Opto-Link Options

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Acknowledgement
Ohio State/Oklahoma/Oklahoma State Universities

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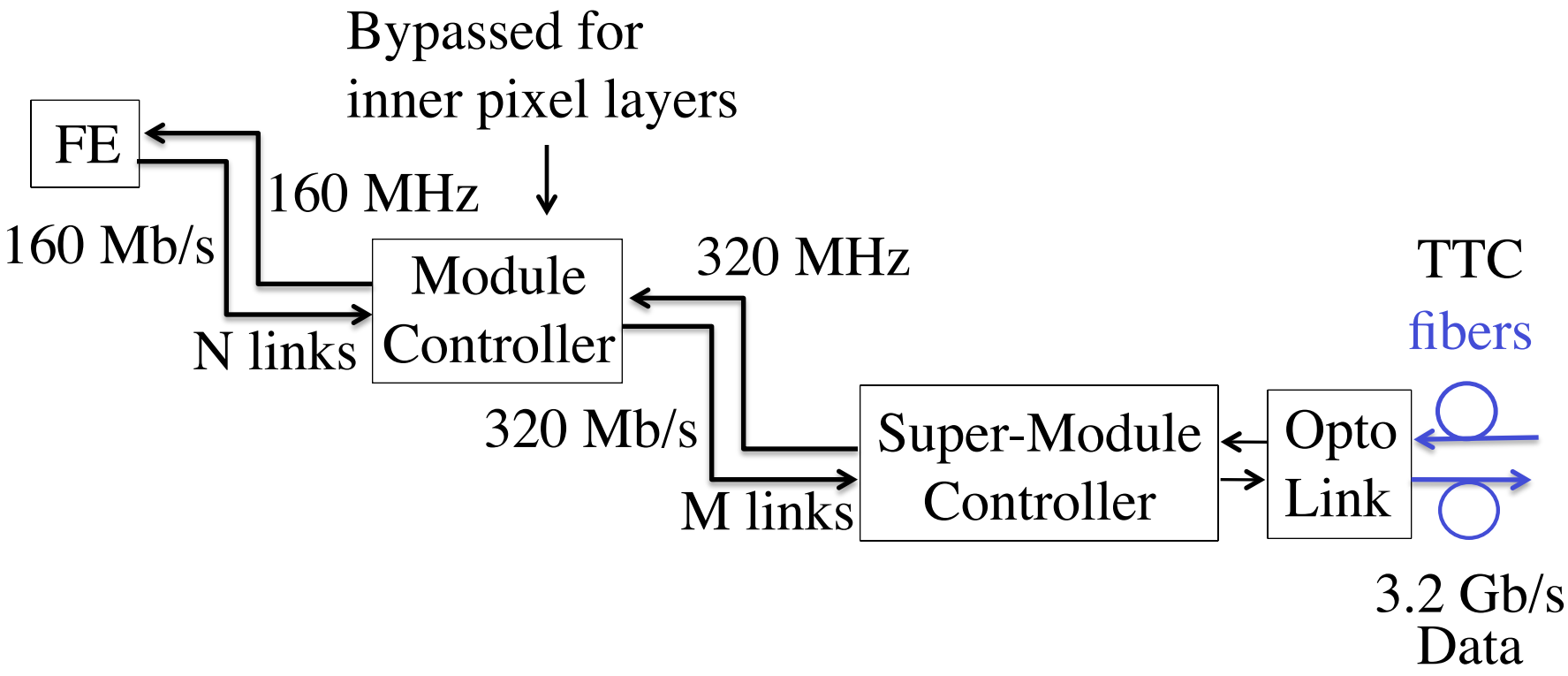
Outline

- Architecture
- PIN/VCSEL arrays
- Opto-pack
- Opto-chips
- Fibers
- Cables
- Summary

Read Out Architect

- G. Darbo, P. Farthouat, A. Grillo, ATL-P-EN-0001

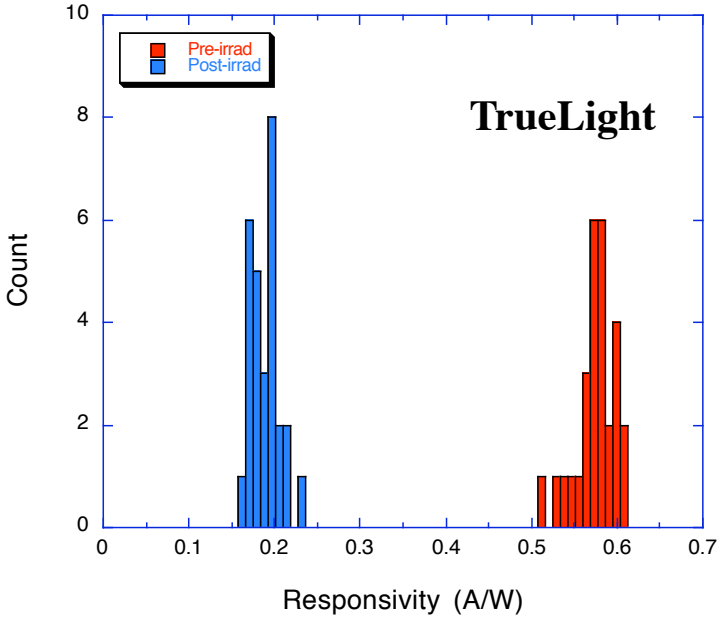


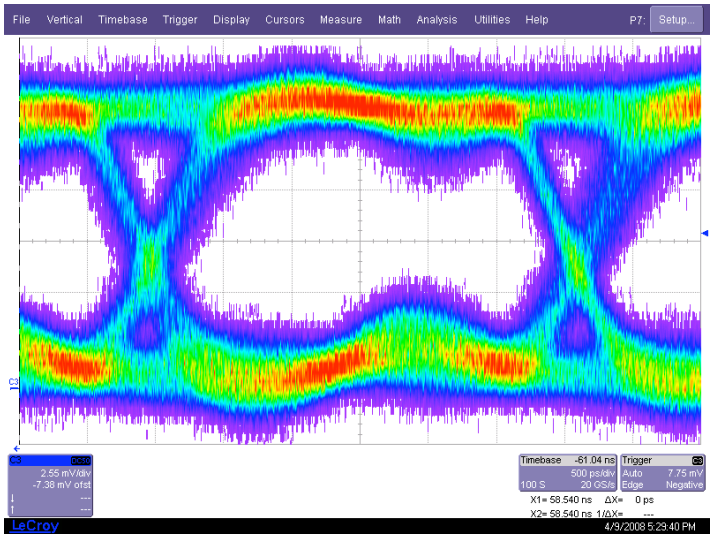
SLHC Opto-Link Channel Count

R	staves	stave width	modules/ stave	½ stave rate	SMC/ stave	Links
cm		cm		Gb/s		
3.7	12	2	24	6.9	6	73
6	20	2	24	4.8	4	79
12	20	4	32	4.3	8	158
16	26	4	32	3.0	4	106
20	33	4	32	2.2	4	132

