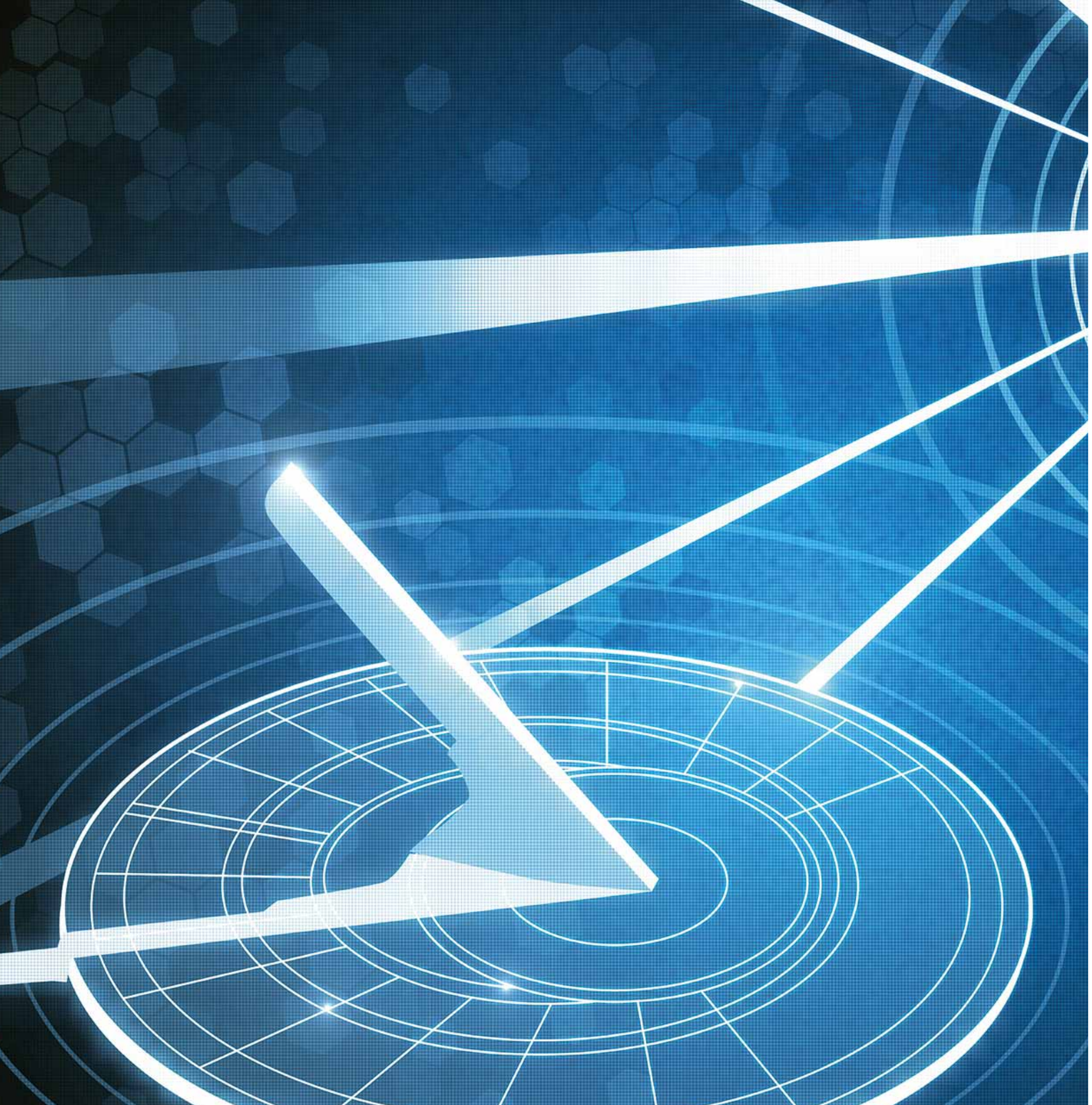

AHCAL Time Calibration

CALICE Analysis Meeting
20.5.2020
Lorenz Emberger

MAX-PLANCK-INSTITUT
FÜR PHYSIK

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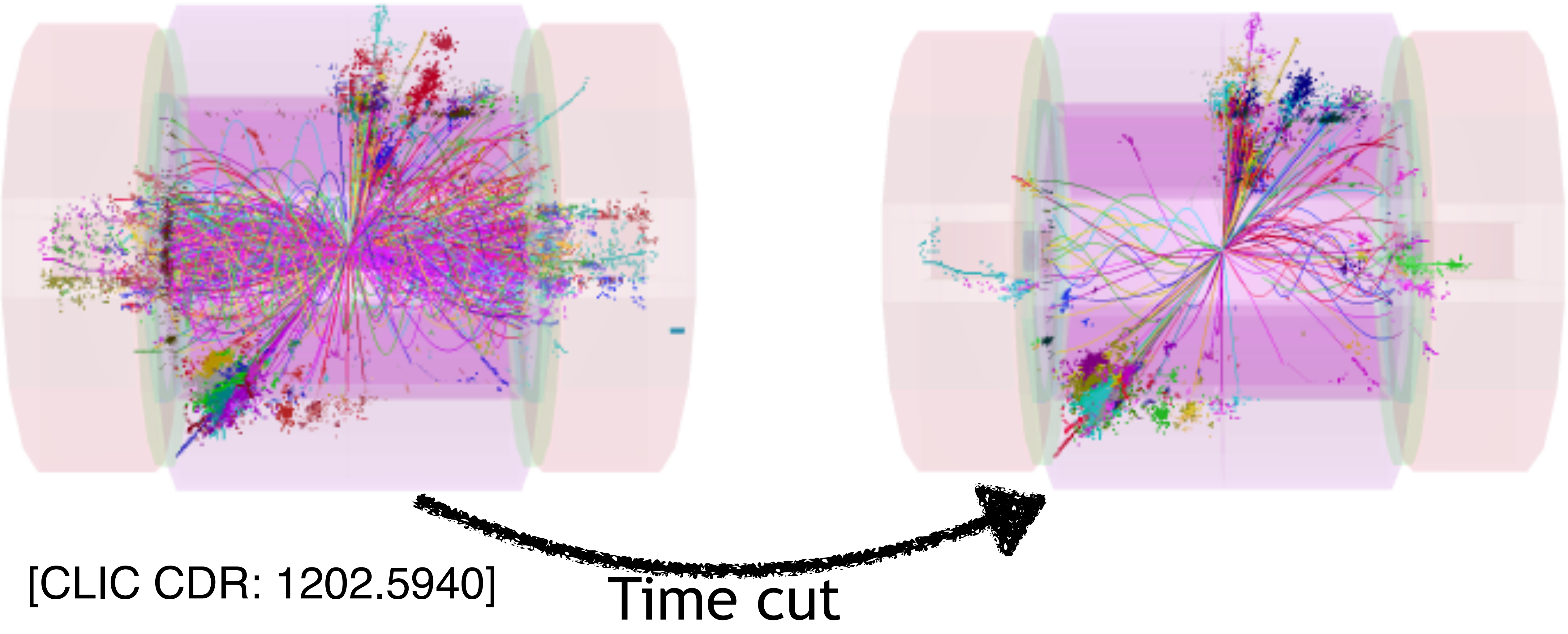
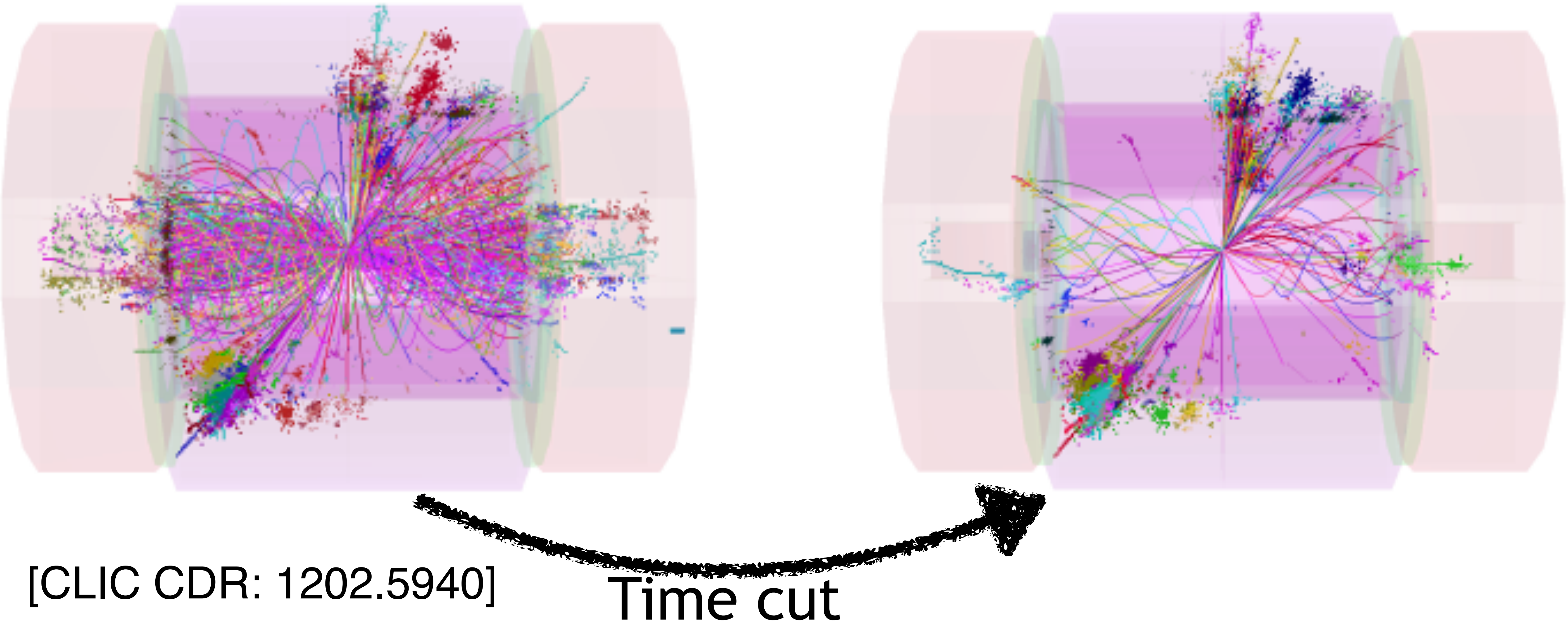


[CLIC CDR: 1202.5940]

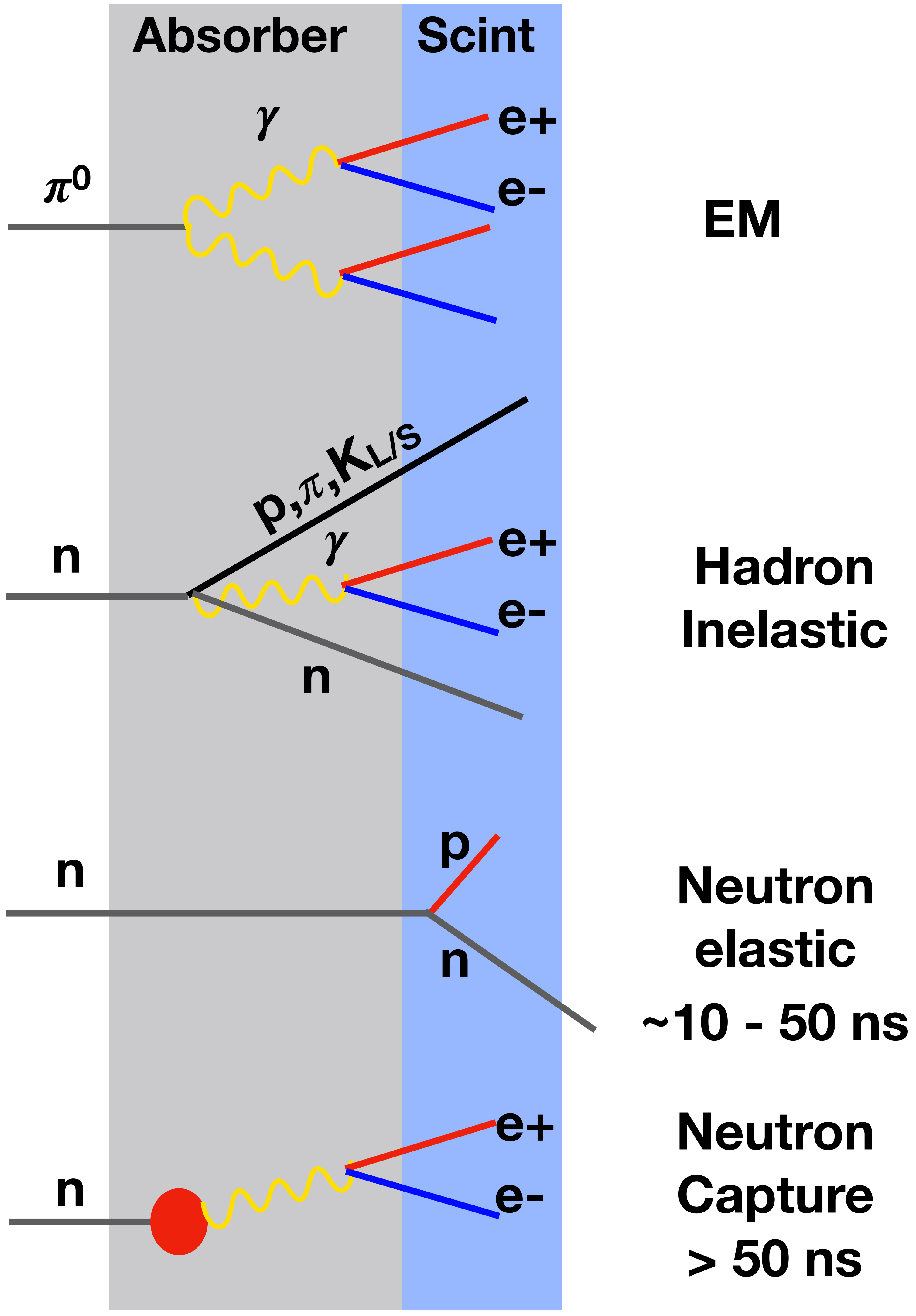
Motivation

Why do we need time information?

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



[CLIC CDR: 1202.5940]



Time Calibration: Hardware

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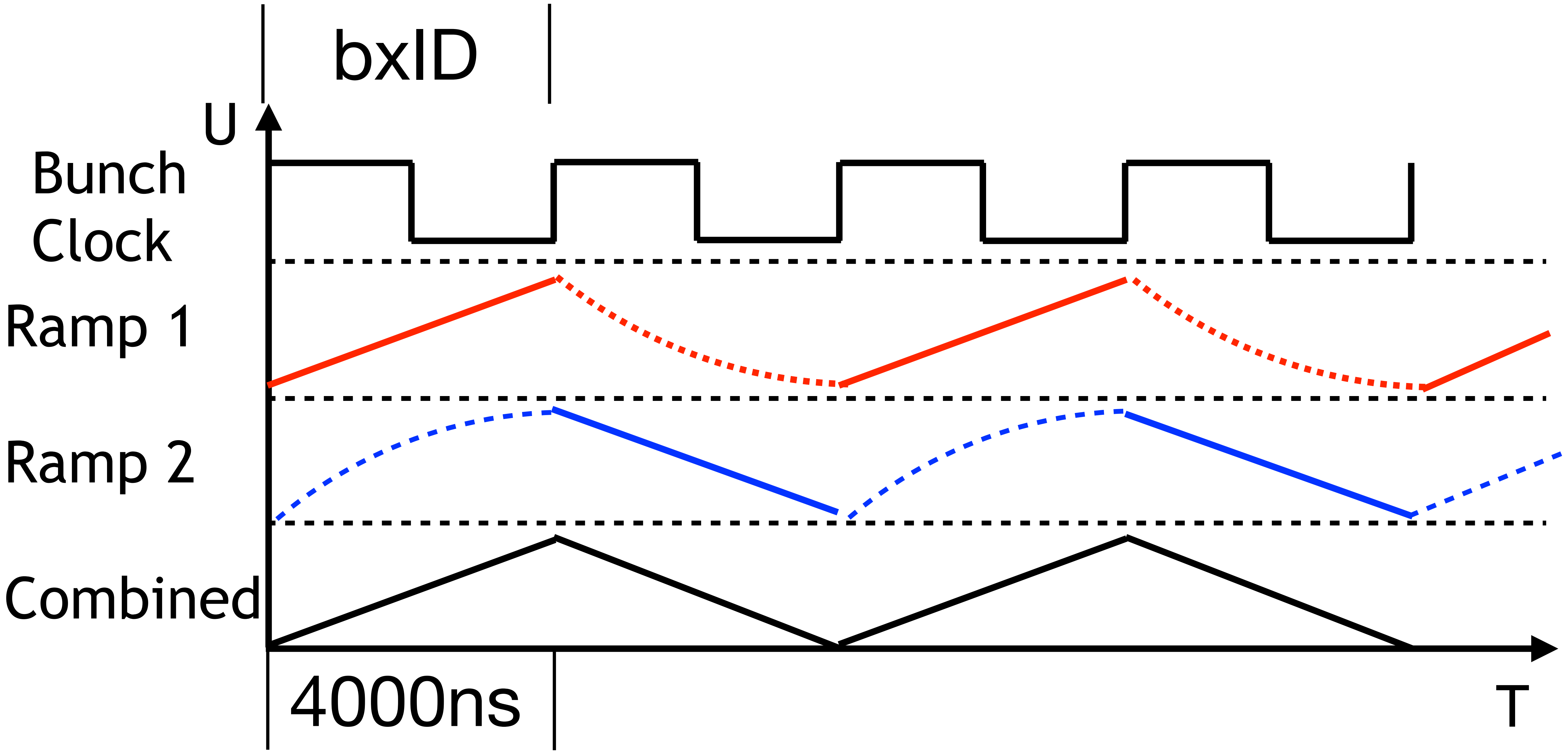
Time measurement with Spiroc2E: <u>TDC</u> (time to digital converter)

1. Common external clock with ~1ns bins

2. Ramp up voltage during one bunch crossing ID



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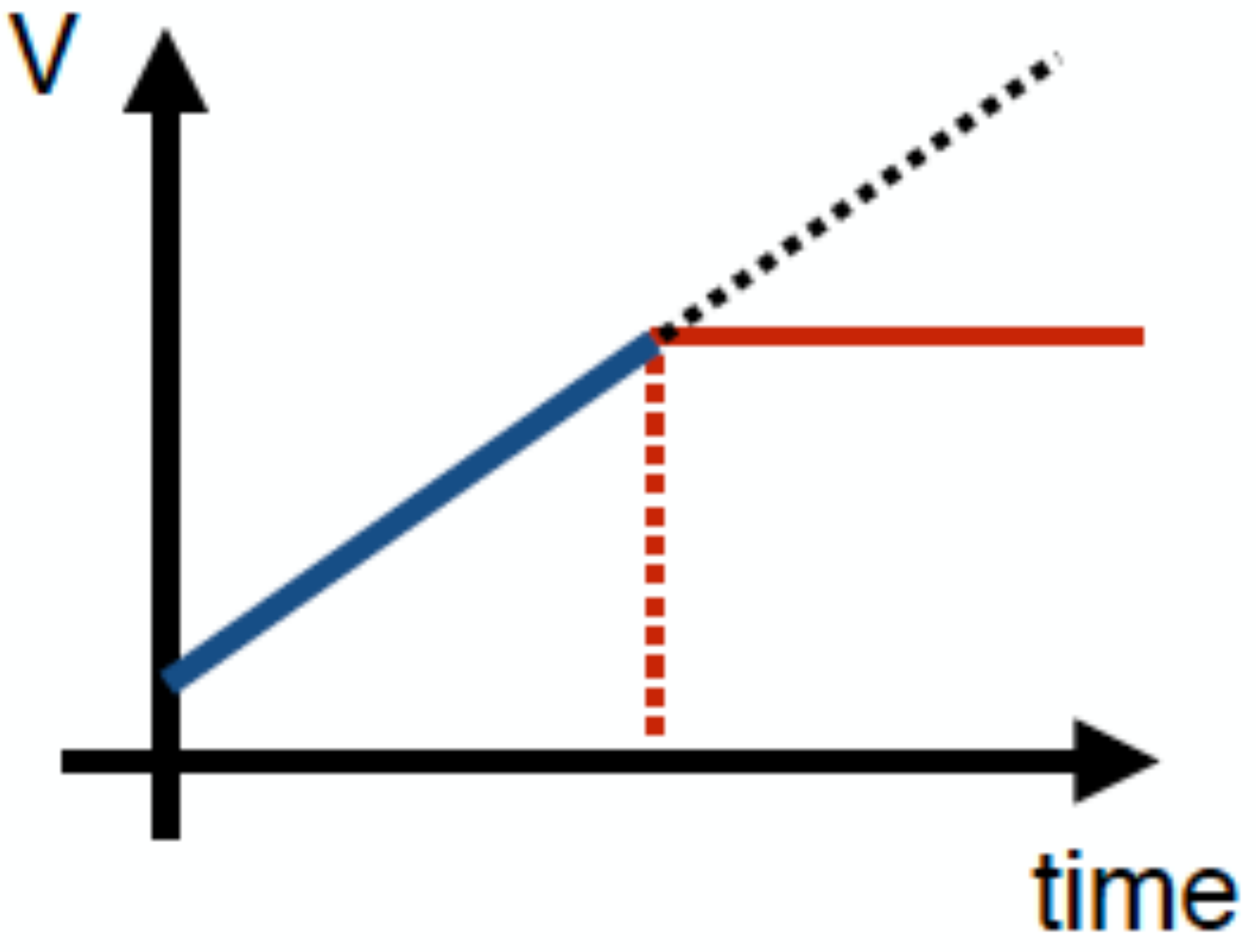

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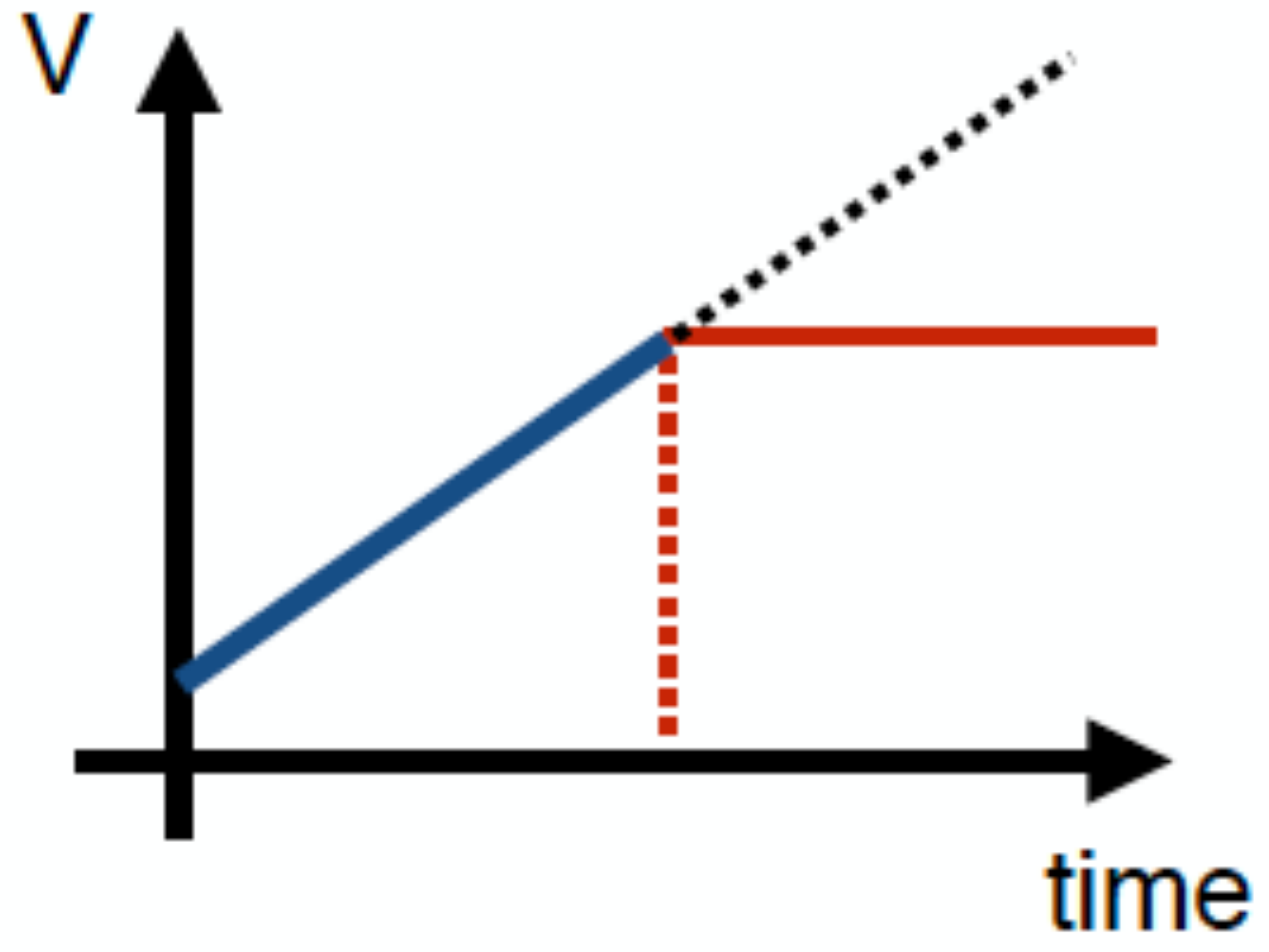

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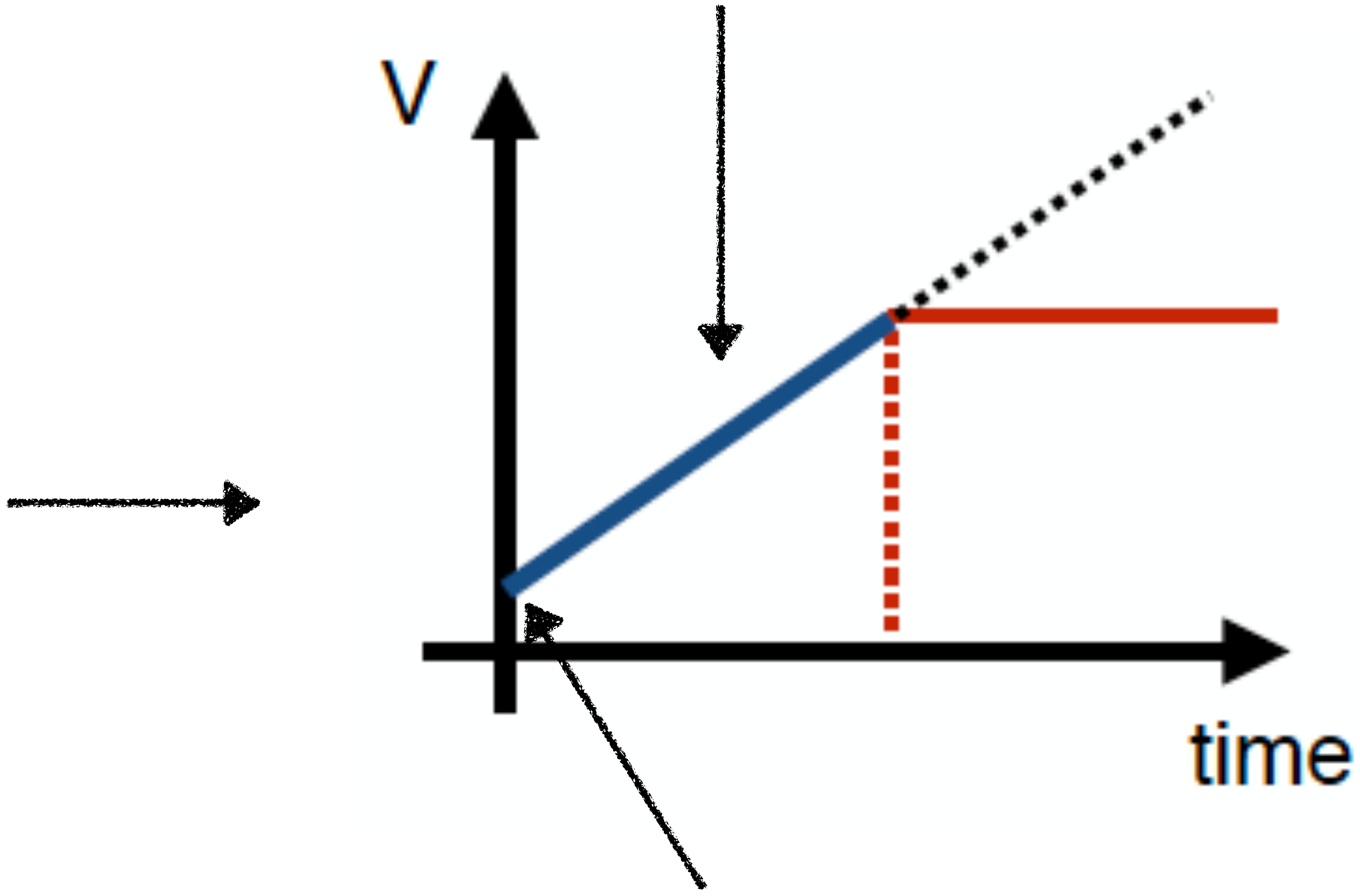
Slope is common to all channels on a chip



Offset is extracted for every memory cell

Time Calibration: Software

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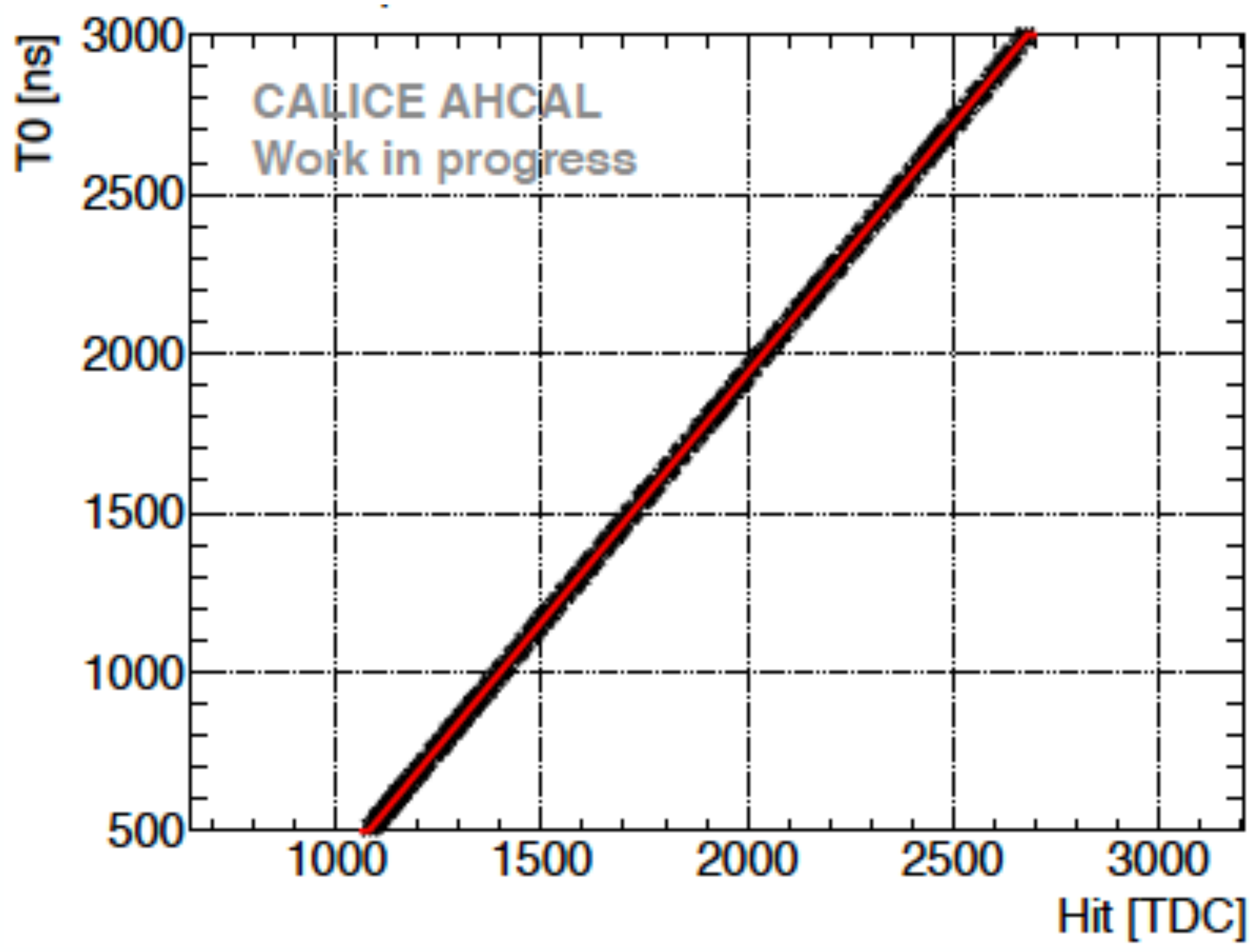
1. Extract slope by plotting reference clock against TDC readings

2. Fit with linear function



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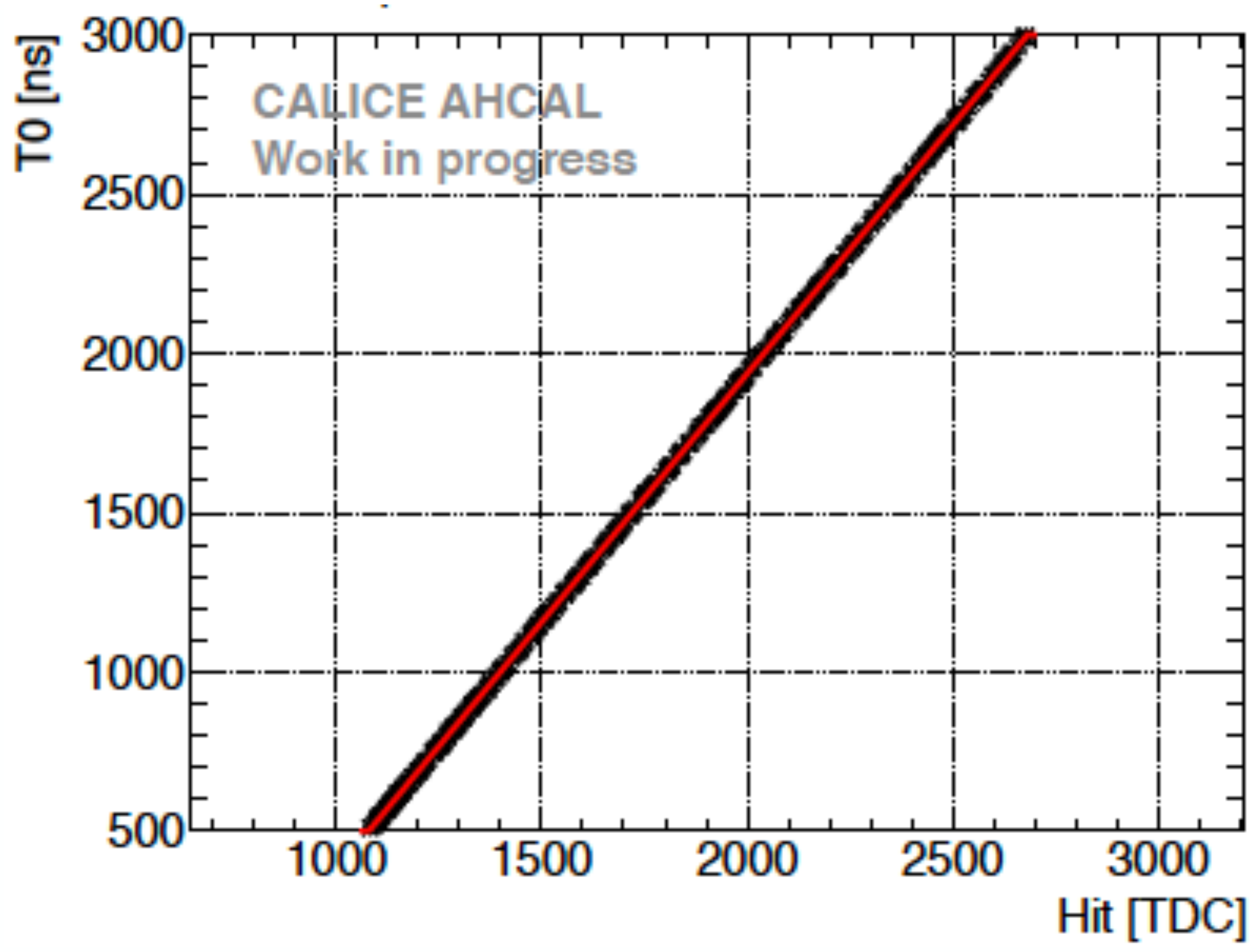
3. Calculate hit time by

