



# Coincidence Analysis with UD of GP13

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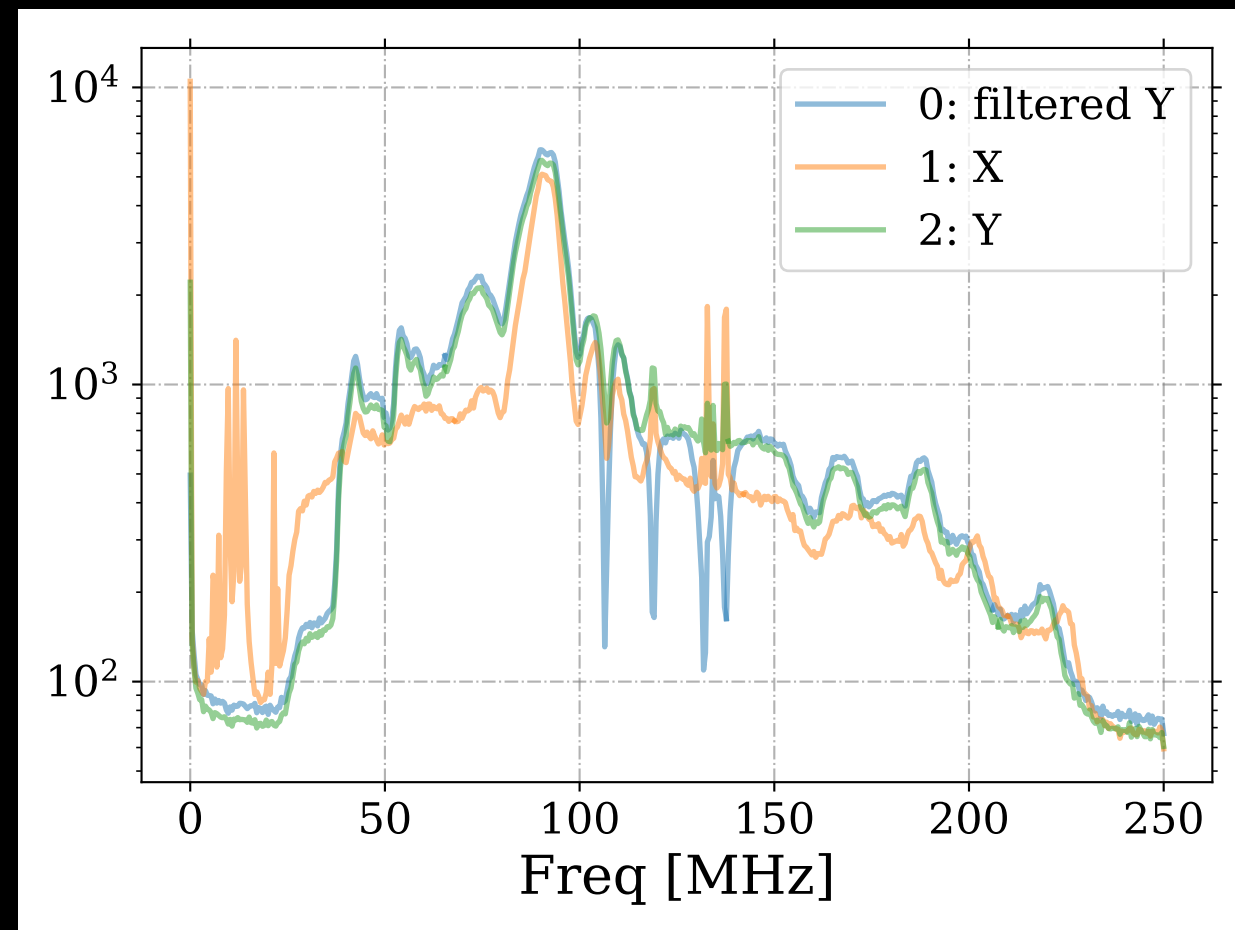
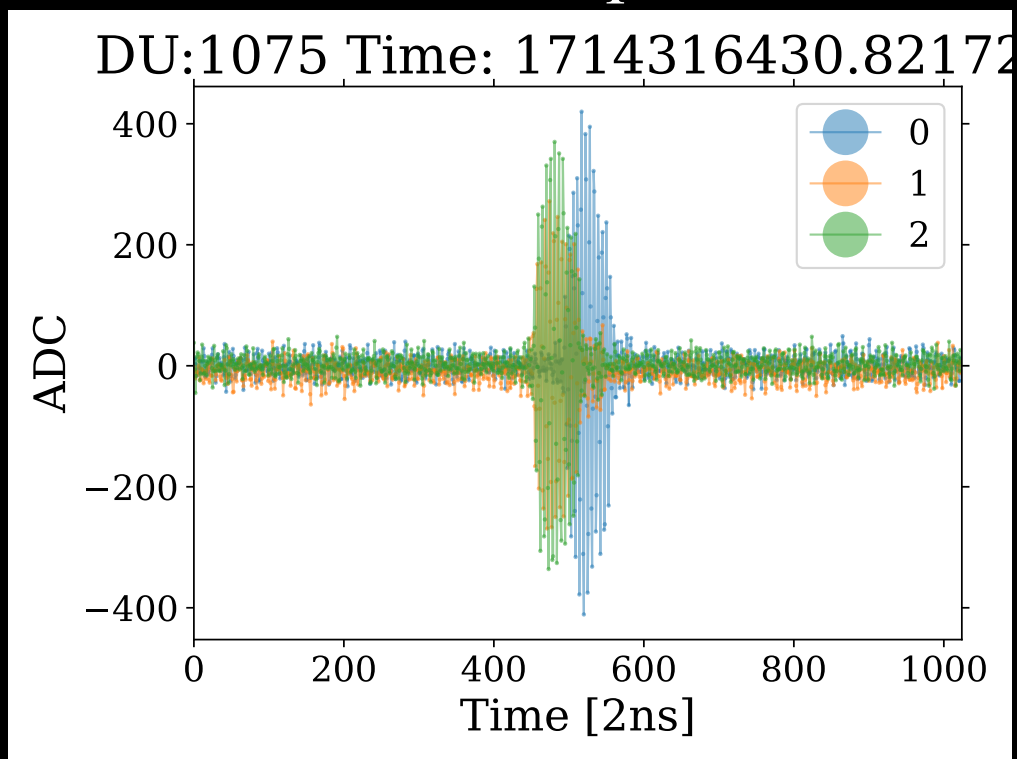
2024.06.03

# Data

- File:
  - GP13\_20240428\_150018\_RUN127\_UD\_RAW\_ChanXYZ\_20dB\_13dus\_BeaconTest\_100M\_001.root
  - GP13\_20240428\_150756\_RUN127\_UD\_RAW\_ChanXYZ\_20dB\_13dus\_BeaconTest\_100M\_001.root
  - GP13\_20240428\_150857\_RUN127\_UD\_RAW\_ChanXYZ\_20dB\_13dus\_BeaconTest\_100M\_002.root
  - GP13\_20240428\_150957\_RUN127\_UD\_RAW\_ChanXYZ\_20dB\_13dus\_BeaconTest\_100M\_003.root
  - GP13\_20240428\_151054\_RUN127\_UD\_RAW\_ChanXYZ\_20dB\_13dus\_BeaconTest\_100M\_004.root
  - GP13\_20240428\_151128\_RUN127\_UD\_RAW\_ChanXYZ\_20dB\_13dus\_BeaconTest\_100M\_005.root
  - GP13\_20240428\_151203\_RUN127\_UD\_RAW\_ChanXYZ\_20dB\_13dus\_BeaconTest\_100M\_006.root
  - GP13\_20240428\_151234\_RUN127\_UD\_RAW\_ChanXYZ\_20dB\_13dus\_BeaconTest\_100M\_007.root
- Number of DUs: 13
- Number of UD events: 6051

