SuperFGD Beam test data analysis session

Electronics response: Time over Threshold studies

Saba Parsa, University of Geneva
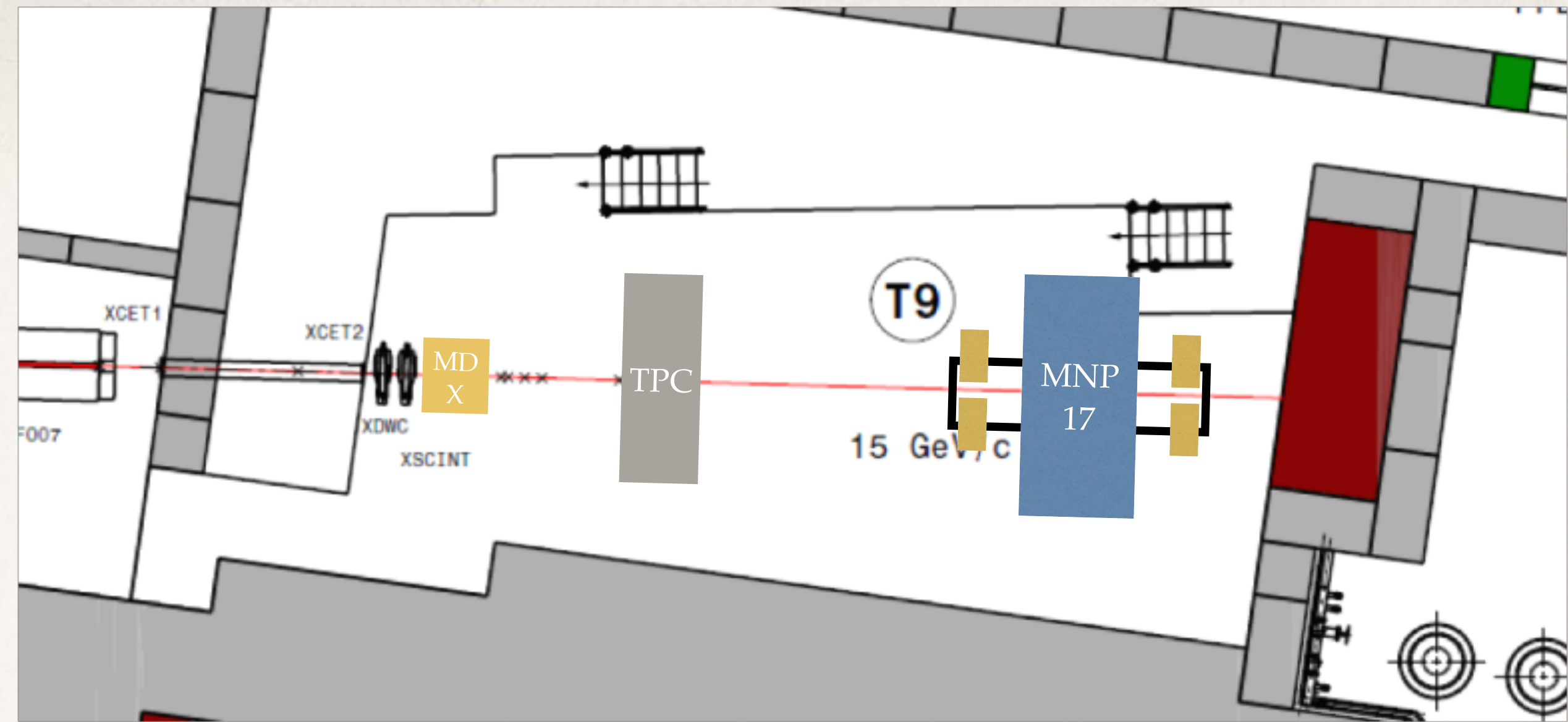
4 October 2018, ND280 Upgrade Meeting, CERN

Outline:

- ✤ **Setup at T9, Aug/Sep beam test**

- ✤ **Data summary**

- ✤ **Calibration**

- ✤ **Hit Time, Hit Amplitude**

- ✤ **Forced L1-Hold**

- ✤ **Electronics recovery time**

- ✤ **Trail time Missing**

Setup at T9 Aug/Sep beamtest

Super FGD prototype Took beam parasitically with TPC group from August 24th to September 5th 2018.
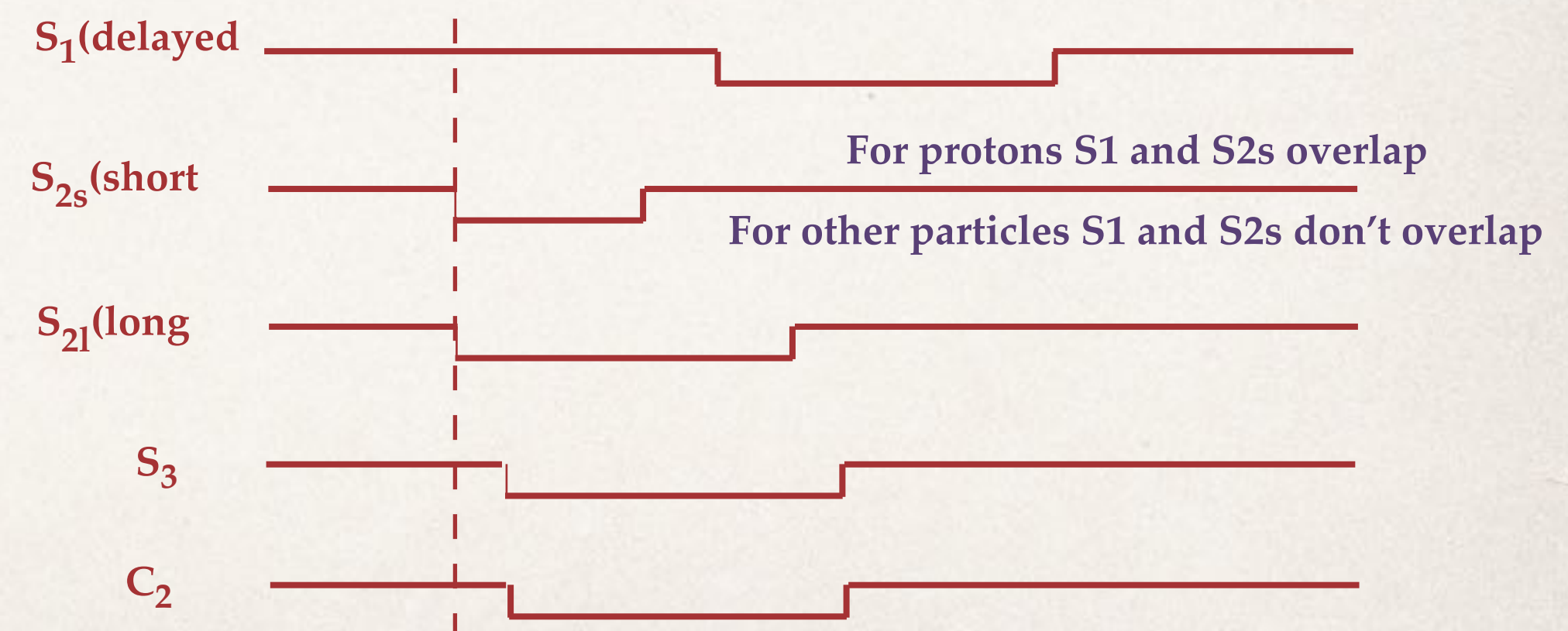

Trigger system

S_1 S_2 S_3

C$_1$ C$_2$ TPC   SFGD

all: $S_{2l} \times S_3 \times S_1$

e: $S_{2l} \times S_3 \times C_2$

p: $S_{2s} \times S_3 \times S_1$

π/μ: all $\times \bar{e} \times \bar{p}$

Signals drawn for the case of electron

S_1(delayed

For protons S1 and S2s overlap

S_{2s}(short

For other particles S1 and S2s don't overlap

S_{2l}(long

S_3

C_2

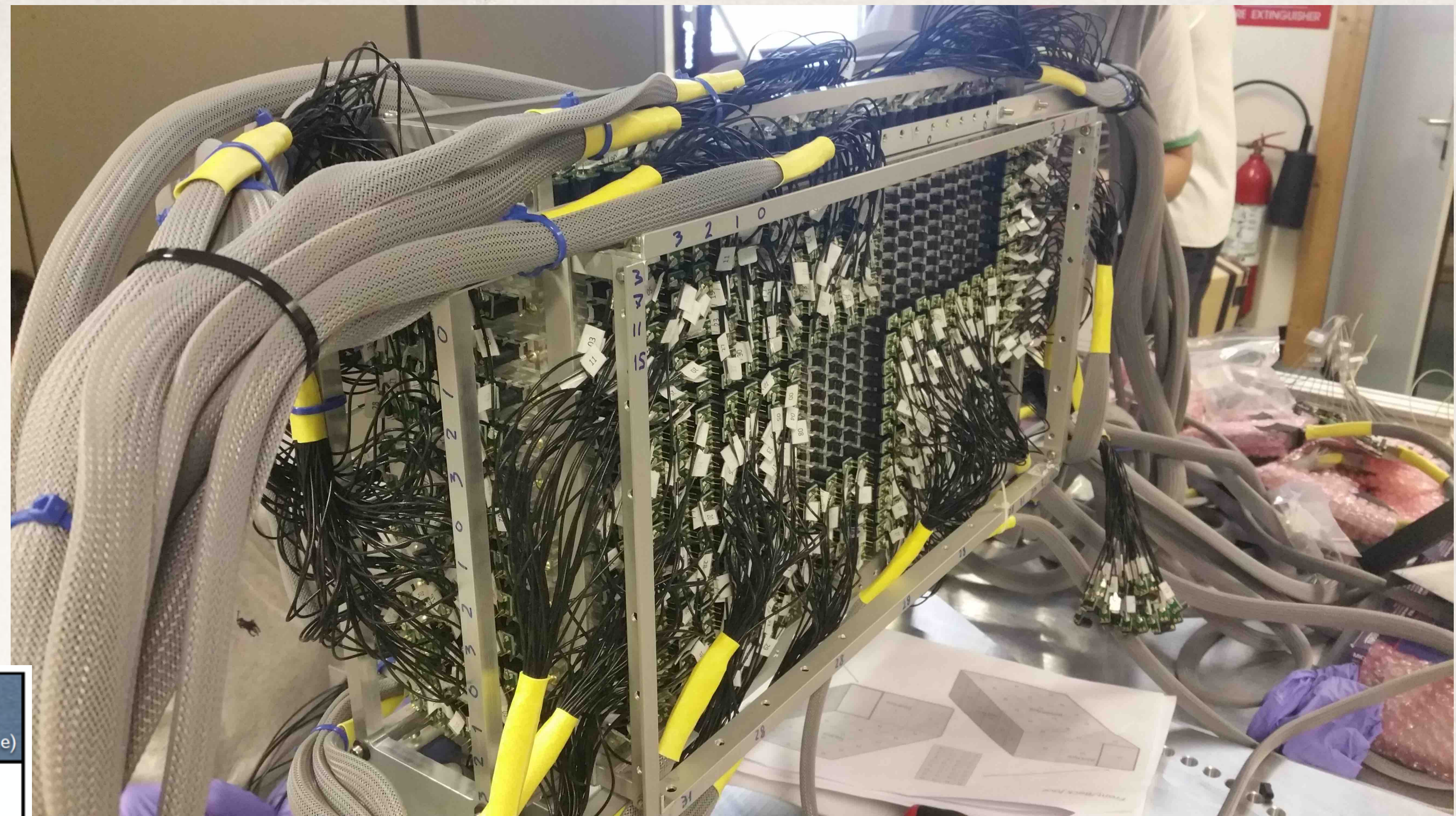# Setup at T9 Aug/Sep beamtest
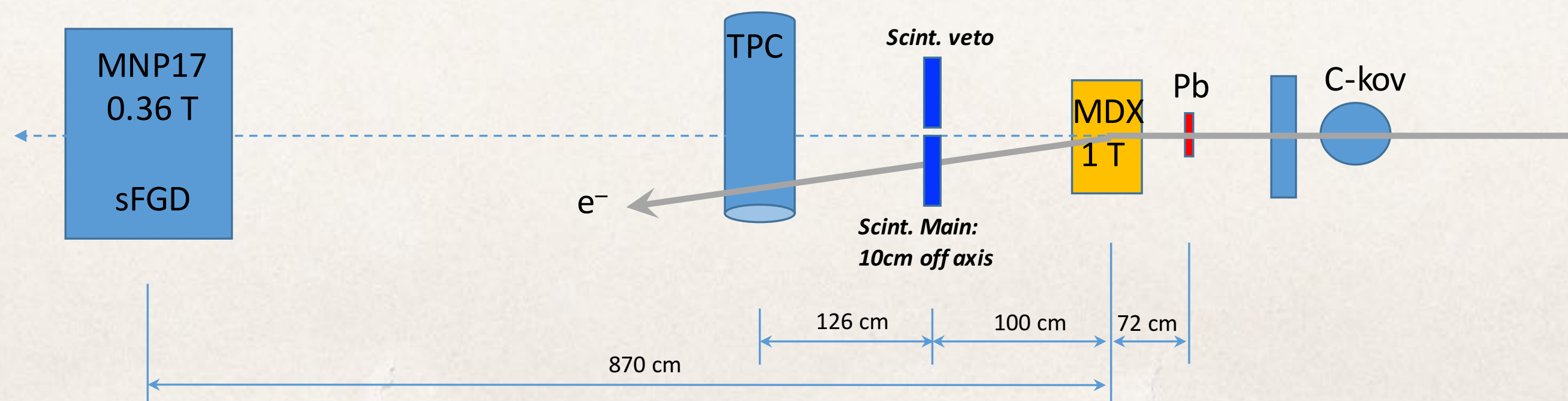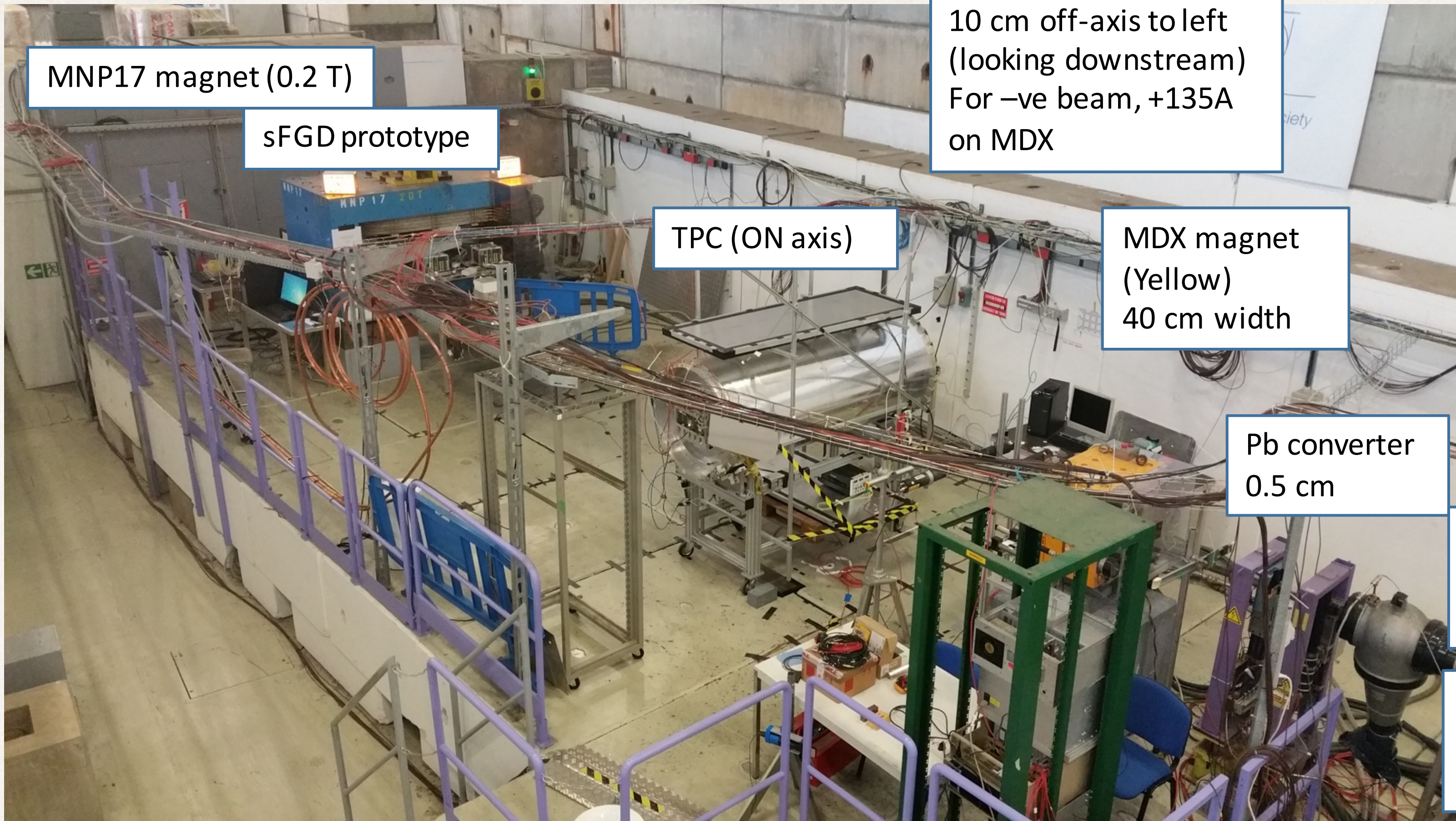
Three MPPC types

The **sorting/cabling sequence**:
- Sorting MPPCs into groups according to operating voltage (V_{op}): **range 100 mV**.
- Further sorting into batches of 32 (to match cable bundles).


Type II × 384   **Type I × 1152**   **Type III × 192**

	S13081-050CS	S13360-1325CS	S12571-025C (used for Baby-MIND, as reference)
Package	Ceramic		Ceramic
Sensitive area	1.3×1.3mm²		1.0×1.0mm²
Pixel pitch	50μm	25μm	25μm
Number of pixels	667	2668	1600
Fill factor	61%	47%	65%
V_{BR}	53±5 V	53±5 V	65±10 V
V_{op}	V_{BR}+3 V	V_{BR}+5 V	V_{BR}+3.5 V
PDE (@450nm, V_{op})	35%	25%	35%
Dark count (typ.)	90 kcps	70 kcps	100 kcps
Gain (typ.)	1.5×10^6	7×10^5	5.15×10^5
Cross talk	1%	1%	>10%

S12571-025C
Top middle
Bottom middle

S13081-050C
Top upstream
Bottom upstream

S13360-1325CS:
Top downstream
Bottom downstream
All sides
All faces

24 cm
8 cm
16 cm
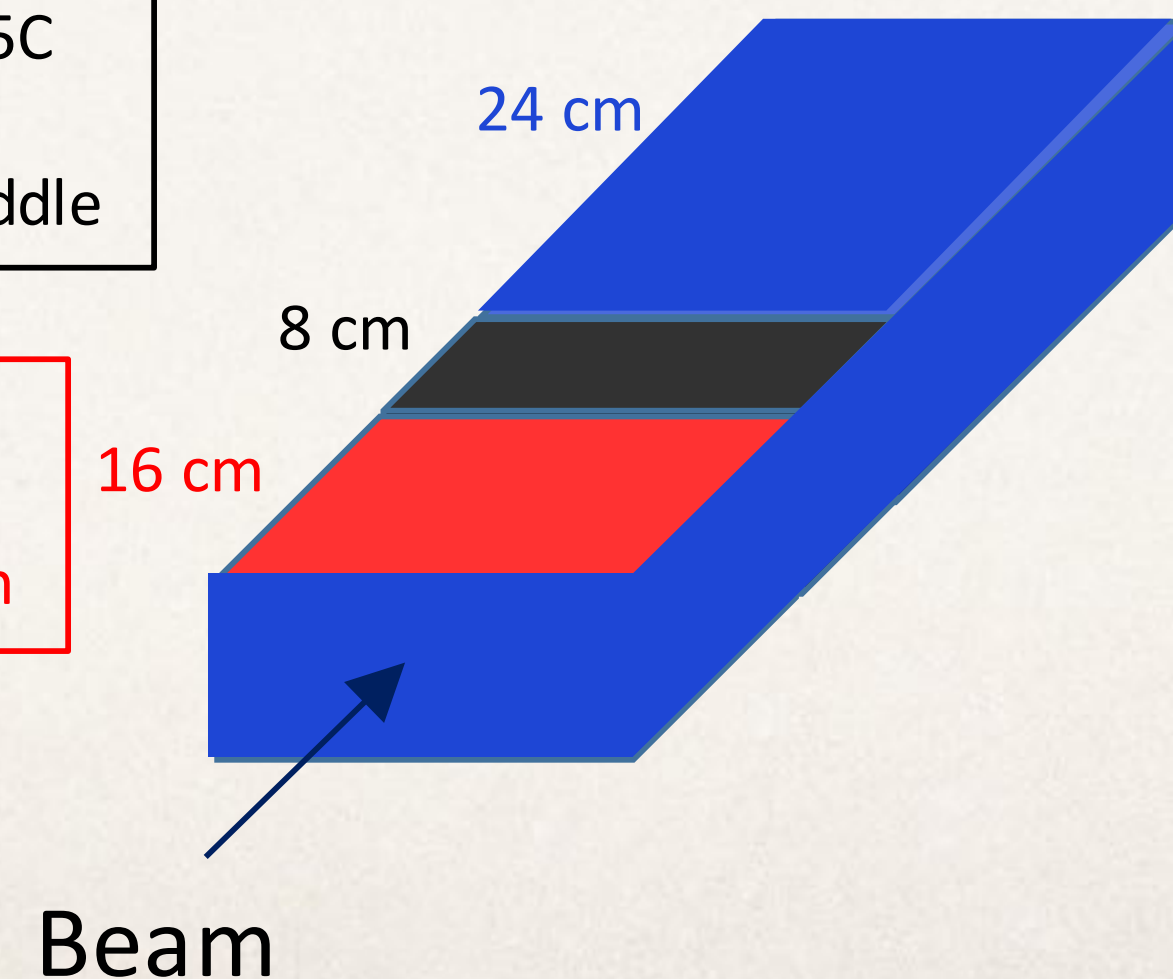
Beam

Data summary

Momentum	Beam type	HG/LG settings	Detector orientation	Magnet MNP 17	Comments
0.8	Hadrons	9 cases	0	ON (135)	3 days
0.5	Hadrons	9 cases	0	ON (135)	3 days
1	Hadrons	9 cases	0	ON (135)	3 days
1	Hadrons	1 case	30	OFF/ON (135,495)	5 hours
-0.8	Hadrons	1 case	30	ON (495)	1 hours
-0.8	Hadrons	1 case	0	ON (135)	7 hours
2	Muon/Hadrons	1 case	0	OFF/ON (135,495)	10 hours
0.5	Muons	1 case	0	OFF/ON (135,495)	9 hours, Lead
-8	Hadrons	1 case	0	OFF	Exotic, paraffin, Pb
-5	Hadrons	1 case	0	OFF	Exotic
-4	Hadrons	1 case	0	OFF	Exotic, Copper
-0.8	Hadrons	1 case	0	ON (135)	Photon, MDX
0.4	Hadrons	1 case	0	ON (240)	Photon, MDX

Signal path
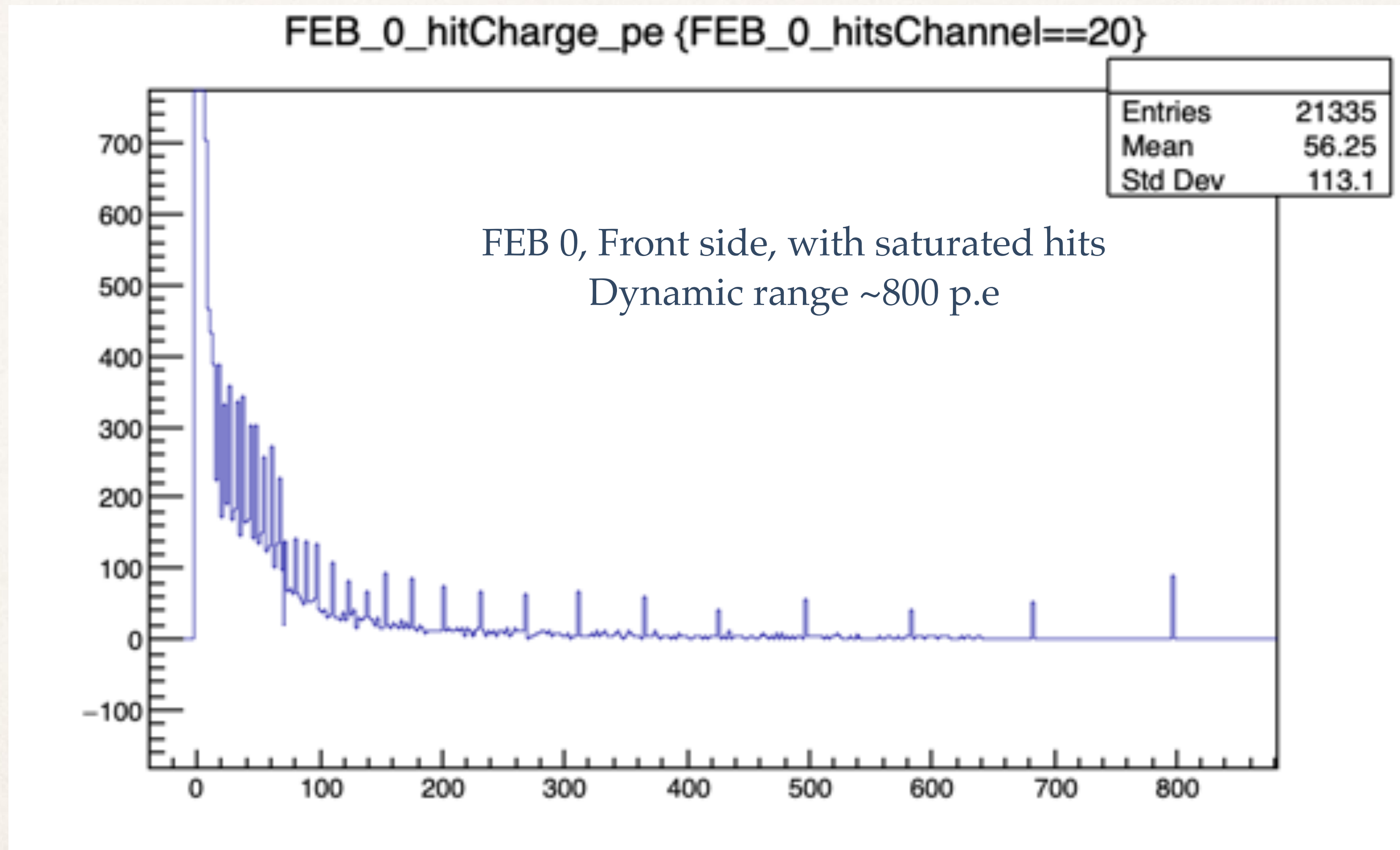
Data signal paths from CITIROC
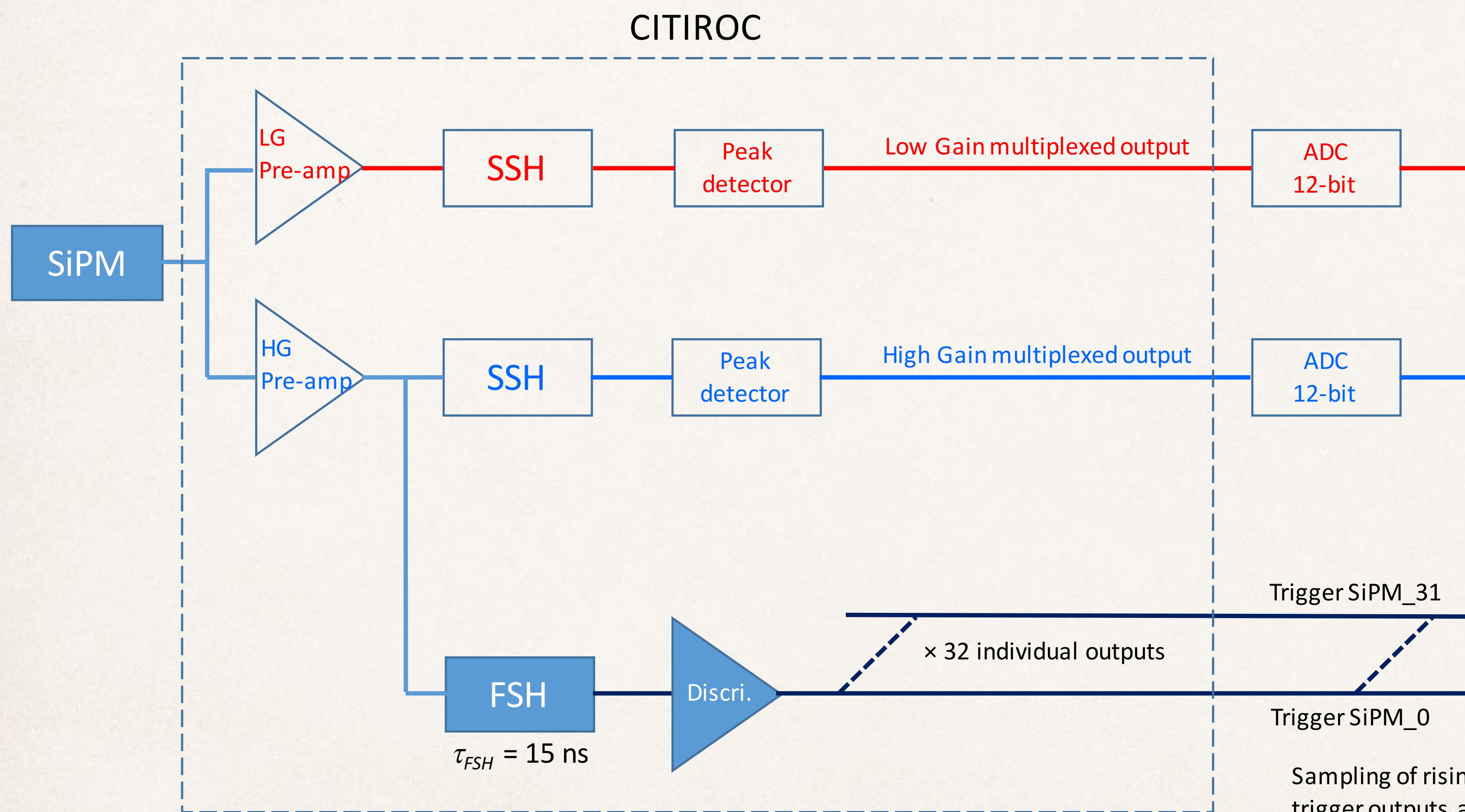
Calibration

