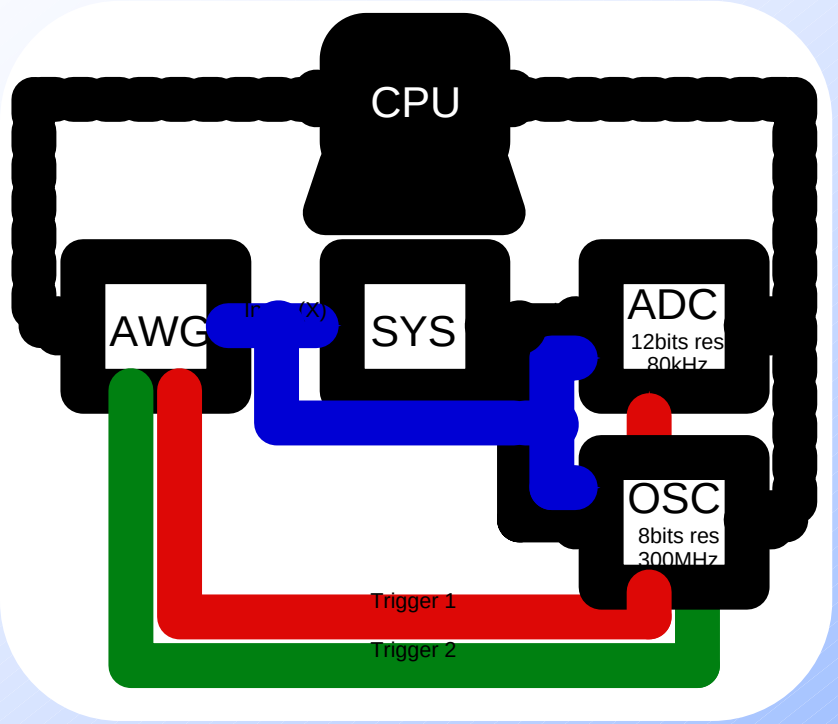
Overview

- Components
  - Details of components in final prototype form
    - Including statistics on large numbers of devices already received
  - Include Lasers, Connectors, Receivers
- Tracker Optical Link Systems
  - Analogue and Digital Links
  - Sub-Assemblies required
    - Will show prototypes of on-detector optohybrids
- Cabling and Interconnection
  - Feasibility of interconnection scheme with chosen connector/cable modularities

Laboratory Functionality Testing

- Obtaining a static transfer curve



- Stage 1:
  - Inject fast ramp (stair-case) into system
  - Measure transfer characteristic using ADC
- Stage 2:
  - Inject slow ramp (stair-case) into system
  - Measure noise at each step

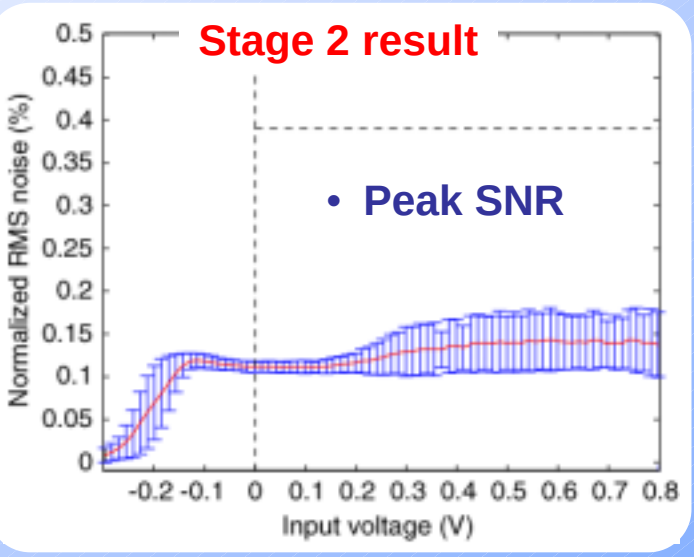
➔ Extract several parameters from the two resulting curves

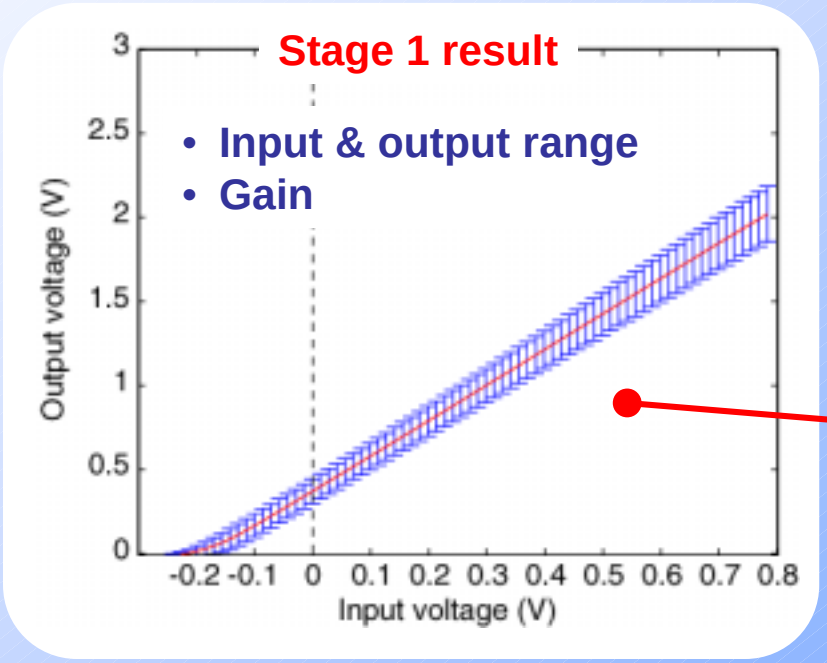
⇨ Gain, linear range, input & output operating range

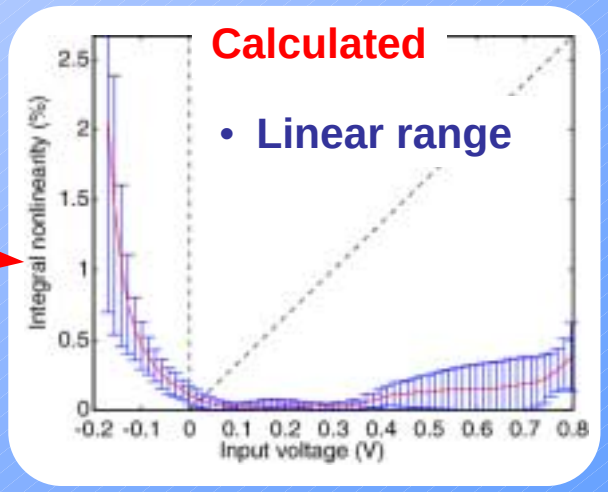
⇨ Peak signal to noise ratio

Static Characteristics

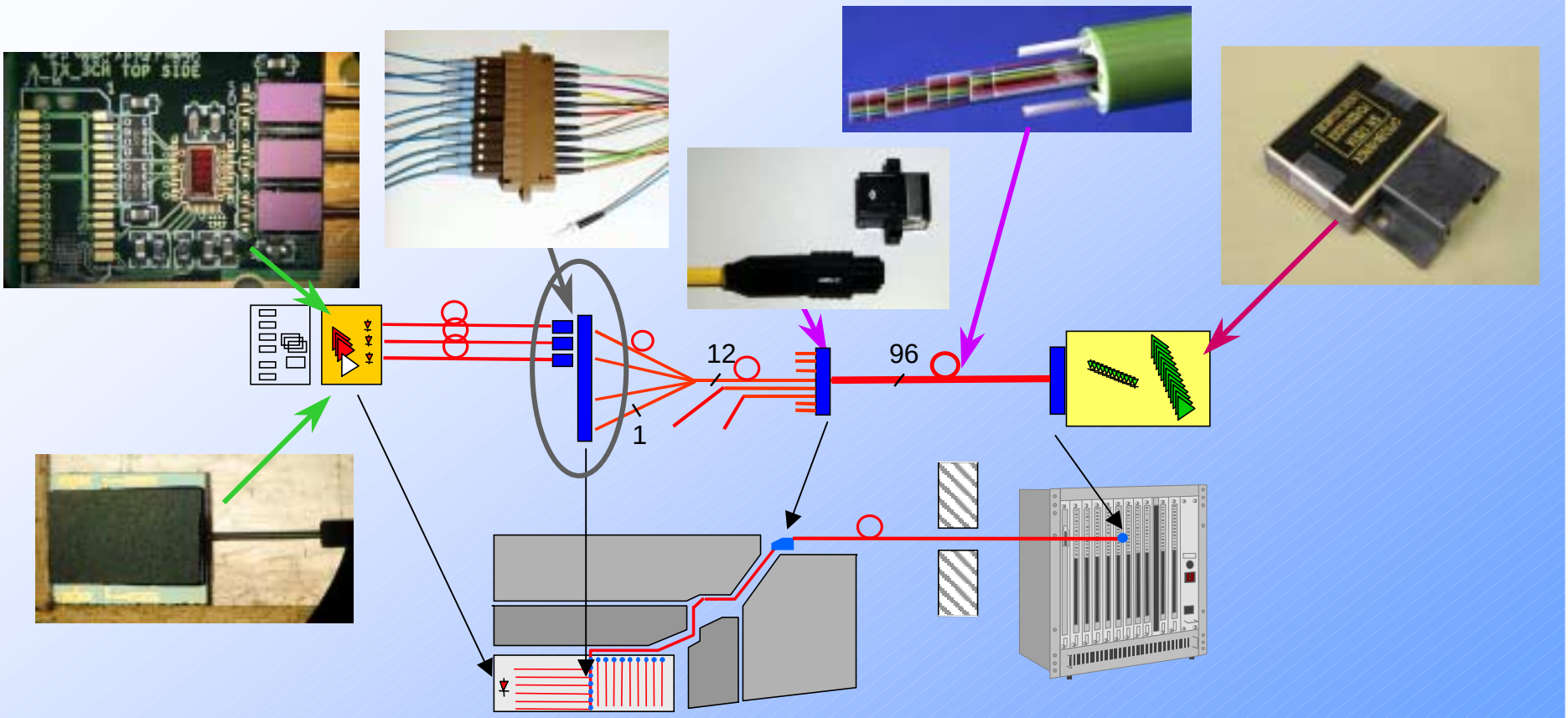
- 20 4-way links tested to yield typical performance
- Averaged data and std. devn. shown







