Tests of Opto-electronics for SuperB: Preliminary Results

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Outline

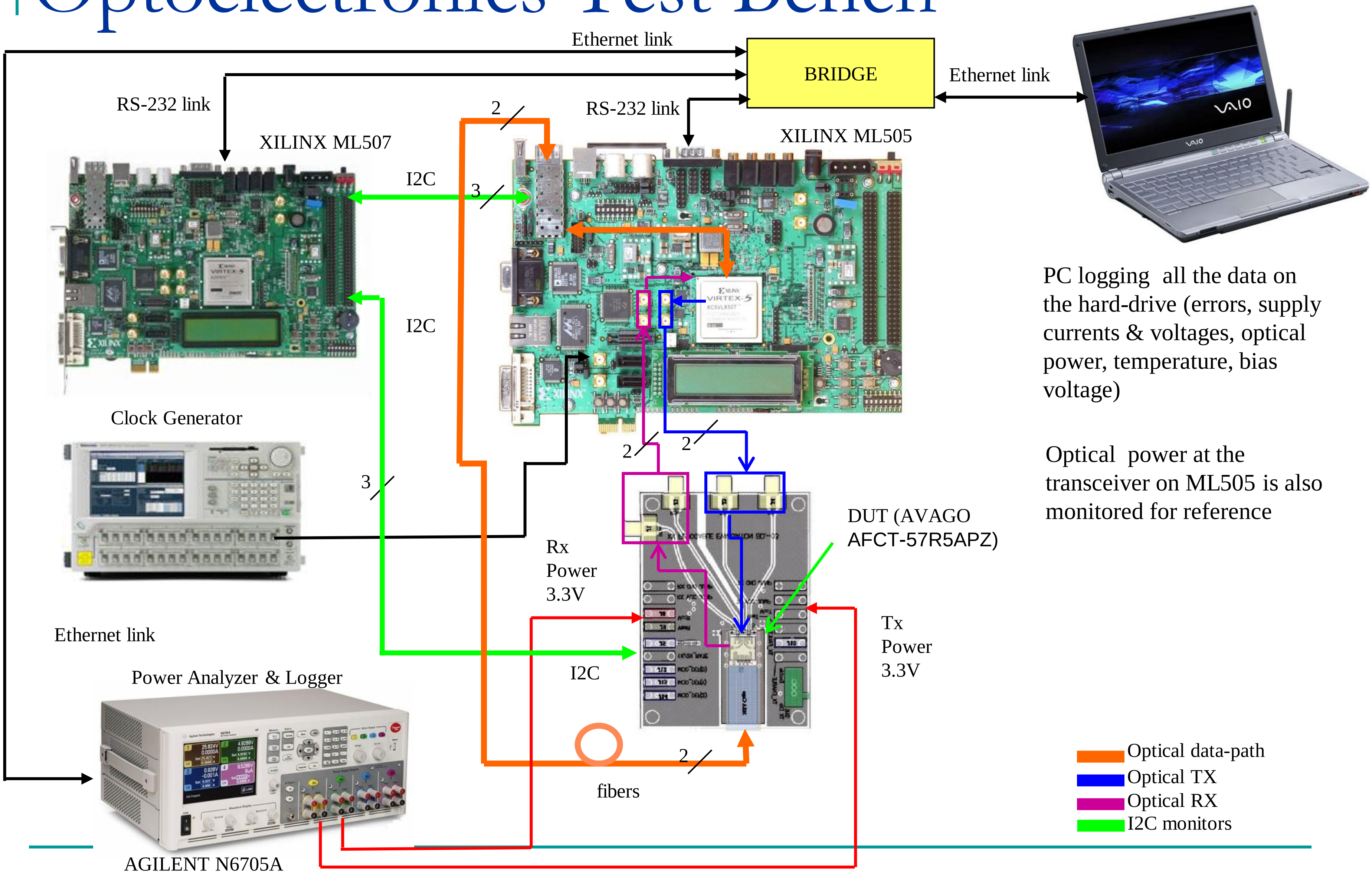
- Avago Optical Transceivers
- Test Bench
- Test Results
- Conclusions

Avago Transceiver

- AFBR-57R5APZ
- High performance 850 nm VCSEL for multi-mode fibers
- Data rate up to 4.25 Gbps
- Link lengths at 2.125 Gbps : 300 m with 50 µm MMF, 150 m with 62.5 µm MMF
- Separate Power Supply for Tx & Rx (3.3 V)
- Embeds uC for real time monitoring of
  - Average transmitted & received optical power
  - Laser bias current
  - Temperature
  - Supply voltage

