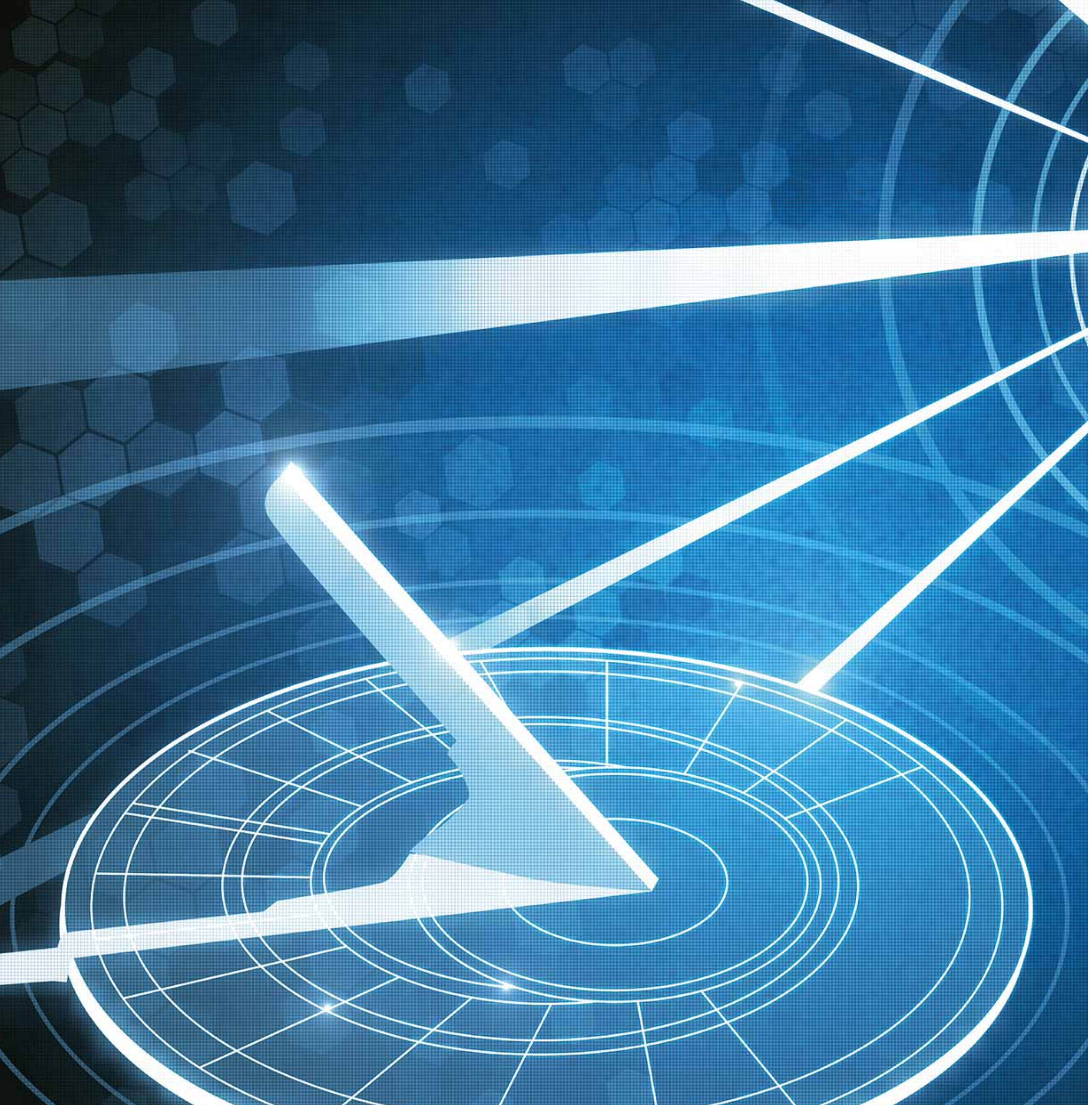

AHCAL Timing

CALICE Collaboration Meeting Everywhere
30.9.2020
Lorenz Emberger

MAX-PLANCK-INSTITUT FÜR PHYSIK

Motivation

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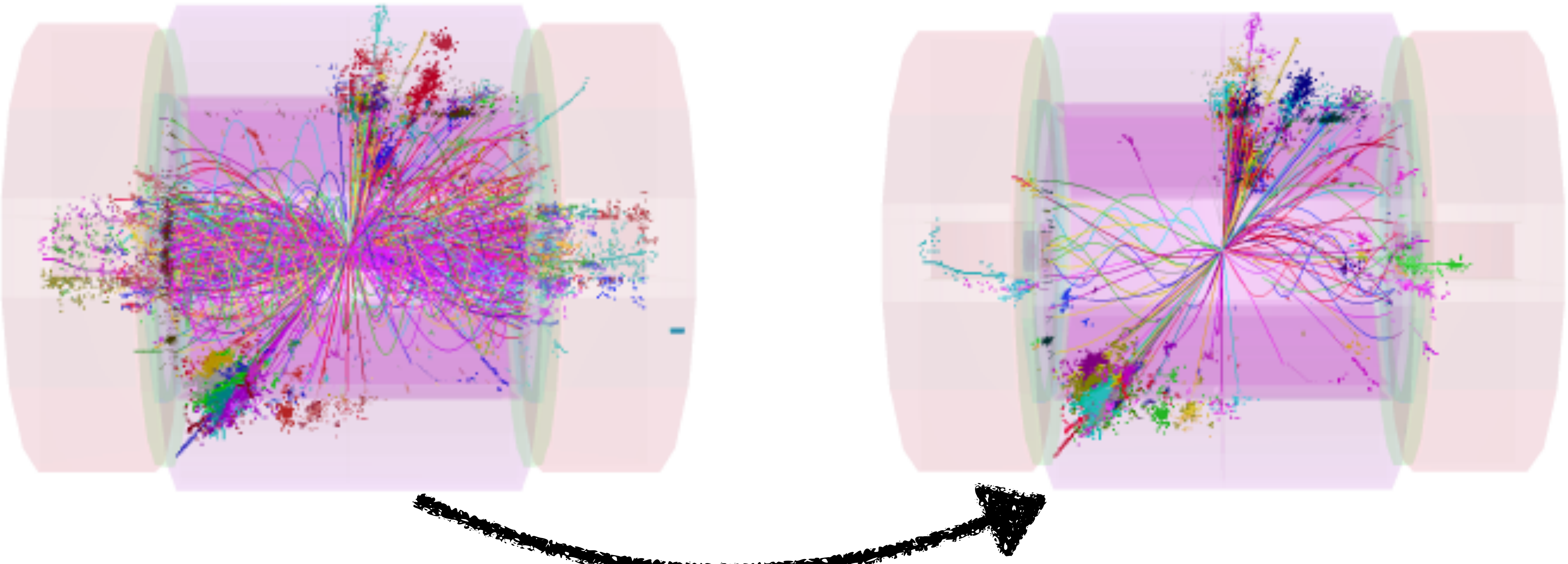
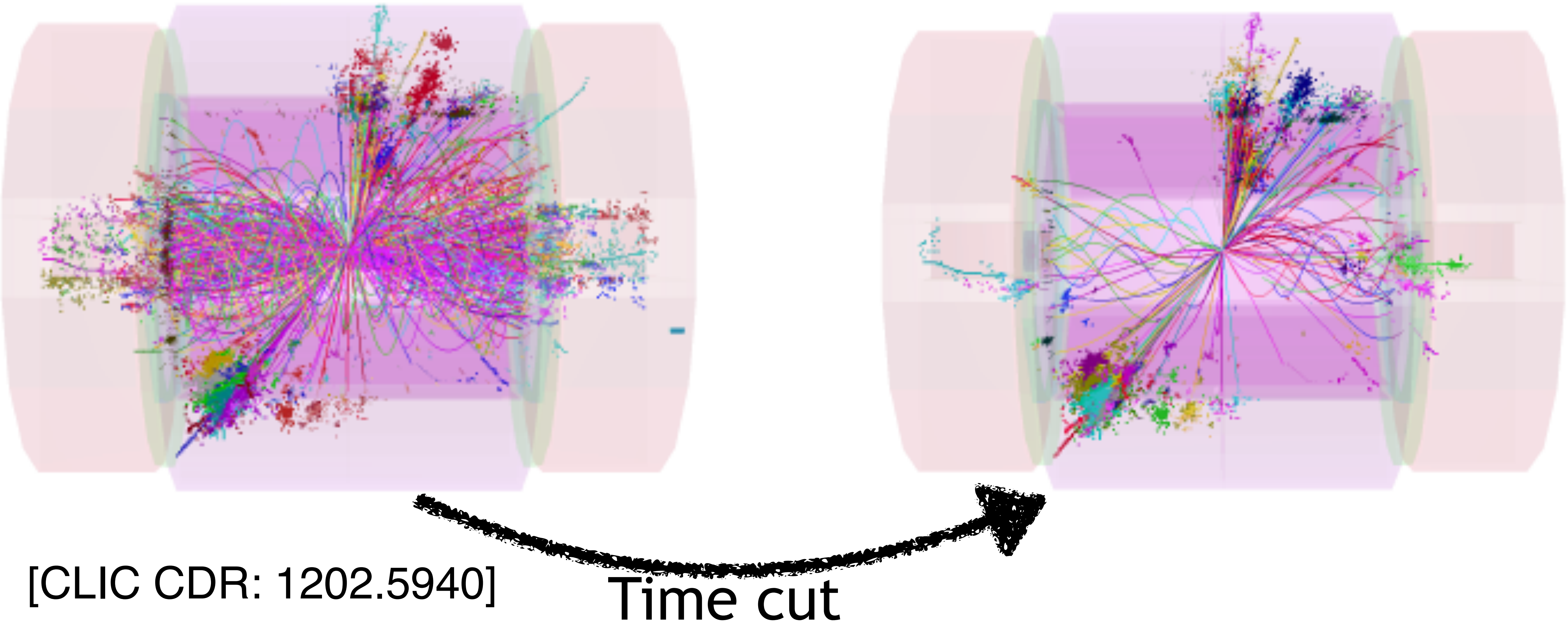


[CLIC CDR: 1202.5940]

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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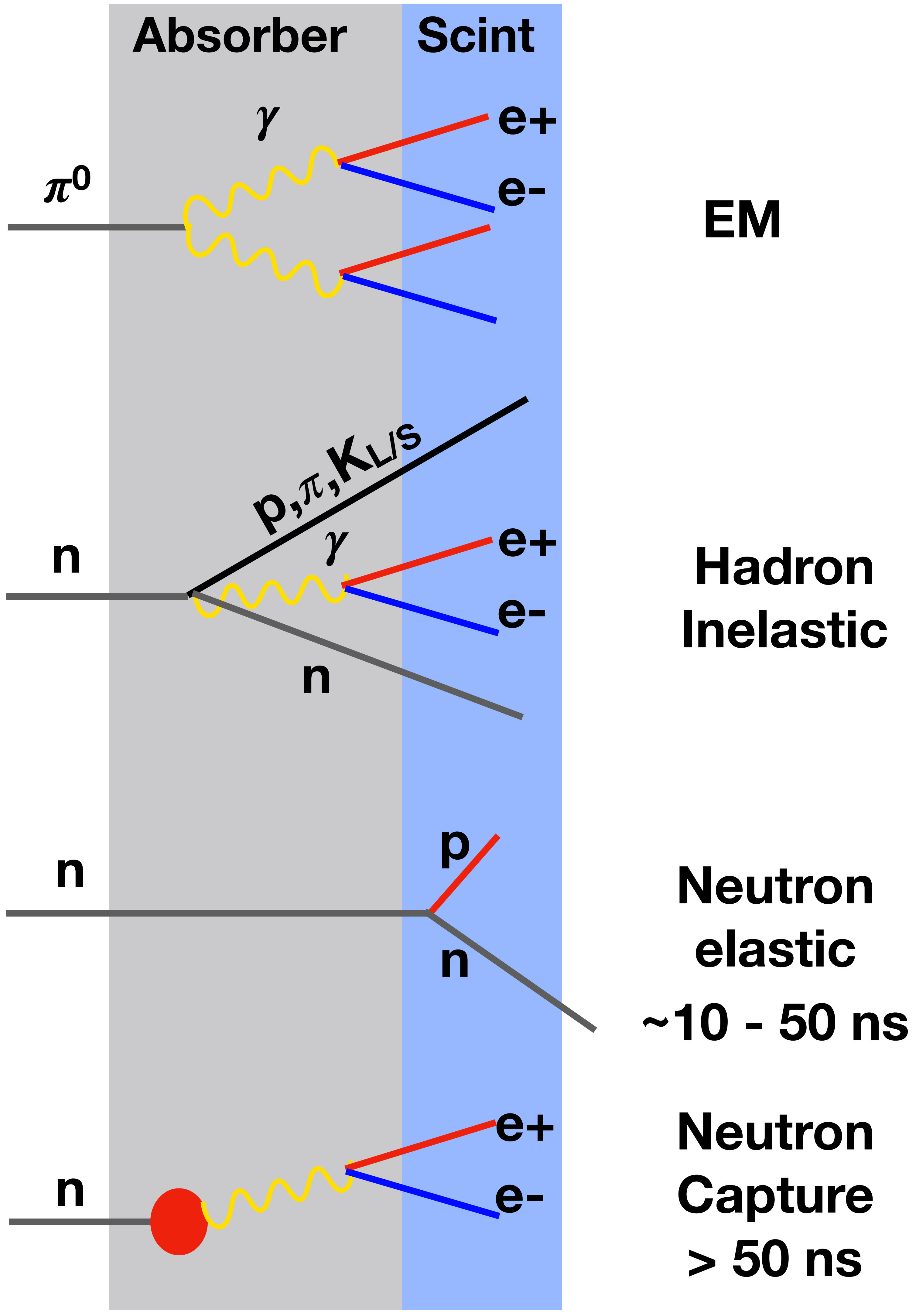

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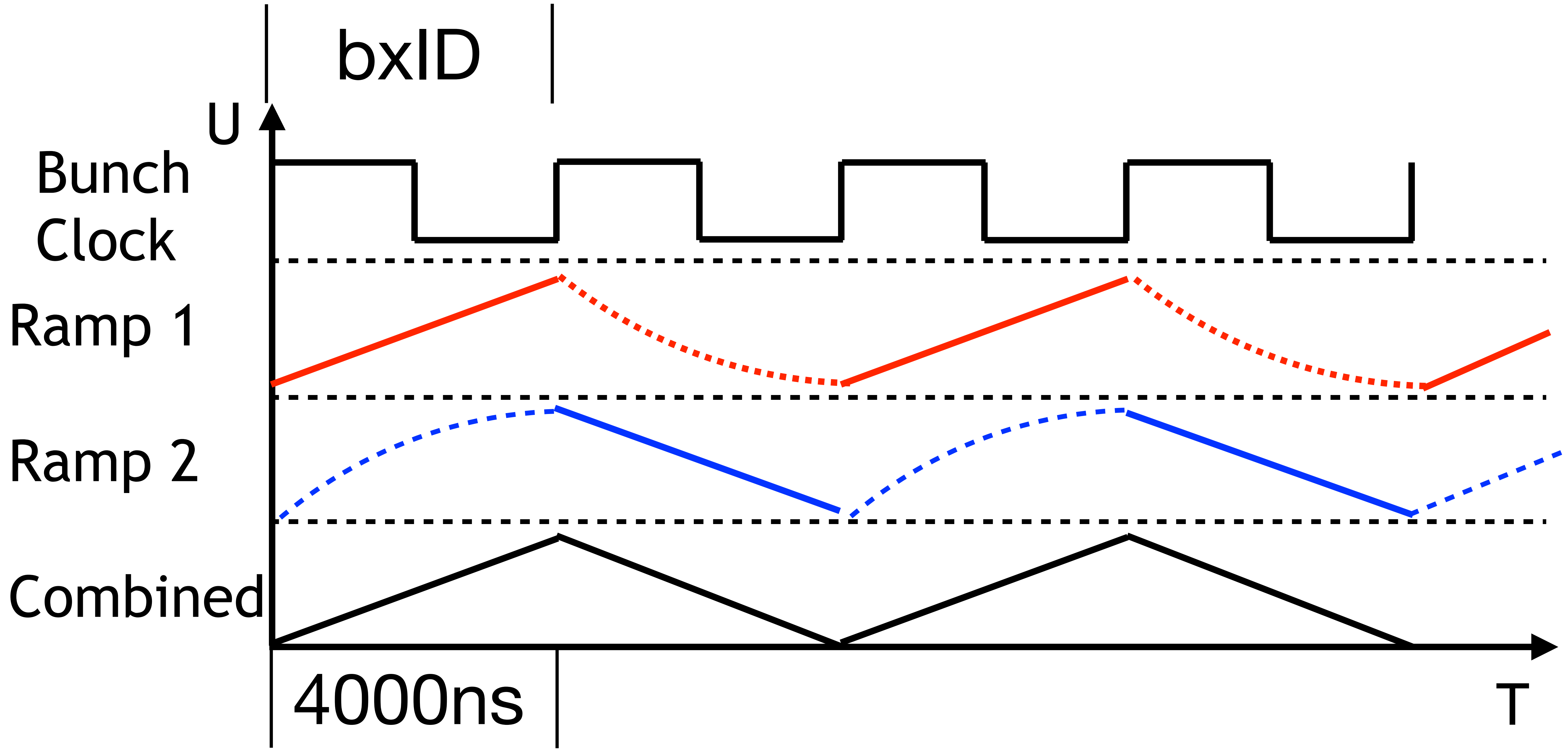
Time measurement with Spiroc2E: TDC (time to digital converter)

1. Common external clock with ~1ns bins

2. Ramp up voltage during one bunch crossing ID



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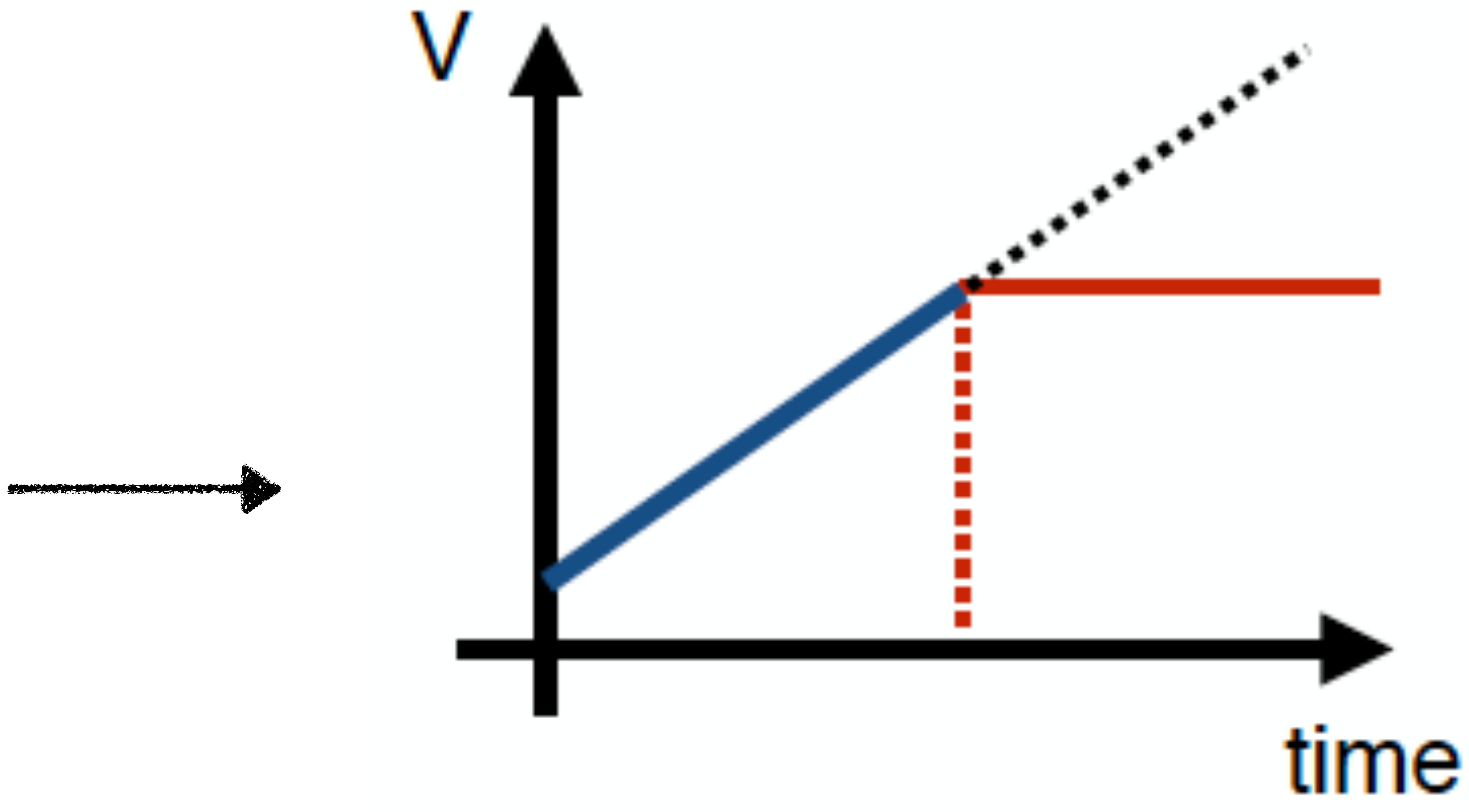

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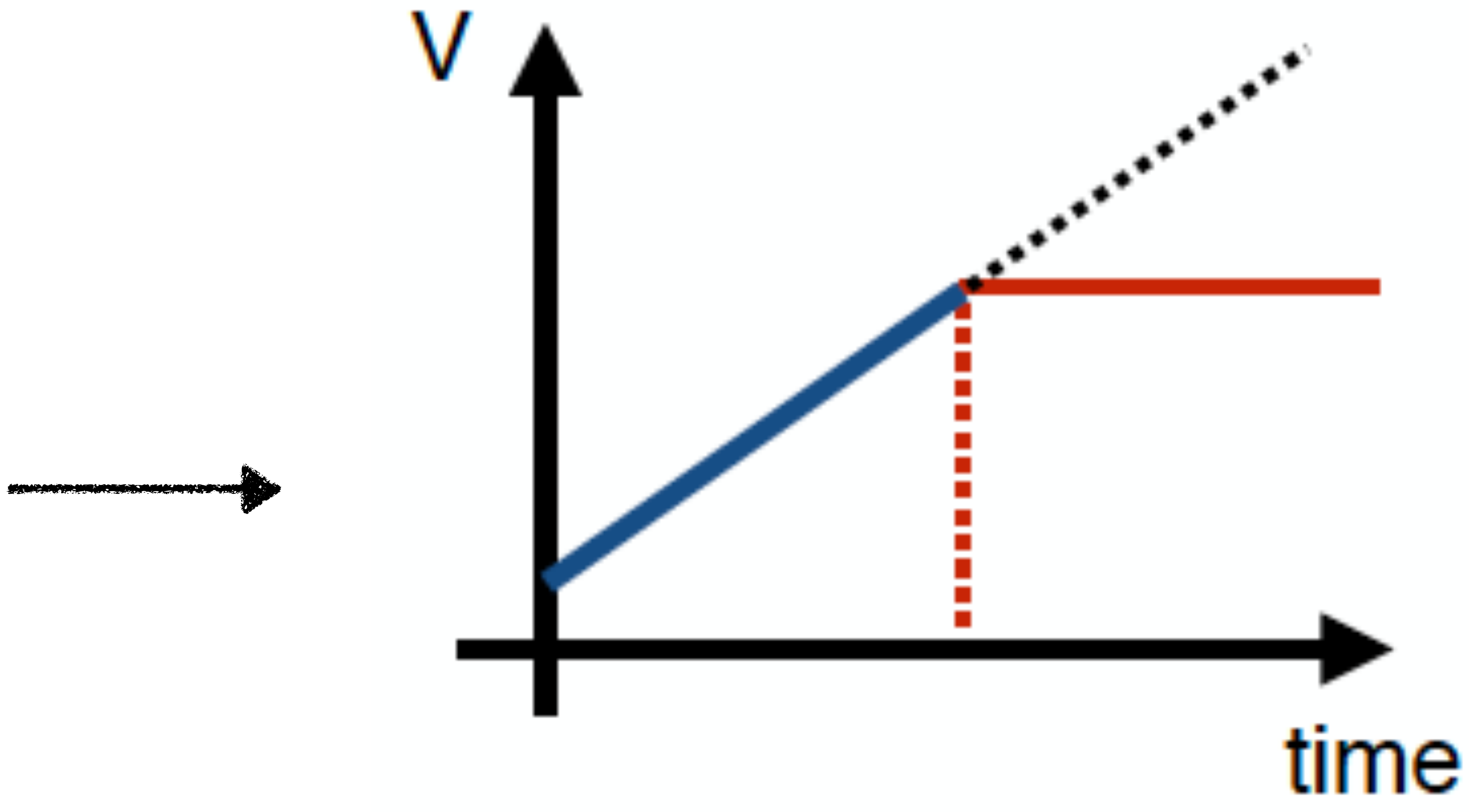

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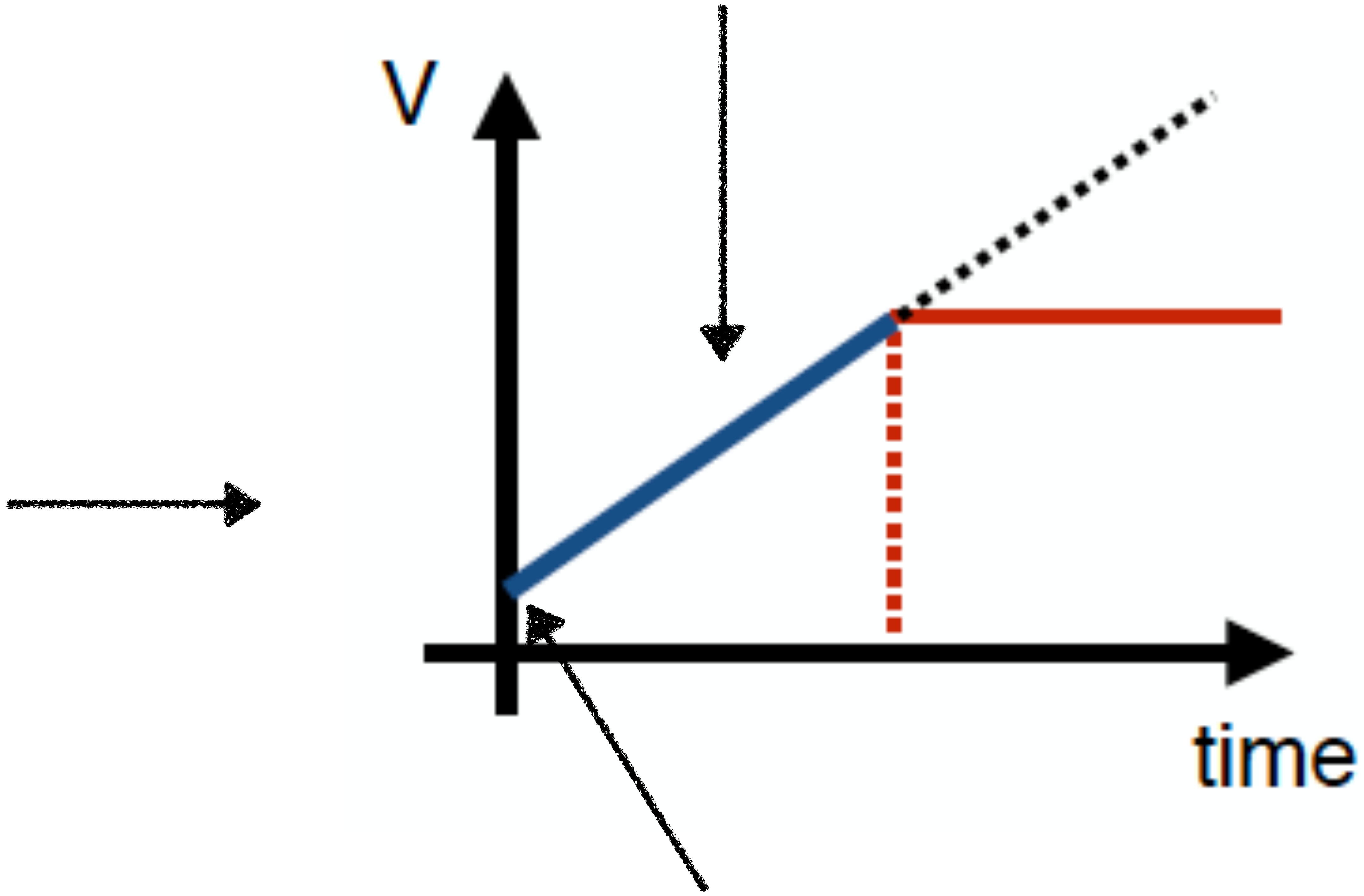
Slope is common to all channels on a chip



Offset is extracted for every memory cell

Time Calibration: Software

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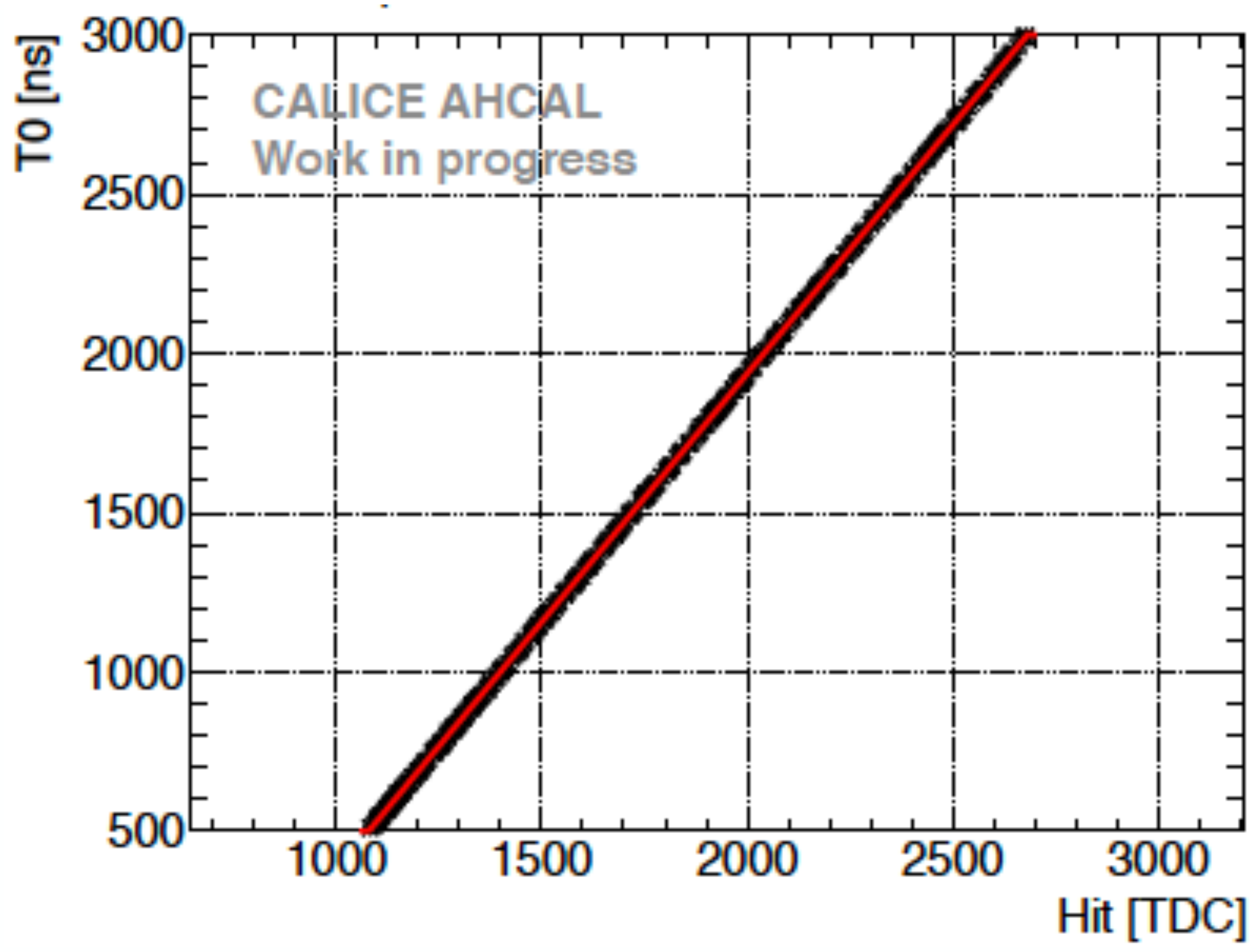
1. Extract slope by plotting reference clock against TDC readings

2. Fit with linear function



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3. Calculate hit time by

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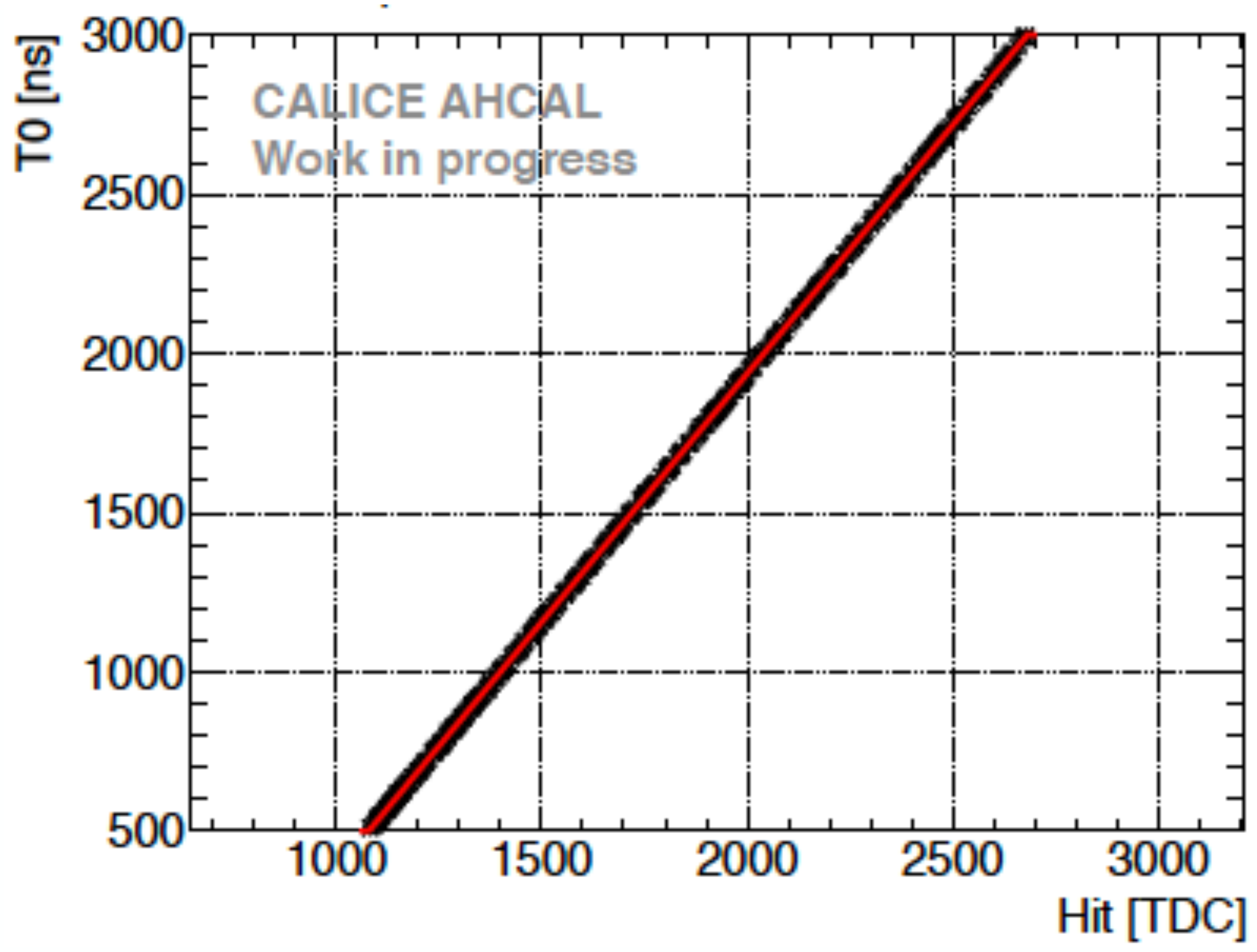

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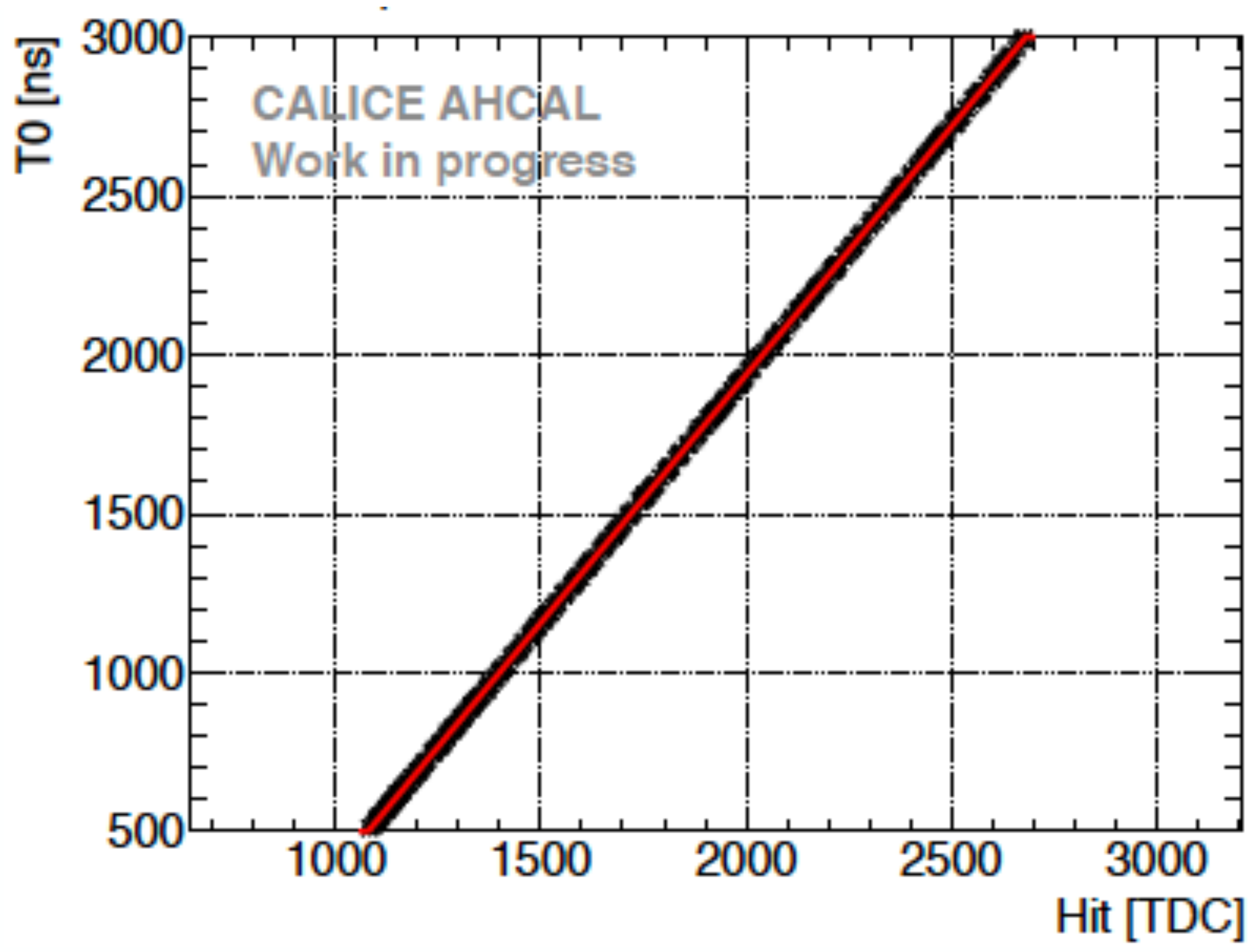
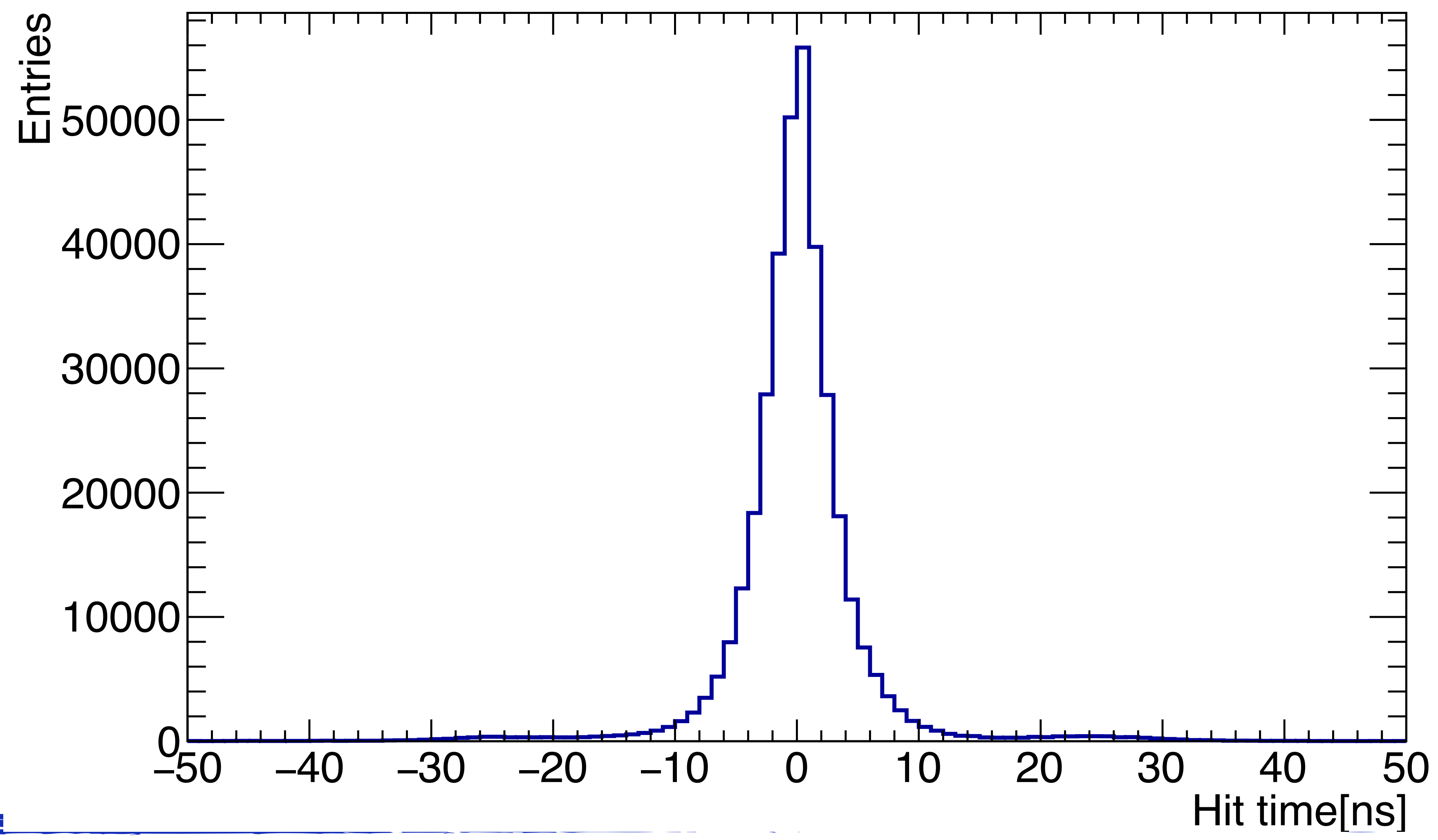
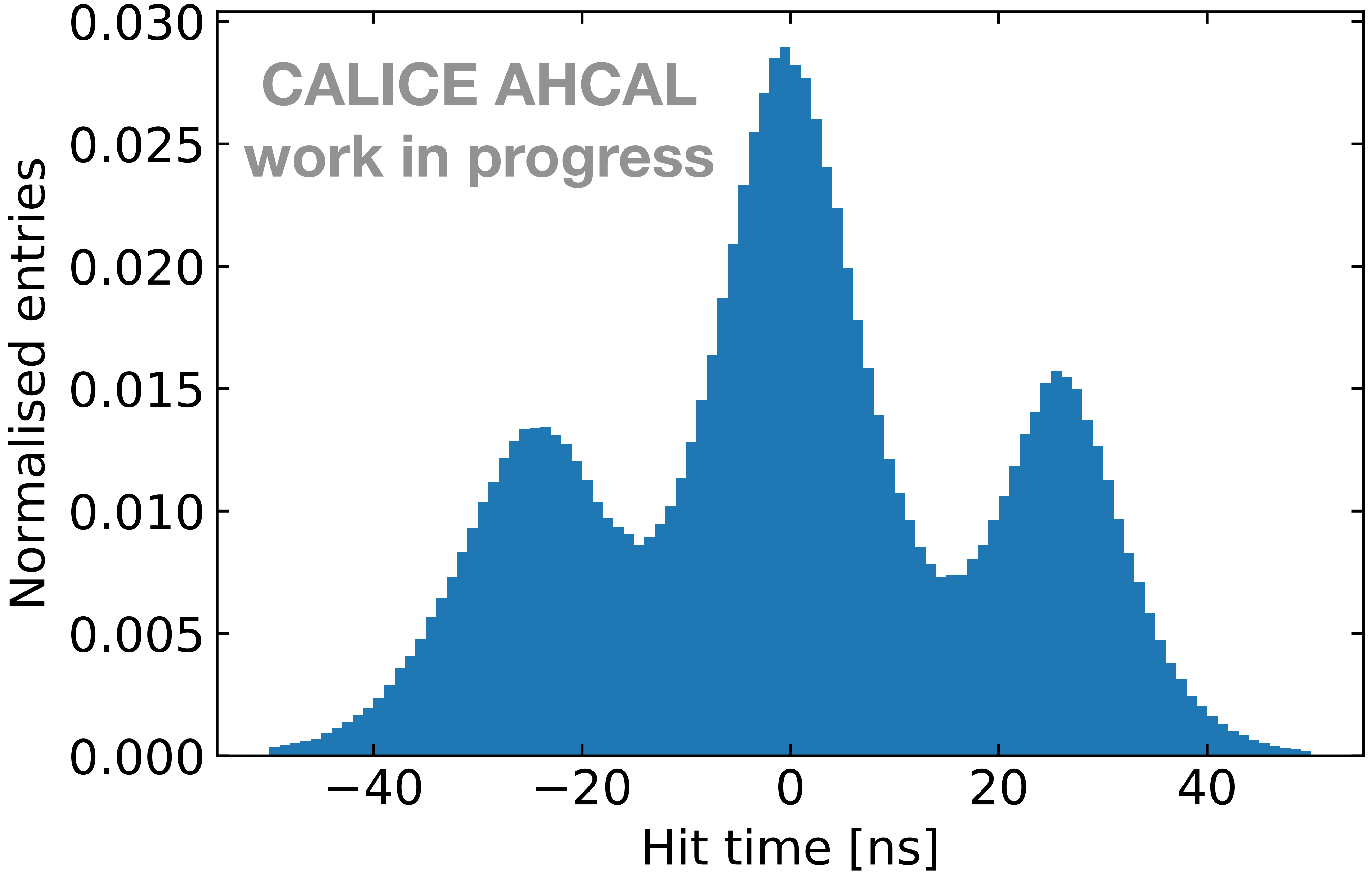
Hit time distribution





Corrections



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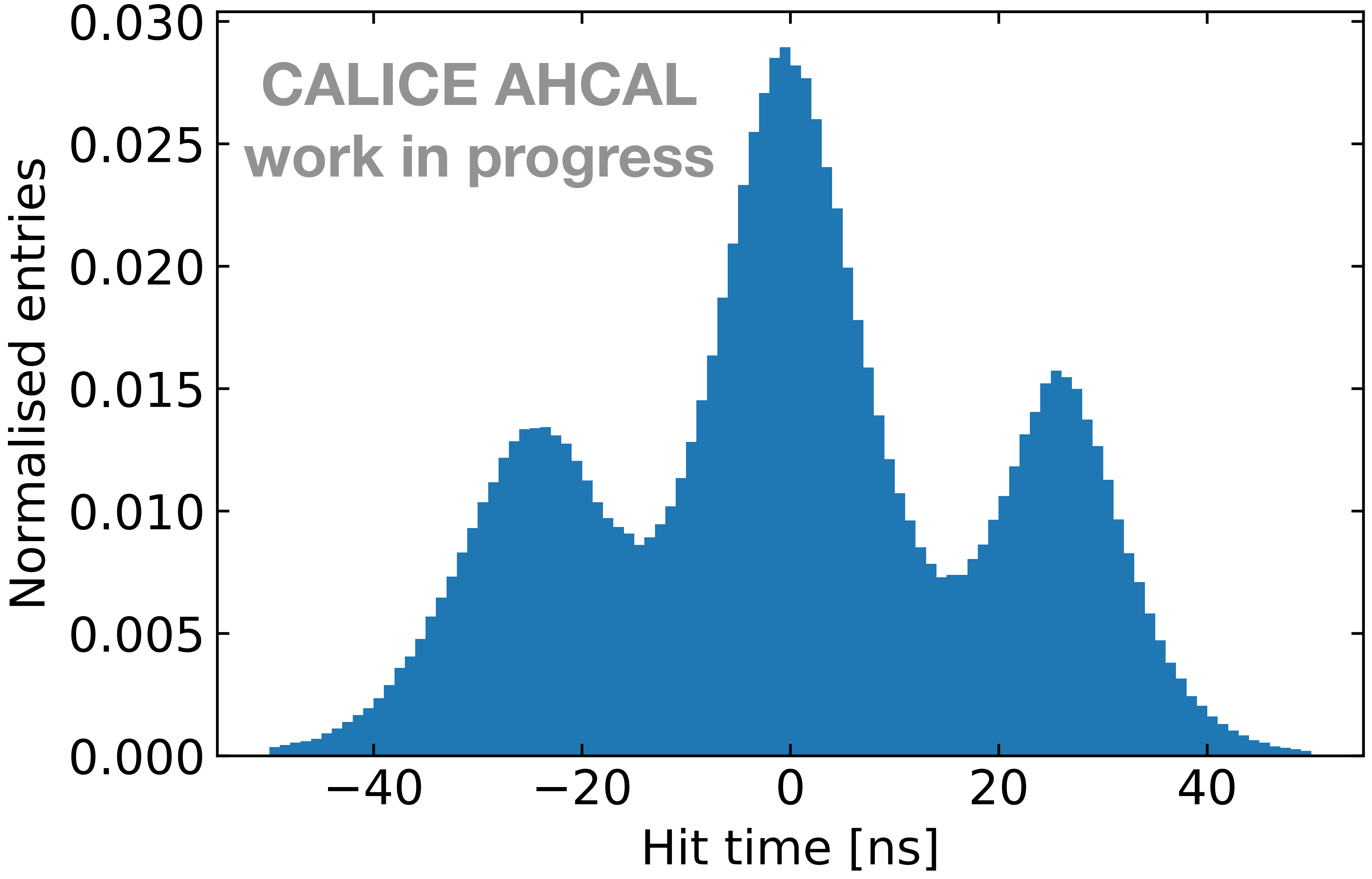

