The Versatile Link

Feasibility Demonstration

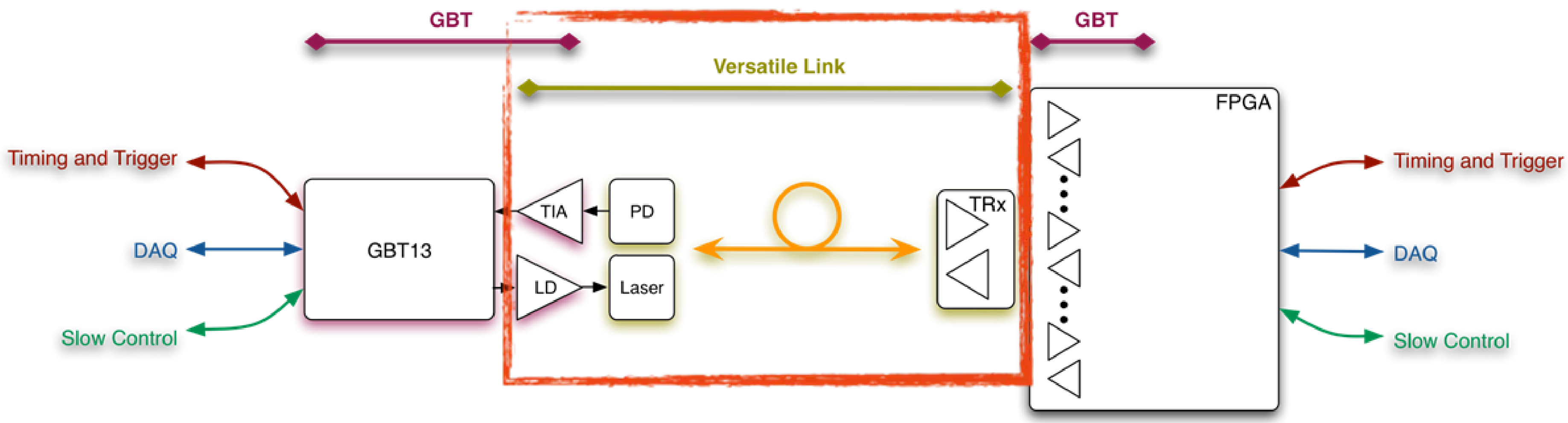
(Project phase II)

Francois Vasey, on behalf of the Versatile Link Team

Versatile Link Project

- Optical Physical layer linking front- to back-end
- Bidirectional, ~5Gbps
- Versatile
  - Multimode (850nm) and Singlemode (1310nm) versions
  - Point to Point and Point to Multipoint architectures
- Front-end pluggable module

- Joint Project Proposal submitted to ATLAS & CMS upgrade steering groups in 2007 and endorsed in 2008
- Project Kick-off: April 2008
  - Phase I: Proof of Concept *(18mo)*
  - **Phase II: Feasibility Study *(18mo)***
  - Phase III: Pre-prodn. readiness *(18mo)*



On-Detector
Custom Electronics & Packaging
Radiation Hard

Off-Detector
Commercial Off-The-Shelf (COTS)
Custom Protocol

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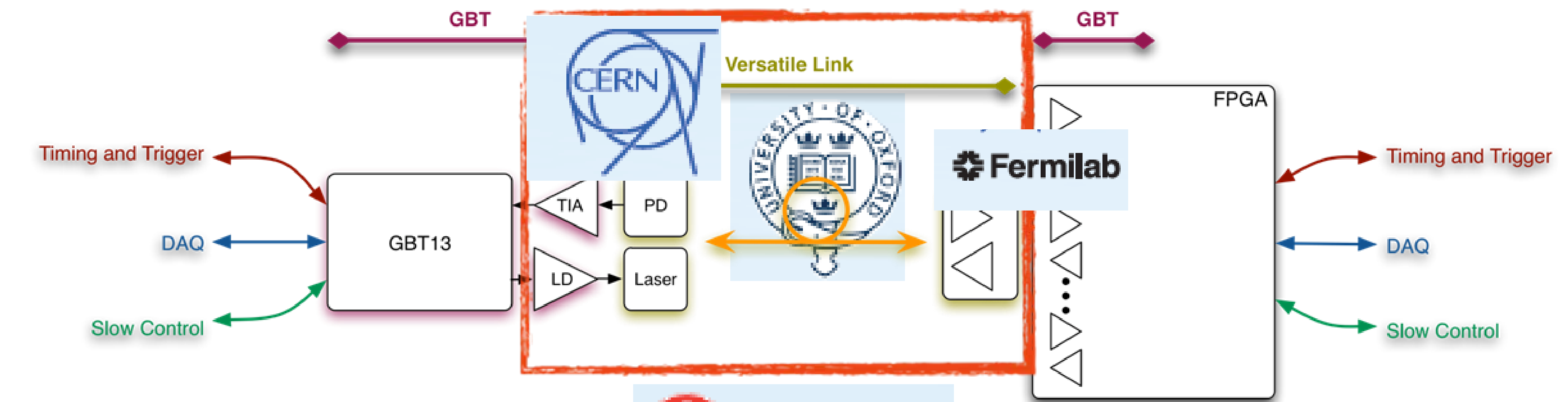

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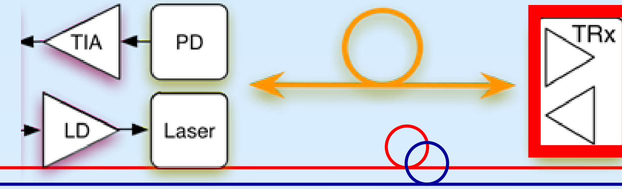
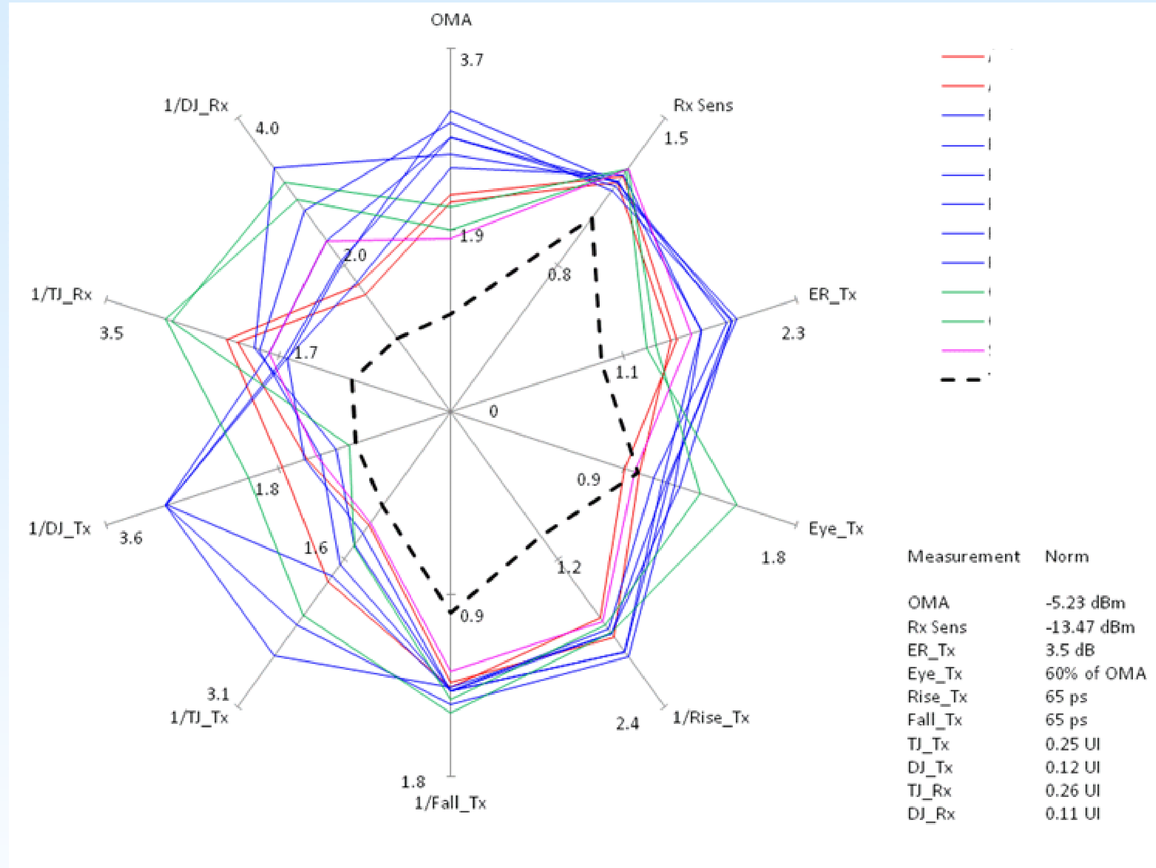
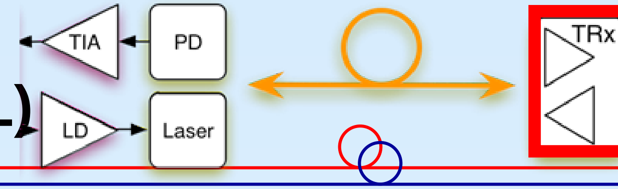
Backend: SFP+ Transceiver (FNAL)



