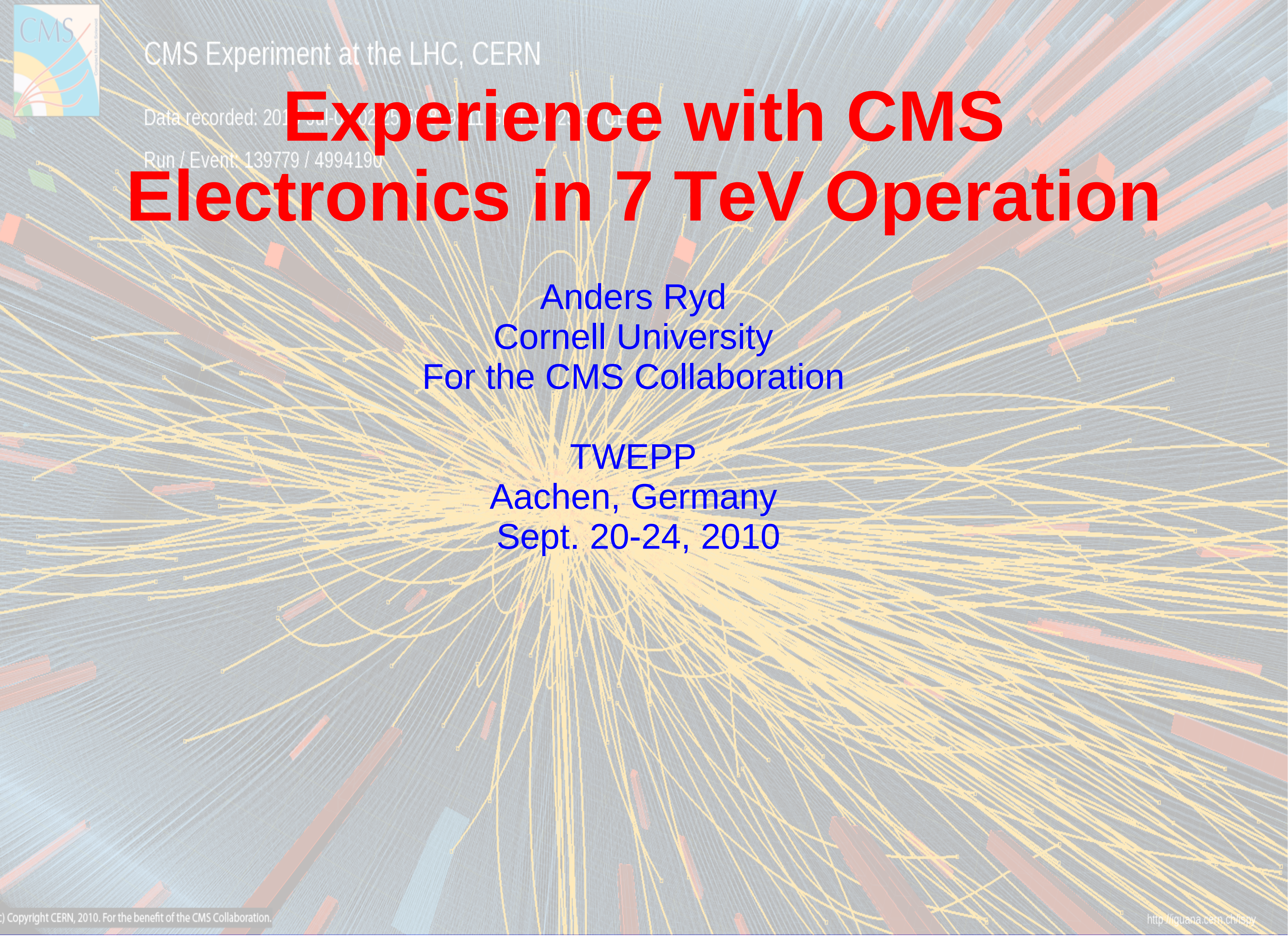

Experience with CMS Electronics in 7 TeV Operation

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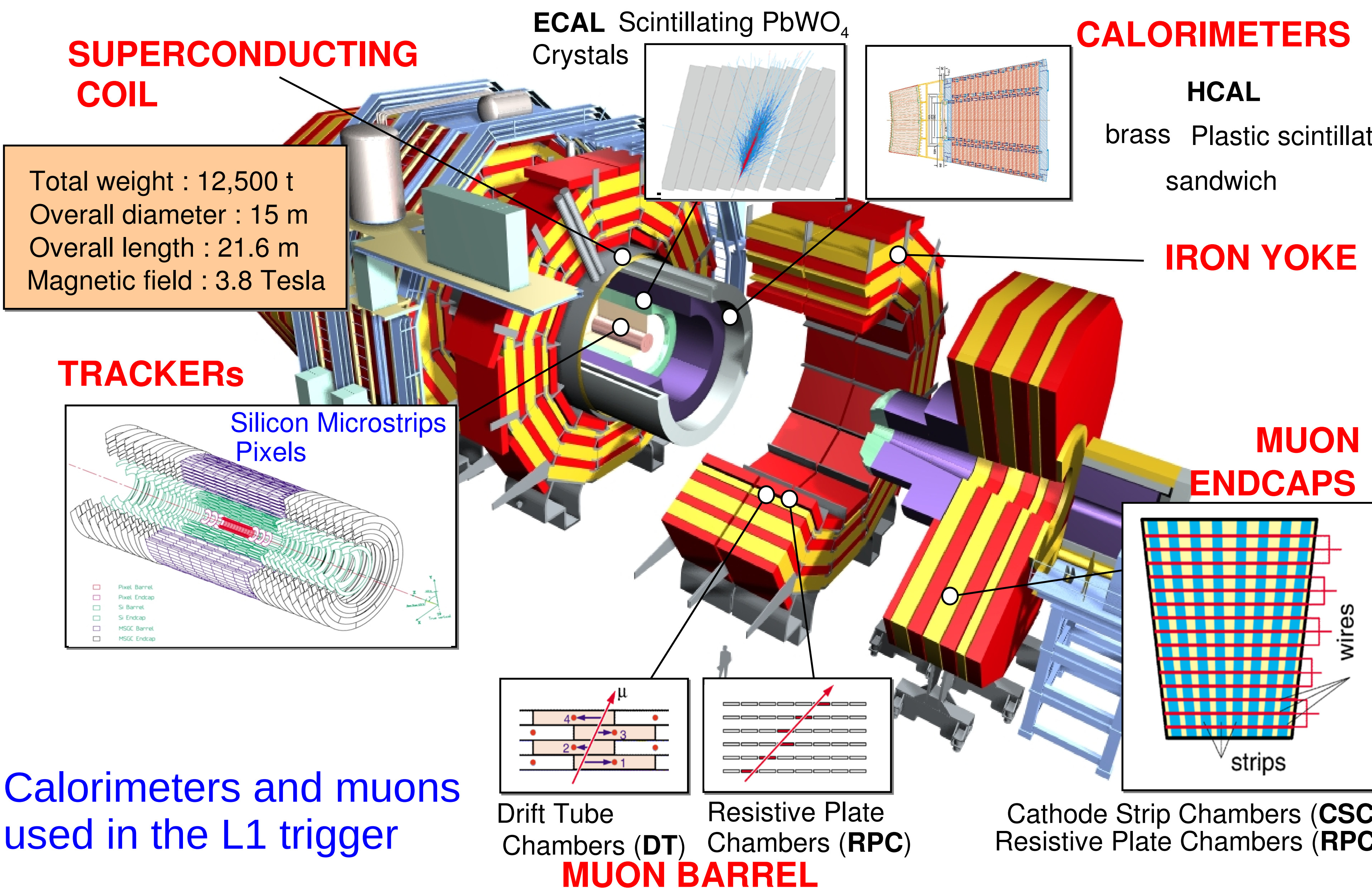
Introduction - Outline