- Total number of SLHC barrel links: 548
  - current LHC barrel links: 1,458
  - ⇨ number of links @ SLHC is manageable
  - ⇨ no need to transmit at higher rate (> 3.2 Gb/s)

Radiation-Hardness of Silicon PIN

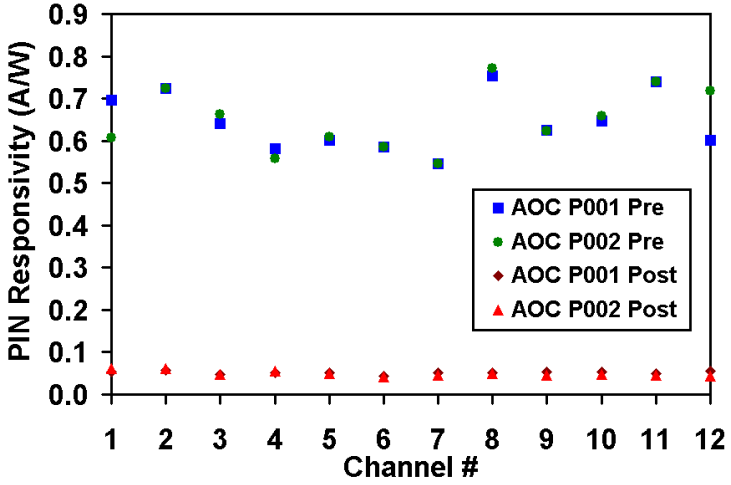


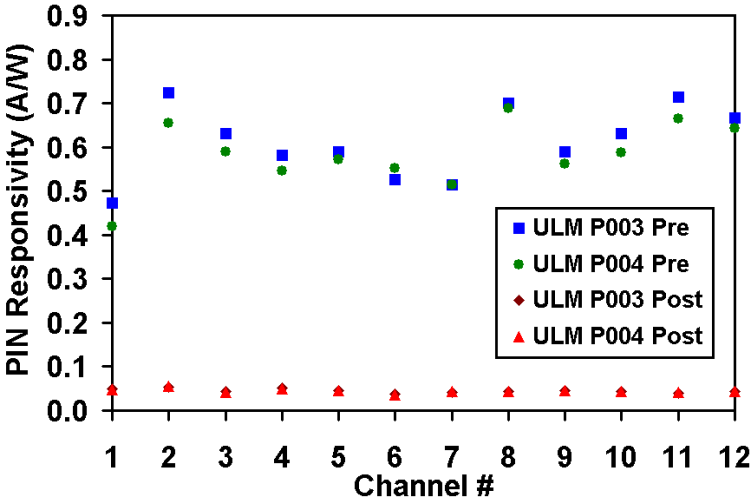


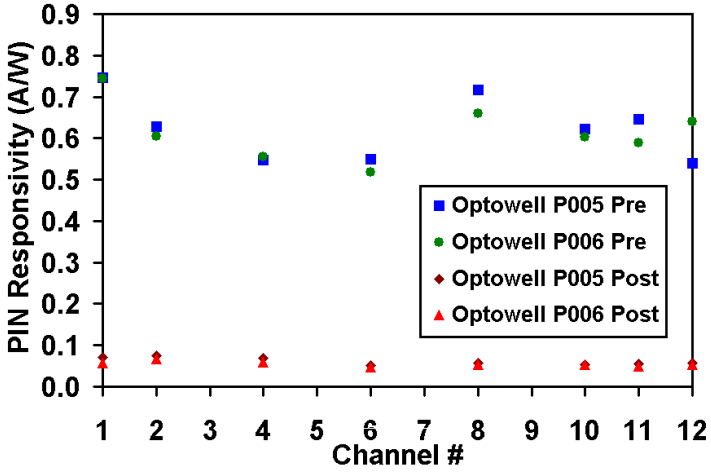
320 Mb/s (irradiated)

- irradiate PIN/VCSEL arrays with 24 GeV protons at CERN
- PIN responsivity decreases by 3x at 114 Mrad
  - SLHC at PP0: 69 Mrad or 1.5 x 10^{15} 1-MeV n_{eq}/cm^2 for $3{,}000^{-1}$ fb with 50% safety factor
- 320 Mb/s transmission is adequate

