

ProtoDUNE-SP photon calibration and timing study using Michel events

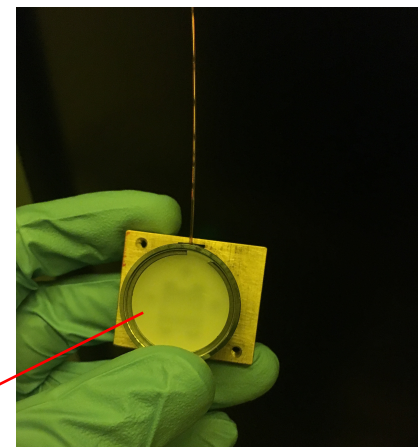
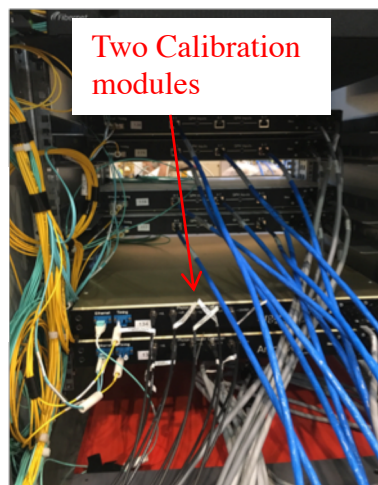
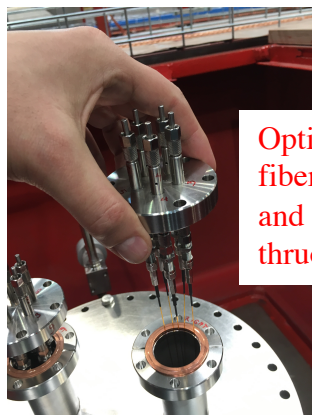
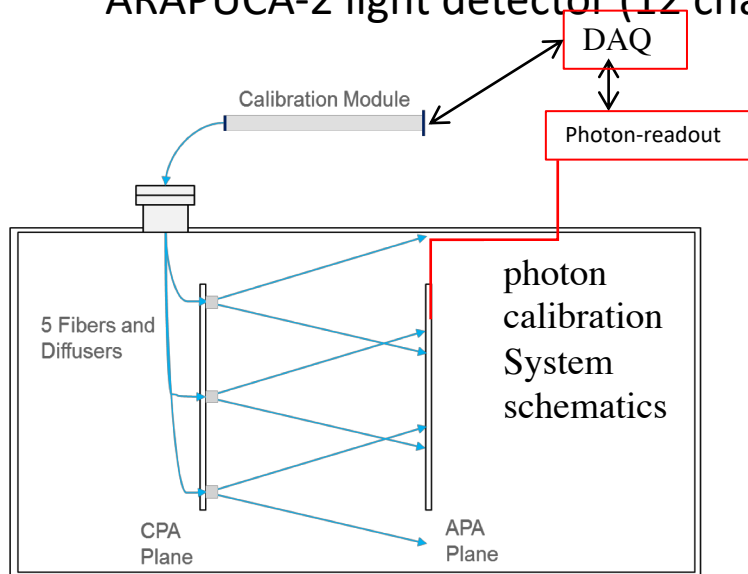
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Photon detector calibration studies

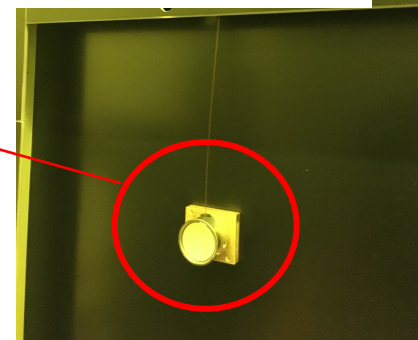
Test of ProtoDUNE-SP photon detector time resolution

➤ Use ProtoDUNE Photon-Detector Calibration/Monitoring System

- Shine 280 nm calibration light from CPA (light diffusers) to APA (photon-detectors)
- Generate double light pulses with external trigger and look at the response of ARAPUCA-2 light detector (12 channels total) within APA-6.



