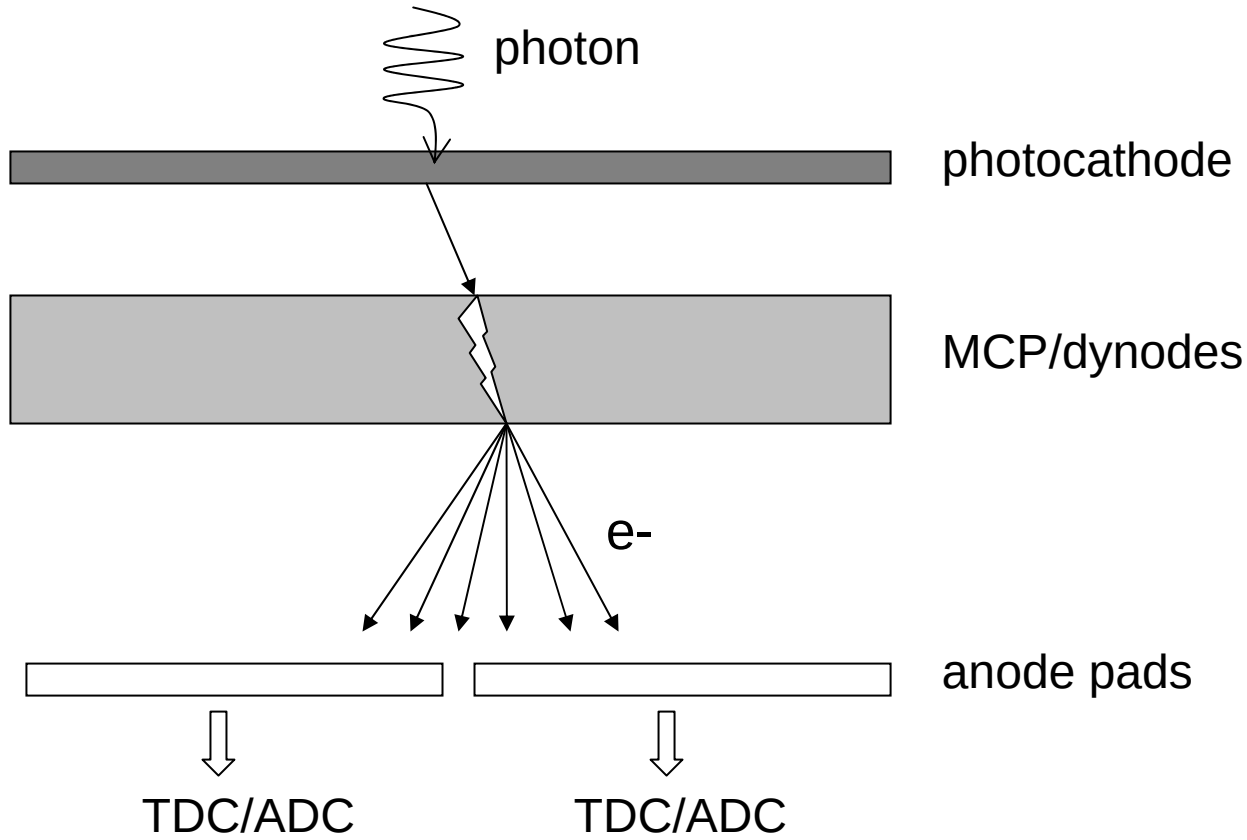
Development of a pad interpolation algorithm using charge-sharing

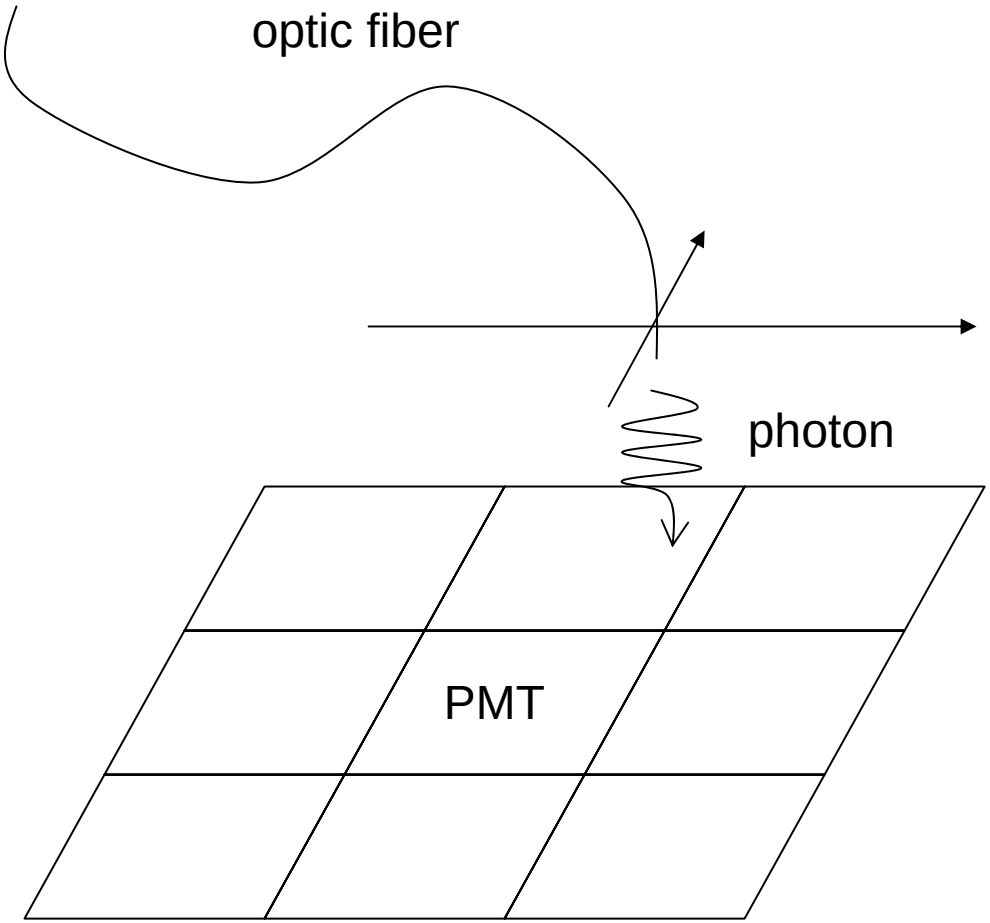
Charge sharing between two pads

- When a photon hits the MCP between two pads, the avalanches shares the charge to two pads.
- We want to find a method to determine the photon position for this type of events using both TDC and ADC information from the two pads.