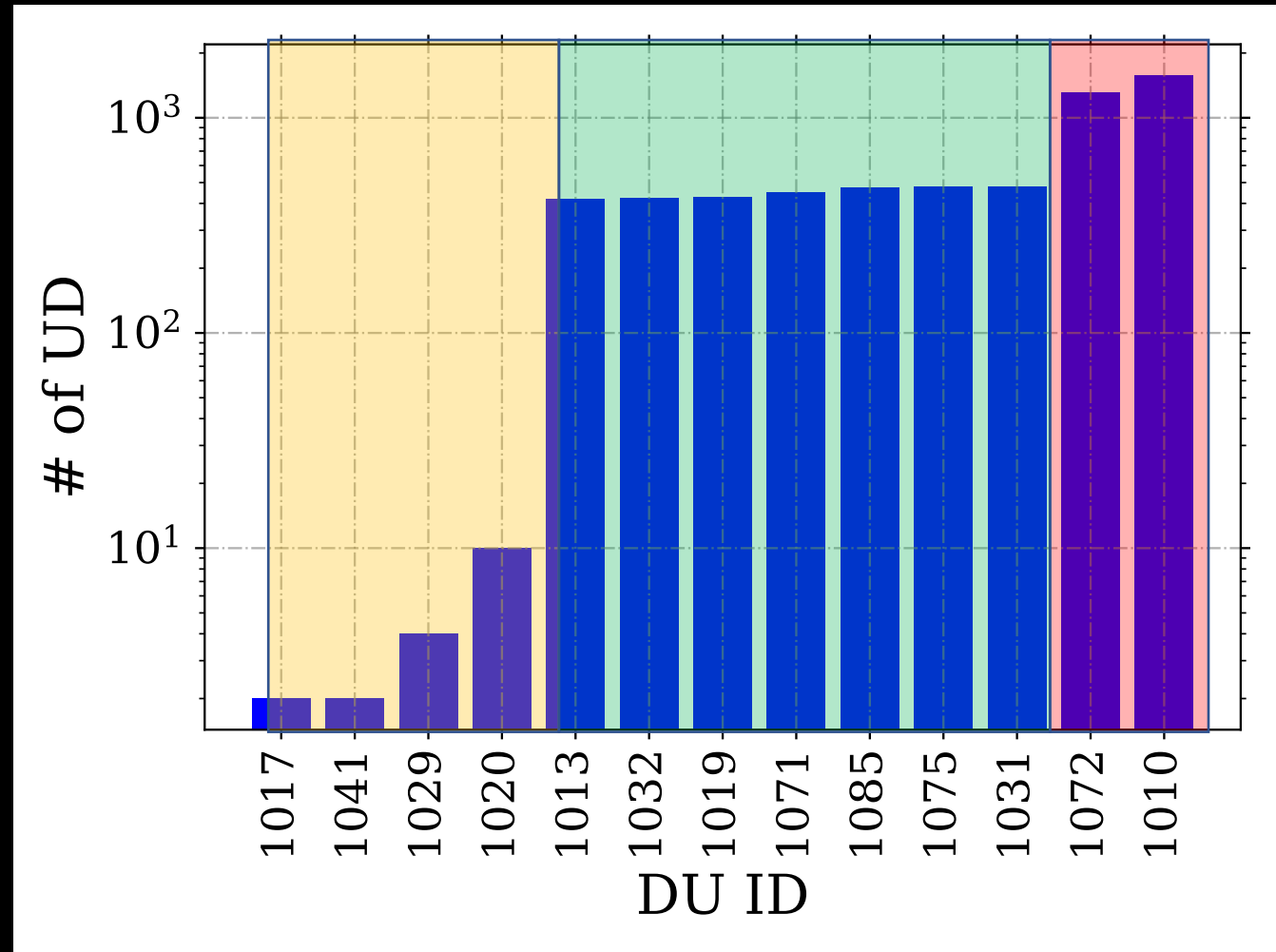
# Beacon Signal

- Pulse at time domain
- 100MHz at FFT spectrum



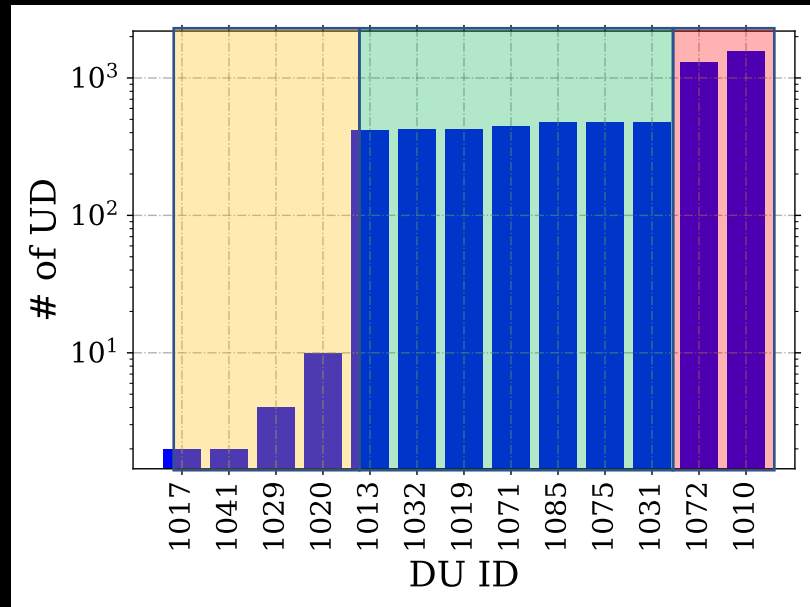
# Number of Pulses

- Three groups
- 1010, 1072: ~1k pulses
- Seven DUs: ~400 pulses
- 1017, 1014, 1029, 1020: <10 pulses

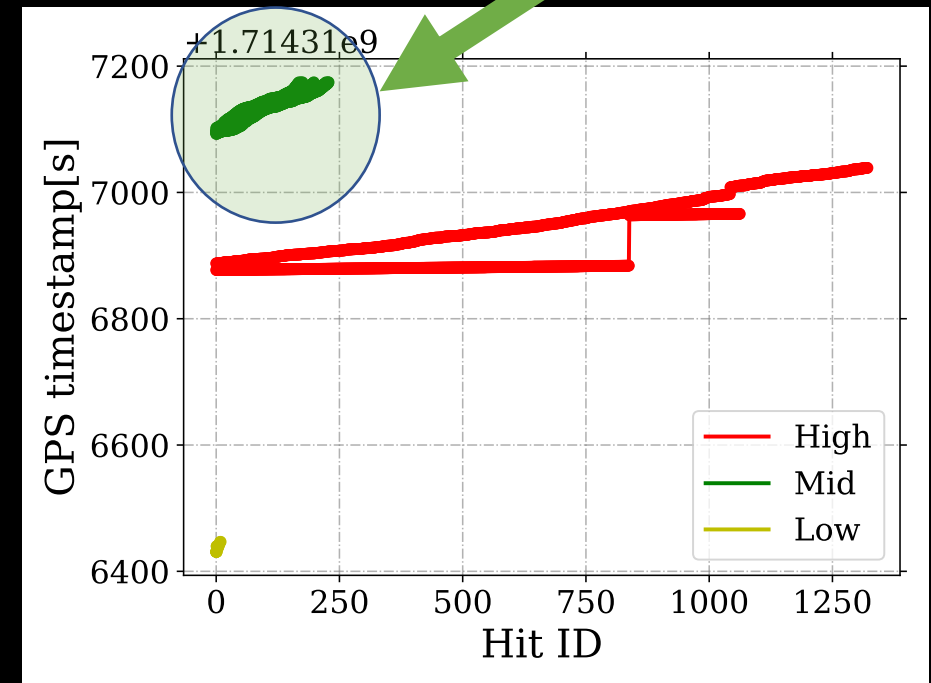


# GPS Timing by DUs

- Three groups divided by pulse number:
  - High: [1010, 1072]
  - Mid: [1031, 1075, 1085, 1071, 1019, 1032, 1013]
  - Low: [1017, 1041, 1029, 1020]

