

# CMS Status Report

121<sup>st</sup> LHCC Meeting – Open Session

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On behalf of the CMS Collaboration

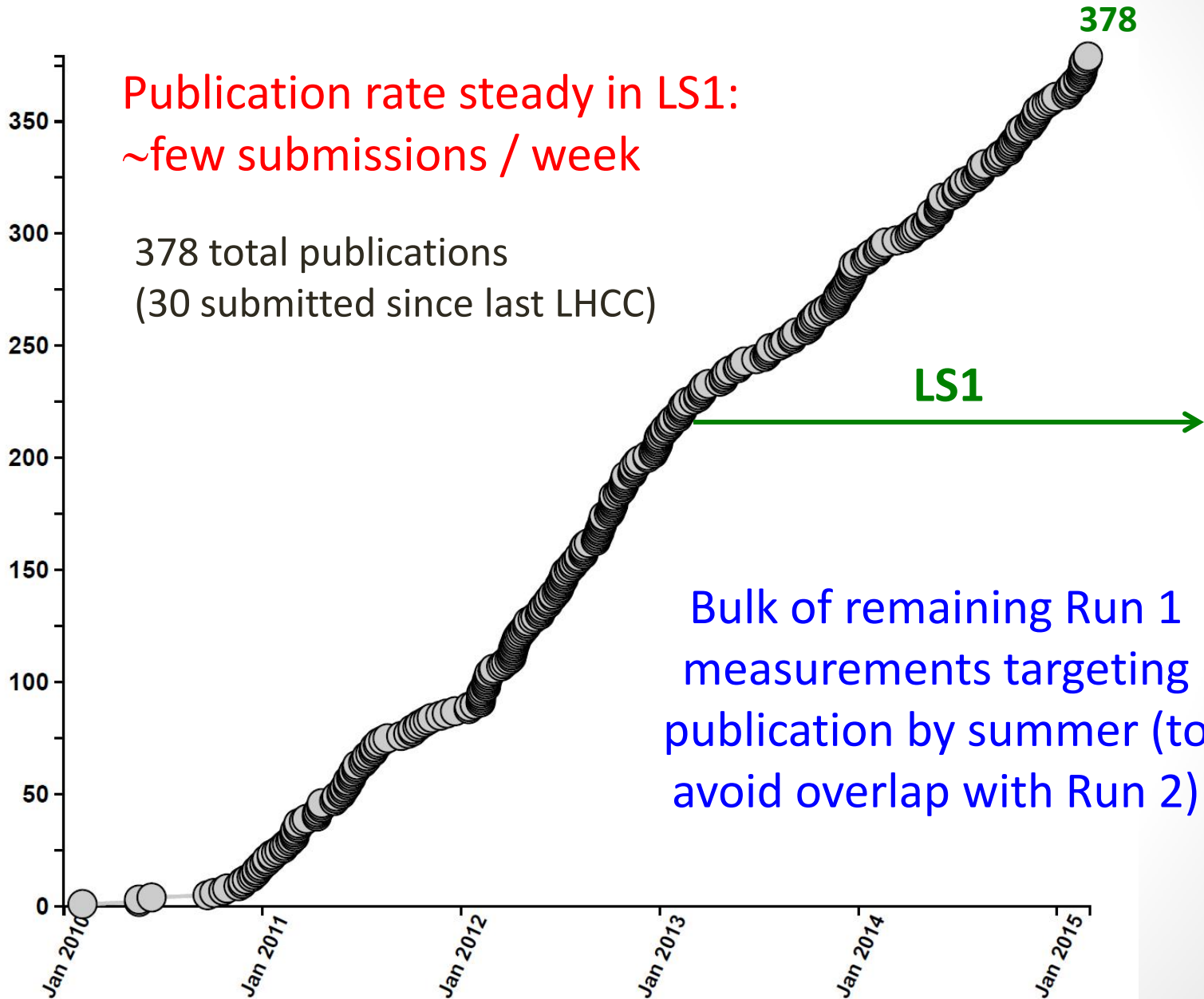
*Recent Physics Results*

*Detector Commissioning Status*

*Computing, Software, Physics Readiness*



# Publication Status



# Recent Physics Highlights



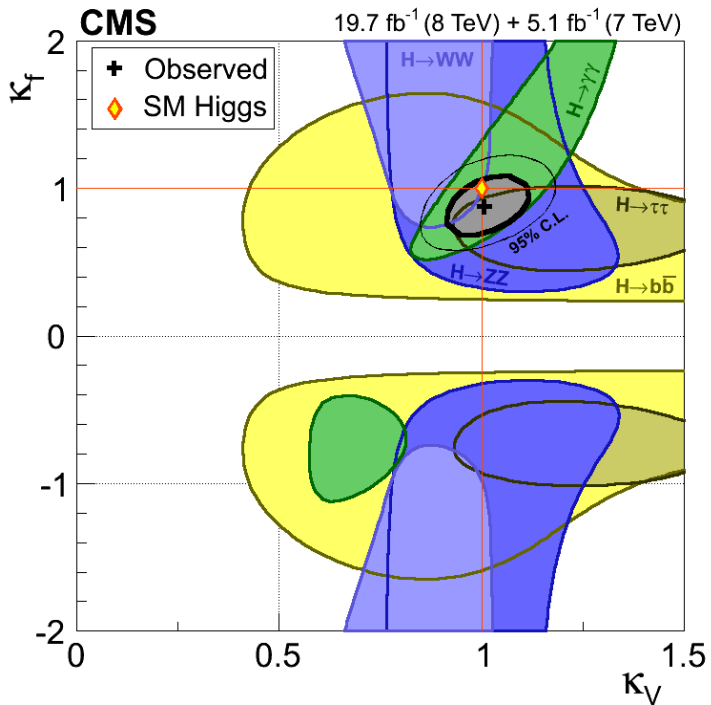
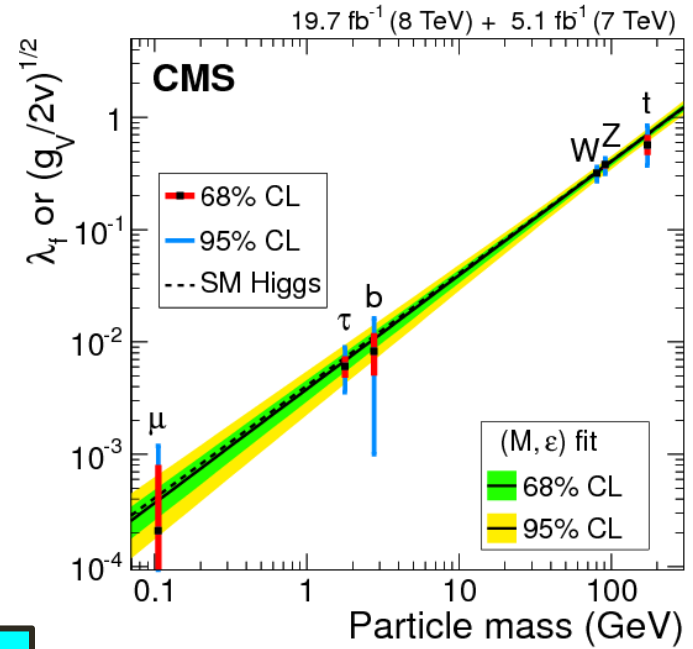
# Higgs Combination

- Five main decay channels all published
- **Combination submitted Dec 30**
- All results consistent with SM Higgs

<https://twiki.cern.ch/twiki/bin/view/CMSPublic/Hig14009PaperTwiki>

$$m_H = 125.02^{+0.26}_{-0.27} \text{ (stat.) }^{+0.14}_{-0.15} \text{ (syst.) GeV}$$

$$\mu = 1.00^{+0.14}_{-0.13} [\pm 0.09 \text{ (stat.) }^{+0.08}_{-0.07} \text{ (theo.) } \pm 0.07 \text{ (syst.)}]$$



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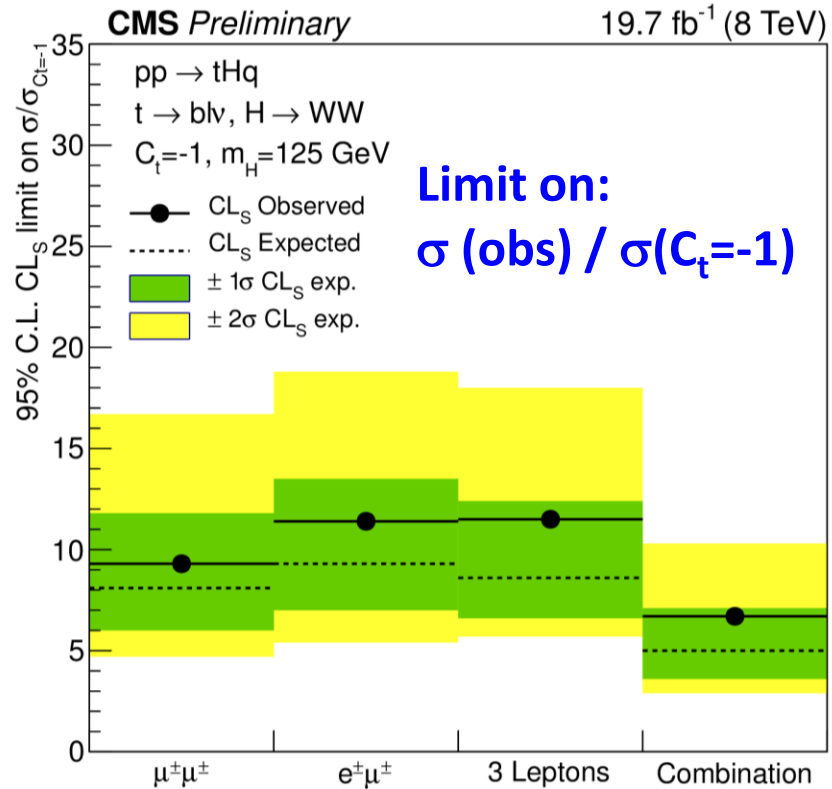
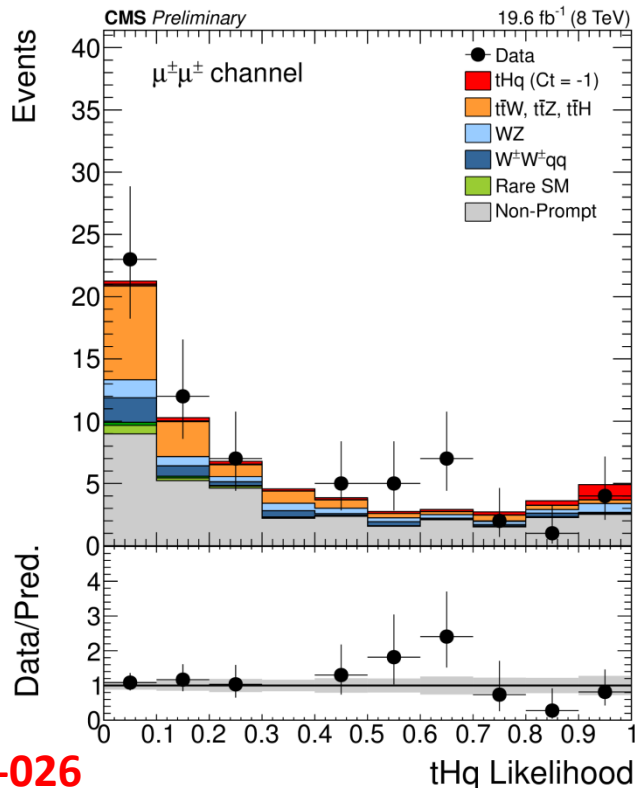
Channel	Obs (σ)	Exp (σ)
H → ZZ	6.5	6.3
H → γγ	5.6	5.3
H → WW	4.7	5.4
H → ττ	3.8	3.9
H → bb	2.0	2.6
H → μμ	< 0.1	0.4

