# Power pulsing with CLICpix2

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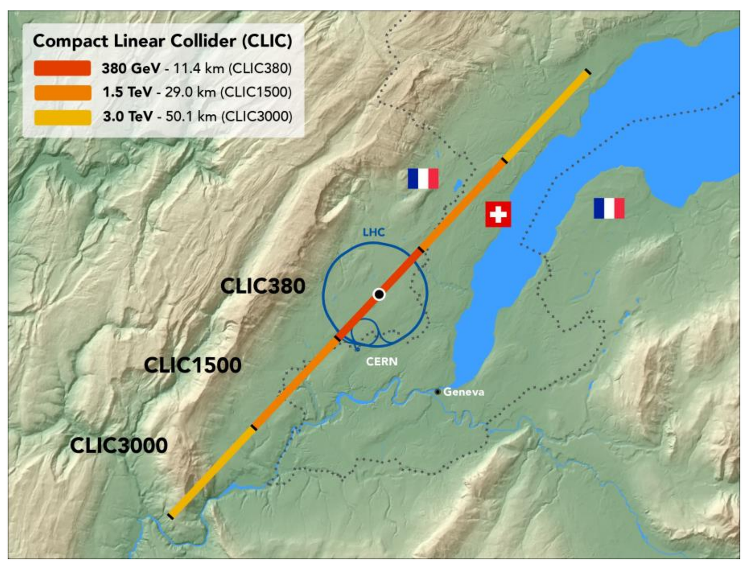
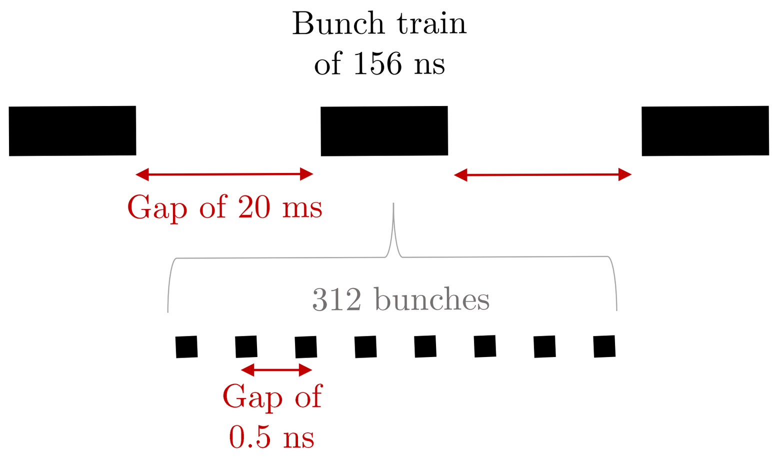
## CLIC – Compact Linear Collider

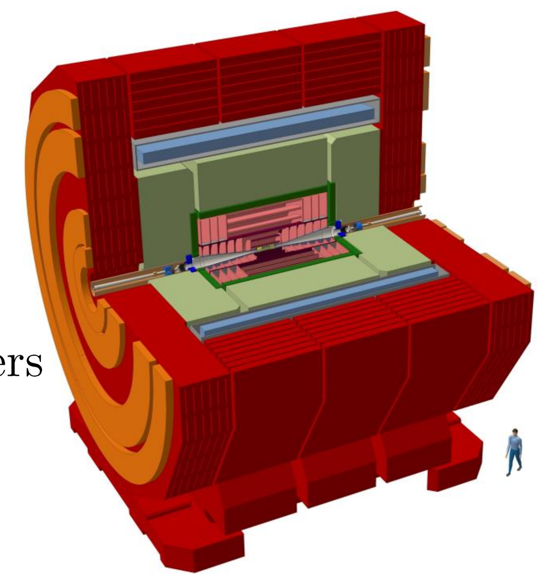



- Electron-positron collider project
- ~ 50 km tunnel
- $\sqrt{s}$ up to 3 TeV
- 2 beam-acceleration scheme:
  - Train repetition: 50 Hz
  - Train length: 156 ns