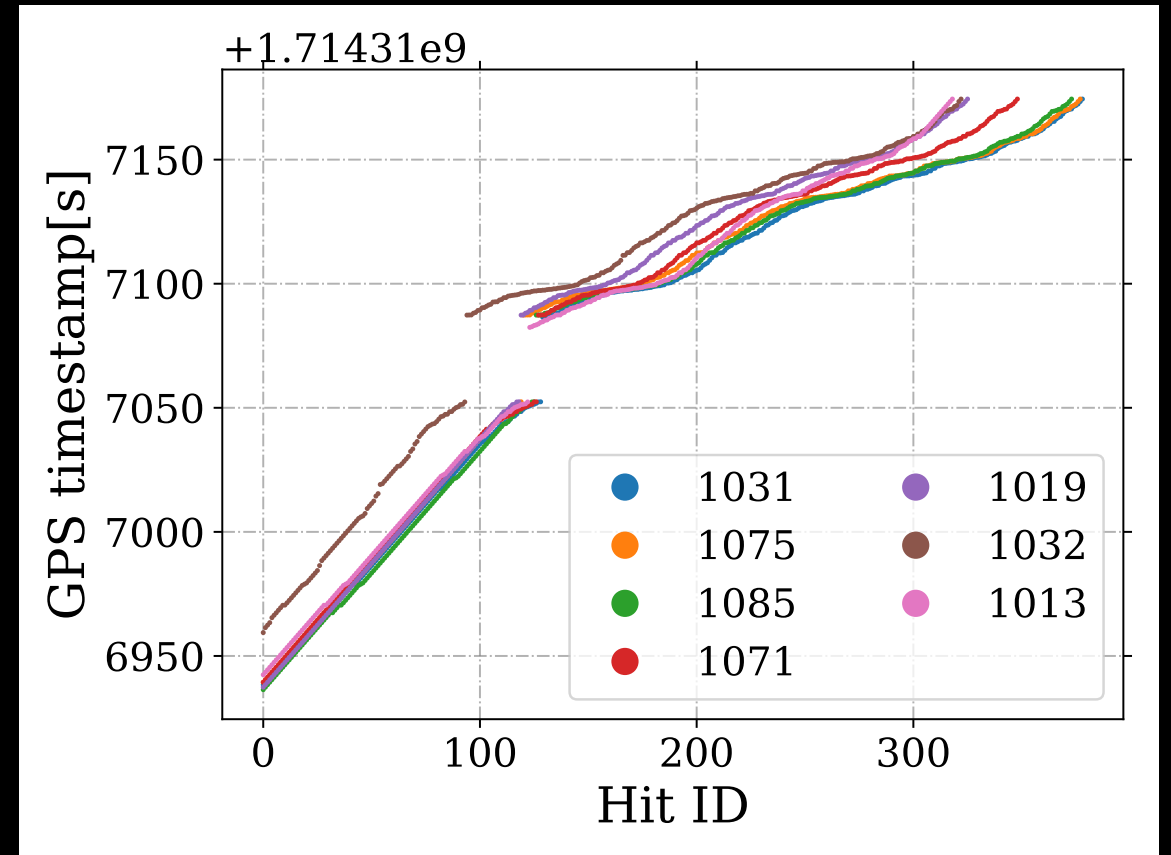
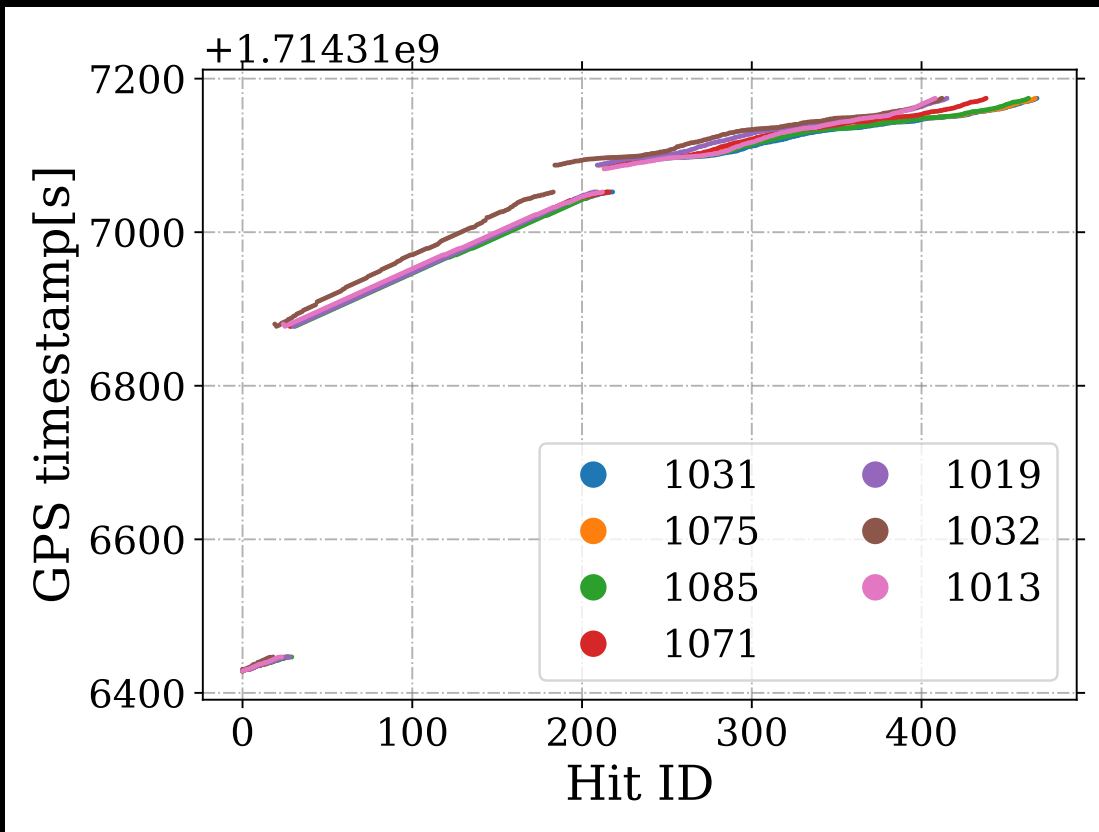


