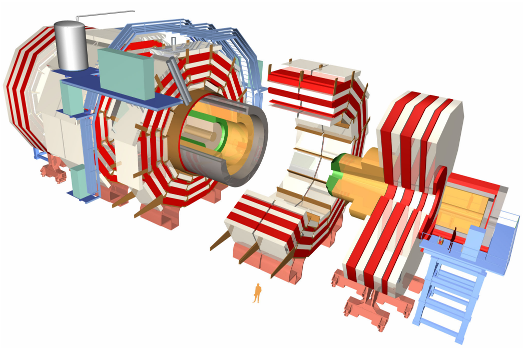
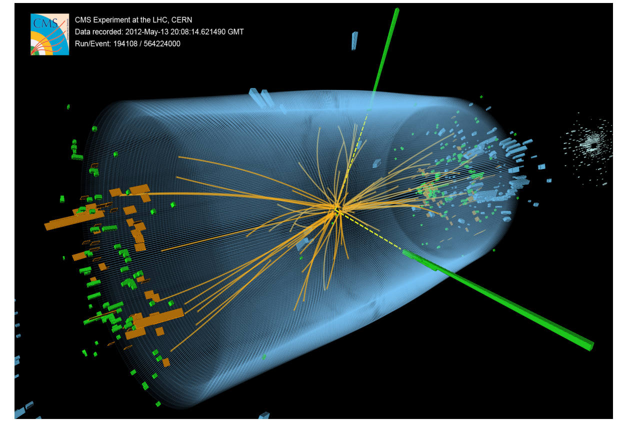





# UK CMS Upgrade Oversight Committee

20 May 2014

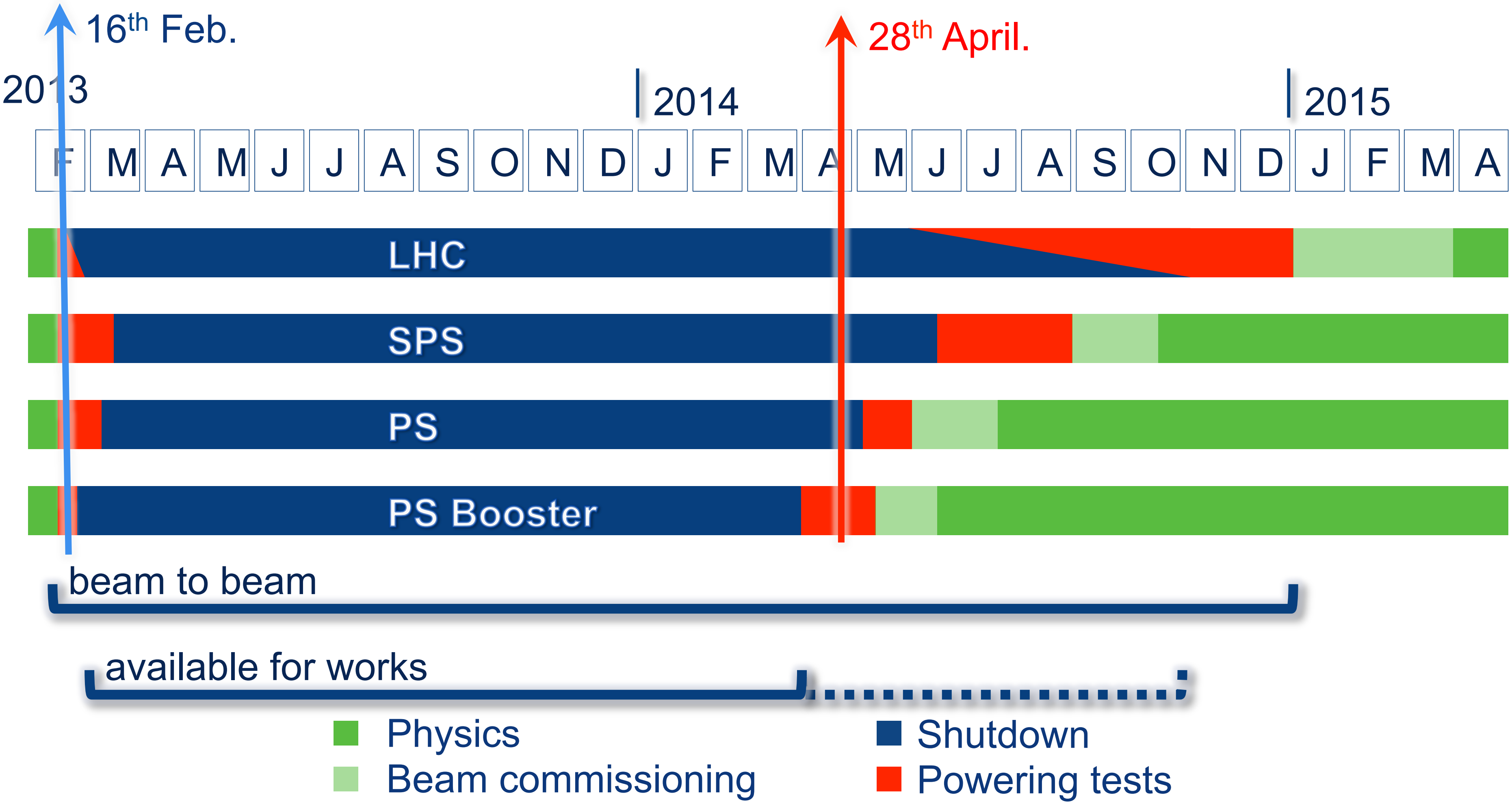

University of Bristol
Brunel University
Imperial College London
Rutherford Appleton Laboratory

Geoff Hall

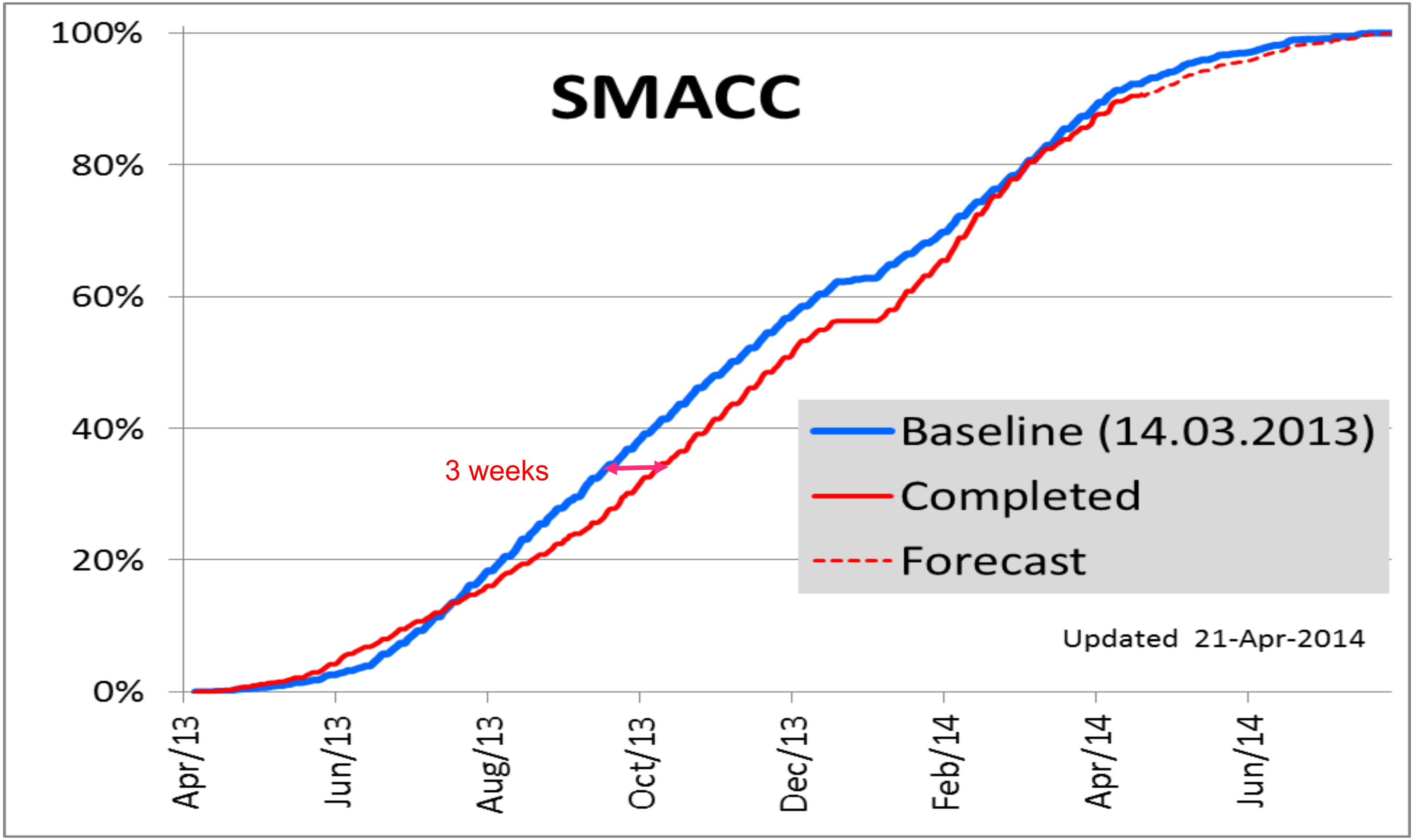
# Overview

- Snapshots of LHC & CMS status
  - LHC: LS1 on schedule and machine very confident to be ready for restart
  - New schedule since December 2013
    - CERN long term planning still unclear (as STFC know well)
  - CMS also on schedule for restart
- Summary of UK upgrade project
  - Recent WP progress
- Finances and other issues