PMT scan configuration

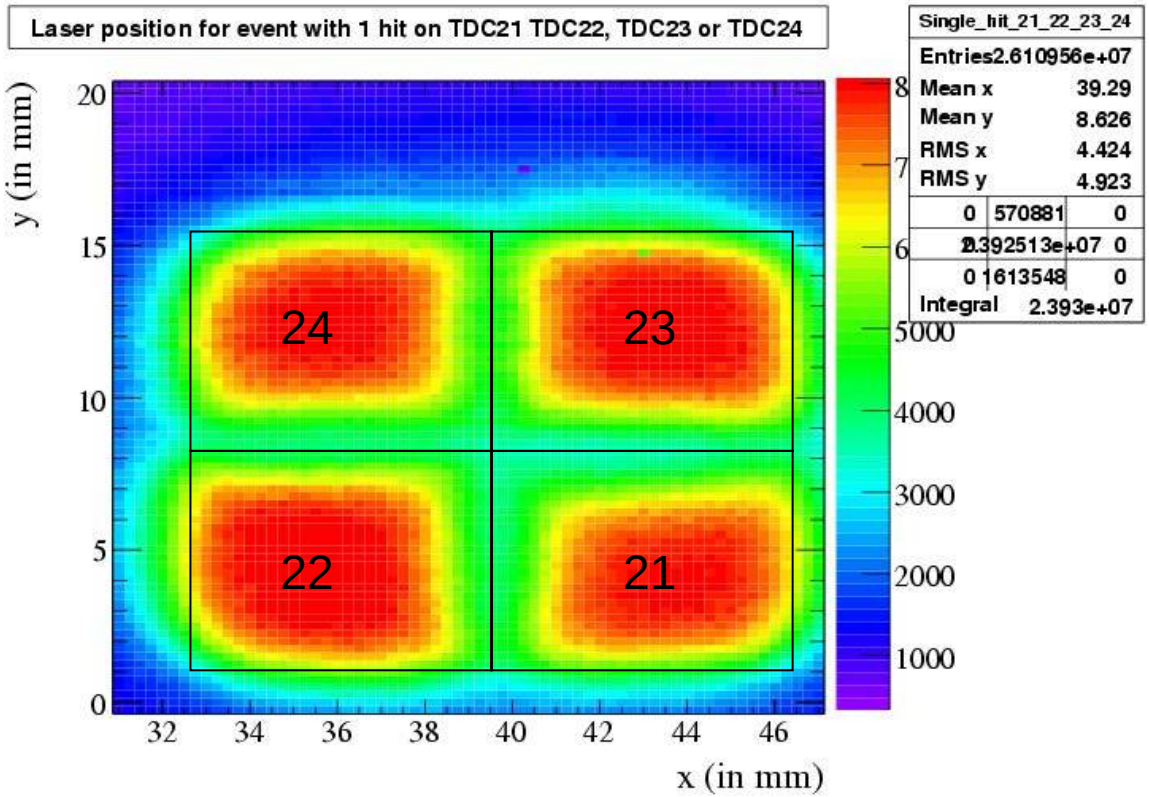
- For PMT scan, the photon are sent by an optic fiber positioned with a precision of few microns. So, we know where the photons hits the pad with an high precision.
- In addition, for each trigger we measure TDC and ADC values. If a TDC value is within a certain window (650 - 900 counts), we call it an event (a photon hit).



Position of laser for single TDC hit

(no ADC information used)

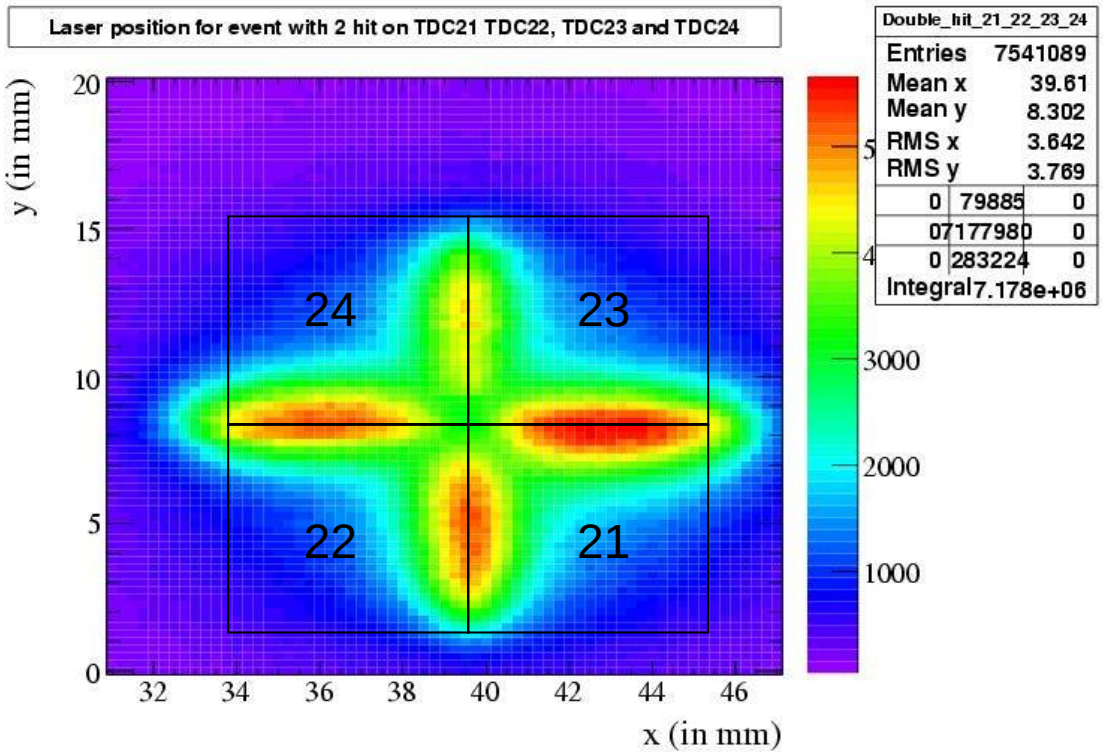
- I have plotted the position of the laser for events with a single TDC hit.
- On the border of each pad, there are fewer single events (probably multiple events).
- Region outside of 4-pad region (blue color) is due (a) photon scatters in the lens optics, or (b) avalanche charge sharing.



Position of laser for double TDC hit

(no ADC information used)

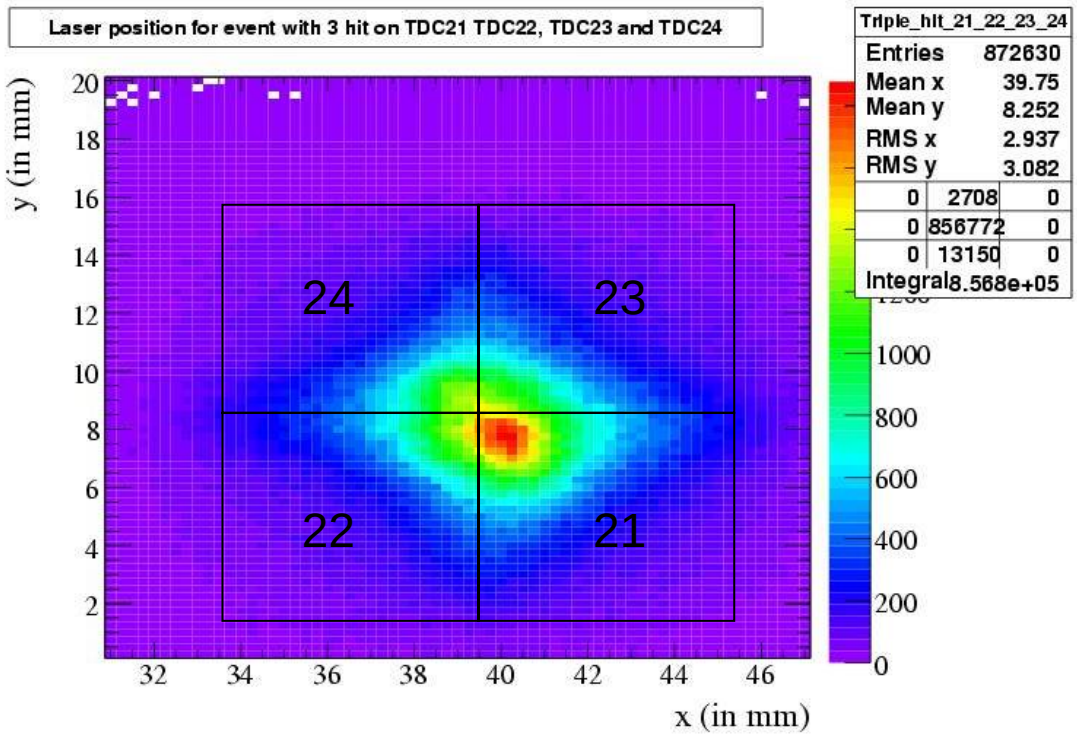
- If two TDC fire at the same time on two pads, I plot one event at the position of the laser beam.
- These types of events happen near the border between two pads.
- In the center of 4 pads, there is less of double events (there is probably triple and quadruple events).



