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CM300Xi with Thermal Chamber at ORNL for wafer scale probing

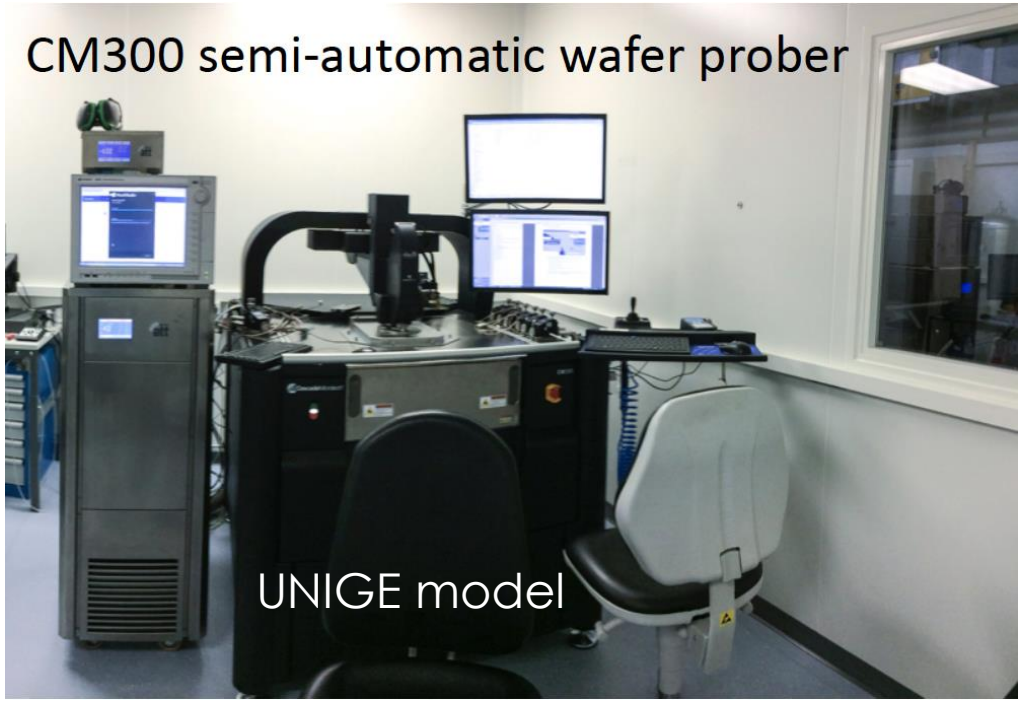
ORNL is managed by UT-Battelle LLC for the US Department of Energy

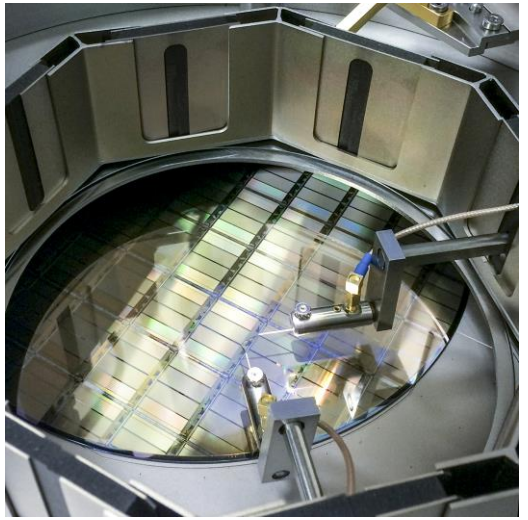
U.S. DEPARTMENT OF ENERGY

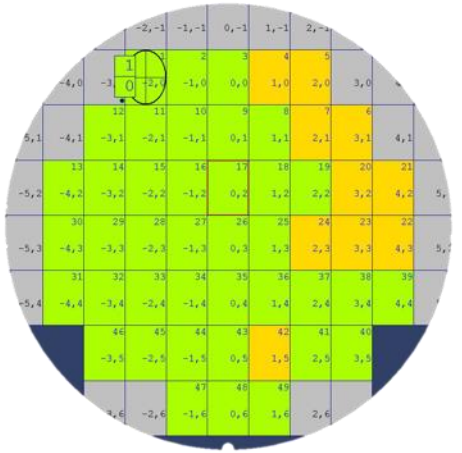
FormFactor CM300xi probe station

300 mm semi-automatic prober installed at ORNL:

- Accommodates 5-300mm sample size
- Light tight and airtight thermal chamber
  - **-60C to 125C testing range**
- Probes :
  - **8 x DC probe for parametric measurement**
  - **2 x RF probes**
  - **1 x XYZ robotic probe with optical probing**
  - **Probe card holder for open, closed top probe cards**
- 4 x Cameras :
  - Top view up to 1000x
  - Bottom-up view (probe alignment)
  - Side view (wafer surface alignment)
  - Auxiliary view (closed top probe card alignment)
- **Fully automated alignment of wafers and dices**
- **Fully programmable for unattended testing**







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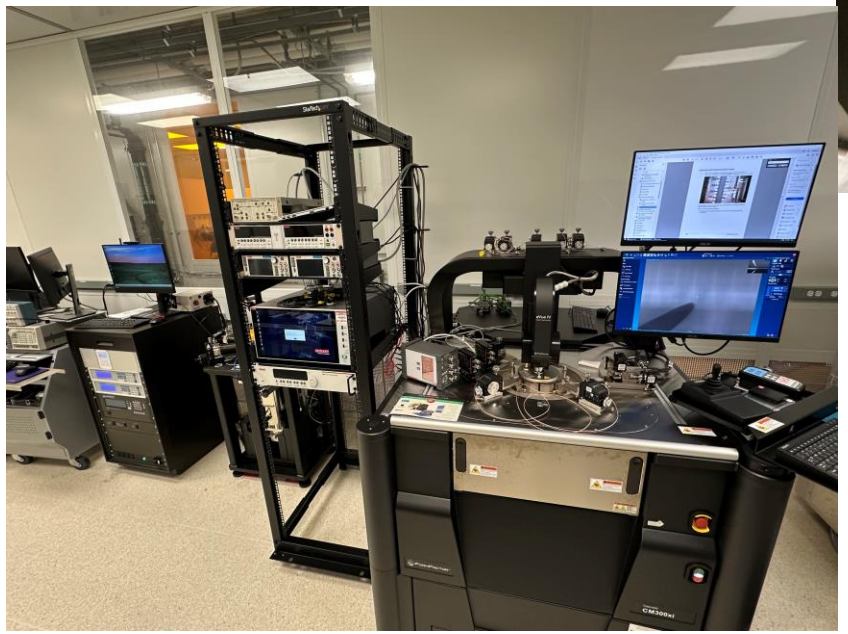
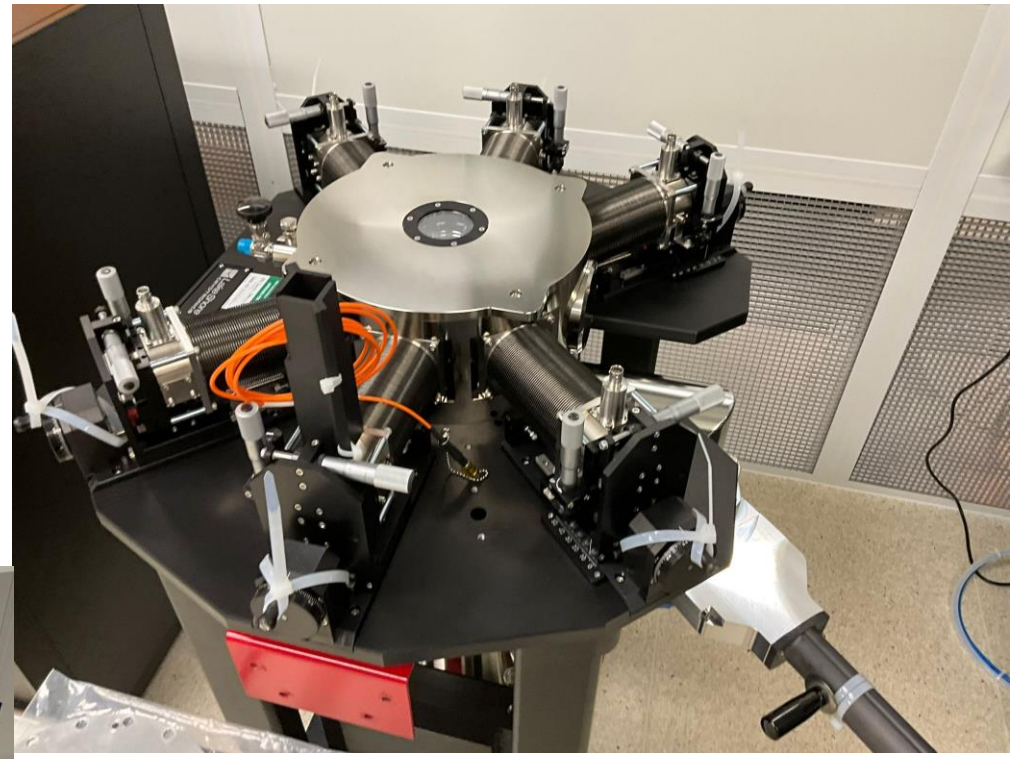
Form Factor CM300xi probe station

Our 300mm Wafer Prober is installed at ORNL in CNMS class 1000 clean room, we made an additional investment on the compressor and dry air system for the thermal chamber





Lakeshore Cryogenic Probe Station in installation next to CM300xi

- 6 x RF/DC probe
- Operation down to 5K
- Magnetic field up to 2.5T (Vertical)
- Sample size up to 4cm