# LS 1 from 16th Feb. 2013 to Dec. 2014

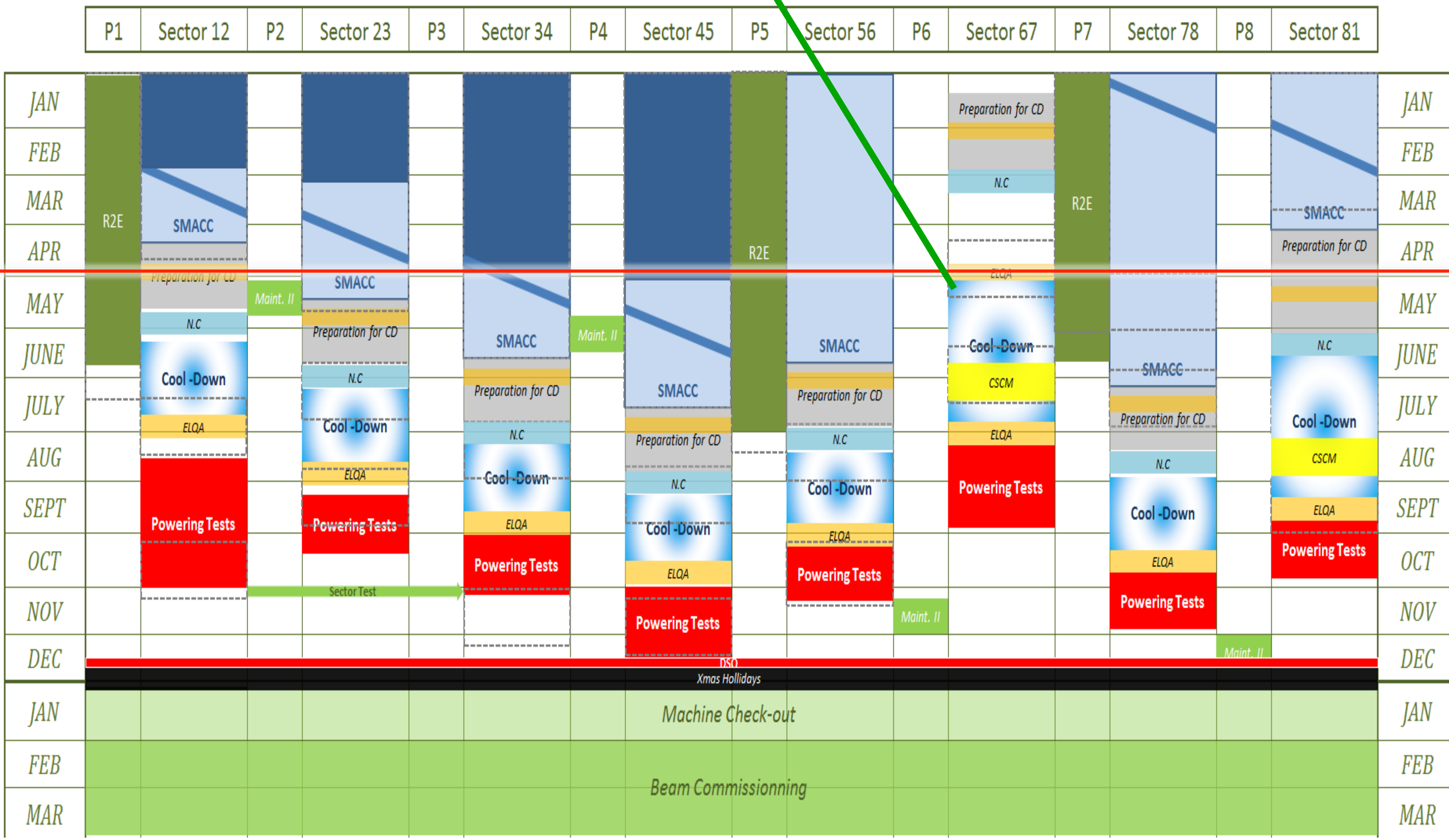


# Superconducting Magnets And Circuits Consolidation Dashboards



# LS 1: LHC status

**1st Cool Down: starting on 7th May**

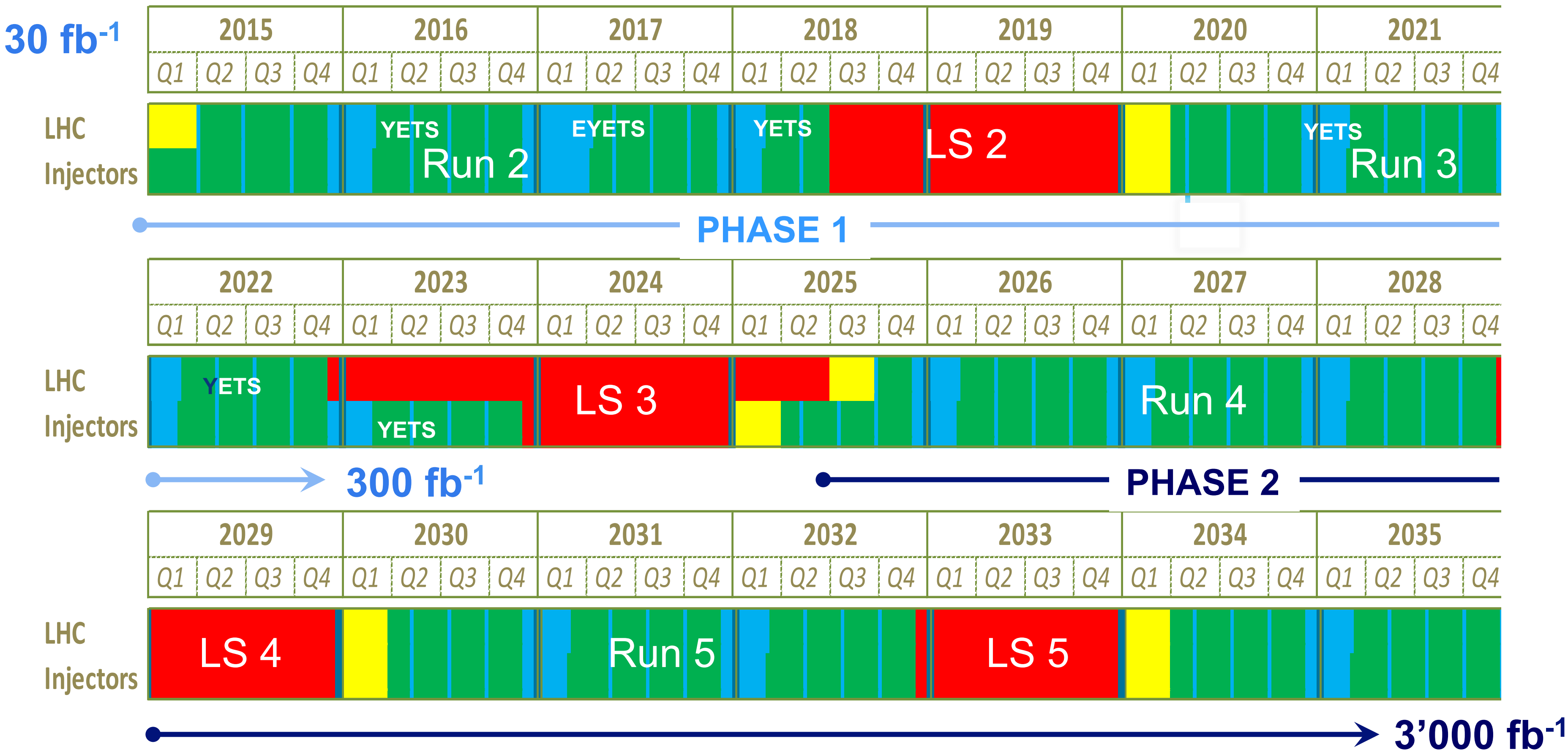


# LHC roadmap: schedule beyond LS1

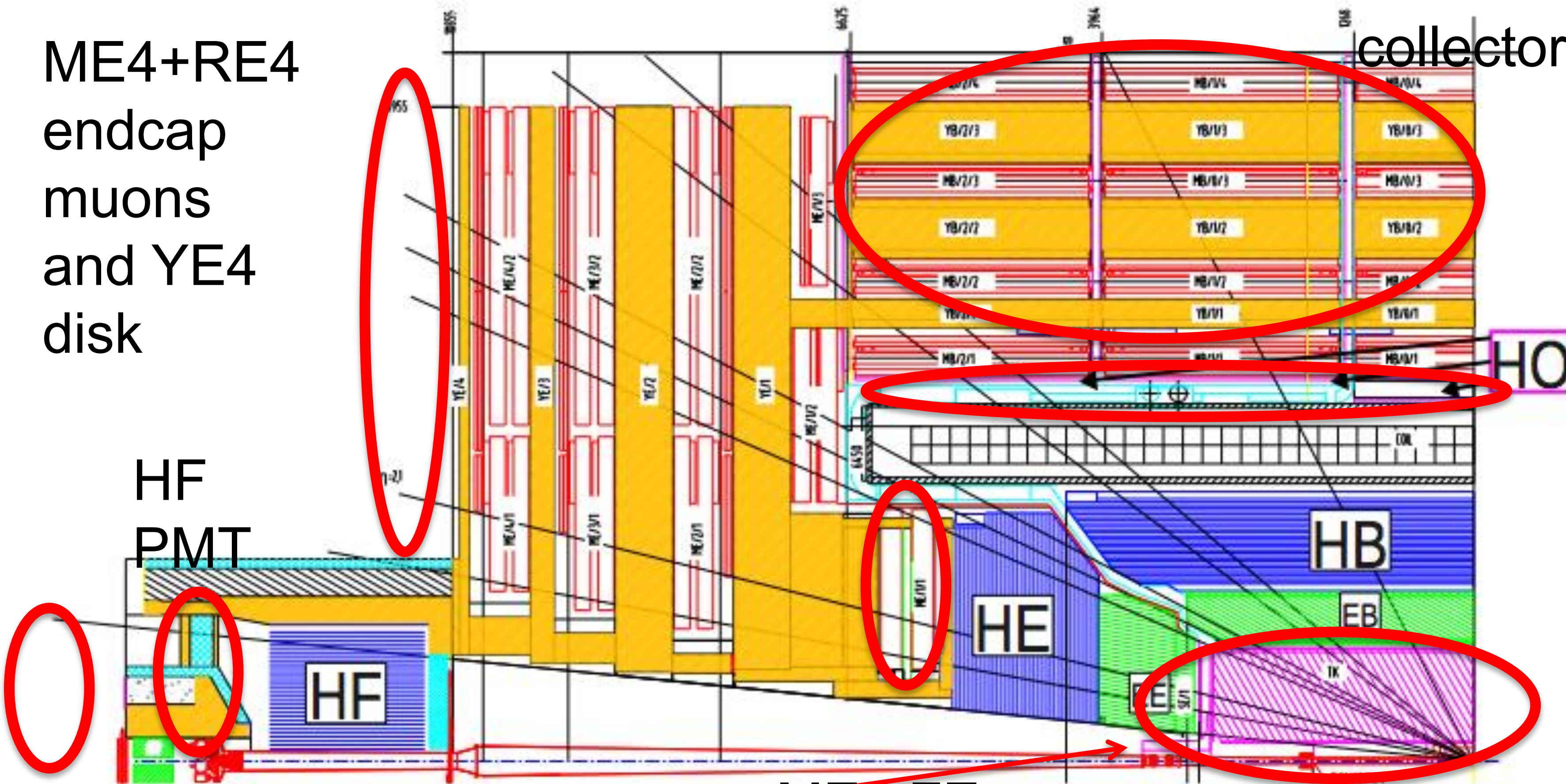
LS2 starting in 2018 (July) => 18 months + 3 months BC
LS3 LHC: starting in 2023 => 30 months + 3 months BC
Injectors: in 2024 => 13 months + 3 months BC

**(Extended) Year End Technical Stop: (E)YETS**

- Physics
- Shutdown
- Beam commissioning
- Technical stop



# Detector activities in LS1




DT sector collectors

ME4+RE4 endcap muons and YE4 disk

HF PMT

BRIL: PLT, BCM1

New central beampipe

ME1 FE electronics

Cold tracker operation

# Long Shutdown Status

- LS1 passed the half way point:
  - Beam pipe : delivered (Be welding problem overcomed), NEG coated, ready to install
  - Tracker cold operation: tested -20(tracker) -25 (pixel) OK : operation at -15. New, high capacity dry air plant required to ensure robustness.
  - Muon coverage completion and consolidation:
    - CSC 4th station: ME4/2: installed and commissioned on both sides
    - CSC 1st station electronics upgrade: chambers extracted and reinserted on both sides
    - RPC 4th station : RE4 + side : DONE , - side : installation ongoing
    - Barrel drift tubes (DT) Sector collector relocation: 4 wheels done, 5th ongoing
  - YE4 (4th endcap disks): competed on both sides (pushback at – end tested successfully)
  - HO HPD replacement with SiPM: done
  - HF PMT replacement: commissioned (on schedule)
  - BRIL: Si-PLT & new BCM1F electronics & BHM : on track. Test beam in DESY successful
  - Surprises: Preshower power feed-through overheat due to underrated capacitor. Dismounted, taken to the surface , opened, fixed, being re-installed
- LS1 endgame: (re-arranged) schedule: in line with LHC restart schedule

# L1 Trigger Upgrade

Note : every acronym with a '7' means a card based on Xilinx Virtex 7 FPGA

Needed for Start of run in

- Global Muon Trigger: — 2016
  - Currently working on compiling firmware for MP7 card
- TCDS ( new timing and control distribution HW) — 2015
  - Received 10 prototype FC7s, production ongoing, installation in July
- Calo Trigger: full trigger preceded by intermediate configuration to be used in 2015
  - ORM-OSLB being installed : deplyed and commissioned in July
  - Milestone: legacy calo trigger recommissioned by July global cosmic run
  - Milestone: have Stage 1 of calo-trigger fully installed and commissioned by march 2015 — 2015
  - MP7 production almost done
  - CTP7 prototype successfully tested
  - Optical patch panel between layer 1 and layer 2 in design — 2016
  - Milestone:Install HW for TDR calo trigger (MP7,TCP7, optical patch panel) by March 2015: (to be tested/commissioned in parallel to Stage1 during 2015)
- Muon Trigger:
  - TwinMux (RDT-RPC concentrator) : prototype being tested — 2016
  - Prototype MTF7 card received and under test
  - Barrel Track Finder: MP7 preproduction card received, developing algorithms

# UK R&D status

# Last 6 months

- WP2: DESY beam test of first prototype 2S module
  - steady progress elsewhere in regular system discussions
- WP3: effort substantially increasing in response to challenges
  - UK work very productive and steady progress
    - including support to rest of project
  - EDR November
    - Revised management since January
- CMS TP in preparation for September submission to LHCC

# WP2 objectives and status

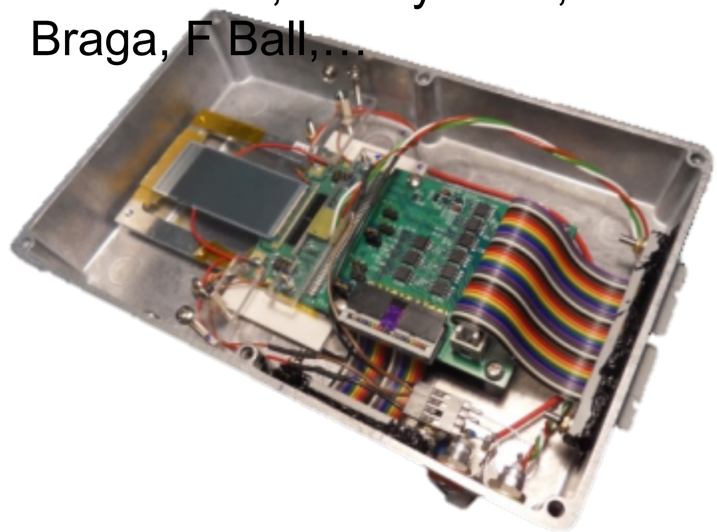
- CBC & 2S-module development for construction project
  - Main issue is evolution of CMS requirements (latency, L1 rate,..)
    - decision due June
  - Have not yet been able to fully revise WP2 schedule
    - Caution with resources until timescale and objectives fully clear

- FC7 for CBC module readout
  - developed in collaboration with CERN
  - large order for TCDS under way after overcoming production problems

- Good progress with CBC2 evaluation
  - radiation tests under way

# Pt module beam test at DESY

M Pesaresi, M Raymond, D Braga, F Ball,…

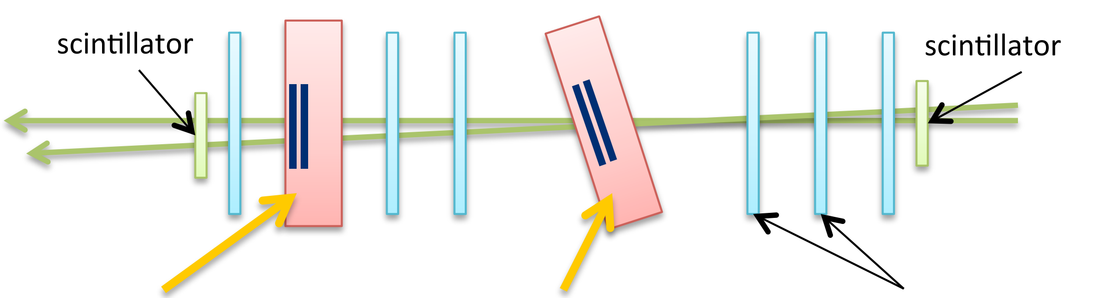


- December 2013
- 4 GeV positron beam
- Datura telescope + 2 pT modules (1 fixed, 1 rotatable) with 2 different strip sensors
- Custom control and DAQ

<u>Module #3 (FIXED)</u>
Infineon, n-type
Sensor 80x300 µm
dL = 2.8 mm
Strip length = 50 mm
#channels = 256

<u>Module #4 (DUT)</u>
CNM, p-type
Sensor 90x270 µm
dL = 2.8 mm
Strip length = 54 mm
#channels = 254

**positron beam**
low angular divergence (small angular error)

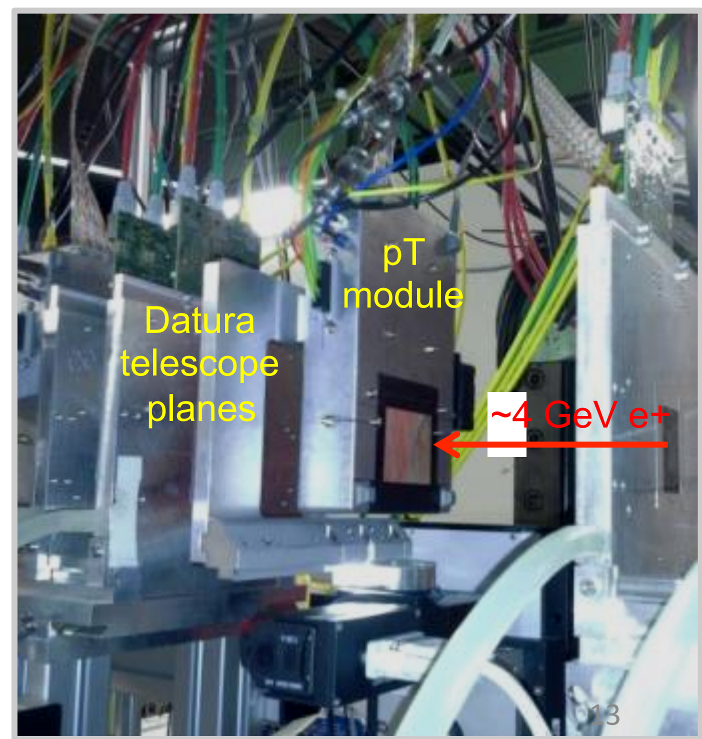



**module #3 on fixed assembly**

**module #4 on rotation stage**

Mimosa26 MAPS (DATURA telescope)

