Commissioning Status for Run-II ATLAS, CMS and LHCb

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on behalf of the ATLAS, CMS and LHCb Collaborations

Outline:

- Introduction
- Run-2 Machine Perspectives
- Commissioning Status: ATLAS
- Commissioning Status: CMS
- Commissioning Status: LHCb
- Conclusion

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A look back … Run-1 in a Nutshell

20 Nov 2009
First beams

8 Nov 2010
PbPb 2.76 TeV/n

Nov 2011
PbPb 2.76 TeV/n

20 Jan 2013
pPb

2009 2010 2011 2012 2013

30 Nov 2009
Collisions @ 2.36 TeV

30 Mar 2010
Stable collisions @ 7 TeV

13 Mar 2011
7 TeV start with beam

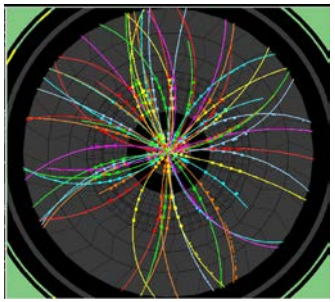
5 Apr 2012
8 TeV start with beam

Feb 14 2013
Start LS1

ATLAS/CMS Pile-up (interactions per bunch crossing)

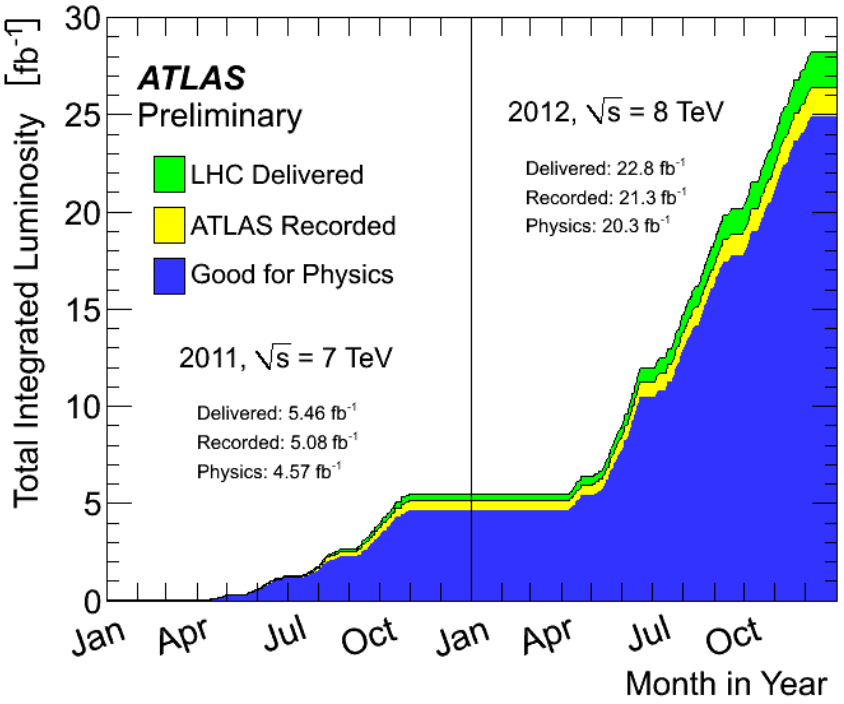
O(2) → O(10) → O(25)

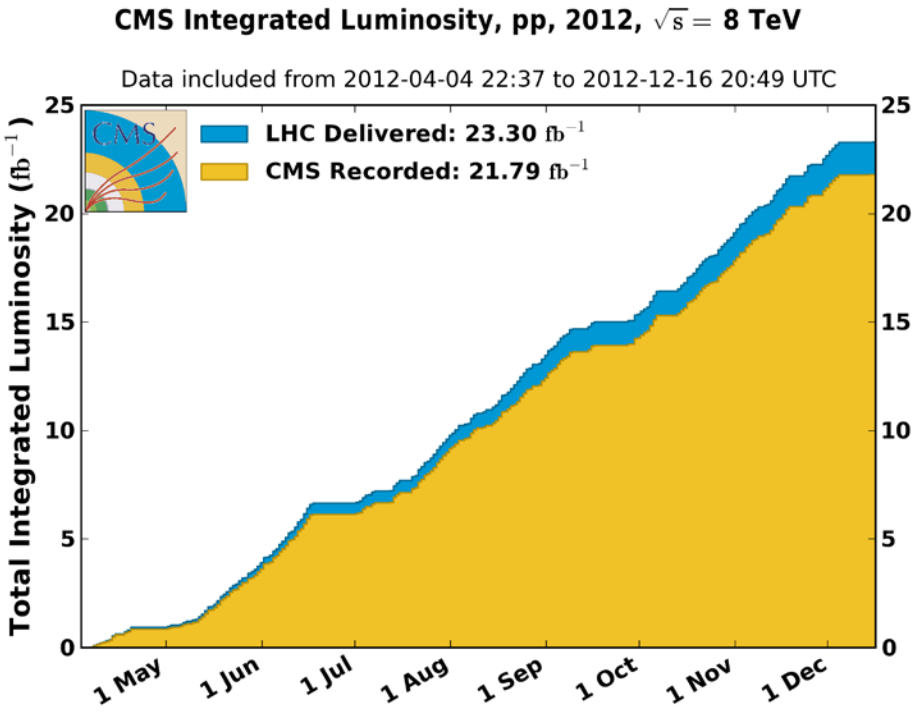
Run-1: 50 ns LHC bunch spacing



ATLAS

Run-1 Achievements: ATLAS + CMS





Recorded Luminosity:

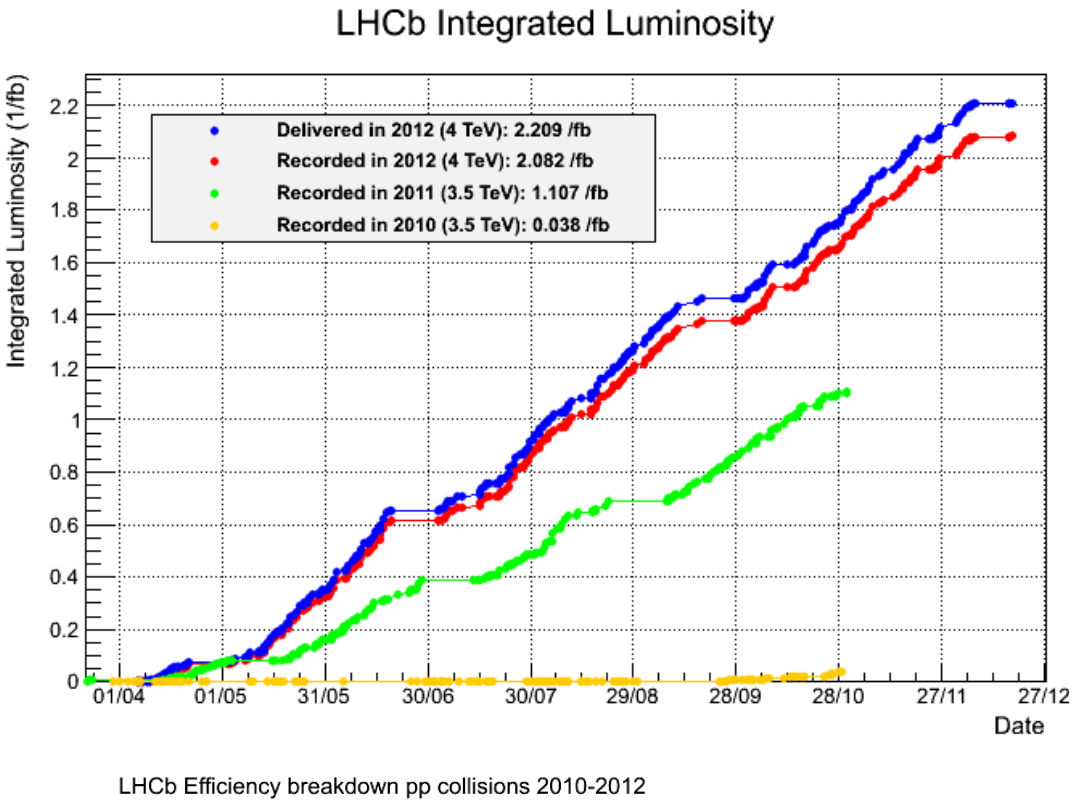
- ~ 5 fb^{-1} @ 7 TeV
- ~ 21 fb^{-1} @ 8 TeV
- Very similar for the 2 experiments

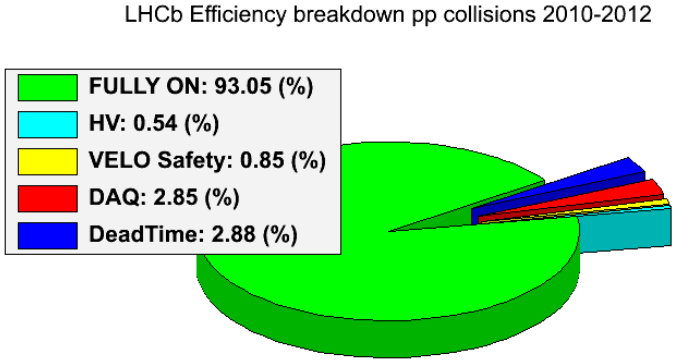
Data Taking efficiency = recorded/delivered luminosity)

- ~94% for both experiment

Data quality selection: "all sub-detector good" – 95%

Run-1 Achievements: LHCb





Integrated (recorded) Luminosity:

- ~ 1.1 fb^{-1} @ 7 TeV
- ~ 2 fb^{-1} @ 8 TeV
- LHCb nominally designed for $2*10^{32}$ cm^{-2} s^{-1} …
- able to run at twice this number with same performance during course of run 1 !

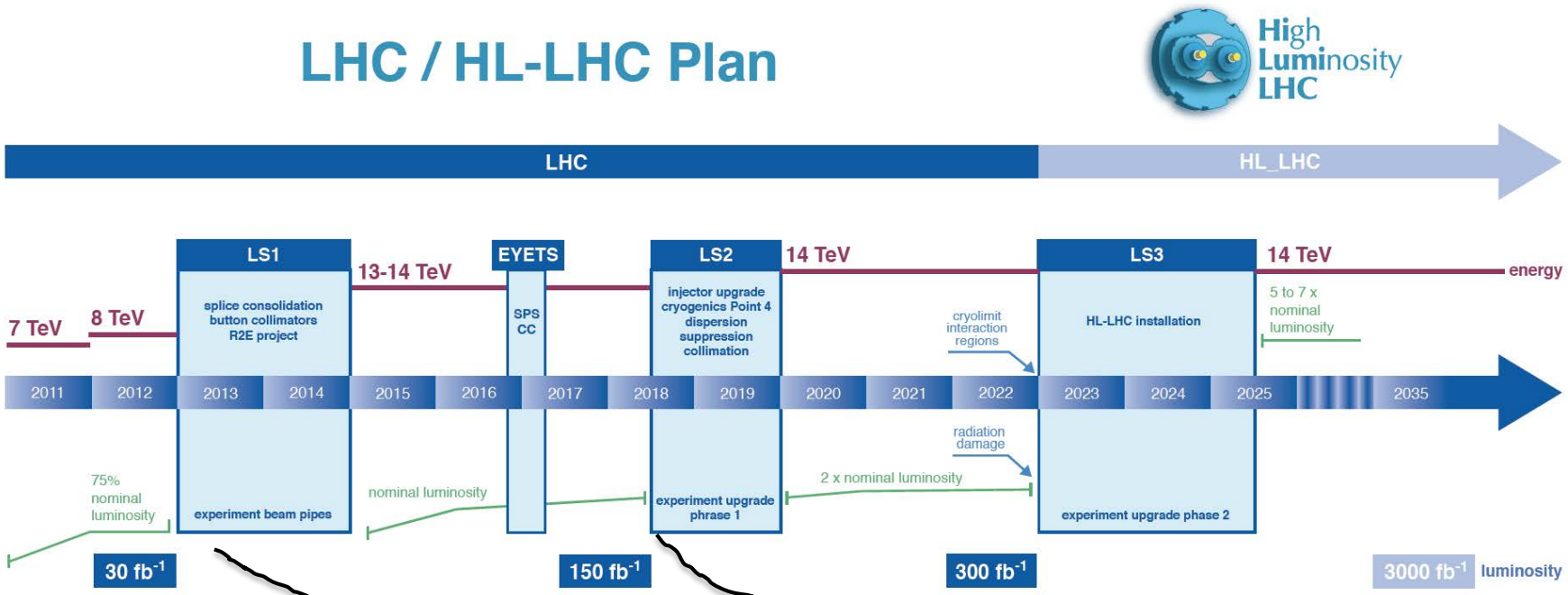
Data Taking Efficiency (recorded/delivered lumi):

- 94%

Data quality selection

- > 99%

Run-2 LHC Plans & Conditions



- $\sqrt{s}$ = 7 (8) TeV
- 50ns bunch spacing
- L_{int} ~ 30 fb^{-1}
- L_{peak} ~ 7.5 · 10^{33} cm^{-2} s^{-1}
- ~1400 bunches total
- Bunch charge: ~1.6·10^{11} p/b
- μ ~ 30 (ATLAS, CMS)
- β^* = 0.6 m (ATLAS, CMS)

