Tracker Optical Link Upgrade
R&D Plans and Status

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Outline

● Experience from Pixel opto-link
● R&D plans
● R&D results
● Summary
Inner Detector Optical Links

- **SCT**: ~ 12,000 links, including data transmission redundancy
- **Pixel**: ~ 4,000 links
  - based on SCT design
- both use driver/receiver of similar architecture:
  - **VDC**: VCSEL Driver Circuit
  - **DORIC**: Digital Optical Receiver Integrated Circuit
Inner Detector Optical Modules

- **SCT harness:**
  - speed: 40 Mb/s
  - single fiber (fragile)
  - short flex to reduce electromagnetic interference
  - many harness flavors

- **Pixel opto-boards:**
  - speed: 80 Mb/s using both clock rising/falling edges
    - B-layer uses two data links to transmit at 160 Mb/s
  - robust ribbonized fiber
  - ~ 1 meter of micro-twisted pairs
    - much reduced radiation level
    - decouple pixel module & opto-link production
      - greatly simplify construction
      - 2 BeO board flavors
Opto-board Production Experience

- few production problems
- upgrade based on pixel link is widely viewed as logical choice

![Graph showing predicted and actual production of 80 Mb/s and 160 Mb/s boards.]](image)

- Total failed boards
Bandwidth Requirements

- **Inner Tracker Opto-Link Upgrade by Gan @ Genova:**
  - pixel tracker:
    - 320 Mb/s: minimum
    - 640 Mb/s: more conservative
    - retain double links for innermost barrel
  - strip tracker:
    - multiple of 40 Mb/s per module

- can current pixel type0 cables & spliced fibers transmit data at 320 or 640 Mb/s?
  ⇒ R&D
Radiation Hardness of VCSEL/PIN

- VCSEL/PIN from several vendors can operate at Gb/s
  - Can they survive SLHC dosage?
    - What is the PIN responsivity after irradiation?
    - What is the PIN SEU rate?
    - What is the VCSEL optical power after irradiation?
    - Can the VCSEL be annealed after irradiation?
      - What VCSEL current is needed for annealing?
  - US plans to characterize VCSEL/PIN from various vendors
    - design of test system in progress at Ohio State
  - SCT group has done neutron irradiations at Ljubljana
  - US/Germany plan to do irradiation at PS in 2006
Result on Neutron Irradiation of VCSEL/PIN

- Truelight VCSEL/PIN arrays were irradiated to various dosages with neutrons at Ljubljana reactor
  - PIN arrays not yet analyzed
  - ten 8-channel VCSEL arrays were irradiated:
    - arrays contained broken channels before irradiation
    - arrays were not biased during irradiation
    - after ~30 hours of annealing:
      - 8 arrays irradiated up to $5 \times 10^{15}$ 1-MeV n$_{eq}$/cm$^2$
        - recover > 70% of optical power
      - 2 arrays irradiated to $10^{16}$ 1-MeV n$_{eq}$/cm$^2$
        - some channels lost all optical power
Result on 2 Arrays after $10^{16}$ 1-MeV $n_{eq}/cm^2$

- **VCSEL array #10:**
  - 7 working channels before irradiation
  - 1 channel drawing no current
  - 1 channel drawing current but produces no light
  - 2 channels: recover $\sim$70% of optical power after annealing
  - 3 channels: same as above but intermittently

- **VCSEL array #2:**
  - 3 working channels before irradiation
  - 1 channel drawing no current
  - 1 channel drawing current but produces no light
  - 1 channel: recover $\sim$15% of optical power after annealing
Implications of Neutron Irradiation Results

- VCSEL is not suitable for SLHC if results are confirmed
  - results might be different if intermediate annealing is possible
- ability to recover 70% of optical power on some channels and intermittently on other channels indicates that problems could be mechanical
- irradiation must be repeated with quality arrays
- US/Germany plan to use 24 GeV protons from PS at CERN next year with monitoring and annealing during irradiation
Bandwidth of Type0 Cables

○ Pixel modules transmit LVDS to/from opto-links with tiny wires
  ✷ barrel: 140 cm of 100 µm wires
  ✷ disk: 60 cm of 60 µm wires
⇒ measure bandwidth and compare to Skewclear (150 cm/400 µm)

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<th>Time (ps) (20-80%)</th>
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<th>Fall (ps)</th>
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Eye Diagrams at 350 Mb/s

Skewclear

barrel
disk
Eye Diagrams at 640 Mb/s

Skewclear

barrel
disk
Eye Diagrams at 1 Gb/s
Summary on Cable Bandwidth

Thinking of using Skewclear?
A picture is worth a thousand words…

- transmission at 320 Mb/s may be adequate
- transmission at 640 Mb/s might be acceptable
- ordering custom micro-twisted cables to see if transmission will improve…

K.K. Gan
US ATLAS Upgrade Workshop
Bandwidth of Spliced Fibers

- Present Pixel: spliced several meters of SIMM with GRIN
  - SIMM: rad-hard pure silica core, low bandwidth
  - GRIN: rad-tolerant, medium bandwidth
- What is the bandwidth of spliced fibers?
  - Result: transmission at 1 Gb/s is quite adequate

![Graphs showing transmission at 1 Gb/s for different fiber lengths.](image)
Summary

● R&D in progress on current Pixel infrastructure
  ● some Truelight VCSEL arrays die at $10^{16}$ 1-MeV $n_{eq}/cm^2$
    ■ problems might be related to quality of arrays
    ■ measurements will be repeated, including at PS
  ● type0 cable may be adequate up to 640 Mb/s
  ● spliced fibers sufficient for 1 Gb/s