ATLAS Systems Safety Review on Laser Systems

Front-end Optical Links

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Overview

- Introduction
- Scope of this presentation (SemiConductor Tracker + EM calorimeter front-end links)
- Anatomy of a front-end link
    - Vertical Cavity Surface Emitting Laser (VCSEL) emitters

(1)

- Overview of EM calorimeter front-end links
- Laser hazard level classifications for EM calorimeter front-end links
- Proposed safety measures for EM calorimeter links

Questions ...

(2)

- Overview of SemiConductor Tracker (SCT) front-end links
- Laser hazard classifications and proposed safety measures covered in D. Howell's talk

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Introduction

• Front-end optical links (FE-Links) are used to connect front-end electronics located on ATLAS to remote data acquisition systems (called Read-Out Drivers - RODs)

• All ATLAS FE-Links plans to use novel Vertical Cavity Surface Emitting Lasers linked to multimode (graded or step index) optical fibres and PIN photo-diodes.

• 'Working Document on Laser Safety for ATLAS' based on SemiConductor Tracker (SCT) and EM (LArg) calorimeter links. Other systems not expected to raise significantly new safety issues and will be added to safety document as system designs mature.

• These systems used are representative of the two classes of FE-Links expected in ATLAS:

  • SCT ⇛ 100kGy / 2×10^{14} n/cm^2 / 40Mb/s / bi-directional / custom design / low mass / non-magnetic

  • LArg ⇛ 0.8 kGy / 0.2×10^{14} n/cm^2 / 1.28 Gb/s / unidirectional / commercial components / crate environment

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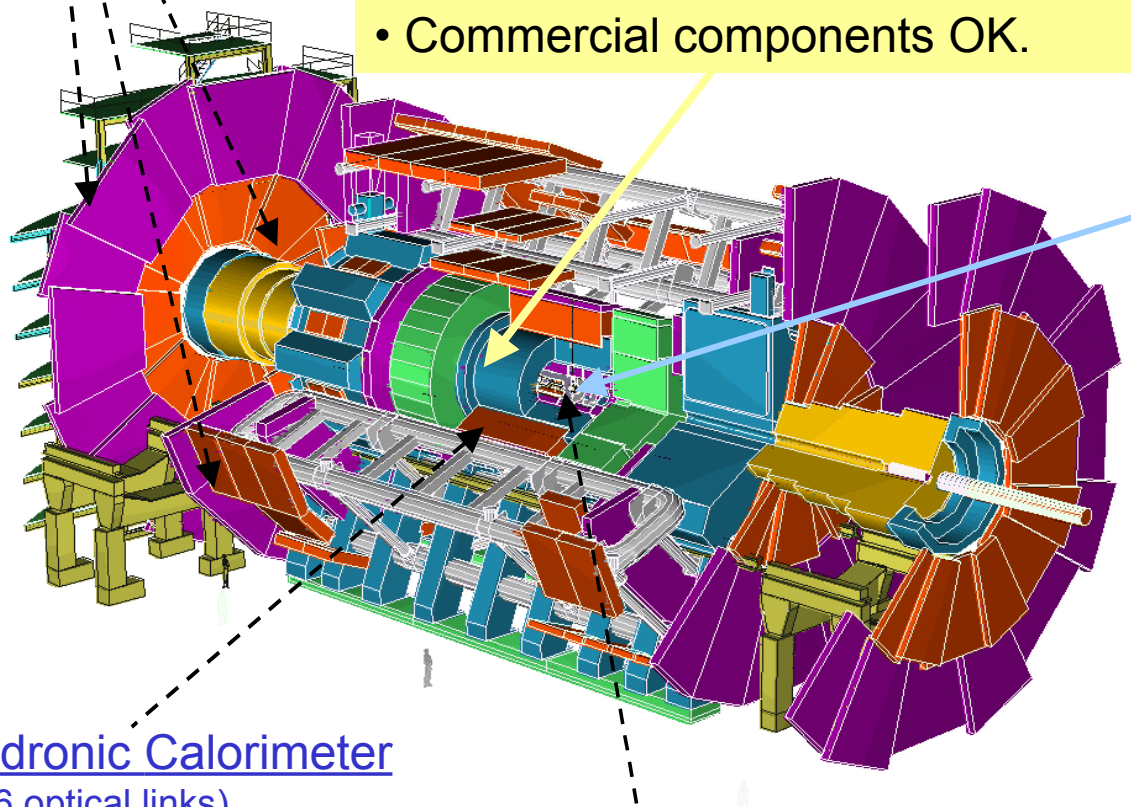
Scope of this Presentation

Muon Systems
(2700 (?) optical links)

- 1500 unidirectional links (to DAQ)
- 100 - 200m fibre length
- 32 bits @ 40MHz = 1.28Gb/s
- Crate environment
- Commercial components OK.

EM Calorimeter



Inner Detector

- Pixel and SCT detectors
- Pixel (40 - 80 Mb/s):
  - 4460 links to DAQ
  - 2230 links from DAQ
- SCT (40 Mb/s):
  - 8180 links to DAQ
  - 4090 links from DAQ
- 90m fibre length
- Non-standard environment
- Custom development needed

Hadronic Calorimeter
(256 optical links)

Transition Radiation Tracker (27000 copper links)

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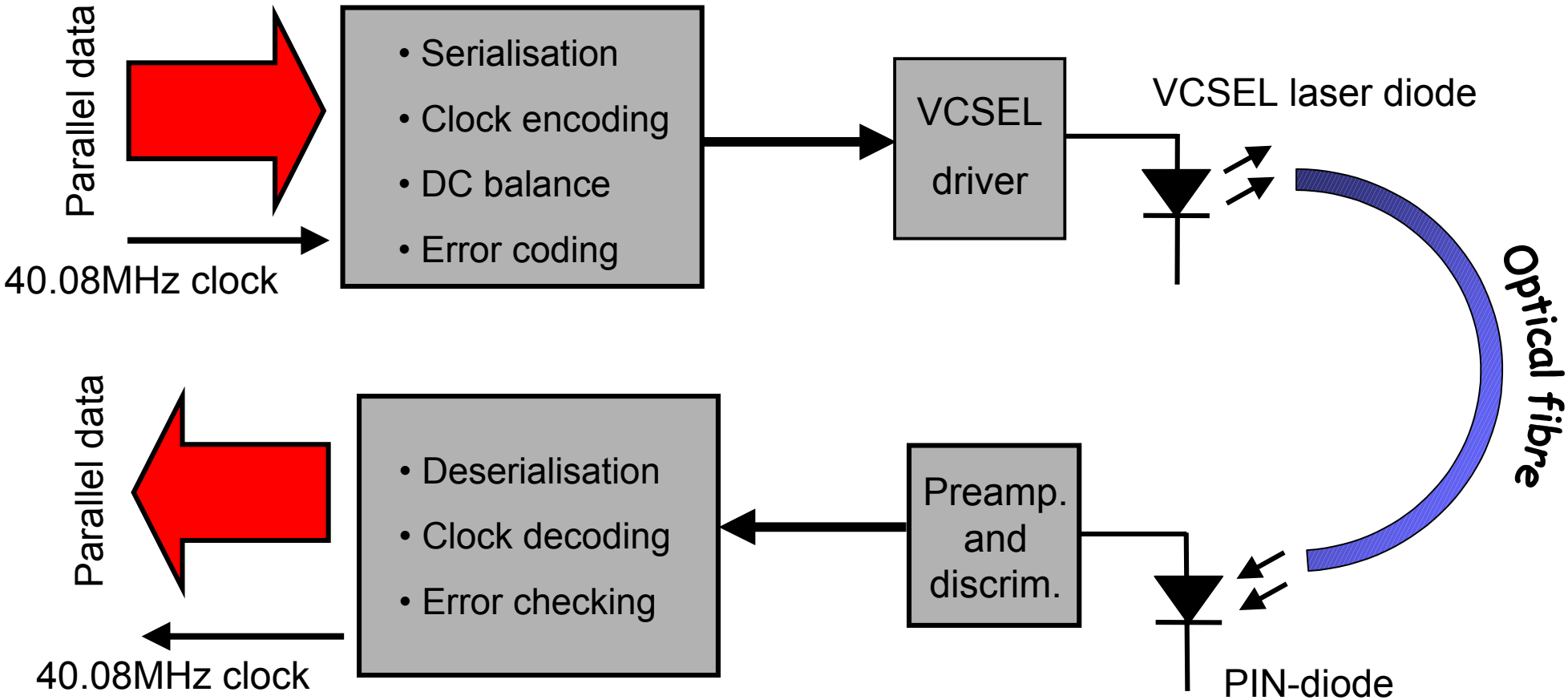
Generic Optical Link



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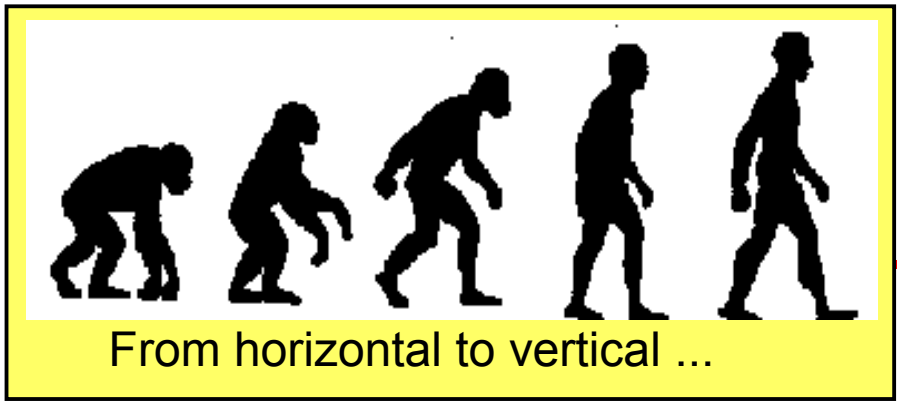
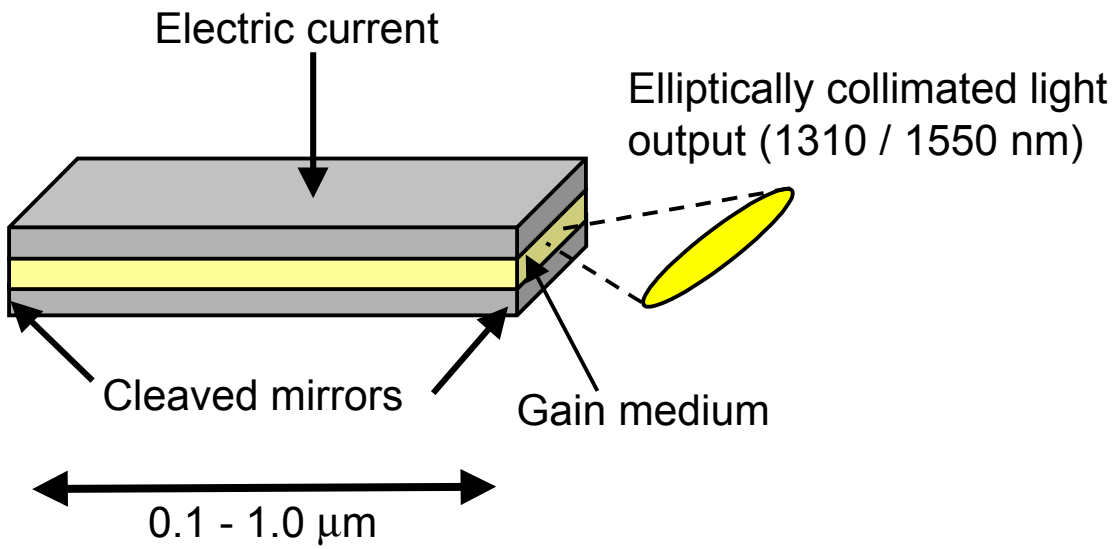
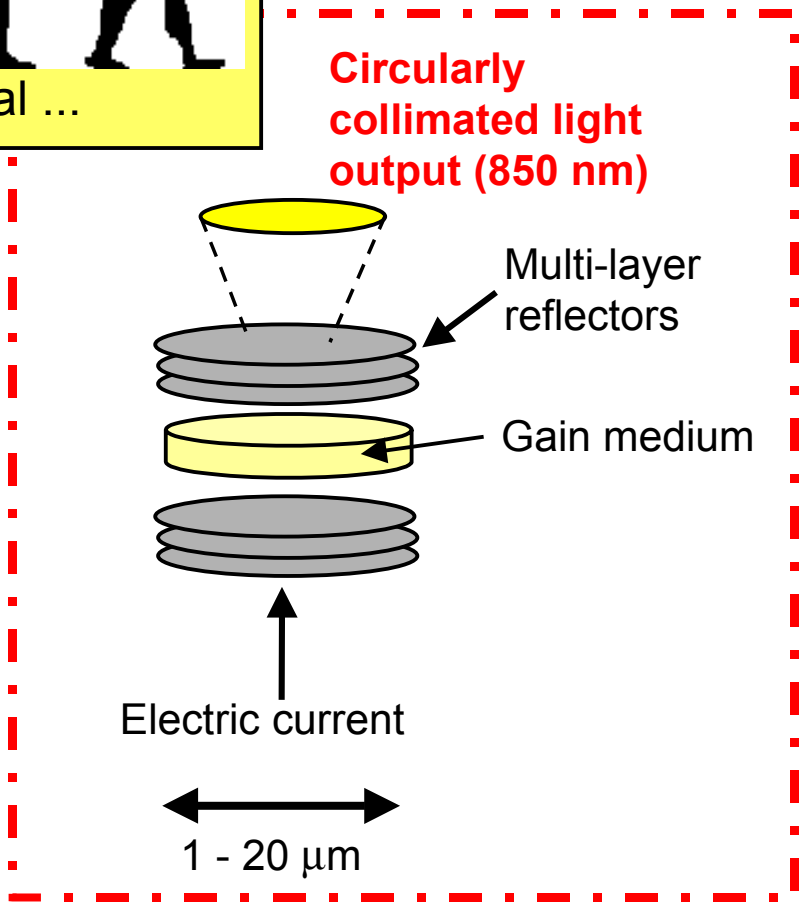
Horizontal and Vertical Cavity Lasers







