Measurement of the time resolution of the KLauS6 ASIC: -Testbeam Report-

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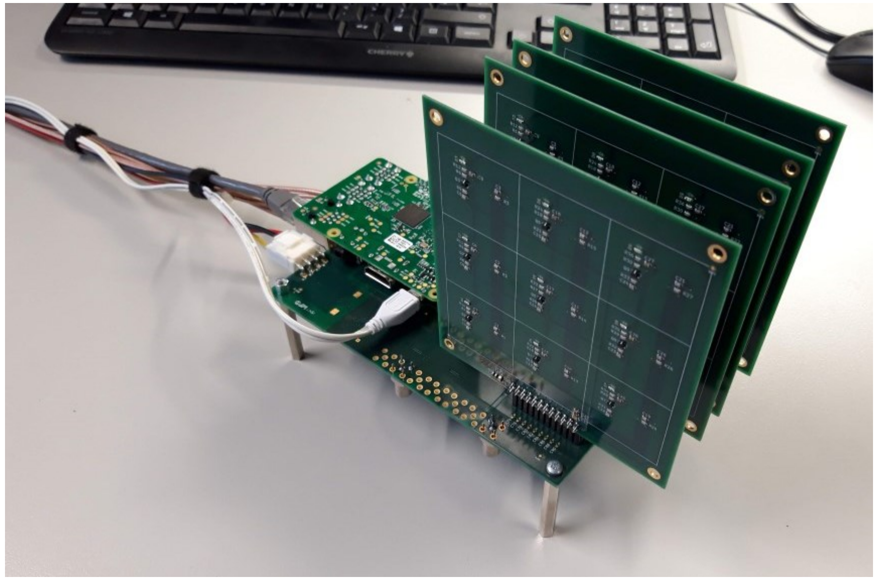
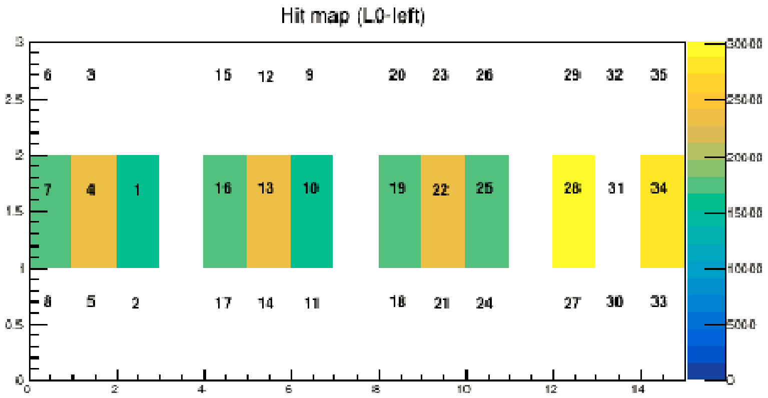
CALICE Collaboration Meeting

09.09.2021

Testbeam Setup 06-2021

- Unpackaged KLauS6b-ASIC on updated K6b-Testboard
- New Chip KLauS6b with fixed bugs
    - TDC bit flip
    - Reset bug in TDC fine counter latches
- 4 sensor layers with 9 channels each
    - 2 types of SiPMs (15 & 25 µm)
    - Central row equipped with tiles → 12 channels (1 broken)
- Previous testbeam in October 2020: Timing resolution <1ns achieved with KLauS6(“a”) and wrong SiPM bias network





Goals and Program

Focus on timing performance in beam with AHCAL tiles

- Main goals in this testbeam:
  - Full calibration of chip for two types of SiPMs
  - Parameter sweeps over HV, Threshold, Input stage bias current to find good working point
  - Cross check results from last testbeam (10-2020)

  → Expect higher impact of timewalk correction on timing performance

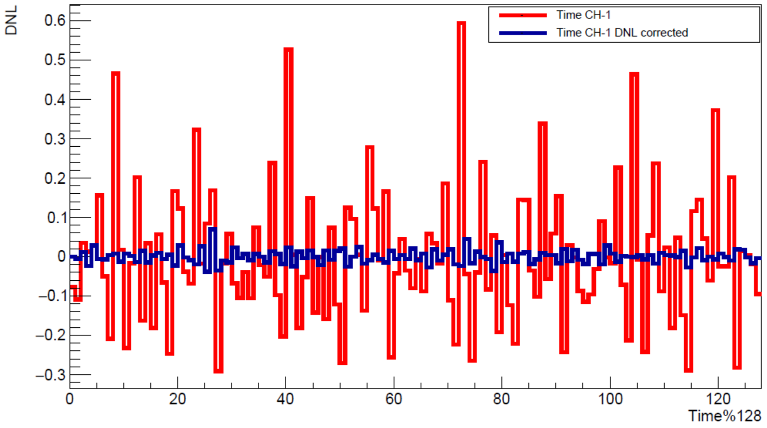
- Additional program:
  - Energy resolved timing studies with tungsten absorbers
  - Power pulsing with full chip (to be analysed)

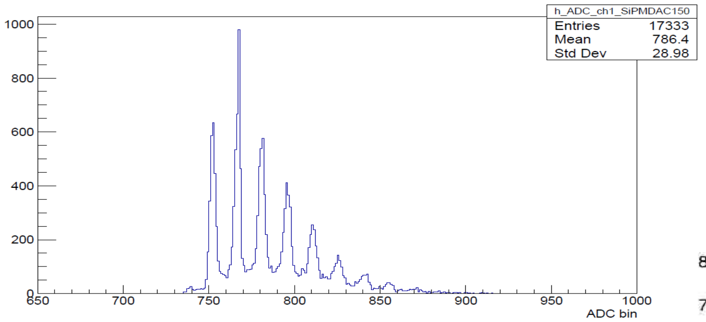
Calibration steps

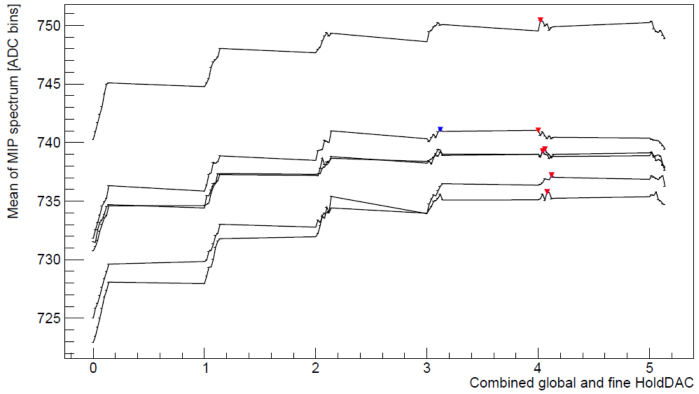
ASIC parameter tuned using LED system & in-beam measurements:

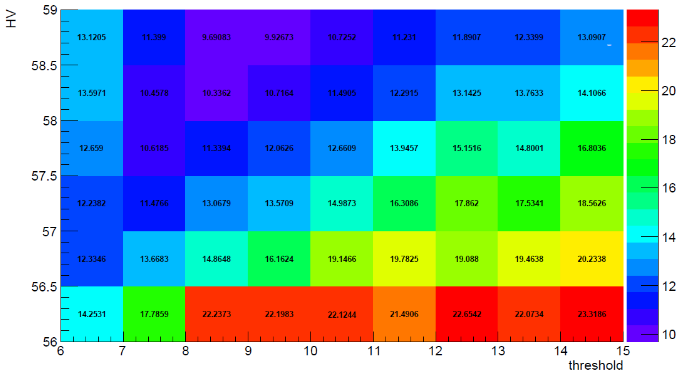
<u>Compromise between noise trigger rates, power and timing performance</u>

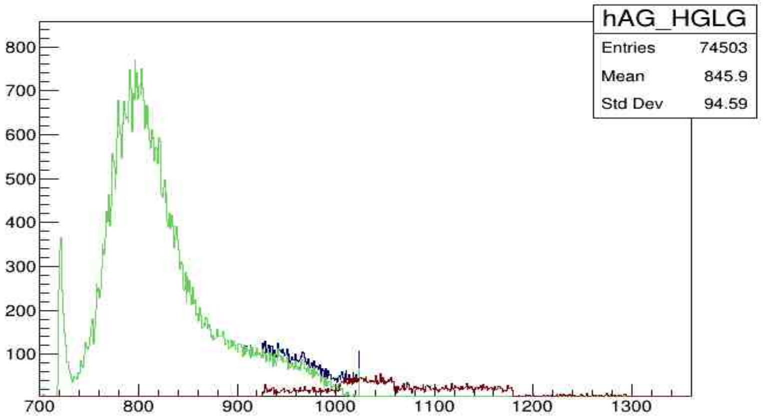
- ADC/TDC DNL correction
- Hold Delay optimization
- SPS Gain uniformization
- Auto Gain inter-calibration
- HV&Threshold tuning





