HA-TPC PROTOTYPE TESTS

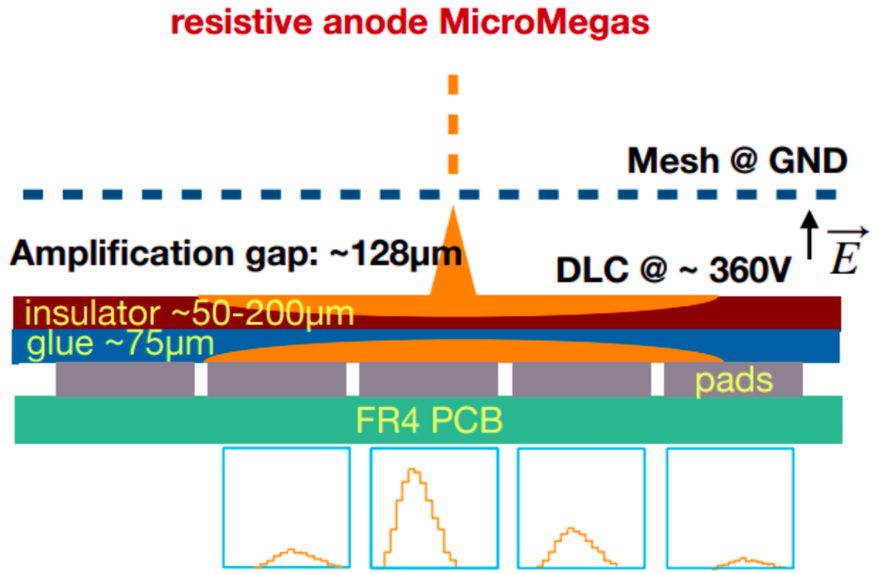
Sergey Suvorov

30.10.2020
Réunion upgrade-T2K

INTRODUCTION

- Different HA-TPC prototypes were tested:

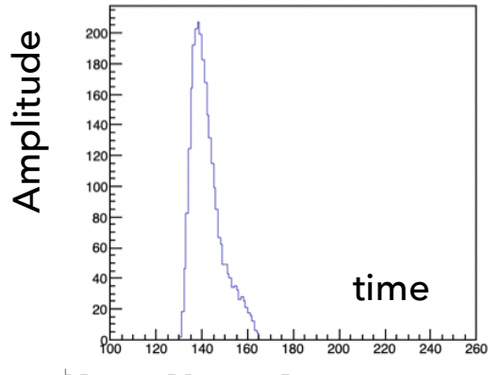
1. MM1 DLC1
   MM: 75 μm glue, 197 kOhm < R < 265 kOhm
   E*lectronics: old FEE*
   tested with beam and cosmic in DESY
2. MM1 DLC2 (clone of 1)
   E*lectronics:* FEE V1
   tested with cosmic in Saclay
3. ERAM #2
   MM: 200 μm glue, 165 kOhm < R < 220 kOhm
   E*lectronics:* FEE V1
   tested with cosmic in Saclay
4. ERAM #3
   MM: 200 μm glue, 150 kOhm < R < 203 kOhm
   E*lectronics:* FEM V2
   tested with cosmic in Saclay



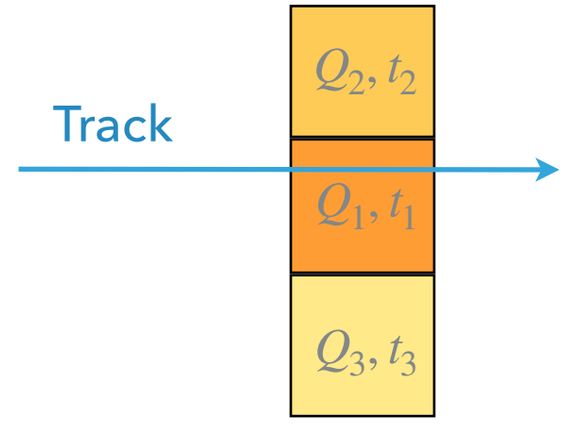
TIME MEASUREMENTS

- The maximum of the waveform is used to measure charge and time.

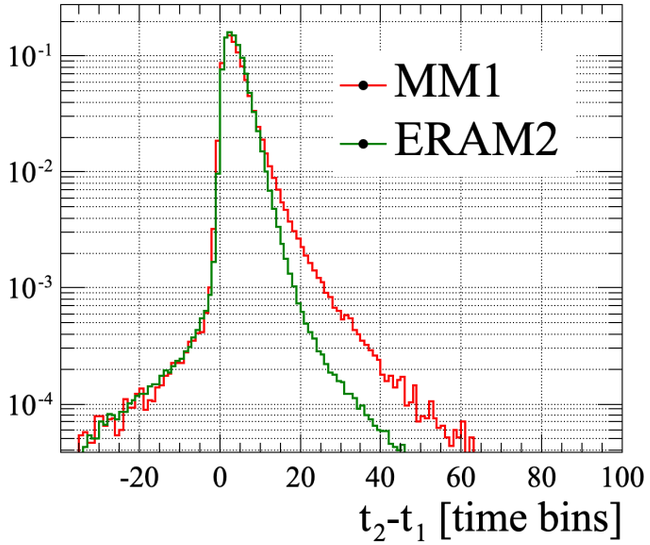
Waveform example:

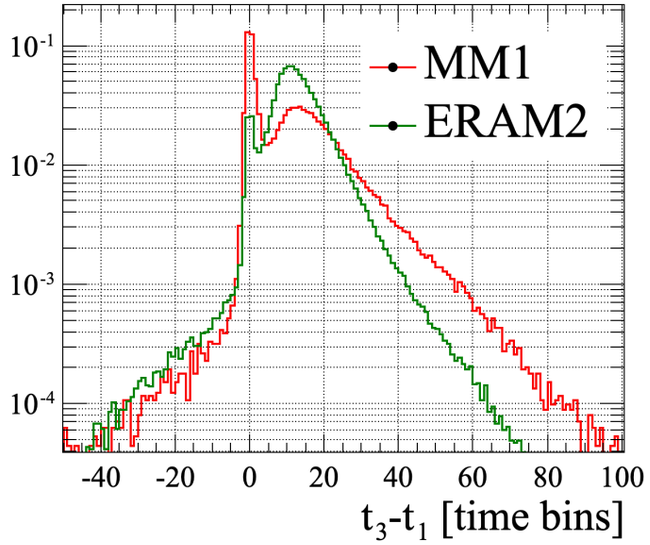


Charge sharing



- Anomaly in the time distributions were found





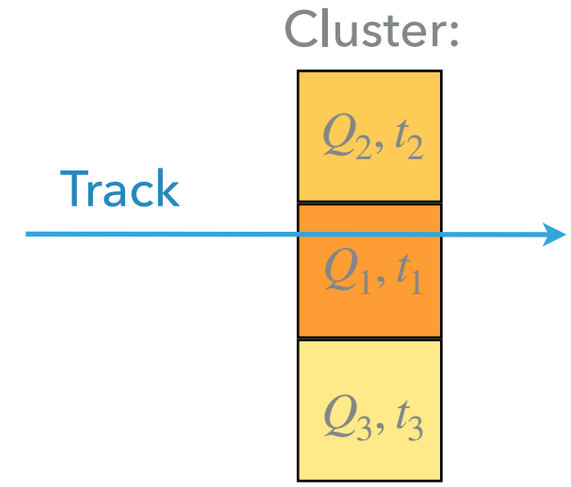
Reference points:

- $t_2 - t_1 < 0$ wrong reco (3%)
- $t_2 - t_1 = 0$ track over pad border
- $t_3 - t_1 \leq 0$ should never happen

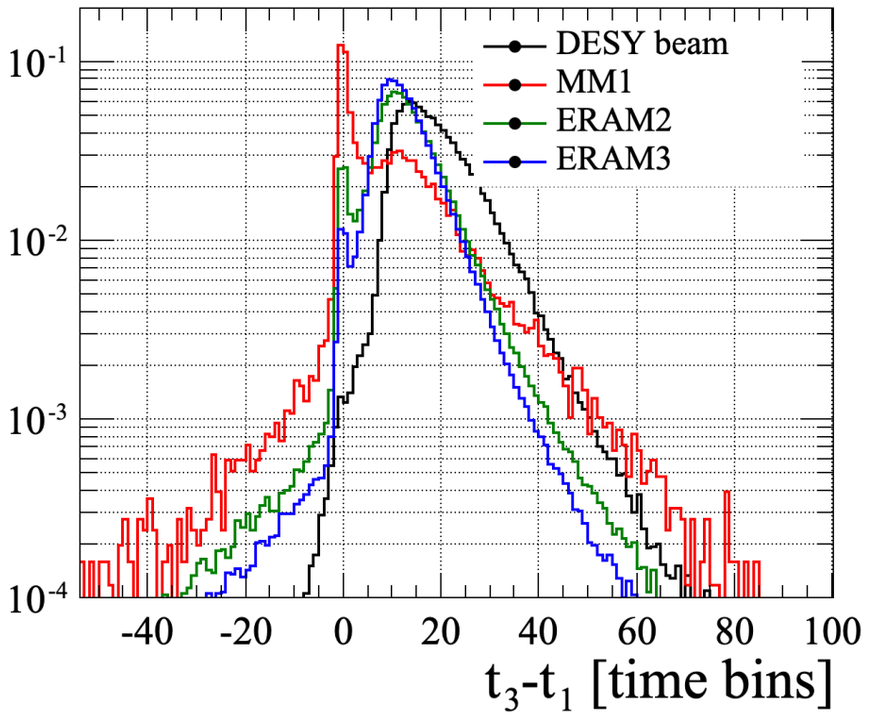
- Peak at $t_3 - t_1 = 0$ is clearly unphysical

TIME MEASUREMENTS

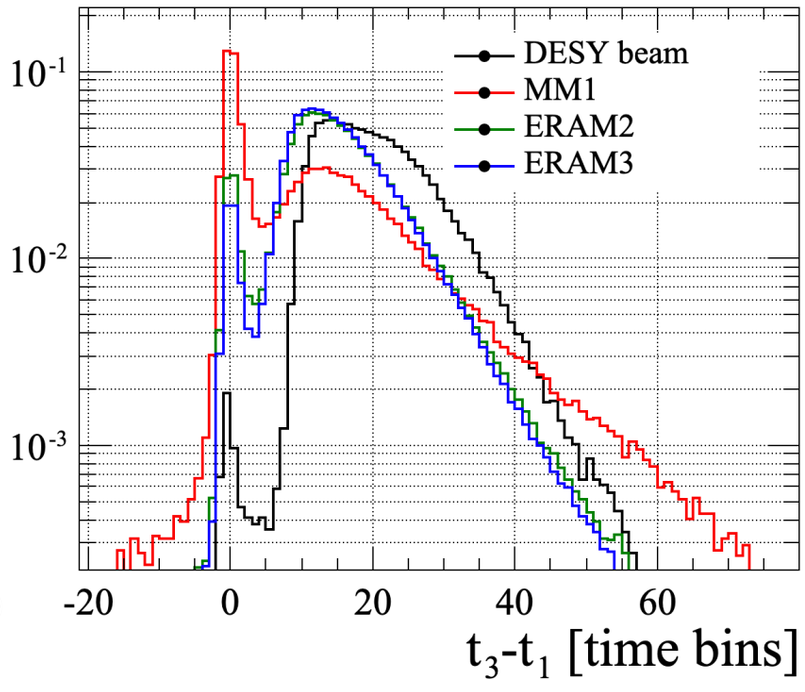
- Compare suspicious $t_3 - t_1$ distribution to DESY beam data
- Only second peak in $t_3 - t_1$ corresponds to proper WF treatment



360 V



380 V



$t_3 \approx t_1$
–>3rd pad WF is treated wrongly
–> wrong charge measurement
–> wrong position

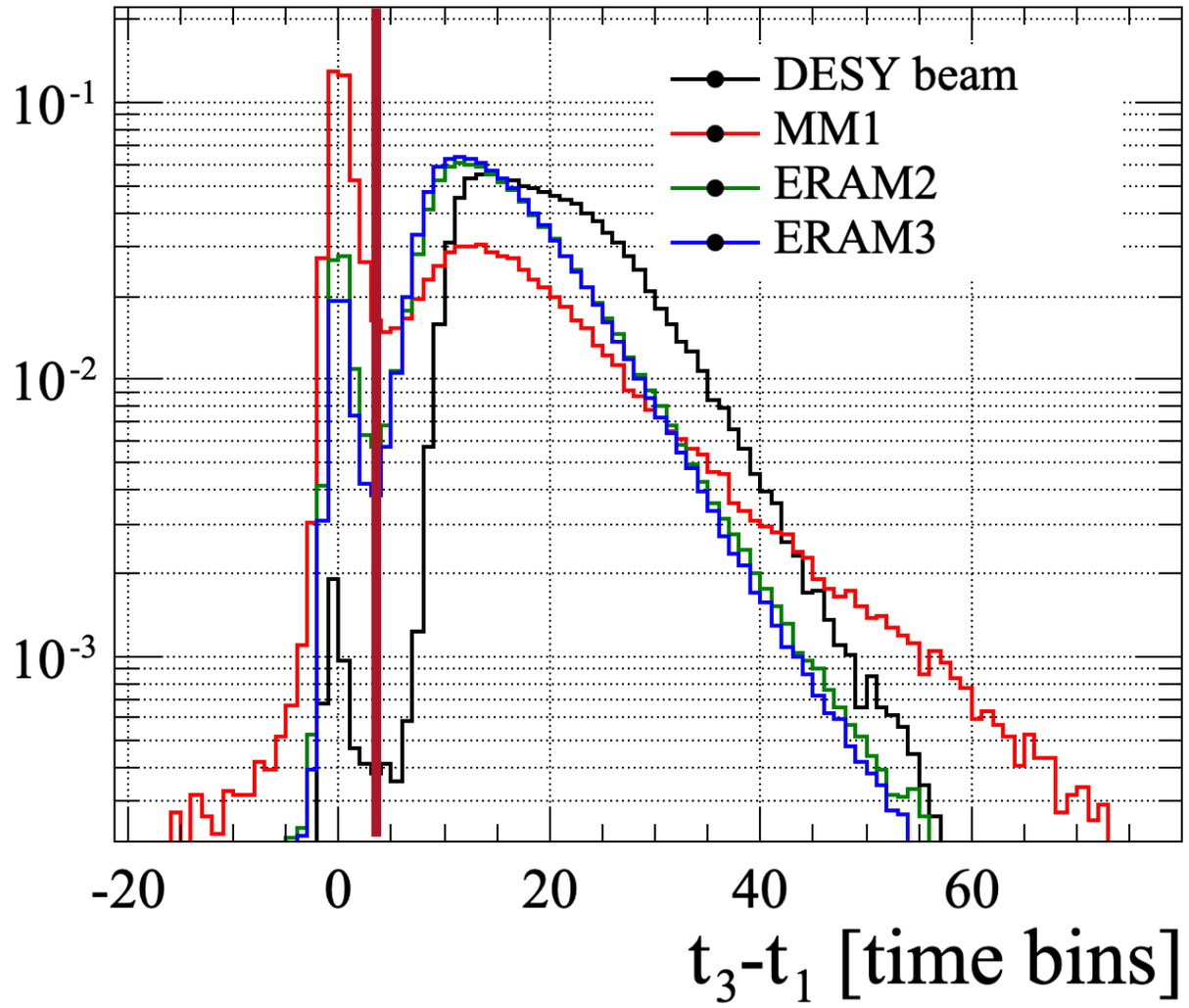
Is DESY and ERAM spatial resolution better because of the better treatment of the WF?

FRACTION OF "BAD" PADS

- Fraction of 3rd pads with $t_3 - t_1 < 2$

	360V	380V
DESY beam	0.8%	0.4%
DESY cosmic	4.4%	-
MM1 Saclay	35.1%	34.5%
ERAM2	8.2%	7.4%
ERAM3	4.0%	5.2%

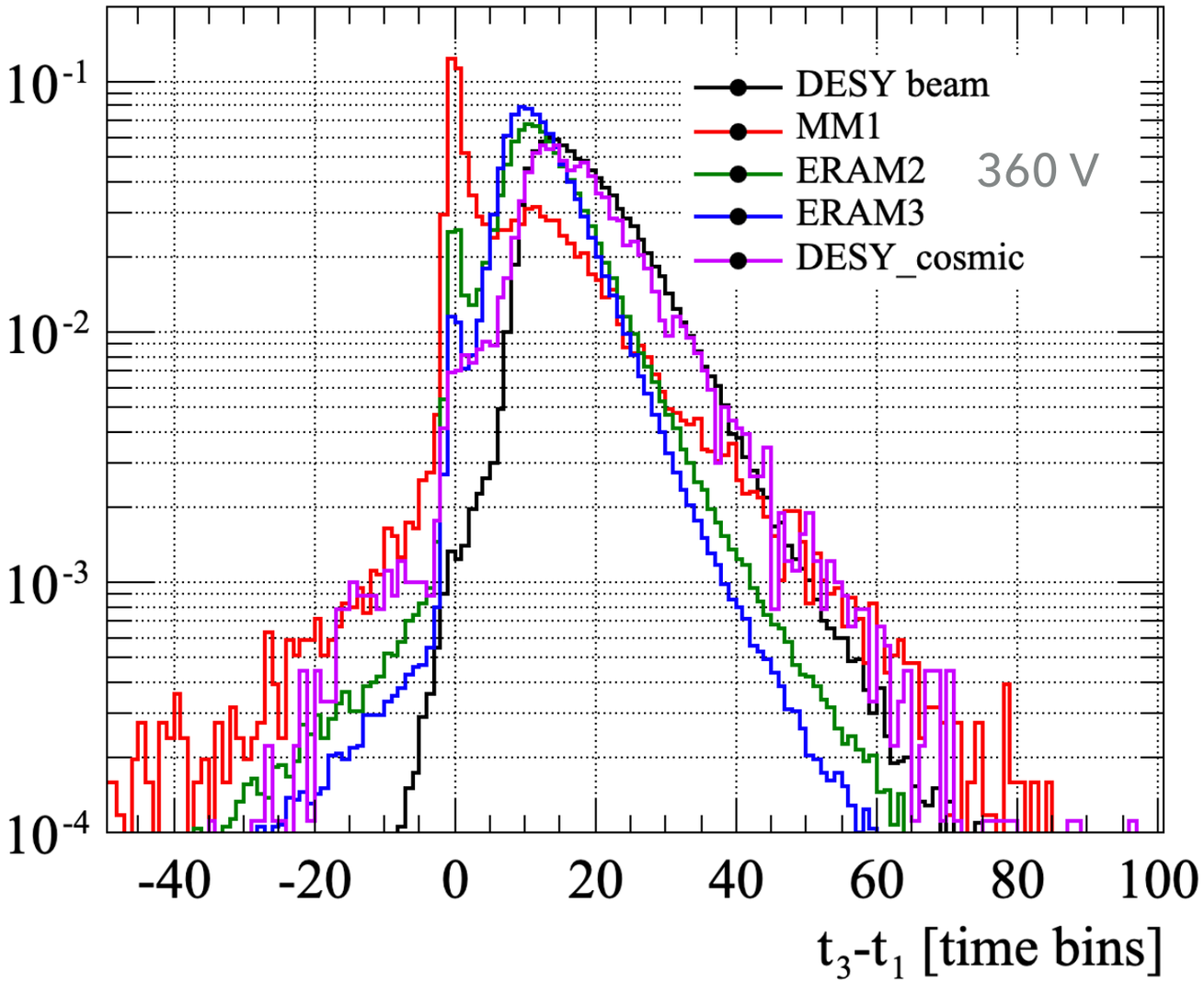
380 V



SPATIAL RESOLUTION

Saclay and DESY
cosmic samples
have different angular
and momentum acceptance

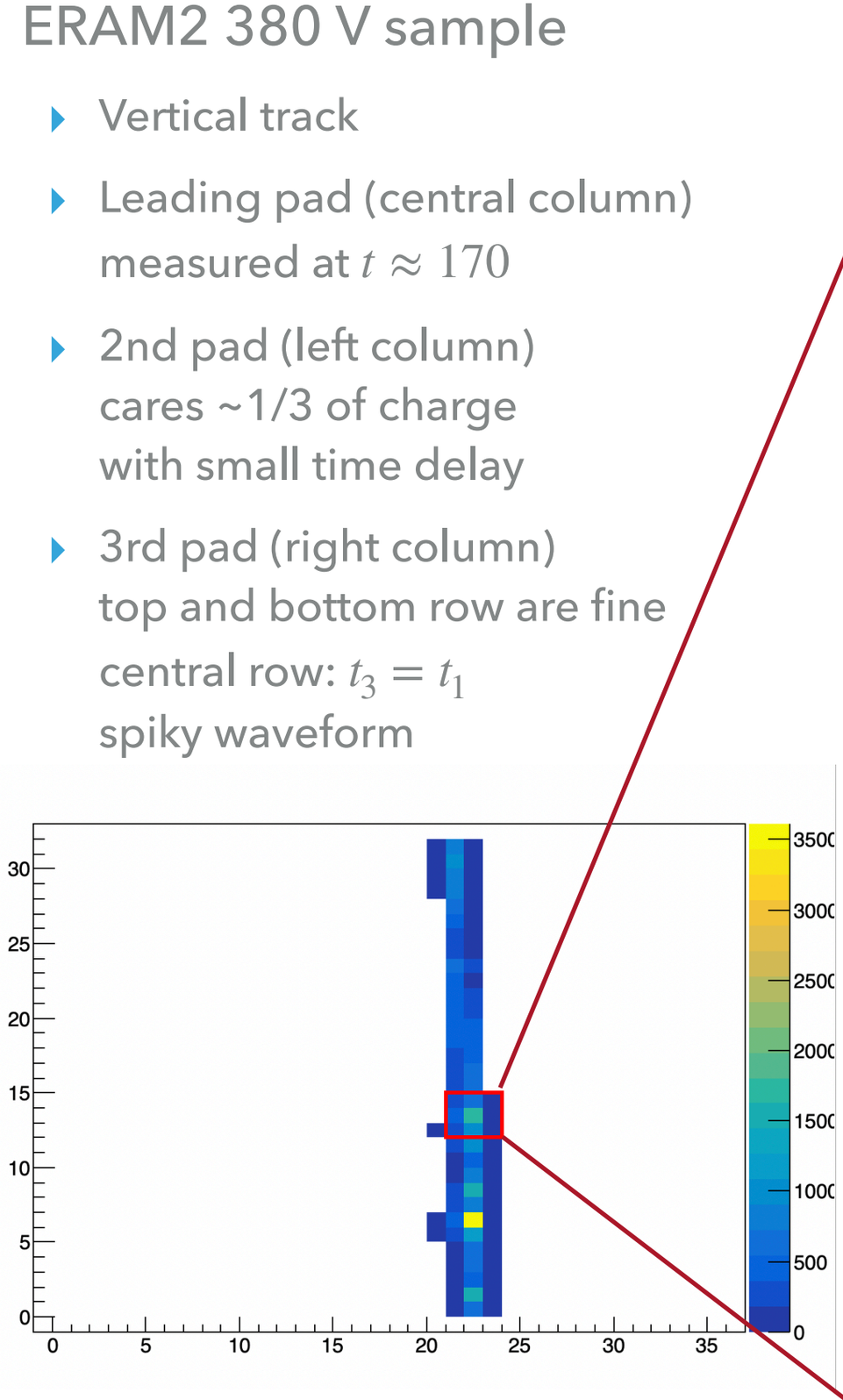
- Correlation between bulk at $t_3 - t_1$
  and the spatial resolution was found
- Clear sequence:
  DESY beam –> DESY cosmic –> ERAM3 –> ERAM2 –> MM1



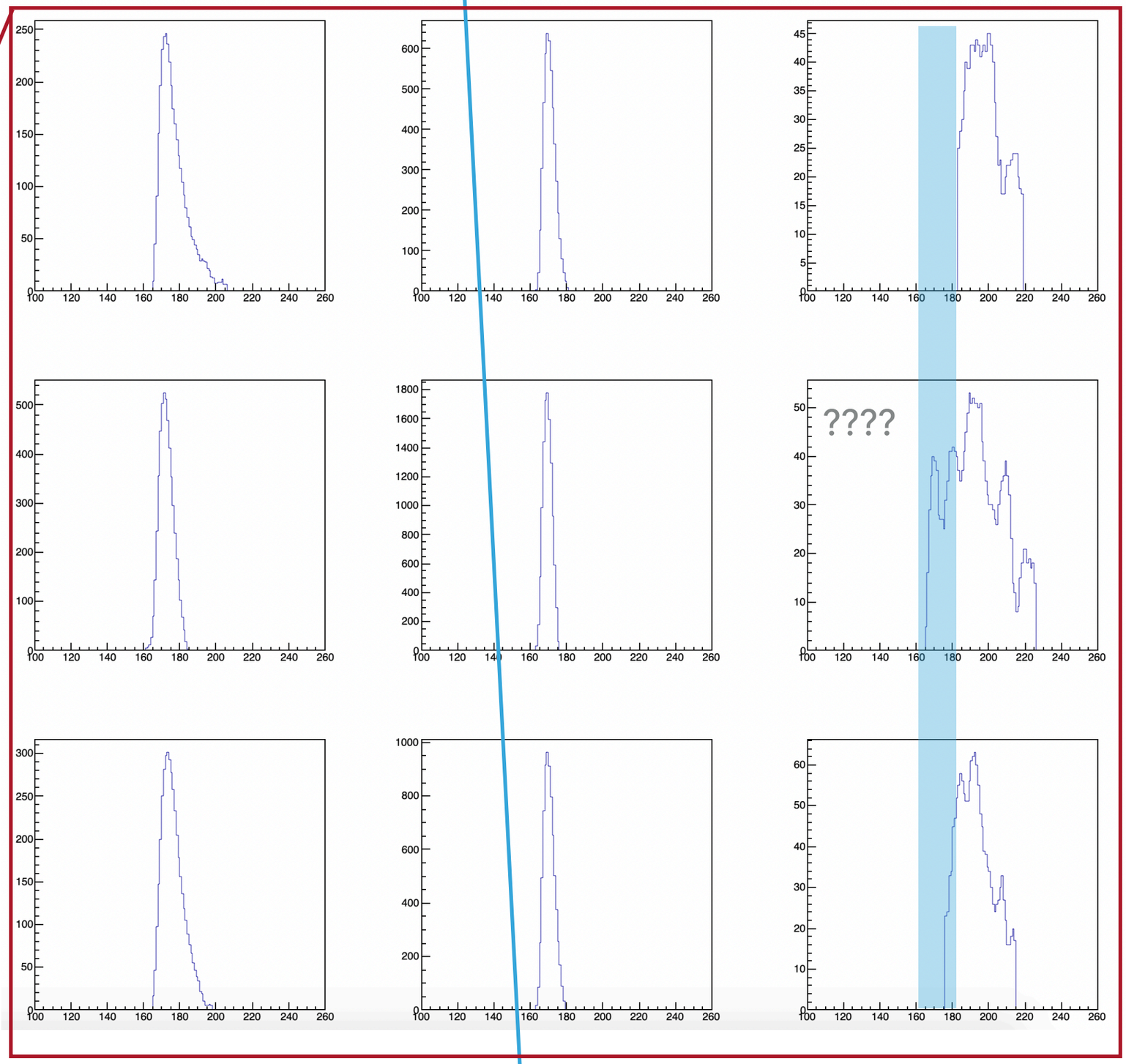
SR	
DESY beam	180 um
DESY cosmic	420 um
ERAM3	427 um
ERAM2	502 um
MM1	714 um

