



Results on Array-based Opto-Links

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March 8, 2011



Outline

- Driver/Receiver Arrays with Redundancy
- VCSEL/PIN Array Irradiation with Protons/Pions
- Summary



Driver/Receiver with Redundancy

- designed an updated version of VCSEL driver and PIN receiver of current ATLAS Pixel detector but with redundancy
 - possible applications include current ATLAS pixel detector and its upgrade, IBL (Insertable Barrel Layer)
 - experience gained from the development/testing of such new chips would help the development of on-detector array-based opto-links for SLHC
 - submission of 1st prototype chip (130 nm) in 2/2010

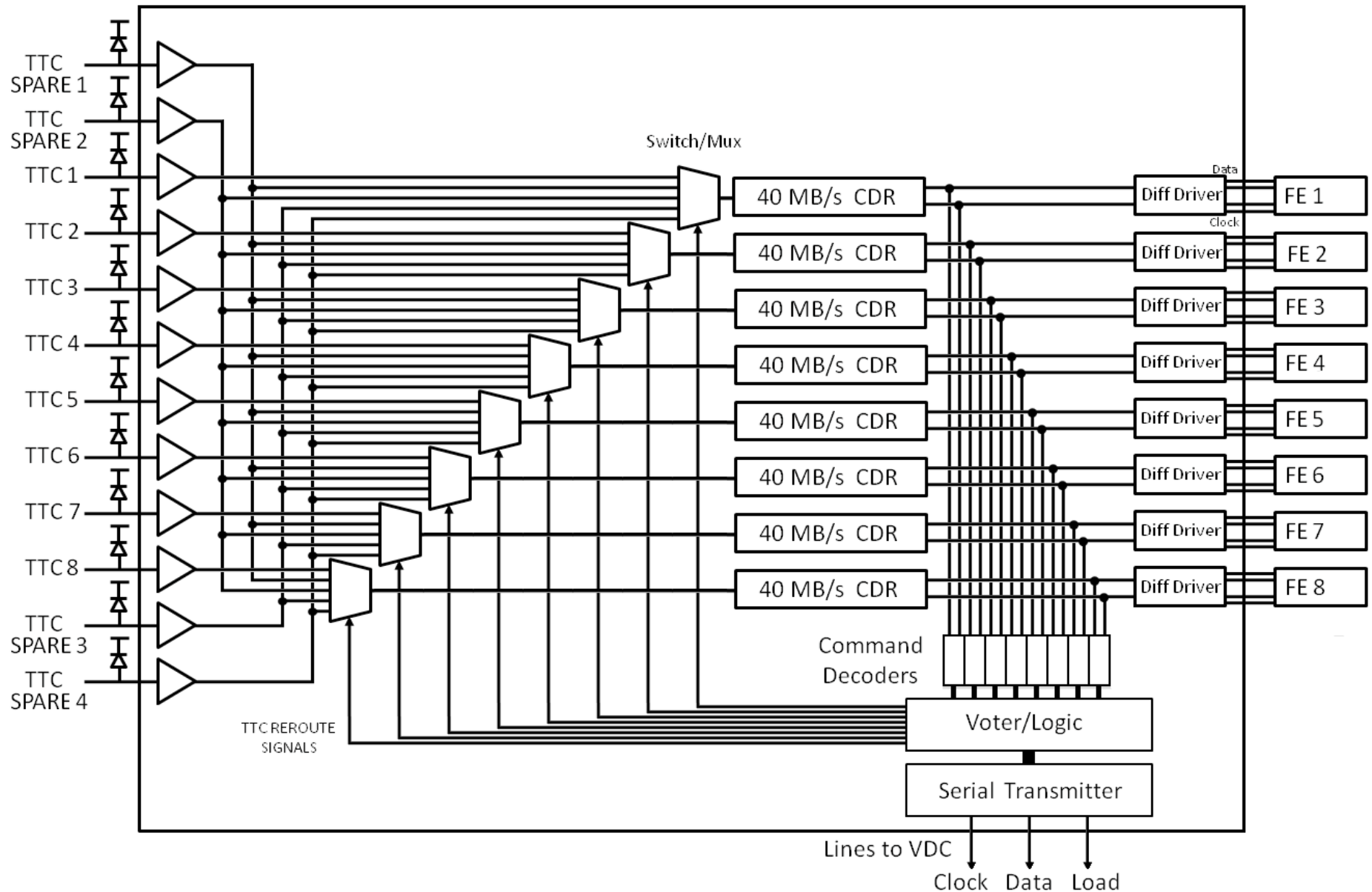


Summary of Prototype Chips

- prototyped 4-channel VCSEL driver and PIN receiver/decoder:
 - ✓ redundancy to bypass broken PIN or VCSEL channel
 - ✓ individual VCSEL current control
 - ✓ power-on reset to set VCSEL current to ~ 10 mA on power up
 - ✓ VCSEL driver can operate up to ~ 5 Gb/s with $\text{BER} < 5 \times 10^{-13}$
 - ✓ receiver/decoder properly decodes signal with low threshold
- ◆ irradiation with 24 GeV protons to 1.7×10^{15} p/cm²
 - ✓ small decrease in VCSEL driver output current
 - ✓ very low SEU rate in latches: $\sim 3 \times 10^{-7}$ /year/link
- ◆ submission of 12-channel chips: 5/2011



2011 PIN Receiver/Decoder





2011 PIN Receiver/Decoder

- Decodes 40 Mb/s bi-phase mark (BPM) signal
- 4 spare PIN receivers for redundancy
- 8 FE-I4 command decoders
 - ◆ Allows remote control by voting between commands received by the 8 FE-I4 command decoders
 - ◆ If one of the 8 inner PIN diodes fail
 - ⇒ signal from one of the 4 redundant channel amplifier outputs can be steered to the digital portion of the failed channel
 - ◆ Majority voting of the command decoder values determines the command to be executed
 - ◆ Allows working control if only 2 PIN channels are alive

