Timing Analysis and Correction for Chip Effects

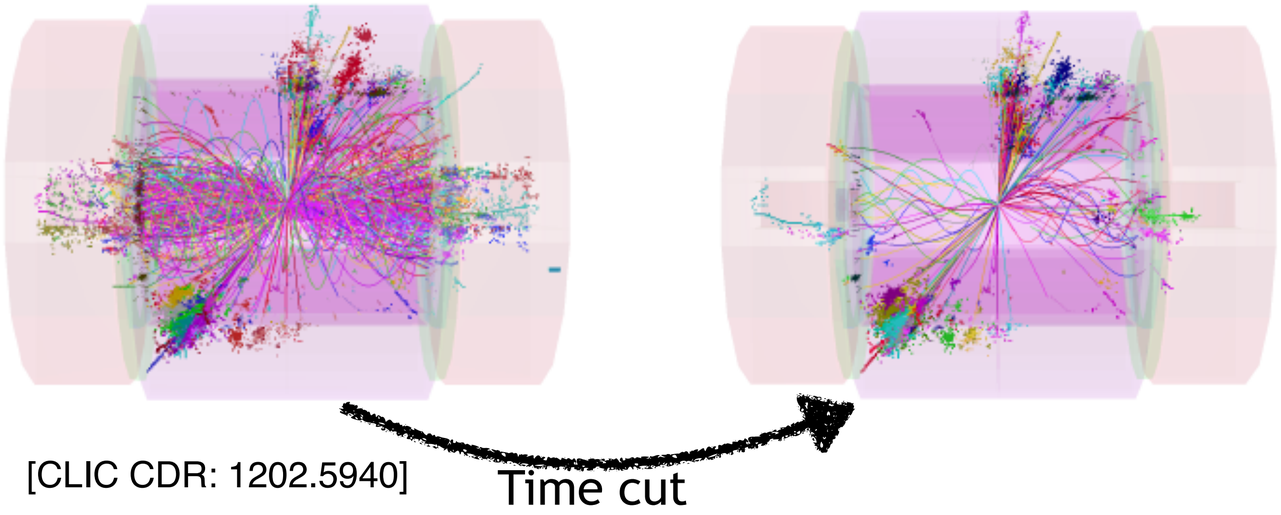
Lorenz Emberger

CALICE Collaboration Meeting
Utrecht
12.4.2019

Motivation

Why do we need time information?

- Reject background



[CLIC CDR: 1202.5940]

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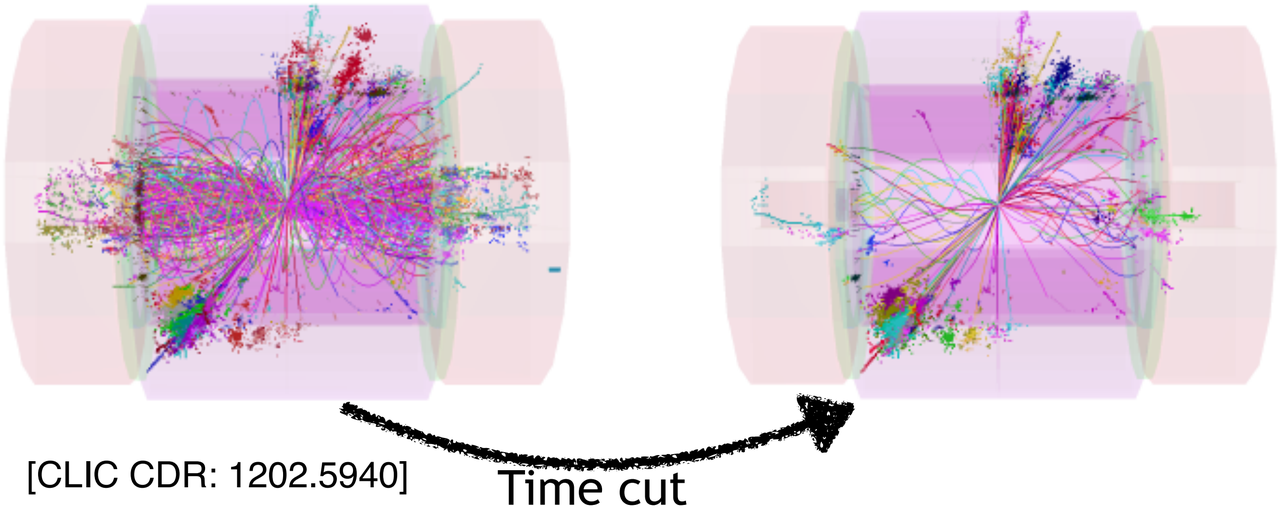
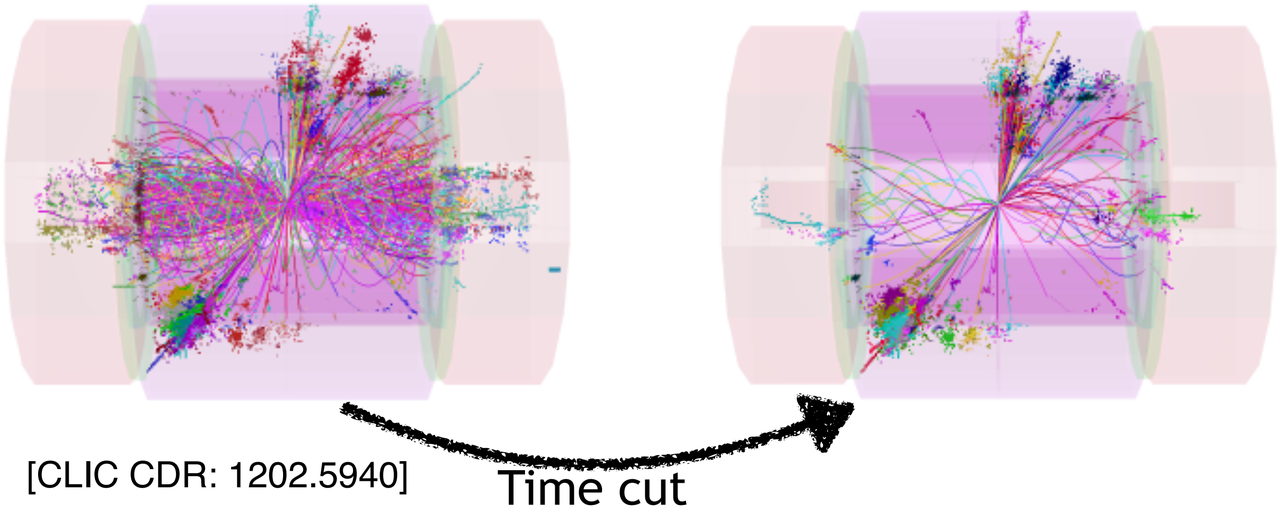


[CLIC CDR: 1202.5940]

Motivation

Why do we need time information?

- Reject background
- Improve clustering
- Use in software compensation to identify components of hadronic showers?



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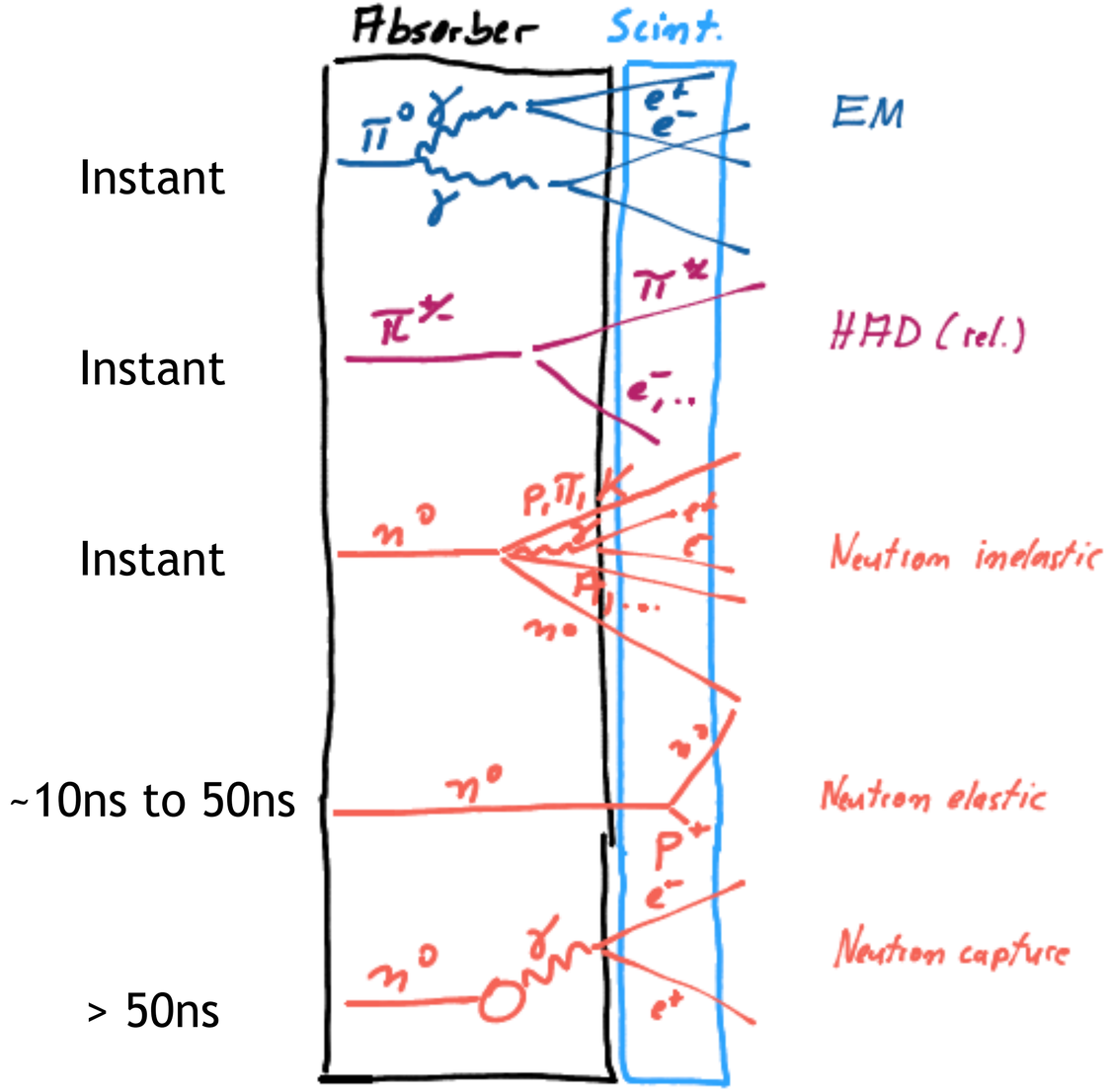
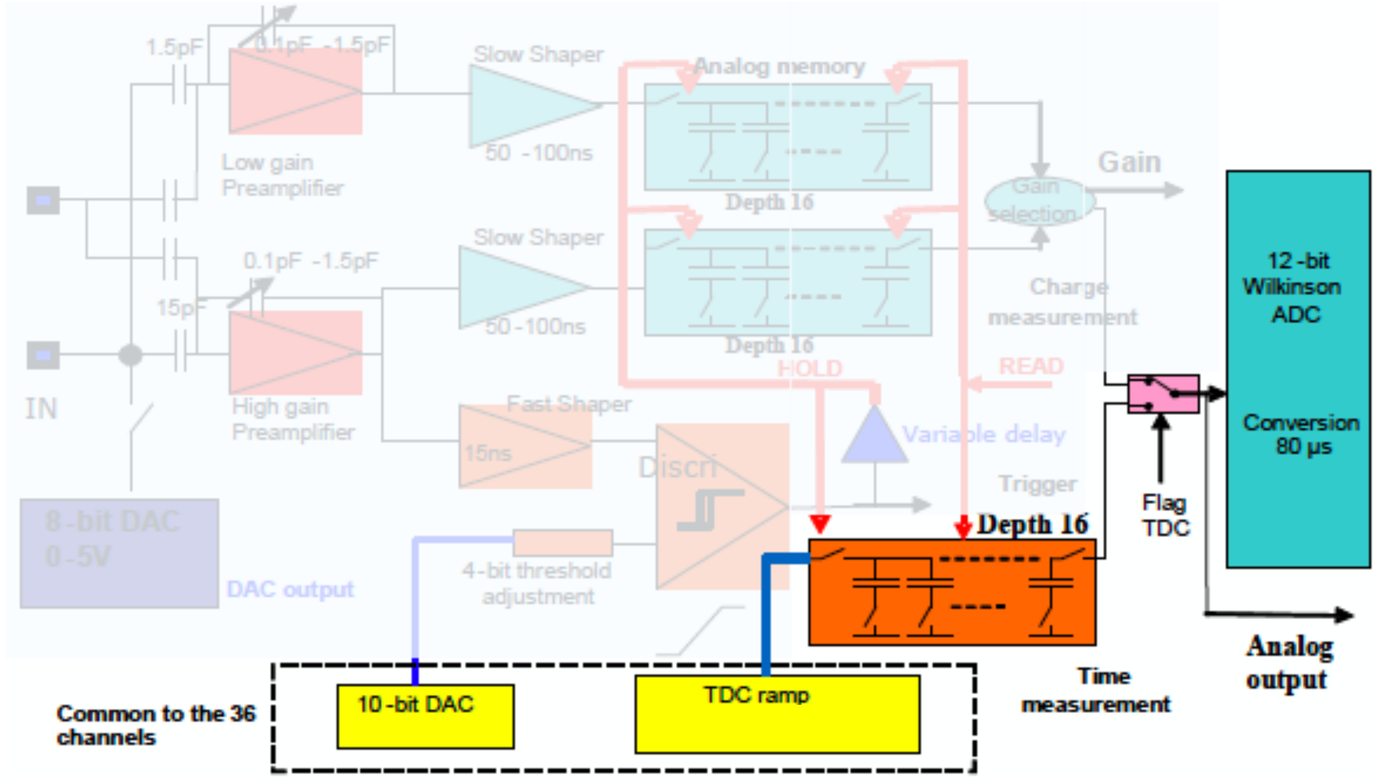