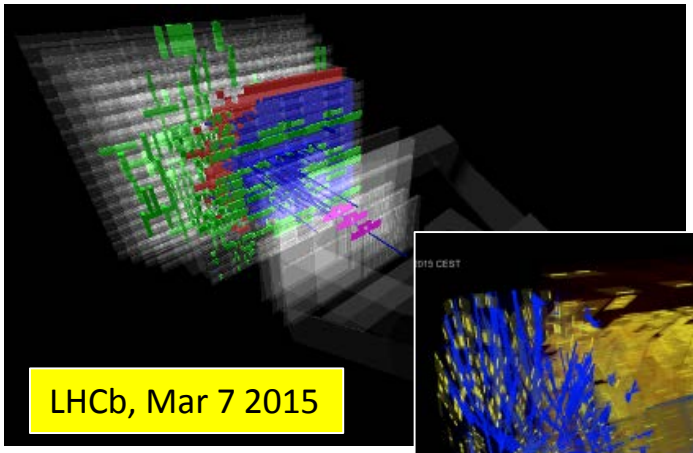
Run-1

- $\sqrt{s}$ = 13 (14) TeV
- 25 ns bunch spacing
- L_{int} ~ 100 – 150 fb^{-1} -- 10 fb^{-1} in 2015
- L_{peak} ~ 1.3 – 1.5 · 10^{34} cm^{-2} s^{-1}
- ~2500 – 2800 bunches total
- bunch charge ~ 1.15 ·10^{11} p/b
- Small emittance/bright beams with BCMS (batch compression, merging, split) scheme (2.4 → 1.3 μm)
- μ ~ 40 (ATLAS, CMS)
- β^* = 0.55 m nominal, 0.8 m in 2015 (ATLAS, CMS)

Run-2

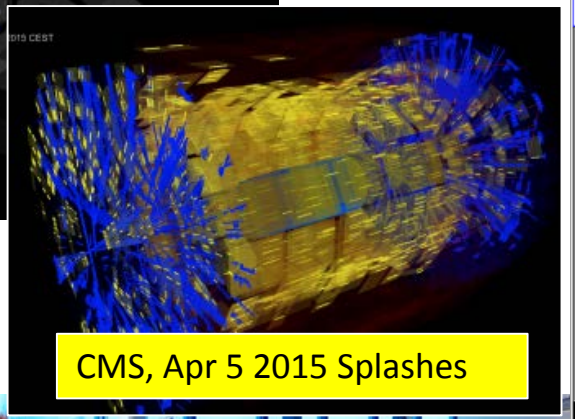
LHC Restart

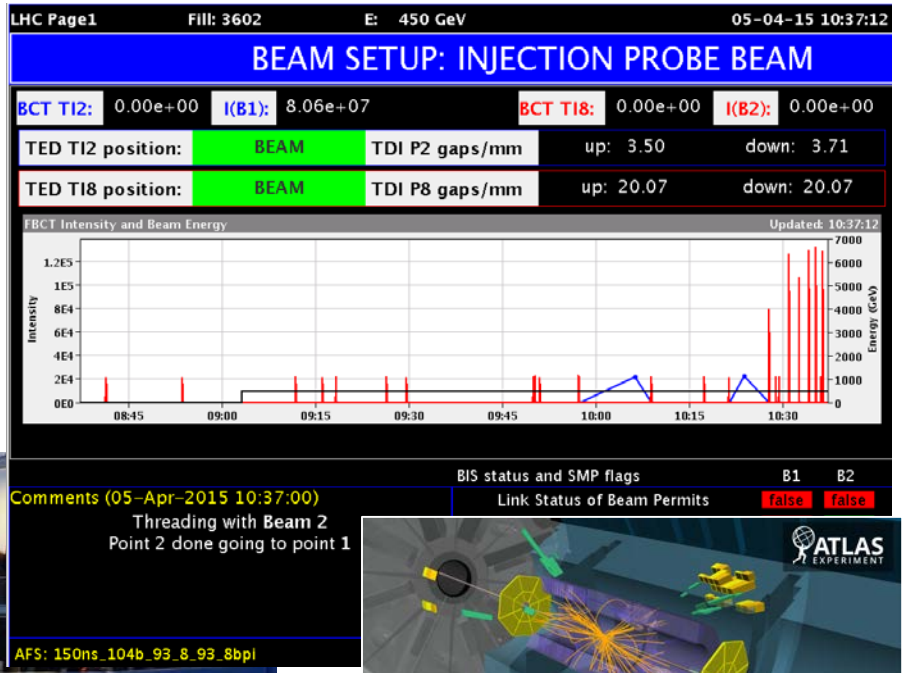
- Experiments ready for beam operations from Feb shafts closed → end of LS1 shutdown
- First beam through transfer lines to stopper TDI in front of LHCb on March 7th

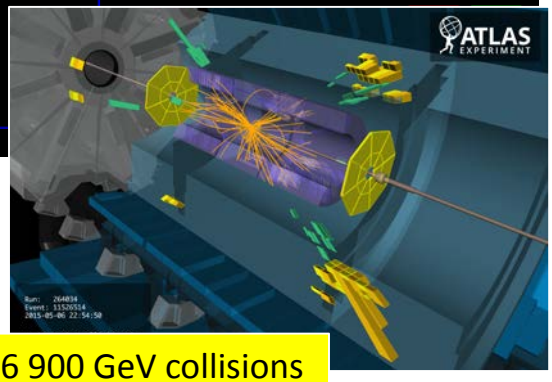


- First circulating beams during Easter on April 5th !

Back in business !

