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(Some) Data Communication At Fermilab

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Fermilab Scientific Computing Division
8th INFIERI Workshop
19 October 2016

Versatile Link Plus (VL+) Common Project - Participant

Rad Hard Optical Links for HL-LHC in Flexible Formats

Three Phase Program Organized into Work Packages Overseen by Collaborators
(Academia Sinica, CERN, FNAL, Oxford, SMU)

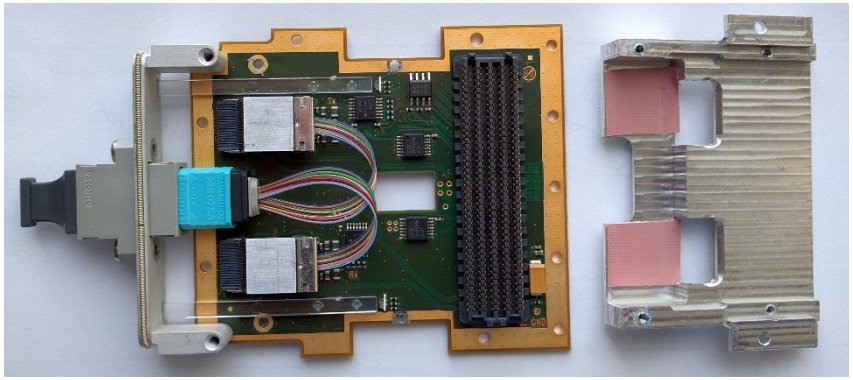
850 nm transmission over Multi-Mode Fiber

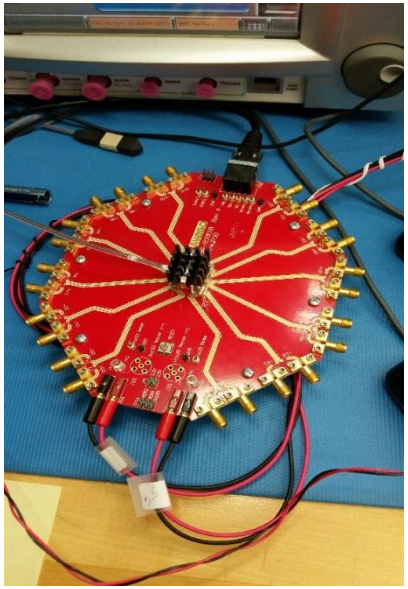
10 Gbps (max) uplink (data from detectors)
2.5 Gbps (nominal) downlink (control and timing)

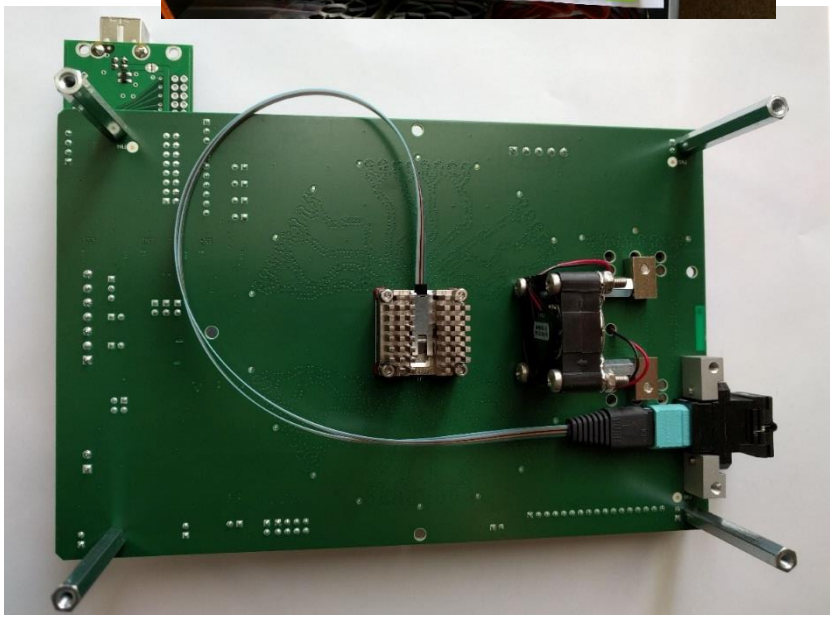
Fermilab Manages 2 Work Packages:

WP6: Back End Components (COTS)
WP7: System Specification and Test

COTS Component Testing – Parallel Optical Engines

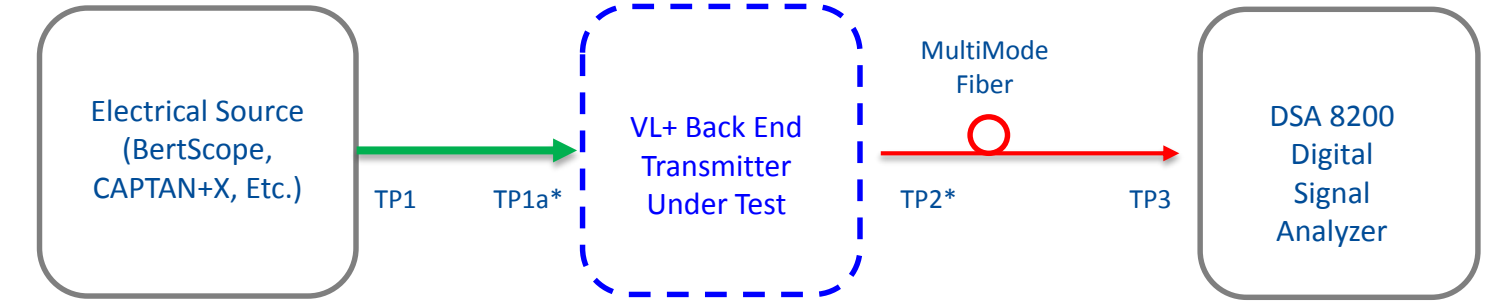




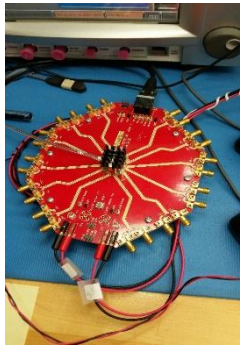


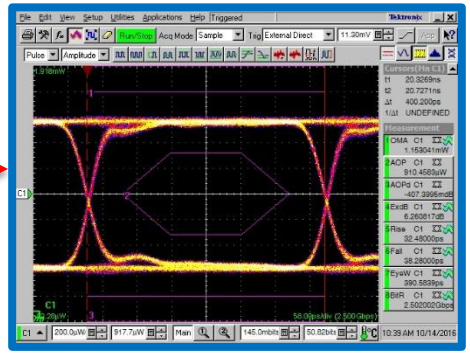
COTS Platforms (evaluation boards and FMC cards)
Custom Platforms (FNAL Real-Time Systems Engineering Designs)

COTS Component Testing – Tx Eye and Jitter



** Relevant Masks Applied*





Tx Eye Measurements:
- Optical Modulation Amplitude
- Extinction Ratio
- Rise and Fall Times
- Eye Opening

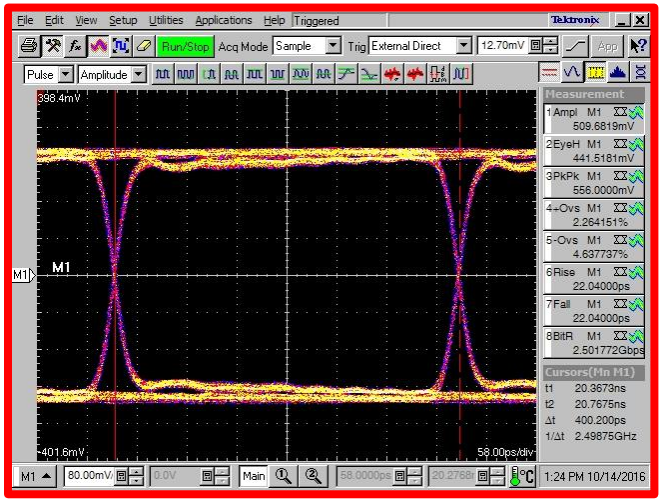
Tx Jitter Measurements:
- Random Jitter (Gaussian, unbounded)
- Deterministic Jitter (bounded)
- Total Jitter (TJ = DJ + 14xRJ)*