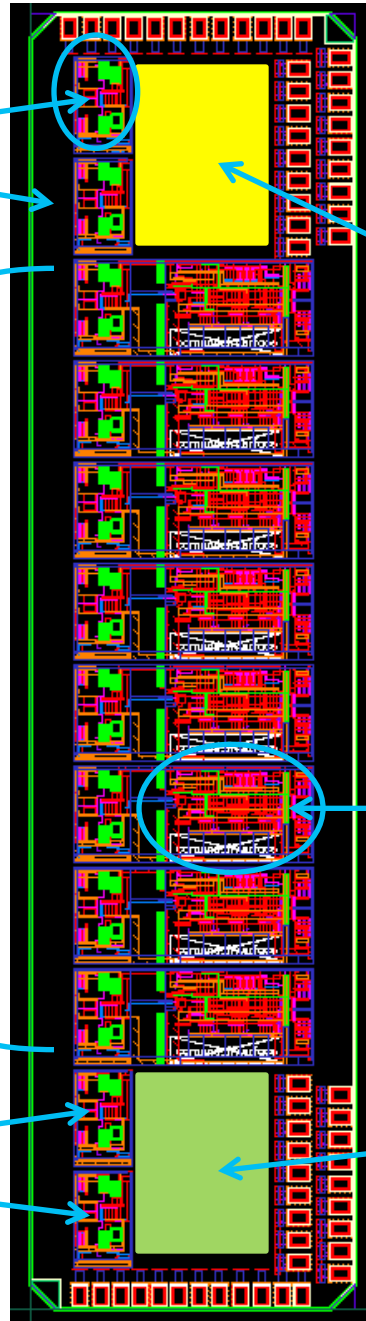


PIN Receiver/Decoder

Spare
PIN amplifiers

8 X
DORIC

Spare
PIN amplifiers
K.K. Gan



600 μm x 900 μm
voltage regulator
2.5 V $\Rightarrow$ 1.5 V

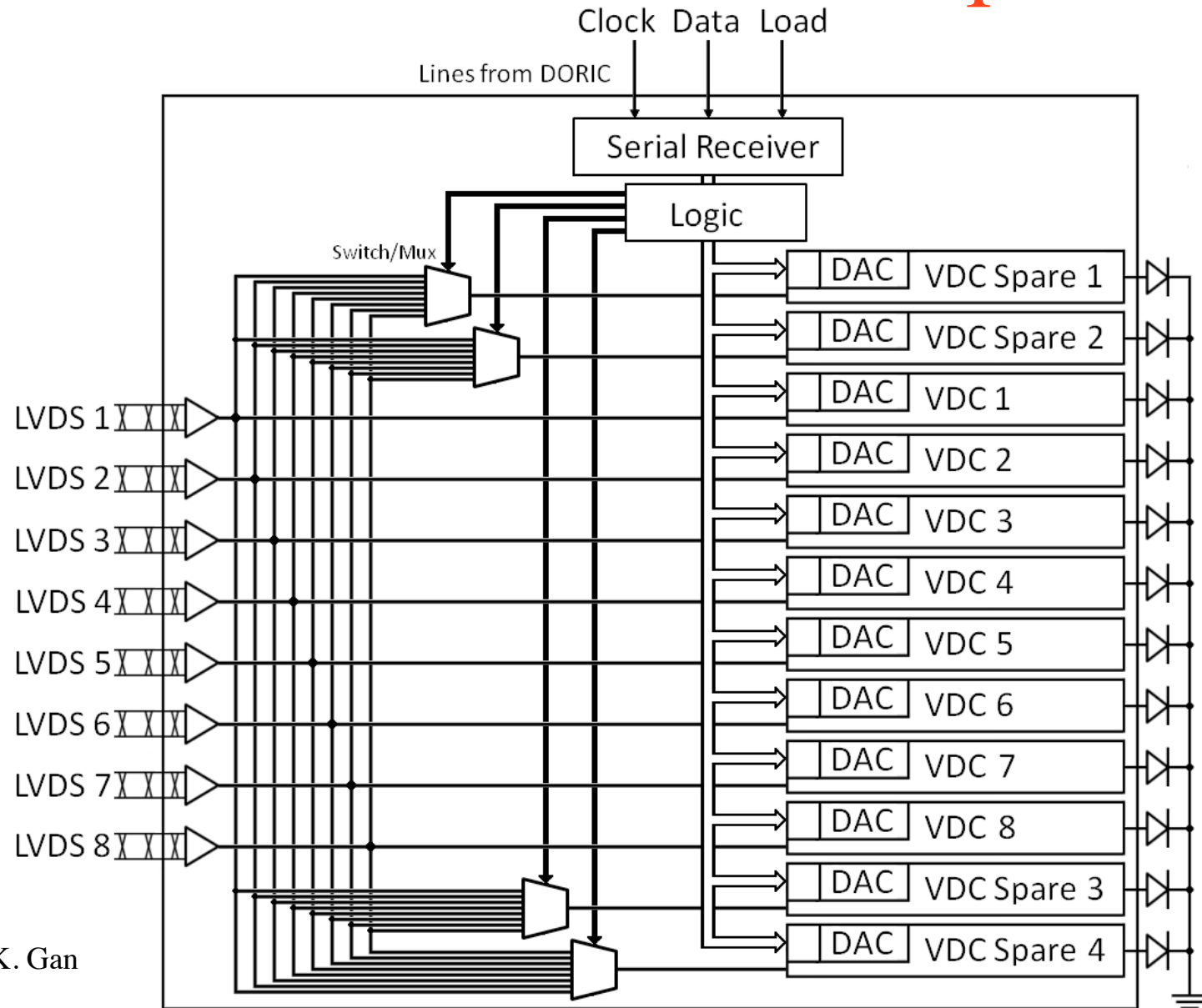
DLL + command decoder
+ LVDS driver

600 μm x 900 μm
control logic

Working Group Meeting



VCSEL Driver Chip





VCSEL Driver Chip

- Designed for 8 channel operation up to 5 Gb/s
- 4 spare VCSEL driver outputs
- Receives serial data from PIN receiver/decoder (command decoder vote) for configuration
- If one of the 8 inner VCSELs fail
 - ⇒ the data signal from the detector can be steered to any of the spare VCSELs



Plan for SLHC Driver/Receiver

- Goal is to design 4-channel chips with GBT driver/receiver
- Use some circuits developed from prototypes
 - ◆ control circuit
 - ◆ high-speed switch/mux
 - ◆ serial transmitter/receiver
 - ◆ redundancy circuit
 - ◆ voltage regulator
- submission date: end of 2011?



