Coincidence Analysis with GP13 and G@A

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2024.06.08

Data of GP13

- UD files:
  - 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
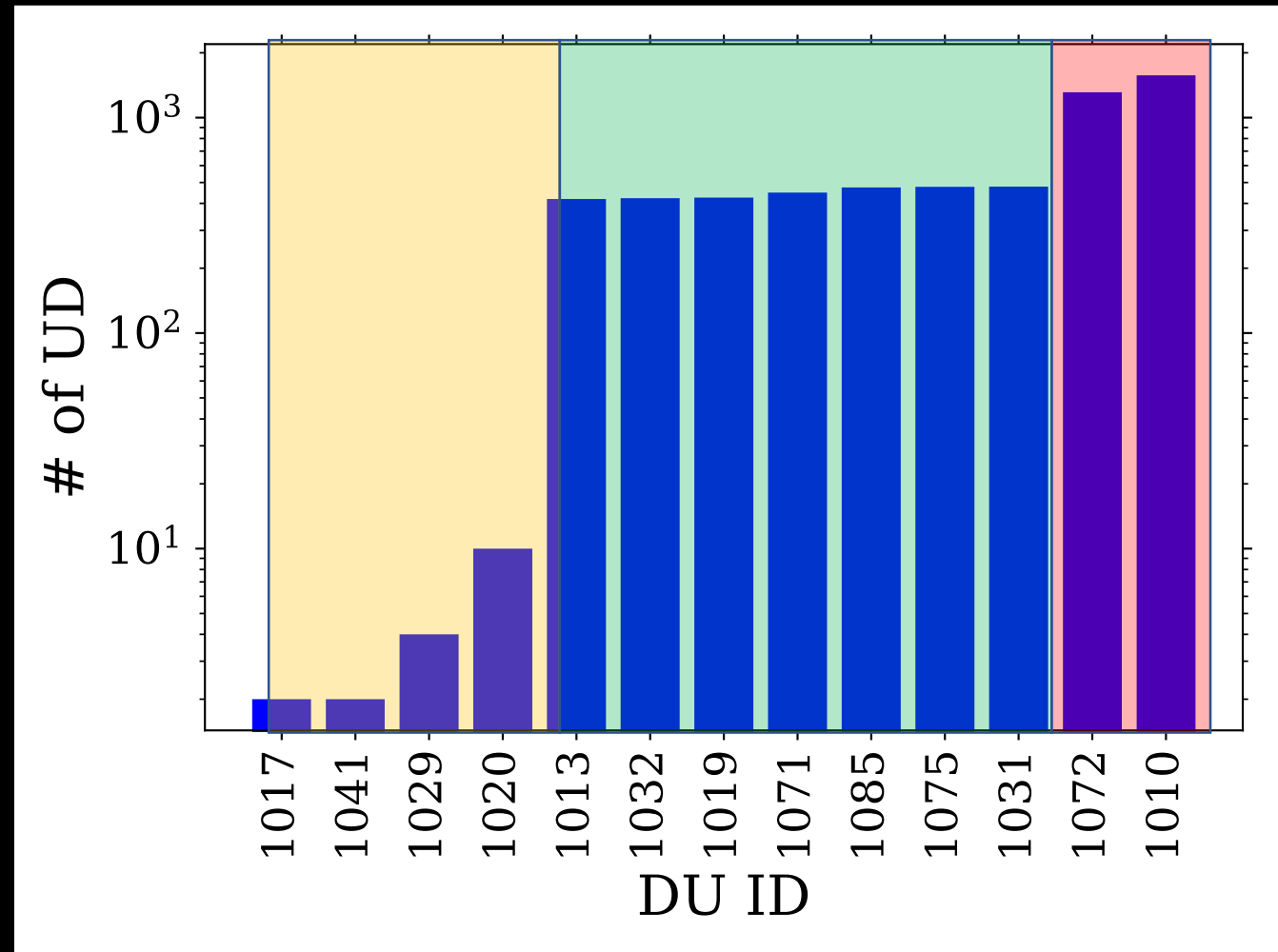- (offline coincidence analysis)

Beacon Signal

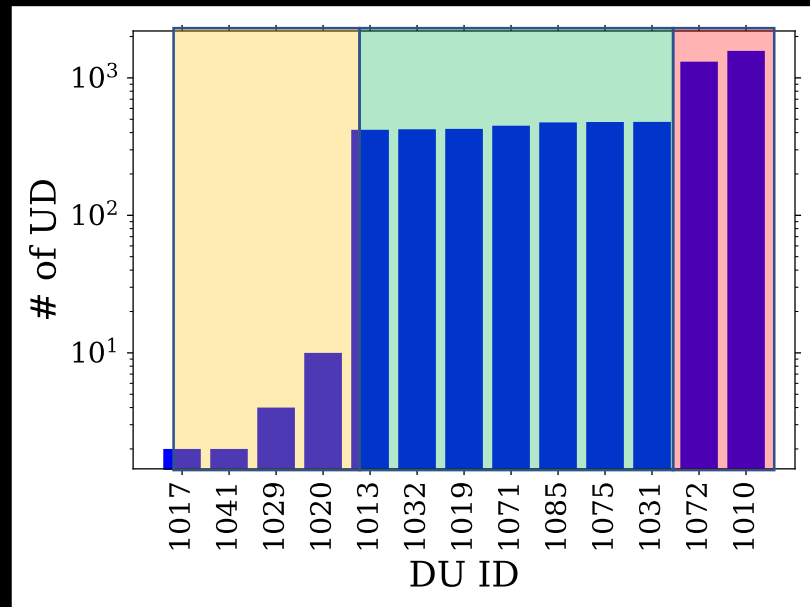- Pulse at time domain
- 100MHz at FFT spectrum
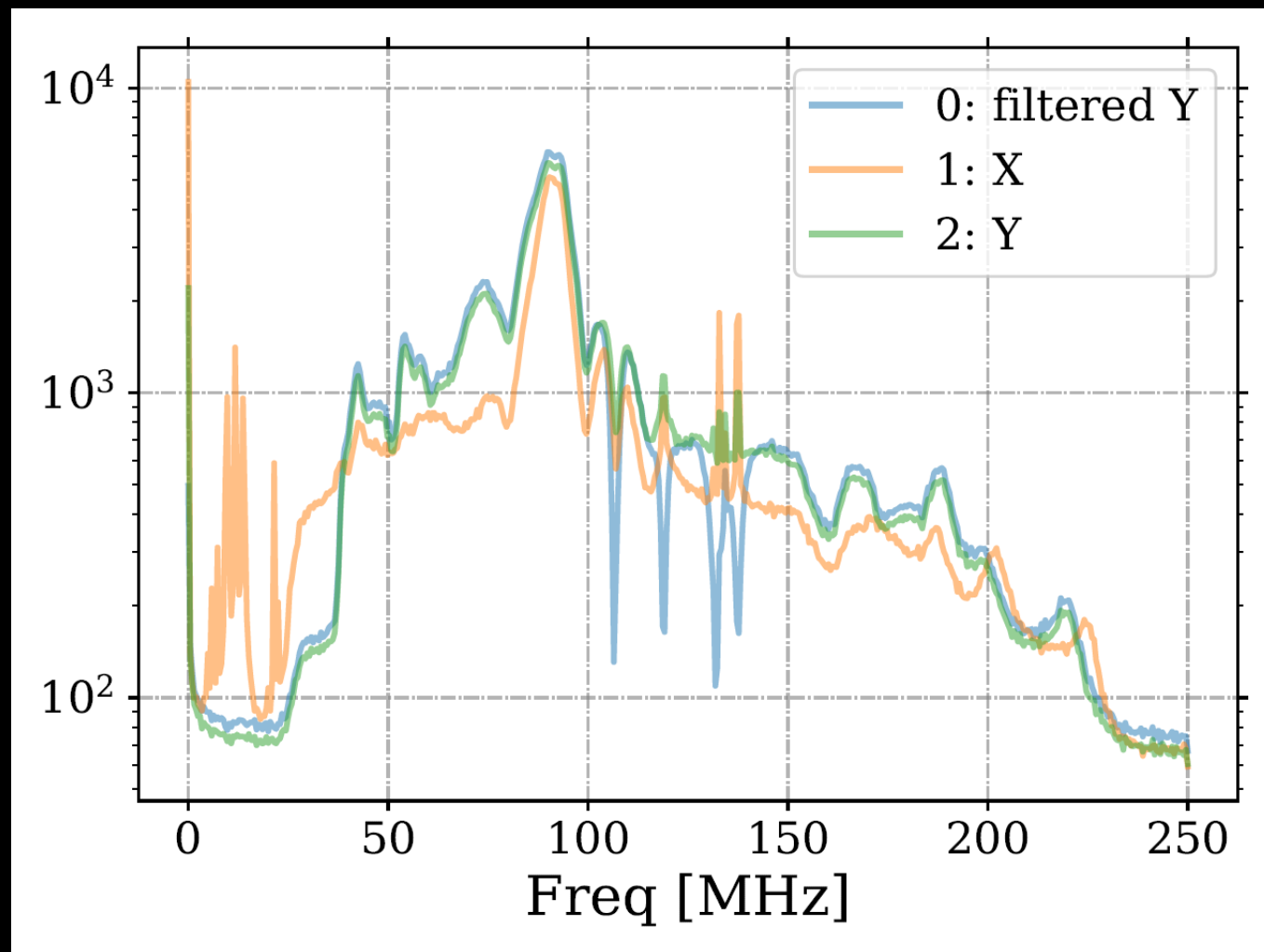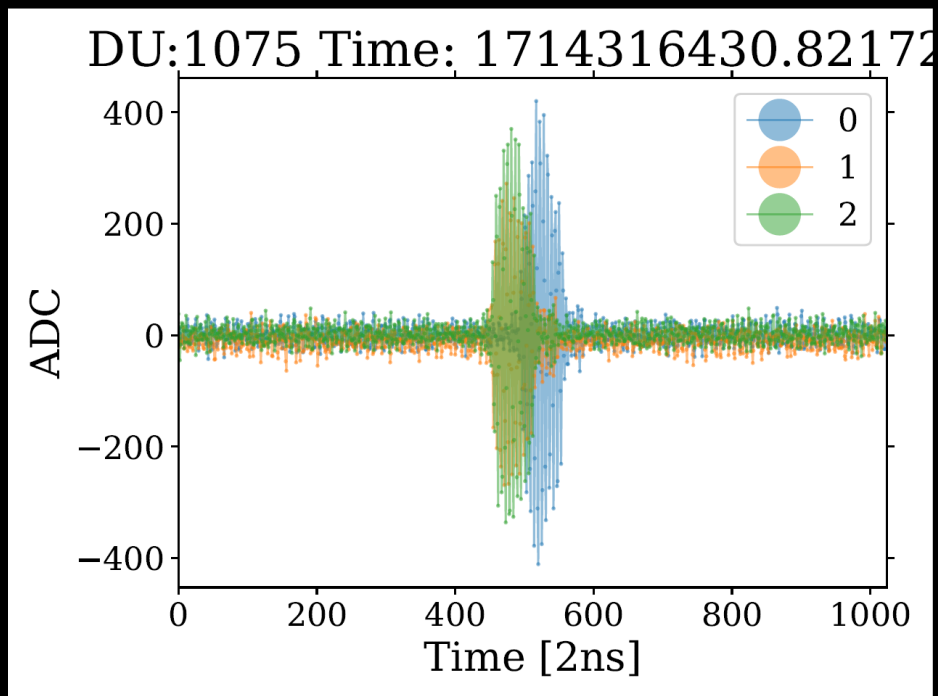
Number of Pulses

