

# Applications of Emerging Parallel Optical Link Technology to High Energy Physics Experiments

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Fermilab

For the Versatile Link Common Project

**Overview of Components and Trends**

**Review of Test Hardware and Components**

**A Look at Emerging Optical Engines**

**Some Test Results**

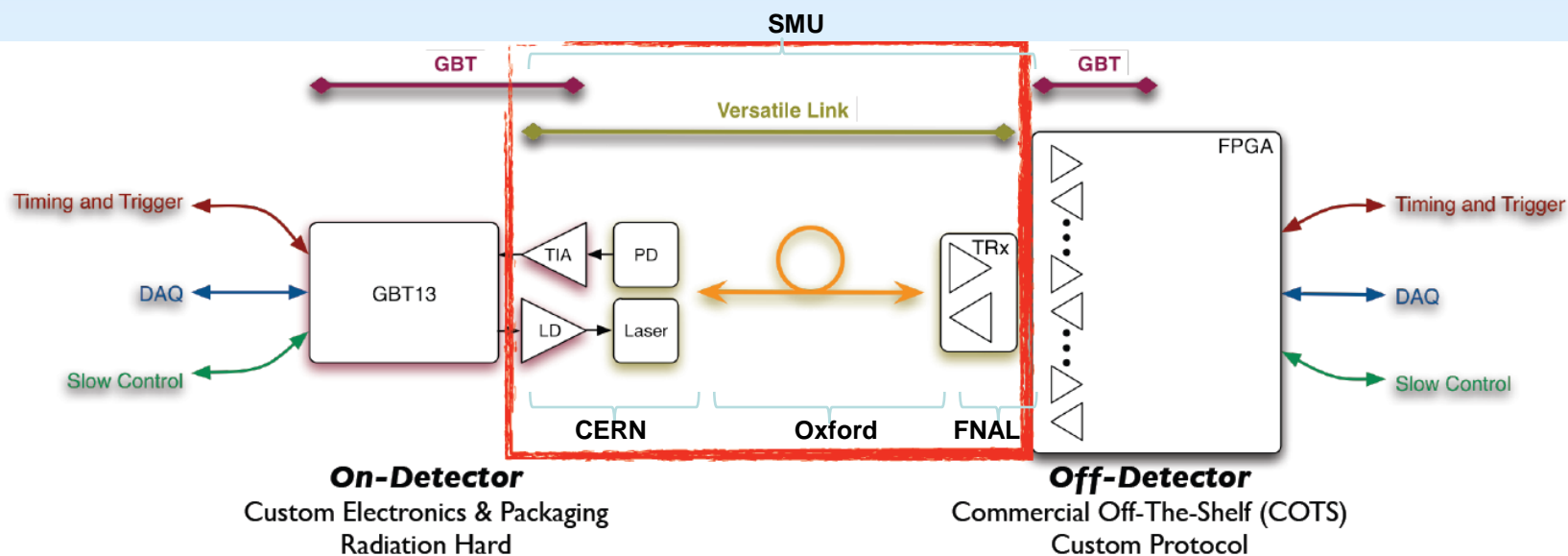
**Future Directions and Acknowledgments**

# Versatile Link Common Project

Versatile Link: CERN-organized common project for ATLAS and CMS

Goal: "Development of a general purpose optical link which can cover

all envisioned transmission applications: a versatile link" @ data transfer rates of up to 5 Gbps.



Work Package 1.1 (Southern Methodist University)  
Point to Point Architecture and System Engineering

Work Package 2.1 (CERN)  
Front End Components (Versatile Transceiver)

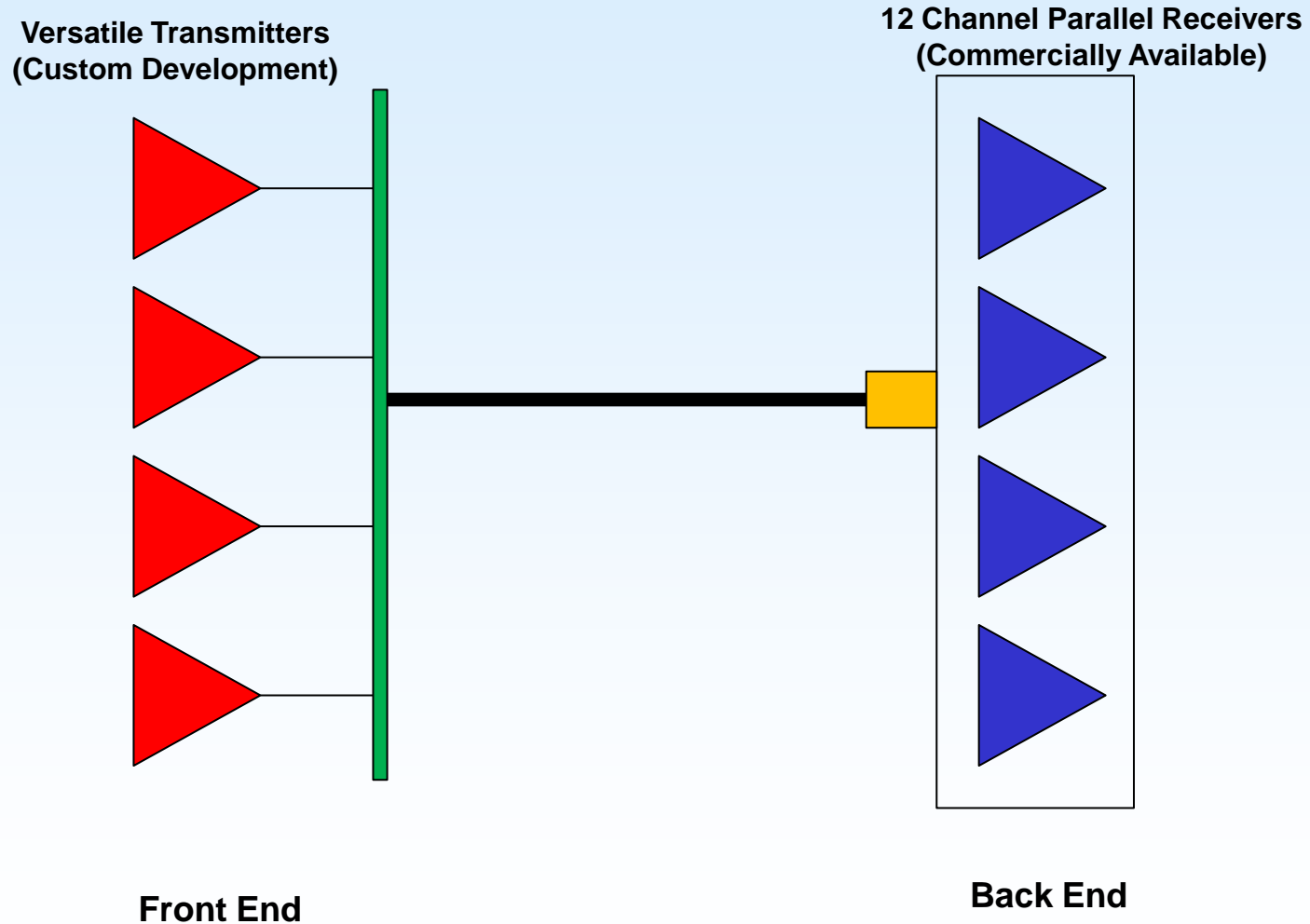
Work Package 2.2 (Fermilab)  
Back End Components (COTS, Off Detector Components)

