CLAWS
Fast Scintillators for BEAST2

DEPFET Workshop 2015

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Outline

- CLAWS Goals
- Global system aspects
- Active elements
- Data acquisition
- Analysis, calibration

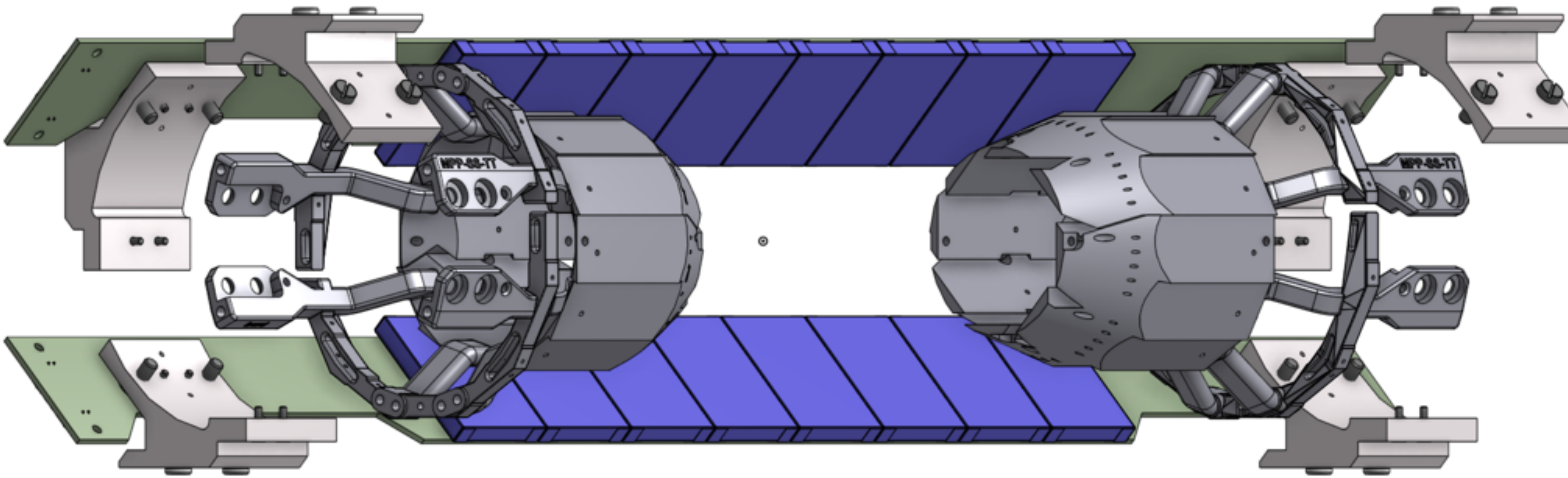
CLAWS Goals - And Requirements

- Measure the time dependence of backgrounds in the PXD region
  - Particular interest in the evolution of the background originating from injection bunches - relative to surrounding bunches
  - ➯ Requires high trigger rates over extended times- one revolution around the SuperKEKB ring takes 10 μs, injection at a few 10 Hz

➯ Want to record time window extending over many BX at each turn over ms time scales

➯ Ideally also have sensitivity to SR photons (starting at ~ 5 keV)

The CLAWS System



- Two ladders at 135 and 225 degrees
  - ~ 31 mm from IP - details to be worked out
  - 8 scintillator tiles per ladder,
  - mounted on PCB carrying one preamplifier per cell

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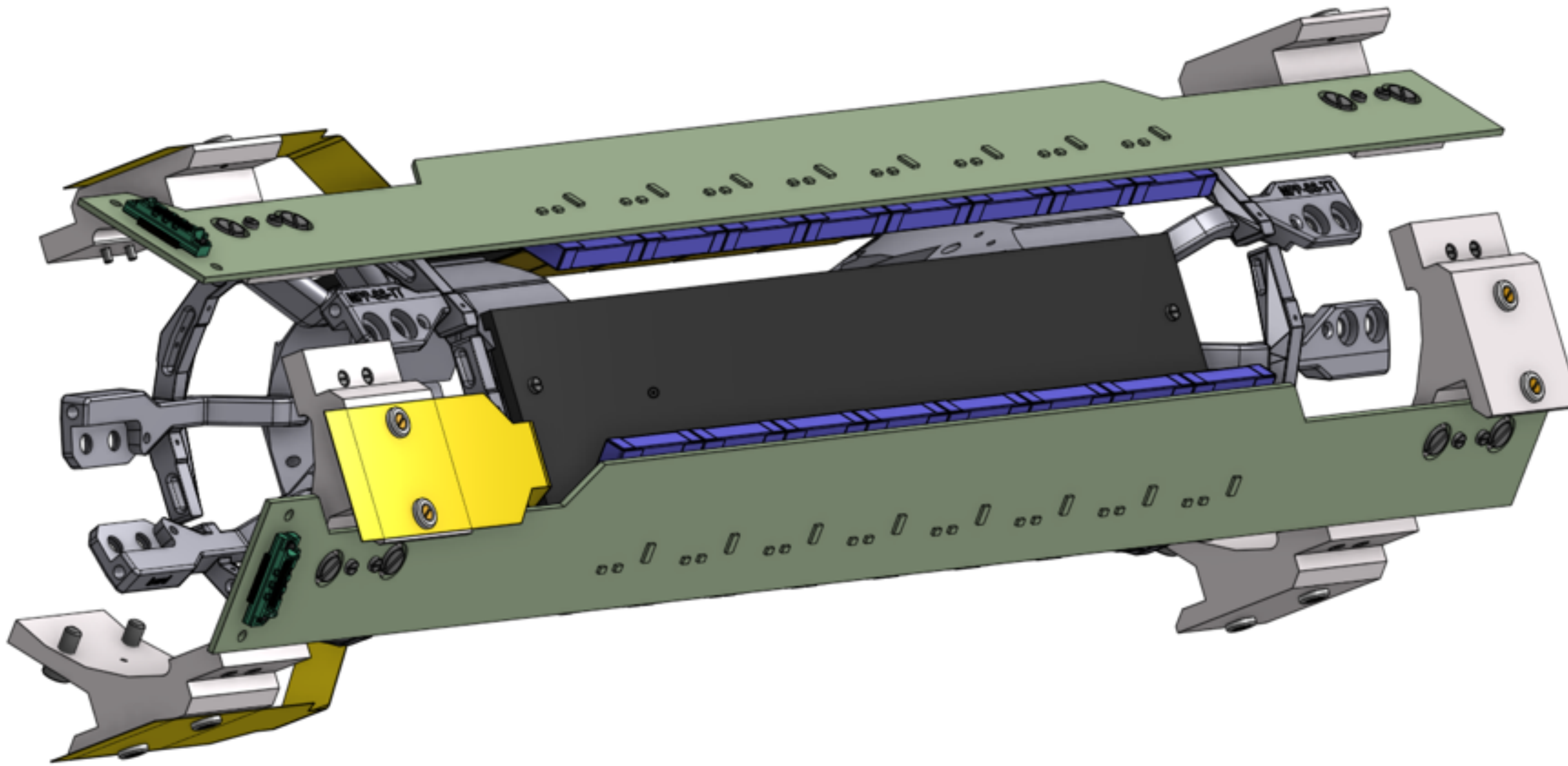
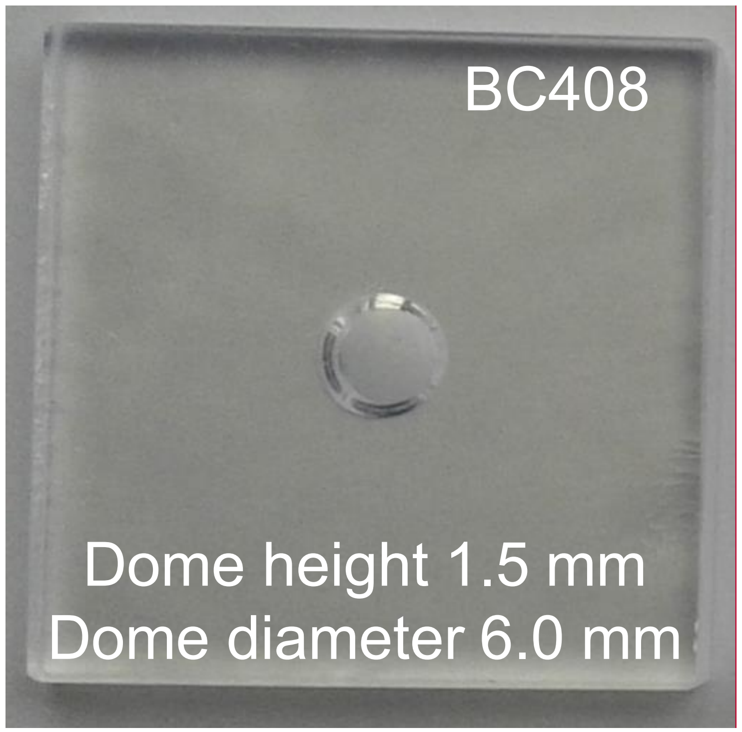
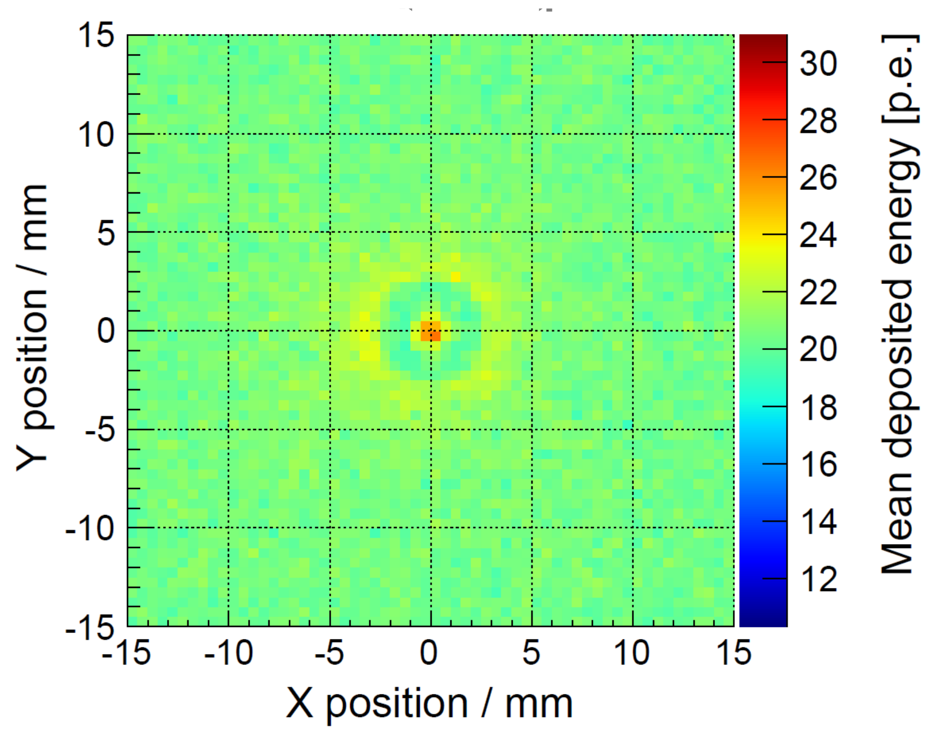