EVENT DISPLAY EXAMPLE

- ERAM2 380 V sample
  - Vertical track
  - Leading pad (central column) measured at $t \approx 170$
  - 2nd pad (left column) cares ~1/3 of charge with small time delay
  - 3rd pad (right column) top and bottom row are fine central row: $t_3 = t_1$ spiky waveform



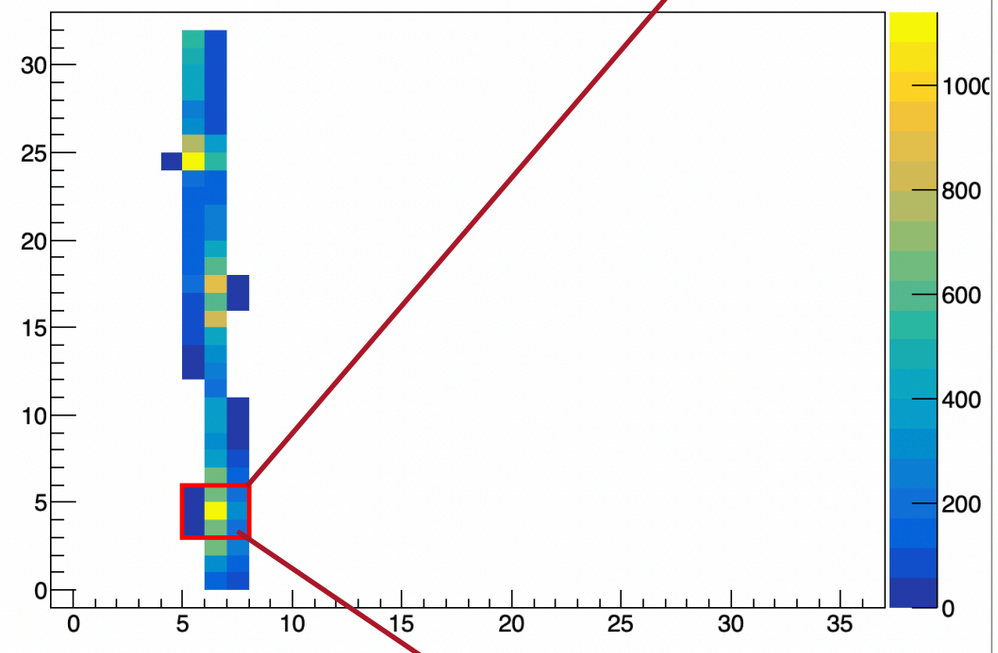
Track position?
based on charge fractions

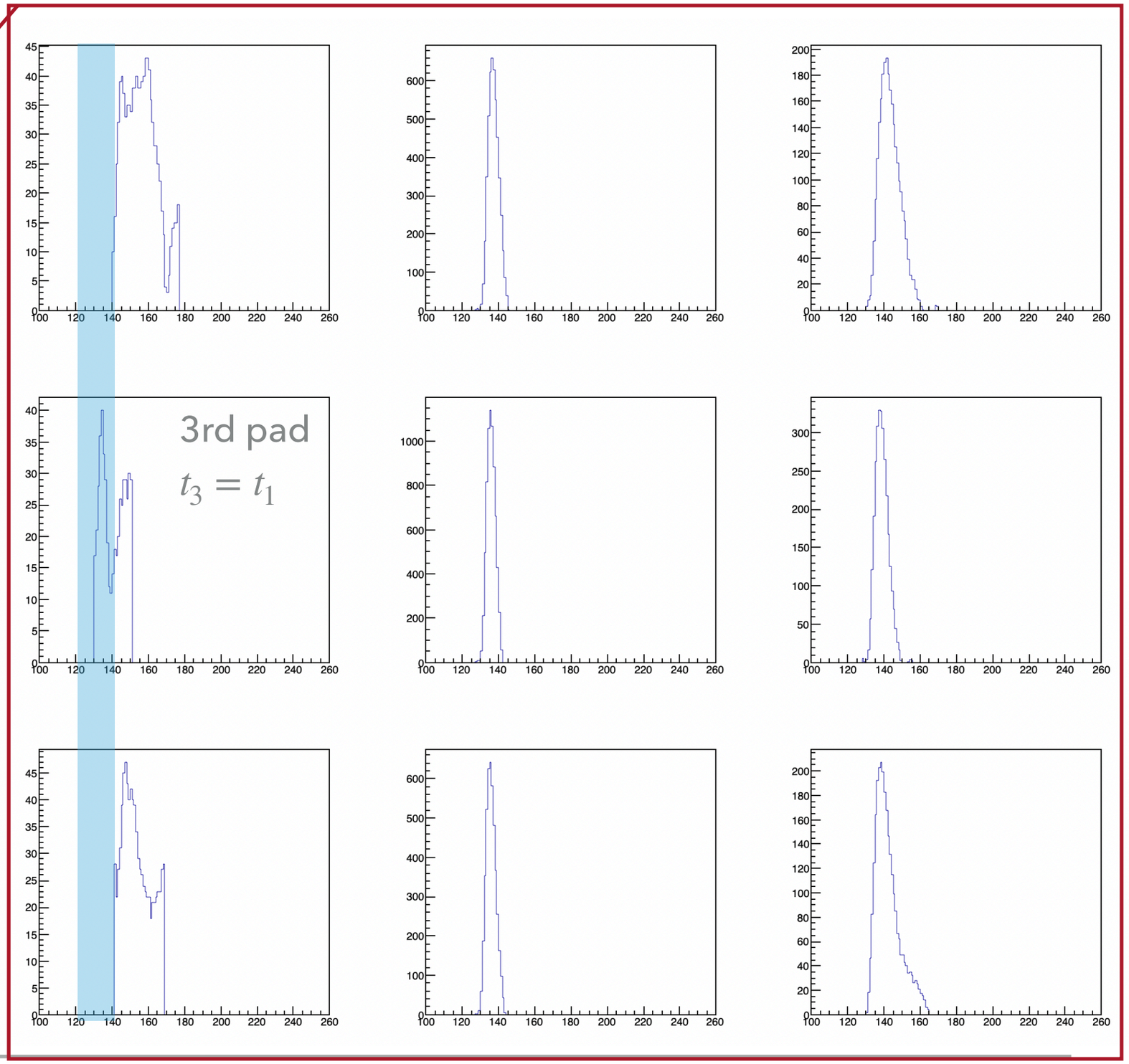


ERAM2 360 V

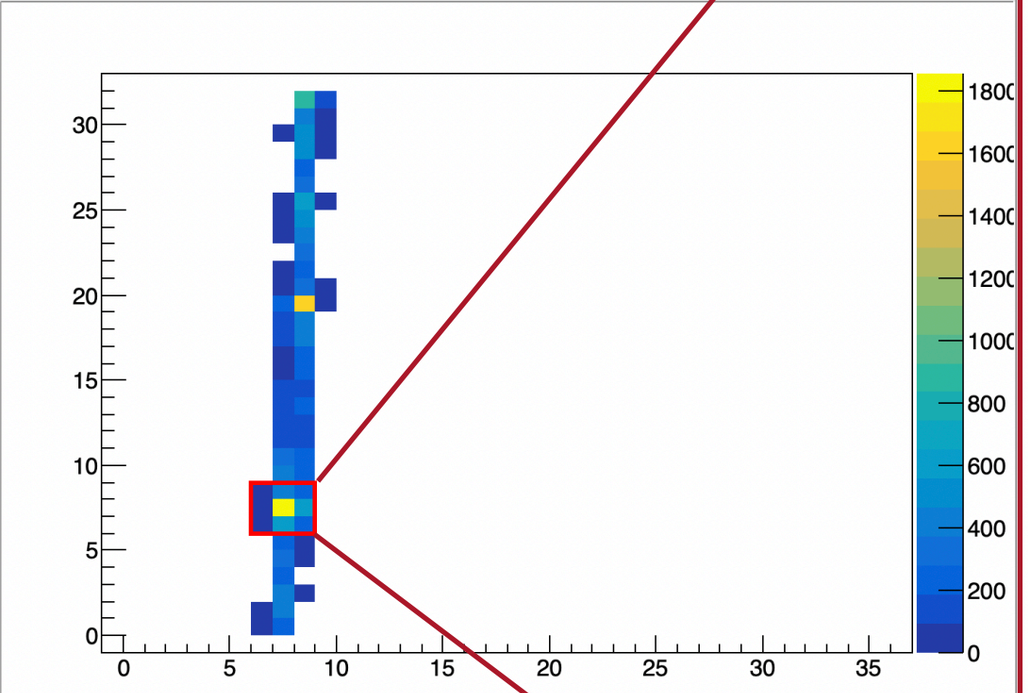
- No pattern recognition/selection is used for the Event Display

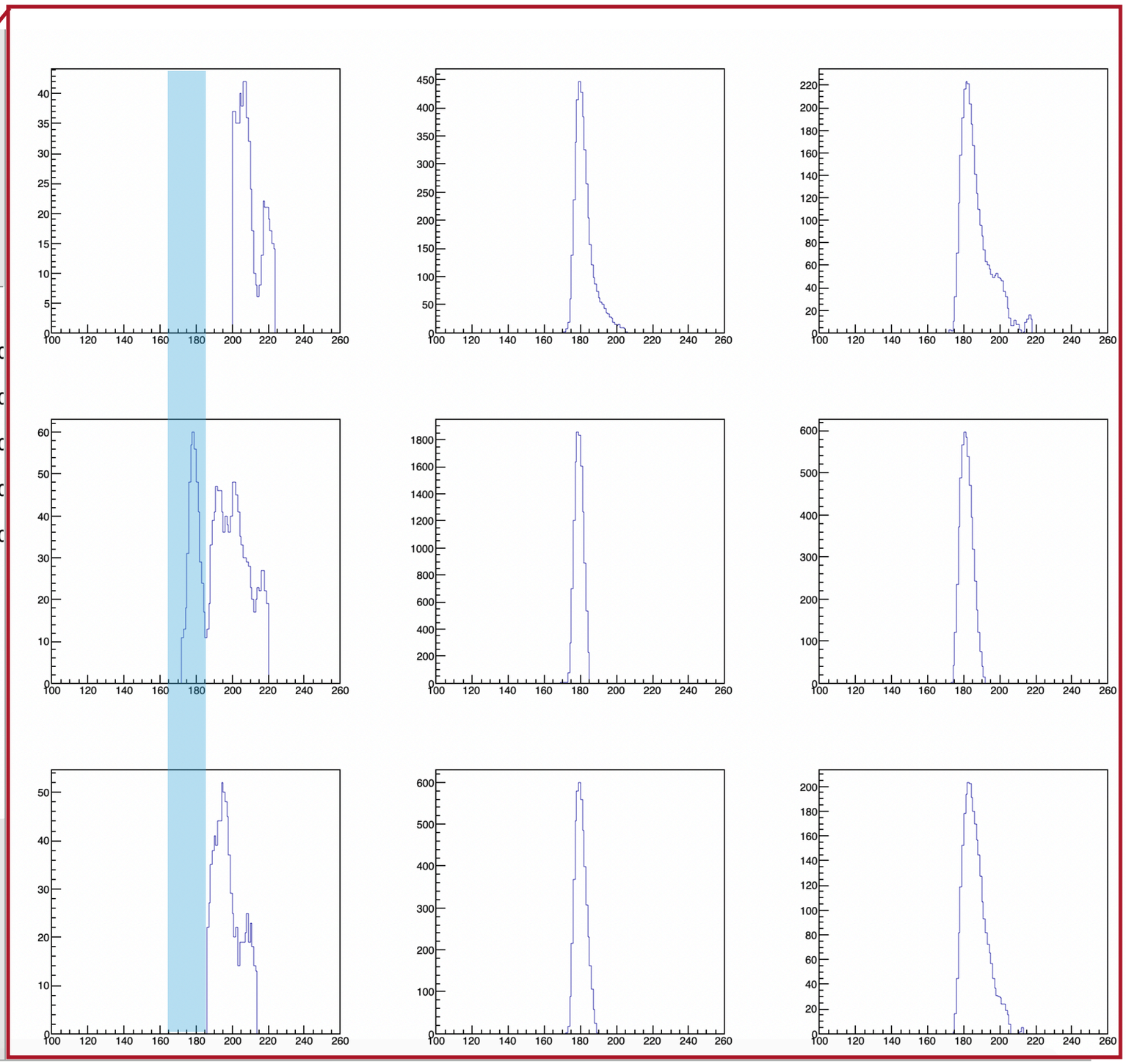
If it’s a noise that pass the threshold why don’t we see the noise all over the detector?





ERAM2 360 V


30
25
20
15
10
5
0
0
5
10
15
20
25
30
35
1800
1600
1400
1200
1000
800
600
400
200
0

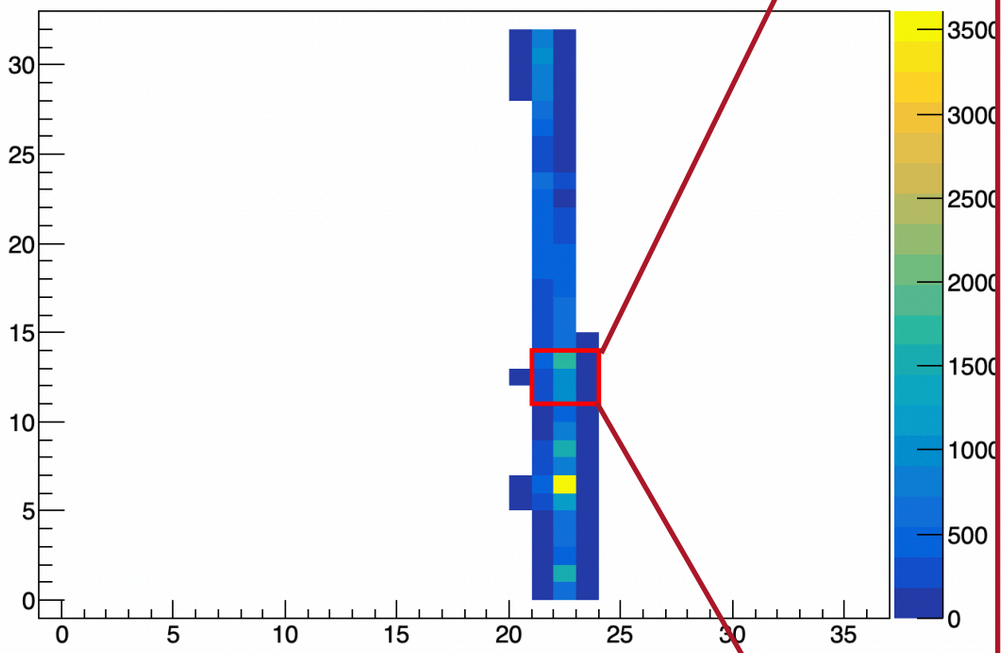


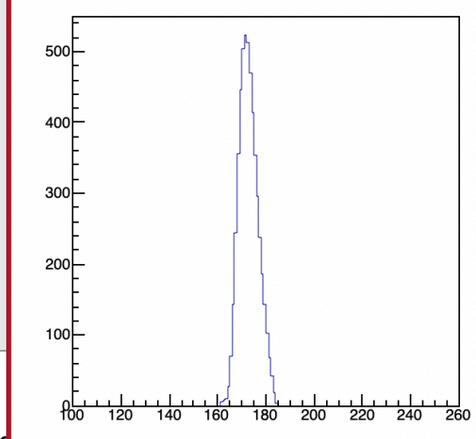
EVENT DISPLAY EXAMPLE

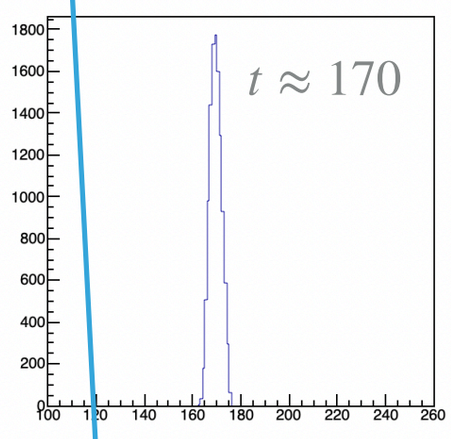
- ERAM2 380 V sample. Same event

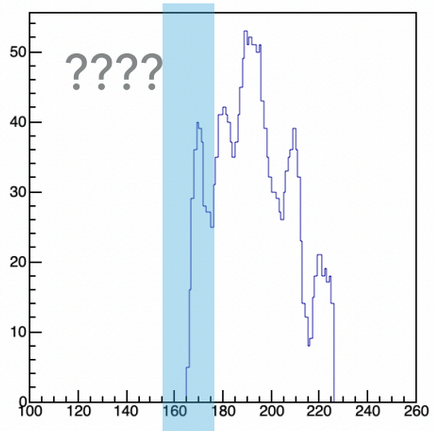
Track position?
based on charge fractions

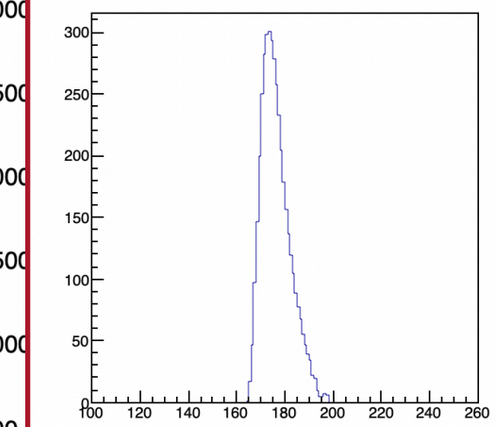
3rd pad (right column)
In second row demonstrates
expected delay.
But in other rows signal appears
immediately (!!) after the leading pad

