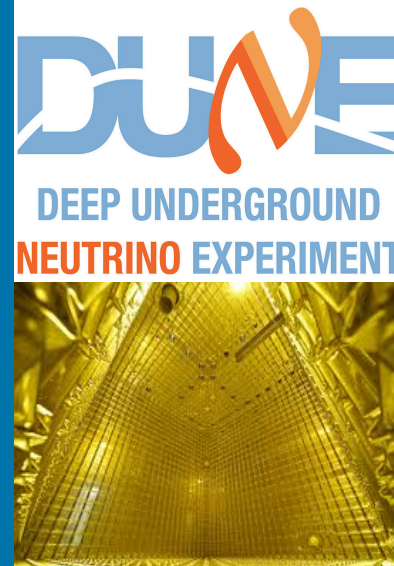


PROTODUNE-SP TIMING STUDIES

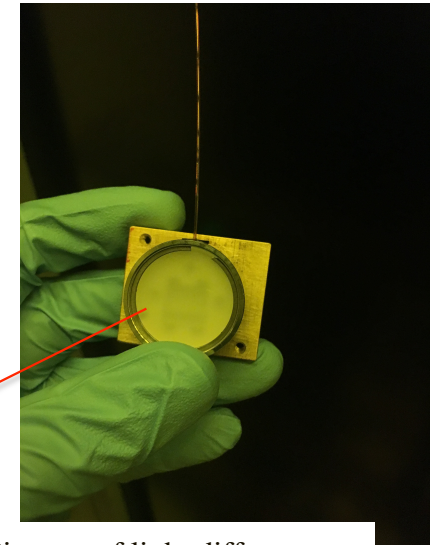
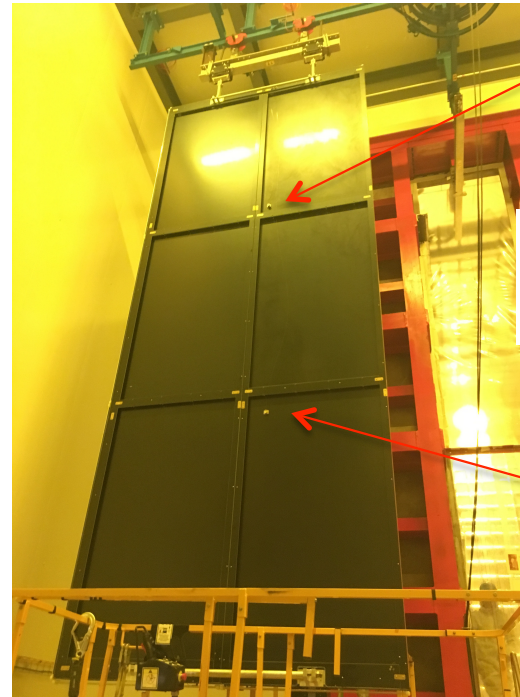
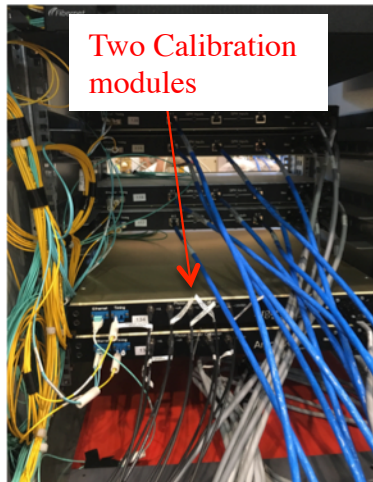
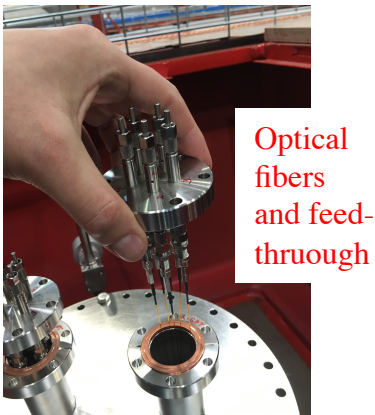
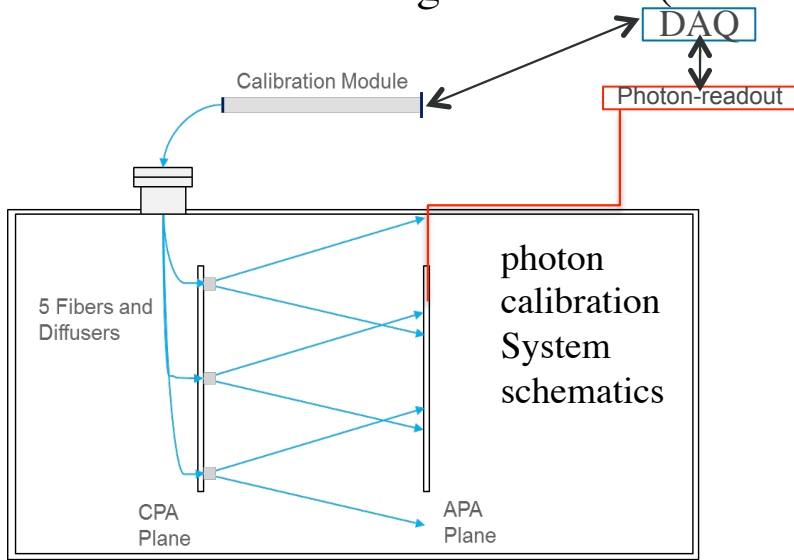