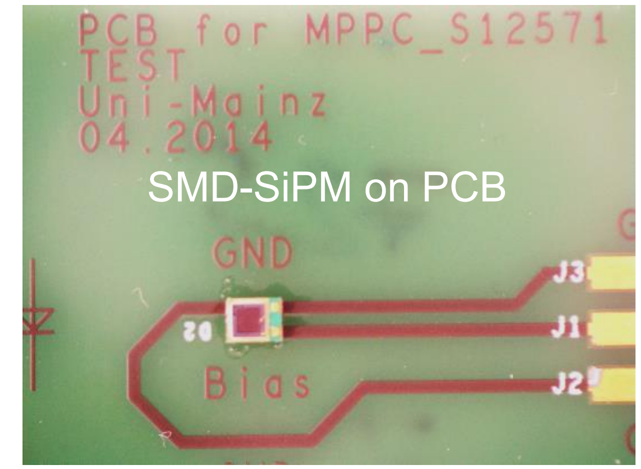
- Mechanical support entirely provided by PCB, fixed to beam pipe support
- Data output: one micro-coax cable per cell (4 on each side per ladder), cables directly soldered to preamp - run on back of PCB
- Additional connections: LV and HV, potentially power for LED calibration system
- Power budget ~ 2 W per ladder

CLAWS Components: Scintillator

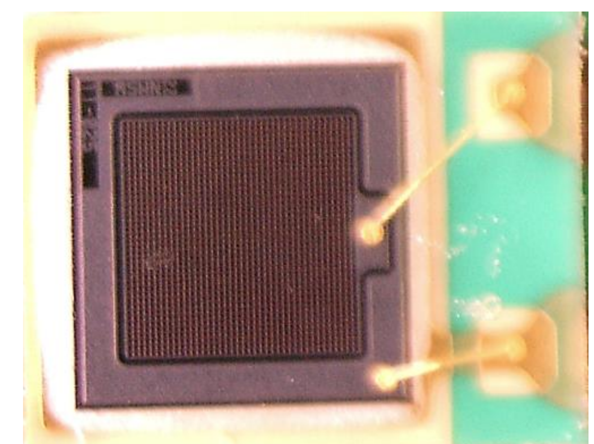
- Standard plastic scintillator tiles, directly coupled to SiPM (via sophisticated air gap)

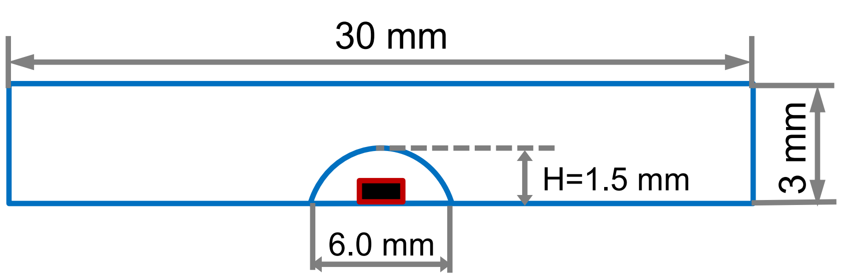






MPPC S12571-025P
1×1mm², 25µm (1600 pixels)

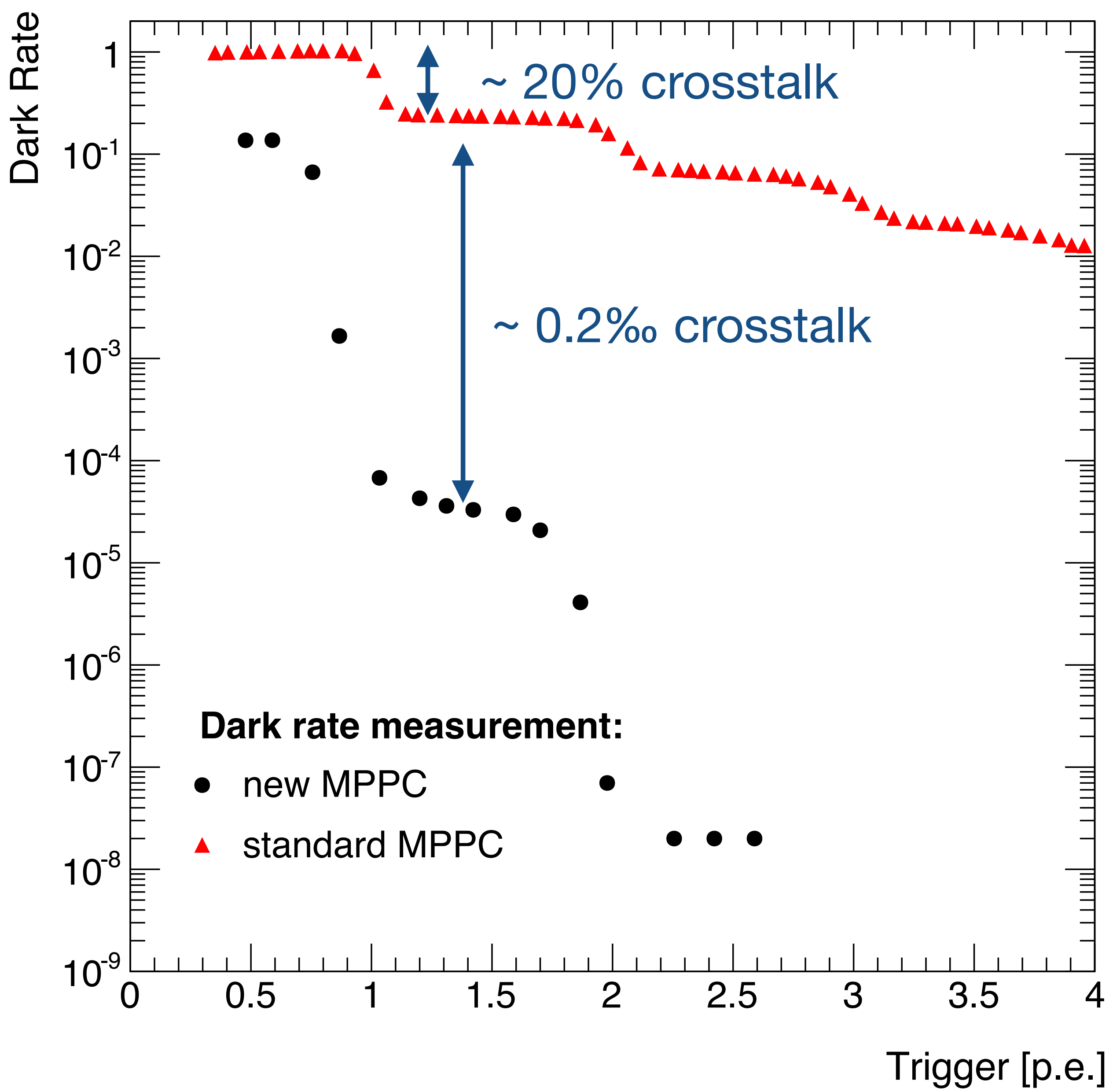




- Scintillator tiles optimised for SMD SiPMs, directly mounted on a PCB
    - Designed at Mainz, inspired by MPP studies - further optimisation for CLAWS planned
    - Tiles will be wrapped in reflective foil

CLAWS Components: SiPMs

- SiPMs are by now fairly standard devices - different options exist
- Still: Quite substantial advances recently - plan to use Hamamatsu MPPCs:



- Current SiPMs: 12571 series from Hamamatsu - still with high noise rates due to interpixel cross talk
- New generation eliminates this problem - plan to use for CLAWS
  - Tested pre-production prototypes LCT4/5
  - In discussions with Hamamatsu to obtain low crosstalk SMD devices with 50µm pixels