Position of laser for triple TDC hit

(no ADC information used)

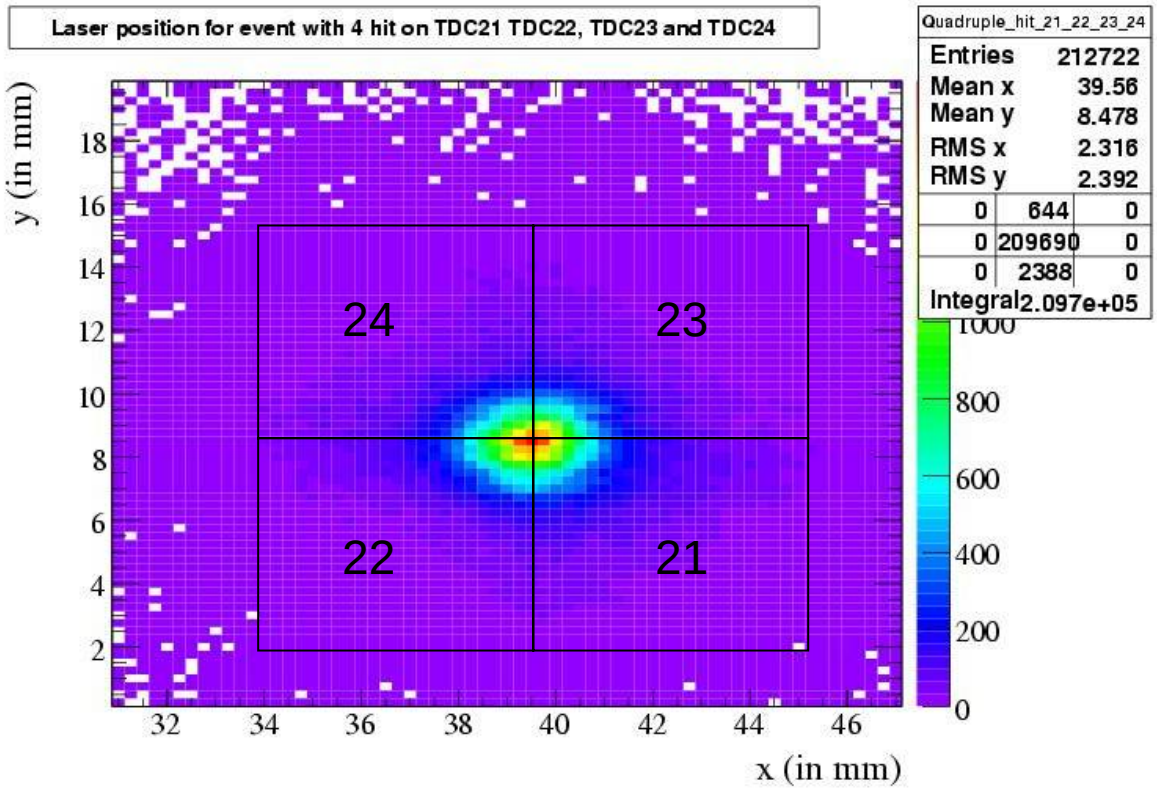
- Triple TDC events happen near the center of the four pad.
- Triple events represent only 10.1% of all multiple events.



Position of laser for quadruple TDC hit

(no ADC information used)

- Quadruple TDC events happen near the center of the four pad.
- Quadruple events represents only 2.5% of all multiple events.

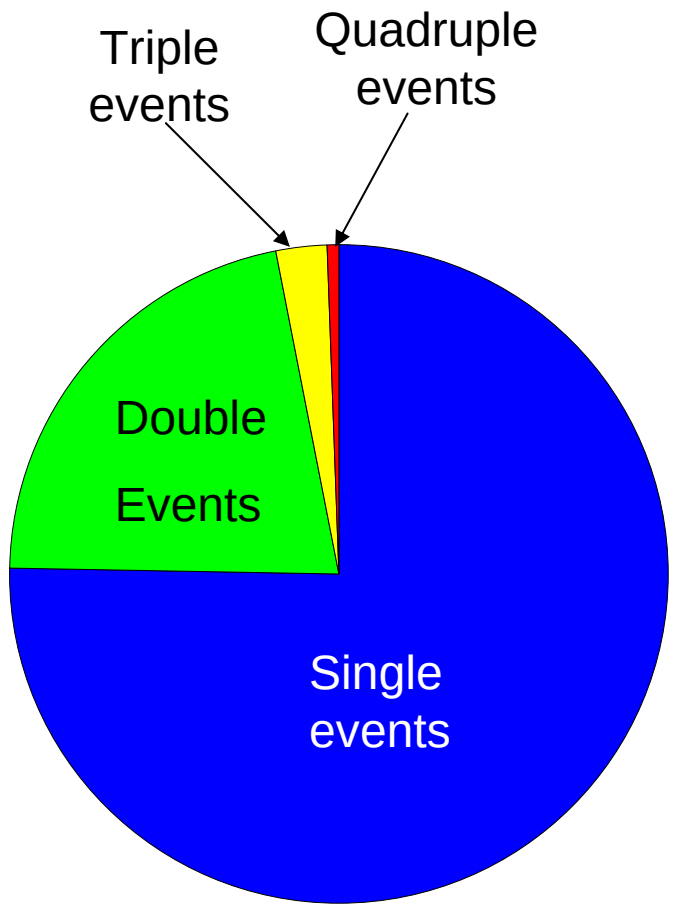


Statistics on TDC events multiplicity

(no ADC information used)

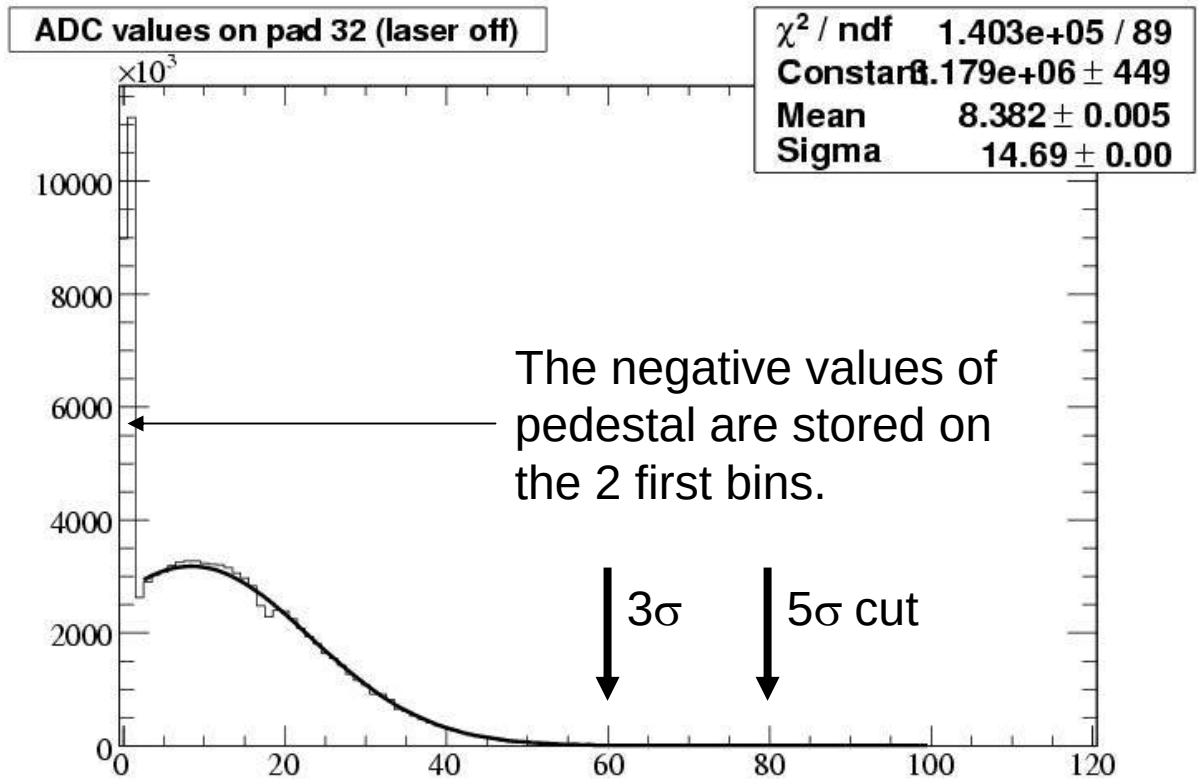
Multiplicity	Number of events	Proportion
1	26 109 560	75.17 %
2	7 541 089	21.71 %
3	872 630	2.51 %
4	212 722	0.61 %