Time Calibration: Hardware

Time measurement with Spiroc2E: TDC (time to digital converter)

1. Common BIF clock with ~1ns bins



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2. Ramp up voltage for maximum 3920ns
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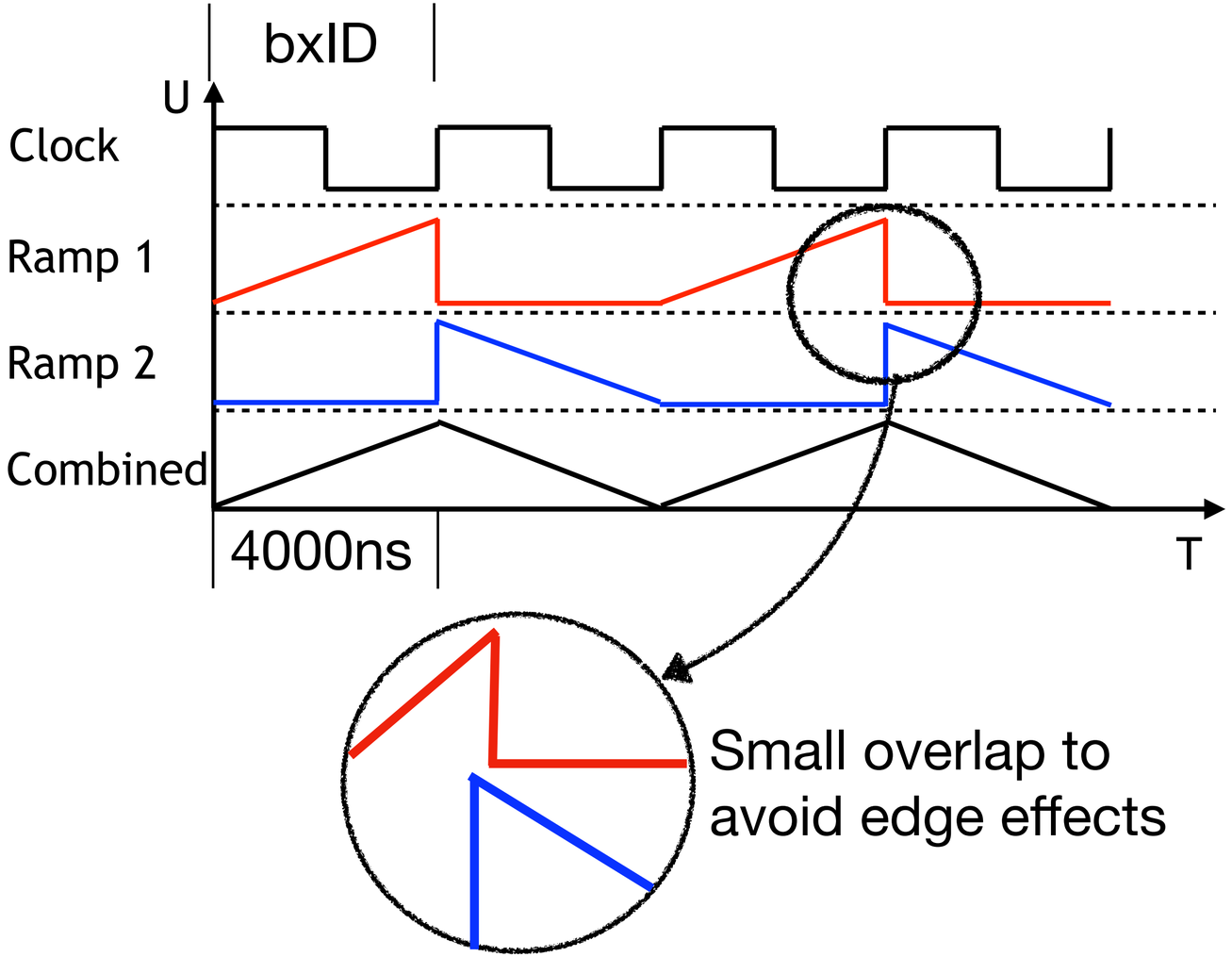

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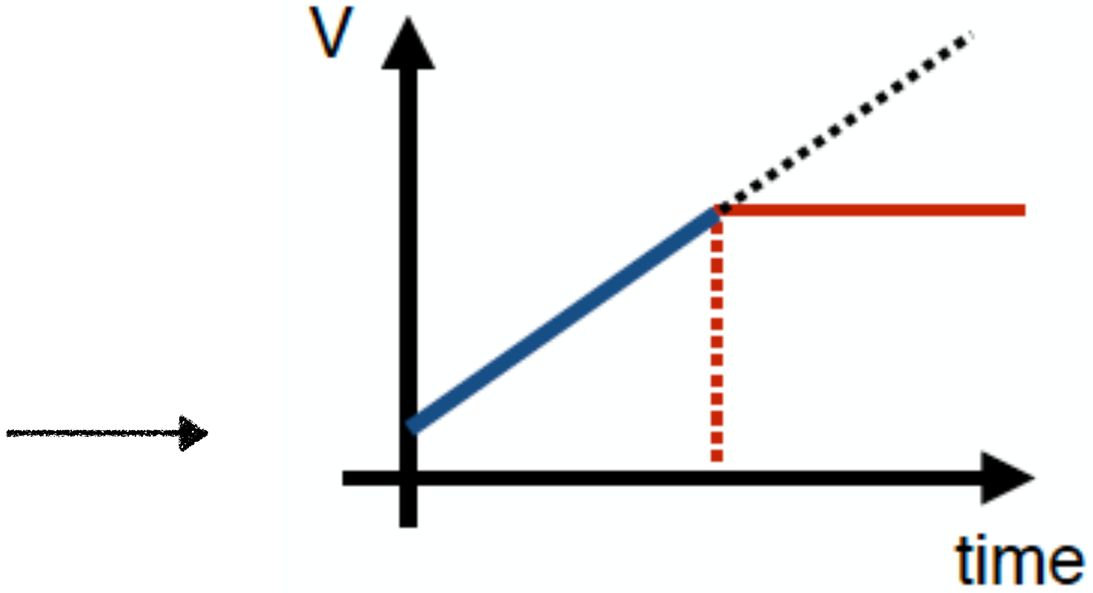

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Time measurement with Spiroc2E: TDC
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1. Common BIF clock with ~1ns bins
2. Ramp up voltage for maximum 3920ns
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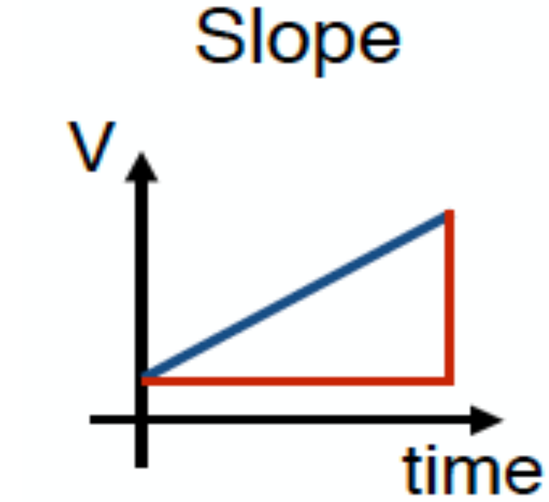
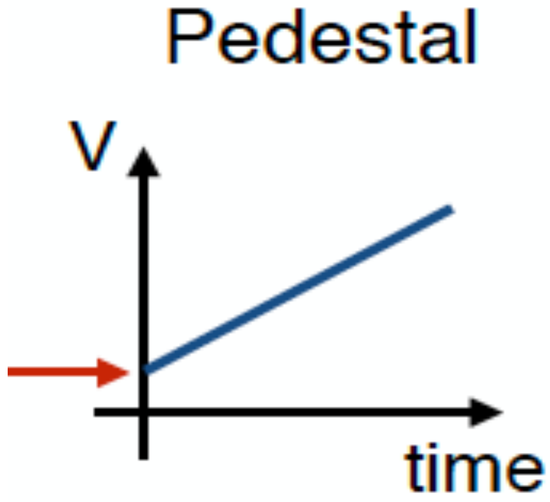
3. On hit, the current voltage is stored in
   one of 16 memory cells
4. Memory cells are digitized
5. Resulting TDC value needs to be
   related to hit time in ns → Calibration



Per chip



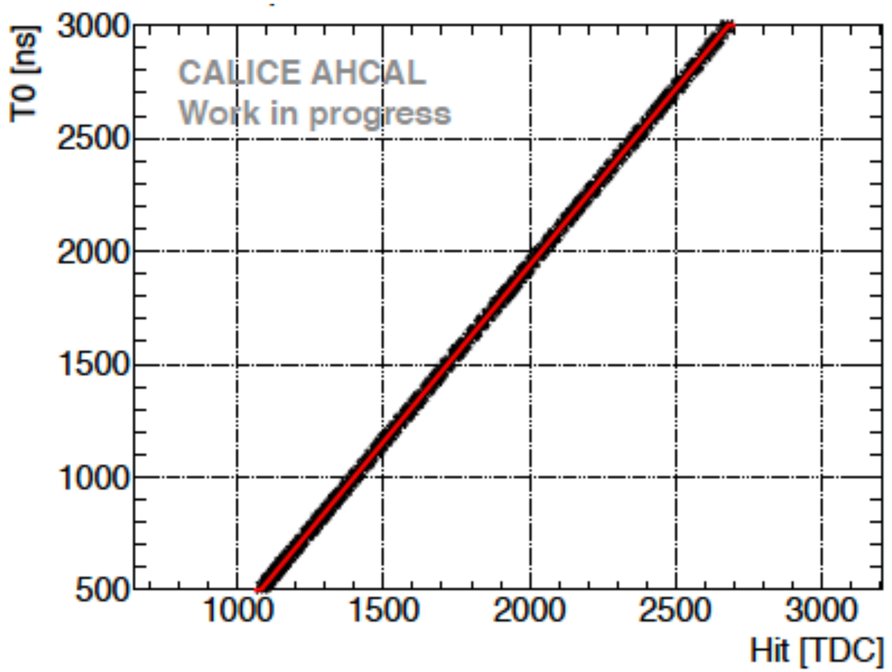
Per memory cell

Time Calibration: Software

All memory cells to be calibrated against common clock (T0[ns]):

1. Extract TDC slope by plotting T0 vs TDC

   - Fit slope for even and odd bxID per chip



Time Calibration: Software

All memory cells to be calibrated against common clock (T0[ns]):

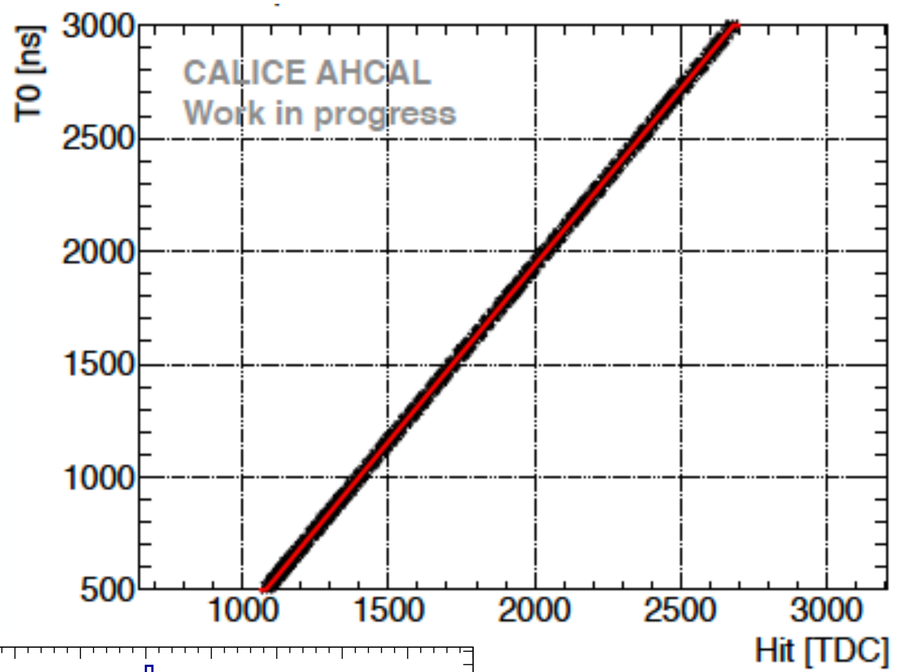
1. Extract TDC slope by plotting T0 vs TDC

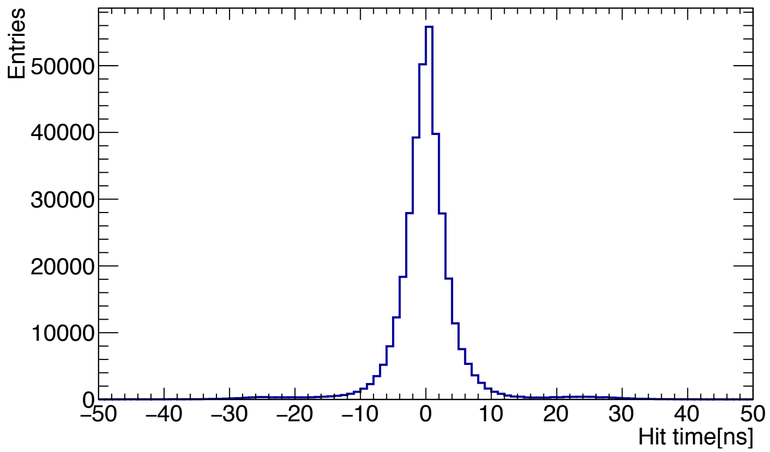
   - Fit slope for even and odd bxID per chip

