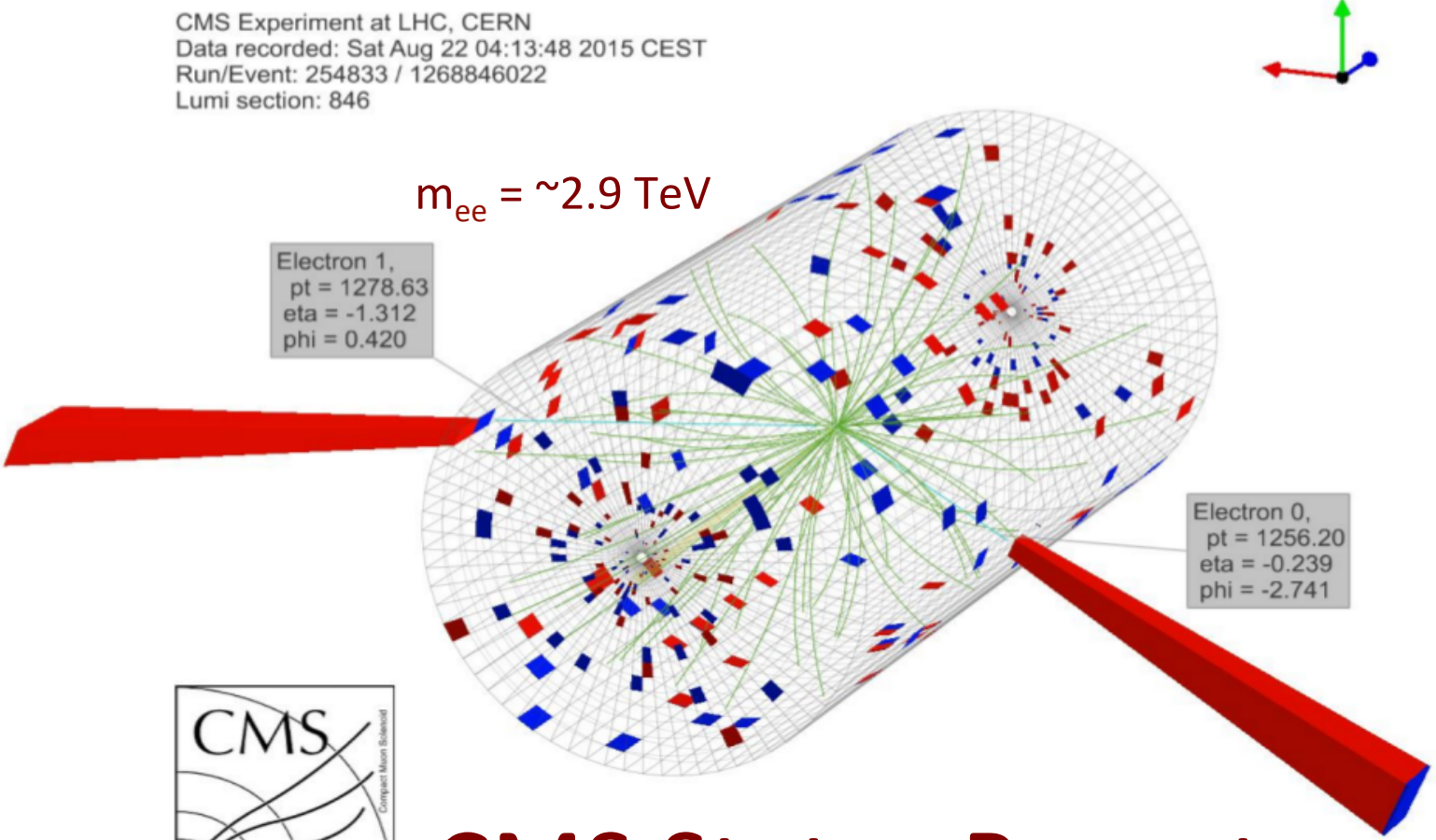


CMS Status Report

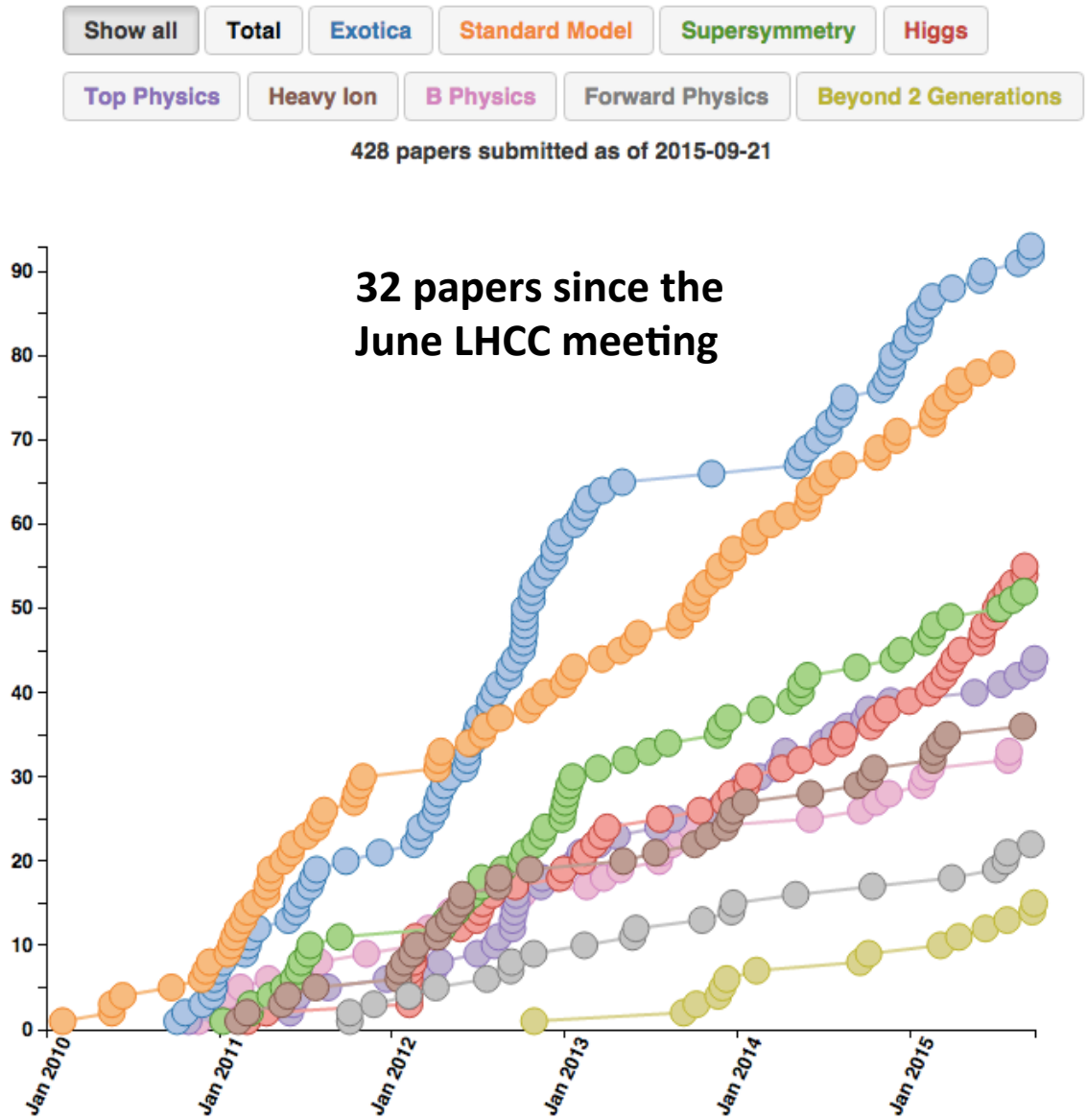
Tulika Bose
Boston University
on behalf of the CMS Collaboration

