

# Timing Calibration - Status Report

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Tokyo Analysis Workshop  
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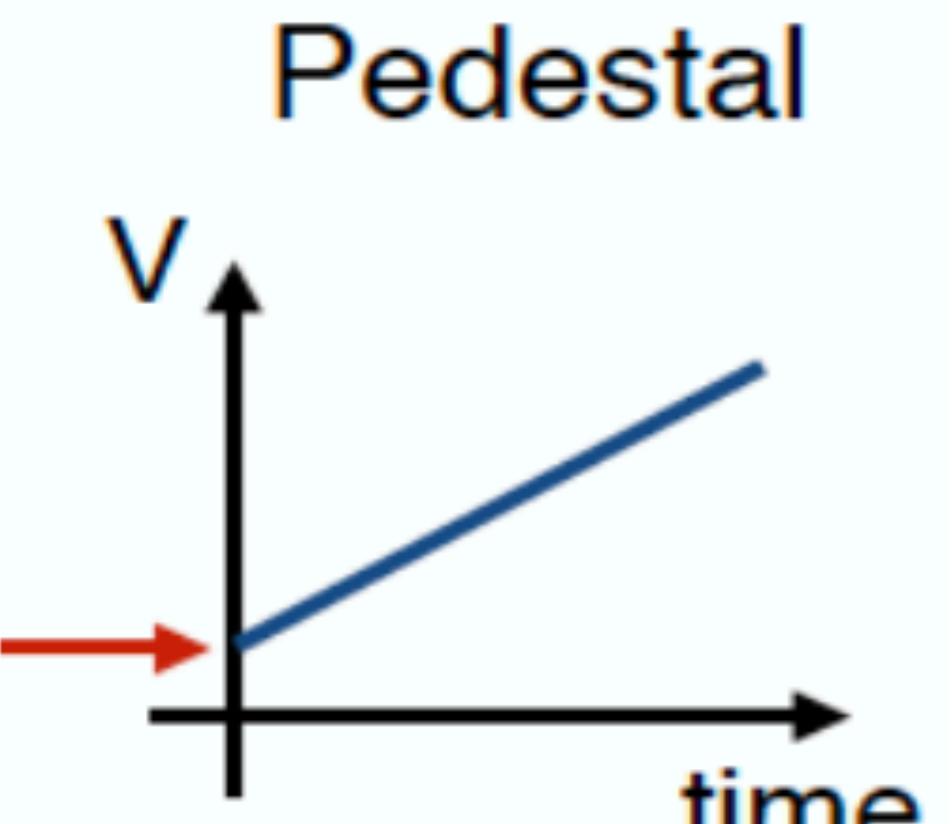
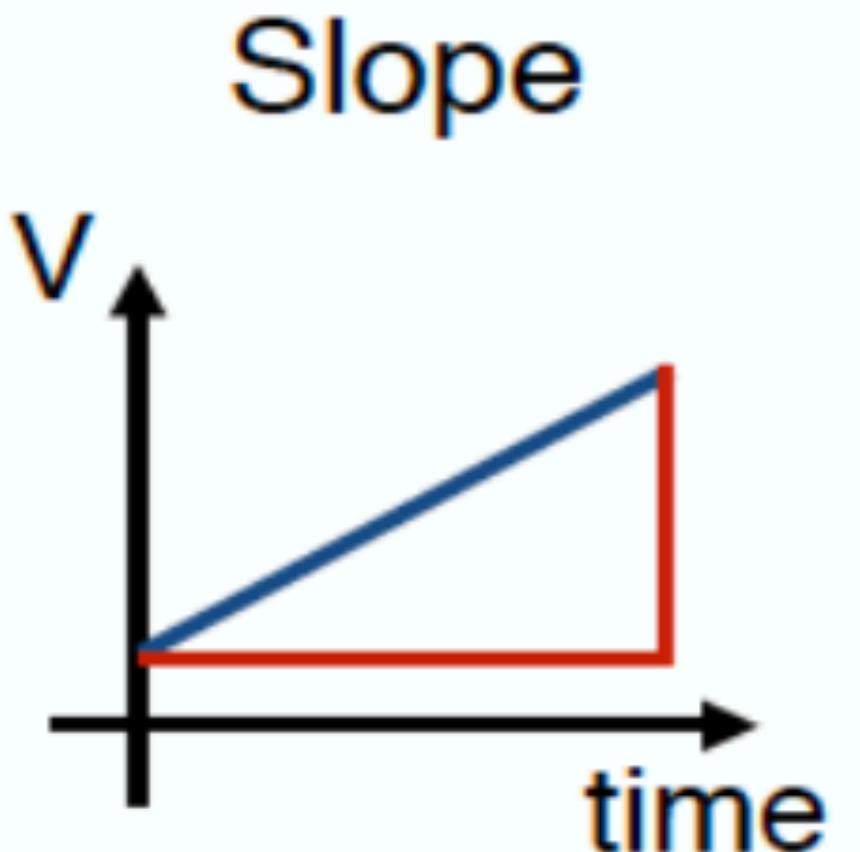
Max-Planck-Institut für Physik  
(Werner-Heisenberg-Institut)



# Reminder - Timing on SPIROC2E

Timing unit on Spiroc2E: TDC

1. BIF gives time reference (bxID)
2. Ramp up voltage for a maximum of 3920ns
  - ▶ Different slope for even and odd bxID
3. On hit, the ramp stops
4. Current voltage is stored in memory cells and digitised by ADC
5. Resulting TDC values need to be related to hit time in ns



# Reminder -Timing Calibration

Memory cells need to be calibrated against BIF reference ( $T_0$ )

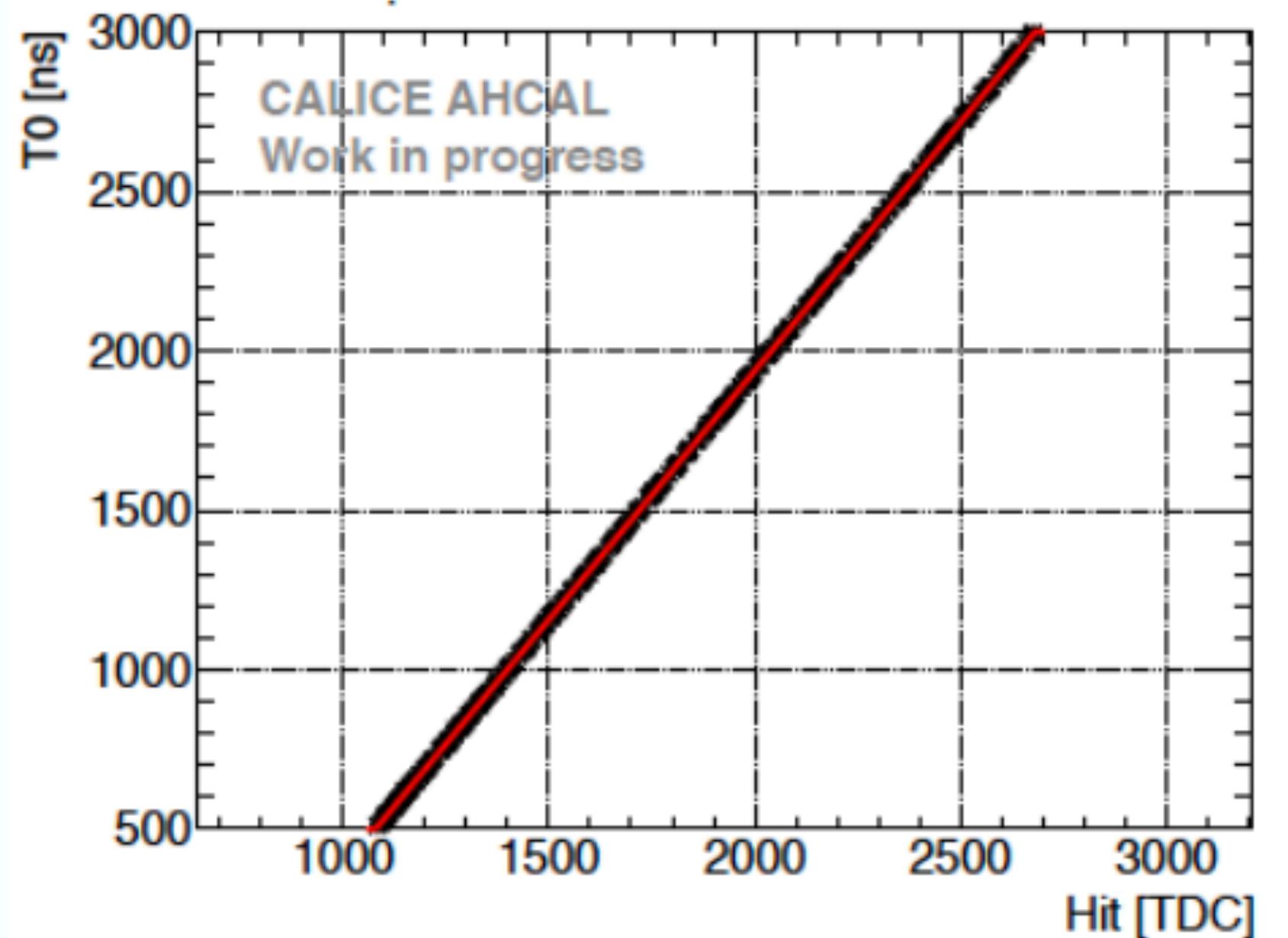
## 1. Extract slope for even and odd bxID per chip

1. Perform robust linear fit between 500ns and 3000ns for first memory cell of each channel
2. Reject hits off by  $>10\text{ns}$
3. Median of all slopes is taken as common slope for chip

## 2. Extract offset for every memory cell

1. Perform linear fit for every memory cell with fixed slope of the respective chip

[calice\\_calib/calib/Ahc2TimingCalibrator.cpp](#)

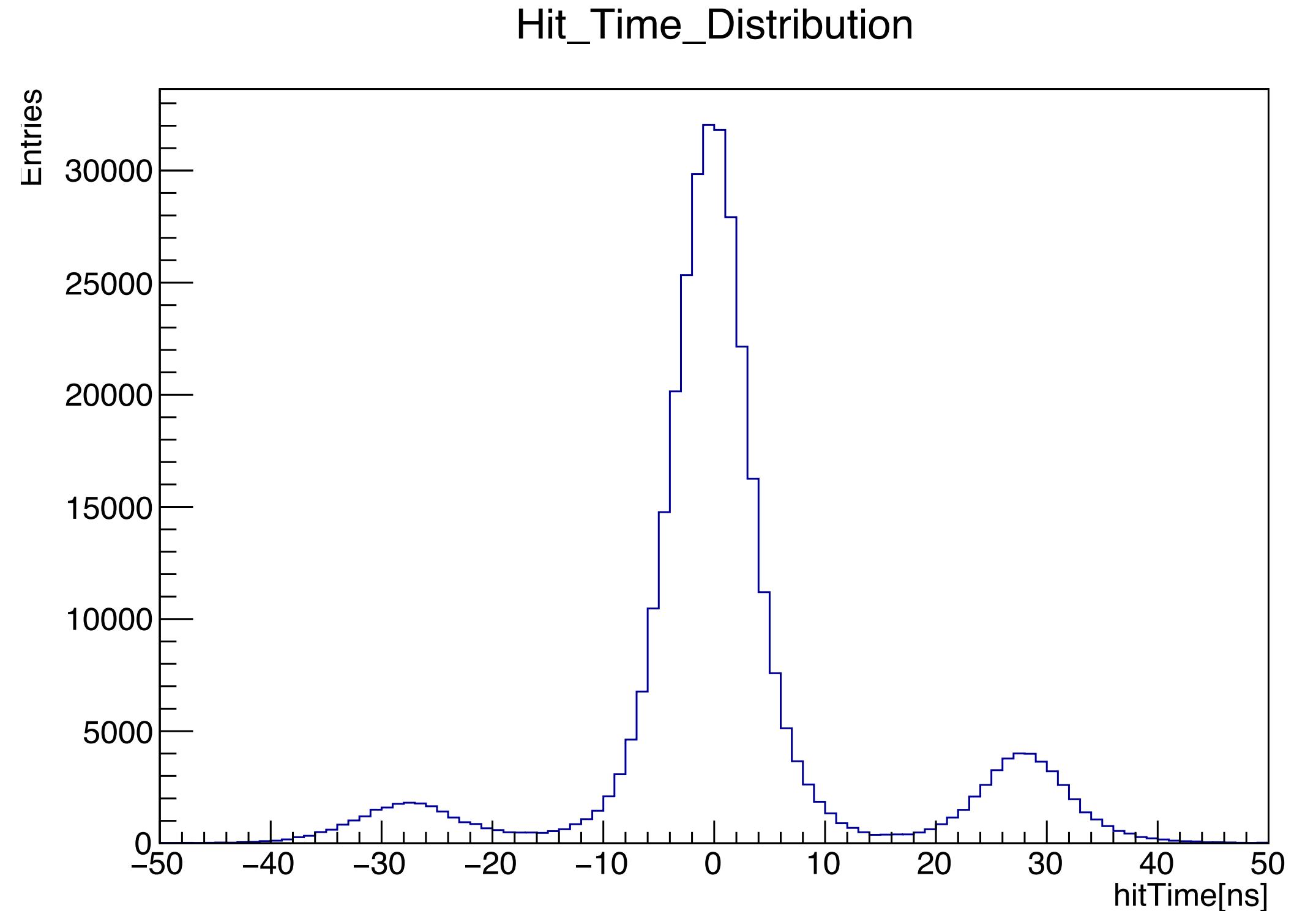


$$t_{hit}[\text{ns}] = \text{TDC}_{hit} \cdot \text{Slope} \left[ \frac{\text{ns}}{\text{TDC}} \right] + \text{Offset} [\text{ns}] - T_0$$

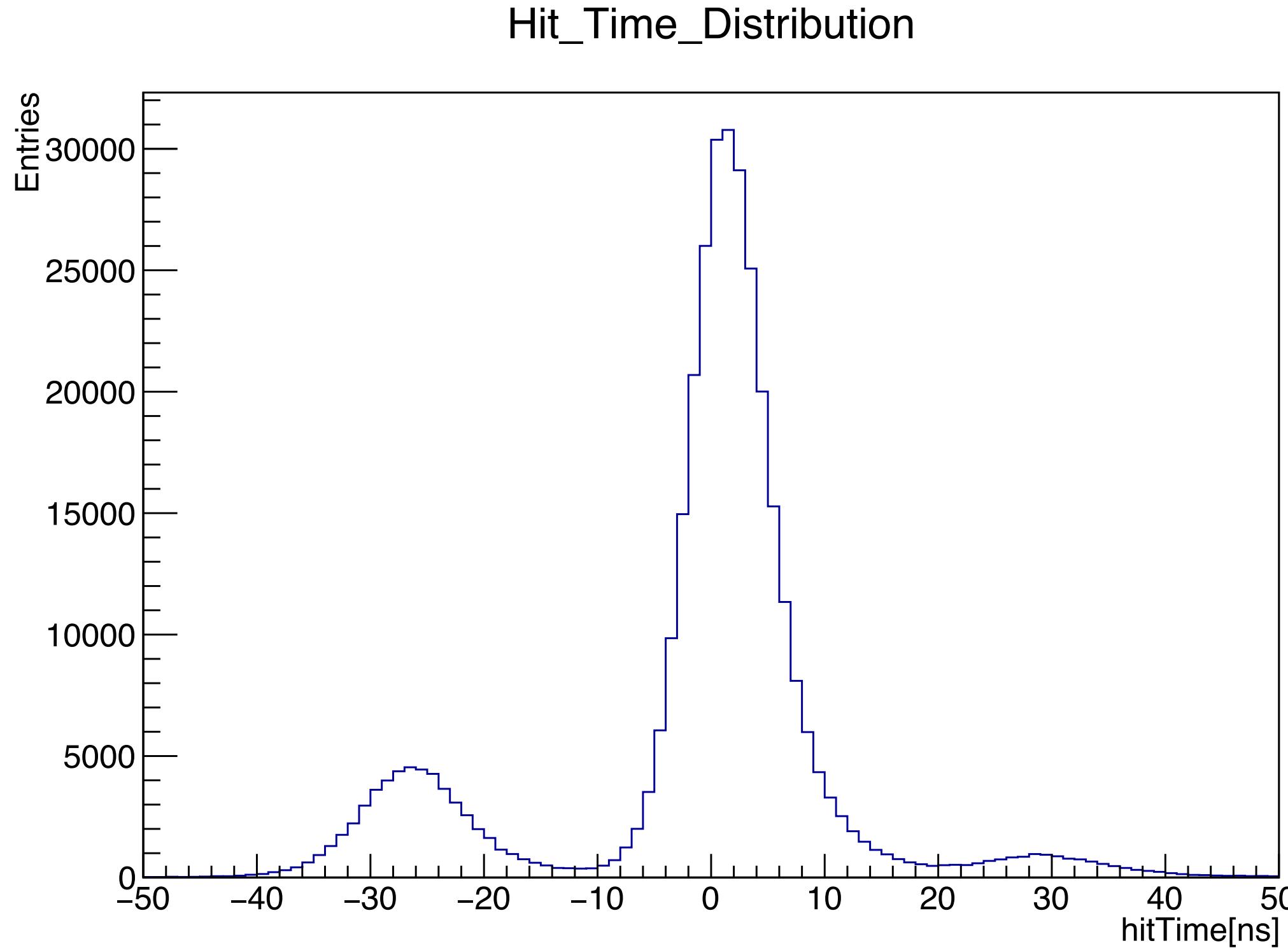


# Starting Point - Satellite Peaks

Even bxID



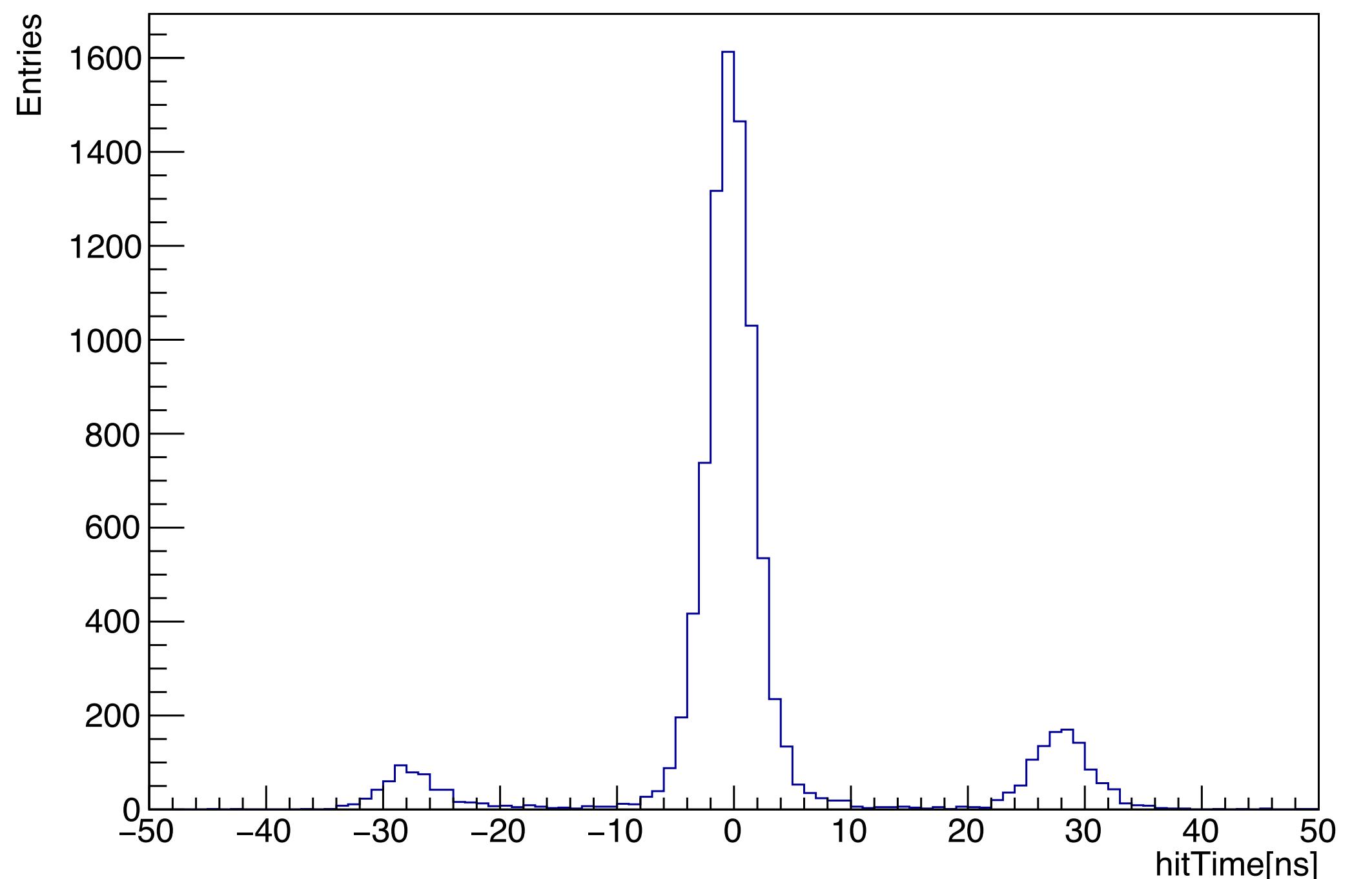
Odd bxID



# Mean Hit Time

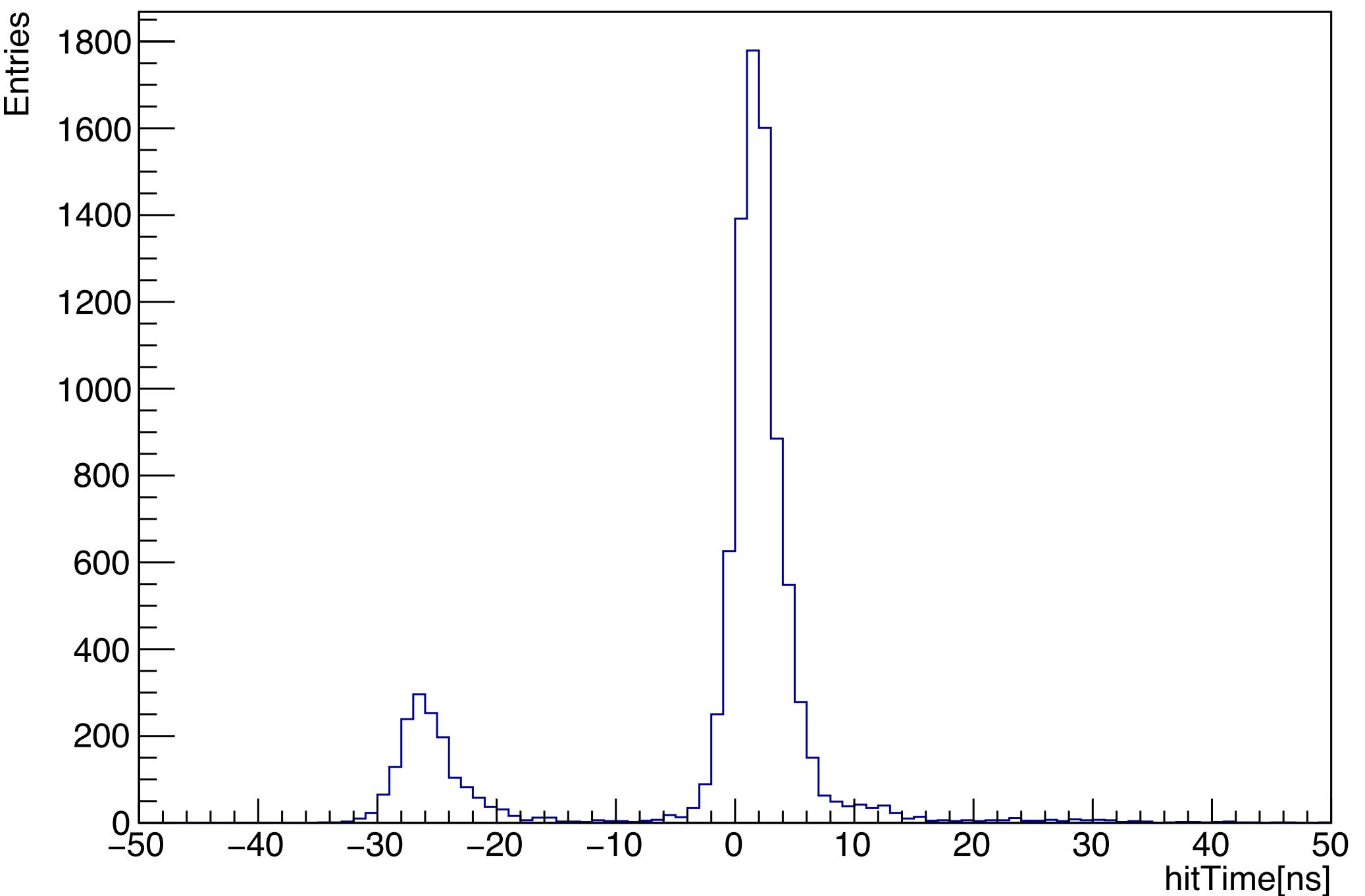
Even bxID

Hit\_Time\_Distribution



Odd bxID

Hit\_Time\_Distribution

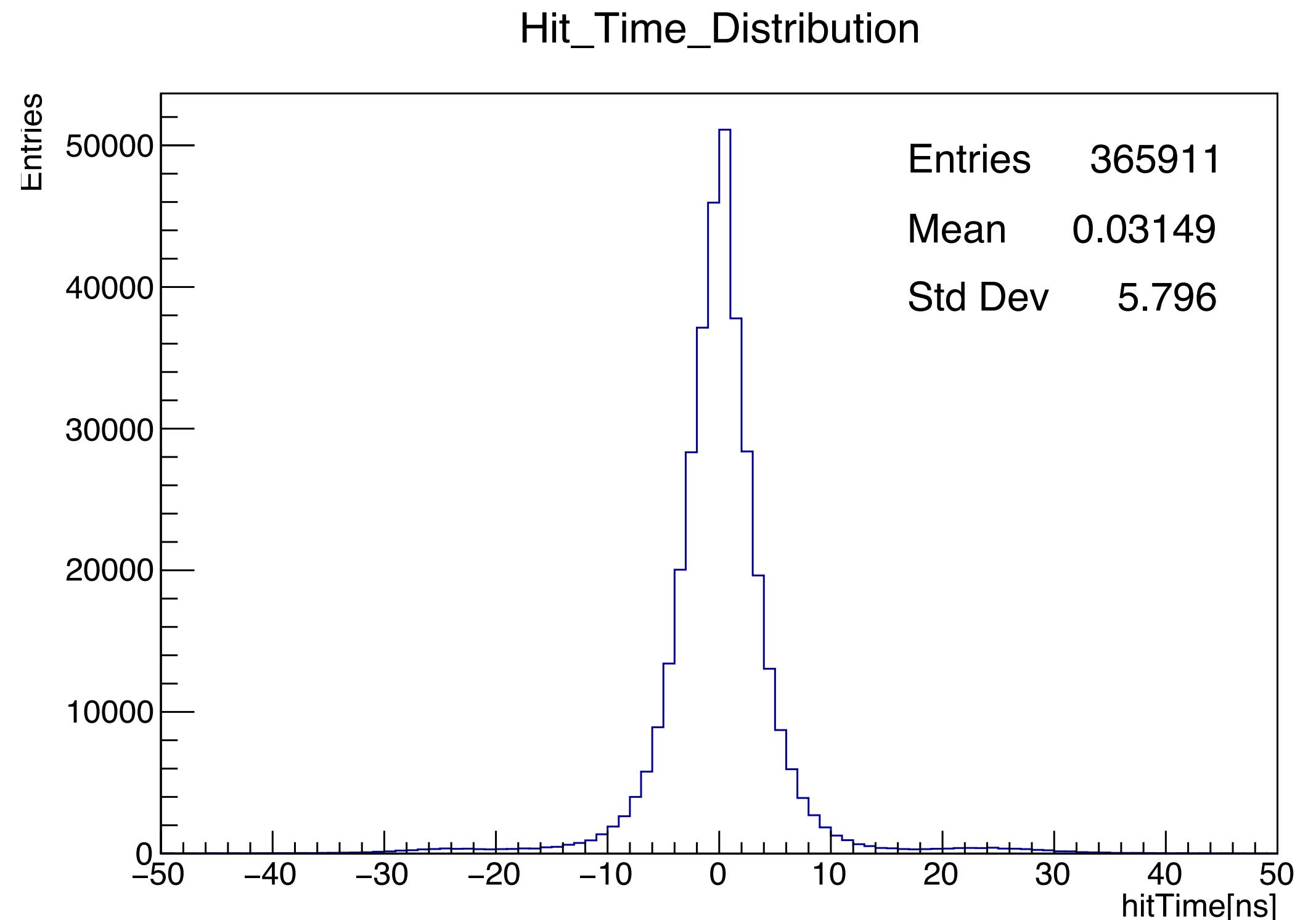


Assumption: Whole event is shifted instead of single hits

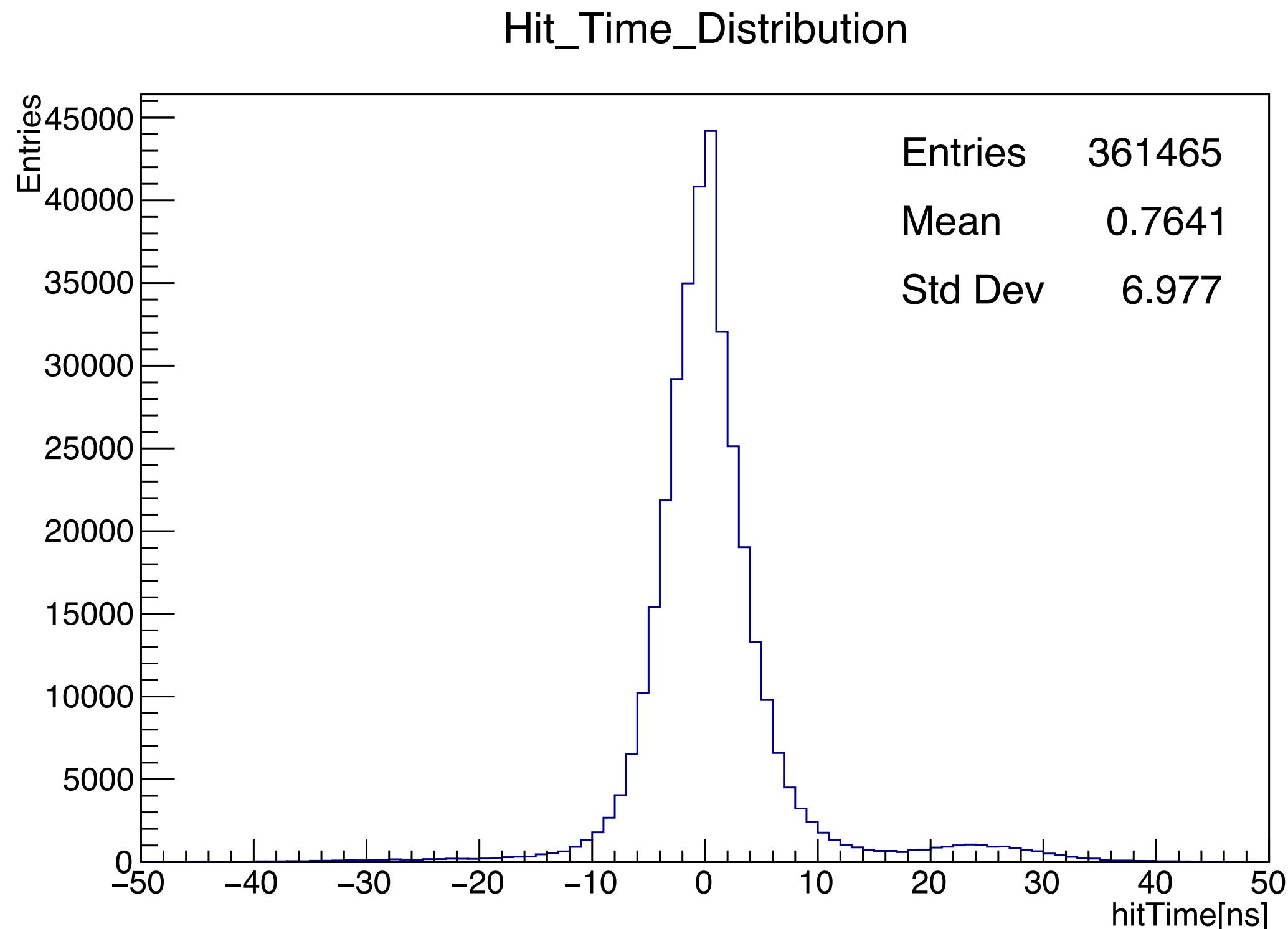


# Correction of Shifted Events

Even bxID



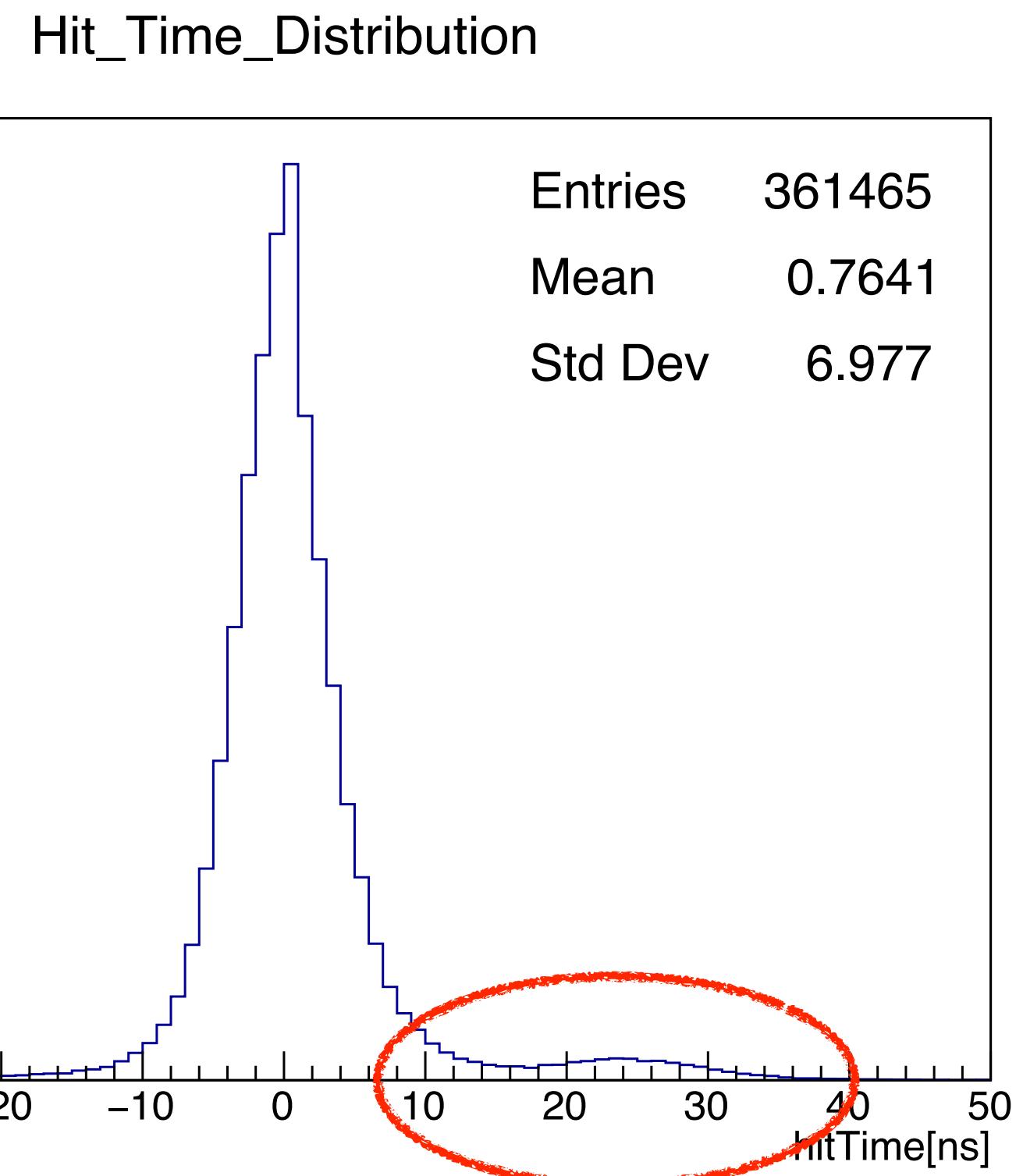
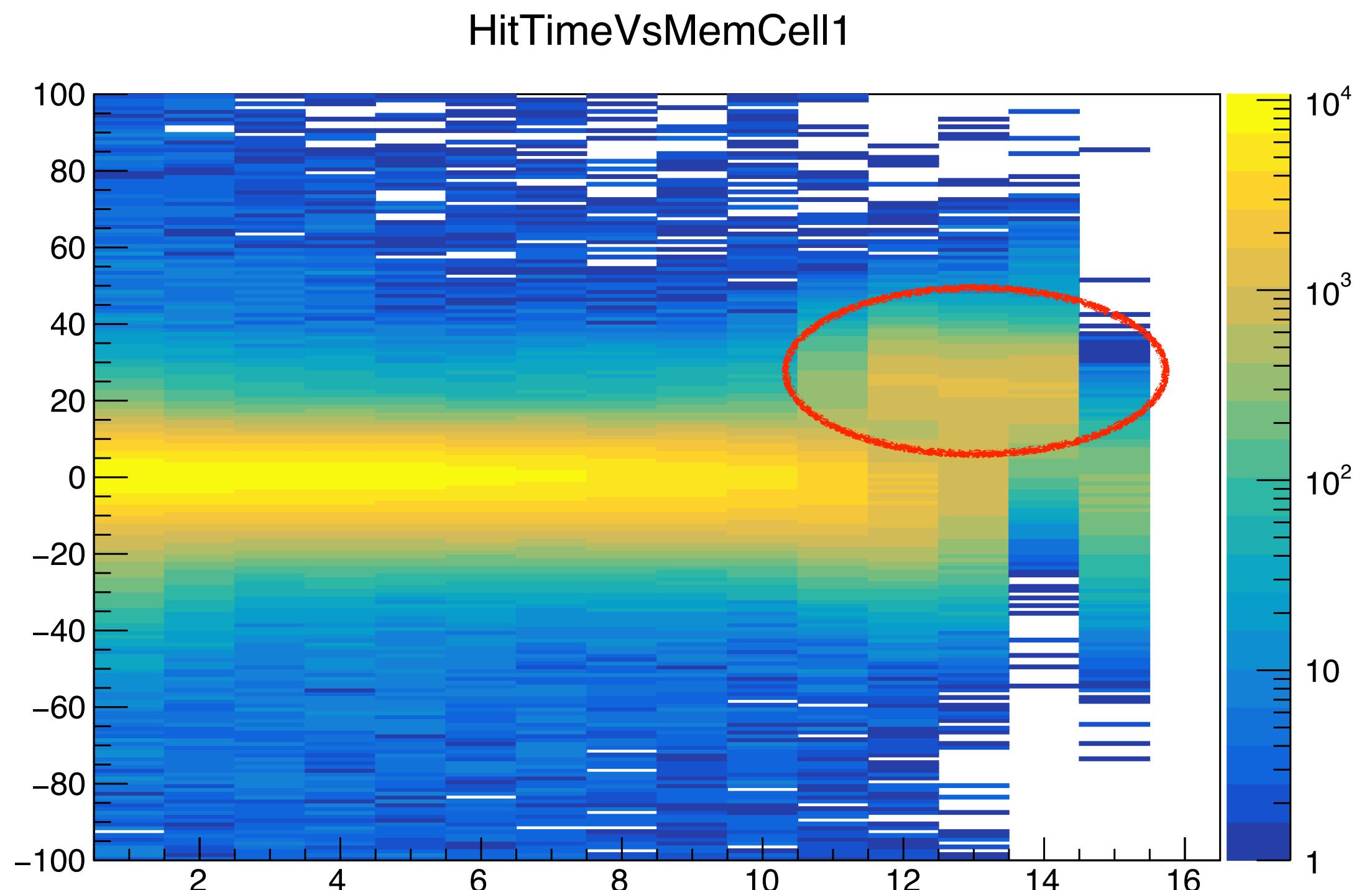
Odd bxID