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



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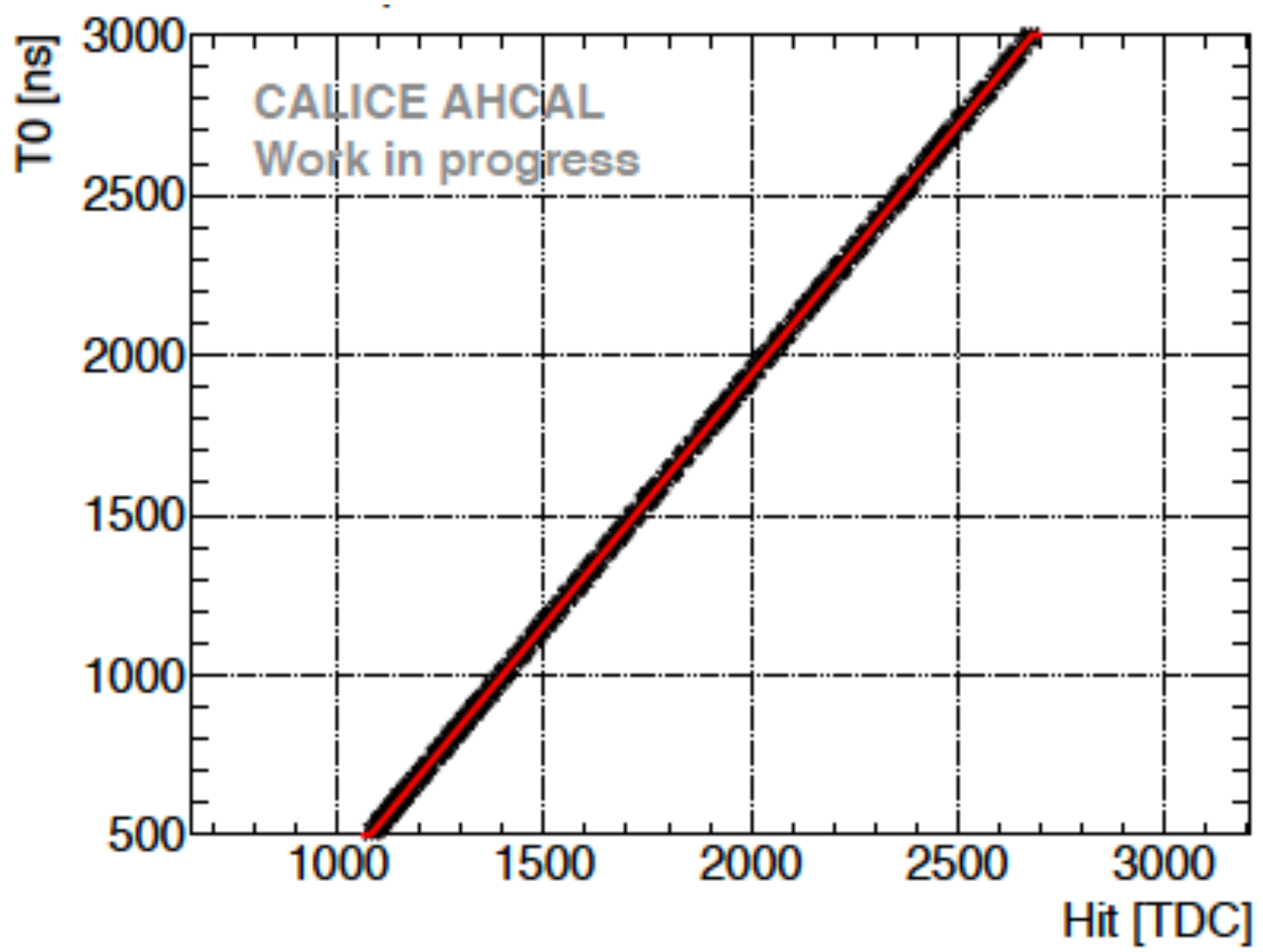
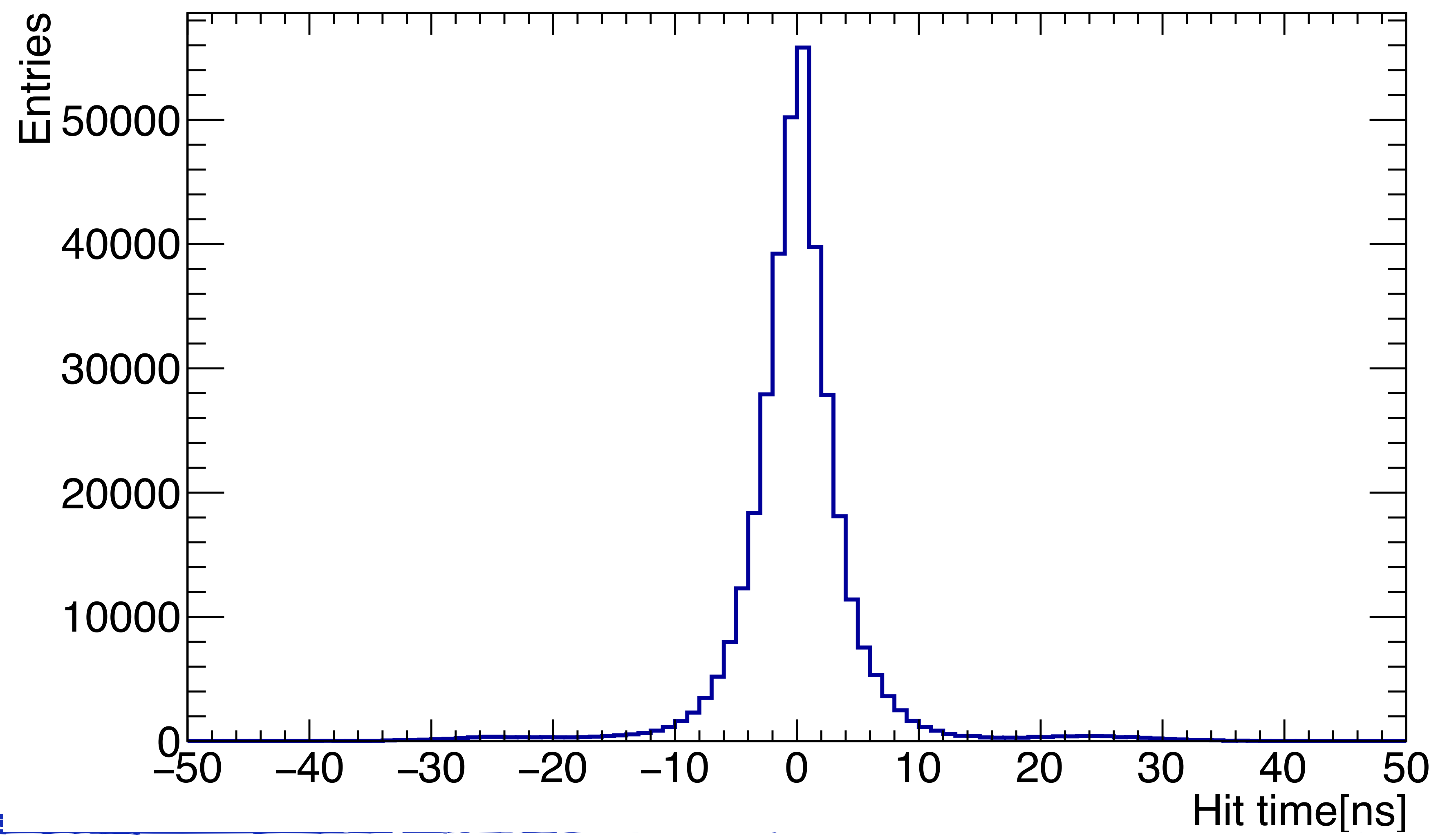


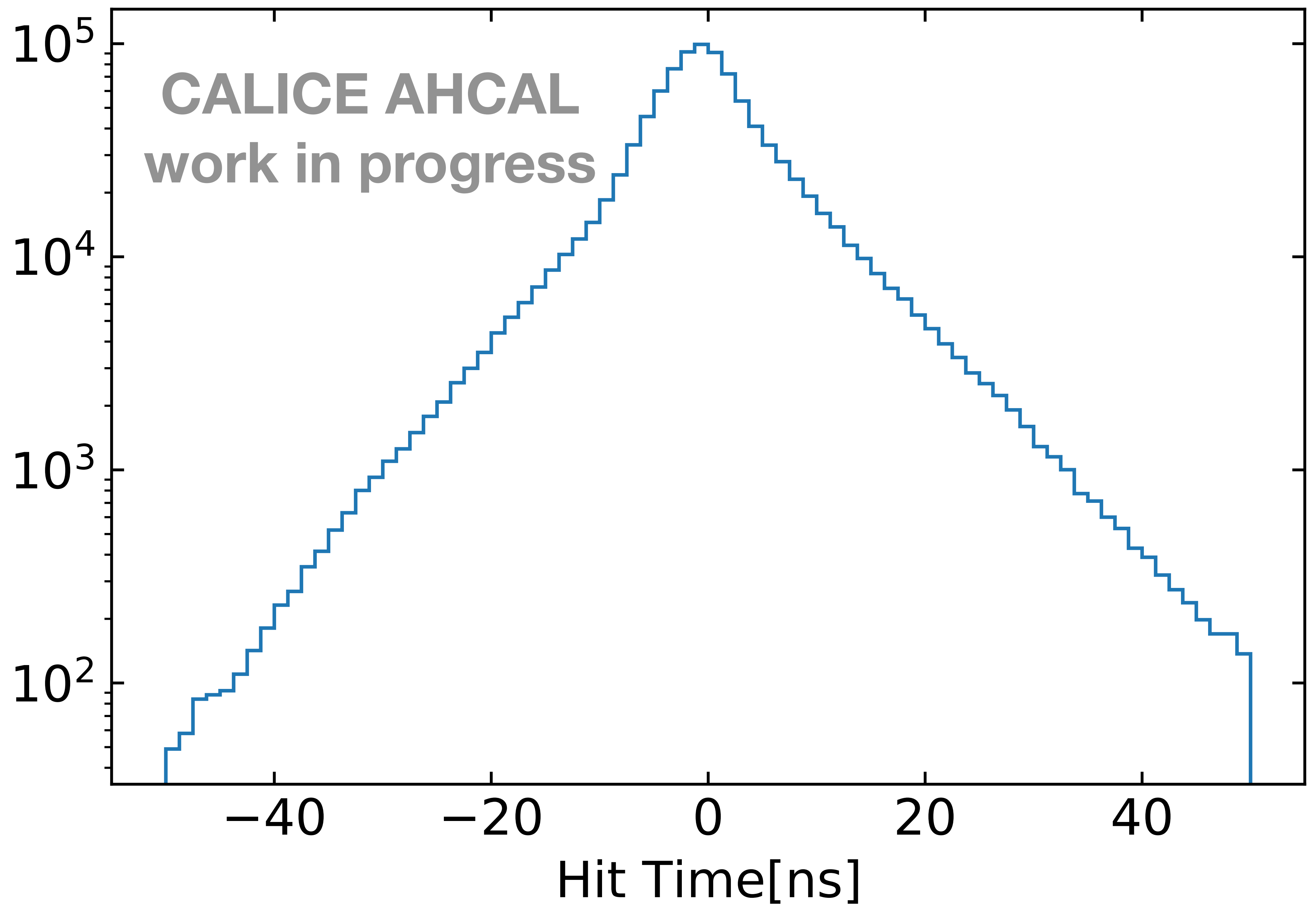
Hit time distribution



The Occupancy Problem

Hit time distribution deteriorates with increasing chip occupancy

Dataset for the results shown in this talk: 10GeV Pions (Run 61316, TB June 2018)



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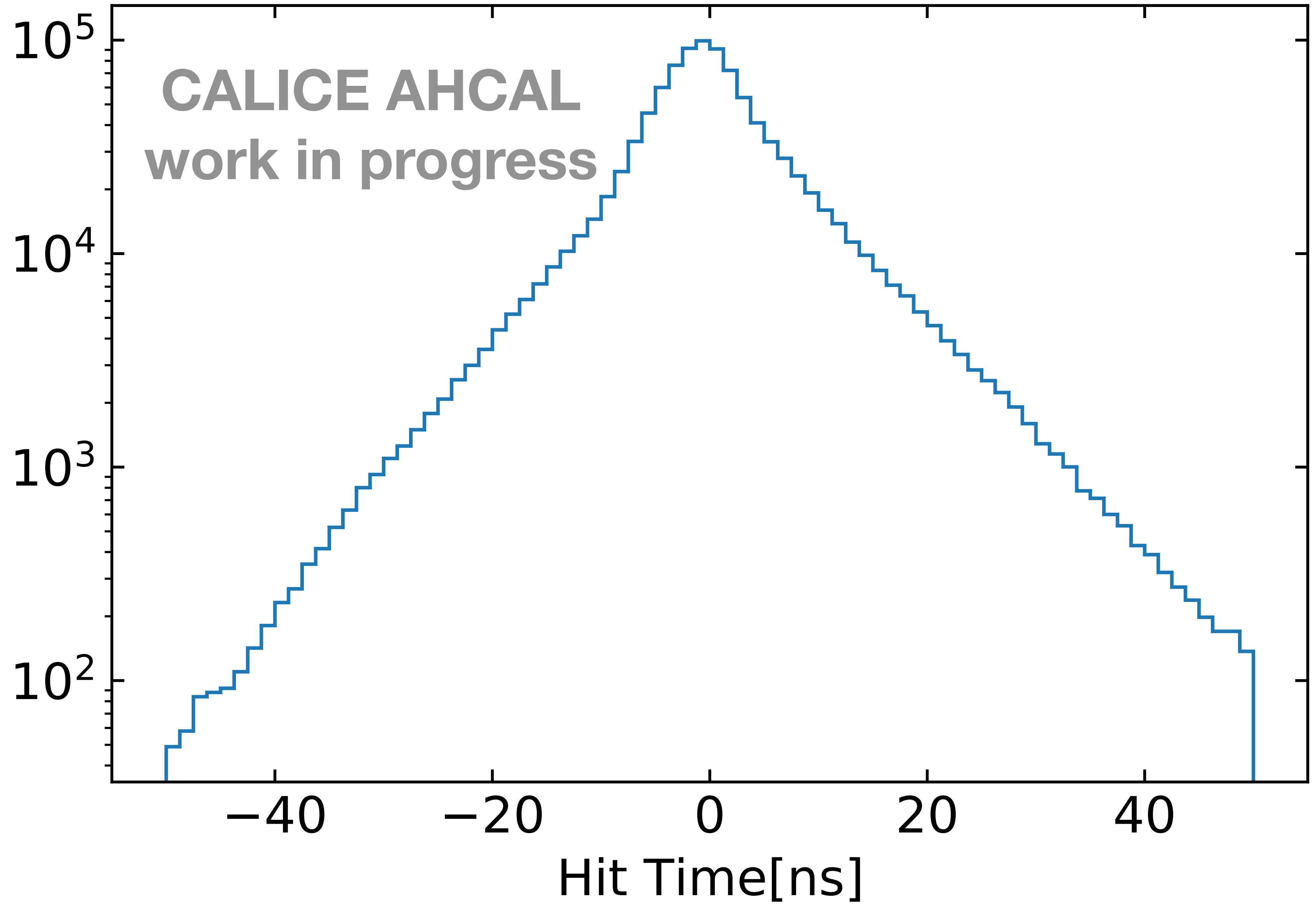
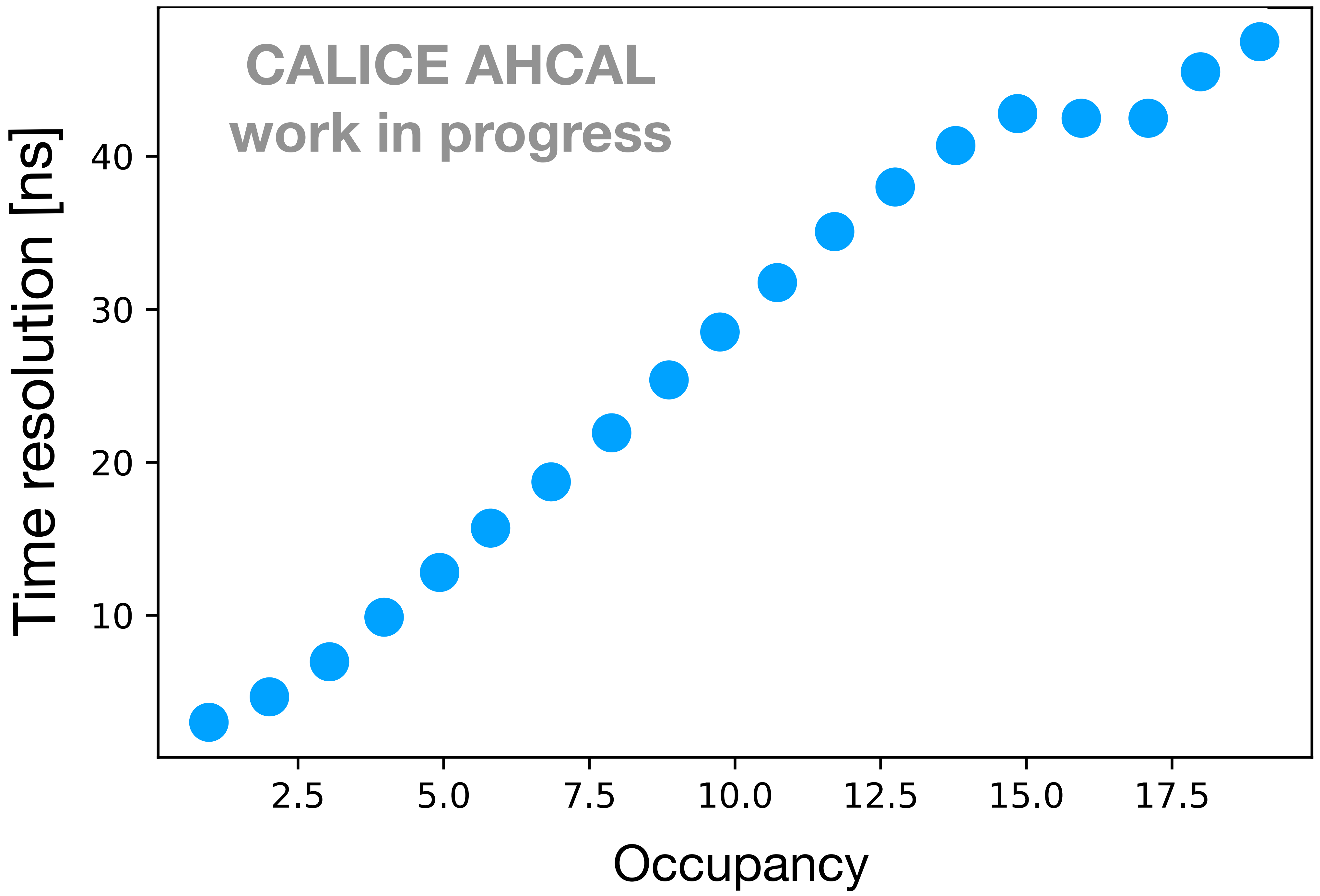
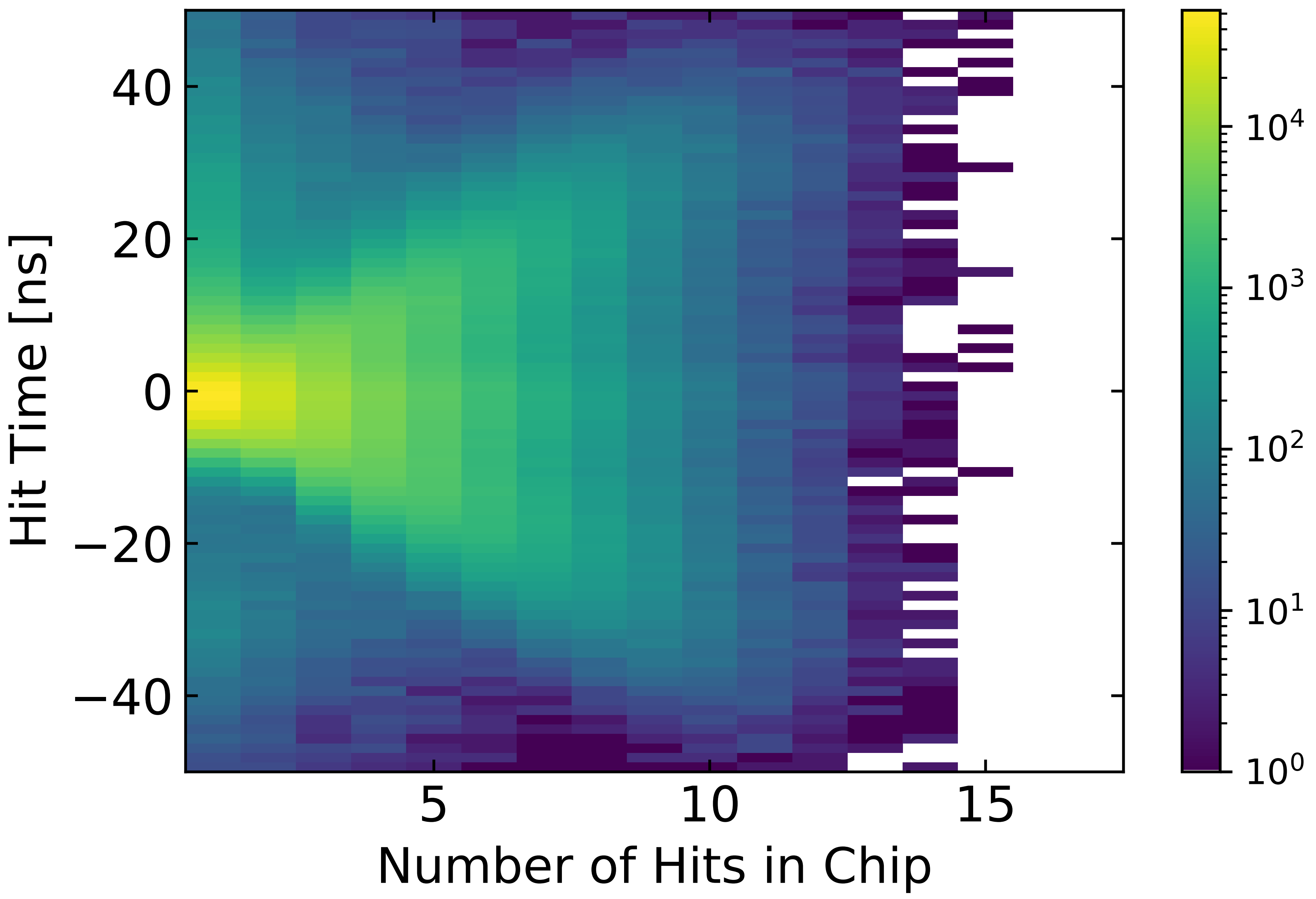




Resolution for occupancy = 1 is at the muon time resolution of ~2.5 ns

The Occupancy Problem



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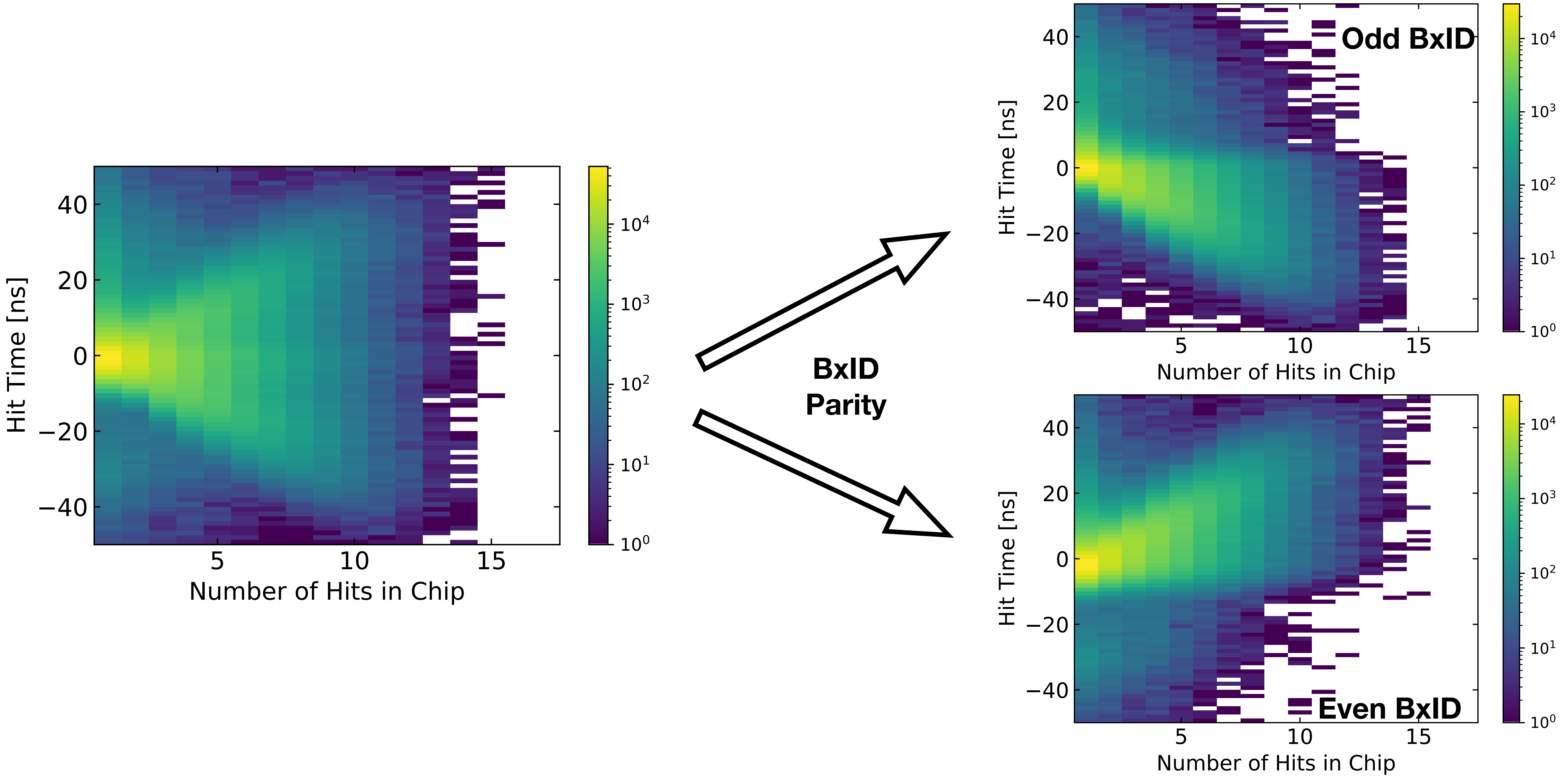

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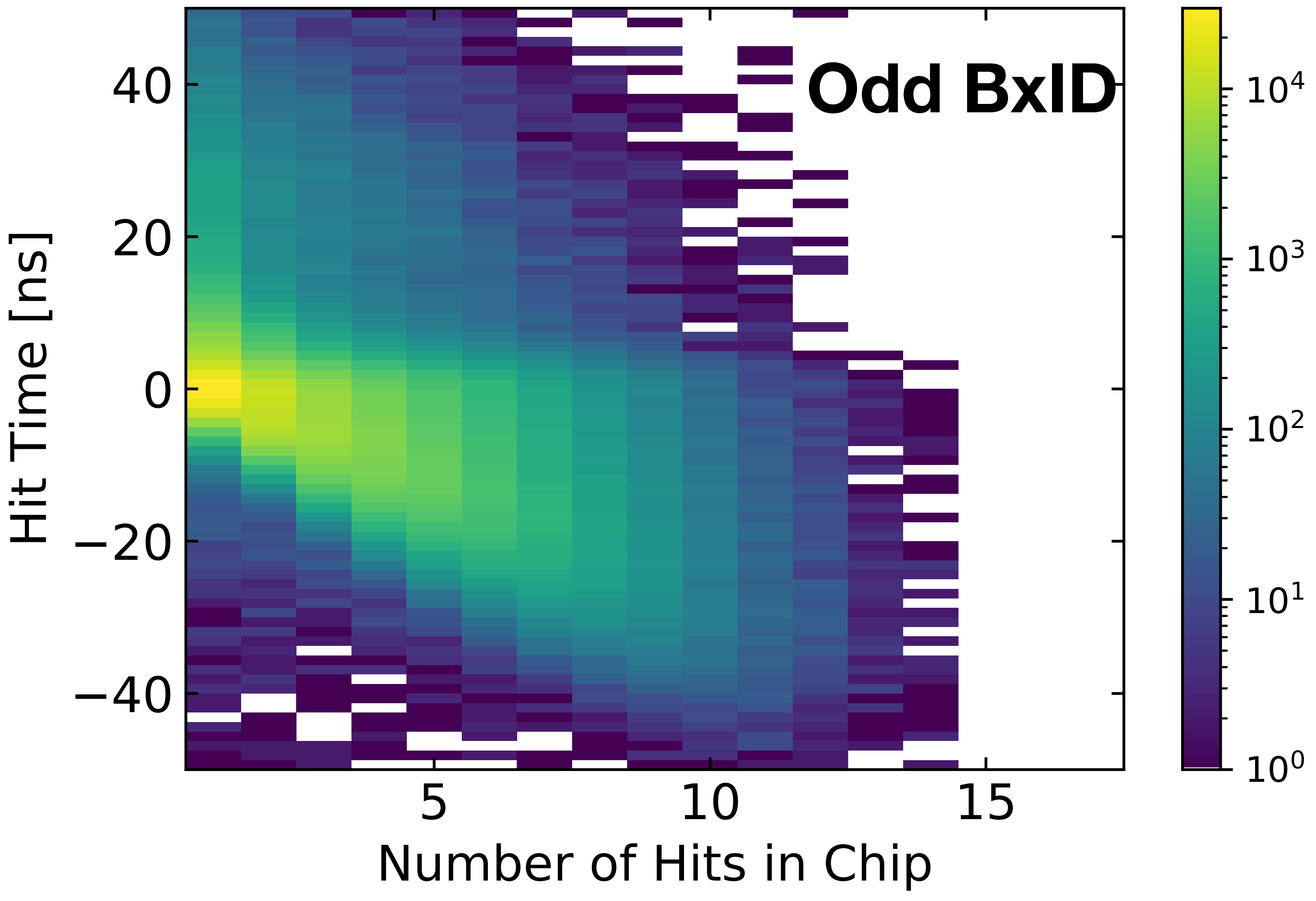

