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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)

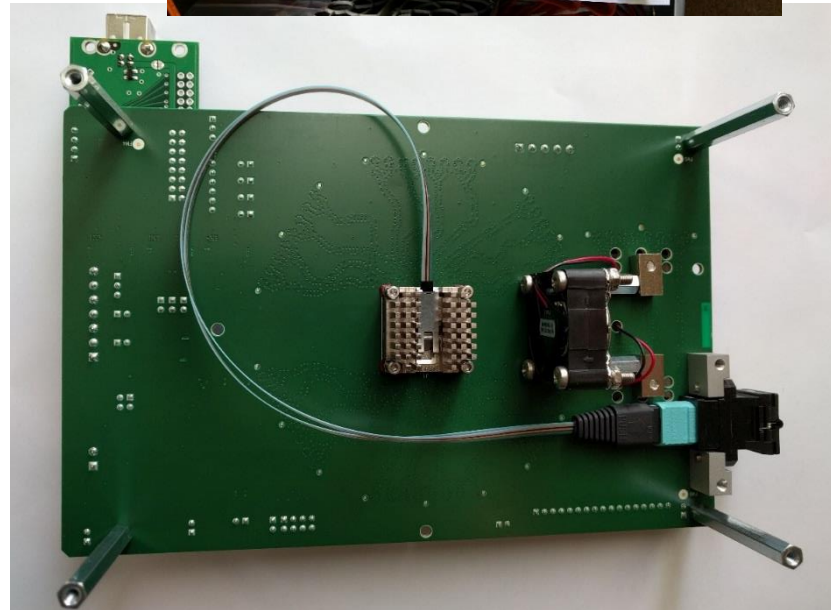
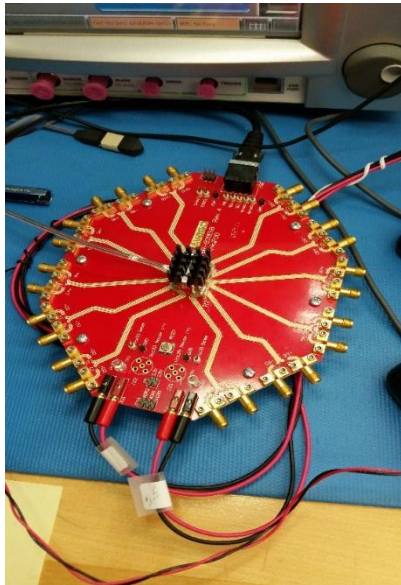
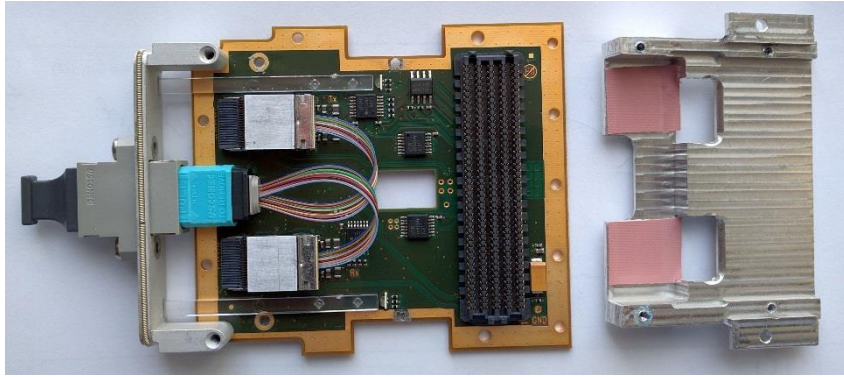
2.5 Gbps (nominal) downlink (control and timing)

Fermilab Manages 2 Work Packages:

WP6: Back End Components (COTS)

WP7: System Specification and Test

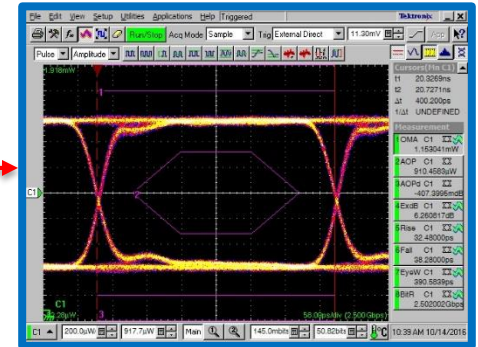
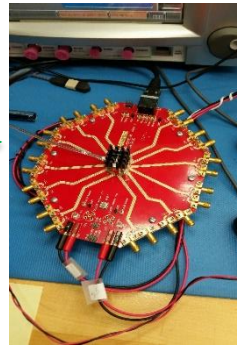
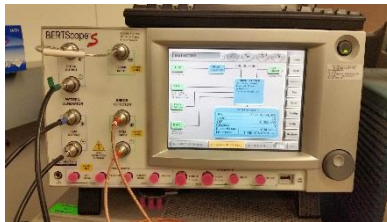
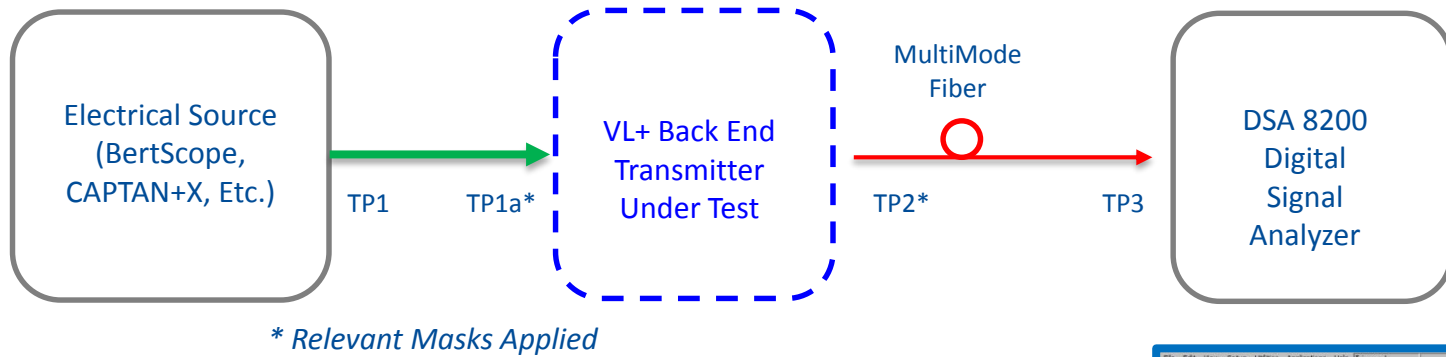
COTS Component Testing – Parallel Optical Engines