Radiation-Hardness of GaAs PIN

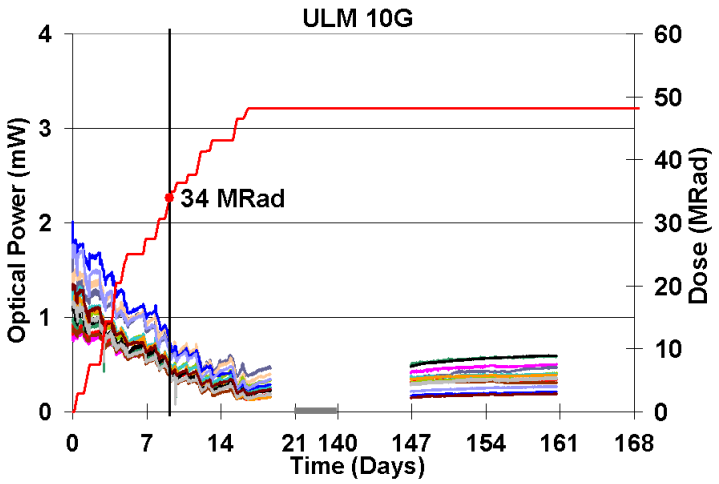


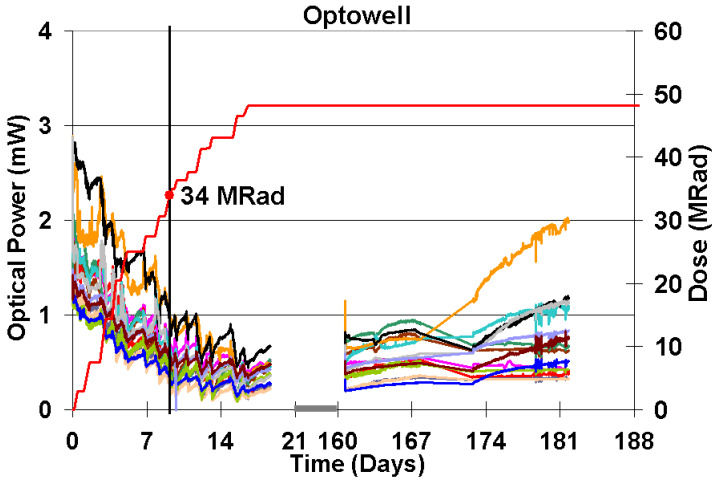


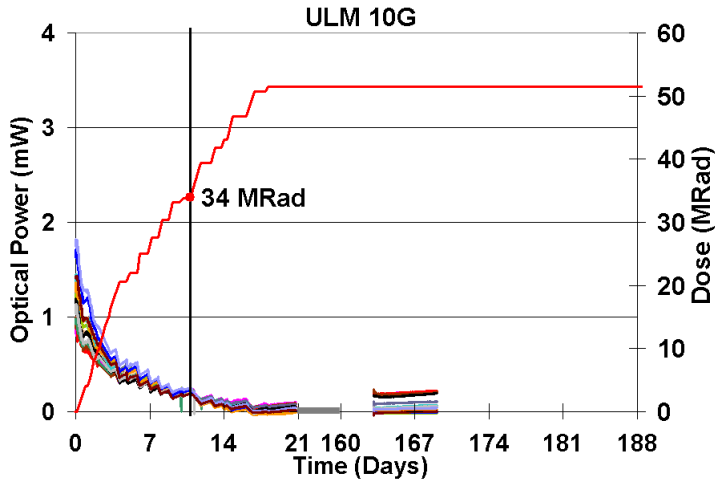


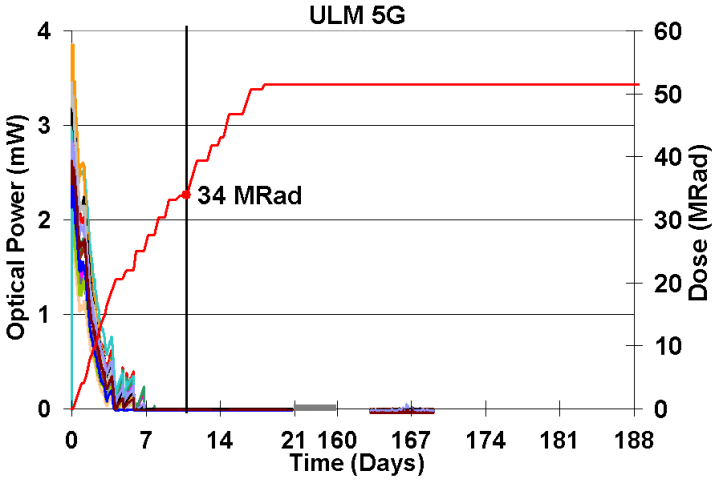
- all arrays are front side illuminated
- PIN responsivities decrease by ~10x at 53 Mrad
- should repeat irradiation to SLHC dosage of 34 Mrad (8.2 x 10^{15} 1-MeV n_{eq}/cm^2)