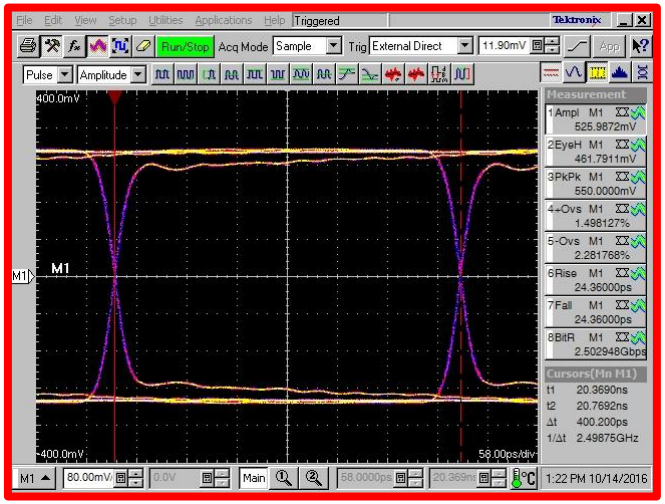
** For BER performance of 10e-12*

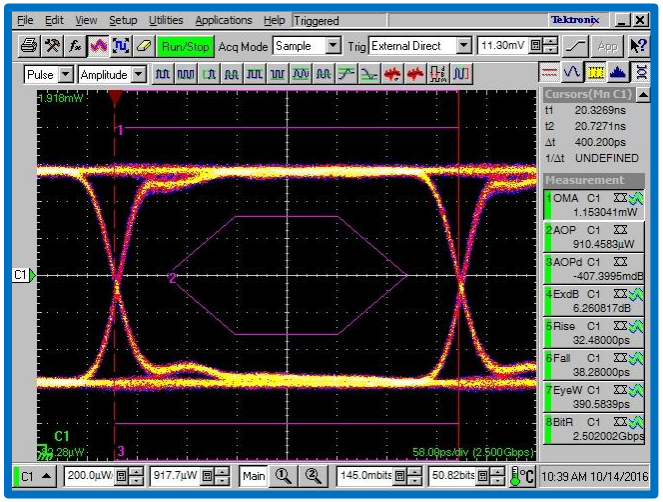
COTS Tx Testing @ 2.5 Gbps

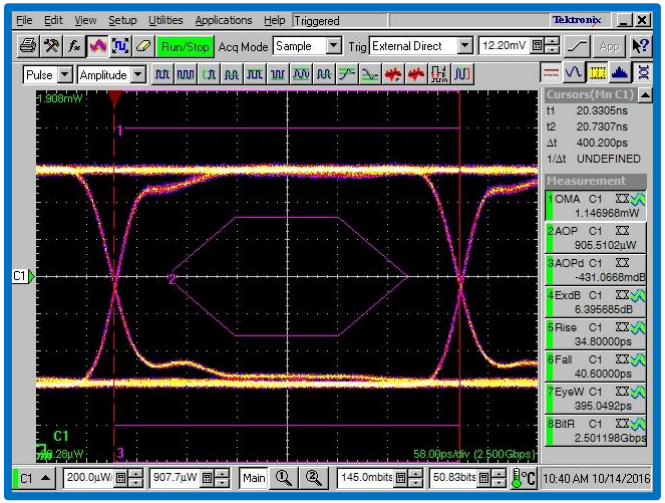
Electrical Excitation

Optical Response









PRBS7 @ 2.5 Gbps

11110000….. @ 2.5 Gbps

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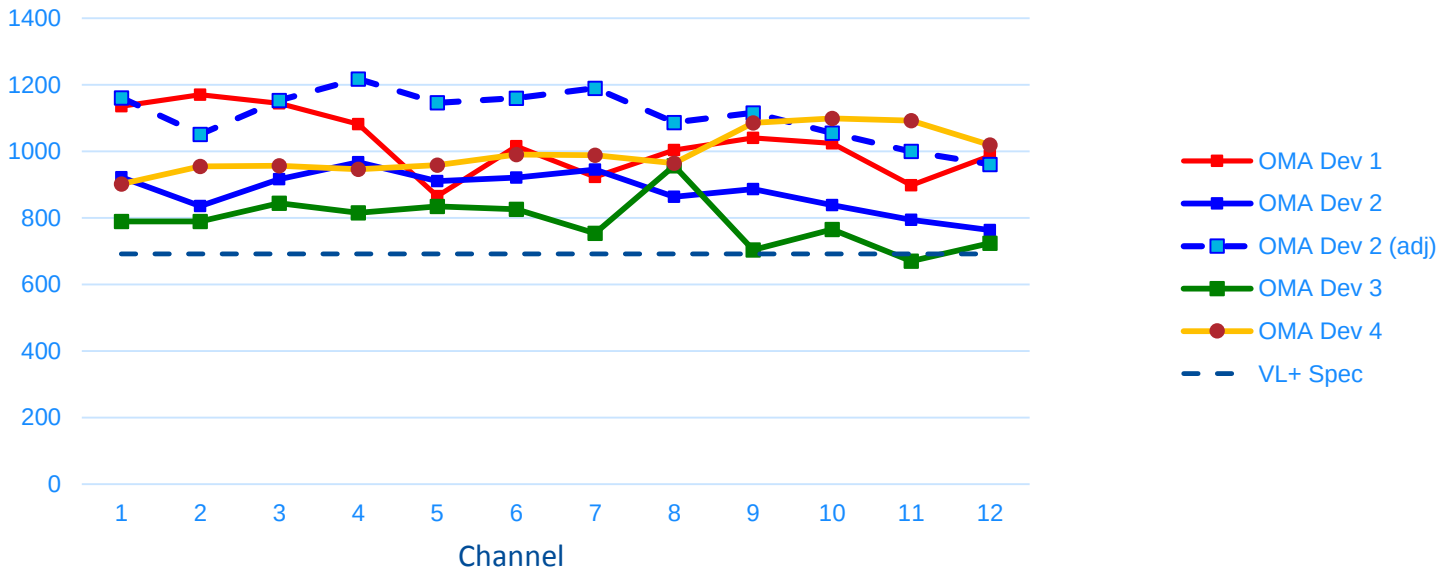
Tx Eye Measurement Channel Performance



Each plot represents a single multichannel device
All channels are plotted and compared to a component spec
Every measurement based on optical/electrical eyes are recorded

Tx Comparative Data and Component Ranking

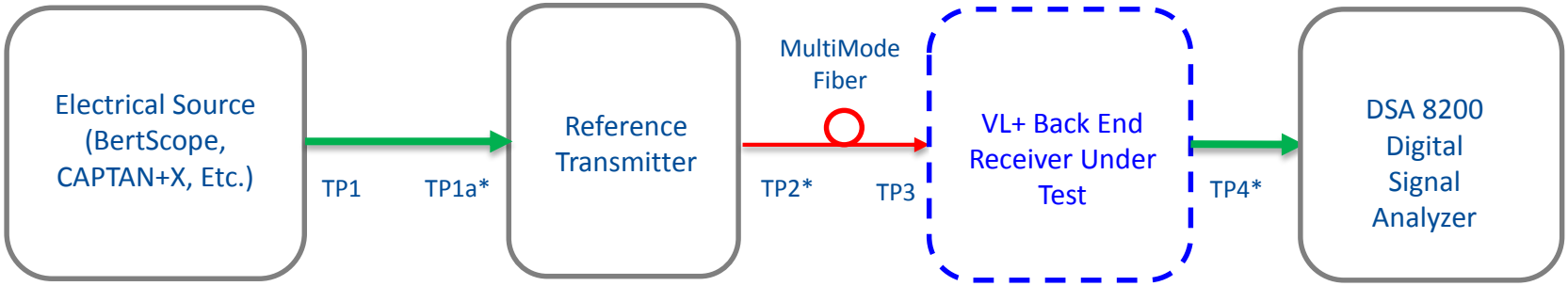
Tx Device Channel Averages:

