Update #2 on the TCLink evaluation
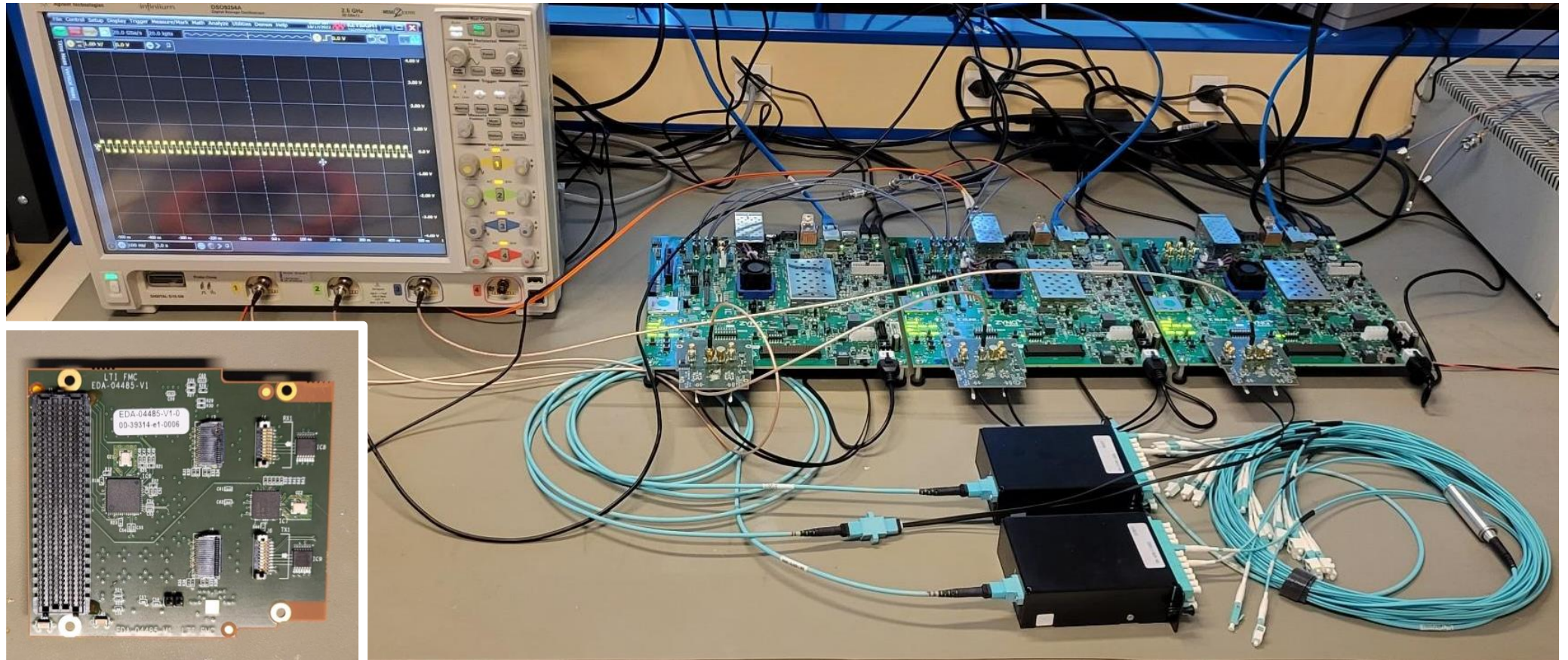