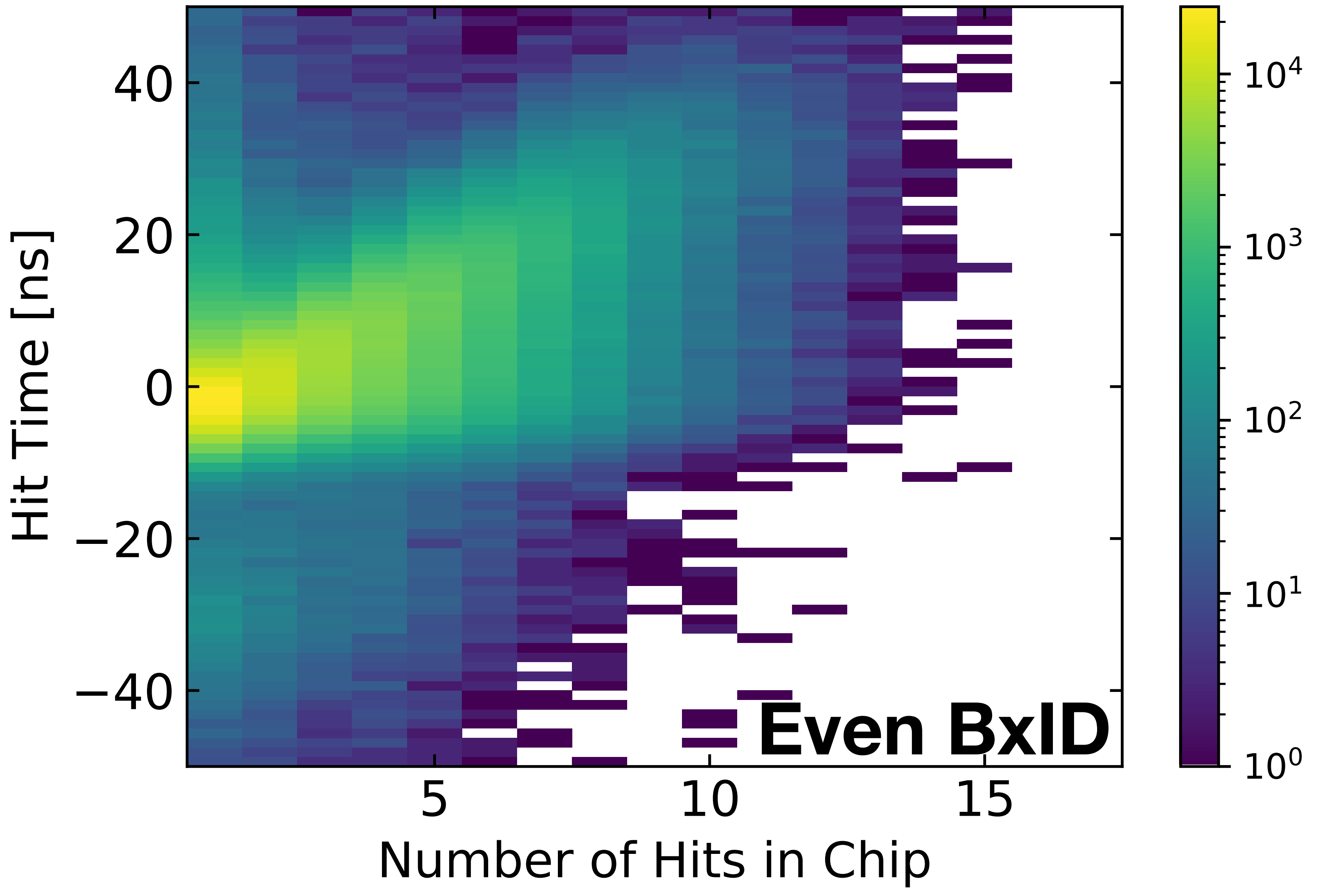

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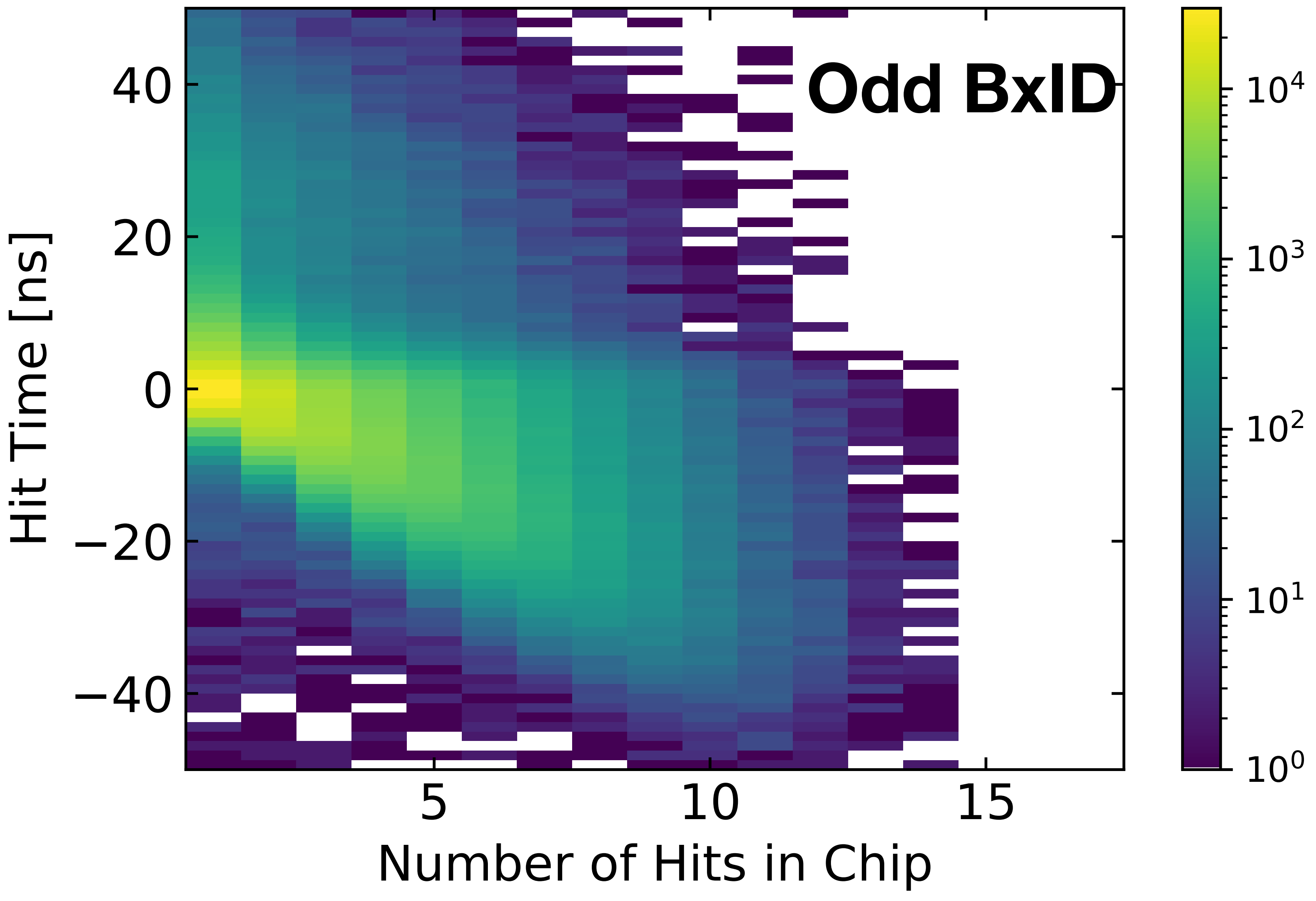
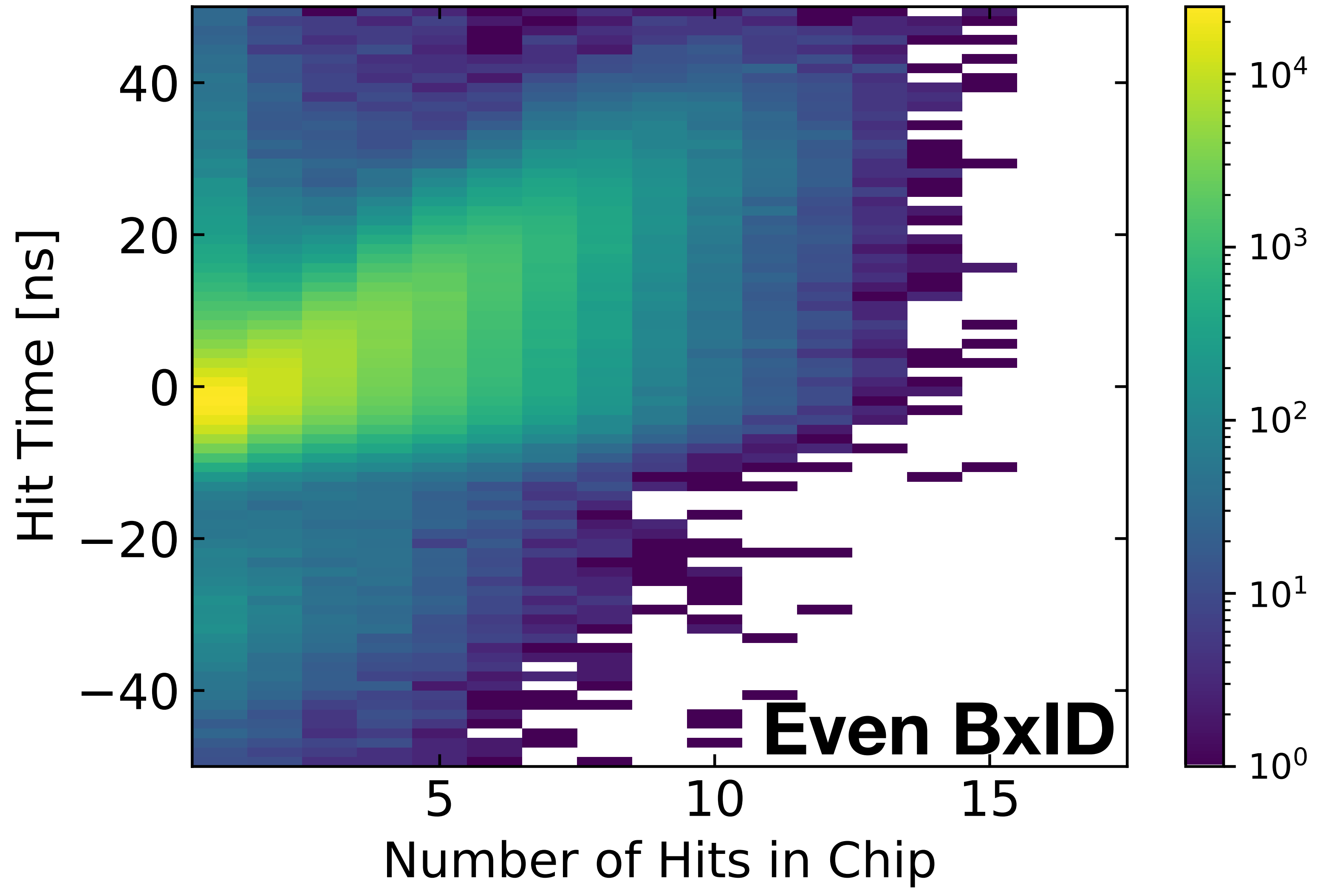
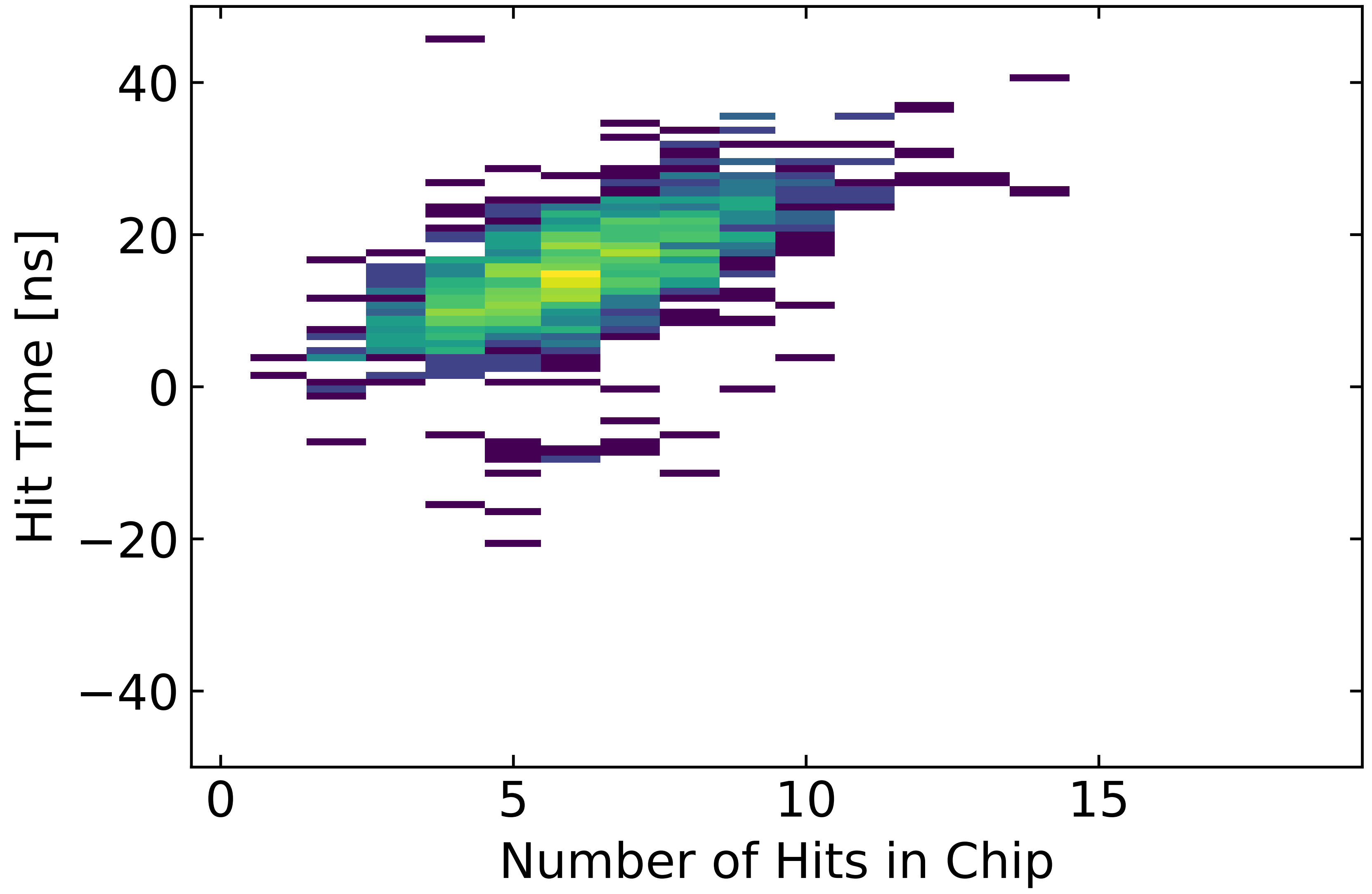
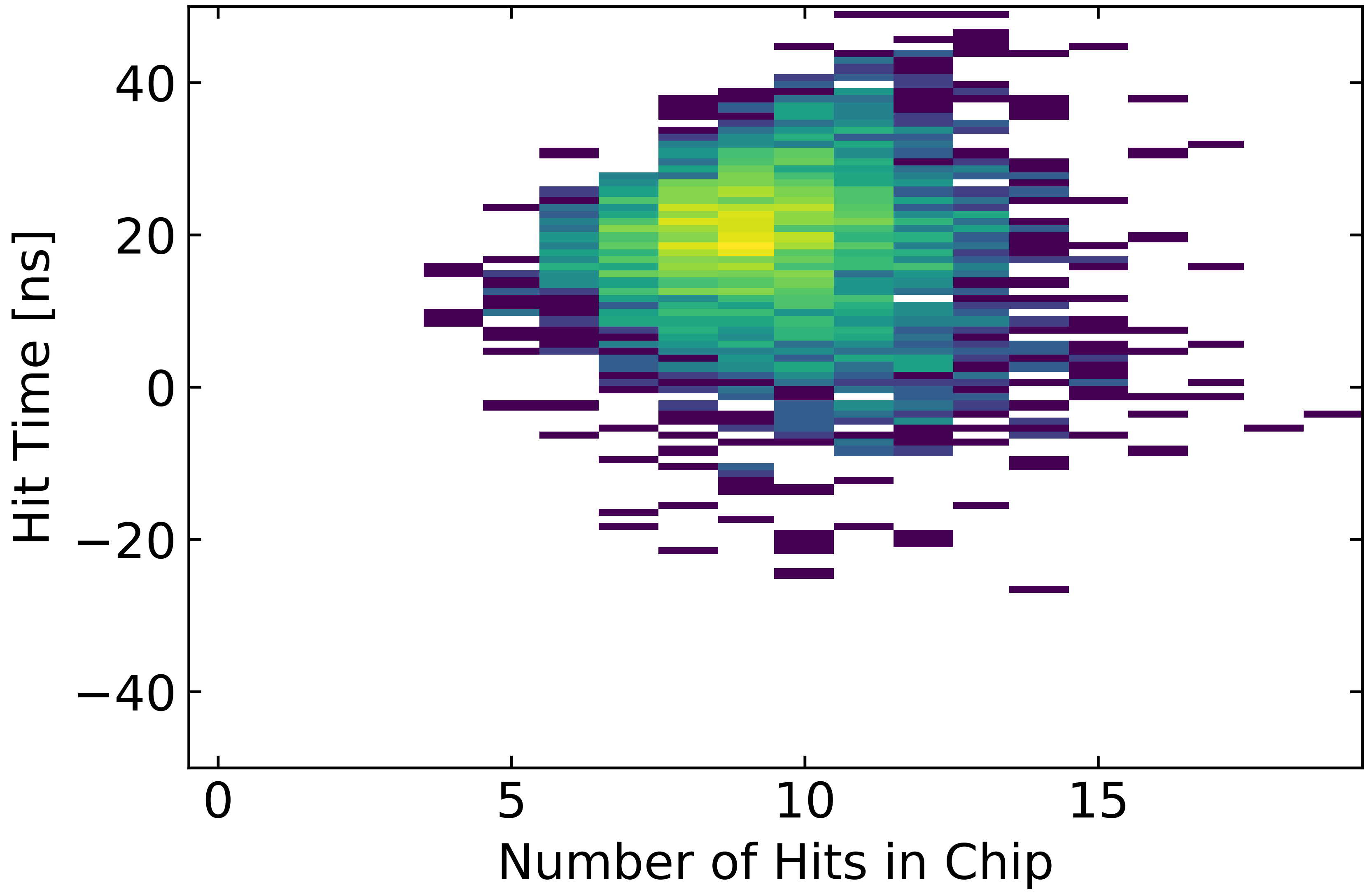




Random individual channels ⇒





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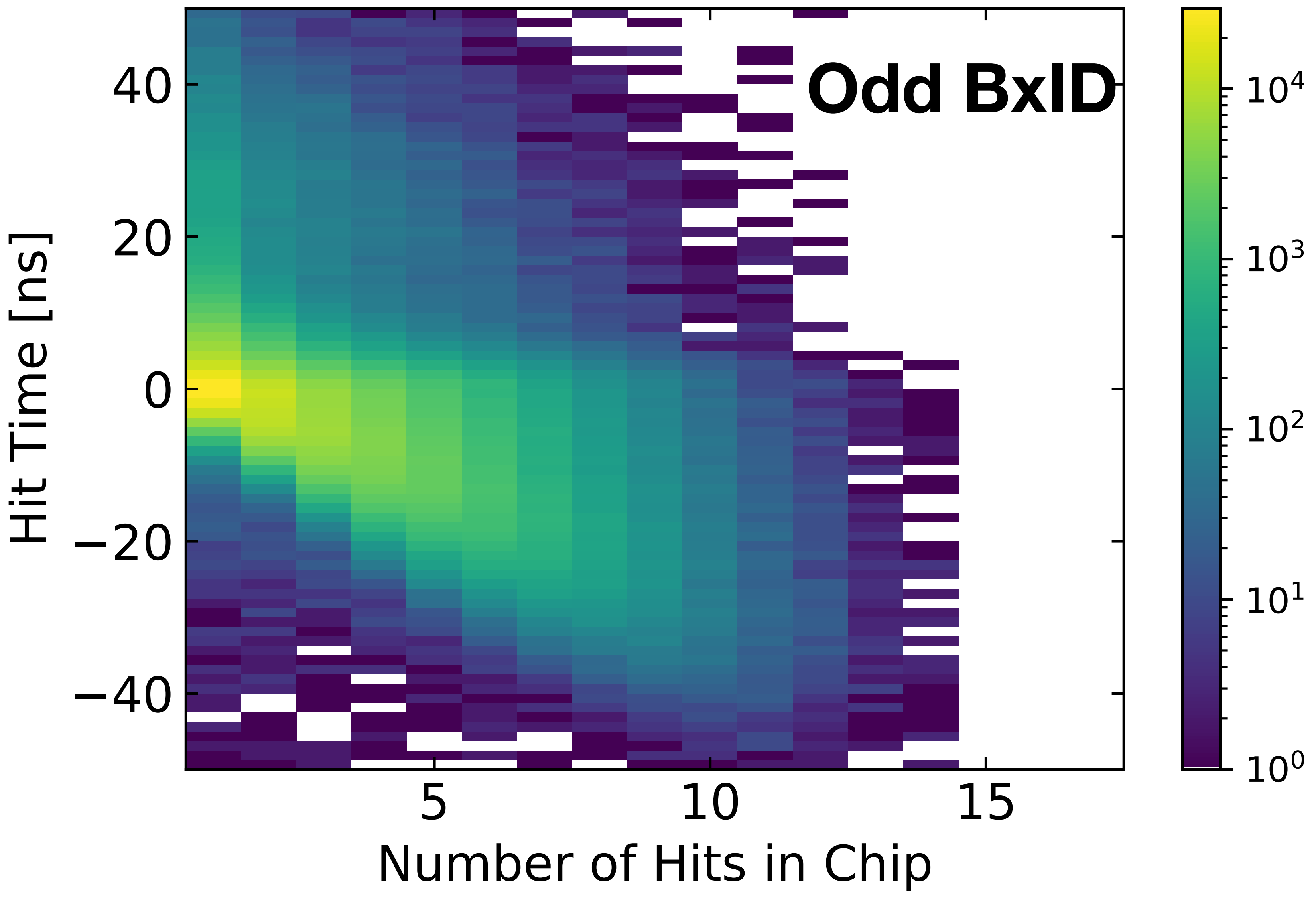

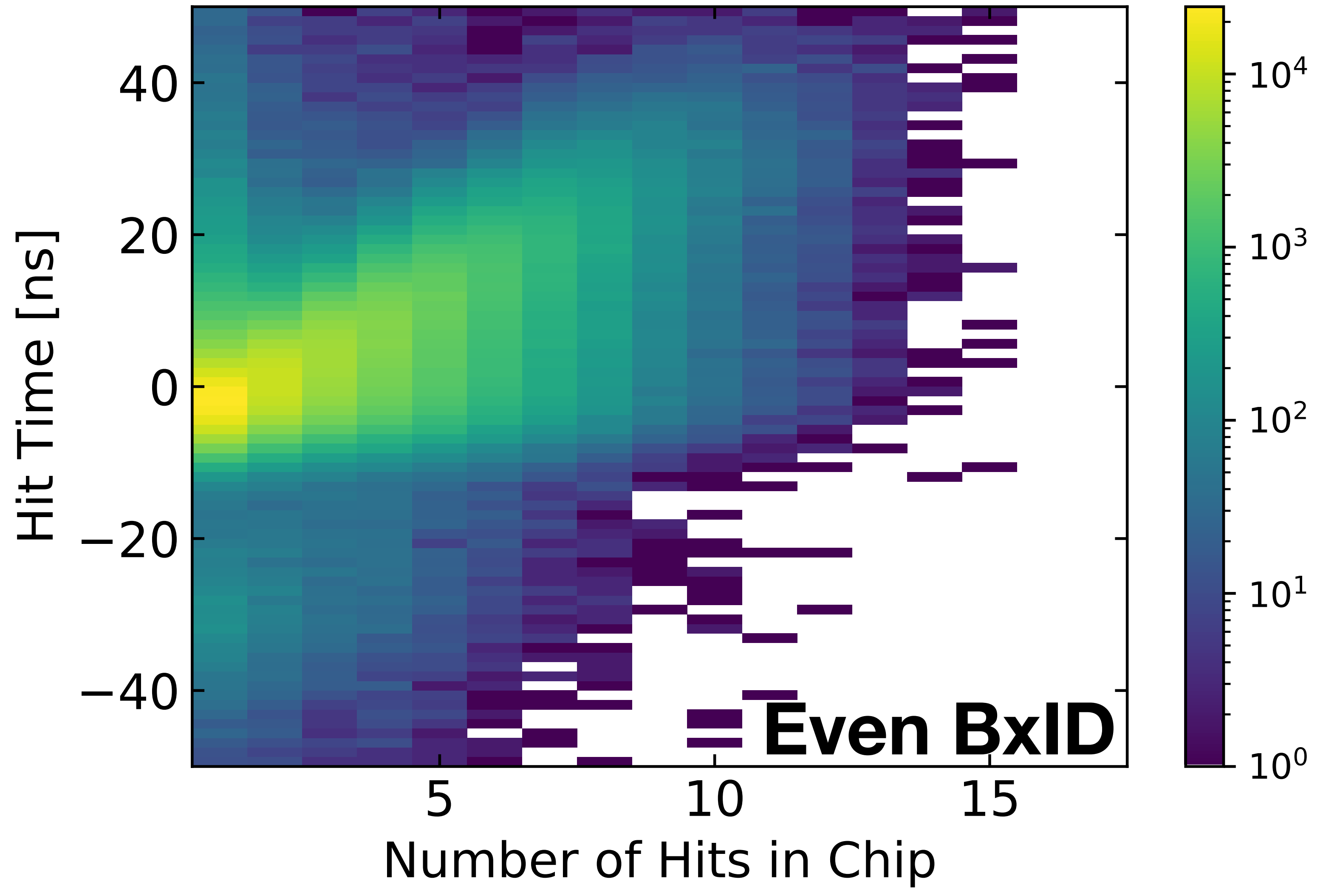

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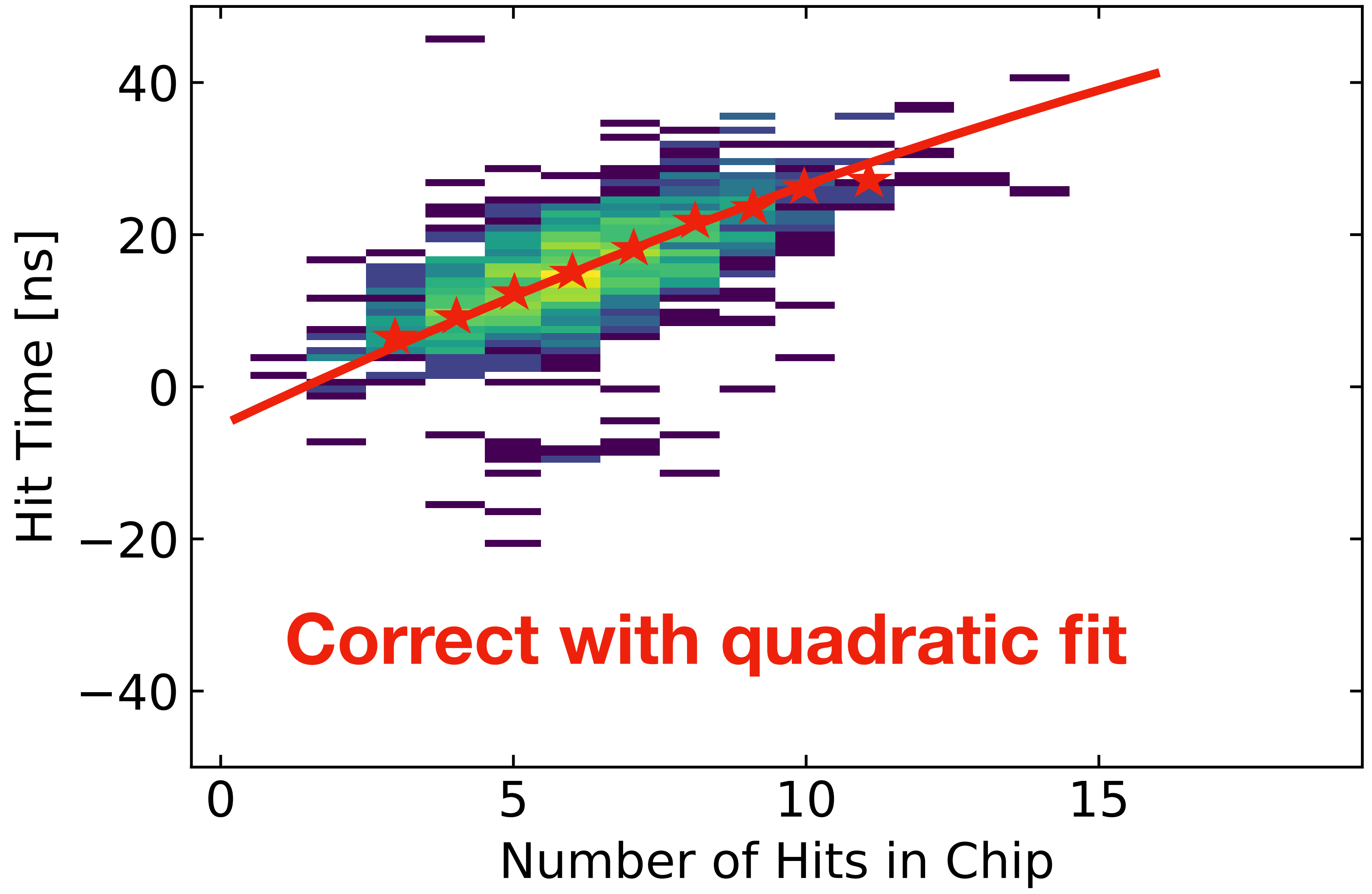

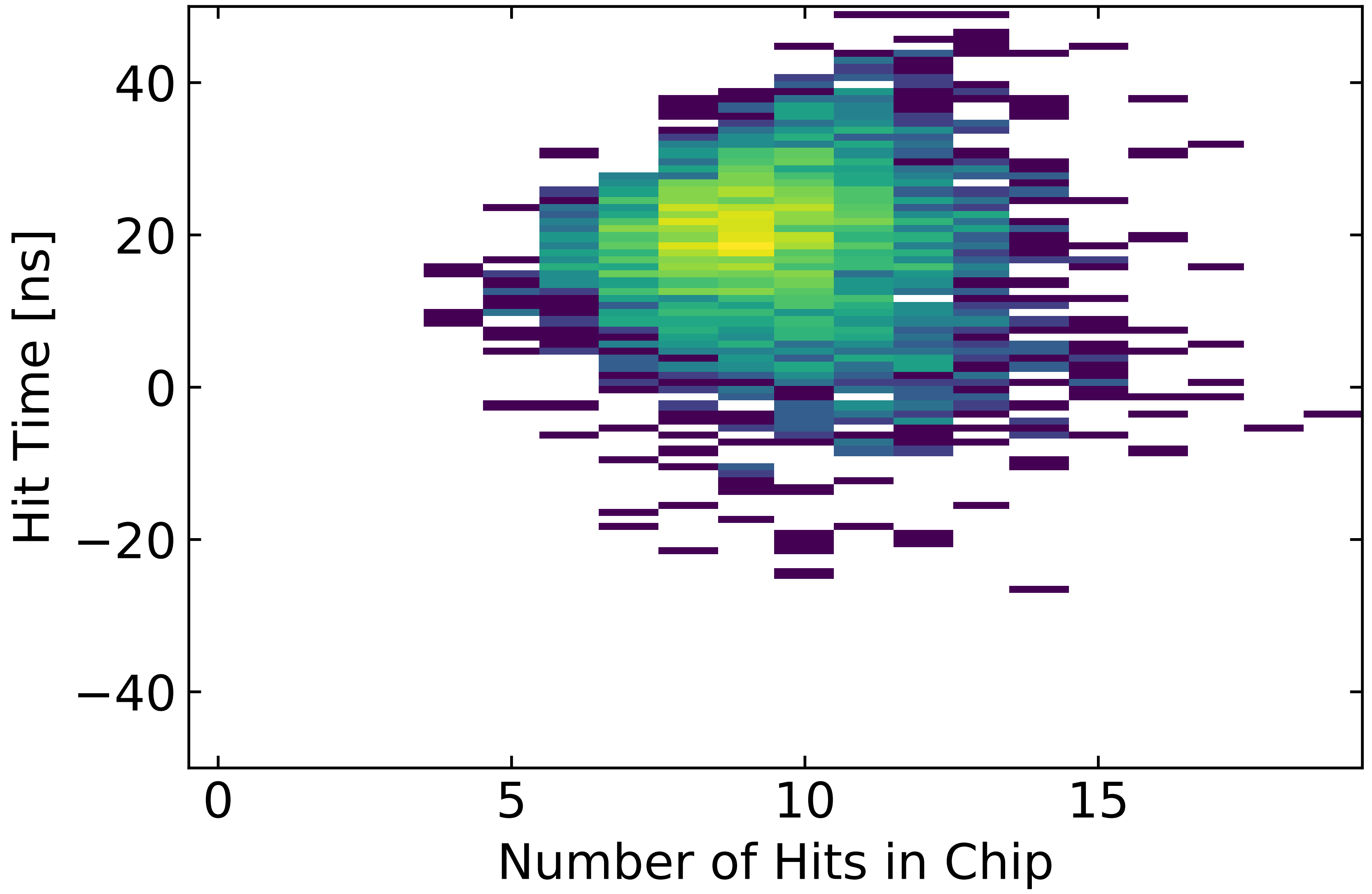

Correction on Channel Level

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Problem: Showers of electrons don't reach the deep layers of the calorimeter

$\Longrightarrow$ Calibration of the full calorimeter not possible with electron runs, use Pions instead

$\Longrightarrow$ Maximum occupancy related shift of hit times for electrons at ~±40ns

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$\Longrightarrow$ Calibration of the full calorimeter not possible with electron runs, use Pions instead

$\Longrightarrow$ Maximum occupancy related shift of hit times for electrons at ~±40ns

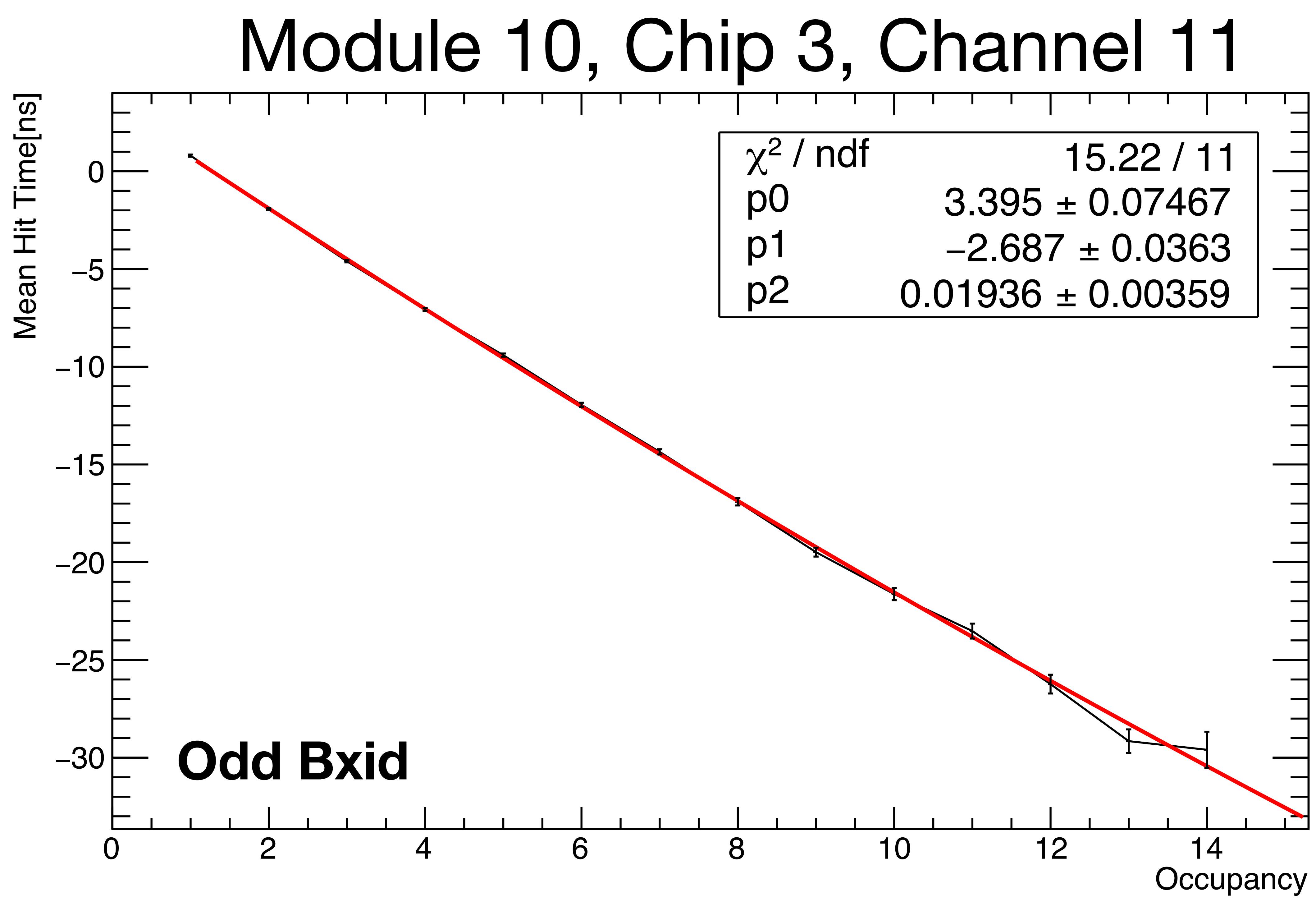
Solution:

- Cut pion hit time spectrum at ±40ns before obtaining the calibration constants
- Mitigate influence of late neutron hits on the calibration constants

Correction on Channel Level

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

Fit individual channels: Correction $= p2 \cdot \text{occupancy}^2 + p1 \cdot \text{occupancy} + p0$



