The Versatile Link

Feasibility Demonstration

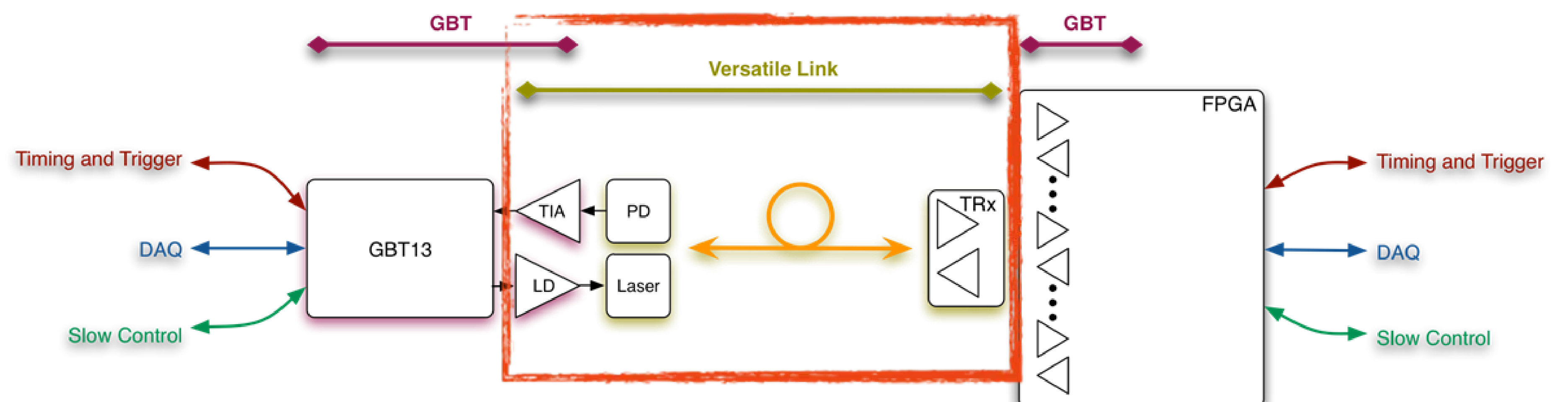
(Project phase II update)

Francois Vasey, on behalf of the Versatile Link Team

Versatile Link Project

Versatile Link

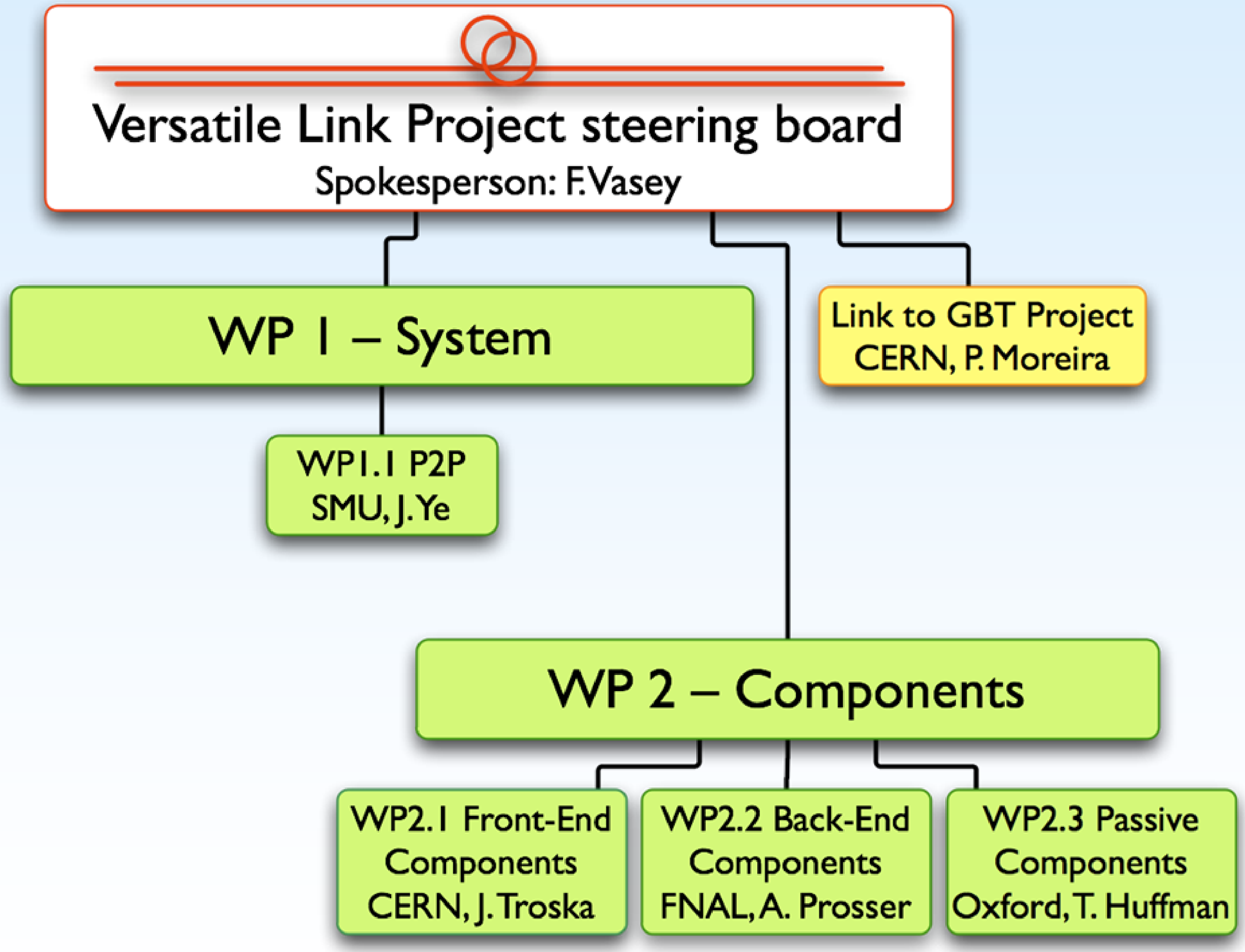
- Optical Physical layer linking front- to back-end
- Bidirectional, ~5Gbps
- Versatile
  - Multimode (850nm) and Singlemode (1310nm) versions
  - Point to Point and Point to Multipoint architectures
- Front-end pluggable module
- Joint Project Proposal submitted to ATLAS & CMS upgrade steering groups 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)*



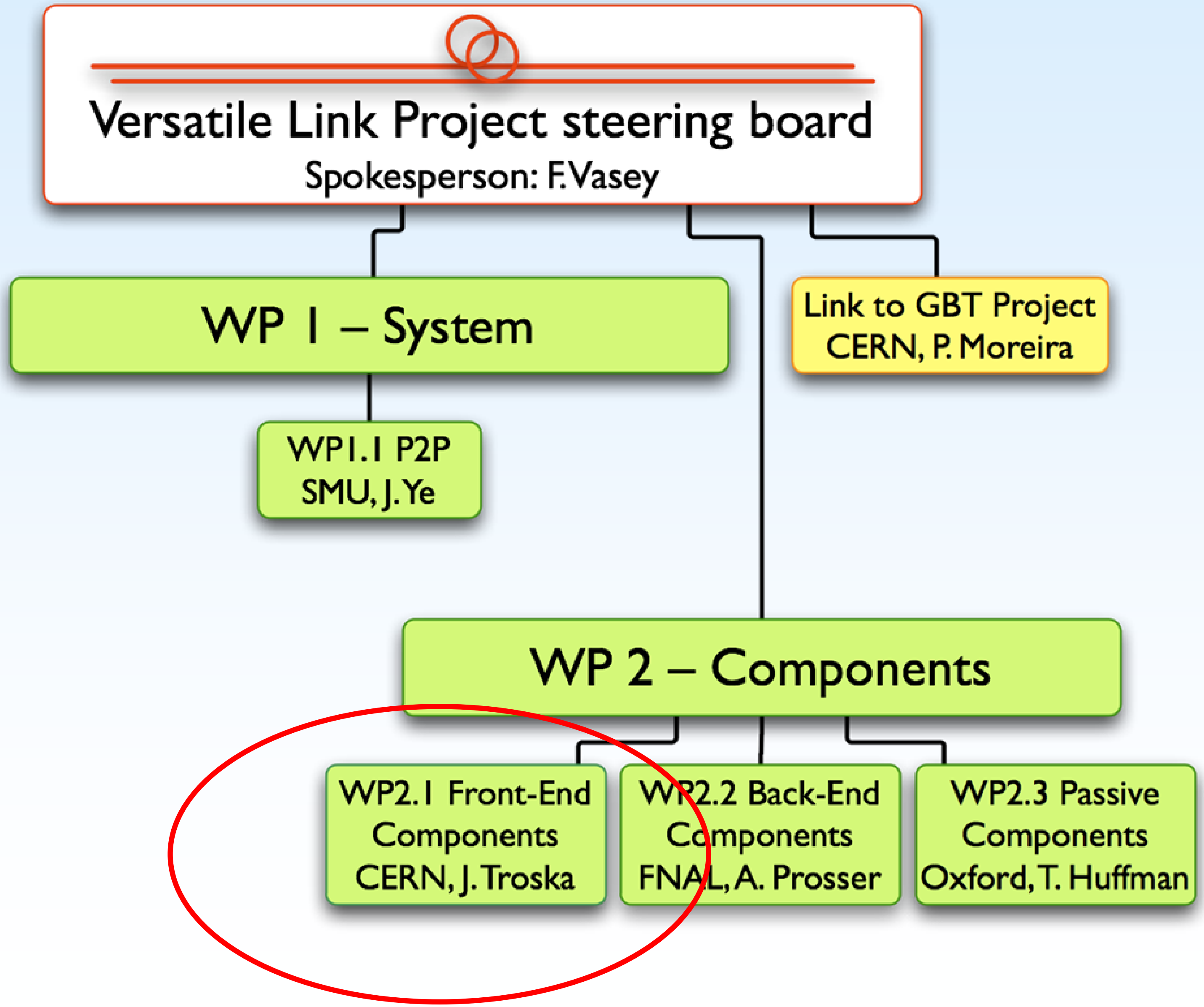
On-Detector
Custom Electronics & Packaging
Radiation Hard

