CMS Tracker, ECAL and Pixel Optical Cabling Experience

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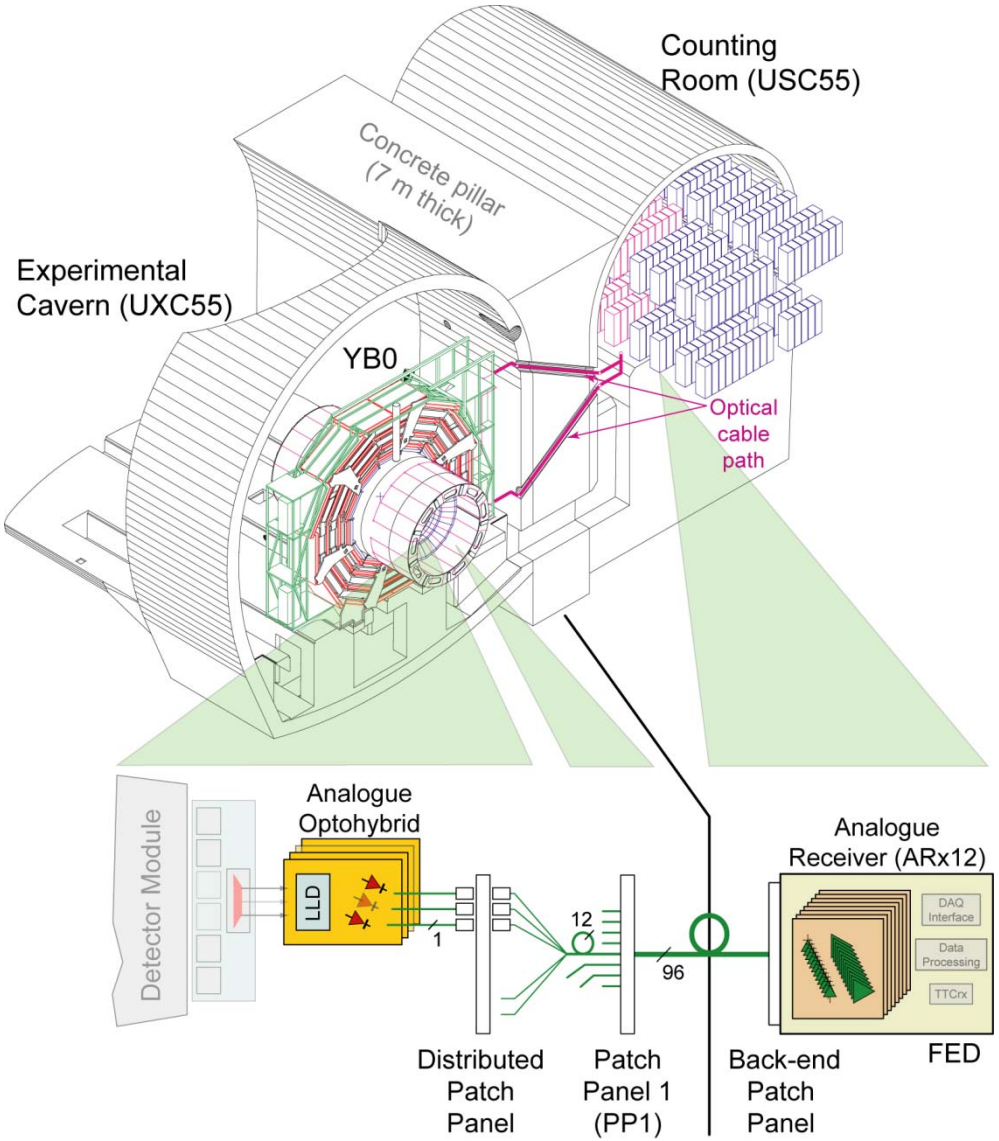
Poster: "CMS Tracker, ECAL and Pixel Optical Cabling: Installation and Performance verification", TWEPP, Sept. 2008

www.cern.ch/cms-tk-opto

CMS Optical Links



Total installed: 52304
readout (analogue/digital) and control (digital) optical links

In YB0:

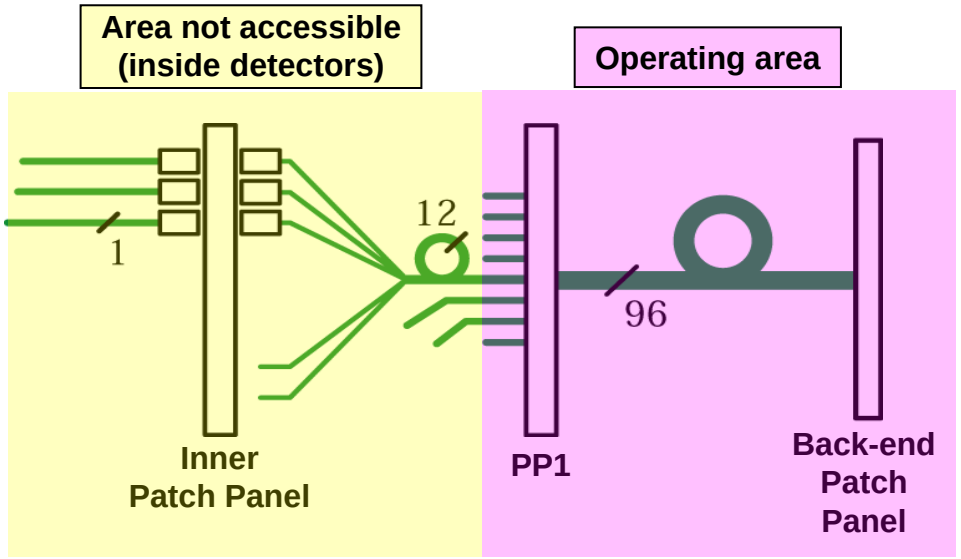
Tracker (TK):	39240
Pixel:	1456
ECAL Barrel (EB):	7272