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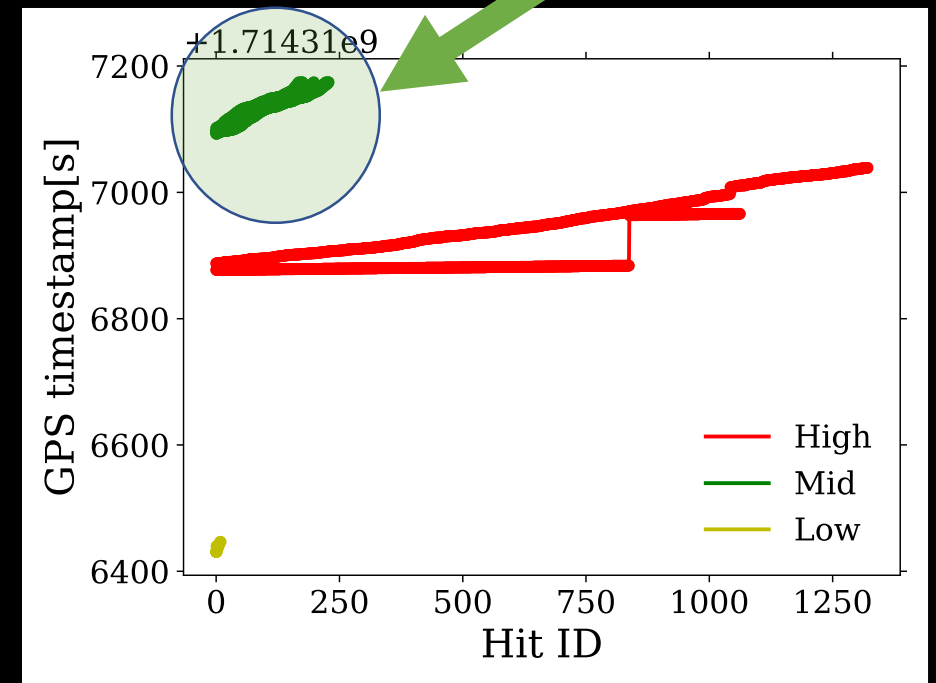- 1017, 1014, 1029, 1020: <10 pulses

GPS Timing by DUs

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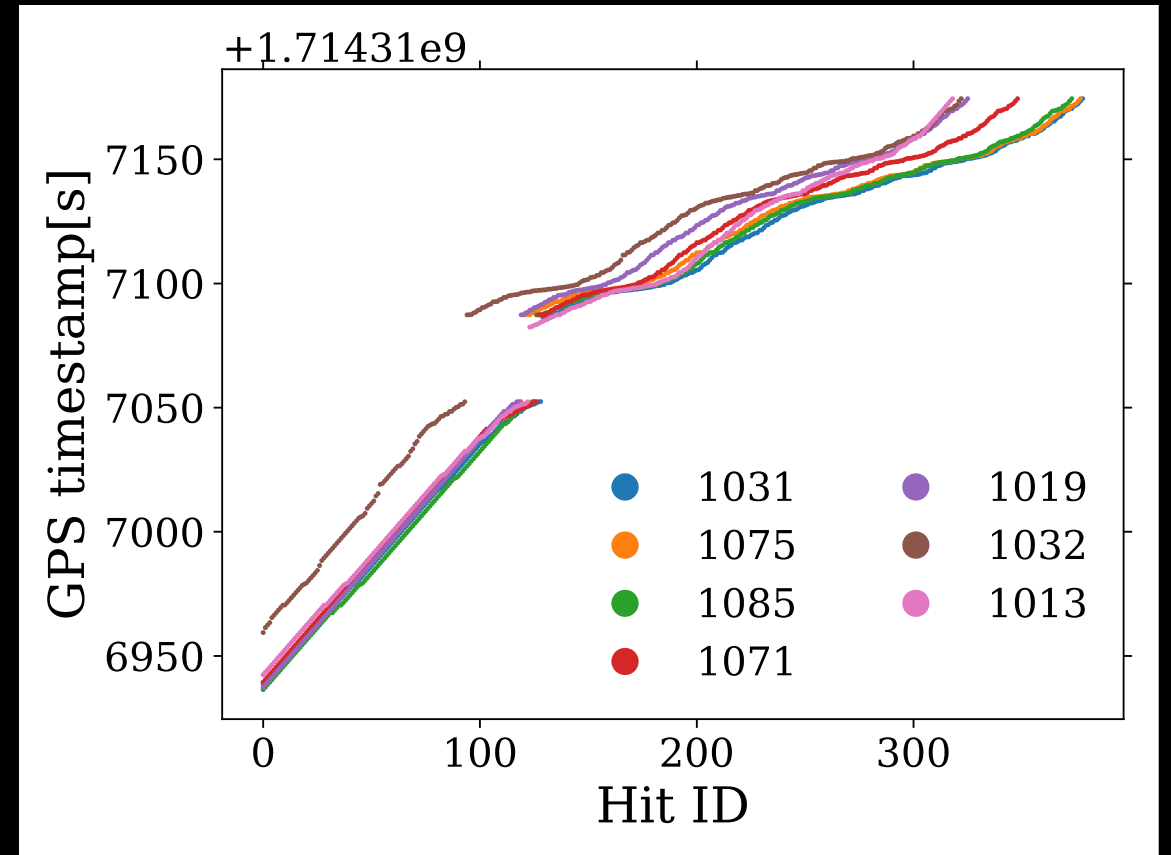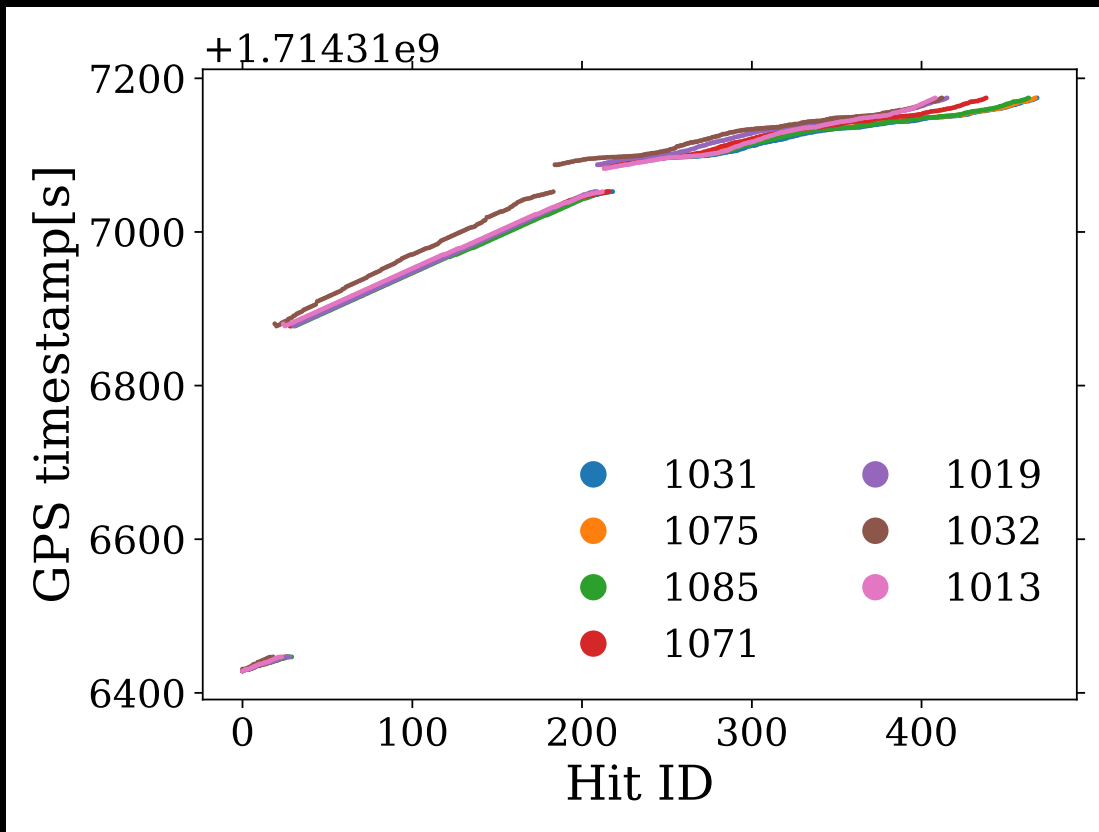 - Low: [1017, 1041, 1029, 1020]