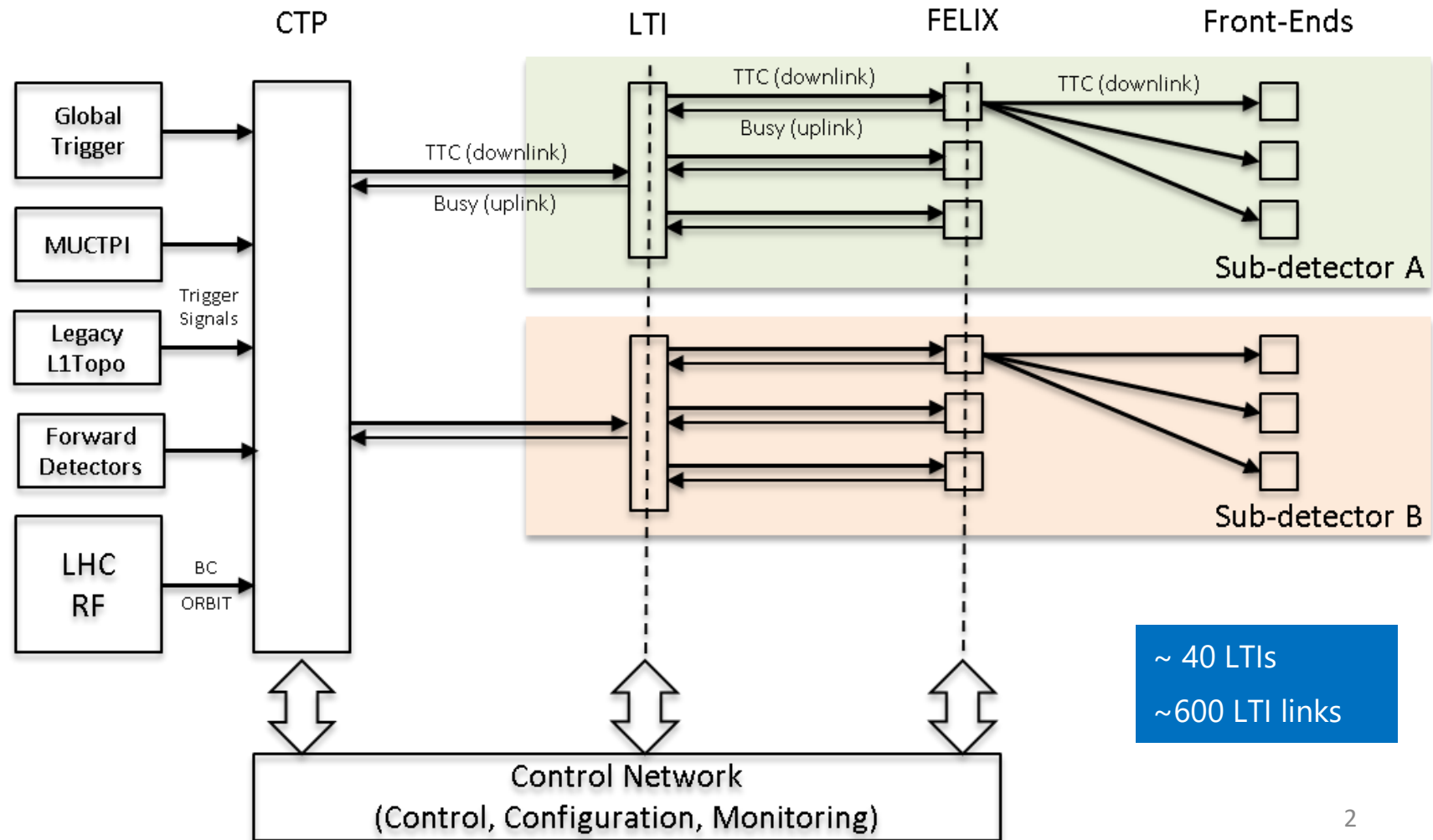# for the ATLAS Phase-2 TTC distribution