Only these DUs are correct /suitable for coincidence analysis



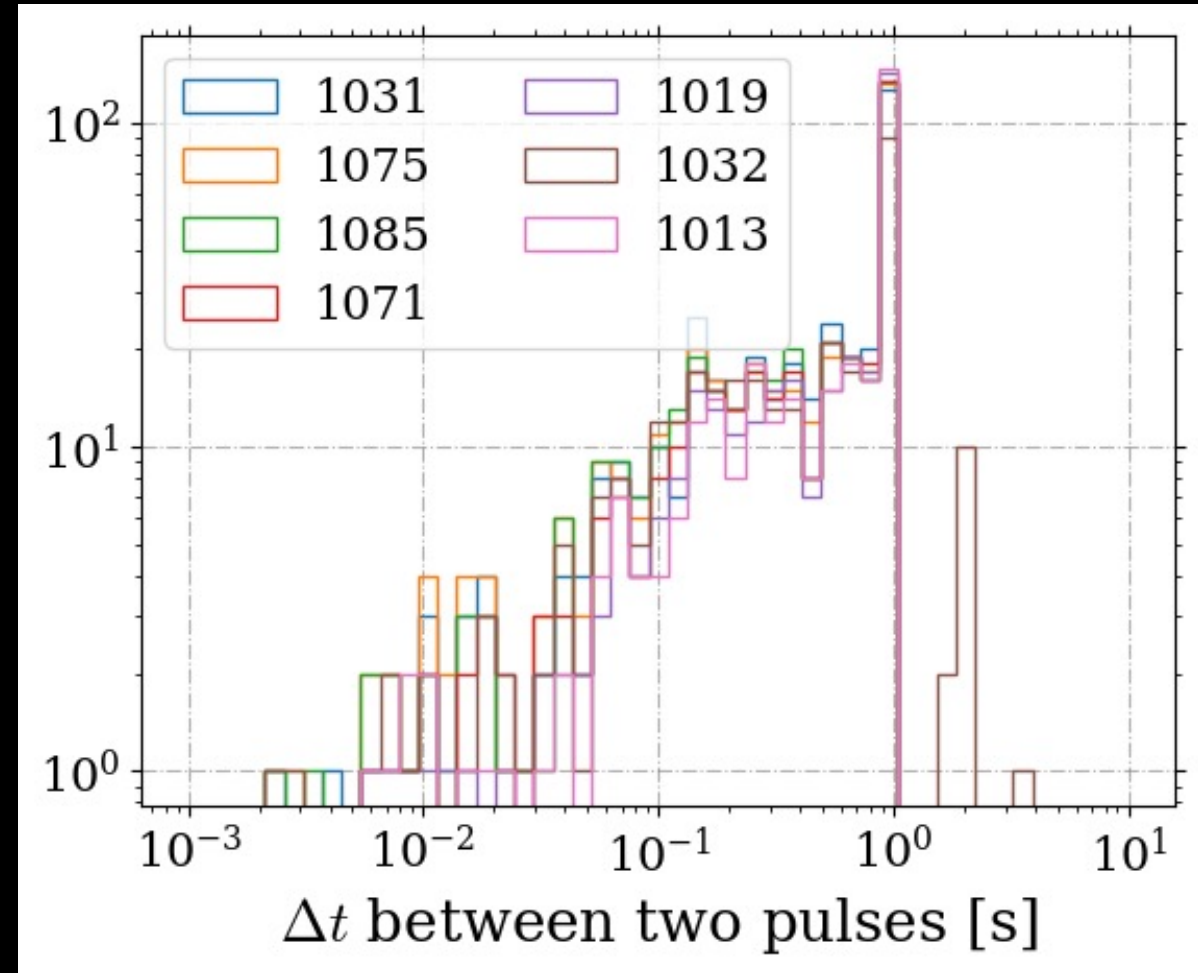
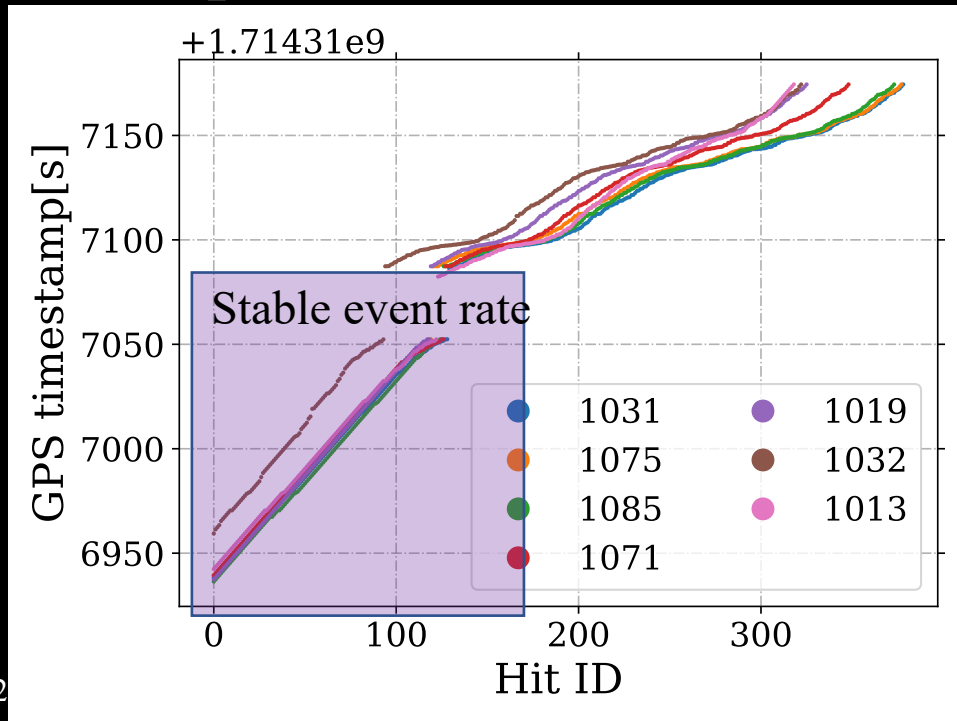
# Zoom-in of Hit Time

- Discontinuity of the GPS timing, change of burst rate?



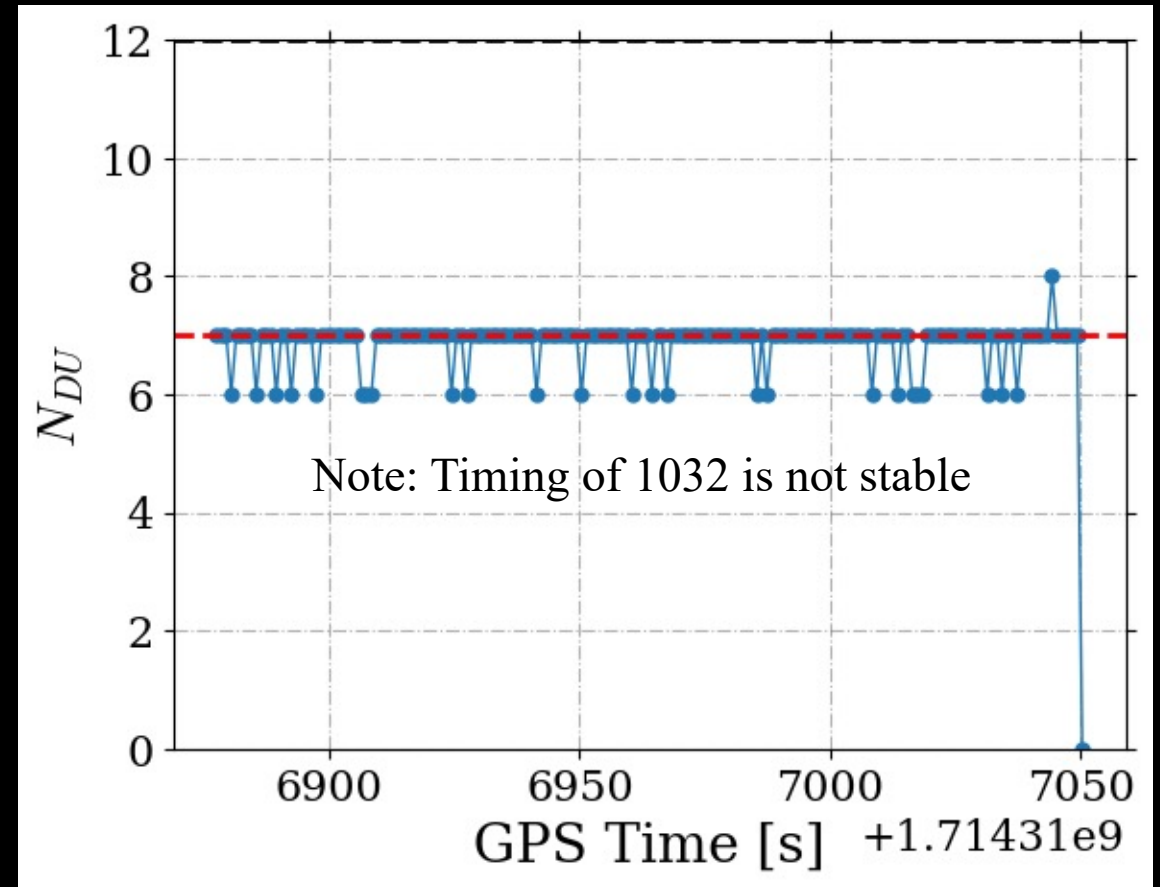
# Burst Rate

- Peak at 1Hz -> The beacon rate?
- Gaussian/Poisson process as noise
- 1032 peaks around 0.5Hz.