LHCC Public Session, September 23rd, 2015

Outline

- CMS Collaboration actively engaged in 3 multi-faceted efforts
  - Run 1 analyses
    - Legacy publications, precision measurements
  - Run 2 at 13 TeV (at 25 ns) has started!
    - Detector operation and data commissioning
    - First Run 2 physics results/publications!
  - Preparation for future upgrades

CMS Publications



428 physics papers submitted

+ 14 performance papers

+ 24 based on cosmics data

2015 --- a very active year

- Many new precision measurements
- **First Run 2 paper!**
- Many more on their way…

Higgs Properties

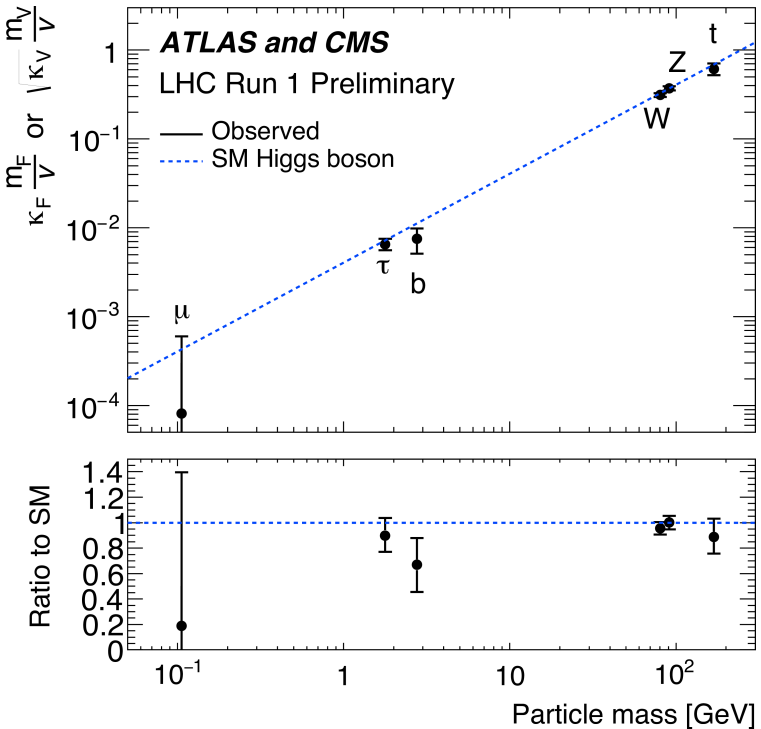
- Closing the chapter for Run 1
  - No deviation from SM couplings
  - No evidence for BSM Higgs (yet)
- ATLAS/CMS Higgs combination

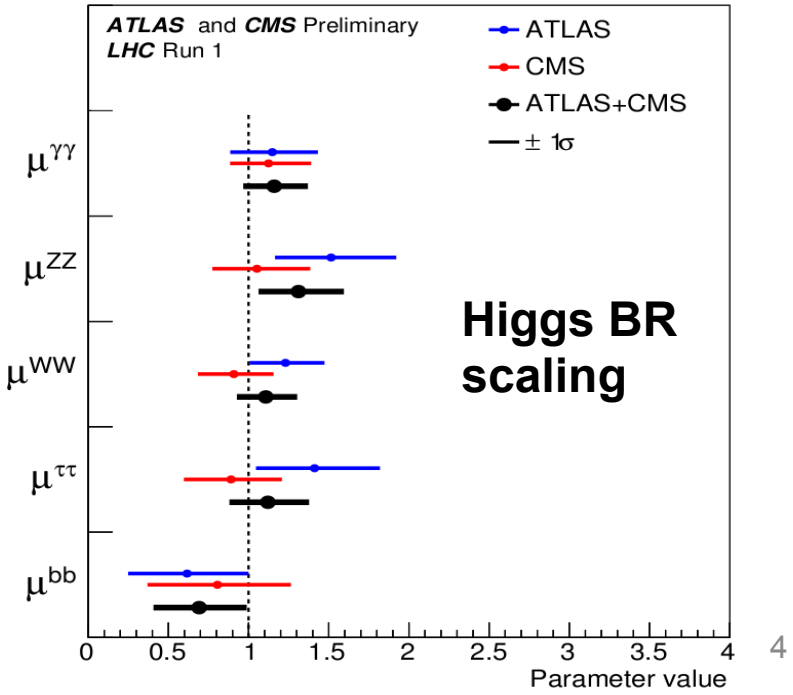
CMS-PAS-HIG-15-002

ATLAS-CONF-2015-044

Conference notes available, combination paper to be submitted soon

$$\mu = 1.09^{+0.11}_{-0.10} = 1.09^{+0.07}_{-0.07}\,(\text{stat})\,^{+0.04}_{-0.04}\,(\text{expt})\,^{+0.03}_{-0.03}\,(\text{thbgd})^{+0.07}_{-0.06}\,(\text{thsig})$$



