Timing Calibration of the CALICE AHCAL Prototype

Lorenz Emberger

Tokyo Analysis Workshop
August 2018

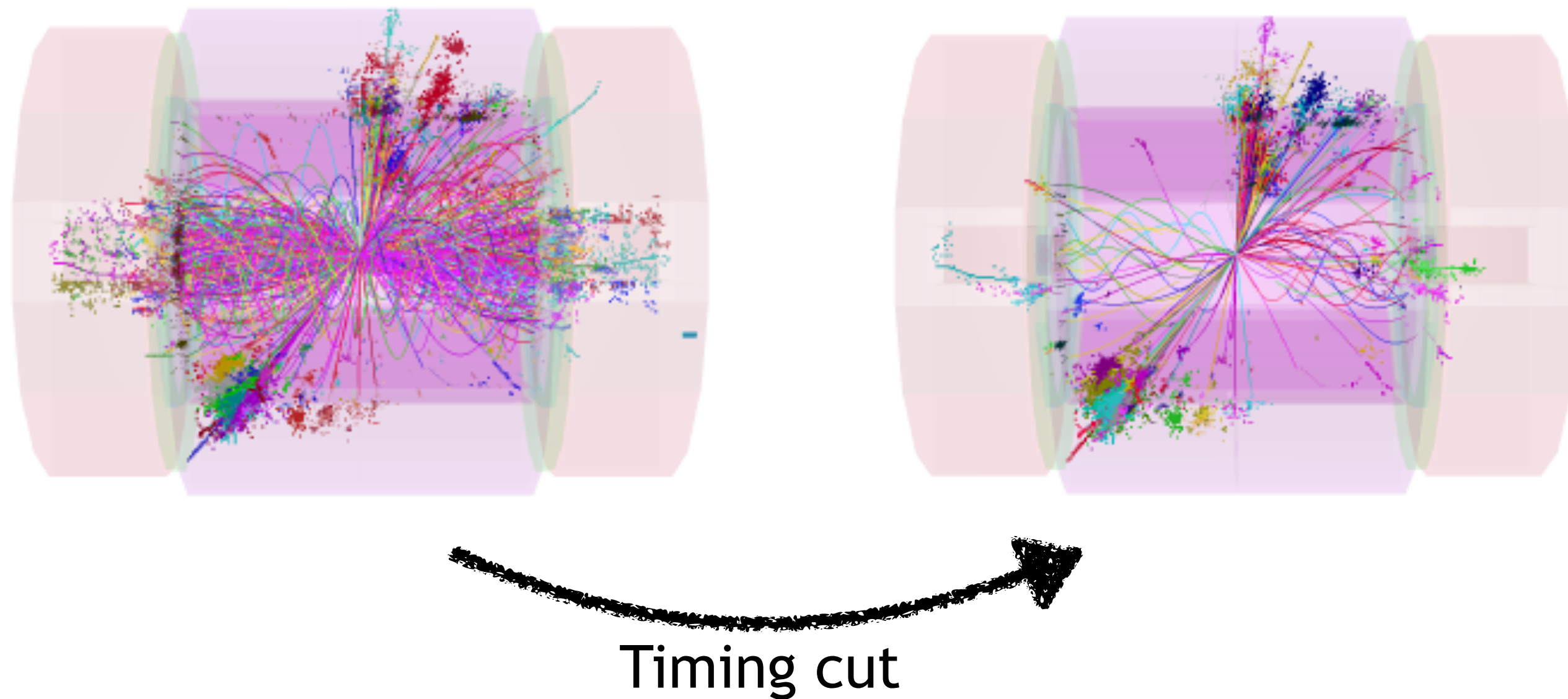Showing work from Christian Graf

Motivation

Why do we need timing?

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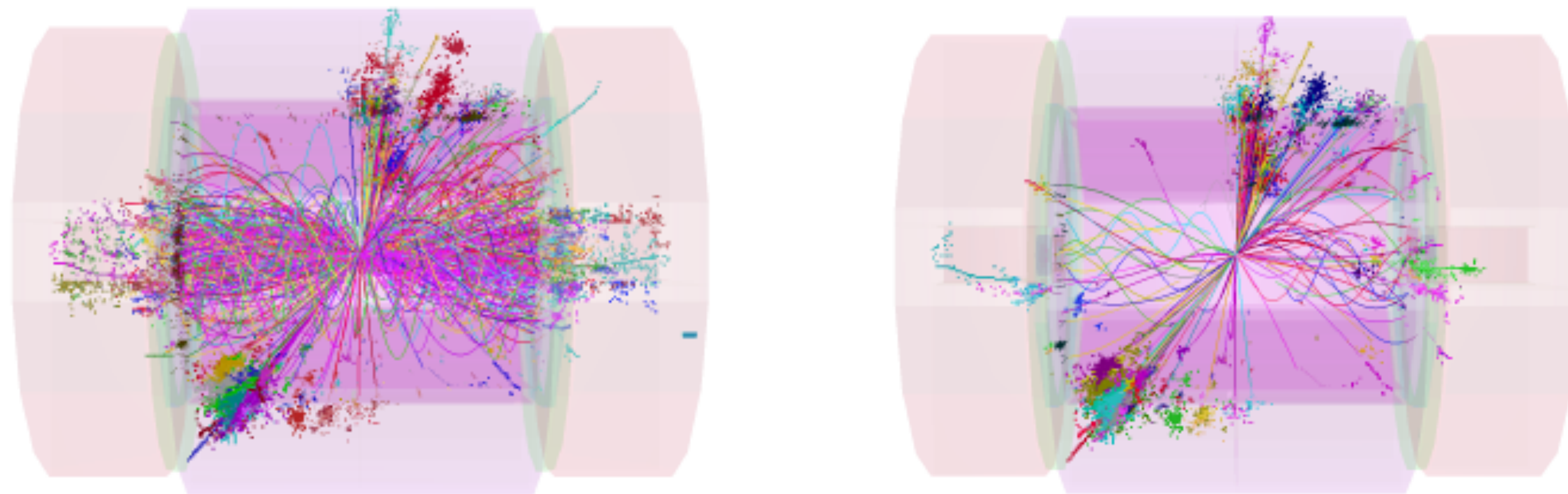
• Reject background

Timing cut

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Why do we need timing?

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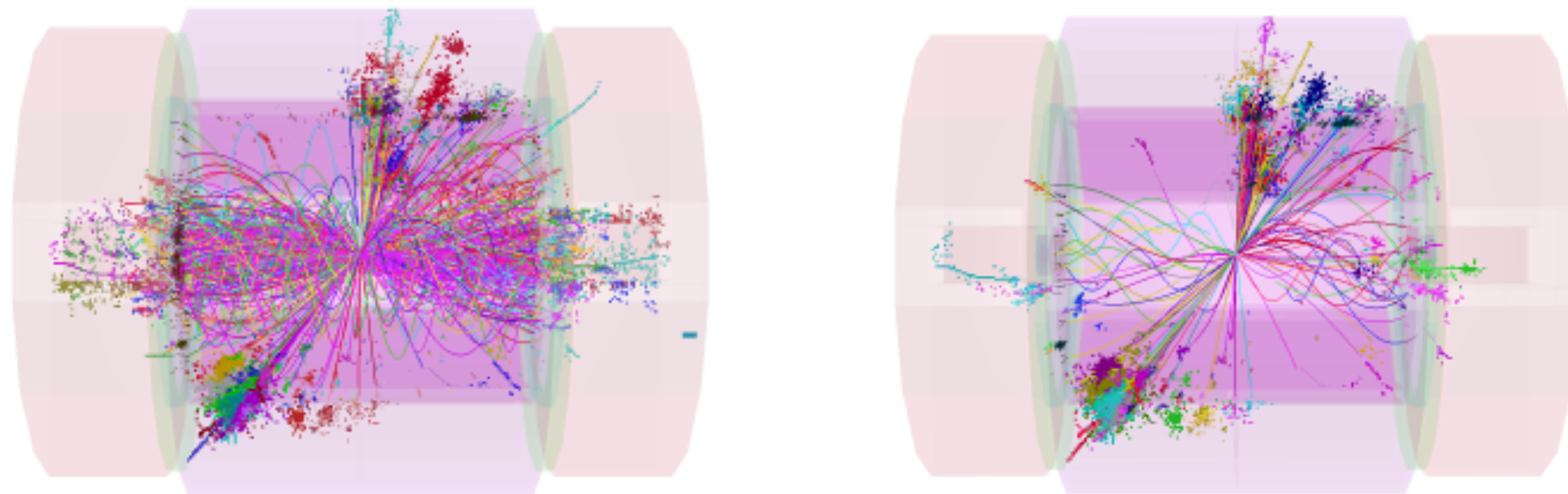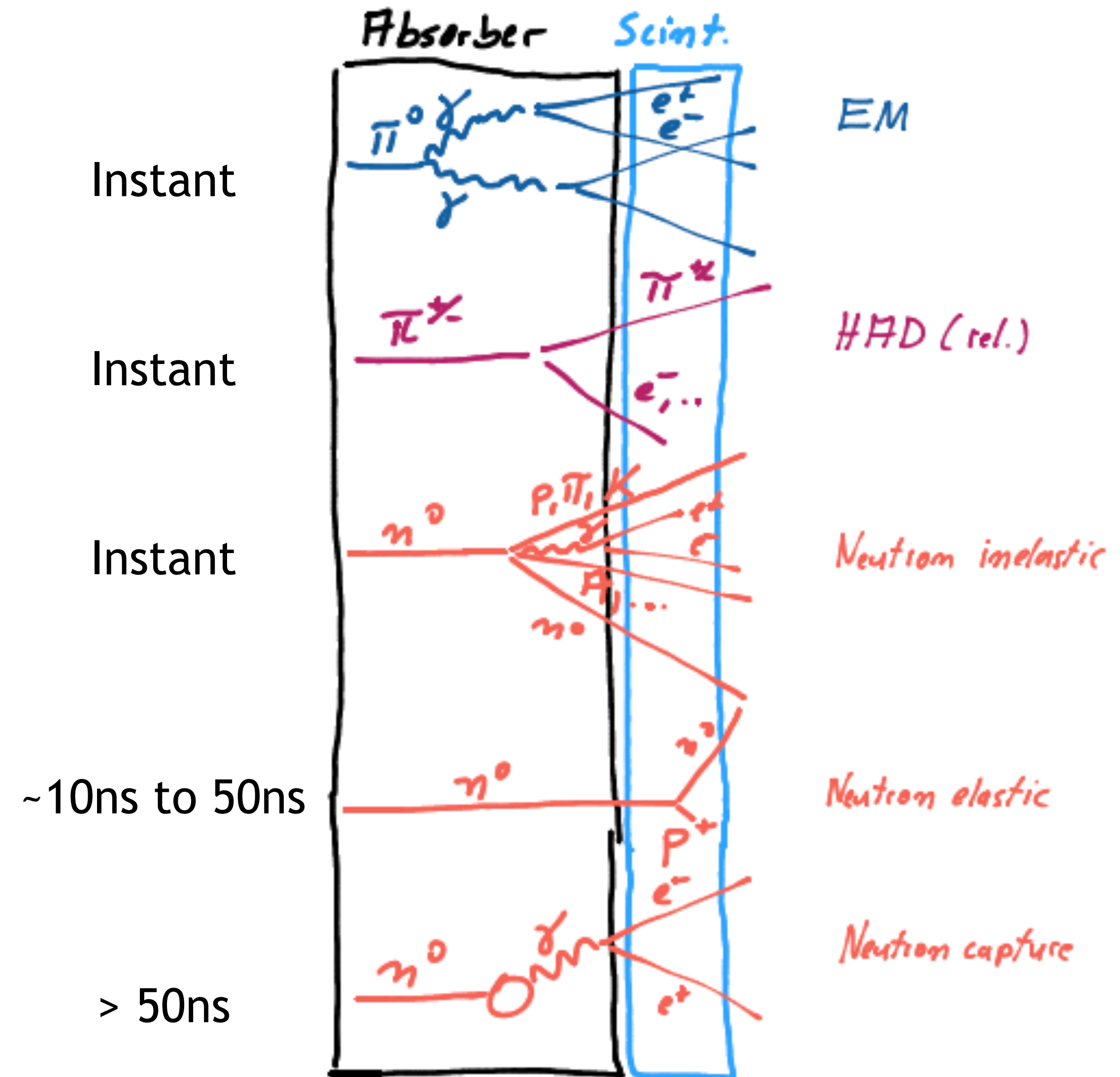
• Aid clustering

Timing cut

Motivation

Why do we need timing?

• Reject background

• Aid clustering

• Use in software compensation to identify components of hadronic showers

Timing cut

Instant

Instant

Instant

~10ns to 50ns

> 50ns

Absorber   Scint.

EM

HAD (rel.)

Neutron inelastic
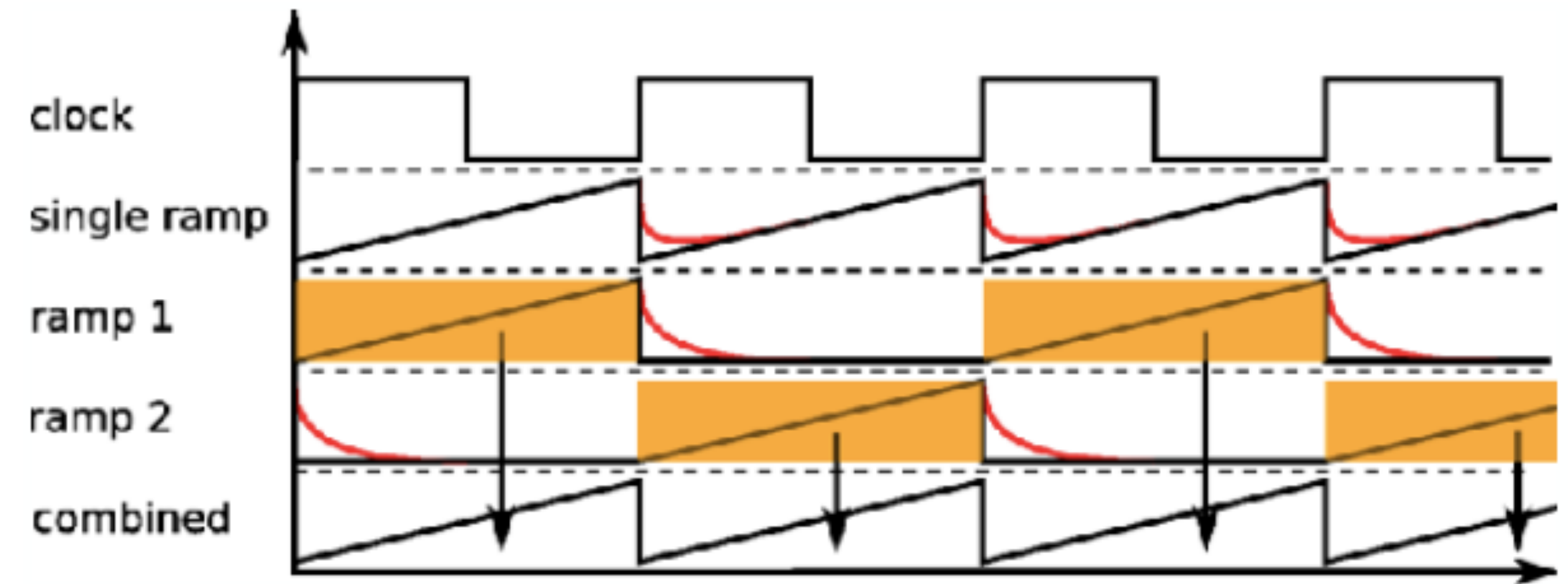
Neutron elastic

Neutron capture

Timing: Hardware

Timing unit on Spiroc2E: TDC

1. BIF gives time reference (BxID)

Timing: Hardware

Timing unit on Spiroc2E: <u>TDC</u>

1. BIF gives time reference (BxID)

2. Ramp up voltage for maximum 3920ns
   ‣ Slope for even and odd BxID

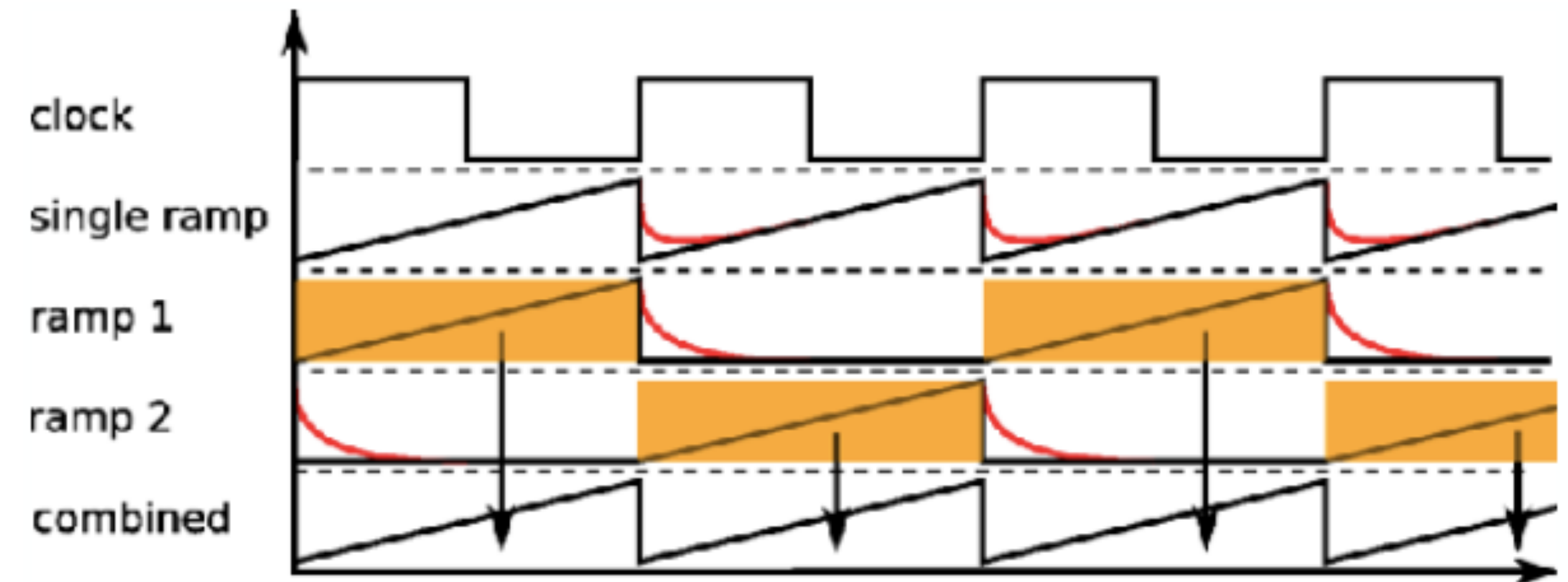# Timing: Hardware

Timing unit on Spiroc2E: <u>TDC</u>

1. BIF gives time reference (BxID)

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   ‣ Slope for even and odd BxID