# Coincidence

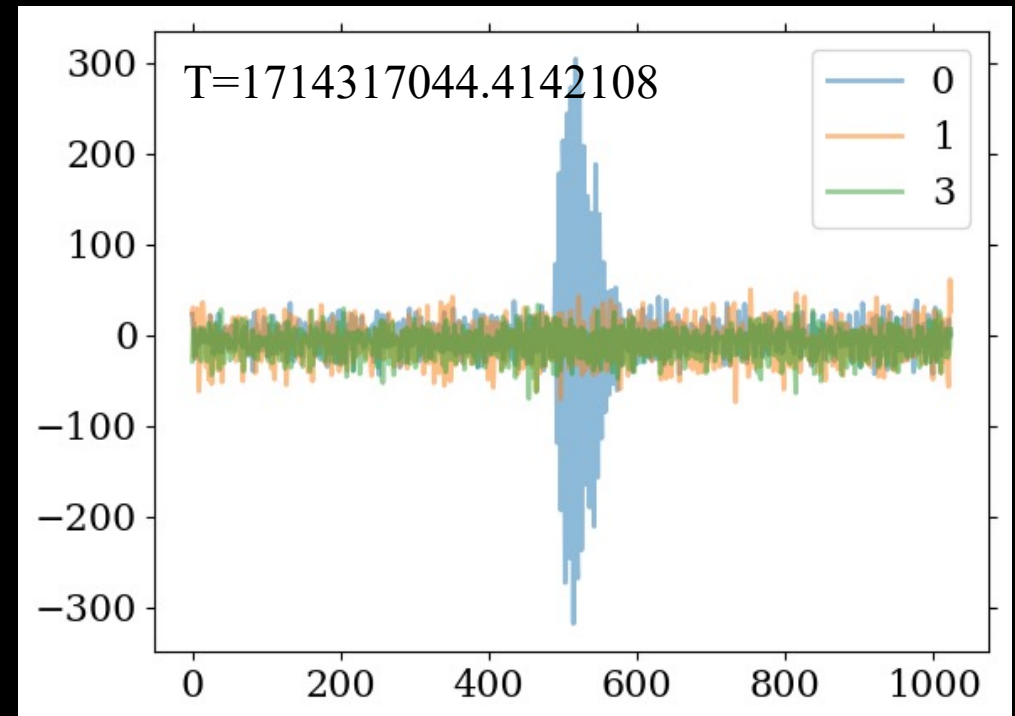
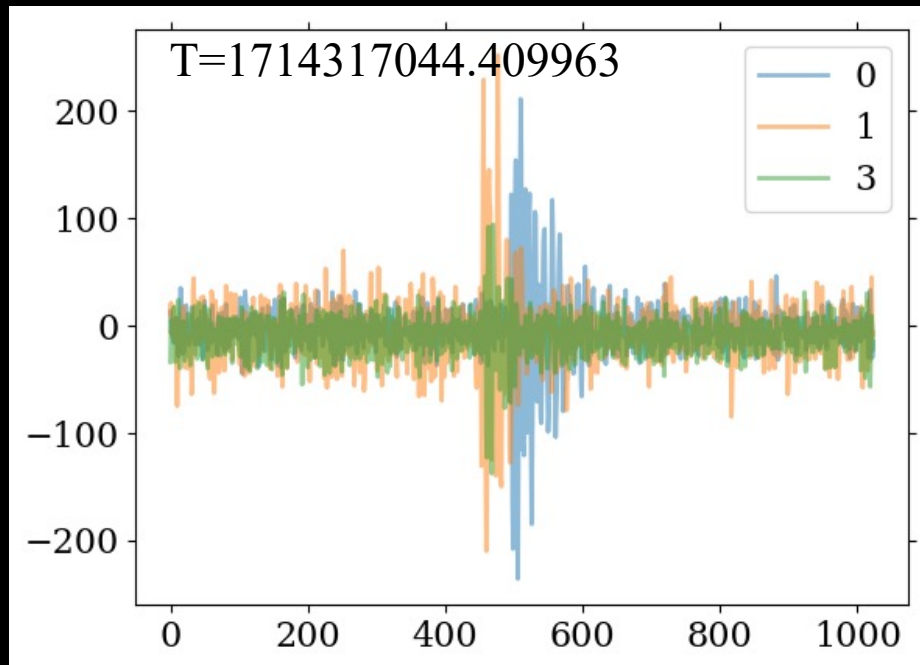
- Coincidence window: 10ms
- Minimum DUs for a CD: 3
- Timestamp to be searched: from 1714316877.41 to 1714317051.41 with stepsize=1s
- Expected 174 events
- Observed 173 events (one event where 1031 occurs twice.)
- Timing of 1032 is off from others.