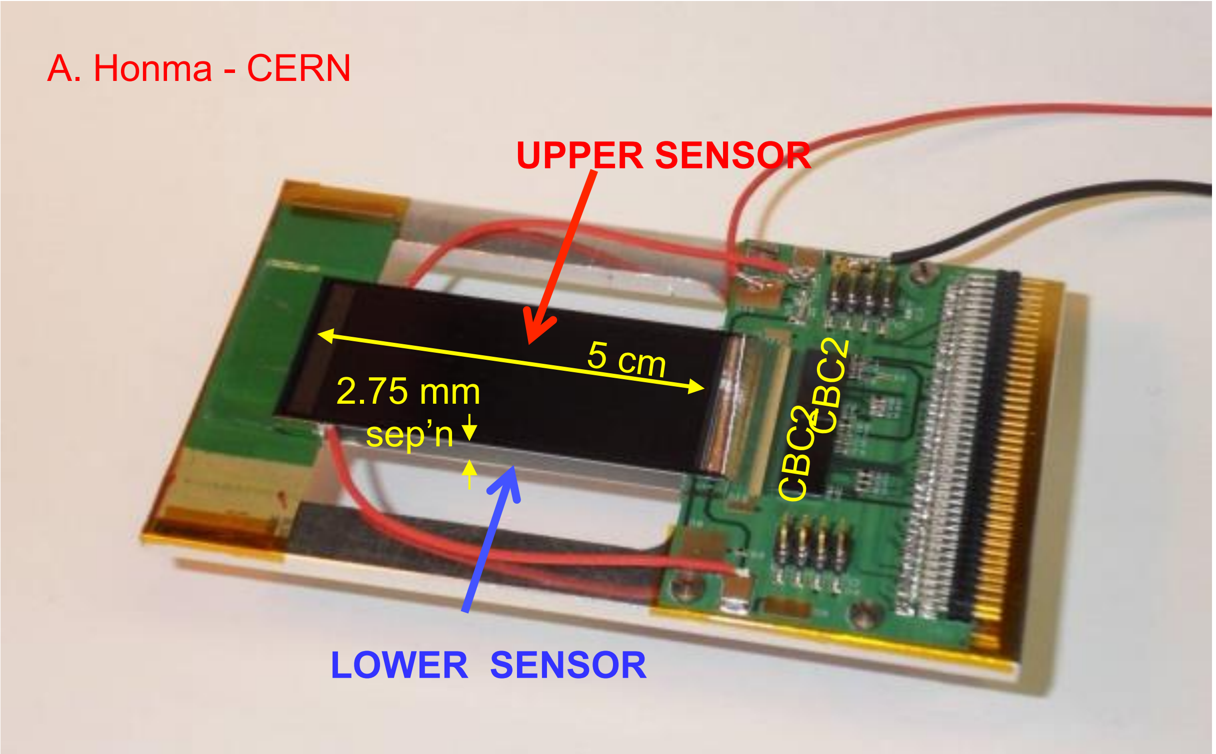
TOP VIEW: strip direction into page



# Pt modules & sensor variants

3 PT modules taken to DESY:

- 2 different sensor types
- one module left as backup

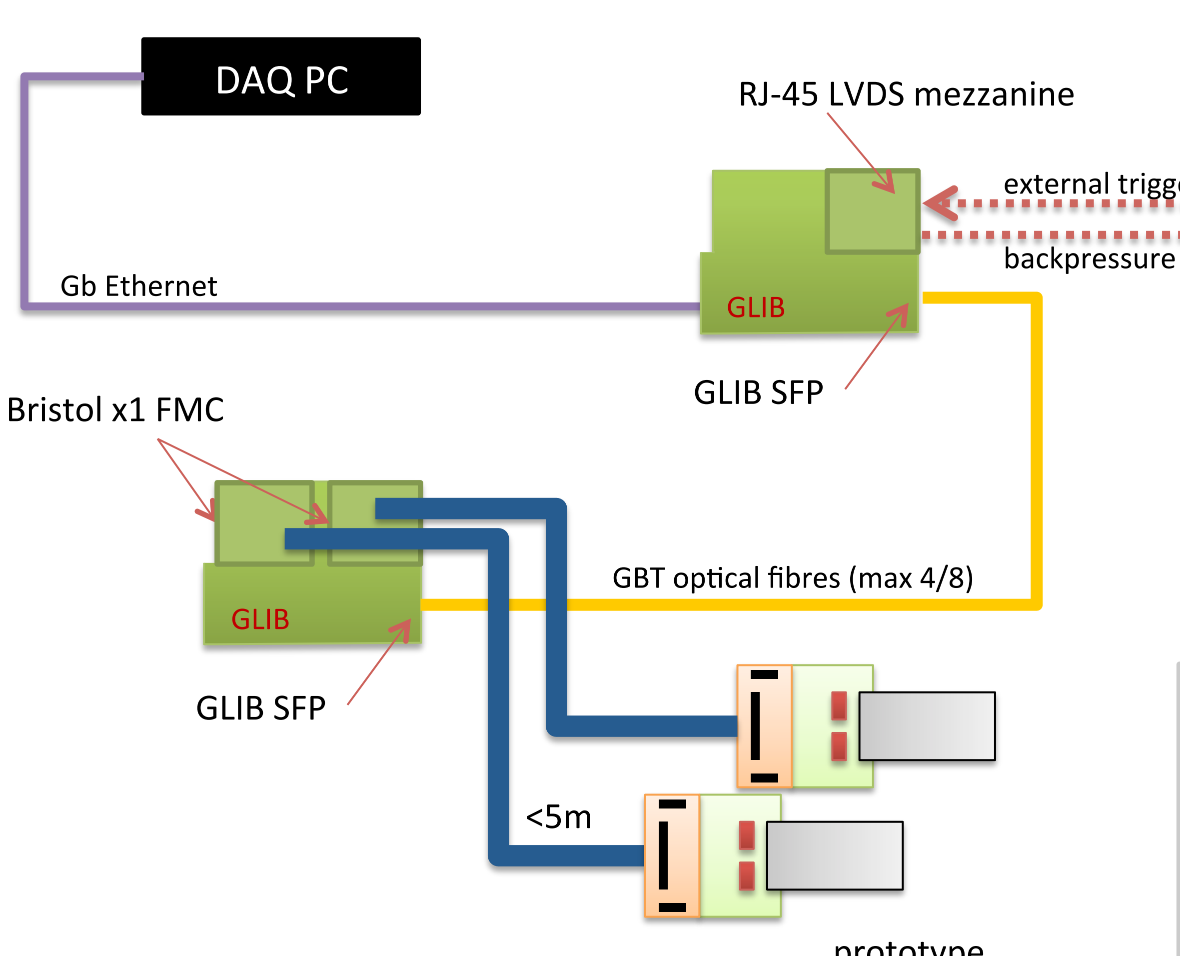


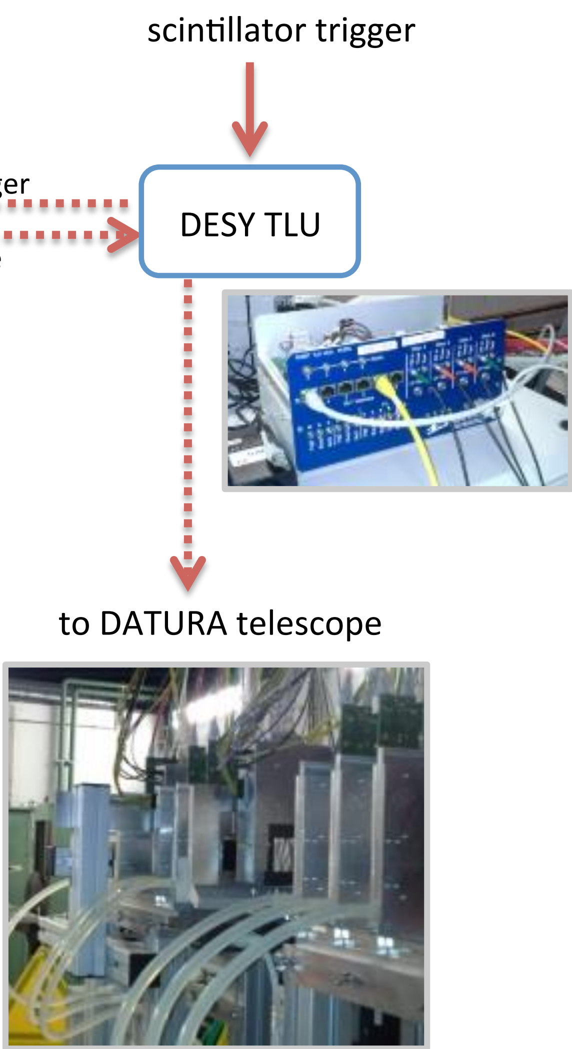

each CBC2 chip takes 127 inputs from upper sensor and 127 inputs fro

| module # | sensor | sensor type | pitch [um] | thickness [um] | length [mm] | # strips | comments | tested |
|---|---|---|---|---|---|---|---|---|
| 3 | Infineon | n-type | 80 | 300 | 50 | 256 | region of disconnected channels | yes |
| 4 | CNM | p-type | 90 | 270 | 54 | 254 | | yes |
| 1 | Infineon | n-type | 80 | 300 | 50 | 256 | noisy strips, disconnected channels, odd low bias behaviour | no/ backup |