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

Project Structure and Partners

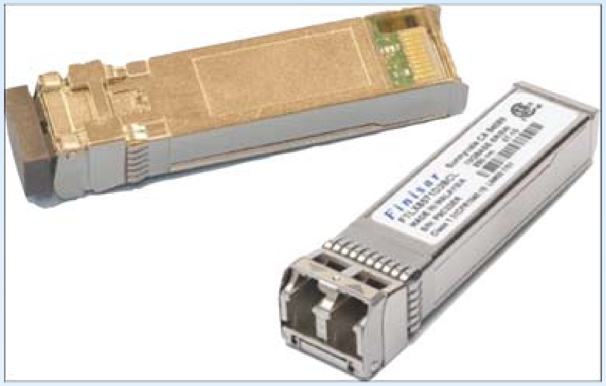


WP 2.1 – Front End Components

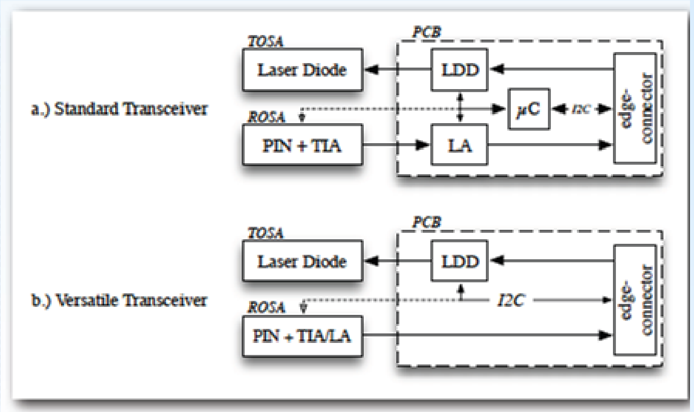


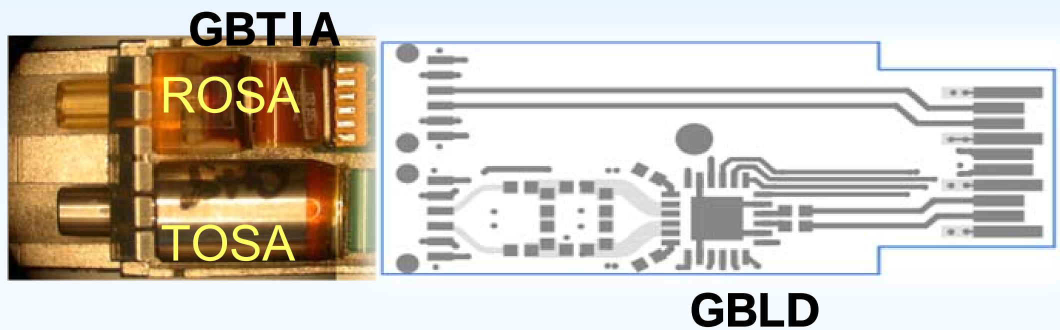
Front End Transceiver, Versatile-TRx

Versatile Link



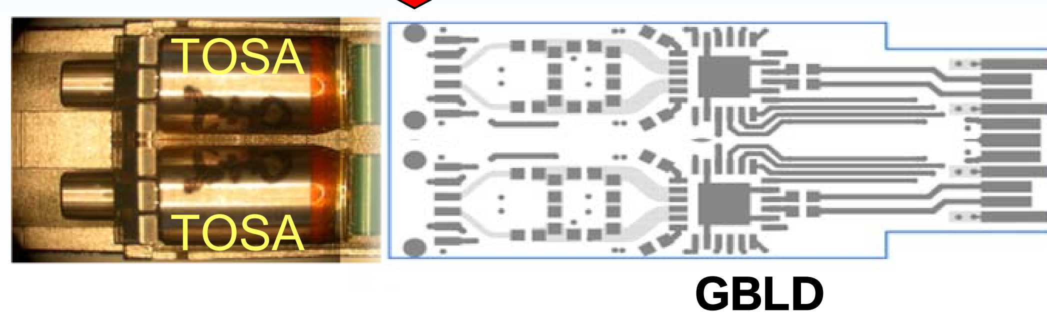
TRx





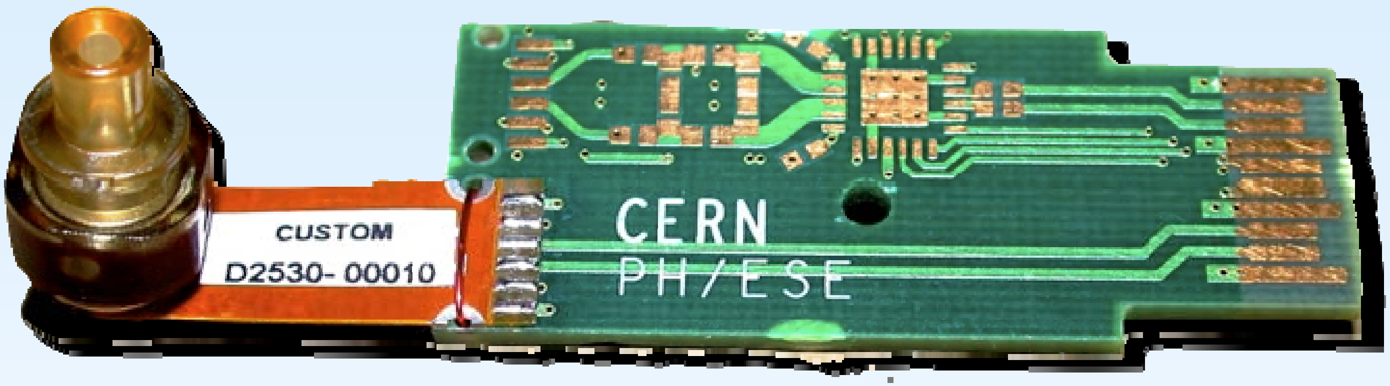
- Low Mass & Volume
  - Minimize material, avoid metals
- Non-magnetic, capable of operating in a magnetic field
  - Requires replacement of ferrite bead used in laser bias network
- Bitrate determined by ASICs: 5 – 10 Gbps
- 850nm and 1310nm flavours

2Tx

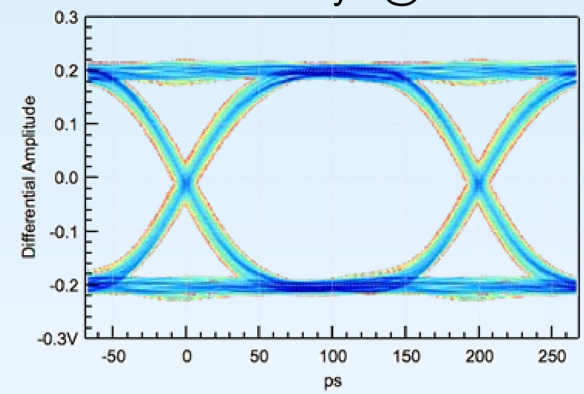


TOSA/ROSA integration on VTRx (CERN)

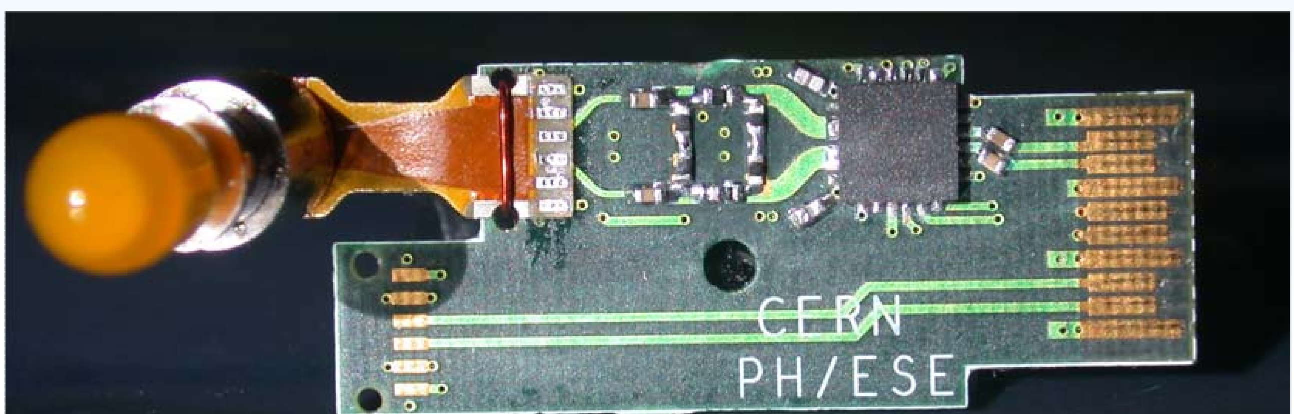
- GBTIA-ROSA on prototype VTRx PCB



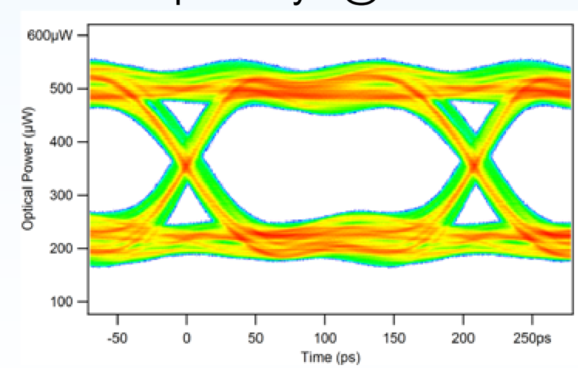
RX electrical eye @ 5 Gb/s



- TOSA and commercial Laser Driver on VTRx PCB



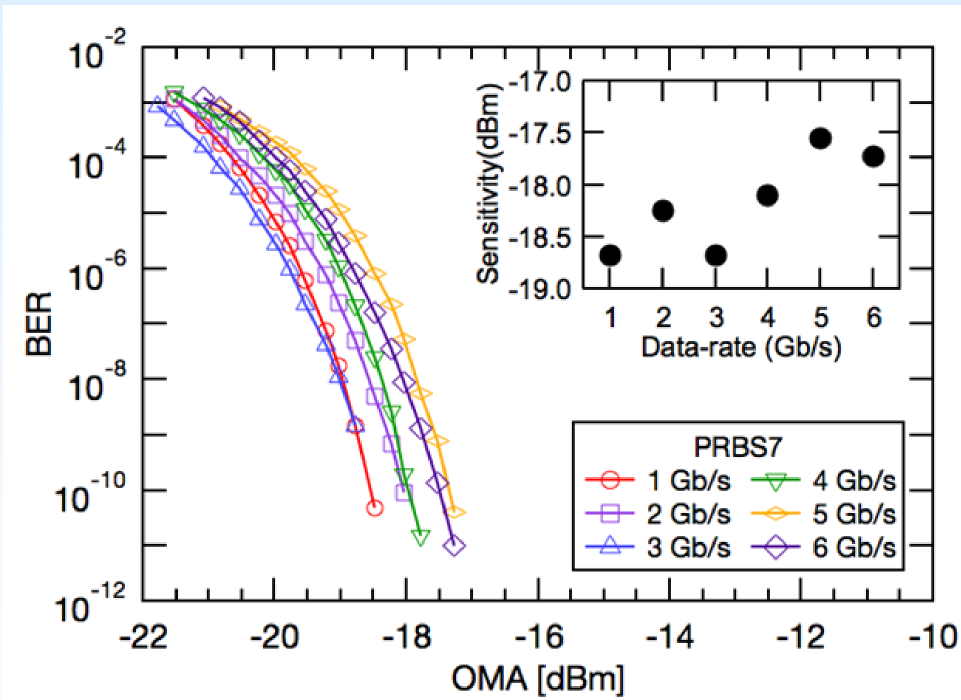
TX optical eye @ 4.8 Gb/s

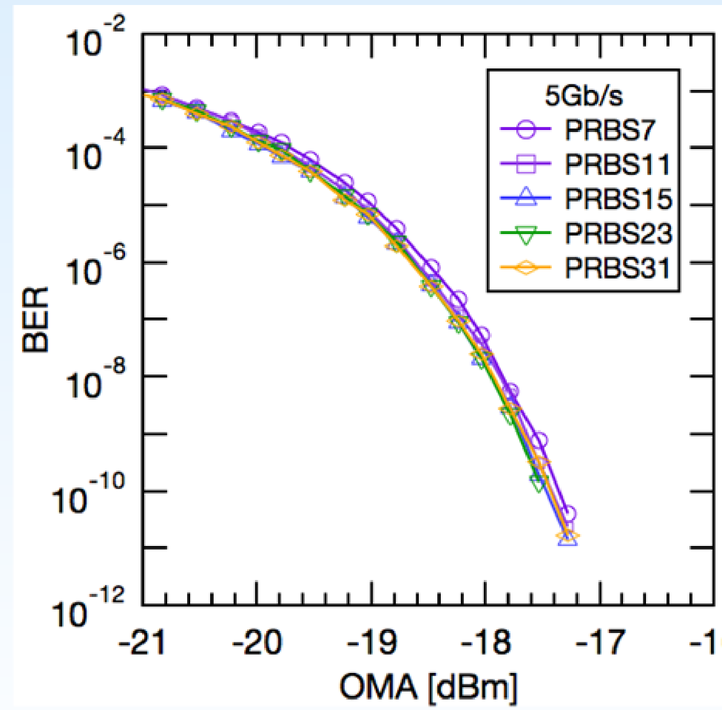


GBTIA ROSA performance (CERN)

