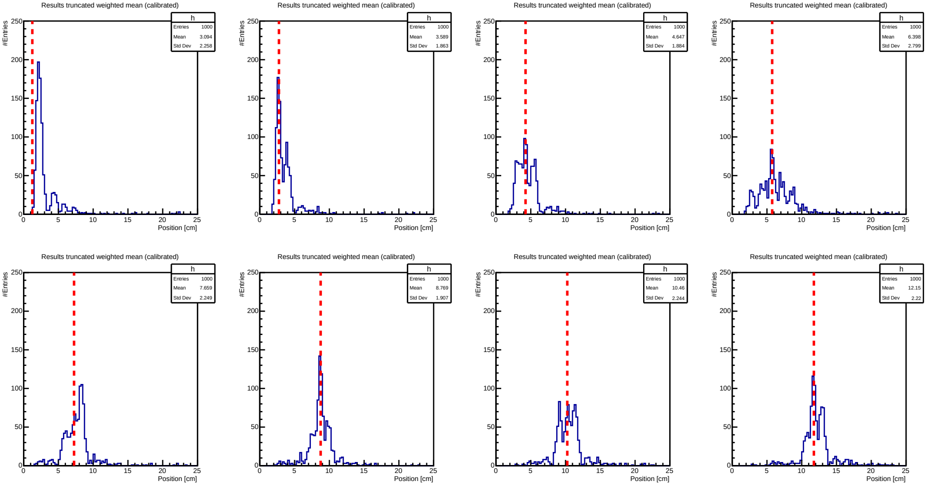
Charge spectrum ch 0 - 7



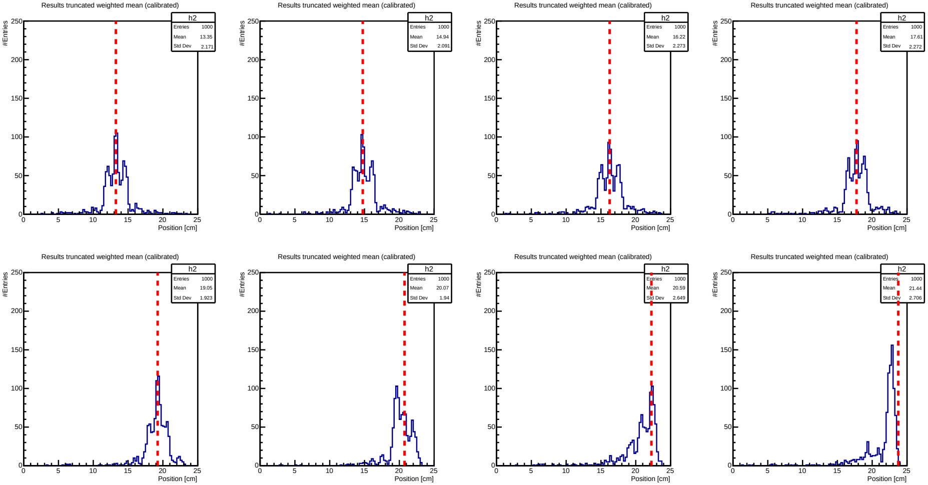
Charge spectrum ch 8 - 15



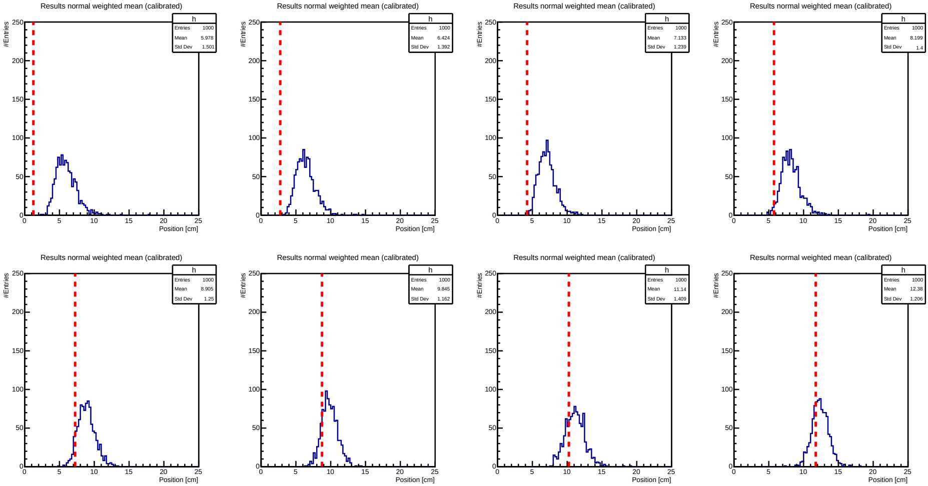
Results truncated mean ch 0 - 7



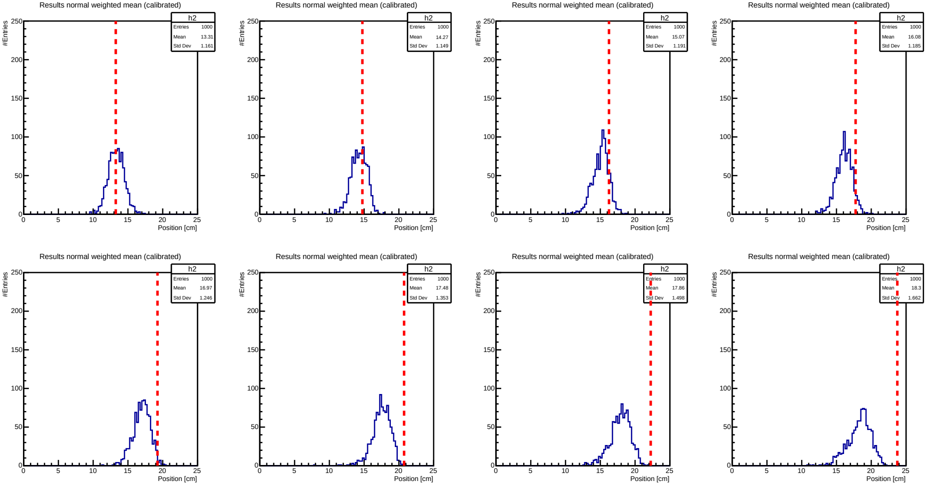
Results truncated mean ch 8 - 15



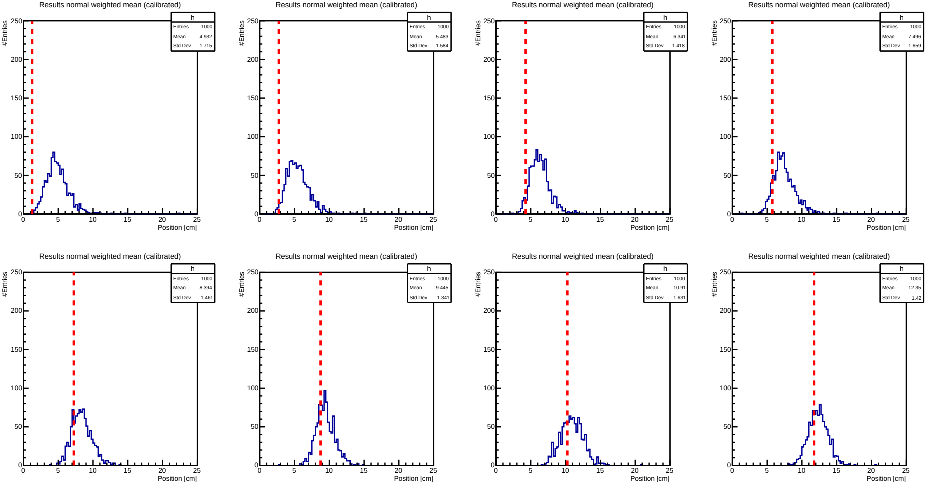
Results mean (th $= 0\,\mathrm{pe}$) ch 0 - 7