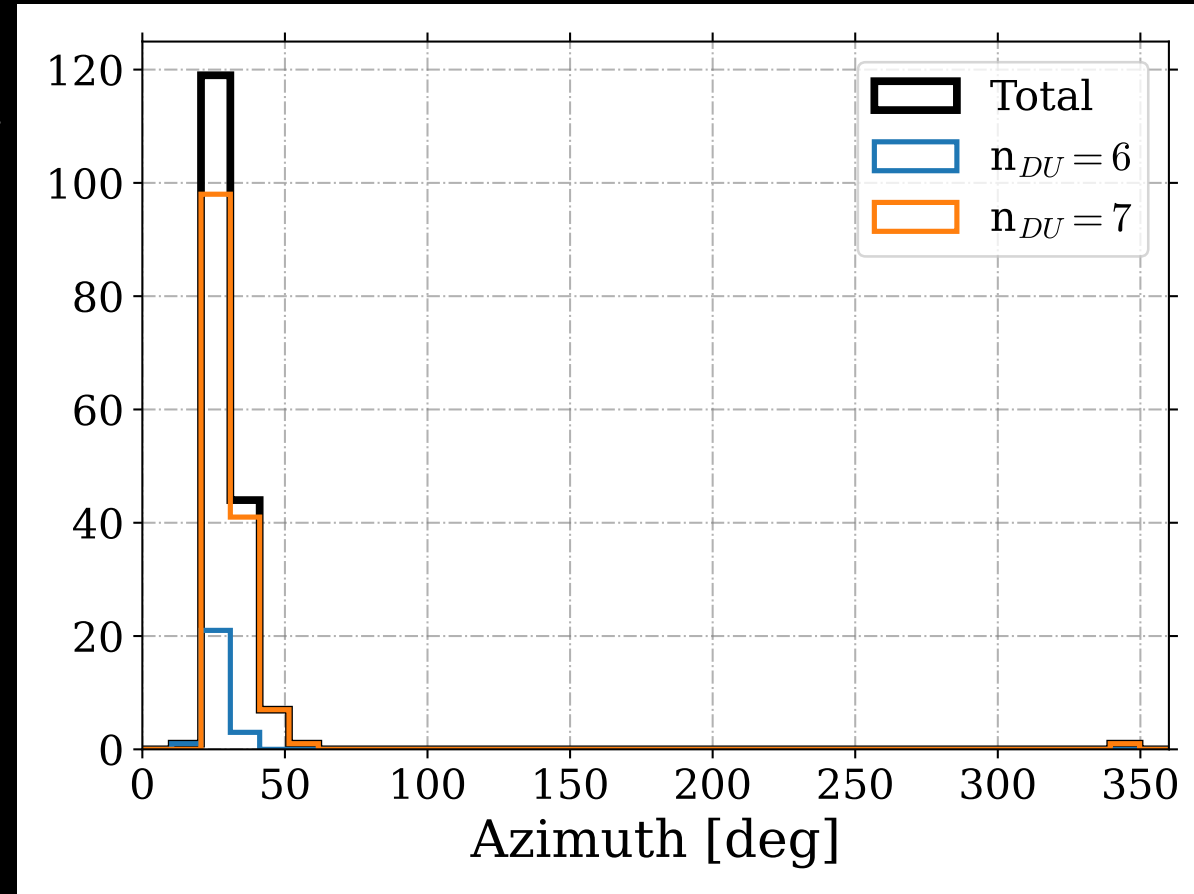
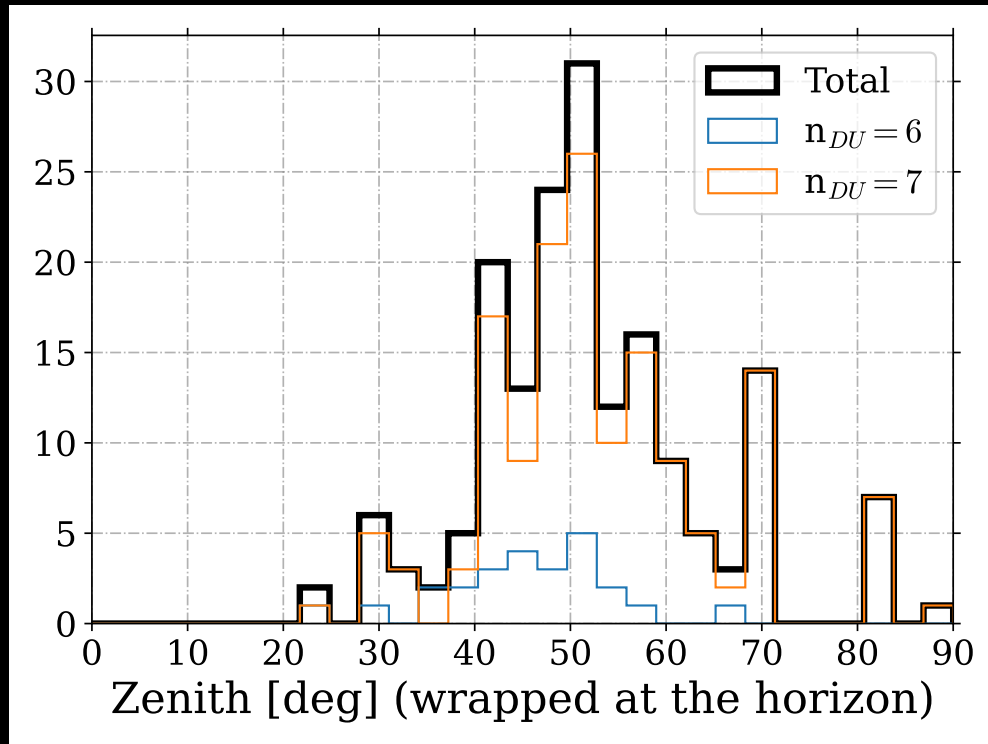
# Non-beacon Pulse for DU1031

- Another pulse likely induced by another source triggered 1031 at a similar time. So, DU1031 appeared twice. But this event is discarded for reconstruction.



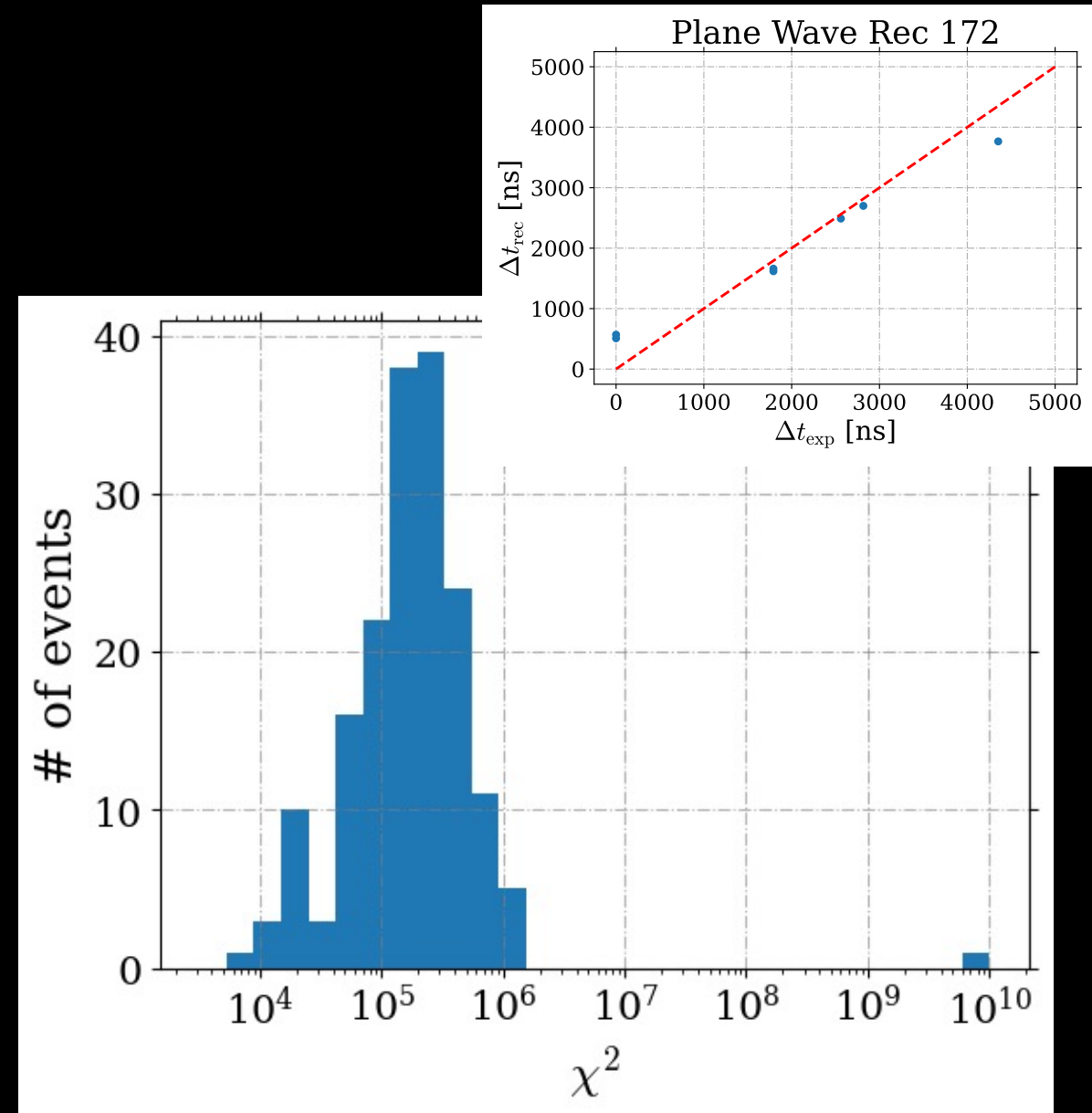
# Direction Reconstruction

- Plane wave fitting
- Spherical wave fitting mostly failed.



