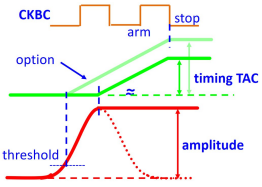
Mu2E time calibration status, 2024-08-06

SPD Tracker group

August 6, 2024

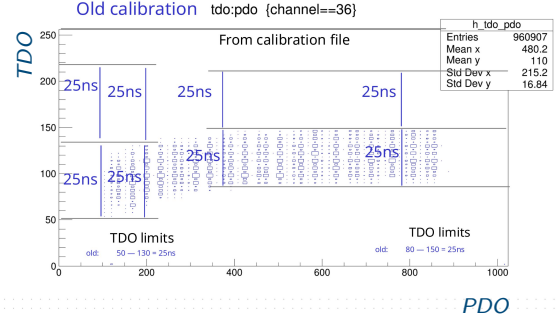
Current calibration: TDO

Time calculation: $t = BCID \cdot 25ns - \left(\frac{TDO - TDO_{min}}{TDO_{max} - TDO_{min}}\right) \cdot 25ns$, where:

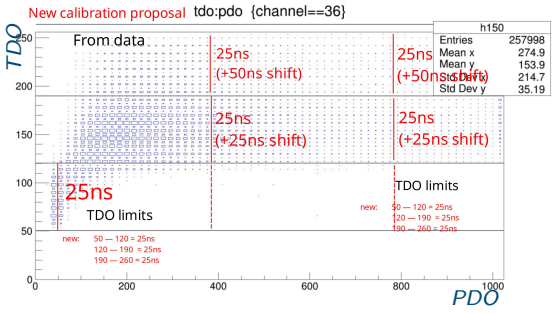


- BCID – 12-bit 25ns counter, common for all channels, does not require calibration
- TDO – 8-bit (?), correspond the time between threshold crossing and the first BCID clock after peak, need calibration
- Current TDO calibration: linear function with TDO_{min} as the moment of BCID change, and TDO_{max} as the 25ns to BCID clock

Current calibration



VB and VM proposal

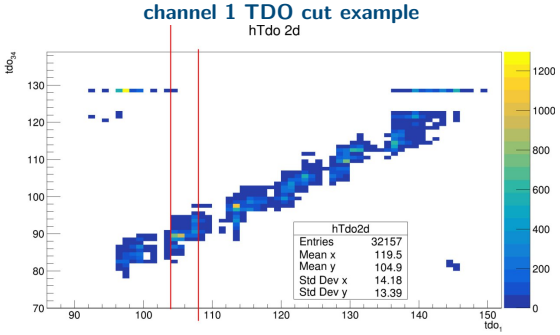


TDO time calibration method

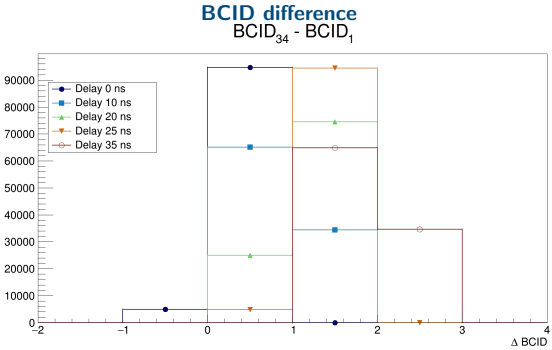
We want to calibrate TDO to ns: $t = BCID \cdot 25ns - f_{cal}(TDO, PDO)$, where: f_{cal} – calibration function
There is a way to construct f_{cal} to have time not to the $BCID$ clock itself, but to the some constant time prior $BCID$ clock

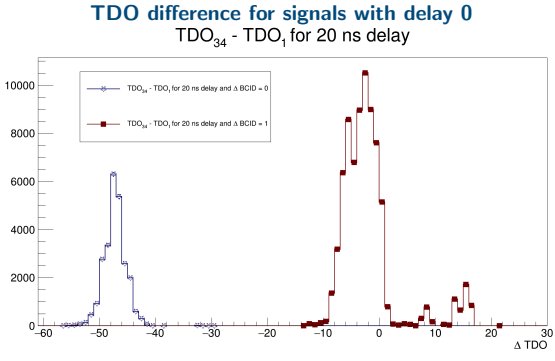
Method:

1. Select two channels (for example, channels 1 and 34)
2. Send "straw-like" signals (see slide 19) to both channels:
   - Synchronious signals to both channels with delay in range $[0, 75]$ ns
   - For channel 1: constant shape, constant charge
   - For channel 34: constant shape
3. Select events with constant time to BCID clock by applying cut to channel 1 TDO
   cut: $TDO_{ch1} = 105$
4. Check the channel 34 TDO for those events (see slide 6)
5. Check the calibrations for different $\Delta BCID$ (see slide 8)
6. Construct BCID-independent TDO calibration (see slide 9)



BCID and TDO diffrence

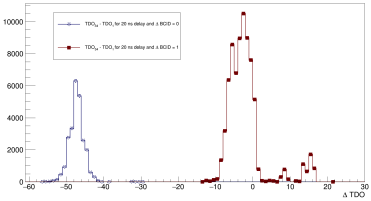




- Blue: $\Delta BCID = 0$
- Brown: $\Delta BCID = 1$

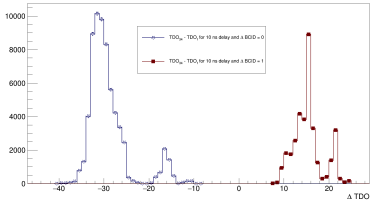
BCID and TDO diffrence

TDO difference for signals with delay 0



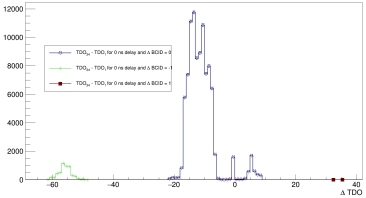
- Blue: $\Delta BCID = 0$
- Brown: $\Delta BCID = 1$

TDO difference for signals with delay 10



- Blue: $\Delta BCID = 0$
- Brown: $\Delta BCID = 1$

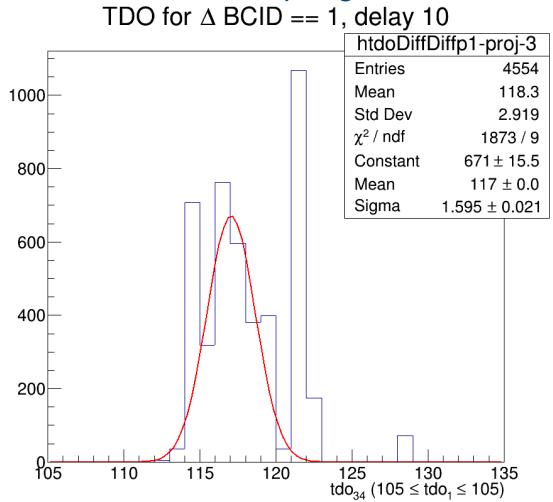
TDO difference for signals with delay 20



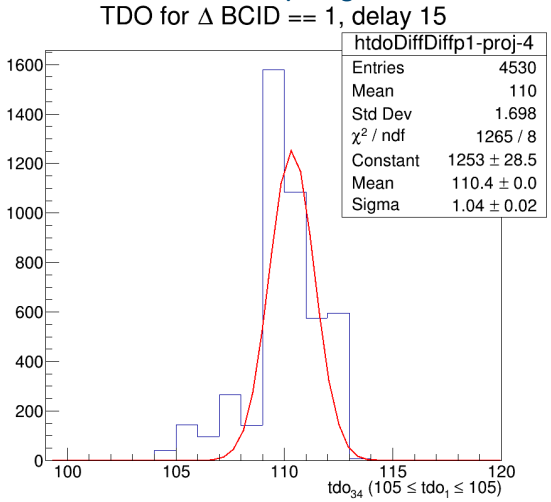
- Blue: $\Delta BCID = 0$
- Brown: $\Delta BCID = 1$
- Green: $\Delta BCID = -1$

TDO fit examples, channel 34 signal charge 210fC

TDO fit example – good ?