Satellite peaks related to ASIC state at the end of a readout cycle:

- Extracted from EUDAQ raw file
- Calibration constants for each possible state, depending on bunch crossing parity

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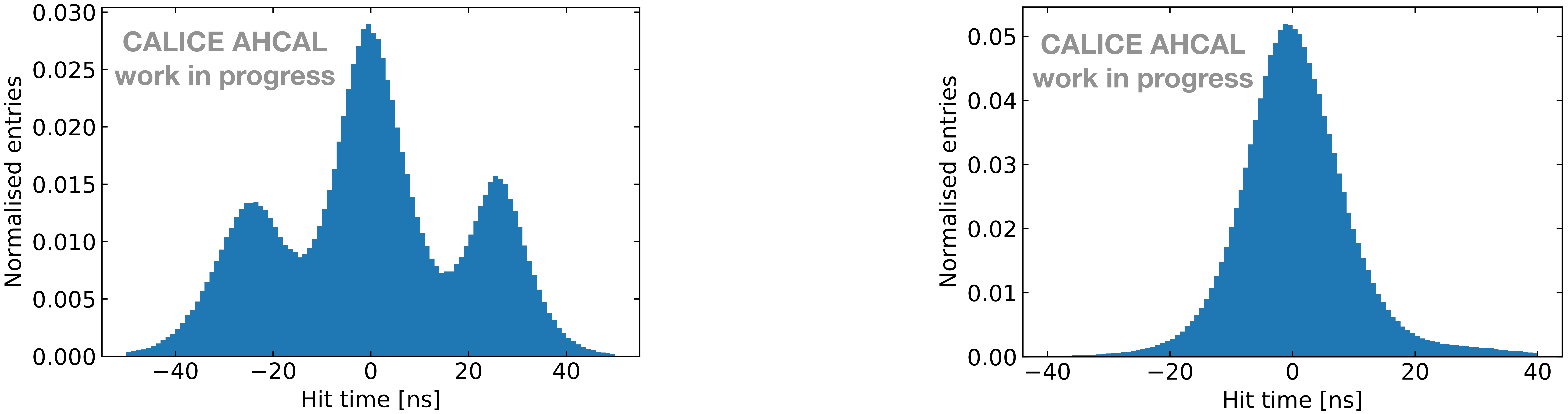

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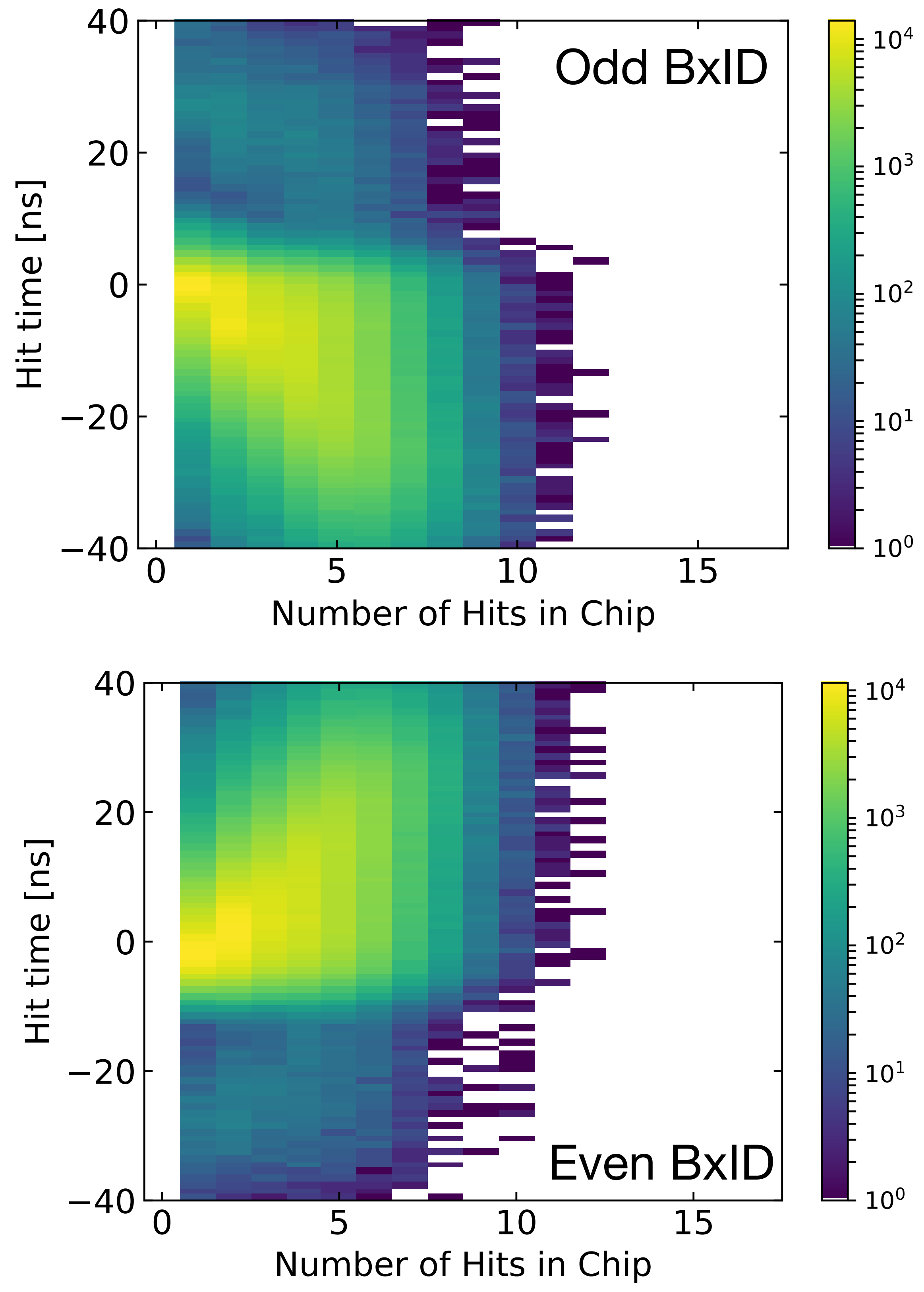

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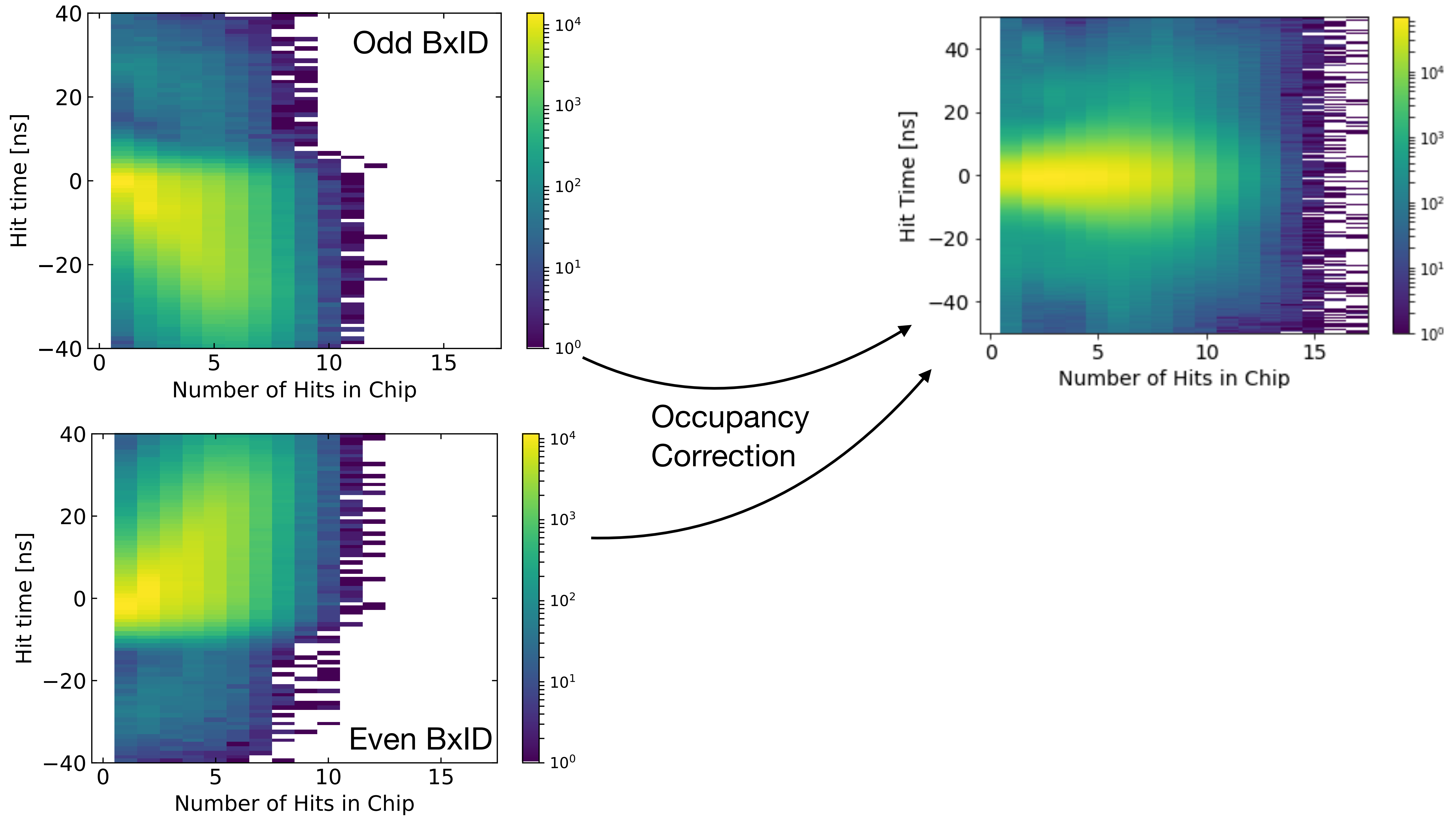

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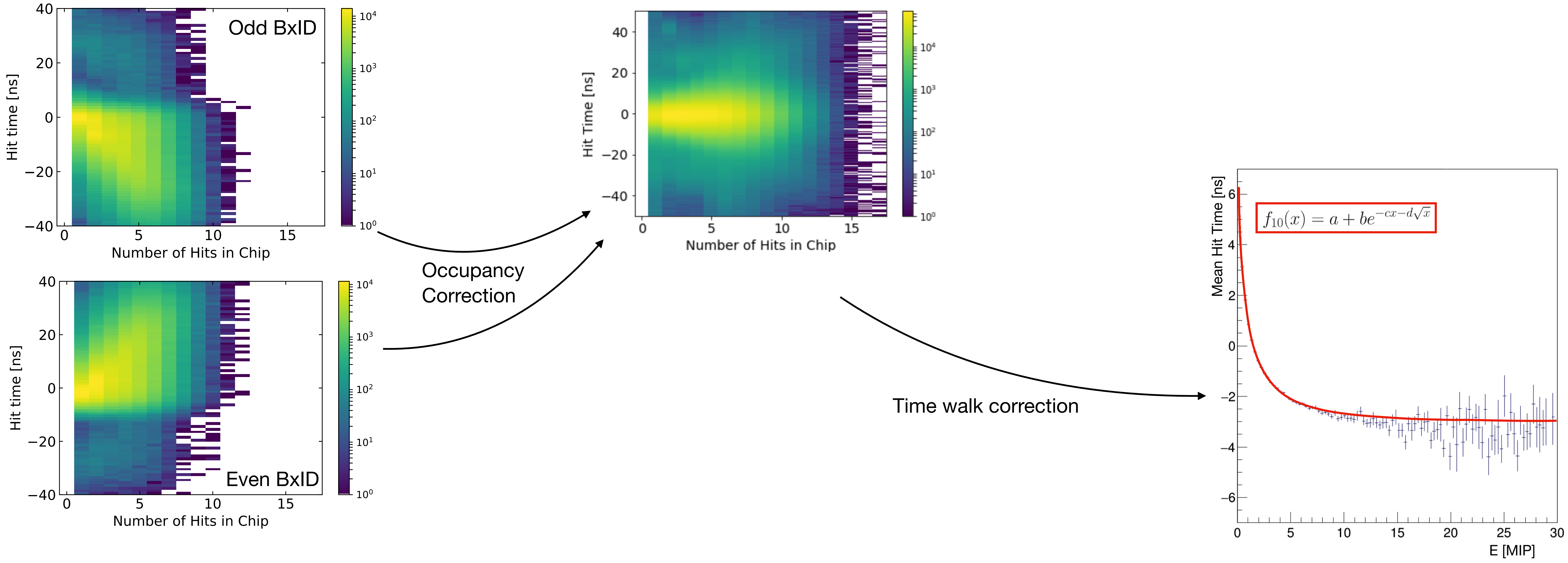

Single Channel Time Resolution

Reconstructed hit times include all the effects in the readout chain:

- Trigger resolution (~1 ns for BIF Trigger)
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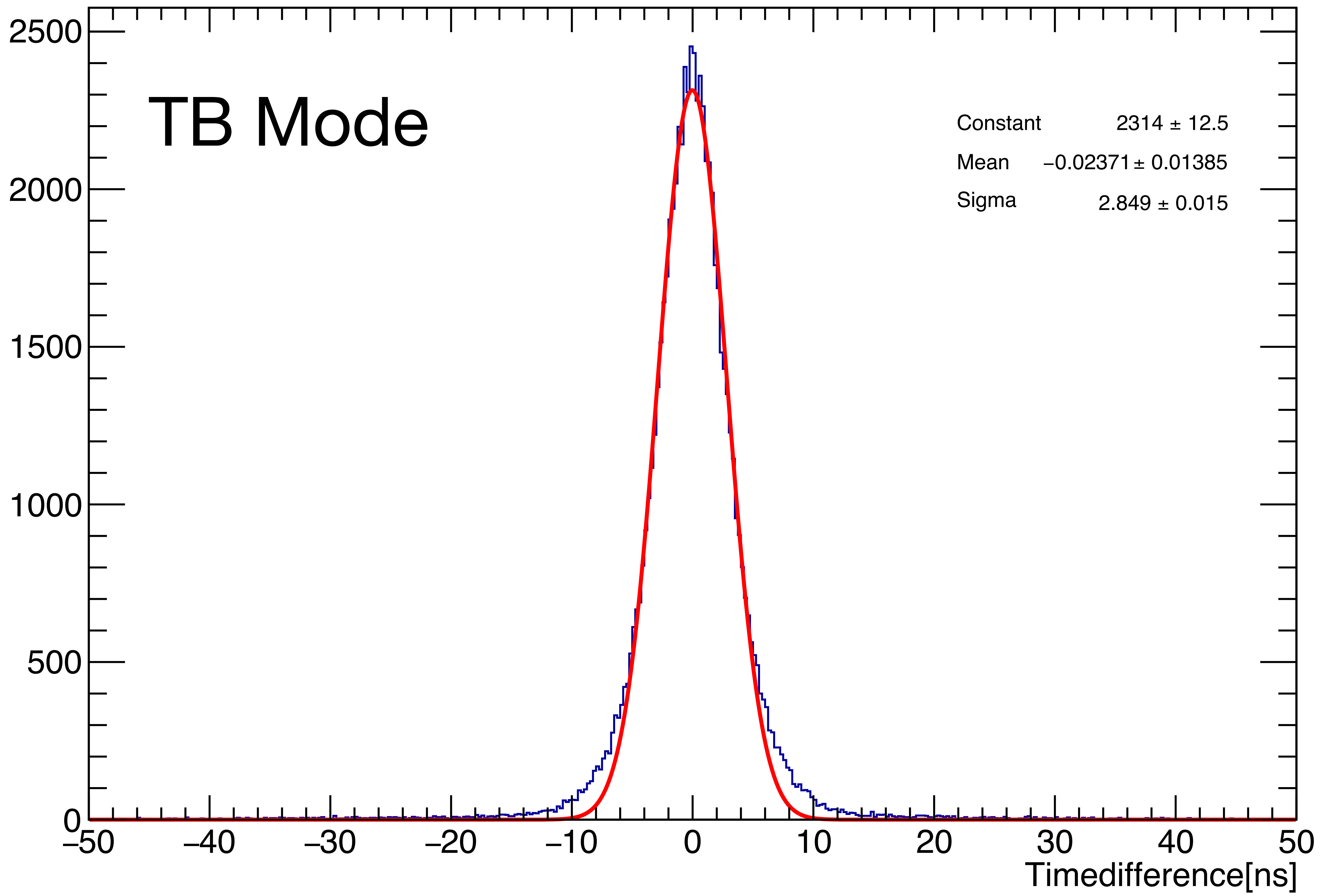
Bunch clock speed: 250kHz
Bunch crossing length: 4000ns

Bunch clock speed: 5MHz
Bunch crossing length: 200ns

Single Channel Time Resolution



Single channel resolution: 2.859/√2 = 2.014ns

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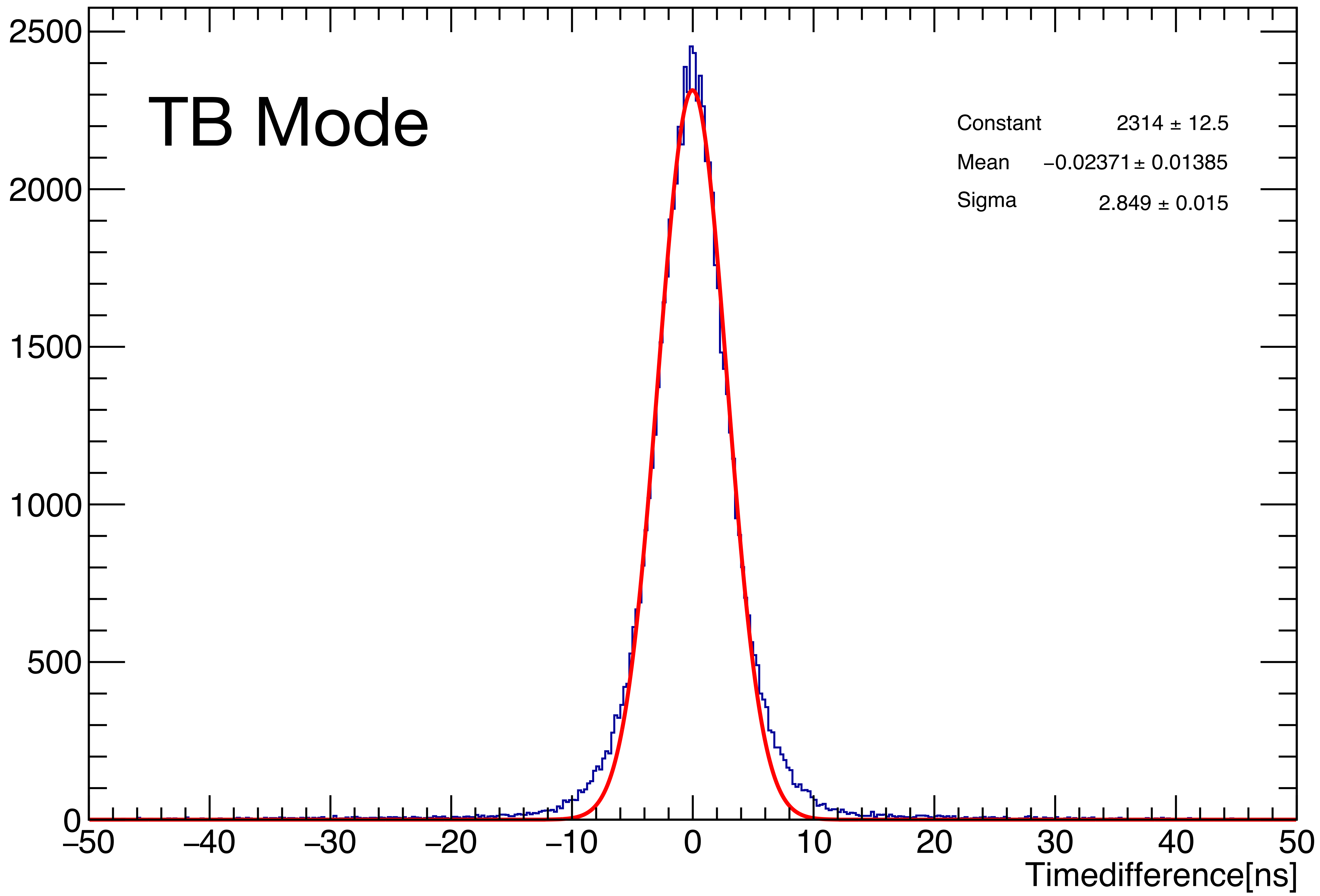

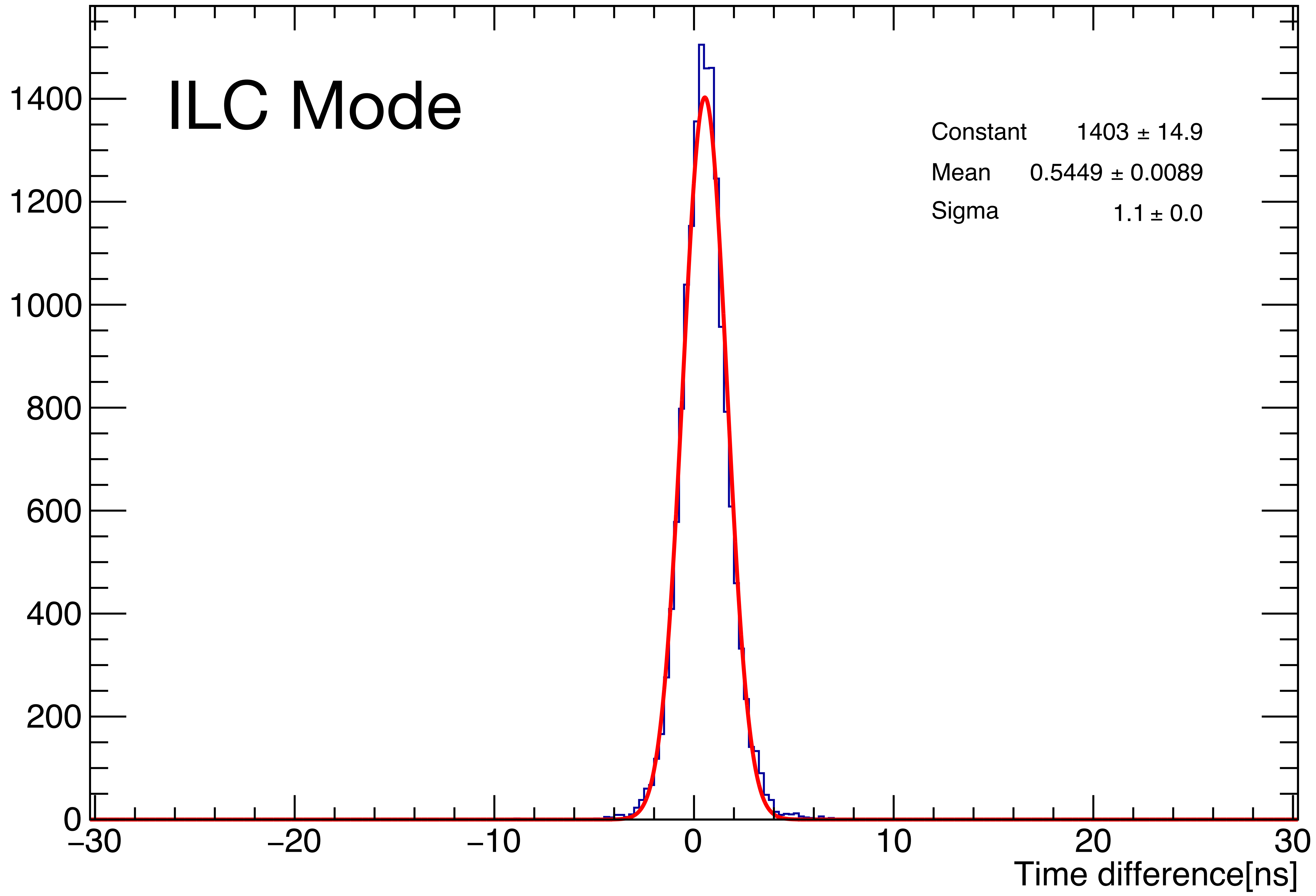

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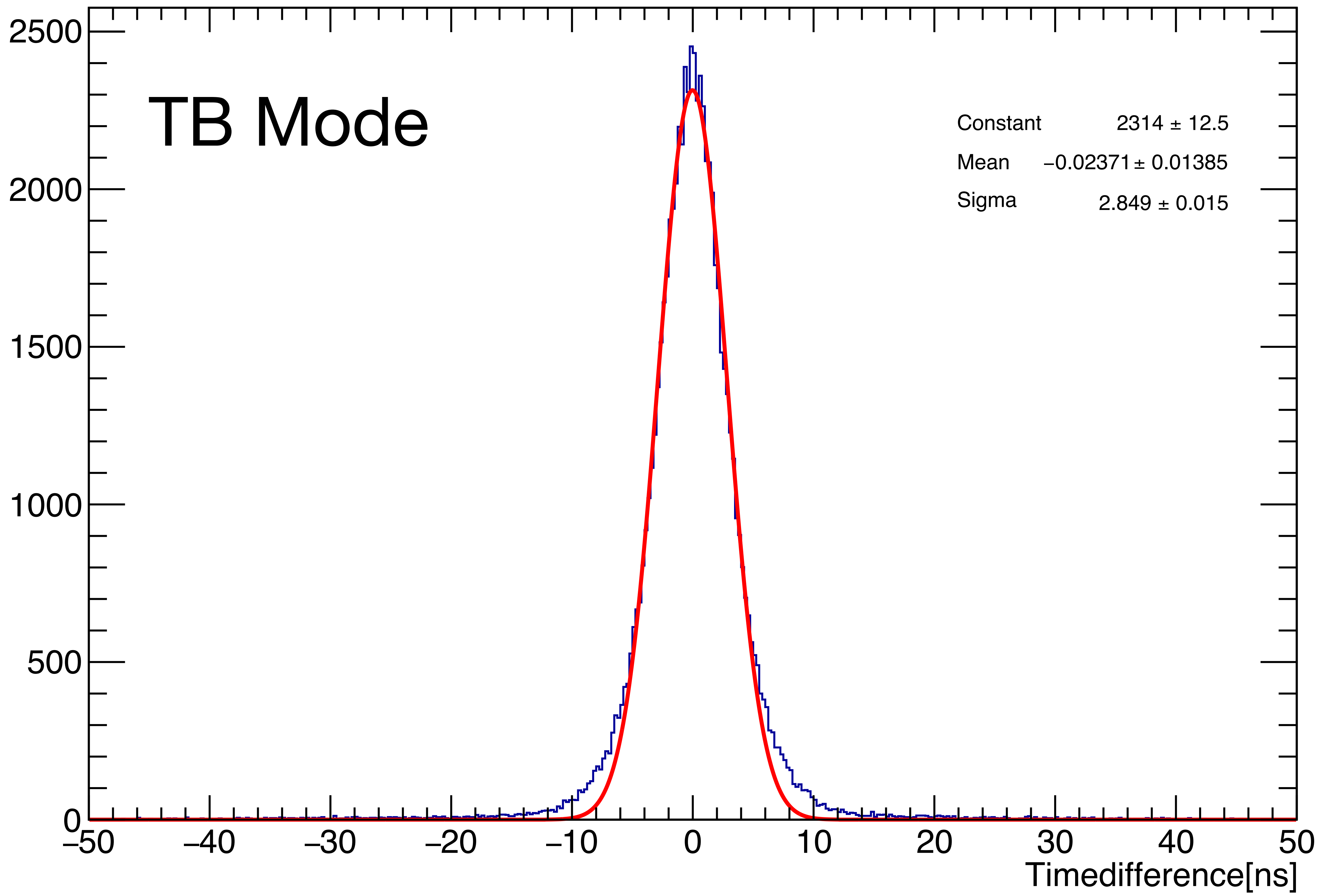

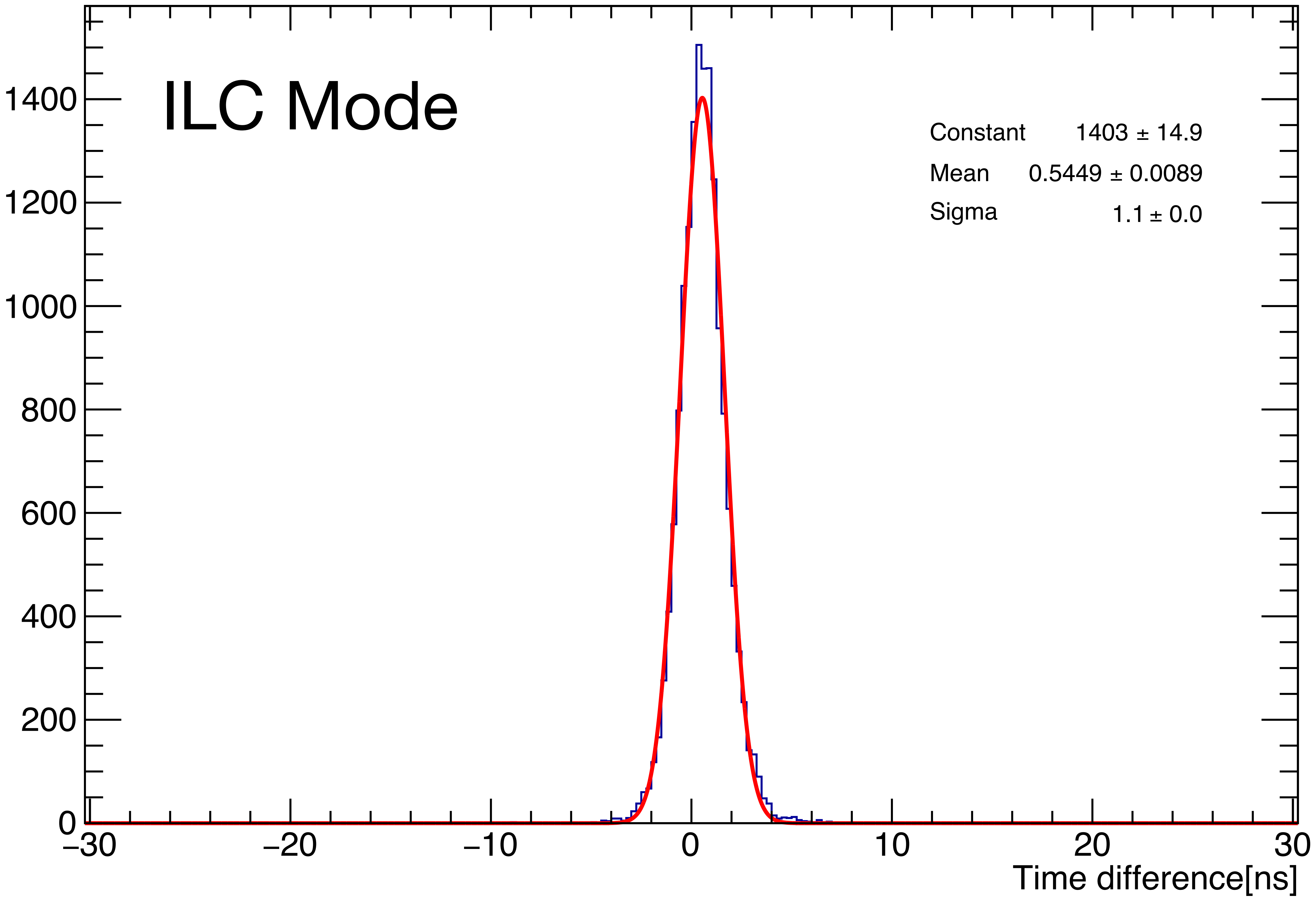

Fit range dependent

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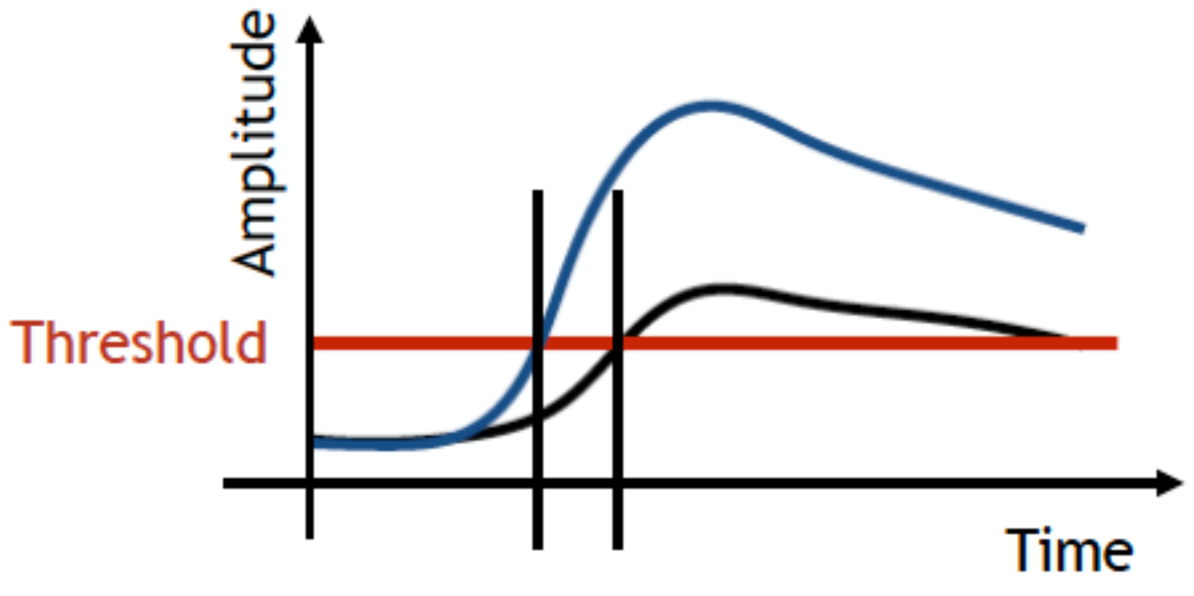
Energy Dependent Time Resolution



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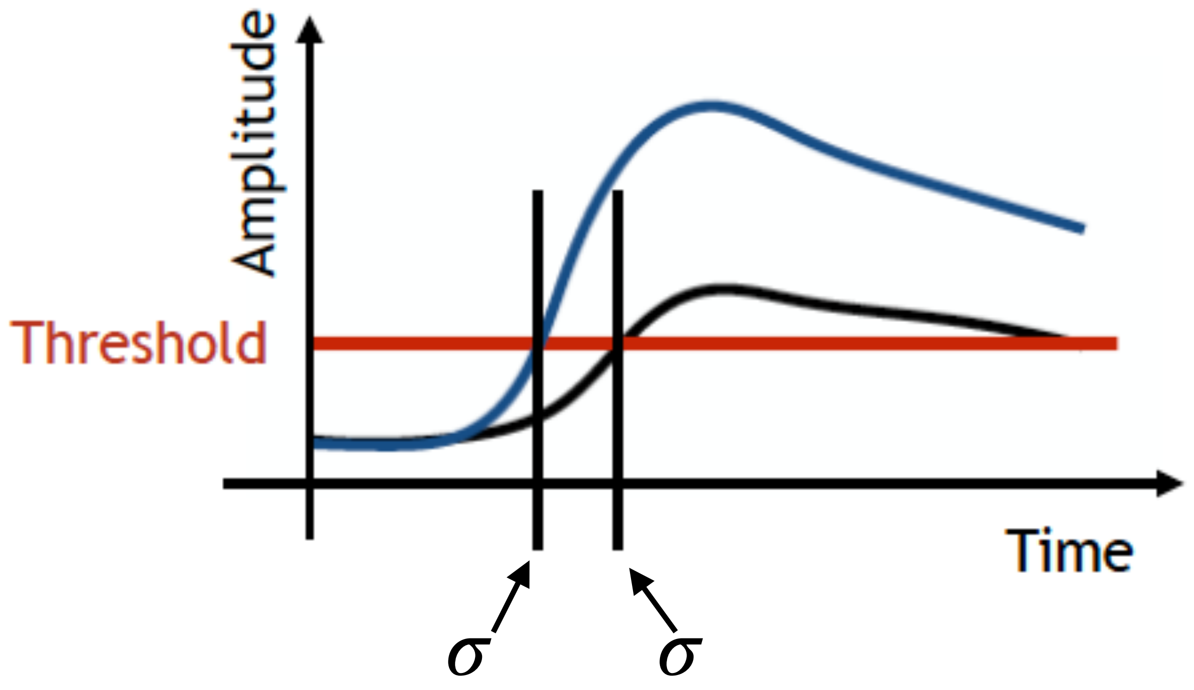

Investigate jitter on crossing of the threshold for same energy

$\Longrightarrow$Toy Monte Carlo

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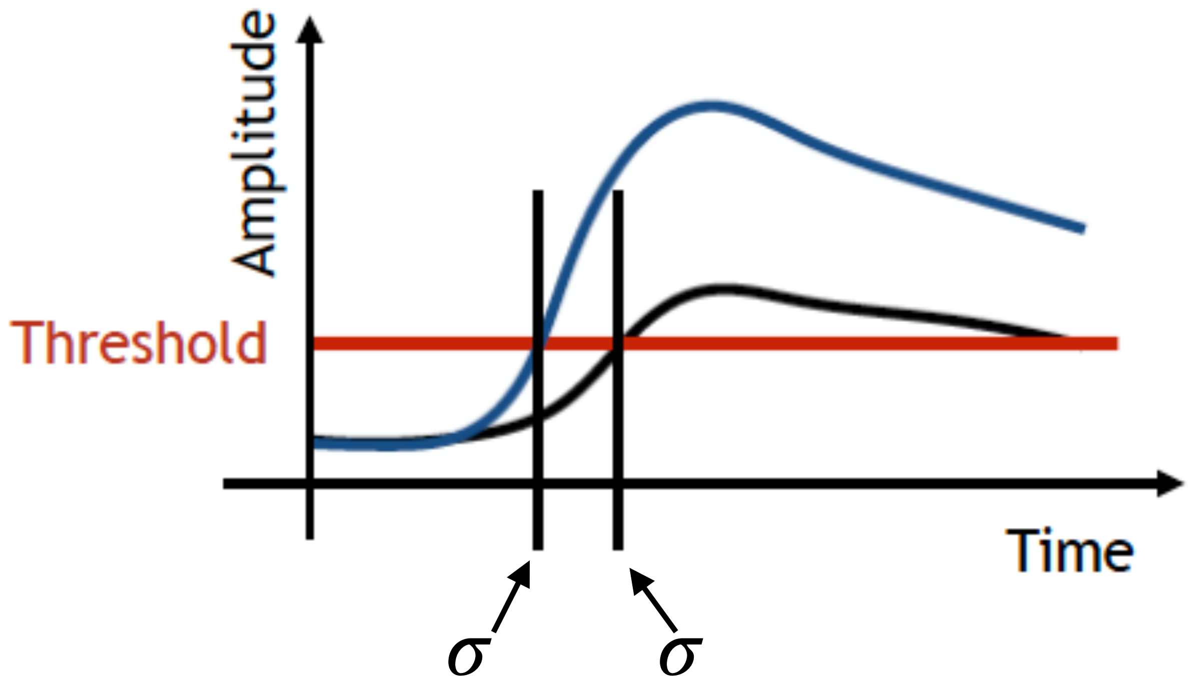

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- Energies=[5pe, 10pe, 15pe, …], Threshold = 3pe (for example)

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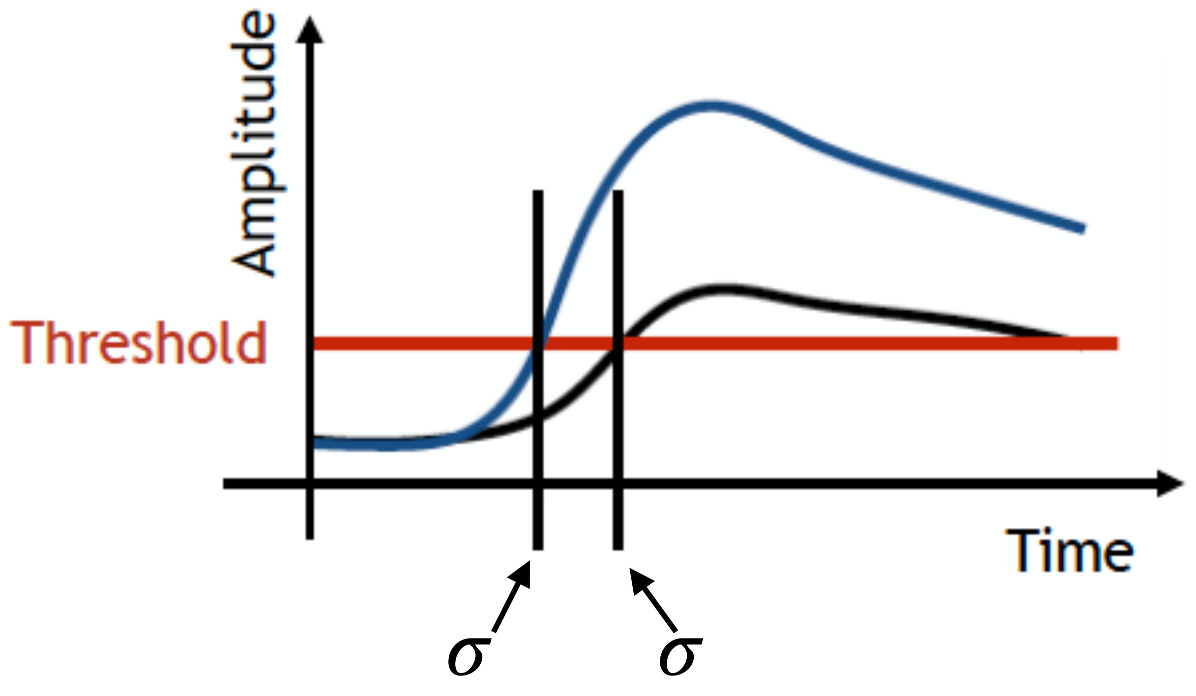

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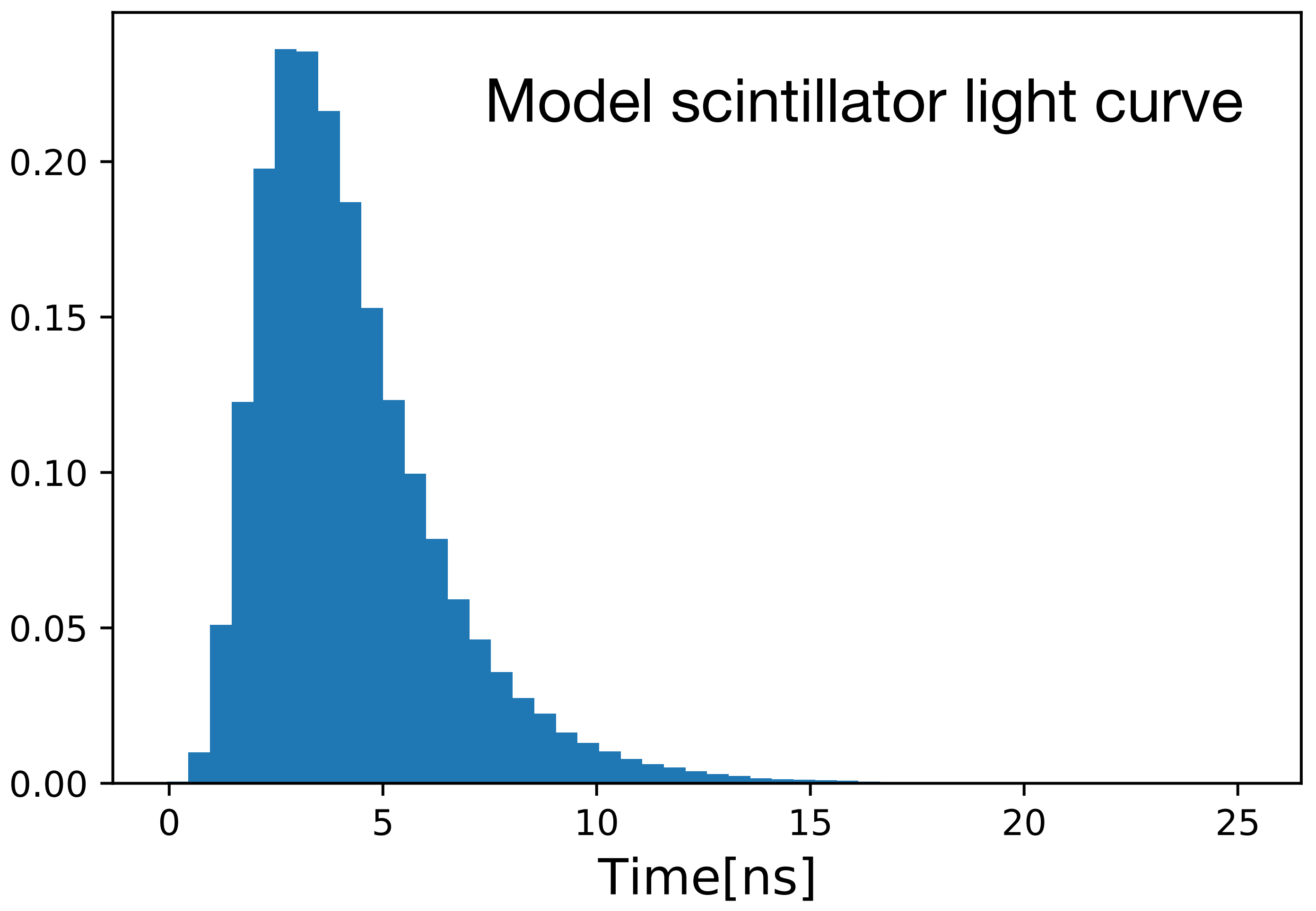

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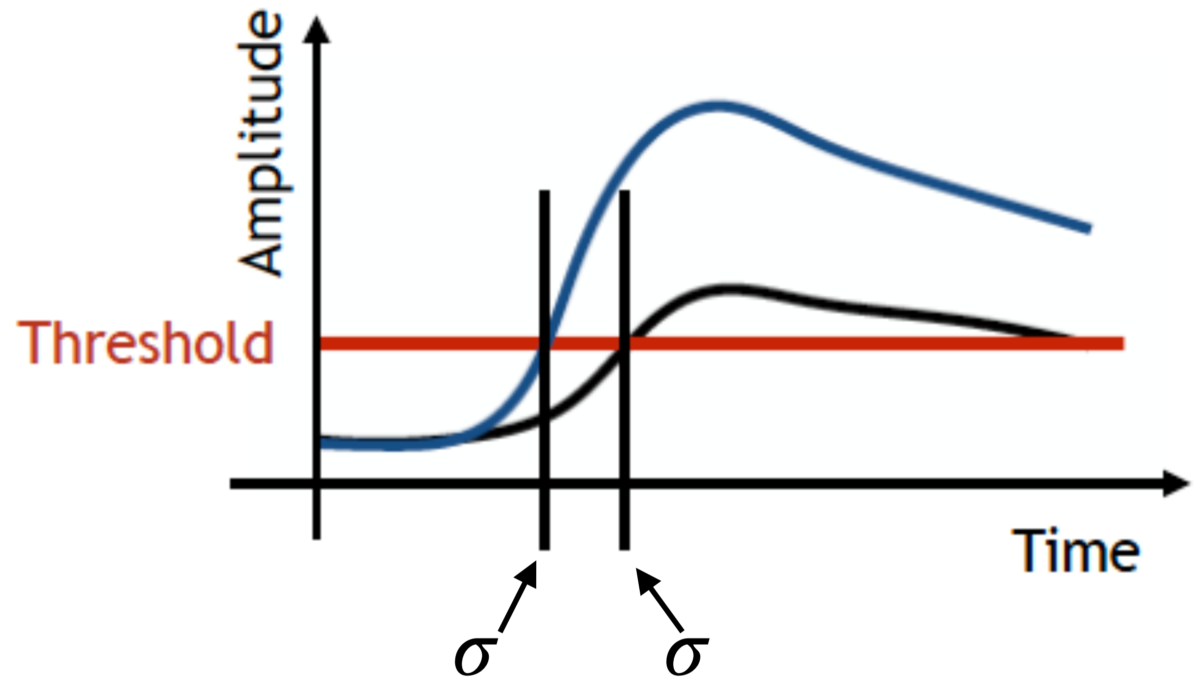

