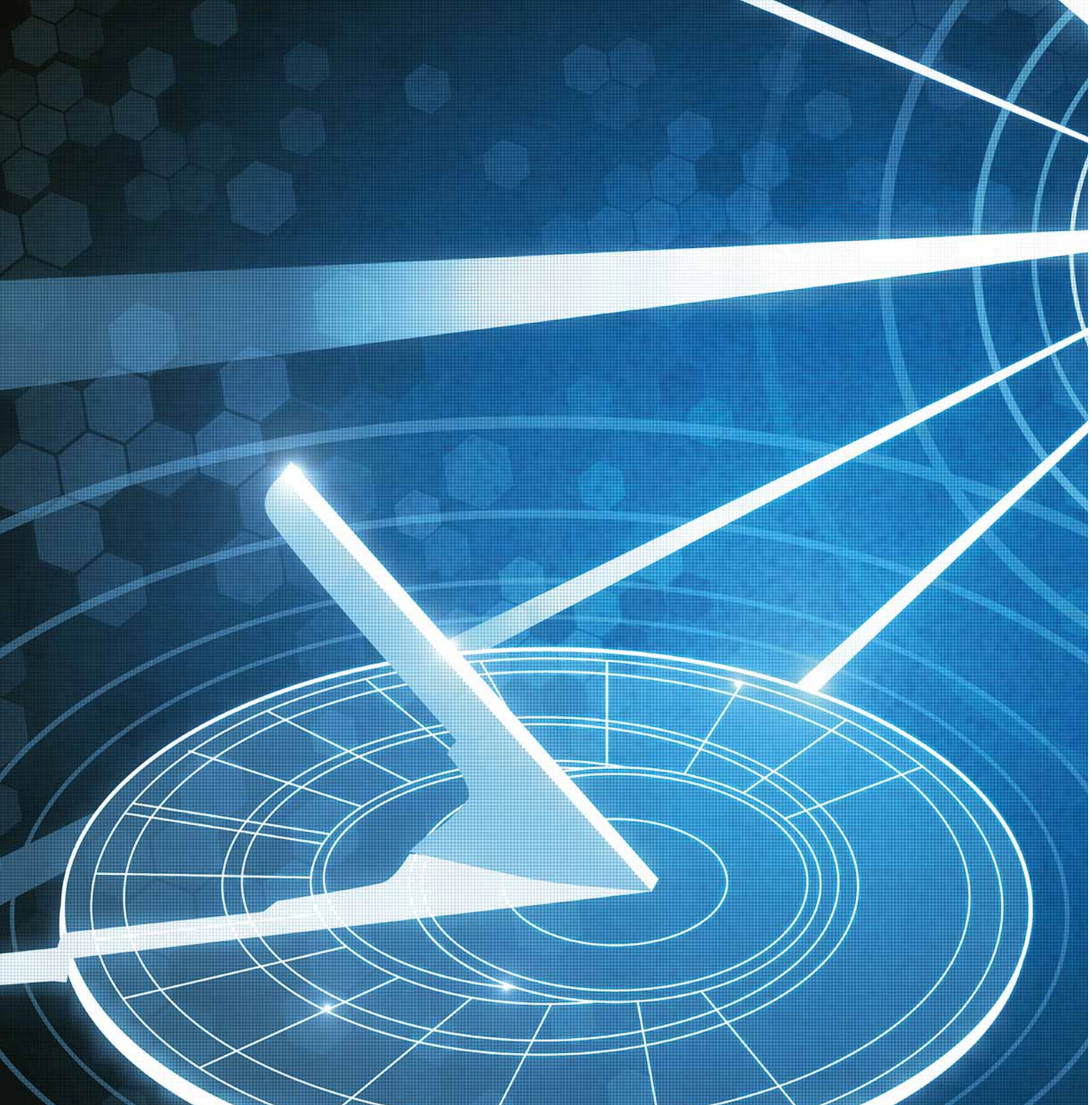


AHCAL Time Calibration

CALICE Collaboration Meeting - Montreal
5.3.2020

Lorenz Emberger

MAX-PLANCK-INSTITUT
FÜR PHYSIK

Motivation

Motivation

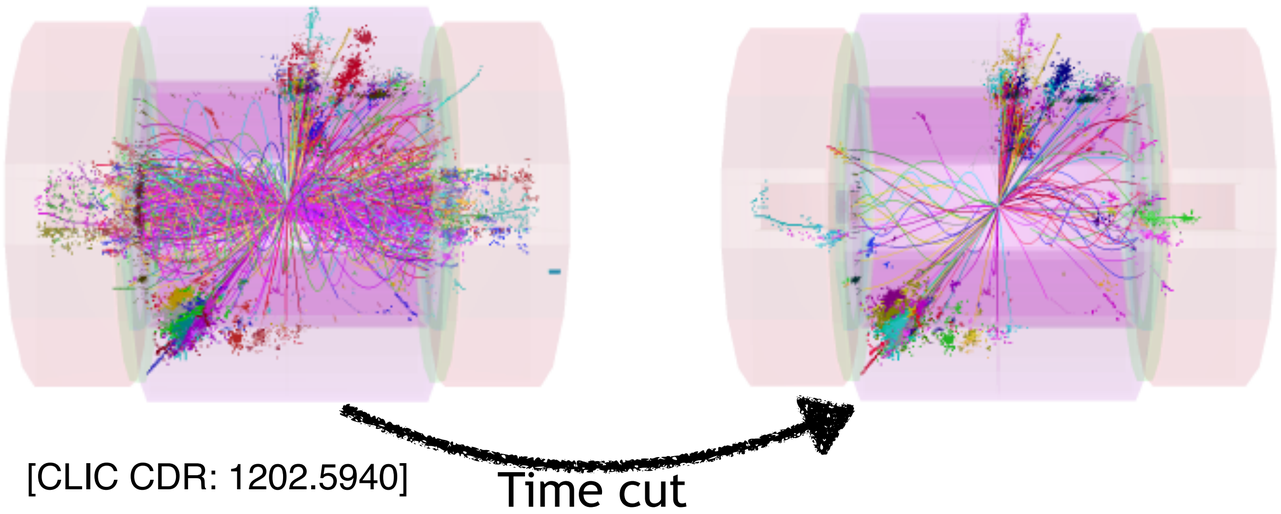
Why do we need time information?

- Reject background
- Improve clustering

Motivation

Why do we need time information?

- Reject background
- Improve clustering

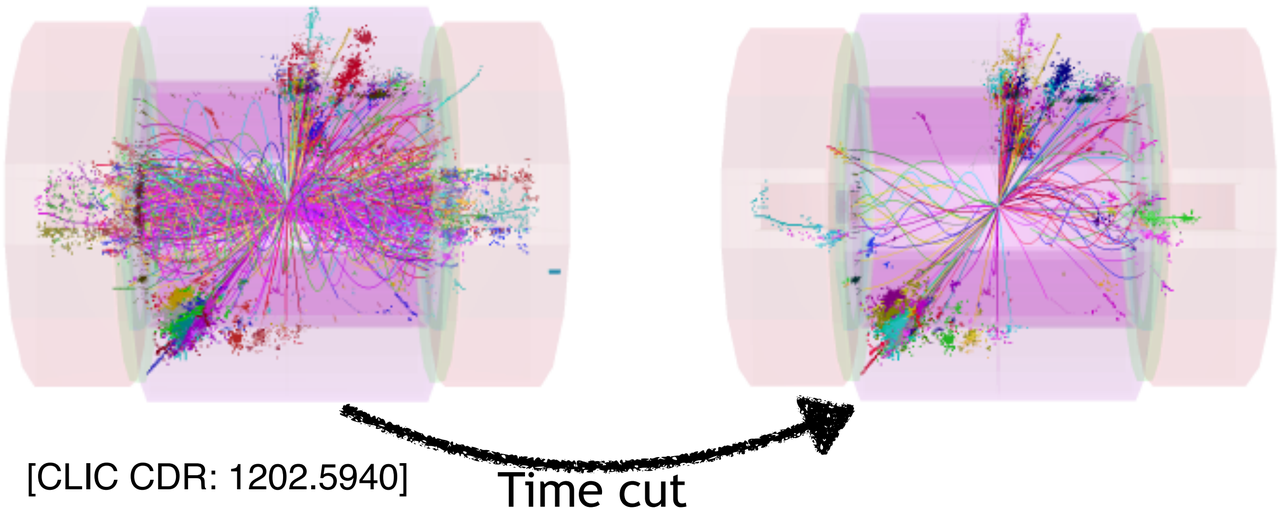


[CLIC CDR: 1202.5940]

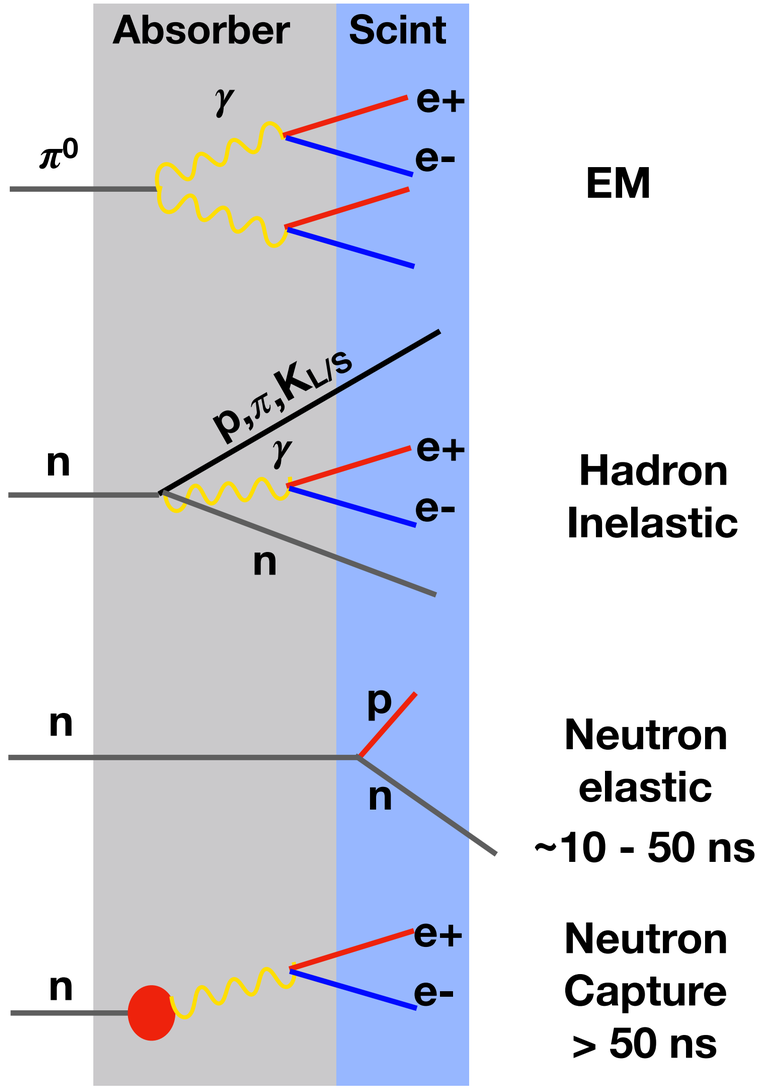
Motivation

Why do we need time information?

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



[CLIC CDR: 1202.5940]



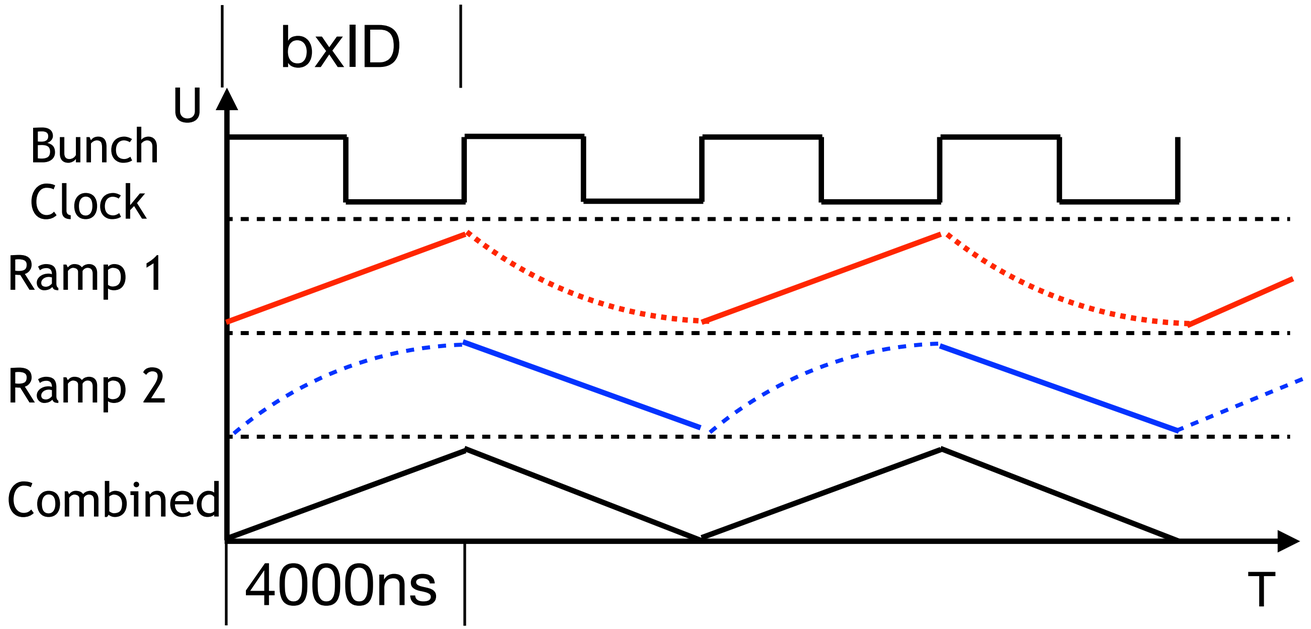
Time Calibration: Hardware

Time Calibration: Hardware

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



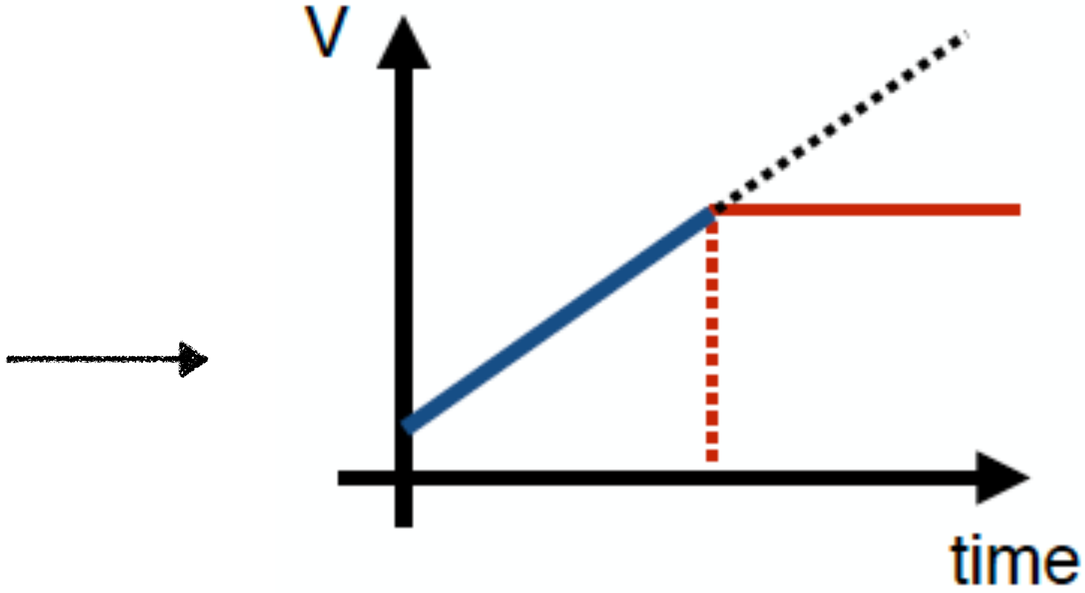
Time Calibration: Hardware

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

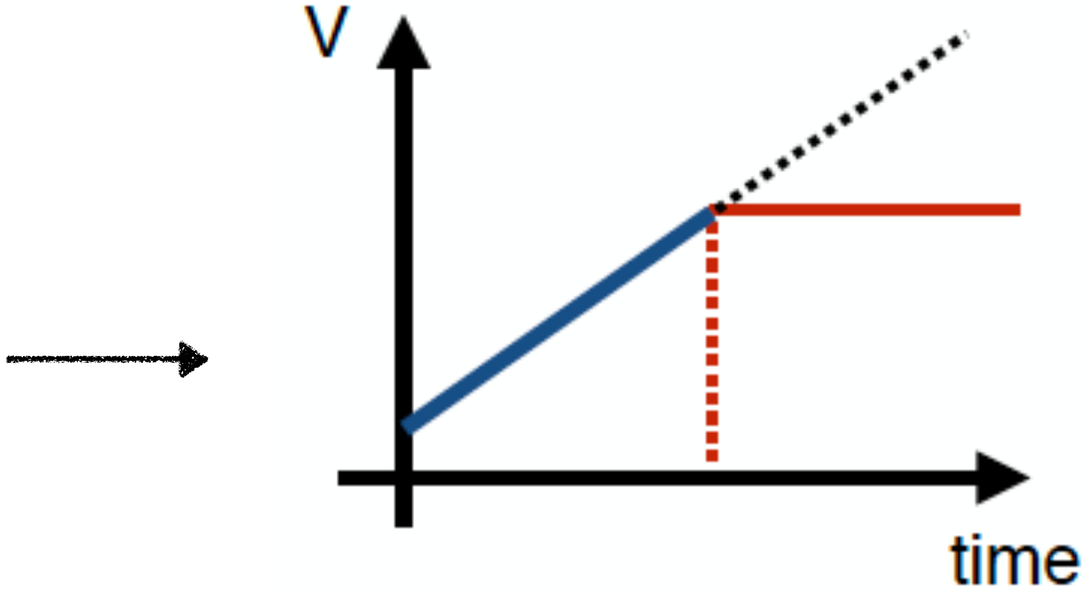
3. On hit, the current voltage is stored in one of 16 memory cells



Time Calibration: Hardware

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
3. On hit, the current voltage is stored in one of 16 memory cells
4. Digitized voltage (TDC readings) need to be calibrated against external clock

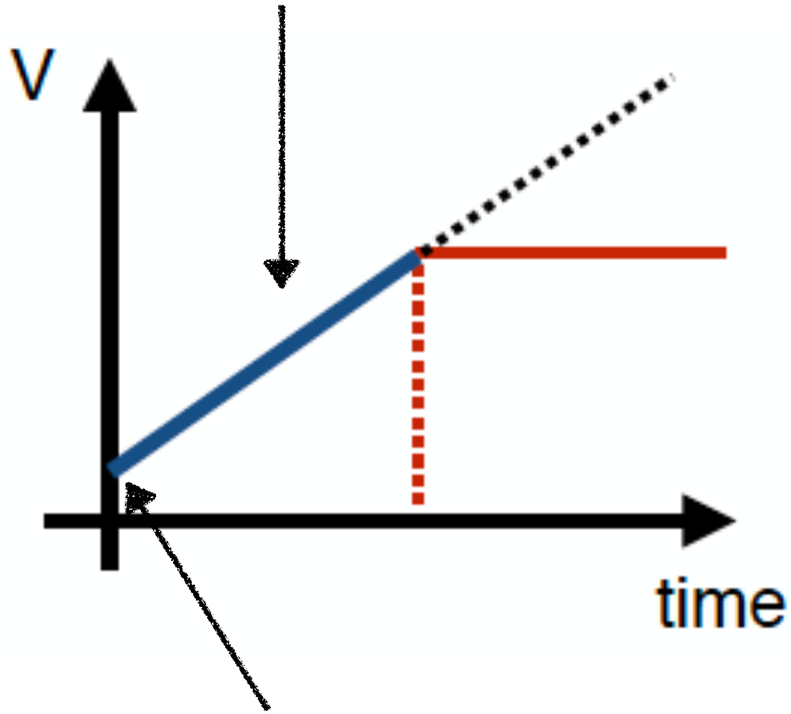


Time Calibration: Hardware

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
3. On hit, the current voltage is stored in one of 16 memory cells
4. Digitized voltage (TDC readings) need to be calibrated against external clock