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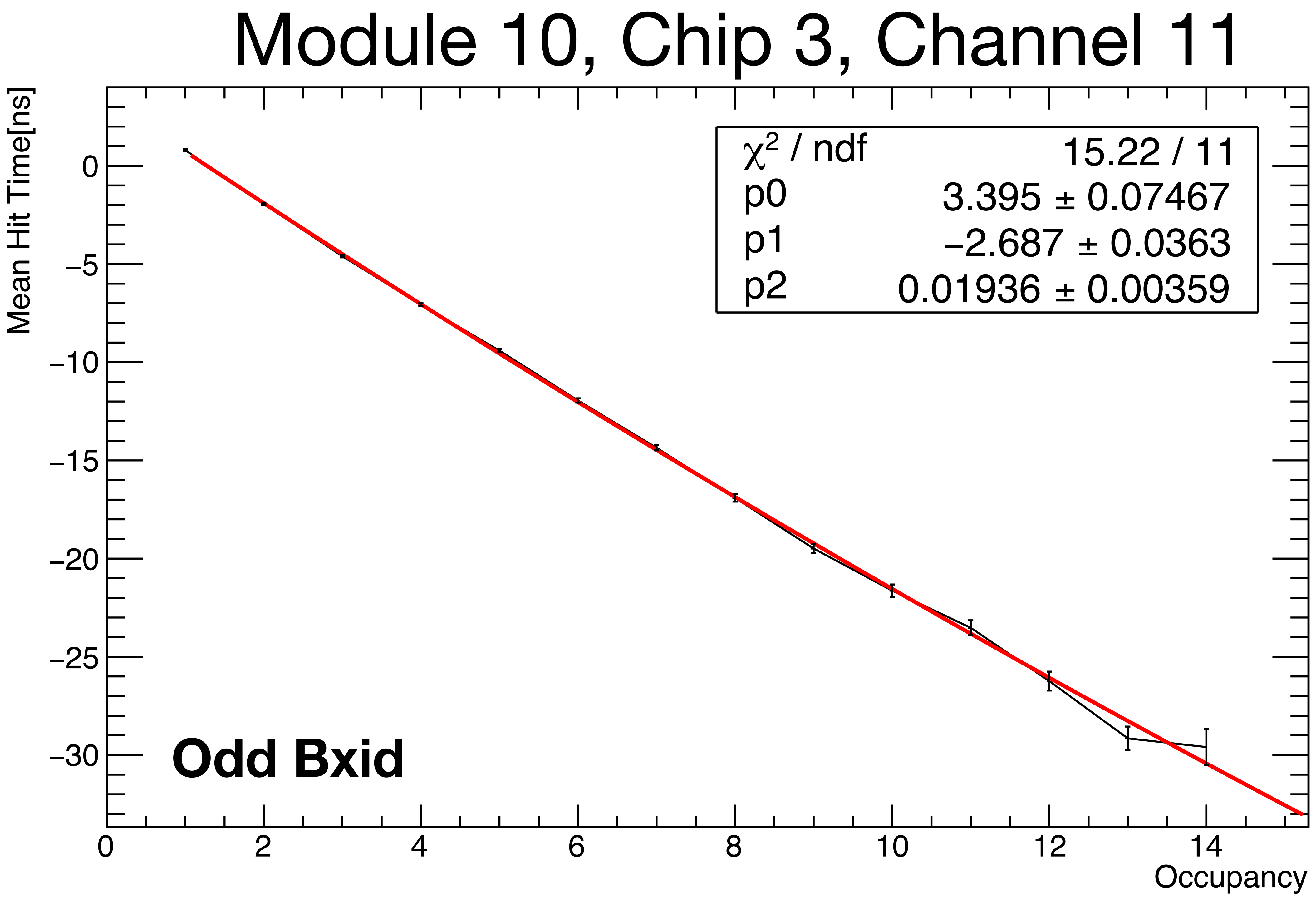

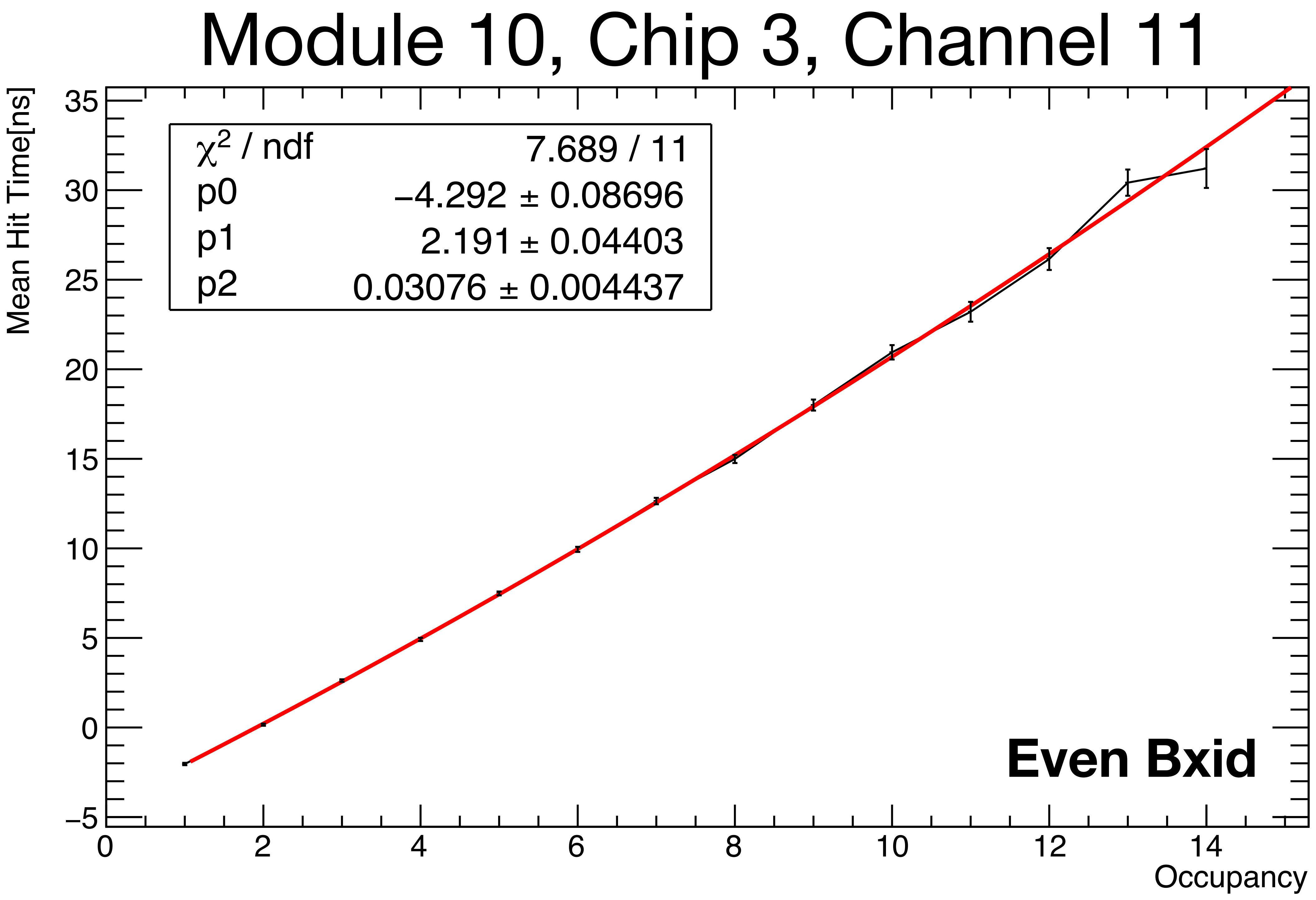

No systematics in the values of the correction factors found!

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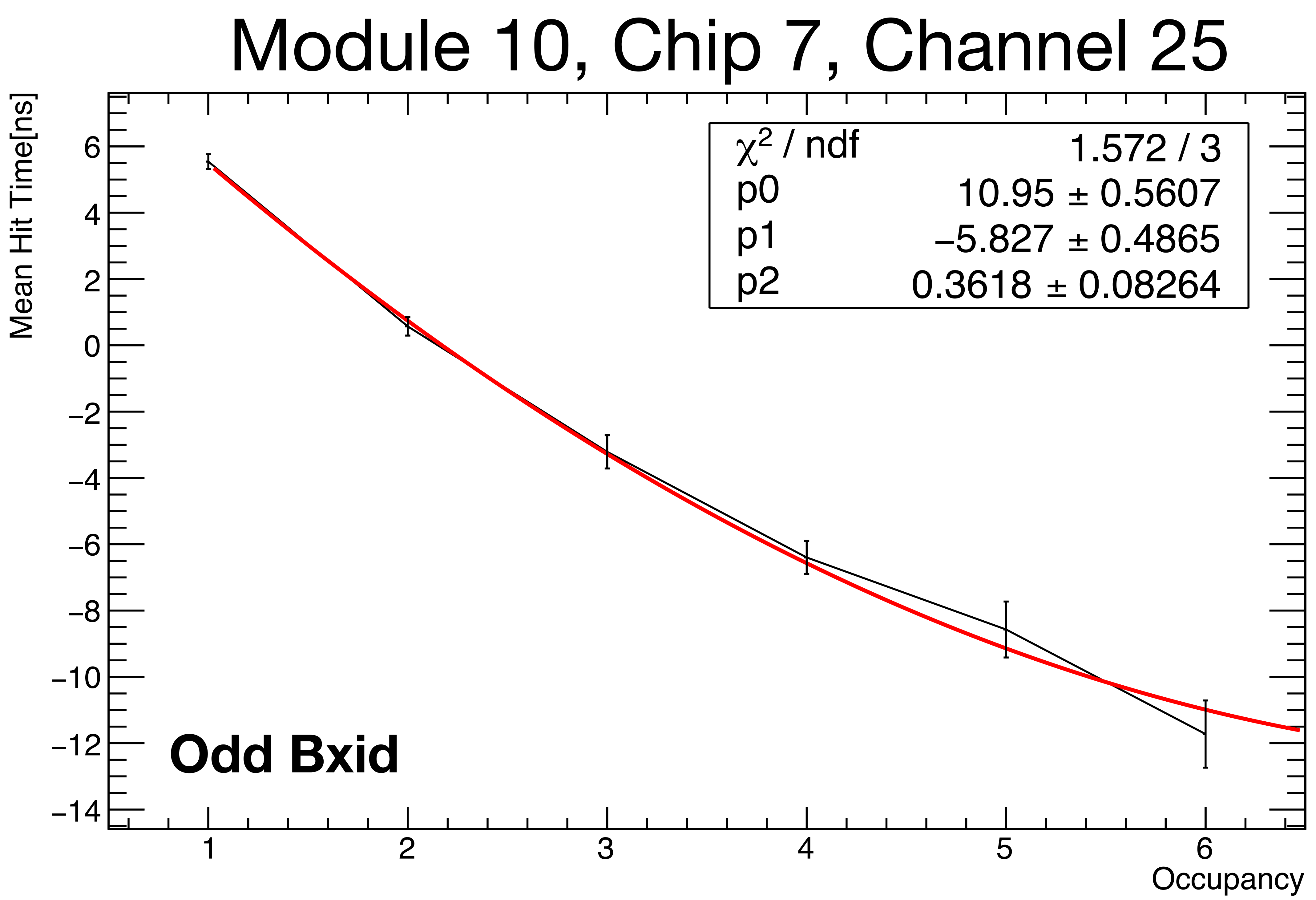

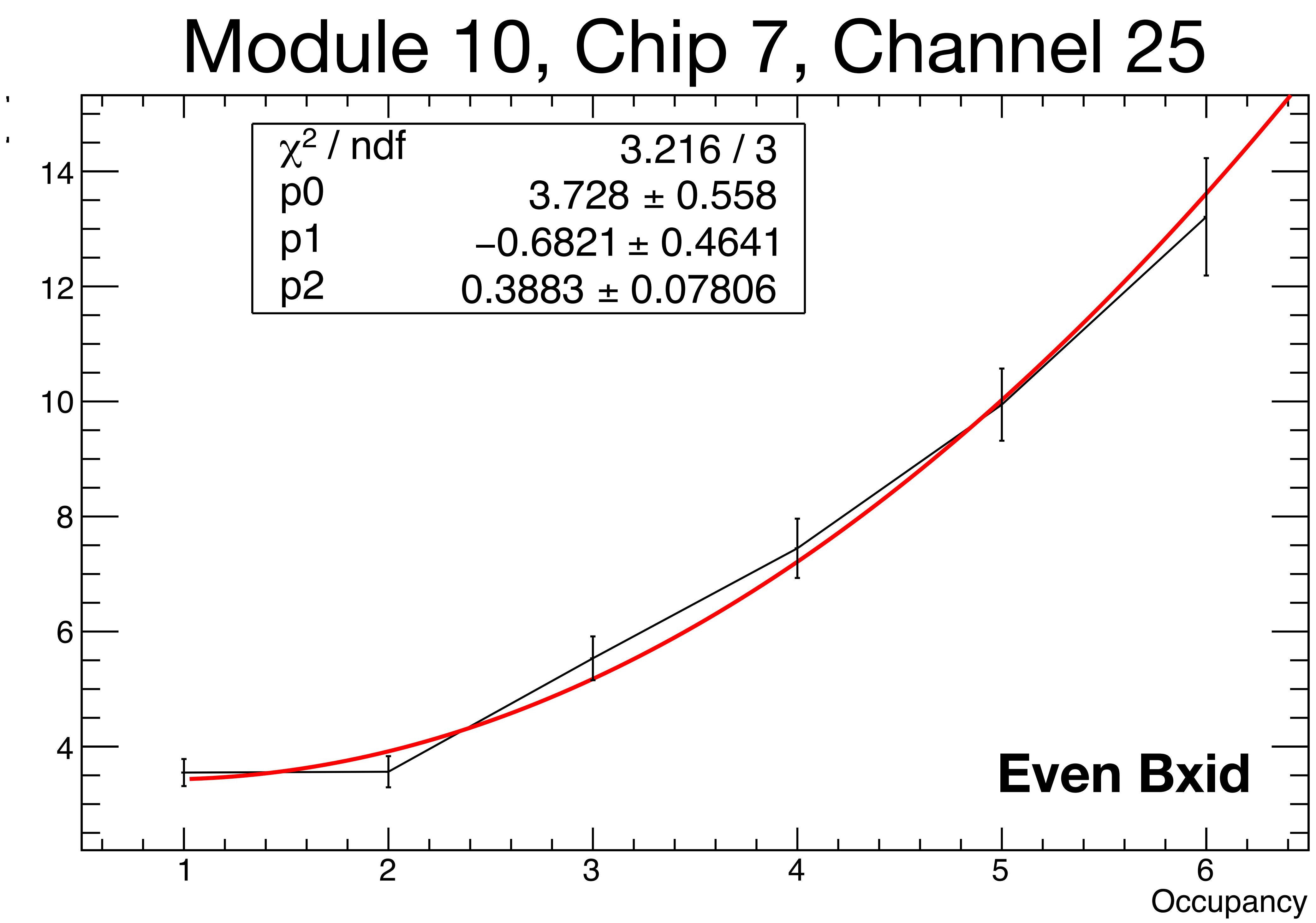

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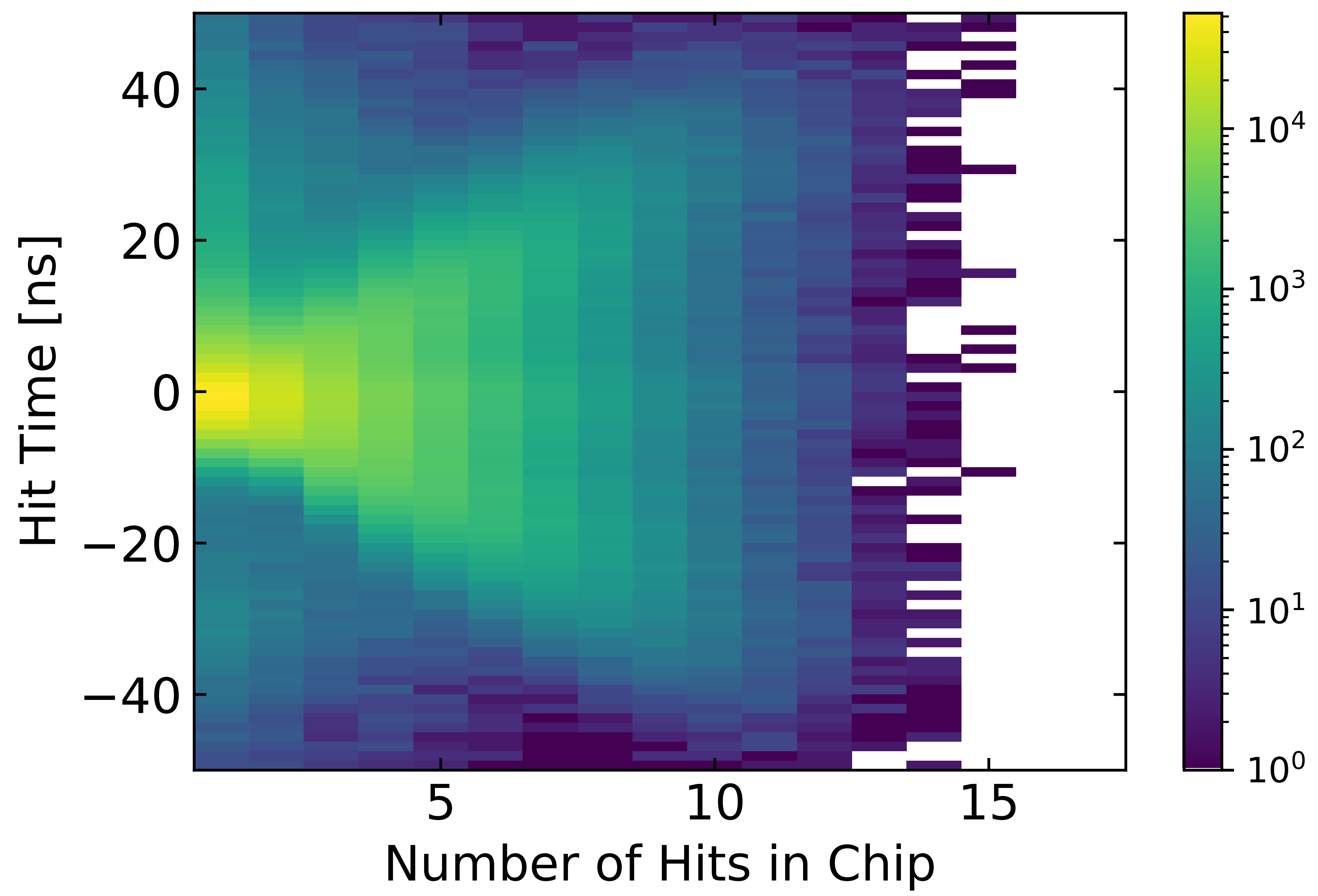

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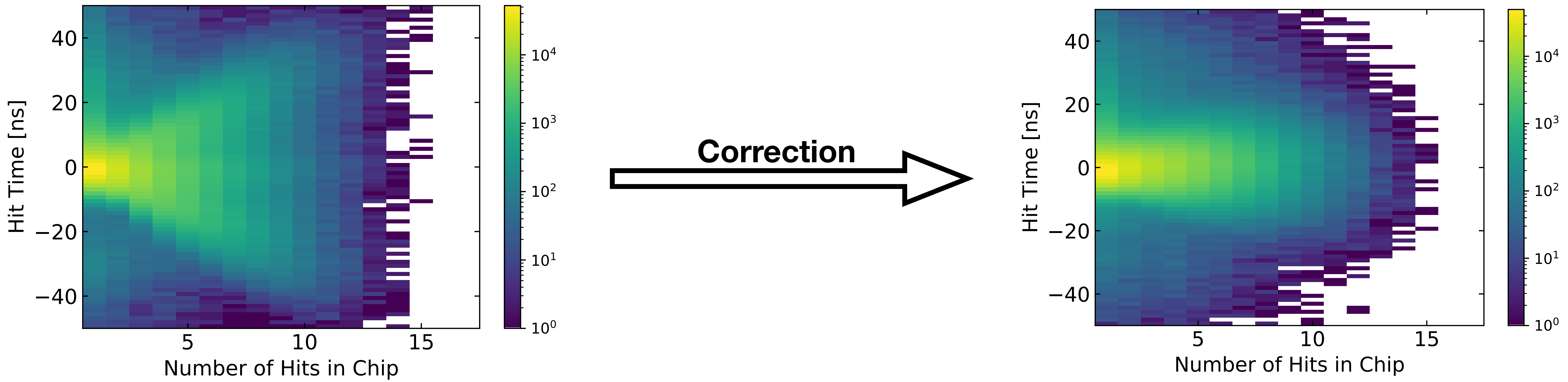

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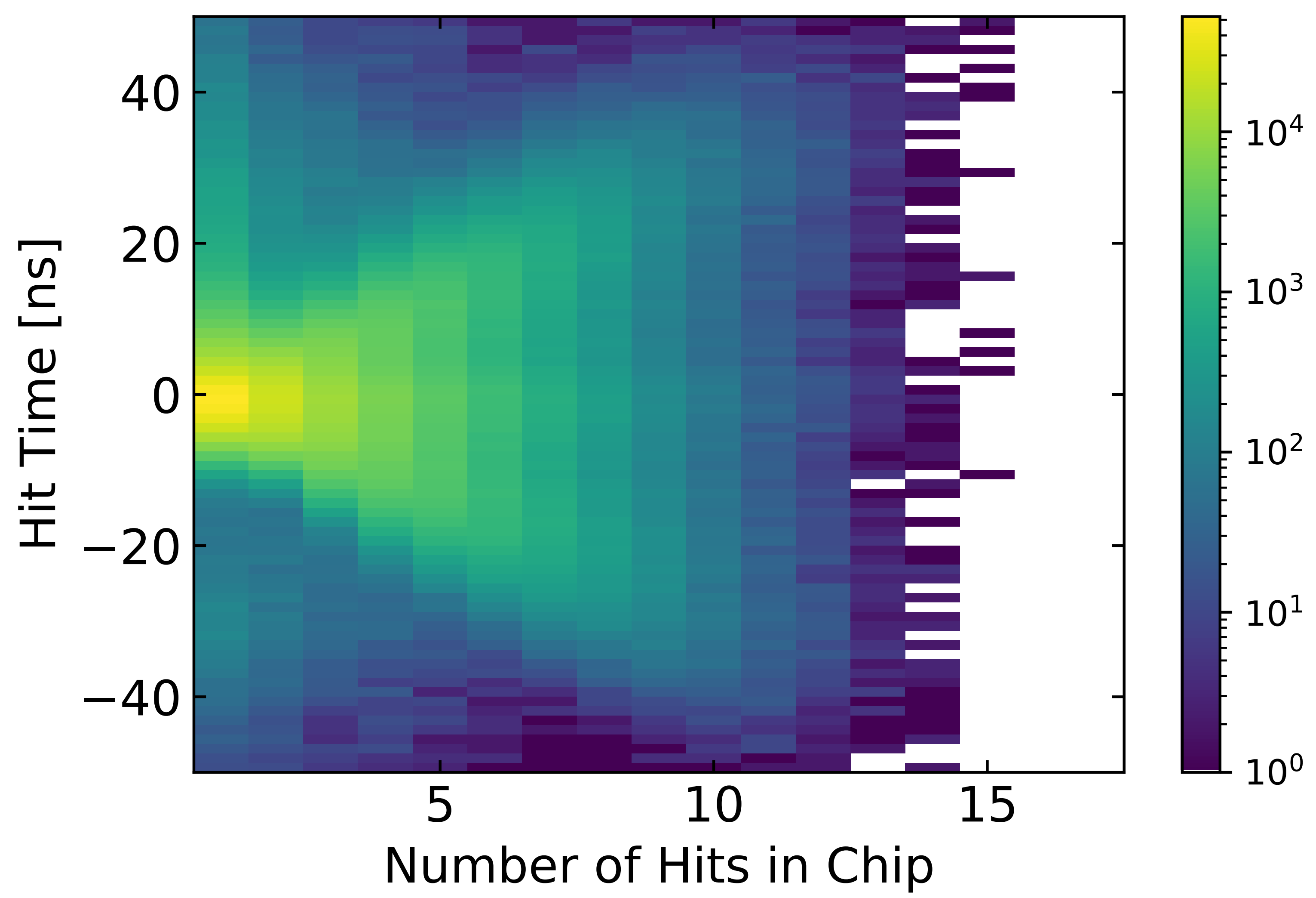
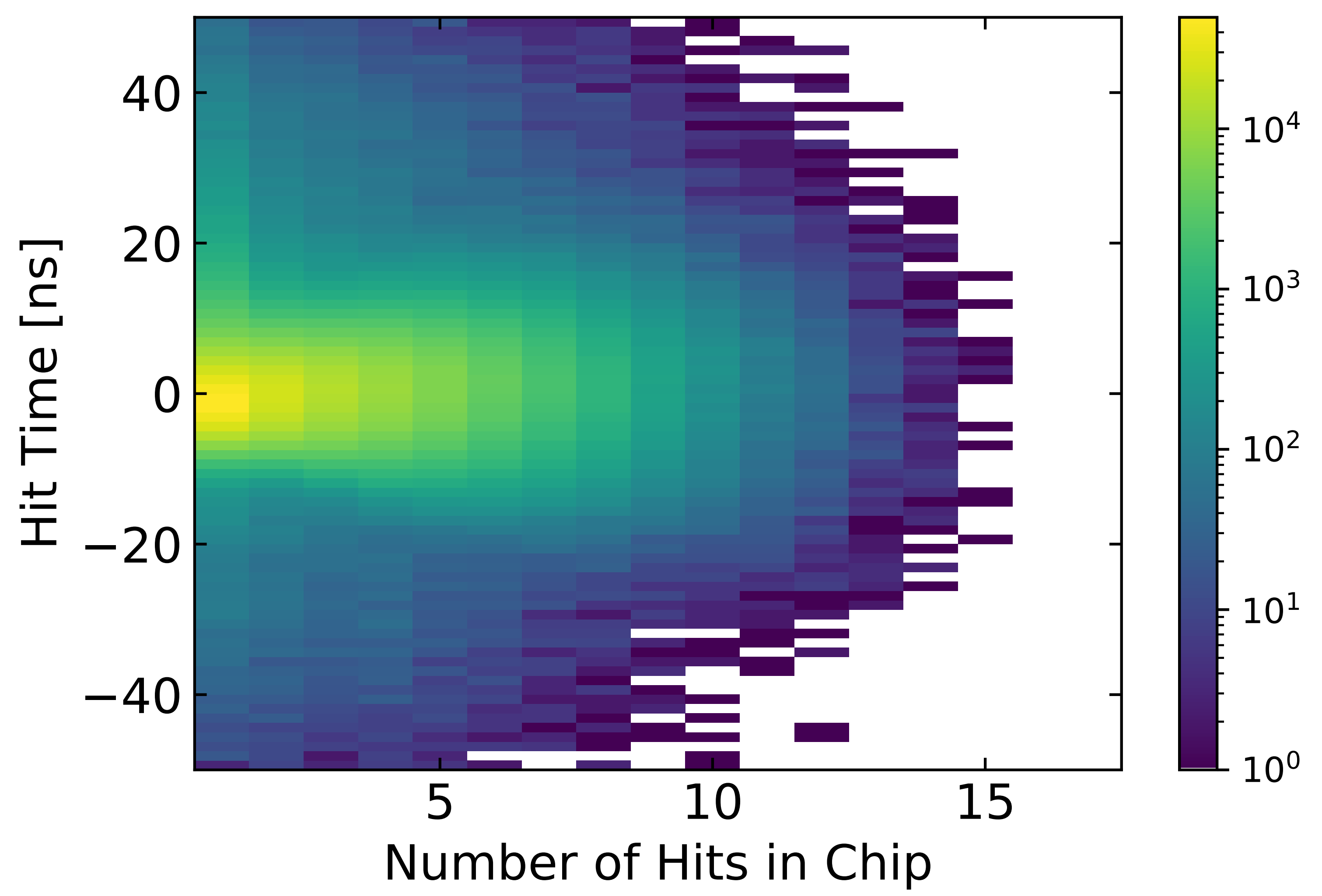
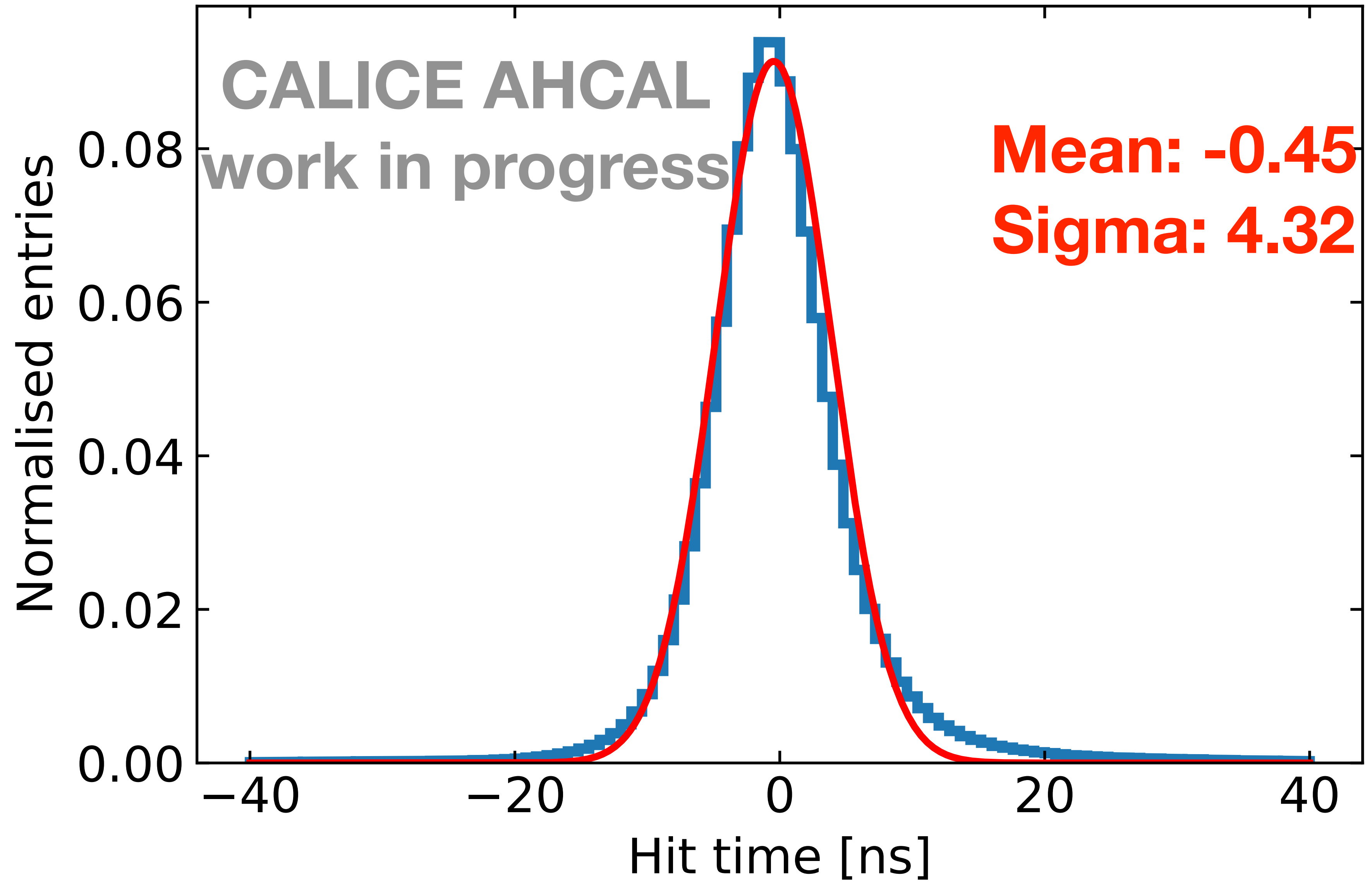
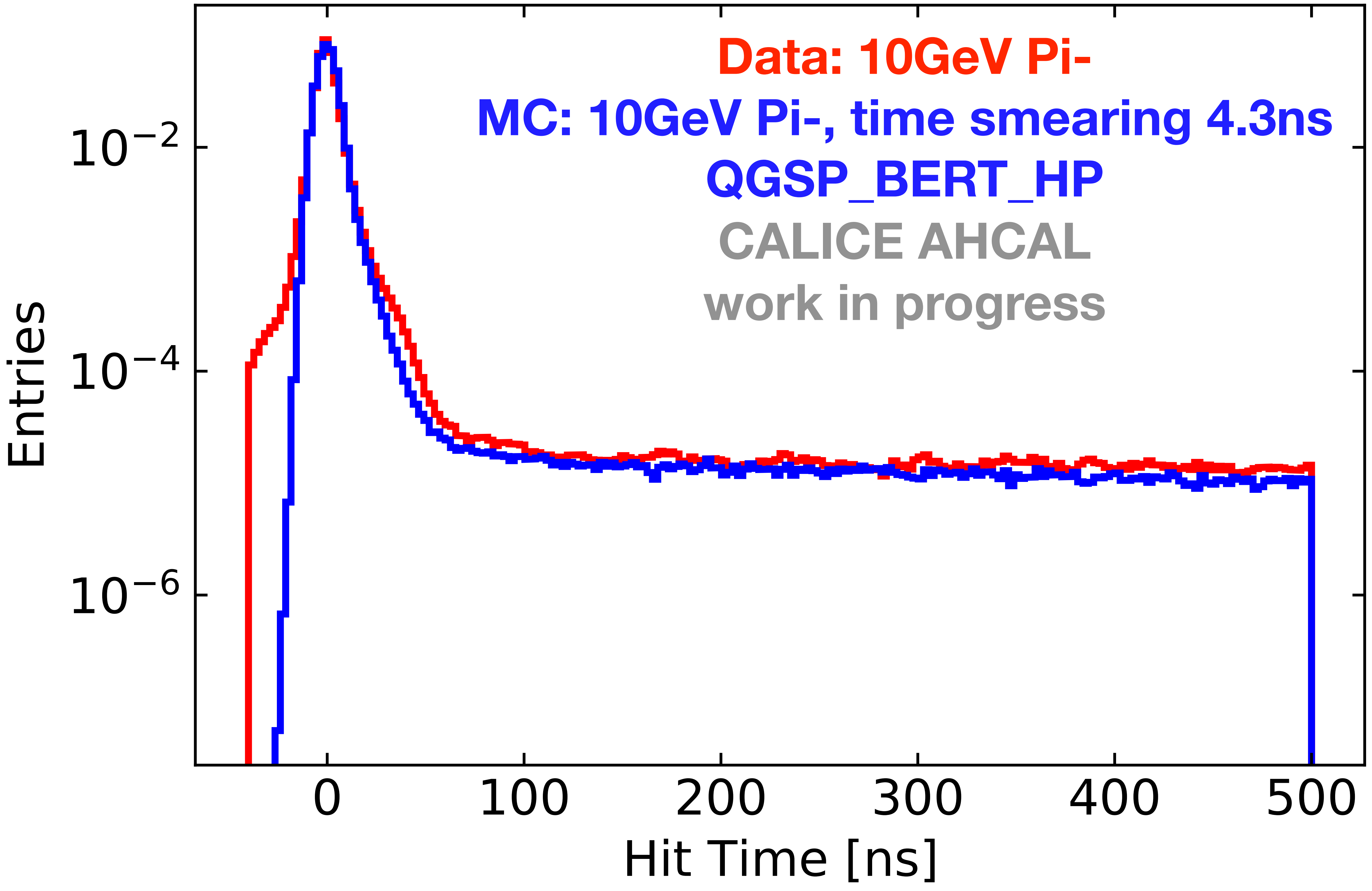






