T3B Scintillators for BEAST2

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Frank Simon

Max-Planck-Institute for Physics

Calorimeter for ILC

Max-Planck-Institut für Physik

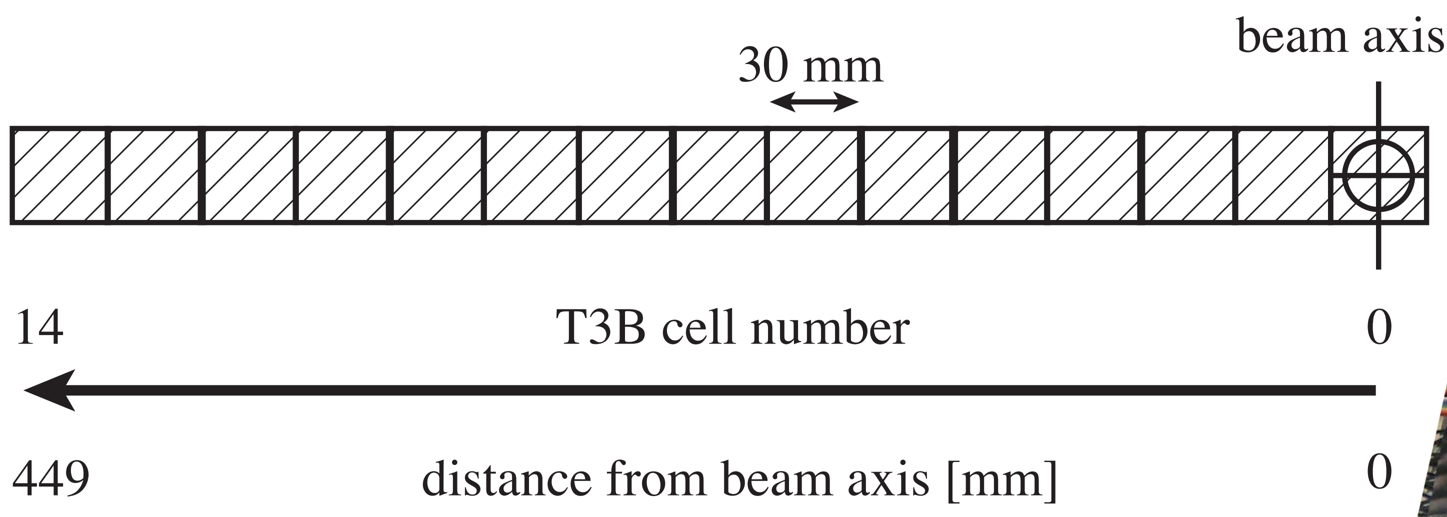
(Werner-Heisenberg-Institut)

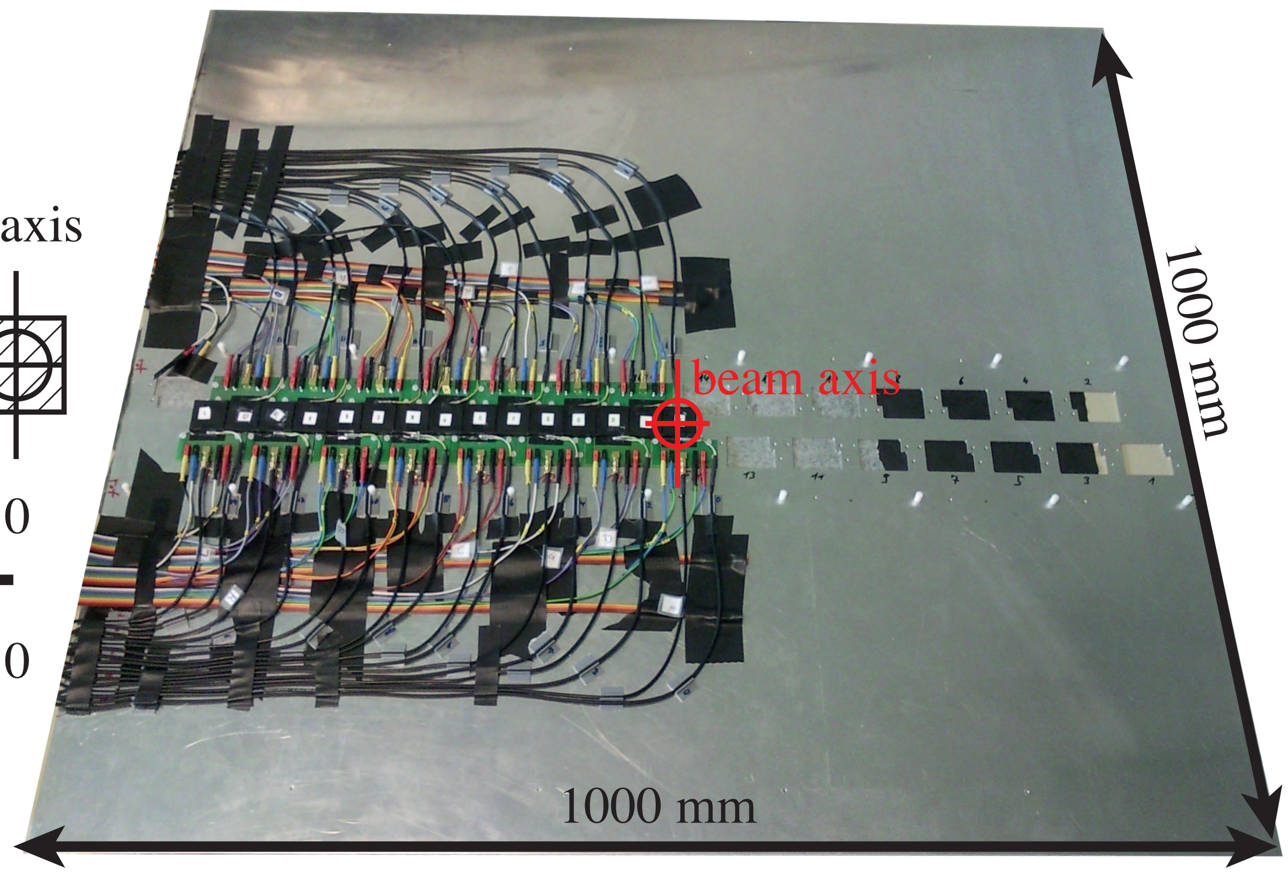
Outline

- The T3B setup
- Active elements
- Data acquisition
- Analysis, calibration & performance
- Towards a system for BEAST2