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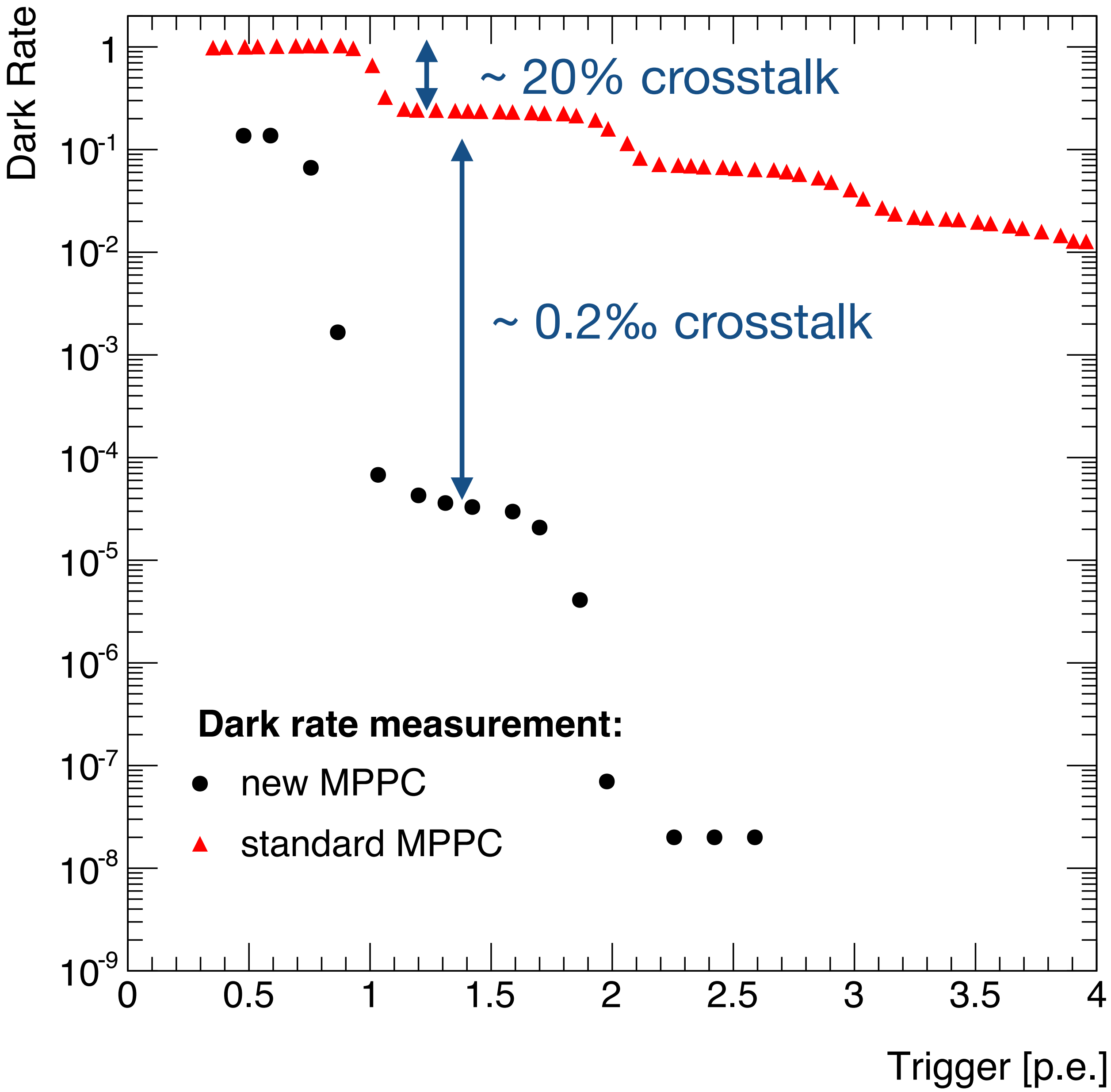

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- Targeted signal amplitude influences SiPM choice
    - With 1 mm^2 ~ 20 keV/photon
    - for small signals need to go to 9 mm^2 sensors - needs some development

CLAWS Components: Readout & DAQ

- Readout system - key requirements:
  - Fast sampling to allow for single photon resolution: ~ 1 GHz or more
  - Long acquisition window per event: 2 μs or more
  - Fast trigger rate: at least as KEKB frequency: 100 kHz

- Adopted solution for CALICE T3B: PicoScope 6403
  - 1.25 GHz sampling for 4 channels per unit
  - 1 GB buffer memory (shared between channels)
  - Burst trigger mode: Maximum rate determined by window length: > 100 kHz for 2.4 μs acquisition window tested and used
  - 8 bit vertical resolution
  - Control & Readout via USB - 4 oscilloscopes connected to one PC with multiple USB busses for maximum readout speed

PicoScopes will sit in counting house - cable length ~ 15 m. Tests ongoing, first measurements with ~ 35 m show signal degradation, but potentially still manageable

CLAWS Components: Readout & DAQ

- Considering upgrade for CLAWS - new generation of Picoscopes available (6404D):
  - 2 GB memory, **USB3 readout**
  - option for continuous data taking until buffer full (e.g. > **100 ms!**) with 800 ps sampling - needs to be tested & confirmed

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DAQ

- Plan to base the CLAWS DAQ on the system used for CALICE-T3B
    - "Home-developed" system based on toolkit provided by PicoTech
- Strategy
    - Record data provided by PicoScopes using event class (QT based) - store each sample by oscilloscopes in full 8 bit
    - Compression on DAQ computer (standard ZIP tool - compresses by a factor of 5 - 10) - then send to secondary computer for further storage management

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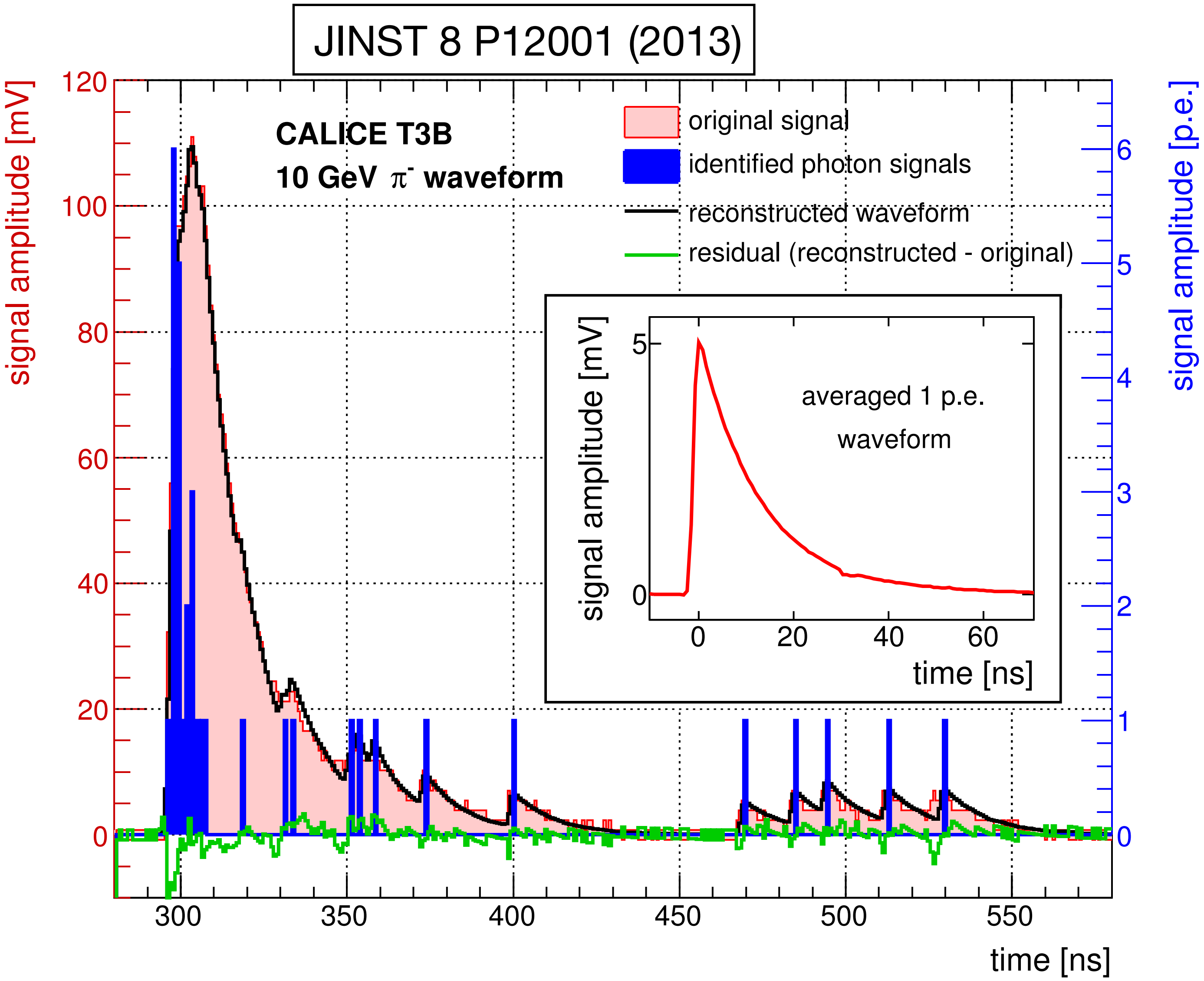
⇨ It seems unlikely that CLAWS can be integrated in other DAQ systems in BEAST2 - very different data structure and measurement philosophy

Data Analysis



Cell-wise reconstruction

- Reconstruction of time of each photon
  - Take raw analog waveform, and determine photon pulses by iterative subtraction
    - Relies on minimum amplitude of ~ 3 bits for 1 p.e. for best performance - limits overall dynamic range
  - “Analog” amplitude mode also possible - for high amplitudes and high dynamic range