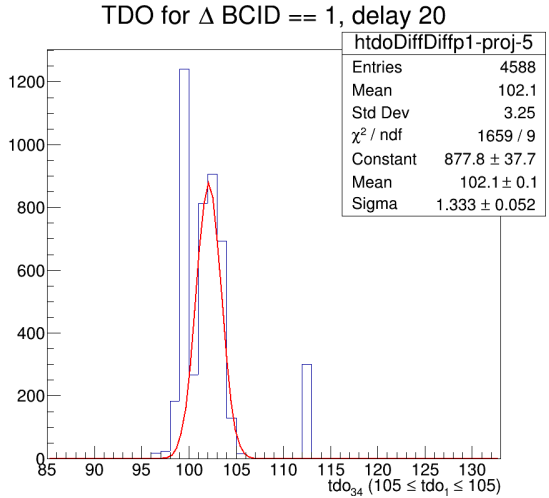
TDO fit example – good ?



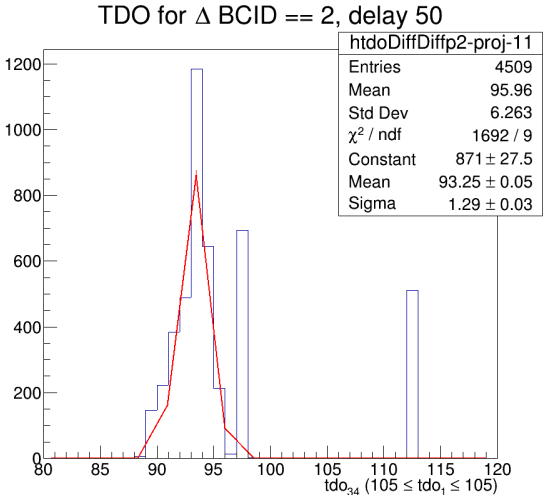
Seems, ADC has less then 8 bit, 5 bit?

TDO fit examples, channel 34 signal charge 210fC

TDO fit example – not-so-good



TDO fit example – not-so-good

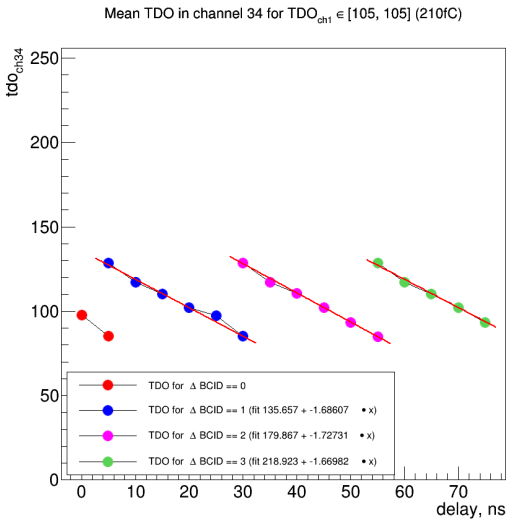


Seems, ADC has less then 8 bit. 5 bit?

Calibration results, channel 34 signal charge 210fC

- We know, that each line (for each $\Delta BCID$) shifted to the 1 $BCID$, which correspond to the TDO window size
- That mean, we can estimate TDO window as the difference between p0 (free parameter) between fit results (see right)
- Also, TDO dependence of the delay shoulde be independent of $\Delta BCID$, since the signal shape stays the same
- So, we need to reconstruct that dependence for the events with the $\Delta BCID = 0$

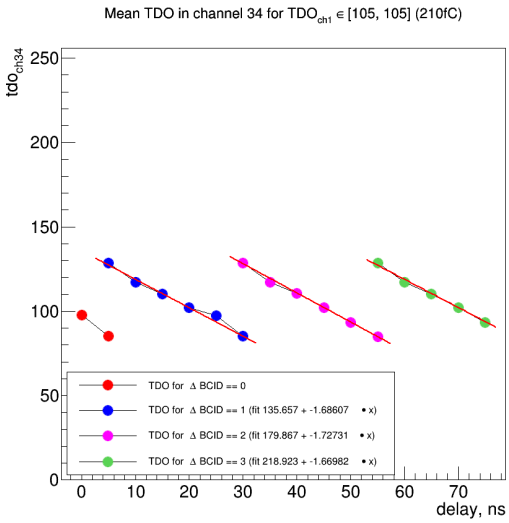
Results for different $\Delta BCID$ fitted with pol1