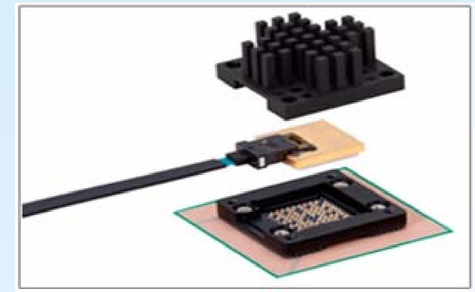


- Testing of SFP+ (850nm and 1310nm) up to 10Gbps
- Reference Components Identified and Procured for Team Use
- Future Work: Detailed Specification of Device Requirements for Versatile Link
- Future Work: Investigation of Higher Power SFP+ Variant

Backend: Parallel Optics Evaluation (FNAL)



Parallel Optical Engine Tx/Rx
(12 channels, 12.5 Gbps/channel)



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

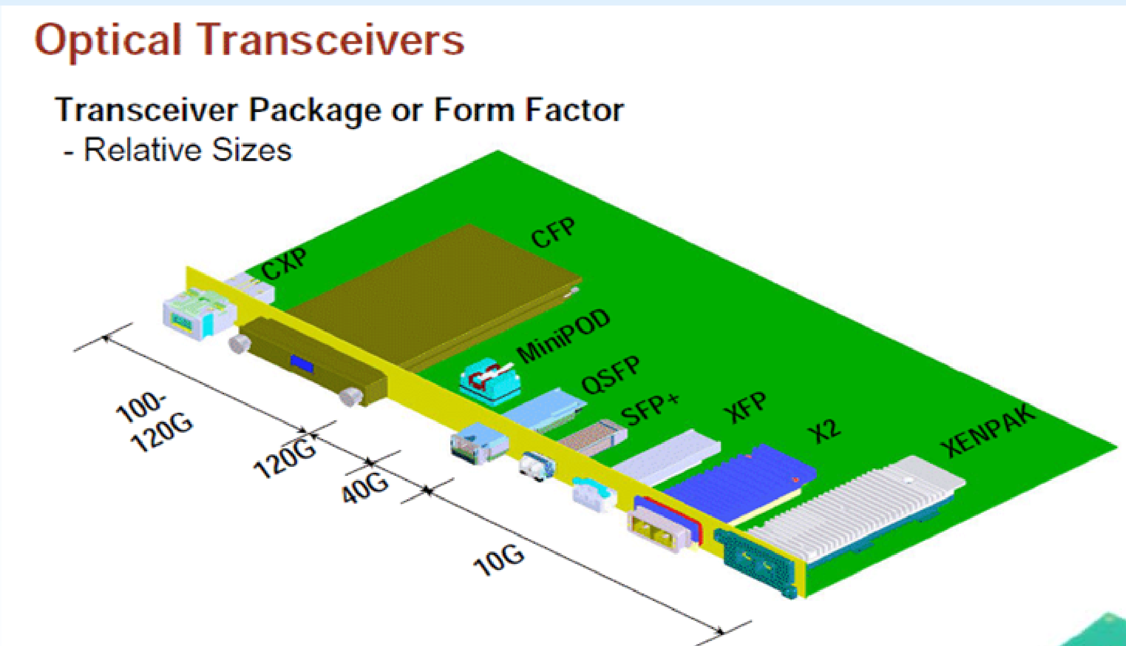
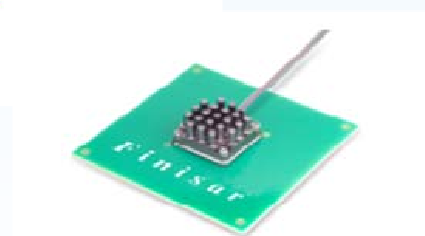


Image Courtesy of Avago Technologies

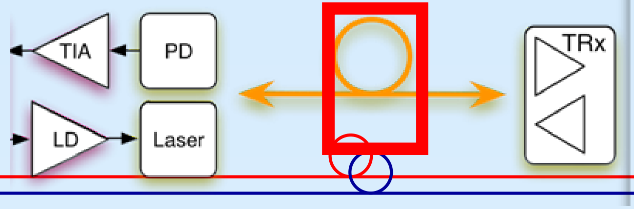
Parallel Optical Engine Tx/Rx
(12 channels, 10 Gbps/channel)



Parallel Optical Engine TRx
(12 channels, 10.3 Gbps/channel)

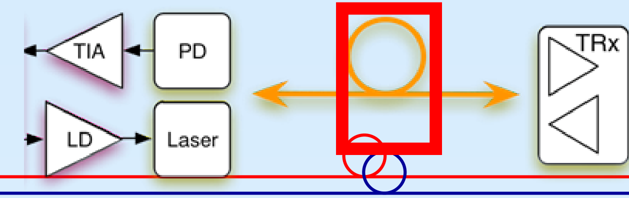
- Fermilab has tested 4x4 Parallel Optics Engines up to 10Gbps
- SNAP12 Tx/Rx Pair Tested at Rates up to 6.25Gbps
- Future Work: Includes the testing of Parallel Optics Engines and design of FMC Card

Passive Components (Oxford)