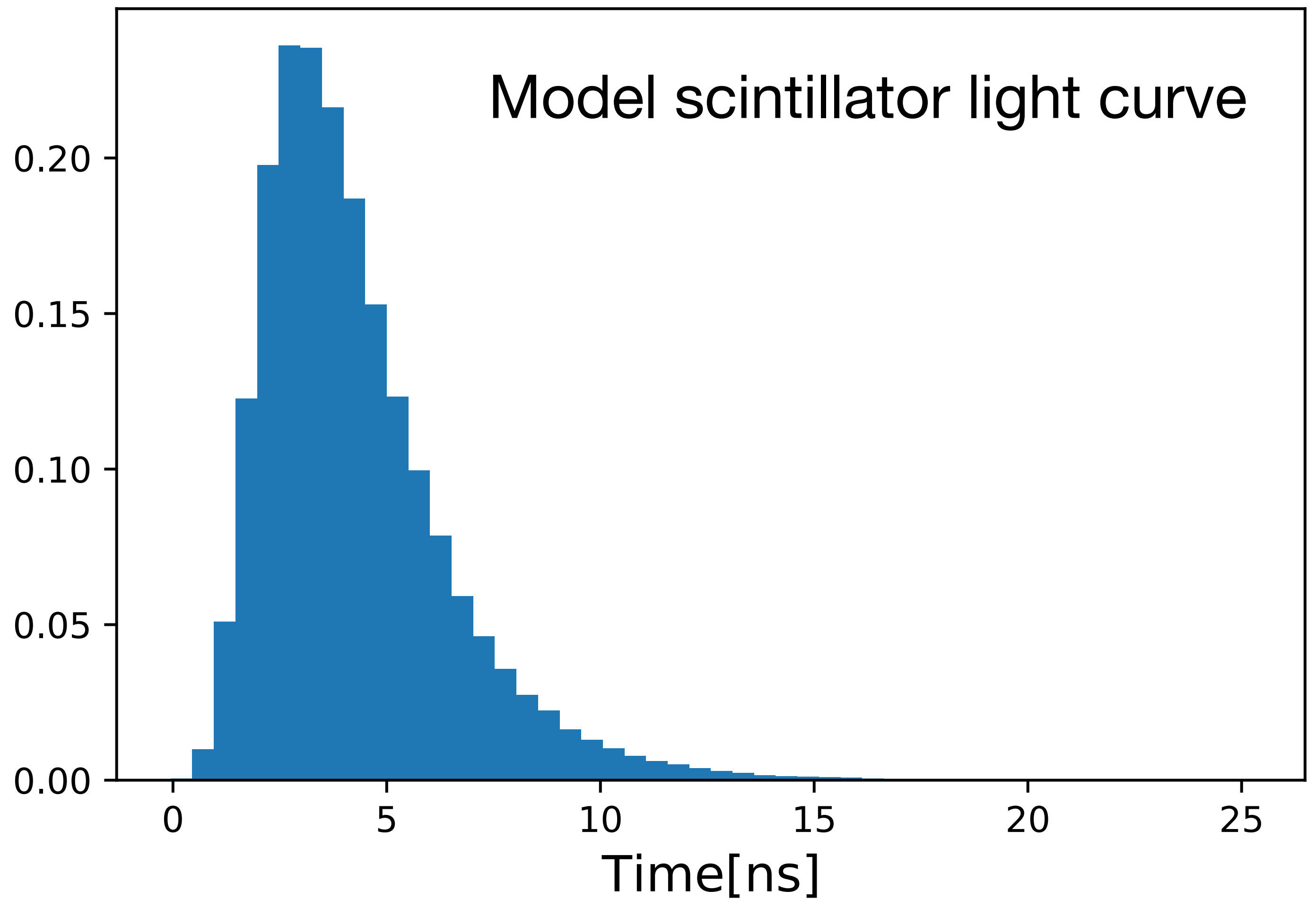

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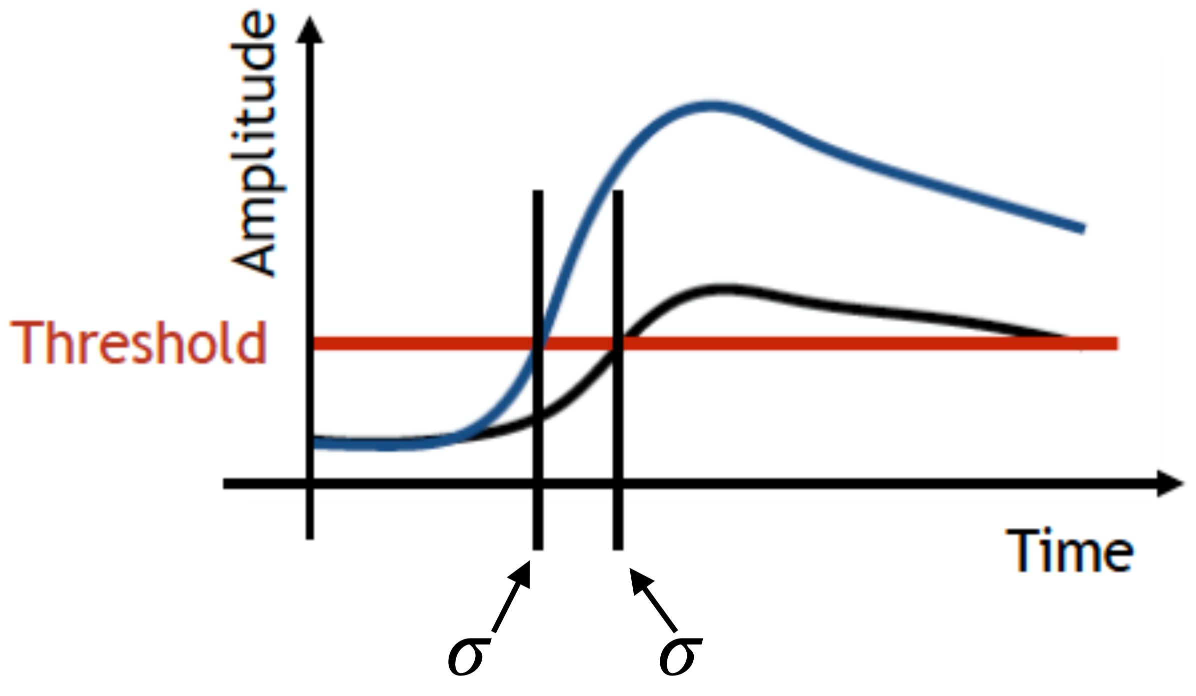

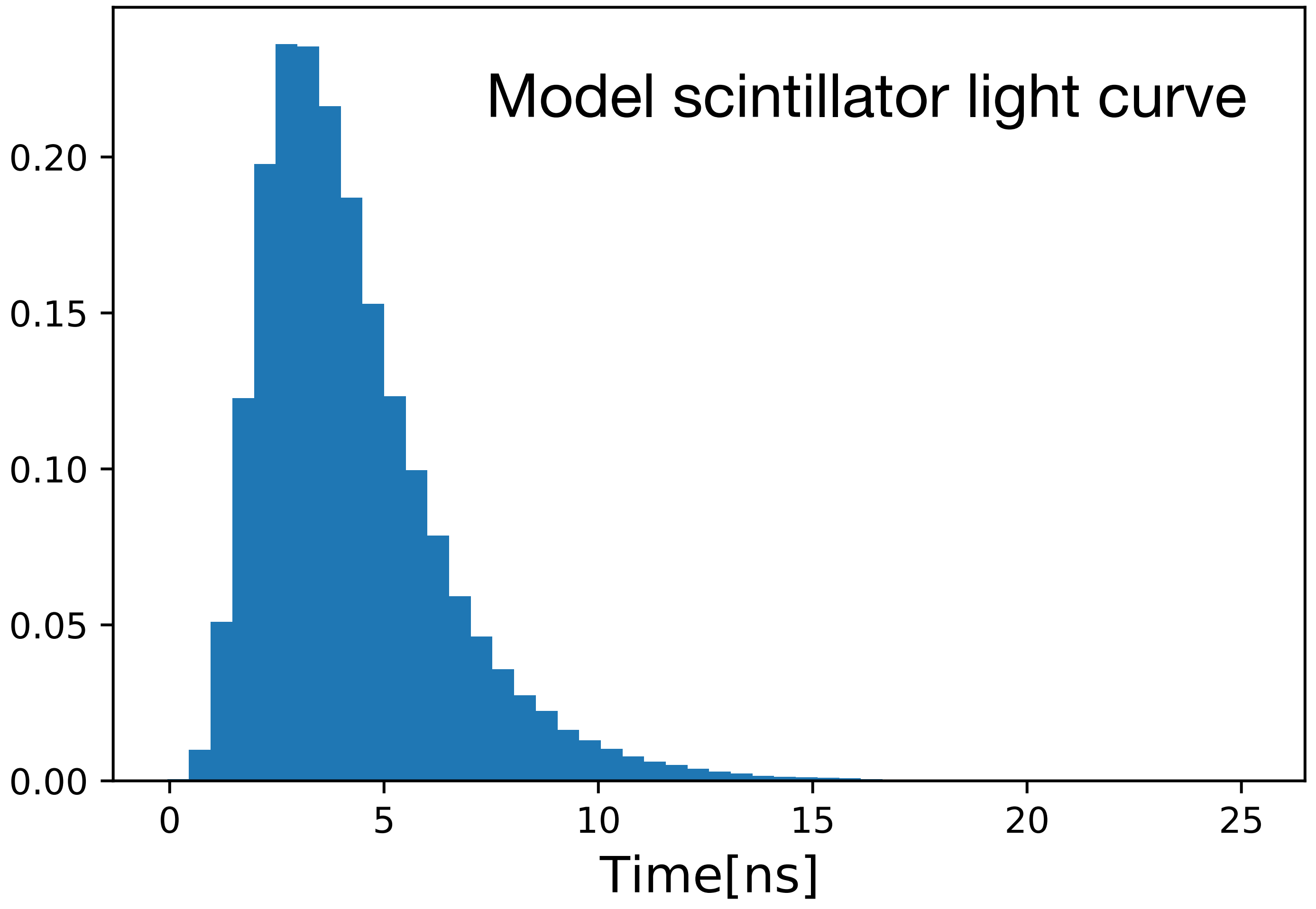

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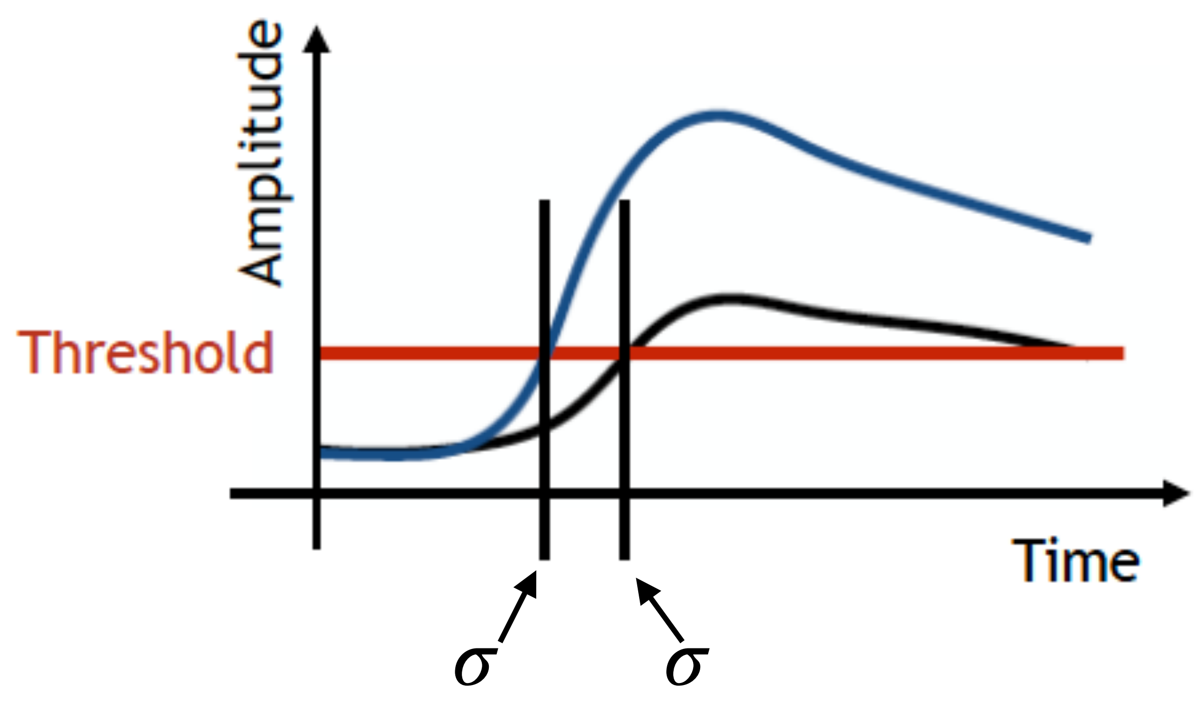

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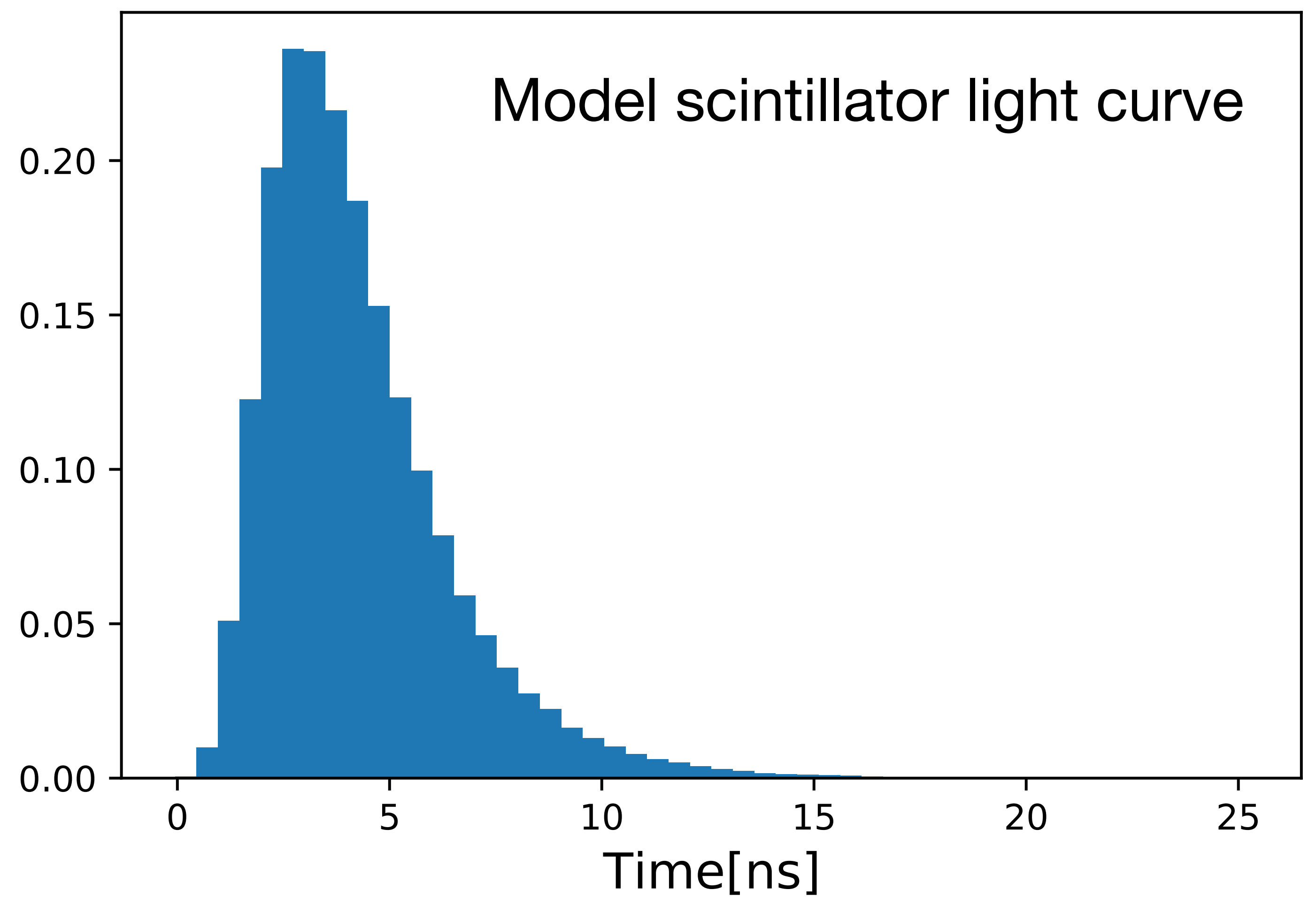

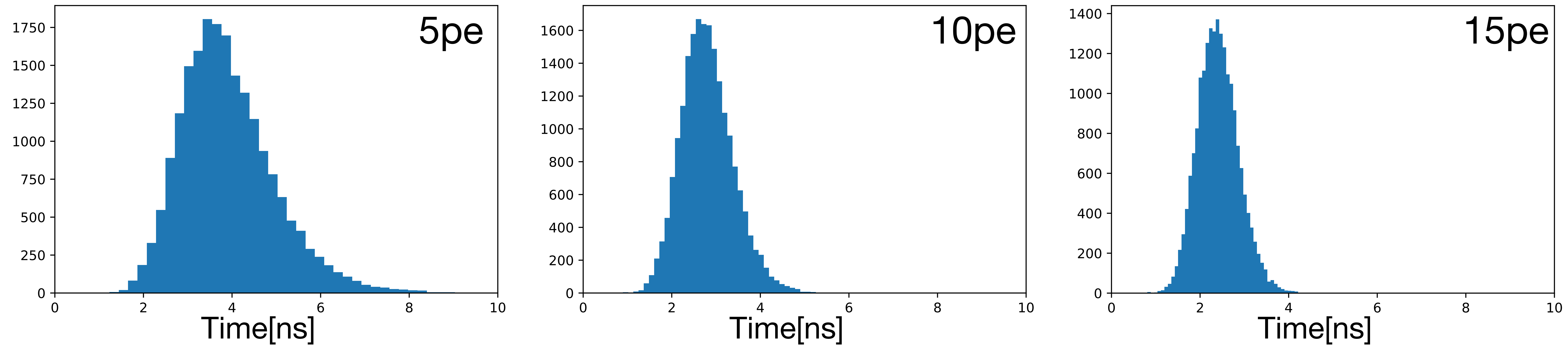

How does the width scale with rising energy ?

Energy Dependent Time Resolution

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Lowest Energy: 7pe

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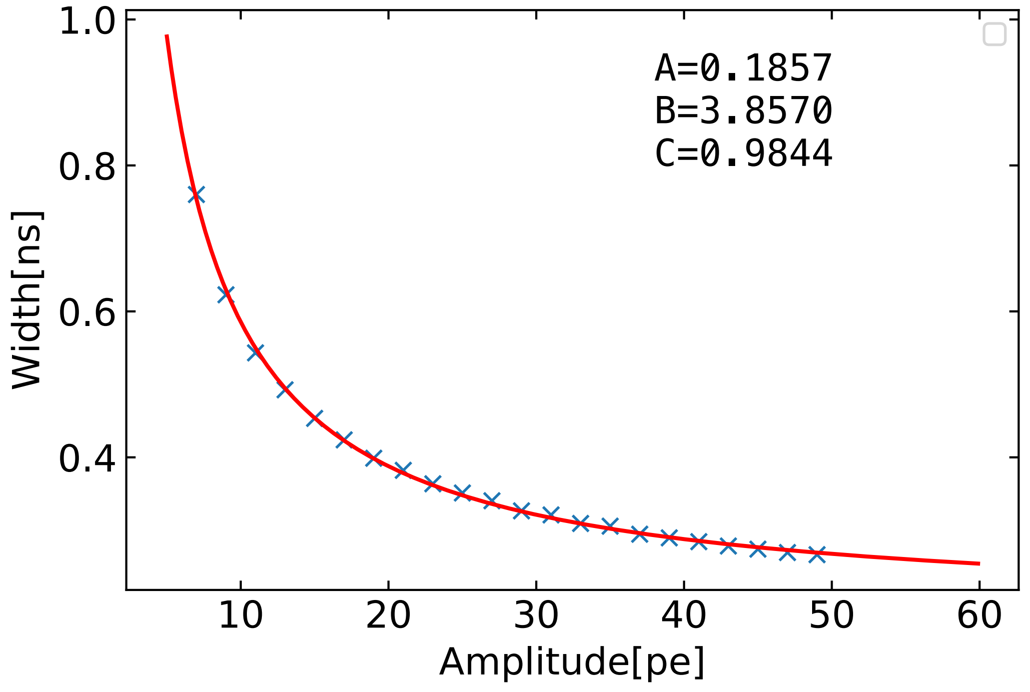

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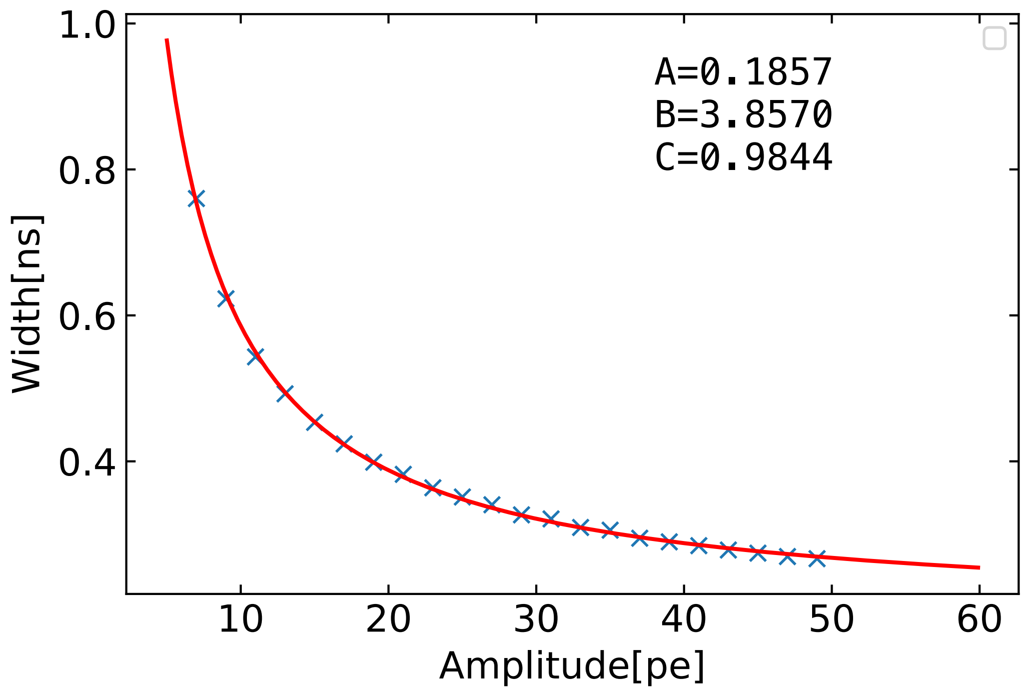

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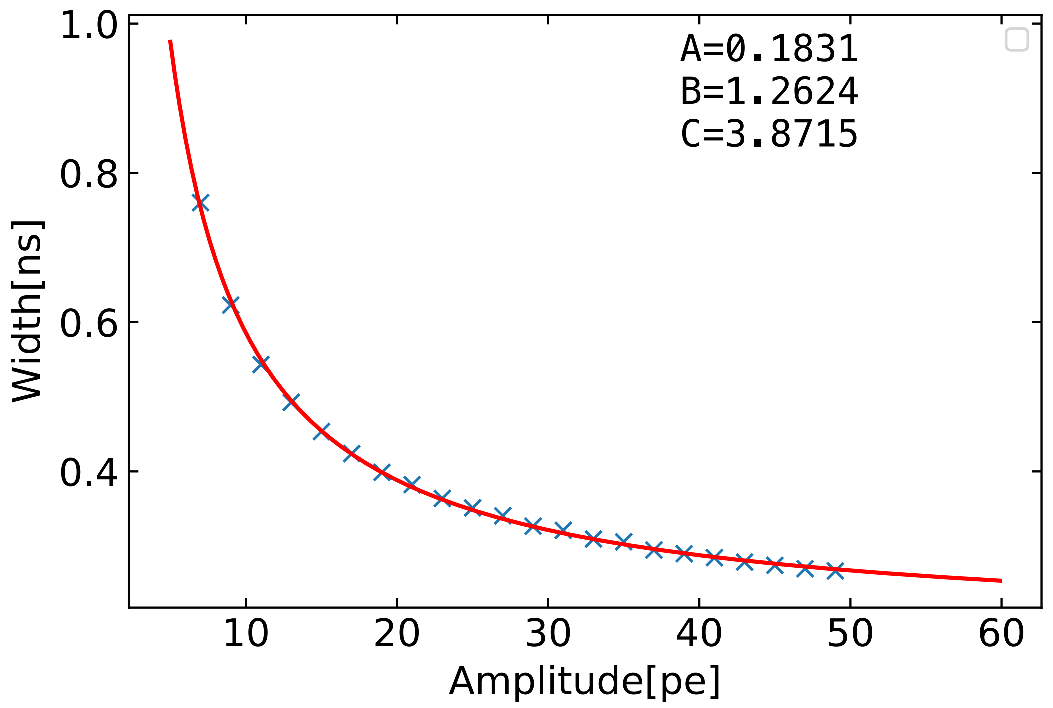

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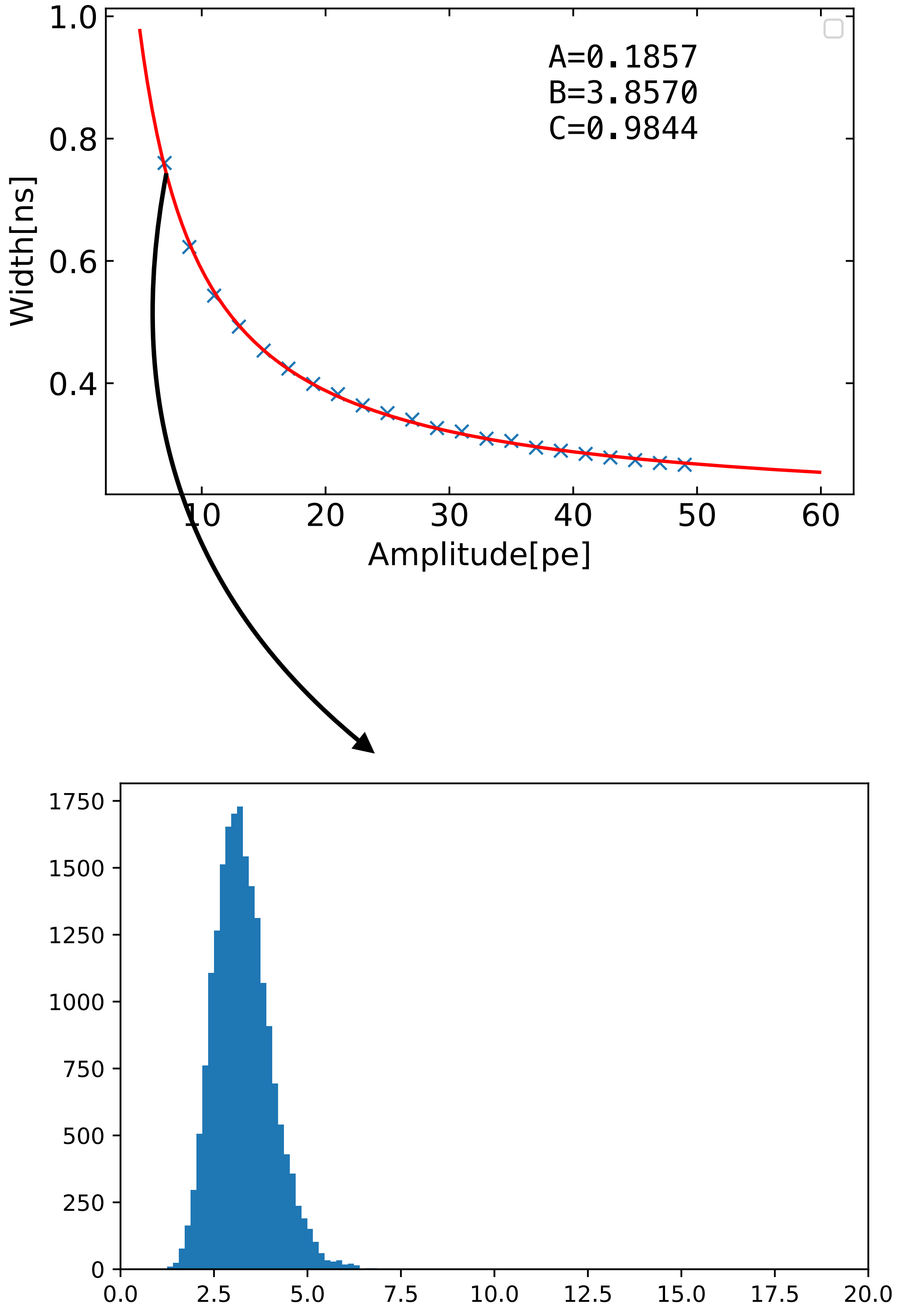

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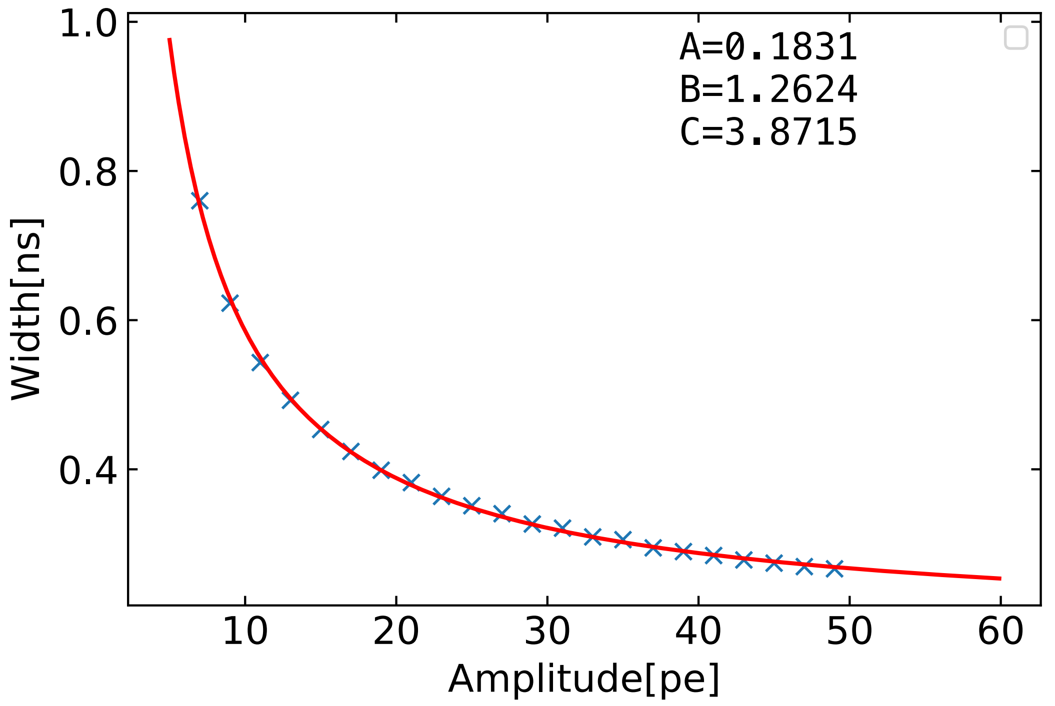

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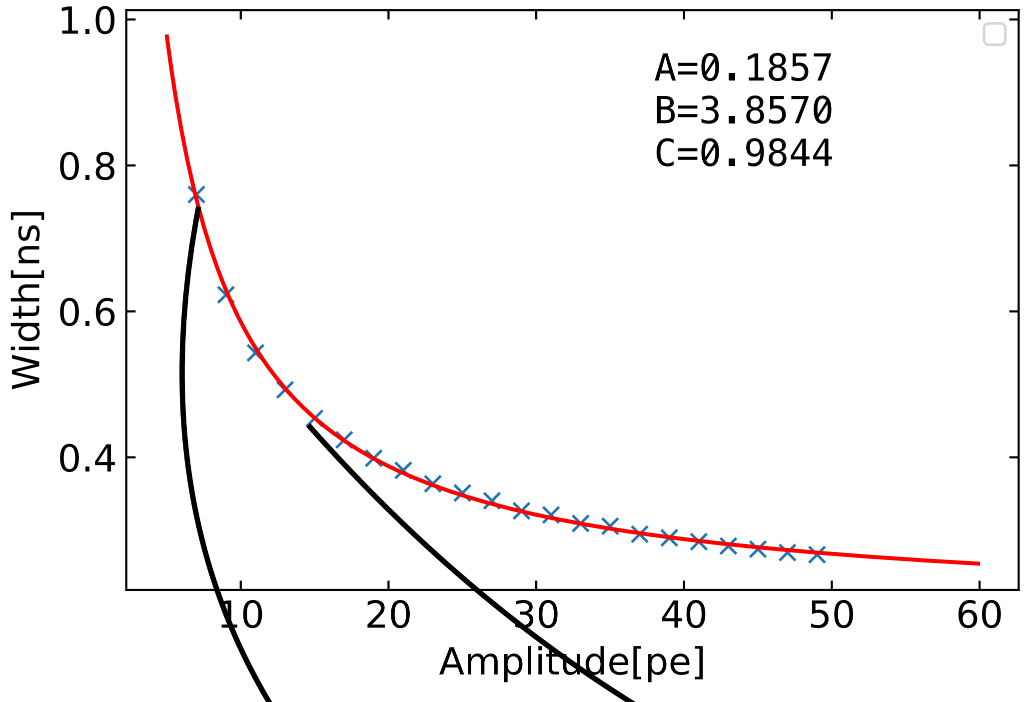

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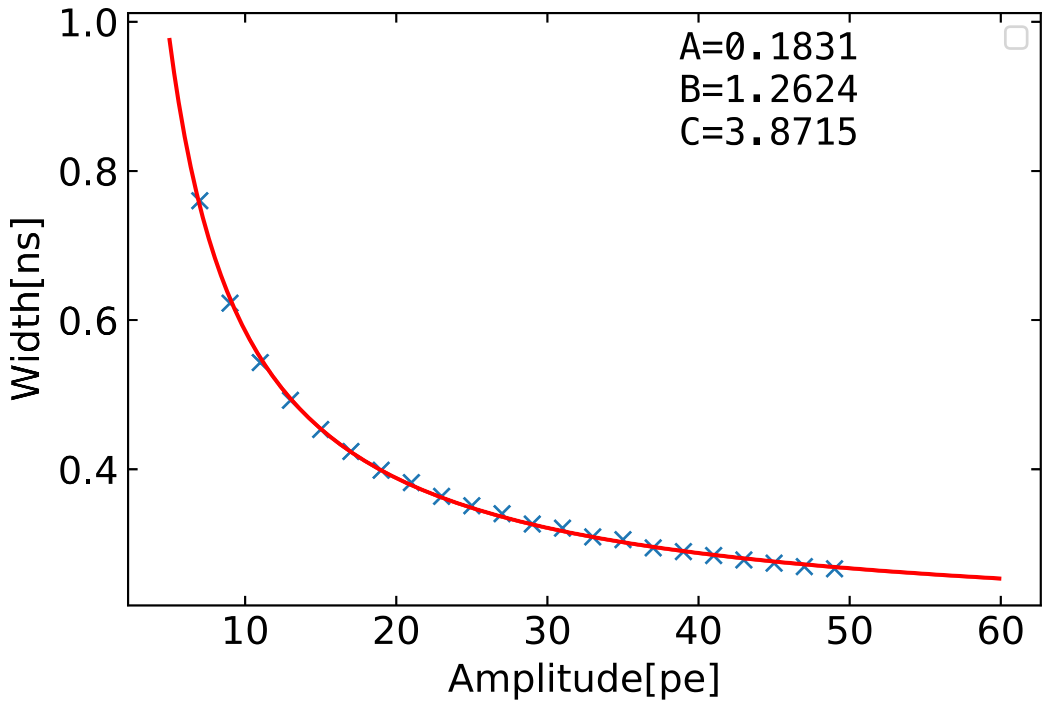

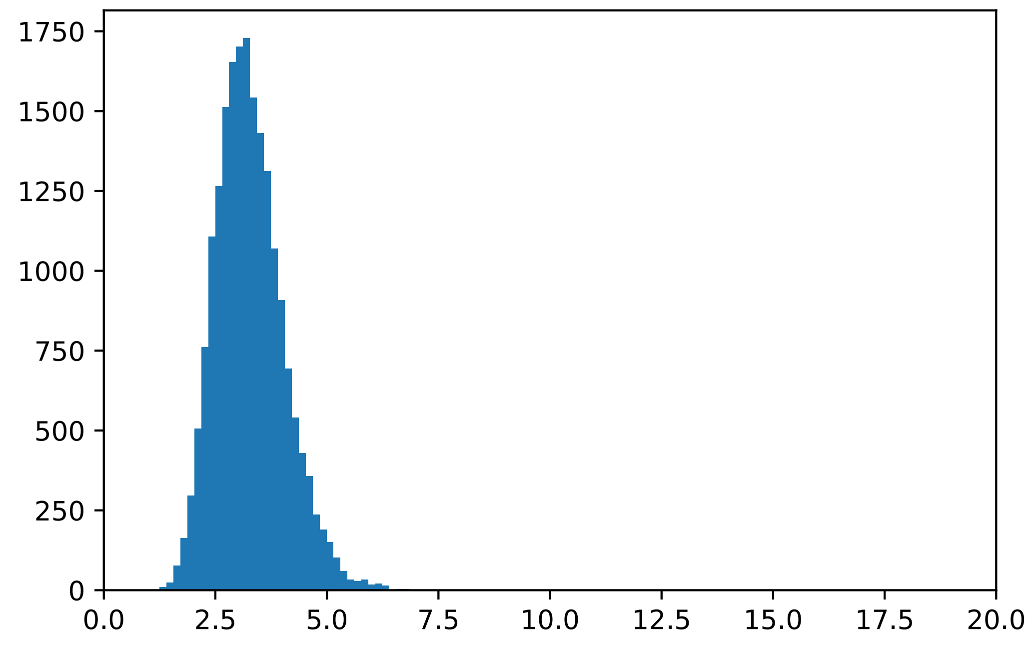

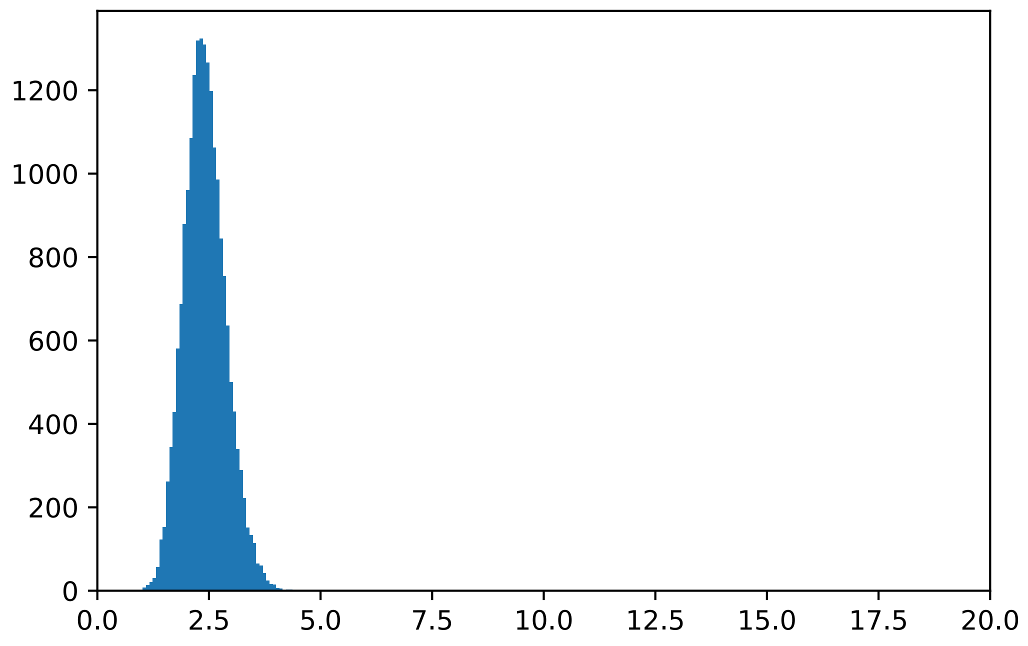

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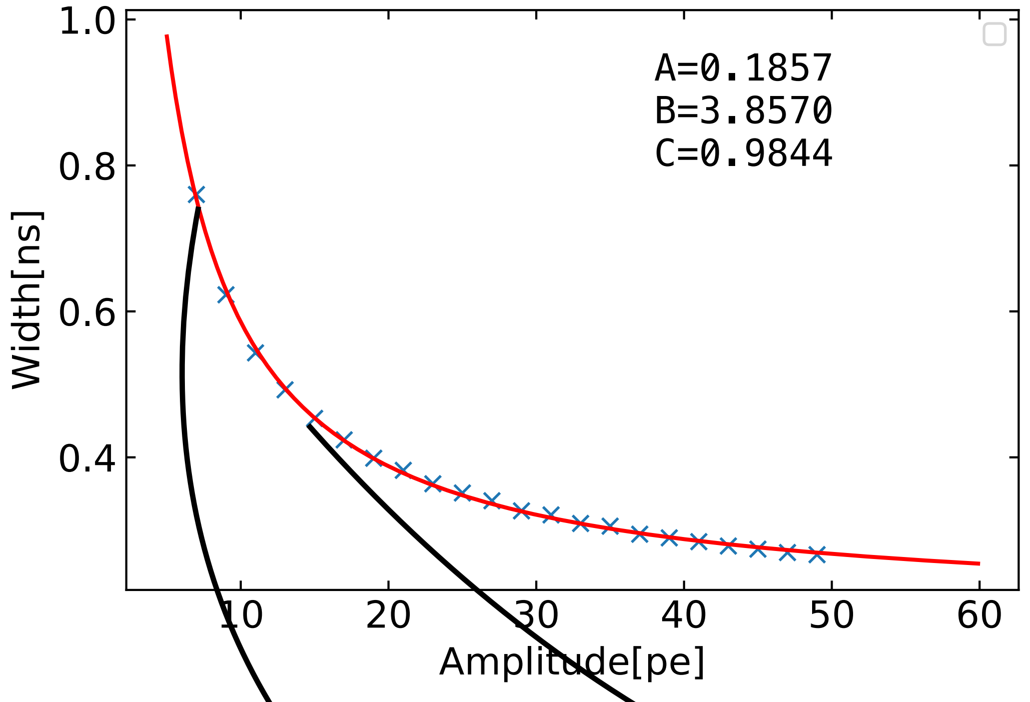

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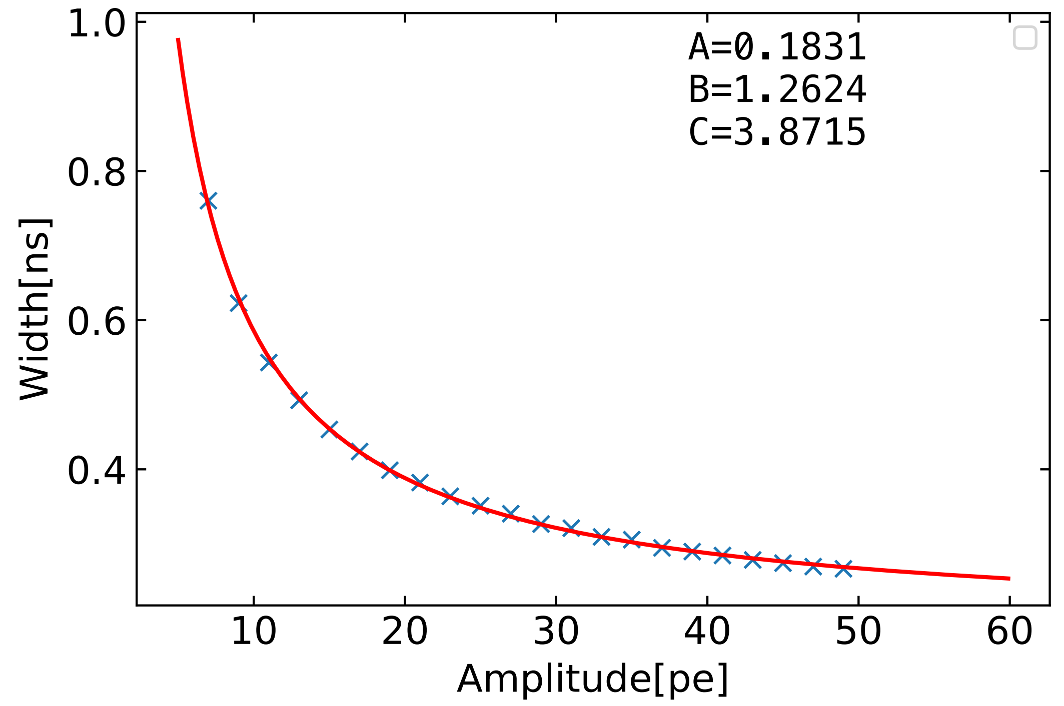

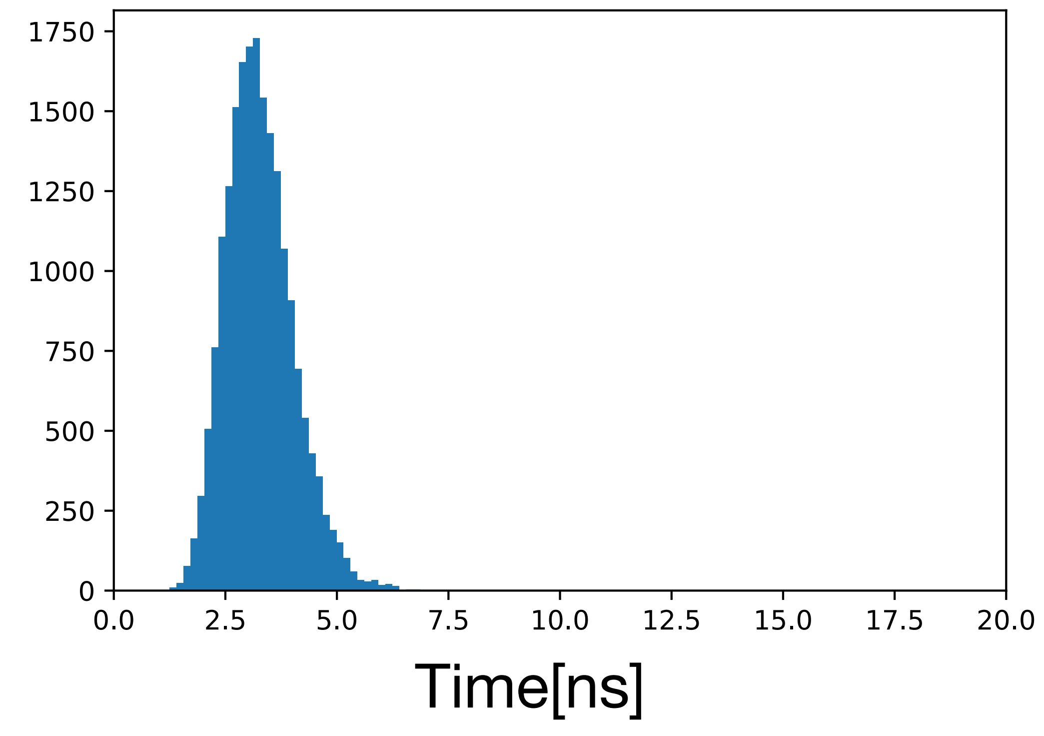

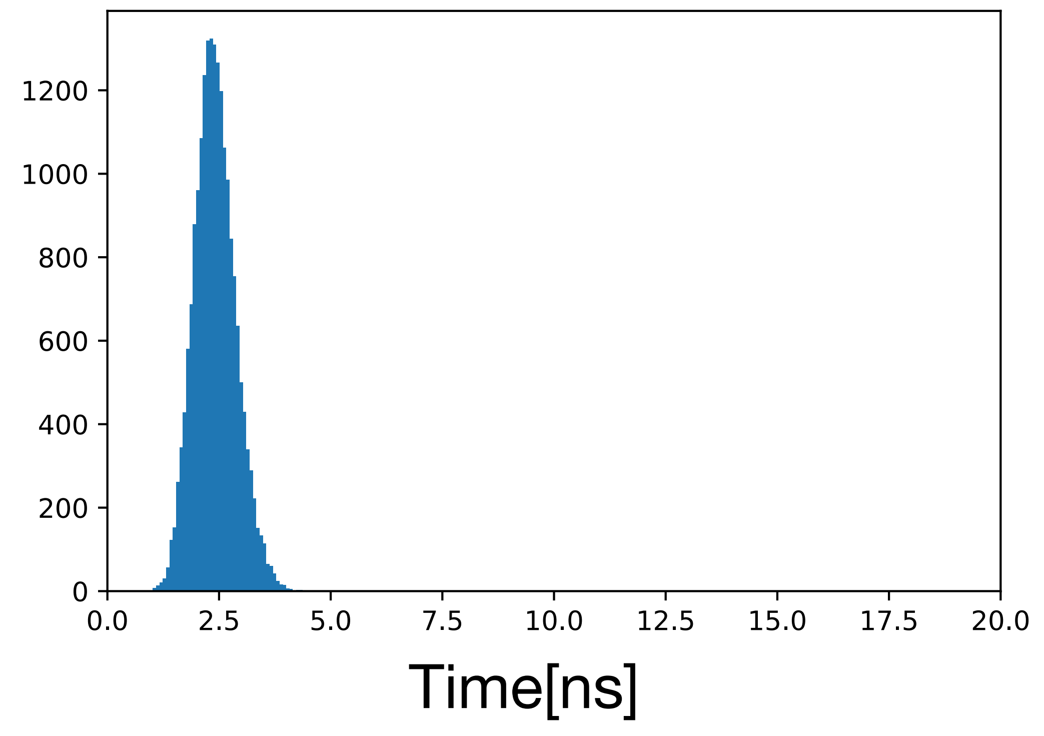

DAQ Threshold: 6pe
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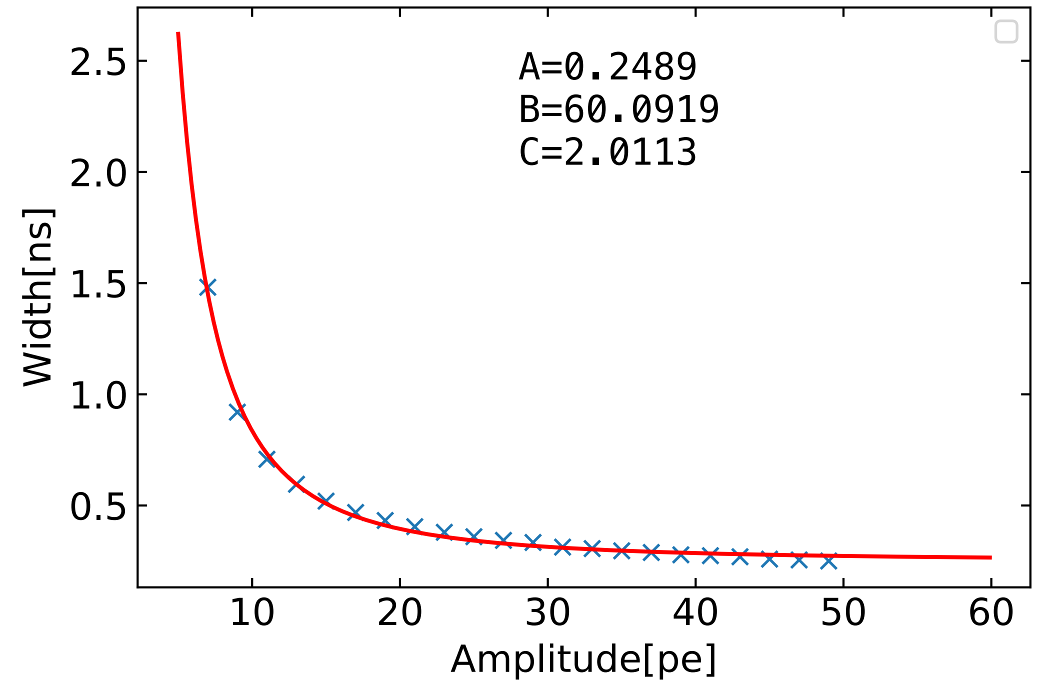