Work Package 2.3 (Oxford University)  
Passive Components

Source: "Versatile Link Status Report"  
Jan Troska  
CMS Tracker Upgrade Meeting  
April 24, 2009

\*See TIPP 2011 Presentation Dr. Annie Xiang, "A Versatile Link for high speed radiation, resistant optical transmission in LHC upgrades"

# Versatile Link Common Project



## Optical Transceivers

Transceiver Package or Form Factor  
- Relative Sizes

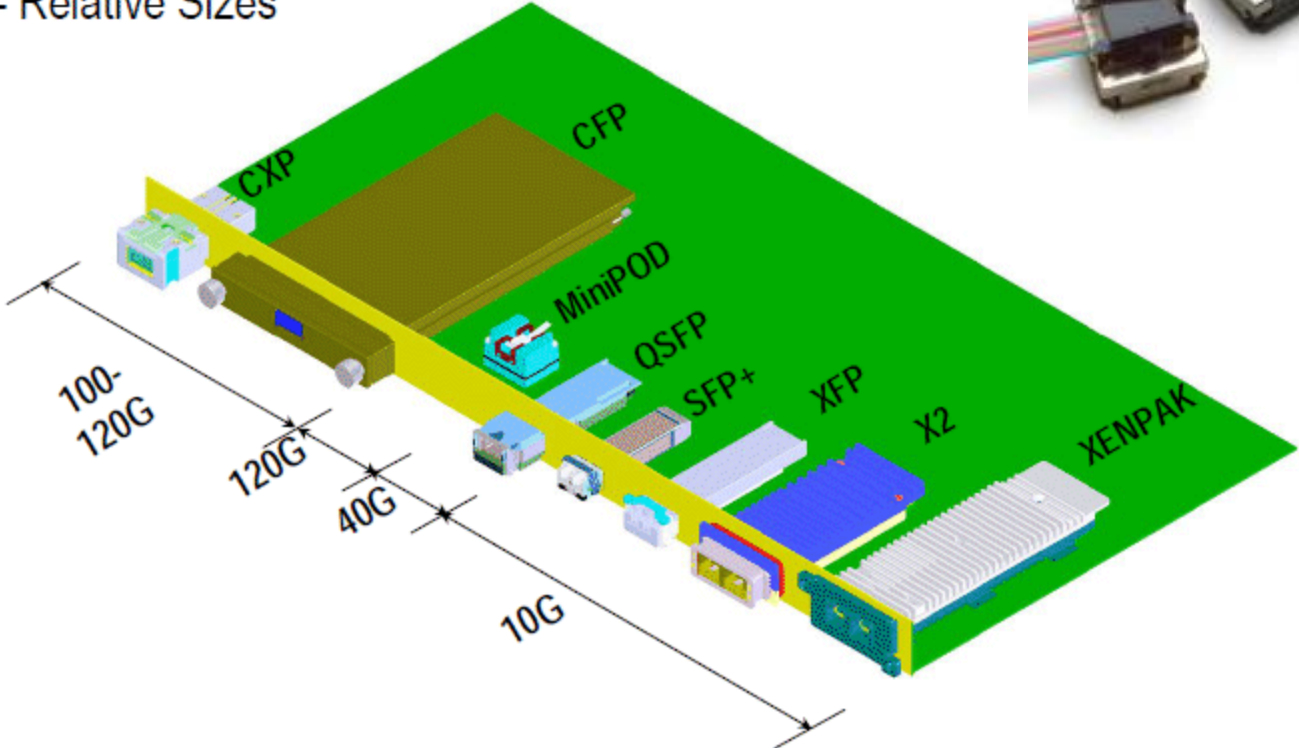
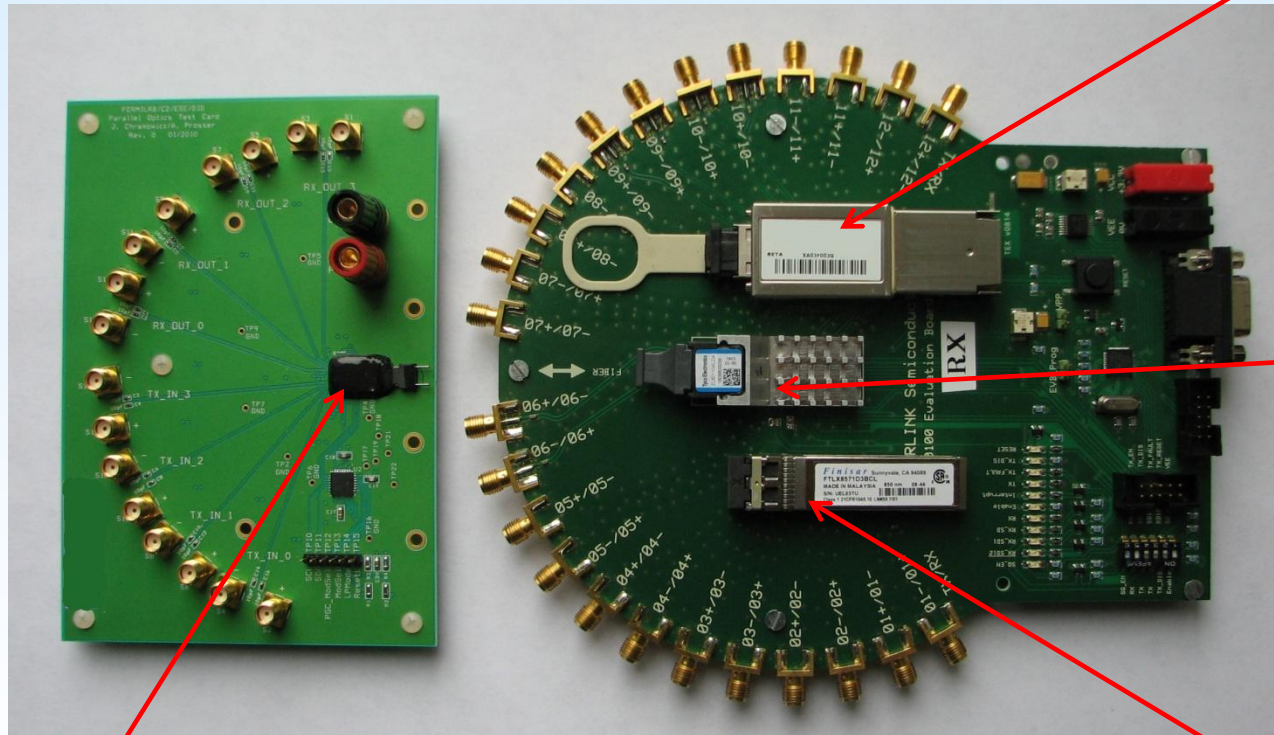