3. On hit, the ramp stops

4. Current voltage is stored in memory cells and digitized by ADC
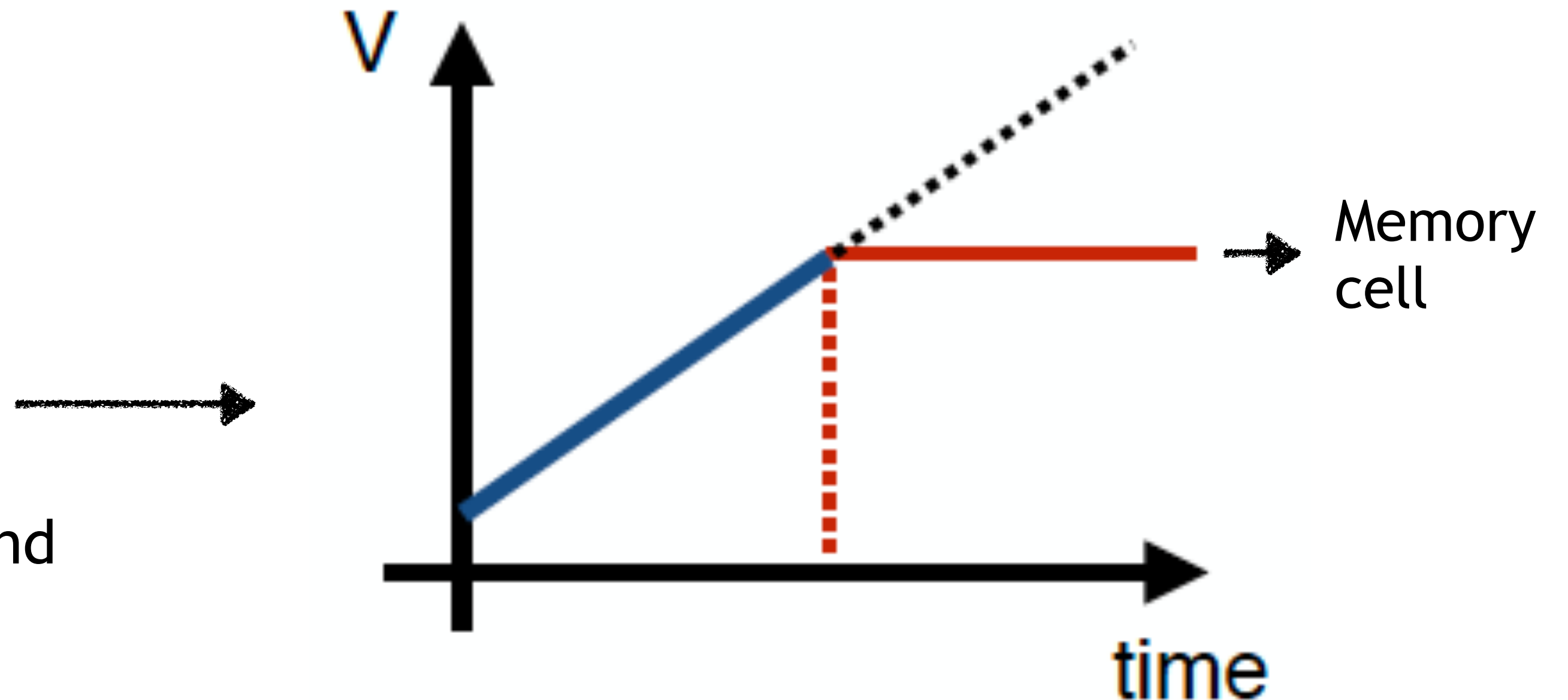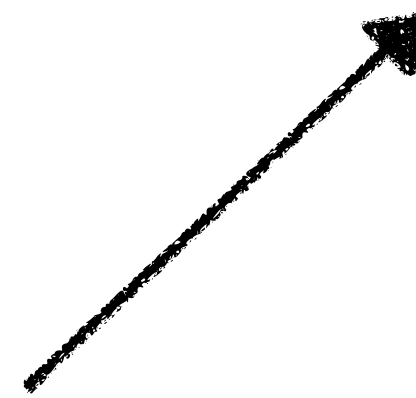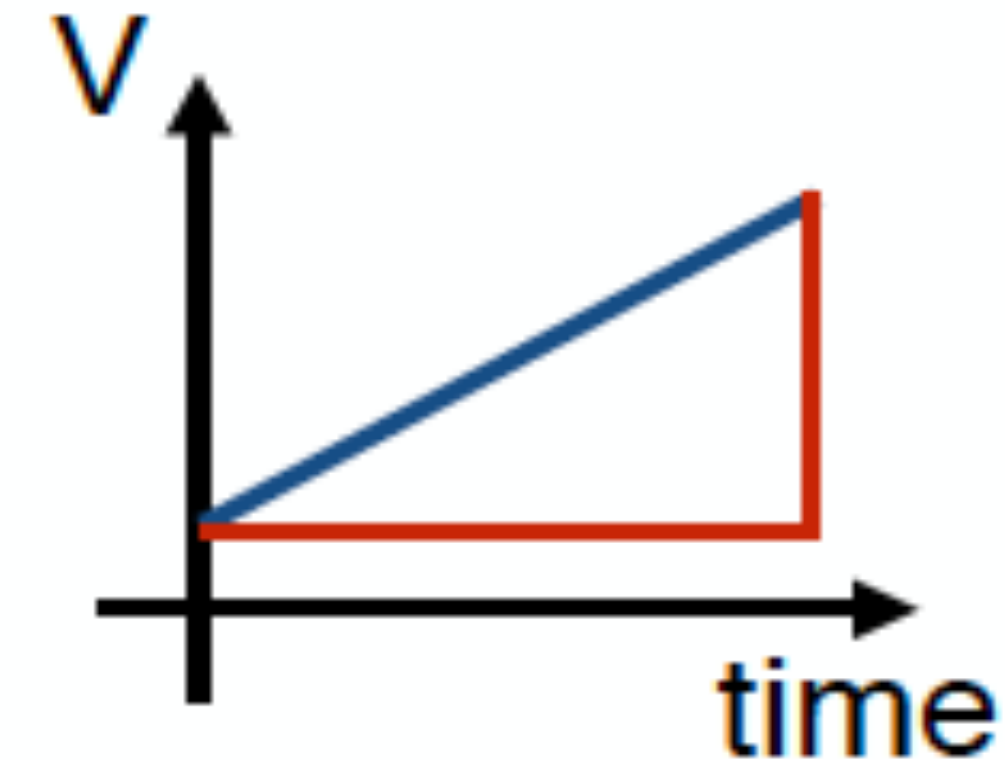
Timing: Hardware

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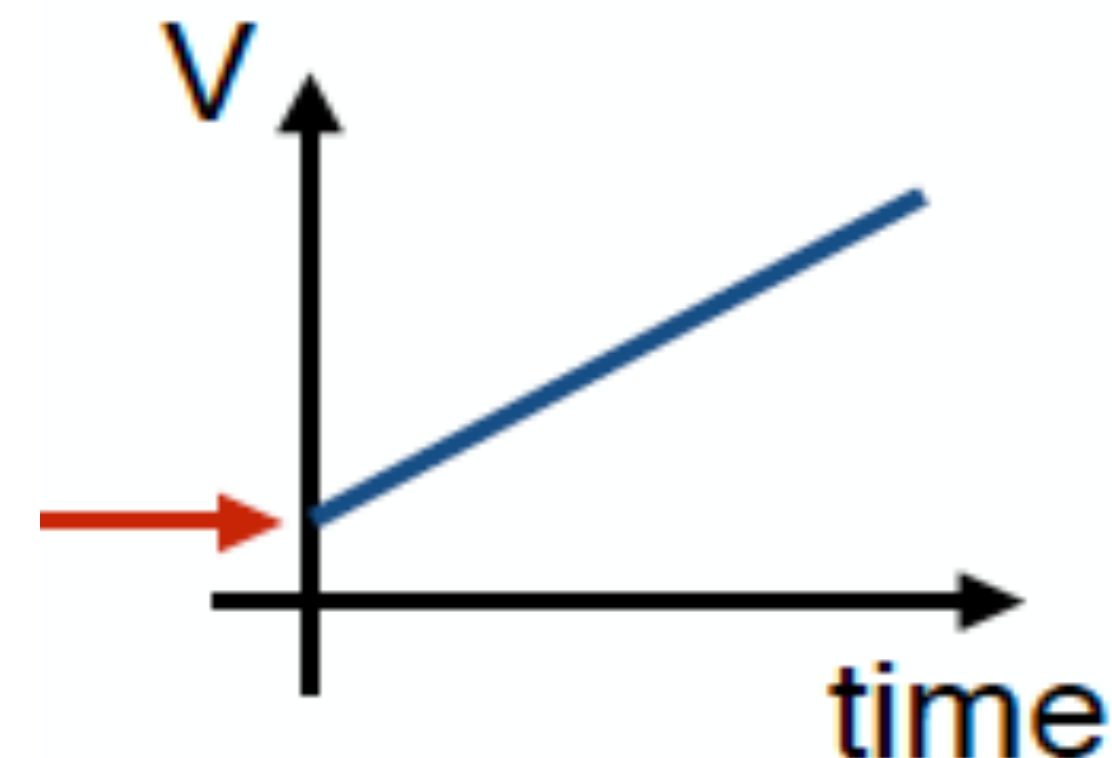5. Resulting TDC value needs to be related to hit time in ns → Calibration

Per chip

Per memory cell

Timing: Calibration

- All memory cells to be calibrated against BIF clock (T0)
- Calibration needs to achieve permill precision to achieve sub-ns time resolution→need ~100 hits per memory cell

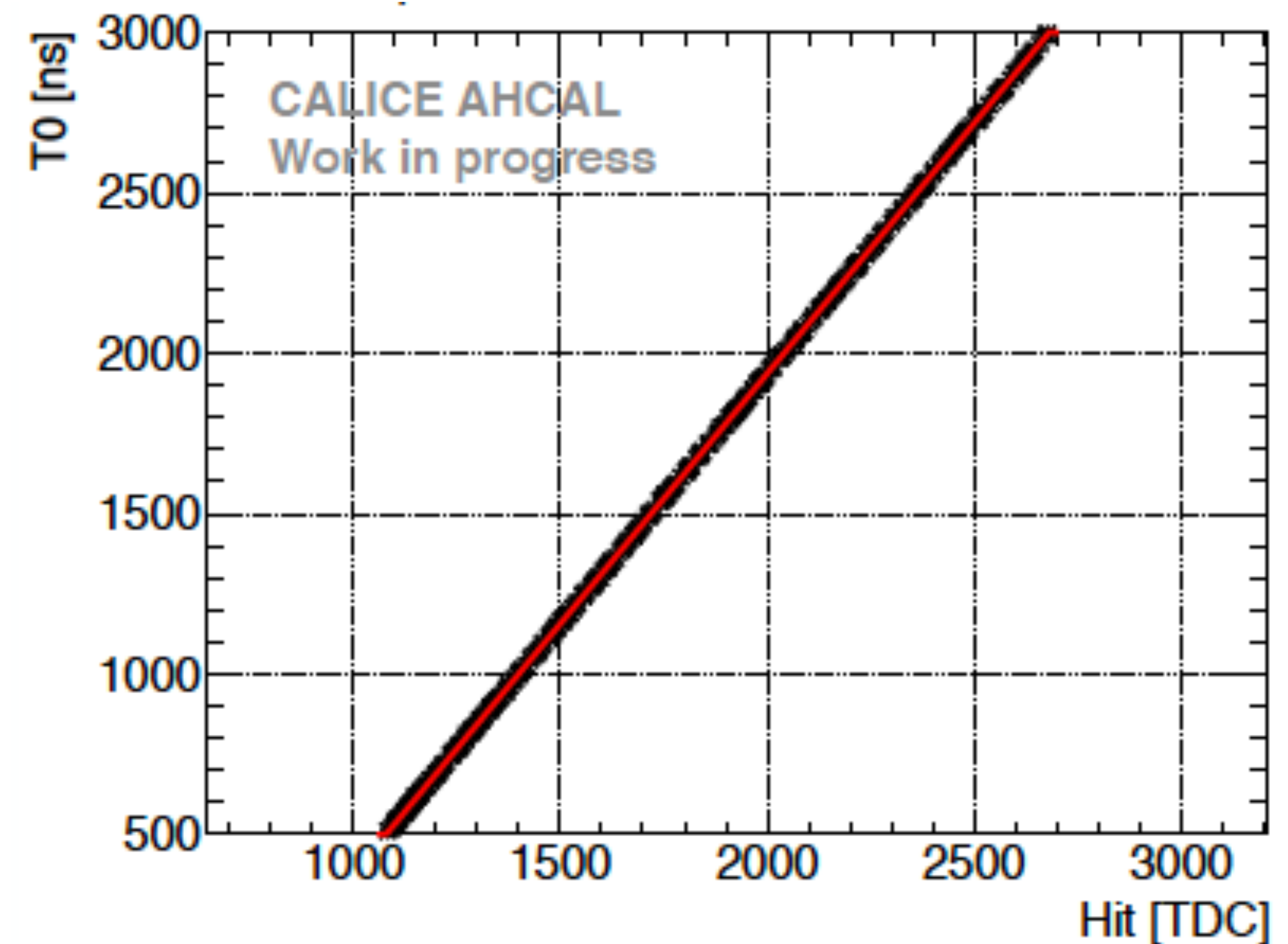calice_calib/calib/Ahc2TimingCalibrator.cpp

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1. Extract slope for even and odd BxID <u>per chip</u>
    1. Perform robust linear fit between 500ns and 3000ns for first memory cell of every channel
    2. Reject every hit which is off by >10ns
    3. Take median of all slopes as common slope for chip

calice_calib/calib/Ahc2TimingCalibrator.cpp

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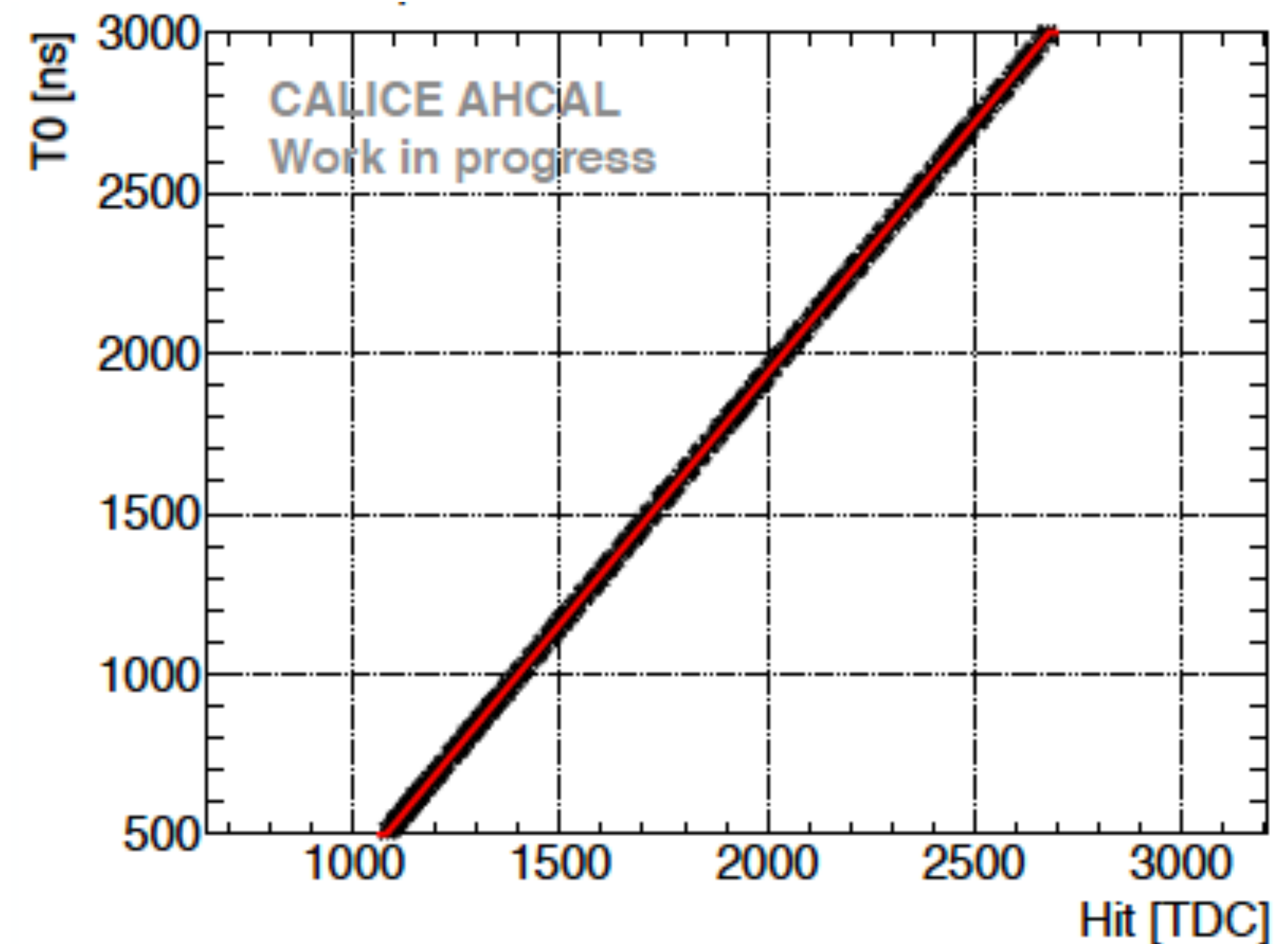
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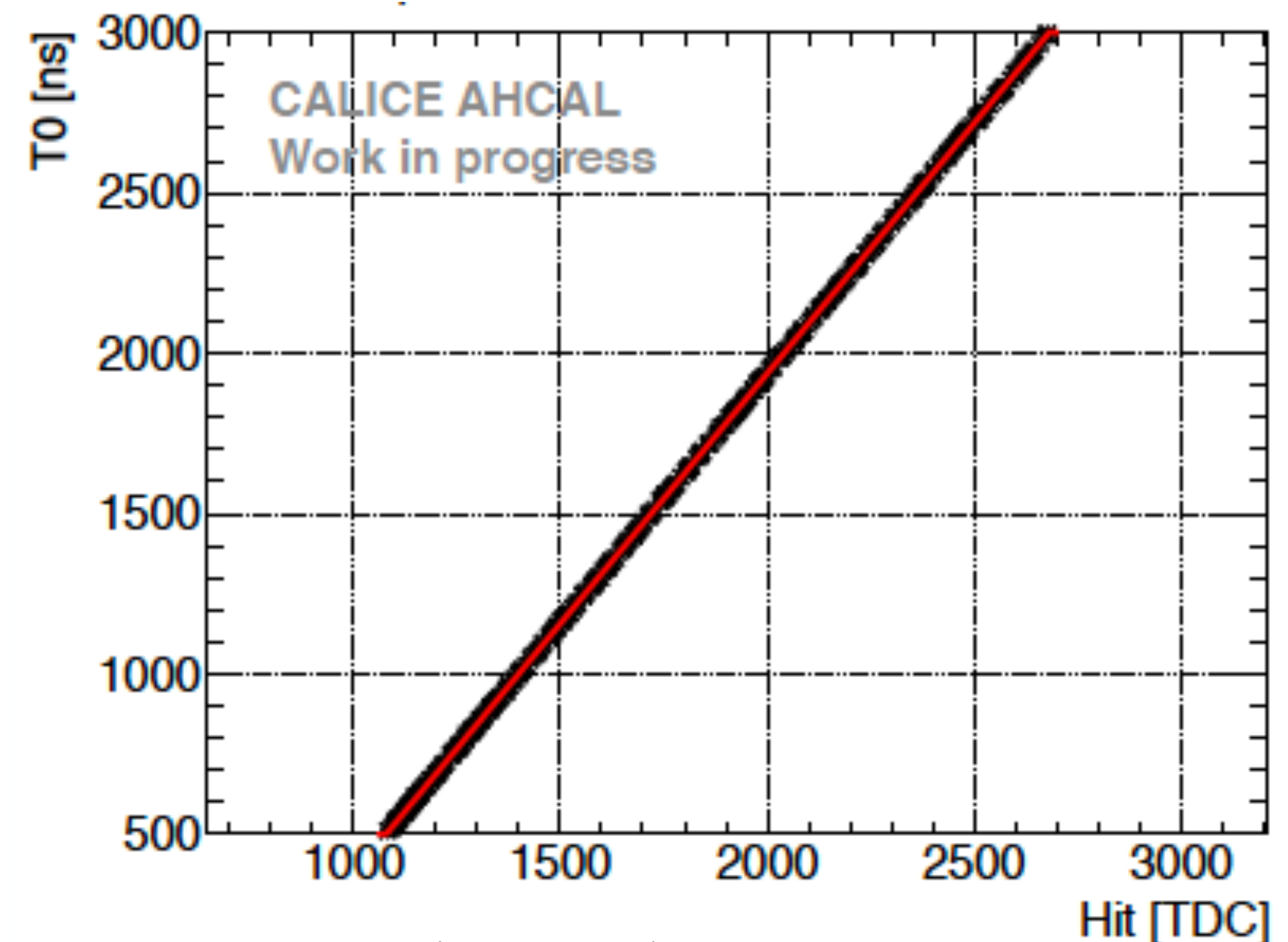
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Not yet on main repository:
- need two additional DB collections
- TimeOffsetMem_Even, TimeOffsetMem_Odd