2. Extract offset for every memory cell (576 per chip)

3. Calculate hit time by

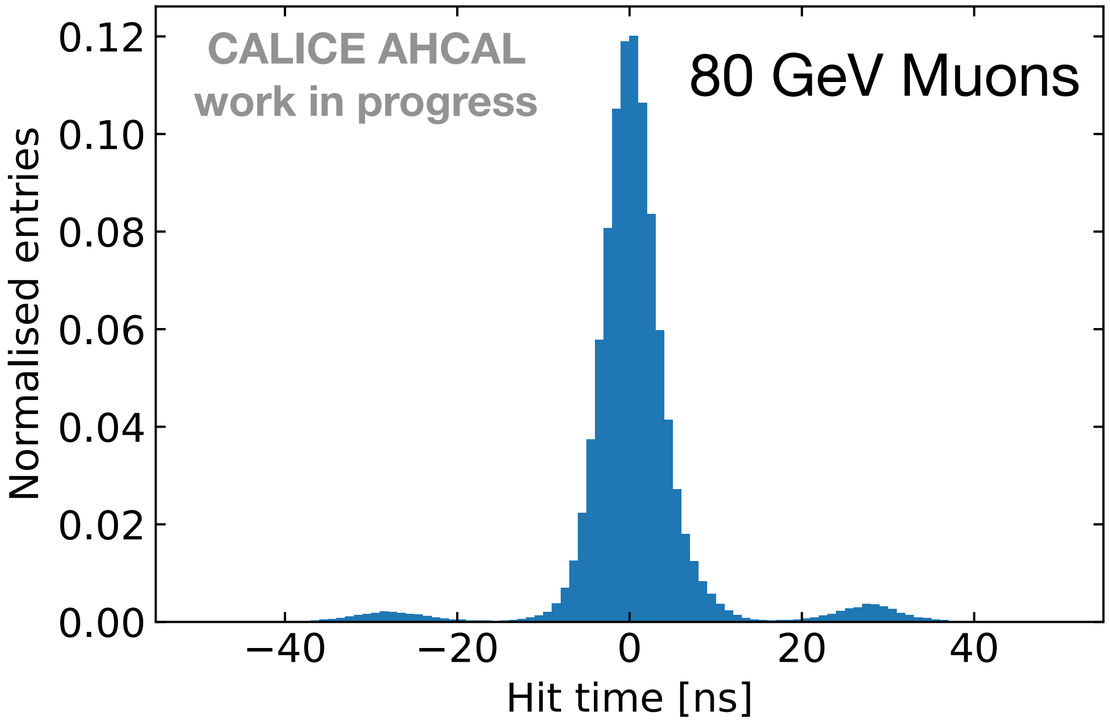
$$t_{hit}[\text{ns}] = \text{TDC}_{\text{hit}} \cdot \text{Slope}\left[\frac{\text{ns}}{\text{TDC}}\right] + \text{Offset}\,[\text{ns}] - T_0$$





Hit time distribution

Muon Time Resolution - CERN 2018



Main peak at 0ns Satellite Peaks at ±28ns

Tried to correct by cuts and event categorisation (shown at the AHCAL Main Meeting 2018)

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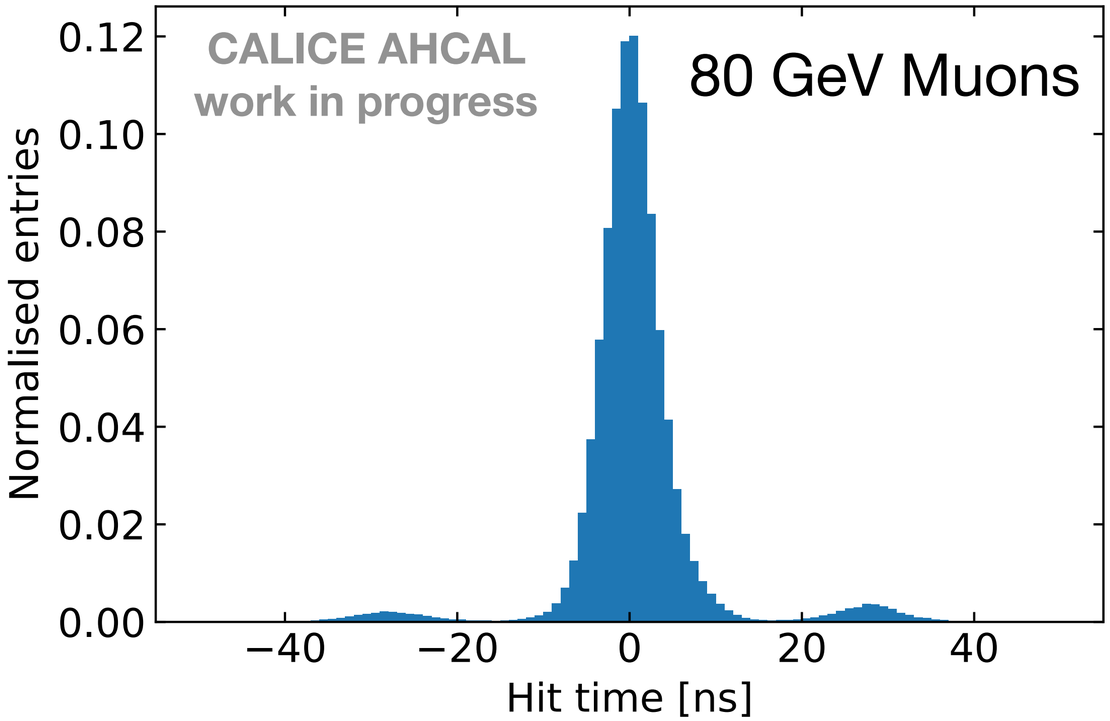

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~3.3ns for Muons
~7ns for Electrons

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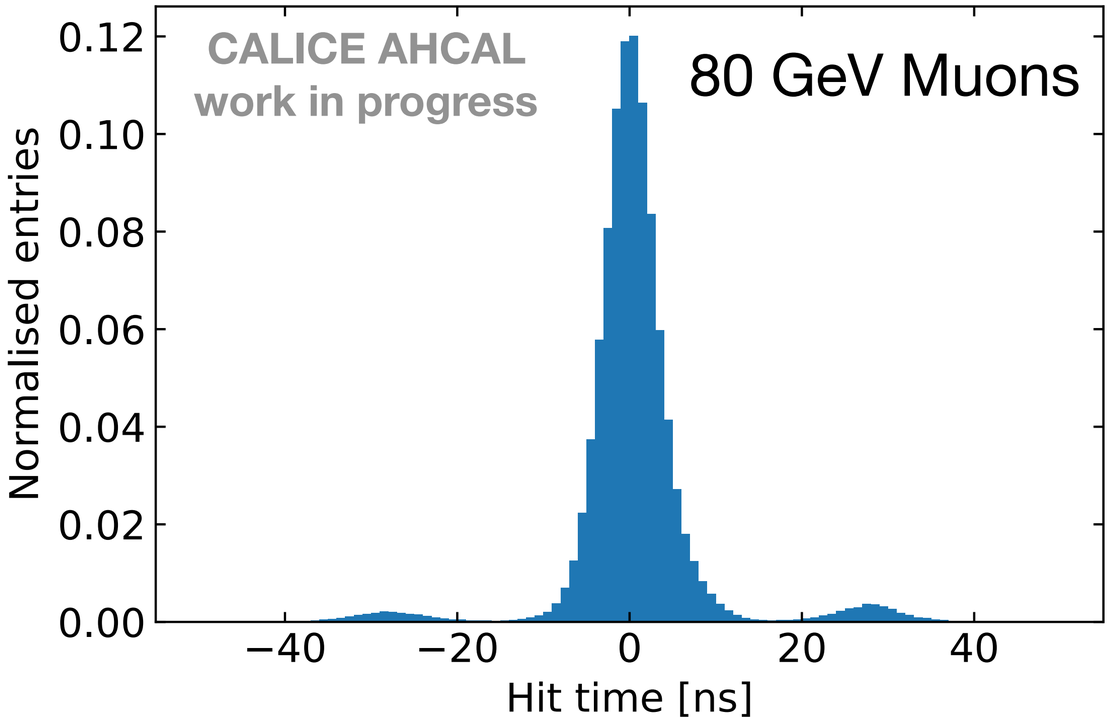

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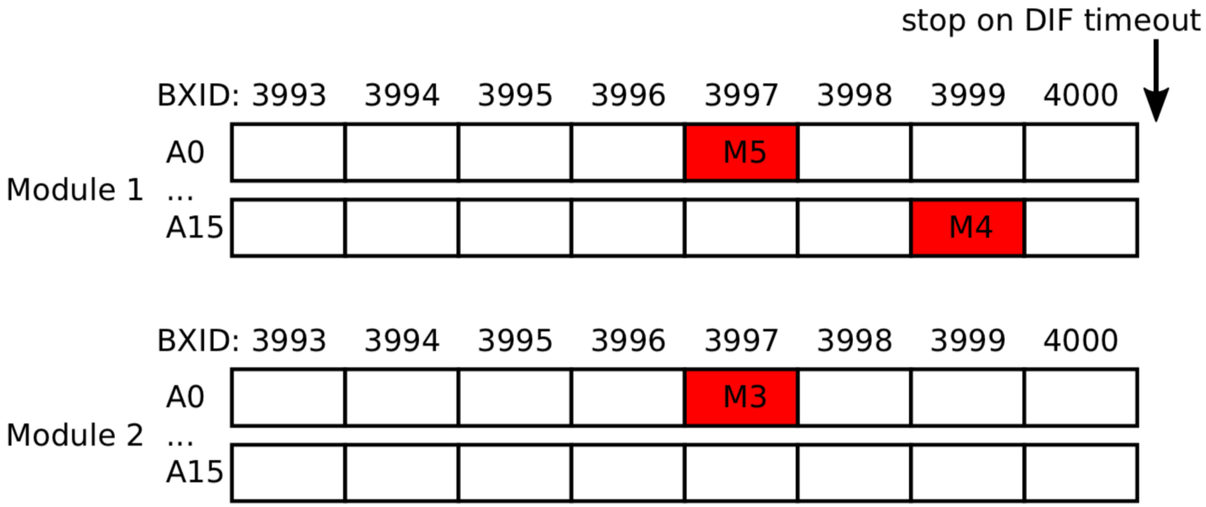
New approach →

Hypothesis: Problem connected with stopping condition of readout cycle

- Shift depends on BxID parity of ASIC with full memory cells
- Direction depends on the BxID parity of the event

Stopping of the Acquisition

Stop after predefined timeout



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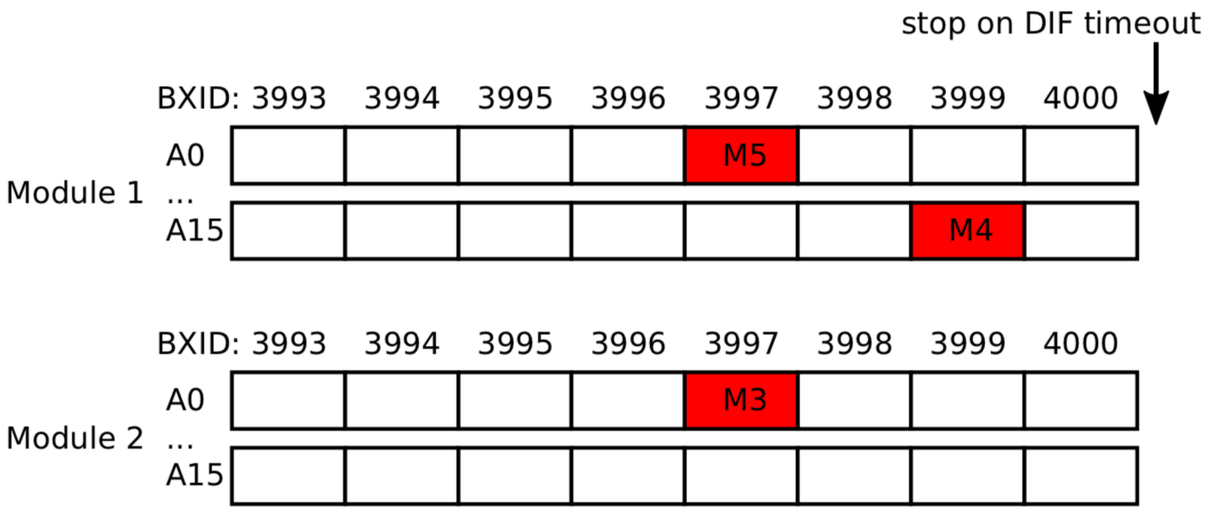
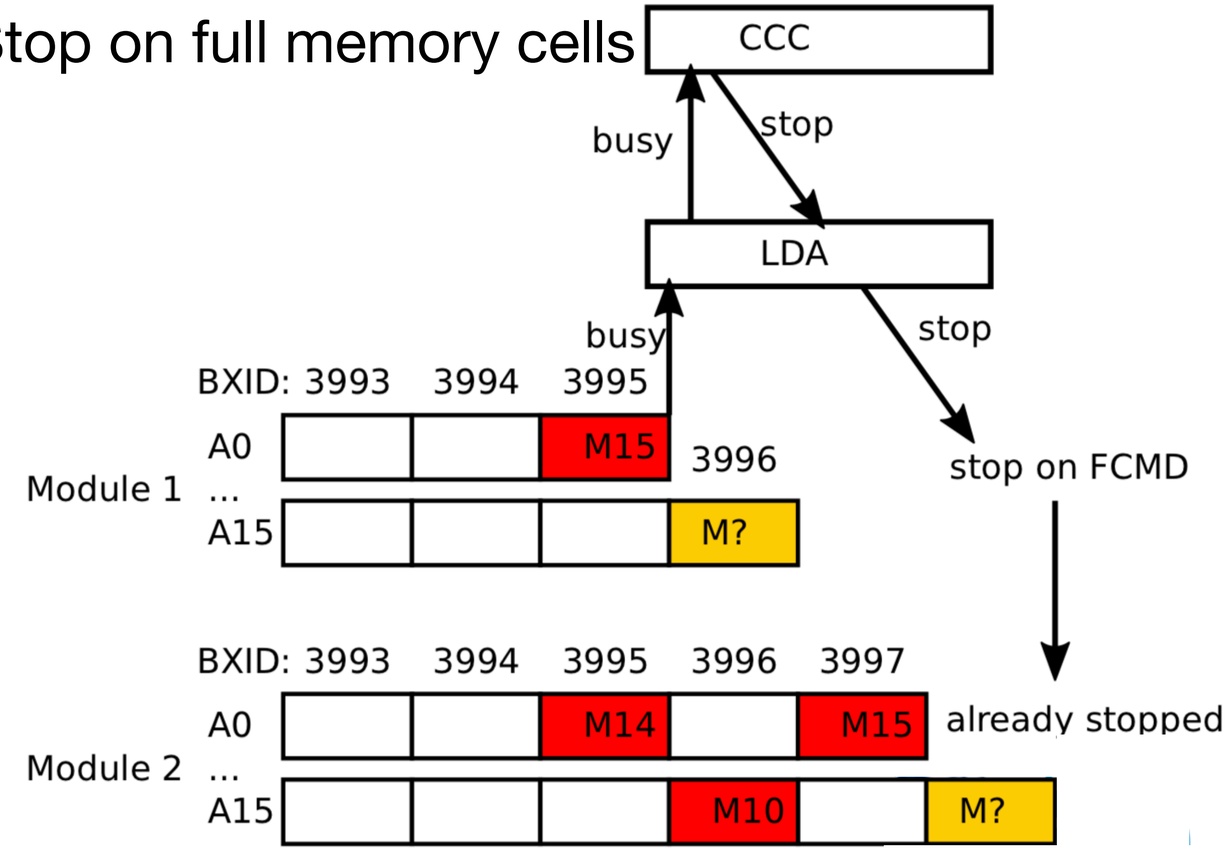