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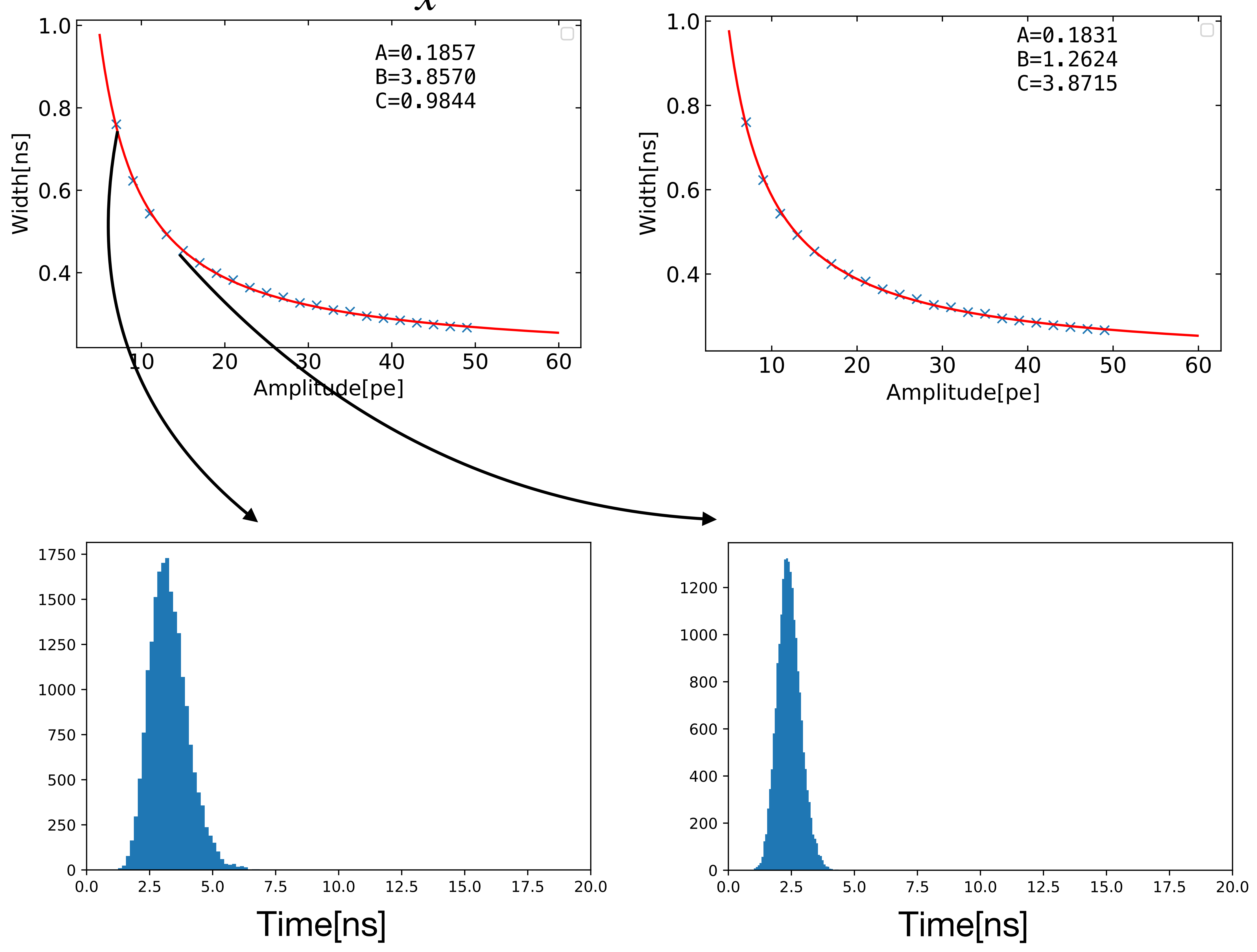

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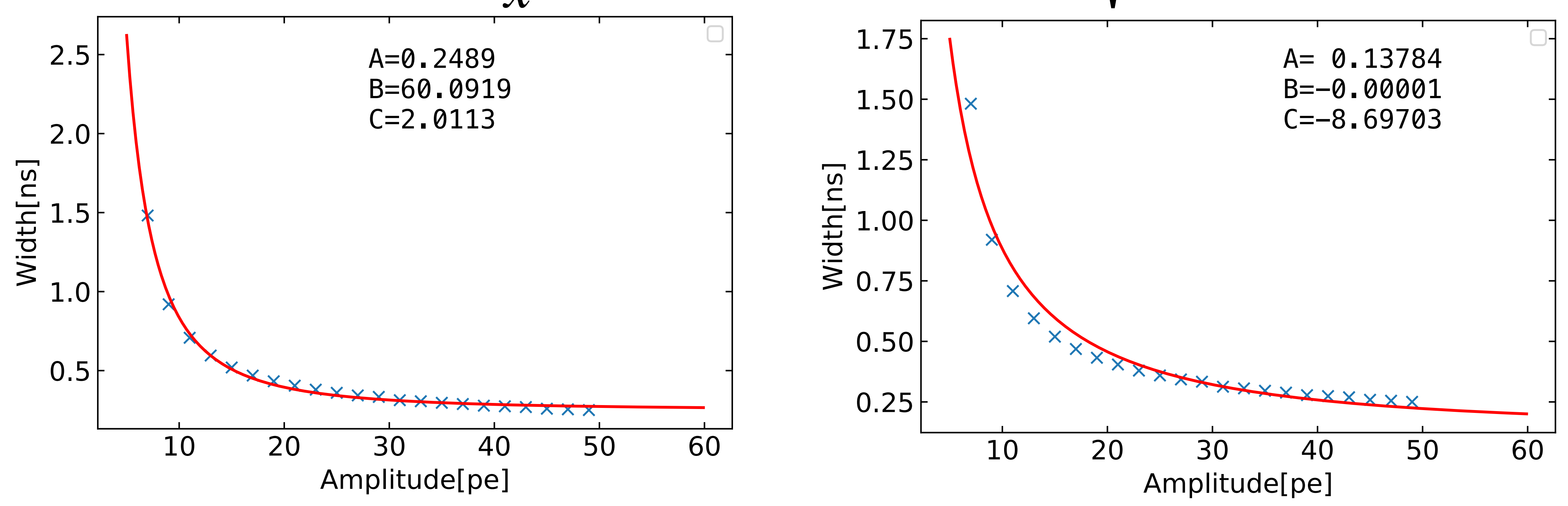

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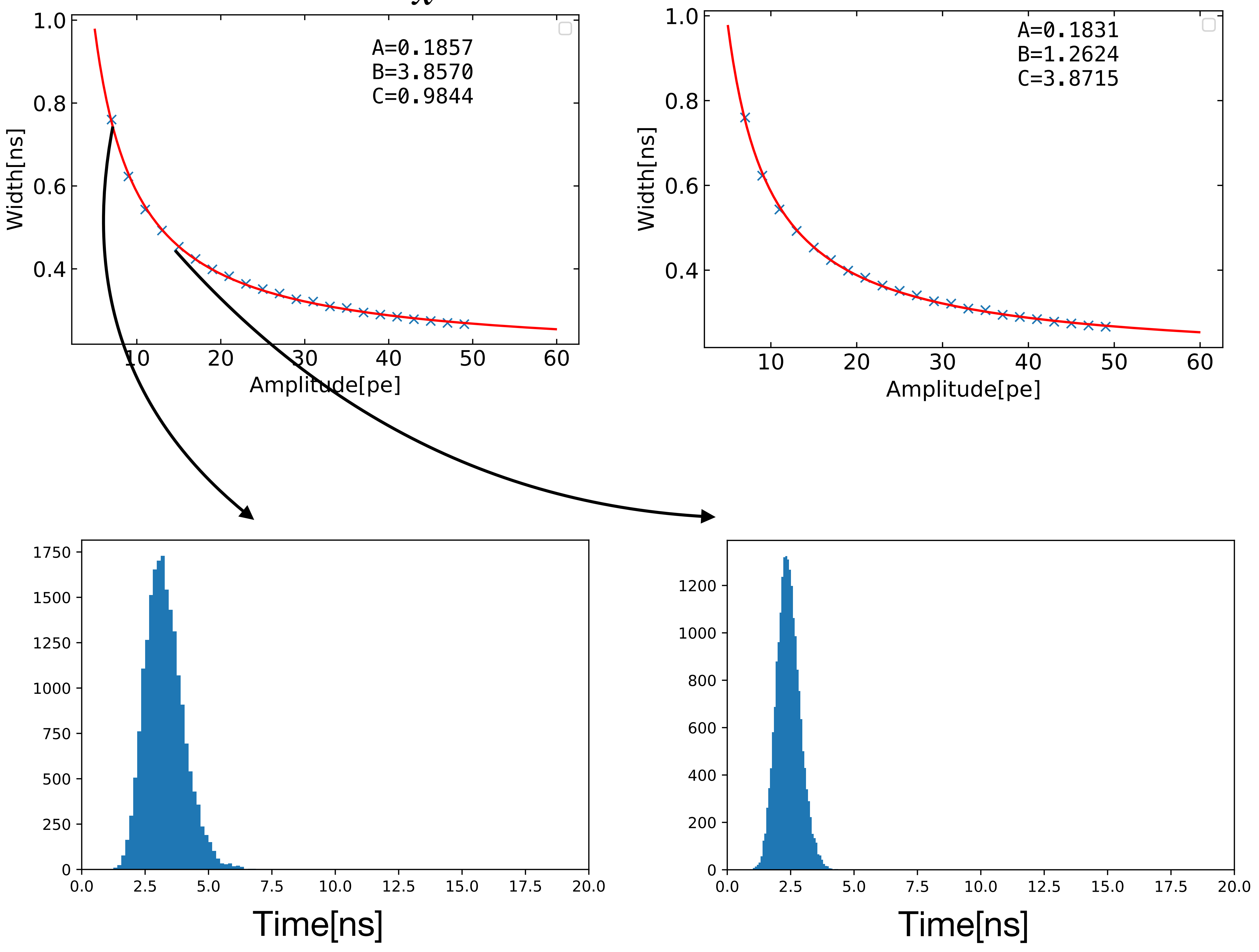

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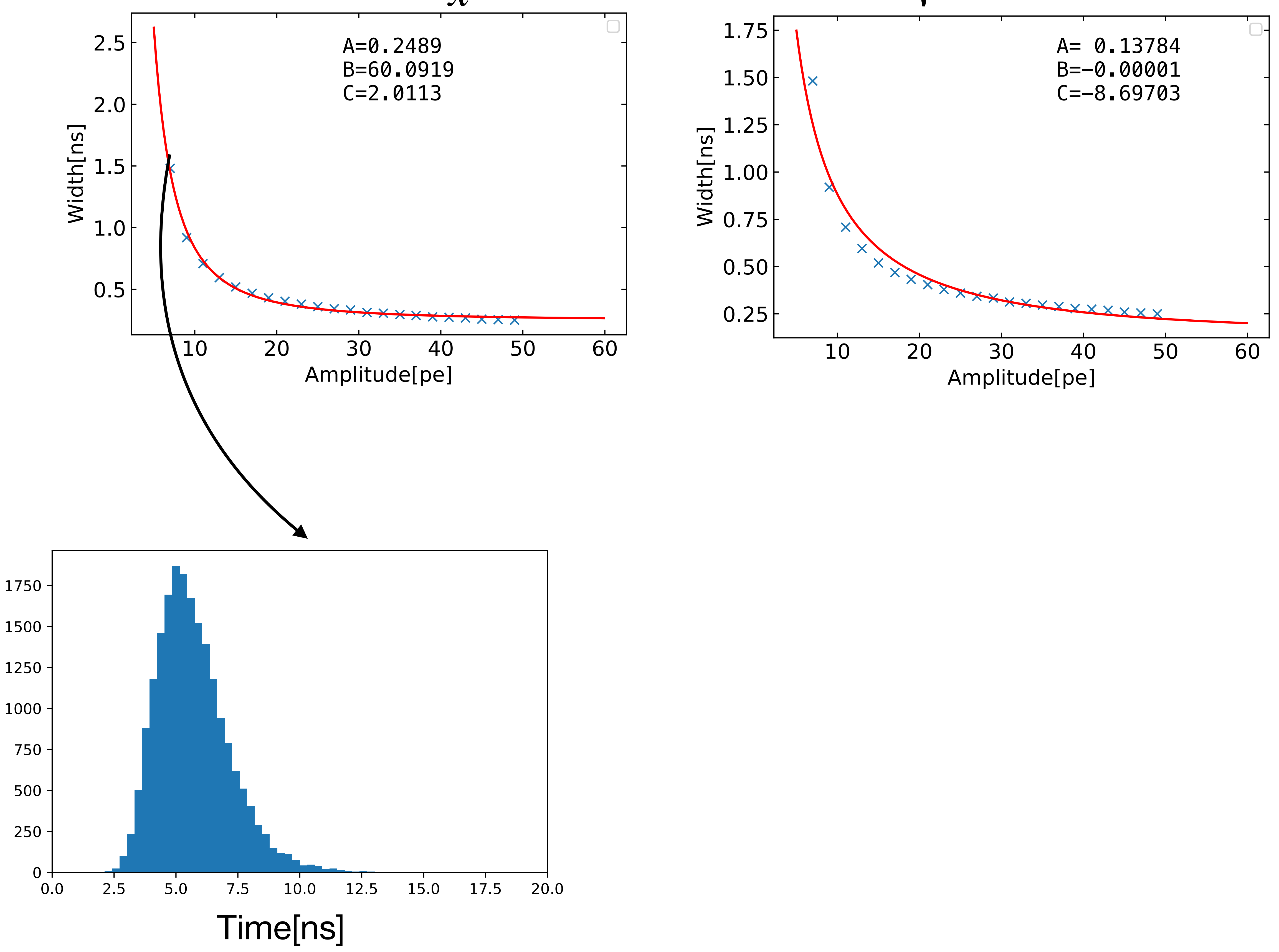

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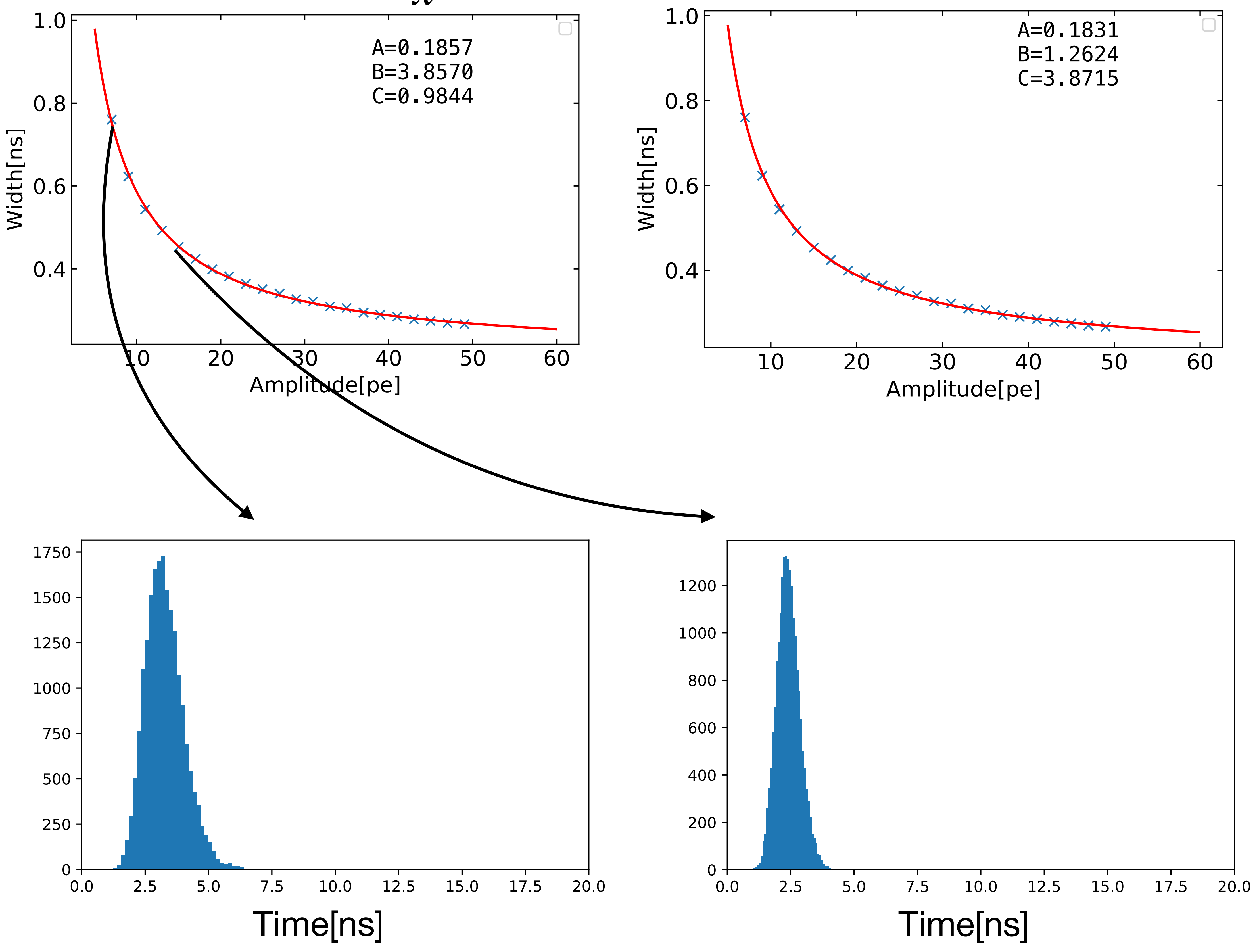
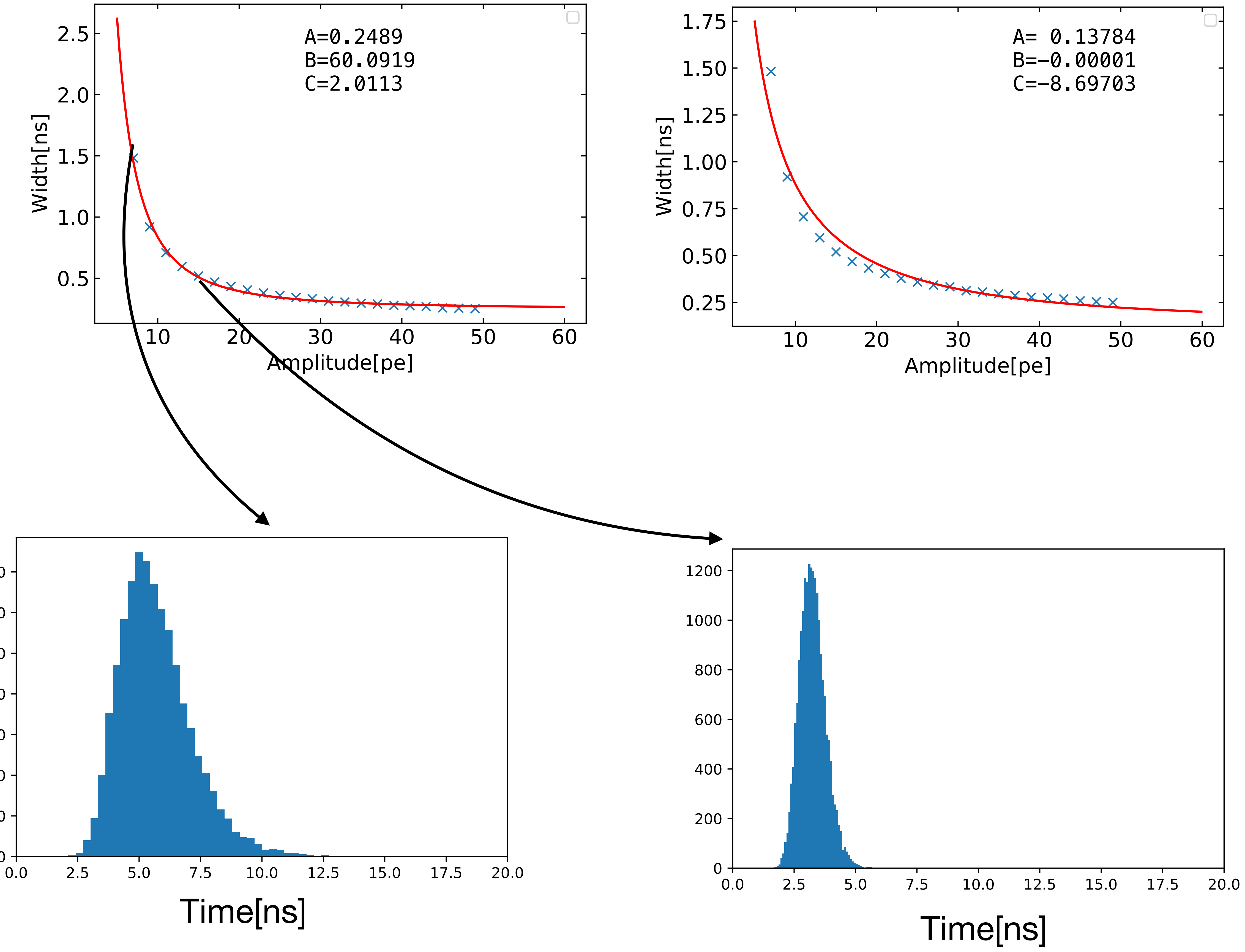


DAQ Threshold: 6pe
Lowest Energy: 7pe

$$Width = A + \frac{B}{x^C}$$

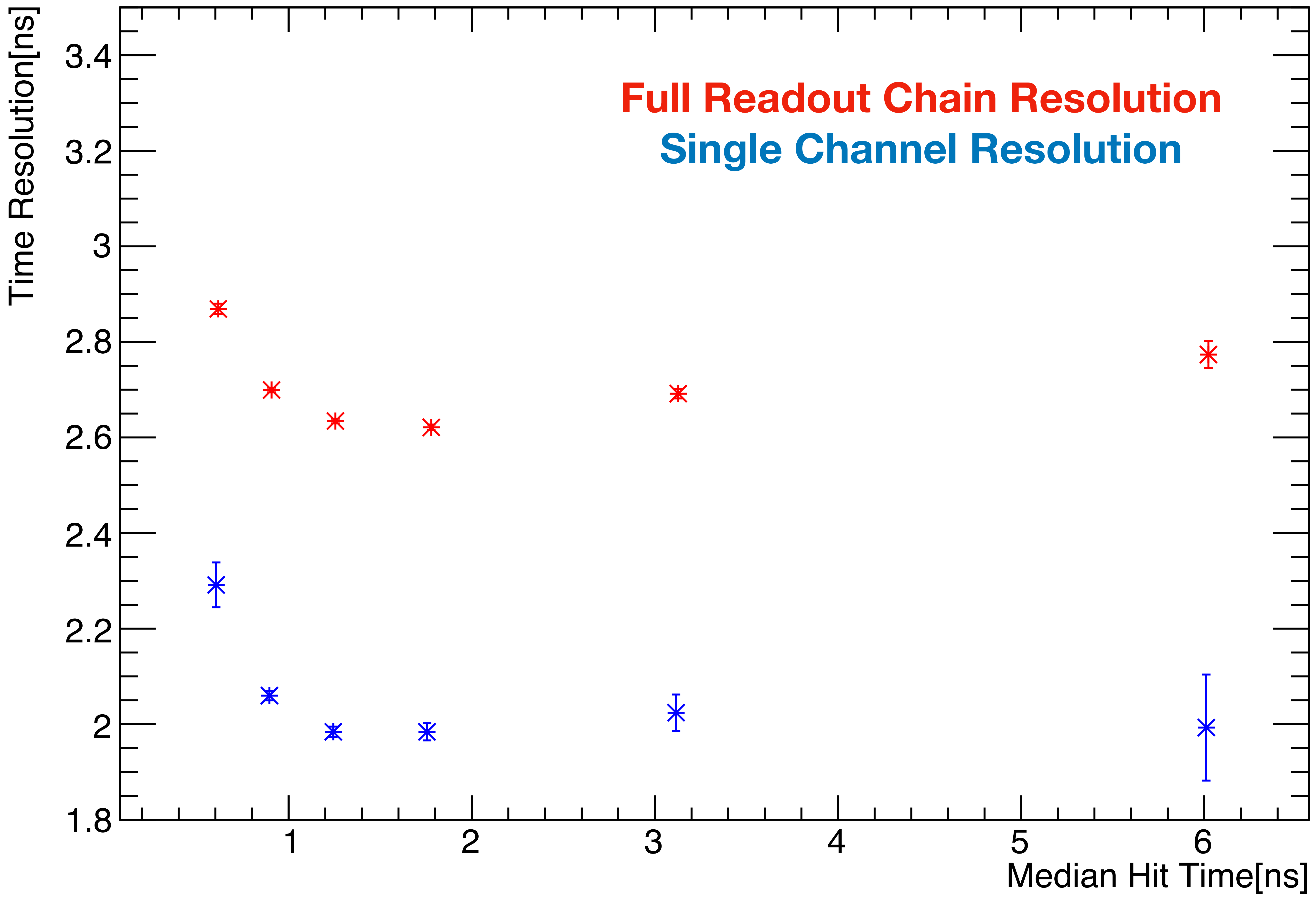
$$Width = \sqrt{A^2 + \frac{B^2}{x} + \frac{C^2}{x^2}}$$



Energy Dependent Time Resolution

Testbeam Mode - Muons

Only MIP tracks selected



Energy bins[MIP]:
0.5 to 0.7,
0.7 to 1.1,
1.1 to 1.5,
1.5 to 2.5,
2.5 to 5,
5 to MAX

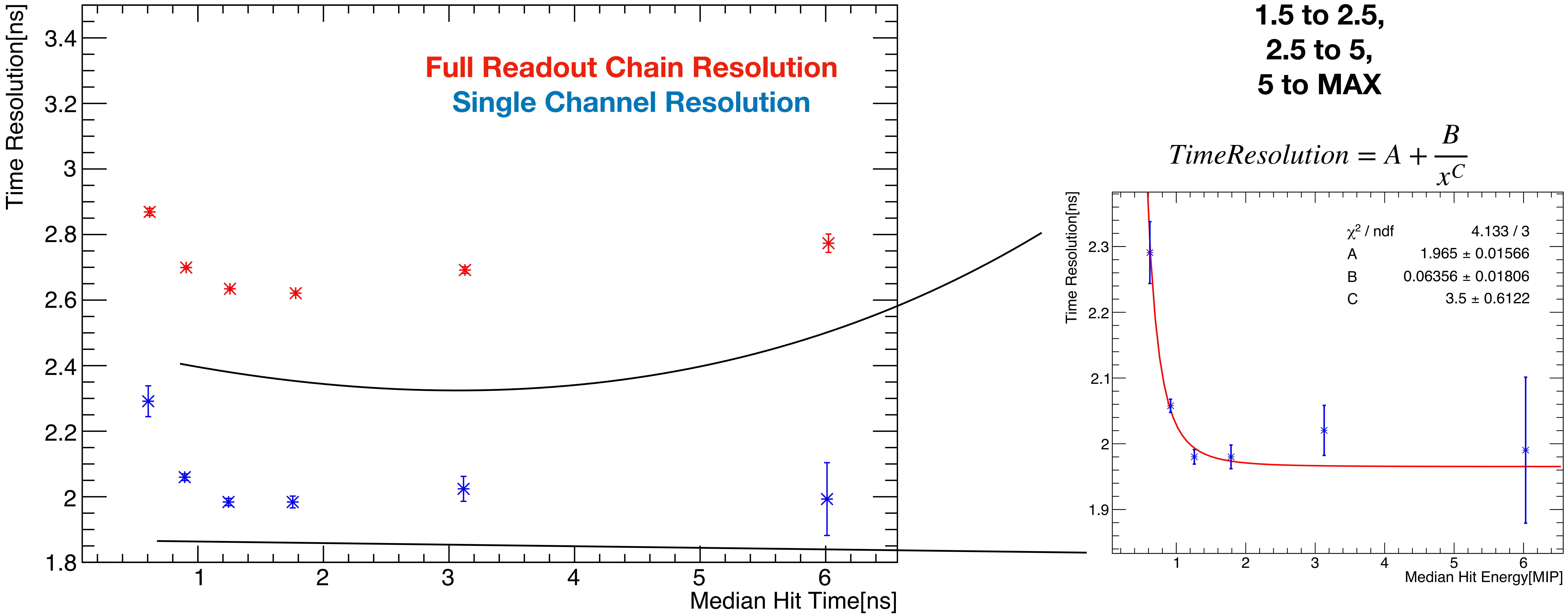
Energy Dependent Time Resolution

Testbeam Mode - Muons

Only MIP tracks selected

Energy bins[MIP]:
0.5 to 0.7,
0.7 to 1.1,
1.1 to 1.5,
1.5 to 2.5,
2.5 to 5,
5 to MAX

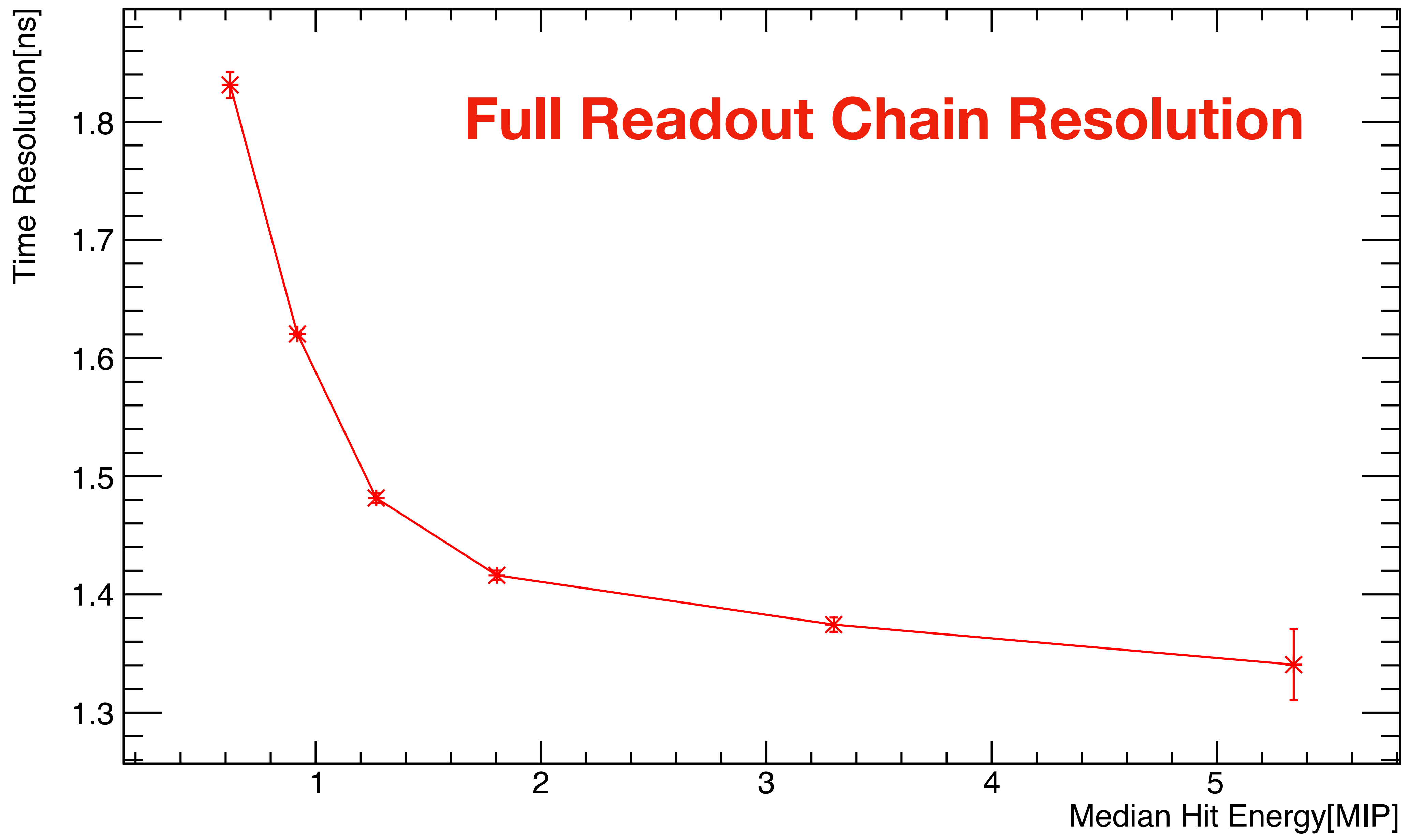
$$TimeResolution = A + \frac{B}{x^C}$$



Energy Dependent Time Resolution

ILC Mode - Electrons

Only tracks selected



Energy bins[MIP]:
0.5 to 0.7,
0.7 to 1.1,
1.1 to 1.5,
1.5 to 2.5,
2.5 to 5,
5 to MAX

Energy dependent single channel resolution:

- <1ns for higher energies
- But: Low statistics, DAQ issue $\Longrightarrow$ further investigation

Conclusion

Calibration and correction in place, also in Software

Single channel time resolution in ILC mode ~0.78ns, design goal reached

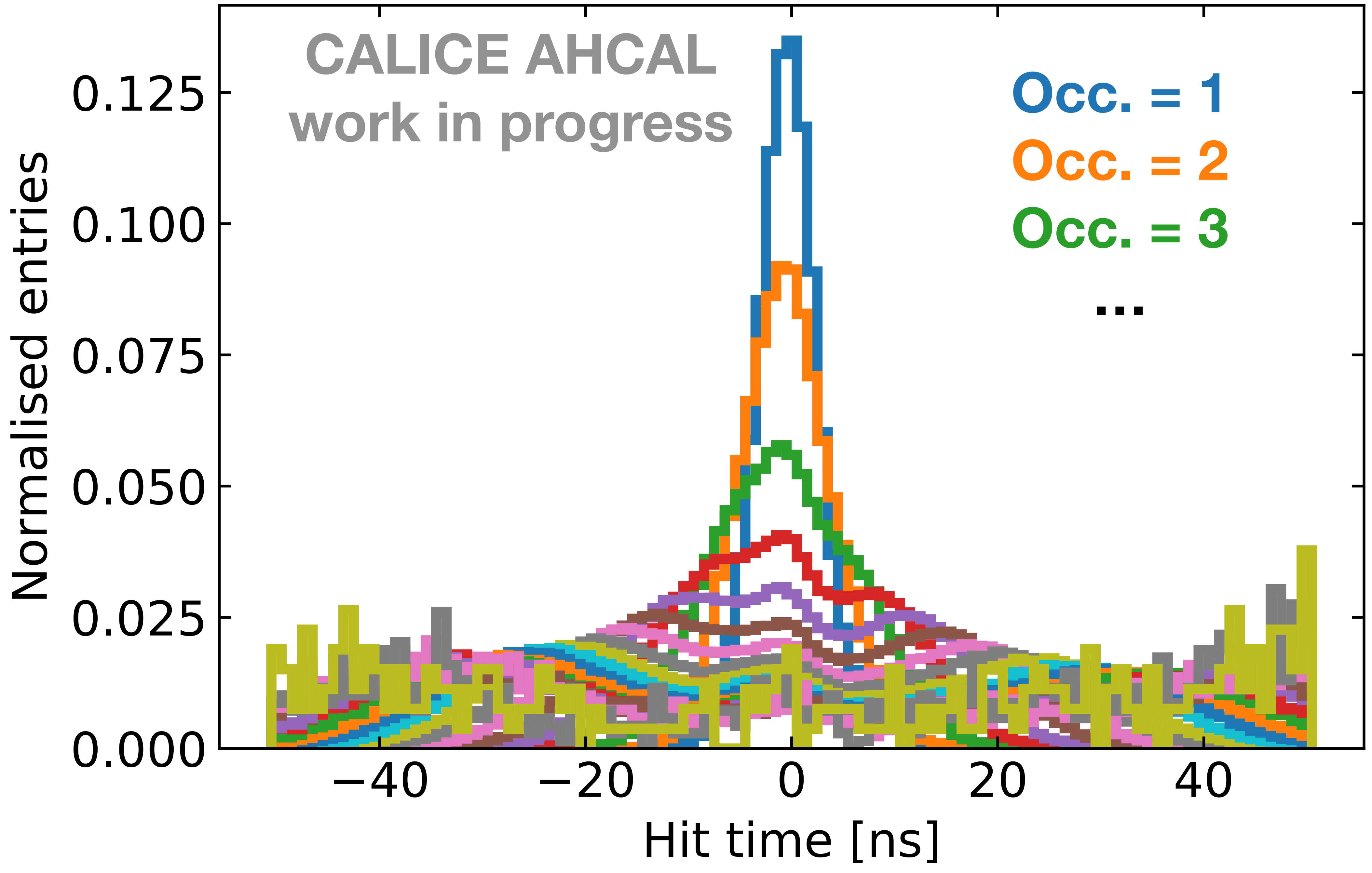
Energy dependency of time resolution confirmed

- In full read-out chain and single channel resolution
- Toy MC, confirm with data in the future