Shift corrects the satellite peaks and does not broaden the distribution

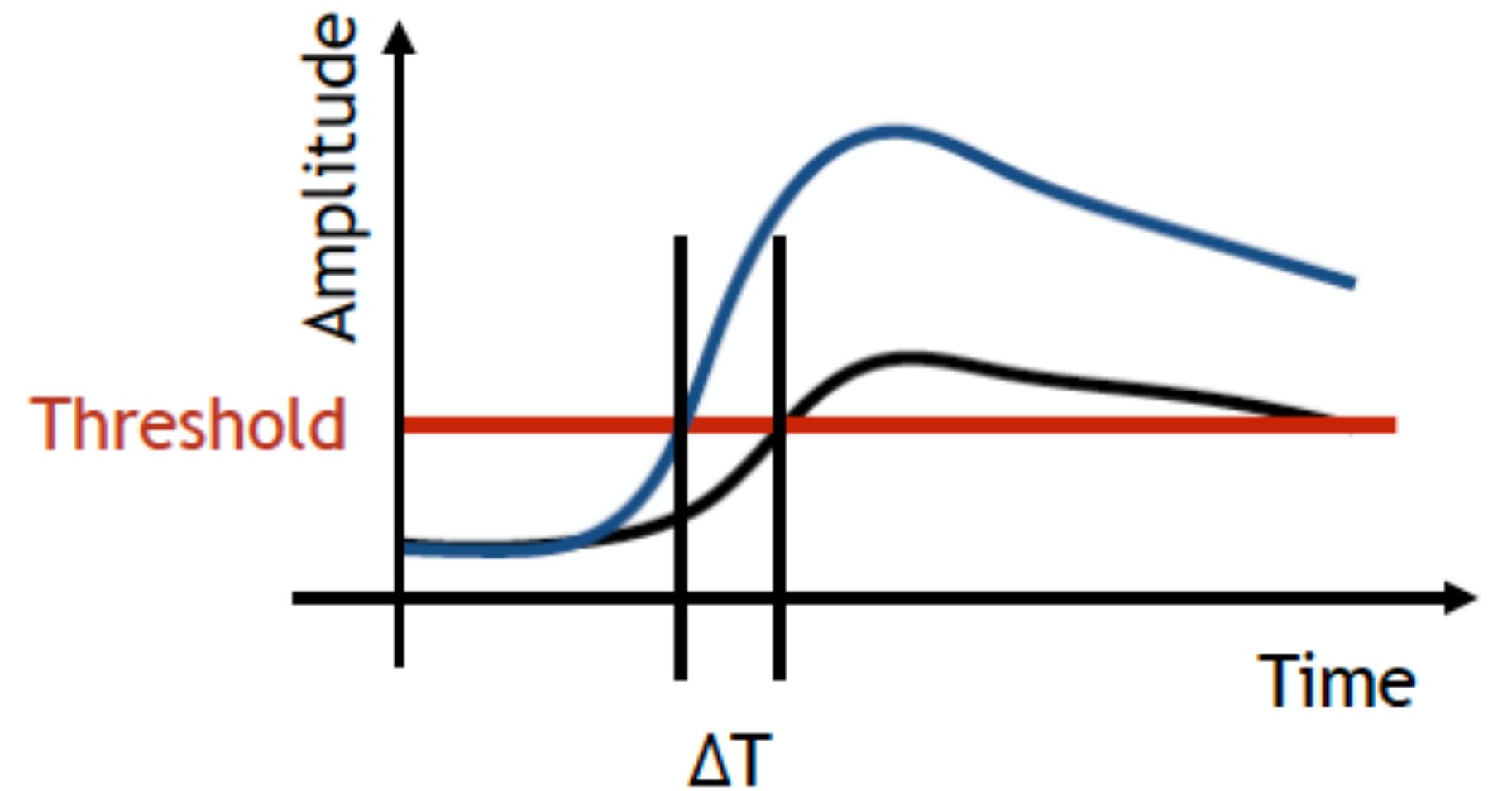
# Correction of Shifted Events

Odd bxID



Shift of hit times in memory cells 11 to 15

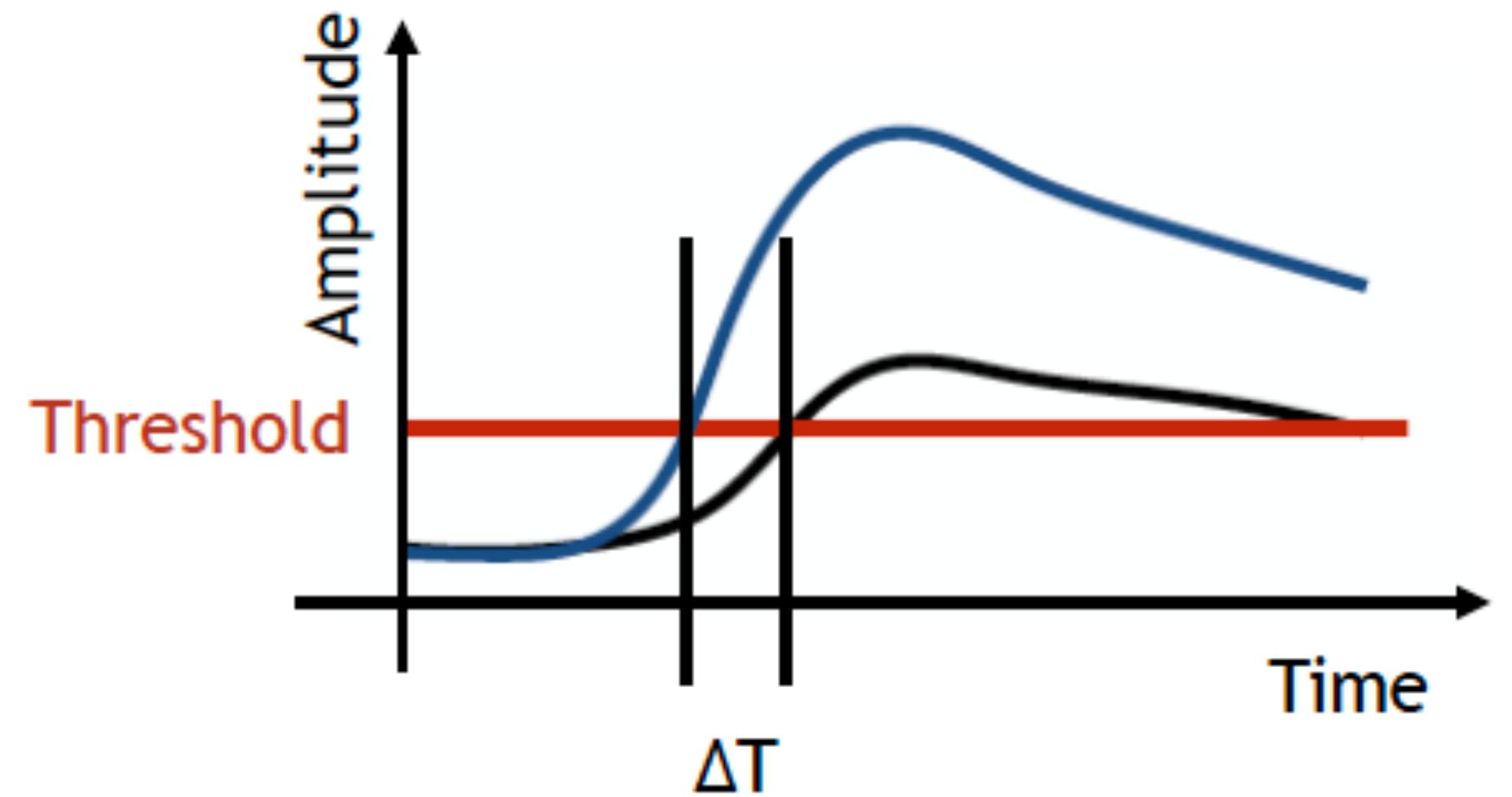
# Time Walk Correction



Higher amplitudes of similar shaped signals cause a steeper rising edge

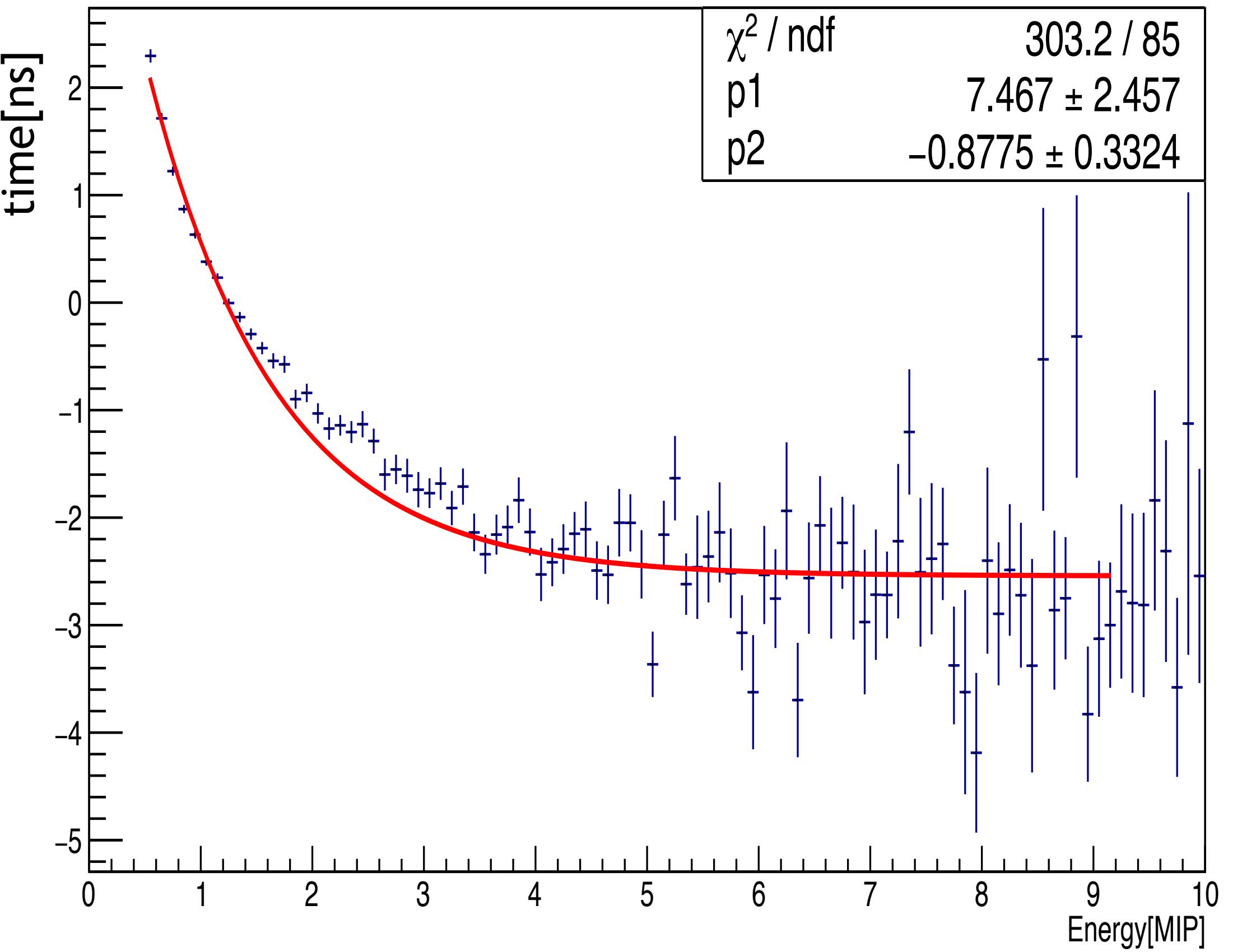
- ▶ Fixed threshold is crossed earlier

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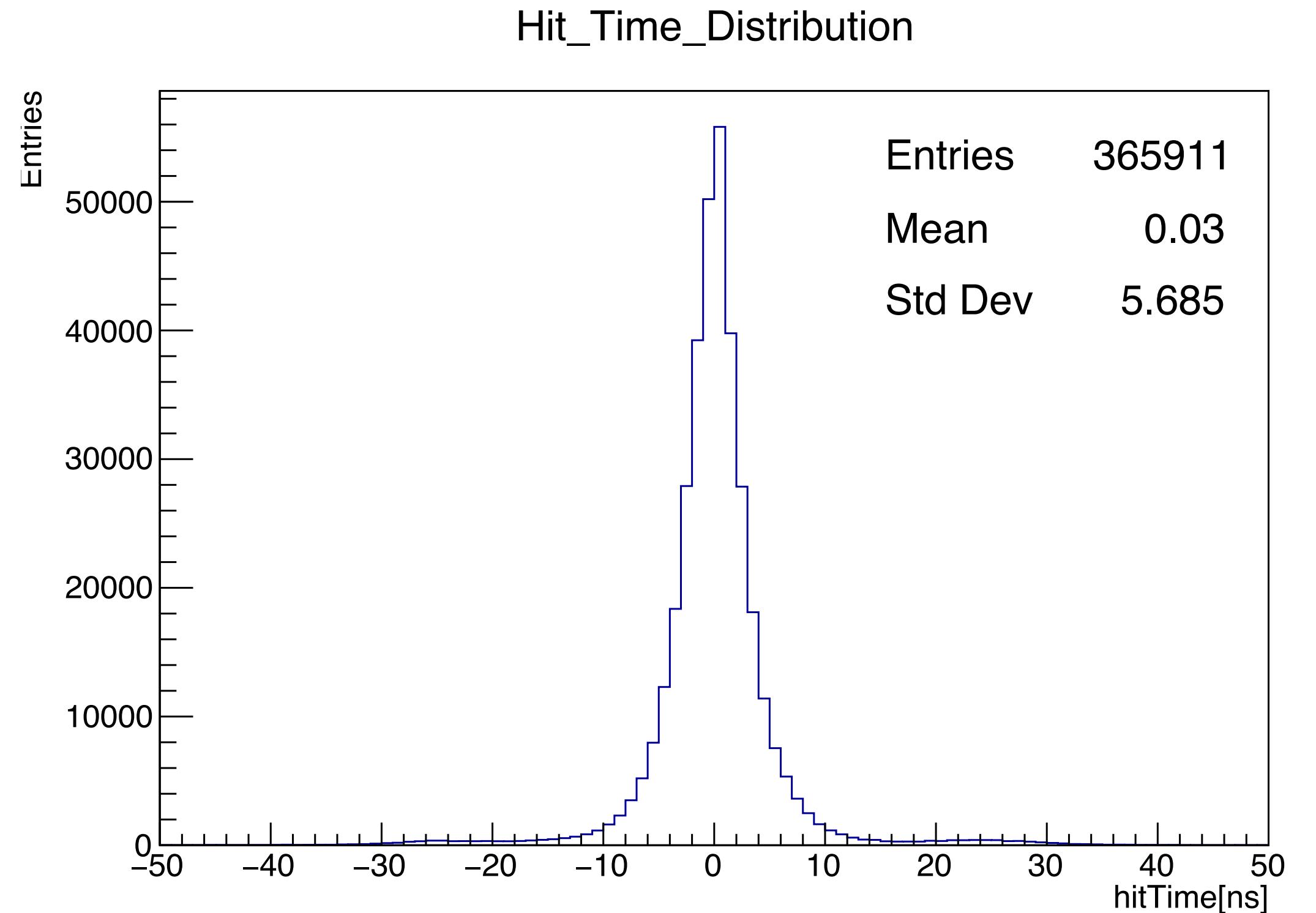
- Fixed threshold is crossed earlier



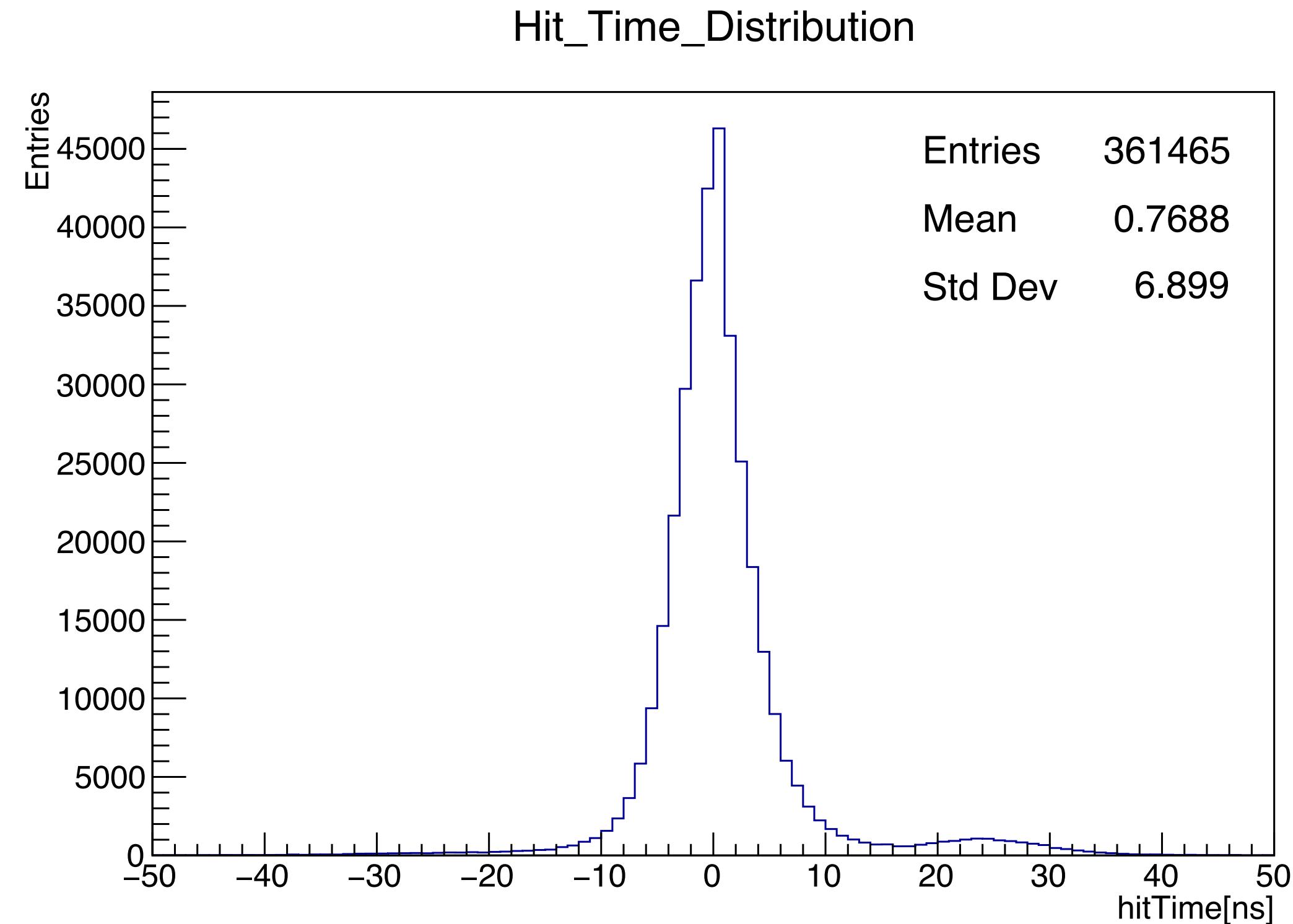
$$t[\text{ns}] = 2.58 + 7.47e^{-0.88 \cdot E[\text{MIP}]}$$

# Time Walk Correction

Even bxID



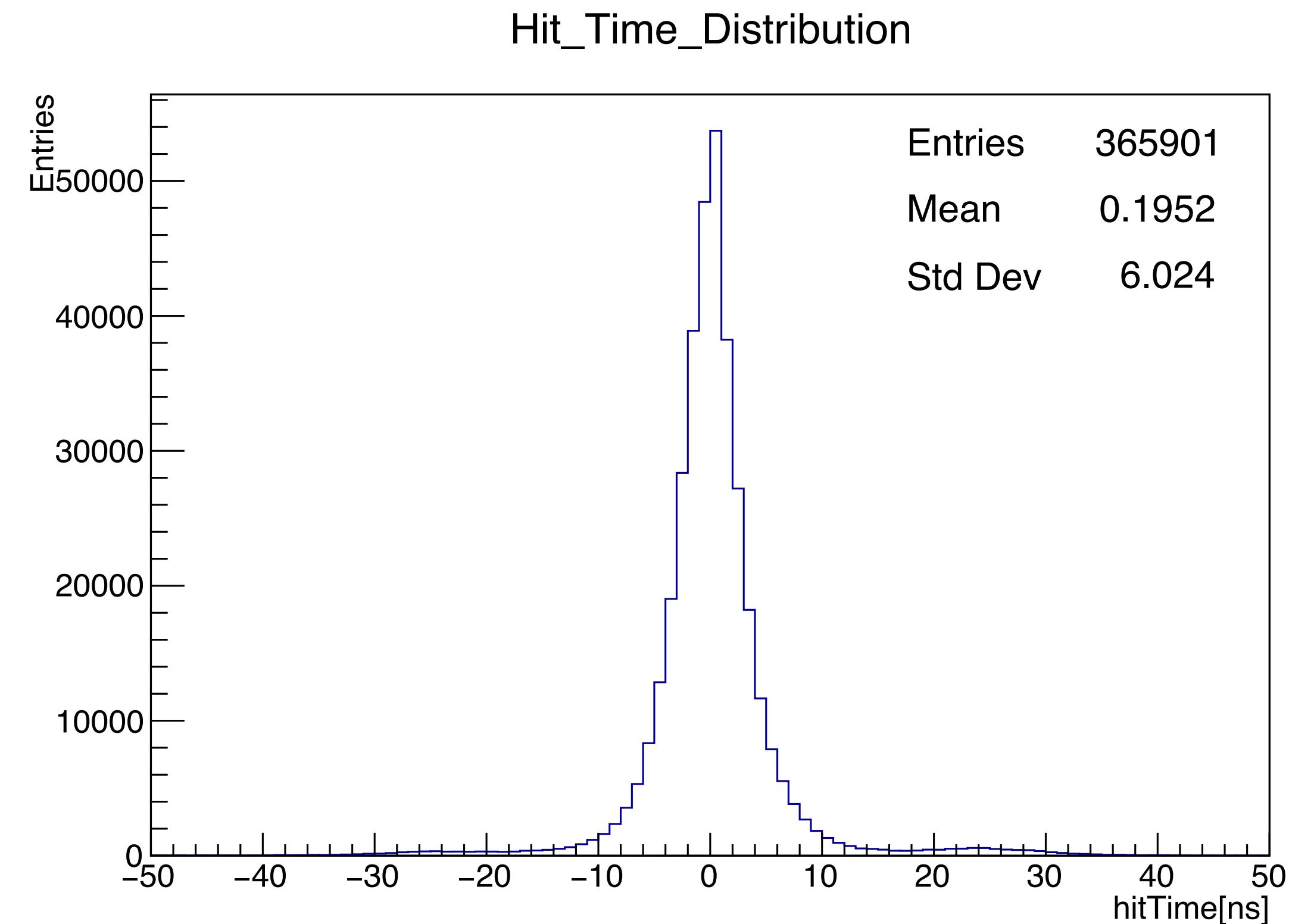
Odd bxID



Shift of hit times in late memory cells causes a deterioration of the time resolution of ~1ns

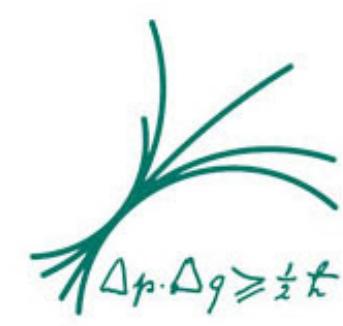
# Muon Time Resolution

## Even and odd bxIDs



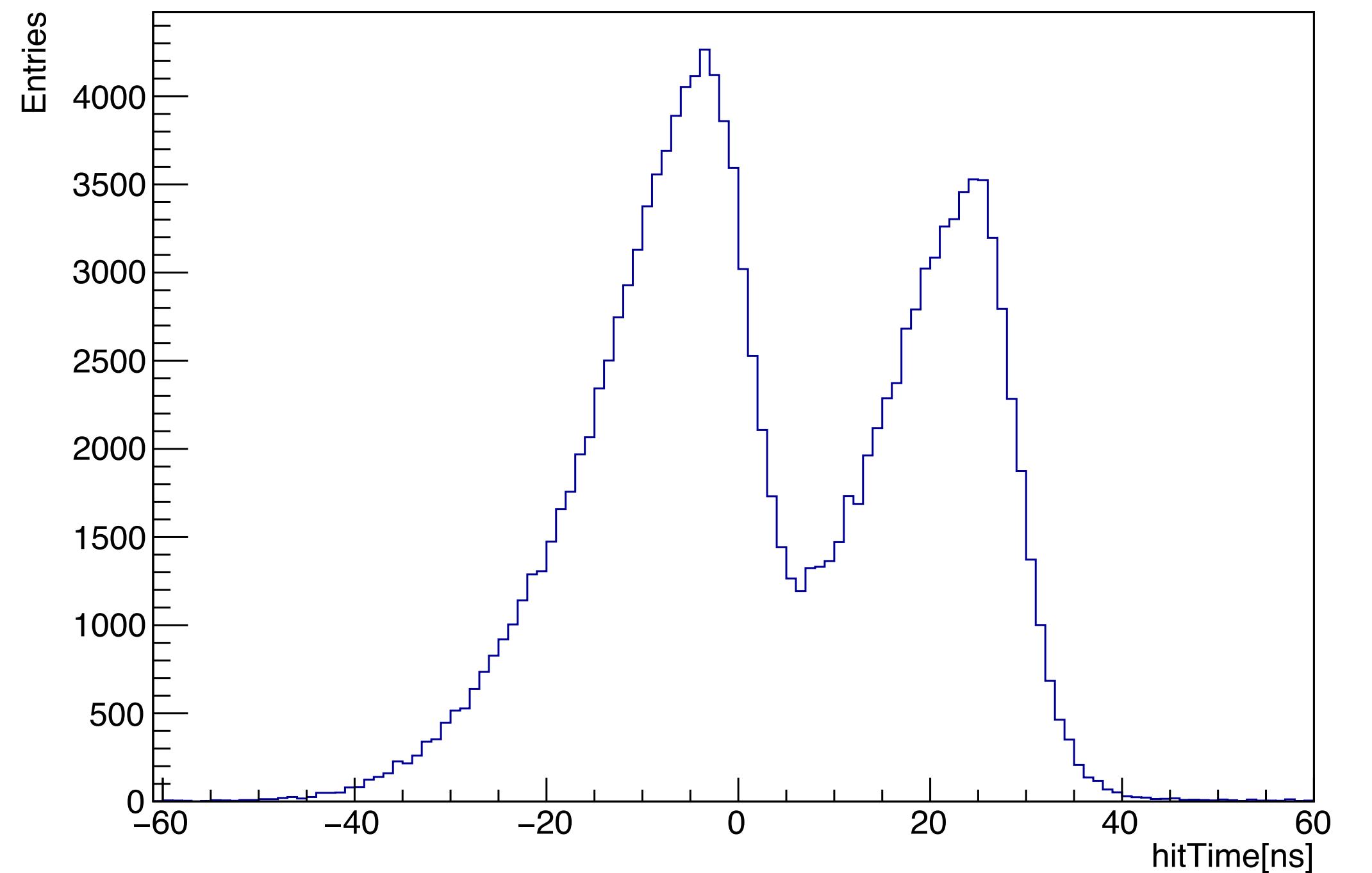
- Correction of the mean hit time per event corrects the satellite peaks in the hit time distribution
- Time walk correction yields only a small improvement
- Bump caused by last memory cells in odd bxID still present