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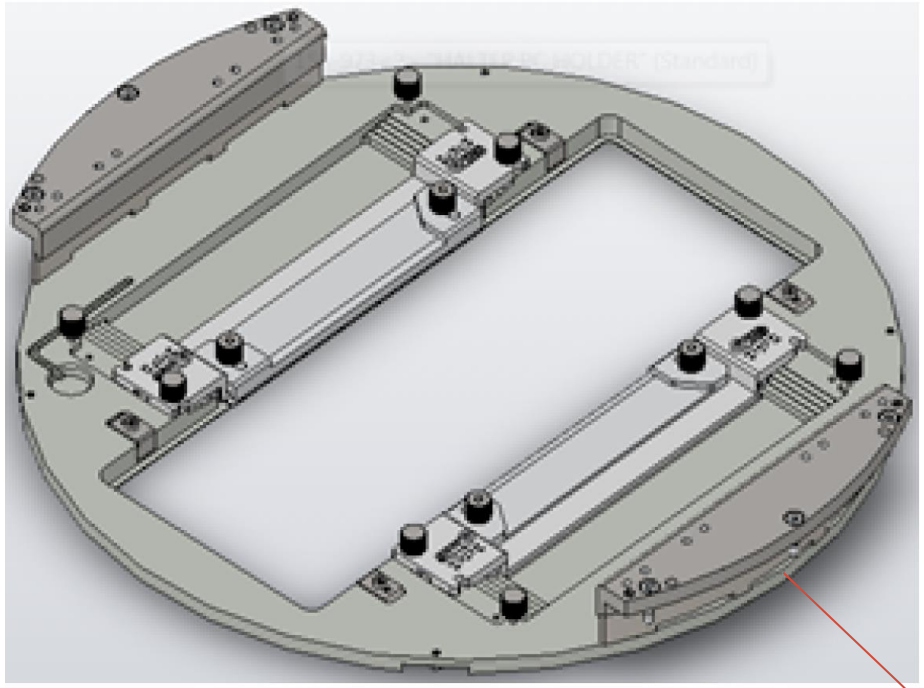
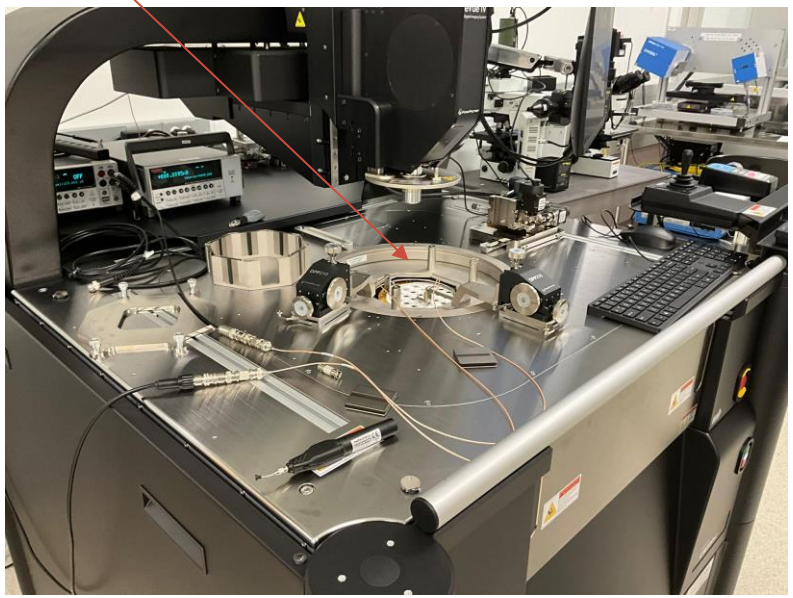
Probe card holder

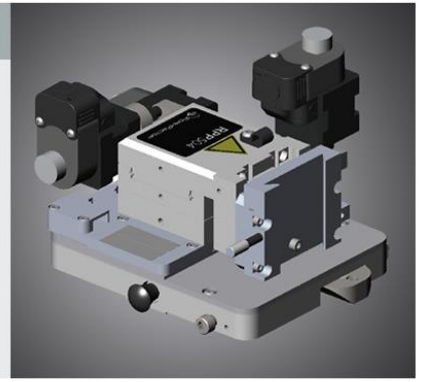


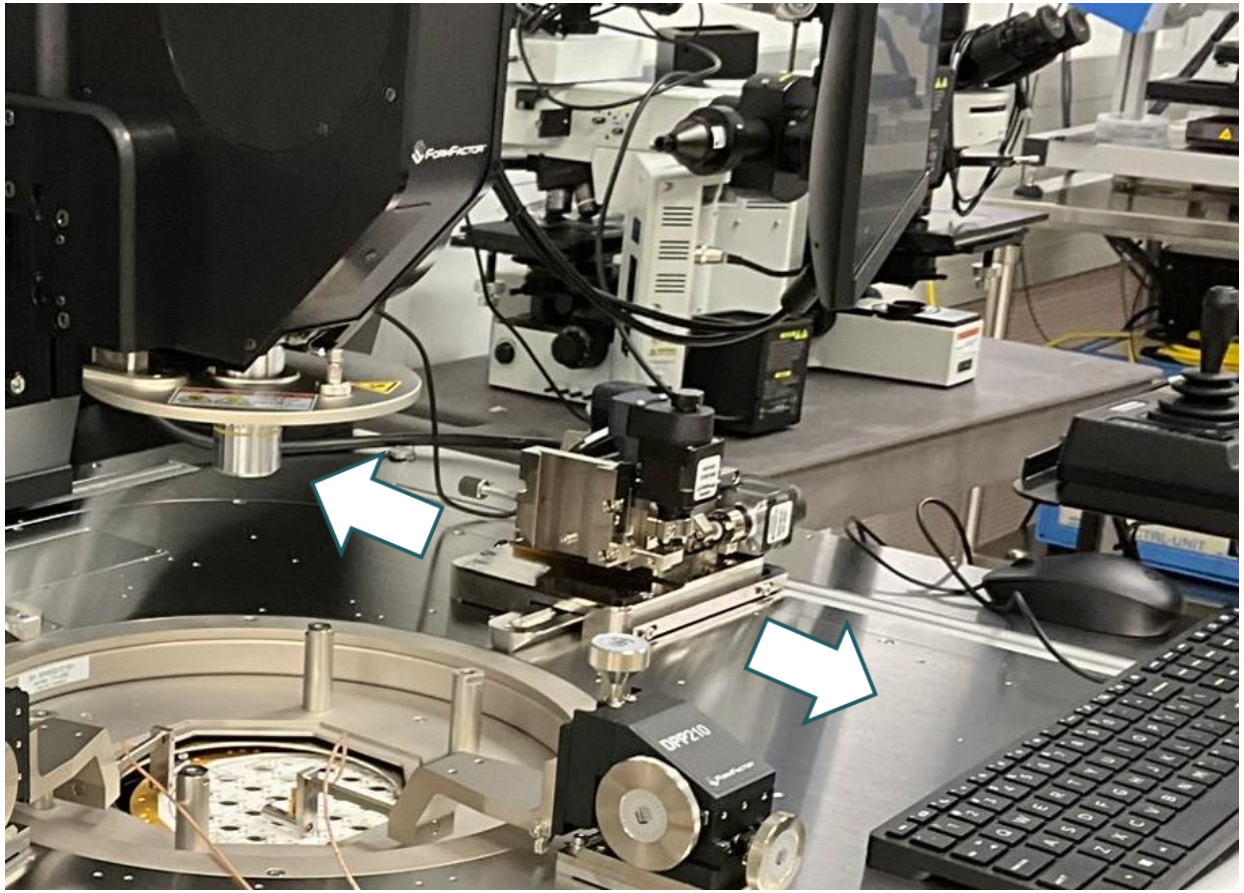


Probe Card Holder*	
Probe card shape	Rectangular
Probe card width	114.5 mm (4.5 in.)
Max. probe card length (standard)	284 mm (11.18 in) /142 mm (5.59 in) from probe center to front/rear
Max. probe card length (HTS)	160 mm (6.30 in) / 80 mm (3.15 in) from probe center to front/rear
Tip drop**, (standard)	3.0 mm to 5.0 mm (0.12 in. to 0.20 in.)
Tip drop** (High Thermal Stability)	4.7 mm (0.185 in.)

Motorized Positioner

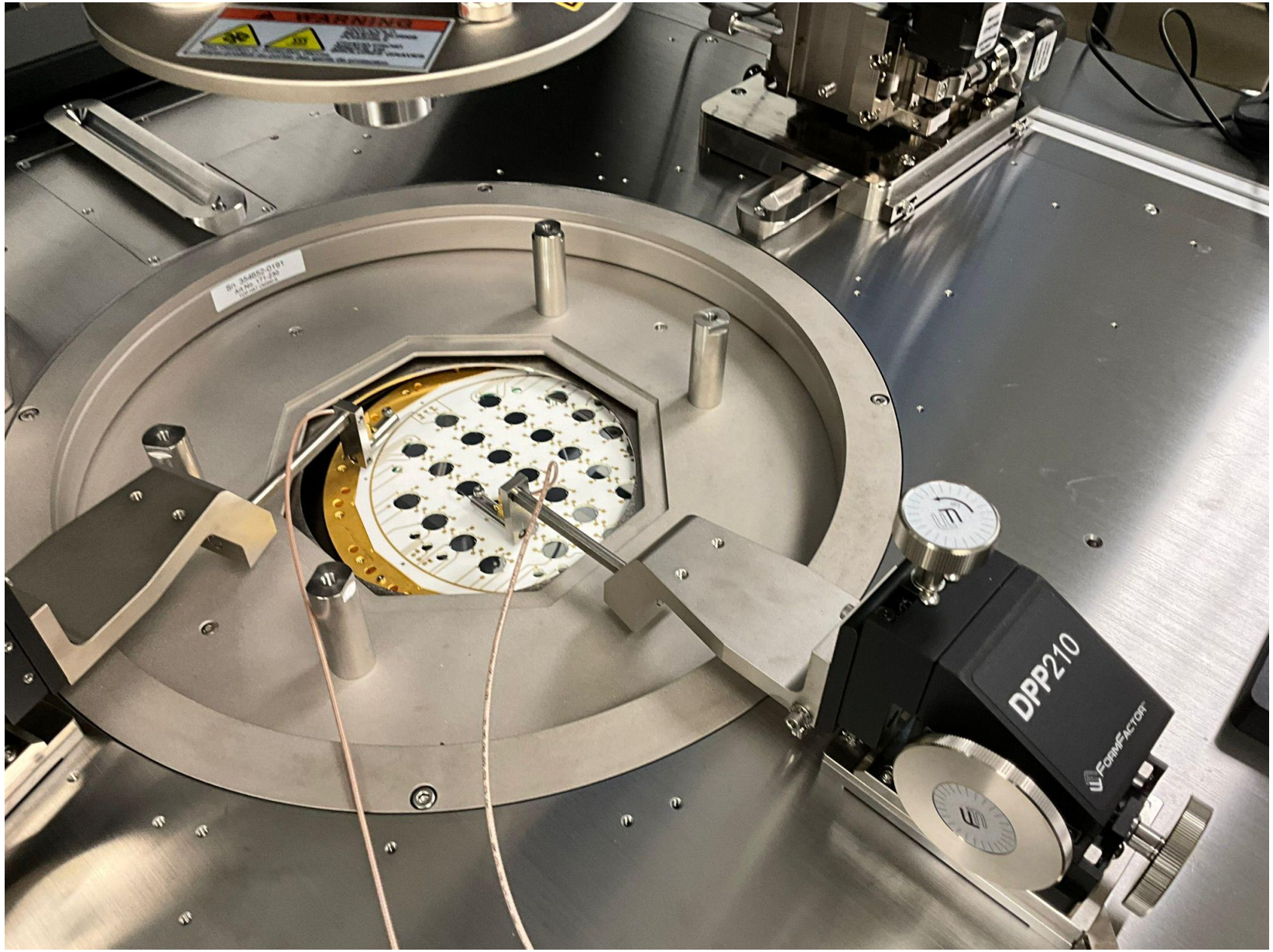
RPP504	
Probe technology	Use with Infinity / ACP / |Z| Probe / T-Wave high performance RF probes
Feature resolution	<1 µm
Travel range (X/Y/Z)	12 mm / 12 mm / 12 mm
Minimum step size	0.3 µm / 0.1 µm resolution
Mounting	Bolt down
Footprint (WxD)	124 mm x 149,5 mm
Applications	Autonomous RF, mm-Wave and THz probing, automatic multi-line TRL