Calibration results, channel 34 signal charge 210fC

- So, we need to reconstruct that dependence for the events with the $\Delta BCID = 0$
- That can be done by:
  - Or shifting all points left to $25 \cdot \Delta BCID$ ns
  - Or shifting all points down to $TDO_{window} \cdot \Delta BCID$
- The global fit can be estimated as mean $pol1$ between all fitted dependences ?

Results for different $\Delta BCID$ fitted with pol1

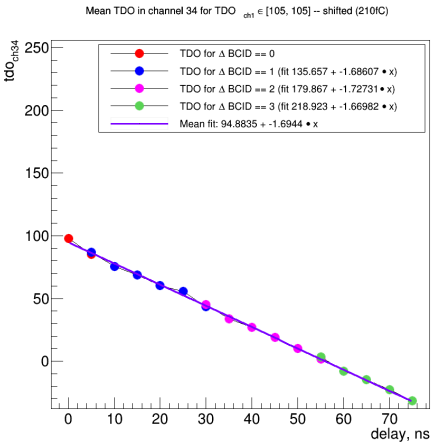


Calibration results, channel 34 signal charge 210fC

NOT ACTUAL. See page 10

- The method "shifting all points down to $TDO_{window} \cdot \Delta BCID$" was used
- The global fit can estimated as mean $pol1$ between all fitted dependences

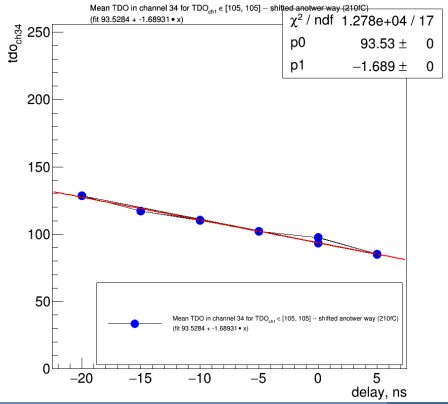
Results after shift down (for events with $\Delta BCID = 0$)



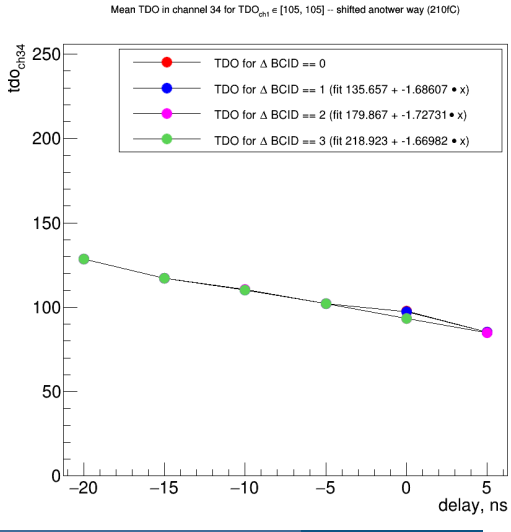
Calibration results, channel 34 signal charge 210fC

- The method "shifting all points left to $25 \cdot \Delta BCID$ ns" was used
- The global fit can be done *pol*1 from all points

Fit result

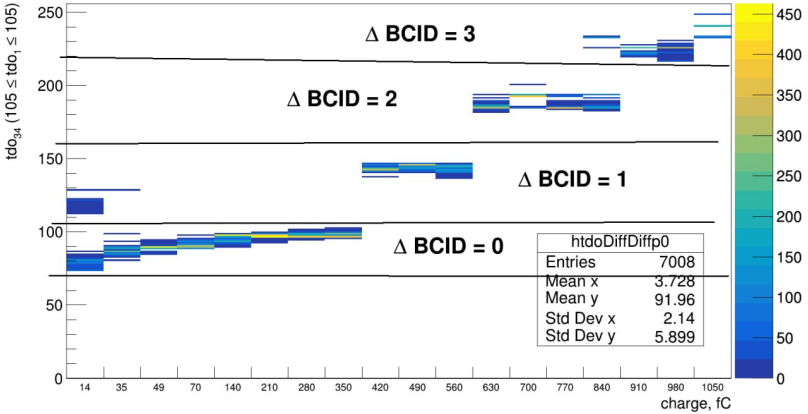


Results after shift left (for events with $\Delta BCID = 0$)