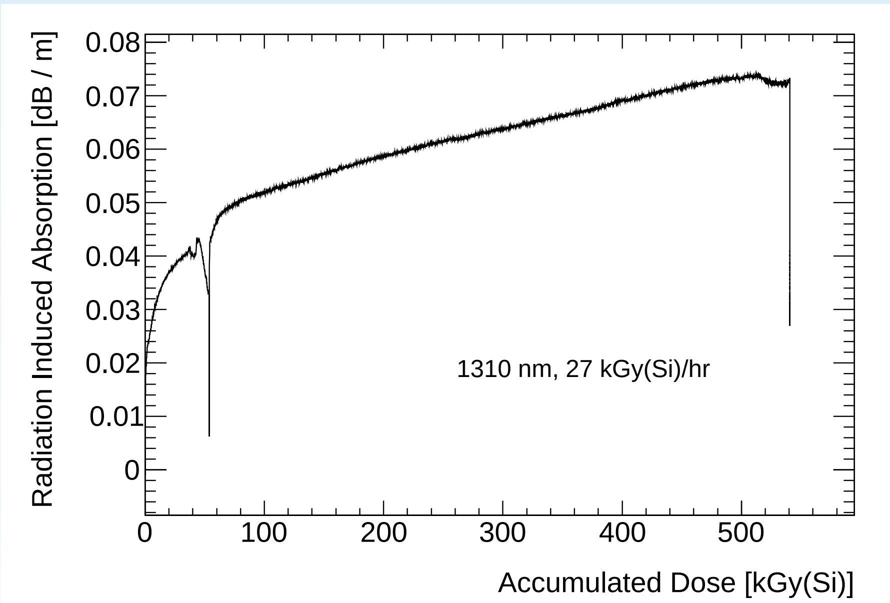


- Radiation Induced Absorption (RIA) in fibres is highly temperature dependent.
- Oxford has developed a CO2 cooling system capable of keeping fibre samples cold (-26 deg C) during irradiation.
- Tests have been performed on five optical fibres. Two were MM graded-index fibres (850nm) while 3 were SM fibres (1310nm).
  - Two of the SM fibres have shown acceptable performance over 500 kGy(Si) dose.
  - The Multimode fibres did not perform as well, showing more than 1 dB/m of loss.
  - The dose rate is very high in these tests
    - 27 kGy(Si)/hr

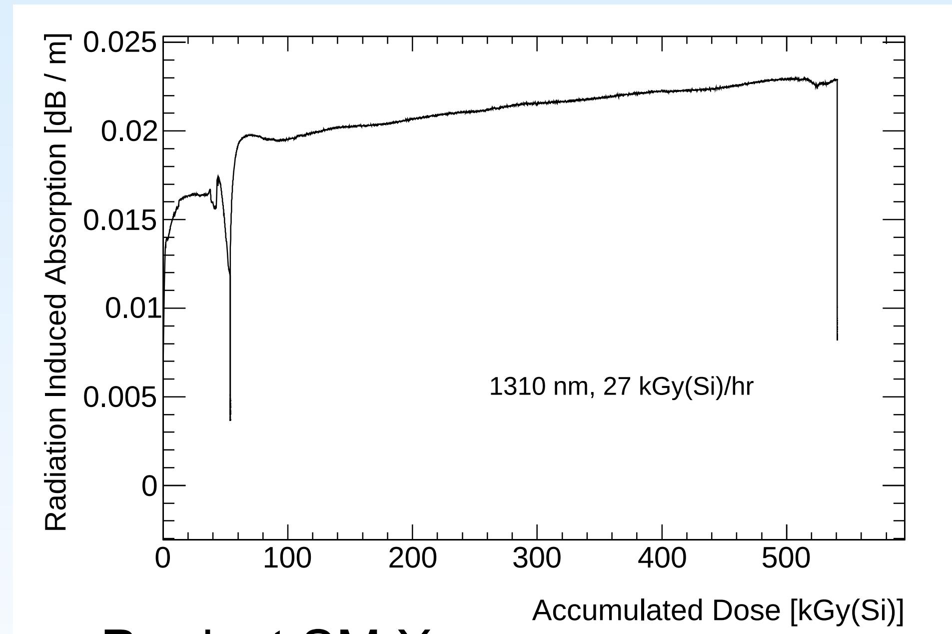
Passive Components (Oxford)



Temperature of exposure = -26 deg. C



Draka SM fibre

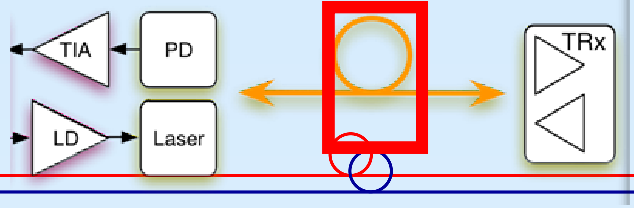


Product SM X

Both of these SM fibres have small attenuation for a typical cable run
For ATLAS or CMS inner detectors. ~0.1 dB from RIA.

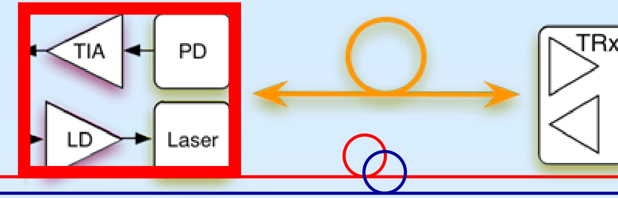
The MM fibres did not fare so well at these very high dose rates.
A run at a lower dose rate up to a full SLHC integrated dose is planned.

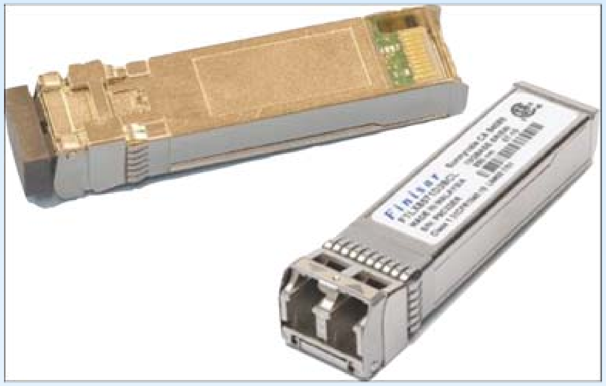
Passive Components (Oxford)

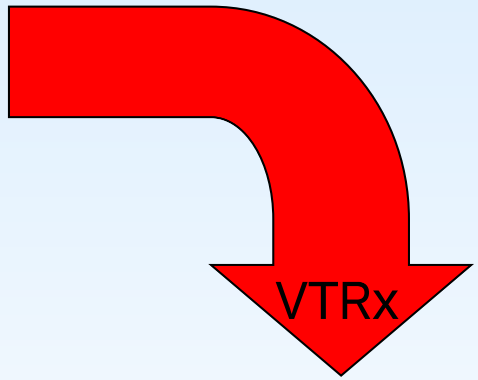


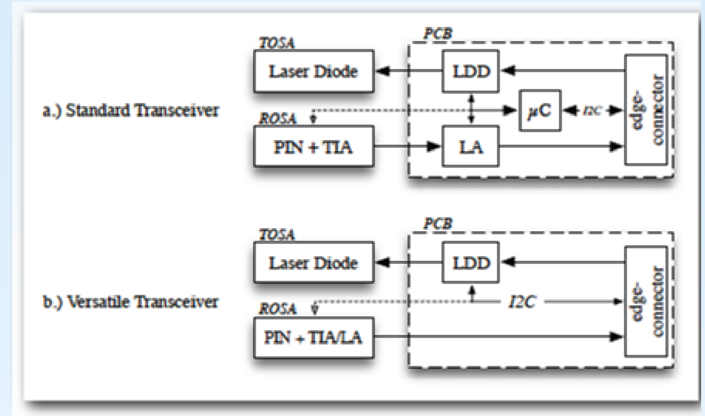
- Fibres are stressed in the cable trays of experiments.
  - Radiation might degrade the mechanical properties of fibres changing the minimum bend radius requirements.
  - Pull tester has been purchased to look at the mechanical effects of SLHC doses upon our candidate fibres.
  - Micro bending tests will allow to detect buffer weaknesses induced by irradiation
- Commercial MPO connectors have been pre-tested and are being irradiated.
  - Commercial LC connector tests will be next.
- Cable may suffer mechanically in a radiation environment as well.
  - Bulk damage and ionizing radiation damage need to be investigated.
  - Proton beam to expose cable candidates is planned
  - Scan-table is currently under test