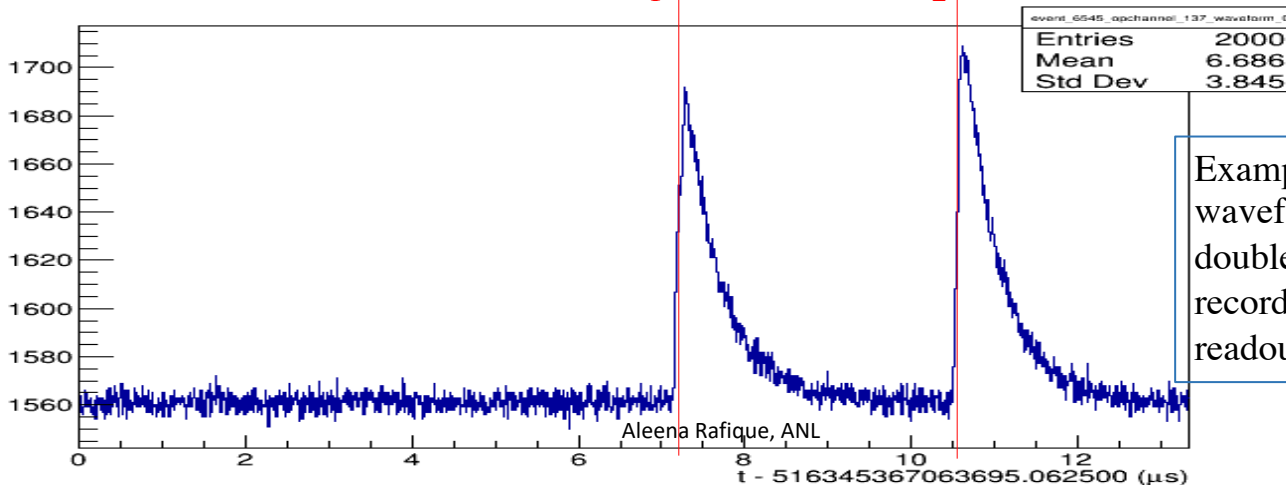
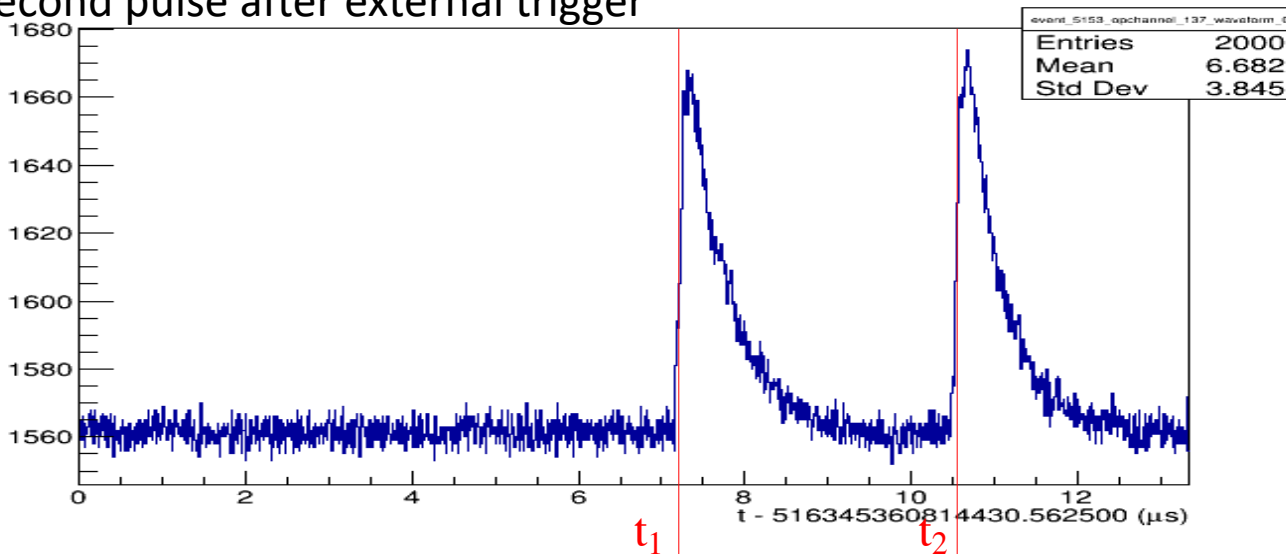
Pictures of light diffusers and fibers integrated with one CPAs at CERN.



Measured double light pulses

➤ Example: ARAPUCA channels; we verified all ARAPUCA channel provide consistent response