HG to photo electron calibration with LED: 4 cases of HG setting
LG and ToT calibrations with beam: 9 cases of HG and LG settings
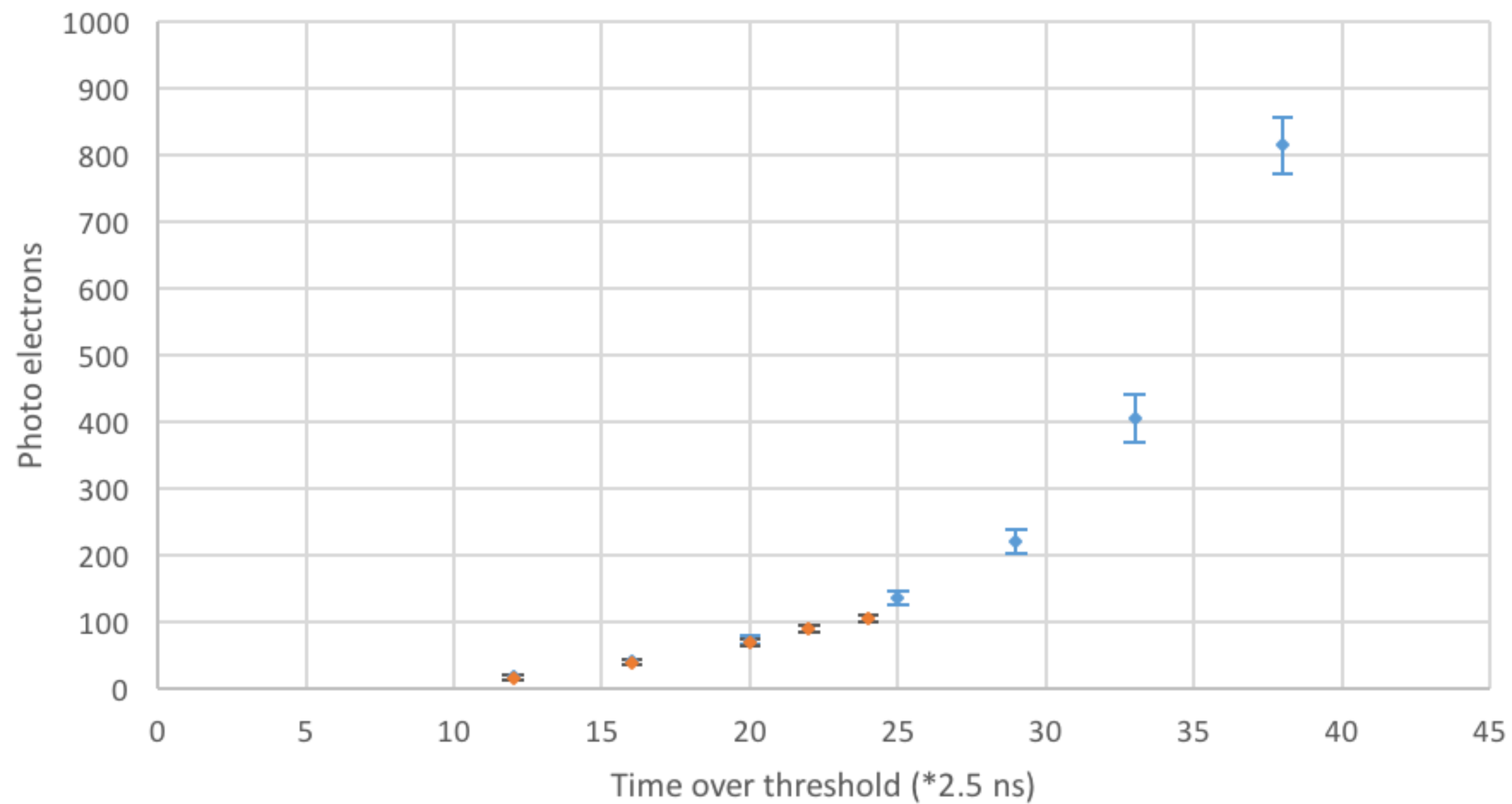**Studies of dynamic range was performed to choose the best settings**

FEB2_Channel84

HG45
HG50
HG55
HG60
Peak₀: -0.53
ADC₀: 74.35

Finding the pedestal

LED calibration Fingerplot

ToT calibration Using HG

LG calibration Using beam

ToT calibration Using LG
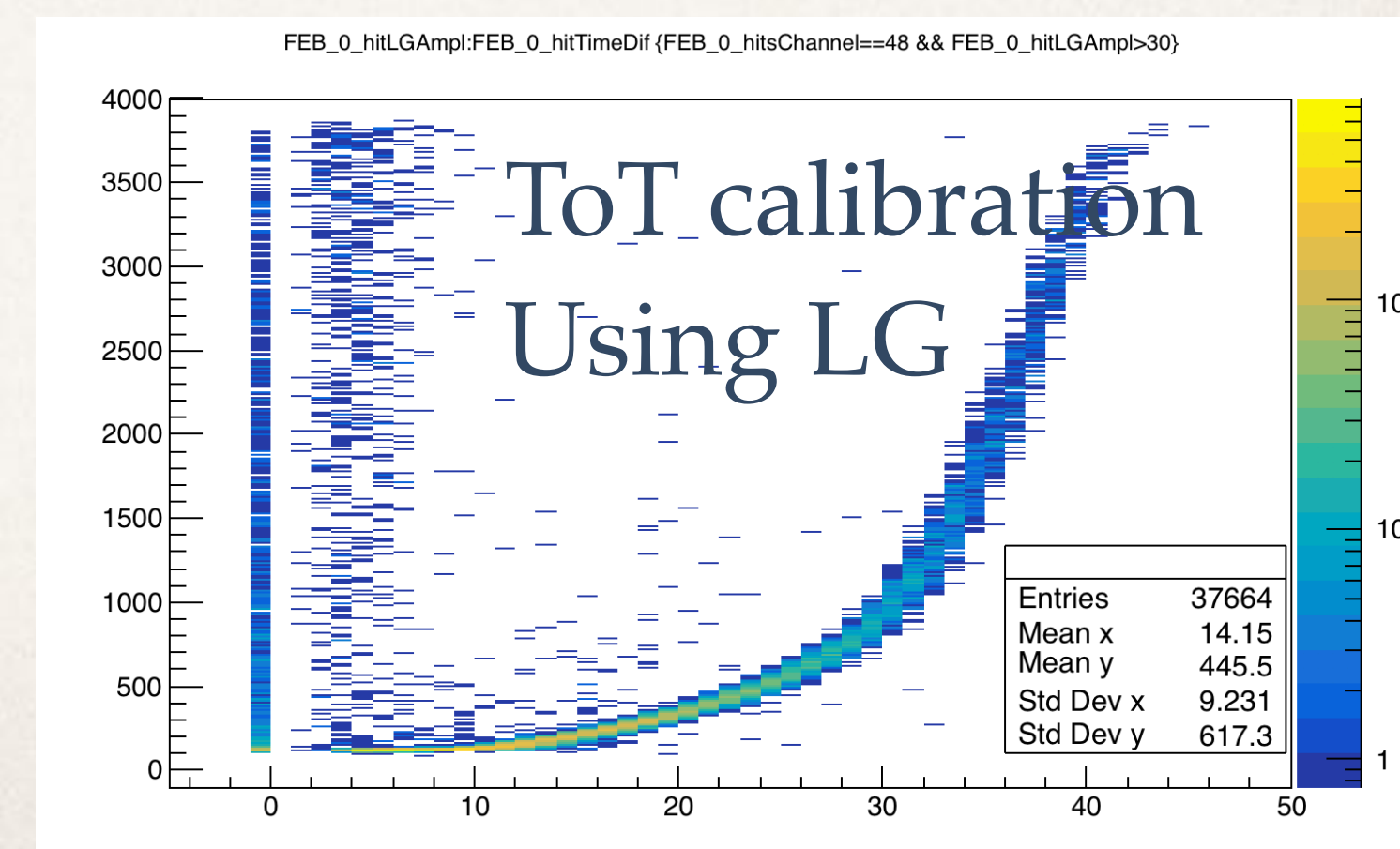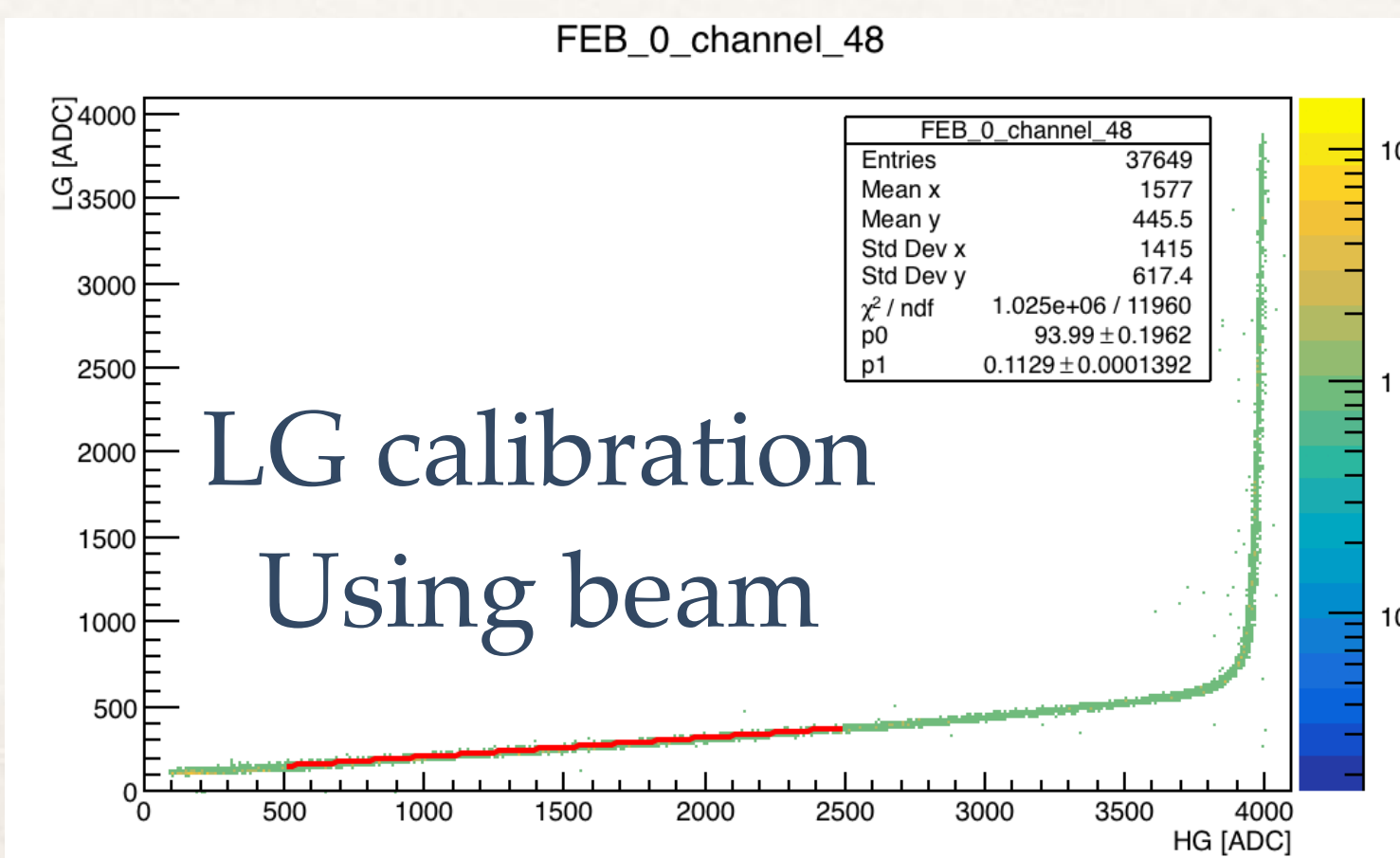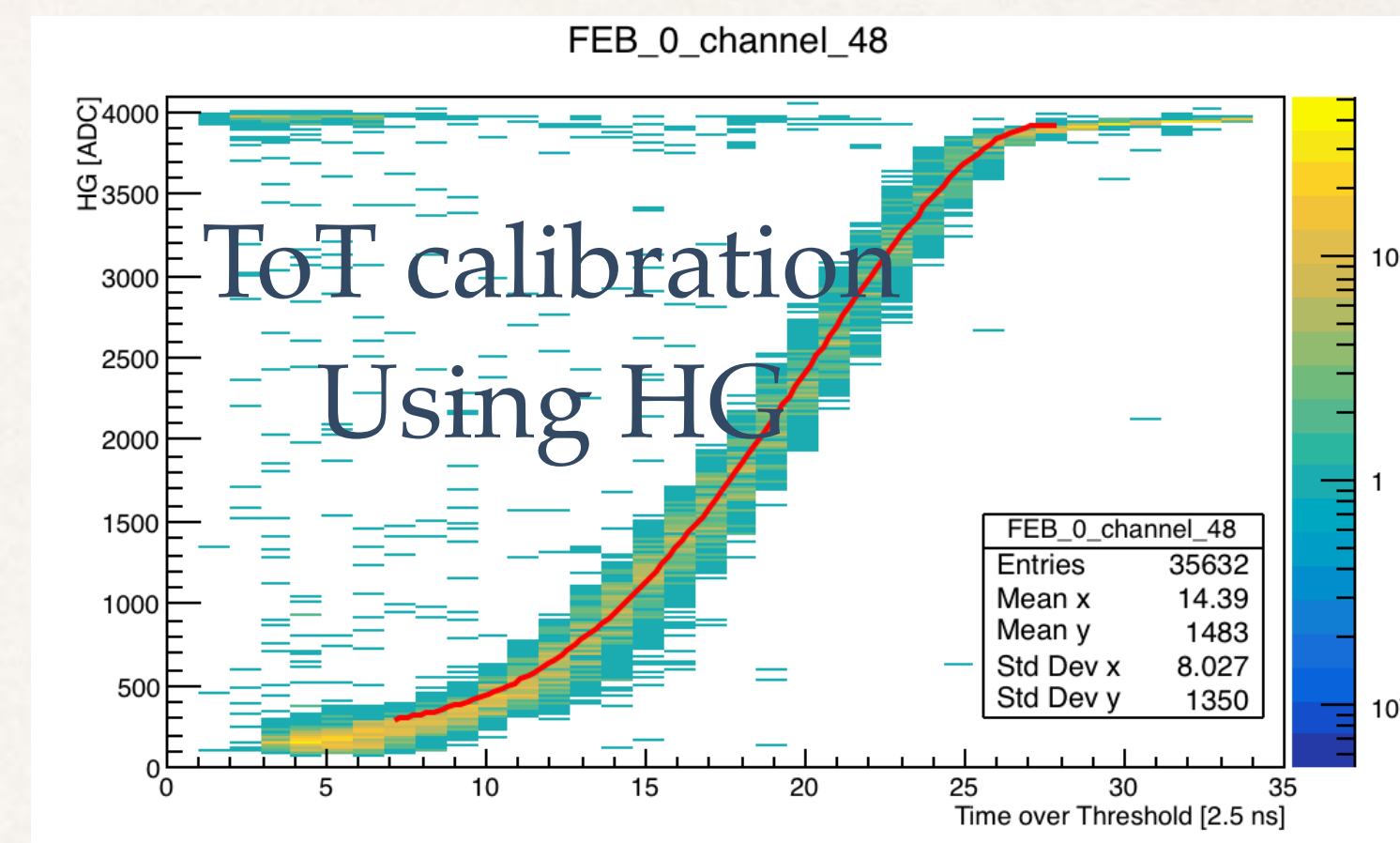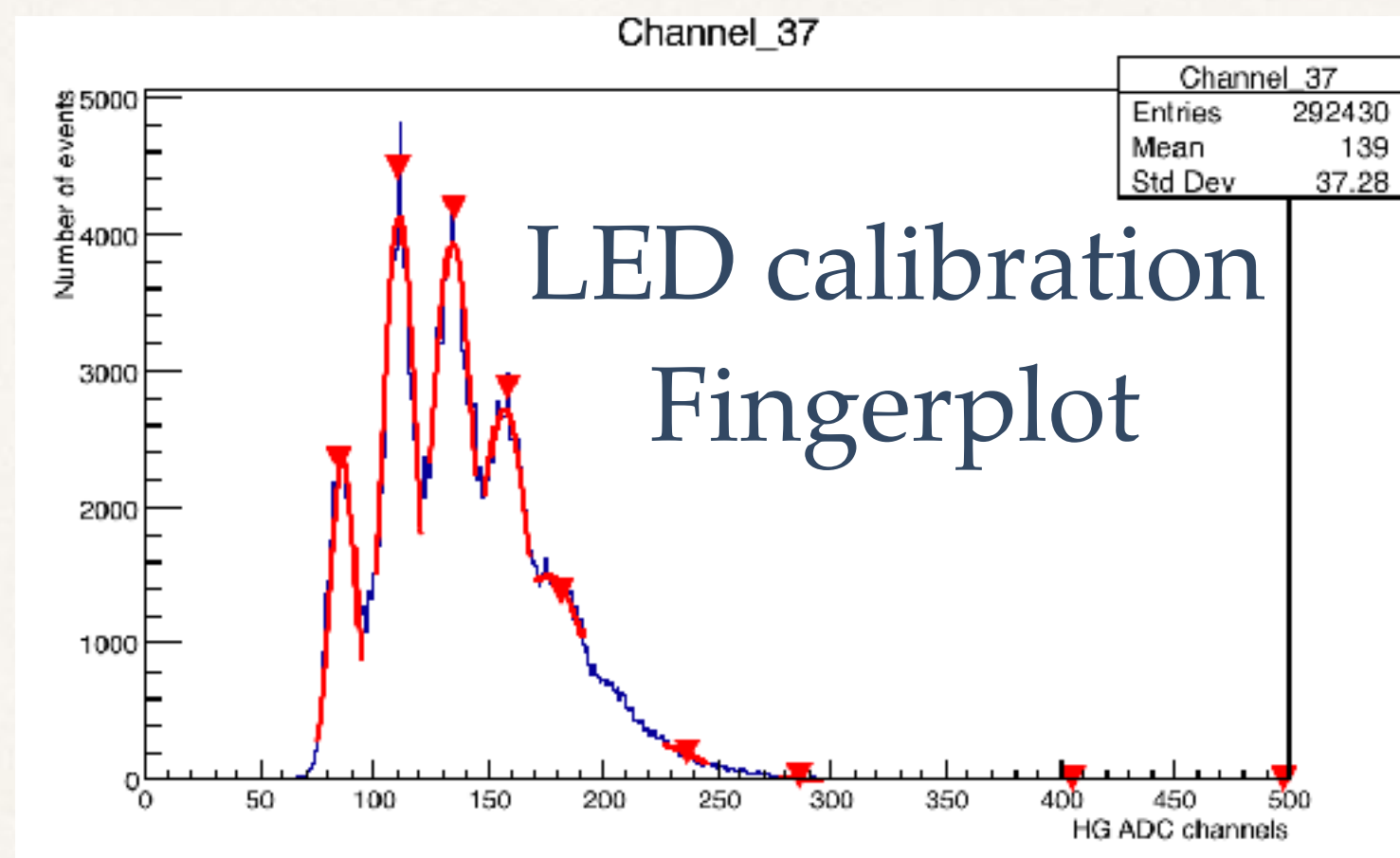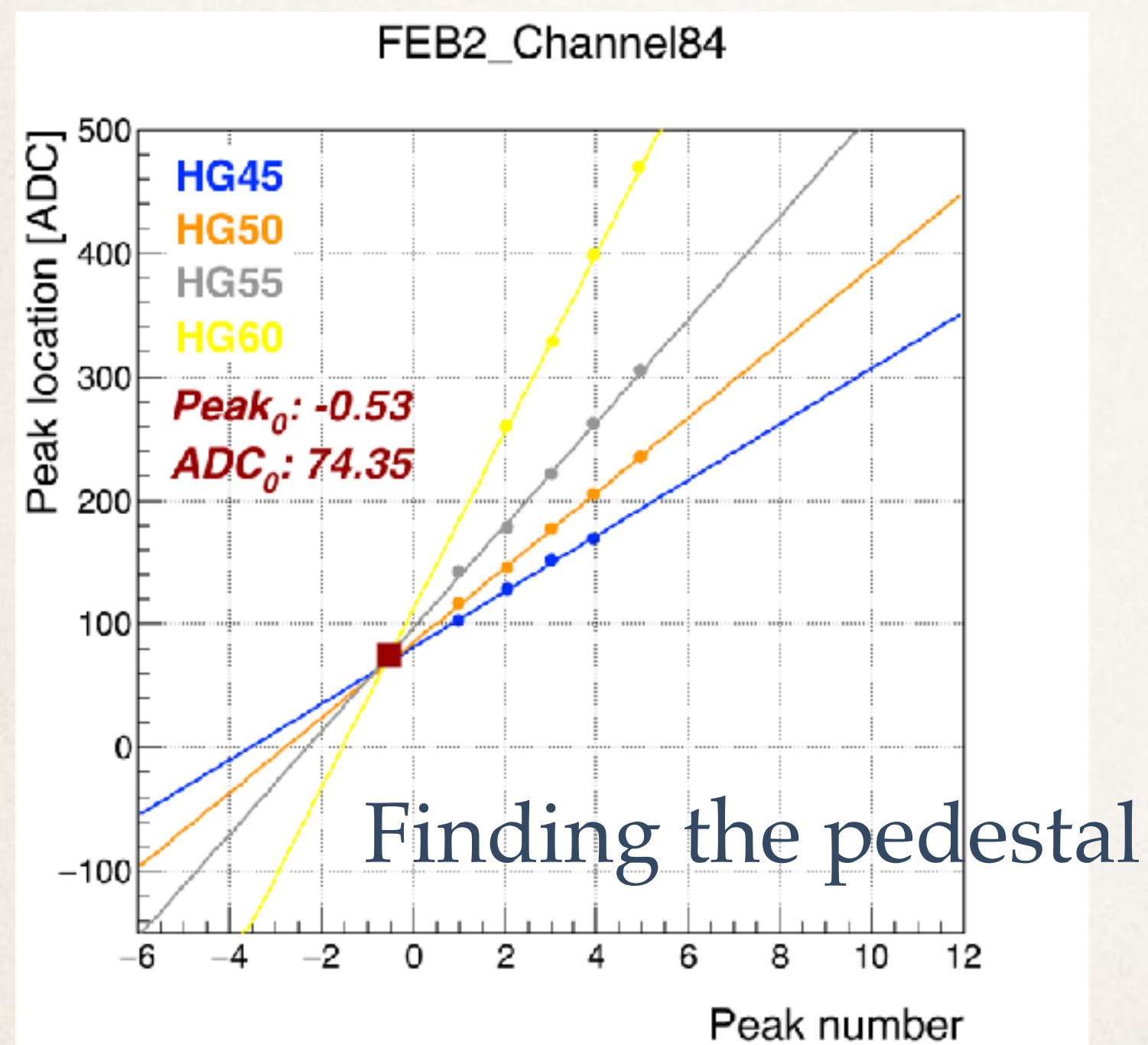
Calibration All hits in p.e