- This talk is given from the view point of CMS run coordination
  - I'm not an electronics expert
- The talk will focus on the experience of operating the CMS detector with LHC beams and look at operational issues that are electronics related.

Outline:

- Overview of CMS
- Beam commissioning
- Detector performance
- Electronics Performance
- Summary

The Compact Muon Solenoid Detector



Calorimeters and muons used in the L1 trigger

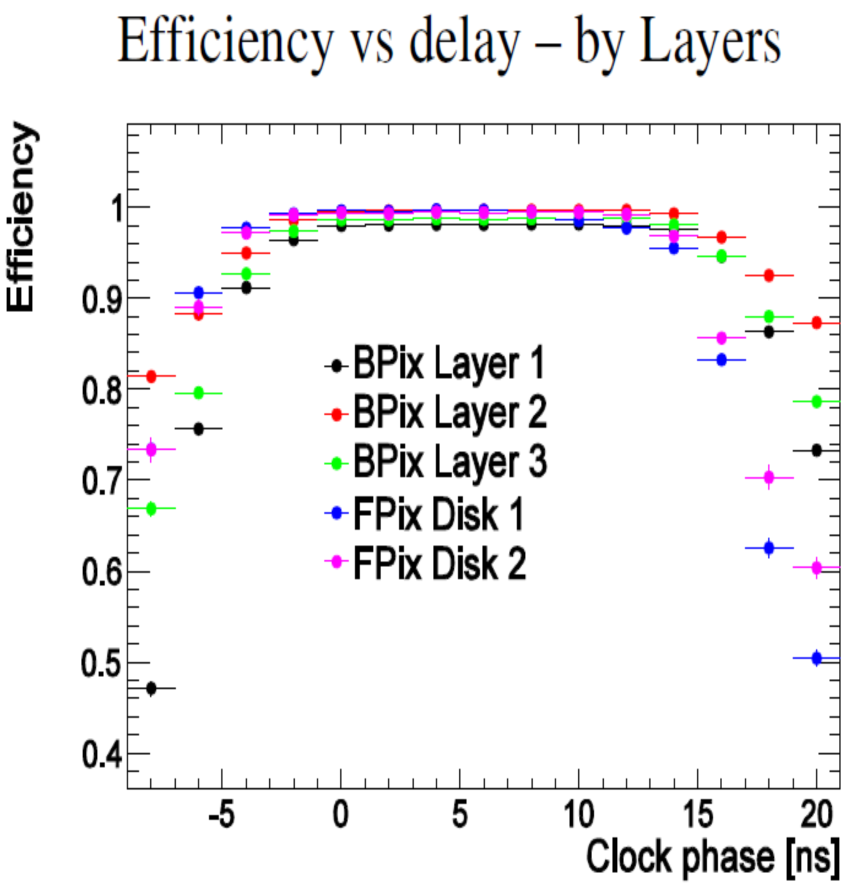
CMS Commisioning

- Before operation with beam CMS have performed extensive detector commisioning with cosmic rays.
  - A number of things such as timing in of detector readout and triggers could not be done until we had beam.
- The design L1 trigger rate for CMS is 100 kHz.
  - This rate has been demonstrated in tests but not stressed in physics running – as the goal is to optimize data taking efficiency.
  - At the highest luminosity reached by the LHC so far, about 10^{31} $cm^{-2}s^{-1}$, the L1 trigger rate has been around 50 kHz.