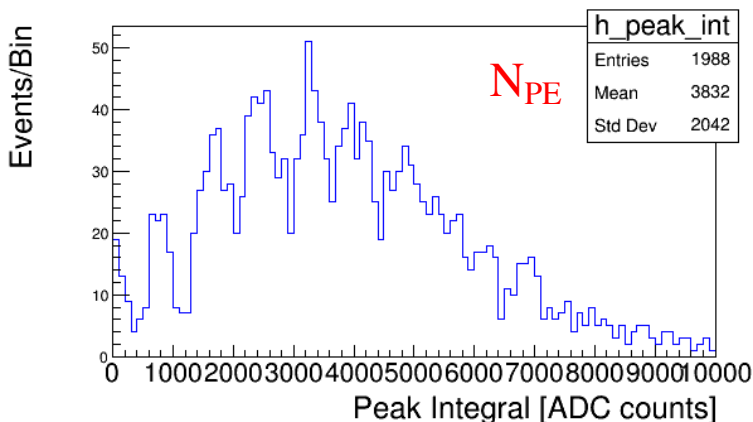
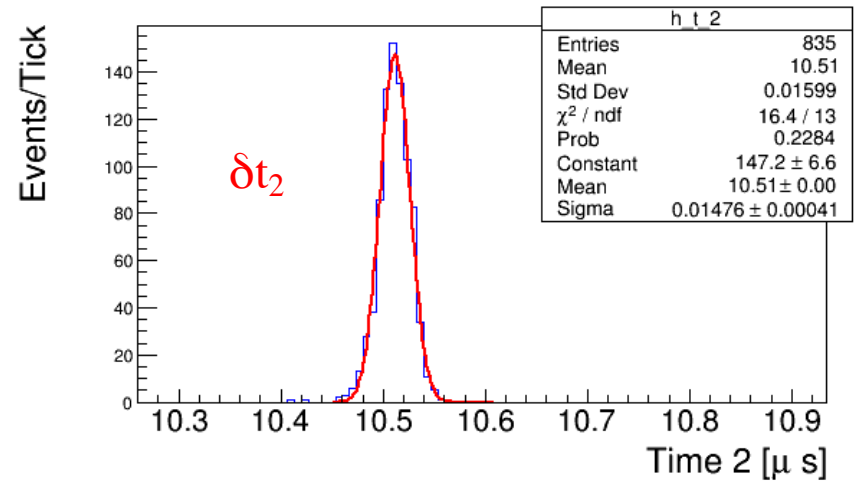
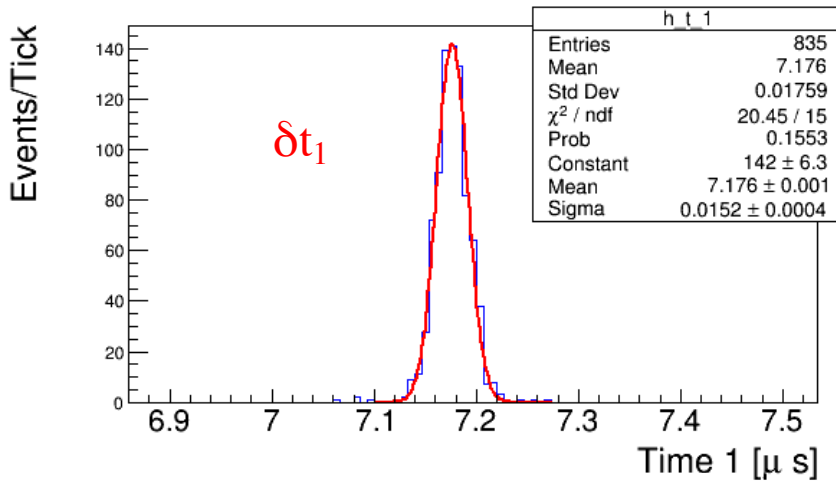
- Collected few thousand of double pulses with recorded response at few PE level
- Determined time (t_1) of the first pulse after external trigger, and/or time (t_2) of the second pulse after external trigger



Example of two waveforms (with double light pulses) recorded by photon readout system

Photon-detector Time Resolution

- Distributions of measured time (t_1) of the first pulse wrt external trigger and/or time (t_2) of the second pulse after wrt trigger provide an estimate of ARAPUCA's time resolution with SSP readout
- Time resolution of photon detection system expressed as width of these distributions is ~ 15 ns in this example at ~ 4 -5PE level (expected to get narrower with the increasing PE)



Timing is stable and timing resolution is well understood, so now will look into physics (cosmics and beam) data

TPC and PD timing studies

Matching track reco (TPC) and Flash time

Track reco (TPC) time:

- Obtained by selecting T_0 tagged cathode piercing muon tracks that decay into Michel electrons

Flash time:

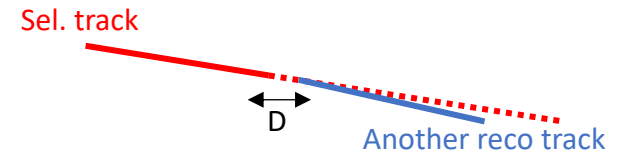
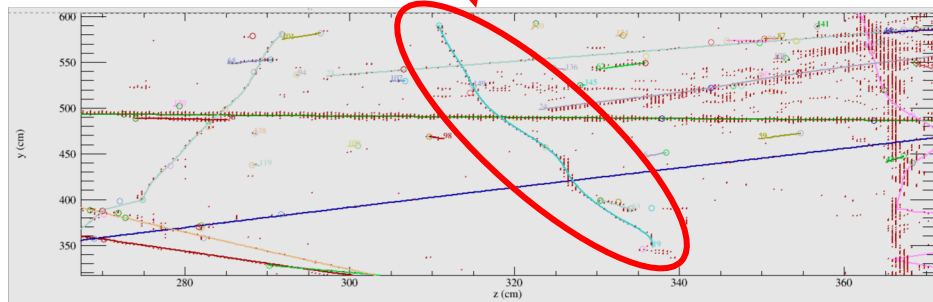
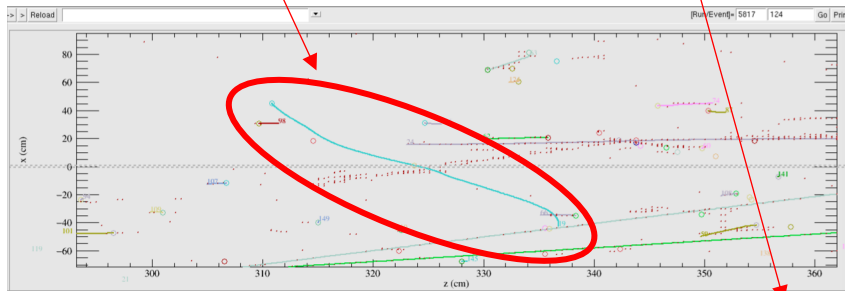
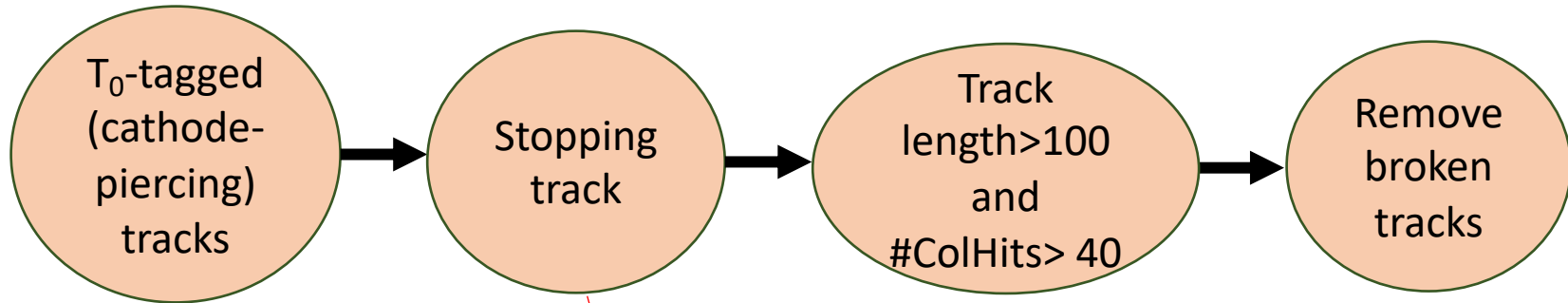
- The closest-in-time reconstructed photon detector time with the TPC time of the selected tracks with respect to the external trigger
- Looked at a sample of 7000 beam events from Run 5817
- All times are taken with respect to the trigger time

Josh Thompson:

<https://indico.fnal.gov/event/19891/contribution/2/material/slides/0.pdf>

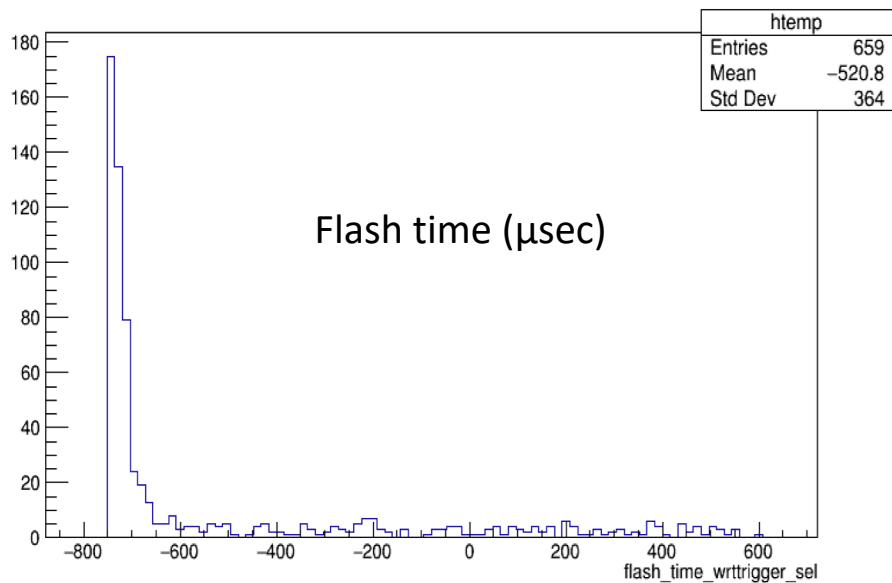
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Event Selection