Versatile Link

- Evaluate impact of data-rate and pattern length on GBTIA ROSA sensitivity

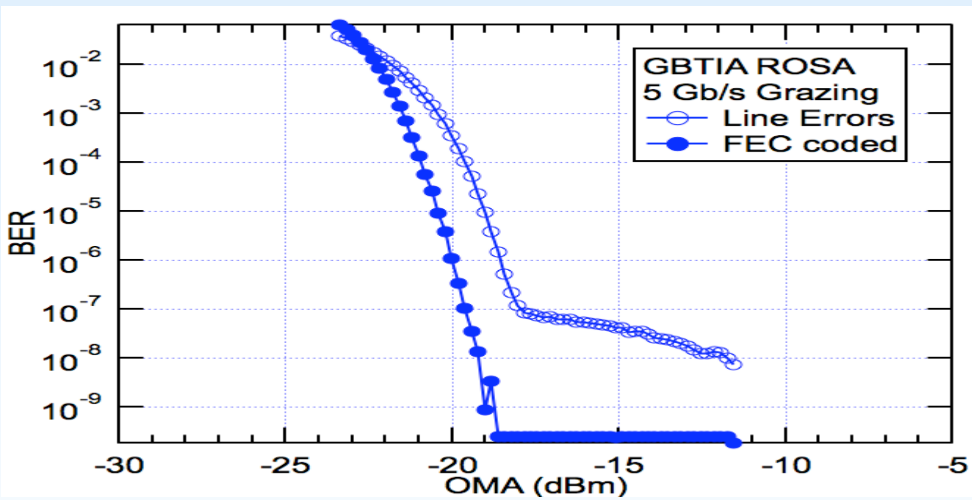


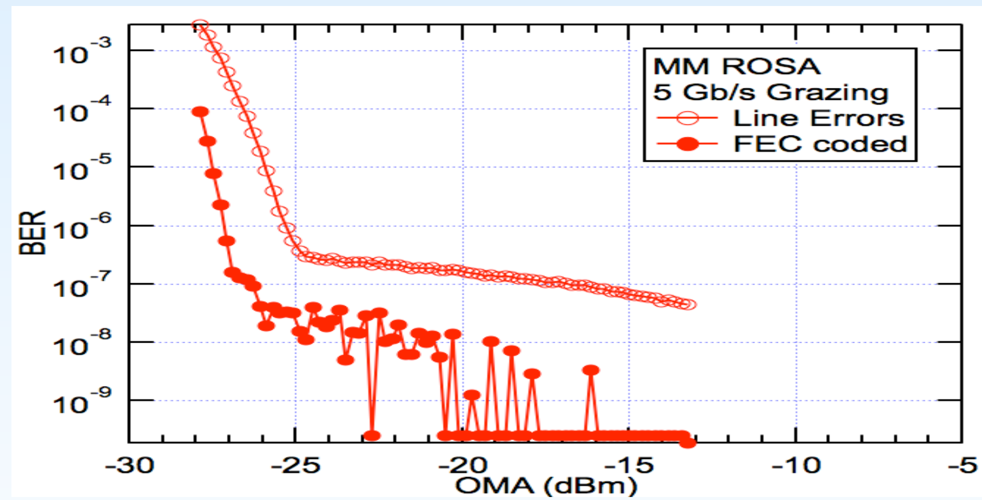


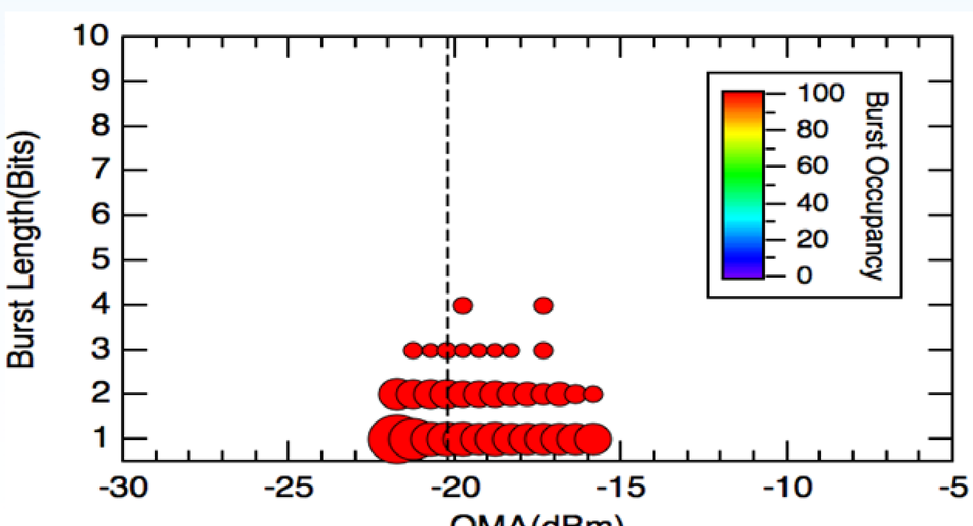
- Favourable comparison to bare-die tests
  - ROSA pkg not detrimental to functionality
- Expected reduction in sensitivity with data-rate
  - Acceptable magnitude
- No pattern length sensitivity

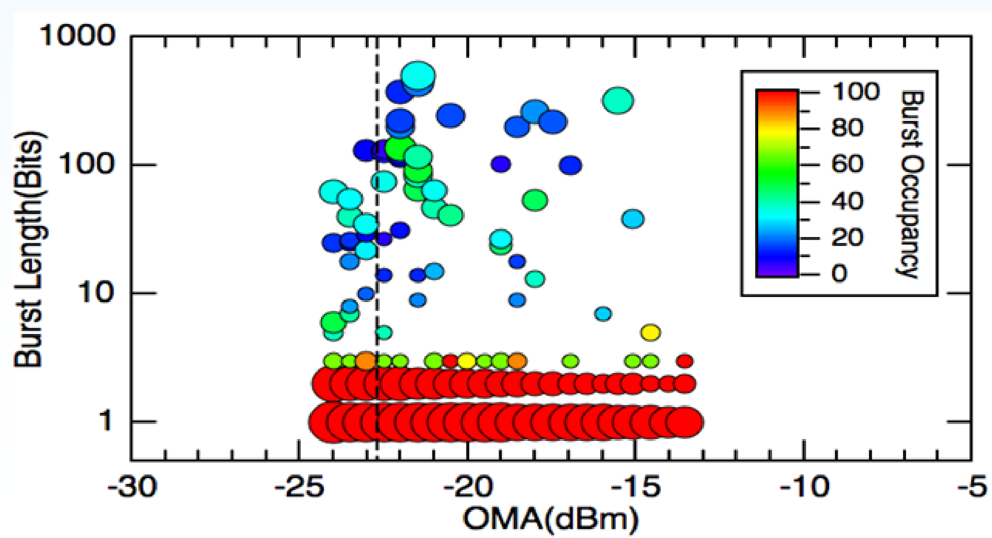
SEU test result preview (CERN)

- 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 ROSAs with unshielded amplifiers

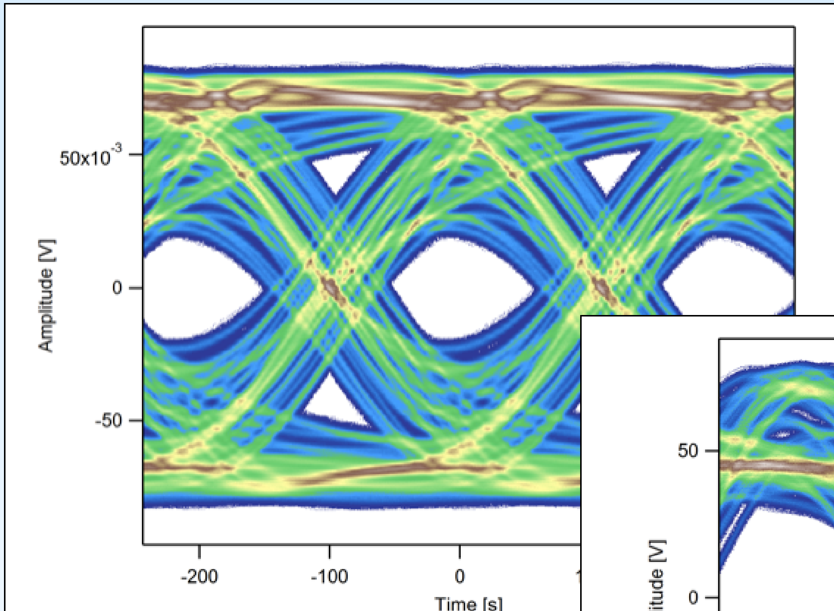






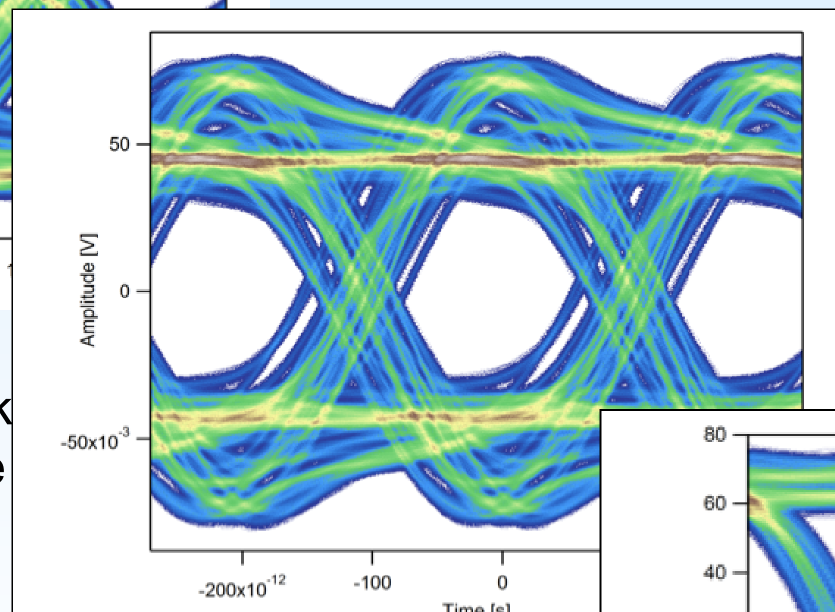


GBLD TOSA performance (CERN)