Device	OMA (uW)	Ext Ratio (dB)	Eye Open (% OMA)	Rise Time (ps)	Fall Time (ps)	TxTJ (UI)	Tx DJ (UI)
Dev 1 Tx	1024	5.32	70.2	41.3	32.1	0.21	0.12
Dev 2 Tx	880	4.79	67.8	40.6	39.6	0.33	0.17
Dev 3 Tx	789	3.42	92.9	41.1	44.0	0.31	0.12
Dev 4 Tx	996	5.53	57.8	24.1	30.0	0.19	0.02

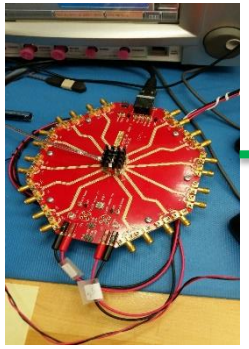
Tx Device Ranking (low score wins):

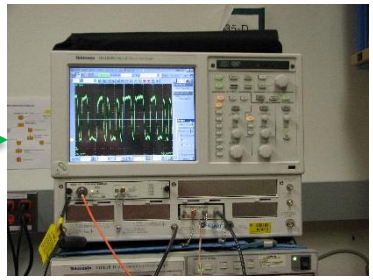
Device	OMA	Ext Ratio	Eye Open	Rise Time	Fall Time	TxTJ	Tx DJ	Total
Dev 1 Tx	1	2	2	4	2	2	2	15
Dev 2 Tx	3	3	3	2	3	4	4	22
Dev 3 Tx	4	4	1	3	4	3	2	21
Dev 4 Tx	2	1	4	1	1	1	1	11

COTS Component Testing – Rx Eye, Jitter, Sensitivity



** Relevant Masks Applied*





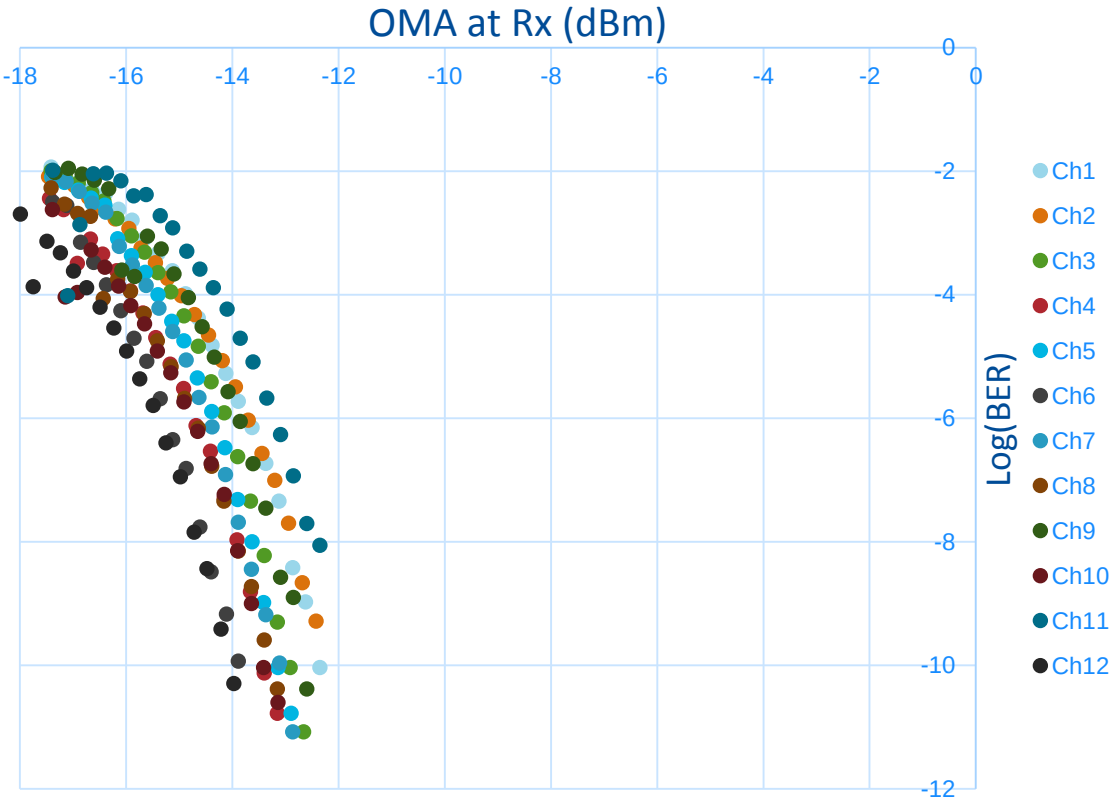
Rx Eye Measurements:
- Rise and Fall Times

Rx Sensitivity

Rx Jitter Measurements:
- Random Jitter (Gaussian, unbounded)
- Deterministic Jitter (bounded)
- Total Jitter (TJ = DJ + 14xRJ)**

