

# Radiation-Hard Optical Hybrid Board for the ATLAS Pixel Detector

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# Outline

- Introduction
- Prototype results
- Proton irradiation results
- Summary

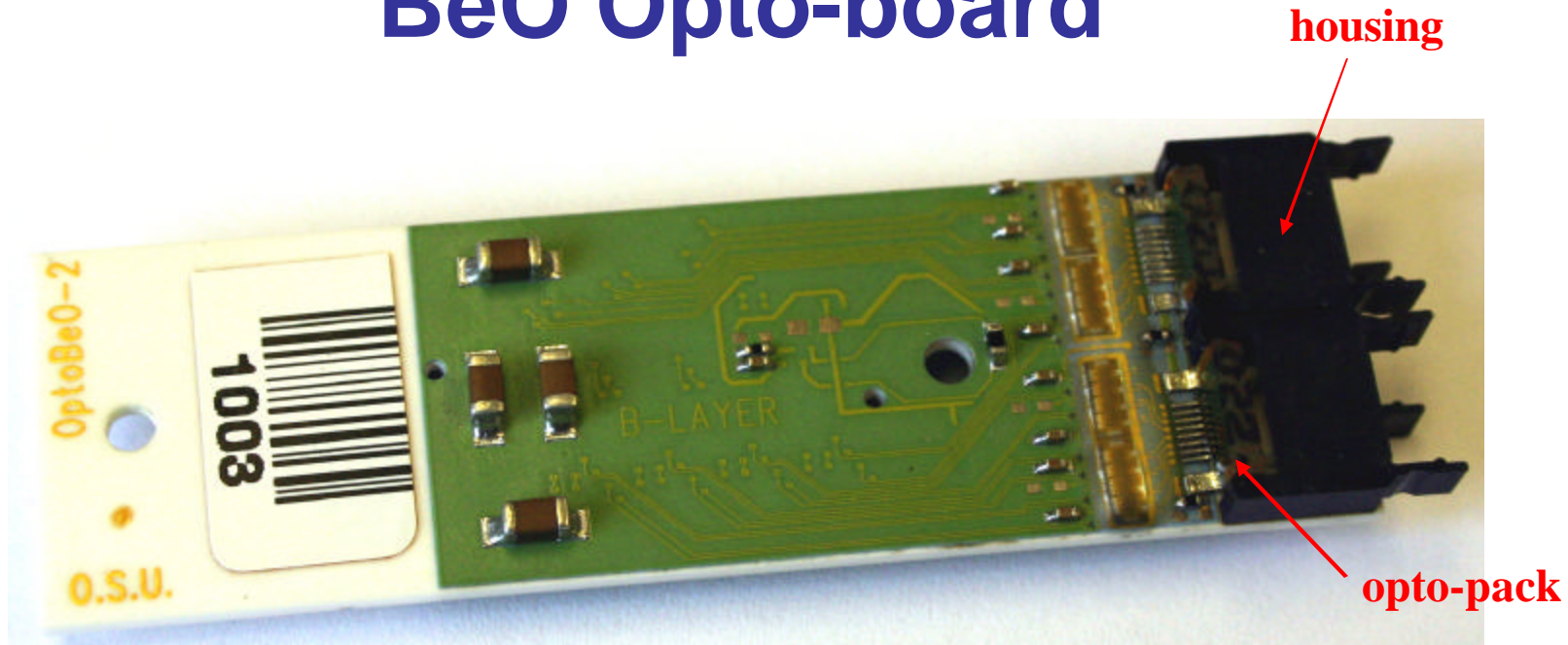
# Opto-board

- Holds VDCs, DORICs, VCSELs and PINs
- Converts **optical signal** ↔ **electrical signal**
- Contains seven optical links, each link serving one Pixel module
- Fabricated in two flavors
  - Layer B: for inner barrel
    - two data links per module to accommodate for high hit occupancy
    - 80 boards
  - Layer D: for outer barrel and disks 1 and 2
    - 430 boards