First LHC Higgs mass combination coming soon!



# Anomalous Higgs-top Coupling

- Large enhancement of tHq cross section expected if  $C_t = -1$ 
  - N.B. : Additional non-SM particles in the loop can modify this prediction
- Added leptonic (WW+ $\tau\tau$ ) channels to existing searches for anomalous tHq production in  $\gamma\gamma$  and bb final states
  - Combination of all channels ( $\gamma\gamma$ , bb, leptonic) in preparation



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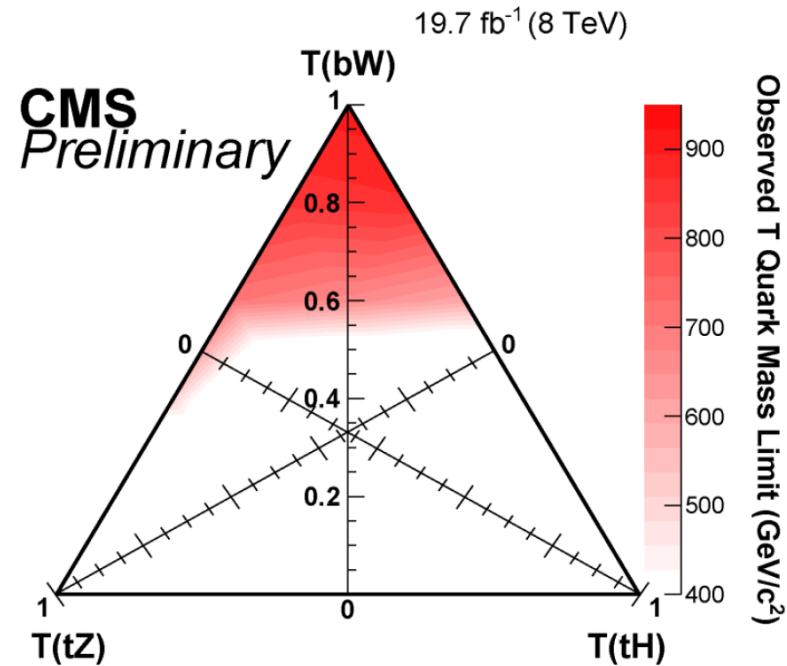
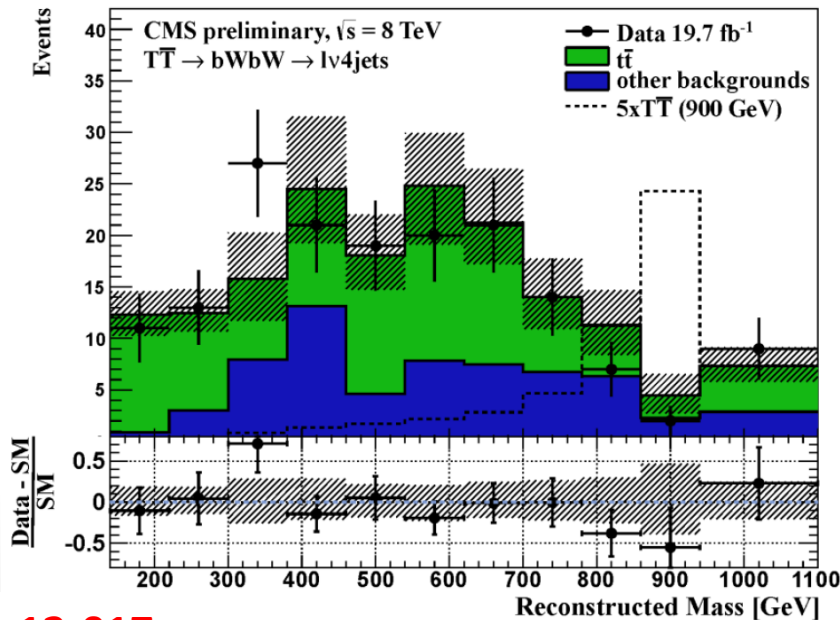
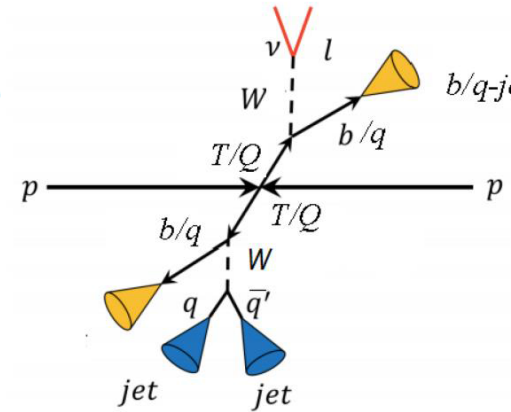


# Search for Vector-like Quarks

- 3<sup>rd</sup> (T) and 1<sup>st</sup>/2<sup>nd</sup> (Q) generation vector-like quarks are searched for in  $W+b/q$  decays in the lepton+jets channel (including merged jets)
- Two primary discriminating variables: mass,  $S_T$

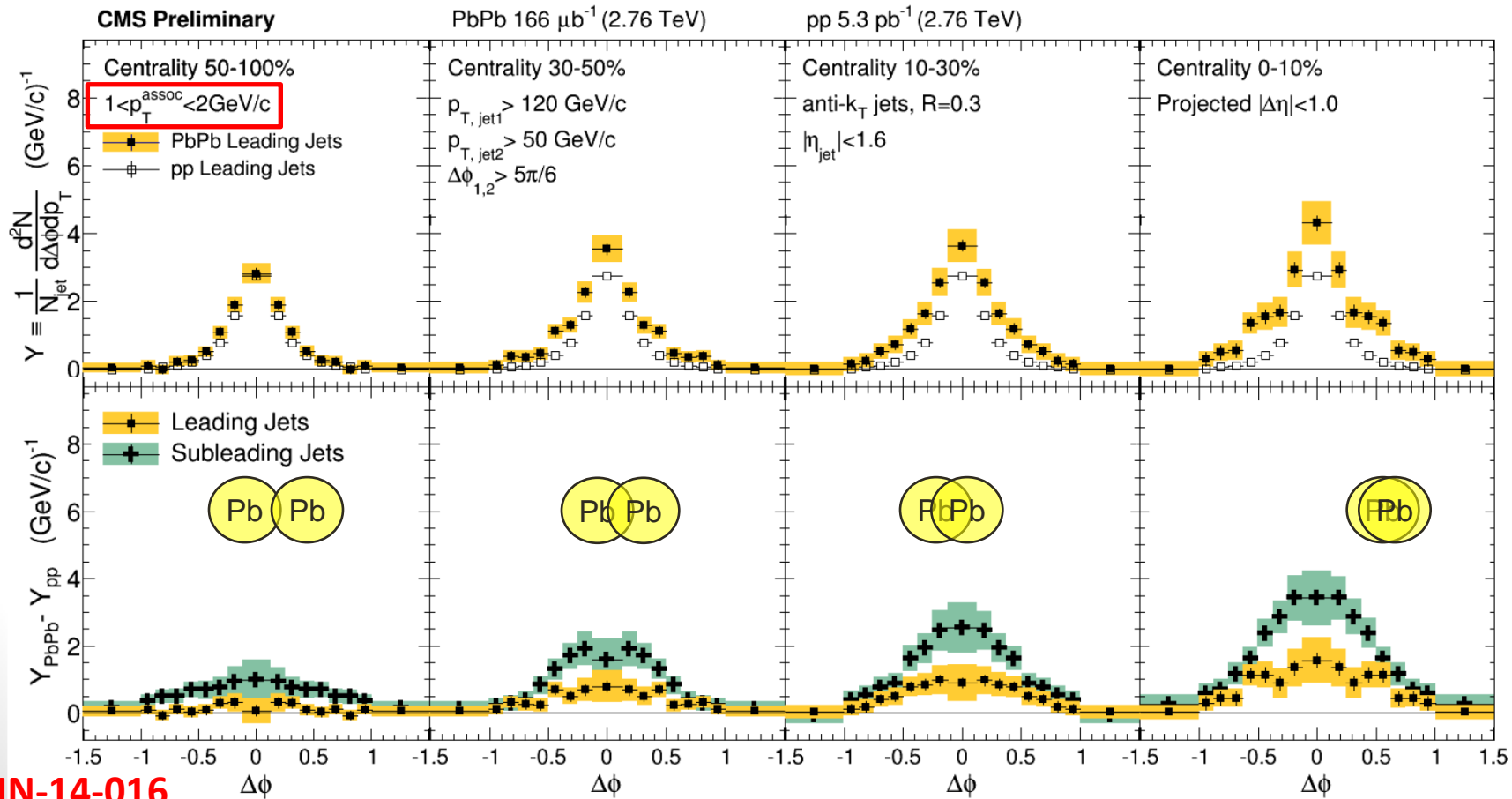
$$S_T = p_T^\ell + E_T^{\text{miss}} + p_T^{J_1} + p_T^{J_2} + p_T^{J_3} + p_T^{J_4}$$