SFP case

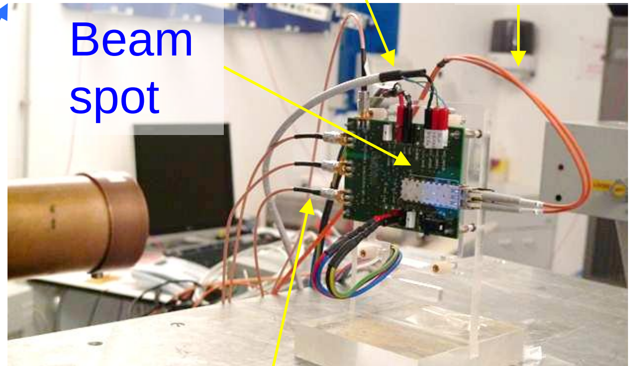
Optoelectronics Test Bench

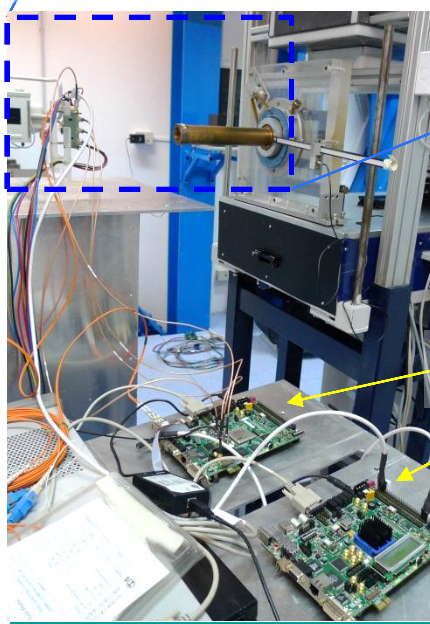


PC logging all the data on the hard-drive (errors, supply currents & voltages, optical power, temperature, bias voltage)

Optical power at the transceiver on ML505 is also monitored for reference

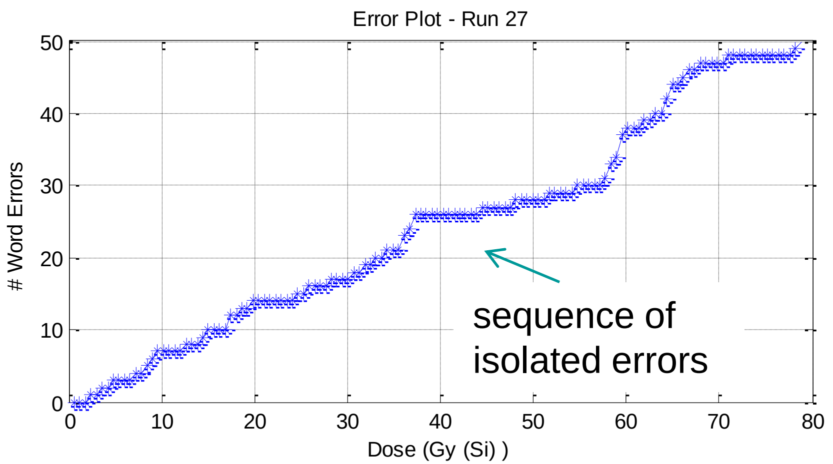
On-Beam Setup

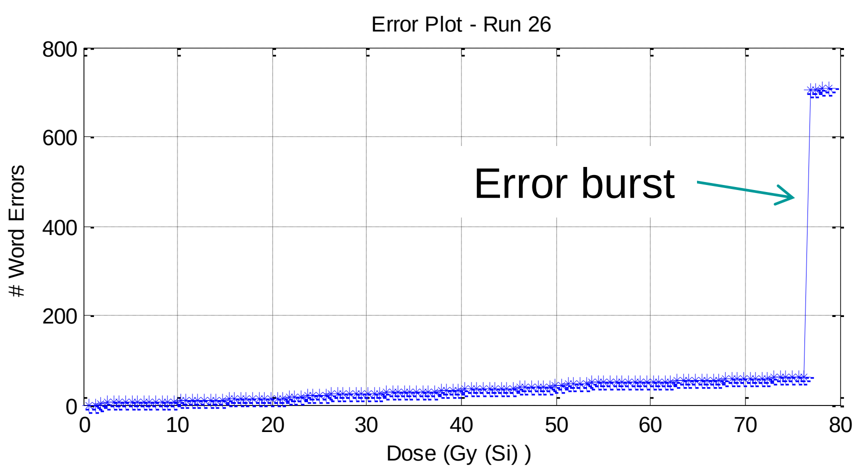




- Test conditions
  - Line rate = 2 Gbps
  - Data encoded with 8b10b protocol
  - Vcc set to minimum (3.0V), typical (3.3V), maximum (3.6V) to investigate for power supply dependence of rad tolerance
  - Runs with different dose rates from 1.2 to 3.8 Gy(Si)/min
  - total dose of 354 Gy (Si)
  - 50 µm multimode fibers
  - 10dB attenuators for the off-beam receiver and transmitter