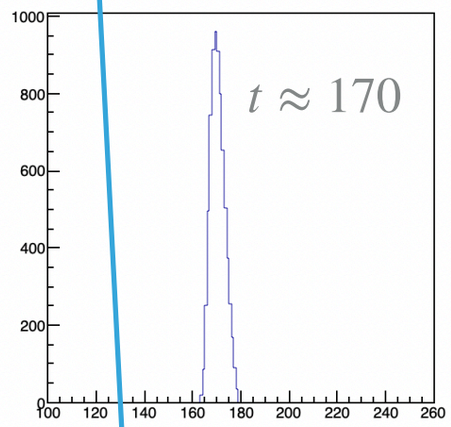


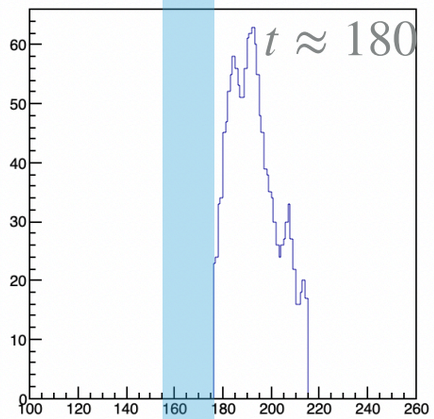


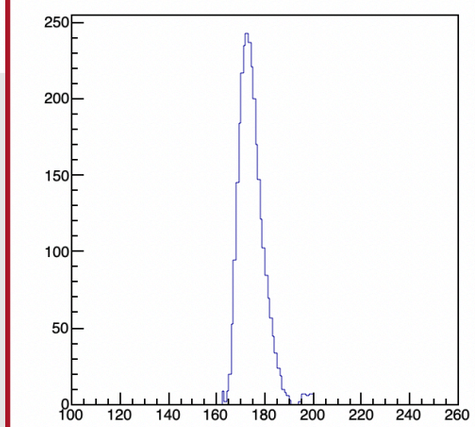


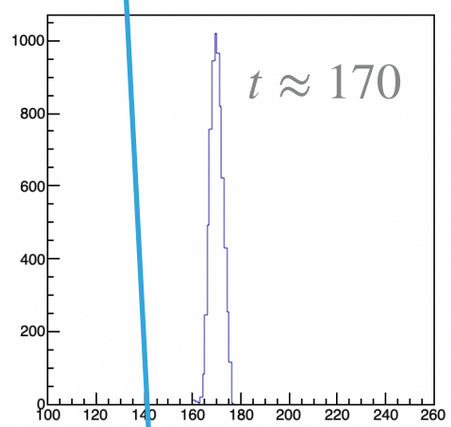


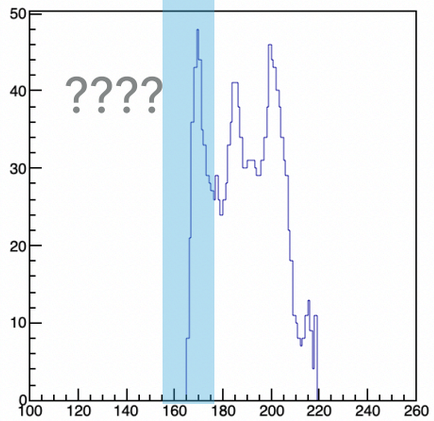




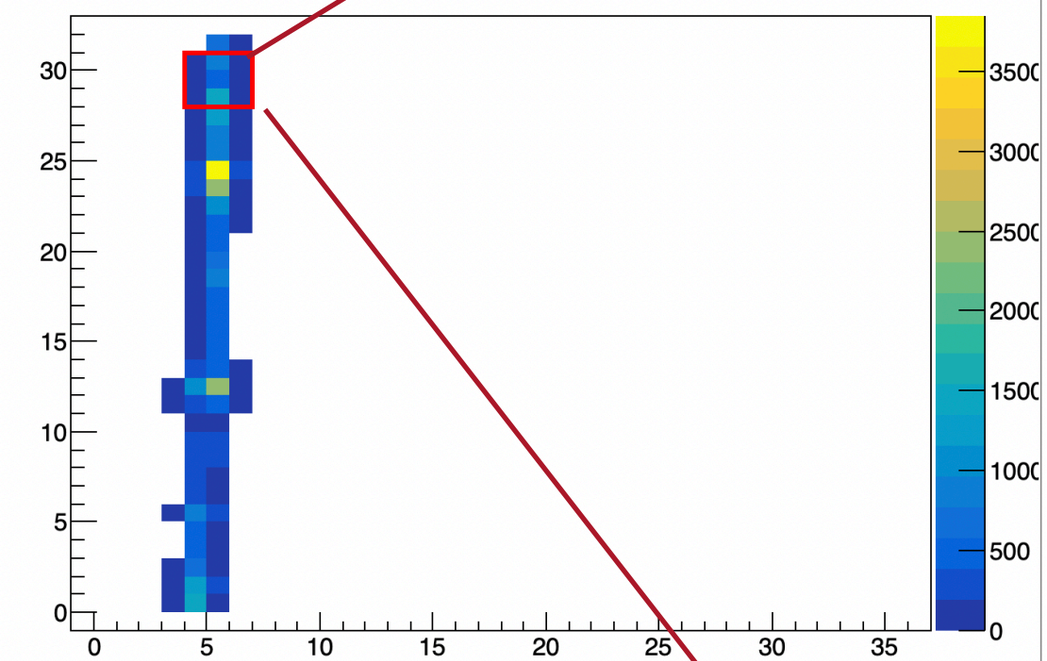


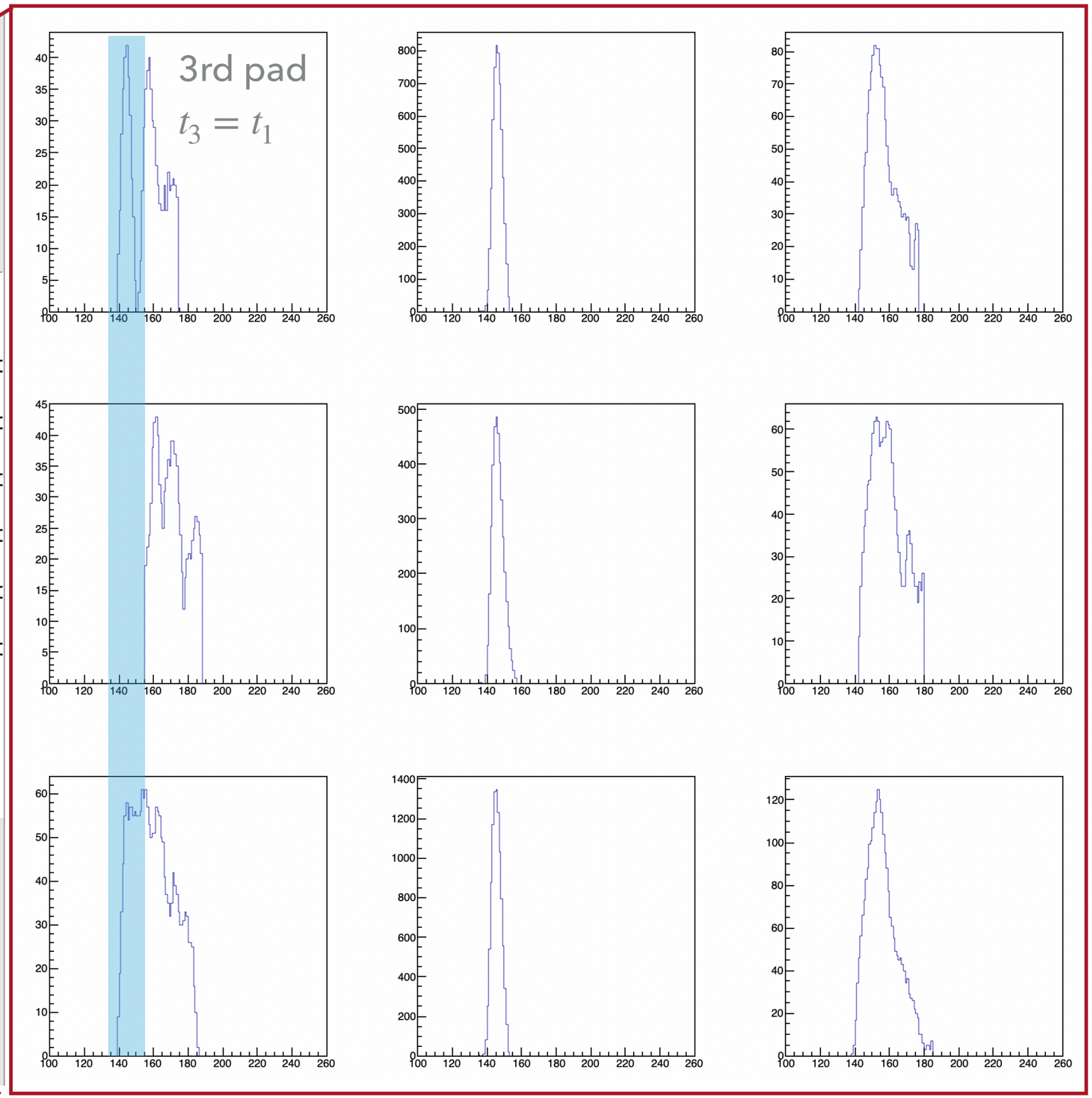




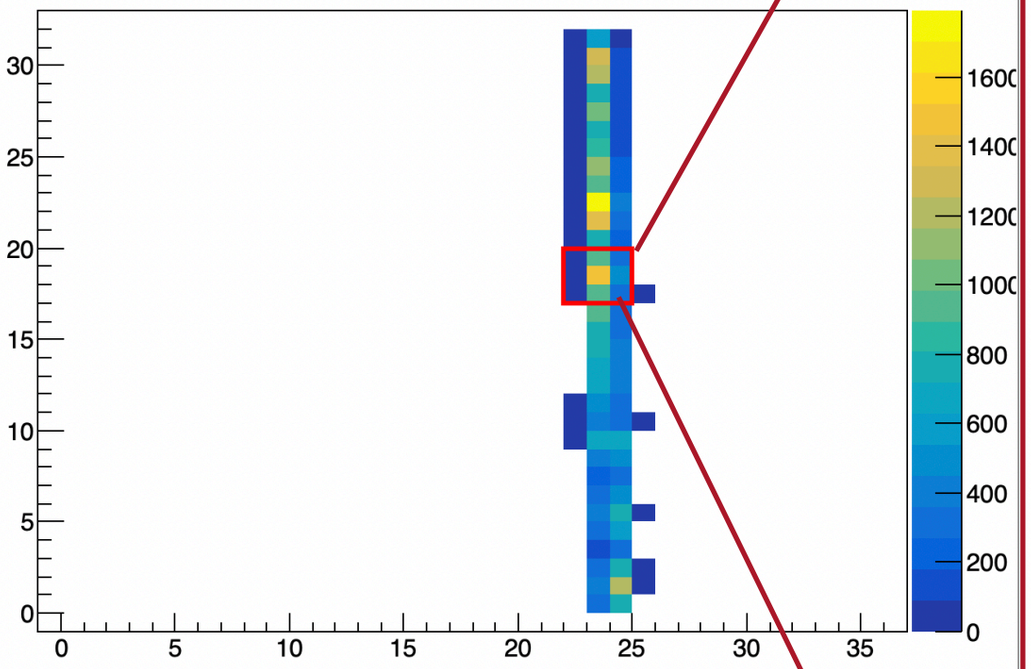


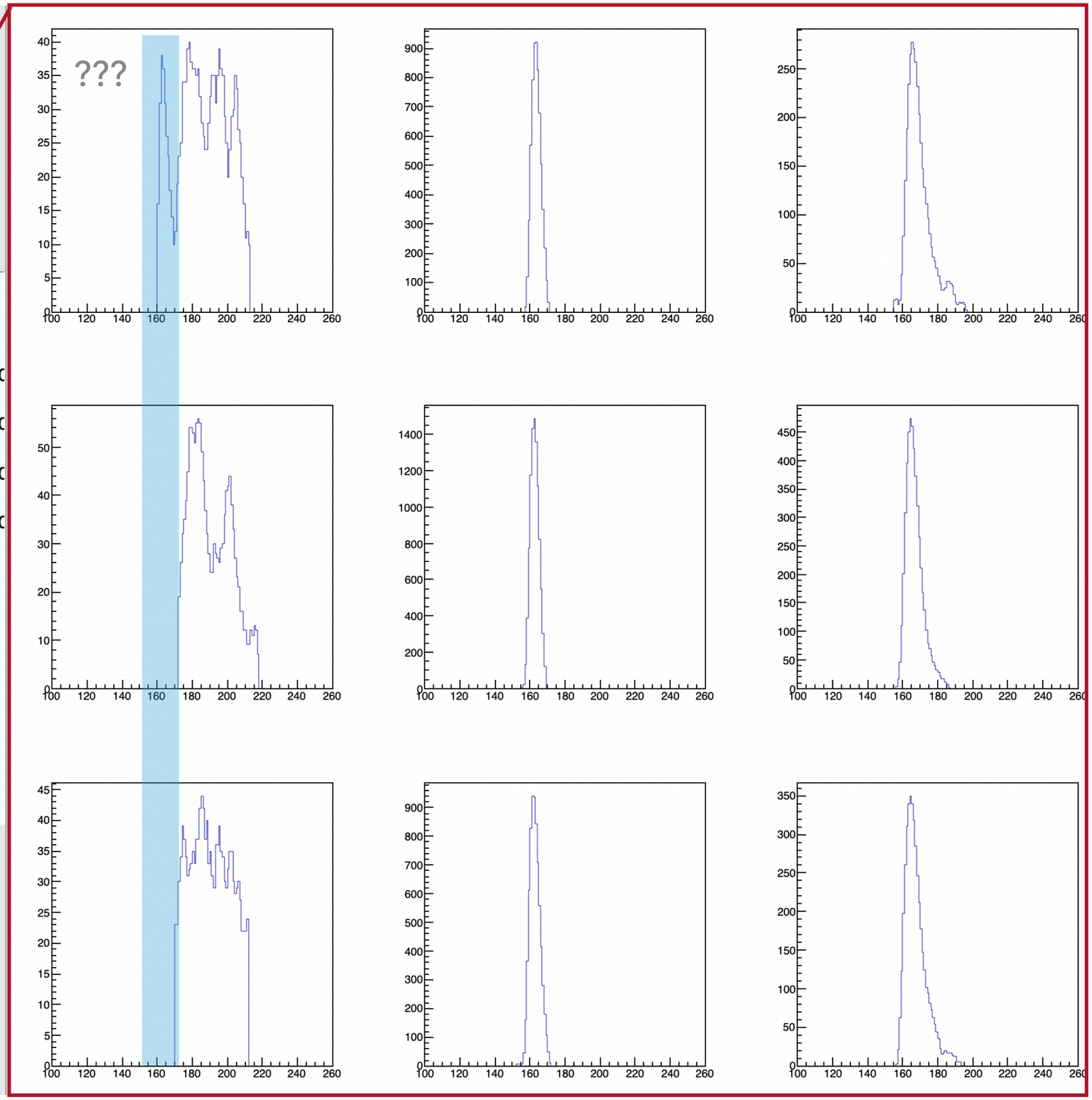
ERAM2 380V





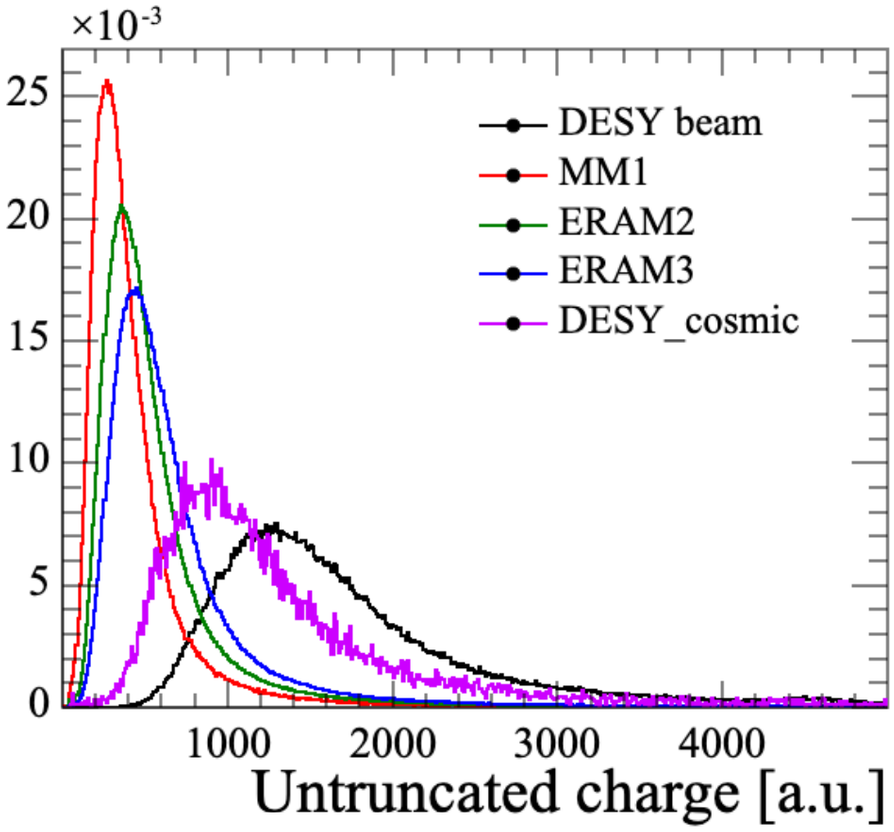
ERAM2 380V



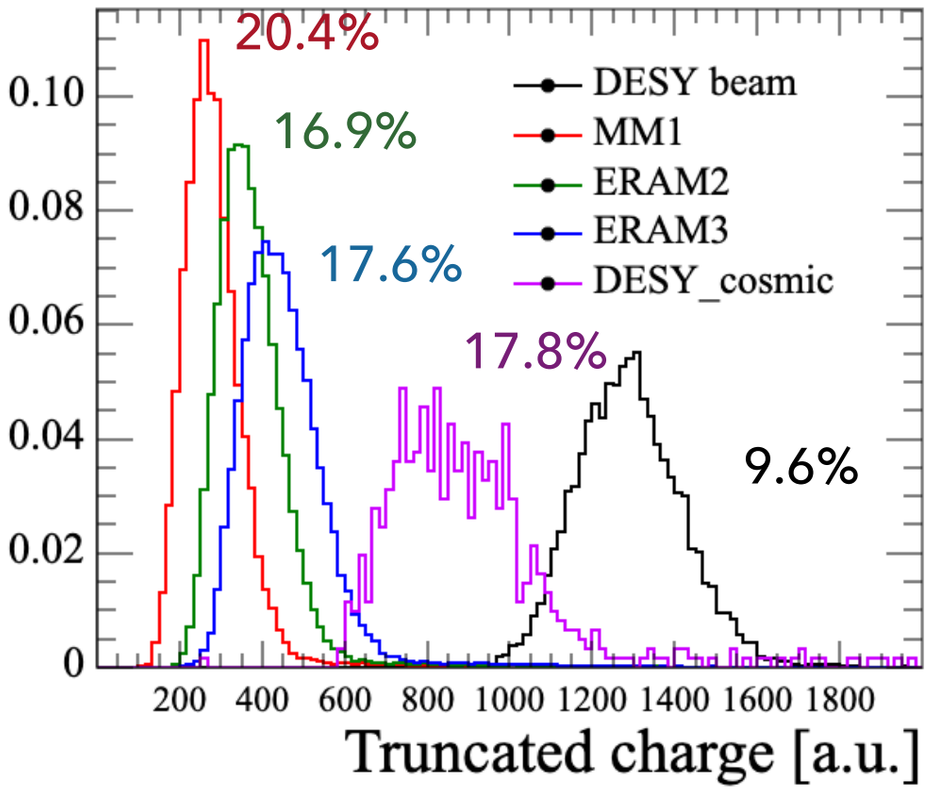


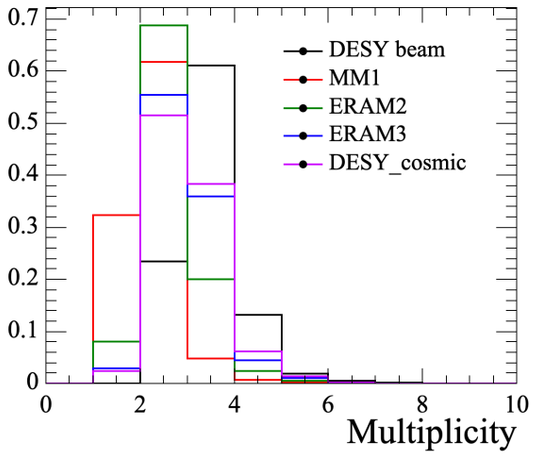
CHARGE COLLECTION

- A tension between charge measurements was observed
  - DESY beam (4 GeV electrons) provide 50% more charge comparing to DESY cosmic
  - But Saclay MM1 and ERAM provide ~twice less charge then DESY cosmic
  - All samples were taken at 360V at DLC and 200 ns peaking



dE/dx resolution

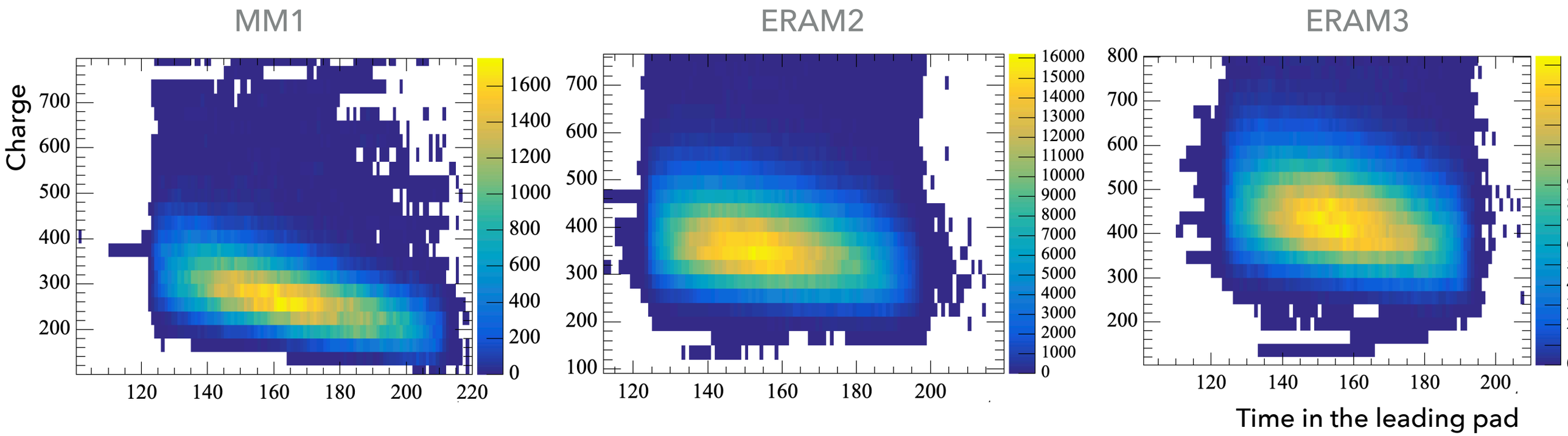




Saclay and DESY cosmic samples have different angular and momentum acceptance

GAS QUALITY

- The dEdx vs time in the leading pad is used to estimate gas quality
  - The “slope” –> attenuation in gas
  - The length in time –> drift velocity



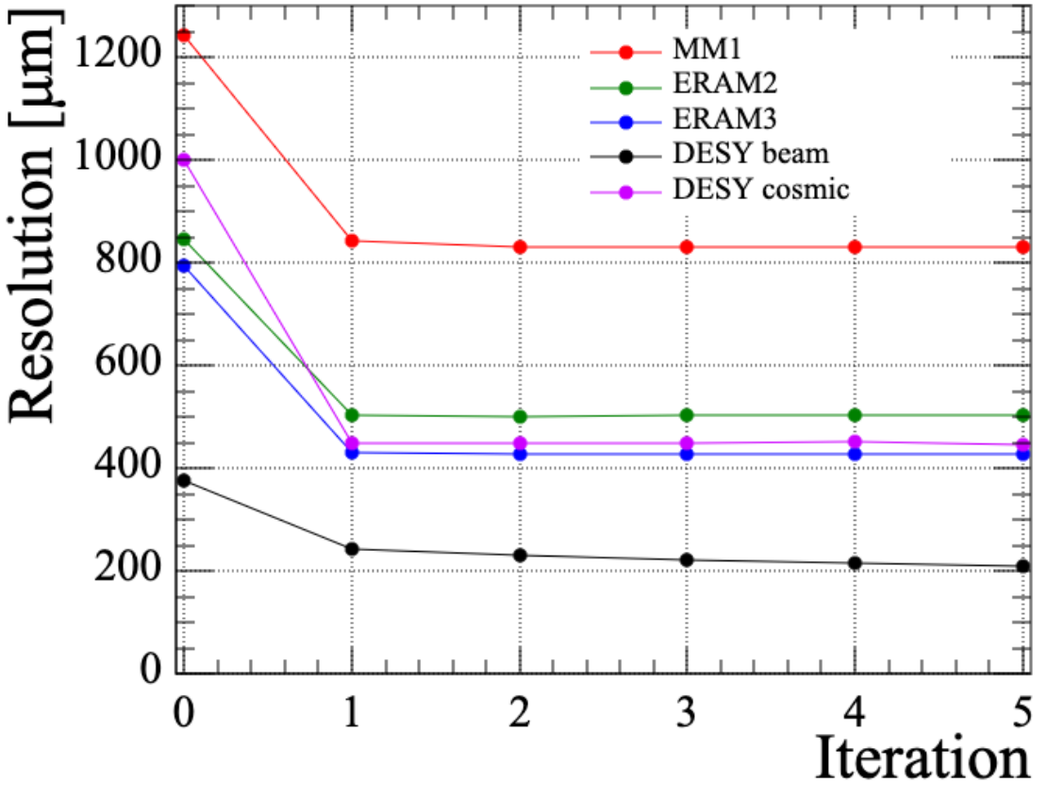
- No anomalies were found
  - MM1 tends to have more severe attenuation and smaller drift velocity
  - But not dramatical

SPATIAL RESOLUTION

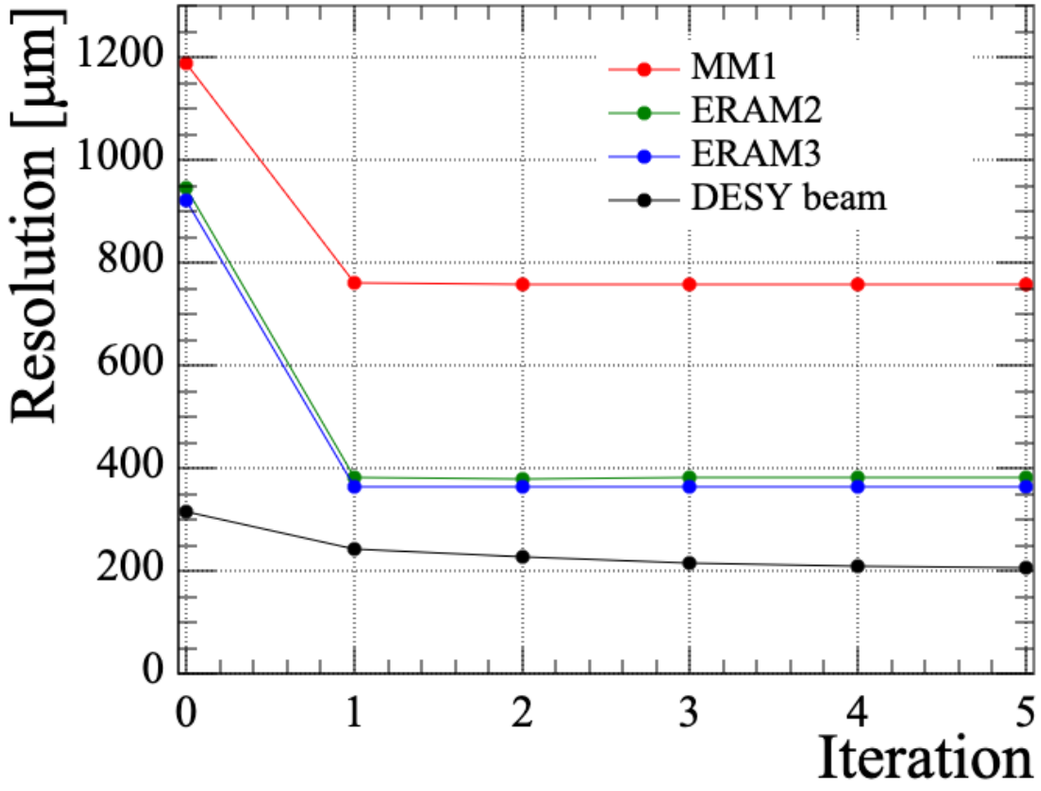
- Angular selection: $|tg\phi| < 0.3$, $|tg\theta| < 0.3$ was used
- Iteration 0 –> Centre of Charge method

Saclay and DESY
cosmic samples
have different angular
and momentum acceptance

360 V



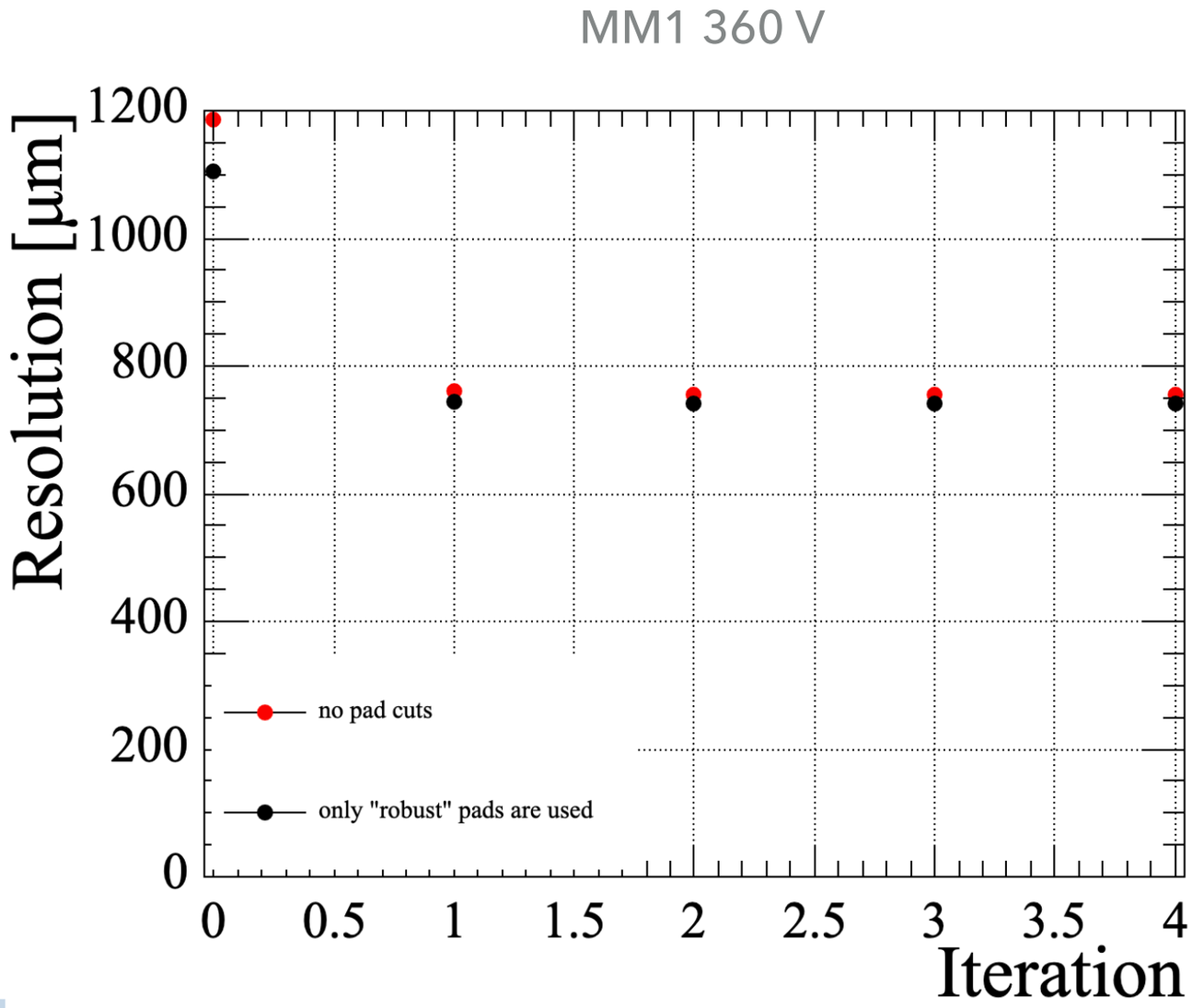
380 V



SPATIL RESOLUTION

- Removing “suspicious” pads from the spatial resolution analysis doesn’t improve result
  - $t_2 - t_1 > 0$
  - $t_i - t_1 > 5$ for $i > 2$

- “Avoiding” pads is not solving the problem
- The essential information is contained in “suspicious” WF and probably “masked”

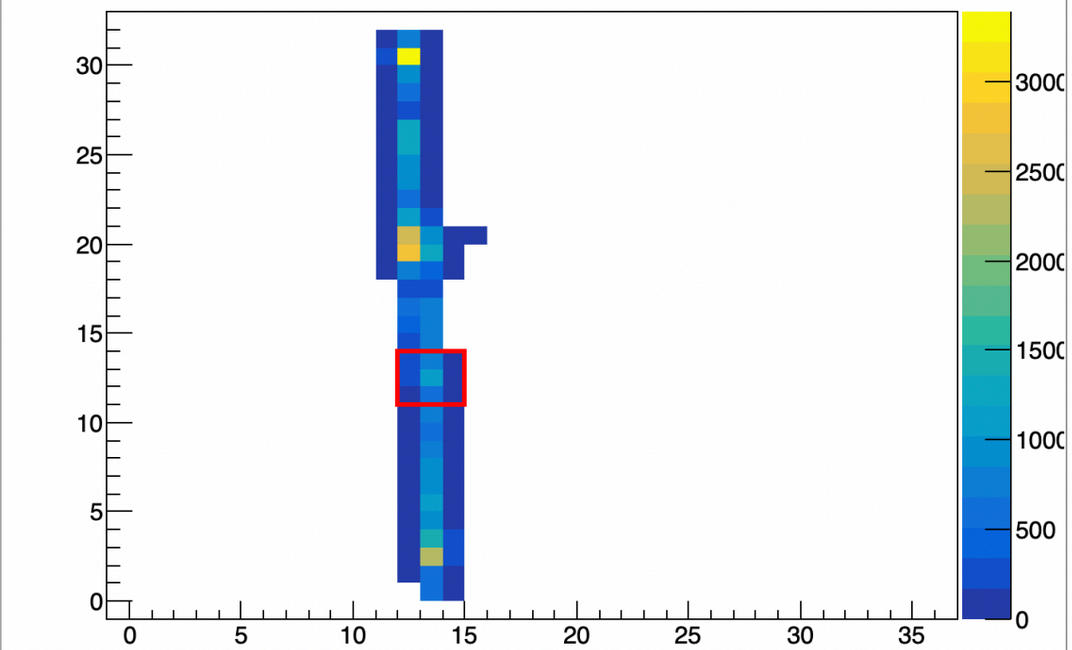


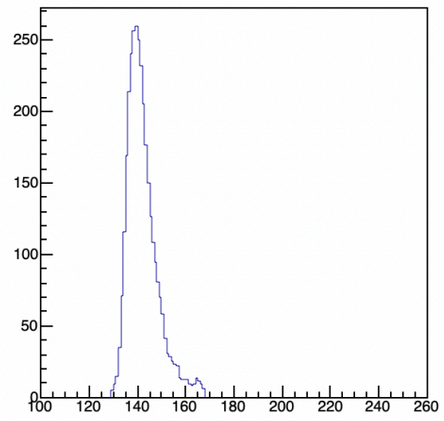
CONCLUSION

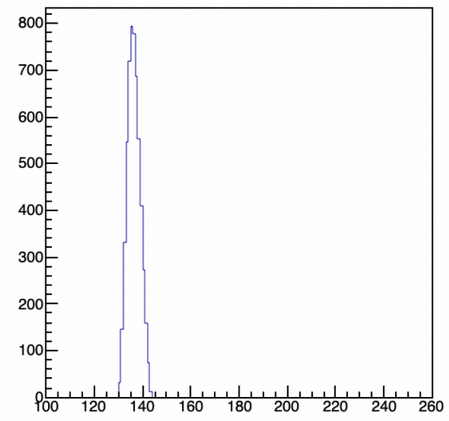
- The wrong time measurement for the 3rd pad was observed
  - The most accurate one is in DESY beam data, the worst in MM1 cosmic
  - Wrong time measurement indicates also wrong charge measurement
  - Wrong charge measurement bias the position measurement
- Coincidence in time between leading pad and 3rd pad may be the indication of the cross–talk in the electronics
  - The array of the capacitors may be read in the wrong way
- The dependence of the spatial resolution over detectors can be caused by the wrong treatment of the WF
- The accuracy of the charge measurement is not affected by the observed phenomena
- The tension between the charge measurements in DESY and in Saclay is not understood