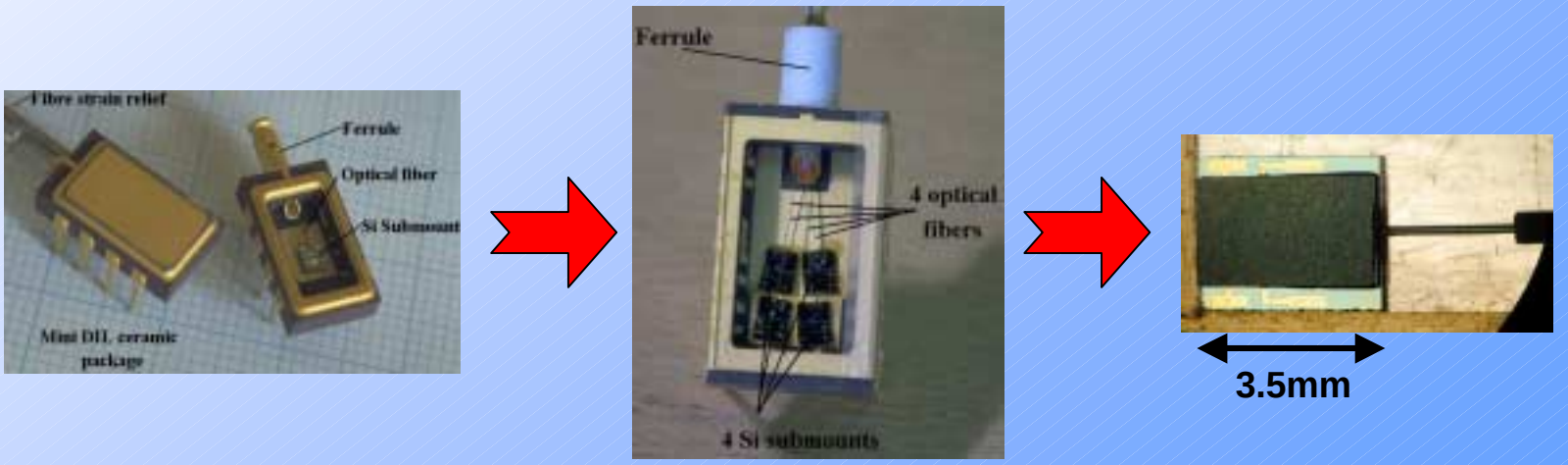
Component Overview



- Final components in virtually all cases
  - Manufacturer feedback & interaction has been imperative
  - All components already tested in final prototype form
  - Awaiting outcome of Invitations to Tender to finalise exact components

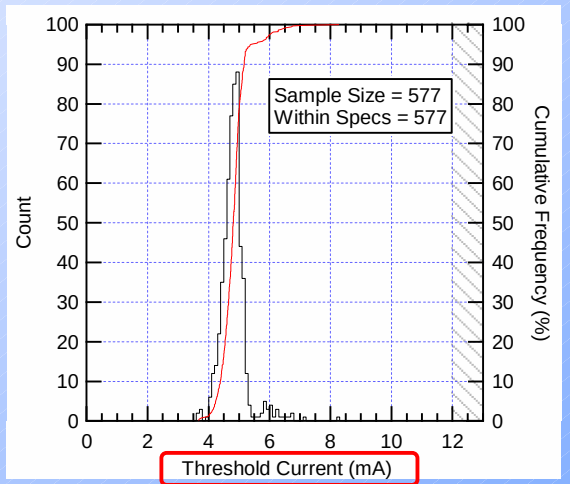
Laser Transmitters

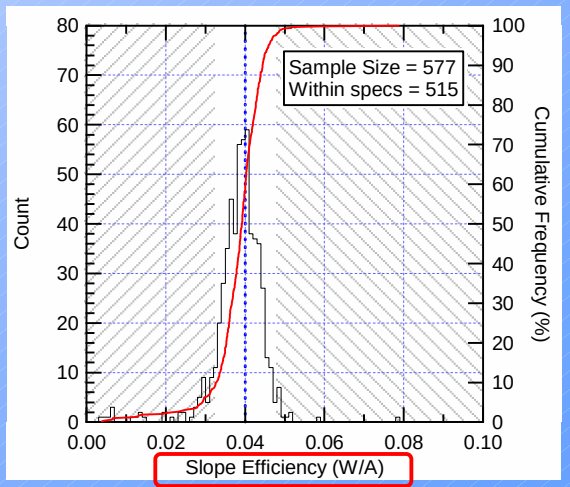
- **Evolution of devices**
  - Manufacturer contacts built up
    - Many manufacturers during project lifetime
    - Confident that most-suitable device chosen
    - Invitation to Tender complete – winner known (ST Microelectronics)
  - Final transmitter die commercially available (Mitsubishi COTS component)
  - Final transmitter package based upon commercial package
    - Very similar submount used in other packaging applications
  - Form factors & modularity now matched to Tracker application
    - Low mass, compact, non-magnetic

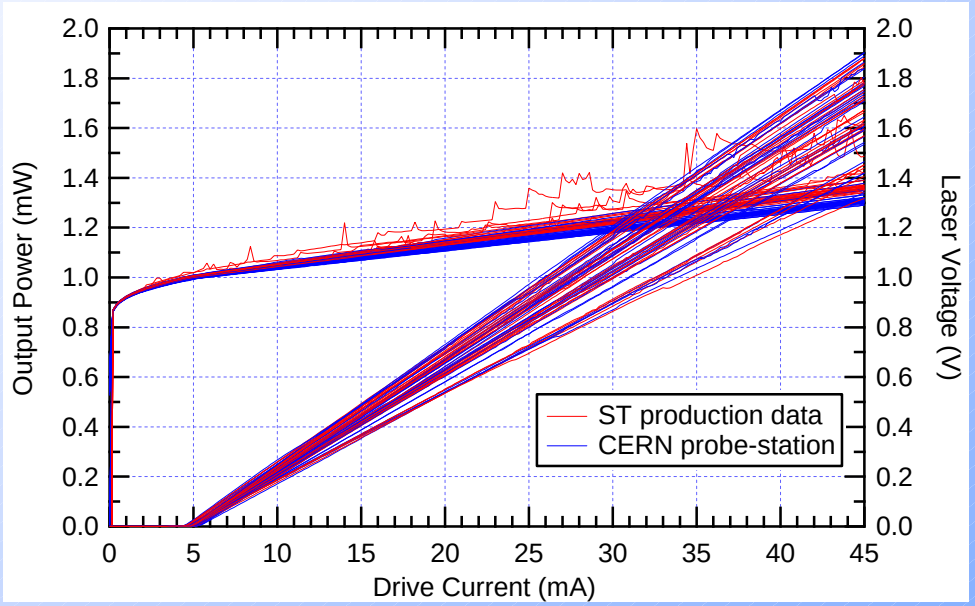


Laser Transmitters – Results 1

- Basic component evaluation example results
  - Final Prototype build at ST
  - Example data from ST
    - Data from order for 500 pieces
    - Confirmed at CERN on sample of 30 devices using probe station