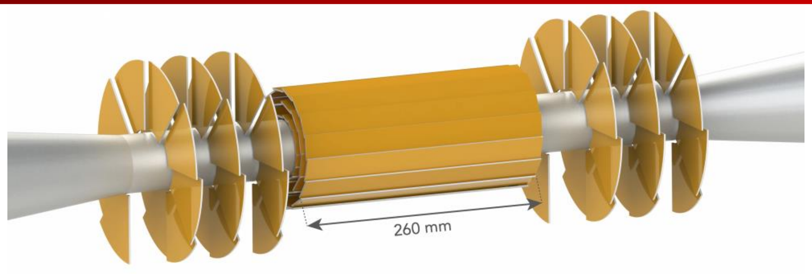



## CLIC Detector

- General purpose detector
- 12.8 m diameter
- Low mass vertexing and tracking system
- Highly granular calorimeters
- 4 T solenoid magnet
- Large muon detector

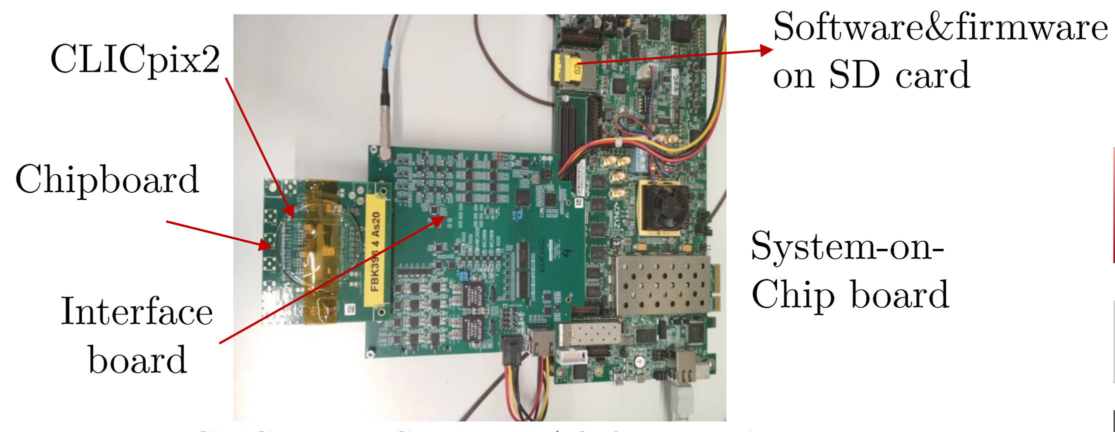


## Silicon Vertex Detector




- 3 barrel and 3 end-cap layers. Area ~ 0.84 m$^2$
- Requirements:
  - Ultra-low mass (~ 0.2% $X_0$ per layer)
  - Single point resolution $\sigma$ ~ 3 µm
  - Time slicing of < 10 ns
  - Low power consumption of ~ 50 mW/cm$^2$

## Experimental Setup

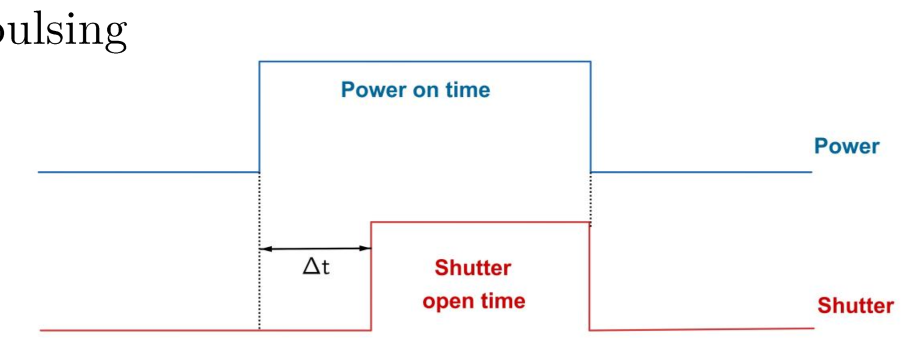



CLICpix2 in Caribou DAQ framework

## Power pulsing

Definition of power pulsing: Provide power in small intervals, and the rest of the time keep the electronics off/in low power mode.