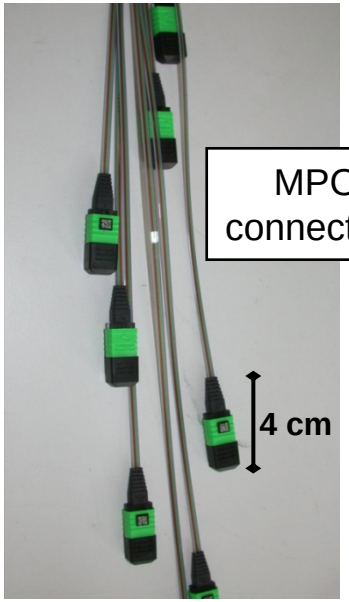
In End-Cap disks (YE+1,YE-1):

ECAL End Caps (EE):	4124
Preshower (ES):	1592

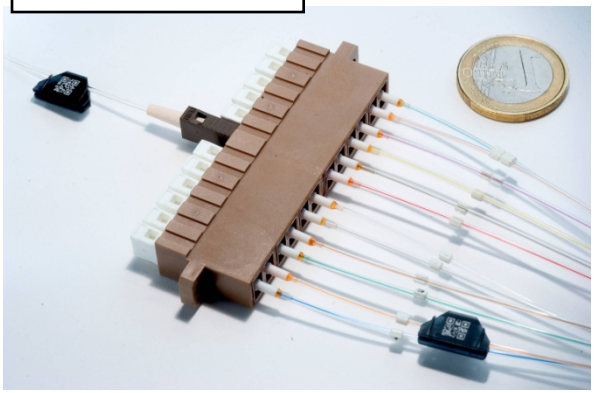
Components: fibres and connectors

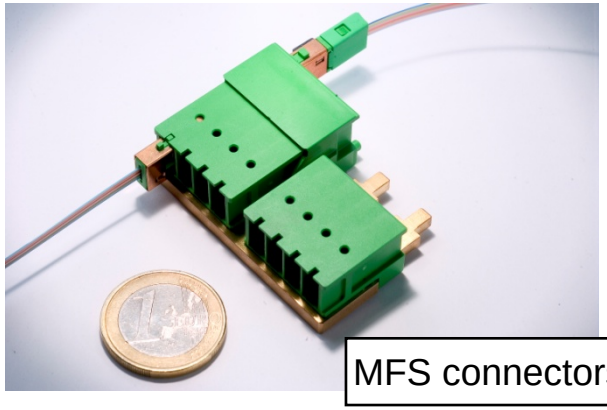
~52000 single pigtailed fibres

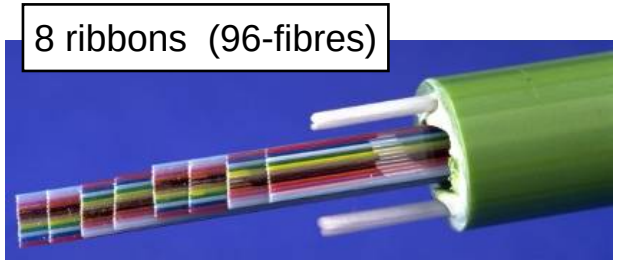




MU connectors







Inner Patch-Panel:
pigtails → 12-way fan-outs

Patch-Panel 1 (PP1):
8 fan-outs → MR cable.
Very dense configuration!

Multi-Ribbon cable (768)
TK: 530
Pixel: 34
EB: 108
EE+ES: 96

ECAL End-Caps and Preshower have MPO connectors at PP1 (and additional PP0)

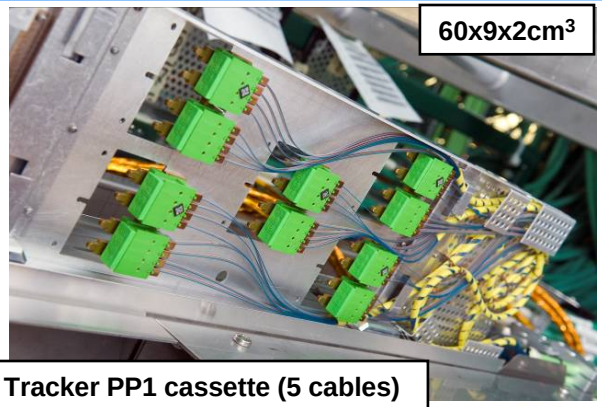
YB0 cabling

Coordination: Karl Gill.

Cabling operations extensively practiced in the past years.

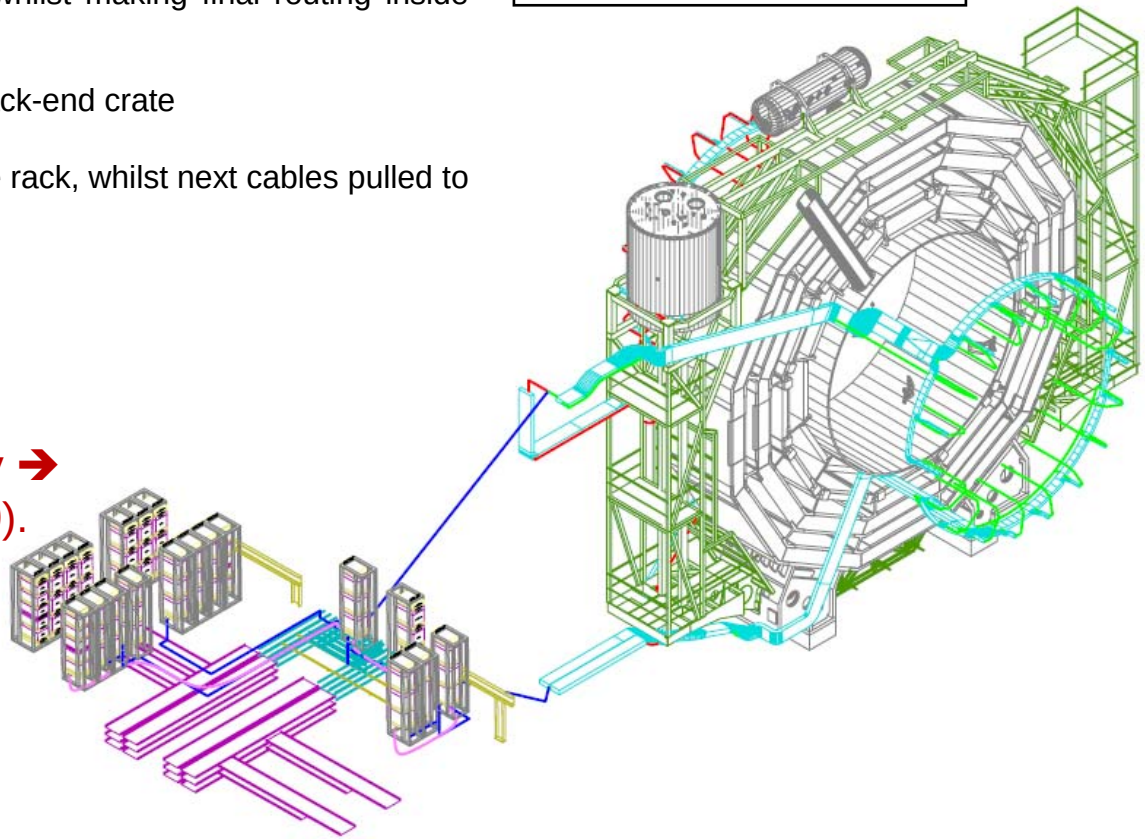
Procedure:

- Pull one cable at a time to PP1 starting from cavern wall (at tunnel entrance)
- Fix in bundles from PP1 back to tunnel, whilst making final routing inside PP1 cassettes
- Pull through the tunnel one by one up to back-end crate
- Collect slack and tie down in USC up to the rack, whilst next cables pulled to PP1
- Testing in shadow of cabling



Tracker PP1 cassette (5 cables)

Progression:
few cables per day ➔ 10 cables/day ➔
➔ **35 cables/day** (cabling crew: ~30).

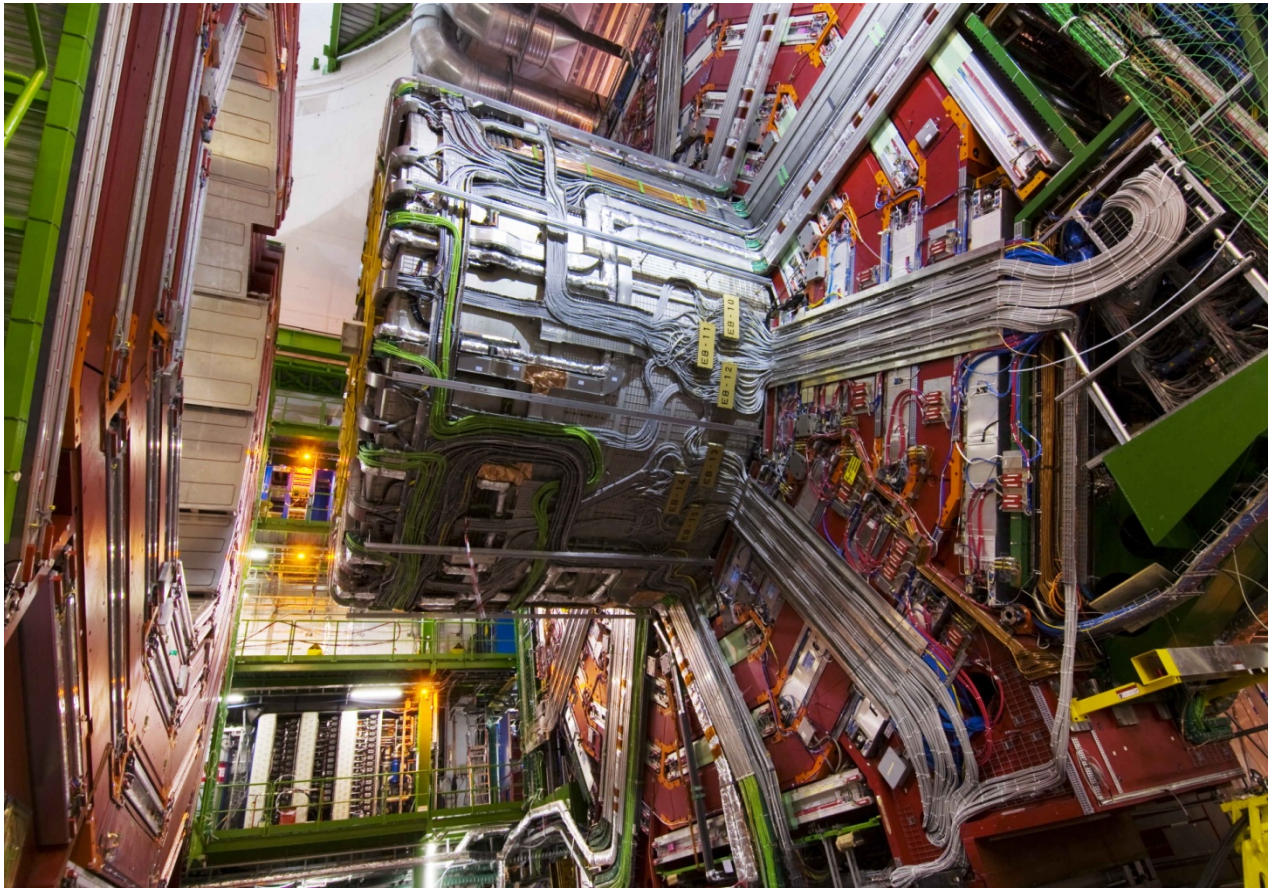


CMS YB0 service completion

23 Nov 07 after installation of:

- ☑ HCAL Barrel
- ☑ ECAL Barrel
- ☑ All services
  - ✓ Tracker pipes and cables
  - ✓ HCAL and ECAL cables
  - ✓ ECAL and Tracker fibres