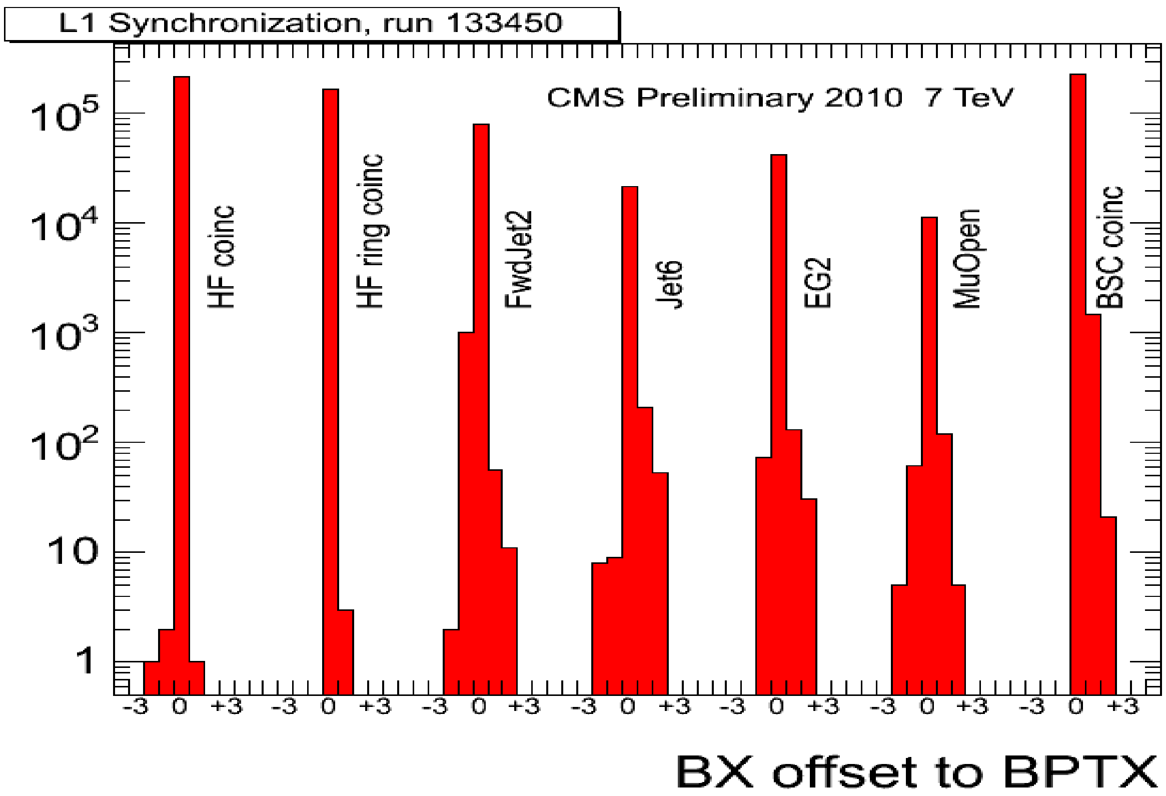
- Since the start of the run on March 30, 2010 the inst. luminosity has increased from about 10^{27} $cm^{-2}s^{-1}$ to 10^{31} $cm^{-2}s^{-1}$, or by a factor of 10^4.
  - The goal for 2010 is to increase the luminosty by another factor of 10.

Time Alignment with Beam

Pixel Timing

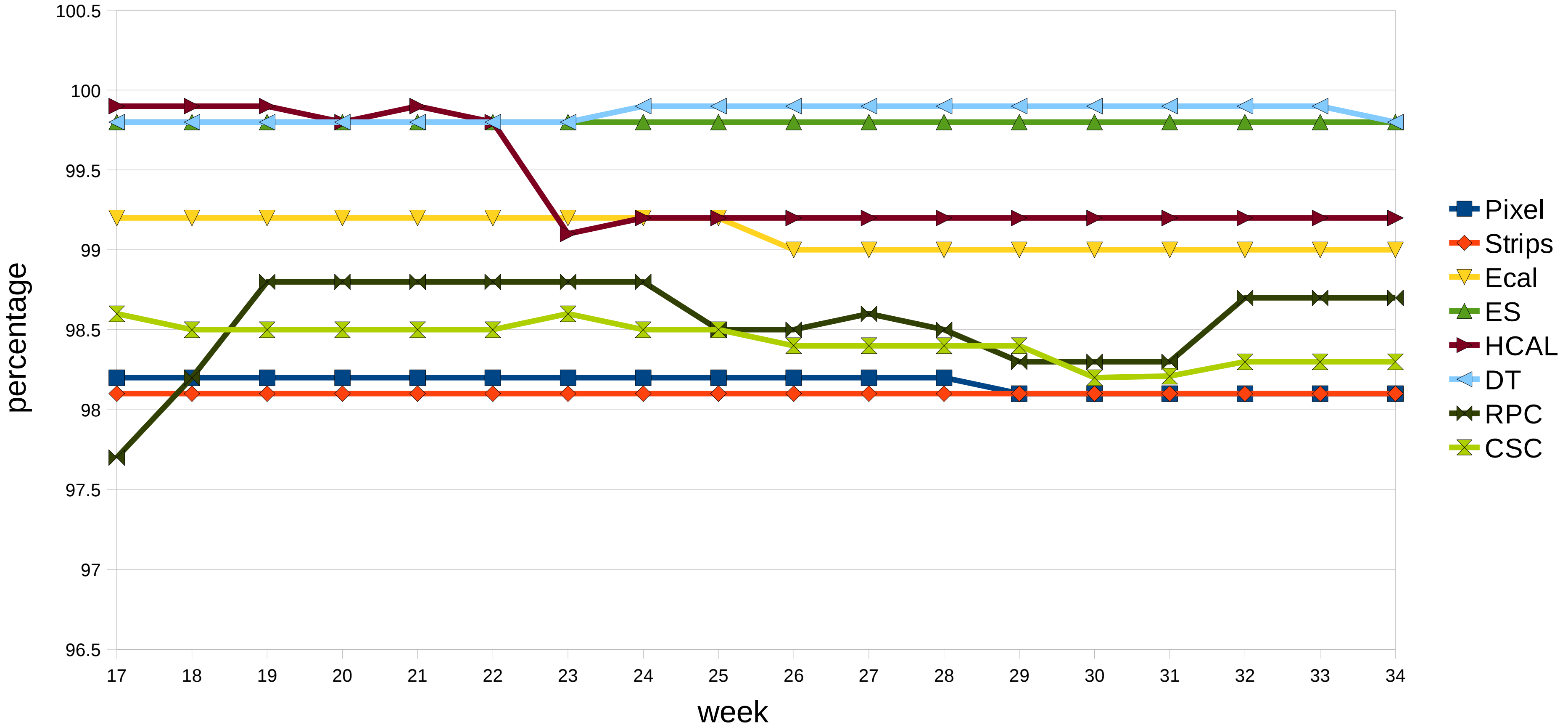


L1 Trigger Timing



- CMS pixel readout is only over one BX (25 ns)
- Before deploying L1 physics triggers they had to be aligned to the LHC clock. Early triggers are particularly bad.