Charge dependence

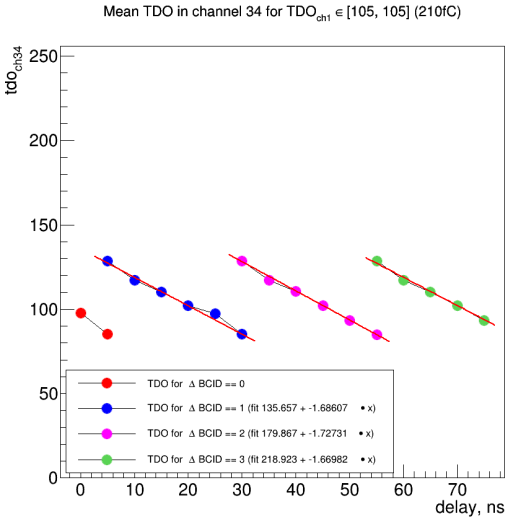
Channel 34 TDO for different charge



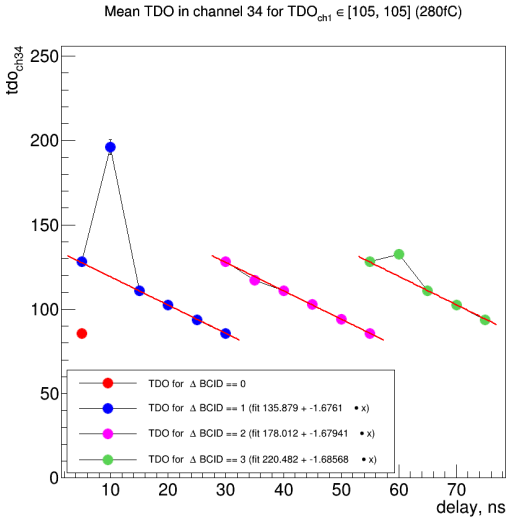
- There is a dependence for the signals with charge lower 200fC (time walk)
- No significant dependence for "high" signals (above 350 fC)