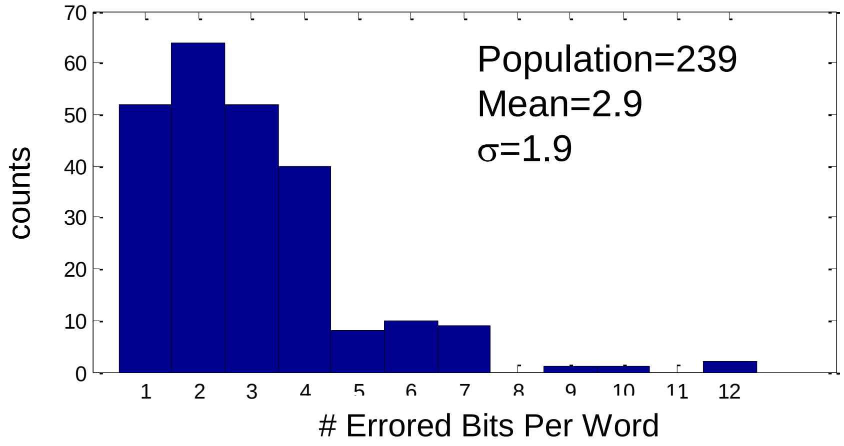
Word Error Trends

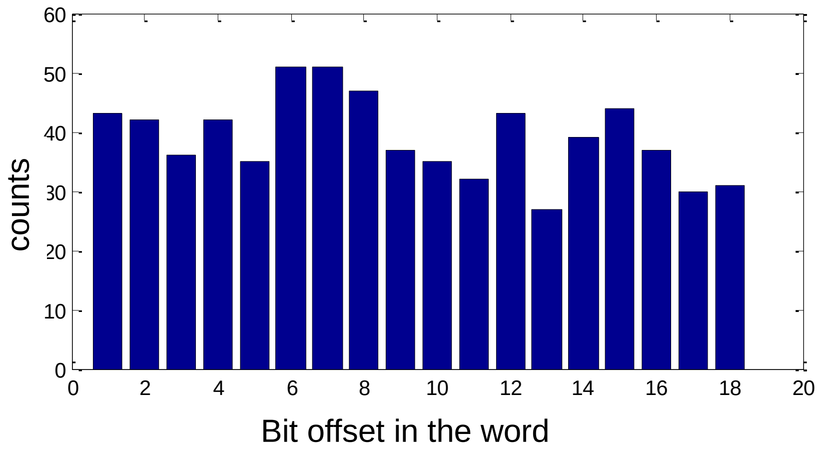




- No errors at all at the transmitter
- At the receiver, both isolated and burst errors ('many' consecutive incorrect words)
- 239 isolated errors
- 4 burst errors (80, 640,710,740)
- What is the cause of error bursts? uC failure? Photodiode? TIA? Discriminator?