Paschalis Vichoudis (CERN) on behalf of the ATLAS Central Trigger team

# ATLAS TTC

PHASE-II

~ 40 LTIs

~600 LTI links

2

PREVIOUSLY

link to previous report

- Shown an improved testbench using new FMC and Firefly optics

- Long measurements (10k over 3 days) revealed worse phase uncertainty than before -> ~30ps peak-to-peak for 1 hop

- The distribution of the phase uncertainty was not gaussian

  -> therefore using sigma as figure of merit was not applicable

- No correlation between after-reset phase uncertainty and DDMTD measurement -> impossible to compensate the initial offset based on DDMTD

- Phase uncertainty not acceptable for certain ATLAS detectors

  -> HGTD, LAr
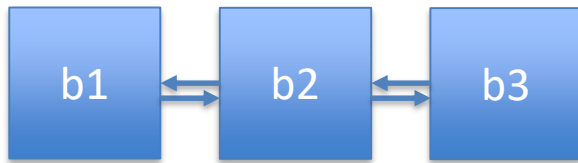
SETUP #1: 2 hops
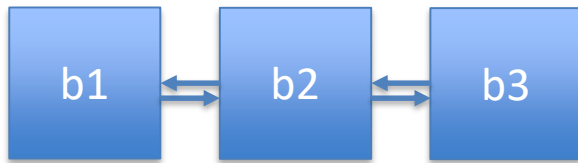
3x ZCU102, GTH , 8b10b