Stop on full memory cells



Figures taken from J. Kvasnicka
AHCAL Main Meeting 2018

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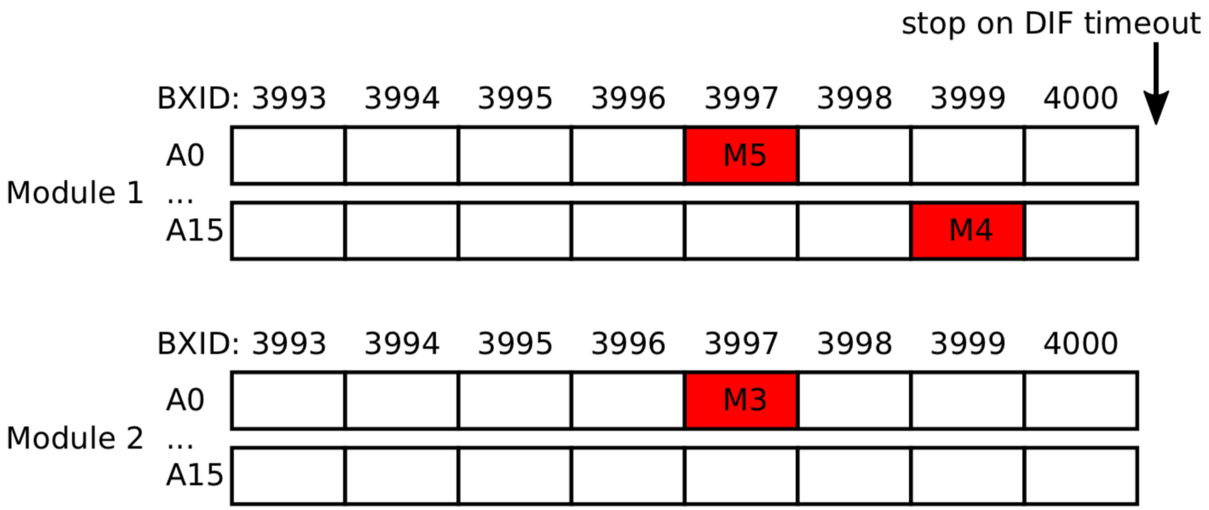

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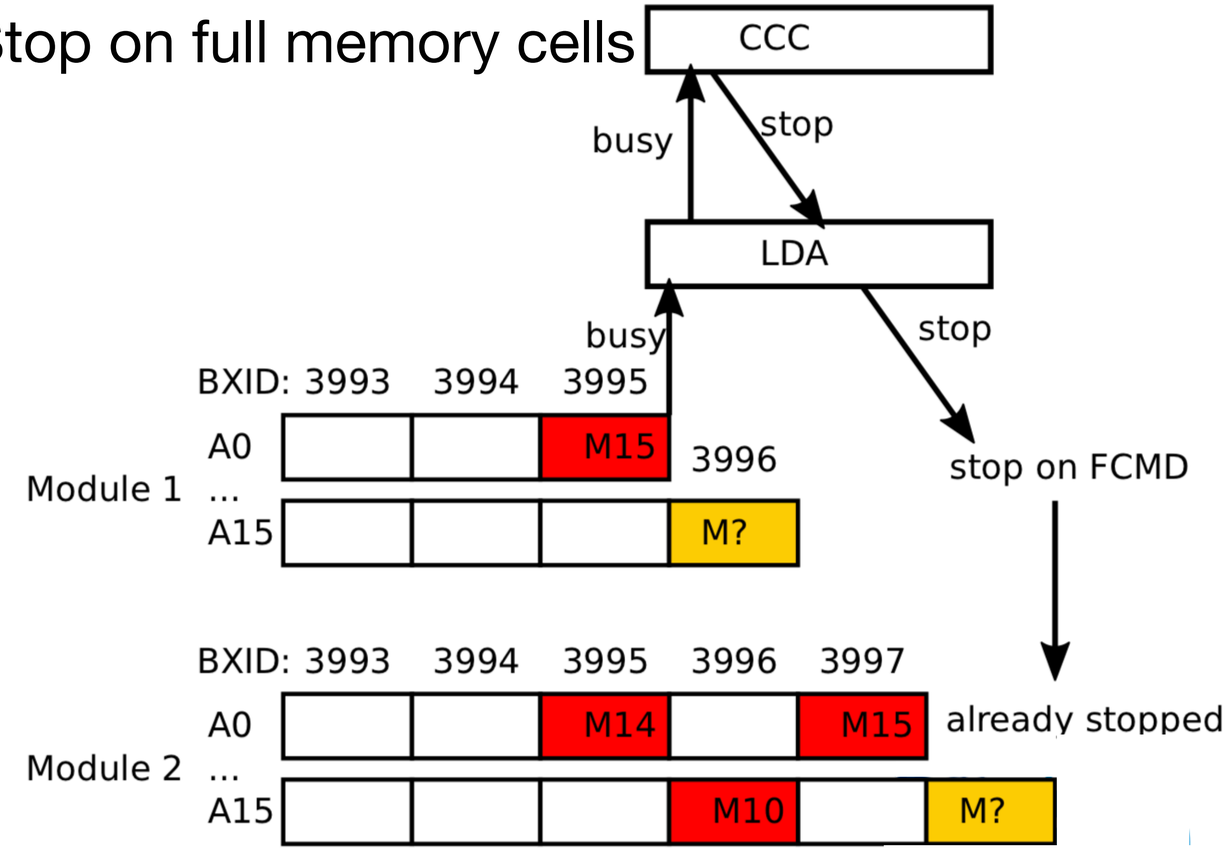


Information on termination of the read out cycle in .slcio files:

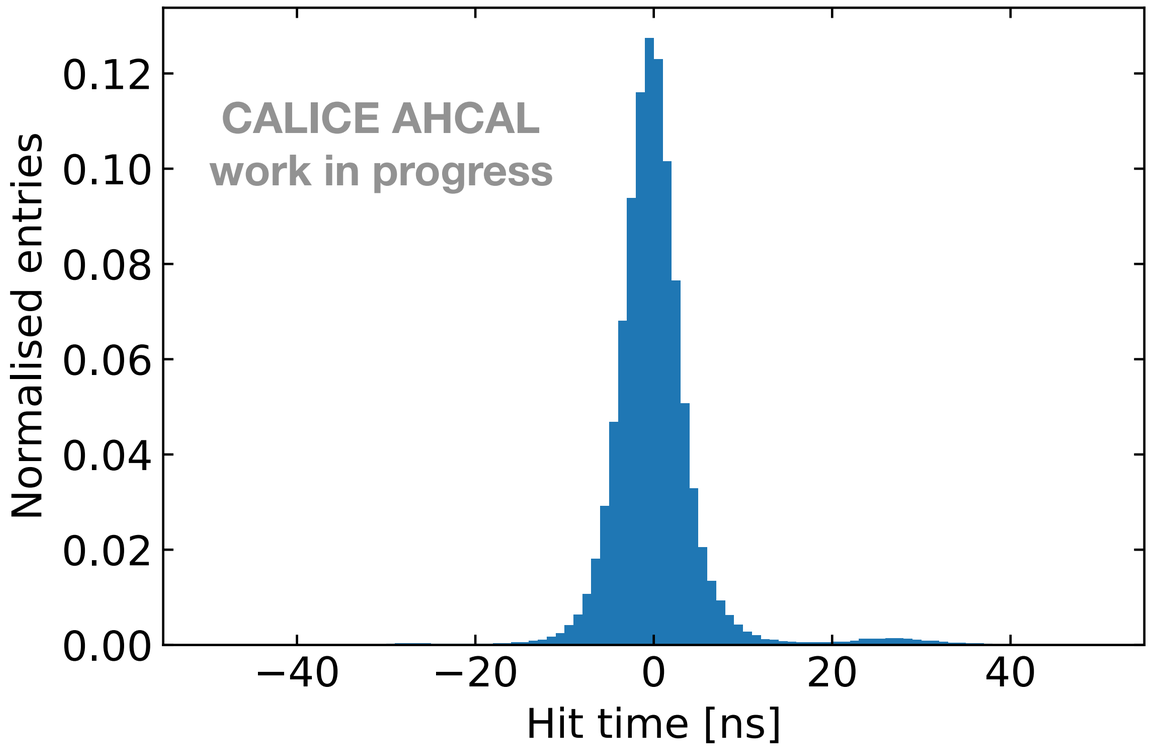
- time out / full memory cell
- First filled ASIC and corresponding BxID

Figures taken from J. Kvasnicka
AHCAL Main Meeting 2018

Muon Time Resolution - CERN 2018

Shift depends on the parity of last bxID in read out cycle ended by full memory cell:

- If odd $\Longrightarrow$ no shift



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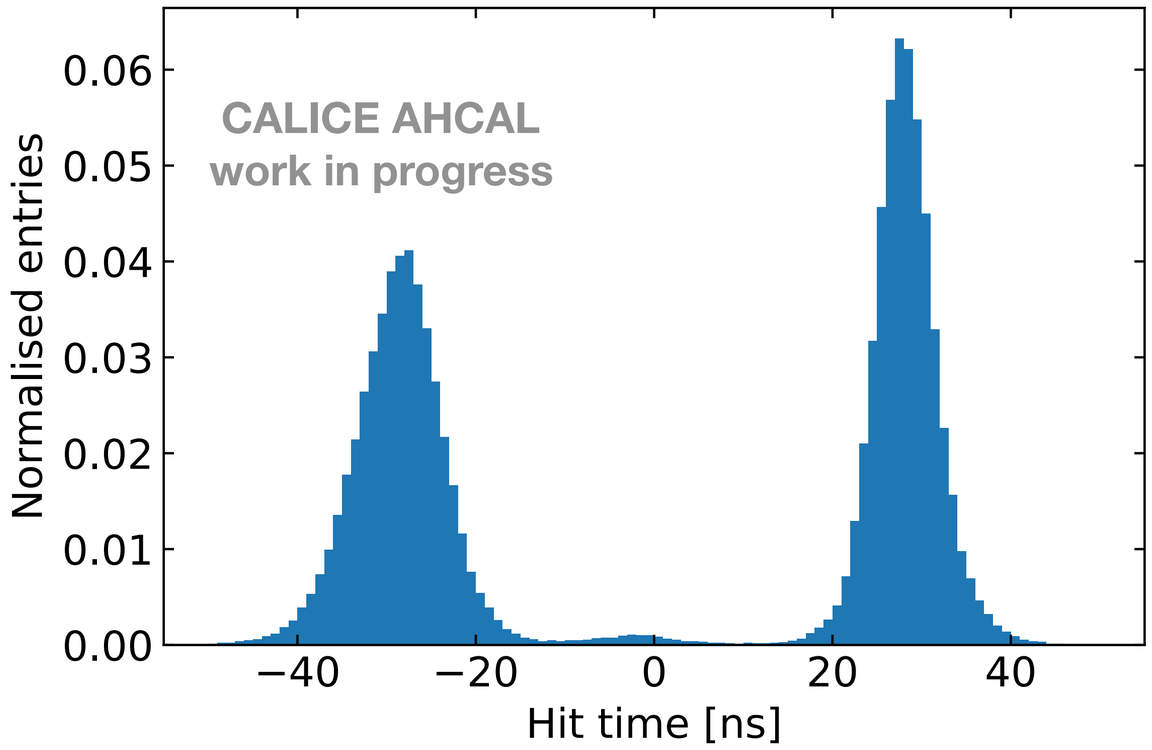

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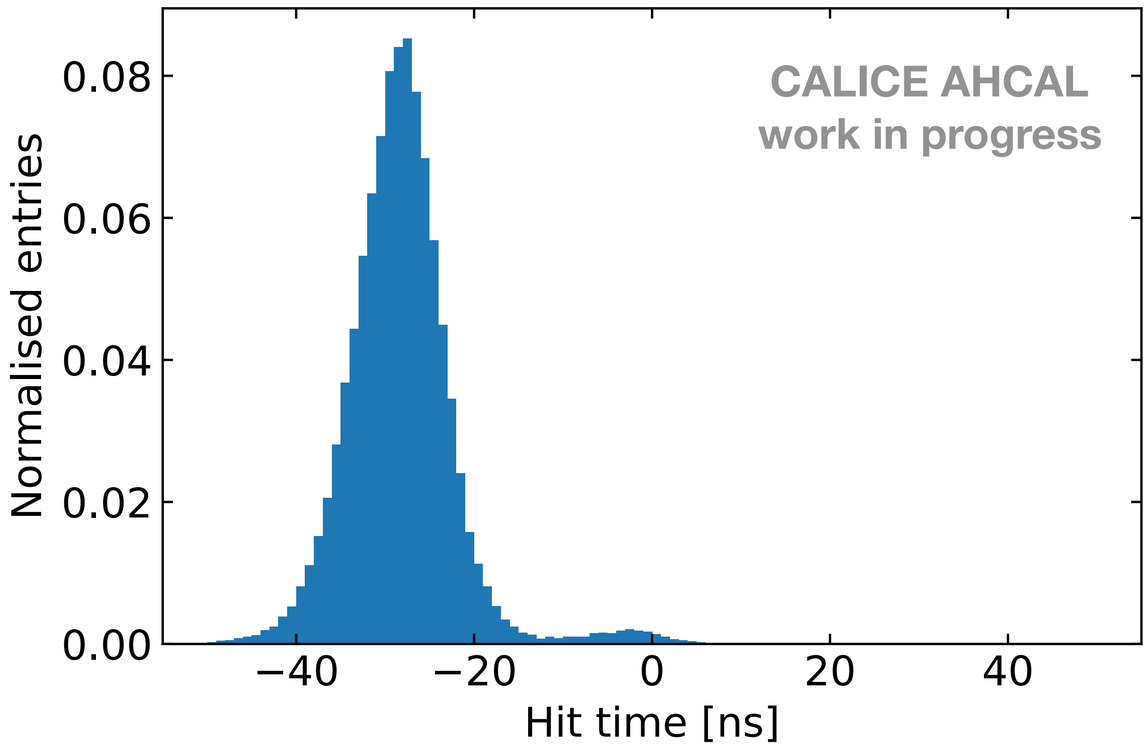