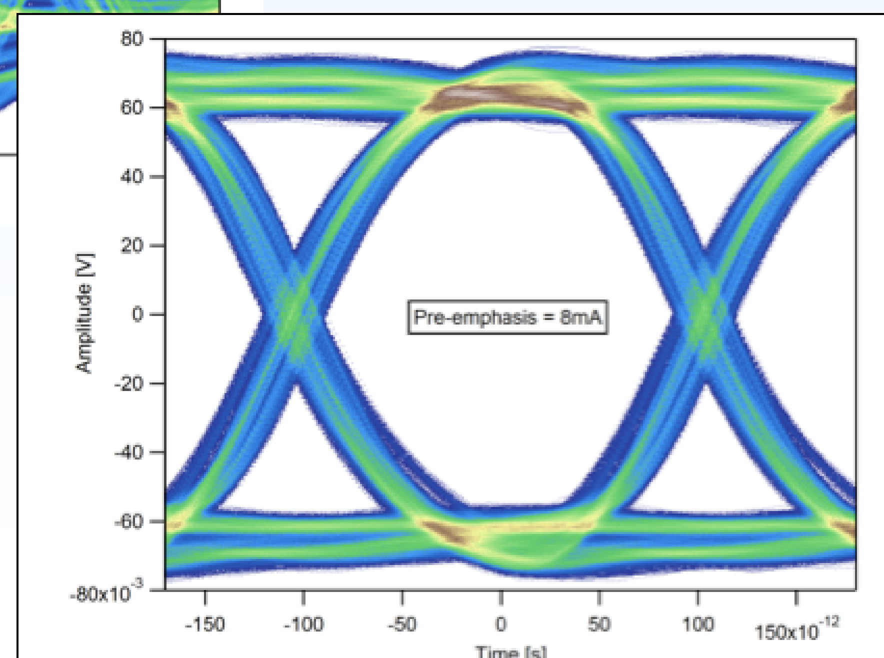


Designers brainstormed their output speed problems and realised that there had been a change in ESD protection diode from v2 to v3

increased input Capacitance



Adding a matching network at input to compensate the diodes improves the eye opening

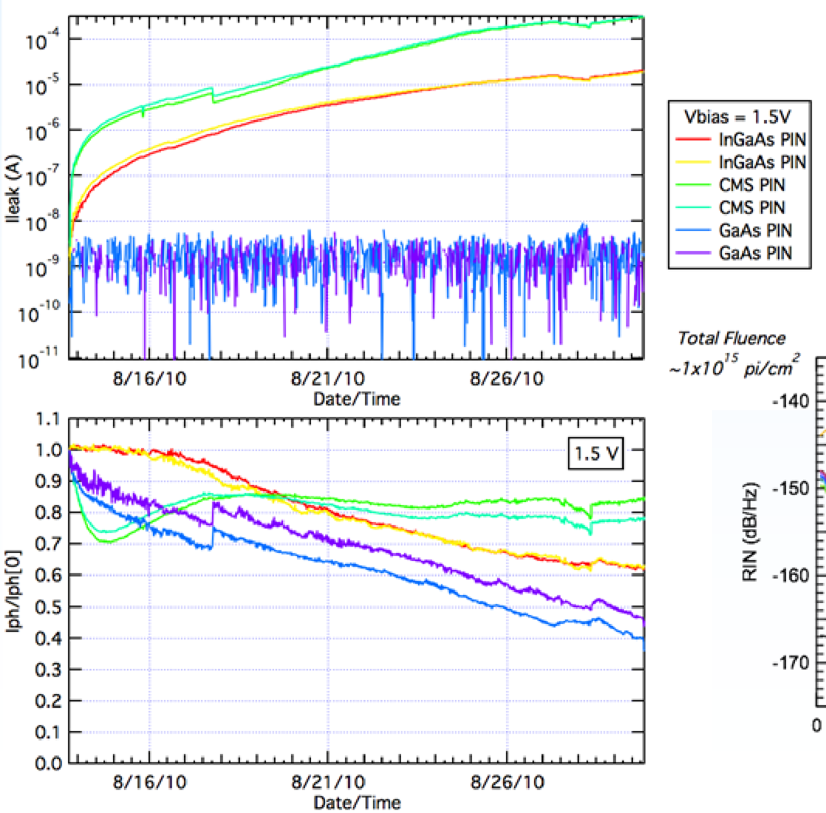


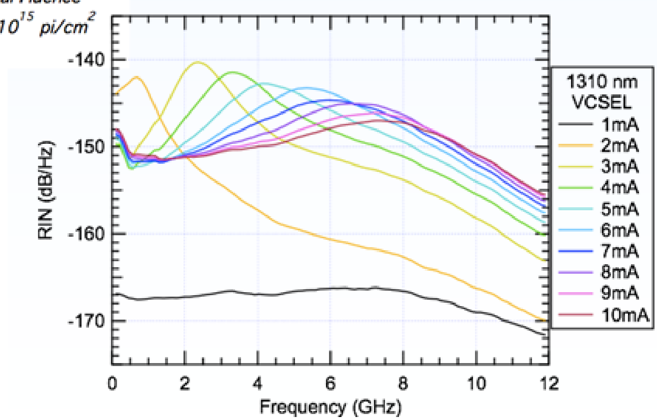
Changing pattern generator dramatically improves the situation (assume lauch termination is much better able to swallow mismatch)

Pion Total Fluence Test (Aug. 2010) (CERN)

Versatile Link

- Cross-check influence of particle species on damage
  - NIEL scaling unproven for complex laser stoichiometry
- End of life prediction
- Online measurement of optical spectra & RIN
  - Track temperature effects & high-speed performance
- Example PIN results show typical behaviour:
  - decreased response
  - increased Ileak (InGaAs)



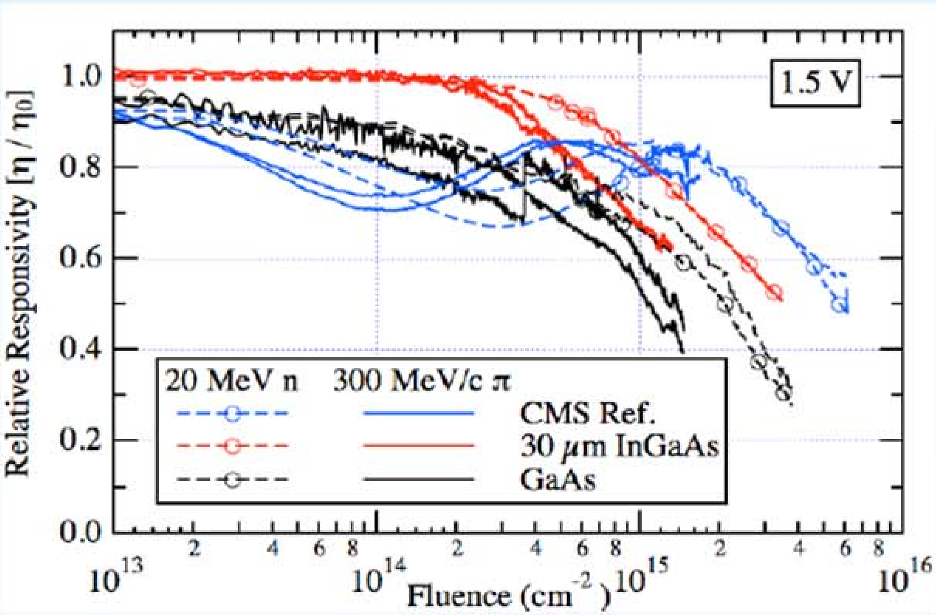


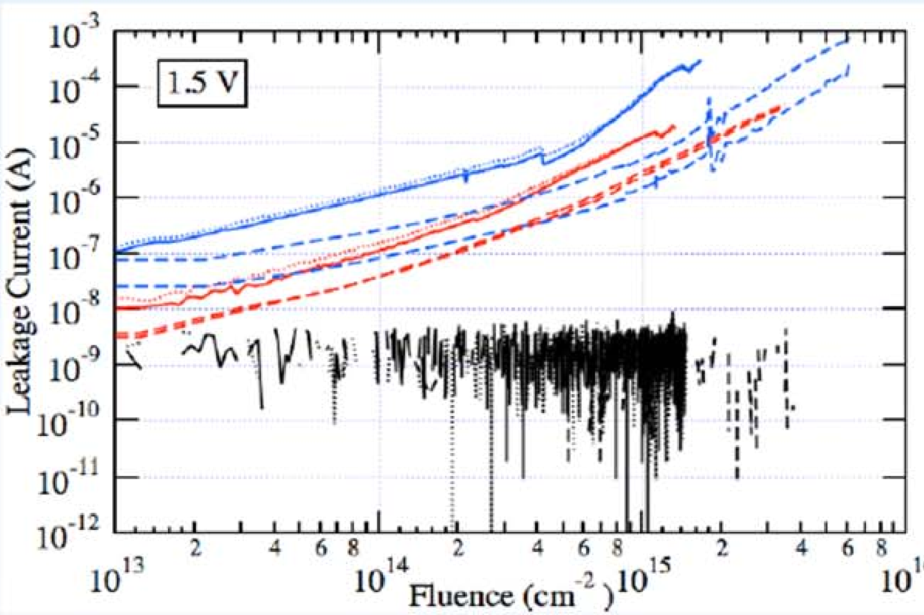
See Poster by P. Stejskal for discussion of laser results

Pion Total Fluence Test (Pins) (CERN)

Versatile Link

- Easy comparison since very little annealing of damage
  - Thus no (little) flux dependence expected

