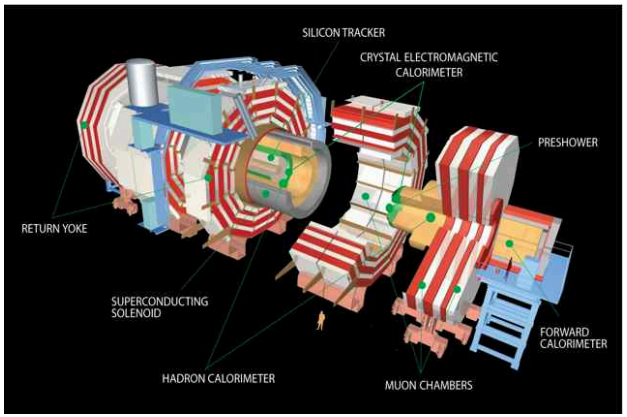
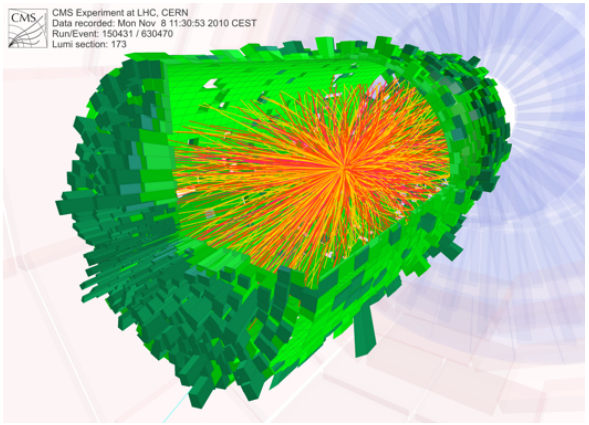




UK CMS Upgrade Oversight Committee

2 March 2011

University of Bristol
Brunel University
Imperial College London
Rutherford Appleton Laboratory

Geoff Hall

Overview

- CMS status
- LHC status and future plans
- UK R&D progress report
- Finances
- Future
  - CMS plans
  - UK CMS plans
- Issues

The scientific production of CMS

It starts to be **sizeable**:

CMS	**56** papers +**9** publication drafts
ATLAS	26 papers+ 9 publication drafts
ALICE	15 papers
LHCb	2 papers+ 3 publication drafts

It is **excellent** in terms of completeness and quality: best limits, new measurements, observation of new effects etc

G. TONELLI, CERN/INFN/UNIPISA CERN_CB74 11 February 2011 10

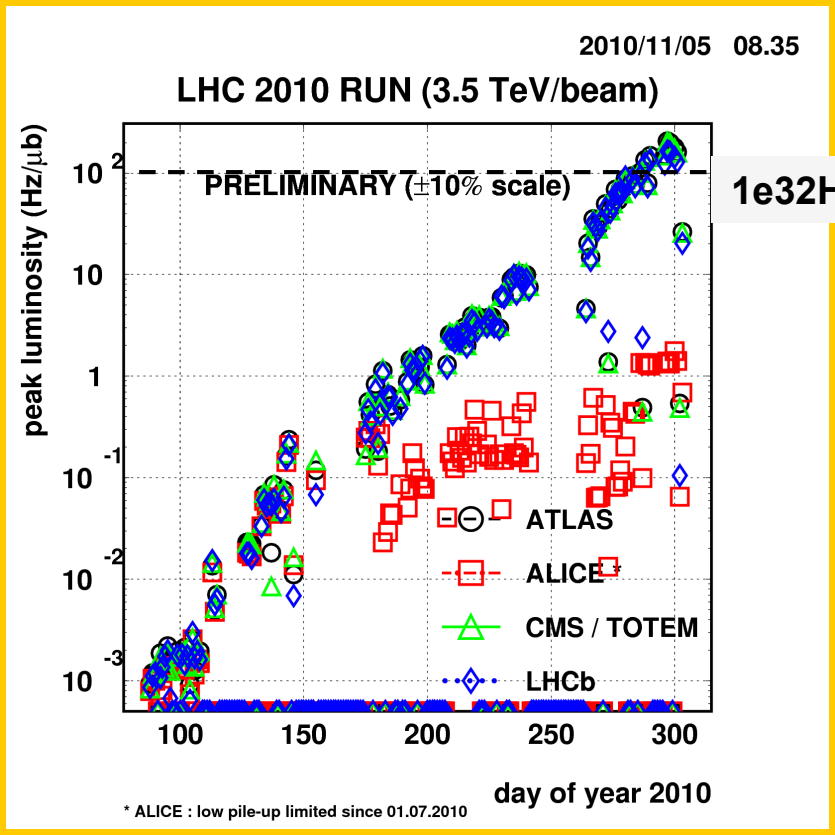
CMS status

- 2010 was a **very** successful year for CMS and LHC: $43 pb^{-1}$ pp
  - + $8.3\ \mu b^{-1}$ Pb-Pb
  - extremely promising couple of years (and more) ahead
- LHC in Technical Stop to 18 February
  - now preparing for beams – cosmic tests and mid-week global runs
  - stable beams now expected by 4-5 March
  - expect gradual start followed by rapid increase in bunches & luminosity
- CMS undertook maintenance interventions
  - went almost completely according to plan
  - interventions increased fluid leak rate in Tracker in one line
    - believed to be related to pressure changes, to be controlled better in future

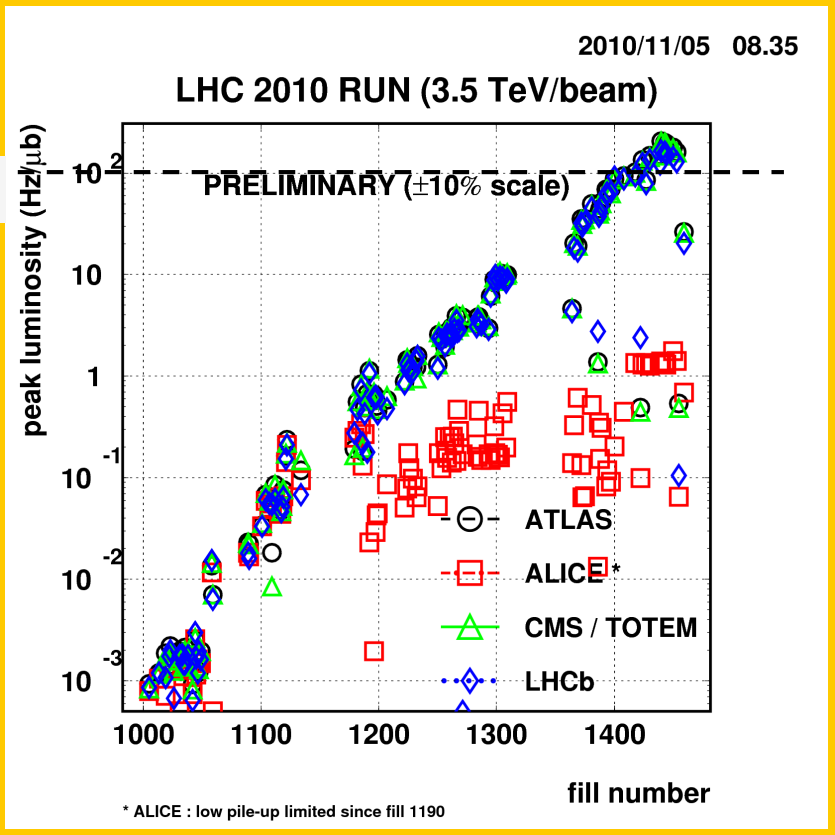
- In 2012 LHC will be operational
  - Two ~continuous years of **all** systems working efficiently
  - Slip of later schedule (tbc)

2010 peak luminosity (protons)

M F-L Chamonix report

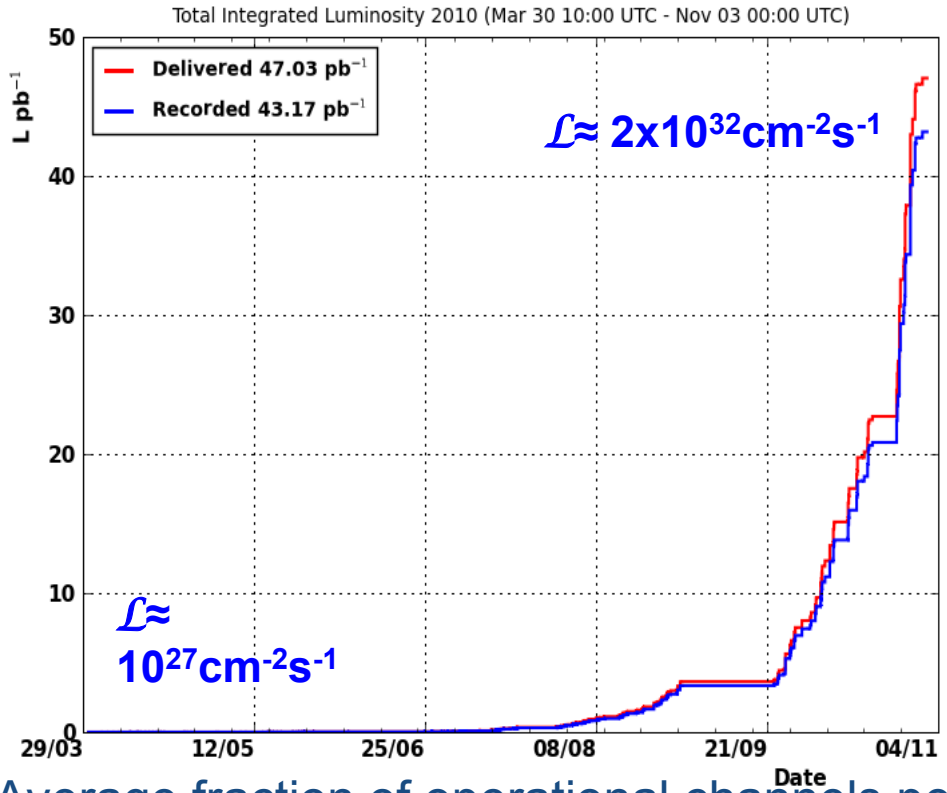


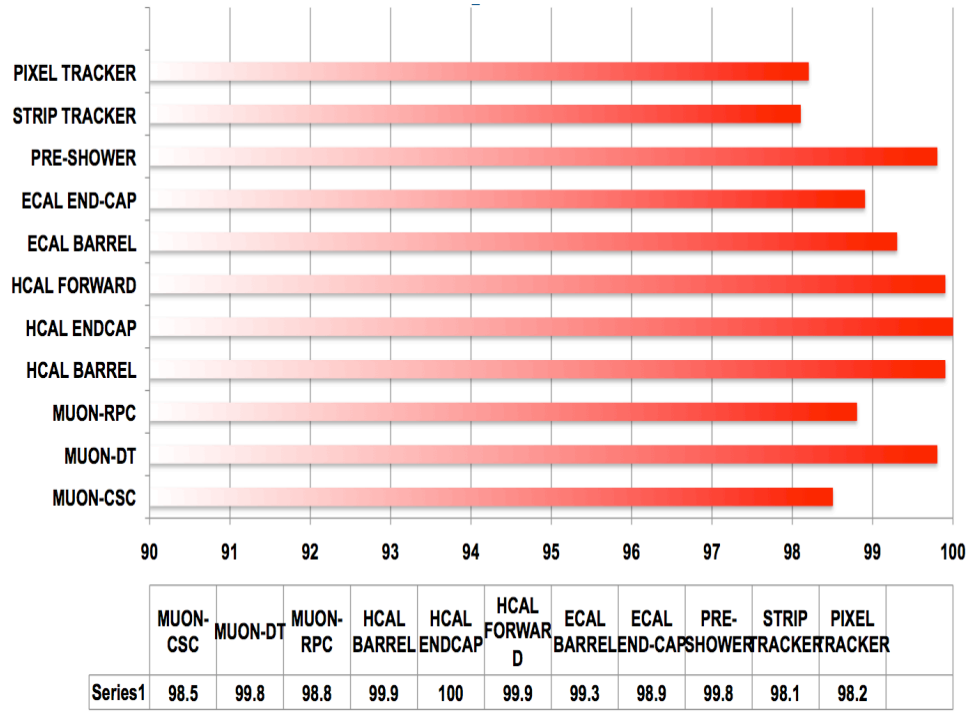
1e32Hz/cm²



LHC and CMS operations in pp.