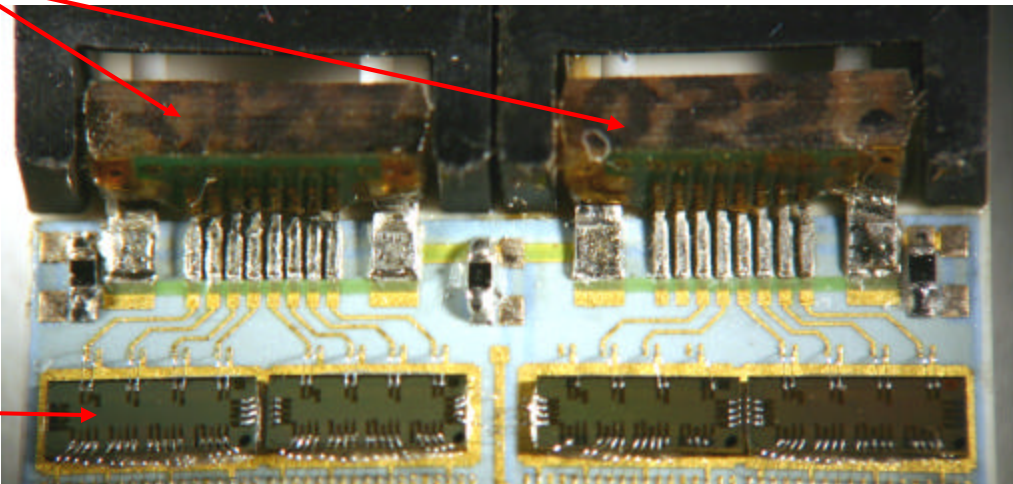
# Status of BeO

- Fabricated with **BeO** for heat management
  - initial prototype with FR4 for fast turn around and cost saving
- 1<sup>st</sup> BeO prototype
  - Many open vias due to insufficient gold filing by the vendor
  - Opto-links work after via repair
- 2<sup>nd</sup> BeO prototype
  - Recycled BeO boards with open vias
  - Many shorts due to over filling by the vendor
- 3<sup>rd</sup> BeO prototype
  - Use more experienced/expensive vendor
  - Produced opto-boards of high quality

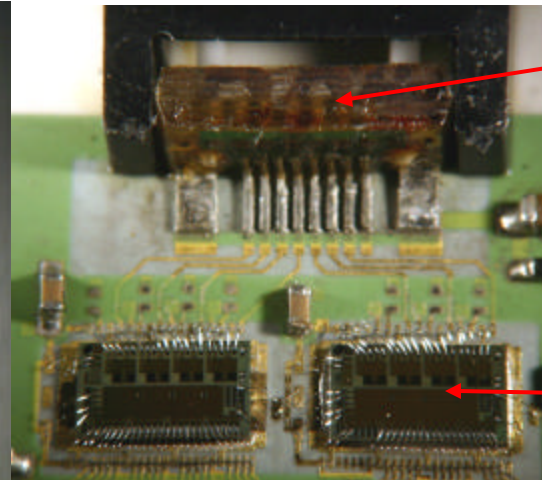
# BeO Opto-board



VCSEL  
Array



VDC

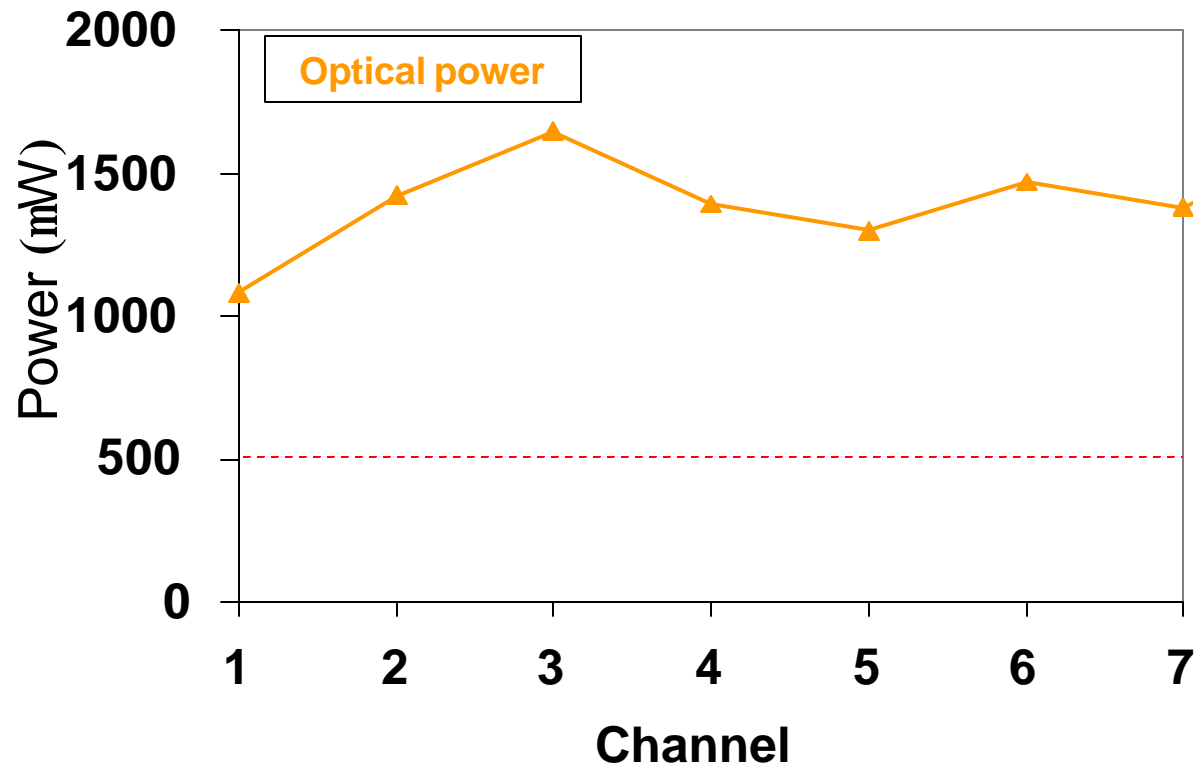


PIN  
array

DORIC

# Opto-board Performance

- Detailed measurements are done on all critical electrical and optical parameters to check performance/quality
  - LVDS rise/fall times, jitter...
  - Optical power, optical rise/fall times, duty cycle...
  - The opto-boards meet or exceed all the pixel detector requirements