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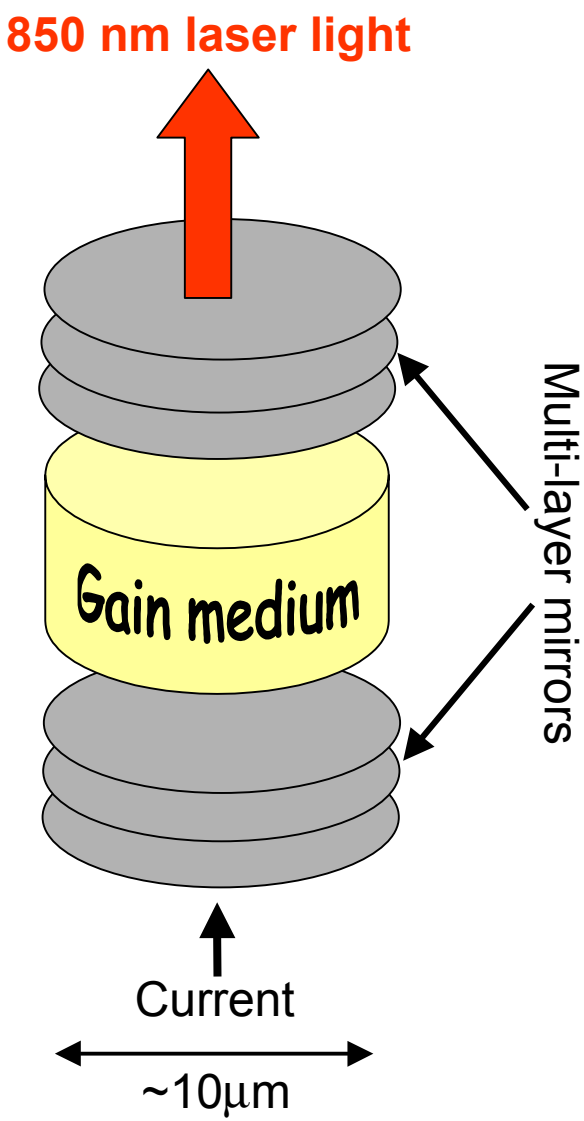
VCSEL Emitter Characteristics

(**V**ertical **C**avity **S**urface **E**mitting **L**aser)

- Surface emitter - test on wafer - cheap!
- High output power (1mW @ 10mA)
- Easy to align efficiently to fibre
- Low threshold current (2-3 mA)
- High intrinsic bandwidth (> 5GHz)
- Excellent reliability (>> 10 years)
- Excellent radiation tolerance …
  - GaAs
  - Small junction dimensions



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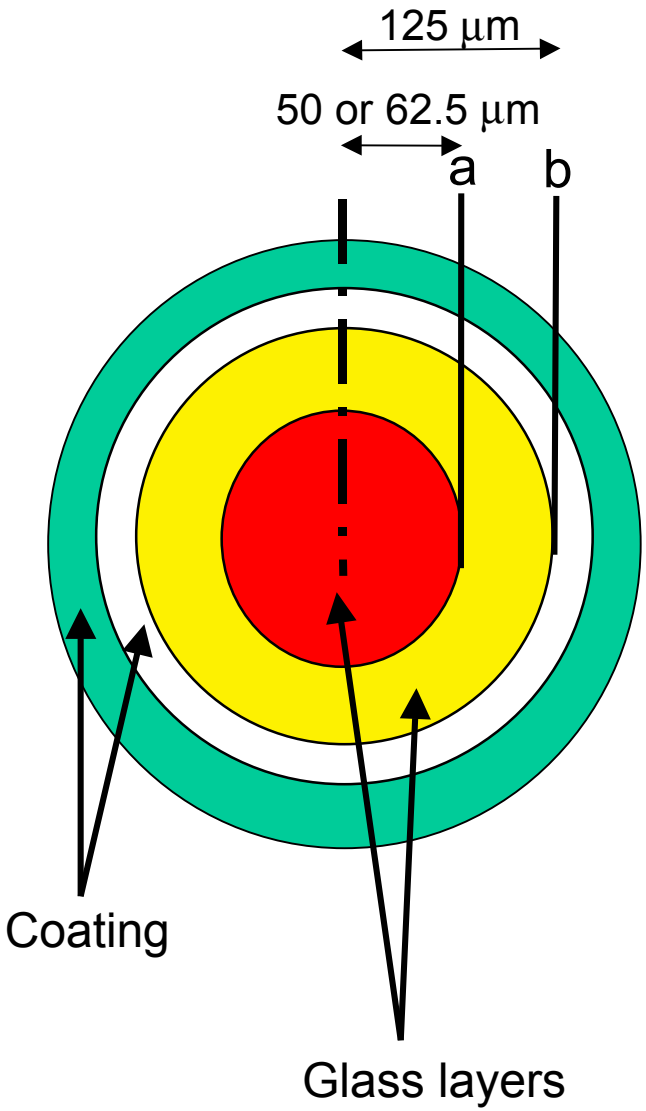
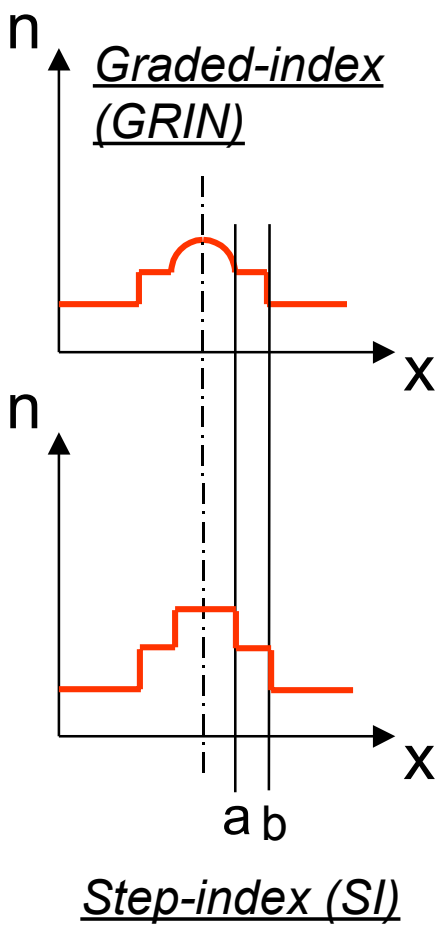
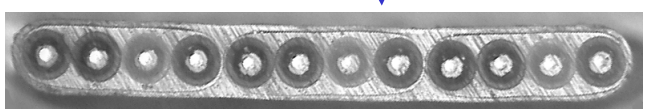
Optical Fibres





- Low divergence, circular beam profile from a VCSEL is easily coupled into a multimode fibre.
- Optical alignment is not a challenge.
- GRIN fibre typically has BW x L of 500 MHz.km. OK for Mb/s and Gb/s.
- Modal dispersion a problem for SI fibres. BWxL typically 50MHz.km. OK for Mb/s only.
- To simplify handling / cabling, fibres can be easily formed into ribbons.



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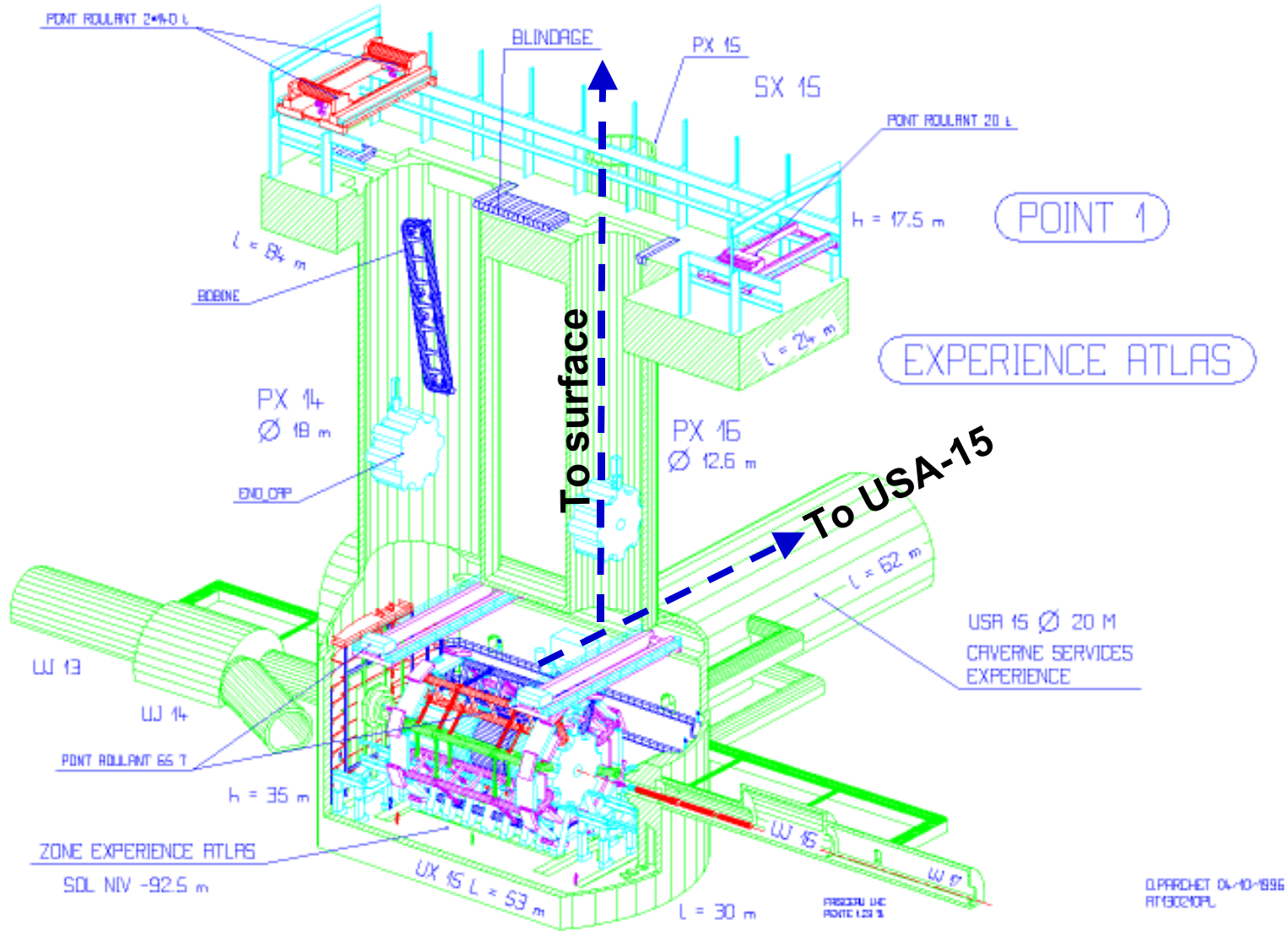
Overview of Fibre Routing in Cavern