Backup

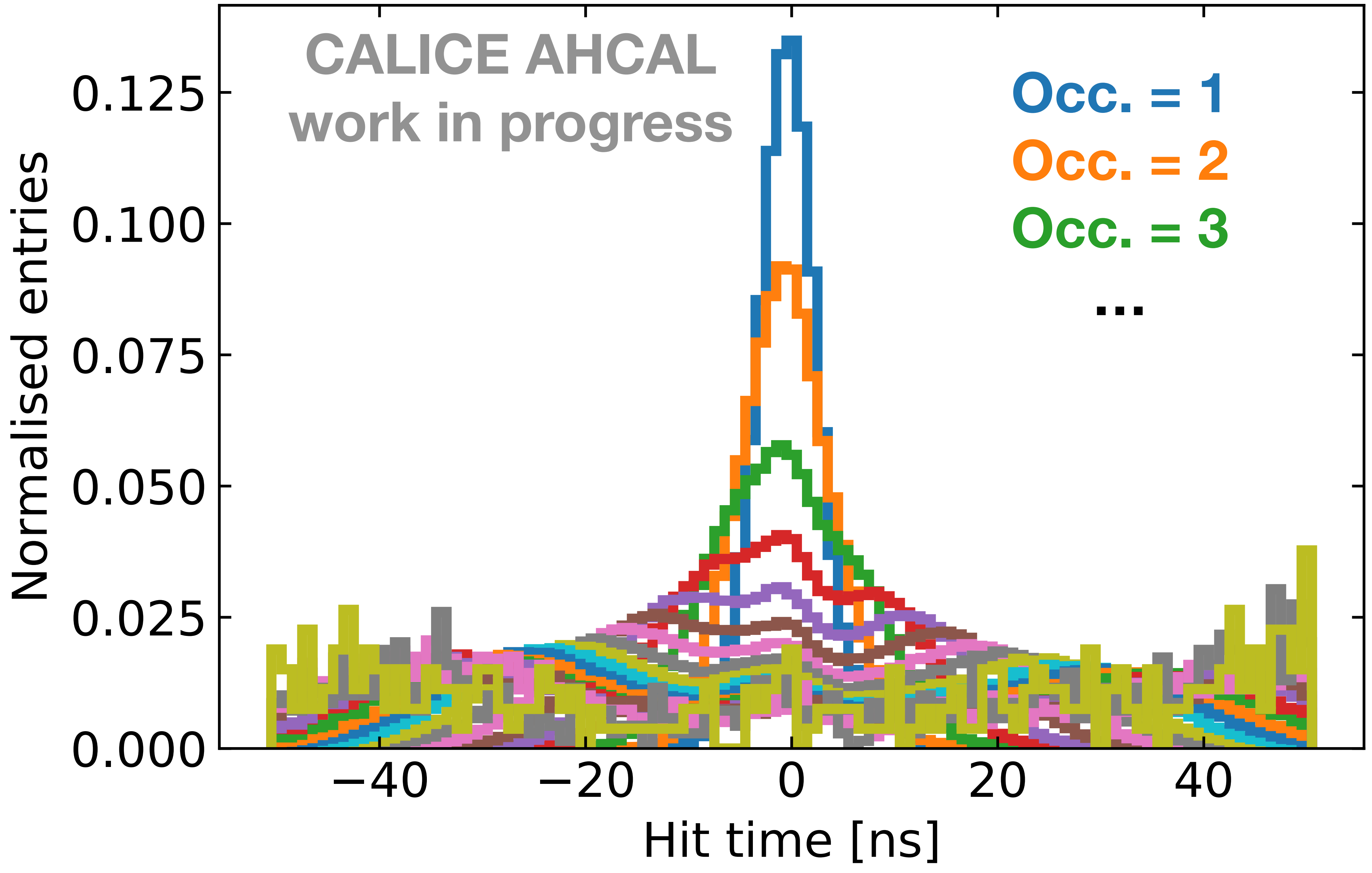
The Occupancy Problem

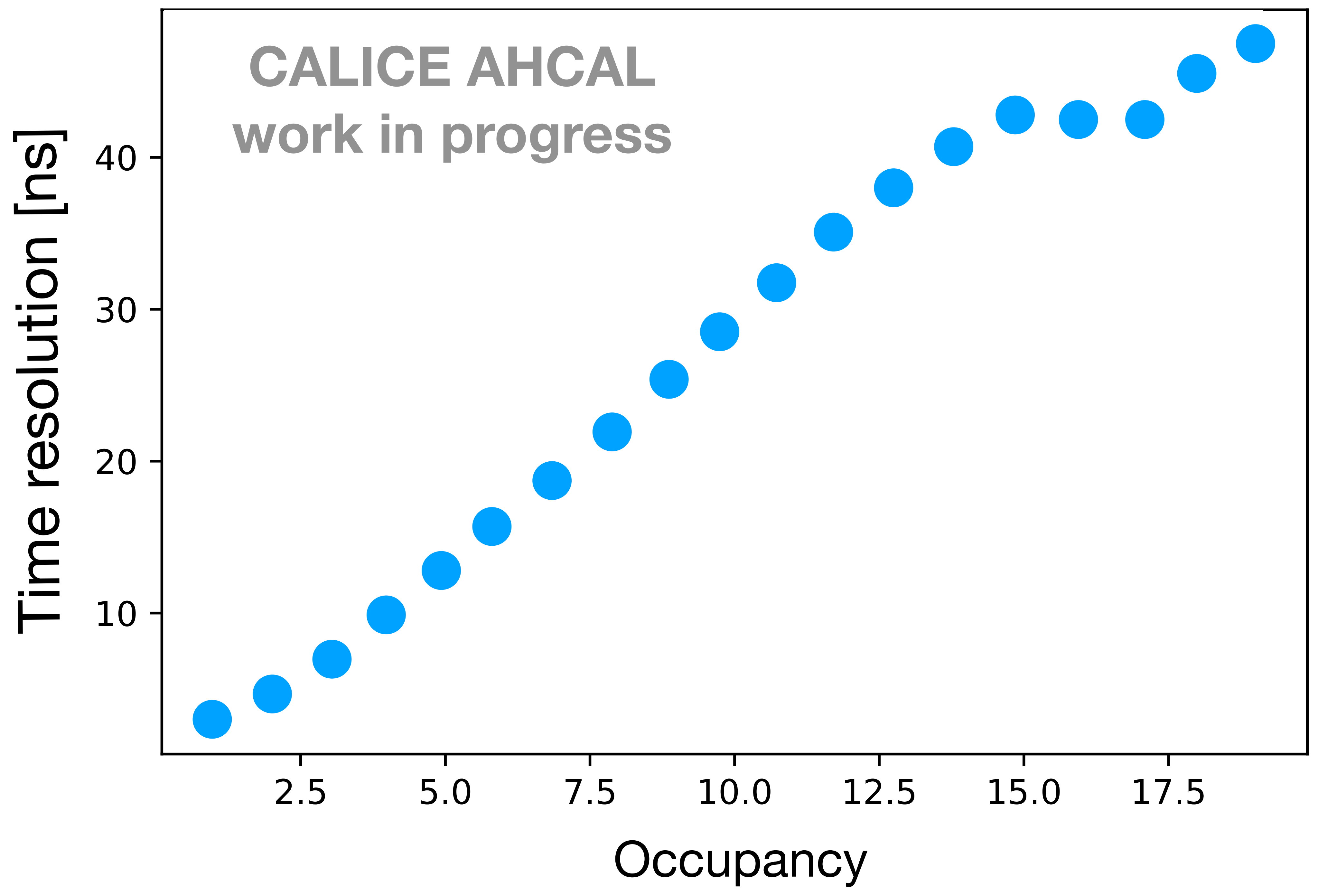
Dataset: 60GeV Electrons



The Occupancy Problem

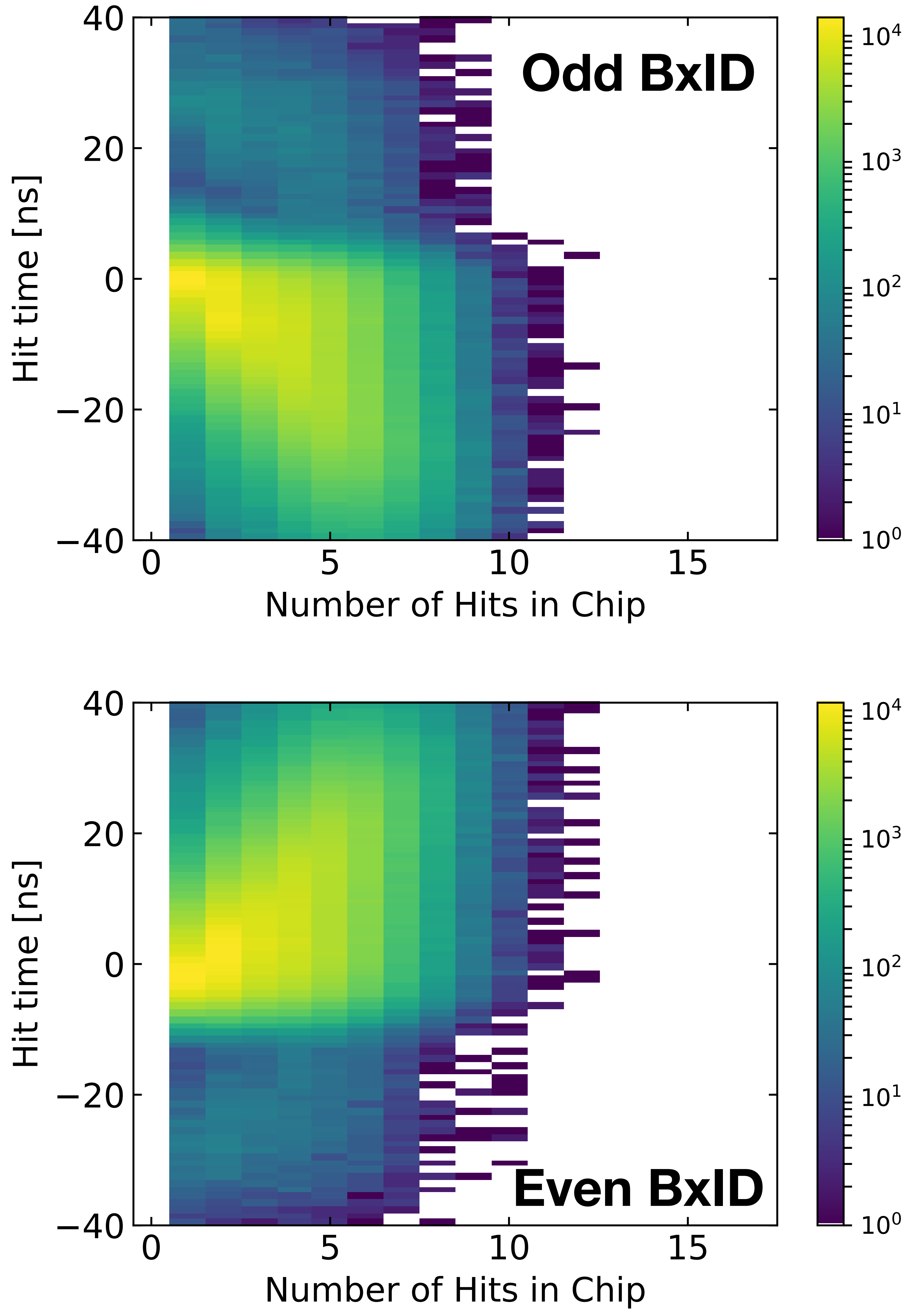
Dataset: 60GeV Electrons



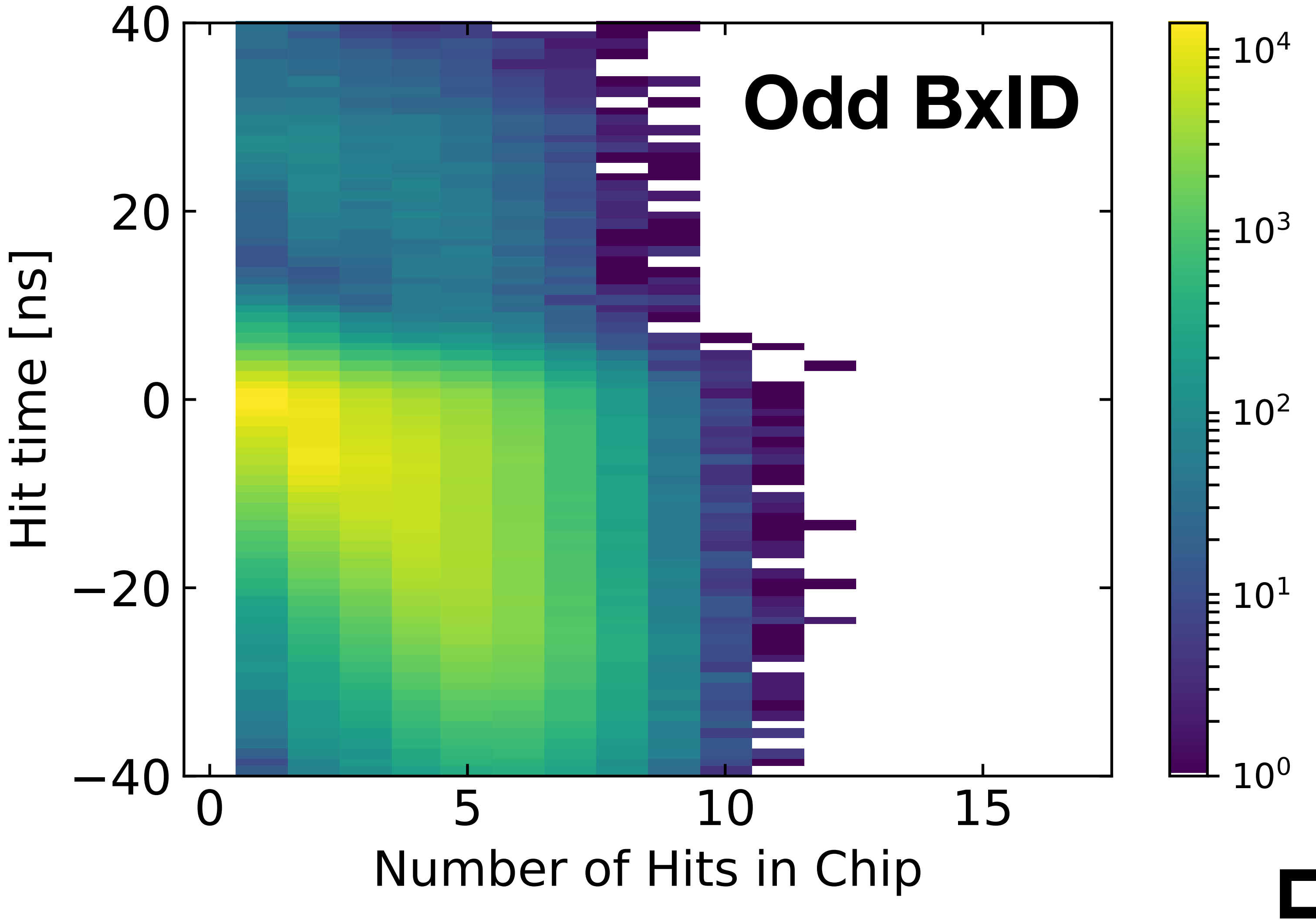


Time resolution is the sigma of a gaussian fit to every distribution

The Occupancy Problem

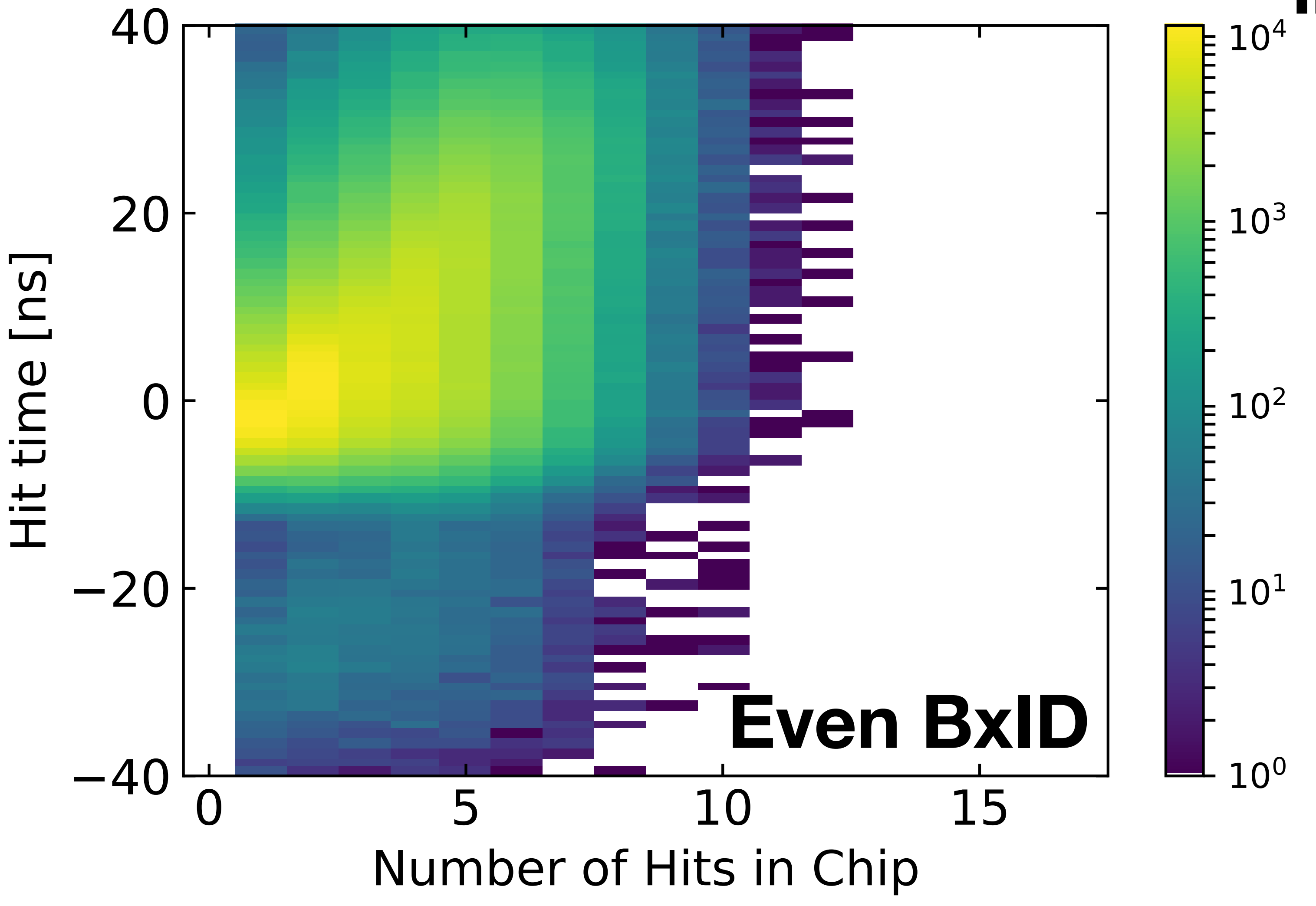


The Occupancy Problem

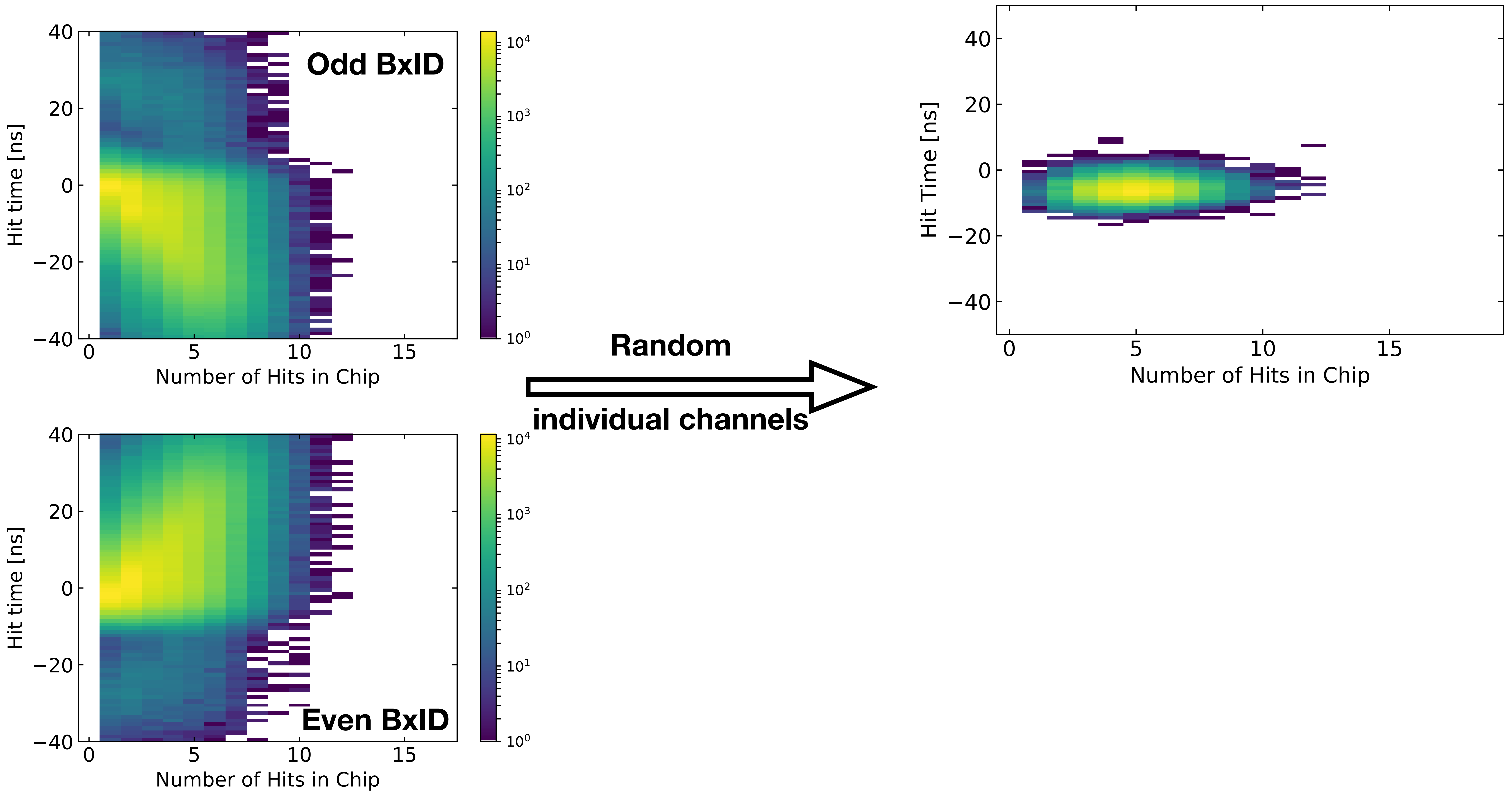


Random

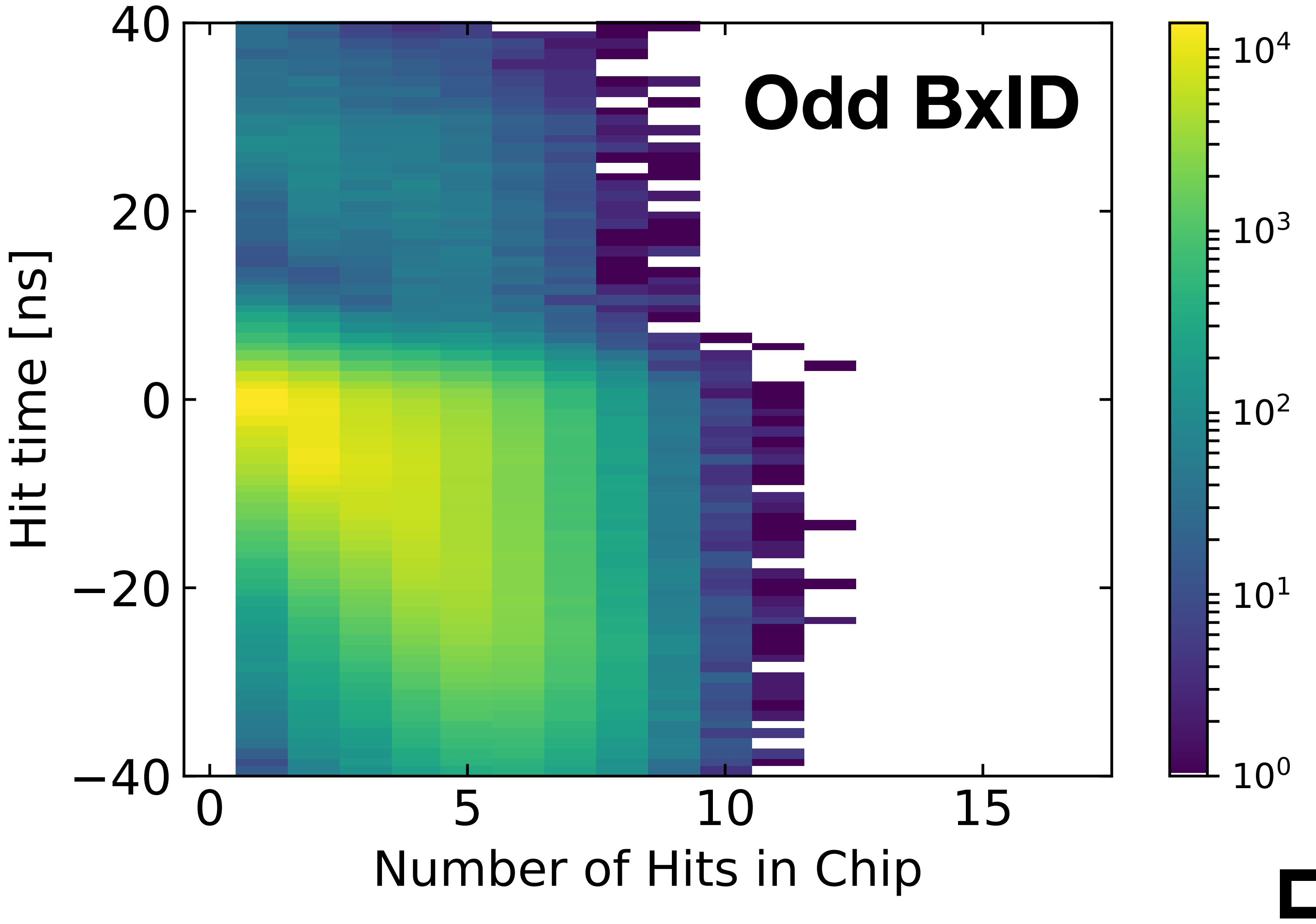
individual channels

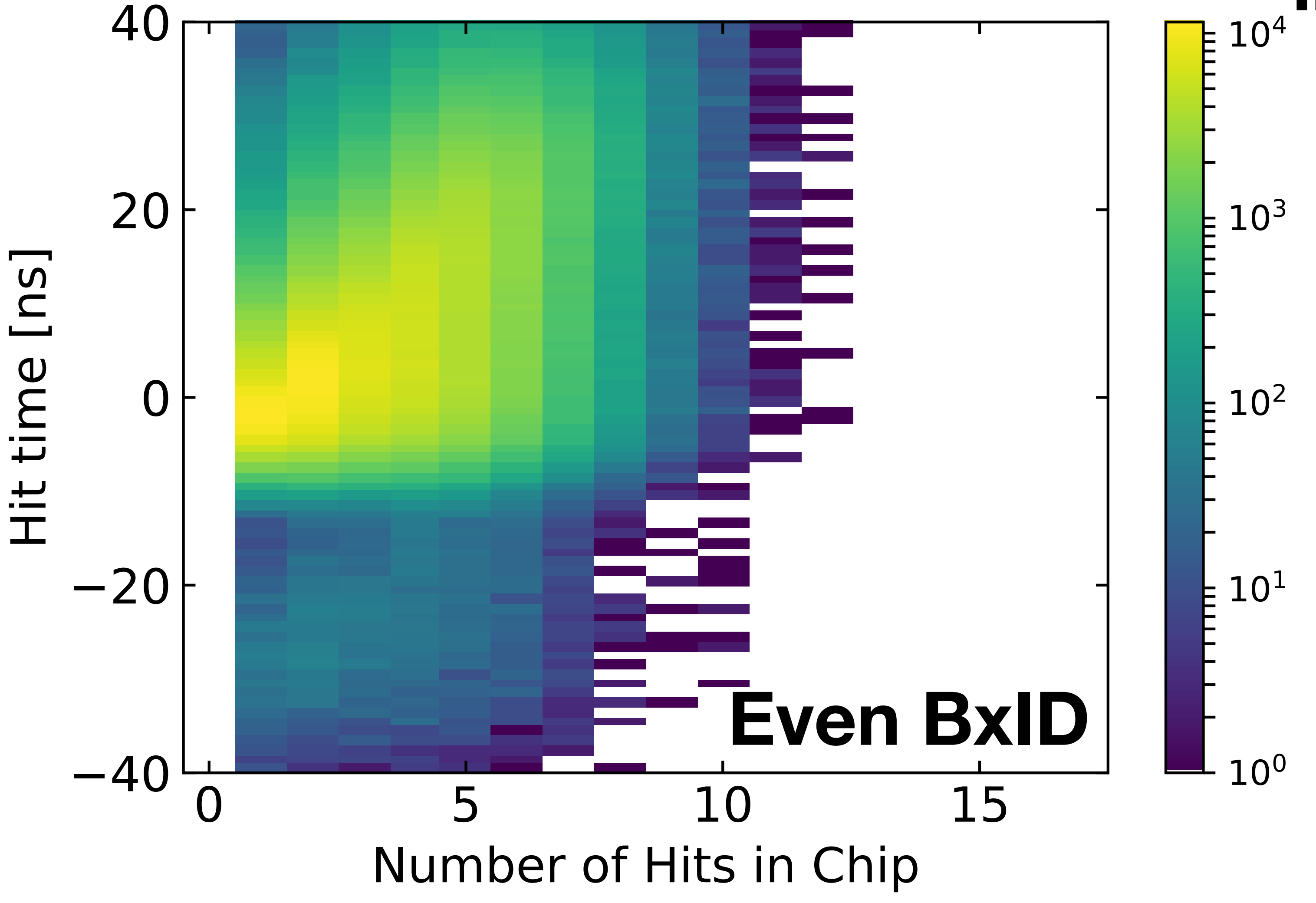


The Occupancy Problem



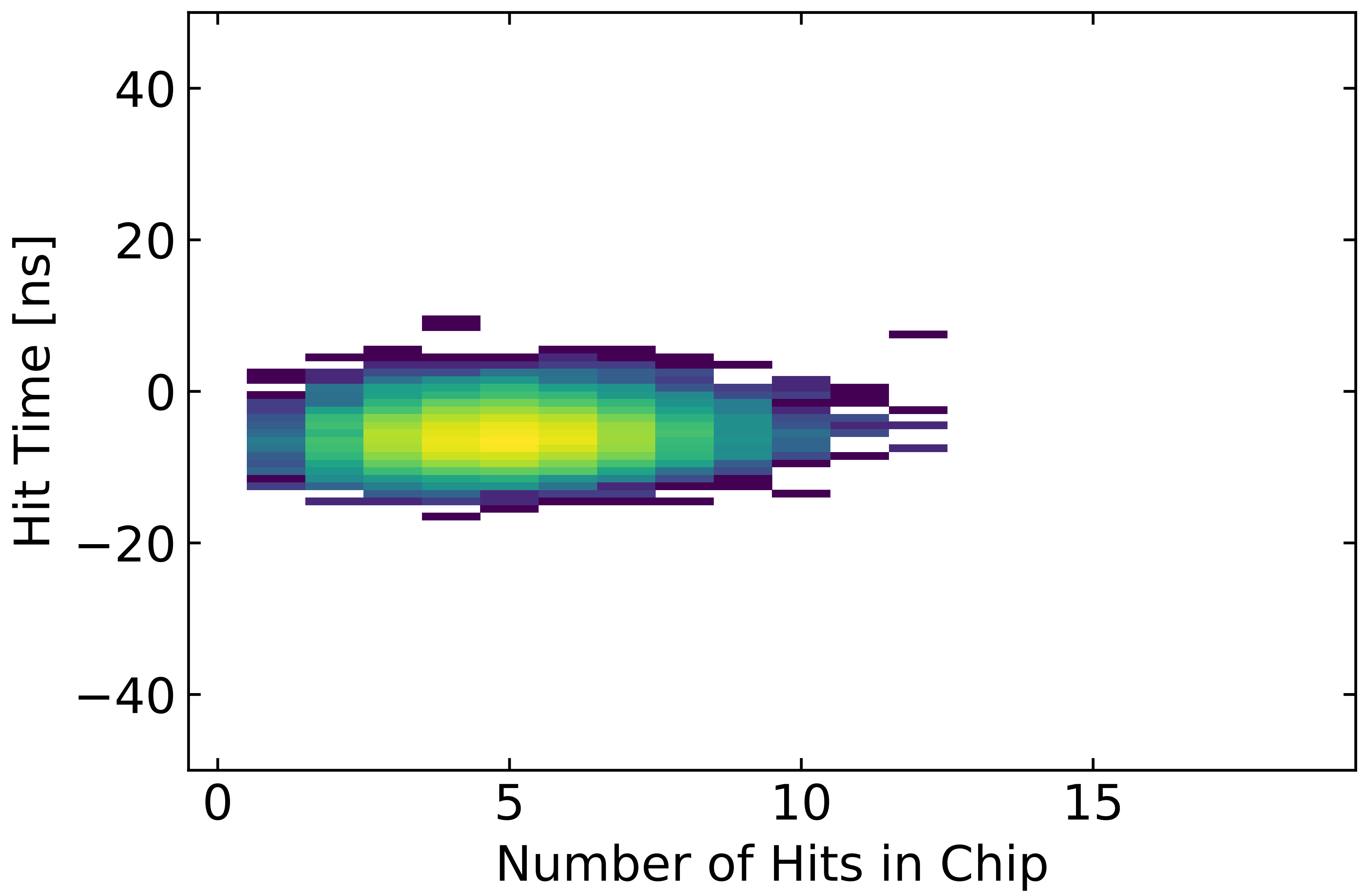
The Occupancy Problem

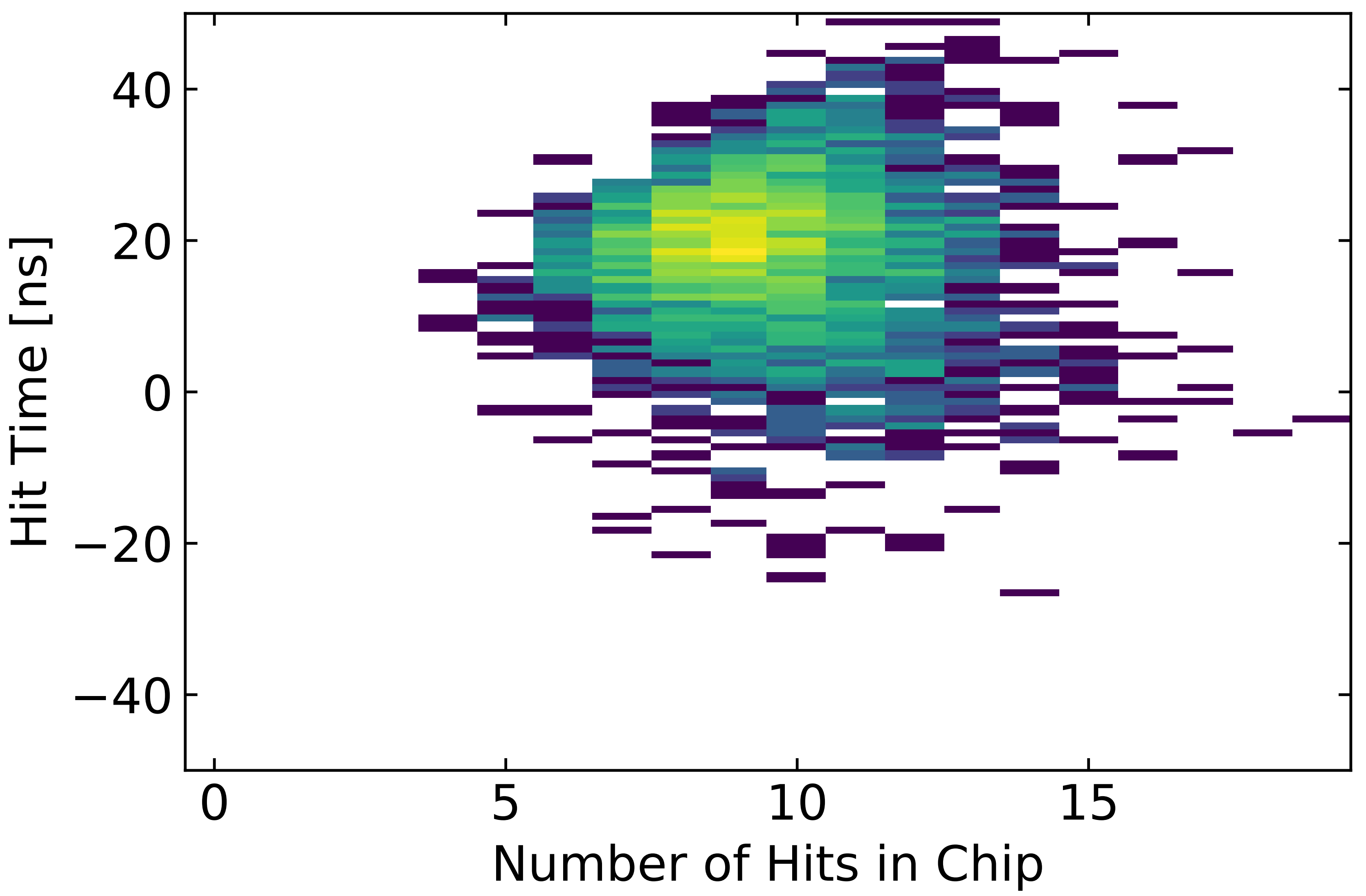




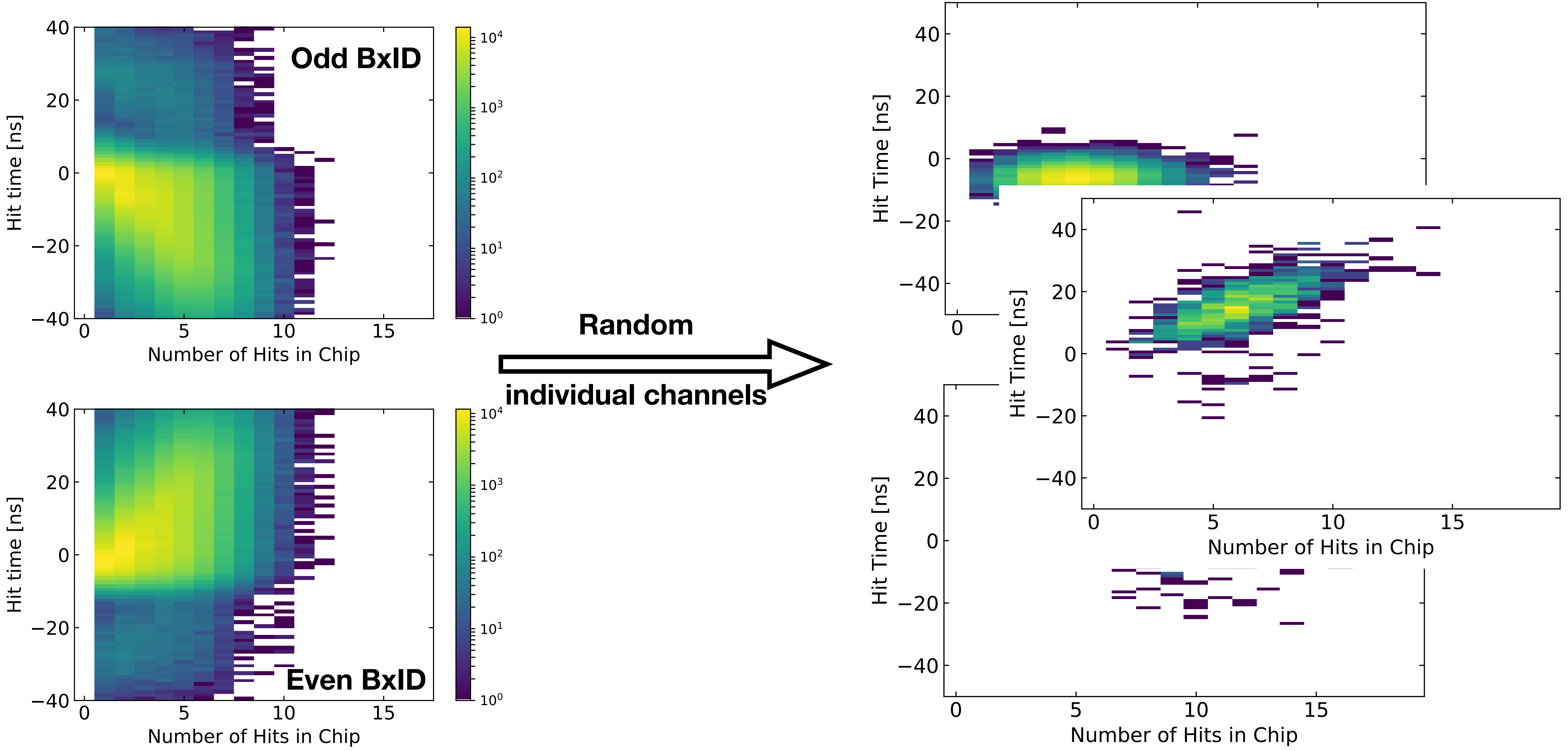
Random

individual channels

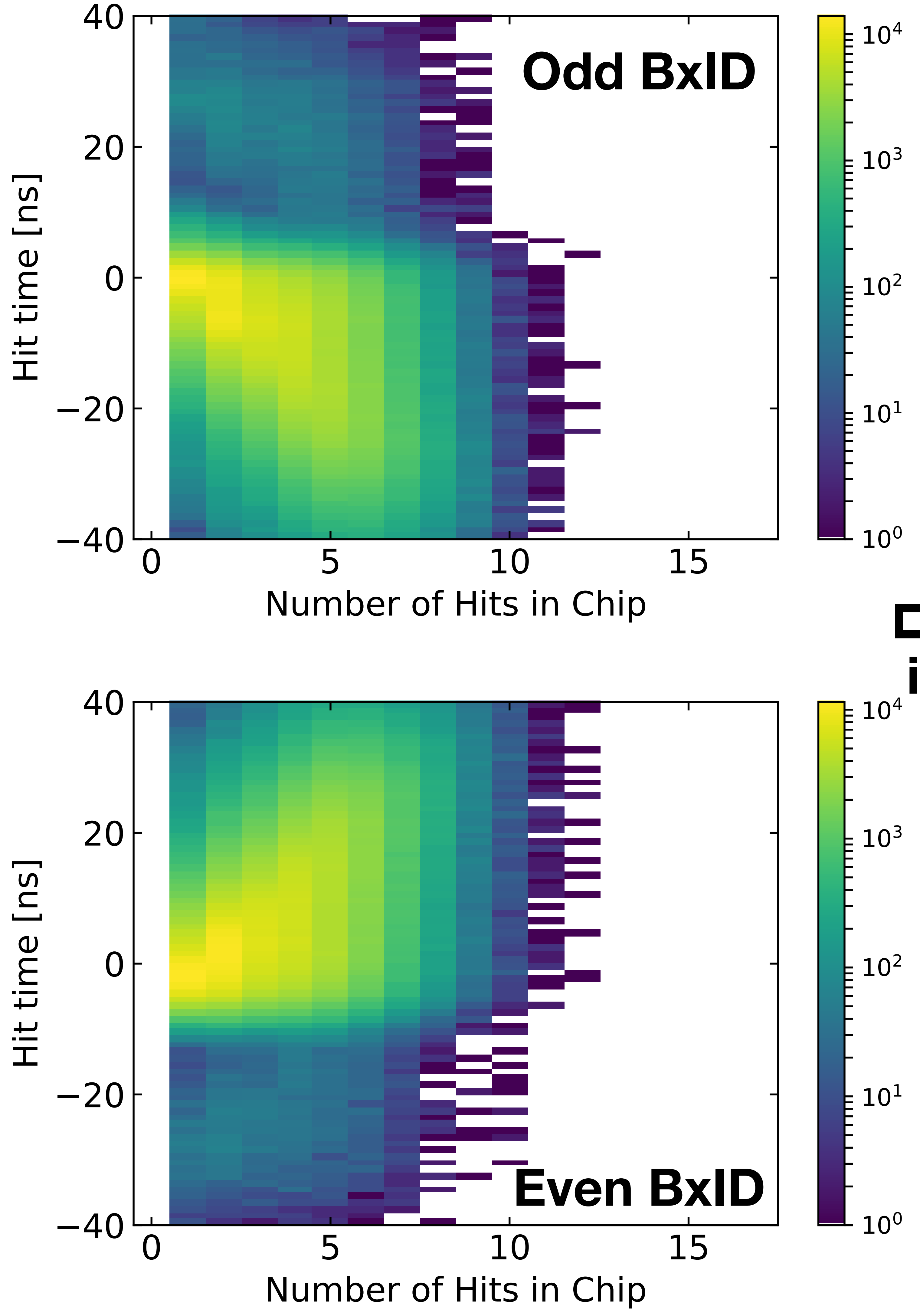


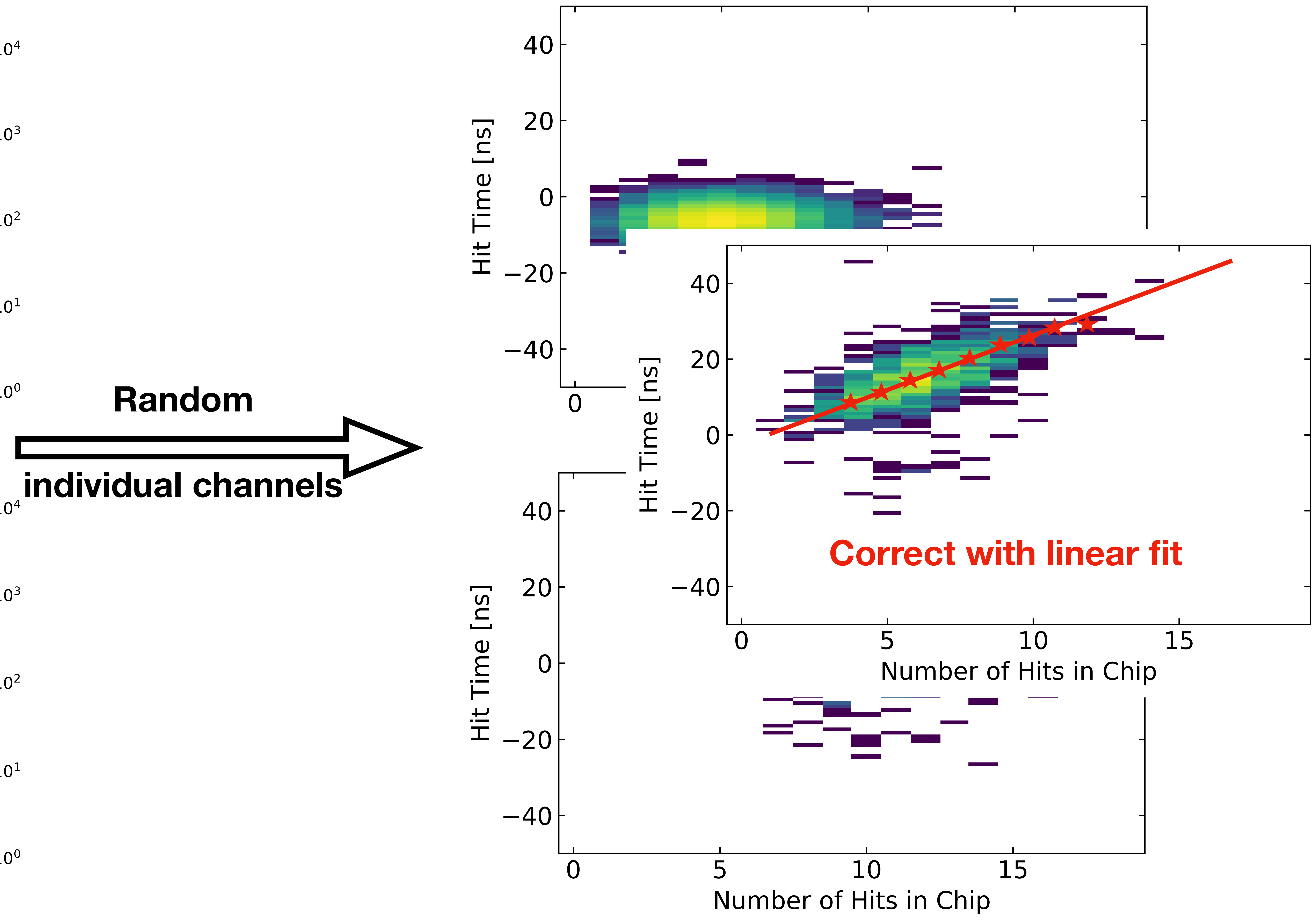


The Occupancy Problem



The Occupancy Problem

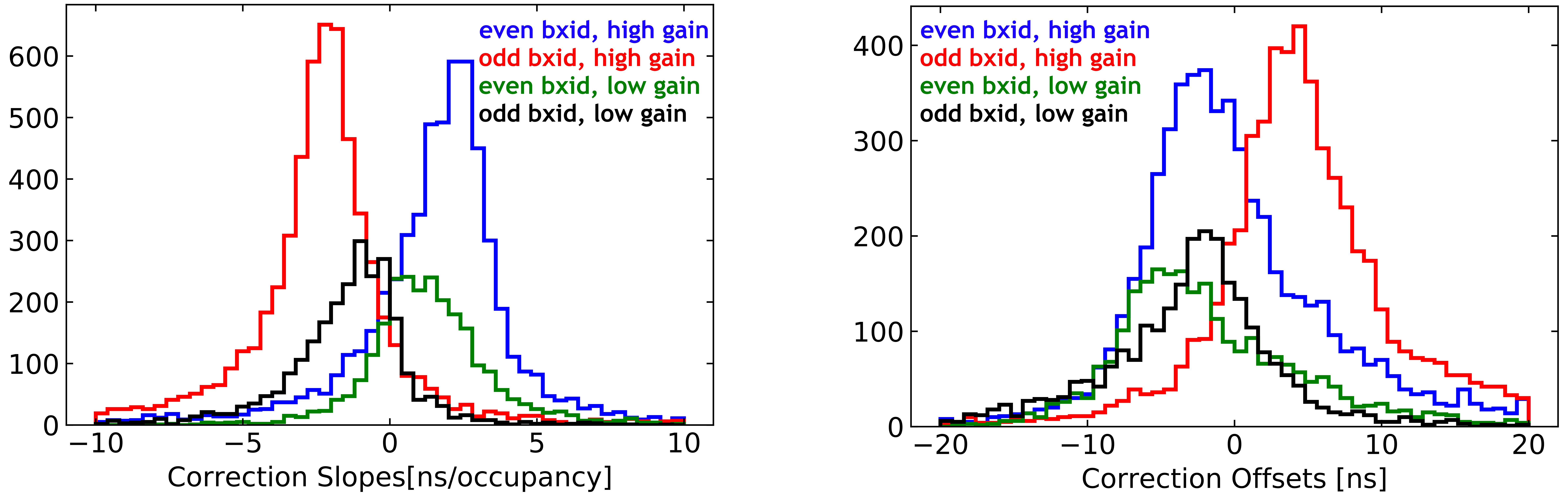




Correction on Channel Level

Split dataset in 4 categories by selecting BxID parity and gain mode

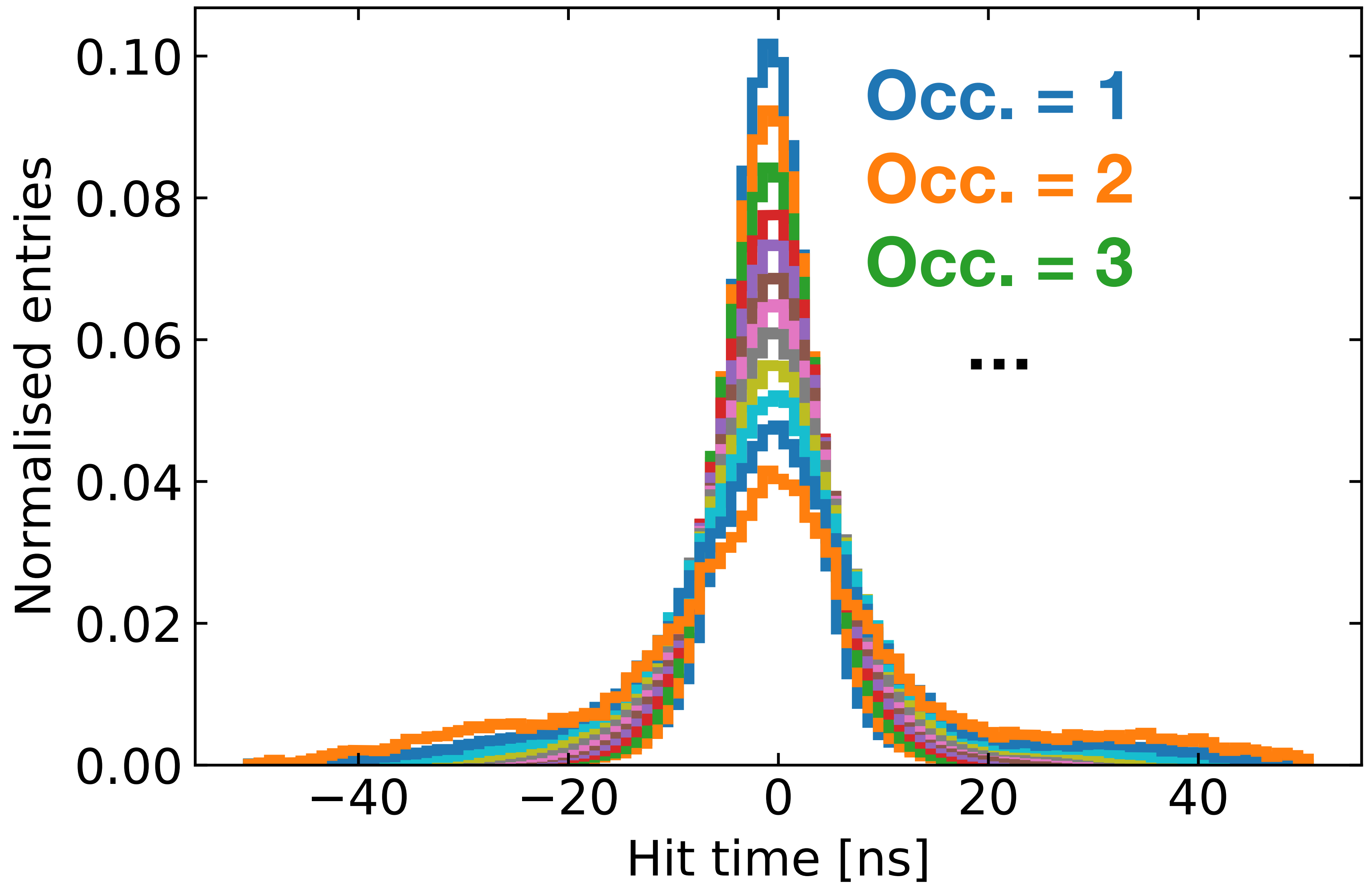
Fit individual channels: Correction = slope x occupancy + offset



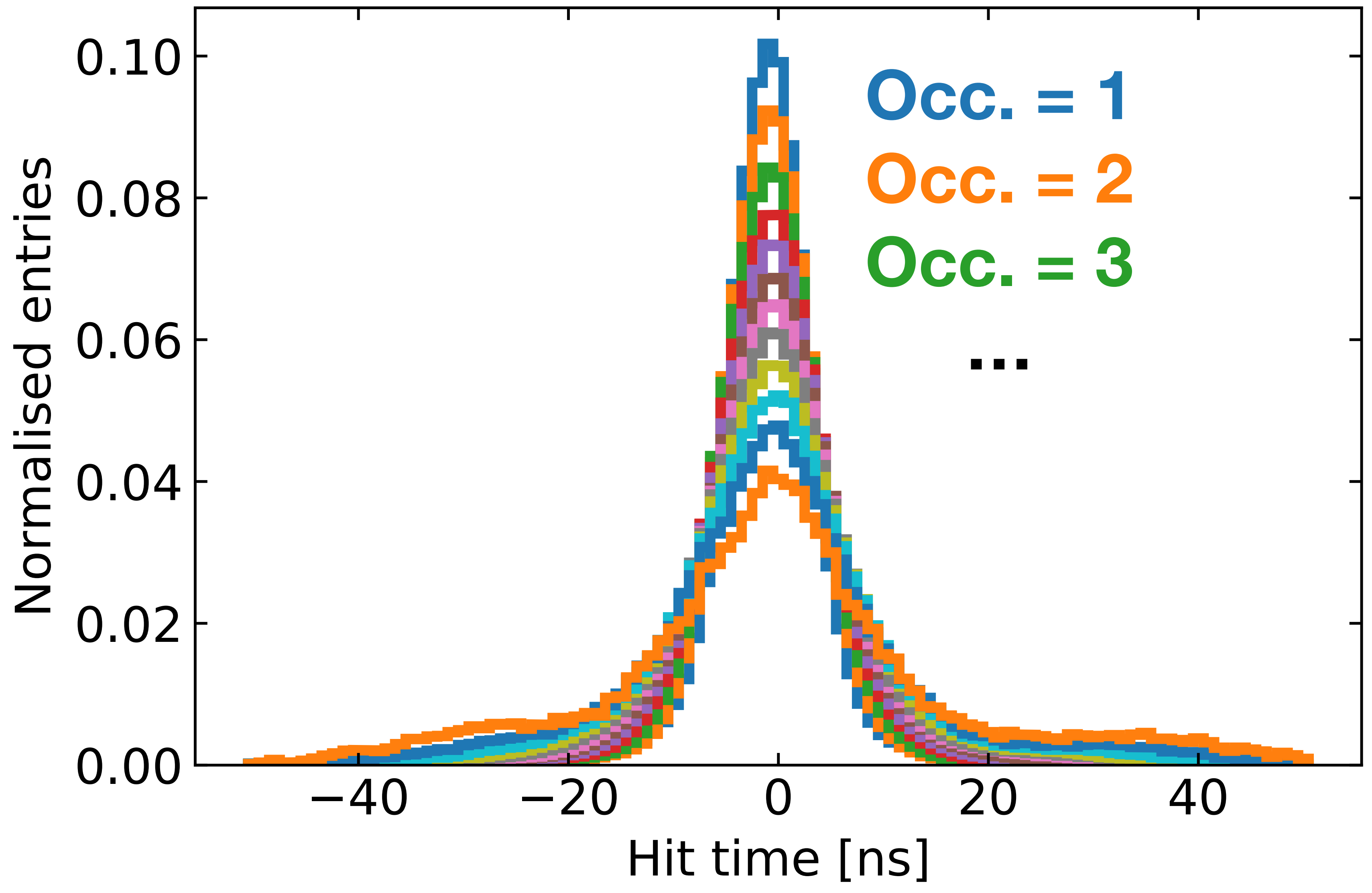
No systematics in the correction factors on chip or channel level found!