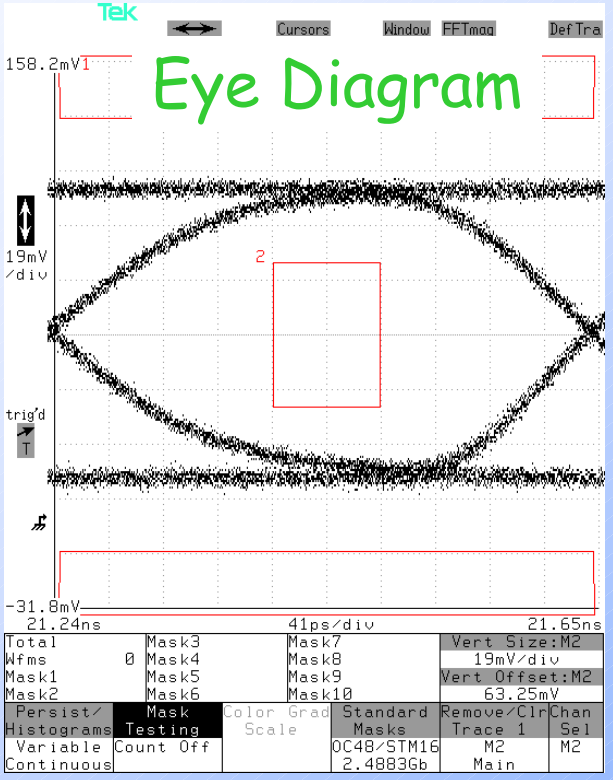


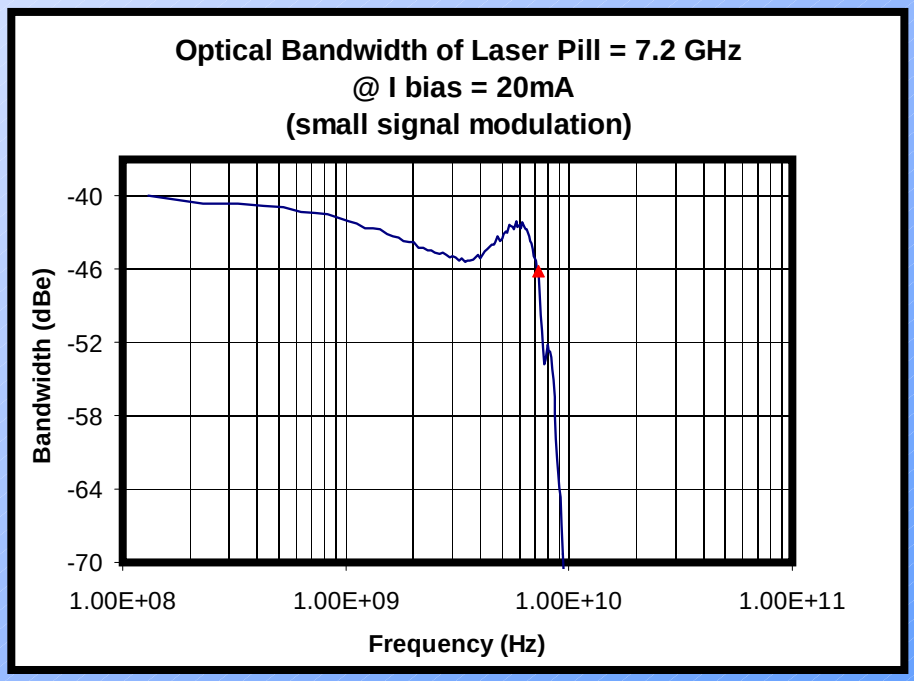


Will show more results of these devices embedded in links later in the presentation

Laser Transmitters – Results 2

- All testing at CERN done with Analogue link in mind
- However, manufacturer data shows device bandwidth sufficient for 2.5Gb/s operation on same submount:





Optical Fibre and Connectors

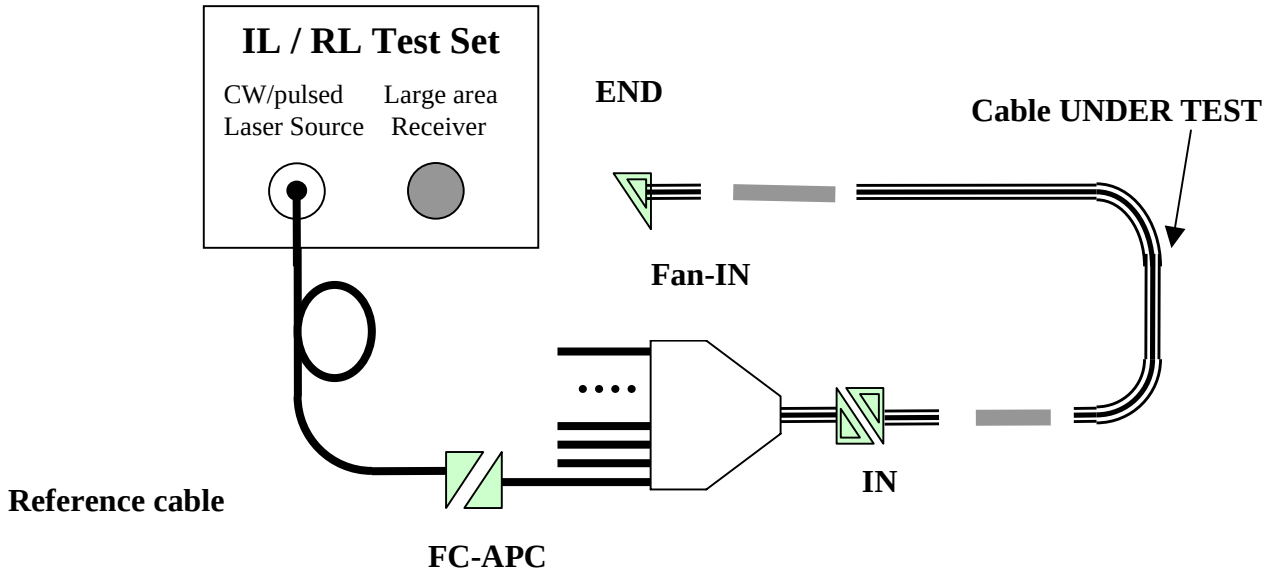
- COTS components specified to be non-magnetic
  - Generic (COTS) nature gives large number of possible vendors
- Single-way connectors
  - Initial testing carried out with bulky standard types
  - Have moved to low-mass, compact final types
- Multi-way (array) connectors
  - Suitable connectors available at start of project
- Fibre
  - 900μm tight-buffered single-mode fibre chosen
- Ribbon
  - Ruggedized 12-way fibre ribbon cable chosen
- Cable
  - 96-way (8x 12-way ribbon stack) custom cable design

Provided by Ericsson

Fibre & Connector Measurements

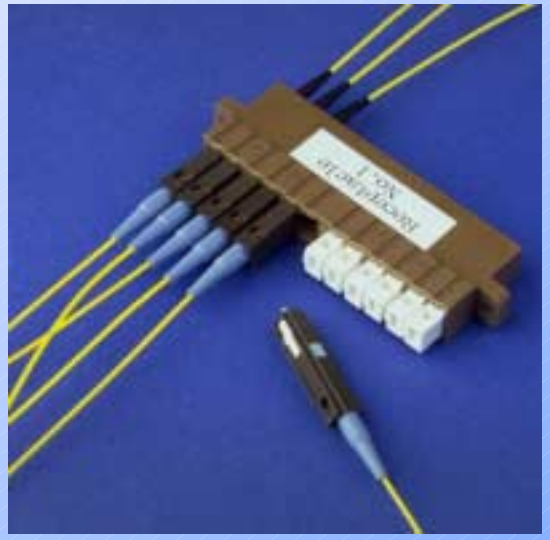
- Single fibre only measured as part of a patch lead
- Pertinent parameters
  - Insertion & Return Loss

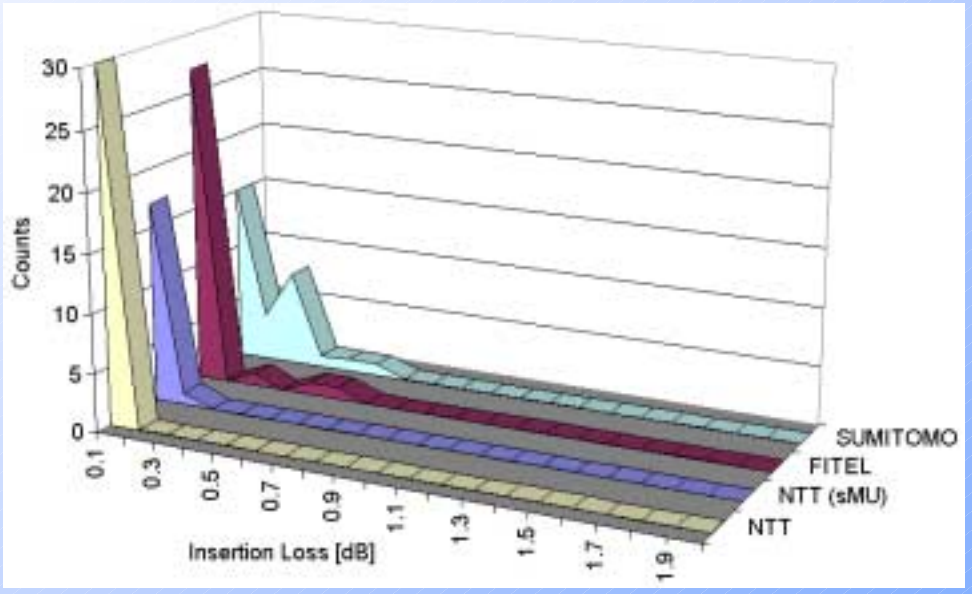
Multi-way connector Test Setup

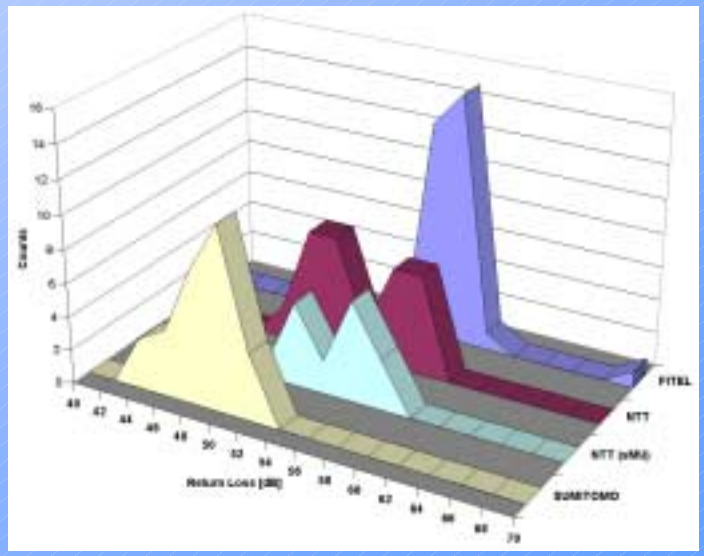


Single-way Connectors

- Single-way connectors
  - 8 types assessed – 2 types retained
    - Still multiple manufacturers available
    - Almost true COTS components
      - ➔ Hence largest # of manufacturers
  - Example of chosen MU & sMU types (highest commercially available single-way connector density):







Multi-way Connectors

- Multi-way connectors
  - 11 types assessed – 3 MT-ferrule based types retained
    - Still multiple manufacturers
- Inivitation to Tender just sent out from CERN