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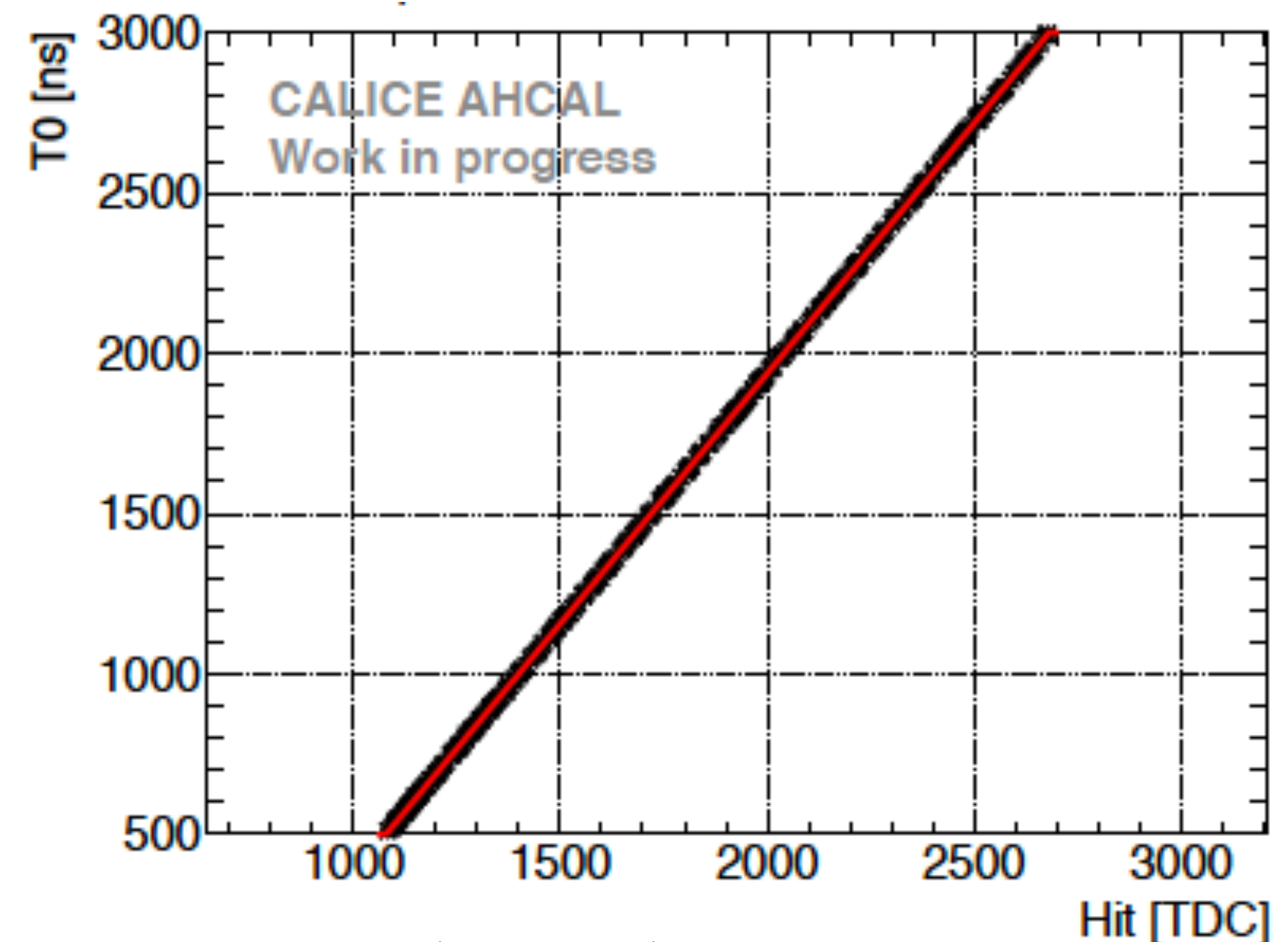   3. Take median of all slopes as common slope for chip

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3. Calculate hit time by

$$t_{hit}[\text{ns}] = \text{TDC}_{hit} \cdot \text{Slope}\left[\frac{\text{ns}}{\text{TDC}}\right] + \text{Offset}\,[\text{ns}] - T_0$$
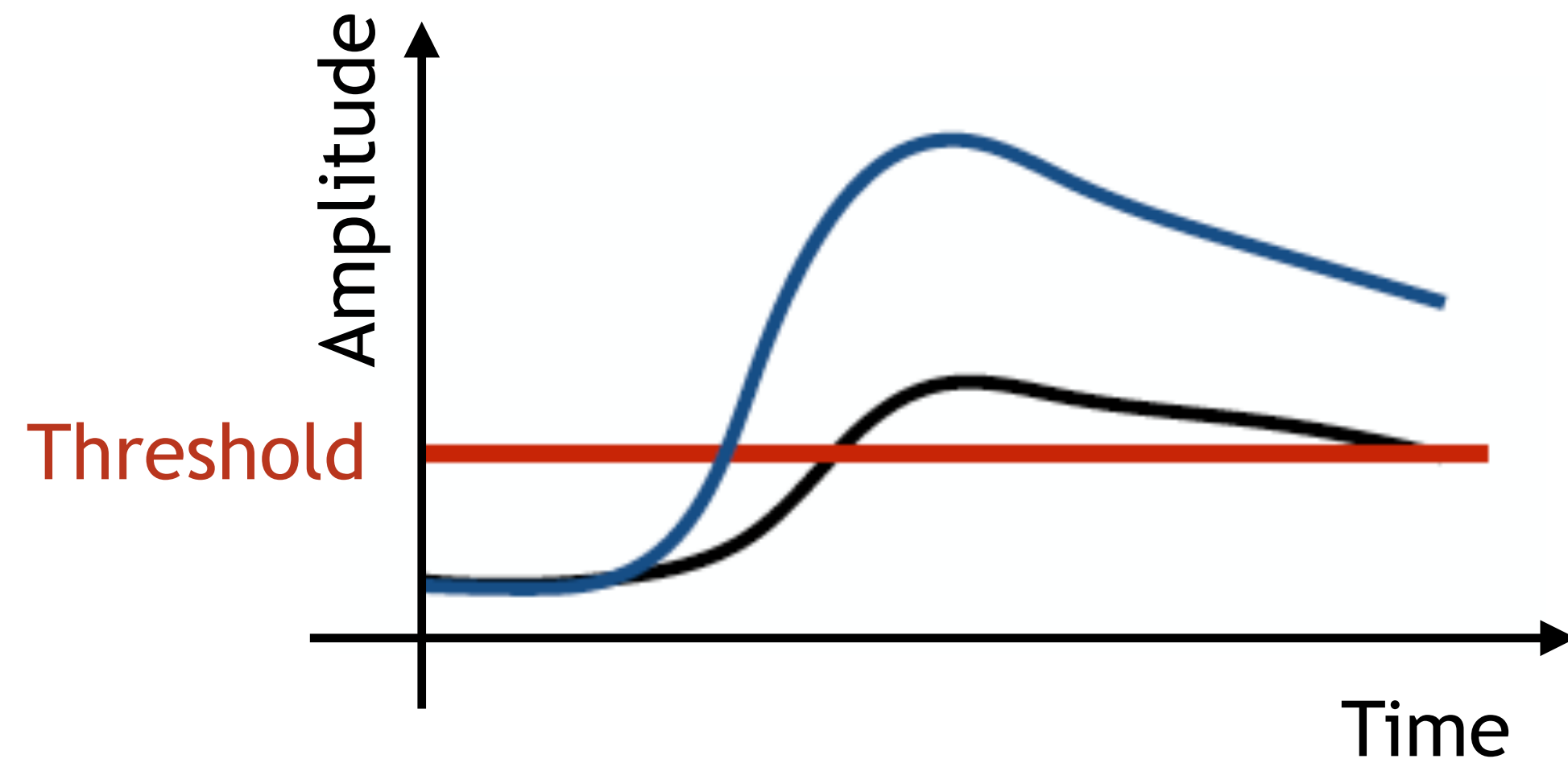
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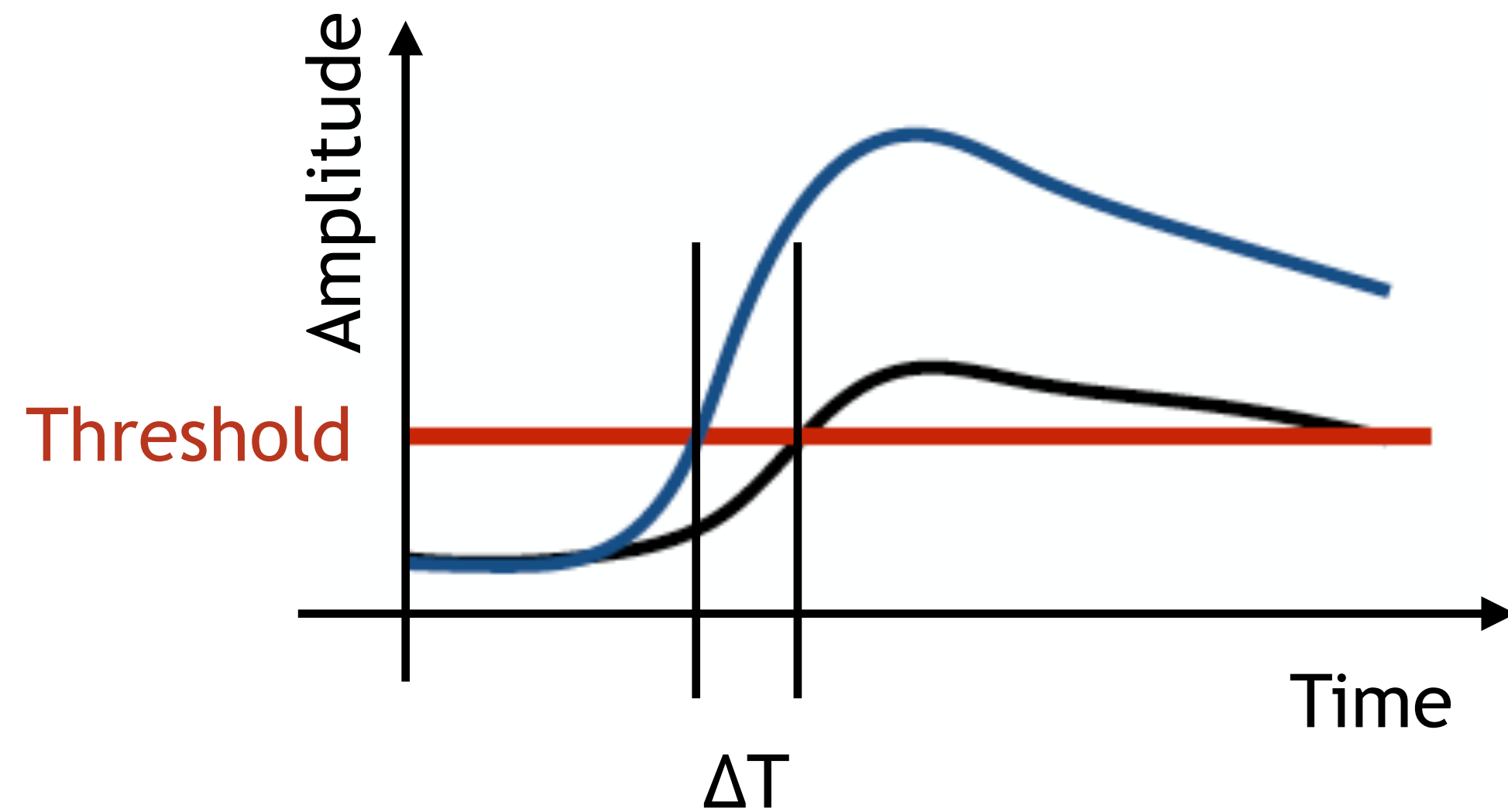
Additional Corrections - To Do's

Time walk correction
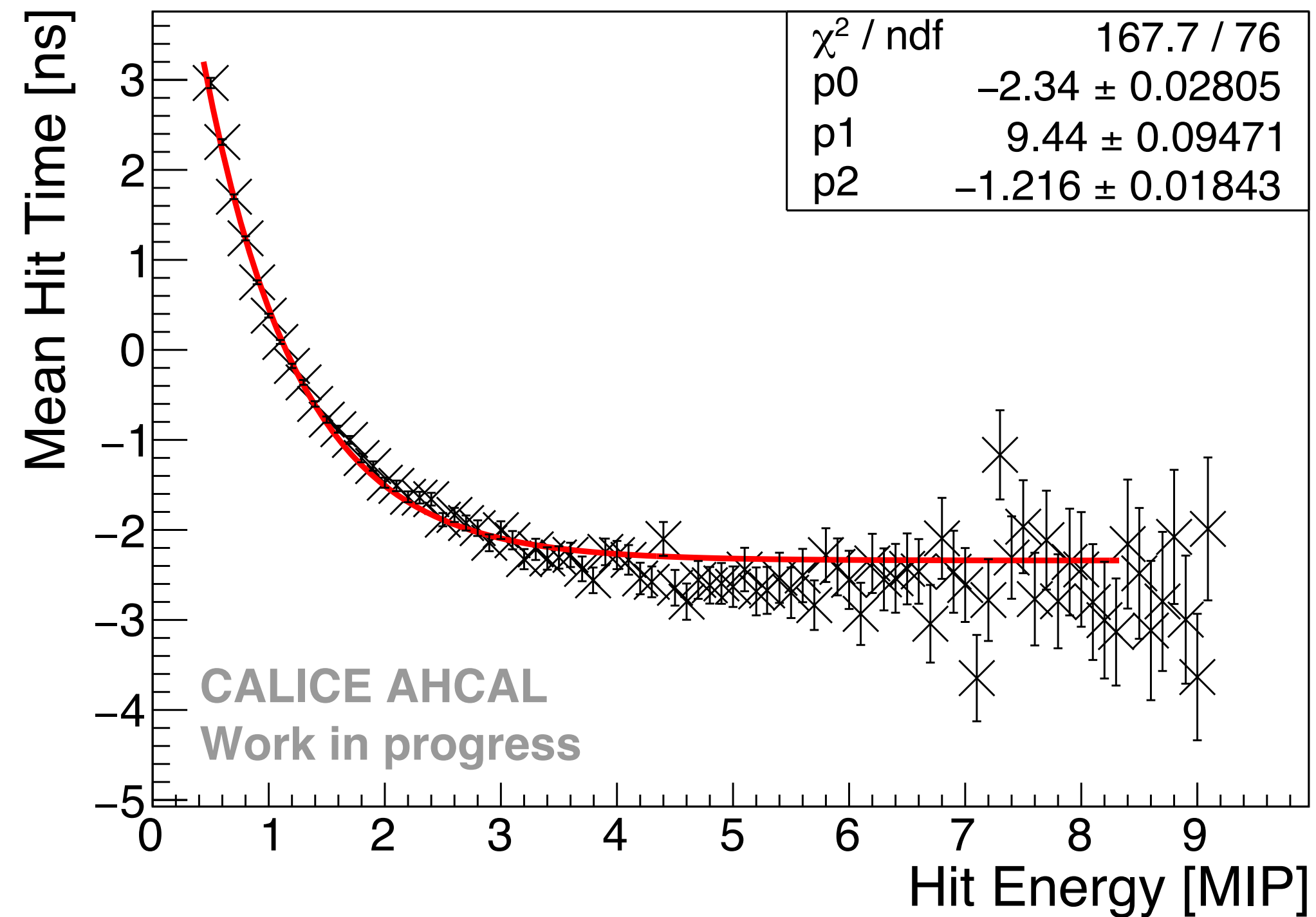
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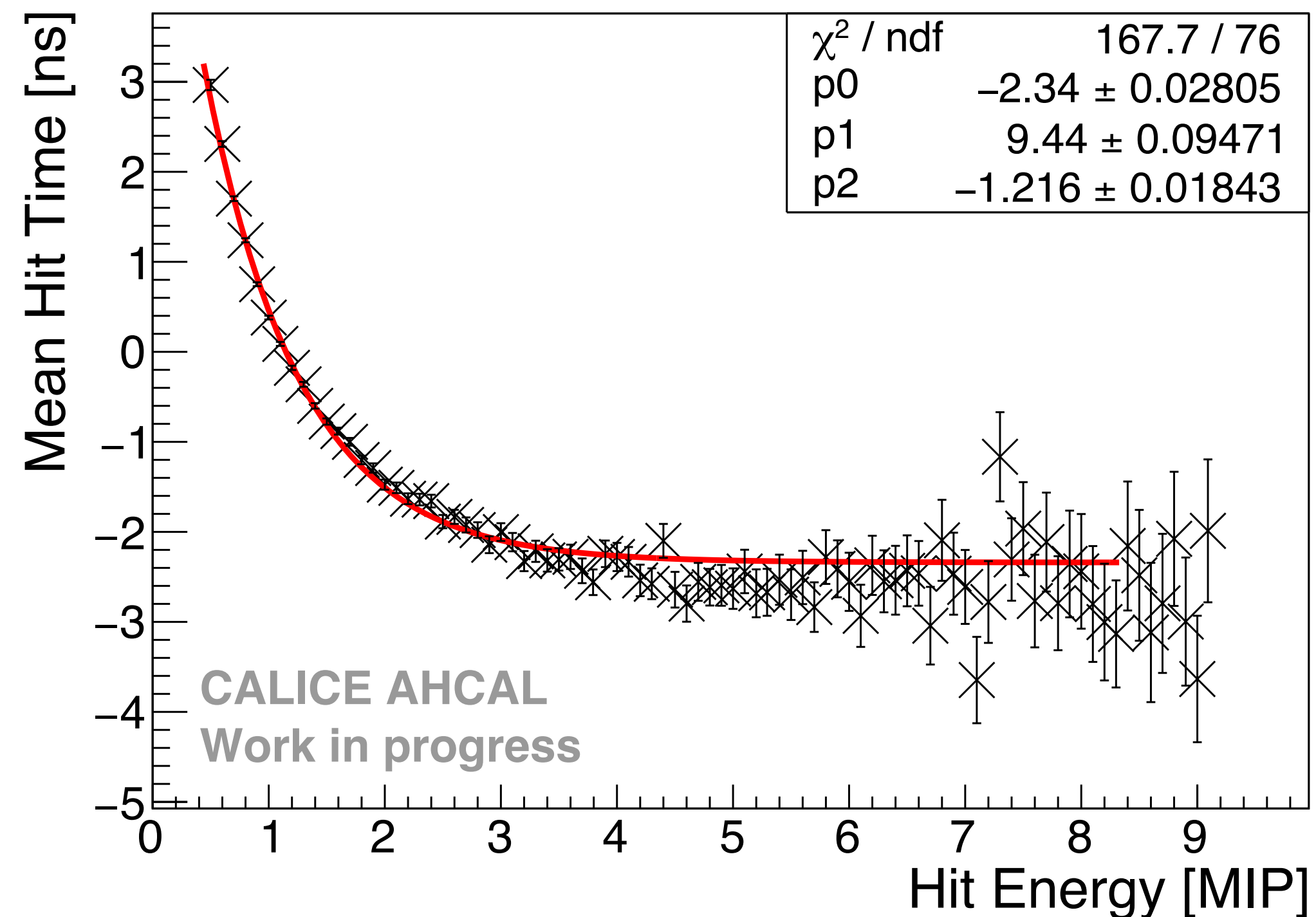
Time walk correction

Add Database entries for correction factors
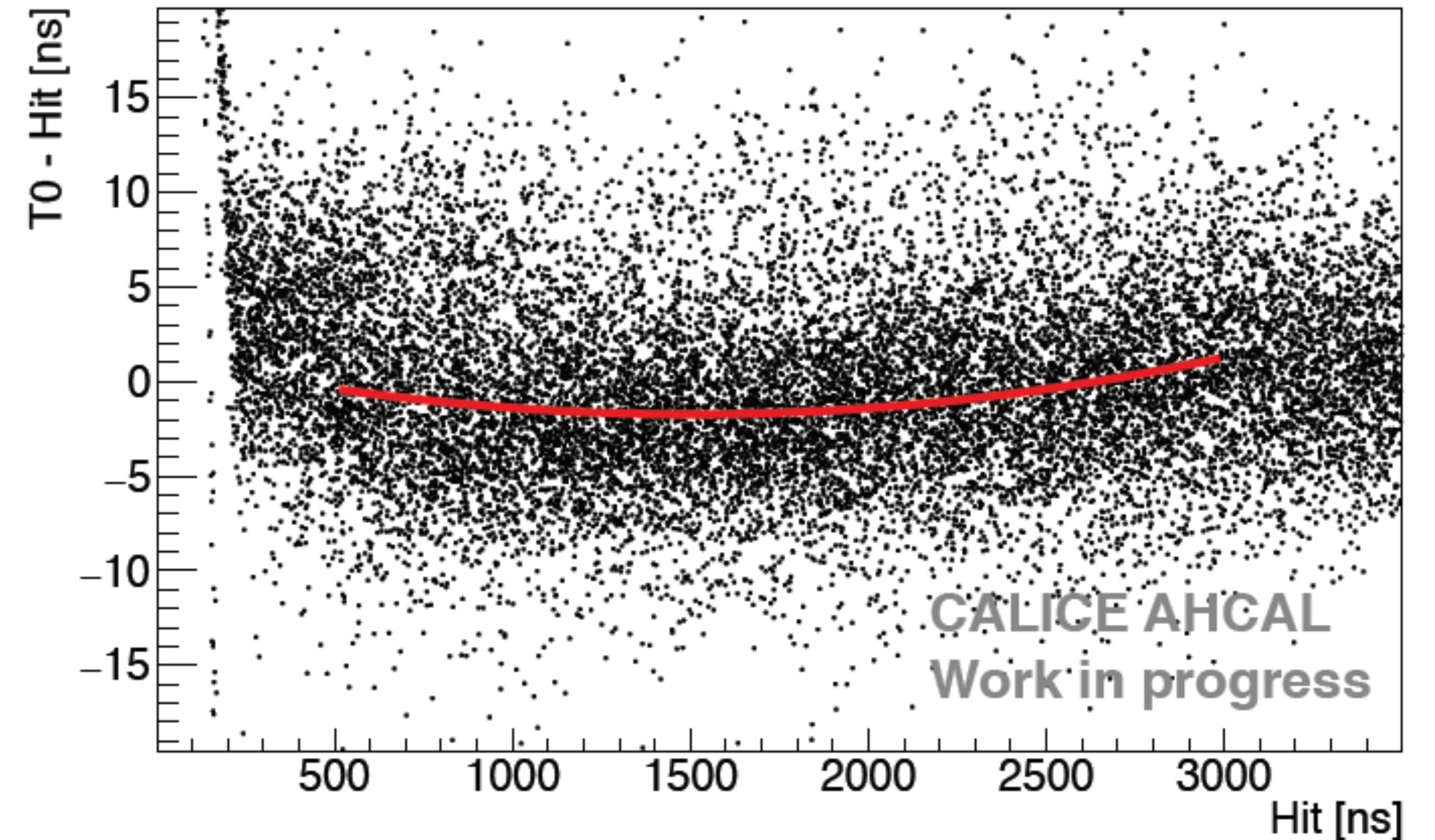
Additional Corrections - To Do's