COTS Platforms (evaluation boards and FMC cards)

Custom Platforms (FNAL Real-Time Systems Engineering Designs)

COTS Component Testing – Tx Eye and Jitter



Tx Eye Measurements:

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

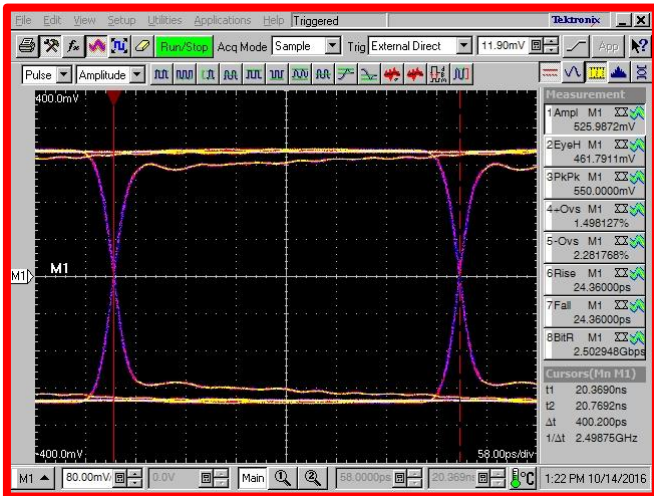
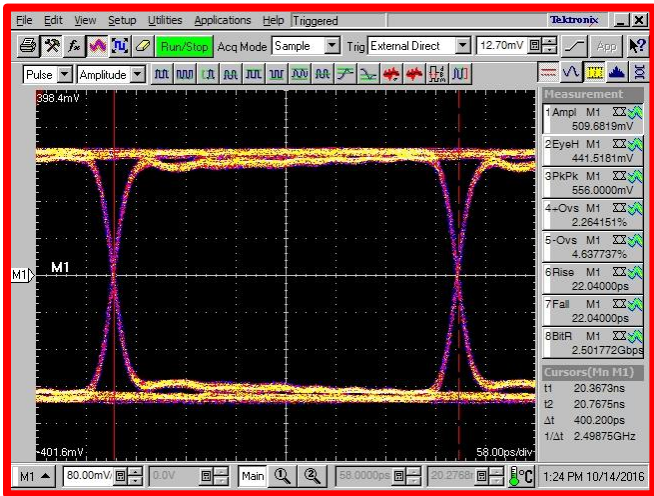
Tx Jitter Measurements:

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

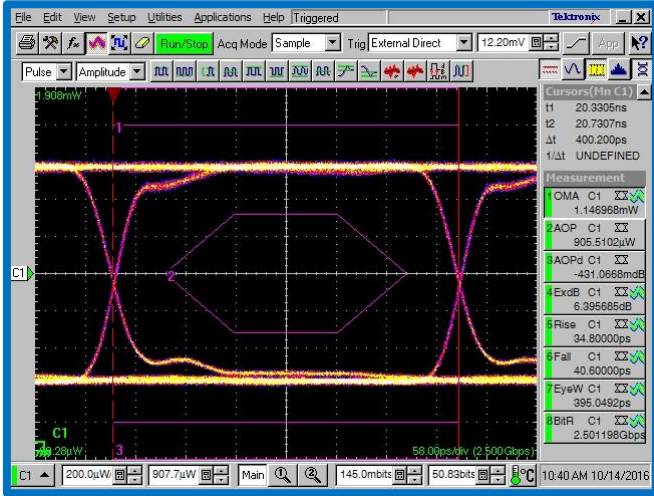
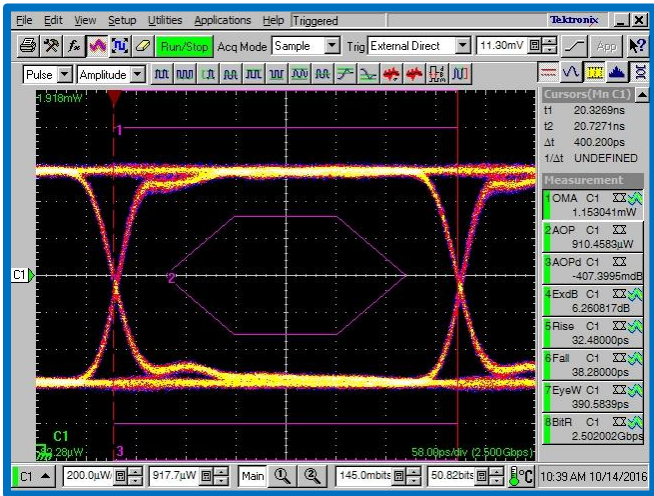
* For BER performance of $10e-12$