- There is a considerable fraction of double events due to the charge sharing. Therefore, it would be useful to use them to improve the photon hit position.
- Concerning triple and quadruple hit, there are few. It's probably sufficient to consider that photon have hit middle of the 4 pads.



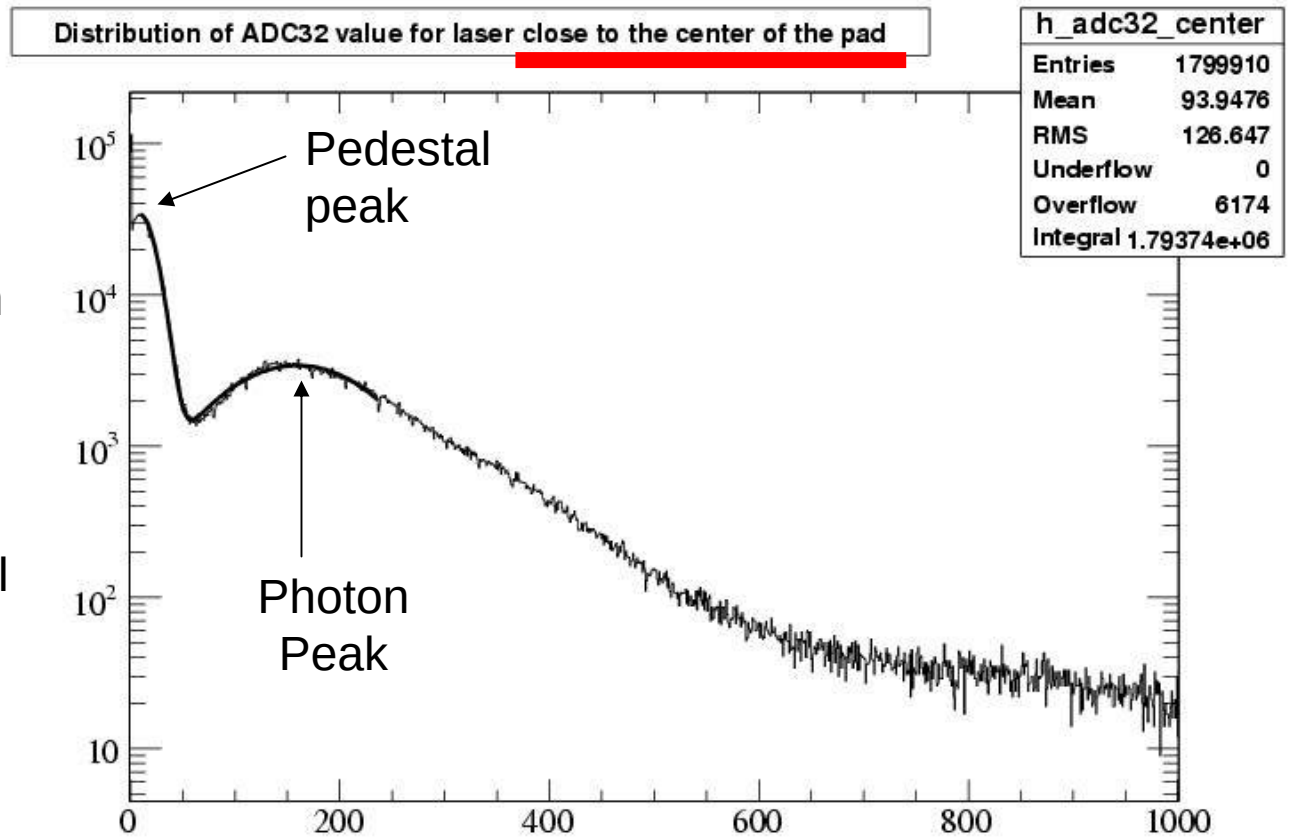
ADC pedestal fit

- I have used the scan 20, where a laser light is blocked, although the laser is on. It measures a pedestal distribution.
- I fit the pedestal distribution for each pad with a ROOT macro and store the results in a file.



Gain measurement

- I fit the ADC distribution of scan 27 with a sum of two gaussian function.
- The first gaussian has only one free parameter (amplitude), the other parameter are parameters found for pedestal run.
- All the second gaussian parameters are free, but their start values are choose in order to catch the ADC peak.

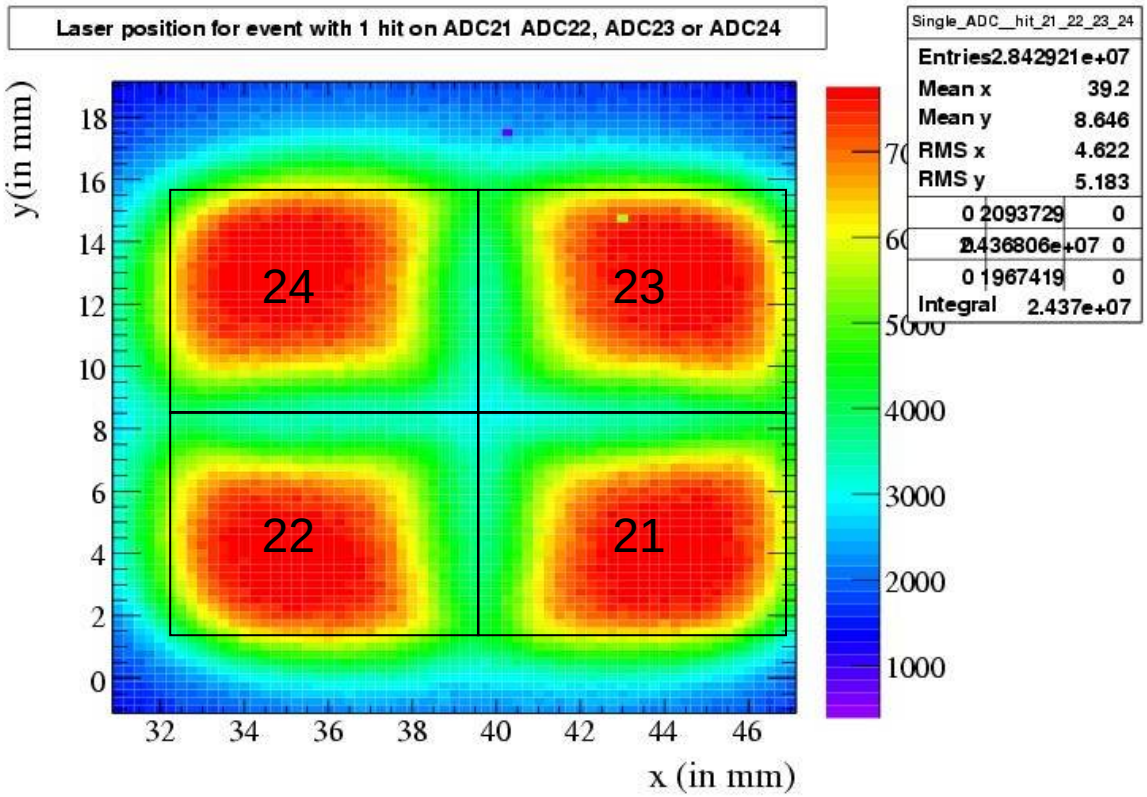


Gain = photon peak position – pedestal peak position

Position of laser for single ADC hit

(no TDC information used)