Image Courtesy of Avago Technologies

# Parallel Optics – Device Comparison

- Emerging Standards (100 GbE) Driven by Telecom and Storage
- Off the shelf and prototype devices evaluated
- High speed, parallel communications in multiple footprints
- For HEP: High Channel Count, Easier Cable Management  
Reduced Board Area (including connectors)



**CXP Transceiver**  
(12 channels TRx, 10 Gbps/channel)

**SNAP12 Transmitter**  
(12 channels, 2.7 Gbps/channel)

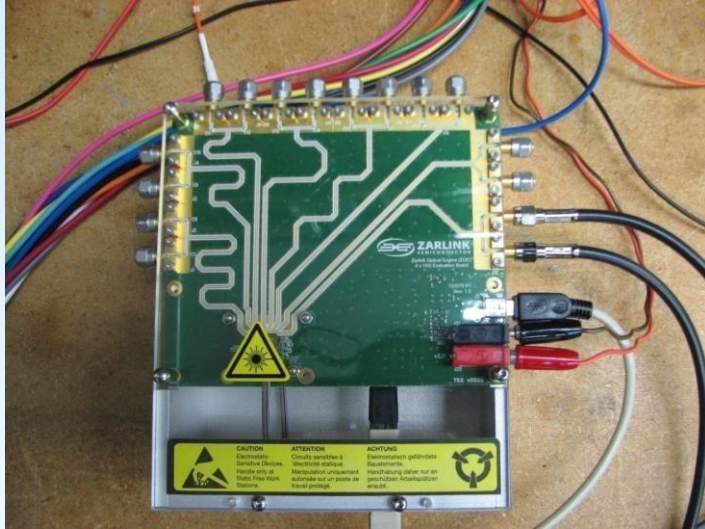
**Parallel Optical Engine Transceiver**  
(4 channels, 6.25 Gbps/channel)  
(Efficient PCB Applications,  
Lower Electromagnetic Noise)