COTS Tx Testing @ 2.5 Gbps

Electrical Excitation



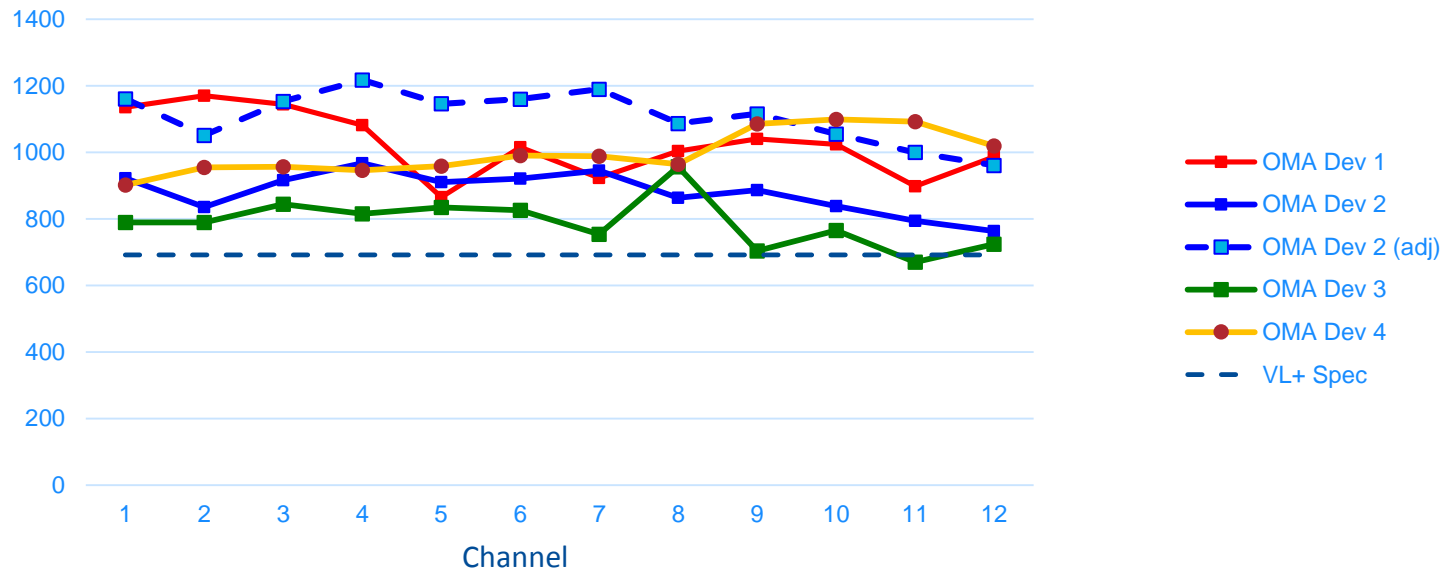
Optical Response



PRBS7 @ 2.5 Gbps

11110000..... @ 2.5 Gbps

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

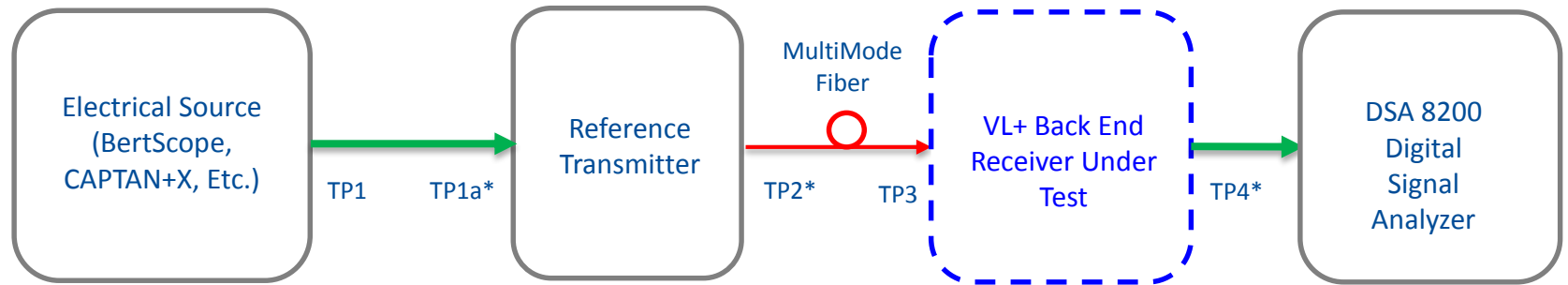
Tx Device Channel Averages:

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

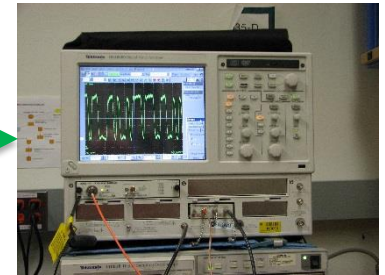
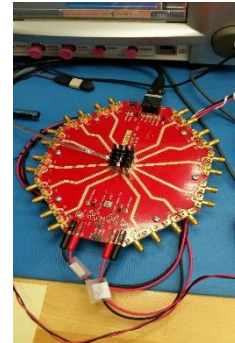
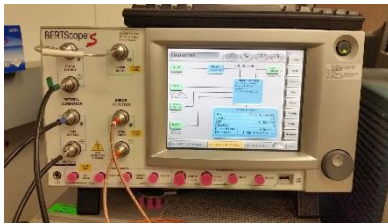
Tx Device Ranking (low score wins):

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*



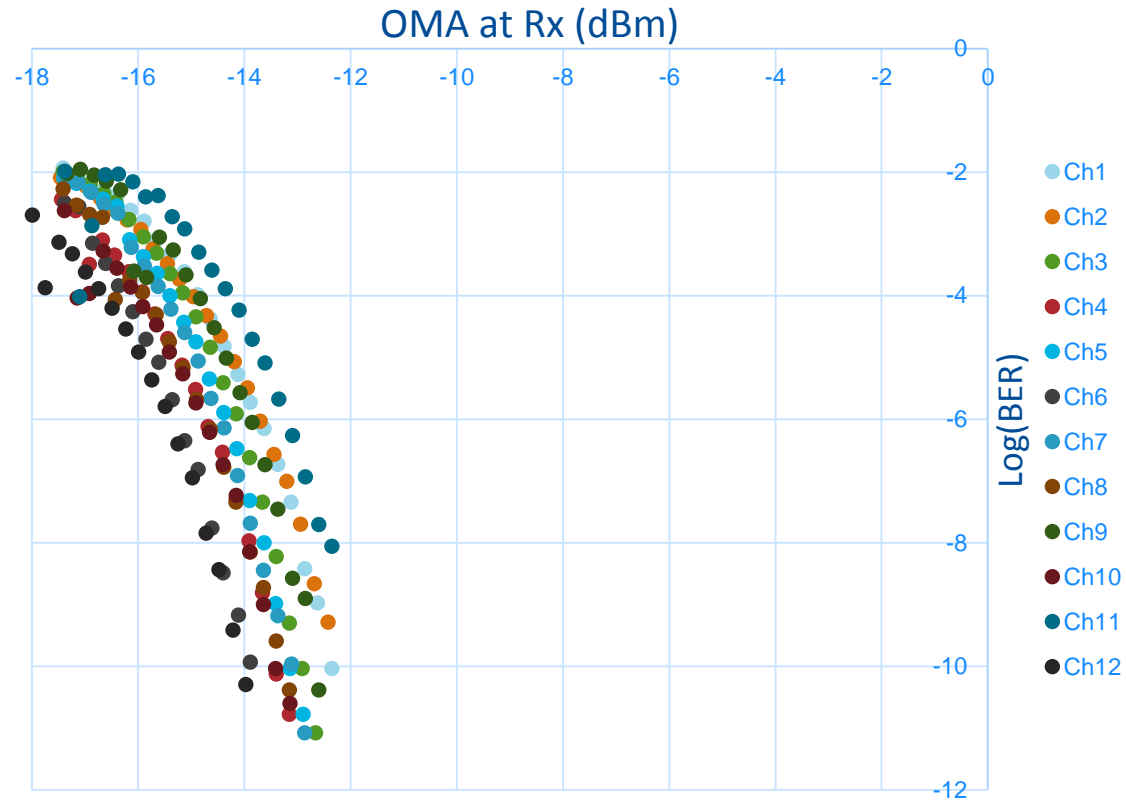
Rx Eye Measurements:
Rise and Fall Times

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

Optical Link Test Automation: BER Testing and Rx Sens.