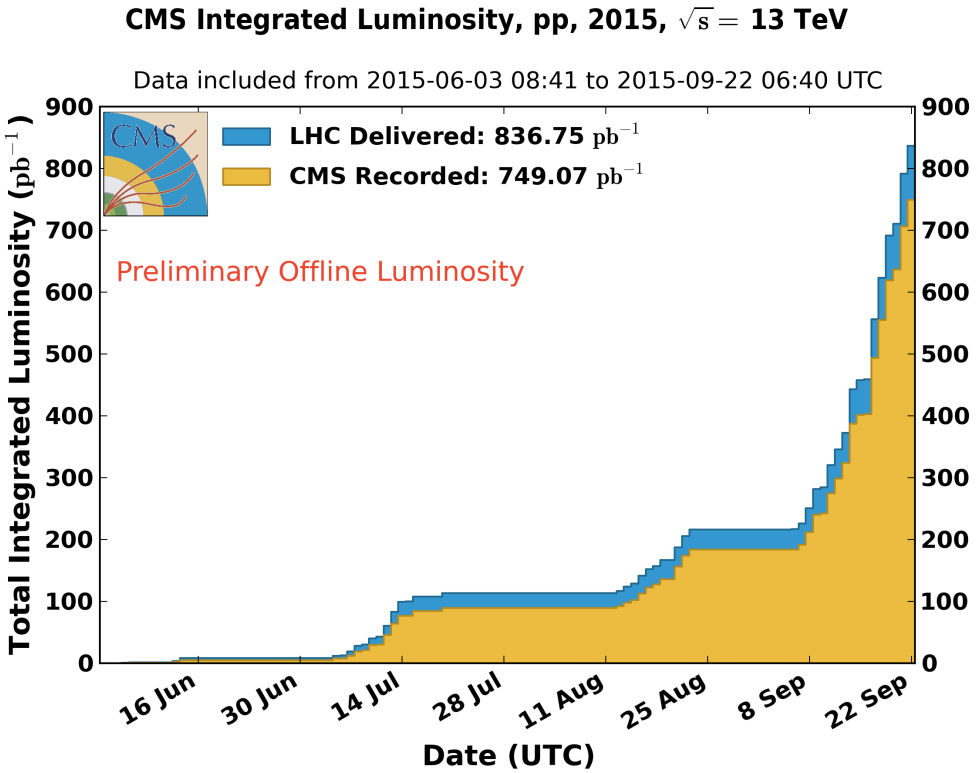


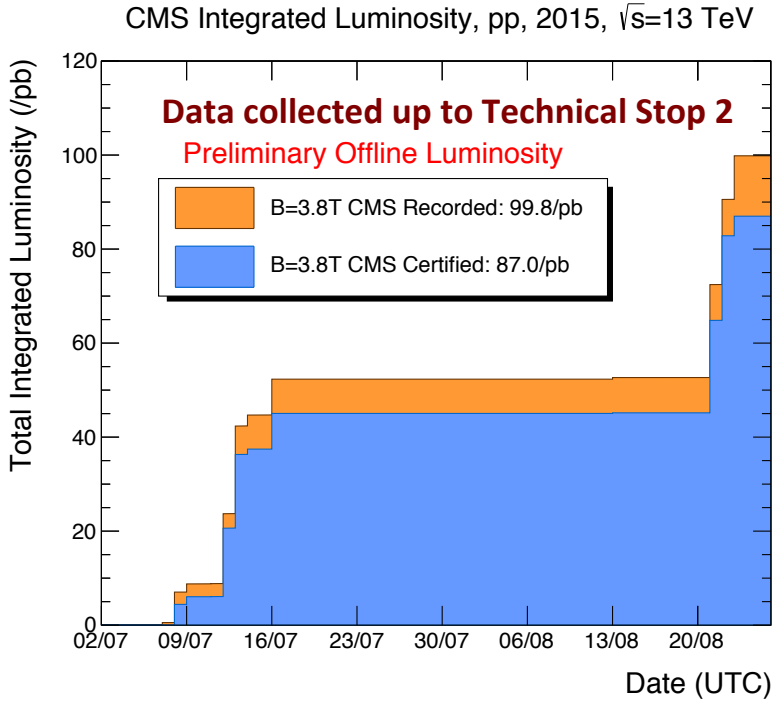
Run 2:

Detector Operation & Physics Results

Luminosity @ 13 TeV

https://twiki.cern.ch/twiki/bin/view/CMSPublic/LumiPublicResults





B = 3.8T:

0.42 fb^{-1} delivered / 0.38 fb^{-1} recorded (90%)

Data collection efficiency increased from ~79% (50 ns) to over 90% (25ns)

Data certification eff: ~87%

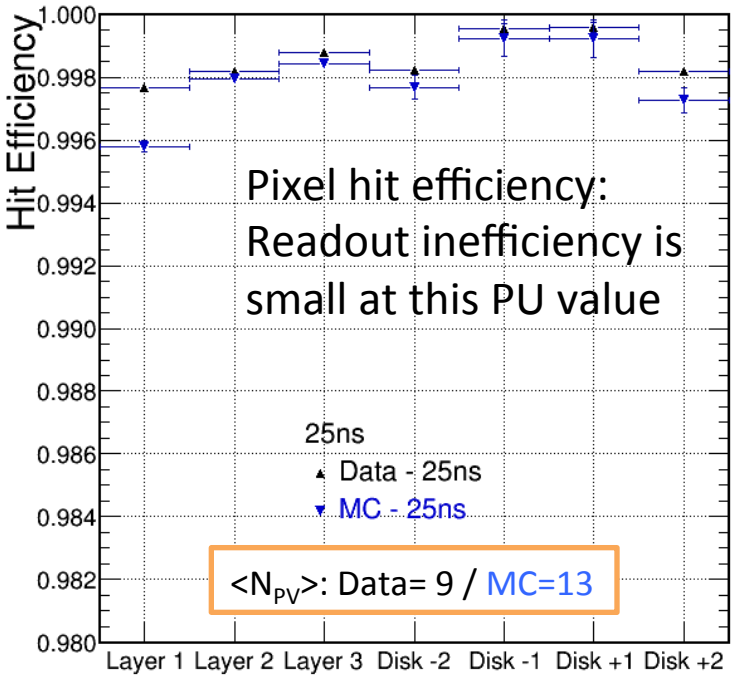
Magnet Cryogenics

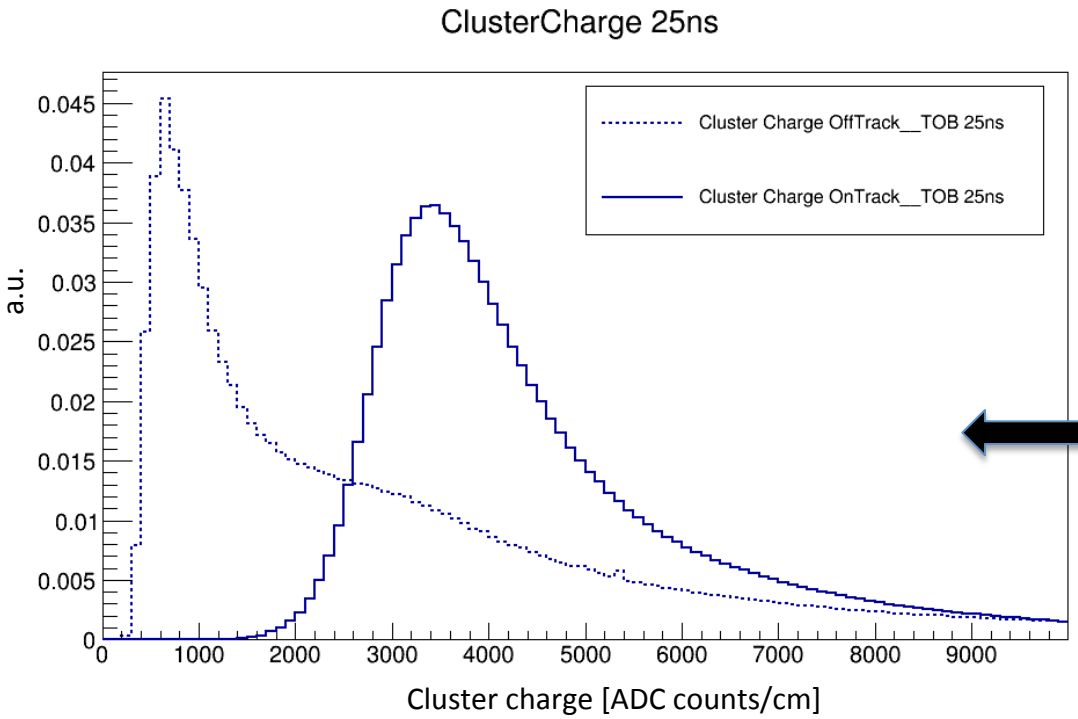
- The CMS magnet has been operating intermittently due to persistent problems in the cryogenic system, consistent with the clogging effect of contaminants in the "Cold Box" that provides liquid helium.
- Last two Technical Stops: several complex and invasive interventions (change absorbers and filters) made in the cold box
  - to make system more tolerant to contamination.
- Still, maintenance procedures to clear contamination are having to be performed much more frequently than normal;
  - Some require stopping the cold-box; which means turning off the magnetic field
  - Trying to synchronize stops with accelerator to minimize impact on CMS data-taking.
- Response to the problem managed by joint CMS-CERN task force. Besides interventions already made:
  - Intensive diagnostic and analysis efforts to improve understanding and optimize interim strategy.
  - In parallel: organizing comprehensive program of component replacement or cleaning for forthcoming technical stops.