**SFP+ Single Channel  
Transceiver**  
(10 Gbps)

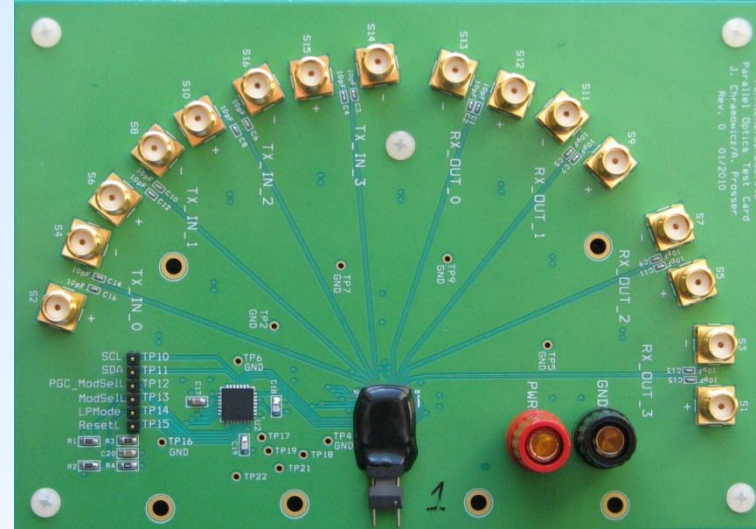


# Parallel Optics – Optical Engine Evaluation Hardware

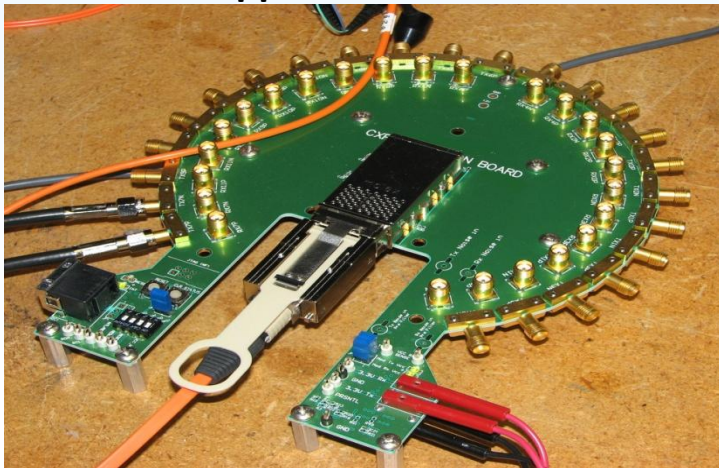
## Vendor Supplied Evaluation Board



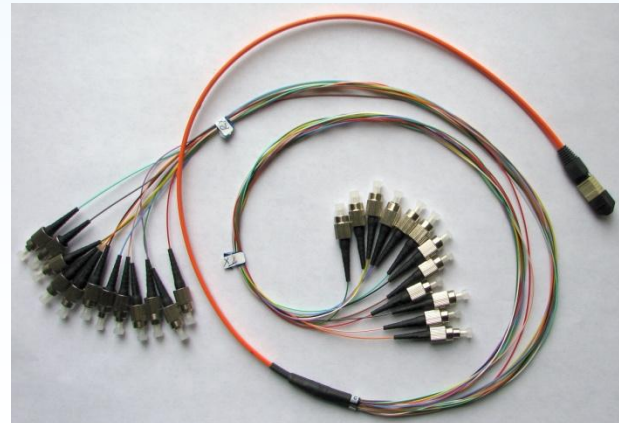
## Fermilab Designed Evaluation Board



## Vendor Supplied Evaluation Board



## Fiber Ribbon Breakout Cable

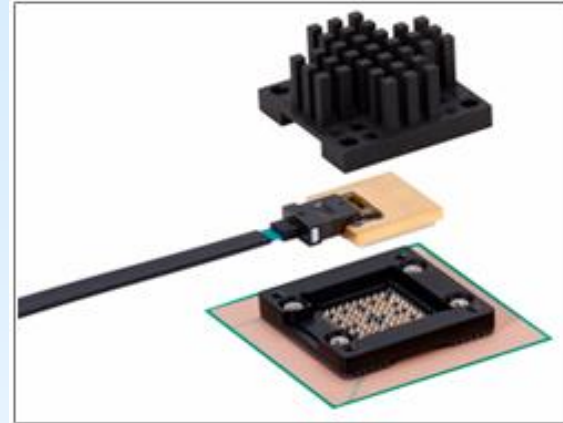


## MTP Connector

# Parallel Optics – Emerging OE Products



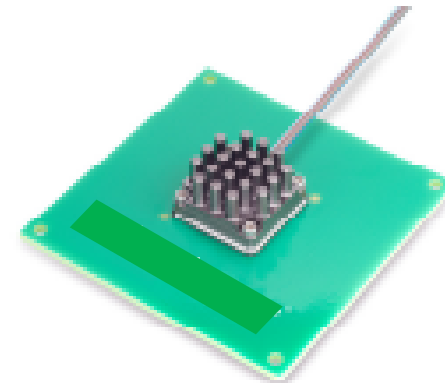
**Parallel Optical Engine Tx/Rx  
(12 channels, 10 Gbps/channel)**



**Parallel Optical Engine Tx/Rx  
(12 channels, 10 Gbps/channel)**



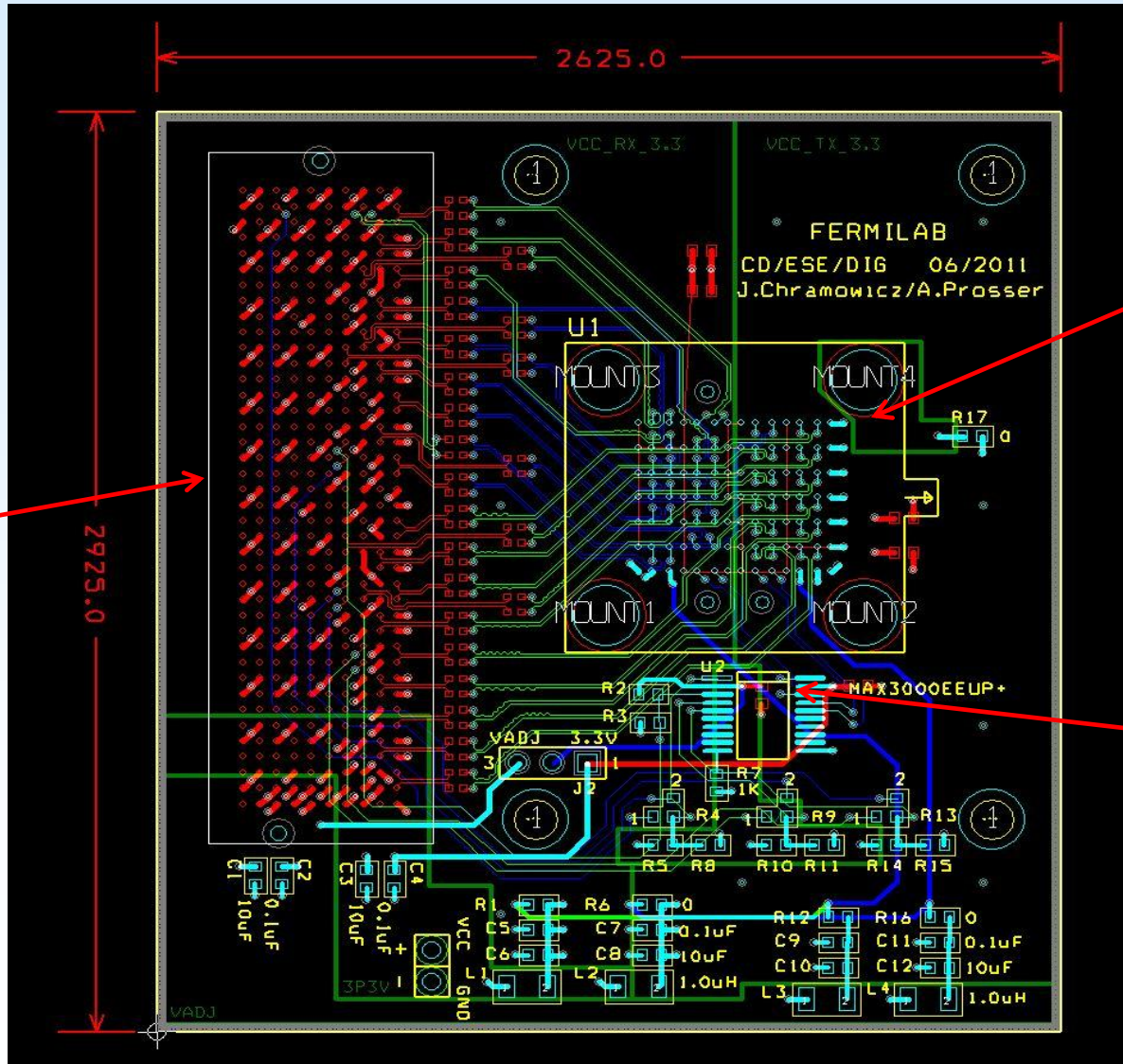
**Parallel Optical Engine Tx/Rx  
(12 channels, 10.3 Gbps/channel)**