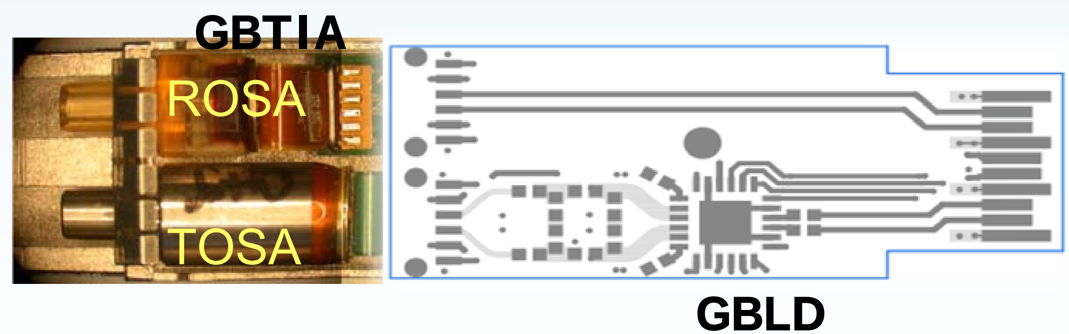
Front End Versatile-TRx, CERN





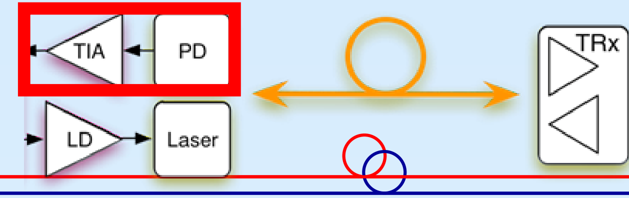




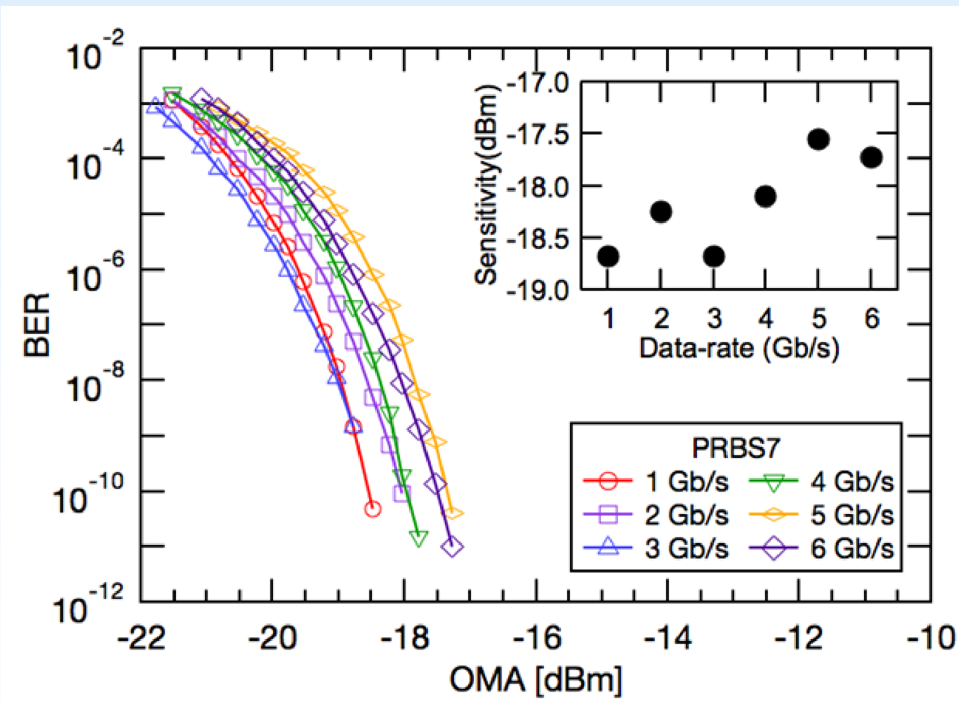


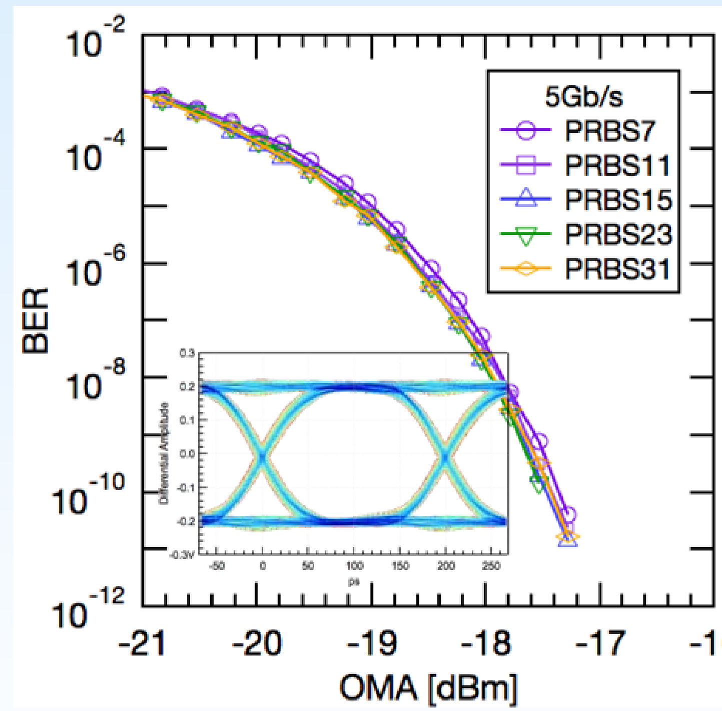
- Low Mass & Volume
  - Minimize material, avoid metals
- Non-magnetic, capable of operating in a magnetic field
  - Requires replacement of ferrite bead used in laser bias network
- Bitrate determined by ASICs: 5 – 10 Gbps
- 850nm and 1310nm flavours

Front End Versatile-TRx, CERN

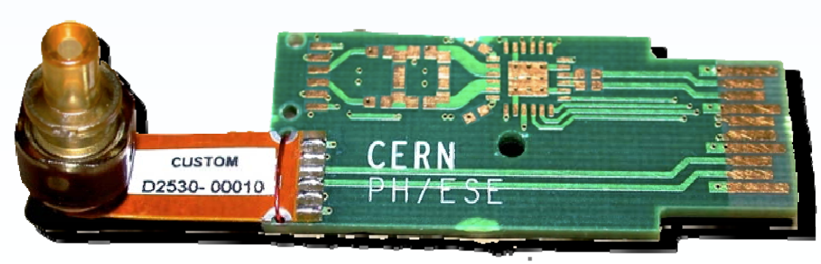


- Rx path: GBTIA successfully integrated with PIN into ROSA
- GBTIA ROSA functional over broad range of data-rates and pattern lengths





- Favourable comparison to bare-die tests
  - ROSA pkg not detrimental to functionality
- Expected reduction in sensitivity with data-rate
  - Acceptable magnitude
- No pattern length sensitivity