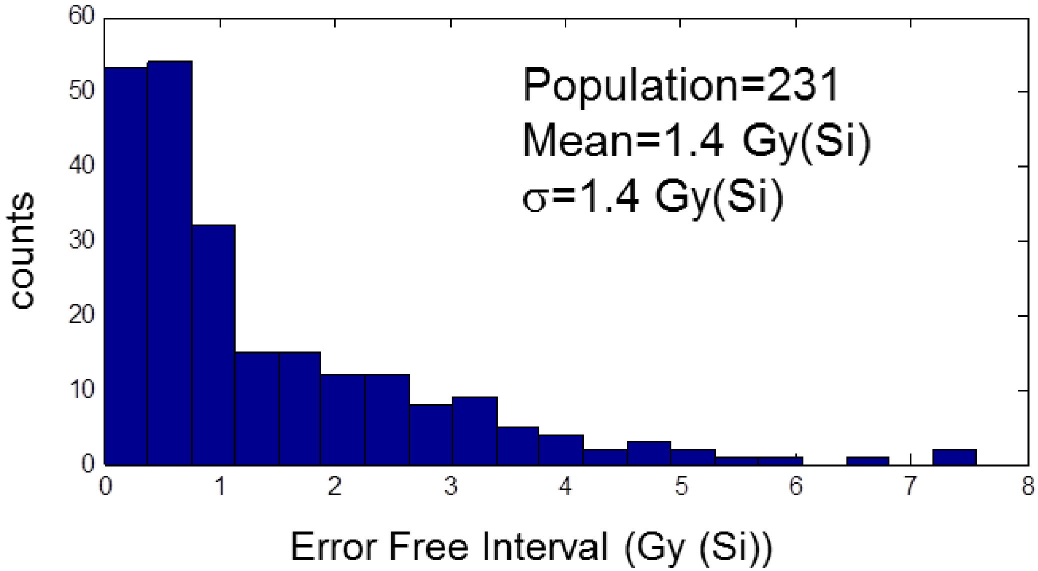
Error Distributions





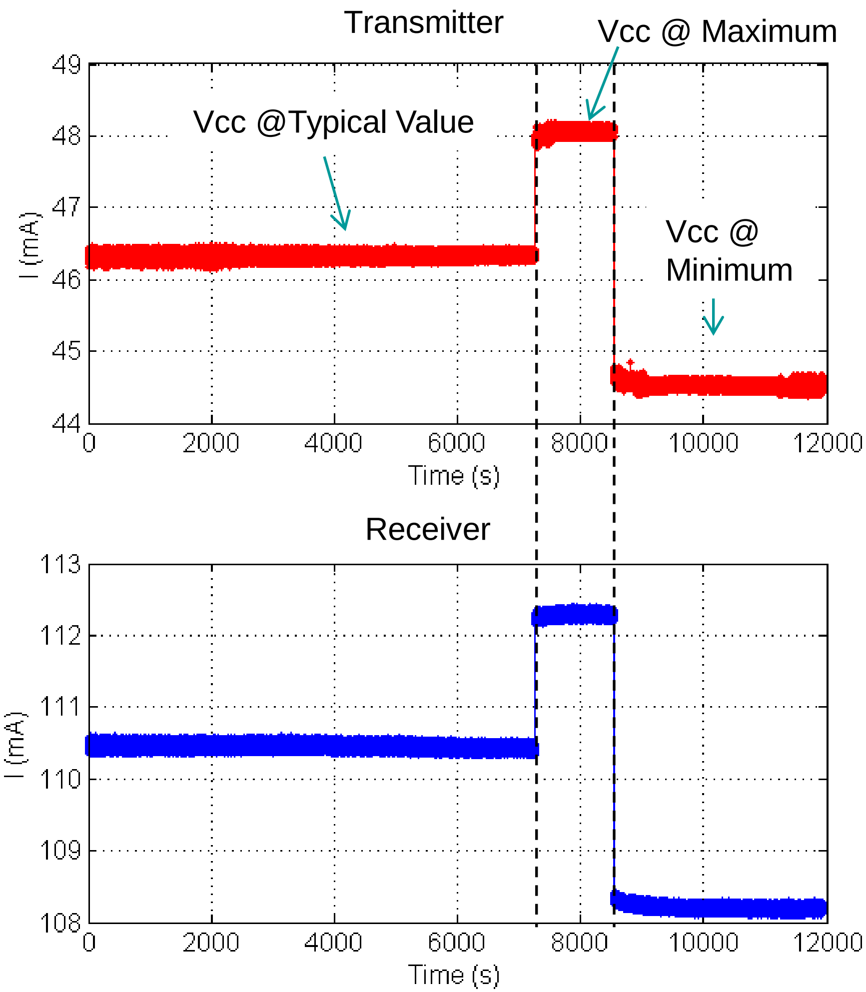
- Overall for the runs, cutting burst errors off
- More than 80% of the word errors have less than 5 incorrect bits
- Nearly flat distribution of bit errors inside errored words