Test Mode

Has Attenuation

Use Single Threshold

Threshold Select

Select PRBS Pattern

PRBS-7

Program Status:

Waiting to start test...

Test Control

Threshold Hit

Error

Bit Count

Error Threshold

0

Errors

Bit Count Threshold

0E+0

Bits

Error Seek Step Interval (dB)

3

dB

Data Gather Step Interval (dB)

1

dB

Data Gather Range (dB)

5

dB

Starting Attenuation (dB)

5

dB

Start Test

GO

Stop Test

STOP

Current Values

	Error Count	Bit Count
SE 0	0	0.000000000000E+0
SE 1	0	0.000000000000E+0
SE 2	0	0.000000000000E+0
SE 3	0	0.000000000000E+0
SE 4	0	0.000000000000E+0
SE 5	0	0.000000000000E+0
SE 6	0	0.000000000000E+0
SE 7	0	0.000000000000E+0
SE 8	0	0.000000000000E+0
SE 9	0	0.000000000000E+0
NW 0	0	0.000000000000E+0
NW 1	0	0.000000000000E+0
NW 2	0	0.000000000000E+0
NW 3	0	0.000000000000E+0
NE 0	0	0.000000000000E+0
SW 0	0	0.000000000000E+0

Current Set Attenuation Value (dB)

0

JDSU Current Power Reading (dBm)

0

Data Gathering Starting Attenuation (dB)

0

Program Control

Output file located in ...\\<Directory of VI>\\BER Reports\\

DSA8200 Resource Name

Board Name/Type

Using Micropod?

1 GPIB0::1::INSTR

SFP

JDSU MAP-200 resource name

Board ID/#

1 GPIB0::7::INST2::INSTR

1234

Target IPv4 Address of CAPTAN

CAPTAN Firmware Version String

192.168.133.8

Stop Program

JDSU Active Insr Handle

STOP

1

Last Revision: BH on 9/8/2016 10:00AM

Working CAPTAN FW Ver.: 0000 0000 1606 2110

Channels to Test

SE 0

SE 1

SE 2

SE 3

SE 4

SE 5

SE 6

SE 7

SE 8

SE 9

NW 0

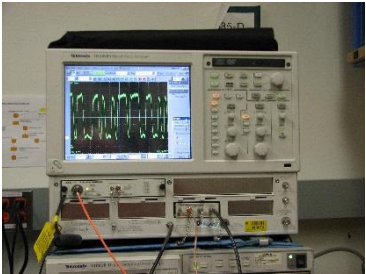
NW 1

NW 2

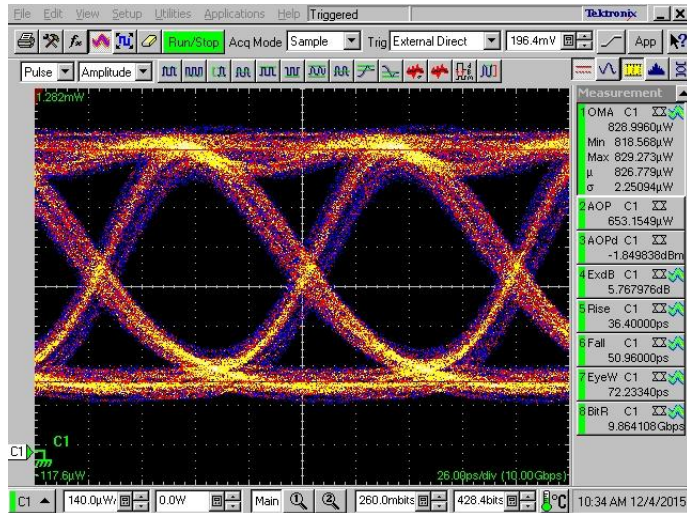
NW 3

SW 0

NE 0



COTS Rx Jitter Characterization - Measurements



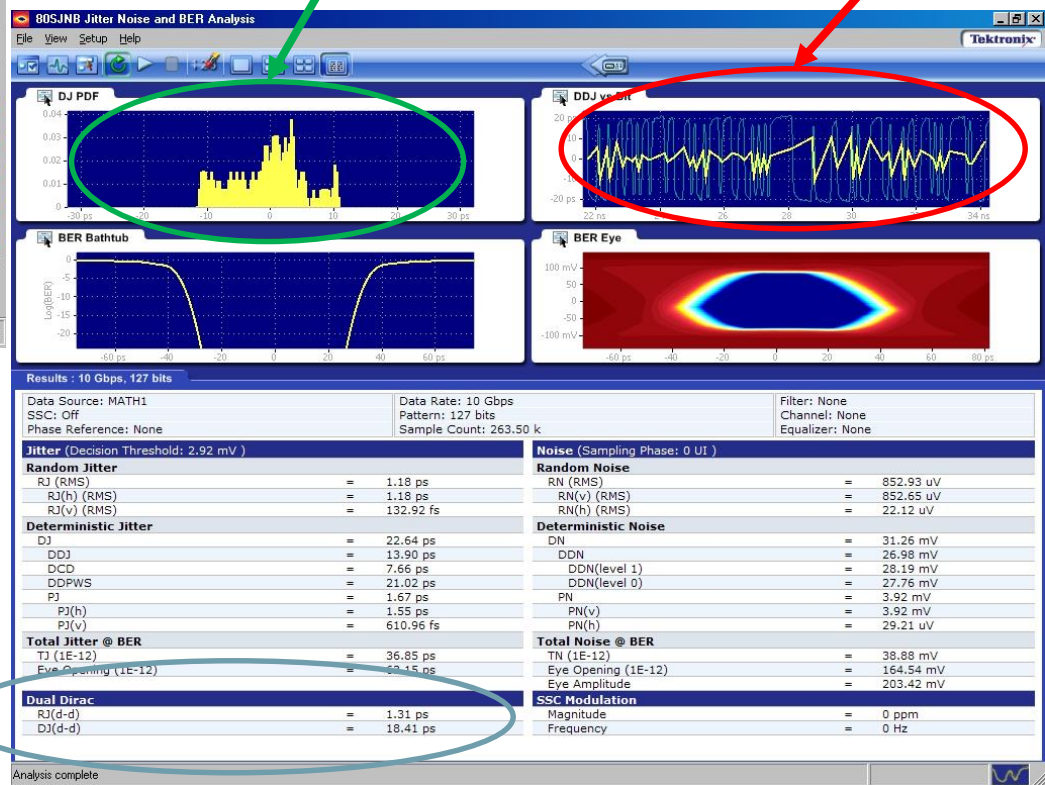
Optical Excitation from
Reference
Transmitter at 10 Gbps