Tungsten Timing
T3B
TestBeam

The T3B Detector

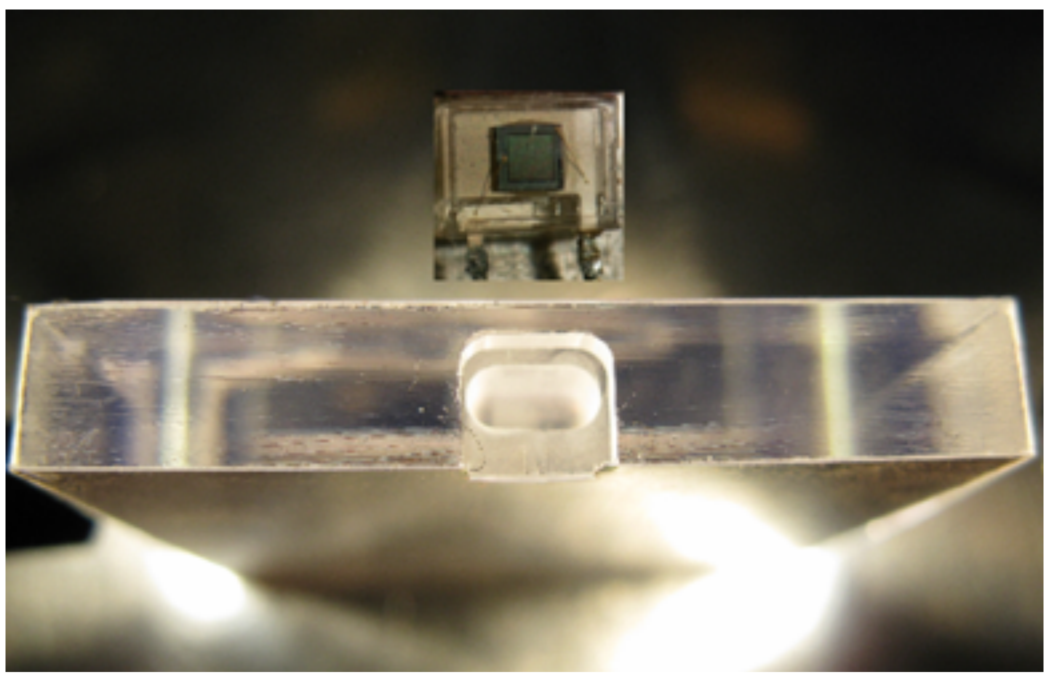


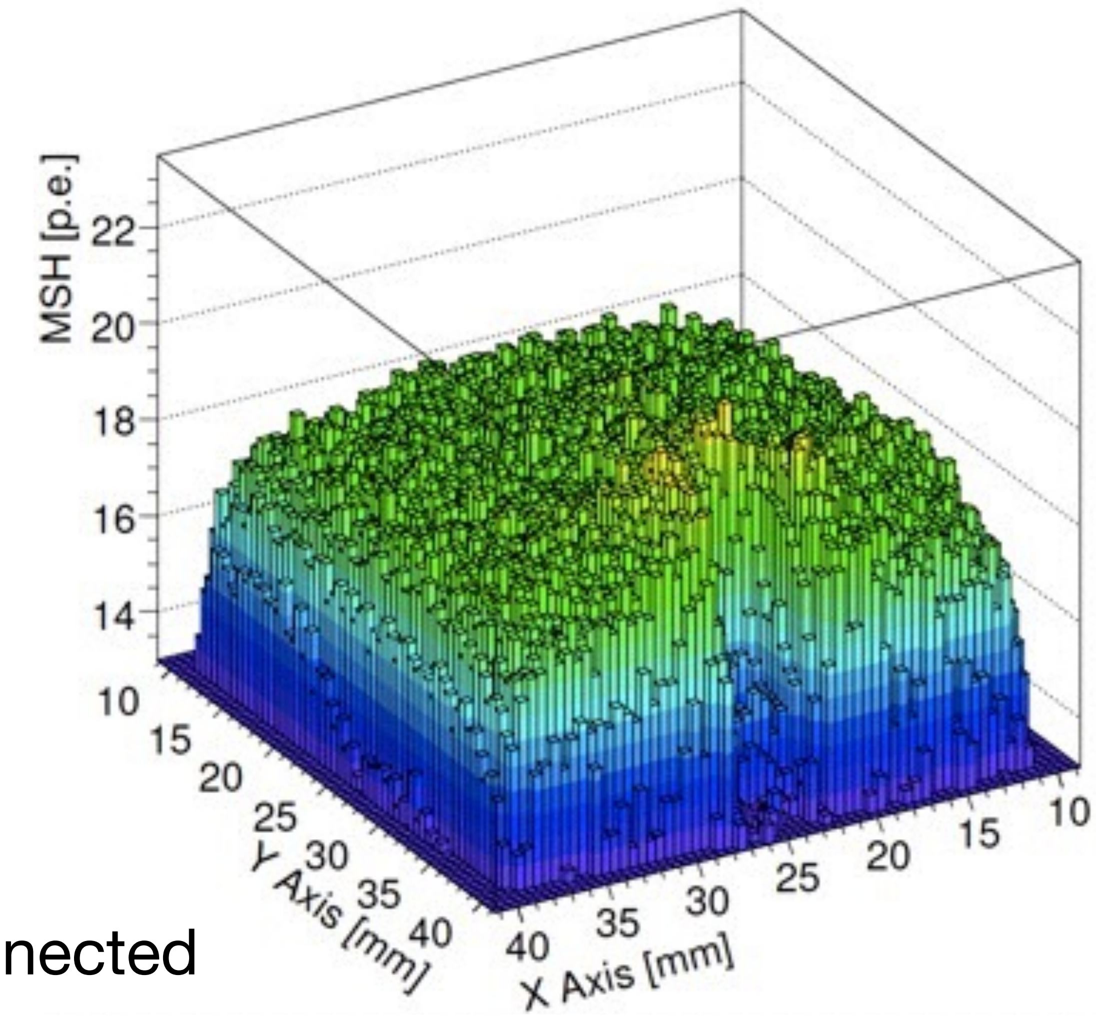


- 15 scintillator cells with SiPM readout
- DAQ based on 4 - channel USB Oscilloscopes (PicoScope), 800 ps sampling, 2.4 μs acquisition per event
- Installed downstream of CALICE calorimeters: W-AHCAL (5 λ), SDHCAL (6 λ)
- With W-AHCAL: Synchronisation of data streams possible (and demonstrated): Allows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