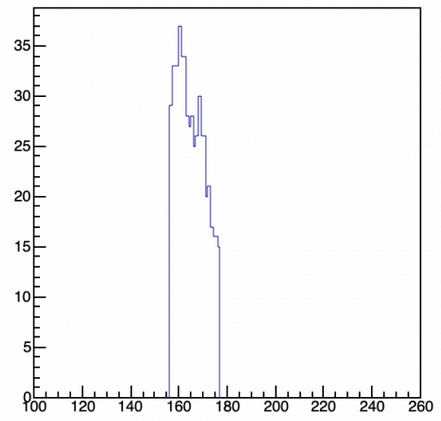
“NORMAL” WF

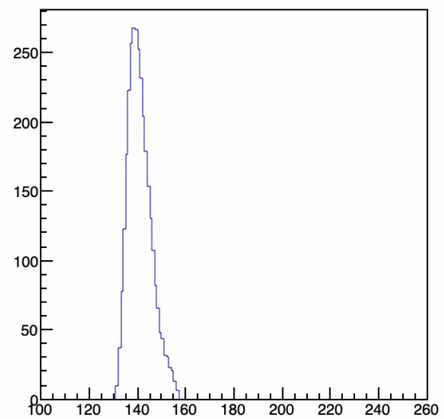
Time delay is in agreement with expectations

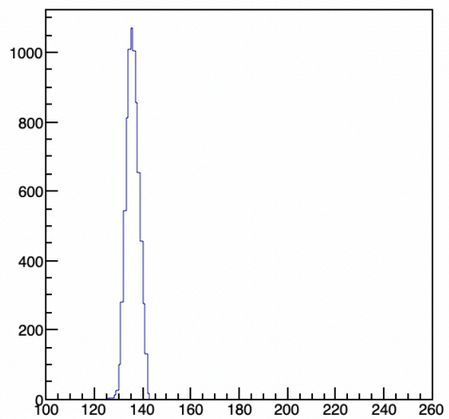


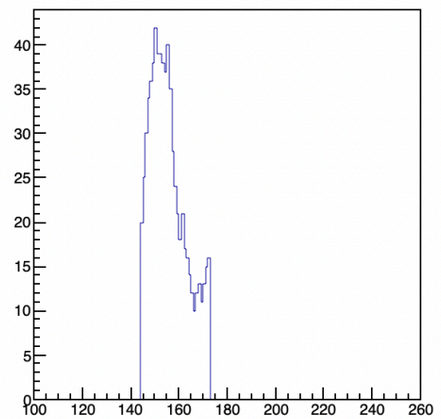


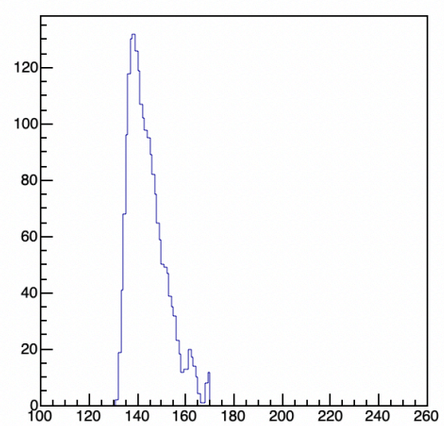


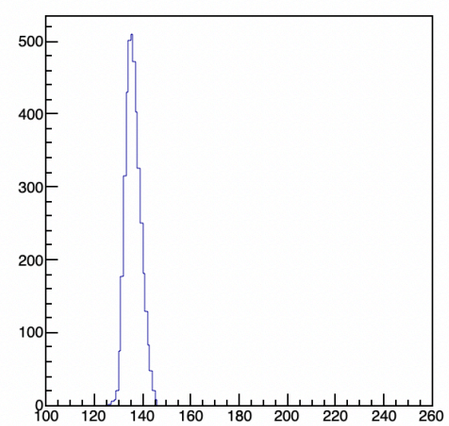


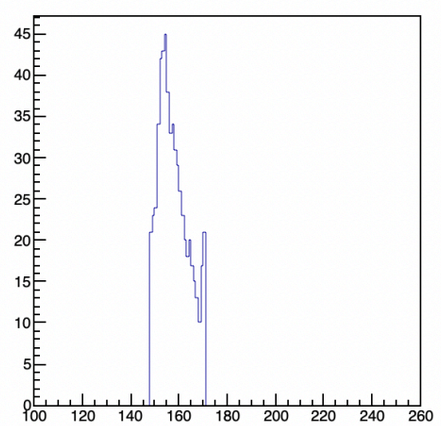




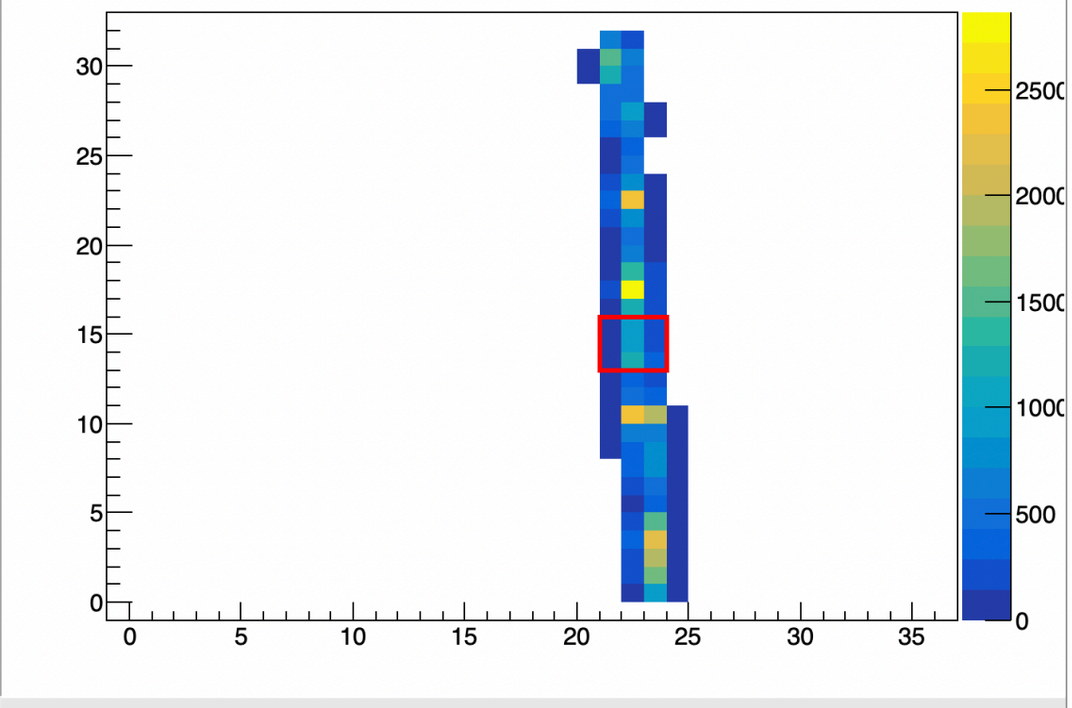


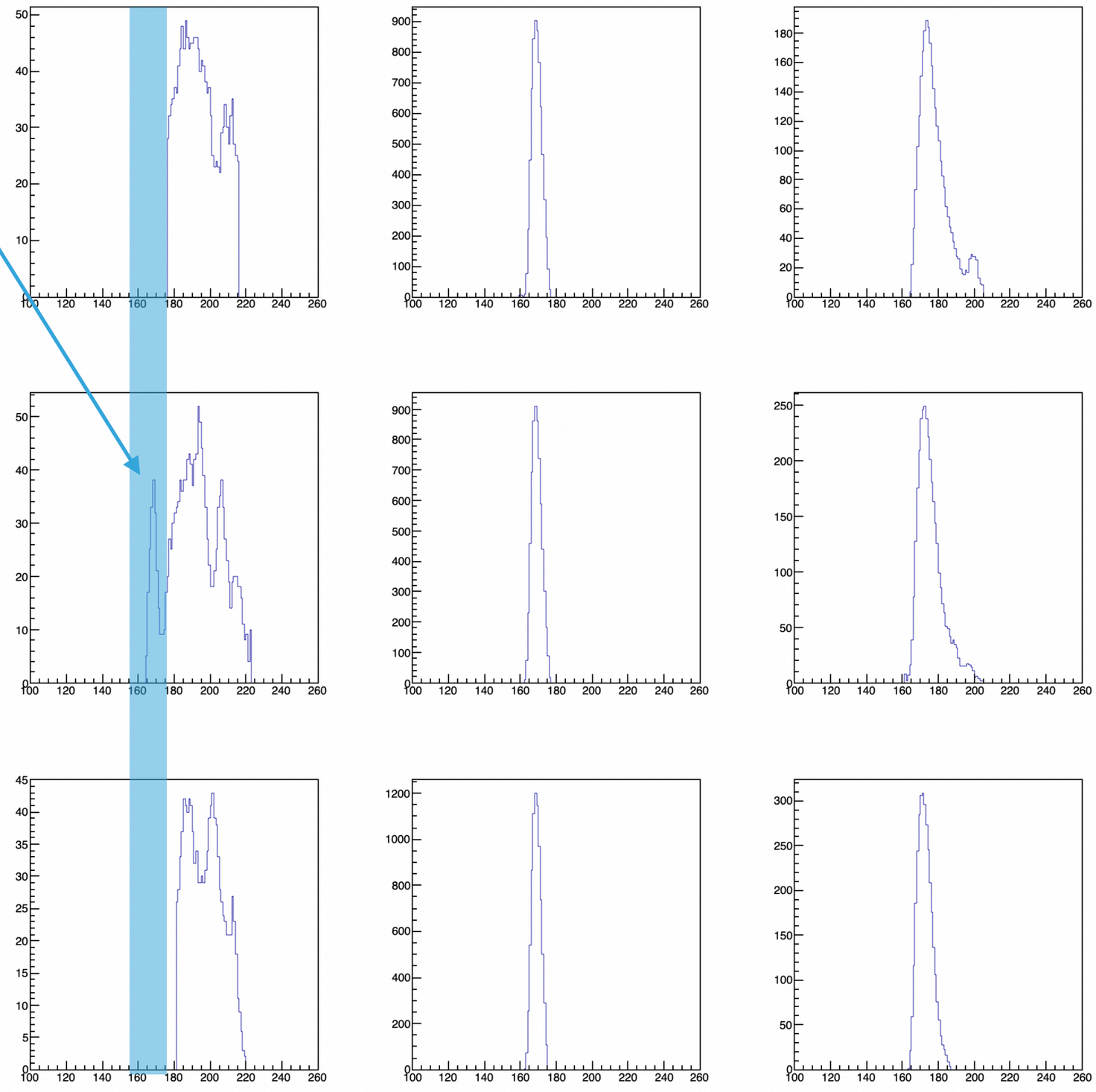






What is the origin of the 1st peak in 3rd pad?
3rd pads below and above didn't see it
if it's a charge sharing pad above/below should see

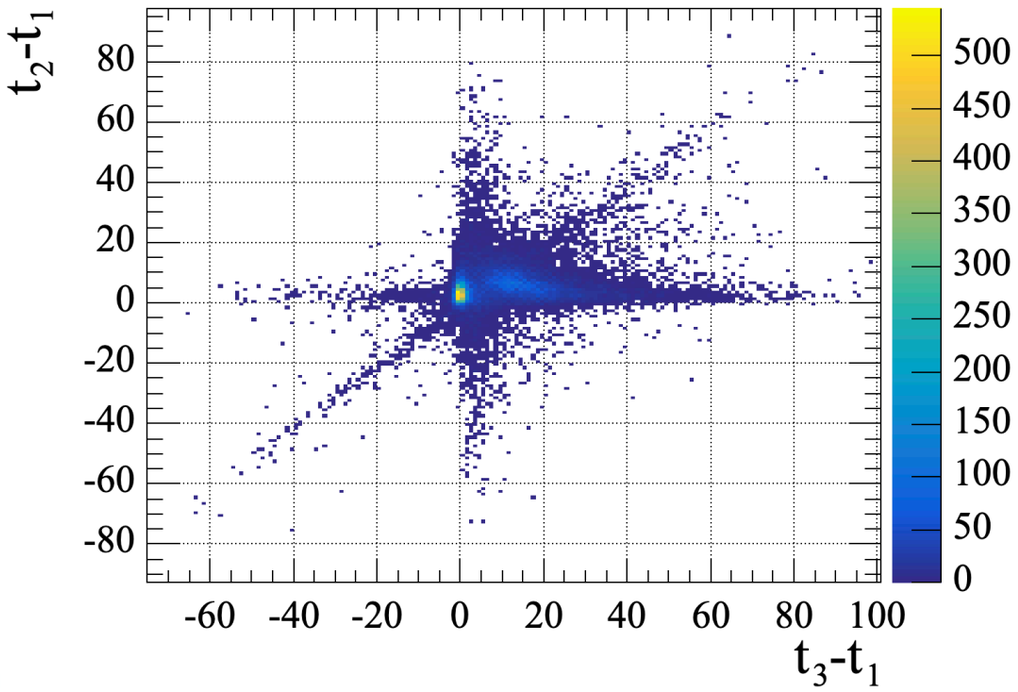




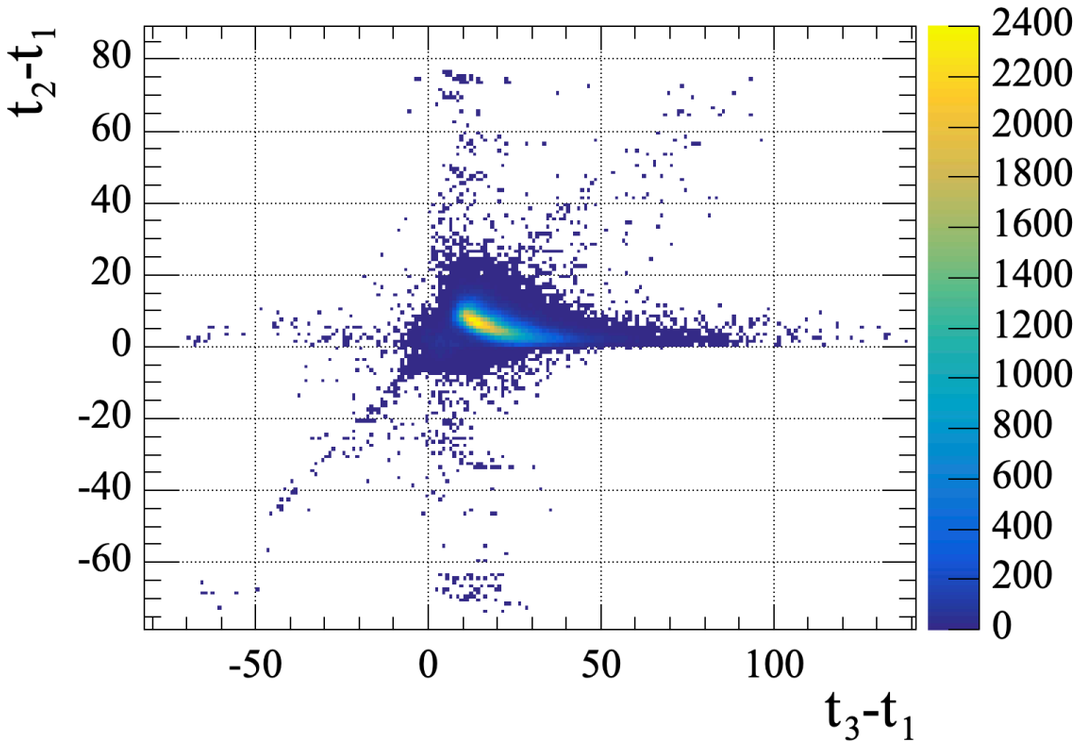
PAD TIME STAMP

- $t_2 - t_1$ vs $t_3 - t_1$ demonstrates interesting pattern

MM1



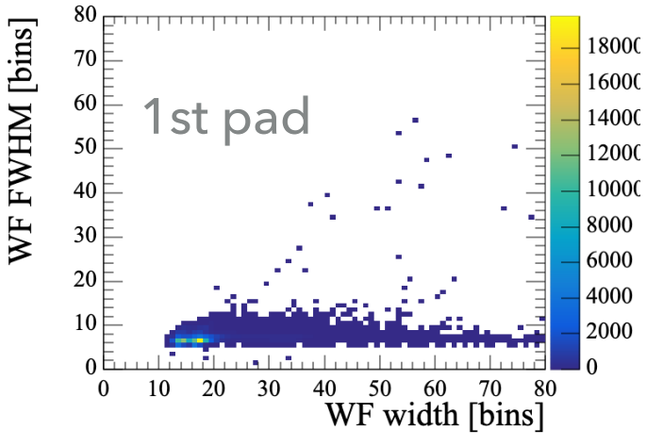
DESY beam

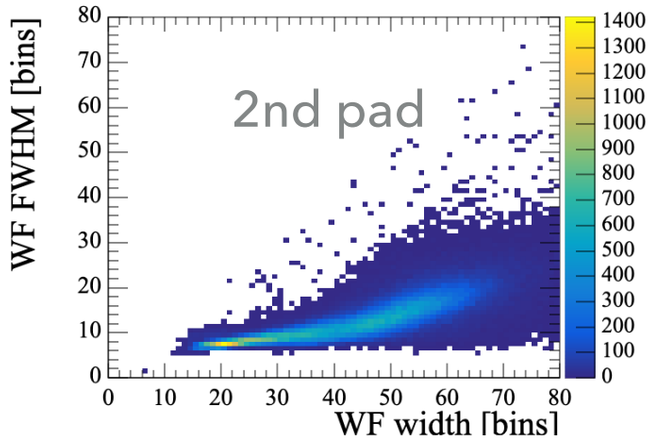


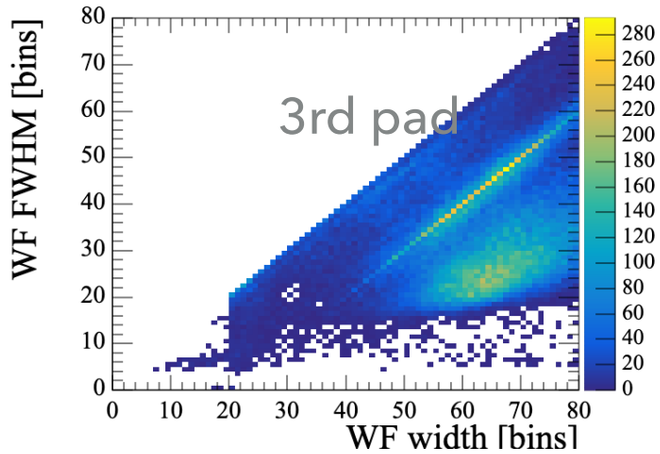
- Bulk at $t_3 - t_1 = 0$ is very clean in MM 1 data
- "Diagonal" pattern come from wrong time measurements –> originated by same reason?

WF WIDTH

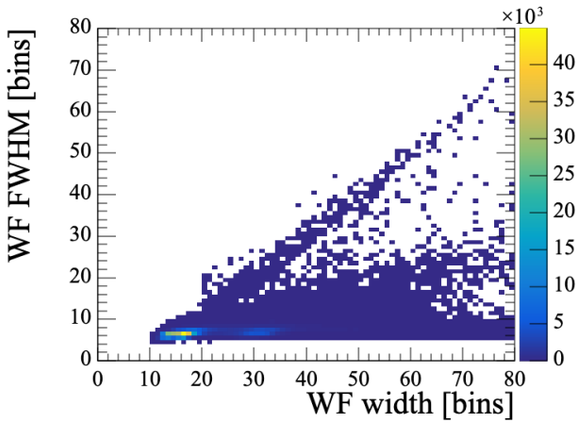
- Other interesting metric is WF width and FWHM

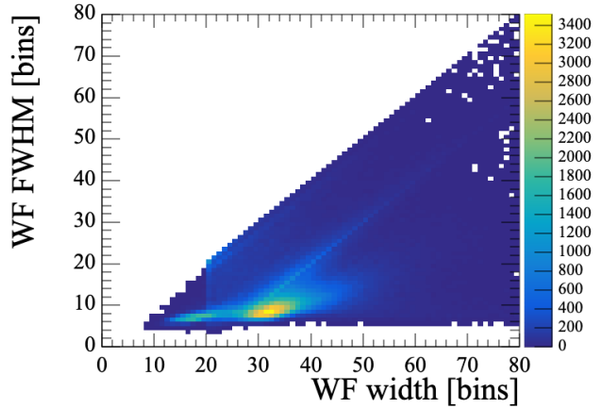


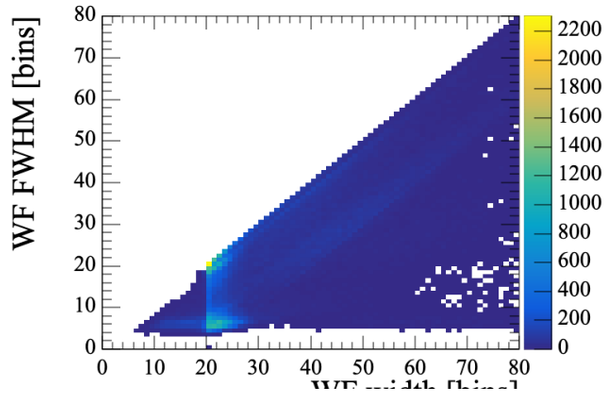




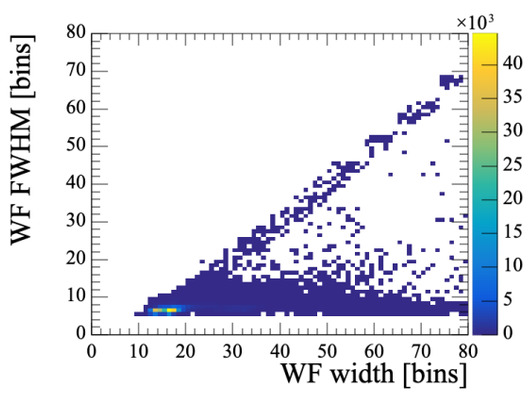
DESY
beam
380 V

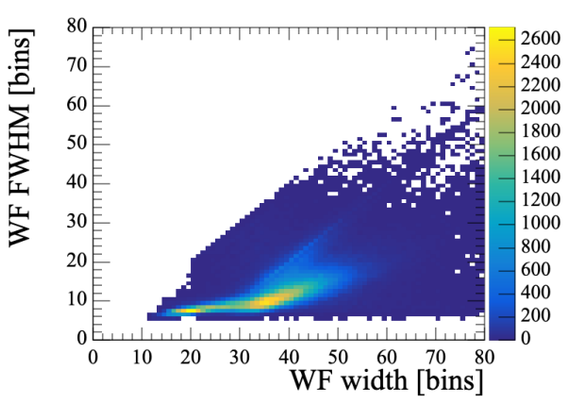


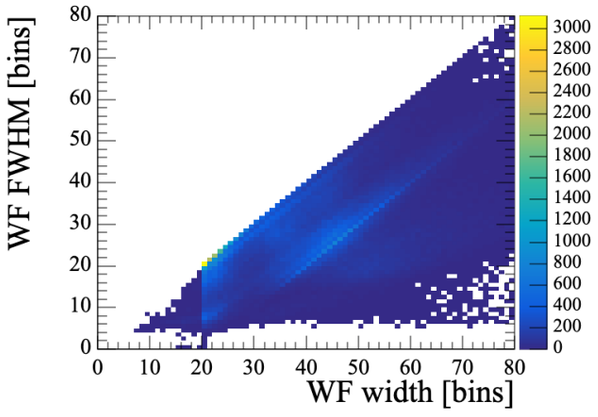




MM1
380 V



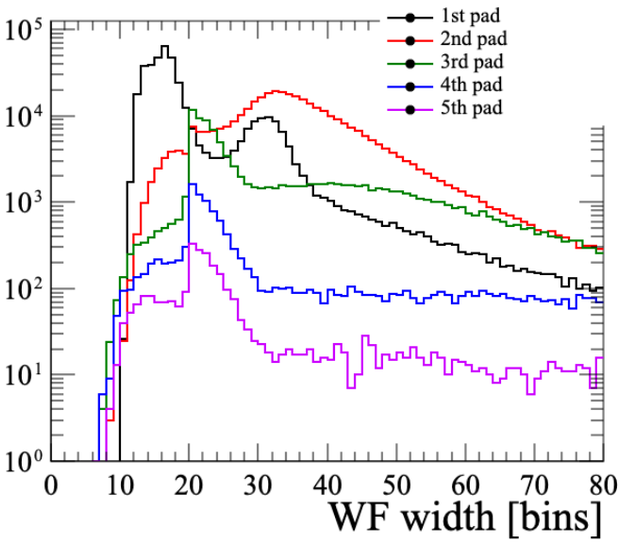


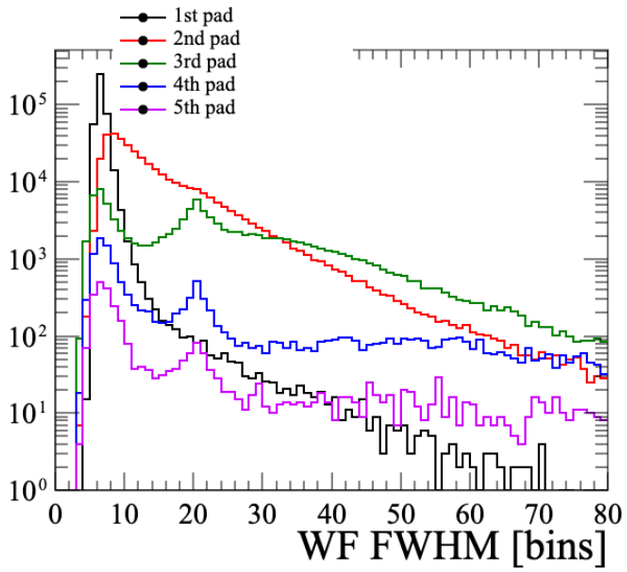


DESY
beam
360 V

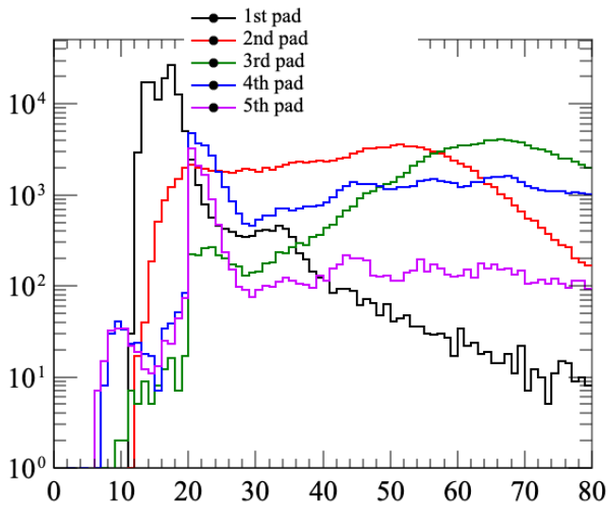
- 3rd pad was cutoff at 20bins width??!!
- In MM data most of the 3rd pads has small width