“Dual Dirac” modeled RJ and DJ

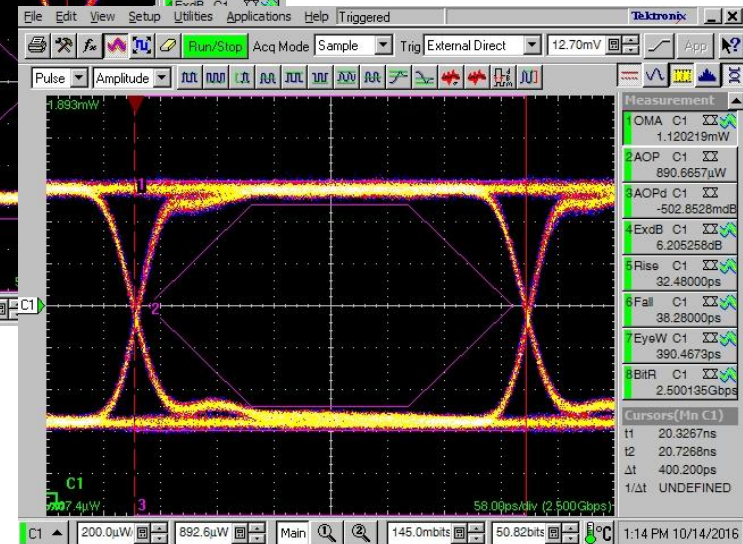
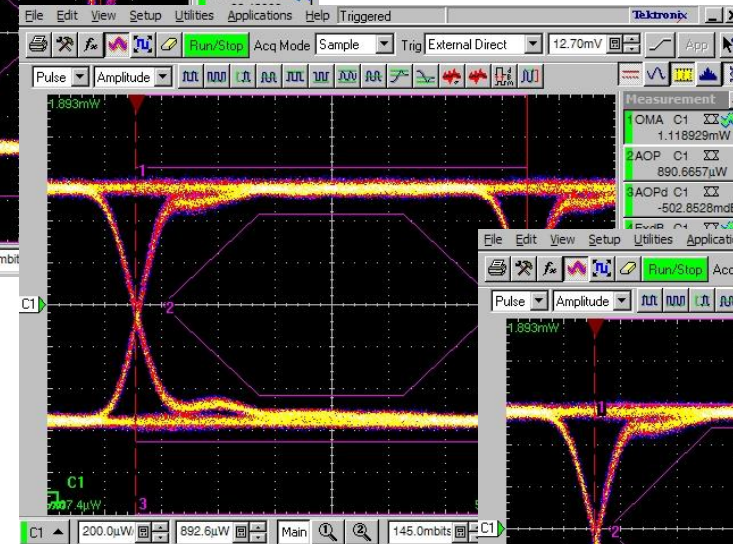
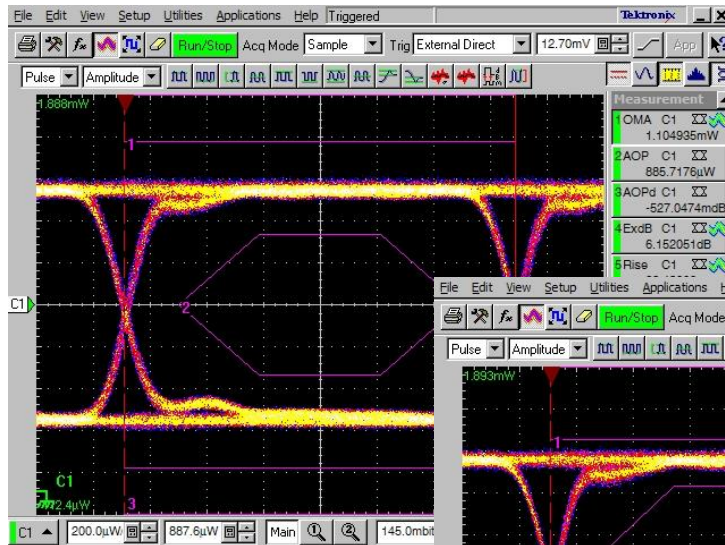
$$TJ = DJ + 14 * RJ$$