About **47pb^{-1}** delivered by LHC and **~43pb^{-1}** of data collected by CMS. Overall data taking efficiency **~92%. 6pb^{-1}** of data integrated in a good fill**.** Excellent performance in coping with more than 5 order of magnitude increase in instantaneous luminosity.

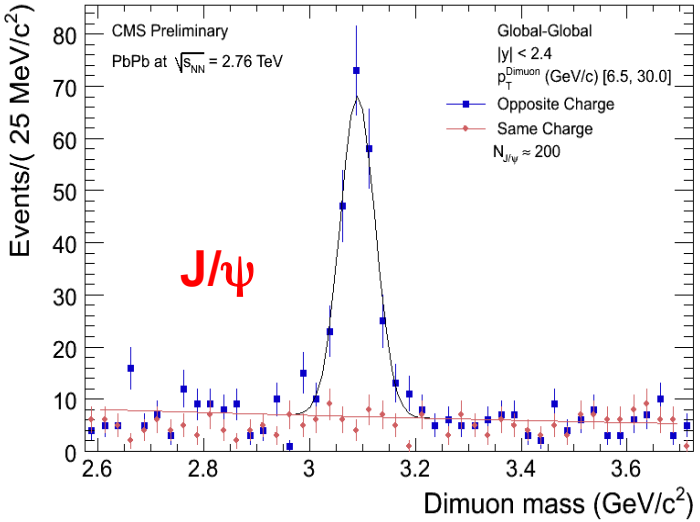


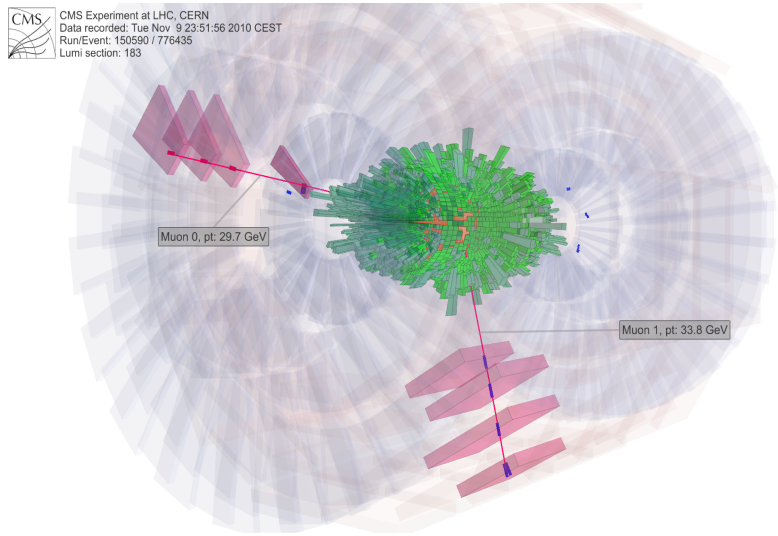


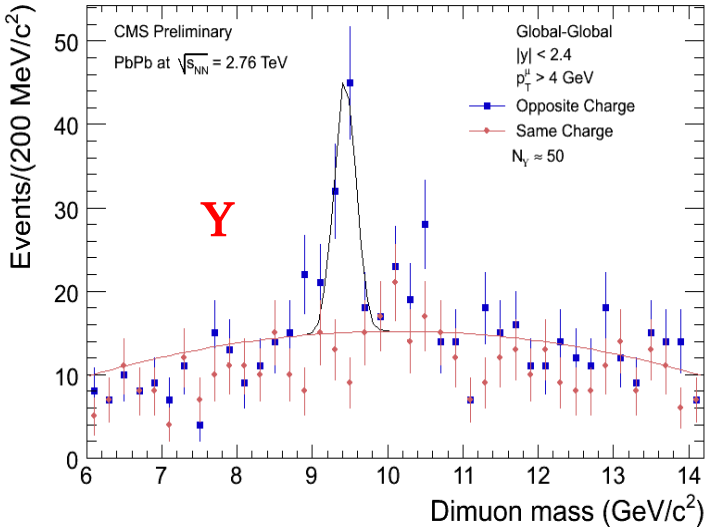
	MUON-CSC	MUON-DT	MUON-RPC	HCAL BARREL	HCAL ENDCAP	HCAL FORWARD	ECAL BARREL	ECAL END-CAP	PRE-SHOWER	STRIP TRACKER	PIXEL TRACKER
Series1	98.5	99.8	98.8	99.9	100	99.9	99.3	98.9	99.8	98.1	98.2

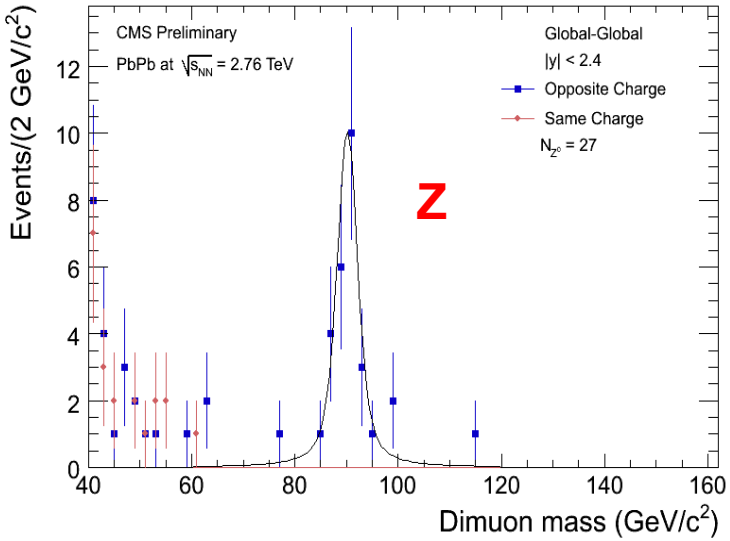
Average fraction of operational channels per CMS sub-system still **~99%. A few problems here and there.** Last few days of pp running tested **50ns** filling scheme. Vacuum (e-cloud) worse than at 150ns. **75ns** vacuum much better. **800 bunches OK.**

First CMS results in HI: Z and di-muons.