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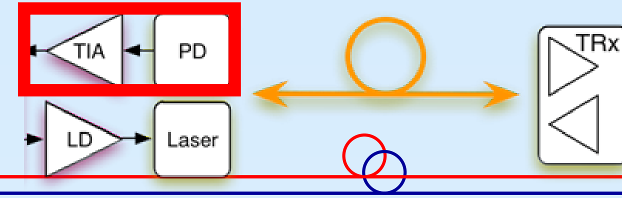
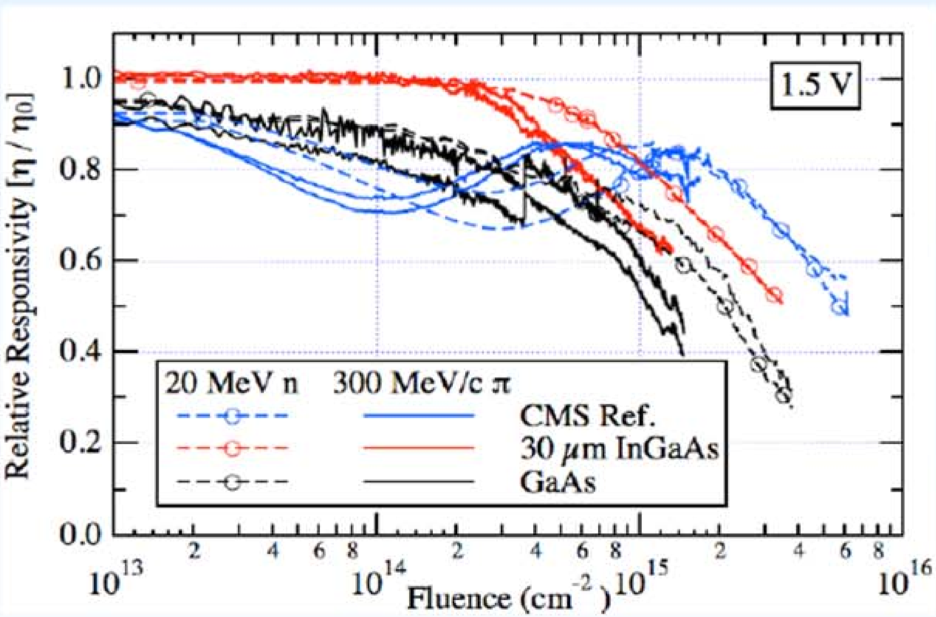
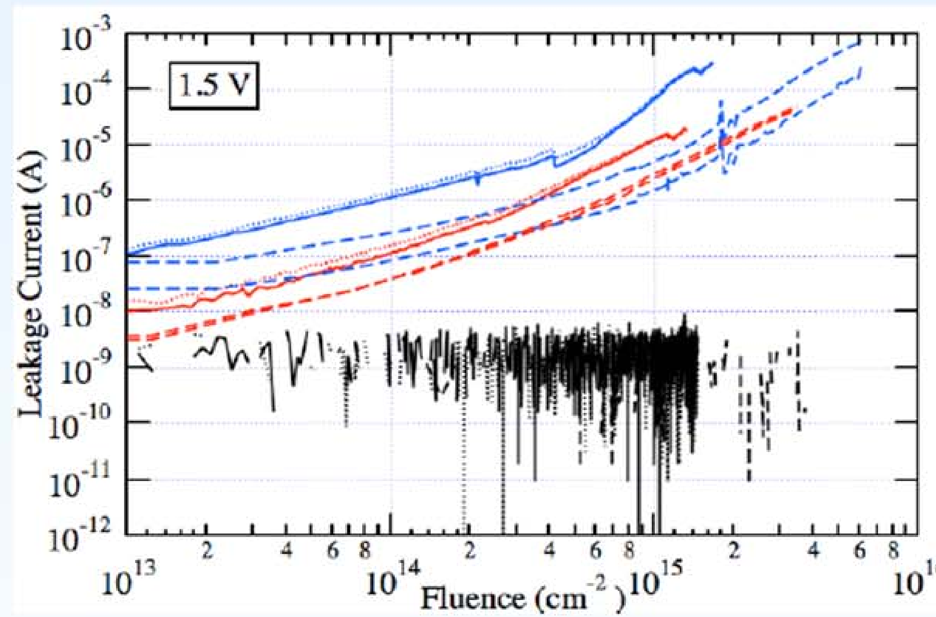


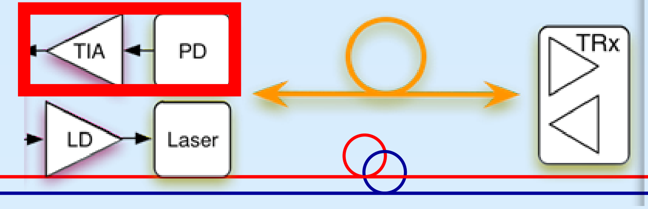
- PIN total fluence resistance test



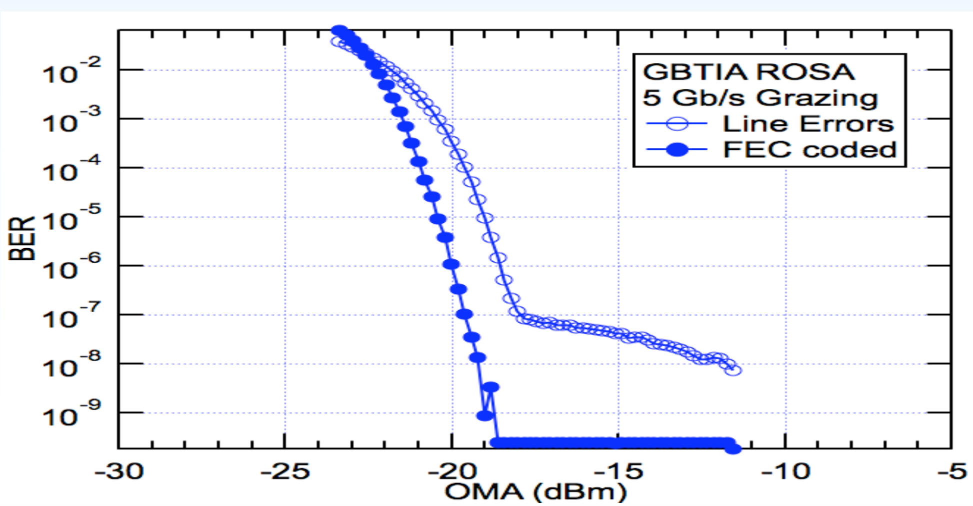


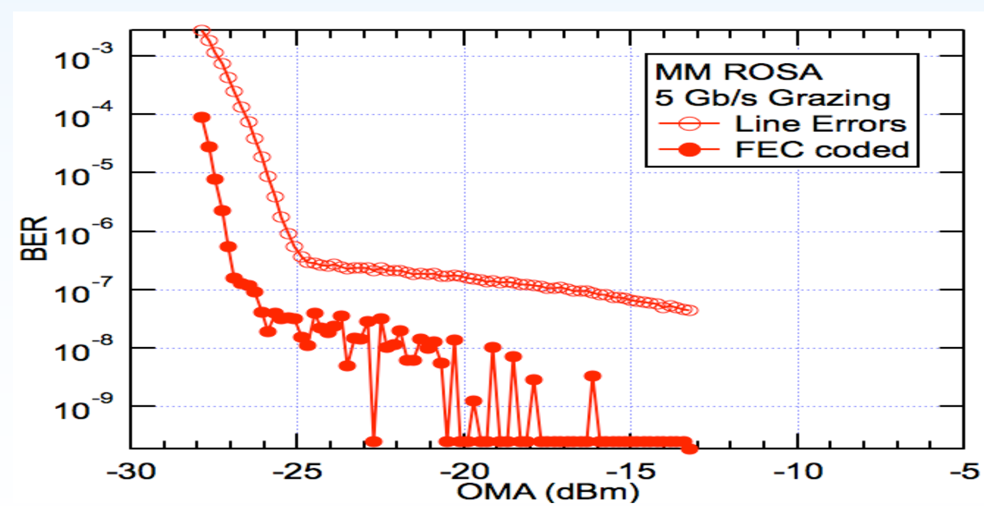
- Approximate damage factors indicate that 300 MeV/c pions are around twice as damaging as 20 MeV neutrons
  - Smaller relative factor for newer devices w.r.t. CMS reference parts
- InGaAs devices' responsivity less affected than GaAs devices
- GaAs devices show no increase in leakage current

