Results on Array-based Opto-Links

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Outline

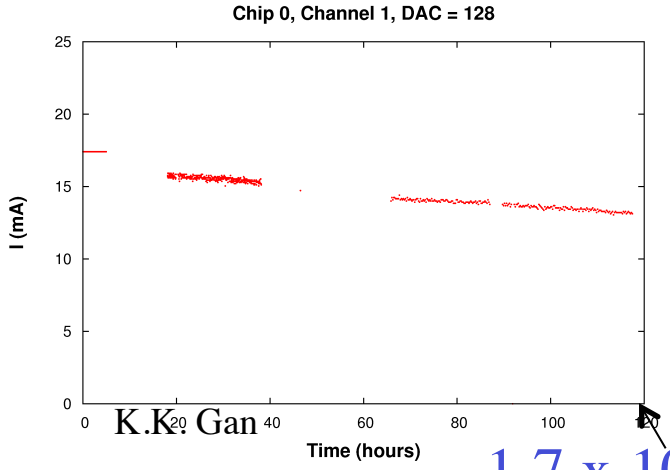
- Driver/Receiver Arrays with Redundancy
- VCSEL/PIN Arrays Irradiation with Protons/Pions
- Summary

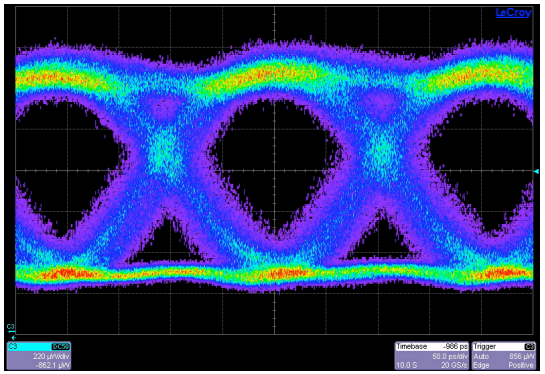
Driver/Receiver with Redundancy

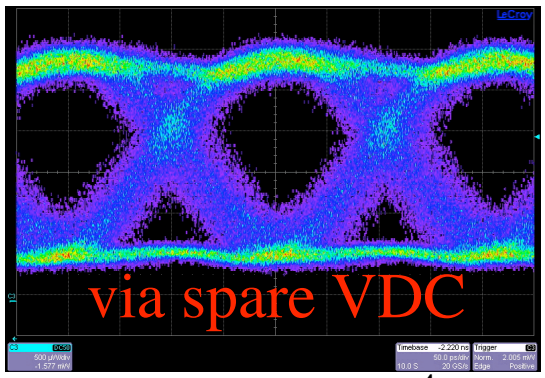
- designed an updated version of driver and receiver of current Pixel detector with redundancy and individual VCSEL current control
  - experience gained from the development/testing of such new chips would help the development of on-detector array-based opto-links for SLHC
  - submission of 1st prototype chip (130 nm) in 2/2010

Summary of IBL Prototype Chips

- prototyped 4-channel driver/receiver after irradiation:
  - ✔ 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 BER < 5×10^{-13}
  - ✔ small decrease in VCSEL driver output current
  - ✔ PIN receiver/decoder properly decodes signal with low threshold
  - ✔ very low SEU rate in latches: ~3×10^{-7}/year/link
  - ◆ submission of 12-channel chip: 2/2011







1.7×10^{15} p/cm^2

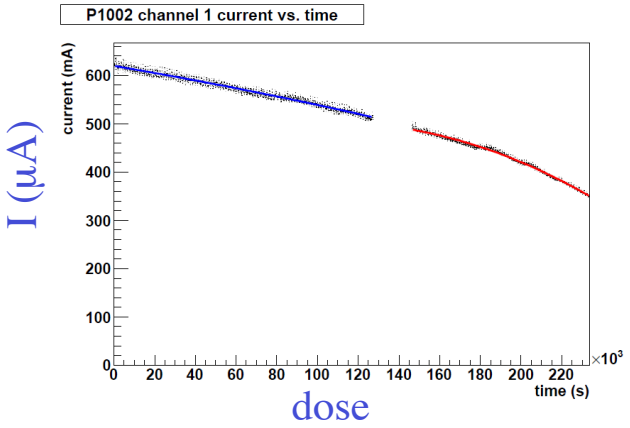
VCSEL/PIN Irradiation

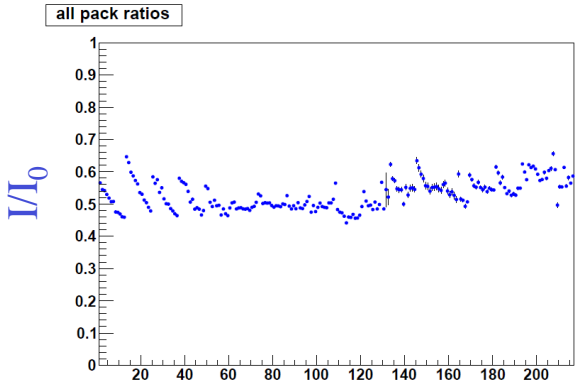
- Study radiation hardness of VCSEL/PIN arrays since 2006:
  - vendors: AOC, Optowell, ULM, Hamamatsu
  - speed: up to 10 Gb/s
  - results: identified following devices for irradiation with 20 arrays
    - Optowell 3.125 Gb/s PIN arrays (2009): large leakage current
    - ULM 4.25 Gb/s PIN arrays (2010):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