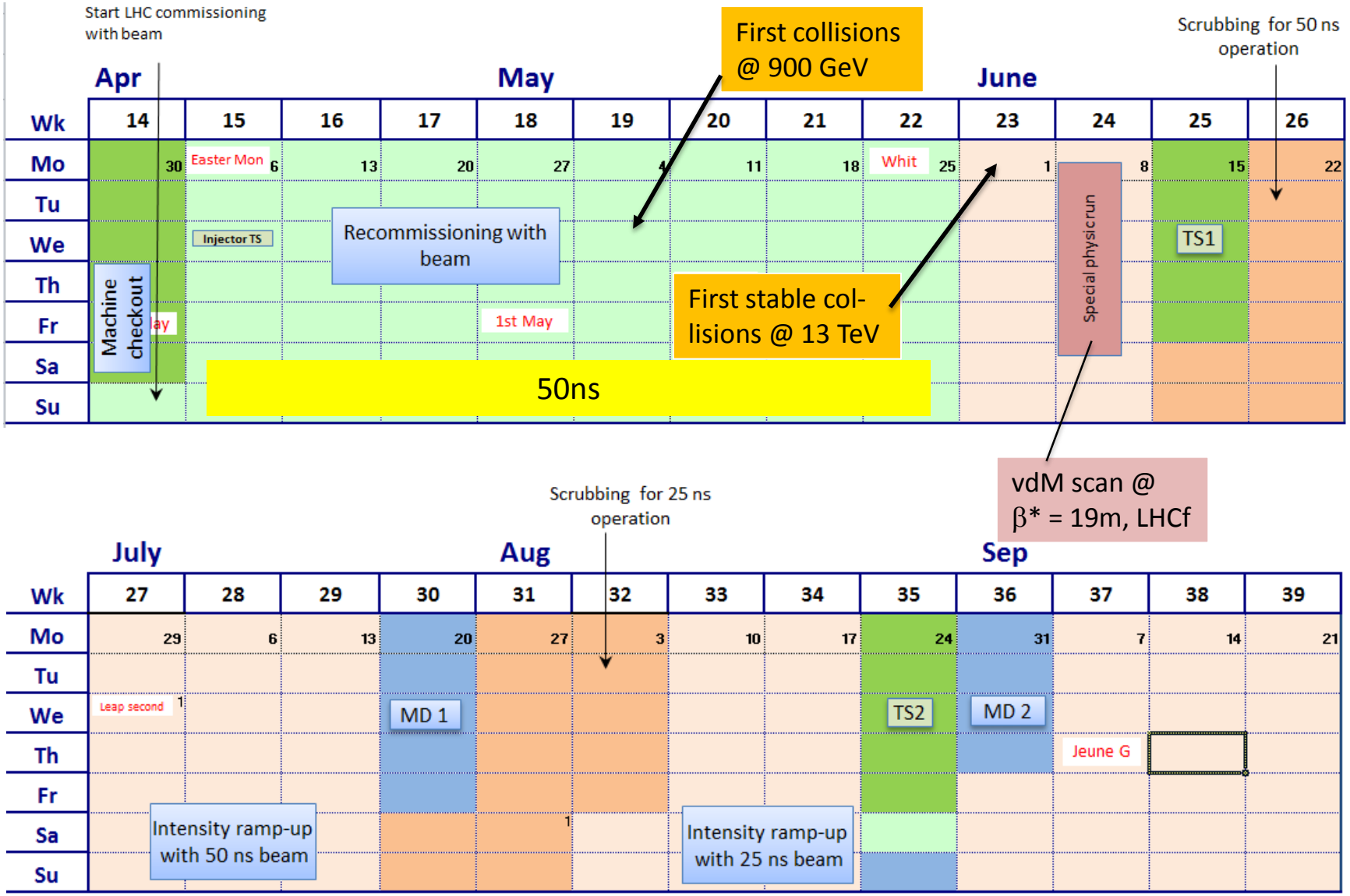






ATLAS, May 6 900 GeV collisions

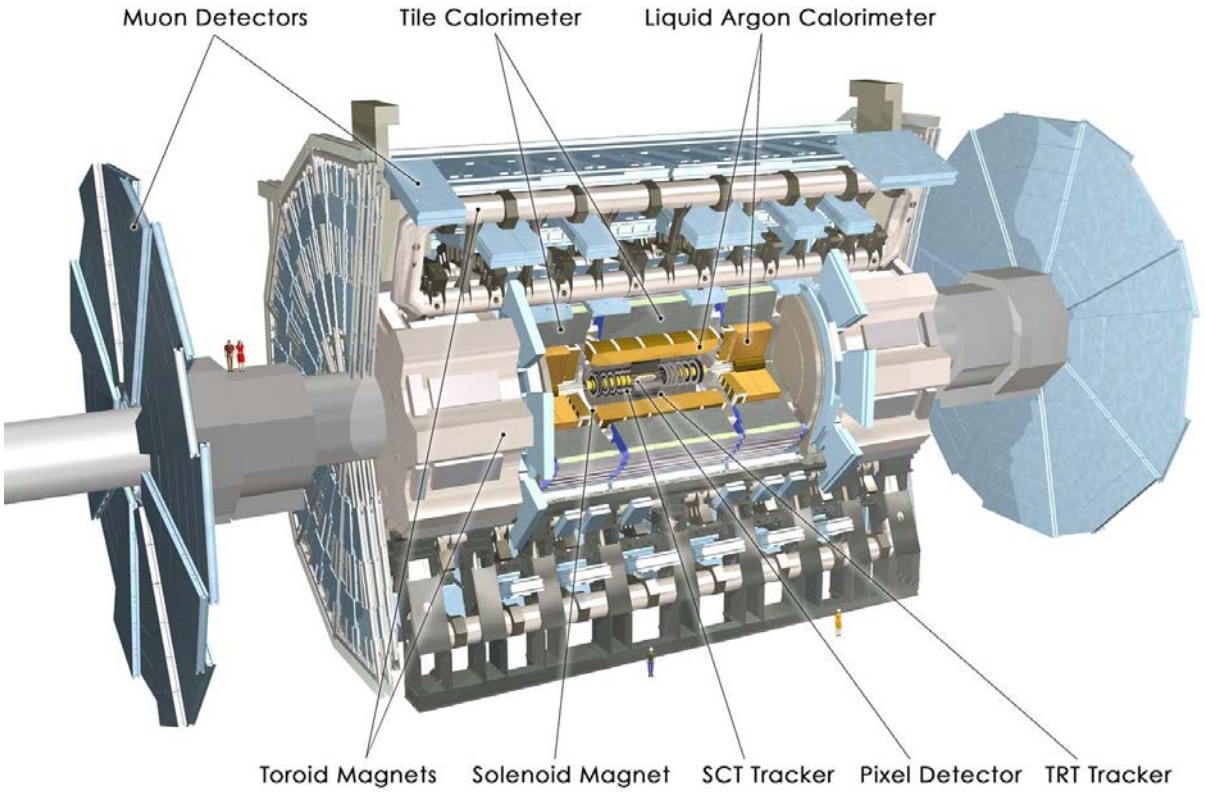
LHC Schedule 2015



v1.4, updated mid April

LS1 Improvements & Additions Commissioning Status

ATLAS



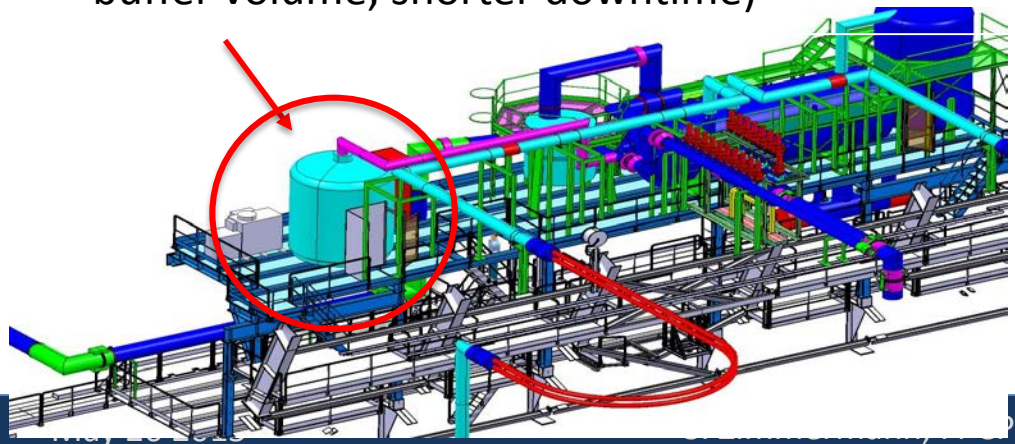
ATLAS: Infrastructure & Magnets

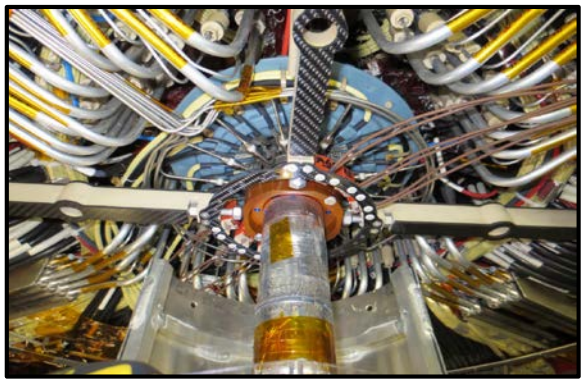
(Selected) LS1 Activities:

- Complete maintenance of safety systems, detector and rack cooling systems (incl. provisions for new systems – IBL), detector gas systems
- Additional 1.5 MVA short-term UPS installation backing up all detector racks
- New beam pipe support with reduced material → reduced contribution to physics background
- Consolidation of ATLAS magnet system, decouple toroid and solenoid recovery in case of fast dump (new He buffer volume, shorter downtime)

1MVA transformer

1MVA UPS in ATLAS SX1 surface building





- All completed and commissioned !!

ATLAS: Muon Spectrometer

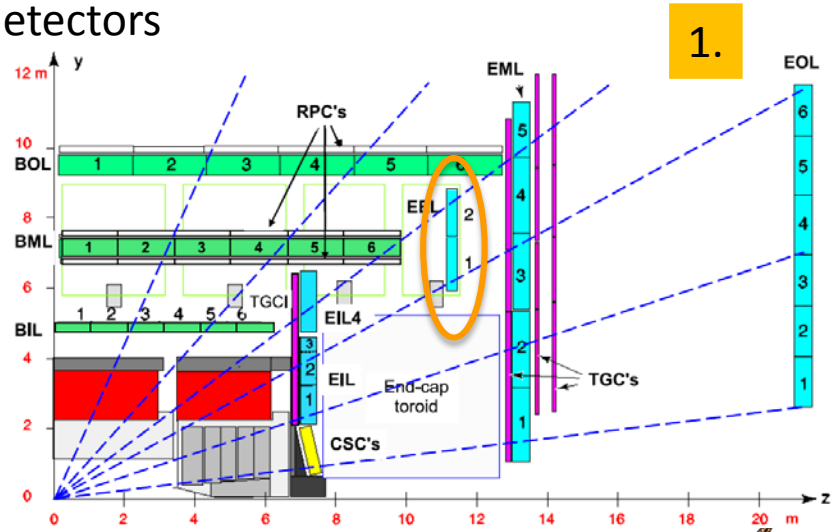
Muon Spectrometer = CSC + MDT + RPC + TGC sub-detectors

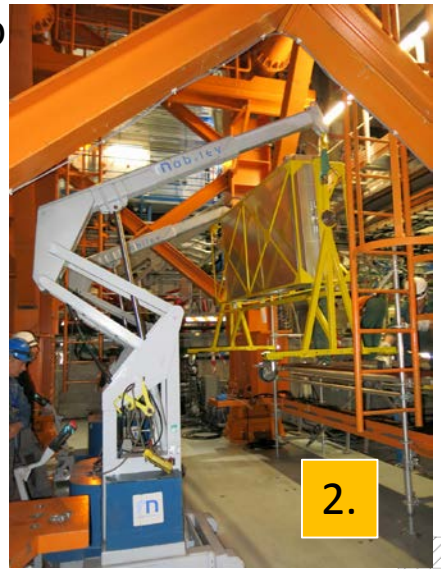
Improving acceptance

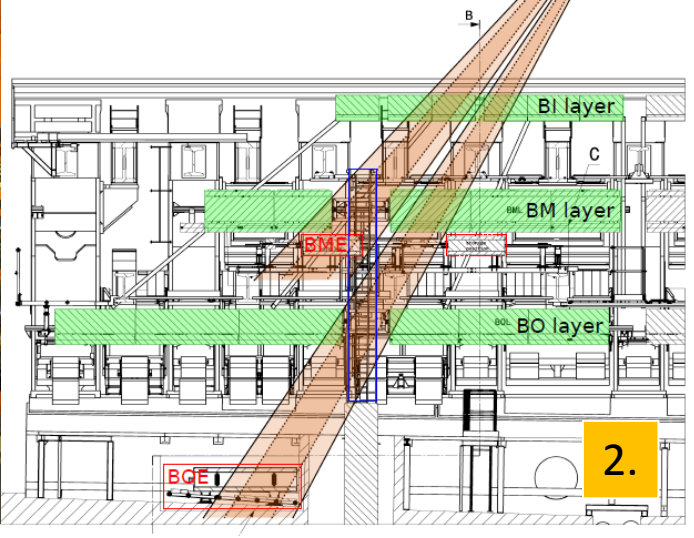
1. Installed remaining EE MDT tracking chambers
   → Nominal TDR configuration (+ ~10% acceptance in 3-station tracks)

2. Installed additional tracking and trigger chambers closing the elevator holes (0.9%)

3. Equipped and commissioned double layer RPC trigger chambers in the feet regio







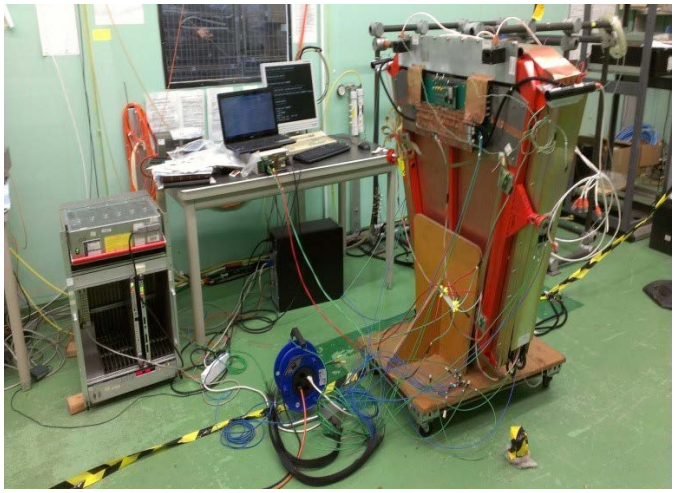
ATLAS: Muon Spectrometer

CSC

- Deployed new readout system, previous system had rate limitations not compatible with 100 kHz L1 rate for run-2

→ Fully commissioned and working well !

- Extracted, repaired and reinstalled chambers with broken HV

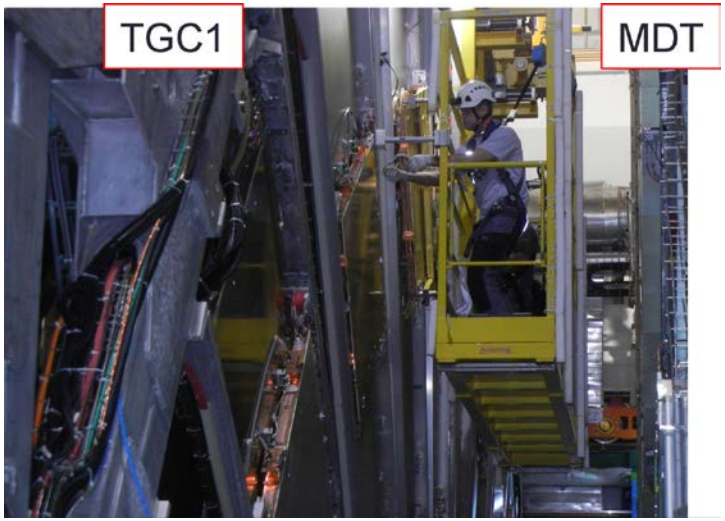


RPC

- Extensive repair campaign for gas leaks (2 teams during almost full LS1)

TGC

- Replaced 27 chambers with HV problems → ~100% working fraction restored
- Added inner endcap station chambers into trigger coincidence to reduce fake L1 muon trigger rate → final commissioning and time adjustment ongoing



MDT

- Alignment with straight tracks: Dedicated cosmics data taken and currently being analyzed, special straight track run with toroid magnet off in ~July during LHC intensity ramp up

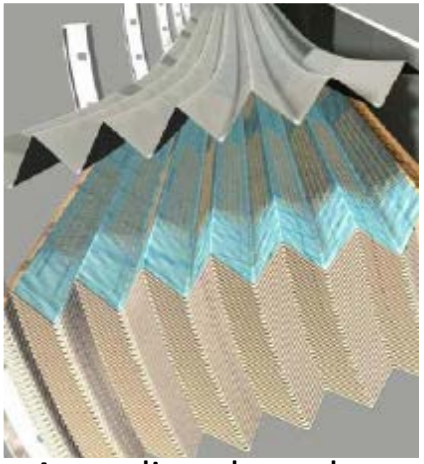
ATLAS: LAR Calorimeter

Liquid Argon technology is used for both electromagnetic calorimeter (barrel & endcap) and in the hadronic + forward endcap calorimeter

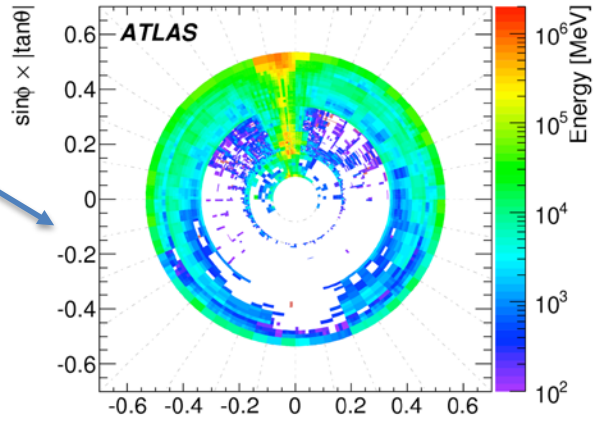
- Repair of broken frontend boards and some broken readout fibers → back to 100% working detector

- Installed new LV power supplies for full detector (higher reliability) – done twice after problems with cracked capacitors detected in spring 2014 → all modules deinstalled, repaired and put back …
- Replaced HV power supplies for part of EMEC and for FCal
  - Precision current reading
  - Fast re-ramping of HV after trip

- Implemented advanced algorithms for online detection of noise bursts and automatic flagging in data quality
- Automatic flagging of hot cells in trigger towers



According shaped electrode geometry for optimal uniformity



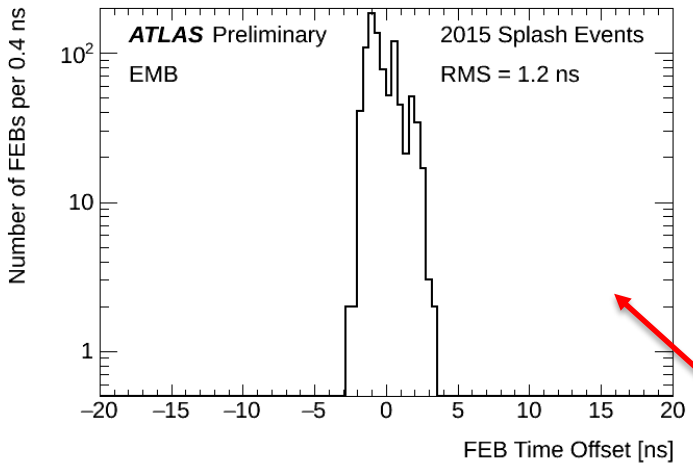
Run-1 noise burst event

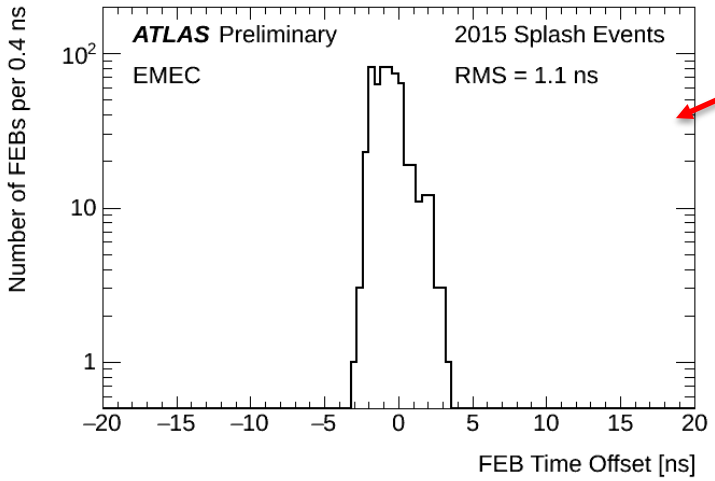
ATLAS p-p run: April-December 2012										
Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
99.9	99.1	99.8	99.1	99.6	99.6	99.8	100.	99.6	99.8	99.5