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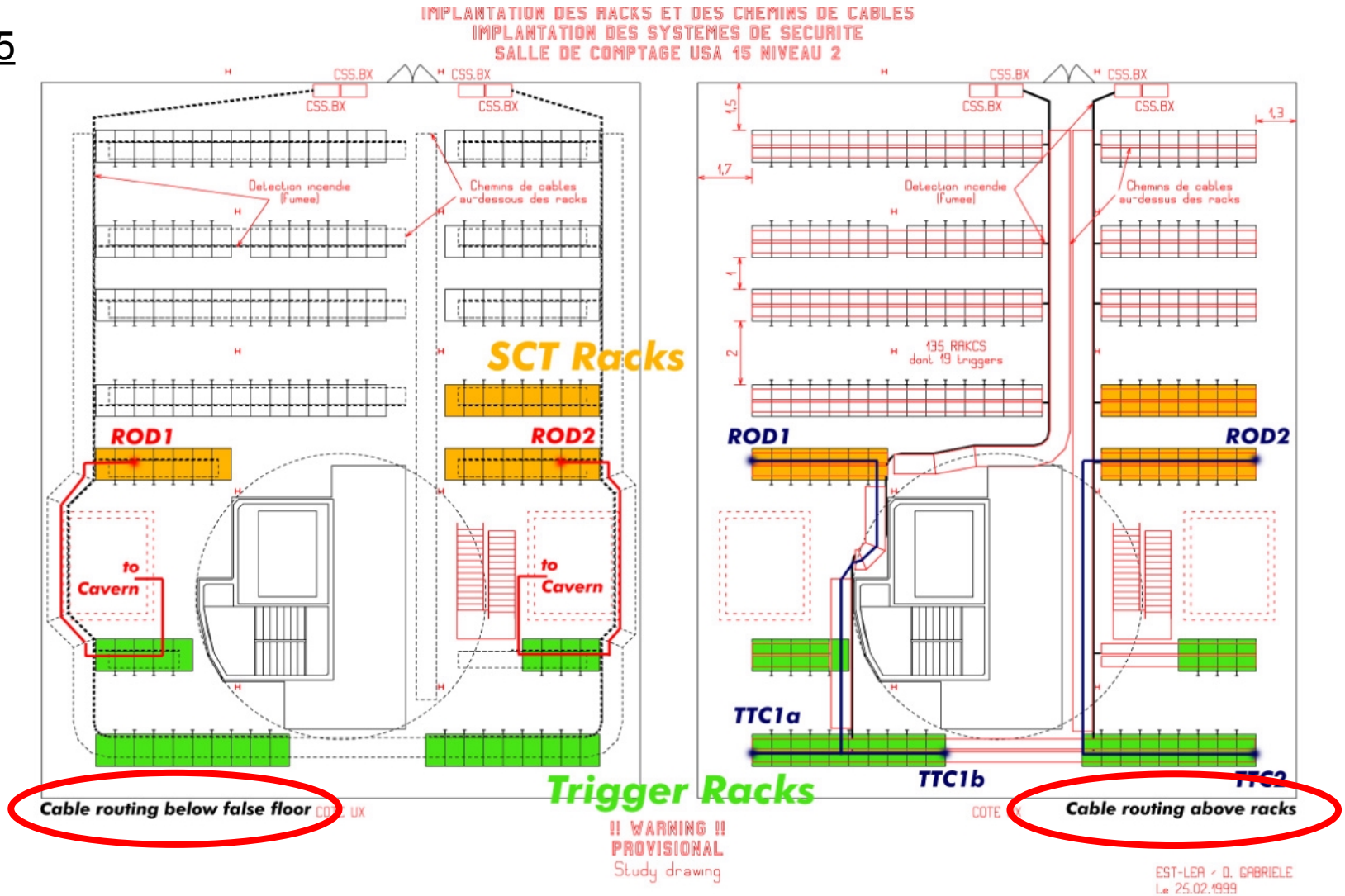
... and in the Counting Room

USA-15



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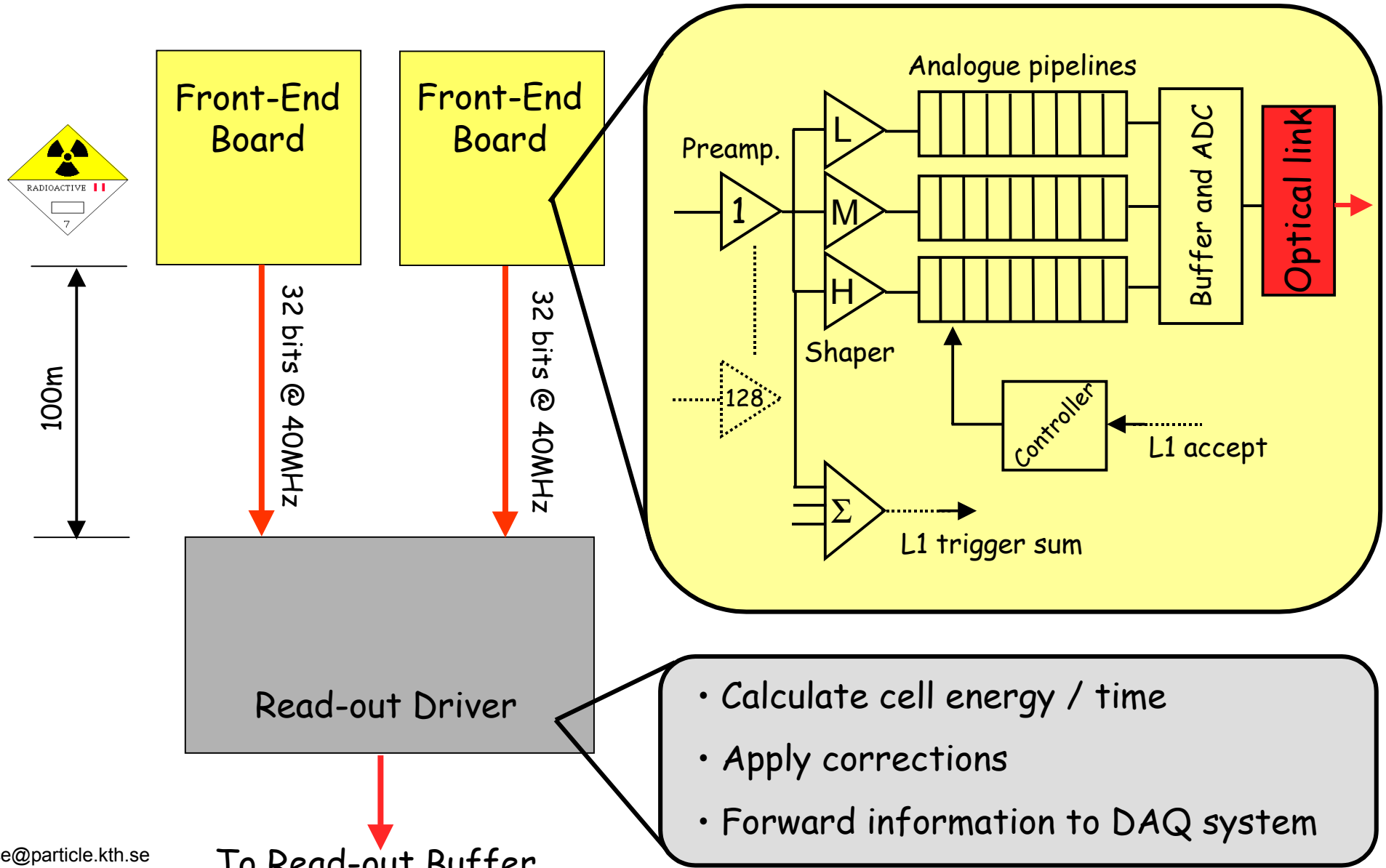
EM Calorimeter Link Layout



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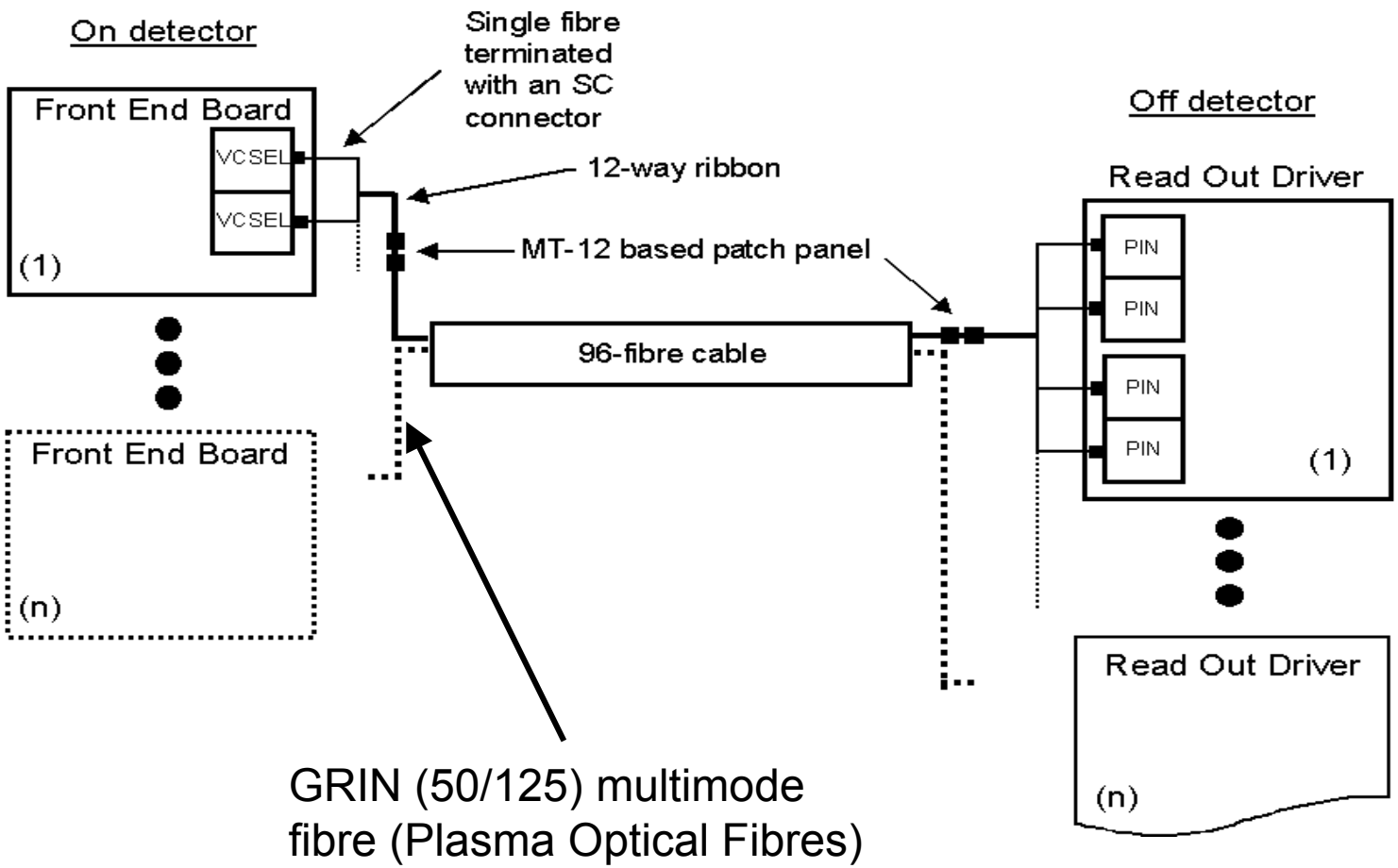
Prototype LArg Link Installation



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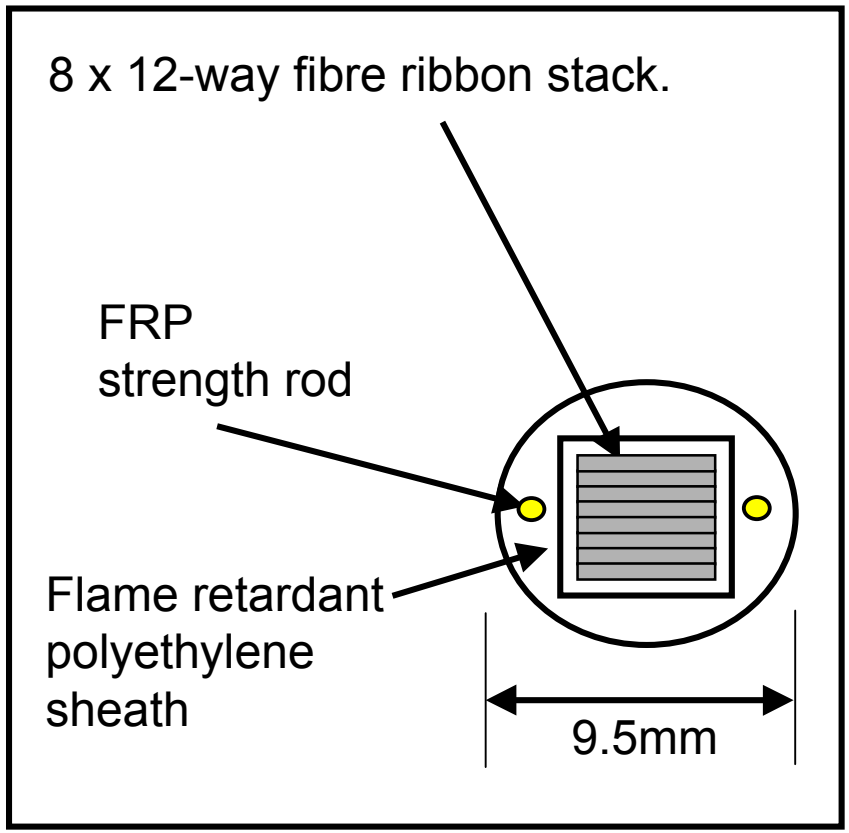
(Based on double optical link per FEB)

Ericsson 96-fibre Cable



- Development in collaboration with CMS tracker (SM fibre for CMS + MM fibre for ATLAS)
- Mechanical tests to IEC 60794 specifications:
  - Repeated bending (OK @ 1000 x 180mm)
  - Tensile strength (OK @ 1.8 kN)
  - Torsional strength (OK @ 5 x ±360^{o}, 1 x ± 2520^{o})
  - Impact resistance (Sheathing break @ 15.7J, ie: 4 kg from 0.4m)
  - Crush resistance (OK @ loads up to 2 kN)
- IEC 332-3 (R / 60s / 2s / 400mm) passed
- Mechanical tests repeated after 1Mrad + 10^{14} n/cm^2. No significant differences in performance.