Slope is common to all channels on a chip



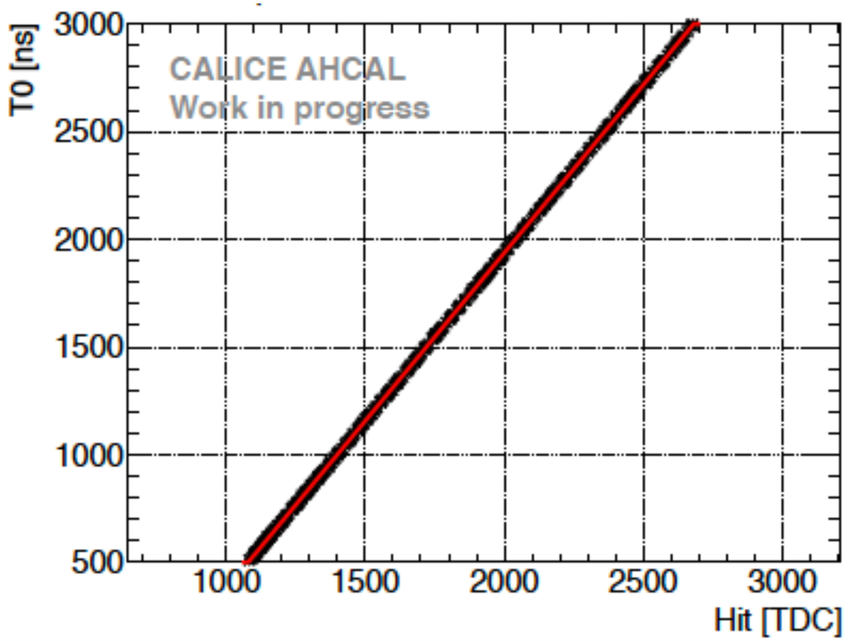
Offset is extracted for every memory cell

Time Calibration: Software

Time Calibration: Software

1. Extract slope by plotting reference clock against TDC readings

2. Fit with linear function



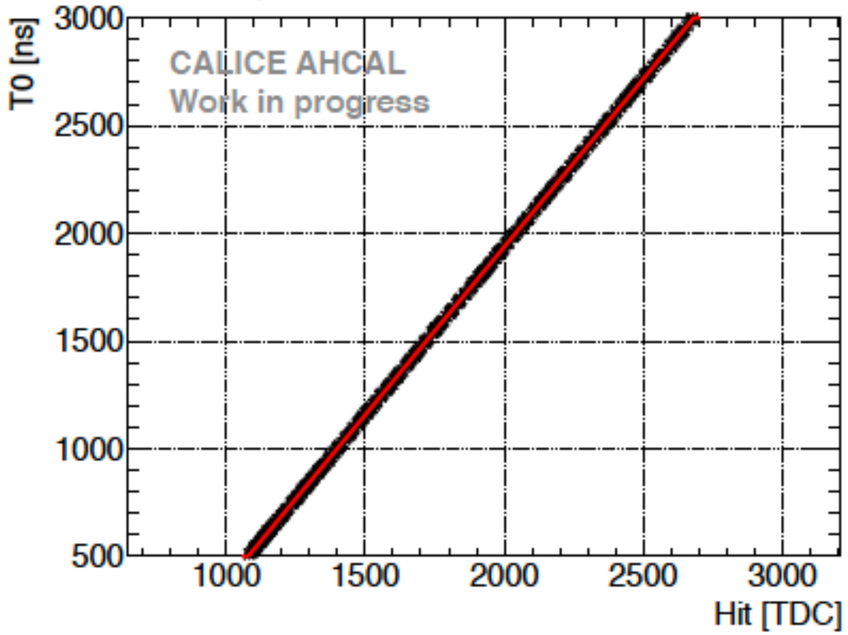
Time Calibration: Software

1. Extract slope by plotting reference clock against TDC readings

2. Fit with linear function

3. Calculate hit time by

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



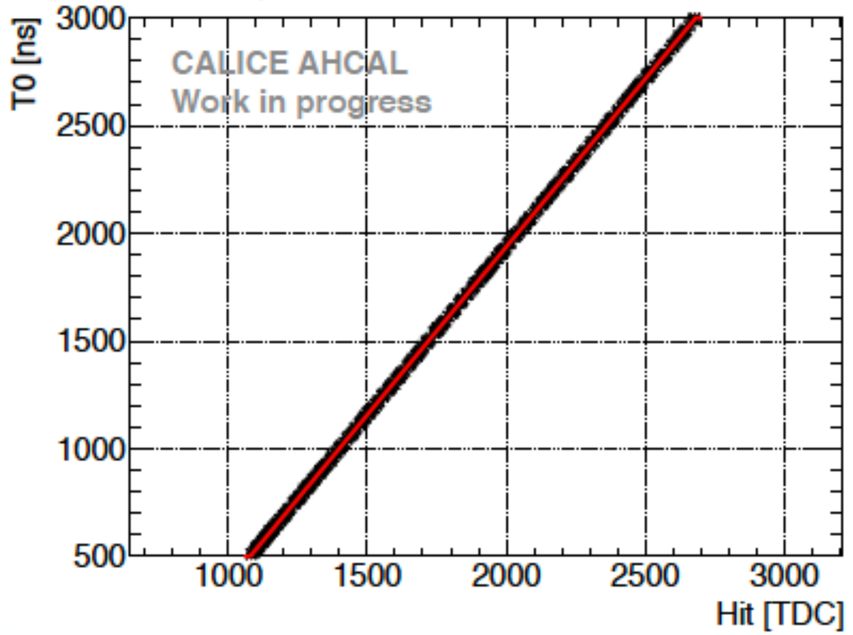
Time Calibration: Software

1. Extract slope by plotting reference clock against TDC readings

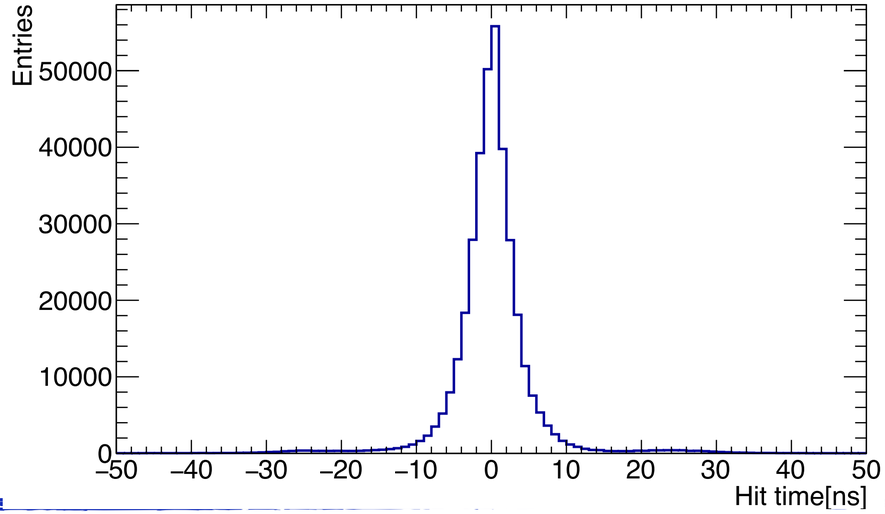
2. Fit with linear function

3. Calculate hit time by

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



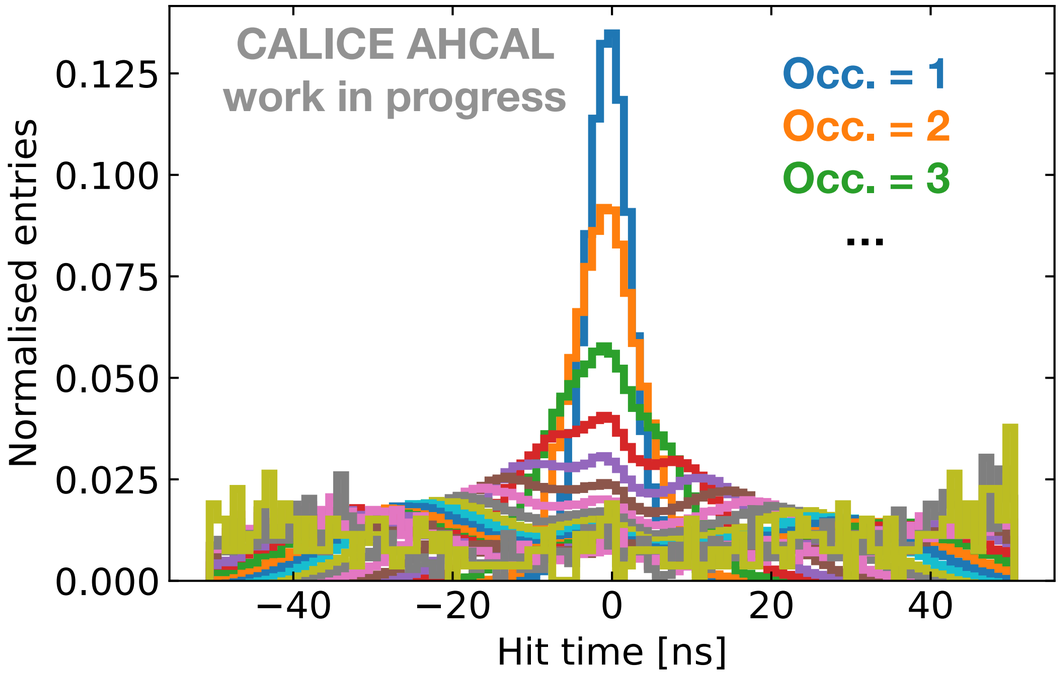
Hit time distribution



The Occupancy Problem

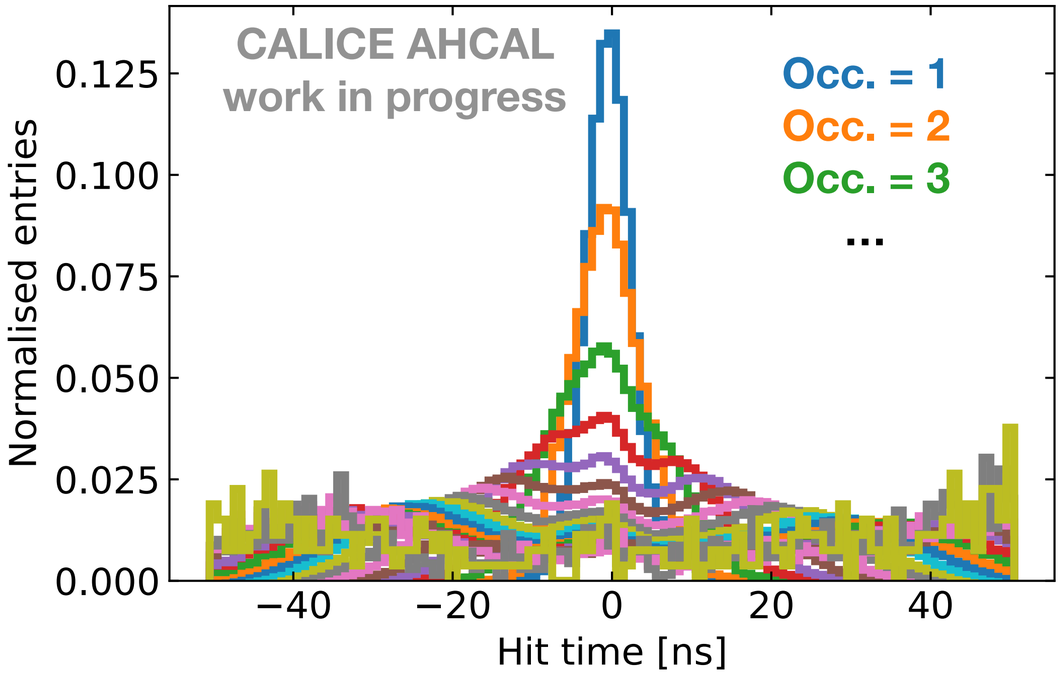
MAX-PLANCK-INSTITUT FÜR PHYSIK

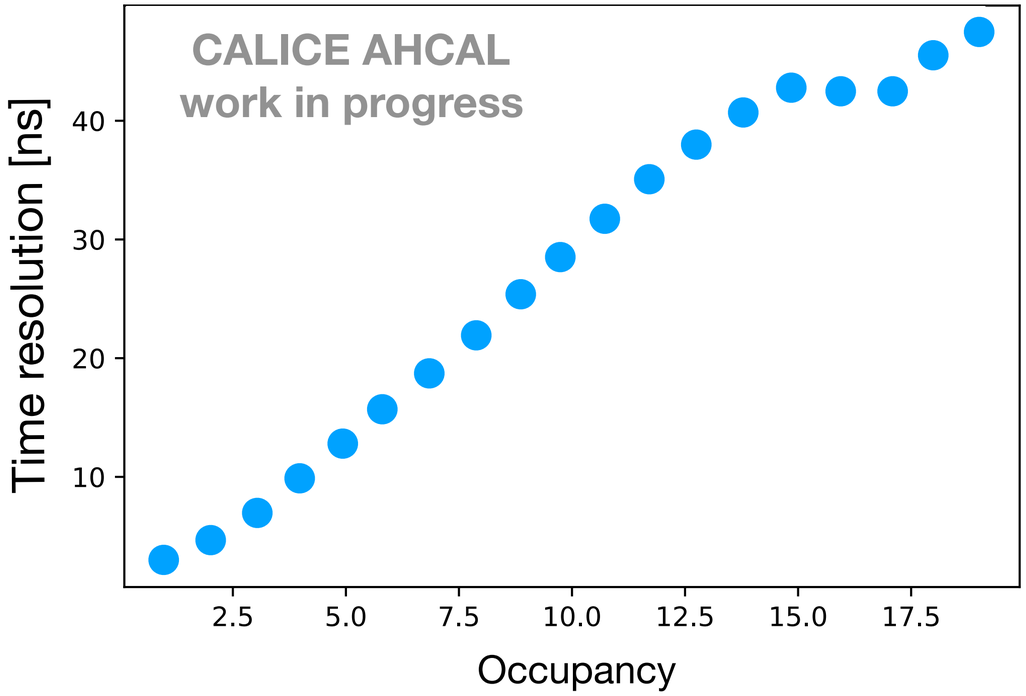
Dataset: 60GeV Electrons



The Occupancy Problem

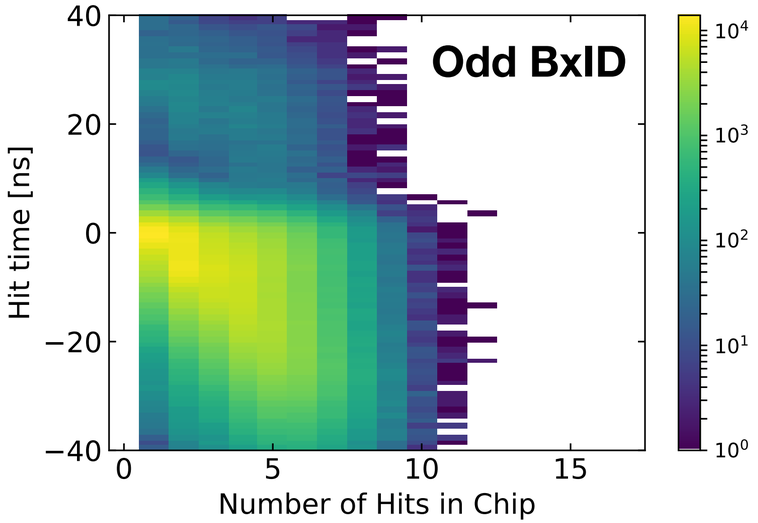
Dataset: 60GeV Electrons

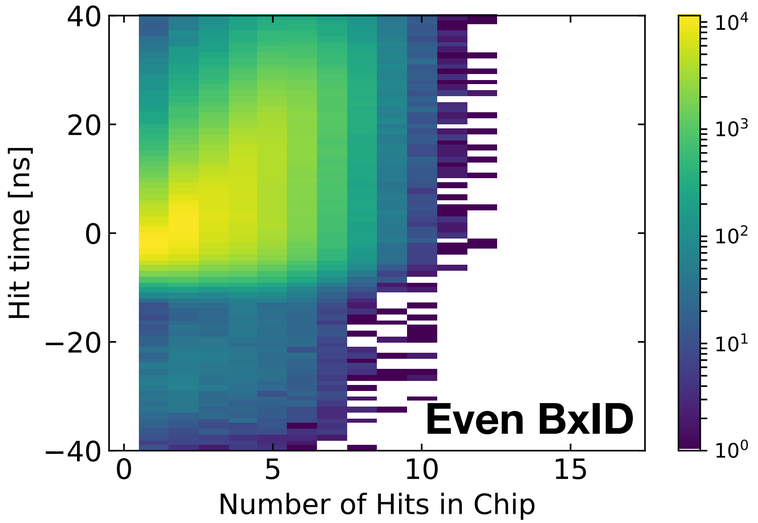




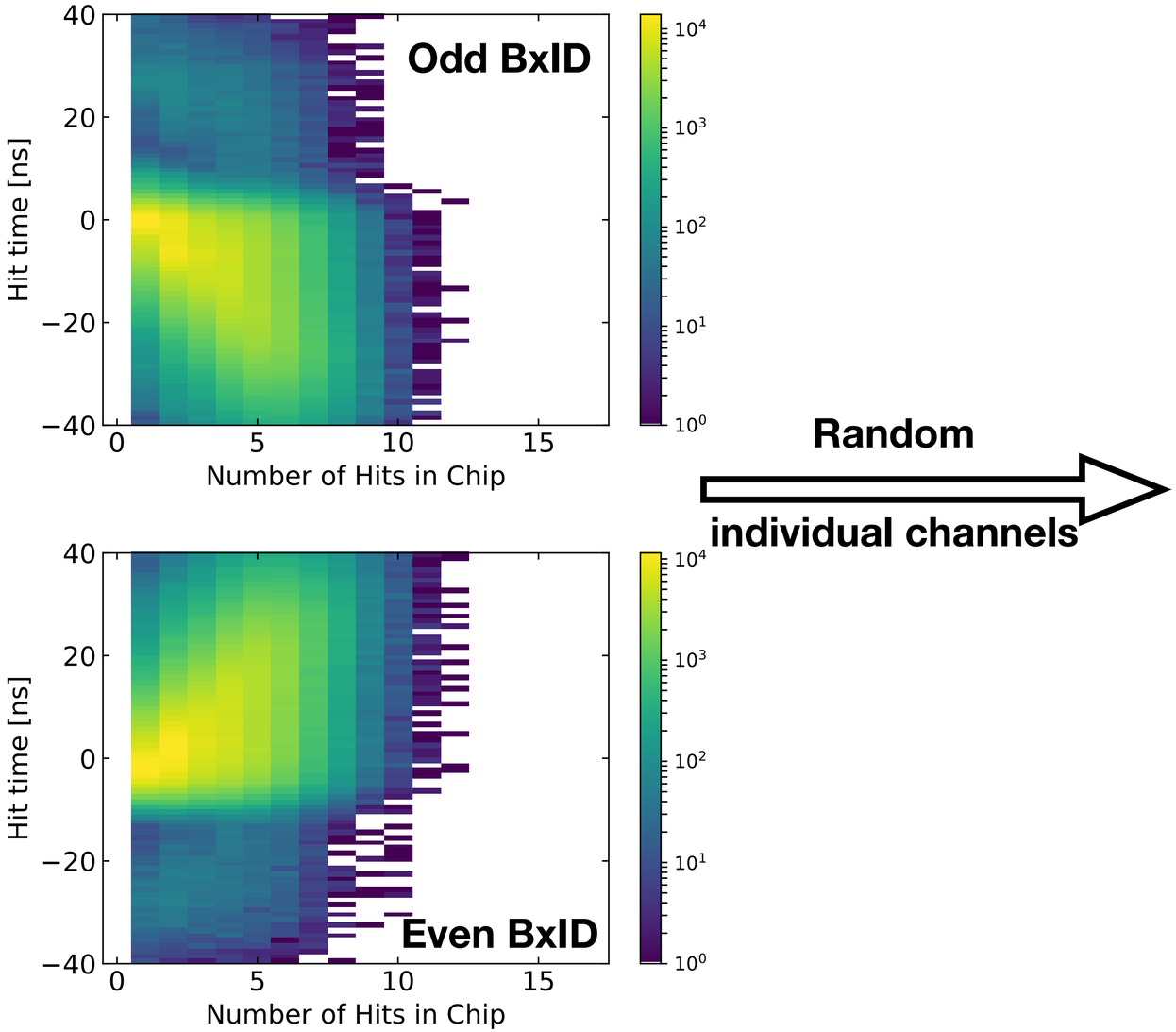
Time resolution is the sigma of a gaussian fit to every distribution