ATLAS LAR: Beam Splash Events

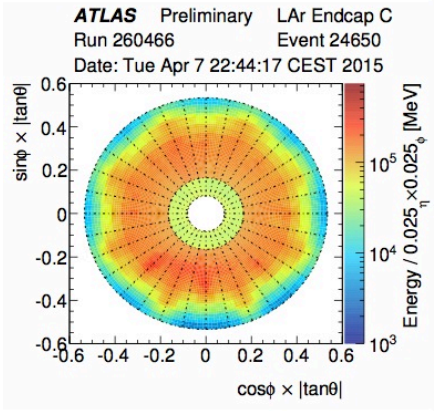
Beam splash events on April 7 on closed collimator before ATLAS

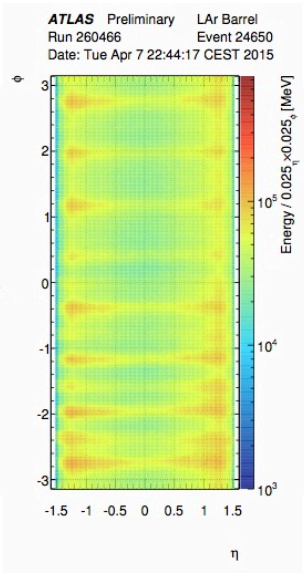
Cell energy distribution

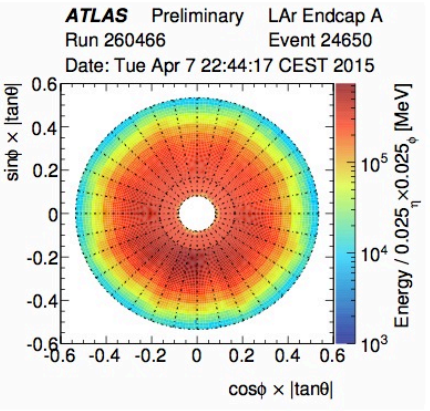


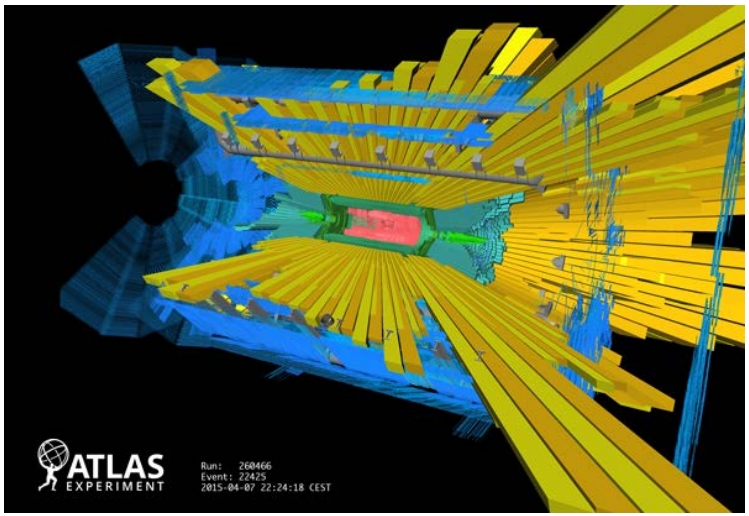


Timing distribution









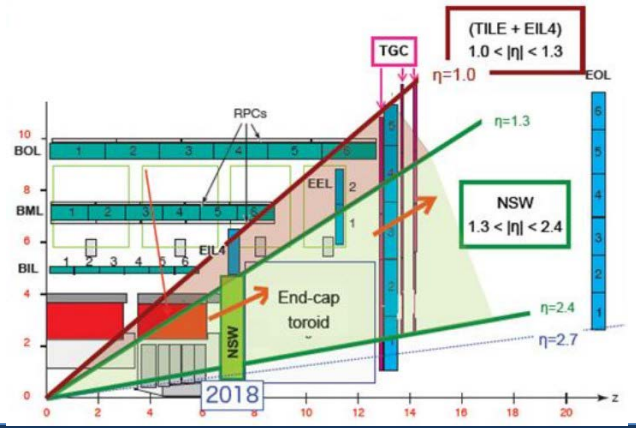
ATLAS: TIL Calorimeter

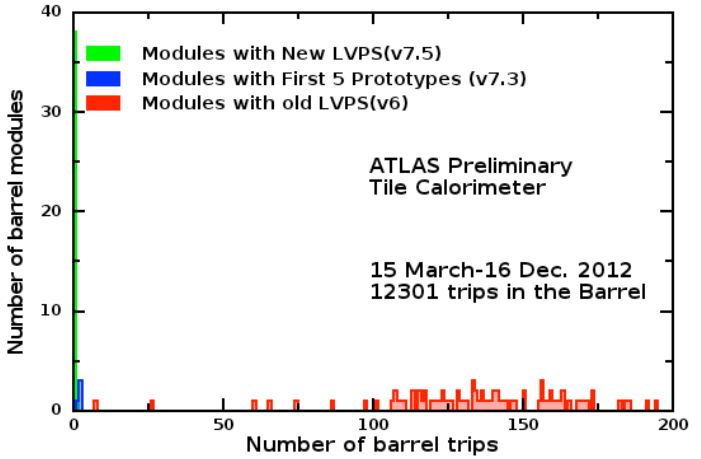
TIL system = hadronic barrel calorimeter, scintillating tiles + iron absorbers

- New Laser-calibration system, currently being commissioned
- First Cs source based calibrations performed
  - Goal is to preserve absolute run-1 energy scale

- Replaced LV power supplies → solved LV trip problem in run-1, main cause for ~1% bad data fraction in run-1 despite automatic recovery procedure

- Consolidation work o frontend electronics drawers to recover 3-5% dead towers towards the end of run-1
- New trigger electronics provides coincidence between TIL and TGC muon chambers → fake rate reduction





ATLAS: Inner Detector – TRT/SCT

Inner Detector = TRT + SCT + PIX + new IBL sub-detector

Transition Radiation Tracker

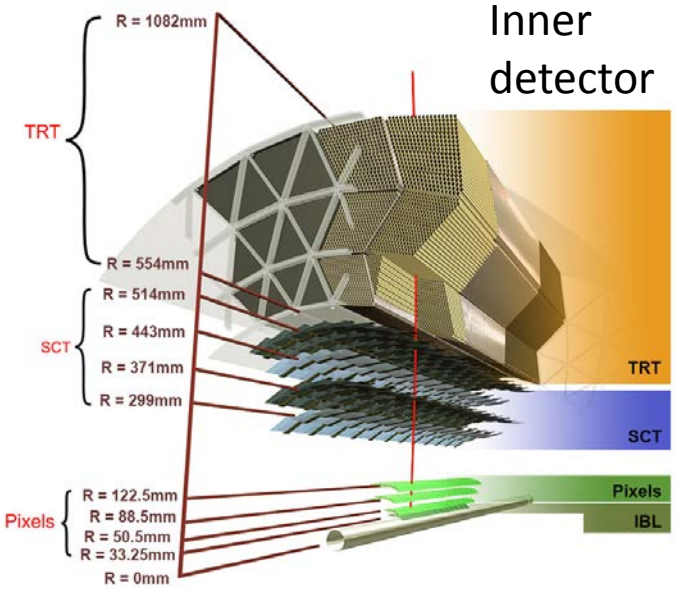
- At the end of run-1 suffered from leaks from cracked gas connections → for run-2 developed option to run part of the detector with Ar instead of Xe-mixture
  - Impact on electron identification is small

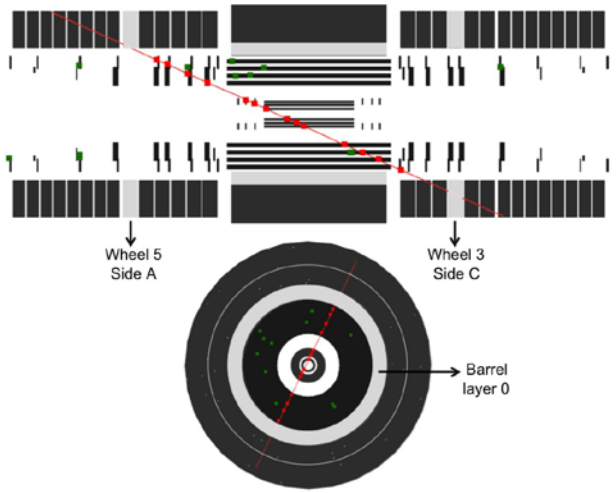
- Upgrade of DAQ and new readout firmware/data compression to cope with high occupancy and >= 100 kHz L1 rate

Silicon Strip Tracker

- Replacement of off-detector optical transmitters which had high failure rate during run-1
- Installation of additional RODs and back of crate cards to cope with run-2 increased pile-up

- Noise and gain identical to run-1, > 99% good channels

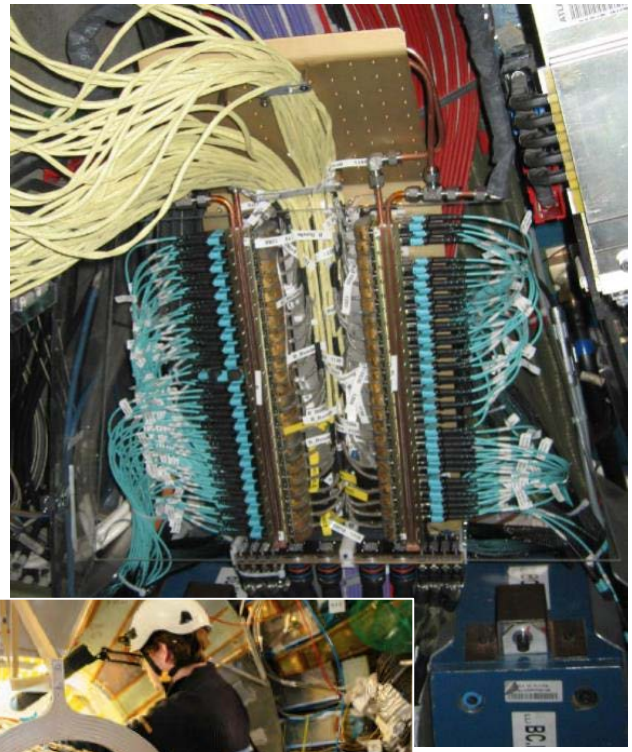




2015 TRT baseline (Xe/Ar)

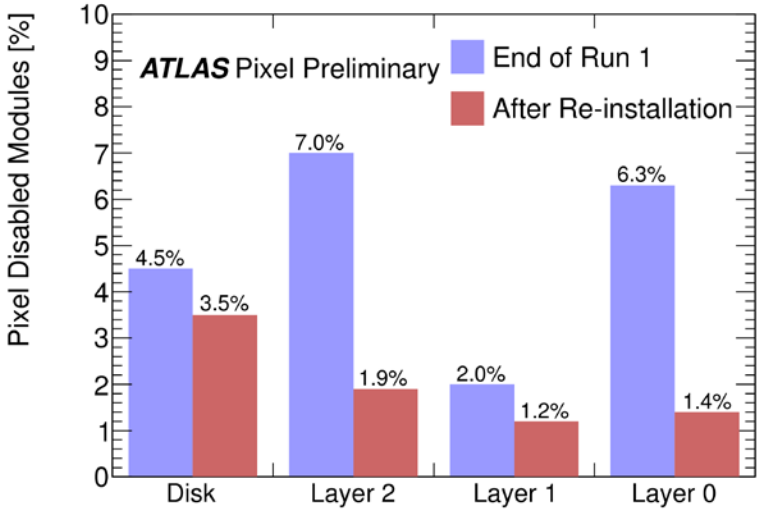
ATLAS: Inner Detector -- PIX

- ATLAS Pixel detector was de-installed and removed from the cavern at the start of LS1 and reinstalled in autumn 2013