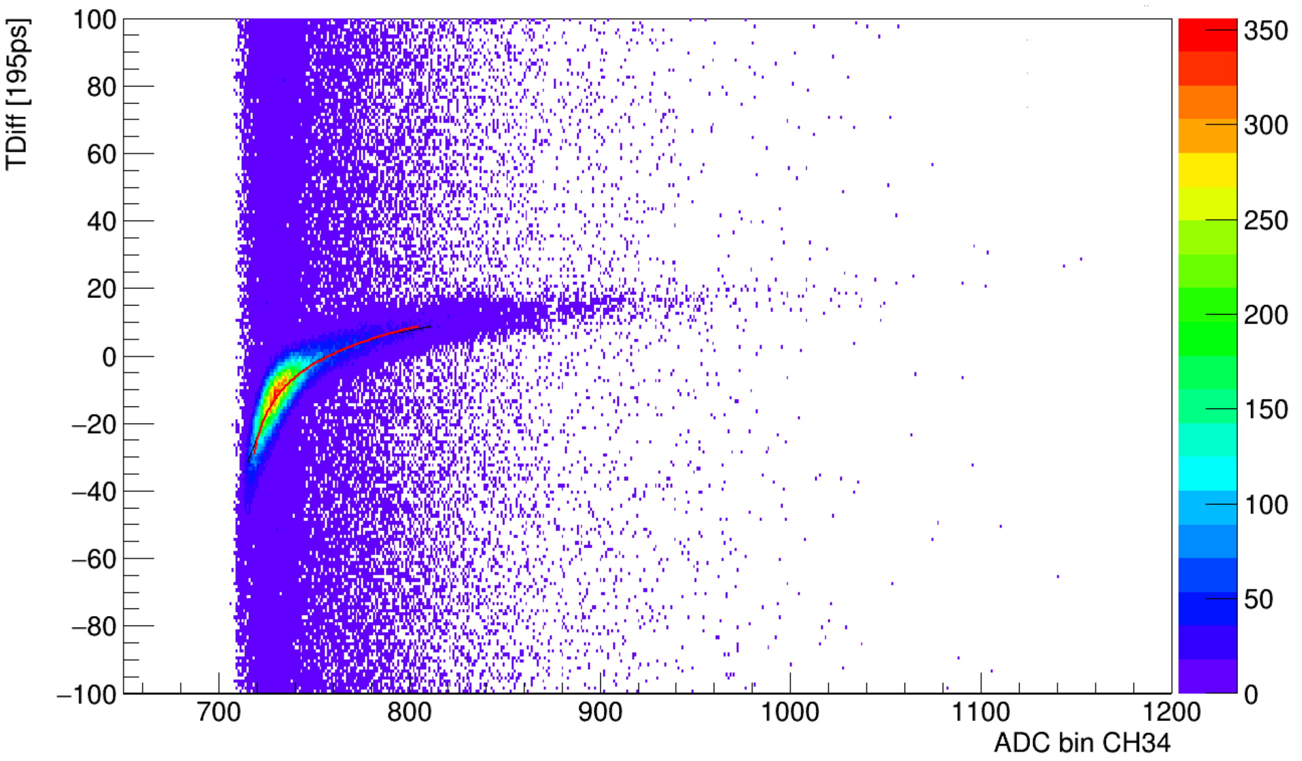




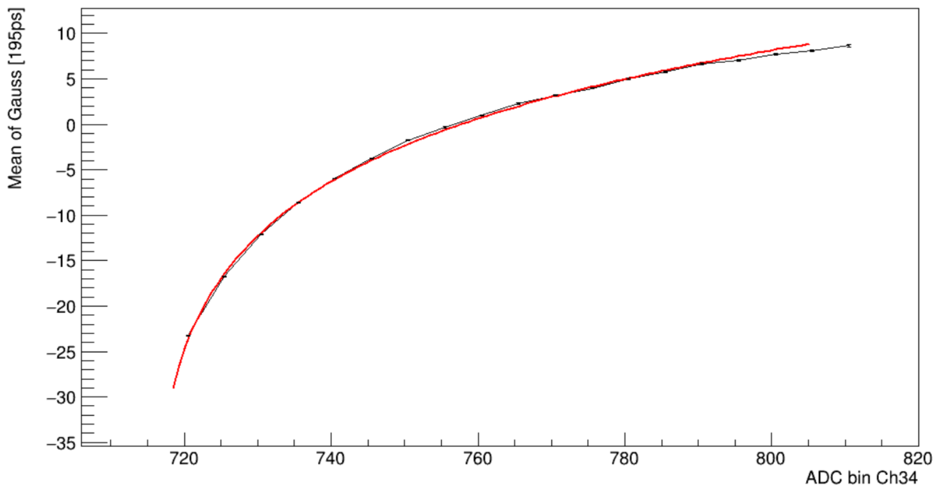


Timewalk Correction

TDiff of CH10-Ch34 vs charge of CH34

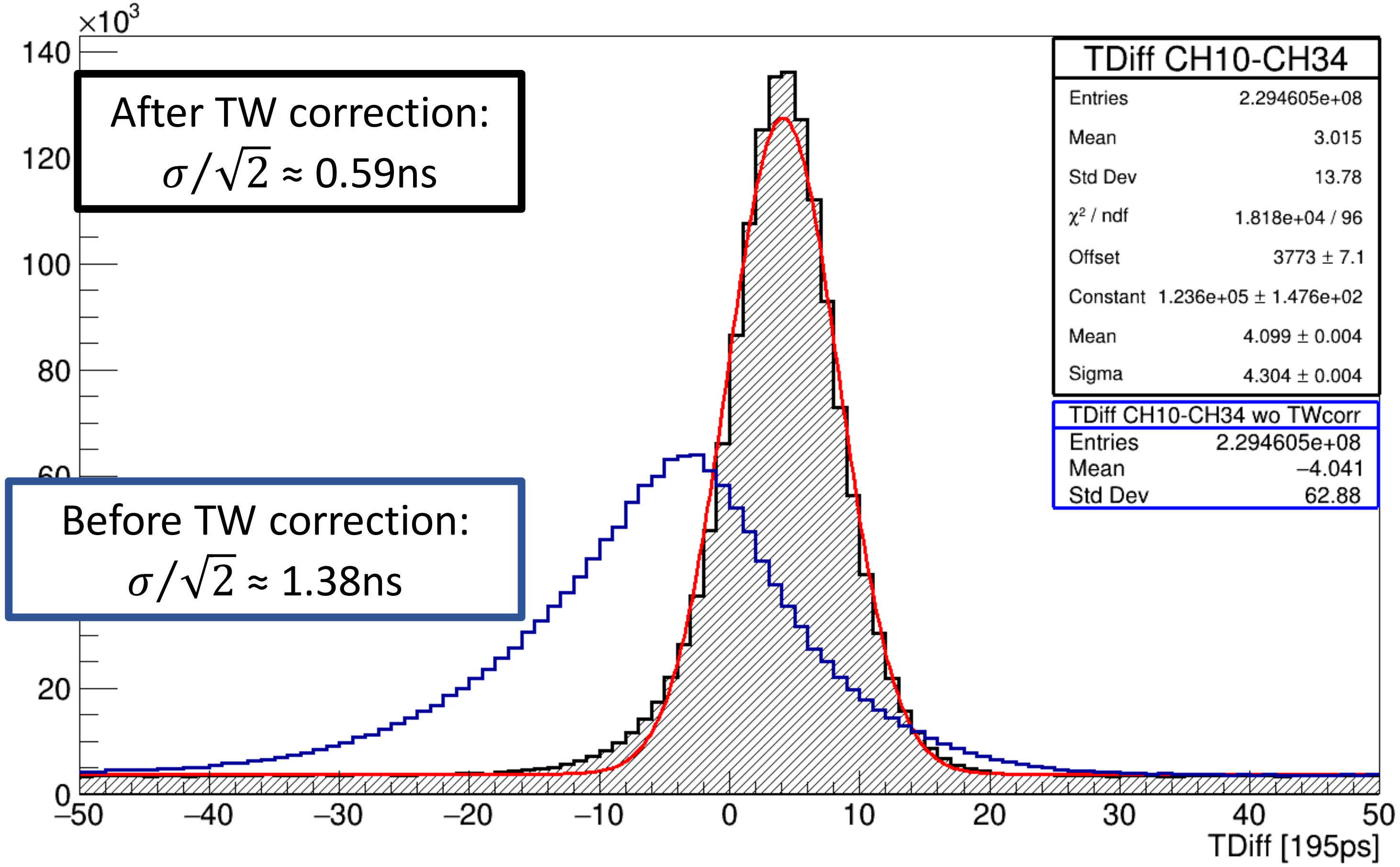


- 2D histogram ΔT vs charge of channel A in narrow energy window of channel B
- Fit energy slices of histogram separately with gauss + constant
- Fit function: $\mu_{\text{Gauss}}(Q) \sim \log(Q)$