Many thanks to TE and EN departments for their exceptional effort

Tracker in Run 2

- Detector is properly configured, calibrated and aligned for 25ns data taking
- Fraction of live channels is stable
  - Pixel: 98.6%
  - Strip: 97.5%

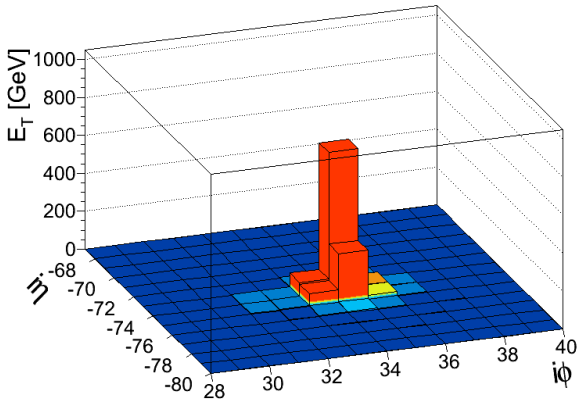




Strip Tracker cluster charge: Out of time contribution is rejected effectively by the track reconstruction

ECAL and HCAL in Run 2

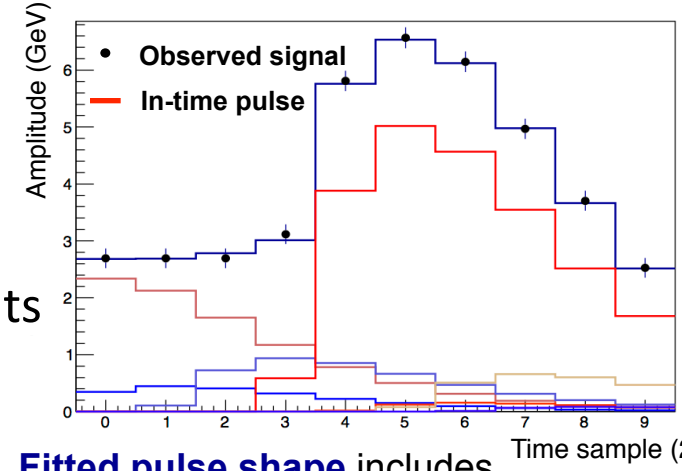
- ECAL and HCAL running stably during collisions at 50/25ns:
  - Detectors are timed in, excellent quality of certified data
  - **Improved** ECAL response corrections (crystal transparency) applied online



ECAL energy deposits for one of the electrons (E_T=1.2 TeV) from 2.9 TeV dielectron evt

- Early data analysis: detector behavior in line with expectations
  - Energy deposits from 2.9 TeV dielectron pair event are well-reconstructed in ECAL

- Validation of new local reconstruction method for Run 2 is ongoing:
  - Allows rejection of out-of-time energy deposits to be made at the earliest stage of the reconstruction chain



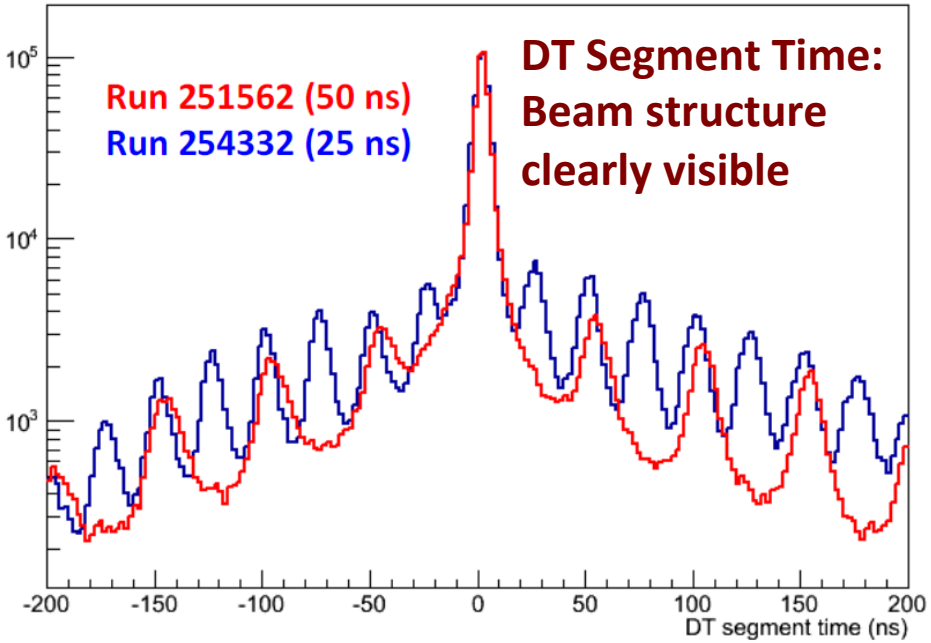
Fitted pulse shape includes
One large **in-time signal pulse** + one **large early pulse** + **three smaller pulses**