Front End Versatile-TRx, CERN



- GBTIA ROSA and COTS MM ROSA SEU test
  - BER due to single bit flips is similar for all devices
  - BER is independent of data rate within the range of investigation
  - Burst lengths limited in PINs and GBTIA ROSAs
  - Longer bursts seen in COTS ROSAs with unshielded amplifiers
  - GBTIA robust against SEU
  - GBT-FEC effective in correcting SEU errors in PIN





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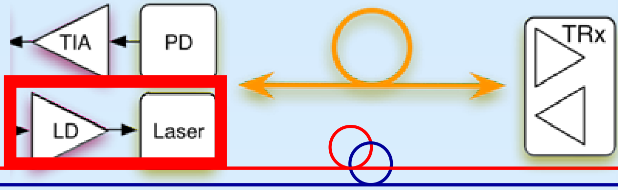
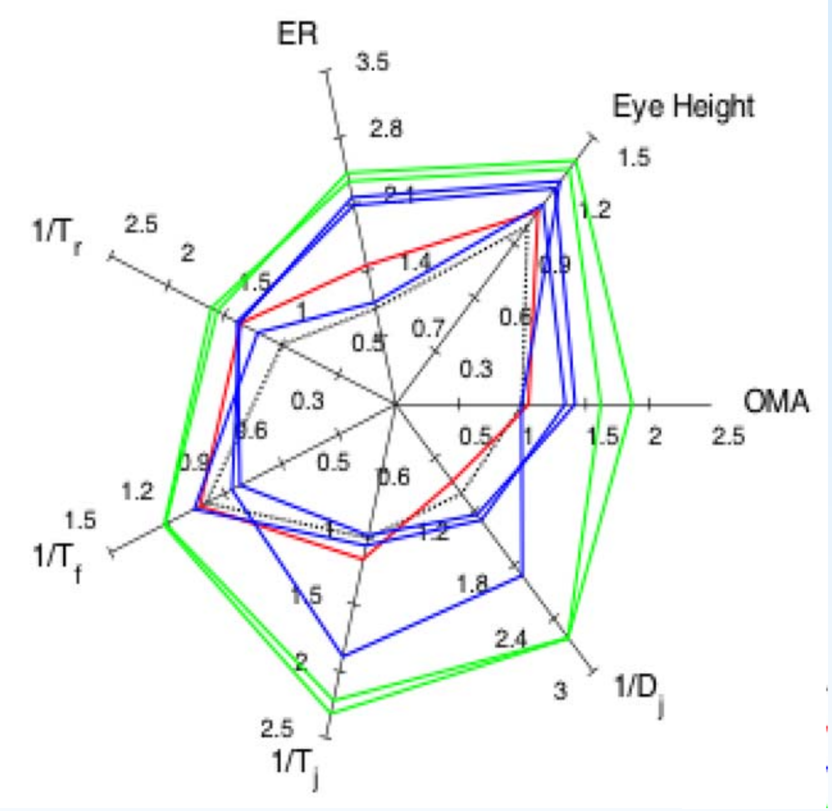
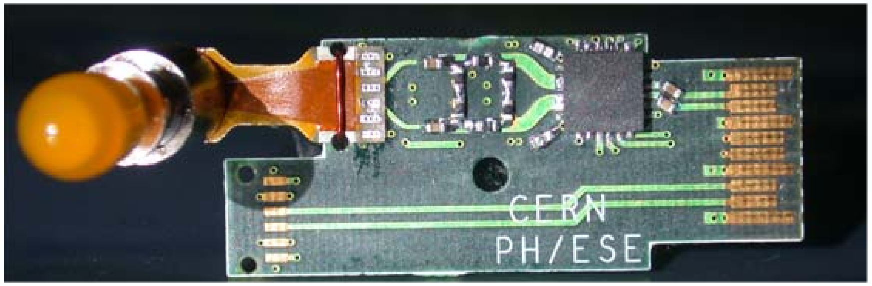


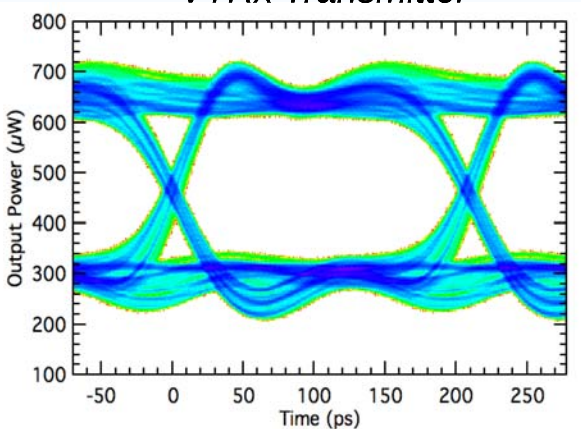
- Tx Path:
  - TOSAs from multiple vendors identified and tested
  - VTRx assembled with commercial LDD to demonstrate concept
  - GBLD V3 not in specs
  - GBLD to be included in VTRx when spec met



Specification
1310 nm VCSEL
1310 nm VCSEL
850 nm VCSEL



VTRx Transmitter



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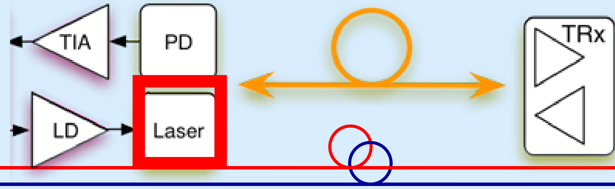
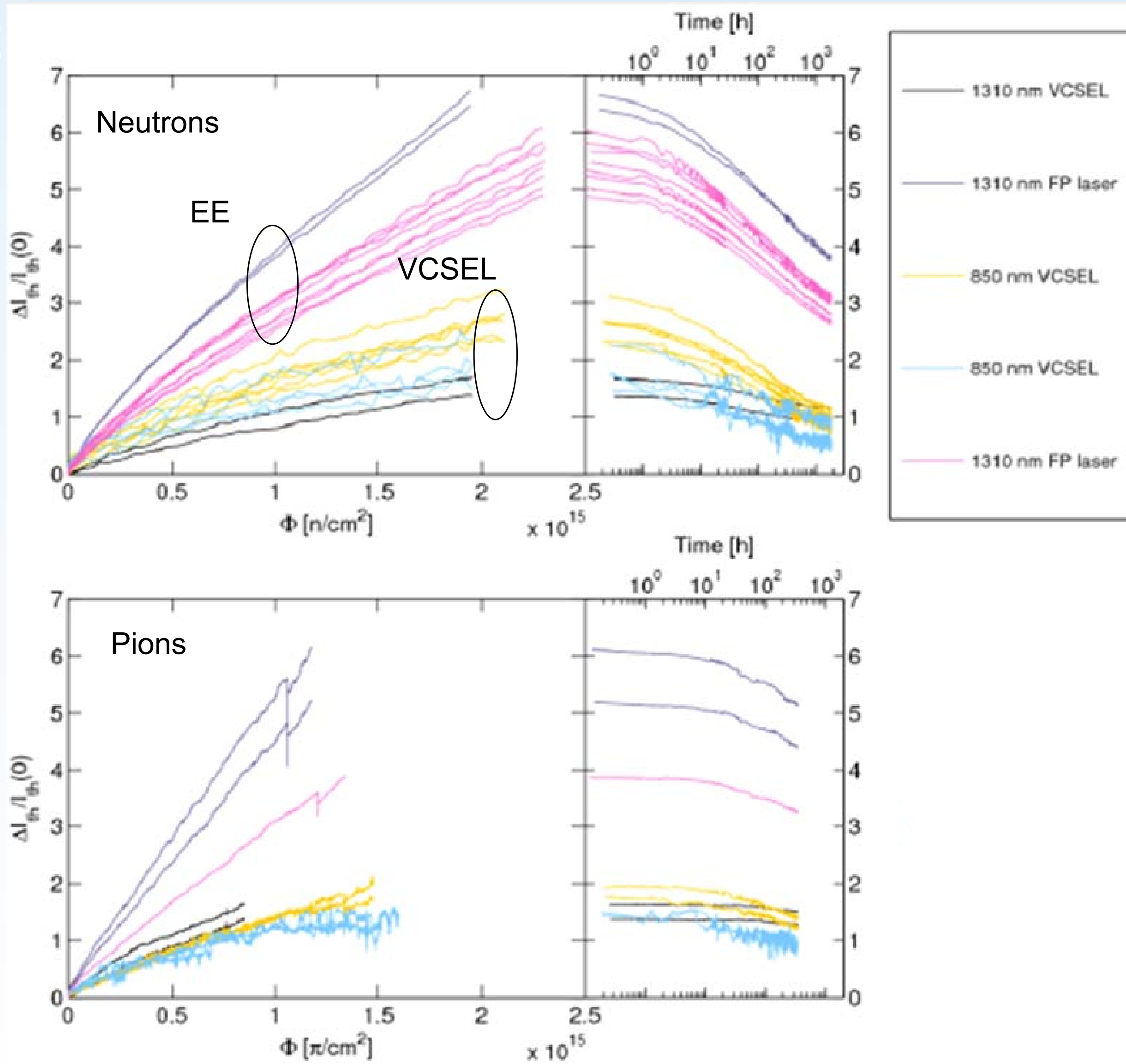
Front End Versatile-TRx, CERN