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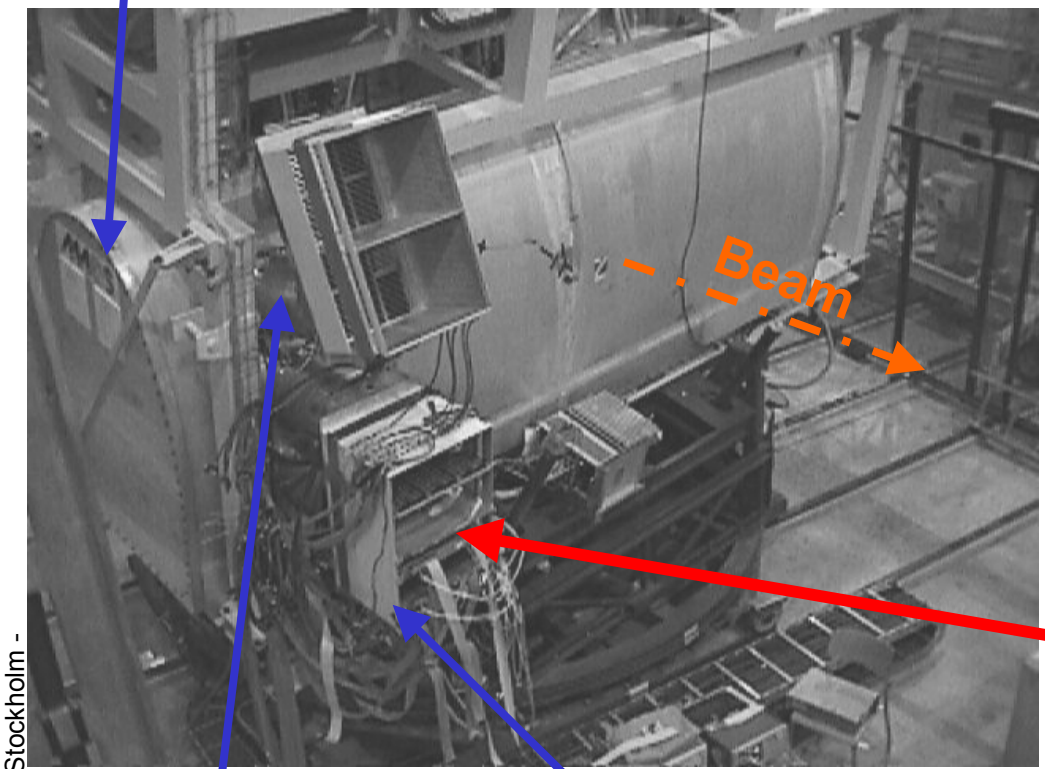
(Proprietary information)

Testbeam Set-up

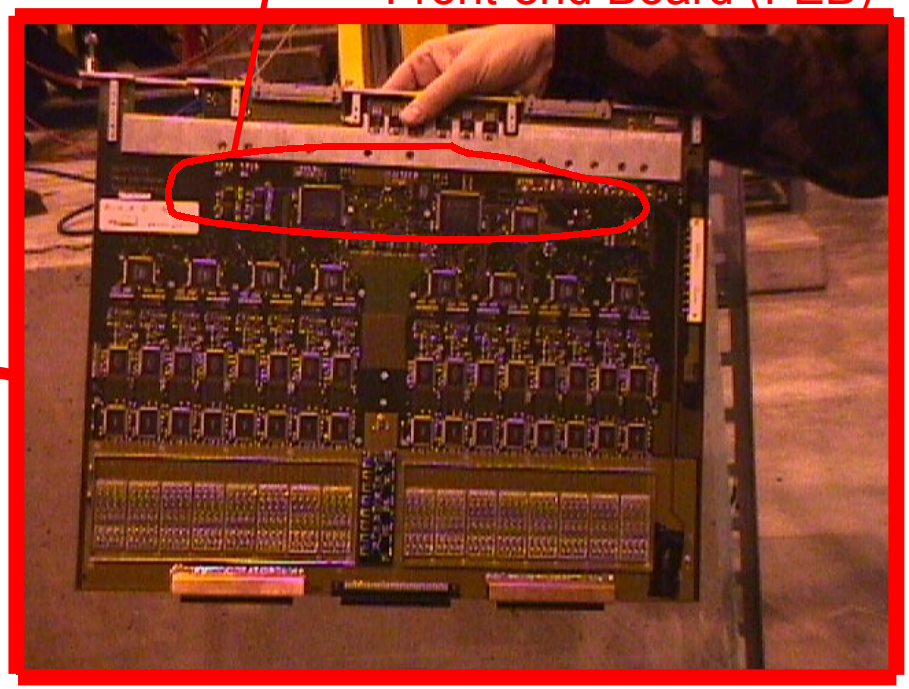
Cryostat

Testbeam



Space for optical link

Front-end Board (FEB)



Feedthrough

Electronics crate

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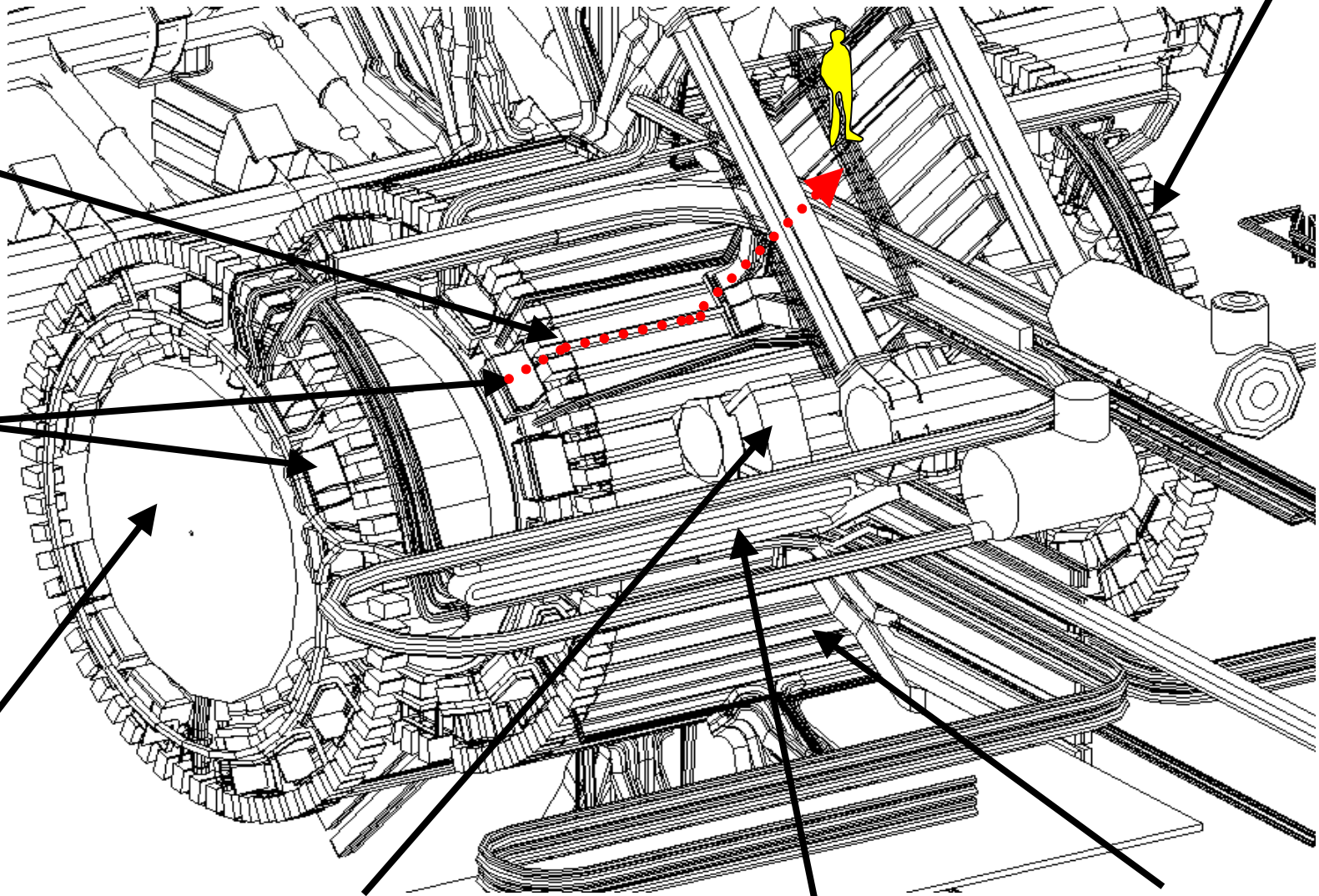
Environment in ATLAS



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Laser Hazard Level Classifications

- Working assumptions:
  - Maximum Fibre Coupled Power = 3mW (guaranteed and fail-safe by design)
  - NA (min) = 0.16 (15^{o} full width emission angle)
- So:
  - **Single fibres / on-detector VCSELs / fibres in cables**: <2.2mW per fibre for 3A and <6.6 mW (5.7mW) per fibre (VCSEL) for k x 3A, so: **k x 3A**
  - **MT-12 connectors**: <0.18mW per fibre for 3A / <0.55mW per fibre for k x 3A, so: **3B**
- Interpret (IEC) ATLAS as an area of 'restricted access'
- Treat k x 3A and 3B hazard levels separately ...

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Safety Measures (1)

- **Single fibres, ribbons, ribbon cables and VCSELs** are **< k x 3A**, so:
  - Mark fibres and cables to distinguish from other services
  - Provide mechanical protection to IEC 794-2
  - VCSEL (PIN) connectors on (off)-detector labelled
  - Provide Automatic Power Reduction (APR) through shuttered VCSEL emitters on-detector and shutter connectors to PIN-diodes at ROD crates
  - NB: Propose shutters are sufficient as power levels in question are a lower end of k x 3A

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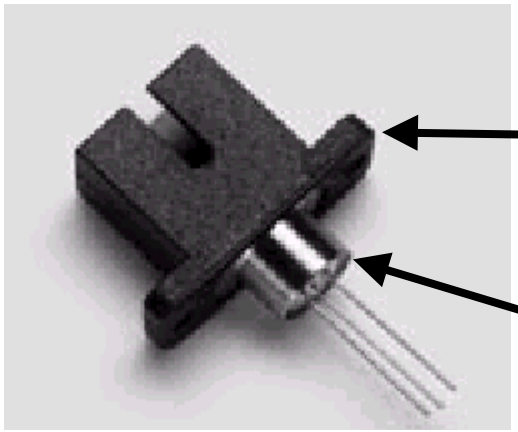
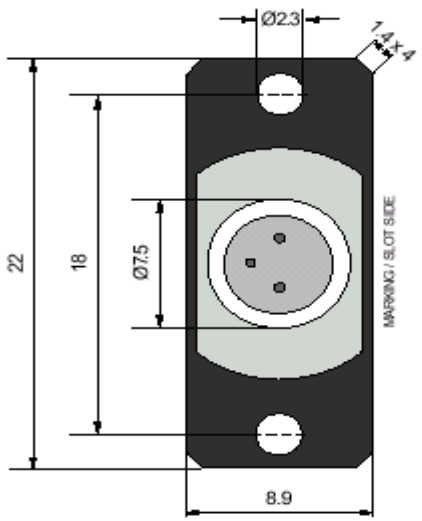
APR for VCSELs and PIN fibres

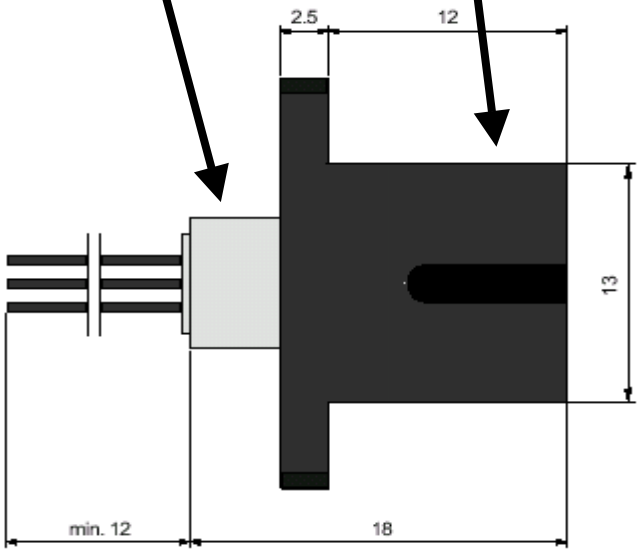


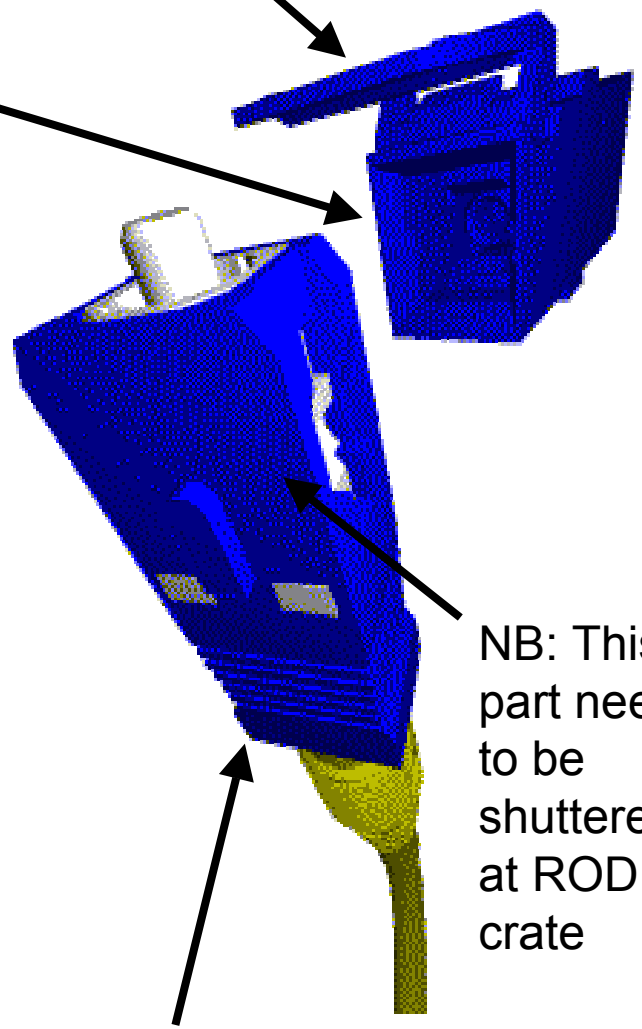
‘SC’ socket adapter

VCSEL emitter in ‘TO’ can

Spring-loaded shutter







NB: This part needs to be shuttered at ROD crate

‘SC’ connector

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Safety Measures (2)

- **MT-12 based patch panels** (on and off-detector) - need to **reduce to < k x 3A**:
  - Totally enclose patch panels (labelled / robust / tool to open / warning lights to indicate active lasers)
  - Three options under consideration:
    - Shuttered MT connectors. Would need to be developed as these do not exist commercially at present.
    - Fail-safe hard wired interlocks to turn off VCSELs if MT-12 connectors are exposed. Would not rely on DCS ('slow controls'). Would be radiation tolerant. May need to be optical in order to fit into detector grounding rules. Proposed actions of this interlock (TBD):
      - Turn off on-detector VCSELs via 'laser inhibit' function built into commercial VCSEL driver chip.
      - Turn off power to a particular partition of the Front-end Crate system. Interlock acts on 500V primary supply located in USA-15.
    - (Operate links with reduced power (< 0.18mW per channel). This is not a favoured solution).