- Observed limits on T (Q) masses: 912 (788) GeV



# Jet-Track Correlations in PbPb

- Study of correlated charged-particle redistribution about the momentum axis of high- $p_T$  jets
- Extending existing studies to lower  $p_T$  and larger angles relative to the jet, well beyond the typical jet-size parameter ( $\sim 0.3$ )



# Toward Run 2: Status of detector commissioning

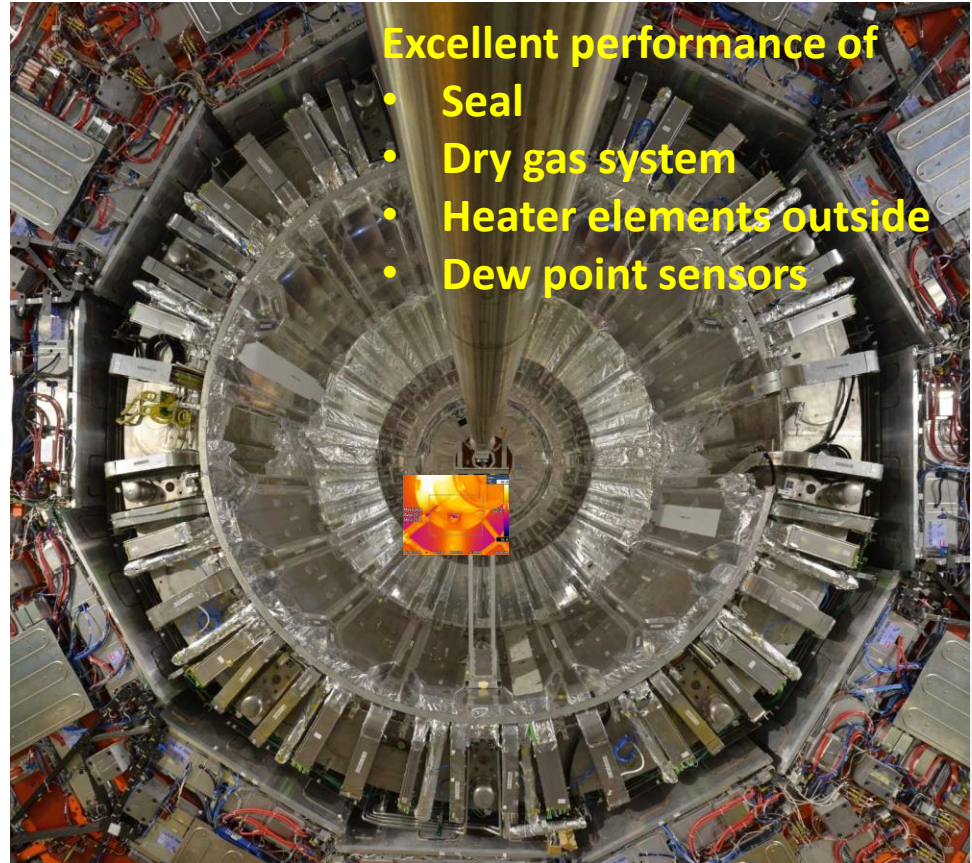




# Tracker – Strips

- Calibration of strips at  $T = -15^{\circ}\text{C}$  completed
- All goals of LS1 met
  - All old and new systems fully functional
  - New additional dry air plant to come this month
- Nothing substantial planned for LS2

Happily taking cosmics,  
first alignment efforts OK

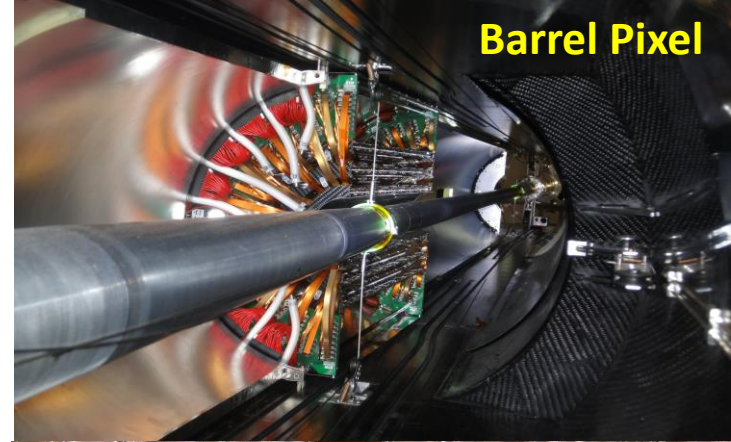


# Tracker – Pixel

- **Barrel Pixel problems fully solved**
  - Lessons learned for Phase I
- **Pixel detector installed before Christmas**
  - Shimming → detector now centered 0:0
  - Very dry environment
  - Including 8 modules with Phase I components – Pilot Blade
- **99.2% of the detector is alive: better than during Run I (96.3%)**
- Pixel calibration at  $T = -10^{\circ}\text{C}$  completed

Happily taking cosmics,  
first alignment efforts OK

Barrel Pixel



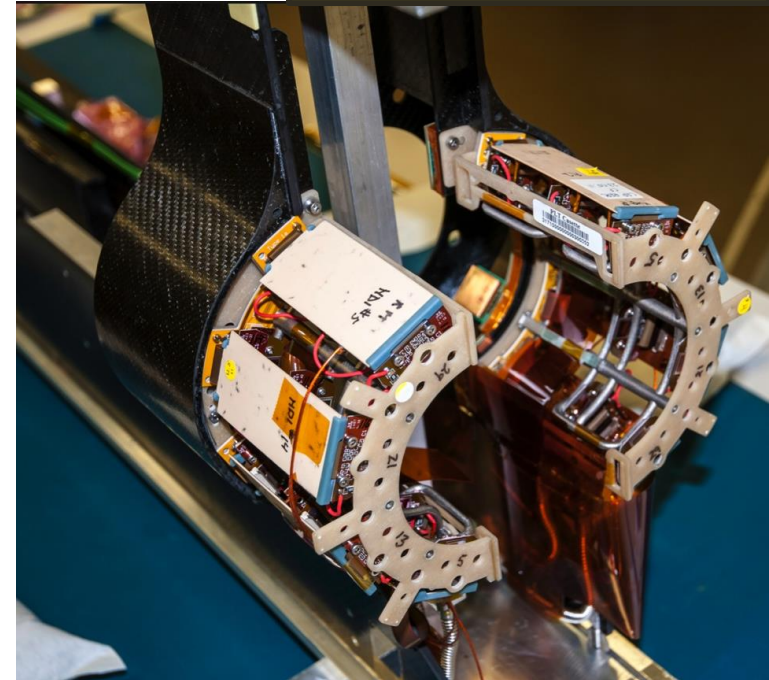


# Pixel Luminosity Telescope

*Si-PLT: Successful installation into  
CMS pixel service tube*

- ✓ 16/16 PLT telescopes (8 telescopes per end)
  - ✓ 48/48 PLT sensors
  - ✓ Target is 1% Statistical error/Bunch/s
  - ✓ Coincidence fast-OR of 3-plane telescopes.
  - ✓ Online and Offline luminometer
- 
- Pressure testing of all cooling lines
  - Survey completed on both ends
  - Tracker volume now closed and commissioning continuing
  - Innovative use of Titanium 3D Printed integrated cooling/support structure