Active Detector Channels



All subsystems over 98% functional.

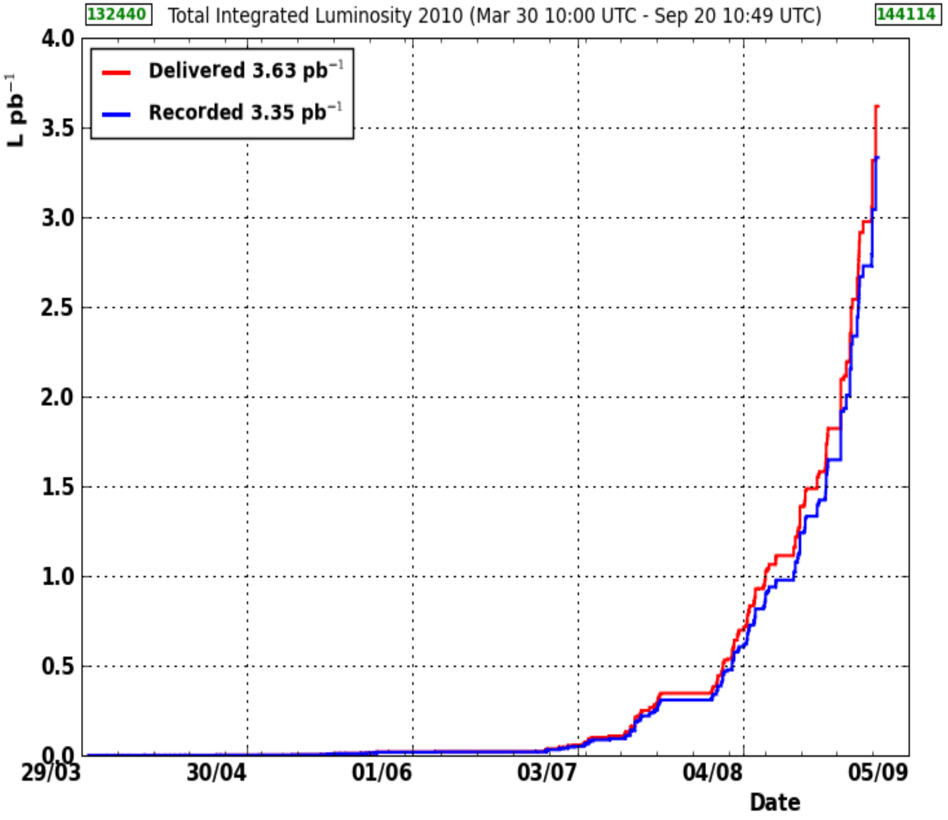
Luminosity Evolution

Luminosity 'knobs' for the LHC:

- Bunch charge, nominal 1.15×10^{11}
- Focus, β*, ultimate 0.55m.
- Colliding bunches

CMS delivered and recorded luminosity

Date	Bunch chg.	β* m	#colliding bunches	L inst.
10-03-30	1×10^{10}	10	1	few$\times10^{27}$
10-04-10	1×10^{10}	2	2	3×10^{28}
10-04-20	1×10^{10}	2	4	6×10^{28}
10-05-15	2×10^{10}	2	8	2×10^{29}
10-06-27	1×10^{11}	3.5	2	5×10^{29}
10-07-02	1×10^{11}	3.5	4	1×10^{30}
10-07-10	1×10^{11}	3.5	8	2×10^{30}
10-07-28	1×10^{11}	3.5	16	4×10^{30}
10-08-15	1×10^{11}	3.5	35	1×10^{31}

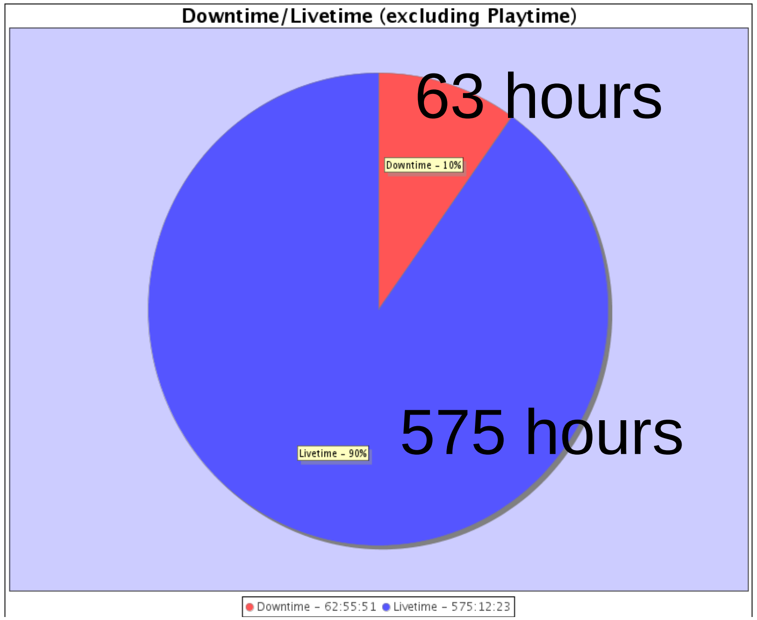


The goal for the rest of the pp operation is to
Increase the number of colliding bunches to ~400
In order to reach a luminosity of 10^{32} this year