To cover full 300mm range, a custom sliding rail can be added to extend the reach of the positioner

Light probe for laser delivery with 5um lens spot



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Nikhef NKF7 Serializer Testing

J. Schambach

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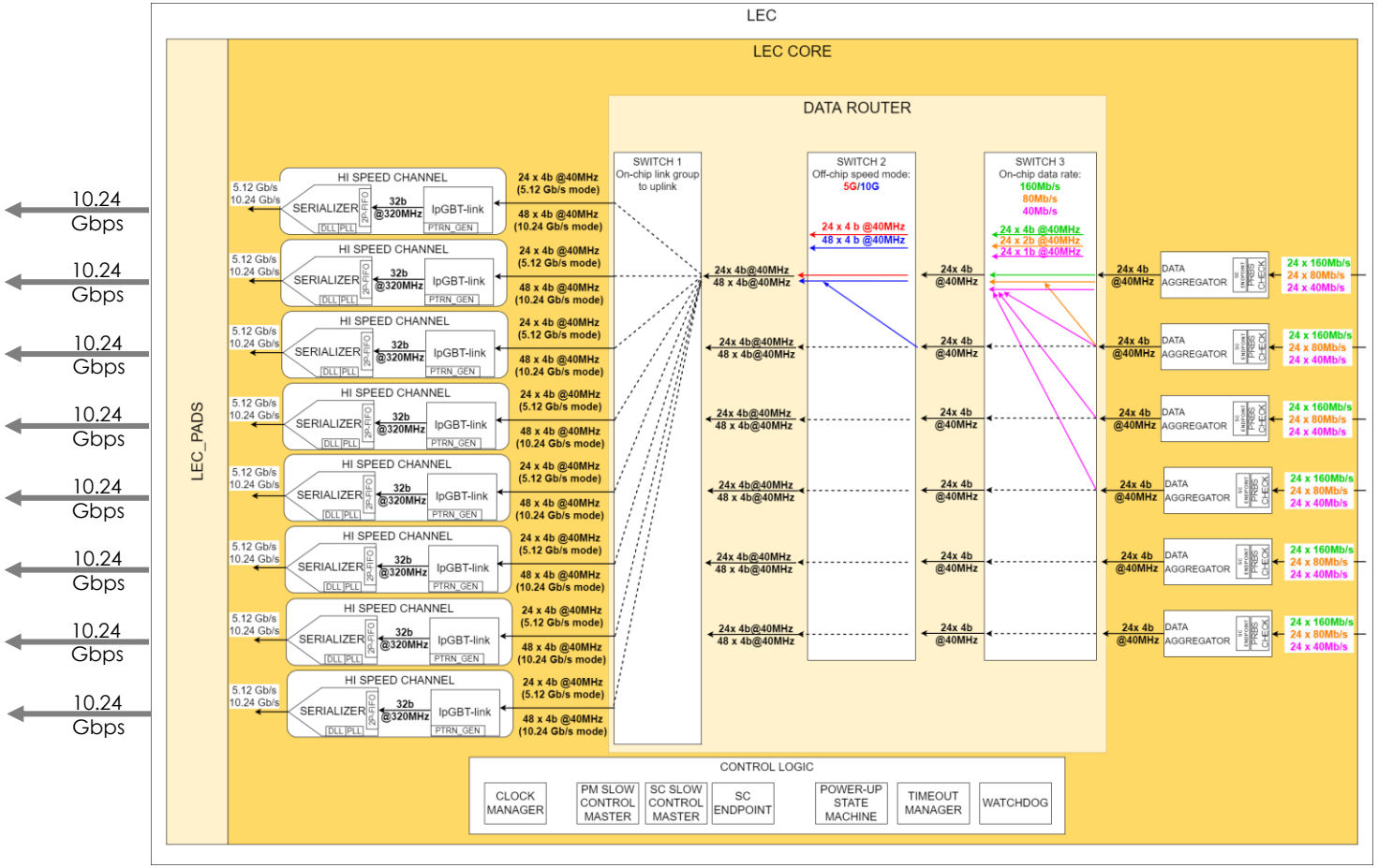
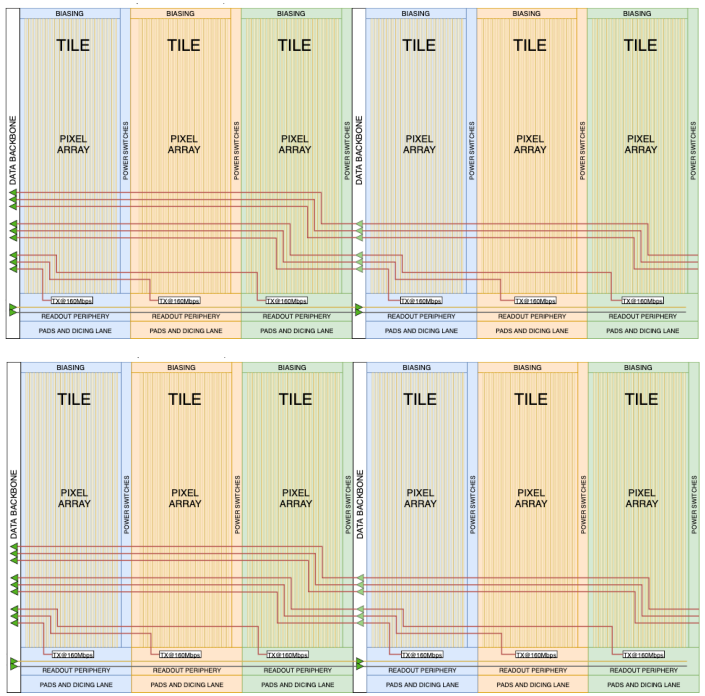
Data Flow – From Tiles to Left Endcap



x 12 RSU

72 Links

72 Links



12-RSU MOSAIX (SVT IB)

The data encoding block is the **lpGBT's TX** core
160 Mbps x 144 = 22.5 Gbps
Full capacity: 8 HS serializers = 80 Gbps (10 Gbps each, only 3 used)
Fallback: 40 Gbps, 5 Gbps each (6 used)
4 serializer data outputs drive one VTRx+

SVT Outer Barrel & Disks

6-RSU LAS
72 Tiles
1 HS serializer = 10 Gbps

5-RSU LAS
60 Tiles
1 HS serializer = 10 Gbps

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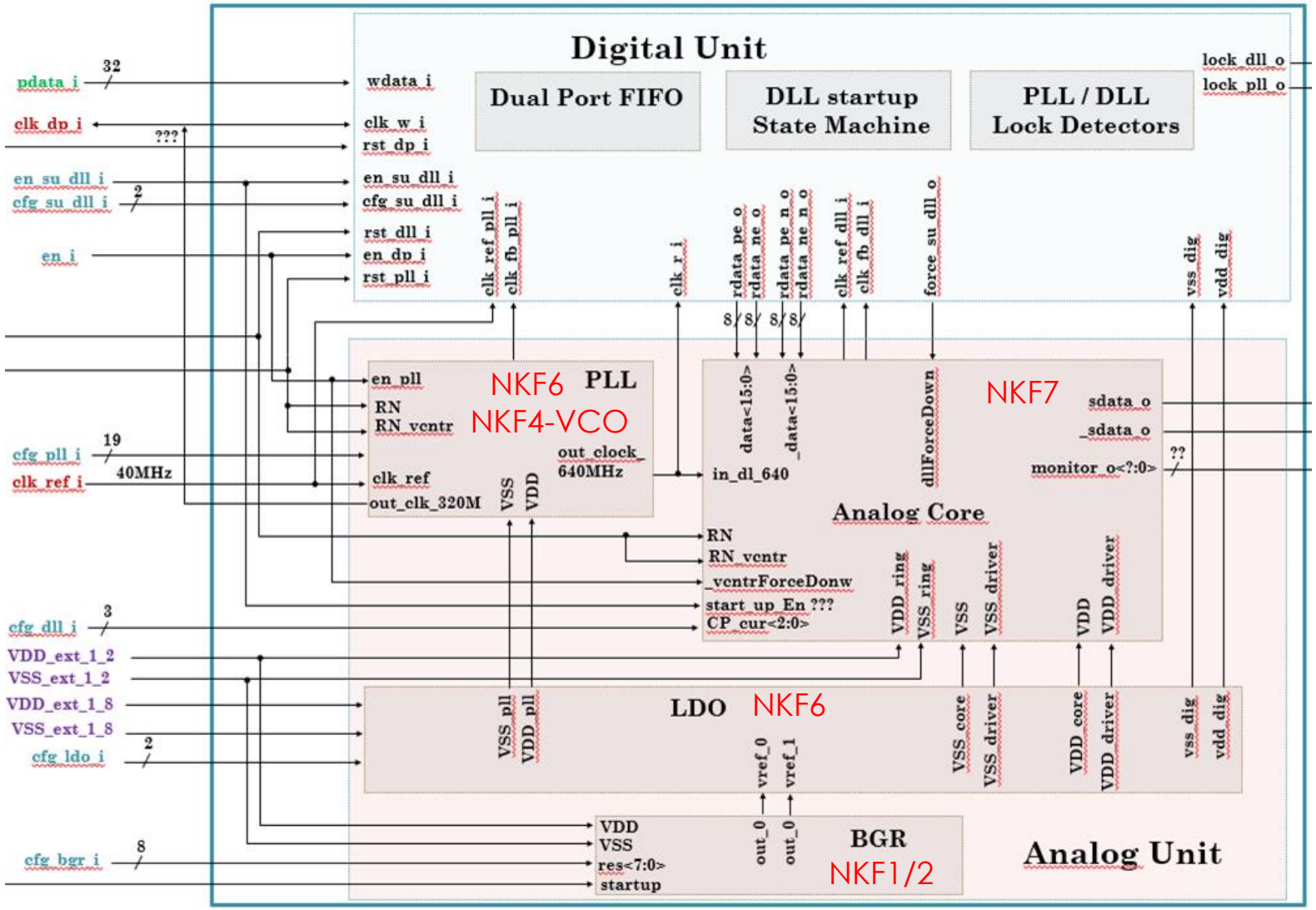
Pathway towards the High-Speed Link