- Overall, VCSELs appear to be more radiation resistant than edge-emitters (EELs)
  - 850 nm VCSELs appear to be more resistant than 1310 nm variants
- Newer EELs are significantly more resistant than older designs
- A full source comparison taking annealing into account is in progress
  - Fast comparison shown



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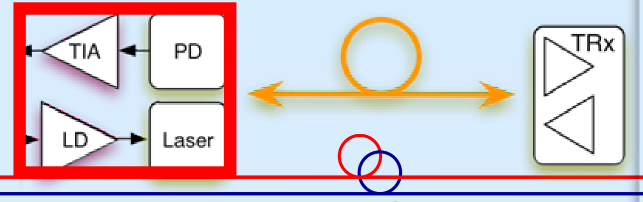
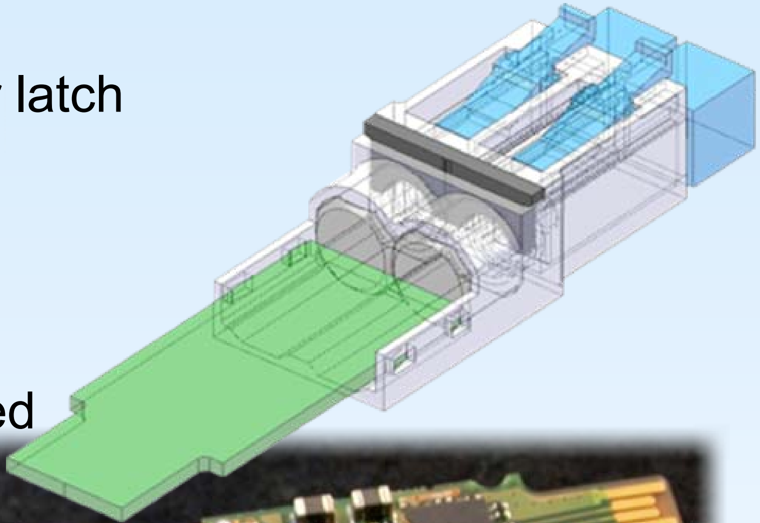
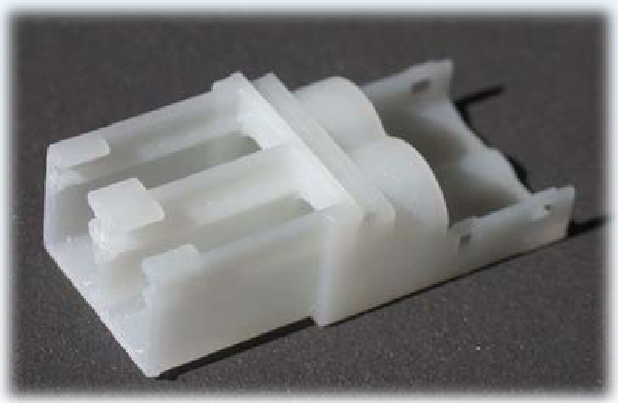
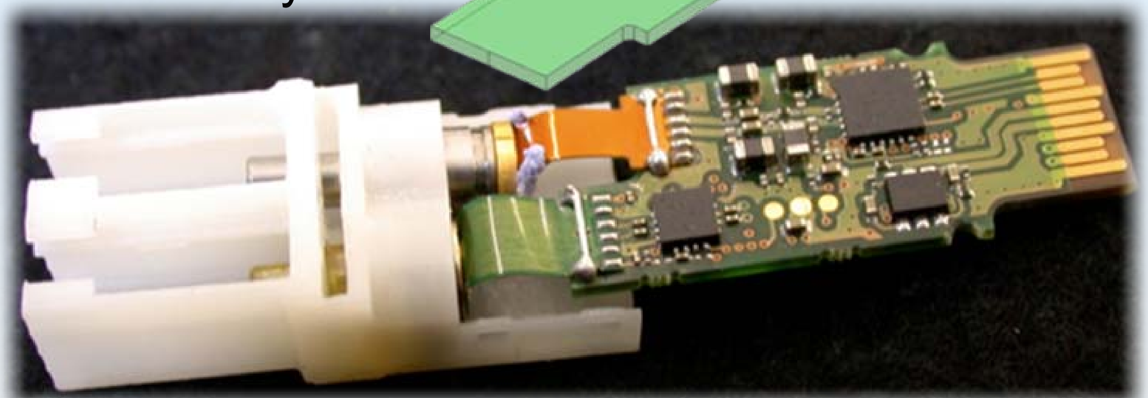
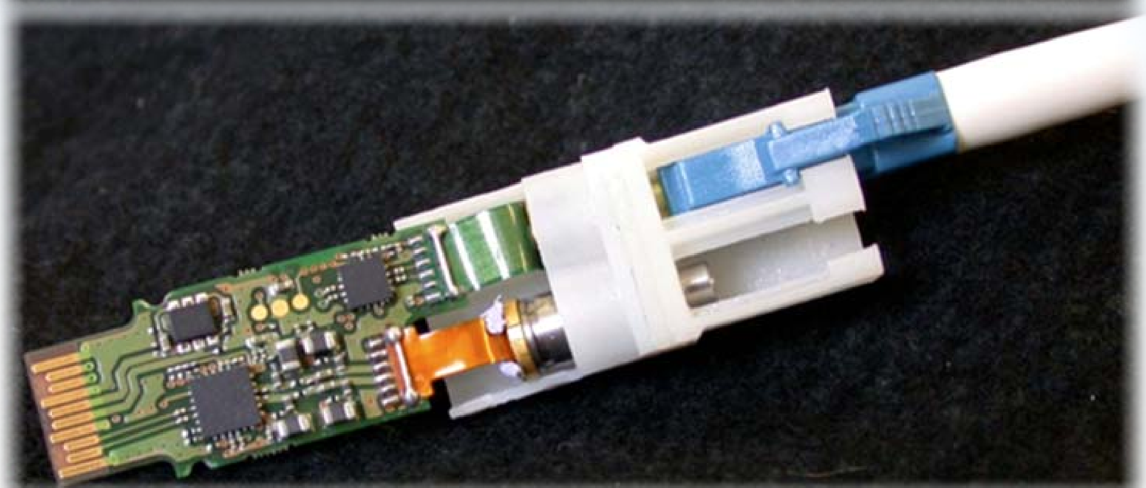