~92% of delivered luminosity captured

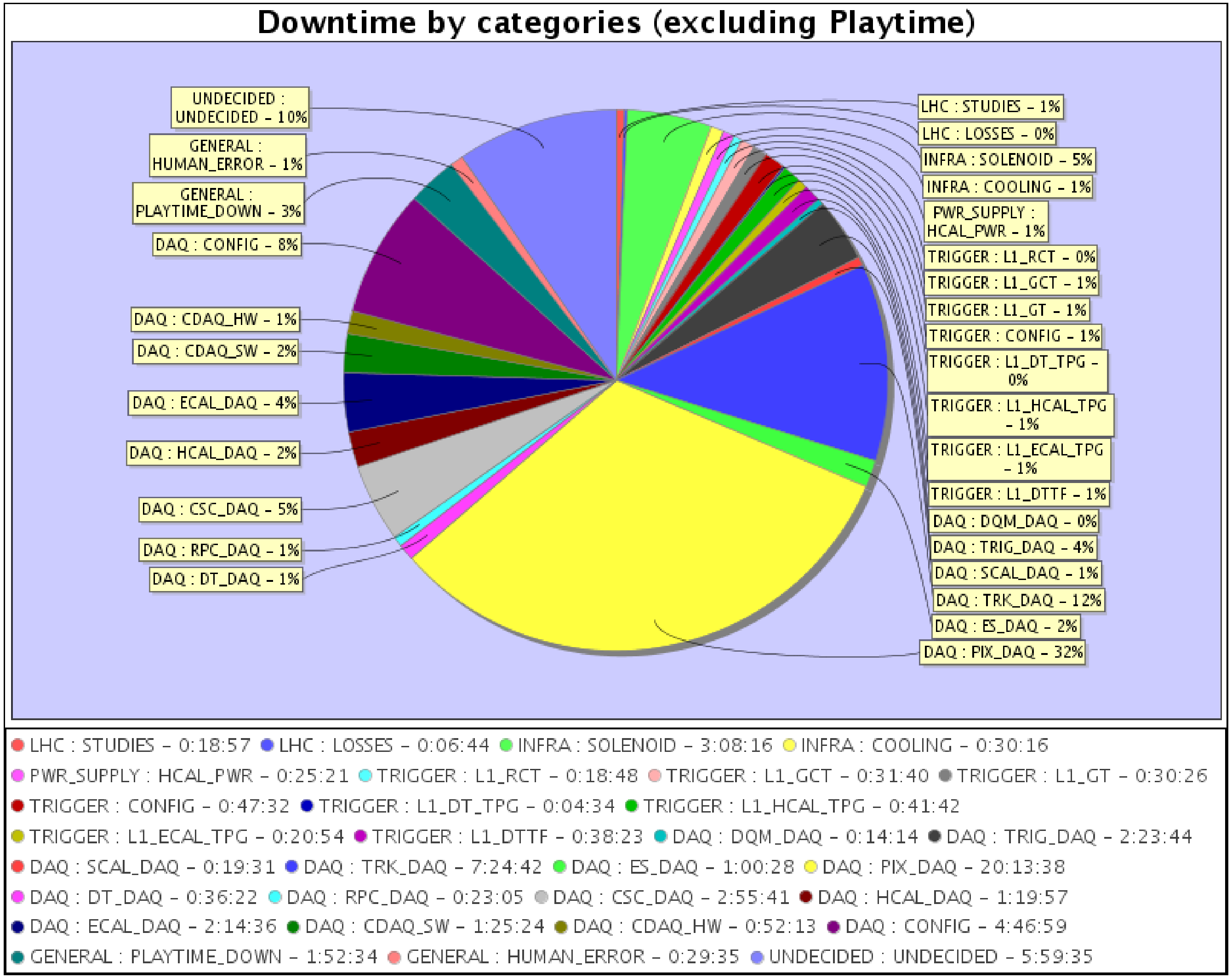
CMS Downtimes in 2010

Uptime with stable beams



- Uptime ~90%
- Different issues has evolved with the increases in luminosity.