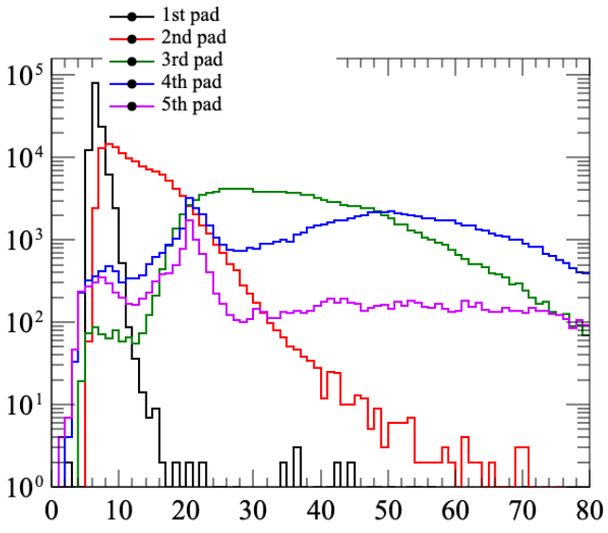
WAVEFORM WIDTH



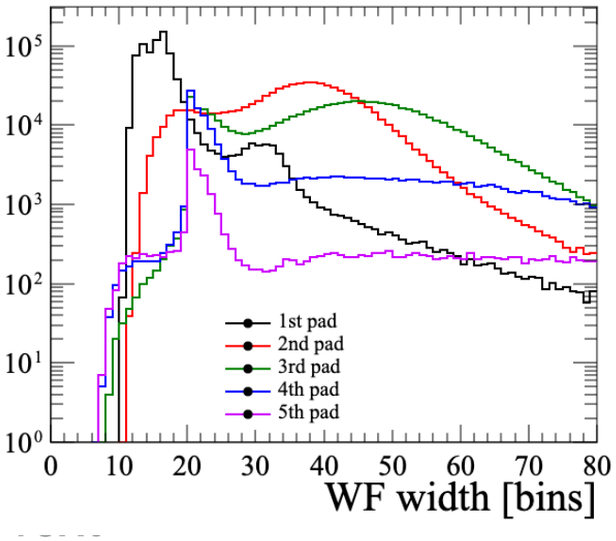


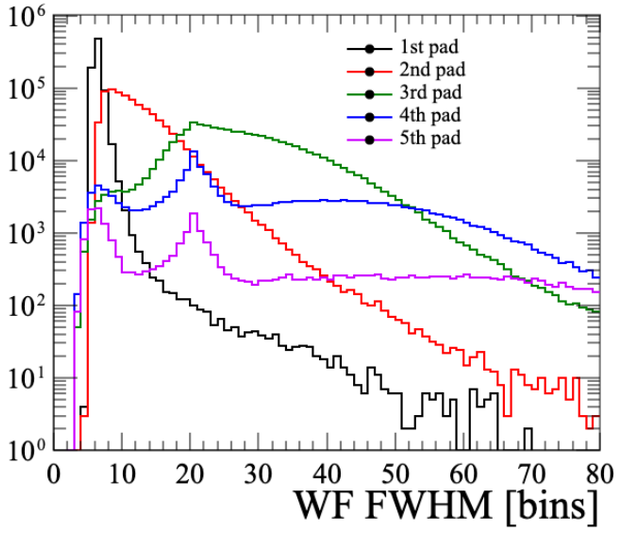
MM1





DESY beam



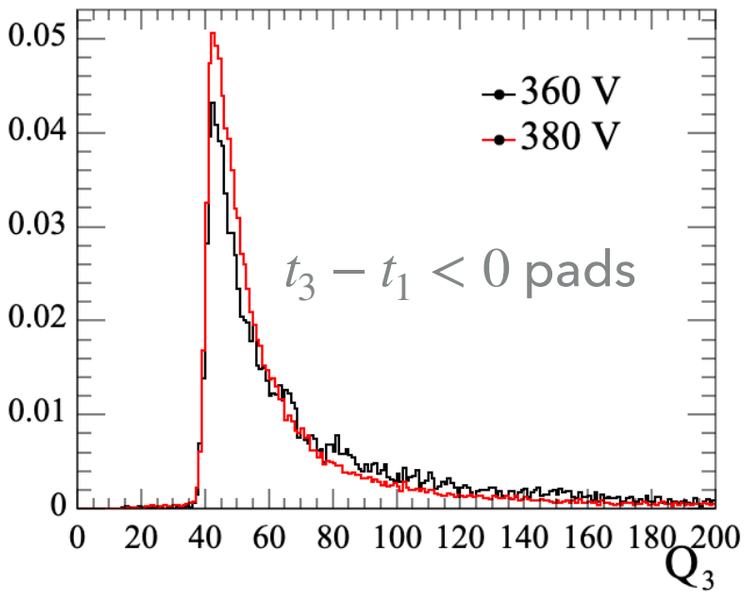


ERAM3

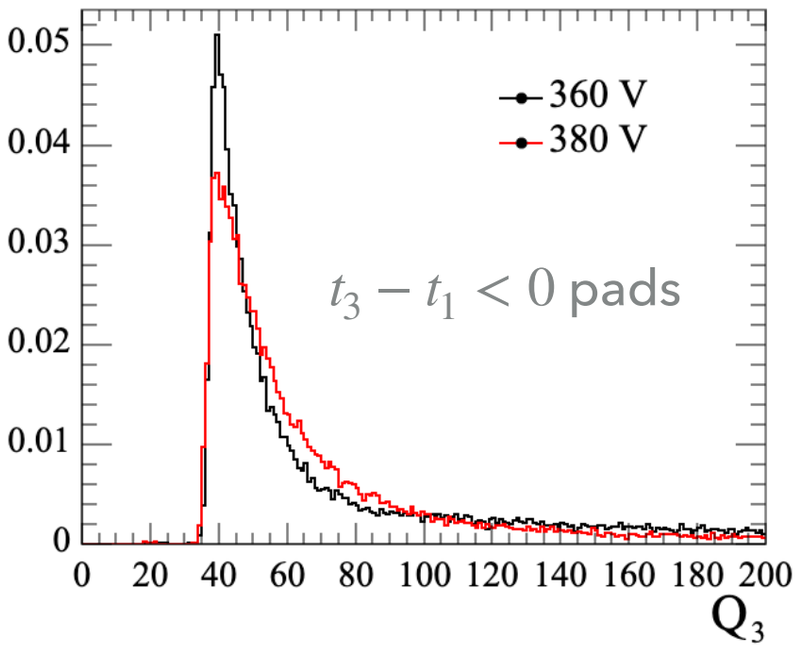
CHARGE IN THIRD PAD

- Charge in the pads with $t_3 - t_1 < 5$ seems not to be affected by DLC voltage
- While most of them has small charge close to threshold
  the tail towards higher charge exists

MM1



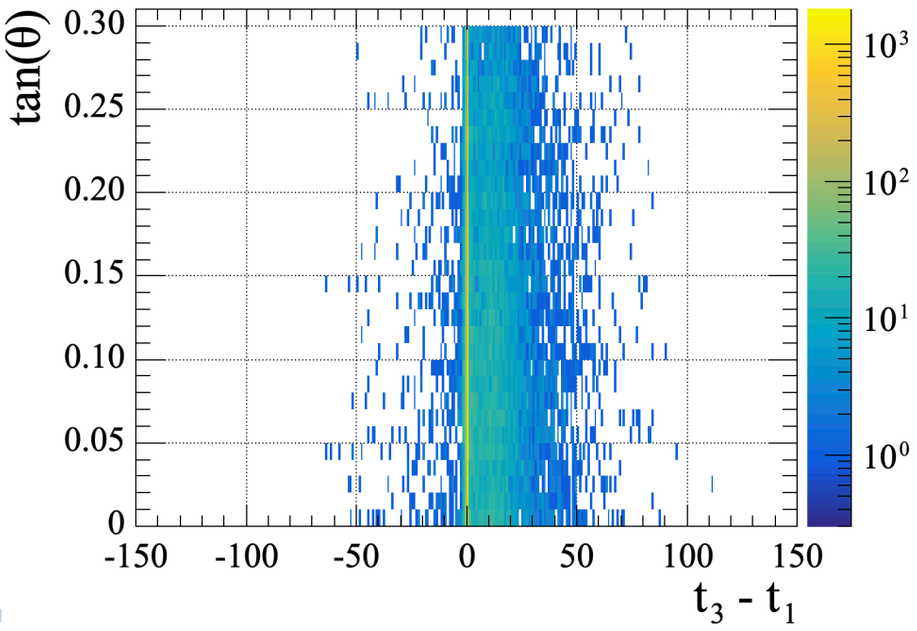
ERAM3



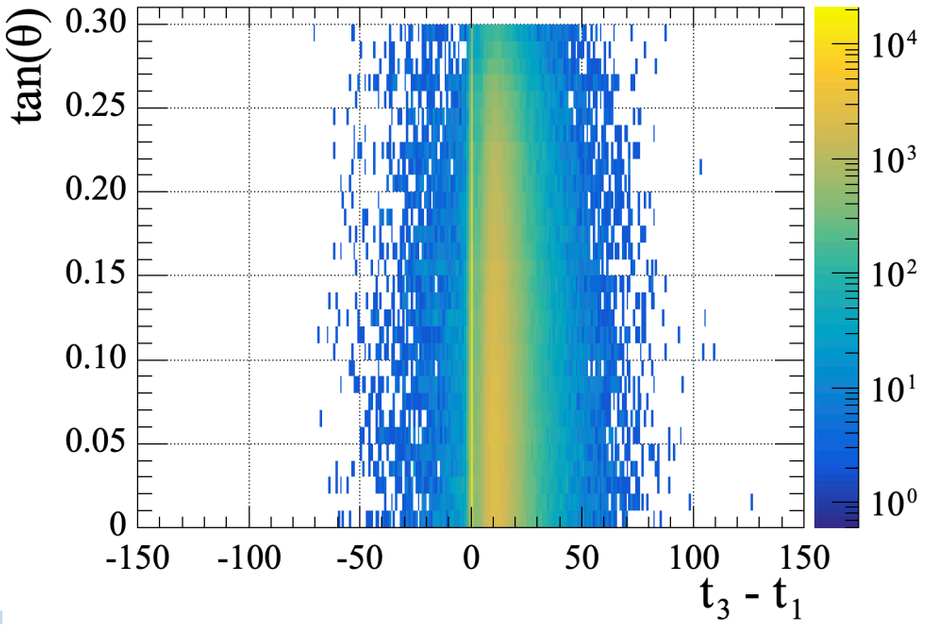
TIME DIFFERENCE

- Hypothesis: time confusion may come from the inclined tracks
  - $t_3 - t_1$ versus the angle w.r.t. MM plane was studied (θ)
  - No dependence was observed