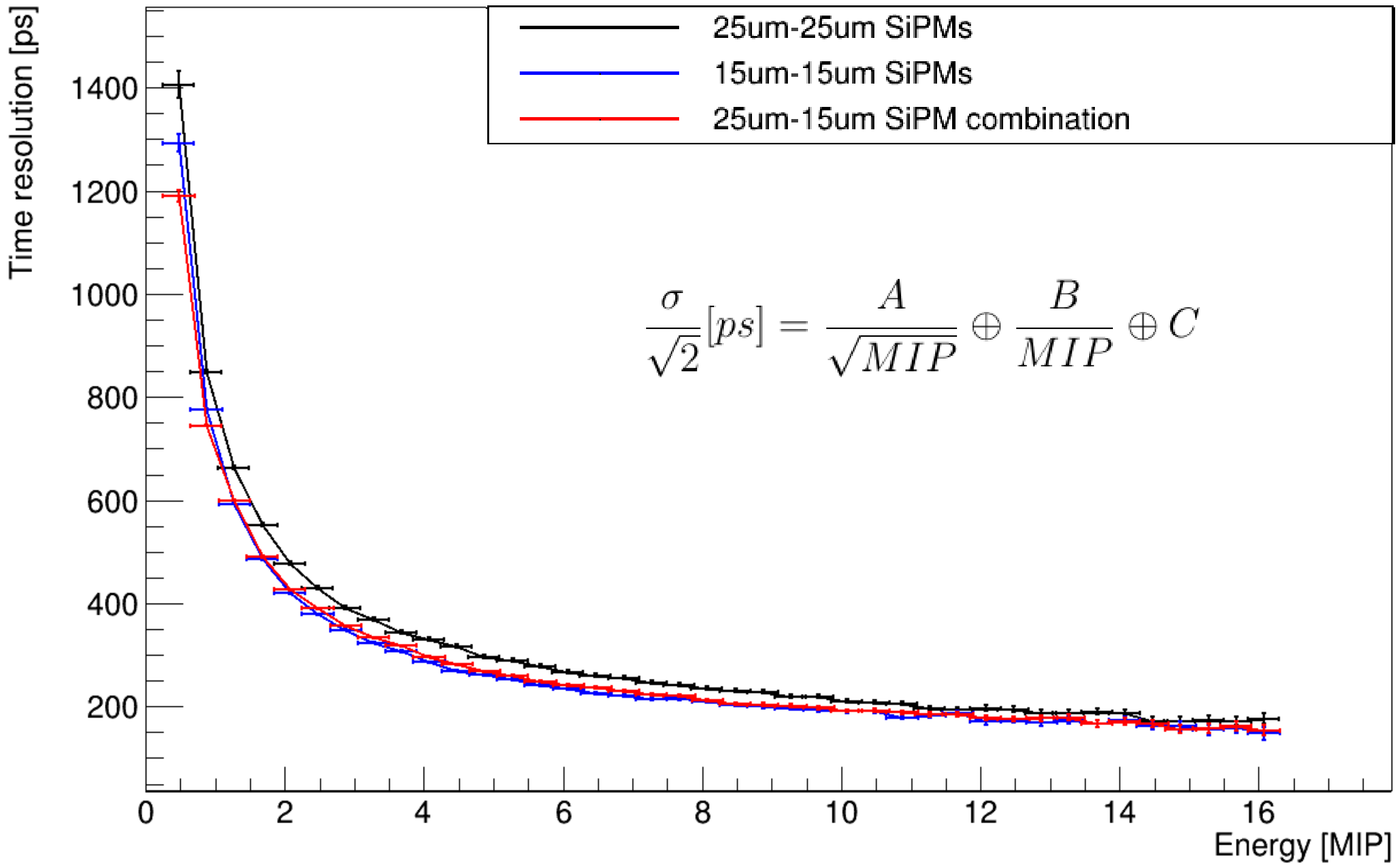
Timewalk Correction – Comparison

Effect of TW correction on time resolution



- Timewalk correction greatly improves timing
- Tails of peak not perfectly described by single Gauss function
  - Time resolution is energy-dependent
  - Timewalk hard to correct for small signals (<<1MIP)

Absorber Runs – Energy-resolved timing



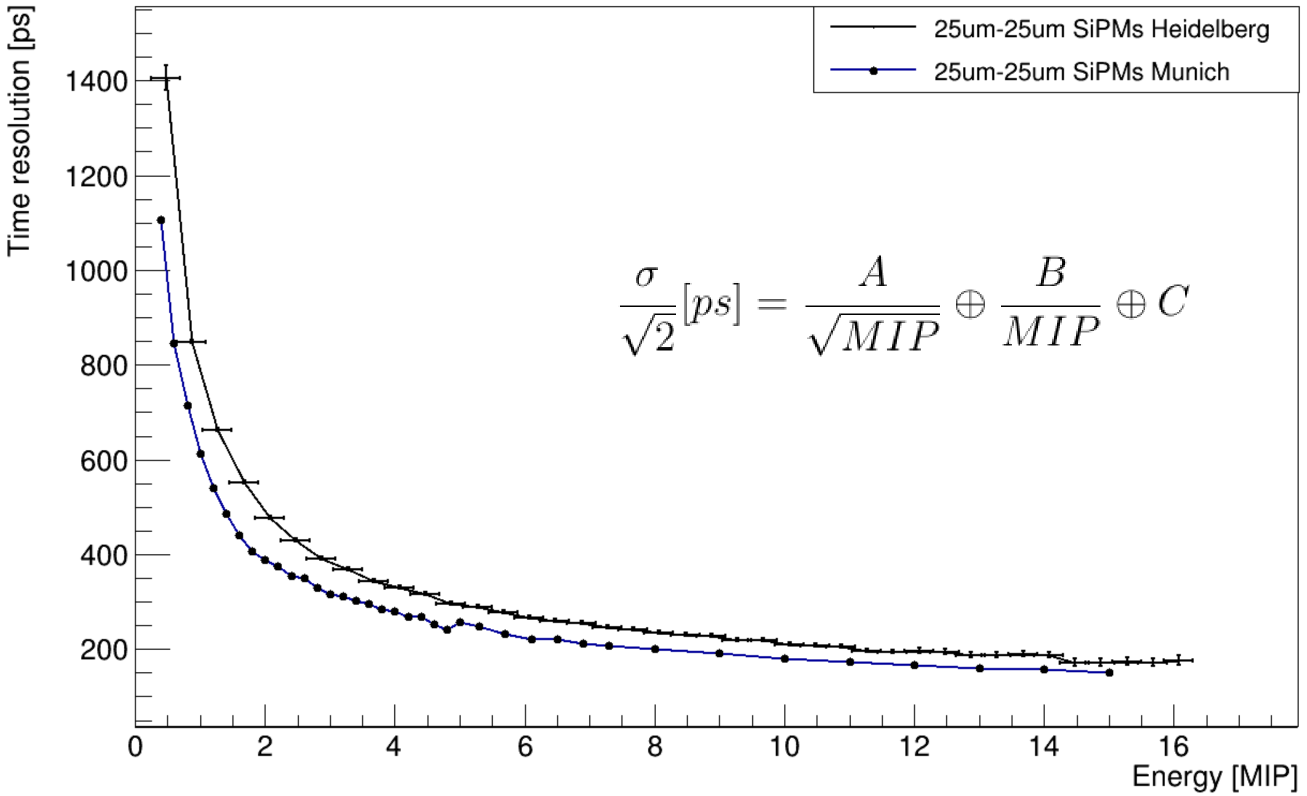
- 2 x 2.5mm tungsten plates
- Channel by channel MIP scaling
- From 0.3 to 16.3 MIP in 0.4 MIP slices
- Energy-dependent time resolution well described by function with three terms:

  A: Statistical term from Poisson distribution of photon generation

  B: Energy-dependent electronic noise

  C: Intrinsic resolution of time measurement (TDC)
- Limited number of tile pairs with unknown quality, no clear trend favouring one type of SiPM