The Occupancy Problem

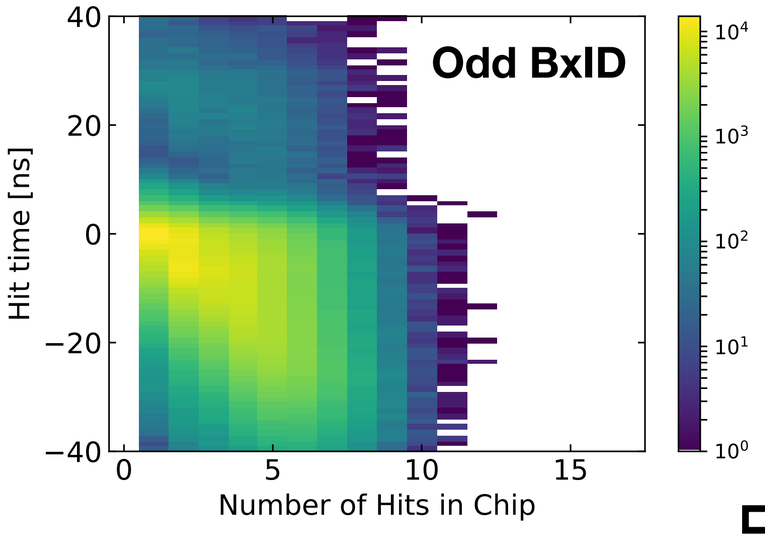


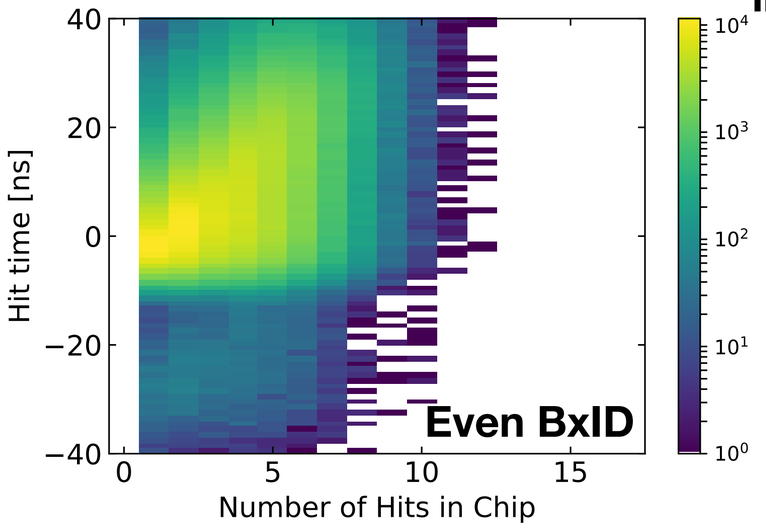


The Occupancy Problem



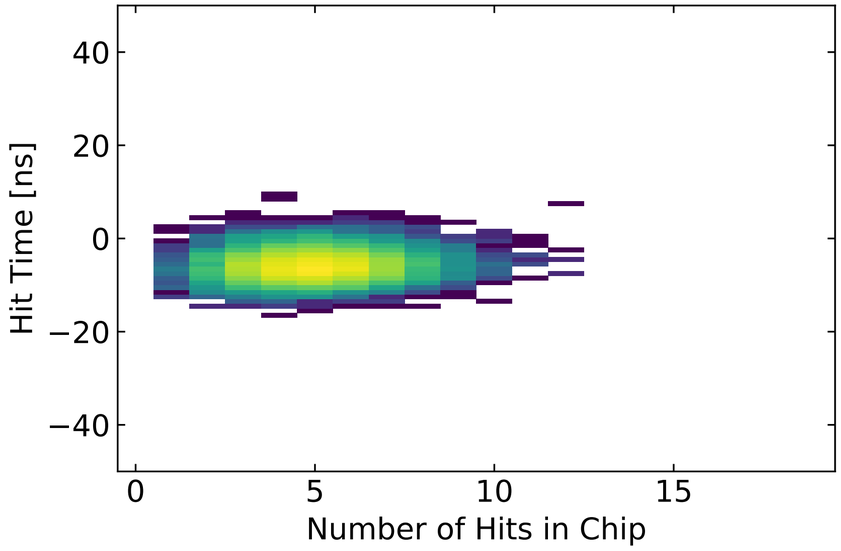
The Occupancy Problem



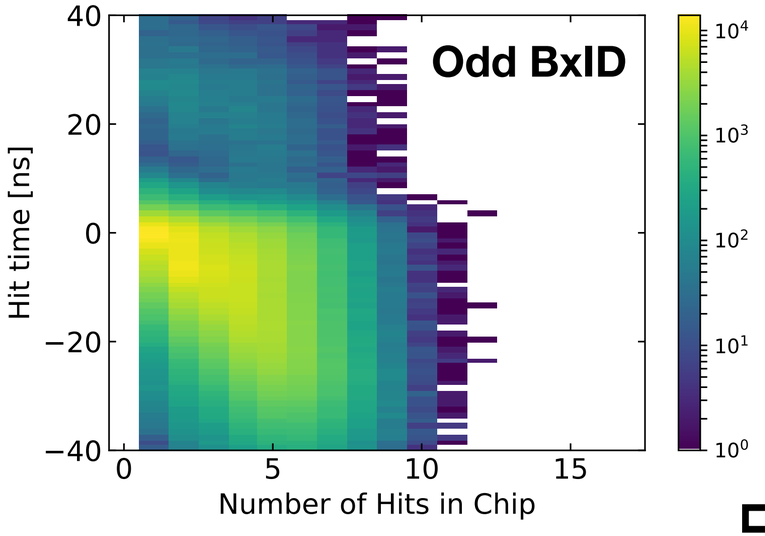


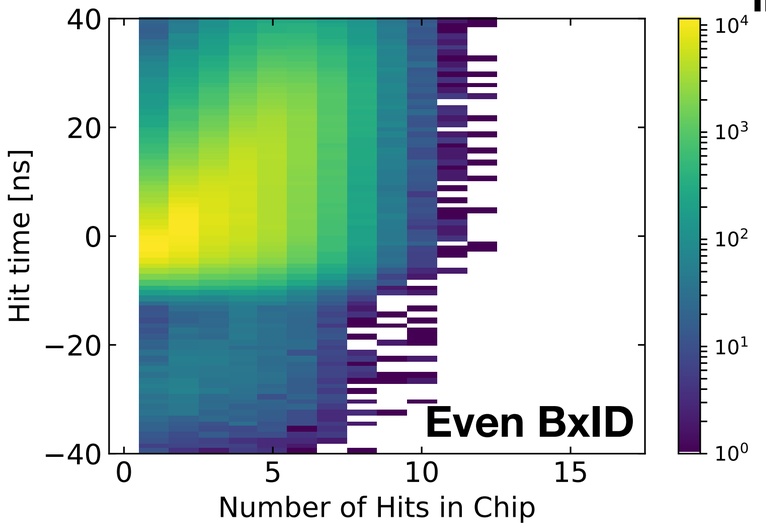
Random

individual channels



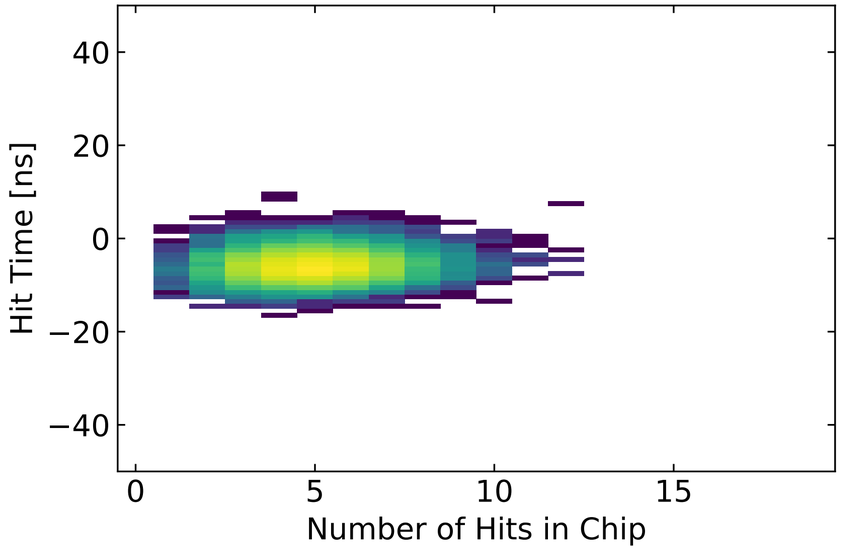
The Occupancy Problem

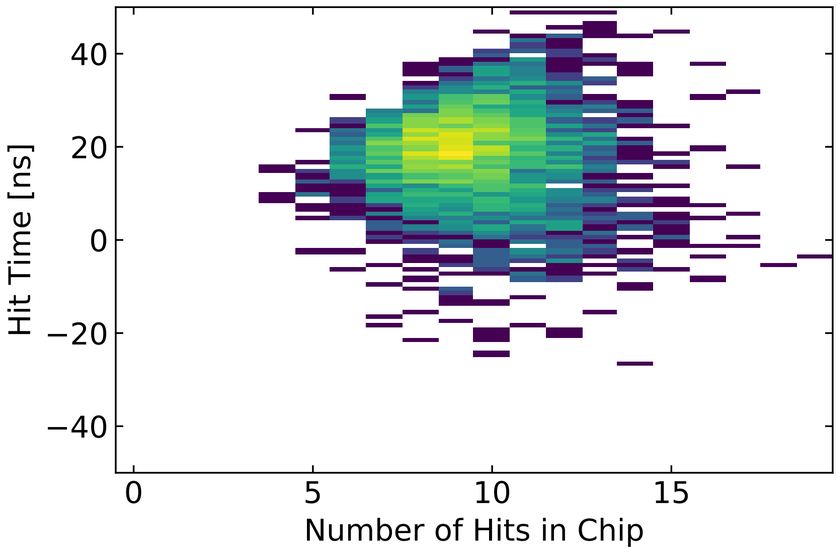




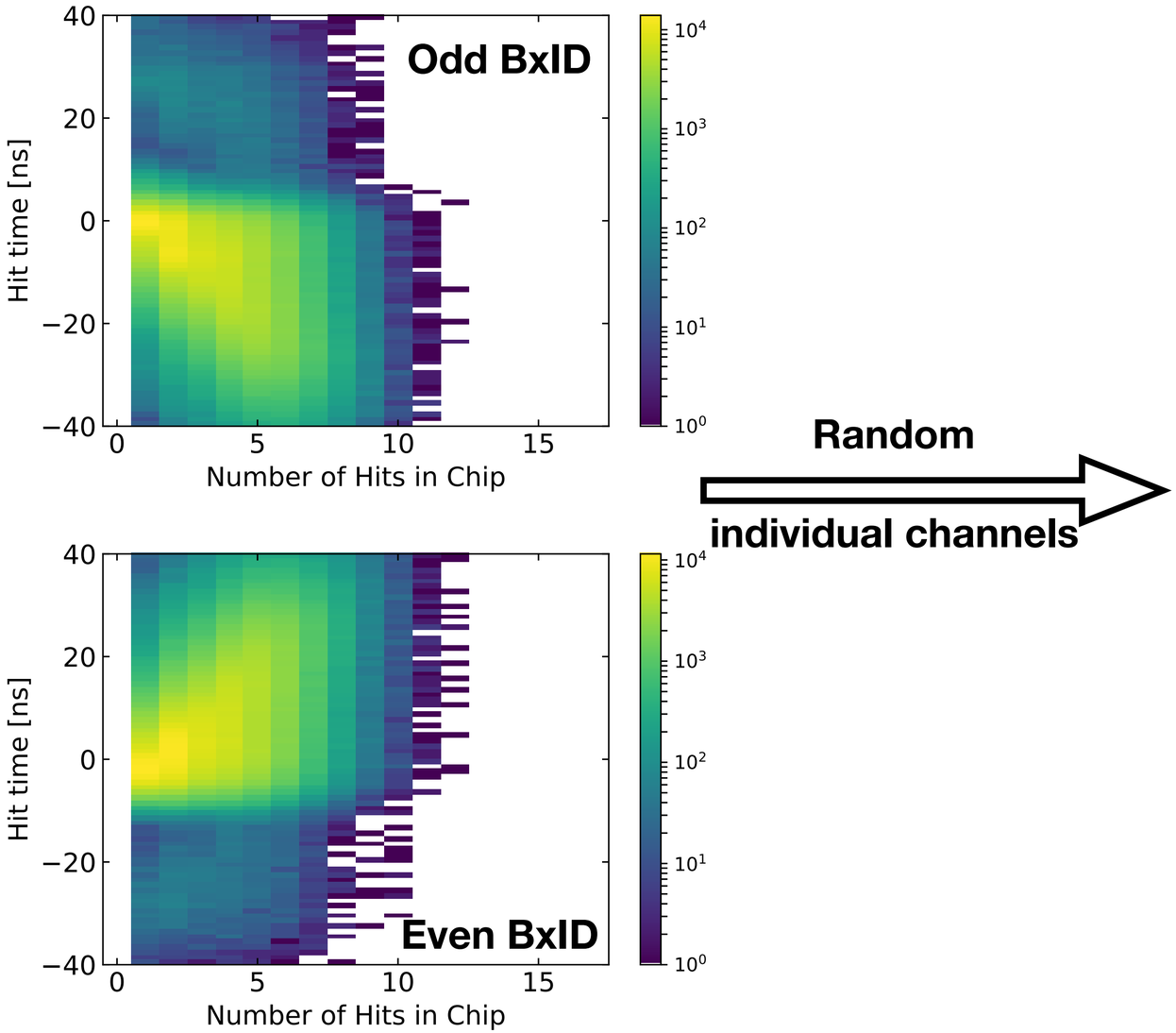
Random

individual channels

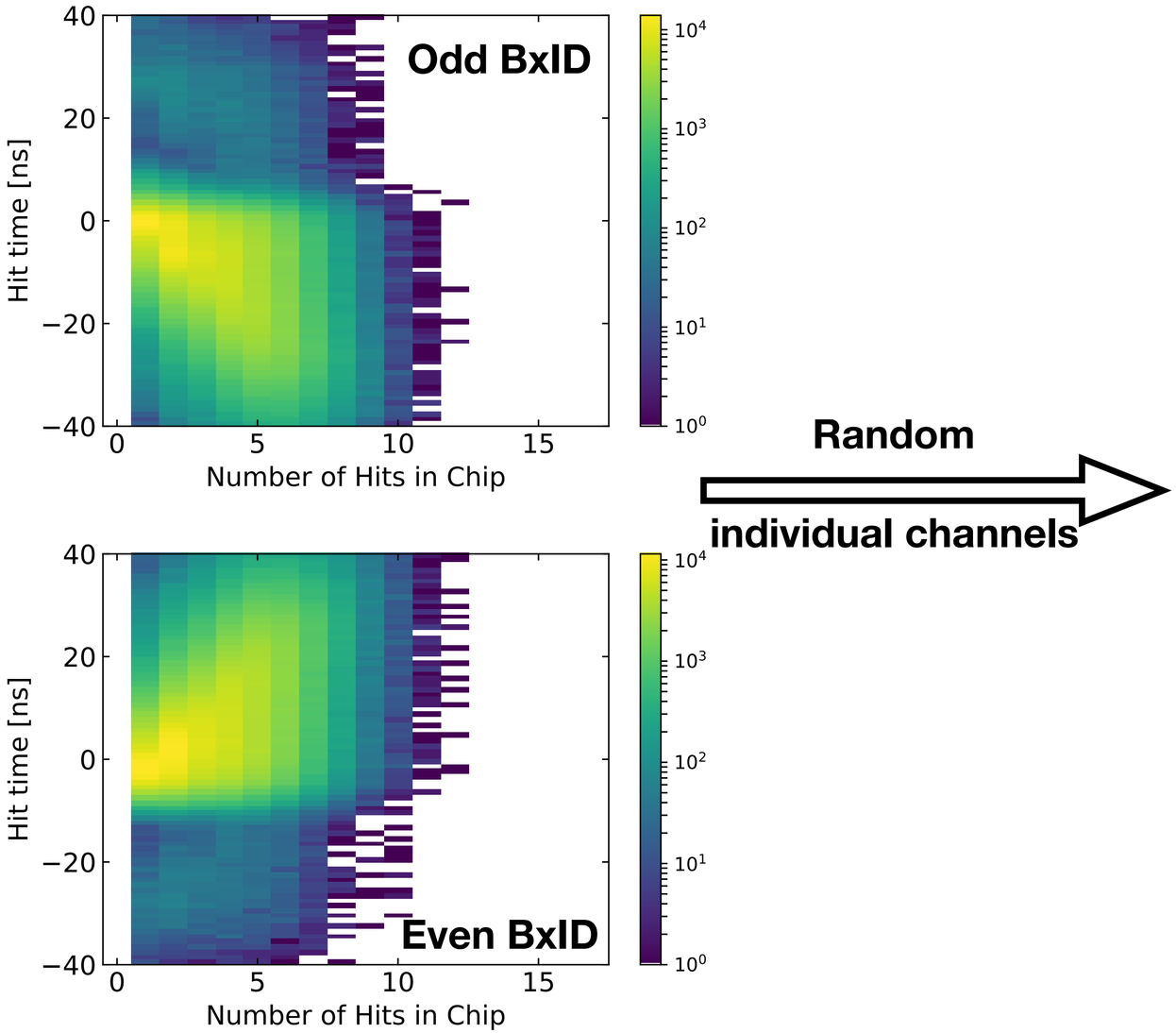


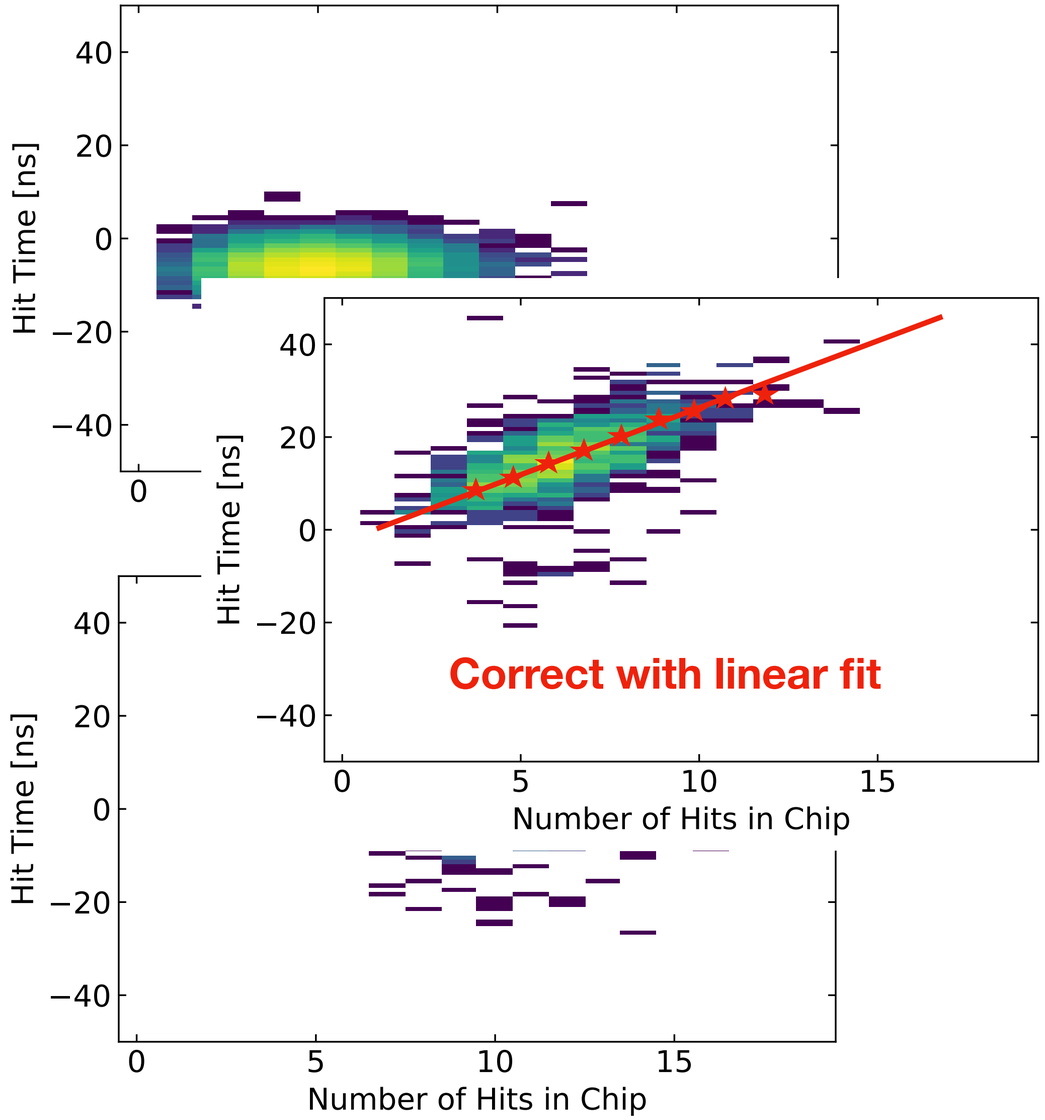


The Occupancy Problem



The Occupancy Problem

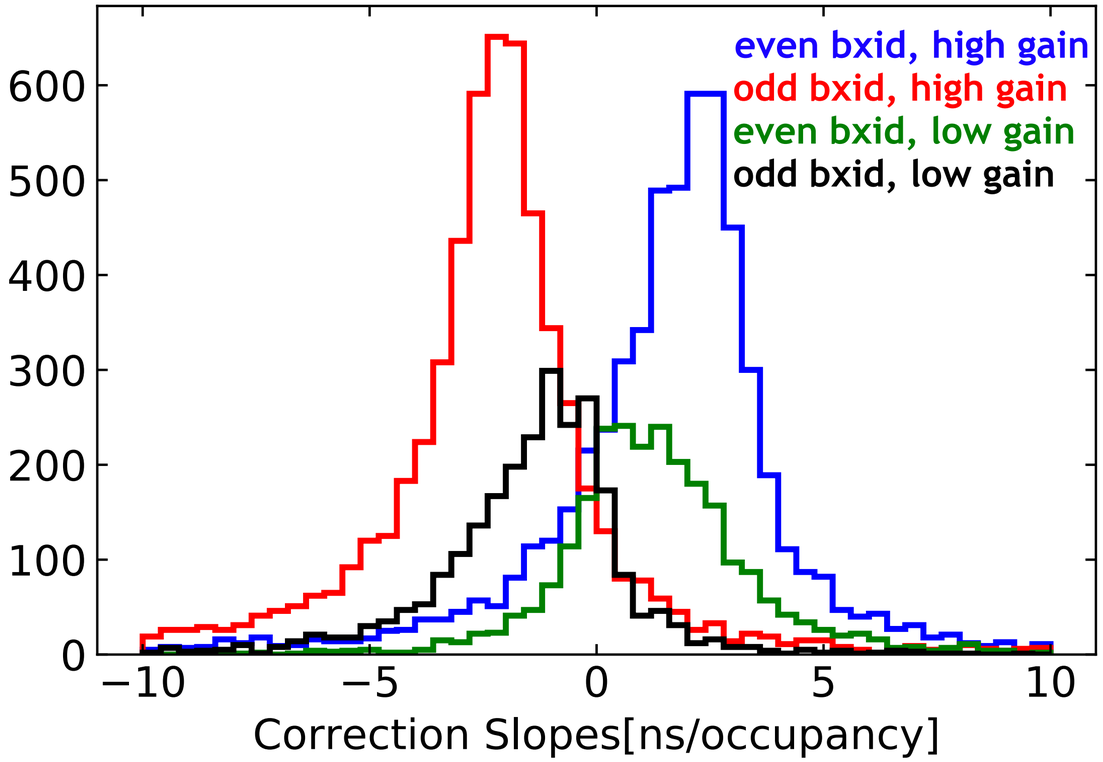


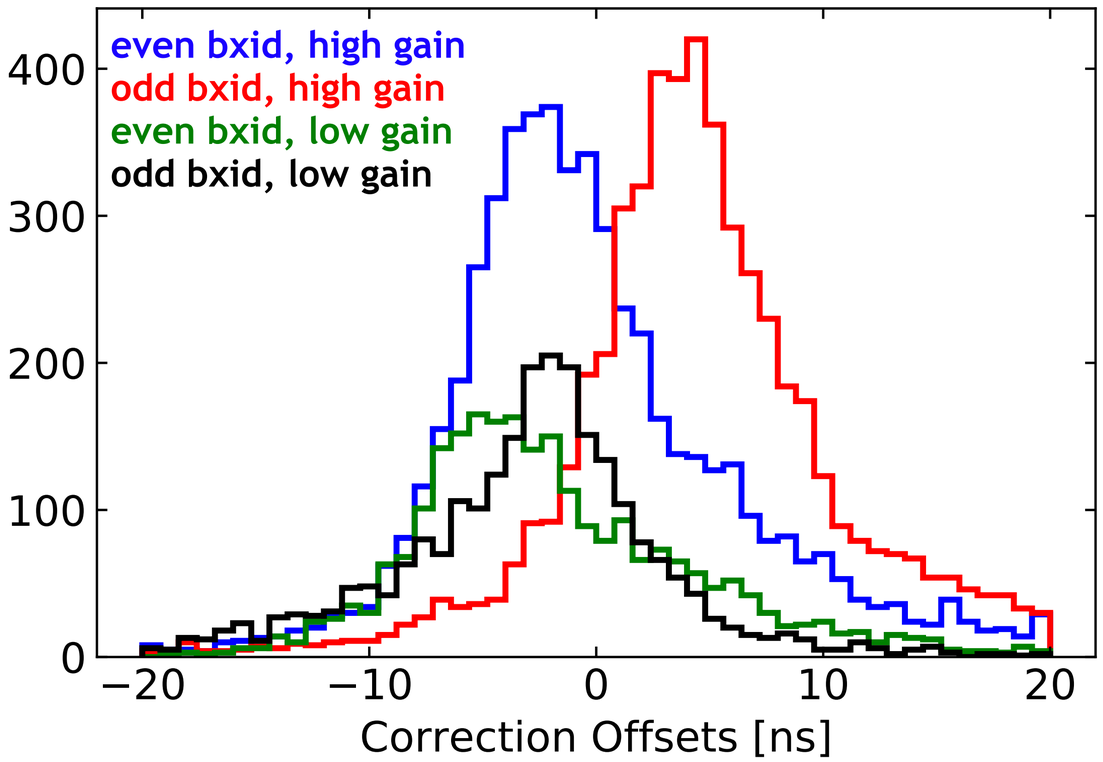


Correction on Channel Level

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

Fit individual channels: Correction = slope x occupancy + offset

