Characterisation Studies of Two Front-end Electronics Chips Designed for SiPM Readout

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Introduction

Future Higgs Factory: Circular Electron Positron Collider (CEPC)

- Boson Mass Resolution (BMR) 3%~4%: stringent requirements on calorimeters

High-granularity calorimeters: 5D calorimetry for precise jet measurements

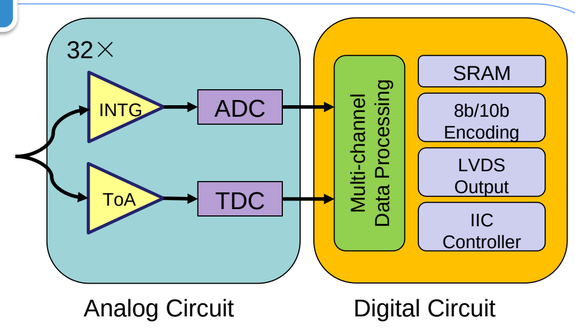
- Crystal ECAL: critical requirements on dynamic range: up to ~10^5 level photons
- Particle Flow Algorithm: good time performance for PID, energy reconstruction, etc.

SiPM readout electronics candidate with large dynamic range: MPT2321-B

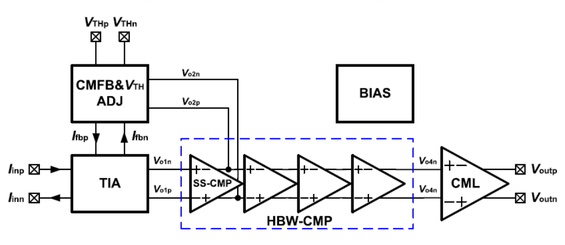
- 32-channel readout, 12-bit ADC and 20-bit TDC per channel
- Large dynamic range: nominal design value 1.8 nC

A picosecond timing ASIC developed for SiPM readout: PIST ASIC

- Promising ToT and ToA performance, 15 mW/channel low power consumption



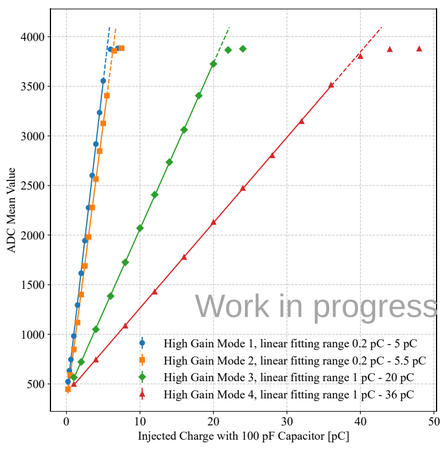
PIST chip
Designed by IHEP

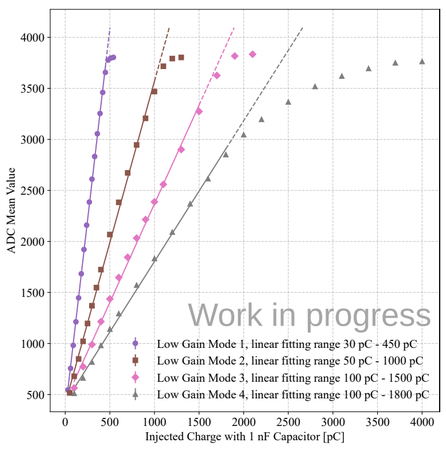


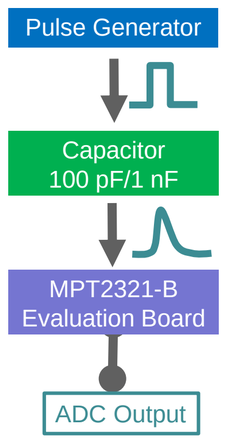
Characterisation of MPT2321-B

MPT-chip response linearity with charge injection

- Excellent linearity with high gain modes
- Low gain mode 4 has the largest dynamic range but also observed non-linearity effects, linear range up to 1.8 nC (with 1 nC capacitor)