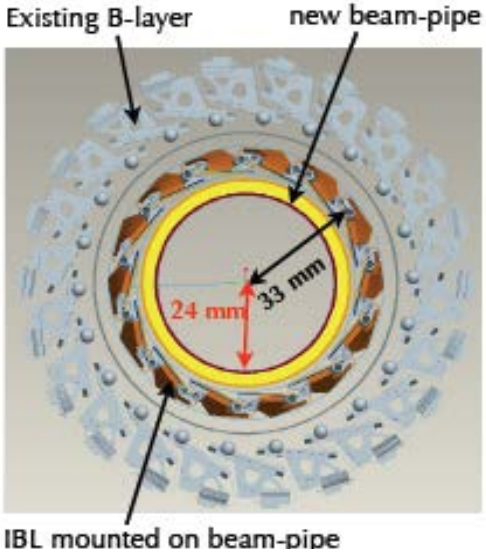


- On-detector services up to innermost patch panel replaced
- Opto-electronics relocated to off-detector location for accessibility outside long shutdowns
- Repaired all accessible module failures

- Increased data bandwidth for run-2 and beyond: Installed additional RODs/ROCs

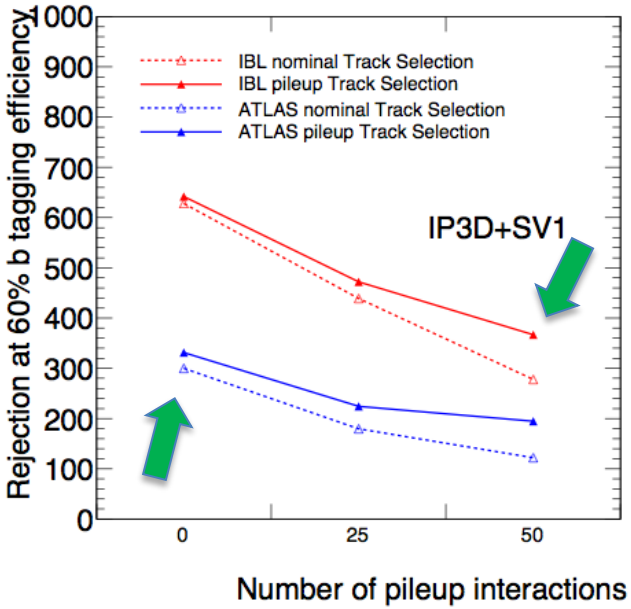


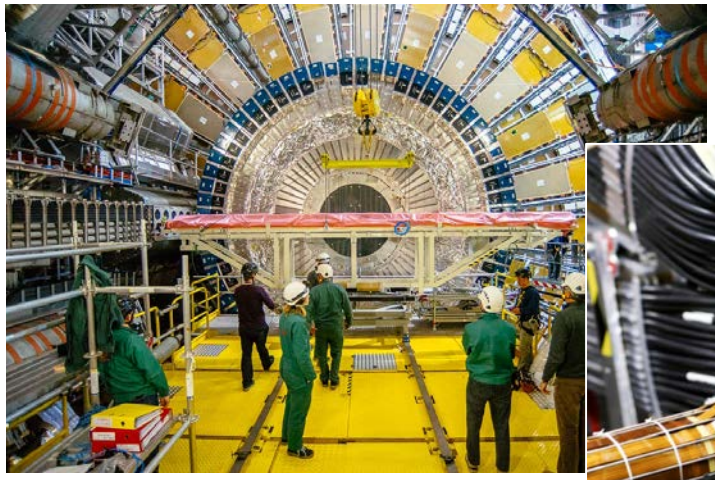
ATLAS Inner Detector – IBL



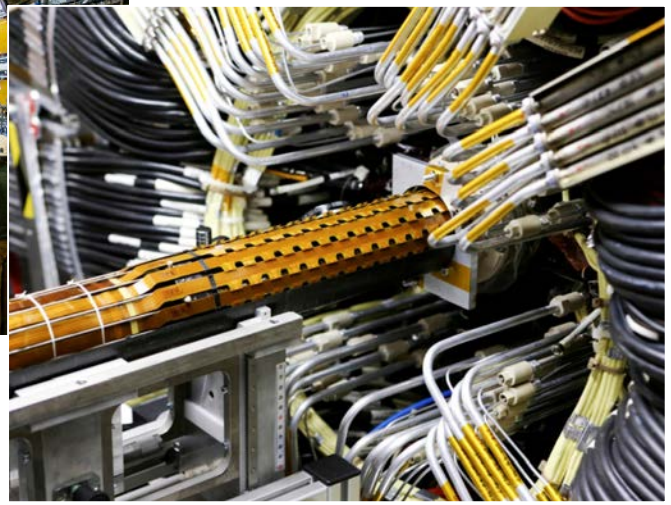
Insertable B-Layer = Major new detector installed during LS1

- additional Pixel layer @ 33mm from the beam axis
- 50 × 250 μm^2 pixel size, compared to 50x400 for Pixel)
- Radiation hard up to LS3 (2023) due to 130 nm CMOS technology
- More robust b-tagging, improved rejection against light jets at high pile-up
- IBL installed in ATLAS in May 2014





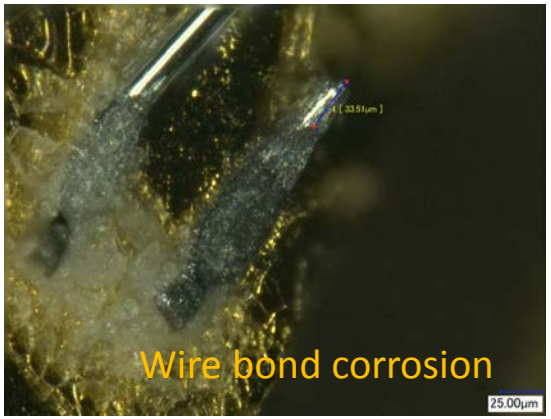
Very tight tolerances



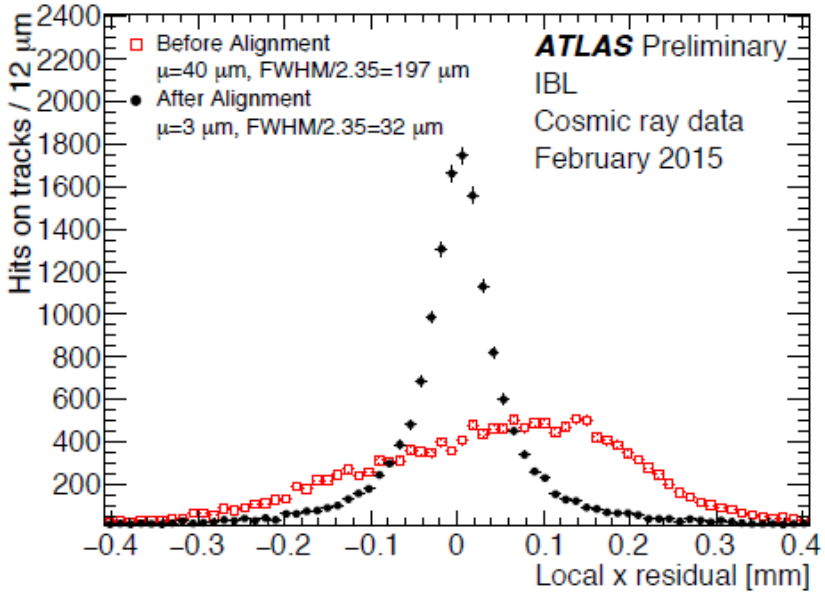
ATLAS Inner Detector -- IBL

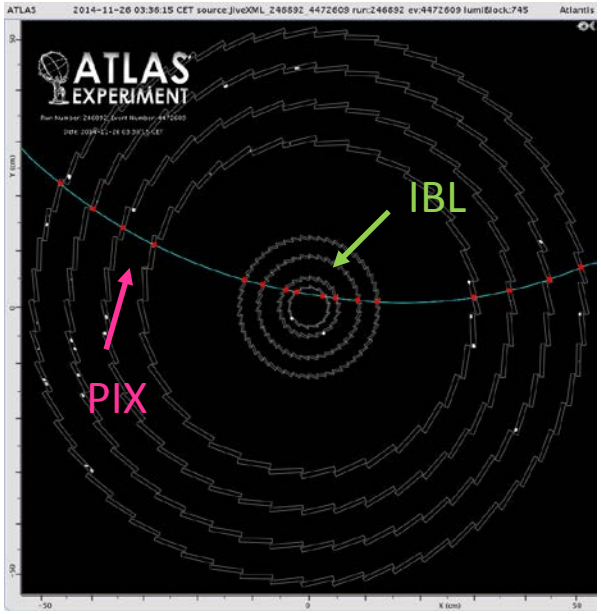
IBL Commissioning, Alignment with cosmics:

- 100% modules working
- > 99.9% channels working when installed
- Problems with wire bond corrosion discovered during assembly were resolved by cleaning and re-doing wire-bonds for half of the staves
- Taking cosmics data together with Pixel since end of 2014, incl. special alignment runs with ATLAS solenoid in spring this year



Global positions known O(1µm), module resolution ~30µm !!

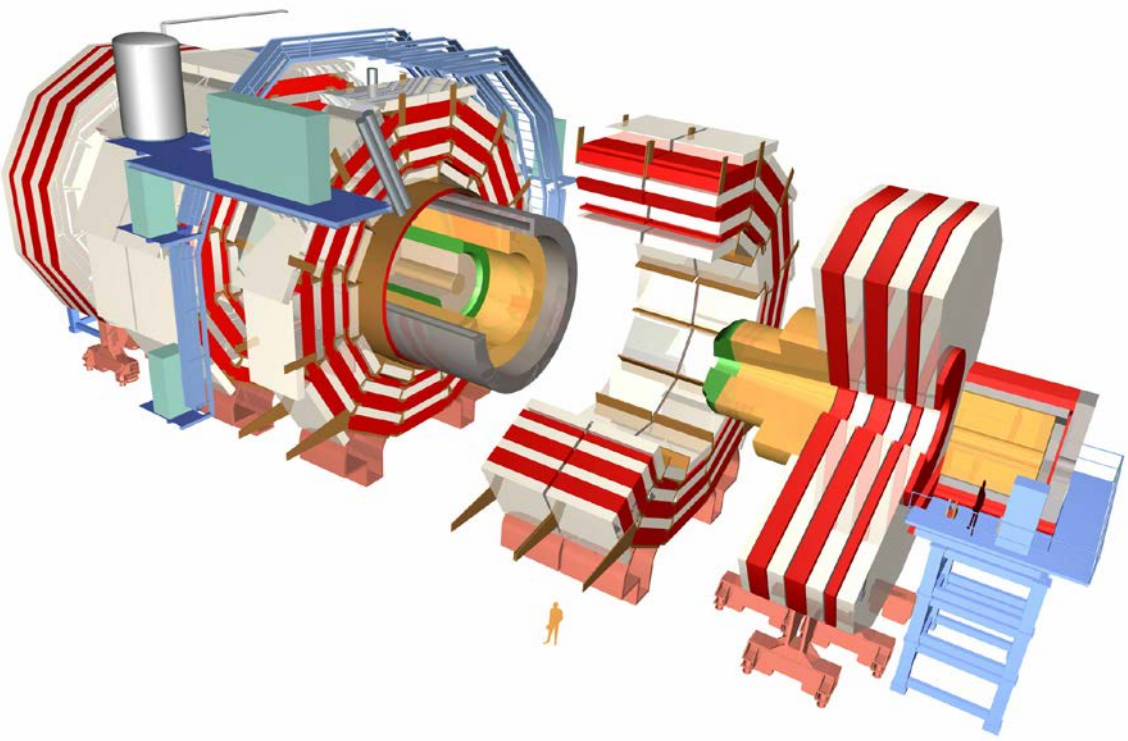




Cosmic muon track with PIX and IBL hits

LS1 Improvements & Additions Commissioning Status

CMS

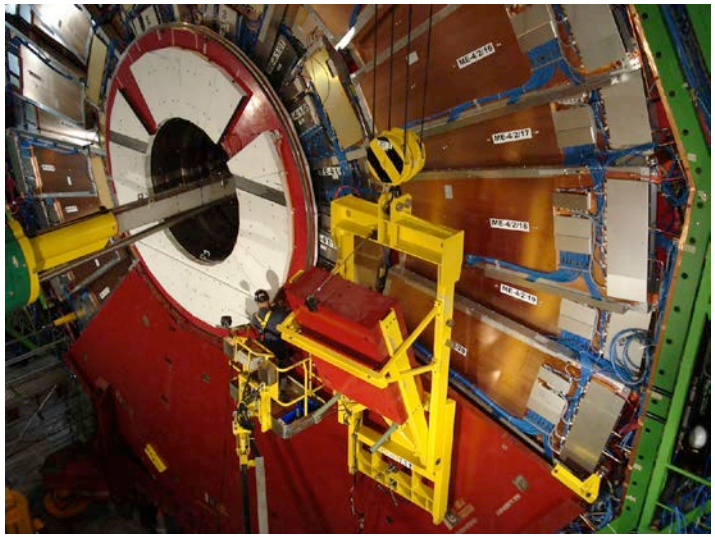


CMS: Infrastructure

(Selected) LS1 Activities:

- Complete maintenance of safety systems, cooling, gas, …

- Installation of new beam pipe
  - Reduced diameter: 45 mm
  - Beryllium material for minimal radiation-length
  - Geometry optimized and ready for new tracker installation in extended end of year shutdown 2016
- Construction and installation of shielding walls in both endcaps to reduce background