# Electron Time Resolution



Even bxID

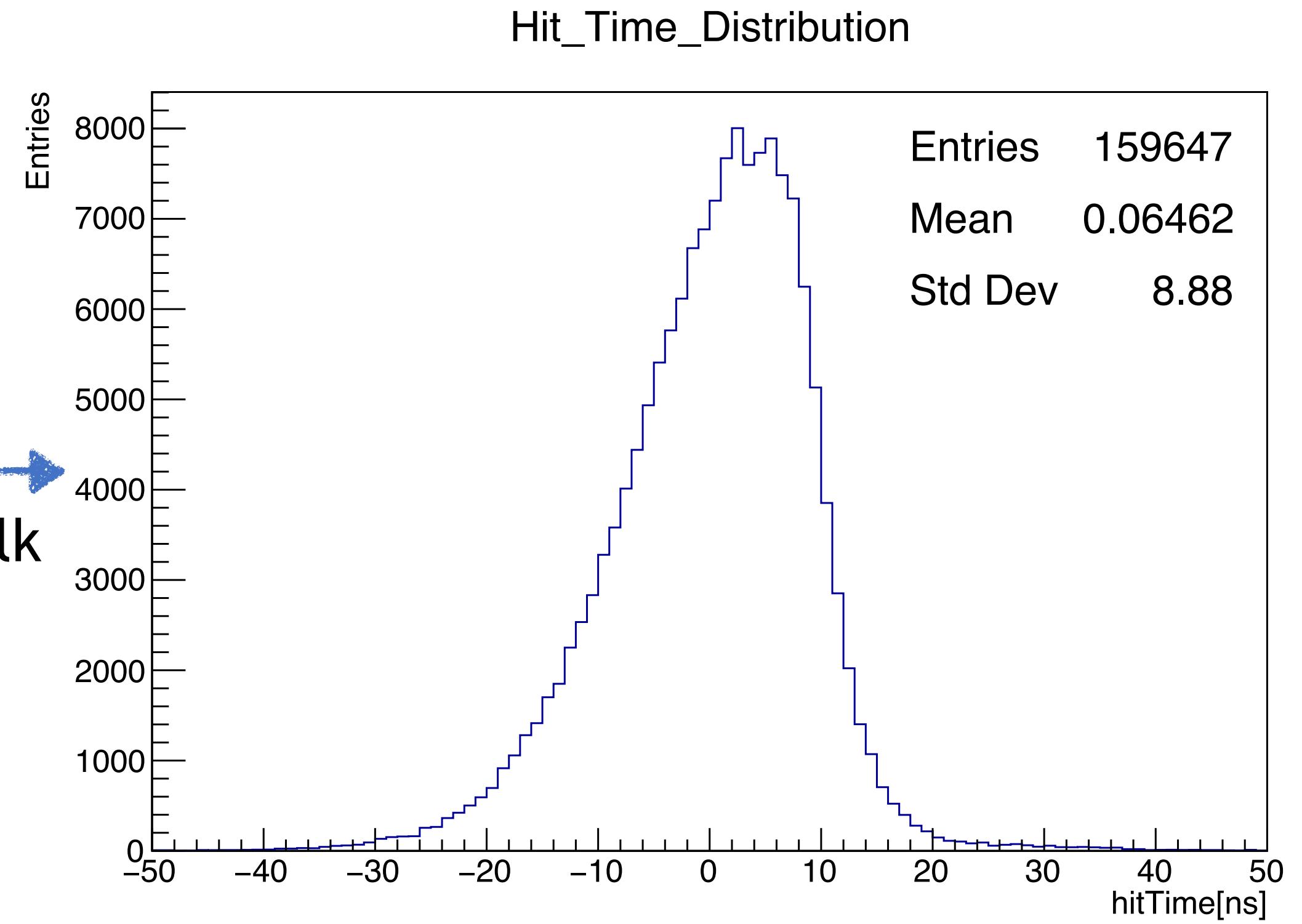
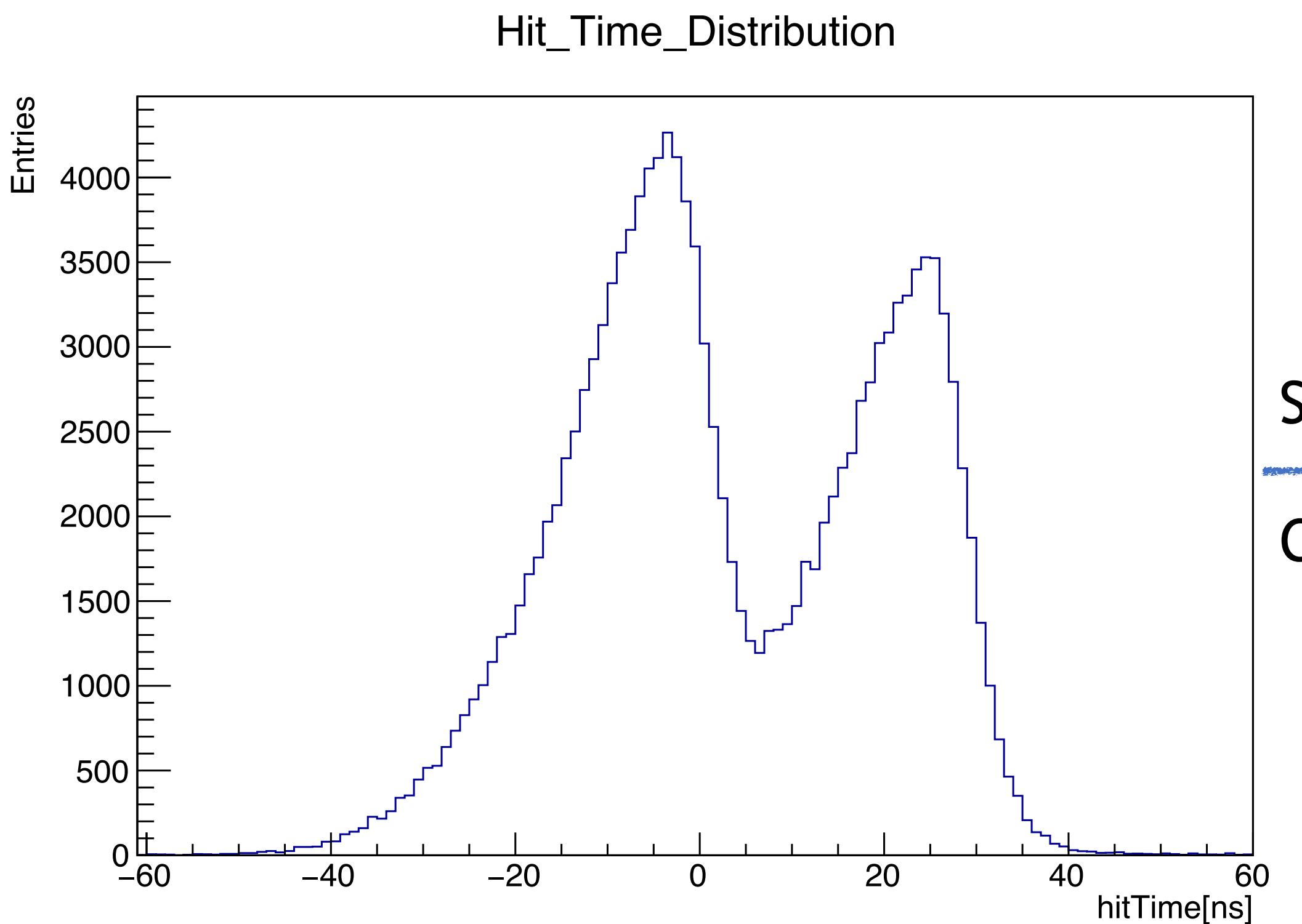
Hit\_Time\_Distribution



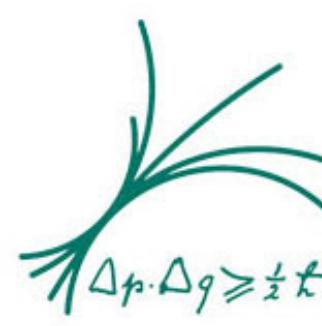
# Electron Time Resolution



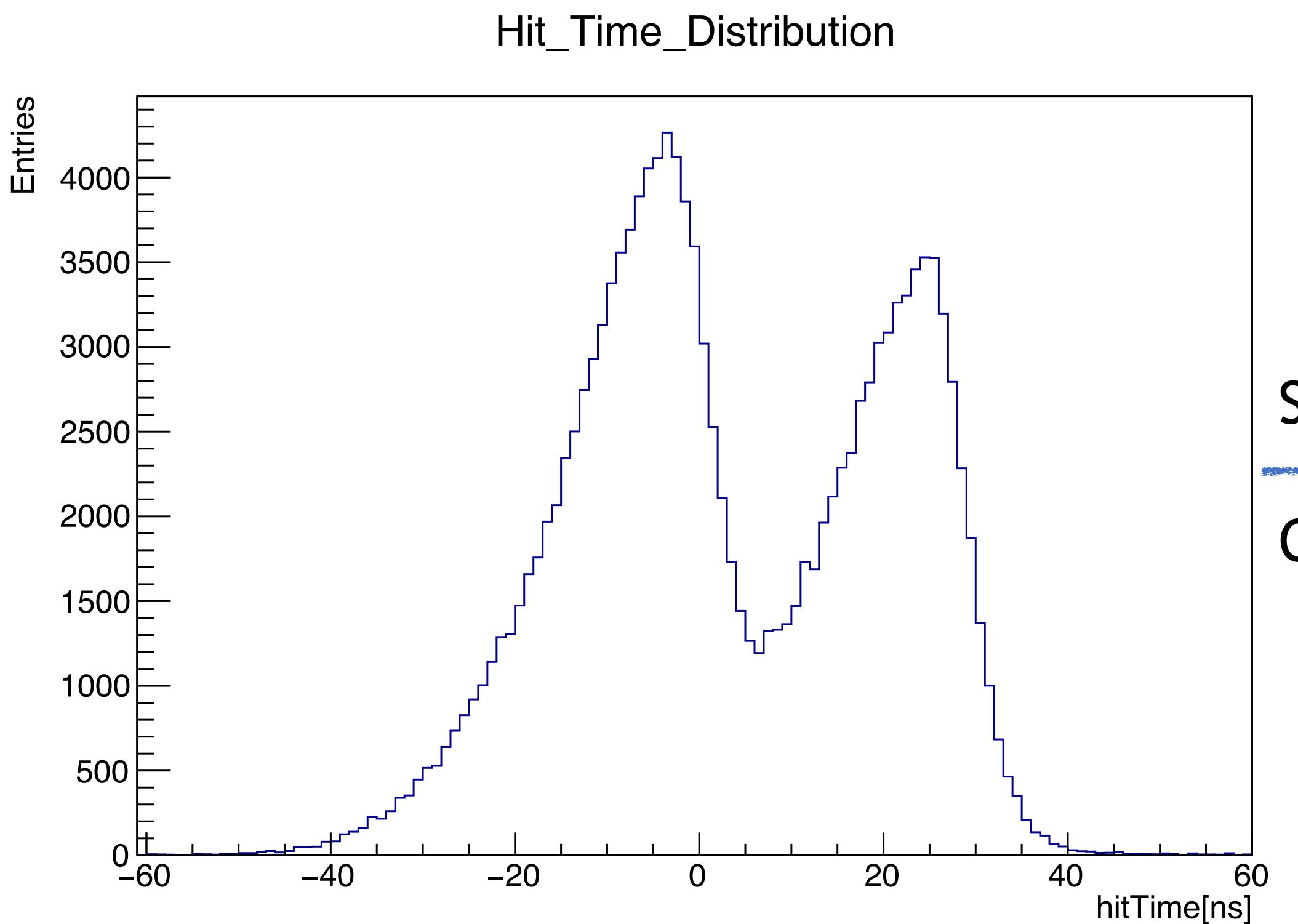
Even bxID



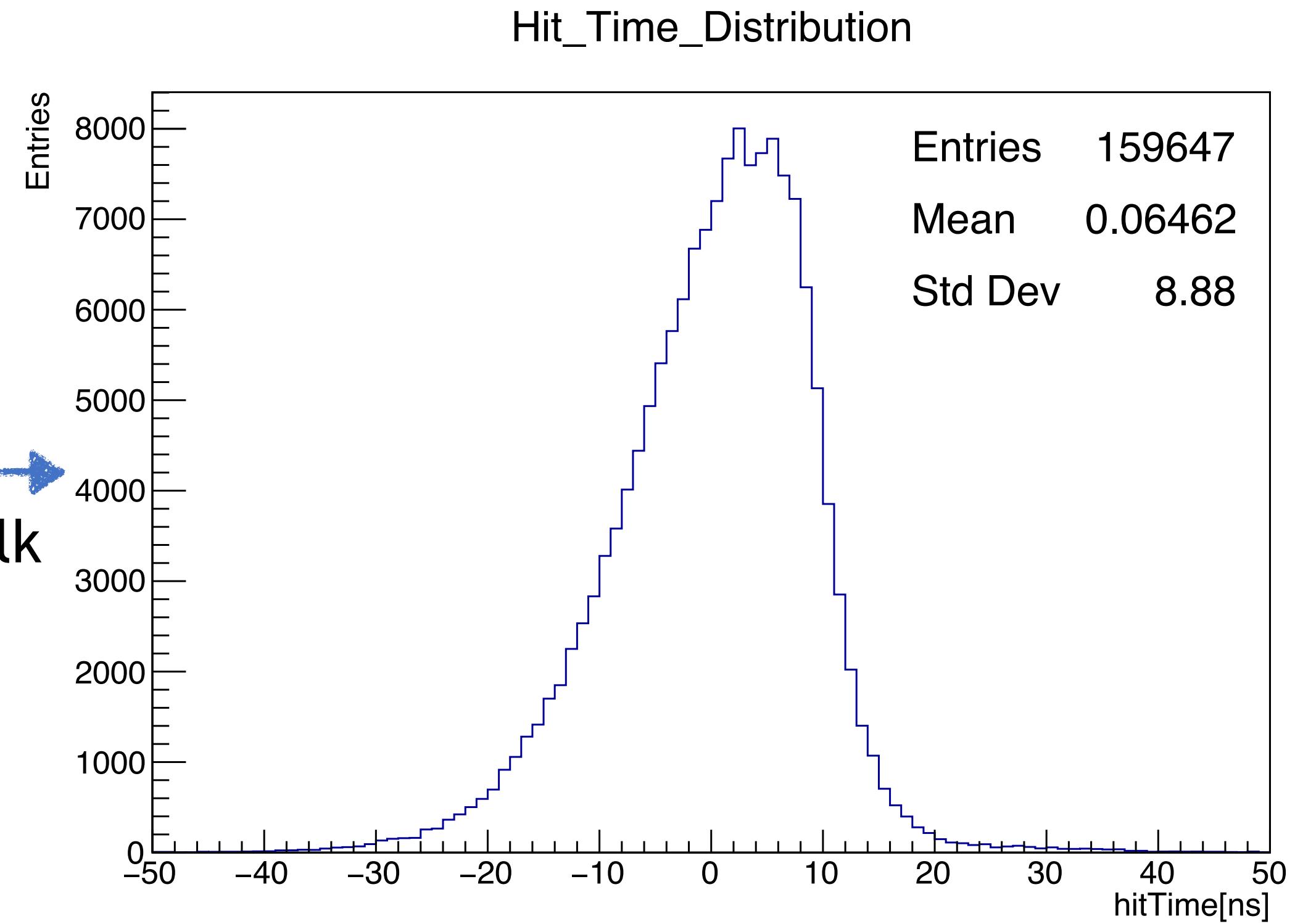
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Even bxID



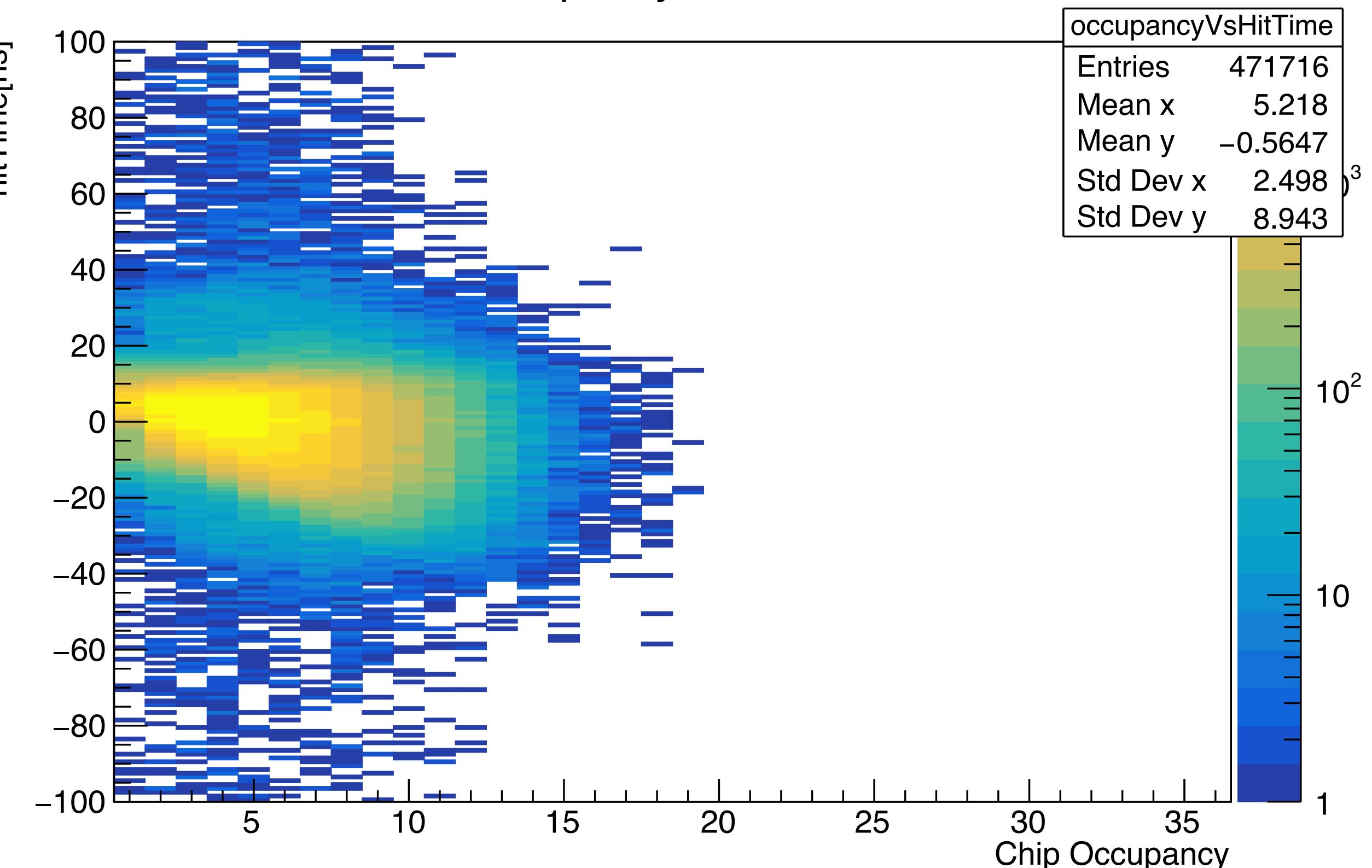
Shift mean  
Correct time walk



Skewed distribution for even and odd bxID → looked at correlations between hit/event variables and time

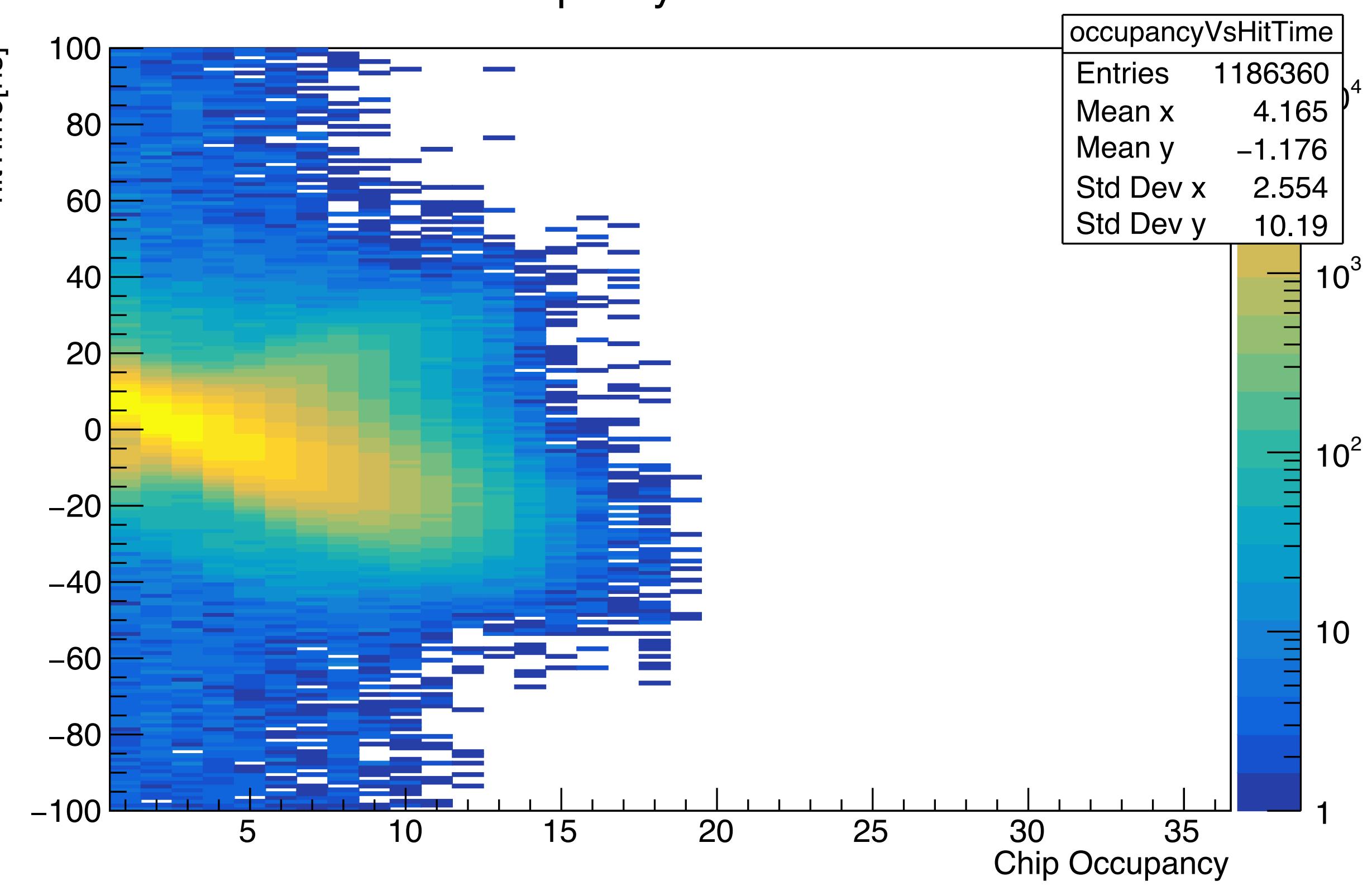
# Chip Occupancy Correction

occupancyVsHitTime



High gain

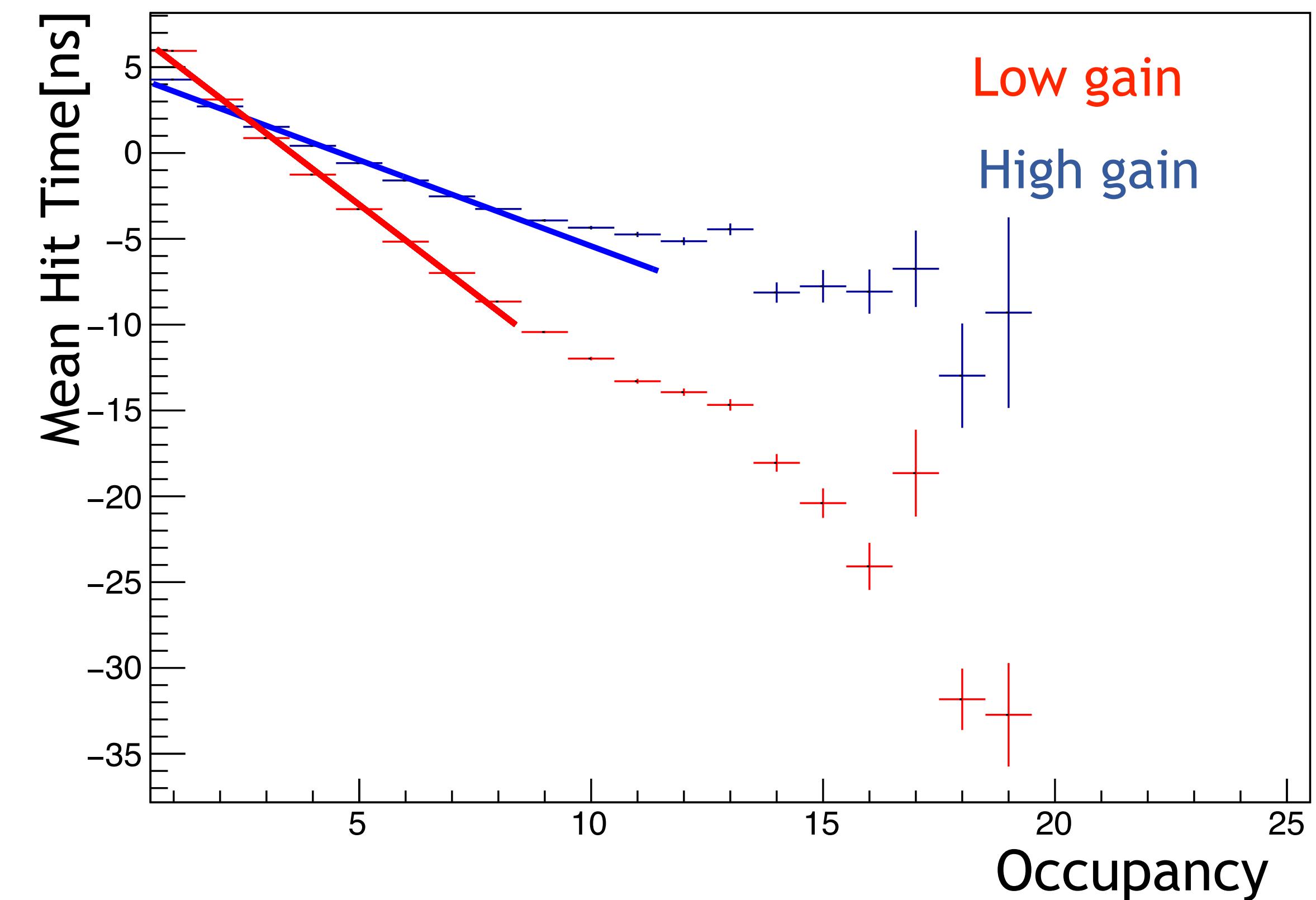
occupancyVsHitTime



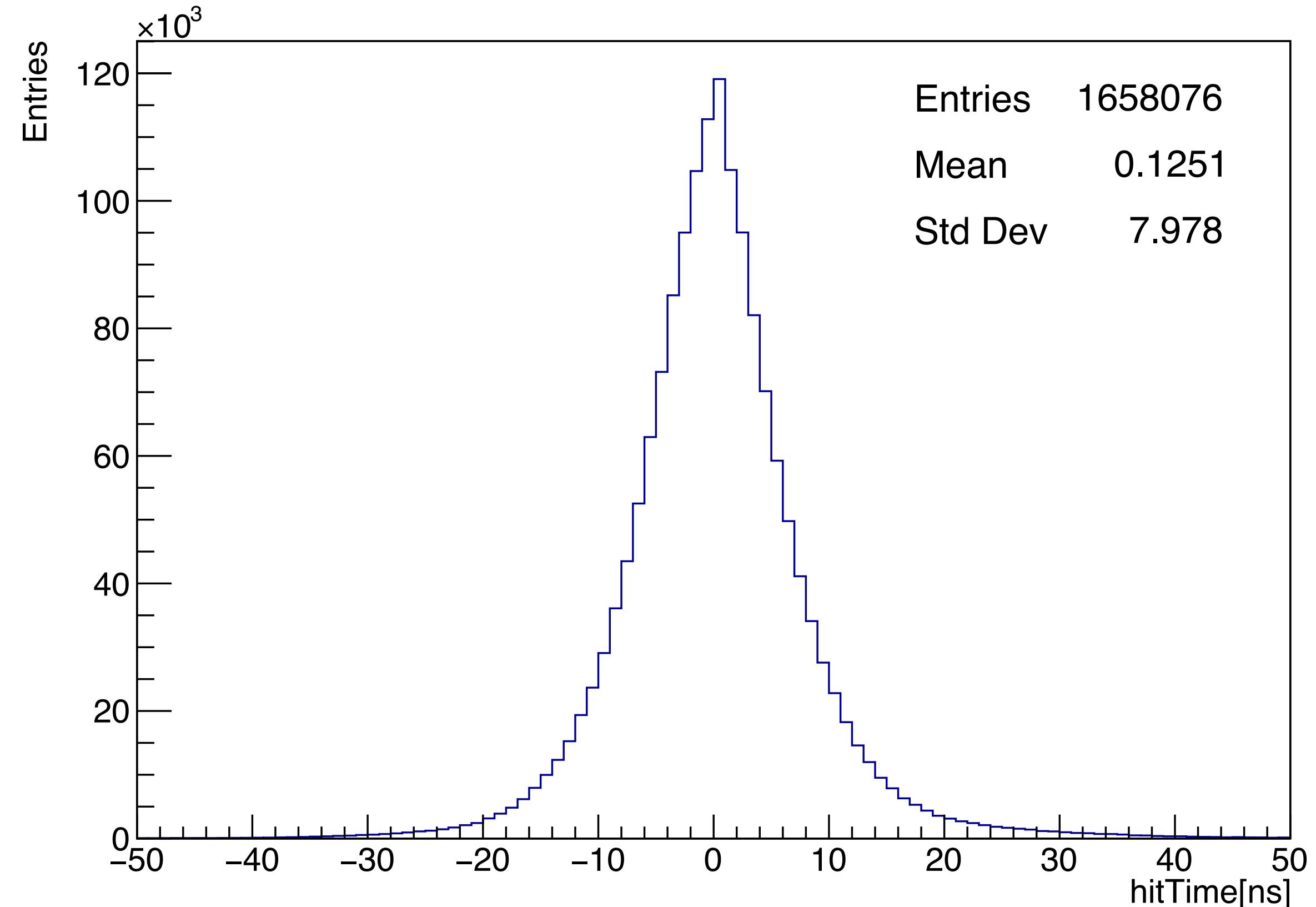
Low gain

# Chip Occupancy Correction

Occupancy for high/low gain hits



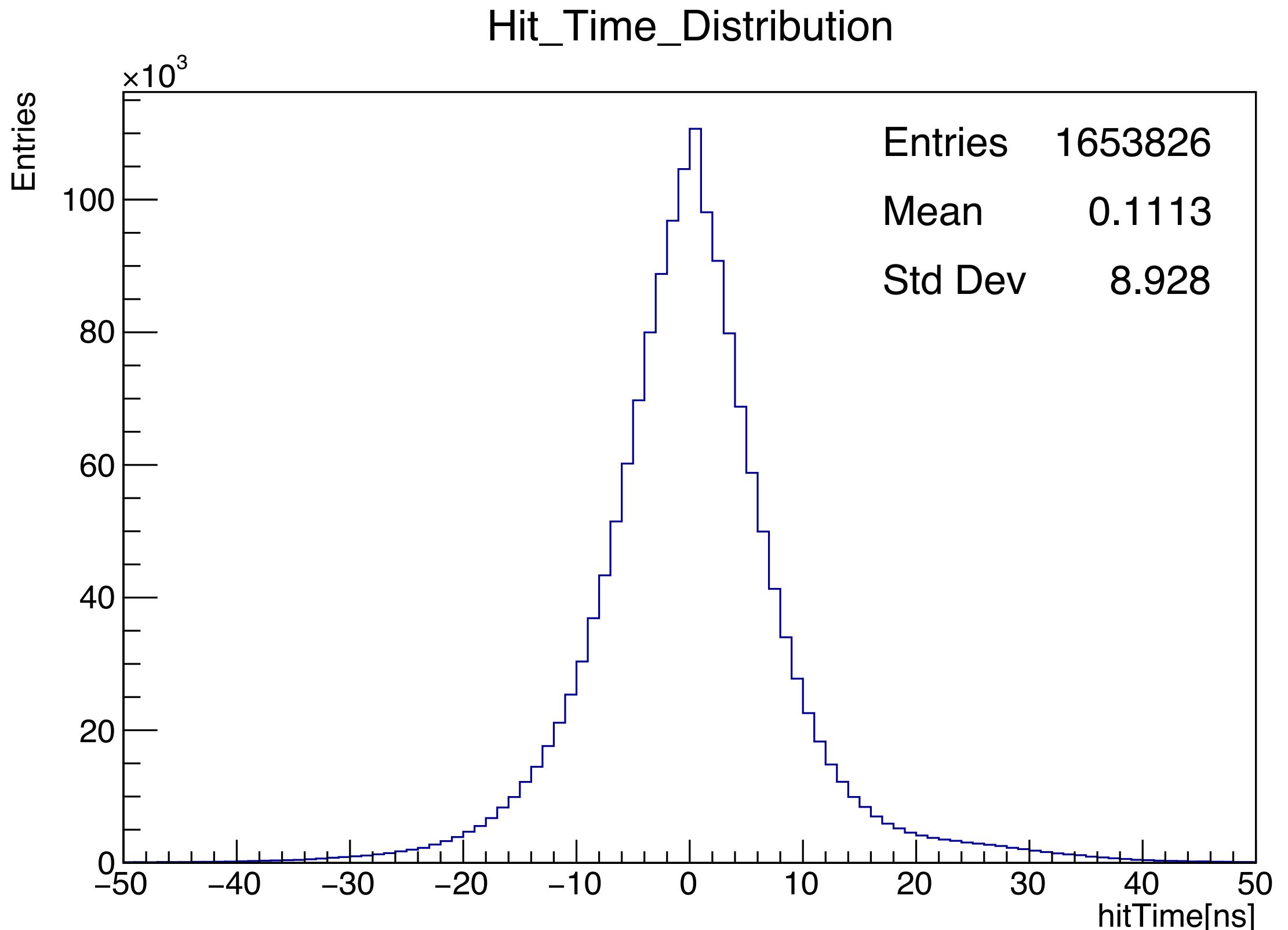
Hit\_Time\_Distribution



Occupancy correction improves the shape and increases the time resolution by ~1ns

# Electron Time Resolution

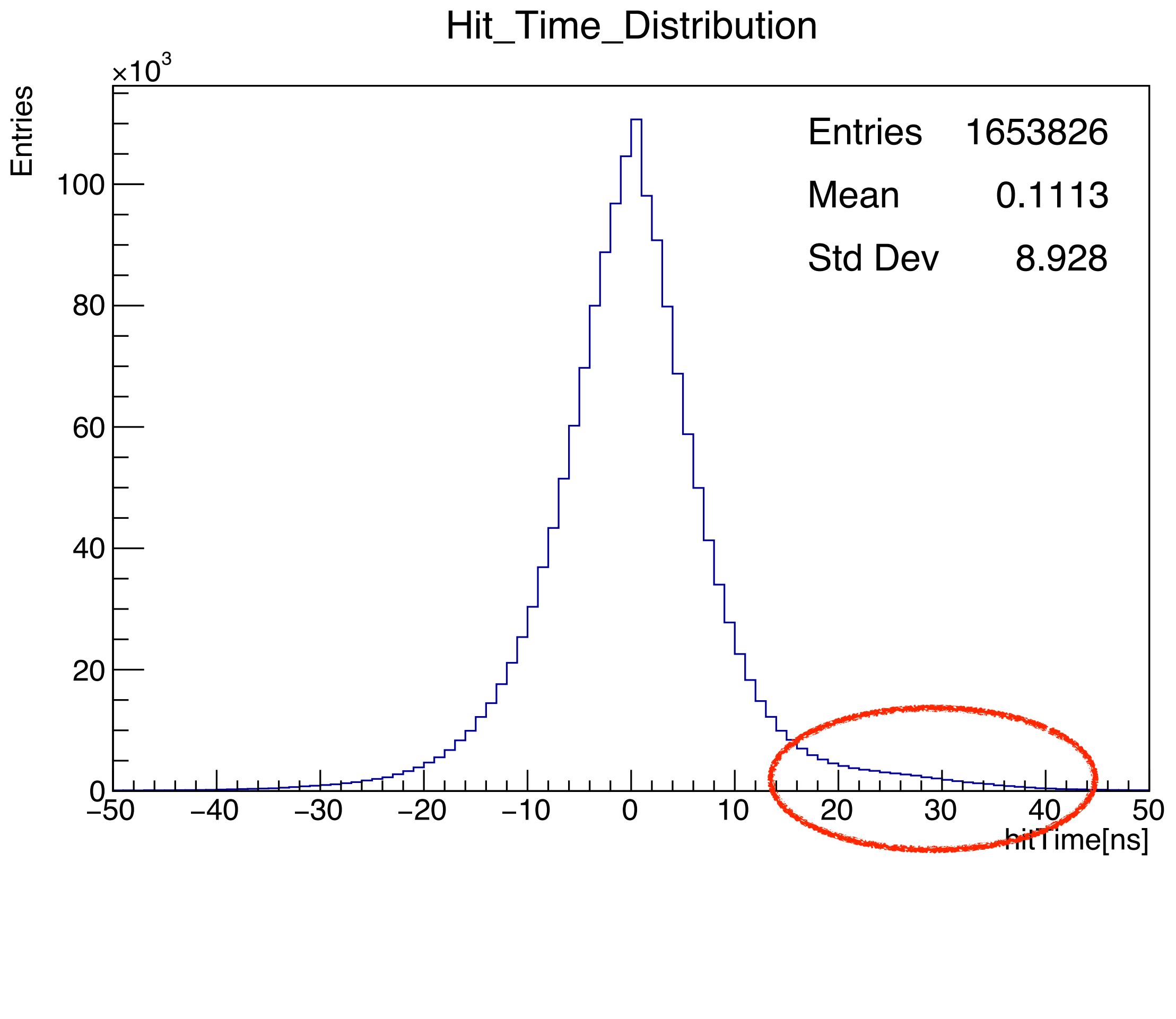
Even and odd bxIDs



- Time resolution of odd bxIDs still worse because of **shift in late memory cells**
- Occupancy correction also fixes the dependence of hit time on hit energy and chip energy