HG in p.e

LG in p.e

ToT in p.e
Note that ToT produces discrete values

Charge in p.e
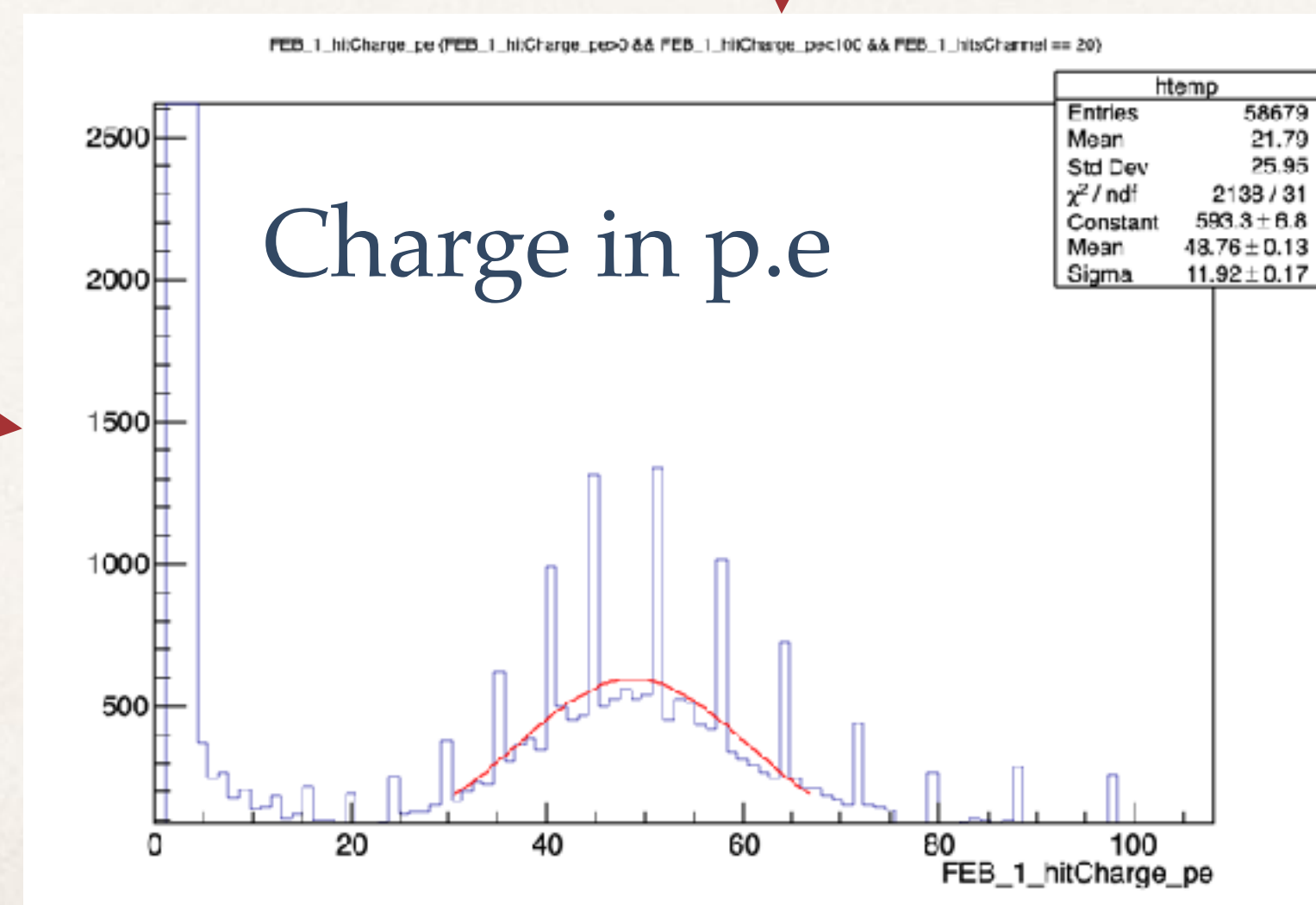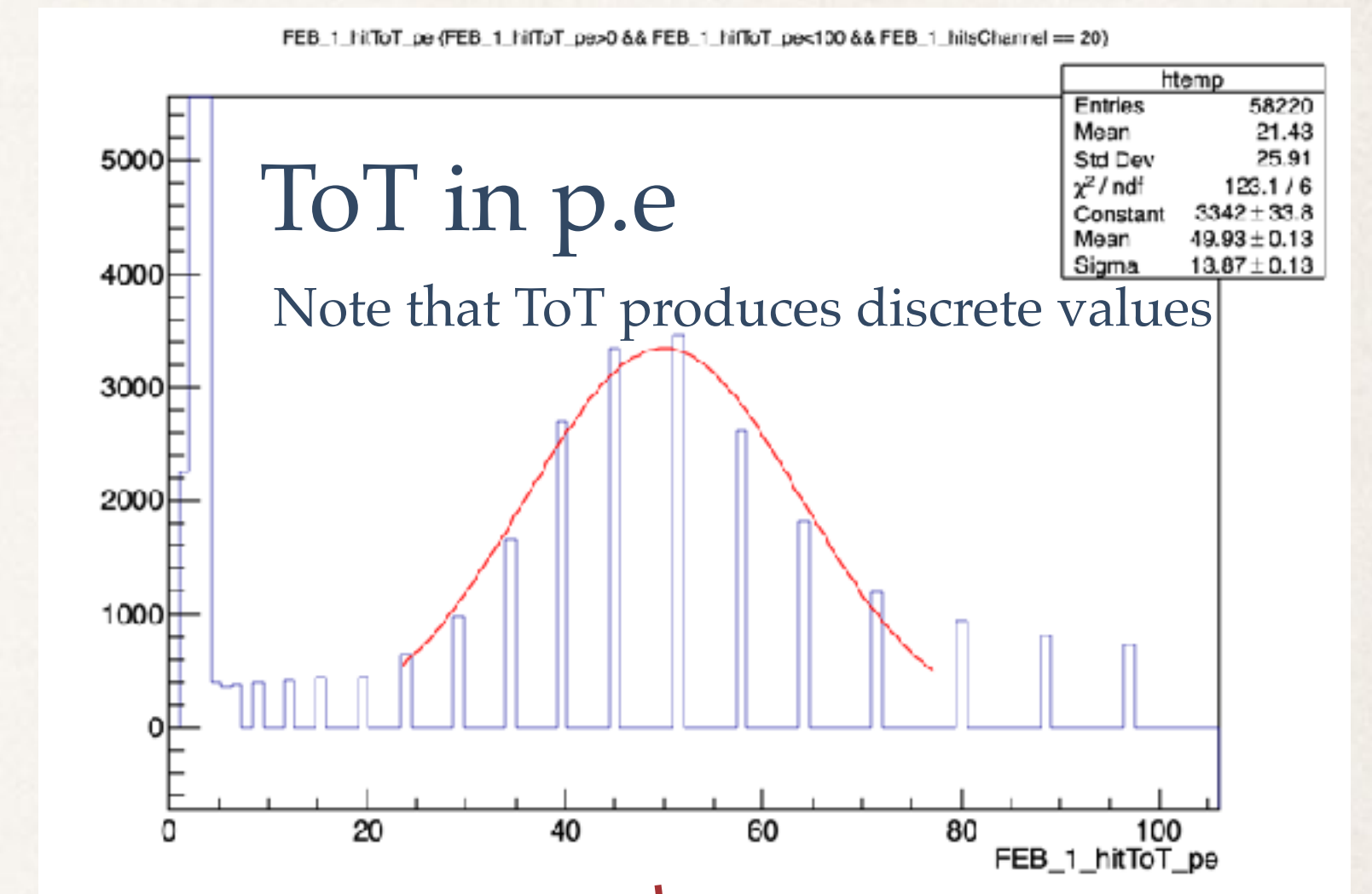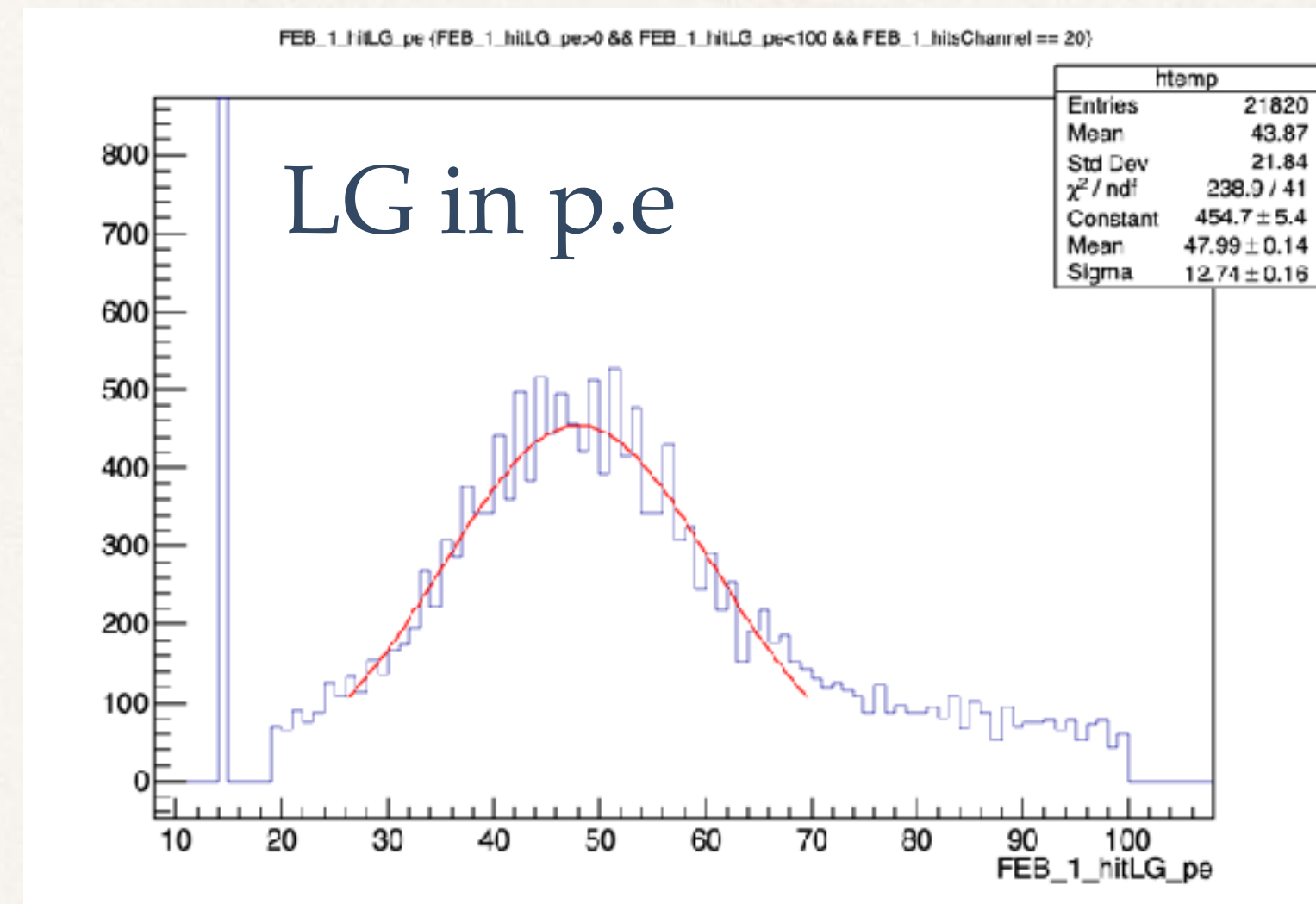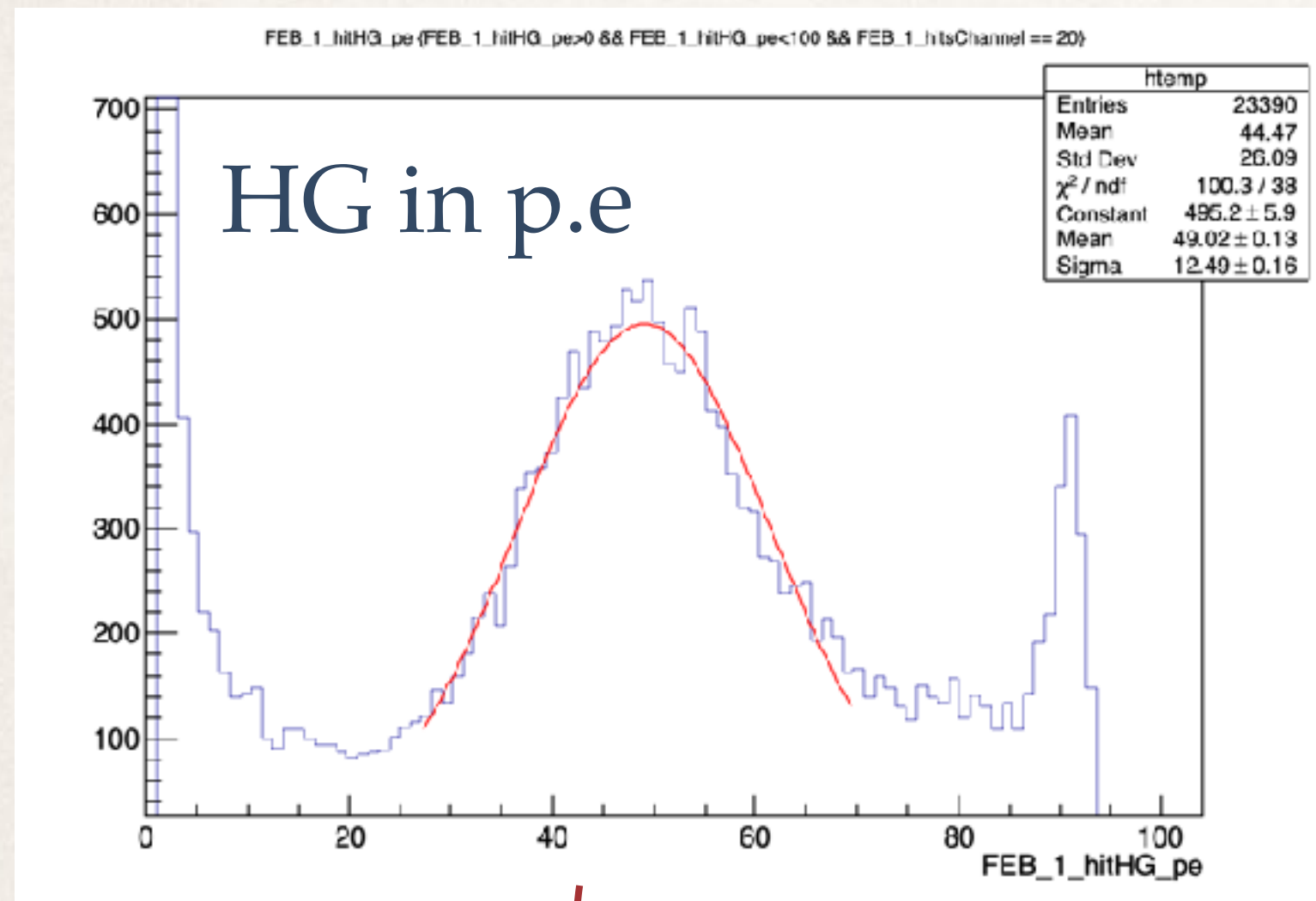
Calibration dynamic range ~ 800 p.e

FEB_0_hitCharge_pe {FEB_0_hitsChannel==20}

Entries	21335
Mean	56.25
Std Dev	113.1

FEB 0, Front side, with saturated hits
Dynamic range ~800 p.e

Calibration, resolution of ToT

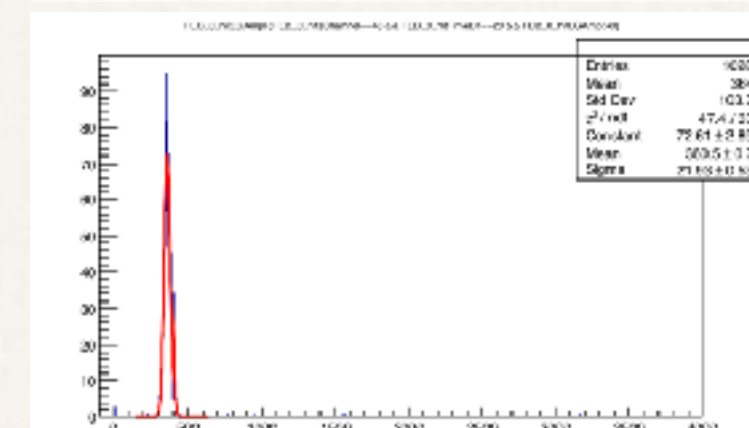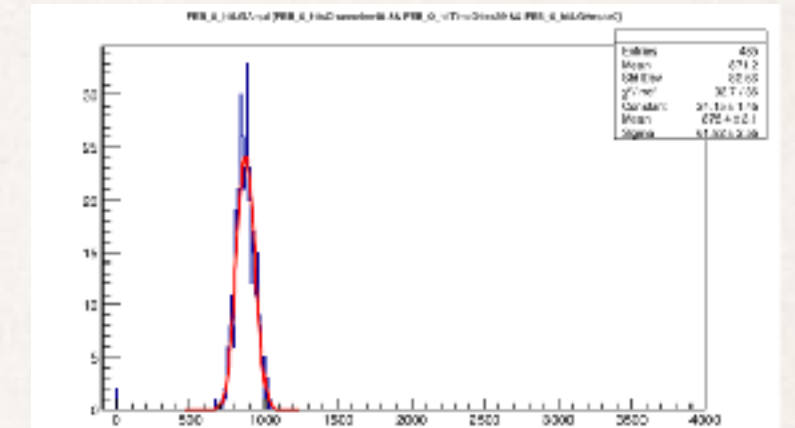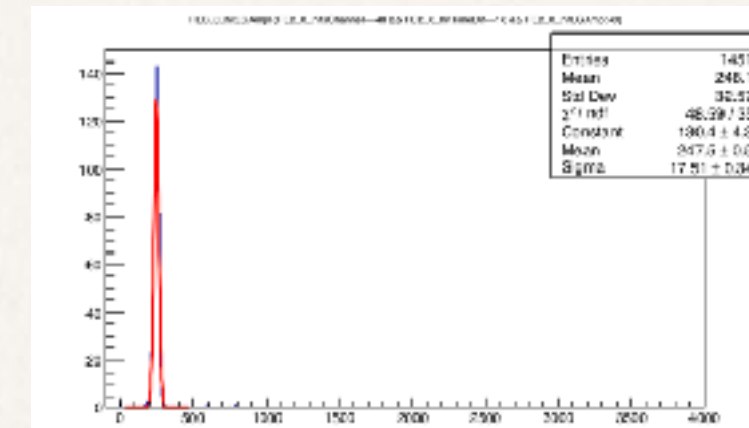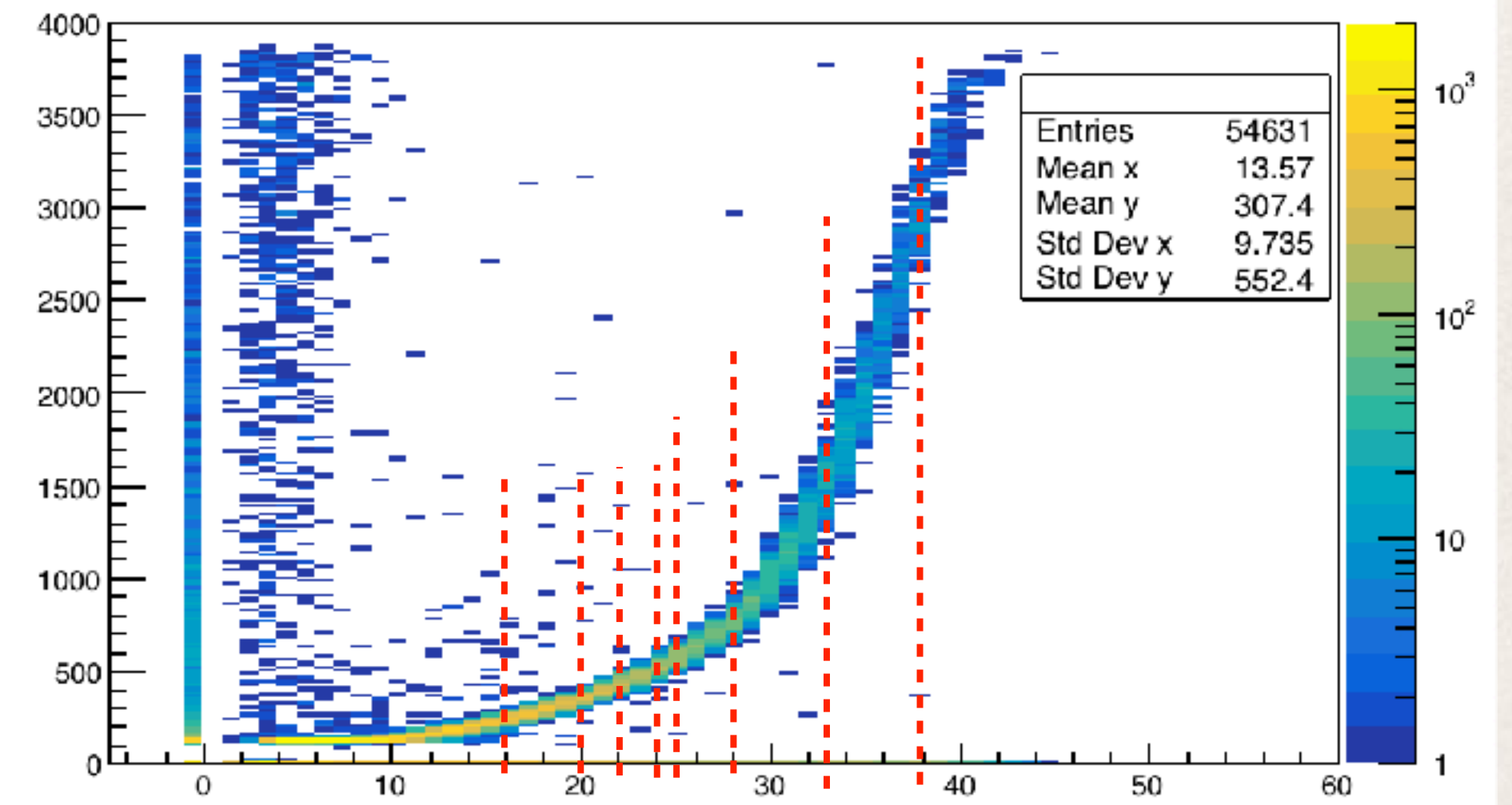Time over Threshold resolution in p.e
Lower HG, Lower LG

FEB_0_hitLGAmpl:FEB_0_hitTimeDif {FEB_0_hitsChannel==48}
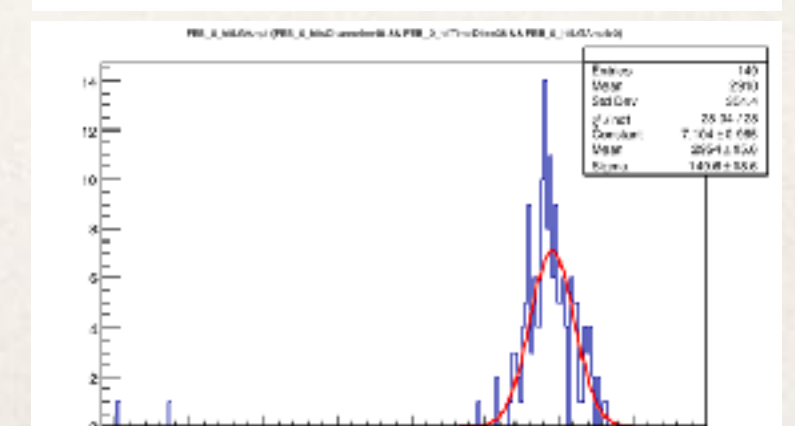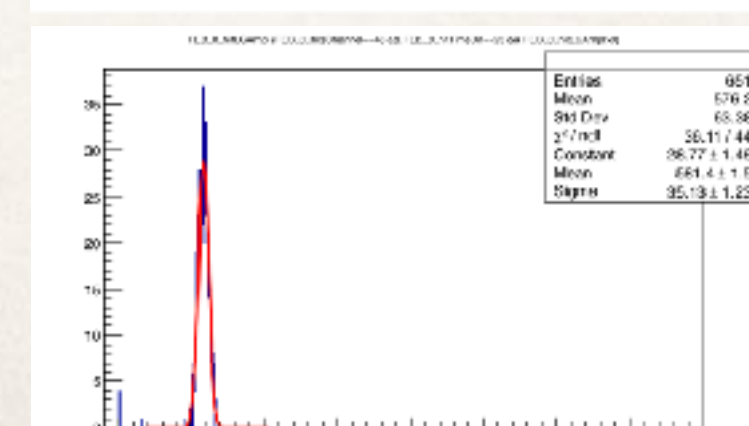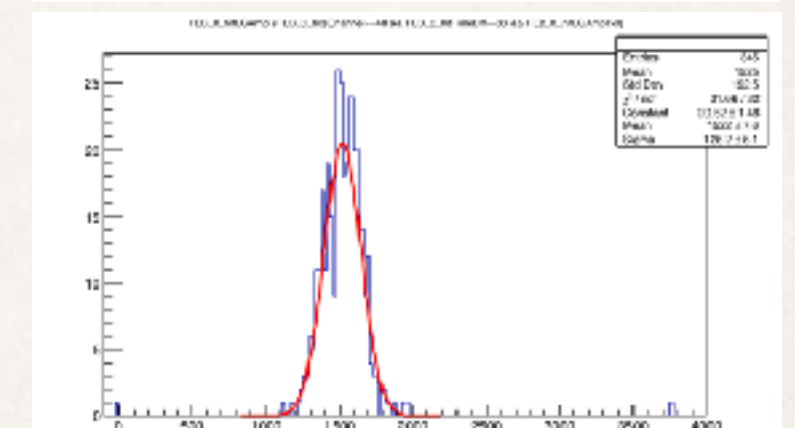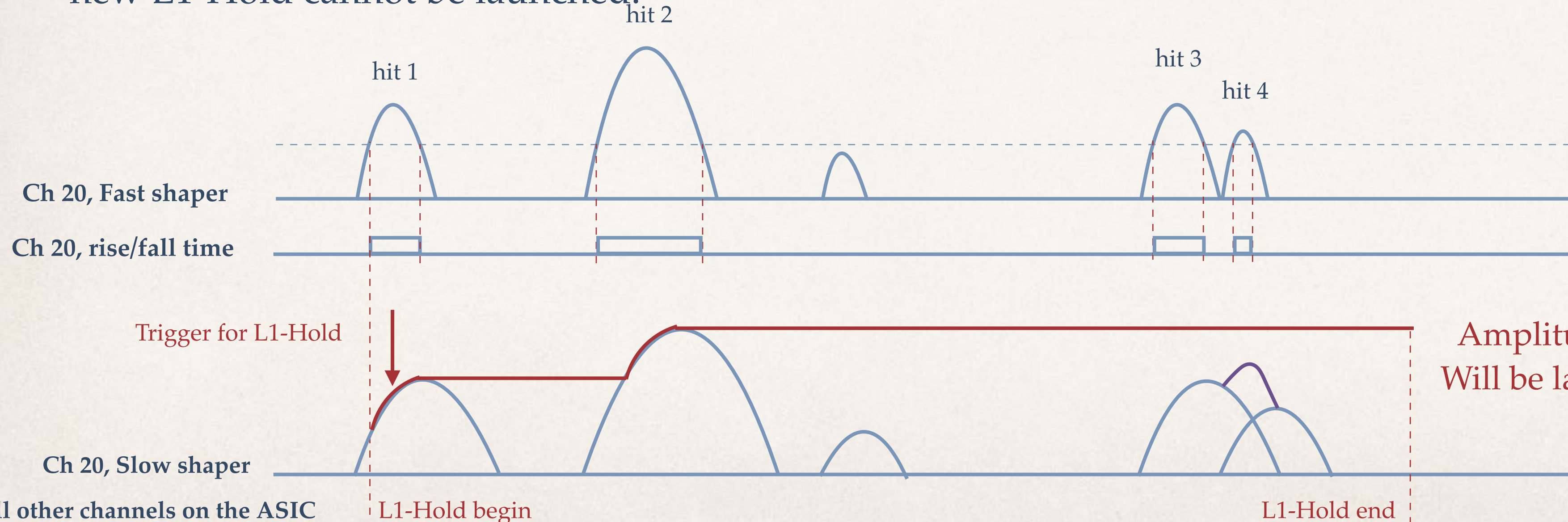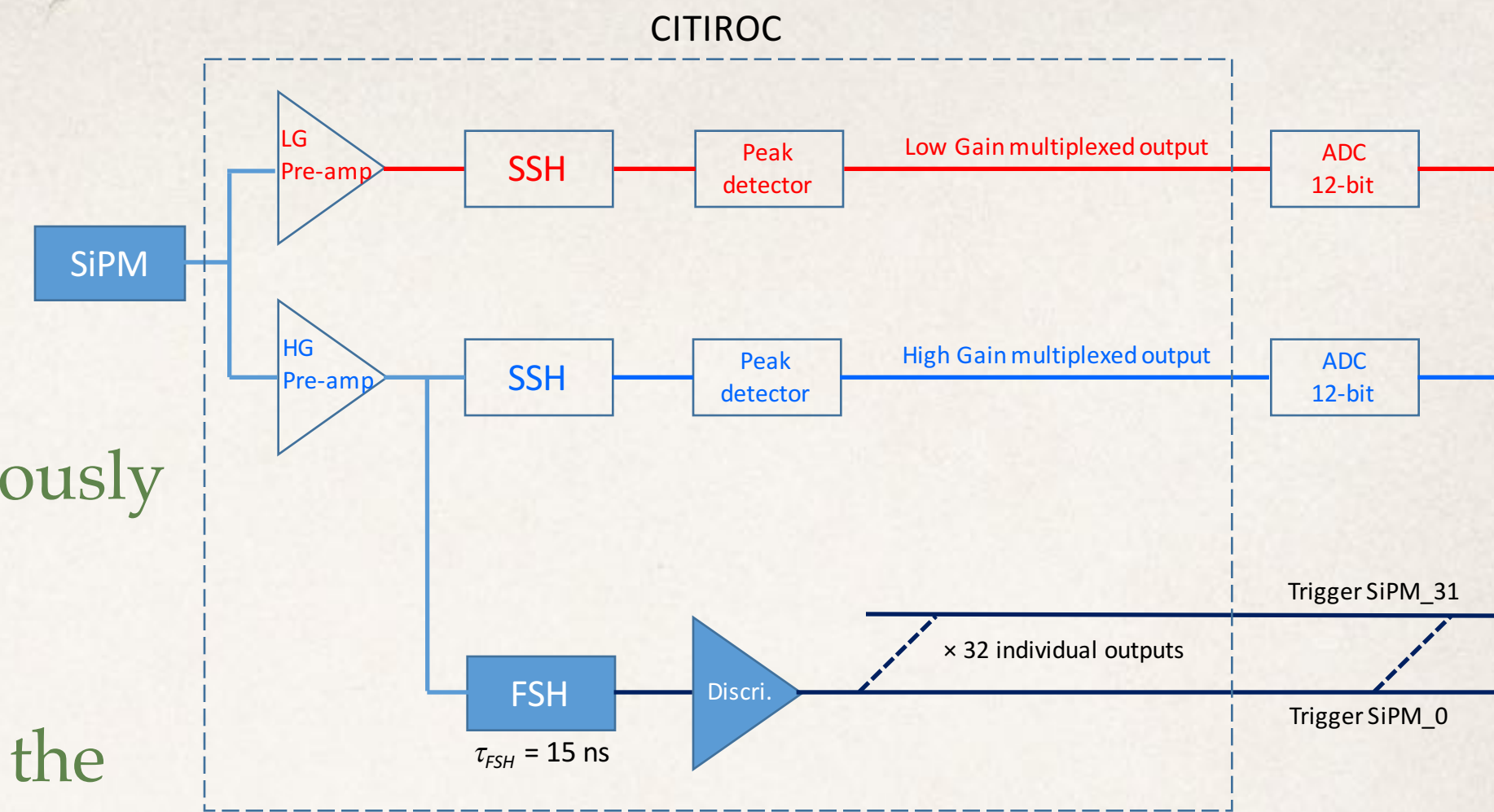
Hit Time, Hit Amplitude