DL@9.6Gb/s, UL@4.8Gb/s, Open Loop

Firmware fix in Rx Equalization
-> LPM instead of DFE

SETUP #1: 2 hops

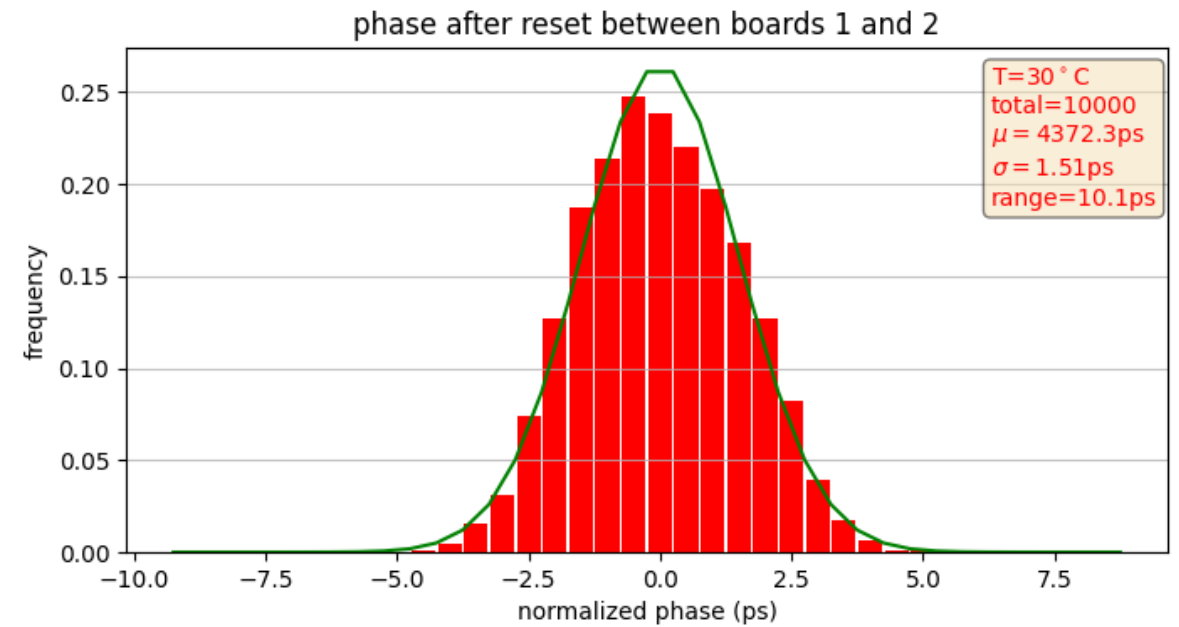- **die temperature (30°C)**

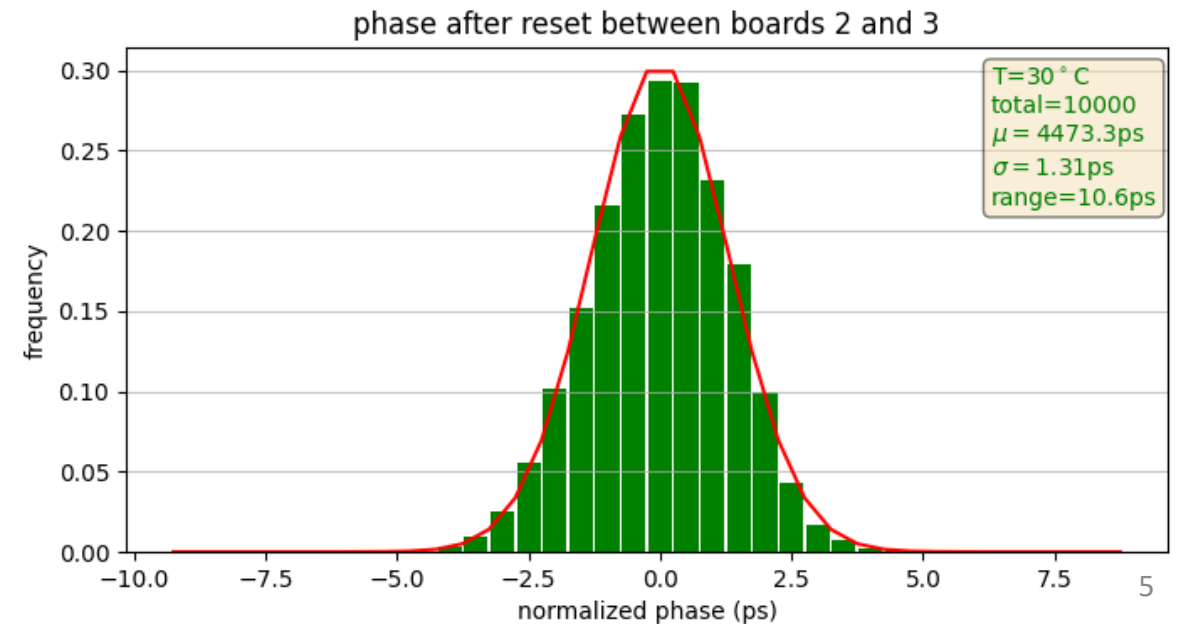**3x ZCU102, GTH , 8b10b**

DL@9.6Gb/s, UL@4.8Gb/s, Open Loop

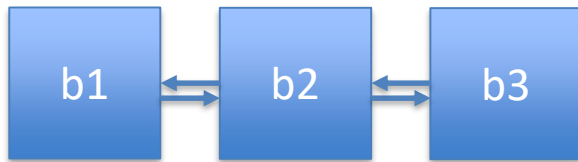**Firmware fix in Rx Equalization**
-> LPM instead of DFE