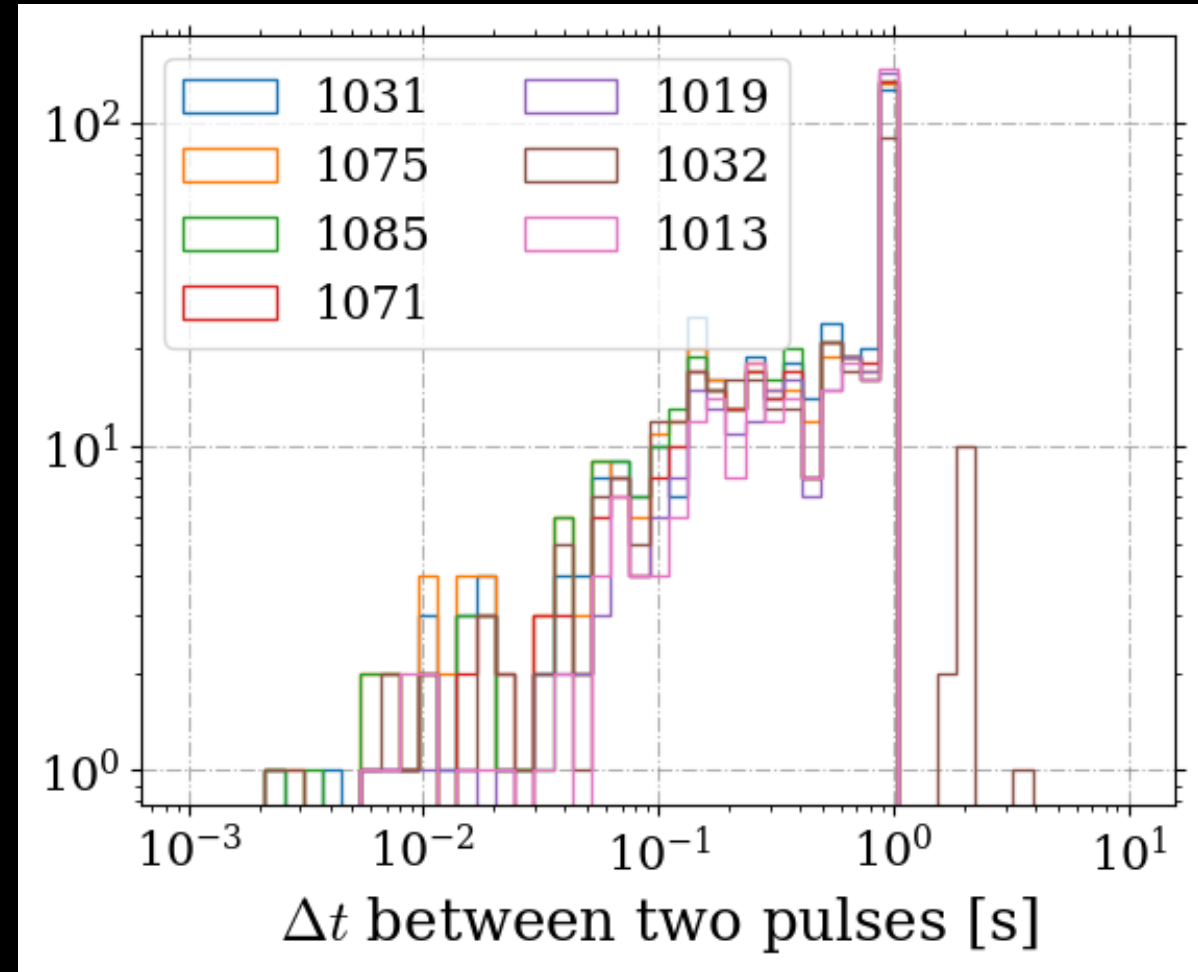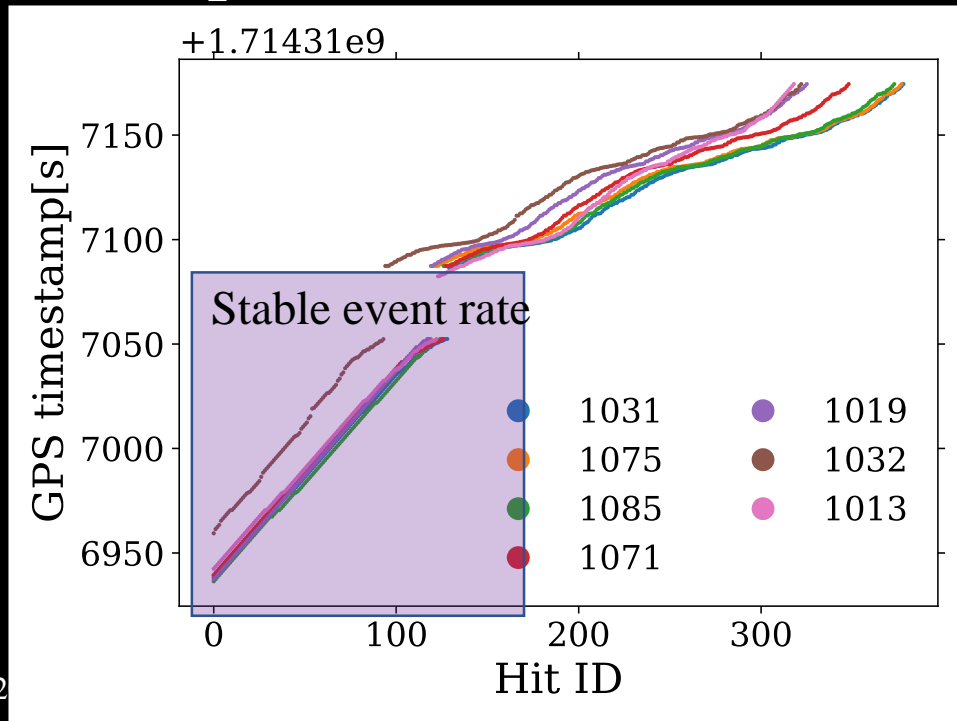Only these DUs are considered for coincidence analysis

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.

Offline Coincidence for GP13

- 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.

Note: Timing of 1032 is not stable
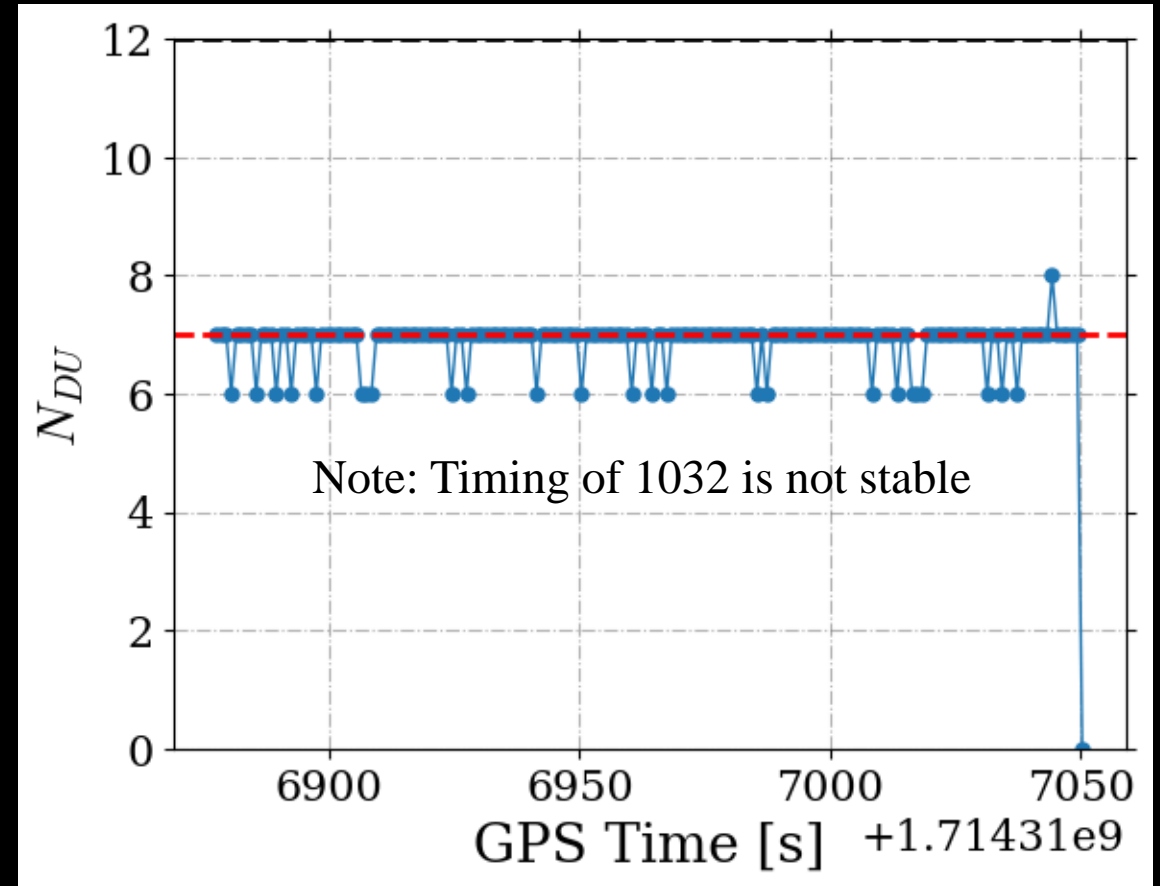
Calibrate GPS Timing with Beacon

- Beacon is set at the central station. (⭐) as DU1076.