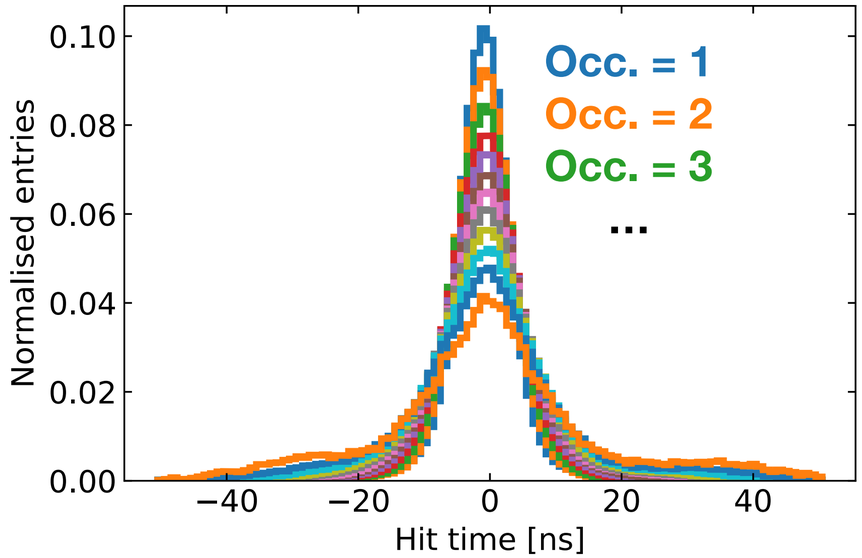




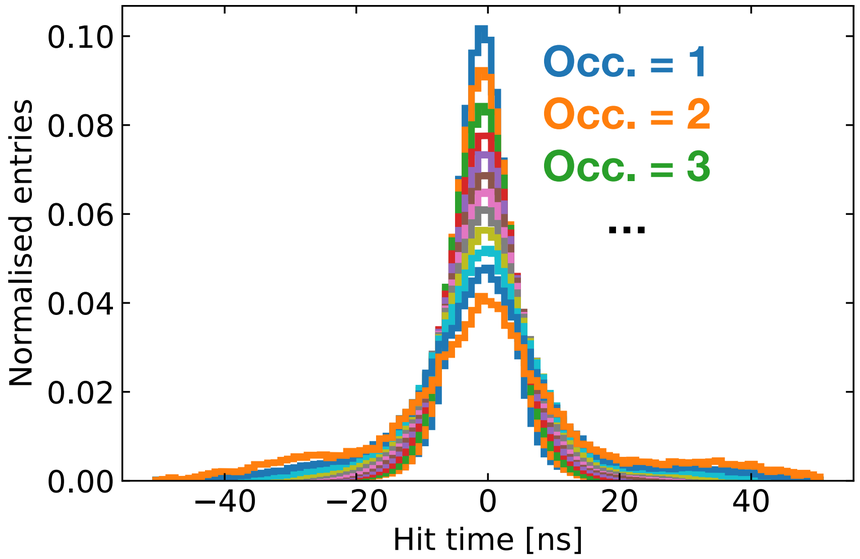
No systematics in the correction factors on chip or channel level found!

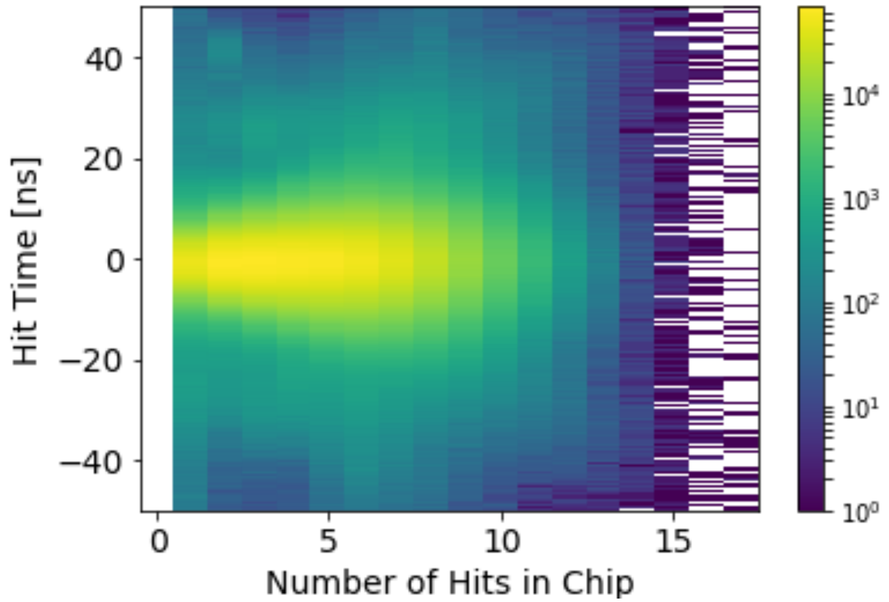
Correction on Channel Level

Correction on Channel Level

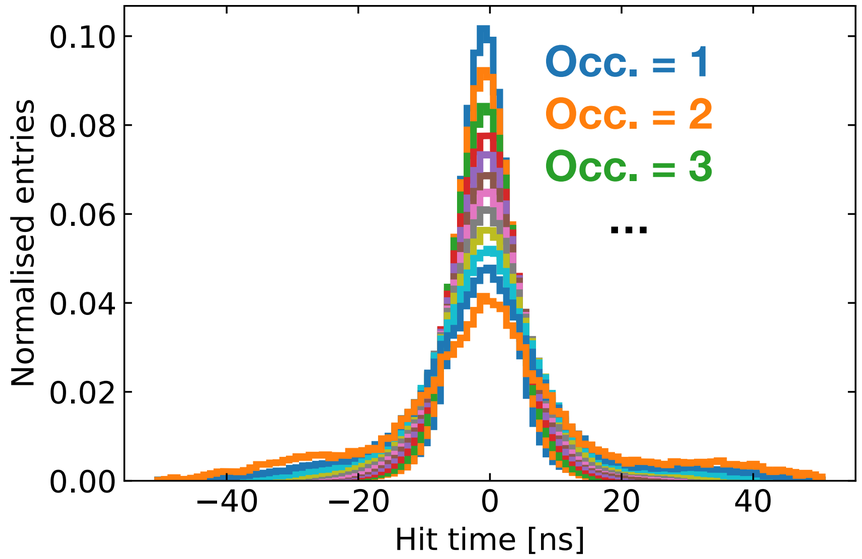


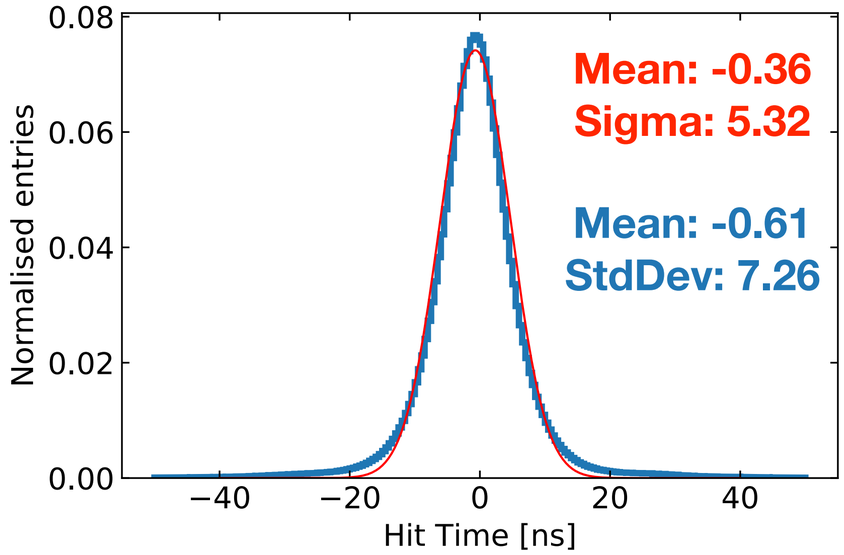
Correction on Channel Level

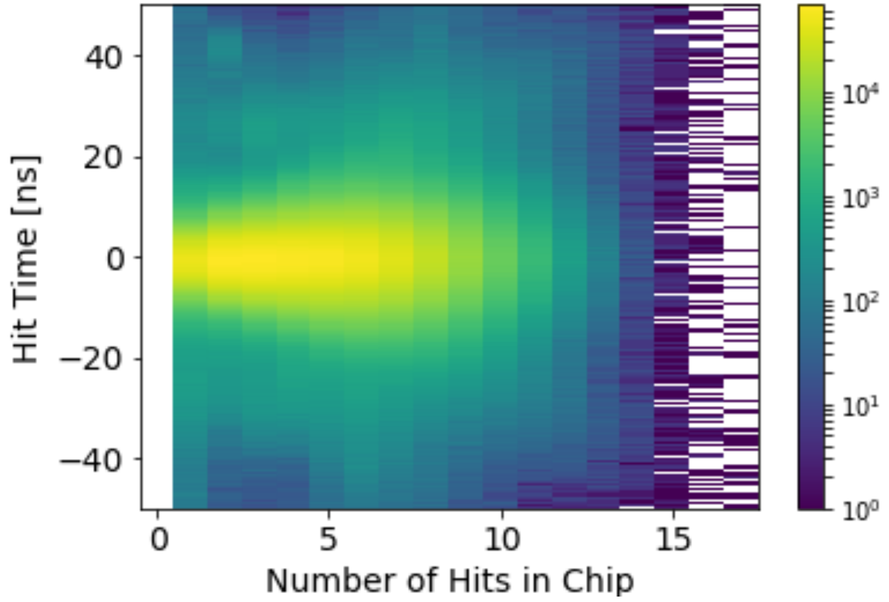




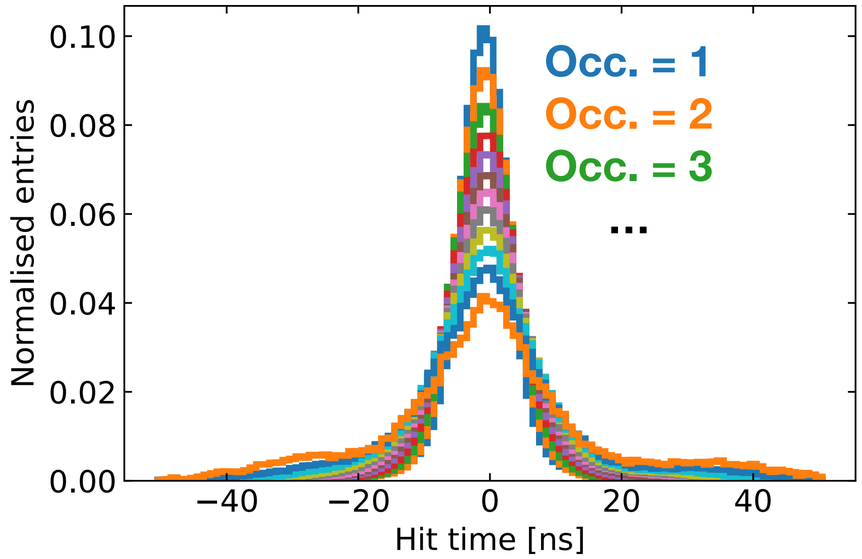
Correction on Channel Level

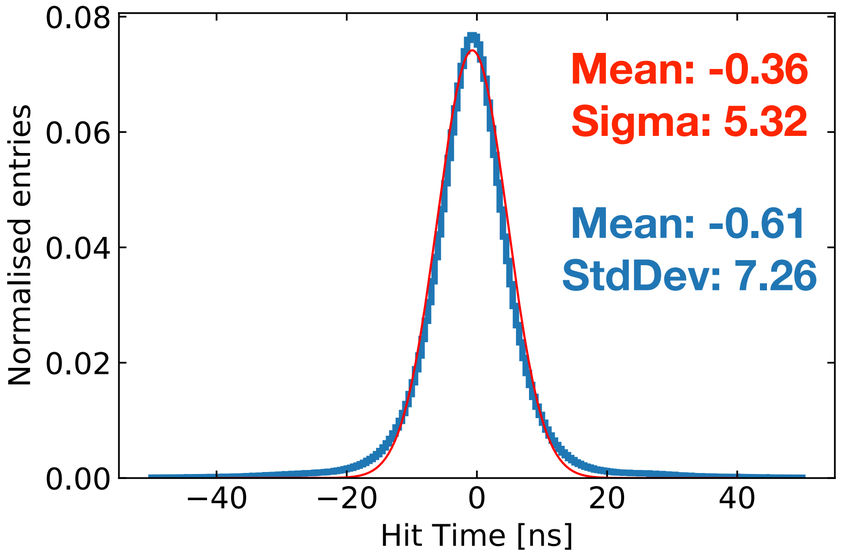


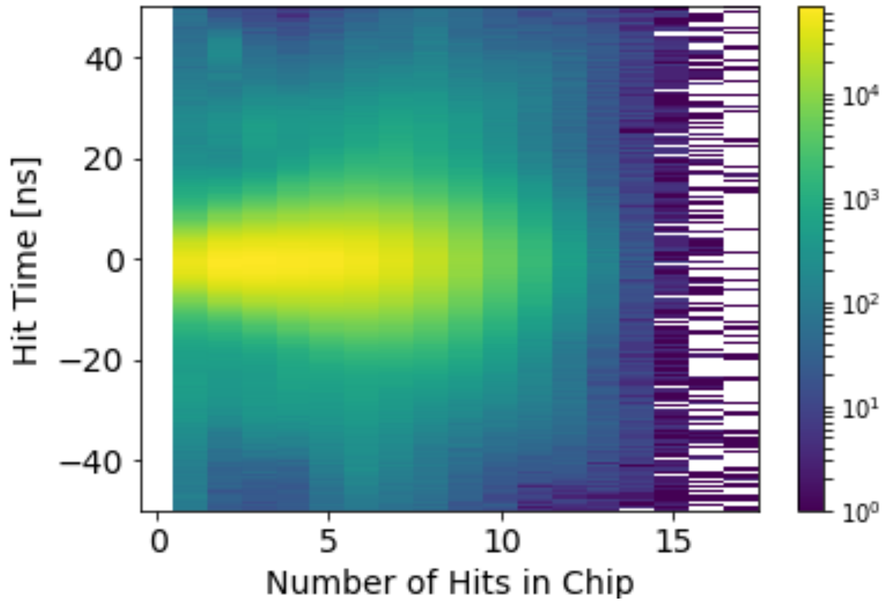




Correction on Channel Level







Channel wise correction outperforms global correction by ~1ns

<u>Problem:</u> 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

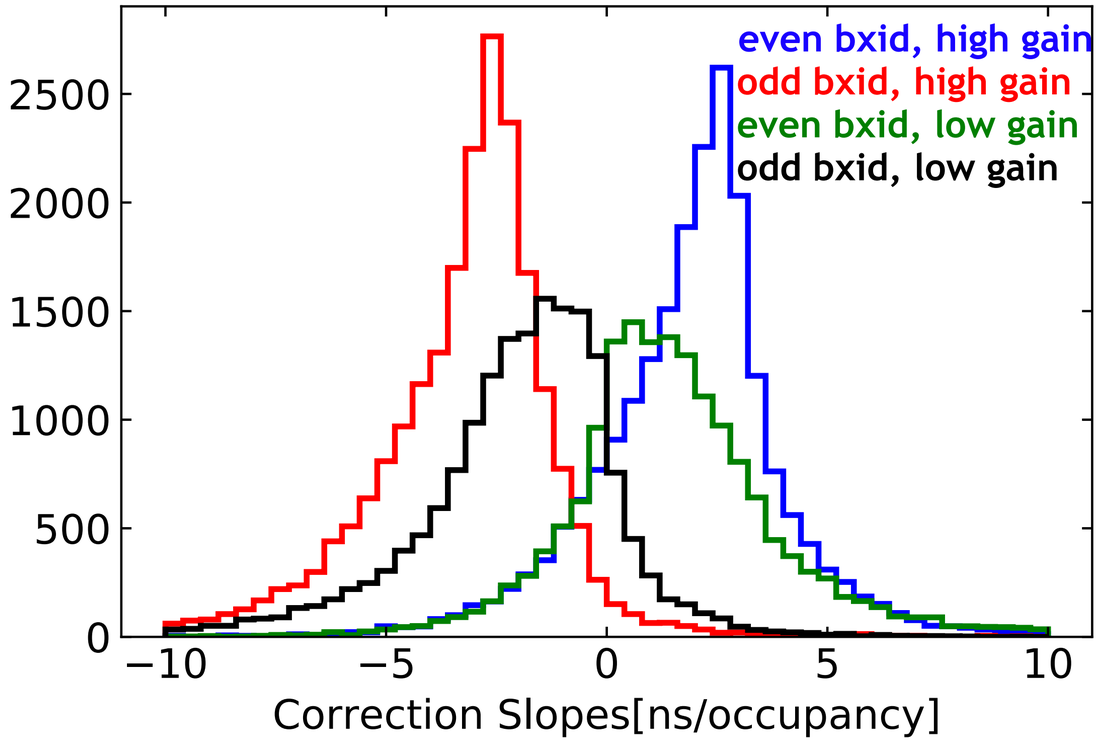
- Fit individual channels: Correction = slope x occupancy + offset