MFS12

SMC12

MPO24

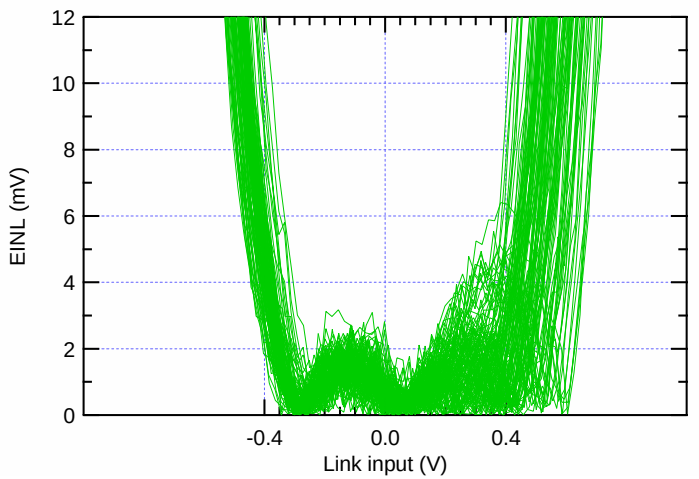
Highest commercially-available fibre density

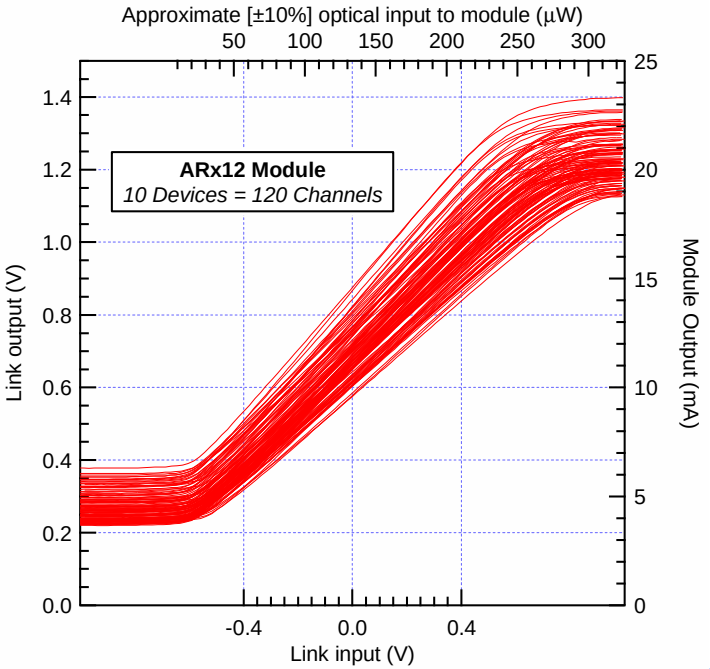
Analogue Receiver Modules

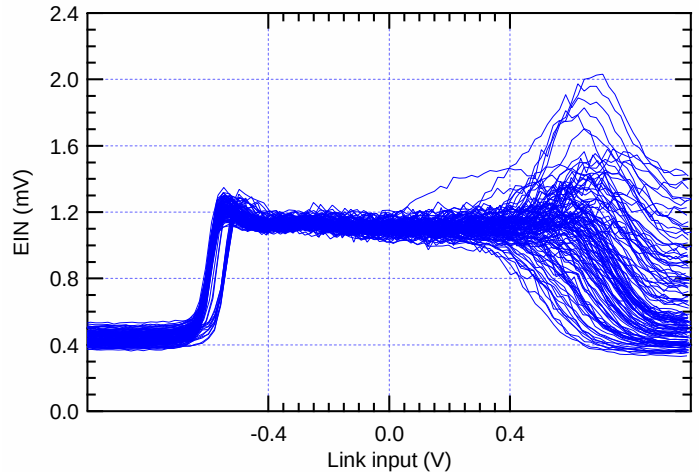
- Based upon the use of a custom Analogue Receiver ASIC design placed inside standard Digital modules
  - Photodiode array same as used for digital receivers
  - Customisation required at the level of the optical coupling units for successful analogue operation
    - Based upon parts already available from manufacturer
- First ASIC design successful
  - Tested in two module types
  - Both modules qualified for Tendering step
- Successful completion of Tendering, manufacturer selected:

Analogue Receiver Module Results

- **120 channels measured**
- "In-system" measurements performed
- Good performance achieved through optimisation of optical interface (angle-polish required)







Component Summary

- Have completed tendering for laser transmitter and chosen the type of laser transmitter to be used in CMS
  - ST Microelectronics Laserpill (with Mitsubishi 1310nm die)
- Have identified fibre, ribbon & cable manufacturer and successfully completed the tendering
  - Ericsson
- Have chosen the single-way connector types to be used in the final system and completed tendering
  - Sumitomo
- Have completed tendering for 12-way Analogue Receiver Modules and chosen the type for use in CMS
  - NGK

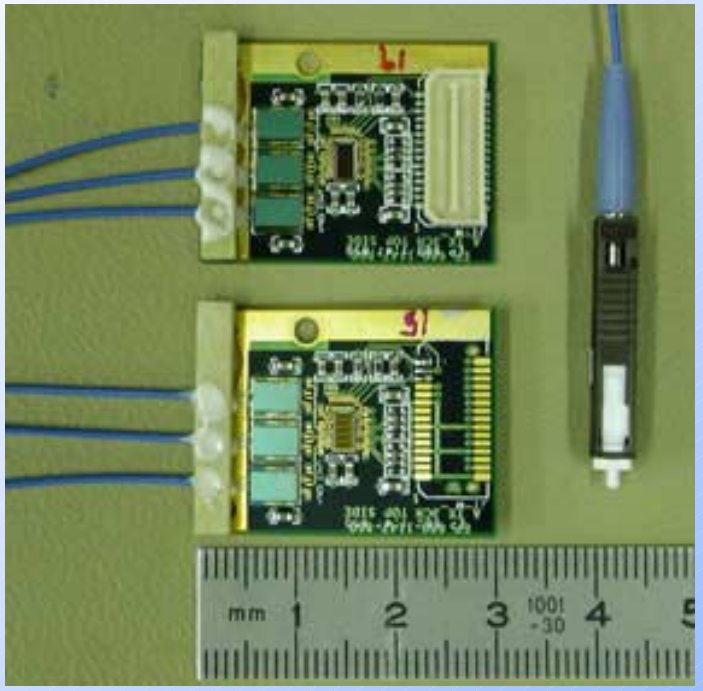
✓ *These choices are based upon lowest cost for in-spec performance of the delivered prototypes*

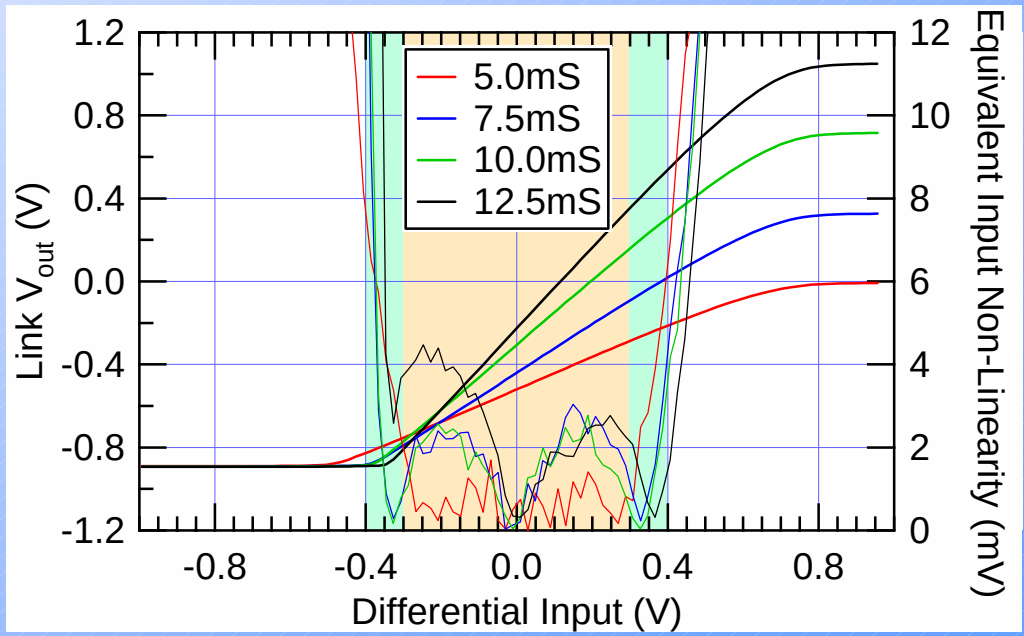
Full Optical Link Systems

- Using described arsenal of components, can start to build the required optical link *systems*
- Analogue Readout Links
  - Support required to house laser transmitter and laser driver ASIC
    - Prototype designs carried out by CERN and Perugia
    - Feasibility shown
  - Analogue optohybrids required for Tracker System Testing
    - Several prototypes ready – one in use
  - Analogue Receiver Modules required for Tracker System Testing
    - Prototype in use already
- Digital Control Links
  - Support required for laser transmitter, laser driver ASIC, photodiode & digital receiver ASIC
    - Prototyped by CERN
  - Off-detector module required
    - Prototype PCI card carrier for commercial devices by Vienna