ZELIMIR DJURCIC AND ALEENA RAFIQUE

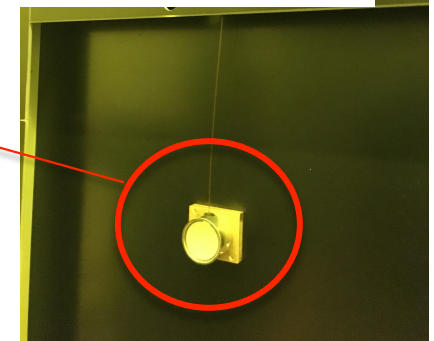
High Energy Physics
Argonne National Laboratory

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-1 light detector (12 channels total) within APA-3.



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

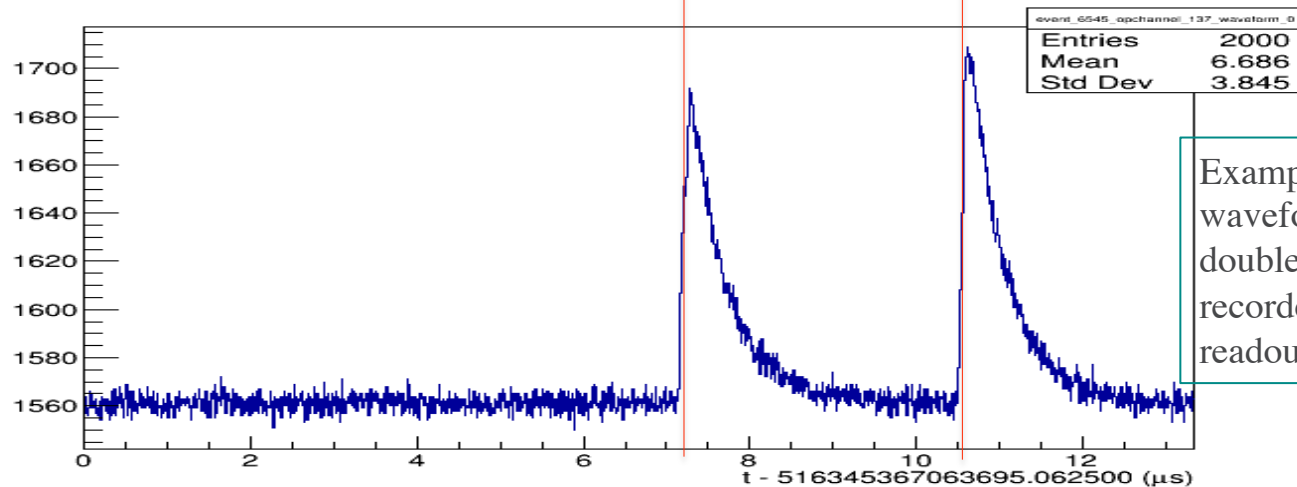
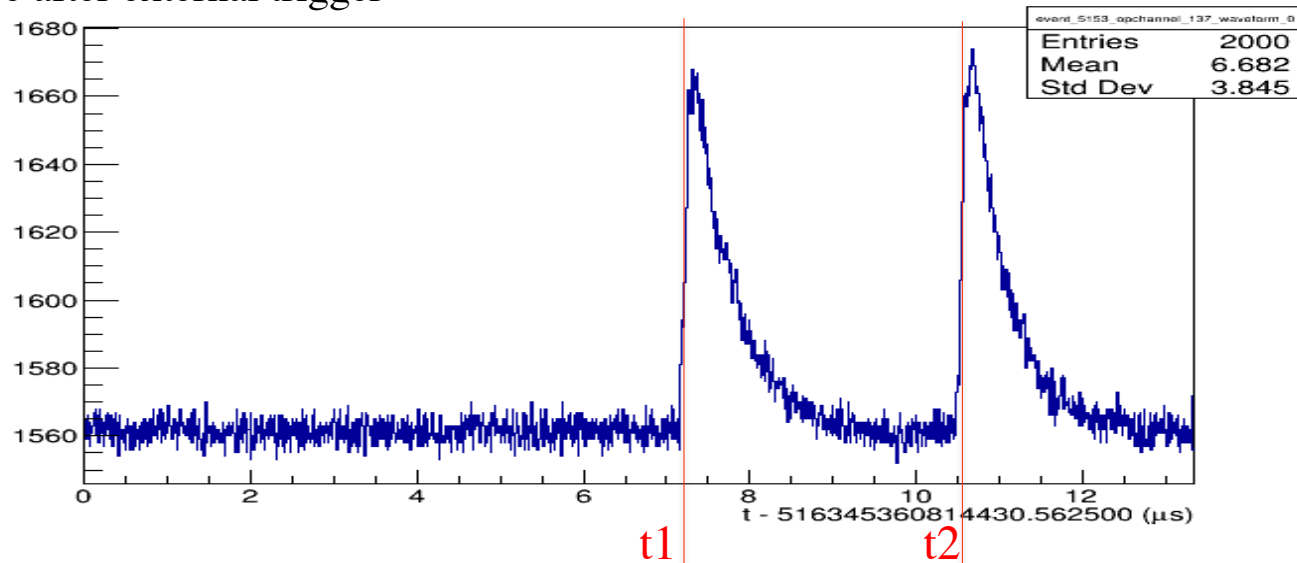