Absorber Runs – Comparison



- Similar measurement from MPI Munich
  ↗Lorenz and Fabian‘s talk @AHCAL session
- Same tile geometry & SiPMs
- Different readout
  - Fast PicoScope with full waveform digitization
- KLauS results close to MPP results

Conclusion

- Dedicated testbeam measurement to assess timing performance of KLauS6b with AHCAL tiles
- Full calibration possible for common usage of 2 types of SiPMs
- Without absorber total time resolution around 600 ps
- Absorber runs show total time resolution of 450 ps
  - No favour for any type of compared SiPM
  - Scintillator is limiting factor (photon statistics)
- At high light yield (>15 MIP):
  Intrinsic resolution of setup (KLauS6 + SiPM + AHCAL tile) ≈95 ps
- Results close to SiPM-on-tile studies from MPI Munich
- Future studies:
  - Power pulsing of KLauS (data to be analysed)
  - Telescope integration for position scans

Backup

Workflow and Overview

Calibration:

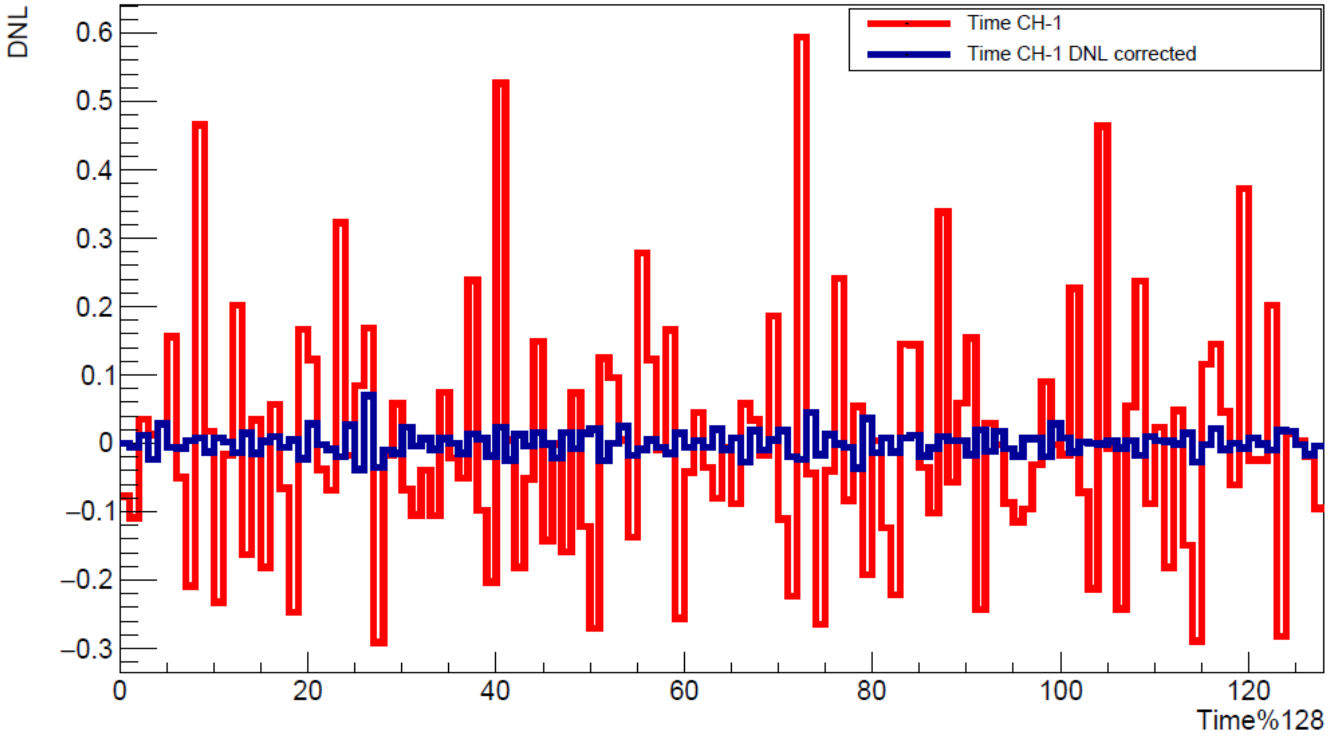
- ADC/TDC DNL correction
- Hold Delay optimization
- SiPM Bias uniformization
- Parameter sweeps to find operating point

Measurements in beam with and without absorber

Analysis:

- Timewalk correction
- Timing for first runs without absorber

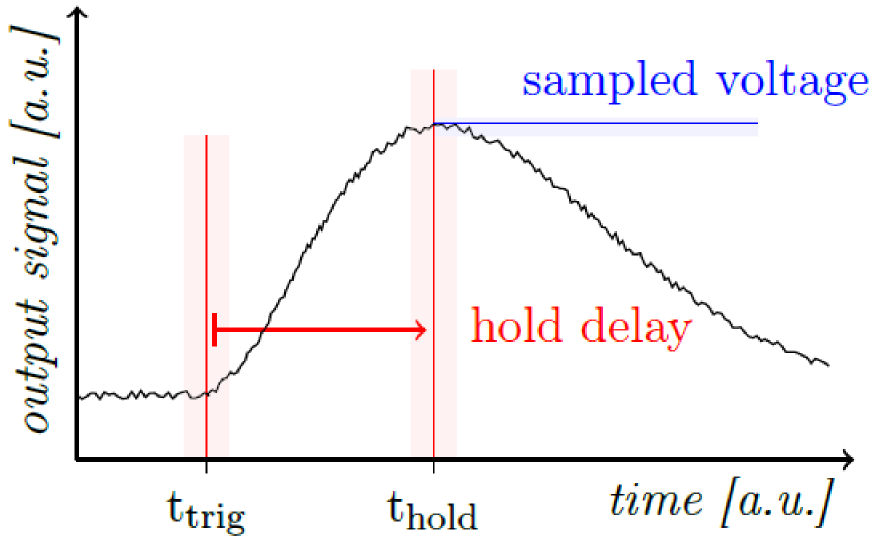
DNL correction



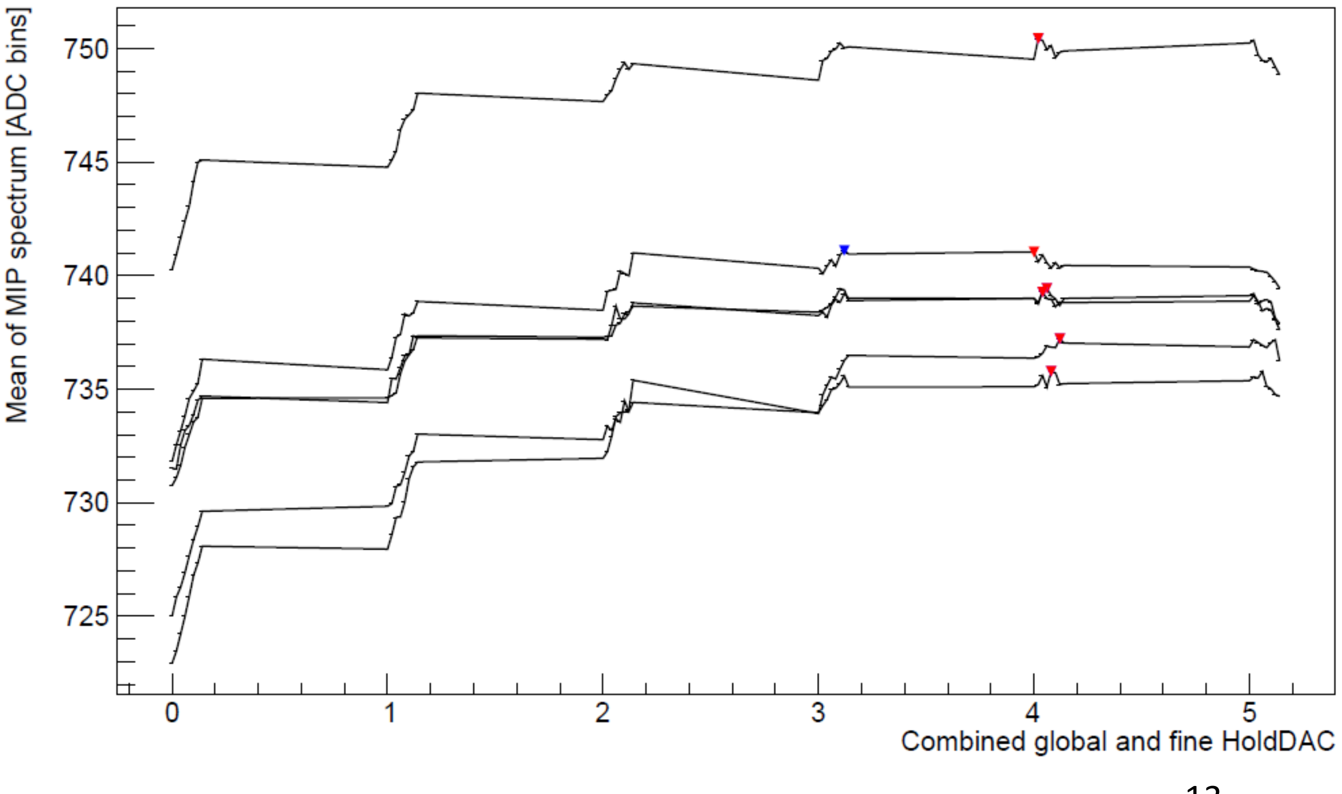
- ADC DNL correction needs extra measurement with slow ramp over full dynamic range of ADC
  - Done in Heidelberg beforehand
- TDC DNL correction (in-situ)
- KLauS calibration object delivers calibrated data for ADC & TDC