Analogue Optohybrids

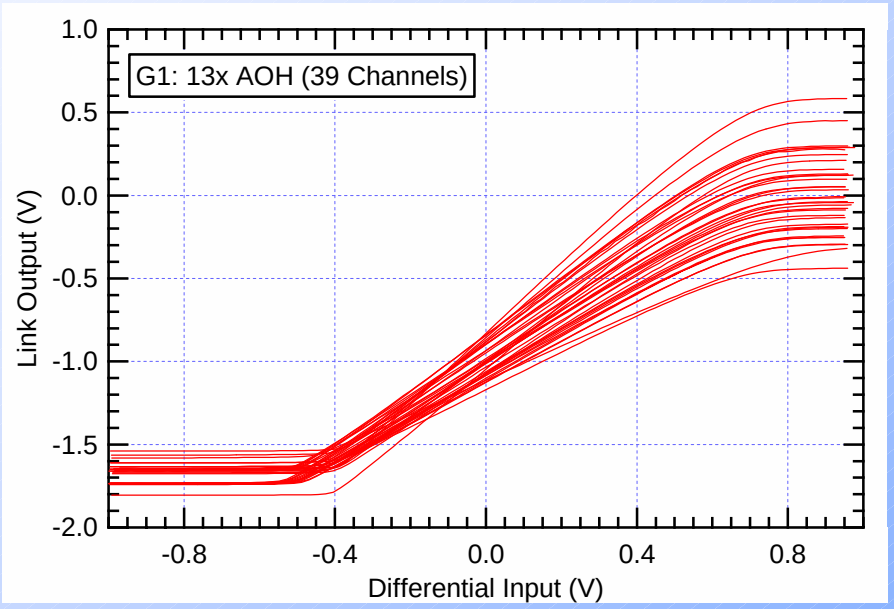
- Prototype designed by CERN for Tracker Outer Barrel and EndCap
- Populated with final prototype laser transmitter and prototype laser driver ASIC

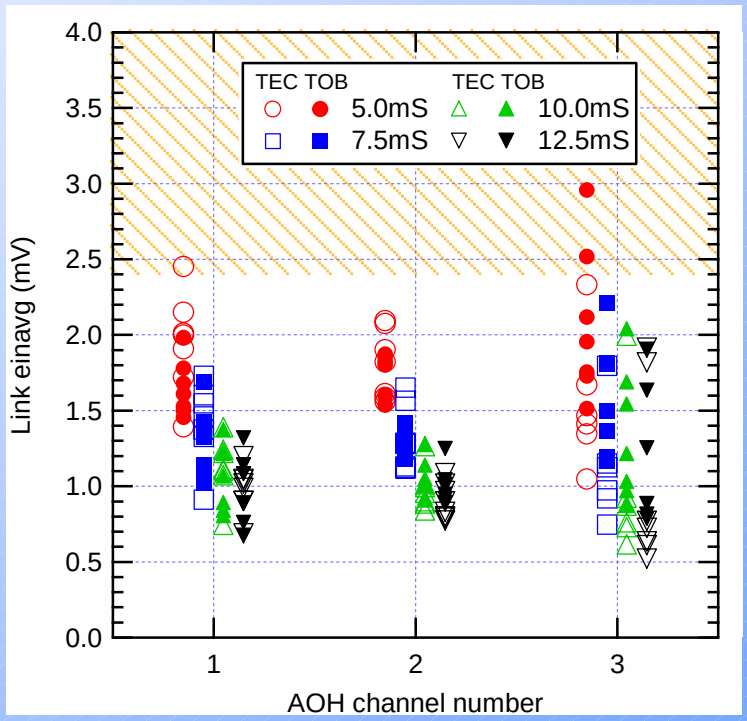




Analogue Optohybrids 2

- 13 out of 19 prototypes fully characterised
- Transfer characteristic
  - Gain values found within spec
  - Linearity meets spec but only just
    - Driven by ASIC
    - Redesigned version now available
    - AOH redesign also required for test

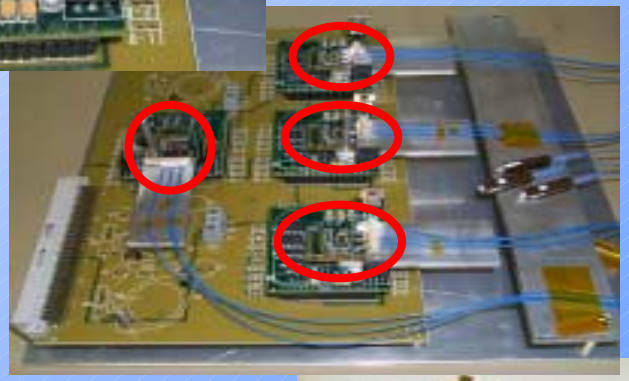


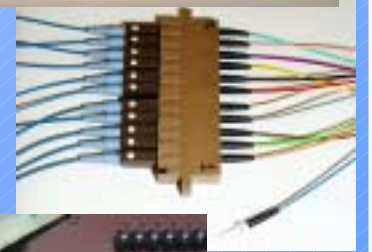


- Noise performance adequate
  - Receiver dependent
  - Measurements done with old Rx package

Full Analogue Optical Link Chain

- **Final prototype components ordered to supply needs of CMS Tracker System Test**
- **First full analogue links assembled**

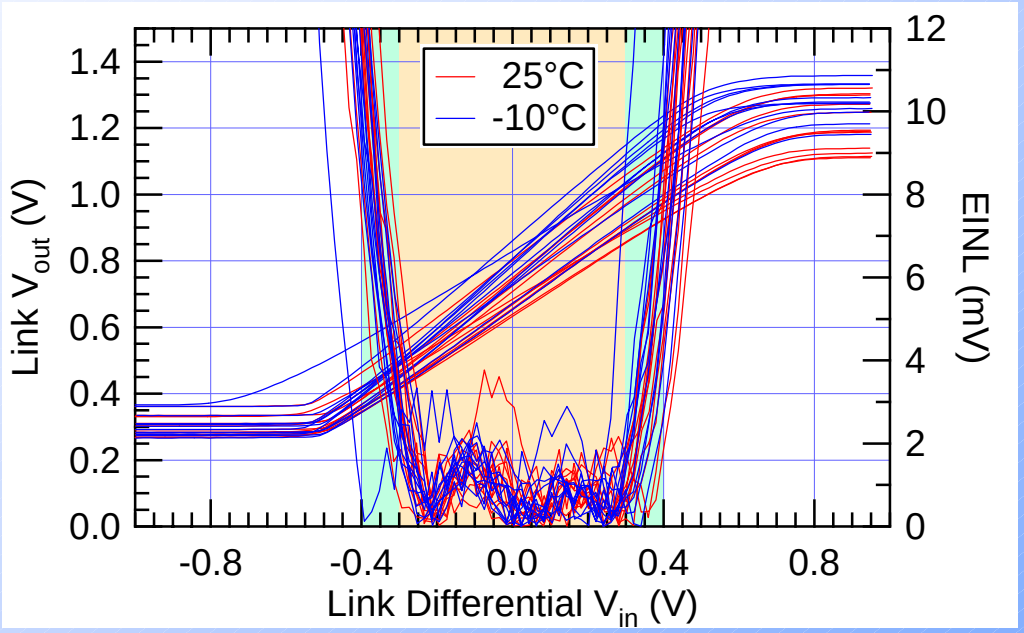


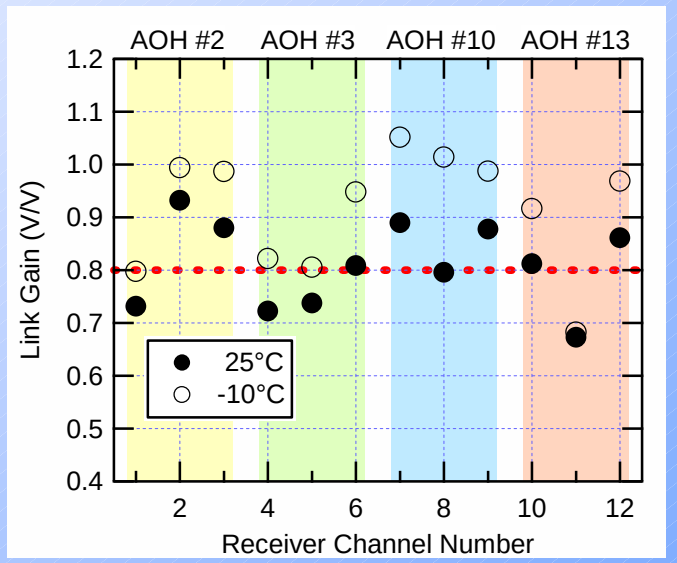


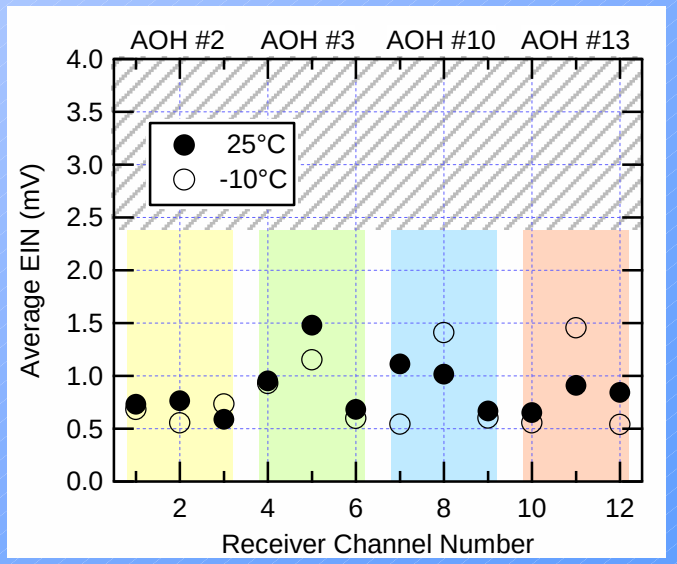
- Laser Transmitters
  - Small form factor ST Laserpill
- Prototype Analogue Optohybrid
  - Designed by CERN for TOB/TEC use
- Fibre & Connectors
  - MU/sMU – single way
  - MPO – 12-way array
- Receiver – final prototypes
  - 12-channel analogue receiver modules (NGK)
- Measurements ongoing