Annealing of VCSEL Arrays



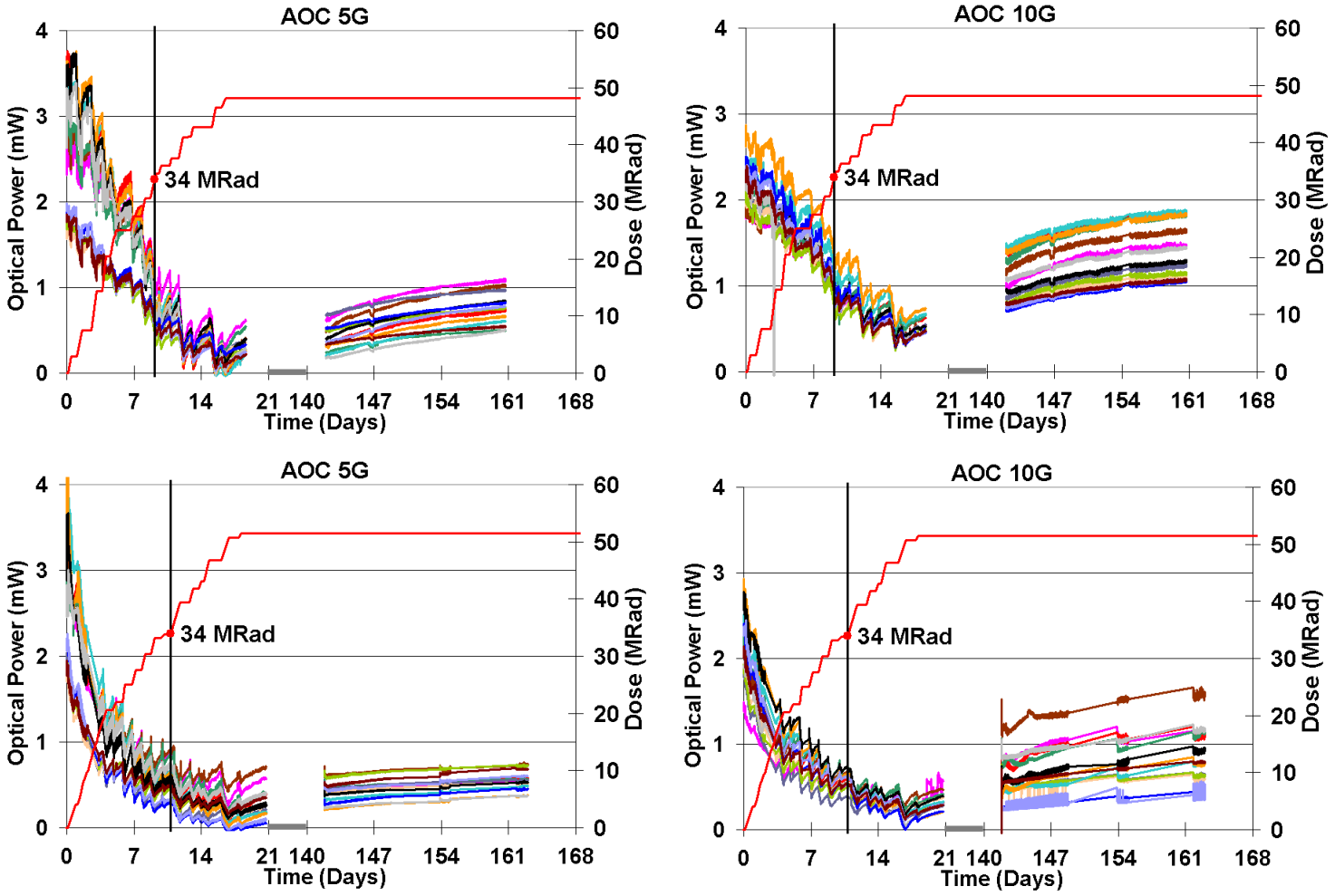






- recovery is slow
- Optowell has the highest annealed power

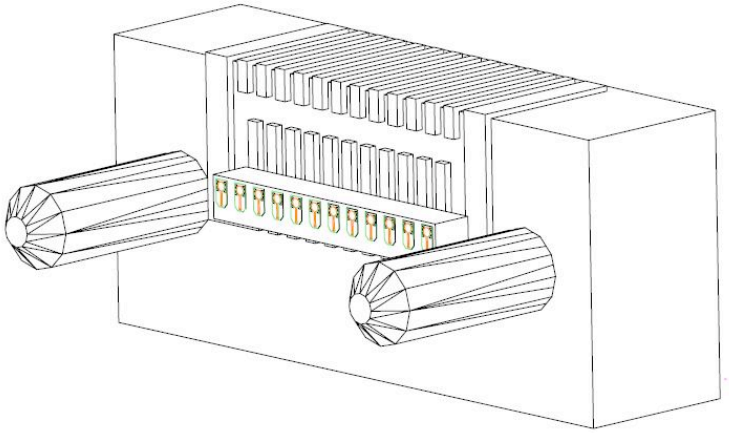
Annealing of VCSEL Arrays

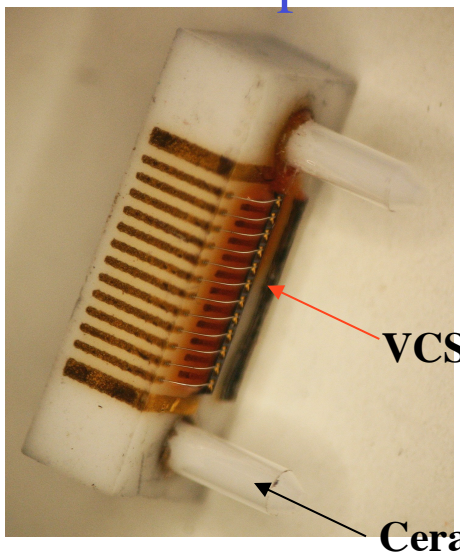


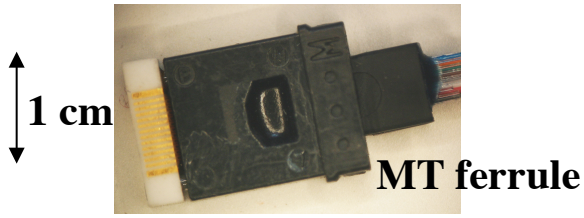
- recovery is slow but adequate annealed power

Opto-Pack

- current pixel detector uses Taiwan optical packages
  - ☹ VCSEL mounted on PCB with poor heat conduction
  - ☹ micro soldering of 250 μm leads is difficult
- Ohio State develops new opto-pack for SLHC
  - uses BeO base with 3D traces for efficient heat removal
  - wire bond to driver/receiver chip
  - new opto-packs have good coupled power
- next: modify MPO connector to replace current housing







Versatile Link

- CERN's project to develop single-channel opto-link:
  - work with vendors to modify commercial opto-packs
  - evaluate radiation-hardness of opto components
  - institutions: CERN, Oxford, SMU
  - work on multiple-channel opto-links (arrays)

  by pixel group complements their effort
  - in close collaboration with VL to take advantage of their R&D

Opto-Chips

- 4 mm^2 prototype chip:
  - PIN receiver/decoder operating at 40, 160 and 320 MHz
    - use bi-phase marked encoding due to the low speed
  - VCSEL drivers operating at 640 Mb/s and 3.2 Gb/s
  - both designs take advantage of LHC experience
  - SMC block: 640 MHz serialization clocks
    - SEU tolerant multipliers (16 x 40 MHz or 4 x 160 MHz)
  - extracted simulations show full functionality
- layout was reviewed at CERN on March 11, 08
- submitted to IBM via CERN to MOSIS on March 24, 08
- delivery date: July 08
- irradiation: August 08
  - study radiation-hardness and SEU