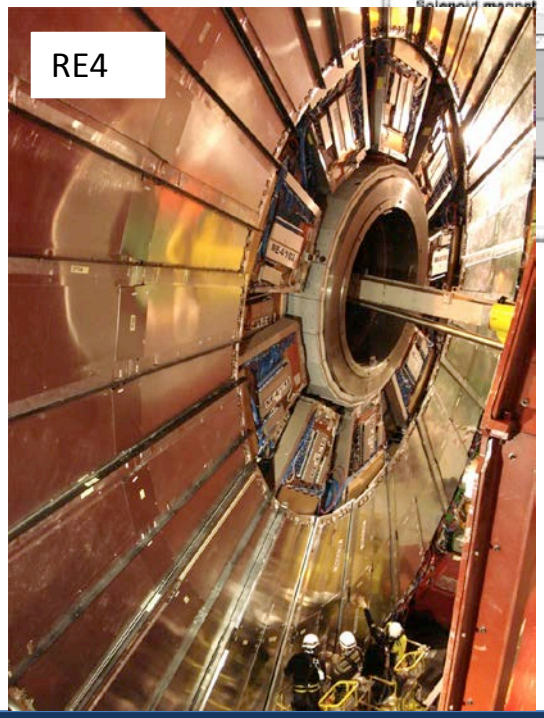


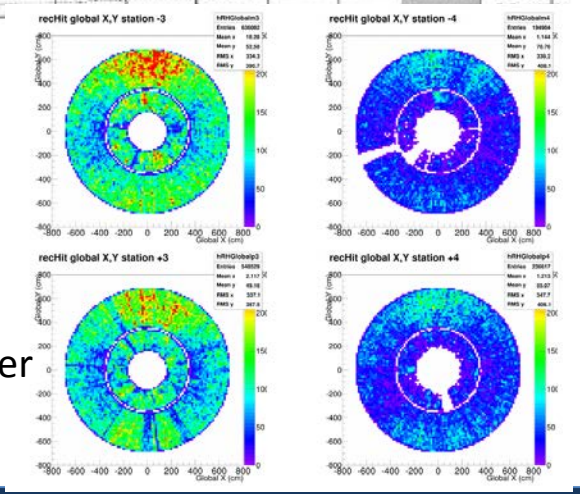
CMS: Muon System

Muon System = Drift Tubes (DT) + CSCs + RPCs

Completion of the 4th layer

- Installed 72 new ME4/2 CSC chambers
- Installed 144 new RE4 RPC chambers
- Excellent performance





Summer 2014

CMS: Muon System

CSC:

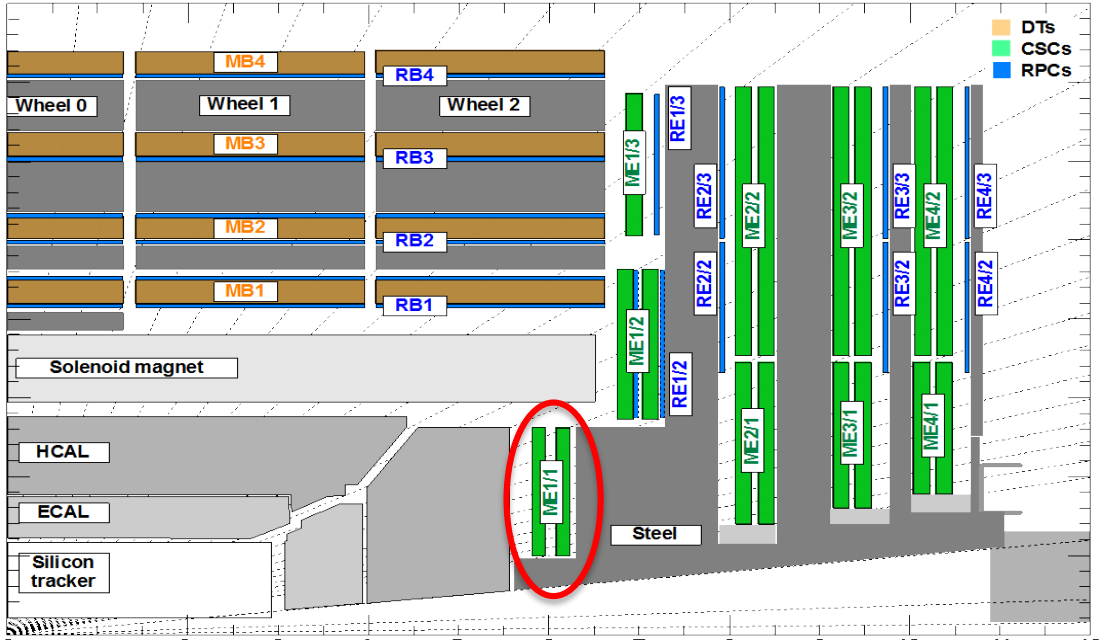
- Removal, refurbishment and reinstallation of ME1/1 chambers/chamber electronics

DT:

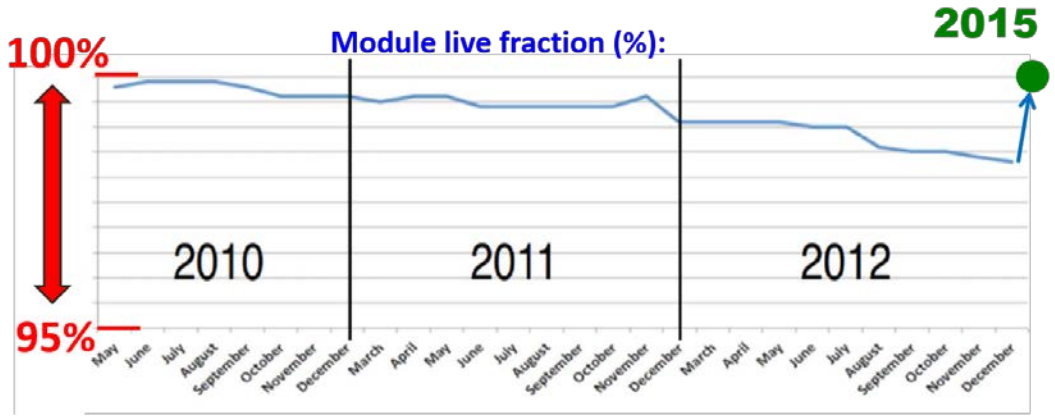
- Recovery of ~ 1.5% degradation of tubes from run-1
- Installed 3500 new optical links, 20 new electronics crates
  → to relocate electronics to more accessible place out side the experimental cavern

RPC:

- Very low noise: < o,1 Hz/cm2
- Low current (no beam): <2µA/chamber
- High efficiency >= 95% average comparable to run-1

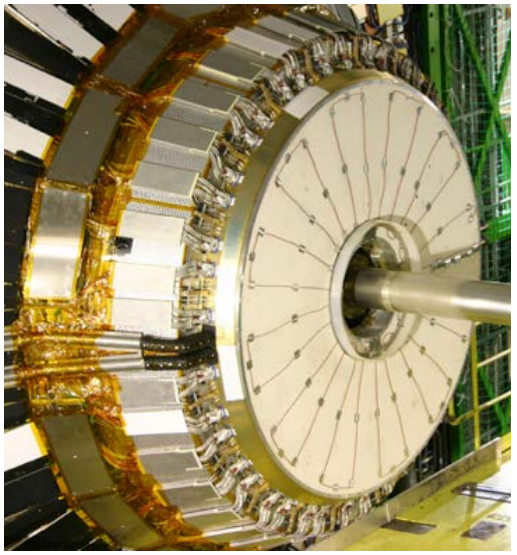


CMS DT



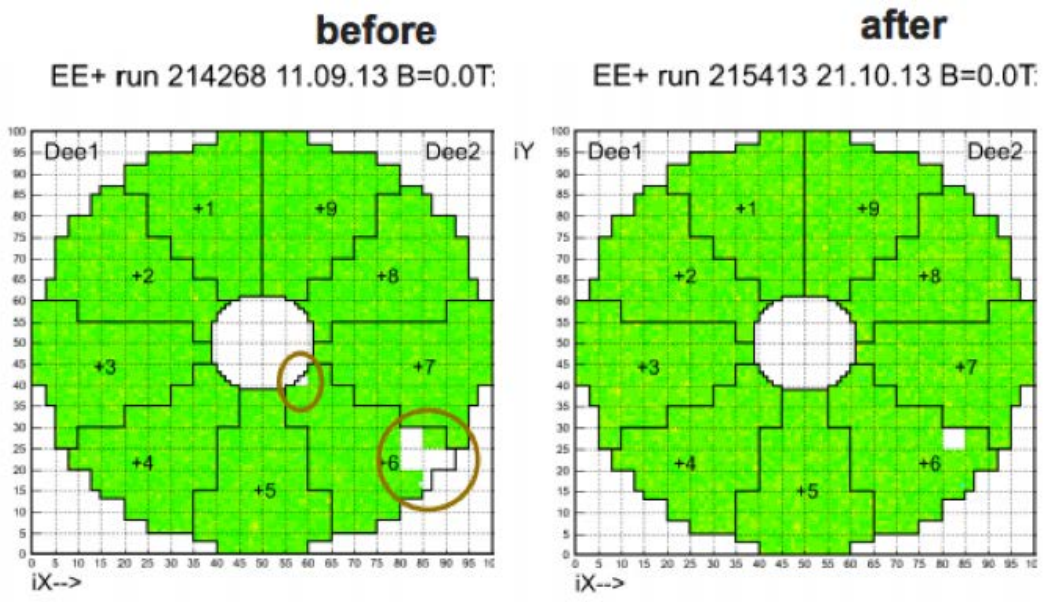
CMS: Calorimeters (ECAL)

- Recovered dead channels due to LV connector fault in the endcap
  - Both ES disks were de-installed during LS1, moved to the surface, repaired and reinstalled
  - → 99.95% channels operational (from 96.8% at end of run1)



- HV connector repair on the pre-shower detectors
- Moved successfully to operating the pre-shower at -8°C for run-2

- New ECAL local reconstruction algorithm with better out-of-time pileup rejection



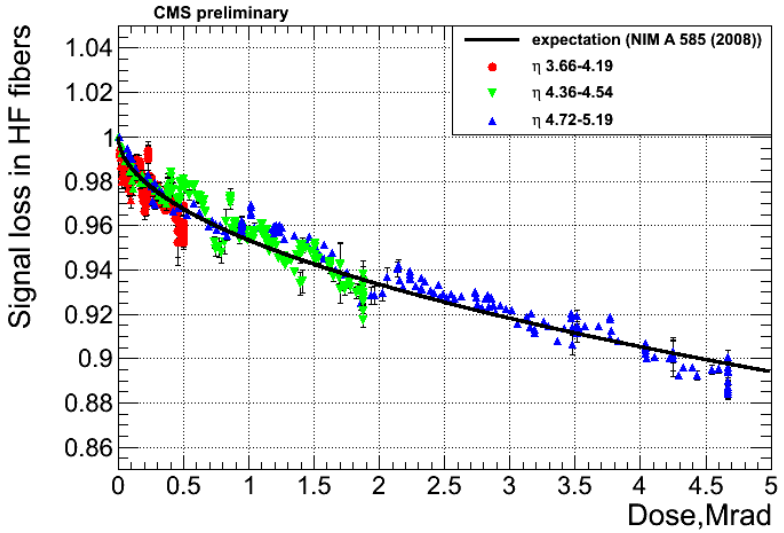
CMS: Calorimeters (HCAL)

Upgrade/Replacement of photo-detectors

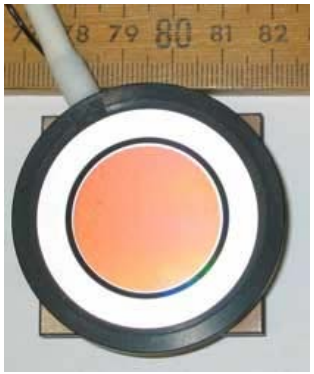
- Magnetic field insensitive, radiation tolerant high-performant SiPMs instead of Hybrid Photo Diodes (HPDs) in all of the HO Barrel
  - Much better identification of MIPs
  - Good for up to 3000 fb-1 integrated lumi, better signal/noise ration than the HPDs
- New thin-window dual-anode readout PMTs in the HF forward region
  - Reduce Cherenkov noise from punch-through muons
  - Reduction of anomalous signals

Other activities

- New back-end electronics for HF installed
- Refurbished and re-established calibration system using radioactive Co-60 sources