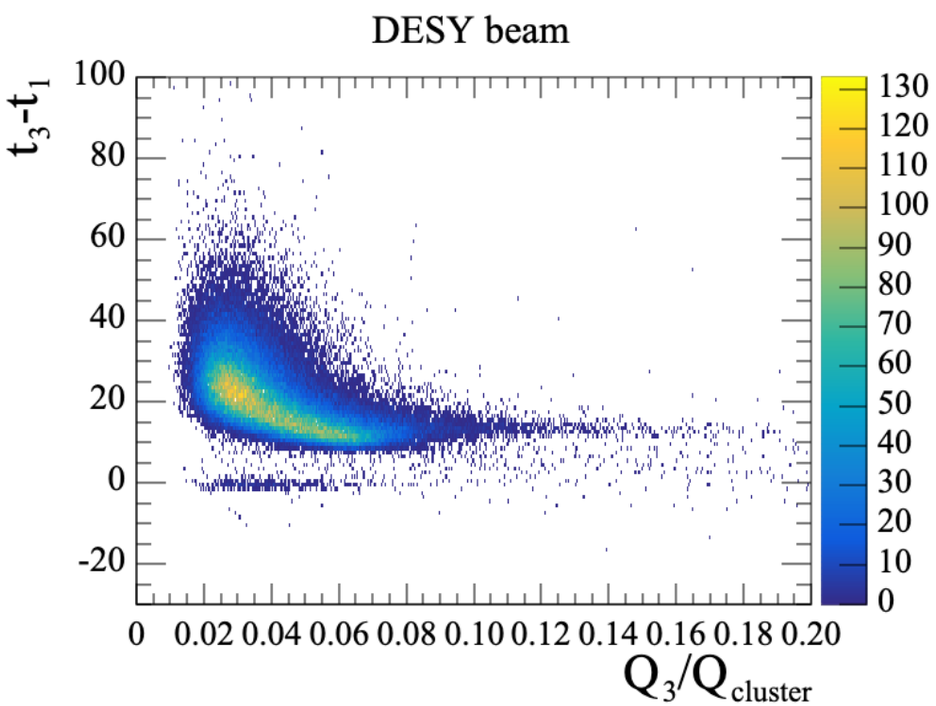
MM1

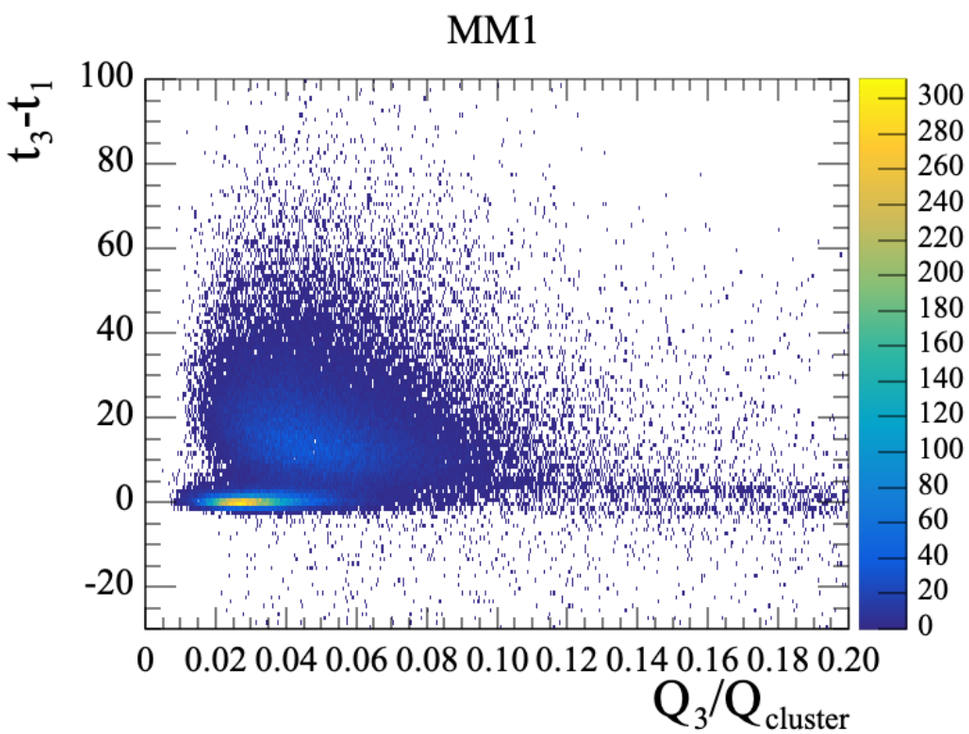


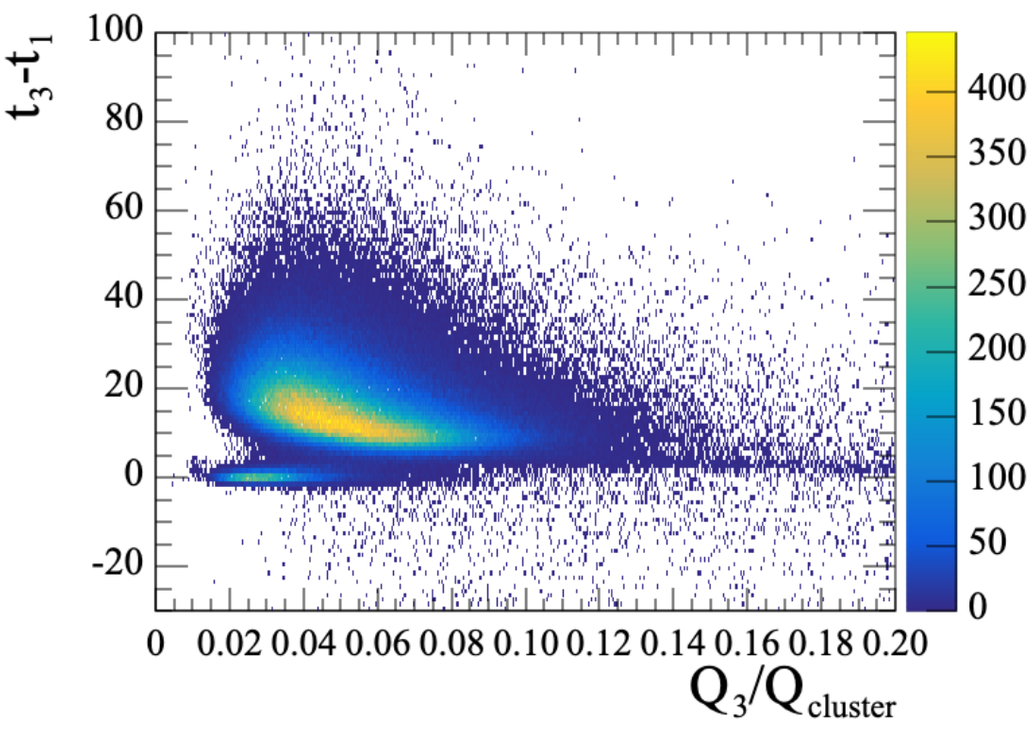
ERAM 2

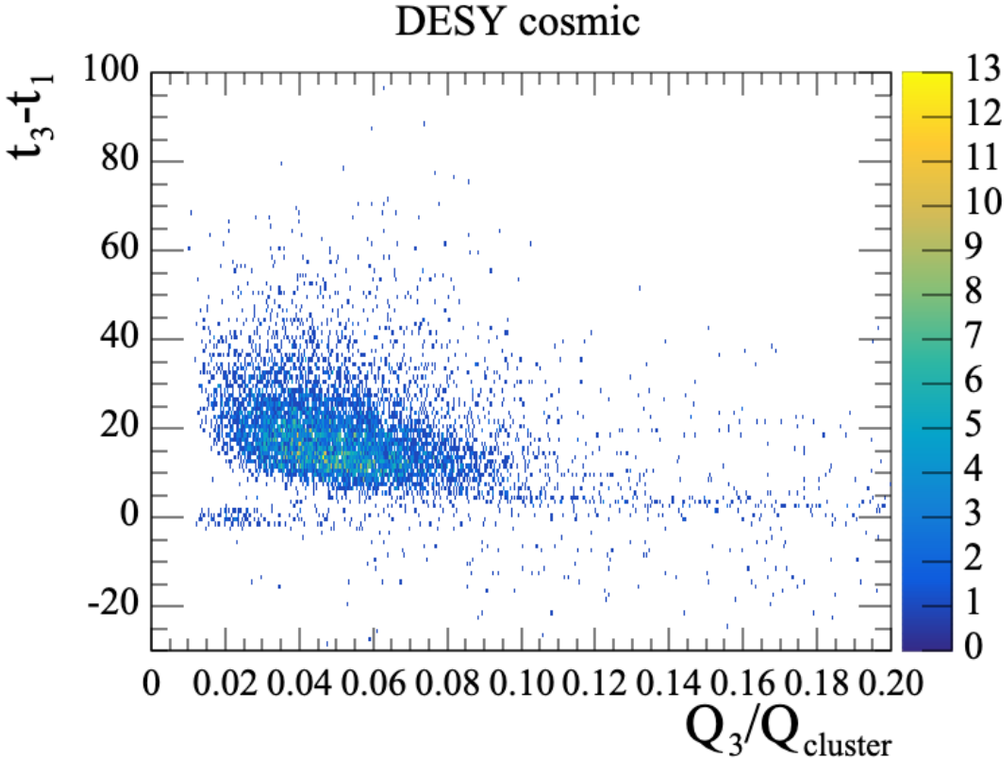


TIME DIFFERENCE VS CHARGE FRACTION

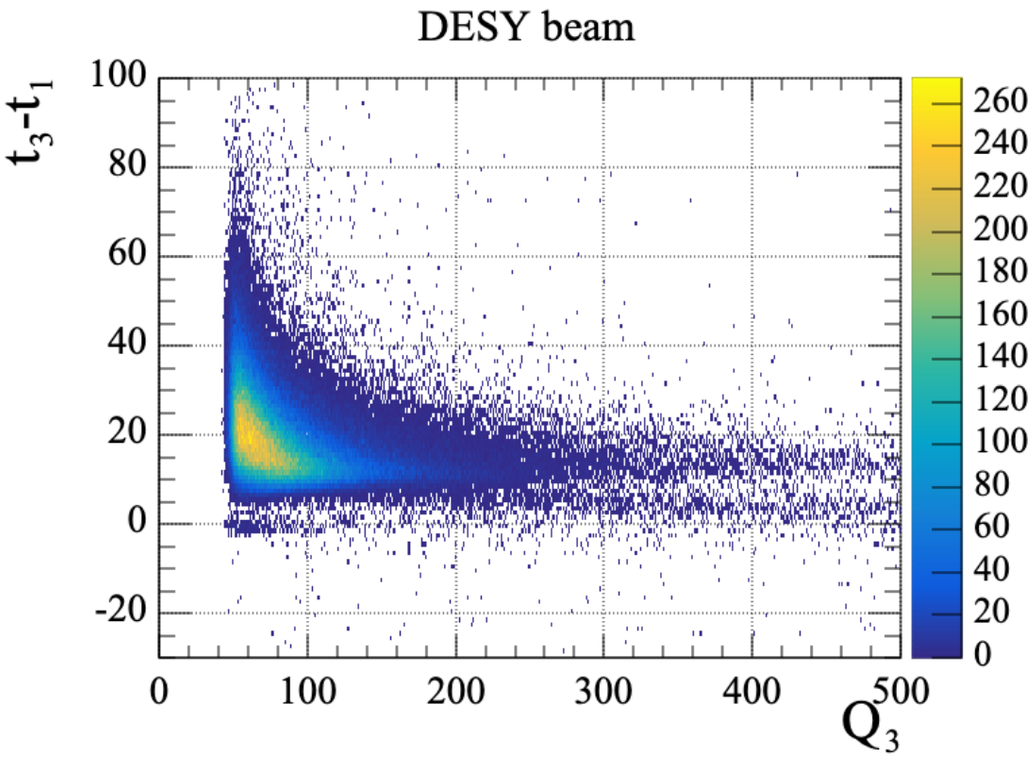


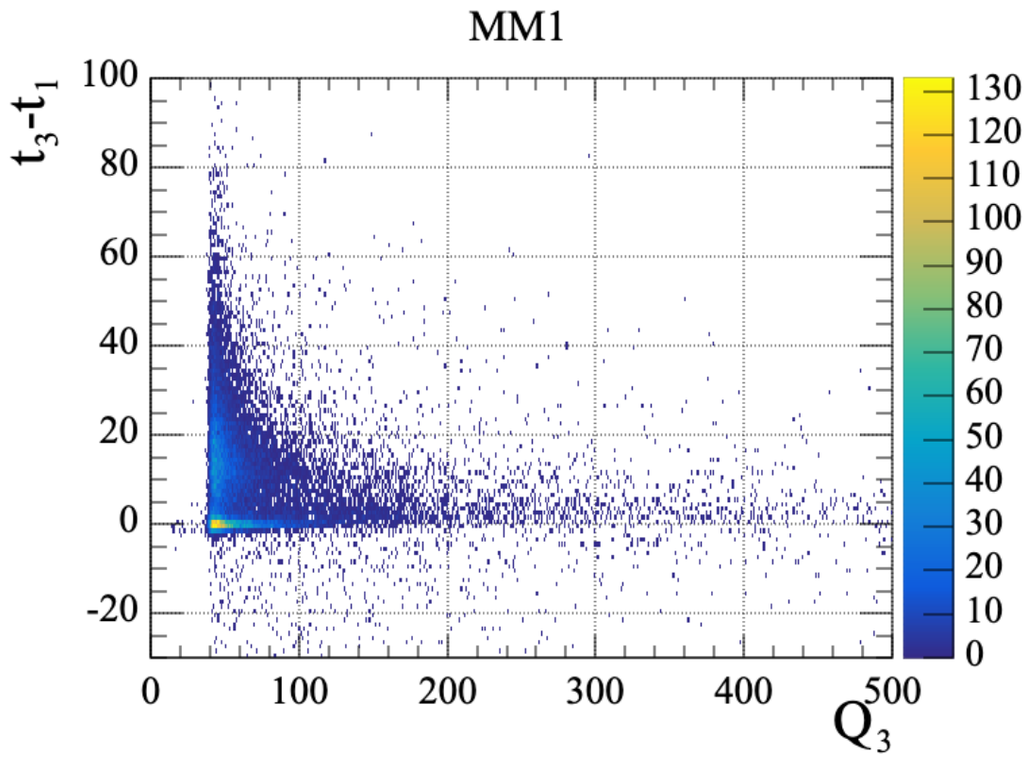


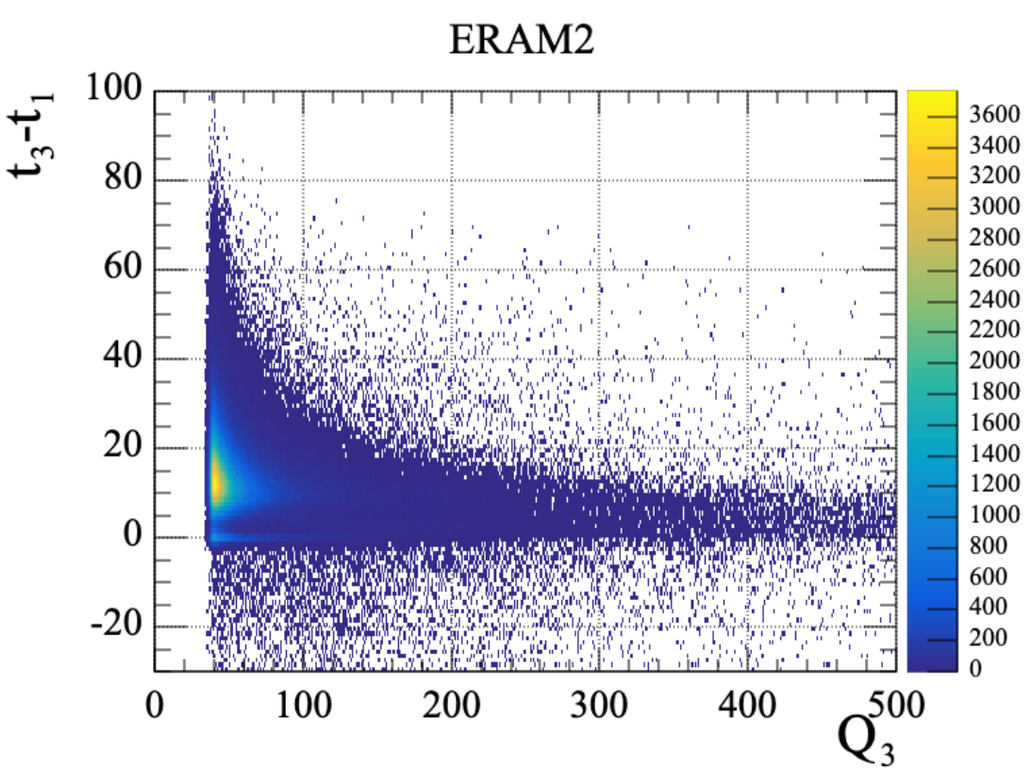


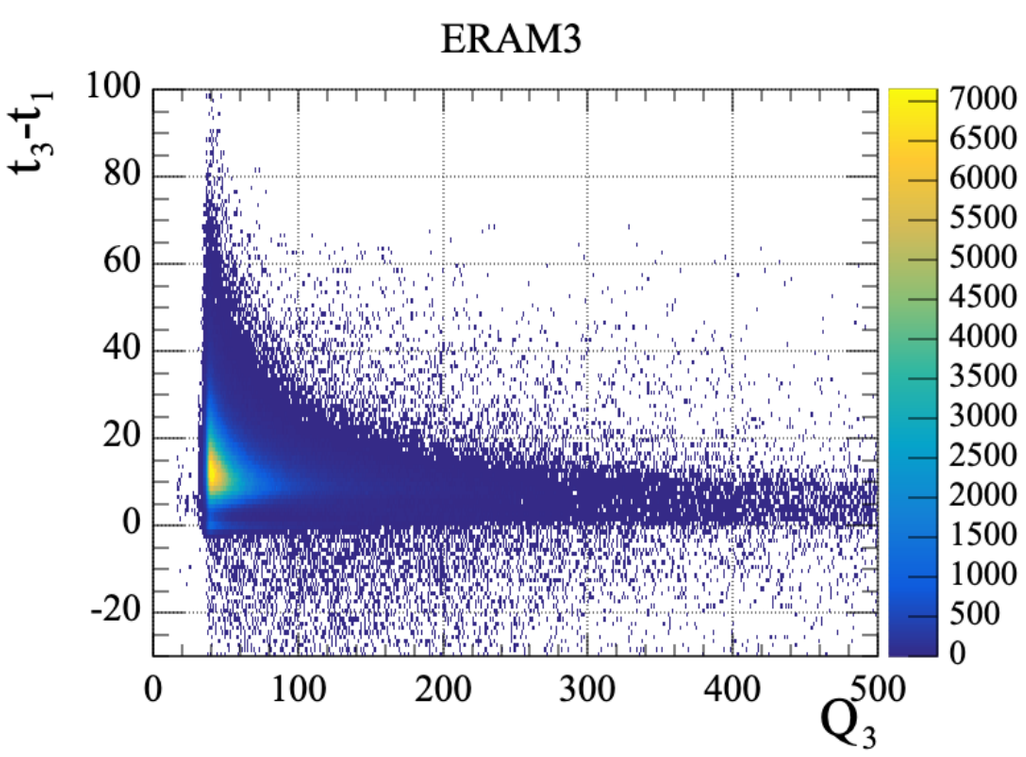


TIME DIFFERENCE VS CHARGE 360V

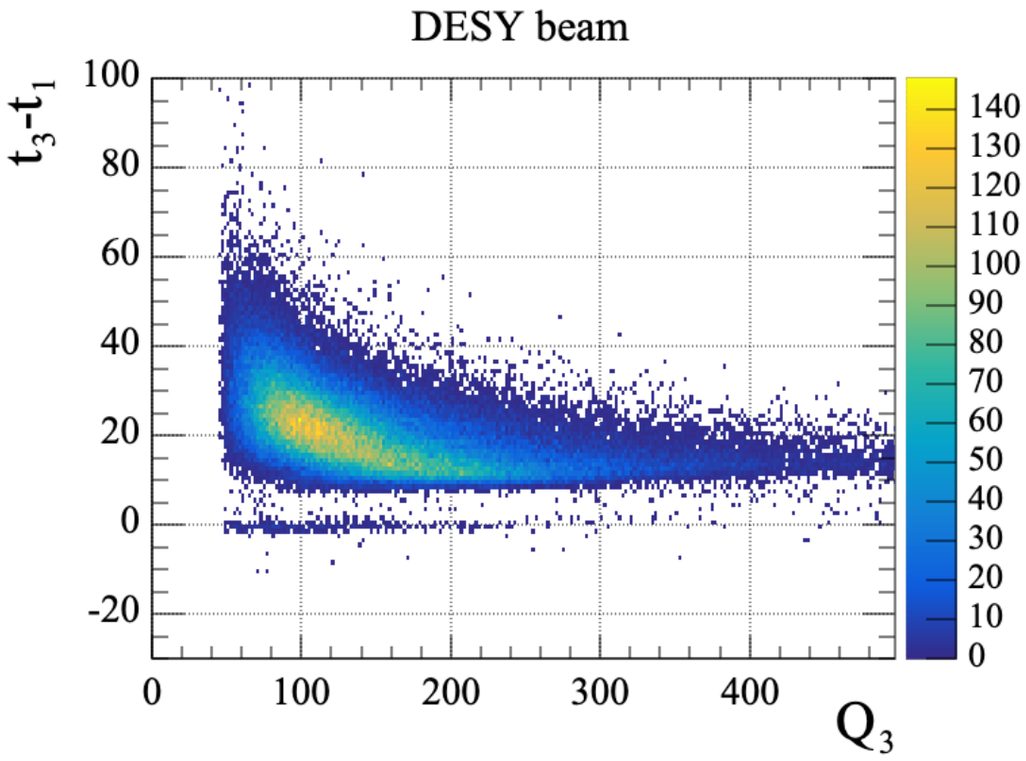


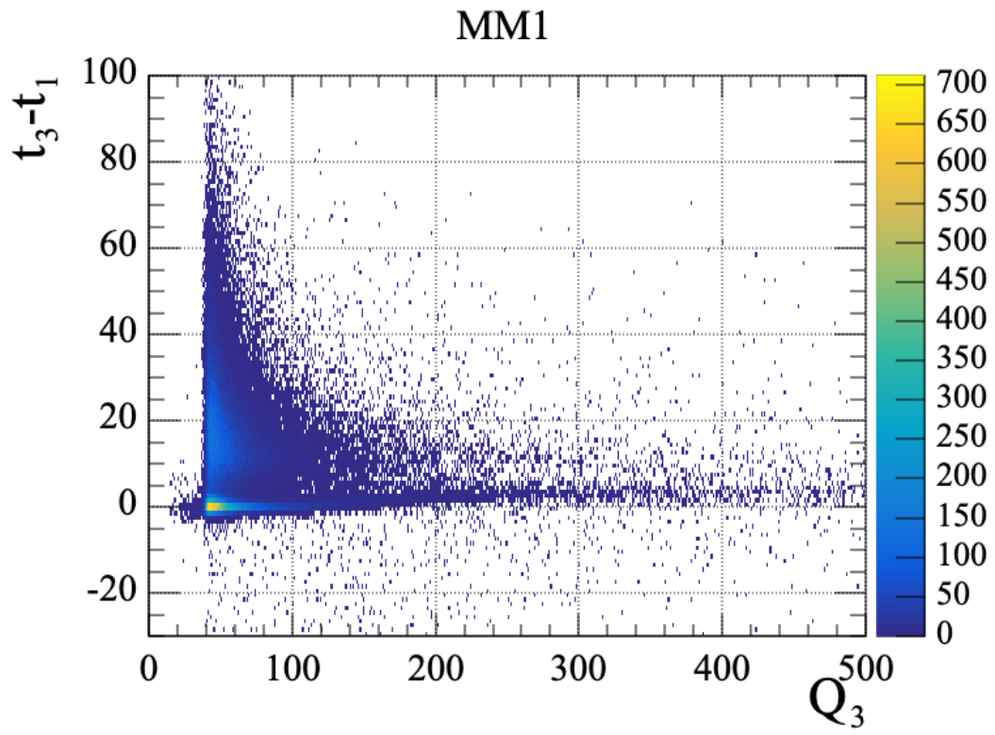


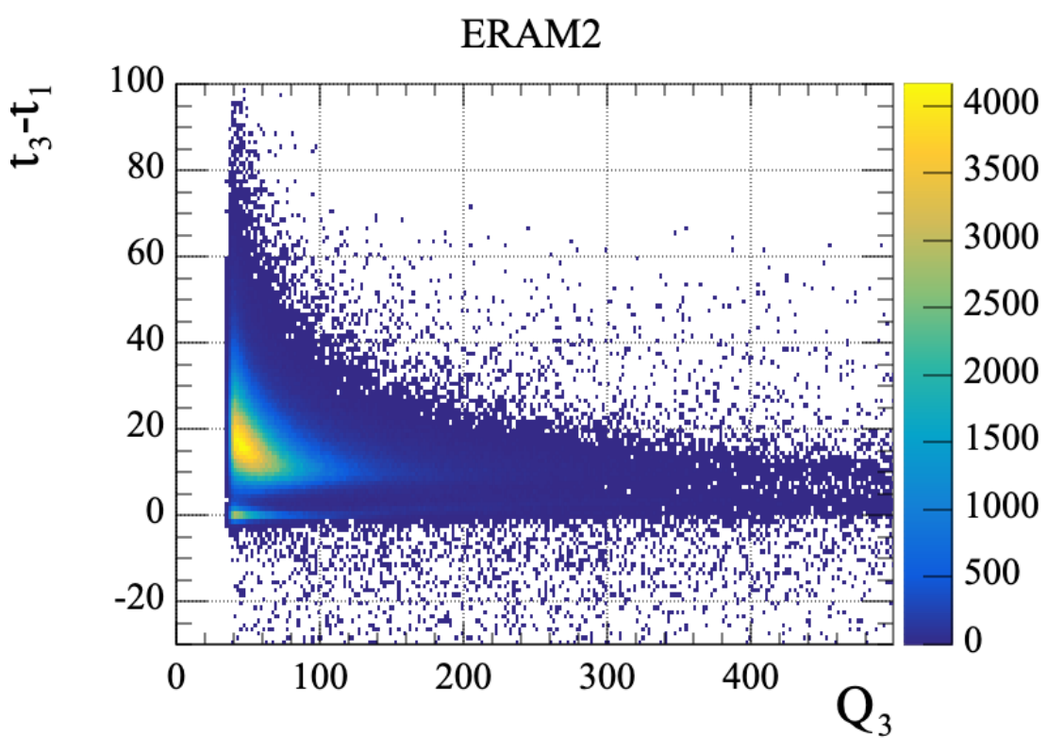


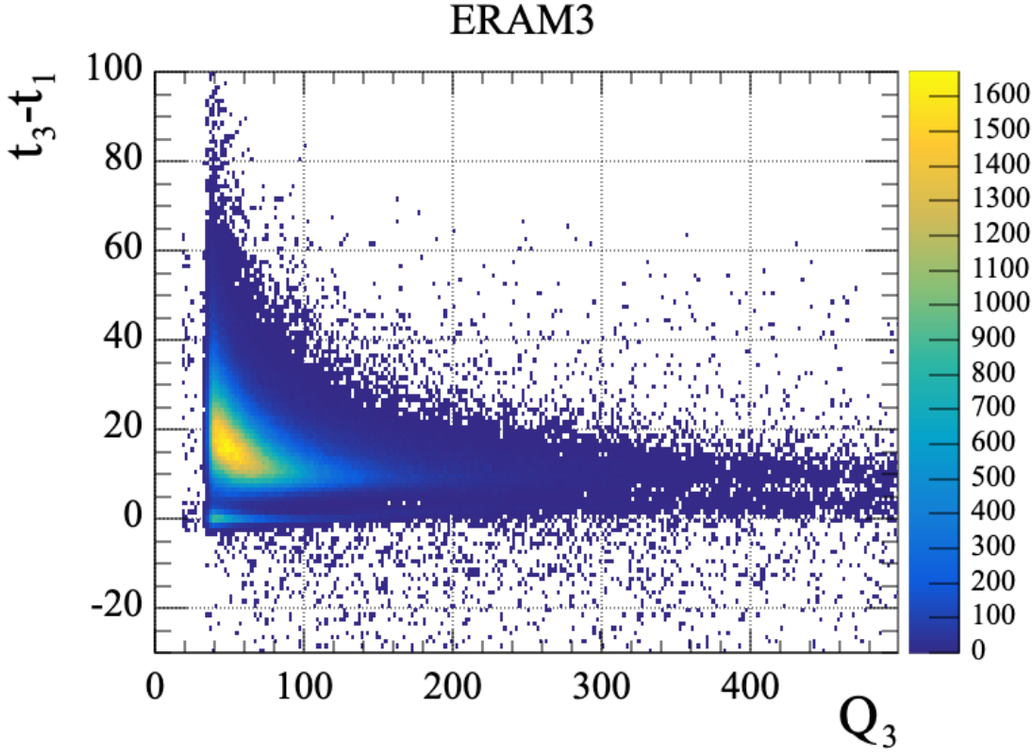


TIME DIFFERENCE VS CHARGE 380V





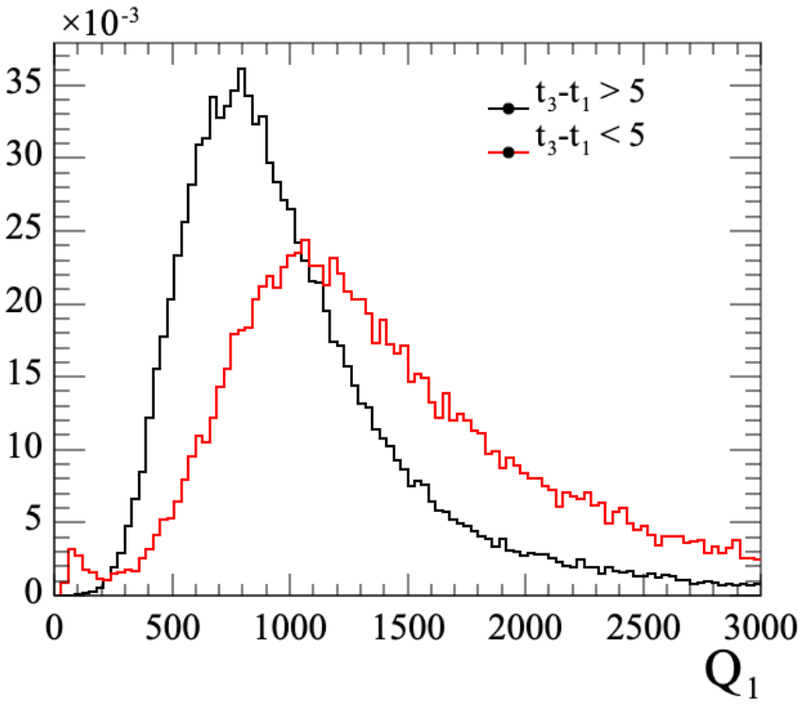




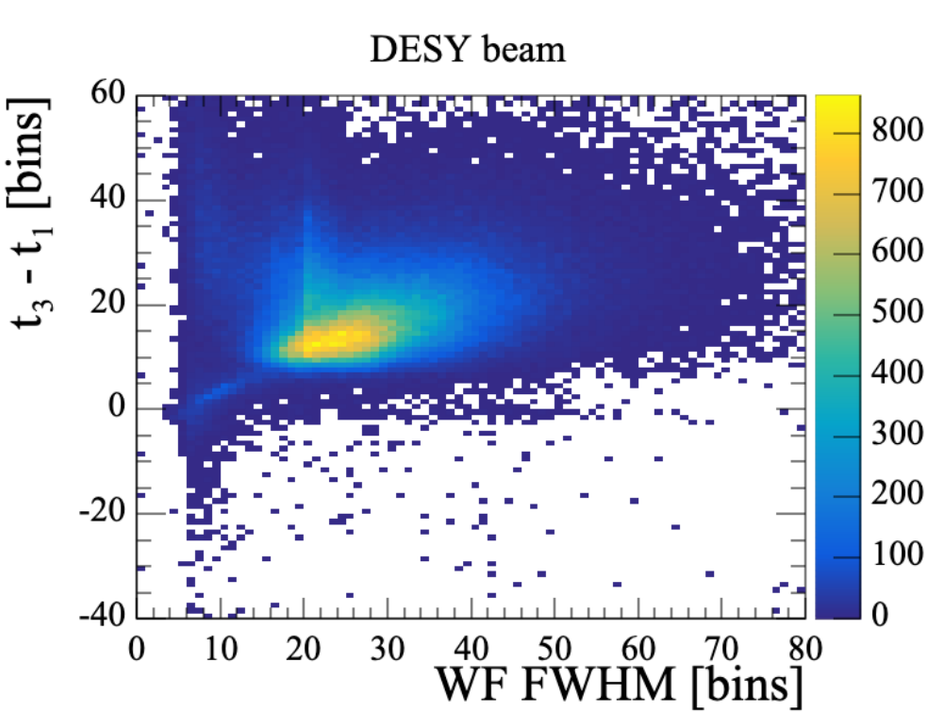
3RD PAD QUALITY VS LEADING PAD CHARGE

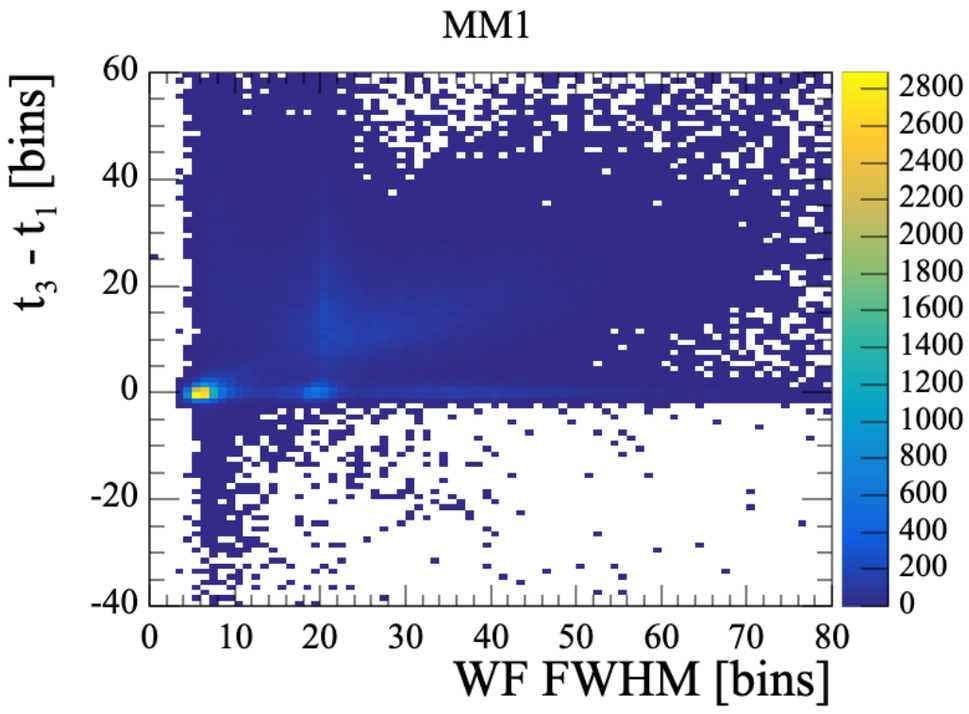
- "Good" and "bad" pads vs. The charge in the leading pad