Hit time is recorded in the <u>Fast shaper</u> signal path:

For signals above discriminator threshold the hit rise/fall time will be continuously recorded. No dead time.

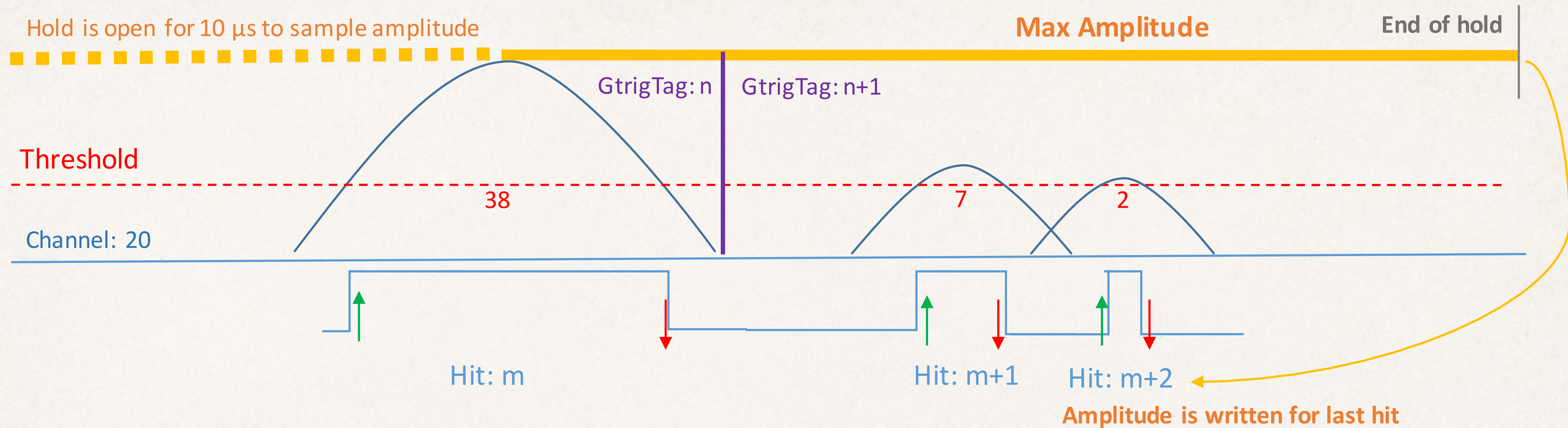**Hit Amplitude** is recorded in the <u>Slow shaper</u> signal path:

When one channel among the 32 channels of an ASIC, records a rising edge in the fast shaper signal path, <u>all 32 channels</u> of that ASIC will start sampling the amplitude for a fixed period defined as L1-Hold (<20μs), and will return the highest value of amplitude during L1-Hold*.

Dead Time: after the end of L1-Hold there is a dead time of 10μs during which a new L1-Hold cannot be launched.

CITIROC

| SiPM → LG Pre-amp → SSH → Peak detector → Low Gain multiplexed output → ADC 12-bit |

| SiPM → HG Pre-amp → SSH → Peak detector → High Gain multiplexed output → ADC 12-bit |

FSH → Discri. → × 32 individual outputs → Trigger SiPM_31 ... Trigger SiPM_0

τ_{FSH} = 15 ns

*Note: If during L1-Hold <u>more than one hit occurs on the same channel</u> the <u>largest amplitude</u> will be latched to the <u>last hit</u>. Which we can correct offline.
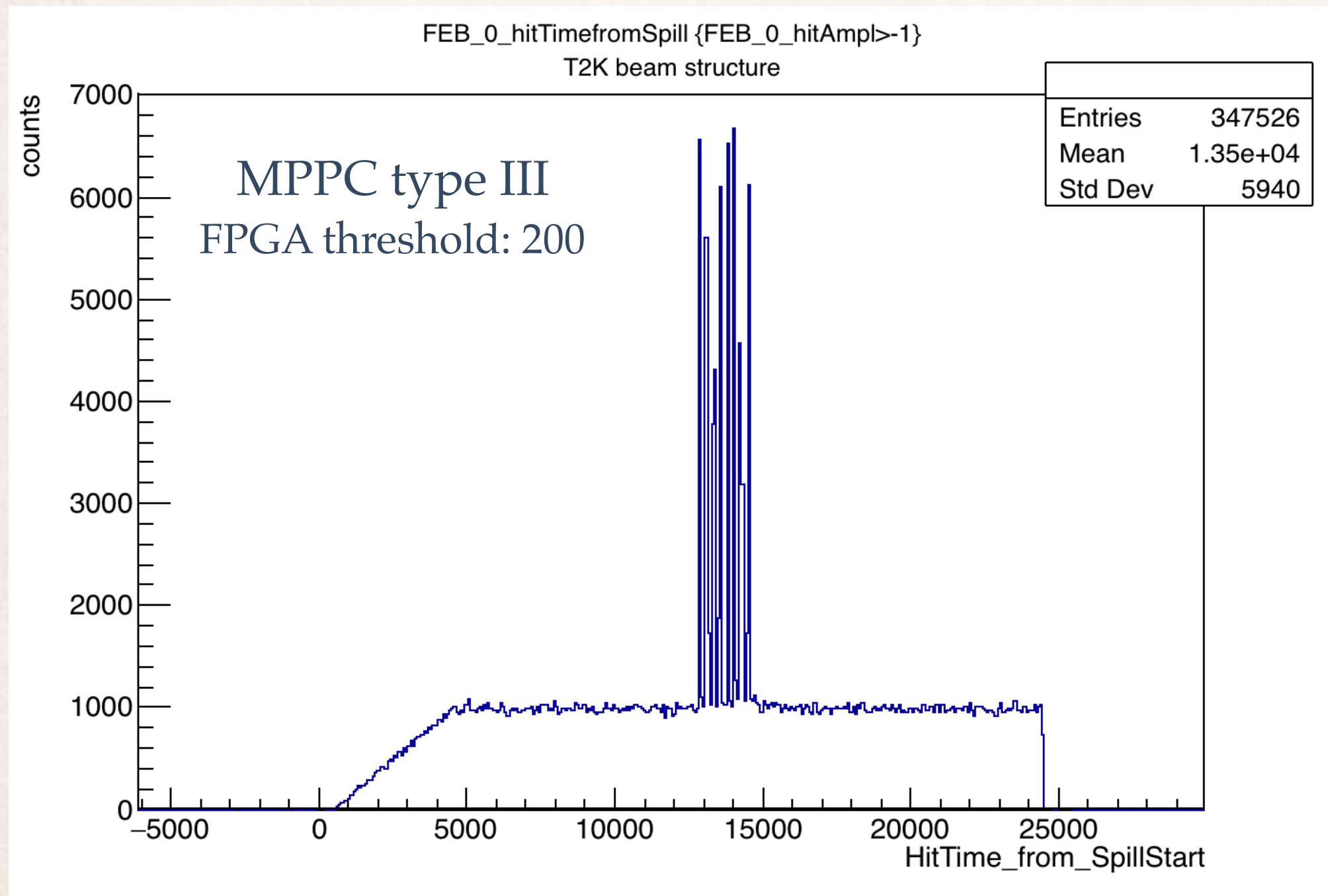
hit 2

hit 1

hit 3

hit 4

Ch 20, Fast shaper

Ch 20, rise/fall time

Trigger for L1-Hold

Amplitude for ch 20 Will be latched to hit 4

Ch 20, Slow shaper

+ all other channels on the ASIC

L1-Hold begin

L1-Hold end

Example from Data

	Row #	GTrigTag	channel	HitTimefromSpill	Amplitude	TimeoverThreshold	LeadTime	TrailTime
*	0 *	429263 *	5000911 *	20 * 203769828 *	1959 *	19 *	220 *	239 *
*	0 *	429532 *	5003291 *	20 * 213292681 *	3680 *	26 *	3073 *	3099 *
*	0 *	429577 *	5003658 *	20 * 214761315 *	237 *	9 *	3707 *	3716 *
*	0 *	429628 *	5004079 *	20 * 216442496 *	916 *	15 *	888 *	903 *
*	0 *	429674 *	5004511 *	20 * 218171241 *	83 *	5 *	1633 *	1638 *
*	0 *	429721 *	5004673 *	20 * 218821564 *	0 *	38 *	3956 *	3994 *
*	0 *	429724 *	5004674 *	20 * 218821772 *	0 *	7 *	164 *	171 *
*	0 *	429725 *	5004674 *	20 * 218821835 *	3789 *	2 *	227 *	229 *
*	0 *	429813 *	5006672 *	20 * 226814383 *	3756 *	29 *	775 *	804 *
*	0 *	429863 *	5012840 *	20 * 251486852 *	231 *	9 *	1244 *	1253 *
*	0 *	432256 *	5200391 *	20 * 101700156 *	0 *	−1 *	1820 *	−1 *
*	0 *	432275 *	5200398 *	20 * 101728627 *	0 *	−1 *	2291 *	−1 *

Forced L1-Hold

Comparison of T2K spill and T9 spill

MPPC type I
FPGA threshold: 80

MPPC type III
FPGA threshold: 80
Dominated by dark count

ZOOM

MPPC type III
FPGA threshold: 200

Acquisition window: $60\mu s$
BabyMIND data
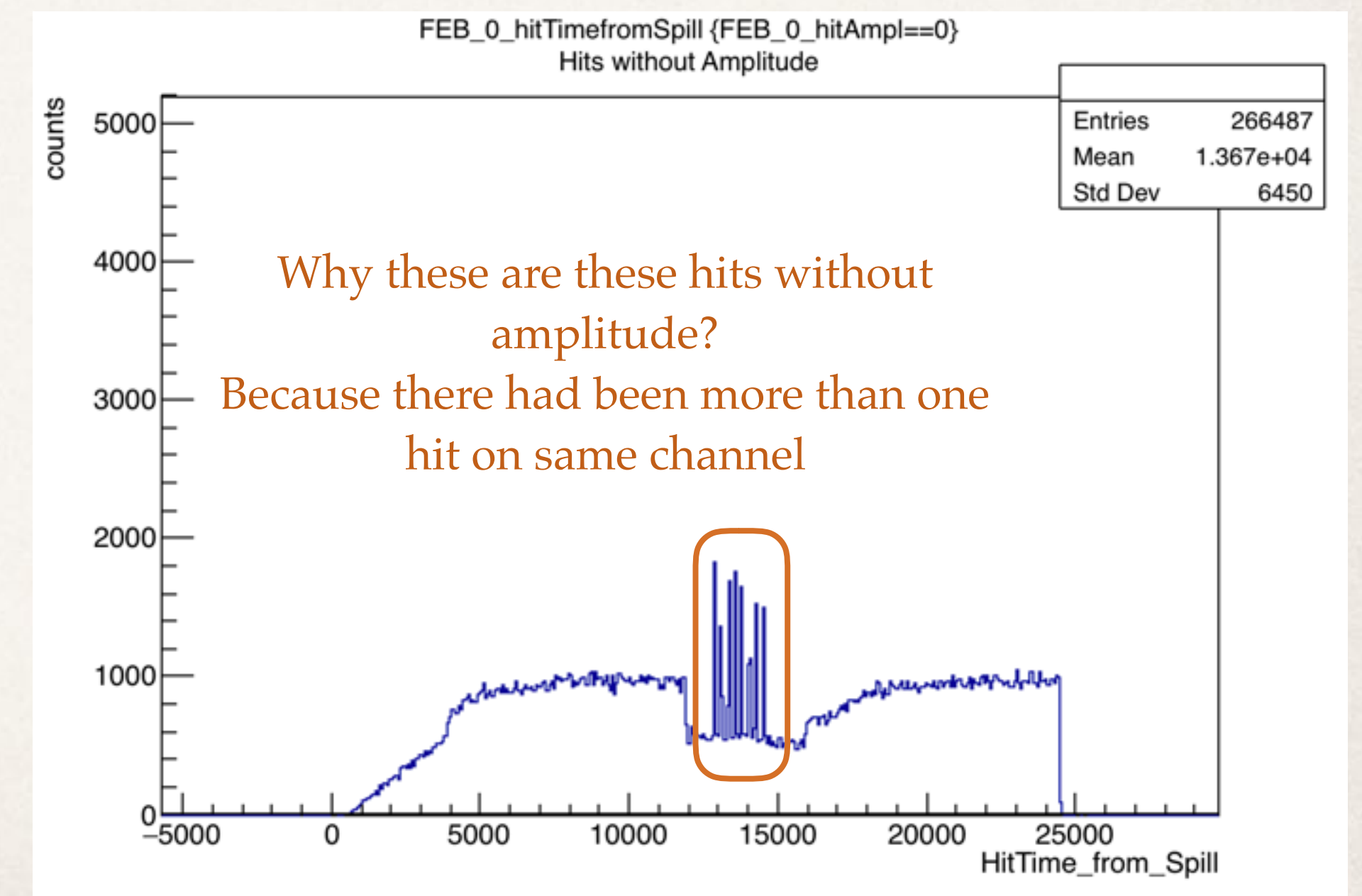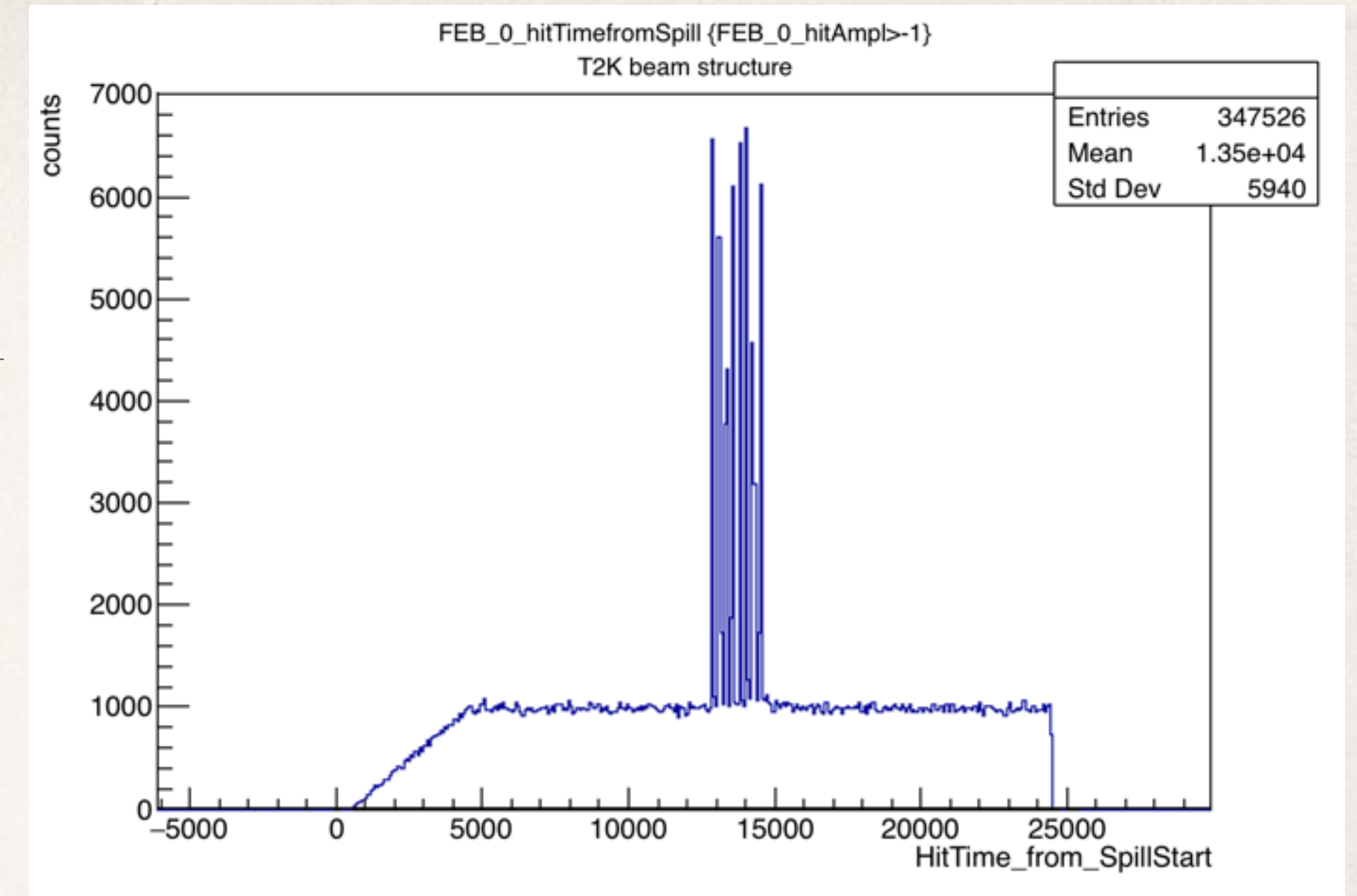
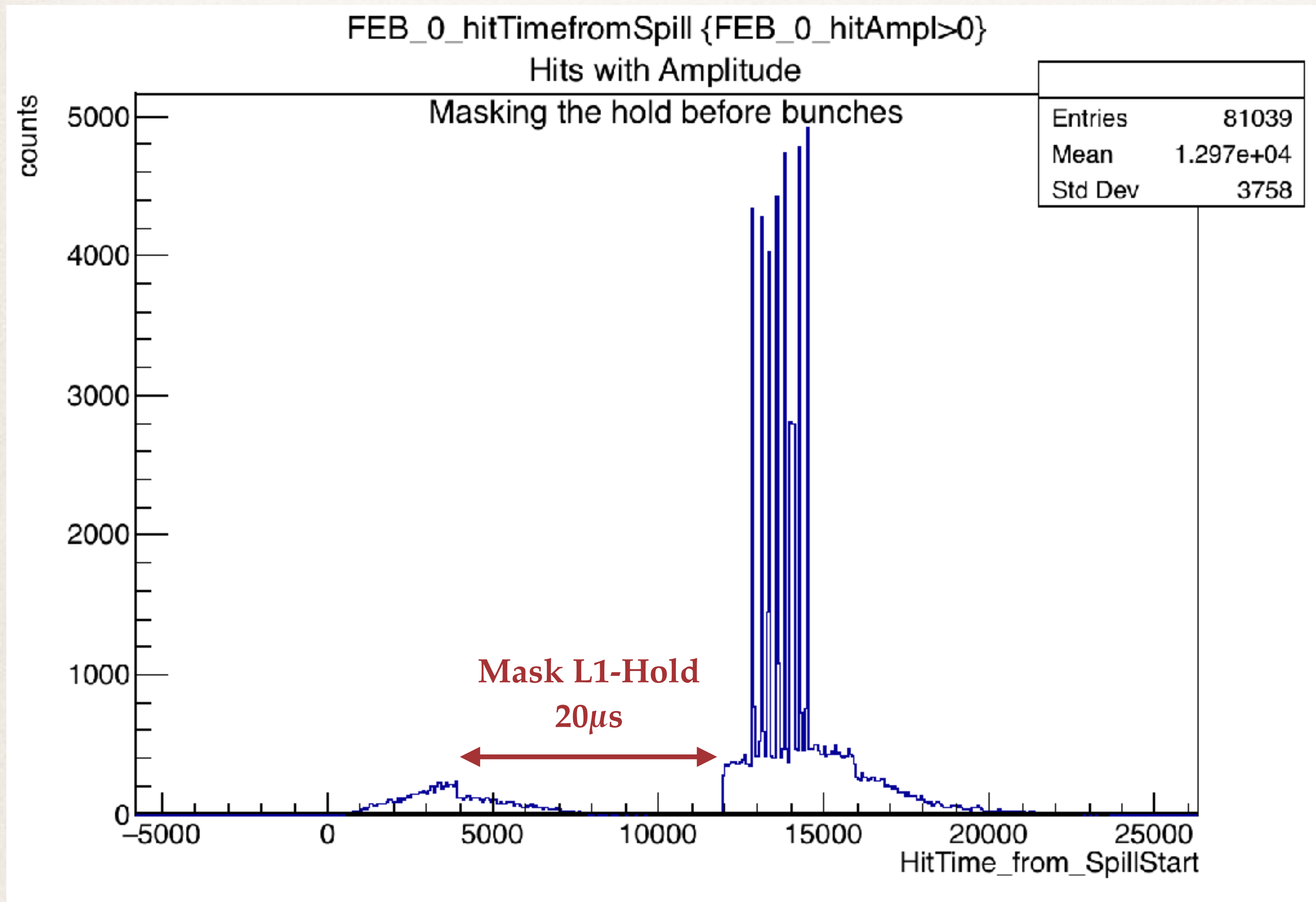With L1-Hold ($< 20\mu s$) we can cover the 8 bunches
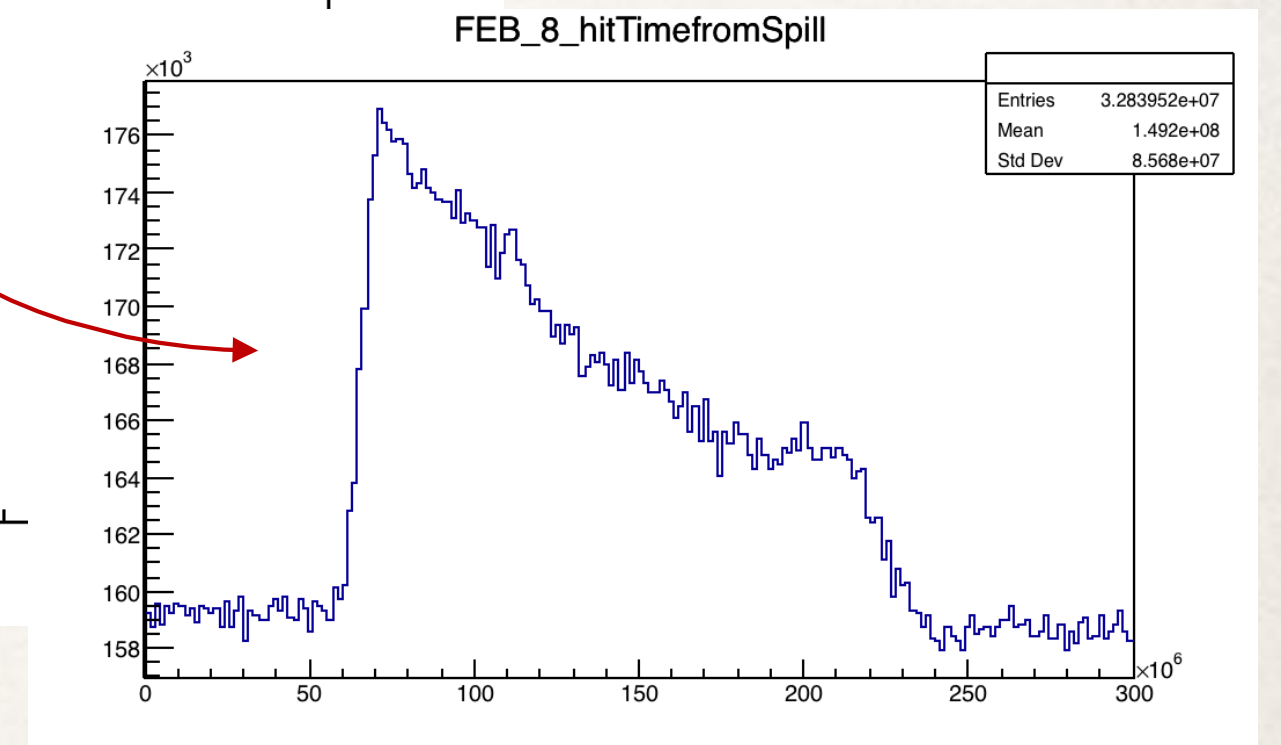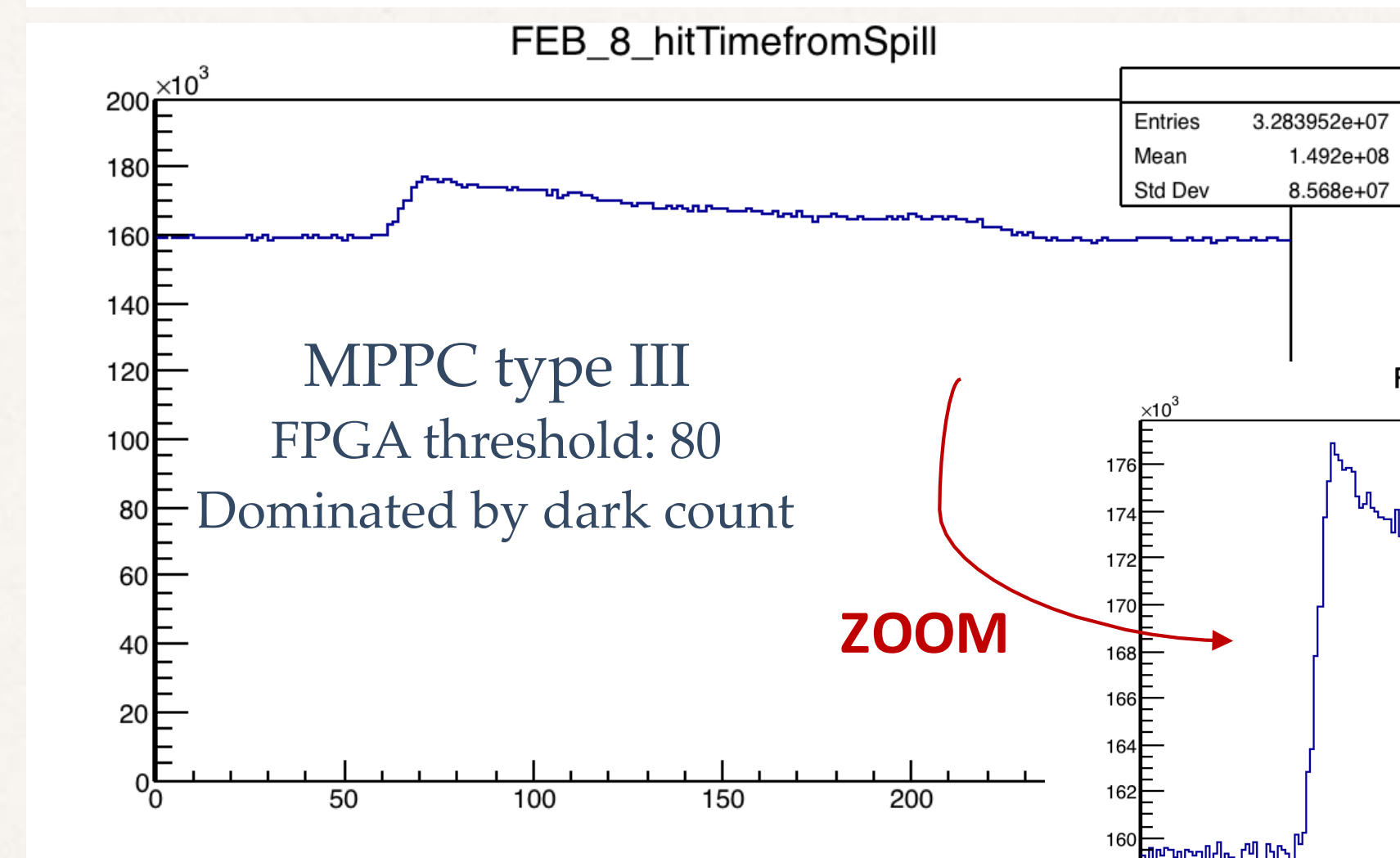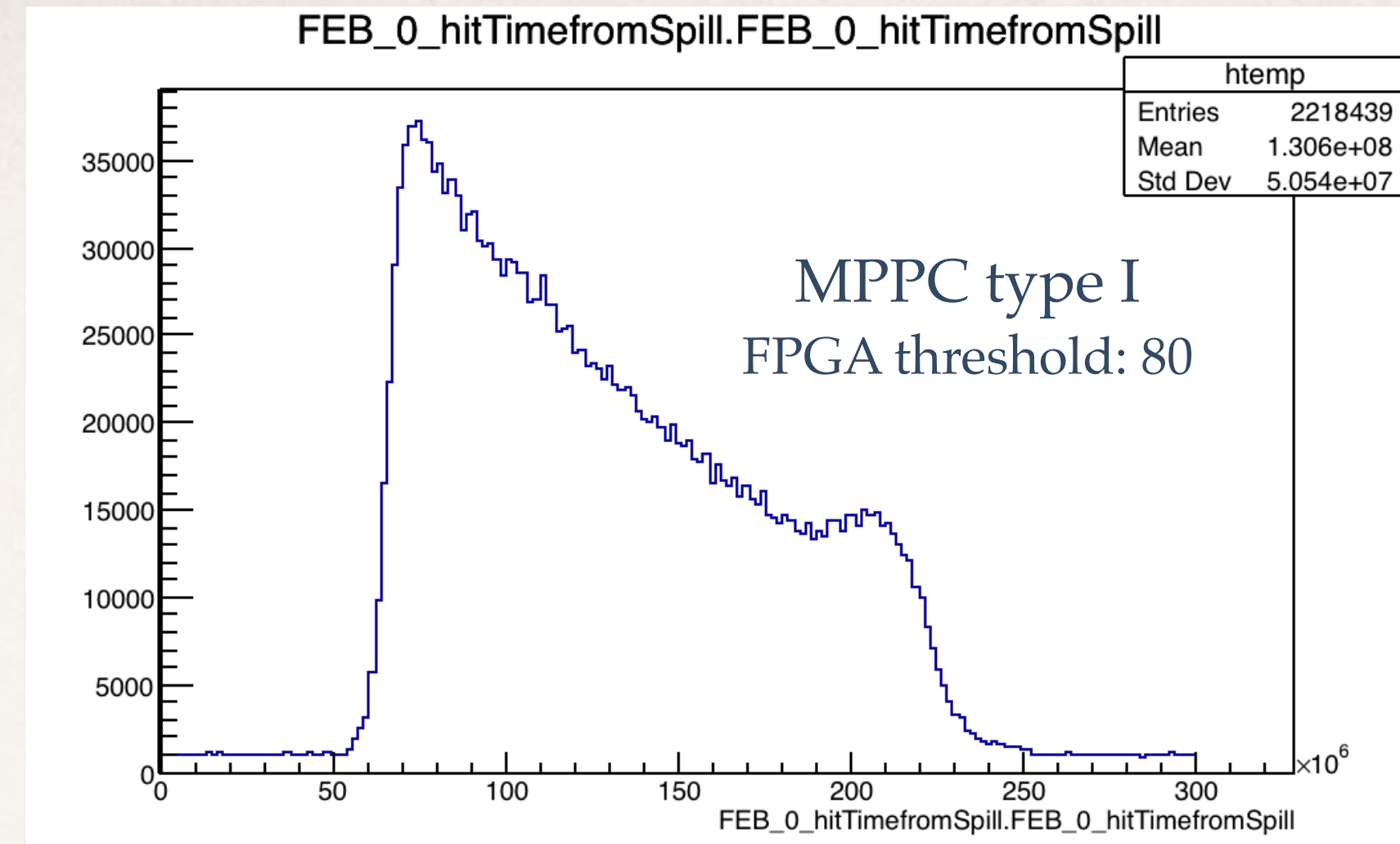
Acquisition window: 750ms