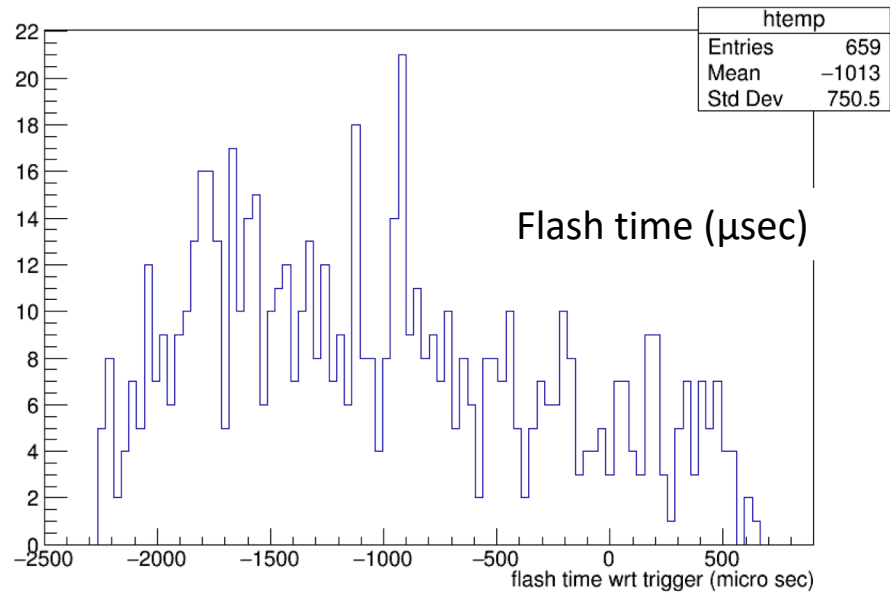


Working on improving Michel electron identification

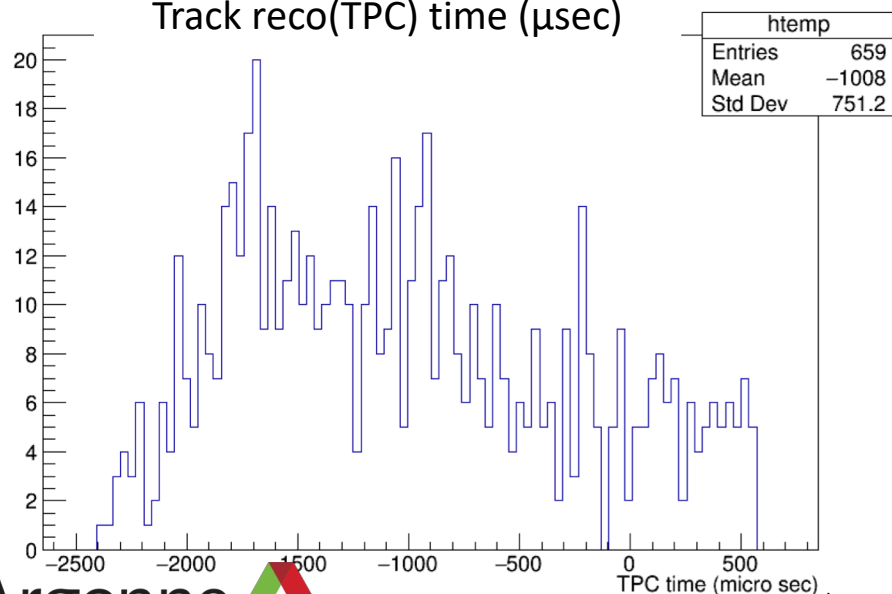
Before



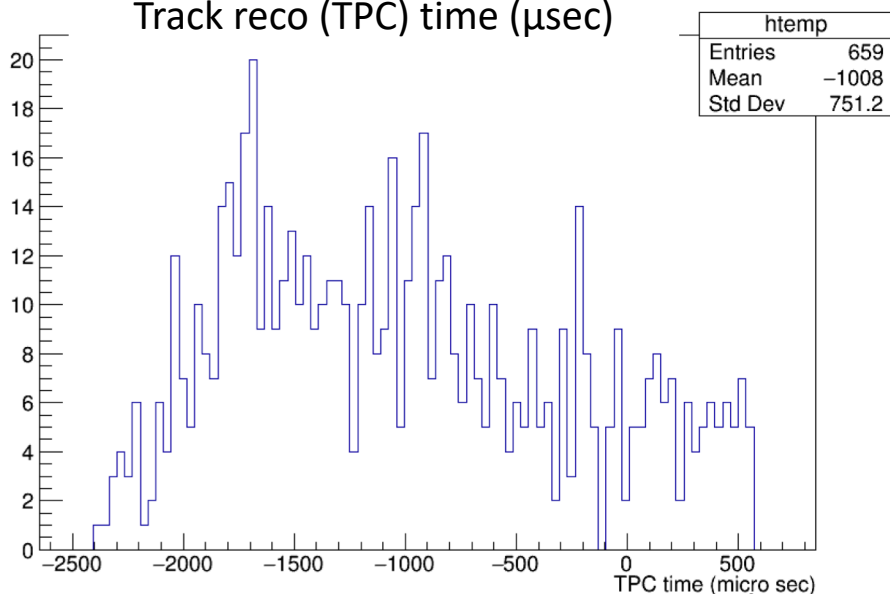
After considering a factor "3"