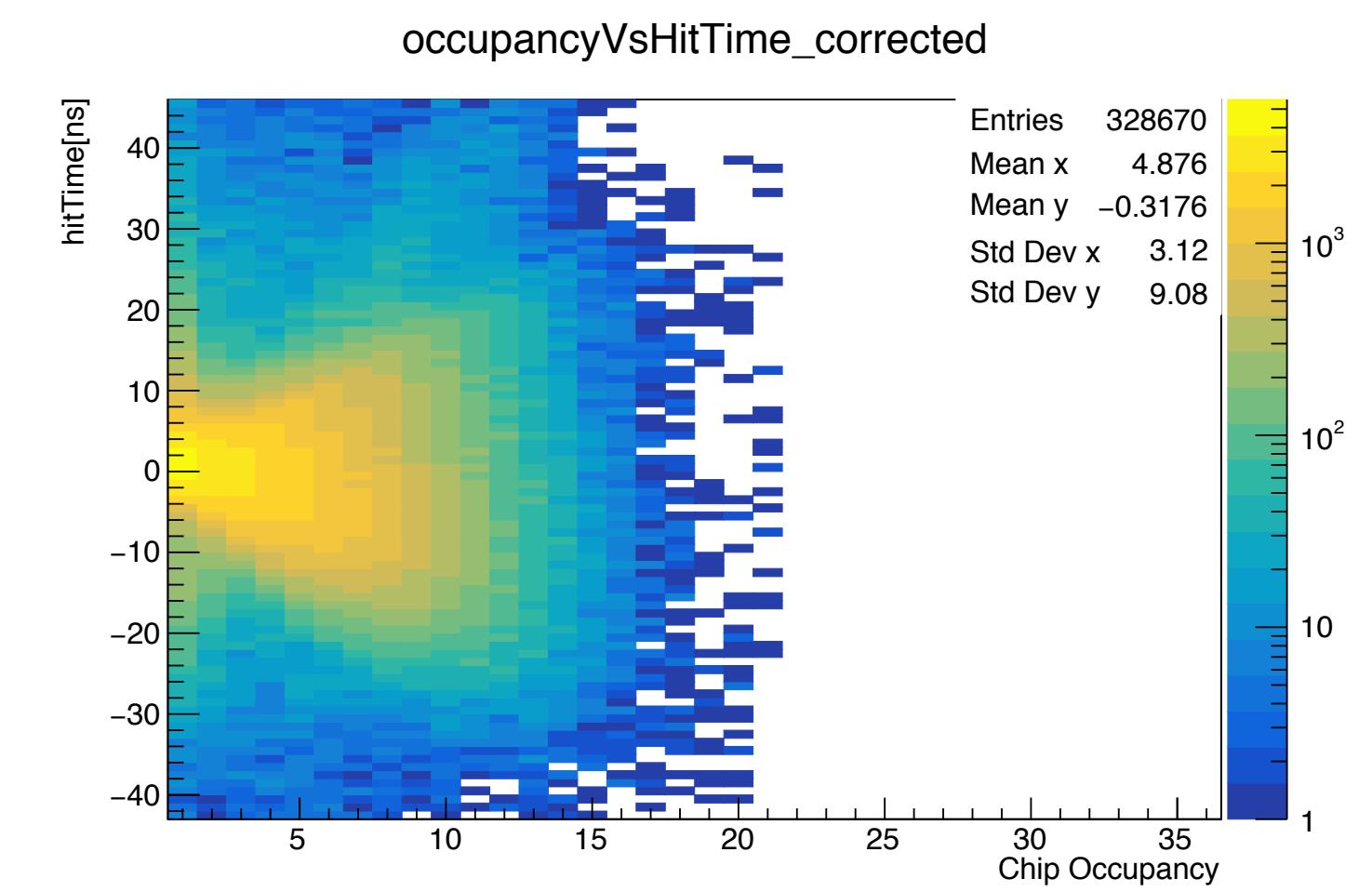
# Electron Time Resolution

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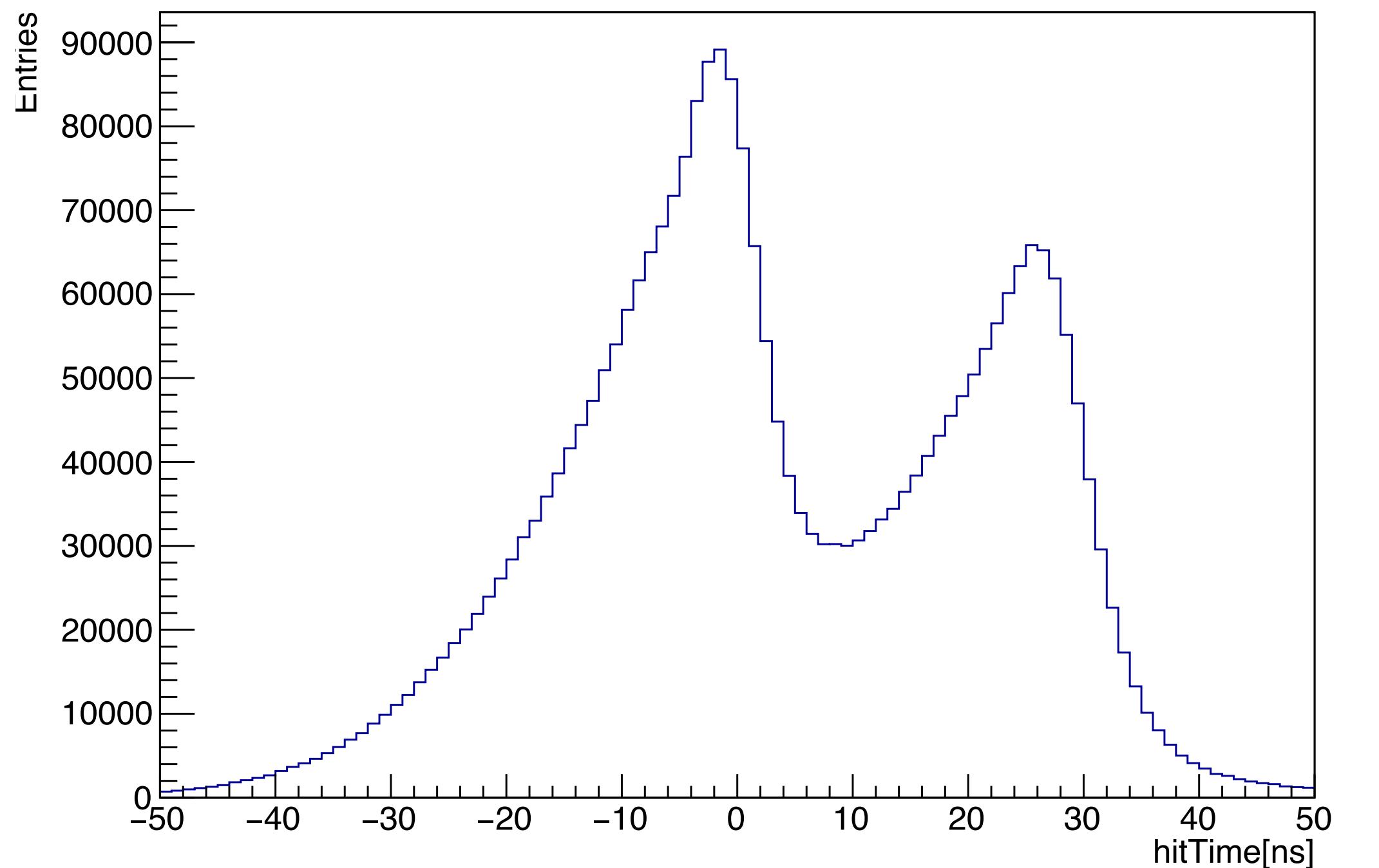
Broadening of hit time distribution for higher occupancies still under investigation



# Pion Time Resolution

Even bxID

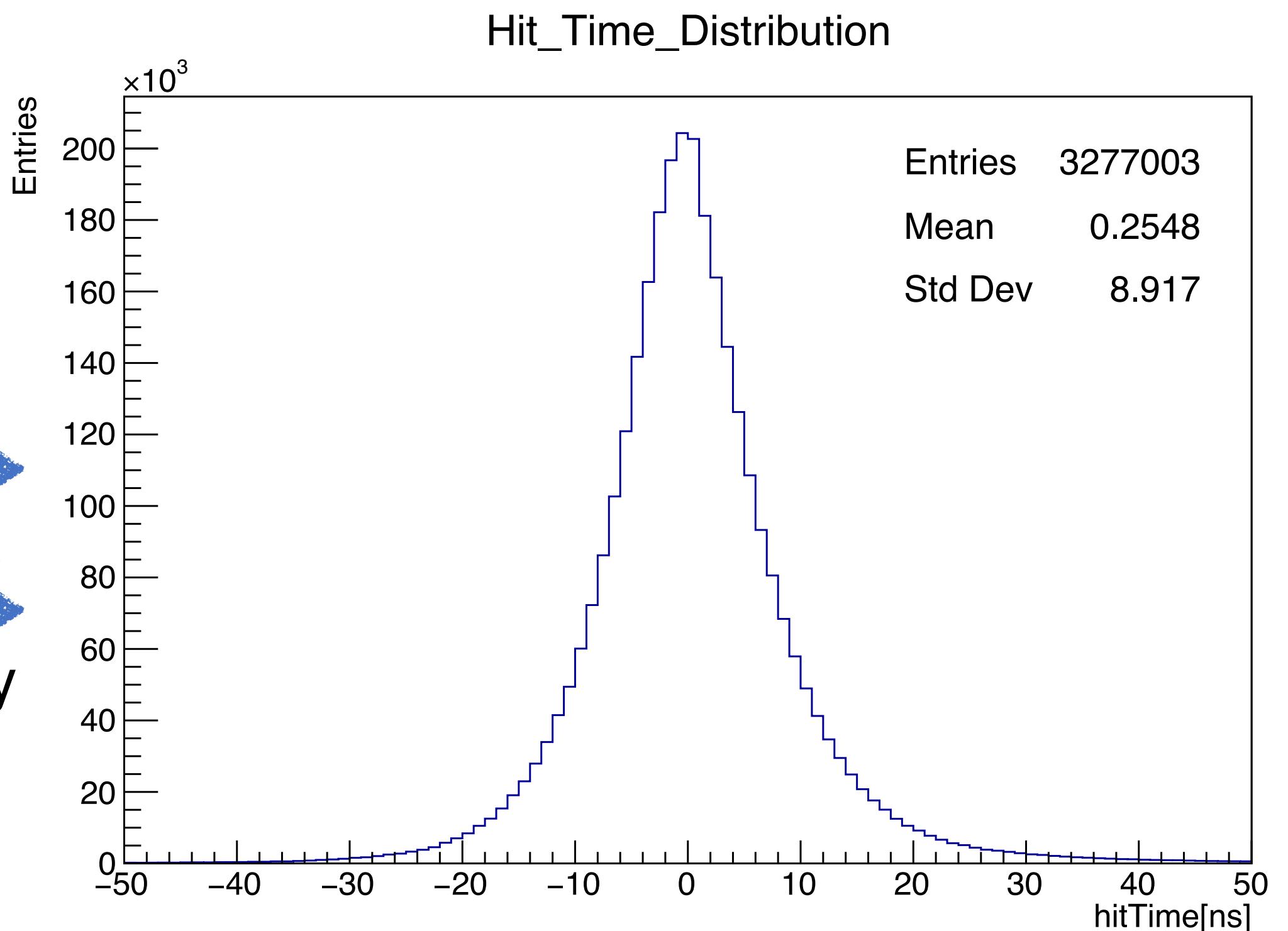
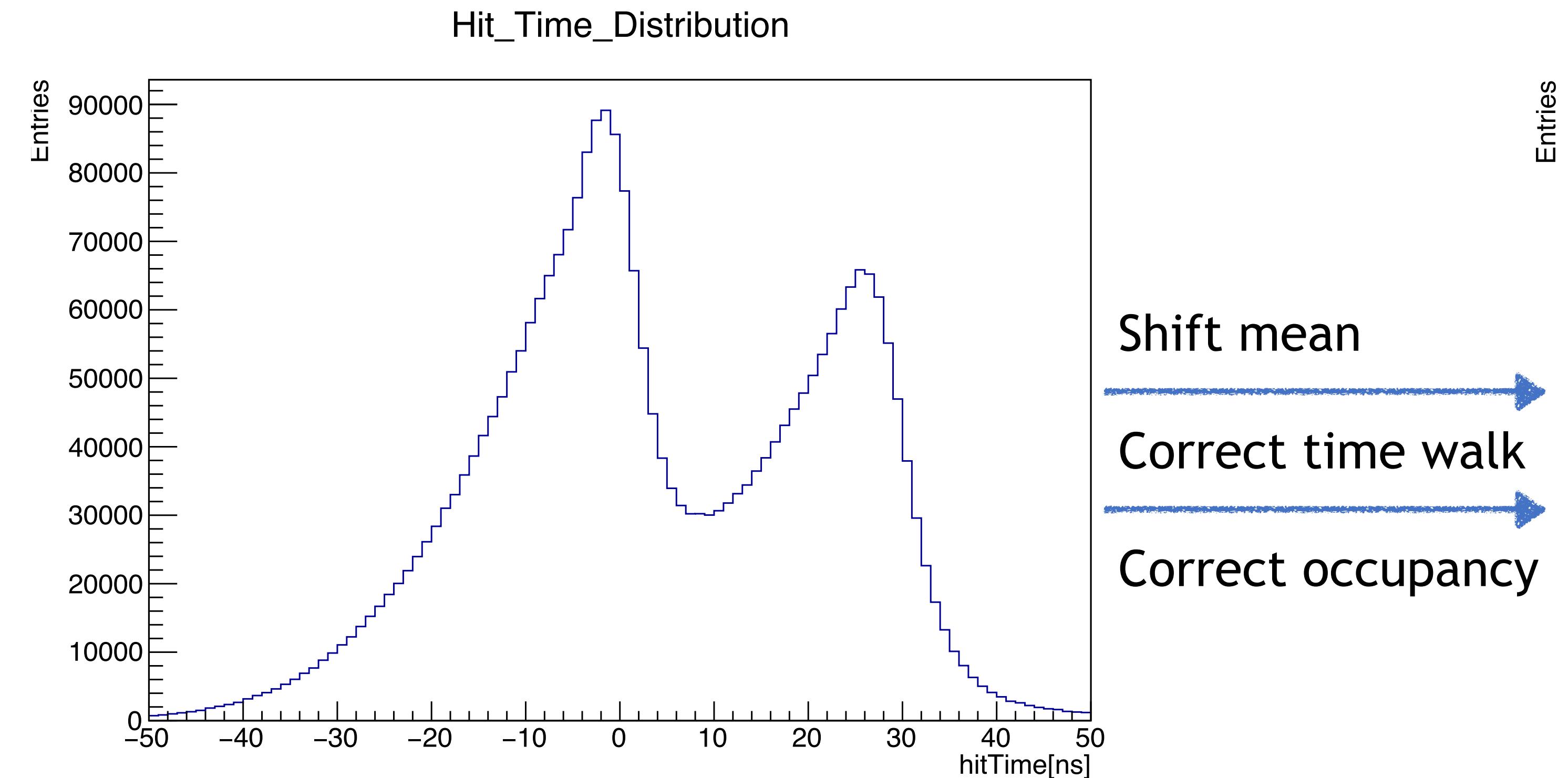
Hit\_Time\_Distribution



# Pion Time Resolution

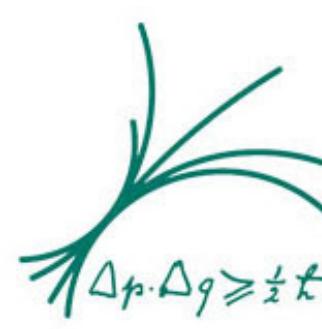


Even bxID

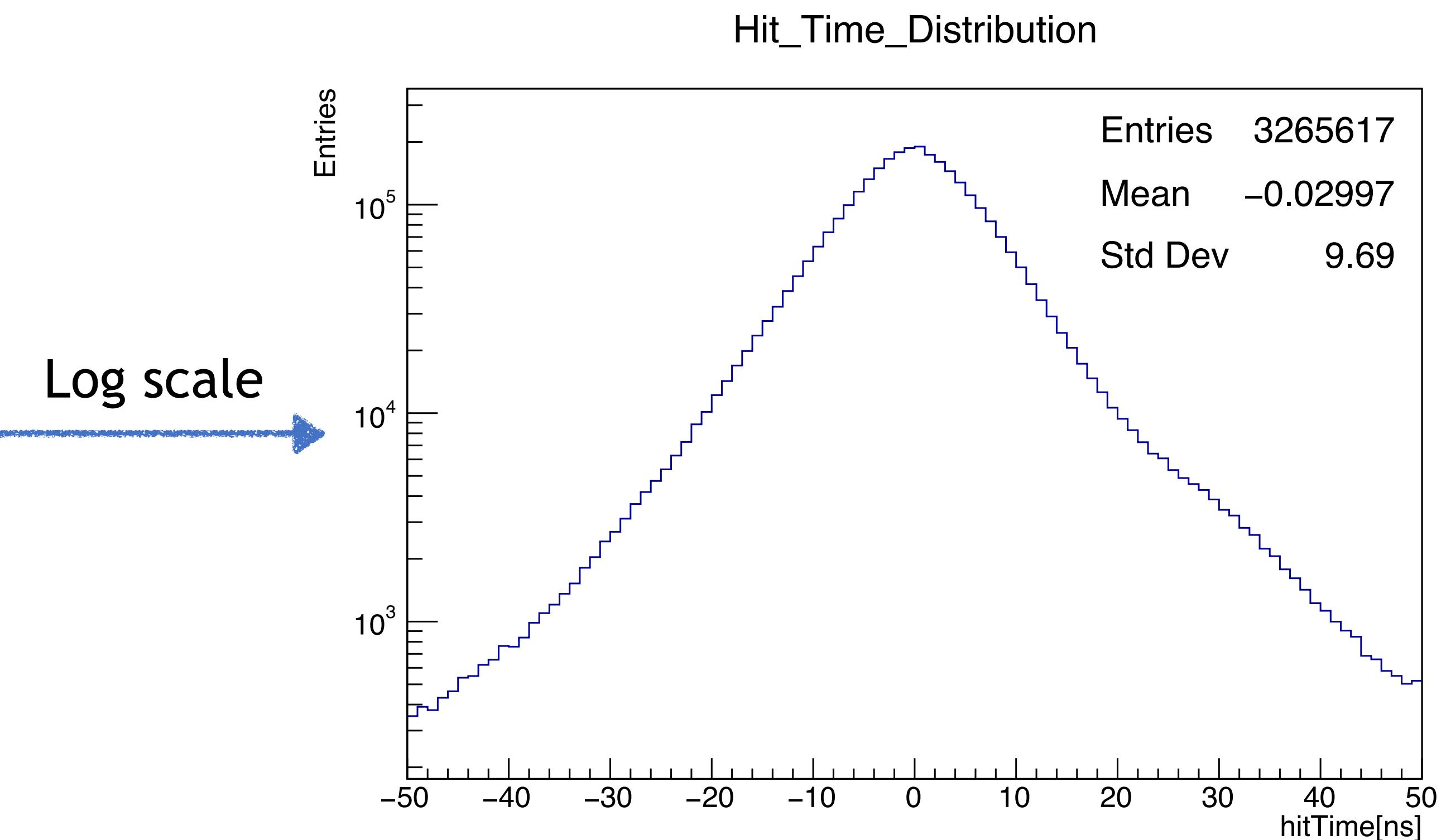
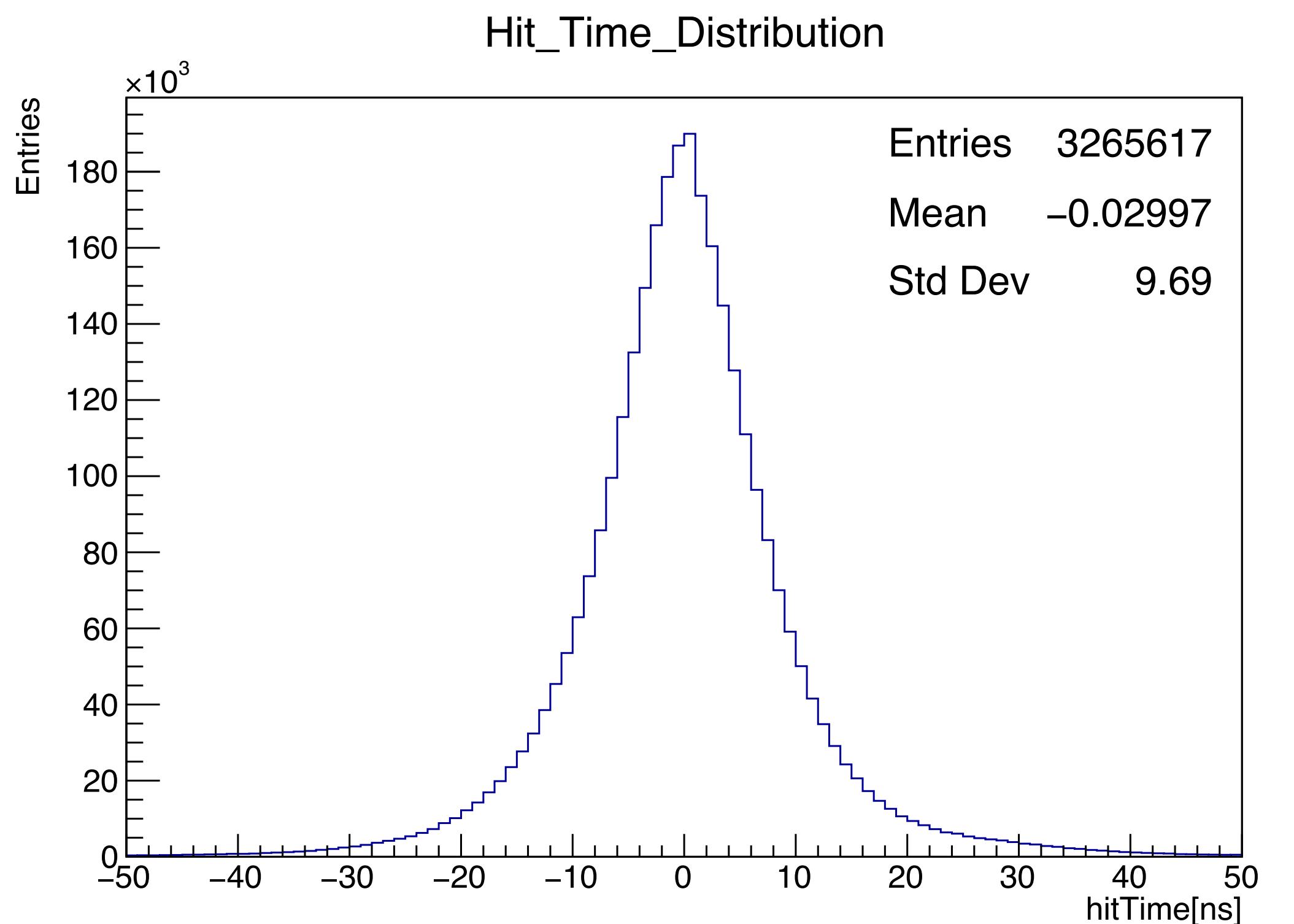


Correction values extracted from muon and electron runs → don't affect late hits in hadronic showers

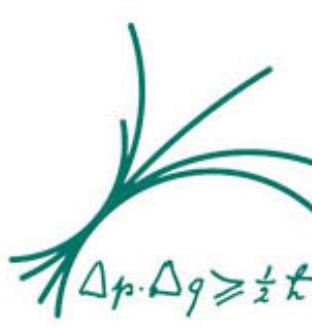
# Pion Time Resolution



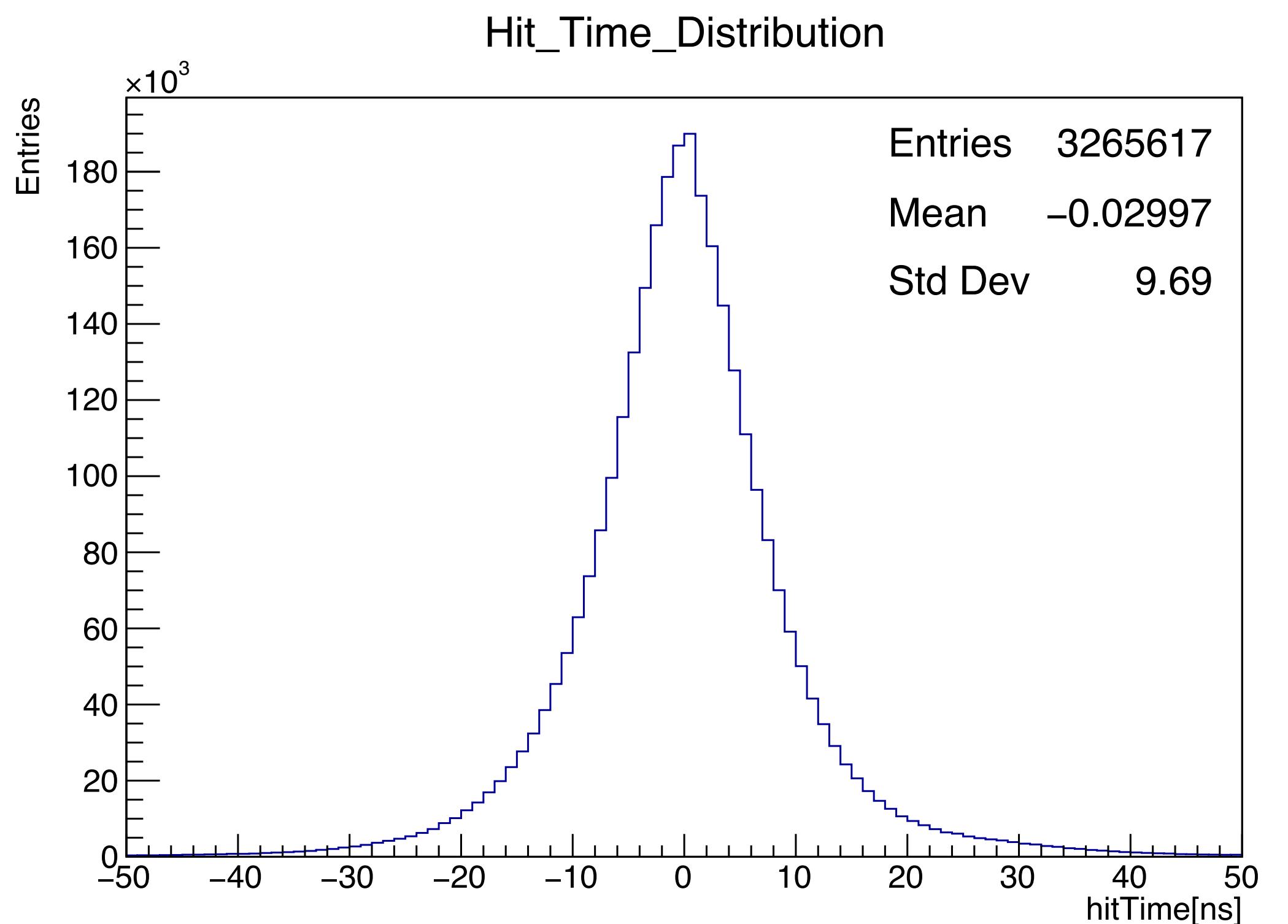
Even and odd bxIDs



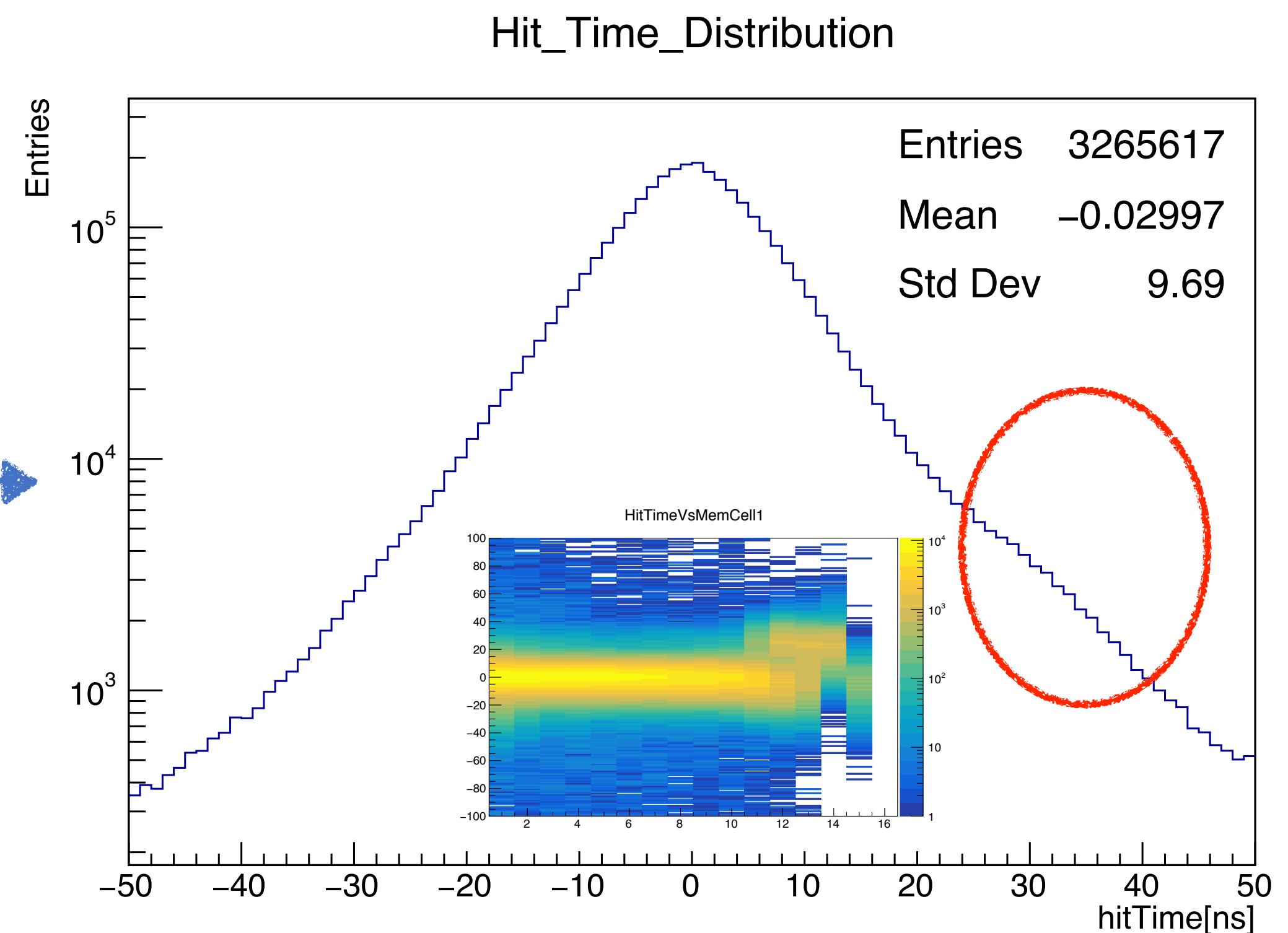
# Pion Time Resolution



Even and odd bxIDs



Log scale →





# Achievements and To Do's

- Corrected satellite peaks for Muons, Electrons and Pions
- Tested time walk correction
- Implemented chip occupancy correction
  - Tried three methods, but no significant difference
  - Improved skewed distributions of electrons and pions
- Resulting time resolutions: ~6ns for muons, ~9ns for electrons, ~10ns for pions



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- Resulting time resolutions: ~6ns for muons, ~9ns for electrons, ~10ns for pions
- Investigate broadening of hit time distribution with rising chip occupancies
  - Look at chip-by-chip correction
- Implement shift of mean event time and time walk in marlin processor
- Investigate/Correct shift of hit time in late memory cells for odd bxID
- Investigate different behaviour of even and odd bxID for Muons
- Investigate PP behaviour and June runs