- VTRx low-mass latch design
  - Working on mechanical design of VTRx connector latch to reduce overall mass of the transceiver
    - Part mechanically associates connector and TOSA/ROSA
  - Rapid prototype plastic samples successfully tested









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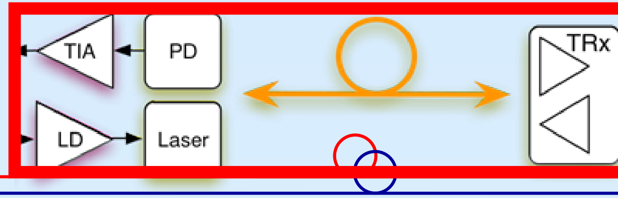
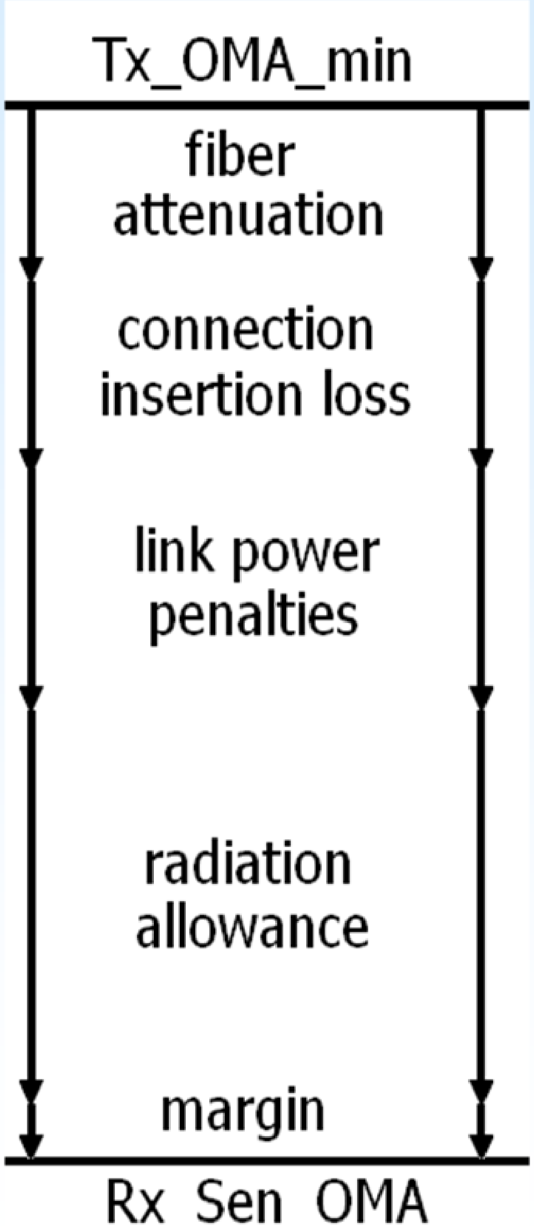
System (SMU)



- Setups, configurations, reference components and test procedures are documented for cross-examination.
  - Link penalty of COTS transceivers over 150meter SMF and OM3 MMF are tested to be below 1.5 dB.
  - TJ, DJ and RJ deducted from BER scan measurement conform well with TIE scope measurement.
  - Measurement with and without standard PLL weighting filter are very close.
- Two sets of test platforms are maintained for lab characterization and for field tests.
  - One based on oscilliscope and BERT. One based on Altera Stratix II GX development ki
  - New Altera Stratix IV GX PCIe kit being setup.
- Power and jitter budgets defined for VL
  - Tx power and Rx sensitivity cap the amount of power for budgeting. They are first derived from vendor consensus, upon available technologies.
  - Link penalties are simulated using 10GbE link model. http://www.ieee802.org/3/ae/public/adhoc/serial_pmd/documents/
  - VL is specifically constrained by radiation degradation of front-end components.



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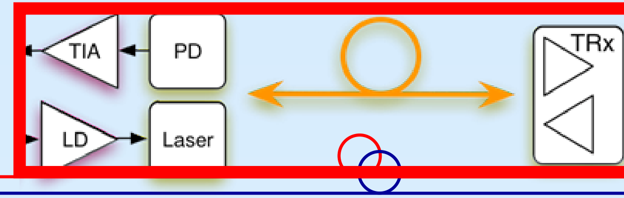

- Power budgets are defined.
- Receiver radiation penalty adjusted in SM links.
- Only rad-hard downlink needs customization.
  - Increase transmitter power to achieve target BER
  - Apply FEC to gain safety margin

	upstream	downstream	upstream	downstream
	MM_VTx_Rx	MM_Tx_VRx	SM_VTx_Rx	SM_Tx_VRx
Min. Tx OMA	-5.2 dBm	0.6 dBm	-5.2 dBm	-5.2 dBm
Max. Rx sensitivity	-11.1 dBm	-13.1 dBm	-12.6 dBm	-15.4 dBm
Power budget	**5.9 dB**	**13.7 dB**	**7.4 dB**	**10.2 dB**
Fiber attenuation	0.6 dB	0.6 dB	0.1 dB	0.1 dB
Insertion loss	1.5 dB	1.5 dB	2.0 dB	2.0 dB
Link penalties	1.0 dB	1.0 dB	1.5 dB	1.5 dB
Tx radiation penalty	0 dB	-	0 dB	-
Rx radiation penalty	-	9.6 dB	-	5.4 dB
Fiber radiation penalty	1.0 dB	1.0 dB	0 dB	0 dB
Margin	1.8 dB	0 dB (1)	3.8 dB	1.2 dB

Summary: VL Options and feasibility

Front-End VL TRx	Fibre	Back-End TRx
EE laser, 1310nm GBLD Drive	SM	LR-SFP+ TRx
VCSEL, 1310nm Check GBLD compliance Voltage		SNAP12'like Rx SM Tx not (yet) available
InGaAs PIN, 1310nm		Opto Engine Rx SM Tx not (yet) available
VCSEL, 850nm Check GBLD compliance Voltage	MM	SR-SFP+ TRx Tx OMA to meet power budget
GaAs PIN, 850nm Responsivity drop under irradiation		SNAP12'like Tx,Rx, TRx Tx OMA to meet power budget
InGaAs PIN, 850nm Responsivity/Leakage to be confirmed	RIA in cold at low dose rate	Opto Engine Tx, Rx, TRx Tx OMA to meet power budget

Conclusions

Versatile Link

- Phase II deliverables (Apr 2011?):
  - Specifications for system and components
  - Shortlist of components meeting the specifications
  - Front-end VTRx integrating GBT ASICs and validated optoelectronics in low mass package
  - Set of irradiation test results for front-end and passive components
  - System demonstrators based on validated components
  - First evaluation of production cost vs volume
- Phase III:
  - Pre-production readiness if users commit
  - To be replaced by interim Phase IIb waiting for users to commit
    - Consolidation till Oct 2011?
    - Then: Arrays? Low power?