*** For BER performance of 10e-12*

COTS Rx Sensitivity Results



Optical Attenuation Introduces Controlled Power Loss to Reach Sensitivity Limit

A plot of a given color represents a single channel of the 12 channel Rx device

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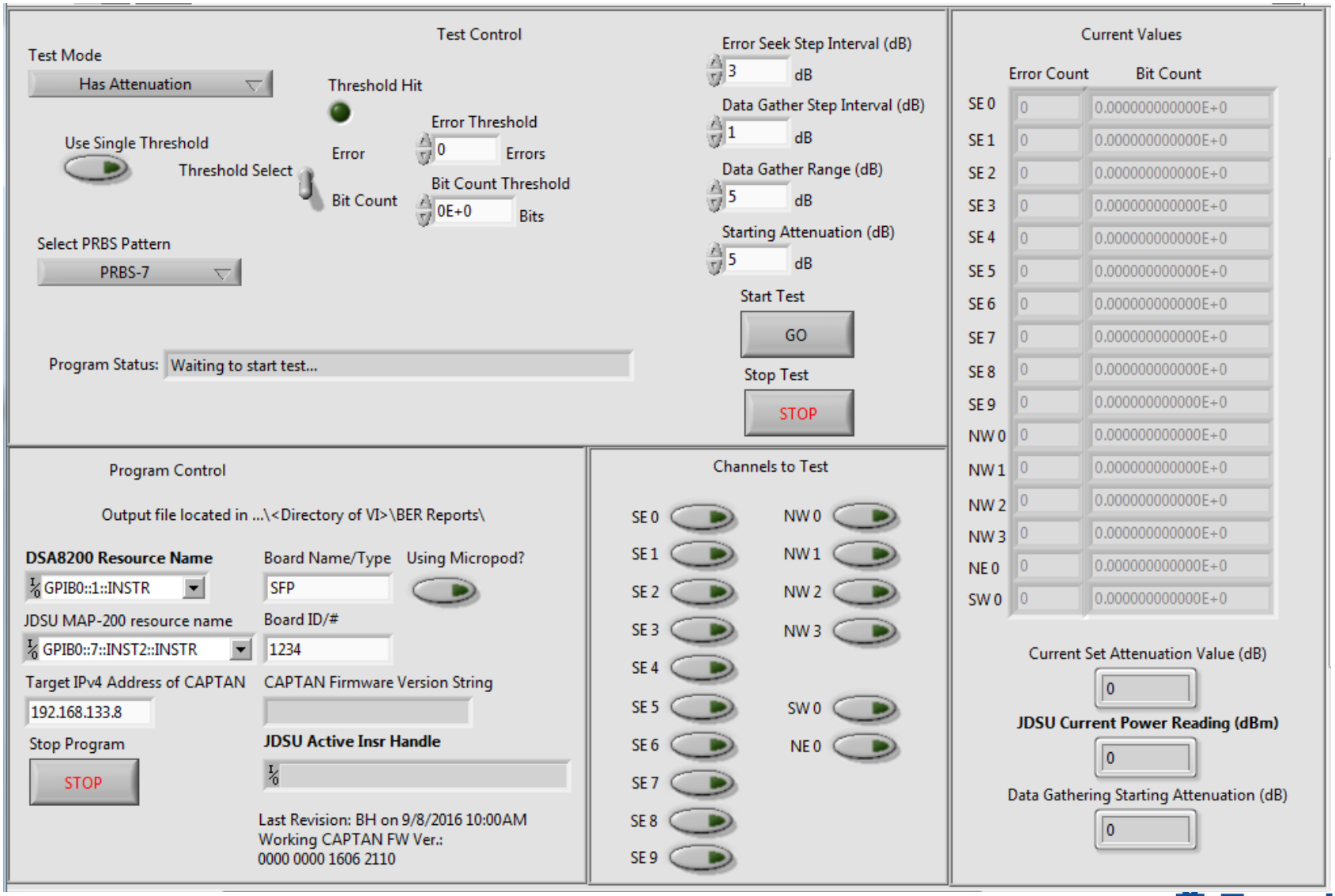
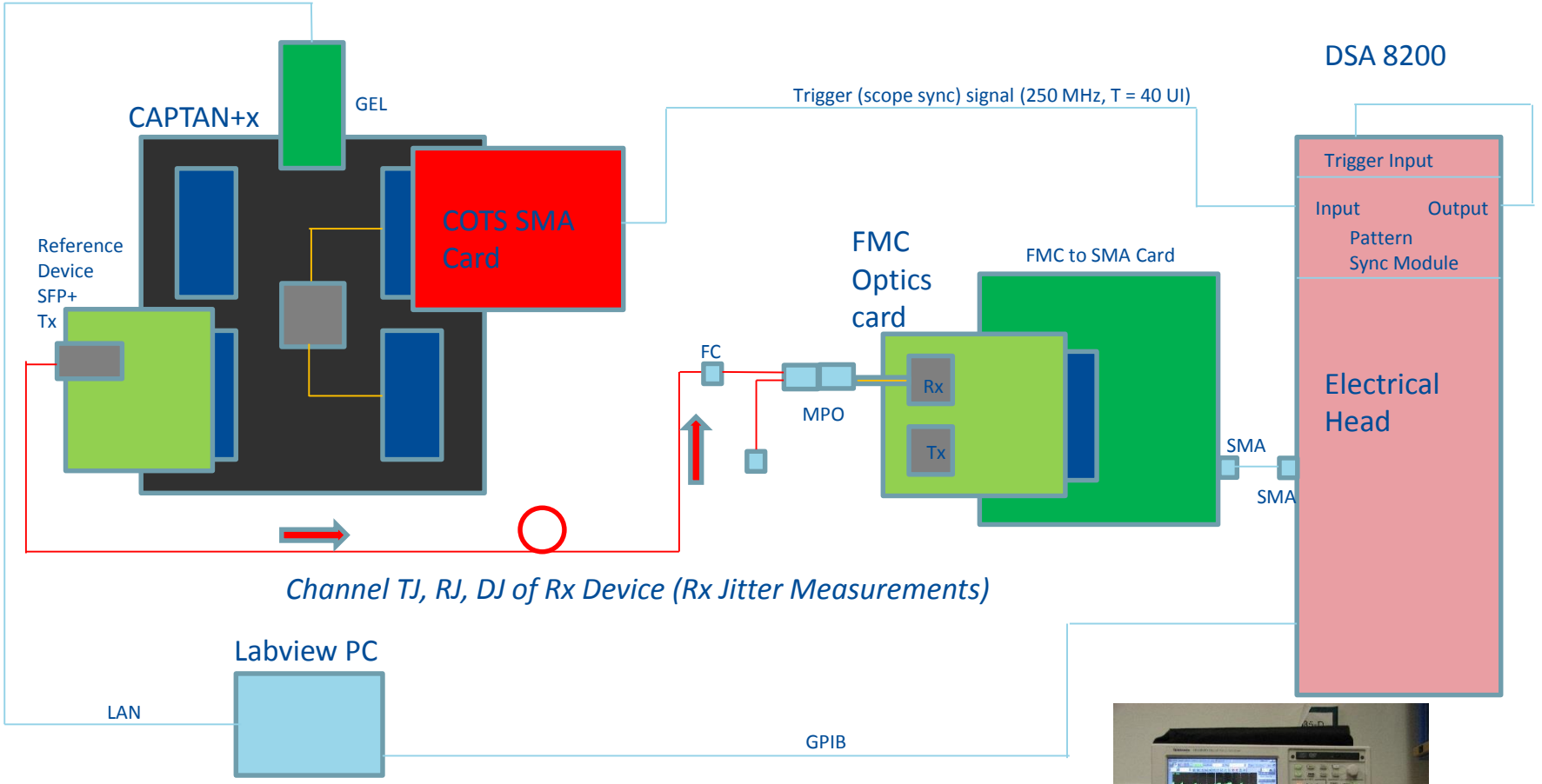
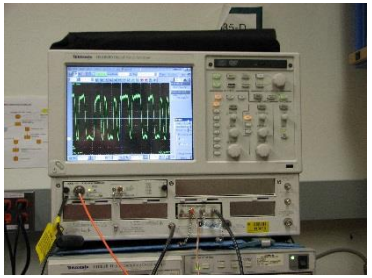
Optical Link Test Automation: BER Testing and Rx Sens.