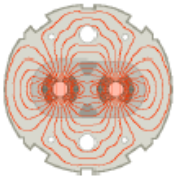


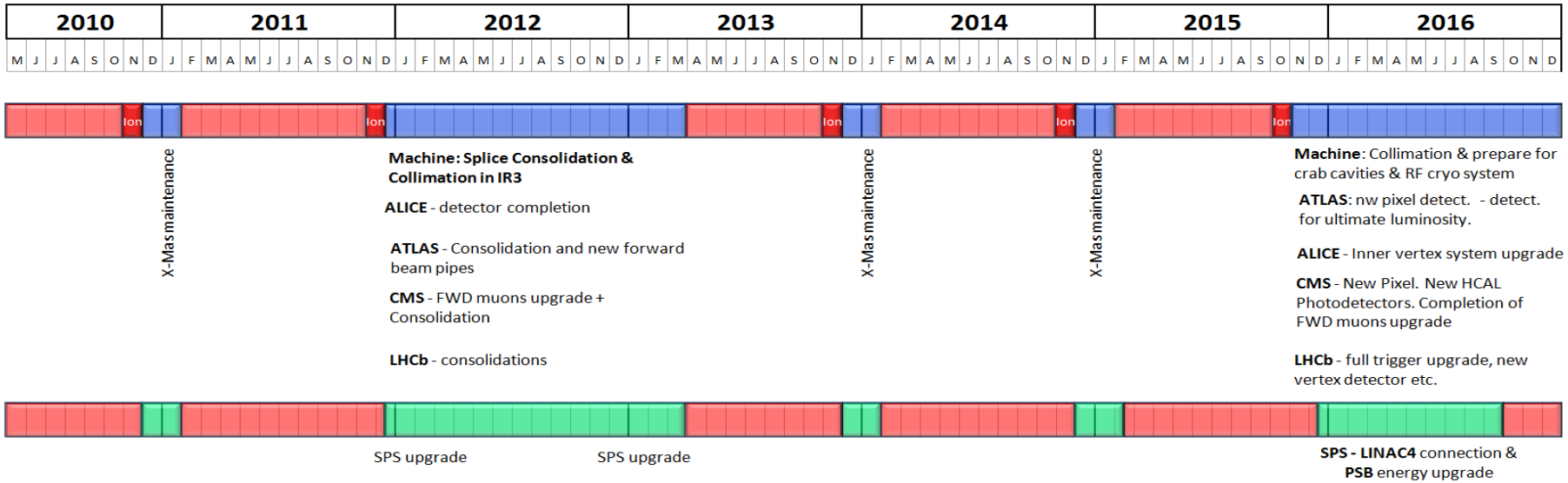


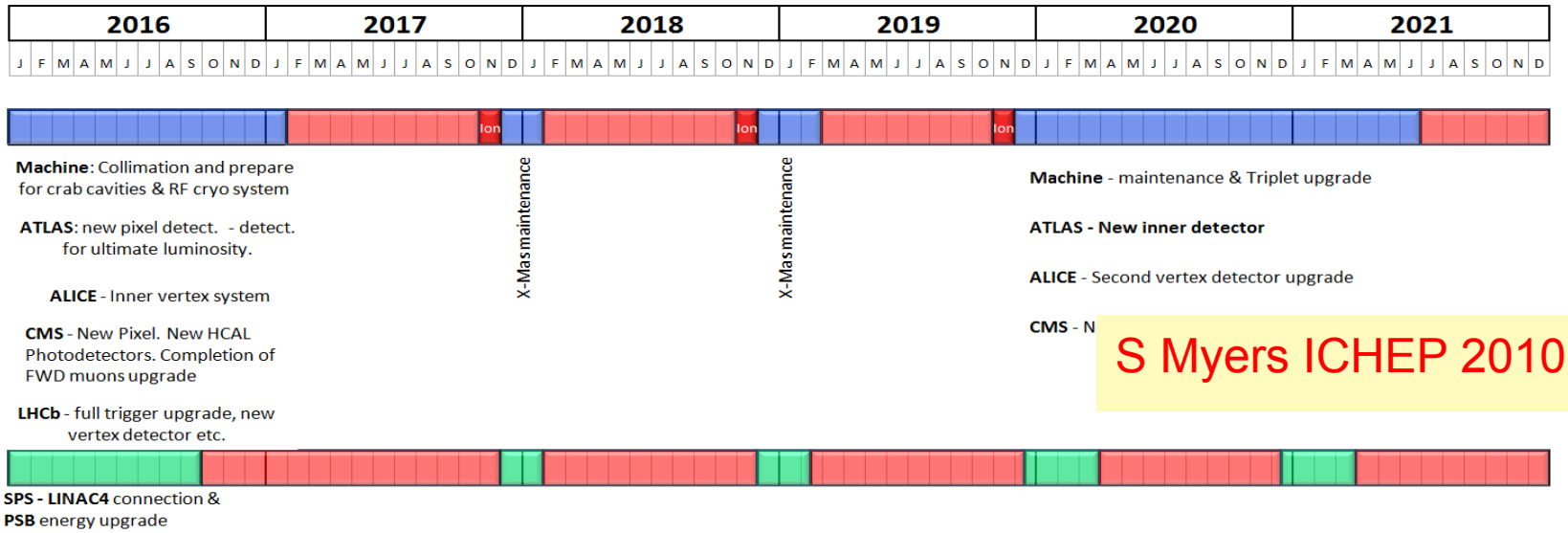
First observation of Z bosons produced in HI collisions and very good chance to study in detail suppression mechanisms of quarkonia in HI collisions.

July 2010

The 10 year technical Plan







S Myers ICHEP 2010

LHC status and future plans

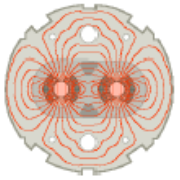
- Reached L = 2 x 10^{32} $cm^{-2}s^{-1}$ at end 2010

- Increase to ~10^{33} $cm^{-2}s^{-1}$ during 2011 remaining at 3.5 + 3.5 TeV
  - 1 fb^{-1} by end 2011 (expectation management)
  - conditions for 2012 not yet defined
  - after 2012, dates uncertain until new 10-year plan defined

- 2013-14: Shutdown for at least 19 months for splices and maintenance

- Beyond this point, ~ one year delay on previous dates seems likely

Decisions from Chamonix



1) LHC will run at 3.5 TeV per beam in 2011

2) Interbunch-spacing in 2011 will be ≤ 75ns

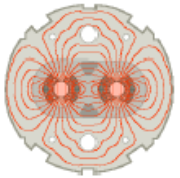
- We'll run very likely at 75ns with scrubbing done at 50ns. **If the scrubbing will work very well we will try to run at 50ns.**

3) The baseline beam parameters in 2011

- 1.2x10exp11 p/bunch; beta* 1.5m; emittance 2.5microns
- With 900 bunches, this will allow us to exceed 10E33.
- The plan is to reach this peak luminosity sometime in May. We might have 0.5-1fb^{-1} of data before the summer conferences.

Summary from G Tonelli

Decisions from Chamonix



4) Goals

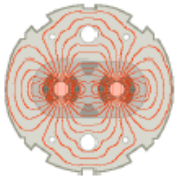
- **a) the official goal for 2011 will stay at 1fb^{-1}**
- **b) internal un-official goal – try to gain factors on this**
- To be explored:
- a) increase the number of days for physics (135/264)
- b) increase of the bunch population 1.4-1.5 E11
- c) reduce beta* to 1.2m
- d) reduce emittance to below 2microns.
- e) increase number of bunches to 1404 if 50ns is feasible.

5) 2012 will be a year of physics

- **Goals for 2012 depend strongly on 2011 performance but target of >10fb^{-1} is considered realistic.**

Summary from G Tonelli

Decisions from Chamonix

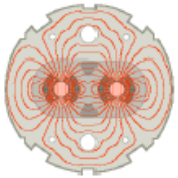


6) There will be a serious impact on our plans for the Upgrade both for LS1 and LS2.

- the first long shutdown (LS1) will be postponed to 2013. The length of the 2013 shutdown will be very likely more than a year. A very complex series of activities must be accommodated.
- There are different scenarios leading to an interval that could exceed 2 years (physics to physics). A review of planning to be made before June.
- There will be an impact also on the subsequent long shutdown (LS2) that will likely slip.
- Proposal: keep the Technical Proposal for the Upgrade as it is.
- Evaluate a few urgent actions: procurement of a new beam-pipe for LS1.
- Re-discuss the timing of pixel project, HBSiPMs and trigger.
- Prepare a new plan compatible with a new schedule for LS1/LS2.

Summary from G Tonelli

Decisions from Chamonix



7)HI-LHC ≥2020+

with the new operational/measured parameters of LHC the perspectives of delivering more than 300fb^{-1}/year sometime after 2020 seem to be more realistic: there was quite some optimism in the performance of HI-LHC.

8) Heavy- Ion runs

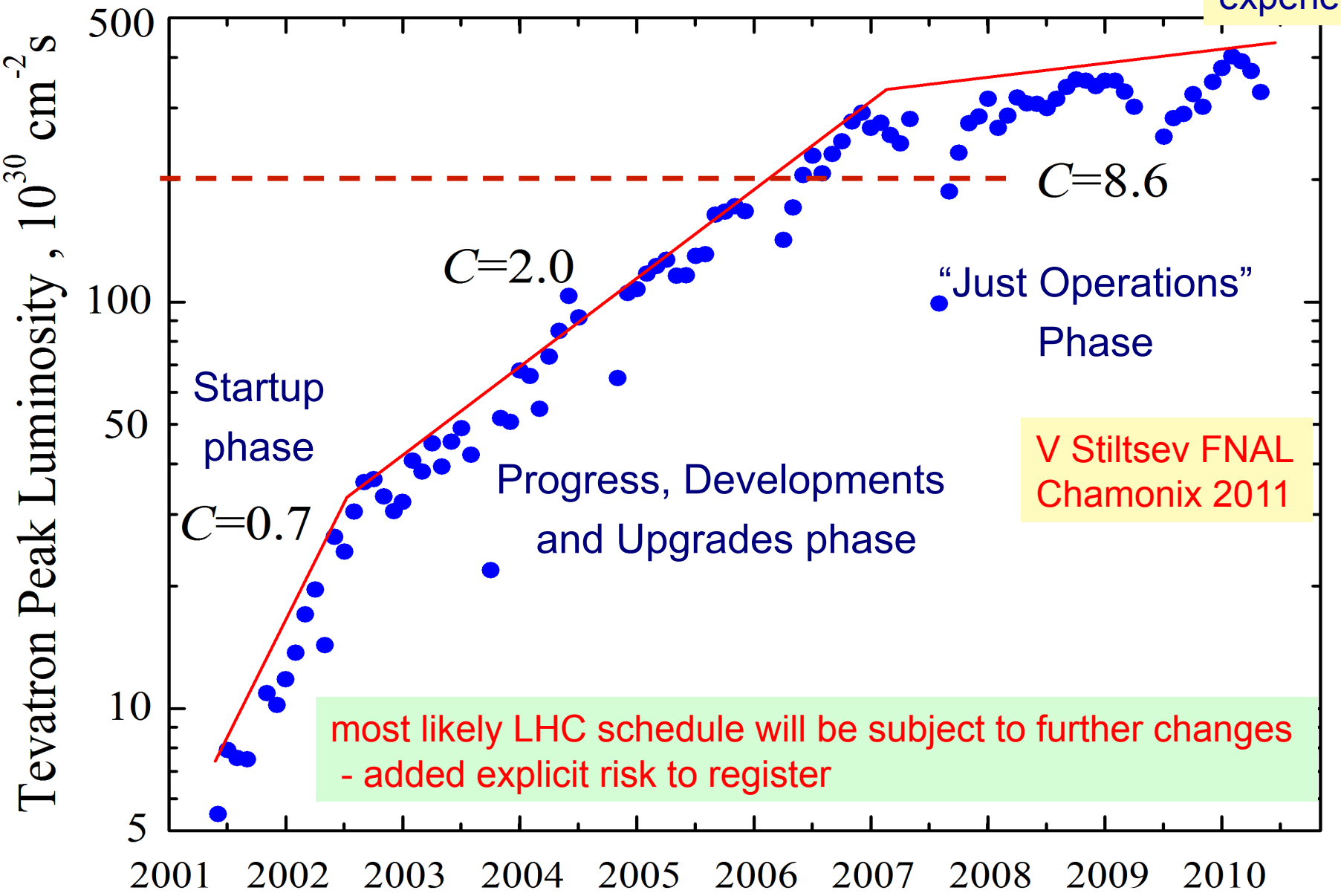
2011 a factor 3-5 more integrated luminosity (but could be higher)

2012 feasibility study for p-PB collisions (very challenging)

Summary from G Tonelli

Tevatron Run II

comparison with experience



UK & CMS upgrade progress

- WP1
  - much progress with WP3 on online software for trigger
  - simulations for Phase I pixel and physics studies underway
- WP2
  - 3-4 months delay in CBC delivery to Imperial – but now under test
  - successful beam tests, which prepared telescope for future measurements
- WP3
  - minor revisions of Mini-T5 prior to larger scale tests
  - good progress with algorithms and software infrastructure

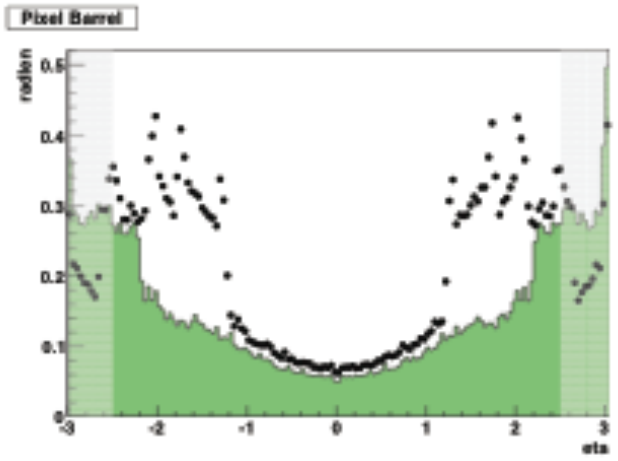
- CMS Technical Proposal submitted to LHCC
  - physics case needs more simulation support