Full Analogue Chain Results

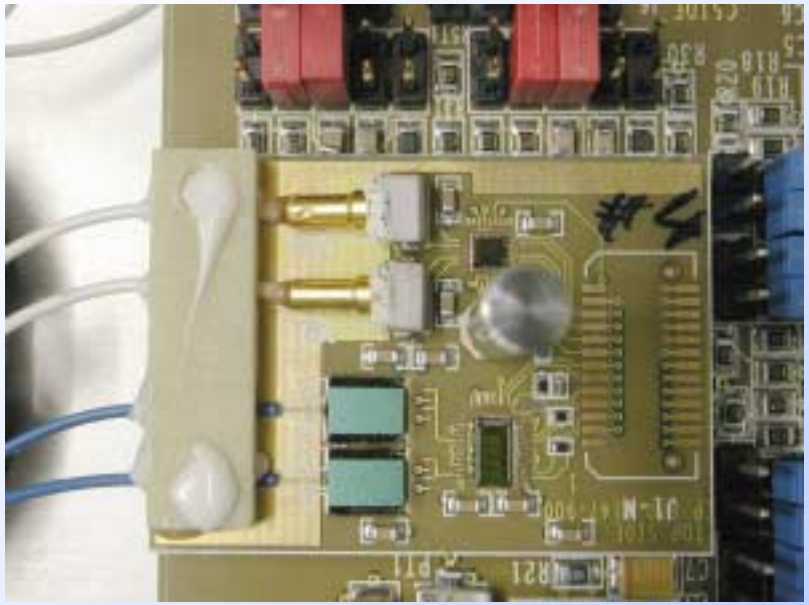
- Static Characteristics shown
- Gain optimisation concept ok
- Noise and Linearity show good performance at room temperature and -10°C



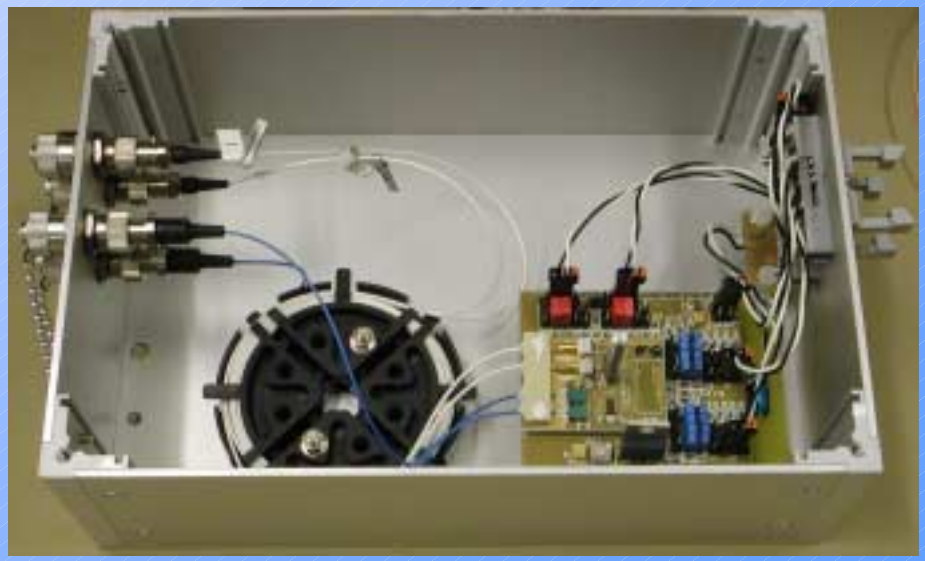




Digital Control Link Prototype



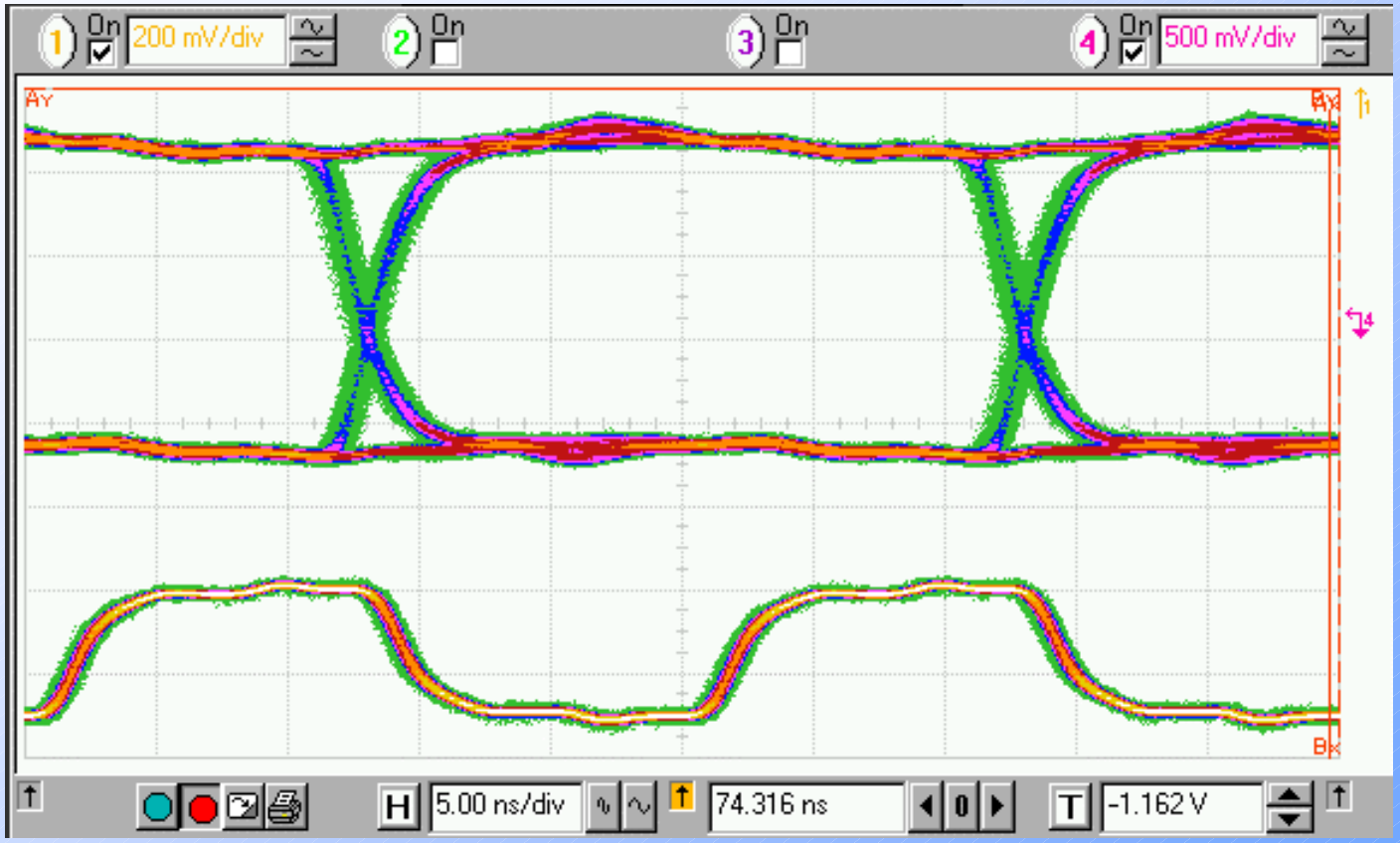
- Digital Optohybrid prototype PCB designed and fabricated at CERN
- Provides support for:
  - 2× Laser Diode
    - Same device as Analogue link
  - 2× Photodiode
  - ASICs: LLD & Rx40



- Operation: 80Mb/s
- First link successfully integrated into Tracker system test environment
- Provides key element of Tracker Control system

Digital Link Performance

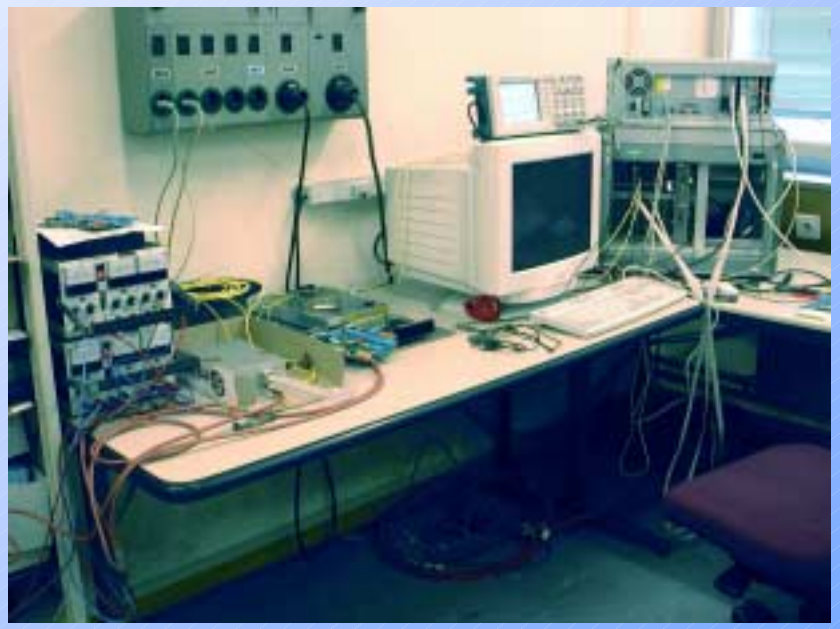
- Operation at 80Mb/s
- BER better than 10^{-12} achieved