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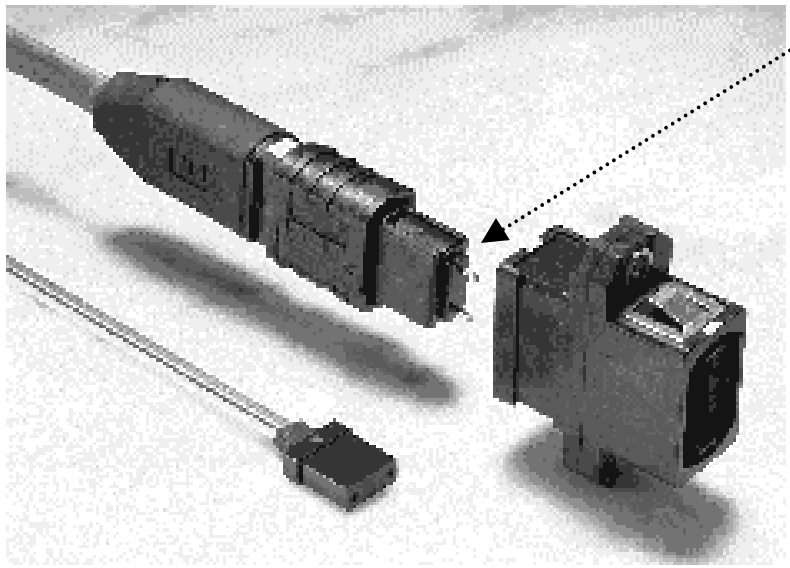
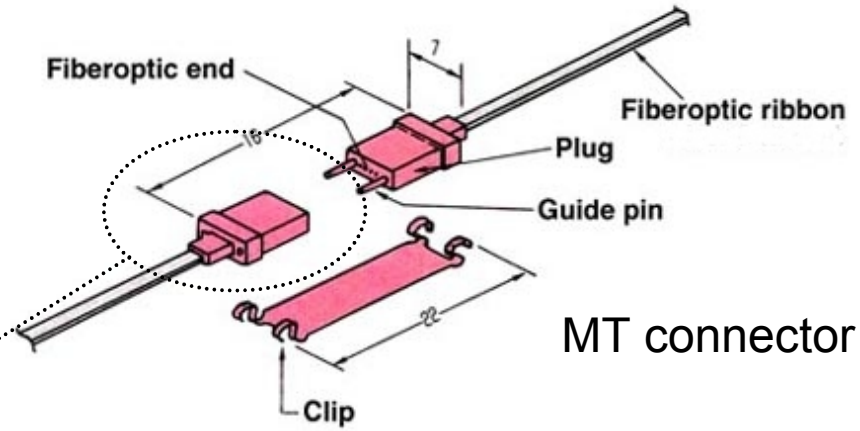
Fibre Ribbon Components

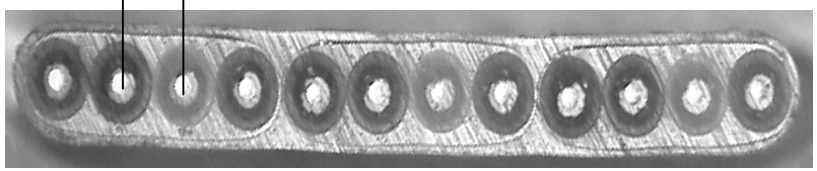
MPO connector





MT connector

250μm



Fibre Ribbon (12-way)

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MT-12 Patch Panels

Trunking

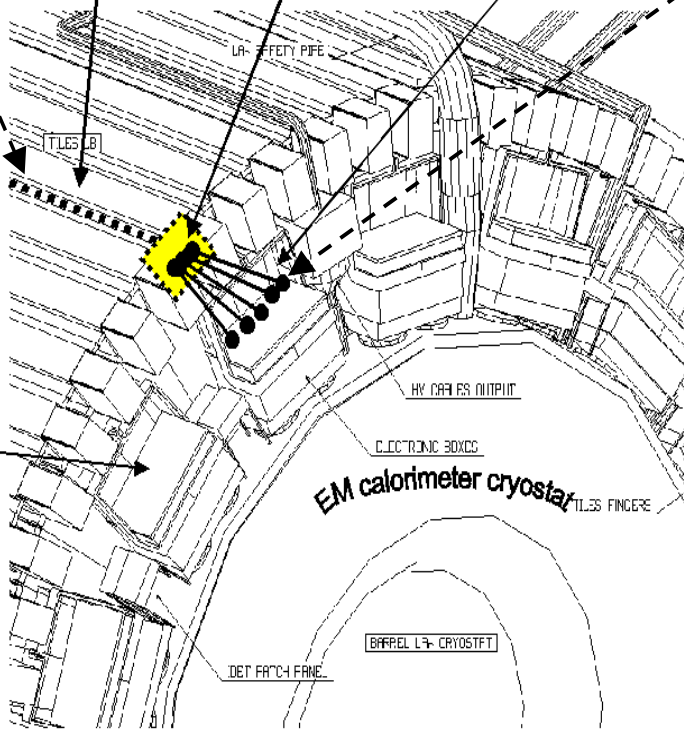
On-detector

96-fibre cable

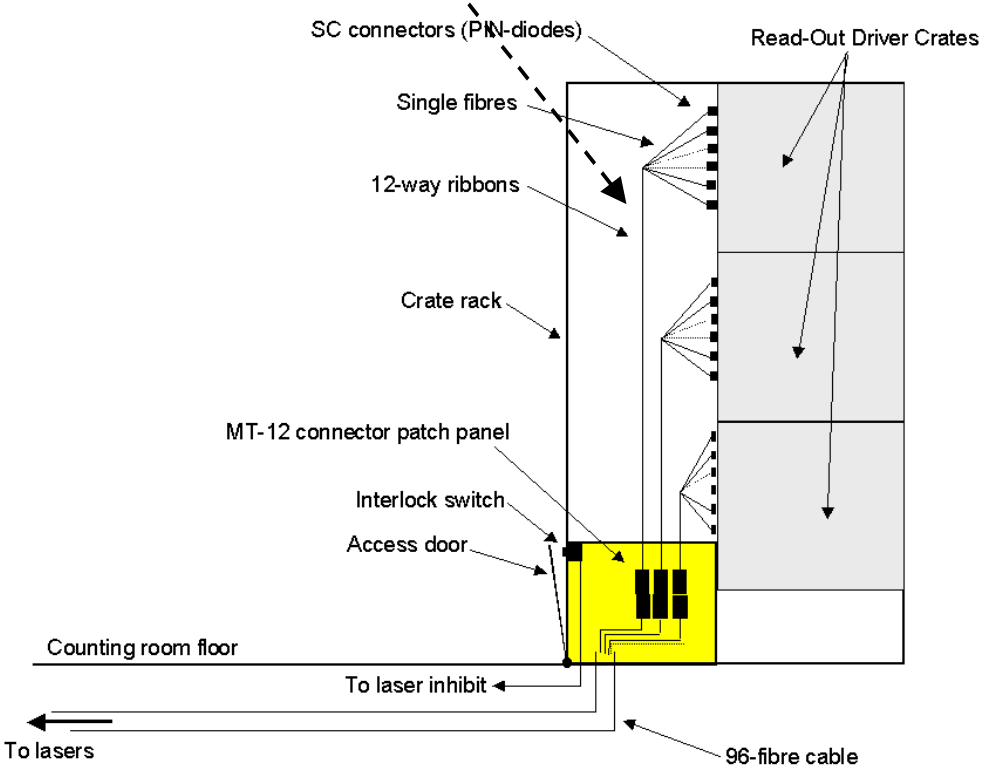
MT-12 patch panel

Single fibres

Flexible stainless steel tubing or Kevlar reinforced plastic tubes etc.



In USA-15



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Summary for LArg Links

- ~3200 unidirectional optical links @ 1.6 Gb/s over 100 - 200 m
- Route map from Front-End Boards to cable:
  - VCSEL emitters on-detector. Marked + shuttered 'SC' connectors.
  - Connected to single fibres. Protected with Kevlar yarn in plastic sleeves.
  - Formed into 12-way ribbons. Protected with flexible stainless steel tubing or equiv.
  - Grouped at MT-12 patch panels. Shuttered / dedicated interlock to VCSELs
  - Groups of 8 formed into 96-fibre cables. Mechanically robust and laid in trunking
- Same hierarchy to break out from cable to PIN-diodes in ROD crates
- Propose that these safety precautions ensure no part of system is > k x 3A.
- NB: Too early to define laser safety rules envisaged for assembly / integration tests and maintenance
- But, will follow the philosophy described above.

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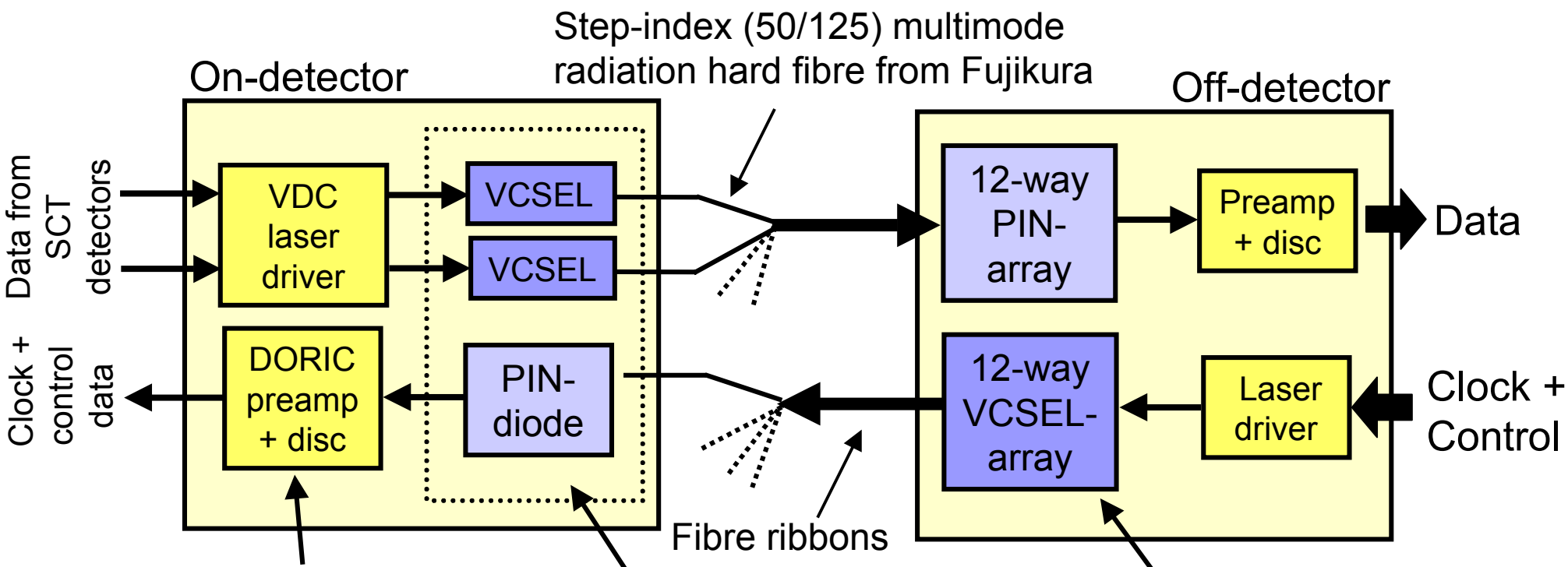
SCT Link System



- VDC + DORIC designed in AMS 0.8mm BiCMOS process. Not a radiation hard process, but:
- Only bipolar NPN transistors used
- Operate transistors with large currents, ie: β is large and less sensitive to radiation damage.
- Designed to be insensitive to changes in β

Custom packaging from Marconi (UK)

Commercial 12-array components from Mitel (for example)

Bi-**P**hase **M**ark encoding used send control data on top of 40MHz system clock. Data is coded using a **N**on-**R**eturn to **Z**ero scheme.