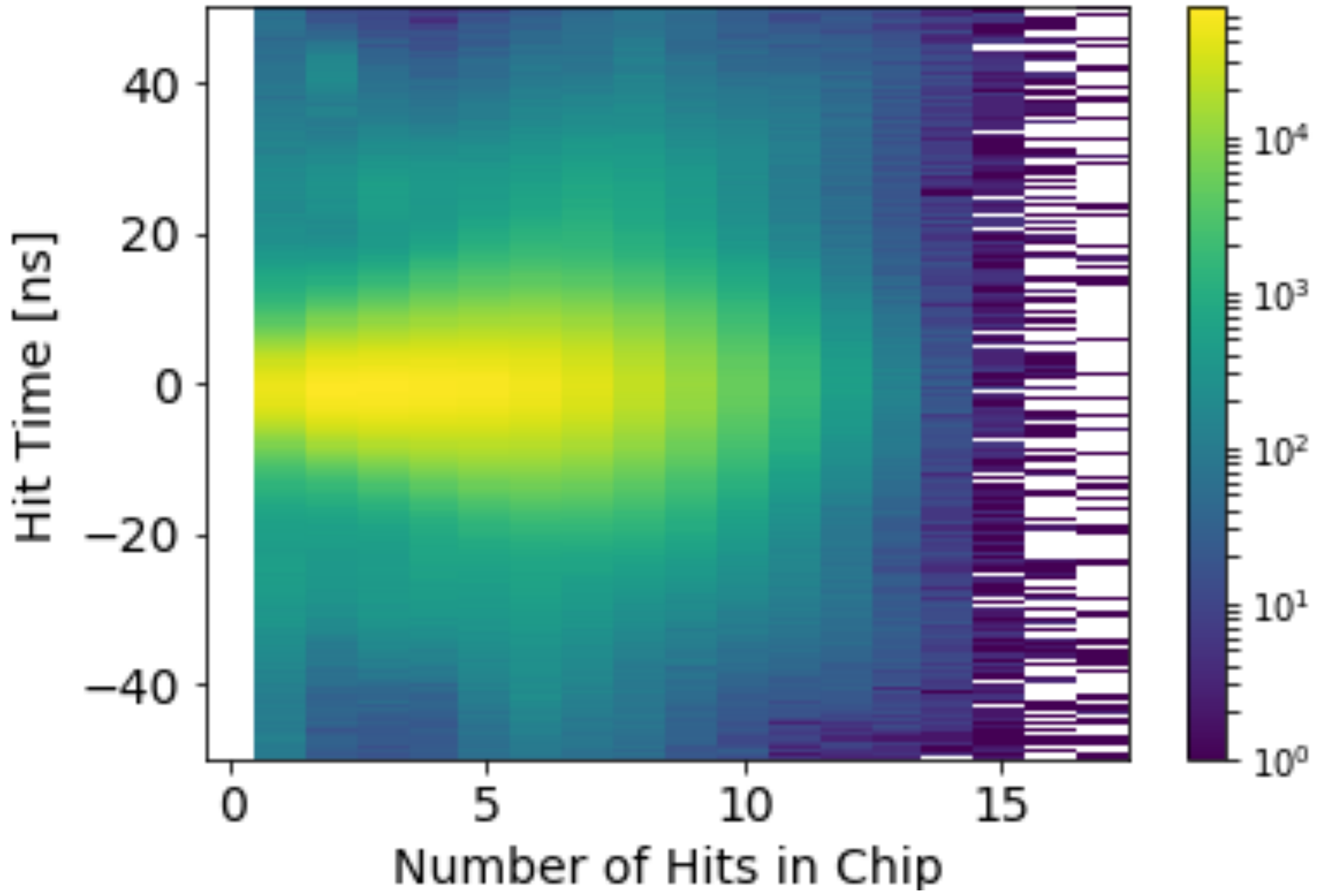
Correction on Channel Level

Correction on Channel Level

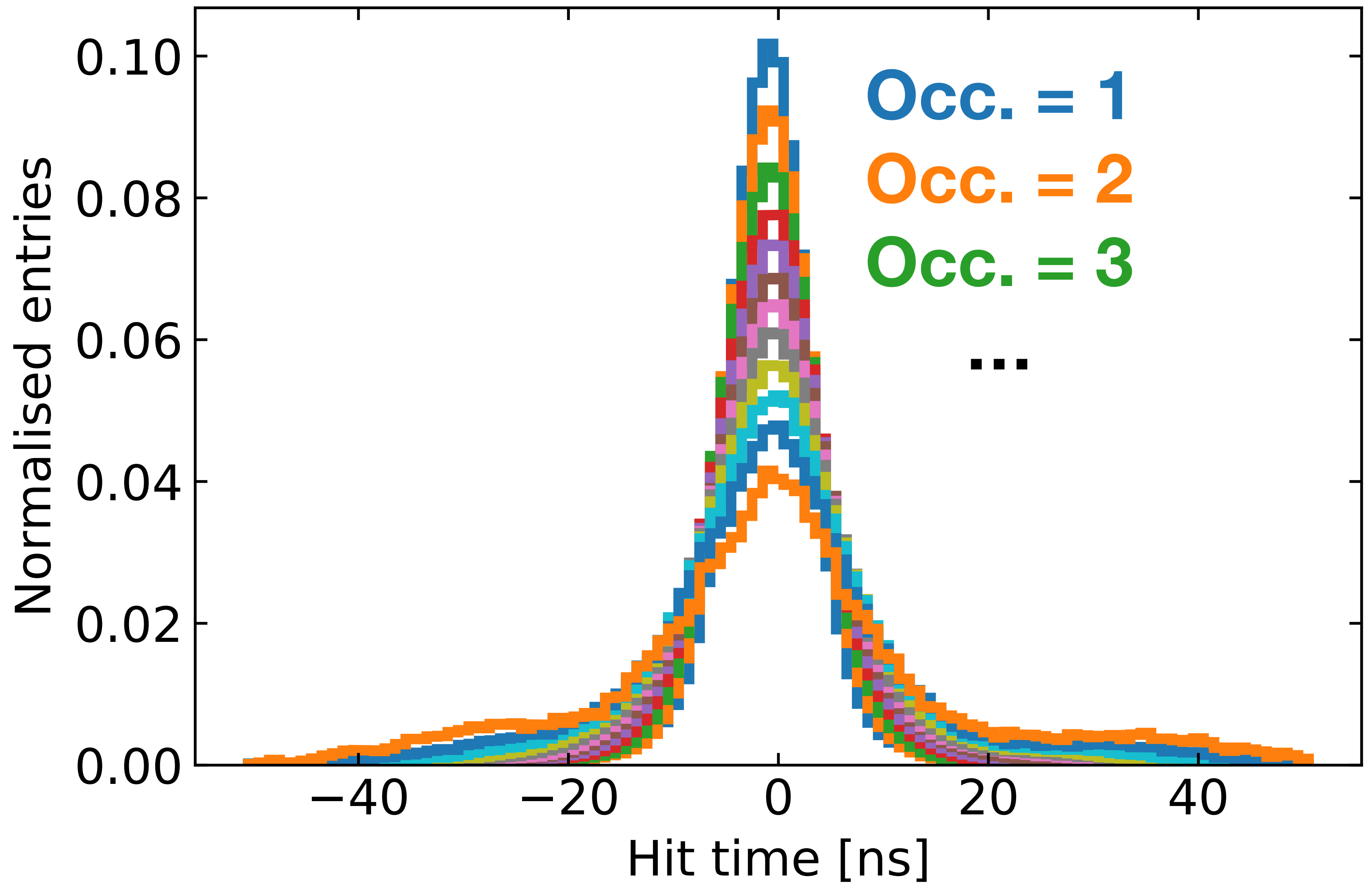


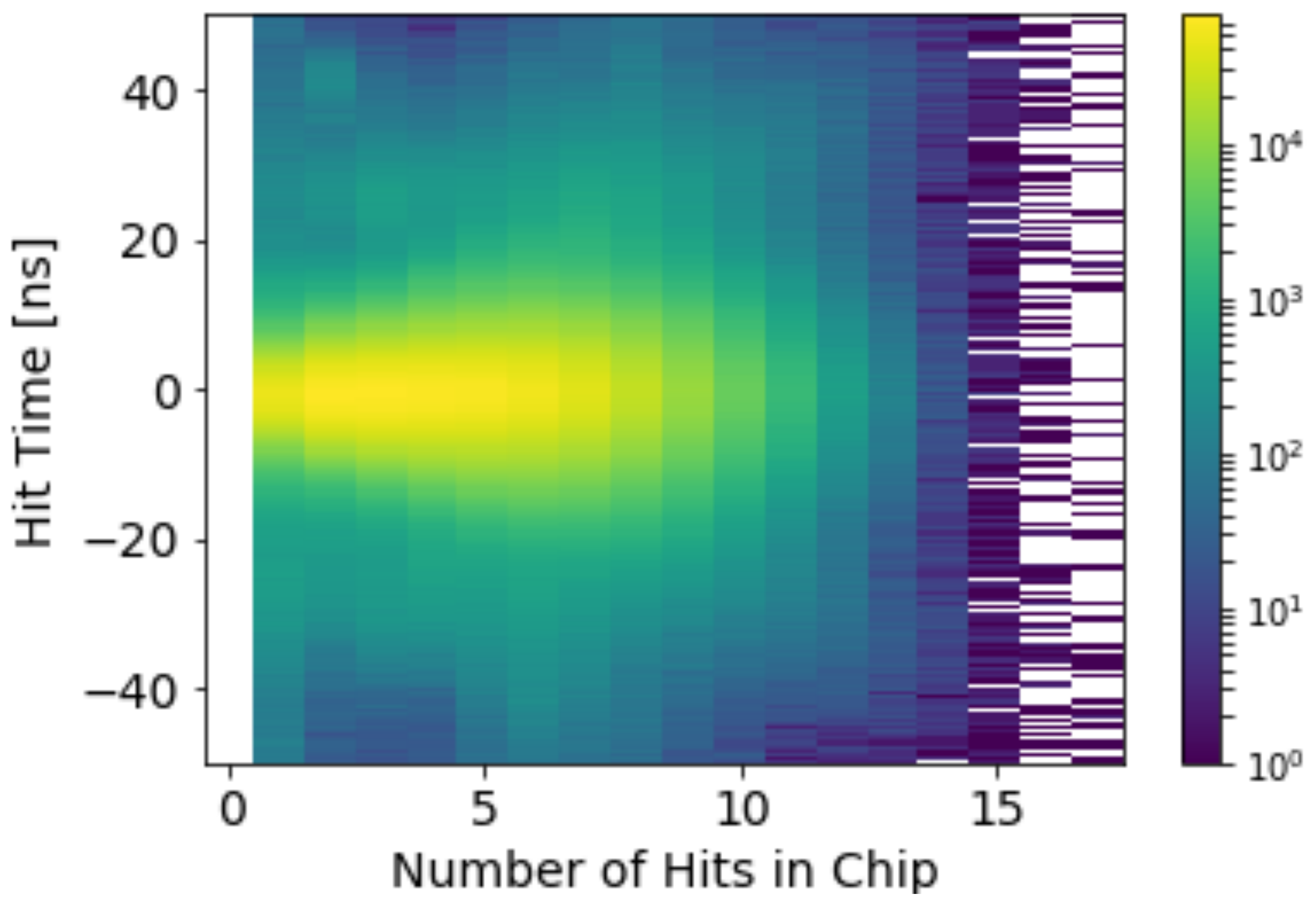
Correction on Channel Level

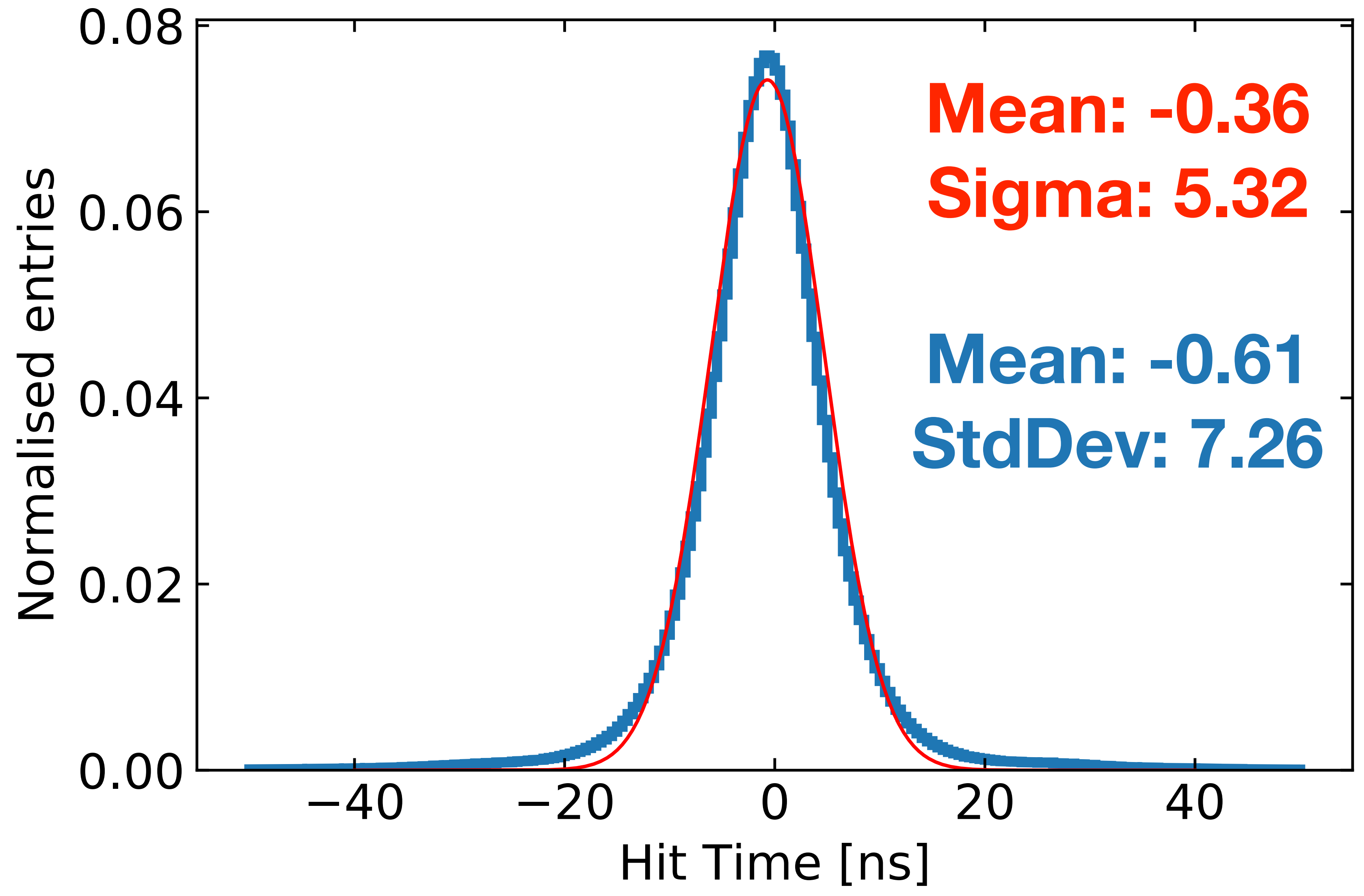




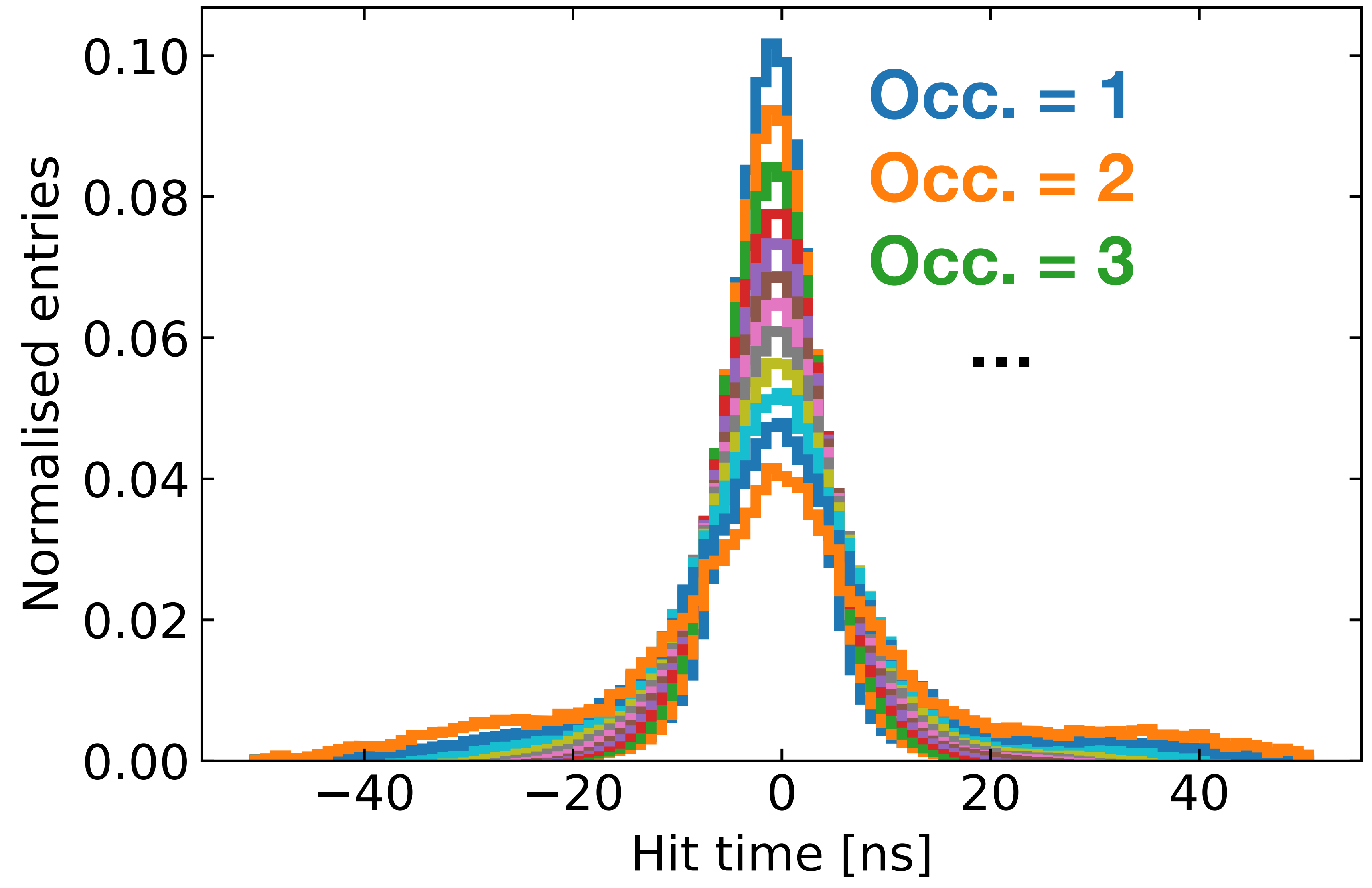
Correction on Channel Level

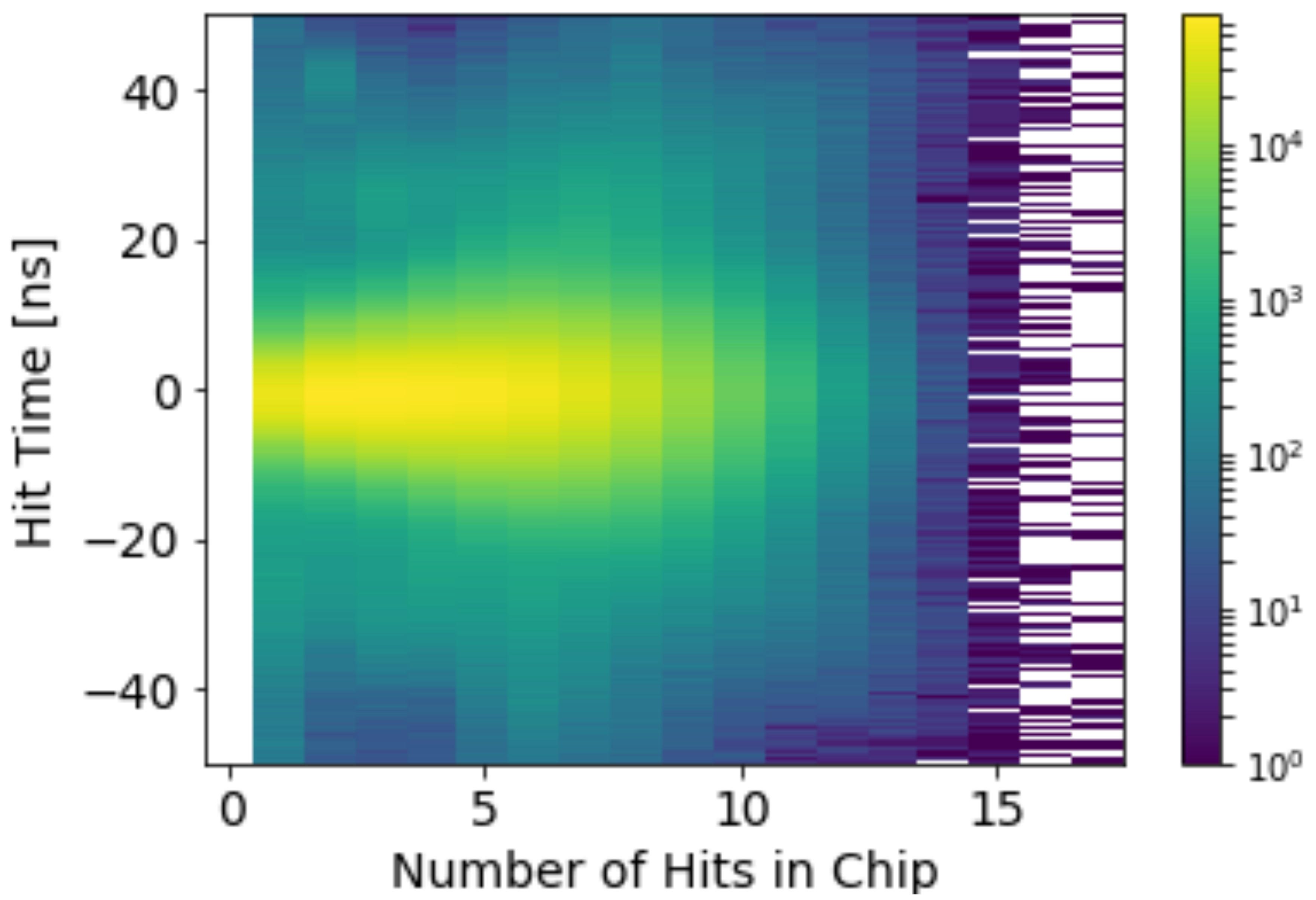


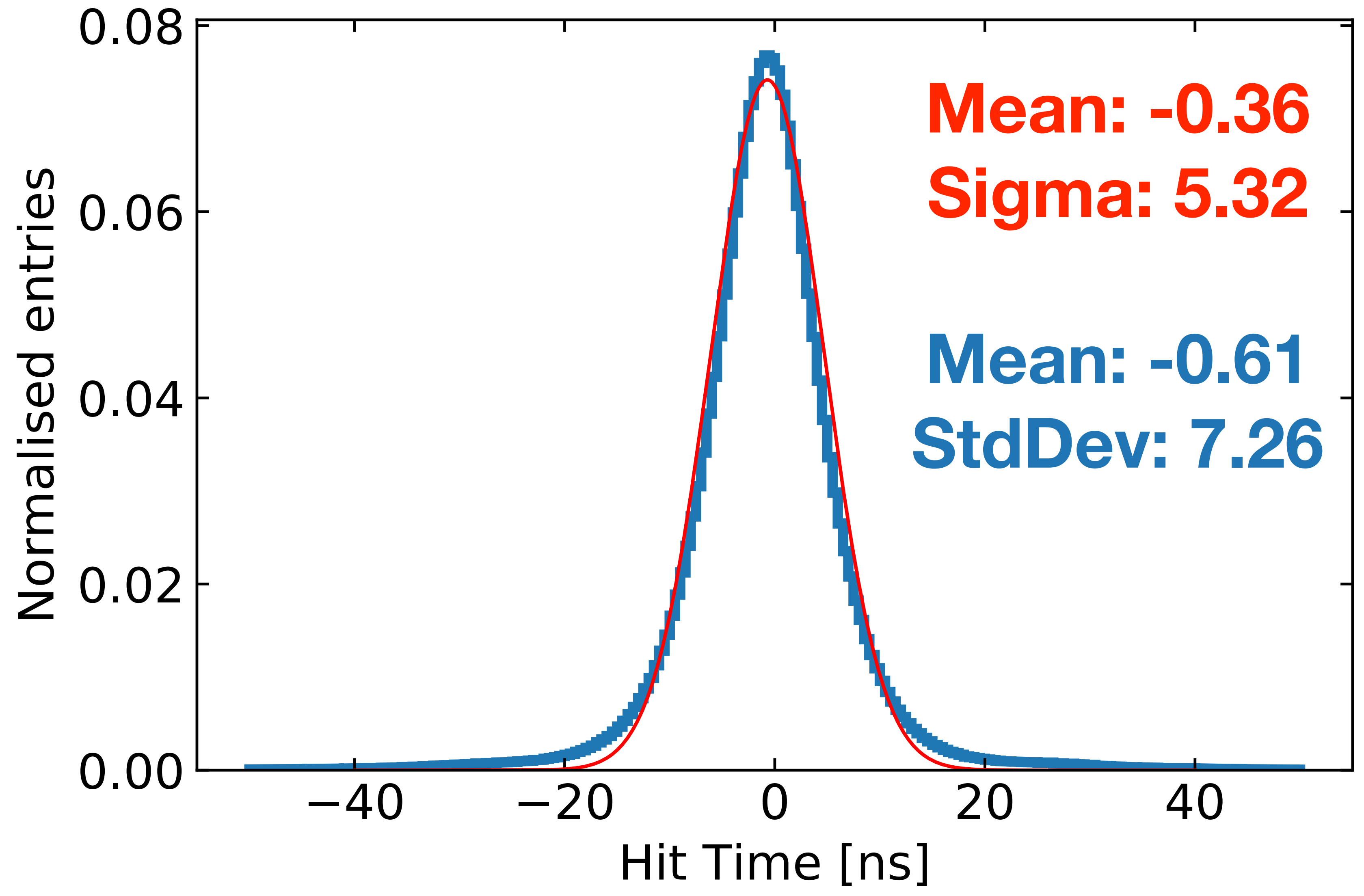




Correction on Channel Level







Channel wise correction outperforms global correction by ~1ns

Problem: Electromagnetic showers don't extend over the full depth

$\Longrightarrow$Try using Pions

Correcting with Pions

Correction obtained with a 40GeV Pion Run from June2018:

- Cut on hit time +- 50ns to reduce influence of late hits on the correction factors, inspired by most shifted channels seen in electron runs

- Fit individual channels: Correction = slope x occupancy + offset

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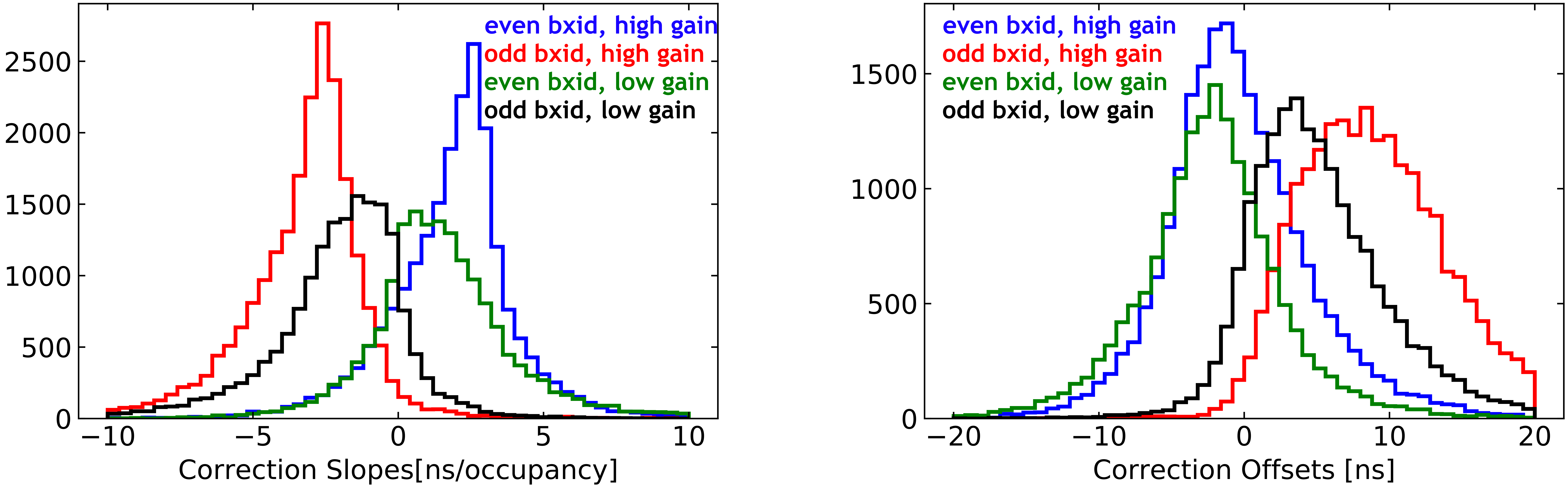
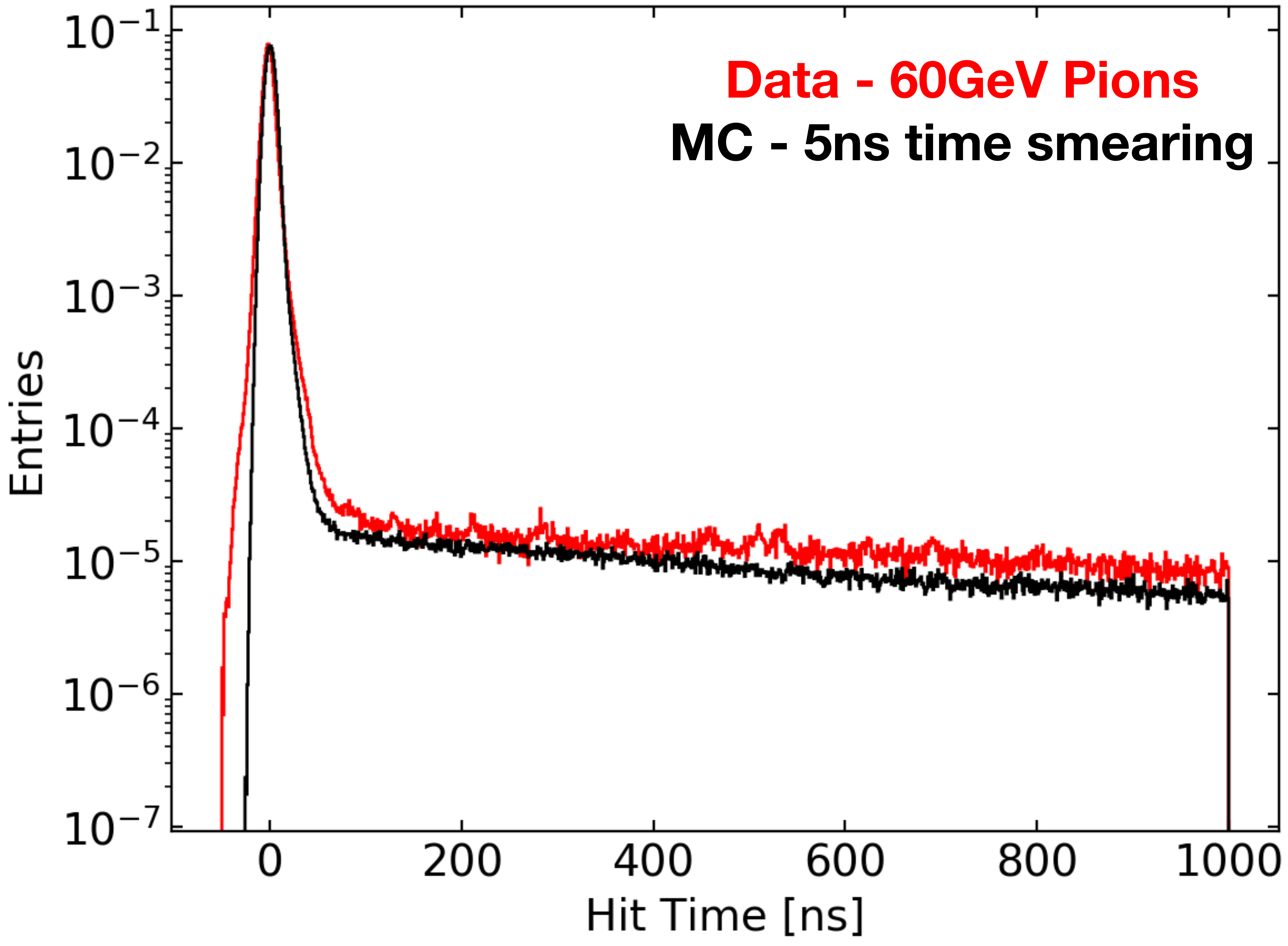
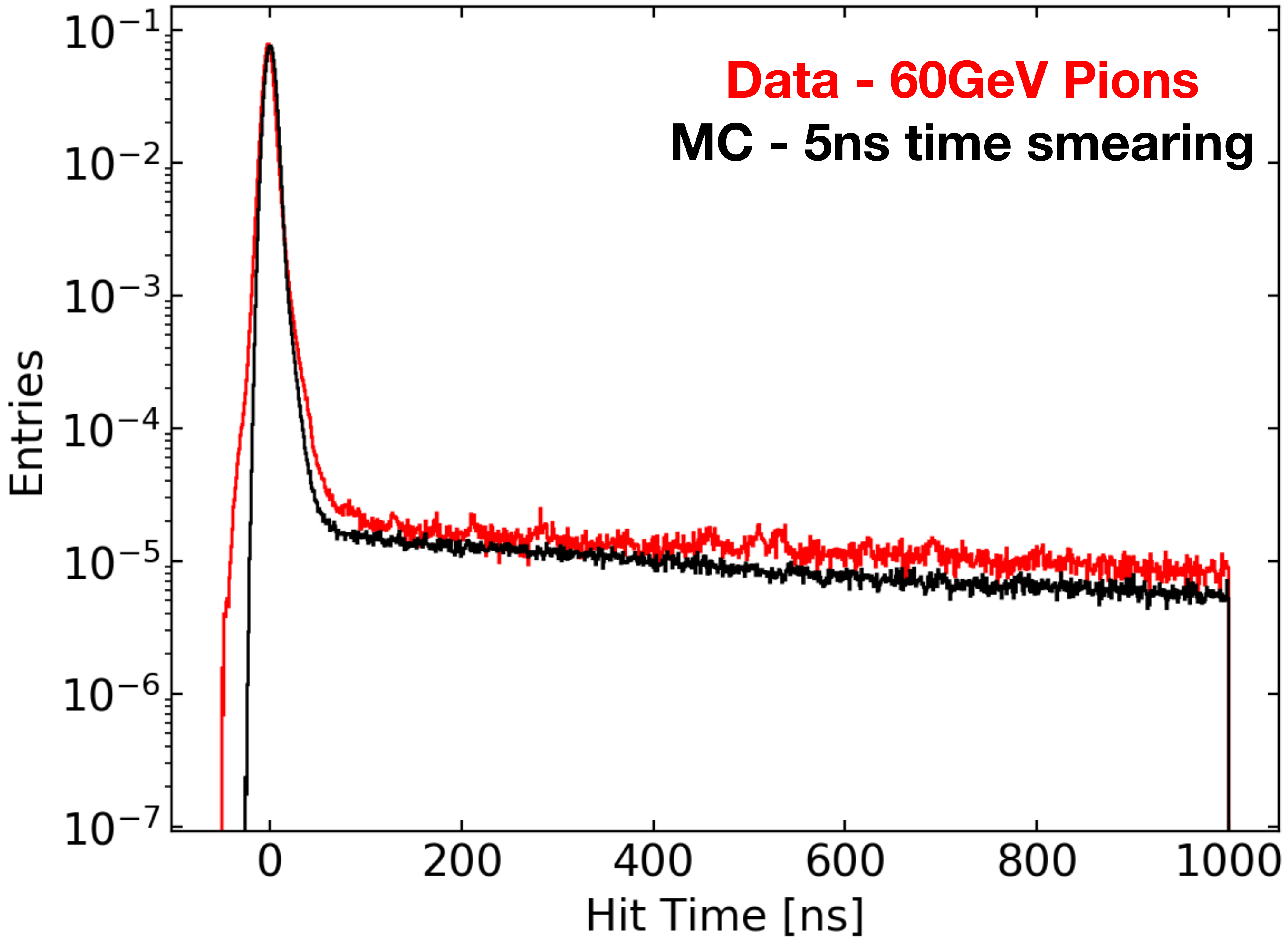


Pion Hit Time Distribution

Pion Hit Time Distribution



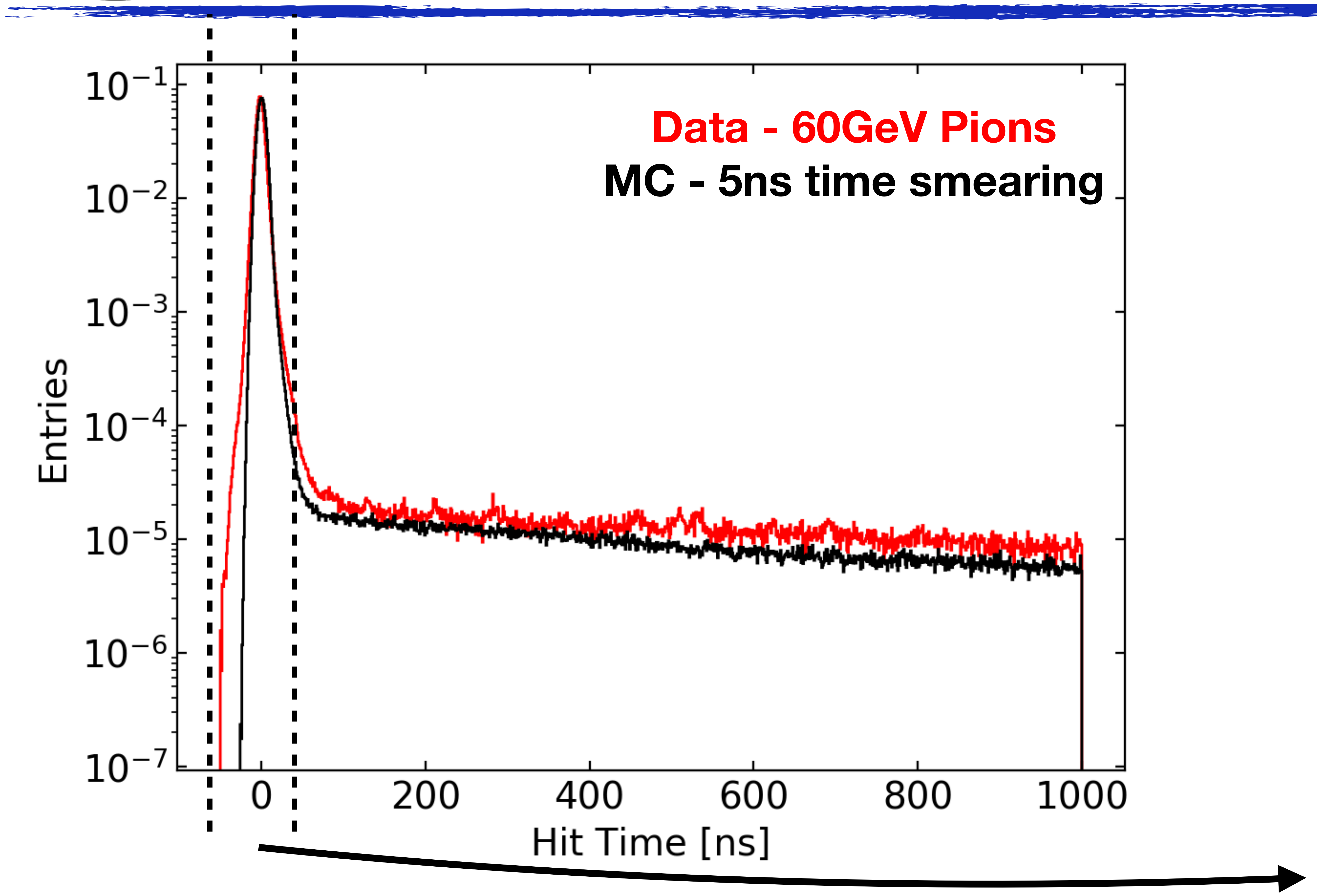
Pion Hit Time Distribution



Data Quality Selections:

- 500ns < BIF Time < 2500ns
- Hit Time < 3500ns
- Number of Hits > 180
- 200 < Depth of COG < 800

Pion Hit Time Distribution



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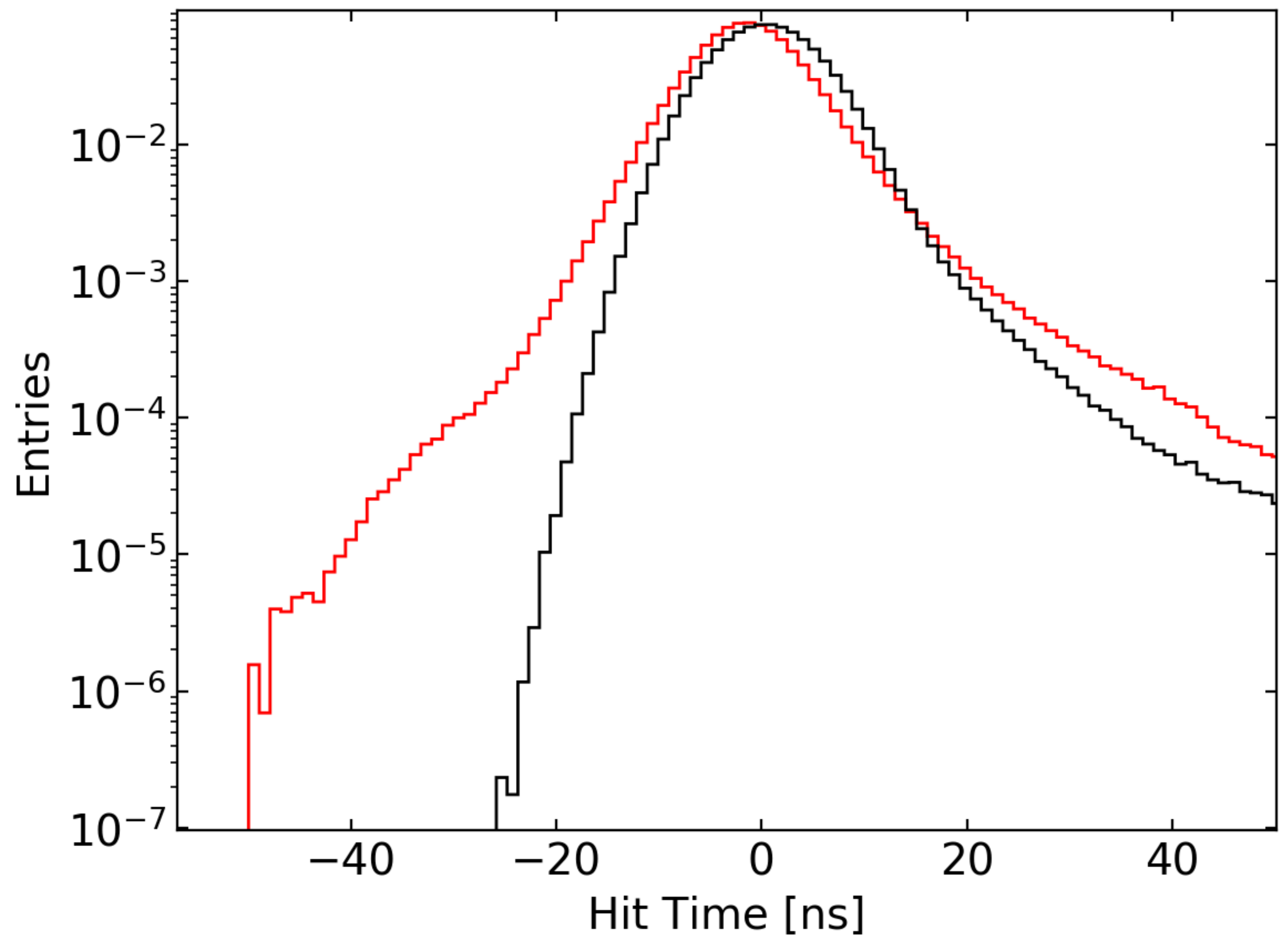
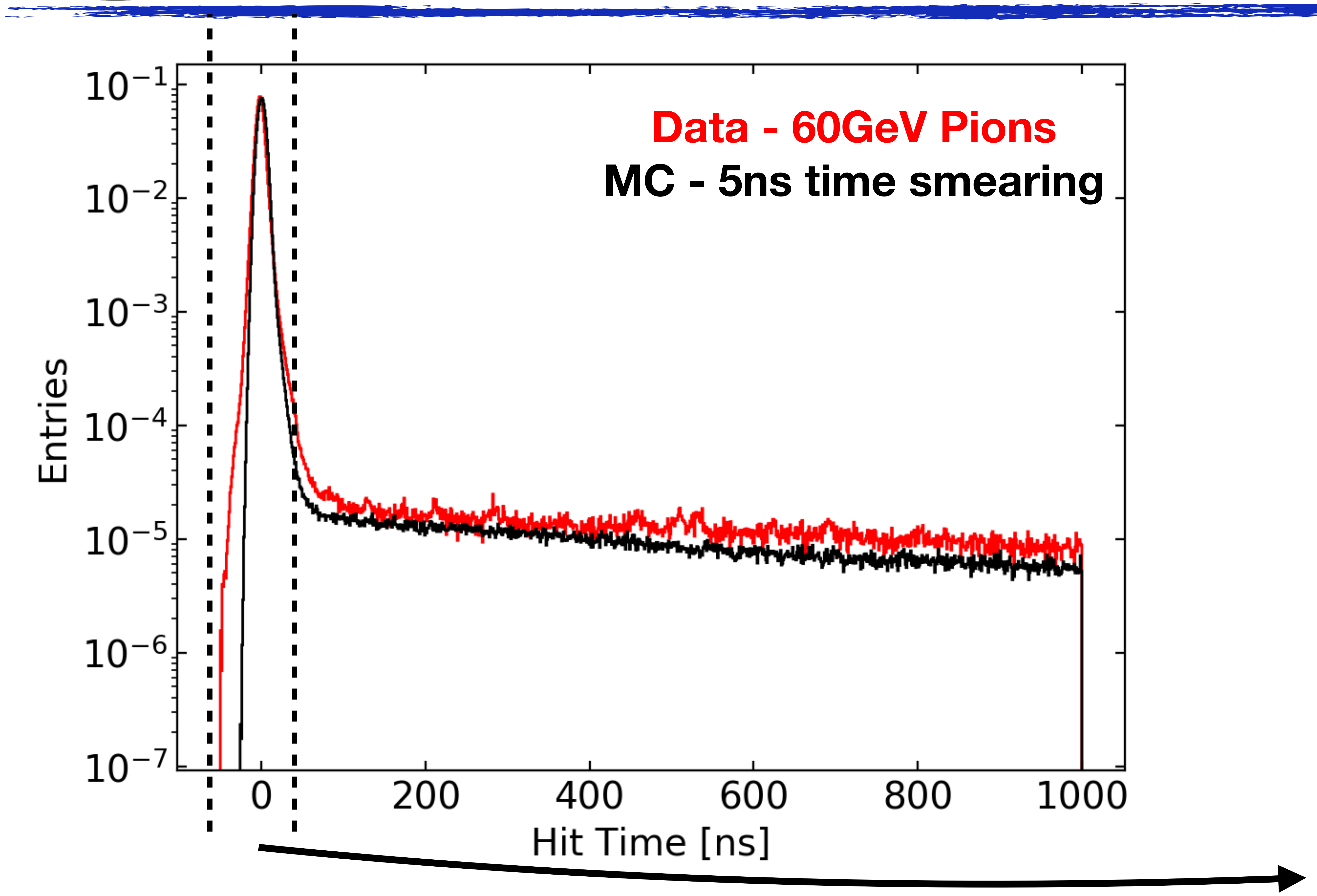