2010-2012 light loss in HCAL HF quartz fibers

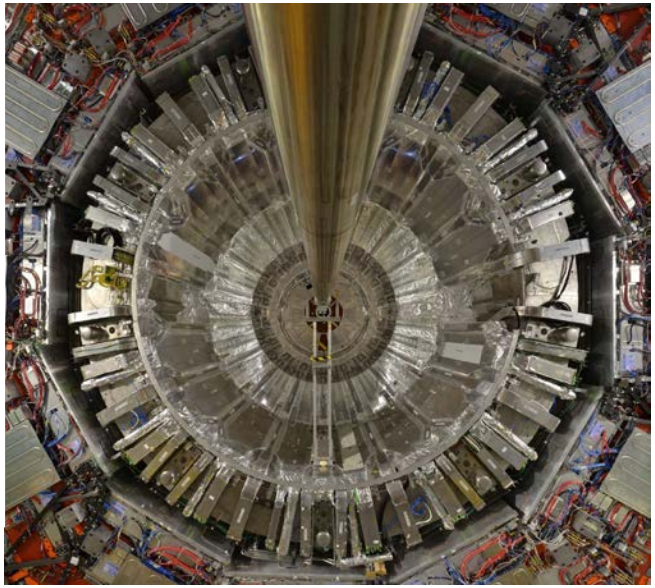


HPD → SiPM

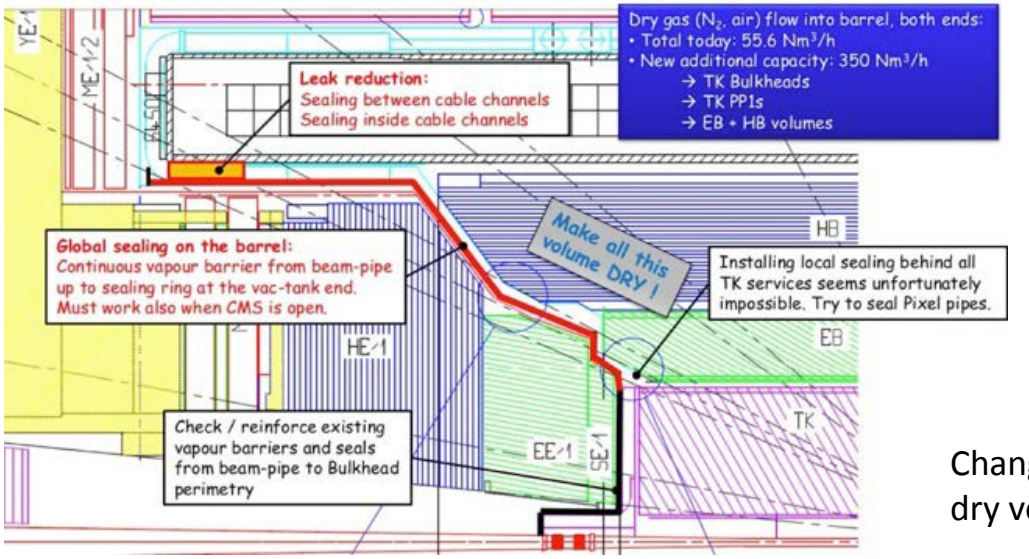
CMS: Strip Tracker

Major difference to run-1: Tracker running "cold" (-10°C .. -20°C) instead of +4°C

- Leakage current doubles every 7°C, plus with increasing radiation dose. Already at ~30% of power supply limit end of 2012 → cold operation ensures efficient performance across run-2
- Dry gas system, new seals, new bulk head panels with heater elements on the outside, dew point sensors and monitoring all working reliably and to specification
- Calibration @ -15 °C completed early this year with cosmics



Si strips with final seal in place



Changes to achieve dry volume

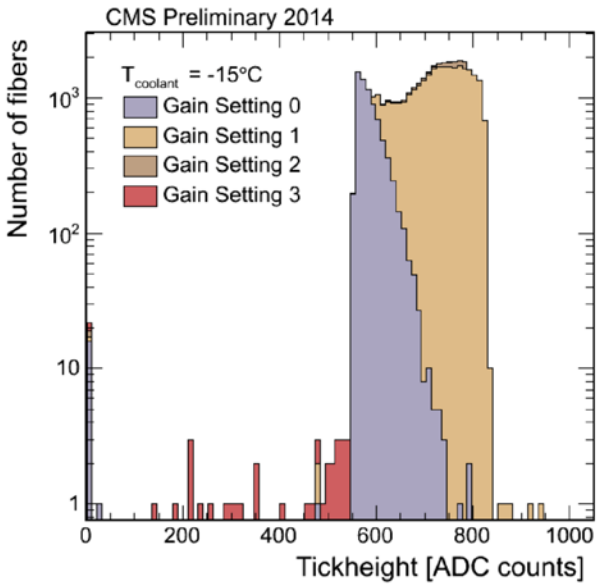
CMS: Strip Tracker Calibration

Main calibration steps:

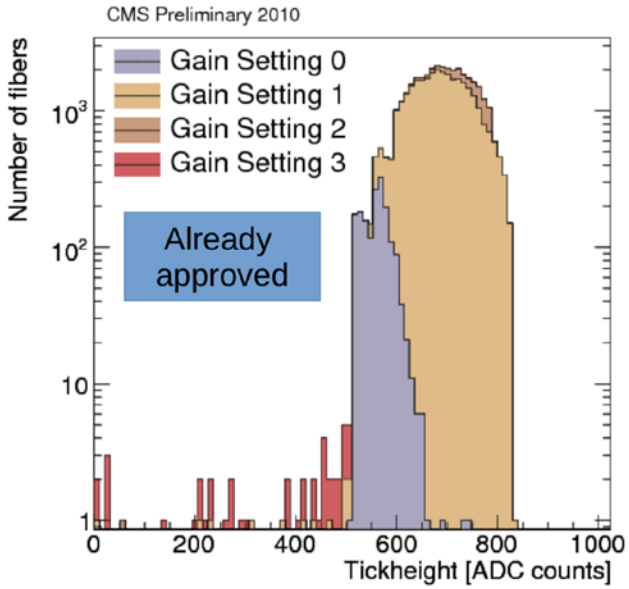
- Internal timing – synchronize channels
- Laser gain tuning
- Chip parameter tuning (pulse shape)
- Noise measurement/optimization
- Trigger timing – align samples with physics events

>= 98% working channels for start of run-2, recovered ~0.5% from end of run-1 !!

Example: Link gain settings “warm” versus “cold”



2014: -15°C cooling plant set point

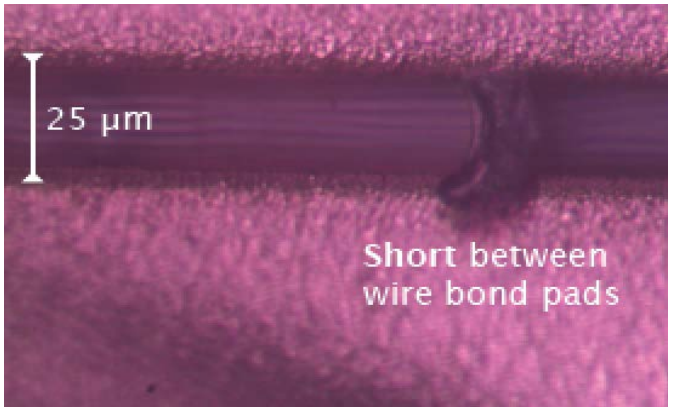


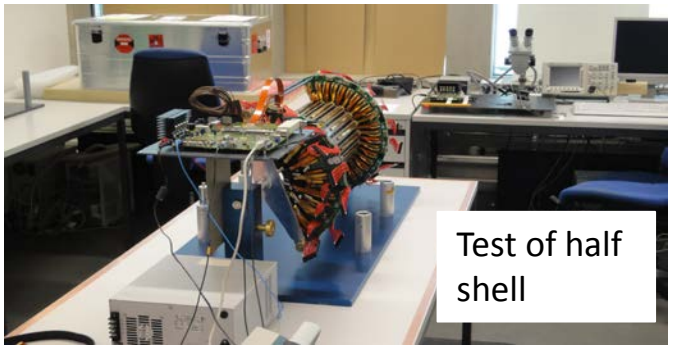
2010: +4°C cooling plant set point

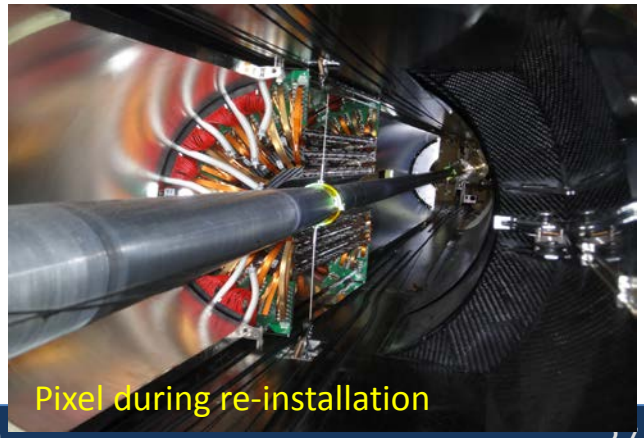
- Link gain increases with decreasing temp.
- Can operate more links at lowest gain setting in 2014
- Link gain is expected to decrease with accumulated radiation

CMS: Pixel Tracker

- Pixel system moved to surface during LS1 and overhauled
- Problems found just prior to reinstallation with 47/192 (1 quarter) of the BPIX not or only partially responding was resolved
  - Ohmic short between wire bonds pads and interconnects
  - Concerned half-shell was reworked at PSI, short removed
- Working detector fraction after repair: 99.2%, compared to 96.3% during run-1 !
- Pixel has been fully calibrated (in cold conditions) with cosmics rays and is ready for physics data taking !

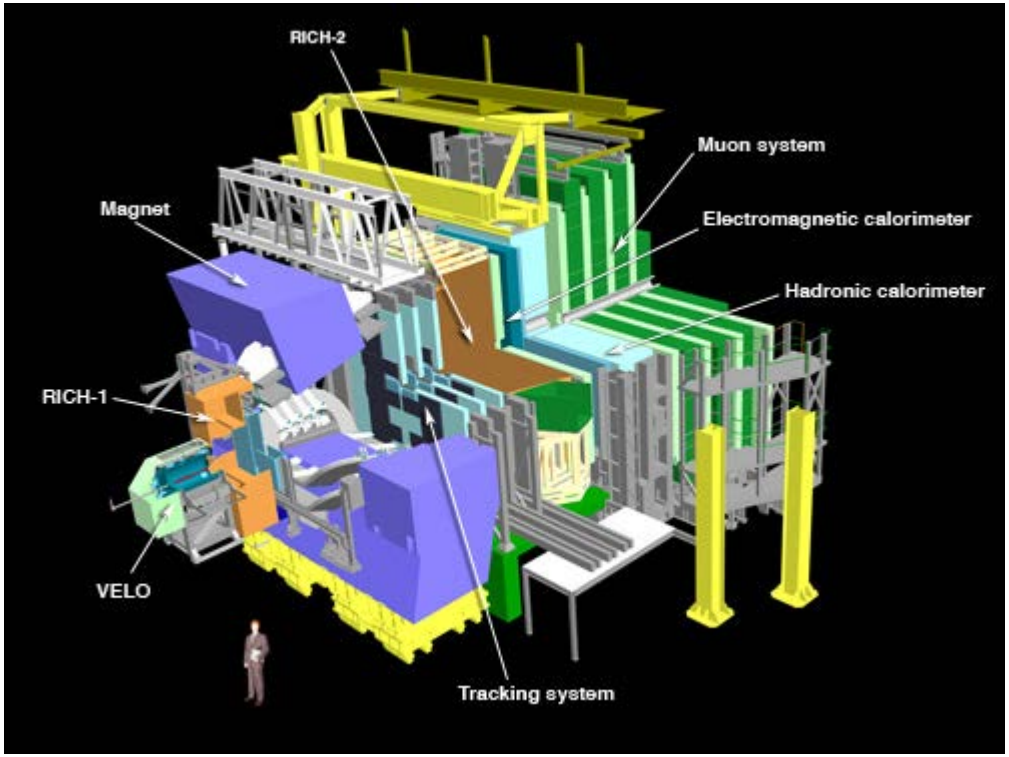



Test of half shell


Pixel during re-installation

LS1 Improvements & Additions Commissioning Status

LHCb



LHCb: LS1 Detector Activities

LHCb plans foresee major upgrade program of the detector in 2018/19 → during LS1, less new elements compared to CMS & ATLAS

Major LS1 activities:

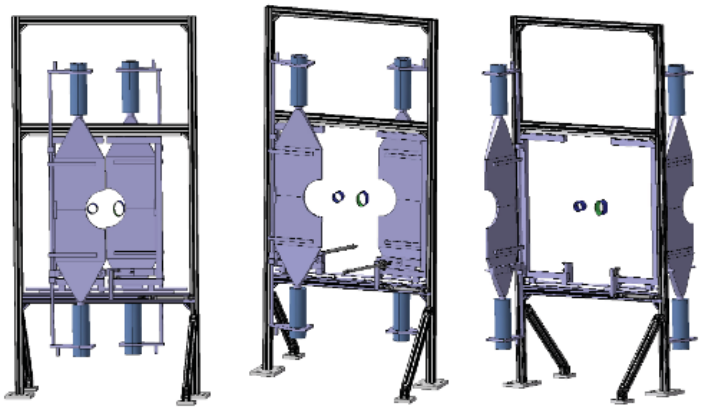
- New beam pipe installed during LS1
  - Be-material, minimizing the radiation length (multiple scattering)
- Replaced 15% of photo tubes in the Hadronic Calorimeter (HCAL)
- Replaced monitoring fibers for Electromagnetic Calorimeter /ECAL) due to degradation in light yield
- RICH: Replaced HPDs