- Performing spherical wave reconstruction based on time of arrivals @ DUs
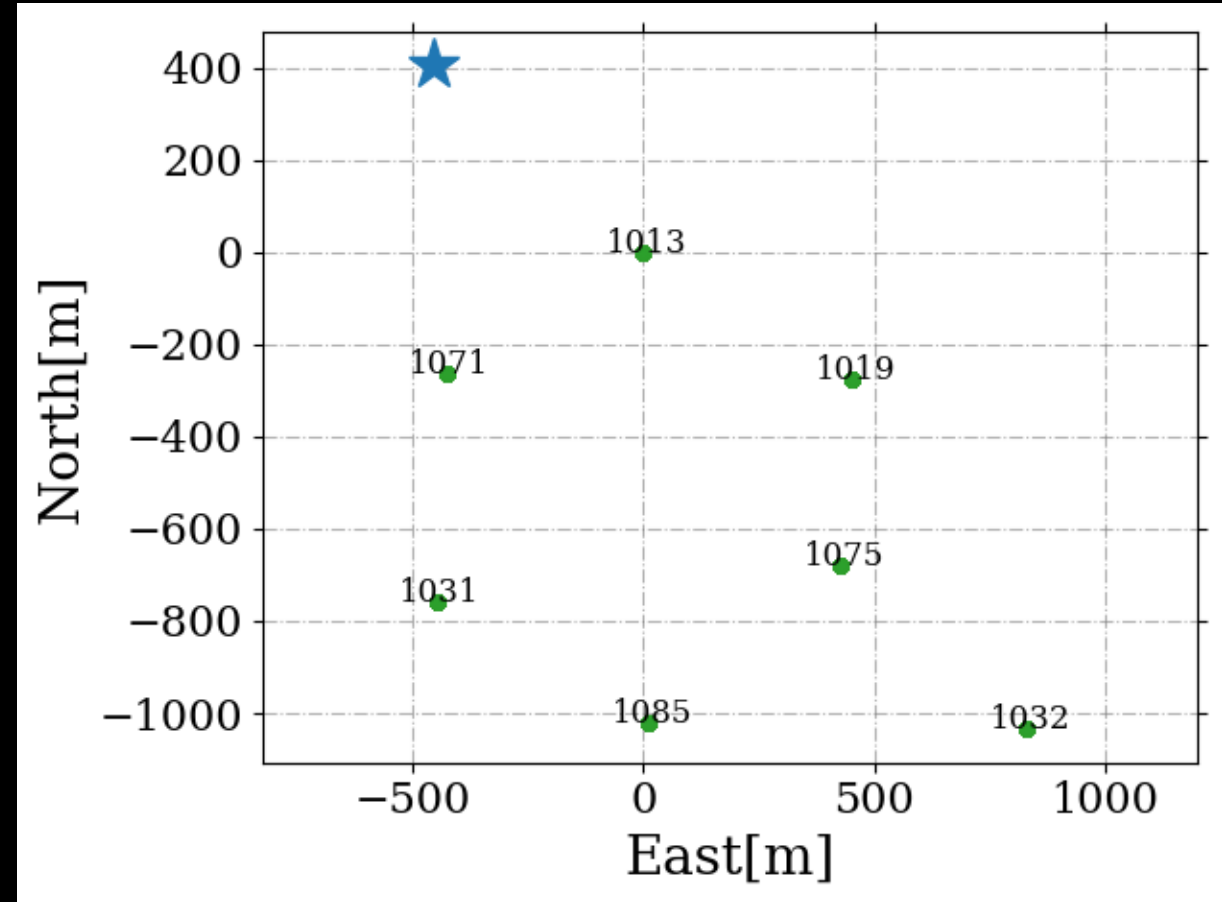
Typical event

- « Delay plot » à la TREND:
  - Plotting measured trigger delay wrt 1st triggered DU vs « model time » computed from isotropic propagation from reconstructed Point Source.
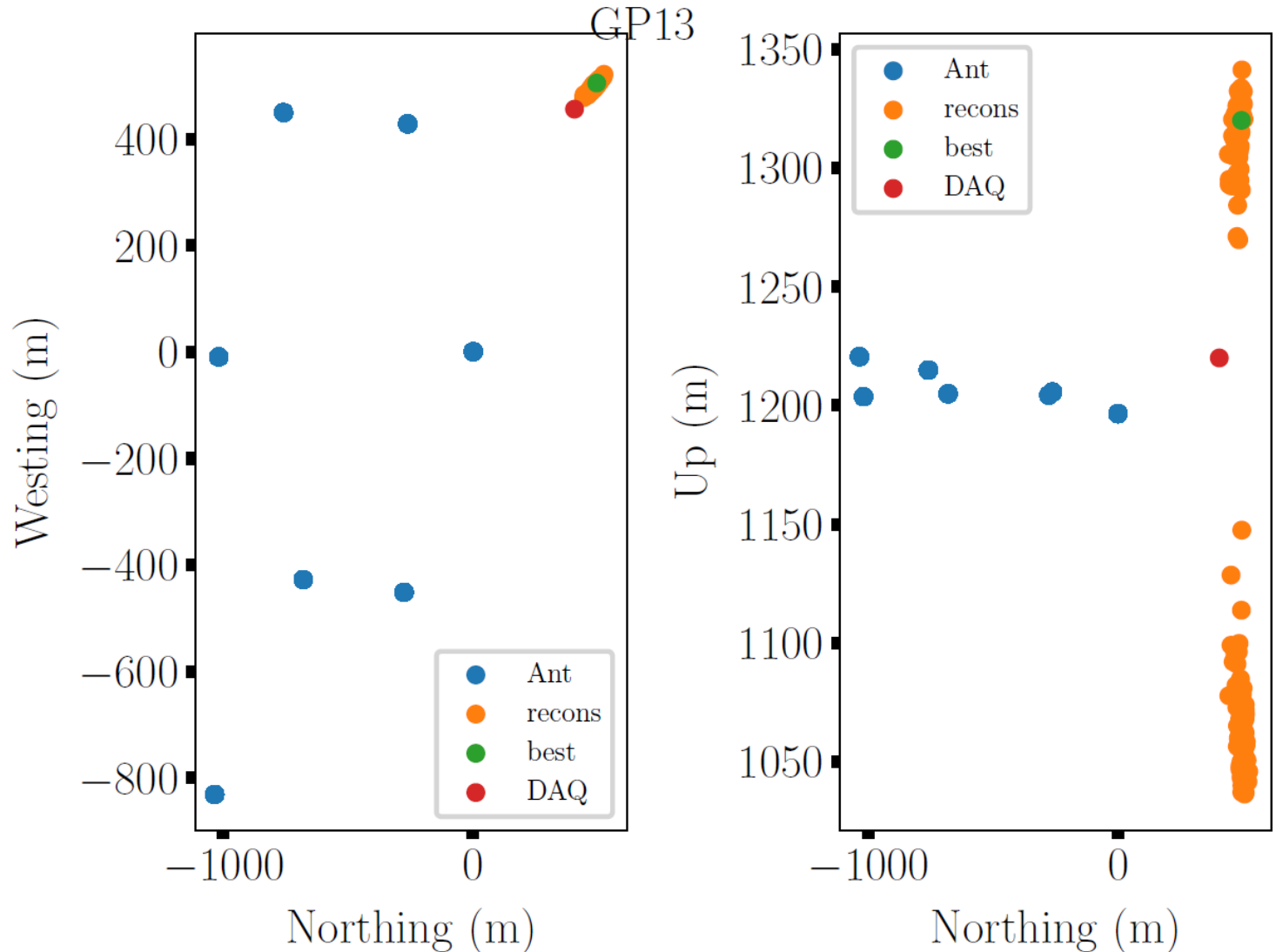 - Also shown in green: time expected from « mean » position (see below)
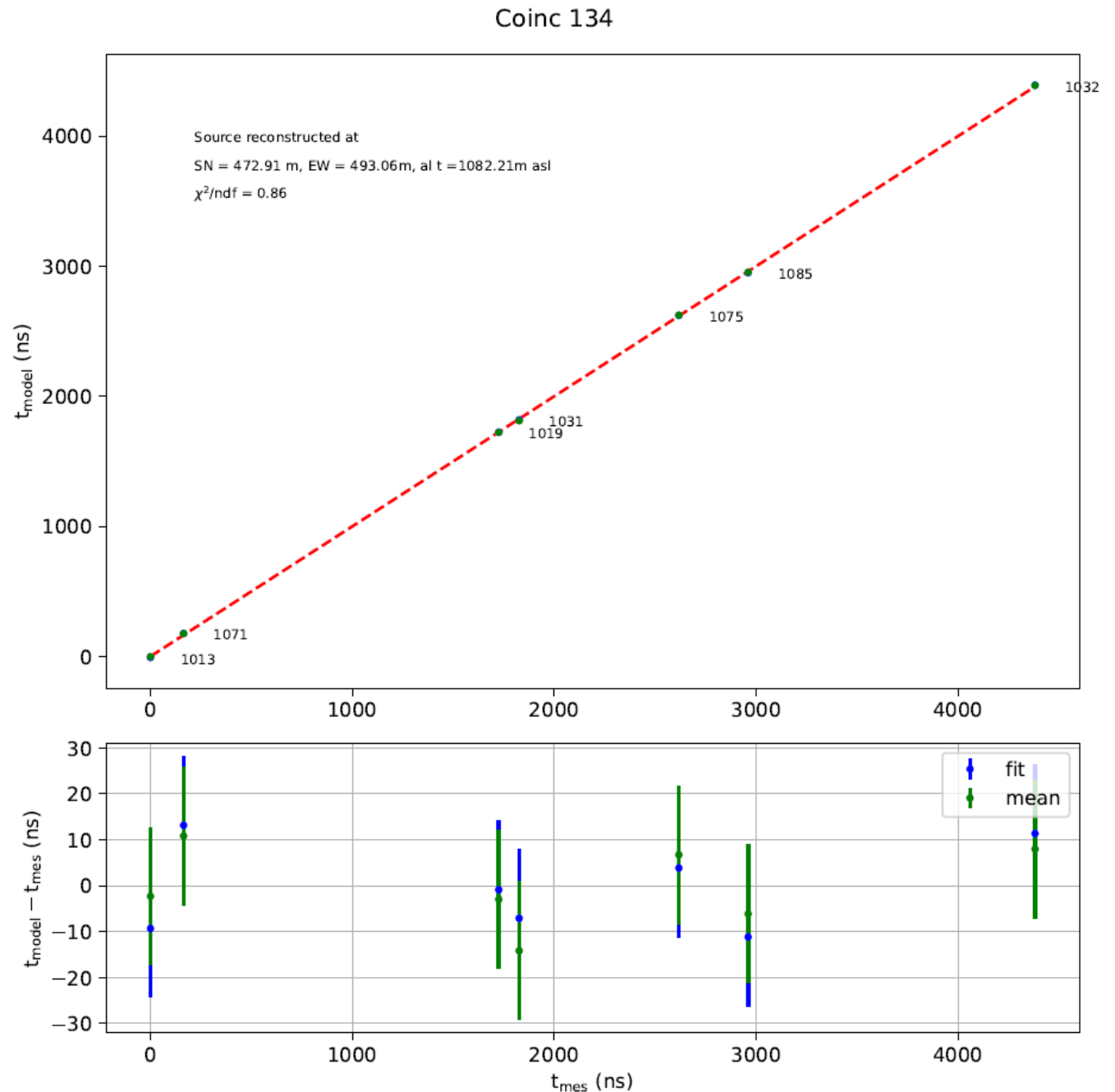
Quality cuts