Calibration obtained with 10GeV, 30GeV and 60GeV Pion runs

Pion Hit Time Distribution



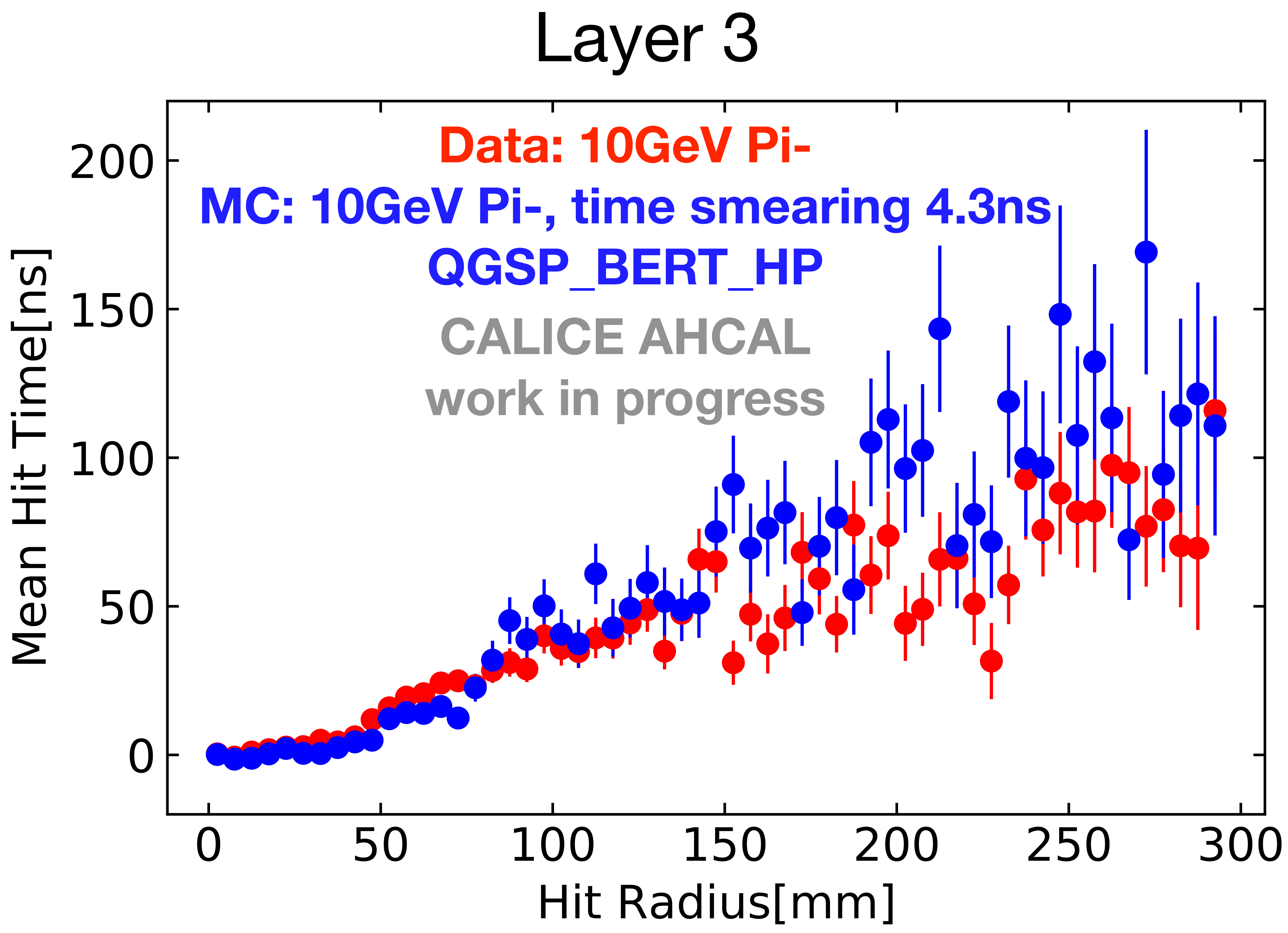
Data Quality Selections:

- 500ns < BIF Time < 2500ns
- Hit Time < 3500ns
- Number of Hits > 80
- 200 < Depth of COG < 800

Occupancy dependent modeling of the hit time in MC

Radius Dependency of Hit Time

Hit radius is defined as distance from hit to center of gravity



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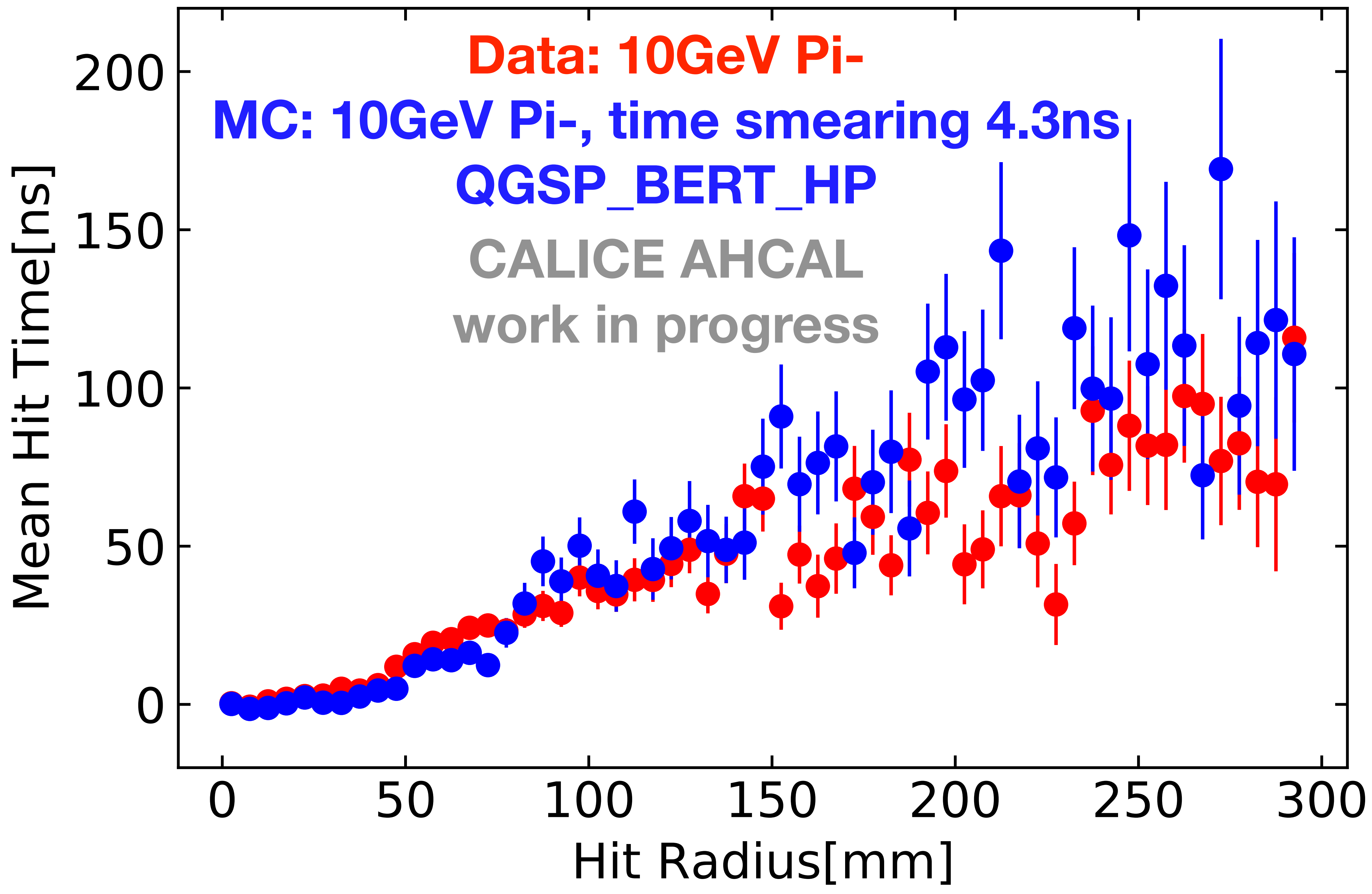
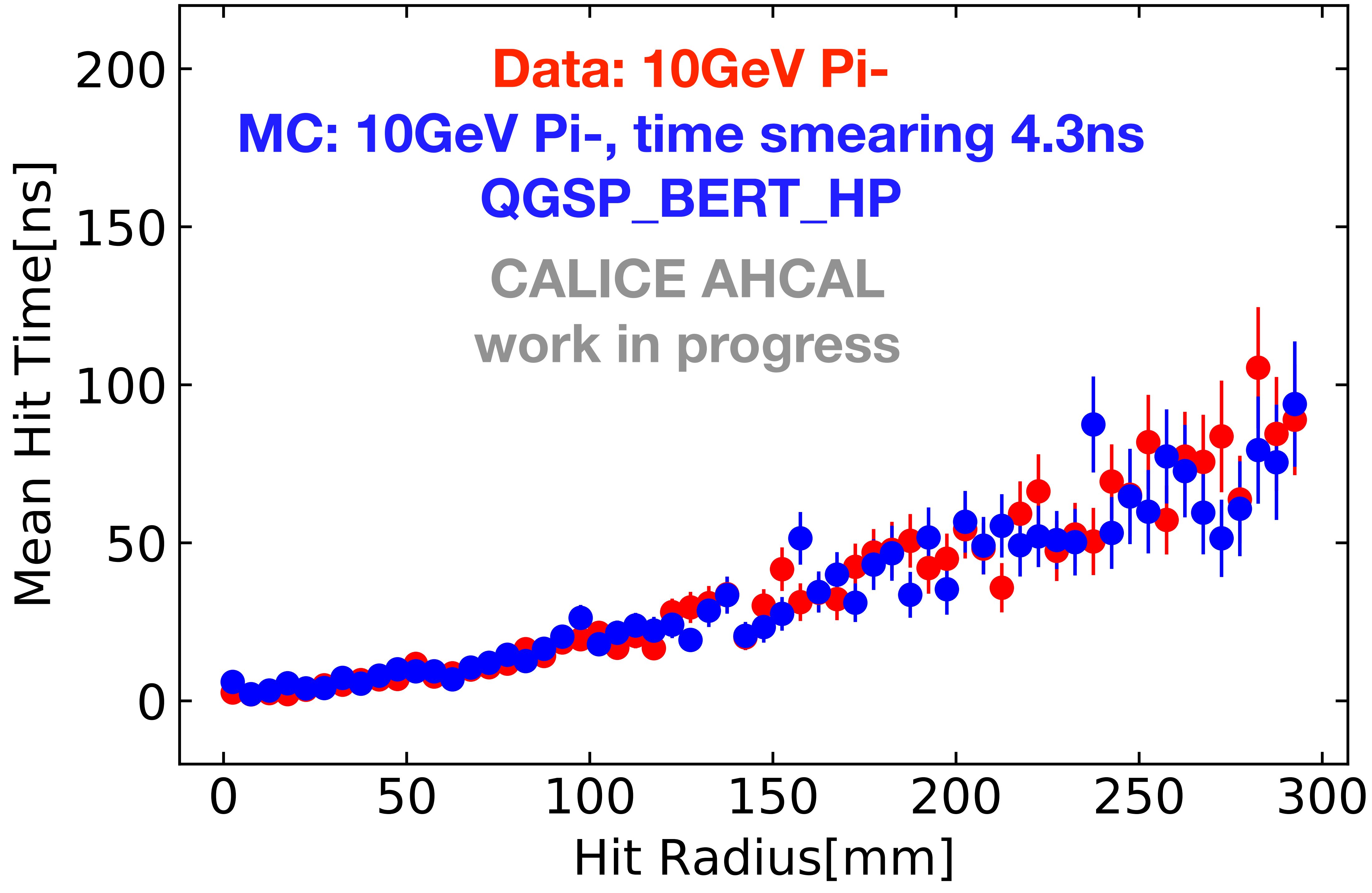
Layer 3

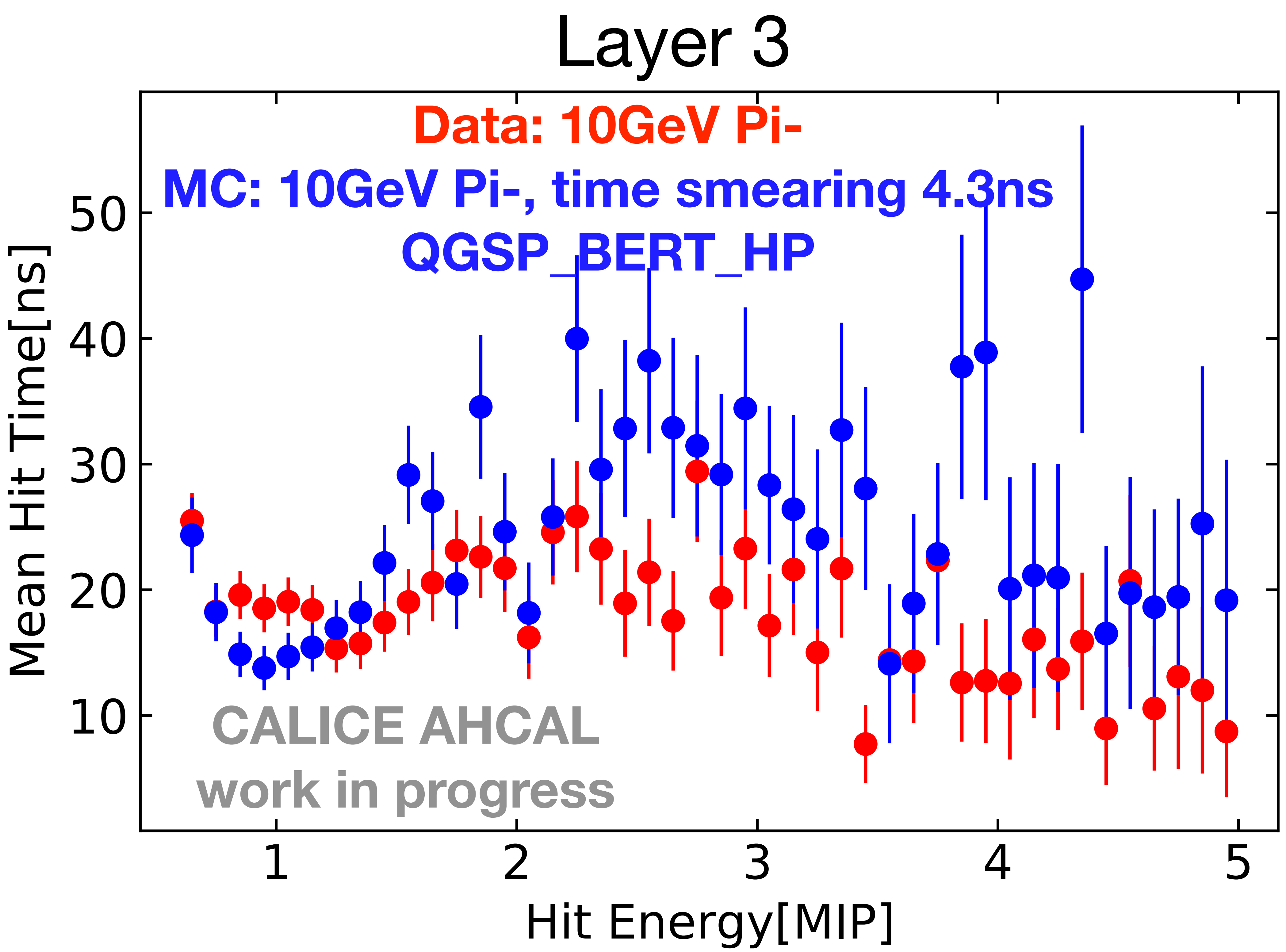


Layer 30



Clear correlation between mean hit time and distance from shower center of gravity

Energy Dependency of Hit Time



Dip around 1MIP in early layers from primary tracks

High energy hits tend to occur earlier

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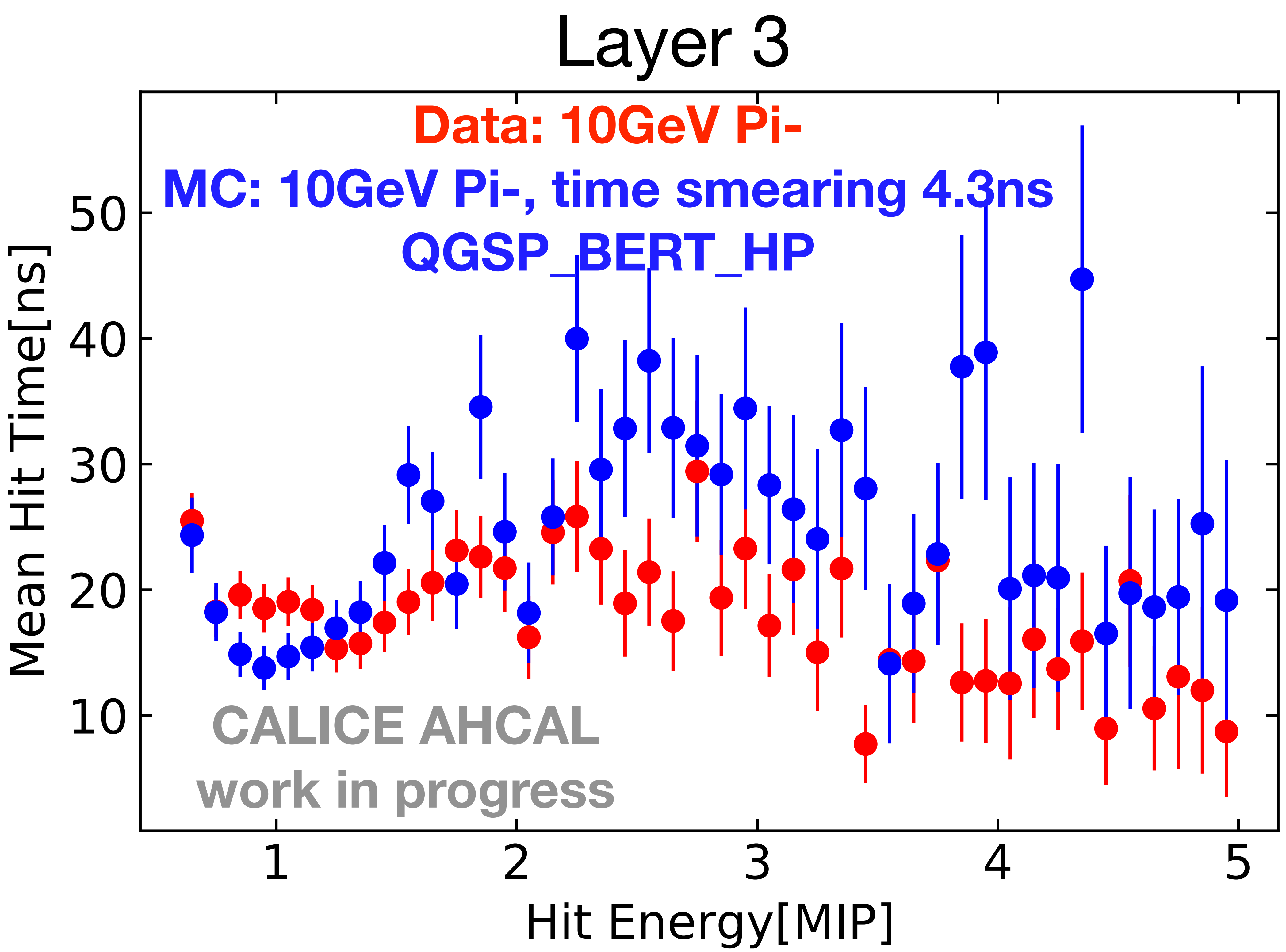

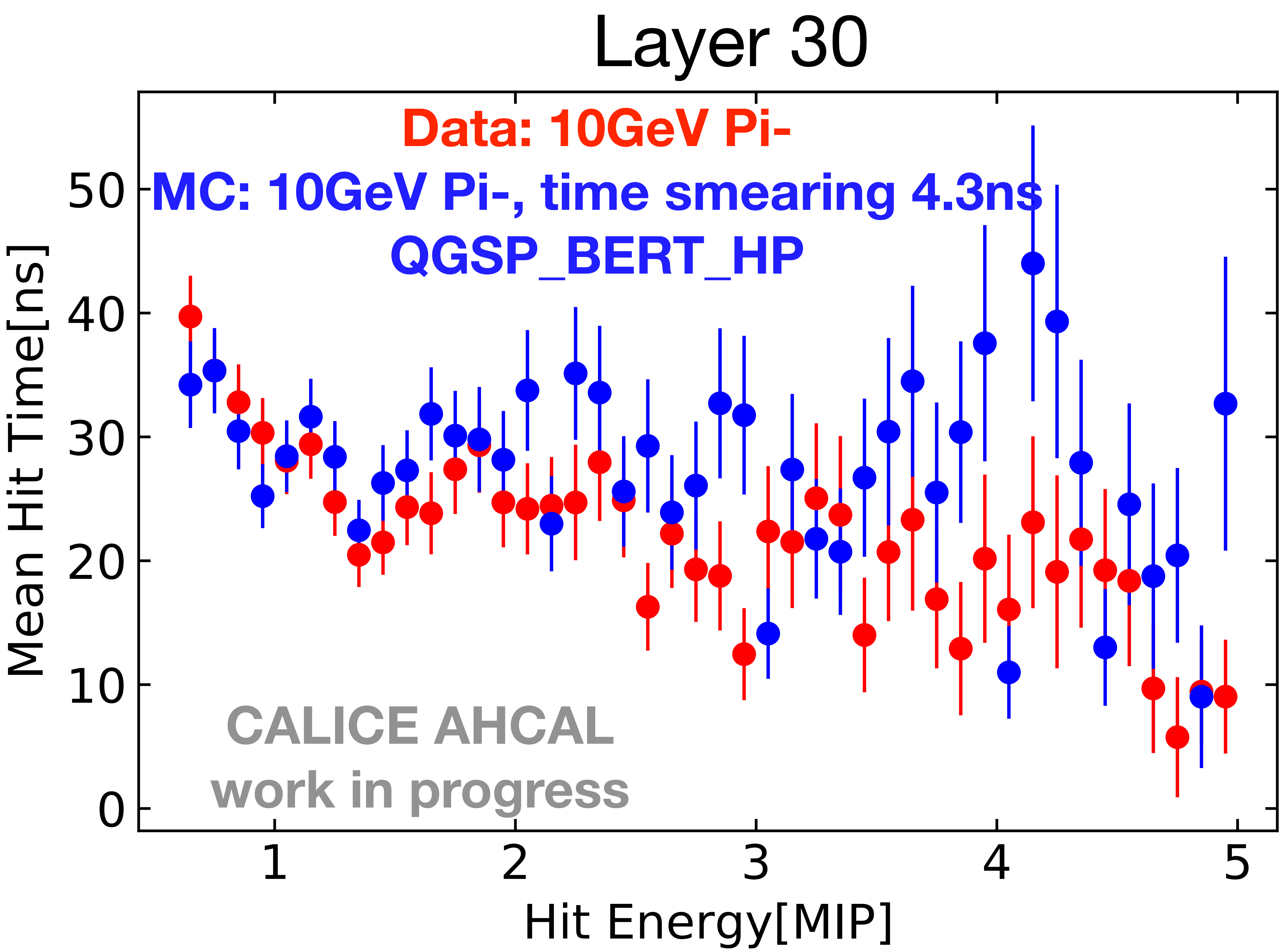

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Transportability of the Calibration

Check applicability of June 2018 calibration to May 2018 data

Important: June runs taken with power pulsing, may runs without power pulsing

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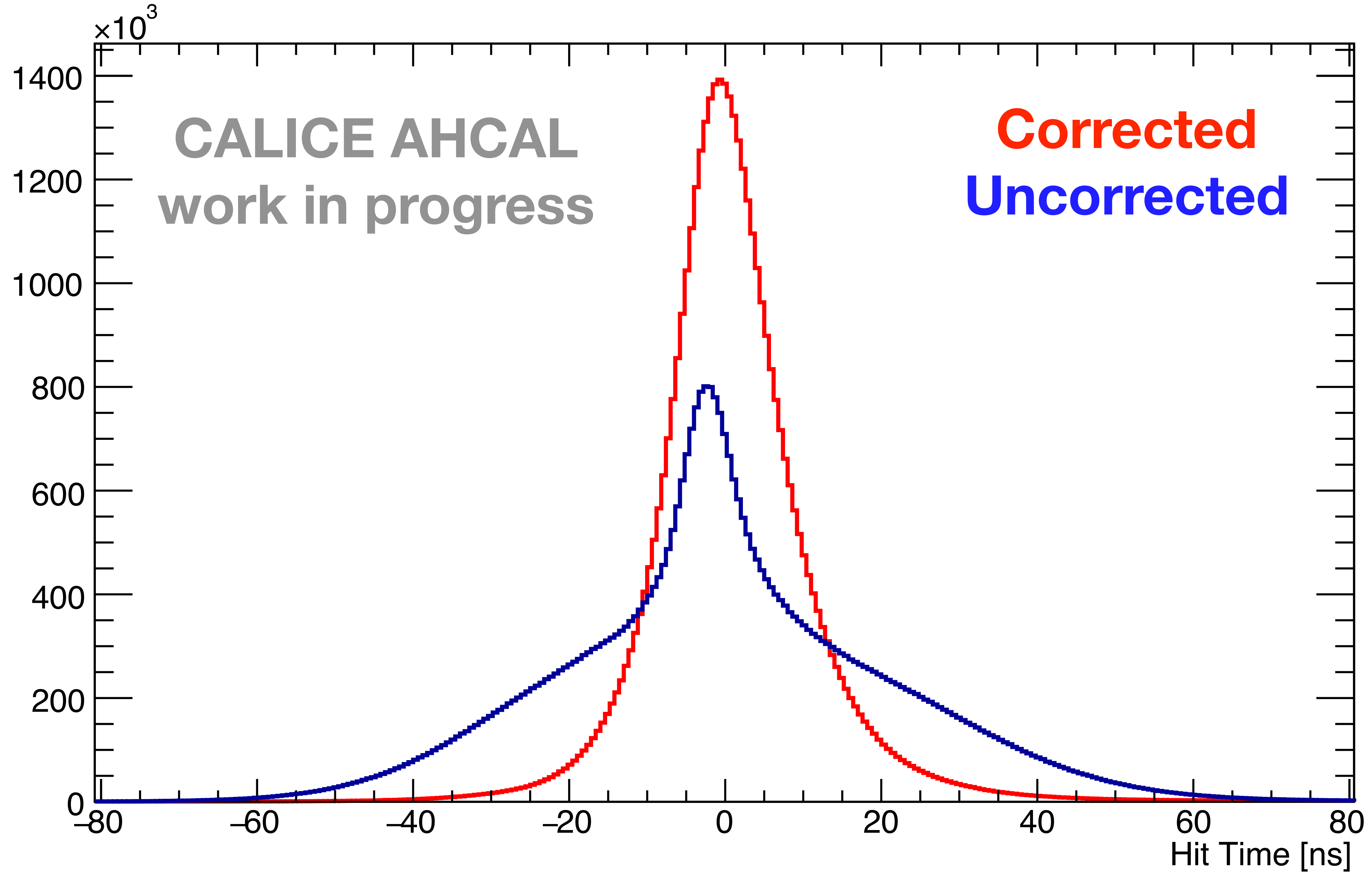

Resolution of the corrected dataset at ~7ns

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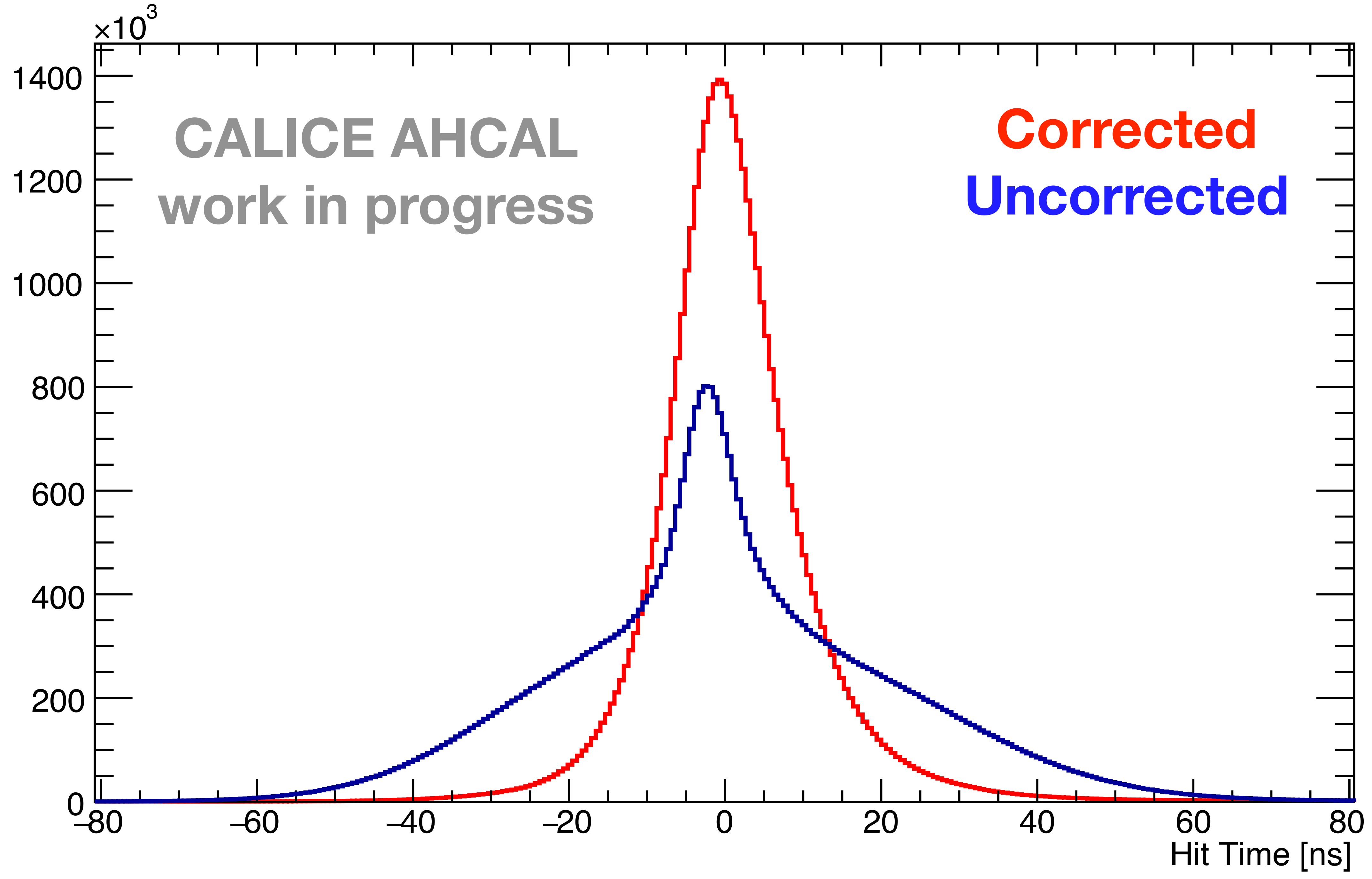

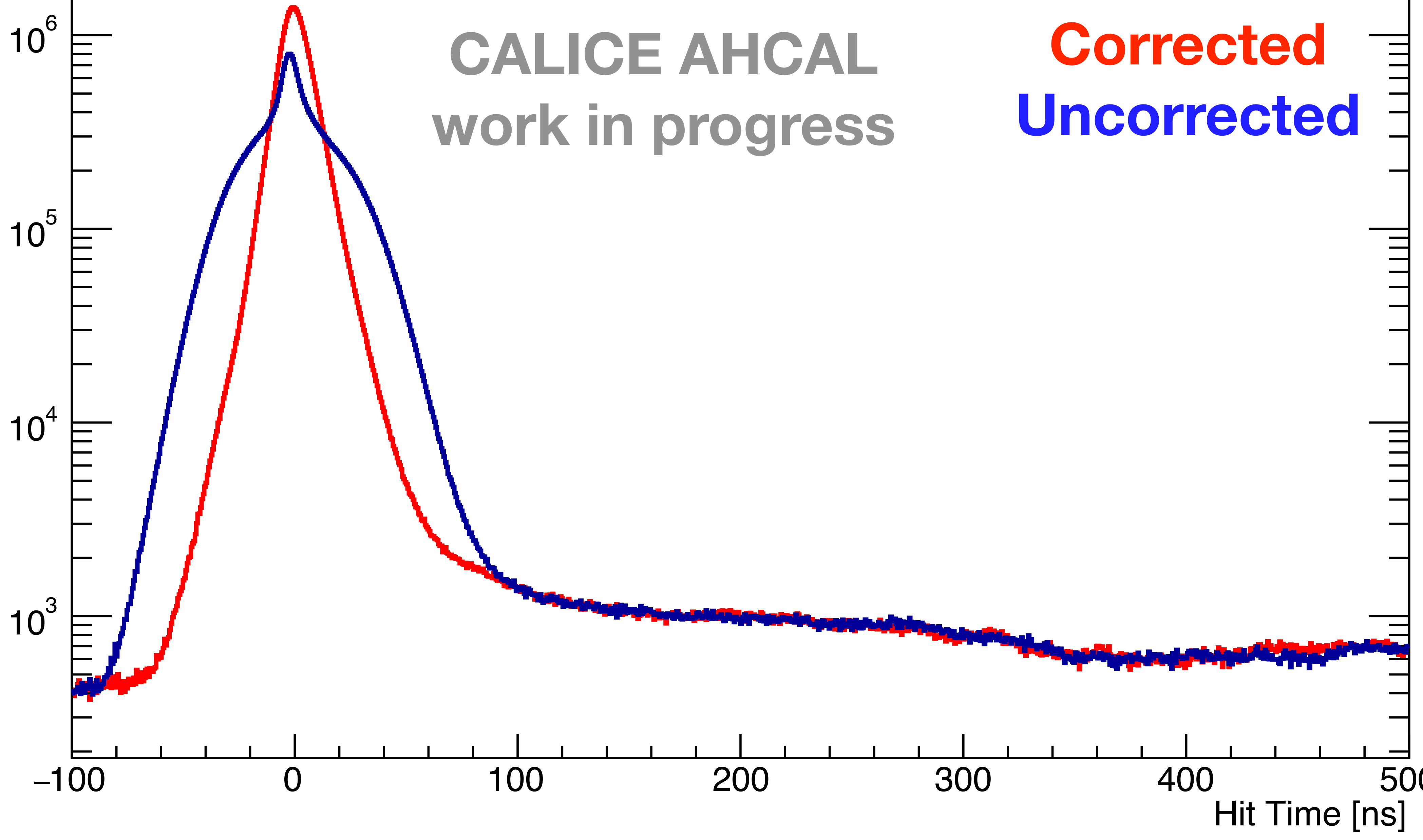

Resolution of the corrected dataset at ~7ns

Conclusion & Outlook

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$\Longrightarrow$Time resolution for prompt hits in pion showers of ~4.3ns

Dependency of the mean hit time on hit radius and hit energy is visible.

Calibration obtained with power pulsing runs from June 2018 also enhances the time resolution of non power pulsing runs taken in May 2018.