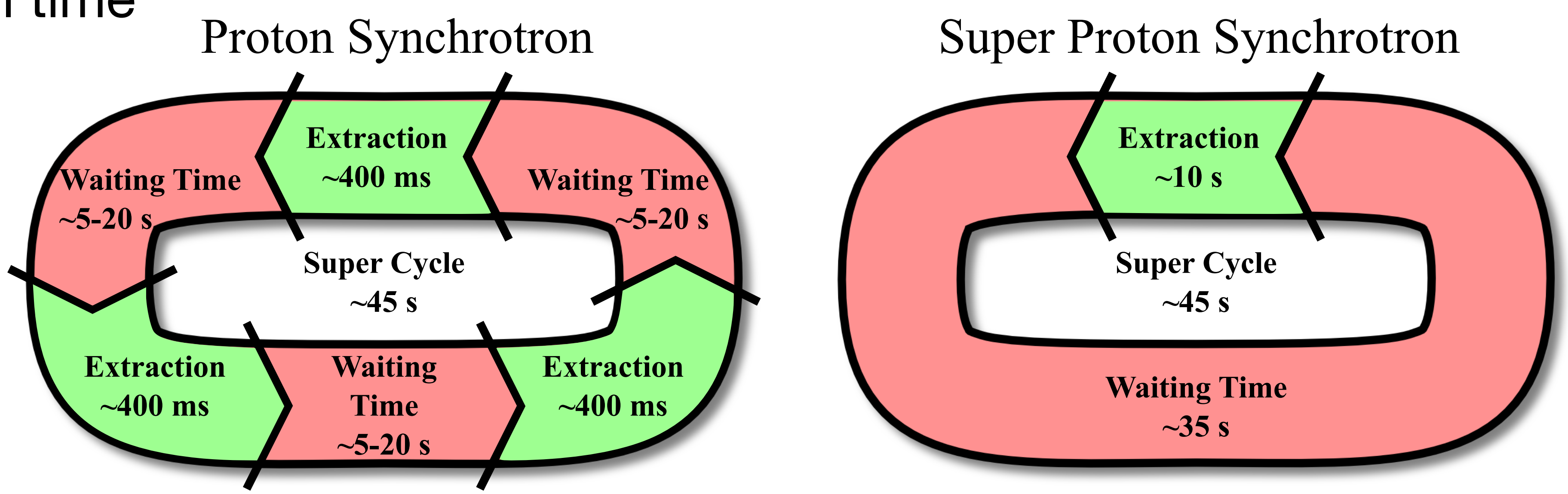
T3B Readout System: Picoscopes

- 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

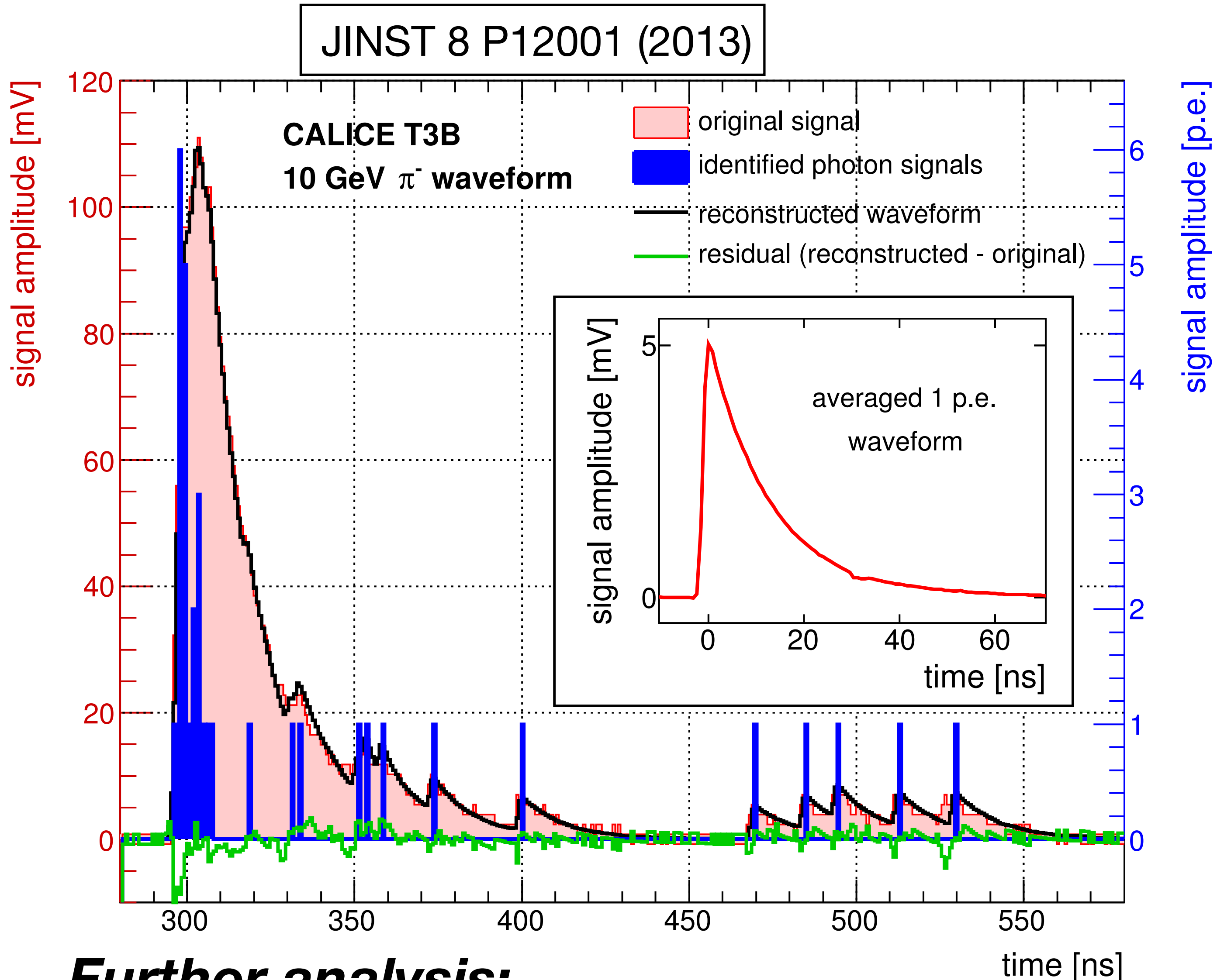
- Based on a test beam environment: Data taking during a “spill”, then readout during off-spill time



- 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)

Data Analysis



Cell-wise reconstruction

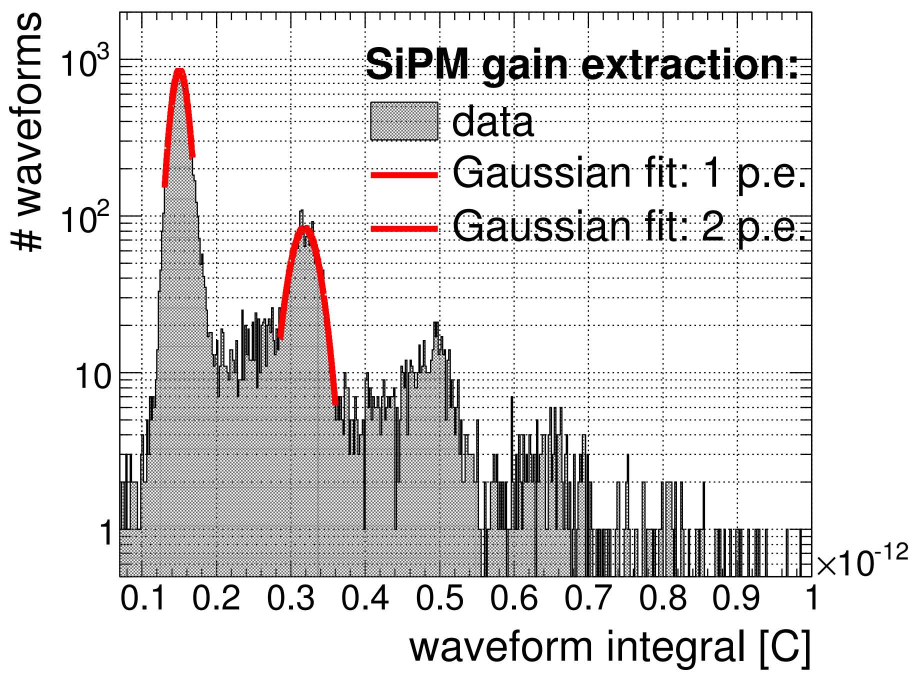
- Reconstruction of time of each photon
- Reconstruct hits by clustering in time - require at least ~ 0.3 MIP equivalents within 9.6 ns
- 1 MIP ~ 20 photons, corresponds to ~820 keV in scintillator