- Chi2 computed from spherical fit assuming σ_{timing} = 15ns

➔171/172 events with x2/ndf<5 ☺
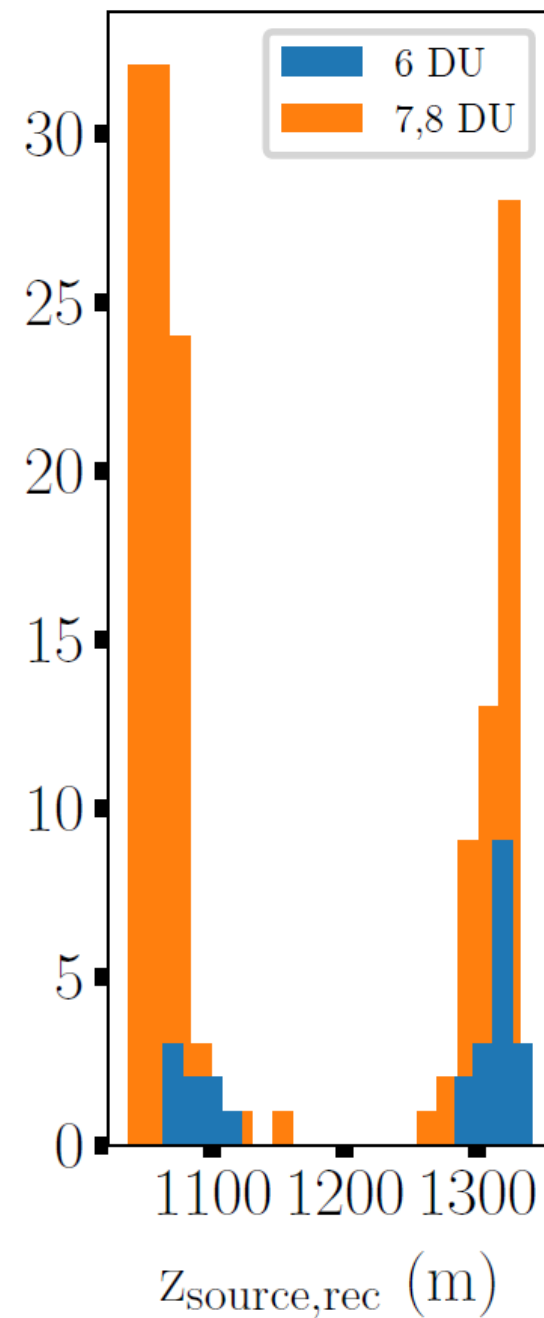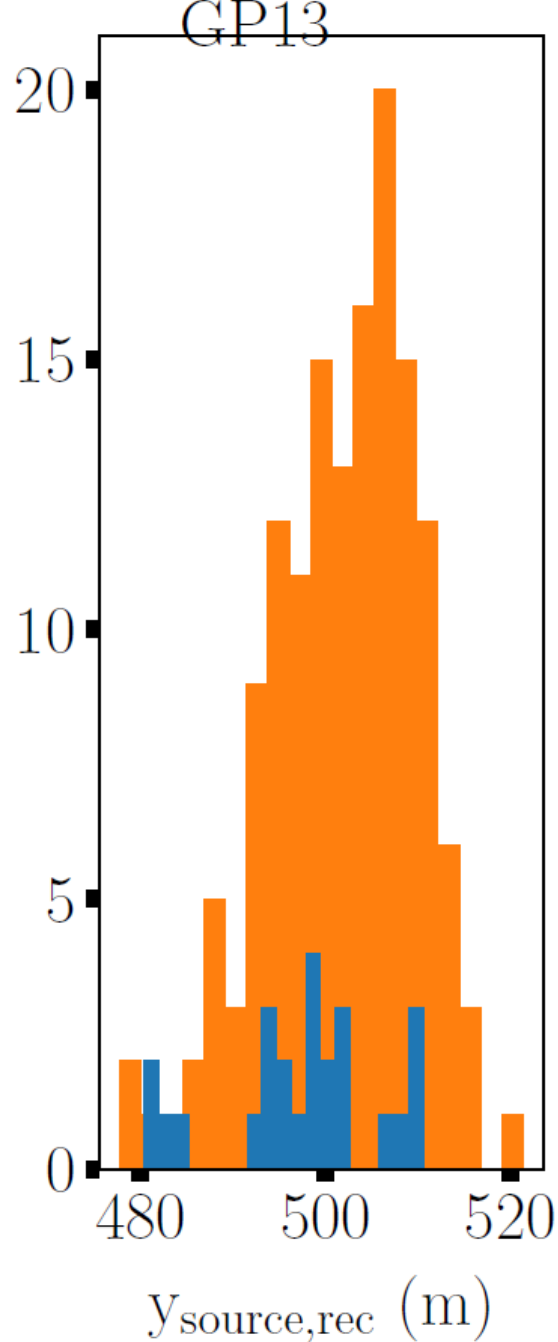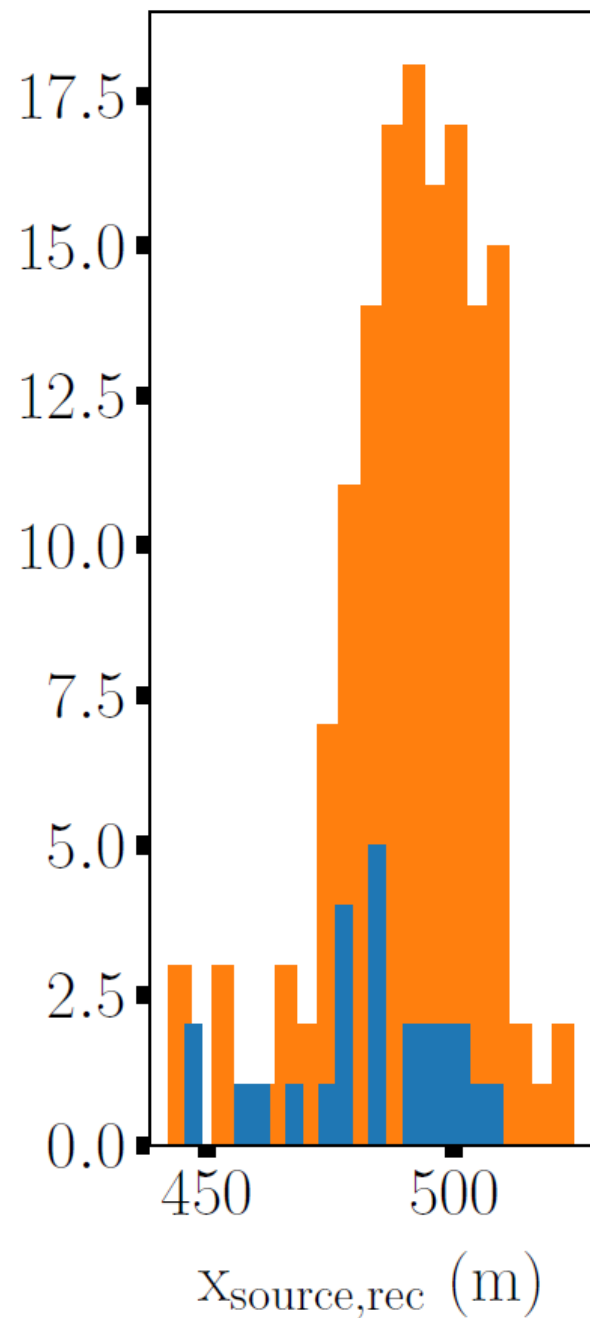
➔ Mean ~1 ☺