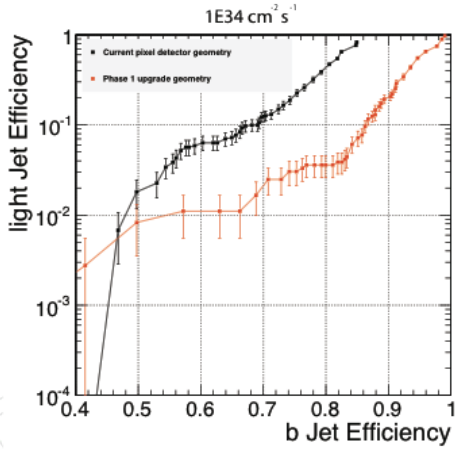
WP1 Status

- Project goals
  - Simulation / optimisation of upgraded tracker & trigger
  - Physics simulations of upgraded detector
  - Online & offline software / firmware for upgraded Phase-I electronics
- Highlights in the last months:
  - Upgrade Technical Proposal simulations
  - Release of online software & firmware framework
  - Plan for upgrade software convergence
  - Layout study contributions
  - Recent start of pixel readout
- Upcoming activities
  - Support / evolution of online framework
  - Detailed physics studies beyond TP
  - Detailed physics case for Phase-I trigger upgrade

Highlight: Upgrade TP

- Phase-I Upgrade Technical Proposal
  - Submitted to LHCC November 2010; incisive + helpful feedback received
  - Physics performance studied in progress (addendum due March 2011)
- UK WP1 contributions (summary of two years' work)
  - Development of flexible tracker software framework [Reid, Grimes]
  - Performance studies of four-layer tracking [Grimes, Goldstein]
  - Definition of physics case and exemplar channels [Newbold]
  - Proposal for trigger online software [Rose, Frazier, Newbold]
  - Integration of upgrade software releases [Newbold]



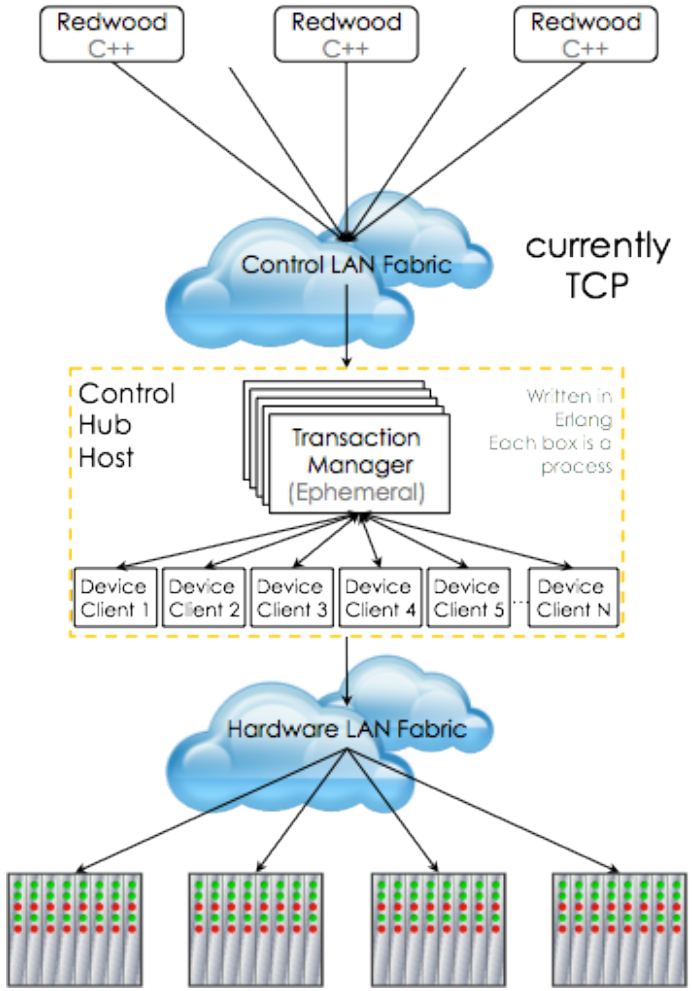


Pixel upgrade performance:
a) Material budget (old vs new)
b) b-tag performance (old vs new)

Highlight: Trigger Software / Firmware

- Firmware is intrinsically hierarchical
- Would like some way of treating software similarly

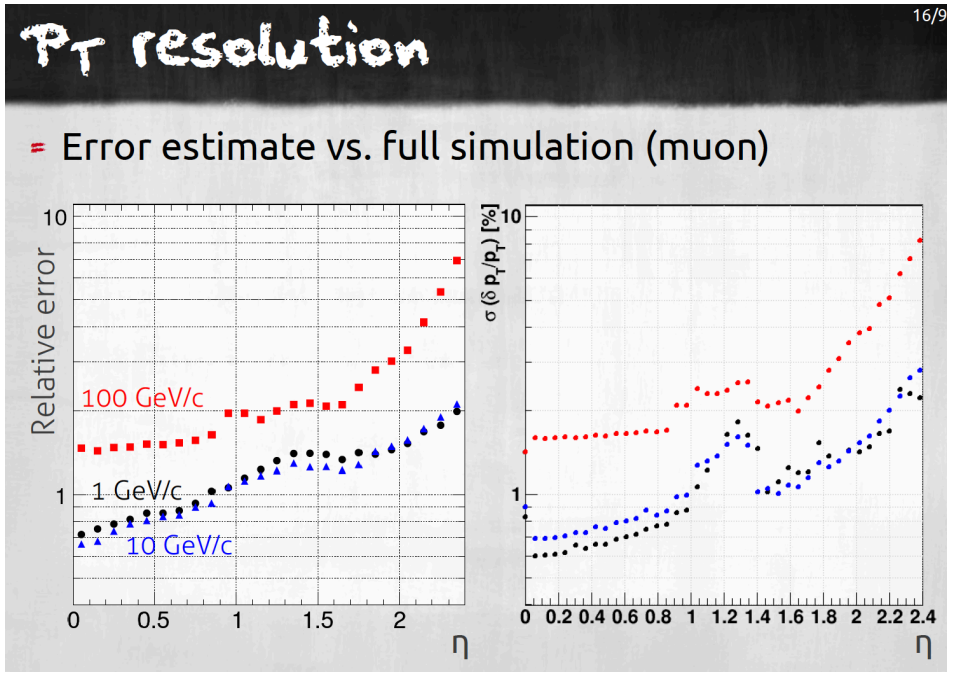
Firmware module/ component/ subsystem	=	XML description	=	Redwood branch
which is constructed from lower level modules down to registers		which references other XML files and module definitions down to the register description		which is a container for child branches and leaves, which represent registers on the bus
VHDL/verilog		XML		Object-Oriented C++



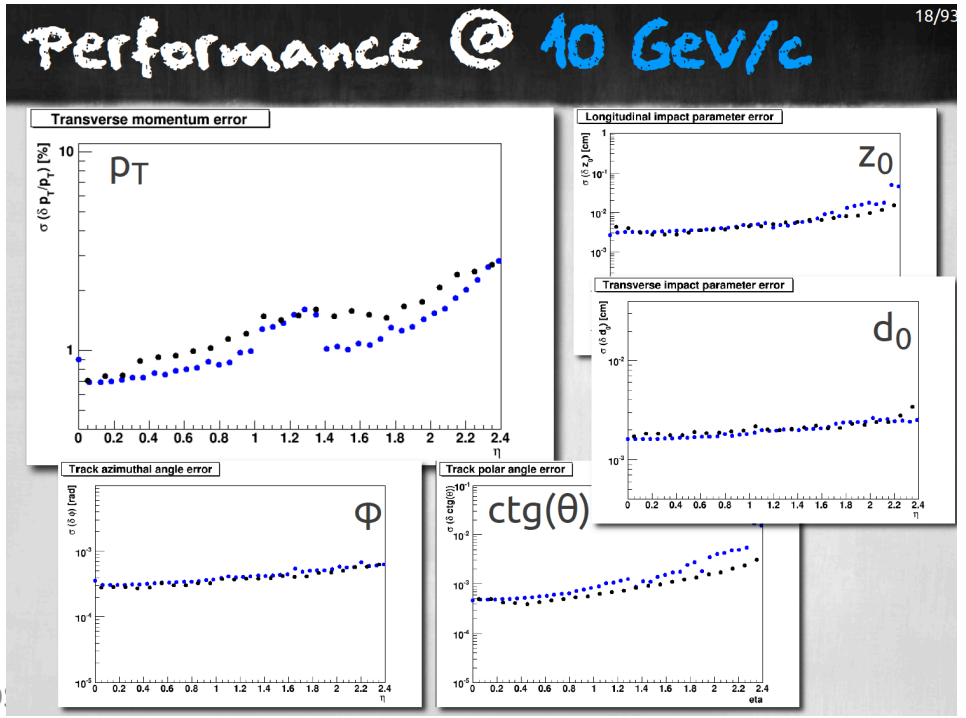
- Coherent online software / firmware
  - [Rose, Frazier, Newbold, Brooke]
  - Covers Phase-I trigger, but potentially all uTCA developments
  - Reduces effort for online components substantially w.r.t. existing CMS system
  - First formal release made Feb 2011
    - Being evaluated by external CMS groups

WP1 related - Tracker layout studies

- Tool developed over last 1-2 years (S Mersi et al, CERN) to compare layouts
  - super-fast, but realistic, modelling of different layout alternatives
  - supplemented by calculations predicting detector resolution (G Hall)
  - full physics studies are only feasible for optimising one chosen design
    - so comparative layout evaluations are vital for selecting practical optimum



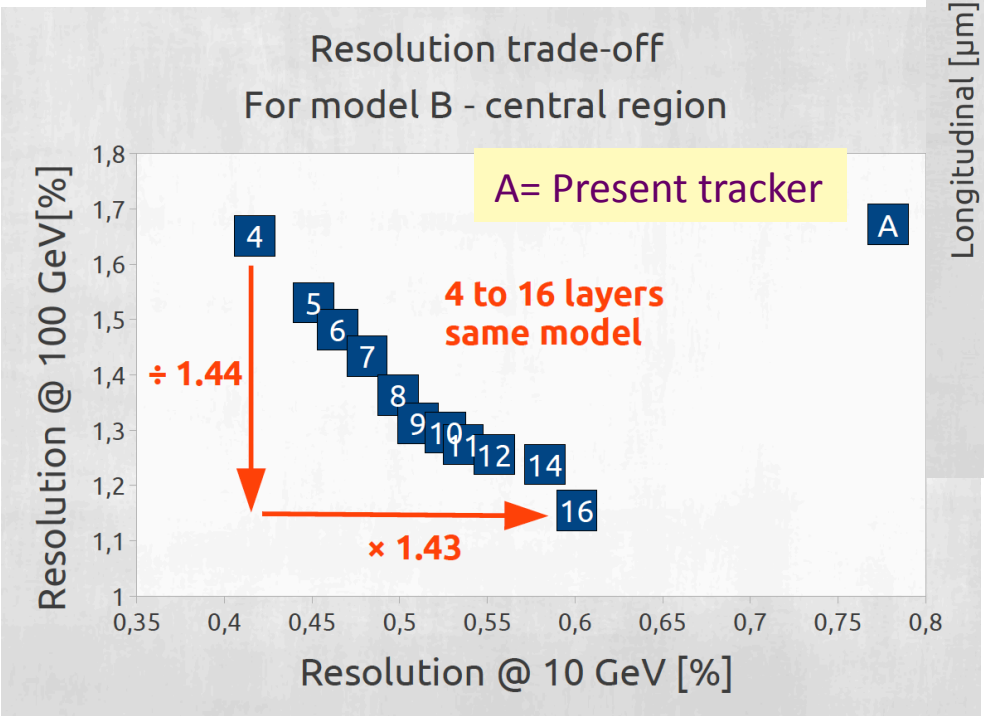
Example results for present Tracker – demonstrating level of accuracy