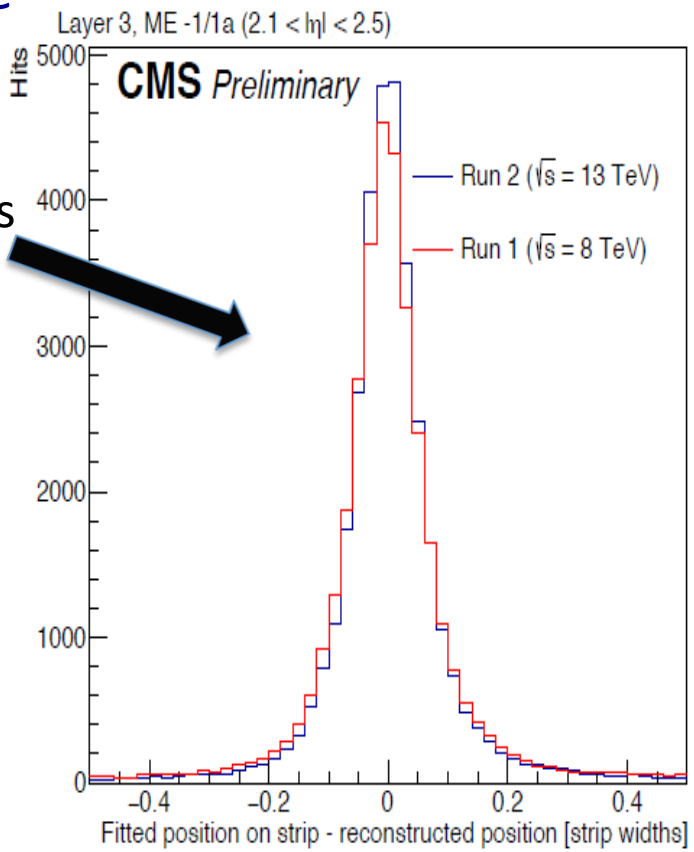
Muon detectors in Run 2

Three technologies [Drift Tubes (DT), Resistive Plate Chambers (RPC) and Cathode Strip Chambers (CSC)]

- CSC: Addition of ME4/2, revision of ME1/1 chambers
- RPC: Fourth muon station in endcap (RE4) added

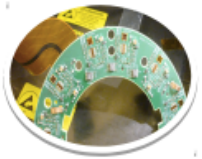
Smooth and stable operation for all three muon detectors in Run 2



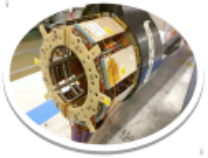


ME1/1a revision ➔ resolution improves by ~20%

Luminosity systems for Run 2

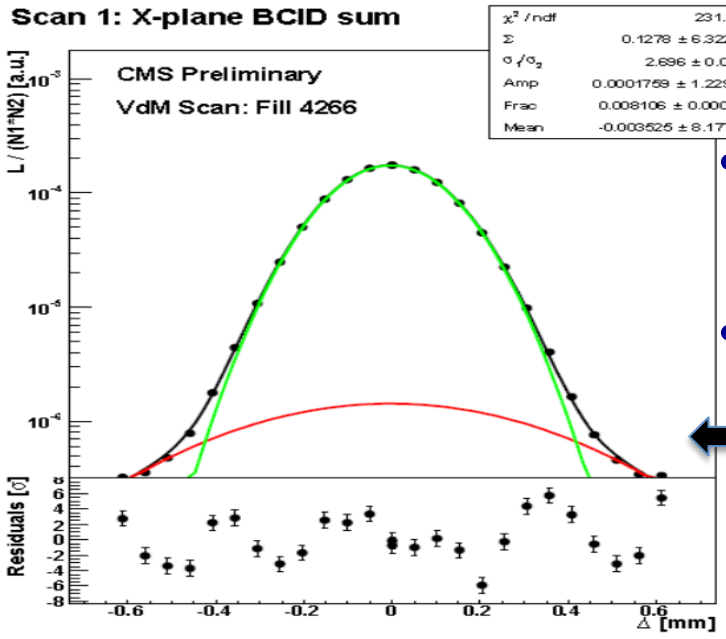


Fast Beam Conditions Monitor(BCM1F)



Pixel Luminosity Telescope (PLT)

HF Luminosity



Beam separation

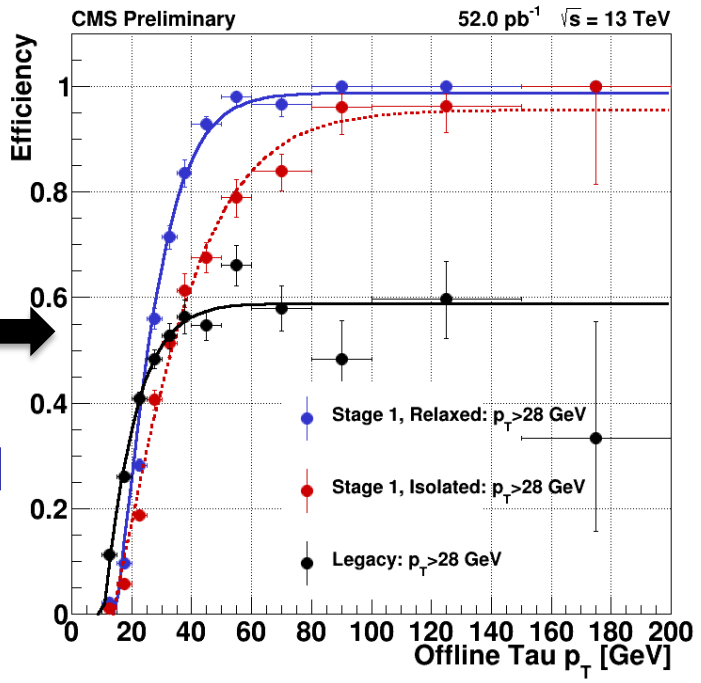
- Focused on stability and understanding of online luminometers
  - Used mini-beam optimizations to derive visible cross sections for online systems with and without magnetic field
  - Excellent system stability, both software and hardware
  - Multiple systems are giving us useful handles on systematics studies
- Excellent performance of new detectors (PLT, BCM1F, Beam Halo Monitor)
- VDM scan campaign successful

PLT Zero Counting VDM Fit

Level-1 Trigger in Run 2

- Switched to the "Stage-1" calorimeter trigger for 25 ns
  - a better tau trigger and pile-up subtraction for jets, isolation, and energy sums

New Tau trigger efficiency with and w/o isolation compared to legacy (Run 1) trigger



- Full trigger upgrade as in TDR (Stage 2) will be deployed in 2016
  - full trigger tower granularity ("region" level used in Run 1)
    - Better position (η x ϕ) and energy resolution, more flexibility
  - Will run in parallel in 2015
  - Installation and commissioning proceeding well
  - Algorithms are being validated

Endcap Track Finder (TF) is fully installed with all CSC inputs validated.