Xishui Tian (田喜水)
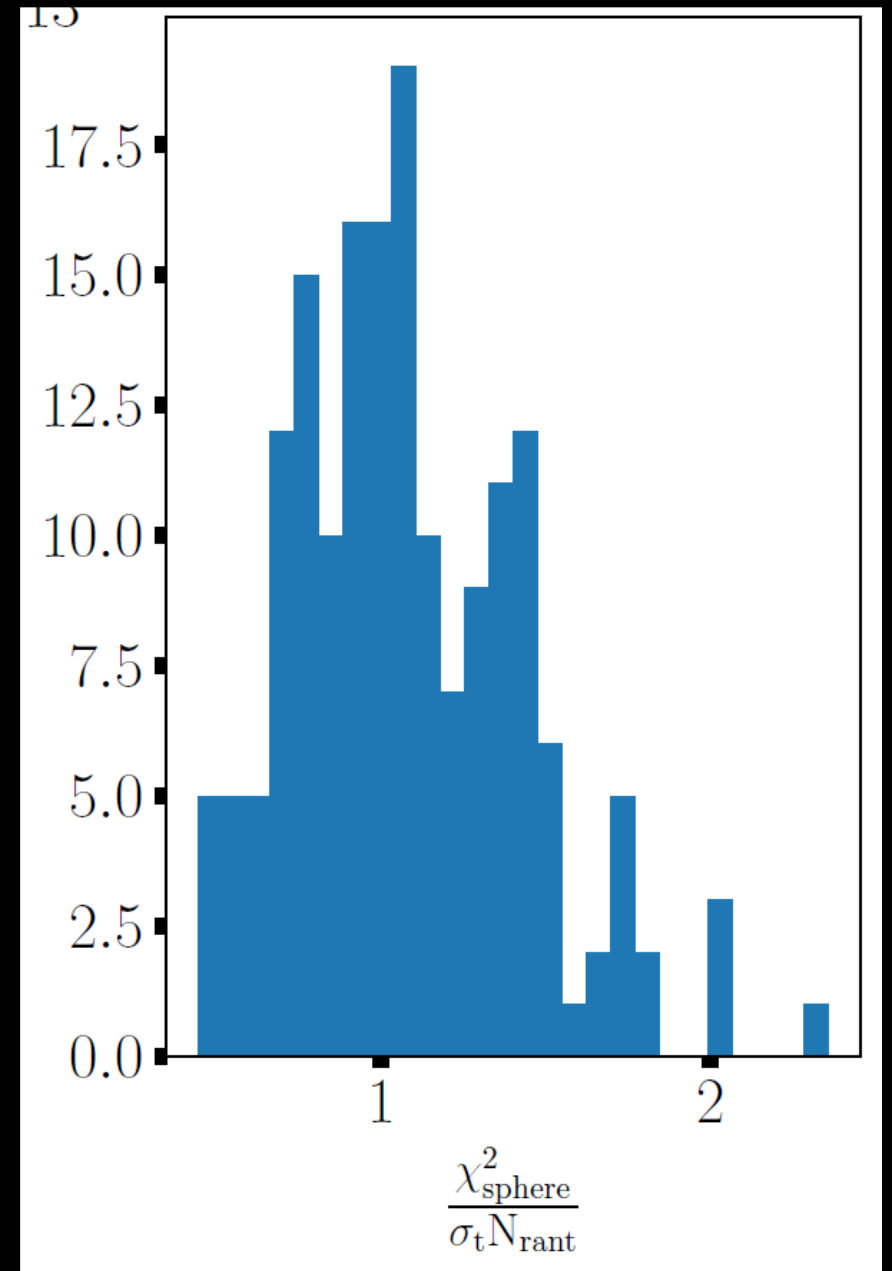
Rconstructed position

- Nominal beacon position [406, 456, 1220]

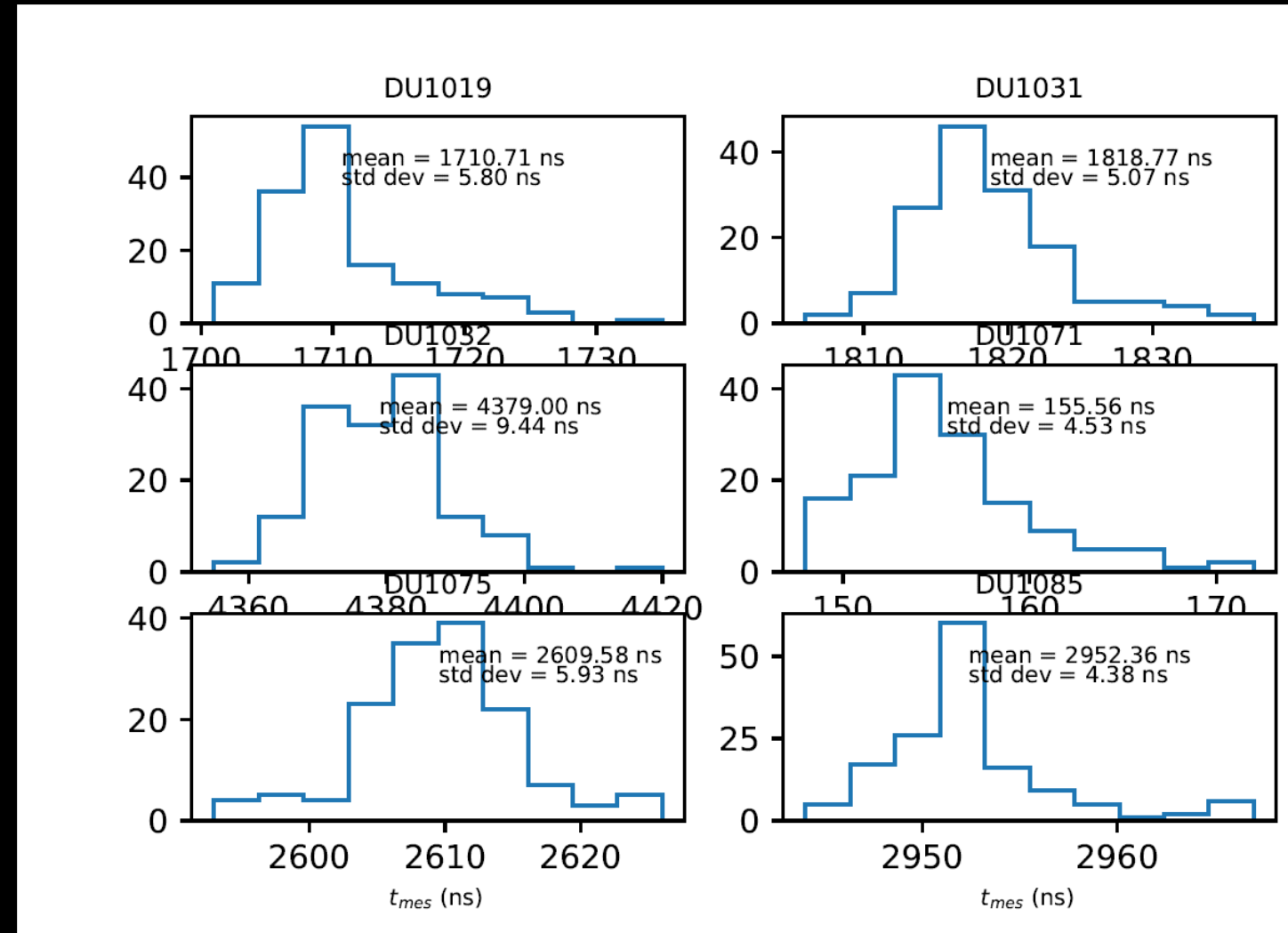- Mean reconstructed position = [490, 501, 1320]

- (Also mirror effect in z)

- σ_x ~15m
- σ_x ~8m ☺

# Some insight on timing resolution

- Distribution of measured trigger time wrt 1st one for all events with 7DUs
  - Very low dispersion!
  - … too good to be true?
- In any case requires
  - more thinking
  - precise measurement of beacon position

Also

- Differences between measured trig time and trig time expected from mean reconstructed source (in ns):
  - DU 1013 , mean= -7.6 std dev= 4.8
  - DU 1019 , mean= 3.9 std dev= 3.8
  - DU 1031 , mean= -11.6 std dev= 5.5
  - DU 1032 , mean= 2.8 std dev= 6.7
  - DU 1071 , mean= 10.7 std dev= 5.0
  - DU 1075 , mean= 6.3 std dev= 4.3
  - DU 1085 , mean= -4.4 std dev= 3.0

- Mean != 0: wrong source position? GPS offset?