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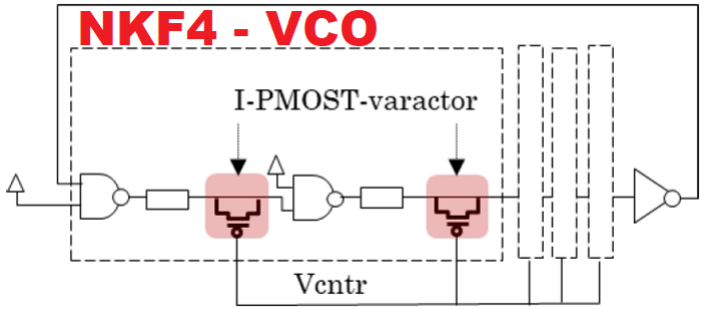
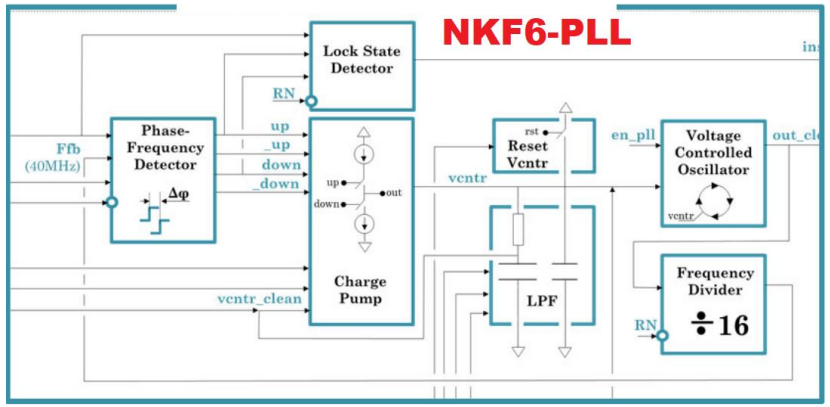
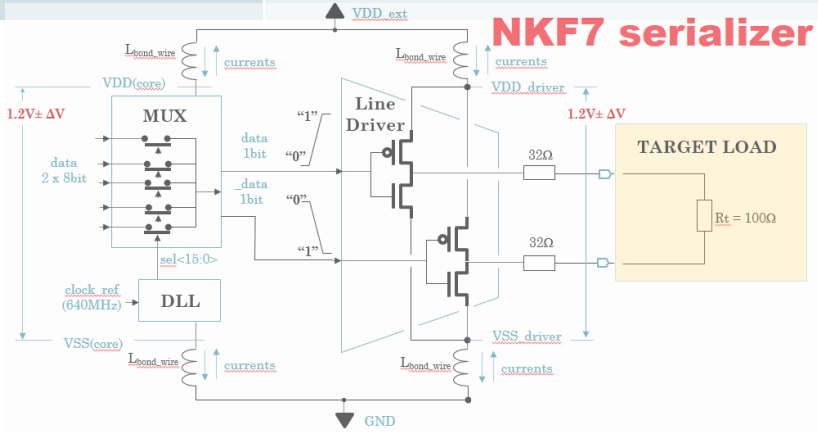
Overview of the Nikhef Chiplets



	NKF	Function	Details	Radiation test
MLR1	NKF1	BandGap Reference	Diode and PNP BGR	Xray: DTMOST preformed best (2% change at 200 Mrad)
	NKF2	BandGap Reference	DTMOS and diode gated BGR	
	NKF3	Temperature Sensor	Diode and PNP TS	Xray: ok
	NKF4	VCO	pch IMOST and nch IMOST varactor	Xray: ok (3.5% change) up to 375Mrad
ER1	NKF5	1 stage LDO + BGR&TS	DTMOS BGR&TS	Not planned
	NKF6	2 stage LDO + PLL		Prague: 32 MeV protons (May 2024)
	NKF7	serializer		





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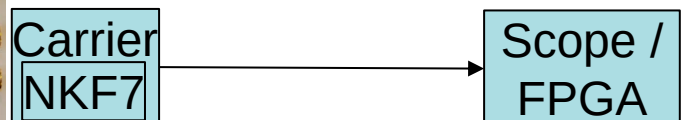
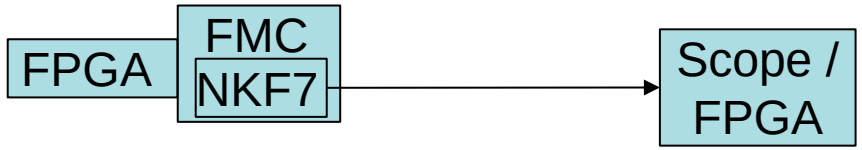
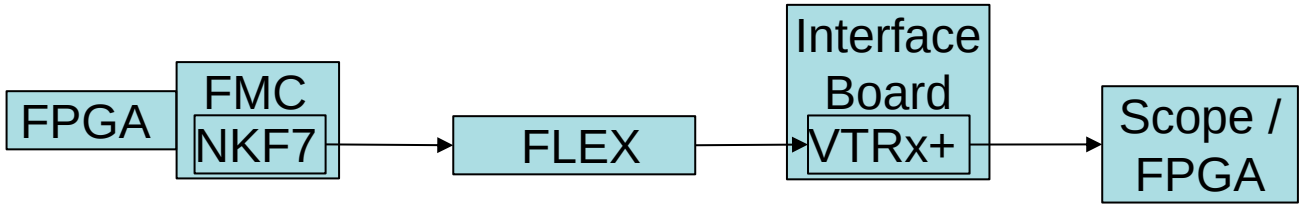
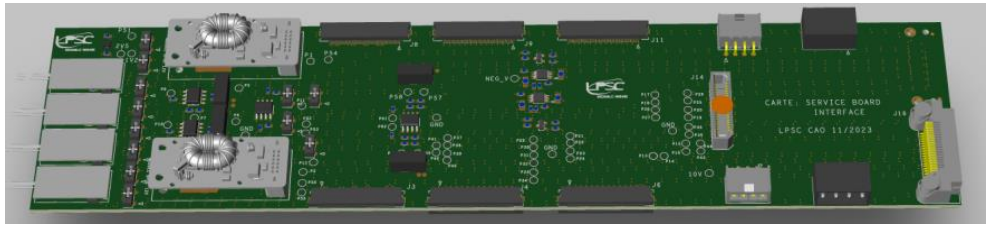
NKF7 Serializer Test Steps

- Characterize NKF7 with fixed 16-bit pattern
  - Scope eye-pattern
  - FPGA BER test
  - Radiation test with Prague 32 MeV protons => Done
- Characterize NKF7 with variable pattern
- Characterize NKF7 + Flex (design by Antoine)
  - Scope eye-pattern
  - FPGA BER test & statistical eye
- Characterize NKF7 + Flex + VTRx+ Transceiver
  - Scope eye-pattern (optical probe or after minipods on CRU)
  - Receiver (minipod / FPGA / CRU) BER test









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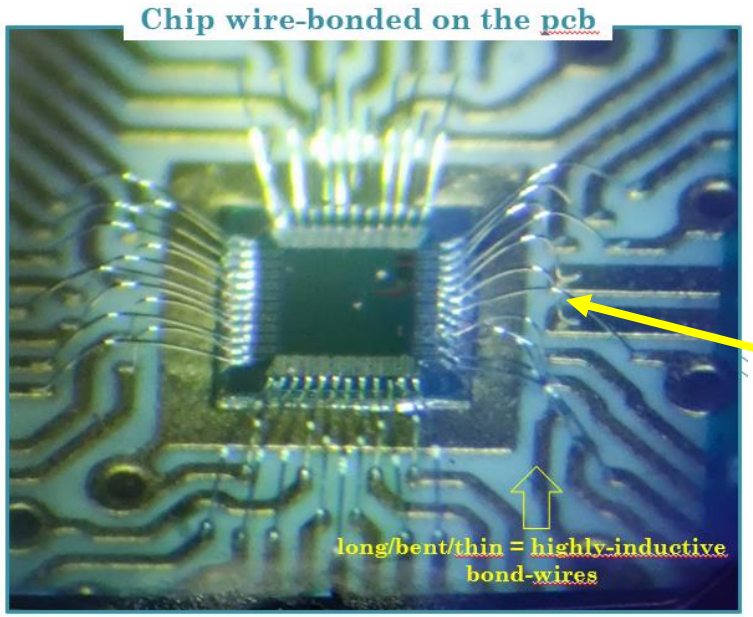
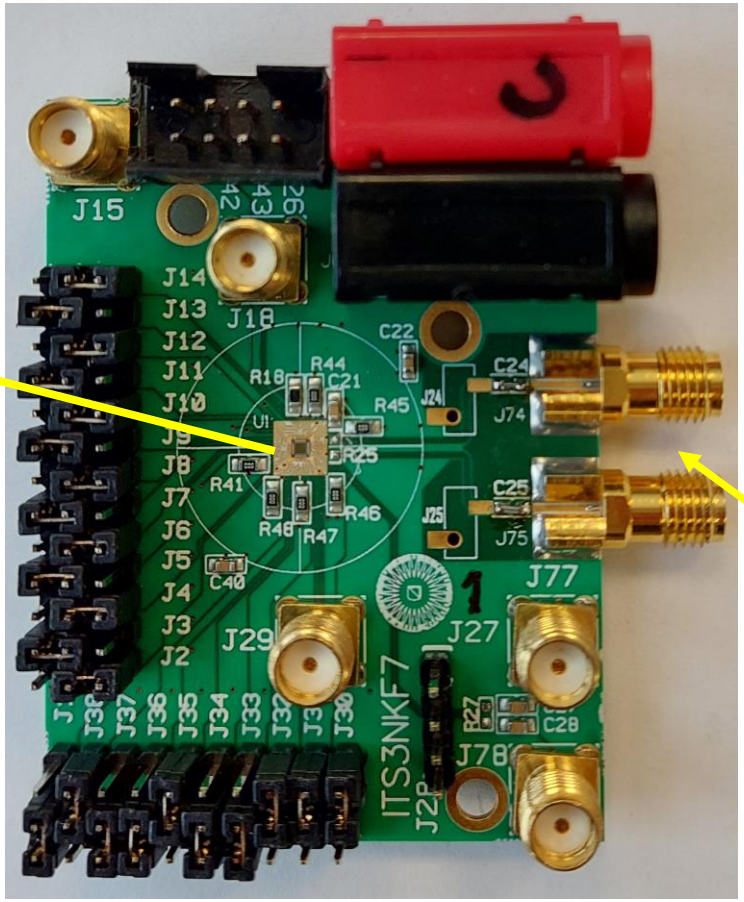
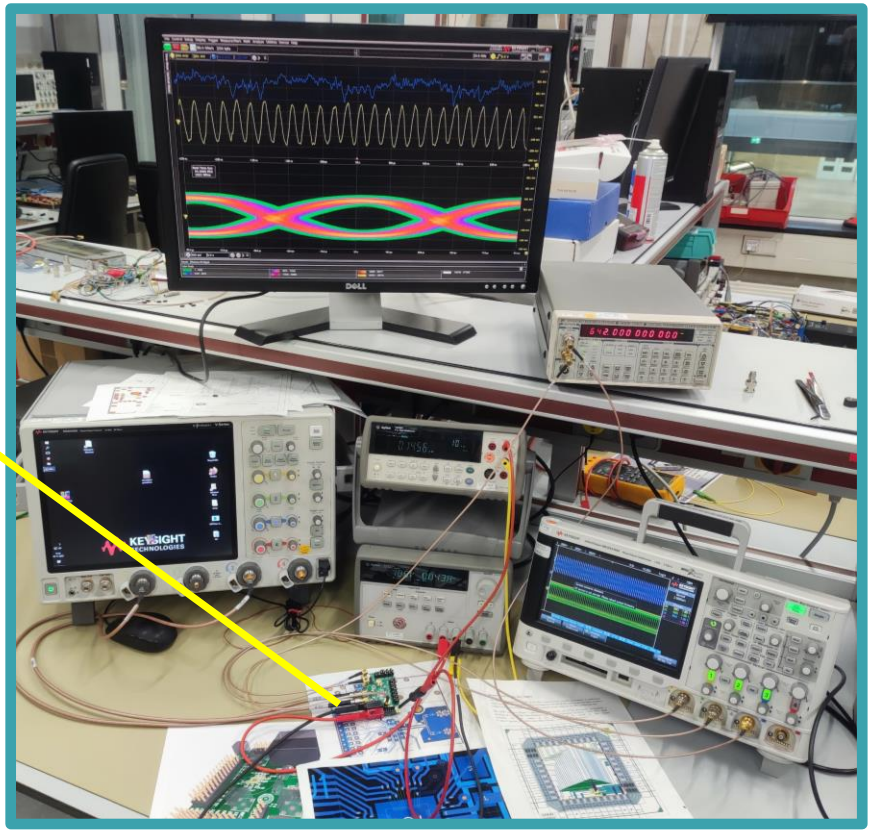
Fixed Pattern Measurements: ITS3NKF7 Test Board