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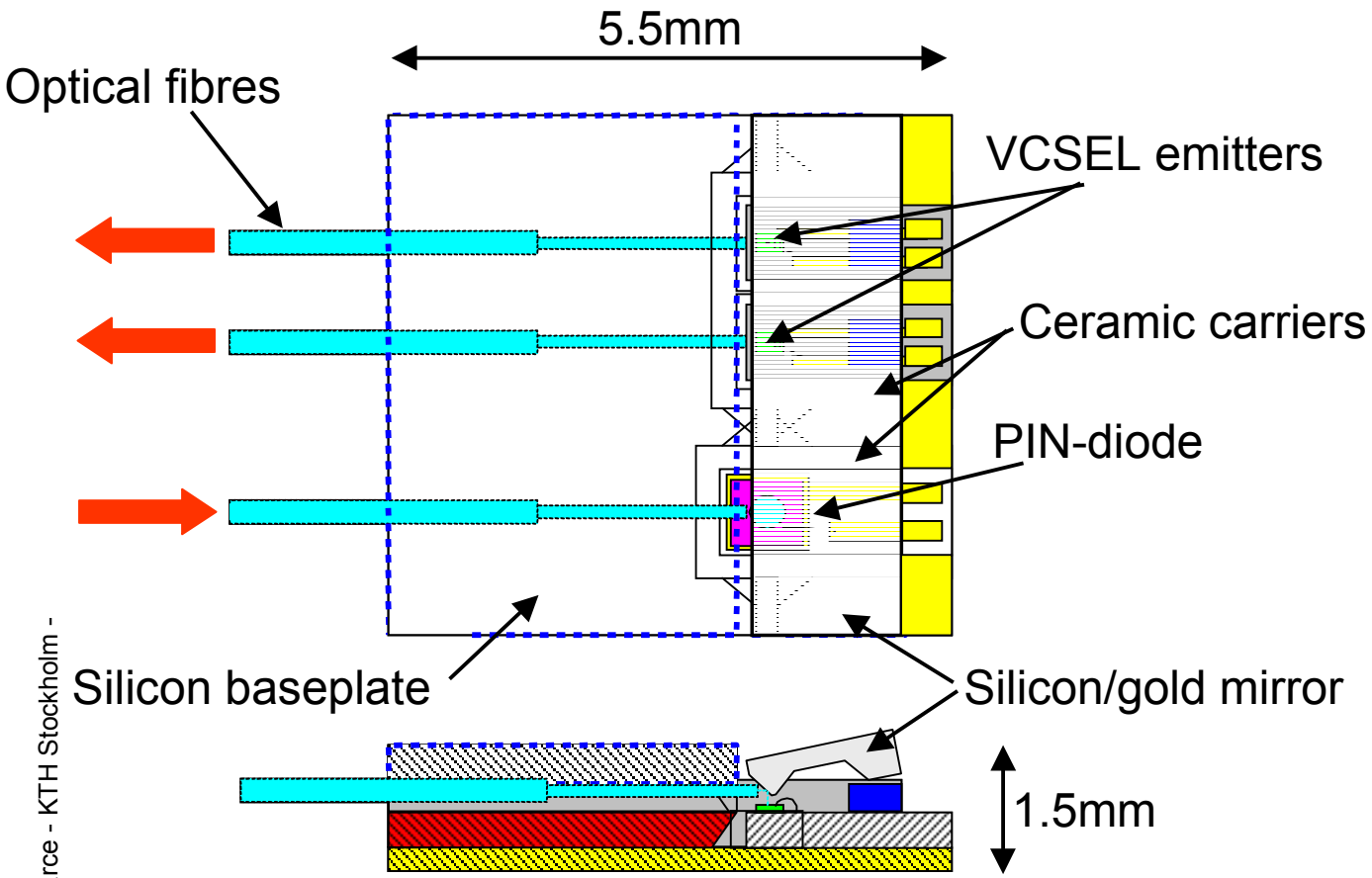
SCT Opto-package

Custom development with Marconi (UK):



- Can couple 0.5mW into a 50μm core fibre
- No micro-lenses needed
- Completely passive alignment with silicon V-grooves
- Light directed by silicon/gold mirror
- Low mass (0.014 X_o)
- Non-magnetic (2T field)

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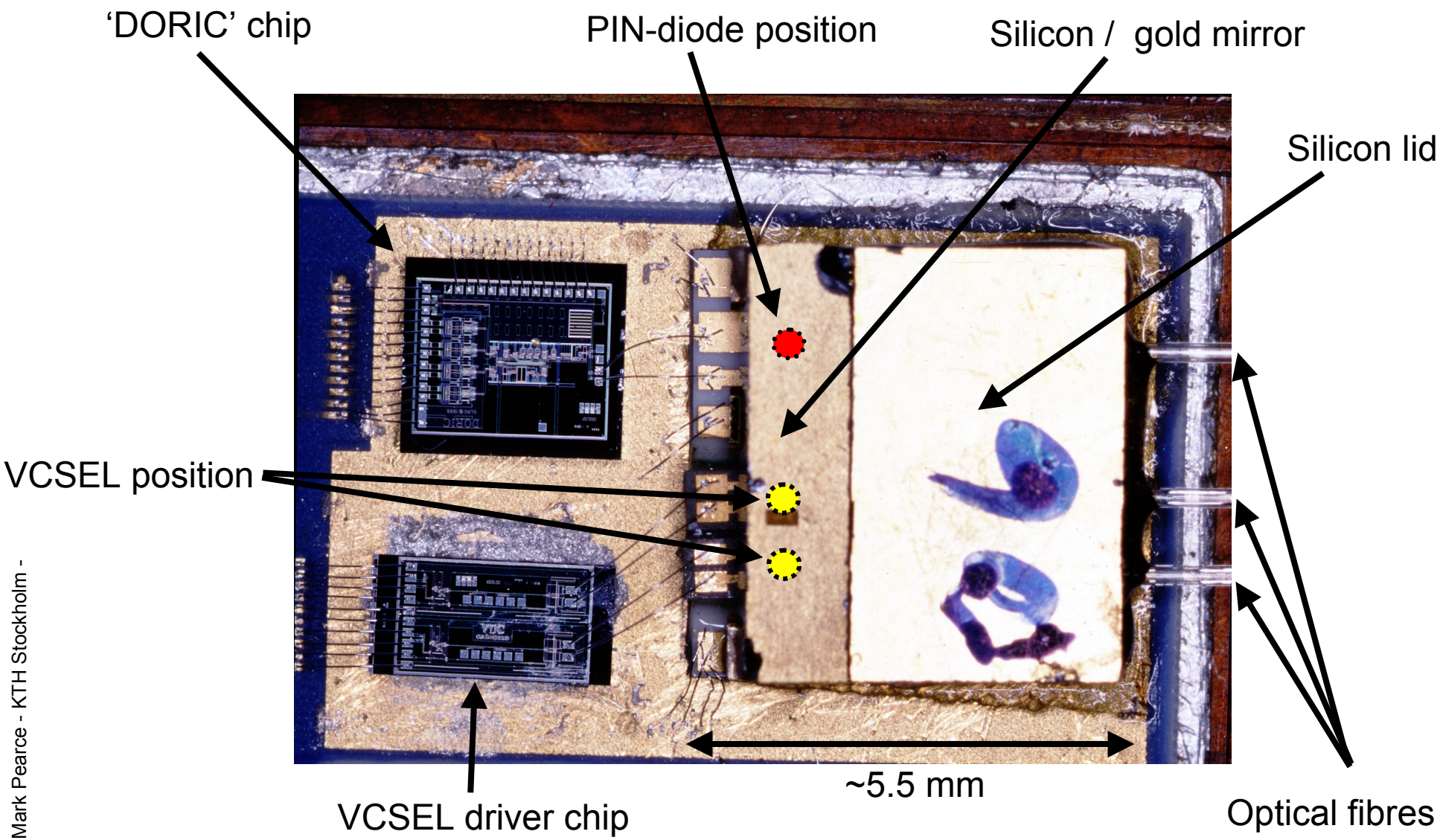
Actual SCT Opto-package



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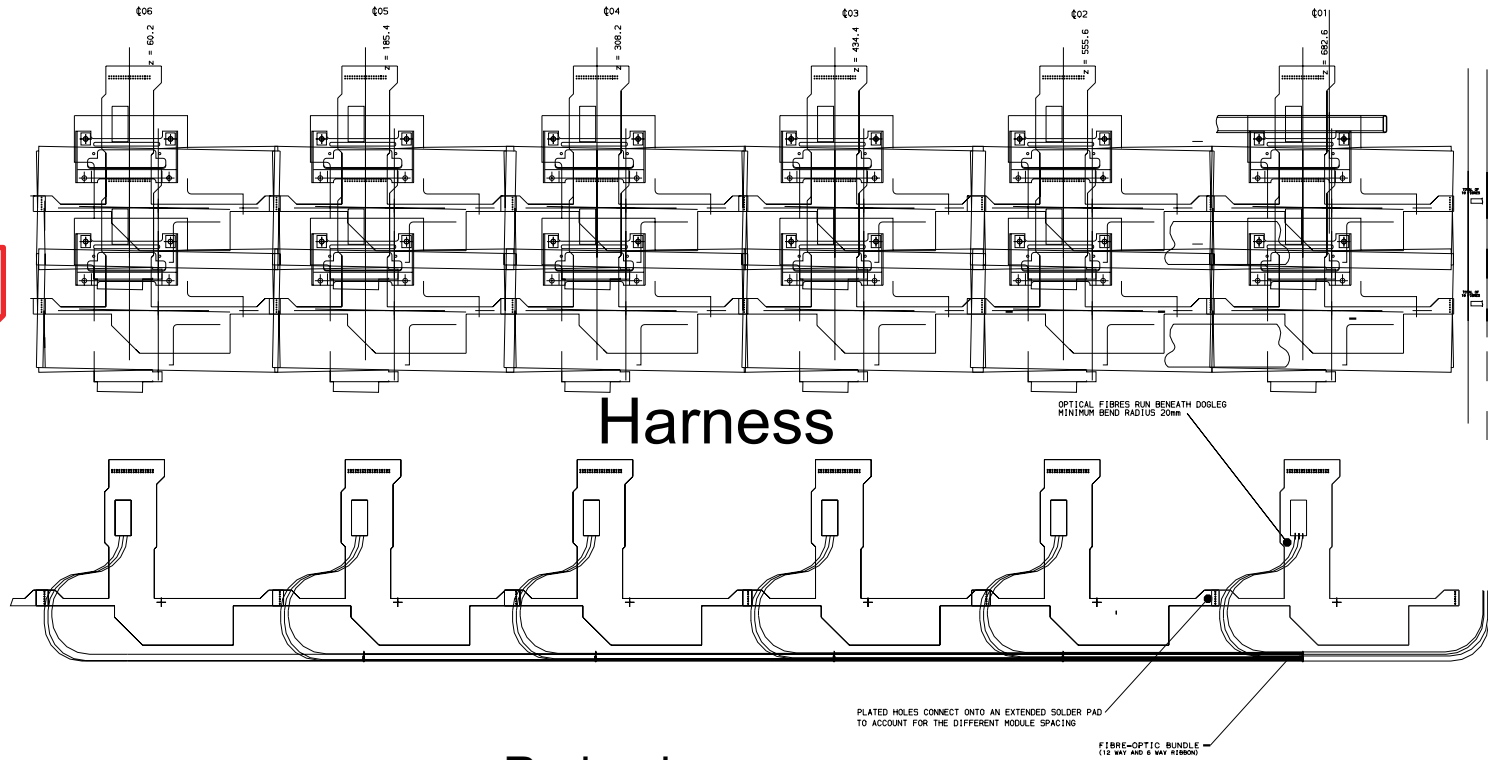
Opto-package Environment