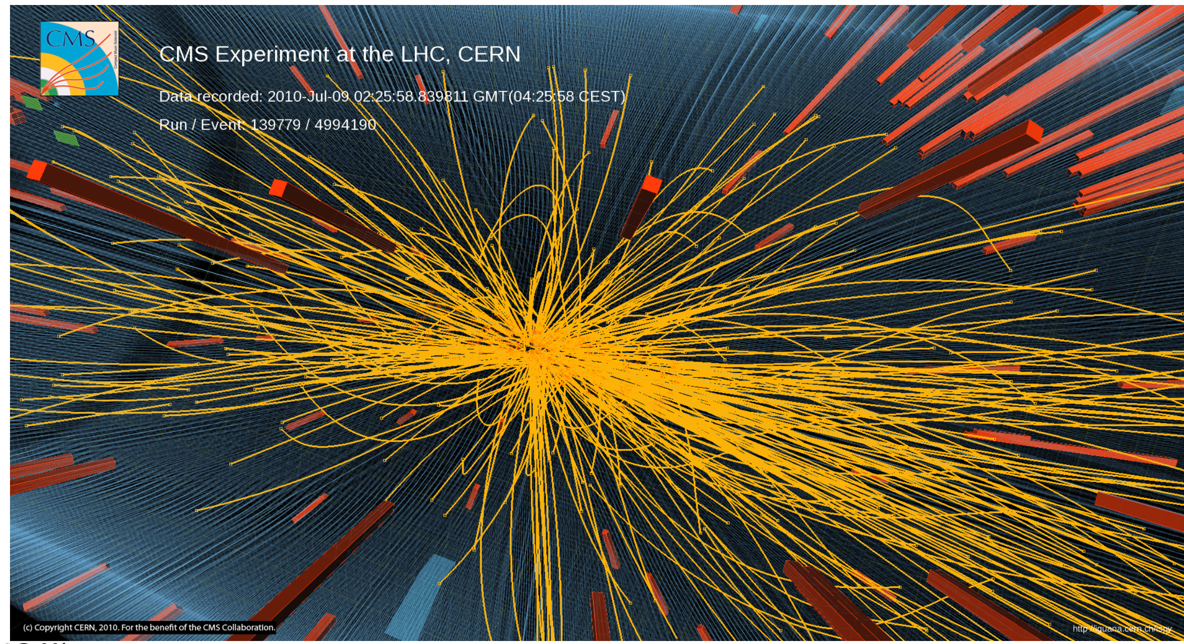
Breakdown of downtimes by type

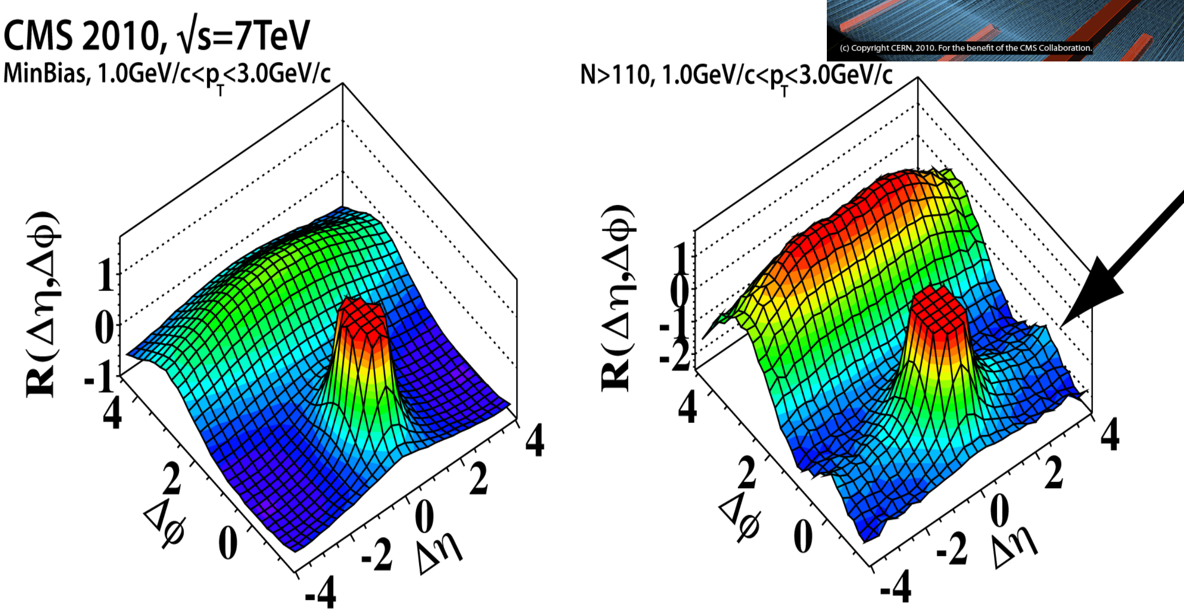


Recent Physics Result

"Observation of Long-Range, Near-Side Angular Correlations in Proton-Proton Collisions at the LHC"

- Unexpected, in proton-proton collisions, correlation of tracks in high multiplicity events.
  - Multiplicities of over 100 tracks/event





- Analysis possible thanks to the excellent performance of the CMS Trigger and DAQ
  - Take large rate of min bias triggers – high L1 rate.
  - Selection of high track multiplicity in the high level trigger.

Experience from Beam Operation

- Overall CMS operation with beams has been very successful
  - Over 90% data taking efficiency – all detectors in readout.
  - Over 90% of recorded data used for physics analysis.
    - As we are not (yet) tracking data taking conditions, like tripped power supplies etc, data are marked bad if not perfect. This data will be recovered when we deploy more realistic MC simulation.
  - We have followed the luminosity evolution by deloying new trigger configuration.
- Never the less, there have been some issues that we have had to address along the way. Some of these issues will be discussed in the next few slides.

Optical Link Failures

- We continue to have failures on the optical links
  - For VME controllers
  - For the event builder myrinet switch
  - For link boards (between VME boards)
- These are commercial components
- These failures don't contribute significantly to the deadtime and are straight forward to replace as they are off the detector.
- I note here also that the optical transmittors used for the data transfer off the detector (e.g. the strip tracker use ~40,000 of these) has had a very low failure rate.