- Optical power at 10 mA significantly above the spec

# Status of Opto-board

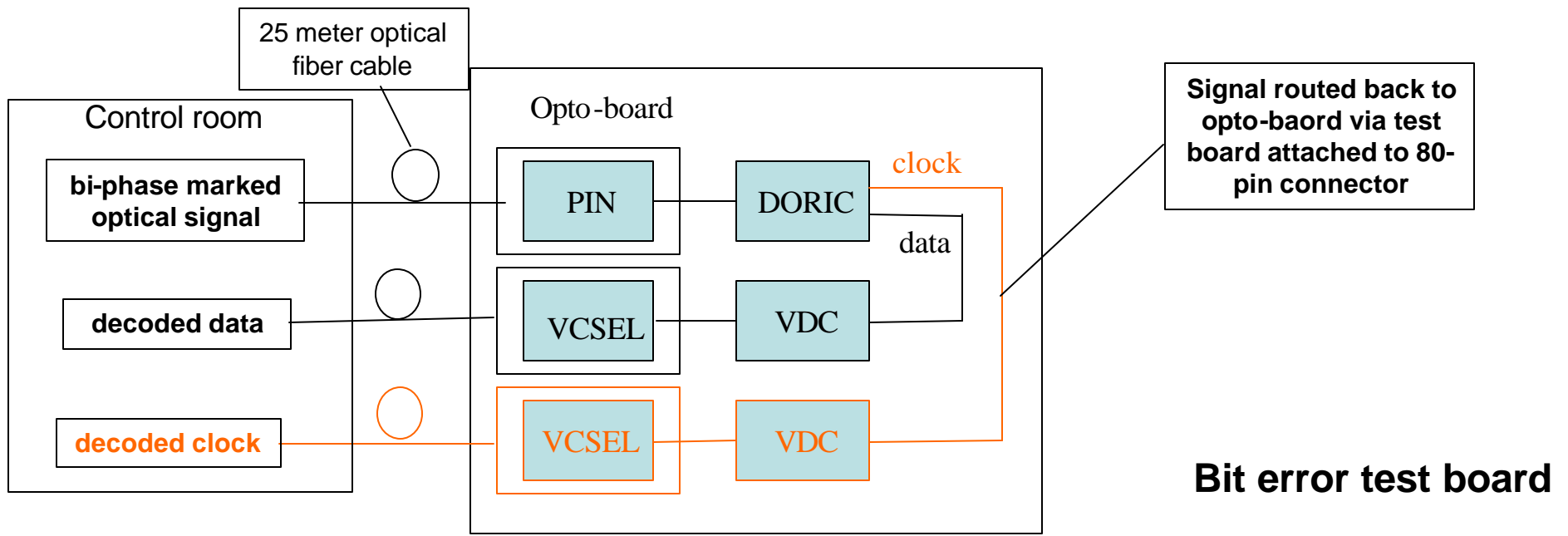
- 28 boards were delivered
  - Equal number of layers B and Disks
  - Populated opto-boards have low noise and good optical power
    - no known circuit design error
  - A few SMD's detached from three boards
  - 80 B-layer opto-boards with layout changes to improve adhesion
    - Expected delivery in September
    - If new opto-boards are satisfactory
      - Produce 430 boards for the outer barrel and Disks

# Radiation Hardness Measurements of Opto-boards

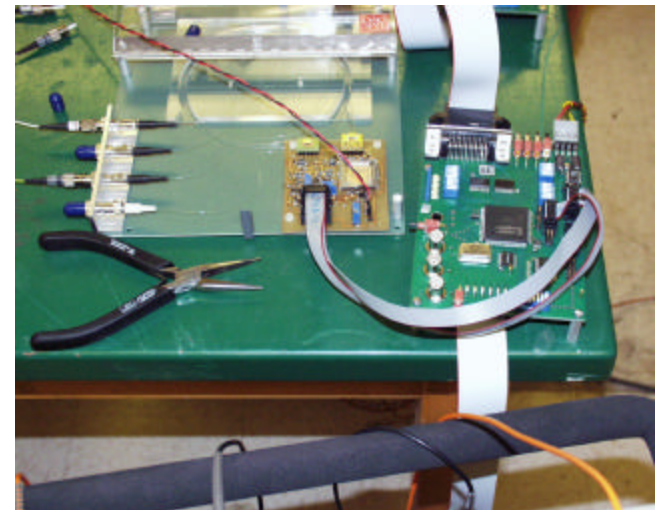
- Important to measure/certify radiation hardness of opto-board and its components:
  - VCSEL and PIN arrays
  - VDC and DORIC chips
  - Wireb-bonds / encapsulant
  - Fibers
  - Glues, etc.
- Use CERN's T7 beam (24 GeV Proton) for radiation hardness
  - T7 shuttle setup
    - Can be moved in and out of beam remotely for annealing