Deterministic Jitter
Probability Distribution

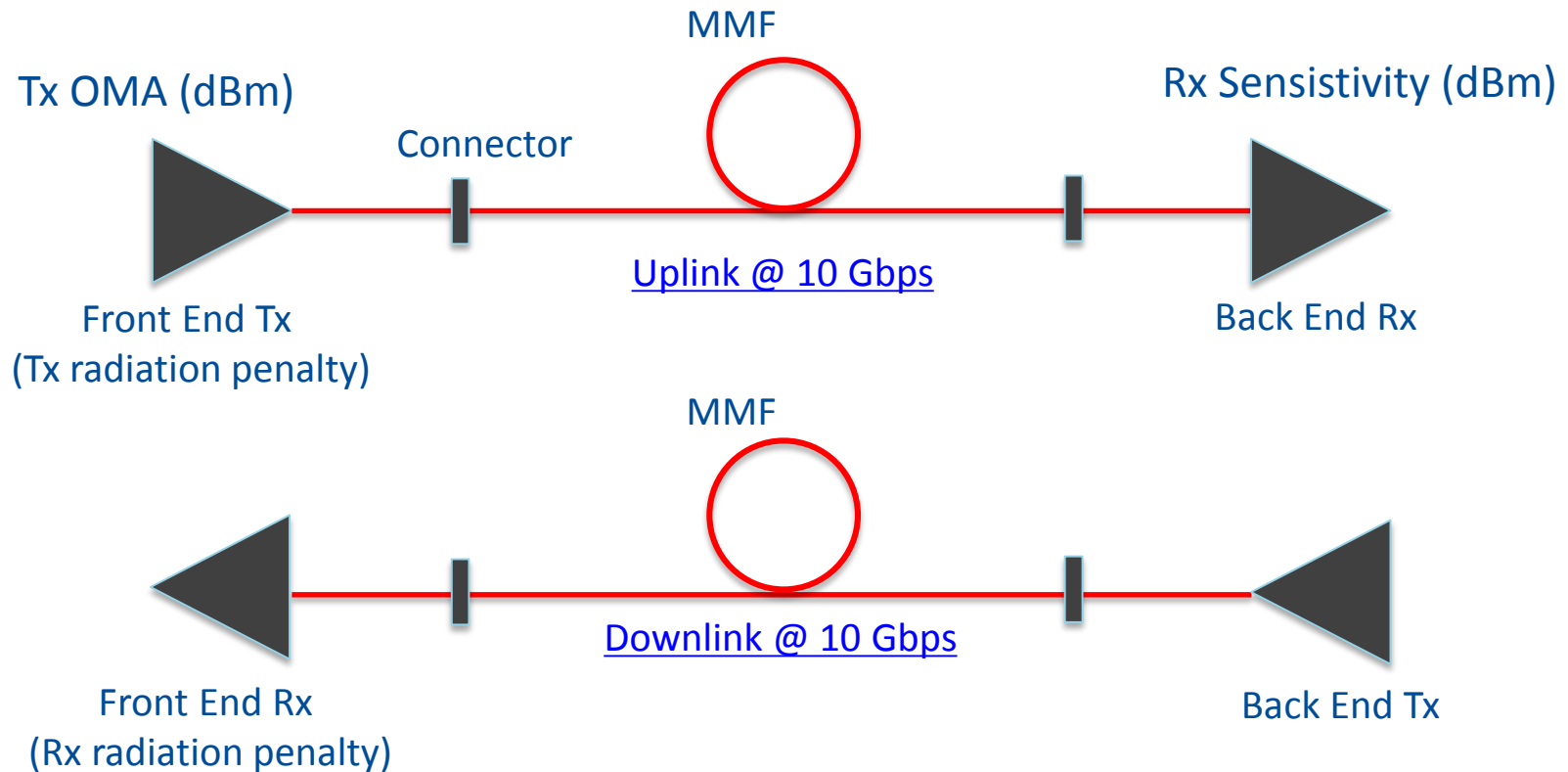
Data Dependent Jitter
(bit by bit for pattern)



Mask Testing and Mask Margin



System Specification – Power Budget



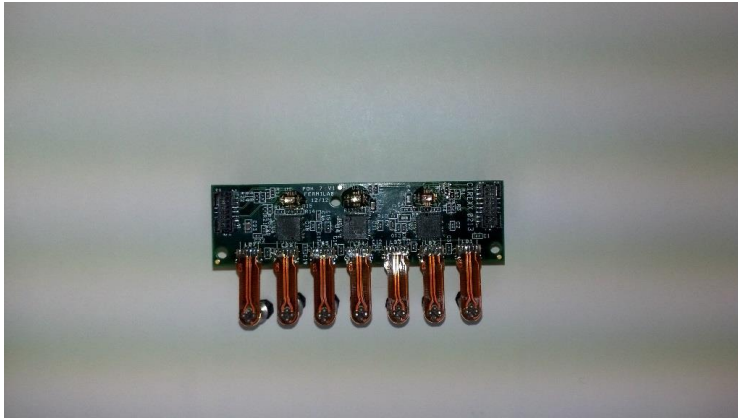
Power Budget (dB) = Tx OMA (dBm) – Rx Sens. (dBm)* - Losses (connectors, attenuation) – “Penalties”

A Few Other Projects ...

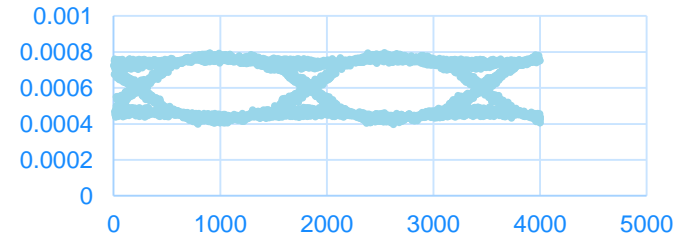
Optical Links for CMS Phase I FPix Upgrades

Off the Shelf Data Acquisition

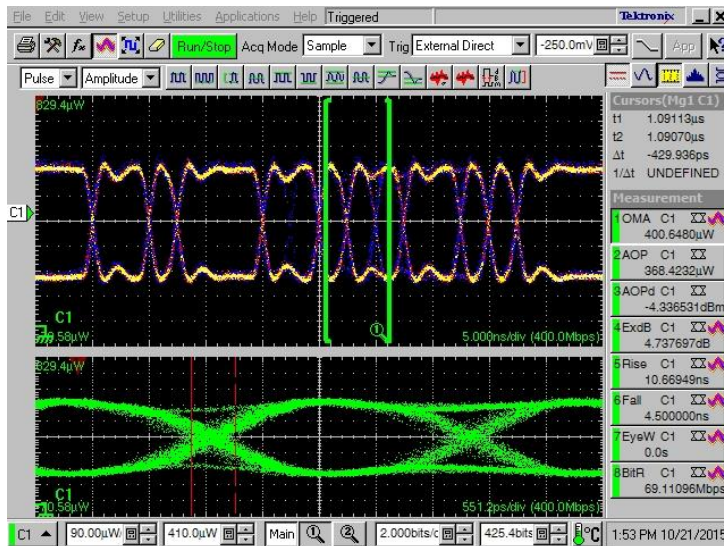
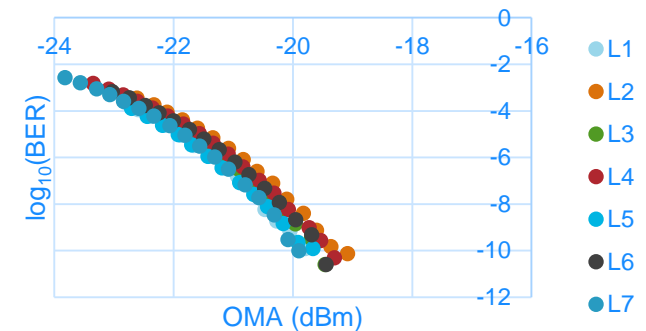
CMS FPix Phase 1 Upgrades – 7 Channel Pixel OptoHybrid