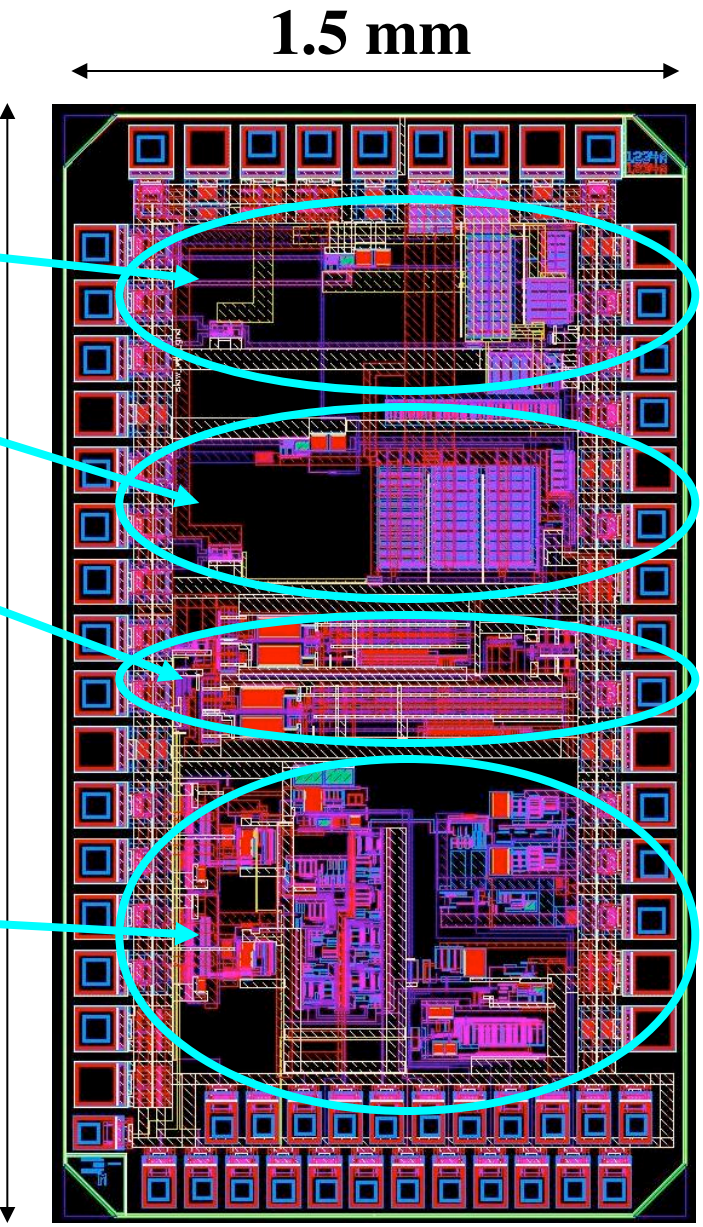
Opto-Chips

640 Mb/s VCSEL Driver

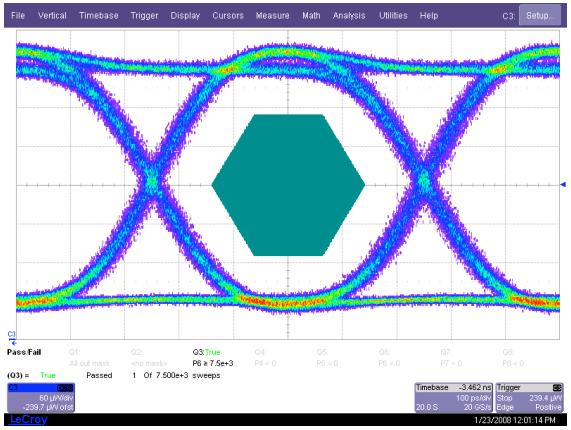
3.2 Gb/s VCSEL Driver

640 MHz clock multipliers (4 x and 16 x)

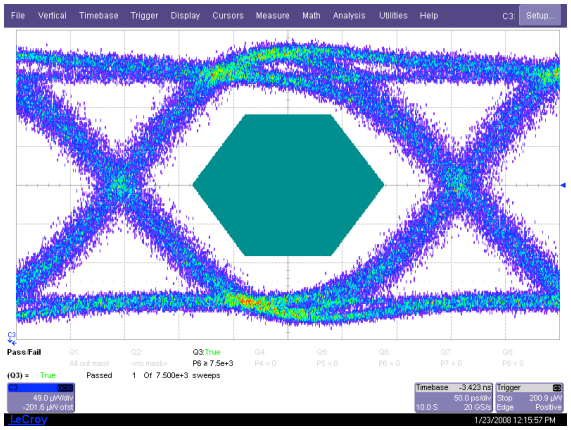
PIN receiver/decoder



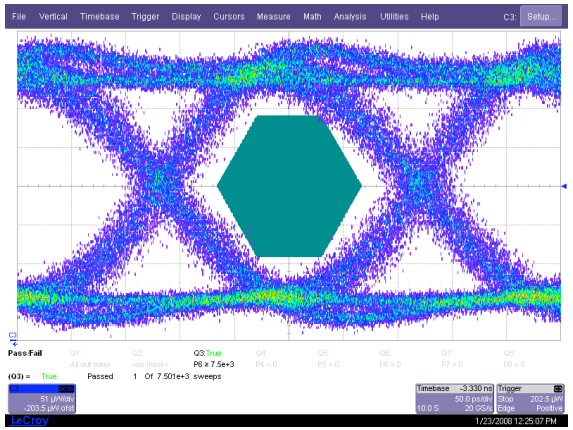
Bandwidth of Fiber



2 Gb/s



3.2 Gb/s



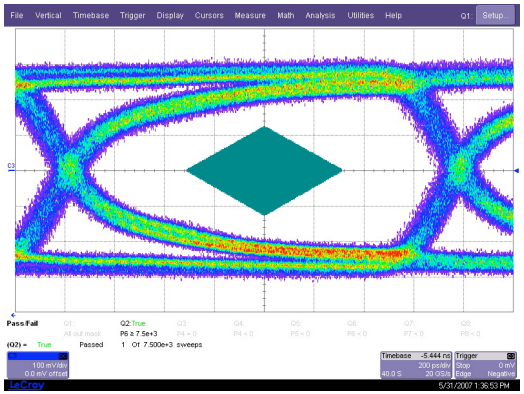
4.25 Gb/s

- current opto-link: 11 + 80 m spliced SIMM/GRIN fiber
  - transmission at 3.2 Gb/s is adequate
  - current SLHC architecture calls for raw rate of 3.2 Gb/s plus 20% overhead for 8b/10b encoding
  - ⇨ more efficient encoding will improve margin of operation
- new Corning fibers have higher bandwidth
  - will be irradiated by Oxford/SMU this summer