Charge dependence

Results for channel 34 signal with charge 210fC

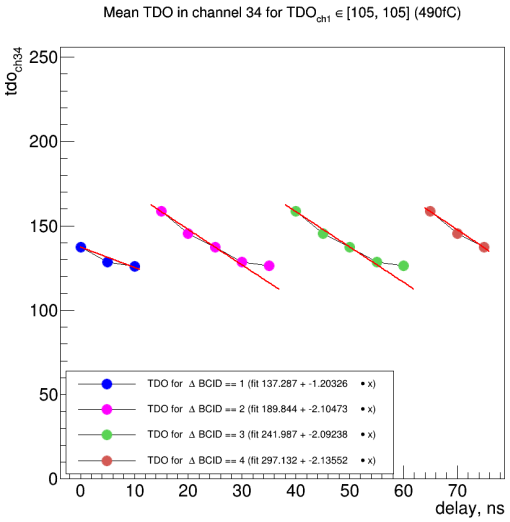


Results for channel 34 signal with charge 280fC

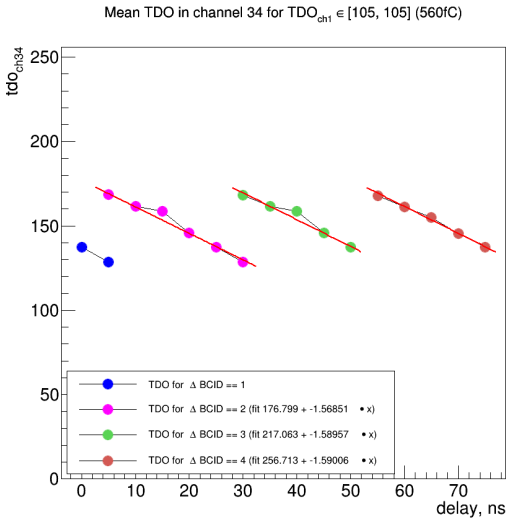


Charge dependence

Results for channel 34 signal with charge 490fC

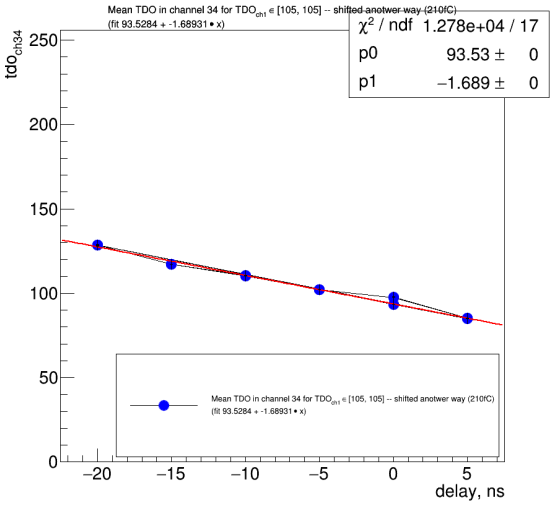


Results for channel 34 signal with charge 560fC

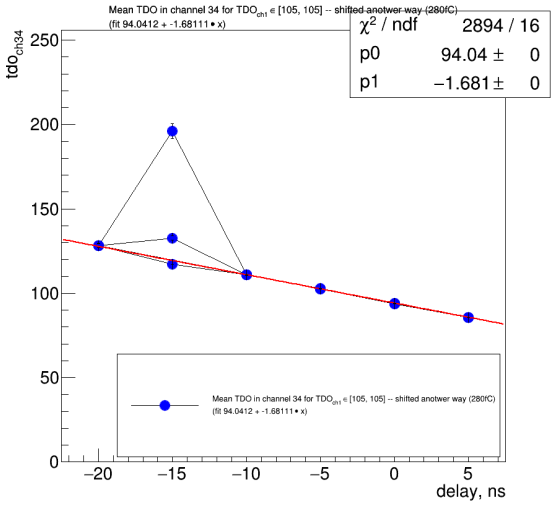


Charge dependence

Results for channel 34 signal with charge 210fC

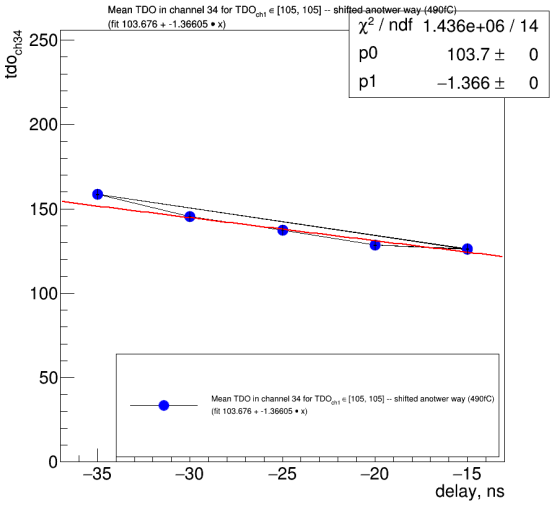


Results for channel 34 signal with charge 280fC