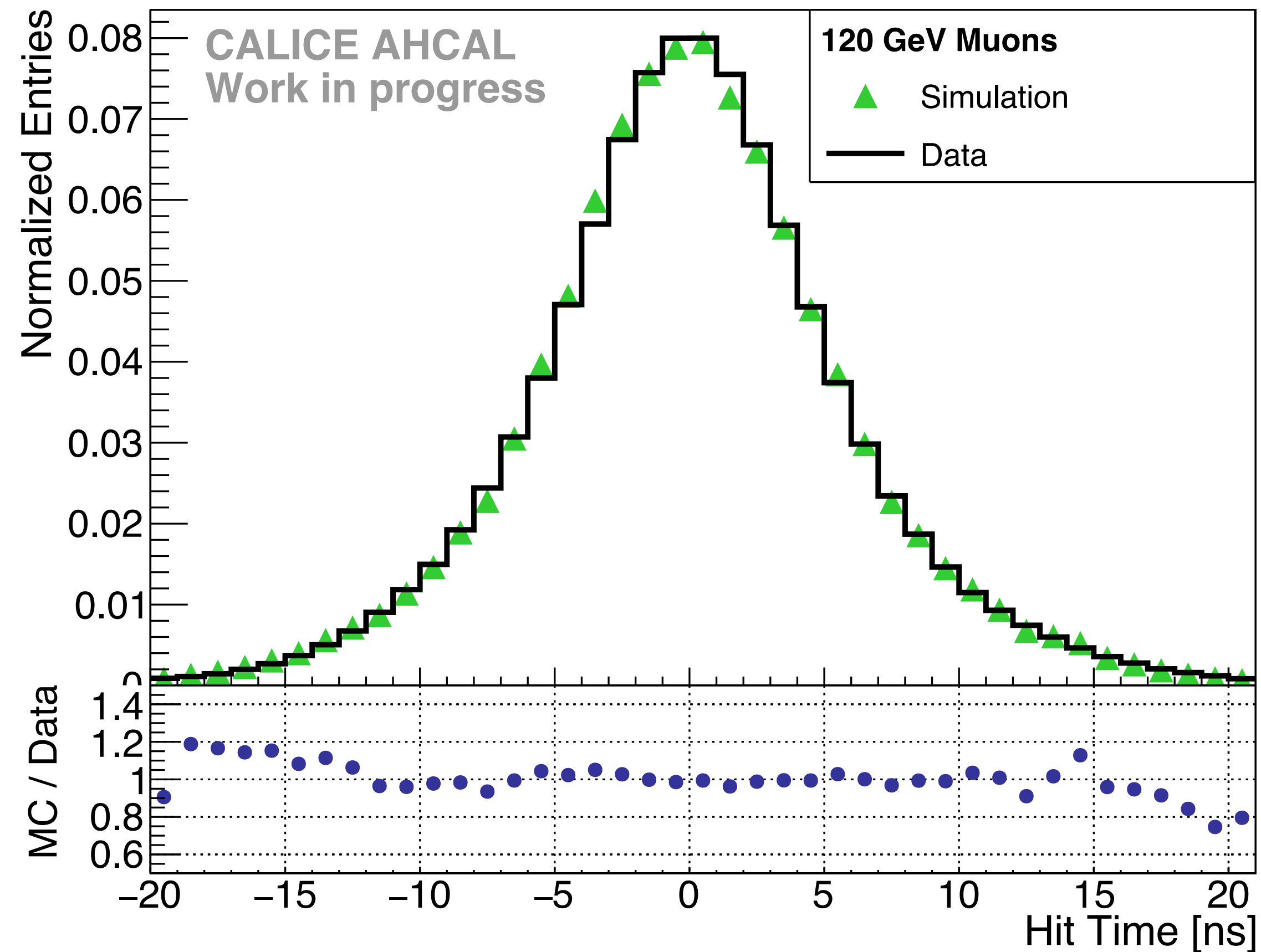Time walk correction

Non-linearity correction

Add Database entries for correction factors

Time Resolution - T0 vs BIF

Time resolution given by the distribution of residuals of the linear fit
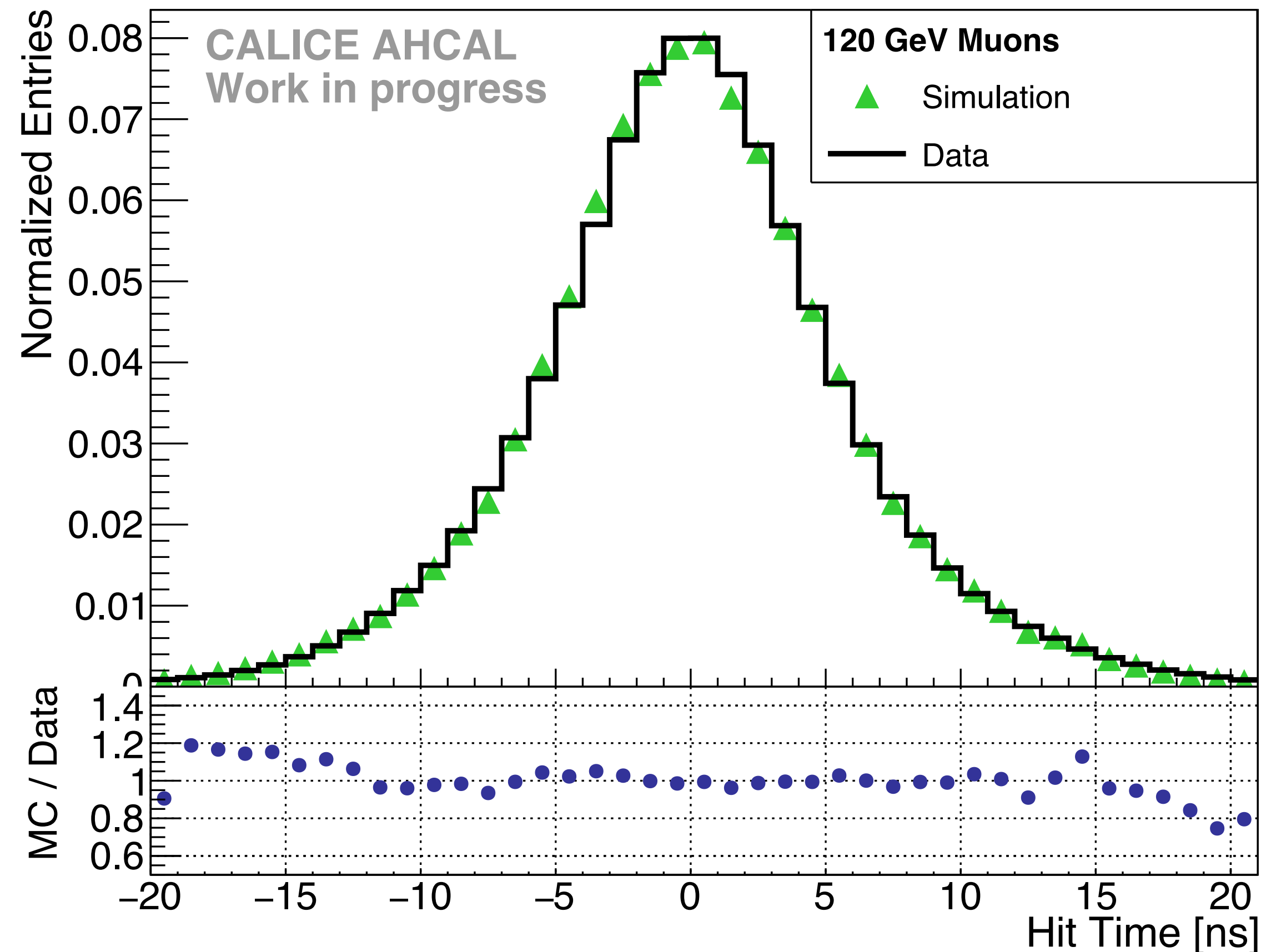

2015 August - T0 Channels
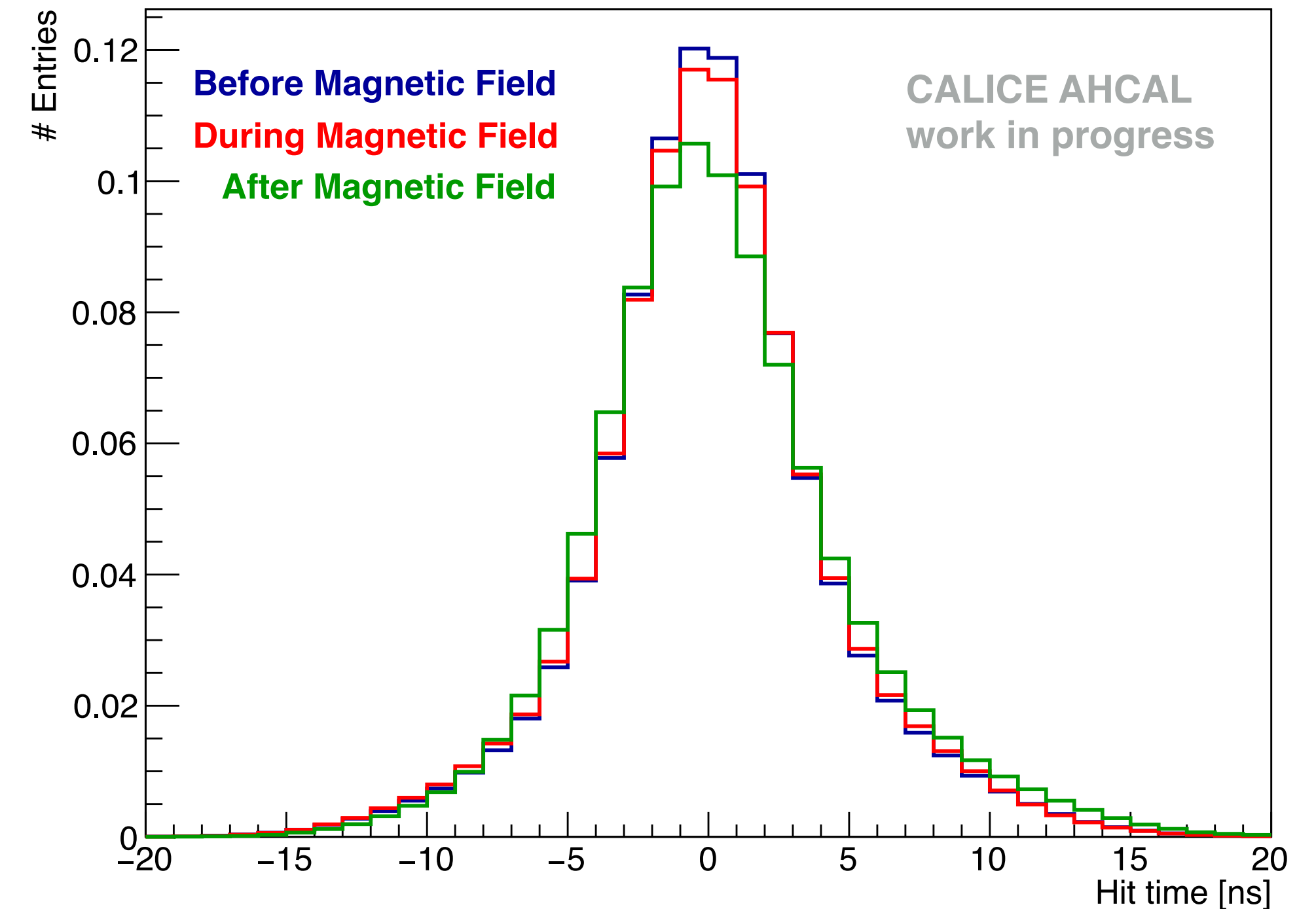
Time Resolution - T0 vs BIF

Time resolution given by the distribution of residuals of the linear fit
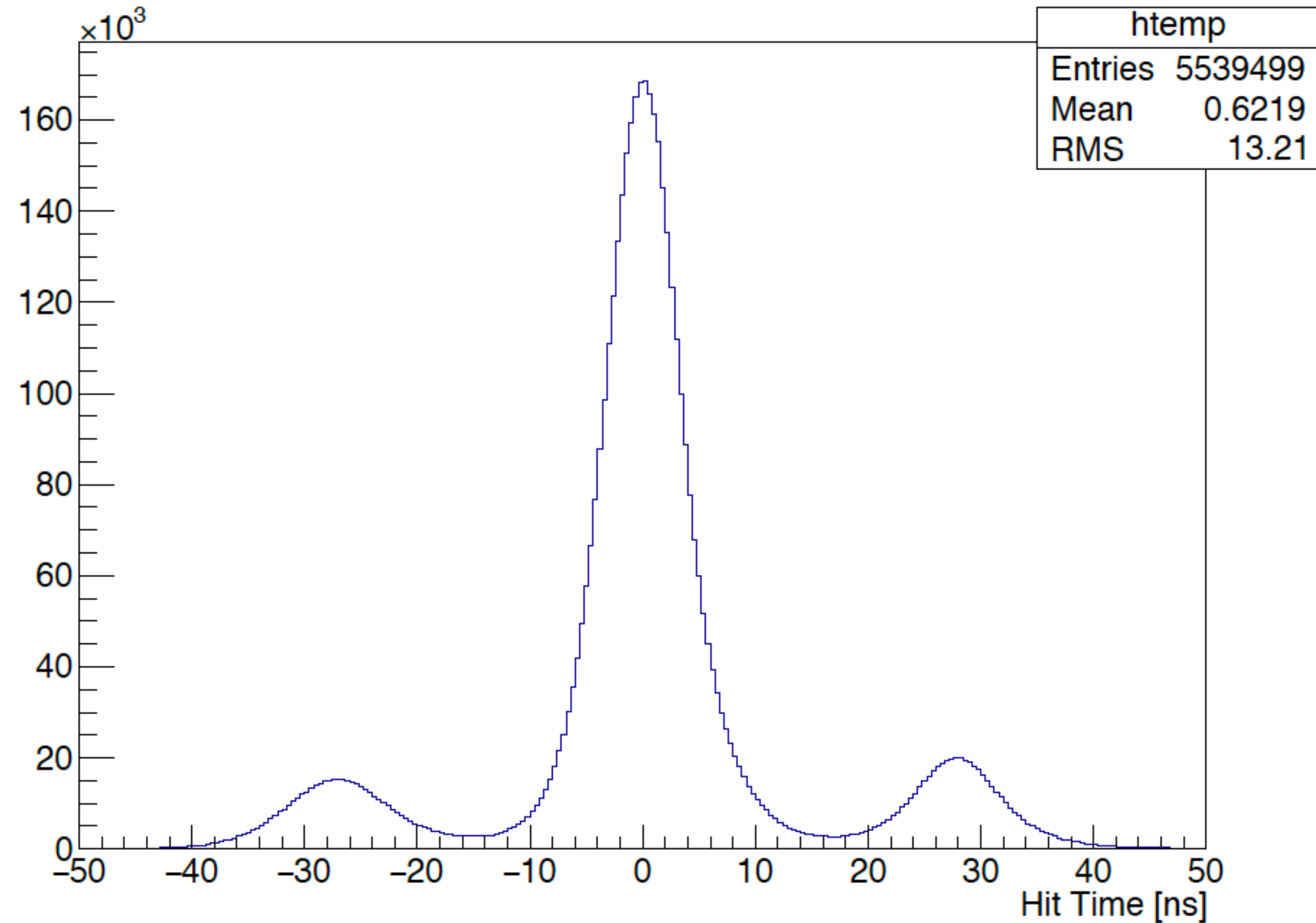

2015 August - T0 Channels

2017 May - BIF Clock

Relative to BIF time: **5ns (FWHM), 4.3ns (RMS)**
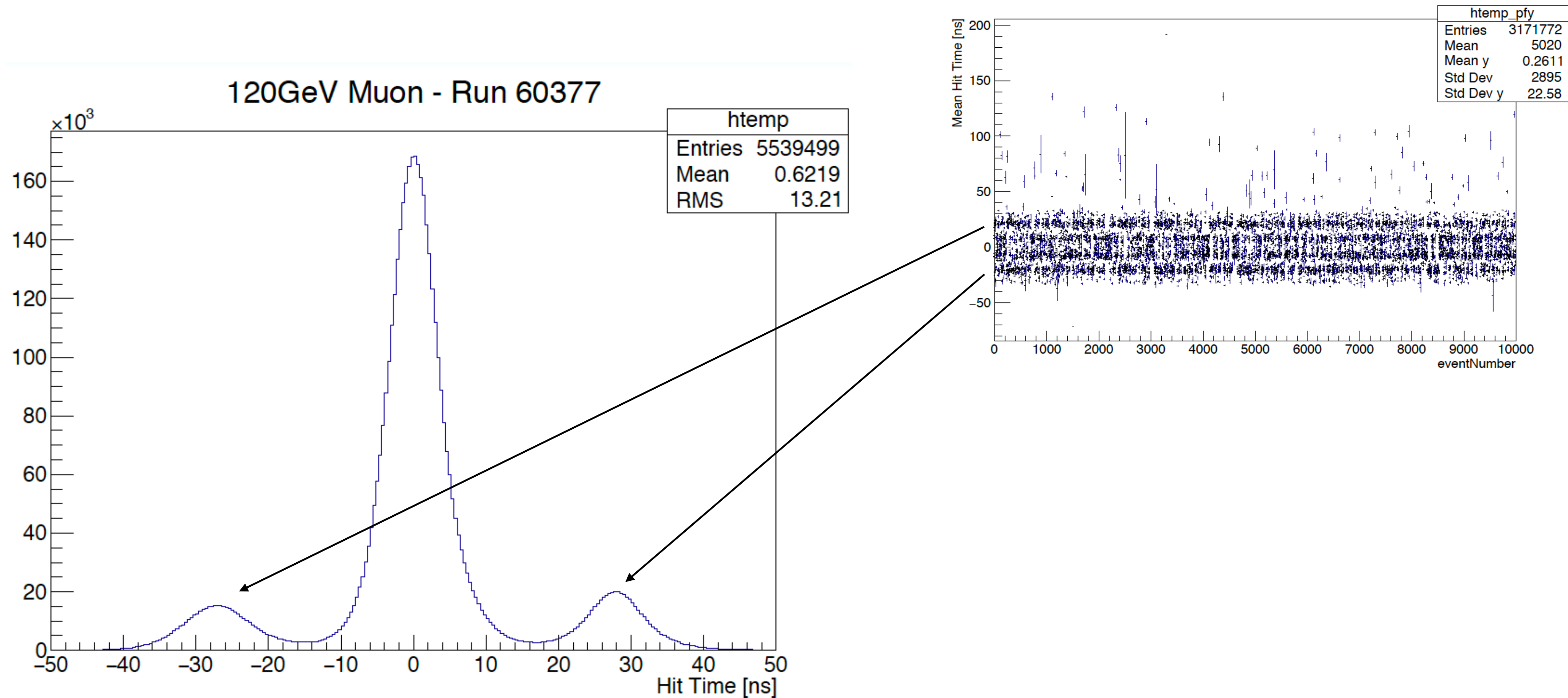
—> **Better muon time resolution with BIF**