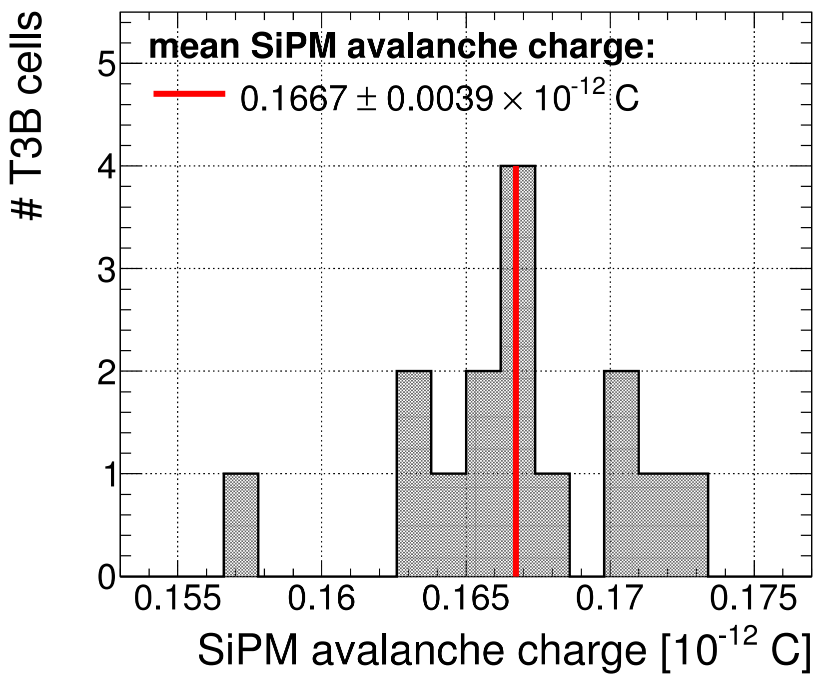
Further analysis:

- For robustness: Use only the first hit in each cell in an event - avoids uncertainties from hit separation, afterpulsing, … High granularity ensures multiple real hits are rare (at the %-level)
- Main observable: “Time of first hit” - Timing given by the second reconstructed photon (SiPM)