PLT IP side of carriage

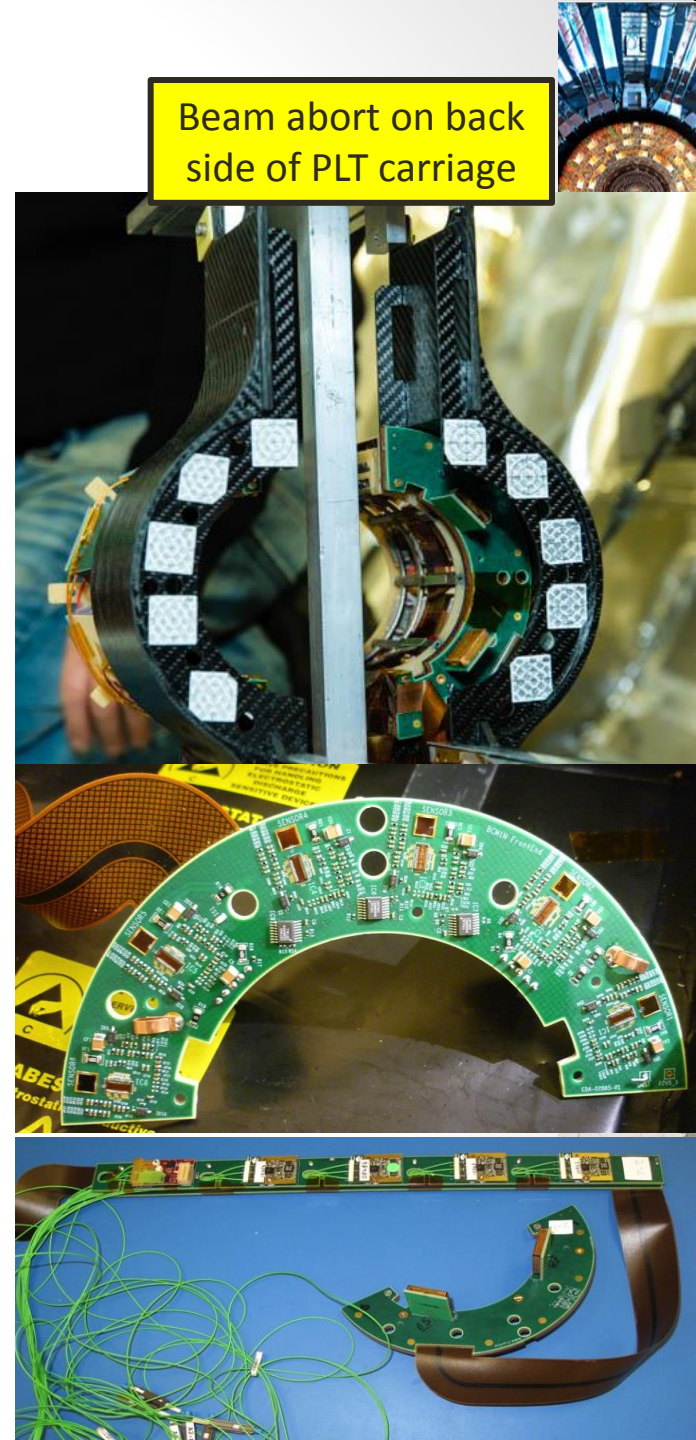
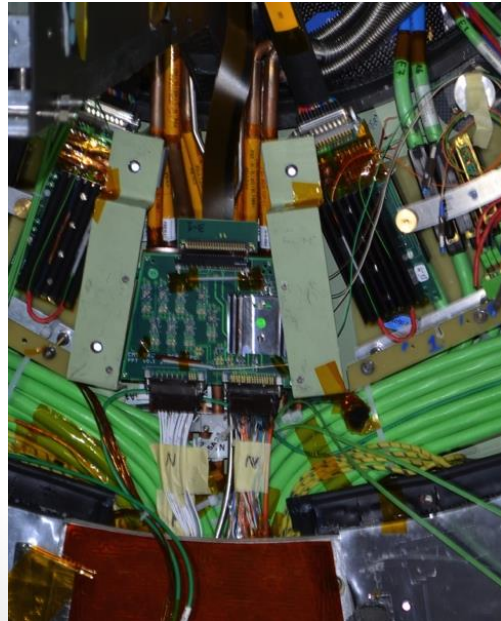


More happy faces

# Beam Monitoring

*Beam Condition Monitor installed, mounted on the PLT carriage*

- ✓ 48/48 BCM1F channels
- ✓ 8/8 BCML channels
- ✓ Numerous FOS temperature sensors on detector
- ✓ Innovative use of a flexible + rigid PCB to handle the dense number of signal paths
- ✓ 1000V operation avoiding the use of connectors in this sensitive very forward location



Beam abort on back side of PLT carriage



# Calorimeters – ECAL

- **Trigger / DAQ**
  - All parts of ECAL (Barrel, Endcap, Preshower) participating in cosmic runs
  - Recommissioning of trigger primitives ongoing
- **Infrastructure**
  - Successfully tested cold operation of the Preshower; will operate at  $-8^{\circ}\text{C}$  during Run 2
- **Detector reconstruction and calibration**
  - New ECAL local reconstruction algorithm with better out-of-time pileup (OOTP) rejection finalised for Run 2, both in offline and in HLT
  - Calibration strategy for 2015 defined, algorithms being retuned for 13 TeV/ 25ns operation





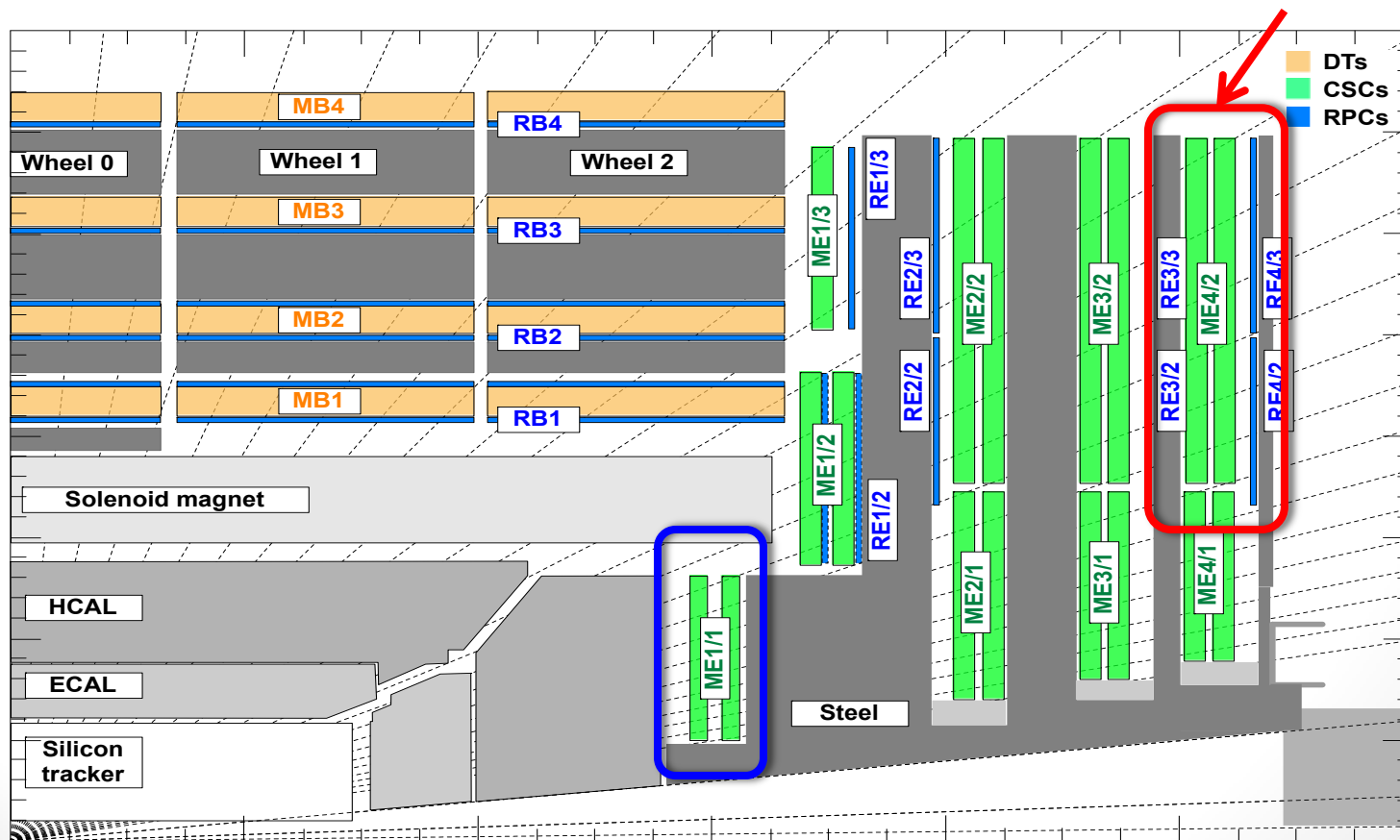
# Calorimeters – HCAL

- **Much improved system after LS1**
  - Field-insensitive, high-performing SiPMs on entire HO
  - Multi-anode, thin-window PMTs in HF
    - Reduction in anomalous signals
  - New back-end electronics for HF installed
    - Pilot project for Phase-1 upgrade
- **Detector reconstruction and calibration**
  - Developed new HCAL local reconstruction algorithm with better OOTP rejection
  - New or improved calibration methods available for all HCAL detectors, in particular
    - HO (new SiPMs) calibration performed with cosmics
    - HF (new PMTs) calibration using wire-source