in flash time



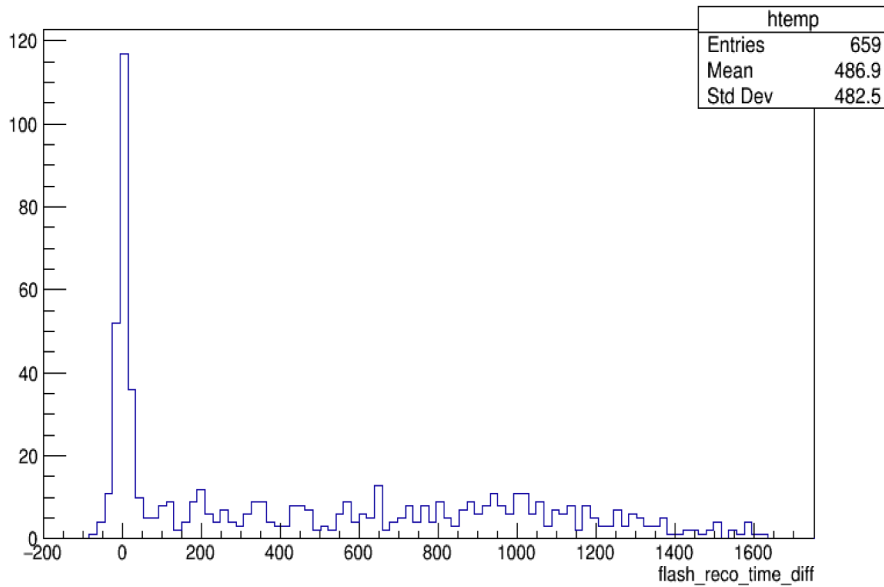
Track reco(TPC) time (μsec)



Track reco (TPC) time (μsec)

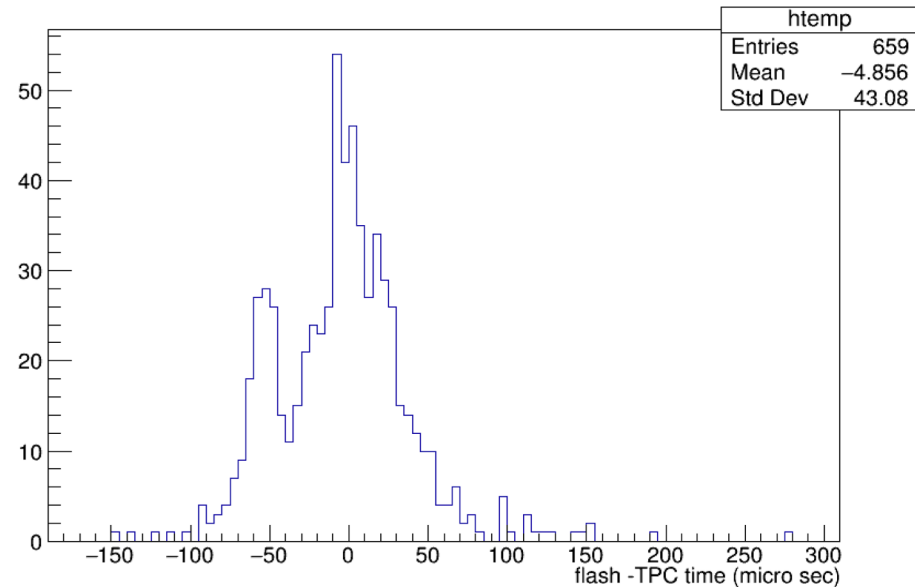


Before



(Flash – TPC) time (μsec)