# Beam test DAQ

M. Pesaresi, IC
L. Gross, IPHC

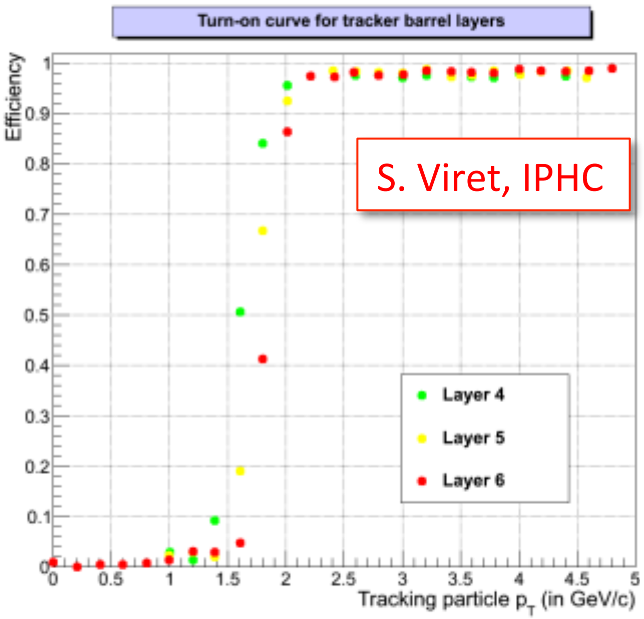


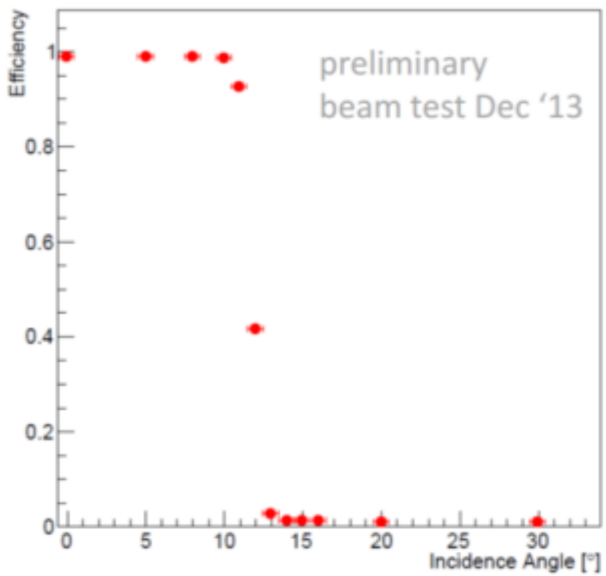



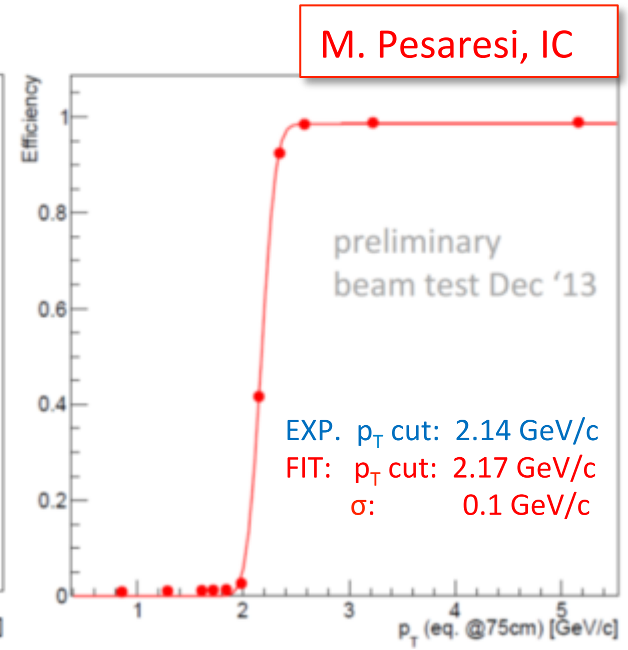

prototype
modules

control and DAQ based on CERN GLIB
emulating GBT functionality

# $P_T$ cut principle demonstrated



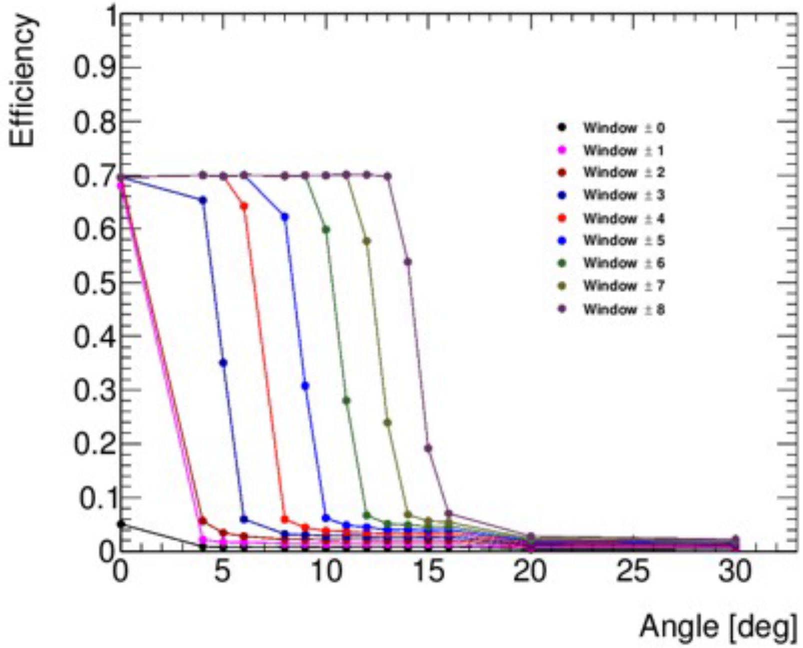

**Pt Selection cut: simulation** ⇨ **measured efficiency** ⇨ **reconstructed $p_T$ cut of r=75cm layer**

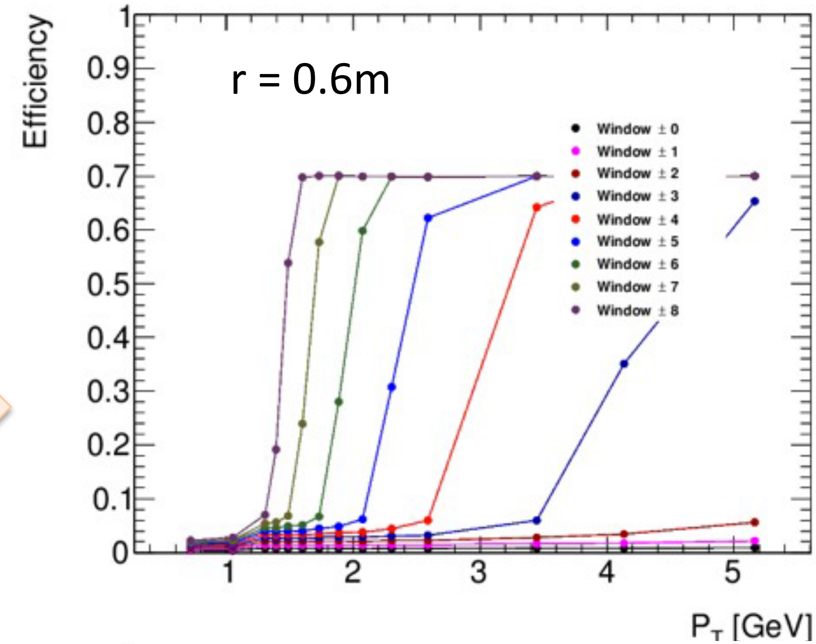
CBC2 correlation window was set to +/- 7 strips; 0 strip offset

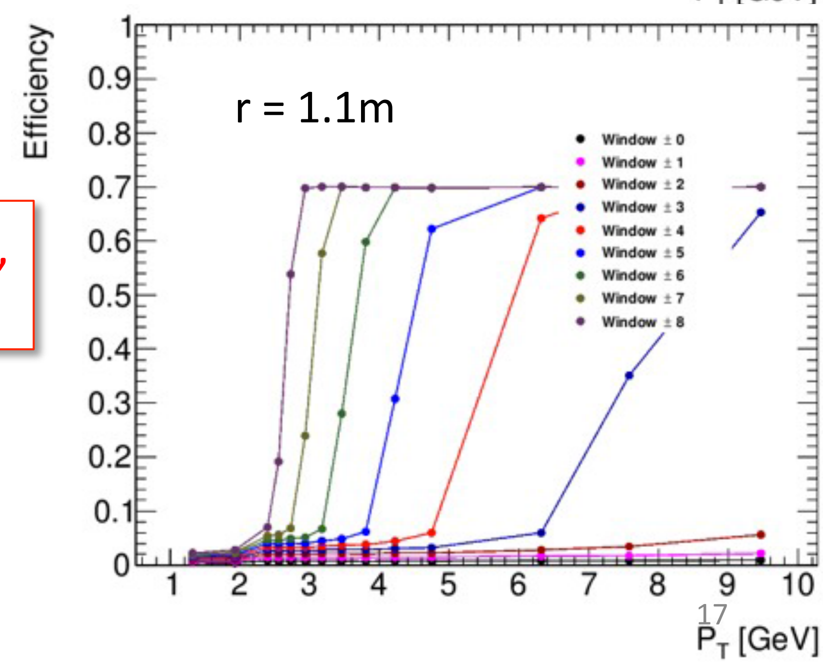
- $P_T$-cut reconstructed from beam test data matches the design one exactly
- Sharp turn-on

→ **First experimental result to prove the stub selection concept!**

## Stub Efficiency vs. Angle ⇨ Reconstructed stub Efficiency vs. $P_T$

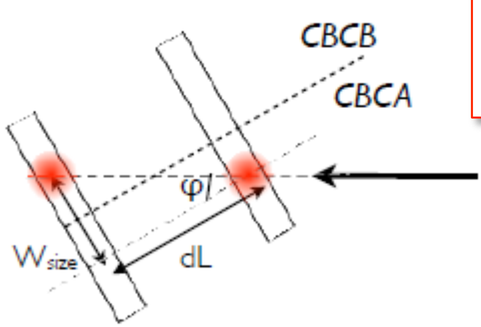



Stub efficiency turn-on angle:

$\varphi = \mathrm{atan}(W_{size}/dL)$

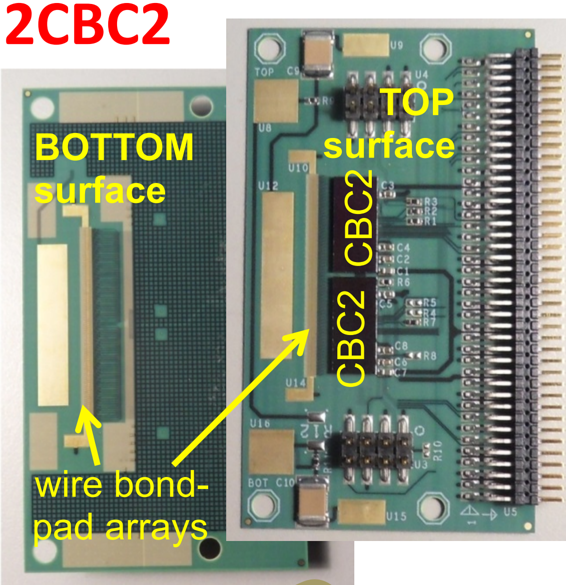


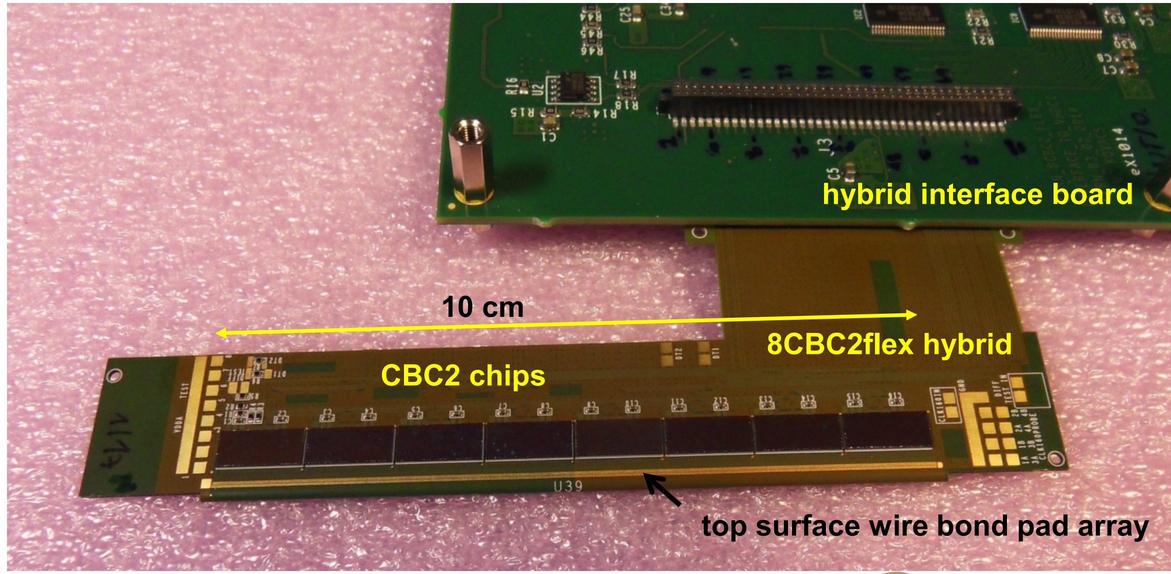

Kirill Skovpen, IPHC

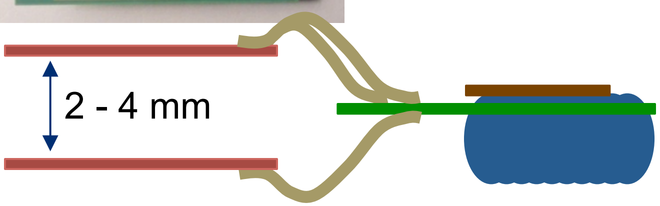
# hybrid developments

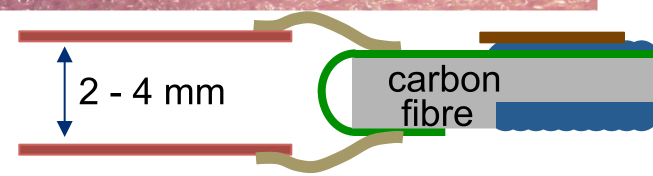
M Raymond, K Uchida,…

**2CBC2**



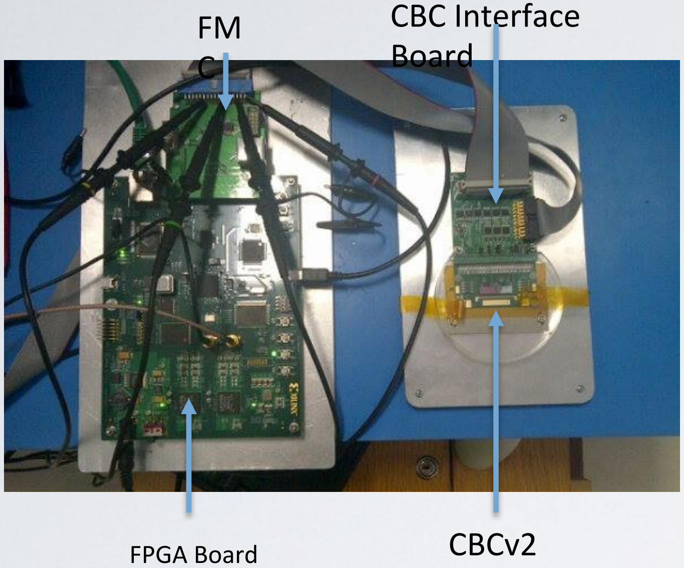




- 2 CBC2
  - 2 chips prototype - available mid 2013
  - 6 layer "rigid" technology
  - – actually quite flexible - only 265 μm
  - fully functional, but flexibility and thickness causes bonding problems when constructing modules

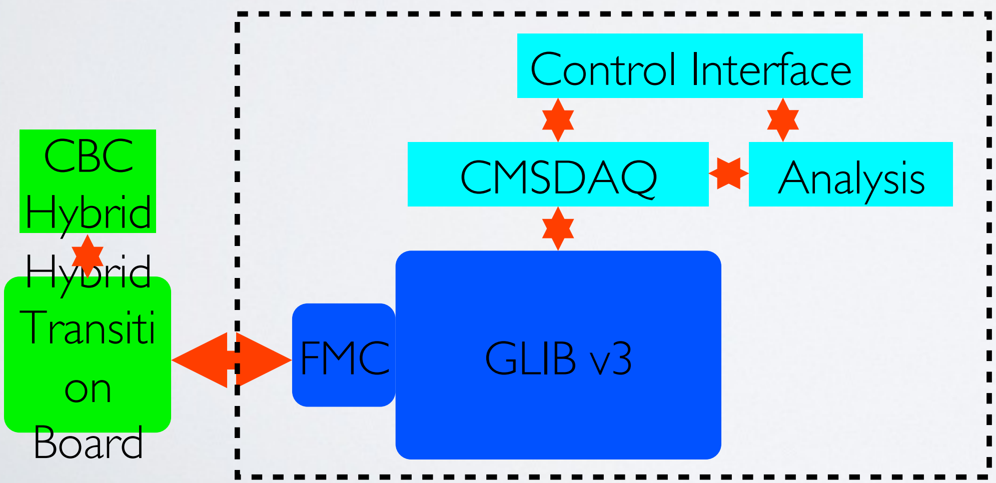
- 8CBCflex
  - – full size 8 chips, 4 layers
  - – "wrap around" hybrid support should help with module manufacture (support thickness can be chosen to achieve desired sensor spacing)
  - – first 2 prototypes recently delivered, currently under test
  - – 100% channels connected and working

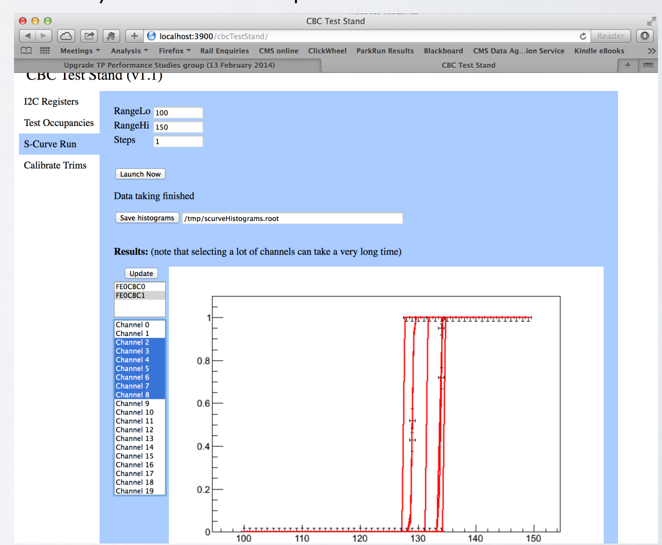
University of BRISTOL
M Grimes, D Cussans, F Ball, …