# Real Time Monitoring

- Real time testing of opto-board system using loop-back setup

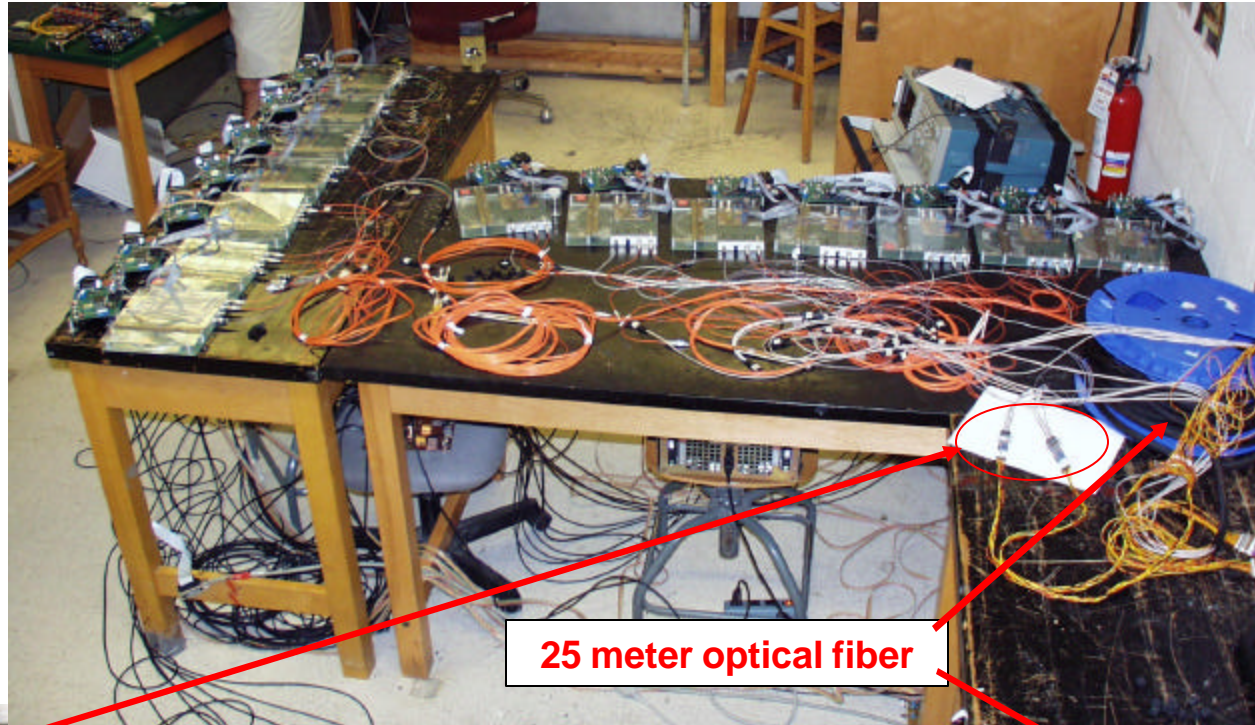


- Compare transmitted and decoded data
  - measure minimum PIN current for no bit errors
- Measure optical power