Error Free Interval



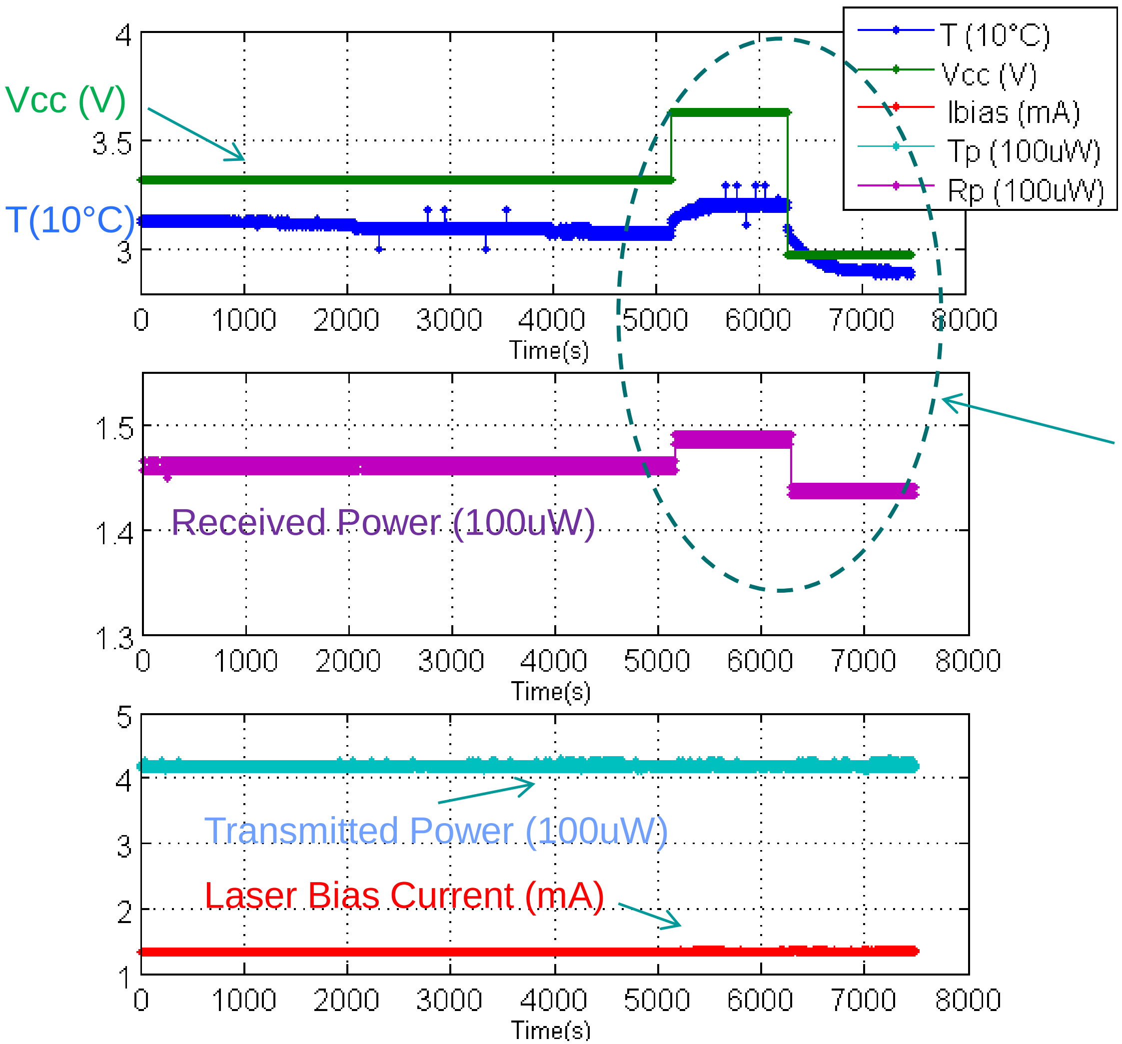
- On average 1.4 Gy (Si) absorbed dose between an error and the next one
- Probably good fit with an exponential (to be done) =>
- Errors are independent events
- Assuming total dose equivalent to 5 kGy (Si) of 62-MeV protons in 10^7 s (43 Gy(Si)/day) =>
- 30 word errors per day

Current Trends



- Current drawn by both tx and rx did not change due to irradiation
- Steps due to intentional variation of the supply voltage (typ to max and max to min)

Optical Power Logs



- Optical power for both tx and rx did not change due to irradiation
- Variation in the received power due to intentional variation of the supply voltage

From Belle

Optical Transceivers vs. γ-Rays

Belle tested the same transceiver

- **AVAGO** **(AFBR-57R5APZ)**
  1. Killed by 3.4-year-equivalent dose (126Gy/h × 160min). [336 Gy]
  2. Killed by 3.0-year-equivanent dose (169Gy/h × 108min). [304 Gy]
- **FINISAR** **(FTLF8524P2BNV)**
  1. Killed by 3.4-year-equivalent dose (126Gy/h × 160min).
  2. Killed by 3.3-year-equivalent dose (169Gy/h × 118min).

Threshold is around 3-year-equivalent γ-ray dose.

- **More rad-hard transceiver option**
  – We will study a more rad-hard 2Gbps transceiver used in PHENIX, which will work for >10-yr-equivalent γ-ray dose.

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From Belle (2)

Estimation of Belle II Radiation

	Neutrons	γ-rays
Dose / electronics	~10^{11} / year	~ 100 Gy / year
Peak energy	~ 5 MeV	~ 8 keV and m_e

Belle II will run for >10 years.

Tough electronics against the radiation is one of key issues for the stable Belle II DAQ.

Hereafter, 1-year-equivalent neutron dose = 10^{11} neutrons
1-year-equivalent γ-rays dose = 100 Gy

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From Belle (3)

FPGA vs. γ-Rays

- **Virtex5 FPGA**
  1. Survived for 7.9-year-equivalent dose [790 Gy]
     - 126Gy/h × 180min + 169Gy/h × 146min.
  2. Survived for 73-year-equivalent dose. [7.2 kGy]
     - 2.1kGy/h × 206min.
  3. Survived for 88-year-equivalent dose [8.7 kGy]
     - 100Gy/h × 60min + 5.4kGy/h × 96min.