sFGD data T9

Forced L1-Hold

Baby MIND commissioning data used Force L1-Hold

FEB_0_hitTimefromSpill {FEB_0_hitAmpl>0}
Hits with Amplitude
Masking the hold before bunches

Entries	81039
Mean	1.297e+04
Std Dev	3758

Mask L1-Hold
20μs

HitTime_from_SpillStart

FEB_0_hitTimefromSpill {FEB_0_hitAmpl>-1}
T2K beam structure

Entries	347526
Mean	1.35e+04
Std Dev	5940

HitTime_from_SpillStart

FEB_0_hitTimefromSpill {FEB_0_hitAmpl==0}
Hits without Amplitude

Entries	266487
Mean	1.367e+04
Std Dev	6450

Why these are these hits without amplitude?
Because there had been more than one hit on same channel
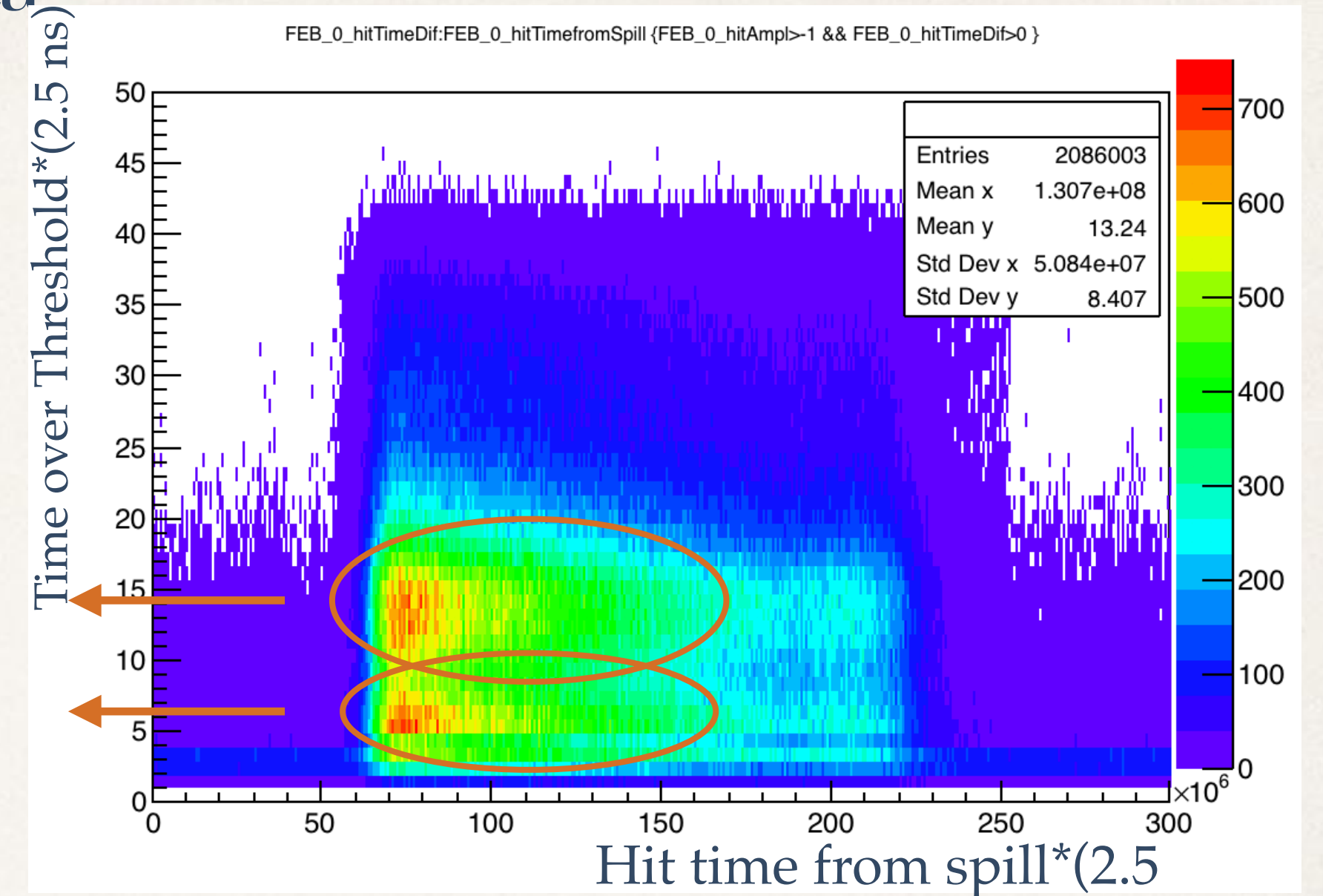
HitTime_from_Spill

Amplitude recording in sFGD beamtest Data

MPPC type I
Front side

All hits: 2086003
Hits with analogue signal path amplitude: 987379 -> 47%
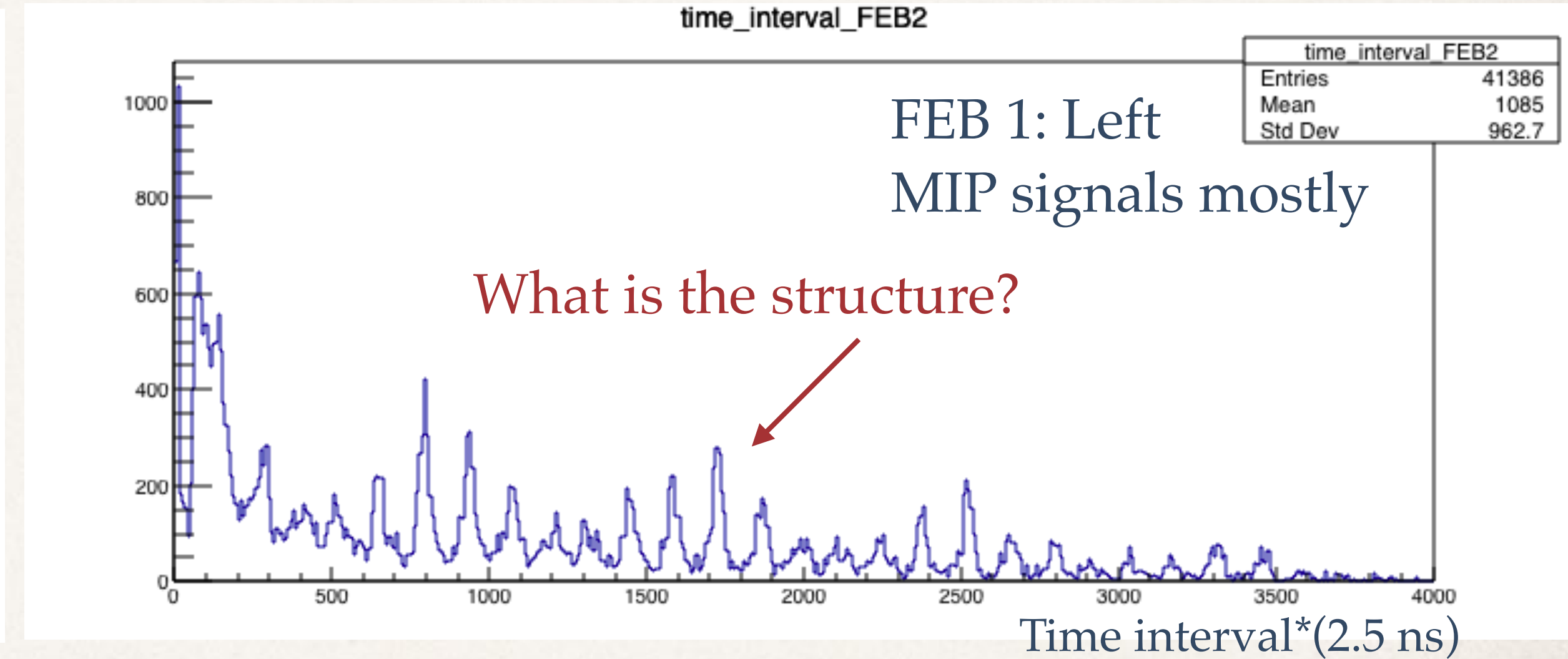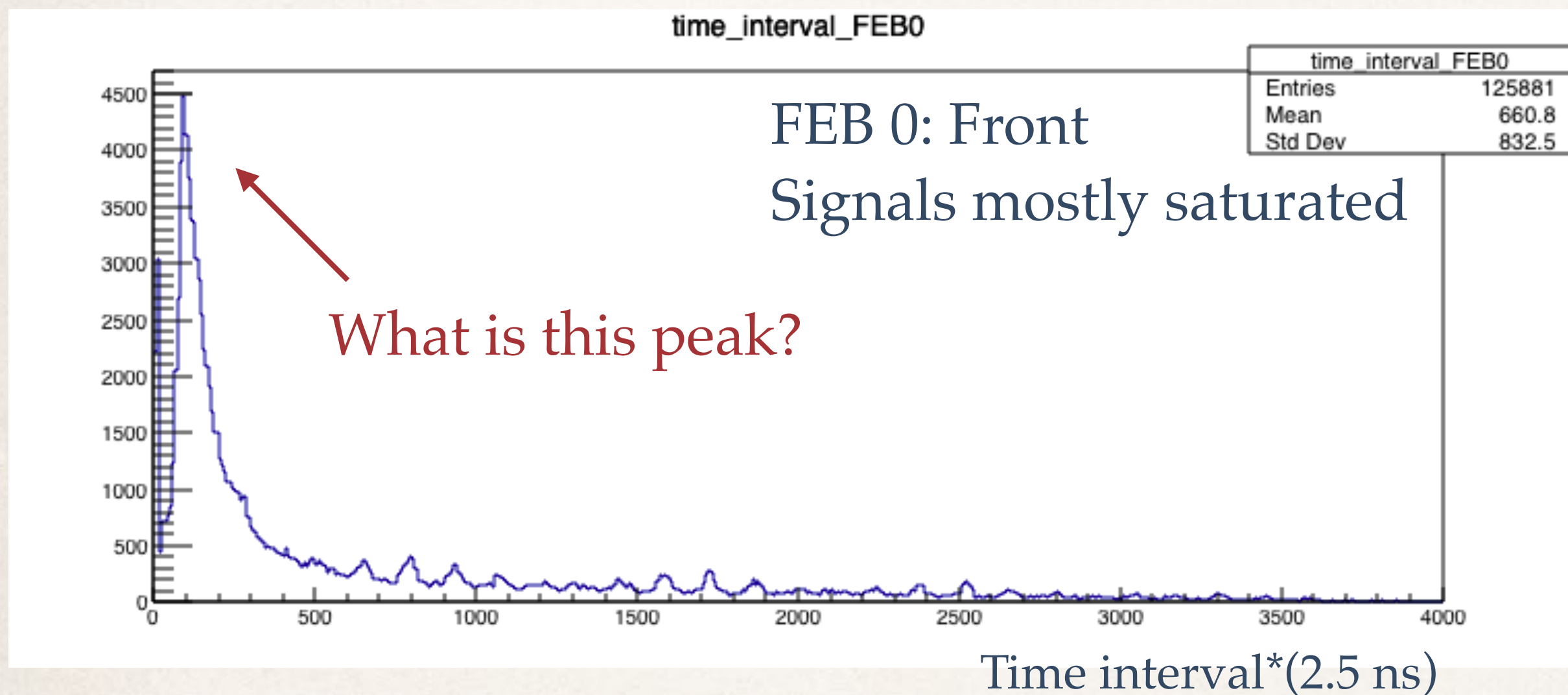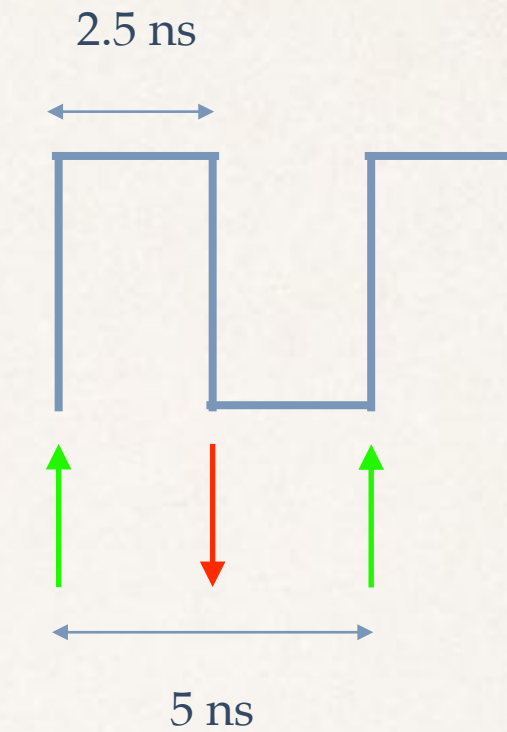
MIP signal

What is this?
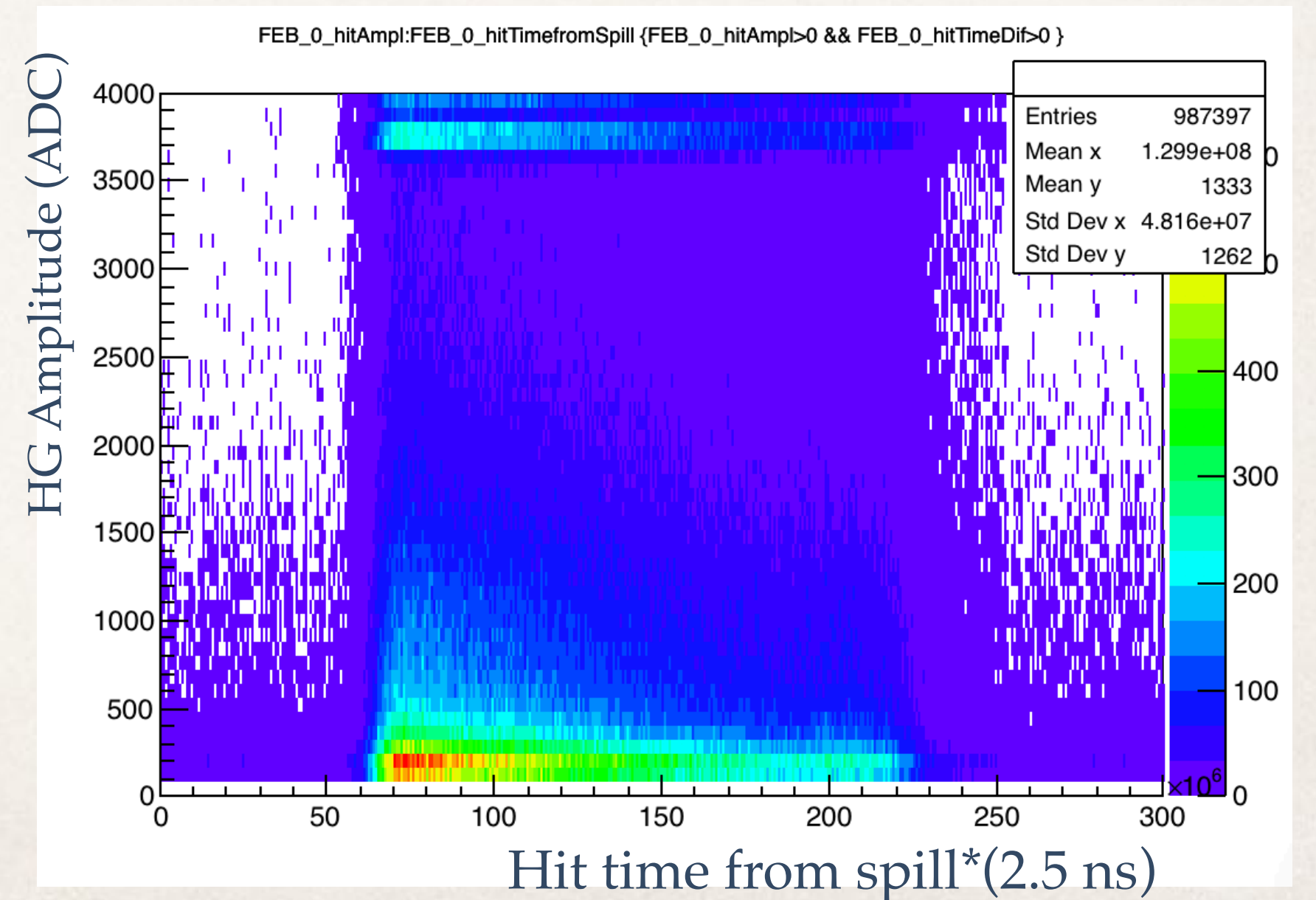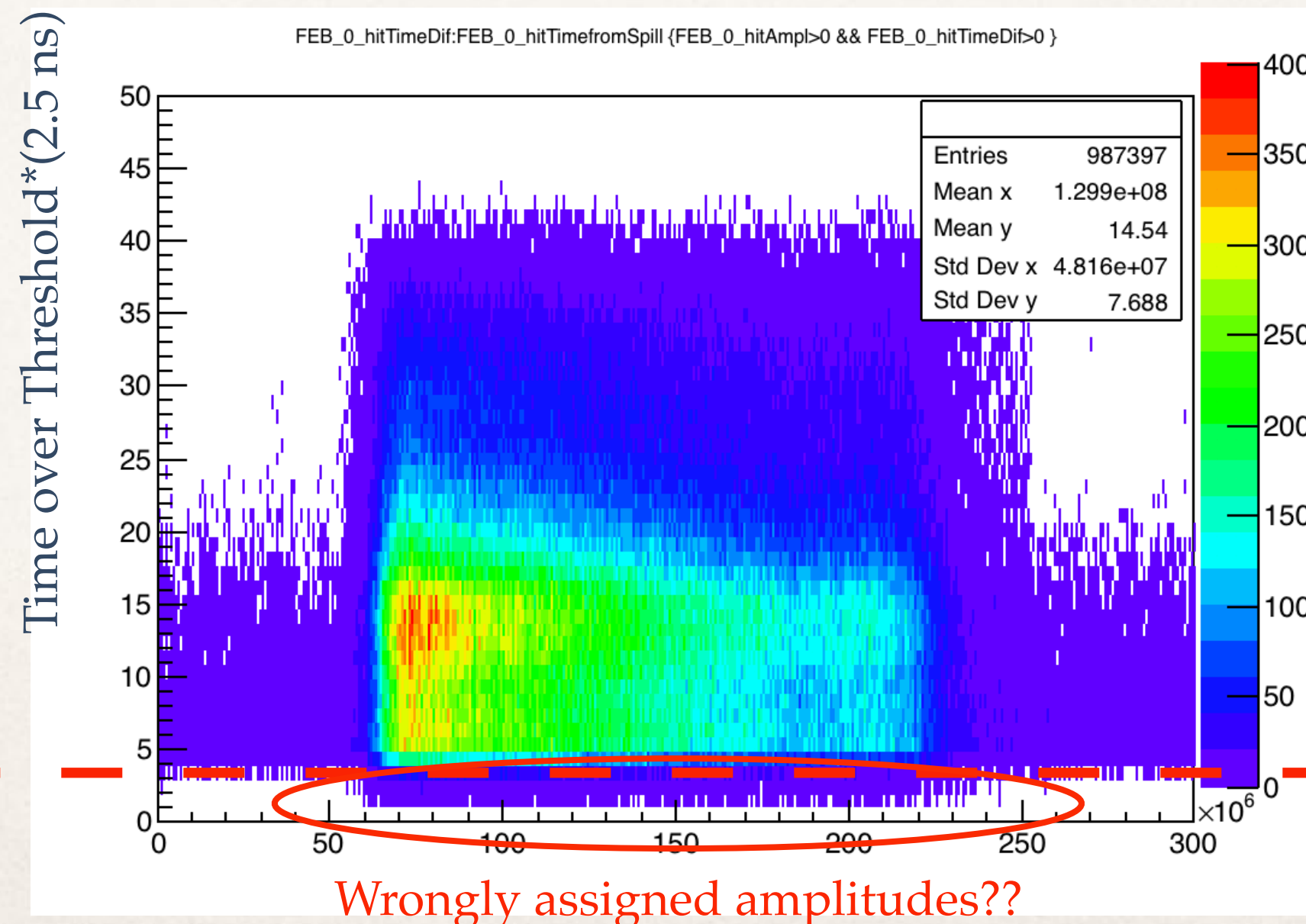
FPGA threshold: 80
Corresponds to ToT: 3

Wrongly assigned amplitudes??