Pion Hit Time Distribution



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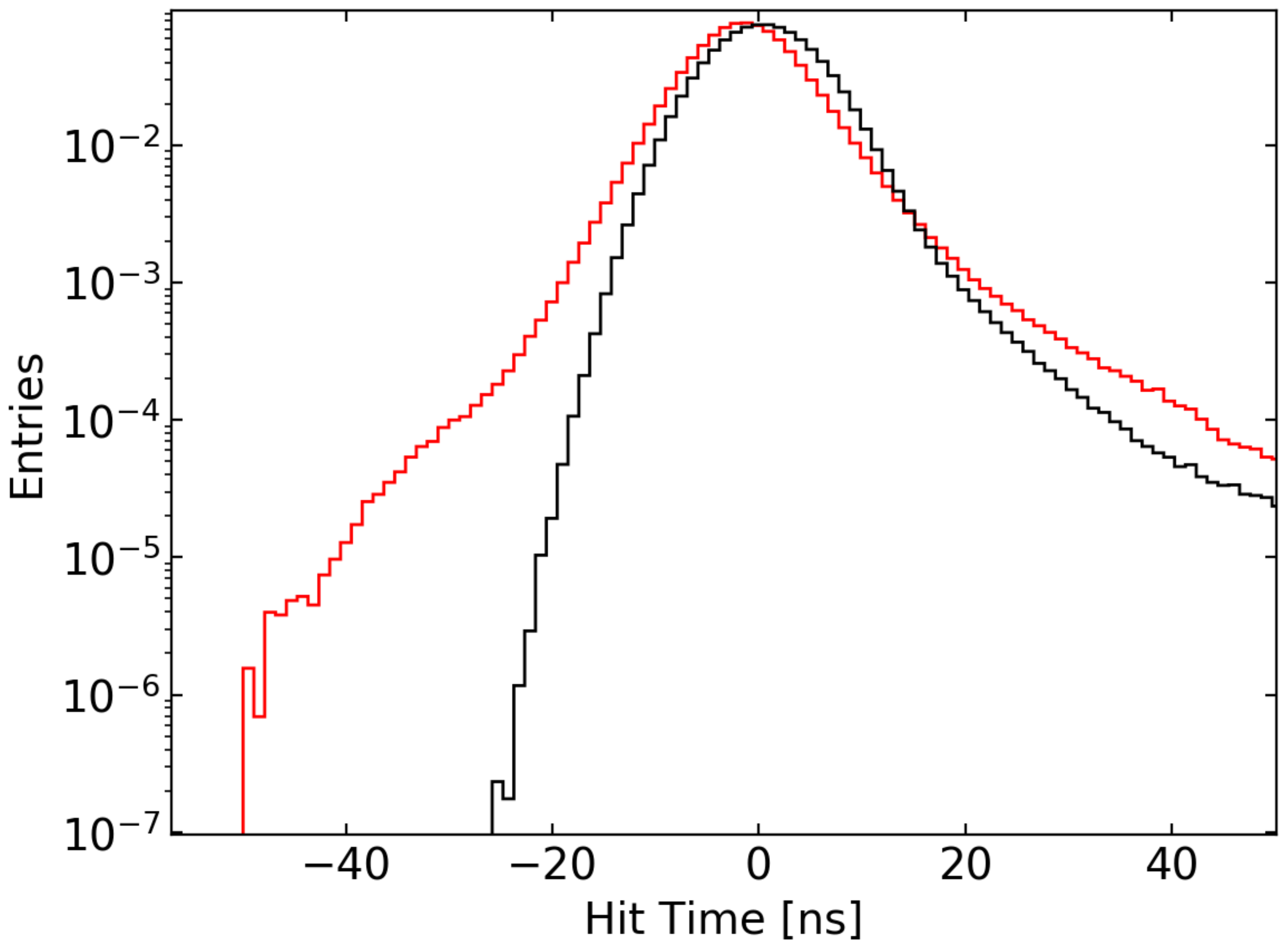
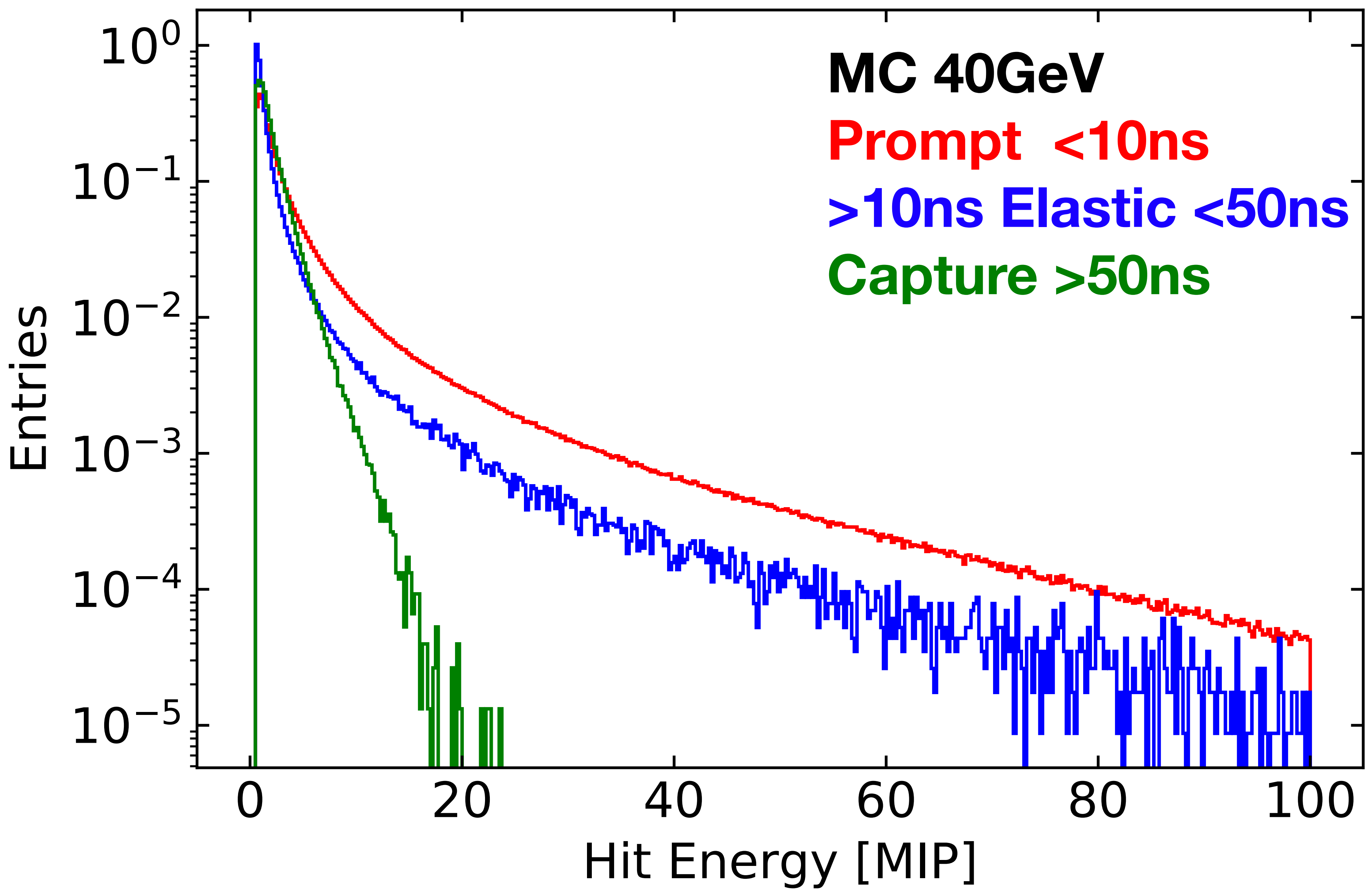


Divide spectrum into prompt (10ns), elastic (50ns) and capture part

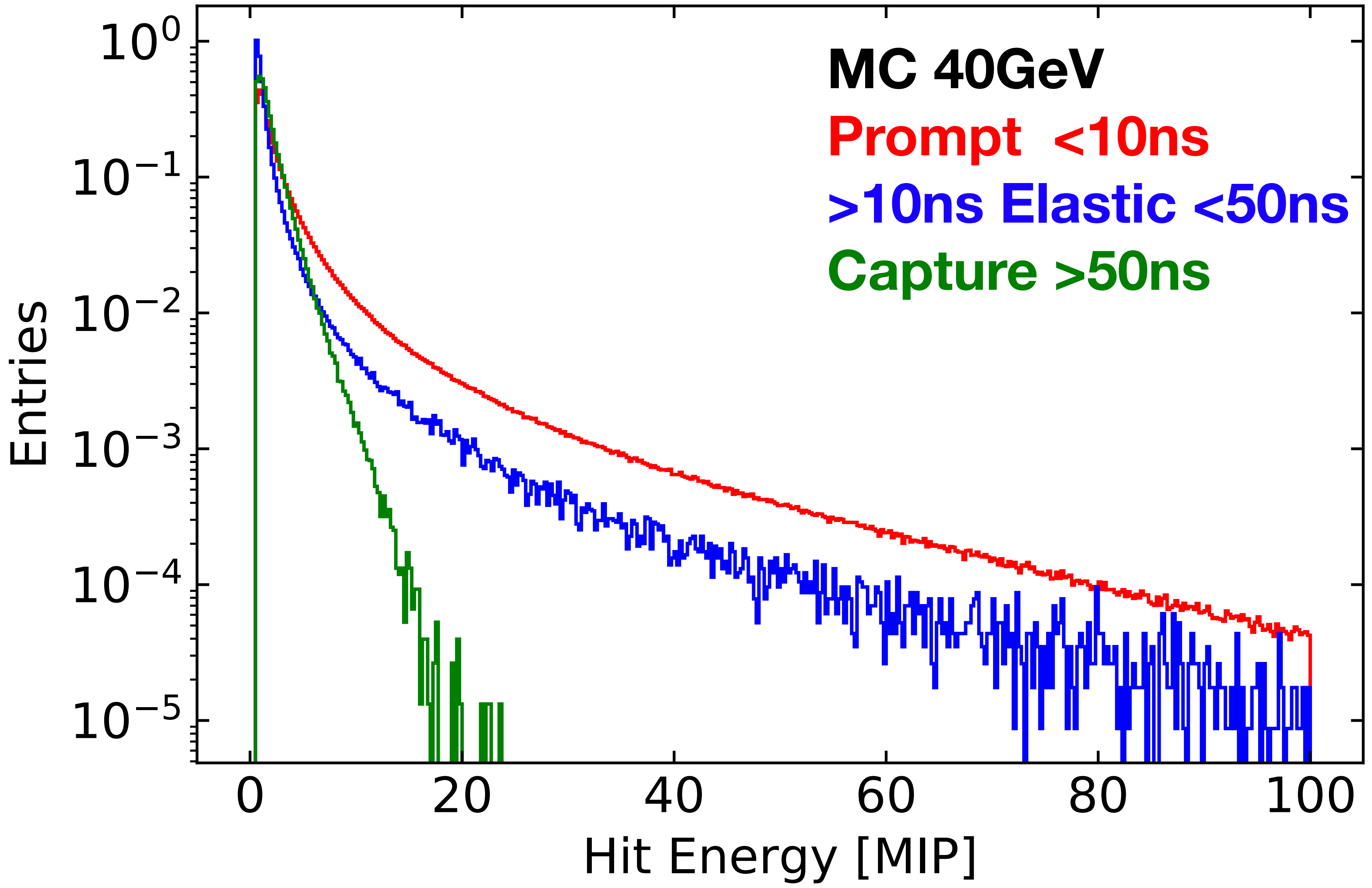
Compare to MC with 5ns time smearing

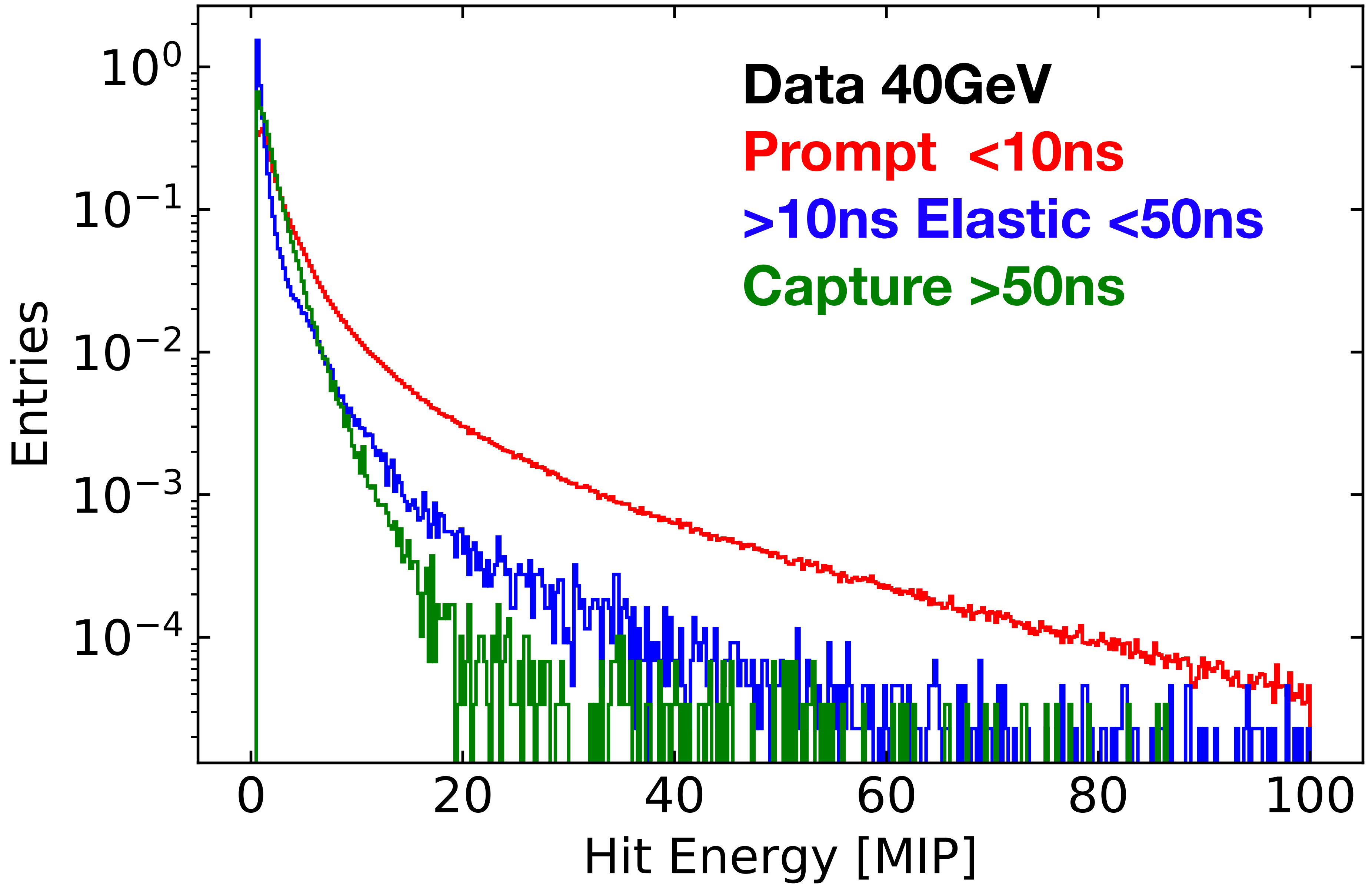
A Look at Pions - Hit Energy

A Look at Pions - Hit Energy



A Look at Pions - Hit Energy





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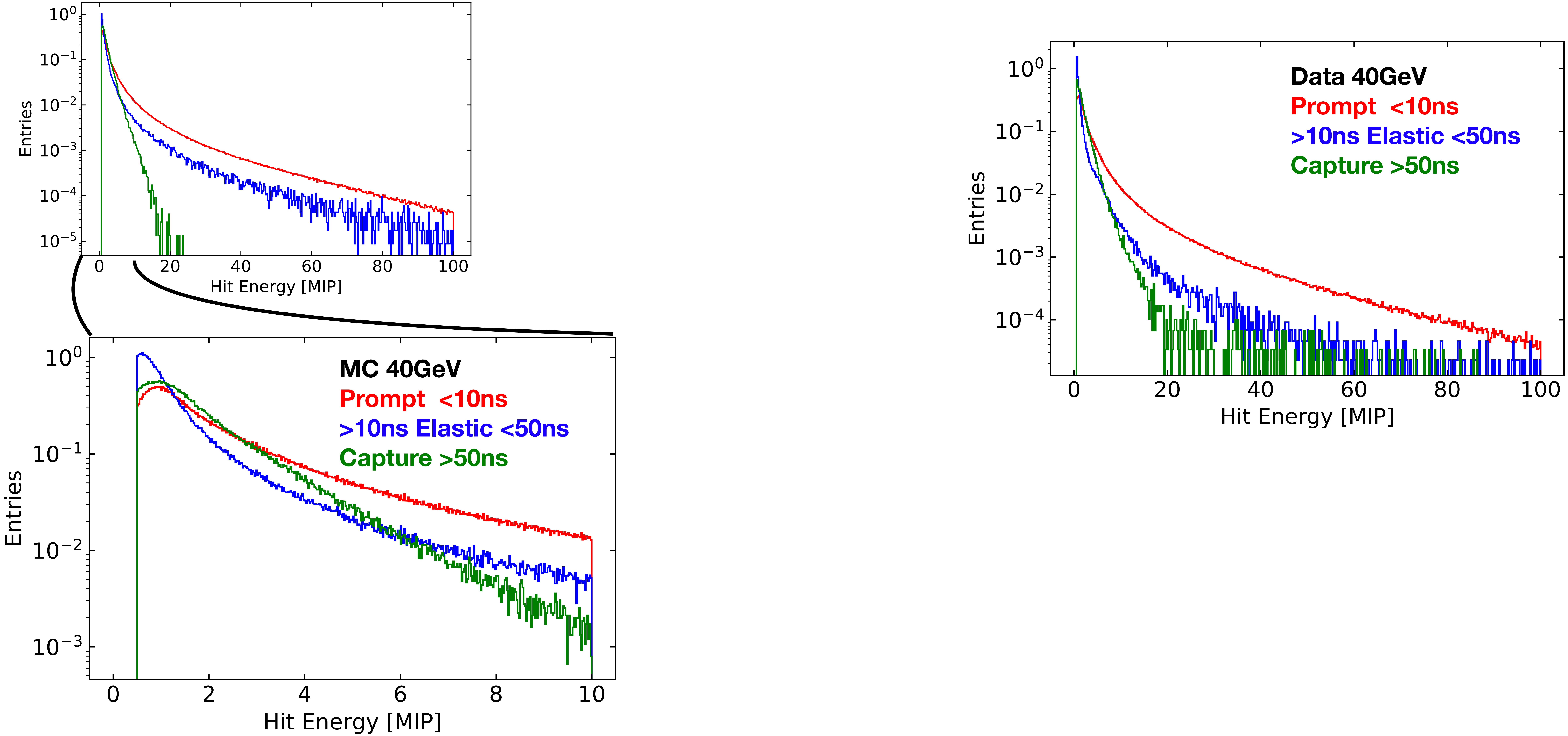
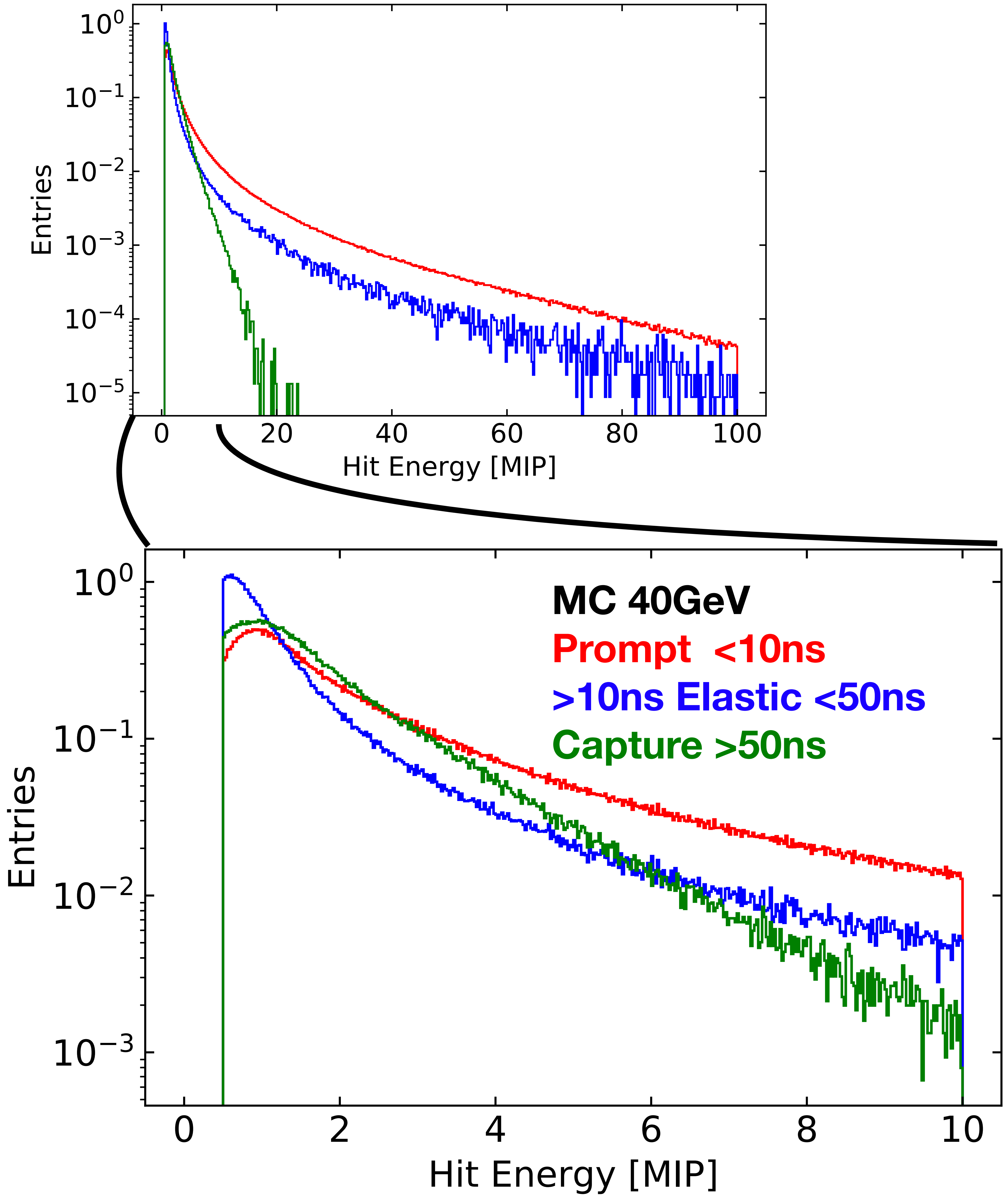
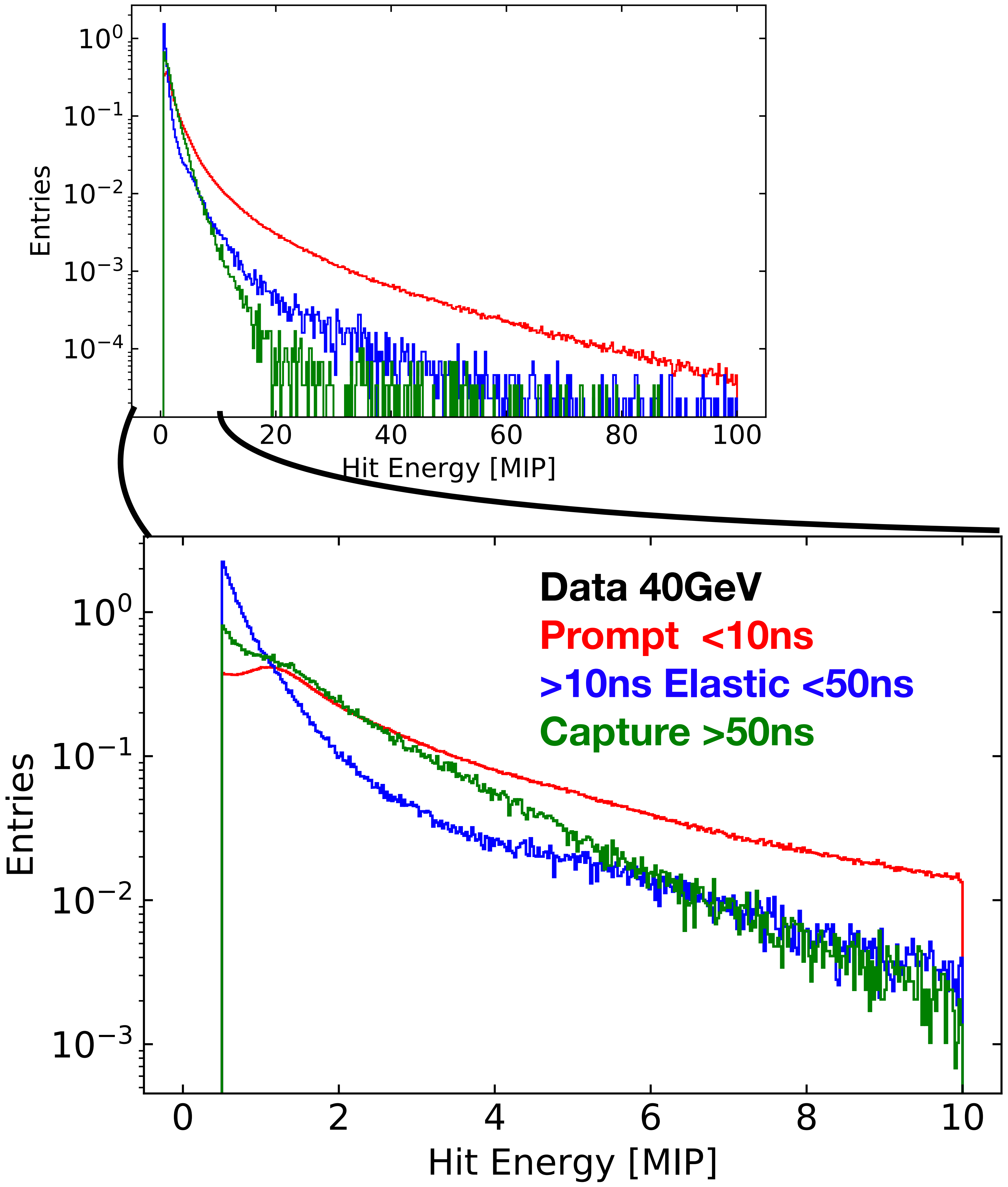
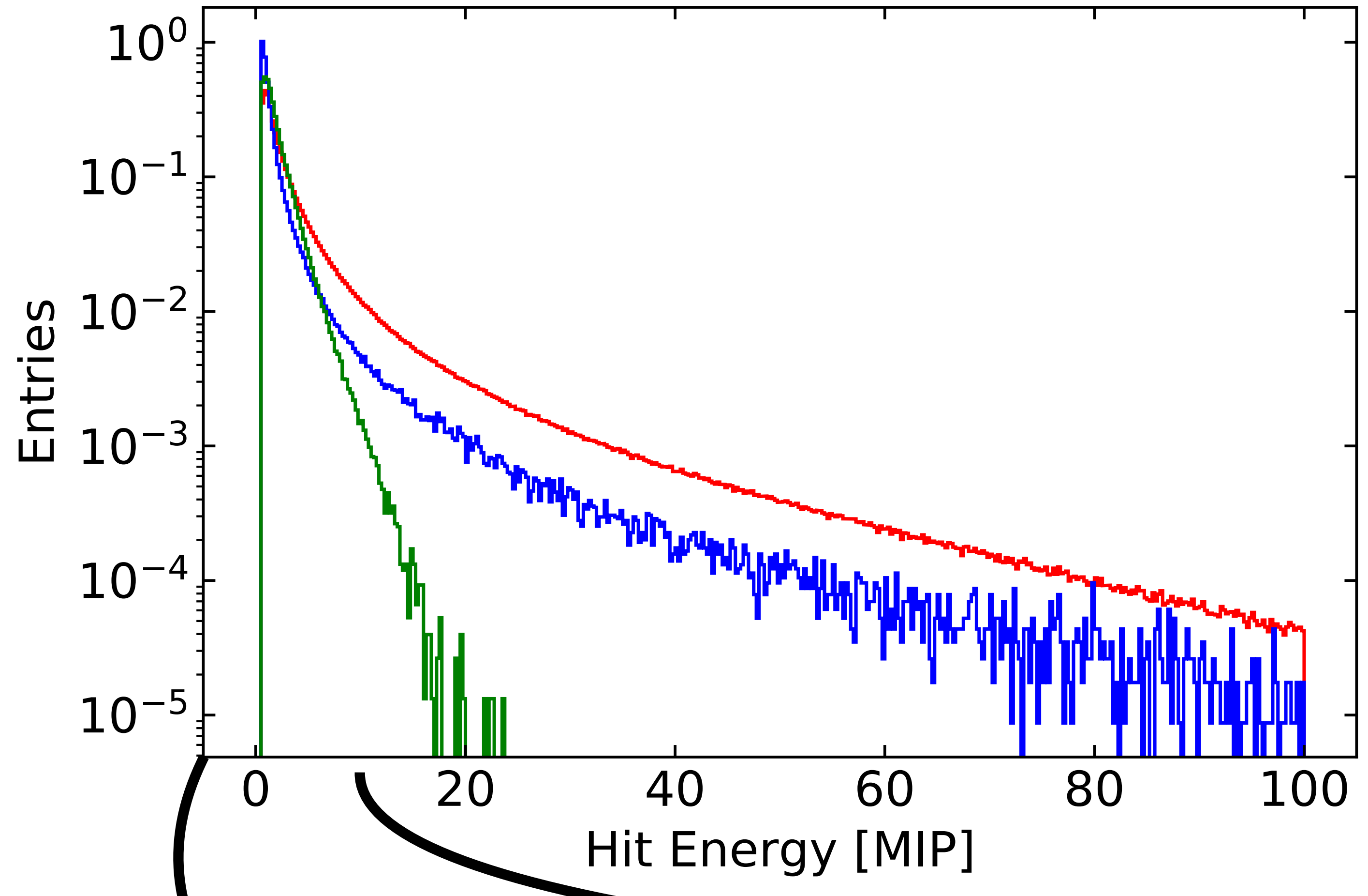