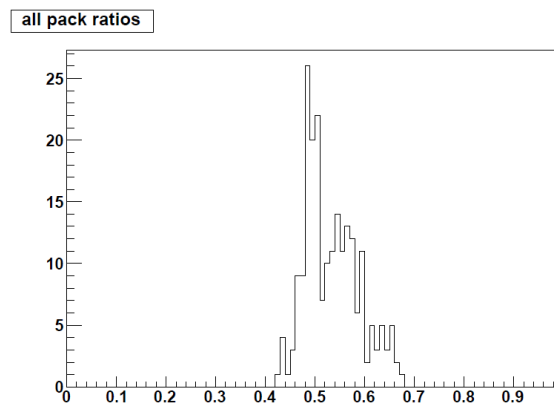
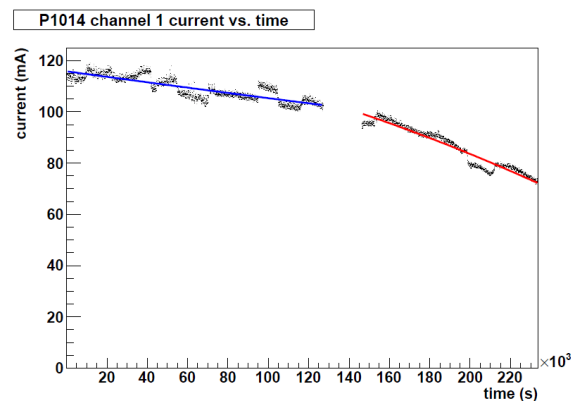
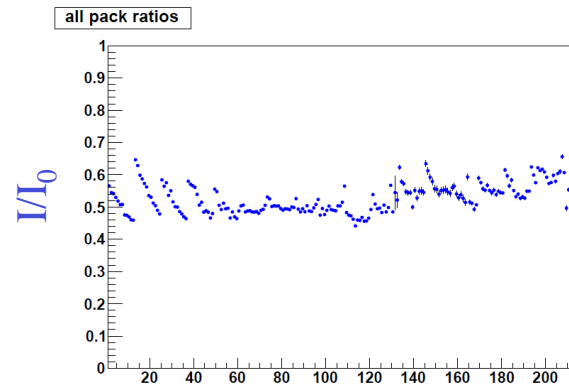
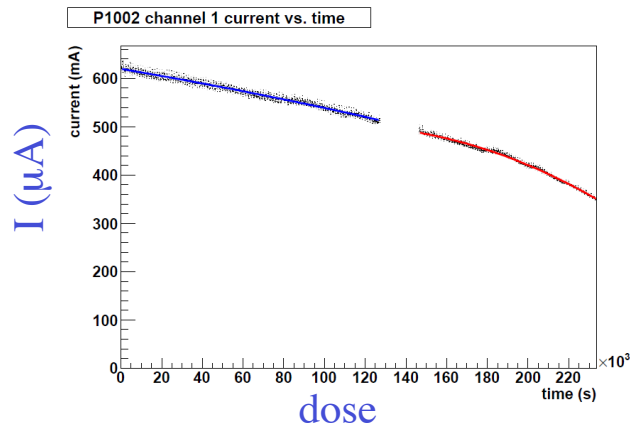
VCSEL/PIN Irradiation

- Study radiation hardness of VCSEL/PIN arrays since 2006:
 - ◆ vendors: AOC, Optowell, ULM, Hamamatsu
 - ◆ speed: up to 10 Gb/s
 - ◆ results: identified following devices for irradiation with 20 arrays
 - Optowell 3.125 Gb/s PIN arrays (2009): large leakage current
 - ULM 4.25 Gb/s PIN arrays (2010): see next slides
 - AOC 10 Gb/s VCSEL (2010): see next slides