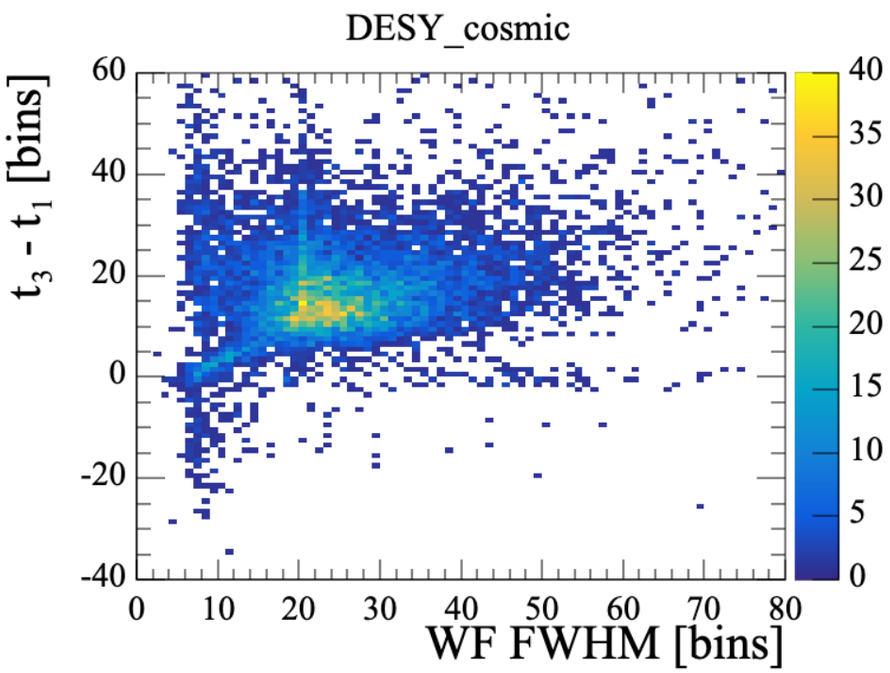
MM1 360 V

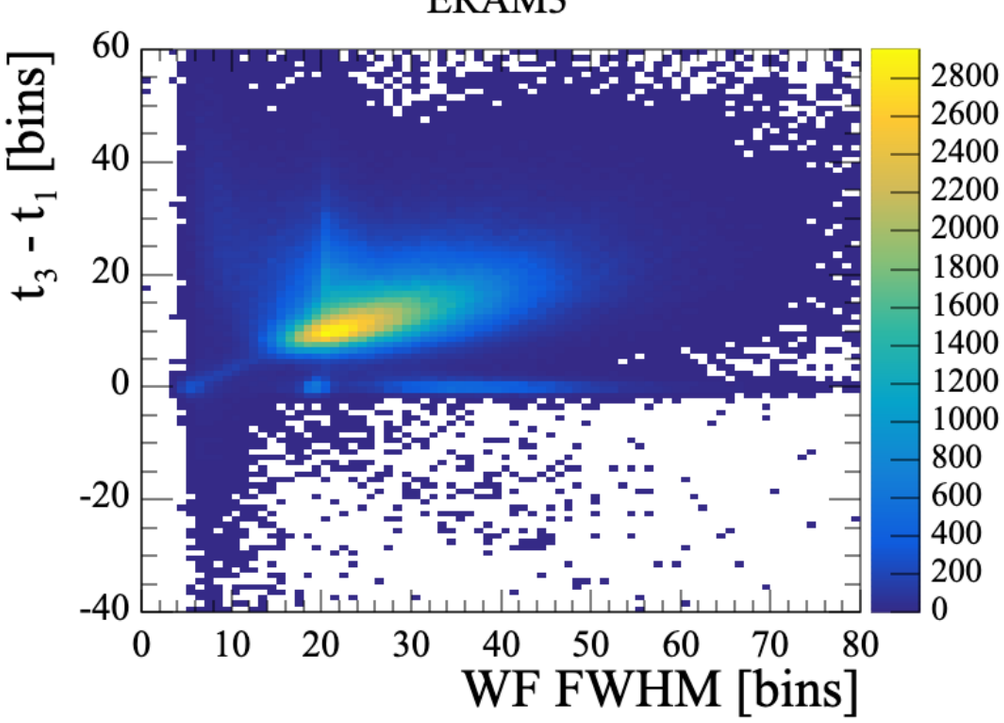


TIME DIFFERENCE VS WF FWHM

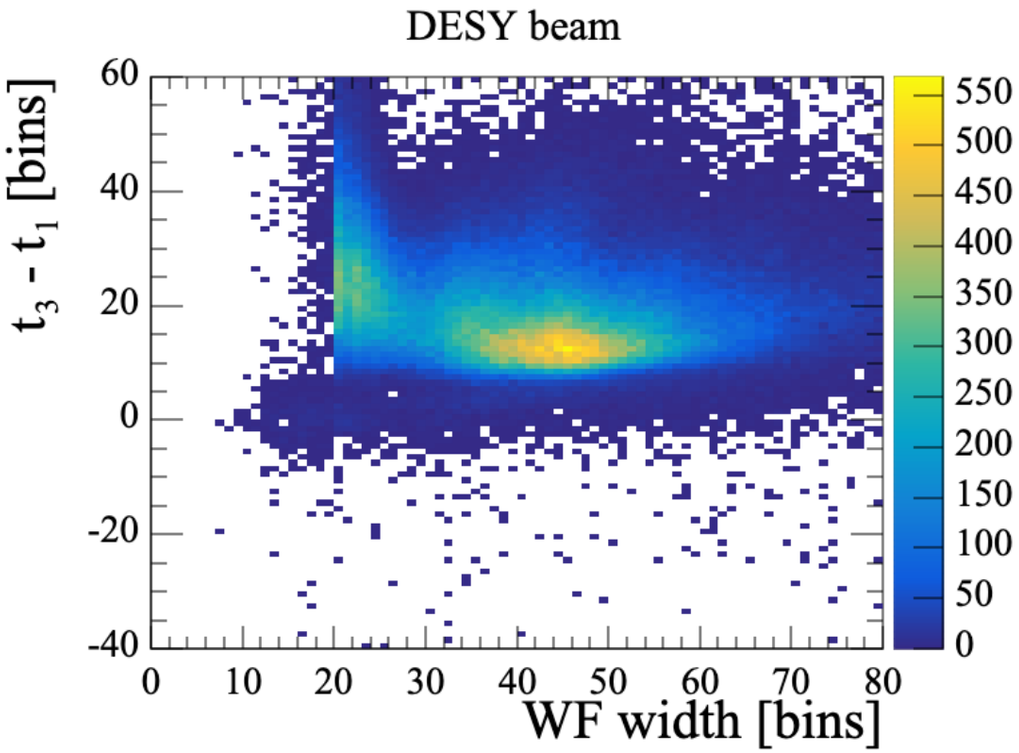


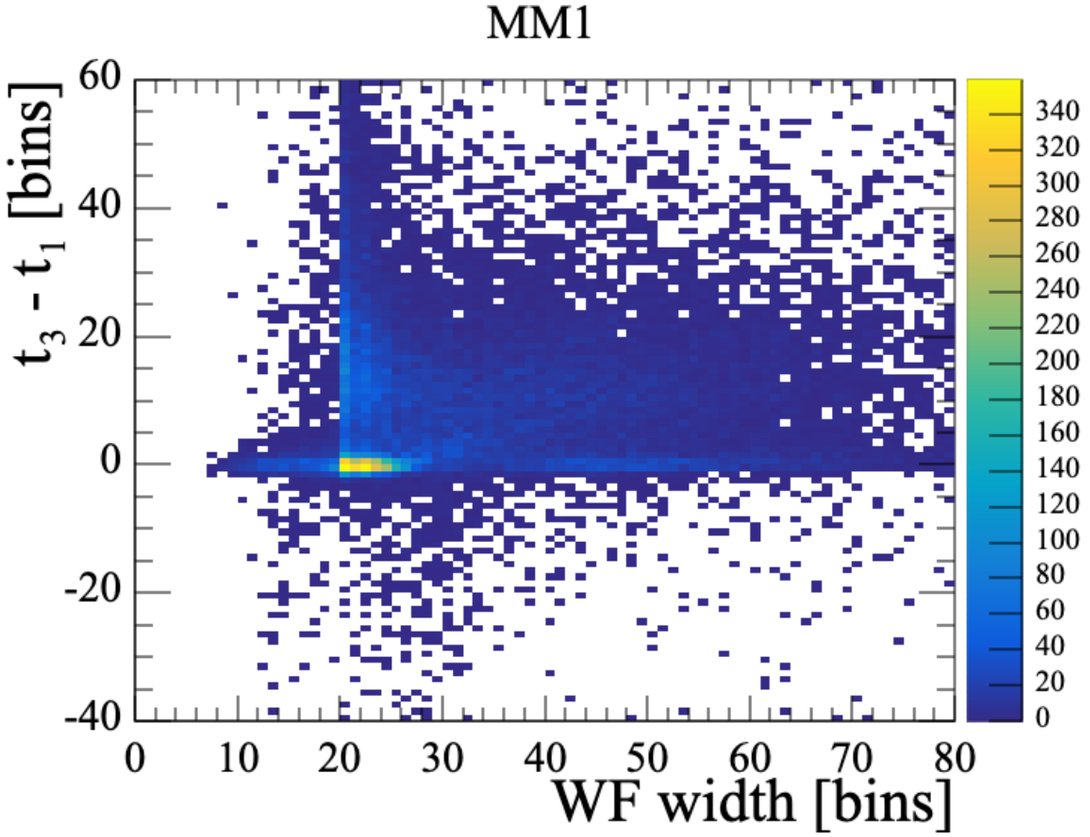


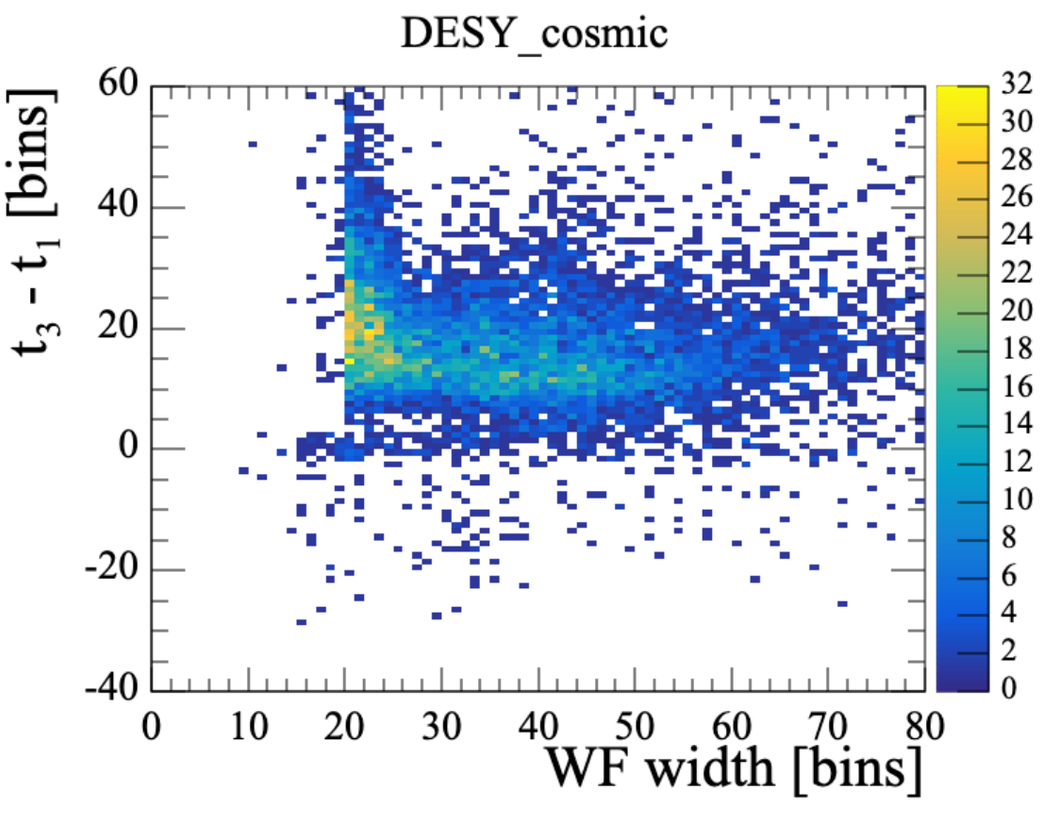


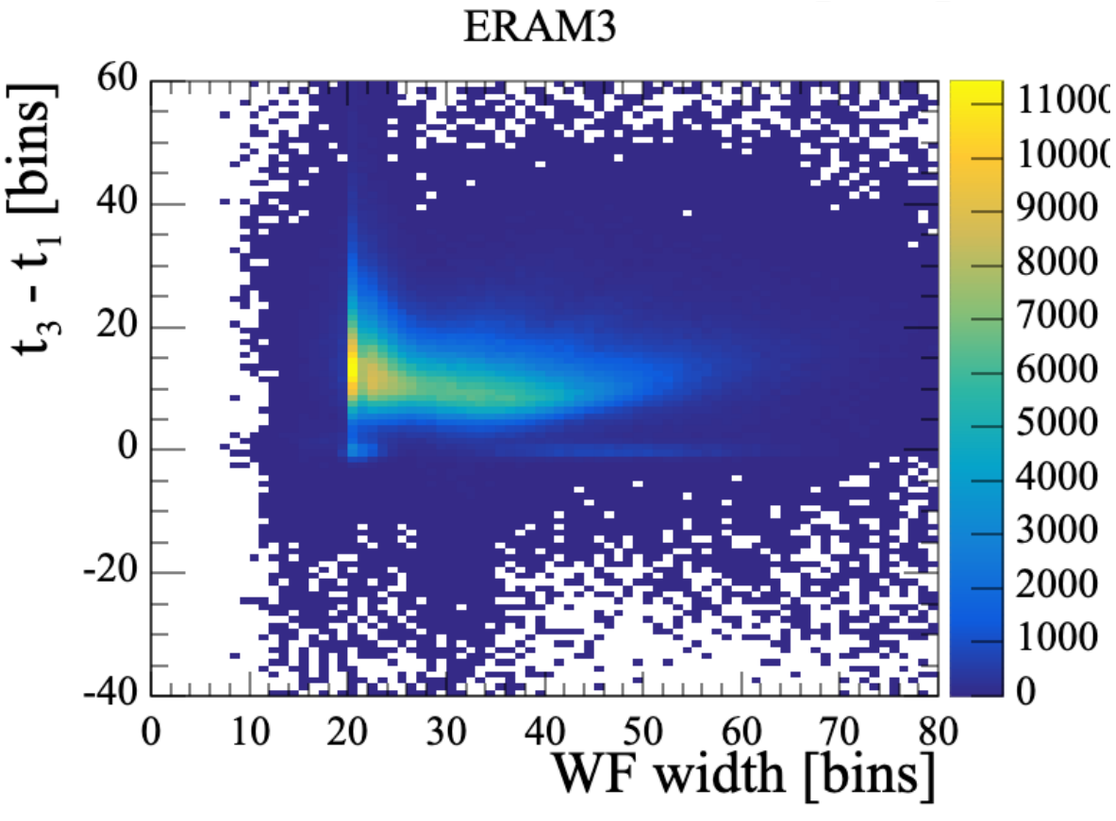


TIME DIFFERENCE VS WF WIDTH 360 V

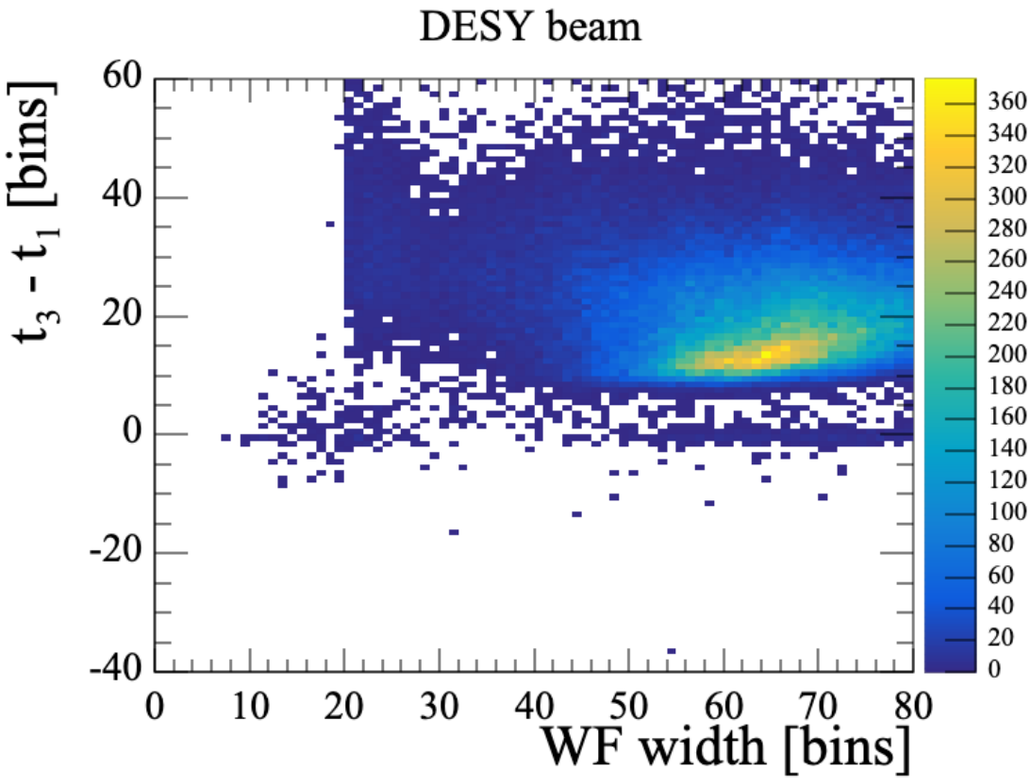


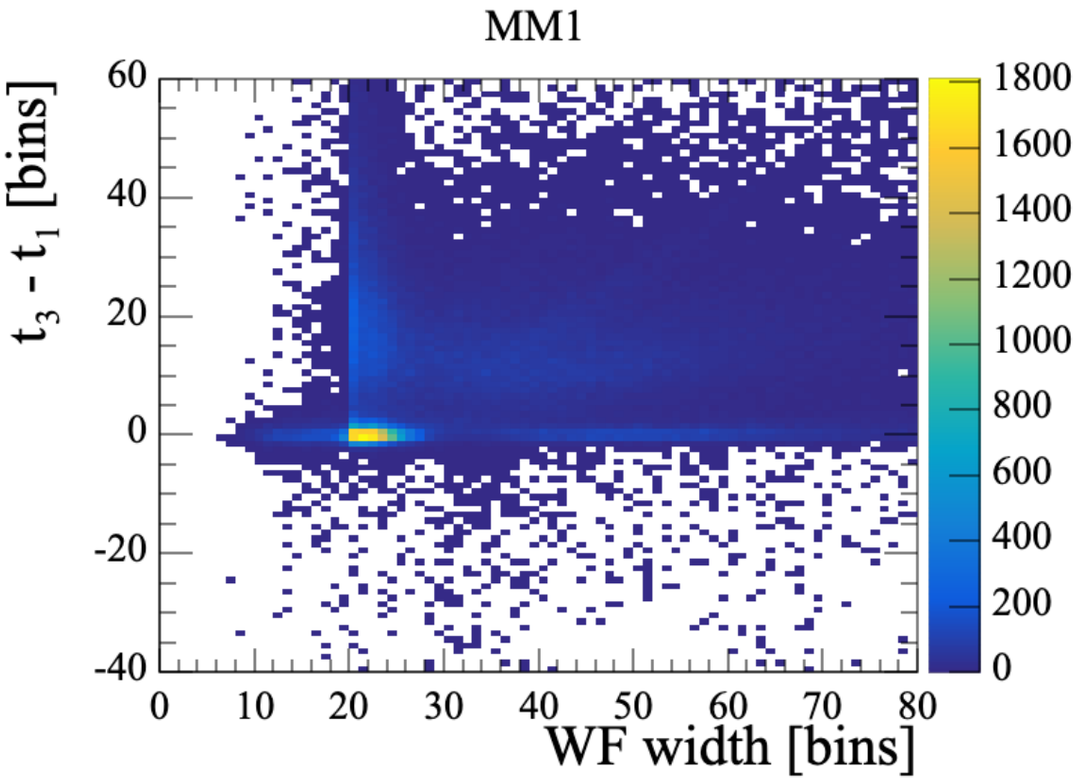


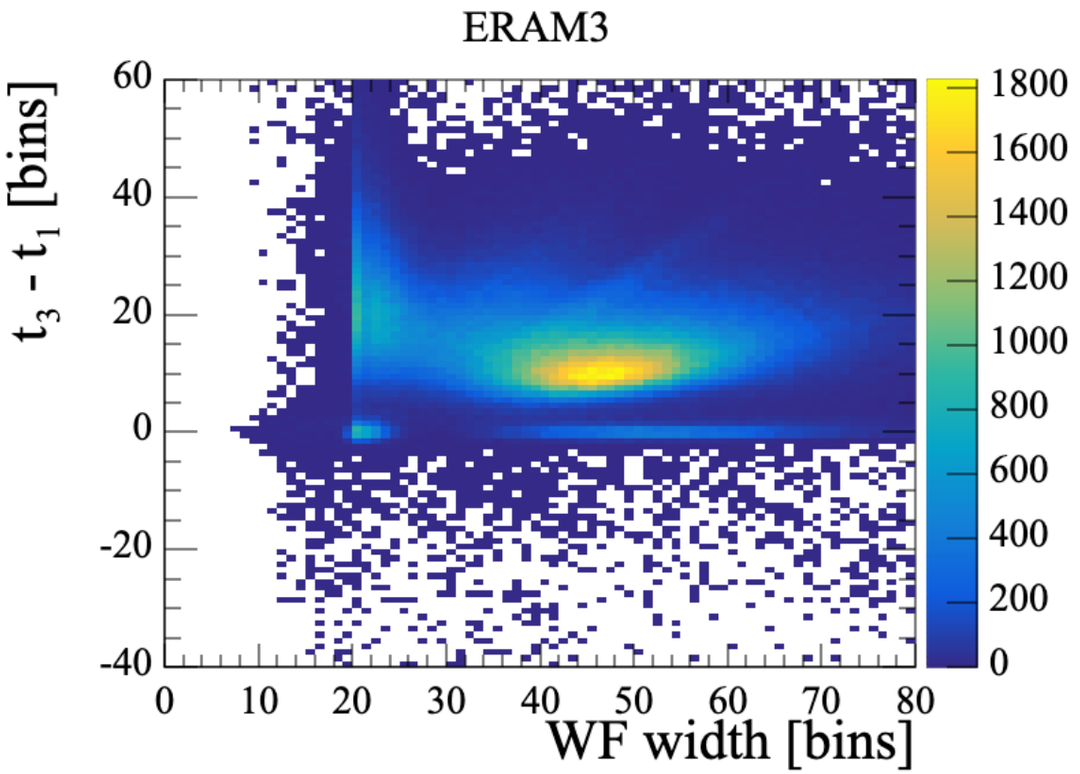




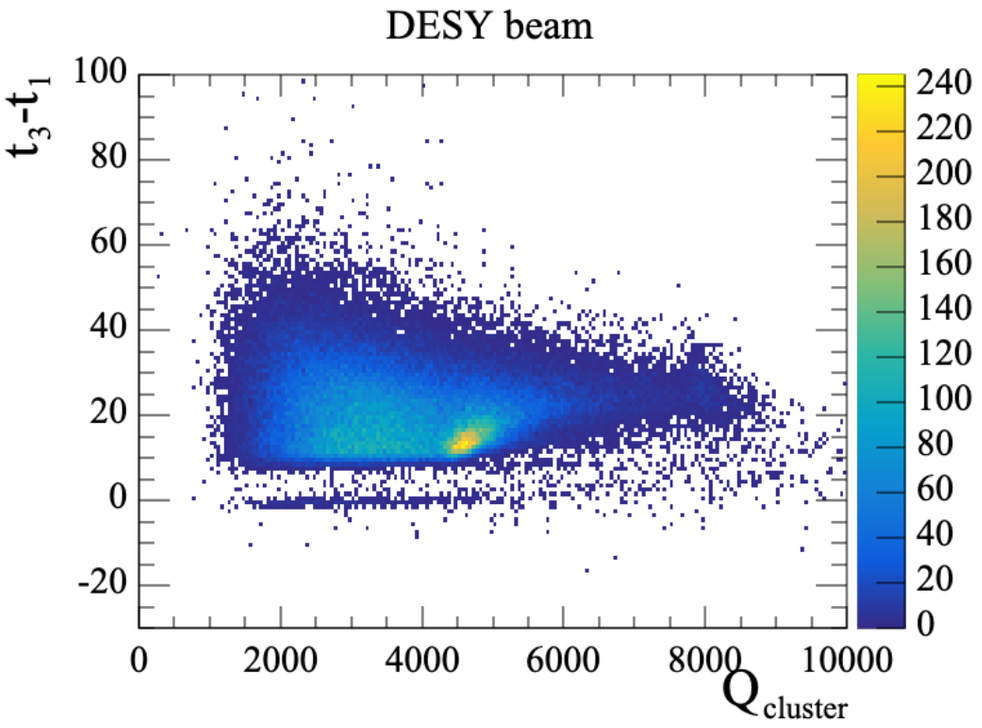
TIME DIFFERENCE VS WF WIDTH 380 V

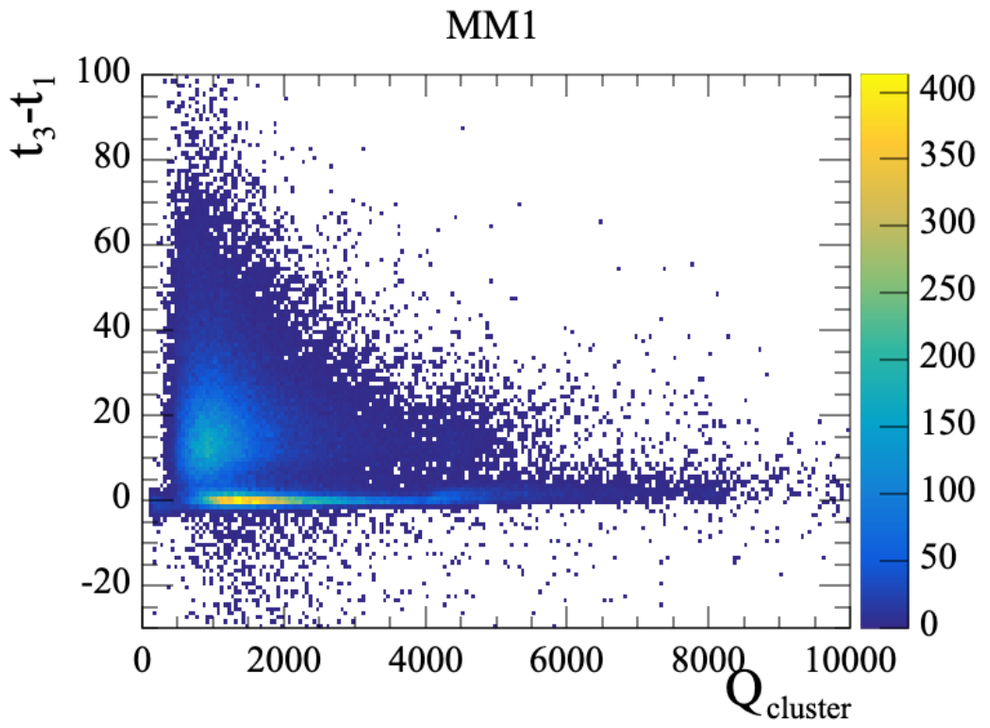


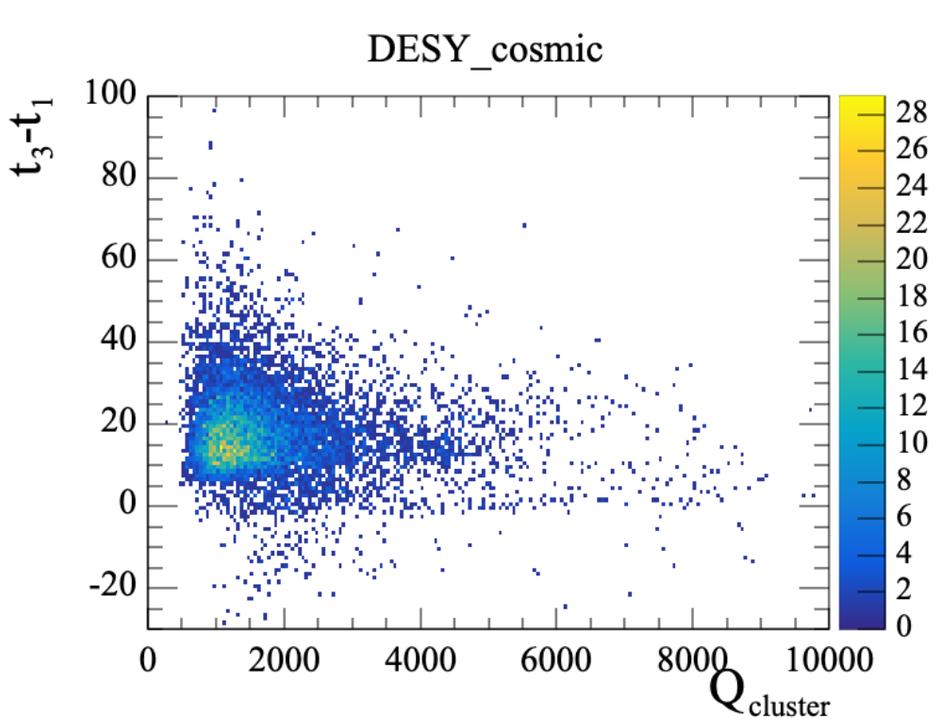


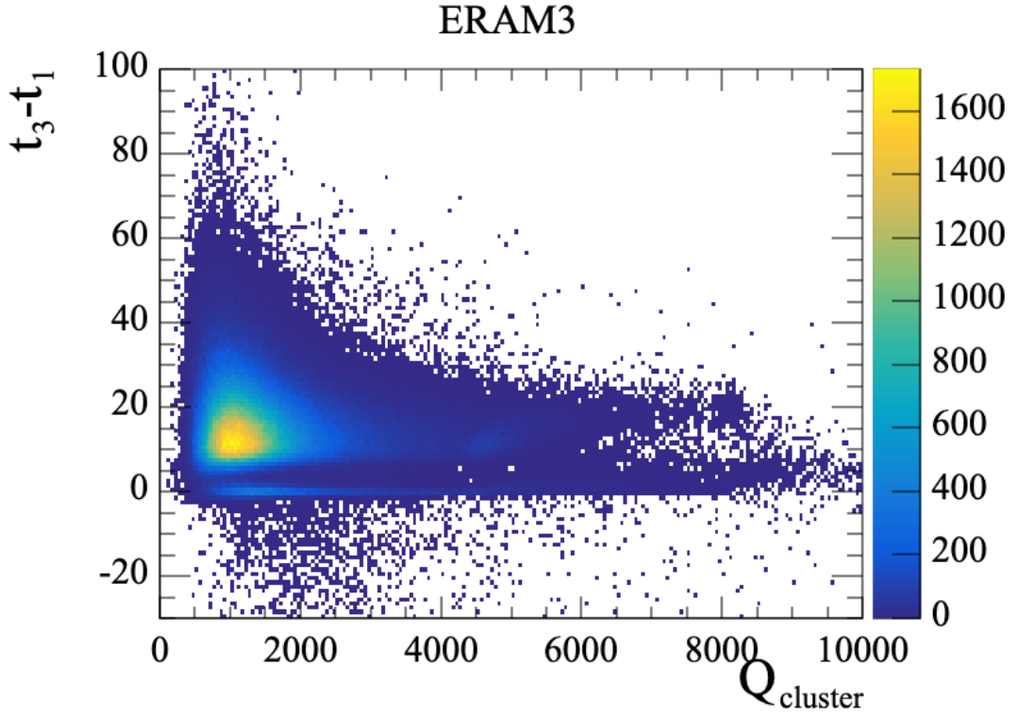


DT VS TOTAL CHARGE



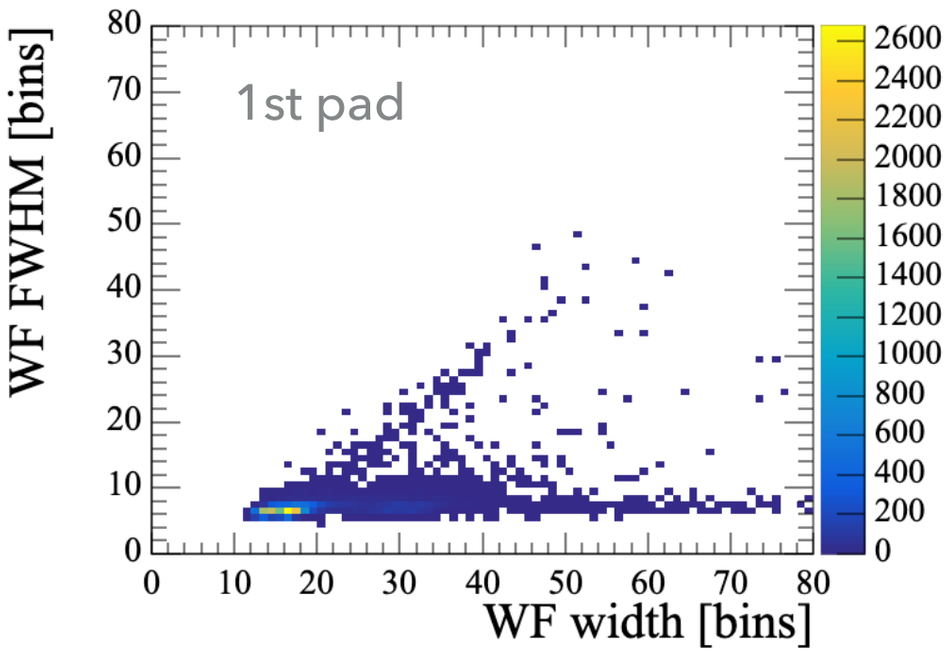


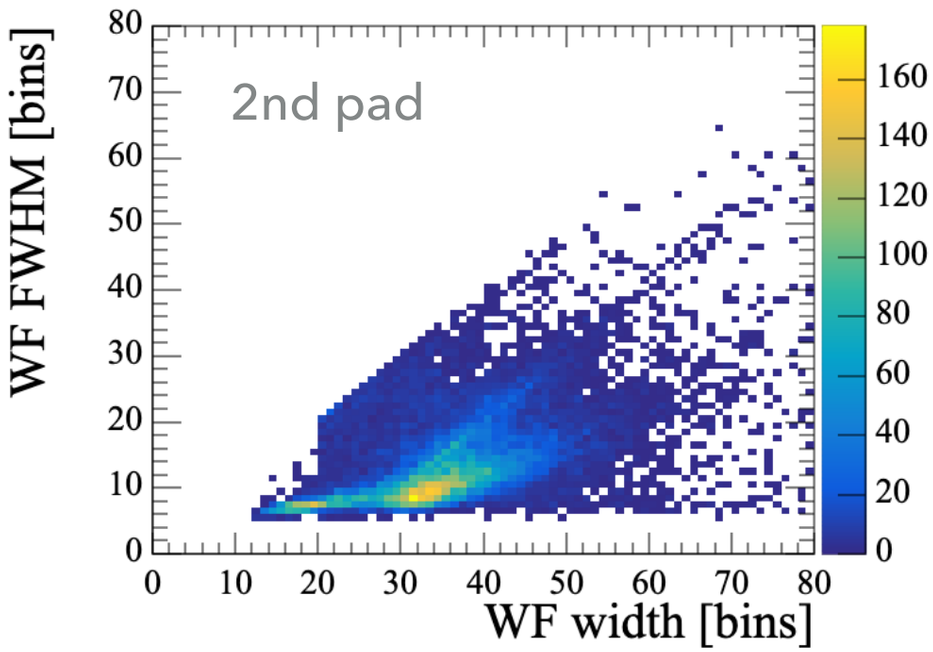


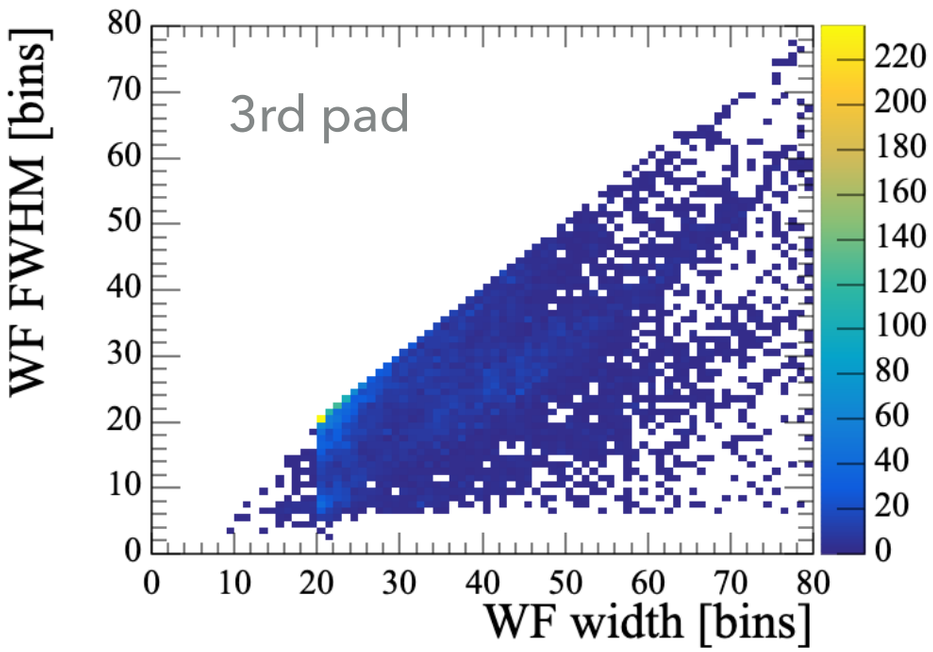


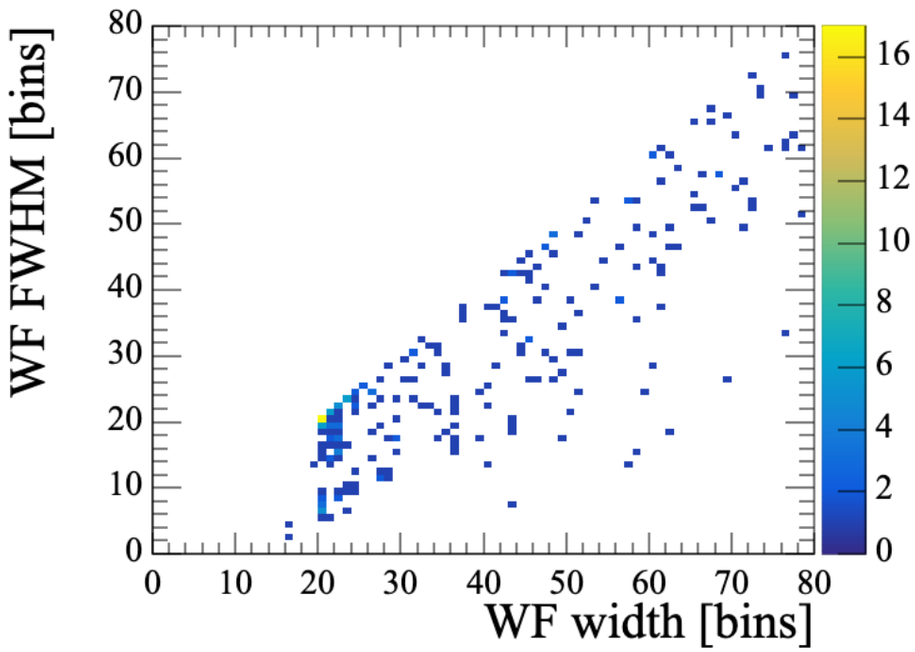
DESY COSMIC 360 V

- WF width

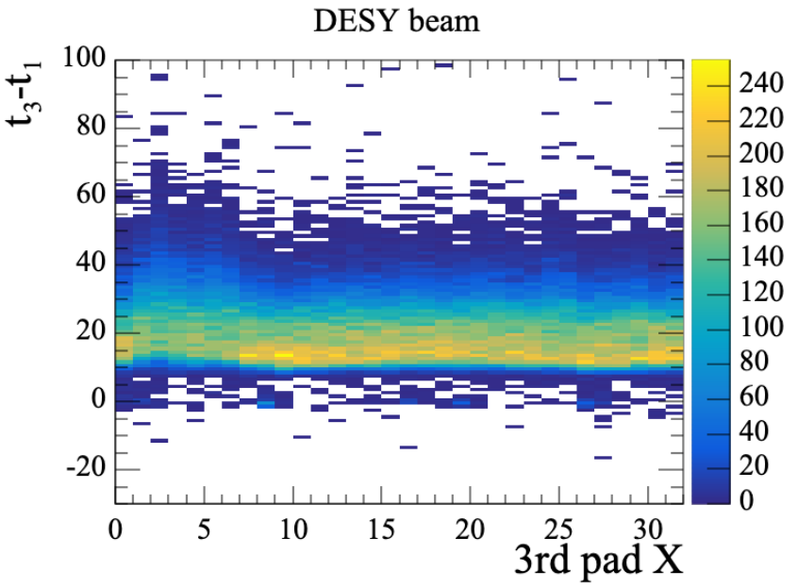


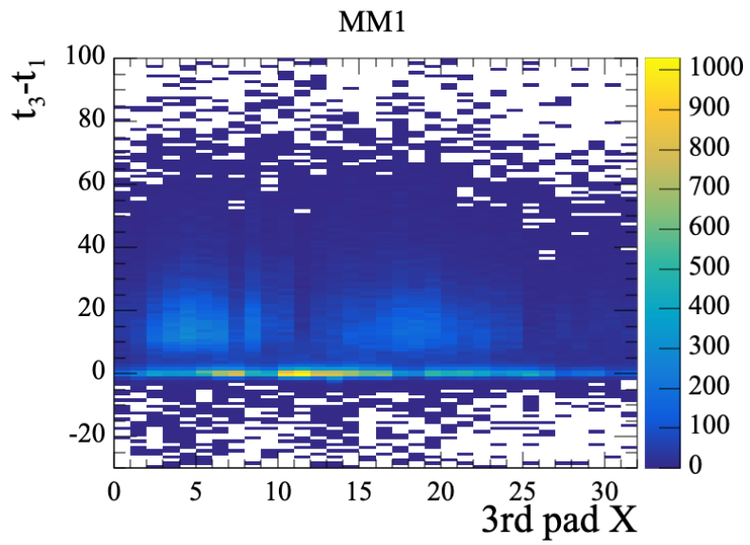


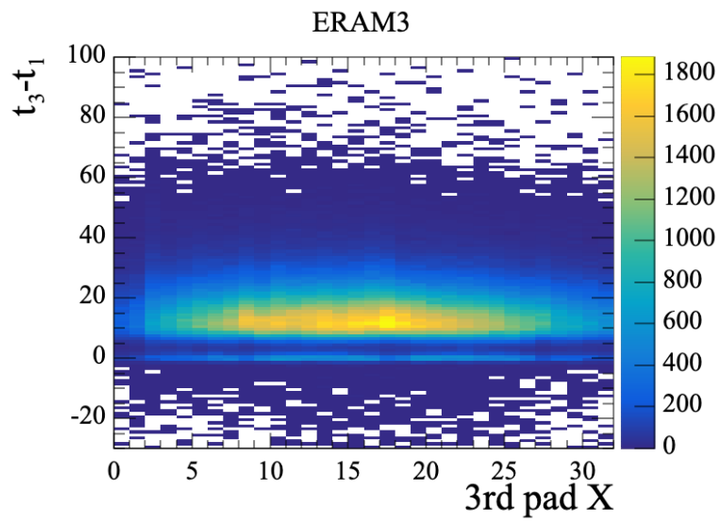


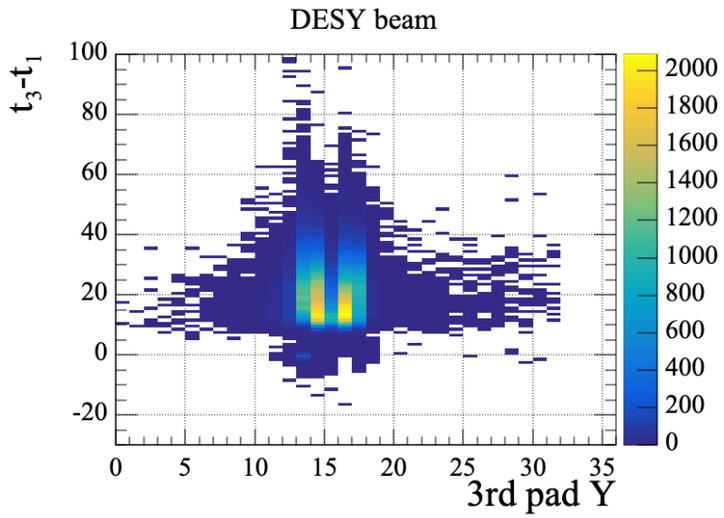


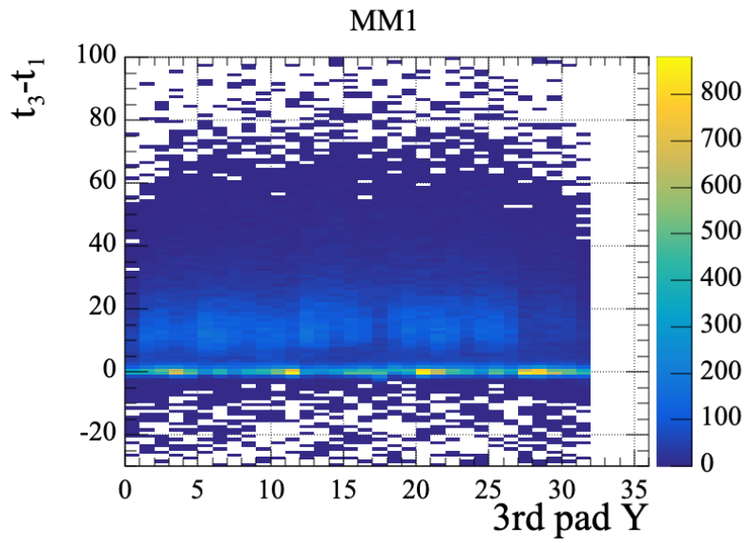
GEOMETRY POSITION

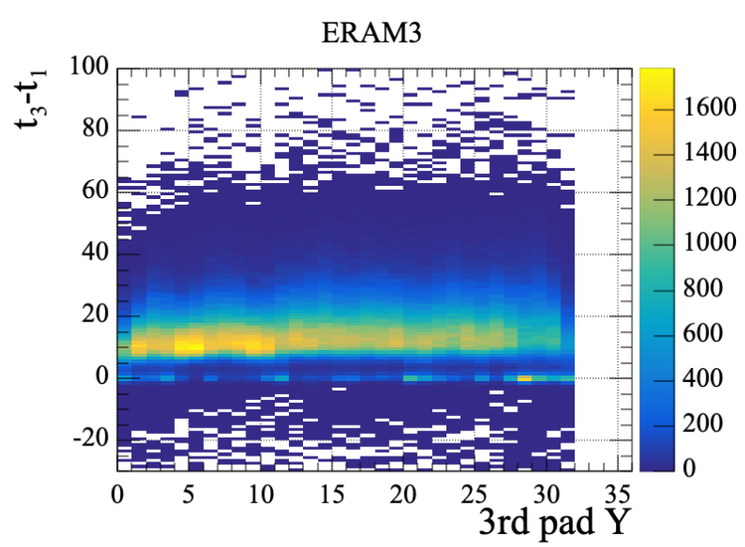








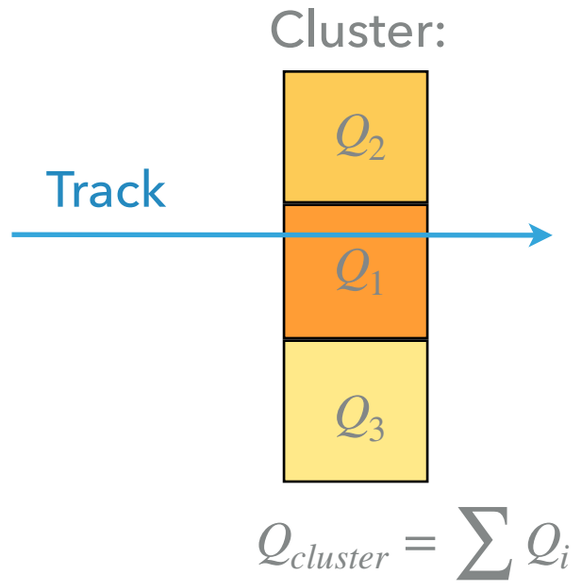




SPATIAL RESOLUTION. PAD RESPONSE FUNCTION

- Avalanche position can be reconstructed with ``centre of charge'' method

$$x_{track} = \frac{\sum \left(x_{pad} \cdot Q_{pad} \right)}{\sum Q_{pad}}$$



- We expect a better precision from ``Pad Response Function (PRF)'':