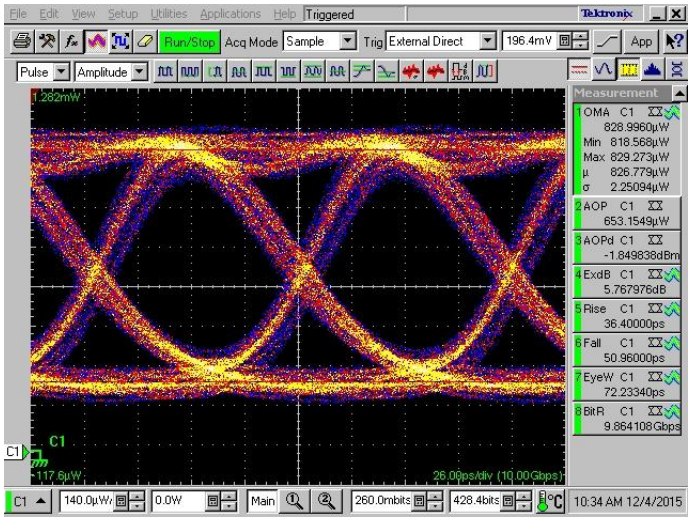


COTS Rx Jitter Characterization - Setup





COTS Rx Jitter Characterization - Measurements



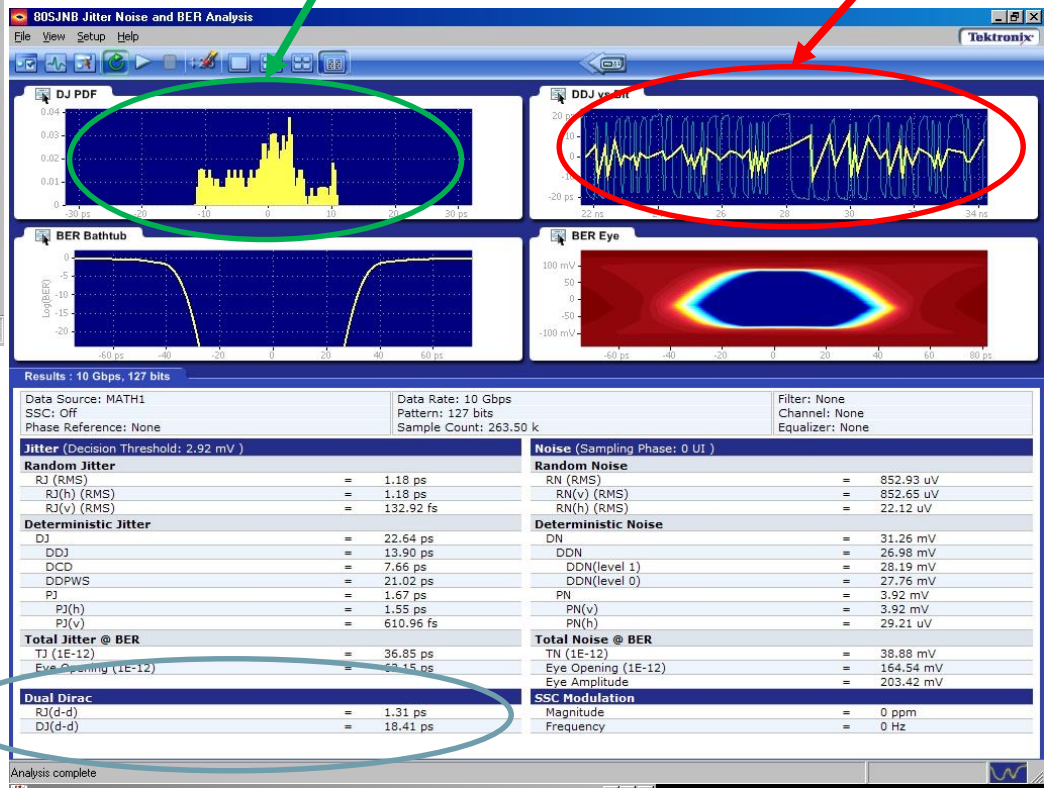
Optical Excitation from Reference Transmitter at 10 Gbps

"Dual Dirac" modeled RJ and DJ

TJ = DJ + 14*RJ

Deterministic Jitter Probability Distribution

Data Dependent Jitter (bit by bit for pattern)



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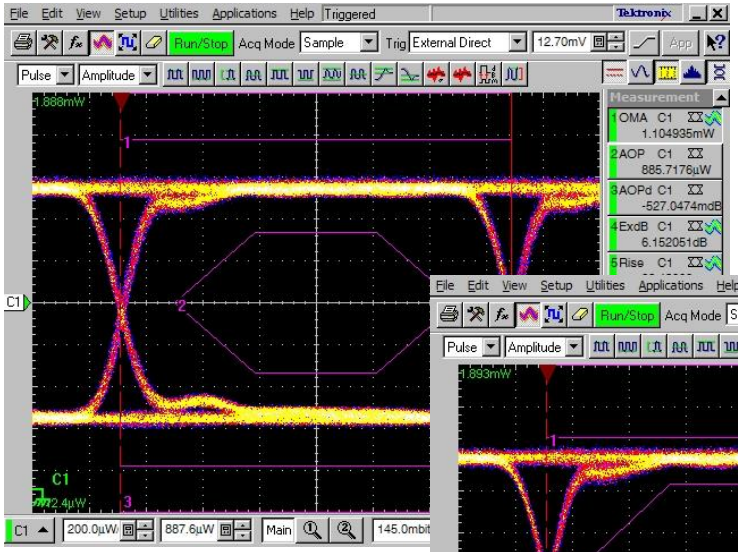
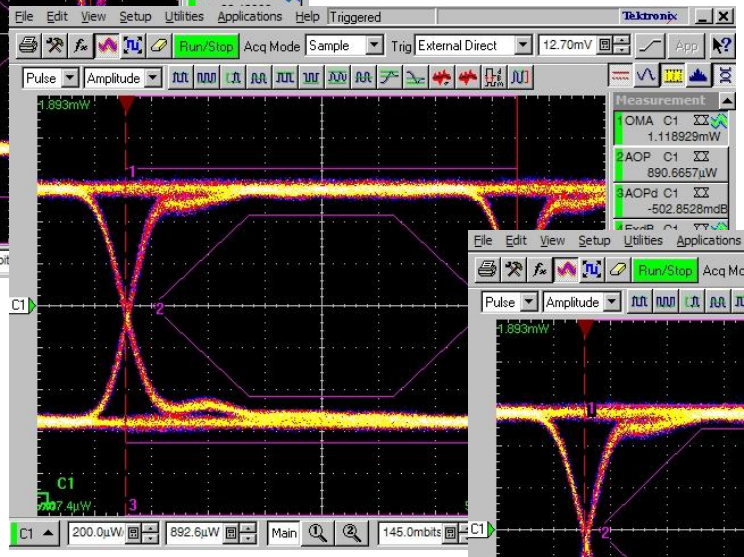
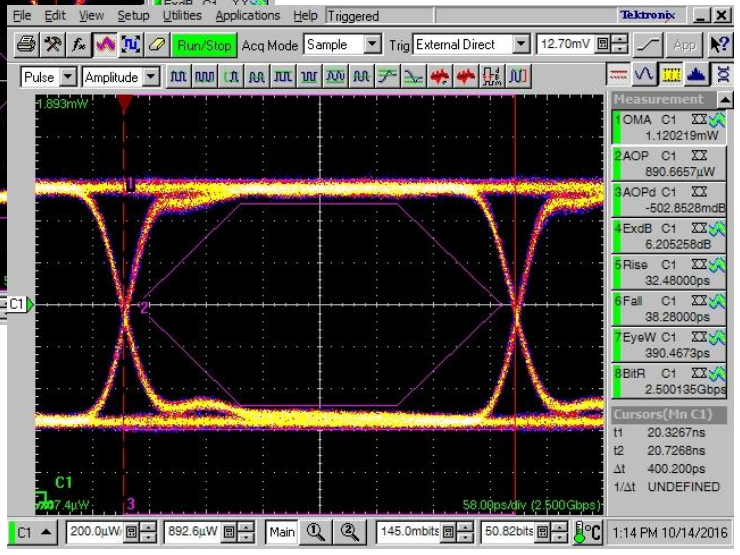
Mask Testing and Mask Margin