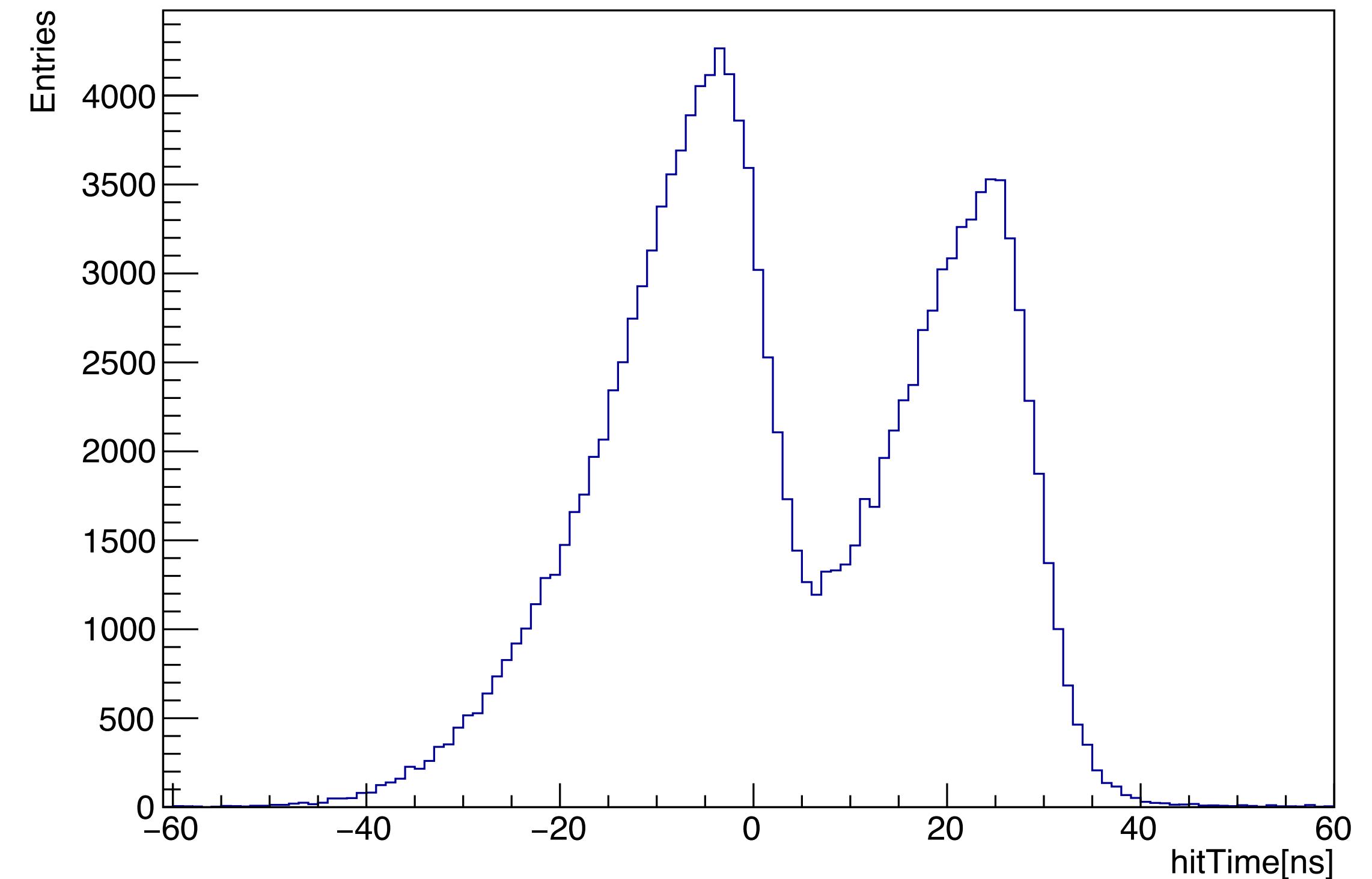


# Backup

# A Look at Odd BxID's

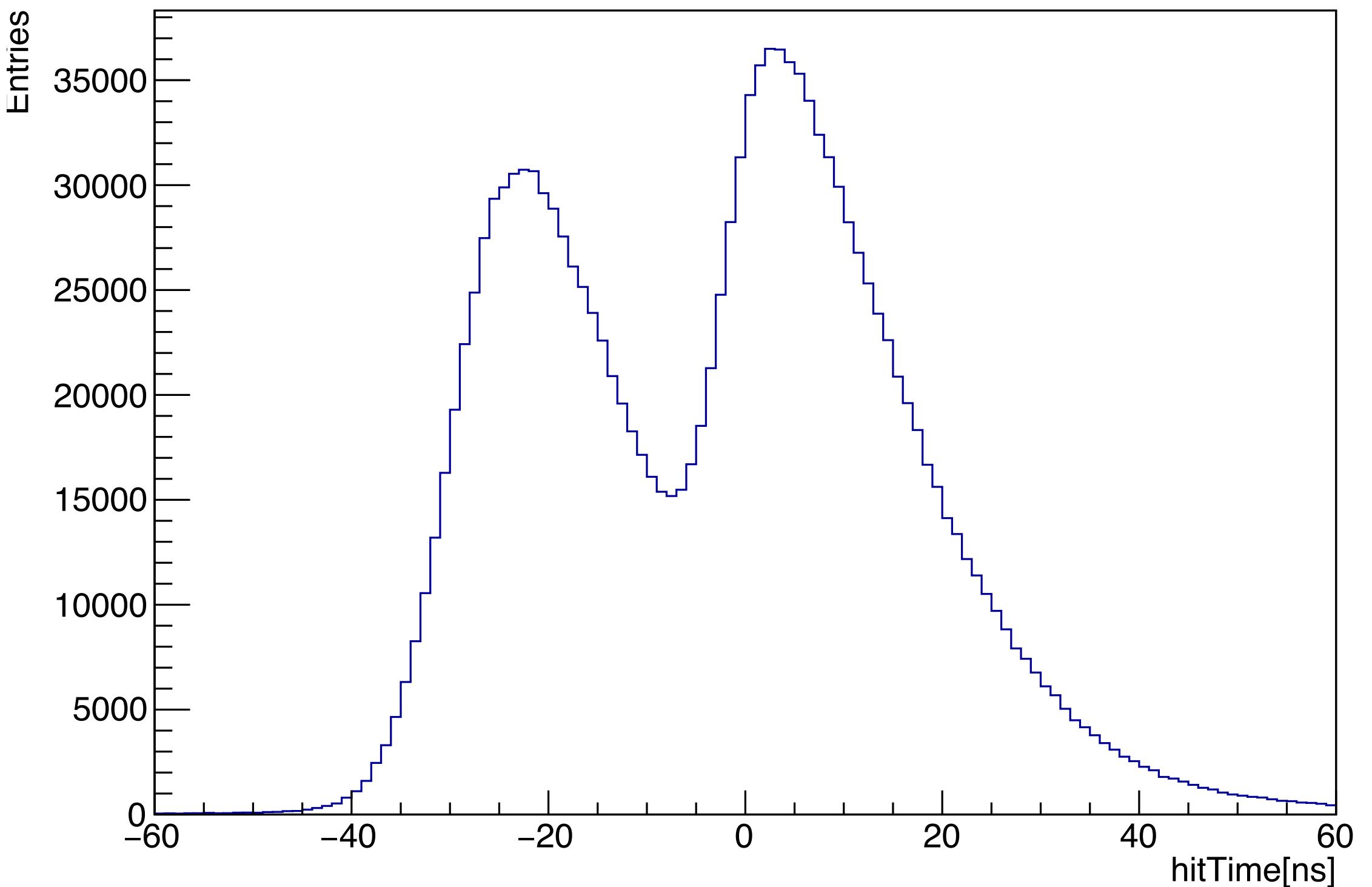


Hit\_Time\_Distribution



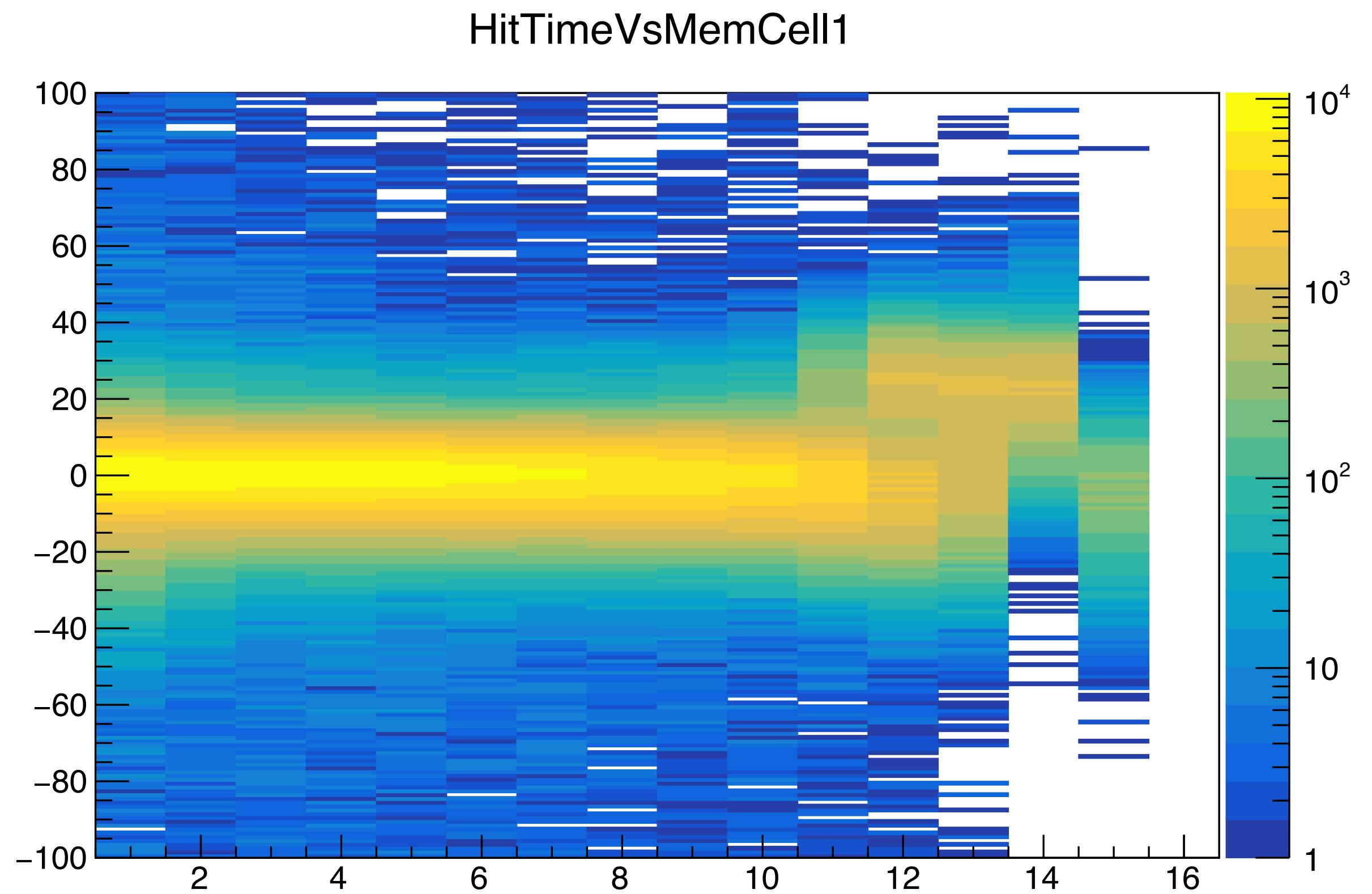
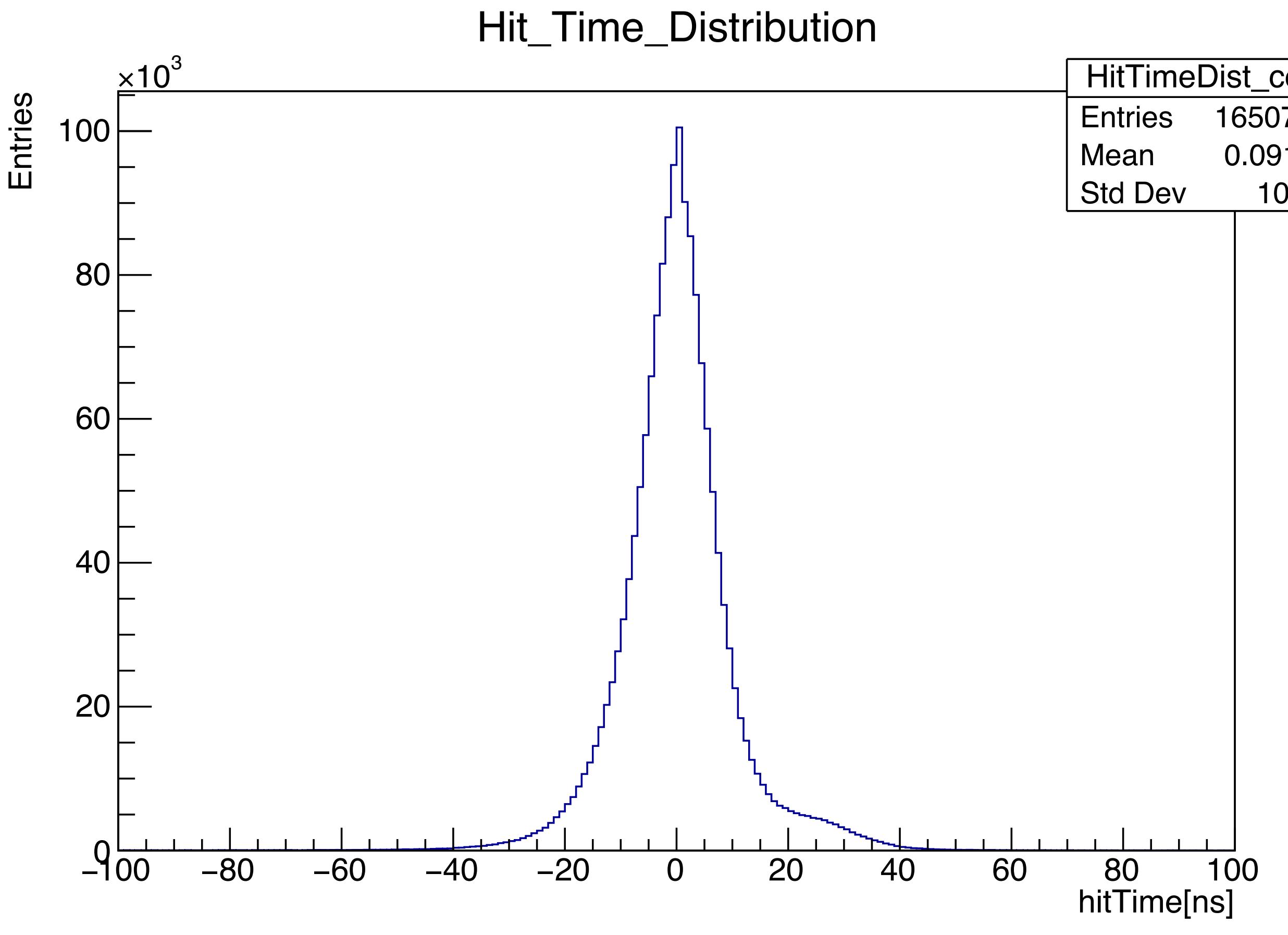
Even bxID

Hit\_Time\_Distribution

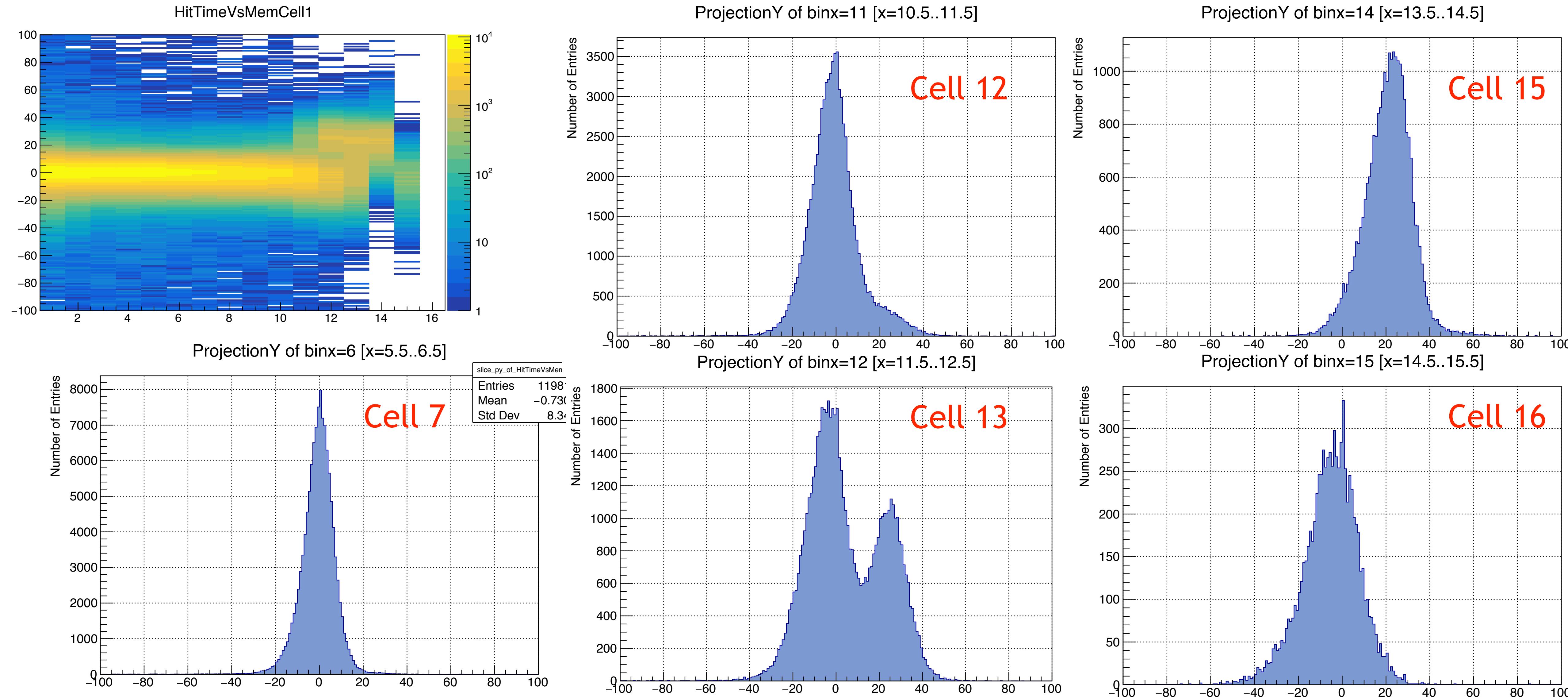


Odd bxID

# A Look at Odd BxID's



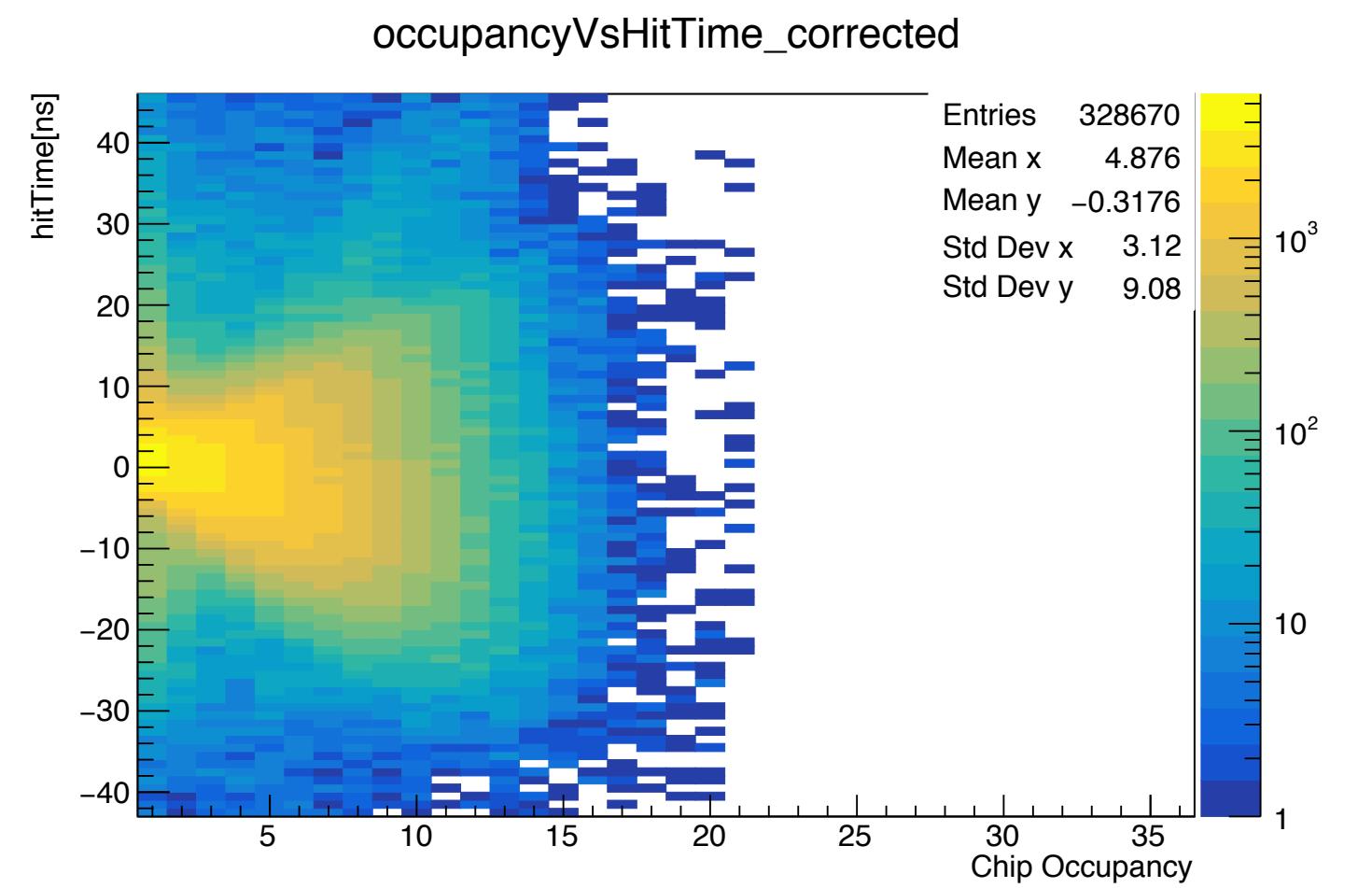
# Backup



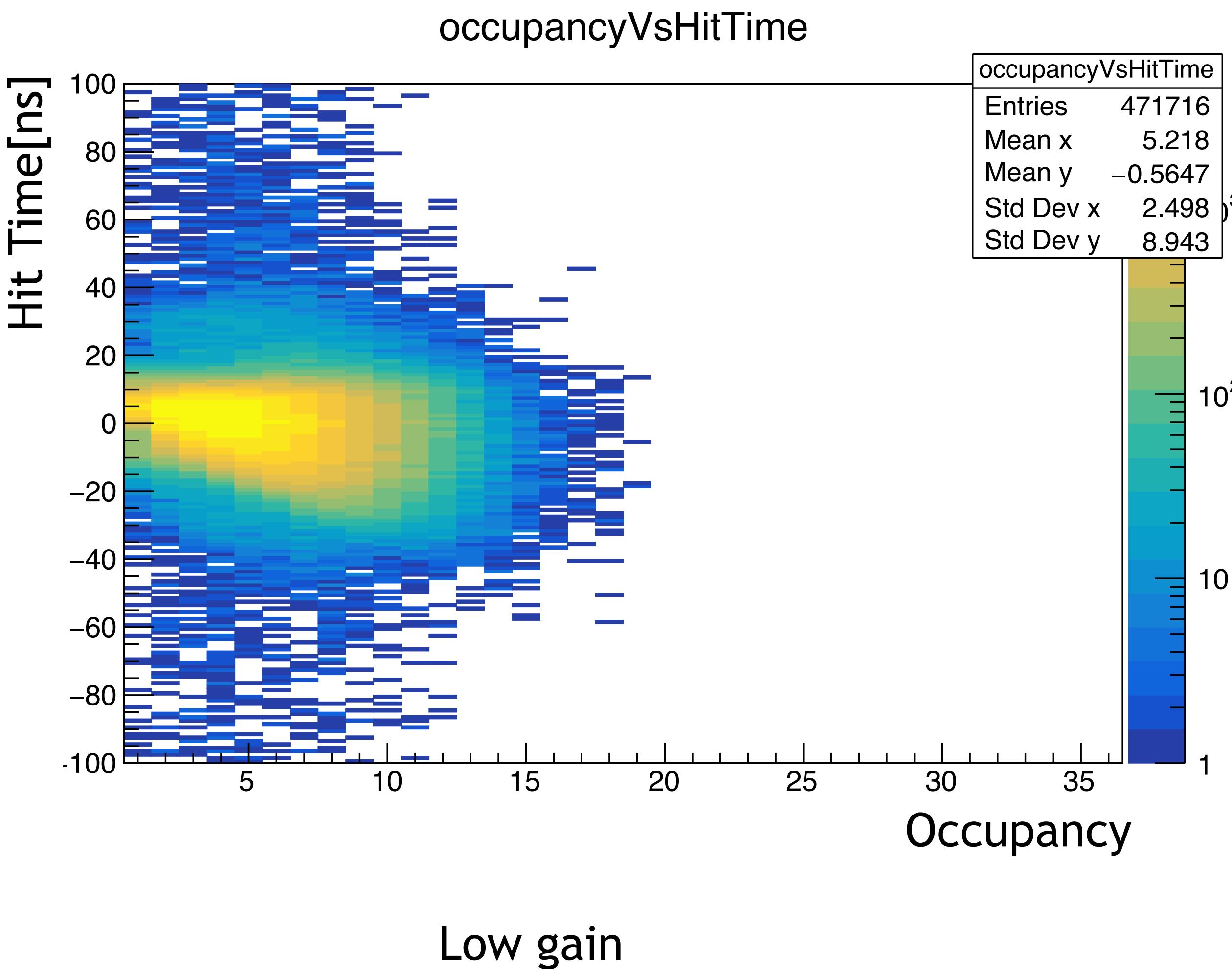


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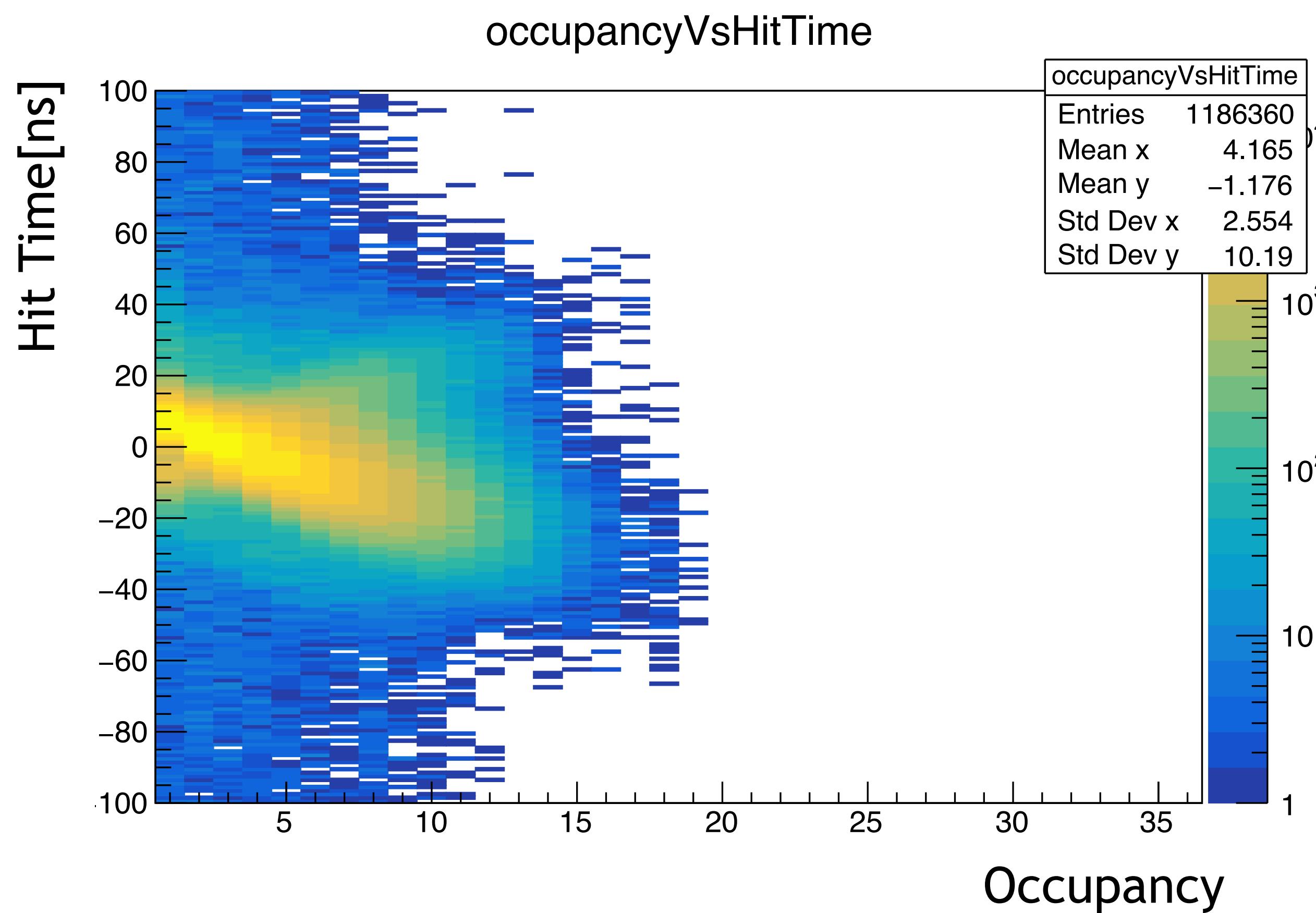
# A Look at Odd BxID's