Hold Delay Optimization in Beam

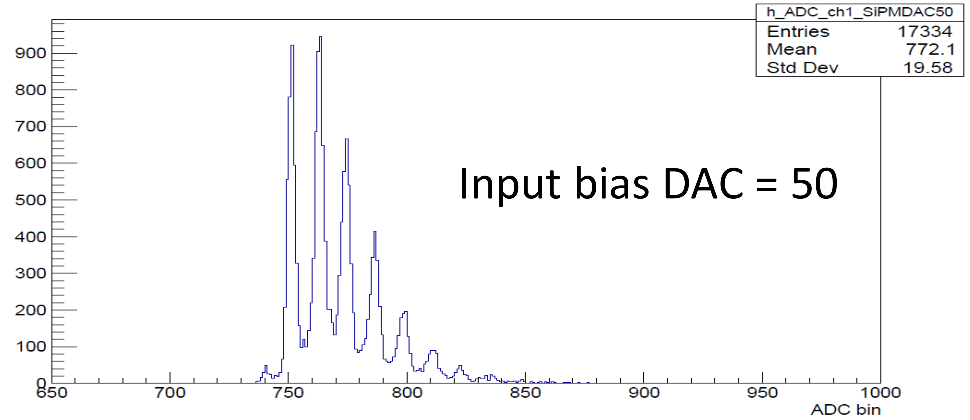
- Only digitize the maximum amplitude of waveform
- „Waiting time“ after Trigger
- Global and fine adjustment
  - Need to find a common value
- Use mean value of MIP spectrum

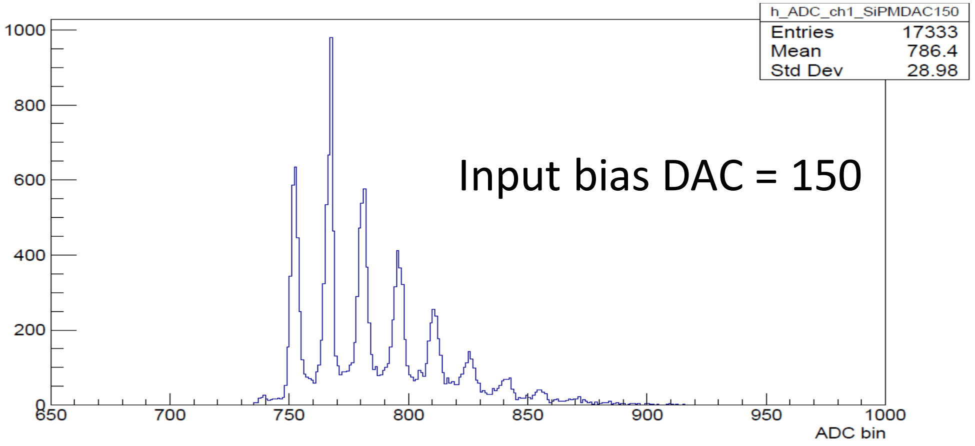


K. Briggl, 2018

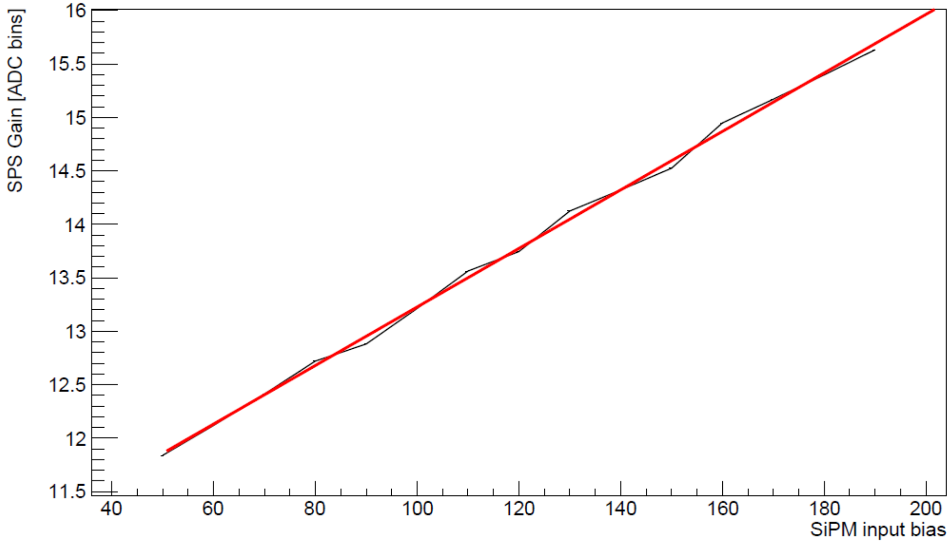


SPS Gain uniformization

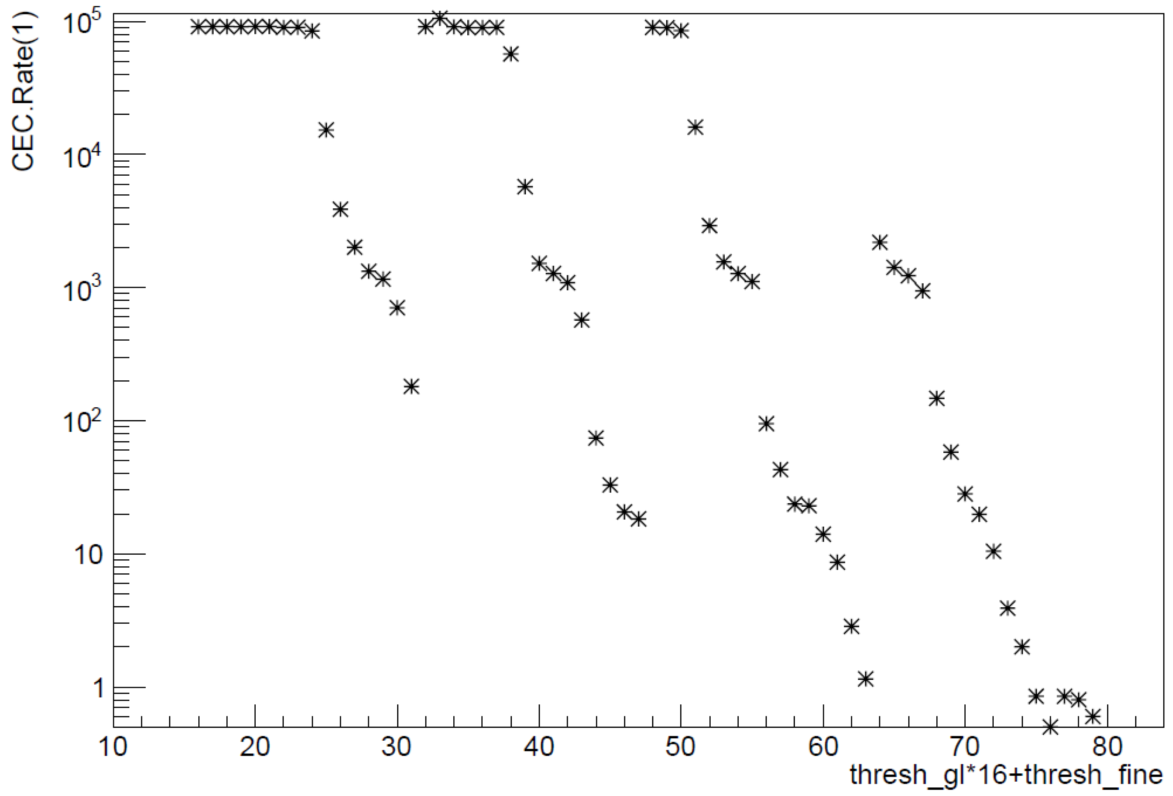




- Adapt bias voltage of the SiPM channel-wise
- Make use of integrated LED system → Single photon spectra



