End-of-Stave Card and Miniature Twinax Cables

ATLAS Upgrade Week, CERN

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Introduction

- sLHC pixel barrel consists of 4 or 5 layers.
- Data rate is between 1 and 12 Gbits/s per stave end.

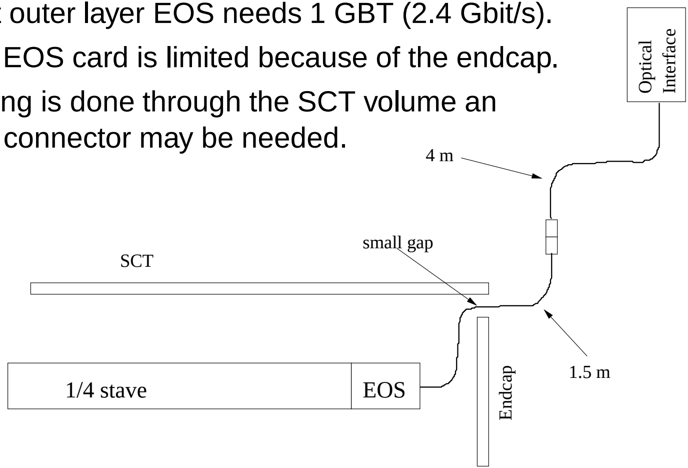
$\Longrightarrow$ Use GBT chips for data transmission.

- Radiation levels are too high for optical transmission.

$\Longrightarrow$ Use micro-coax inside the tracker.

Outer Layer Layout

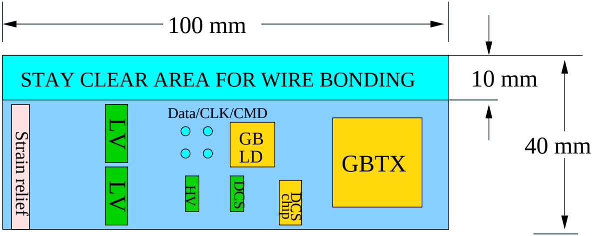
- 2 outermost layer EOS only need half a GBT.
- Upper and lower stave side could share one GBT.
- Innermost outer layer EOS needs 1 GBT (2.4 Gbit/s).
- Space for EOS card is limited because of the endcap.
- If the routing is done through the SCT volume an additional connector may be needed.



End of Stave Card

End of stave services:

- GBTX area 20 mm × 20 mm, some guess.
- GBLD area 10 mm × 10 mm, guess.
- DCS chip, 5 mm × 10 mm, pure guess.
- DCS, HV connectors: 10 mm × 3 mm (Panasonic AXE).
- Data/CMD/CLK connectors: 2 mm diameter. These could also be 1.5 m long pig tails.
- Power: 13 mm × 5 mm Panasonic P5KF 40 pins. This assumes DC-DC conversion.

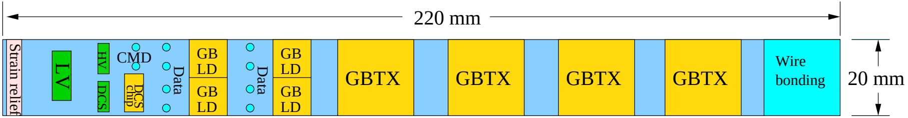


Services

- Data: 1 Twinax 1.2 mm $\times$ 2 mm.
- Clk/Cmd: 1 Twinax 1.2 mm $\times$ 2 mm.
- HV: 8 twisted pairs 36 AWG copper
- DCS: 5 twisted pairs 36 AWG copper
- LV: 18 pairs of 25 AWG Cu clad Al.
- Sense wires: 1 pair 36 AWG Cu.
- Packing factor of 2.
- Jacket
- Total volume: 54 mm^2.
- In comparison no DC-DC has 75.3 mm^2, serial power 36.7 mm^2.

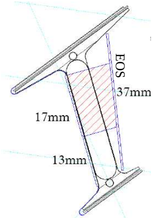
End of Stave Card - Inner Layer

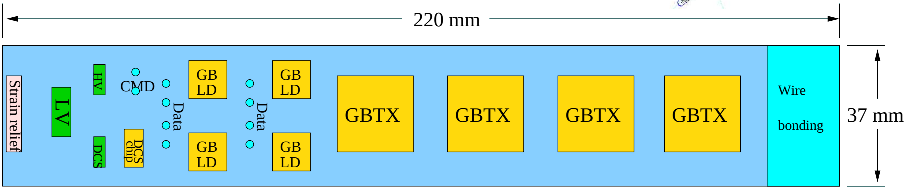
- The innermost layer is only 2 cm wide.
- The data volume is 12 Gbit/s ($\Longrightarrow$ 4 GBTX needed).
- Not clear if it is possible to place 4 GBTX on a card this narrow.
- The length of the card is not limited by other components.
- The increase in stave length, however, could be an issue for the mechanical structure.