- Maintenance and overhaul of cooling, gas, safety and other infrastructure systems

- Campaign to partially remap the LHCb magnetic field
- Installation of BCAM alignment sensors on the inner tracker to monitor the position

LHCb: HeRSChel

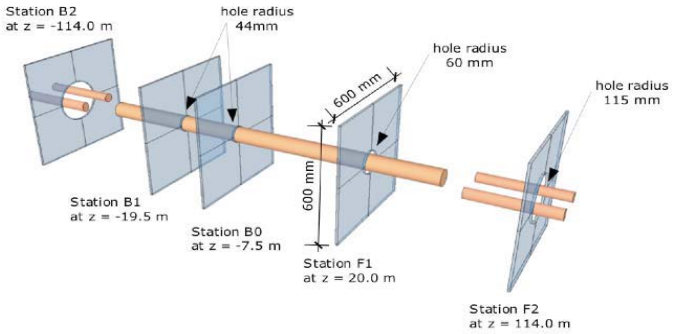
New High Rapidity Shower Counters for LHCb

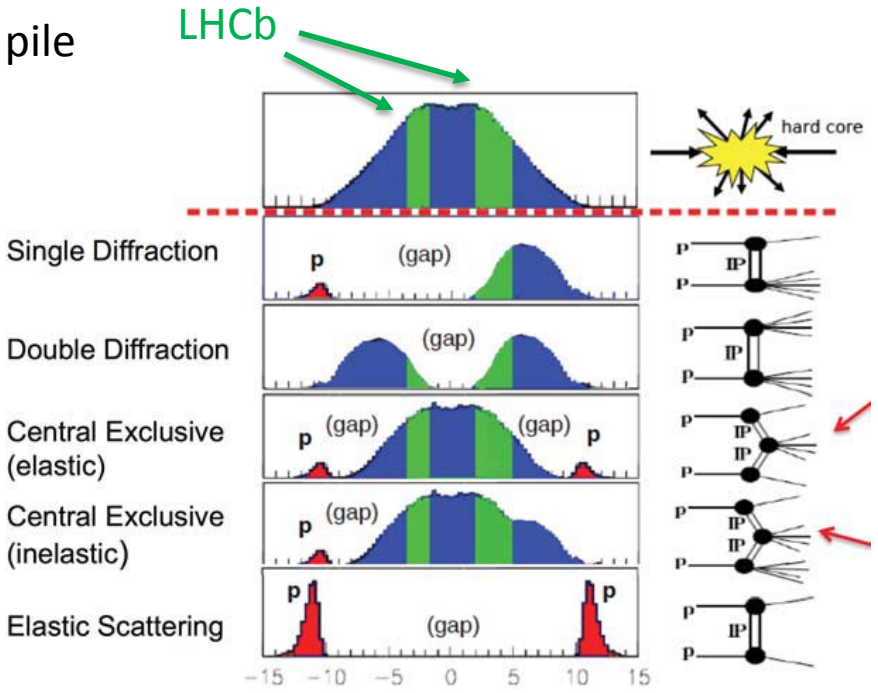


- Plastic Scintillator planes with PMTs on both sides of the LHCb experiment, placed in the LHC tunnel
- Retractable from the beam axis outside stable beams

- Tag background in high eta region between $\eta = 5..8$
- Study central exclusive production in run-2 low pile up data taking
  - Challenge to establish the rapidity gap

- Interesting also for luminosity and beam background understanding

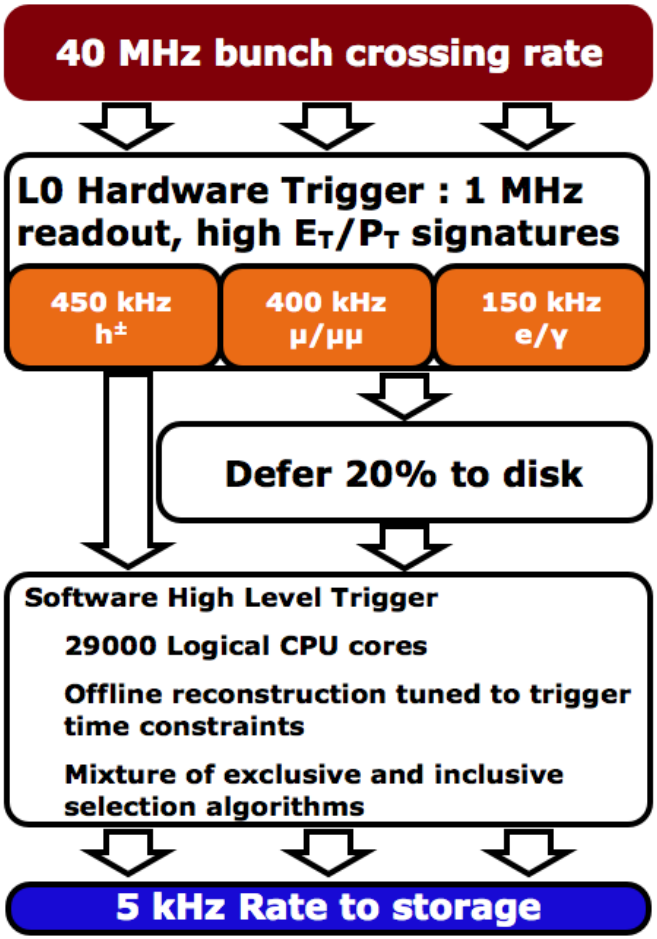


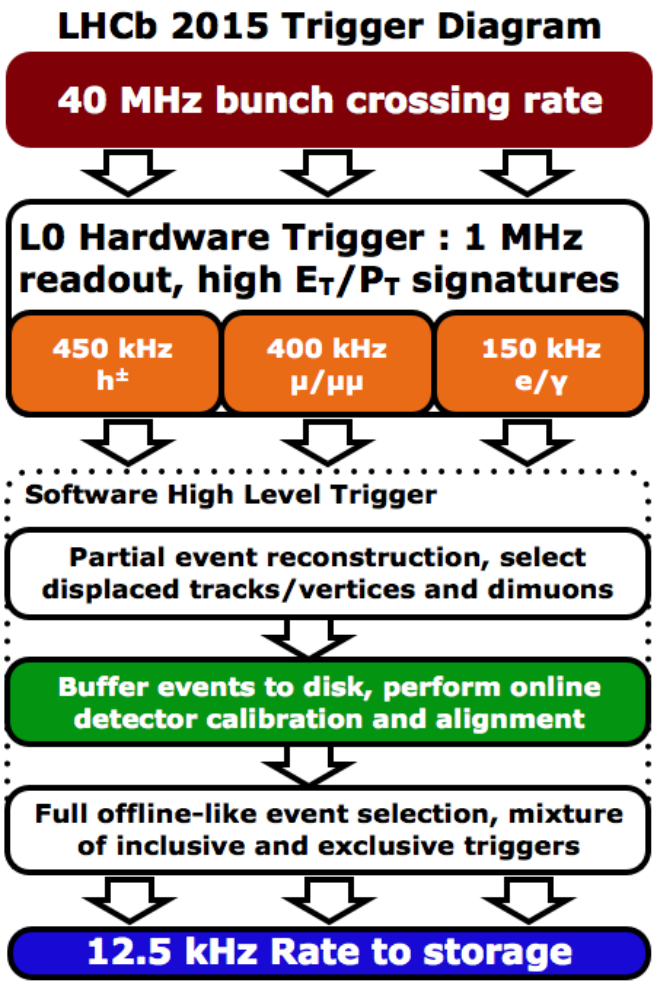


LHCb: Trigger

Biggest change between run-1 and run-2 is for the trigger + online calibration (incl. alignment)

2010-2012





- Split High level trigger
- Fast reconstruction and initial selection run on each event
- Online calibration + alignment in 2nd step
- Same track reconstruction online as offline
- Enriched selection + higher data rate stored

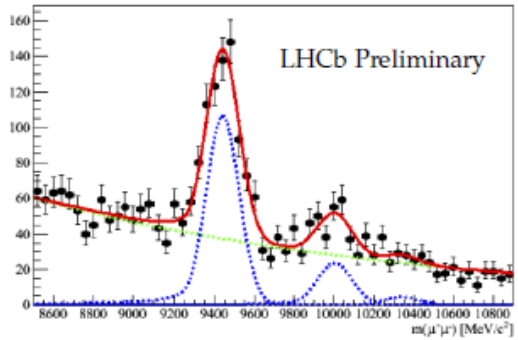
LHCb: Online Calibration & Alignment

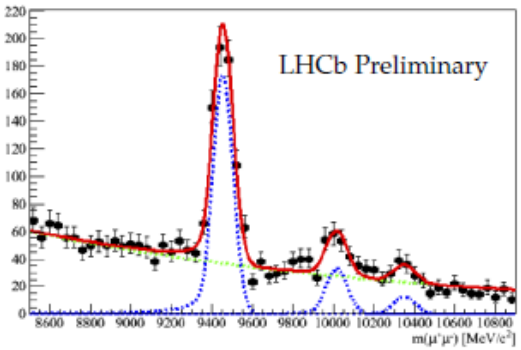
Run-2:

- Automatic real-time alignment procedure for the tracking detector and the RICH
- Online calibration for calorimeters and RICH

→ Minimize difference between online and offline, especially since also HLT and offline use same reconstruction, different from run1 !

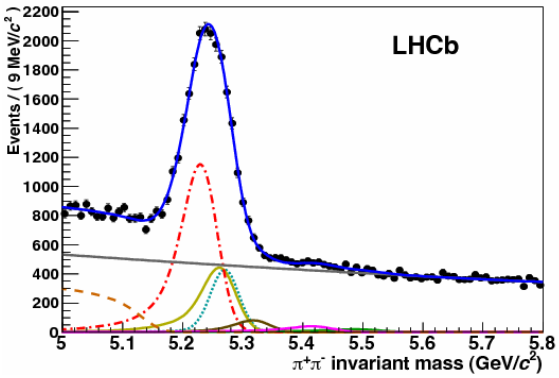
→ Increased trigger efficiency and tighter selection, including for particle ID

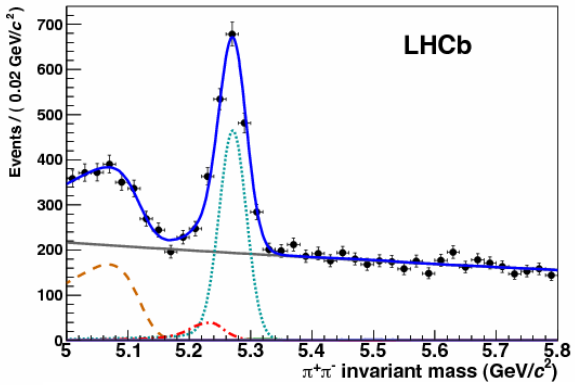




Example: Y→ μμ
92 → 49 MeV/c2 from first to sub-sequent alignments
(B. Storaci, CHEP 2015)

Example: $B^0 \rightarrow \pi^+ \pi^-$ without and with additional PID cut
(B. Storaci, CHEP 2015)





LHCb: Online Calibration & Alignment

RICH

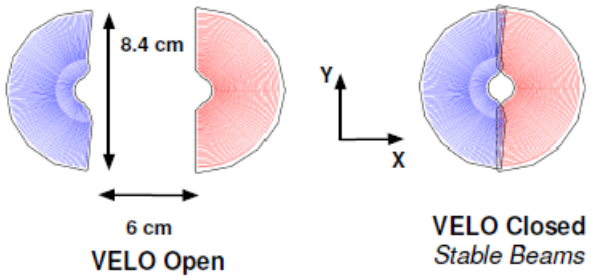
- new HLT calibration for each run
  - Gas refractive index
  - Drift of photo detector gain

Calorimeters

- Regular gain adjustments needed
- In run-1 done using LED system in interfill gaps
- For run-2 perform fill by fill using occupancy based method

Detector alignment

- At the beginning of each fill → update constants when needed
- Vertex locator (VELO) Half shells move for each fill when stable beams is reached – alignment precion O(few µm)
- Time variations over few weeks of the tracker alignment, partially due to magnetic field polarity change
- RICH mirror alignment rare variations
- Little or no variations expected for the Muon chamber alignment



Conclusions

- Beams back in the LHC machine since beginning of April concluded a very itense 2 year long shutdown
- Major maintenance, consolidation and upgrade work completed for ATLAS, CMS and LHCb
  - ATLAS and CMS reached their nominal configuration (CMS 4th muon layer, ATLAS EE muon chambers)

- All 3 detectors have been running intense commissioning with cosmics since (many) months, and are completing commissioning with beam splashes, single beam and initial collisions
- All 3 detectors are in very good shape with numbers of dead channels similar to the one at the beginning of run-1

- Eagerly awaiting first physics run with stable beams !