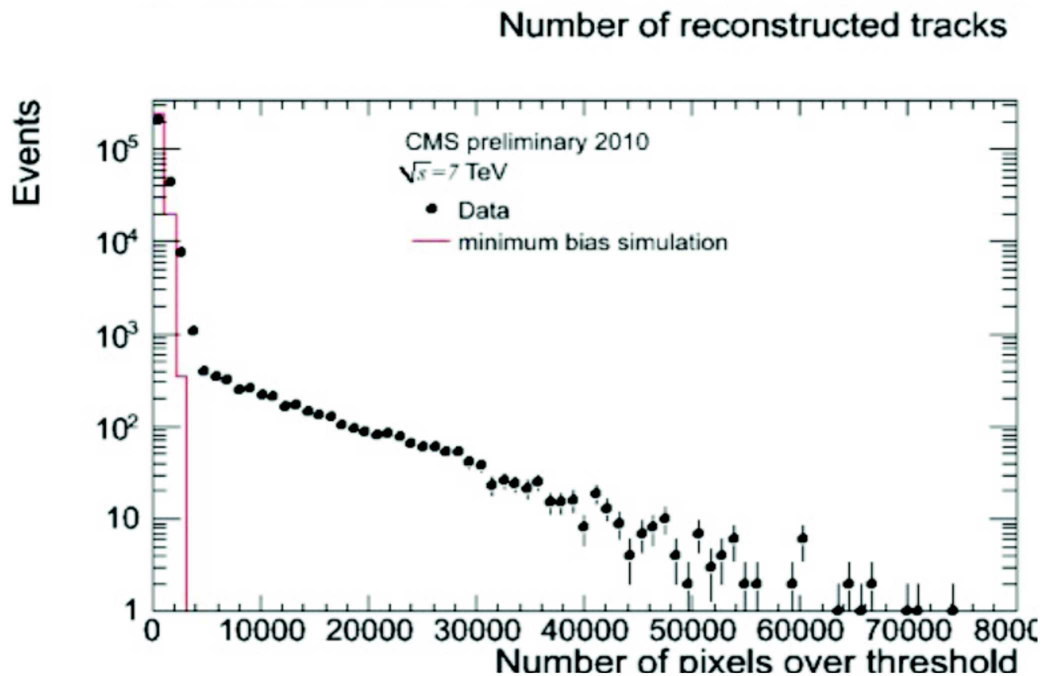
CSC Firmware Reload Issue

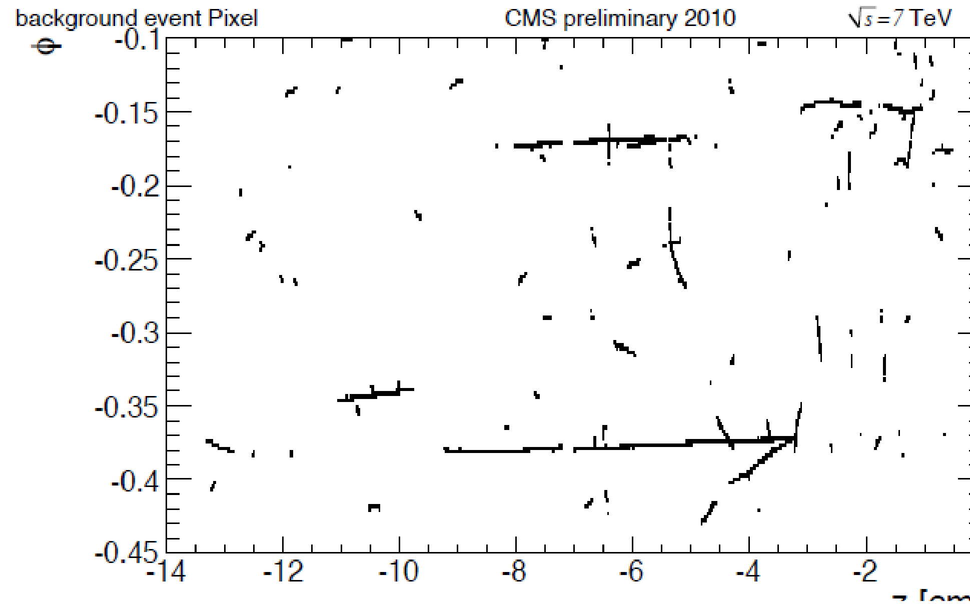
- Xilinx EEPROMs used by the CSC readout come from a faulty batch.
  - Approximately once a day a bit flips ($1\rightarrow0$) and firmware can not be loaded to FPGA as if fails a checksum.
- We are working around this problem by reloading the firmware to the affected EEPROMs when a problem is detected.

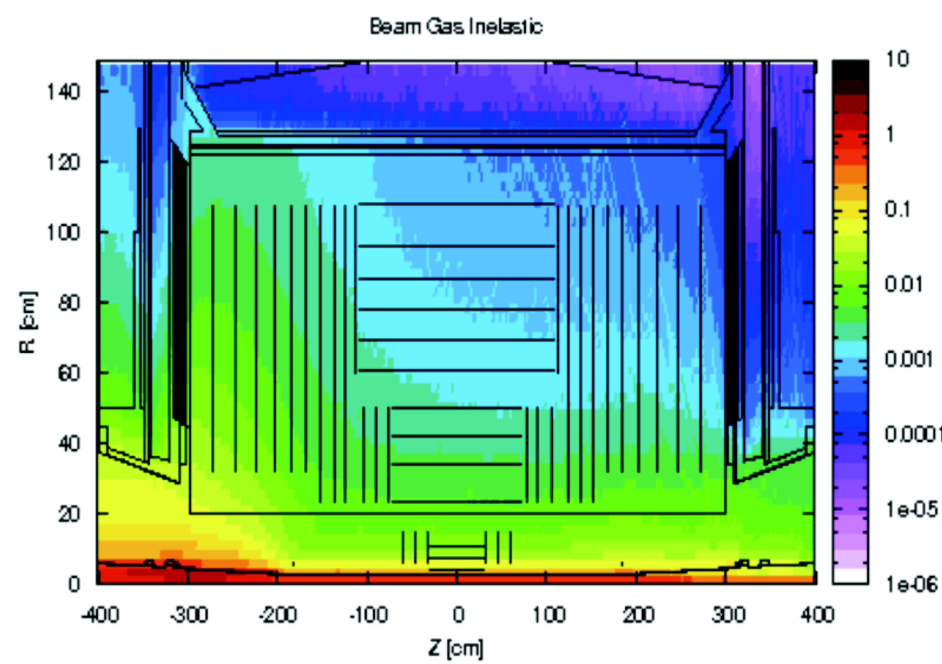
'Turbine' Failures and Power Supplies

- In 2009 all 'Turbines', fan units for rack cooling, were replaced as there were mechanical failures (bearings) on the old fans.
- However, there are some yet not understood electrical failures seen on the new turbines.
  - We have had 6 such failures this year. Units were replaced and removed from the experimental cavern. The removed units were seen to work after removal.
- The CAEN power supplies for the strips and pixel detectors had a significant infant mortality rate after installation in 2008.
  - In the 2010 run these power supplies have been much more stable.

Pixel High Occupancy Events







- Events with occupancy much larger than expected from minbias events seen in the pixel detector.
  - Tracks parallel to the barrel pixel modules – source along beam line.
- Readout of these high occupancy events in the pixels takes long time.
  - Readout and recovery modified in frontend readout firmware.