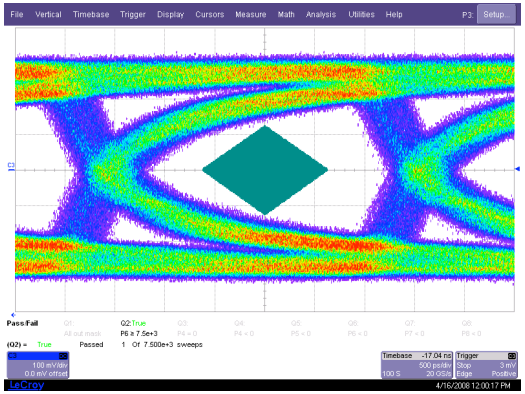
Eye Diagrams

100 μm current pixel cable

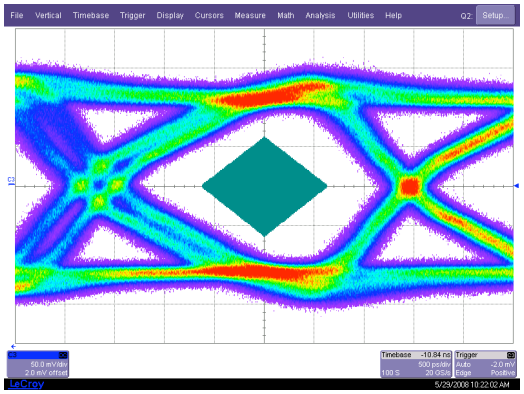
640 Mb/s
1.4 m



320 Mb/s
3 m



320 Mb/s
4 m
Pre-emphasis

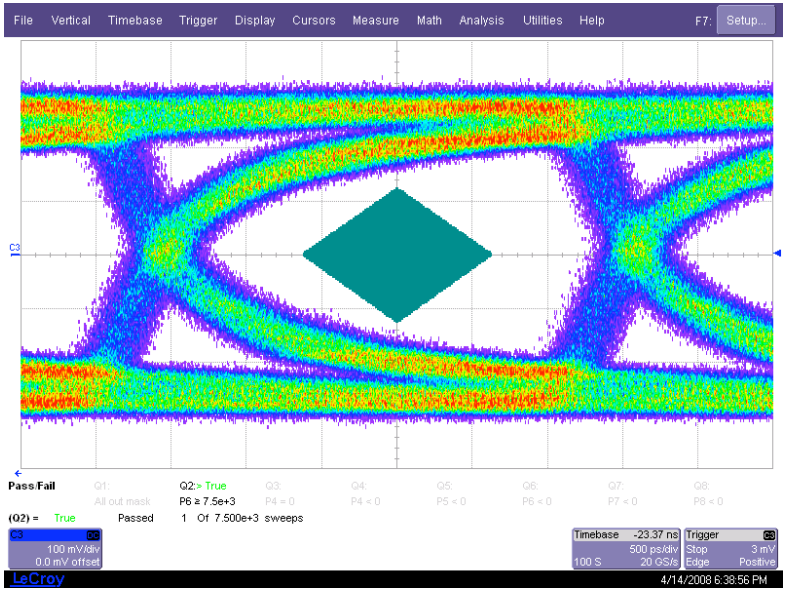


- Signals from modules can be sent to current PP0 location (1.4 m)
- Signals from modules (320 Mb/s):
  - can be transmitted up to ~ 3 m
  - can be transmitted up to ~ 4 m with pre-emphasis

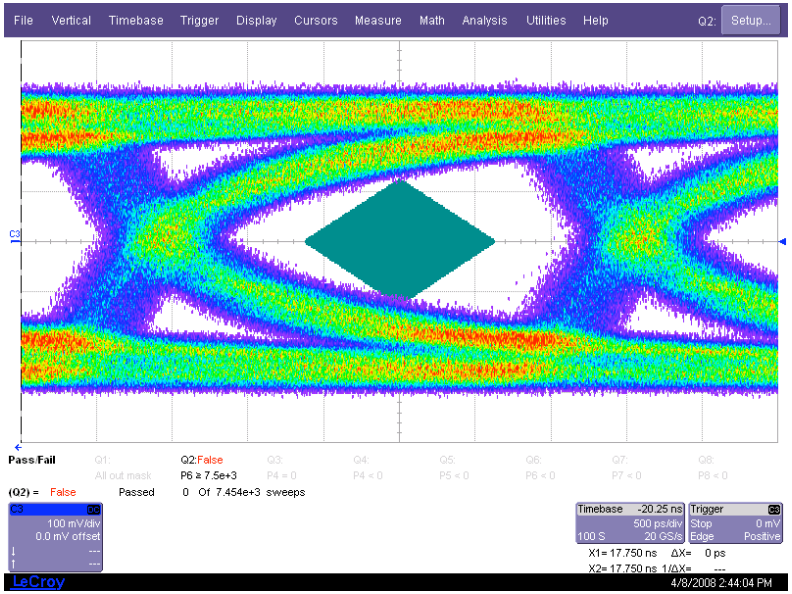
Eye Diagrams

1 mm TRT shield twisted pair (320 Mb/s, 100 Ω)