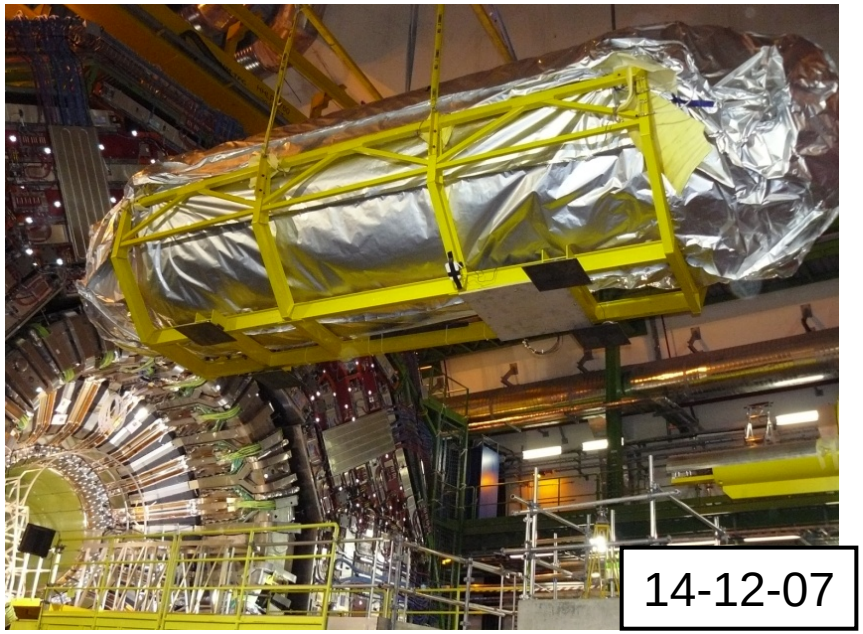
Last 50% was done in 2 weeks.



YE+1 and YE-1 cabling completed in **June 08**
(University of Minnesota team, coordinator: A. Singovski)

Tracker insertion and fibre connections

ECAL Barrel connection + DAQ checks completed before TK insertion.



Tracker Cabling and Connection campaign:

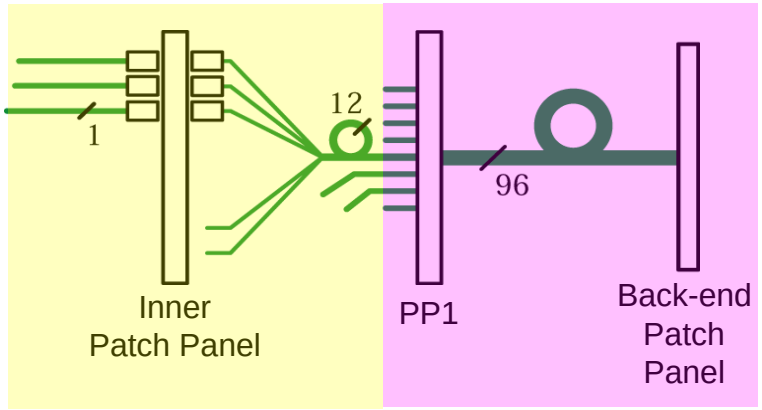
- 980 pipes, 2330 cables, **3600 fan-outs**, plus…
- **Started 8-1-08**
  - up to 4 teams of 2 people on fibres
    - each team could lay ½ PP1 a day on average
    - approximately 70 fan-outs
- **Completed on time 23-3-08**
  - including Pixel services

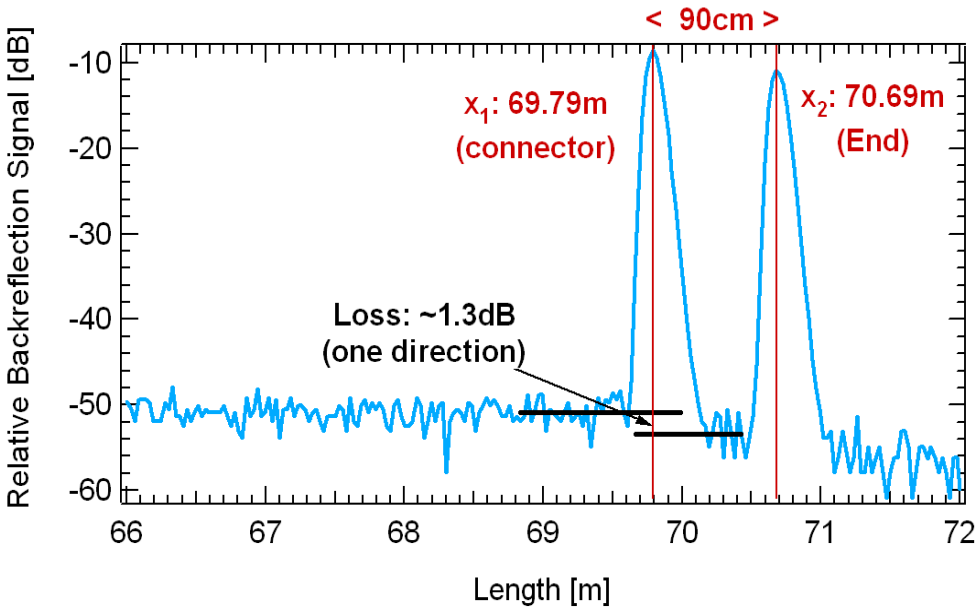
Testing followed closely in shadow of connections
- usually a day behind
- 3-4 testers plus supervisor

Optical Link Quality Control Program

Main objectives:

- cabling **installation acceptance**;
- PP1 **connections validation**;
- total working **length measurement** with precision **better than 20cm** ⇒ sync. of TK readout to ~1ns.





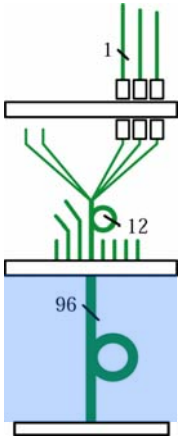
Method: high-resolution OTDR

CMS Optical Links:
- short distances
- many connectors
- accessibility only on one end

Used for troubleshooting too.

D.Ricci et al. "Quality control of the CMS Tracker and ECAL installed optical cabling", TWEPP, Prague, Sept. 2007.