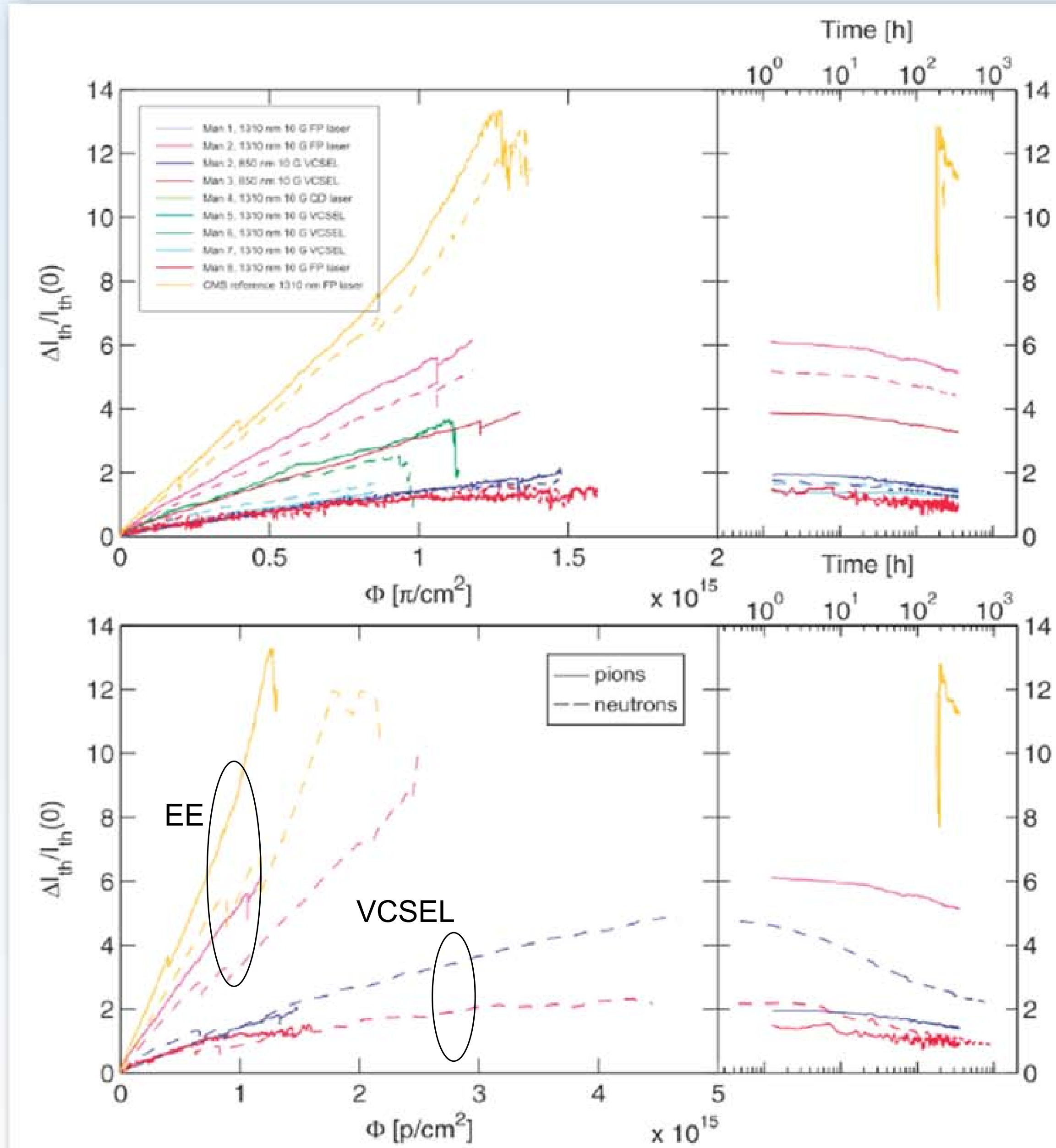




- Approximate damage factors indicate that 300 MeV/c pions are around twice as damaging as 20 MeV neutrons
  - Smaller relative factor for newer devices w.r.t. CMS reference parts
- InGaAs devices' responsivity less affected than GaAs devices
- GaAs devices show no increase in leakage current

Pion Total Fluence Test (Lasers) (CERN)

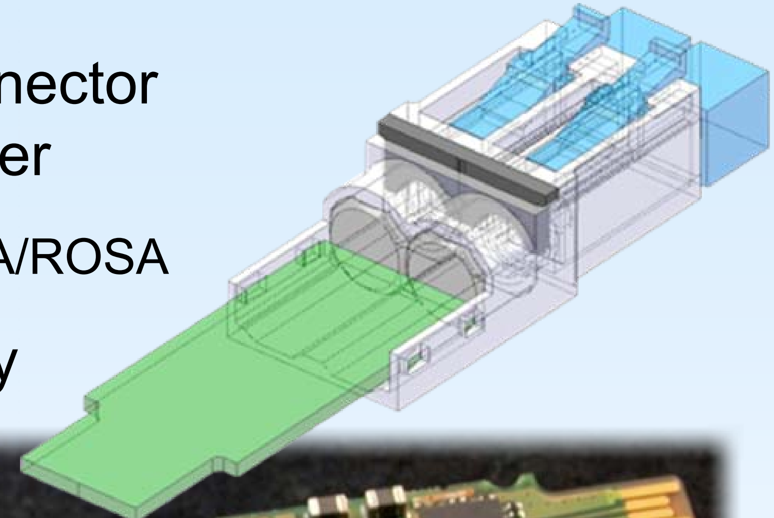
- Overall, VCSELs appear to be more radiation resistant than edge-emitters (EELs)
  - 850 nm VCSELs appear to be more resistant than 1310 nm variants
- Newer EELs are significantly more resistant than older designs
- A full source comparison taking annealing into account is in progress
  - Fast comparison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

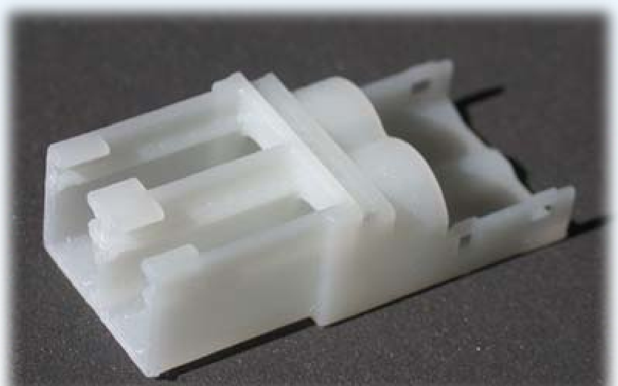


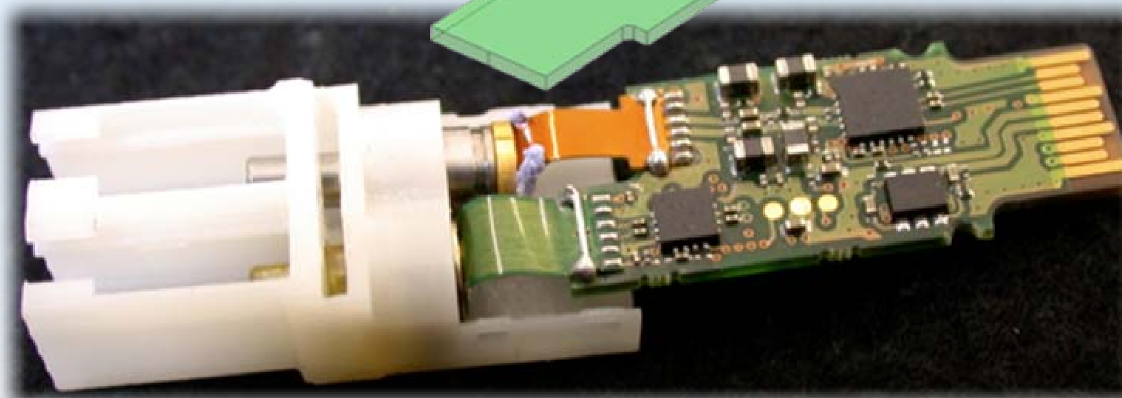
VTRx low-mass latch design (CERN)