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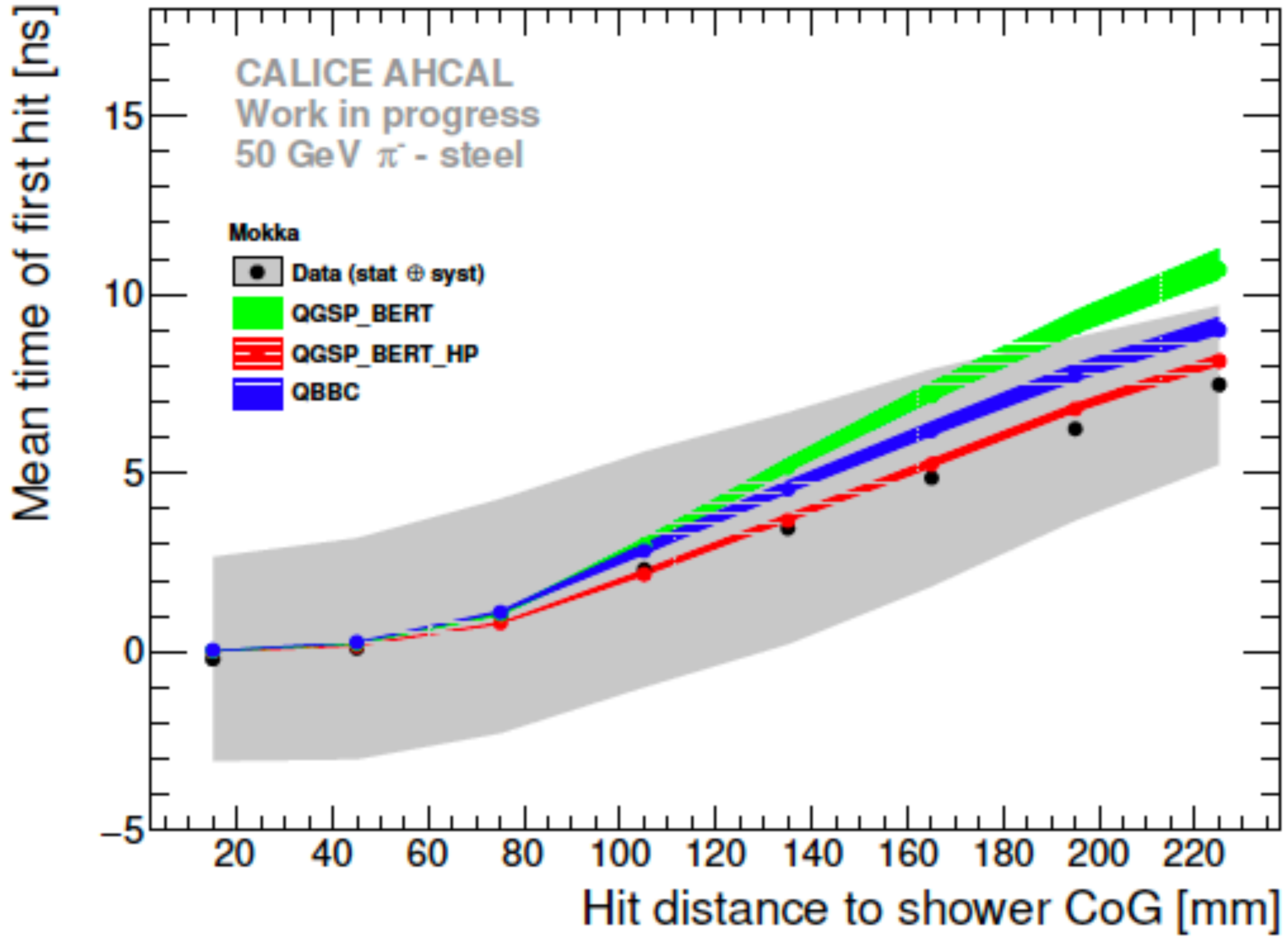
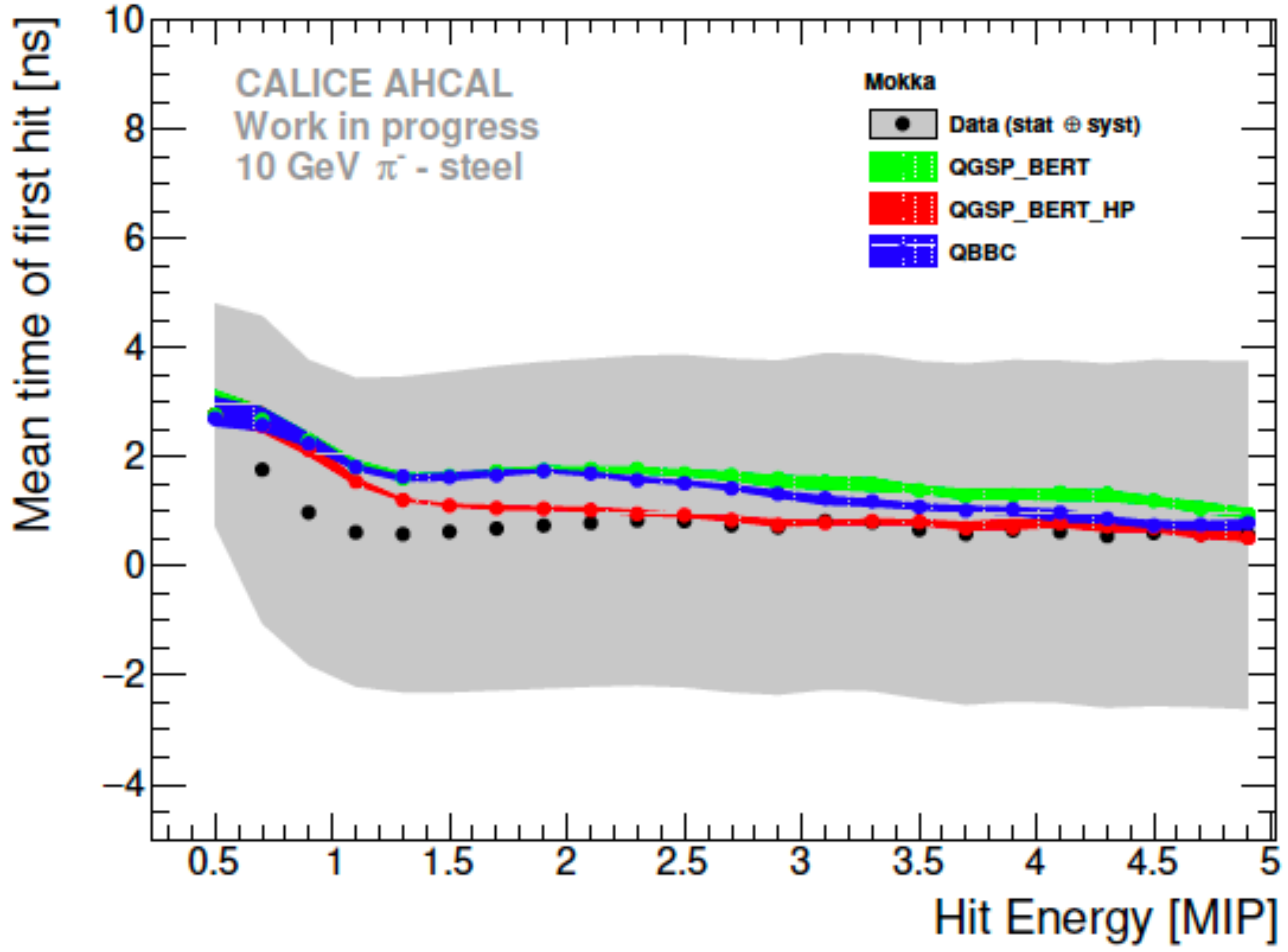
Future Steps:

- Obtain calibration for May 2018
- Redo radius end energy dependency analysis of hit time with defined shower start layer and more robust definition of the mean hit time (e.g. mean90)
- Modeling of the occupancy in monte carlo

Backup



(a) Modules 3 to 10



Taken From Eldwan Brianne, PhD Thesis

Old channel wise calibration

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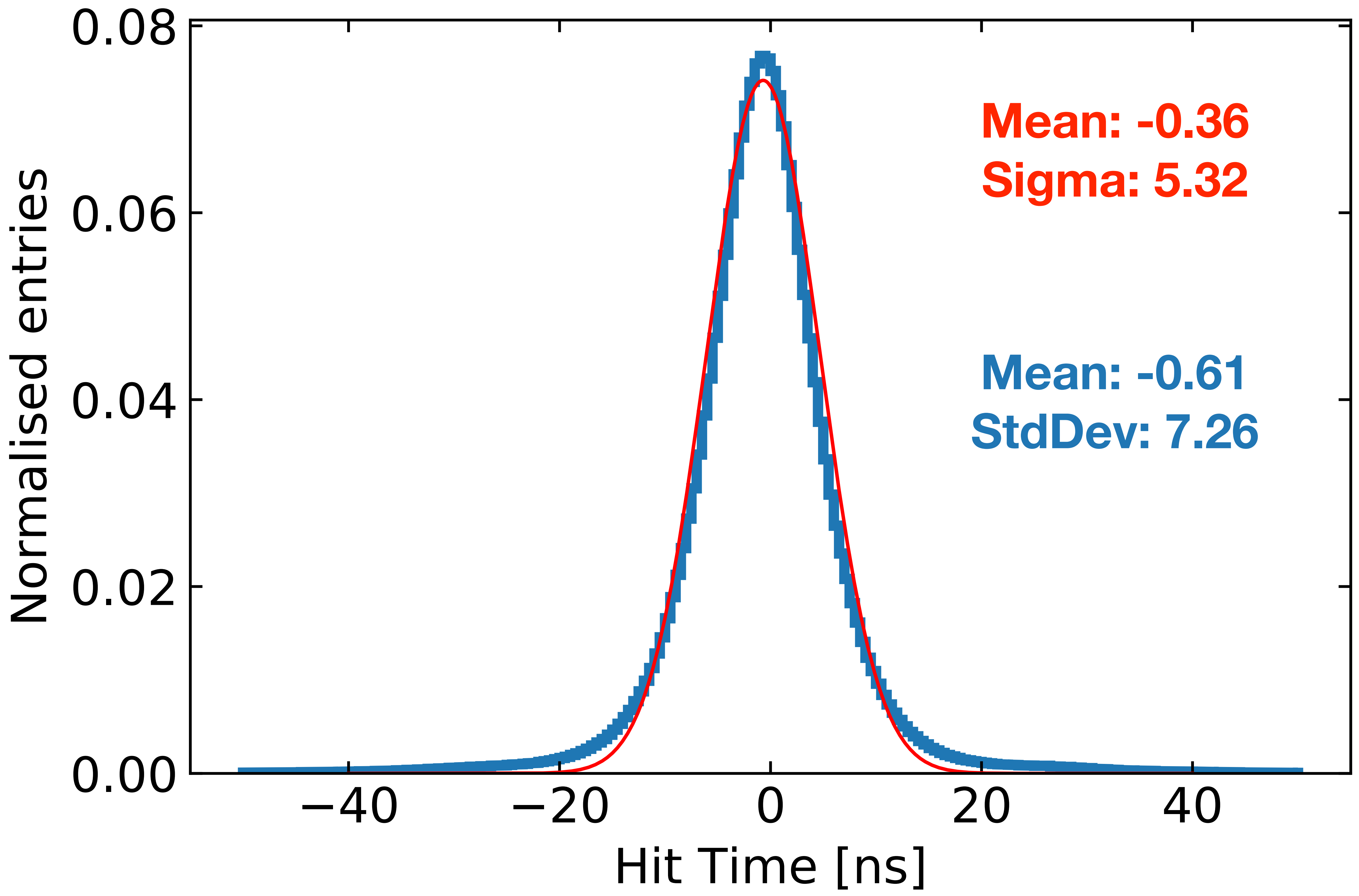

Correcting with Pions

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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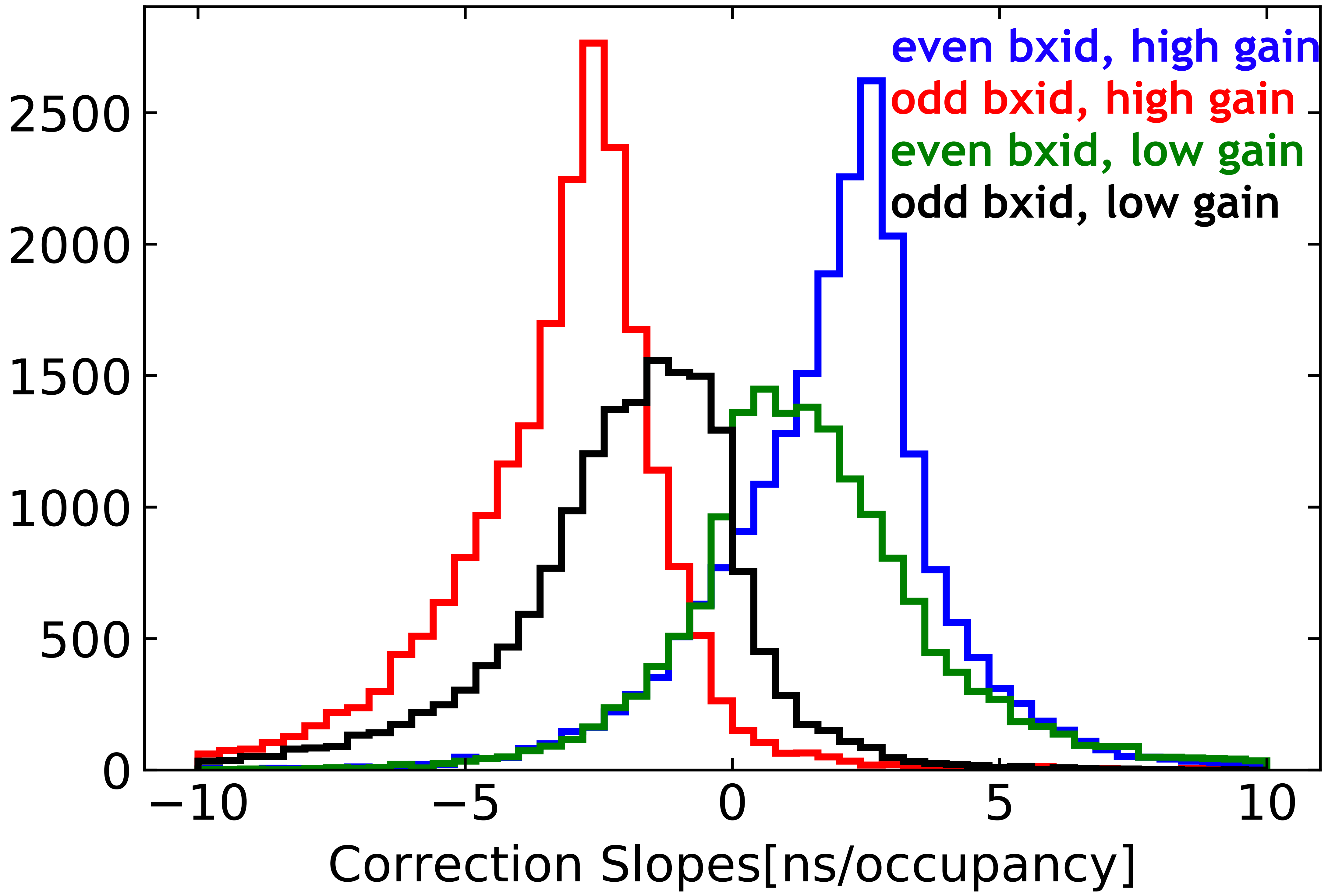

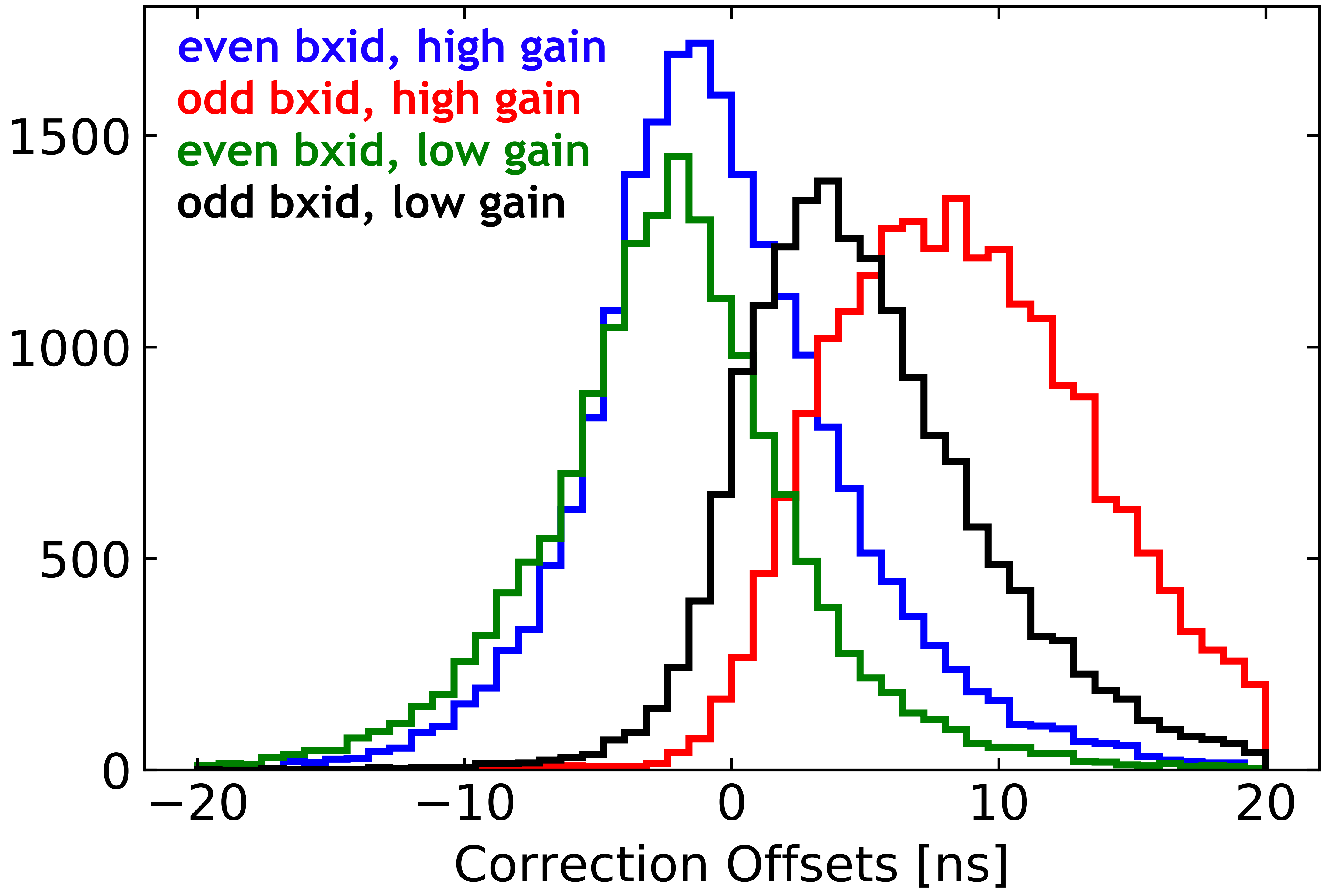

A Look at Pions - Hit Energy

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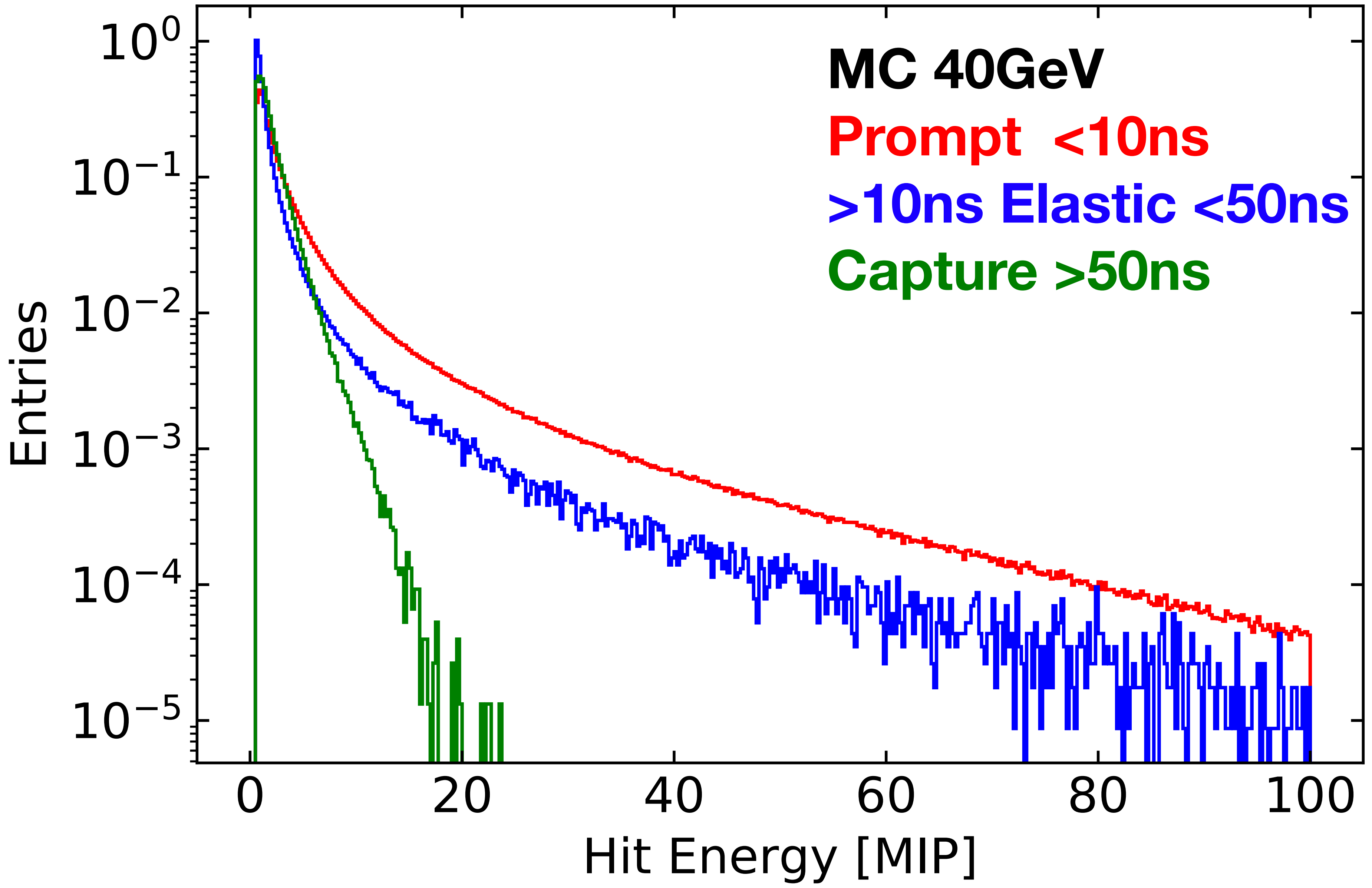

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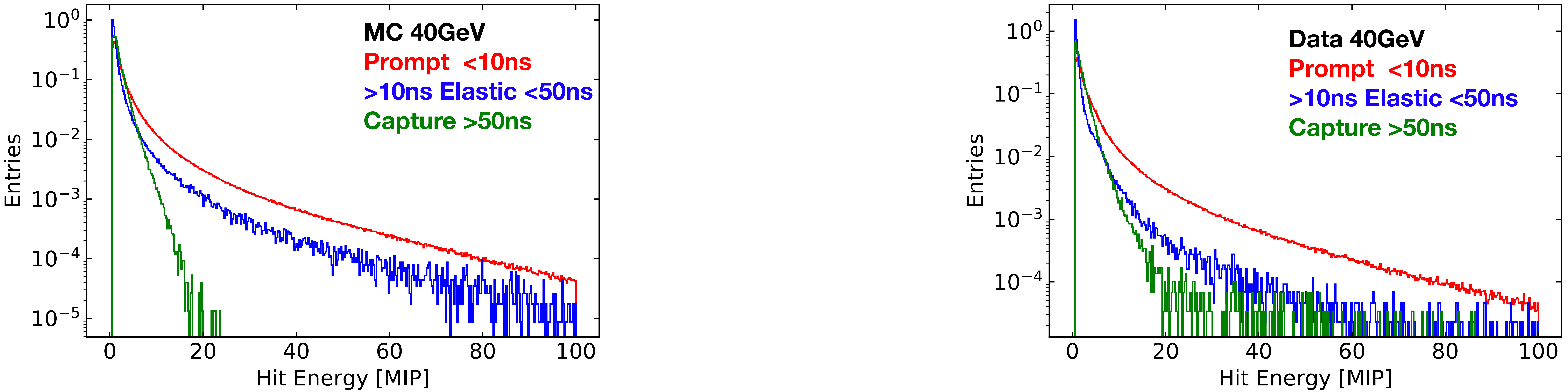

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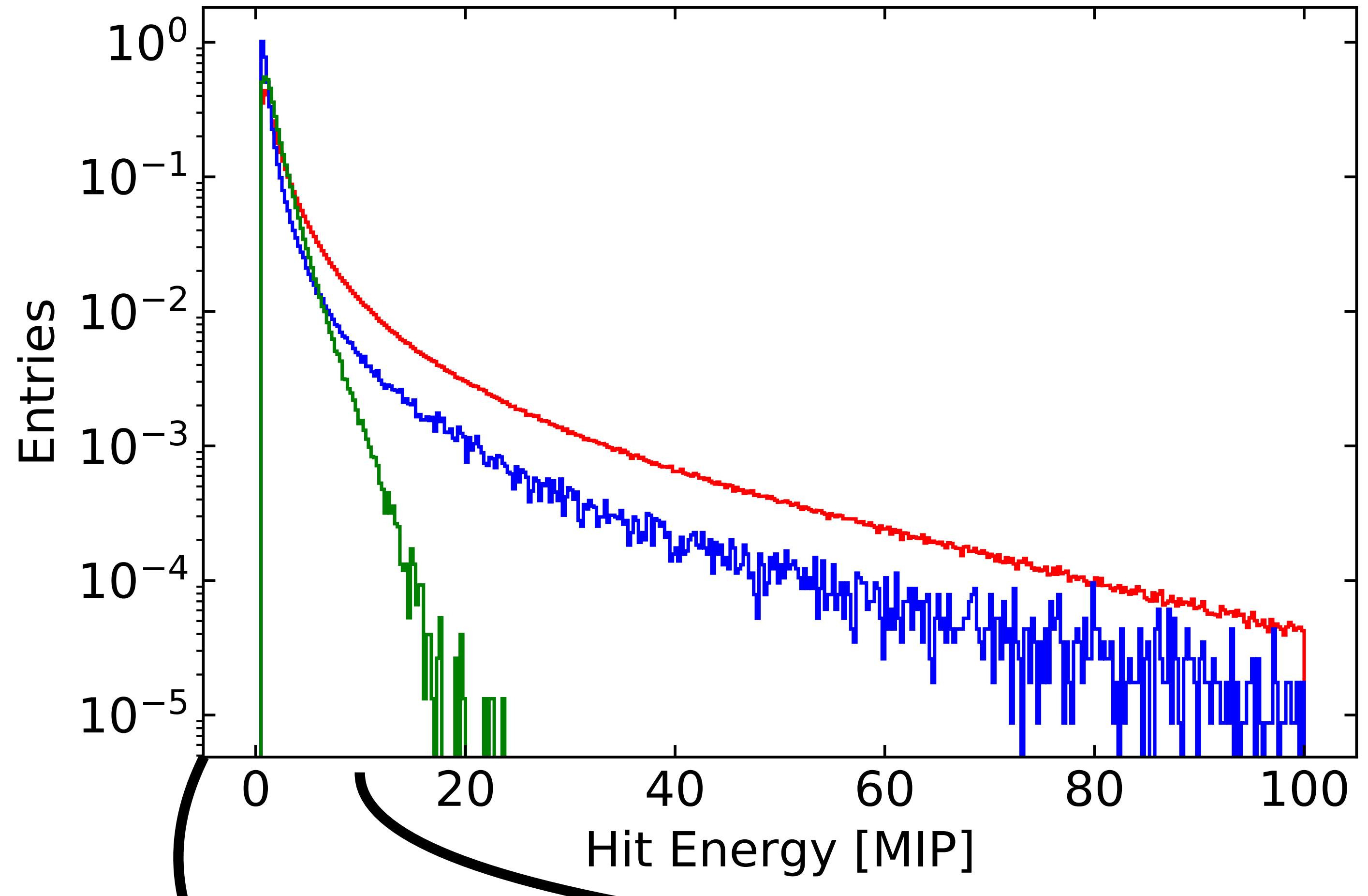