The Virtex5 is tough against γ-ray dose.

We observe no SEU.

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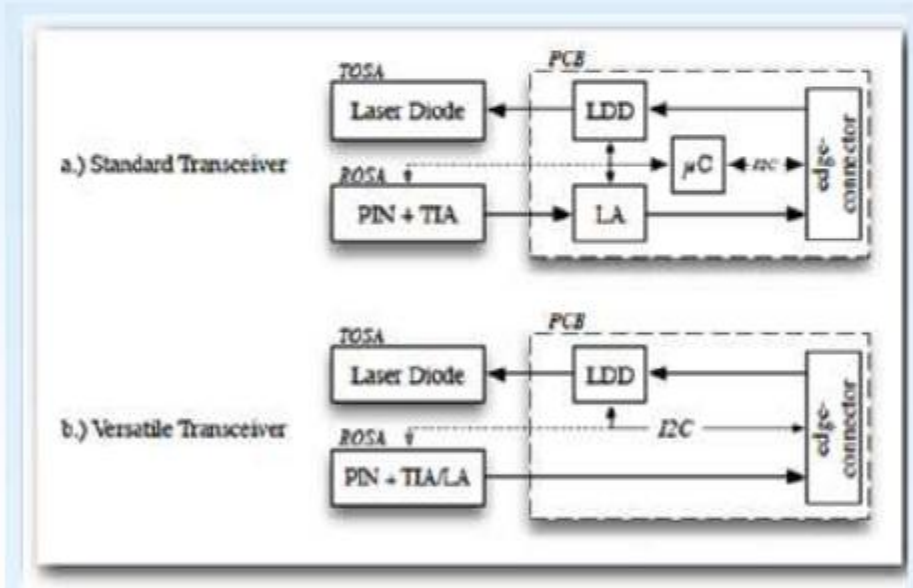
From Versatile Link

March '12

Front-end Transceiver: VTRx (CERN)

Versatile Link

- Adapt commercial SFP+ Transceiver → laser in hermetic TO can.
  - Low mass, small & non-magnetic
  - Radiation-tolerant
- Two flavours
  - 850/1310 nm
- Bitrate 5 to 10 Gbps
  - Depends on ASICs
- Radiation-tolerant ASICs (GBT project)
  - Laser Driver: GBLD
  - *p-i-n* receiver: TIA/LA



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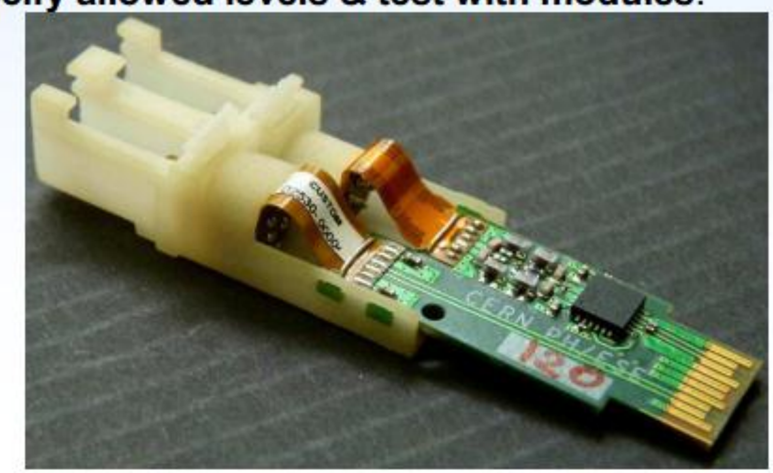
From Versatile Link (2)

March '12

VTRx Package Developments

Versatile Link

- Prototypes VTRx (TX & RX) and dual VTTx produced using rapid prototyping.
- Tested over temperature range from -30C to +60C.
- Will produce 30 prototypes for users.
- EMI testing
  - **No indication of excess emissions**
  - **Need to specify allowed levels & test with modules.**