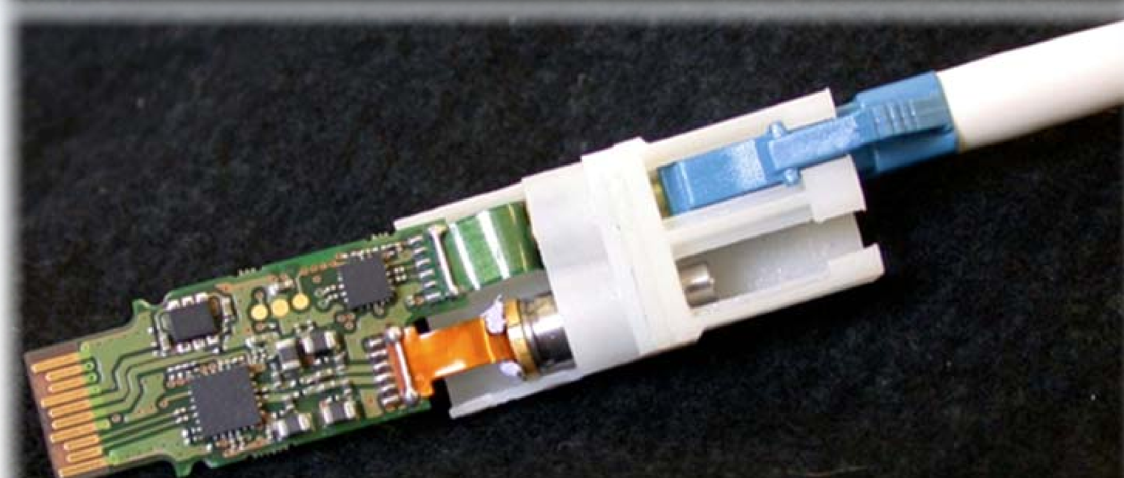
Versatile Link

- 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

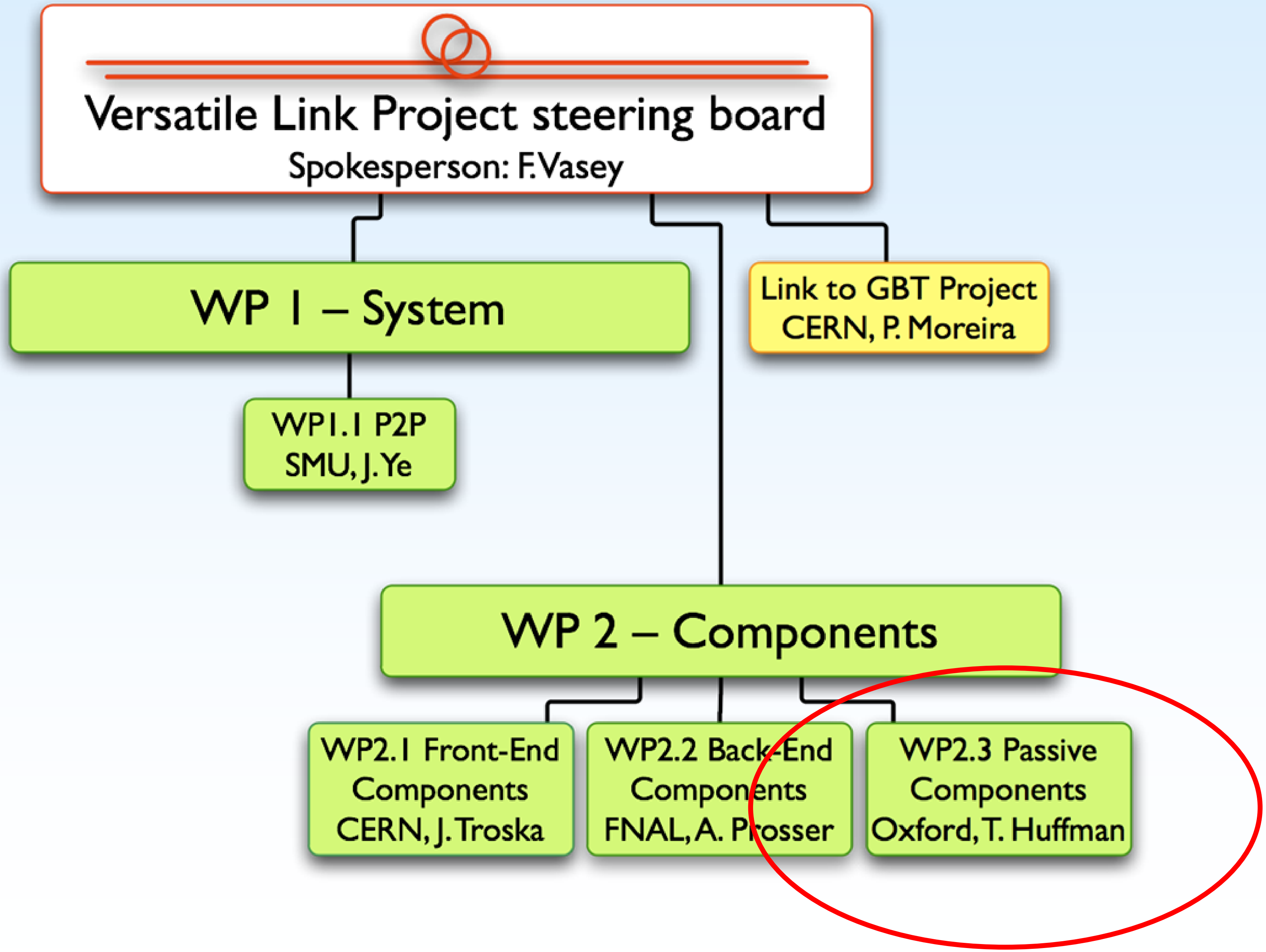








WP 2.3 – Passive Components



WP2.3 Optical Components (Oxford)

- Radiation Induced Absorption (RIA) in fibres is highly temperature dependent.
- Oxford has developed a CO_2 cooling system capable of keeping fibre samples cold (-26 deg C).
- Tests have been performed on five optical fibres. Two were MM graded-index fibres (850nm) while 3 were SM fibres (1310nm).

WP2.3 Optical Components (Oxford)

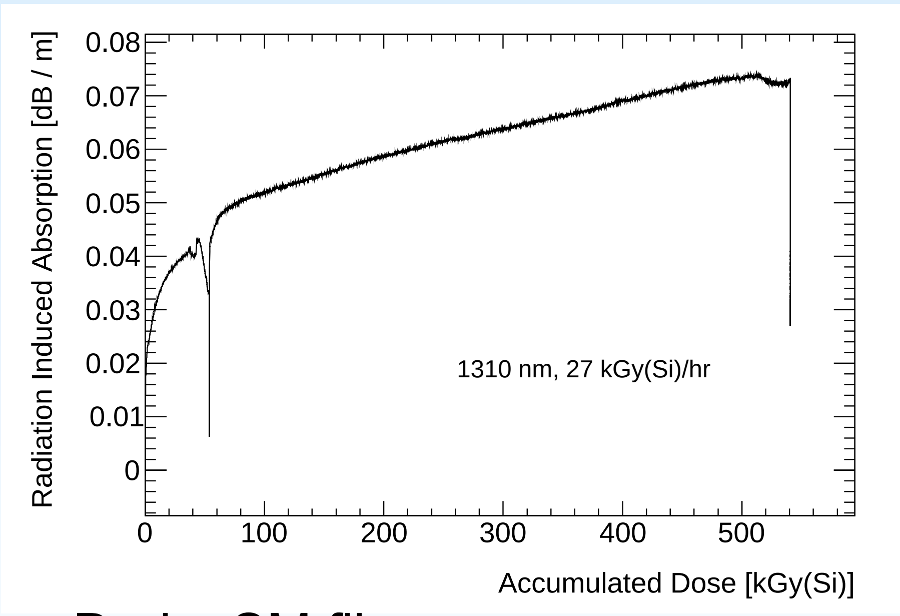
Versatile Link

- Two of the SM fibres have shown acceptable performance over 500 kGy(Si) dose.
  - Product X
  - DrakaElite™ Super RadHard Fibre
- The Multimode fibres did not perform as well, showing more than 1 dB/m of loss.
  - At face value this is a problem
- The dose rate is very high in these tests
  - 27 kGy(Si)/hr

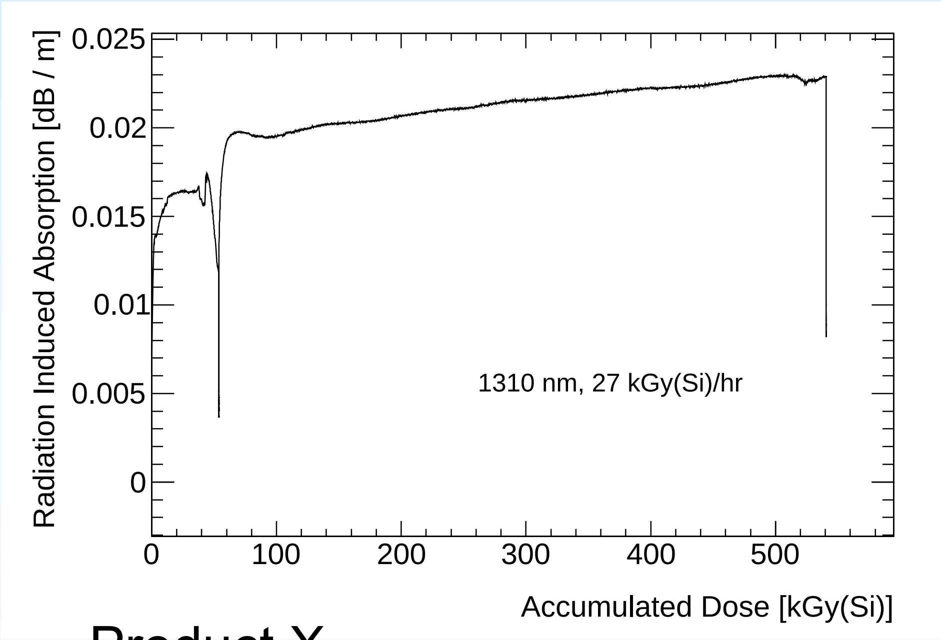
Fibre Radiation Test (Oxford)

Versatile Link

Temperature of exposure = -26 deg. C



Draka SM fibre



Product 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.
We are planning a run at a lower dose rate up to a full SLHC integrated dose.

WP2.3 Optical Components (Oxford)

Versatile Link

- 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.
- Initial tests of Corning InfinicorSX+ (MM) and Corning SMF-28 (SM) look promising.
  - They will be exposed to SLHC dose to see if we can detect any effect on mechanical strength.

WP2.3 Passive Optical Components (Oxford)

Versatile Link

- Status of PLC coupler and MPO connector radiation study
- Several commercially available PLC couplers have been pre-tested, irradiated, and post-tested.
  - Data analysis is on-going and will be the subject of a JINST paper
- Commercial MPO connectors have been pre-tested and are being irradiated.
  - Commercial LC connector tests will be next.

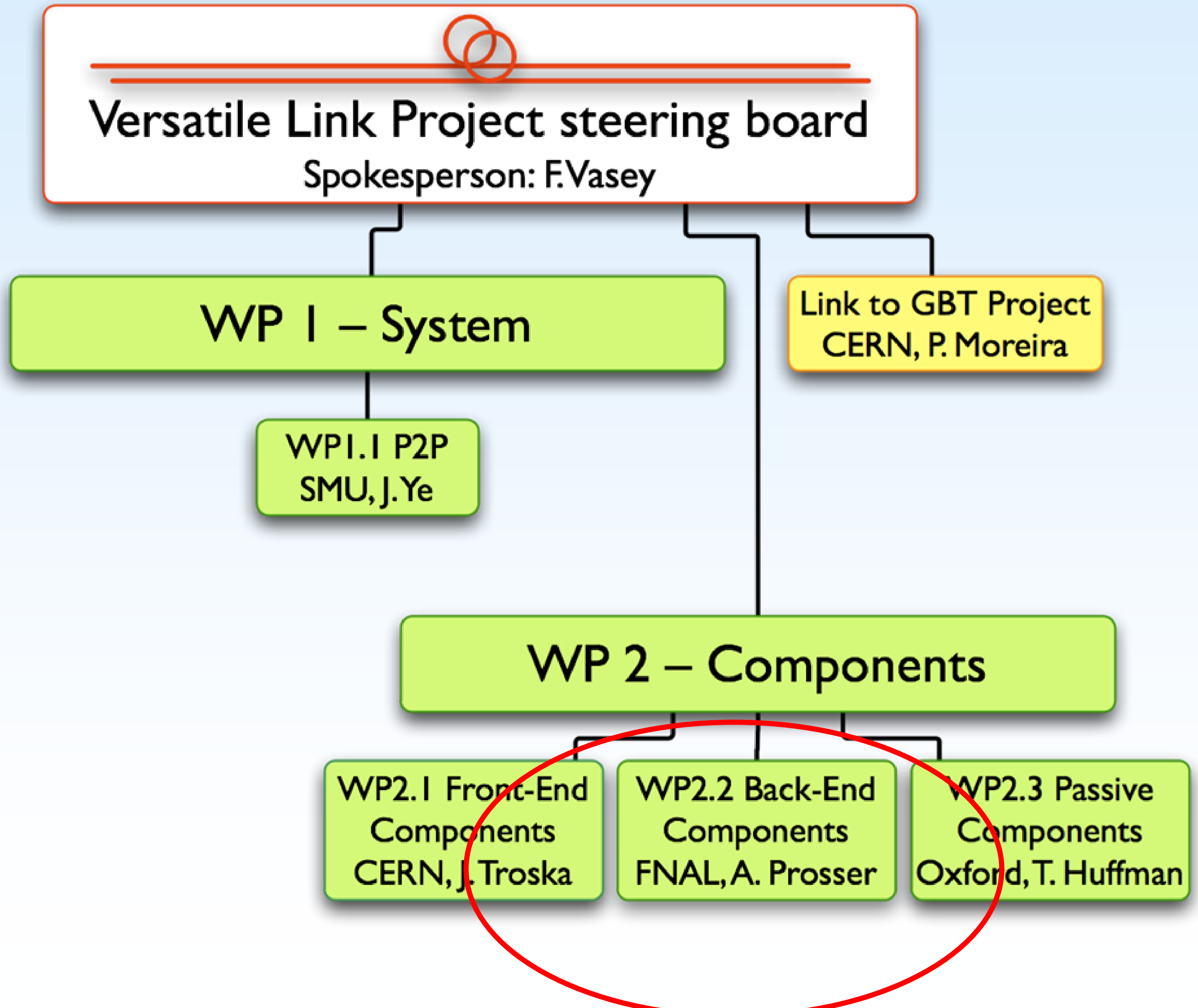
WP2.3 Passive Optical Components (Oxford,

Versatile Link

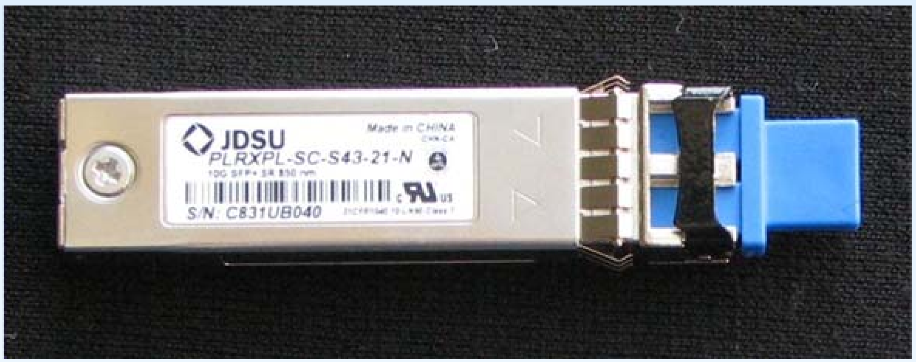
- Cable may suffer mechanically in a radiation environment as well.
  - Bulk damage and ionizing radiation damage.
  - Birmingham has agreed to let us use their proton beam to expose cable candidates
  - Scan-table is currently under test
    - Up to 1m of cable can be accommodated
- Current ATLAS ID cable (from Ericsson) will be first candidate.
  - Working with industry to perform the analysis.