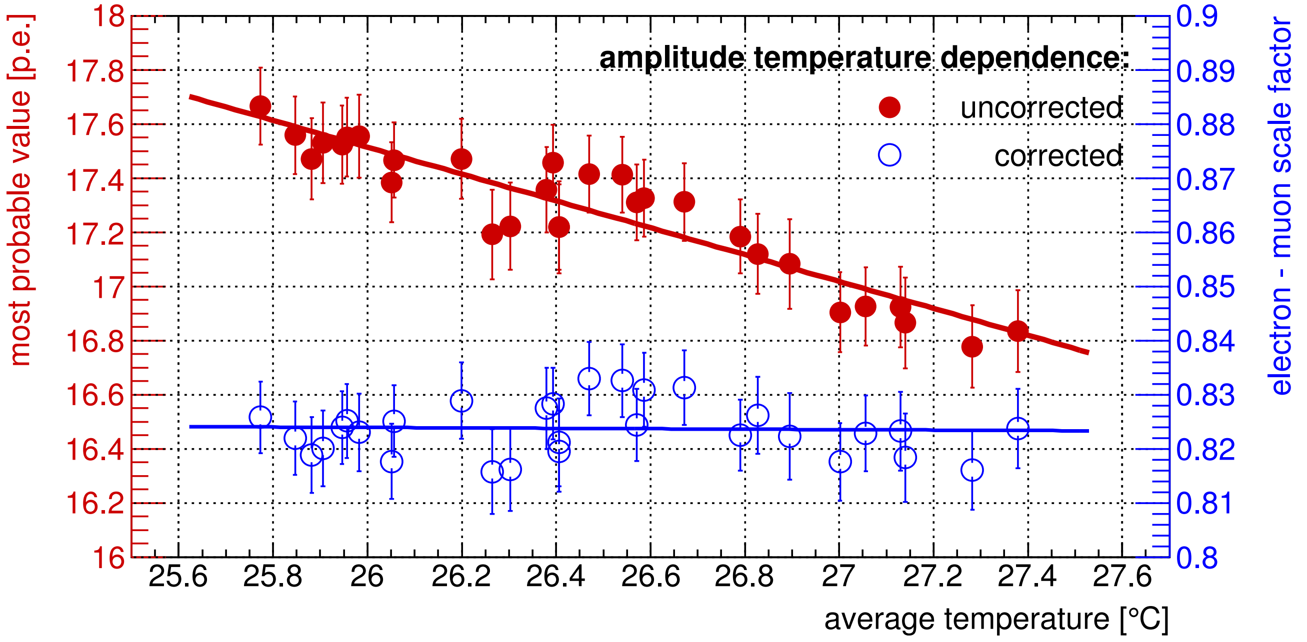
Calibration

- Calibrated on dark noise taken between spills



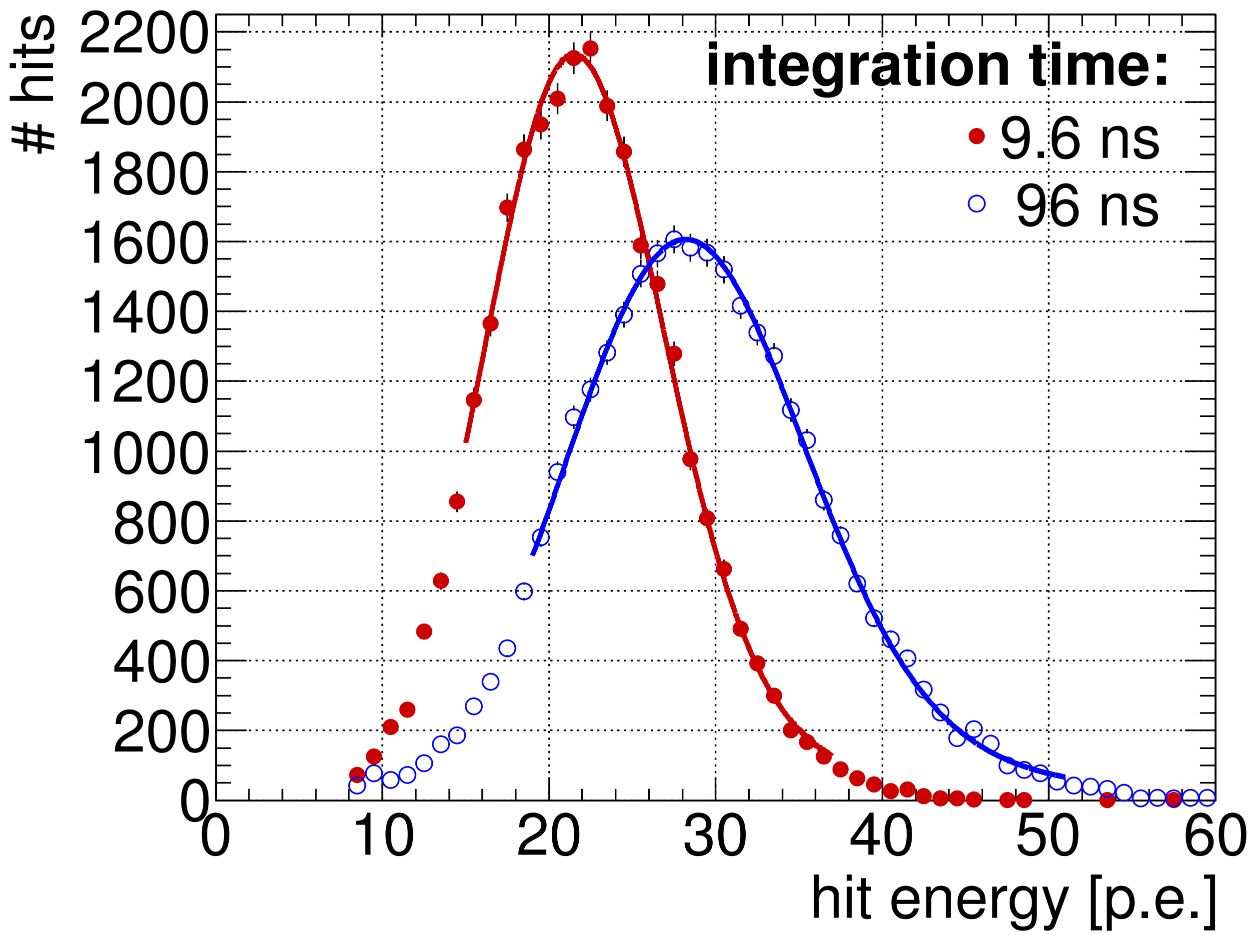


- Constant temperature monitoring used to correct temperature effects

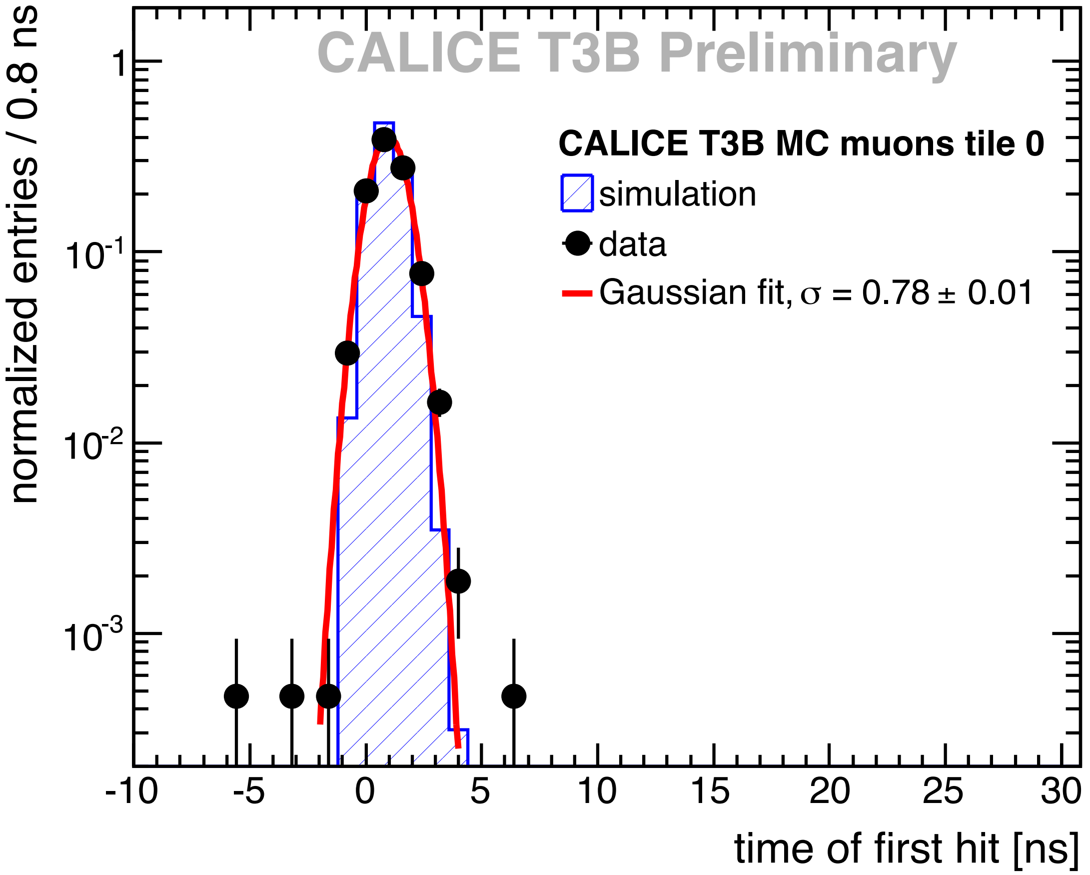


Performance

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



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



Towards a System for BEAST2

- First step: We have an acronym: **CLAWS** (s**C**intillation **L**ight **A**nd **W**aveform **S**ensors)