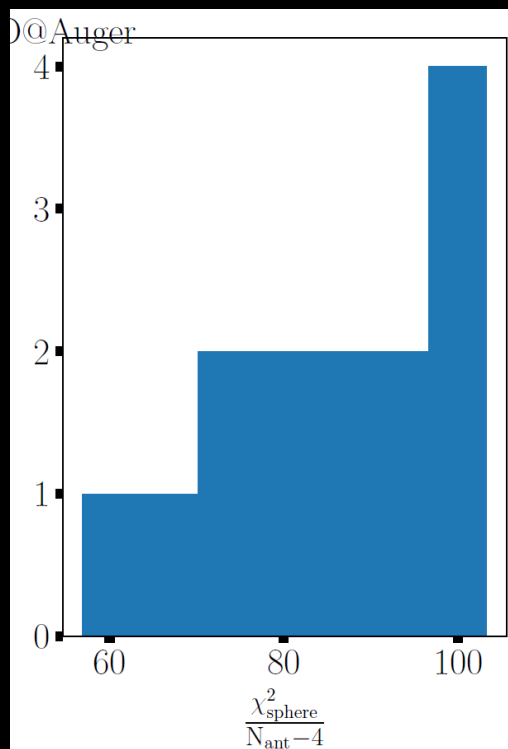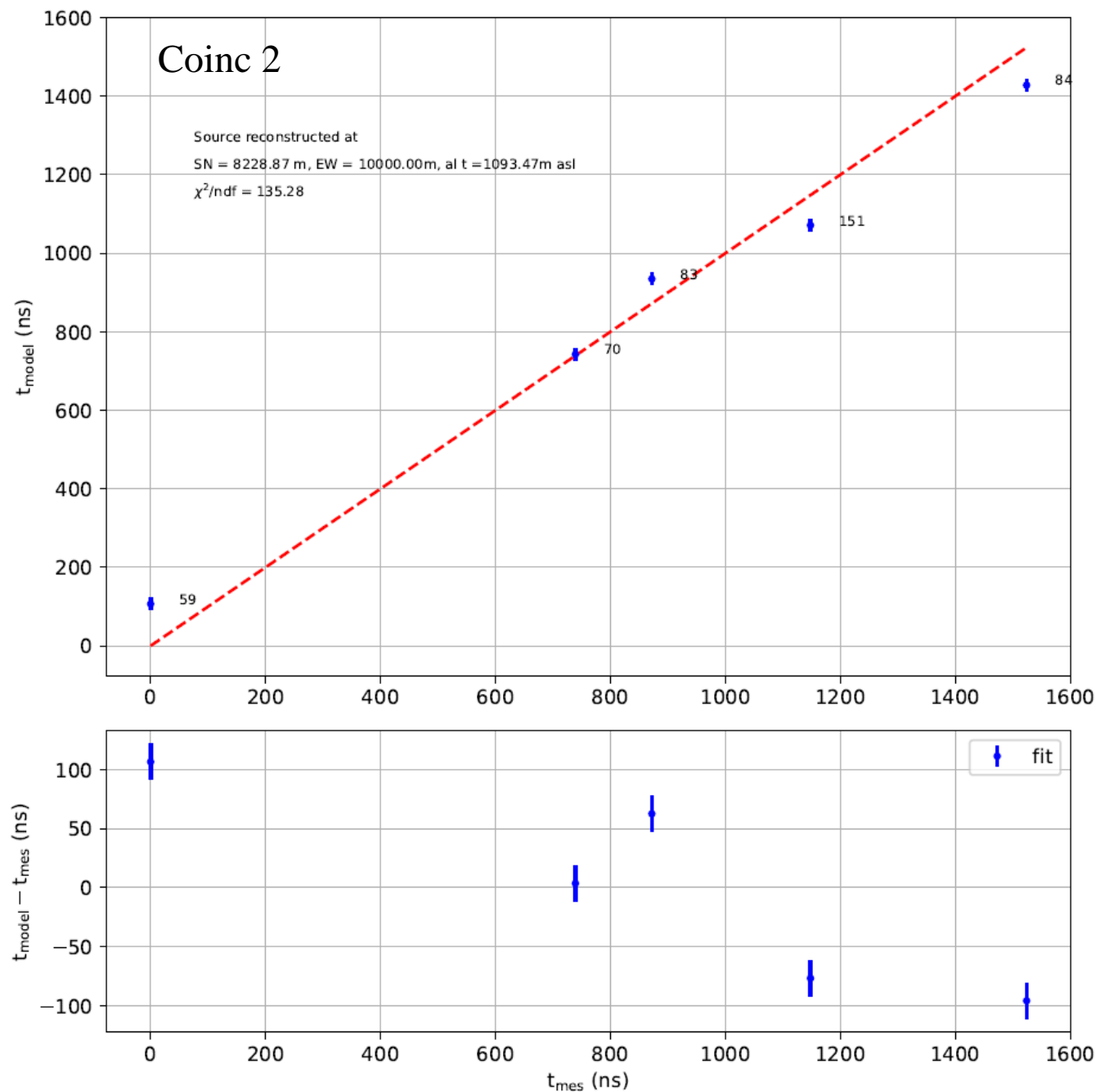- Sigma: same comments as previous slide
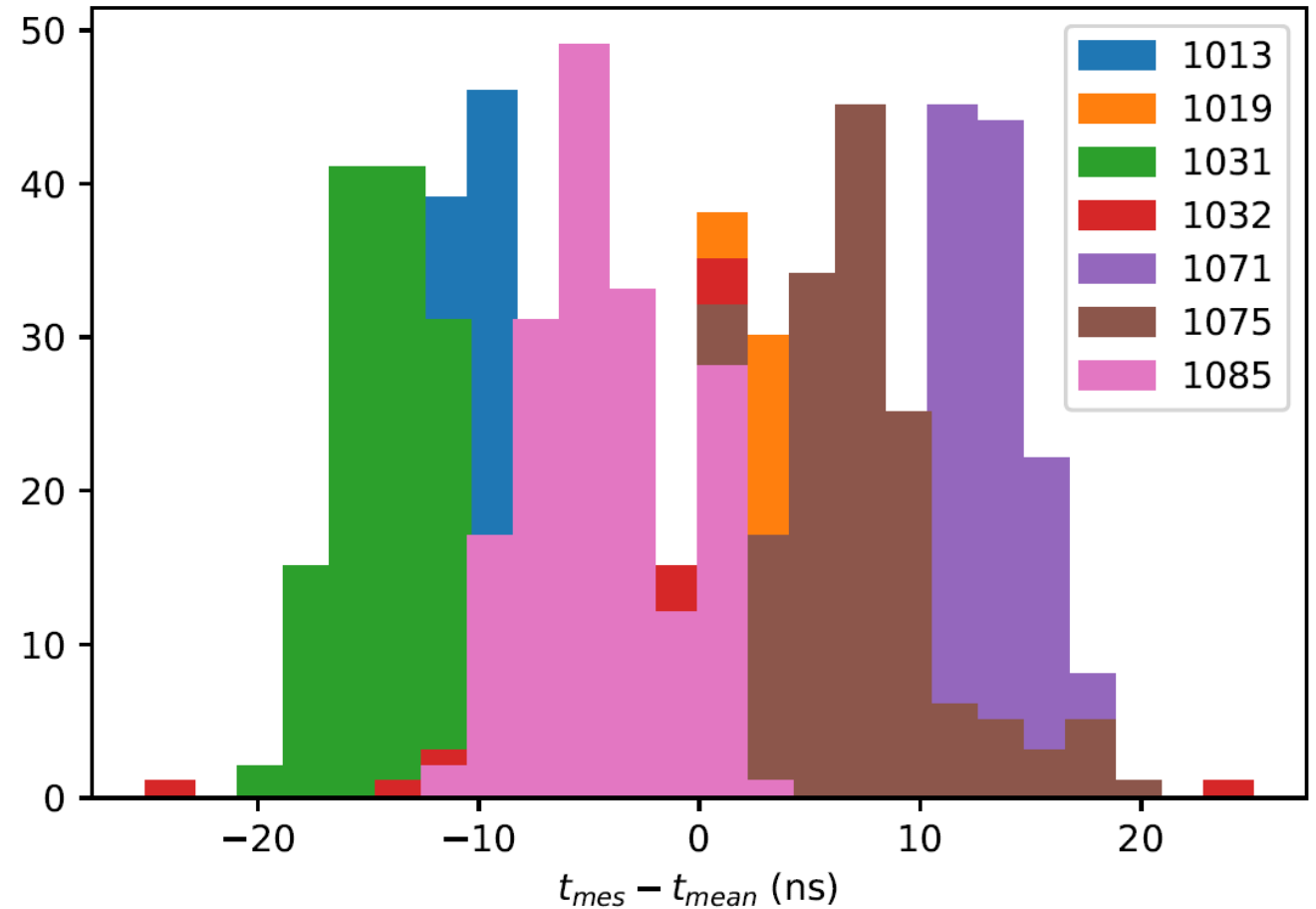
Data of G@A

- CD file: gaa_20240427_224428_RUN003002_CD_phys.root
- Number of DUs: 5 (59, 70, 83, 84, 151)
- Number of CD events: 14
- Indices of events: 4475, 4605, 6801, 6802, 6803, 6819, 6825, 6829, 6840, 6845, 6847, 6862, 6917, 7568
- (online coincidence)