# Test stand



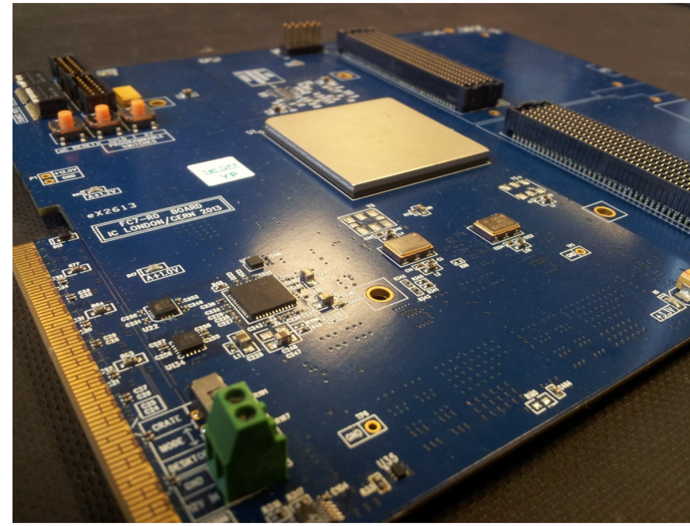

- Common test platform for CBC hybrids and modules
  - Development/prototyping and production
- Based on FPGA board (currently CERN GLIB)
- Mezzanine cards and control/analysis software from UK
- Current version uses full CMS DAQ chain
  - "Lightweight" version bypassing CMS software next
- Being used by CERN hybrid developers and others



# FC7 status

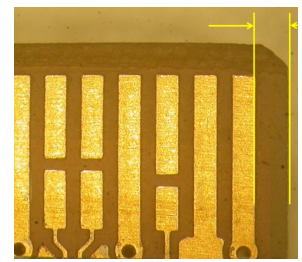
M Pesaresi

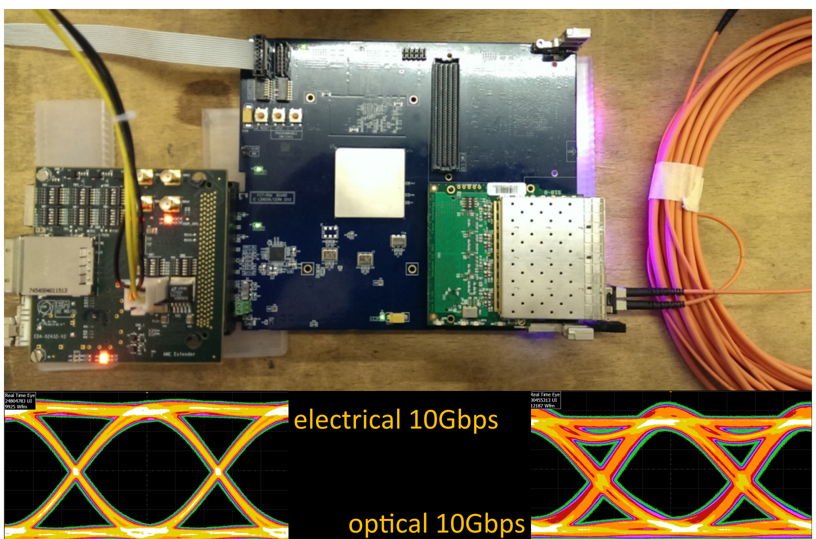


**flexible, µTCA compatible card for generic CMS data acquisition/control uses - joint CERN/UK project**

- pre-production completed in January 2014 after informal market survey, two manufacturers selected (Hapro, Norway; ExceptionPCB, UK)

- excellent build quality, especially with Hapro – no further issues with mechanical tolerances or delamination






**pre-productions used to assemble semi-automated test stand, all boards pass test suite**

- high speed serial links validated at 10Gbps

- full system level f/w available, ready to implement user-specific applications

# WP3 objectives and status

- Calorimeter trigger for next running period
  - good progress with new (co-)PM since January: C. Foudas
    - November EDR and new SP identified problems
  - much better planning in place and pressure on US to meet commitments
    - complete project plan (provided to OSC)

- optical splitters now mostly installed
  - progress with Stage-1 interim trigger, with UK continuing to support
  - commitment from SP to ensure TDR trigger in 2016

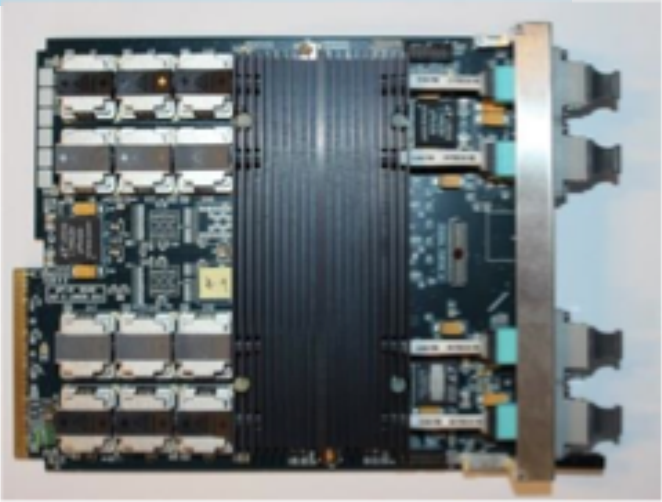
- Recent UK progress
  - **Excellent** progress in all areas of project
  - It remains true that the most dependable and substantial contributor to the trigger upgrade is the UK

# L1 Trigger: Overview

- Key project objectives remain unaltered
  - Project is on schedule, and well within predicted cost envelope
- Improvement of current CMS calorimeter trigger
  - Preparations under way; make early use of UK hware, software and firmware
  - First interoperability tests with existing hardware successful in April 2014
- Infrastructure for testing of new trigger in parallel with old in 2015
  - Procurement for infrastructural components under way
  - Final software systems being prepared for testing at CMS site
- Design and deployment of new time-multiplexed trigger
  - Final MP7 modules are now in production; first modules at CERN
  - Realistic trigger algorithms being tested now

# Trigger Hardware

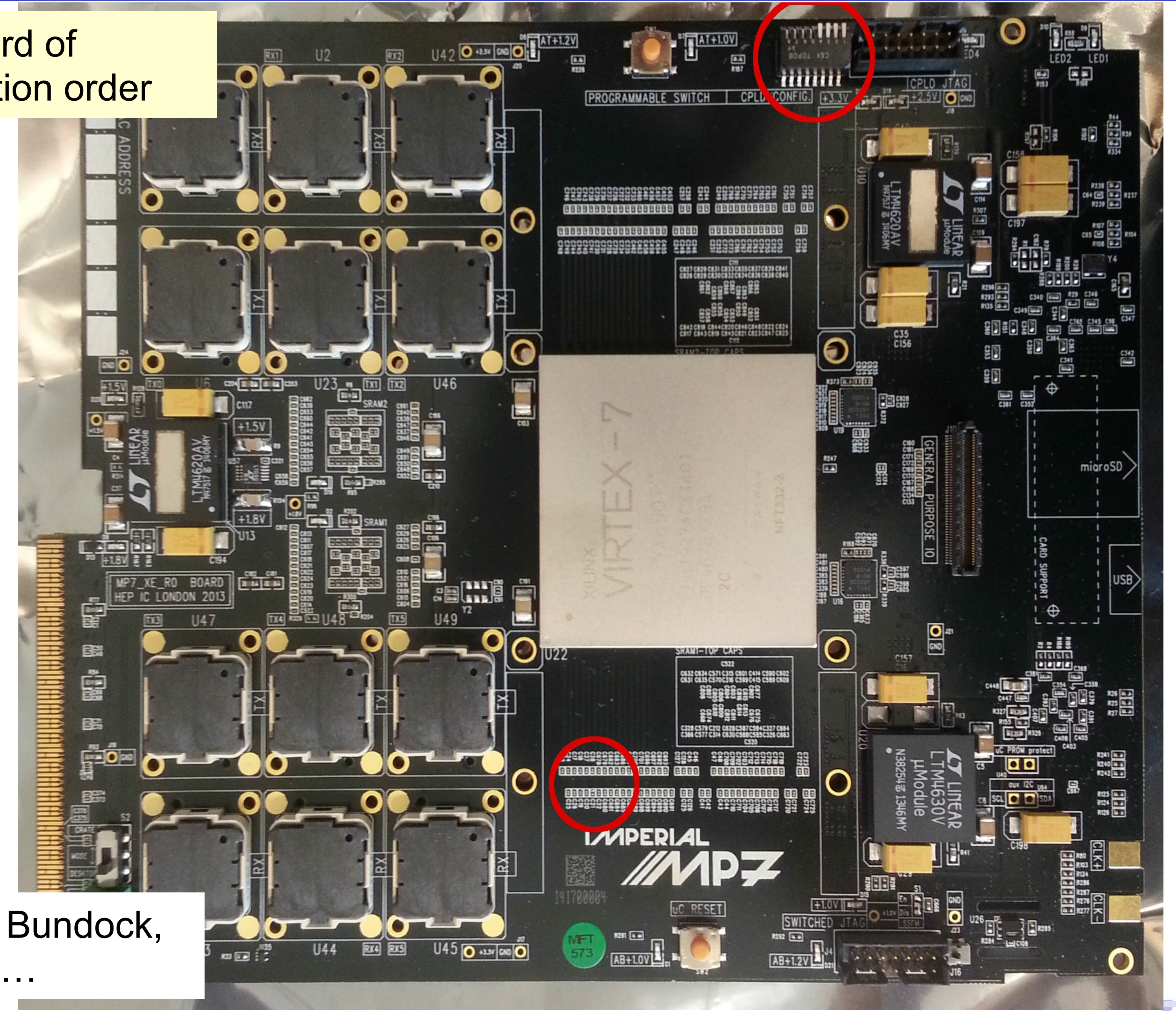
- UK hardware
  - Final iteration of MP7 now in our hands
    - First production boards at CERN
  - Contract for fabrication of up to 30 more modules
  - Hardware in use by groups around Europe



- Trigger hardware overview
  - oSLB / oRM optical components almost 100% installed and commissioned
    - Replace copper serial links, for parallel operation of new calo trigger
  - Interim trigger data formatter module (oRSC) finally tested at CERN
    - UK-specified communication protocols for MP7 input
    - (& much firmware and other support)
  - First prototype version of US Layer 1 module (CTP7) tested at CERN
    - Delivery of CTP7 remains the biggest risk to the trigger upgrade project
    - Contingency plan to use MP7, can be completed within the CMS schedule

# MP7-XE

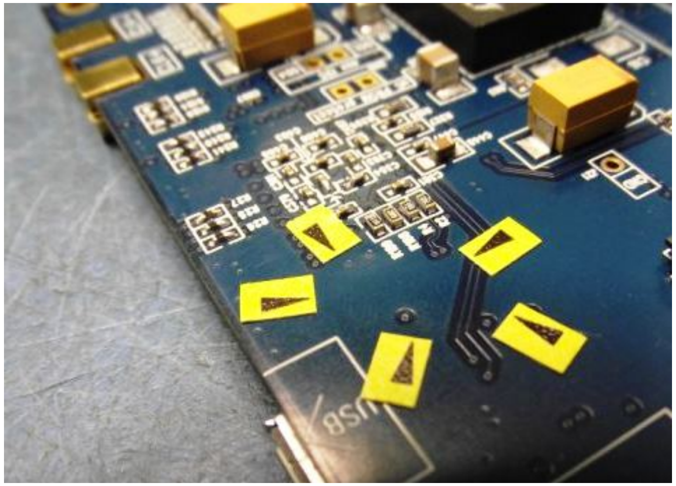
First card of production order




G Iles, A Bundock, A. Rose,…

# Blistering (i.e. local de-lamination of the PCB)

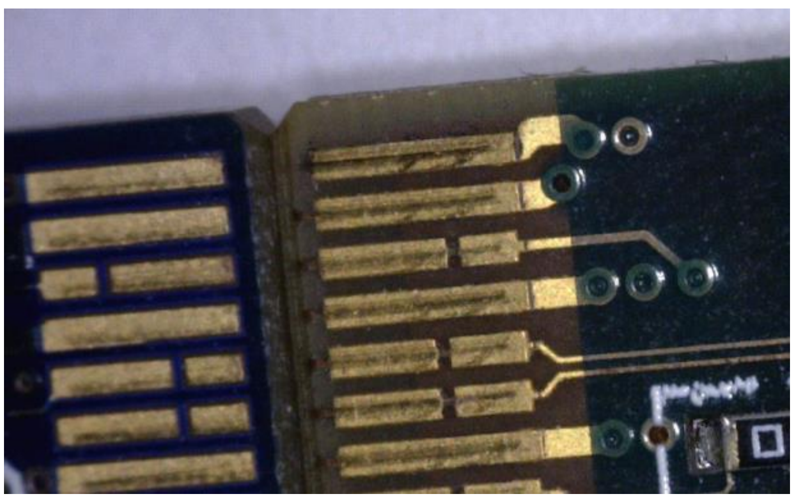
- PCB based on Nelco N4000-13-SI-EP
  - Good high speed signal characteristics, but not the easiest material to work with.
- Blistering observed on a prototype
  - Water absorption considered most likely cause
  - Material hygroscopic
  - Could also have been contamination
- Improved handling of laminates and PCB during assembly..
  - Tested new procedures with simulated assembly of cards.
  - Problem seemed solved
- Problem recurred on Preproduction
  - Alternative PCB material
  - TUC-TU872SLK-SP
  - Validated with FC7 cards



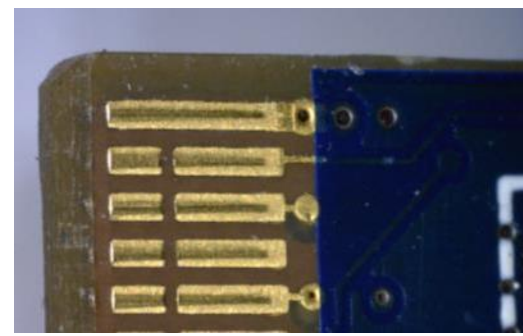
# AMC edge connector

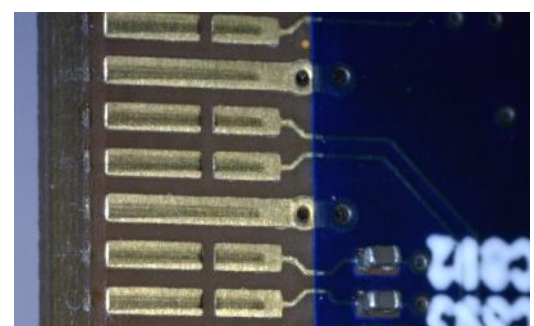
- PCB edge connector quality originally insufficient
  - Improved cutting at PCB manufacturer
  - Tender process had a required capability list for the manufacturer, which included precise cutting.

- Incorrectly manufactured hot-swap contacts
  - New process at PCB manufacturer avoided this issue.