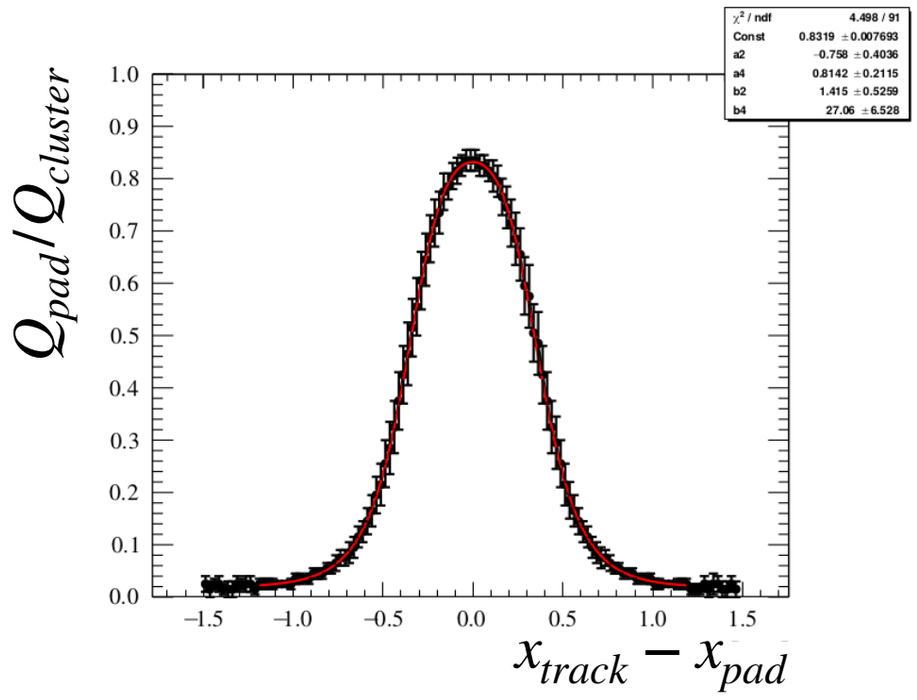
$$Q_{pad}/Q_{cluster} = PRF\left(x_{track} - x_{pad} \right)$$

- With known PRF the track position in a cluster is reconstructed with:

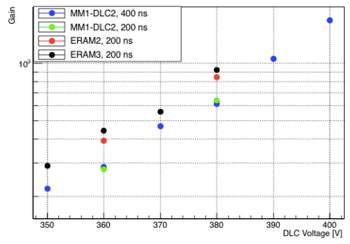
$$\chi^2 = \sum_{pads} \frac{Q_{pad}/Q_{cluster} - PRF\left(x_{track} - x_{pad} \right)}{\sigma}$$

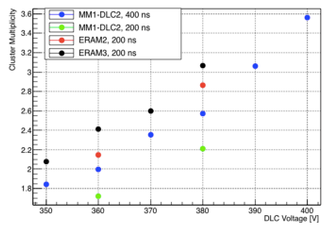
- The PRF is fit with analytical function:

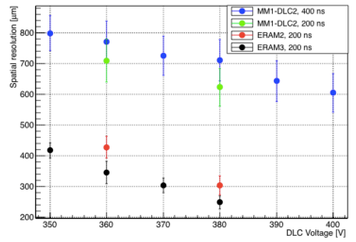
$$PRF\left(x, \Gamma, \Delta, a, b \right) = \frac{1 + a_2 x^2 + a_4 x^4}{1 + b_2 x^2 + b_4 x^4}$$



MM1 VS ERAM2

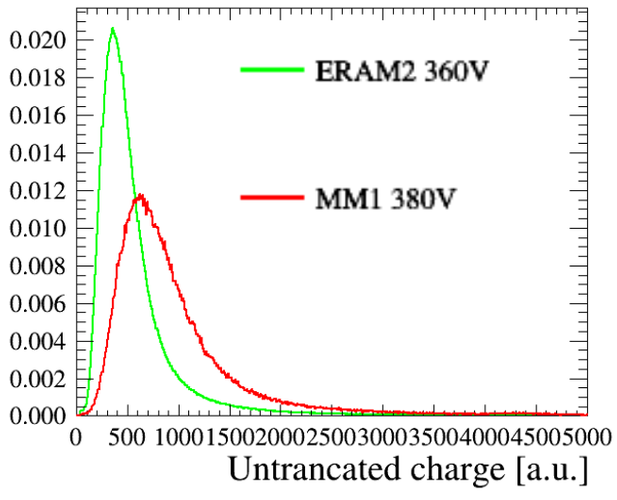


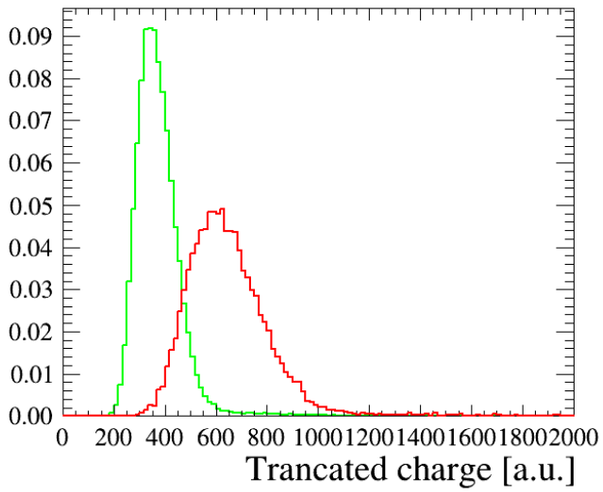


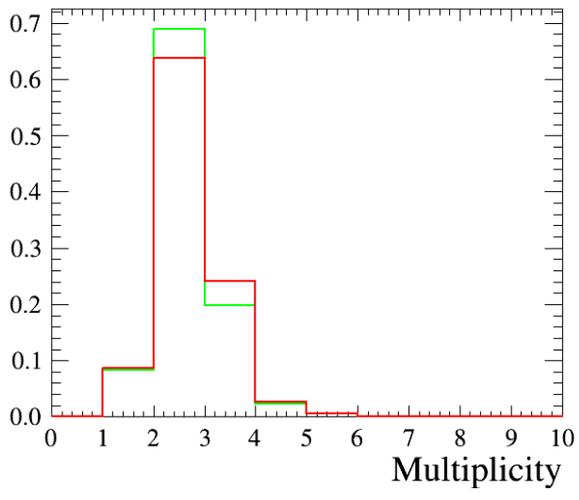


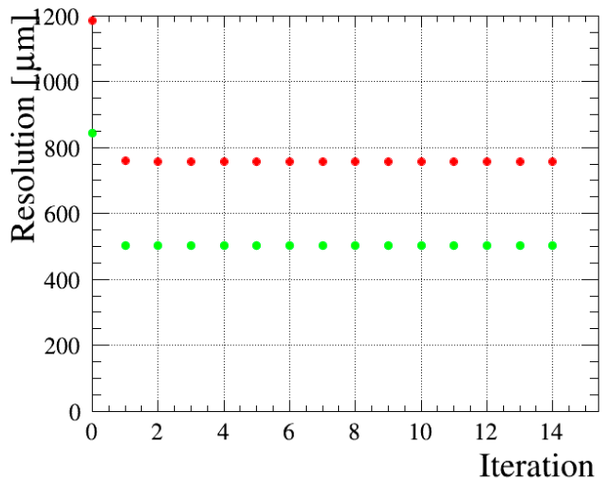
- From Samira's slides:
  - MM1 at 380V provides more charge and higher multiplicity than ERAM2 at 360V
  - MM1 at 380 has worse spatial resolution then ERAM2 at 360V

Tension?



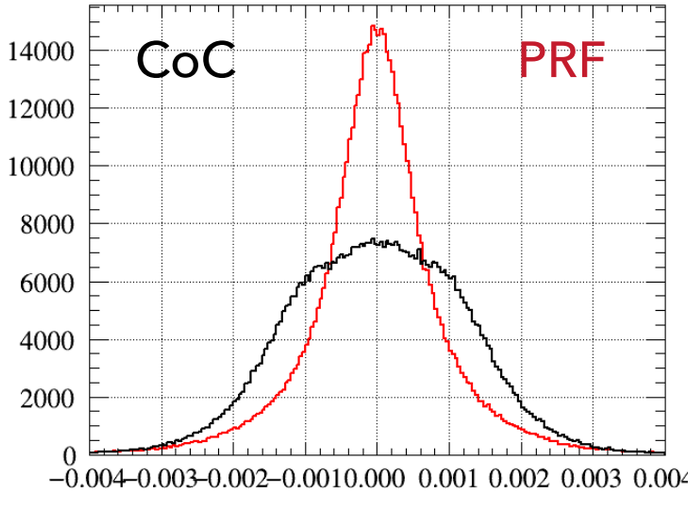




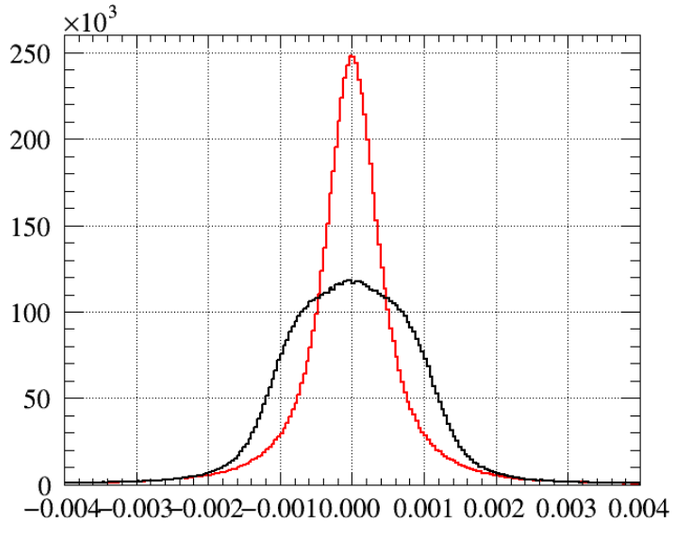


- Residuals:

MM1 380V



ERAM2 360V



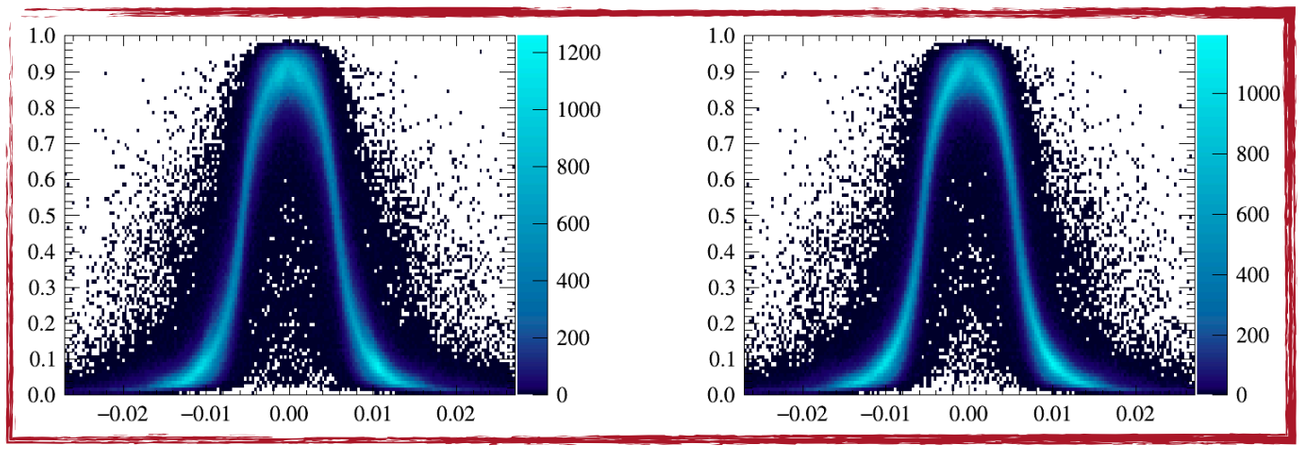
PRF affects both detectors in a similar way

It's not a method feature!

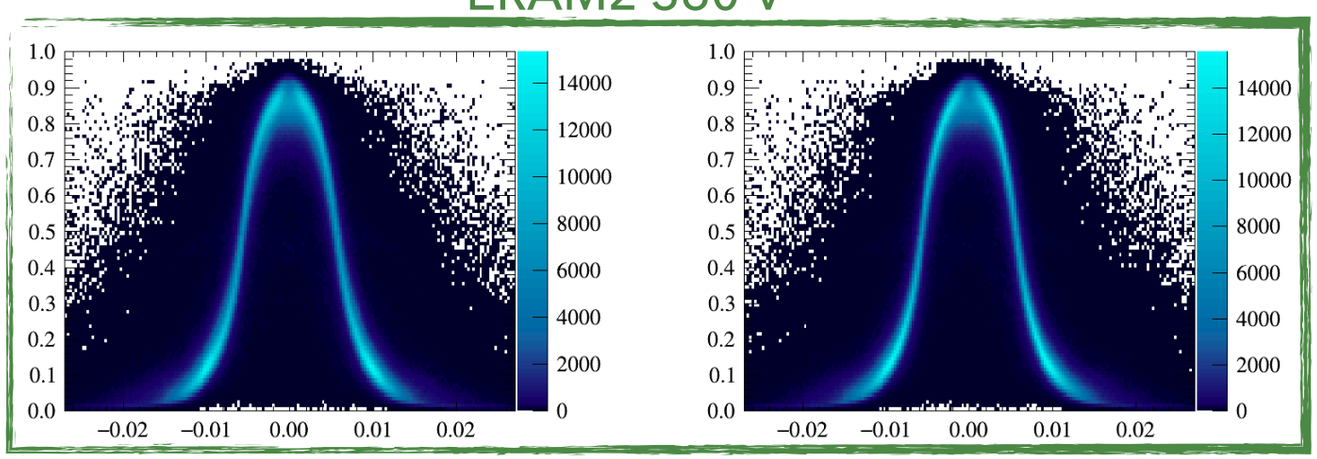
MM1 VS ERAM2

- PRF is **not** dramatically better for ERAM2

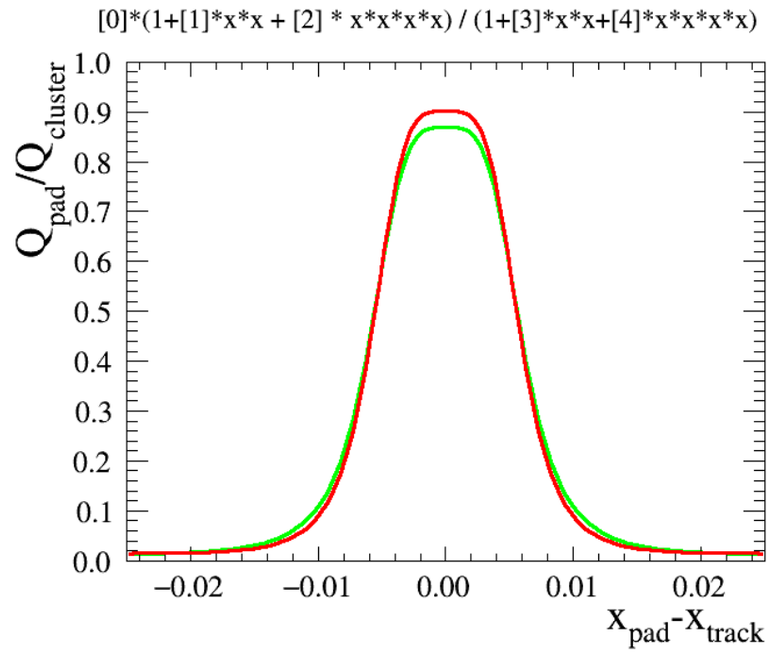
Iter 0 MM1 380V Iter 15



ERAM2 360 V



PRF function fit
at 15th iteration



- Both scattered plot and analytical function don't look different