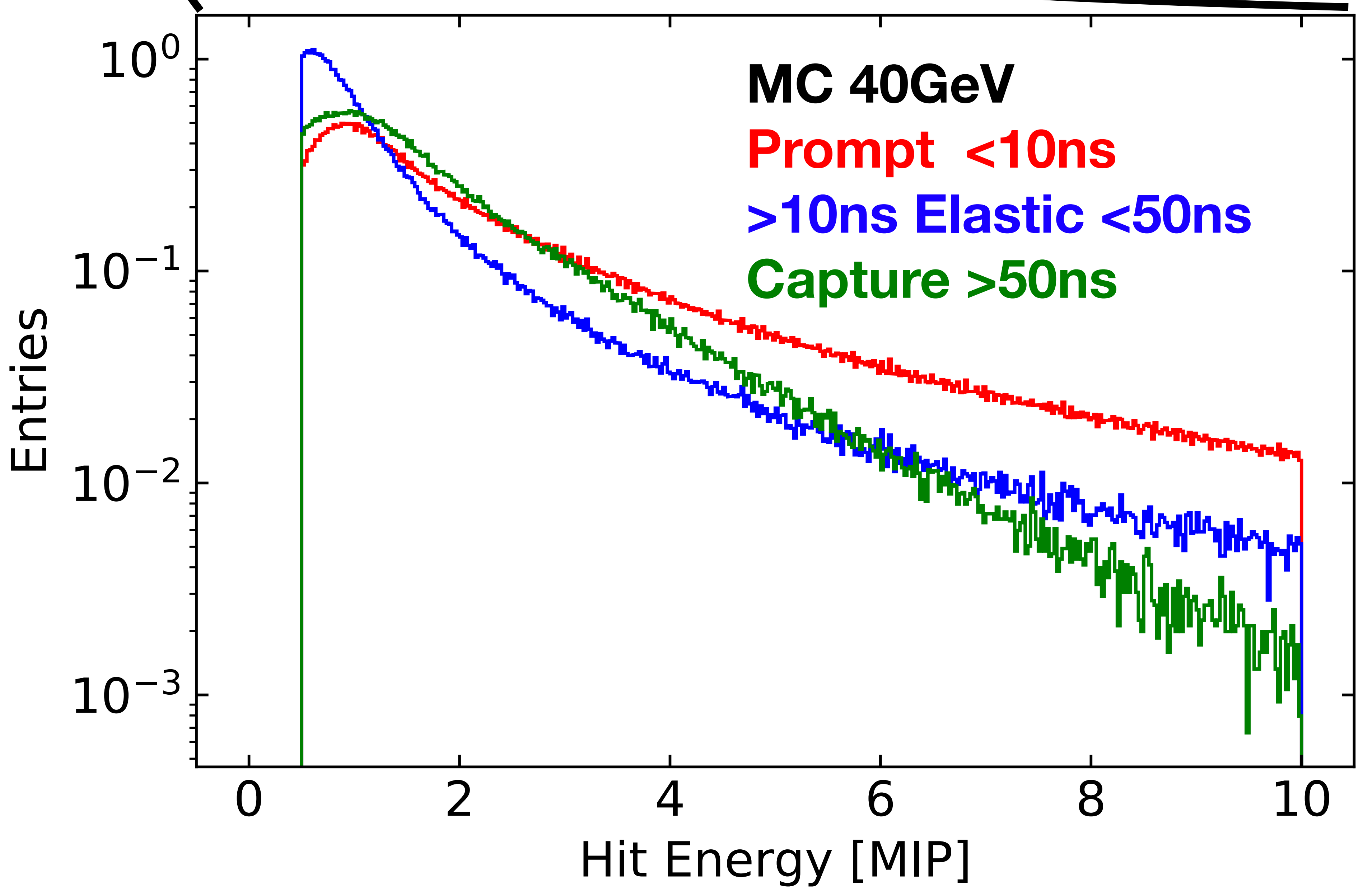

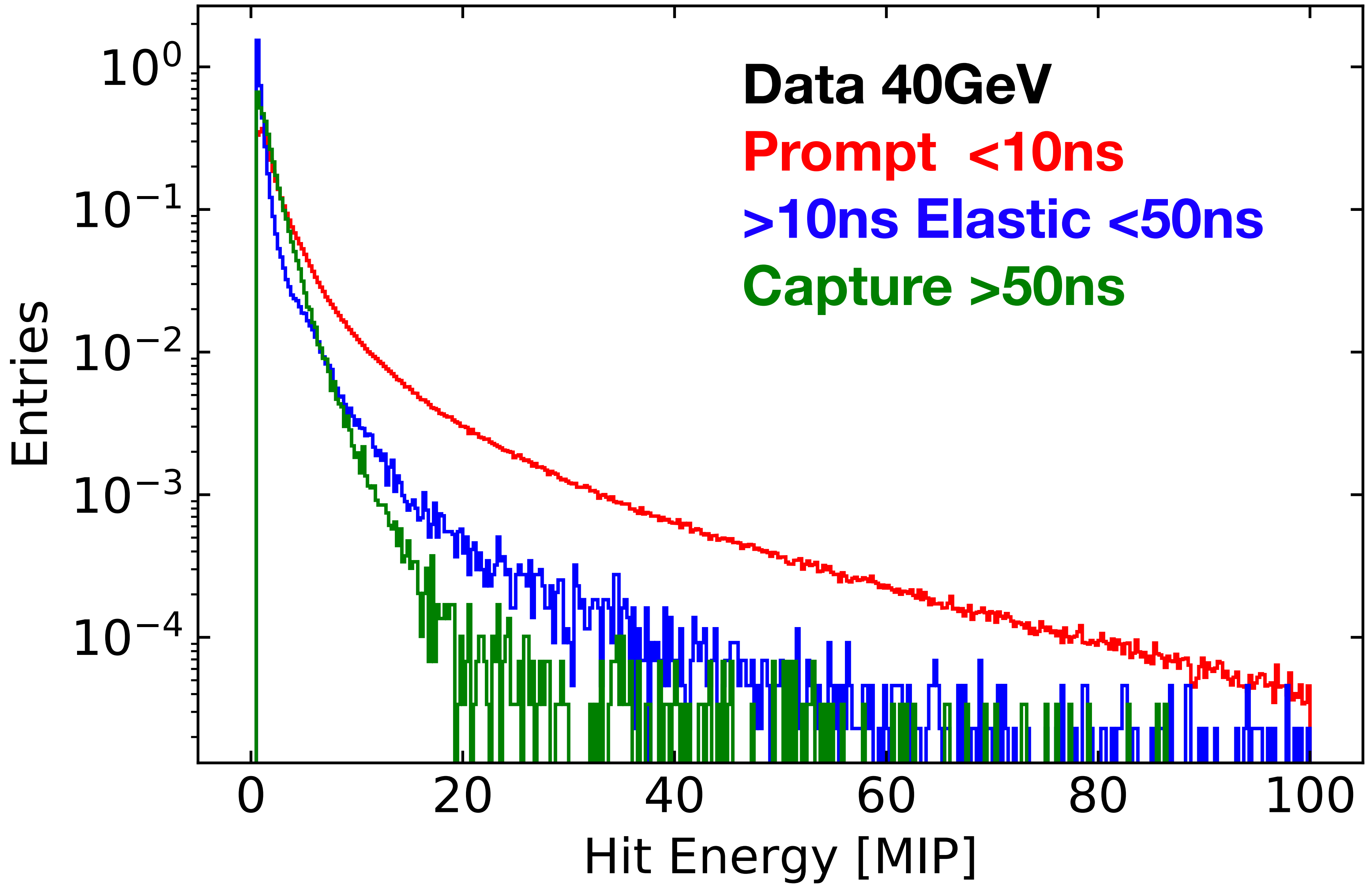

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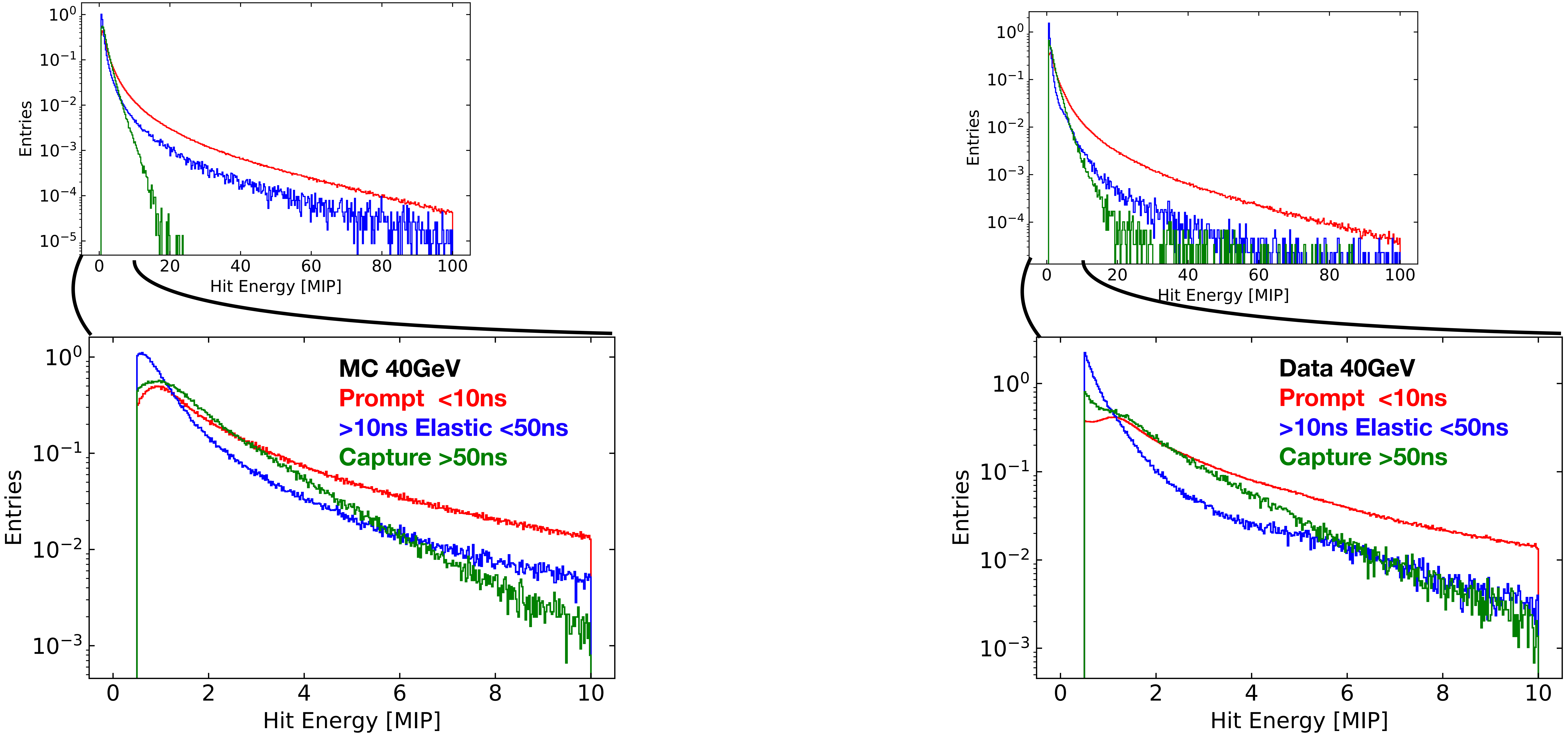
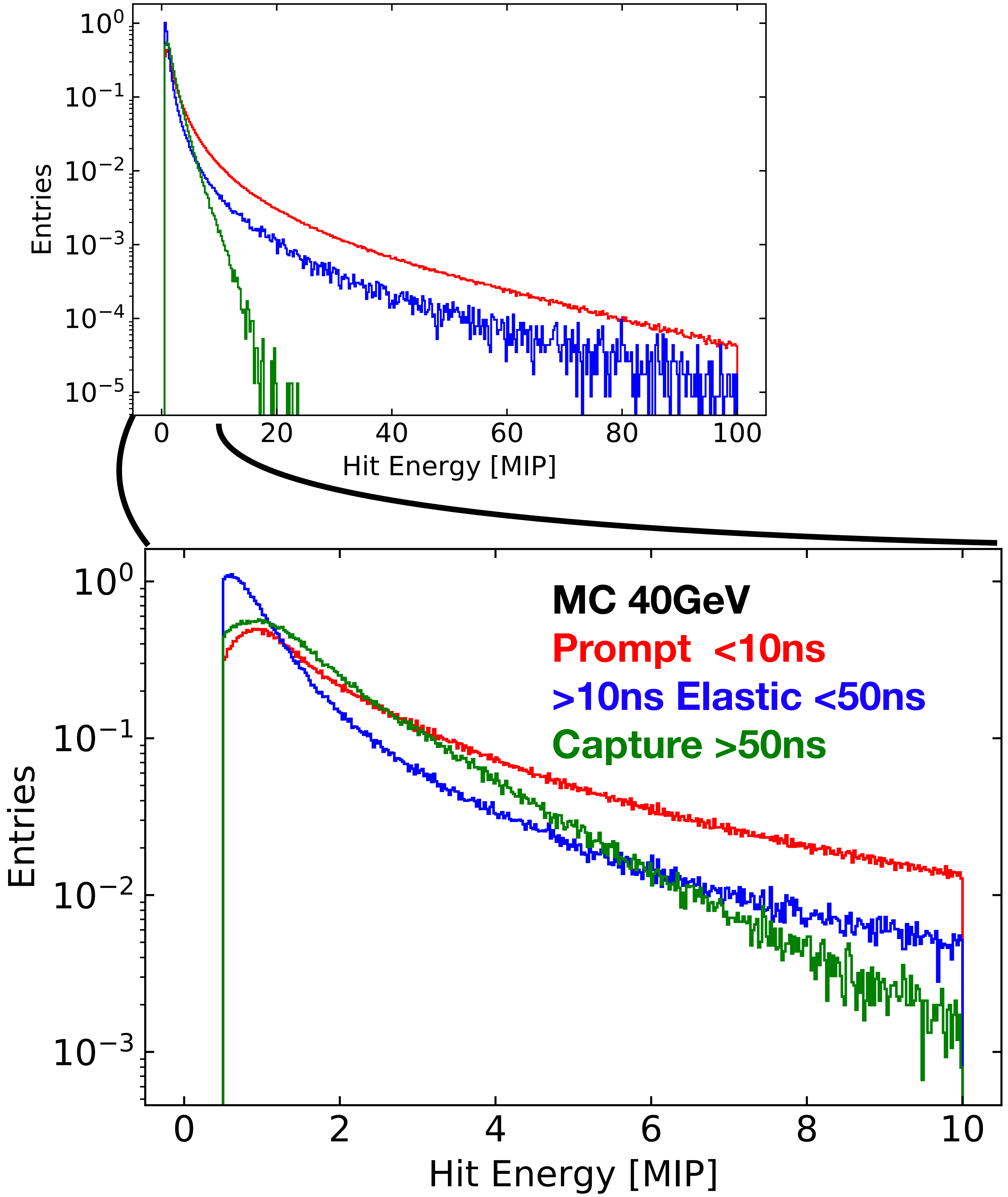
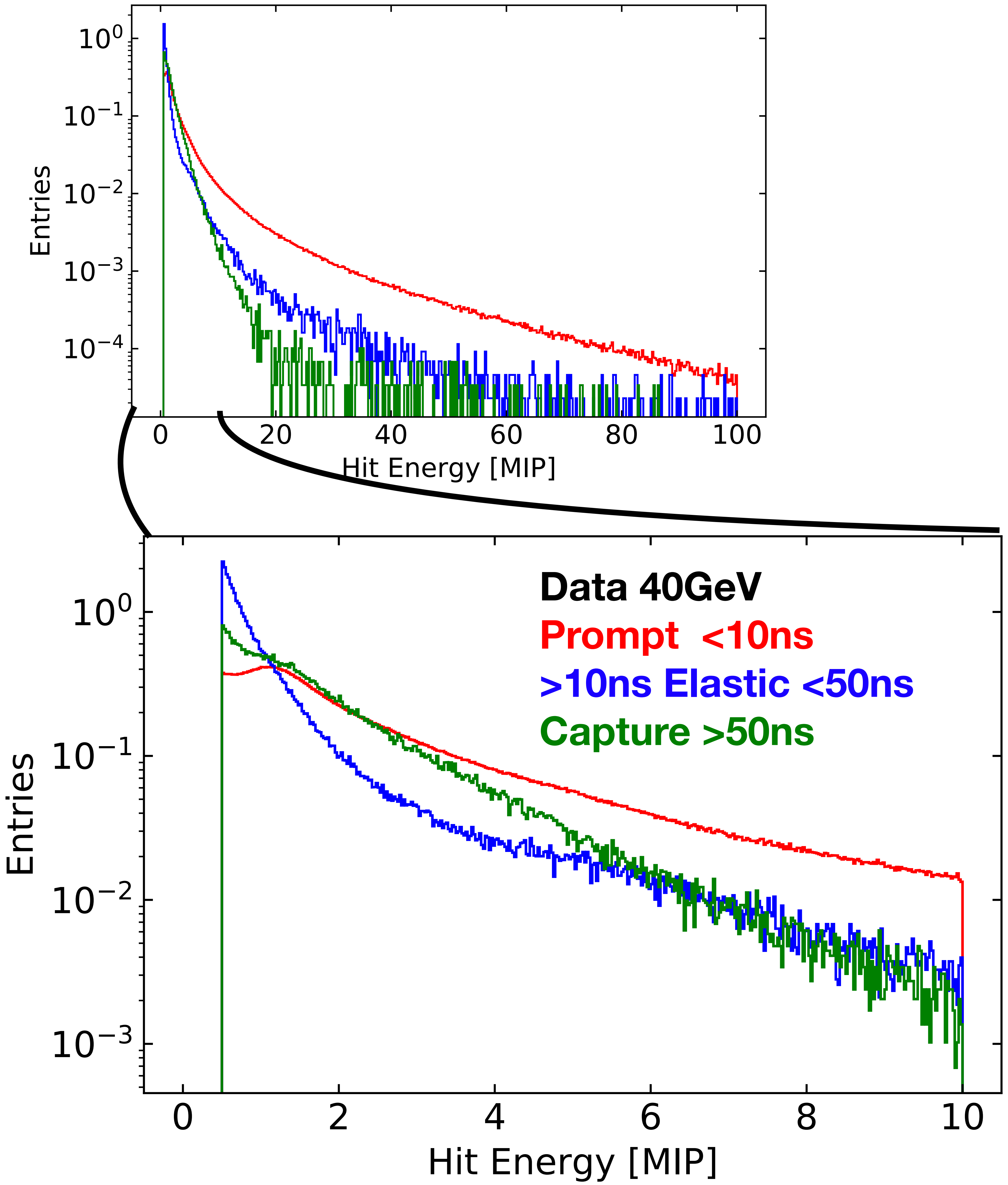