Endcap TF

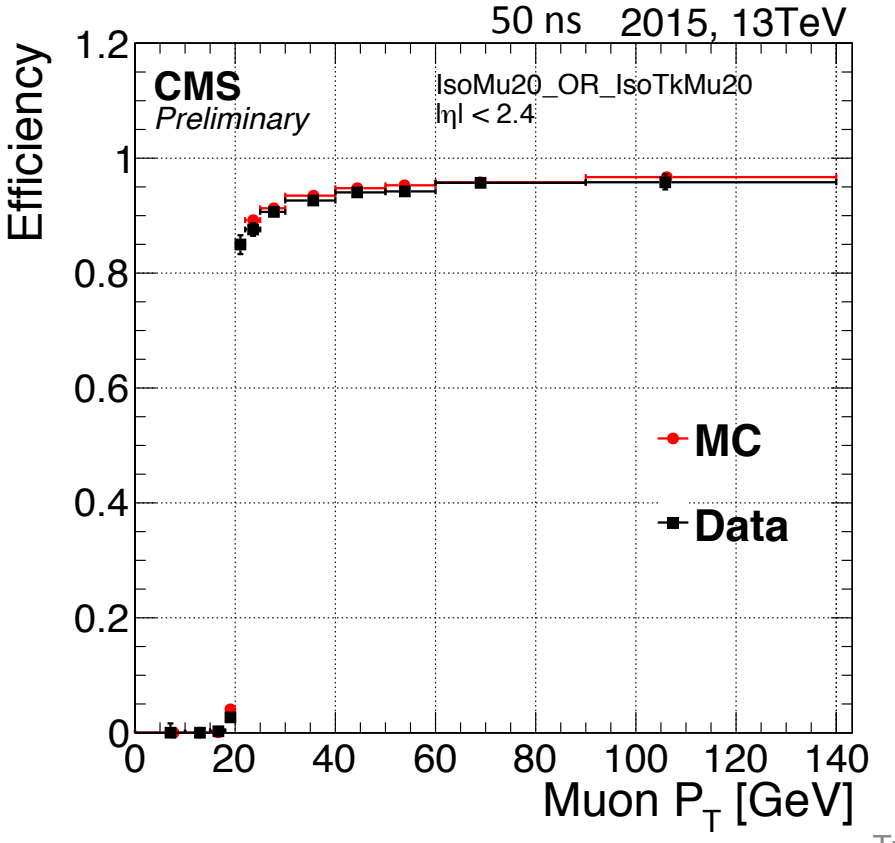
High-Level Trigger in Run 2

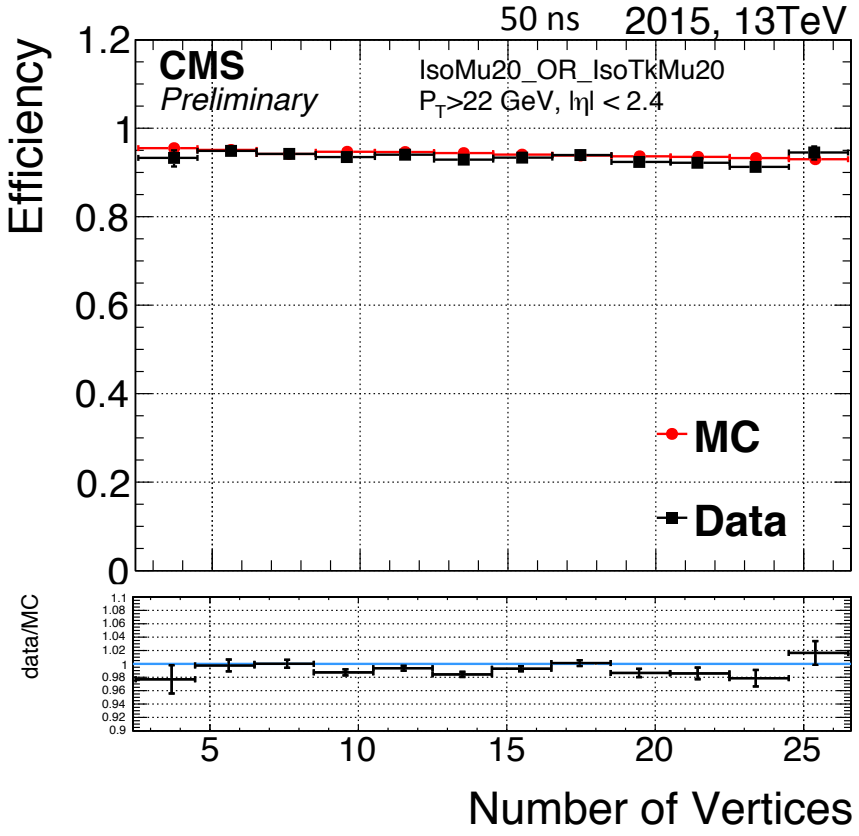
- Successful operation of the HLT for physics data-taking during 50 ns and 25 ns ramp up.
  - Also collecting data for detector calibration/alignment & commissioning
  - Deployed special menus: VDM scan and low pileup runs for FSQ/HIN, dedicated menu for runs with magnet off
- Level-1 and HLT menus in place targeting different scenarios:
  - 50 ns runs: peak luminosity of 5E33cm^{-2}s^{-1} (PU ~ 30)
  - 25 ns runs: peak luminosities of **3.6E33-1E34 cm^{-2}s^{-1} (PU 20 – 40)**
- Menus have taken into account feedback from data; also fine-tuning to different LHC scenarios
- Include significant improvements in trigger algorithms to handle the expected increases in rate (due to the increase in center of mass energy) and pileup

High-Level Trigger in Run 2

- L1 & HLT rates and HLT CPU usage compatible with online, offline & physics requirements
- Successful commissioning of improvements in HLT algorithms

Isolated Muon Trigger





DAQ for Run 2

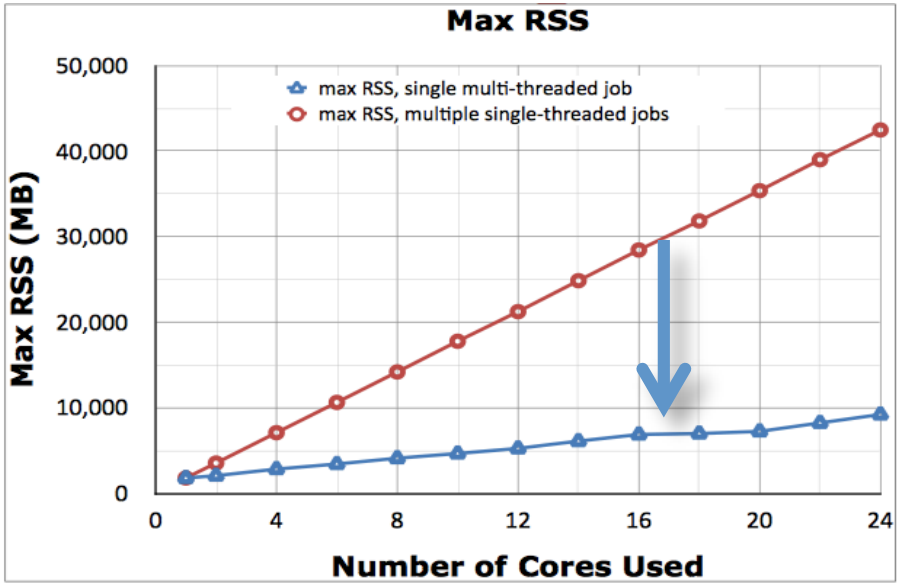
- Entirely new DAQ system (DAQ2)
  - Support for legacy and new (uTCA based) back-end electronics (L1 trigger upgrade and HCAL forward)
  - New equipment (PC, 40/56 Gbps networking, storage to Lustre)
  - File based HLT, monitoring with Elastic data analytics tool
  - **Operating well!**