- I have plotted the position of the laser for events with a single ADC hit above the cut.
- On the border of each pad, there are fewer single events (probably multiple events).
- Region outside of 4-pad region (blue color) is due (a) photon scatters in the lens optics, or (b) avalanche charge sharing.

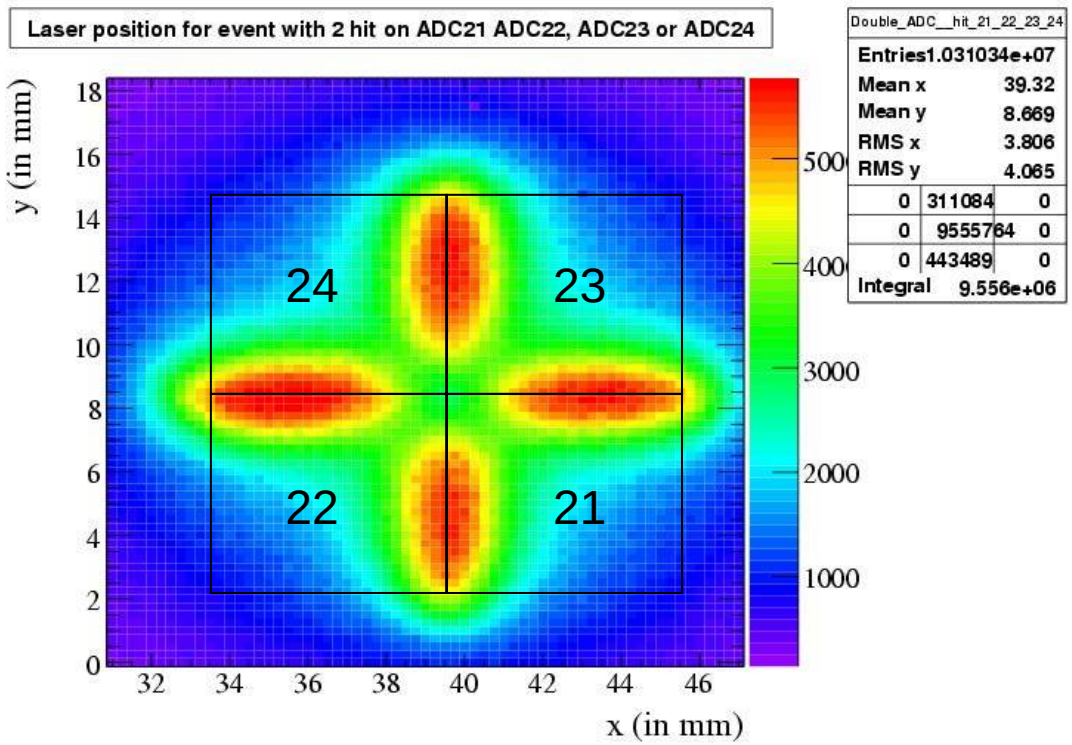


ADC Cut = 3σ

Position of laser for double ADC hit

(no TDC information used)

- If two ADC above the cut fire at the same time on two pads, I plot one event at the position of the laser beam.
- These types of events happen near the border between two pads.
- In the center of 4 pads, there is less double events (there is probably triple and quadruple events).

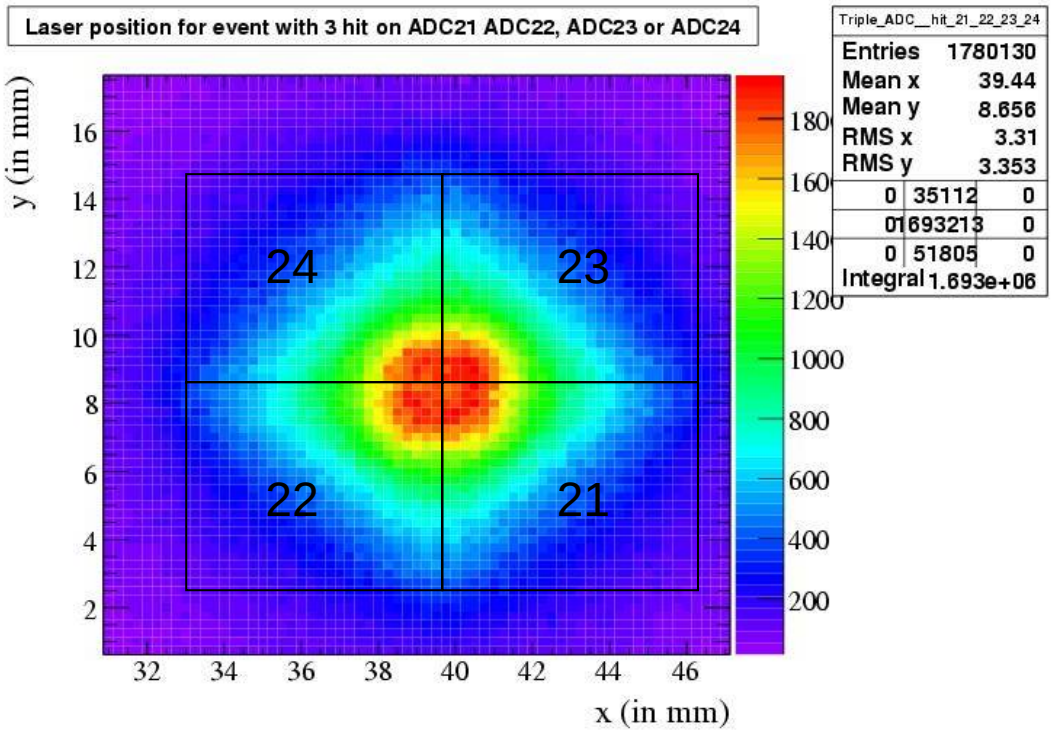


ADC Cut = 3σ

Position of laser for triple ADC hit

(no TDC information used)

- If three ADC above the cut fire at the same time on three pads, I plot one event at the position of the laser beam.