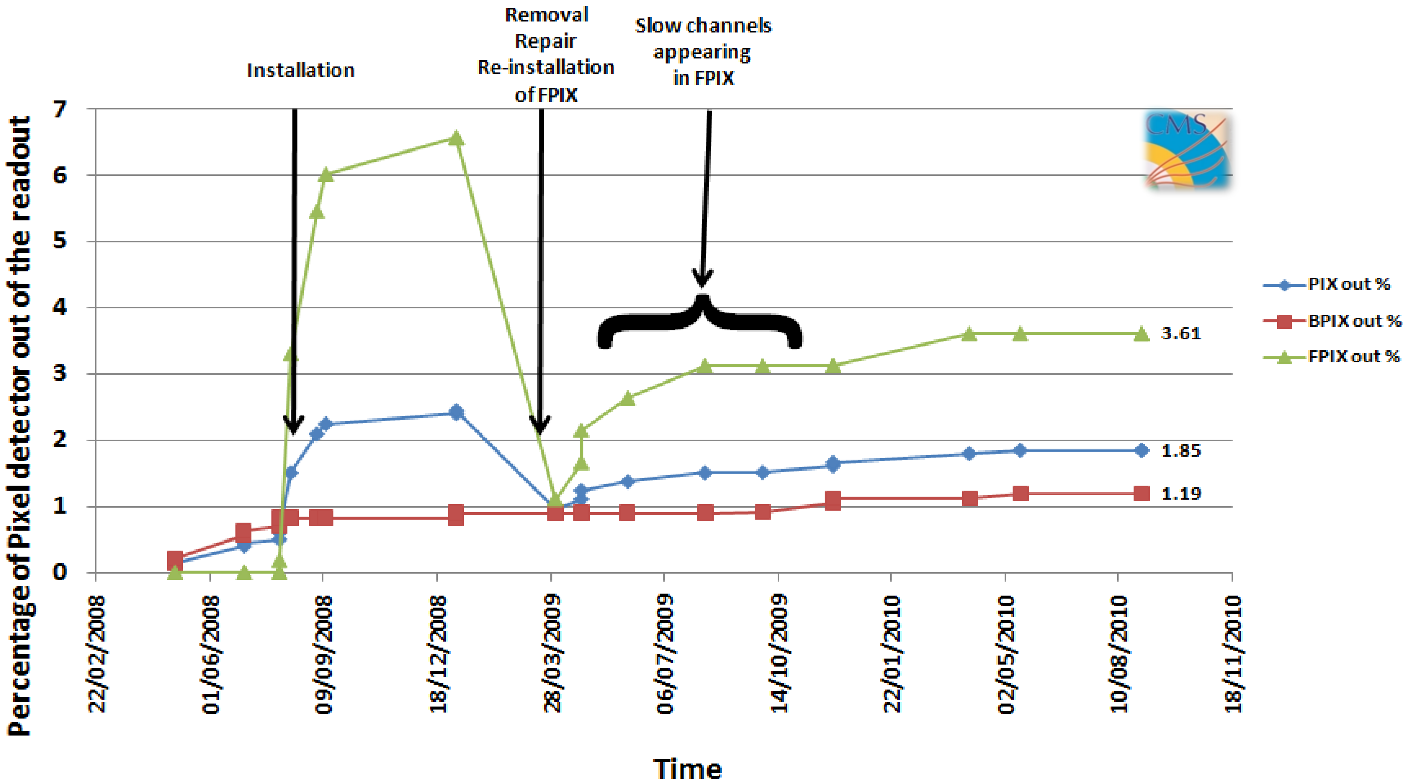
Pixel 'Busy' Firmware Problems

- In order to avoid the out-of-sync problems with large pixel events the pixel readout raises busy to stop triggers was introduced.
- This mechanism worked fine, but a few feds (out of 40) started to generate sync-lost-draining in the DAQ at rates above ~20 kHz
  - This means that a readout driver sent either more or less events than other readout drivers – something that the central DAQ can not handle.
- After ~1½ months of hard work from the pixel group a solution was finally found – reducing the slew rate of the FPGAs eliminated this problem.
  - This points to some noise source, but this has not yet been understood.
- However, we now operate the pixels without it causing the DAQ to fail.

- This problem and the debugging lead to almost 50% of the CMS down time in July and August. This corresponds to about 5% down time.
  - For a long time we could only reproduce the problem with beam

Pixel 'Slow Channels'

- The largest loss of channels in the CMS pixel detector comes from a failure in which the signal raise and fall time degrades to the point that meaning full signals can not be decoded.
- About 2% of the FPIX channels lost at the start of 2010 run
  - Channels worked when the detector was just installed
- Seems to have stabilized now – no new channels have developed this problem in the last few months.



CMS demonstrated that the pixel detector could be removed, repaired, and reinserted in a period of 3 months.

Wirebonds and Repetitive Triggers

- The early LHC commissioning used very few bunches – one or two colliding at CMS.
- Our early commissioning triggers, zero bias, just triggered on the bunch crossing.
  - This caused repetitive triggers at frequencies from few kHz to tens of kHz
  - This is in the range where you could potentially break wirebonds (CDF experience).
- This complicated trigger commissioning by making sure that we did not allow repetitive triggers in the dangerous range.
  - Deployed protection against repetitive triggers.
  - At certain trigger rates we need to add random triggers to avoid deadtime from this protection.

- Lesson: Should more carefully have discussed and understood the LHC commissioning plan.

Maintaining Experts

- CMS consists of many different (electronics) components
  - There are many experts for these different components
- Already today we have seen problems with access to experts for diagnosing and intervening on problems.
  - This will continue to be a challenge as more of the people that worked on the original system move on to other projects/experiments etc.
- We will need to actively review the status of both spares and personel required to operate the experiment.

Conclusions

- CMS has operated with high efficiency since the start of 7 TeV operations on March 30, 2010.
  - We have recorded >90% of the luminosity delivered by the LHC in stable beam conditions.
- All subdetectors operating with an active channel fraction greater than 98%.
- The detectors have been timed in to the LHC beam
  - L1 physics triggers have been deployed.
- Problems that has come up in operation are being addressed.

- Next step is a factor of 10 increase in luminosity over the next 6 weeks – LHC operation resumed on Wed. with stable beams again.