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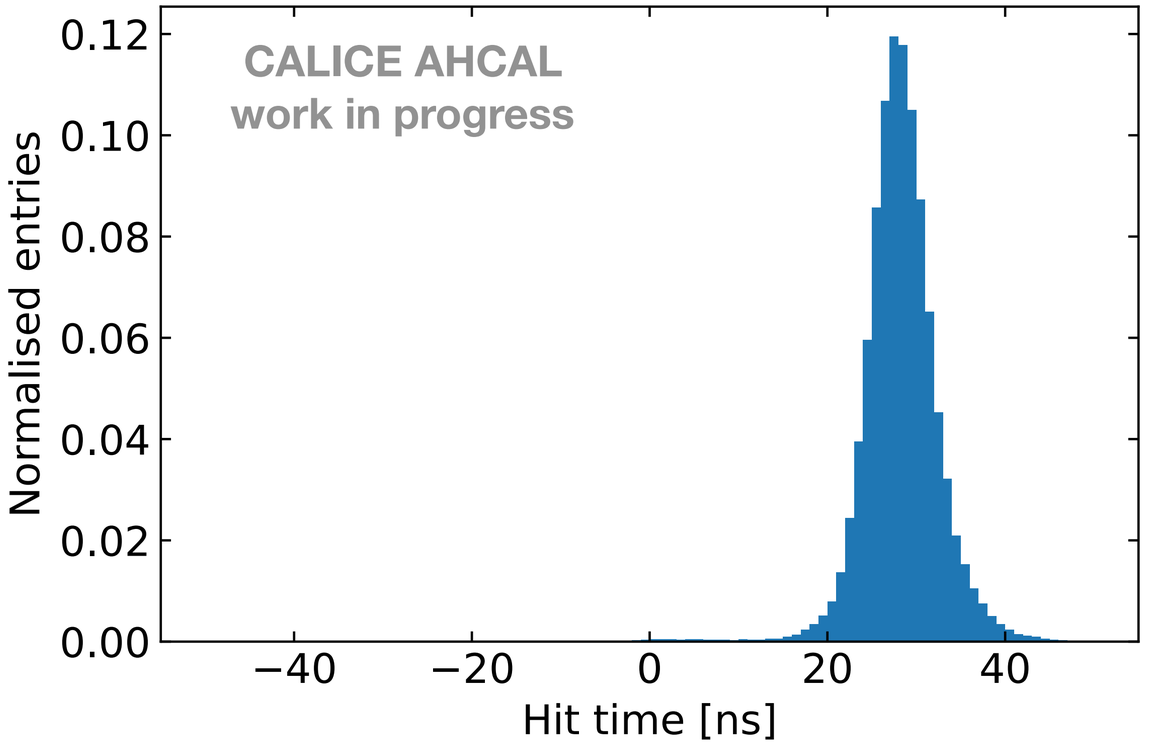

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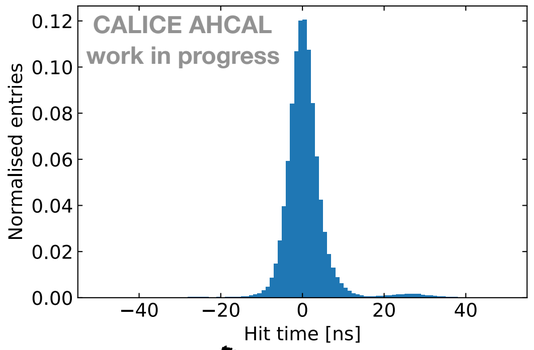
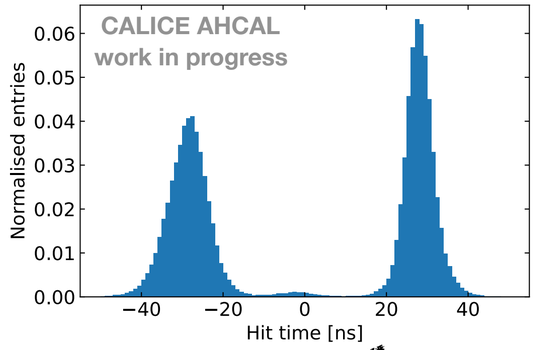
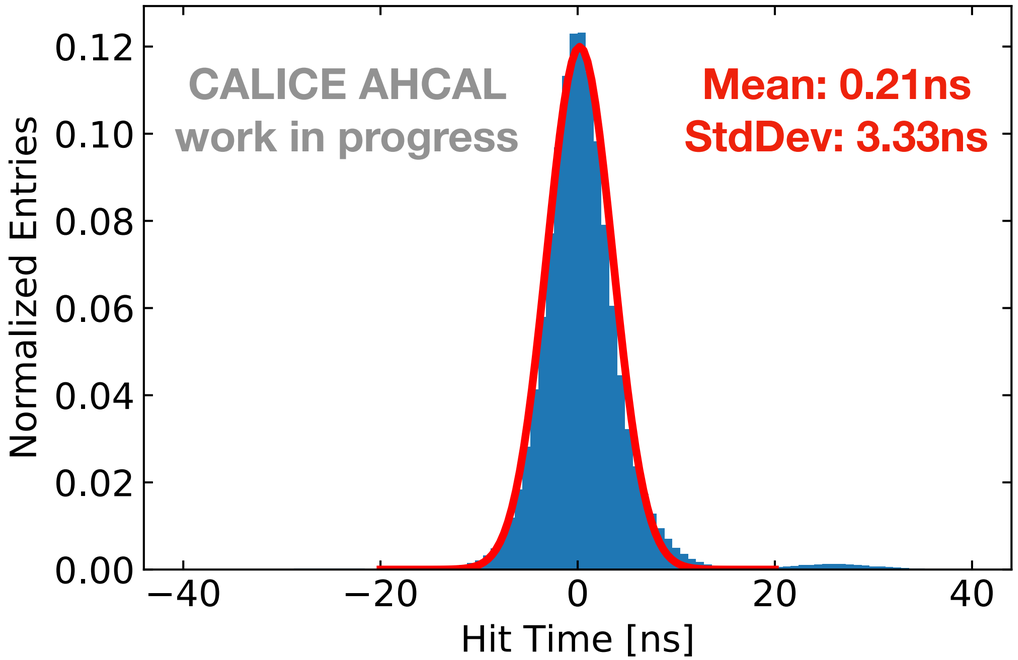
Deterministic chip effect, can be corrected





shift



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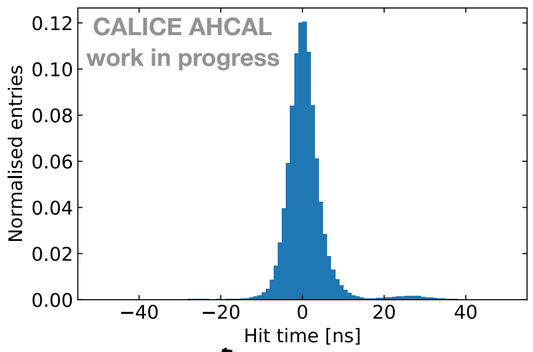
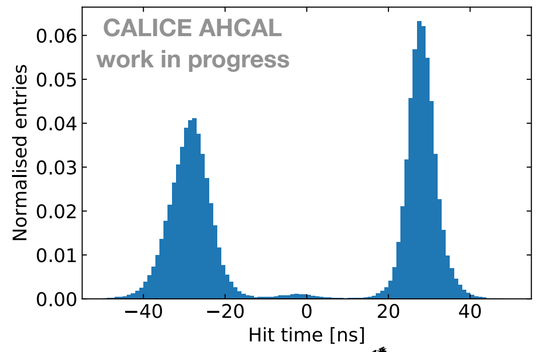
Remaining bumps due to shifted calibration constants $\Longrightarrow$ under investigation





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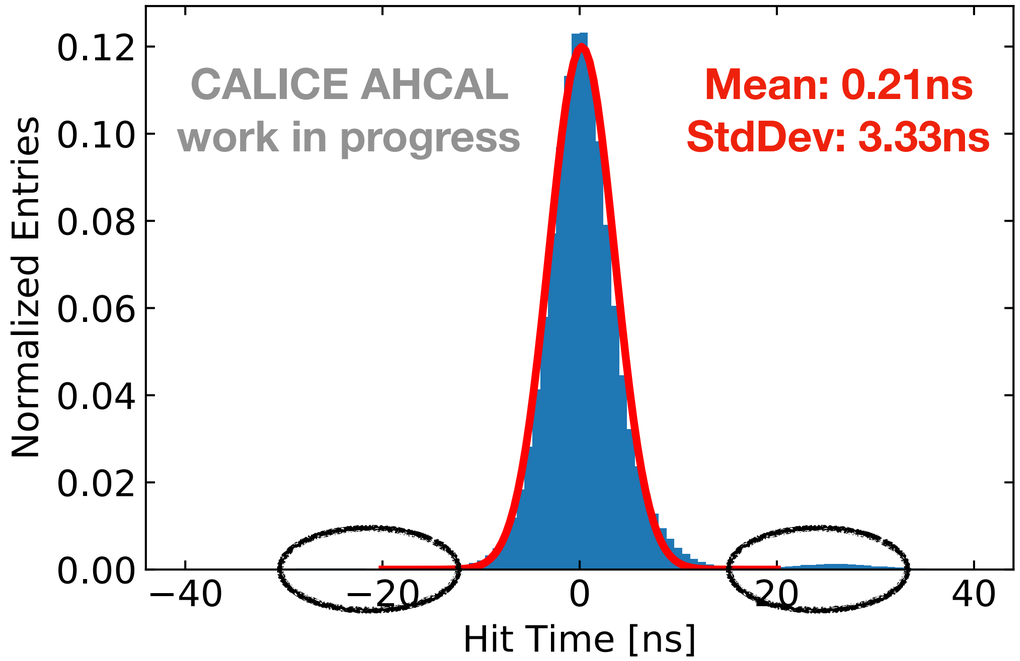
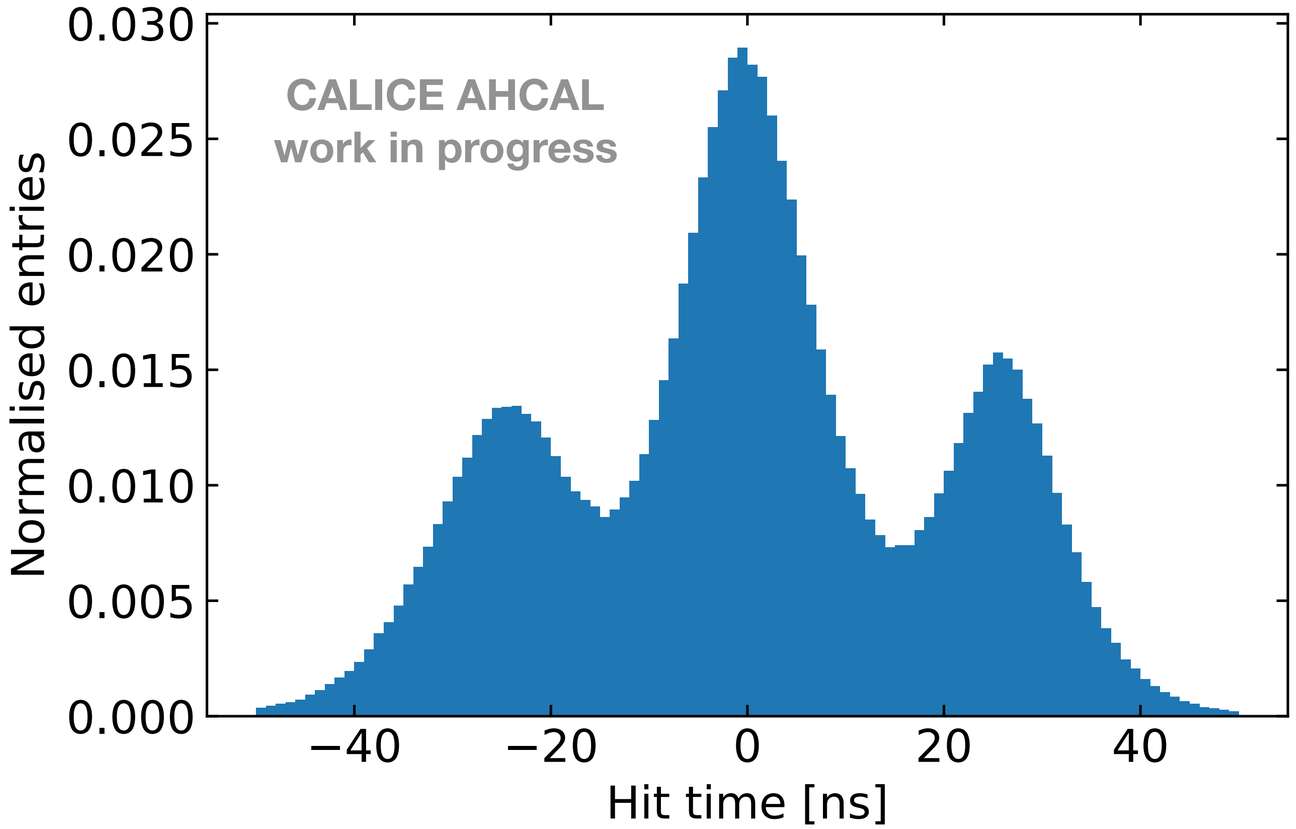