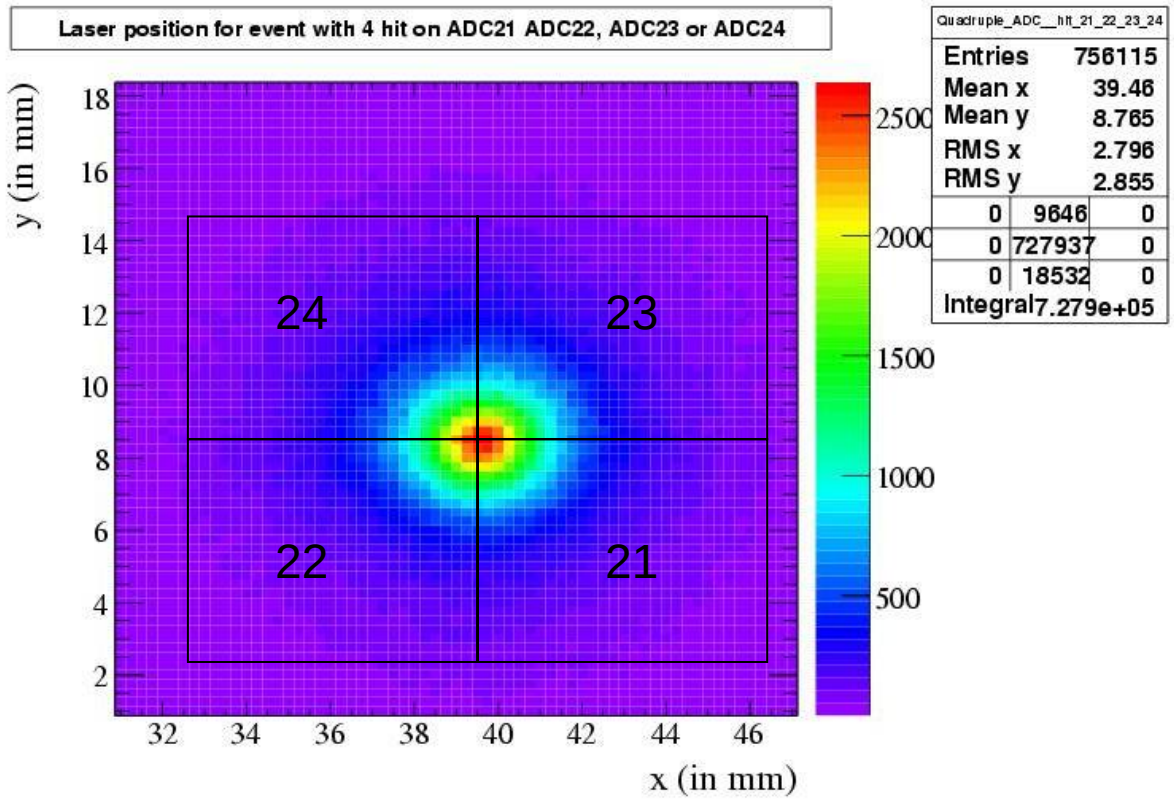


ADC Cut = 3σ

Position of laser for quadruple ADC hit

(no TDC information used)

- If four ADC above the cut fire at the same time on four pads, I plot one event at the position of the laser beam.



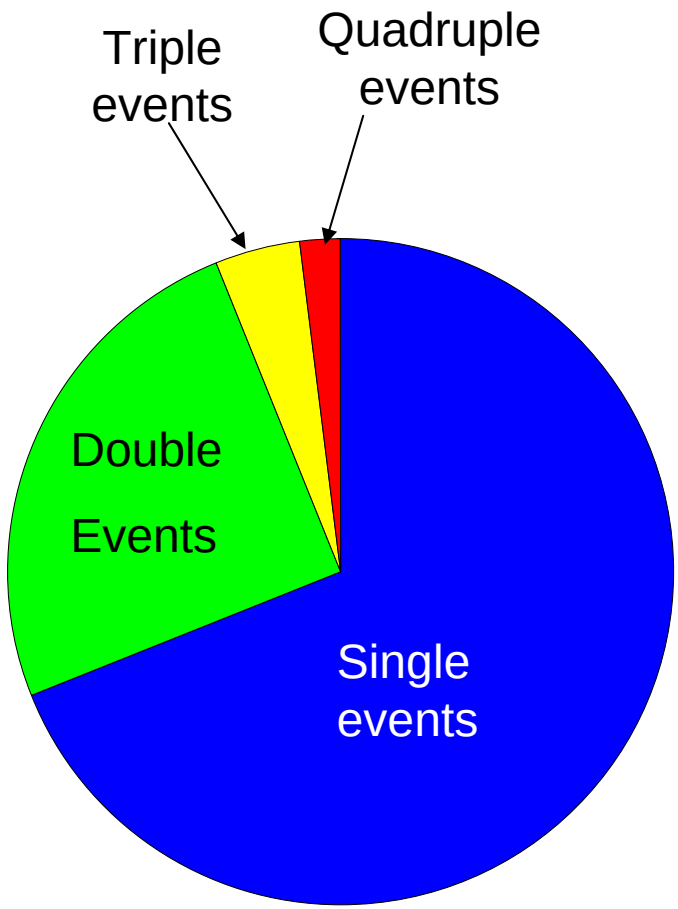
ADC Cut = 3σ

Statistics on ADC events multiplicity

(no TDC information used)

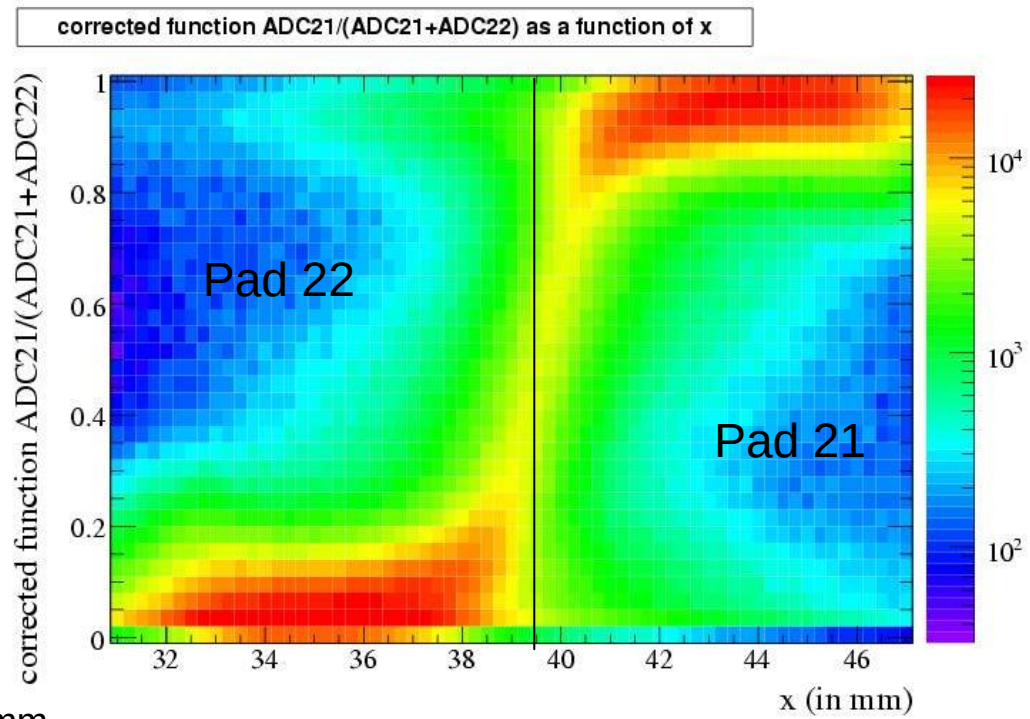
Multiplicity	Number of events	Proportion
1	28 429 210	68.88 %
2	10 310 340	24.98 %
3	1 780 130	4.31 %
4	756 115	1.83 %

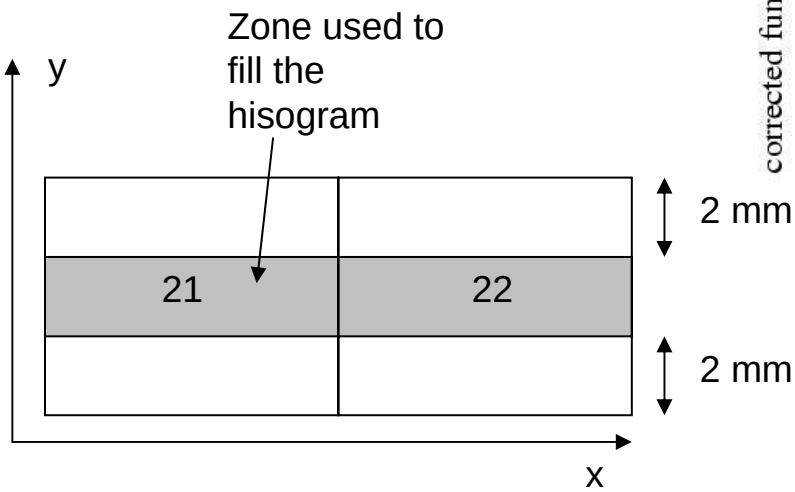
- The proportion of multiple hit is more important for ADC.
- So, if there is a TDC hit only, it would be useful to use the ADC in order to find with a better precision, where is the photon.