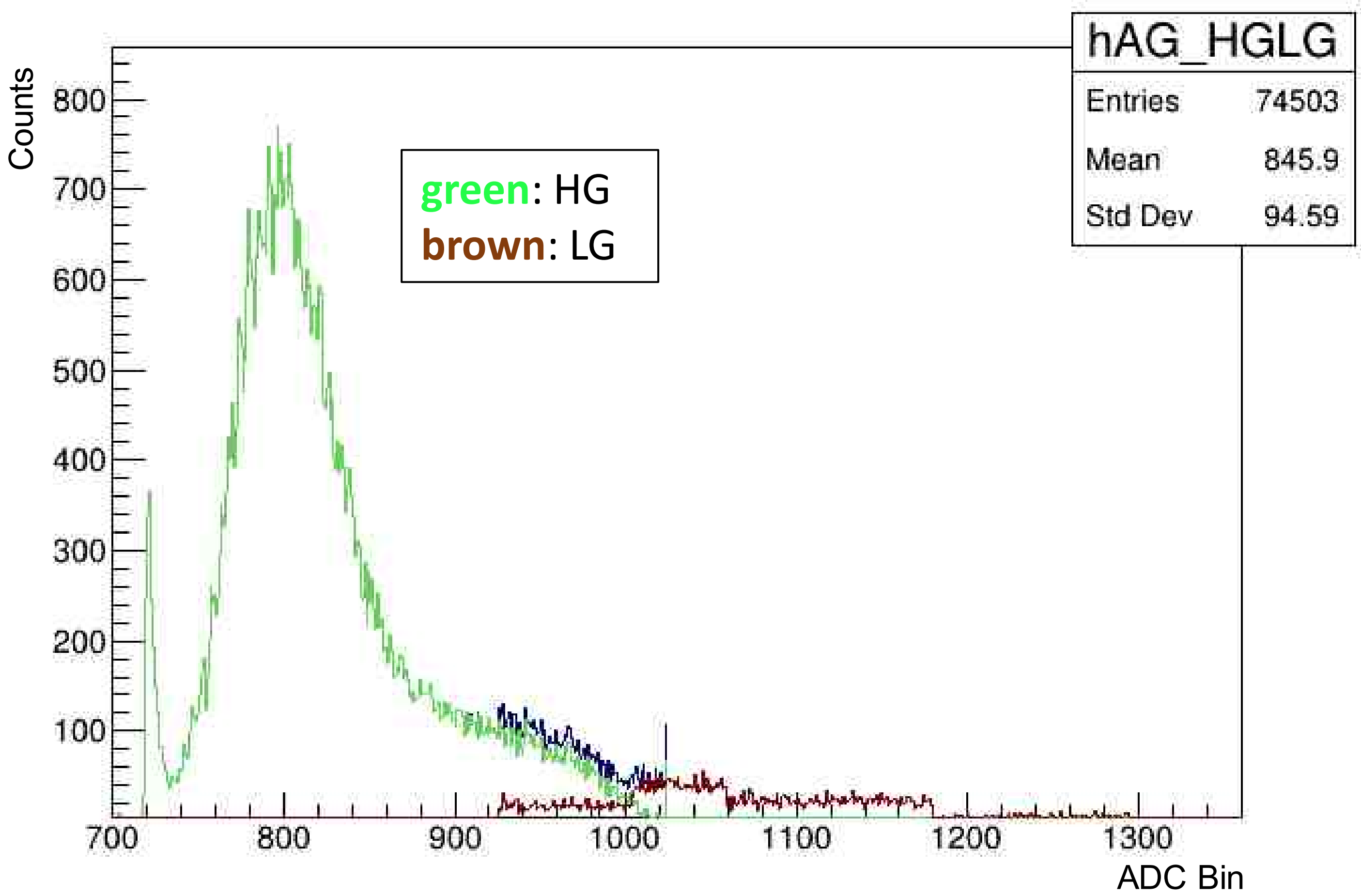
Threshold CEC scans



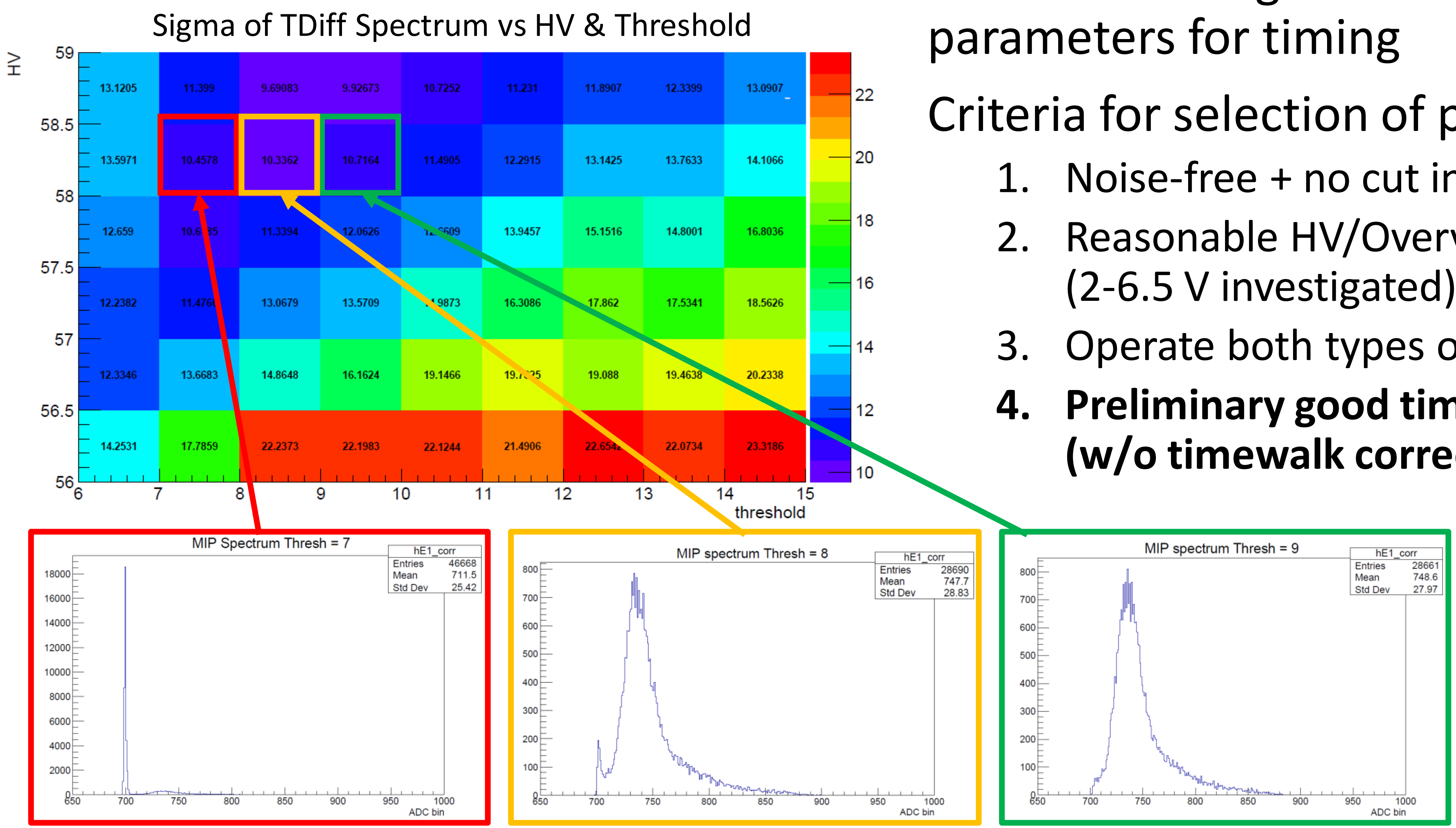
- Channel Event Counter (CEC) scans for rising threshold
- Relation #fired pixel - threshold
  - Uniformity between channels
- Here: Run only with DCR
  - Reduction up to the 2.5th pixel

Auto Gain Calibration

- Extract scaling between branches HG – LG for later timewalk correction
  - Measure MIPs in beam with different branch selections and look for efficiencies