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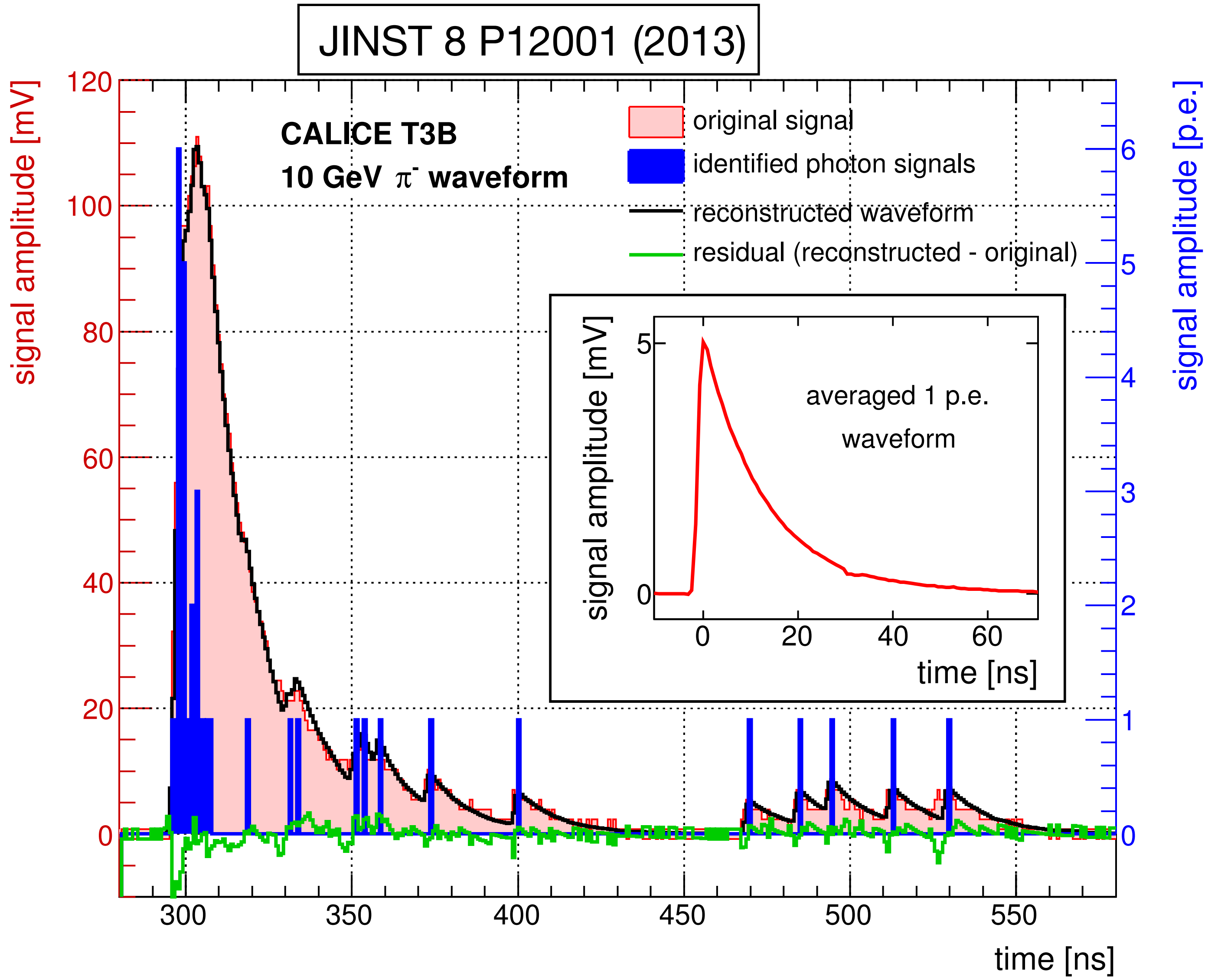

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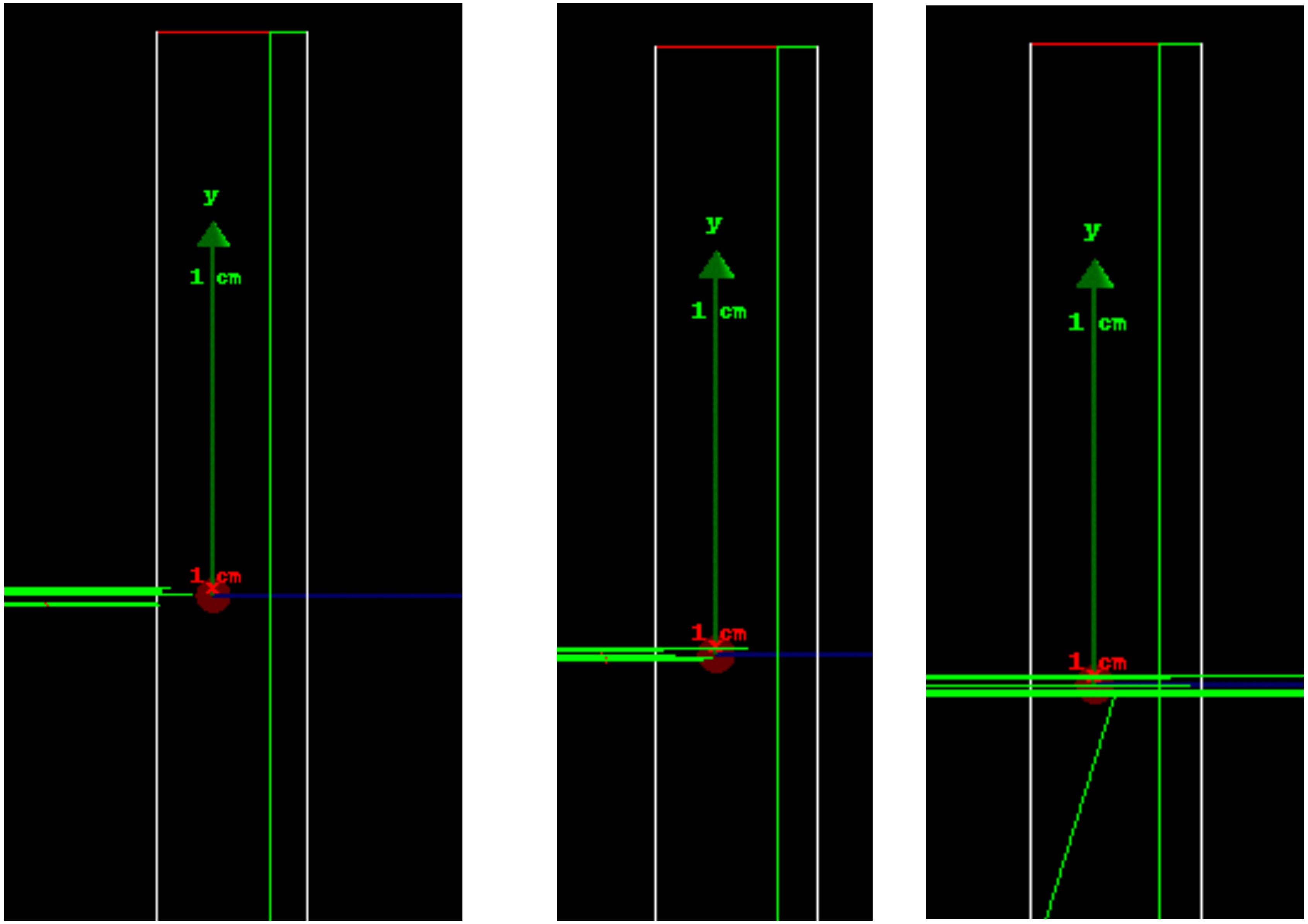
- Further analysis based on reconstructed photons
- New SiPMs with elimination of cross-talk will allow much lower minimum signal levels
  - Thermal noise and afterpulsing still exists, but is limited to single photon signals

Potential for X-Ray Sensitivity

- Simple simulation study - 3 mm plastic scintillator on a PCB, scintillator covered by reflective foil (with varying metal thickness for illustration)