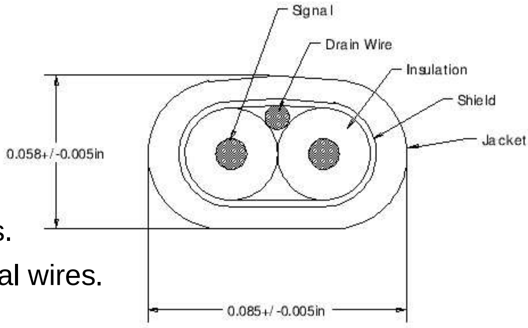
Inner Layer - Alternative Placement

- With the I-beam structure for the inner layers shown by Neal Hartman on Monday there is the option of placing the EOS card between the layers.
- Advantage: 3.7 cm width makes EOS layout look a lot more reasonable.
- Disadvantage: EOS is now (at least partly) inside the tracking volume.
- Large material spike because of radial placement.
- No cooling for the EOS in this scheme.
- One could also place the EOS for both layers outside the tracking volume but
this would require a longer I-beam.





Twinax Cable



- Copper clad Aluminum wires.
- AWG 30 (0.25 mm) OD signal wires.
- Polyethylene dielectric.
- Aluminum foil shield and drain wire.
- Polyurethane jacket.
- Total size 1.25 mm x 1.95 mm.
- ca. 0.05 % X_0 on average (with 2 cables per outer stave).

A prototype of the cable has been produced.

Rate Measurements

Cable Length	Max Rate
4 m	8.2 Gbit/s
6 m	6.2 Gbit/s

Comments

- A key element for the transmission is pre-emphasis. Without pre-emphasis even a 4-m long RG223 cable will not do 5 Gbit/s.
- An equalizer at the receiving end helps but is not crucial.
- The target rate for GBT is 5 Gbit/s.

Is this cable sufficiently radiation hard?

Irradiation at Los Alamos

- 3 cable samples were included in the August irradiation at Los Alamos.
- They were placed lengthwise into the 800 MeV proton beam.
- The total fluence as calculated from the number of pulses was $1.72 \cdot 10^{16}$ protons.
- The total fluence as measured by the 3-d sensor leakage current was $4.5 \cdot 10^{15}$ neutrons/cm^2.
- The total fluence as measured by the Al dosimeters was
  - $1.69 \cdot 10^{16}$ protons/cm^2 in front of the cables.
  - $1.18 \cdot 10^{16}$ protons/cm^2 behind the cables.
- The cables were very hot right after irradiation (about 1 rad/hr).
- After 6 weeks they read 10 mrad/hr on contact.
- Thank you to Martin Hoeferkamp (UNM) and Leo Bitteker (LANL) for their support during the irradiation.

Setup


Beam pipe
Irradiation box
Cables
Beam stop
Alignment laser

Irradiation Results

- Irradiation could have an effect on the
  - Dissipation factor which is the most important parameter in data transmission at high rate.
  - Dielectric constant. This would cause a change of cable impedance.
- A bit error rate test was run before and after irradiaton of the cable samples.
- All 3 cables still transmitted error-free at 6.2 Gbit/s.
- The cable impedance was measured before and after irradiation. No change was observed.
- The polyrurethane jacket did not show any hints of deterioration.

No radiation damage was observed.

Comments

- A maximum rate of 6.2 Gb/s in the lab may not have sufficient margin.
- The 32 AWG ground drain wire is quite brittle for soldering.
- It would probably be a good idea to move to 28 AWG signal wires and a 30 AWG drain wire.

Summary and Outlook

Summary:

- The Twinax cable performs very well electrically.
- It is radiation hard at a fluence of 10^{16}.
- A slightly larger radius might be preferrable for more margin.
- The attachment to the EOS card could be through micro connectors or a soldered pig tail.

Outlook:

- Test transmission using GBLD chip.
- Find a suitable connector for the connection at 1.5 m.
- Eventually test the system with the GBTX chip.