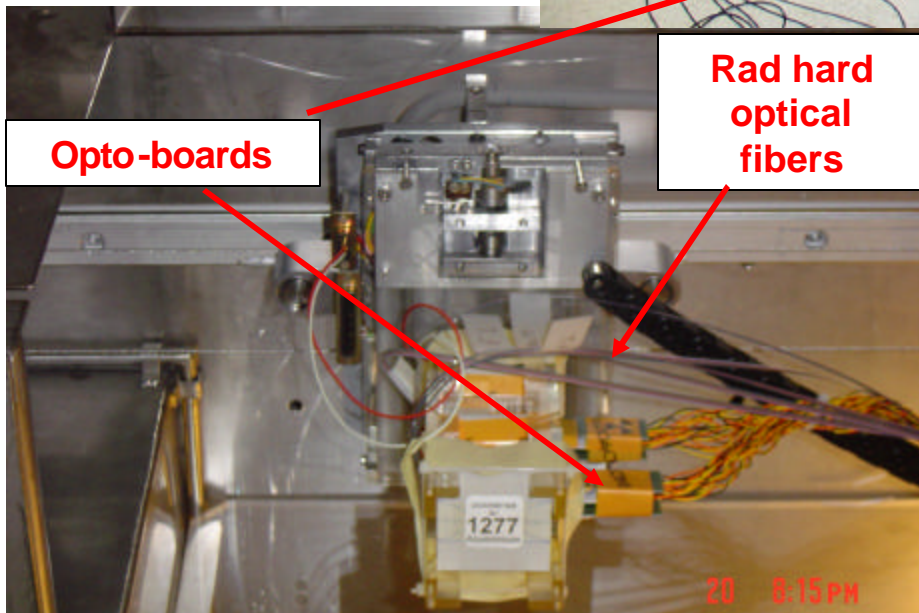


# Setup for CERN T7 Shuttle

Shuttle test electronics prior to shipping to CERN

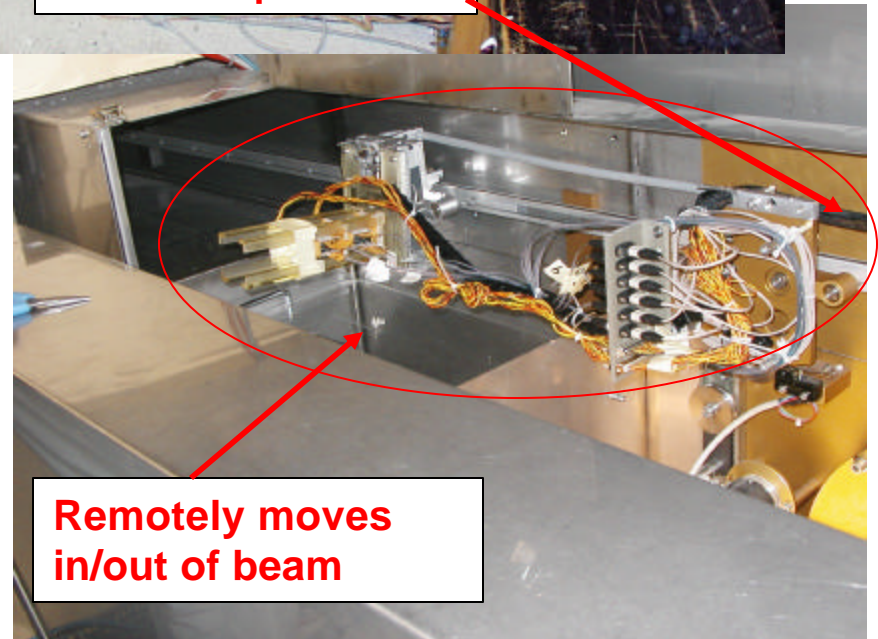


25 meter optical fiber