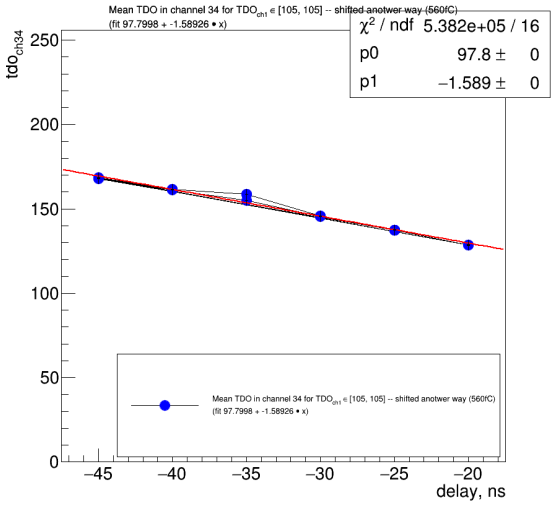


Charge dependence

Results for channel 34 signal with charge 490fC

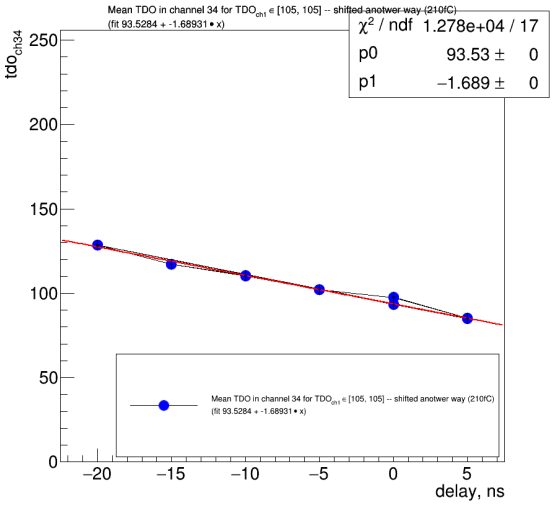


Results for channel 34 signal with charge 560fC

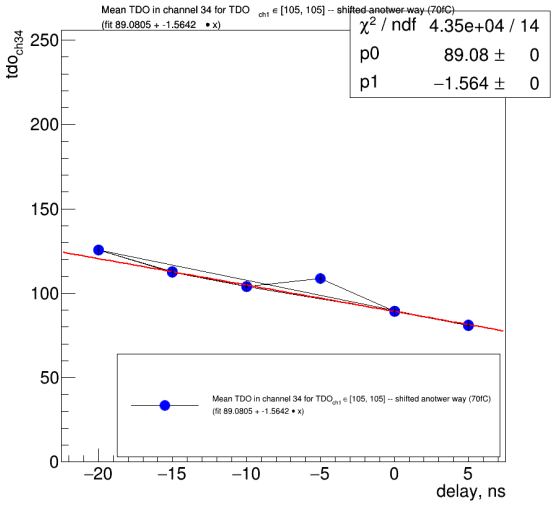


Charge dependence – small charges

Results for channel 34 signal with charge 210fC



Results for channel 34 signal with charge 70fC



Charge dependence – table

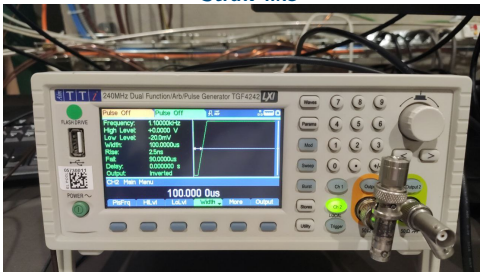
pol1 fit results for different charges

Charge	p0	p1
70 fC	89.08	−1.56
210 fC	93.53	−1.69
280 fC	94.04	−1.68
490 fC	~~103.7~~	~~−1.37~~
560 fC	97.8	−1.59

