Extracting TOP Trigger PDFs from Data + Plans

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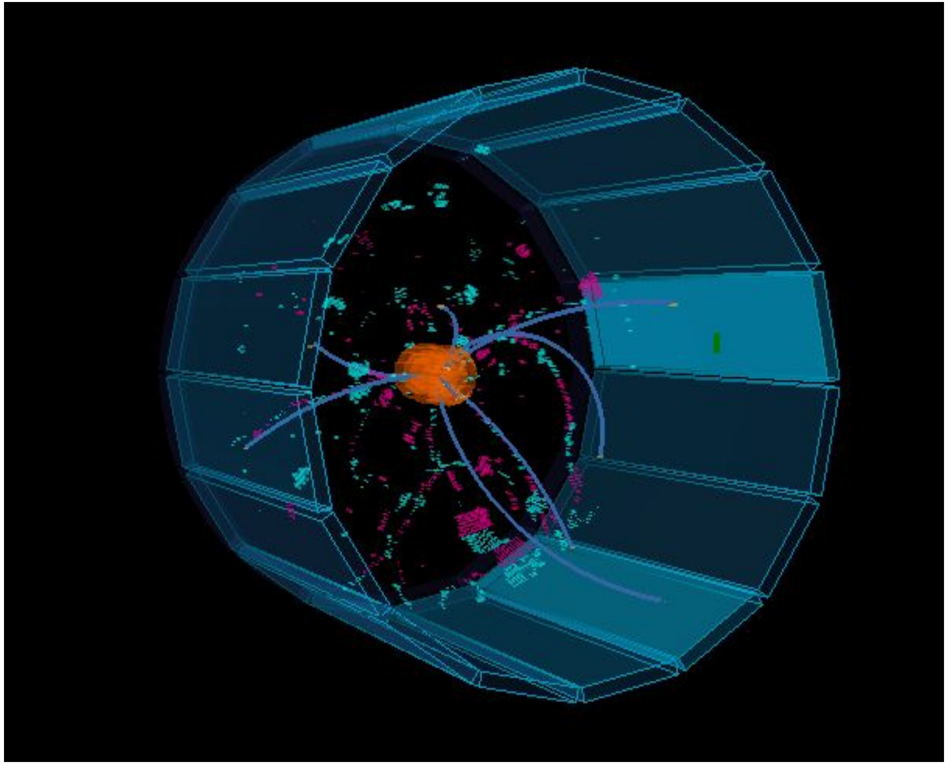
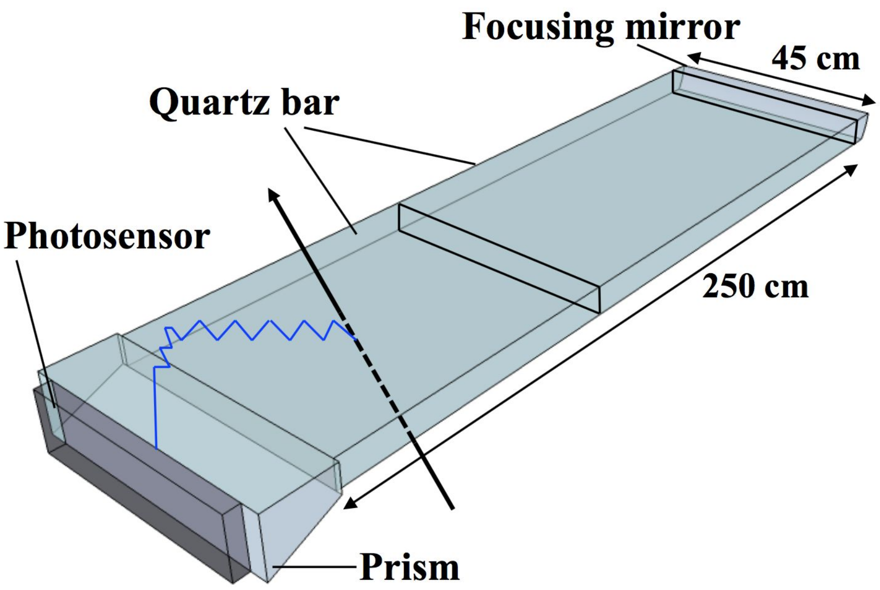
Event Display



- 16 TOP bars cylindrically arranged around the beam pipe, in between the Central Drift Chamber (CDC) and the Electromagnetic Calorimeter (ECL).
- The blue lines are the charged particle tracks, and you can see a few of them entering the TOP bars.