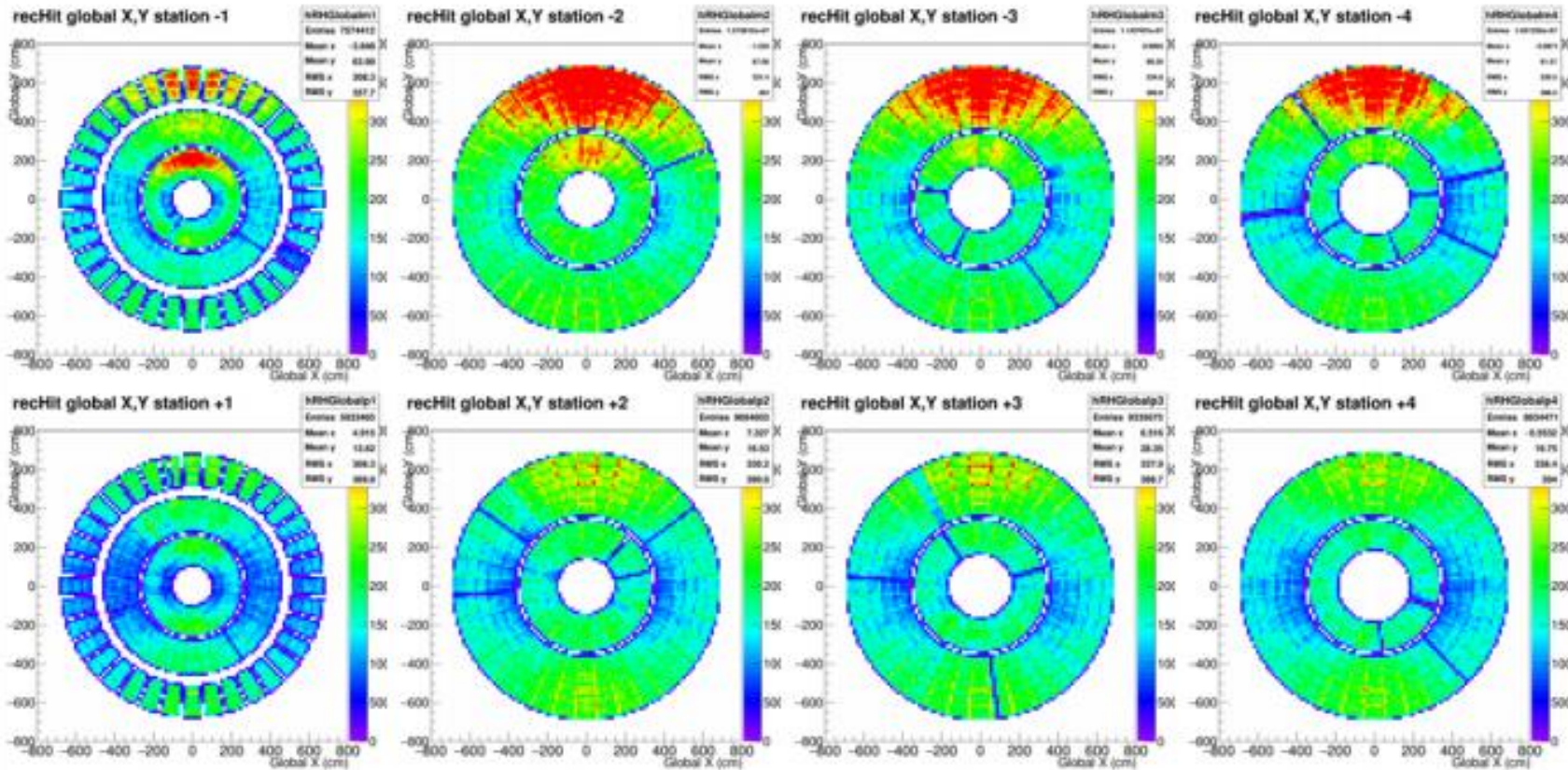
# Muon System in LS1

- CMS Muon System has three sub-systems: Drift Tubes (DT), Cathode Strip Chambers (CSC), Resistive Plate Chambers (RPC)
- Removal, revision, re-installation of ME1/1 chambers
- 4<sup>th</sup> muon station added: 72 (144) new CSC (RPC) chambers



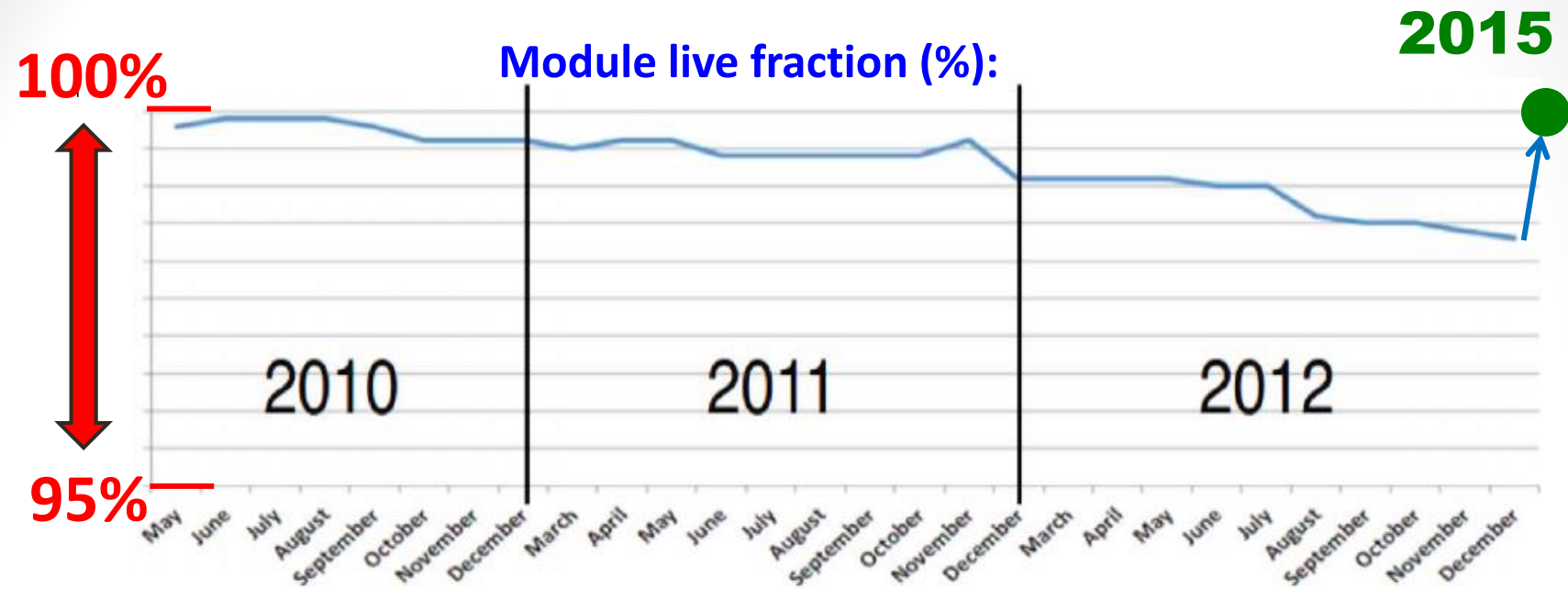
# Muons – CSCs in Cosmic Run

- LS1 upgrades: 468 → 540 CSC chambers
- Much better percentage of channels giving good data
  - ~99.5% versus Run 1 (was 99 → 97% steady degradation)





# Muons – DTs in LS1

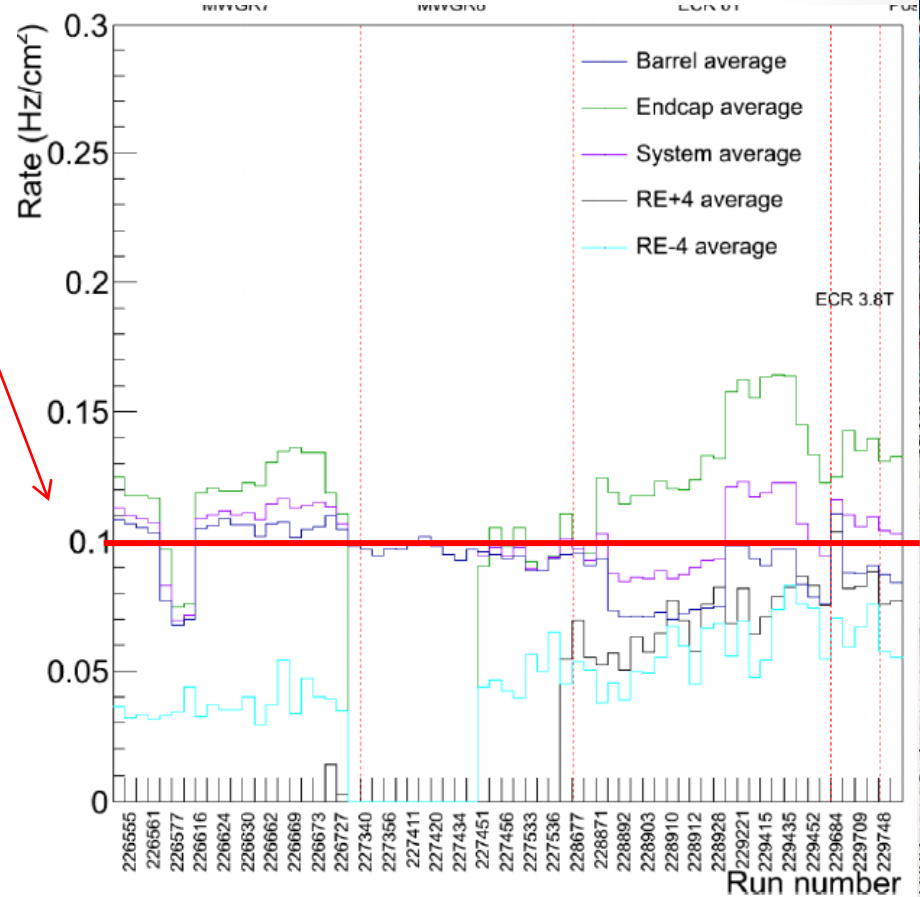


- Minor (~1.5%) degradation in live fraction corrected
- Improved accessibility to electronics during the run:
  - installed 3500 optical links, 20 new crates, for relocating part of the electronics out of the experimental cavern



# RPCs in Cosmic Runs

- **Fully commissioned**
  - Very low noise ( $0.1 \text{ Hz/cm}^2$ ) and current ( $< 2 \mu\text{A}$  per chamber)
  - Efficiency studies with cosmics showing results compatible with 2010 running (avg eff  $\sim 95\%$ )





# DAQ Readiness

- **New DAQ**
  - Acquire data from “legacy” and new back-end electronics
  - New equipment (PC, 40/56 Gbps networking, Lustre storage)
  - Operational, with performance at least as good as in Run 1
- **Trigger**
  - New High Level Trigger (HLT) nodes delivered
  - Will provide CPU budget of  $\sim 300$  ms/event @ 100kHz
  - New Trigger Control and Distribution System now operational
- **To complete before Run 2 physics:**
  - Install and commission full system (HLT and network)
  - Fixes, as well as functional and performance enhancements
  - Commission DAQ for luminosity detectors



# Trigger Status

- **L1/HLT menus for  $1.4 \times 10^{34}$  Hz/cm<sup>2</sup> @ 25 ns ready**
  - Most challenging conditions: ~double energy, lumi, pileup (~40)
  - Acceptance similar to that of 2012
  - Optimized treatment of OOTP for ECAL (HCAL coming)
  - **Total rate fits in budget of 1.35kHz peak for 1kHz average offline rate**
- **First version of L1/HLT menus for  $7 \times 10^{33}$  Hz/cm<sup>2</sup> (25ns)**
  - More relaxed requirements at both L1 and HLT: lower thresholds and/or prescales; cpu/rate studies ongoing
  - First version of  $5 \times 10^{33}$  Hz/cm<sup>2</sup> (50ns) L1 menu available, HLT coming
- **Commissioning activities**
  - Successful operation of the HLT during cosmic running
  - Regularly providing HLT menus for global CMS operation, individual sub-detectors (MiniDAQ), DAQ tests
  - Improvement ongoing for online DQM, as well as L1 and HLT rate monitoring



# Run Coordination

- **Done:** extensive campaign to commission new hardware, including 9 Mid-Week Global Runs + Extended Cosmic Run/Magnet Test
  - Deployed new data acquisition system
  - Deployed/exercised new Trigger Control/Distribution System
  - Re-established legacy trigger and timing after signal splitting
  - Incorporated/commissioned new subsystem items
- **In progress:** collecting cosmic rays to align detector at B=0T and B=3.8T (400 hrs = 170M muon triggers each)
  - Feb-March: Cosmic RUn at ZERo Tesla (CRUZET)
  - Mid-March: Cosmic Run At ~Four Tesla (CRAFT)
- **First beams:** preparing commissioning plan to deliver physics quality data to CMS physicists as soon as possible upon startup
  - Beam commissioning: focus on timing
  - 1<sup>st</sup> collisions: refine timing, HV scans, alignment, van der Meer scans, ...