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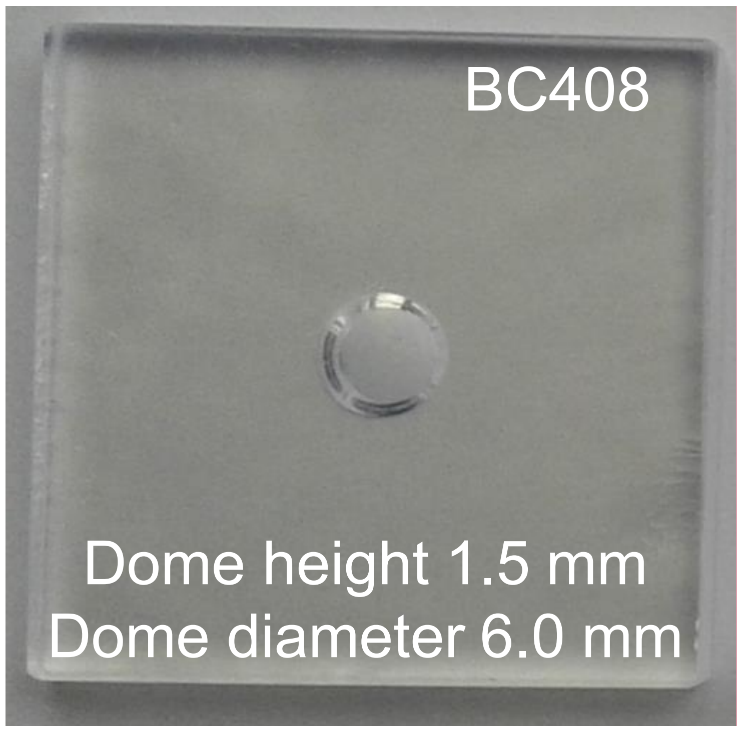
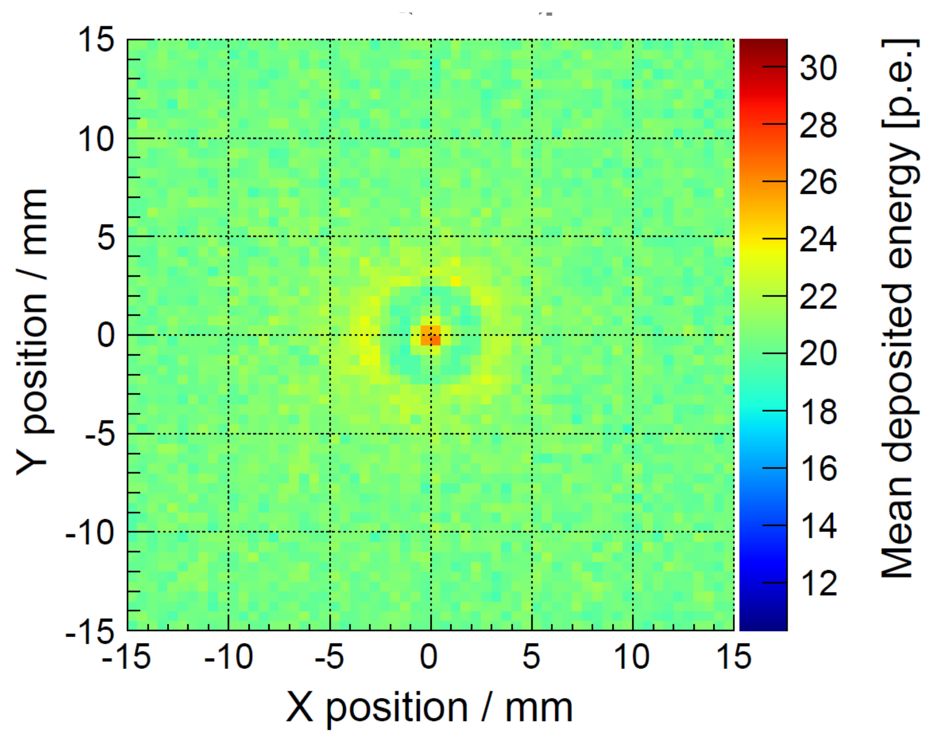
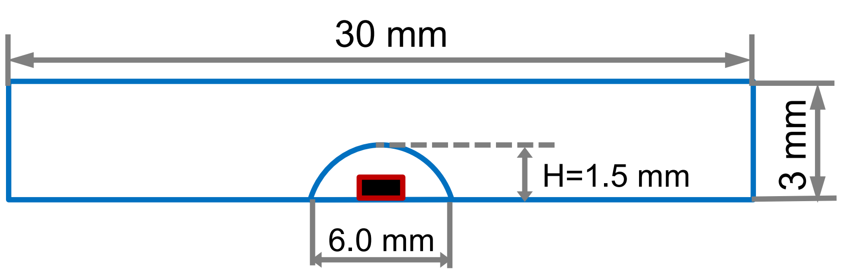
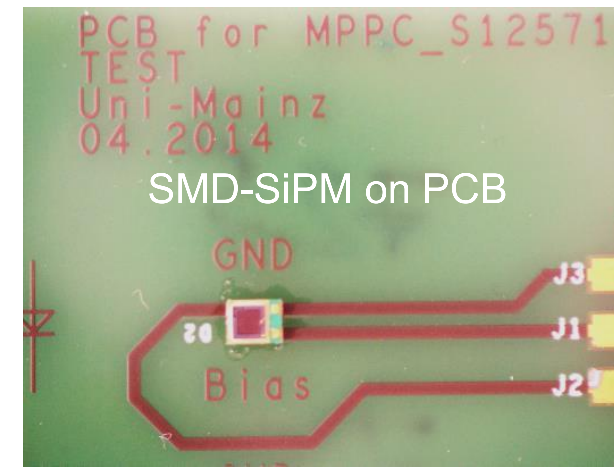
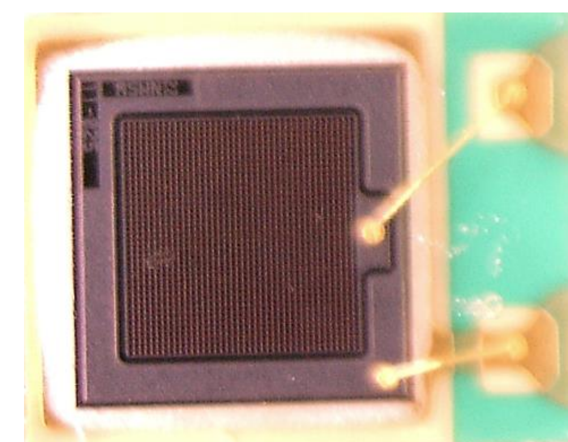