Measured Double Light Pulses

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

-Collected few thousand of double pulses with recorded response at few PE level

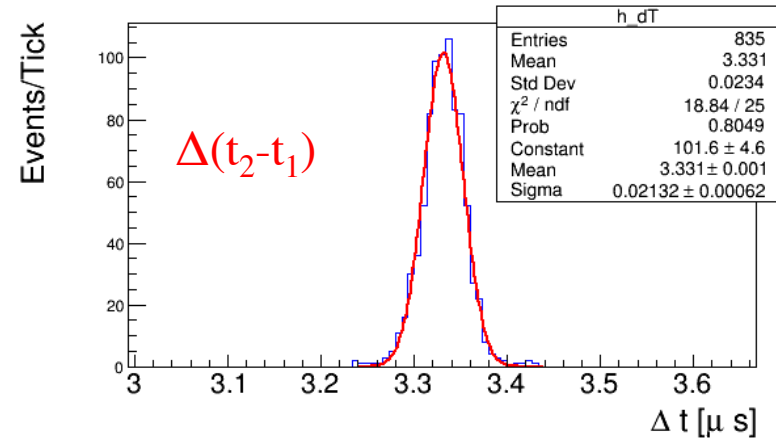
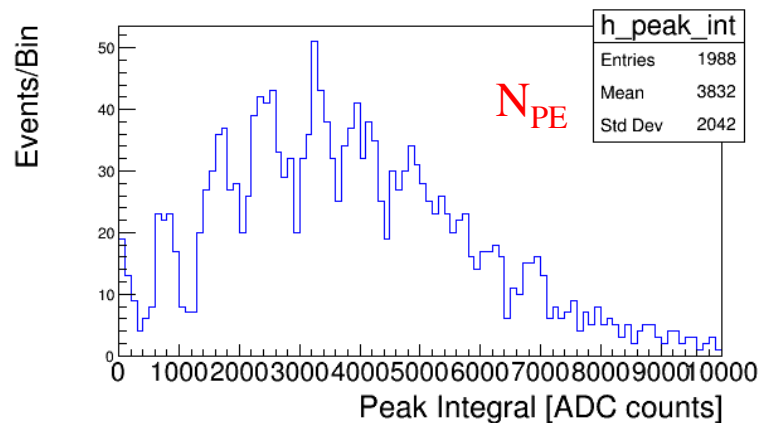
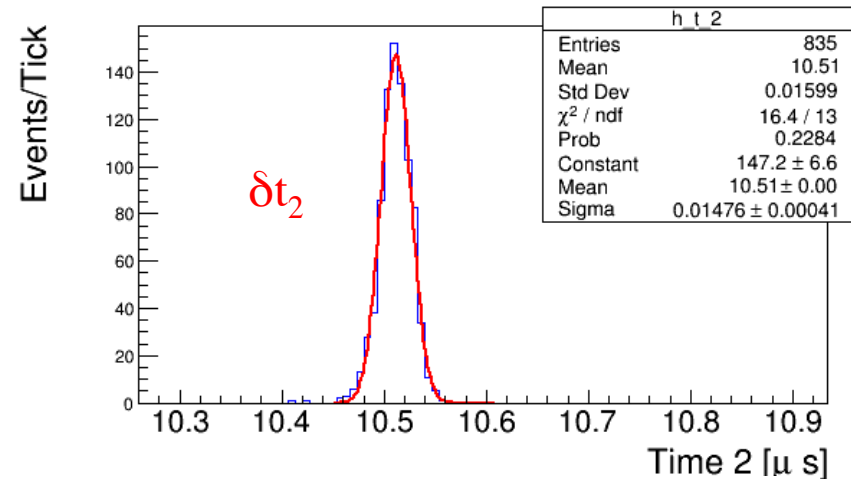
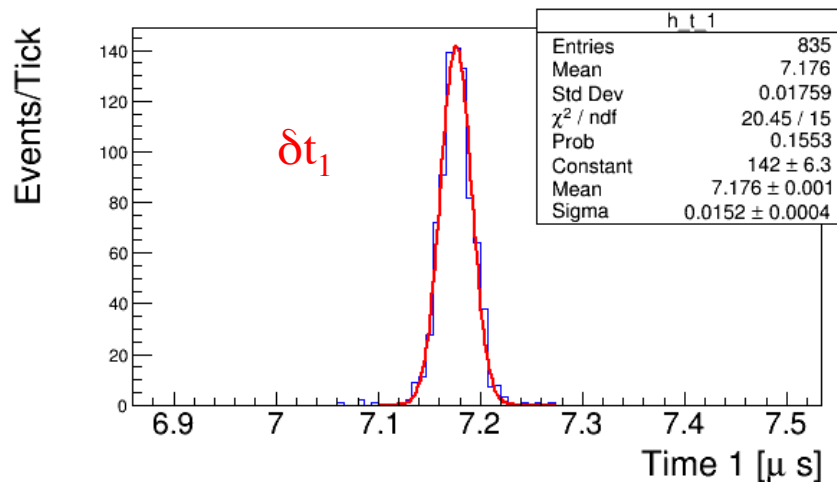
-Determined time (t_1) of the first pulse after external trigger, and time (t_2) of the second pulse after external trigger



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 (and there is also t_2-t_1 time)
- Time resolution of photon detection system expressed as width of these distributions is ~ 15 ns in this example at $\sim 4-5$ PE level (expected to increase with the increasing N_{PE})



4

- Timing/time-resolution looks good, and now we go look into physics (cosmics and beam).