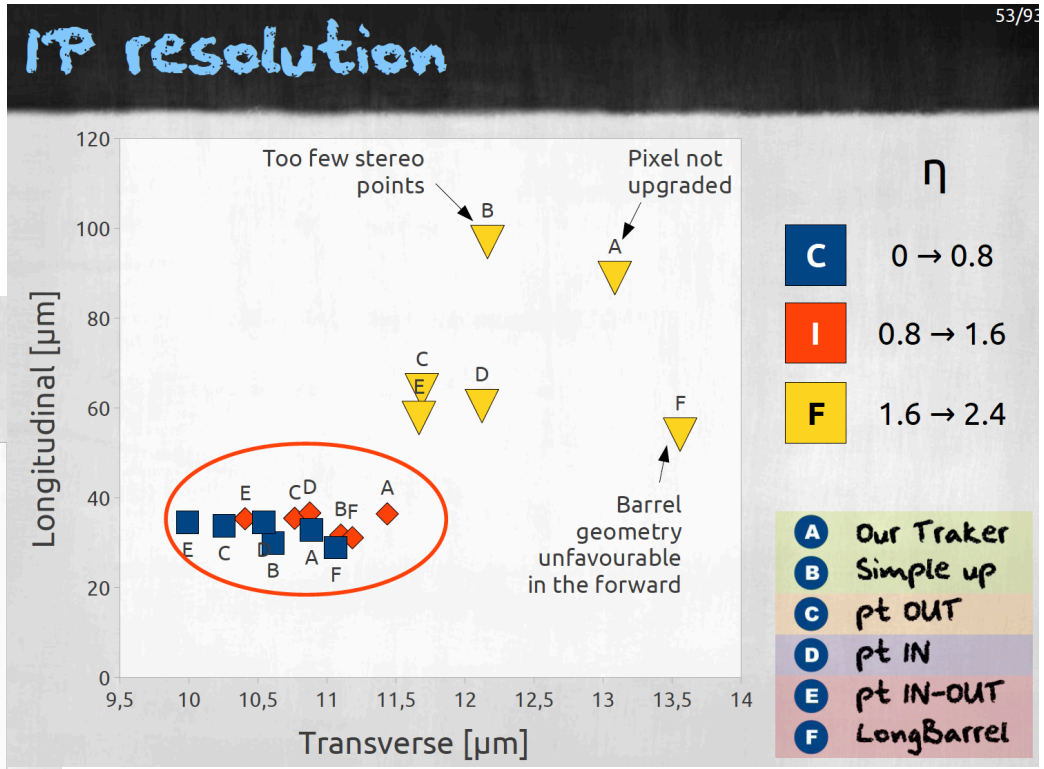


Tracker layout comparisons

- Examples of comparisons of possible future layouts (S Mersi, CERN)
  - key point was to model multiple scattering correctly (and future material budget!)

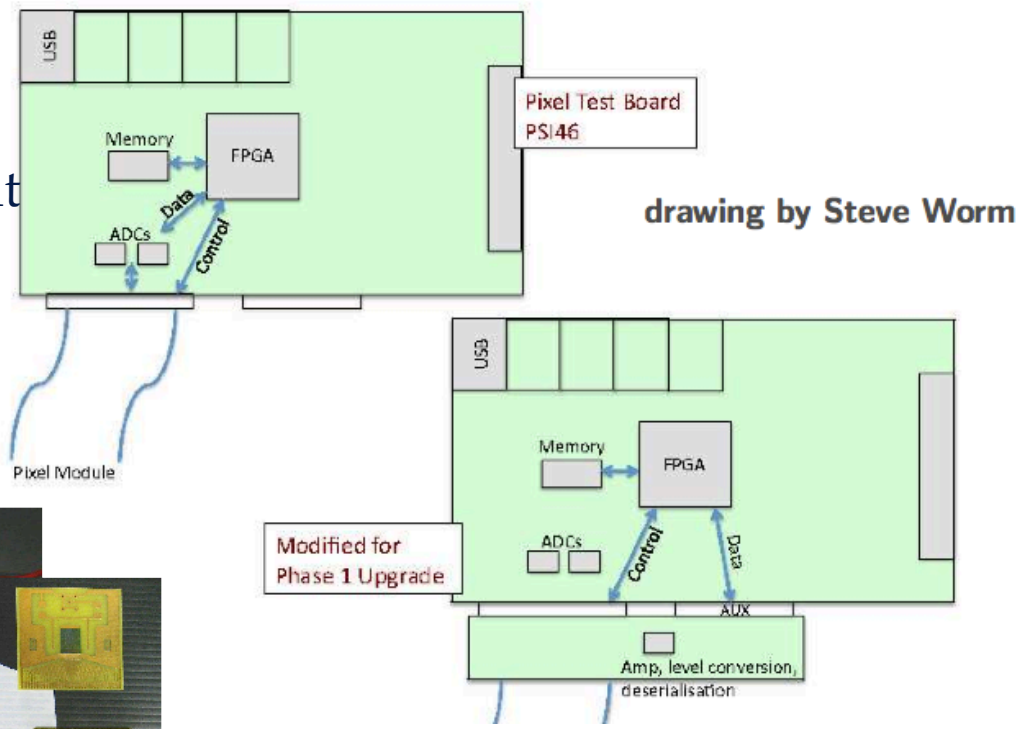
allow to understand layout impact on power (in detail), channel count, no. layers, material, angular, impact parameter and momentum resolution, impact of trigger layers,…

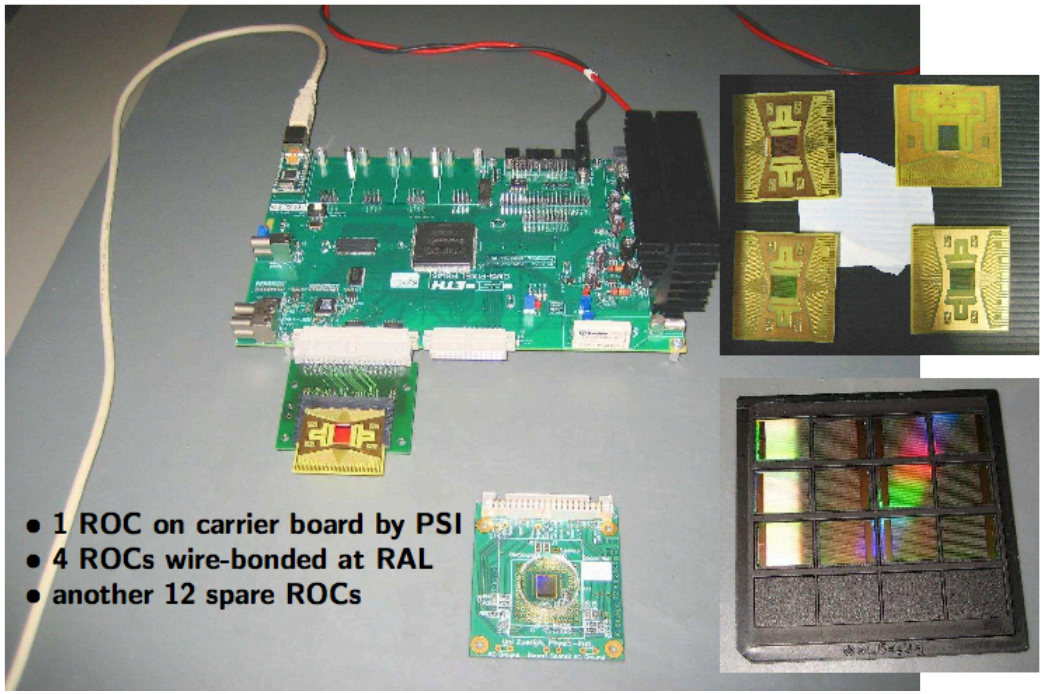




New activity: Pixel Readout

- Work recently begun
  - [Harder, Durkin, Worm]
  - Possible route to role in pixel readout
  - Not envisaged in WP1 proposal
    - doesn't yet have plan or deliverables
    - funding: staff only at present





Whither WP1?

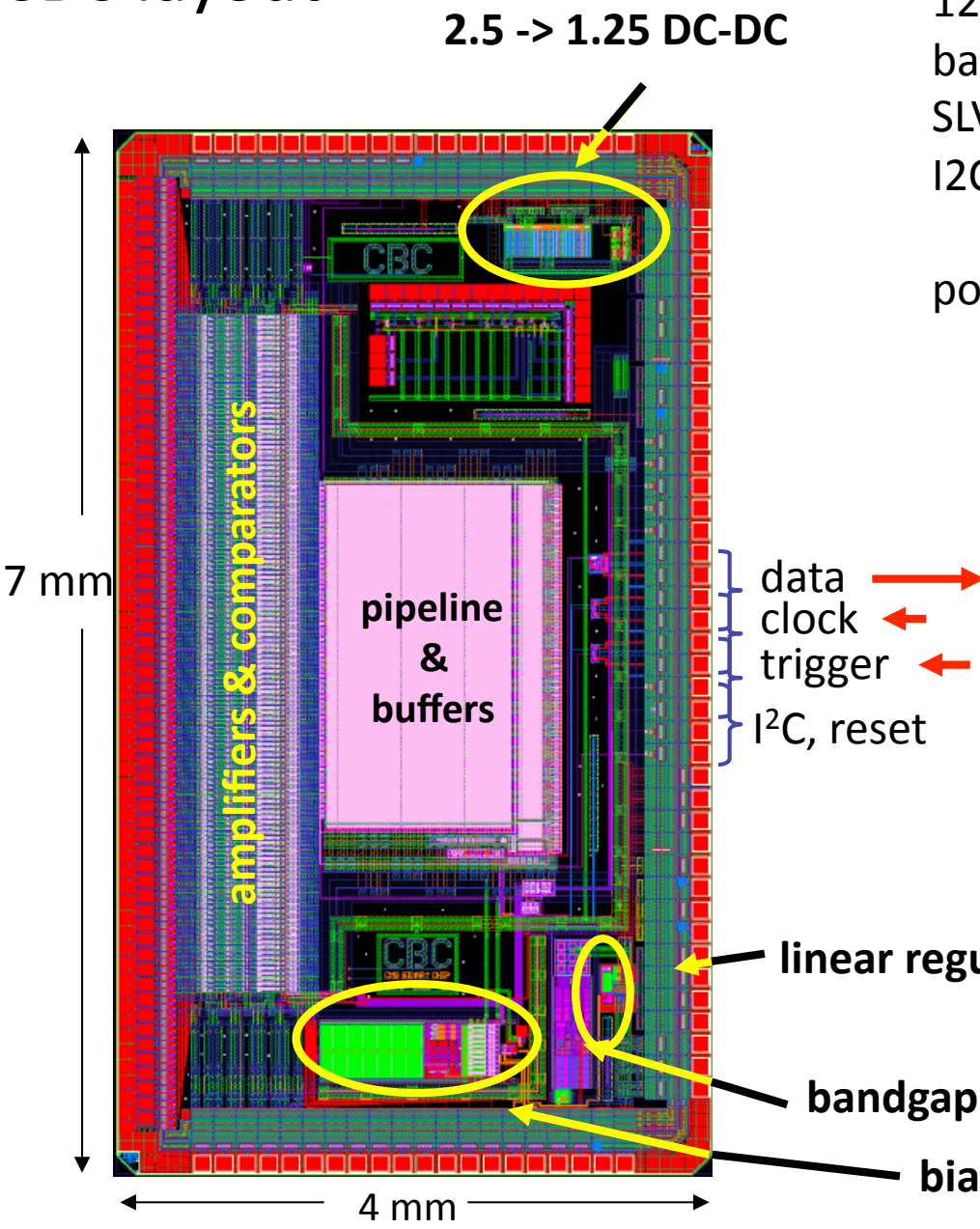
- Current situation
  - Project has *coherently* shifted / grown in scope
    - A reflection of evolving goals of the overall CMS project
    - Close links developed to WP2 & WP3 work
  - Current manpower funding formally ends in Q4 2011
  - We have taken responsibility for deliverables to CMS
    - Online software / firmware; upgrade offline software
- Forward look
  - We believe WP1 activities are timely, relevant, highly visible in CMS
  - Current funding can be stretched until Q1 2012
    - If sufficient flexibility is allowed by STFC
  - Need to re-synchronise WP1 with project
    - ends early but work is needed
  - Review project structure – WP1 has added a new activity
    - not a natural place, and not yet funded