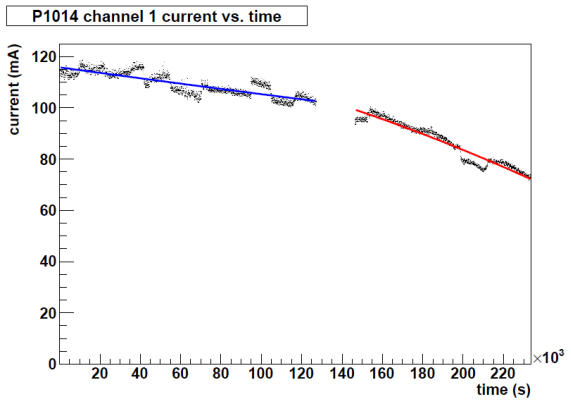
Irradiation of PIN with Protons

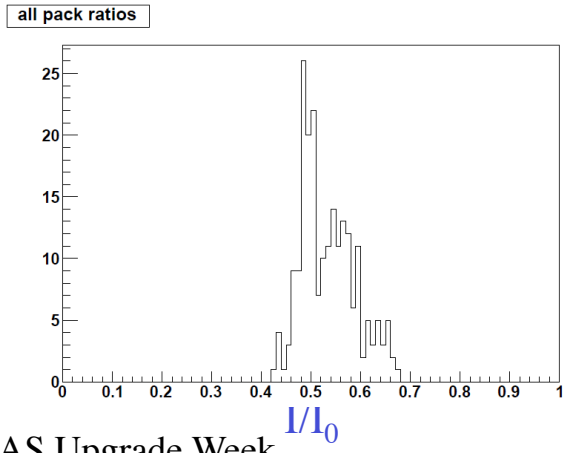
20 ULM 12-channel PIN arrays (4.25 Gb/s) were irradiated to a dose of 1.0 x 10^{15} p/cm^2 (24 GeV/c)

- decrease in PIN responsitivity is modest





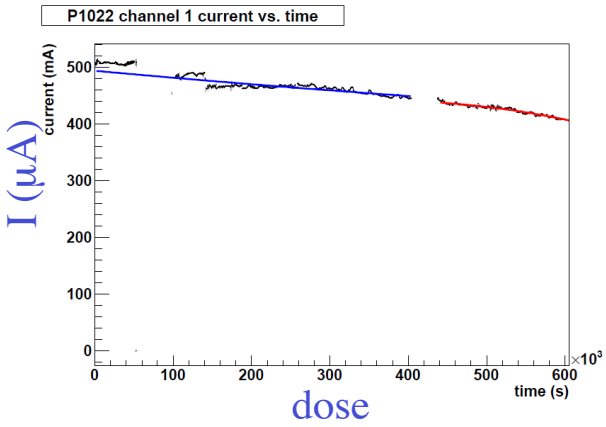




Irradiation of PIN with Pions

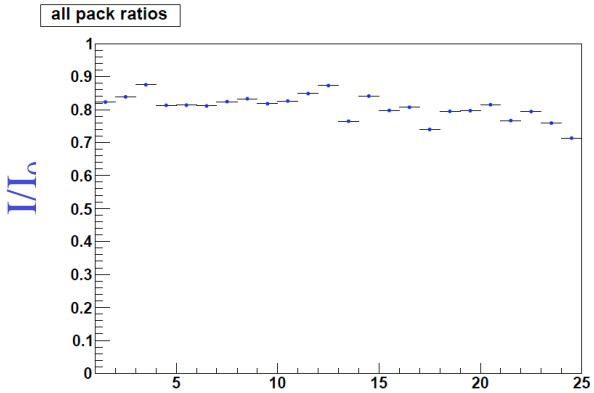
2 ULM 12-channel PIN arrays (4.25 Gb/s) were irradiated to a dose of 4.3 x 10^{14} π/cm^2 (300 MeV/c)