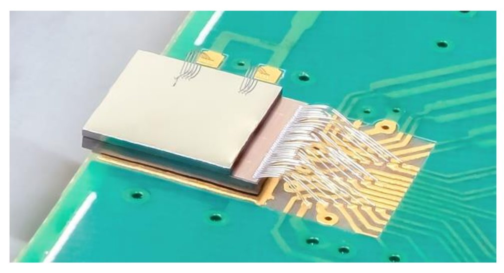
- Long gaps between bunch trains allow for power pulsing




- Reduce power consumption
- Reduce heat dissipation
- No need for cooling pipes, air flow cooling sufficient to remove heat
- Satisfies low material budget

## CLICpix2

- Readout chip developed to meet requirements of CLIC vertex detector
- Small pitch: 25 µm
- Area: 25 × 12 µm$^2$
- 128 × 128 pixel matrix
- Simultaneous time (ToA) and energy (ToT) measurements



CLICpix2 planar assembly

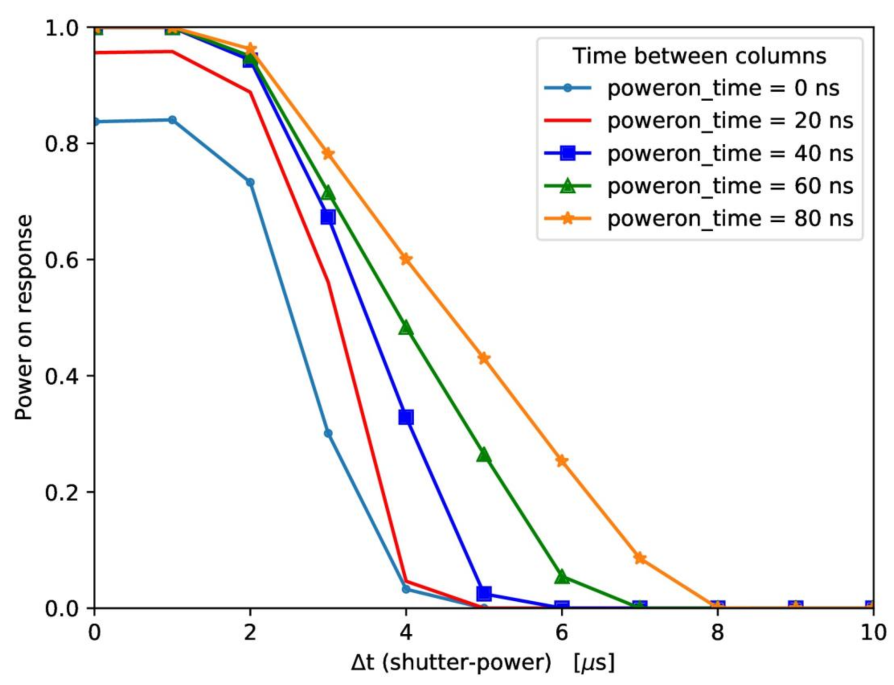
- Analogue power pulsing in CLICpix2: turn off/in low power mode most power consuming nodes of analogue circuitry (amplifier and discriminators)

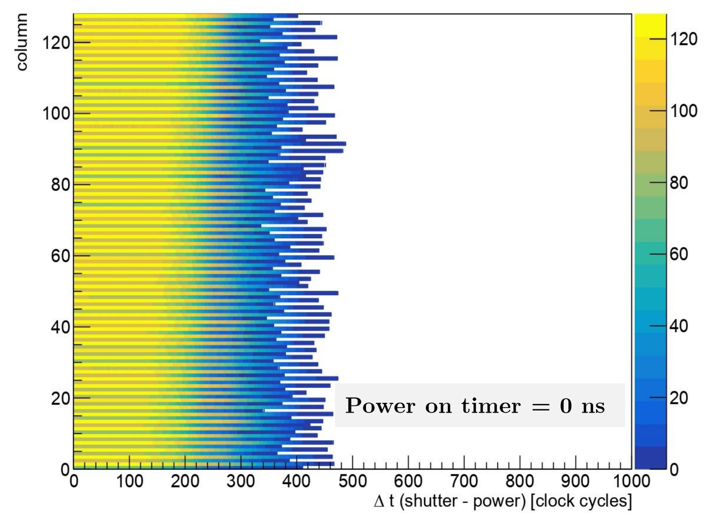
## Analogue Power Pulsing results for CLICpix2