Backup slides

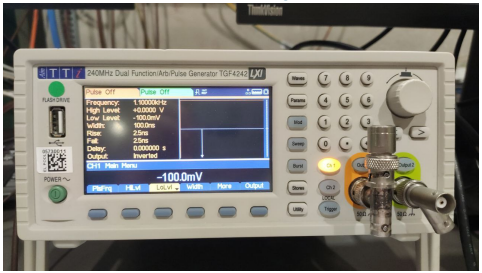
Test signal examples

Straw-like



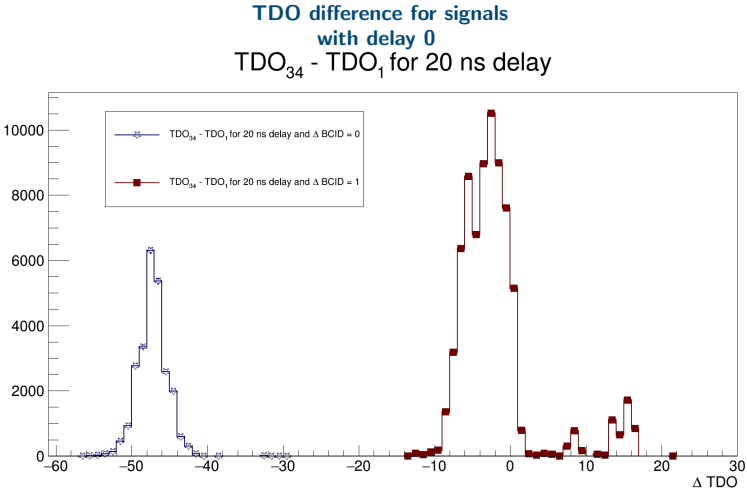
- High level: 0
- Low level: variable
- Width: 100 μs
- Rise edge: 2.5 *ns*
- Fall edge: 900 μs
- Output: inverted

NIM-like



- High level: 0
- Low level: variable (-100 mV / -700 mV)
- Width: 100 *ns*
- Rise edge: 2.5 *ns*
- Fall edge: 2.5 *ns*
- Output: inverted

BCID and TDO diffrence



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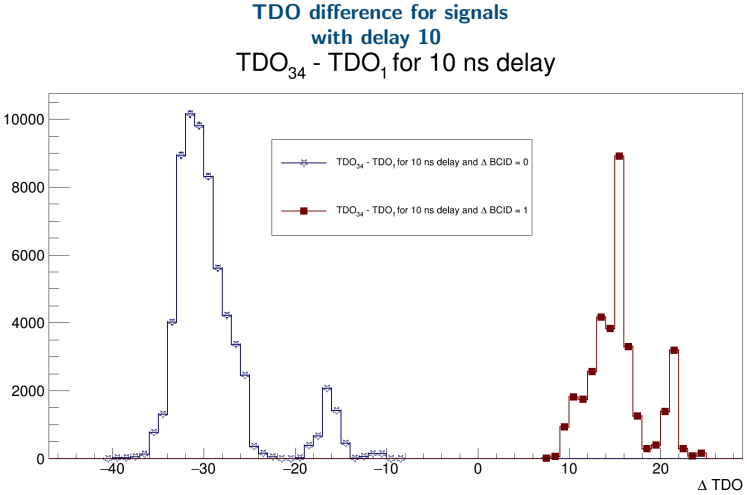
BCID and TDO diffrence



- Blue: $\Delta BCID = 0$
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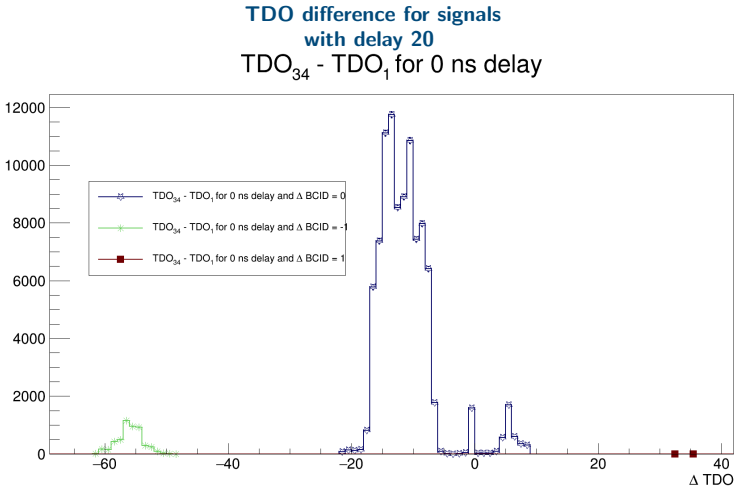
BCID and TDO diffrence



- Blue: $\Delta BCID = 0$
- Brown: $\Delta BCID = 1$
- Green: $\Delta BCID = -1$

PDO for 3mV/fC, 25ns