MPPC S12571-025P
1×1mm², 25µm (1600 pixels)



- Scintillator tiles optimised for SMD SiPMs, directly mounted on a PCB
  - Designed at Mainz, inspired by MPP studies

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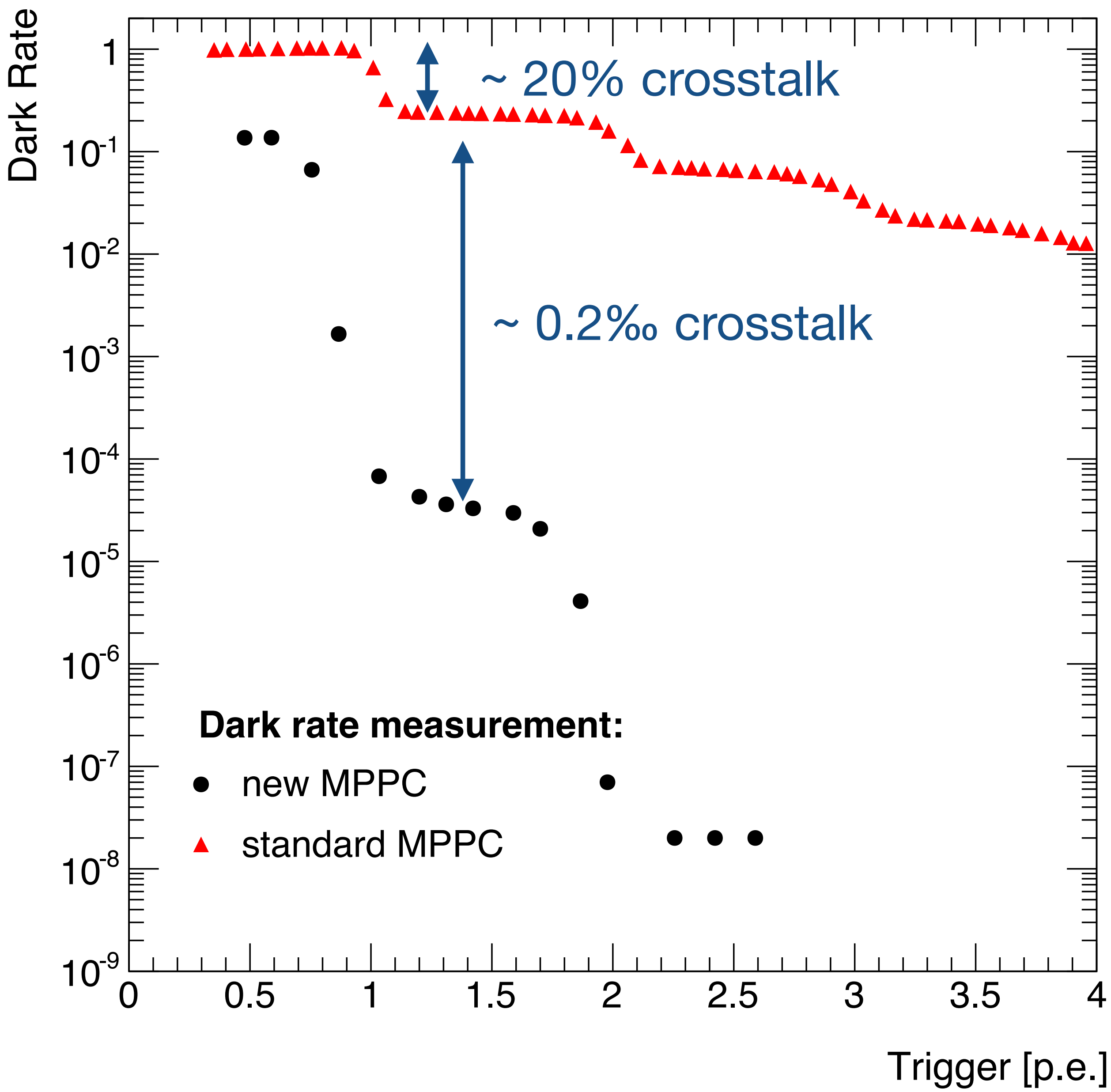

- Current SiPMs: 12571 series from Hamamatsu - still with high noise rates due to interpixel cross talk
- New generation (not yet officially available) eliminates this problem - plan to use for CLAWS
  - The challenge: Also eliminates our calibration strategy - need to find a new solution, for example based on LEDs

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- Demonstrate technical feasibility:
  - Cable length to counting house - Picoscopes are not fit for operation in magnetic field, and are not radiation hard: Need to test if current pre-amps can drive the full distance to the counting house (~ 10 m)
    - If not: develop repeater board

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- Understand requirements:
  - What exactly will we measure with this system?
  - What are the expected energies?
  - What are the expected rates?