The TOP Detector

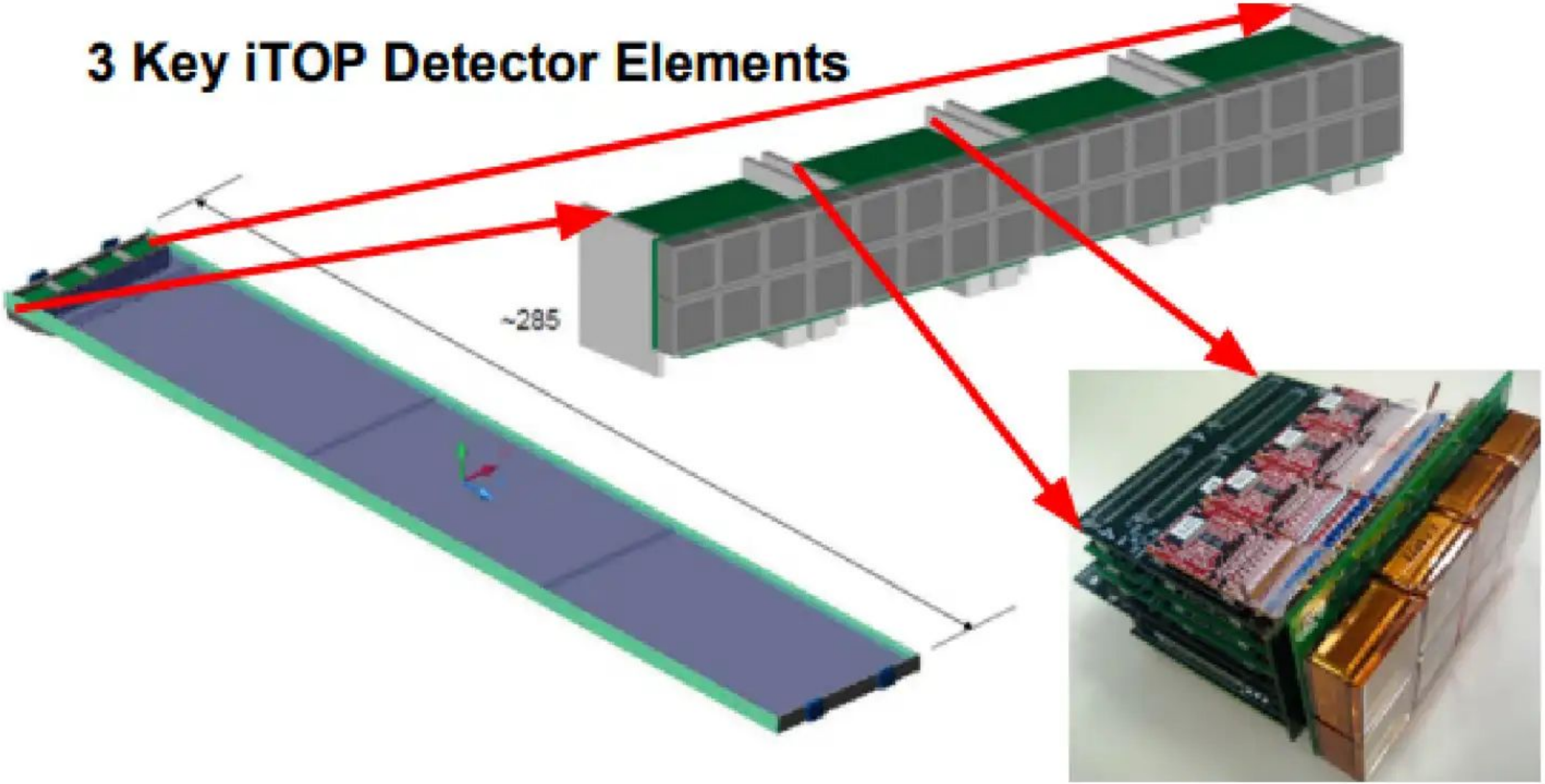


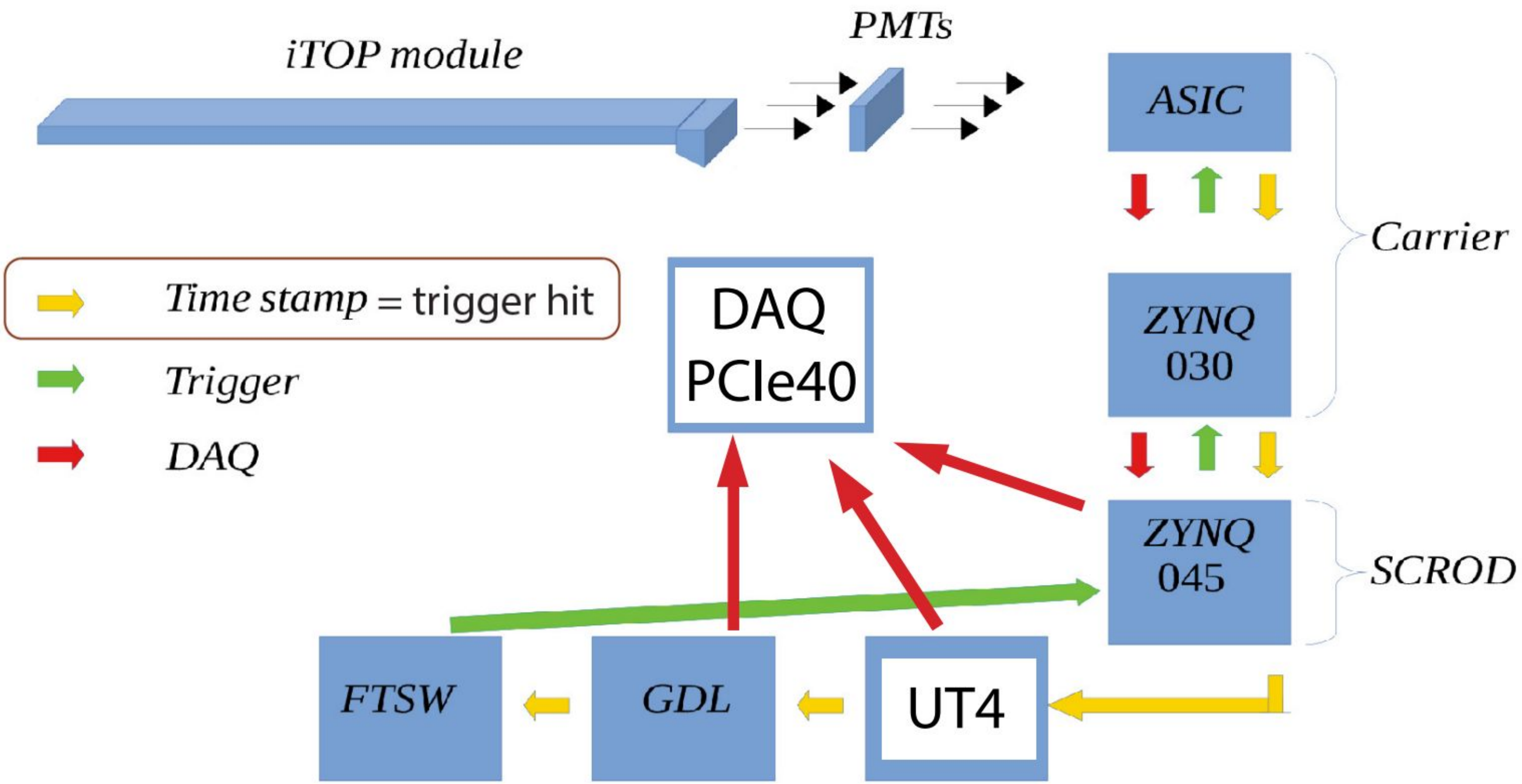
- The TOP detector is composed of 16 of the modules or bars shown on the left.

- The back-end of the bar has an array of PMTs and the front-end has a reflective mirror.

- A charged particle can enter the top bar and generate Cherenkov photons. Depending on where the charged particle entered the bar, the arrival time of the photons will change.