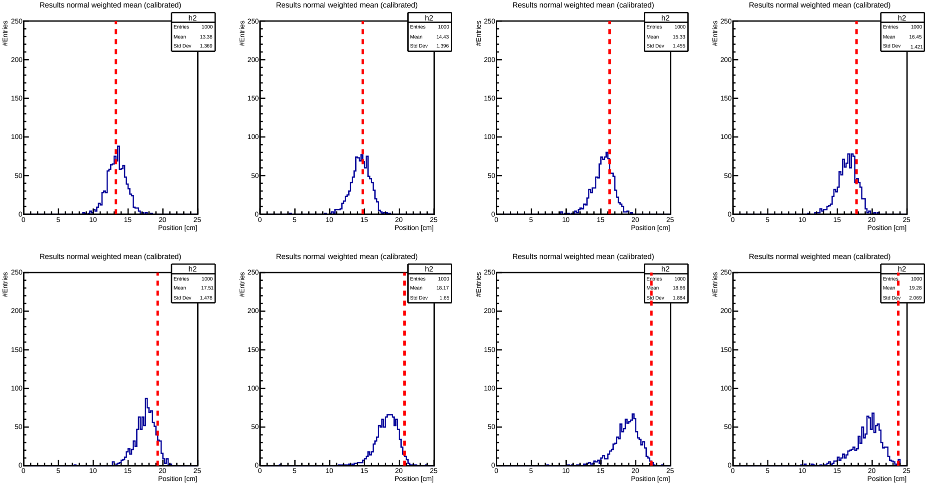
Results mean ($\mathrm{th} = 0\,\mathrm{pe}$) ch 8 - 15



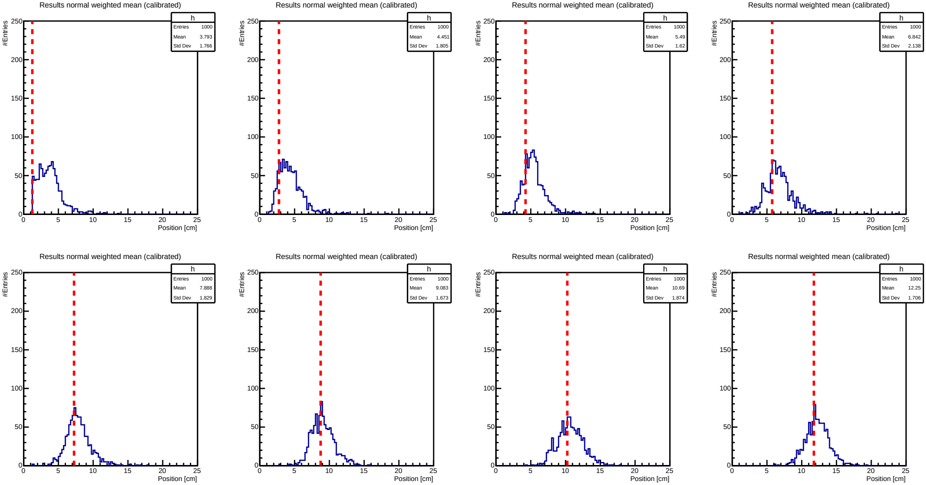
Results mean ($\mathrm{th} = 2\,\mathrm{pe}$) ch 0 - 7



Results mean (th $= 2\,\mathrm{pe}$) ch 8 - 15



Results mean (th $= 4\,\mathrm{pe}$) ch 0 - 7



Results mean (th $= 4\,\mathrm{pe}$) ch 8 - 15