4 keV 5.9 keV 20 keV



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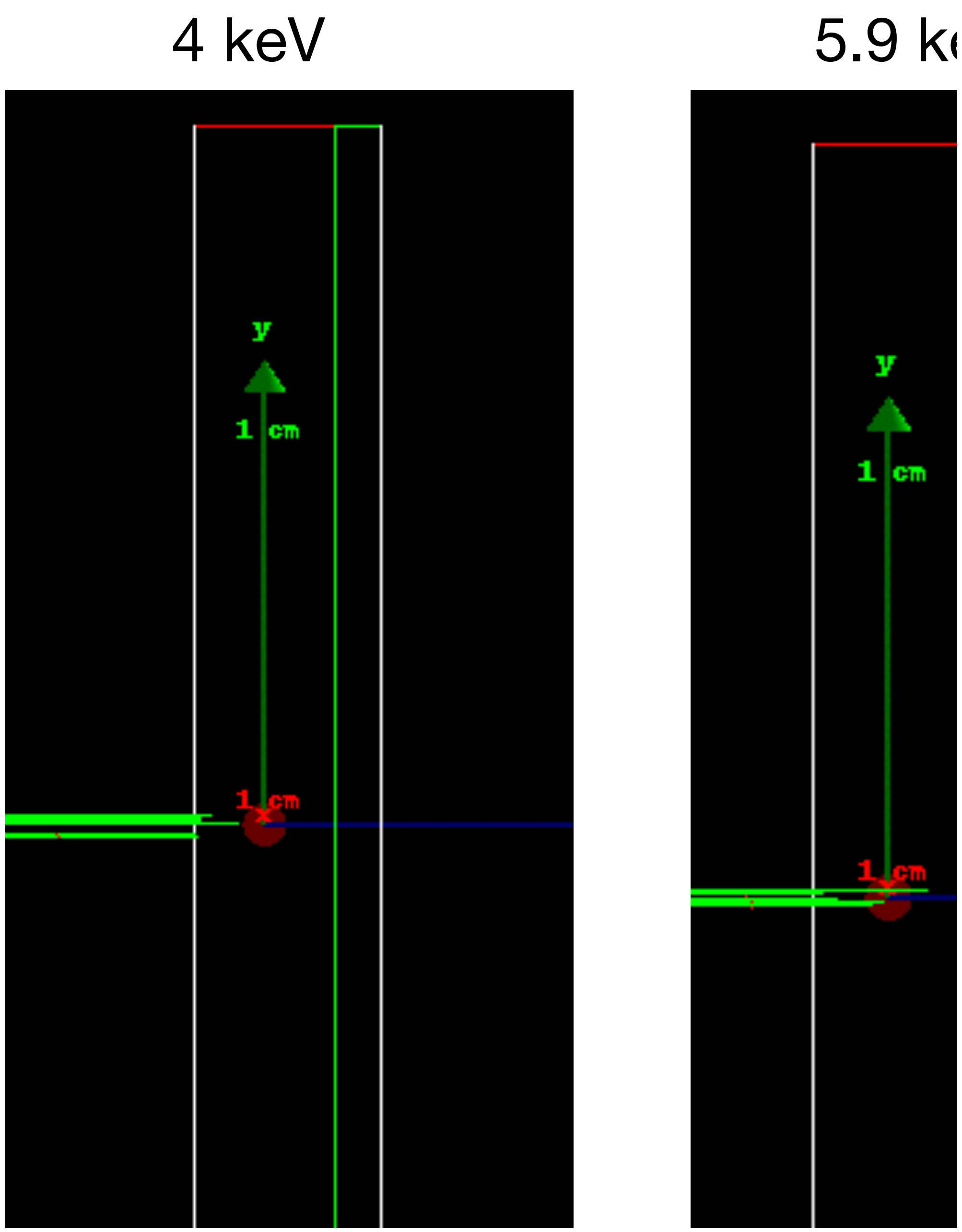
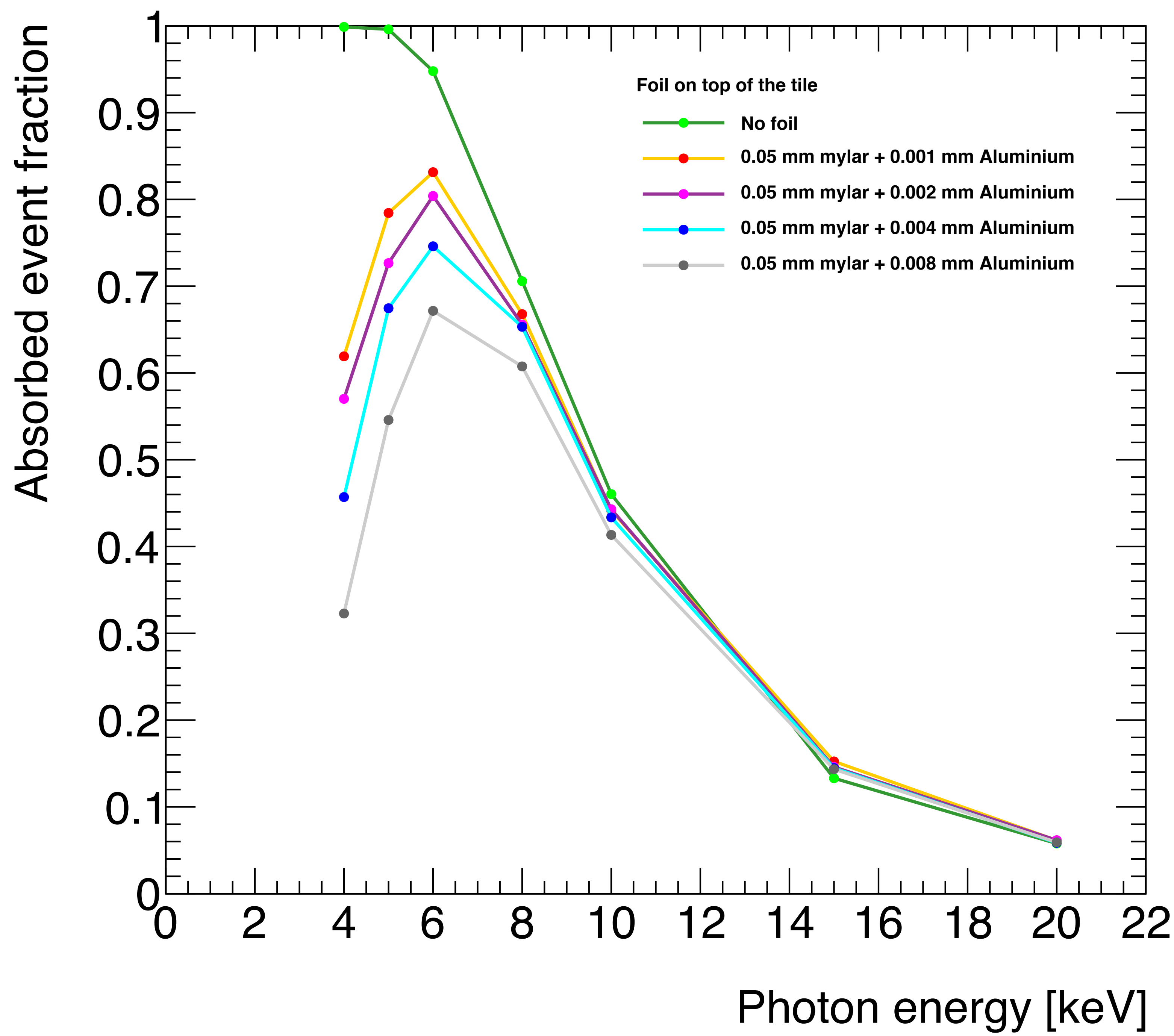




Summary

- First steps: We have an acronym: **CLAWS** (s**C**intillation **L**ight **A**nd **W**aveform **S**ensors) and a logo - thanks to Martin Ritter
- First idea for detector exist - based on development of Scintillator Tile / SiPM development for highly granular calorimeters

Summary

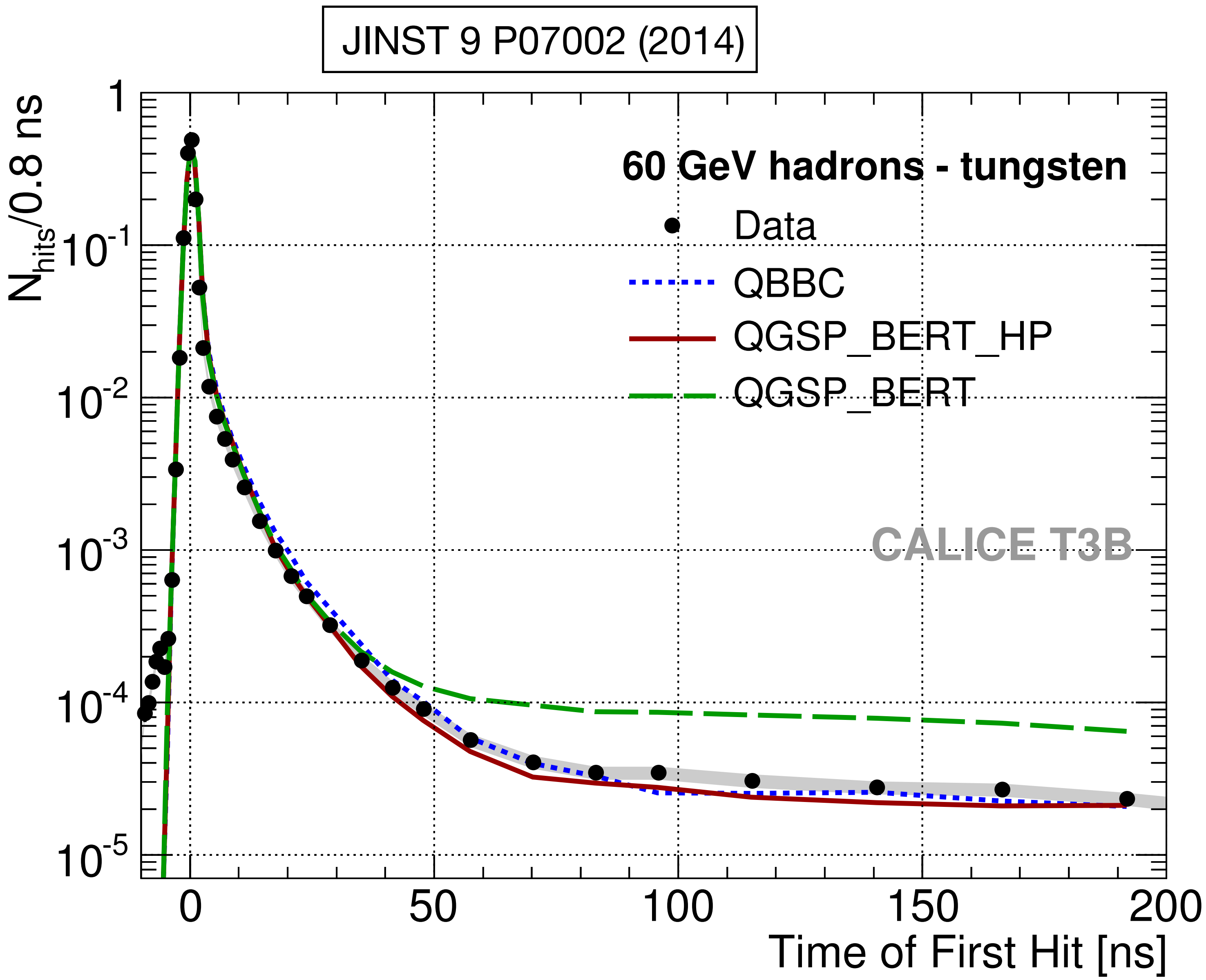
- First steps: We have an acronym: **CLAWS** (s**C**intillation **L**ight **A**nd **W**aveform **S**ensors) and a logo - thanks to Martin Ritter
- First idea for detector exist - based on development of Scintillator Tile / SiPM development for highly granular calorimeters

Next steps:

- Demonstrate technical feasibility:
  - Cable length to counting house - Currently testing if current pre-amps can drive the full distance to the counting house (~ 15 m) - If not: develop repeater board
  - Test X-ray sensitivity with ^{55}Fe source
- Develop CLAWS system
  - Mechanical design, including support, cable routing, …
  - Scintillator & SiPMs - Adapt to CLAWS requirements, react to performance of new devices from Hamamatsu
  - Adapt DAQ system to BEAST2 requirements, explore new Picoscope options
- Understand expected signals - first simulations under way (Martin, Igal, …)

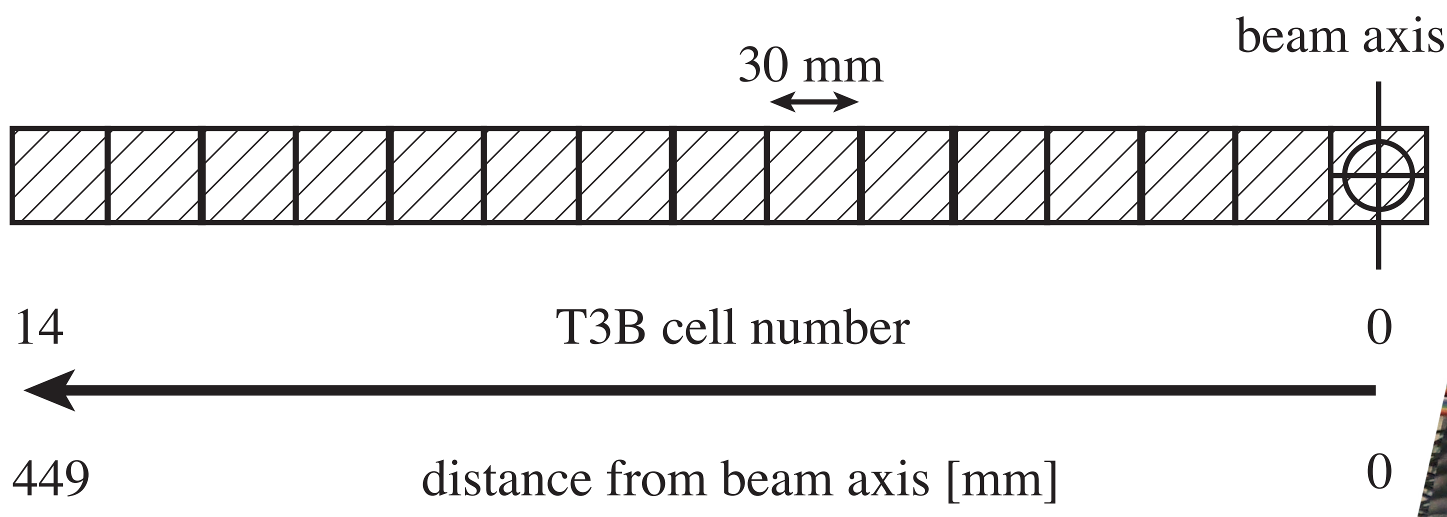
Backup

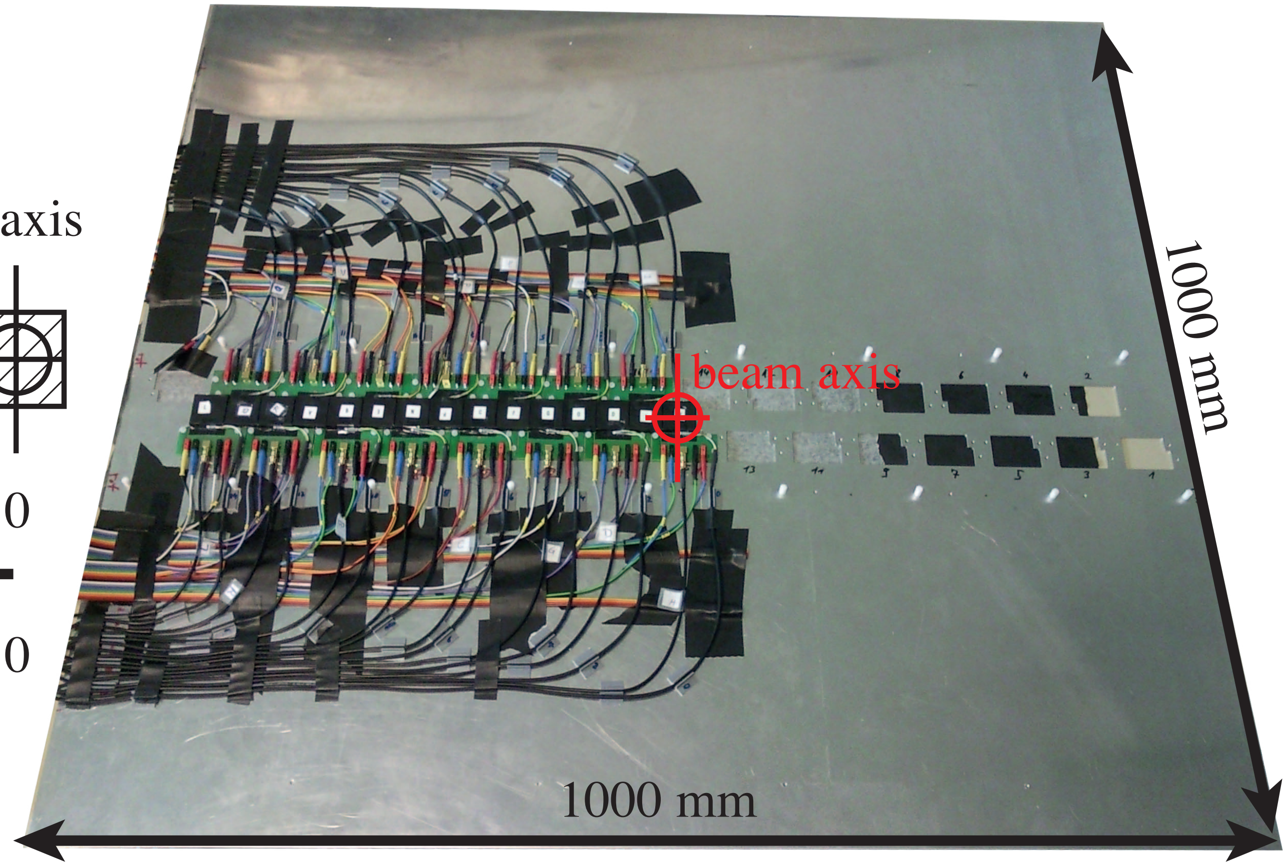
The Power of the System - One Example



- Accurately measure the time structure of hadronic showers - with late shower components on levels of 10^{-4} to 10^{-6} of the main signal