Electronics recovery time

Time Interval between two consecutive hit rising edges

❖ Technically from FPGA time sampling perspective, the minimum value possible for the time interval of two rising edges is two clock ticks = 5 ns

2.5 ns

5 ns

time_interval_FEB0

time_interval_FEB0	
Entries	125881
Mean	660.8
Std Dev	832.5

FEB 0: Front
Signals mostly saturated

What is this peak?

Time interval*(2.5 ns)

time_interval_FEB2

time_interval_FEB2	
Entries	41386
Mean	1085
Std Dev	962.7

FEB 1: Left
MIP signals mostly

What is the structure?

Time interval*(2.5 ns)

Electronics recovery time

We can define four categories of cases, based on the size of the first and second signals
1. MIP + Dark count
2. MIP + MIP
3. Dark count + MIP
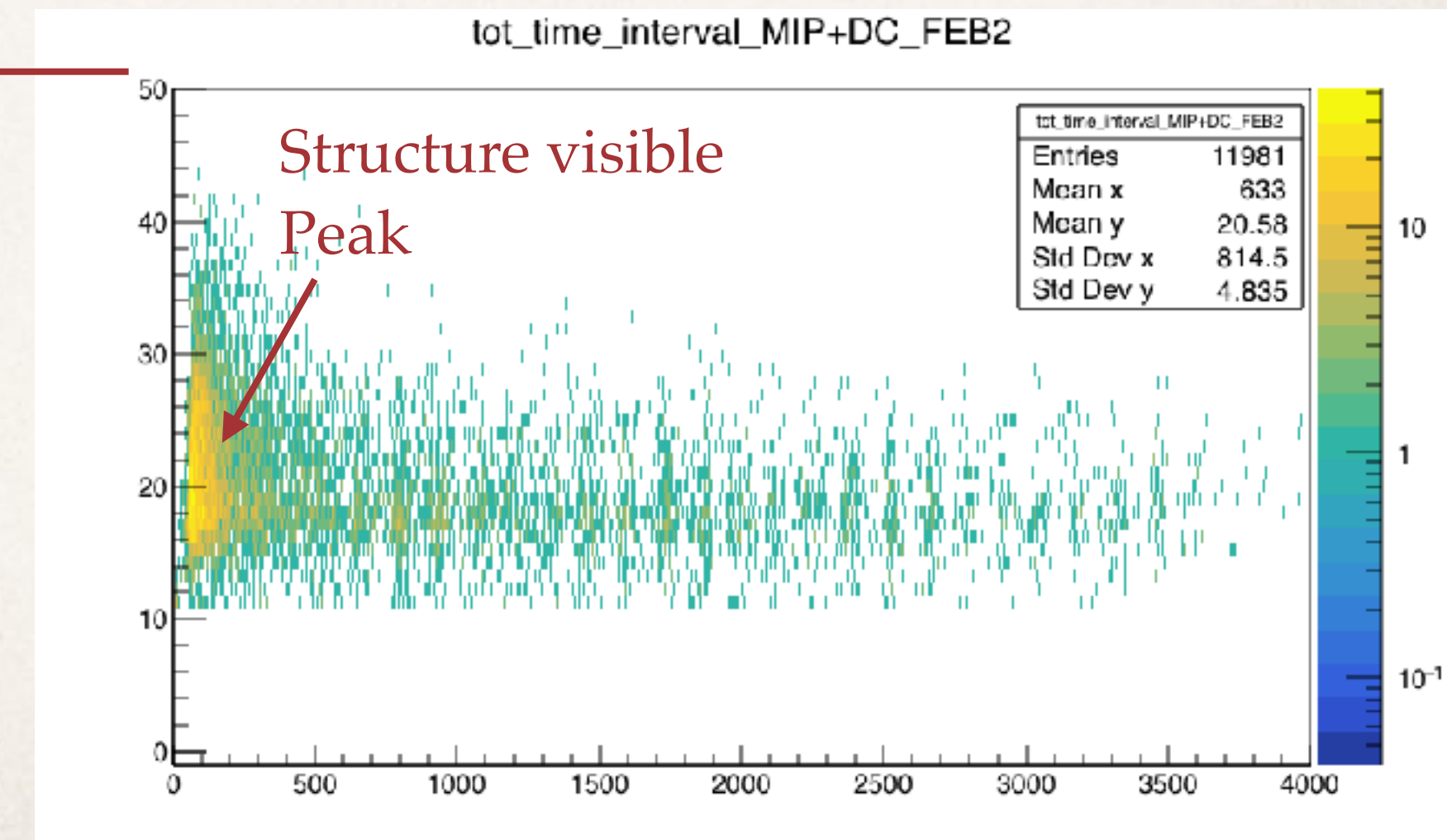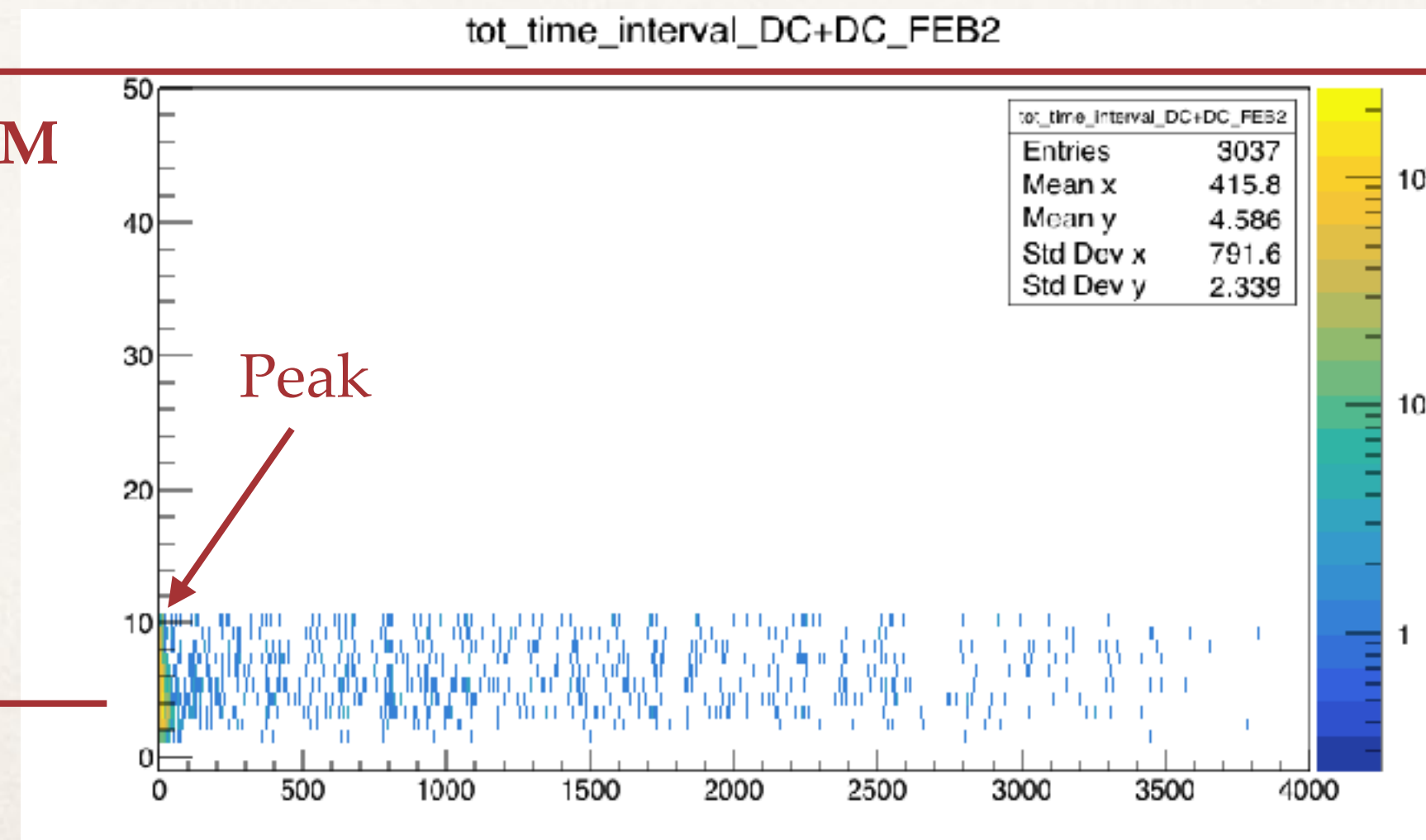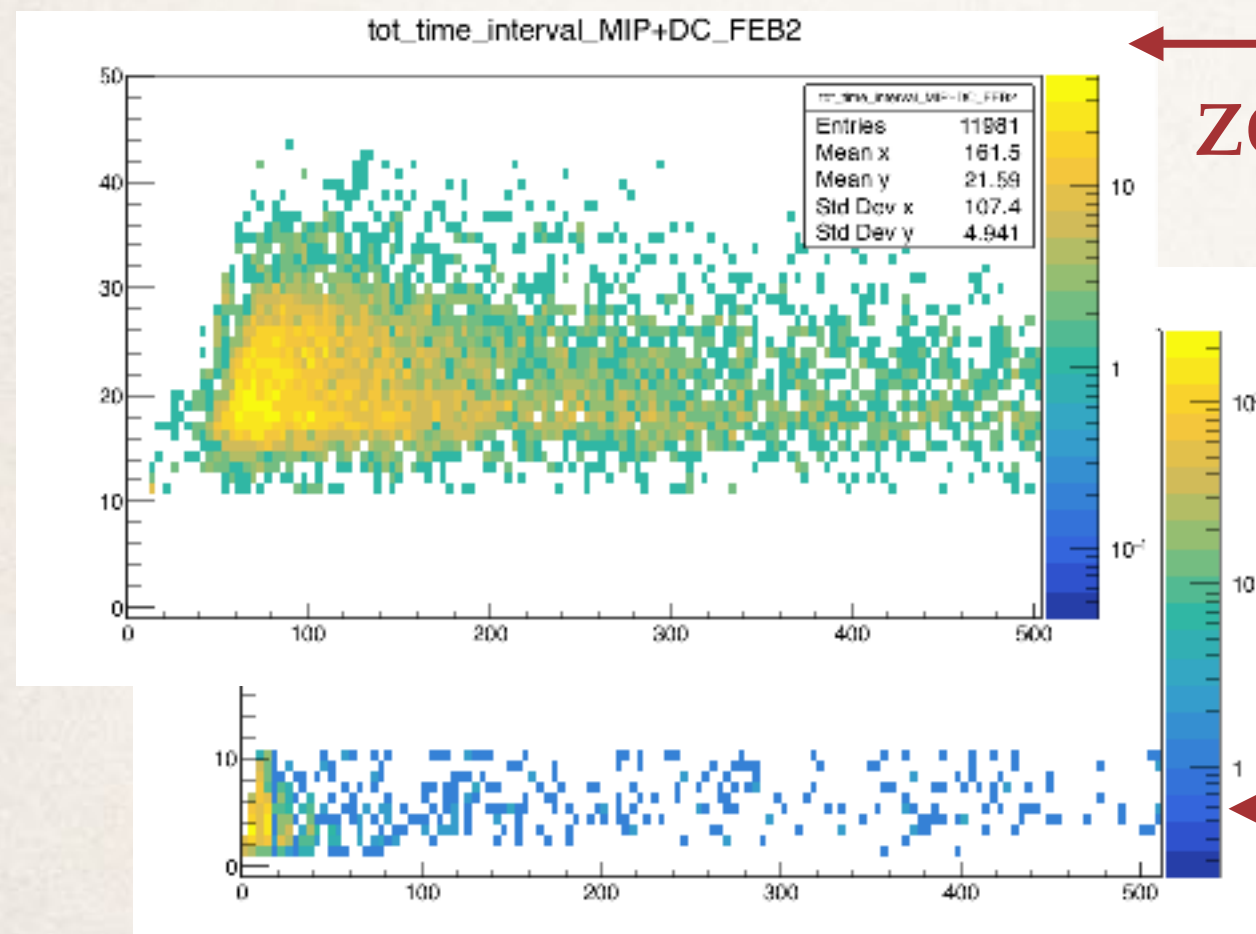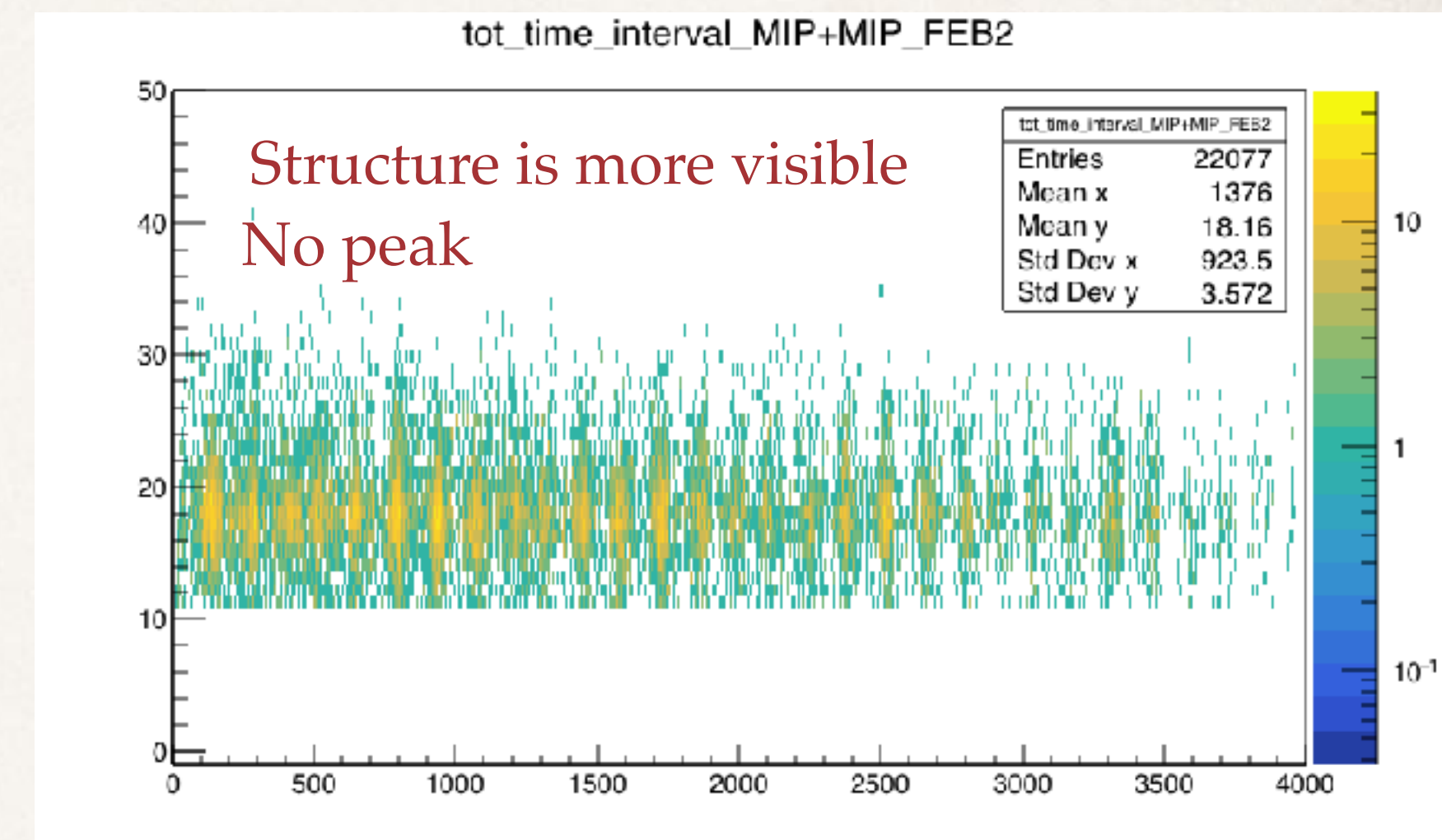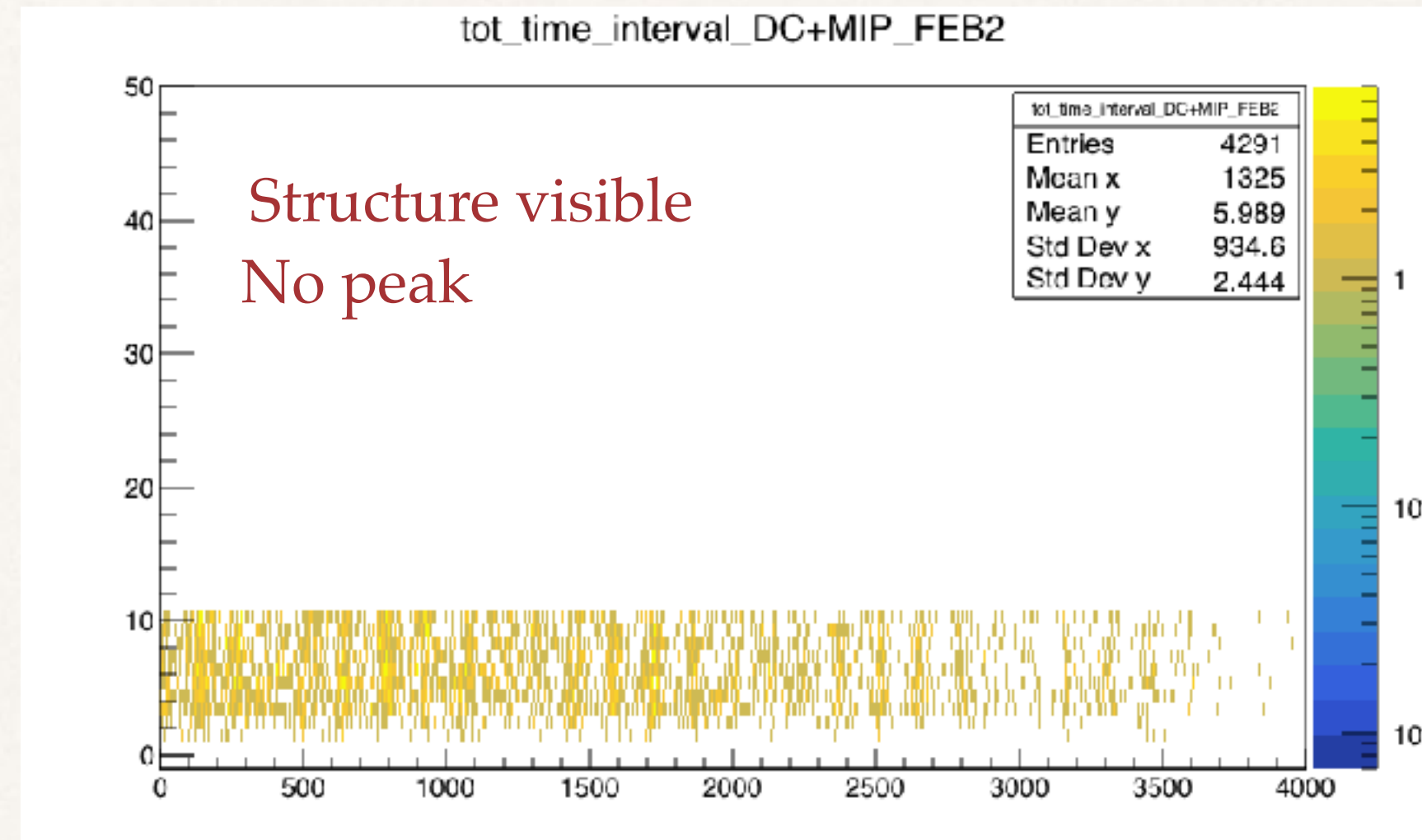4. Dark count + Dark count
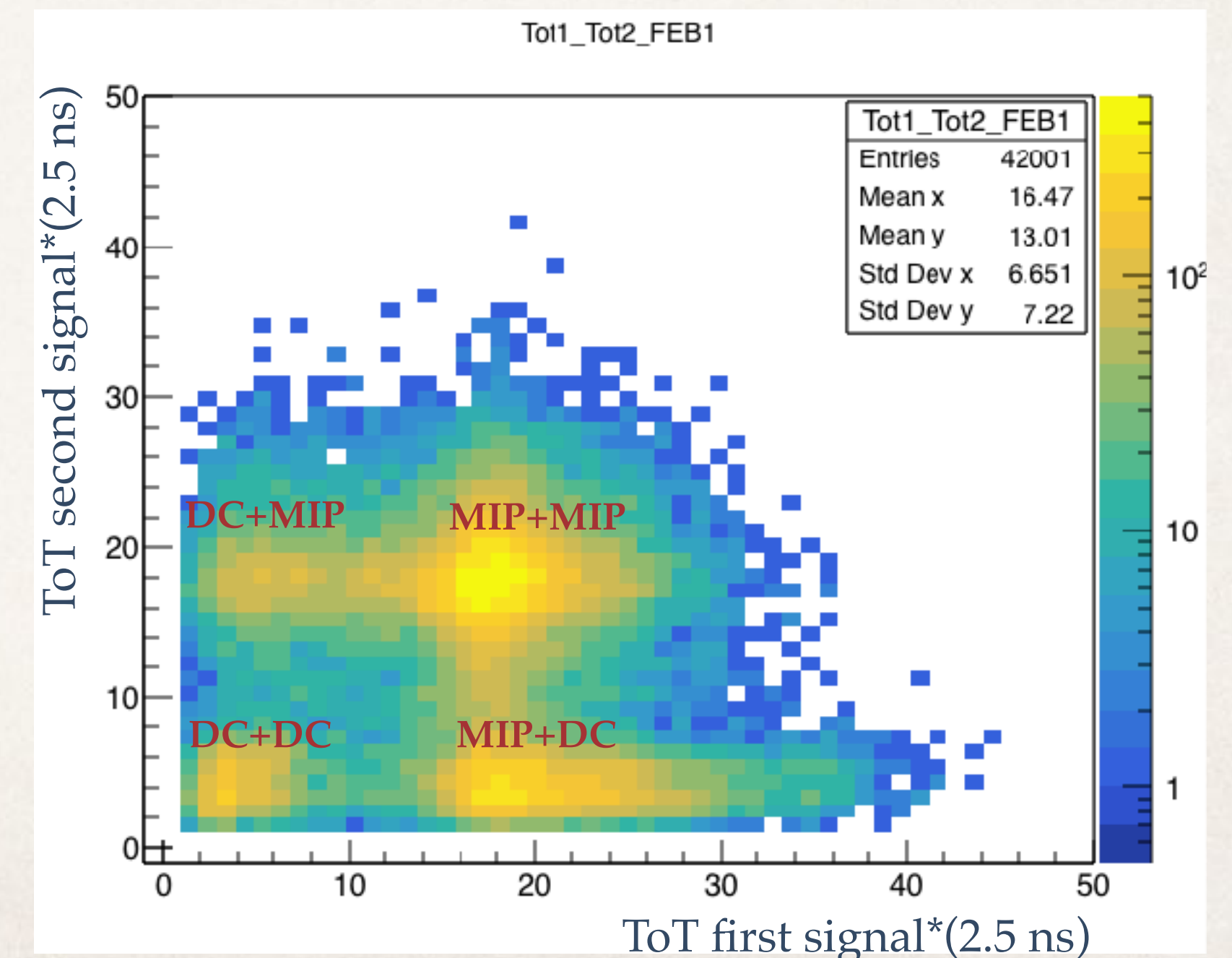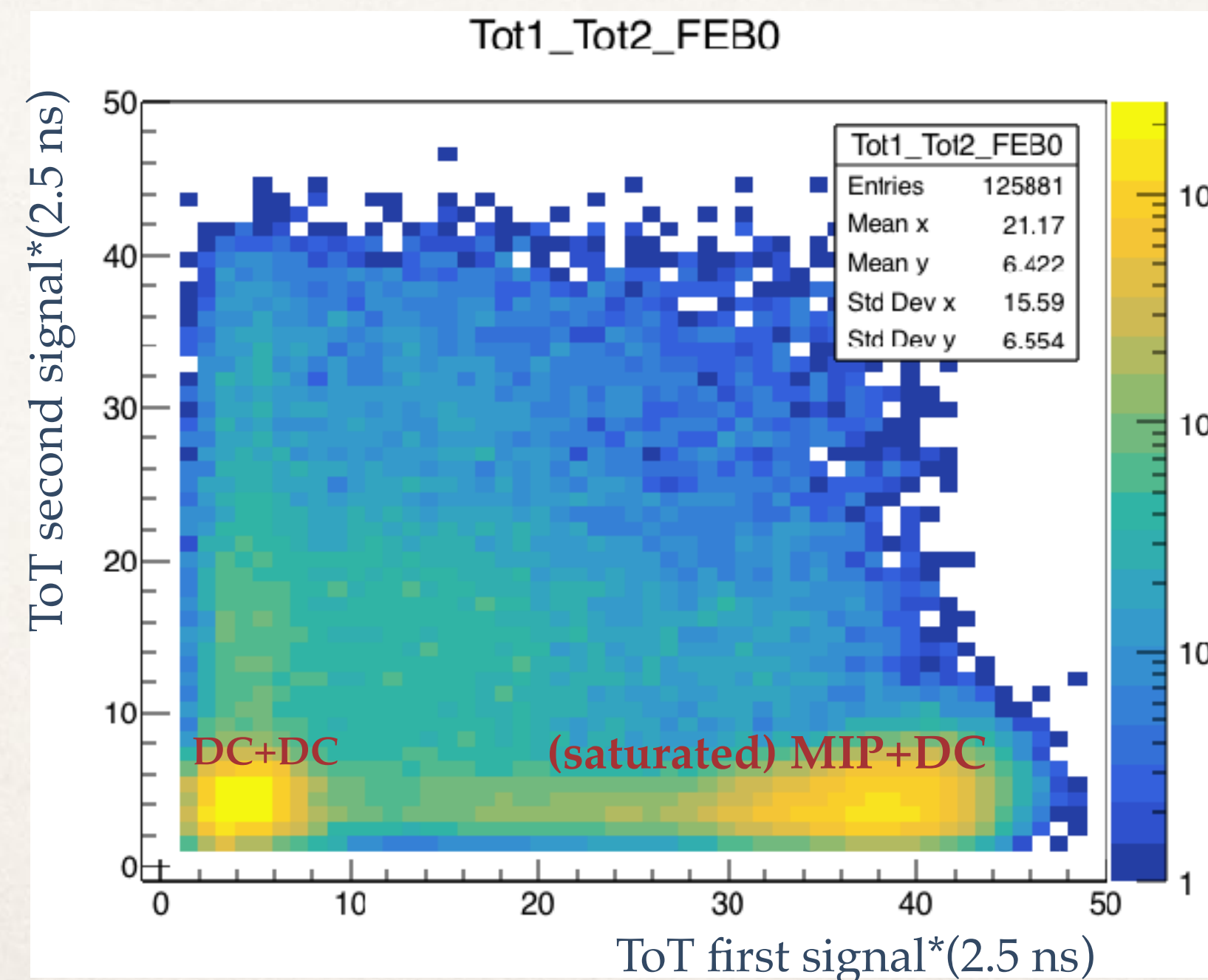
Electronics recovery time