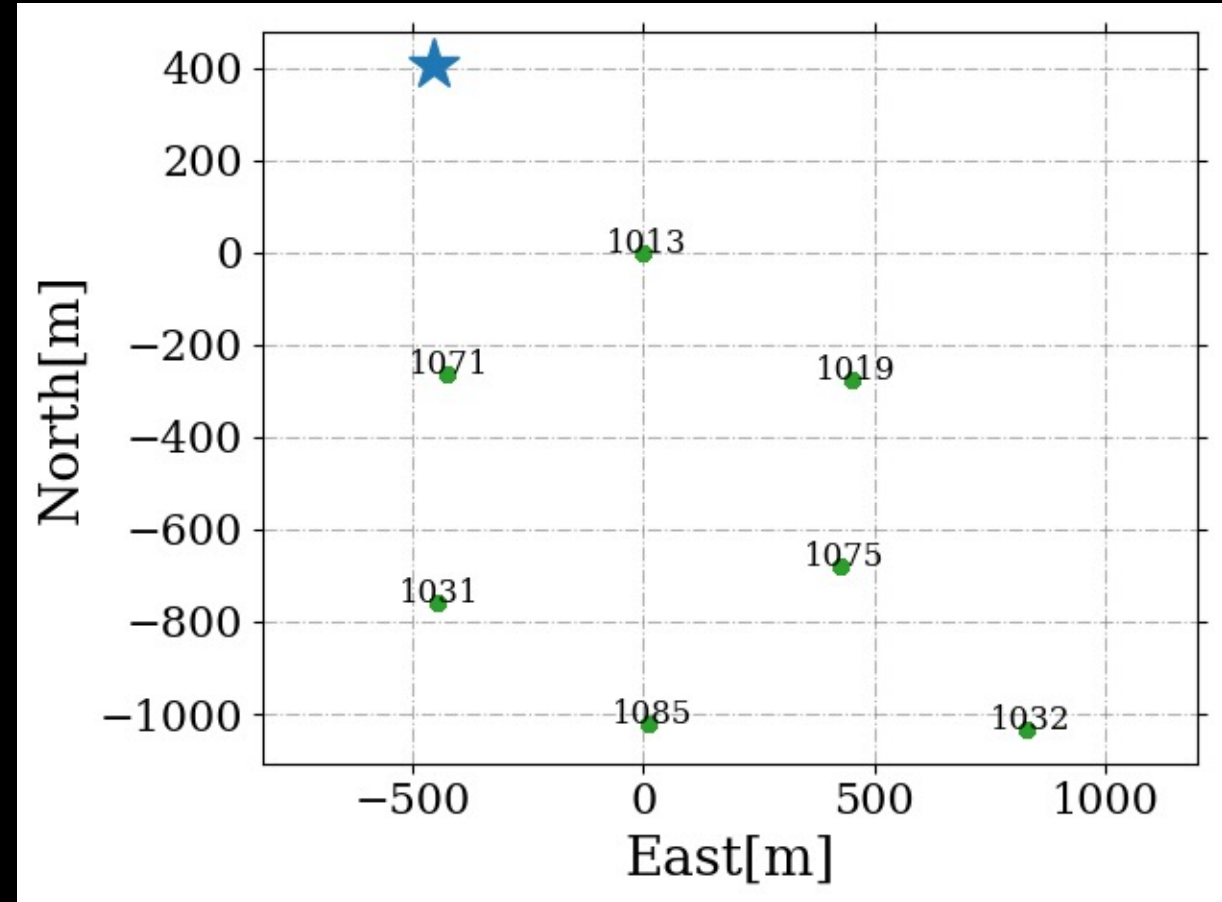
# $\chi^2$ Distribution

- The distribution peaks around  $2E5$ .
- Considering the GPS timing (PPS signal error):
  - Fixed mode:  $\sigma \approx 15\text{ns}$ ,  $\chi^2_v \approx 888$
  - Survey mode:  $\sigma \approx 50\text{ns}$ ,  $\chi^2_v \approx 80$
- GPS timing is probably wrong.



# Calibrate GPS Timing with Beacon

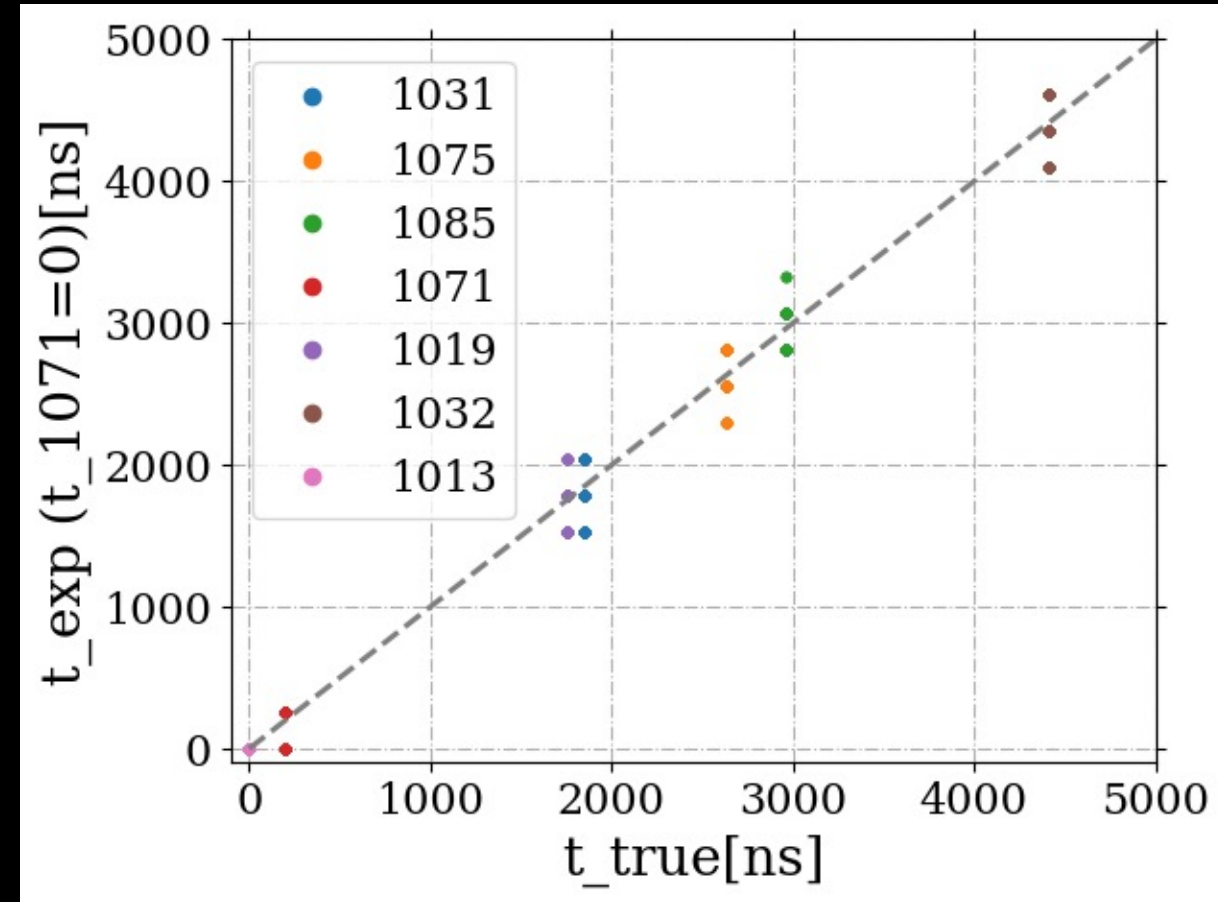
- Beacon is set at the central station. (★) as DU1076.
- The relative arrival time at each DU is calculated by the distance.
- By comparing the observed trigger time and the expected arrival time, a relative calibration among the seven DUs can be achieved.
- The timing reference is set to DU1071.