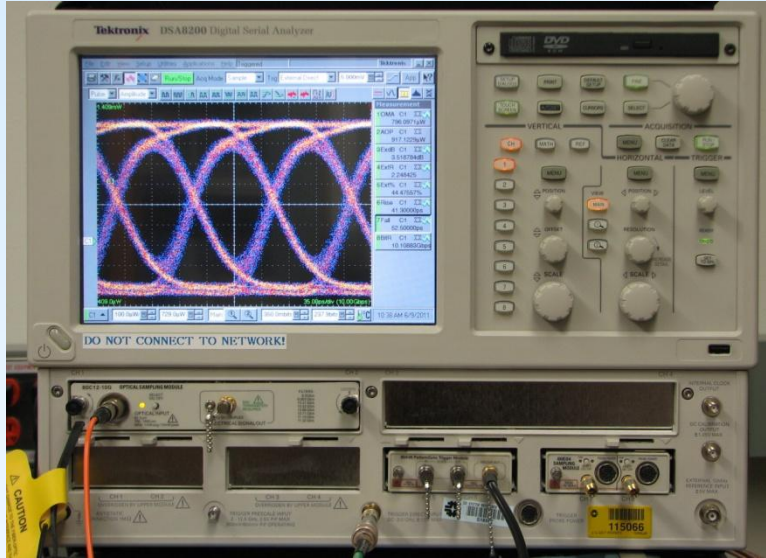
**Parallel Optical Engine TRx  
(12 channels, 10 Gbps/channel)**



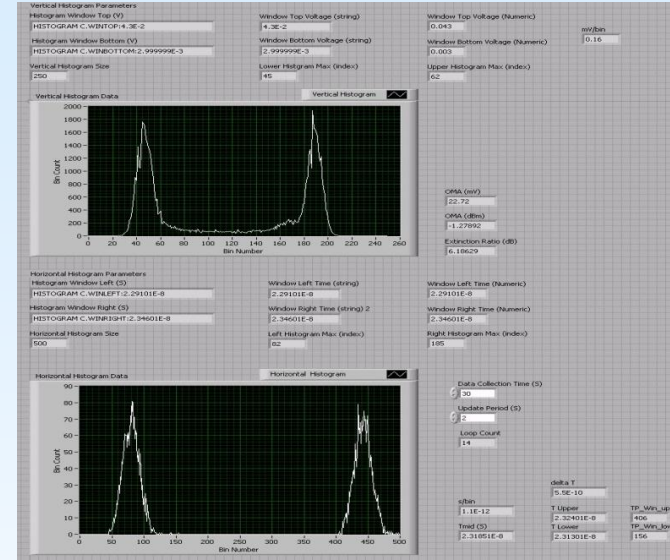
# Parallel Optics – Optical Engine Mezzanine



## Digital Signal Analyzer (Eye Patterns, Jitter)



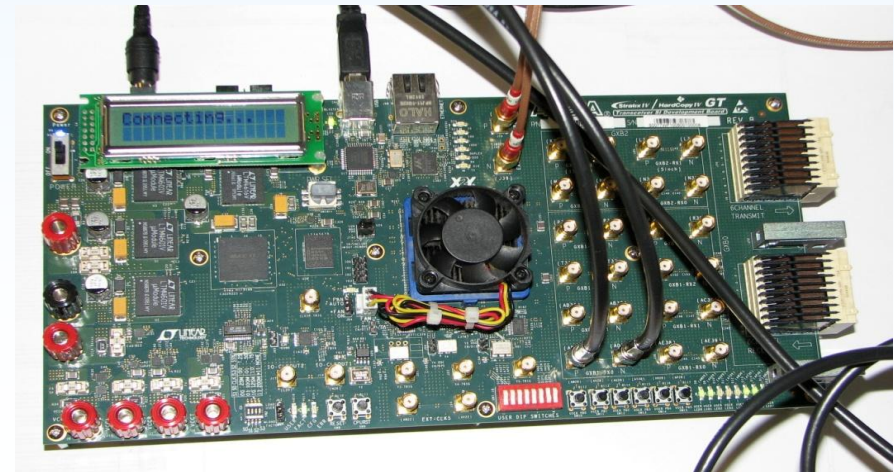
## Labview VIs (Histogram Analysis)