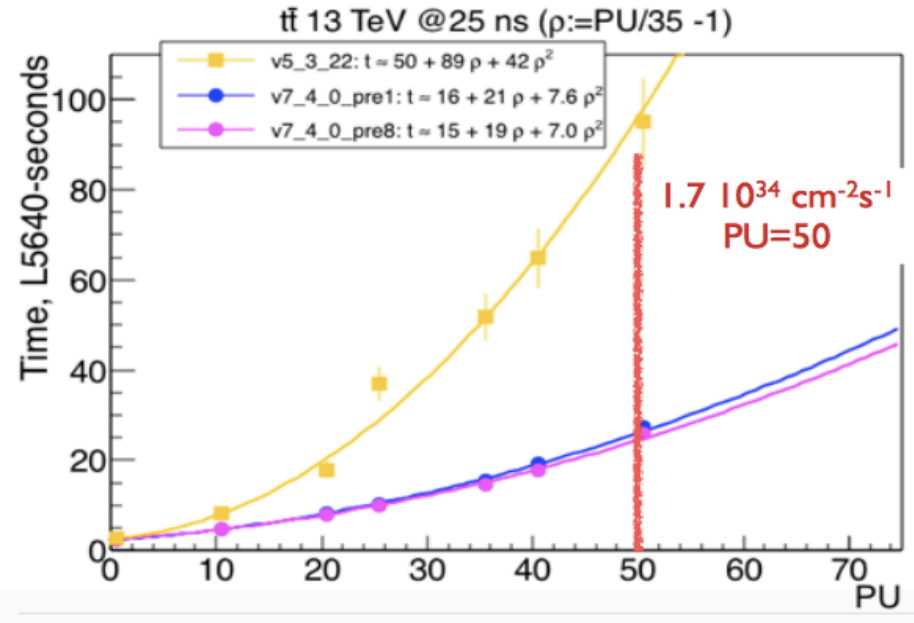
- New Trigger Control and Distribution System
  - Provides additional partitions for new Trigger/detector systems
  - Provides synchronisation signals for Lumi and beam monitoring detectors

- Updated online cluster & extended HLT farm

Offline and Computing for Run 2

- Collaboration-wide effort to meet Run 2 challenges within resource constraints
- Large performance gains
  - Simulation: factor of 2 gain in CPU utilization
    - Primarily by reducing time spent tracking low-energy particles in Geant4
  - Reconstruction: Large gains, particularly in tracking area and algorithms appropriate for 25 ns conditions
- CMS Tier-0 is multi-threaded!
  - Large memory savings

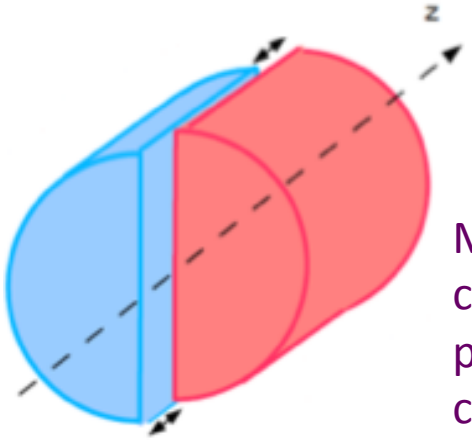




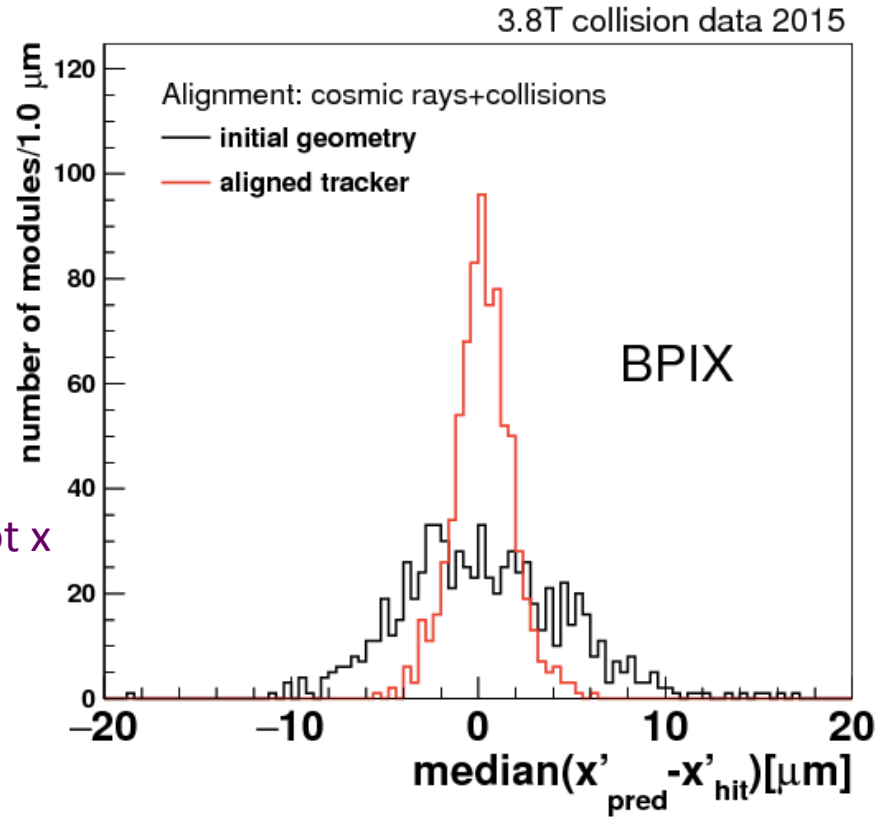
Alignment and Calibration

- Good alignment and Calibration crucial for high-quality early physics
  - with cosmic muons before data-taking start
  - with early data, with automatic online workflows (prompt calibration loop) and offline studies

correcting for large structural movements of Pixel Detector (correlated to thermal and B field cycles)