Trunk-cable test results



	Total ribbons	Broken/ Stressed	Repaired/ Replaced
Tracker	4240	10 (0.2%)	10 (100%)
Pixel	500	2 (0.4%)	2 (100%)
ECAL Barrel	864	2 (0.2%)	2 (100%)
ECAL End-Caps	1032	3 (0.3%)	3 (100%)
Preshower	344	2 (0.6%)	2 (100%)

100% trunk-cable tested!

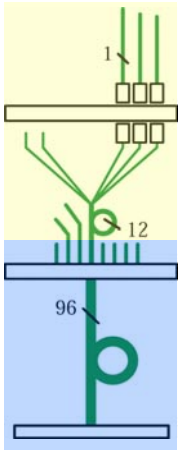
TRACKER and **PIXEL** (564 cables)

- 80% tested from inside YB0
  - 2 people, difficult working conditions
- Moved to back-end after completing installation
  - Could do with 3-4 people (2 OTDRs)
- ~50% of cables found to have been mounted in wrong PP1 slot
  - 2 days (for ~2 people) to remount

ECAL and **Preshower** (204 cables)

- 100% tested from the back-end

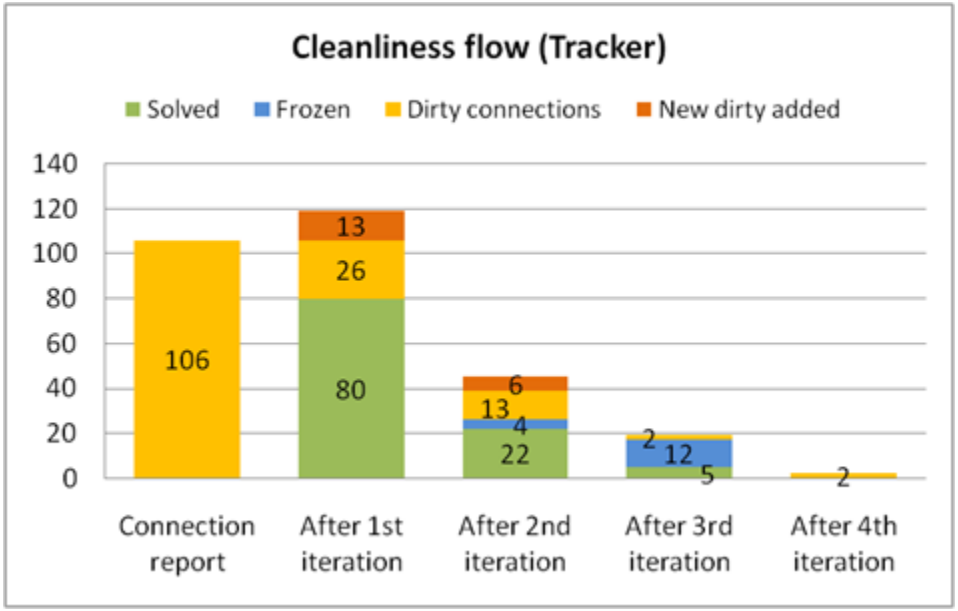
Full-link test results



	Connected fan-outs	Total tested	Broken/ Stressed	Repaired/ Recovered	Dirty/Bad connections	Recovered	MU flagged for DAQ
Tracker	3600	100%	10 broken 6 stressed (0.4%)	12 (1 lost; 3 stressed) (75%)	106 PP1 + 19 added (3%)	107 (86%)	1075 (3%)
Pixel	184	16%[b]	0	0	16[d] PP1 (7%)	15 (94%)	19 (5%[e])
ECAL Barrel	720	100%	0	0	38 PP1 (5%)	no action	344 (5%)
ECAL End-Caps	424	94%[c]	0	0	44 PP1 (11%[e]) 41 PP0 (10%[e])	25 (29%) 60 no action	24 (1%[e])
Preshower	System not yet installed						

[b] troubleshooting; [c] 61% only 2 fibres/ribbon tested; [d] PP1 connections 100% tested; [e] of total tested.

- Done using map of "suspect" channels to check, re-clean or repair
  - Suspect MU flagged (no access);
- EB connections: no intervention (access difficult and high risks)
  - System is digital (more robust)
- EE: ~50% of ribbons found to have been connected in wrong PP1 position
  - Due to database error;
  - 2 days (for ~4 people) to re-map/re-connect
- Precise length measurement provided to TK (and ECAL) for synchronization



Link Performance Verification (Tracker)

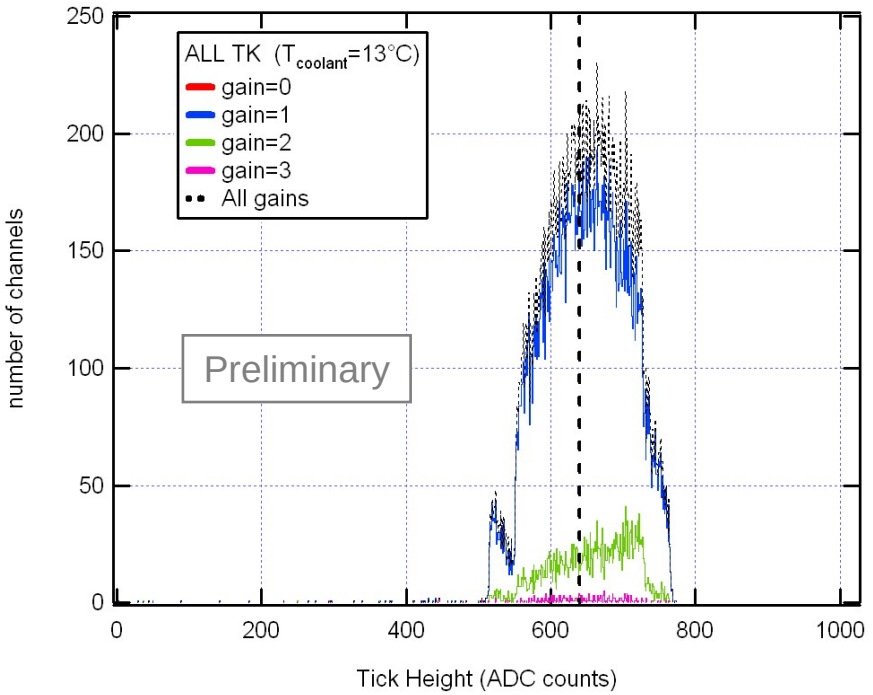
Analogue links ⇒ monitoring of link parameters (e.g. overall link gain distribution)