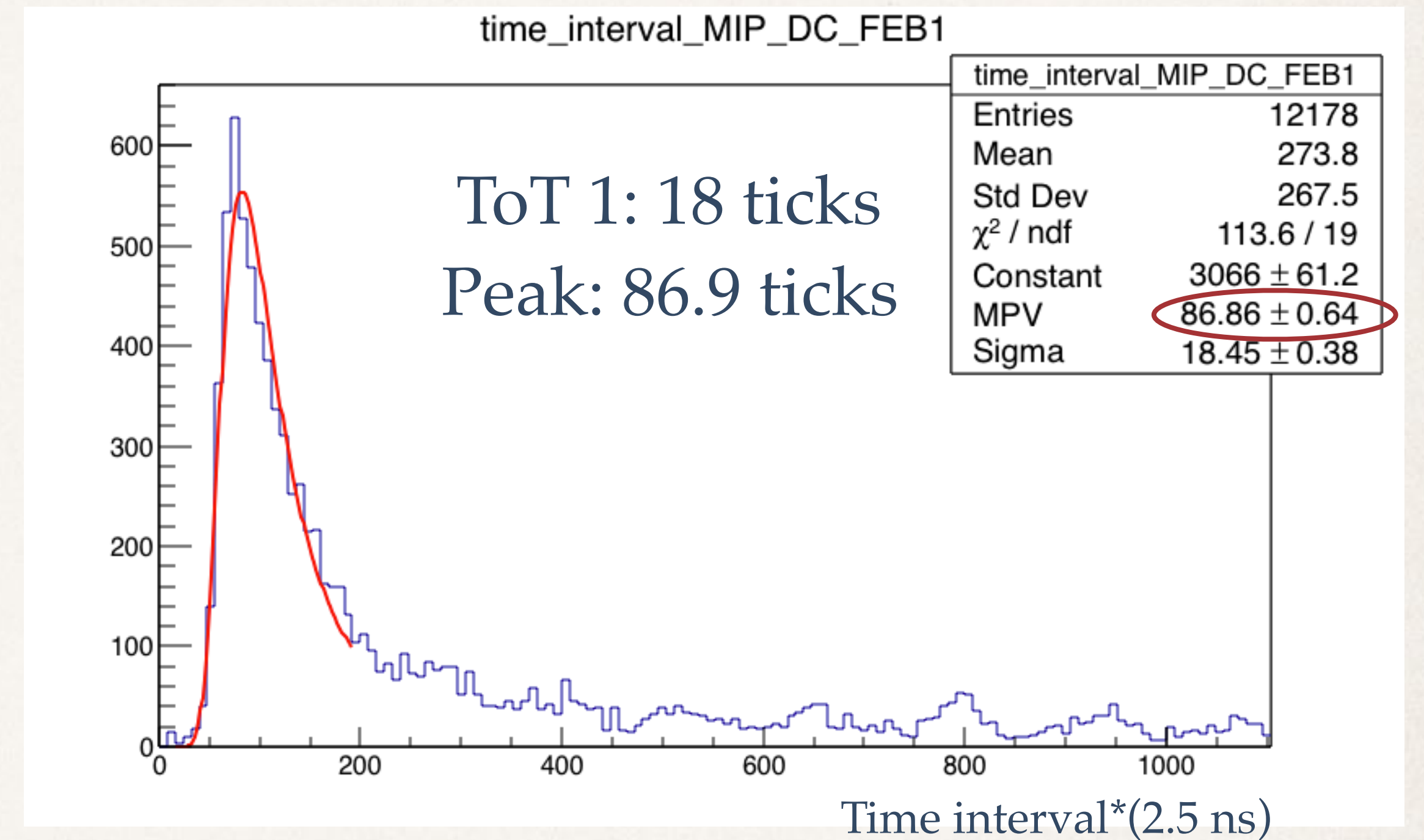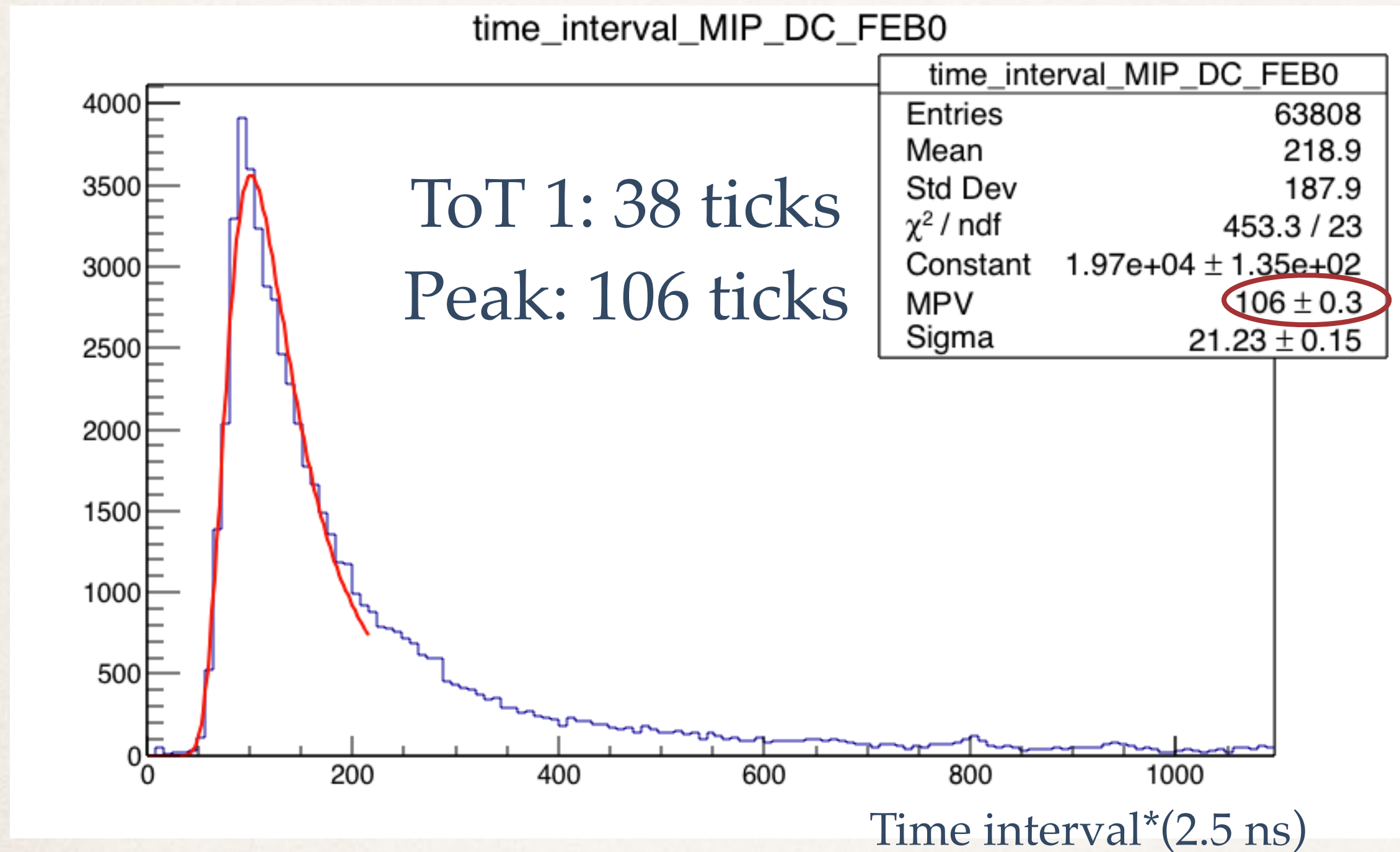## ToT of first signal vs Time interval

My guess:
* The structure is probably beam structure (~340 ns)
* Peak is probably after pulse

# Electronics recovery time

After pulse?

The location of the peak seams to be correlated with ToT of first signal

Trail Time Missing

Sometimes in the data files we records hits which has lead time but not trail time. This is very strange and we have to investigate why it happens

Noisy environment?
->If CITIROC receives a lot of noise and interpret it as hits on many channels in a very short time interval, there is a possibility that the FIFO related to hit time information gets full and some of the information get lost.

Threshold

Lead time   Trail time
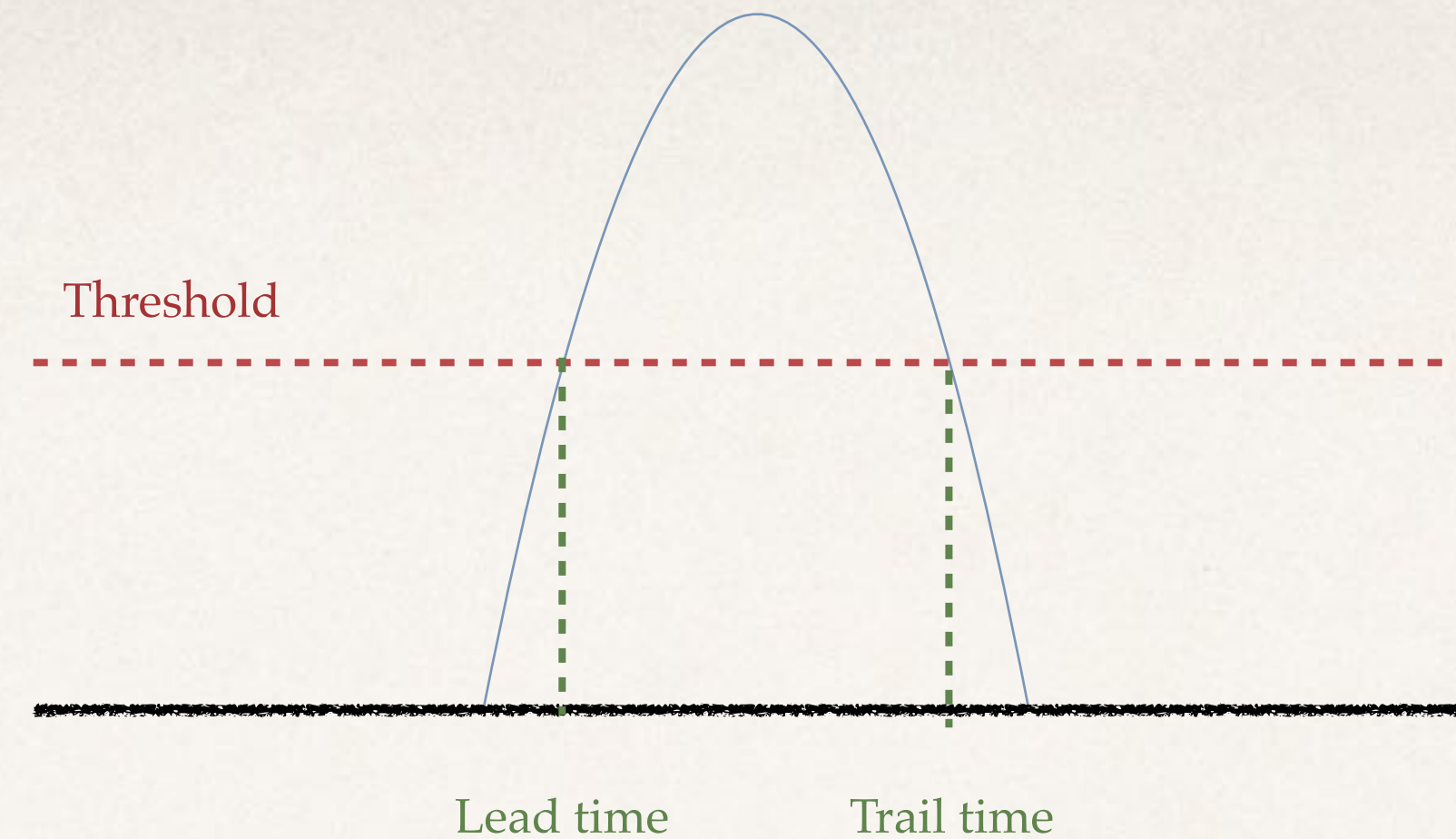
✤ How often does it happen?
✤ Why does it happen?

- Is the FIFO full?
- Is it related to data rate?
- Is it related to MPPC types?
- Is it related to different power supplies for HV?
- Is it related to the orientation of MPPC pins?
- Is it noise generated by MNP Magnet?
- Is it noise generated on FEB board itself?

Trail Time Missing

- Plots below show hit distribution in spill window (750 ms)
    - Left plot: all hits
    - Right plot: hits missing trail time
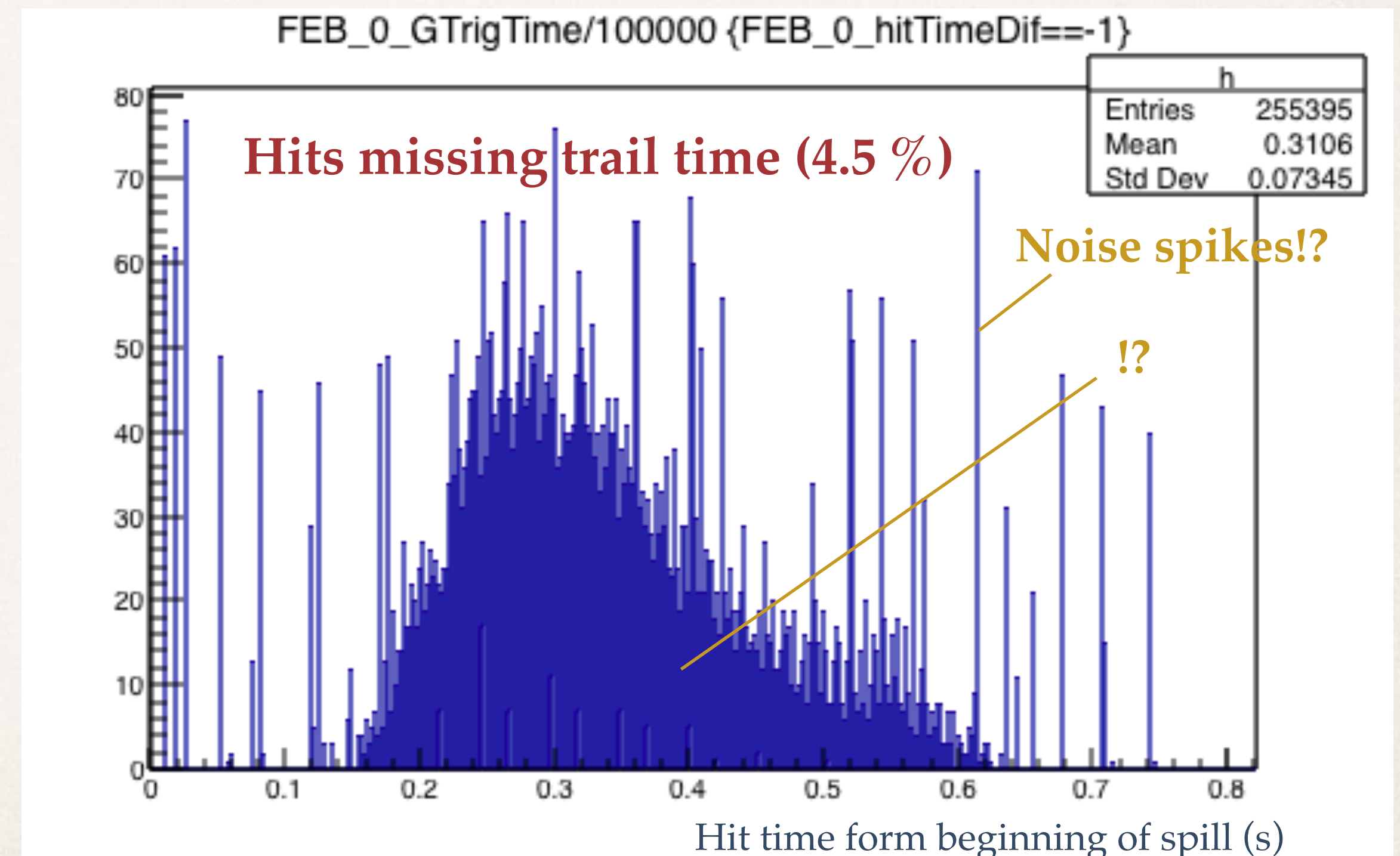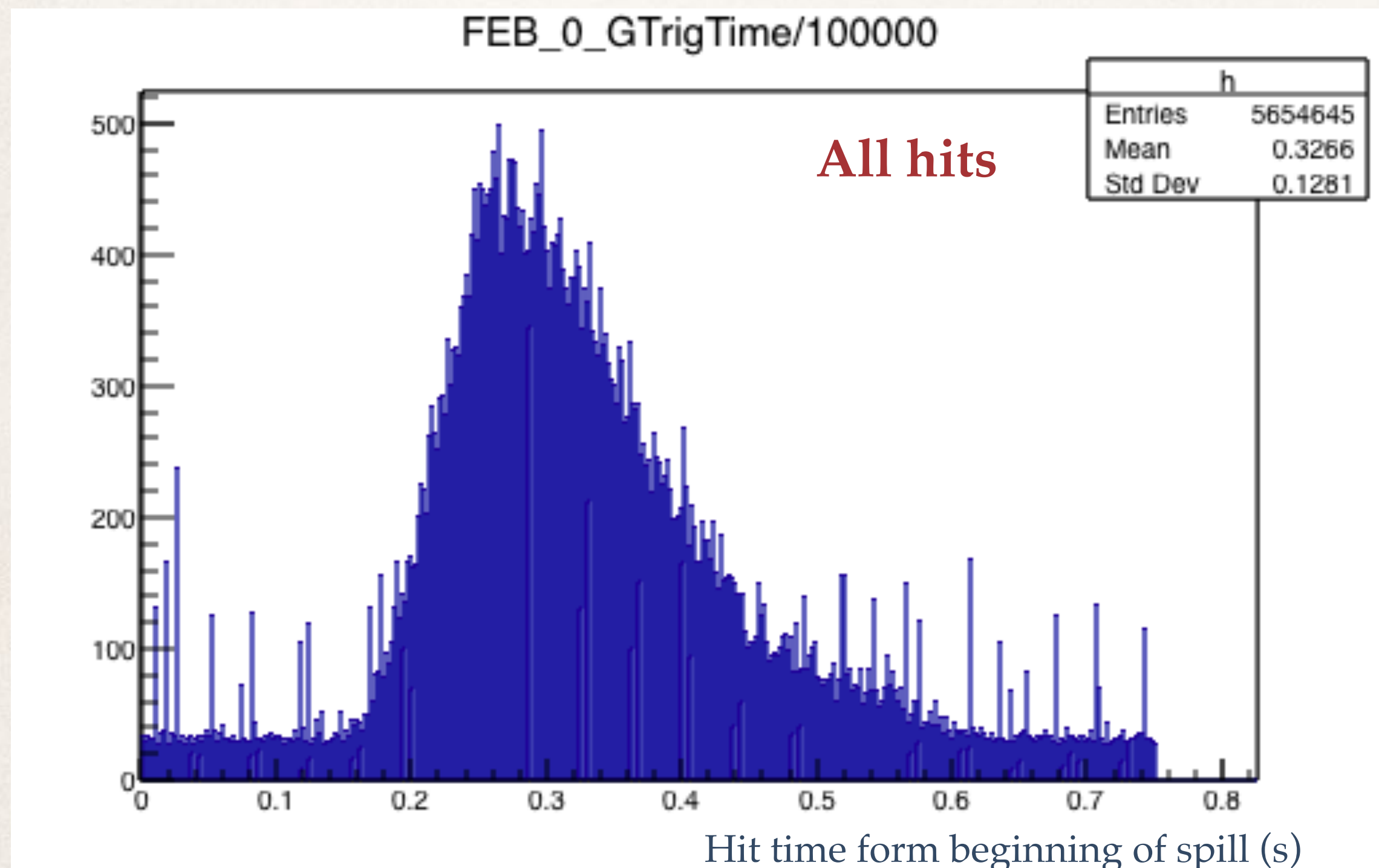
Trail Time Missing

FEB #	Total hits	Missed trail	Missed/Total	Side	MPPC Type
0	6420504	238073	3.708011084	Front	I
1	4872908	242276	4.971897684	Right	I
2	3811959	258759	6.788084552	Left	I
3	5559817	50532	0.908878835	Top	II
4	5780705	100094	1.731518906	Top	II
8	49422070	86716	0.175460073	Top	III
9	5663626	42706	0.754039903	Bottom	II
10	4406775	88834	2.015850594	Bottom	II
11	56867550	134759	0.236969942	Bottom	III
16	6528835	291721	4.46819379	Back	I
17	4293637	473581	11.02983322	Left	I
18	2011237	77320	3.844400237	Top	I
19	2317792	89041	3.84163031	Top	I
20	2639245	89613	3.395402852	Top	I
24	4502912	471529	10.4716459	Right	I
25	2121279	76858	3.62319148	Bottom	I
26	2544892	93171	3.661098388	Bottom	I
27	2428070	90565	3.729917177	Bottom	I

% Hits missed trail

No. Hits missed trail

All hits

23
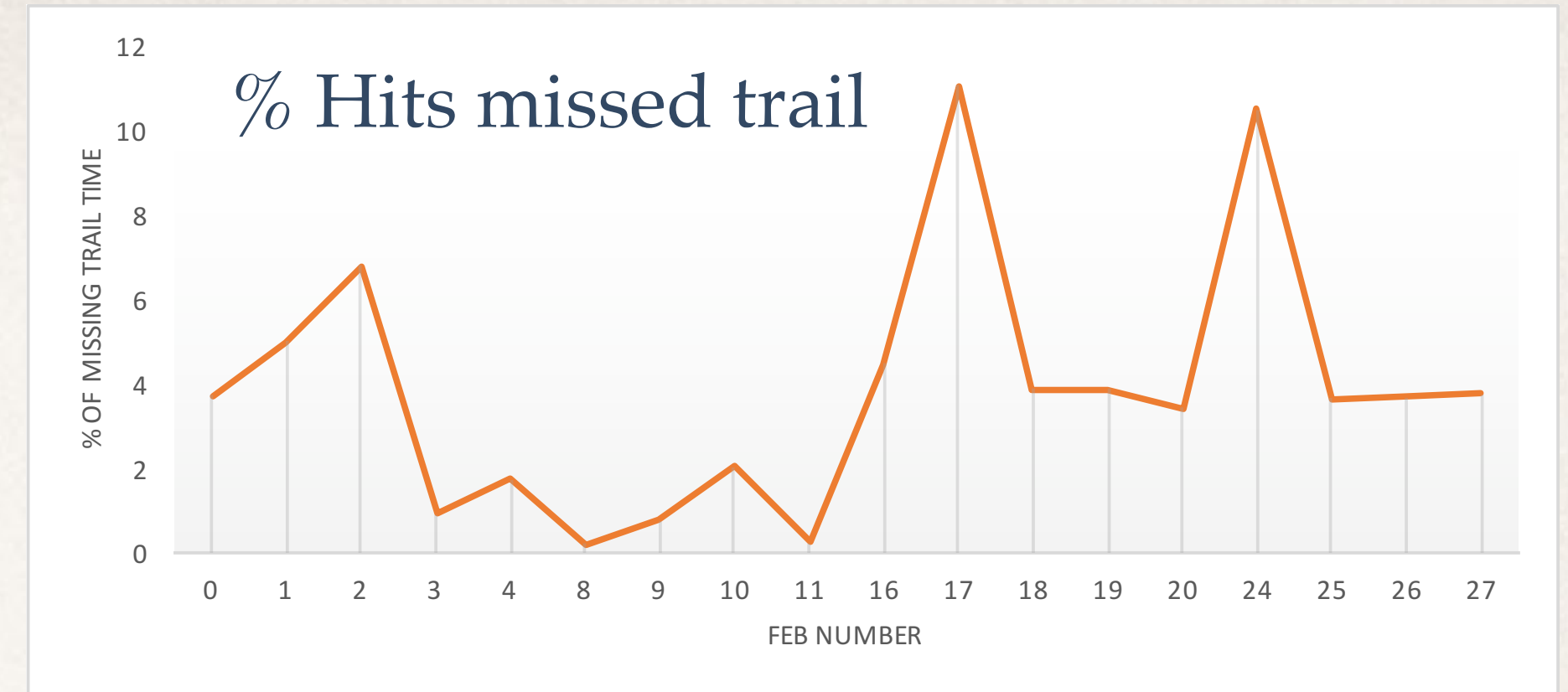
Trail Time Missing

What can we read from these plots?

1. The noisiest MPPC type III has the smallest percentage of trail missing. -> (Not related to data rate)
2. Comparing only the FEBs reading top/bottom
   - MPPC type1 ~ 100000   ~ 4% -> external HV source 1 (no filter)
   - MPPC type2 ~ 80000   ~ 1-2% -> external HV source 2 (no filter)
   - MPPC type3 ~ 120000   ~ 0.2% -> Internal HV source (noise filter exist)
3. Comparing only MPPC type1 different sides of sFGD
   - Top/bottom type1 ~ 100000   ~ 4%
   - Right/left C type1 ~ 450000   ~11%
   - front/back type1   ~ 250000   ~ 4%
   - -> pick up noise by MPPC pins? Direction dependent?

% Hits missed trail

No. Hits missed trail

All hits

Thank you for your attention

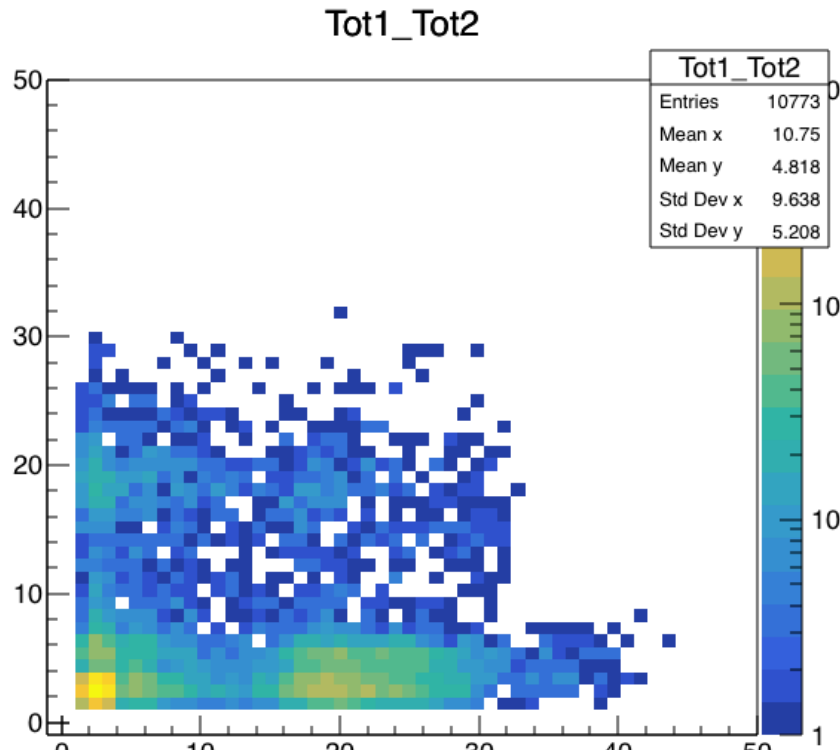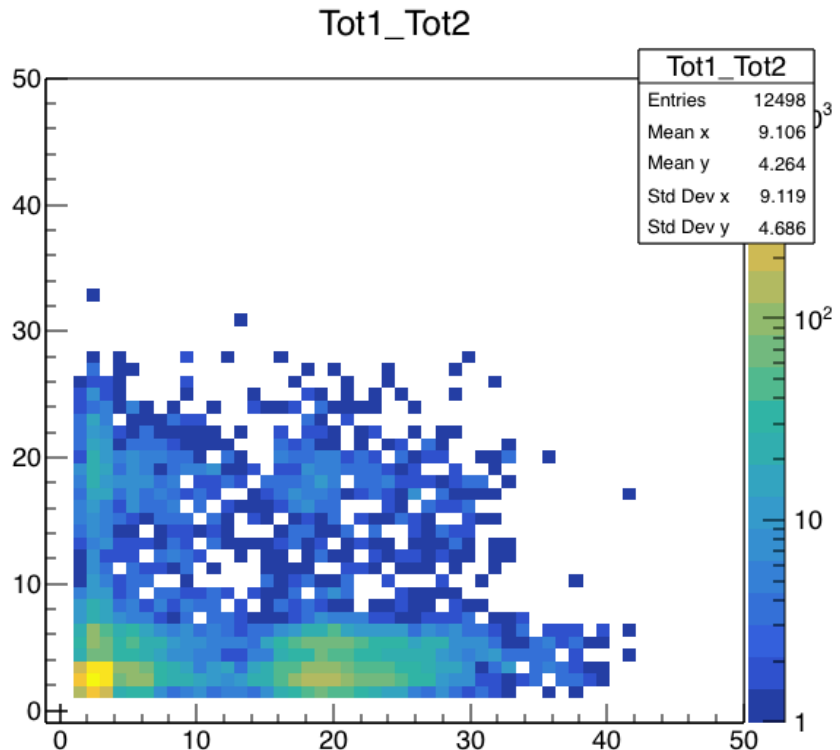Is there any question?