Standard Optical Mask
At TP2



Mask Margin = 50%



Mask Margin = 75%

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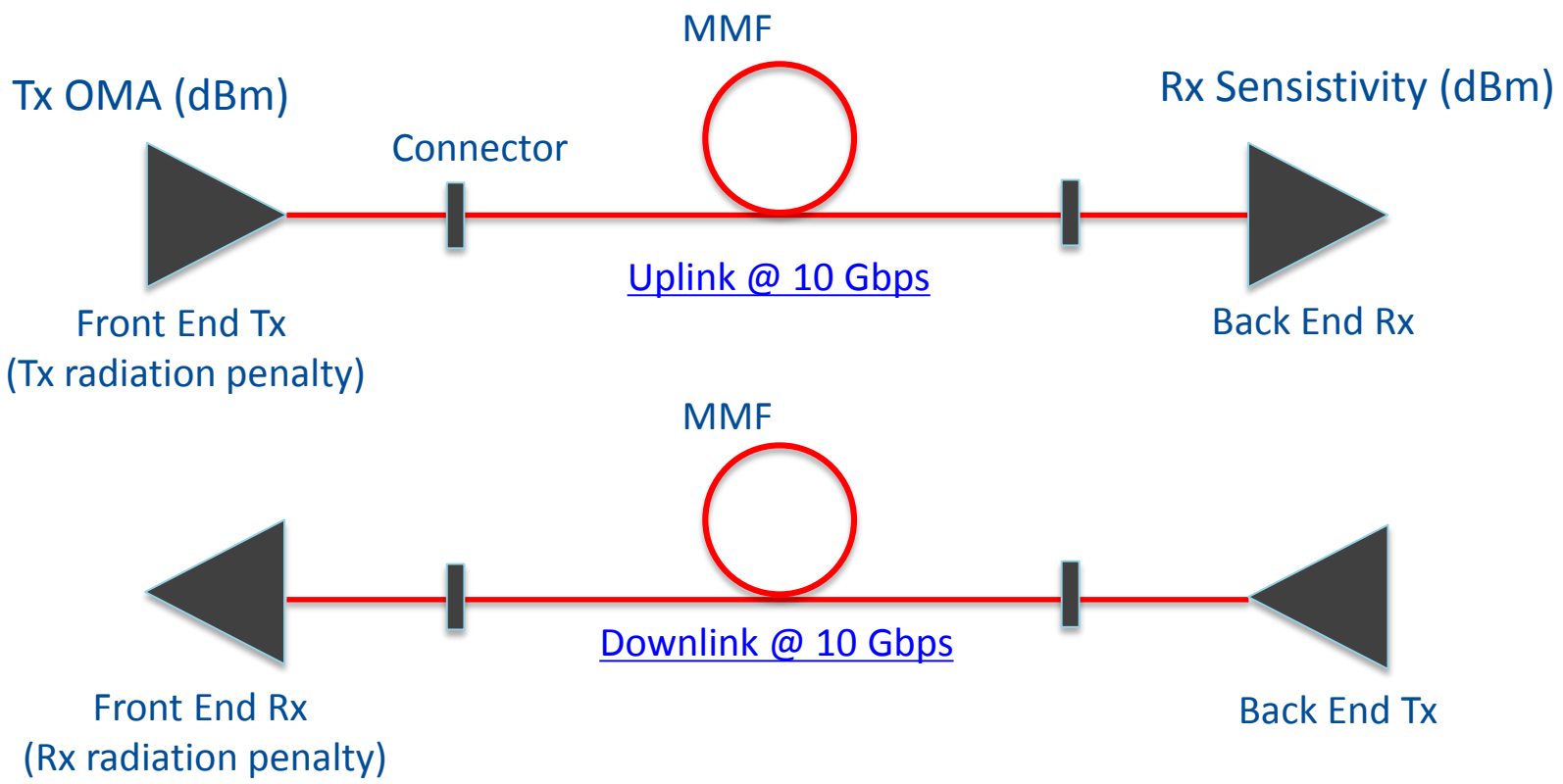
System Specification – Power Budget



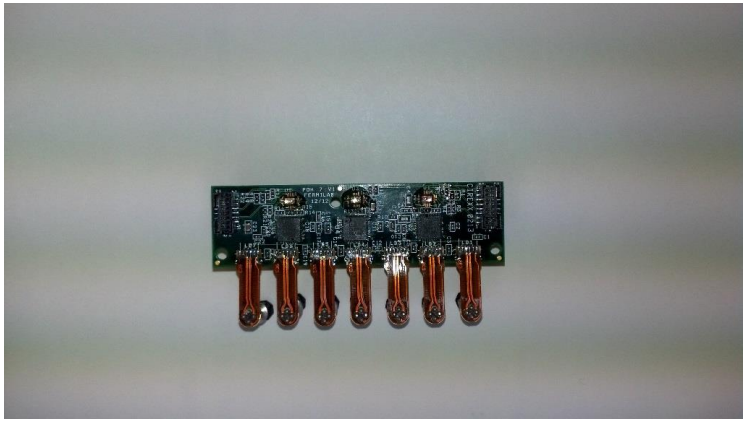
Power Budget (dB) = Tx OMA (dBm) – Rx Sens. (dBm)* - Losses (connectors, attenuation) – "Penalties"

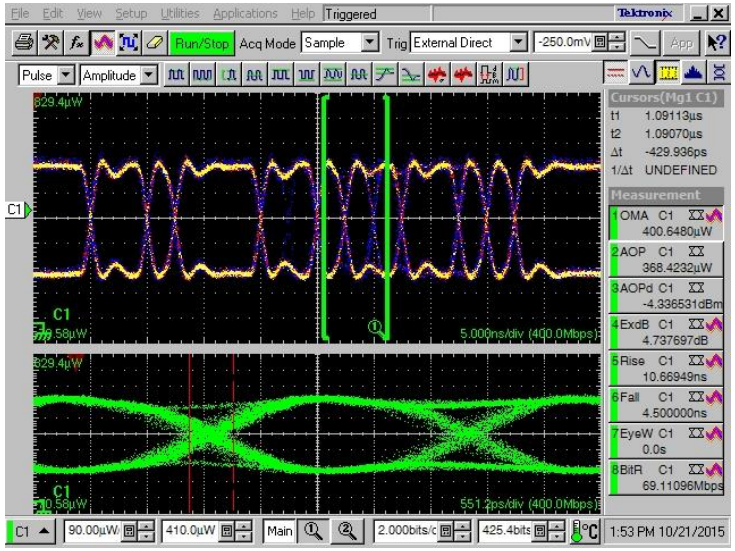
A Few Other Projects …

Optical Links for CMS Phase I FPix Upgrades

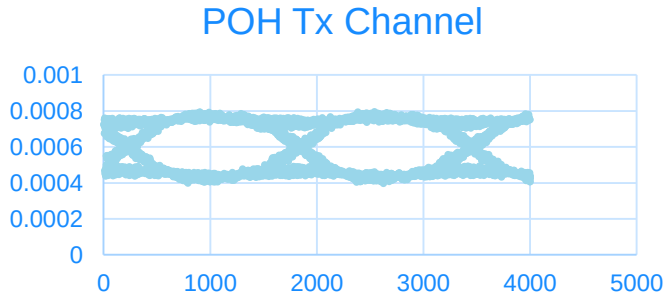
Off the Shelf Data Acquisition

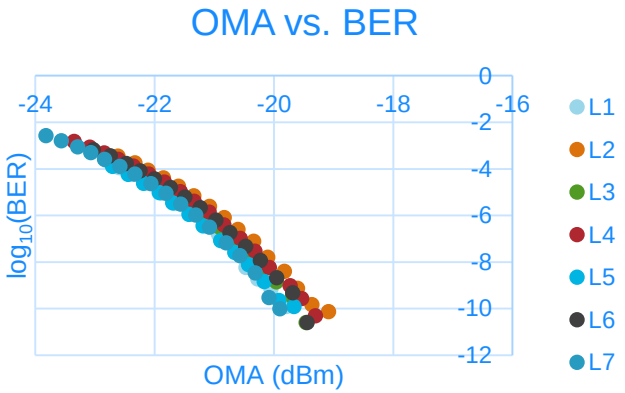
CMS FPix Phase 1 Upgrades – 7 Channel Pixel OptoHybrid