- Fixed pattern via jumpers
- External clock input via SMA
- Serializer output to SMA







- Good output signals at 5Gbps
- At 10Gbps some distortions
- Simulations suggest distortions from bond wire inductance

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First results at 10.27 Gbps

NWO Netherlands Organisation for Scientific Research

Output differential signals assymetry / distortion effect

Operation at 10.27Gbps, 16-bit data pattern : 0101010..., F_clock_ref_DLL = 642MHz , chip2(black)

VDD_driver = VDD (core) = 1.366V	VDD_driver = VDD (core) = 1.2V	VDD_driver = VDD (core) = 1.15V

CM signal: (Vout_p + Vout_n) / 2

Diff signal: Vout_p - Vout_n

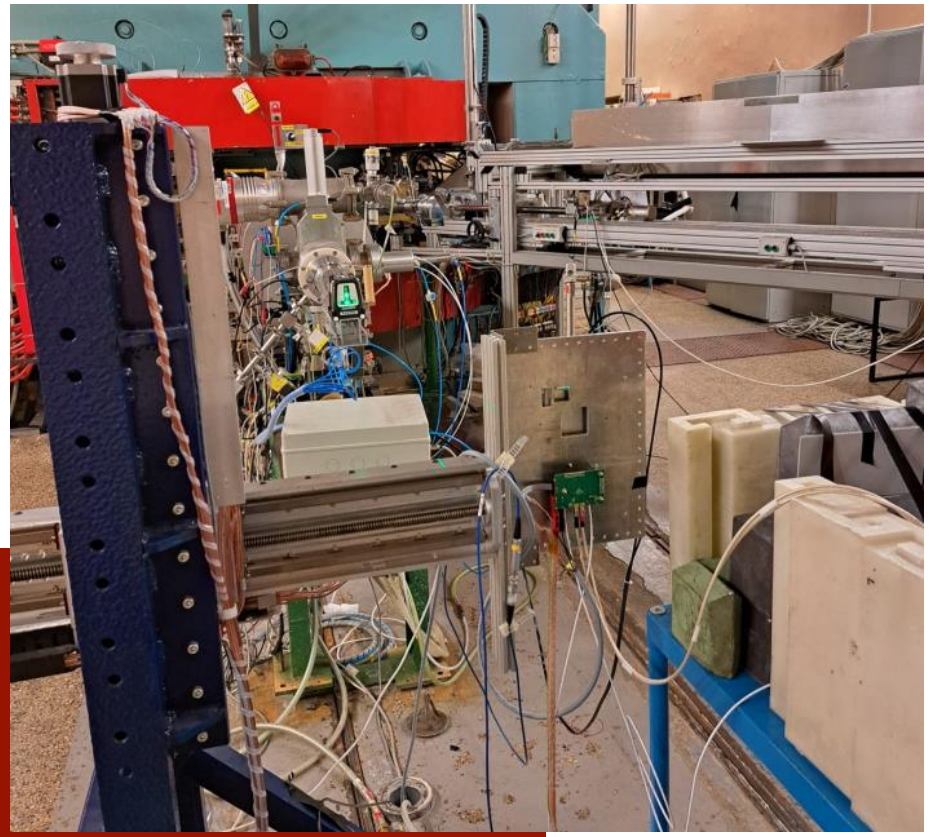
Eye Diagram @ Diff signal

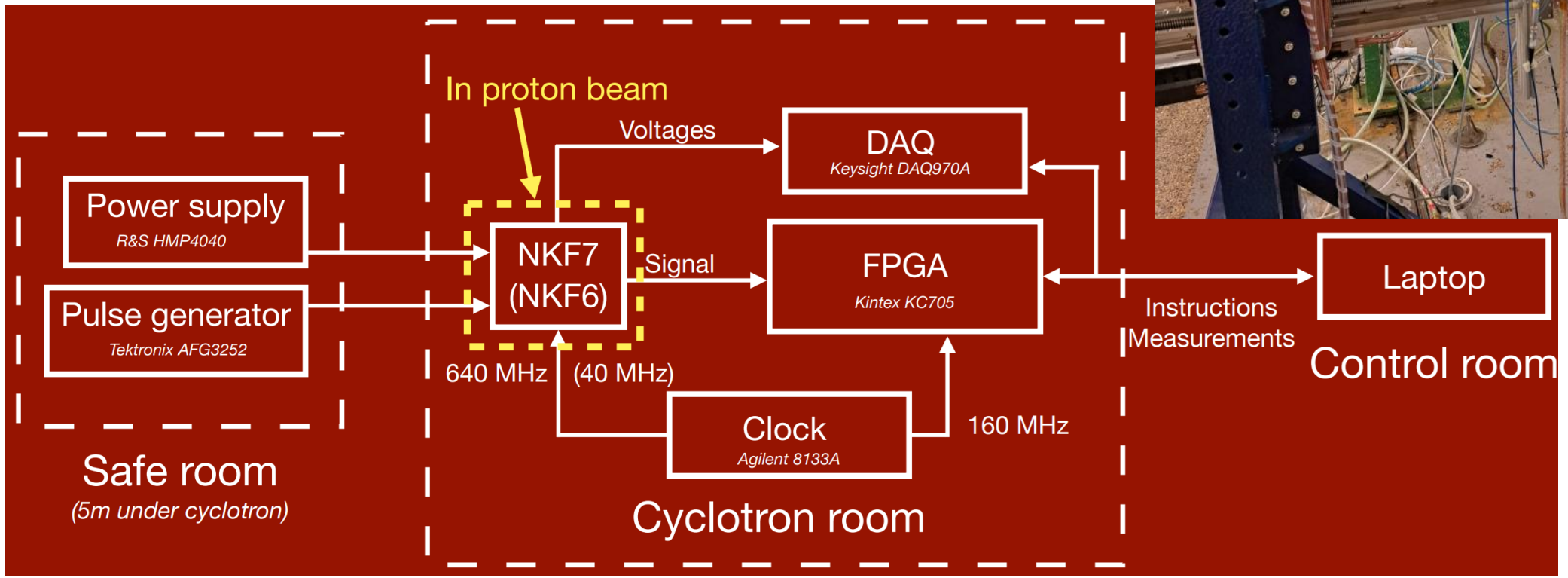
- the output signals assymetry (distortions) are periodic and synchronous to a 16-bit data pattern (reference clock period)
- **the effect is less pronounced at higher power supply voltages (1.366V)**
- it looks like the transistors are not fast enough to cope with the required switching speed causing the distortions at 10Gbps

Beam Test in Prague May 2024

- Fixed pattern 0x5555
- 32 MeV protons, typical flux 10^9 protons/cm^{2}s

SEU cross-section < 1.5 10^{-12}





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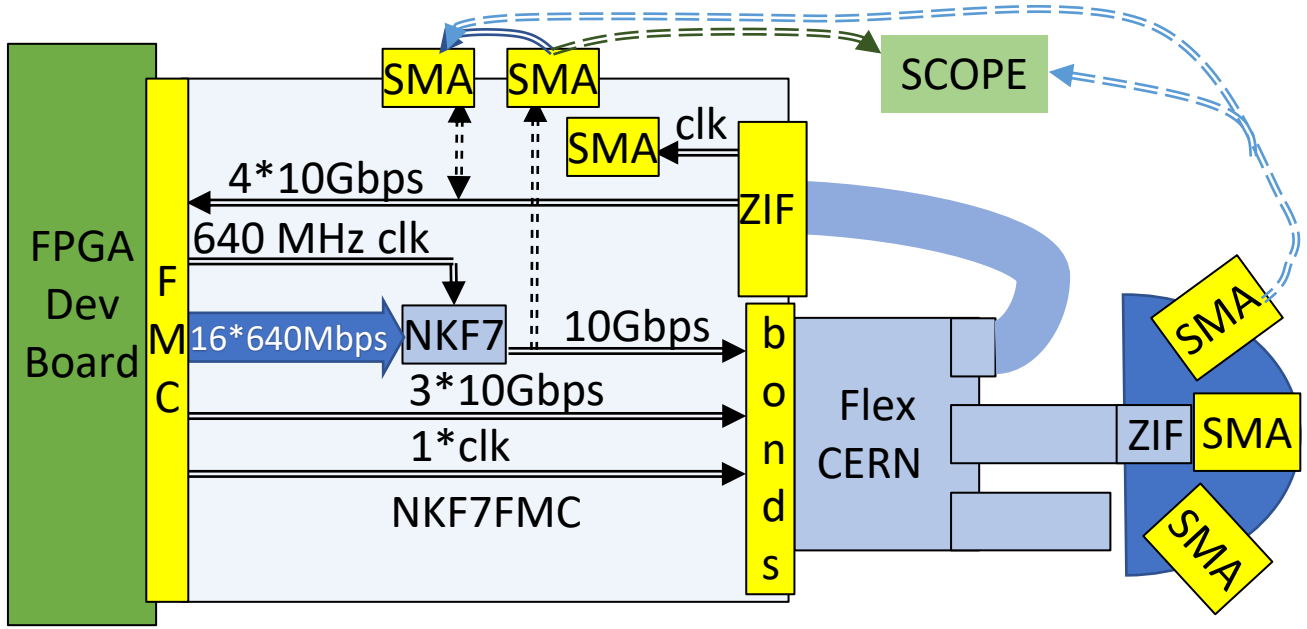
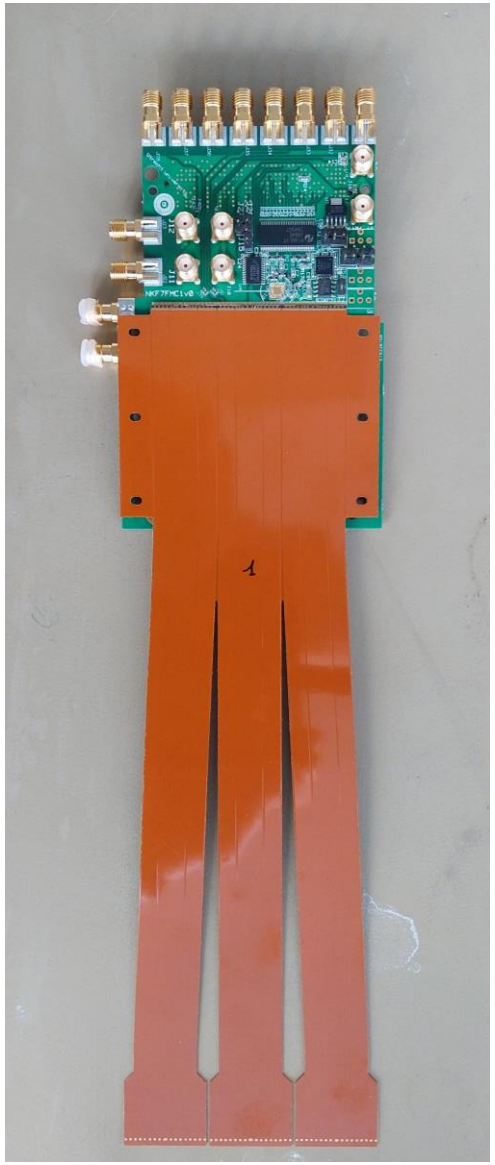
NKF7FMC Concept