Electron Time Resolution - CERN 2018

Time resolution deteriorates:

- Broadening of the hit time distribution with rising chip occupancy
  - Preliminary occupancy correction applied



Electron Time Resolution - CERN 2018

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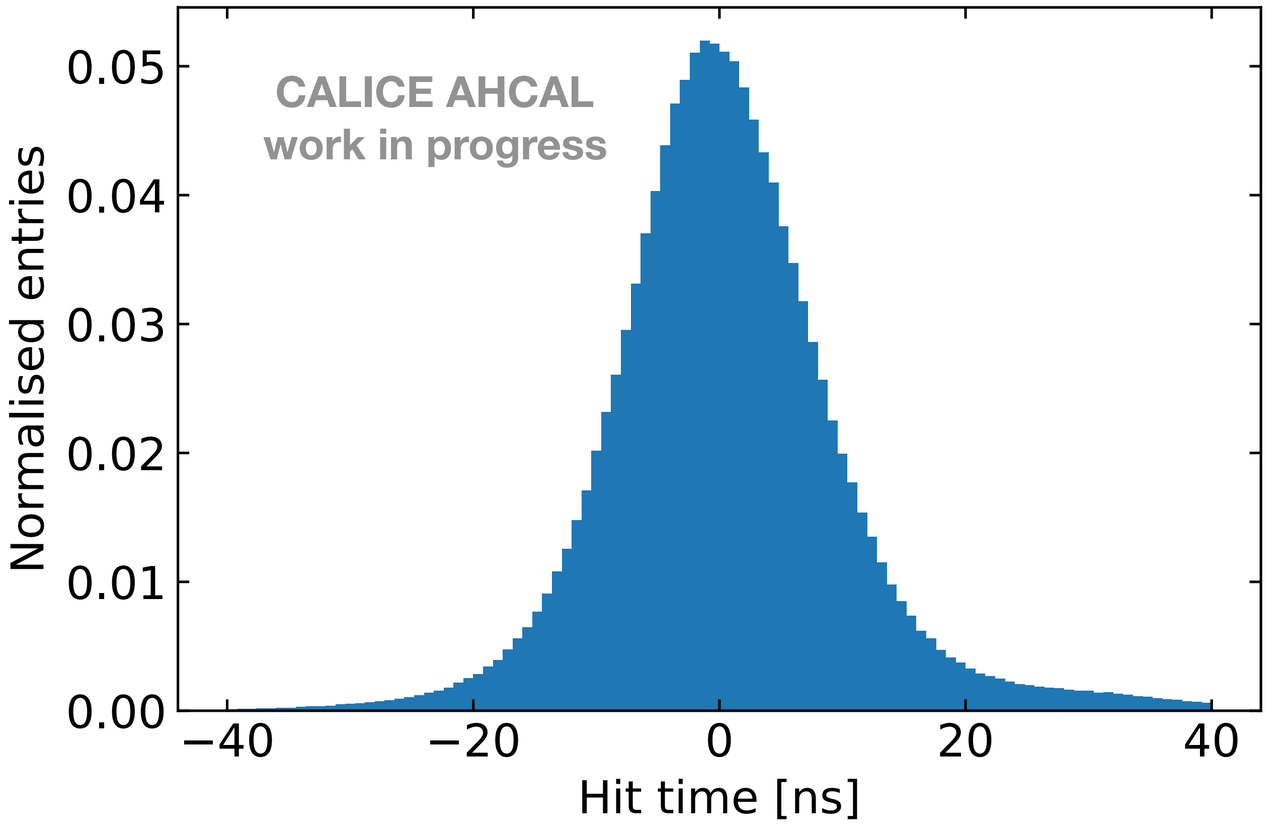
Shift correction identical to muons

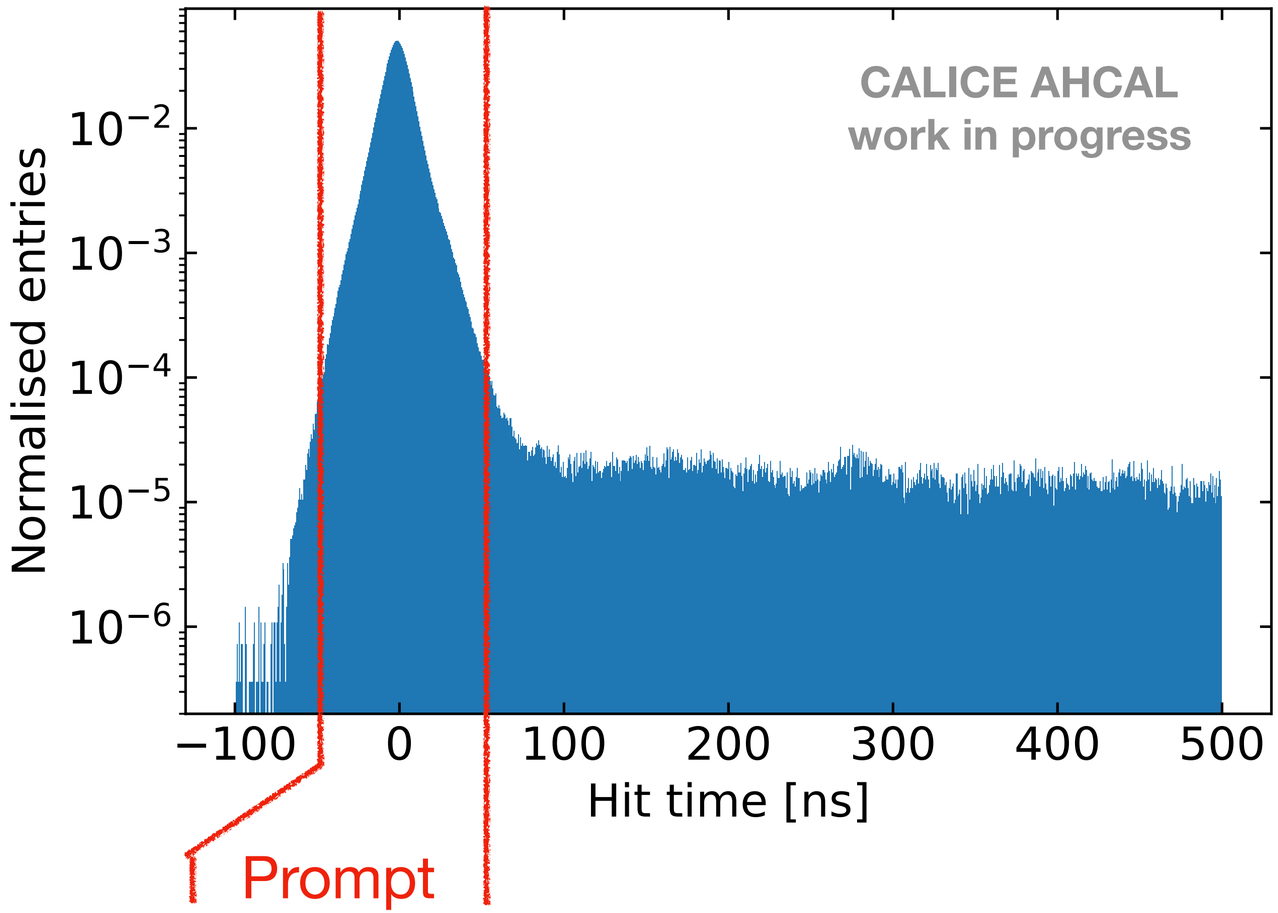
Time resolution at 6-7ns



A Look at Pions

Subjected to same chip effects:

- Time resolution of main peak comparable to electrons



A Look at Pions

Subjected to same chip effects:

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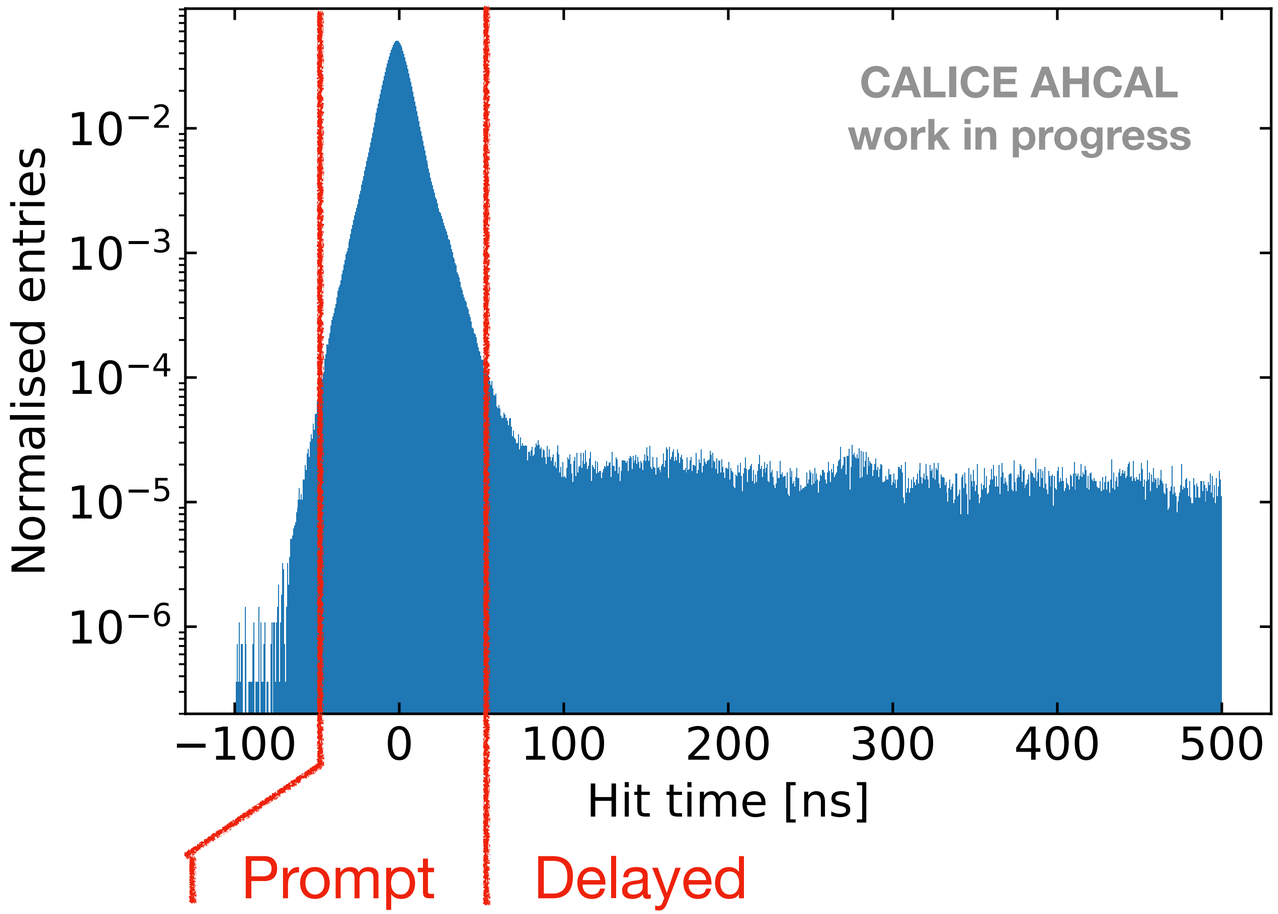
Visible “physics tail”:

- Delayed energy depositions from:
  - Elastic neutron scattering
  - Neutron capture $\Longrightarrow$ decay, deexcitation of nucleus

$\Longrightarrow$ Use to identify shower components



Conclusion

Chip effects observed in hit time distribution:

- Connected to state of detector at the end of a read out cycle
  - Shift only occurs if one chip issued busy in an even BxID
  - Positive shift for even BxID events, negative shift for odd

Achieved muon time resolution: ~3.3 ns without time walk correction

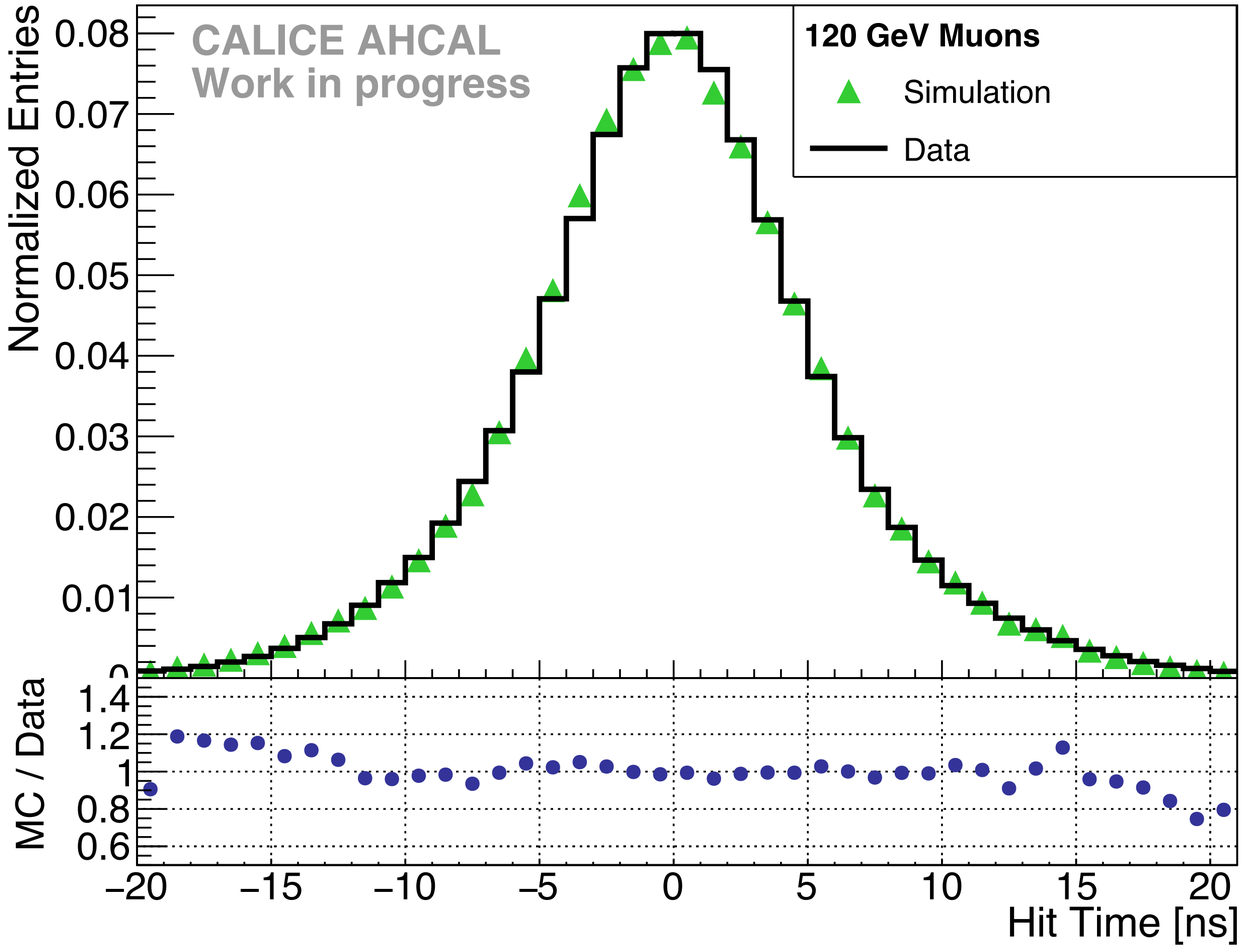
Achieved electron time resolution: ~6 - 7ns after occupancy correction, without time walk