TK Checkout: validation of the Tracker cabling and connections when <u>detector is powered-on</u>

- managed by DAQ team
- uses a DB to monitor the installation and summarize the cable status

Opto-team involved in:

- troubleshooting (of the back-end connections)
- checking/correct DAQ connection database
- correlation OTDR-DAQ data (ongoing)
- gain distribution comparison with previous studies (*S.Dris, CMS note 2006/145*, ongoing)
- medium/long term link monitoring (under definition)



Total channels	Blind/Low gain	Recovered cleaning (BE)	Still recoverable	Other causes	Total lost
39240	391* (1%) in 163 connectors	255 (0.65%) 74 connections inspected	24 (0.06%)	74 (0.19%)	38* (0.1%)

September 2008 Tracker 99% functional!

***including lost known from integration and OTDR test on full links.**

Conclusions

- Optical cabling and connections for Tracker, Pixel, ECAL **completed** by Aug. 2008
  - **768 cables (96-way)**; **~5500 connections** at PP1/PP0 (+ back-end connections);

- **Practicing** procedures/tools (past 2 years) gave **decisive contribution**:
  - procedures (cabling + test) revealed to be **robust** and **people well trained**;
  - maintaining efficiency required fibre team to be involved also in non fibre-related activities;

- **Systematic test campaign (OTDR)** carried out for cabling/connections validation + length measurements
  - **~52000 optical links tested** (twice considering the trunk-cables)
  - PP1 connection-test allowed a **proactive debug** while waiting for DAQ (moved focus on back-end);

- Results are **excellent**:
  - Trunk cables: 0.3% broken ribbons (**100% repaired/replaced**)
  - Full-links: 1 TK fan-out broken non repairable (**0.03%** of total channels)
    - 166 cleaning interventions at PP1;
    - ~ 1400 MU connections and ~180 MFS flagged for DAQ;
- **Tracker** performance verification: only **0.1% channels lost**
  - 163 connectors cleaned/inspected at back-end (**65% success**)
  - Measured **lengths stored** and cabling/connection **database validated**
  - Ongoing: DAQ/OTDR comparison, link parameters analysis

Extra slides

Practice

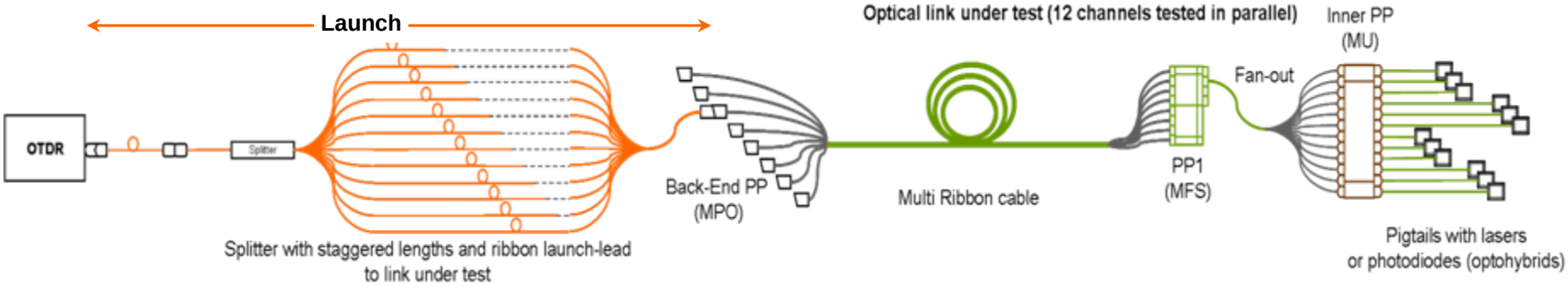
Practice runs:

- ✓ CMS **Magnet Test** on surface **June 2006** (5 cables)
  - "External" cable team
  - One cable at a time
  - Several ribbons broken (probably by walking upon them).
- ✓ **Tracker Integration Facility Oct.06-Apr.07** (~100 cables)
  - None broken.
- ✓ **Trial installation underground at P5 Aug. 2007**(2 cables)
  - Cables pulled together.
  - 1 cable twisted too much.
- ✓ **Final YB0 cabling (Oct. - Nov. 2007)**
  - Always pulled one cable at a time.
  - ECAL sectors done first (3 cables/sector; ~half day/sector).
  - Immediate testing of early cables.

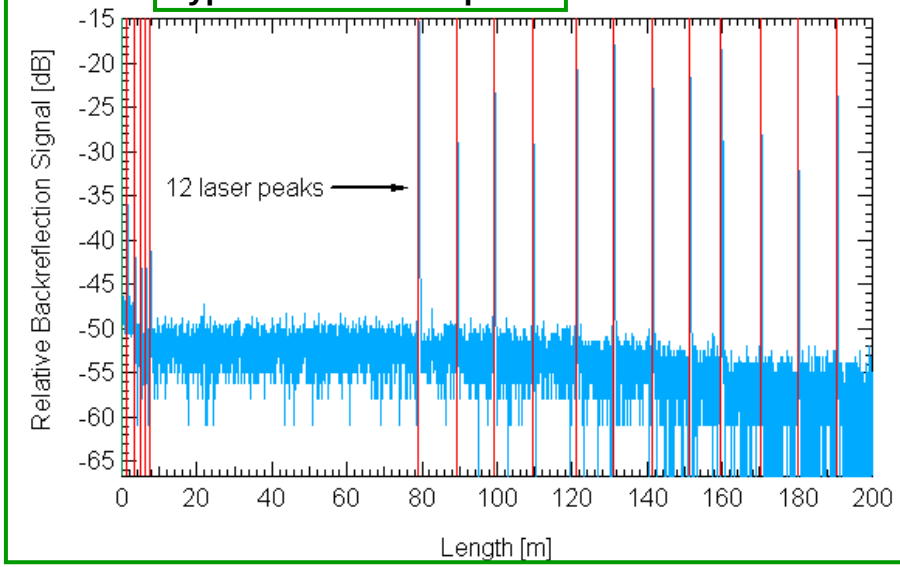
Cable Preparation (Apr. 2007 – Oct. 2007)