Muon Time Resolution - May 2018
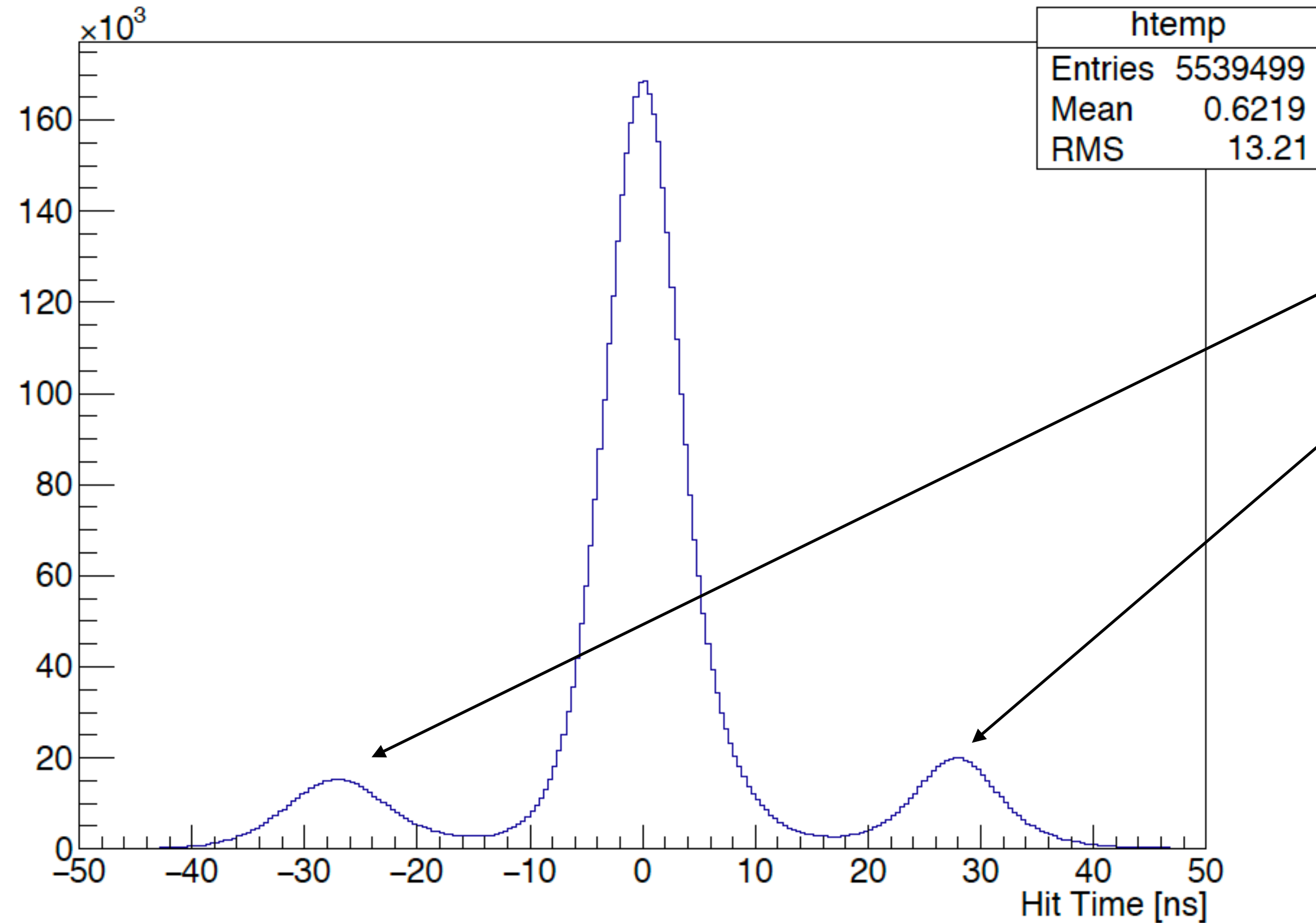
Muon Time Resolution - May 2018

Shoulders increase with increasing rates

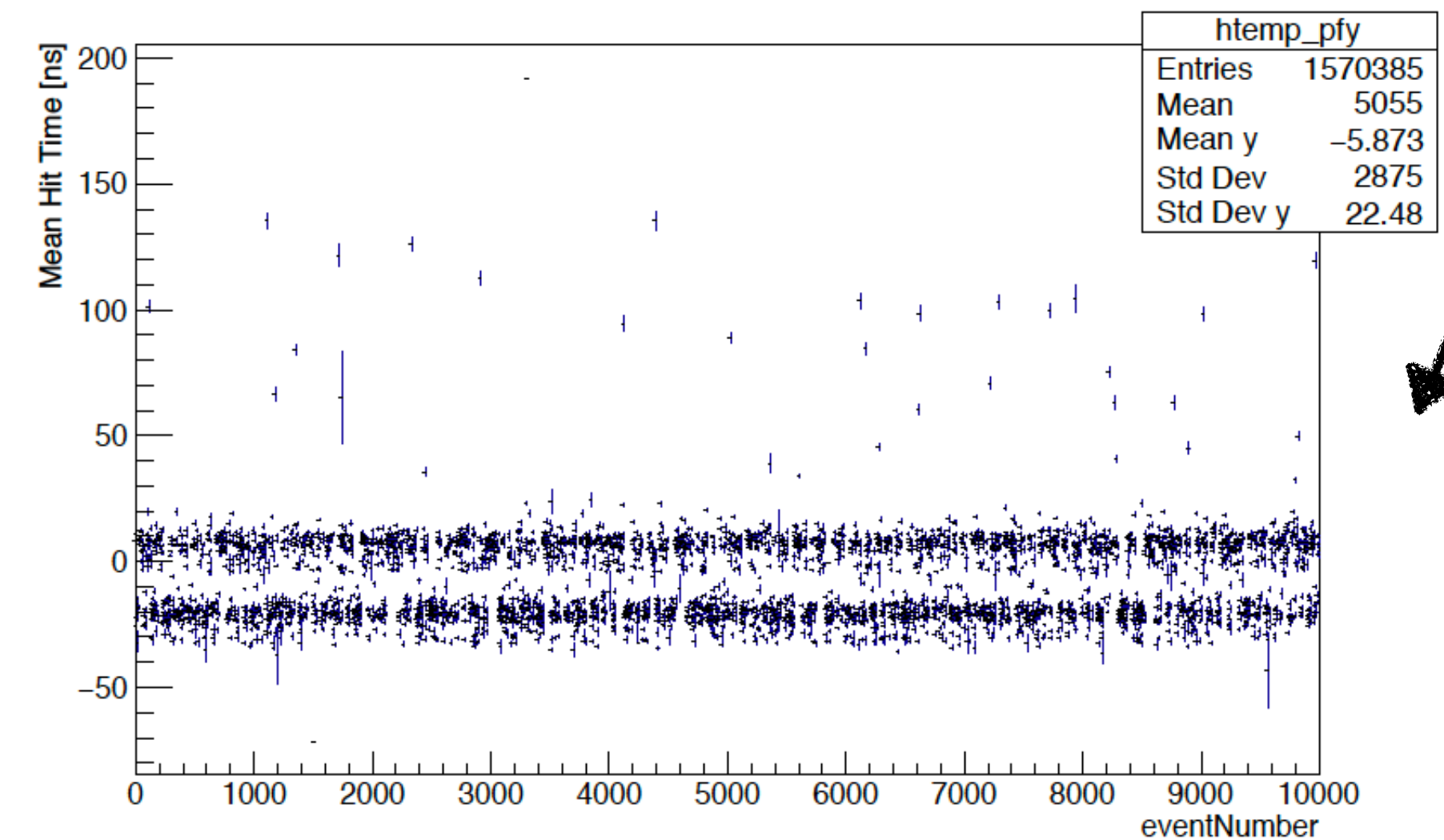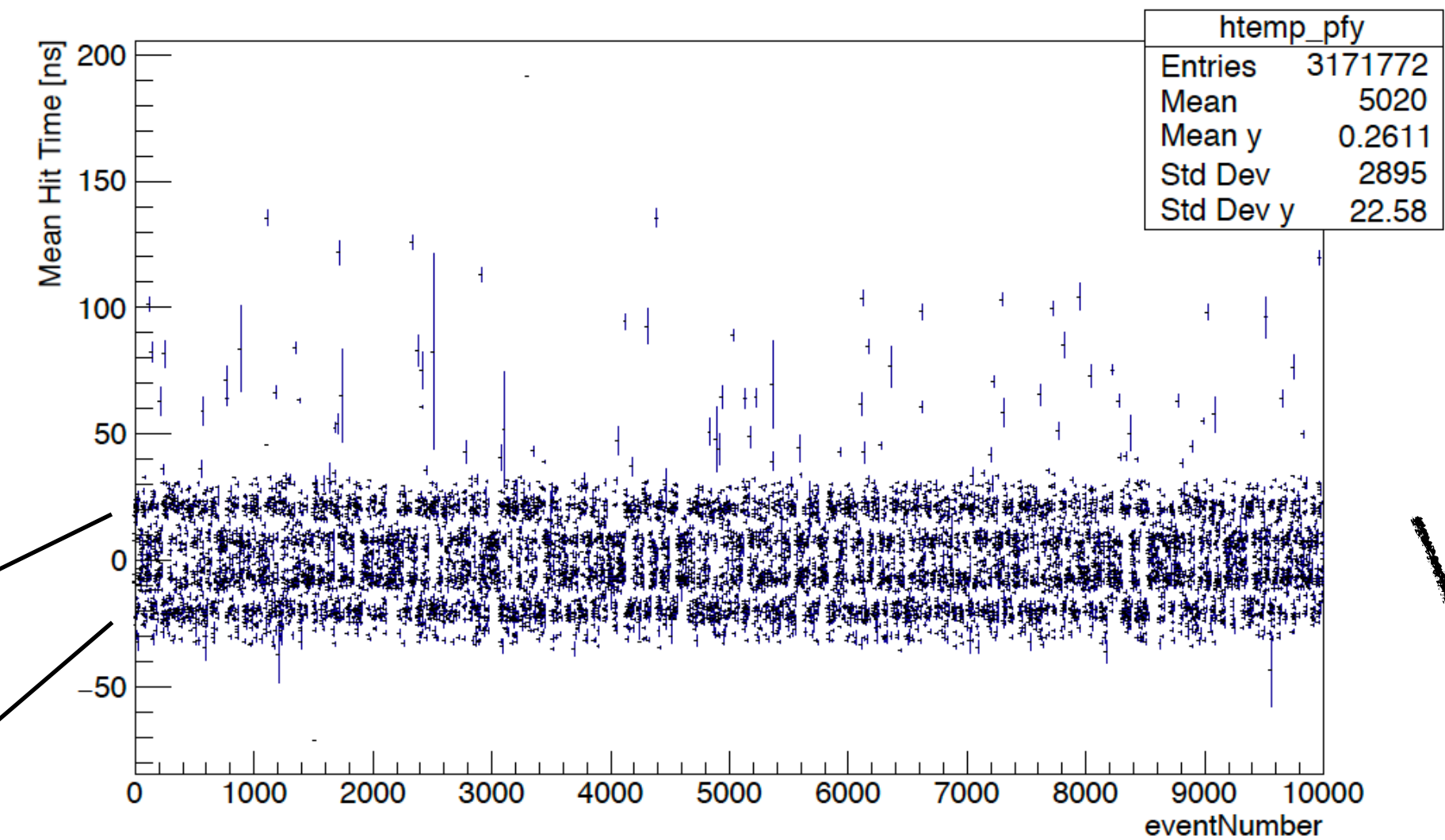# Muon Time Resolution - May 2018
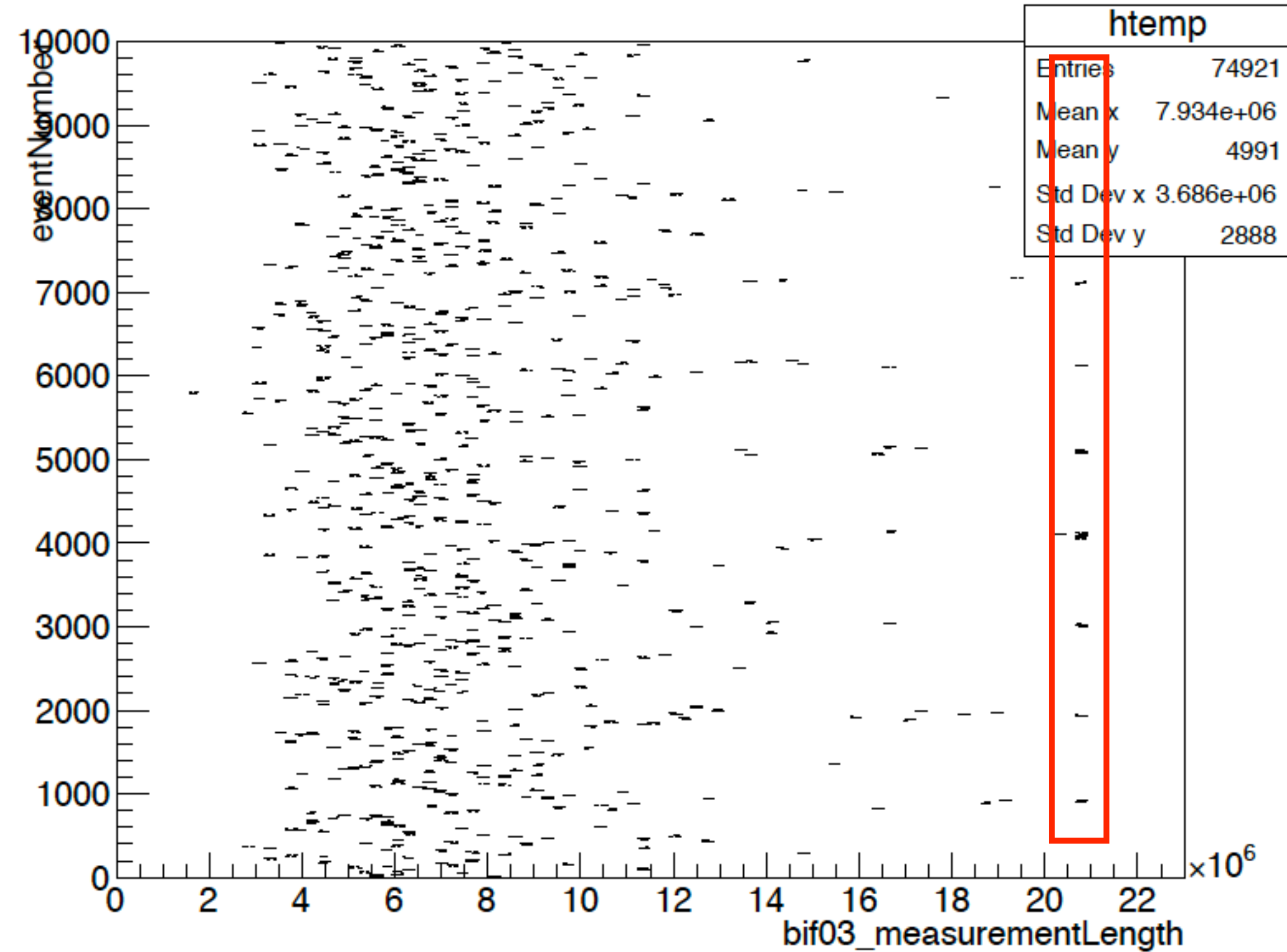

120GeV Muon - Run 60377

htemp	
Entries	5539499
Mean	0.6219
RMS	13.21

htemp_pfy	
Entries	3171772
Mean	5020
Mean y	0.2611
Std Dev	2895
Std Dev y	22.58

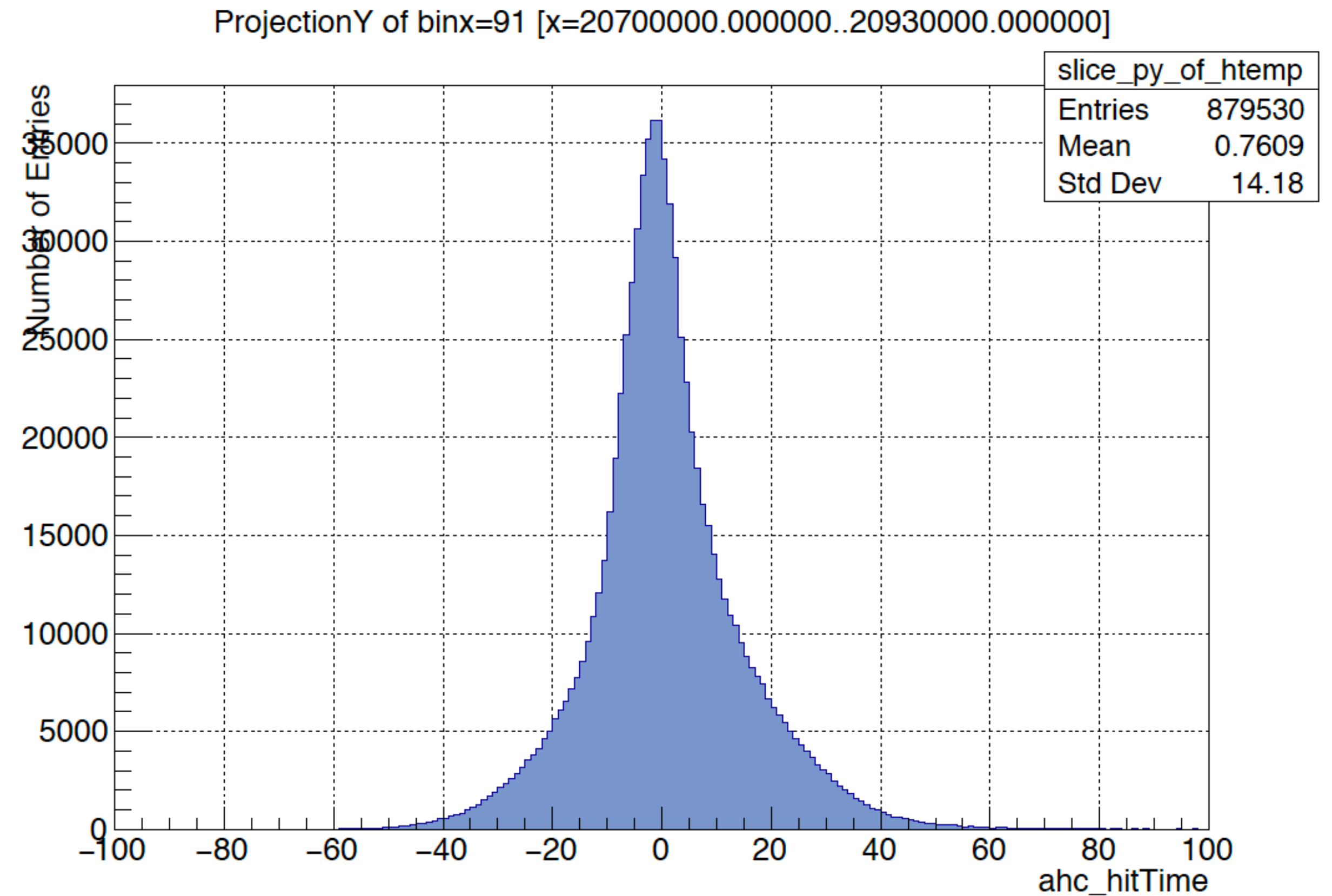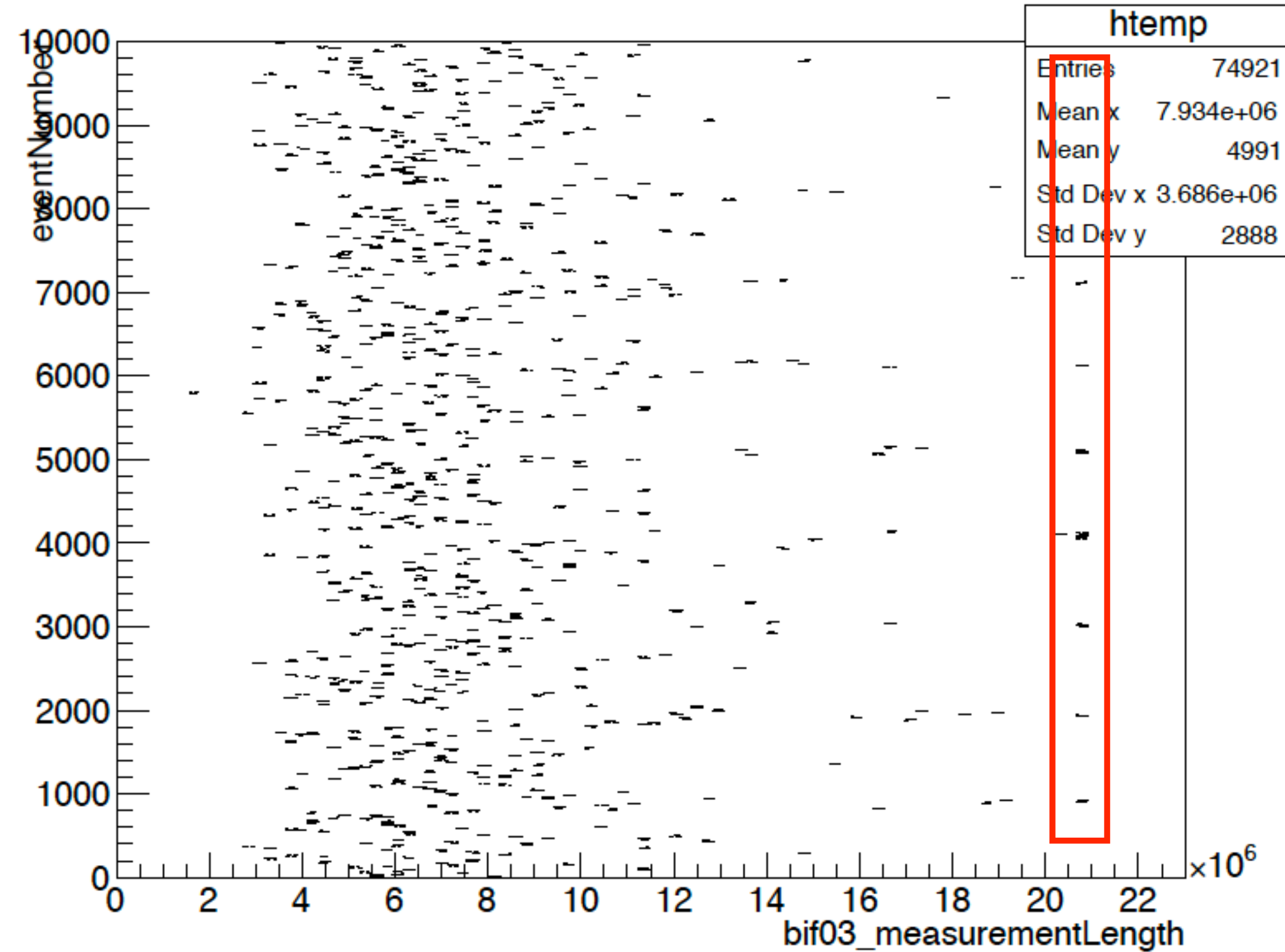| htemp_pfy	
Entries	1570385
Mean	5055
Mean y	−5.873
Std Dev	2875
Std Dev y	22.48