4 m



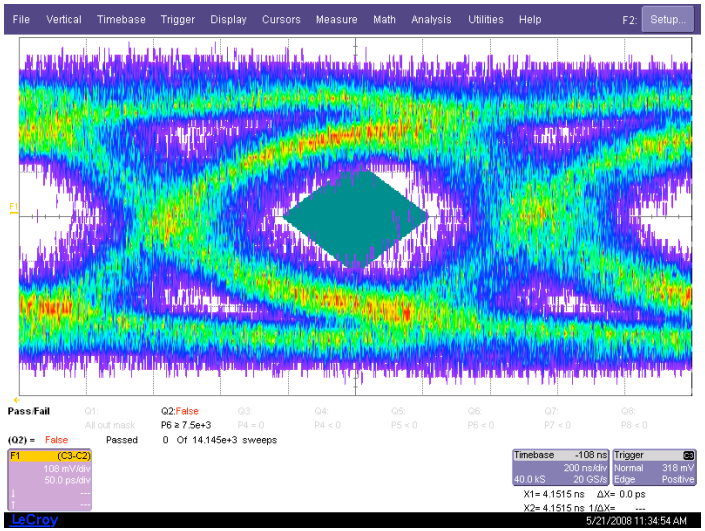
5 m

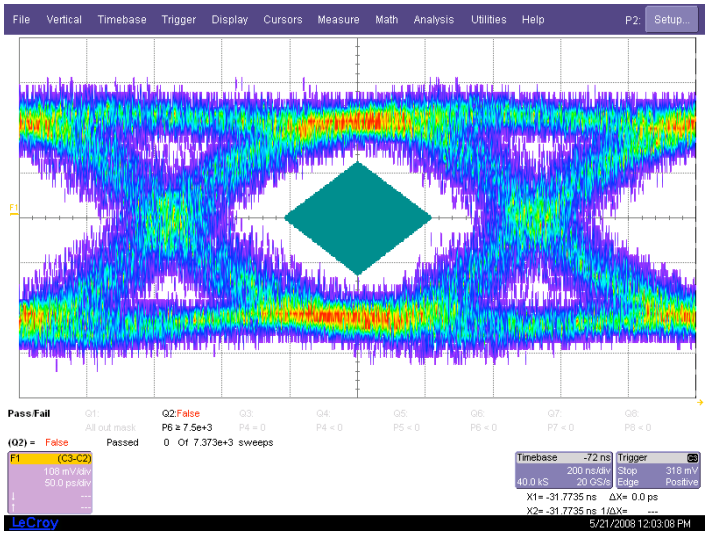


- Signals from modules (320 Mb/s) can be transmitted up to 4 m

Eye Diagrams

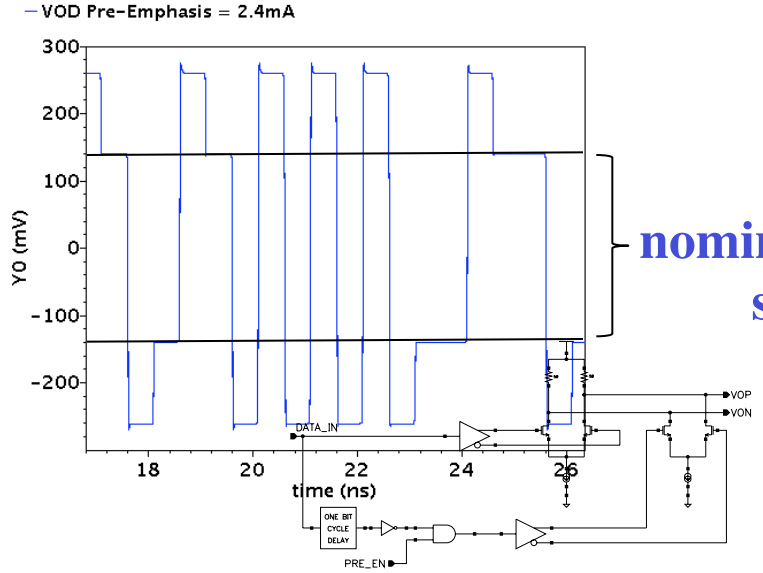
Pre-emphasis





- Use 4 m of Belden 1674A micro coax with 1.2 mm OD
  - transmit LVDS signals at 3.7 Gb/s on two coax
- Use Altera Stratix II GX to study pre-emphasis settings
  - use 8B/10B encoding
- pre-emphasis opens up the eye diagram

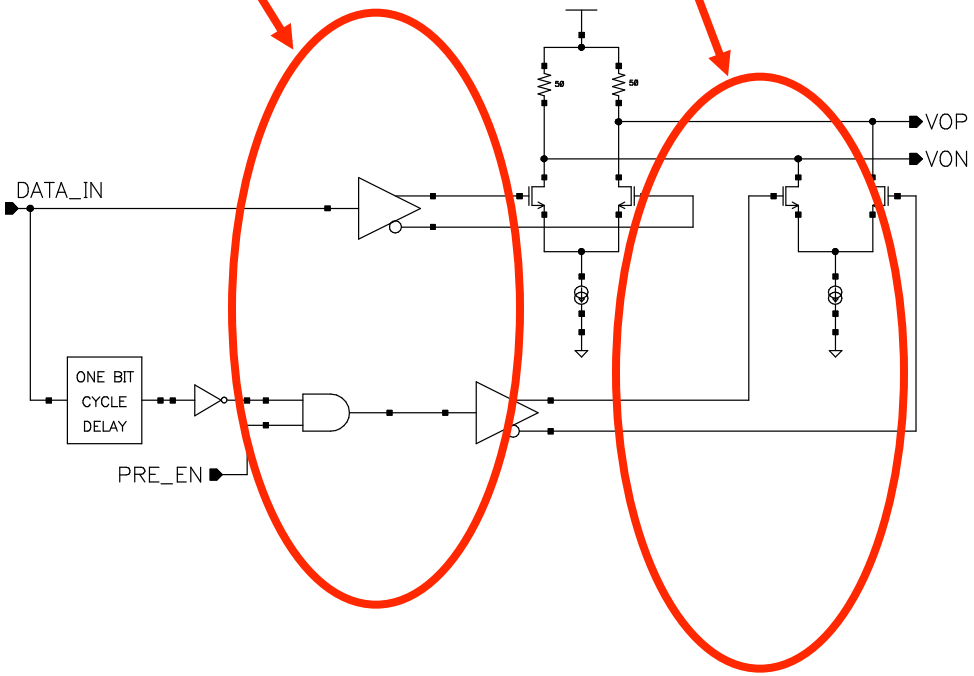
CMOS Driver with Pre-Emphasis



nominal

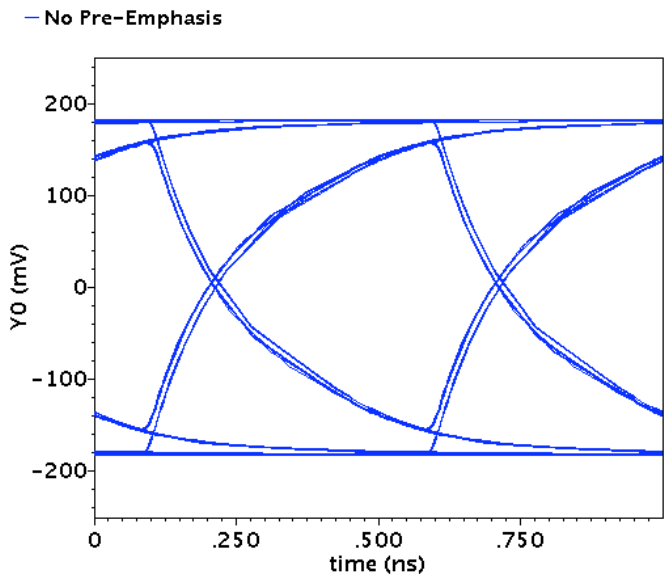
pre-emphasis tap supplies additional current as needed