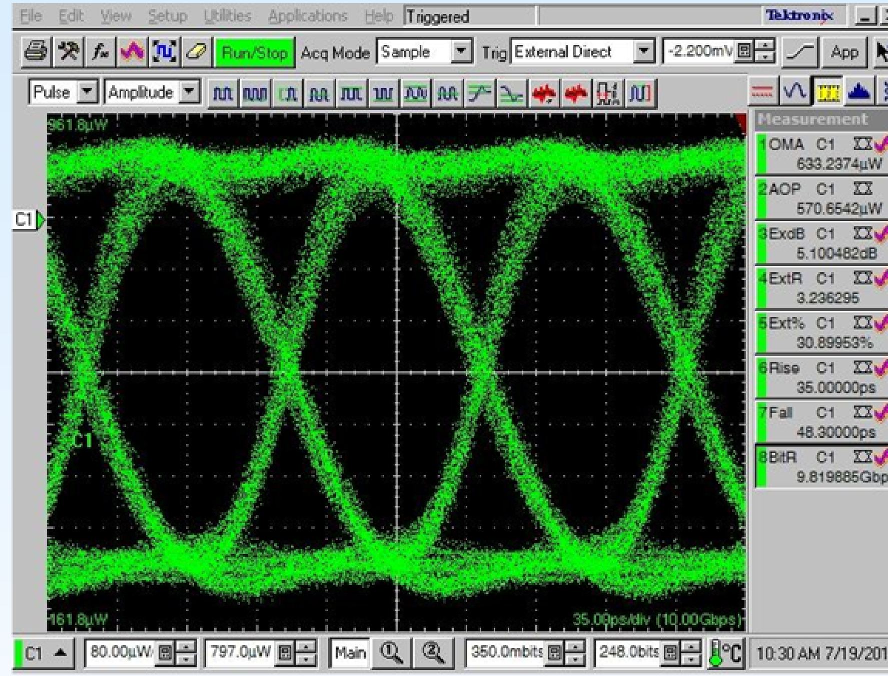
WP 2.2 – Back End Components

Versatile Link



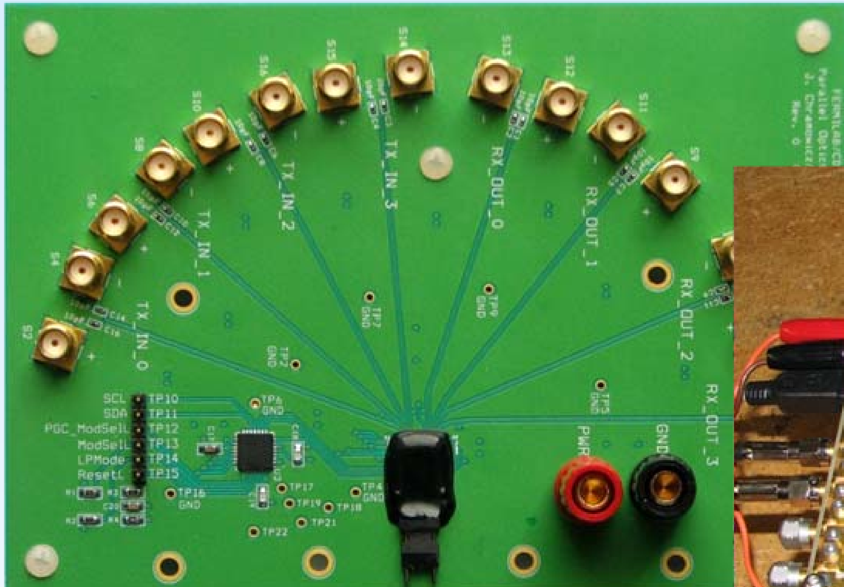
WP2.2 - SFP+ Testing (FNAL)

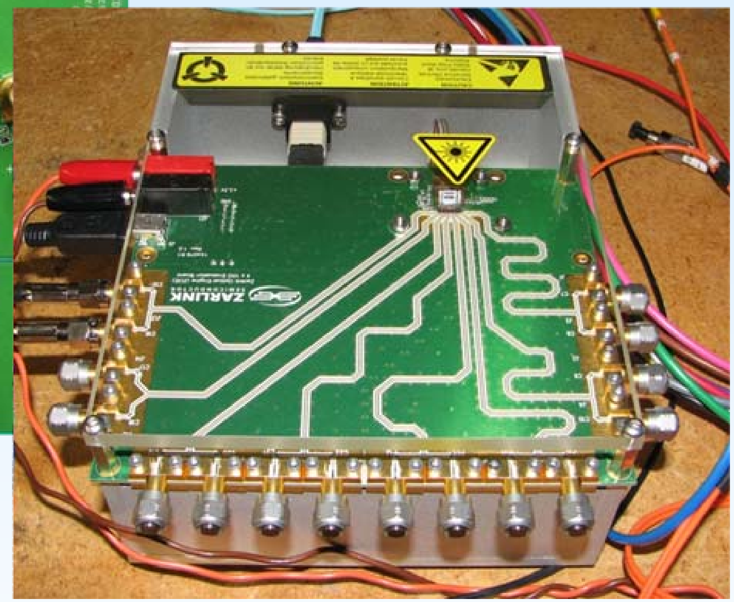


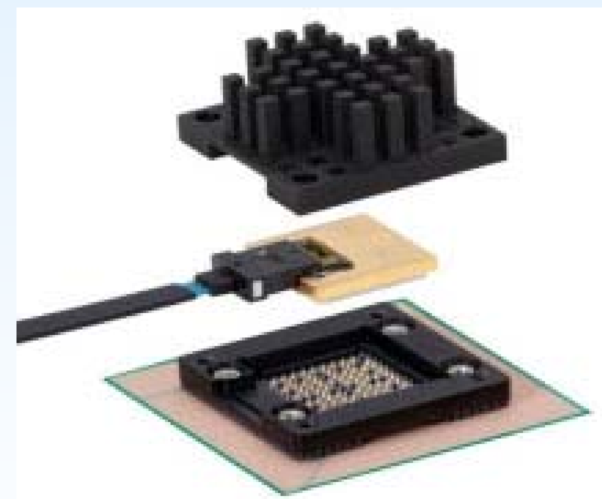


- Testing of SFP+ (850nm and 1310nm) up to 10Gbps
- Reference Components Identified and Procured for Team Use
- Future Work: Detailed Specification of Device Requirements for Versatile Link
- Future Work: Investigation of Higher Power SFP+ Variant

WP2.2 - Parallel Optics Evaluation (FNAL)



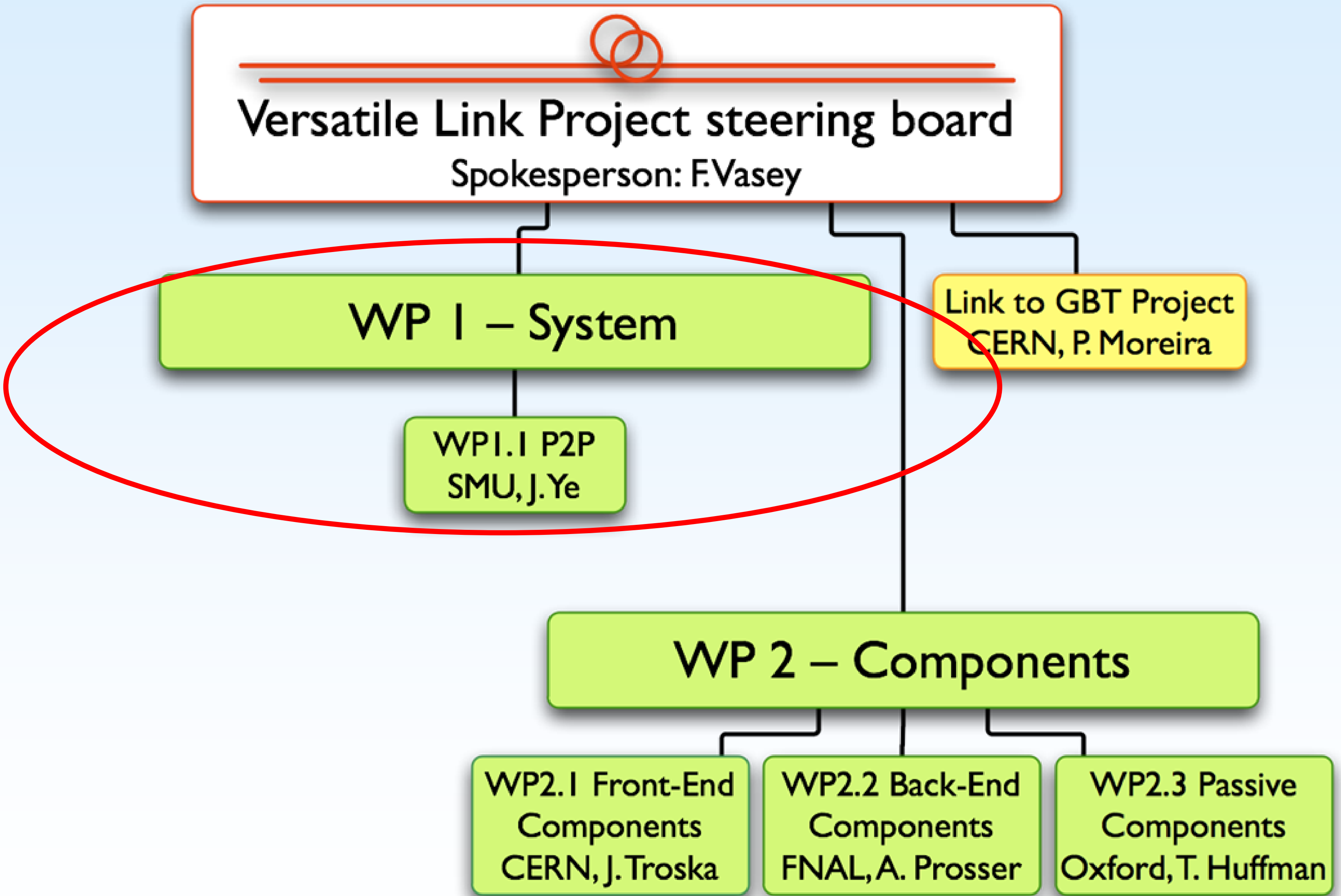




- Fermilab has tested 4x4 Parallel Optical Engines up to 10Gbps
- SNAP12 Tx/Rx Pair Tested at Rates up to 6.25Gbps
- Future Work: Includes the design of Parallel Optical Engine FMC Card