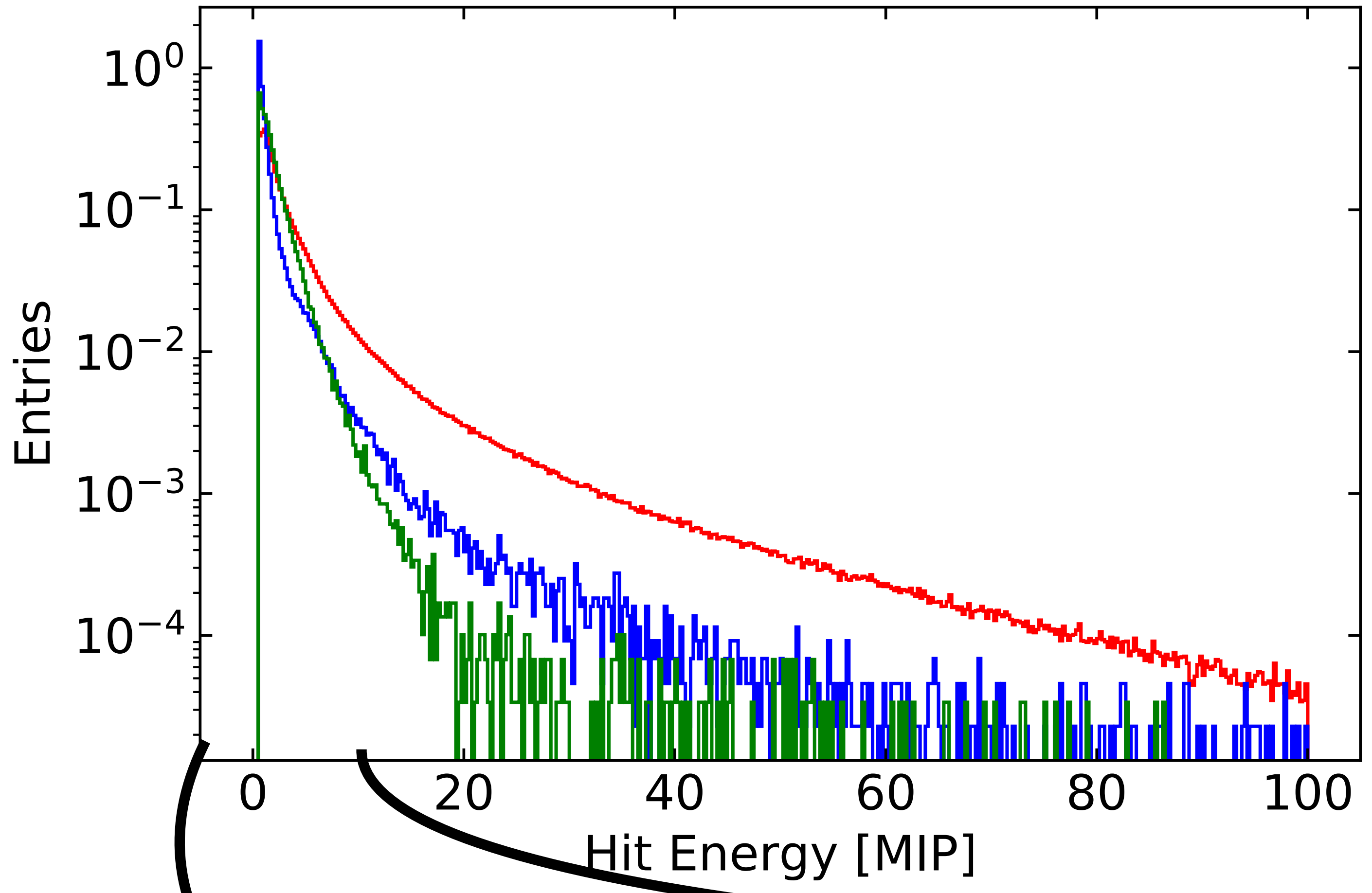
A Look at Pions - Hit Energy

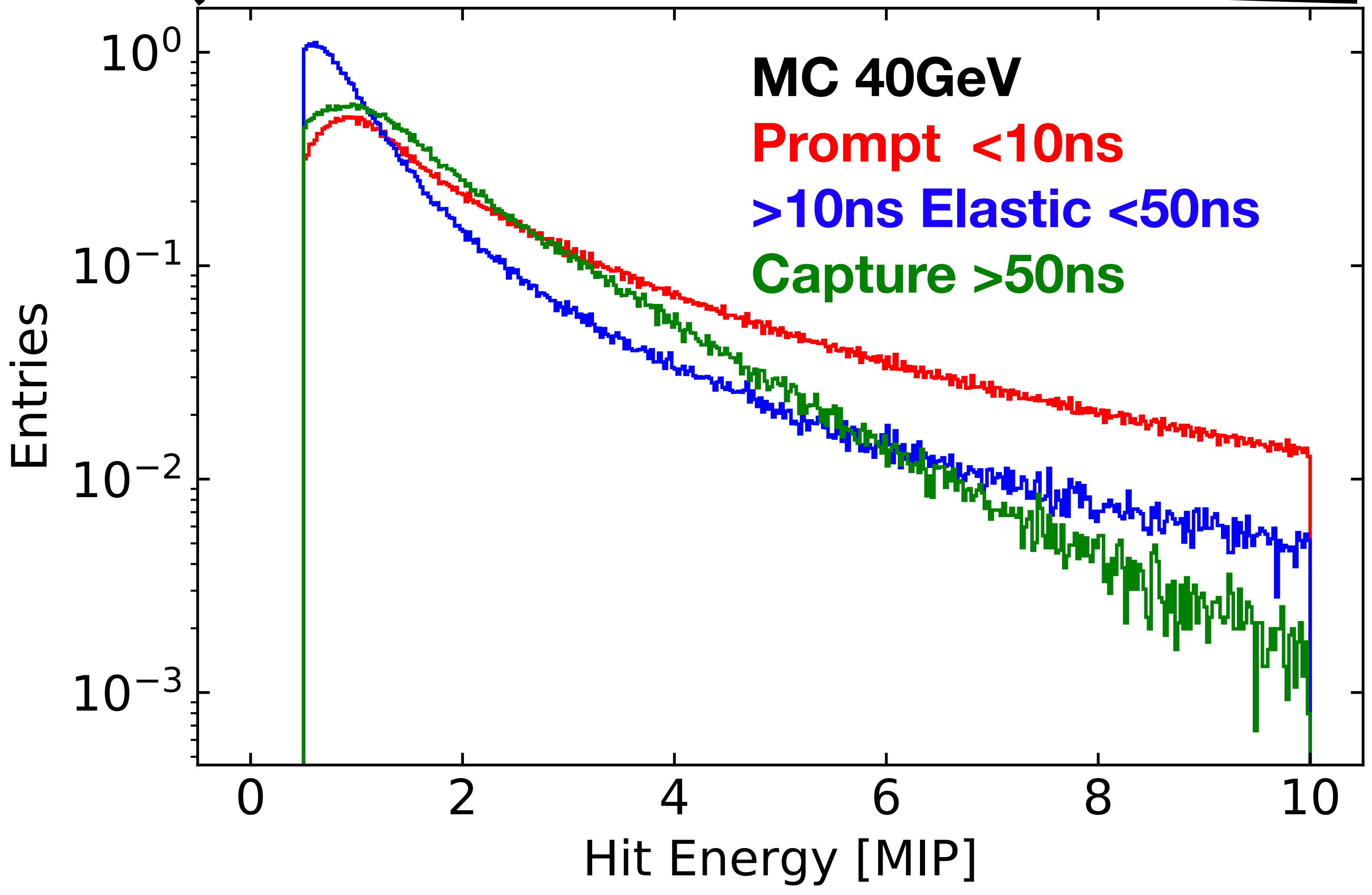




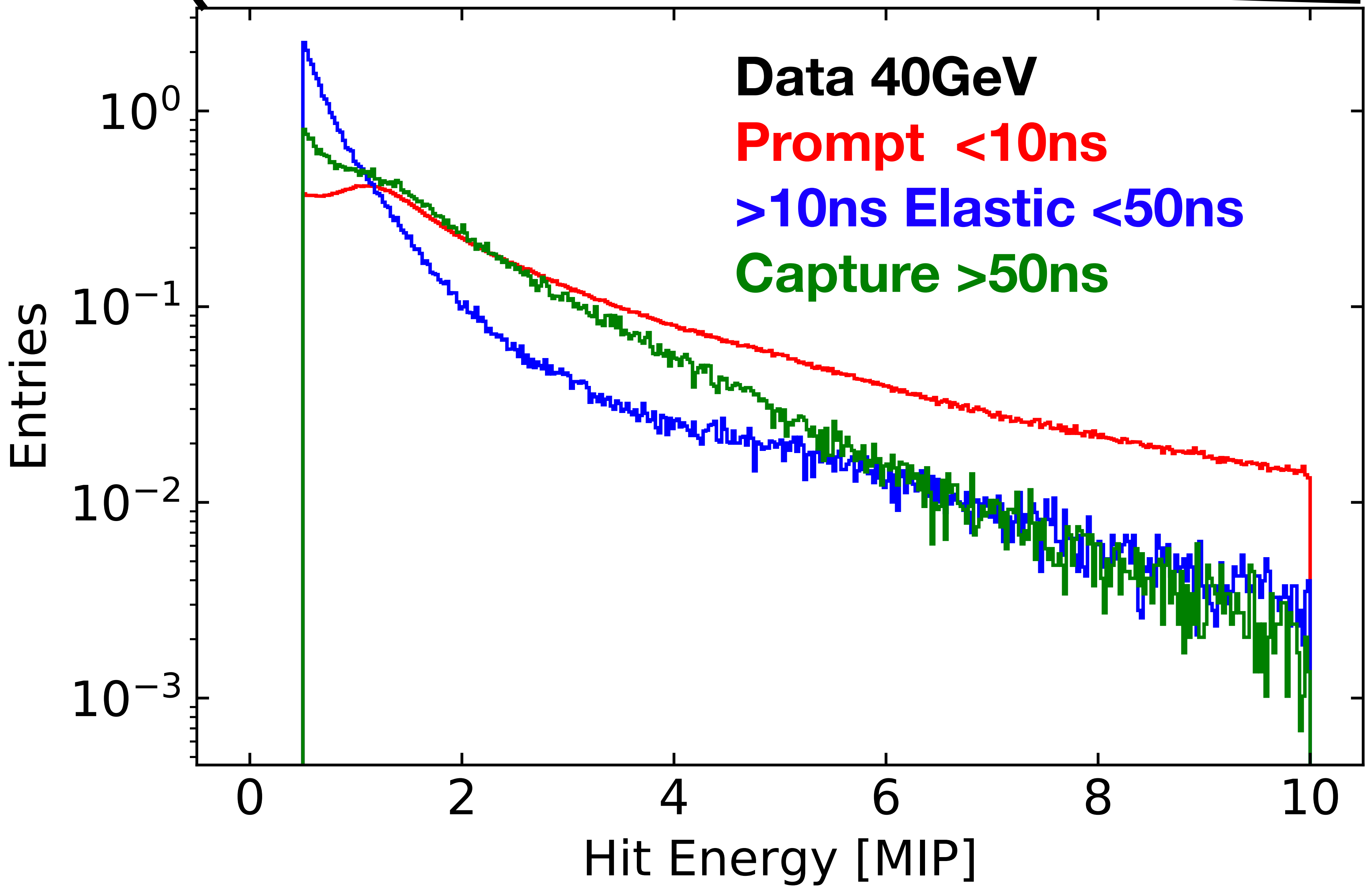
A Look at Pions - Hit Energy





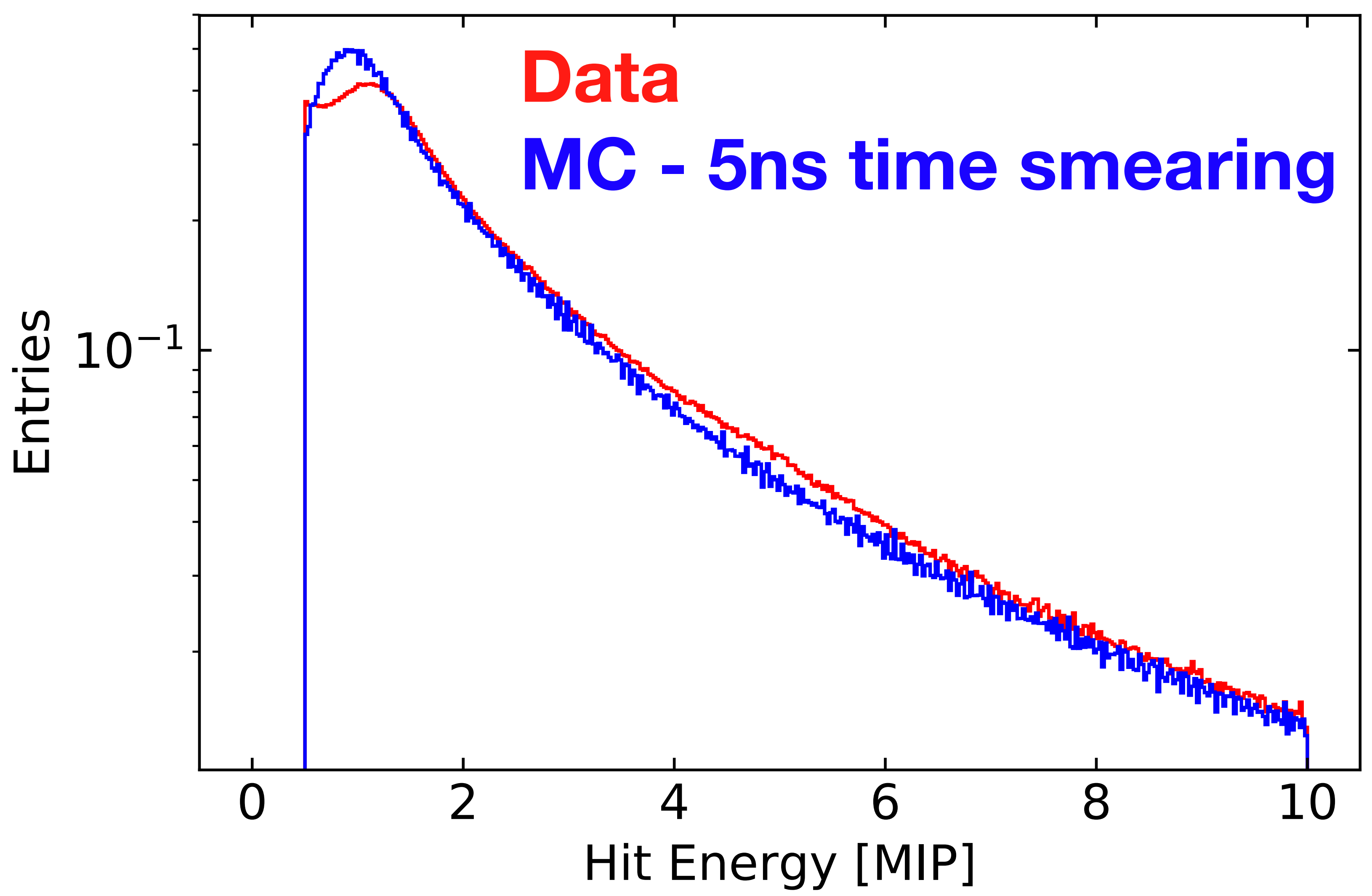


Global features are similar

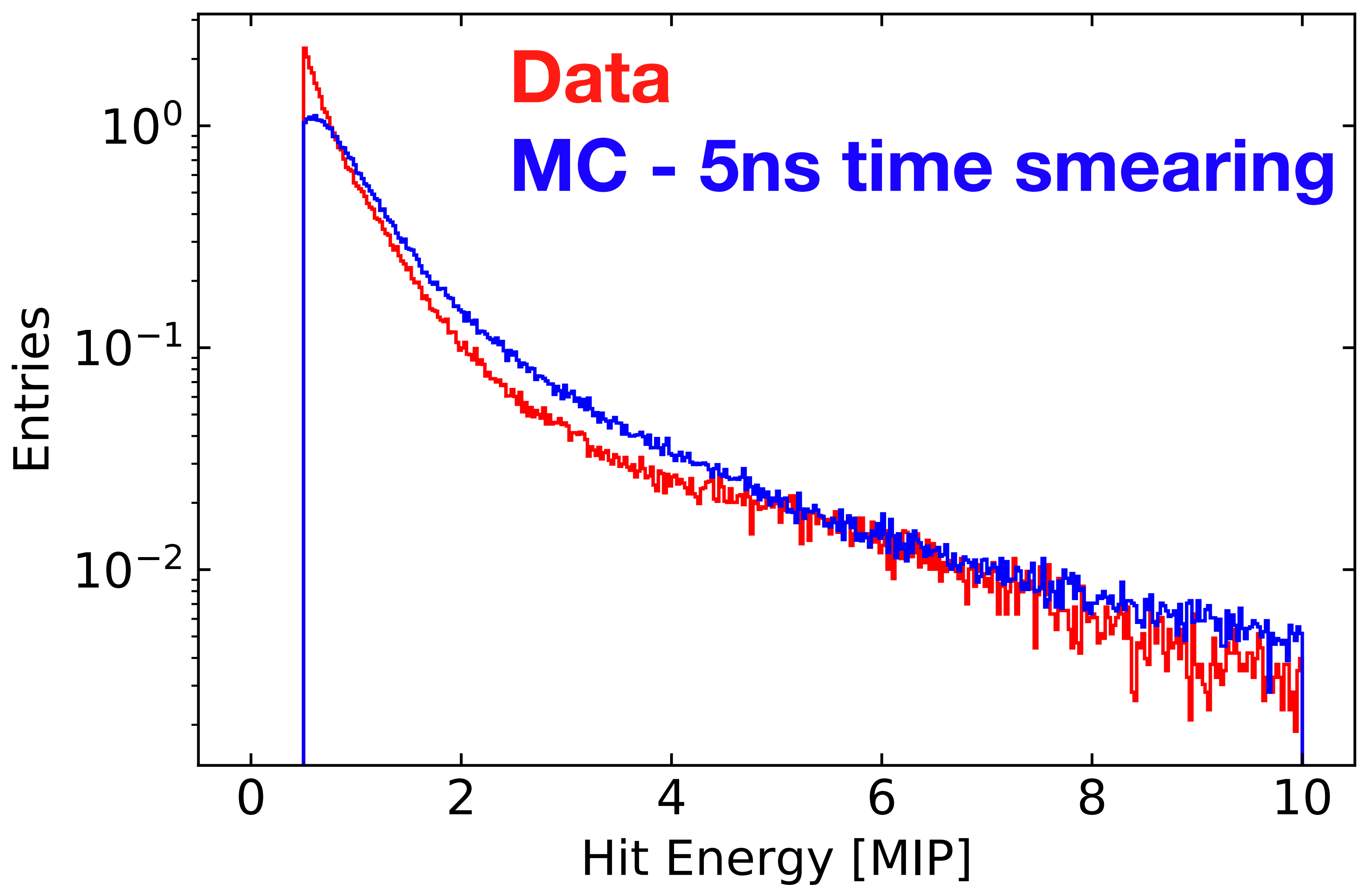


A Look at Pions - Hit Energy

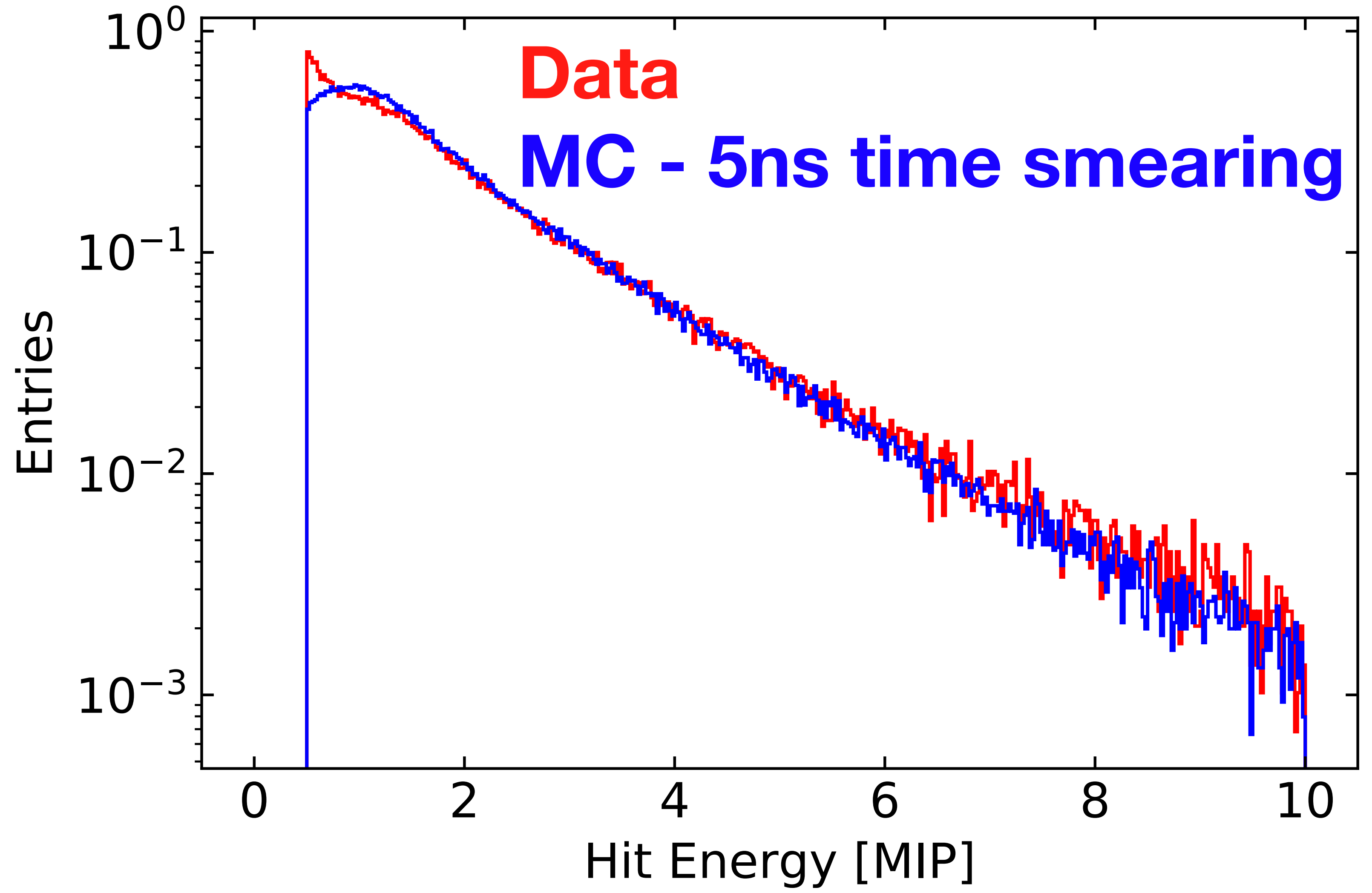
Prompt: hit time <10ns



Elastic:10ns< hit time<50ns



Capture: hit time >50ns



A Look at Pions - Hit Energy

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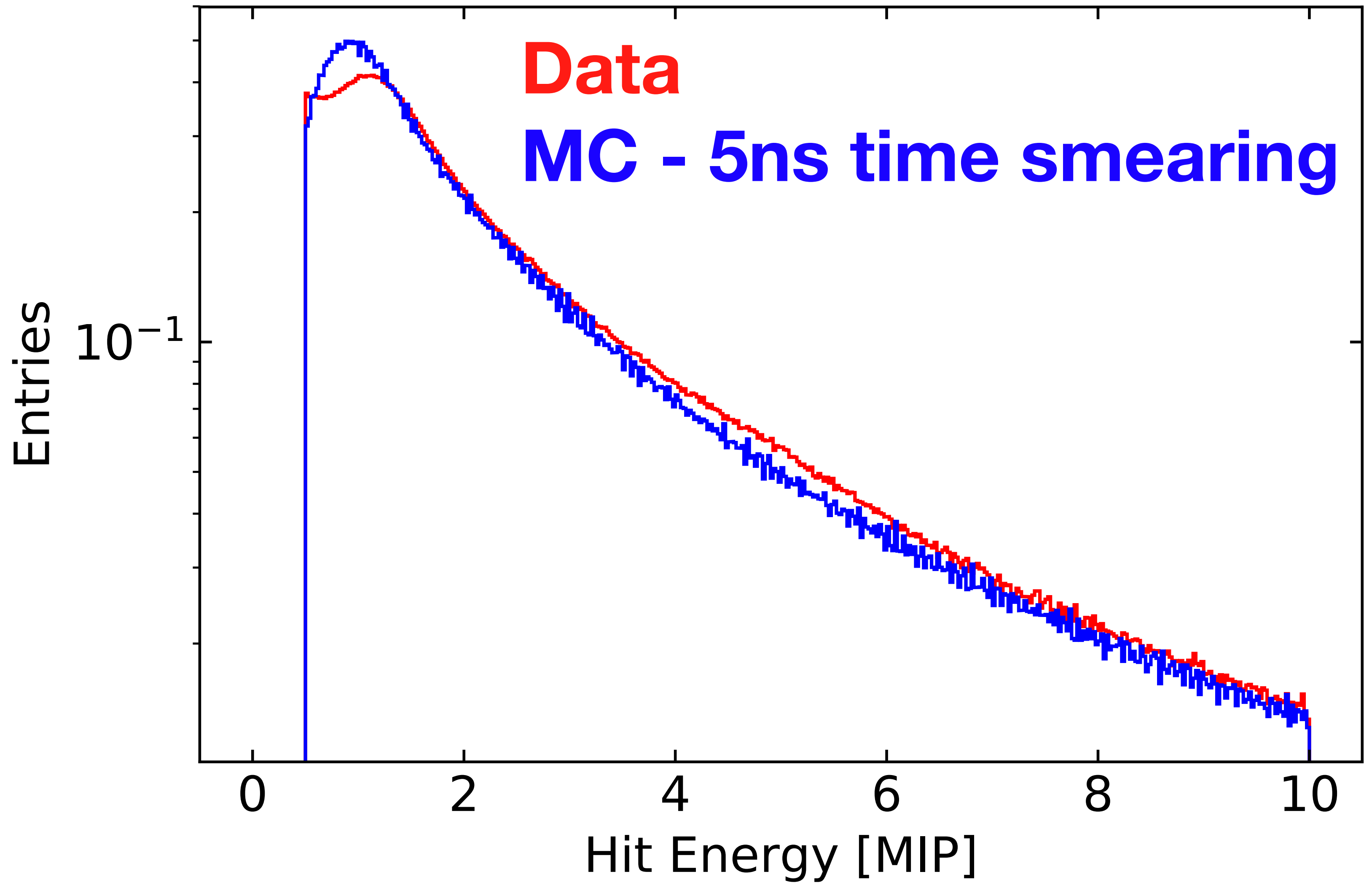
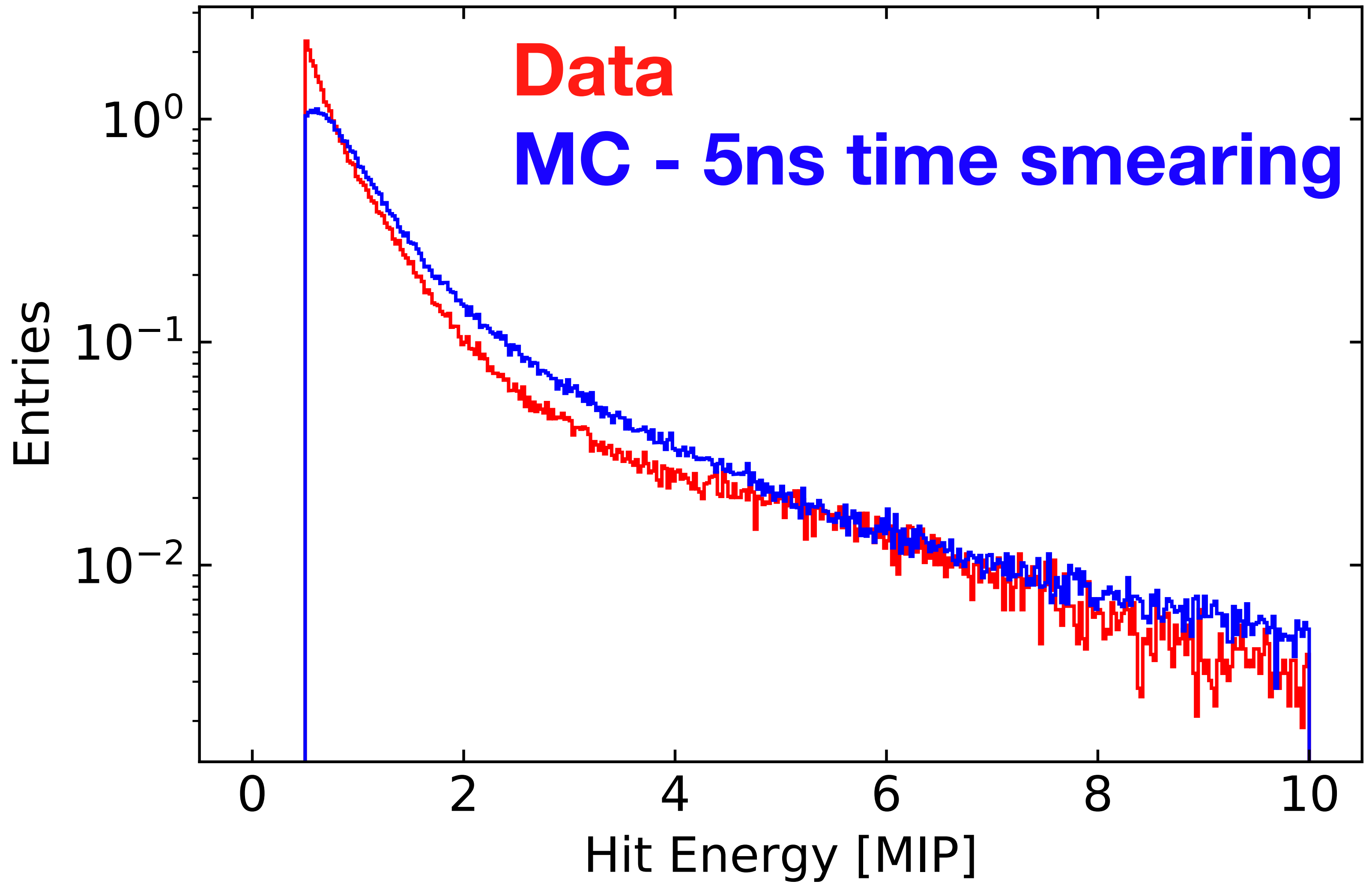
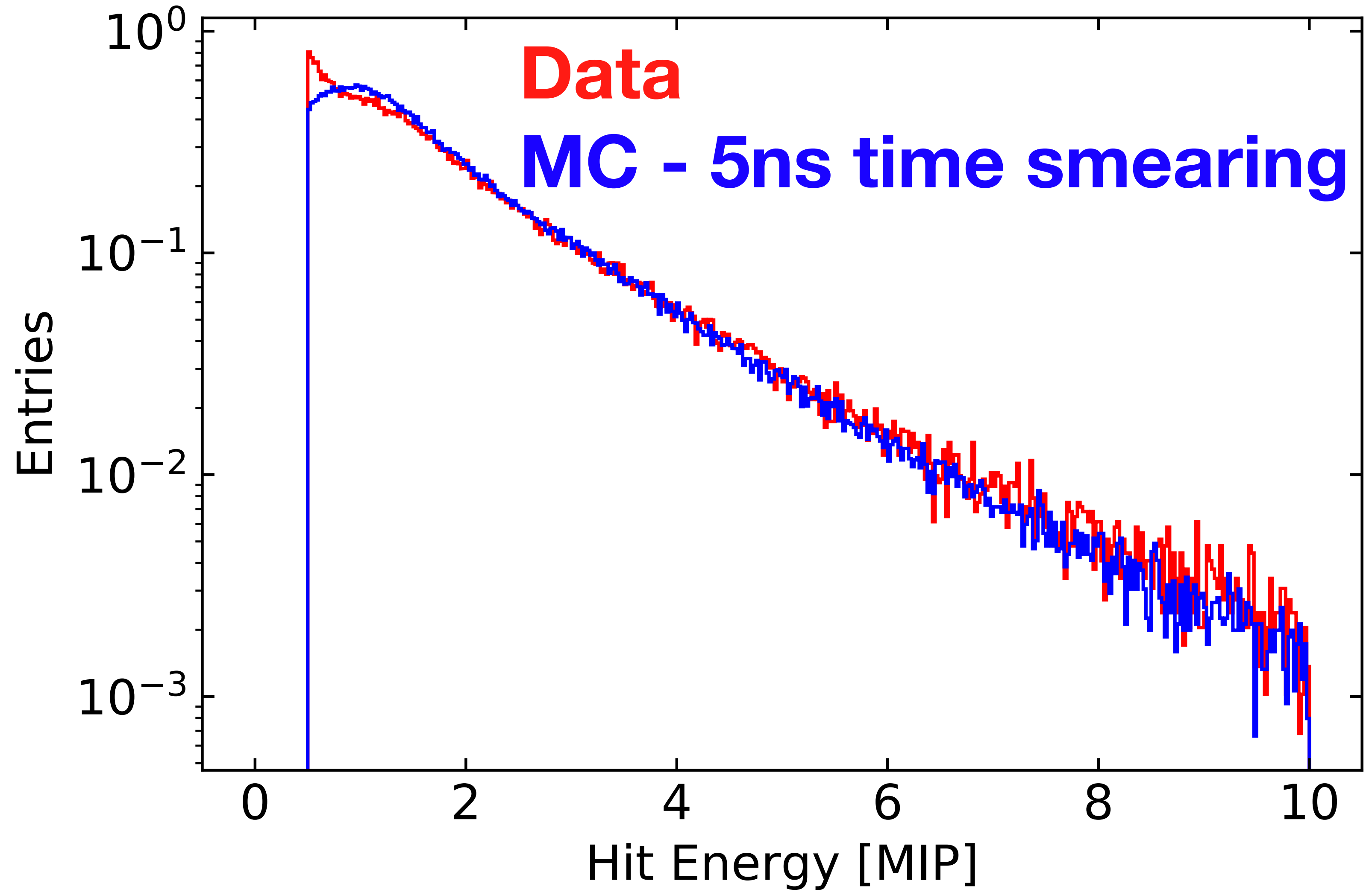


Elastic:10ns< hit time<50ns

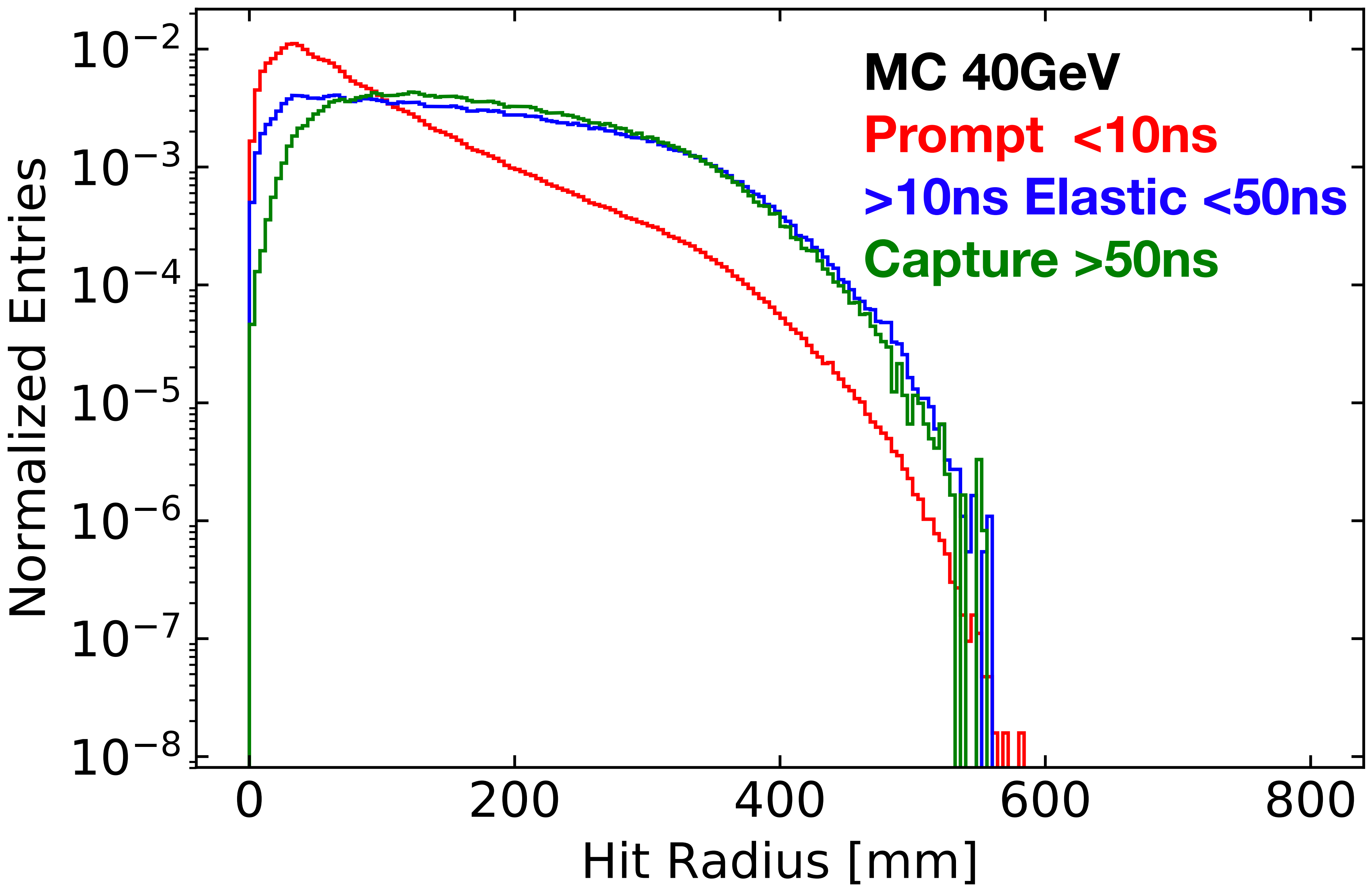


Capture: hit time >50ns

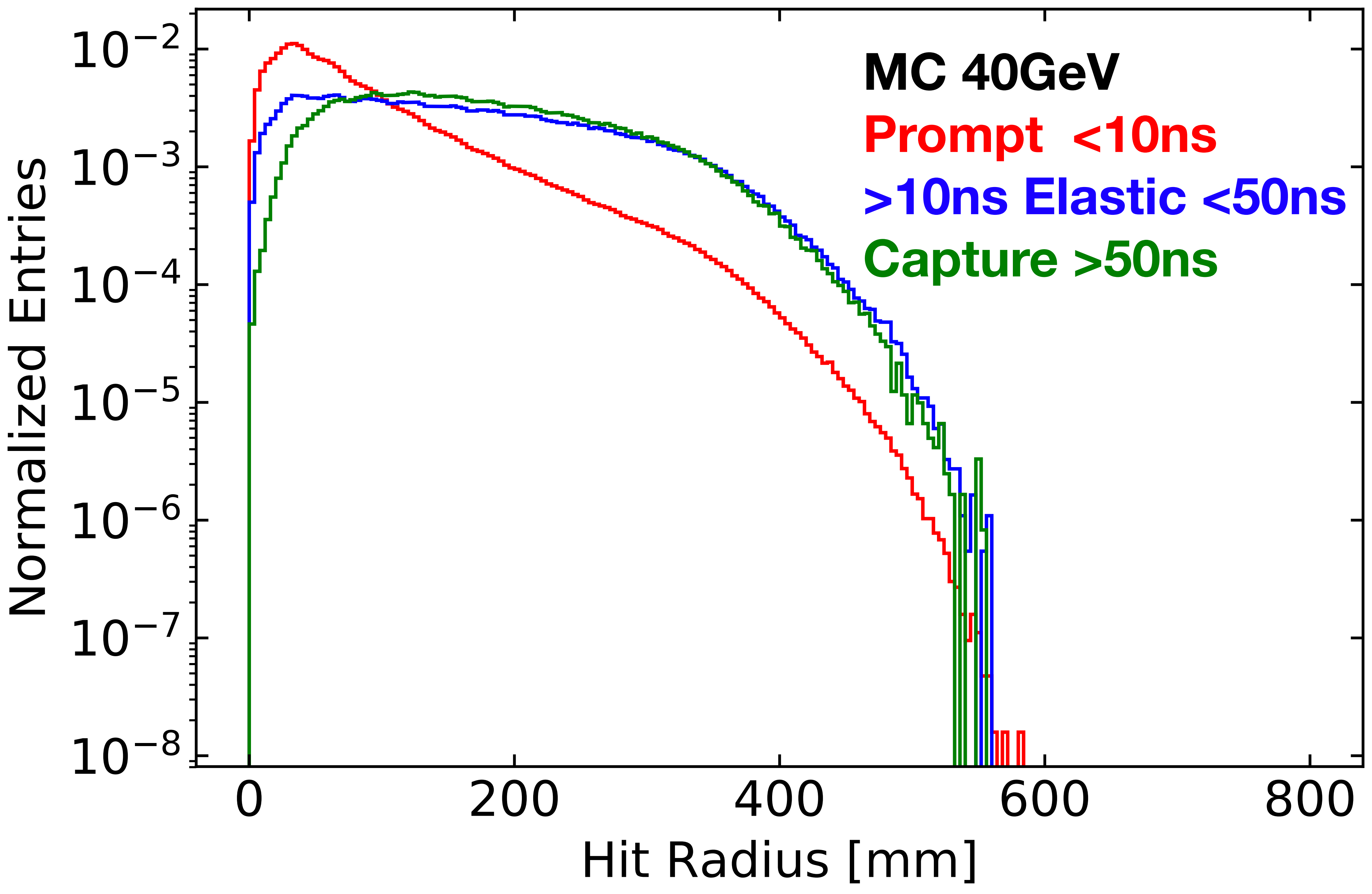


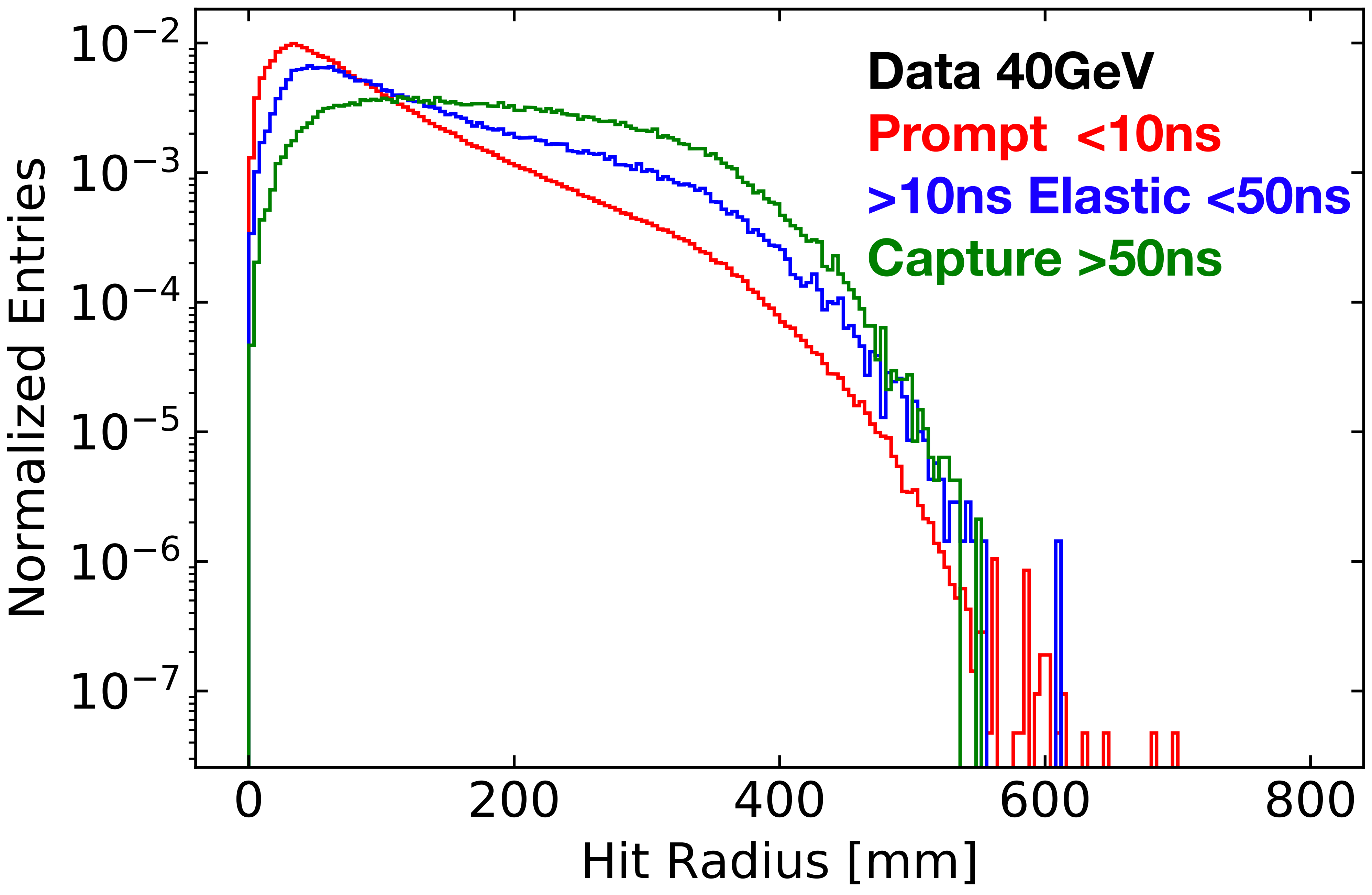
Disagreement in the low hit energy region

A Look at Pions - Hit Radius



A Look at Pions - Hit Radius





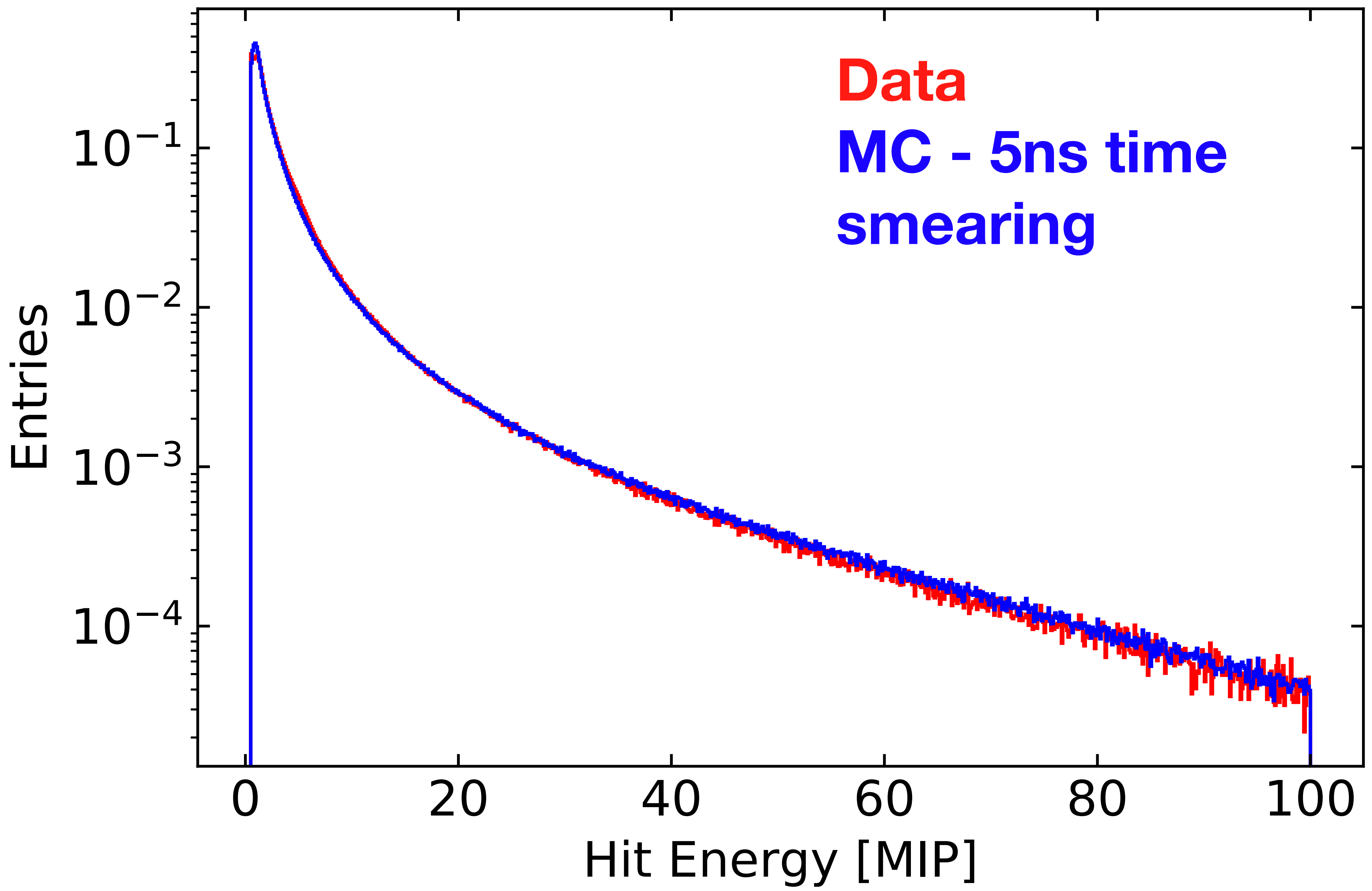
A Look at Pions - Hit Energy

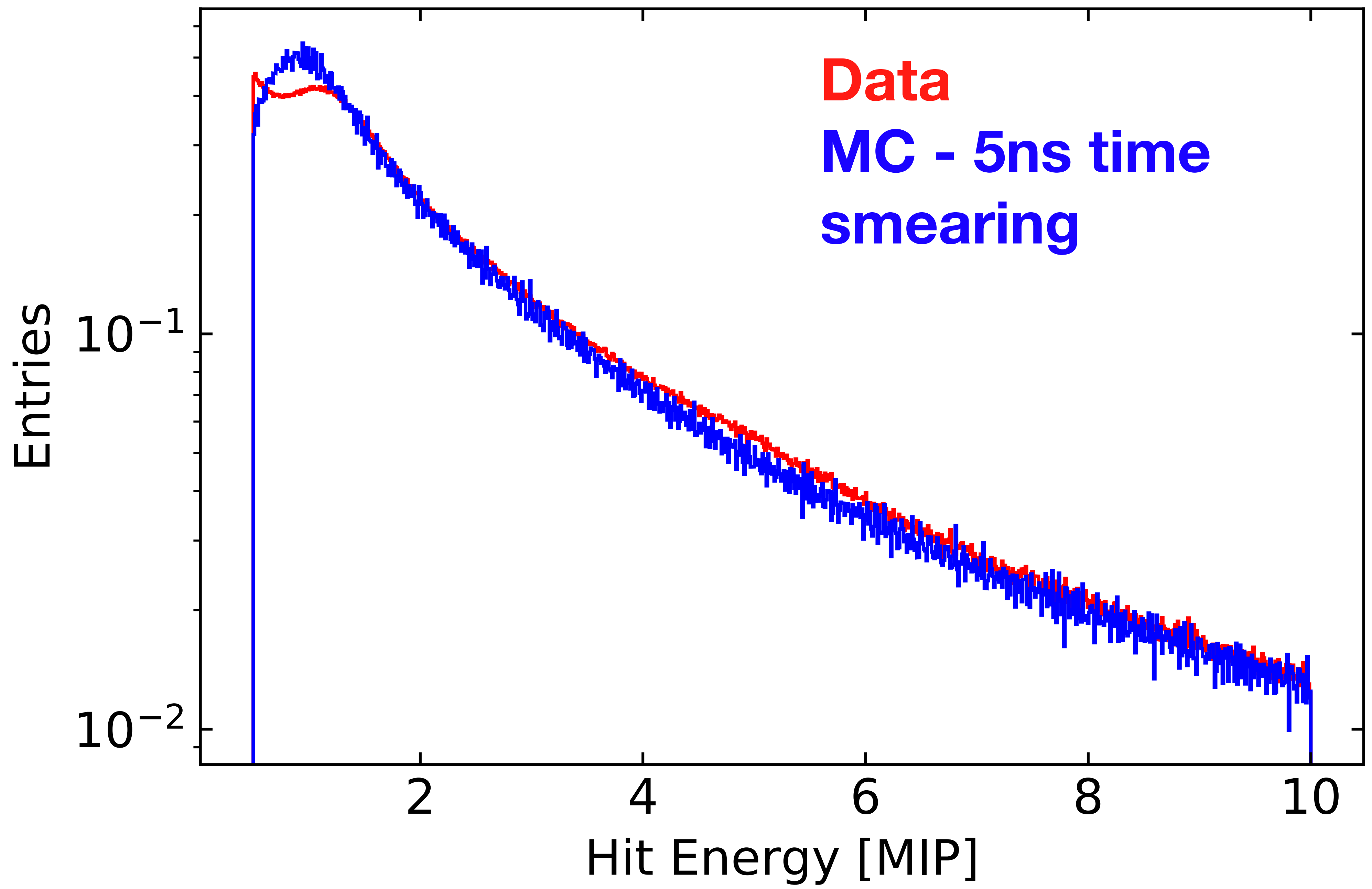
Prompt: hit time <10ns | Elastic:10ns< hit time<50ns | Capture: hit time >50ns

Overlap of prompt and elastic part in data

Similar shape of data and MC in the capture part

Hit Energy - Data vs MC





Conclusion

Occupancy correction on channel level outperforms global correction by ~1ns

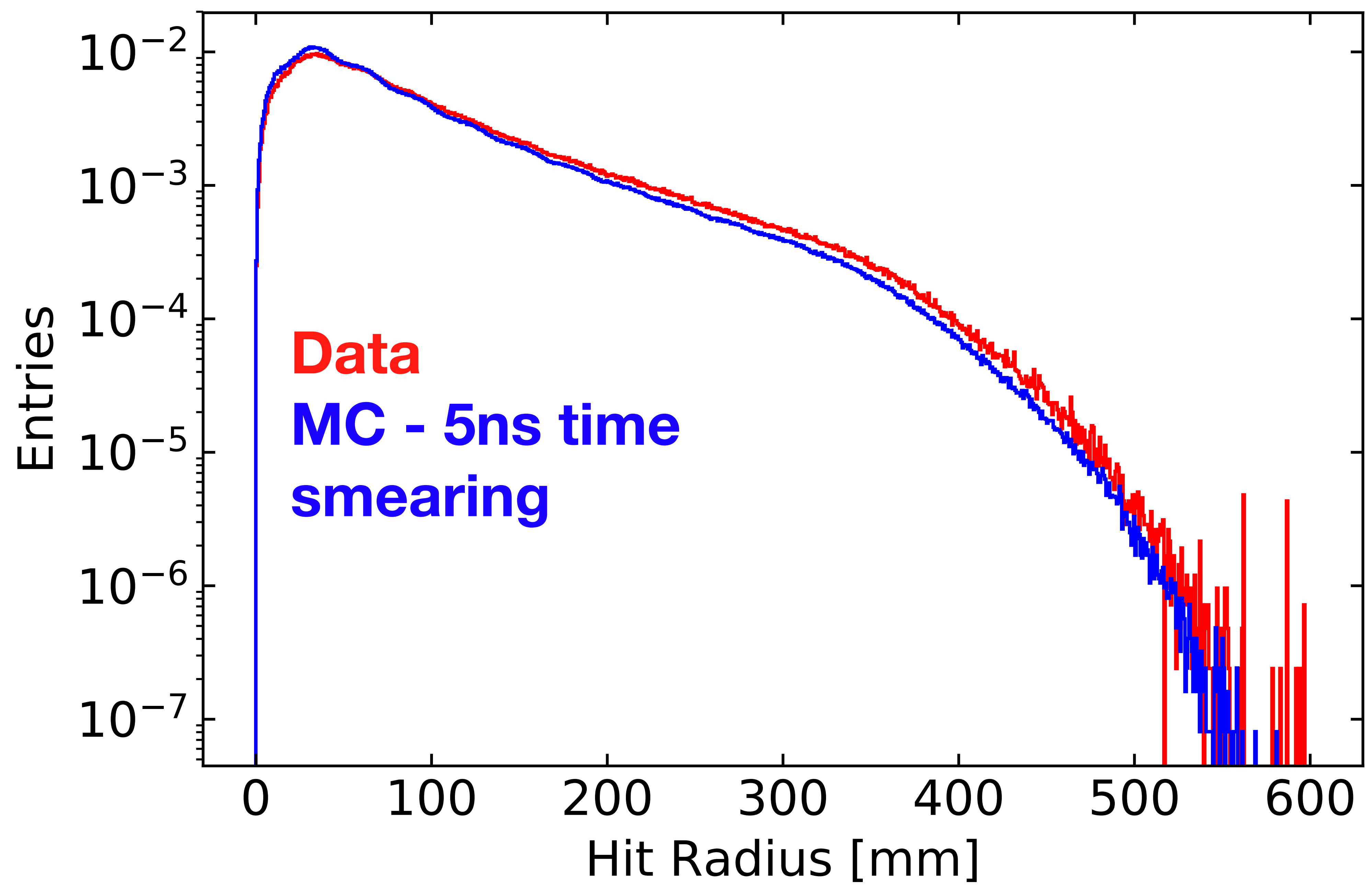
Time resolution for showers @ ~5.5ns

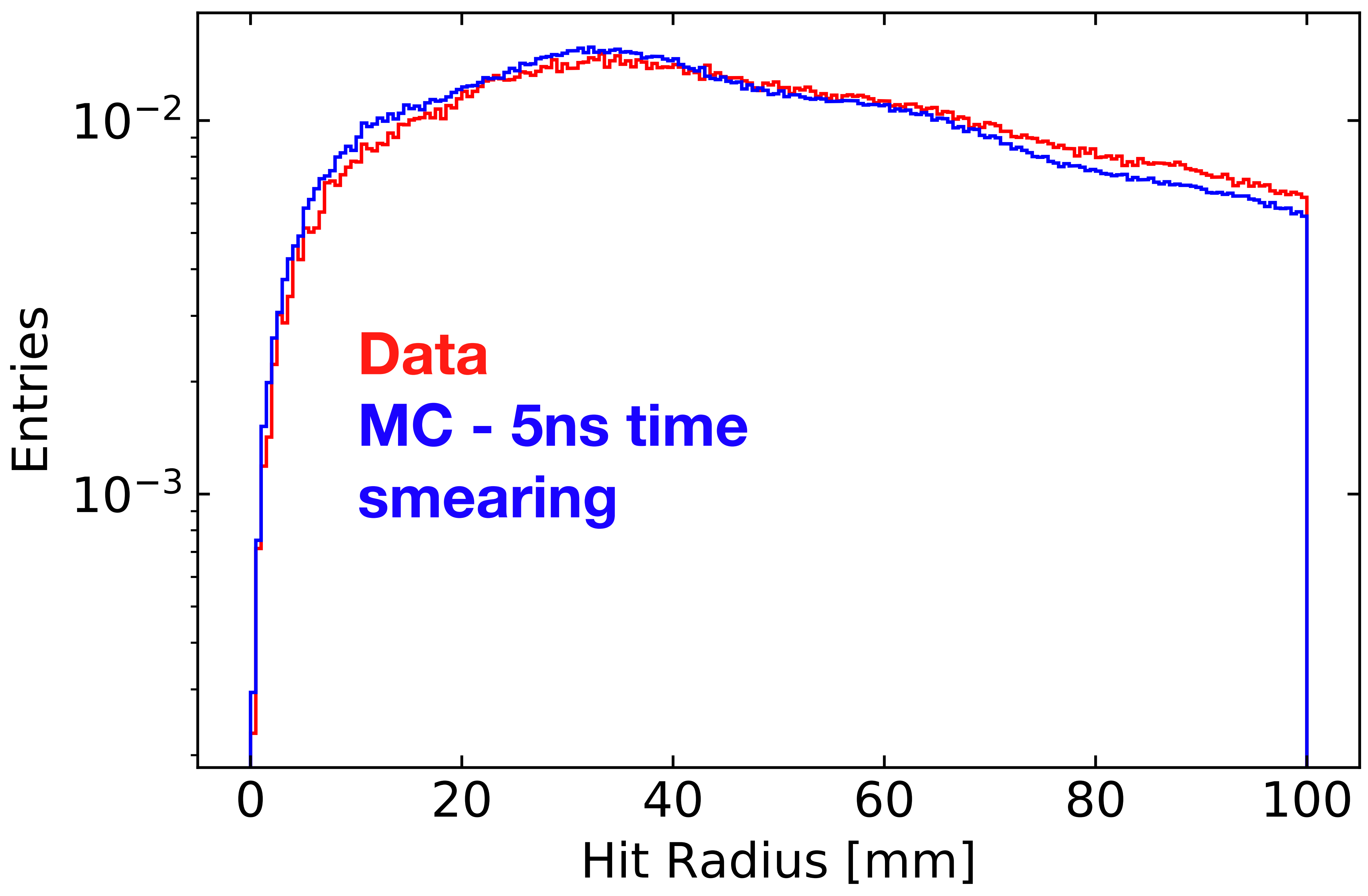
$\Longrightarrow$ Correction over the full depth possible with pion showers

Compared to MC, the prompt and elastic part still overlap

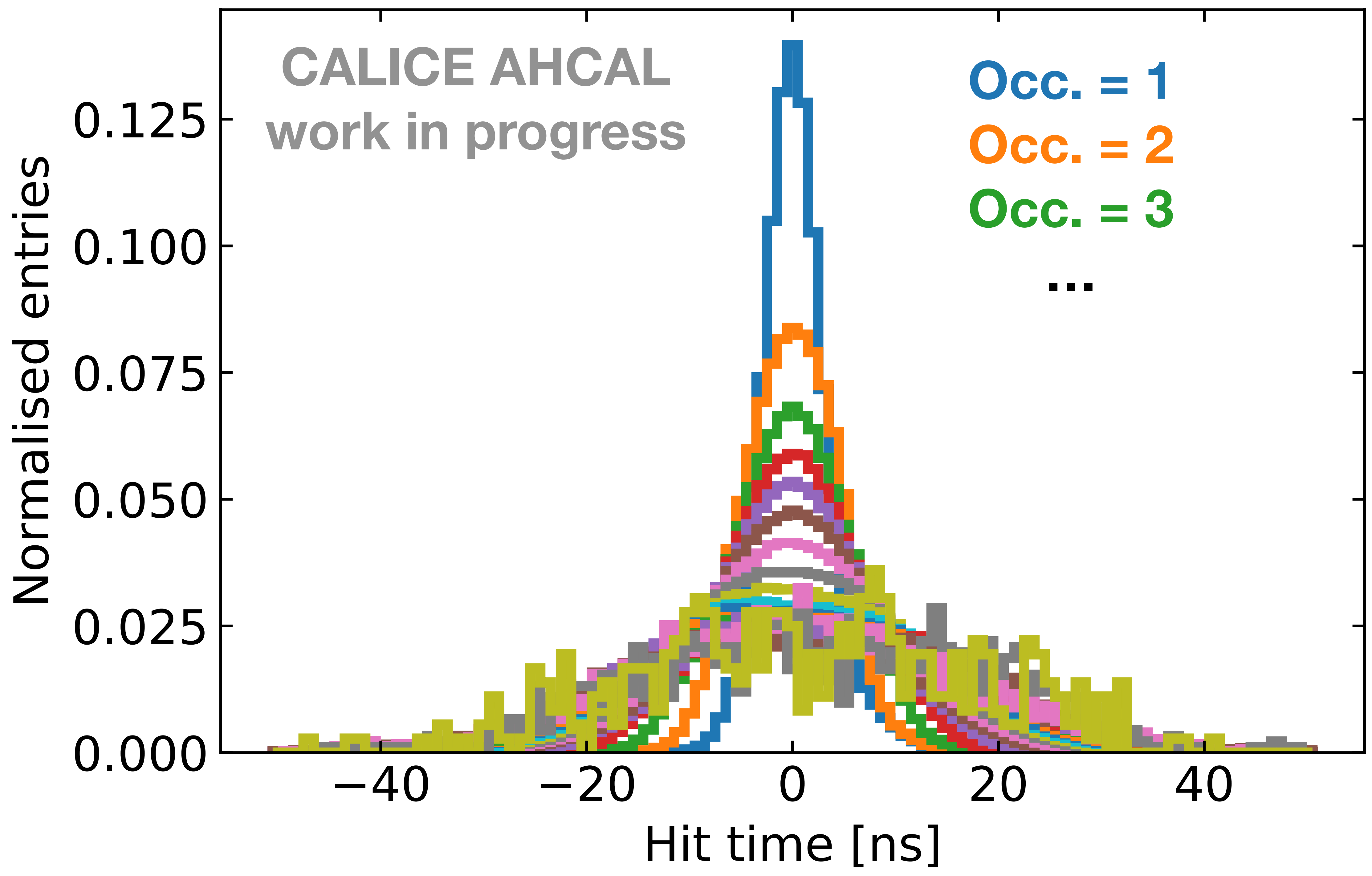
$\Longrightarrow$ broadening of the hit time distribution with rising occupancy not fully corrected

Hit Radius - Data vs MC

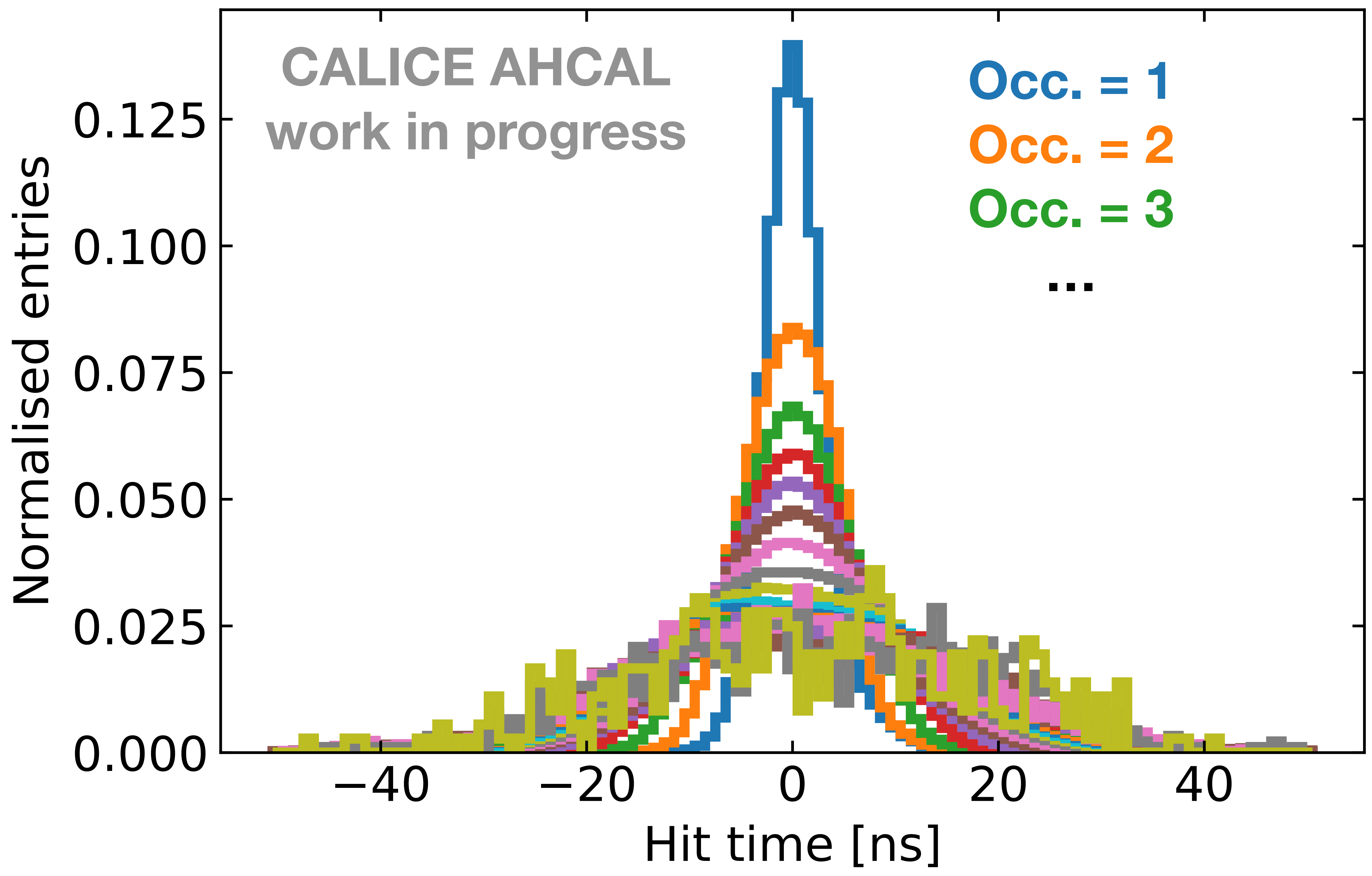


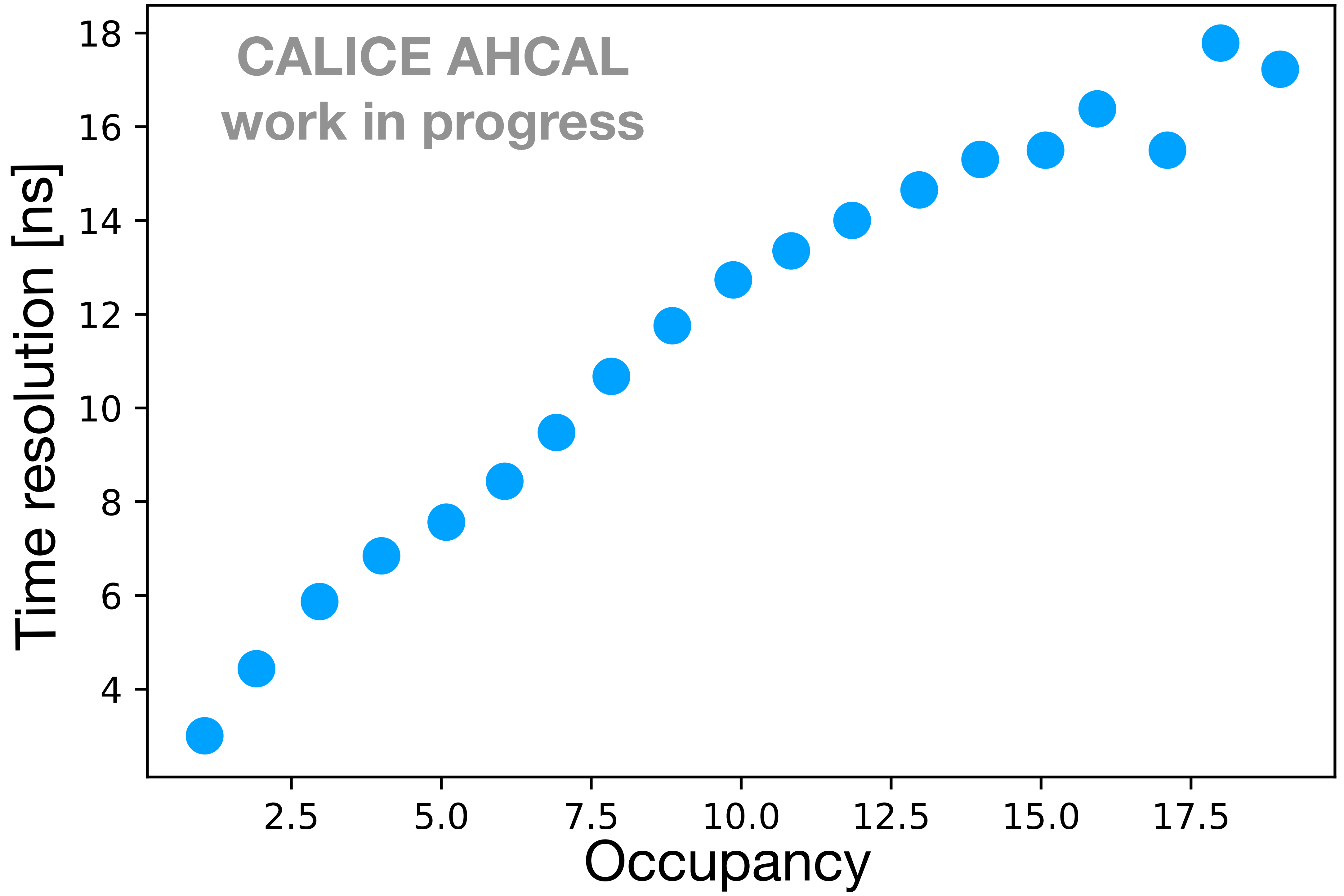


Global Correction



Global Correction





- Time resolution is the sigma of a gaussian fit to every distribution
- Occupancy correction shifts the mean to ~0 ns
- Time resolution is increased from ~45ns to ~18ns for occupancy of 19