Each entry is the mean value of ~100k scope measurements
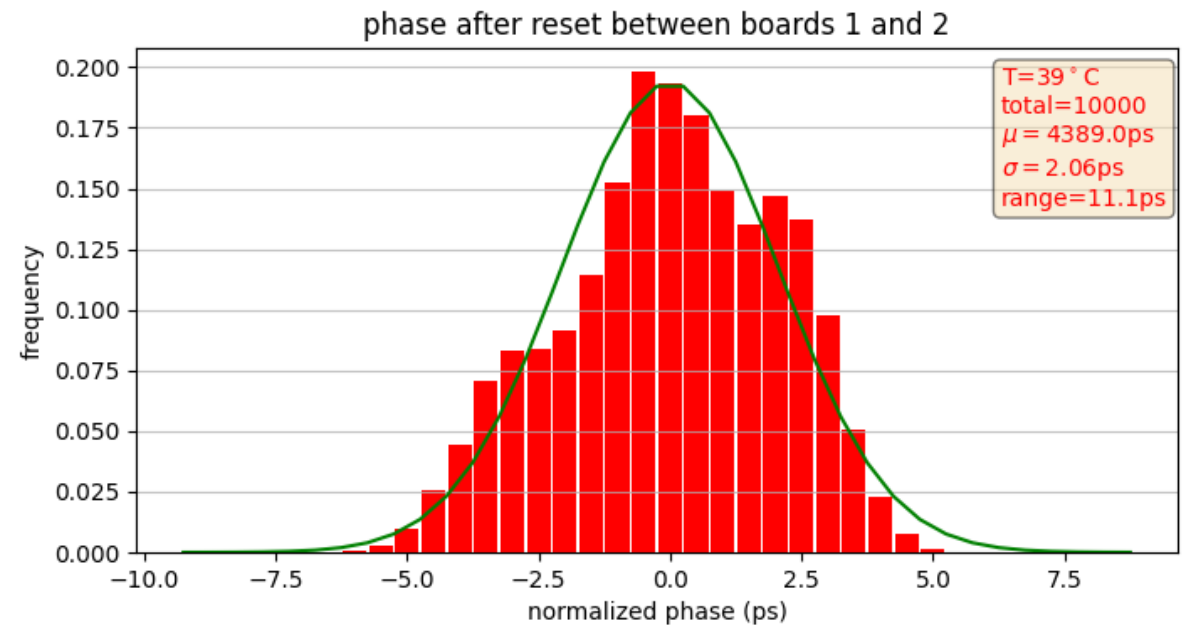
SETUP #1: 2 hops

- **die temperature (39°C)**

```
┌──────┐     ┌──────┐     ┌──────┐
│  b1  │◄───►│  b2  │◄───►│  b3  │
└──────┘     └──────┘     └──────┘
```