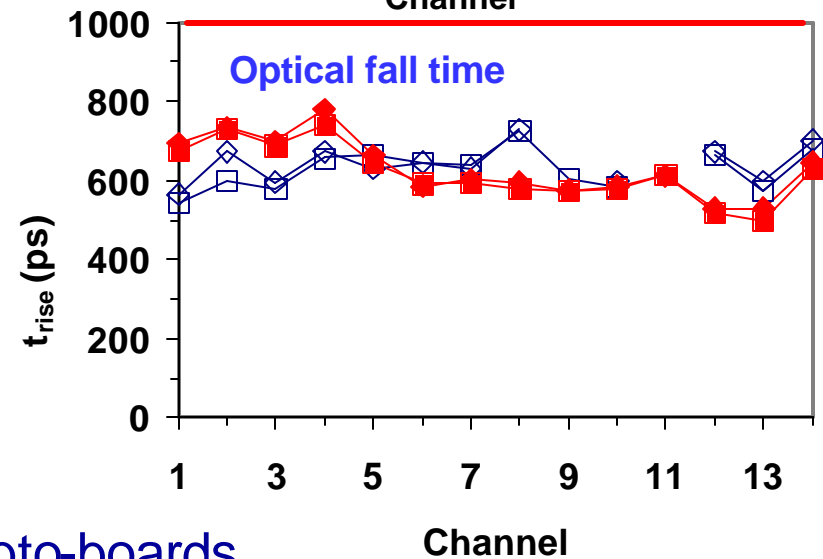
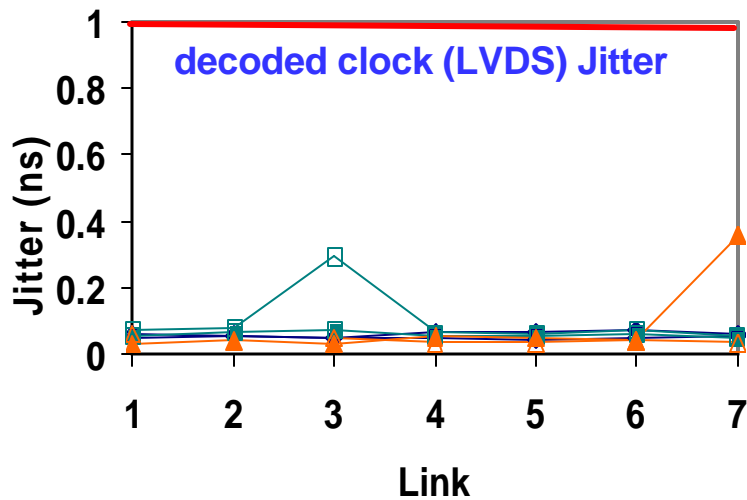
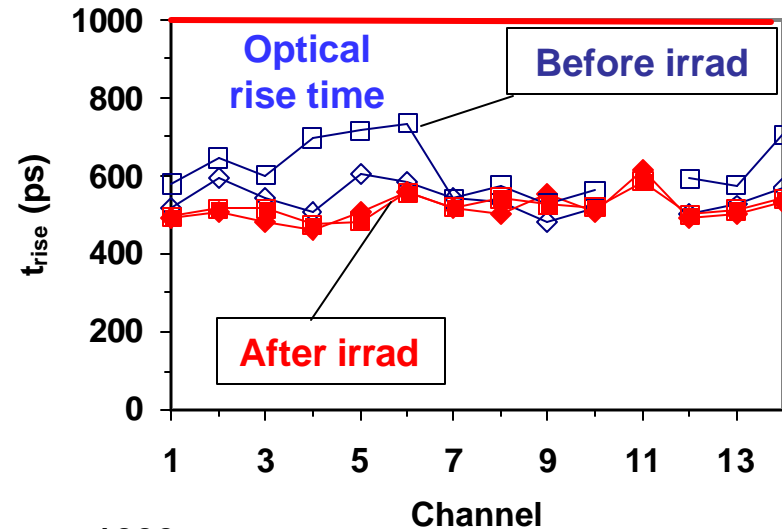
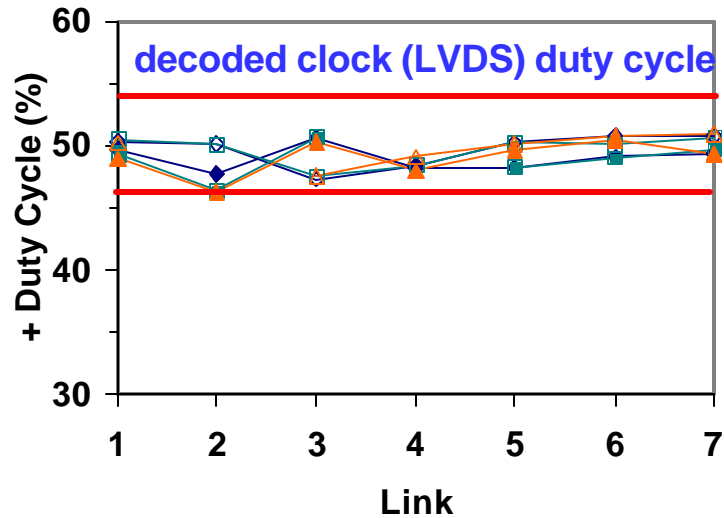
Opto-boards