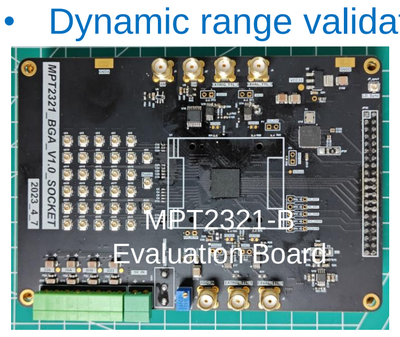


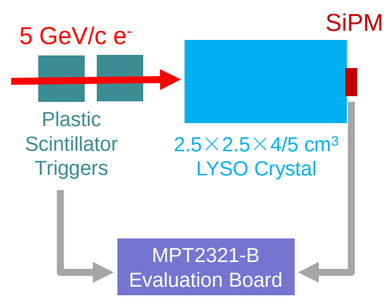




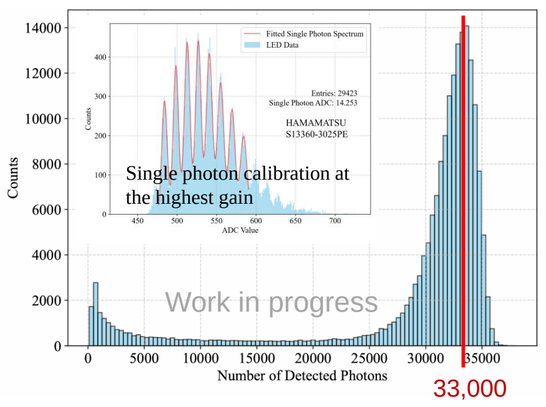
Beam-test: first test of MPT-chip with high energy particles

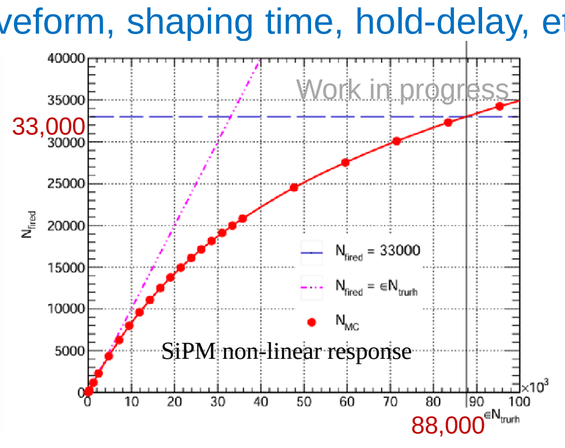
- Dynamic range validation with crystal + SiPM units





- Electron response: MPV ~33,000 detected photons (at lowest gain)
  - Very close to the non-linear region (~3000 ADC channel)
- Toy Monte Carlo for SiPM saturation modelling
  - Geant4 optical simulation: ~82,000 photons (w/o saturation effects)
  - SiPM response: 88,000 input photons for 33,000 detected photons
  - MC generally consistent with the Geant4 simulation
- For SiPMs used with 7×10^5 gain: 33,000 photons → 3.7 nC charge
  - Note: The actual ADC is not simply equal to the input charge
  - Output depends on signal waveform, shaping time, hold-delay, etc.