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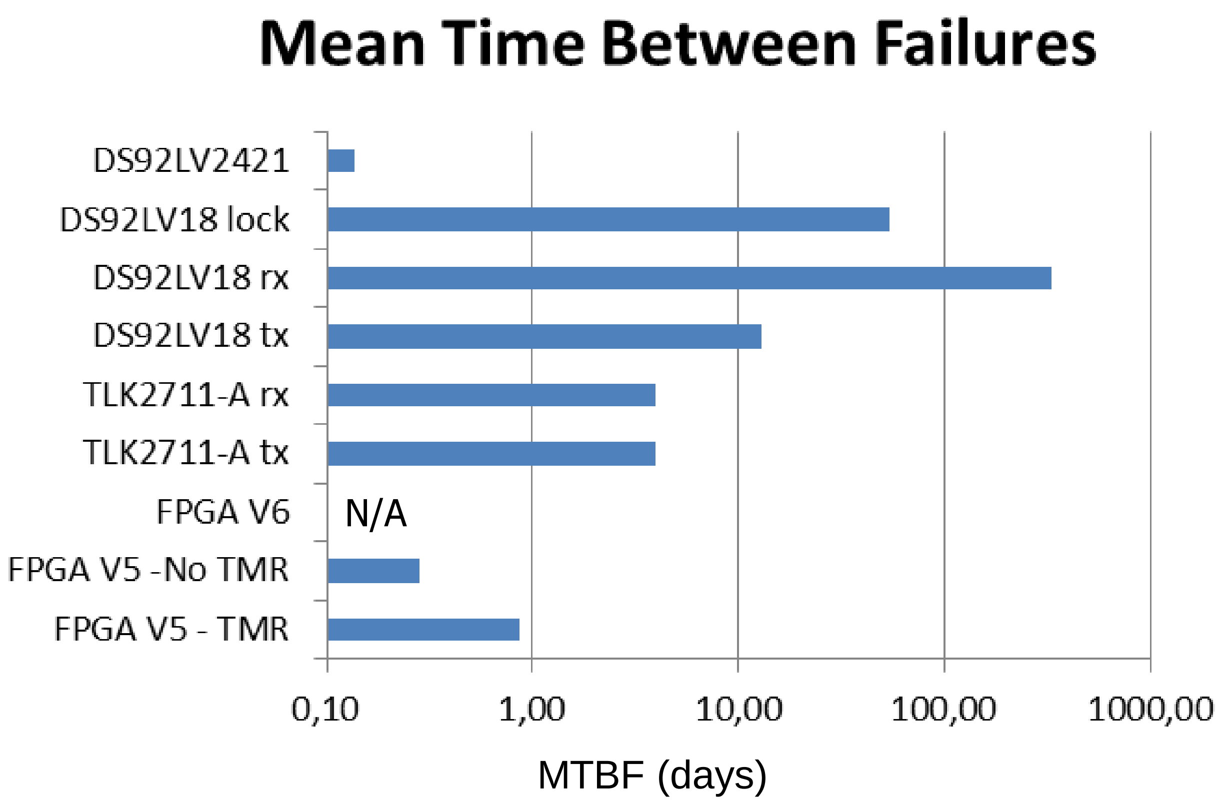
Conclusions

- This test has been performed with 8b10b coding, and the following considerations might depend on that
- For a total dose equivalent to 5 kGy (Si) of 62-MeV protons in 10^7 s we get ~ 30 word errors (~ 90 bit errors) per day
- Error composition: isolated (98.4%) and burst errors (1.6%)
- Assuming to use the most reliable SerDes we tested (DS92LV18)
  - optical transceivers would be the dominant source of errors
  - 10% of word errors trigger losses of lock (i.e. loss of recovered clock) => 9 per effective day => in a sense this would be less reliable than FPGA-based links
- Belle tested the same optical transceiver and reports devices cannot tolerate more than 320 Gy (Si) of γ
- Belle aims at deploying FPGAs on detector, V5 tested with γ neither SEUs nor TID effects
- Versatile Link prototyped 5 Gbps optical transceivers
- We will have the next testbeam in July (Catania, 62-MeV protons), will further test the optical transceivers without coding