Rad hard optical fibers



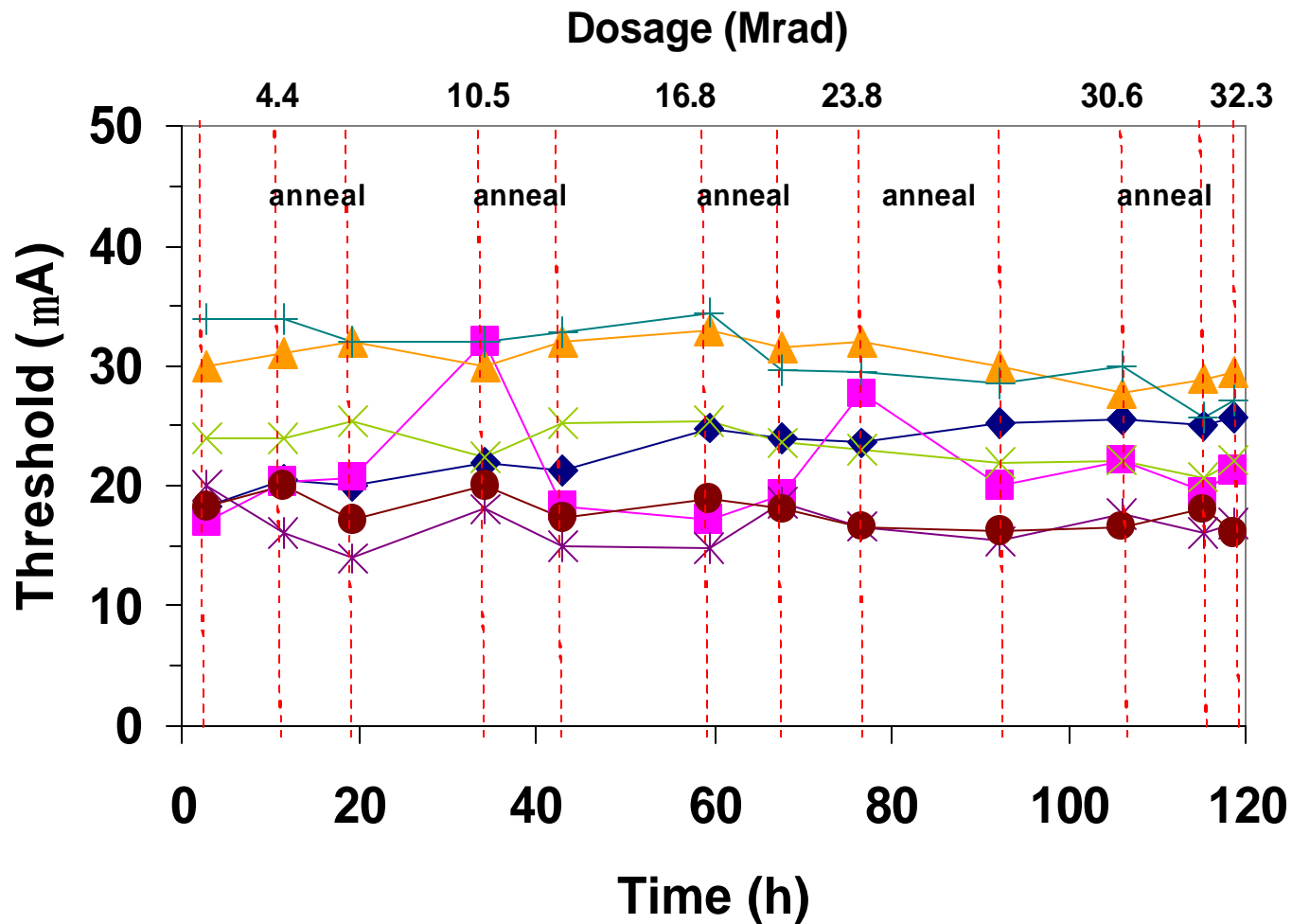
Remotely moves in/out of beam

# Rise/Fall times, Jitter, and Duty Cycle



- Each plot shows the results for two opto-boards
- No degradation in rise/fall times
- Decoded clock duty cycle and jitter within the limits after irradiation