3x ZCU102, GTH , 8b10b

DL@9.6Gb/s, UL@4.8Gb/s, Open Loop

Firmware fix in Rx Equalization
-> LPM instead of DFE

"HEATER" code from https://github.com/hdlguy/heater.git

phase after reset between boards 1 and 2

T=39°C
total=10000
μ = 4389.0ps
σ = 2.06ps
range=11.1ps

Each entry is the mean value of ~100k scope measurements

phase after reset between boards 2 and 3

T=39°C
total=10000
μ = 4487.1ps
σ = 1.28ps
range=9.4ps

SETUP #1: 2 hops

- **die temperature (49°C)**

b1 ⟷ **b2** ⟷ **b3**

3x ZCU102, GTH , 8b10b

DL@9.6Gb/s, UL@4.8Gb/s, Open Loop

Firmware fix in Rx Equalization
-> LPM instead of DFE

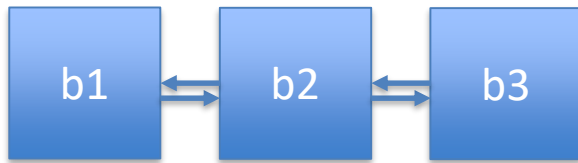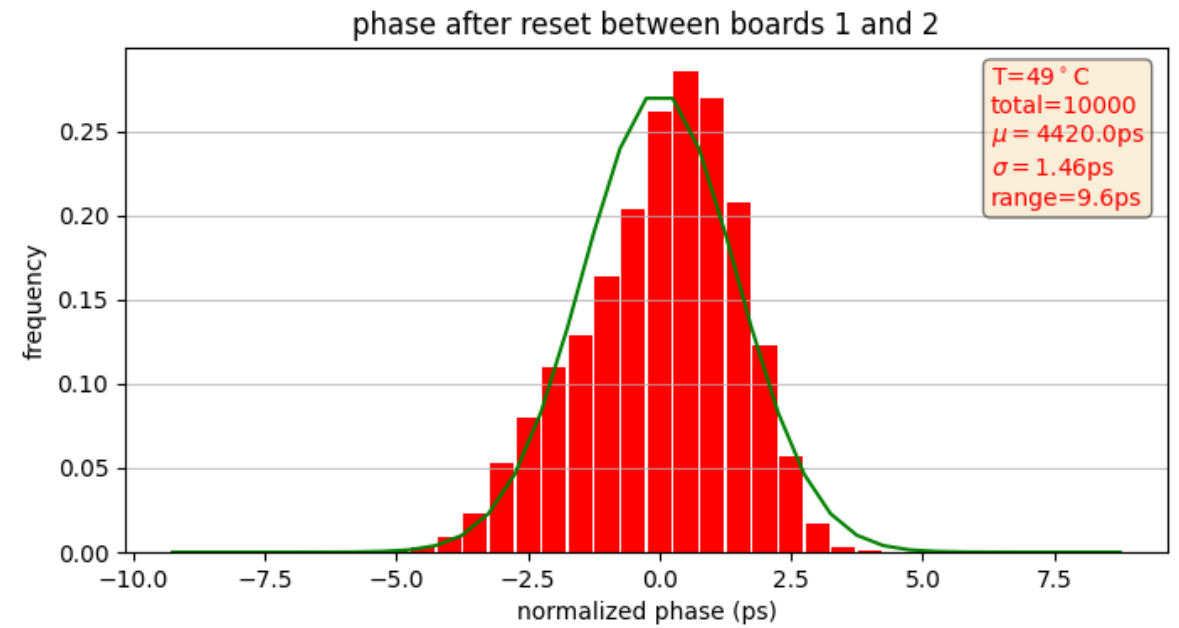"HEATER" code from https://github.com/hdlguy/heater.git

phase after reset between boards 1 and 2

T=49°C
total=10000
$\mu = 4420.0$ps
$\sigma = 1.46$ps
range=9.6ps

Each entry is the mean value of ~100k scope measurements

phase after reset between boards 2 and 3

T=49°C
total=10000
$\mu = 4513.3$ps
$\sigma = 0.94$ps
range=7.5ps

SETUP #1: 2 hops

- **First observations**

✓ Better performance measured between on b2-to-b3

- Gaussian histogram not distorted

✓ Strong and non-linear temperature dependency

- b2-to-b3 Δphase = 14ps from 30 to 39°C (1.6ps/°C)
- b2-to- b3 Δphase = 26ps from 39 to 49°C (2.6ps/°C)

✓ Lower uncertainty at 49°C in respect to 39°C!!!

- 39°C: phase (min-max)=9.4ps, σ(phase)=1.28ps
- 49°C: phase (min-max)=7.5ps, σ(phase)=0.94ps

SETUP #2: 1 hop/2 branches

- **die temperature (36 °C)**

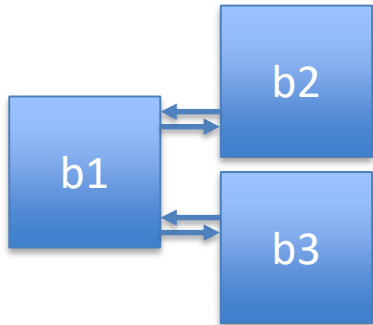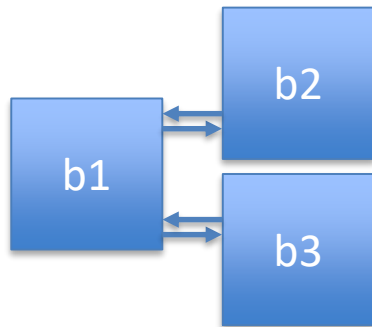**3x ZCU102, GTH , 8b10b**