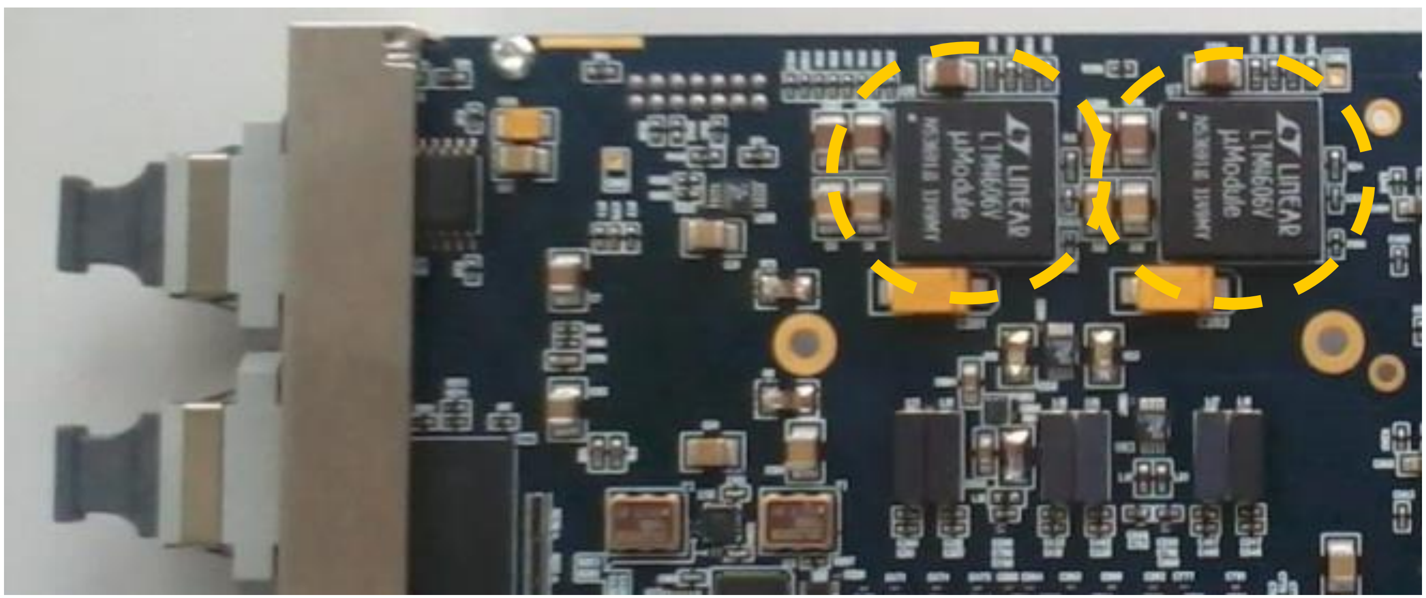
**Poor alignment**





# LGA (Land Grid Array) Part Soldering

- Repeated problems mounting LGA parts
  - Discussed with assembly company
    - Improved paste mask design
    - Both x-ray and power-up tests at assembly company

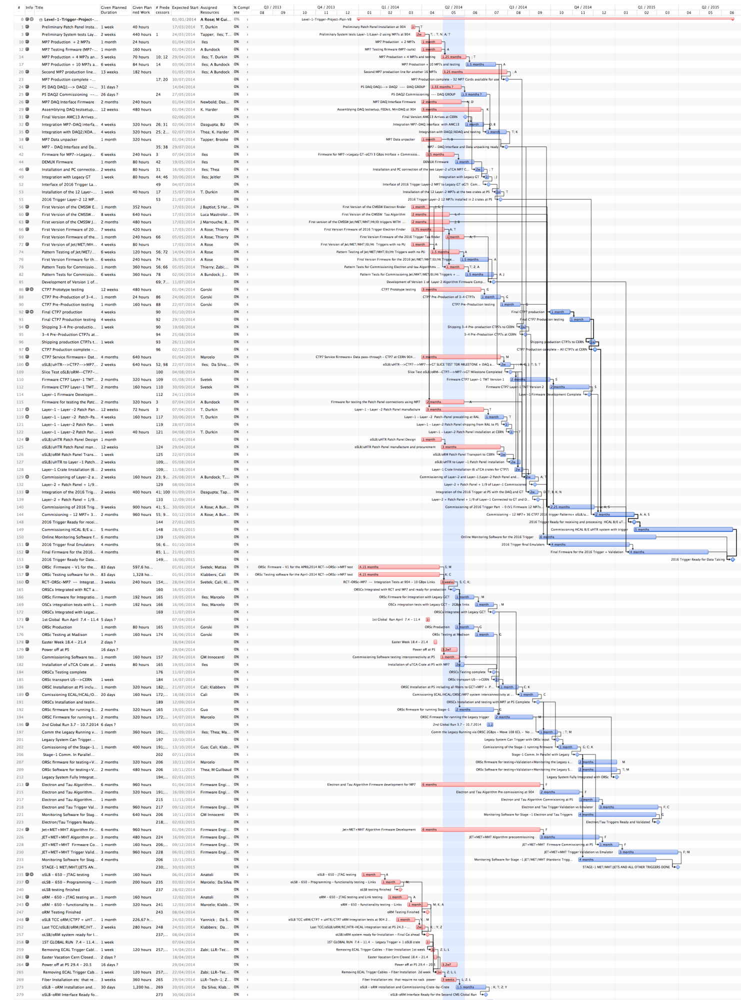


# Firmware, Software and Testing

- Infrastructural components
  - UK has responsibility for the key infrastructure for upgrade electronics
  - IPbus system now proven at the final required scale in realistic conditions
    - Performance exceeds CMS requirements – now also in use by ATLAS, ALICE, LHCb
  - Delivery of DAQ hardware is behind schedule, close to critical path
    - Our fallback plan for integration tests this summer is use of IPbus DAQ
  - Trigger online software led by A. Thea (UK), progressing on schedule
- Test & installation programme
  - April/ May 2014: Interim trigger integration tests, progressing well
  - July 2014: Key trigger upgrade slice test
    - UK hardware, software, firmware components are essentially ready – apart from DAQ
    - Detailed test goals and procedures are now being defined between groups
  - September 2014: Integration with upgraded CMS TTC, DAQ systems
  - September 2014: Installation of UK hardware for interim and final trigger
  - Calo trigger test and installation programme led by S. Paramesvaran (UK)
- More details on algorithm firmware in following slides

# Schedule

(C Foudas), A Tapper, D Newbold, G Iles



- **Trigger project planning**
  - Revised schedule by CMS management
    - *Endpoints unaltered, driven by LHC schedule in 2015/16*
  - UK components largely unaffected; consistent with prior CMS UK planning and resources
  - Details of final installation, optical routing, etc, now essentially firm
- **Conclusions**
  - Trigger upgrade on track for installation
  - No major technical problems encountered
  - Final hardware available; risk reducing

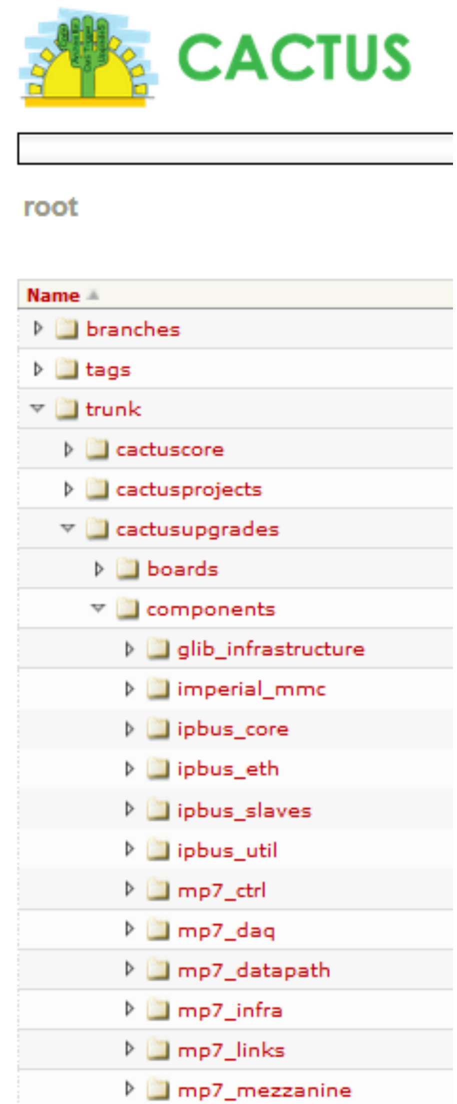
# MP7 Core Infrastructure Firmware

G Iles, D. Newbold, A. Rose, S. Dasgupta,…

- All core MP7 infrastructure firmware complete & tested except readout
  - Pending on US firmware block for communication to AMC13

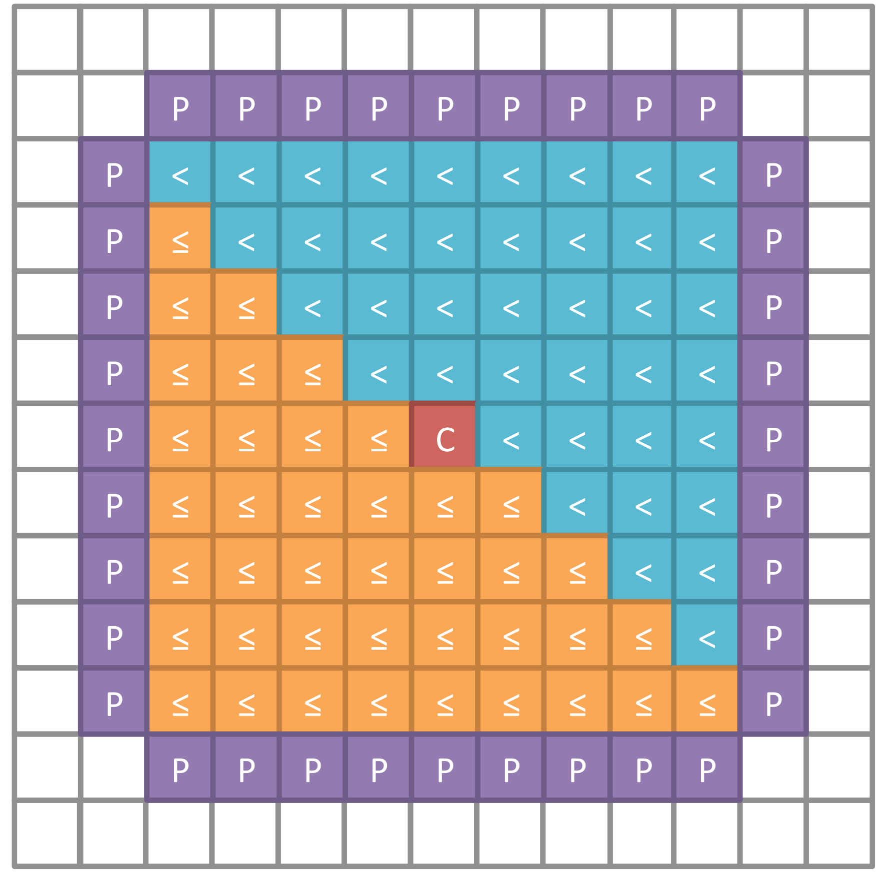
- All code well maintained
  - SVN repository
  - Comprehensive instructions on Wiki

- Future tasks:
  - Upgrade of setup scripts to take advantage of latest Xilinx software release
  - Add project specific  infrastructure firmware
    - E.g. 3G & 5G links,



# Current status of TMT jet algorithms

- Jets
  A. Rose +
  J. Marrouche (*now CERN*)
  - 9×9 sum of trigger towers at every site
  - Fully asymmetric jet veto calculation
  - Local ("Donut") or Global pile-up estimation
  - Full overlap filtering
  - Pile-up subtraction
  - Pipelined sort of candidates in ϕ
  - Accumulating pipelined sort of candidates in η
- Ring sums
  - Scalar and Vector ("Missing") ET
  - Scalar and Vector ("Missing") HT

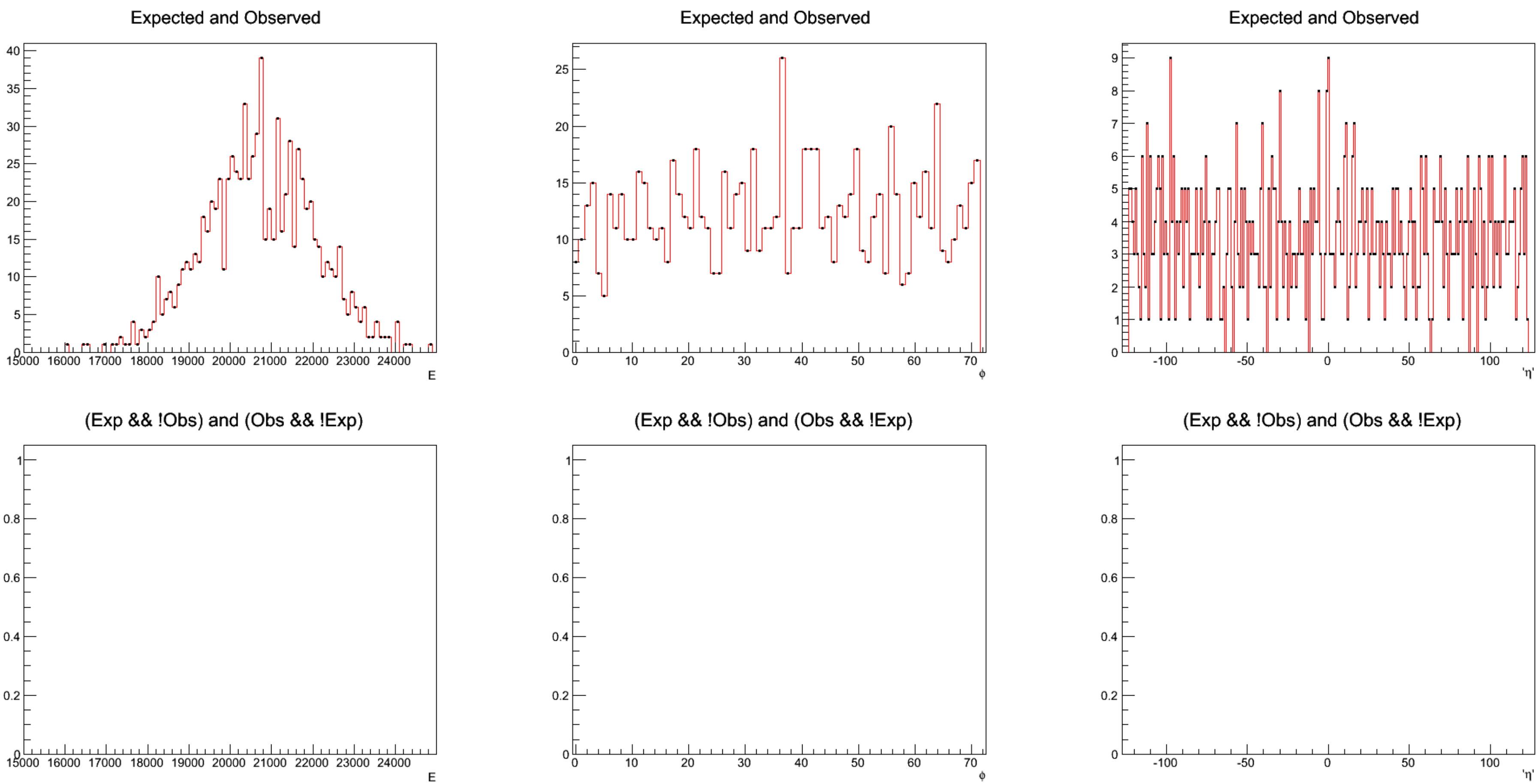



9×9 jet at tower-level resolution

50% LUT utilization <u>INCLUDING</u> links, buffers, control, DAQ, etc.
Runs at 240 MHz