Cables assigned to specific path, protected and packed for P5

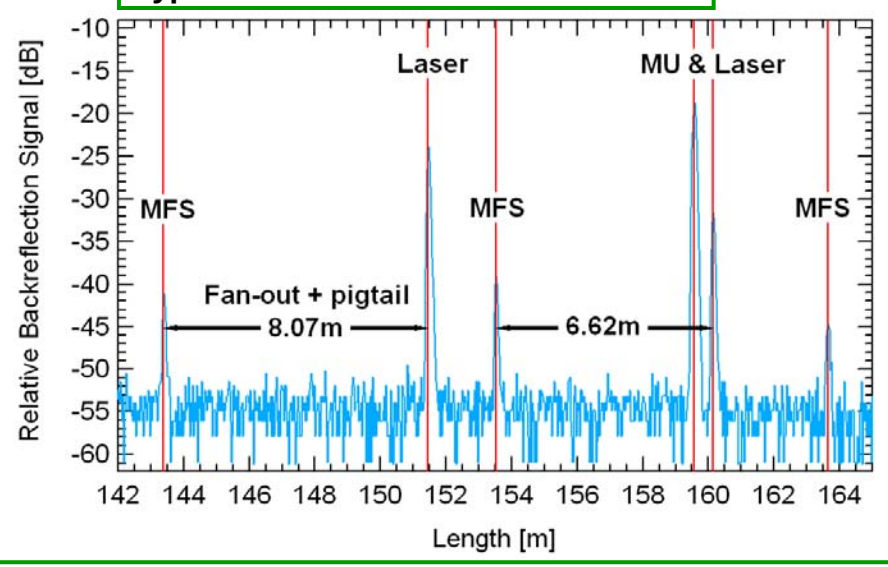
OTDR + splitter



Typical trace with splitter



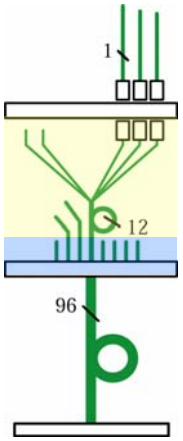
Typical when MFS and MU are visible



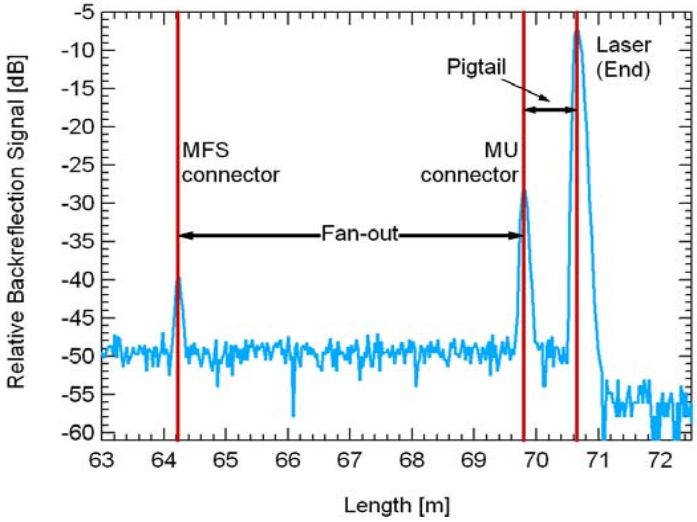
Time of measurement: **19min/cable** (96-fibres)

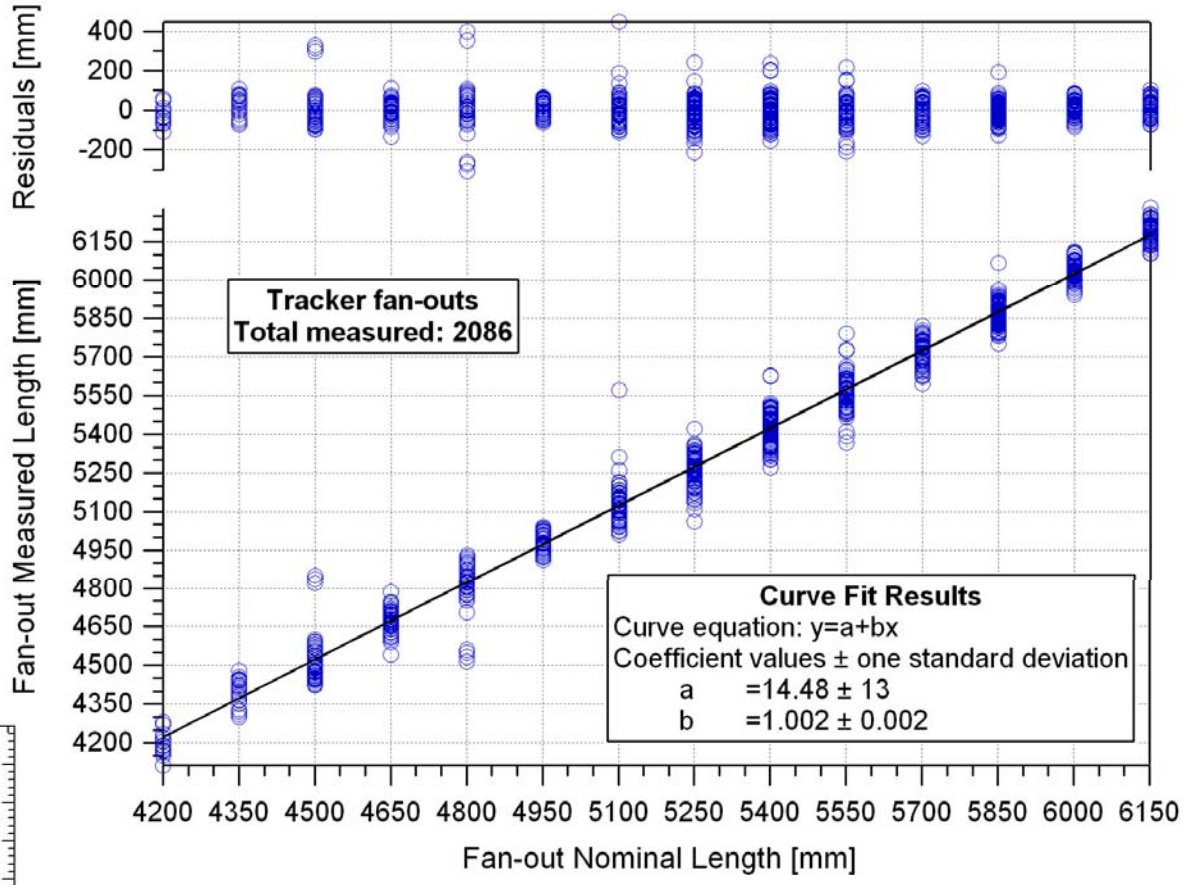
A configuration with an optical SWITCH was used for detailed analysis and troubleshooting