Study of corrected function ADC21/(ADC22+ADC21) = f(x)

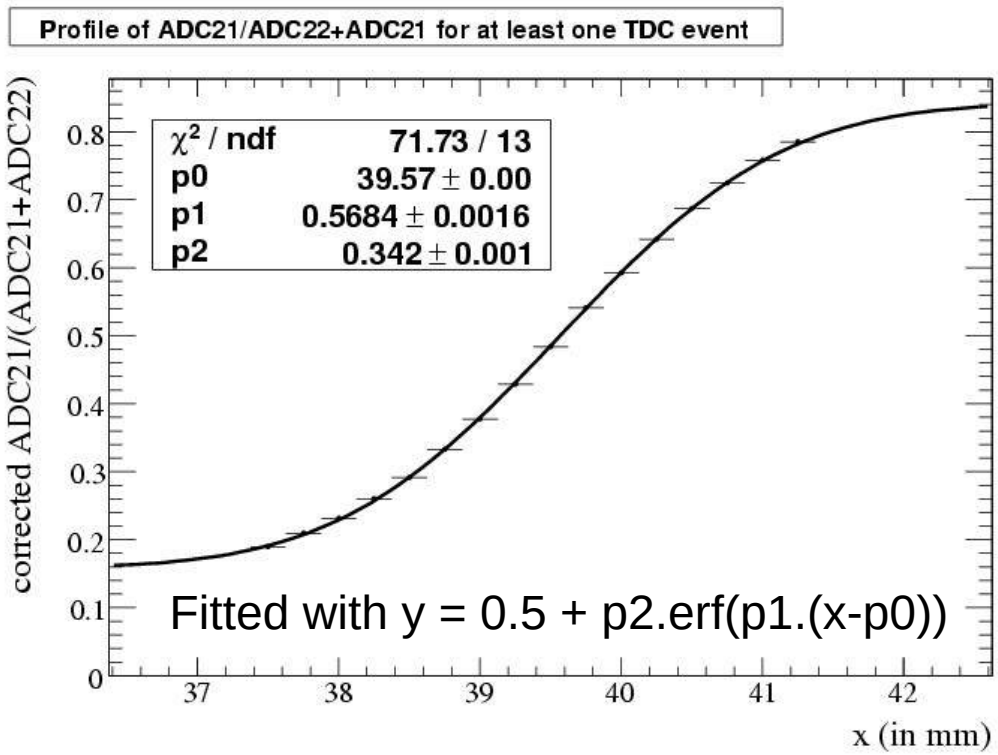
- Each ADC value is corrected with a formula: ADC_{cor} = (ADC-Pedestal Peak Position)/Gain
- Events are cut if the ADC of the two pads are under 5σ ADC cut.





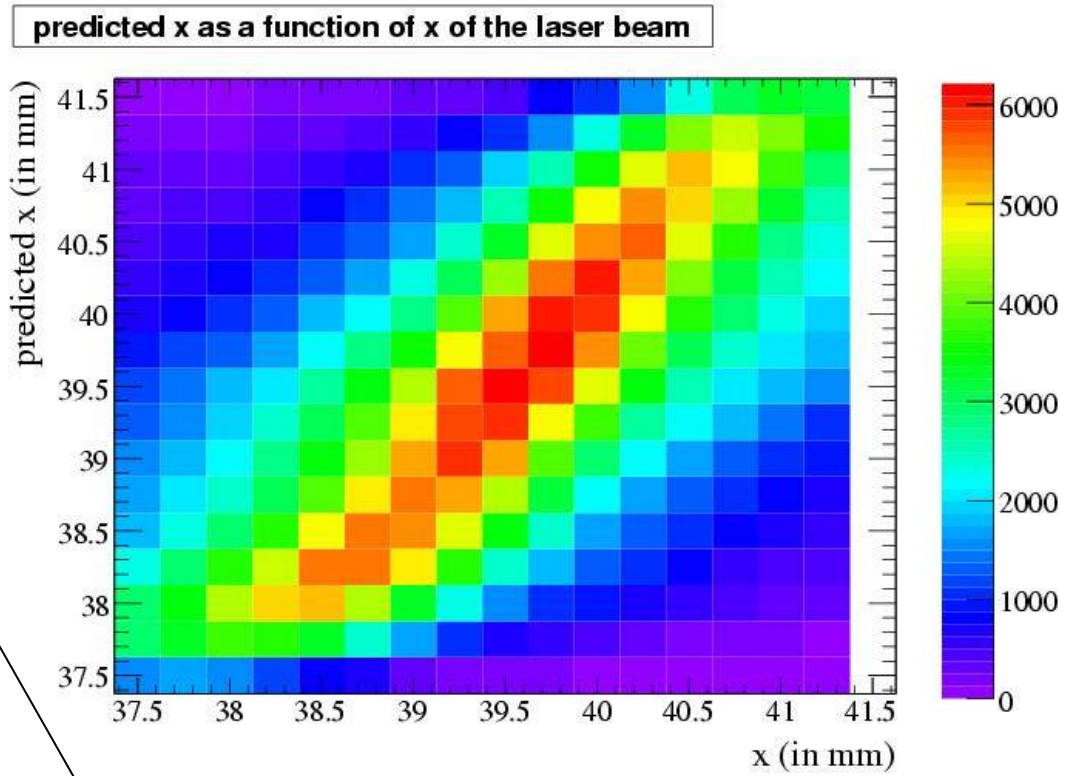
Fit of corrected function ADC21/(ADC22+ADC21) = f(x)

- I have extract the profile function of the previous graph on a 2mm range around the border in order to have only the ratio of ADC as a function of x or y (depends of the border choose).
- For different pads, p1 varies between 0.51 and 0.61. ps varies between 0.35 and 0.44.
- I have generated a file containing the results of fits of all borders (Fit_Profile.txt).
- Events are cut if the ADC of the two pads are under 5σ ADC cut.

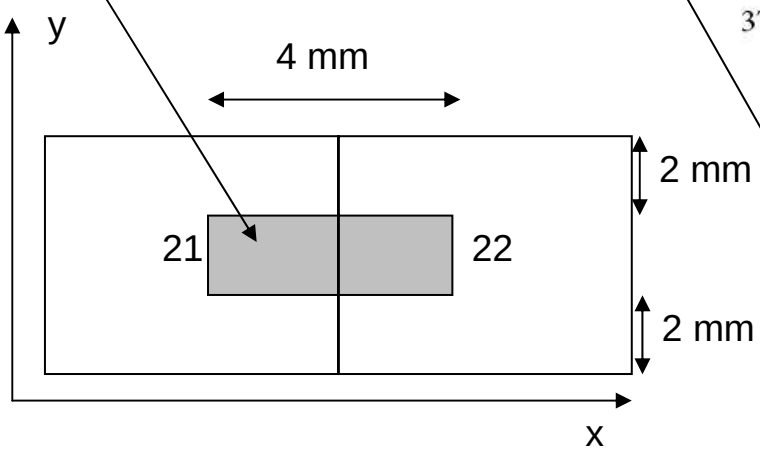


Test of interpolation

- An event is interpolated if there is a TDC hit on pad 21 or 22 and ADC 21 and ADC 22 pass a 3σ ADC cut. There is a cut on the ADC Ratio (0.1<Ratio<0.9).