Back-up Slides

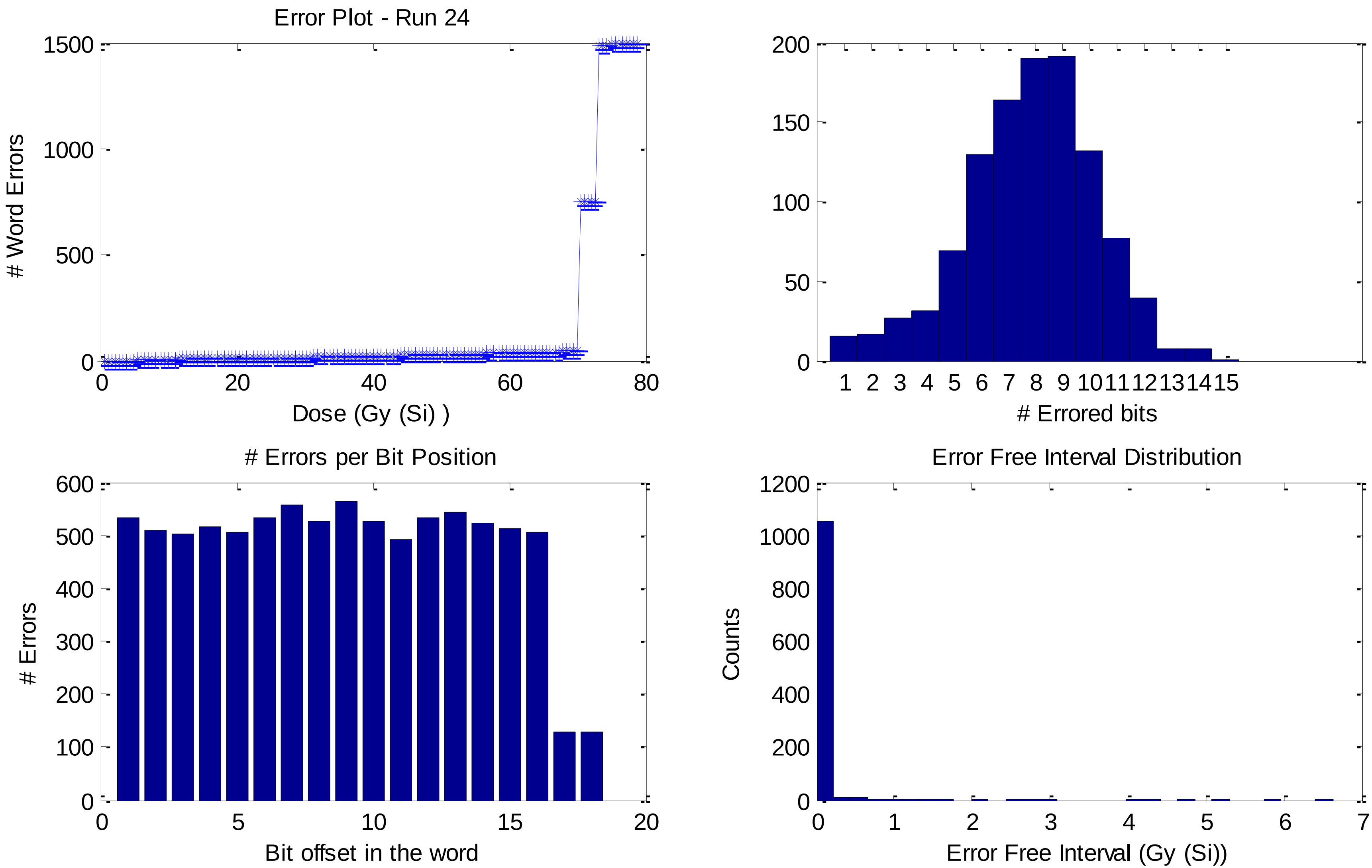
Summary of SerDes Performance

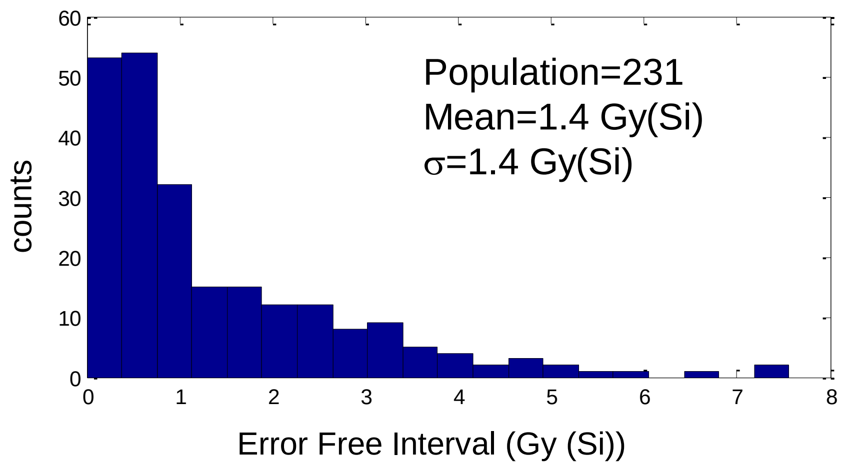


Expected failure rates at SuperB for a 5 kGy (Si) dose in one effective year (10^7s)

- DS92LV2421: no current variations, but many burst errors even in mild irradiation conditions, it is the least tolerant device
- DS92LV18: SEUs and current variation due to TID
- TLK2711A: SEUs and unrecoverable failure at 460 Gy (Si)
- V5 FPGA: SEUs and current trend removed by re-configuration, no TID effects
- The DS92LV18 is the most reliable among the tested SerDeses to date

Burst Errors




Population=231
Mean=1.4 Gy(Si)
σ=1.4 Gy(Si)
counts
Error Free Interval (Gy (Si))
0
10
20
30
40
50
60
1
2
3
4
5
6
7
8