SWF recons

- Point source reconstructed <u>kilometers</u> away with spherical fit
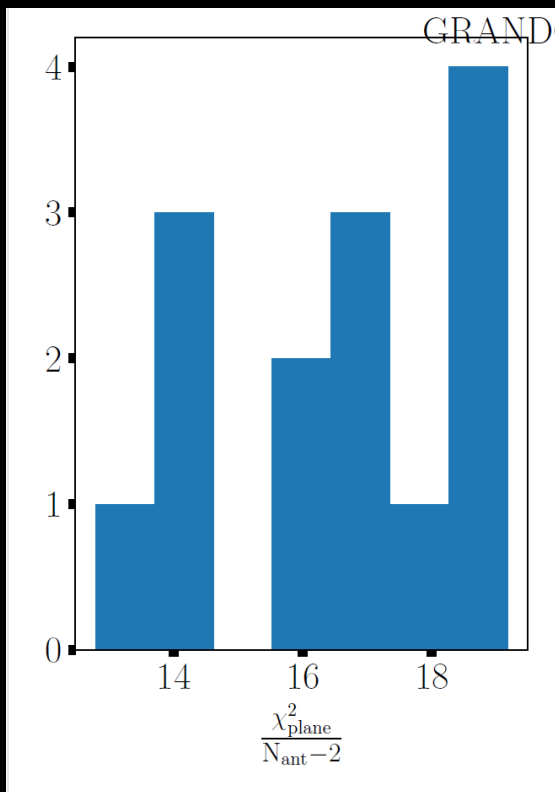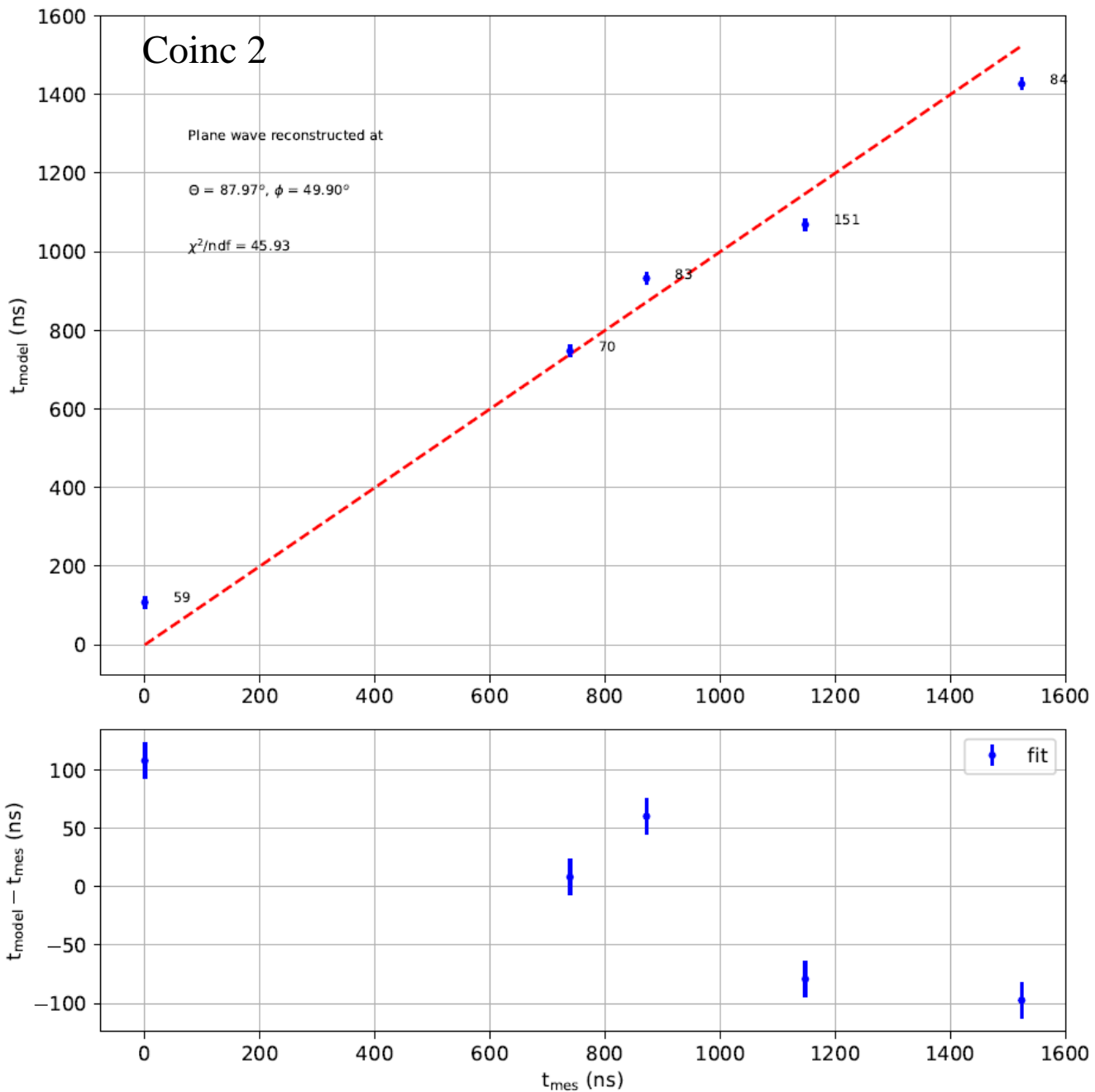
- Yet rather bad Chi2 ☹

PWF recons

- Valid for distant sources
- Fit (and Chi2) ~ identical as spherical
➔ to be understood

Coinc 2

Plane wave reconstructed at
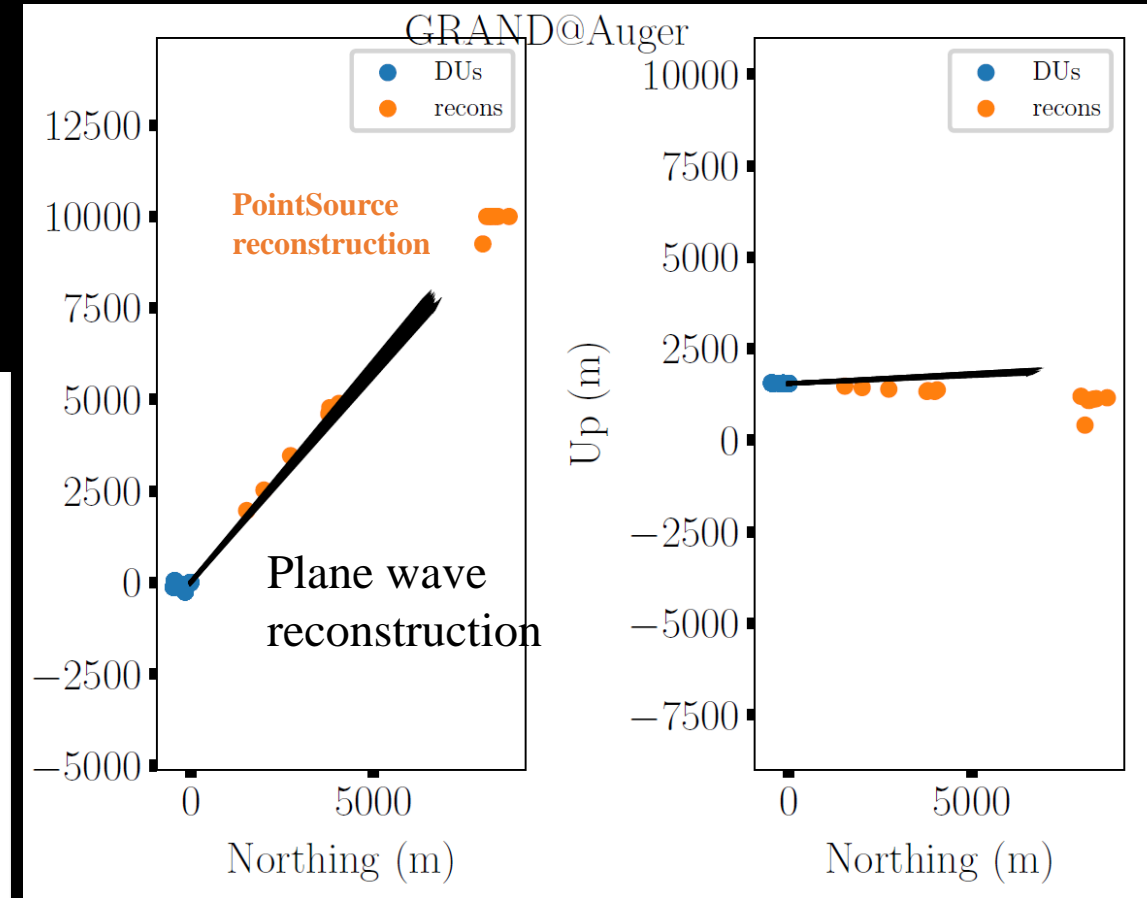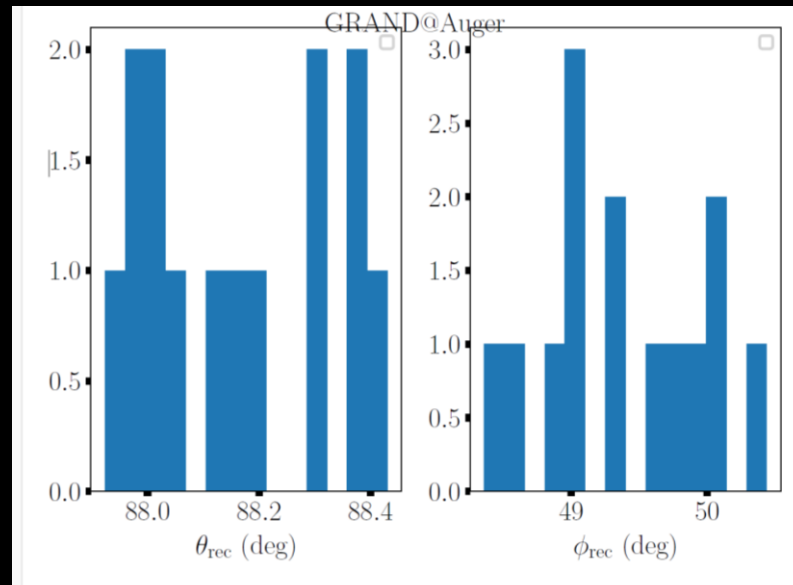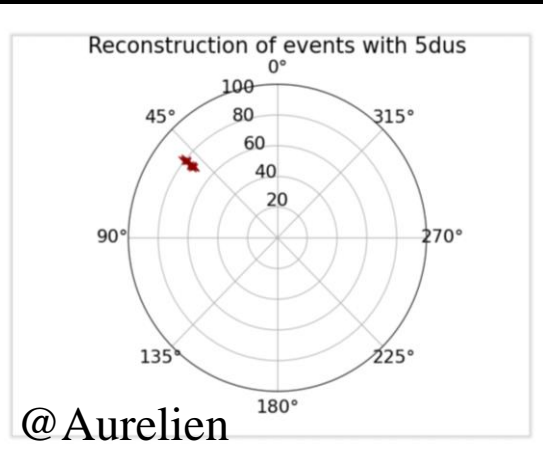
$\Theta = 87.97°, \phi = 49.90°$

$\chi^2/ndf = 45.93$

Direction reconstruction

- Sources cluster nicely along same origin: horizon + North-West

- Results of SWF, PWF and Aurelien's analysis are consistent

@Aurelien

PointSource reconstruction

Plane wave reconstruction

Conclusion

- We CAN reconstruct coincident data both at GP13 & G@A. That means that, at least for a fraction of time,
  - Trigger works (L1 @ GP13, L1+L3 @ Auger)
  - Timing works
  - This is an important milestone ☺!
- A lot remains to be understood to conclude commissioning
    - Reconstruction
      - Too good timing resolution @ GP13?
      - Too large offsets @ Auger
    - More generaly
      - Detection efficiency (to what fraction of coincident waves emitted during the period studied do correspond those detected?)
      - Stability? What happened the rest of the time (GP13)?
      - Sensitivity (use Galactic signal)