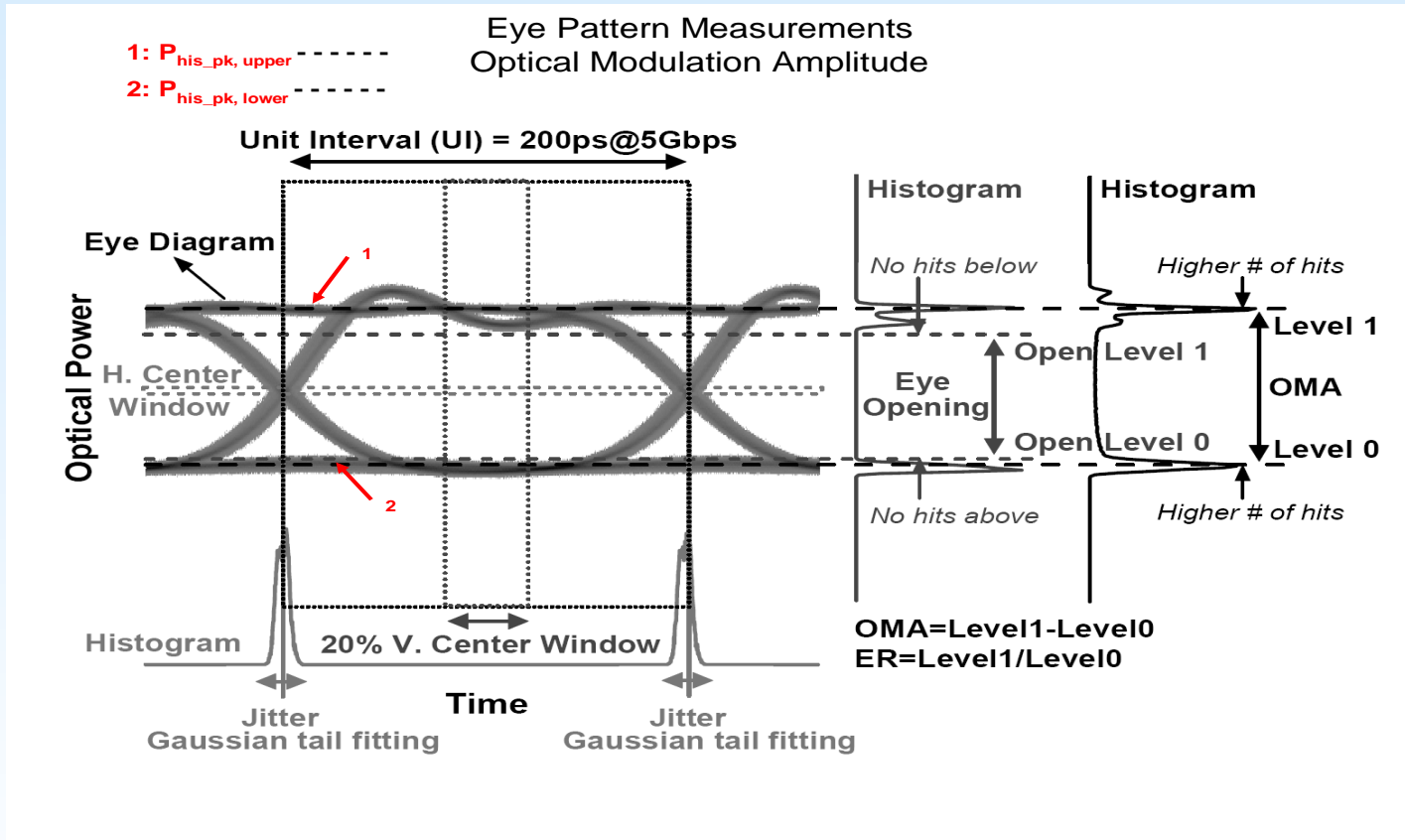


## Variable Optical Attenuators (Receiver Sensitivity)



## FPGA Signal Integrity Kit (BERT, PRBS Generation)





### Transmitter Measurements

Measurement	Target Value
Optical Modulation Amplitude (OMA)	3.2 dBm*
Transmit Eye Extinction Ratio	3.0 dB
Transmit Eye Opening	60% of OMA
Transmitter Rise Time	52 ps
Transmitter Fall Time	52 ps
Transmitter Total Jitter	0.25 of UI
Transmitter Deterministic Jitter	0.12 of UI