WP2

- ASIC (CBC) development (M Raymond, L Jones)
  - CBC submitted on MPW early July
    - Expected back end October
  - Unexpected high volume of business at foundry, which delayed this run
  - Cutting of wafers in January, die arrived 12 February, tests began 15 Feb
- Beam telescope for module tests (M Raymond, M Pesaresi, J Fulcher, W Ferguson, G Hall, O Zorba)
  - commissioned in UA9 crystal channeling studies for LHC collimation
- Future FED development (J Coughlan, M Siyad)
  - initial evaluation of GBT firmware

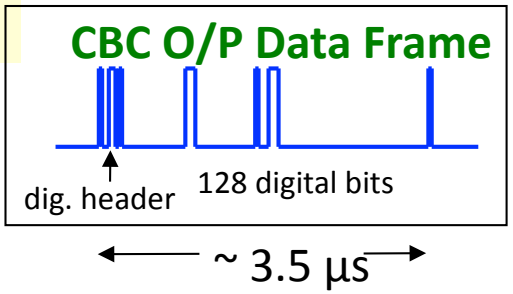
- Module and system development
  - Collaboration with other CMS institutes, especially CERN, ongoing
  - Decisions following CBC tests on priorities for next steps

CBC layout

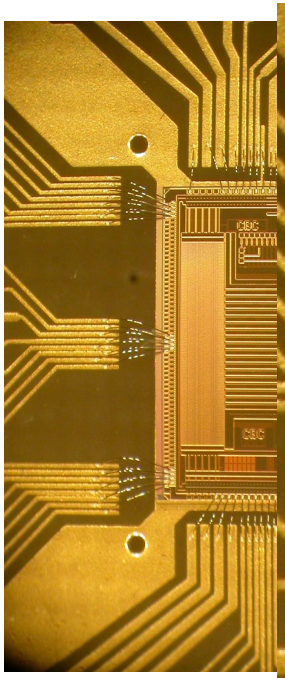


128 inputs, 50 mm pitch
back edge pads mostly power
SLVS data out, clock and trigger in
I2C slow control

power features included
- DC-DC switched capacitor (CERN)
- low dropout linear regulator
  - uses CERN bandgap for reference



setup

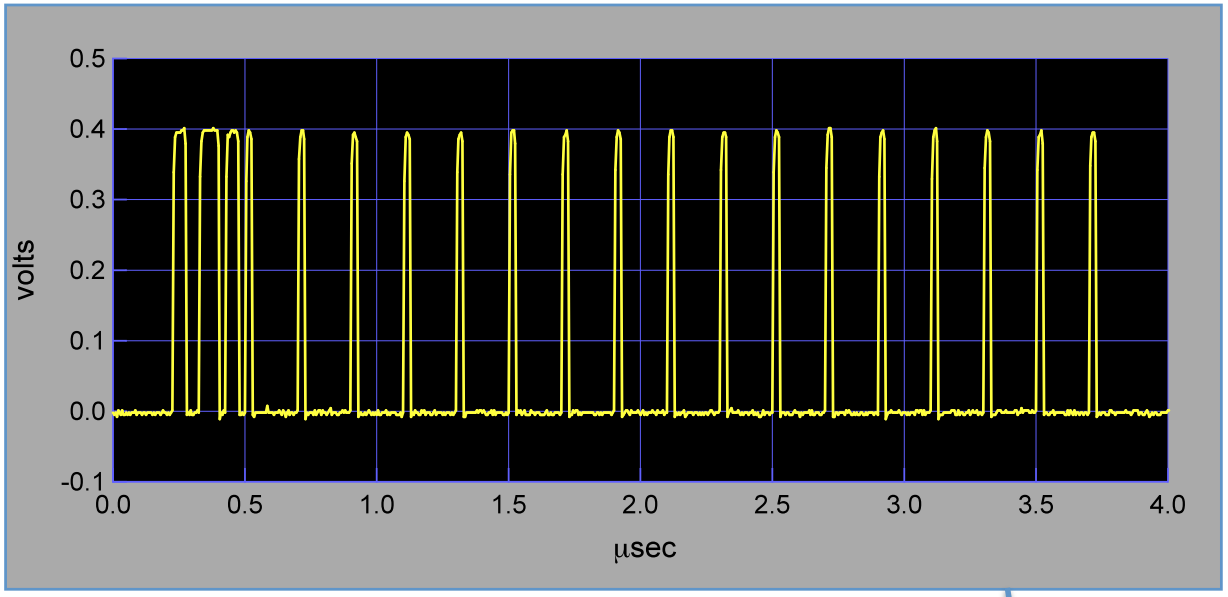


test
charge
injection

ow control
ut interface

CBC testing status (M Raymond)

- early results promising
  - ~ 7 days testing so far
- fast & slow interfaces
  - fully functional
- power consumption low
  - < 500 mW / channel target
- can inject signals and see output data
  - detailed study not yet begun but results seem close to expectations
    - signal amplitude, noise
- some issues with bias generator can be fixed with simple workarounds
  - will not affect test programme
- yield probably high
  - no failures from 6 plugged in so far
- many months testing expected…



scope picture of digital header followed by "hits" produced by test pulse input feeding every 8th channel

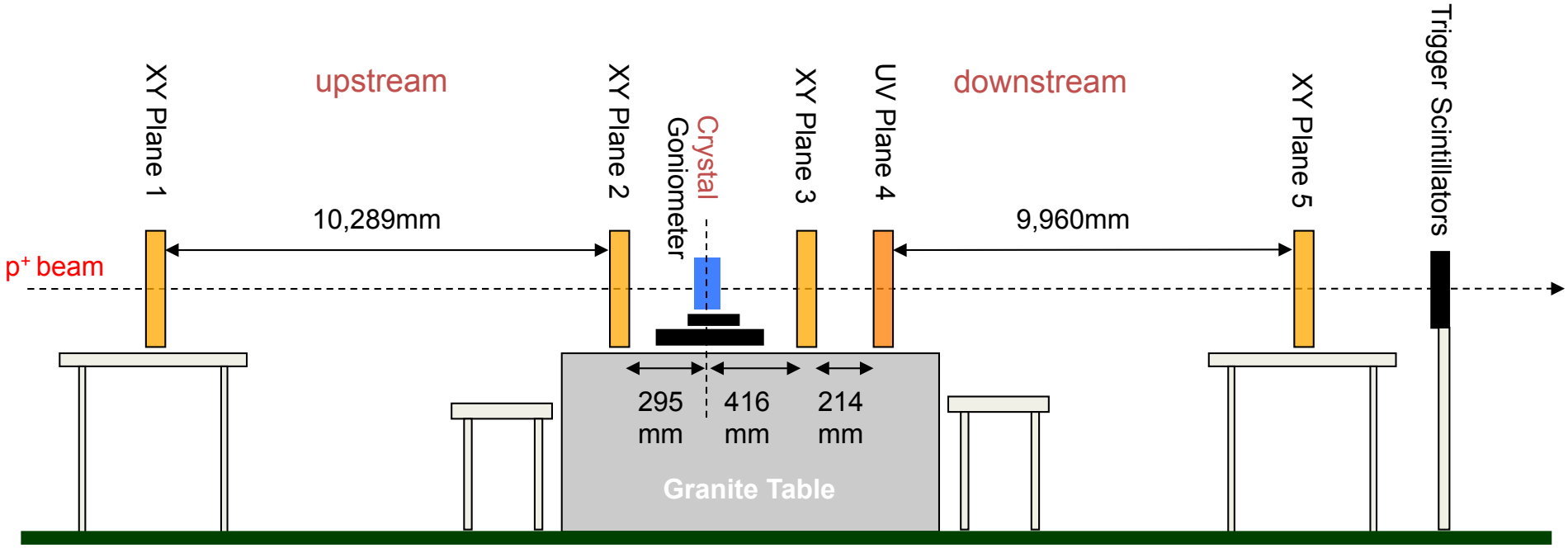
CBC plans

- Evaluation studies - ~1 year
  - laboratory tests
  - module development – CERN + CMS collaboration
  - beam tests – requires module and new DAQ (APVe)
  - SEU studies

- CBC design options – two major lines
  - C4 (coarse pitch, low cost) bump bonded variant
    - collaboration with CERN and others
  - CBC + cluster finding, trigger logic
    - double-layer, pT selection module
    - collaboration with Lyon, CERN
  - aim for submissions at end 2011

Beam telescope

- Constructed in preparation for future module tests
  - benefits from CMS Tracker DAQ hardware, software – and expertise
    - FED, APV25s, 100m fibres, custom control system, multi-core PCs
    - fully commissioned DAQ, with high rate compared to other systems
  - ready for CBC module tests, later this year
    - to be adopted for other CMS Tracker tests in future