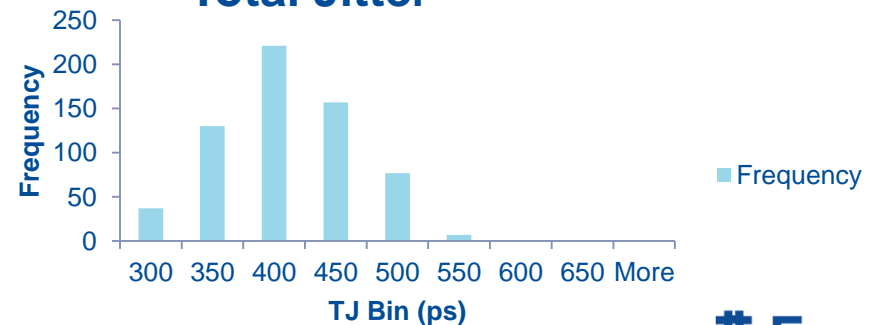
POH Tx Channel



OMA vs. BER

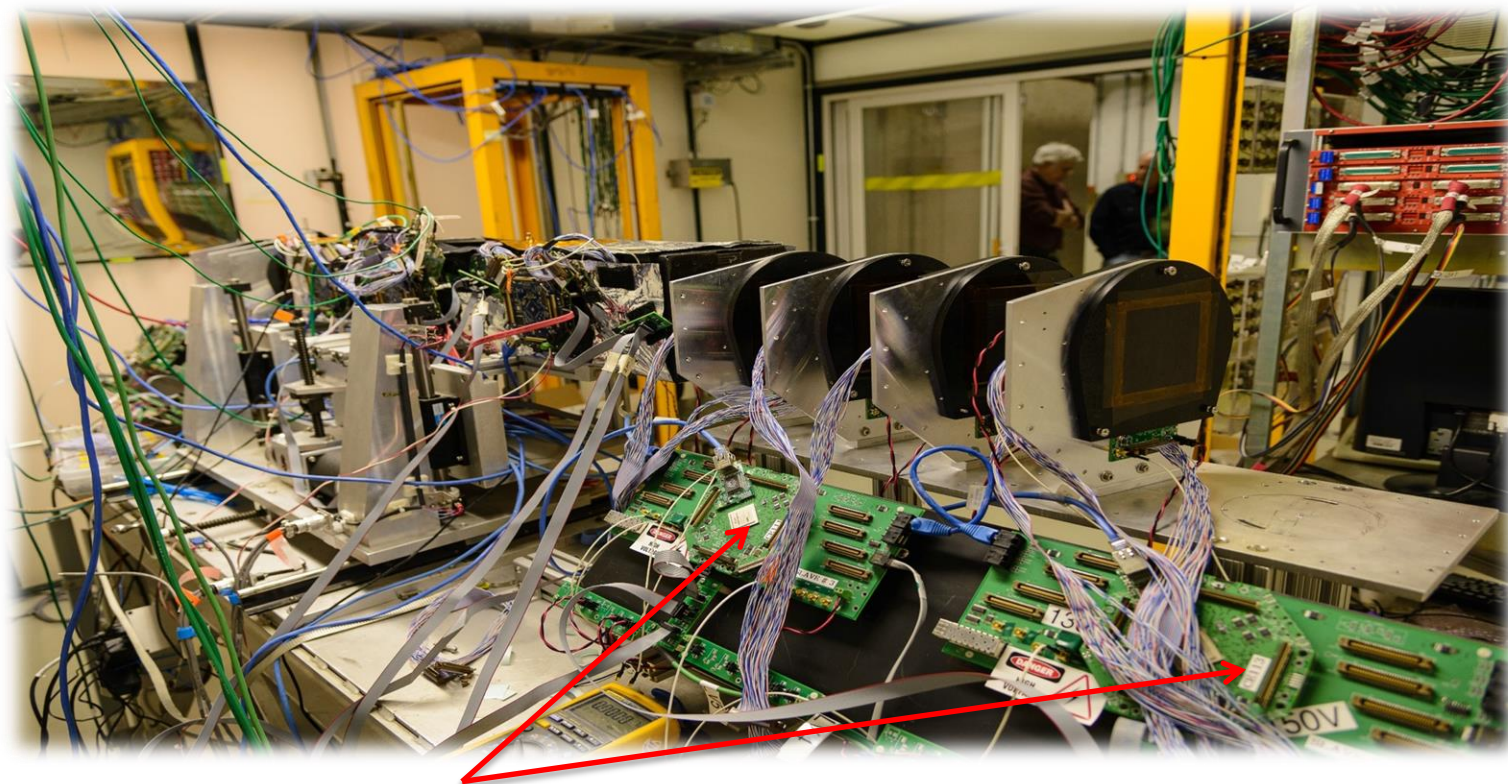


Total Jitter



Collaboration of CERN, ETHZ, FNAL, PSI

CAPTAN Nodes – Foundation of the Pixel and Strips Telescope



CAPTAN: Compact And Programmable daTa Acquisition Node

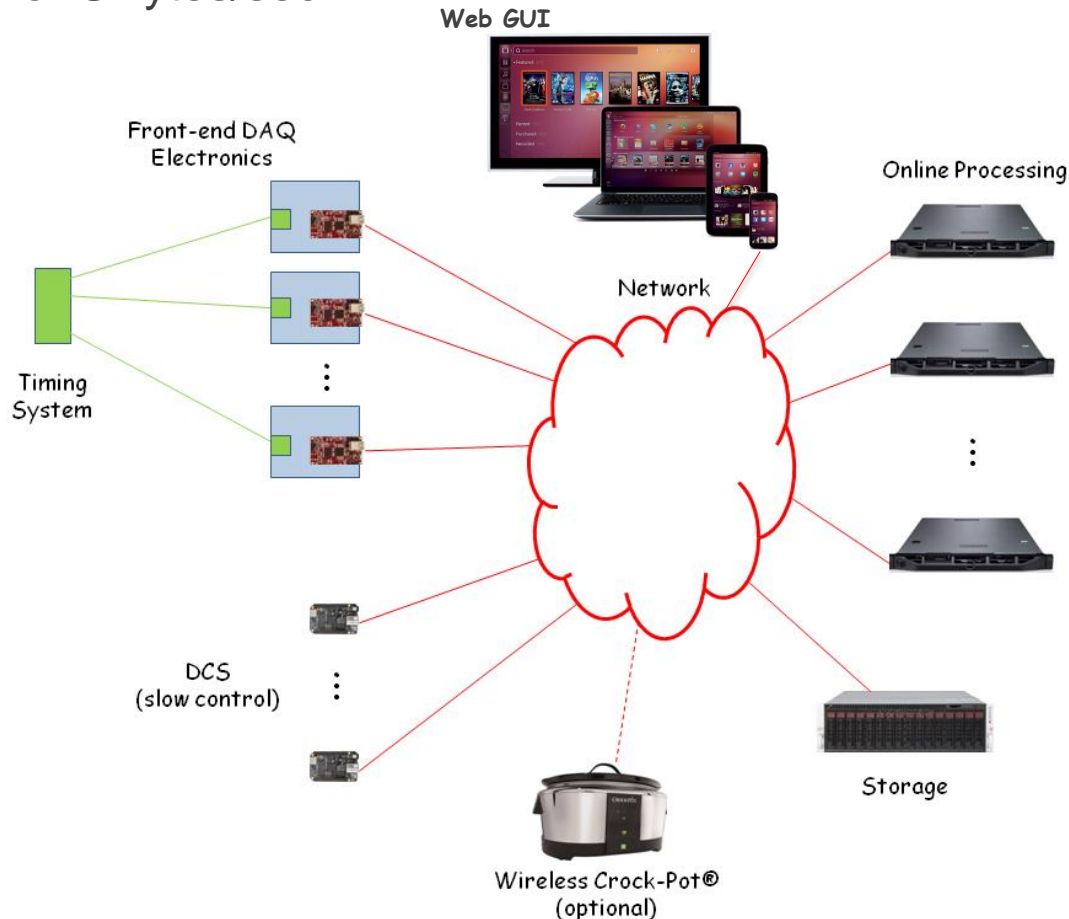
Introducing the (New) CAPTAN+