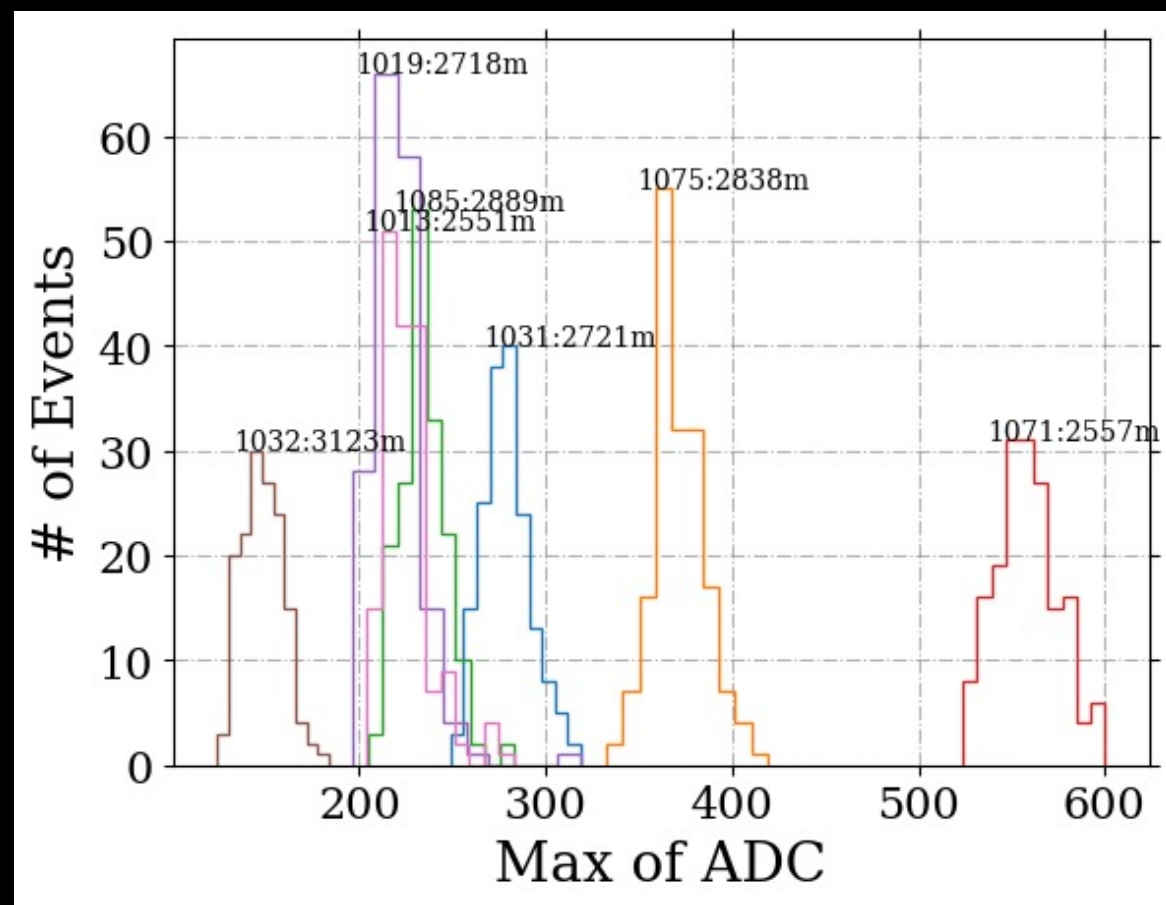
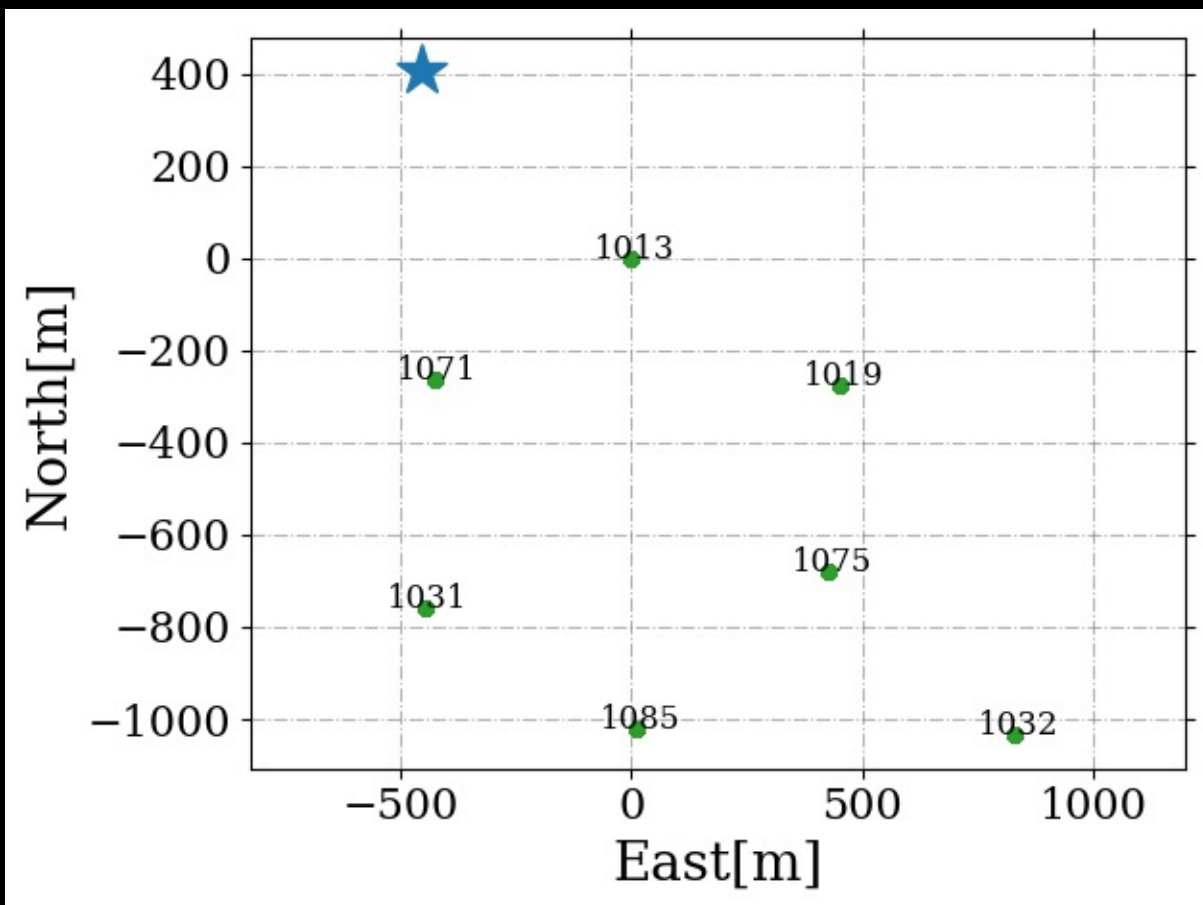
# Observed vs. Expected Arrival Time

- 256/512 ns variation for one DU?
- Likely induced by mis-coding of some bit
- Time shift with respect to DU1013:

DU	$\Delta t[\text{ns}]$
1031	-33
1075	-34
1085	-22
1019	-45
1032	-31
1071	-43



# Peak Amplitude at ChY



# Conclusion

- To run in trigger mode, GPS should be stable and accurate.
  - GPS time differs by 256/512ns from central value.
  - GPS offset between DUs is  $\sim O(10\text{ns})$
- Needs more investigation on the data.
- Check GPS times in the lab, e.g., measuring the PPS signal