Irradiation of PIN with Protons

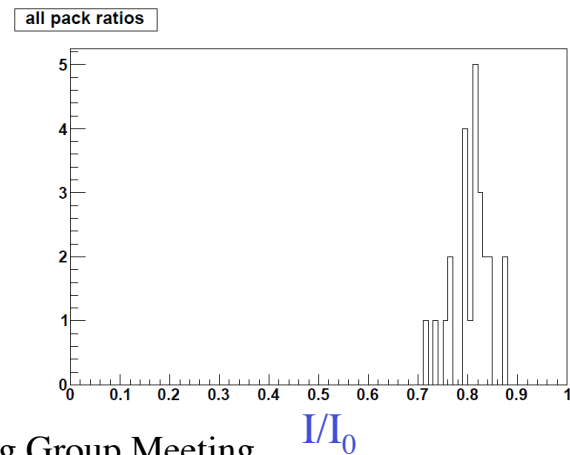
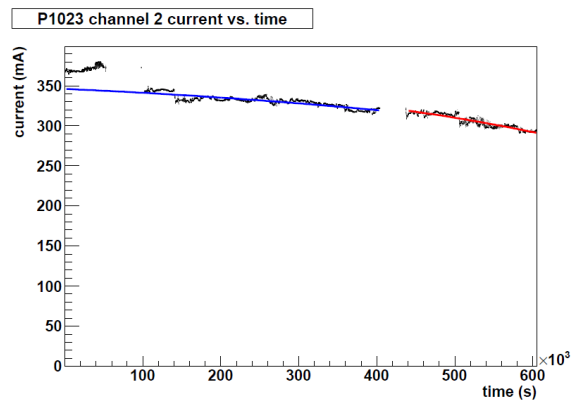
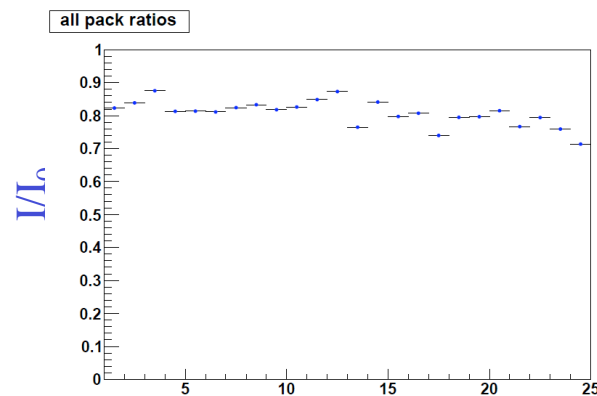
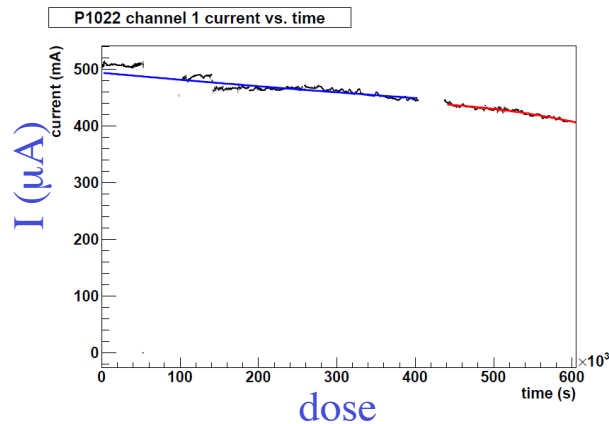
- 20 ULM 12-channel PIN arrays (4.25 Gb/s) were irradiated to a dose of 1.0×10^{15} p/cm² (24 GeV/c)
- ◆ decrease in PIN responsivity is modest





Irradiation of PIN with Pions

- 2 ULM 12-channel PIN arrays (4.25 Gb/s)
were irradiated to a dose of $4.3 \times 10^{14} \pi/\text{cm}^2$ (300 MeV/c)
- ◆ decrease in PIN responsivity is small