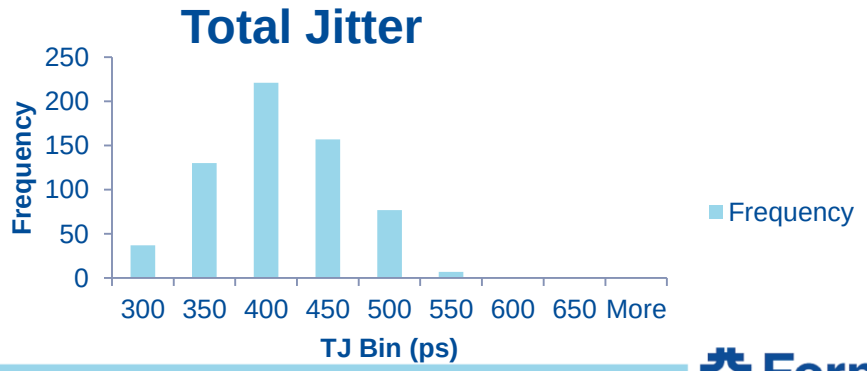




Collaboration of CERN, ETHZ, FNAL, PSI







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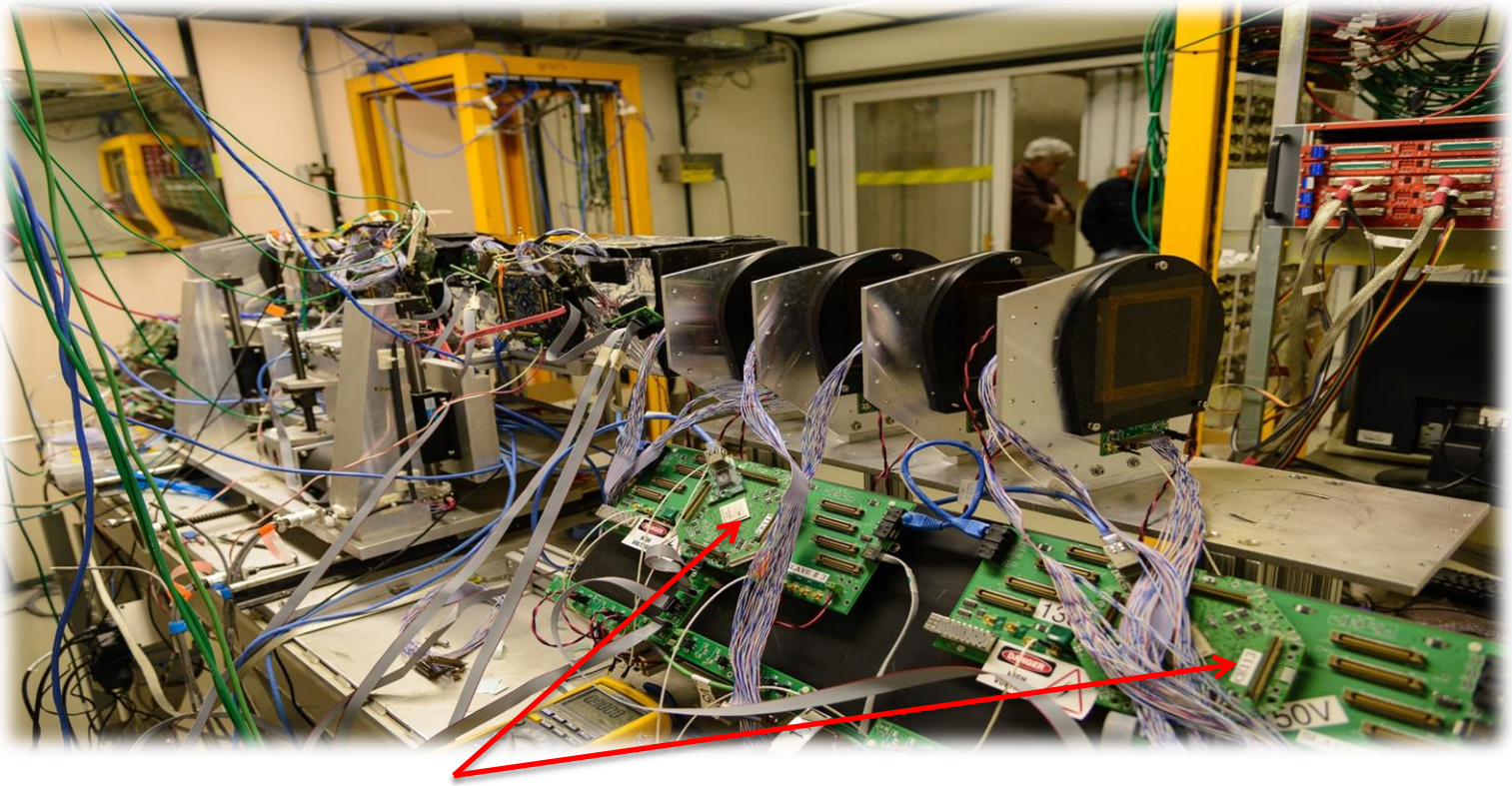
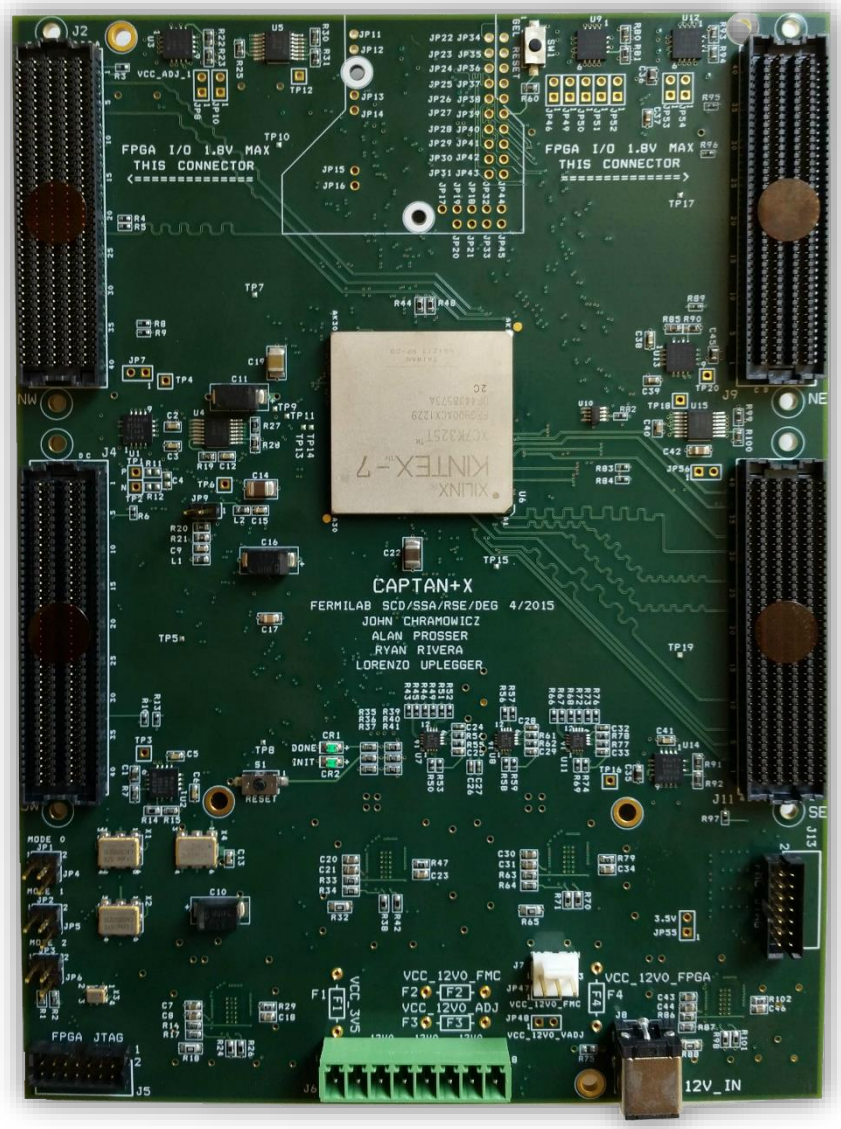
CAPTAN Nodes – Foundation of the Pixel and Strips Telescope