A Look at Pions - Hit Energy

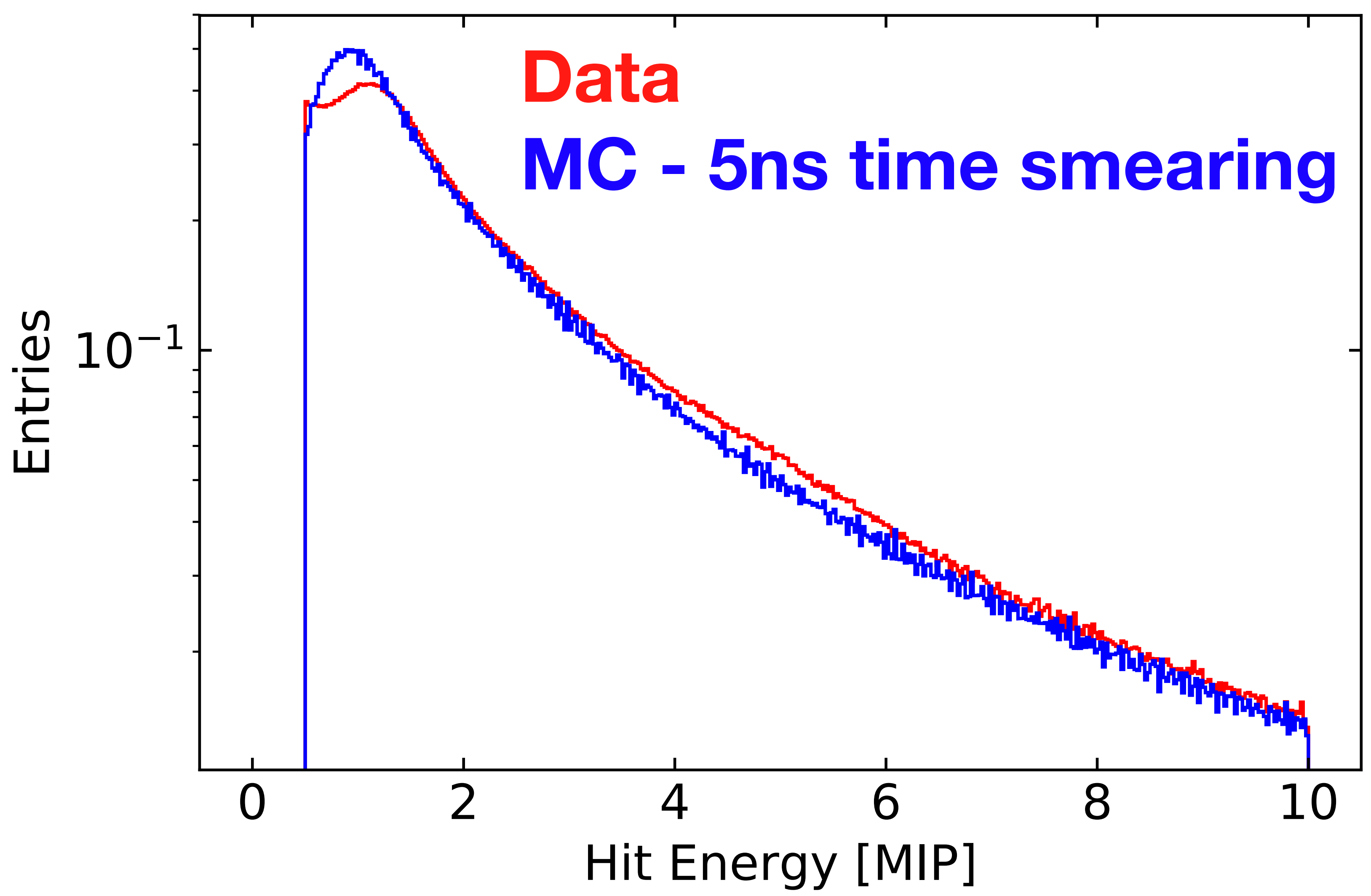


Global features are similar

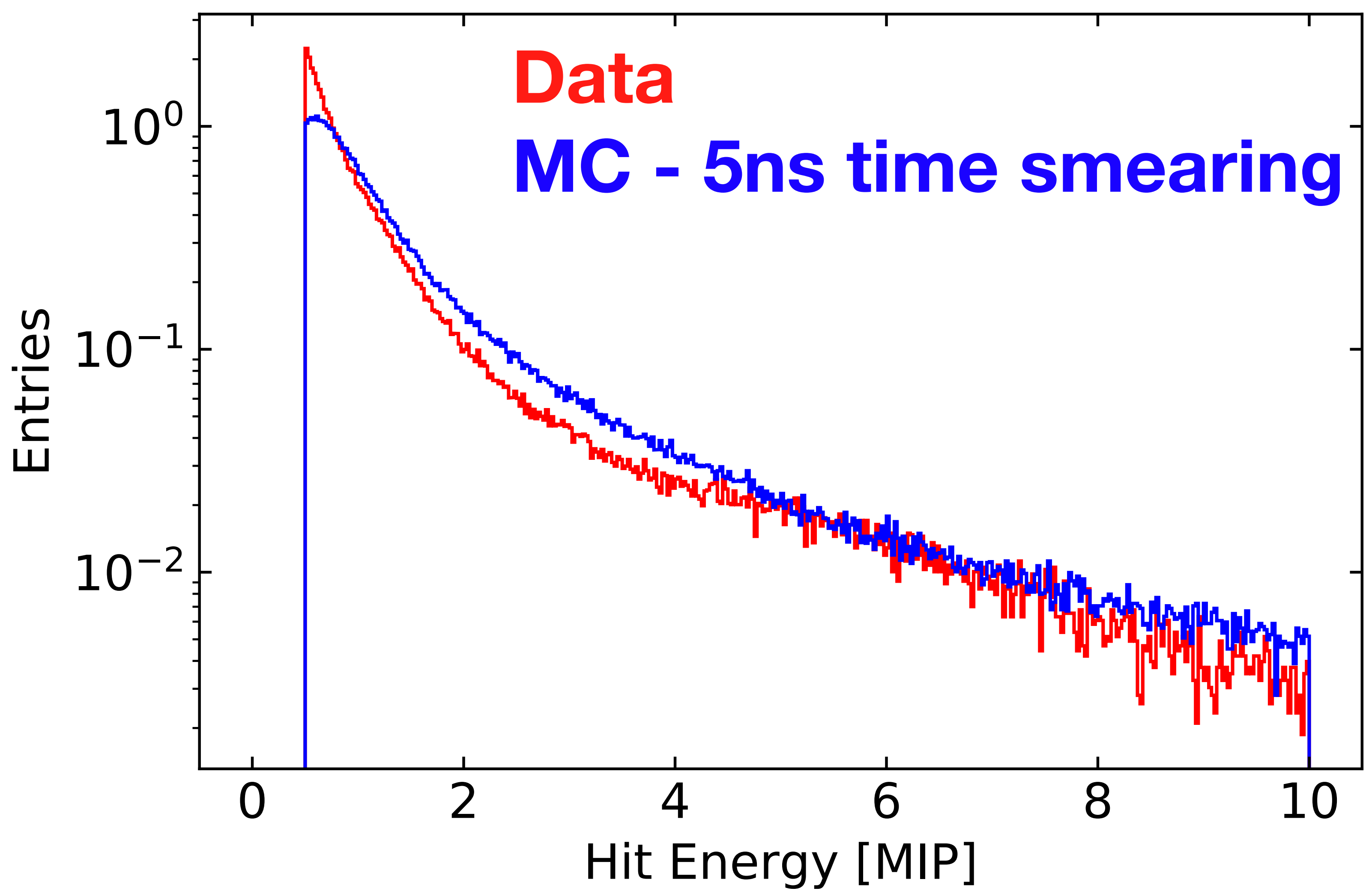


A Look at Pions - Hit Energy

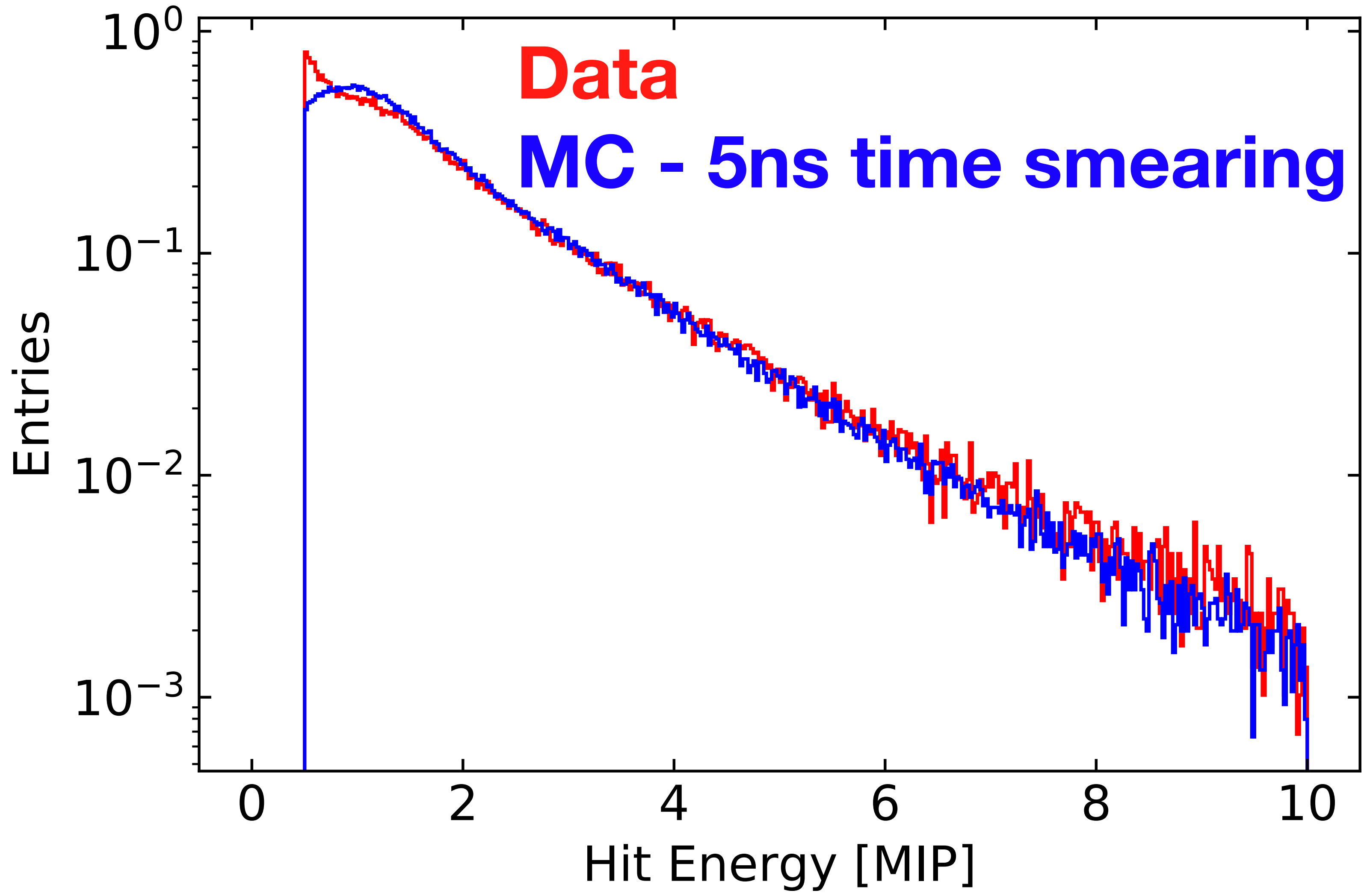
Prompt: hit time <10ns



Elastic:10ns< hit time<50ns

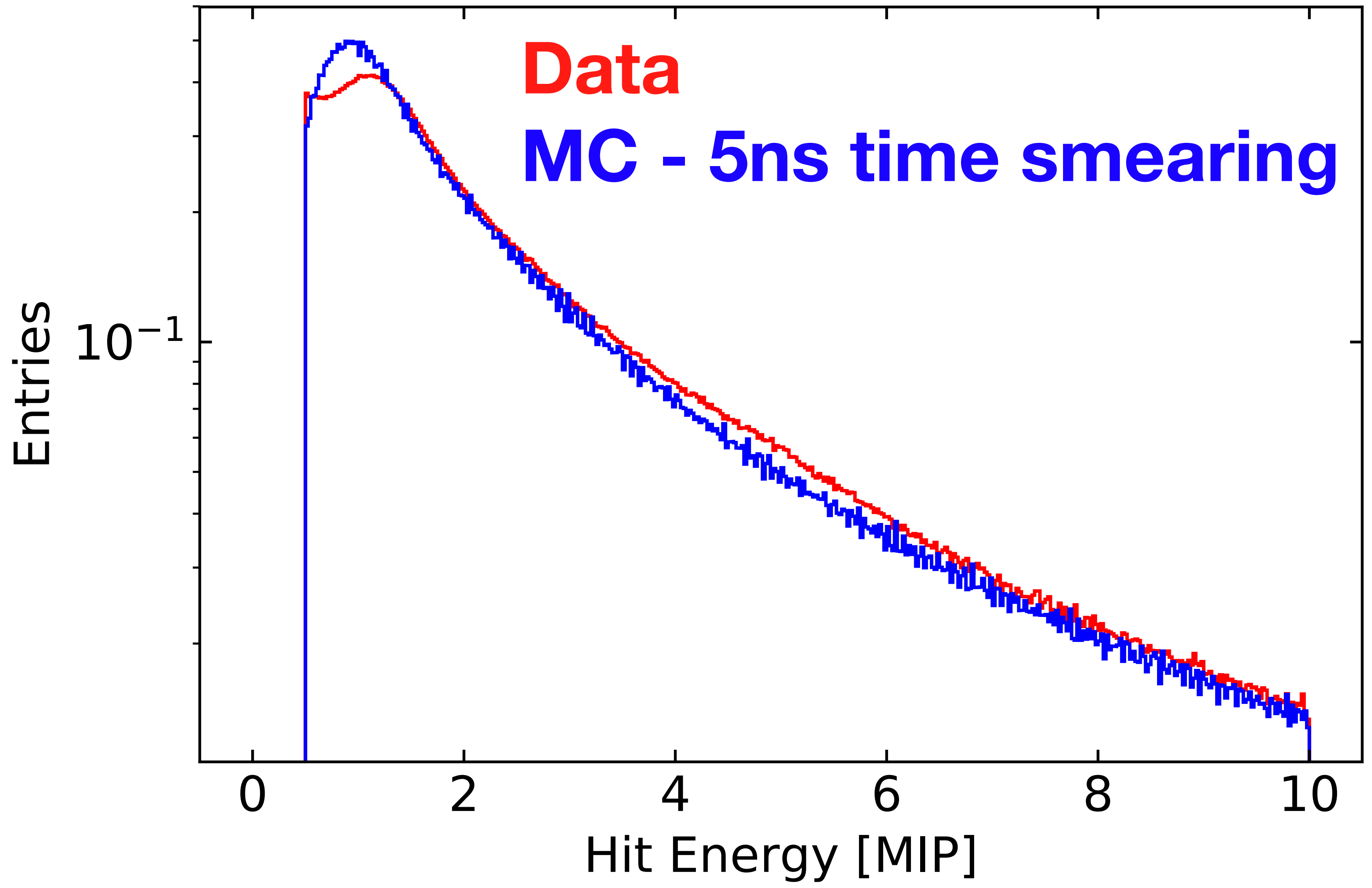


Capture: hit time >50ns

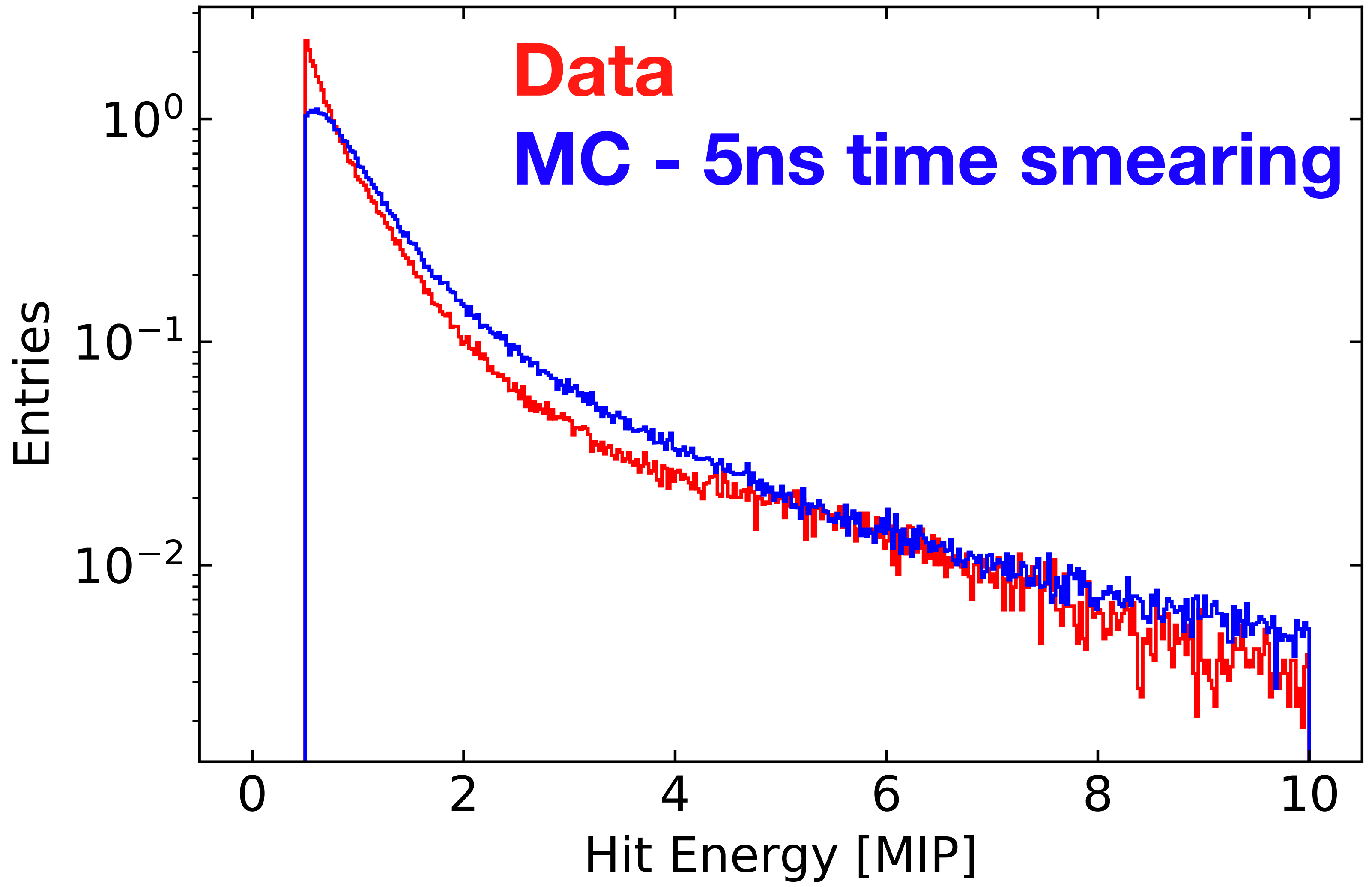


A Look at Pions - Hit Energy

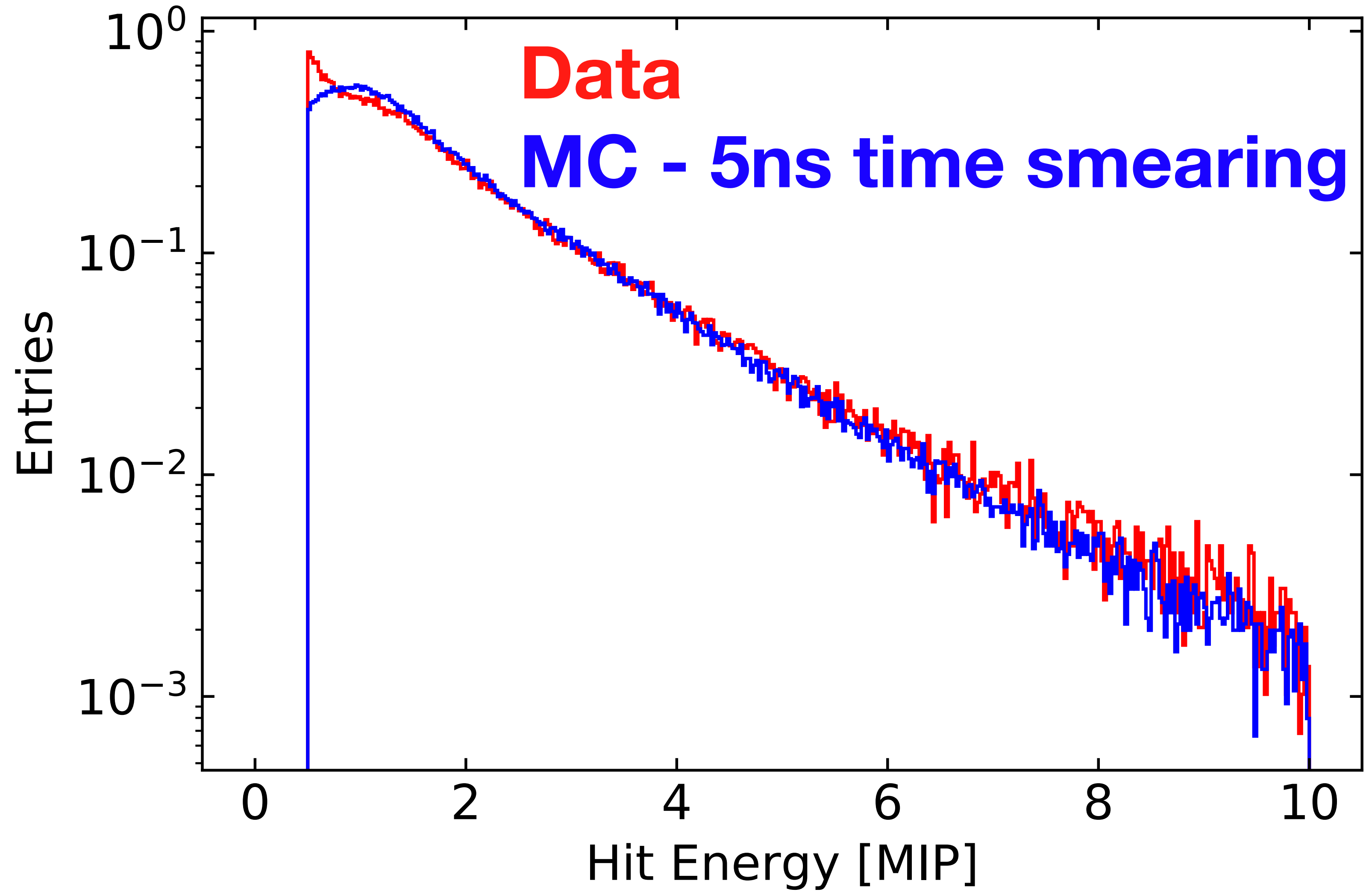
Prompt: hit time <10ns



Elastic:10ns< hit time<50ns

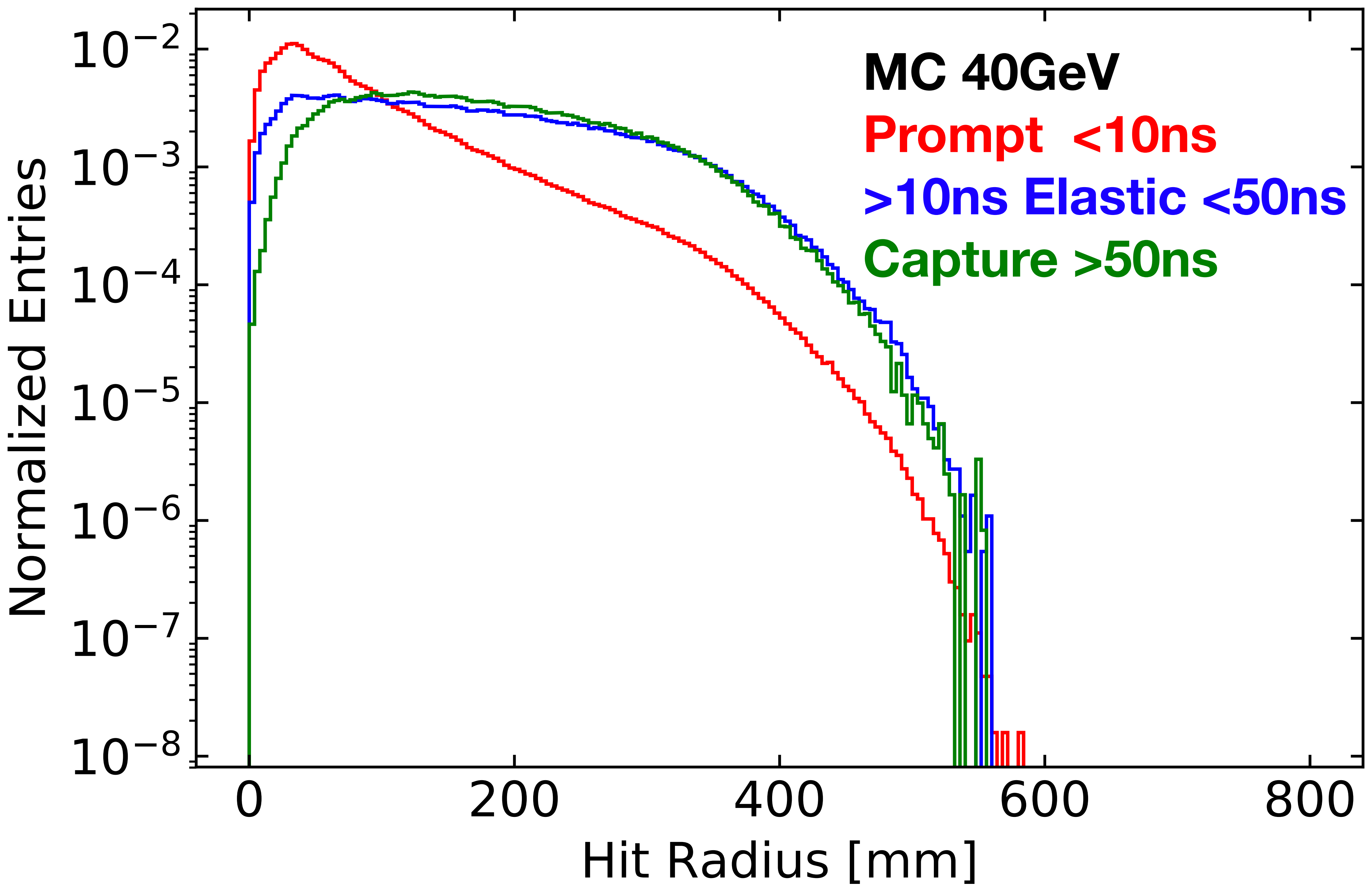


Capture: hit time >50ns

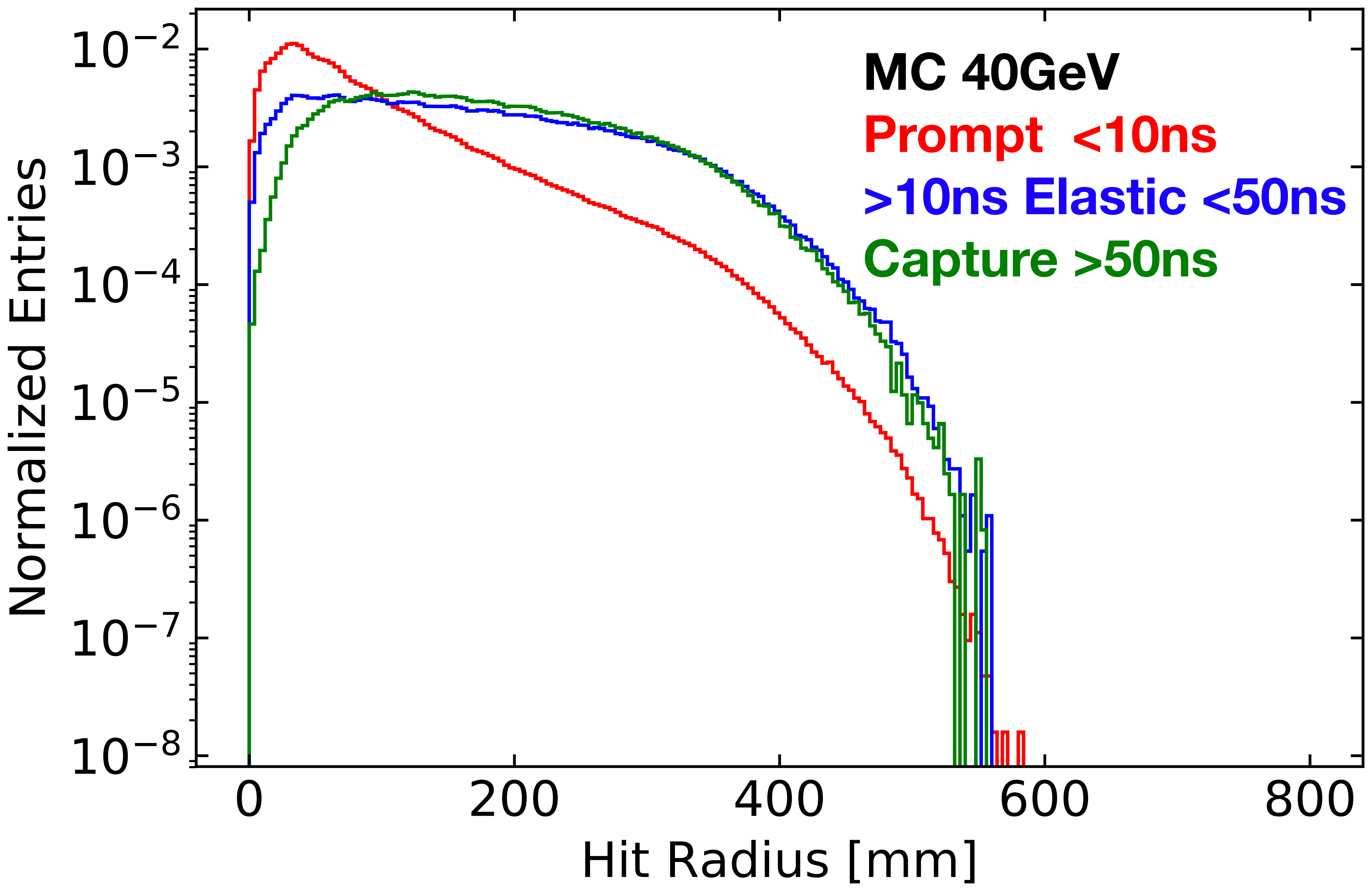


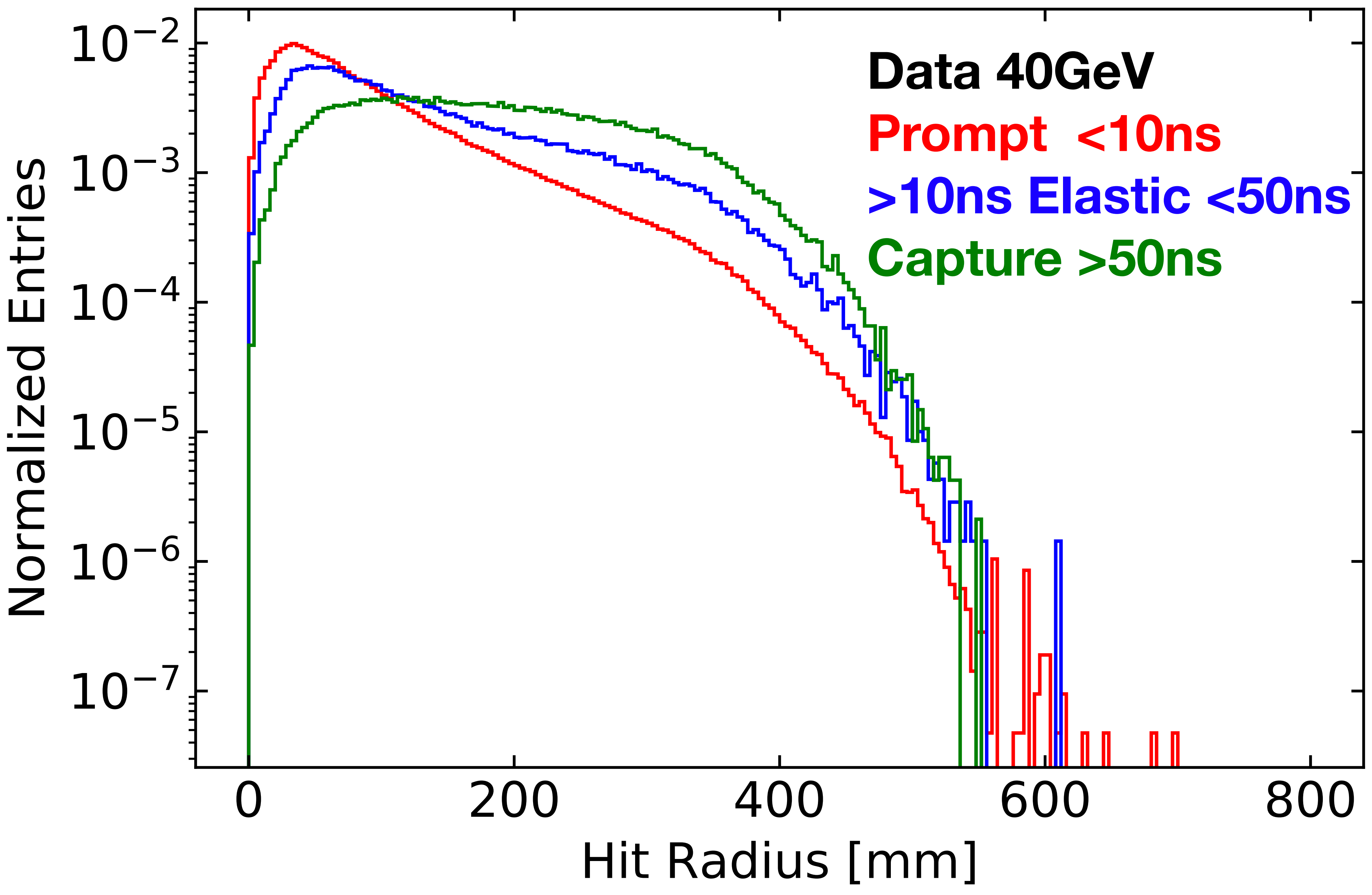
Disagreement in the low hit energy region

A Look at Pions - Hit Radius



A Look at Pions - Hit Radius





A Look at Pions - Hit Energy

Prompt: hit time <10ns

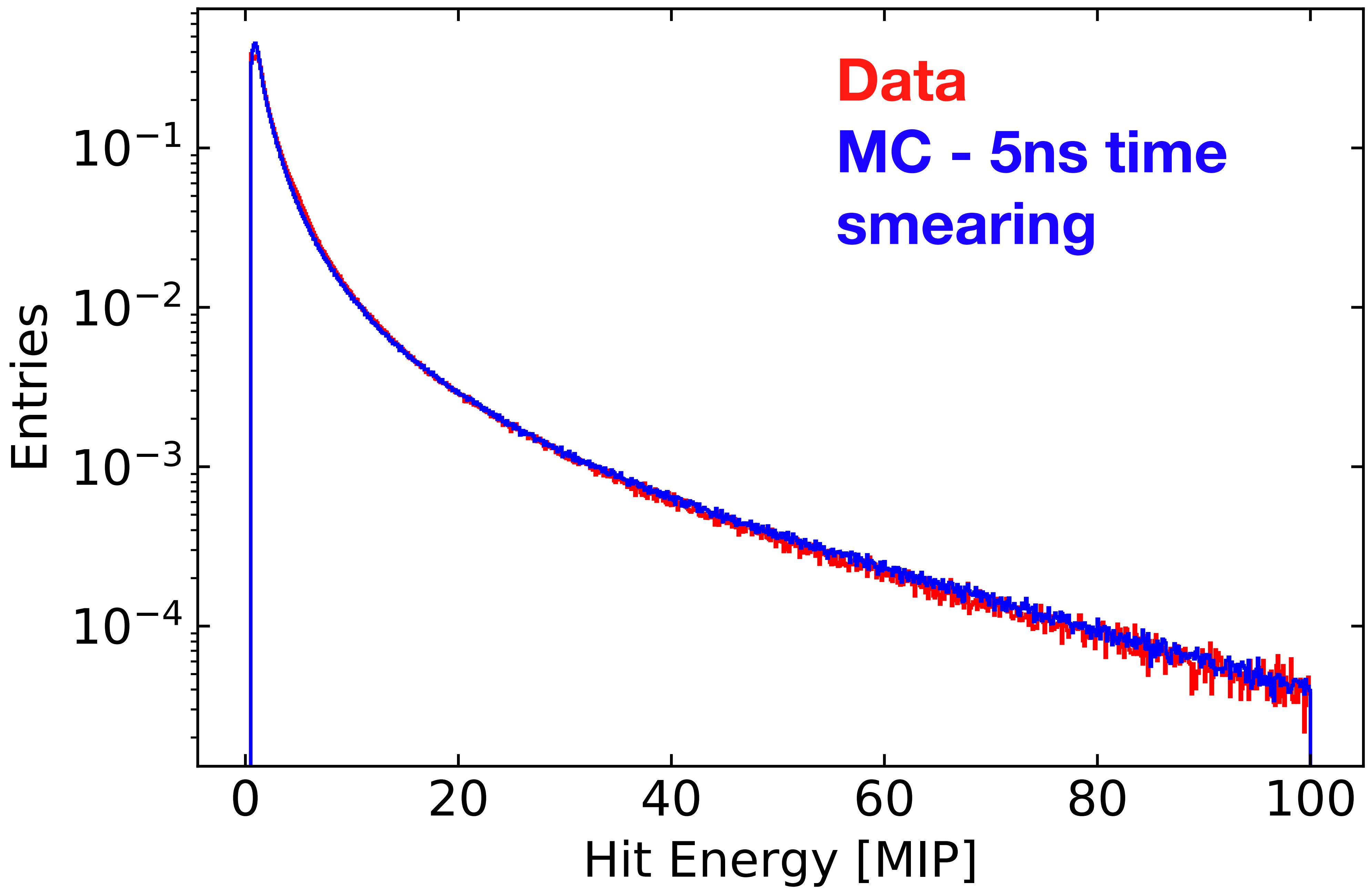
Elastic:10ns< hit time<50ns

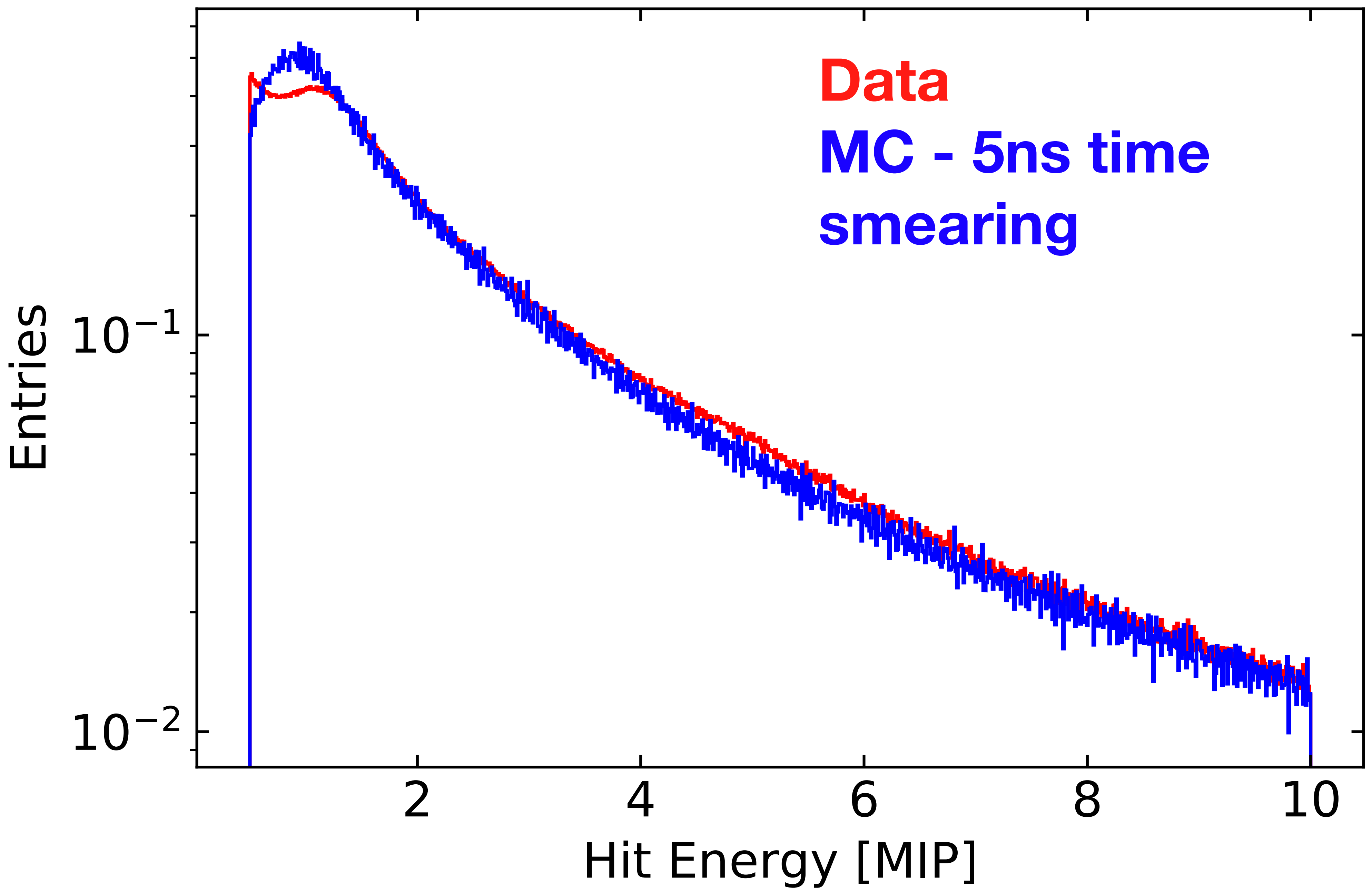
Capture: hit time >50ns

Overlap of prompt and elastic part in data

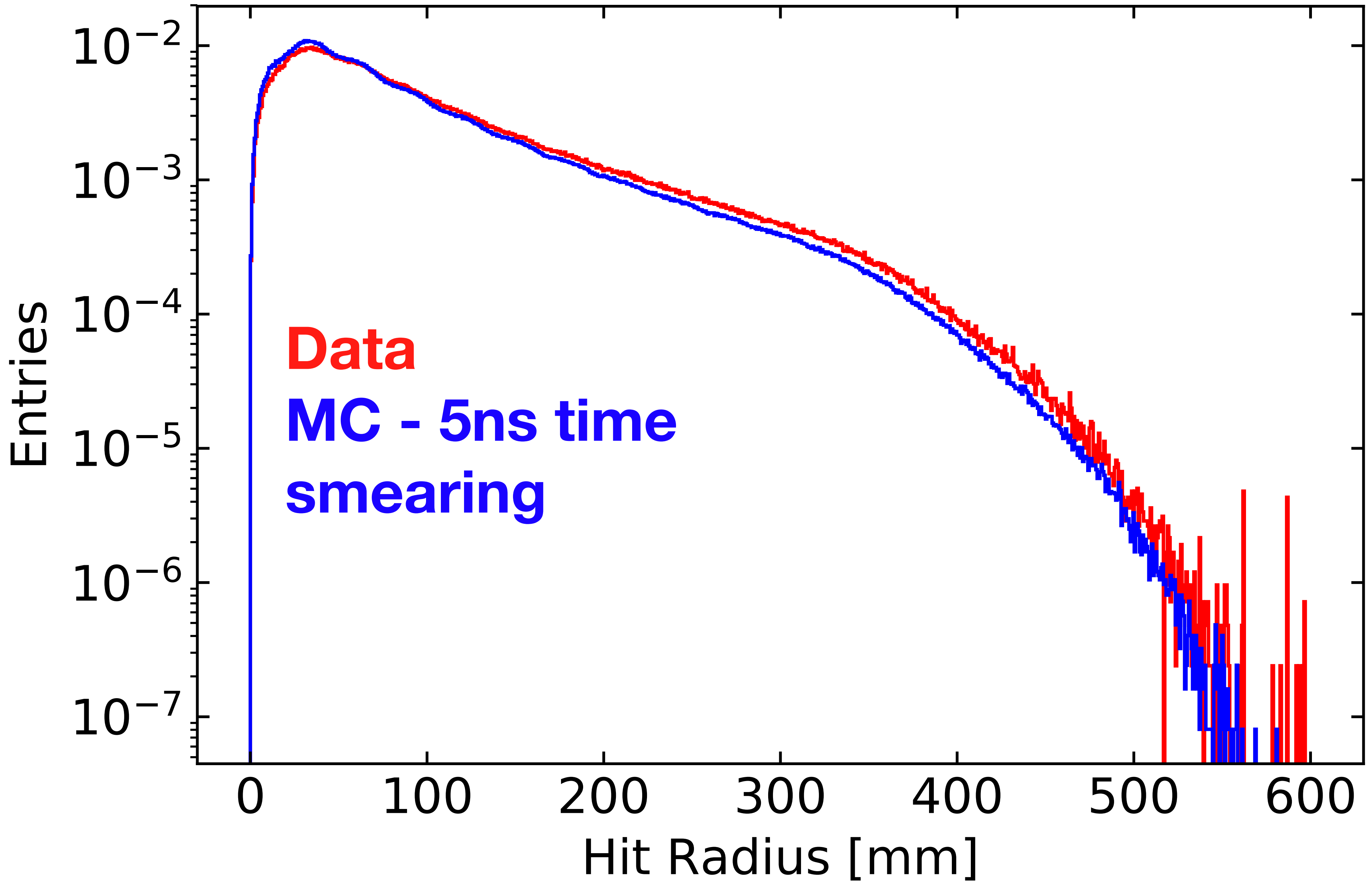
Similar shape of data and MC in the capture part

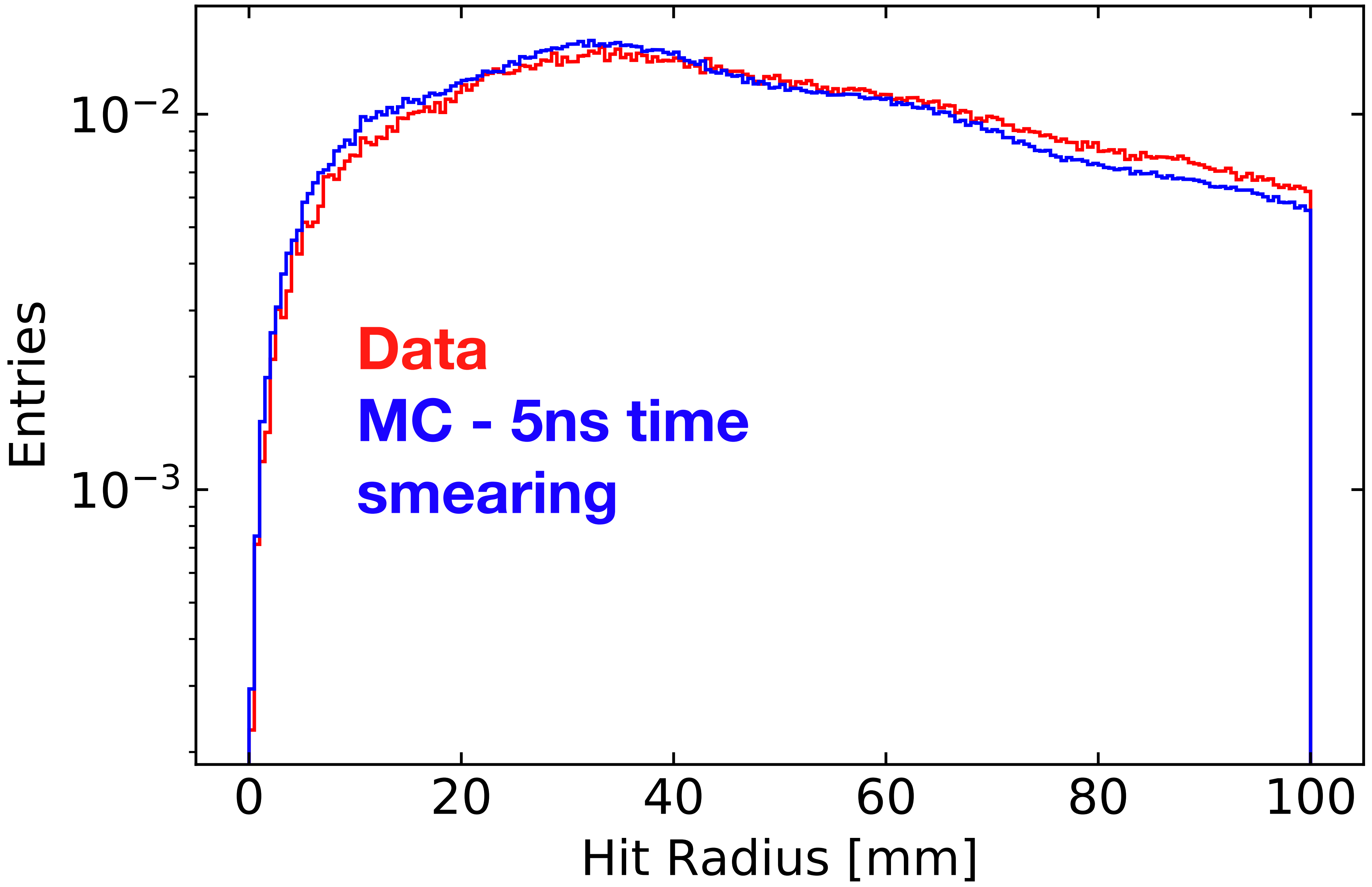
Hit Energy - Data vs MC



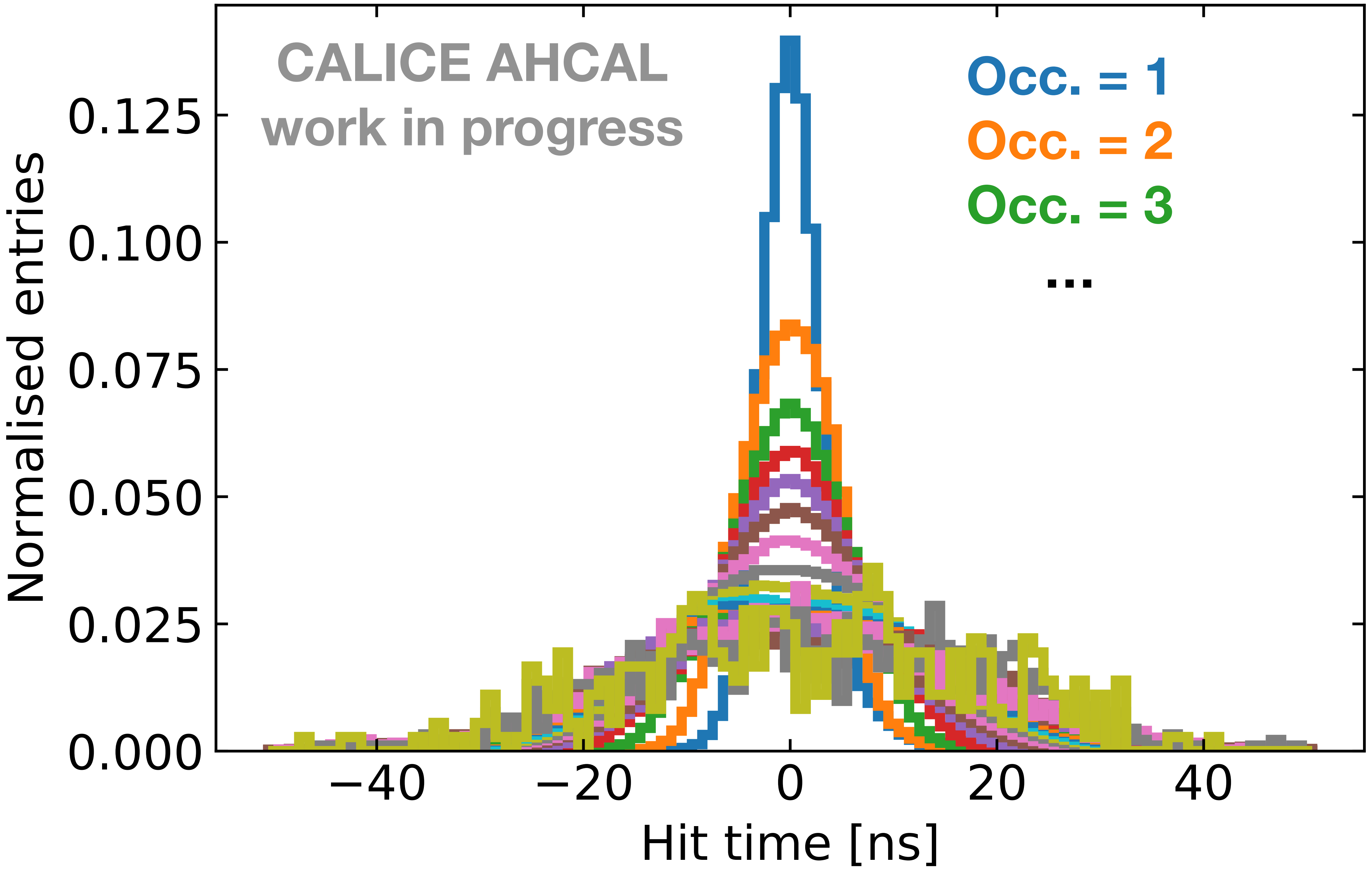


Hit Radius - Data vs MC

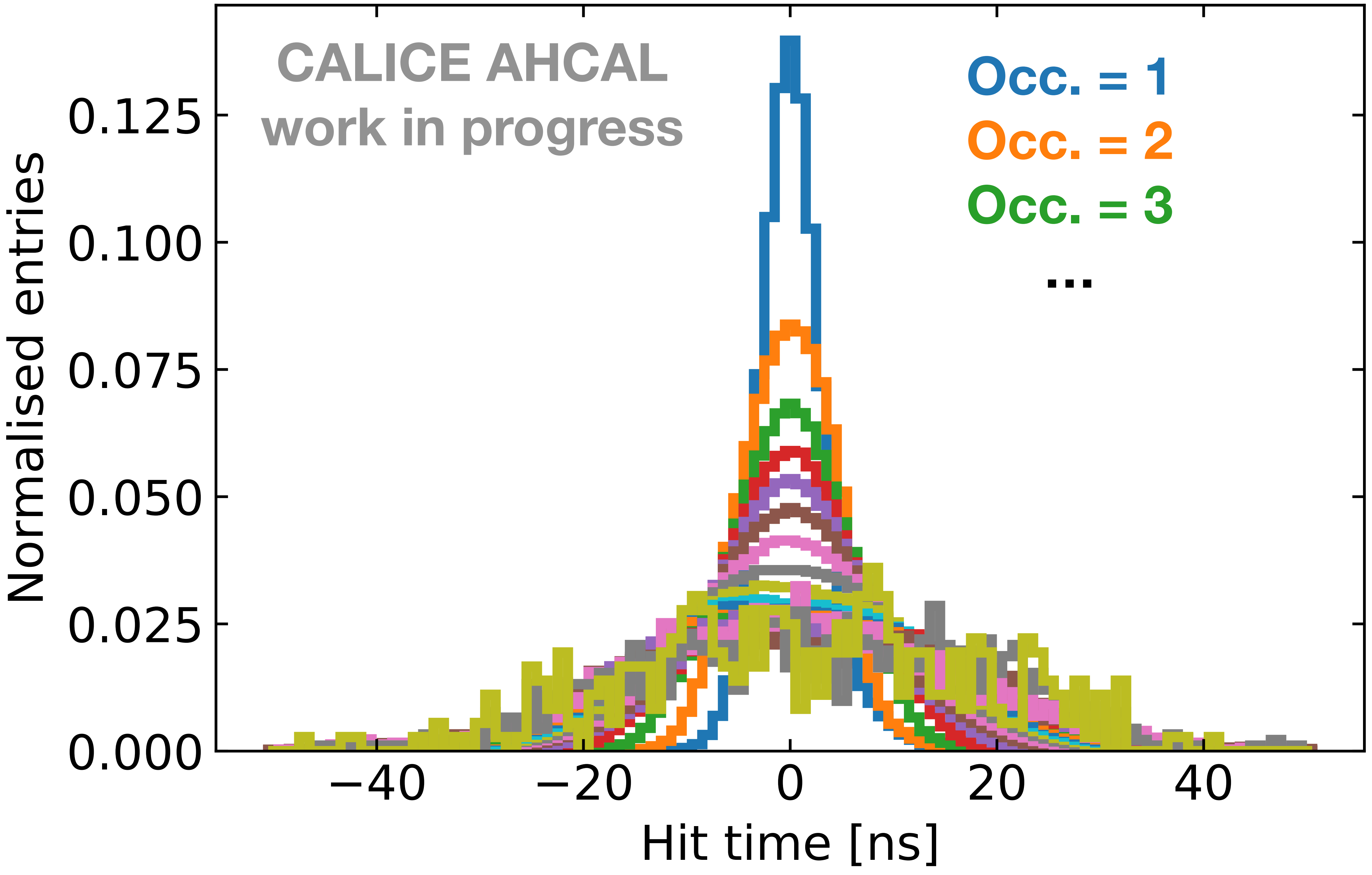


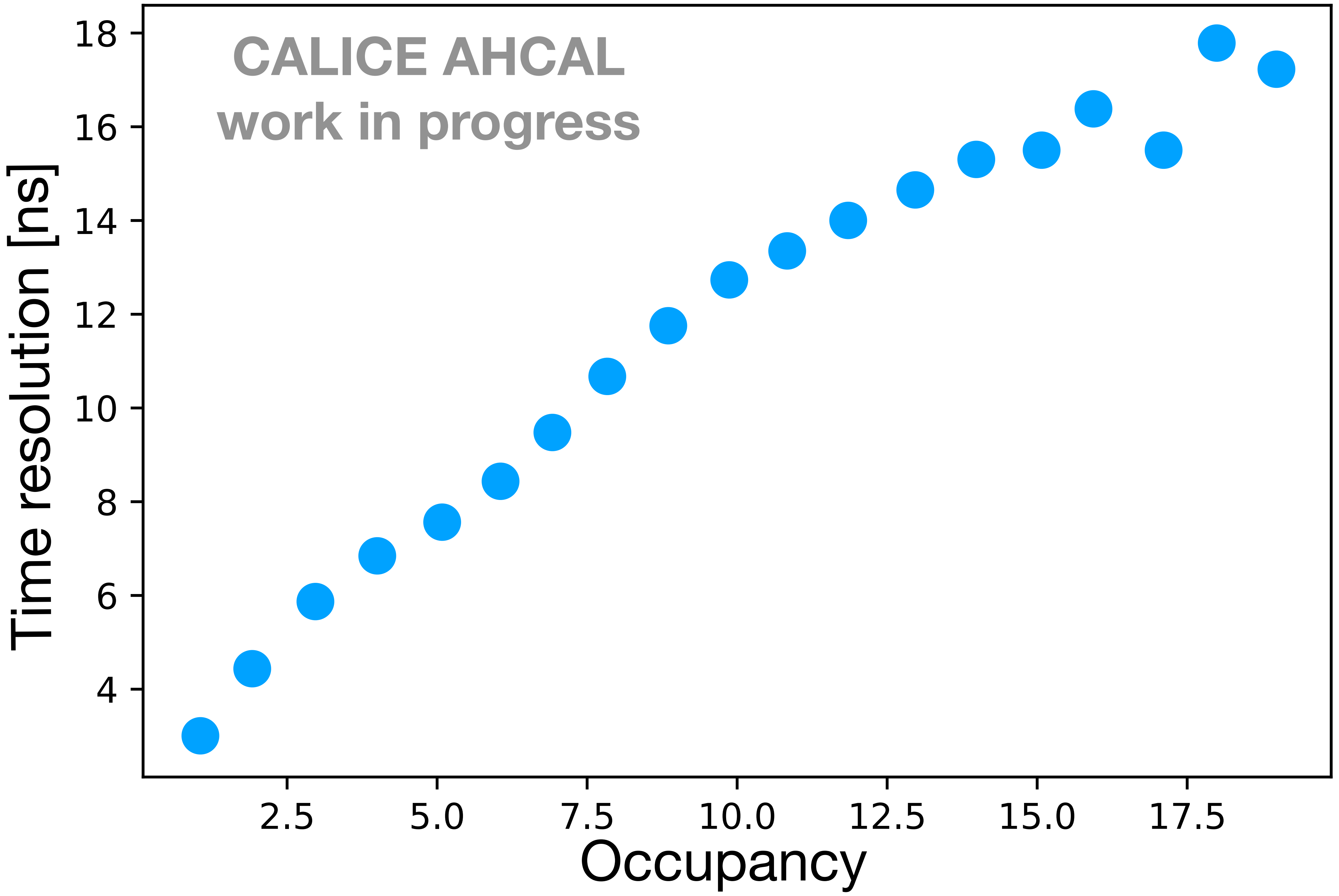


Global Correction



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