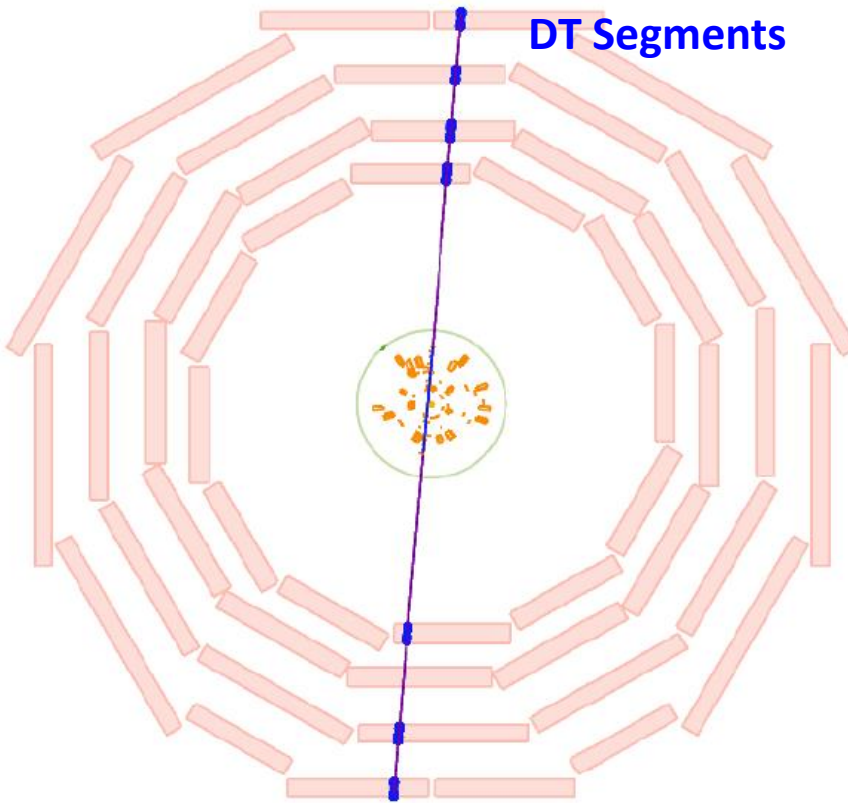


# Example Cosmic Ray: Jan 30, 2015



CMS Experiment at LHC, CERN  
Data recorded: Fri Jan 30 11:05:30 2015 PST  
Run/Event: 233235 / 741  
Lumi section: 9  
Orbit/Crossing: 2118582 / 2506