Back up slides

Calibration

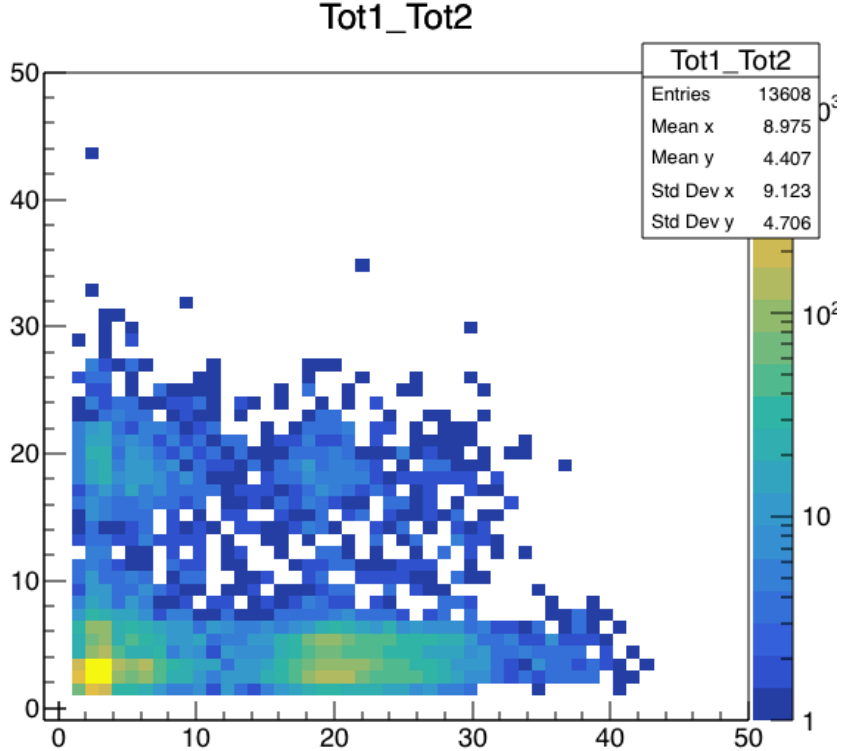# HG/LG settings
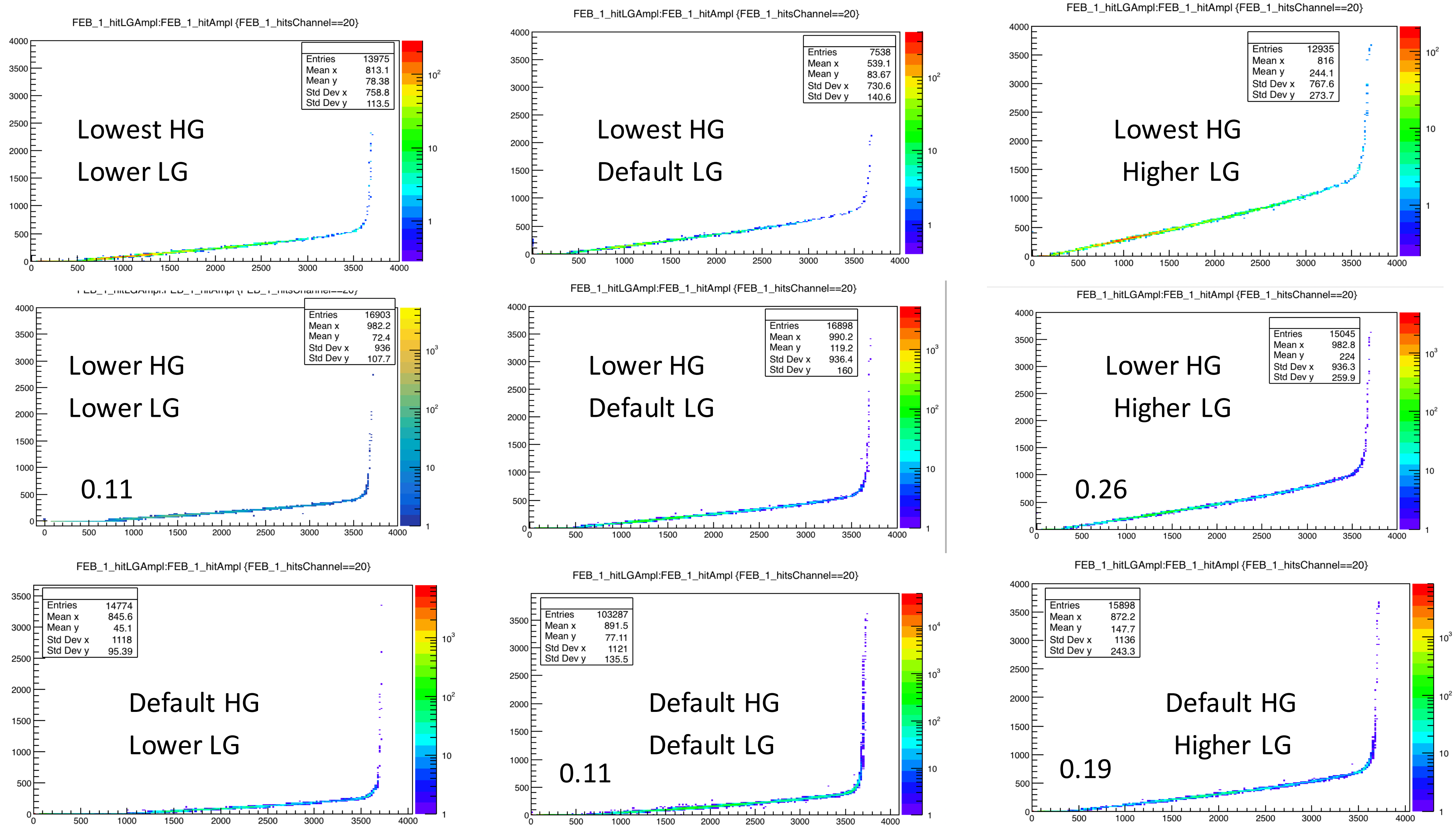
FIFO

MCR0 and MCR1
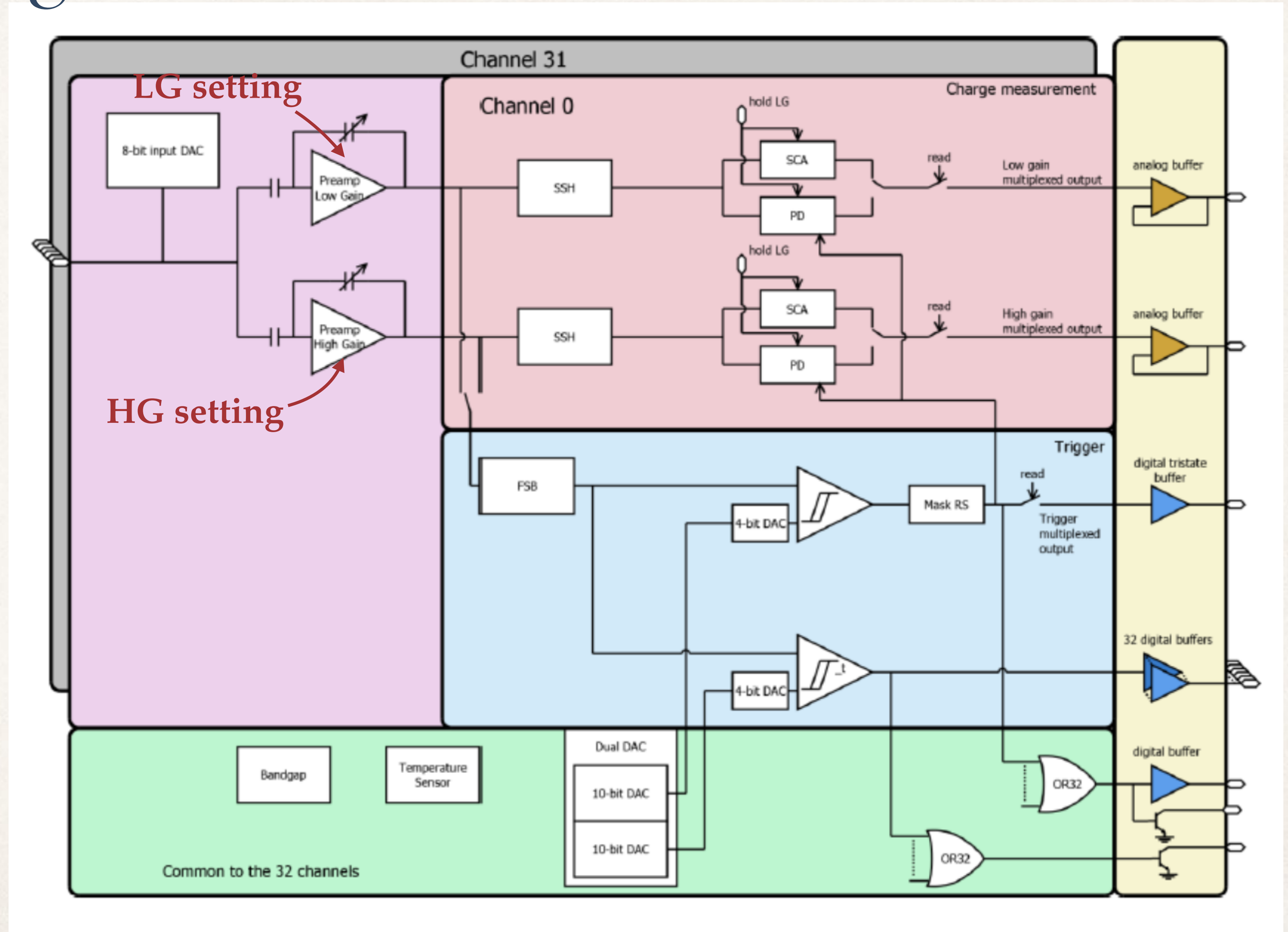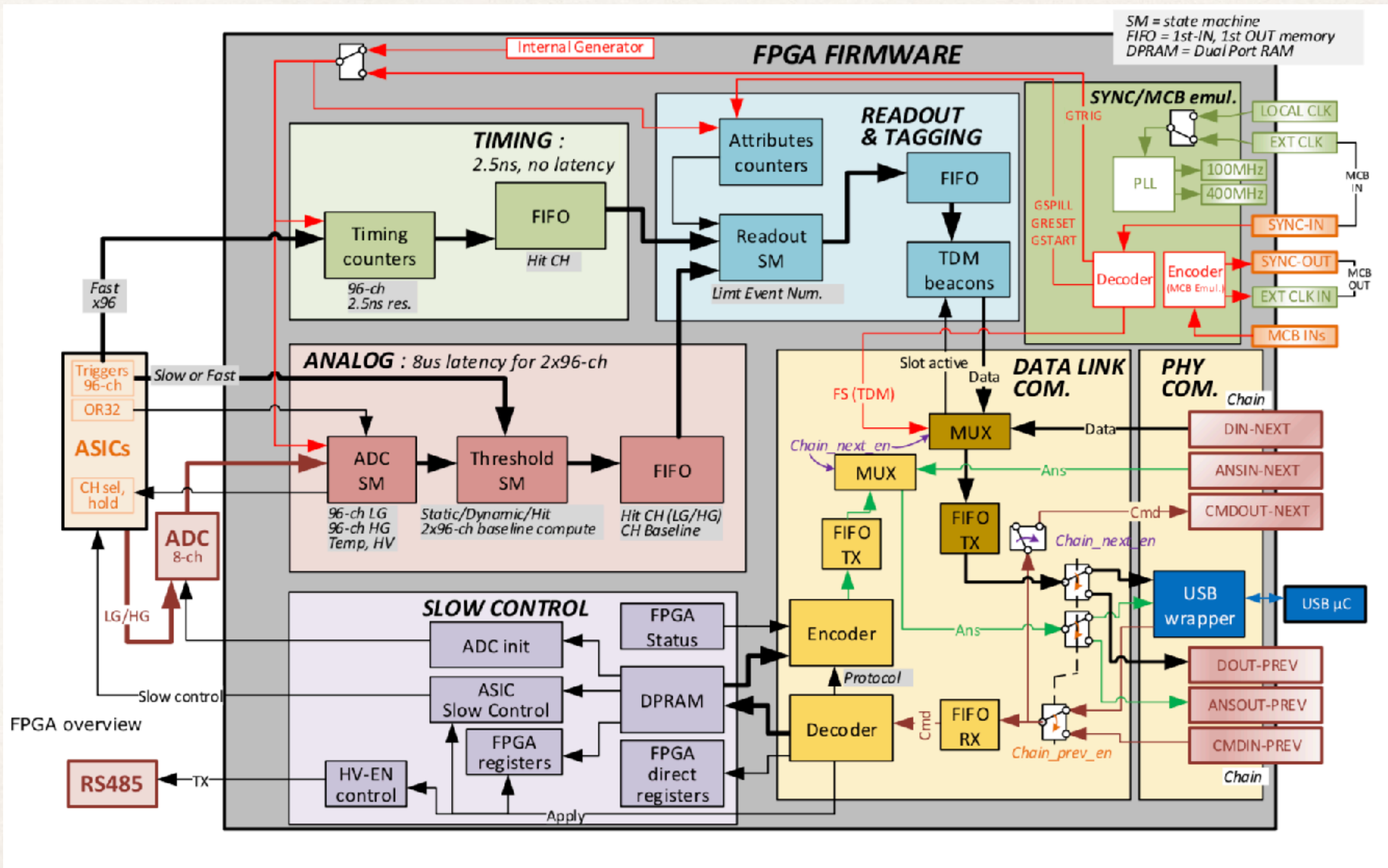
ToT 1 vs ToT 2
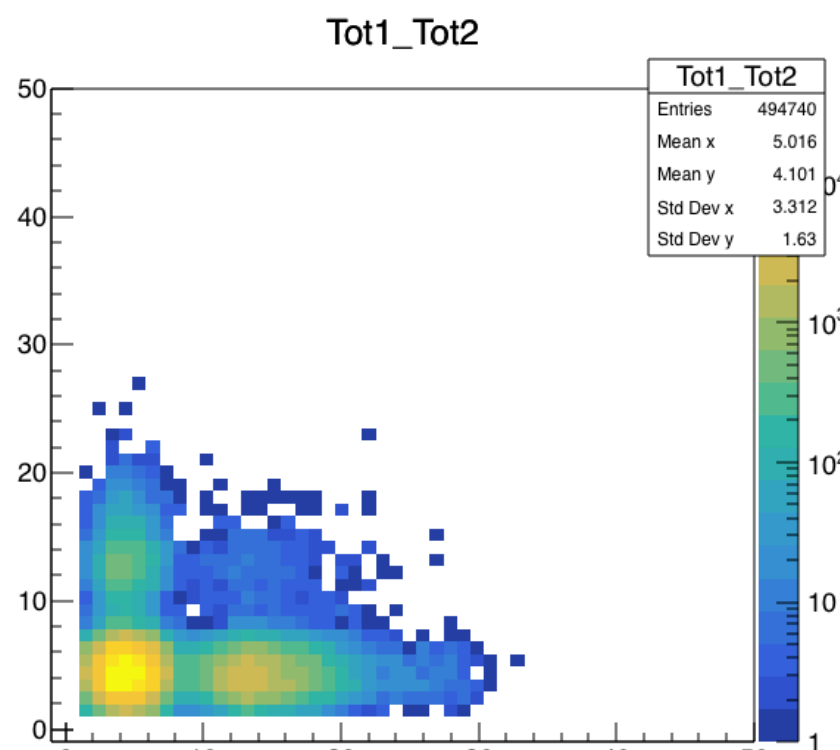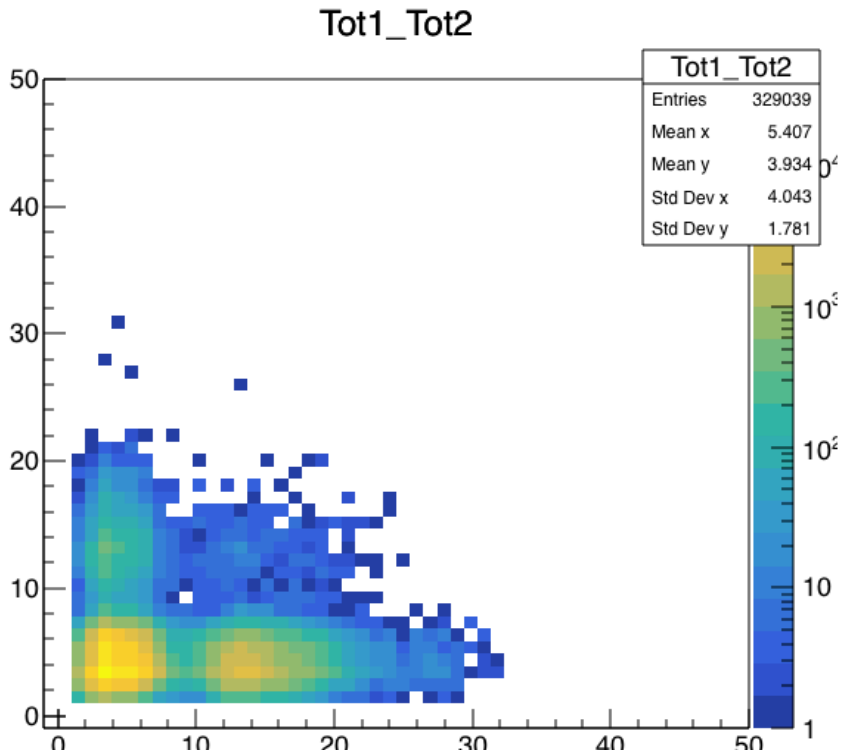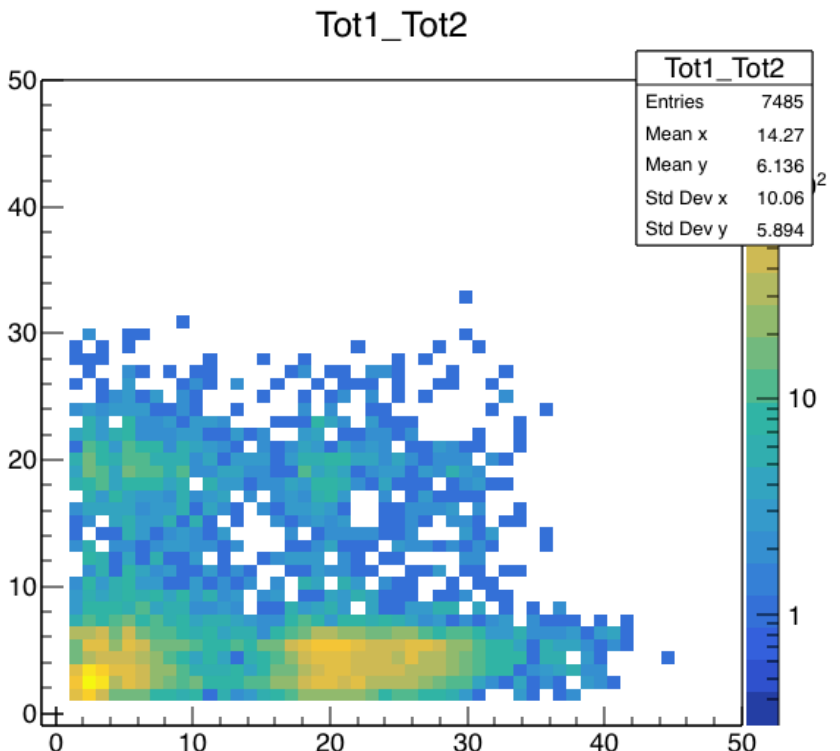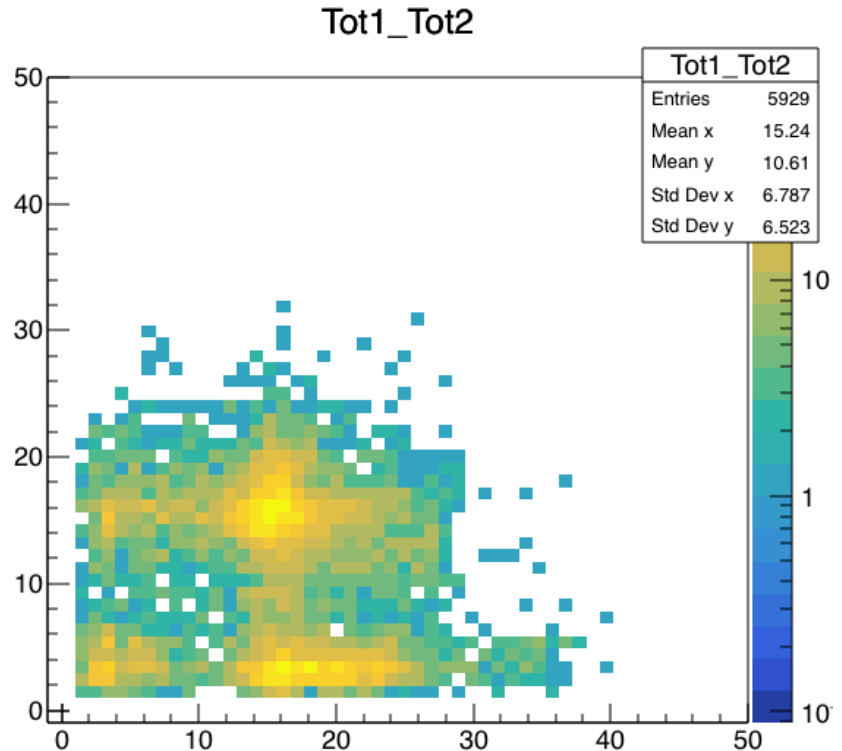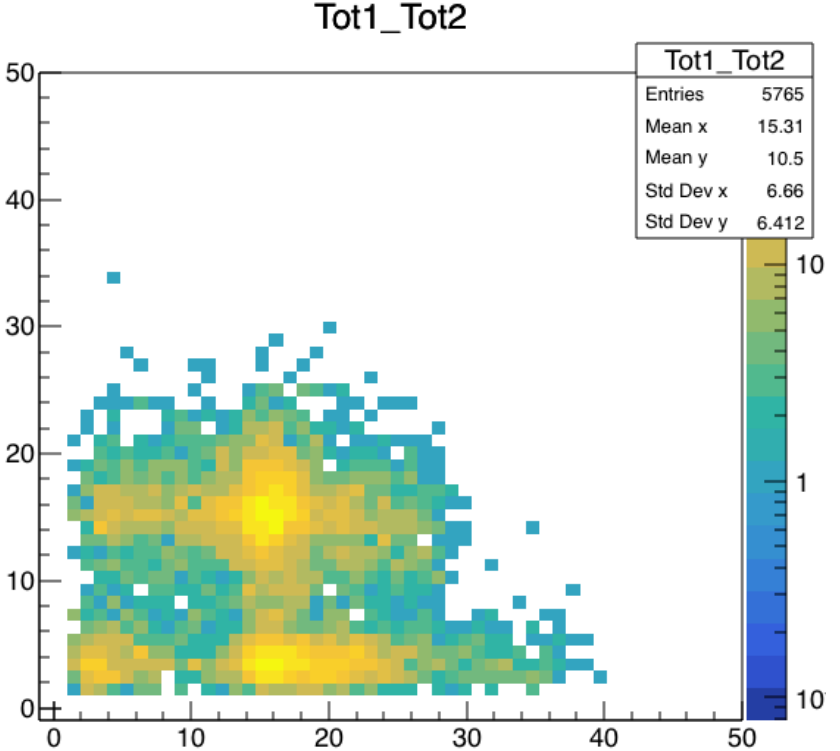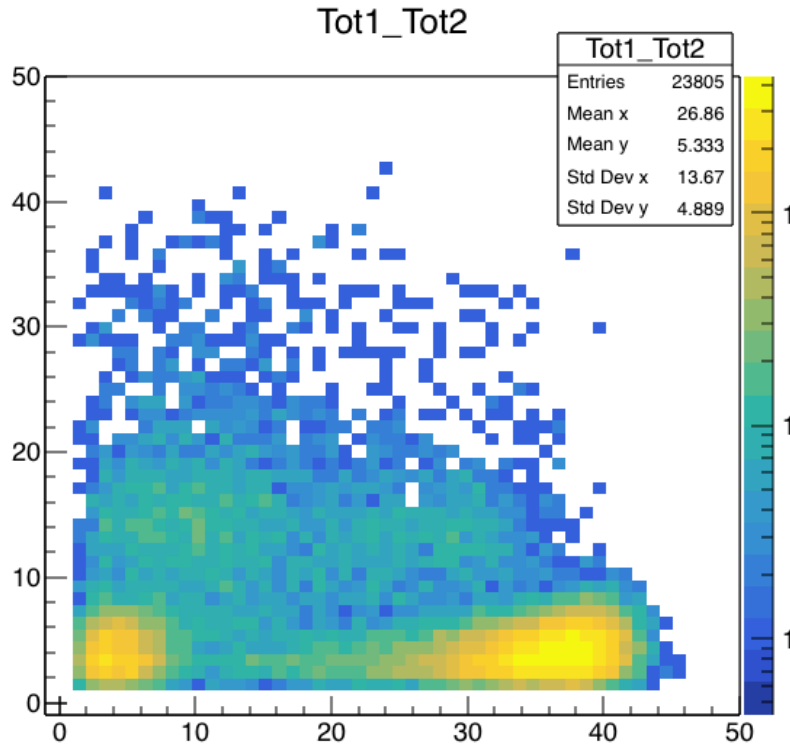
Time interval between hits

MCR2 and MCR3

ToT 1 vs ToT 2