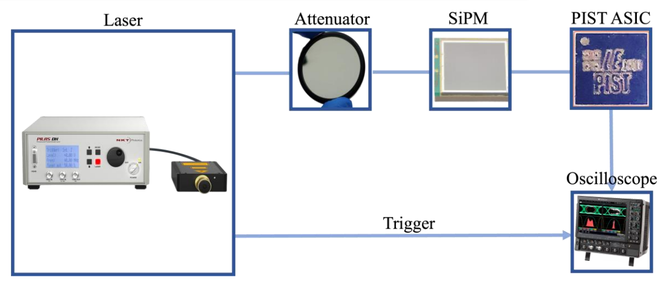




Lab tests of PIST-chip

Test stands with laser diode

- To quantify the response of the PIST ASIC to SiPM signals

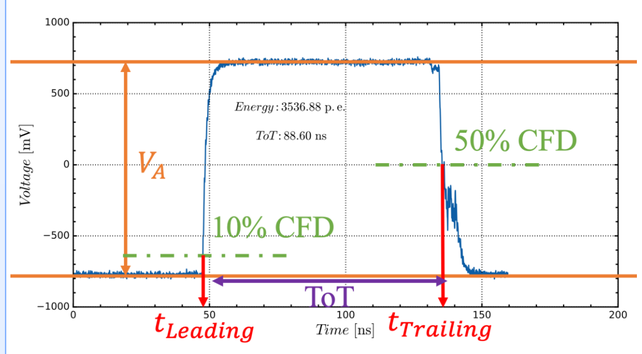


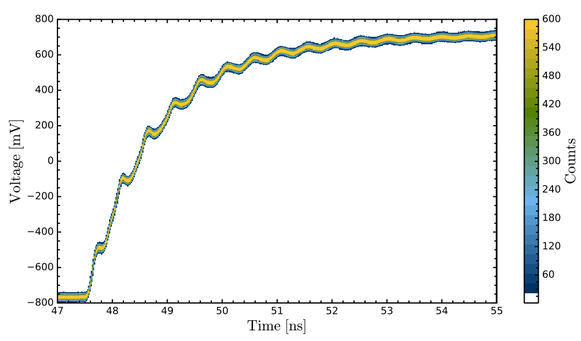
Waveform description:

- Dynamic range: -780 mV to 780 mV
- Fast leading edge with low noise level, especially the bottom of the leading edge

Functions: use constant fraction discriminator (CFD) for timing

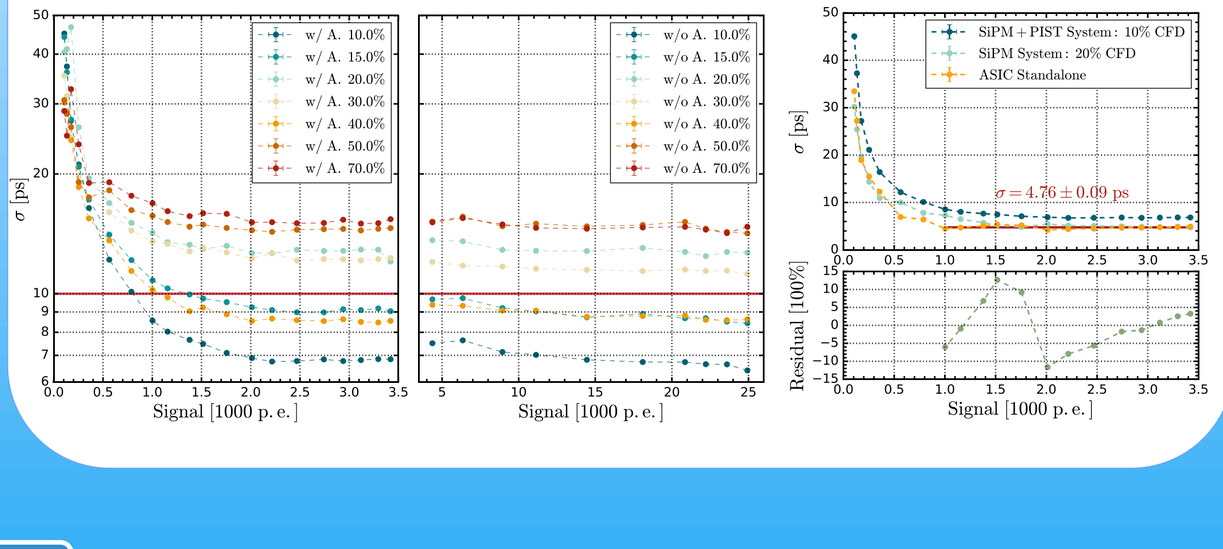
- Time of Arrival (ToA): timing measurement
- Time-over-Threshold (ToT): energy measurement





Experimental Results:

- **Timing performance**
  - 10% CFD turns out to be optimal for the timing performance
  - Within the dynamic range of 100 p.e. to 25k p.e., σ < 50 ps, varies from 7 ps (plateau) to 30 ps (1 MIP = 200 p.e.)
  - Decomposition analysis of time resolution contributions:
    - $\sigma_{SiPM+PIST} = \sigma_{SiPM} \oplus \sigma_{PIST}$ = (5.1 ⊕ 4.8) ps
- **ToT performance:**
  - Can cover the SiPM response spanning from 560 p.e. to 25,000 p.e.



Conclusions

- Successfully conducted the laboratory and beam experiments of new SiPM readout chips
  - MPT-chip: good S/N and moderately large dynamic range
    - Capable for single photon calibration, detecting ~33,000 photons with 25 μm pixel SiPM
    - Could be improved by utilizing SiPMs with lower gains, reducing shaping time, etc.
  - PIST-chip: low power consumption with 10 ps level time resolution
    - Good time resolution: 30 ps at MIP level and can achieve 7 ps with larger SiPM signal
    - ToT response: ranging from 560 p.e. to 25,000 p.e.

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