3 Key iTOP Detector Elements

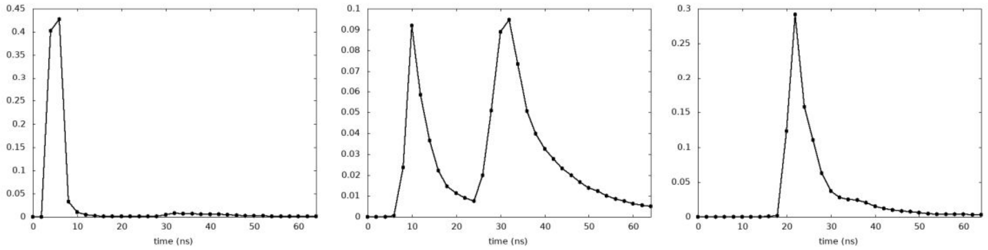


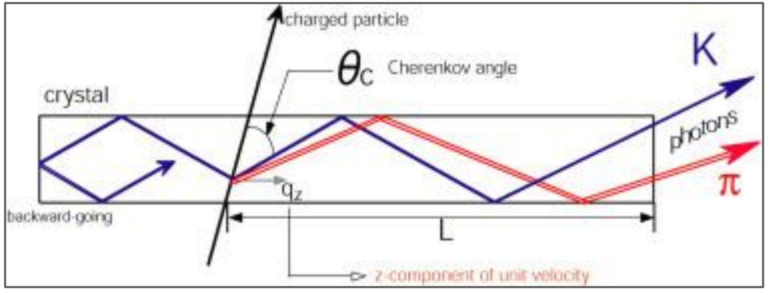

iTOP module
PMTs
ASIC
Carrier
ZYNQ 030
ZYNQ 045
SCROD
Time stamp = trigger hit
Trigger
DAQ
DAQ PCIe40
FTSW
GDL
UT4

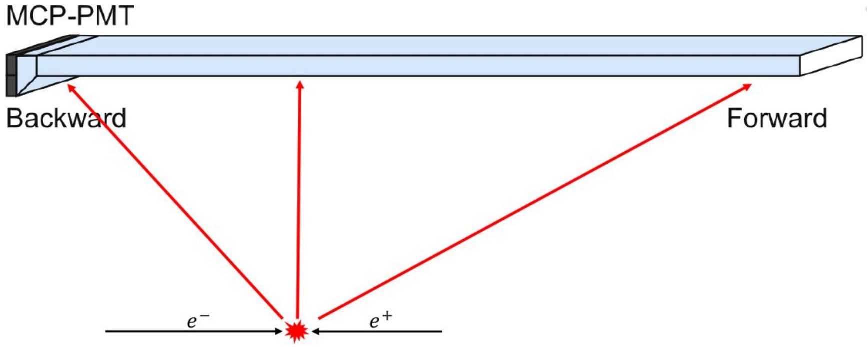
Collision Time (t0) Extraction

- TOP trigger firmware uses a likelihood-based approach to determine the collision time (t0) of a possible event.
- The TOP bar is divided into 10 logical segments of equal length. We prepare 10 probability density functions (PDFs) for each segment of the bar. PDFs here are histograms that represent the distributions of photon arrival times at the PMTs.
- In FW, these 10 PDFs are stored as 10 log-likelihood LUTs. Real-time histograms of photon arrival times are compared against all 10 PDFs and the PDF with the largest log-likelihood is selected as the best match.
- From the selected PDF, we can determine the most probable position the charged particle entered the bar. From the real-time histogram, we can extract the collision time.

Several examples of TOP TRG PDFs







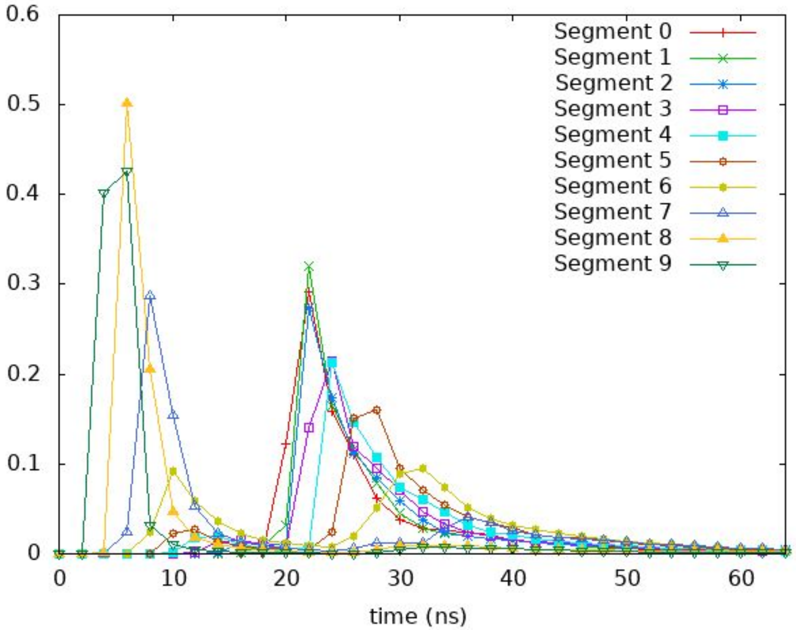
Left: Distribution of photon arrival times from a charged particle that hits the slot very close to PMTs