- 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



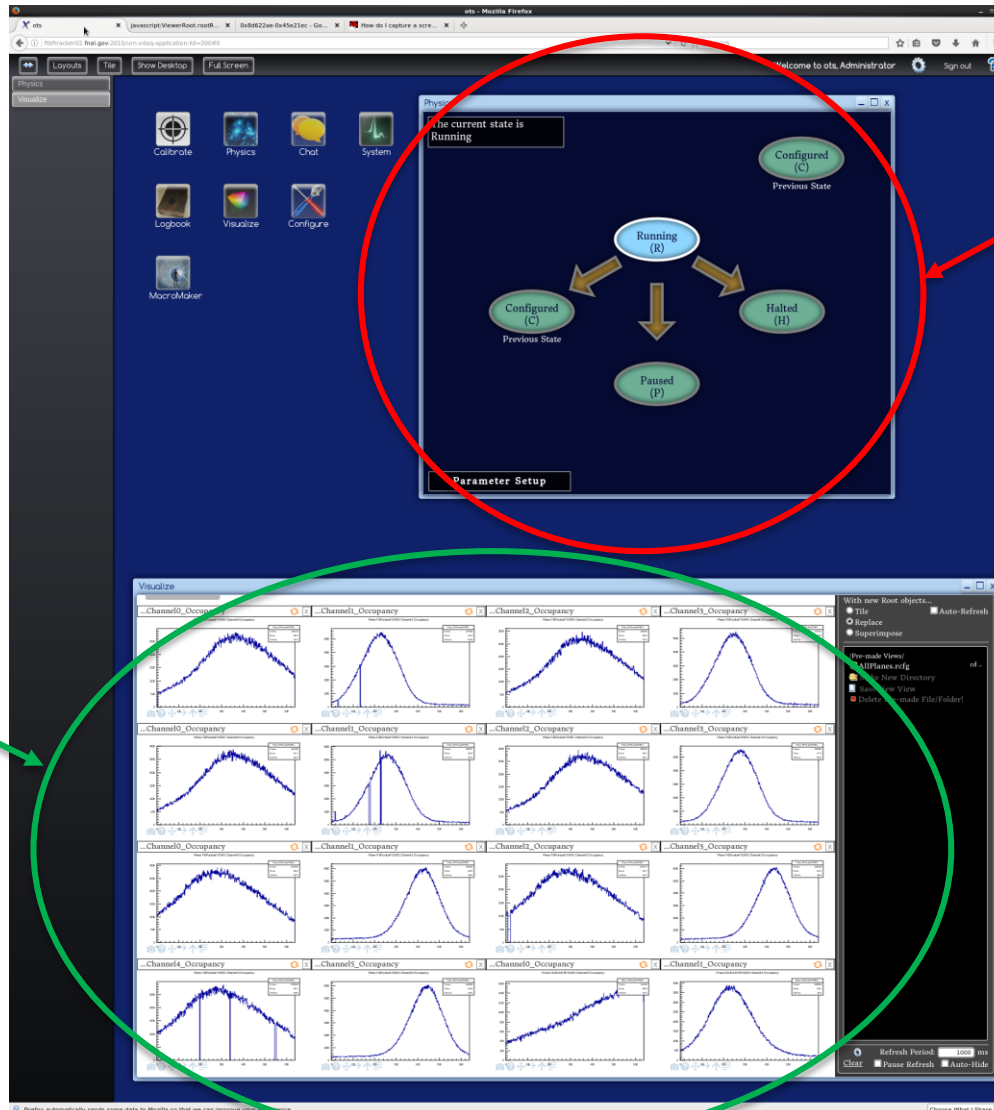
Off the Shelf Data Acquisition (OtS DAQ)

- 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)

Real Time
Beam Profile
Monitoring
Via Strips
Telescope



SW
State Machine
Control

Conclusion

Thank You For Your Attention.

Questions?