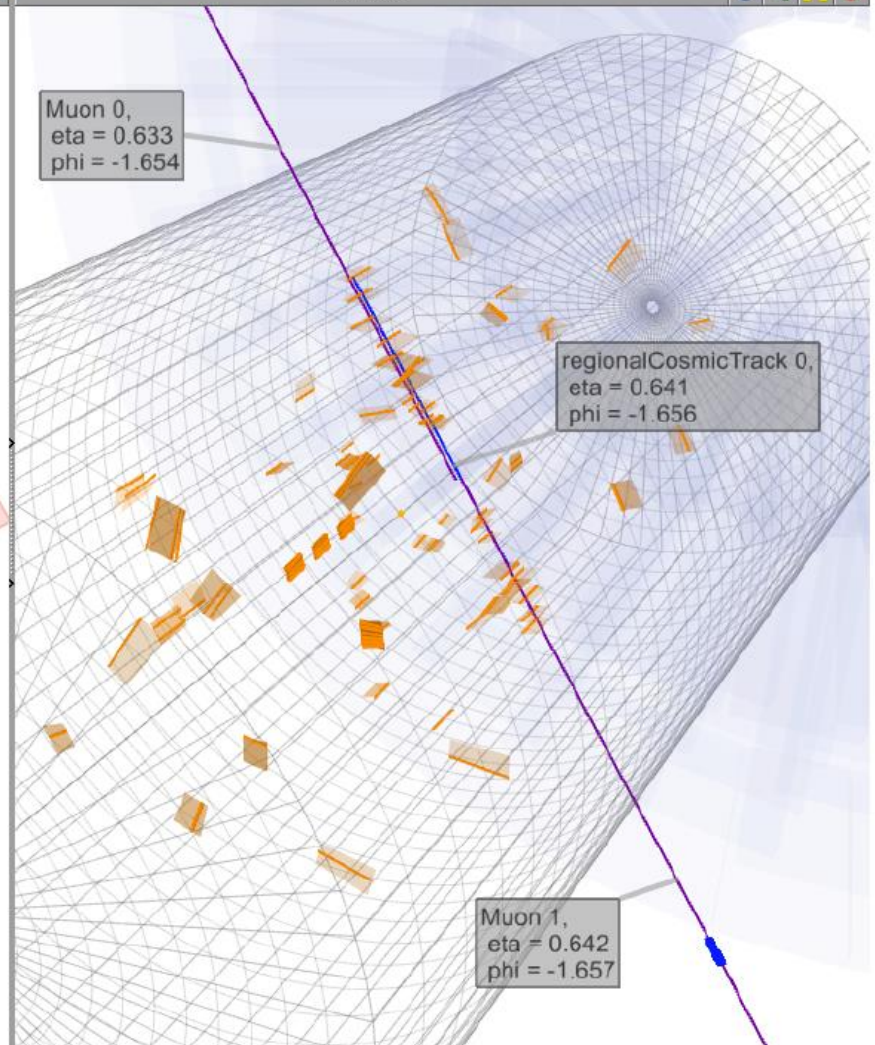
DT Segments



Muon 0,  
eta = 0.633  
phi = -1.654

regionalCosmicTrack 0,  
eta = 0.641  
phi = -1.656

Muon 1,  
eta = 0.642  
phi = -1.657



Extensive use of cosmic rays to commission CMS in LS1



# Toward Run 2: Computing, software, physics readiness

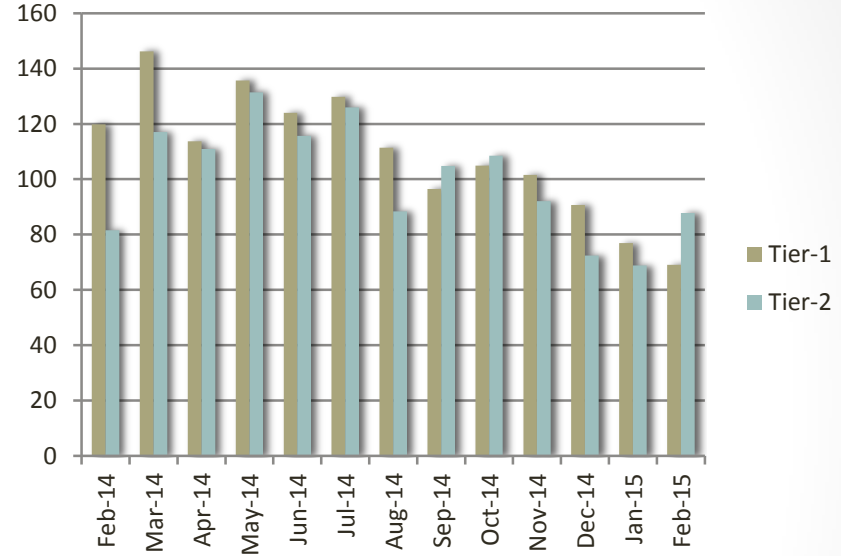




# Computing/Offline in LS1

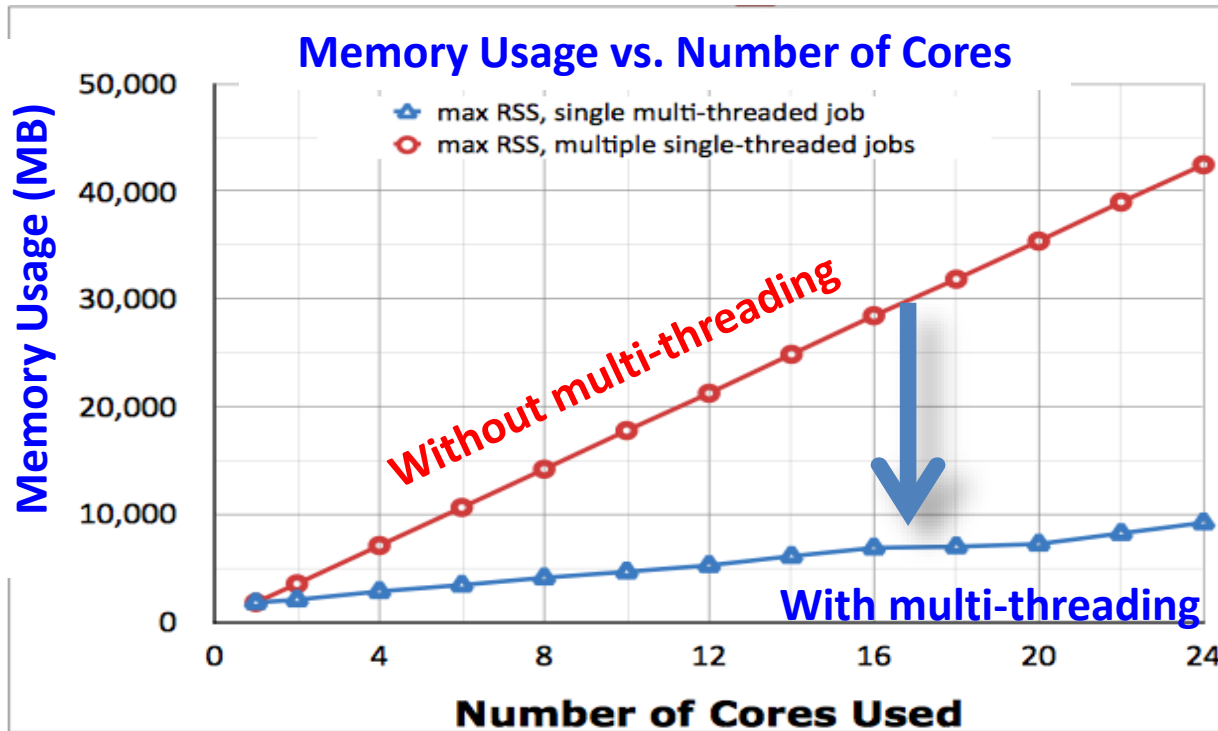
- CMS resource utilization was high for most of LS1; general drop at start of 2015 (development period)
- Changes in Computing in LS1:
  - Additional Flexibility in the way resources are accessed
  - Improved Performance on the way resources are used
  - Optimized Access to data
- Instrumental for these changes has been the adoption of:
  - Logical separation between the Disk and Tape storage systems
  - Dynamic Data Placement
  - Improved Distributed Analysis Tool (CRAB3)

CMS Resource Utilization



# Computing/Offline for Run 2

- **Next-generation framework based on multi-threading approach**
  - Processing higher Run 2 trigger rates efficiently; lower memory usage
- Developed “miniAOD” data format ~10 times smaller than what was used in Run 1: target ~80-90% of users
- Achieved needed technical improvements in simulation, including move to GEANT 4.10 for use in multi-threading framework



# Preparing for Run 2 MC Production

- **Generation and simulation**

- Overall budget of ~1B events for startup needs (reco'd twice; 50/25ns)
- PYTHIA8 samples already produced (~1/3 of overall budget)
- Validation of LO and NLO generators using 8 TeV data

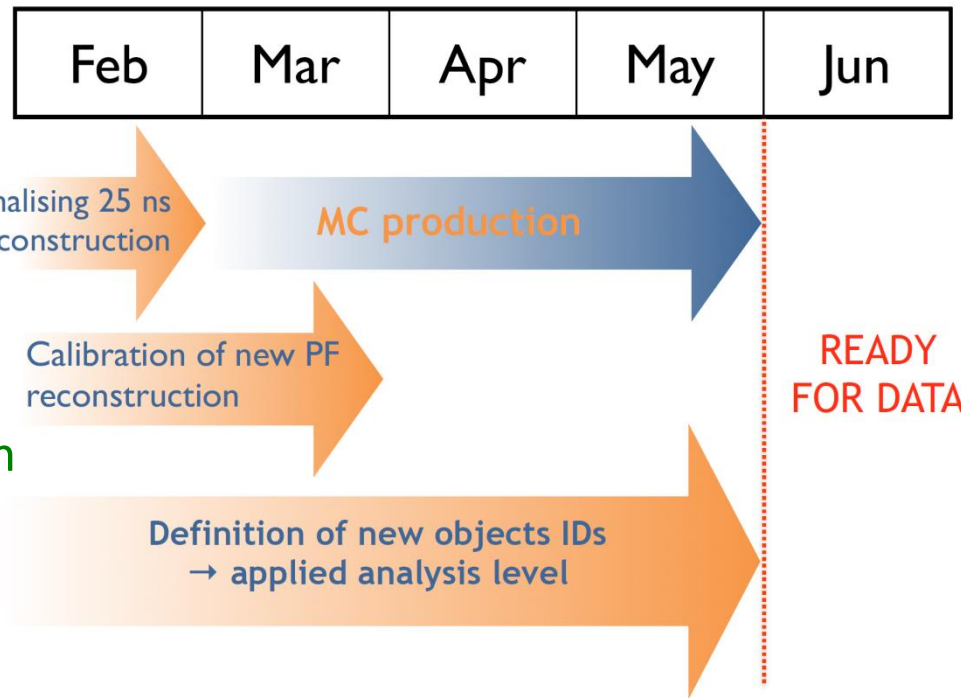
- **Reconstruction, calibration and plans**

- Recalibration of Particle Flow algorithms for new PU-resilient calorimeter local reconstruction

- **Realistic set of alignment and calibration conditions**

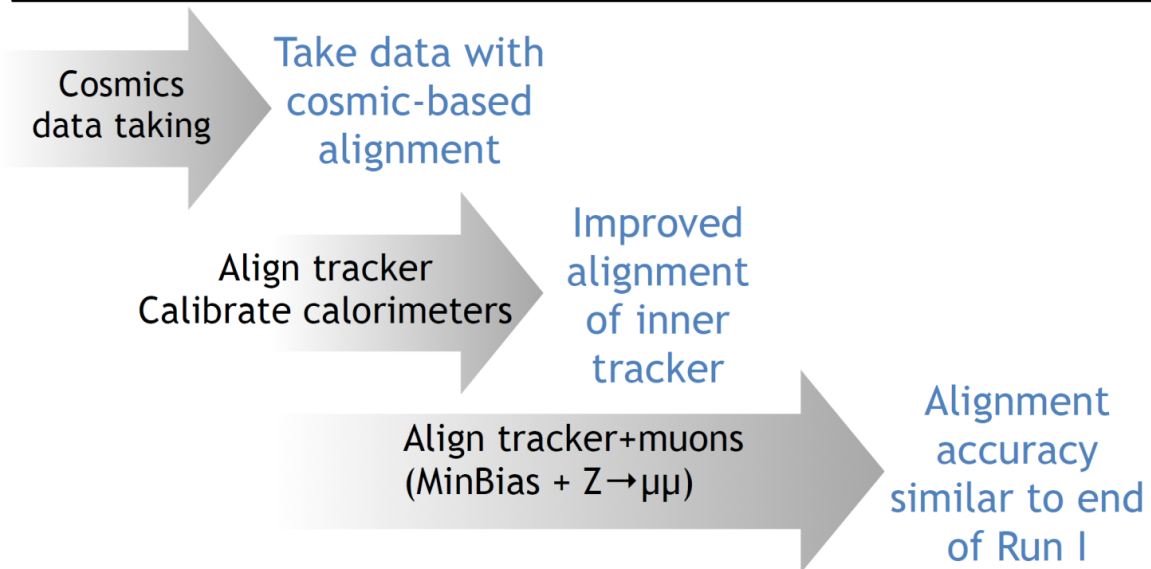
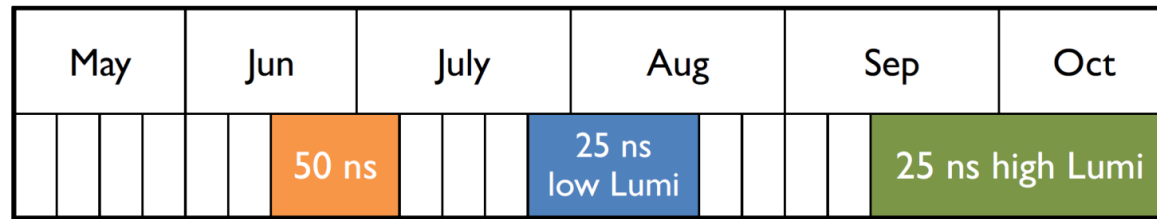
for MC production being validated (next slide)

- **Target date for production @ 50 and 25ns is end of March**



# Detector Alignment & Calibration

- Detailed planning for detector alignment, calibration, and data reprocessing well underway
  - Alignment obtained from cosmic ray data for start of 50ns run
  - Alignment obtained from first collision data for start of 25ns run
  - Achieve “end-of-Run1” alignment precision for high-lumi 25ns running