Calibration constants picked up chip effects $\Longrightarrow$ expect improvement after recalibration with corrected data

$\Longrightarrow$ reprocessed muon scan from May 2018 with new information currently under investigation

Backup

Muon Time Resolution - CERN 2015



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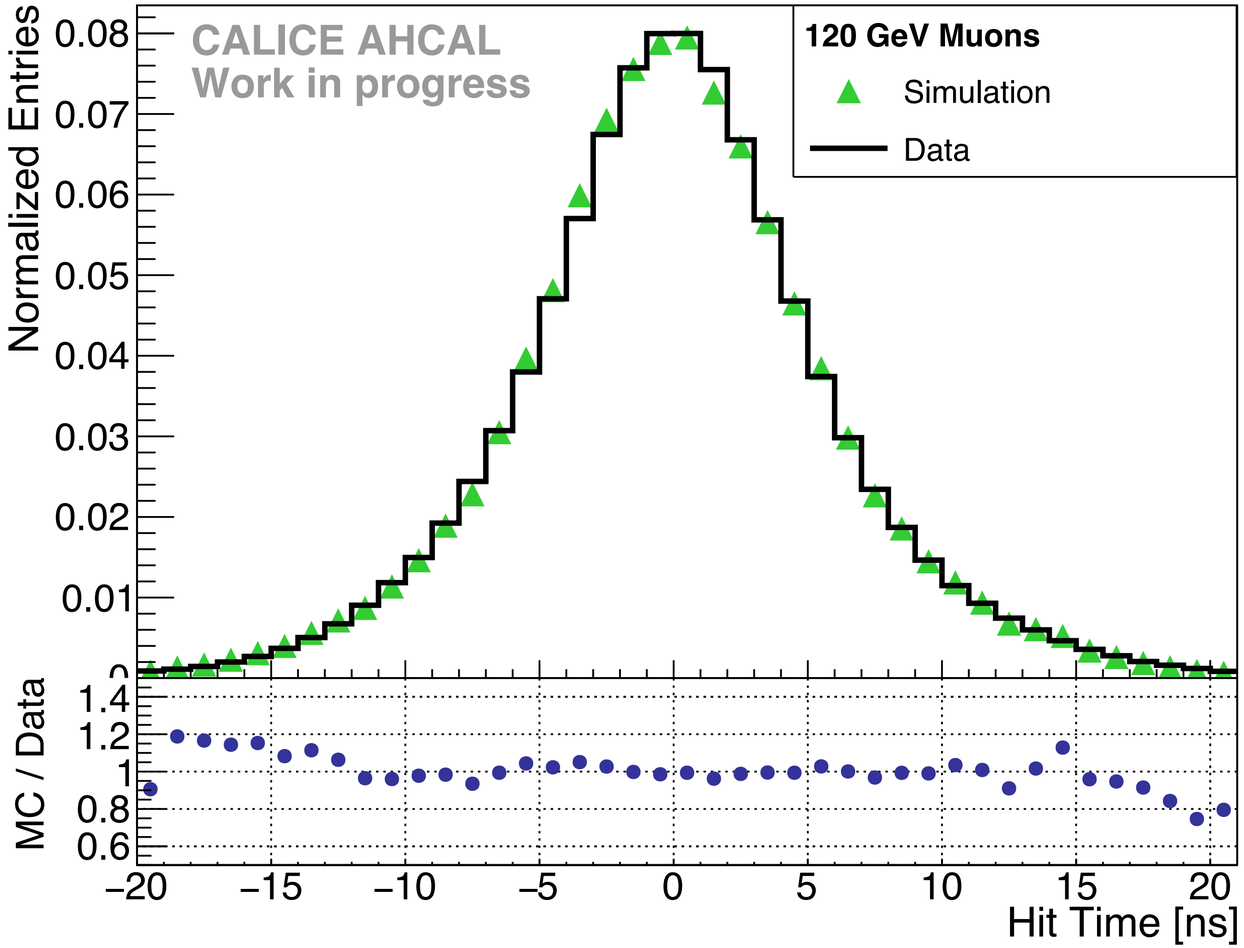


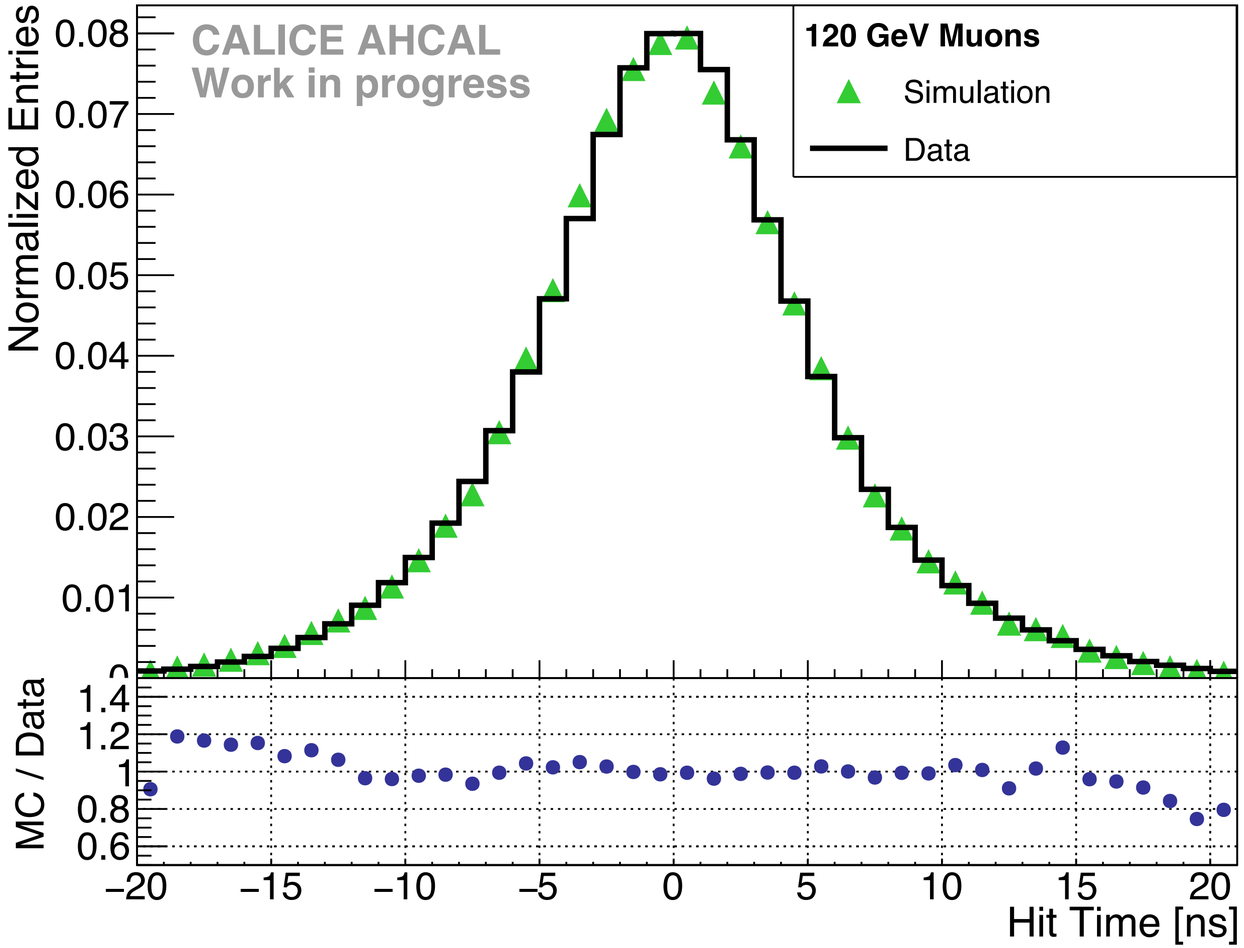
Tungsten absorber

Time reference given by T0 channels:

- Trigger scintillator connected to normal AHCAL channel

Time resolution: 5-6ns

Muon Time Resolution - CERN 2015



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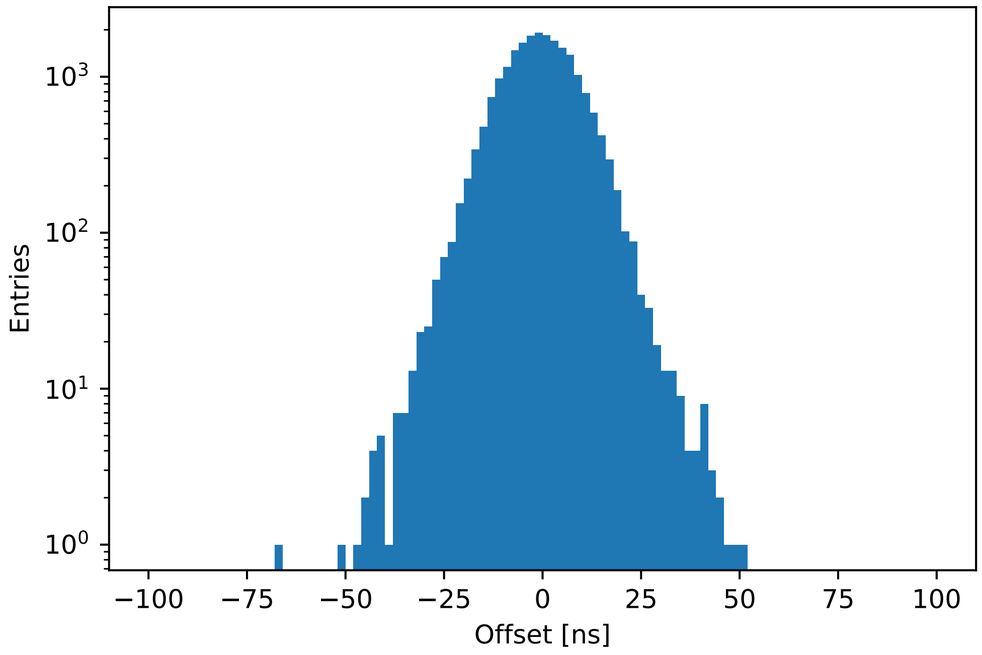
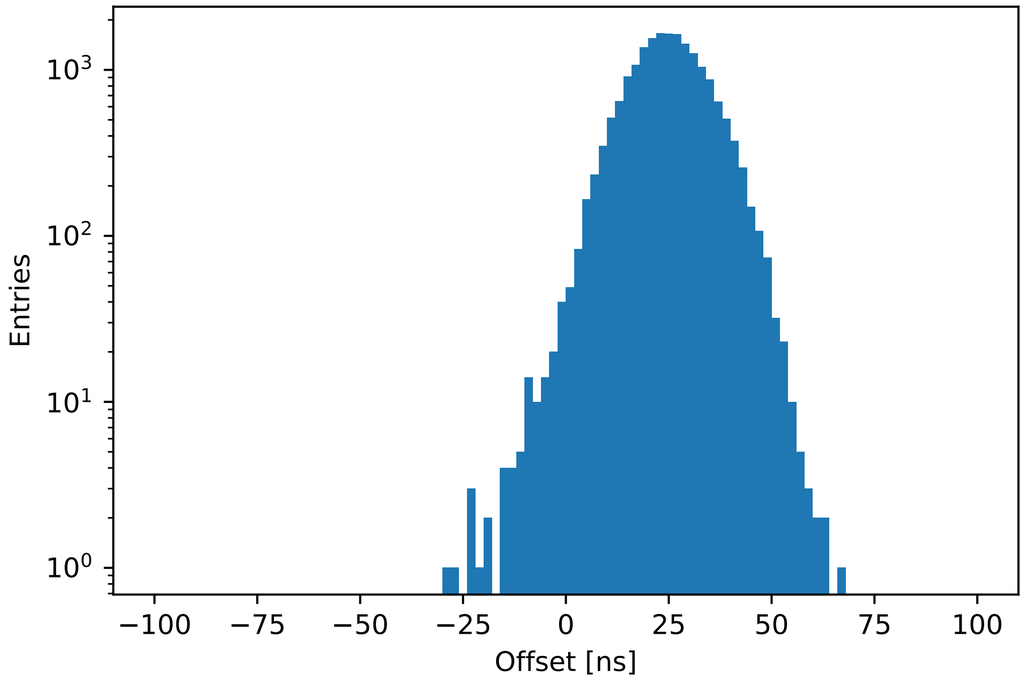
2017: Implemented Beam Interface Module (BIF) → provides external clock