Matching Track Reco (TPC) and Flash (PDS) time

Track reco time:

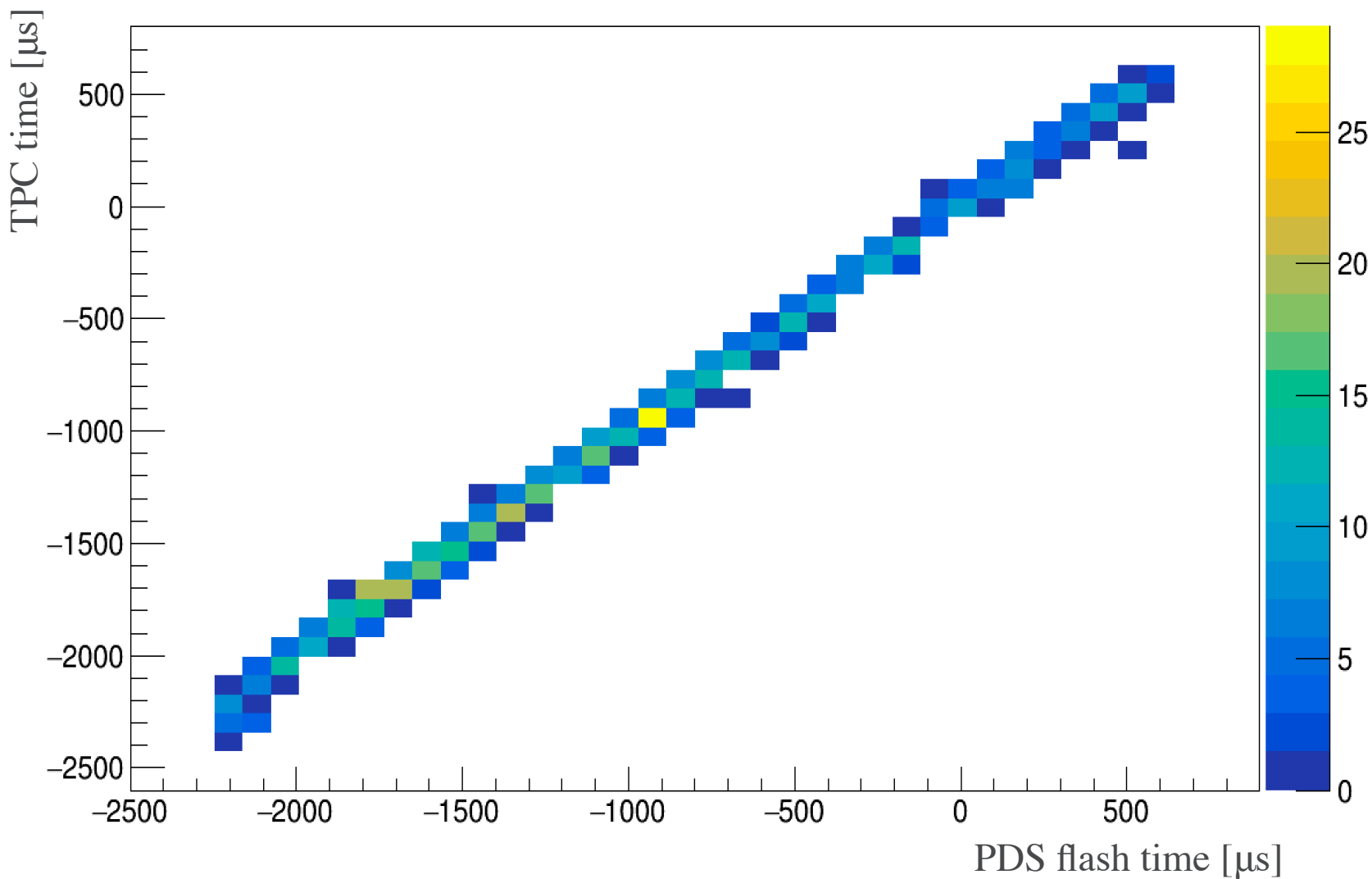
- Obtained by selecting T_0 tagged cathode piercing muon tracks that decay into Michel electrons

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

Correlated track reco (TPC) and Flash (PDS) time

trkreco:flash_time_wrtrigger_sel



- With capability to correlate TPC (for charge) and PD (for improved timing) systems we expect to improve cosmics/beam selection and energy reconstruction.