DL@9.6Gb/s, UL@4.8Gb/s, Open Loop

Firmware fix in Rx Equalization
-> LPM instead of DFE

SETUP #2: 1 hop/2 branches
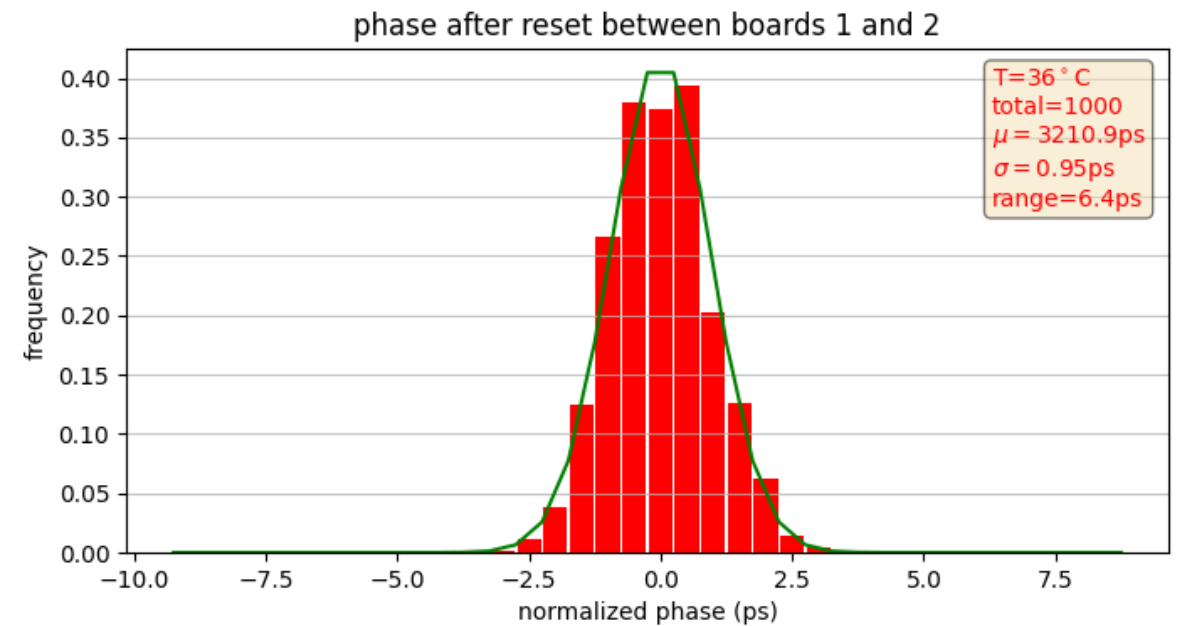
- **die temperature (36 °C)**

3x ZCU102, GTH , 8b10b

DL@9.6Gb/s, UL@4.8Gb/s, Open Loop

Firmware fix in Rx Equalization
-> LPM instead of DFE

phase after reset between boards 1 and 2

T=36°C
total=1000
$\mu = 3210.9ps$
$\sigma = 0.95ps$
range=6.4ps

Each entry is the mean value of ~100k scope measurements

phase after reset between boards 1 and 3

T=36°C
total=1000
$\mu = 3727.4ps$
$\sigma = 0.53ps$
range=3.9ps

SETUP #2: 1 hop/2 branches

- **First observations**

    ✓ Better performance measured on b1-to-b3
- Even though low statistics (only 1000 resets)

    ✓ Is there a discrepancy between boards of the same type?
- The links involving board 3 seem to perform better in both setups

SUMMARY

- Phase uncertainty target for ATLAS : 30ps (CTP to FE)

- Significant improvement after firmware fix (LPM instead of DFE)

  -> uncertainty per hop drops to ~10ps (min-max), 1.5ps (sigma)

- 1-hop/2-branch test revealed inconsistencies between boards of

  the same type -> clear indication that larger testbenches are needed

- Tests so far only with GTHs, working to incorporate GTYs

  -> devkits to be added: VCU118 & KCU116

- Strong temperature dependency in results

  -> need to understand better its behaviour, linearity etc

- Working on the compensation of phase shift due to temperature

  -> close the loop in SW while ramping the temperature

- Aim to conclude studies in Q1/2023