Zone used to fill the histogram

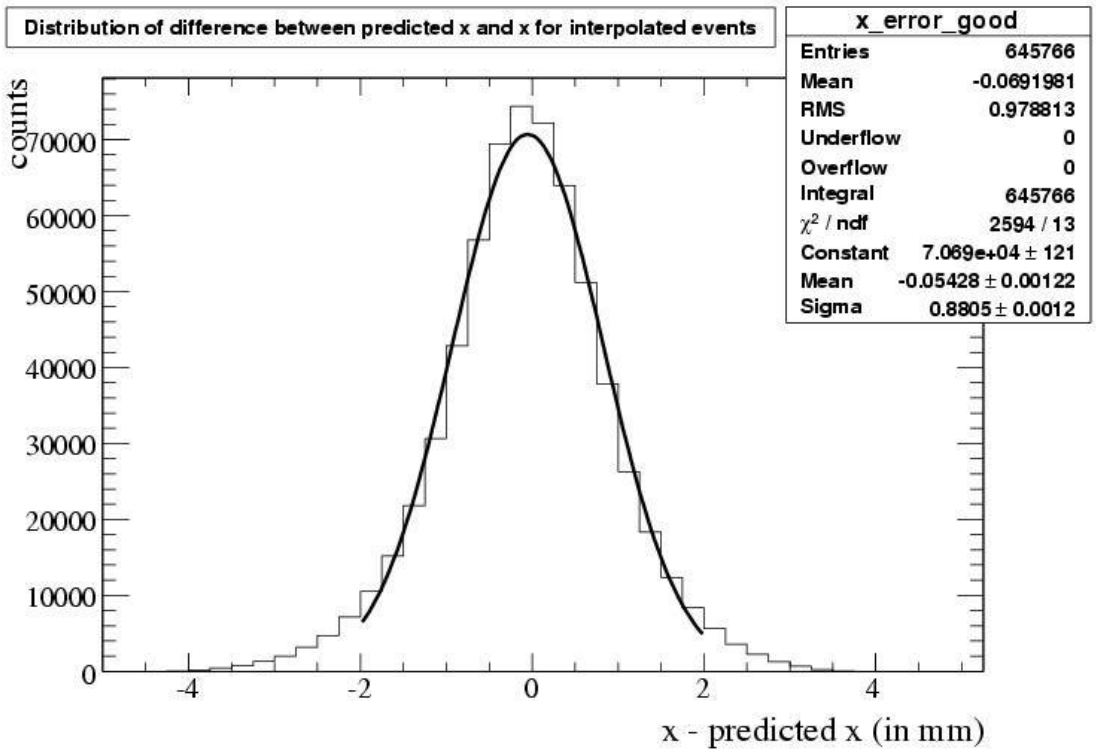


Ratio = ADC21cor/(ADC21cor+ADC22cor)

$x_{predicted} = 39.57 + erf^{-1}((Ratio-0.5)/0.5684)/0.342$

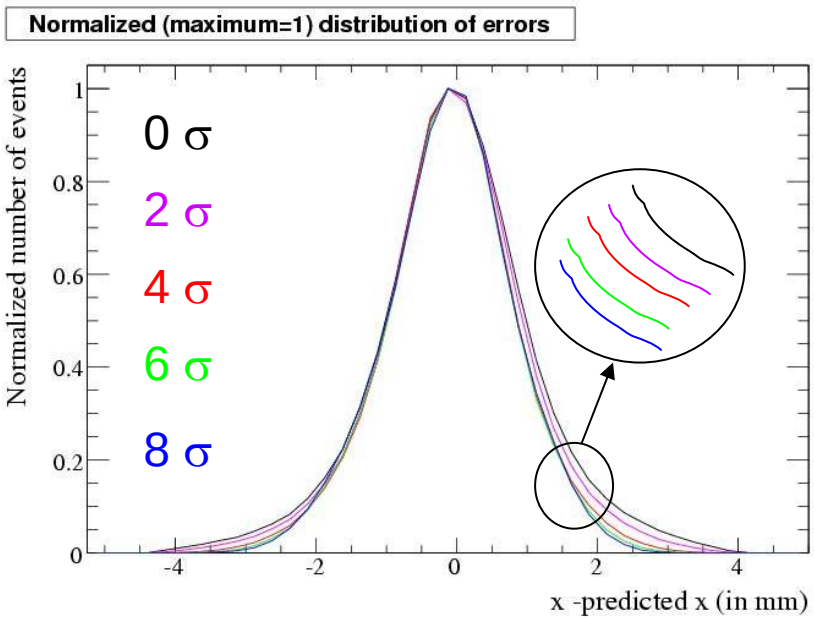
Estimation of error on x

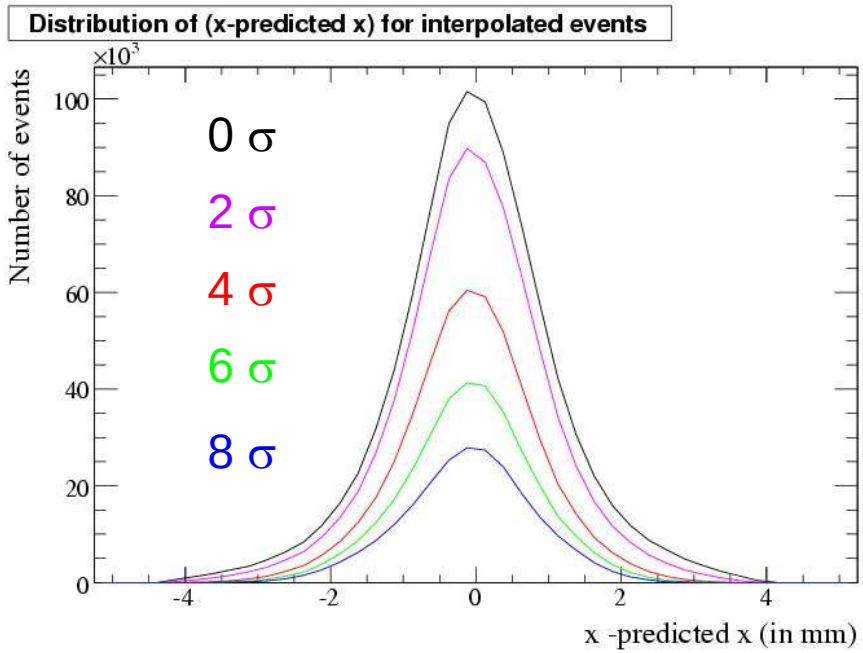
- The cut are the same as in the previous slide.
- The error is more little than 1mm. Consequently, the precision is significantly better than the size of a pad.
- The error distribution is not a gaussian. There is a large tail due to (a) photon scatters in the lens optics, or (b) avalanche charge sharing, or (c) a S/N ratio.



Effet of S/N on the tail

- When cut on pulse height (ADC) increases, a number of events decreases and a tail of the distribution becomes shorter.
- A compromise have to be done on pulse height (ADC) cut.





- A large tail corresponds to poor S/N ratio, which corresponds to small pulse heights.

Conclusion

- 90% of multiple hit are double hit.
- Double hit are essentially localized near the border of 2 pads.
- In order to improve the measurement of photon position, it’s possible to use ADC information if the photon hit near a border.
- The error made with this method is typically 0.9 mm.