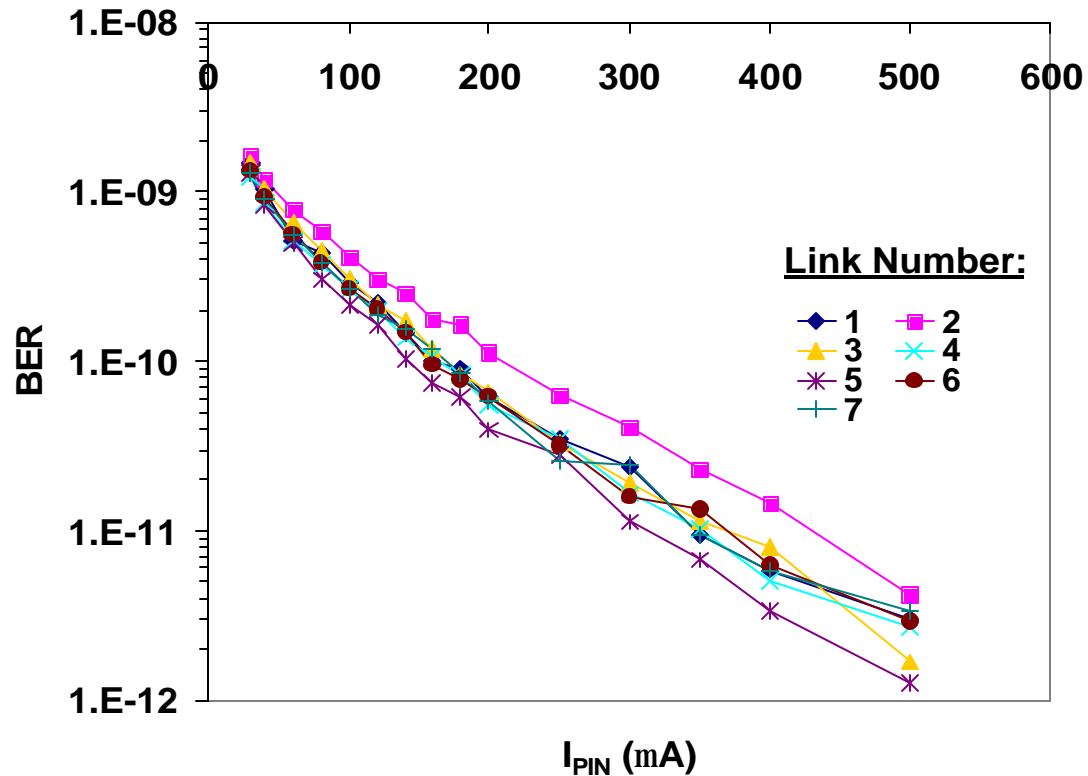
# PIN Current Threshold vs Dosage



- PIN current thresholds for no bit errors remain constant

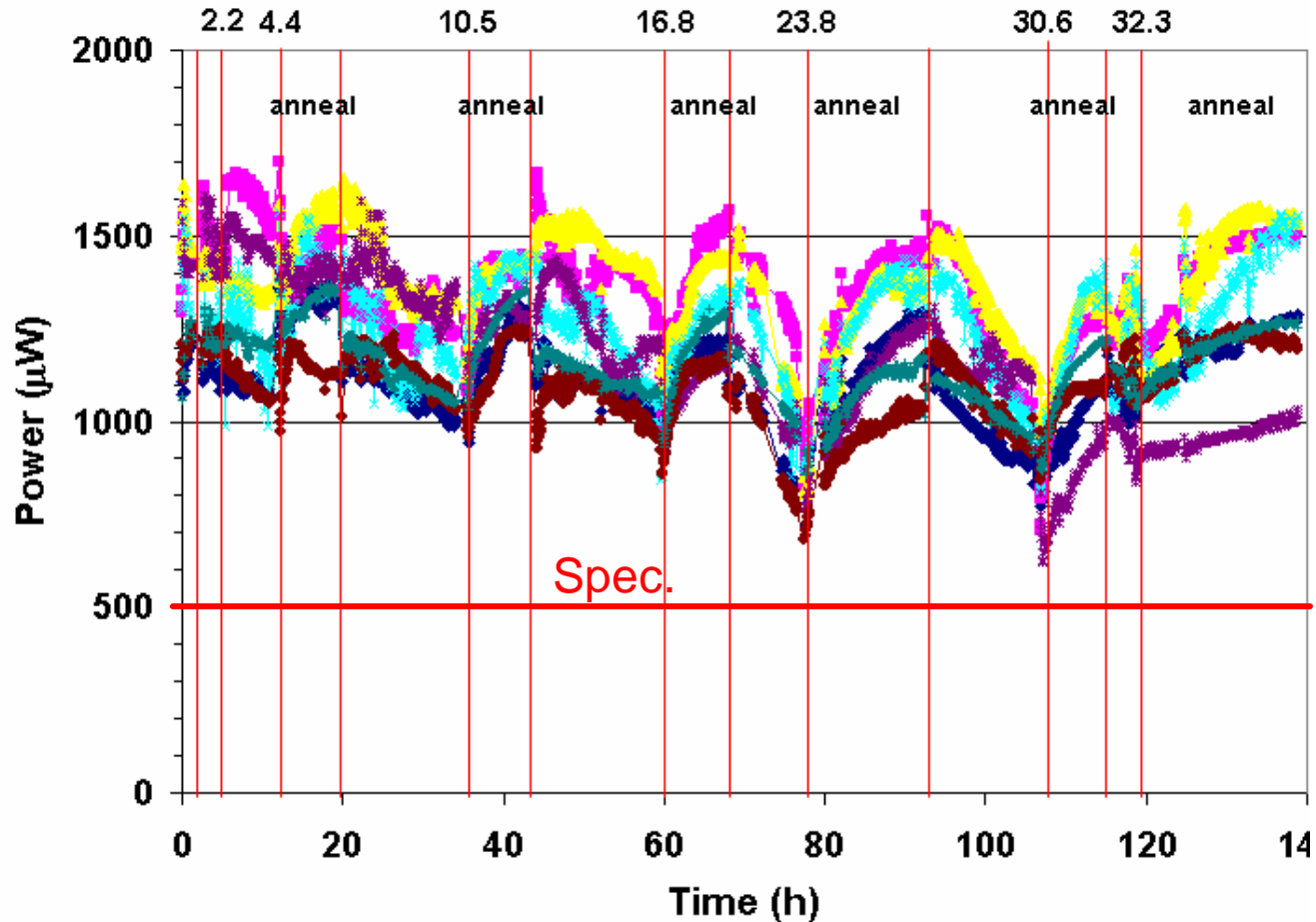
# Proton Induced Bit Errors in PIN

- Convert bit errors to bit error rates at opto-link



- Bit error rate decreases with PIN current as expected
- Bit error rate  $\sim 3 \times 10^{-10}$  at 100 mA (1.4 errors/minutes)
  - DORIC sepc  $10^{-11}$

# Optical Power vs. Dosage



- Irradiation procedure  $\sim 5$  Mrad/day (10 hours), with annealing rest of the day
- Optical power decreases with dosage as expected
- Limited annealing recovers some lost power
- Still good power after 30 Mrad

# Summary

- Several pre-production opto-boards have been fabricated
  - Meet all the pixel detector requirements
  - Excellent optical power
- No degradation in performance with up to 32 Mrad proton irradiation
  - Low PIN current for no bit error
  - Annealing recovers most of the lost power
- Start opto-link production in September 2004
  - Complete production by September 2005