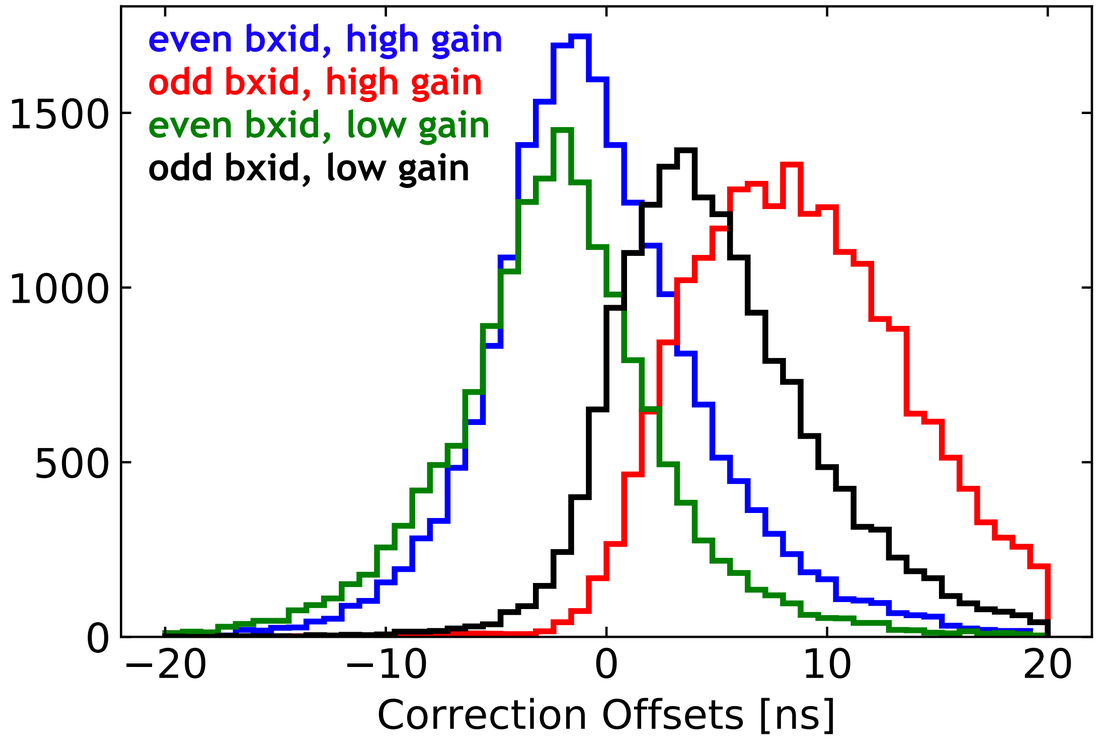
Correcting with Pions

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

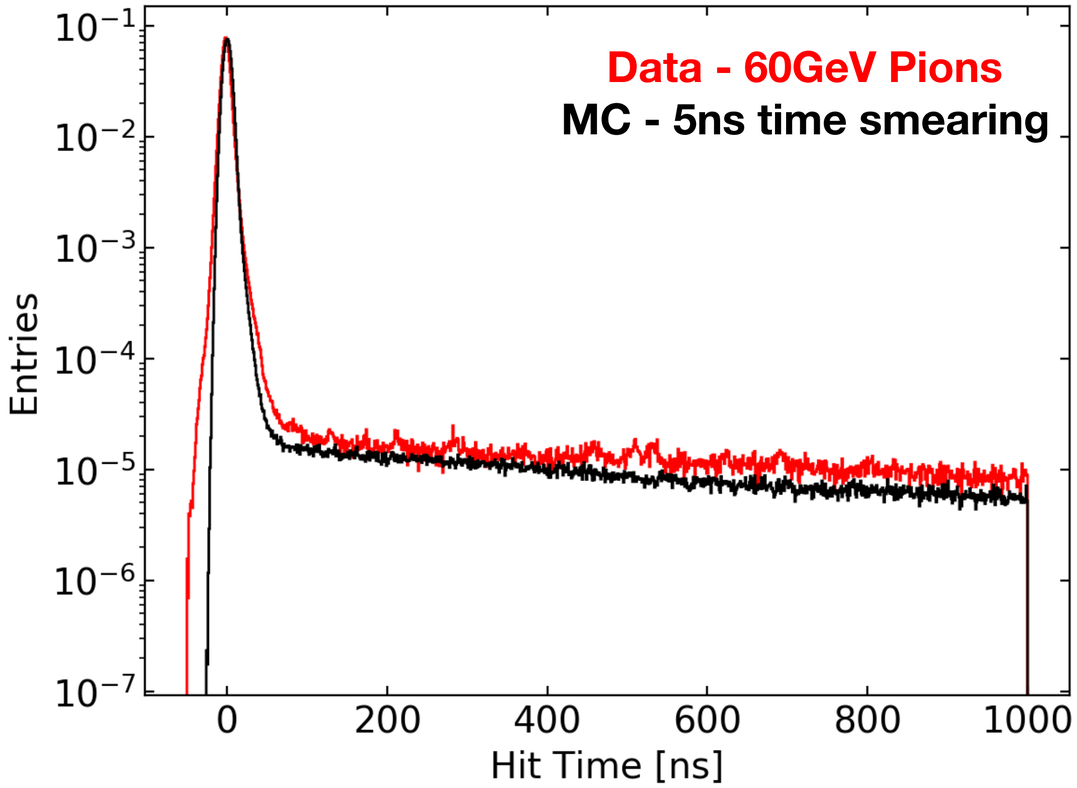
- Fit individual channels: Correction = slope x occupancy + offset



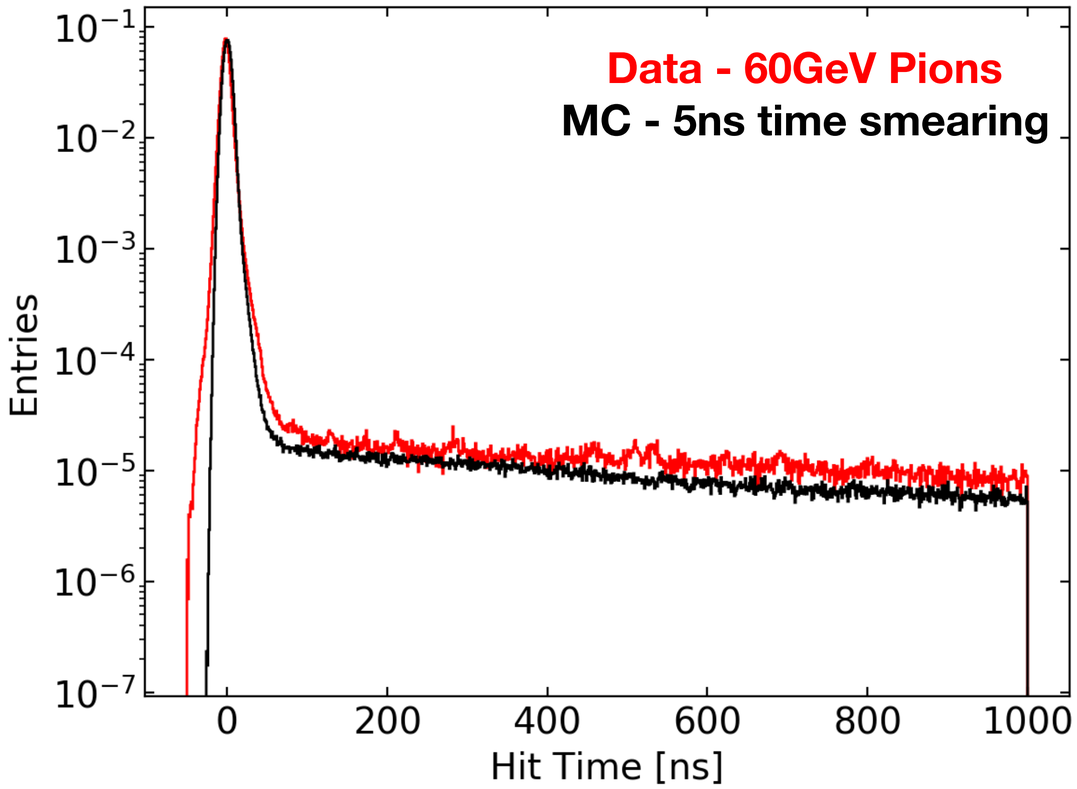


Pion Hit Time Distribution

Pion Hit Time Distribution



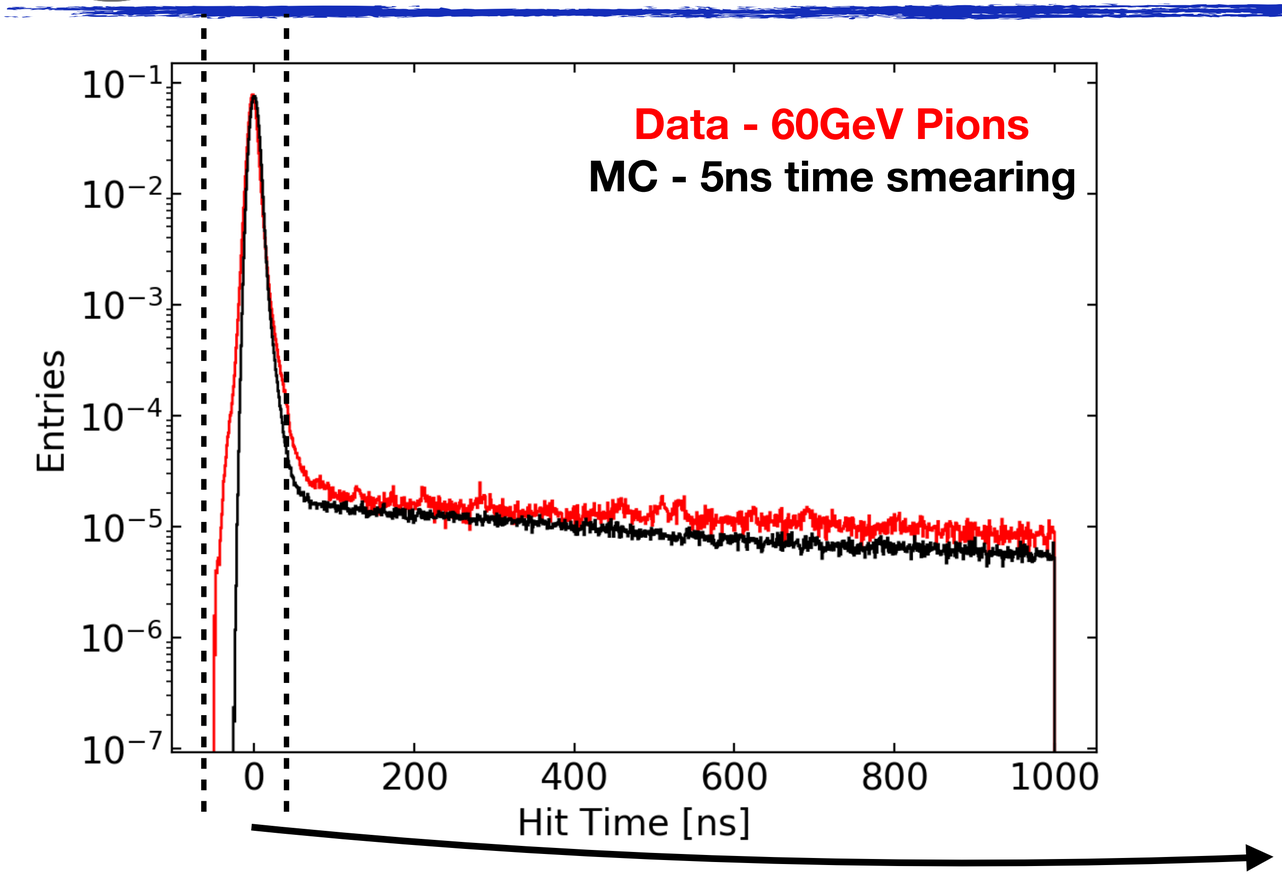
Pion Hit Time Distribution



Data Quality Selections:

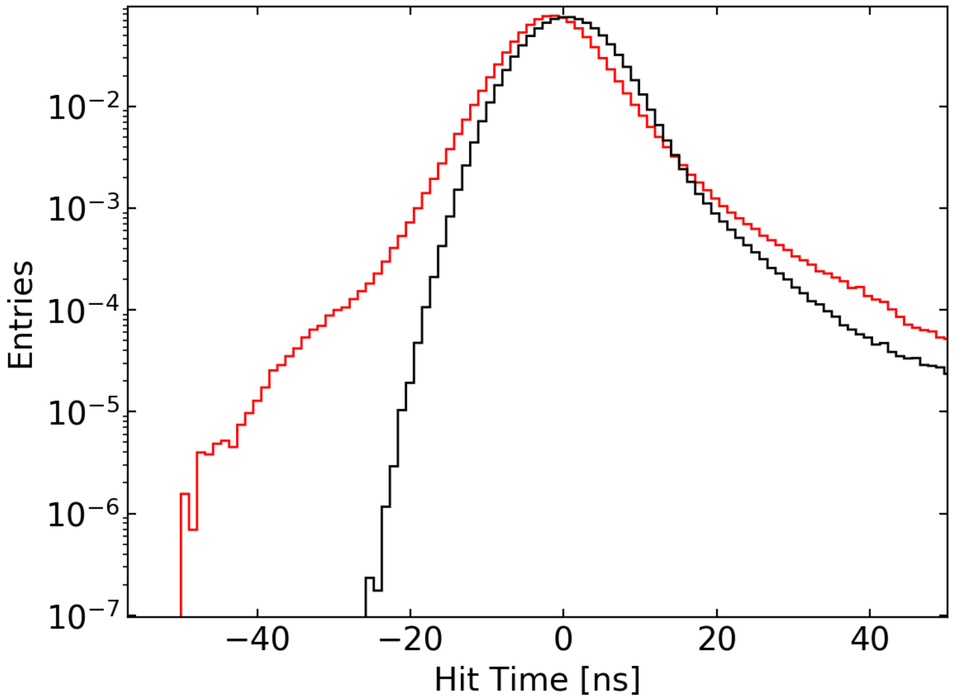
- 500ns < BIF Time < 2500ns
- Hit Time < 3500ns
- Number of Hits > 180
- 200 < Depth of COG < 800

Pion Hit Time Distribution

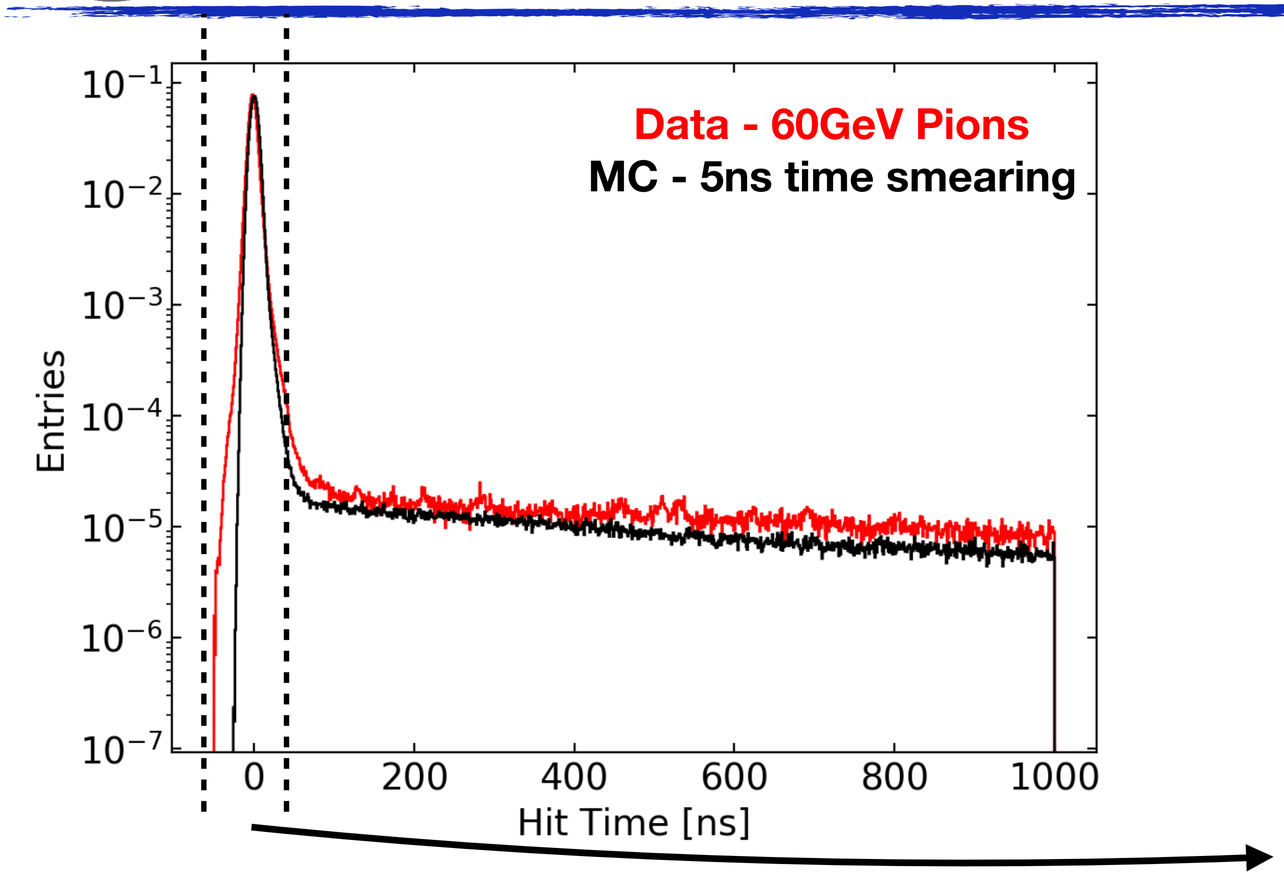


Data Quality Selections:

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



Pion Hit Time Distribution

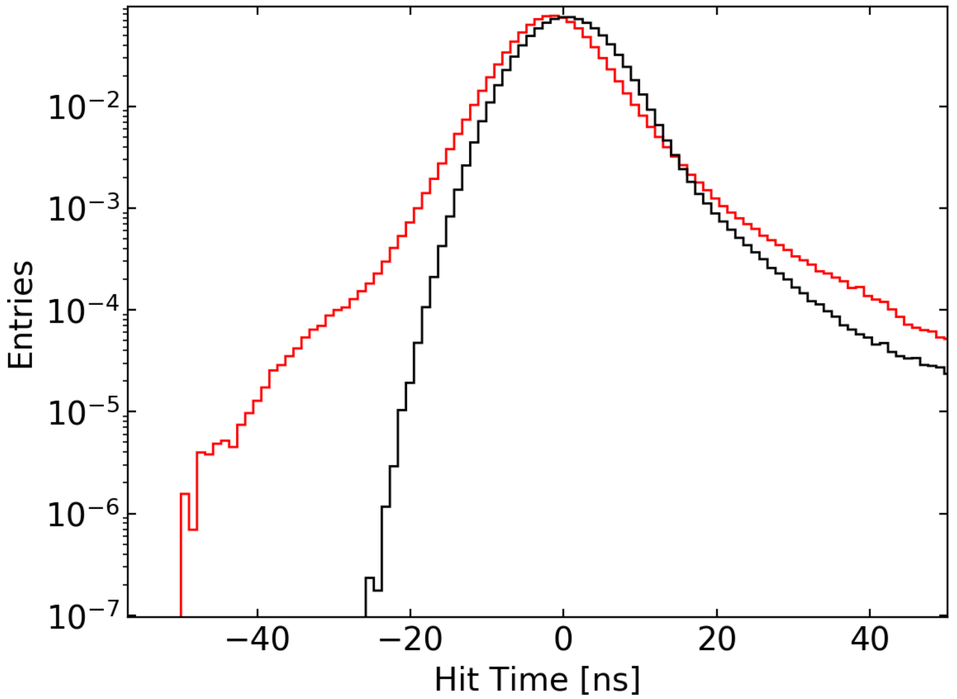


Divide spectrum into prompt (10ns), elastic (50ns) and capture part

Compare to MC with 5ns time smearing

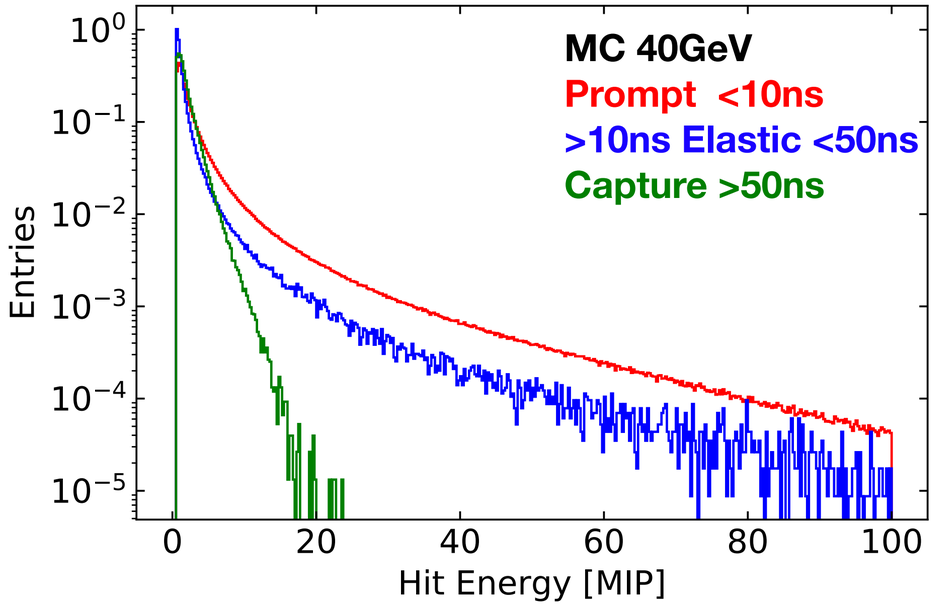
Data Quality Selections:

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

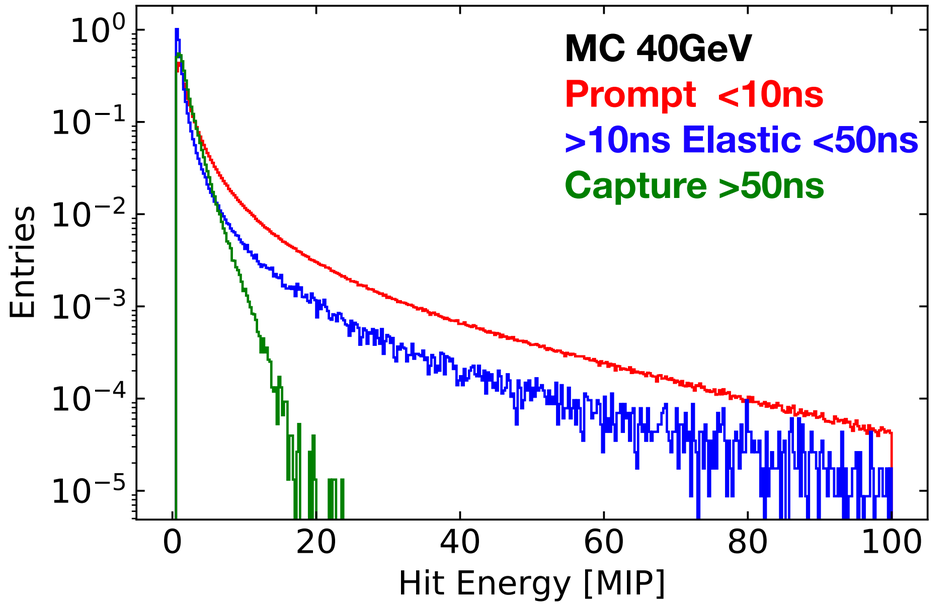


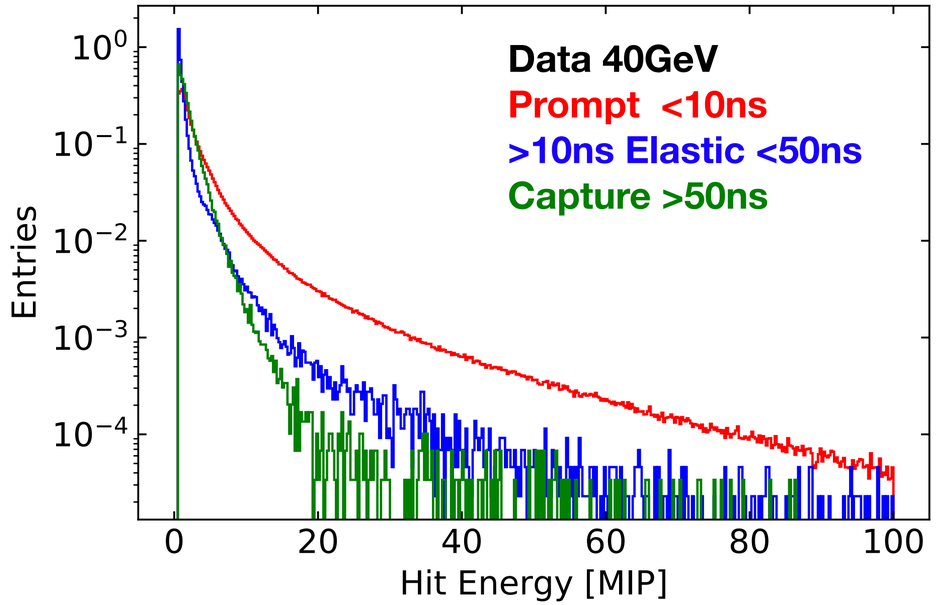
A Look at Pions - Hit Energy

A Look at Pions - Hit Energy

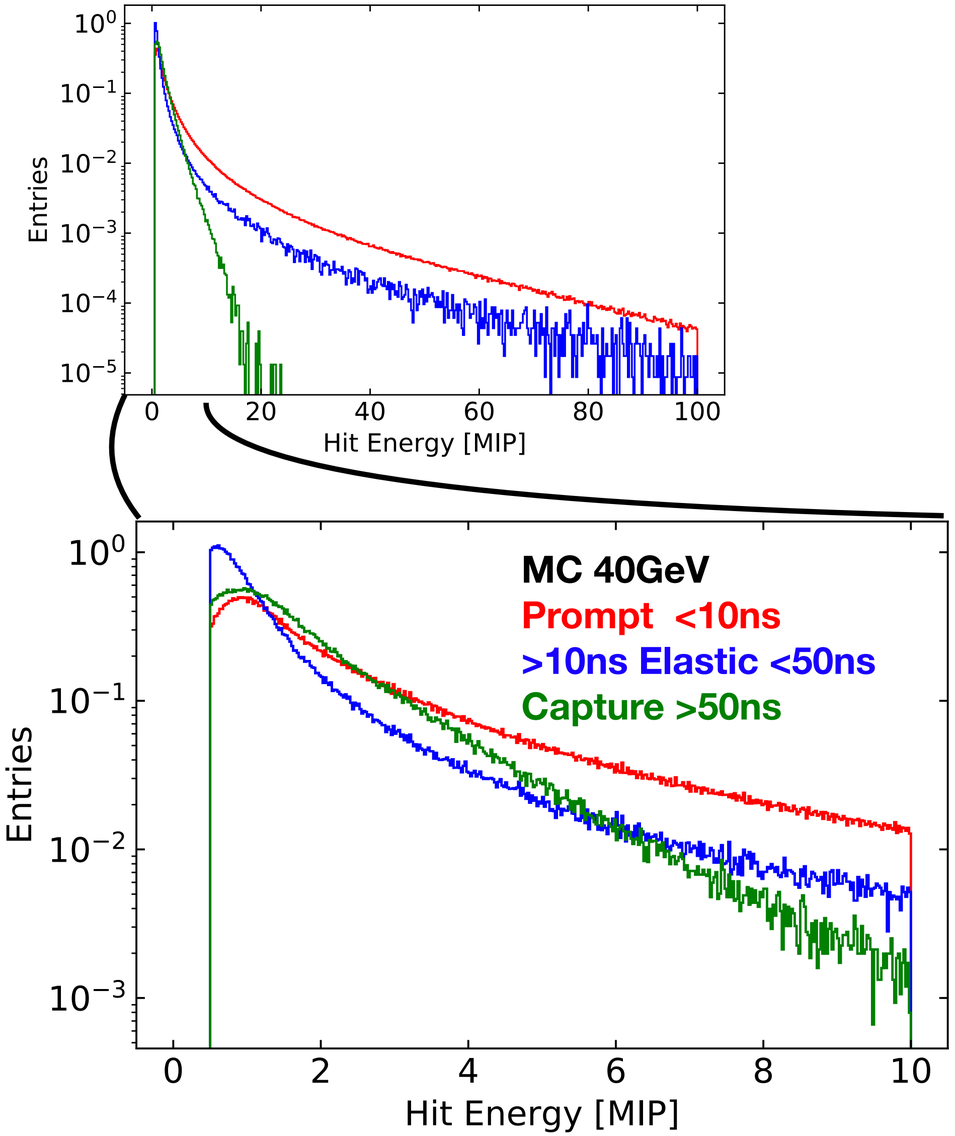


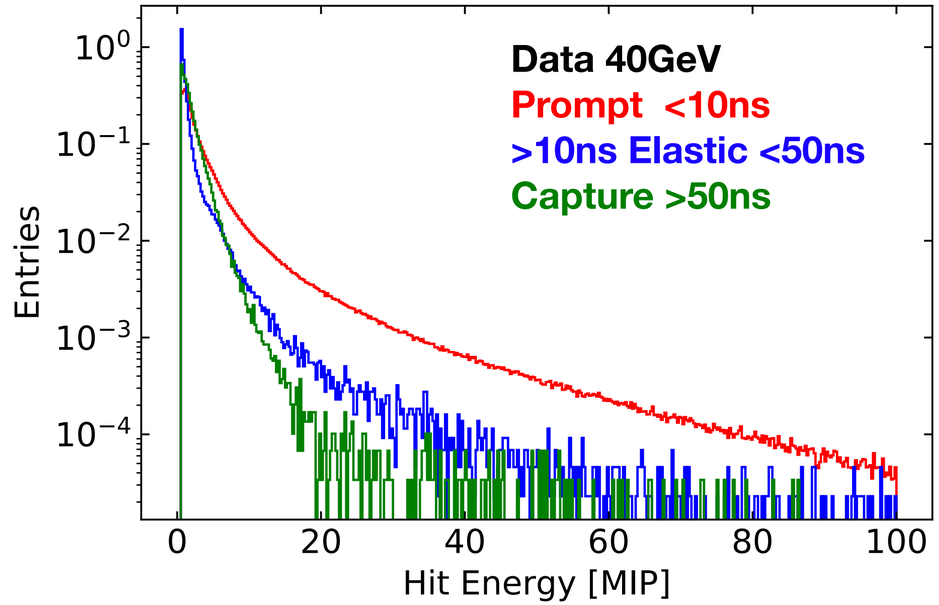
A Look at Pions - Hit Energy



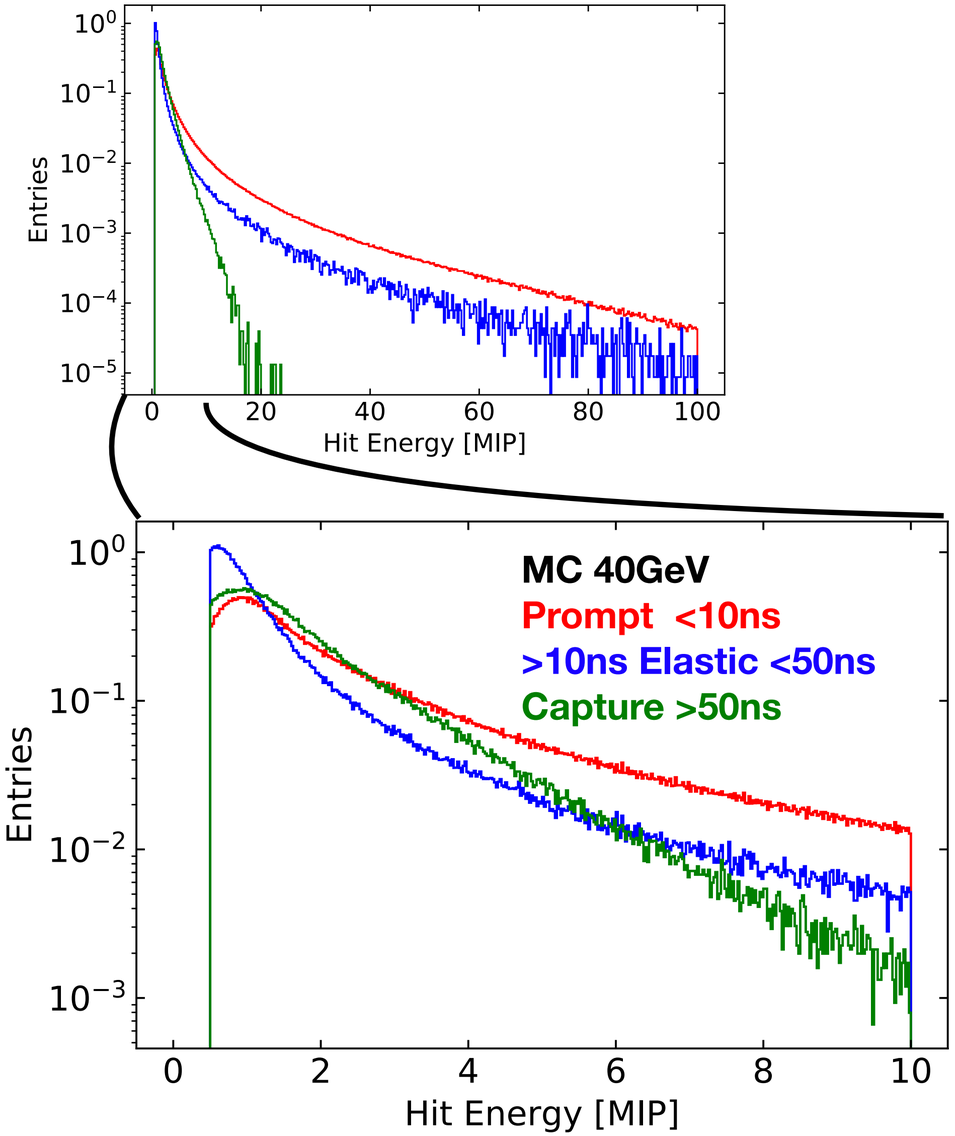


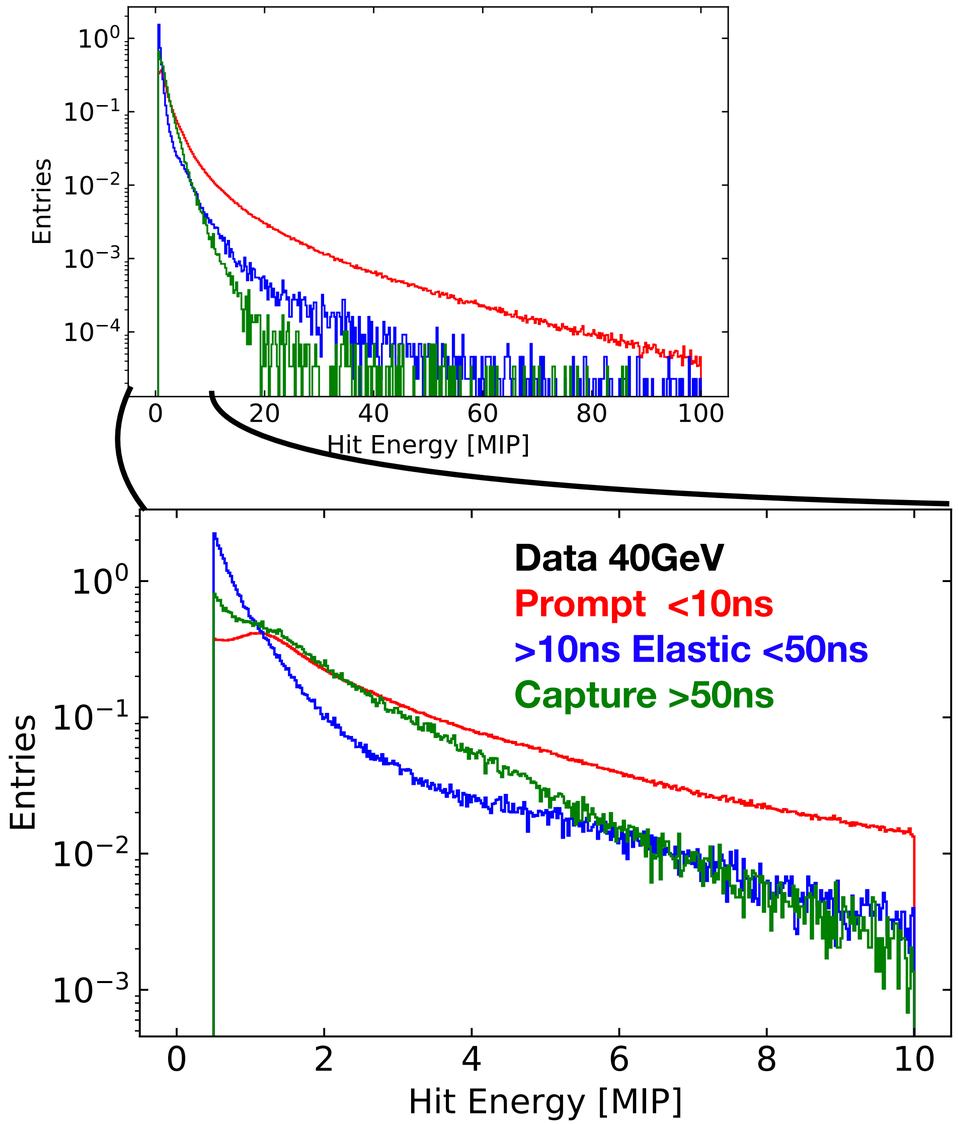
A Look at Pions - Hit Energy



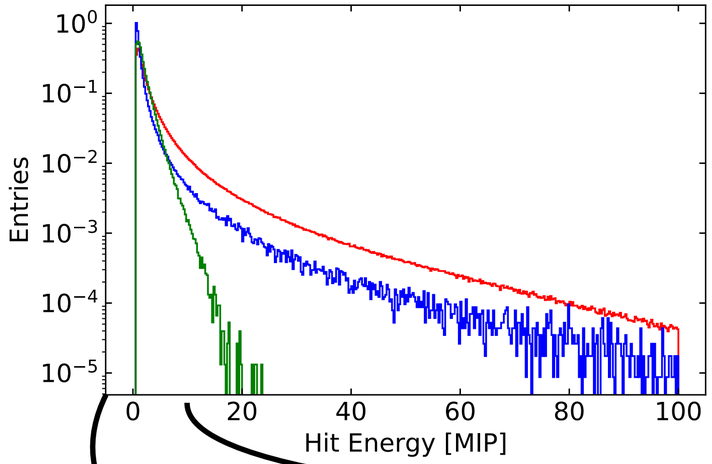


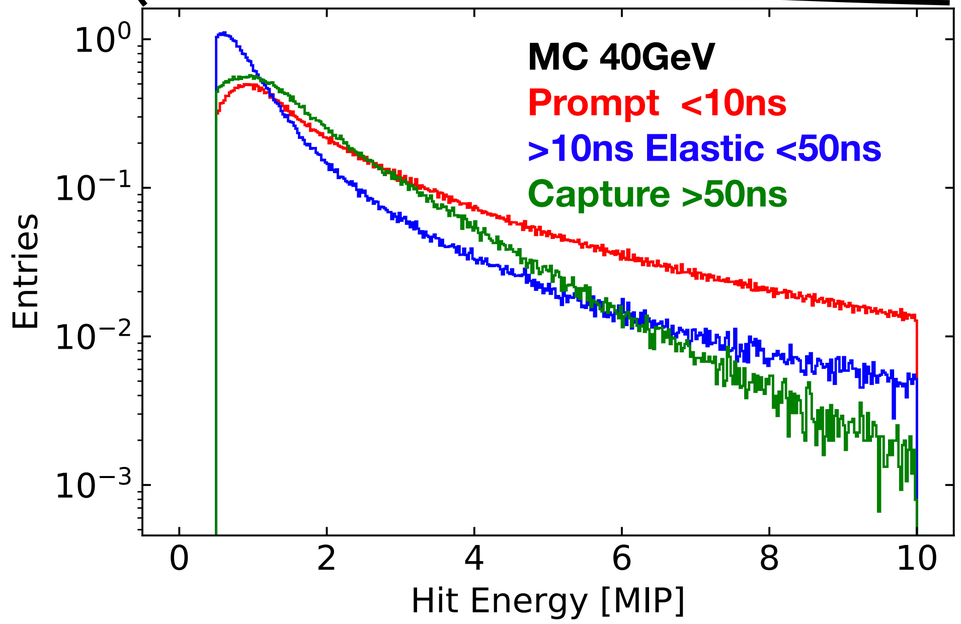
A Look at Pions - Hit Energy



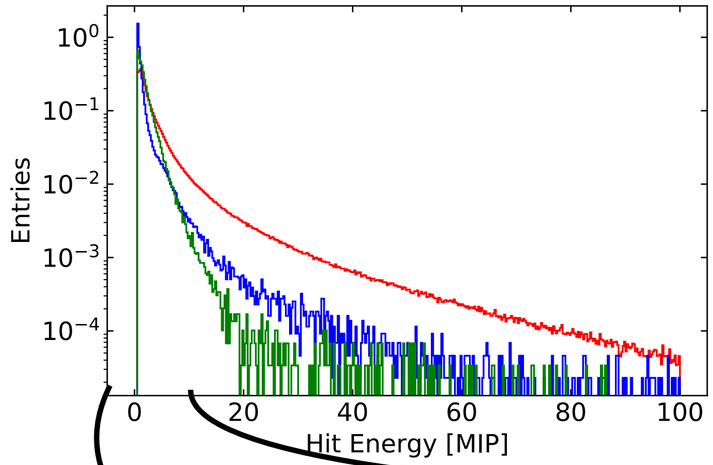


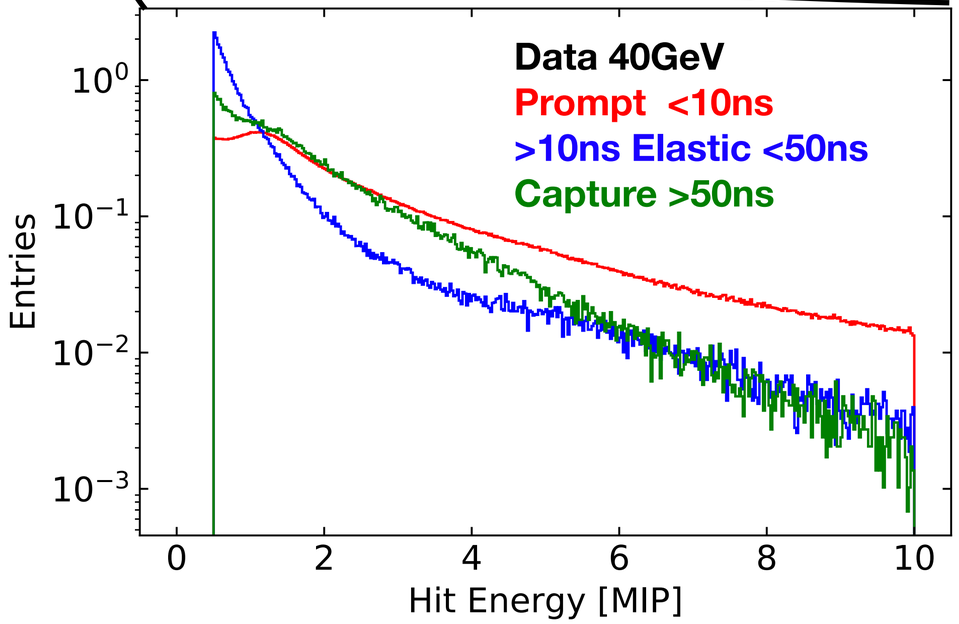
A Look at Pions - Hit Energy





Global features are similar

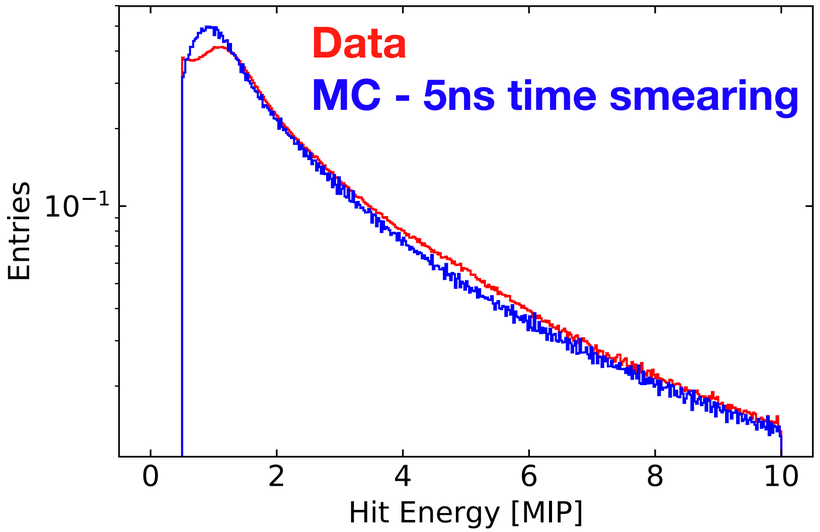




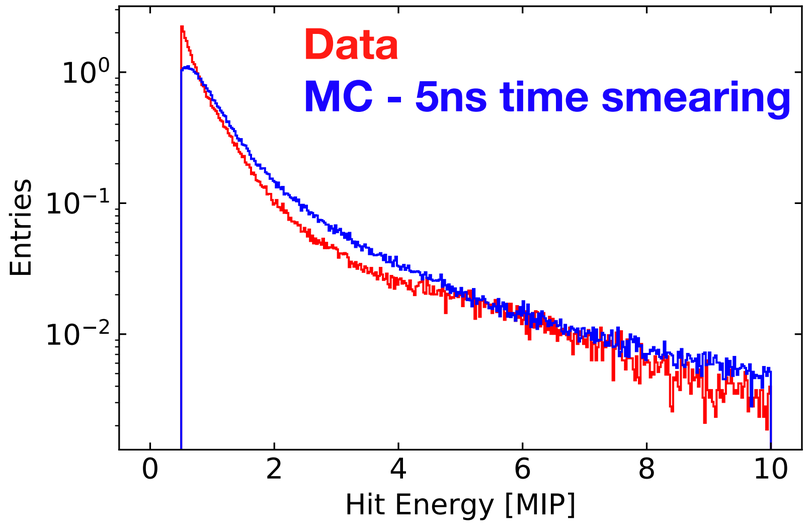
A Look at Pions - Hit Energy

MAX-PLANCK-INSTITUT FÜR PHYSIK

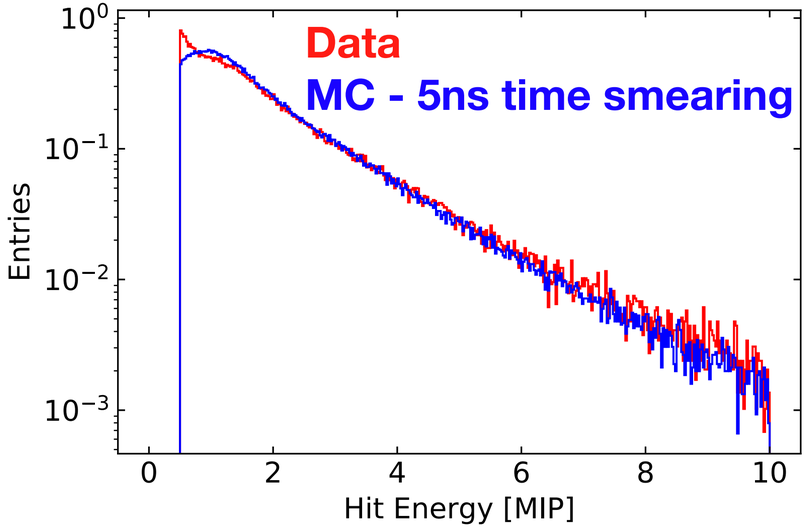
Prompt: hit time <10ns



Elastic:10ns< hit time<50ns



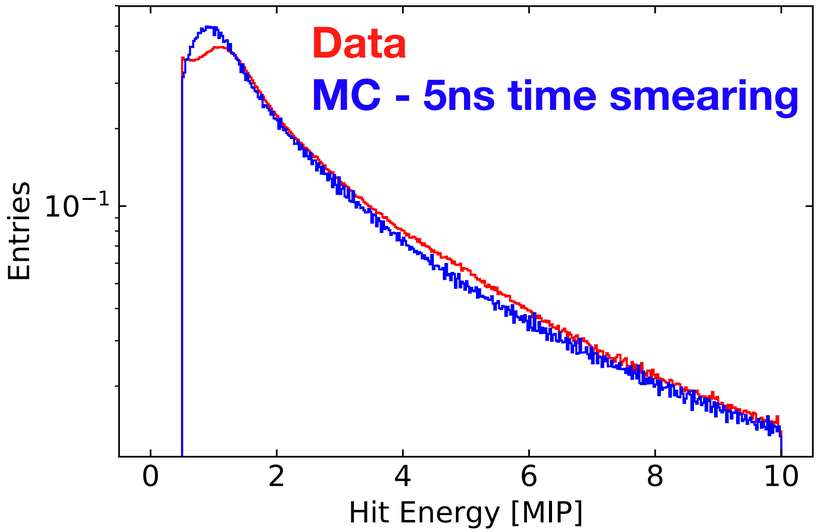
Capture: hit time >50ns



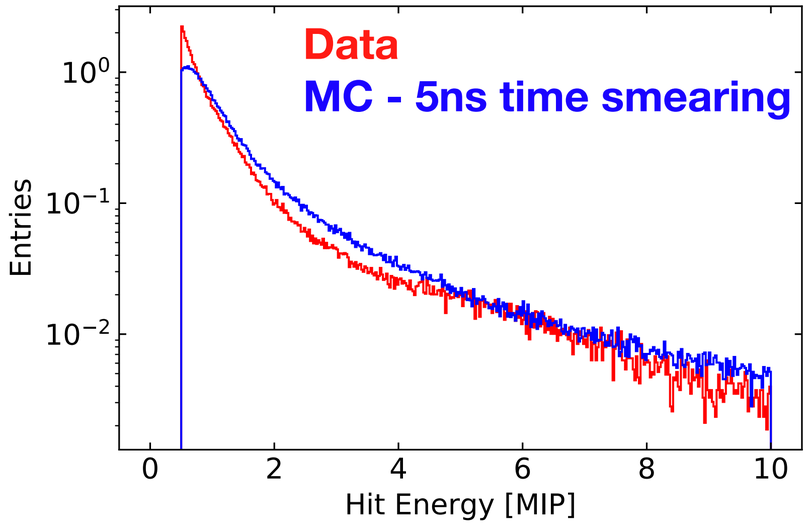
A Look at Pions - Hit Energy

MAX-PLANCK-INSTITUT FÜR PHYSIK

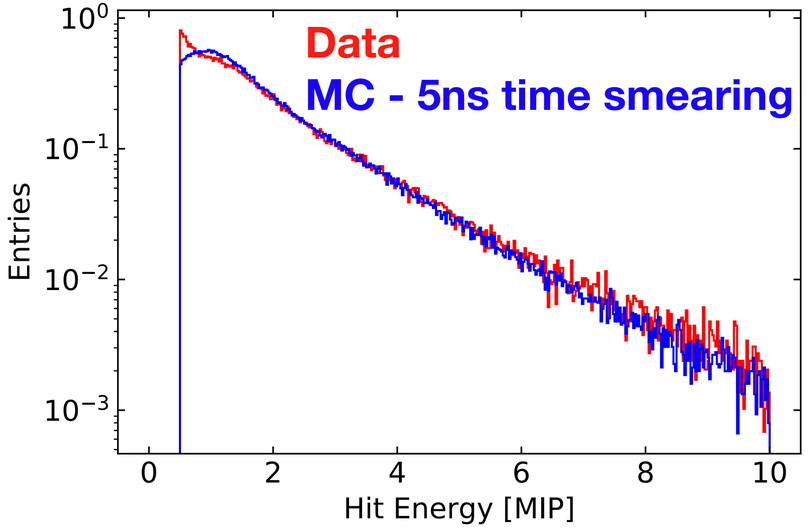
Prompt: hit time <10ns



Elastic:10ns< hit time<50ns

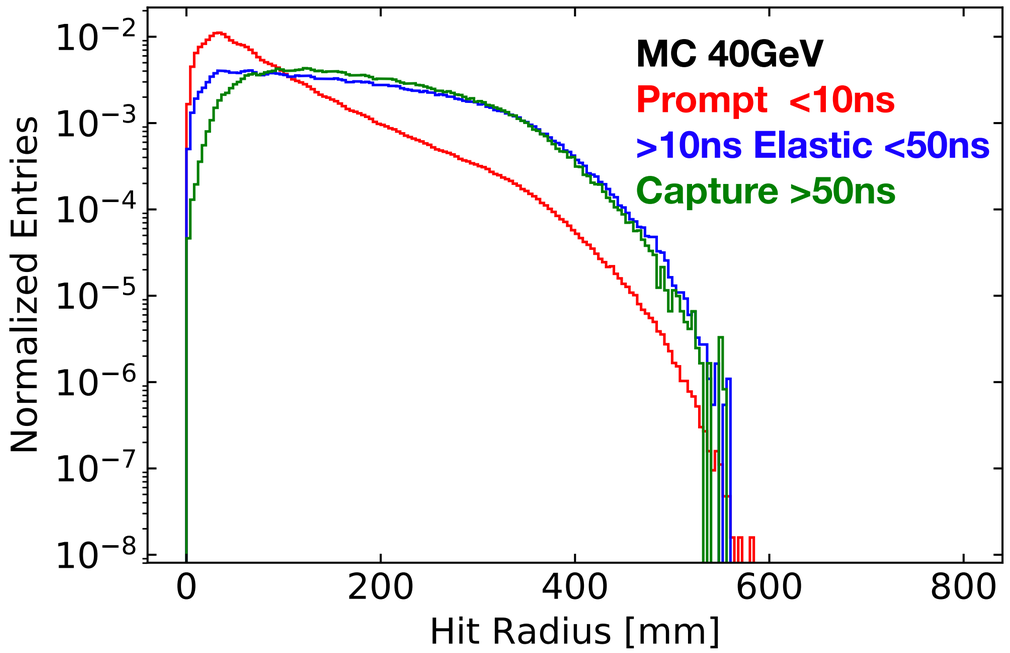


Capture: hit time >50ns

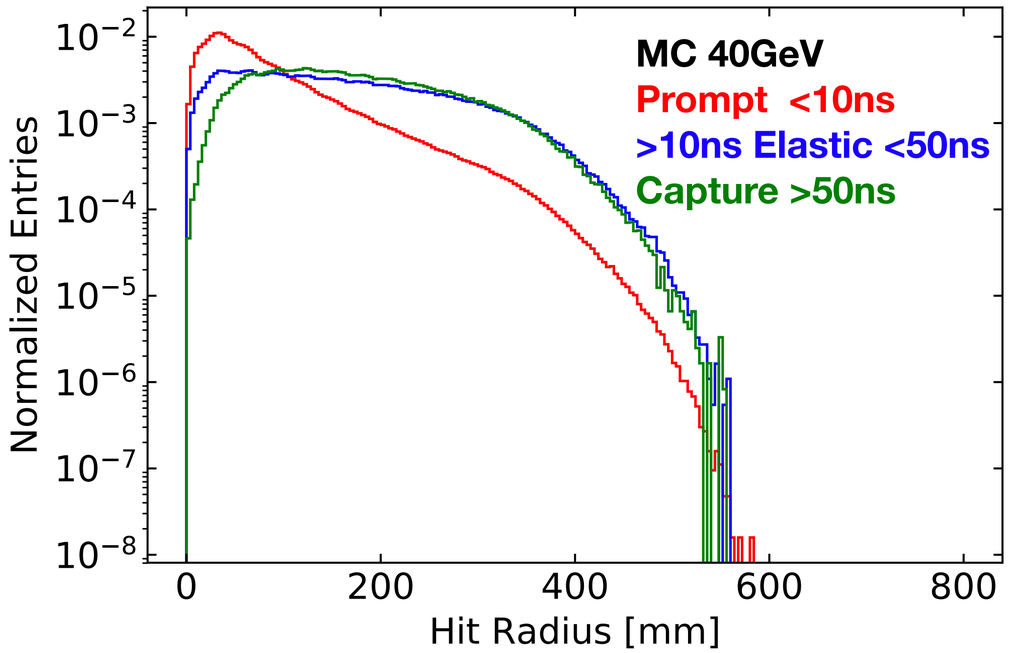


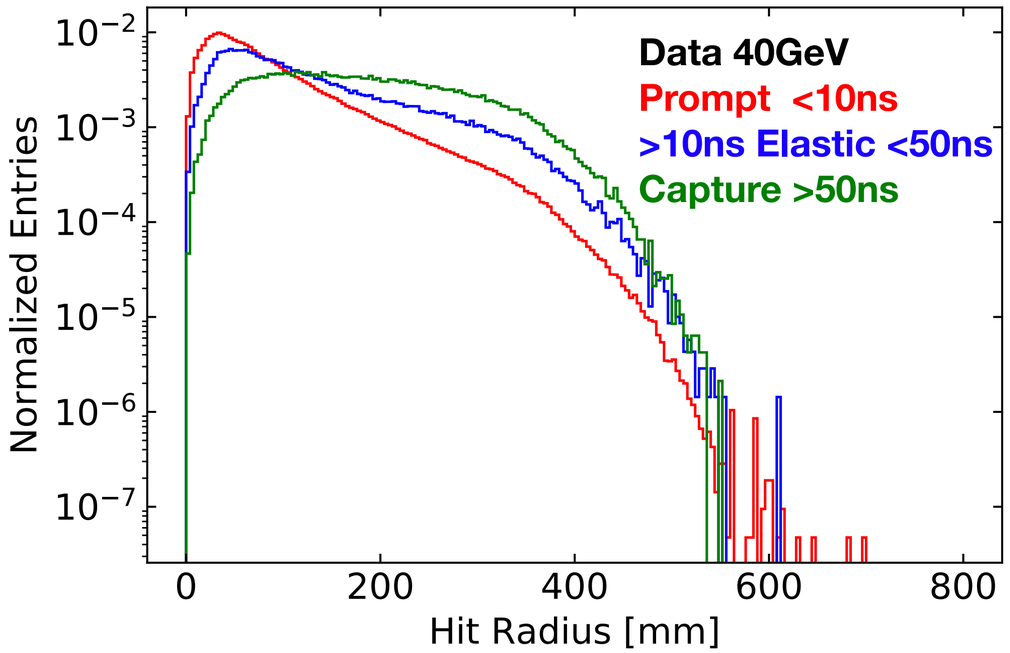
Disagreement in the low hit energy region