After considering a factor of
“3” in flash time

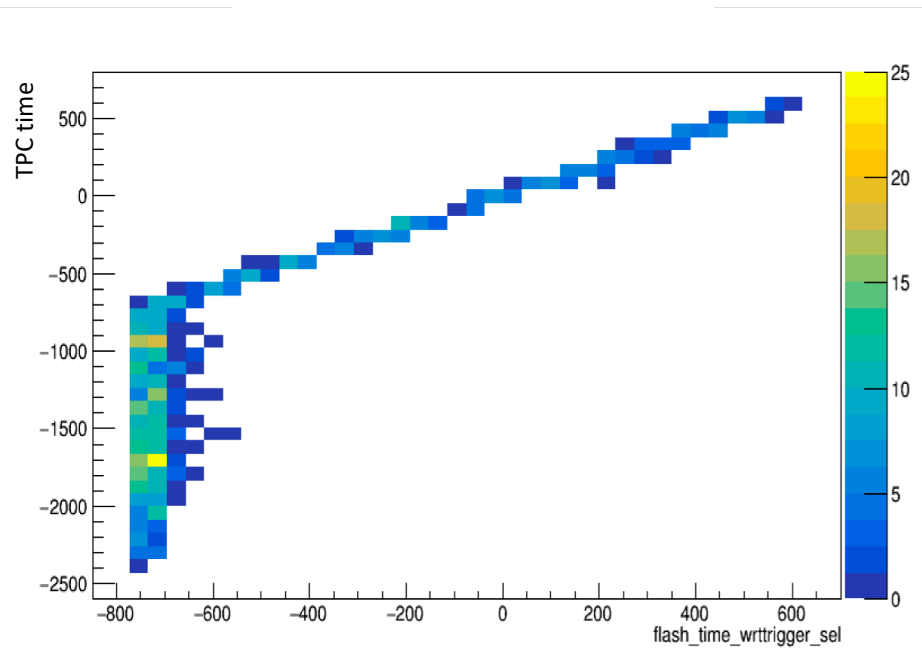


(Flash – TPC) time (μsec)

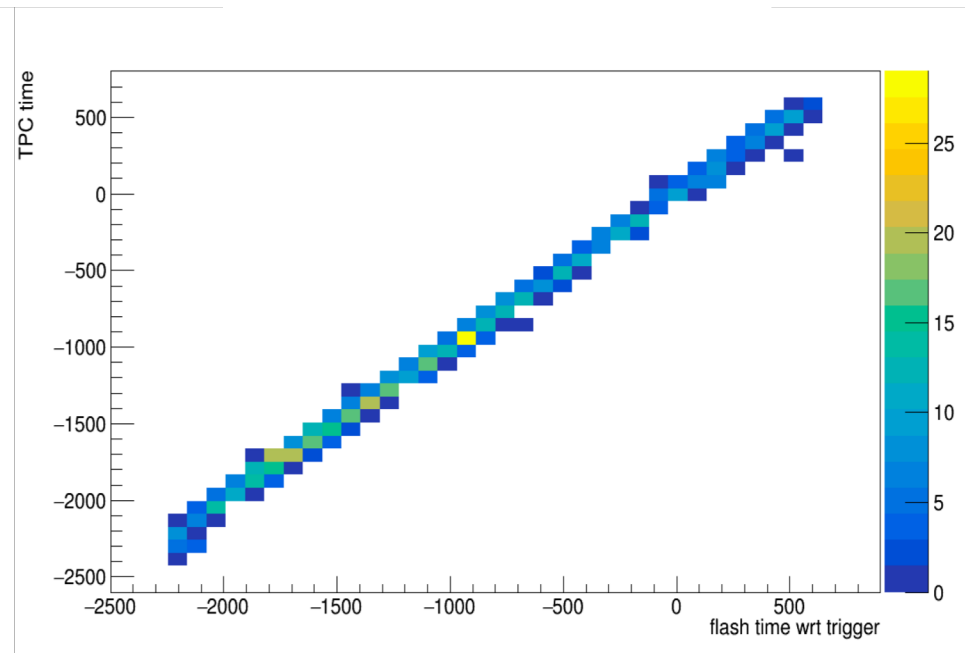
Two peak structure, needs to
be understood

Before

After considering a factor of
“3” in flash time

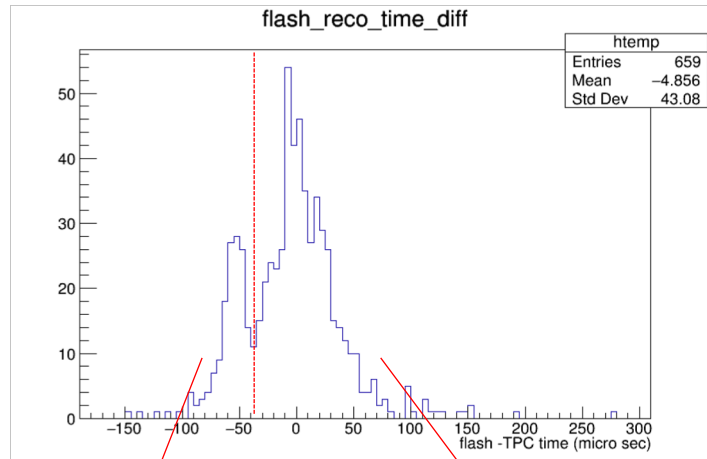


Flash time vs. TPC time (μsec)