# Occupancy Electrons -Low/High Gain

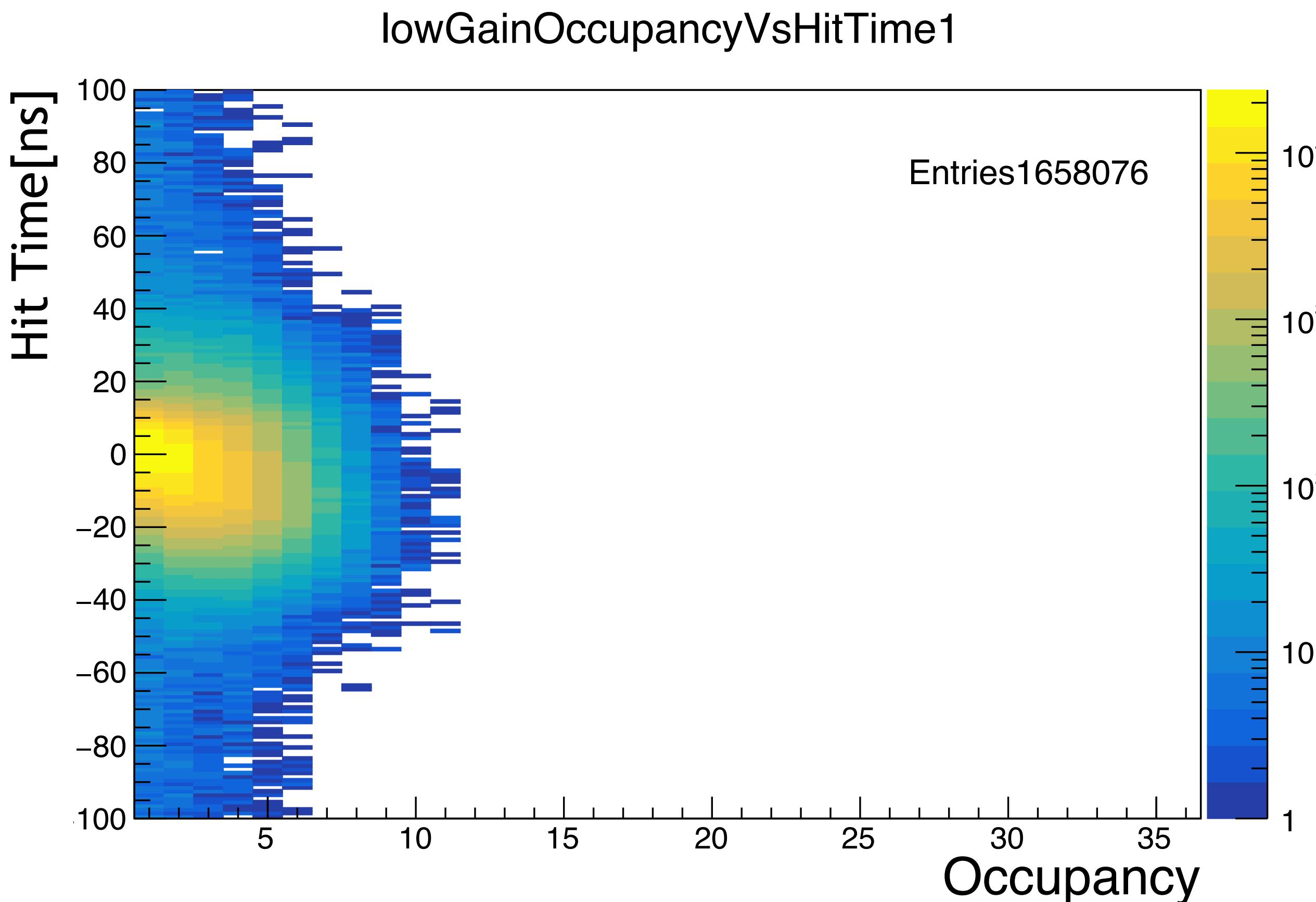


Low gain

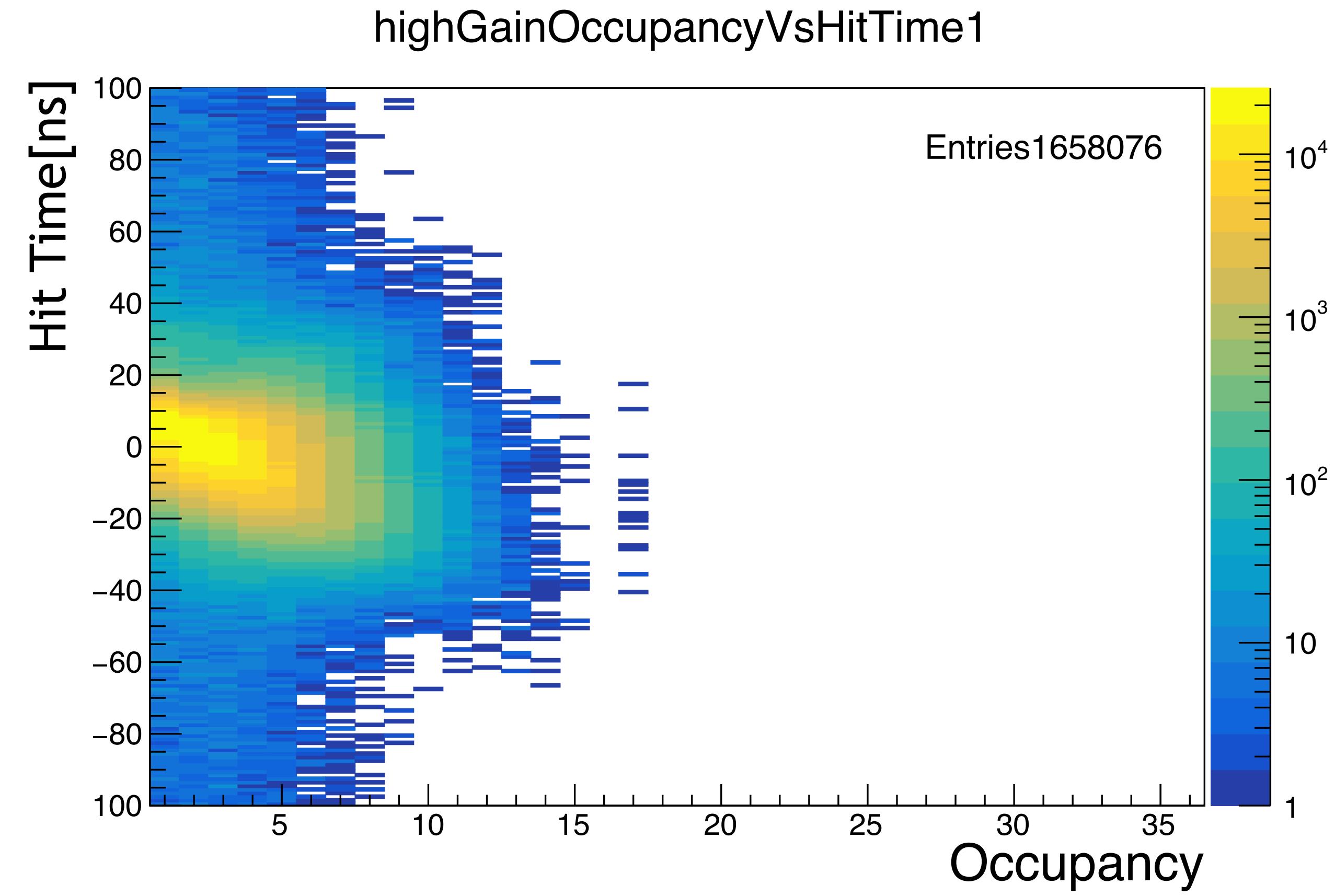


High gain

# Low/High Gain Occupancy - Electrons



Low gain

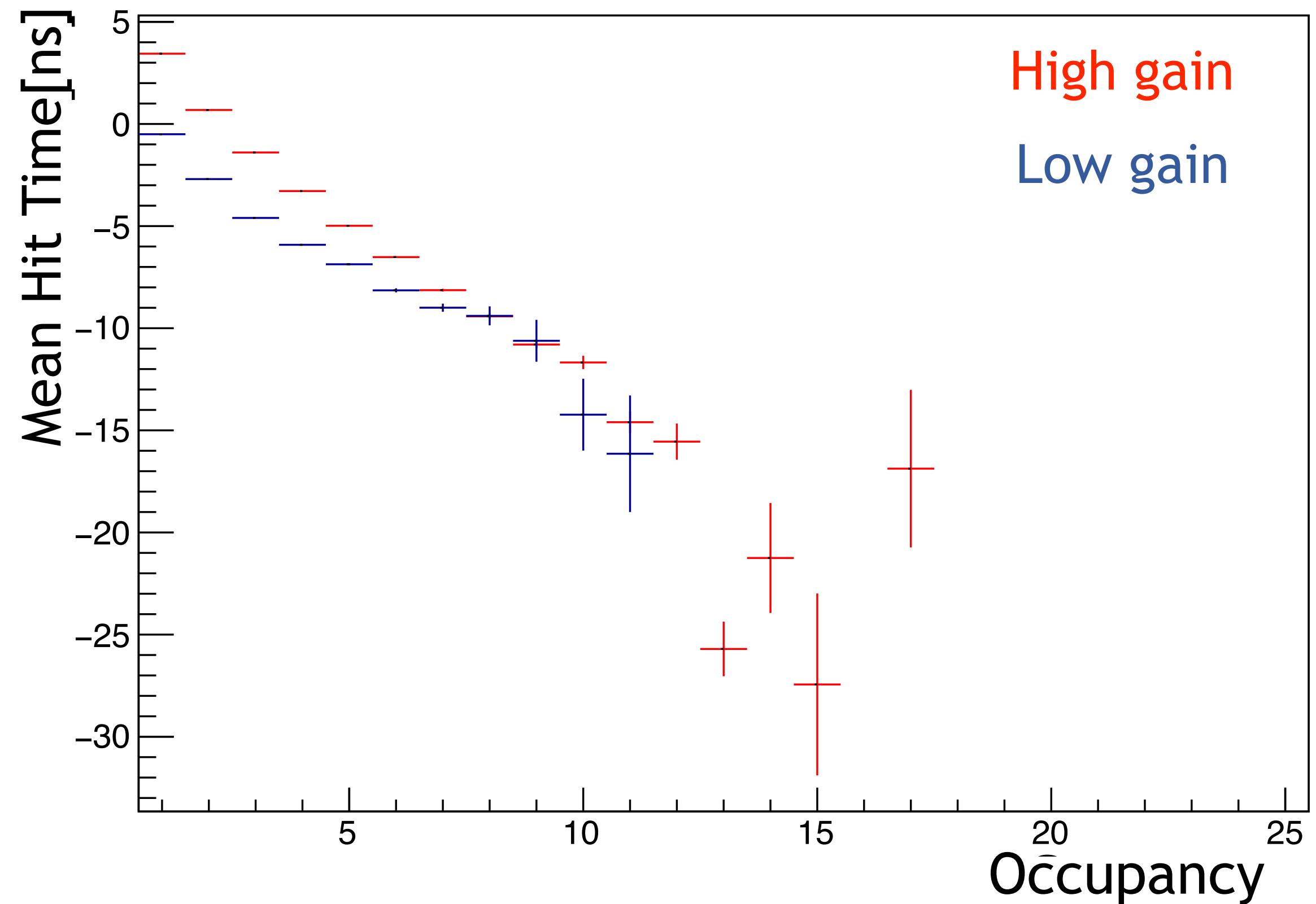


High gain

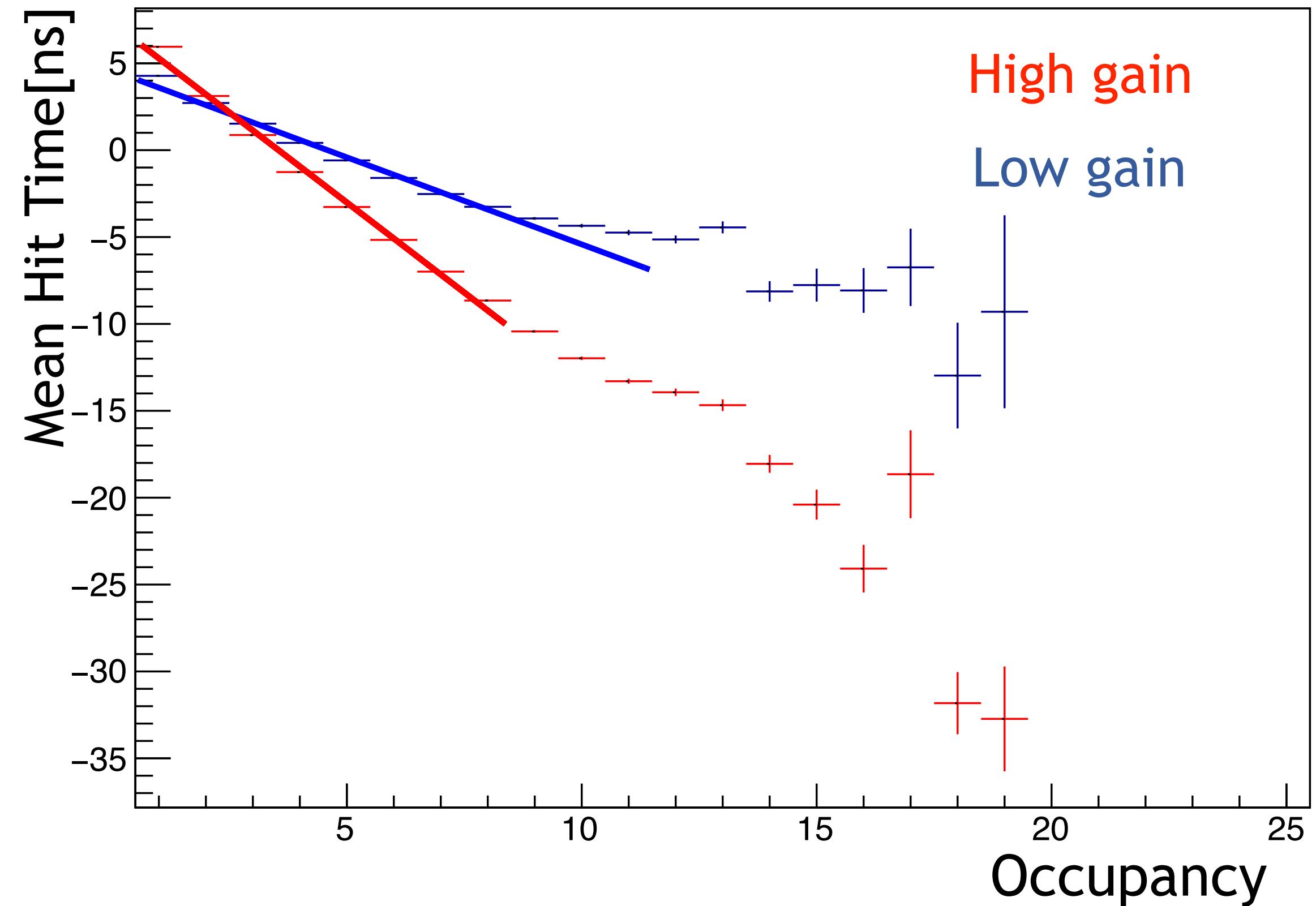
# Occupancy Electrons



High/Low gain occupancy for all hits



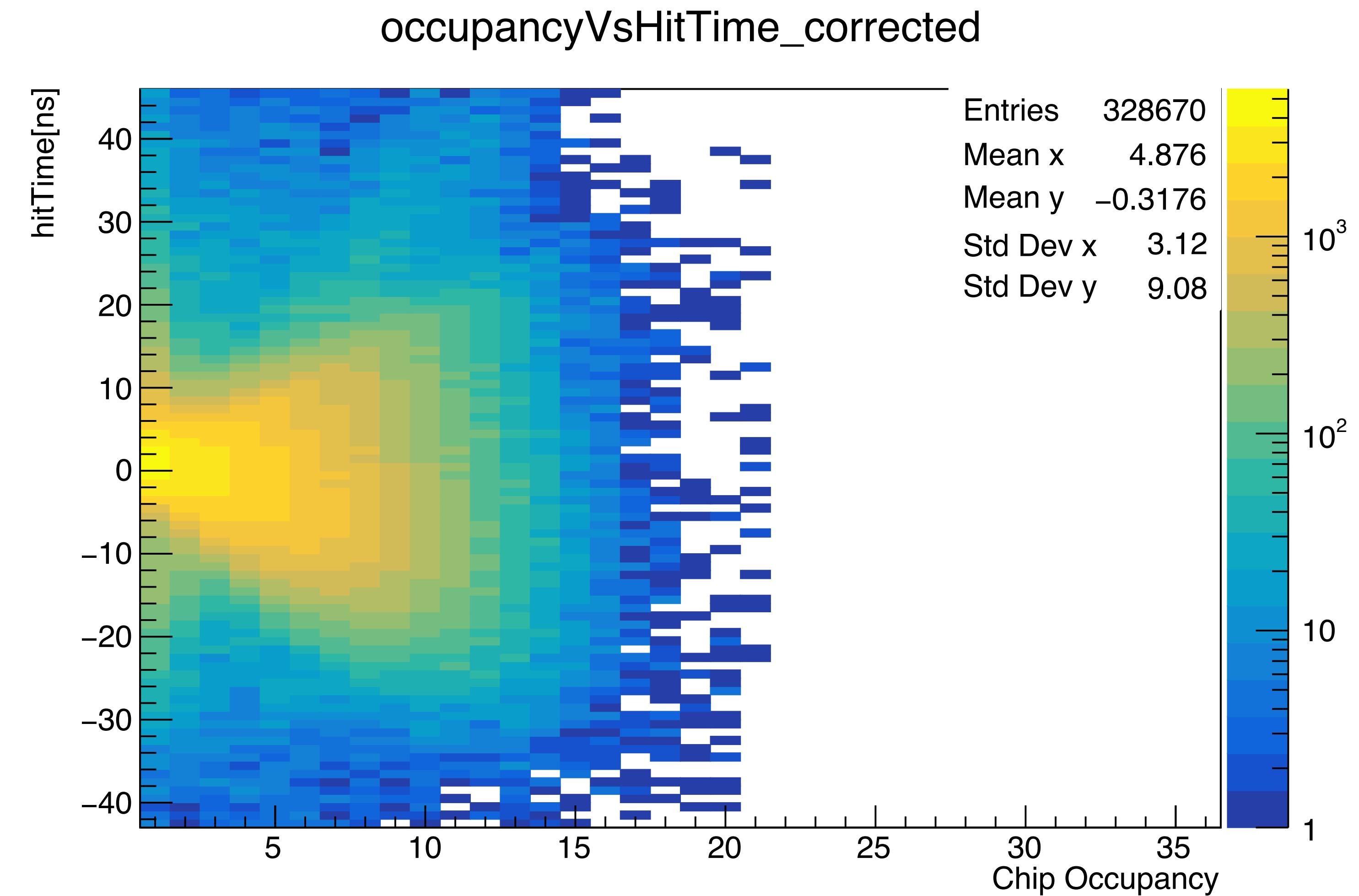
Occupancy for high/low gain hits



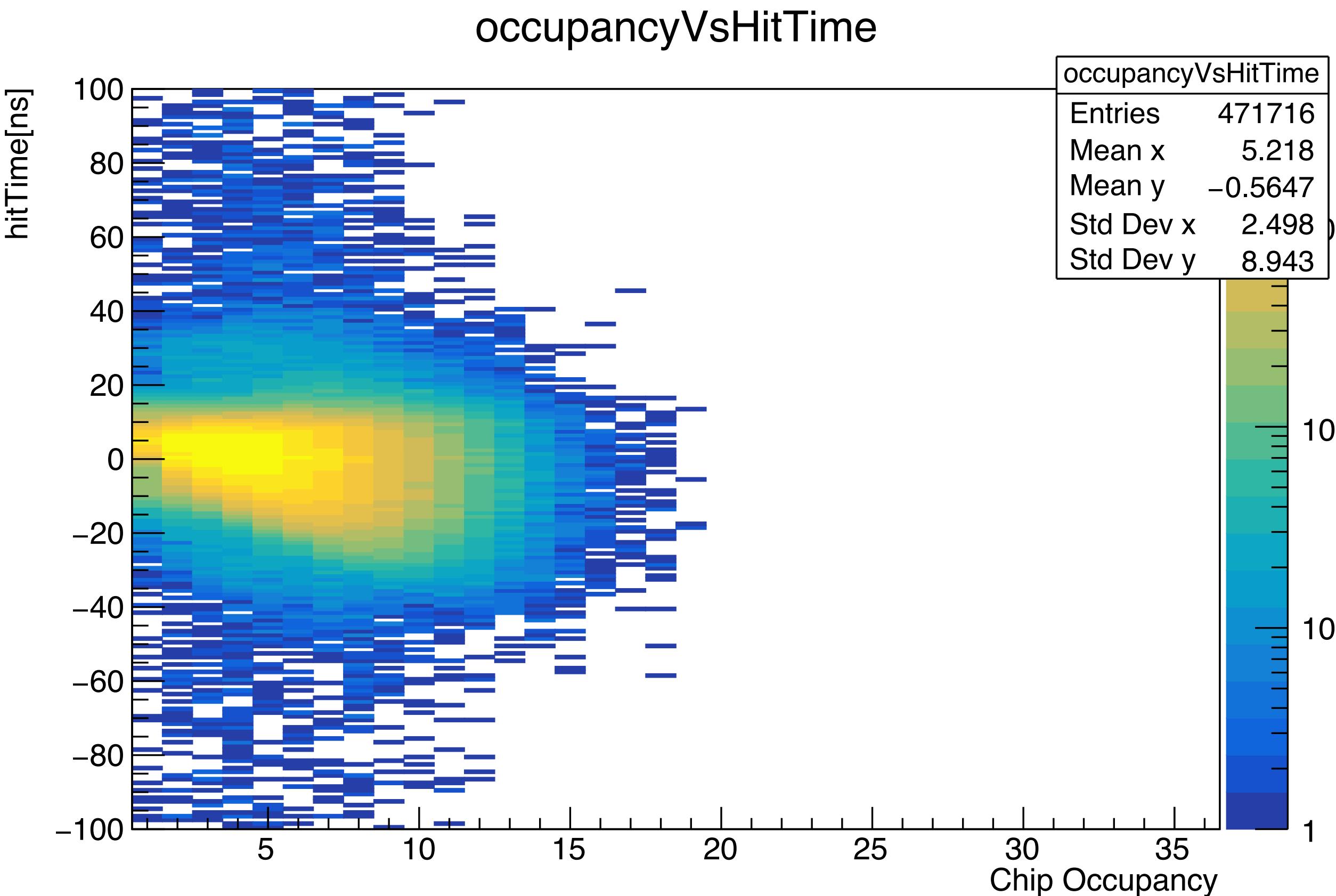
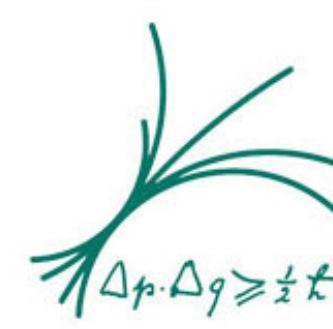


# Backup

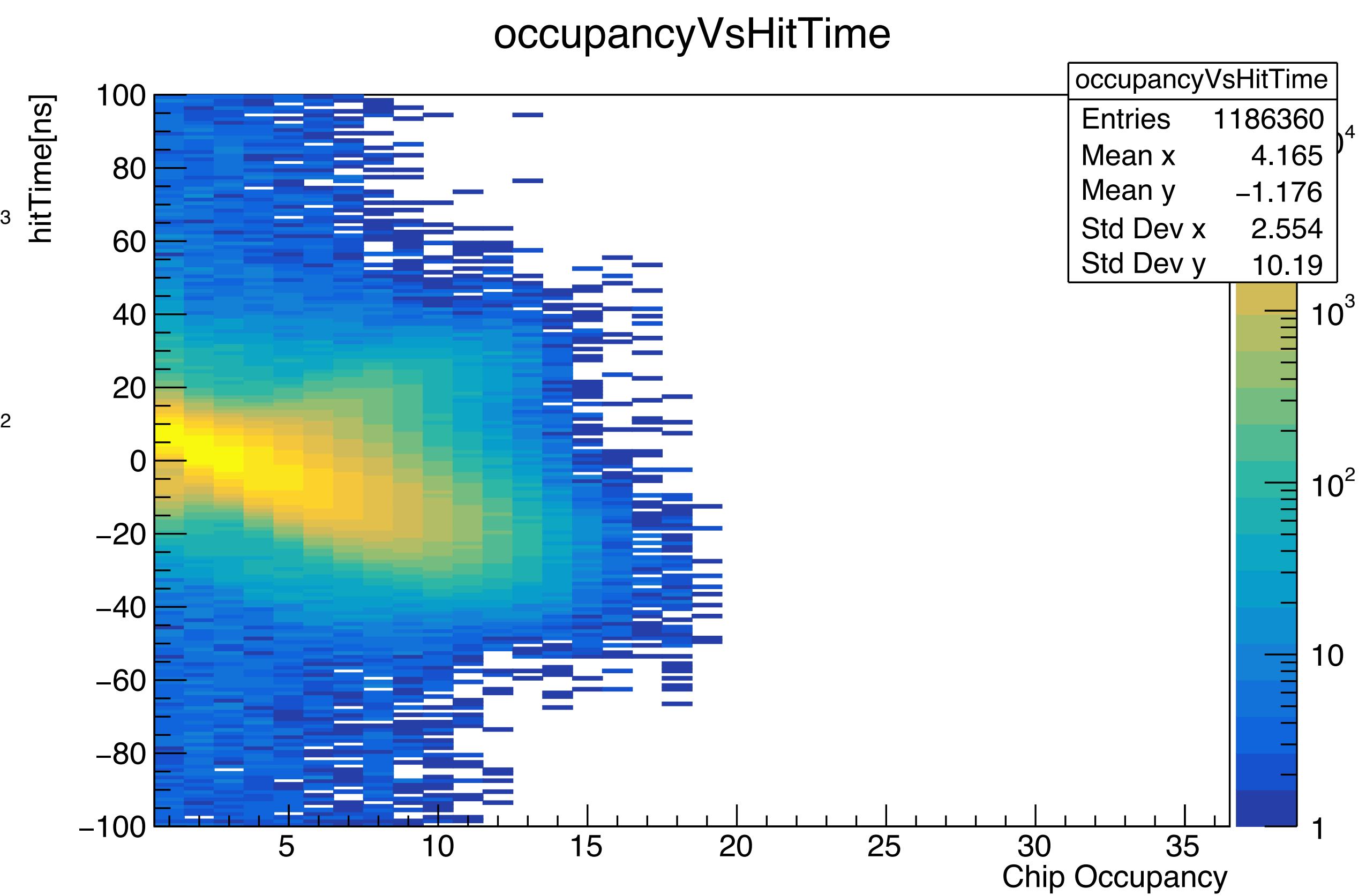
# Occupancy Electrons



# Occupancy Electrons - High/Low Gain



Low gain

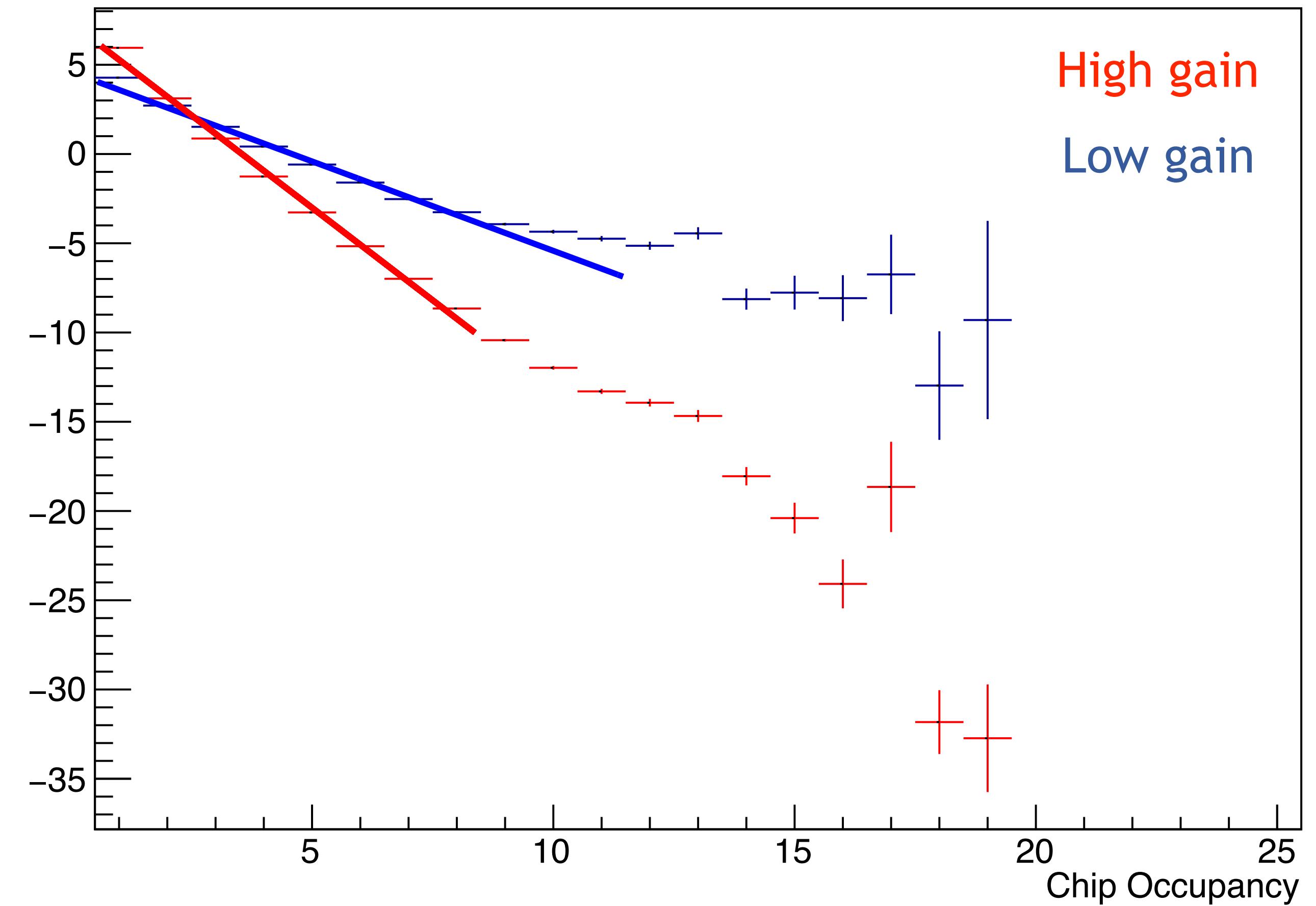


High gain

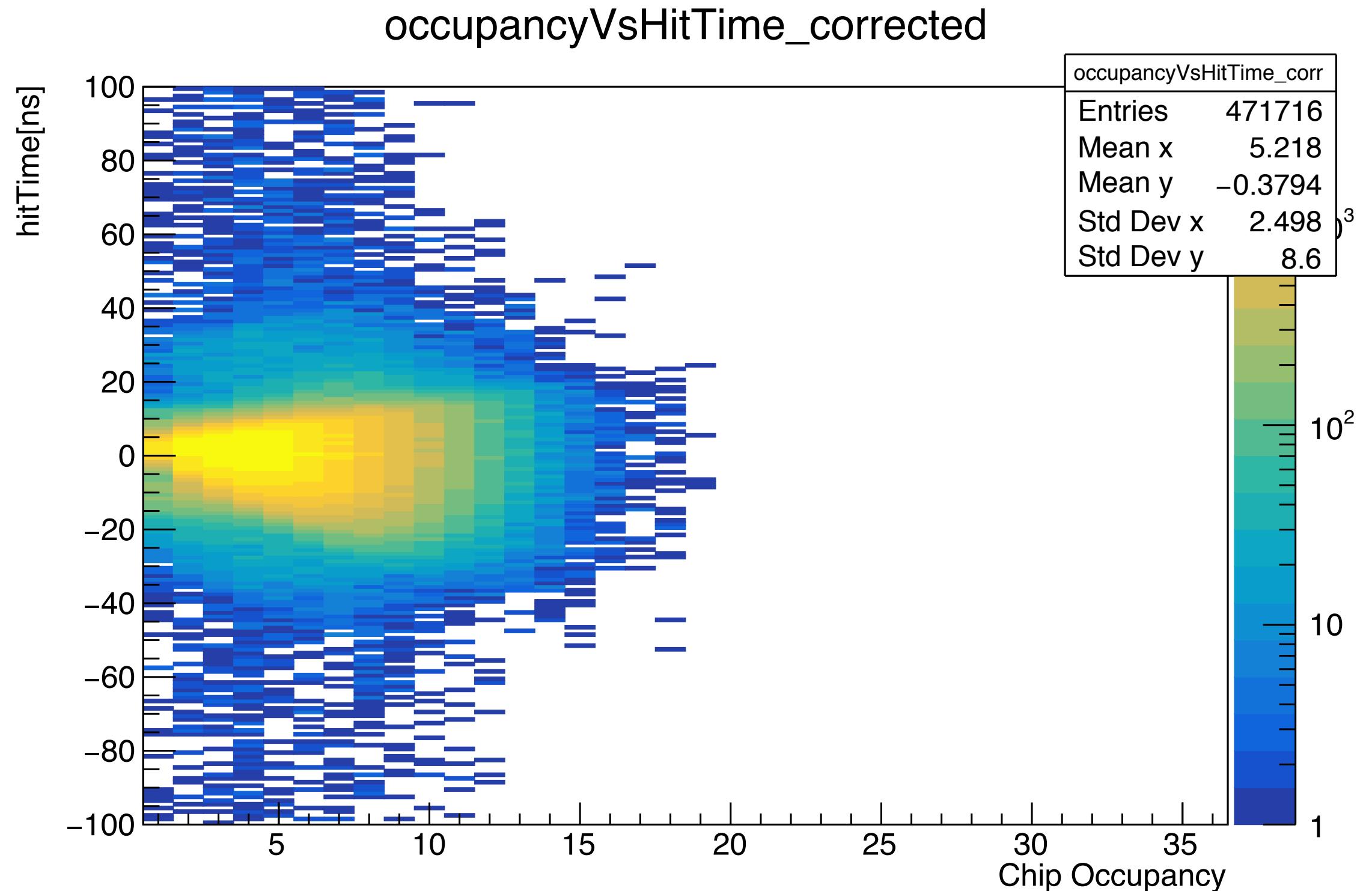
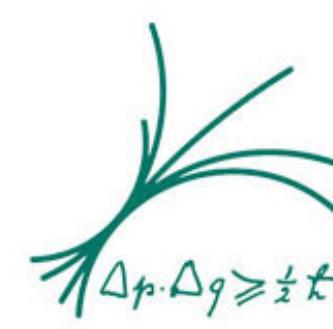