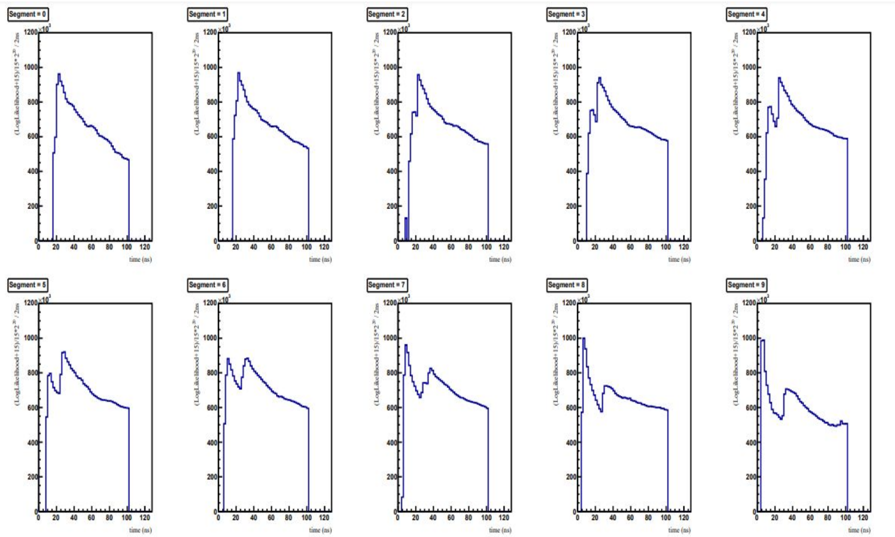
Middle: For a particle at normal incidence, some of the photons (in the first peak) travel toward the PMTs, while other photons (in the second peak) travel in the opposite direction, are reflected in the mirror, so their travel times are longer.

Right: Photons from charged particles that hit the slot far away from PMT arrive at PMT with some delay

Current Status of PDF Matching

PDFs were originally prepared using GEANT4 based Monte Carlo Simulation. However, these PDFs could be improved if prepared with real data.





Project Goal and Methodology

- Instead of using simulation, we will use real data (data from tracks and timing information) to prepare PDFs.

- Starting with a track, a new object called TOPTrack is created. TOPTrack is an extrapolated track hit (with a pion hypothesis) to the TOP detector.

```
 * Constructor from mdst track - isValid() must be checked before using the object
 * @param track mdst track
 * @param digitsName name of TOPDigits collection
 * @param chargedStable hypothesis used in mdst track extrapolation
 */
explicit TOPTrack(const Track& track, const std::string& digitsName = "",
                  const Const::ChargedStable& chargedStable = Const::pion);
```

- From the TOPTrack object, the module ID of the TOP bar that the track intersects can be determined.

- We can use the TRD2TTS converter to represent TOP main readout hits as trigger timestamps. Alternatively, we can use actual timestamps from UT4 TOP trigger readout.

Methodology cont'd.

```
const ExtHit* exthit = trk.getExtHit();

if (exthit->getDetectorID() != myDetID) continue;
if (abs(exthit->getPdgCode()) != pdgCode) continue;

TVector3 position = exthit->getPosition();

TVector3 momentum = exthit->getMomentum();
```

- The extrapolated hits (ExtHit) object tells us about the track entrance position to the detectors using GEANT4 and detector geometry. We filter the hits for just the TOP detector and pion hypothesis.
- Then we can determine the position and the momentum in which the charged particle track intersected the TOP bar.