Shift in Calibration Constants

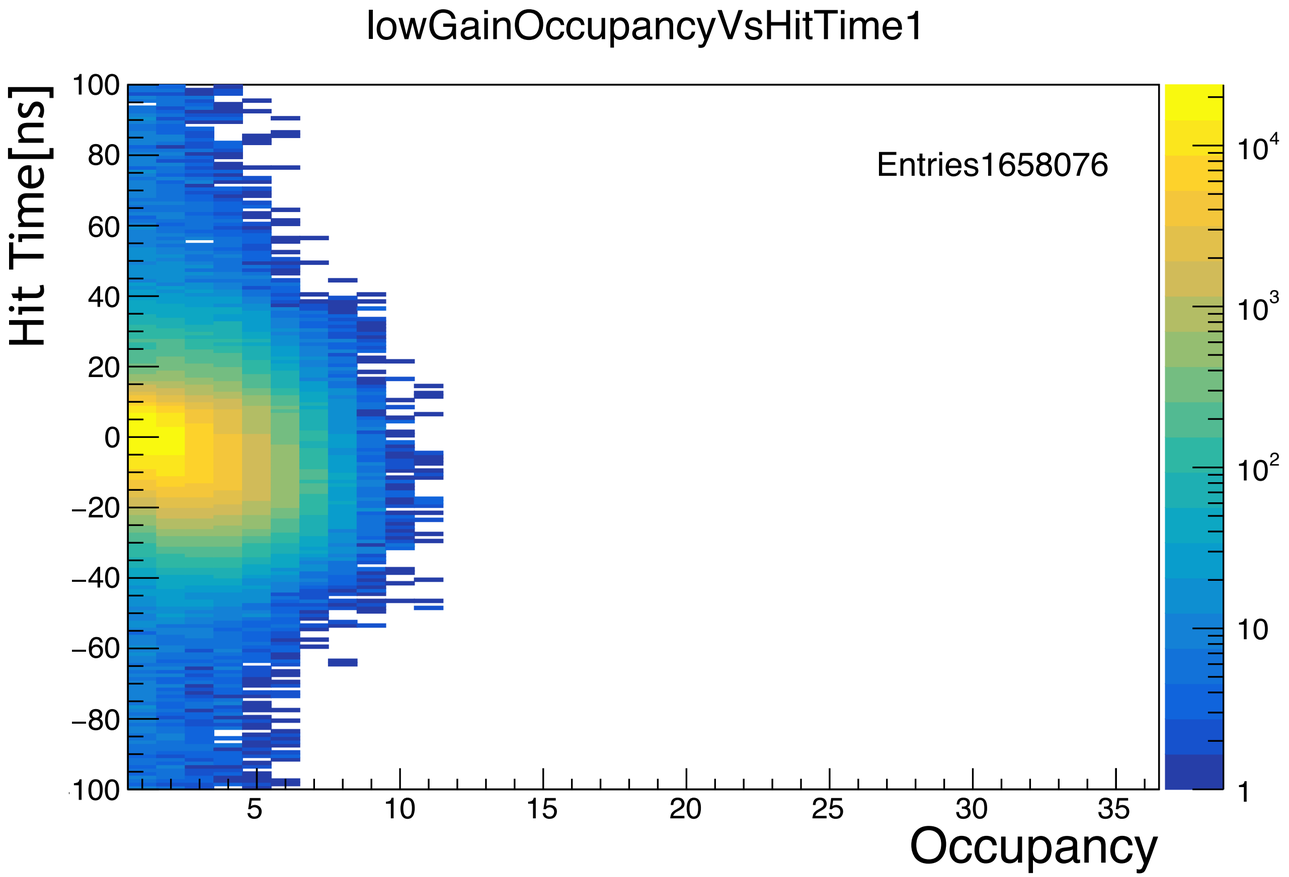
Memory cell 2



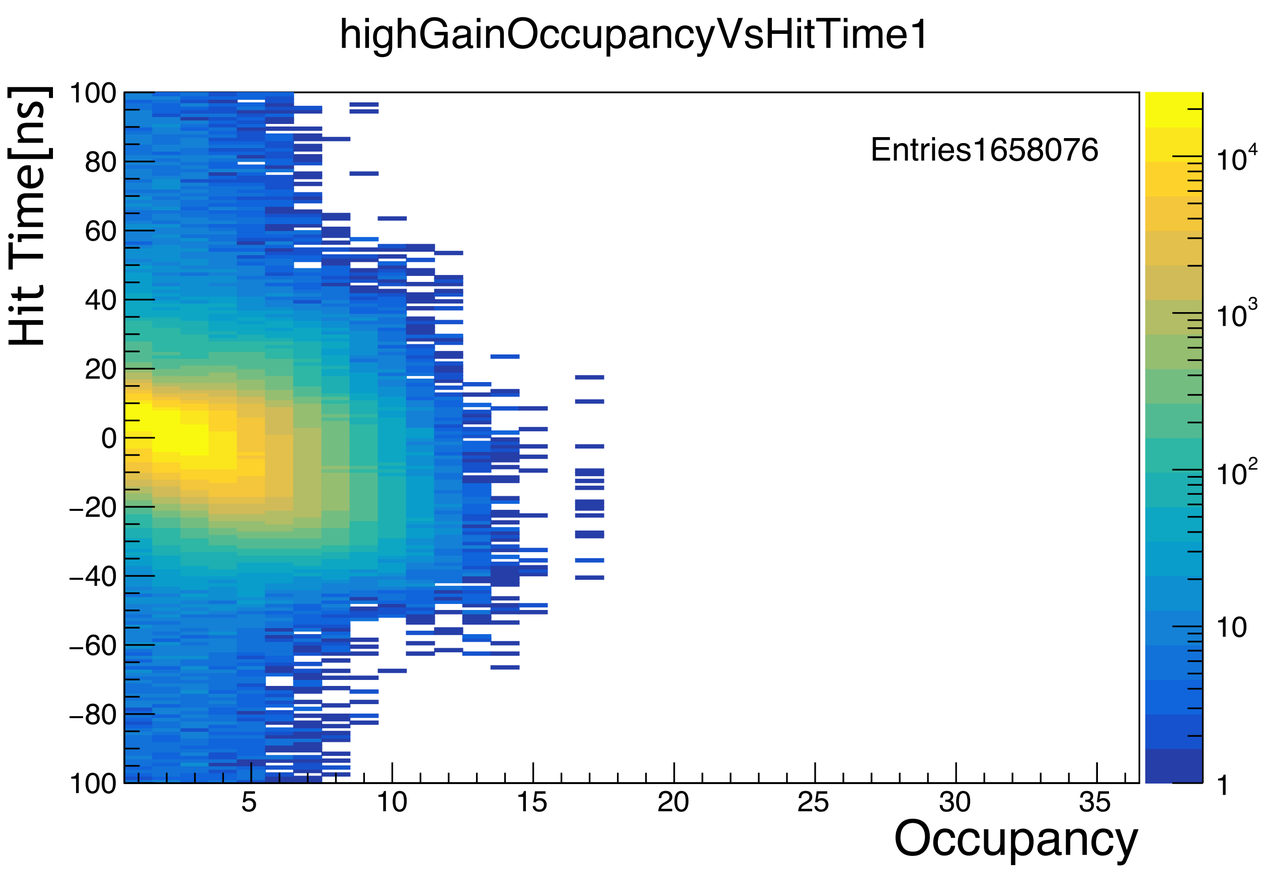
Memory cell 14

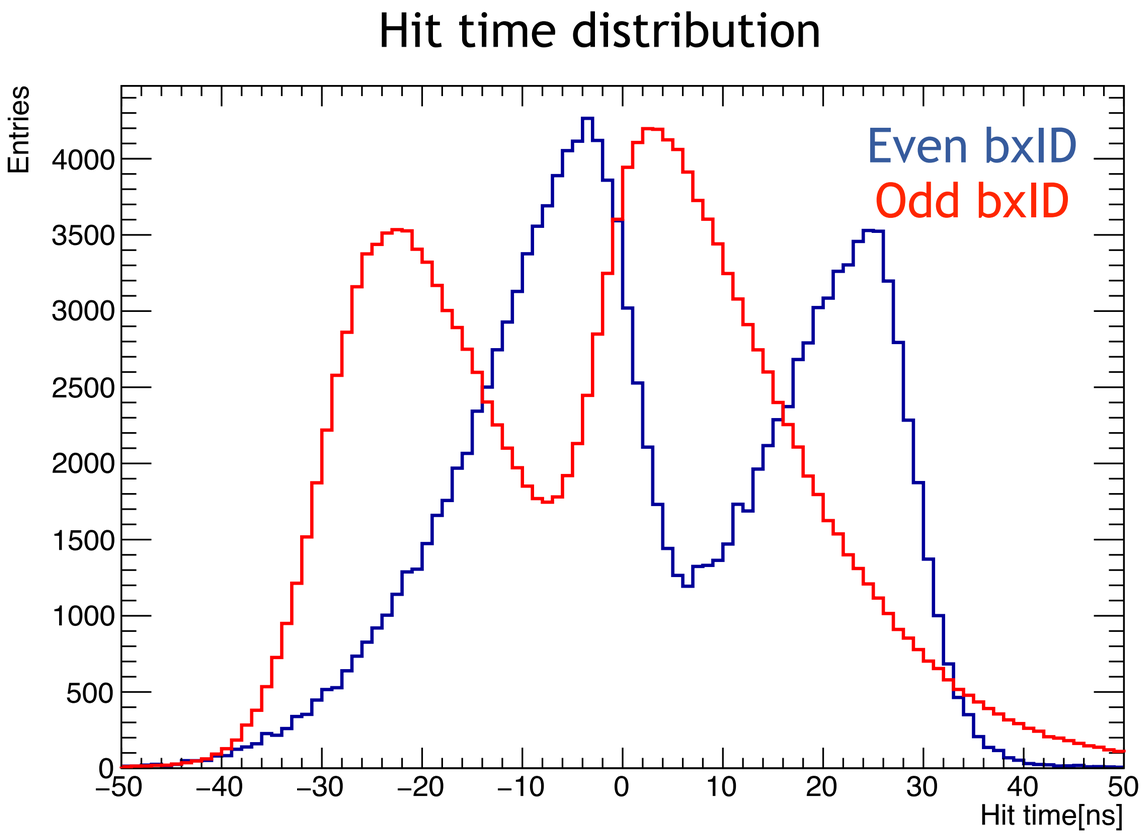
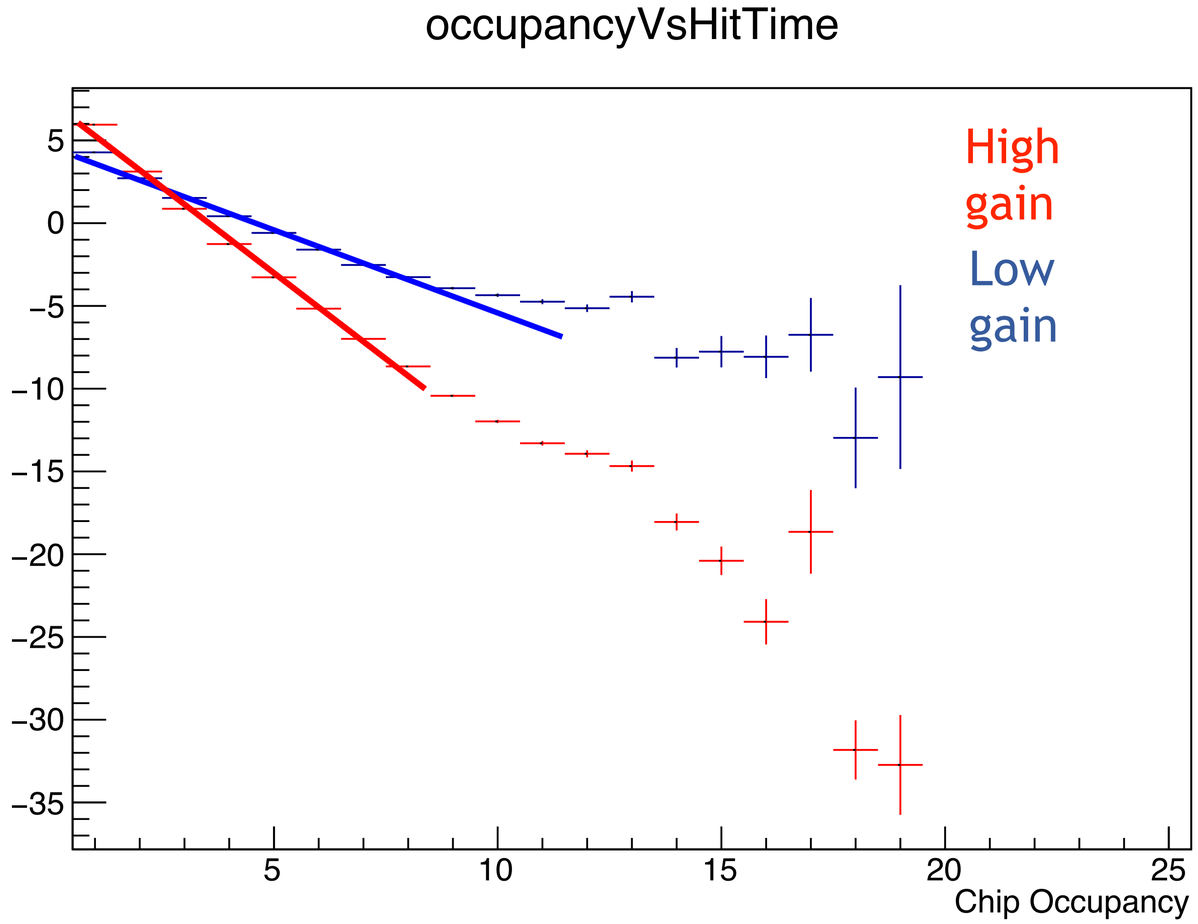


Occupancy



Low gain



High gain

Occupancy Correction