### Target Value

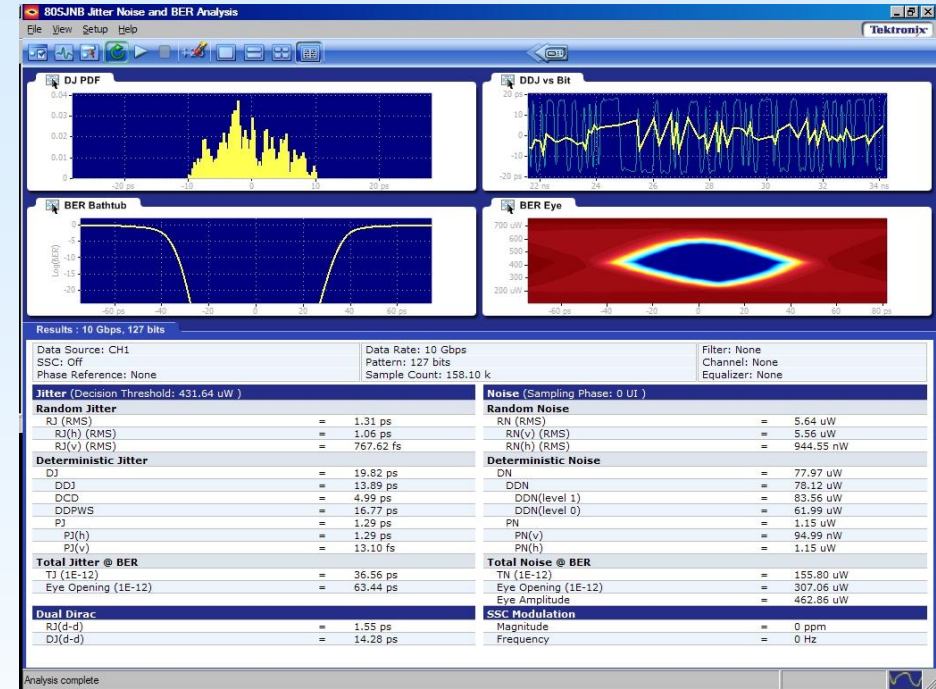
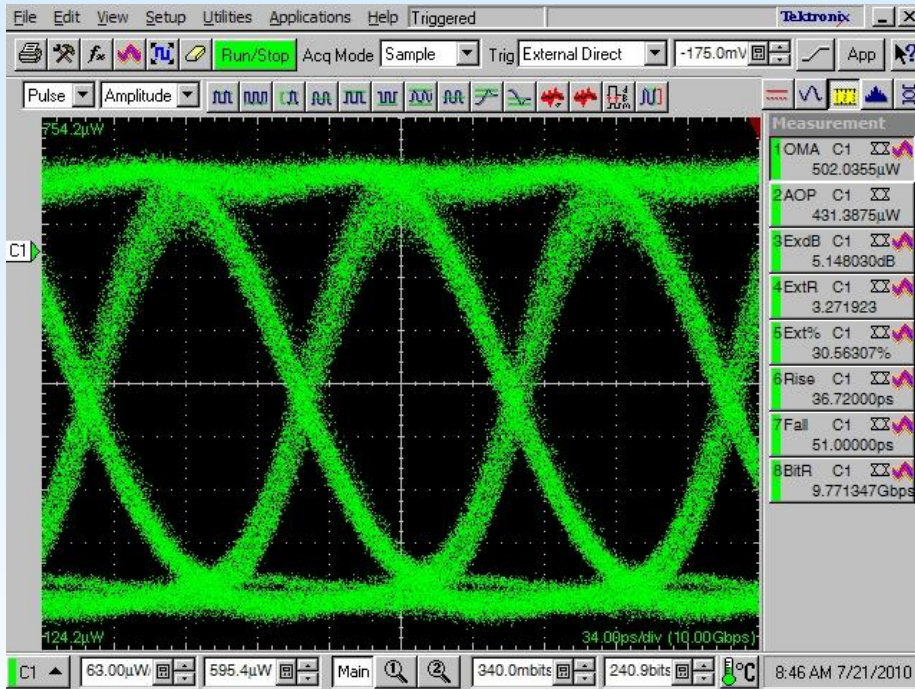
### Receiver Measurements

Measurement	Target Value
Receiver Sensitivity	-11.1 dBm
Receiver Total Jitter	0.34 of UI
Receiver Deterministic Jitter	0.14 of UI

### Target Value



# Optical Transceiver Test Measurements



## Industry Standard Measurements and Apparatus

Eye Diagram Measurements:

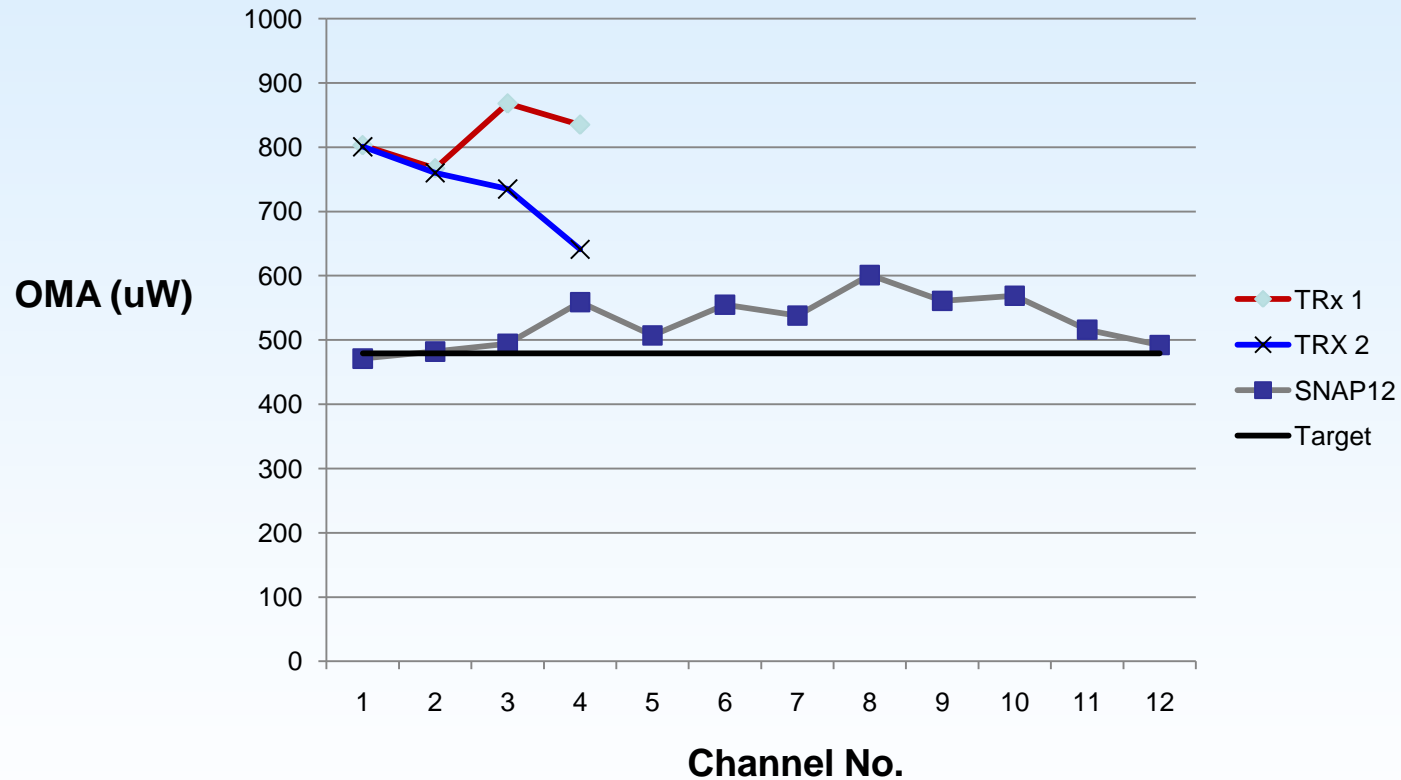
- Optical Modulation Amplitude
- Extinction Ratio
- Rise/Fall Times