Select odd BxID

Shoulders increase with increasing rates

Pion Time Resolution - May 2018

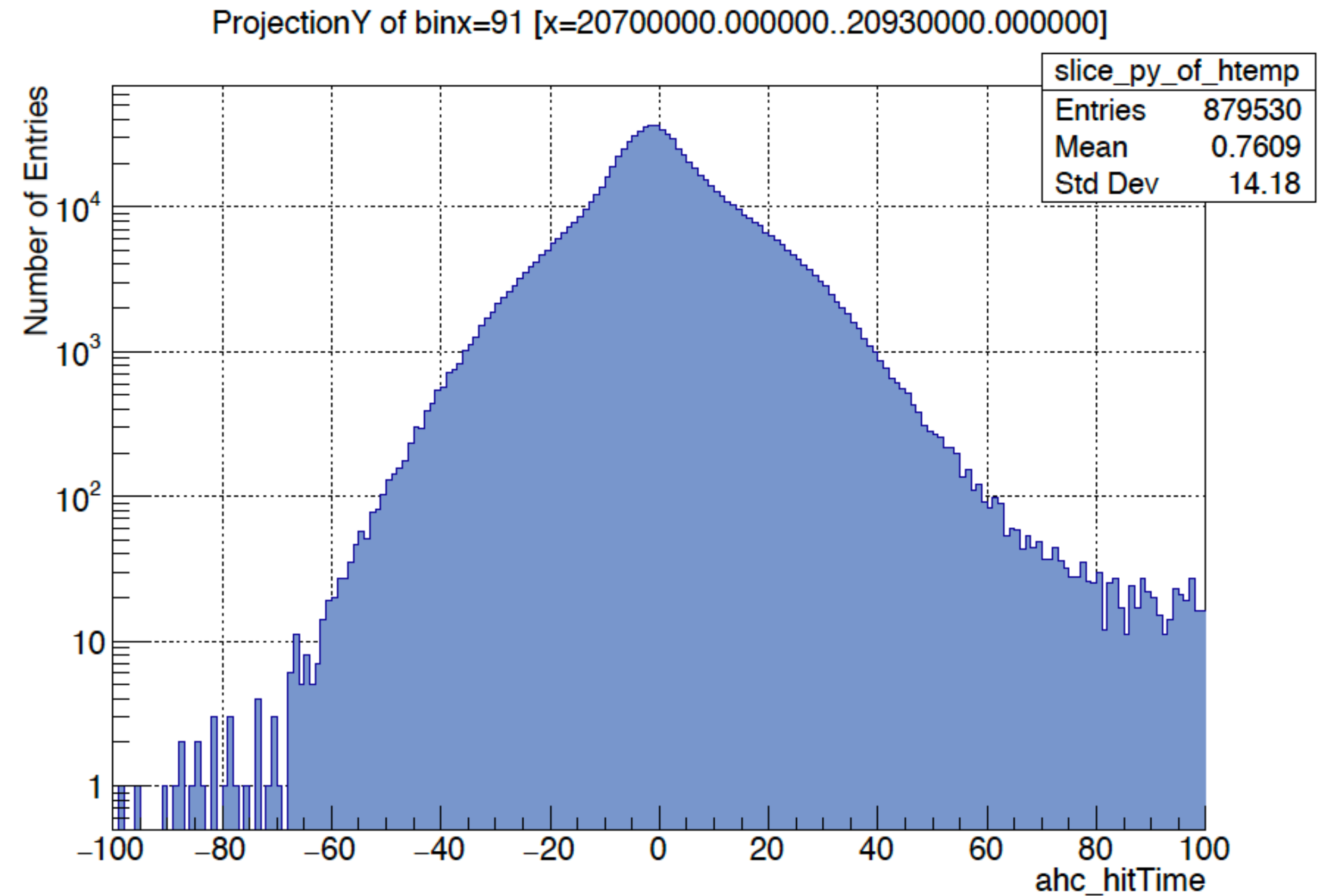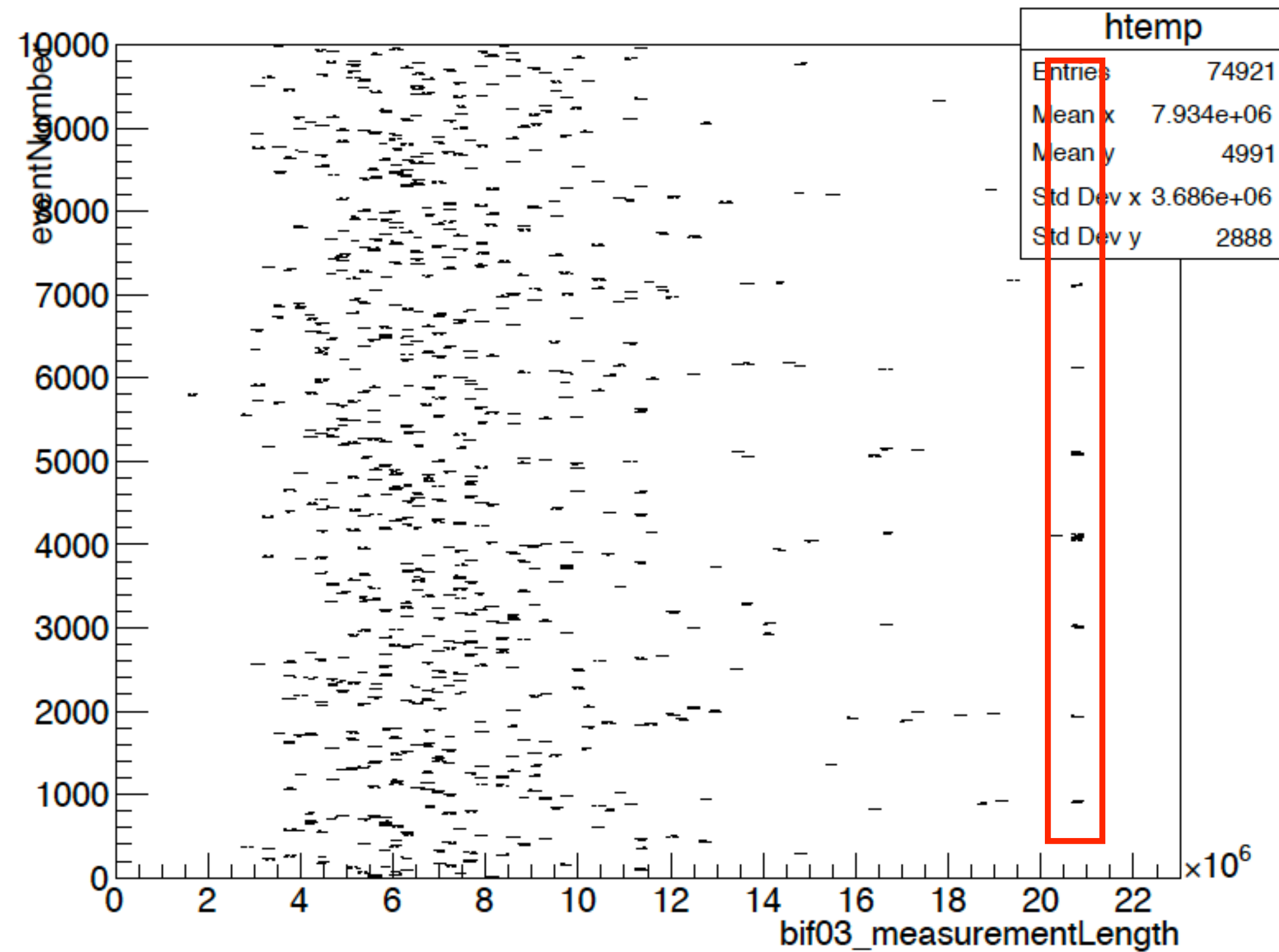# Pion Time Resolution - May 2018

Cut on measurement length

Pion Time Resolution - May 2018

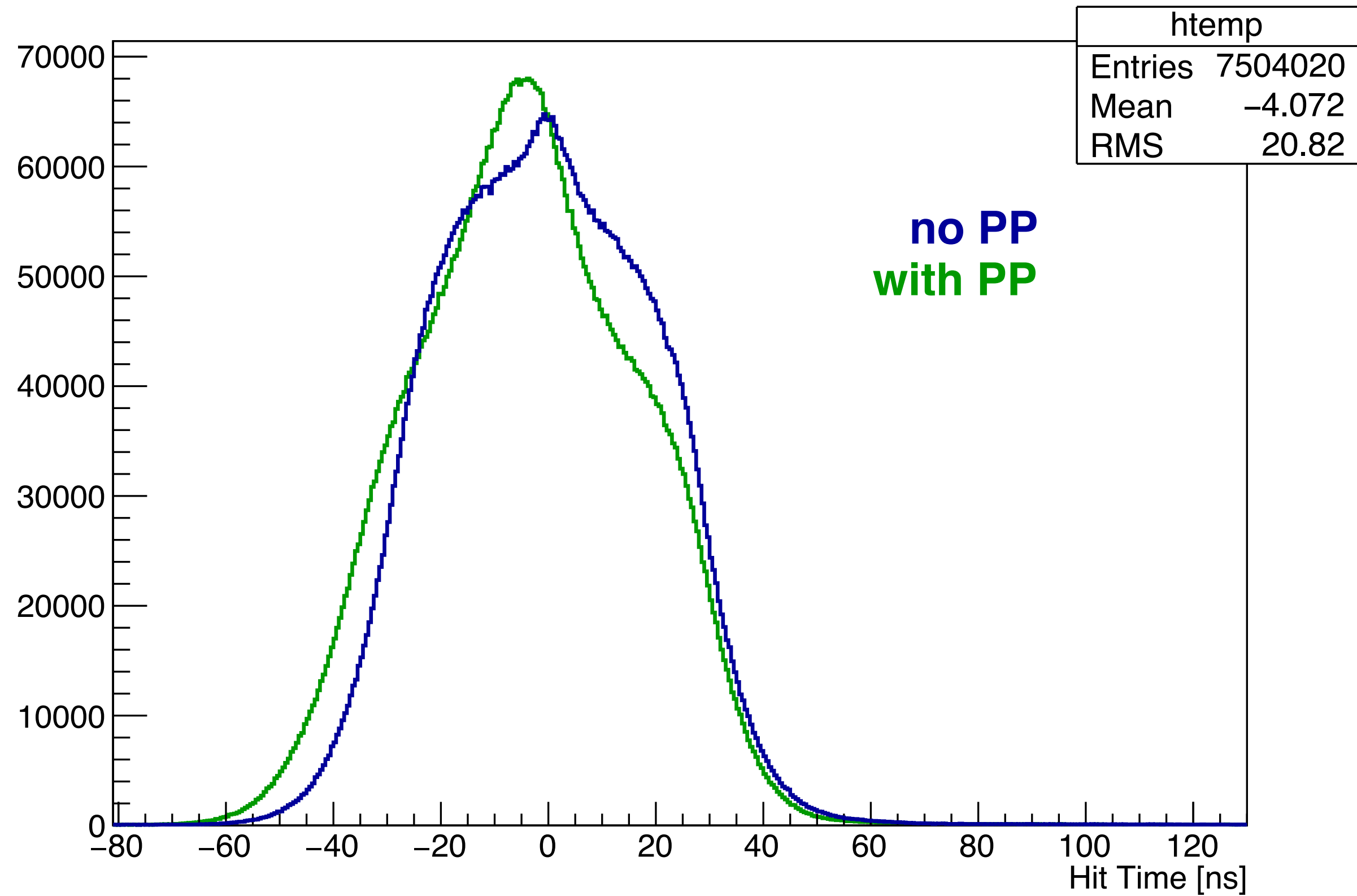# Electron Time Resolution - May 2018

Calibrated Hit Time 50 GeV Electrons

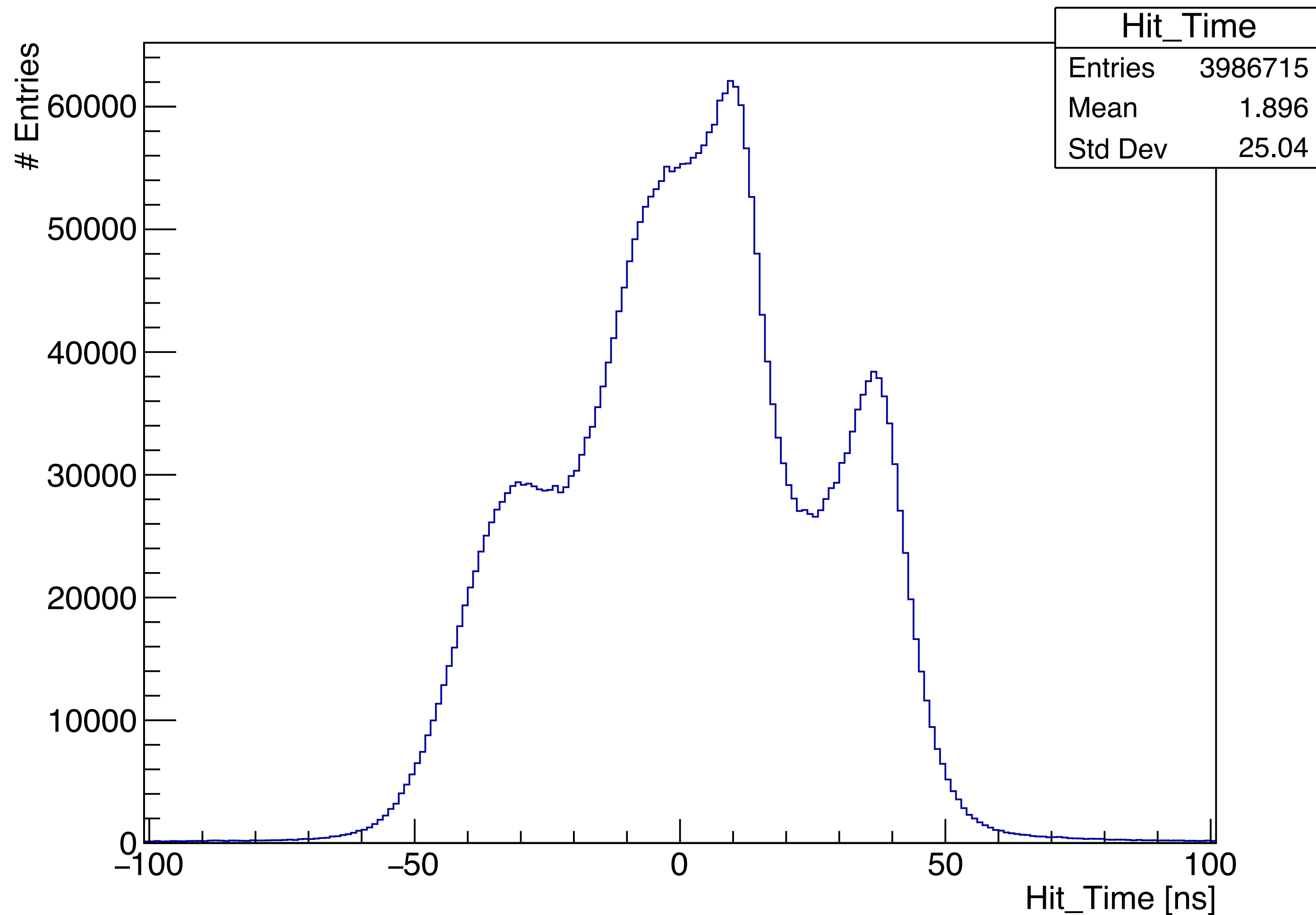| htemp	
Entries	7504020
Mean	−4.072
RMS	20.82

no PP
with PP

- Shoulders present in both modes

- PP shifts the peak to negative hit times
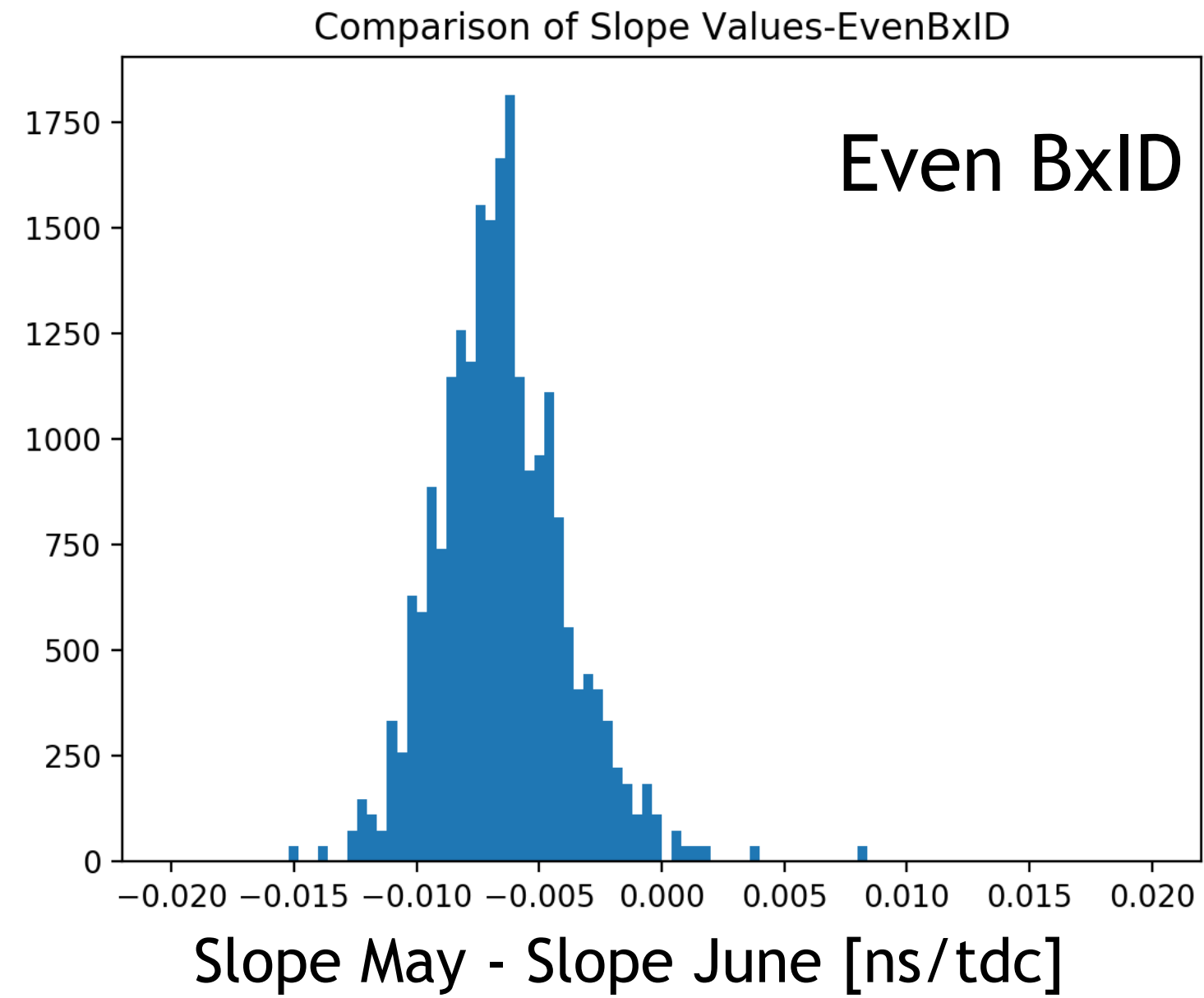
Pion Time Resolution with PP - June 2018