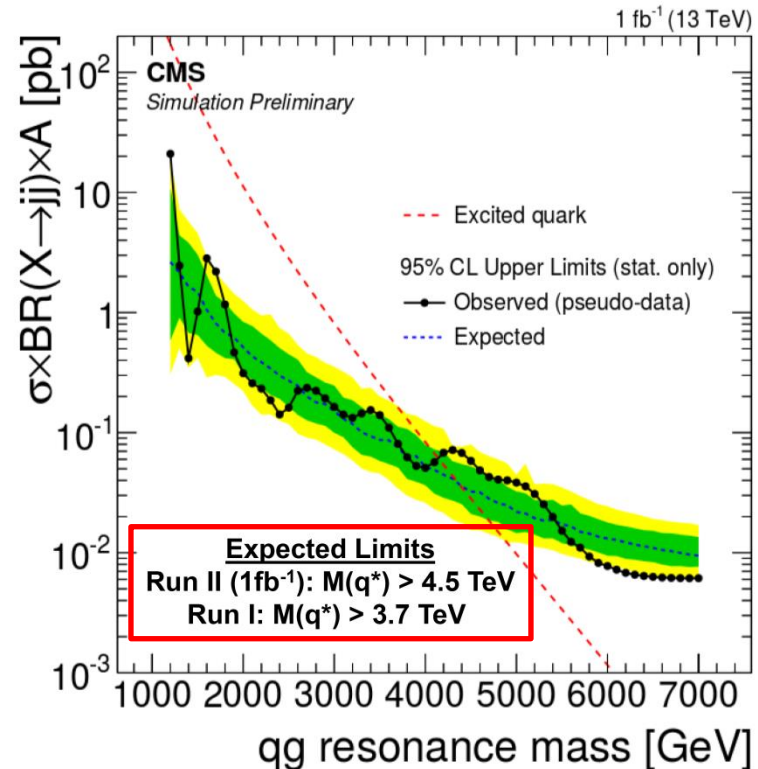
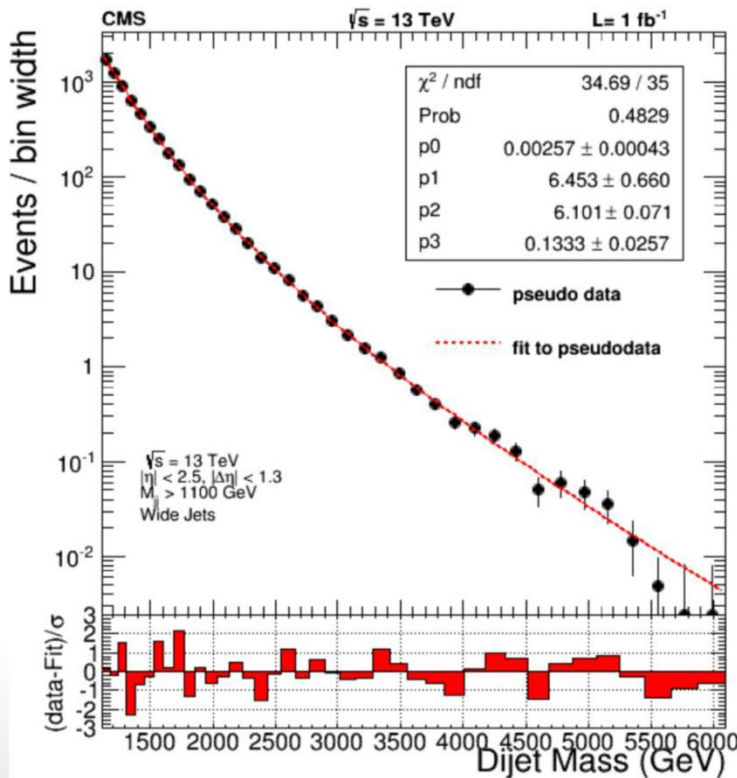




# Physics Preparation for Run 2

- **PHYS14 exercise ongoing since November**
  - Targeting early Run 2 analyses: SM (b, onia, top, W, Z), Exotic and SUSY searches, and Higgs “rediscovery”
  - Recycled GEN-SIM (~300M events) reco’d with near-but-not-final reconstruction algorithms, and first version of  $7 \times 10^{33}$  Hz/cm<sup>2</sup> menu

## Example: dijet resonance search @ 13 TeV with 1 fb<sup>-1</sup>



# Heavy Ion Preparations for Run 2

- **The 2015 Ion Period will be the first high luminosity Pb run in the LHC Ion program**
  - Peak Lumi:  $3.7 \times 10^{27} \text{ cm}^{-2}\text{s}^{-1}$ , interaction rate  $\sim 30\text{kHz}$
  - 8 times higher than the 2011 PbPb interaction rate, and **4 times higher than the LHC design value!**
- **Physics emphasis of the CMS HI Group for Run 2:**  
Exploiting the high  $p_T$  reach of the high luminosity Ion LHC
  - $Z^0$ -jet, photon-jet correlations
  - TeV-scale jet quenching
  - Differential studies of pathlength/system-size/flavor dependence
    - photon-jet correlations vs photon  $p_T$ , centrality, event plane
    - b jets, charmonium, and bottomonium production
- **High Integrated luminosity is essential; 5 TeV pp reference data needed adjacent in time (or coincident) with the PbPb sample**



# CMS HI Beam Request for Run 2

- **Beam energy for PbPb running**
  - Default 5.1 TeV (i.e. 6.5 ZTeV)
  - 5.02 TeV preferable if achievable without loss of running time
- **For the PbPb run we expect  $\sim 1 \text{ nb}^{-1}$  delivered**
  - Requires optimization of the fill length to account for rapid ion burnoff
    - Long fills (8h) + lumi leveling (ATLAS/CMS) give only  $\sim 0.6 \text{ nb}^{-1}$  / experiment
    - Short fills ( $\sim 3\text{-}5\text{h}$ ) give the expected  $\sim 1 \text{ nb}^{-1}$  for CMS (and ATLAS)
  - CMS strongly favors the short-fill scheme, i.e.  $\sim 60\%$  more luminosity
- **5 TeV pp reference data are essential**
  - Should be recorded in 2015, preferably before the Ion run period, or, if necessary, during Ion run
  - Integrated luminosity matching the PbPb data set is needed
    - $\sim 40 \text{ pb}^{-1}$  pp luminosity corresponds to  $1 \text{ nb}^{-1}$  of PbPb data
    - No limitation on event pileup





# Summary

- **LS1 has been a fruitful harvest for Run 1 physics results**
  - Pushing to publish bulk of remaining analyses by summer
- **Extensive programme of detector and infrastructure maintenance, consolidation, repair and upgrade scheduled for LS1 has completed successfully**
  - Thanks to the hard work of CMS teams, contractors, CERN technical depts and PH Dept technical groups!
- **Computing and software algorithms updated for Run 2**
  - New event reconstruction mitigates effect of 25ns pile-up
- **Proton and Heavy Ion Physics preparation in full swing**
  - Expect to have MC samples with final reconstruction available before the start of Run 2
- **In parallel, work continues on the CMS detector upgrade for the High-Luminosity LHC**



# Backup Slides



# Phase 2 Upgrades: The detector

## Trigger/DAQ

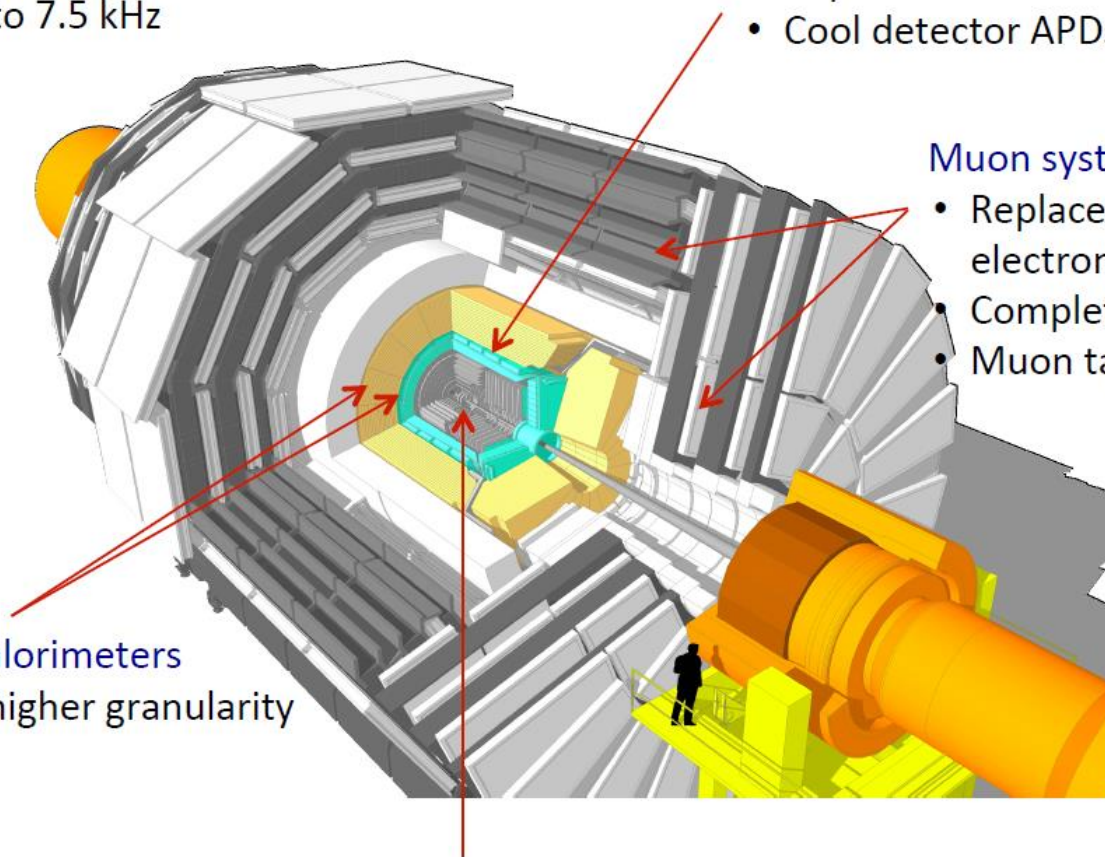
- L1 with track up to 750 kHz - 12.5  $\mu$ s latency
- HLT output up to 7.5 kHz

## Barrel EM calorimeter

- Replace FE electronics
- Cool detector APDs

## Muon systems

- Replace DT & CSC FE electronics
- Complete RPC coverage
- Muon tagging  $2.4 < \eta < 3$



## Replace Endcap Calorimeters

- Rad. Tolerant - higher granularity

## Replace Tracker

- High granularity – less material- better  $p_T$  resolution
- Selective readout of outer tracker at 40 MHz for L1 trigger
- Extend  $\eta$  coverage to 4





# Phase 2 Upgrades: Physics highlights

Variety of physics results presented at ECFA

**Higgs pair-production studies** (cross-section 40.2 fb at  $\sqrt{s}=14$  TeV)

- Parameterized object performance tuned to CMS Phase II detector at  $\langle\text{PU}\rangle=140$
- **bbyy channel:**
  - 320 events produced at  $3000\text{fb}^{-1}$ , relatively clean
  - 2D fit of  $M_{bb}$  and  $M_{yy}$  distributions
- **bbWW channel:**
  - 30000 events produced at  $3000\text{fb}^{-1}$ , large backgrounds
  - Neural Network discriminant to suppress  $t\bar{t}$  background
- bbbb and  $bb\tau\tau$  final states also under consideration