The T3B Detector



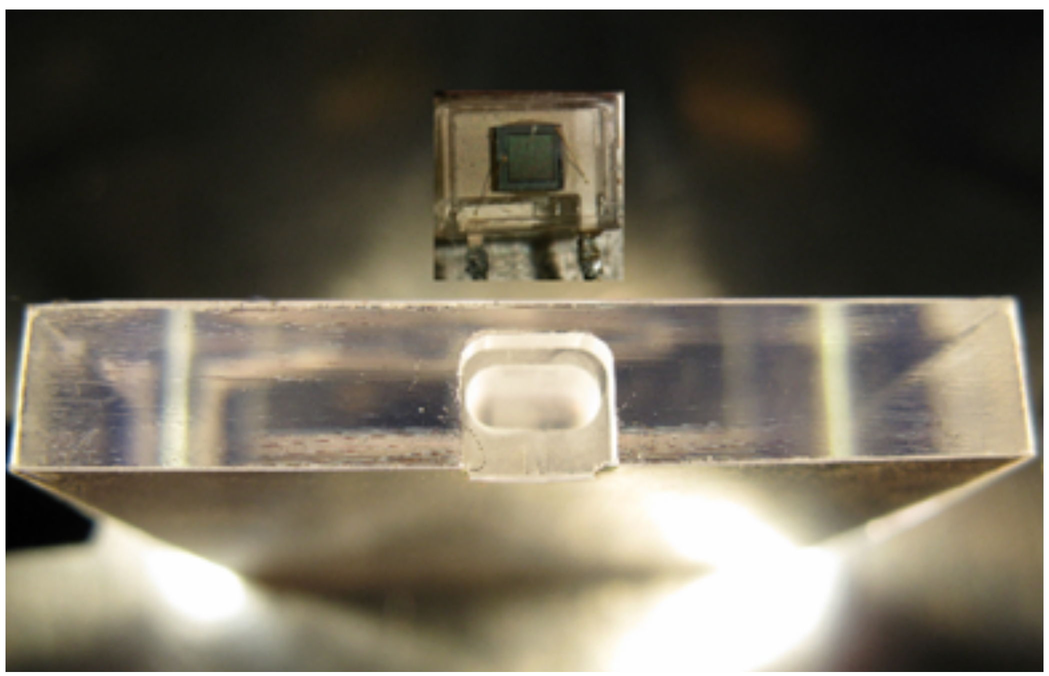


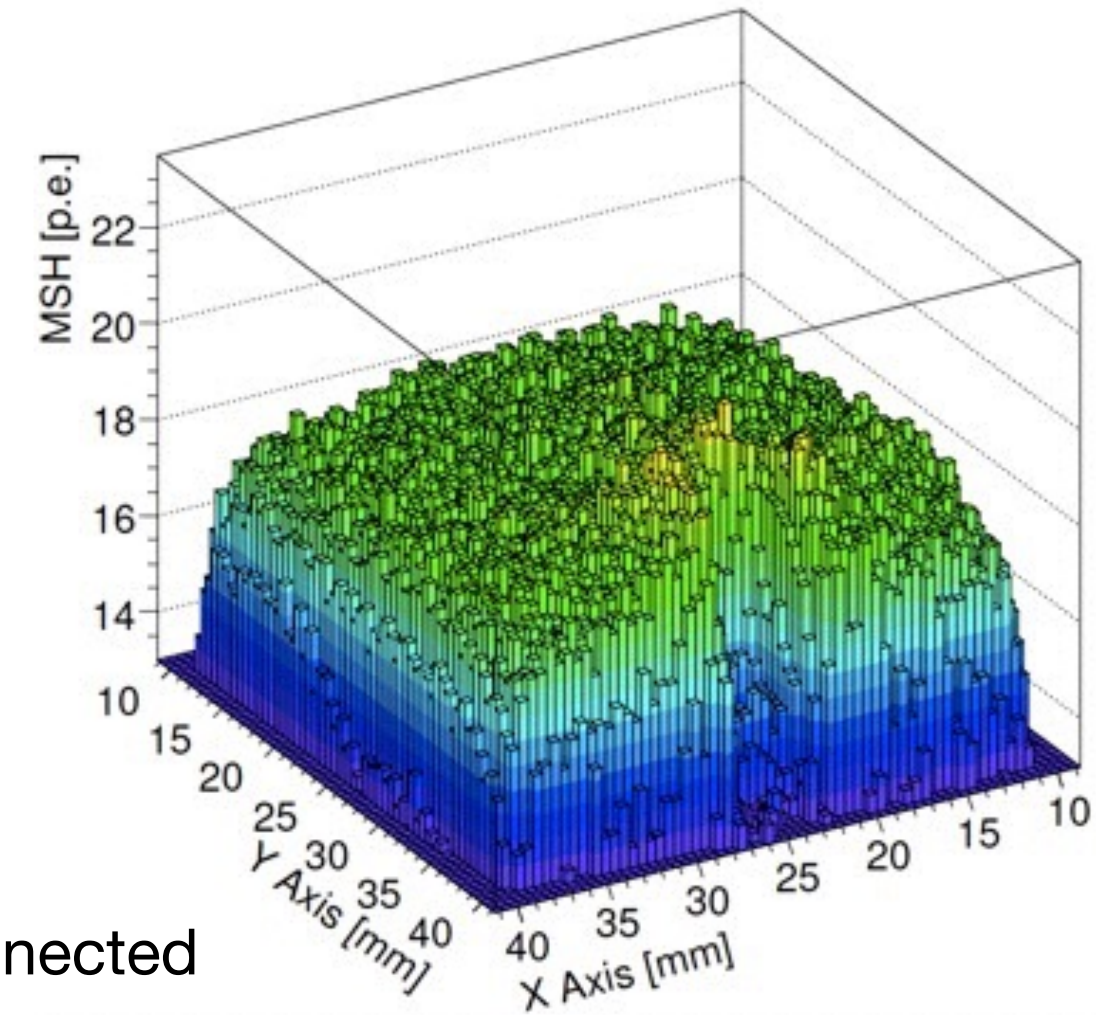
- 15 scintillator cells with SiPM readout
- DAQ based on 4 - channel USB Oscilloscopes (PicoScope), 800 ps sampling, 2.4 μs acquisition per event
- Installed downstream of CALICE calorimeters: W-AHCAL (5 λ), SDHCAL (6 λ)
- With W-AHCAL: Synchronisation of data streams possible (and demonstrated): Allows for event-by-event identification of shower start

▸ Optimised to study the time structure of hadronic showers with a small number of detector cells

T3B Active Elements: Scintillator Tiles & SiPMs

- Based on plastic scintillator tiles directly read out by SiPMs
  - fiberless coupling - improved time resolution, reduced mechanical complexity
  - scintillator geometry optimised for uniform response

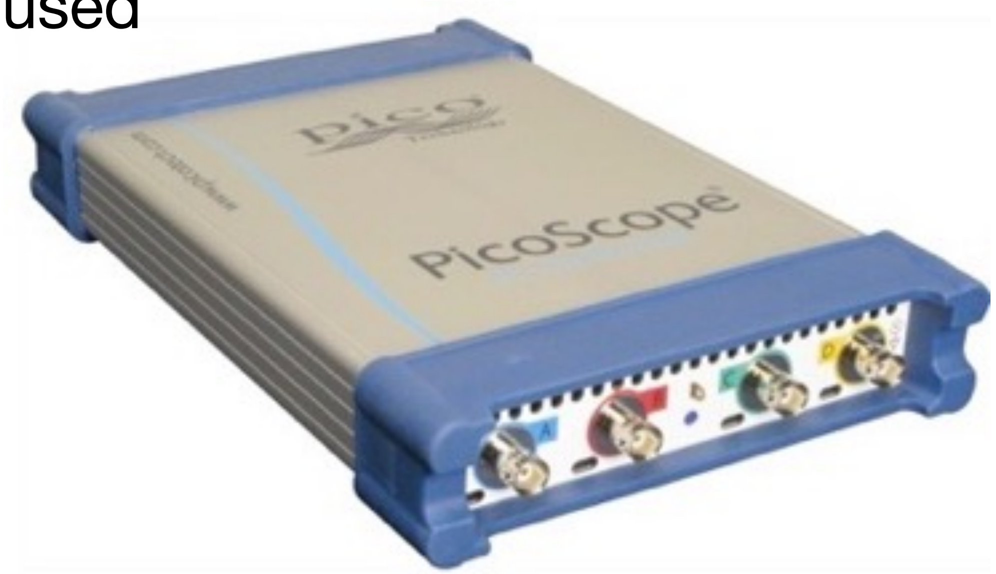




- One pre-amp per cell - currently each cell connected to a separate little board
- Analog SiPM signals to oscilloscope readout via coax cable

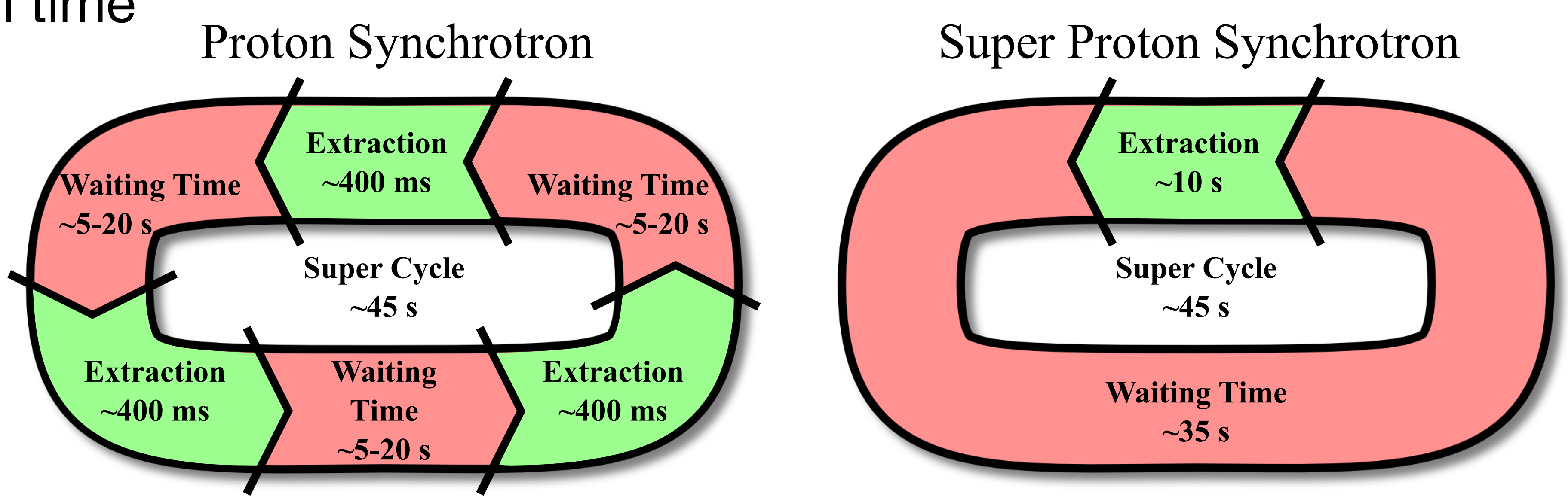
T3B Readout System: Picoscopes

- Key requirements:
  - Fast sampling to allow for single photon resolution: ~ 1 GHz or more
  - Long acquisition window per event: 2 μs or more
  - Fast trigger rate: faster than the CALICE HCAL, > a few kHz
- Adopted solution for T3B: PicoScope 6403
  - 1.25 GHz sampling for 4 channels per unit
  - 1 GB buffer memory (shared between channels)
  - Burst trigger mode: Maximum rate determined by window length: > 100 kHz for 2.4 μs acquisition window tested and used
  - 8 bit vertical resolution
  - Control & Readout via USB



T3B Readout Scheme

- Based on a test beam environment: Data taking during a “spill”, then readout during off-spill time