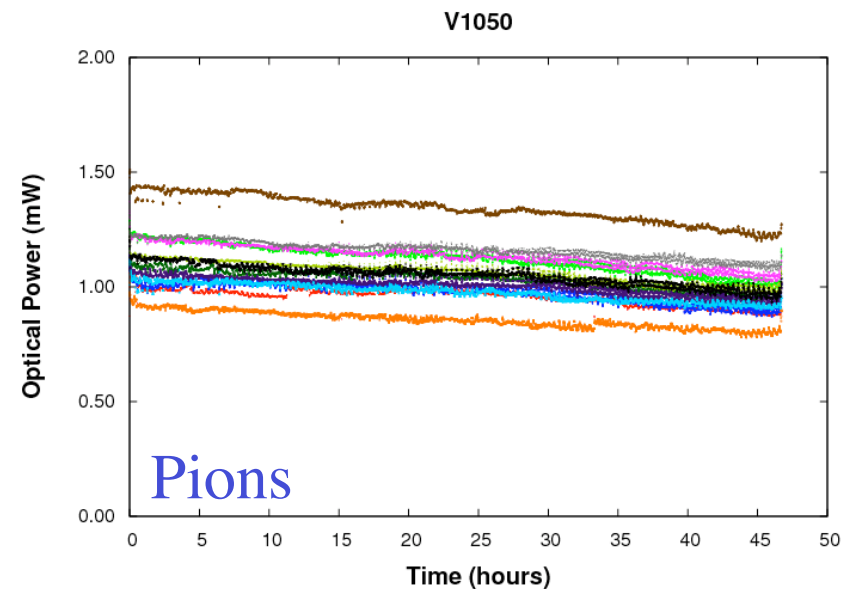
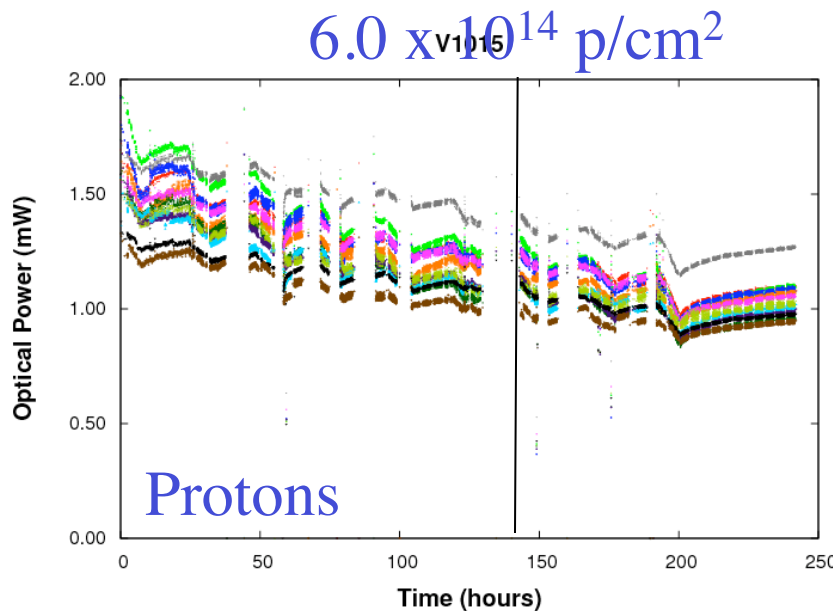
Test of NIEL Hypothesis

- NIEL hypothesis:
 - ◆ damage is proportional to the non ionizing energy loss (NIEL)
 - ◆ 300 MeV pion is 1.5 more damaging than 24 GeV protons
 - ◆ decrease in PIN responsivity with $4.3 \times 10^{14} \pi/\text{cm}^2$: 81%
 - ◆ decrease in PIN responsivity with $6.4 \times 10^{14} \text{p}/\text{cm}^2$: 76%
 - ⇒ consistent with NIEL hypothesis



Irradiation of AOC VCSEL arrays

- AOC 10 Gb/s VCSEL arrays were irradiated:
 - ◆ 12 arrays to a dose of 8.0×10^{14} p/cm² (24 GeV/c)
 - ◆ 1 array to a dose of 4.1×10^{14} π /cm² (300 MeV/c)
 - ◆ decrease in optical power is modest
 - ◆ test of NIEL hypothesis complicated by annealing...





Plan for VCSEL/PIN Array Irradiation

- AOC 10 Gb/s VCSEL arrays:
 - ◆ NIEL study: need to perform proton irradiation with no annealing
 - ◆ need to repeat proton irradiation with higher statistics
 - half of arrays produced no light before irradiation last summer
 - AOC claimed due to material from sticky membrane
- ULM 10 Gb/s PIN arrays:
 - ◆ will test two of these newly available arrays to start



Summary

- 4-channel driver/receiver chips with redundancy and other improvements work well
- 12-channel driver/receiver chips will be submitted in May
- submission of 4-channel driver/receiver for SLHC in November???
- ULM PIN arrays: modest decrease in responsivity after irradiation
 - ◆ damage from pion/proton consistent with NIEL hypothesis
- AOC VCSEL arrays: modest decrease in opto-power after irradiation
- more irradiation of 10 Gb/s PIN/VCSEL arrays in summer 2011