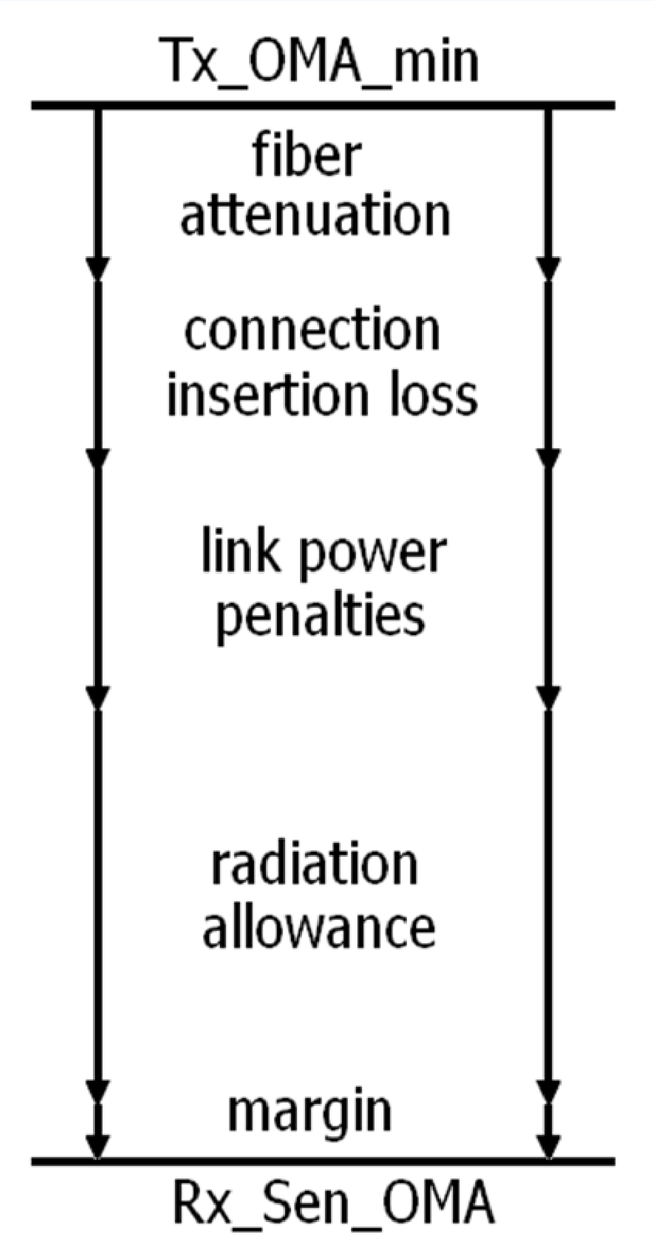
WP 1 – System

Versatile Link



VL Power Budget (SMU)

- 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/
- Based on simulation results, we propose to allocate 1.0 dB for MM and 1.5 dB for SM versatile link impairments. These results are verified by BER measurements on commercial transceiver modules.
- VL is specifically constrained by radiation degradation of front-end components.



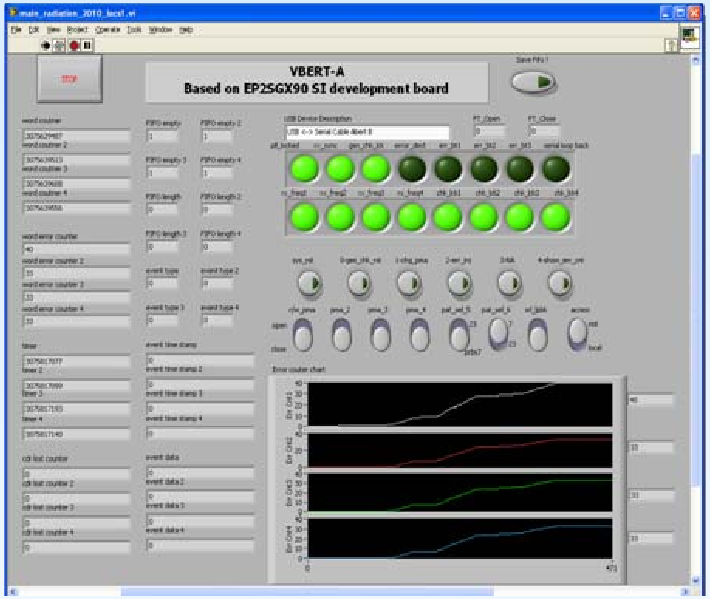
Versatile Link Proposed Power Budget (SMU)

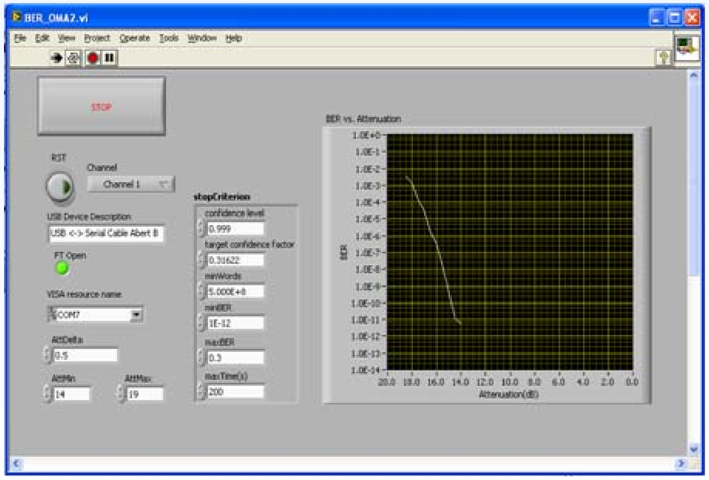
configuration/parameter	MM_VTx_Rx	MM_Tx_VRx	SM_VTx_Rx	SM_Tx_VRx
Transceiver power level				
Tx OMA min	-3.8 dBm	-2.0 dBm	-3.2 dBm	-2.8 dBm
Rx Sensitivity OMA	-11.1dBm	-13.1dBm	-12.6 dBm	-15.4 dBm
Power budget (Tx - Rx)	7.3 dB	7.3 dB	9.4 dB	9.4 dB
Fiber attenuation	0.6 dB	0.6 dB	0.1 dB	0.1 dB
Connection and splice 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 irradiation degradation	-	-	-	-
Rx irradiation degradation	-	7.0 dB	-	9.0 dB
Fiber irradiation degradation	1.0 dB	1.0 dB	-	-
Margin	3.2 dB	0.0 dB	5.8 dB	0.0 dB

- Extrapolated sLHC irradiation degradation deduced. Two downlinks run deficit. Extra power needed from Tx/Rx.
- Increased Tx power means less yield or special order from vendor. Increased Rx sensitivity means measureing every module, but VRx by design should have good sensitivity.
- After more stringent requirements on downlink Tx/Rx., all links now meet budget.
- Excess uplink power budget allows for higher data rate or longer length.

Versatile Link BER Tester (SMU)

- Versatile EVM kit includes: SFP+ carrier board, BER tester IP (VHDL+LabVIEW) based on Altera Stratix II GX signal integrity board.
- Current VBERT features
  - Simple physical layer protocol. PRBS (7,23,31) generator and error detector.
  - Error logging FIFO with 5Mbps throughput. Reserved stack to save all link status info.
  - Four duplex channels, up to 6.25Gbps, with analog adjustment.
- Current VBERT tests
  - In lab BER vs. OMA test routine.





Summary: Options (1)

Versatile Link

Front-End VTRx	Fibre	Back-End TRx
EE laser, 1310nm	SM	LR-SFP+ SNAP12 Opto Engine
VCSEL, 1310nm		
InGaAs PIN, 1310nm		
VCSEL, 850nm	MM	SR-SFP+ SNAP12 Opto Engine
GaAs PIN, 850nm		

Summary: Options and pending issues (2)

Front-End VTRx	Fibre	Back-End TRx
EE laser, 1310nm Drive current	SM	LR-SFP+ SNAP12/QSFP Opto Engine Tx or TRx Array availability Tx-OMA
VCSEL, 1310nm Compliance voltage, Operation in the cold, Availability, Reliability		
InGaAs PIN, 1310nm Radiation induced leakage@Vbias		
VCSEL, 850nm Compliance voltage, Operation in the cold, Reliability	MM Radiation Induced Attenuation in the cold	SR-SFP+ SNAP12/QSFP Opto Engine Tx-OMA
GaAs PIN, 850nm Rad-induced Responsitivity drop		
InGaAs PIN, 850nm Radiation induced leakage@Vbias		
GBLD Availability GBTIA Power rails		

Summary: Options and pending issues (3)

Versatile Link

Front-End VTRx	Fibre	Back-End TRx
EE laser, 1310nm Drive current	SM	LR-SFP+ SNAP12/QSFP Opto Engine Tx or TRx Array availability Tx-OMA
VCSEL, 1310nm Compliance voltage, Operation in the cold, Availability, Reliability		
InGaAs PIN, 1310nm Radiation induced leakage@Vbias		
VCSEL, 850nm Compliance voltage, Operation in the cold, Reliability	MM Radiation Induced Attenuation in the cold	SR-SFP+ SNAP12/QSFP Opto Engine Tx-OMA
GaAs PIN, 850nm Rad-induced Responsitivity drop		
InGaAs PIN, 850nm Radiation induced leakage@Vbias		
GBLD GBTIA Availability Power rails		

- Many of the pending issues are related to CMS/ATLAS tracker environment (low temperature, high radiation flux)
- Versatility might mean radtol and radhard variants are developed with different timescales

Summary: Options and pending issues (4)

Front-End VTRx RadTol	Fibre	Back-End TRx
EE laser, 1310nm Drive current	SM	LR-SFP+ SNAP12/QSFP Opto Engine Tx or TRx Array availability ~~Tx-OMA~~
VCSEL, 1310nm Compliance voltage, ~~Operation in the cold,~~ Availability, Reliability		
InGaAs PIN, 1310nm ~~Radiation induced leakage@Vbias~~		
VCSEL, 850nm Compliance voltage, ~~Operation in the cold,~~ Reliability	MM ~~Radiation Induced Attenuation in the cold~~	SR-SFP+ SNAP12/QSFP Opto Engine ~~Tx-OMA~~
GaAs PIN, 850nm ~~Rad-induced Responsitivity drop~~		
InGaAs PIN, 850nm ~~Radiation induced leakage@Vbias~~		
GBLD Availability / GBTIA Power rails		

Conclusions

- 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
  - To be replaced by interim Phase IIb?
    - Consolidation? Arrays? Low power?