Module connector

Opto-package DORIC & VDC

Redundancy Connection

Dogleg

Control Fibre

Data Fibres

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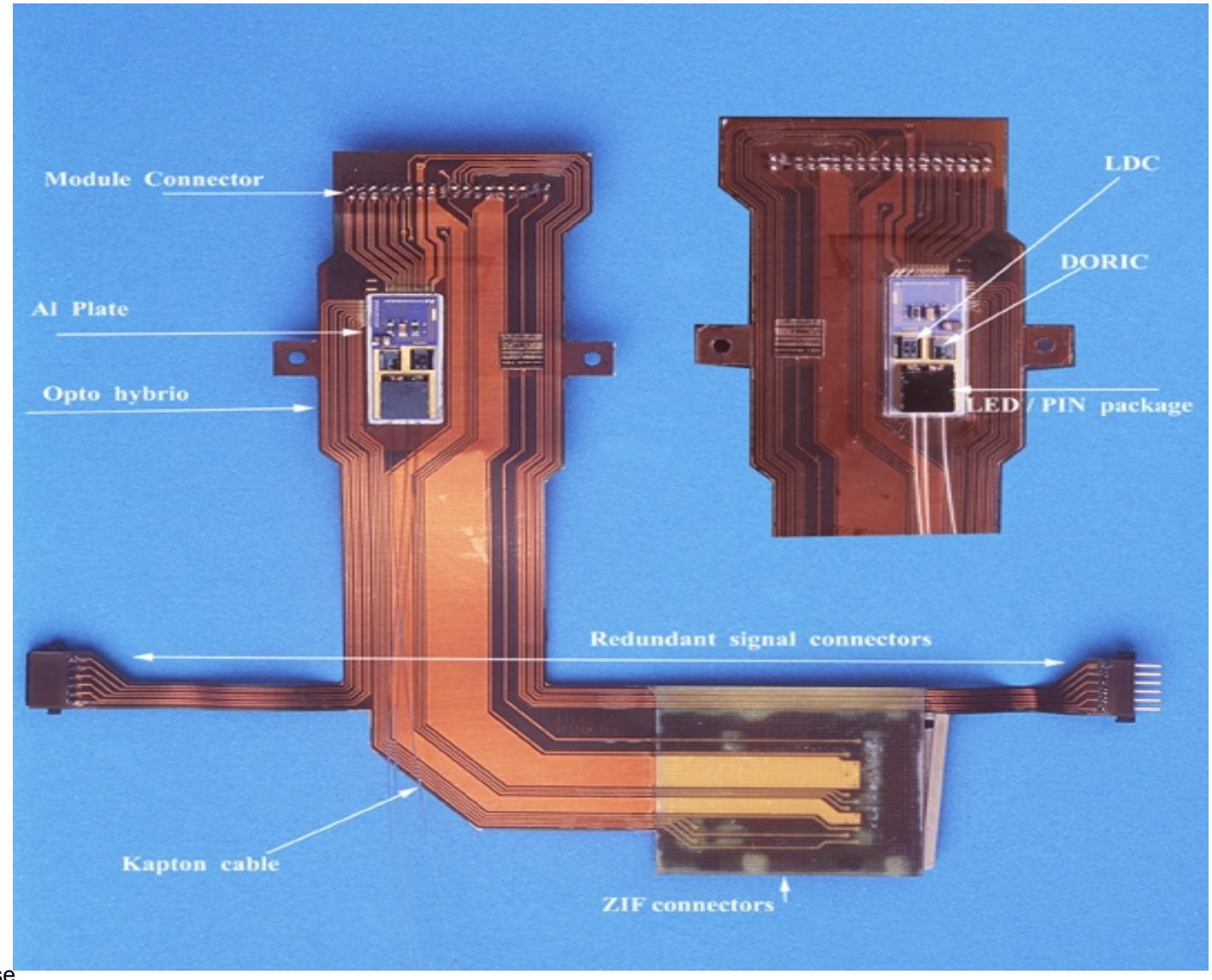
‘Dogleg’ Assembly



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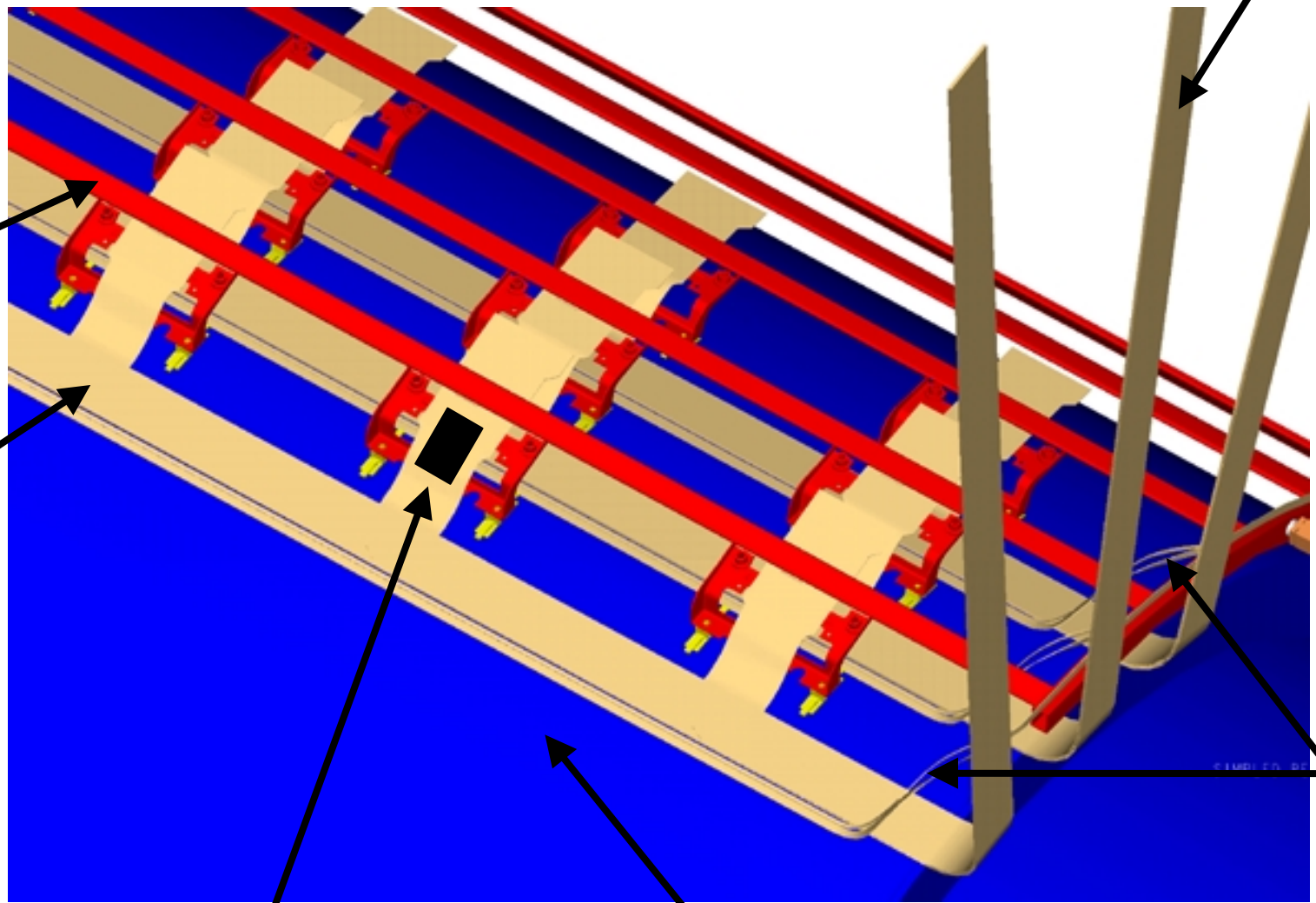
Harness Integration



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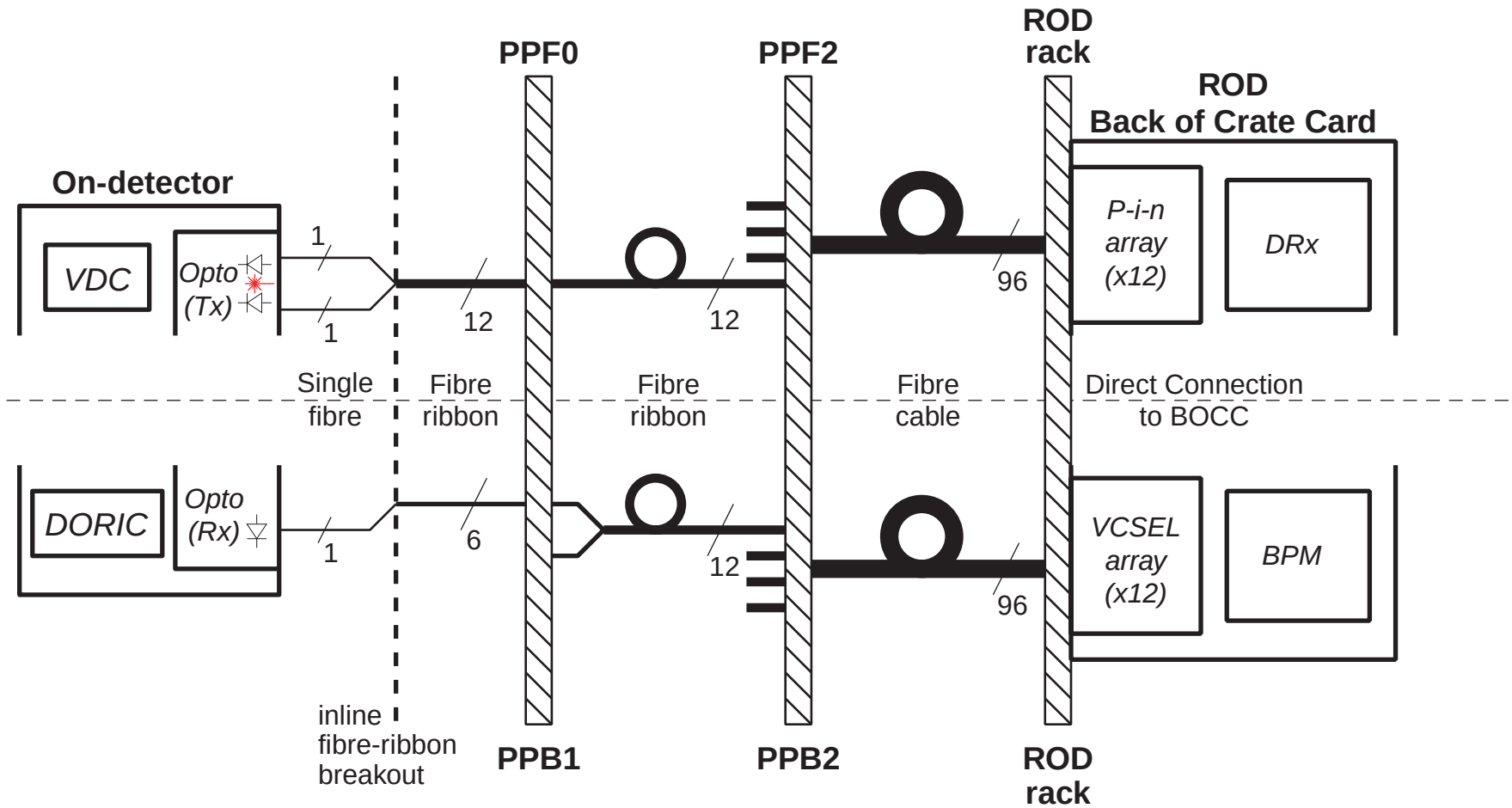
Patch Panels



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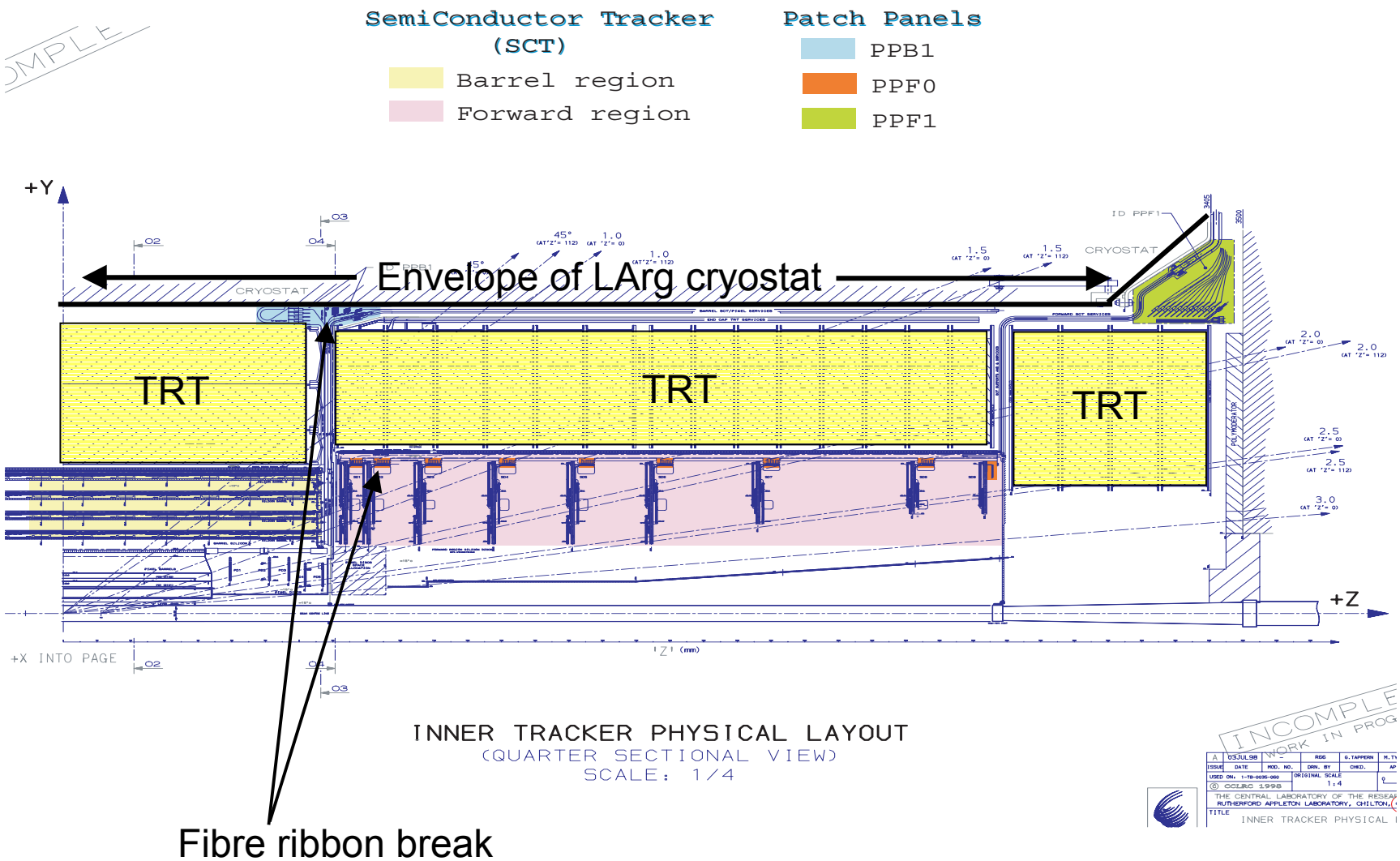
Location of Patch Panels