Modus operandi



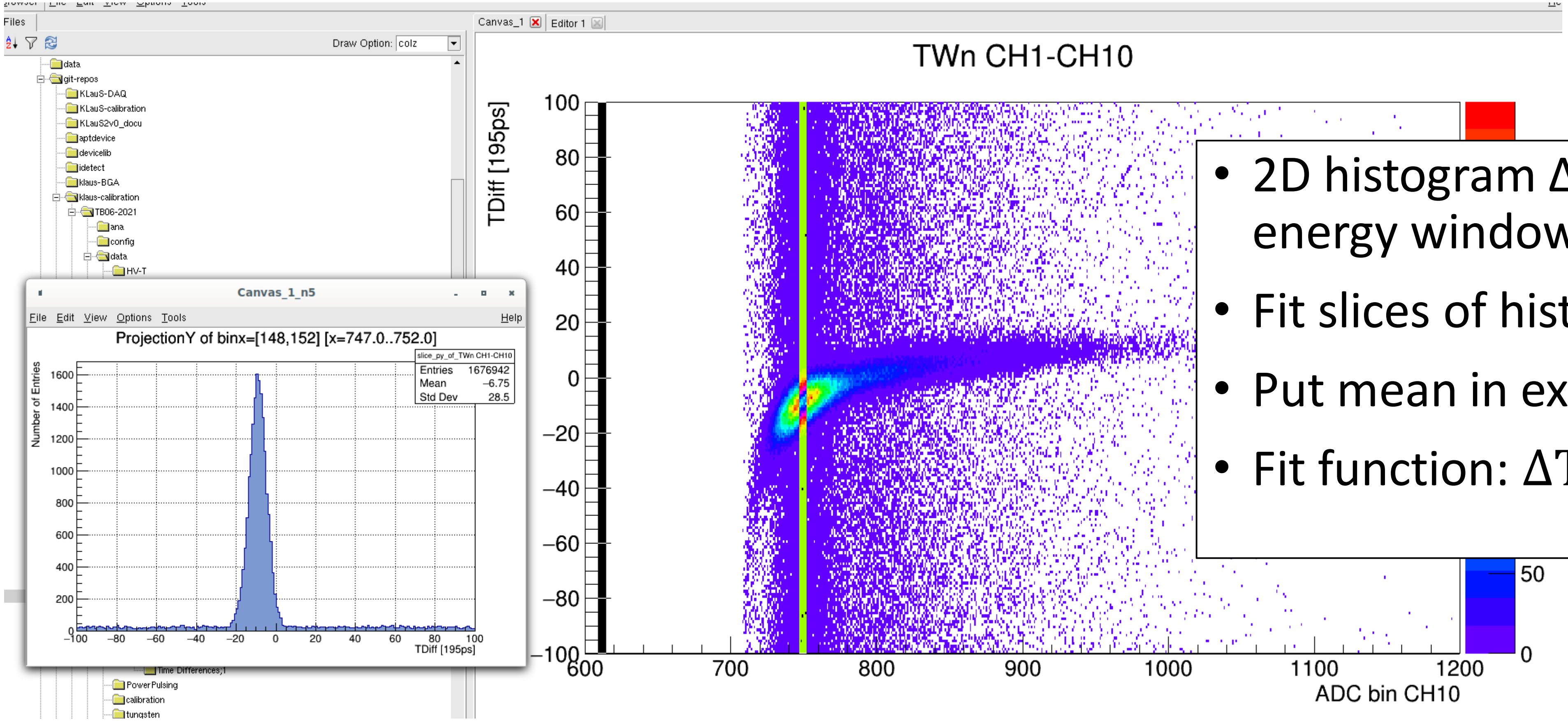
Input stage bias current, Threshold and SiPM bias voltage are most crucial parameters for timing

Criteria for selection of parameters

1. Noise-free + no cut into MIP spectrum
2. Reasonable HV/Overvoltage on SiPMs (2-6.5 V investigated)
3. Operate both types of SiPMs together
4. **Preliminary good timing performance (w/o timewalk correction)**

Timewalk correction

TDiff of CH1-Ch10 vs charge of CH10 with one Fit slice



- 2D histogram ΔT vs charge of ChA in energy window of ChB
- Fit slices of histogram separately
- Put mean in extra graph and fit this
- Fit function: $\Delta T \sim \log(Q)$

Combinatorics in continuous readout

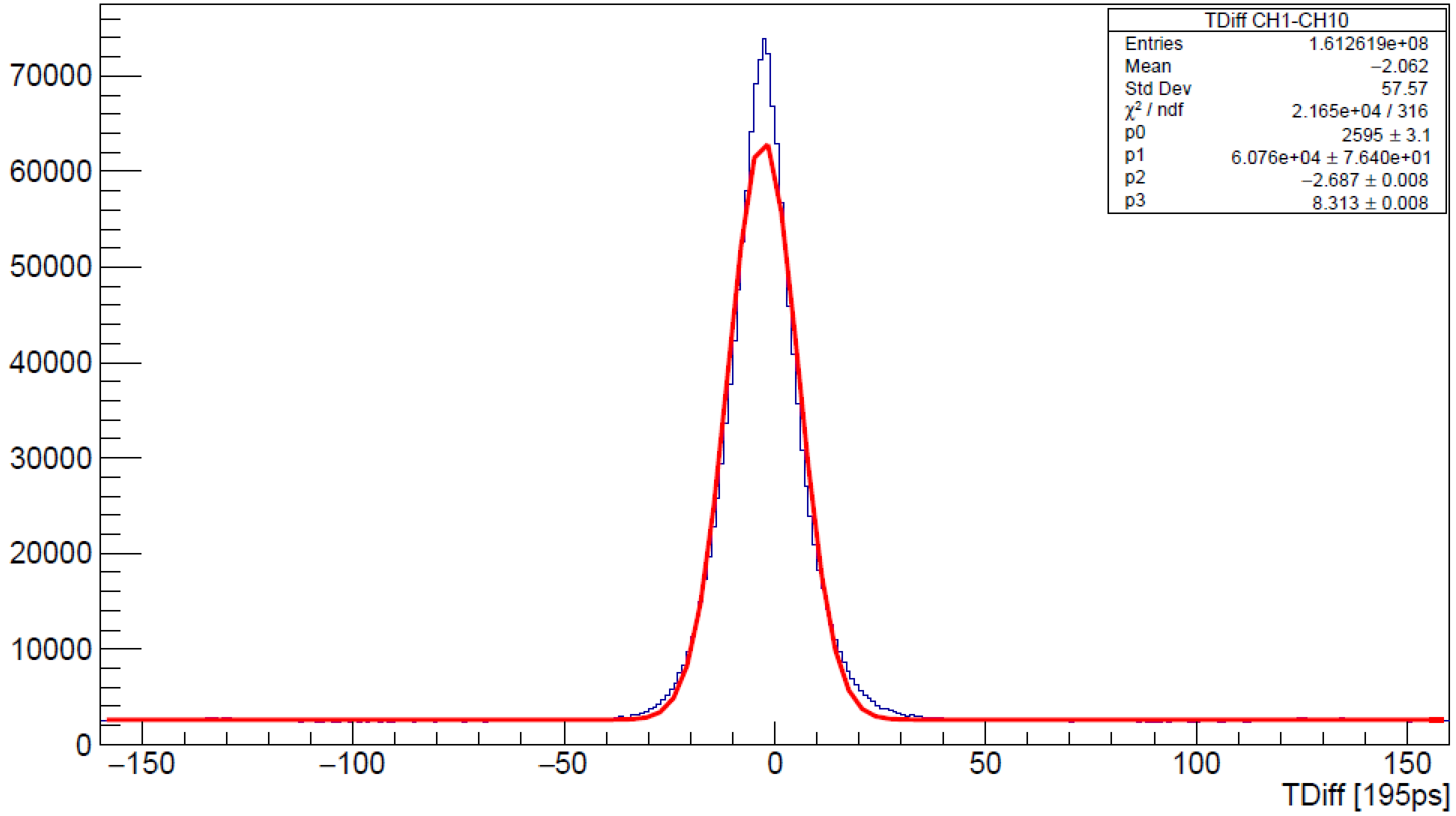
Flat background in ΔT spectrum from combinatorics

- Length of readout cycle not well defined, but long
- Necessary for continuous readout of data
- @TB: increased readout speed → Less combinatorics