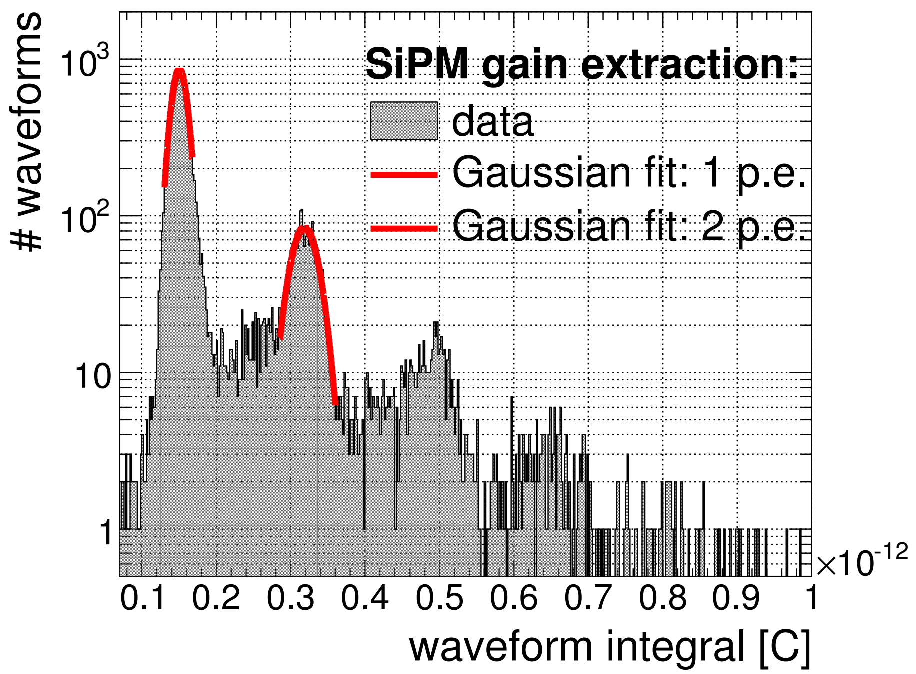


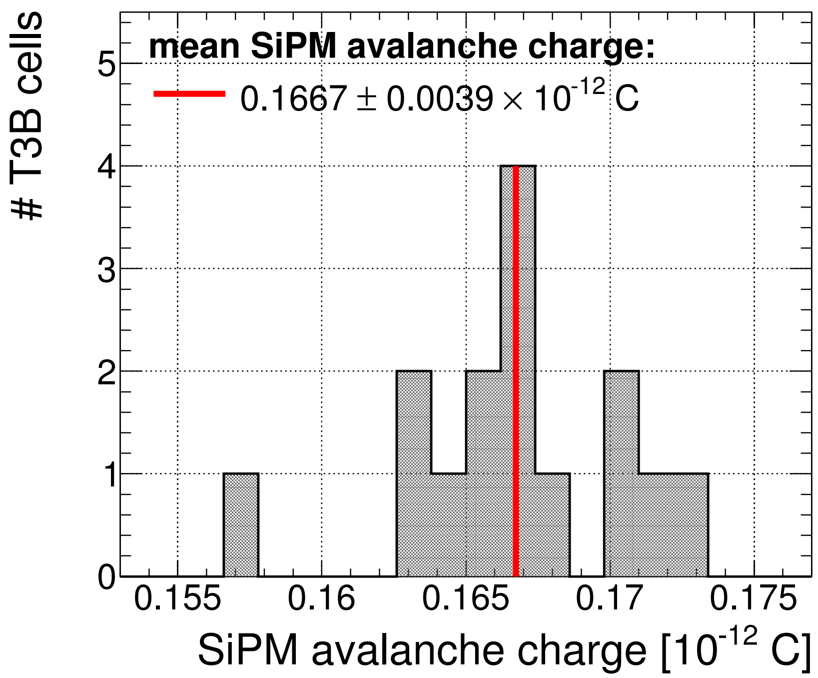
- Typical operation mode:
  - Up to 10k triggers per spill - data volume:
    - 3000 samples/ev, 8 bit per sample: 240 Mbit/ch/spill => ~ 1 Gbit / picoscope/spill
    - with four scopes: 500 MB/spill - read out over USB2
    - requires parallel readout over four controllers to read in less than 30s

- Summary: Record 10k events with high rate, then read out for ~ 30s, record again…
  (NB: The number of recorded events before readout can be higher by x 5, then readout takes longer)

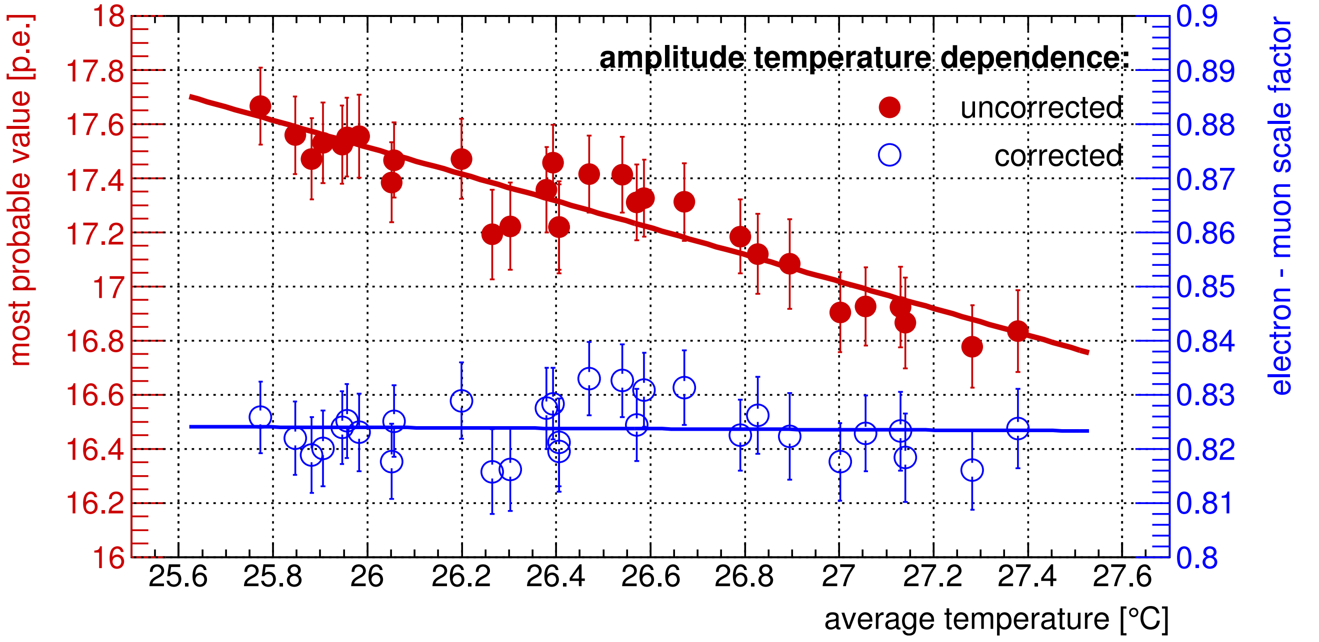
Calibration

- Calibrated on dark noise taken between spills



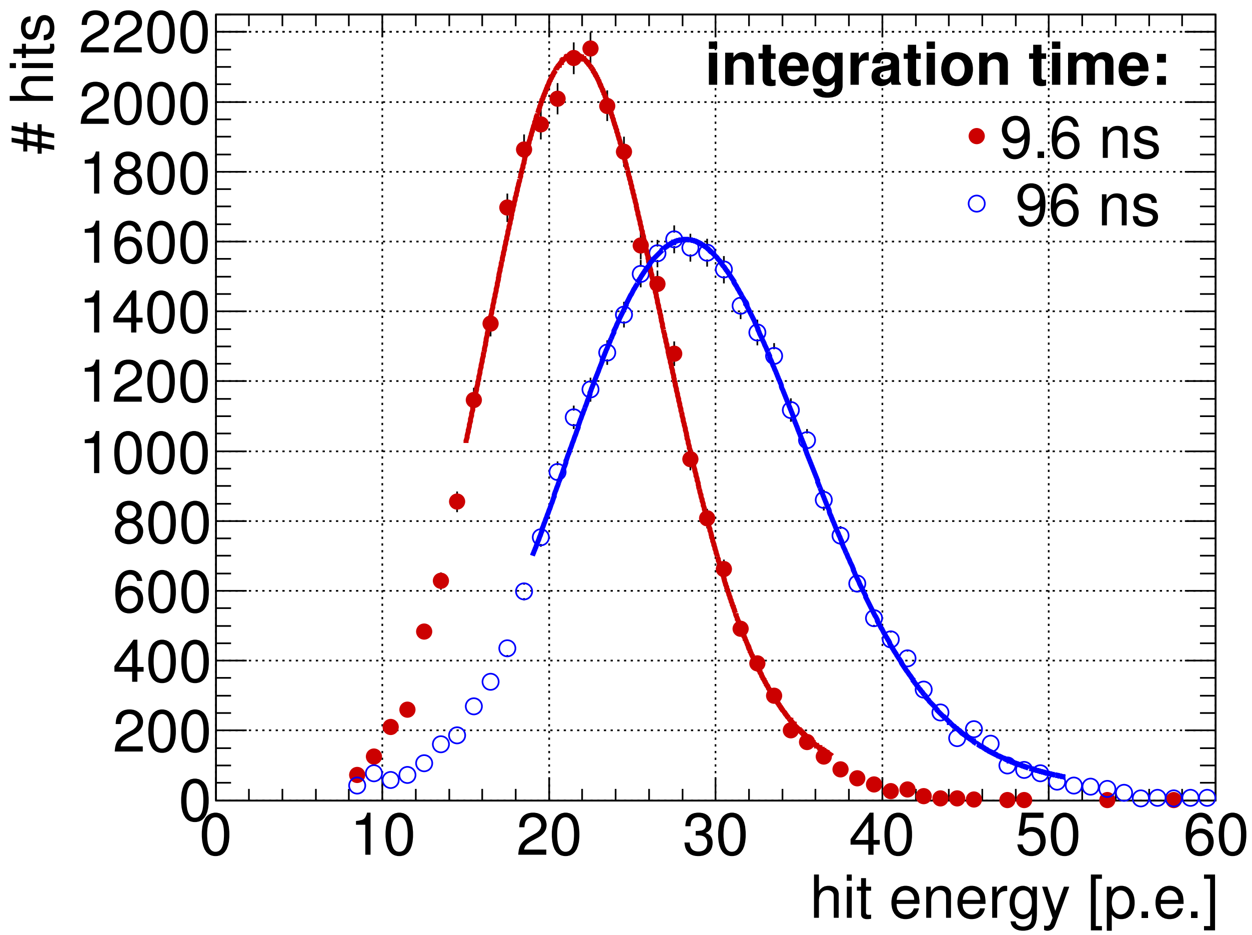


- Constant temperature monitoring used to correct temperature effects



Performance

- Reconstructed amplitude for particle signals depends on integration time (afterpulsing of photon sensor)



- Time resolution of complete system (including CALICE trigger) < 800 ps