Jitter Analysis:

- Deterministic Jitter (including decomposition)
- Random Jitter (Gaussian, unbounded)
- Eye Opening @  $10^{-12}$  BER

## Transmitter Measurement

(each point is a different channel; each line is a different device)

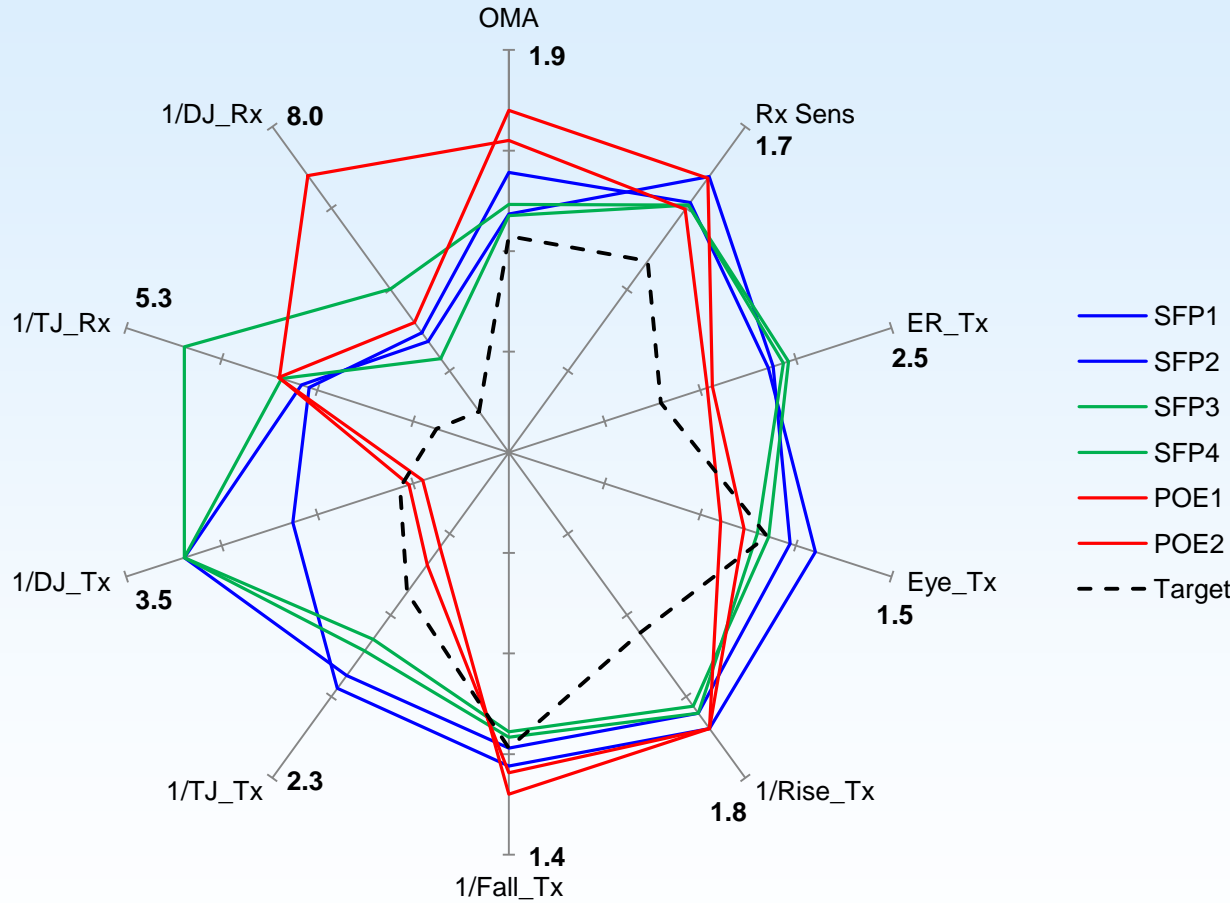


**Data Collected at:  
5 Gbps**



# Parallel Optics Device Measurements

**Data Collected at:  
10 Gbps**



Measurement	Norm
OMA	-3.2 dBm*
Rx Sensitivity	-11.1 dBm
Ext. Ratio	3.0 dB
Tx. Eye Opening	60% of OMA
Tx Rise Time	52 ps
Tx Fall Time	52 ps
Tx Total Jitter	0.25 of UI
Tx Deterministic Jitter	0.12 of UI
Rx Total Jitter	0.34 of UI
Rx Deterministic Jitter	0.14 of UI

\* Calorimeter Grade Version

**Continue to work with vendors on the testing of emerging products**

**Provide our Versatile Link collaborators with prototype test platforms**

**Develop per channel specifications for parallel devices for Versatile Link**

**Document test results and provide engineering support from lessons learned**

**Identify and recommend suitable multi-channel receiver modules for the Versatile Link**

# Acknowledgments

**This work has benefitted greatly from the support of our Versatile Link colleagues at:**

**CERN**

**Oxford University**

**Southern Methodist University**