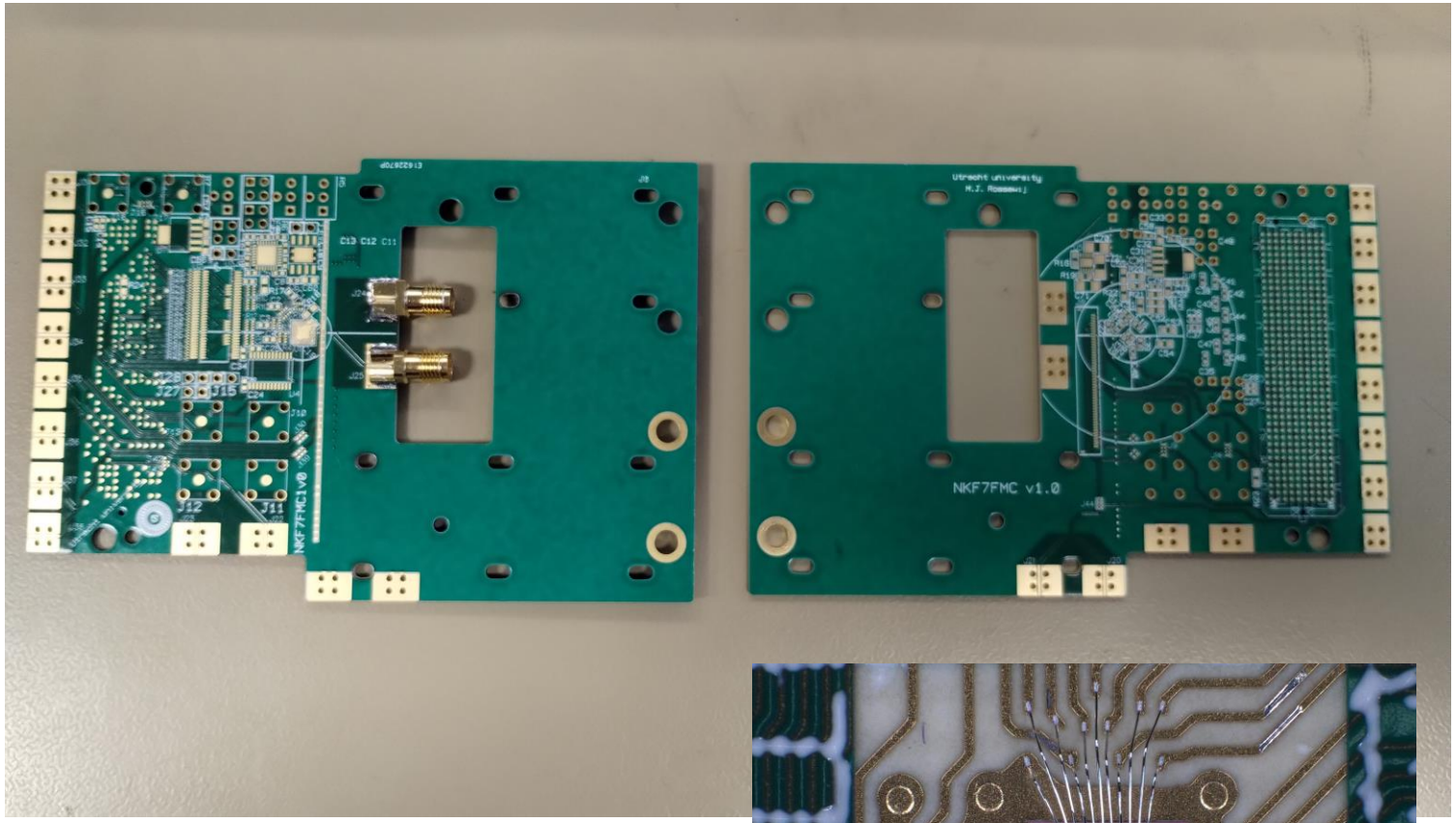
- NKF7 16bit data controlled by FPGA
  - Allows for PRBS or (8b/10b encoded) data
- Data input rate 640Mbps
  - Are NKF7 inputs fast enough?
  - Use fast interface (e.g. FMC)
  - No switches, jumpers & capacitors on data lines
  - Measurements showed CMOS 1.2V not feasible
    => Use differential signals.

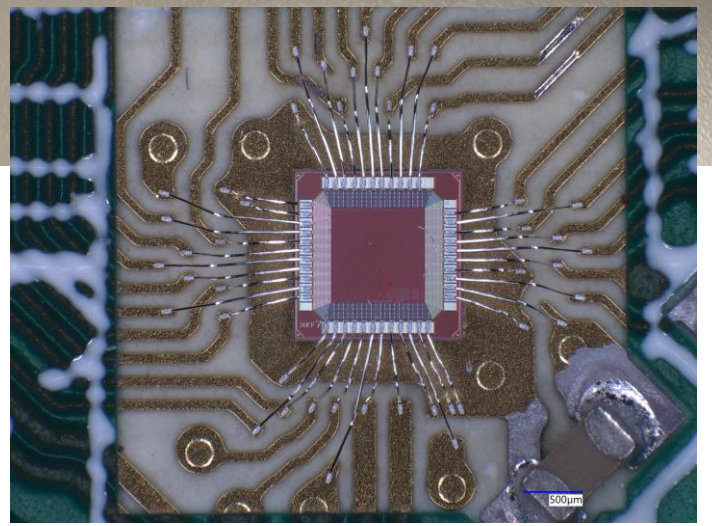


- NKF7 10 Gbps data output:
  - to SMA connectors (scope or loopback to FPGA transceiver input)
  - CERN ITS3 designed Flex cable
- 3 adjacent high-speed lines (+ clock line) connected to FPGA transceivers
  - Allows for transmission & xtalk tests
- CERN flex cable either goes to
  - SMA breakout board (to scope)
  - Loop back to the NKF7FMC ZIF connector
- Minimize bond wire length & power decoupling capacitors closer to NKF7 to reduce PS network inductance