- decrease in PIN responsitivity is small

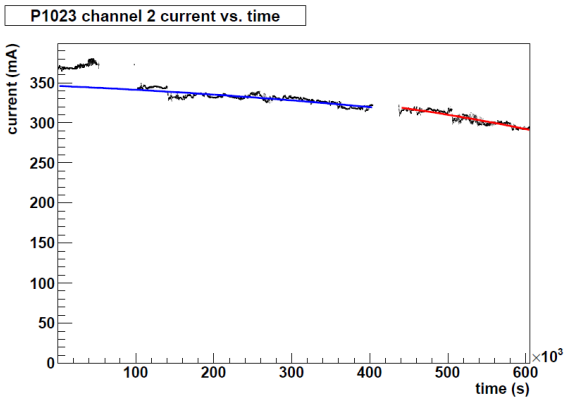


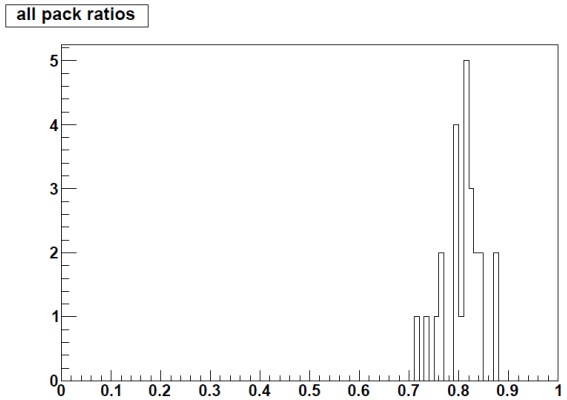
I (μA)

dose



I/I$_0$





I/I$_0$

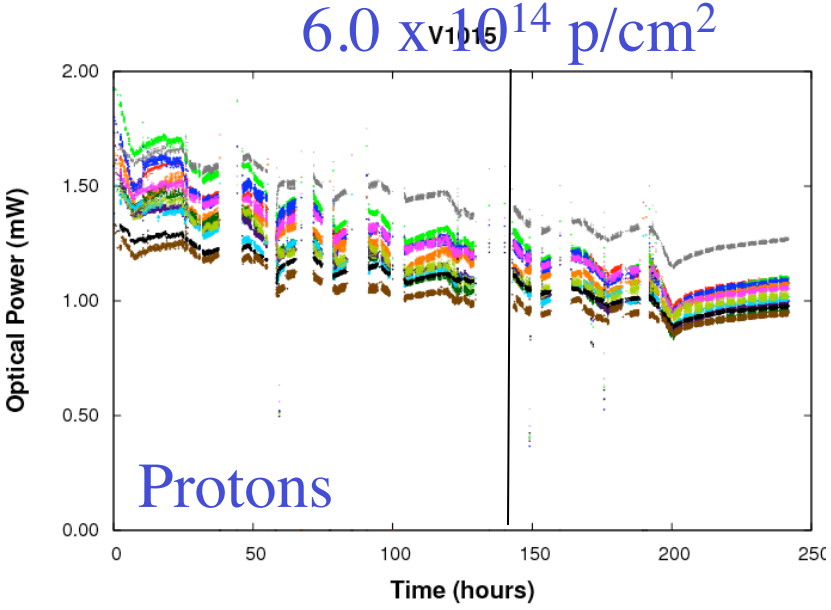
Test of NIEL Hypothesis

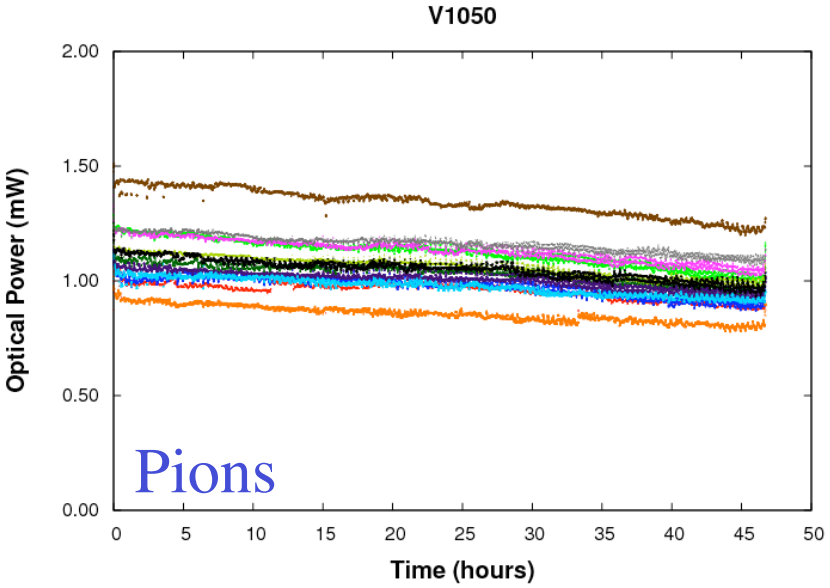
- NIEL hypothesis:
  - damage is proportional to the non ionizing energy loss (NIEL)
  - 300 MeV pion is 1.5 more damaging than 24 GeV protons
  - decrease in PIN responsivity with 4.3 x 10^{14} π/cm^2: 81%
  - decrease in PIN responsivity with 6.4 x 10^{14} p/cm^2: 76%
  - ⇨ consistent with NIEL hypothesis

Irradiation of AOC VCSEL arrays

- AOC 10 Gb/s VCSEL arrays were irradiated:
  - 12 arrays to a dose of 8.0 x 10^{14} p/cm^2 (24 GeV/c)
  - 1 array to a dose of 4.1 x 10^{14} π/cm^2 (300 MeV/c)
  - decrease in optical power is modest
  - test of NIEL hypothesis complicated by annealing…

6.0 x 10^{14} p/cm^2





dose

Summary

- 4-channel driver/receiver chips with redundancy and other improvements work well
- 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