Telescope Performance

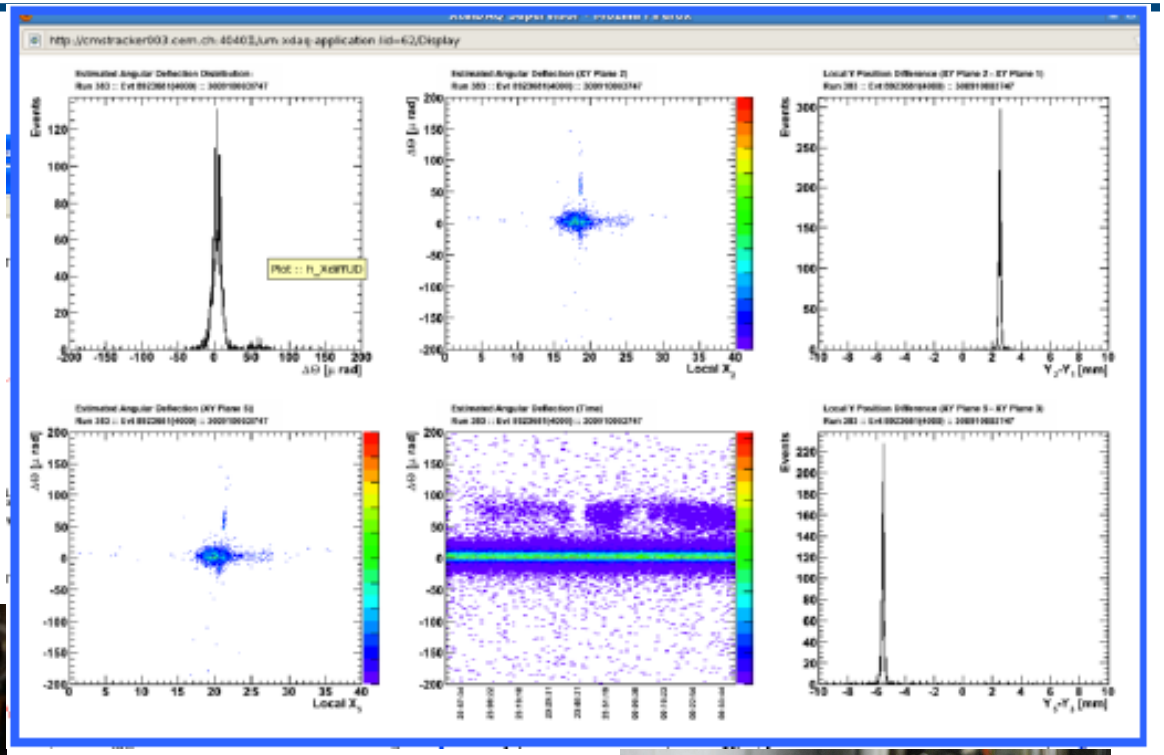
System performed well

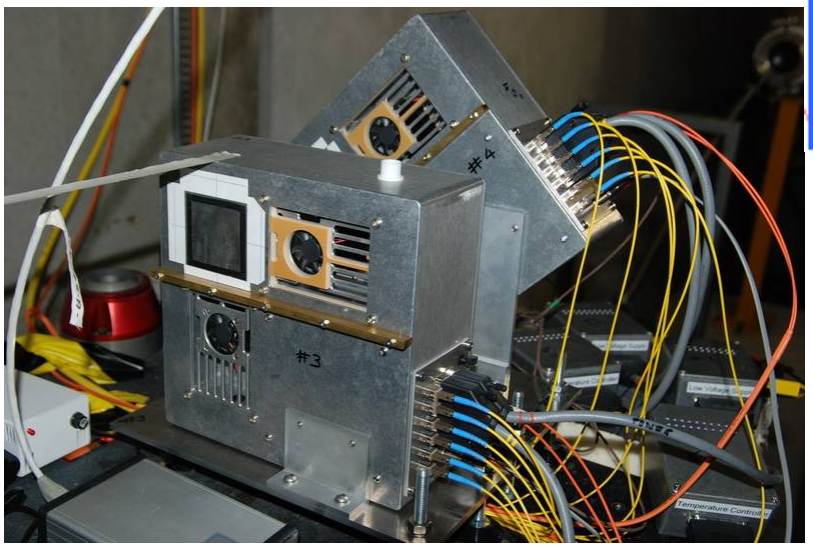
excellent angular & spatial resolution
~7μm, 5.2μrad (two arms)

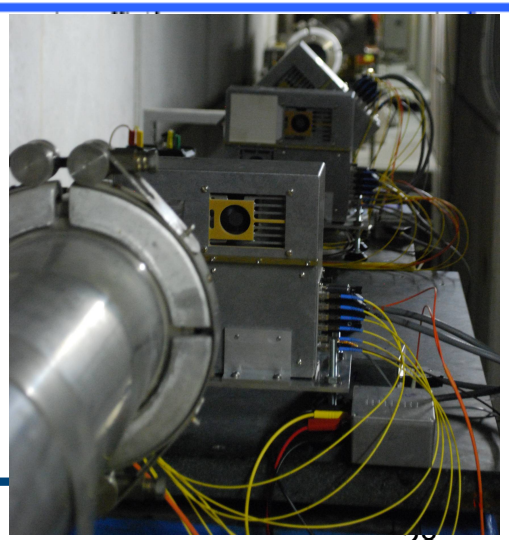
full CMS-based DAQ and monitoring

high rate ~7kHz, to be increased further

JINST paper ready to submit

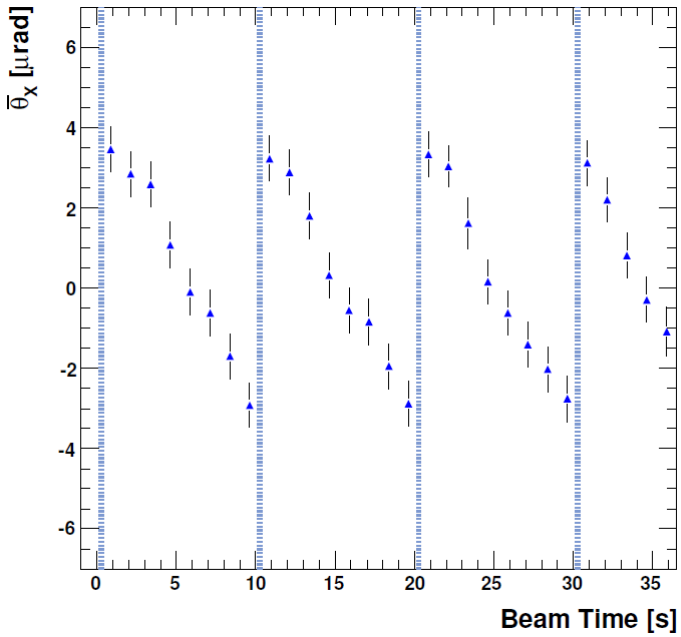


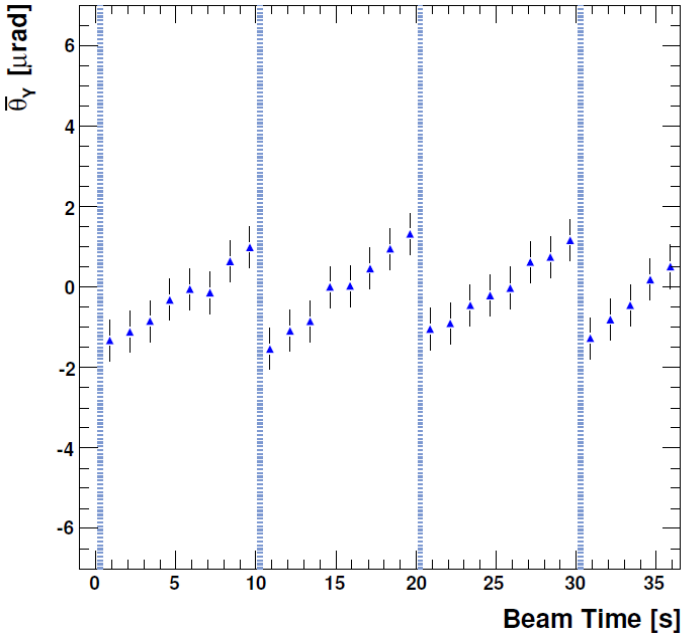




Periodic beam deflection discovered

- During data analysis, a shift in the beam direction was discovered over the course of a run
- Beam deflection is periodic with period equal to that of spill (~10s)



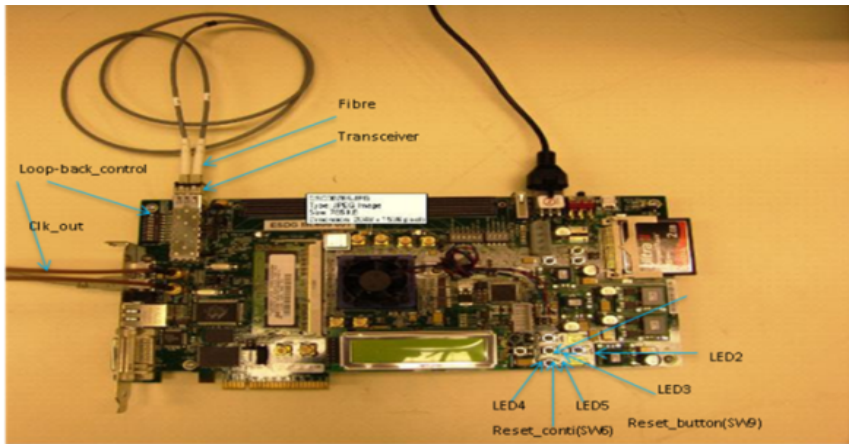


- Total deflection measured at 6.5μrad in x and 2.5μrad in y over a spill
- Will clearly increase divergence – and possibly other channeling measurements to date, or in future

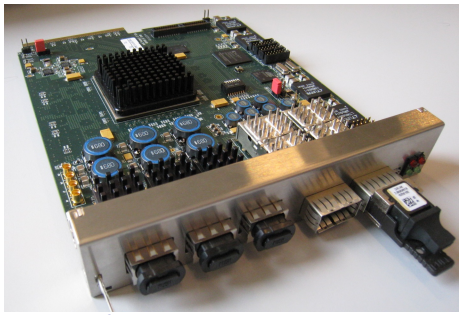
sFED developments

- Develop firmware VHDL modules and test on commercial FPGA development boards (M Siyad, J Coughlan: RAL TD)
  - Full time engineer on project since September
- Ported CERN Giga-Bit Transceiver (GBT) FPGA Kit to Xilinx Virtex 6
  - CERN FPGA implementation of GBT ASIC logic
  - Adapted design from electrical to optical fibre SFP+ transceiver links
  - Report written and adapted design submitted to CERN GBT group
- Currently developing FPGA VHDL design
  - interface GBT data links to ultra-fast external memory interfaces

- Next steps:
  - integrate with CMS Ethernet controls software
  - port design to Mini-T card at RAL
    - when available