Run 61375 - 30GeV Pions PP - June18 - May18 Calibration Constants

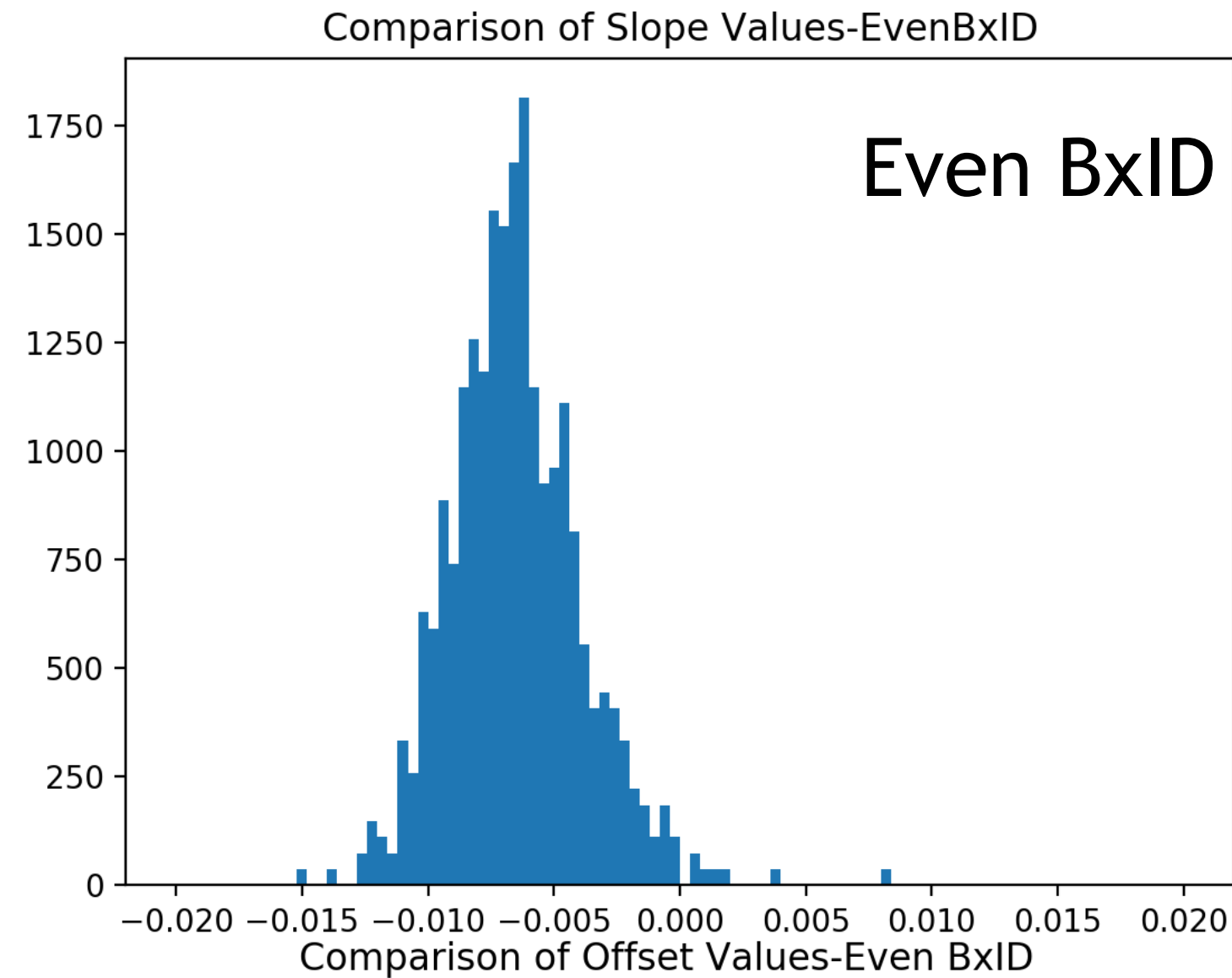| Hit_Time	
Entries	3986715
Mean	1.896
Std Dev	25.04

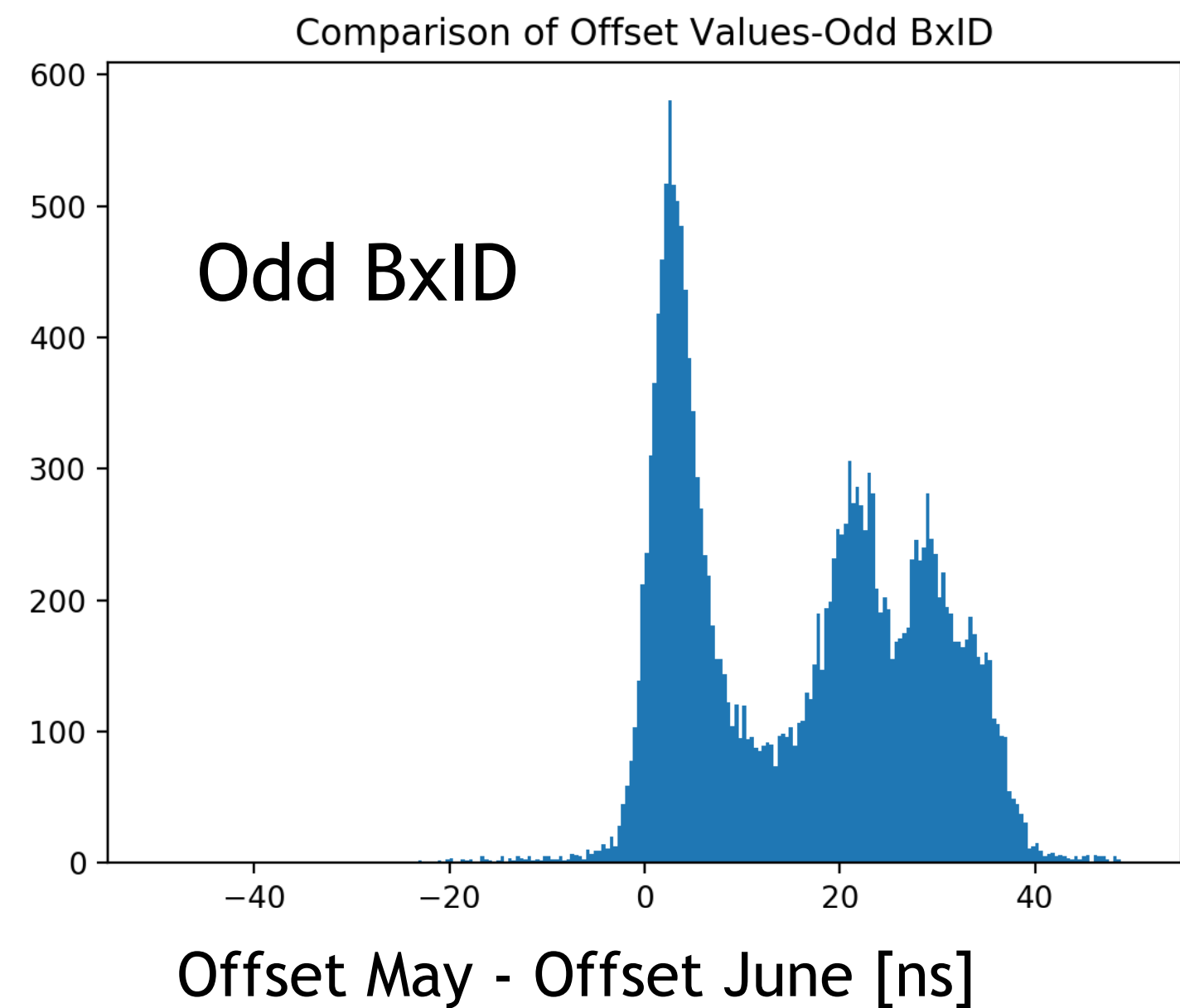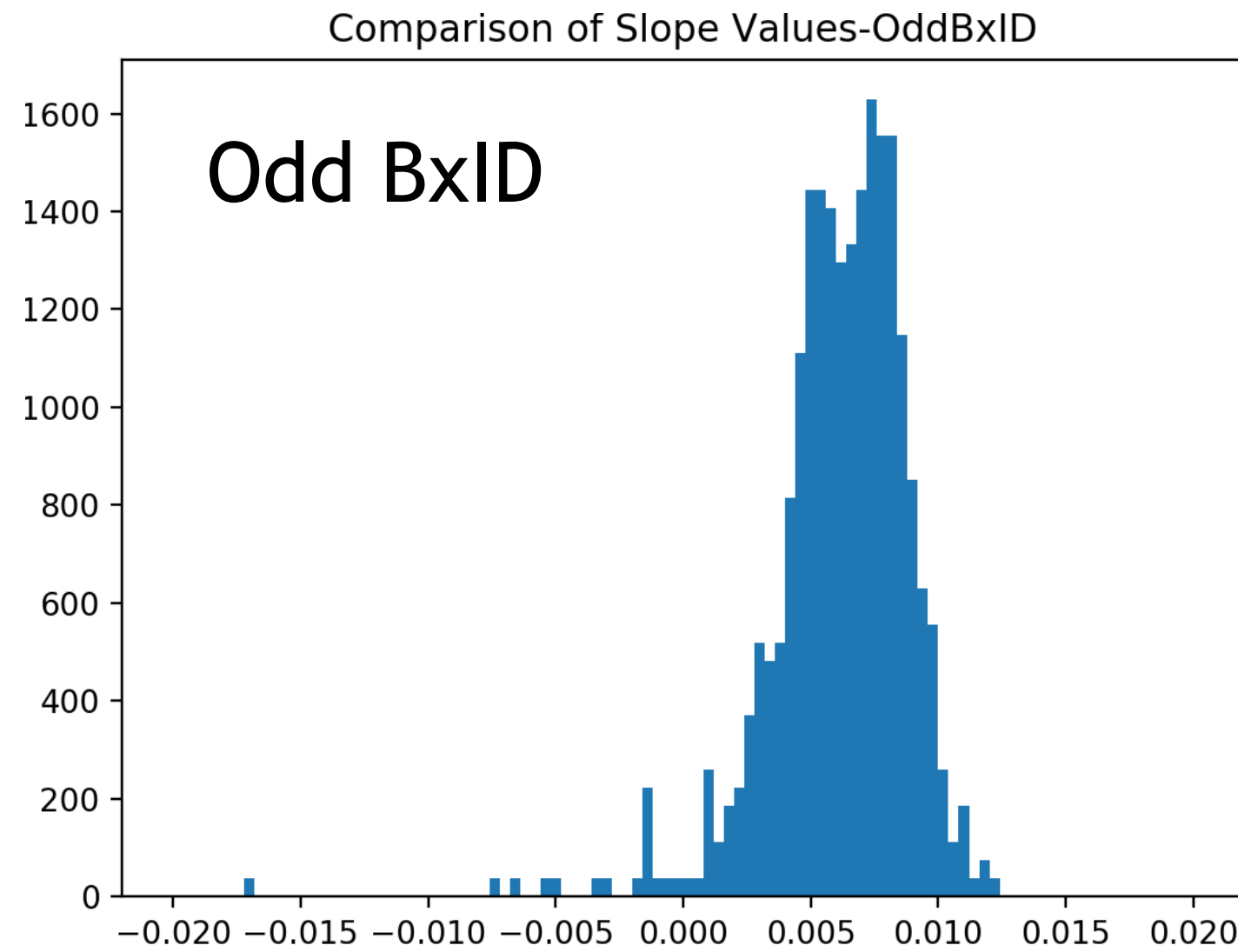- Used time calibration from May 2018
  - Done without PP

- Tailcatcher and Tokyo module excluded

- Reasonable distribution
  - With respect to shoulders

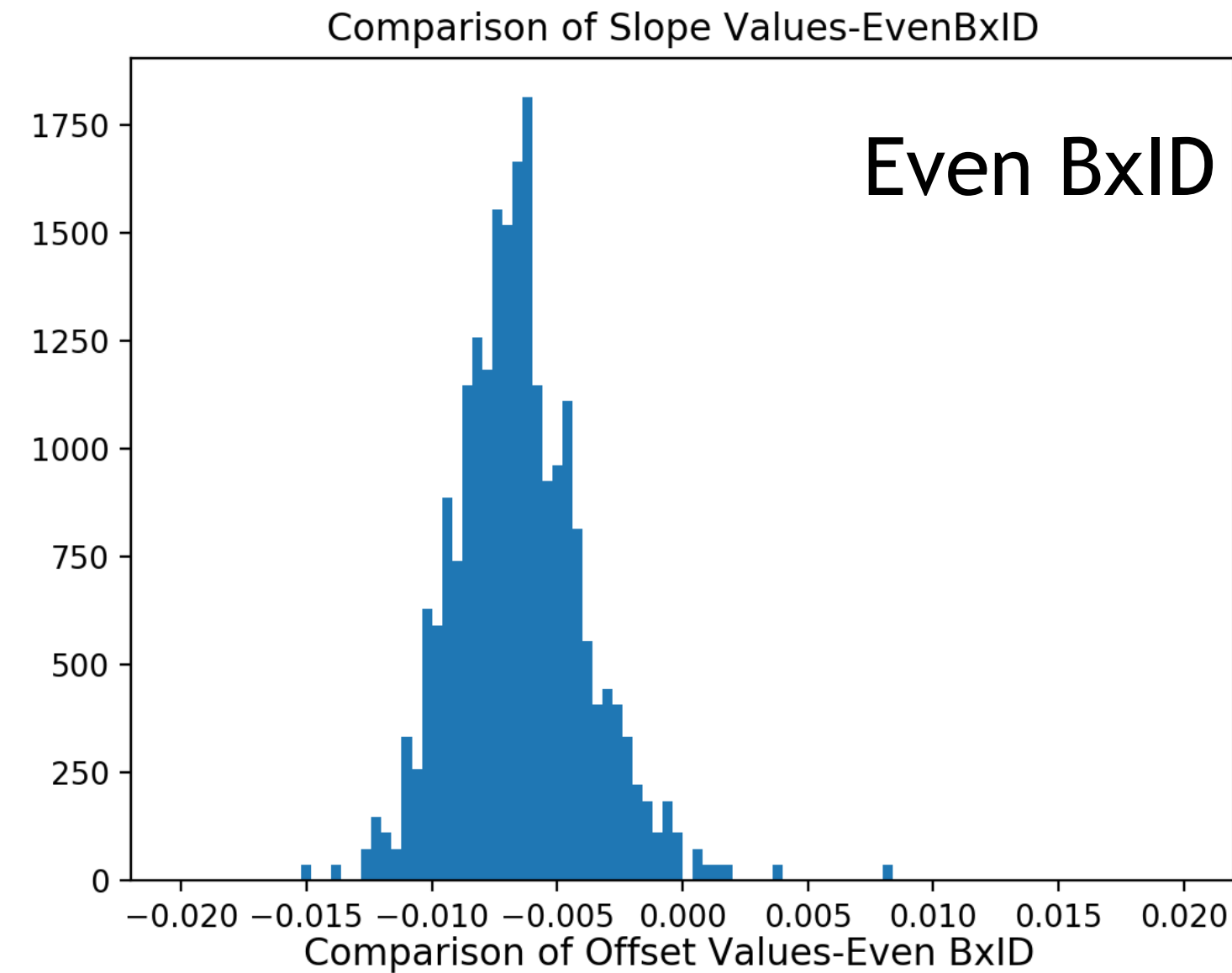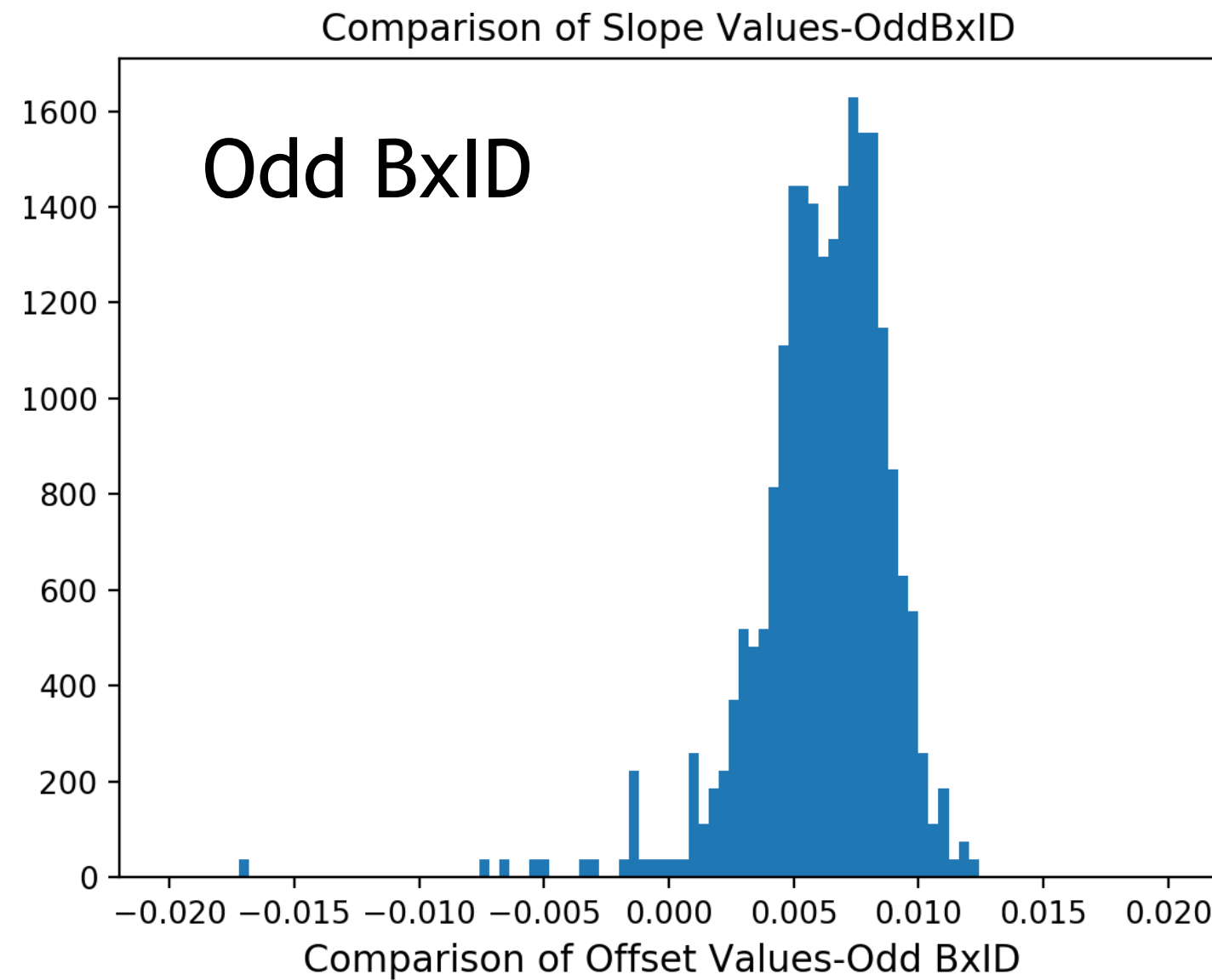# Fit Parameters per Channel - May vs June

Comparison of Slope Values-OddBxID

Odd BxID

Slope May - Slope June [ns/tdc]

Comparison of Slope Values-EvenBxID

Even BxID

Slope May - Slope June [ns/tdc]
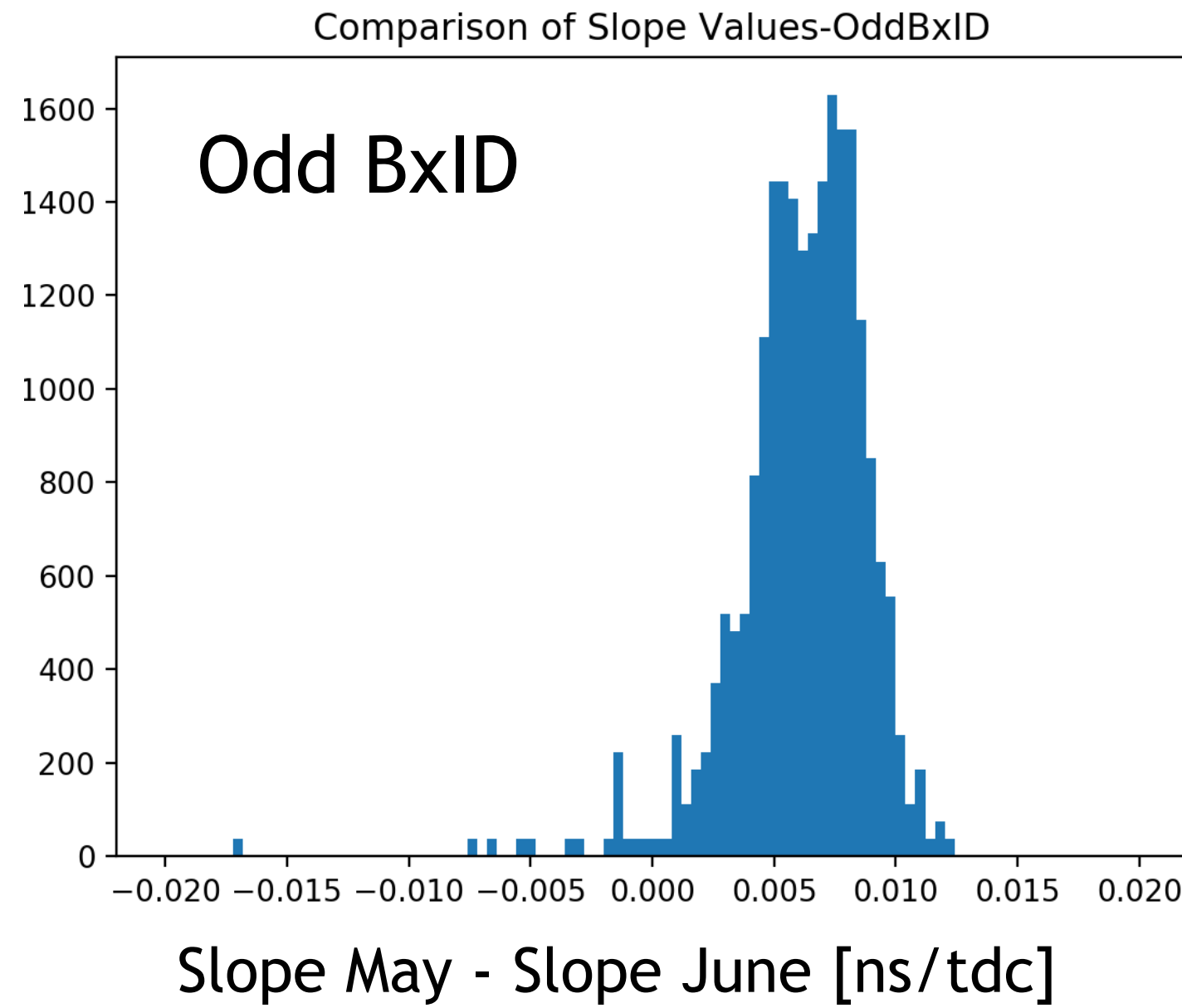
Fit Parameters per Channel - May vs June