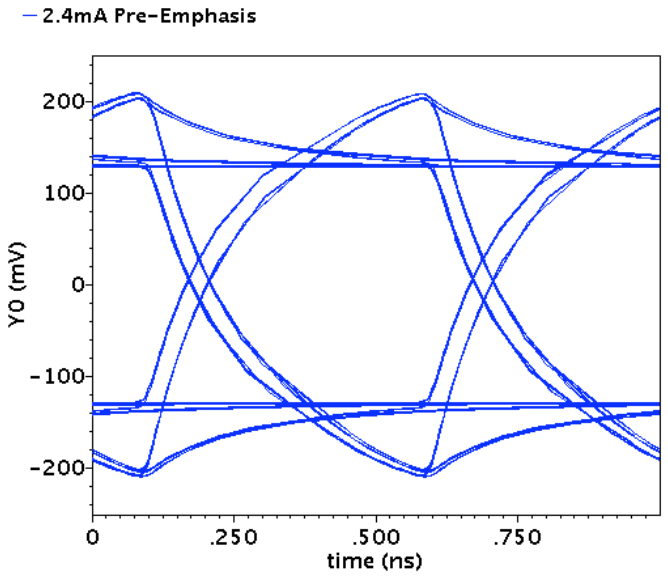
set nominal drive current



preliminary 130 nm design

CMOS Driver Simulation





Pre-emphasis

- Preliminary test with RC transmission line:
  - pre-emphasis opens the eye diagram

Opto-Link Locations

- Use skinny cables to transmit 320 Mb/s signal
  - no further R&D needed for 3 m transmission
  - modest R&D on pre-emphasis needed up for 4 m transmission
    - minimum material (8 x 2 x 150 μm (0.28 mm^2) cables)
- Use TRT micro cables to transmit 320 Mb/s to 4 m
  - no further R&D needed
    - significantly more material (8 x 2 x 127 μm cables + insulation)
- Use micro coax to transmit 3.7 Gb/s to 4 m
  - significant R&D needed:
    connector, cable material, ASIC, radiation-hardness, SEU
  - significantly more material (2 x 1.2 mm (2.3 mm^2) cables)

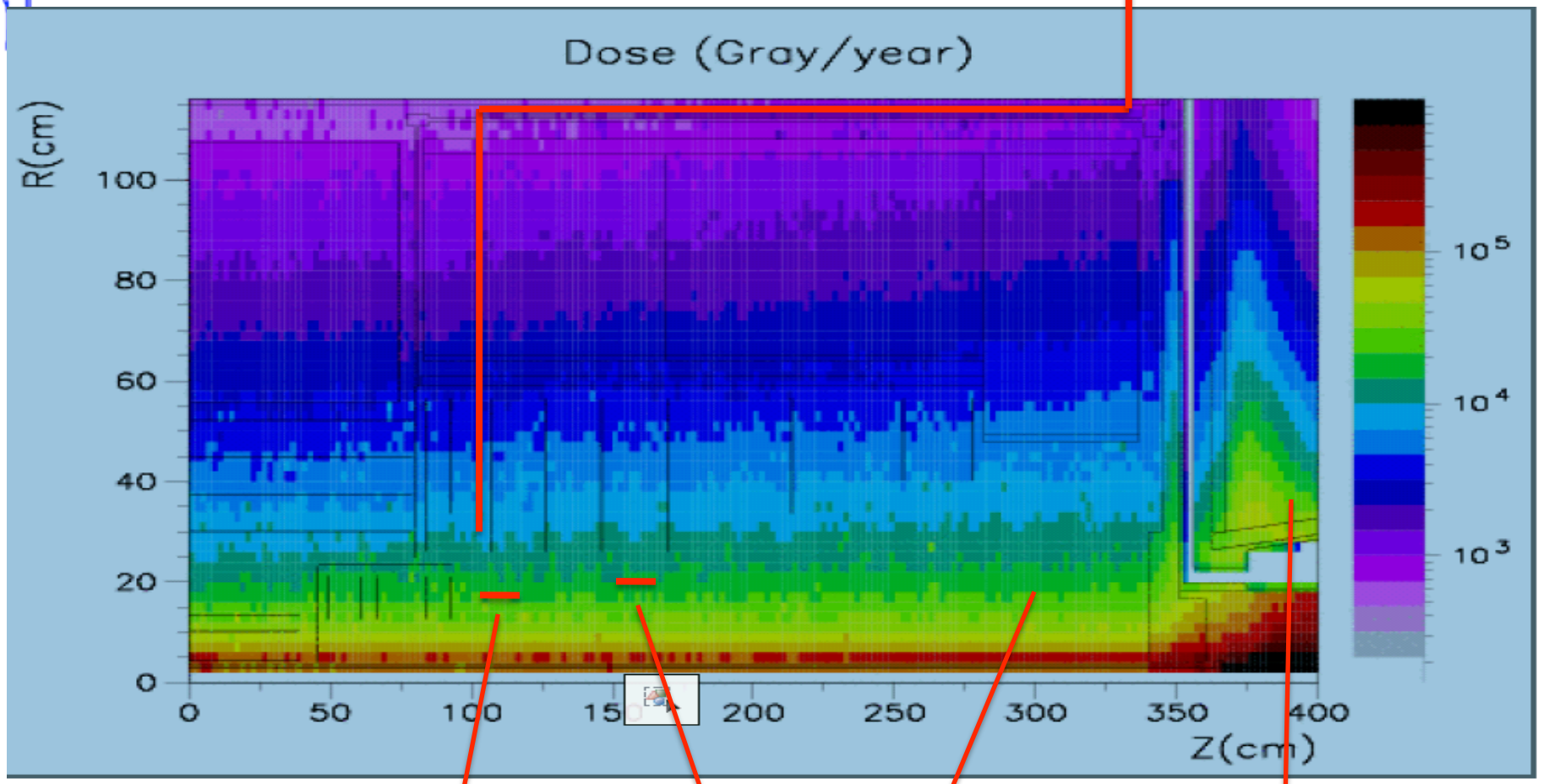


Figure 5.6 Annual doses (Gy/Year) assuming 10^7 s at high luminosity.

SLHC SCT fibers

OSP bottom/ISP top

OSP top

320 Mb/s on skinny cable

- **320 Mb/s on skinny cable with pre-emphasis**
- **320 Mb/s on TRT cable**
- **3.7 Gb/s on coax cables**

Summary

- Basic components satisfy the SLHC needs:
  - VCSEL/PIN, fibers, opto-pack
- proto-type chip will be evaluated in summer, including irradiation
- high-speed transmission in 4 m cable:
  - 320 Mb/s transmission on skinny wires minimize material and requires modest R&D
  - 3.2 Gb/s transmission on coax add significantly more material and requires significant R&D