Storing the Information

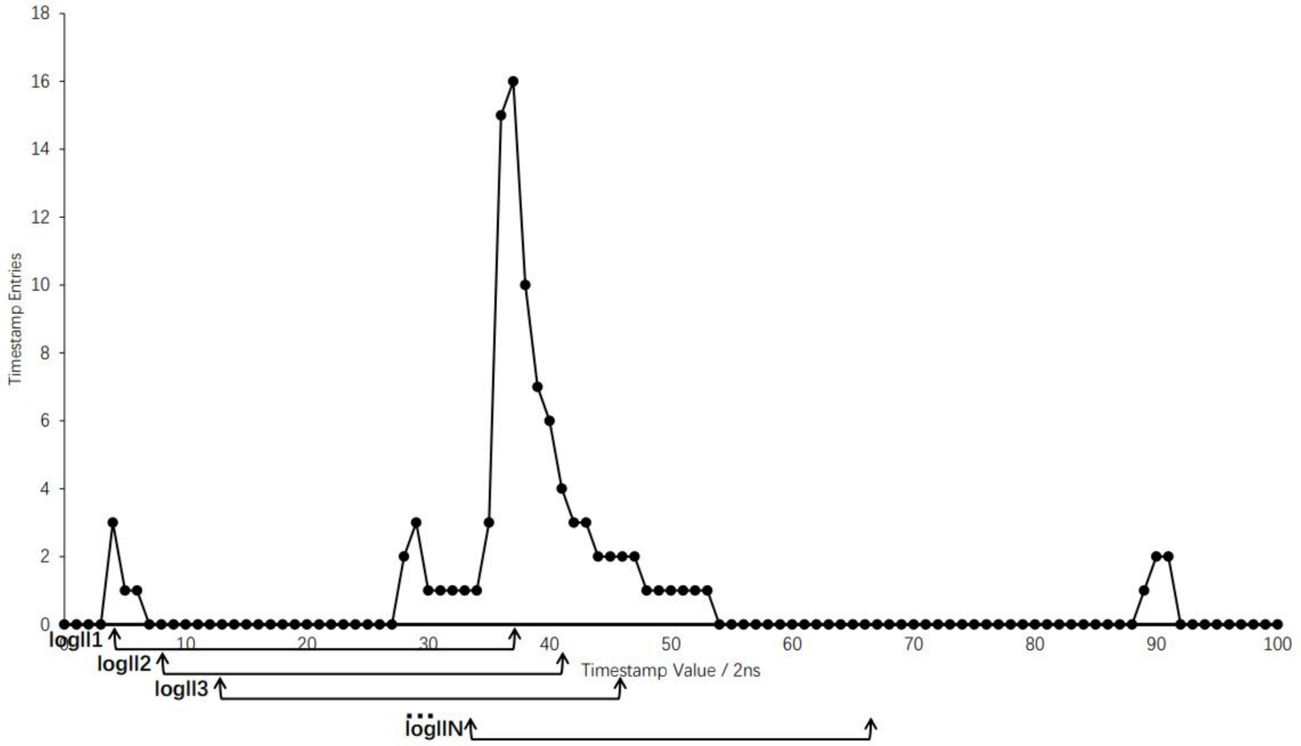
- A lot of information has been extracted, and now we need data structures to read out all of this.
- Three data structures (at least):
  - 1. Timestamps from all TOP bars that are matched to tracks.
  - 2. Module ID of TOP bars that tracks have intersected.
  - 3. Tracks that have intersected the TOP bars.
- Another data structure to store entrance position of tracks to the TOP bars and the momentum.
- Expected workflow: use CDSTs on GRID, prepare the information, use it locally to produce PDFs

Ongoing developments / studies (with V. Savinov)

1) Main goal: try to improve timing resolution and the efficiency of TOP TRG t0 decisions
2) Data-based PDFs would be just one contribution to improve t0 resolution (but not the efficiency)
3) A better algorithm is needed: we are trying to develop such an algorithm since last year
4) ML-based studies to suppress bunches of timestamps from beam background are in progress
5) Changes are necessary in the trigger data path in TOP FEE (collaborating with Hawaii on this)
6) In particular, we need to be able to mask off “offending” channels in TOP FEE in real time
7) Studies of injection veto in TOP FEE are in progress
8) Continue our work to make UT4 FW run at a higher frequency clock (128MHz -> 512MHz)
9) As an alternative to 512MHz we are investigating to change the way we merge trigger data

Backup slides

Sliding-Window Algorithm



TOPTRG UT4 Timestamps vs. TOP Main Readout Hits