Example of measured lengths: fan-outs



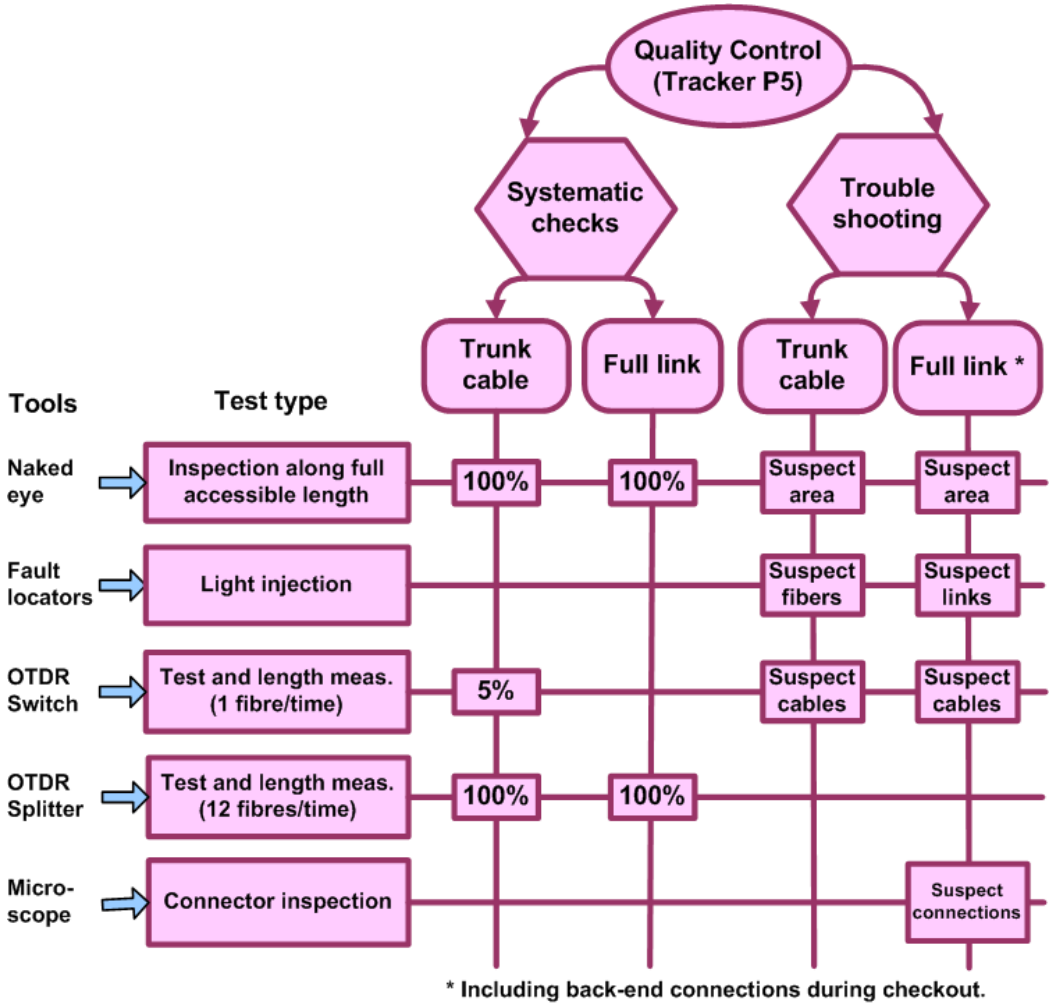
MU visible ⇒ measure of fan-out and pigtail lengths



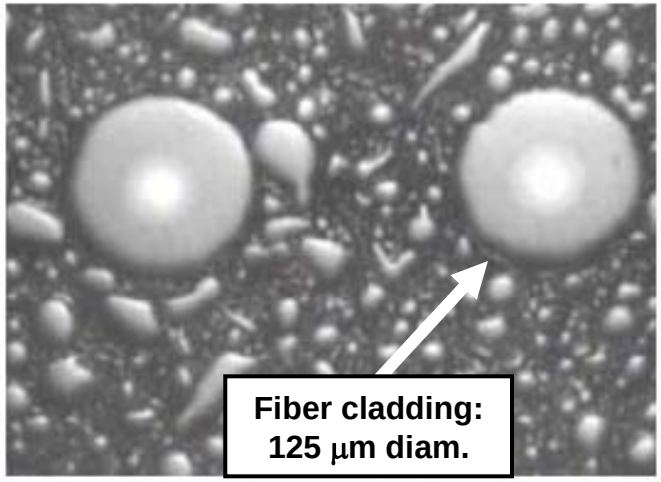


Cabling map validated!

Tracker QC program



Microscope MPO inspection



Similar for other systems