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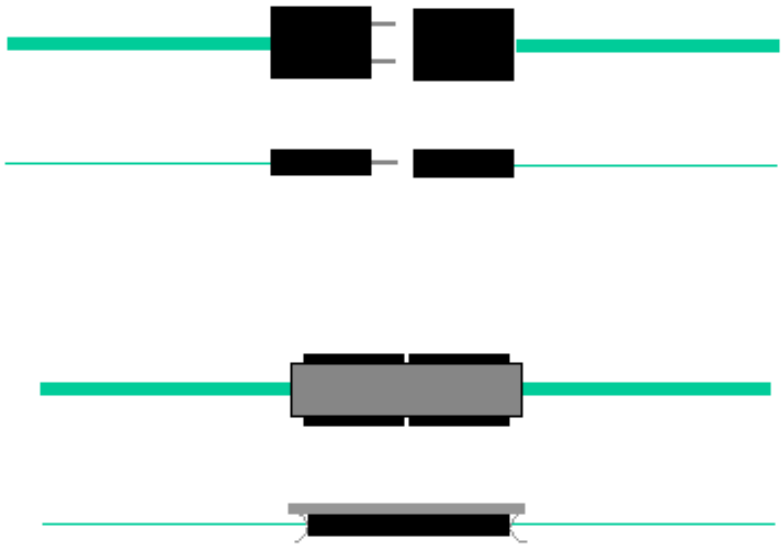
The 'Fibre Clip'

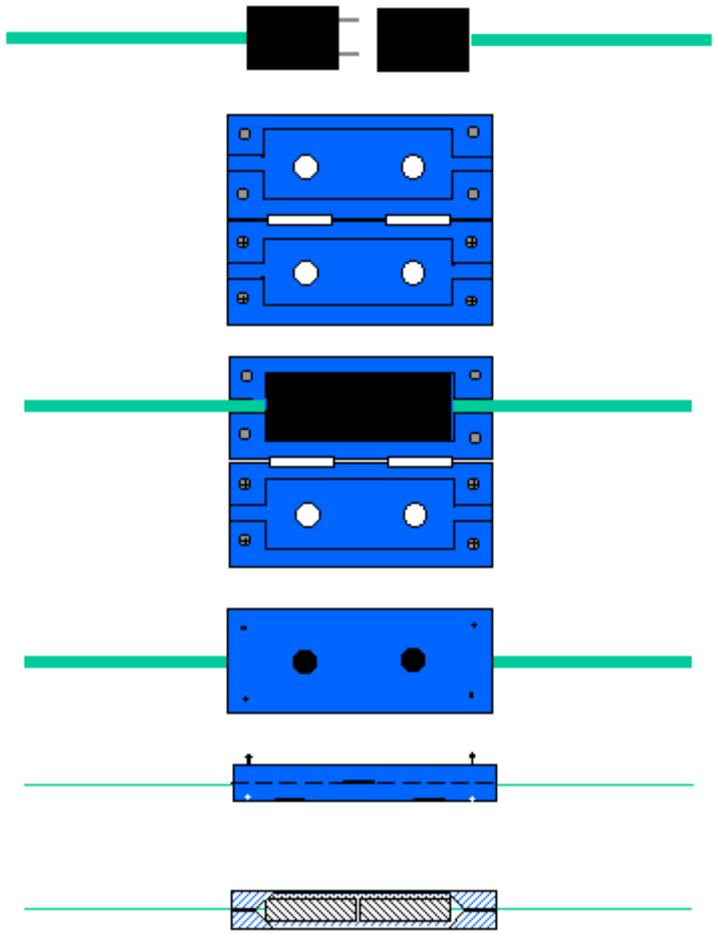
Present Spring Clip



low mass + cheaper

... non-magnetic

FibreClip



Proposed for all SCT patch panels

NB: Prototype design!

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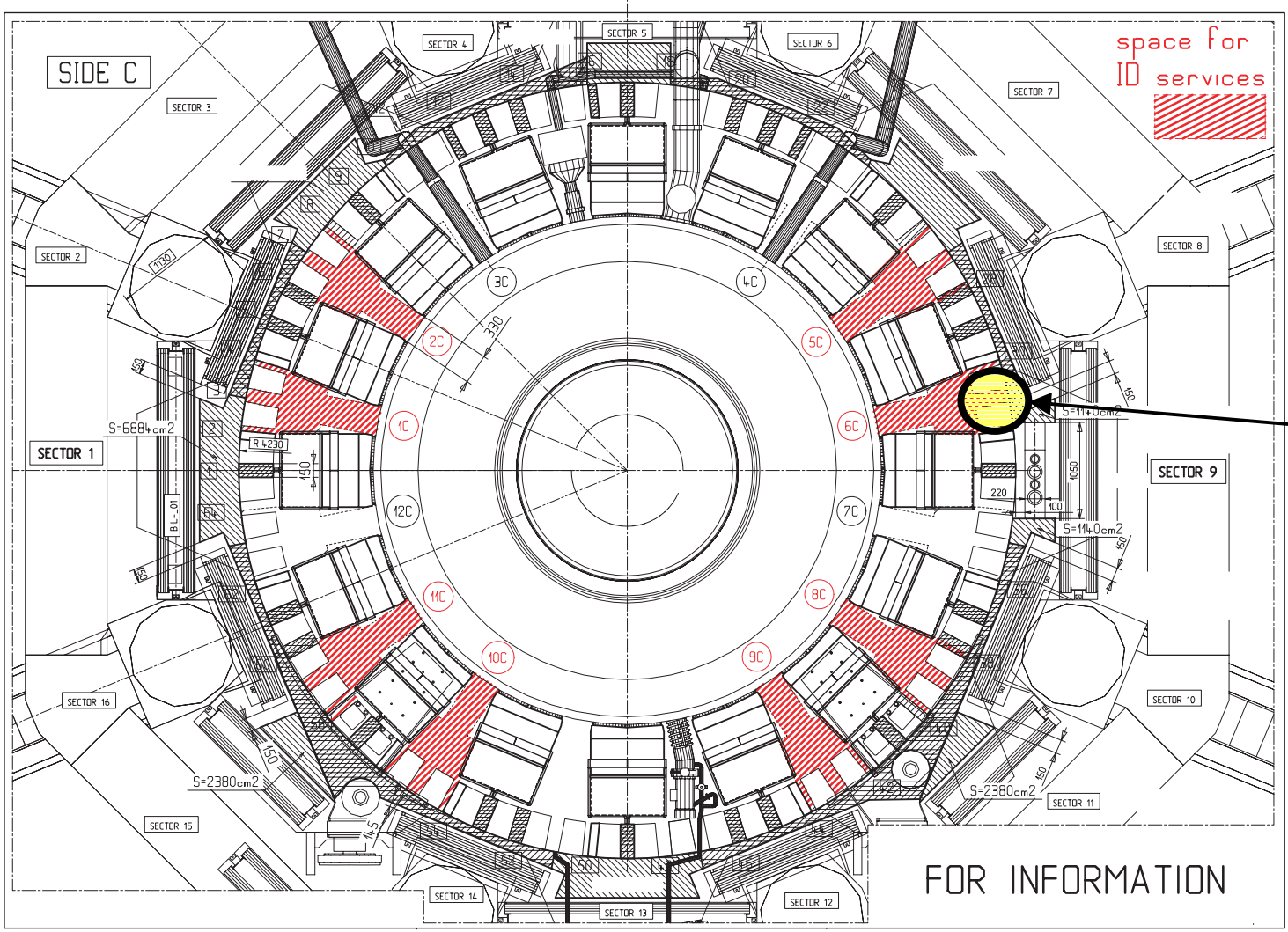
PPB(F)2 Patch Panels



Patch panel for conversion from ribbons to Ericsson Cable in this vicinity

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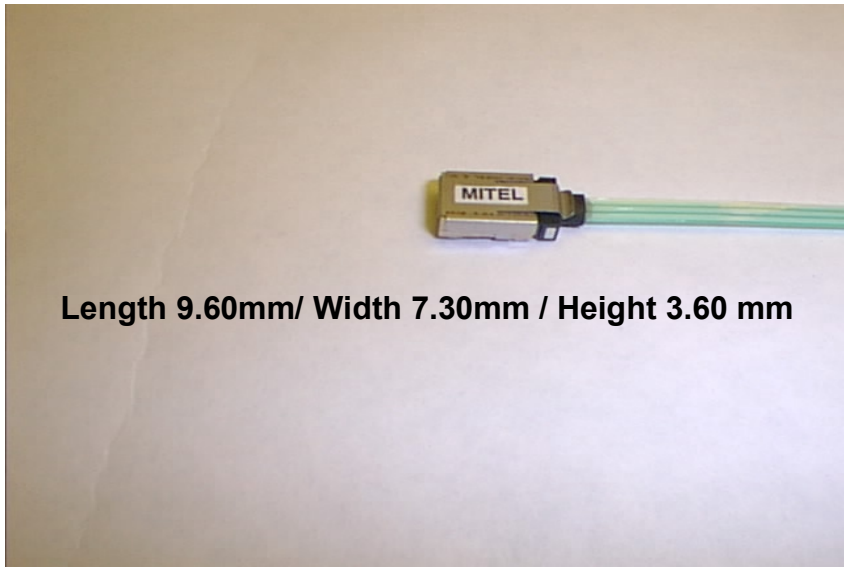
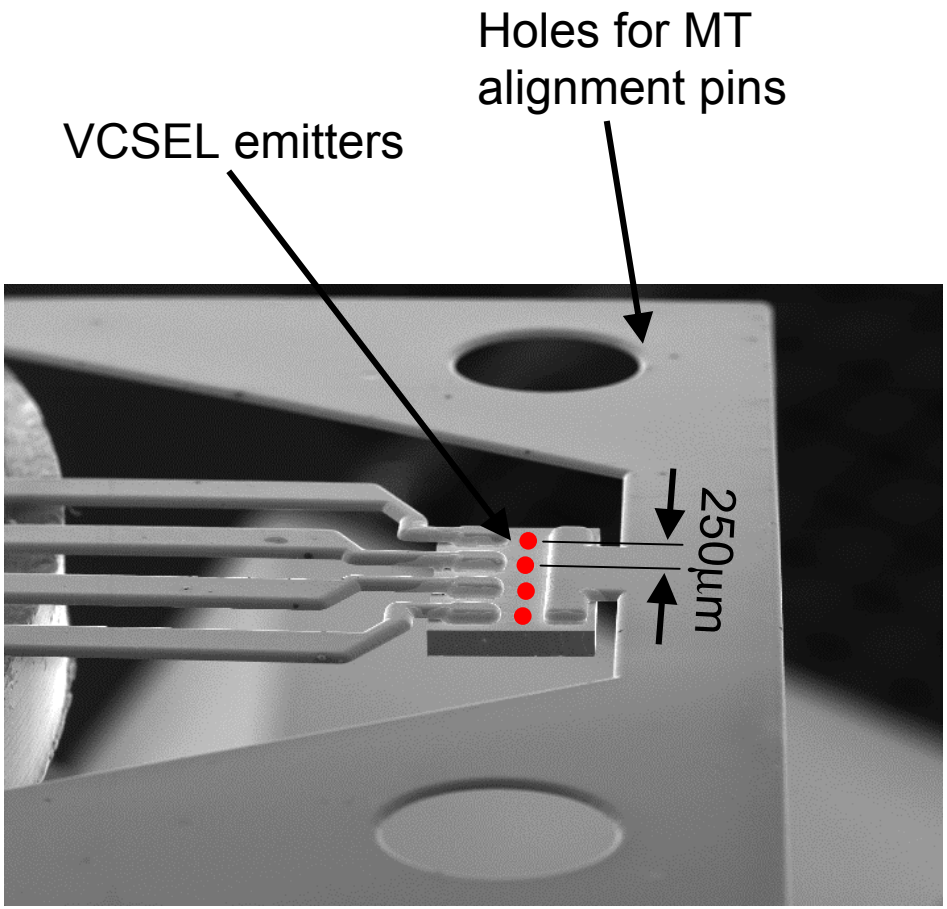
Off-detector VCSEL / PIN Arrays





(12-way devices required for final design)

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