Timing Fit: Gauss + Constant

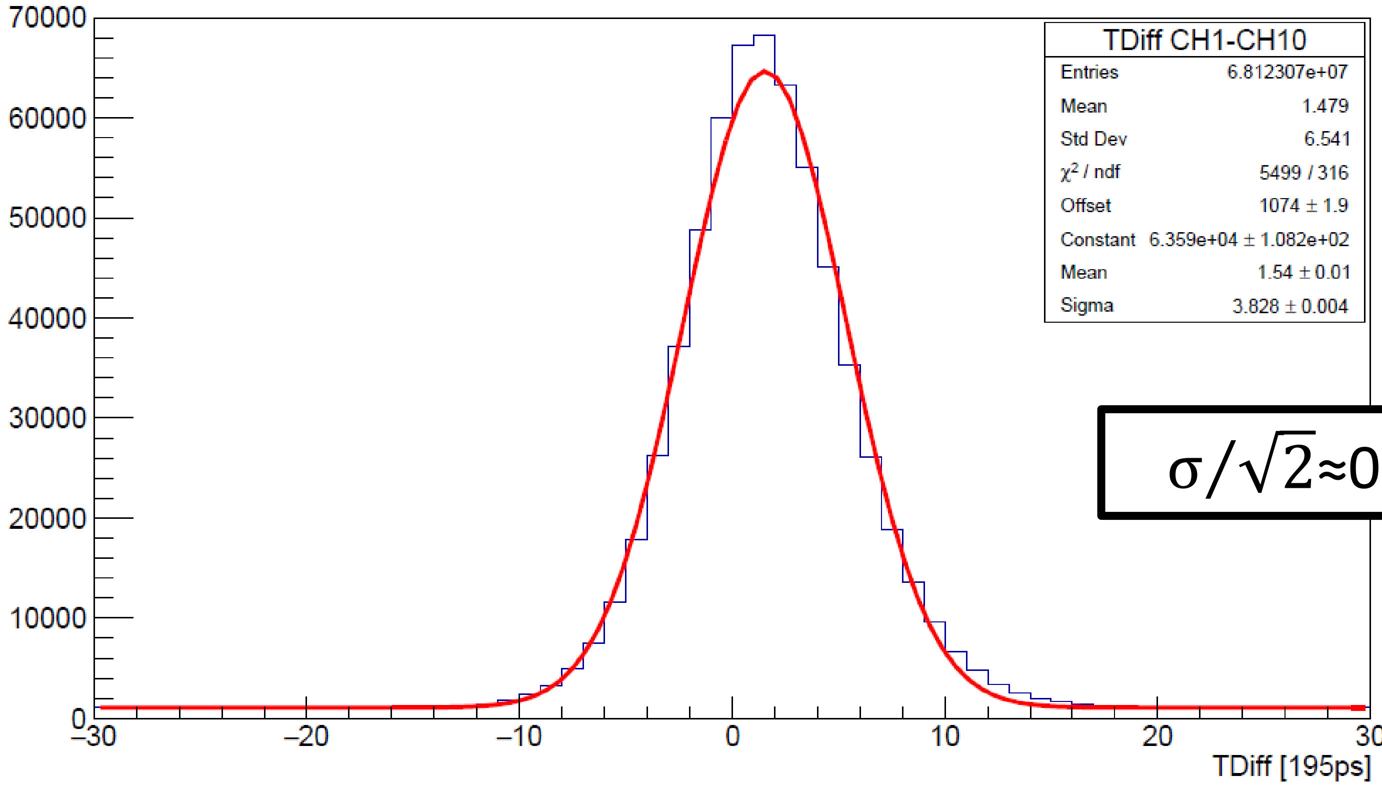
- $\text{Resolution} = \frac{\sigma_{gauss}}{\sqrt{2}} \cdot 195ps$

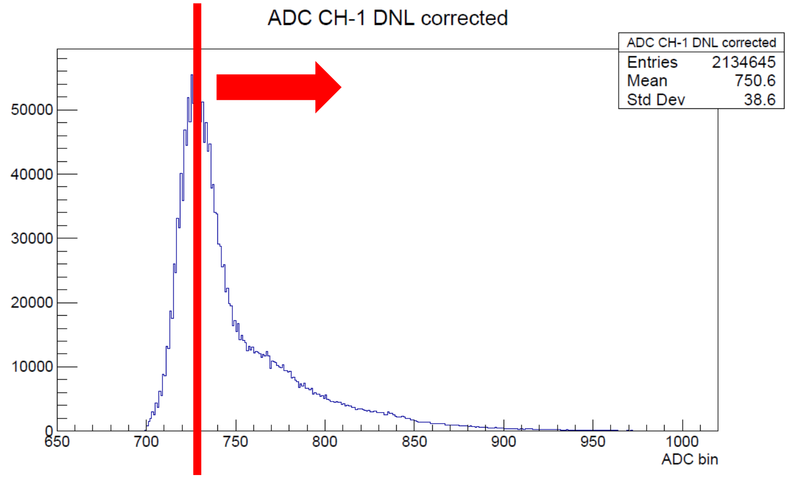
TDiff spectrum between CH1 and CH10, not TW corrected



Timing performance @ 1 MIP

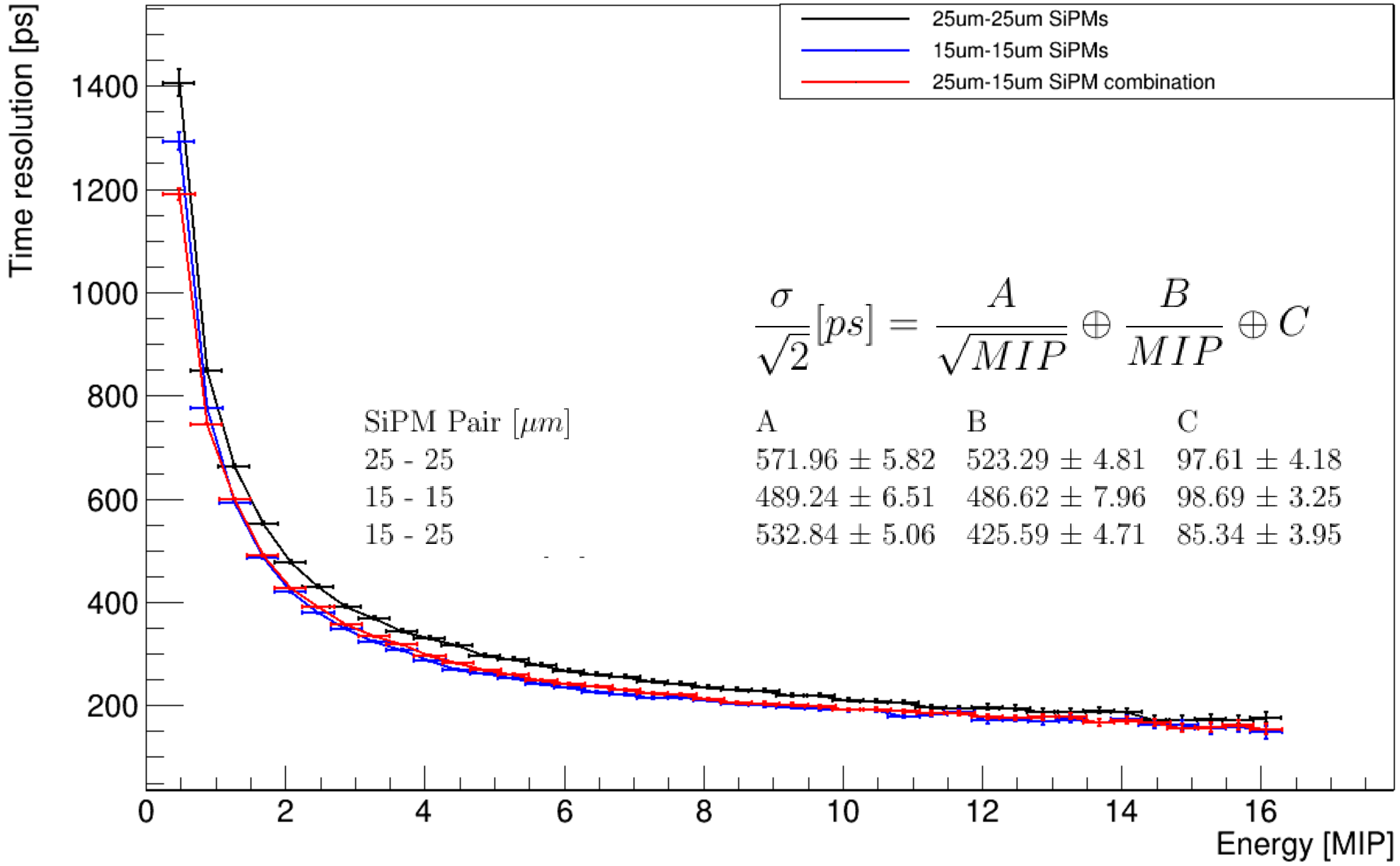
Energy cut to 1MIP level for first high statistic run





$\sigma/\sqrt{2} \approx 0.53\text{ns}$

Absorber Runs – Energy resolved timing



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