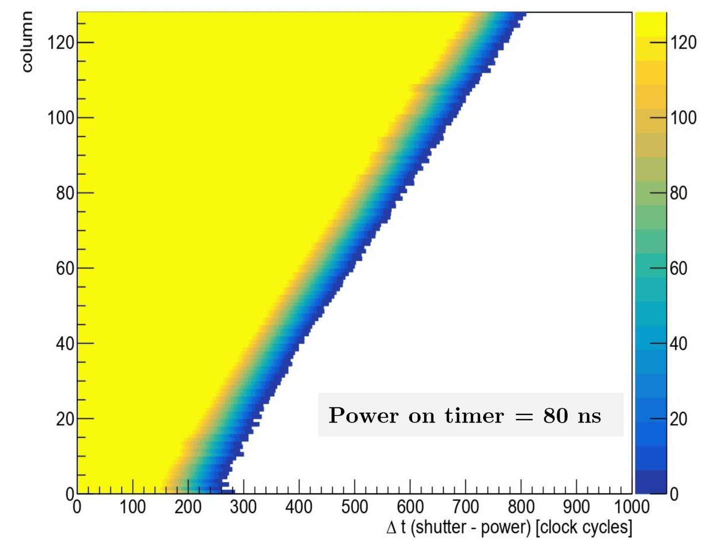
### Power on response

Study power on response, fraction of pixels firing after turning on the power (no particle signal).

- Pixel columns can be powered on with delay between consecutive columns to avoid peaks in power.
- Delay defined as 'power on timer'.

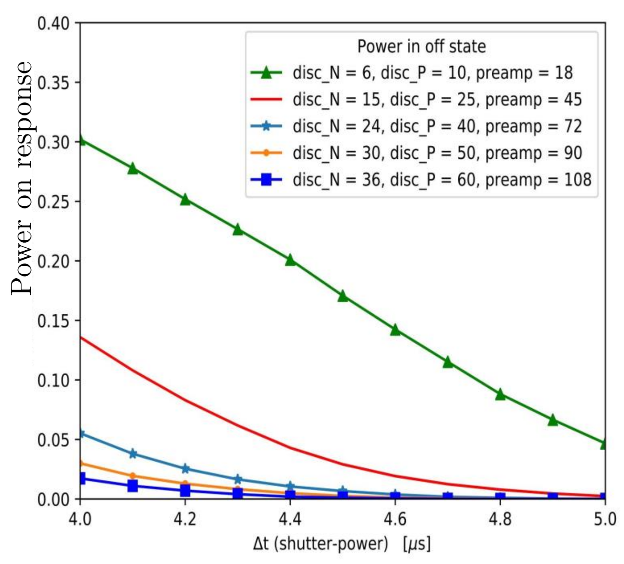



- Different delays (power on timers) visible in power on response over pixel matrix.
- For power-on timer of 40 ns the chip is quiet (ready to detect a particle) after ~ 6 µs.

### Power on response for different power-off states

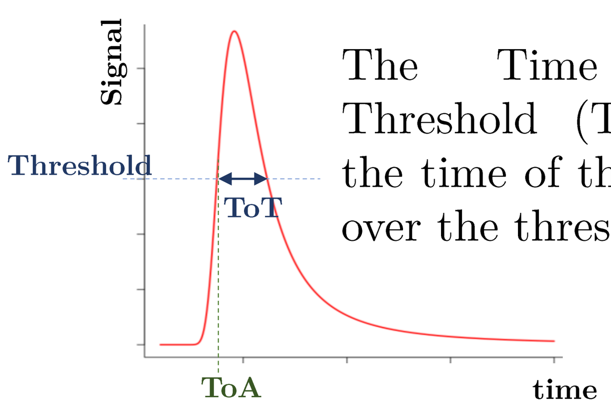



- A balance needs to be found between saving power and reducing Δt.