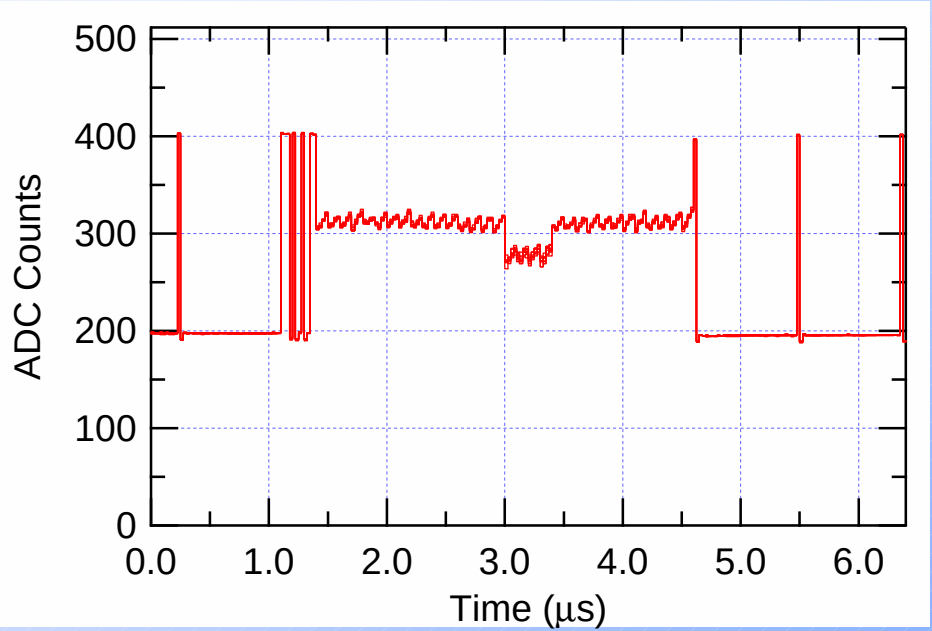


Eye Diagram: Electrical output after one loop of the digital control link system

Tracker System Test

- Analogue and Digital Links successfully integrated into Tracker System Test Bench
- System measurements being made
  - Scale up to TOB ROD





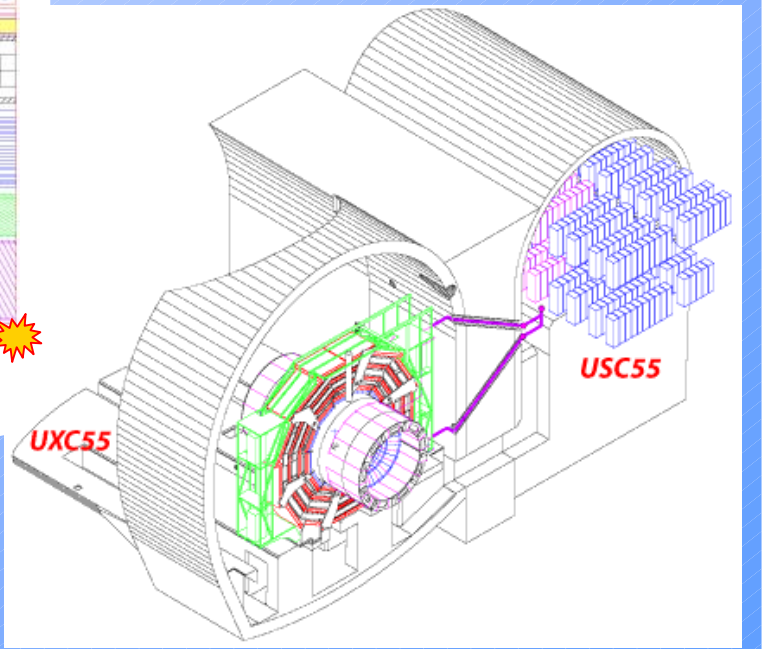
Example Dataframes after digitisation

Tracker Link Systems Summary

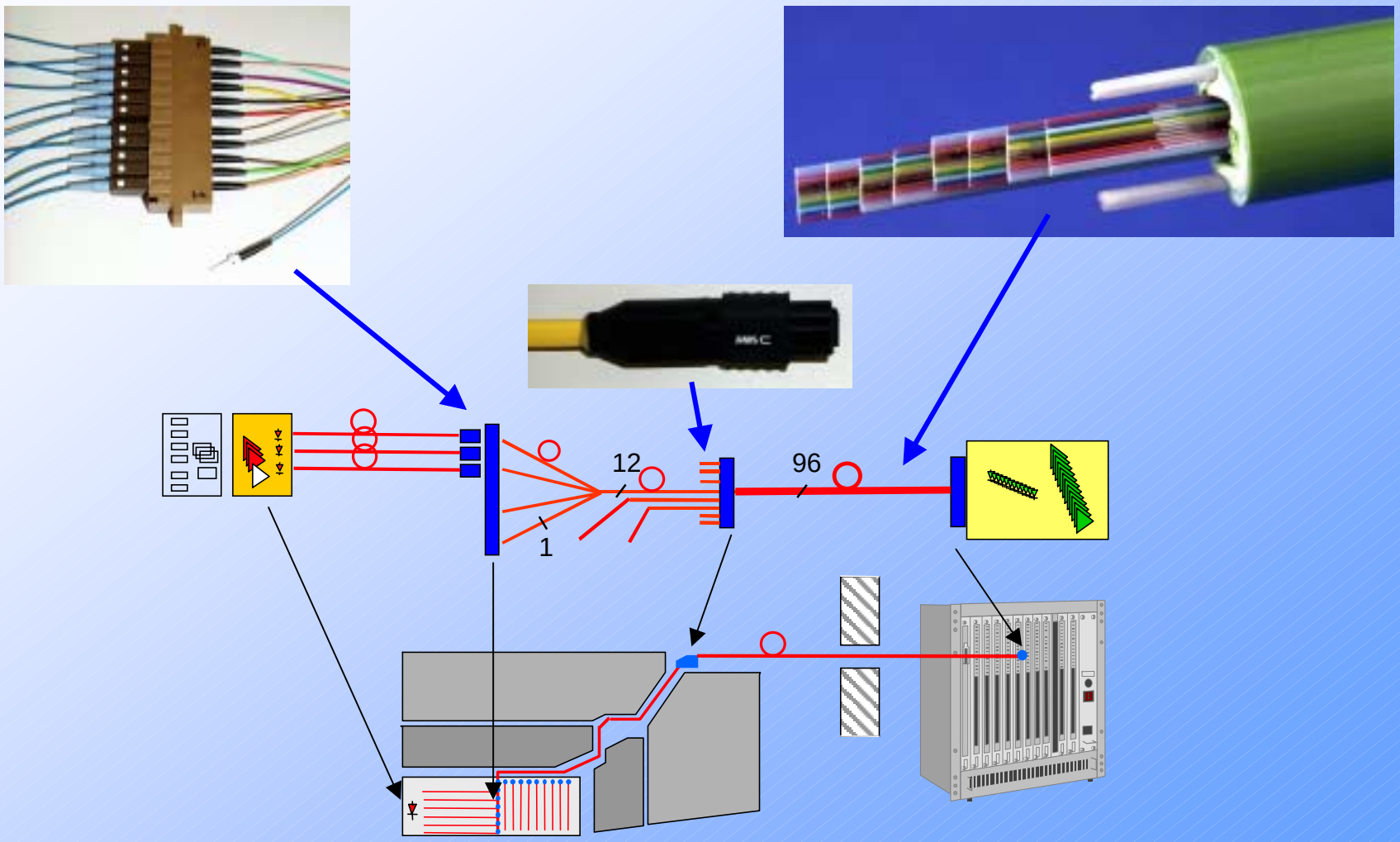
- Analogue Readout Links
  - Analogue link design proven to meet specifications
  - All components now in use are final prototypes
  - First full optical readout link chain integration successful
- Digital Control Links
  - Digital link design proven to meet specifications
  - All components now in use are final prototypes
  - First full optical control link chain integration successful
- Operation in System Test
  - Integration into system started successfully

Cabling Overview

- Detail of study to determine feasibility of connection of front-end to back-end via patch panel in HCAL crack



Cable Types



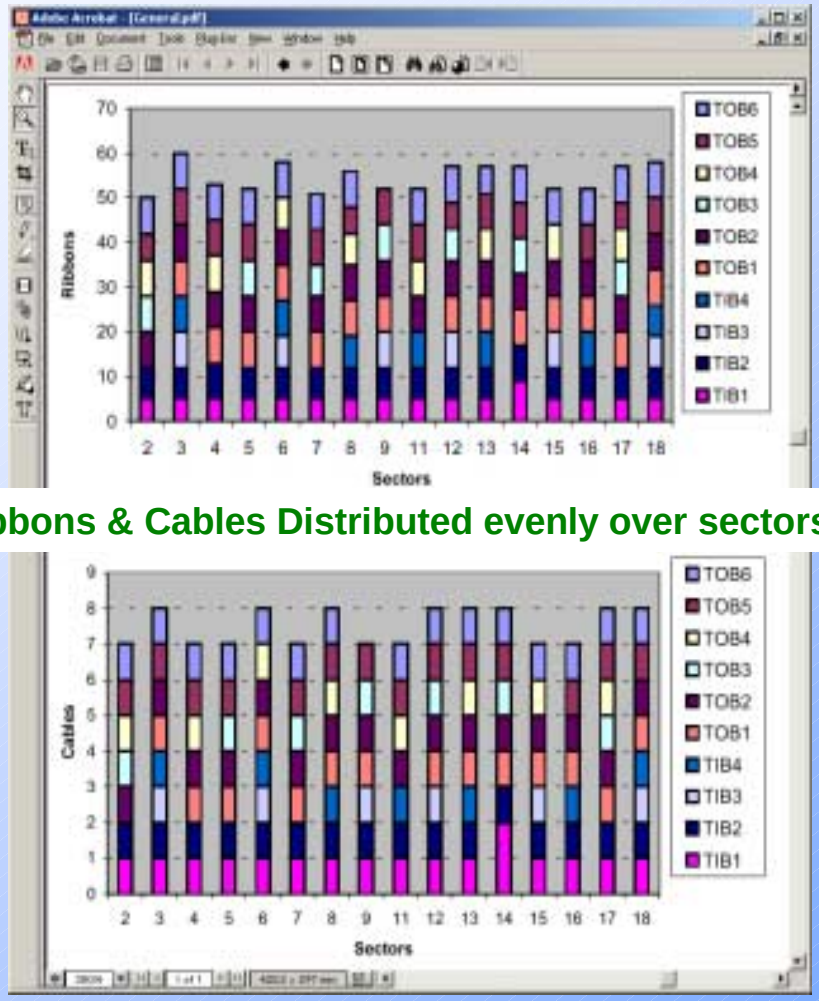
Cabling of the Tracker Volume

- Distribution of fibres
  - Linking up actual positions of modules in space
- Initial layout done from optical link side
  - Feasibility established for all parts of Tracker
    - See following slides
    - Documentation available to interested parties
  - Discussion opened
    - Integration team, Tracker community
  - Groupings defined for readout, control and cooling systems as a result of this work (for TOB/TEC)