WP3: Trigger Development

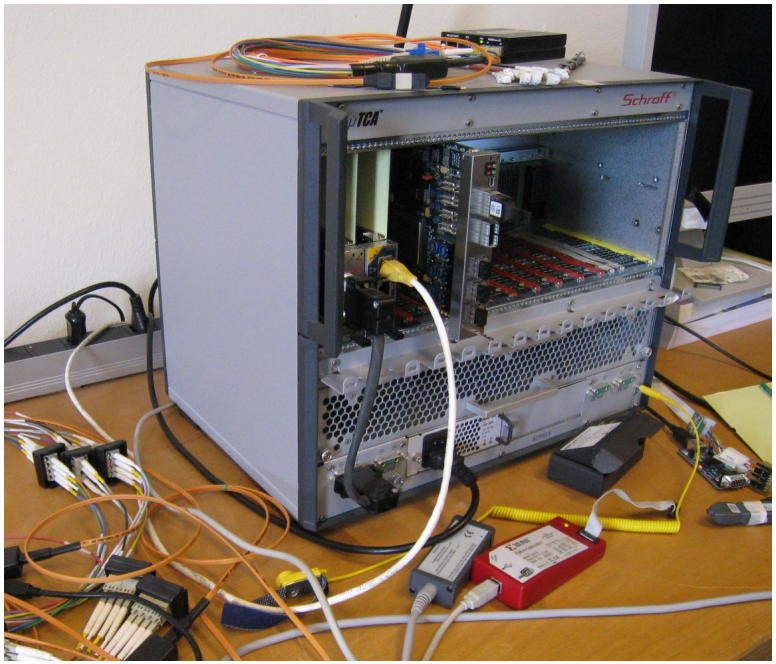


- Demonstrator system
  - MINI-T5: Virtex 5 based MicroTCA card (160Gb/s and 100Gb/s optics)

- Proposed novel trigger architecture to CMS
  - CMS Note submitted
  - Discussion on upgrade trigger architecture is under way

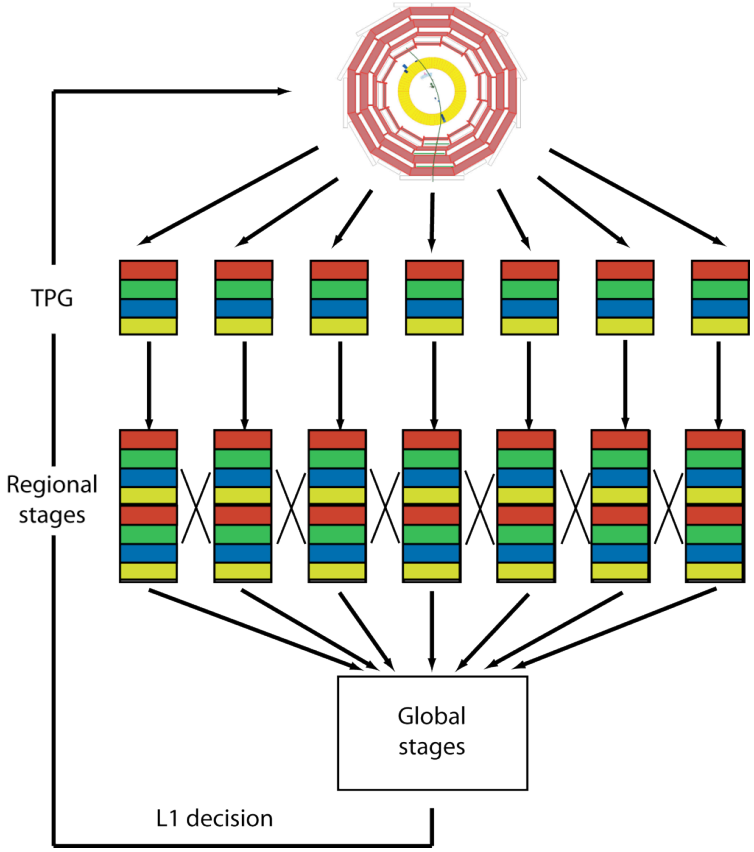
- Playing a substantial role in system design (G Iles)
  - Proposed MicroTCA card for Clock, Control, DAQ
    - Implemented by E Hazen (Boston, US)
  - Organising common aspects (e.g. crate purchase)
- Supplying advanced Hardware Access Library (A Rose, R Frazier)
  - Software collaboration between WP1 and WP3
    - Based on protocol from J Mans (Minnesota, US)

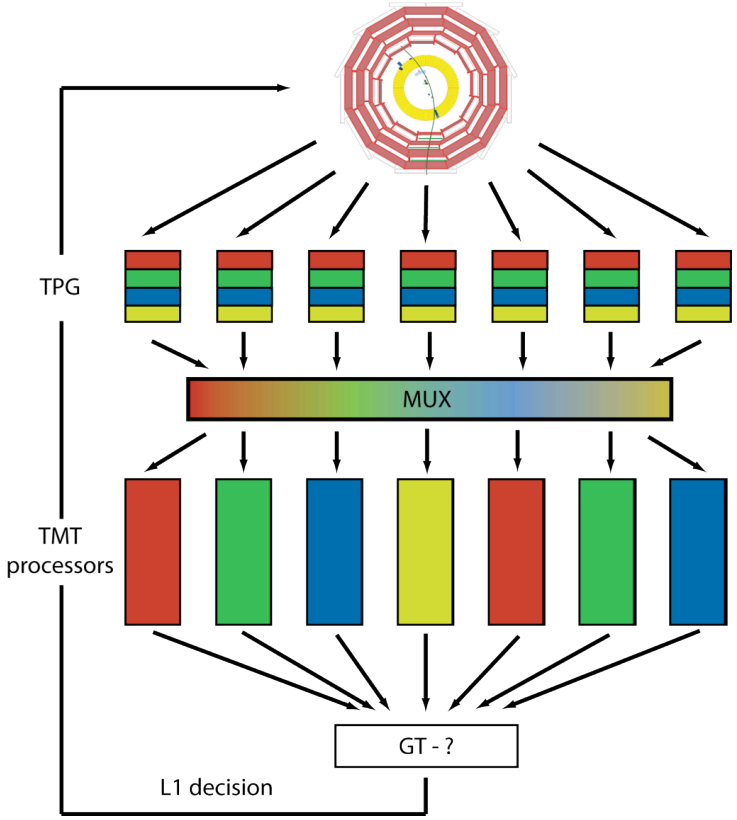
WP3: Demonstrator System



- Two cards produced:
  - Rev 0: Original
  - Rev 1: Alternate optics (supply issue)
- New manufacturing run in a few weeks
  - Rev 2: QDR II ram added (request)
  - Will make approx 12 cards if all OK
  - Enables large scale system test
- Firmware infrastructure
  - Complete (link setup, DAQ, control)
- Firmware algorithms
  - Elec/Tau complete (based on Wisconsin 2x2 cluster algo)
  - Algo size and speed not an issue

Time-Multiplexed Trigger: Concept





- The key problems of triggering remain the same as in 1995
  - Concentration of dataflow into a single processor
  - Limitations on algorithms due to internal bandwidth limits
  - Understanding and optimising what is going on

WP3: 2011 Plans

- Two parallel developments

- (a) System Tests
  - Most infrastructure in place or soon to be (e.g. crate, hub, etc)
  - Start in earnest in April (MINI-T5:Rev2 cards back)
  - Initial 6-12 months, moving towards final system

- (b) Final Hardware design
  - Based on Virtex 7
  - Some dependence on architecture choice
    - Primarily number of 10G links (x36 or x48)
    - Choice: Balance - Cost, BRAM, Logic and Links
  - CMS collaboration: Wisconsin, (Vienna) + UK

CMS planning

- New pixel detector project well defined
  - 4 barrel layers + 2 x 3 endcap disks
  - Significant contributions “guaranteed” from existing collaborators, plus some new partners (DESY, Aachen, CERN, Taiwan, Italy) with clear roles
  - stronger physics case needed to demonstrate cost/benefit
- Upgraded Calorimeter trigger
  - architecture under discussion
  - physics studies to justify
- More detailed long term plan to be defined
  - be ready for worse case conditions 2 x 10^{34} $cm^{-2}s^{-1}$ & 50ns bunch spacing
  - LHC planning must precede CMS
- Long term R&D (full Tracker and trigger) remains very high priority
  - potential Tracker risk if cooling is problematic
  - must also plan cautiously, despite excellent performance to date

Possible UK contributions to future CMS

- Trigger effort has strong UK support, based on more advanced progress than elsewhere in hardware/firmware/software
  - good existing collaboration to build on (Wisconsin, Vienna,…)
- Tracker: development of eventual detector is long term – but cannot be deferred
  - CBC, module, FED and DAQ: contributions and strong collaboration (esp. CERN)
    - must not forget DAQ upgrade and its likely impact
- Is there scope for UK contribution to Phase I pixel system?
  - interest from RAL PPD

- Continuity of funding required to match timing of proposal for construction & long term R&D
  - proposed bridging the gap for next tranche to start ~ April 2013
  - proposal ~ early 2012

WP evolution

- We have been flexible in use of WP1 staff at RAL PPD to cope with a difficult funding period
  - but need to cleanly distinguish new staff entering project and ensure WP1 deliverables are met
  - propose a separate WP for evaluation of pixel contribution
    - new milestone added for provisional project outline:
      - should evaluate feasibility & cost in first instance
- WPs also have different end dates
  - logical at approval but no longer fits needs
  - WP1, WP2, WP3 already adapted to long term CMS requirements
  - Pixel WP needs similar coherence
    - plan, deliverables and funding – if demonstrated to be feasible
- Possible next steps
  - bridging funds to, say, Mar 2013 to match proposal for long term R&D and construction funding
    - submission early 2012, giving time for CMS decisions on overall LHC schedule

Summary

- Continued good progress
  - CBC delayed but good progress in early testing - next steps reasonably clear
  - Trigger progress very good, and sound basis for contribution to CMS upgrade
- CMS and LHC upgrade planning
  - schedule uncertain again, for a few months
- Finances
  - spending gradually increasing, with larger commitments expected in 2011/12
    - Working Margin (£230k) not yet touched
  - Use of RAL PPD staff
    - distinguish staff entering project in new WP (& milestones)
    - understand effort available for WP1
  - Bridging to next period for construction and long term
  - SSC & budget reporting – well known problem
- Staff changes
  - O Zorba left, interviews for replacement imminent

Further information

CBC testing programme

- baseline performance (conventional (clean) powering scheme)
  - digital functionality
    - fast (Ck/T1 - SLVS) & slow control (I2C) interfaces setup and operation
  - analogue functionality
    - amplifier pulse shape, noise, linearity,..
    - CIN dependence, signal polarity dependence, across chip & chip-to-chip uniformity
    - leakage current tolerance
  - comparator
    - timewalk, threshold tuning and uniformity, hysteresis
  - all above will depend on bias generator settings
    - => large parameter space to cover
  - power consumption
- powering options studies
  - supply sensitivity with/without various on-chip options
- longer term
  - temperature effects (~ all of above vs. T), tests with sensors, radiation: ionizing & SEU sensitivity, test beam

Sensitivity: 1,2,5,10 fb^{-1} @7 TeV