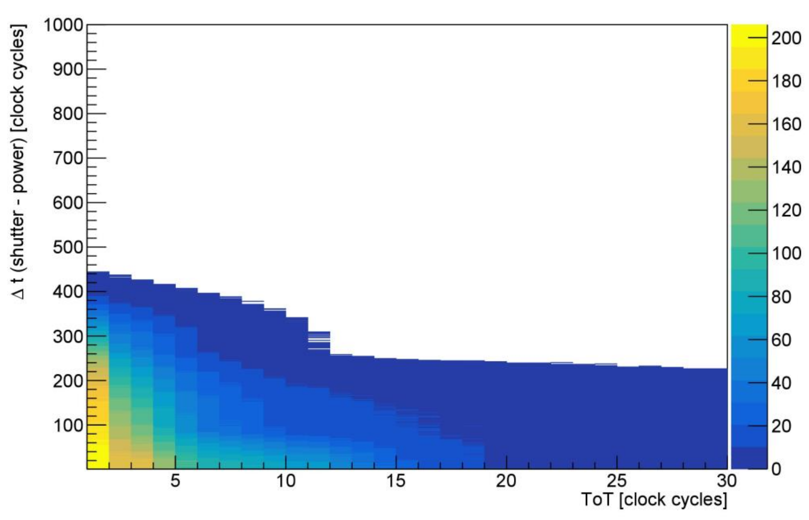
- Can we find an optimum power off state?

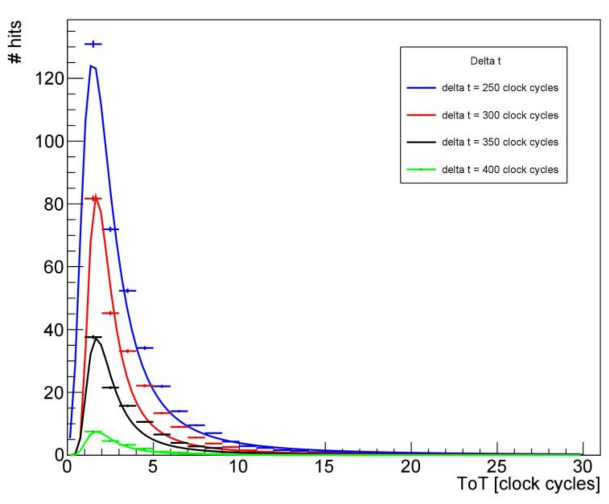
  → Work in progress.

### Power on response of ToT




The Time over Threshold (ToT) is the time of the pulse over the threshold.




Power on response peaks at low ToT values.

- Can we distinguished from a real particle hit?

  → To be studied in a next step.

## Summary & Outlook

**Summary:**

- Power pulsing for the CLIC vertex detector to reach ultra low mass requirement.
- CLICpix2 designed to meet CLIC vertex detector requirements, including power pulsing functionality.
- Study of power on response from power pulsing in CLICpix2: Chip is quiet (ready to detect a particle) after a few µs.

**Next steps:**

- Measure power consumption, find optimum w.r.t. power on response for different power off states.
- Source measurements with Sr90 to distinguish between the signal and power on response.
- Test-beam data analysis to calculate efficiency during power pulsing.

## References

[1] CLIC 2018 Summary Report (CERN-2018-005-M, arXiv:1812.06018)
[2] Perez Codina, E. (2019). *TimePix3 performance in power pulsing operation* (No. CLICdp-Conf-2019-002)
[3] E. Santin, P. Valero and A. Fiergolski. *CLICpix2 User´s Manual (2016)*