TIB/TOB Overview

	Rods	APVs	Fibres / Rod	Fibres	Ribbons Needed / Layer
TOB6	74	36	18	1332	111
TOB5	66	36	18	1188	99
TOB4	60	48	12	720	60
TOB3	54	24	12	648	54
TOB2	48	60	30	1440	120
TOB1	42	60	30	1260	105
TIB4	54	24	12	648	54
TIB3	46	24	12	552	46
TIB2	38	72	36	1368	114
TIB1	28	72	36	1008	84

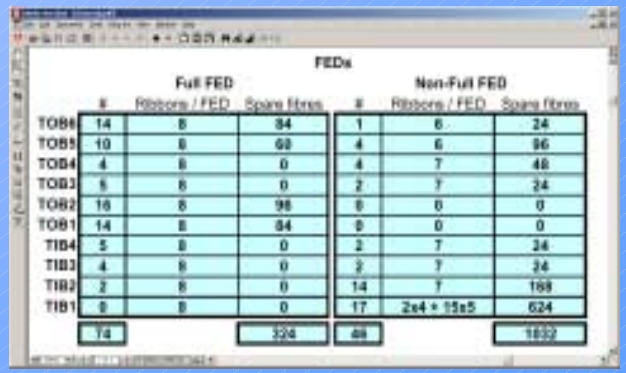
Layout data



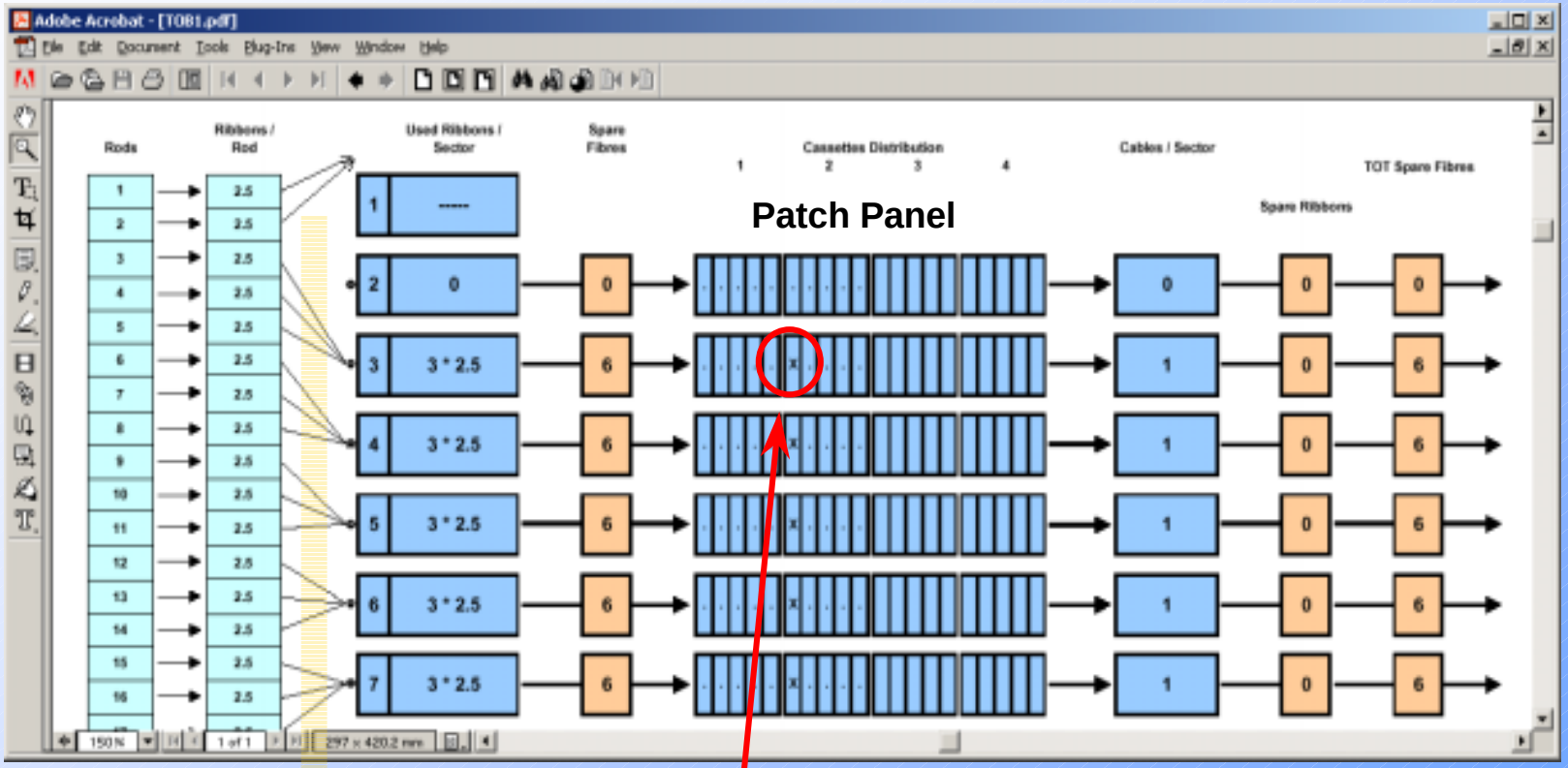
Ribbons & Cables Distributed evenly over sectors

Spare Fibre/Ribbon availability shown in documentation

FED requirements



TIB/TOB Routing

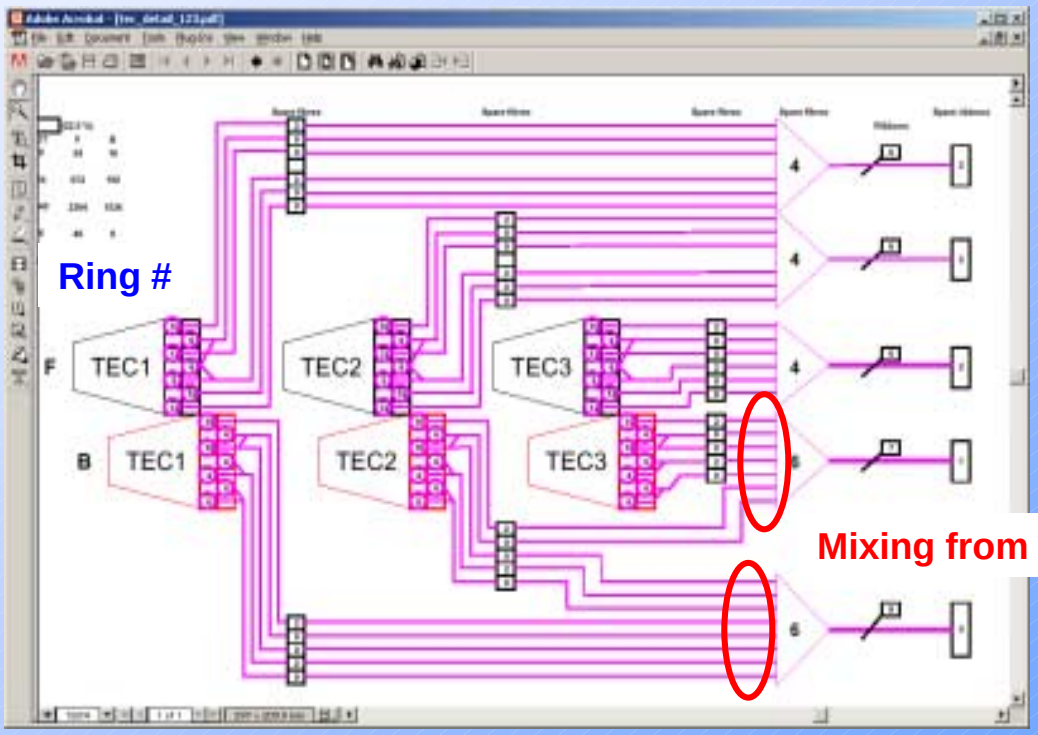


Mixing fibres from different RODs occurs here

To obtain Cable modularity of 8 ribbons at Patch Panel

TEC

- Very similar tables for overview and patch panel
  - See documentation
- Fan-in to ribbons slightly different due to Petal geometry



Cabling Summary

- Long-standing communication with Integration team
  - Space budgets in place and respected
- Feasibility of layout and grouping of individual fibres from the front-end into ribbons and cables established
  - Now linked to powering and cooling grouping scheme for TOB/TEC
- Components in place
  - Fibre/Ribbon/Cable tender closed
    - Ericsson fibre, rugged ribbon and cable chosen
  - Single-way connector tender closed
    - Sumitomo MU and sMU chosen

Summary

- Components
  - Proven functional requirements met by final prototypes
    - Relatively large sample sizes tested (1% of production quantity)
  - Ready for production of link components
- Tracker Optical Link Systems
  - First demonstrator analogue and digital links shown
  - In the process of integrating with full tracker readout and control system to assess interoperability
- Cabling and Interconnection
  - Initial studies of routing done with optimisation from optical link point of view
  - Feasibility proven – chosen component modularities map onto the physical detector layout