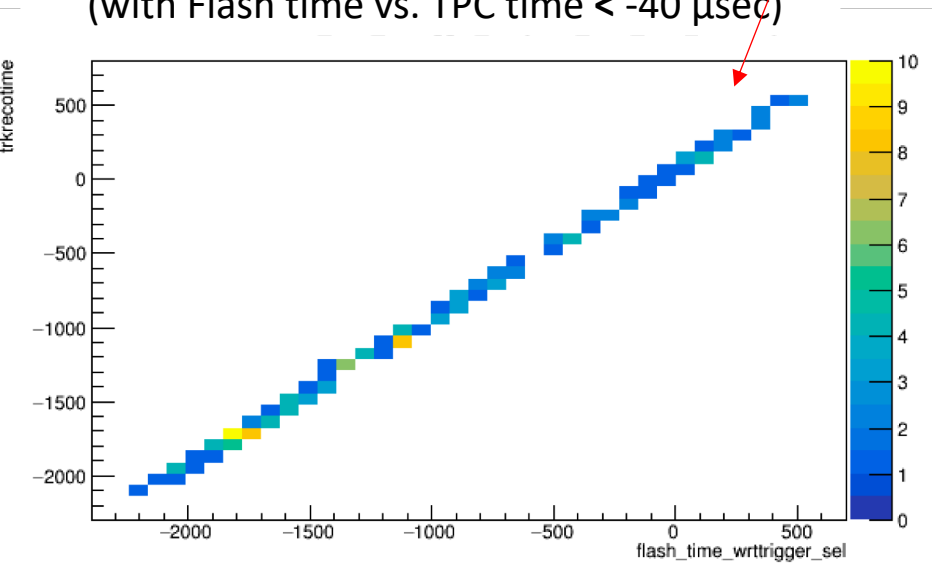


Flash time vs. TPC time (μsec)

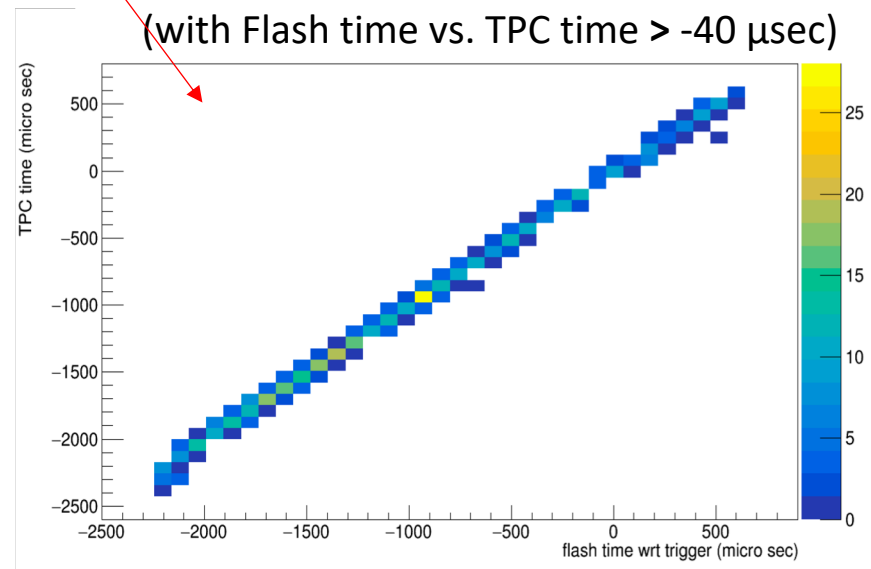
After considering a factor of “3” in flash time



Flash time vs. TPC time
(with Flash time vs. TPC time < -40 μ sec)



Flash time vs. TPC time
(with Flash time vs. TPC time > -40 μ sec)



This time difference does not affect the correlation b/w the TPC and PD systems

Summary and next steps

- Time resolution of the photon detector system is ~ 15 ns at ~ 5 PE level
- Factor of “three” in flash time gives better results
- Positive linear correlation between TPC and flash time
 - Indication of the time match between two systems
- **Next steps:**
 - The peak around (-50) μ sec in difference plot needs investigation
 - We will utilize both TPC (for charge) and PD (for improved timing) systems for the Michel electron selection and energy reconstruction.