# Occupancy Electrons - High/Low Gain

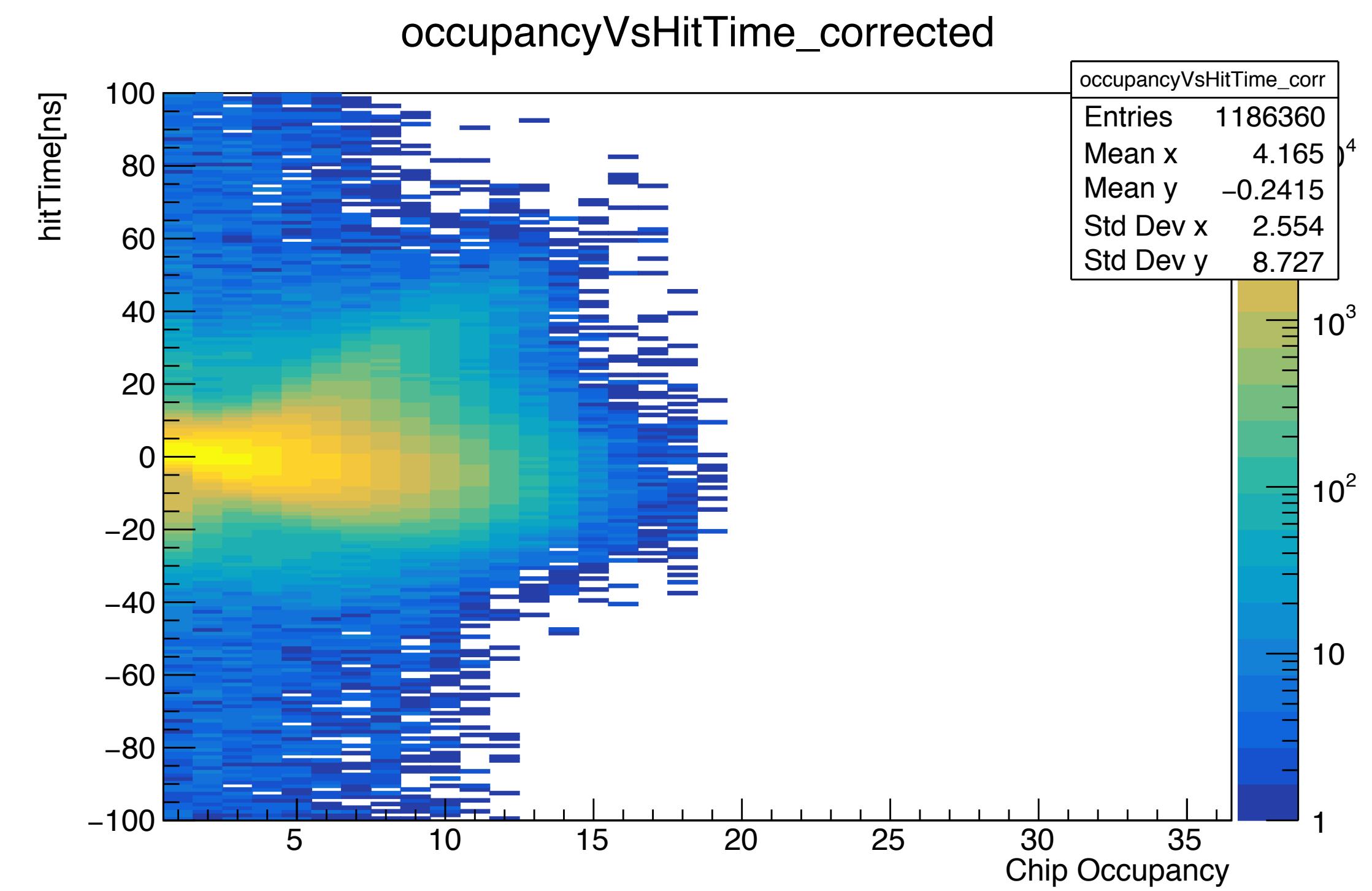
occupancyVsHitTime



# Occupancy Electrons - High/Low Gain



Low gain

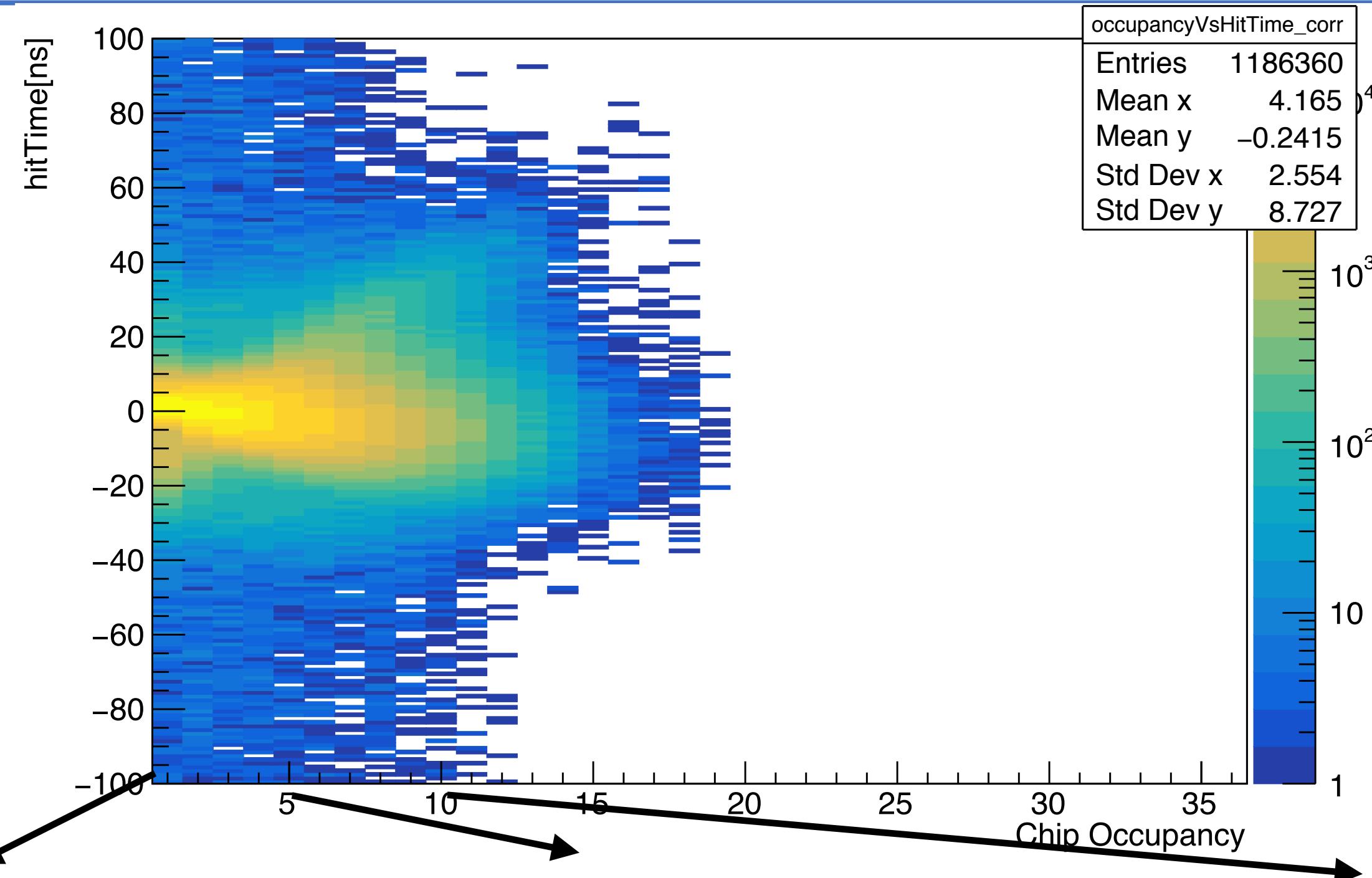


High gain

# Occupancy Electrons - High Gain

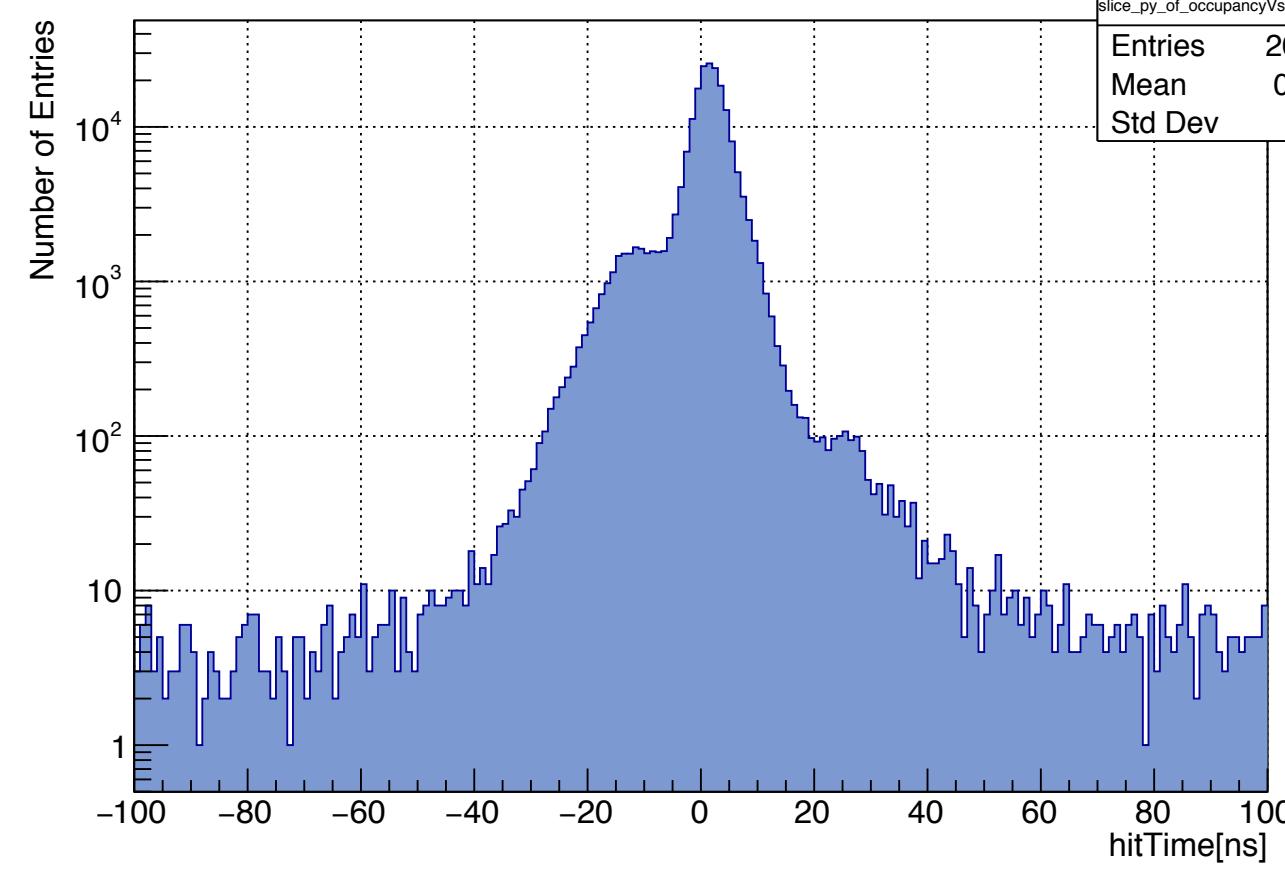


High gain

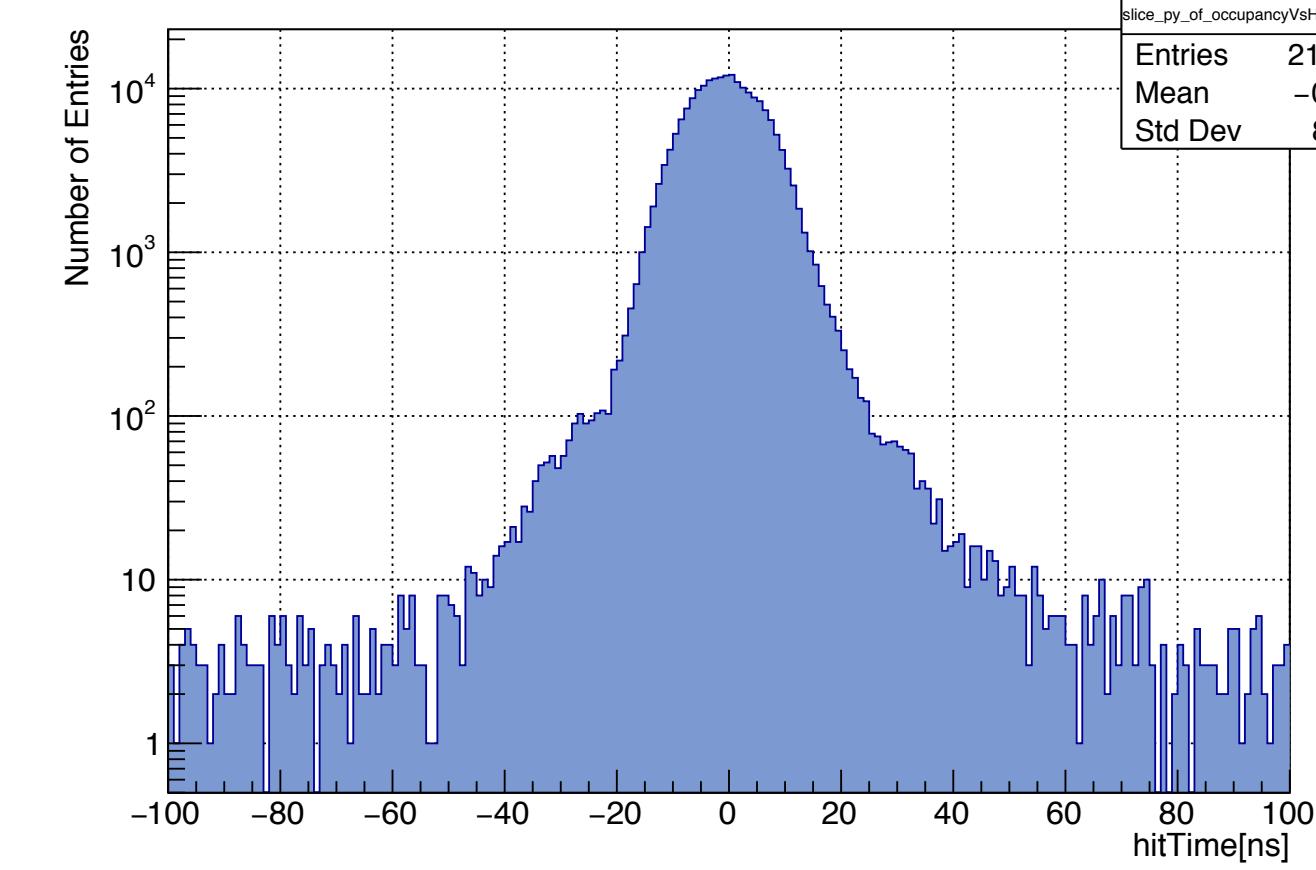


Only even bxID

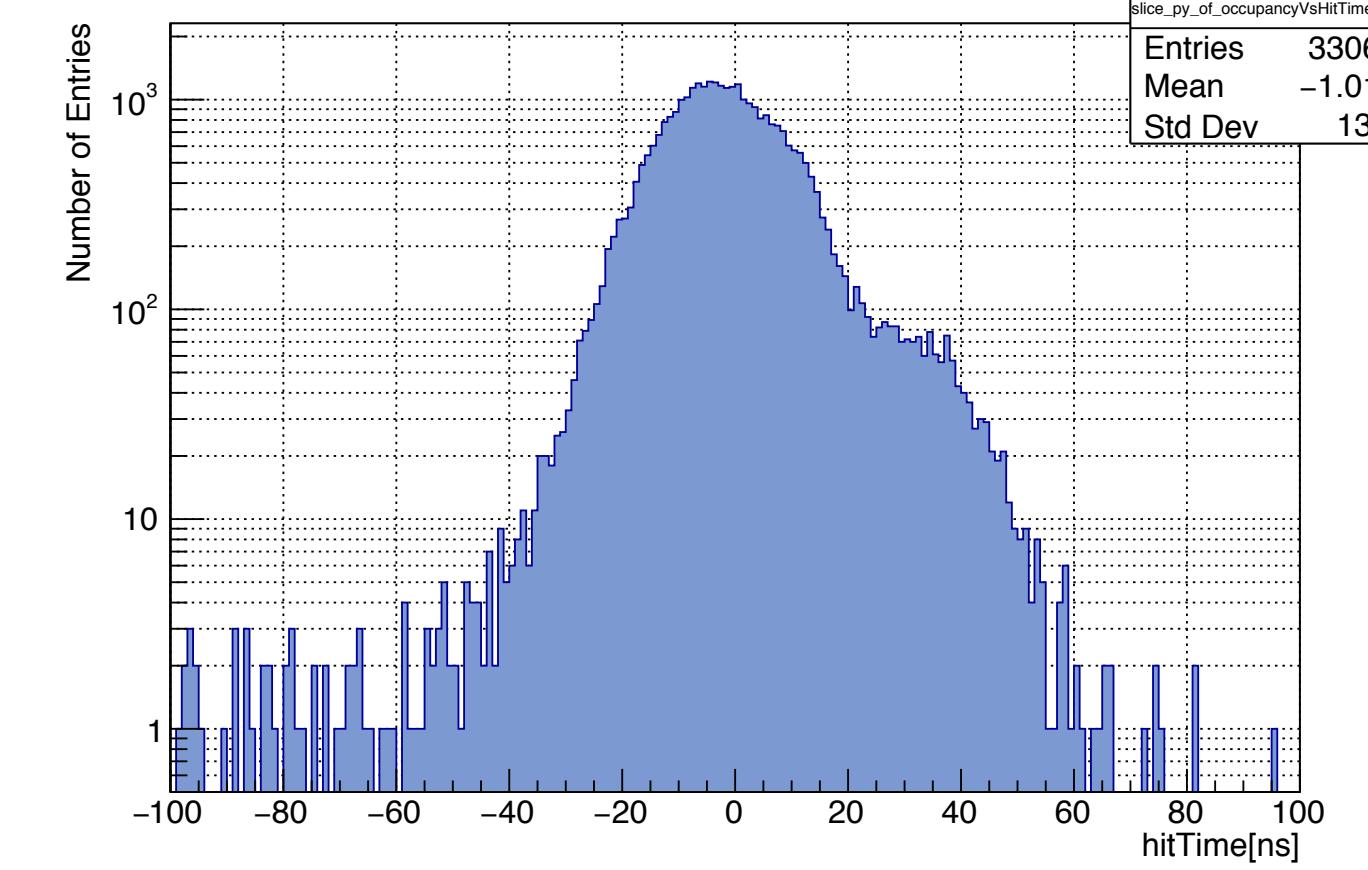
ProjectionY of binx=1 [x=0.5..1.5]



ProjectionY of binx=5 [x=4.5..5.5]



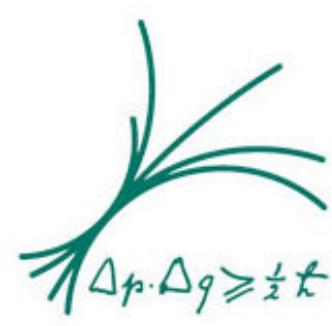
ProjectionY of binx=10 [x=9.5..10.5]





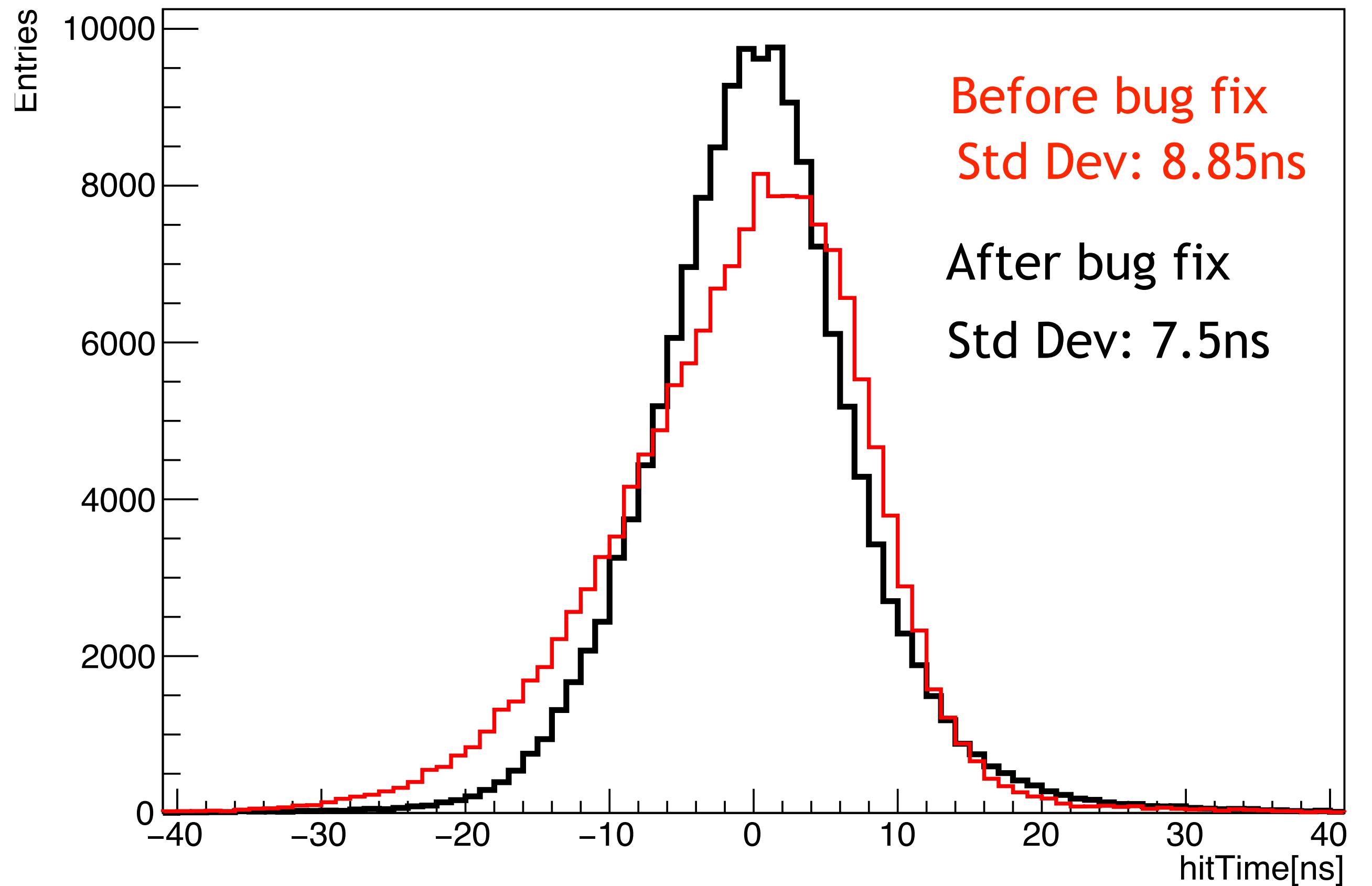
# Backup

# Correction Electrons @ 50GeV

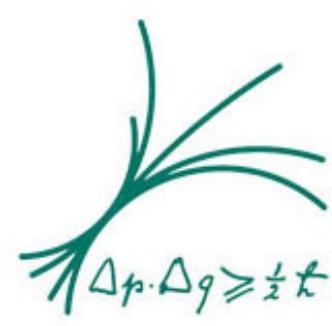


Only even bxID

Hit\_Time\_Distribution

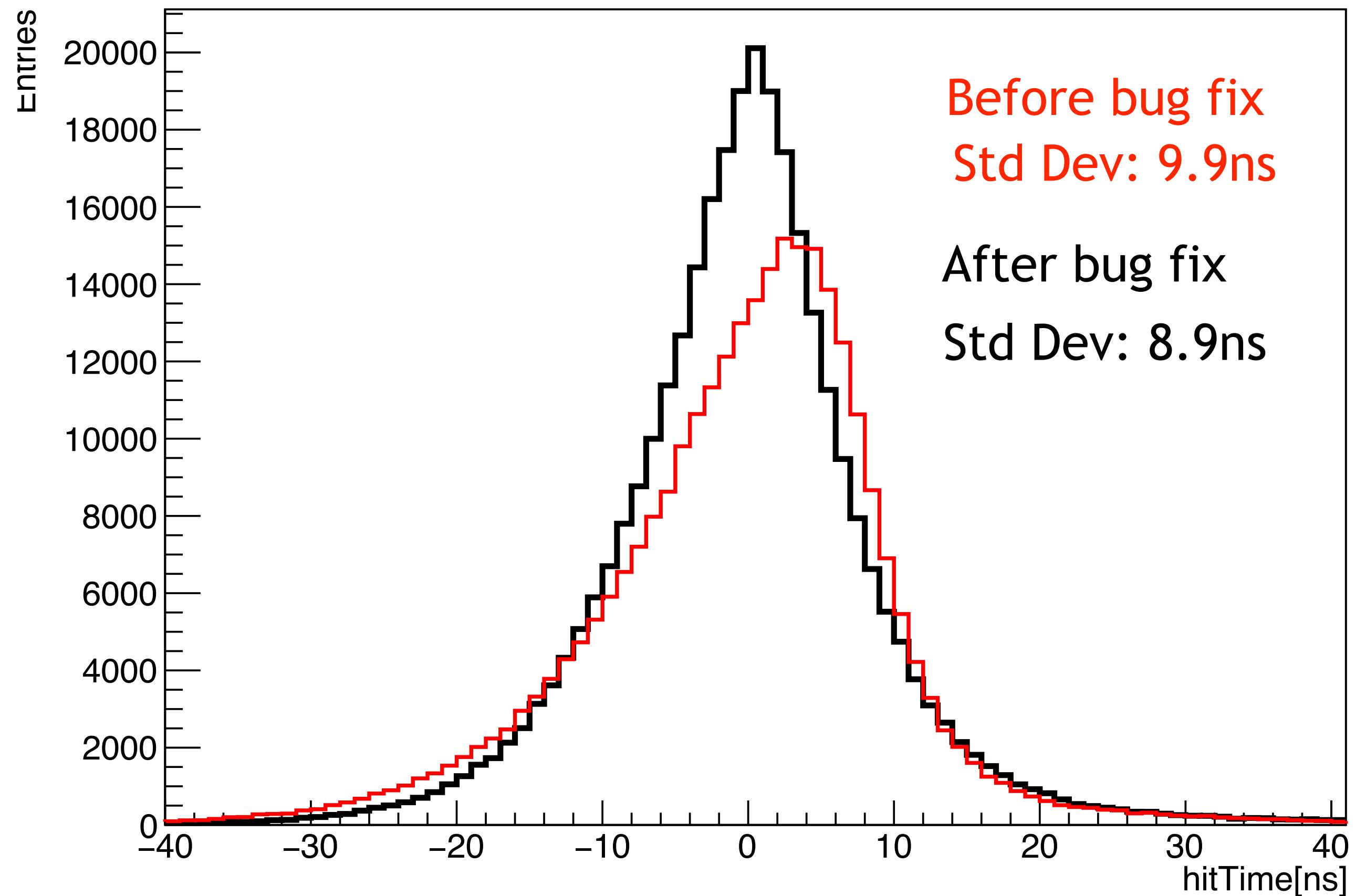


# Correction Pions @ 60GeV

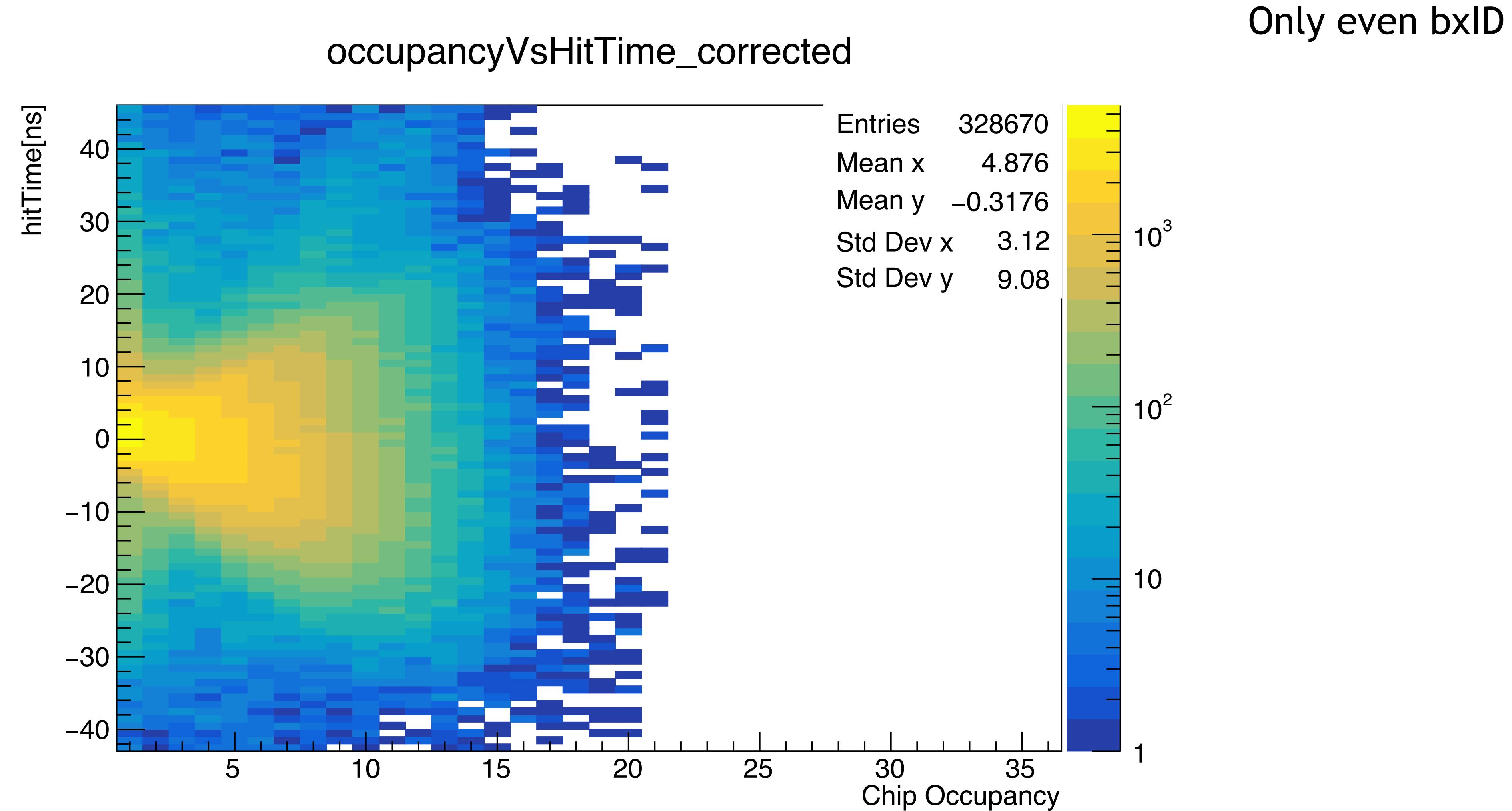
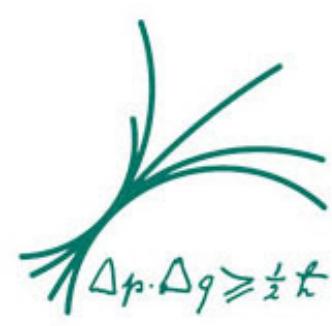


Only even bxID

Hit\_Time\_Distribution



# Correction Pions @ 60GeV

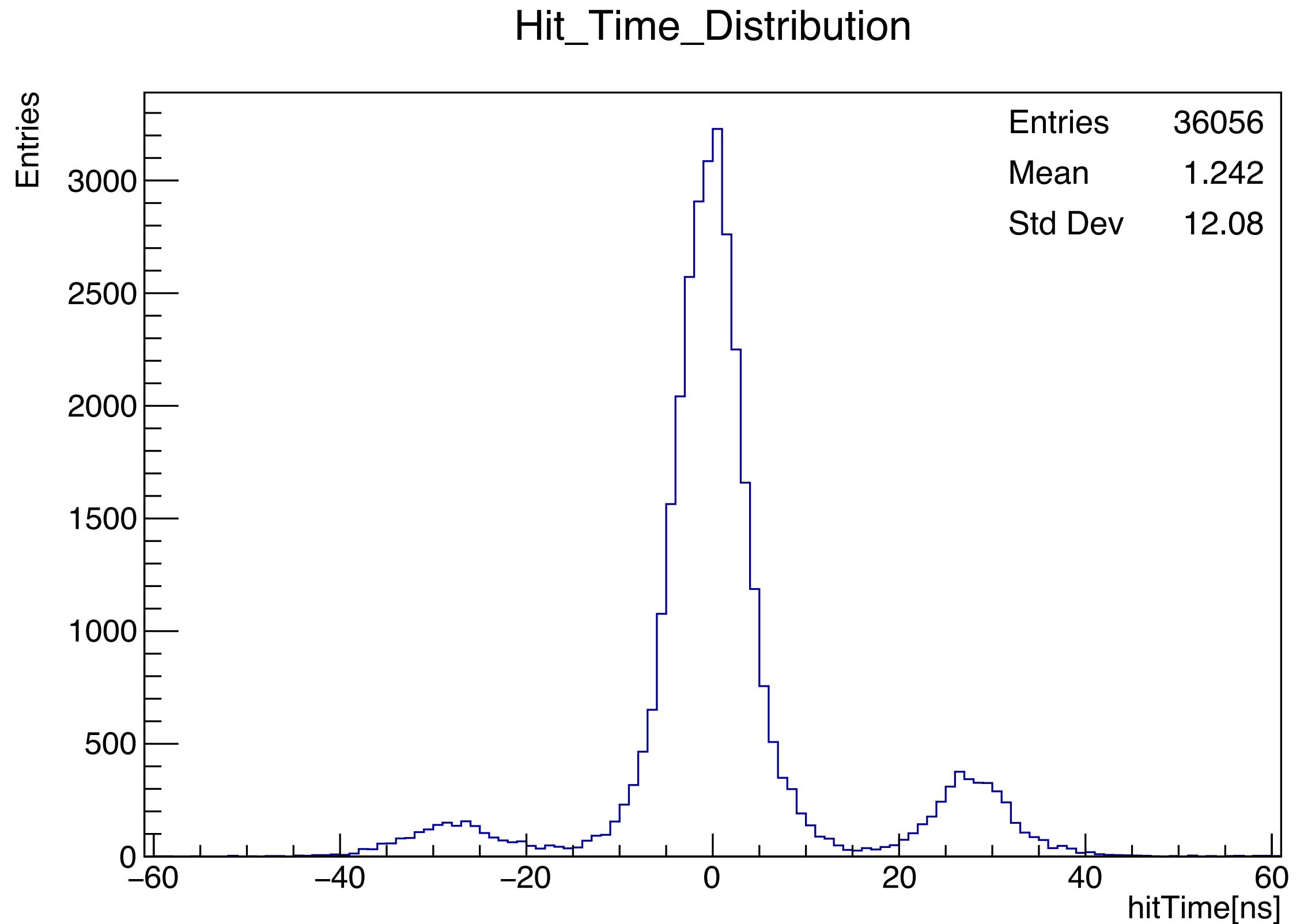




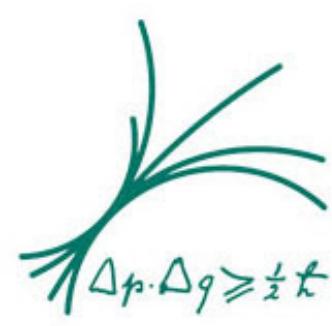
# Backup

# Problem

Only even bxID

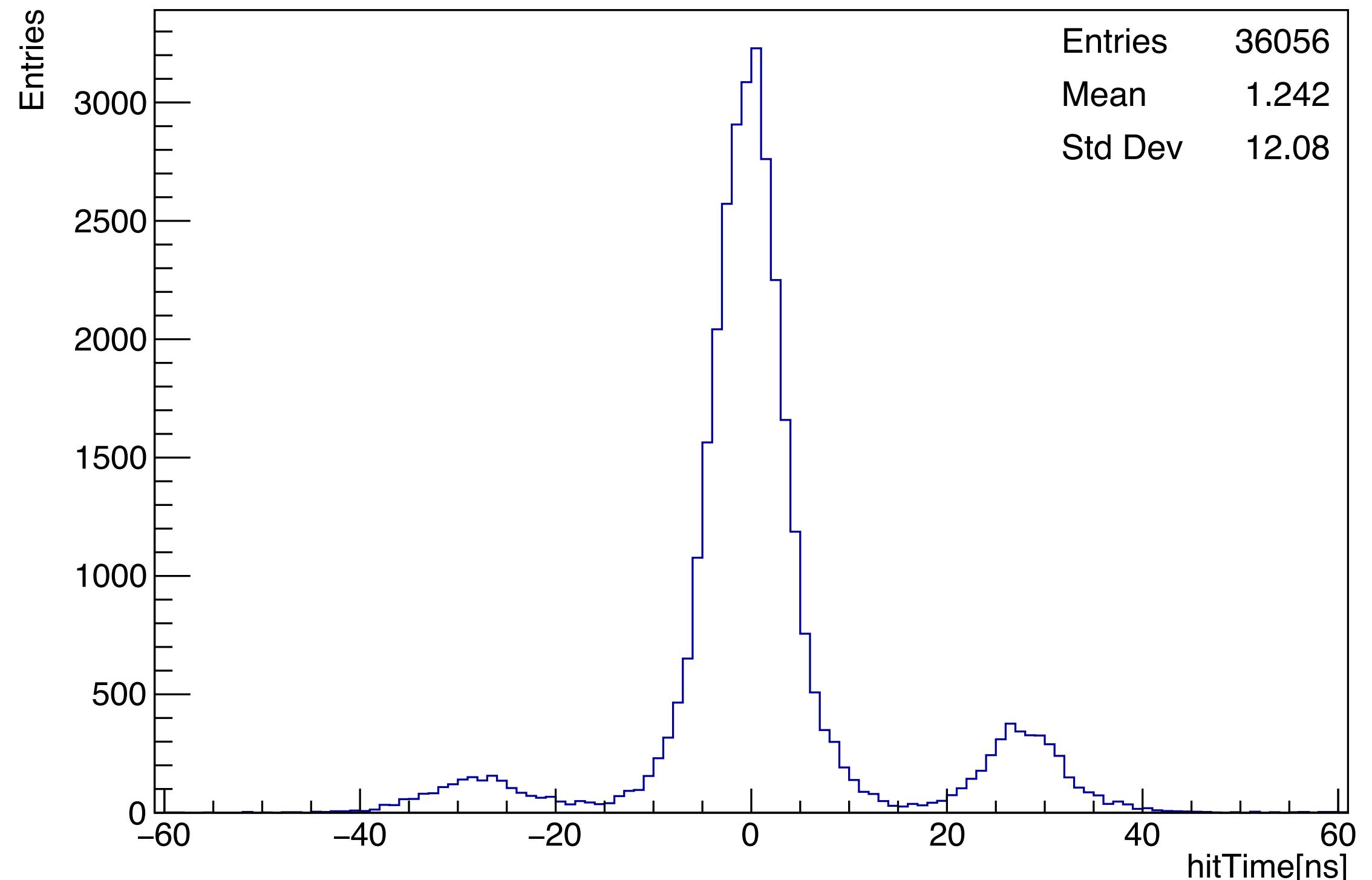


# Correction Muons @120GeV



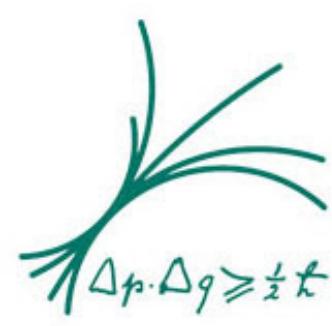
Only even bxID

Hit\_Time\_Distribution



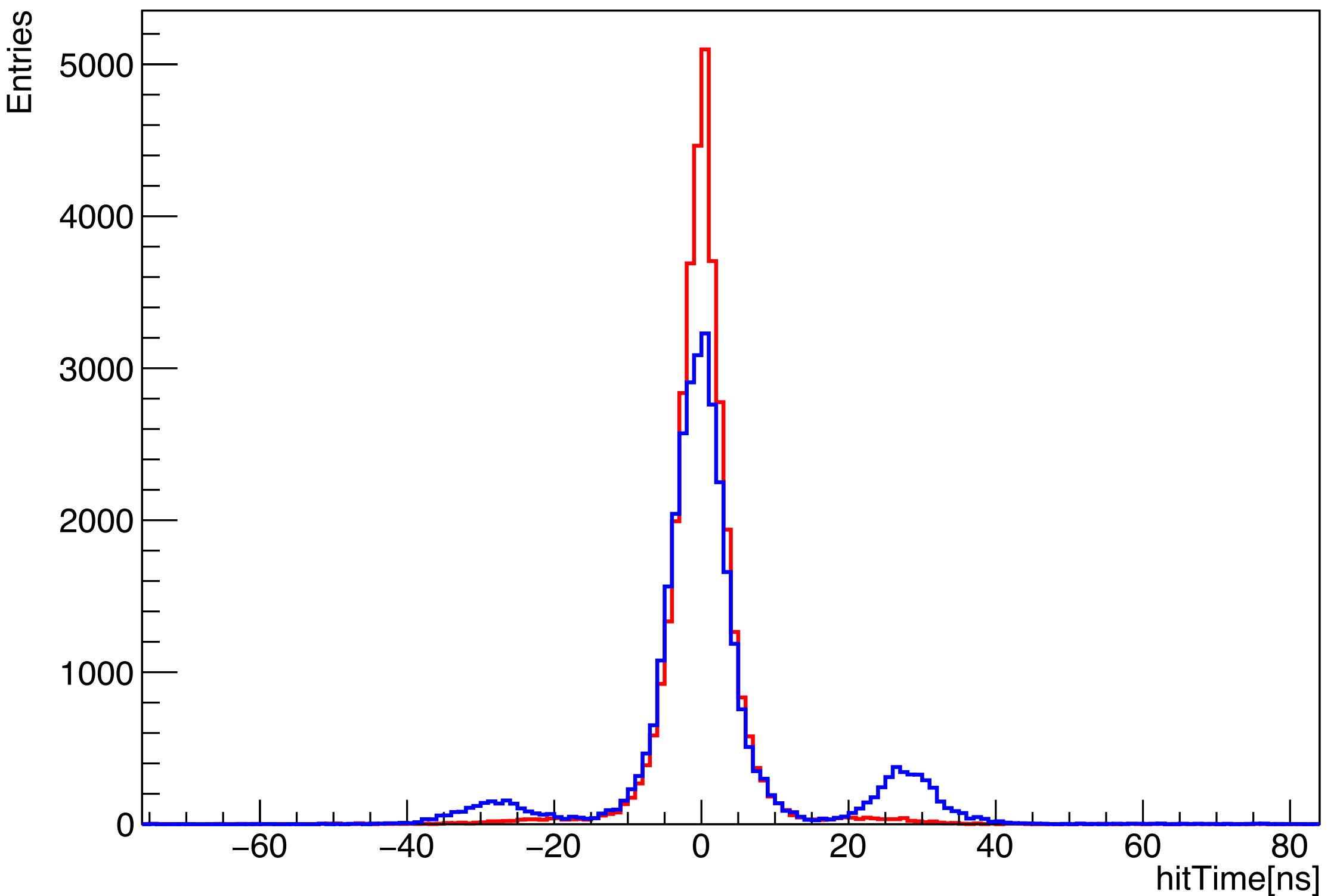
Correction 1: Shift mean hit time per event to 0