CAPTAN: Compact And Programmable daTa Acquisition Node

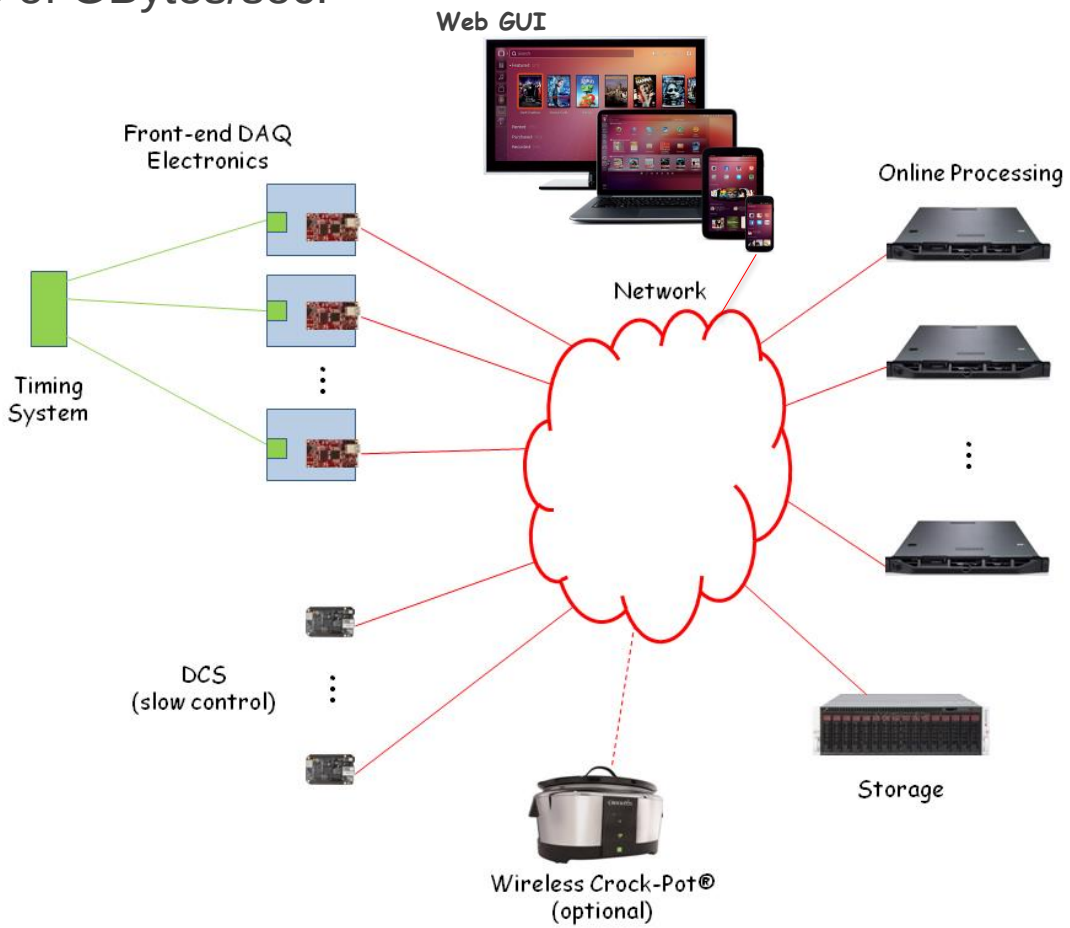
Introducing the (New) CAPTAN+

- CAPTAN+ (“CAPTAN plus”) is the next generation CAPTAN card.
  - Based on Xilinx 7 series.
  - Artix and Kintex versions of the board.
- **Features:**
  - Gigabit Ethernet
  - 4 FMC connectors, 16 Links
  - 360 GPIO

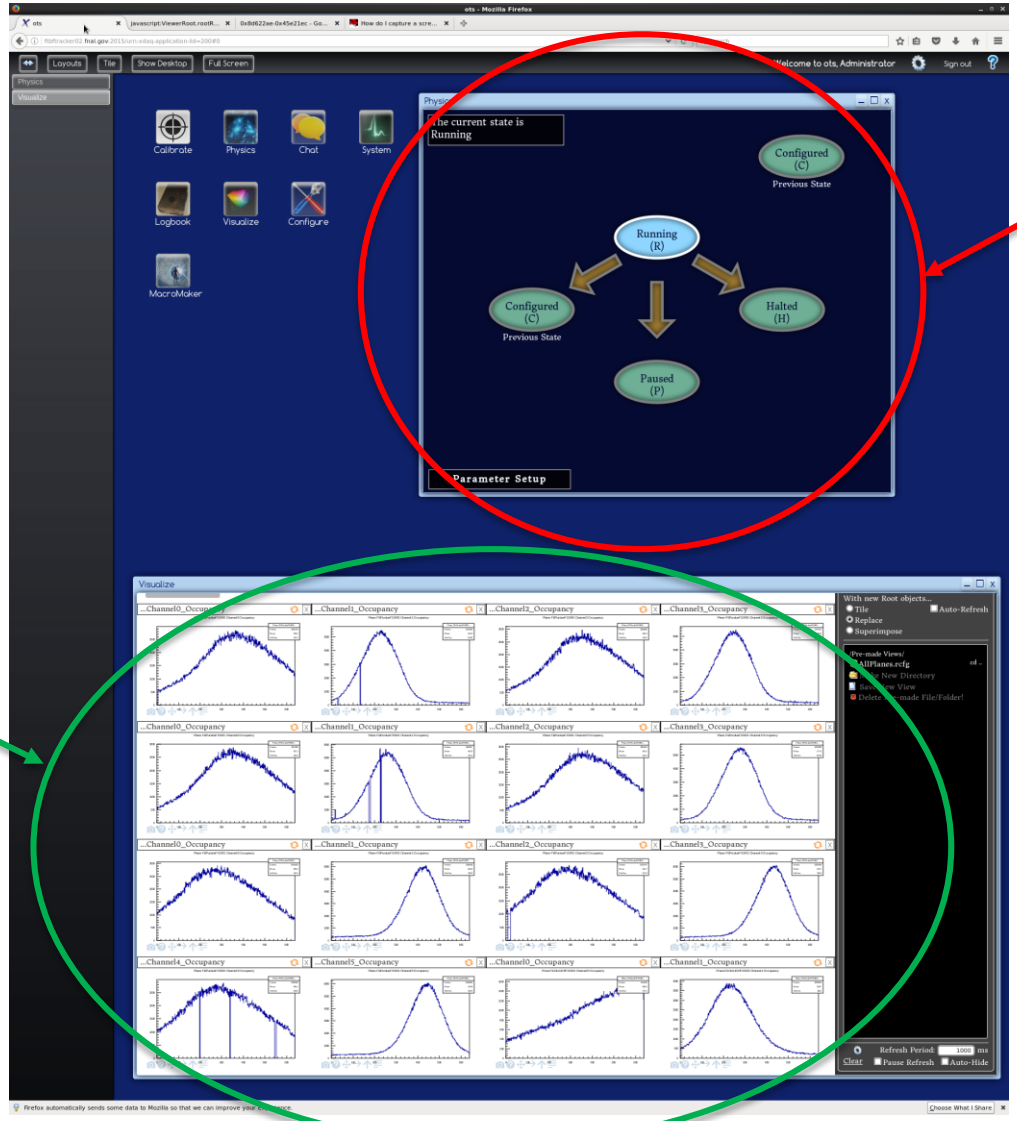


Off the Shelf Data Acquisition (OtS DAQ)

- We are developing a **low cost**, data acquisition architecture **as a service**, based on commercial **IoT** technology that is **scalable** from a few MBytes/sec to hundreds of GBytes/sec.



OtS DAQ Software Development (Web GUI)



SW
State Machine
Control

Real Time
Beam Profile
Monitoring
Via Strips
Telescope

Fermilab

Conclusion

Thank You For Your Attention.

Questions?