Fit Parameters per Channel - May vs June

Comparison of Slope Values-OddBxID

Odd BxID

Comparison of Slope Values-EvenBxID

Even BxID

Comparison of Offset Values-Odd BxID

Odd BxID

Offset May - Offset June [ns]

Comparison of Offset Values-Even BxID

Even BxID

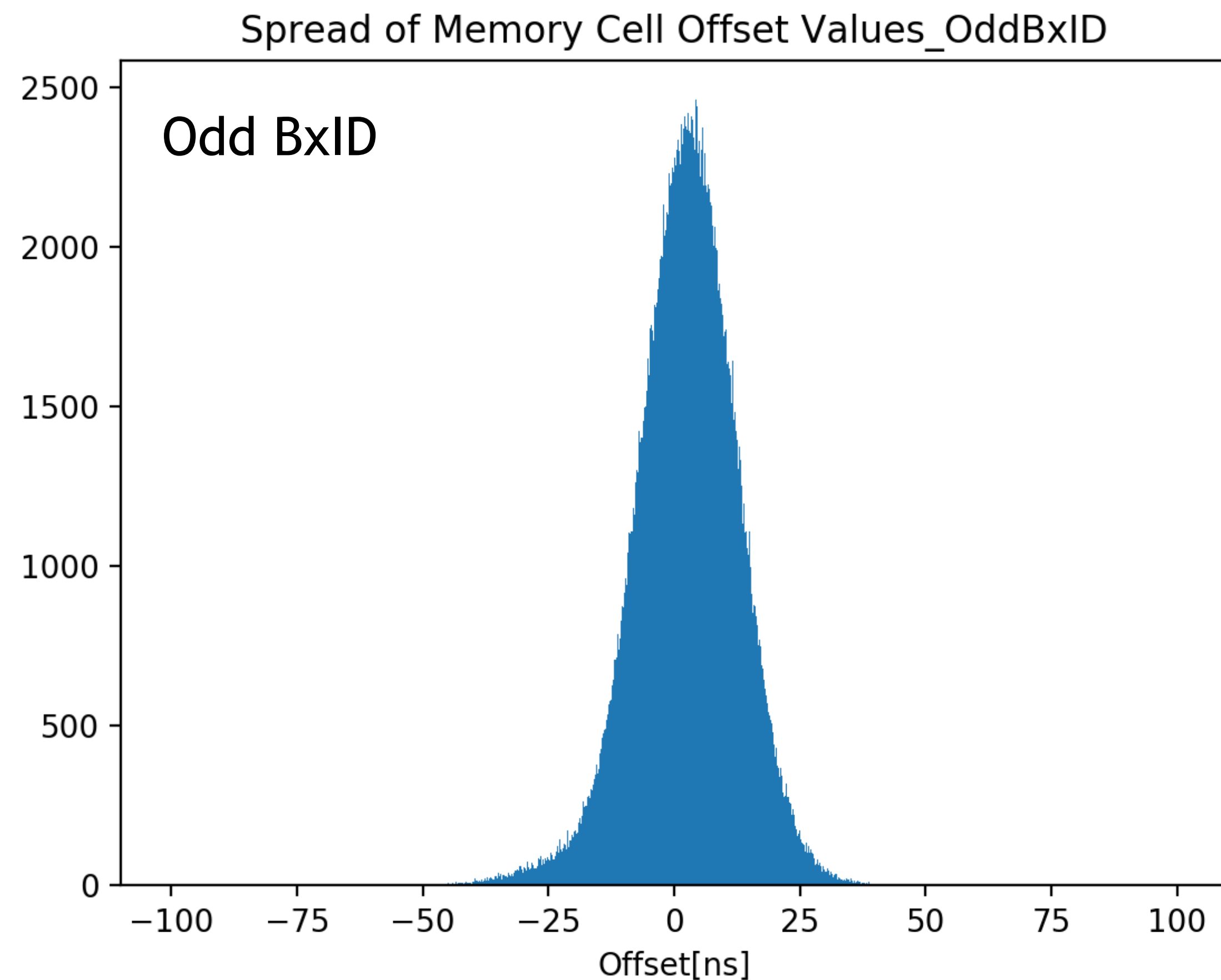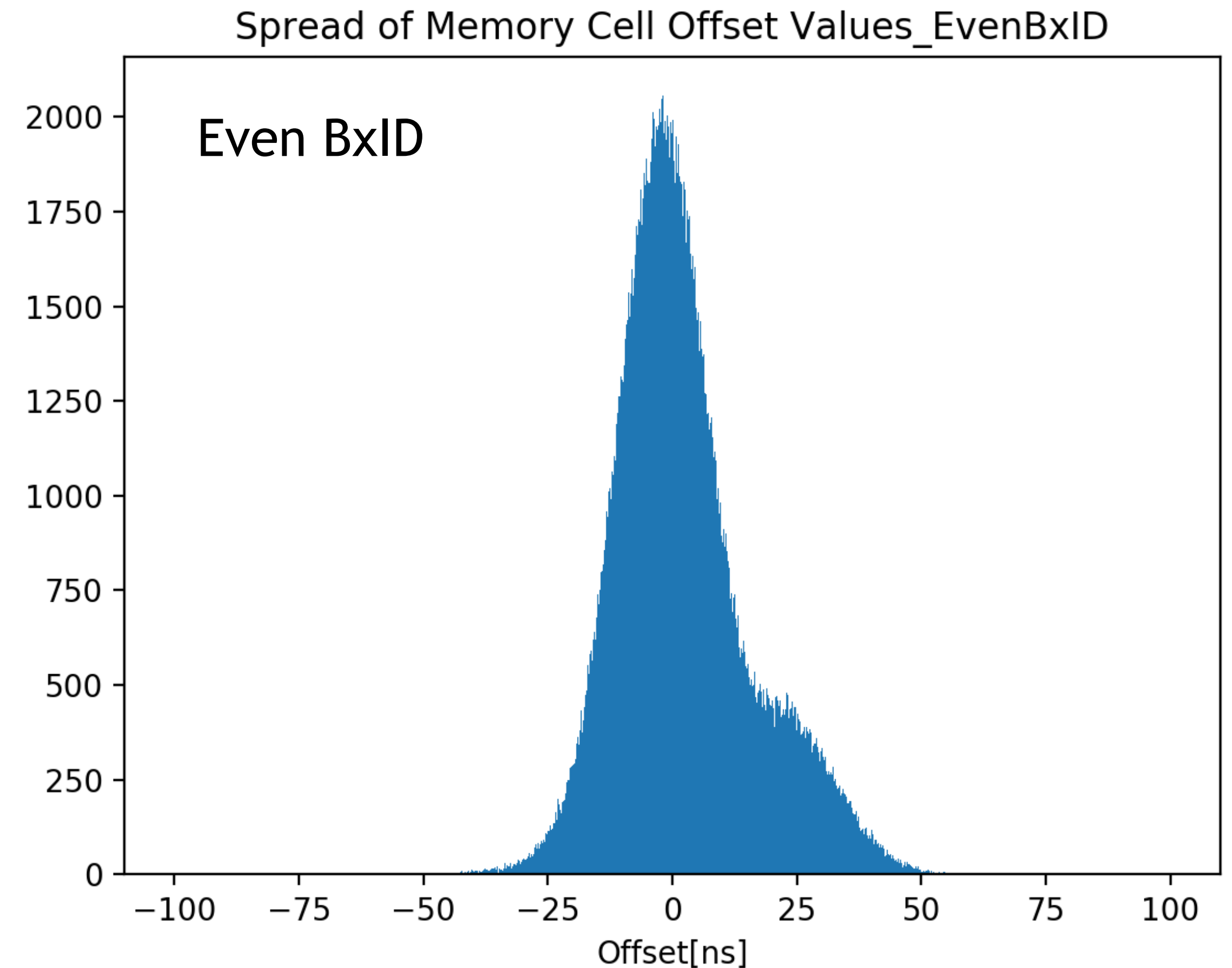Offset May - Offset June [ns]

- May calibration done <u>without</u> power pulsing
- June calibration done <u>with</u> power pulsing

- May translate the comparison to <u>PP vs No-PP</u>

Spread of Memory Cell Offset - May 2018

Spread of Memory Cell Offset Values_OddBxID

Odd BxID

~16% non-calibrated

Spread of Memory Cell Offset Values_EvenBxID

Even BxID

~19.5% non-calibrated

To do's

By (proposed) priority:

1. Identify reason for shoulders in time resolution and try to reject/<u>recover</u>

2. Add database entries for time walk correction, non-linearity and Memory cell offset

3. Implement time walk and non-linearity correction as Marlin processor

4. Investigate difference between PP and No-PP

5. Investigate failure of robust fit

Backup

Time Calibration

Implementation

- Implemented as marlin processor

- Calibration working for TDC ramp slopes and offsets between channels

- **Time walk correction and non-linearity correction missing**

  - —> Current time resolution ~6-7ns (no quality cuts)

Performance

- Fits need to be done with per mille precision

- ~100 hits per memory cell needed (min. 30)

- ~370k memory cells

- 10'000 fits take about 5min. Calibration should be feasible within few hours

- Adds few *ns* to resolution if we don't have all memory cells calibrated

Example Channel: T0 Time over Hit TDC

RANSAC
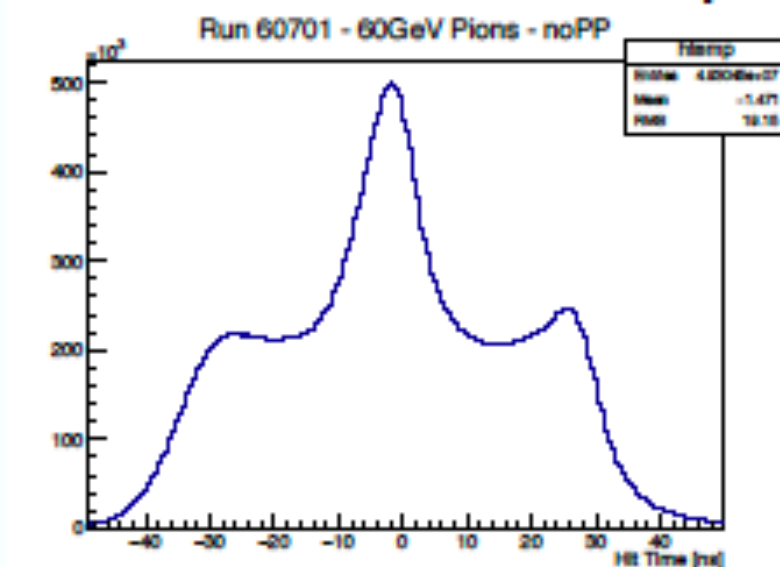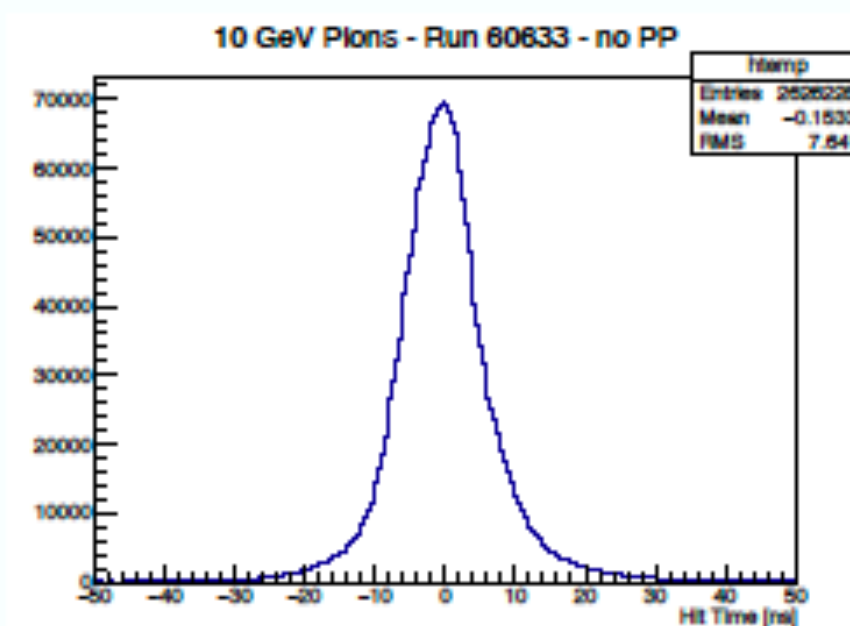Theil-Sen
Root robust fit

Backup
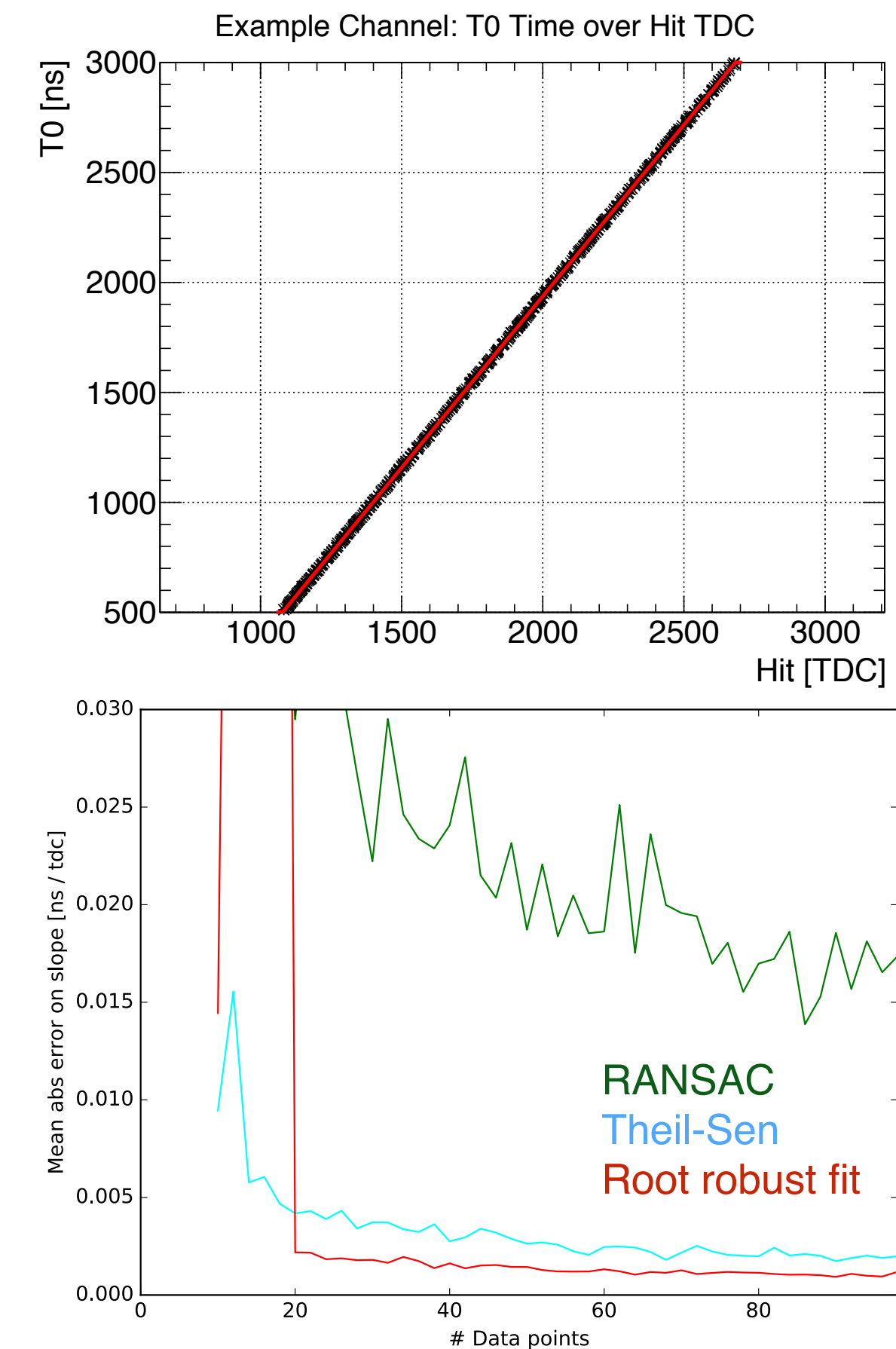
Higher Rates

- 10GeV give **nice time resolution**

- Shoulders problem increases for increasing rate

- From first look:
  There does not seem to be a problem for **high chip occupancies** (at least not as severe as in 2015)
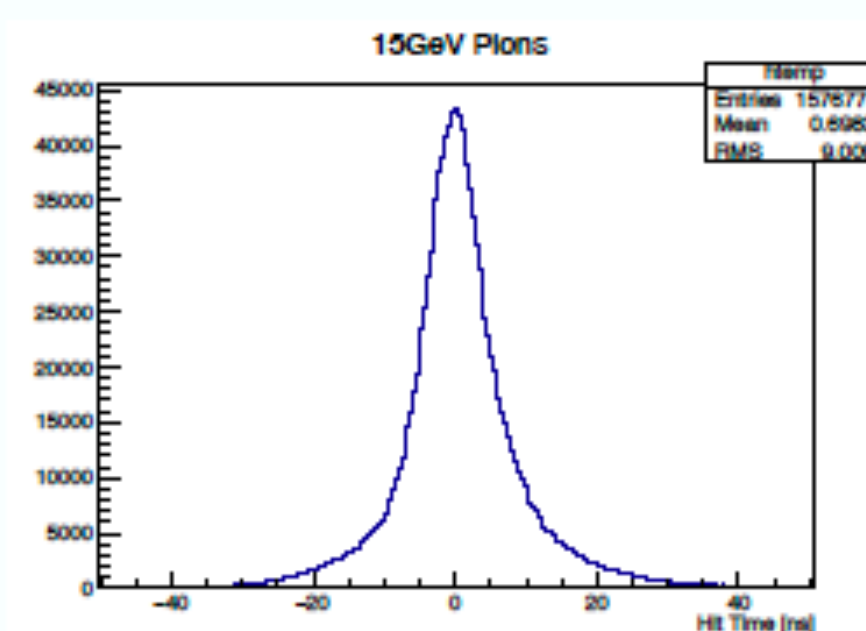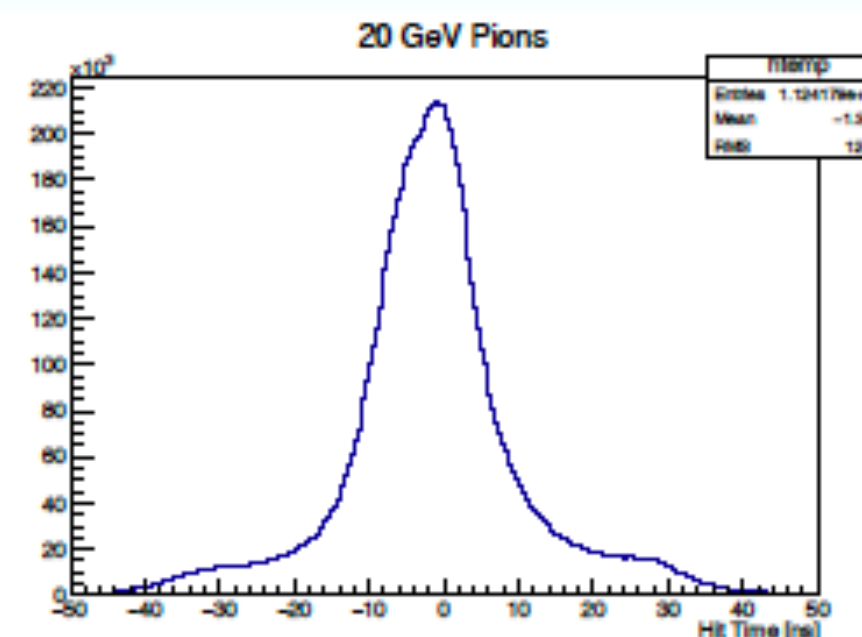
60GeV: 1100 E/sp

10GeV: 600 E/sp   15GeV: 360 E/sp   20GeV: ? E/sp   30GeV: 1200 E/sp

Christian Graf   Group Meeting - 13.06.2018   11