A Look at Pions - Hit Radius



A Look at Pions - Hit Radius

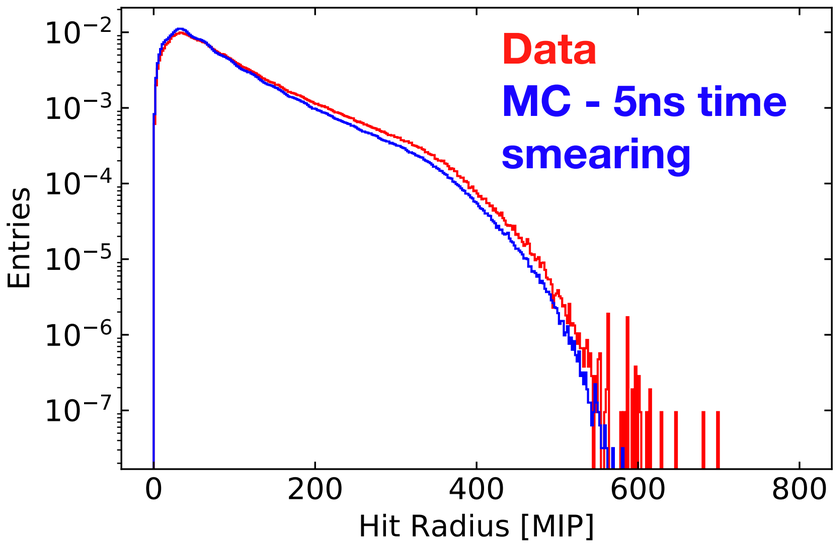




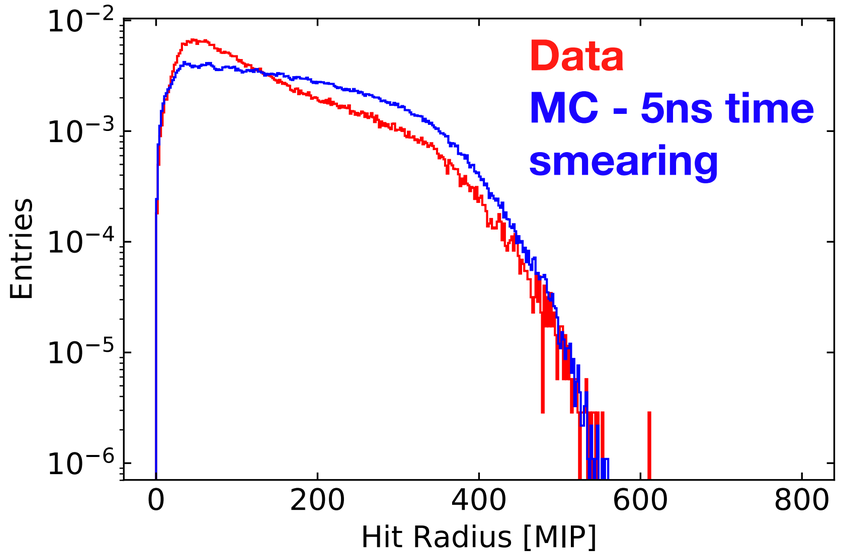
A Look at Pions - Hit Energy

MAX-PLANCK-INSTITUT FÜR PHYSIK

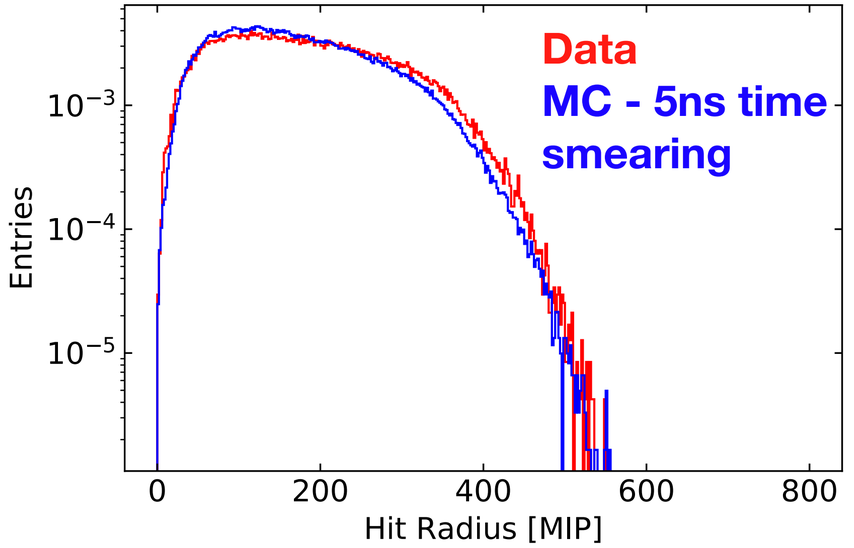
Prompt: hit time <10ns



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

Conclusion

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

Time resolution for showers @ ~5.5ns

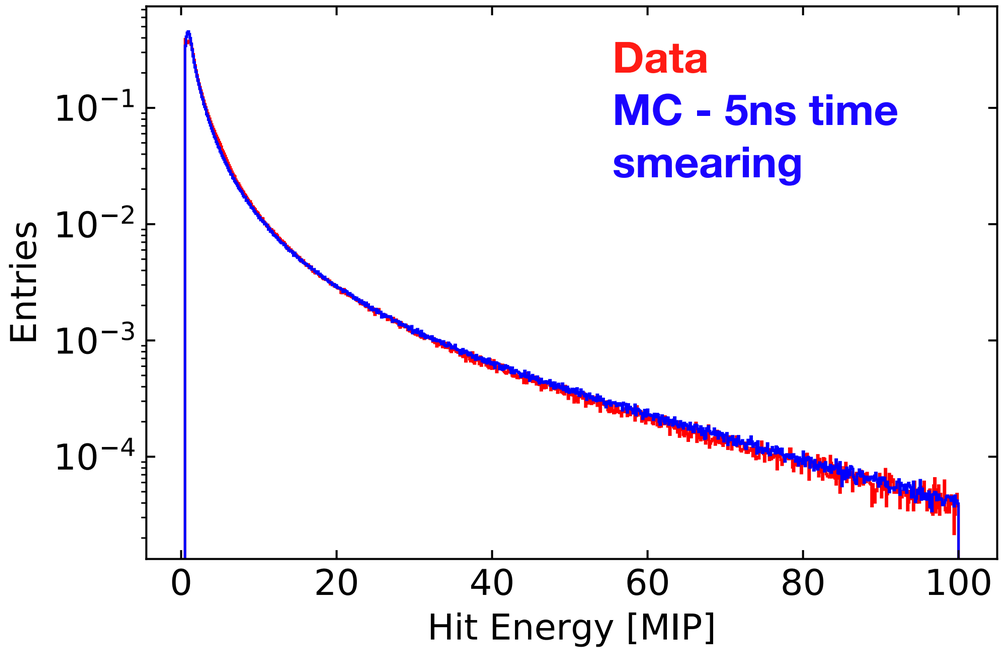
$\Longrightarrow$ Correction over the full depth possible with pion showers

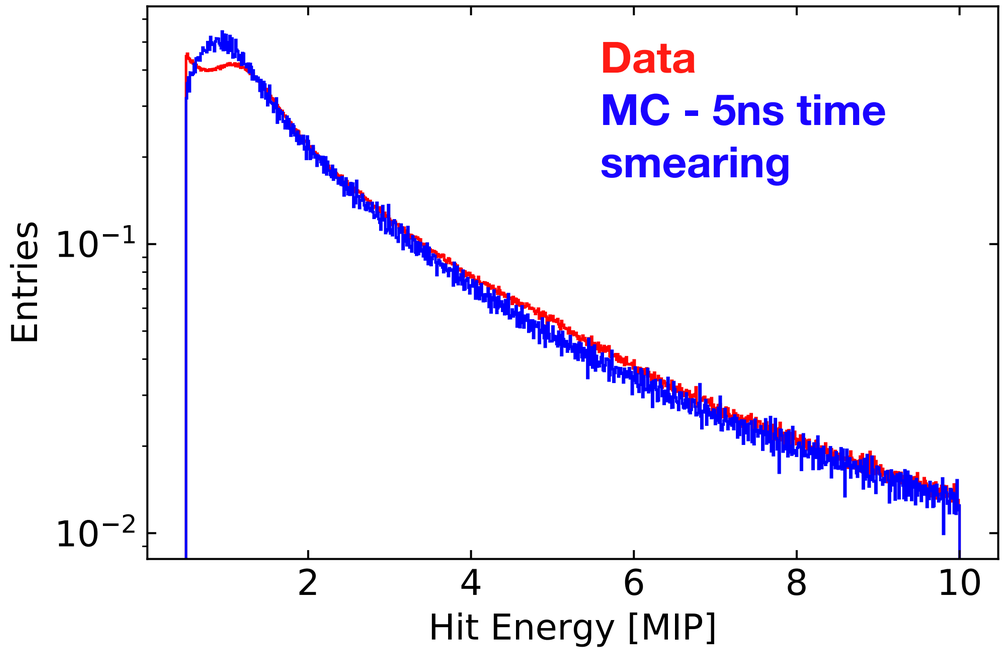
Compared to MC, the prompt and elastic part still overlap

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

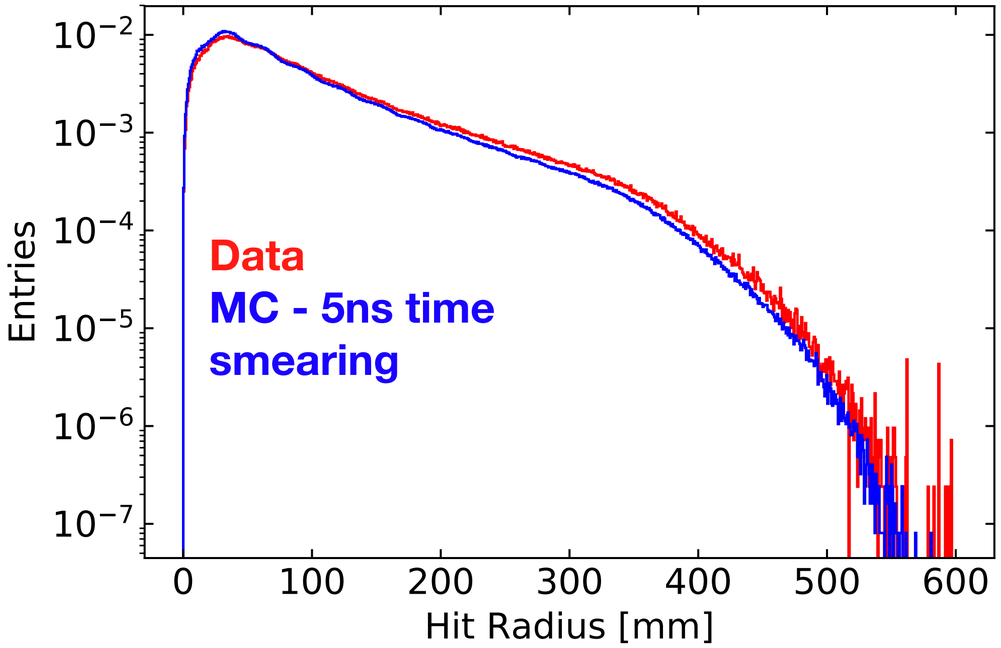
Backup

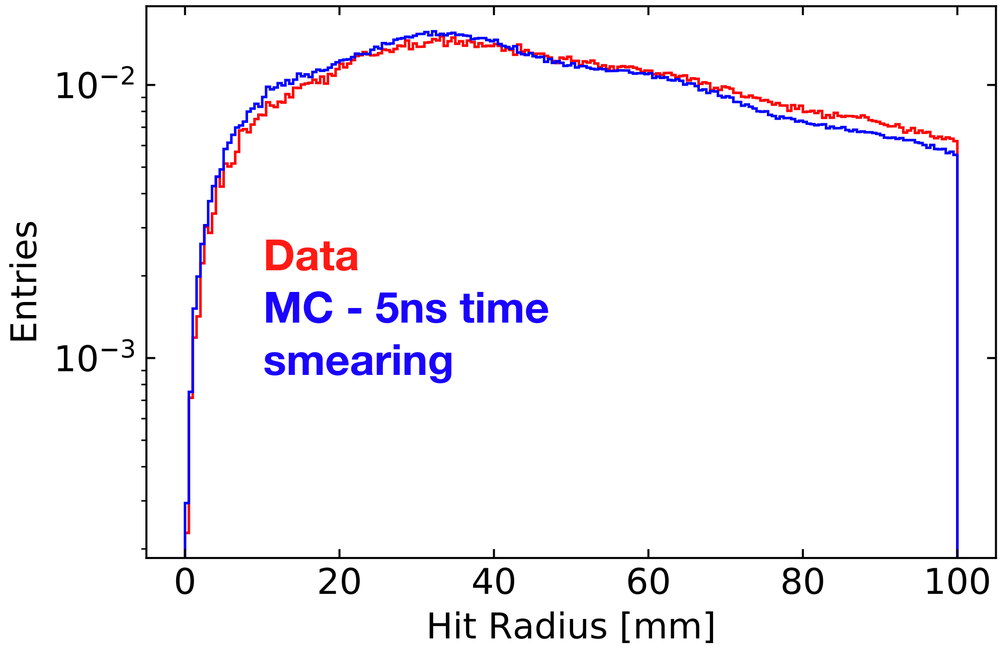
Hit Energy - Data vs MC



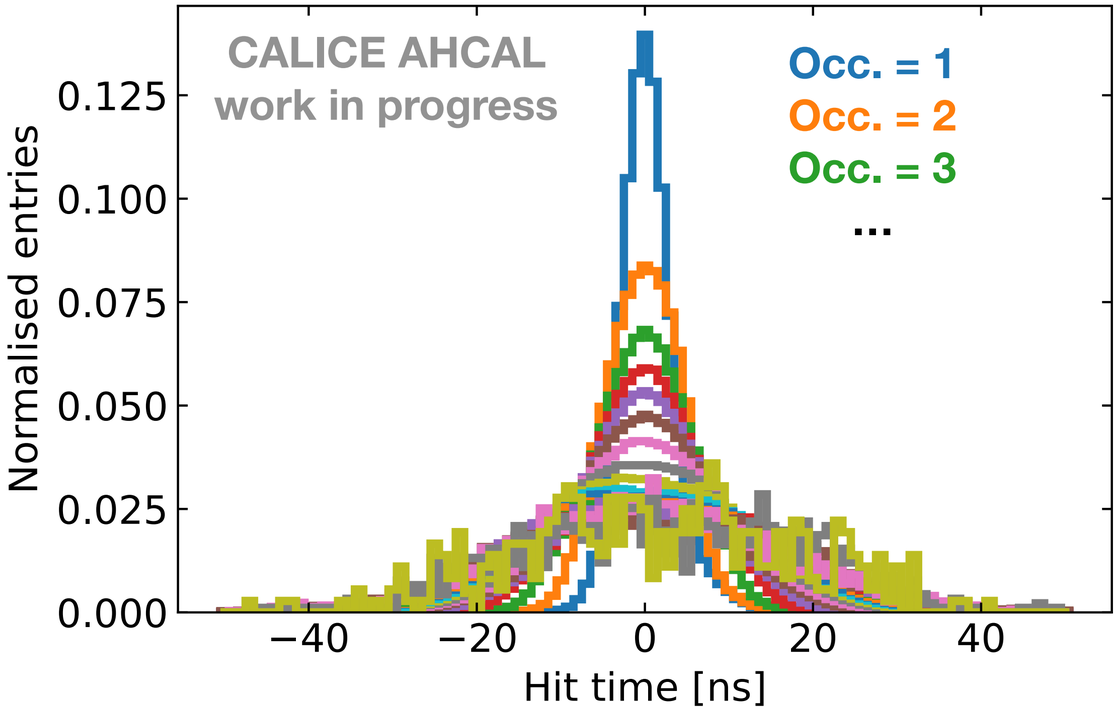


Hit Radius - Data vs MC

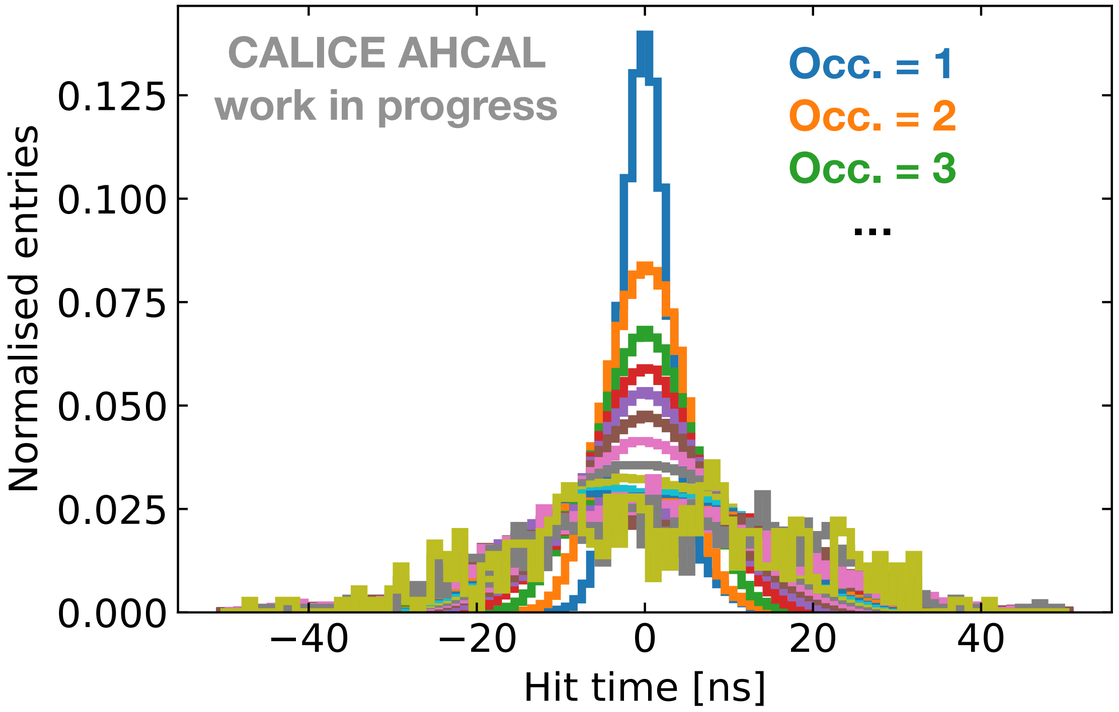


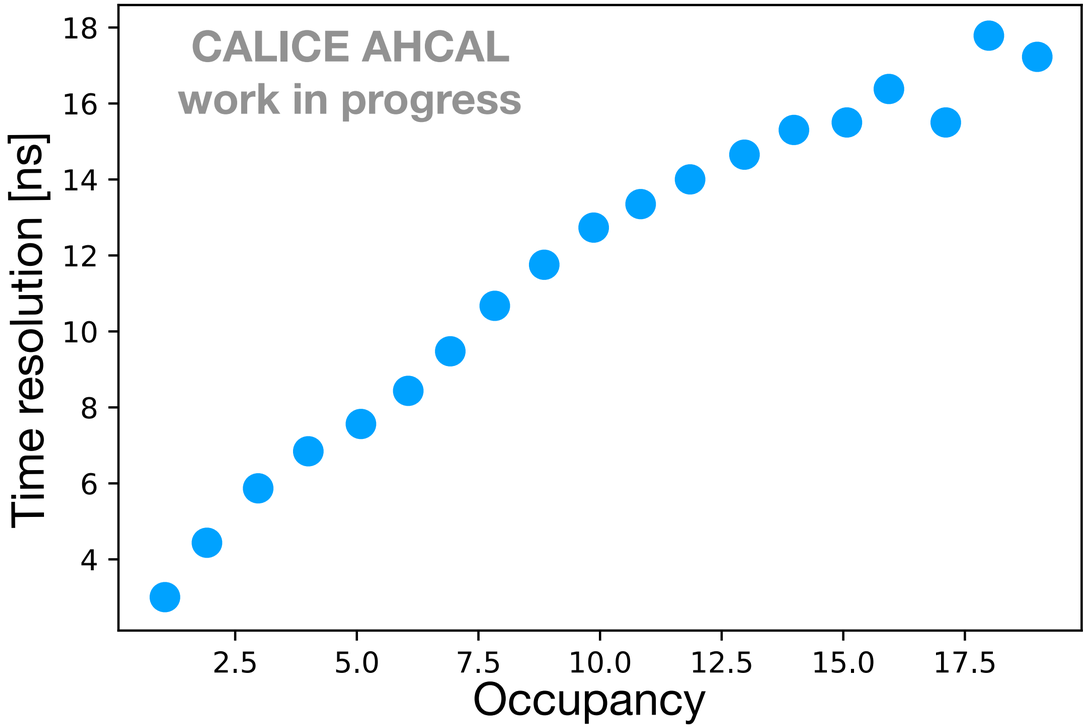


Global Correction



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