# First verification of code

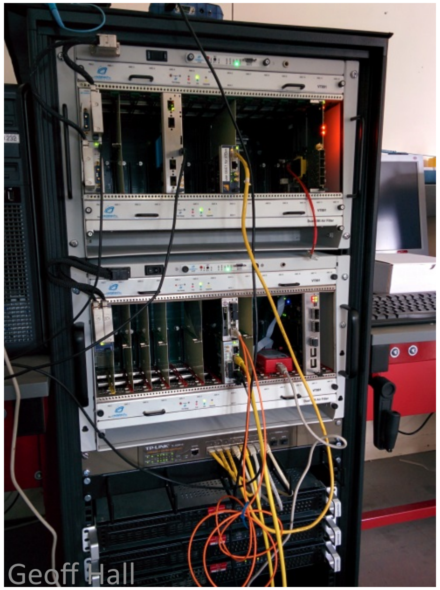
- Perfect agreement (since draft slides)
  - to be compared with full CMSSW emulation very soon



# µTCA infrastructure

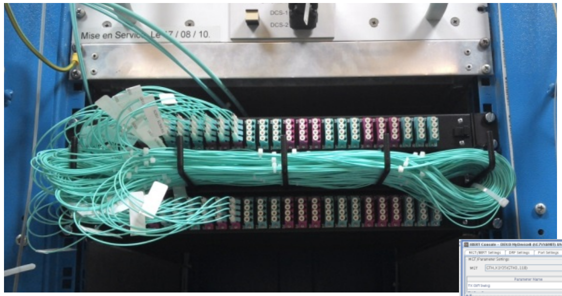
K Harder

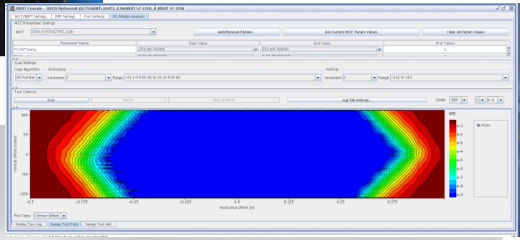
- Test stand at RAL
  - Platform with all relevant boards (incl AMC13)
  - Checking interoperability of modules from different manufacturers (MCH, power)
- Test crate at CERN B904
  - Full crate using obsolete boards
  - Testing operations with realistic power and network infrastructure

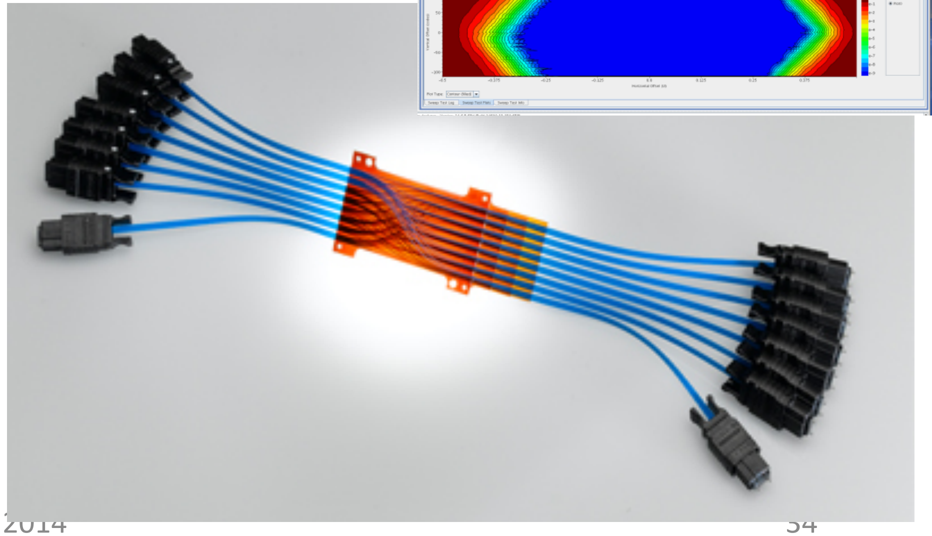


# Optical patch panels

T Durkin RAL







- Connects two trigger layers
  - but can be deployed in interim trigger and TPG-L1
- Initial studies used traditional fan-out and multiplexing units cross connected with LC patch cords
- Verified low bit error rate
  - 63U size unit
  - market survey of alternatives.
- Molex Flex Plane may be a cost-effective alternative

# L1 Trigger Online Software for LHC Run II

A Thea

**Goals and ongoing activities**

- Maintenance and consolidation the software of **legacy L1 trigger**, for the commissioning of the upgraded trigger at Run II start.
- Development of µTCA-based control software for the upgrade, to be integrated in CMS, replacing **~90% of the existing online code** by the end of 2016

**UK Involvement**

- Coordination of the L1 online software project
  - Responsibility for planning online software activities
- Trigger Upgrade
  - Authorship of the baseline **architecture for µTCA-based trigger software** in CMS
  - Strong involvement in the implementation of the **common software and database** structure
- Calo Trigger
  - Development of the control software for **MP7 boards for 2015 and 2016 upgrades**
- Legacy Global Calorimeter Trigger
  - Maintenance and consolidation of the existing system

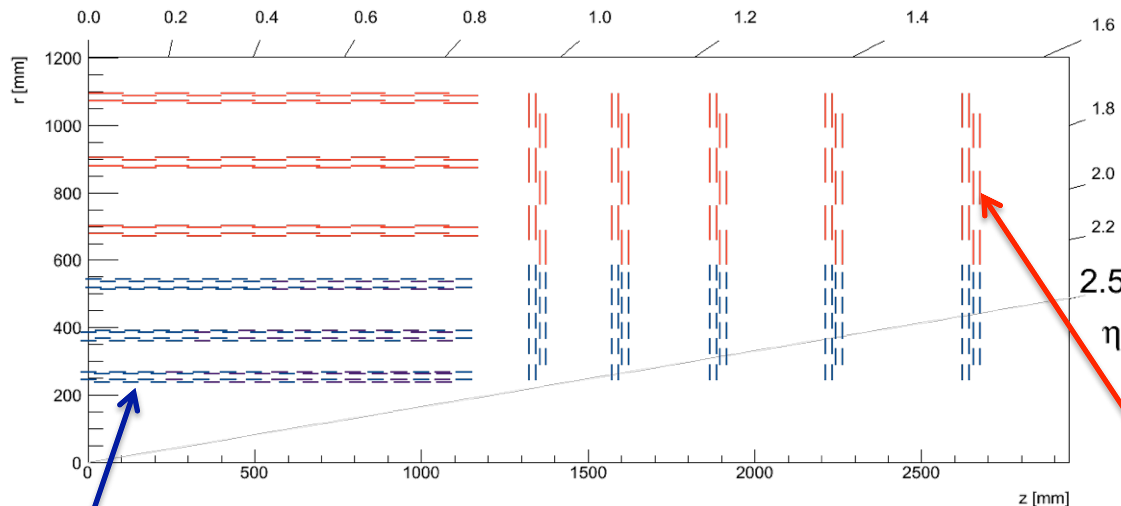
**Progress status**

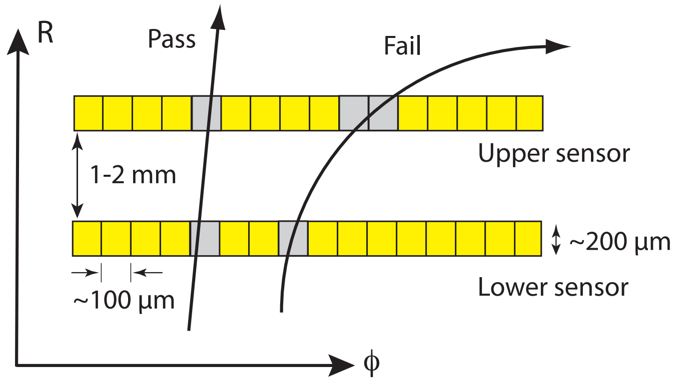
- UK team took the leadership in **several key aspects of L1 Trigger online software**
- All the tasks under direct UK responsibility are in an **advanced development stage**
- Concerning lack of manpower dedicated to software in the rest of the L1 trigger project. The overall progress will need to be tracked closely over the next months.

# Future developments

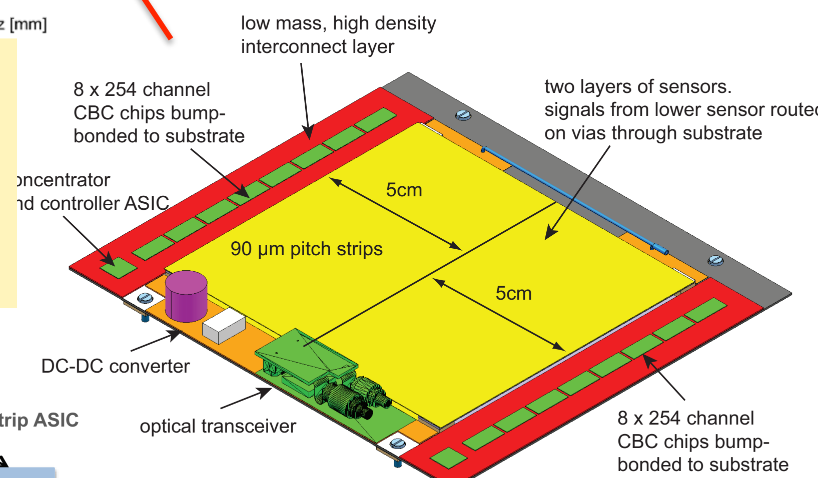
- This activity spans both WPs and all groups
  - simulations to model data flow and performance
  - evaluation of track-trigger architecture
- NB much, if not all, inspired by UK activities
  - pT-modules
  - trigger and tracker hardware developments
  - TMT architecture
- Significant UK lead, which we would like to preserve
  - new concept for track-trigger which can be demonstrated with existing hardware
  - MP7 would already be sufficient to build it
    - further technology gains therefore expected

# CMS Phase II Outer Tracker design

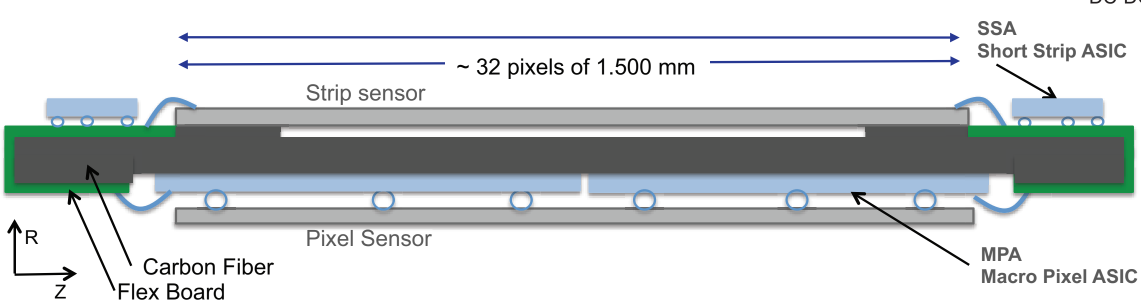


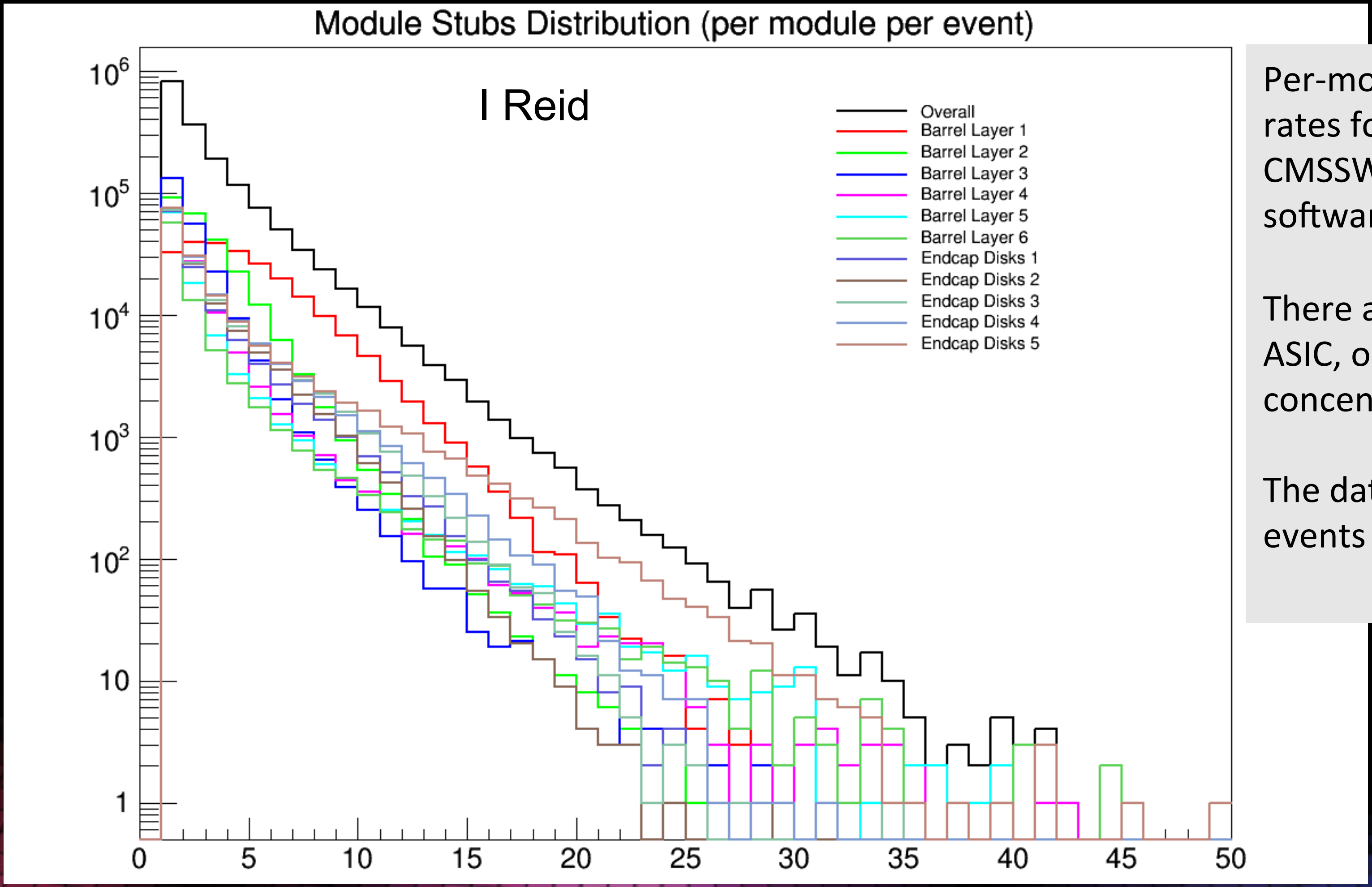

- ~15000 modules transmitting
  - $p_T$-stubs to L1 trigger @ 40 MHz
  - full hit data to HLT @ 0.5-1 MHz




~7100 PS-modules




~8400 2S-modules




Per-module per-event stub rates for the default CMSSW_6_2_0_SLHC12 software release.