NKF7FMC Pictures







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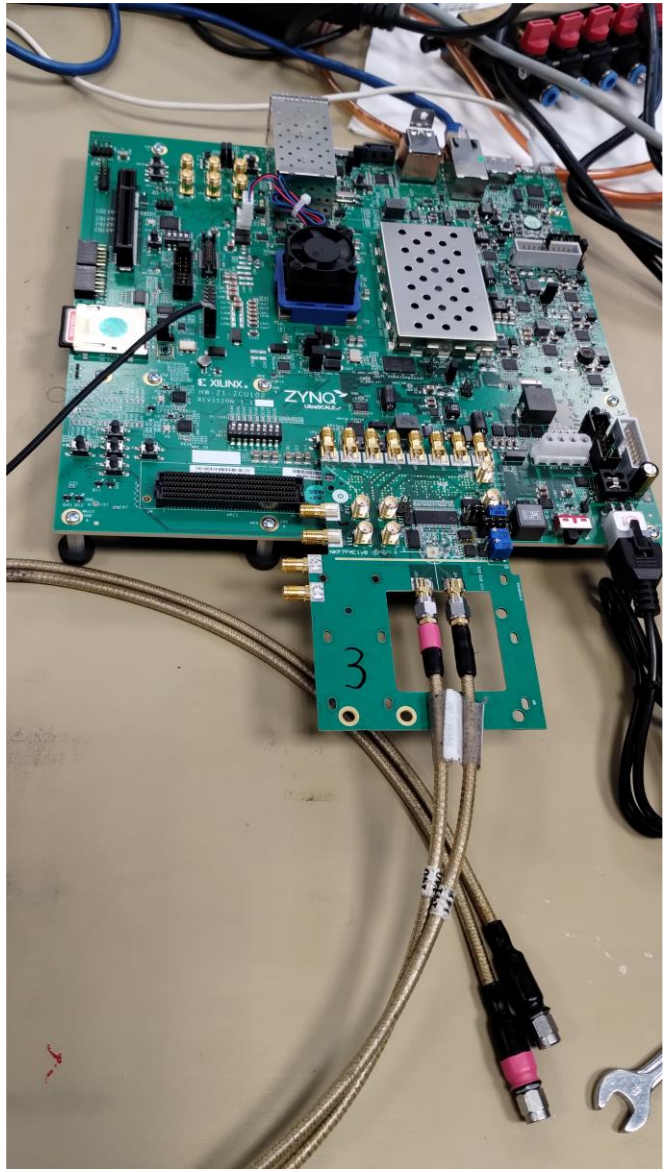
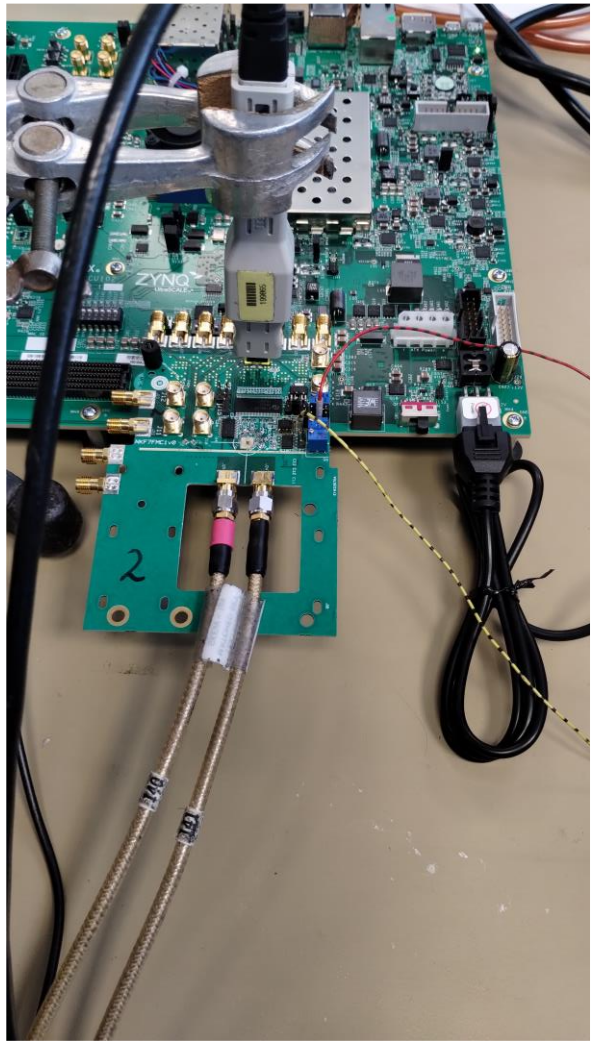
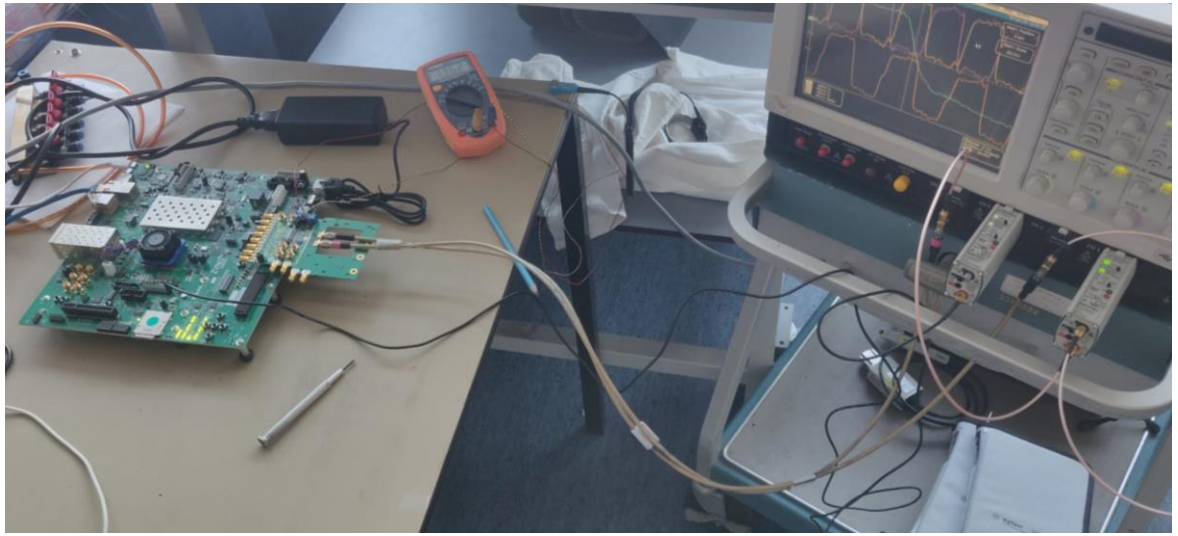
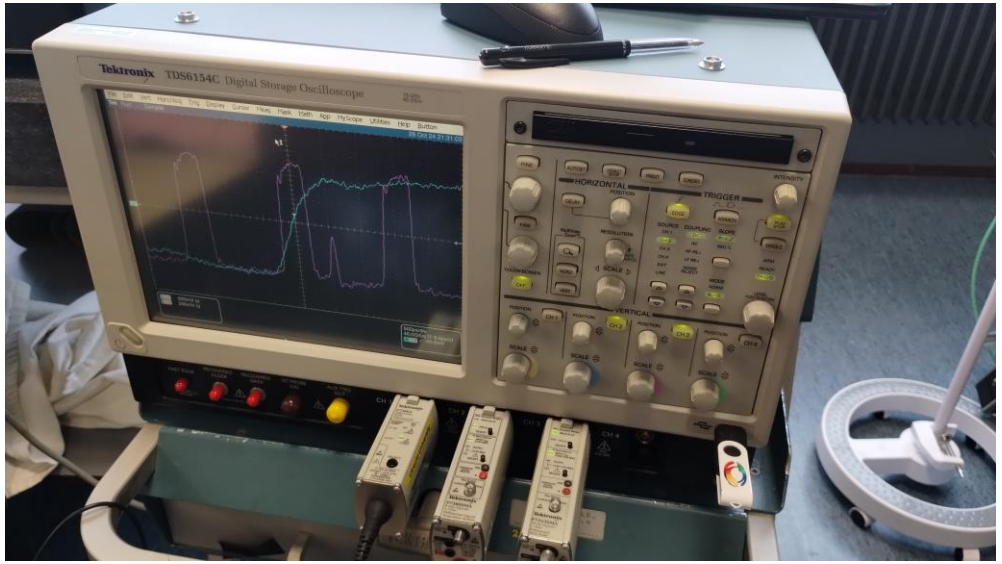
ZCU102 with NKF7FMC









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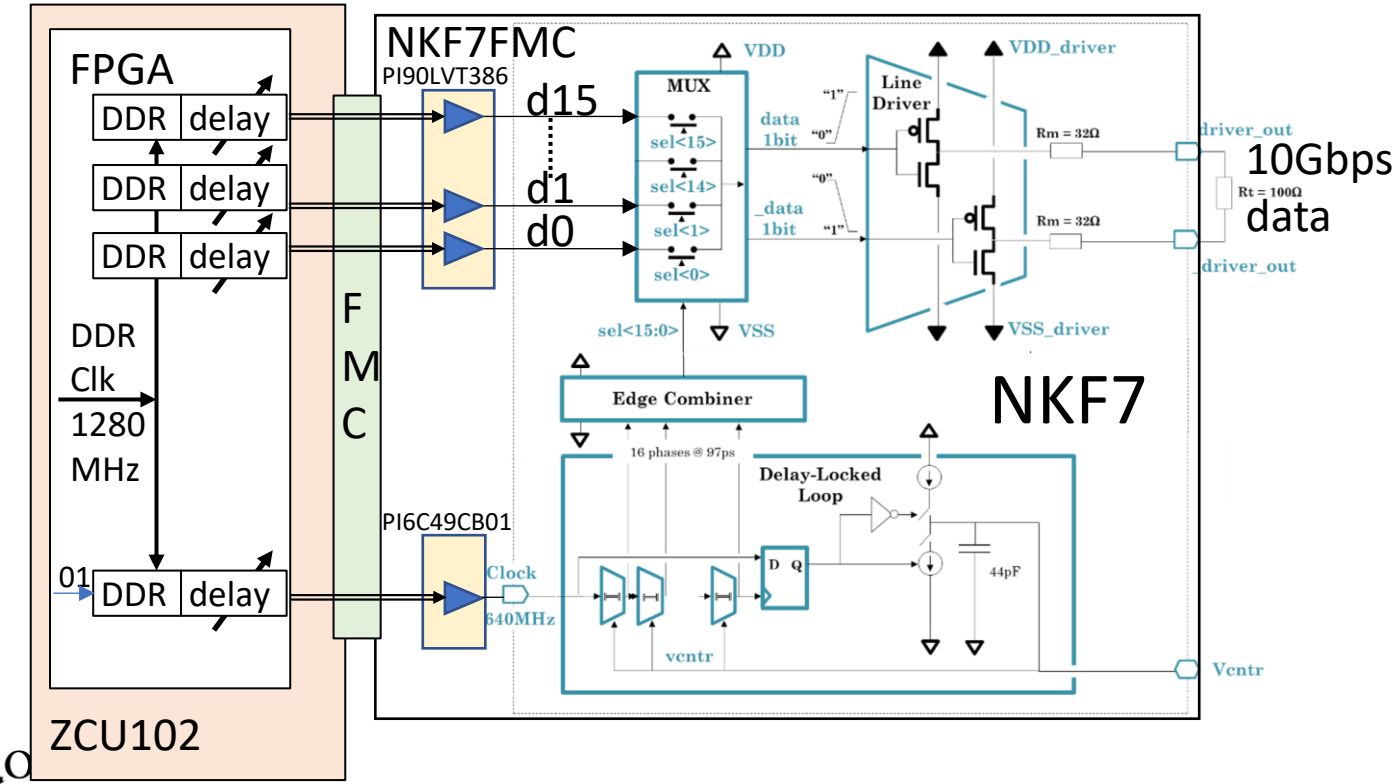
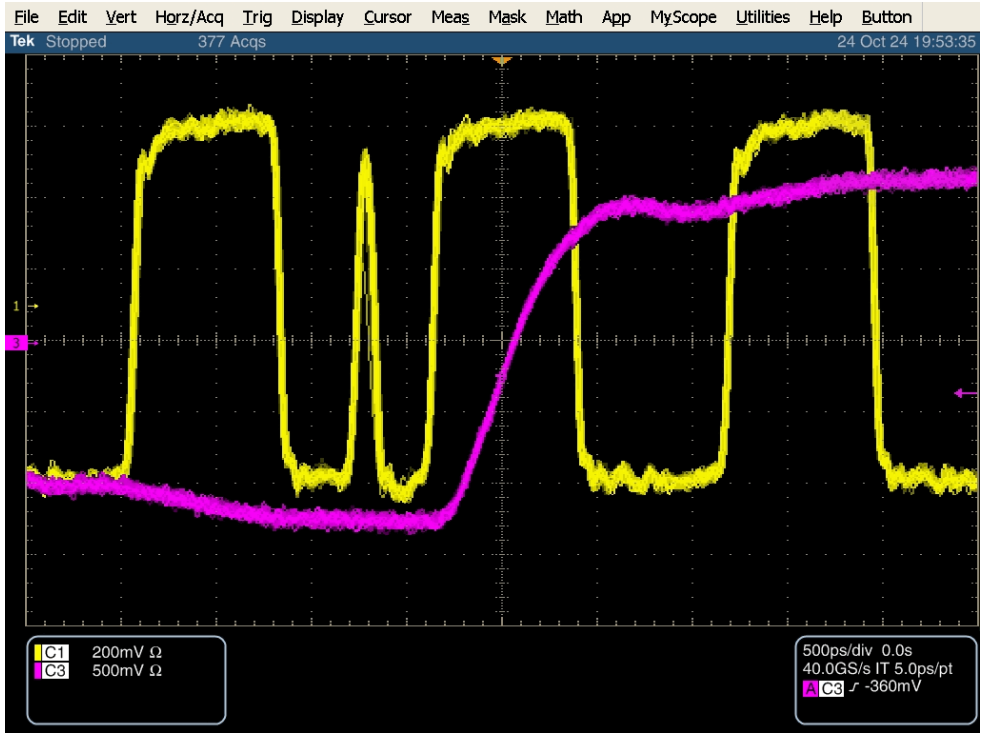
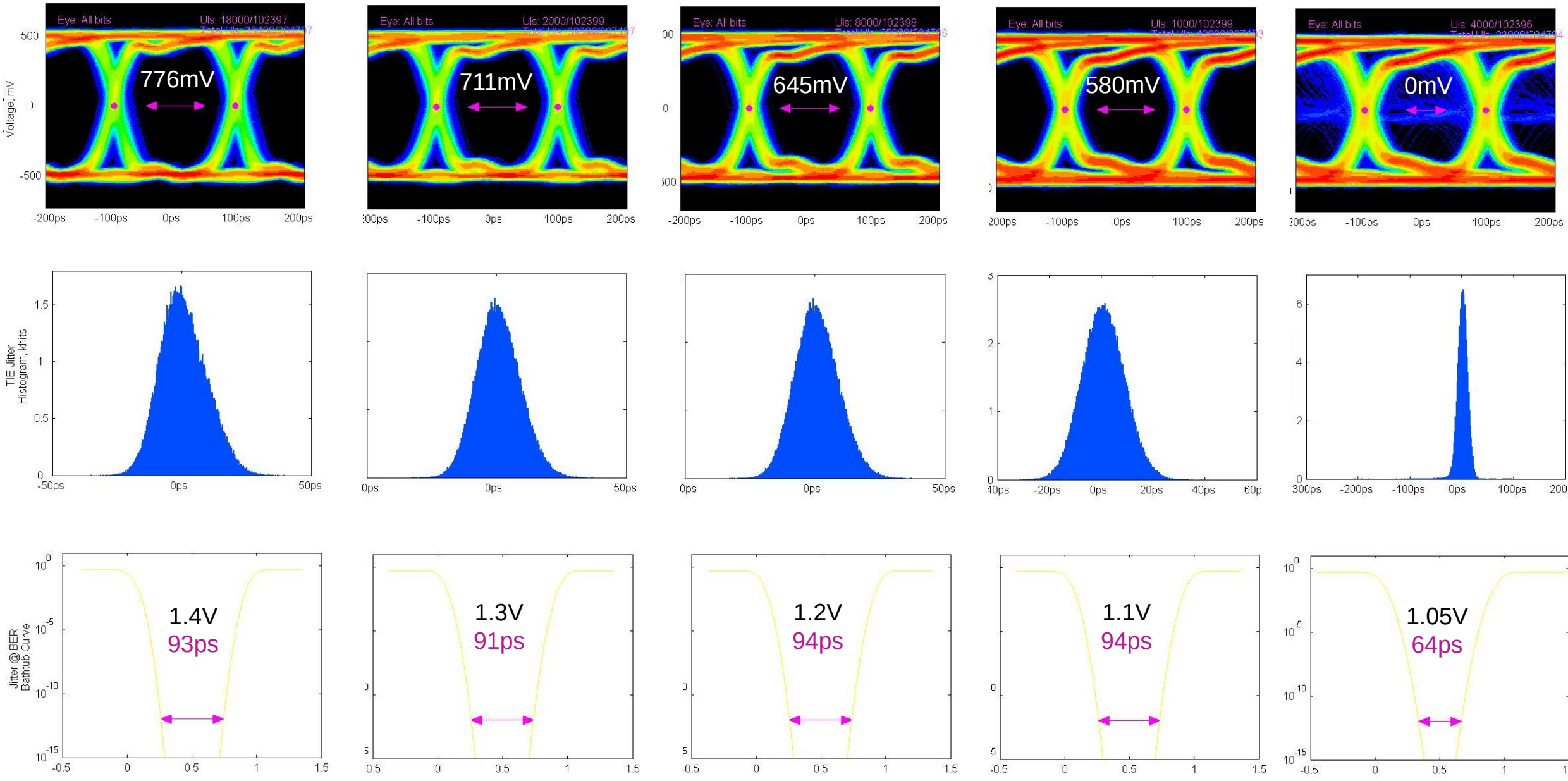
ZCU Firmware with variable (parallel data) bit delays