# Correction Muons @120GeV



Only even bxID

Hit\_Time\_Distribution

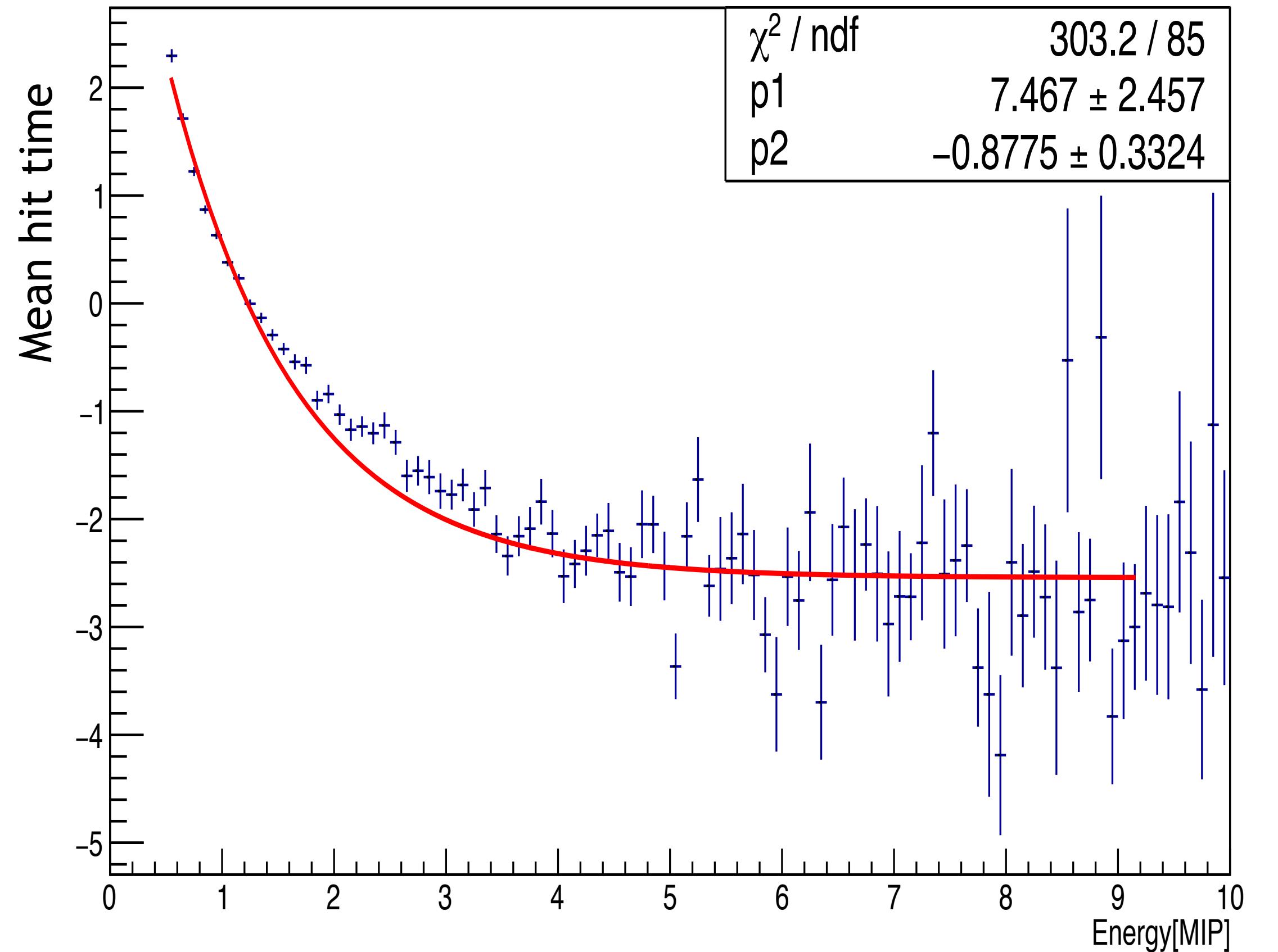


Correction 1: Shift mean hit time per event to 0

Correction 2: Time walk correction

# Correction Muons @120GeV

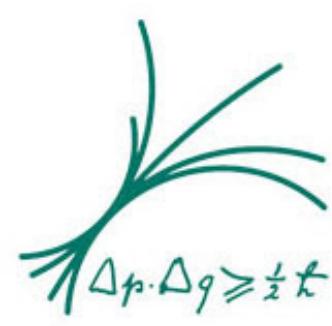
Only even bxID



Correction 1: Shift mean hit time per event to 0

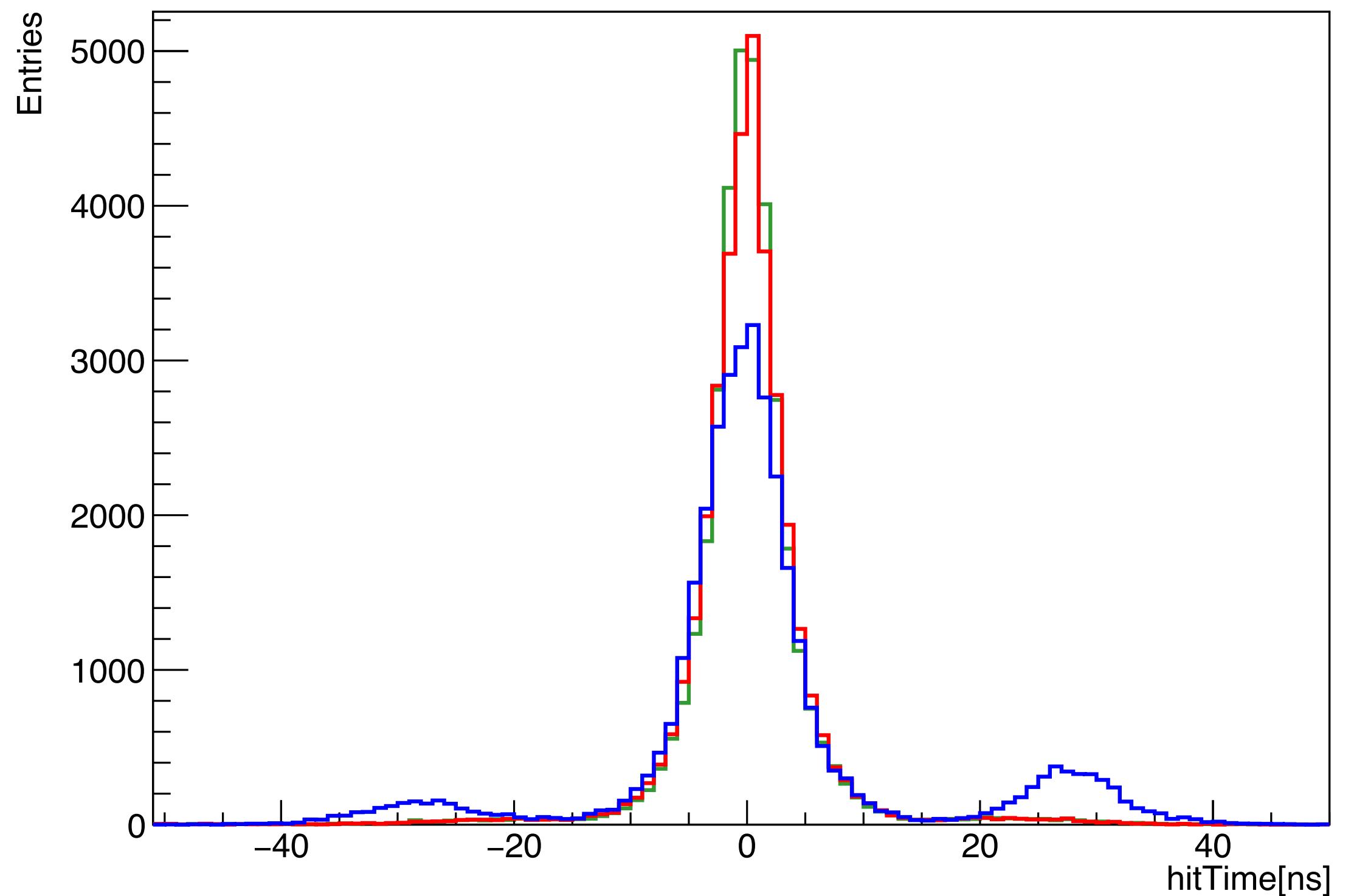
Correction 2: Time walk correction

# Correction Muons @120GeV



Only even bxID

Hit\_Time\_Distribution



Correction 1: Shift mean hit time per event to 0

Correction 2: Time walk correction

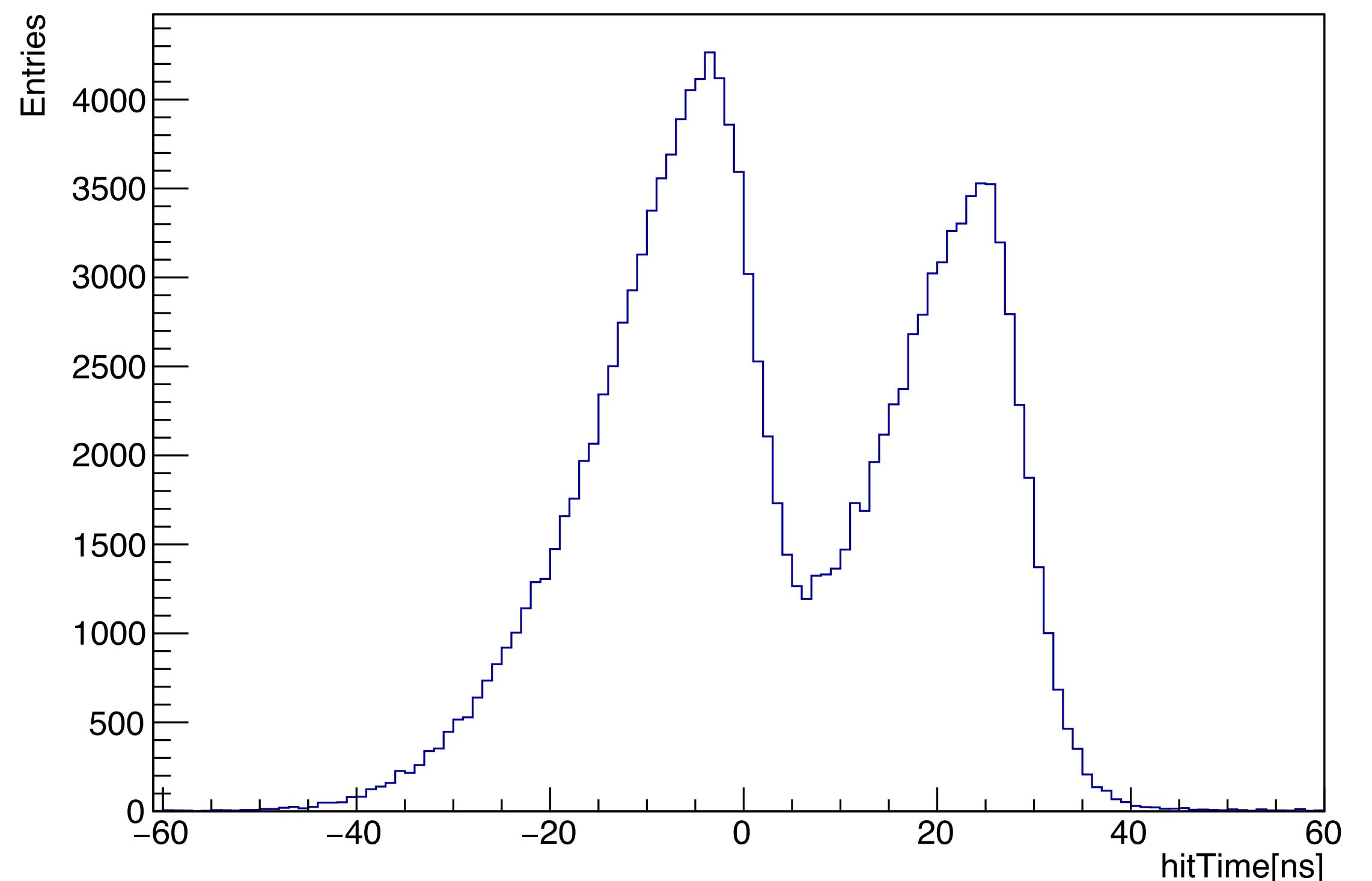
Std Dev: 5.6ns

# Correction Electrons @ 50GeV

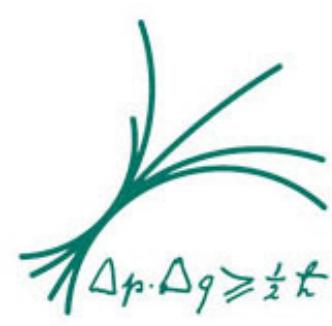


Only even bxID

Hit\_Time\_Distribution

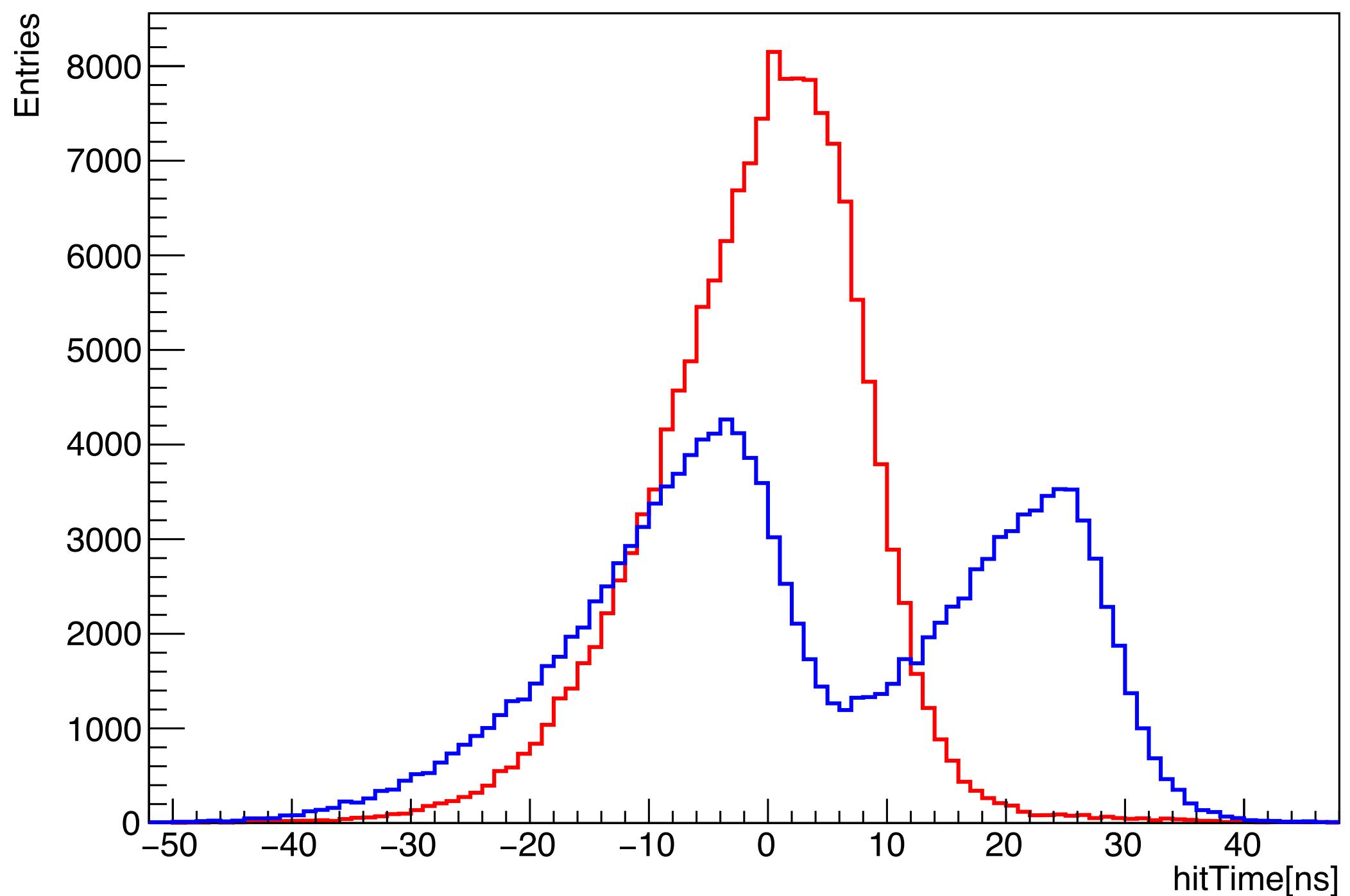


# Correction Electrons @ 50GeV



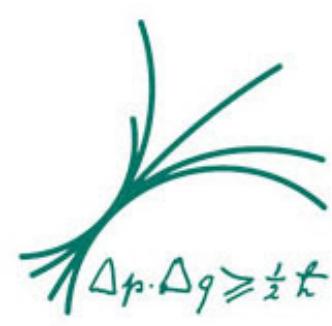
Only even bxID

Hit\_Time\_Distribution

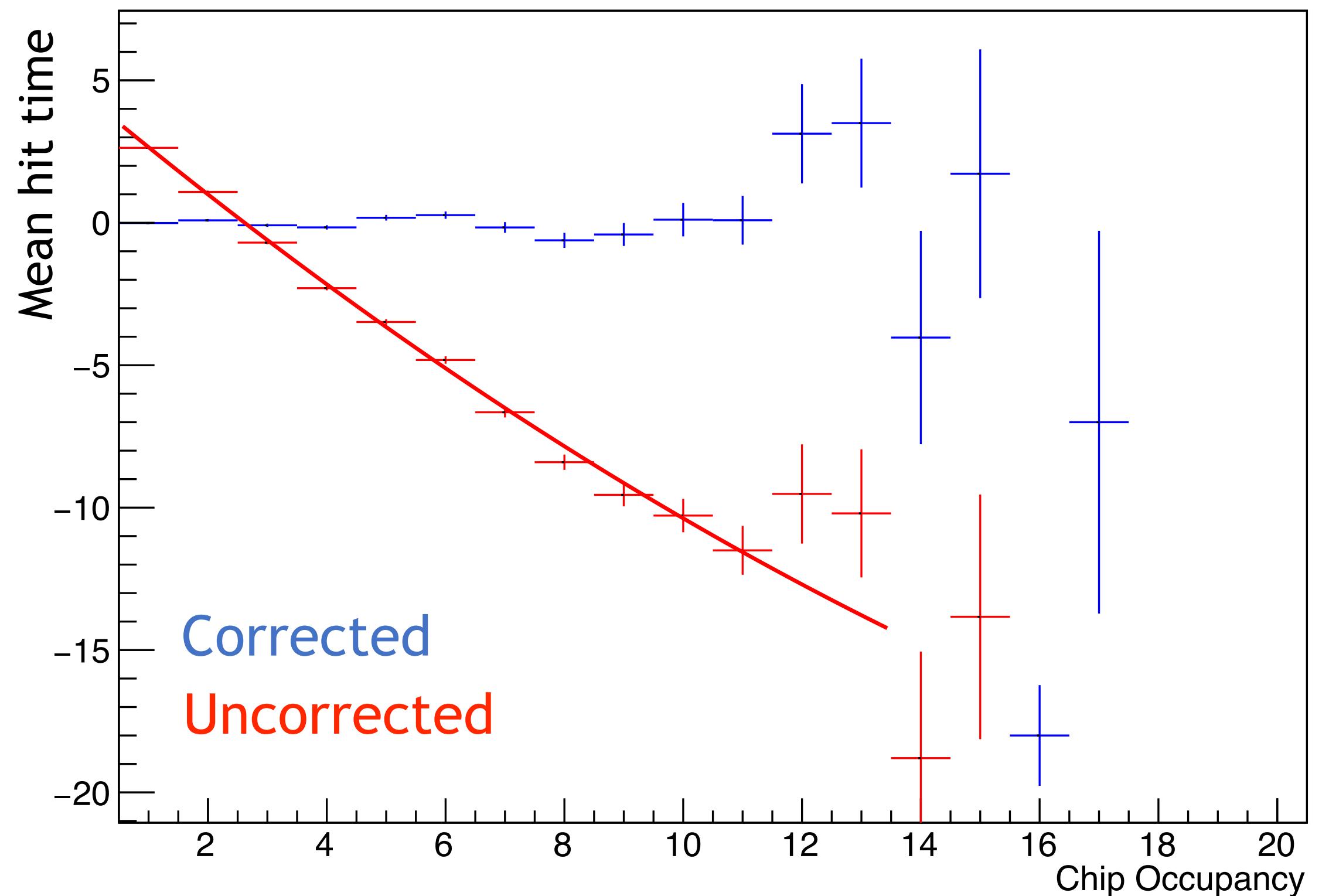


Correction 1: Shift mean hit time per event to 0

# Correction Electrons @ 50GeV



Only even bxID



Correction 1: Shift mean hit time per event to 0

Correction 2: Time walk correction (from Mouns)

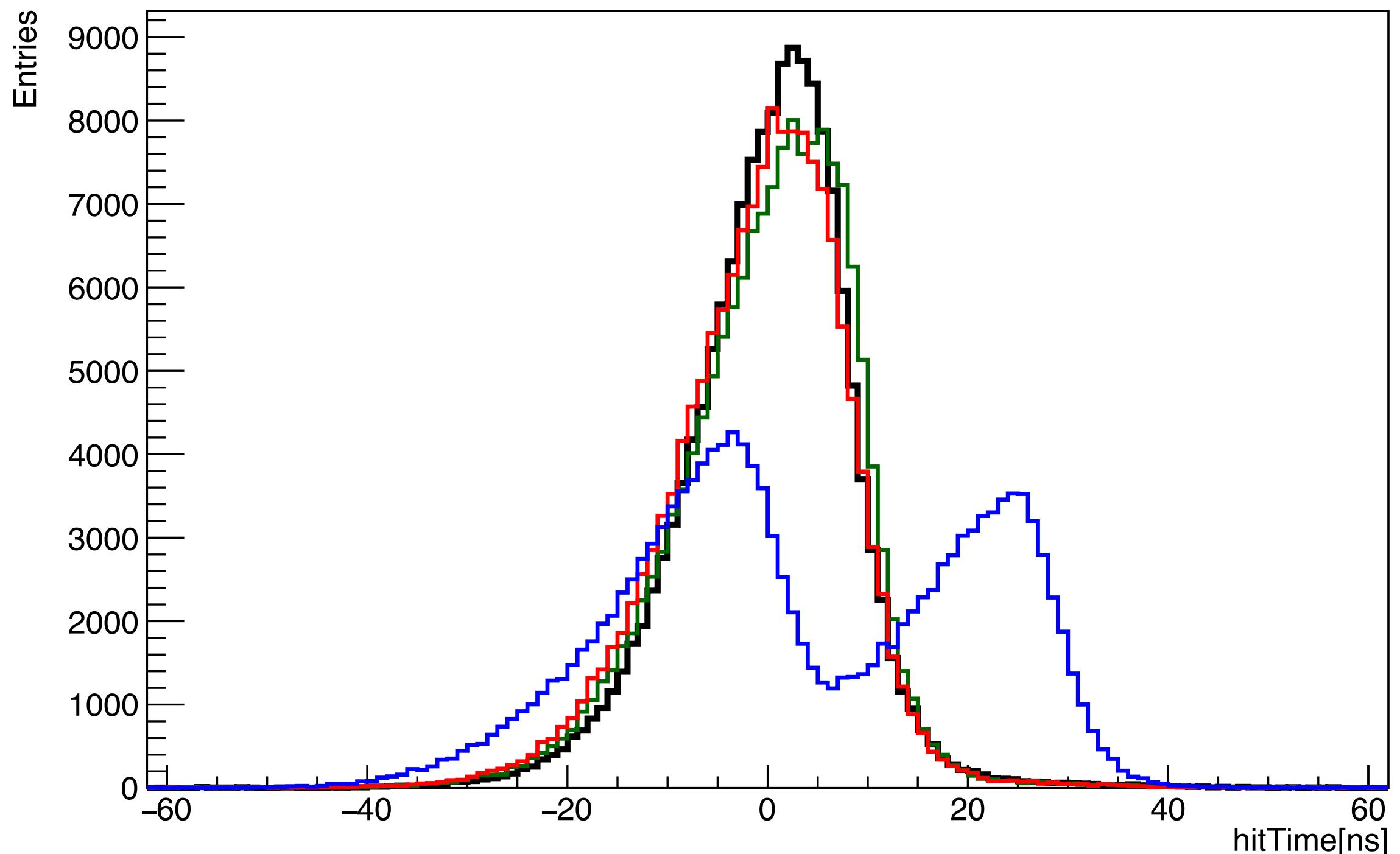
Correction 3: Chip occupancy correction

# Correction Electrons @ 50GeV



Only even bxID

Hit\_Time\_Distribution



Correction 1: Shift mean hit time per event to 0

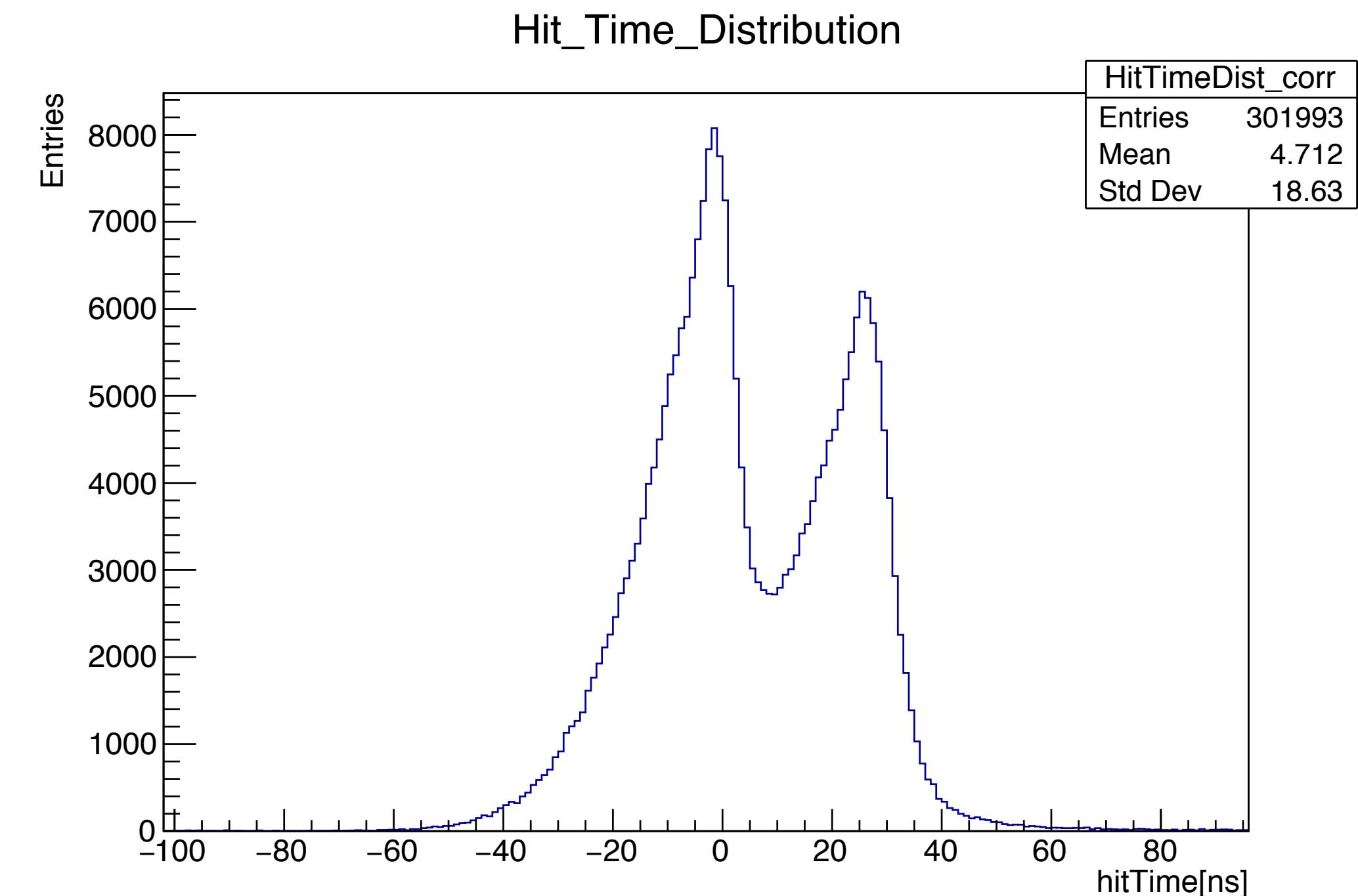
Correction 2: Time walk correction (from Mouns)

Correction 3: Chip occupancy correction  
Std Dev: 8.4ns

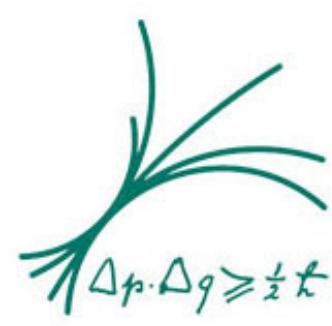
# Correction Pions @ 60GeV



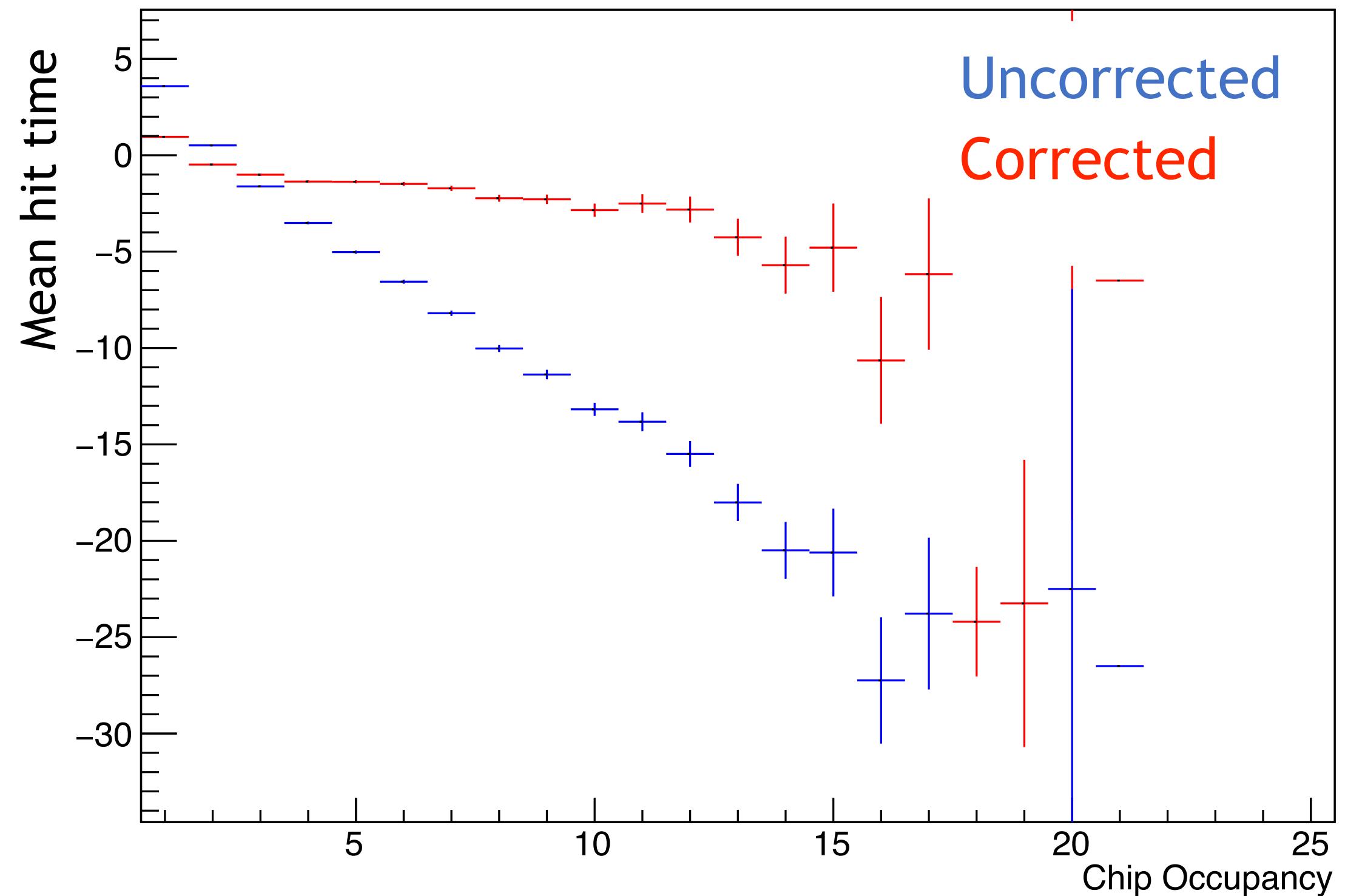
Only even bxID



# Correction Pions @ 60GeV



Only even bxID



Correction 1: Shift mean hit time per event to 0

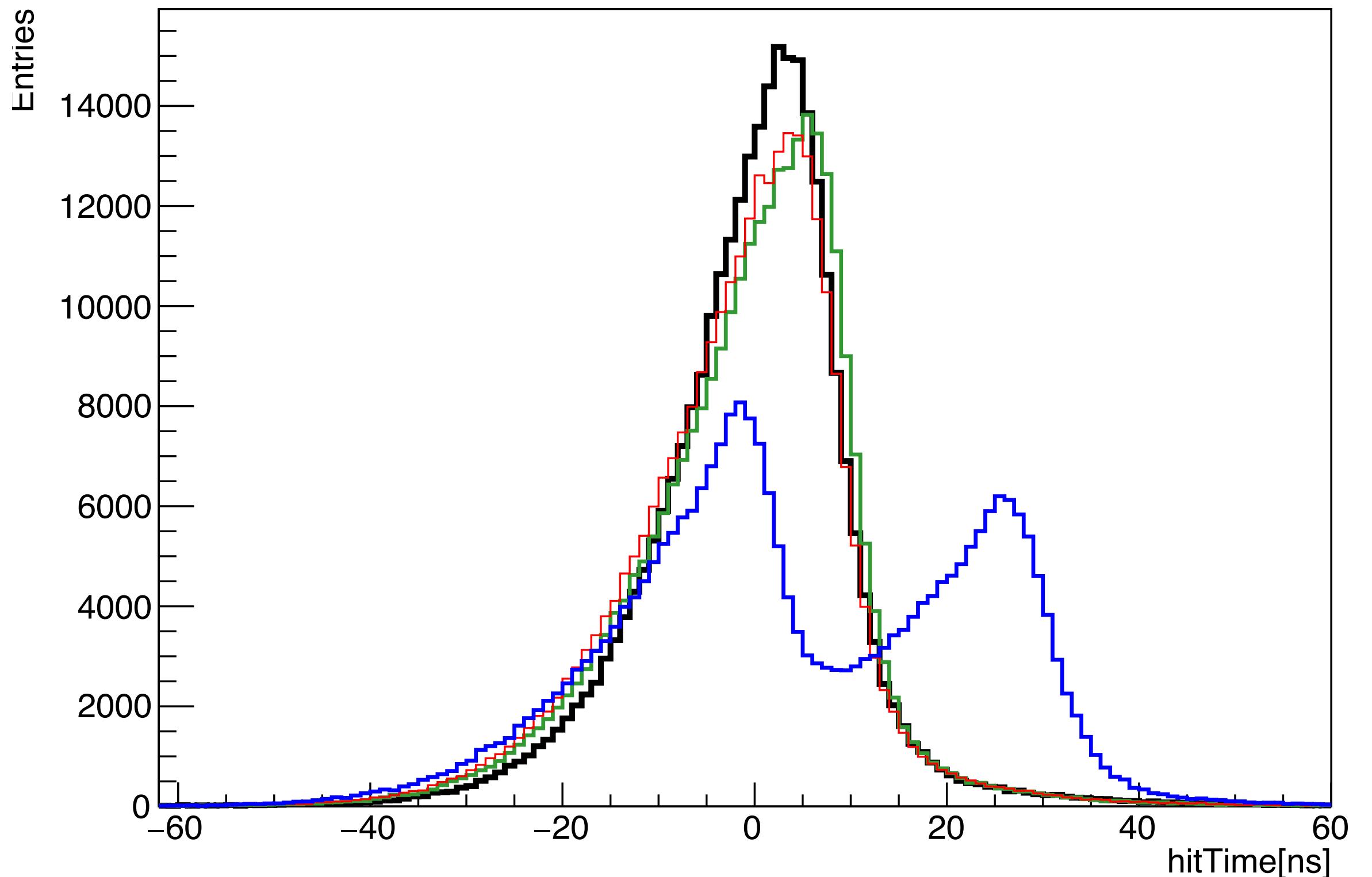
Correction 2: Time walk correction (from Mouns)

Correction 3: Chip occupancy correction (from Electrons)

# Correction Pions @ 60GeV



Hit\_Time\_Distribution



Only even bxID

- Correction 1: Shift mean hit time per event to 0
- Correction 2: Time walk correction (from Mouns)
- Correction 3: Chip occupancy correction (from Electrons)  
Std Dev: 10.53ns

Conclusion: left flank of the corrected distribution not yet understood