There are no cuts on stubs/ ASIC, or stubs/ concentrator, etc.

The data sample is 250 events with <PileUp>=140.

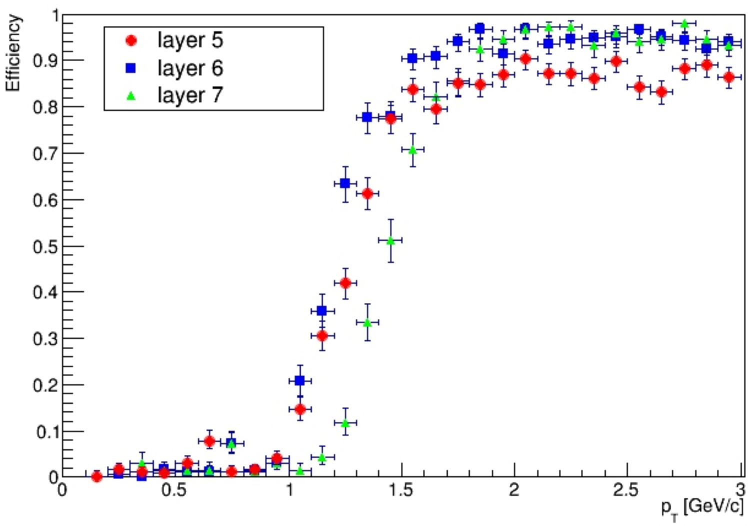
T James, C Laner

# High pileup simulations

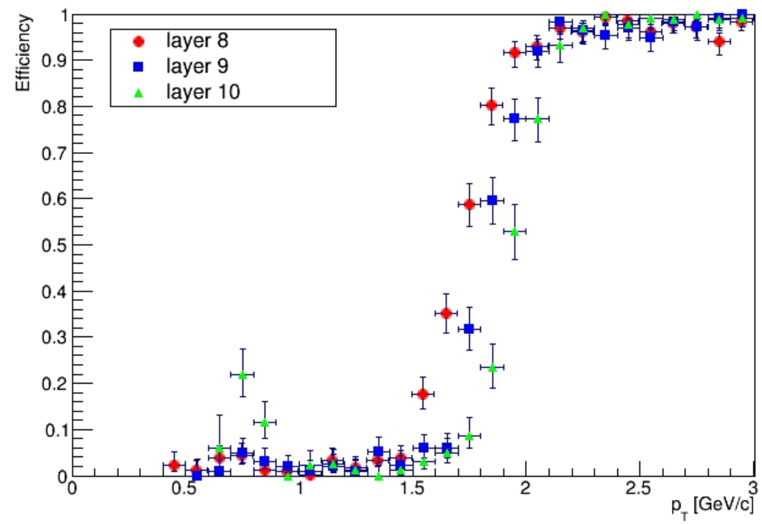
## Barrel Efficiency at Low $P_T$, Separated by Barrel Layer

*Efficiency =2*number of accepted stubs/total number of clusters*

**PS Modules**




**2S modules**




- Low Efficiency in layer 5 as high $\eta$ coverage brings total efficiency down
- Turn on curve between 1 and 2 GeV/c in PS and between 1.5 and 2.5 GeV/c in 2S

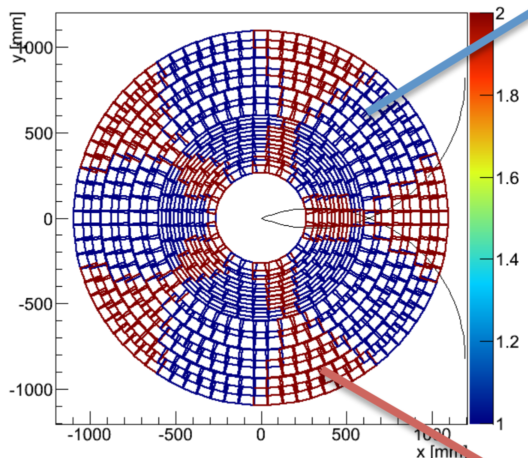
*Data Set: 10,000 muon + antimuon particlegun events, random $P_T$ 0-3 GeV/c*

Above 3 GeV – Efficiency constant

# What are advantages of TMT?

- “All” the data arrive at a single place for processing
  - in ideal case avoids boundaries and sharing between processors
  - however, does not preclude sub-division of detector into regions
    - which may be essential for a large data source like a tracker
- Architecture is naturally matched to FPGA processing
  - parallel streams with pipelined steps at data link speed
- Single type of processor, possibly for both layers
  - L1 = PP: Pre-Processor  L2 = MP: Main Processor
- One or two nodes can validate an entire trigger
  - spare nodes can be used for redundancy, or algorithm development
- Many conventional algorithms explode in a large FPGA
  - timing constraints or routing congestion for 2D algorithms
- Synchronisation is required only in a single node
  - not across entire trigger

M Pesaresi, A. Rose,
G. Hall, D. Newbold




## from non-shared modules

68 FE links
3.2Gbps per link

4 bidirectional DAQ links
10Gbps per link


to one TR

24 TRG links
10Gbps per link

## from shared (boundary) modules

68 FE links
3.2Gbps per link

4 bidirectional DAQ links
10Gbps per link

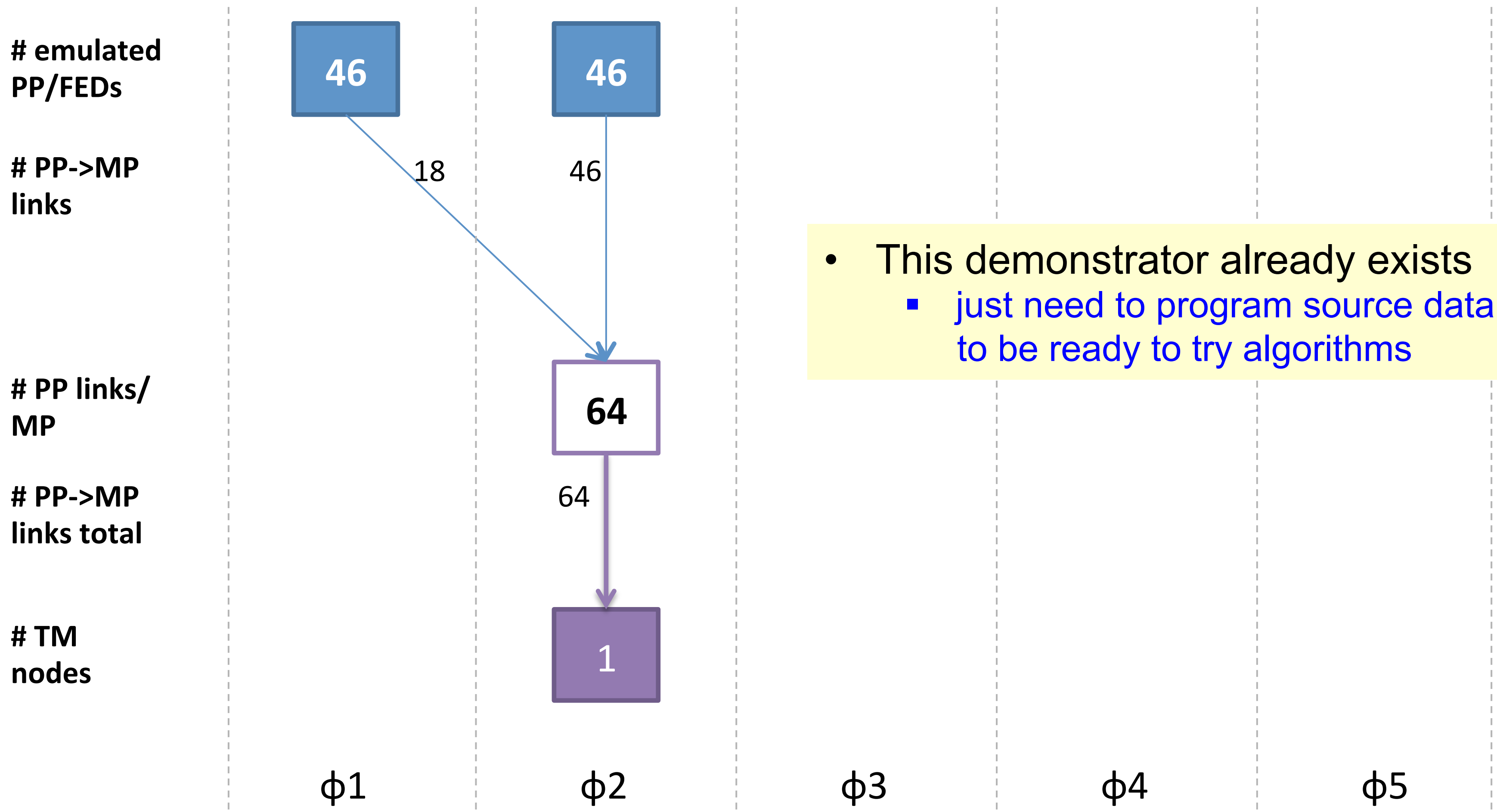

to two TRs - 24 TRG links to each

48 TRG links
10Gbps per link

4 DAQ links per PP/FED allows a maximum bandwidth of 40Gbps (~588Mbps available per tracker module)

# even simpler demonstrator

**2 MP7s emulate event data from 1 out of 5 regions, one out of every 24BX**




- This demonstrator already exists
    - just need to program source data to be ready to try algorithms

# Finances

- Expenditure
  - WP2: FC7
    - further CBC manufacture not imminent
  - WP3: MP7 orders and optical components
  - Total: ~£58k at Imperial
- Significant purchases via CERN
  - invoiced in current FY, or orders yet to be completed
  - ~£28k (FC7) + £294k (WP3)
    - *£187k MP7 orders, plus FPGAs, optical components and other assembly, components*
- Solutions found to place orders in multiple locations from central grant
  - but leads to several complications
  - further CERN orders will not use SBS but be paid direct to CERN from Imperial
- Reporting in new financial table format
  - how to include CG grant spending?

# Conclusions

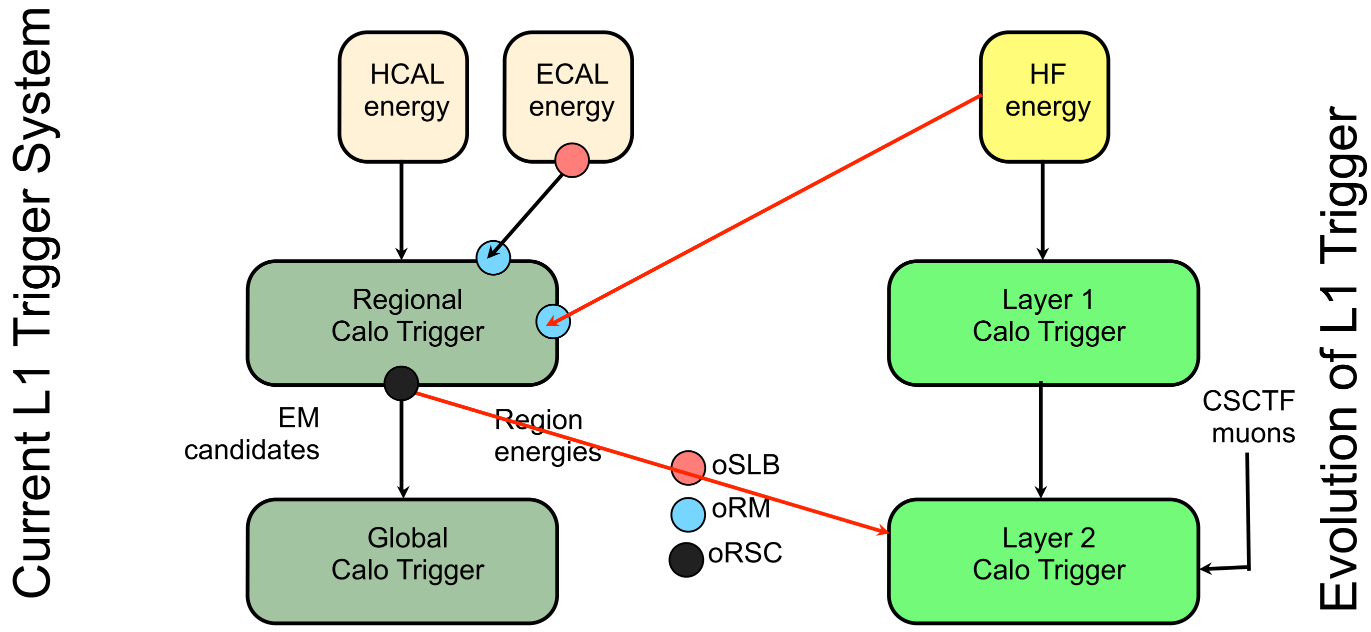
- Trigger project entering the assembly phase
  - main questions concern US deliverables
  - otherwise continued good progress with UK parts

- Revision of milestones
  - done for trigger but not WP2
  - should be clearer by next OSC

# Further information

# Intermediate trigger - 2015

- Limited to use current RCT and current GT




- Significant performance improvements possible in eγ, τ and jets
- Prototype processor cards and (new) oRSC cards to duplicate signals
- Retains data to legacy GCT for easy rollback with just reconfiguration