- Firmware can send either fixed patterns or PRBS patterns at 640 MHz via HSSIO
- Enabled the firmware to set a variable bit sequence for fixed patterns in time.
  - Created 4 time slots (640 MHz fits 4 times into 160 MHz)
  - One can set a sequence for each time slot.
- Adjust bit delays until all bits appear in same frame

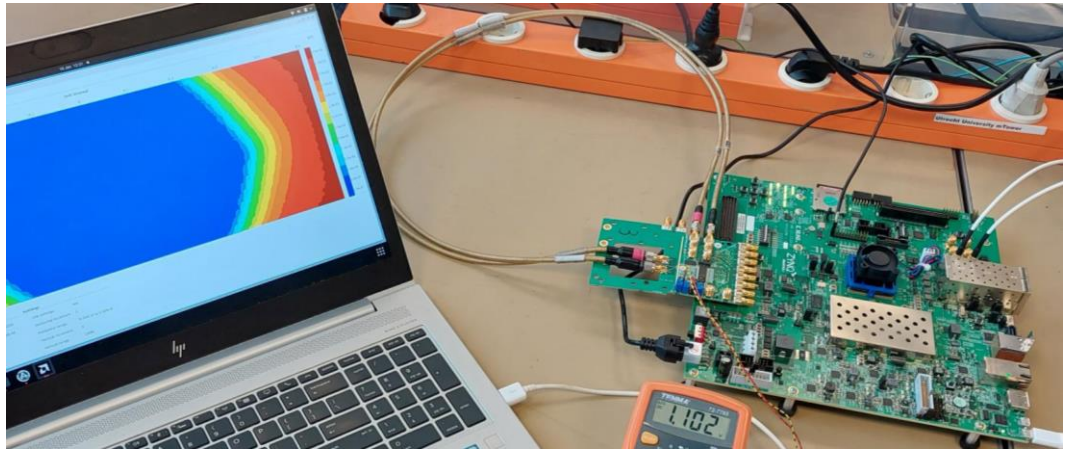




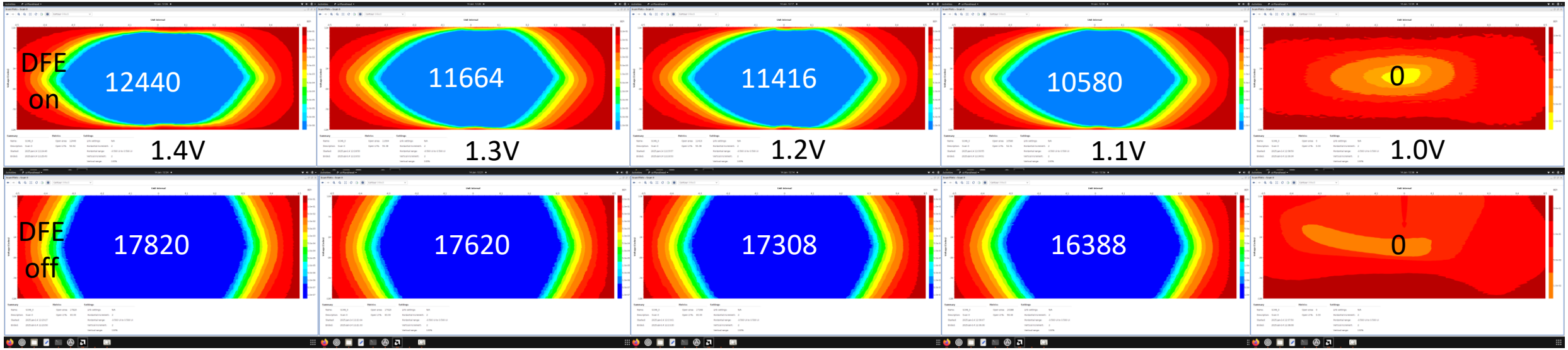
Oscilloscope Eyes with PRBS @ 5Gbps



FPGA Transceiver Statistical Eyes



Conclusion:
At 5.12 Gbps NKF7 operation seems stable
(within certain parameters)



PRBS7, DFE off: 1.35V, 0 error in 20 hrs => BER< $3*10^{-15}$

1.1V, 0 err 20 hrs => $3*10^{-15}$ <1.06V BER explodes

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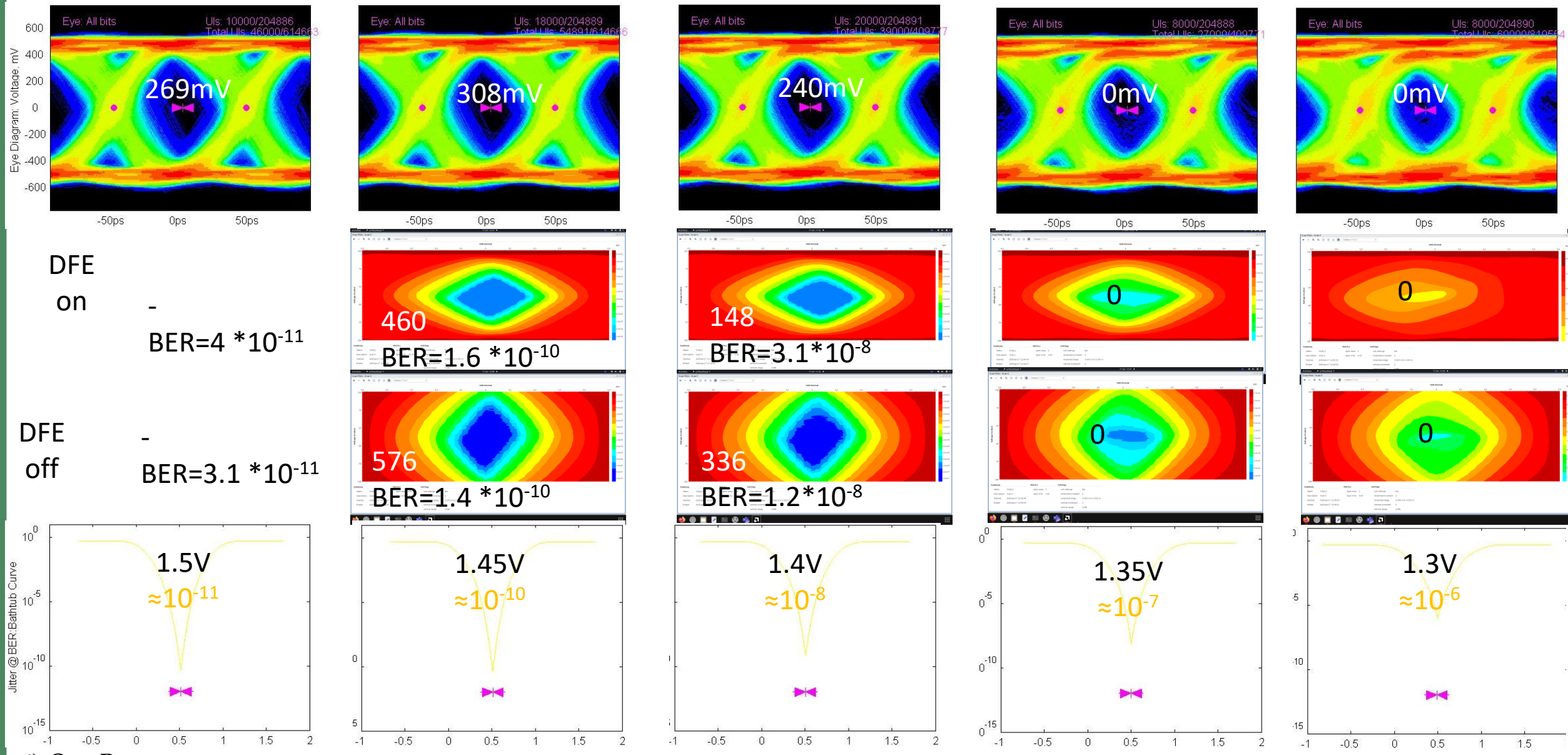
PRBS7 Pattern @ 10.24 Gbps



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