Optical Links
for HEP on-detector electronics

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HEP on-detector electronics

- Sensor specific amplifier
- Analog to digital converter
- Optical link to off-detector electronics
  - Data link: transmits physics data and monitoring information to off-detector electronics
  - Control link: transmits trigger, clock, configuration and control signals to the on-detector electronics
- Calibration to the on-detector electronics

Optical link

- Data link:
  - Radiation tolerant: requiring ASICs plus specially selected laser diodes (VCSELs) and fibers (multi-mode).
  - High data throughput: example ATLAS LAr phase-2 link, about 400 Tbps over some 40,000 fibers with 10 Gbps per fiber.
  - High board level density: small component packaging, low channel power dissipation.
  - Transmission distance: about 150 meters, a challenge on MM fiber with NRZ binary coding for speeds much beyond 10 Gbps.
  - Industry trend (for data centers): PAM4 (pulse-amplitude modulation with 4-levels). We should investigate radiation tolerant, HEP specific optical transmitter ASIC with PAM4 so that we can better match the off-detector electronics which are COTS (components of the shelfs). With PAM4, 20 Gbps per fiber can be a near future goal, with 56 Gbps per channel as a further target.
  - In ultra high radiation environment such as inner trackers, VCSELs may degrade faster than CMOS. We should look into options to extend the operation life of VCSELs (making them comparable with CMOS) in these applications.

Optical link

- Control link:
  - More stringent requirements on radiation tolerance because of the signals it transmits.
  - Low bandwidth requirements but also low SEU (single event upset) tolerance. The optical detector (a p-i-n diode, to convert the optical signal to electrical) is an energy detector, will respond to passing particles. This problem is currently addressed at system level with FEC (forward error correction) at the expense of data bandwidth and ASIC complicity, still difficult in case of long strings of SEUs. Possible solutions in the amplifier ASIC?
  - The p-i-n diode is also susceptible to TID (total ionizing dose) and NIEL (nonionizing energy loss) damages. Some measurements but few solutions on this issue. We need to search for solutions to extend the operation life of the p-i-n diodes. Currently this is the main limiting factor to place optical links close to sensor readout ASICs in inner trackers.