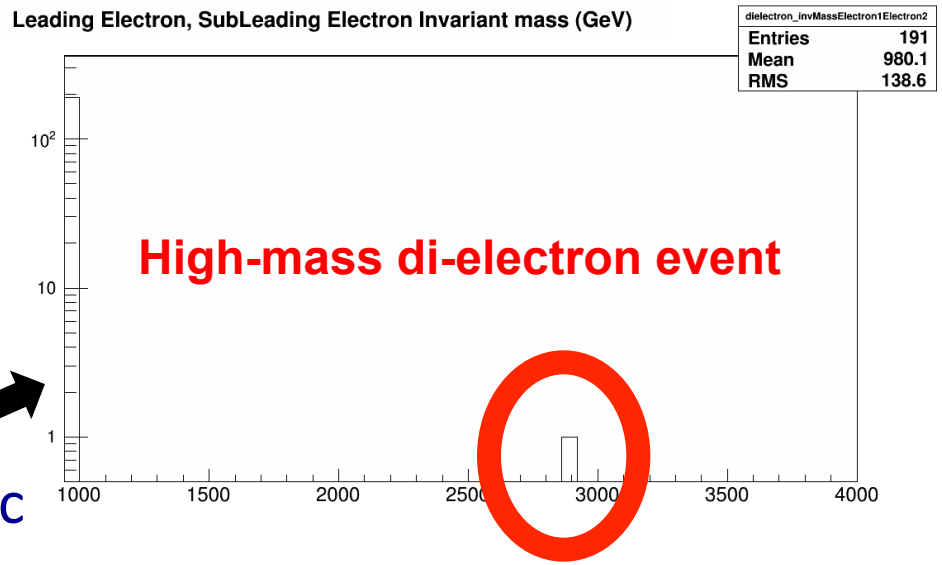
Measurement of beam-spot x coordinate from pixel performed with prompt calibration loop

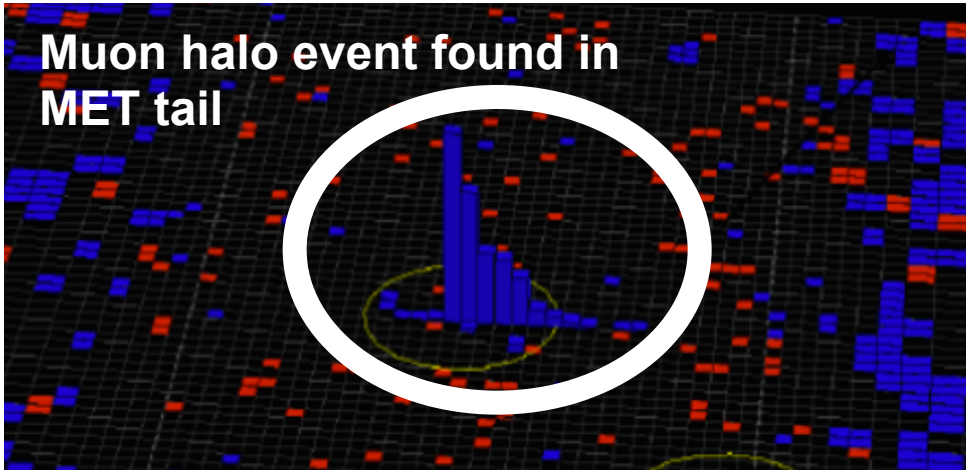


Preparing for new physics…

- During shutdown, implemented strategy to investigate relevant kinematic tails: this is where
  - a typical new-physics signal falls
  - also where noise-induced background could fall
- DQM monitoring plots of kinematic tails
- Hotline: selection of O(10) events with large MET, large jet p_T, etc, for detailed checks

Online DQM

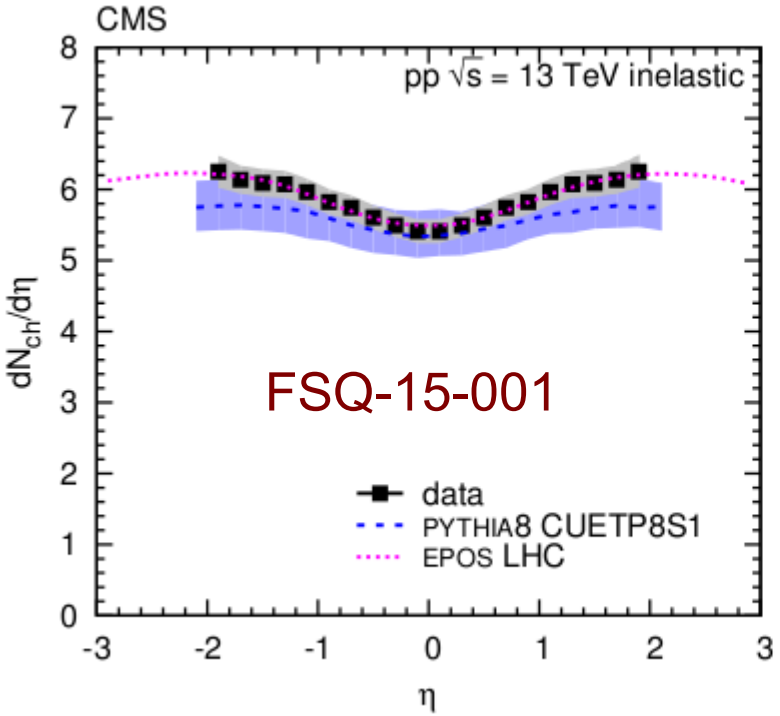


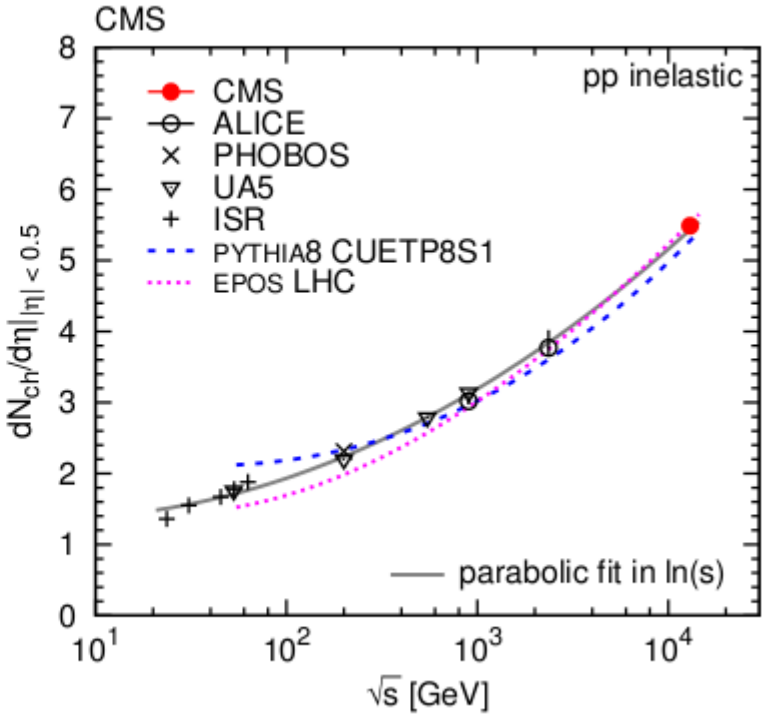


Run 2 Physics Highlights

dN/dη: first LHC Run 2 publication!

Analysis performed w/o magnetic field and with the pixel detector
Two methods used and combined (tracklets and 3-hit tracks)





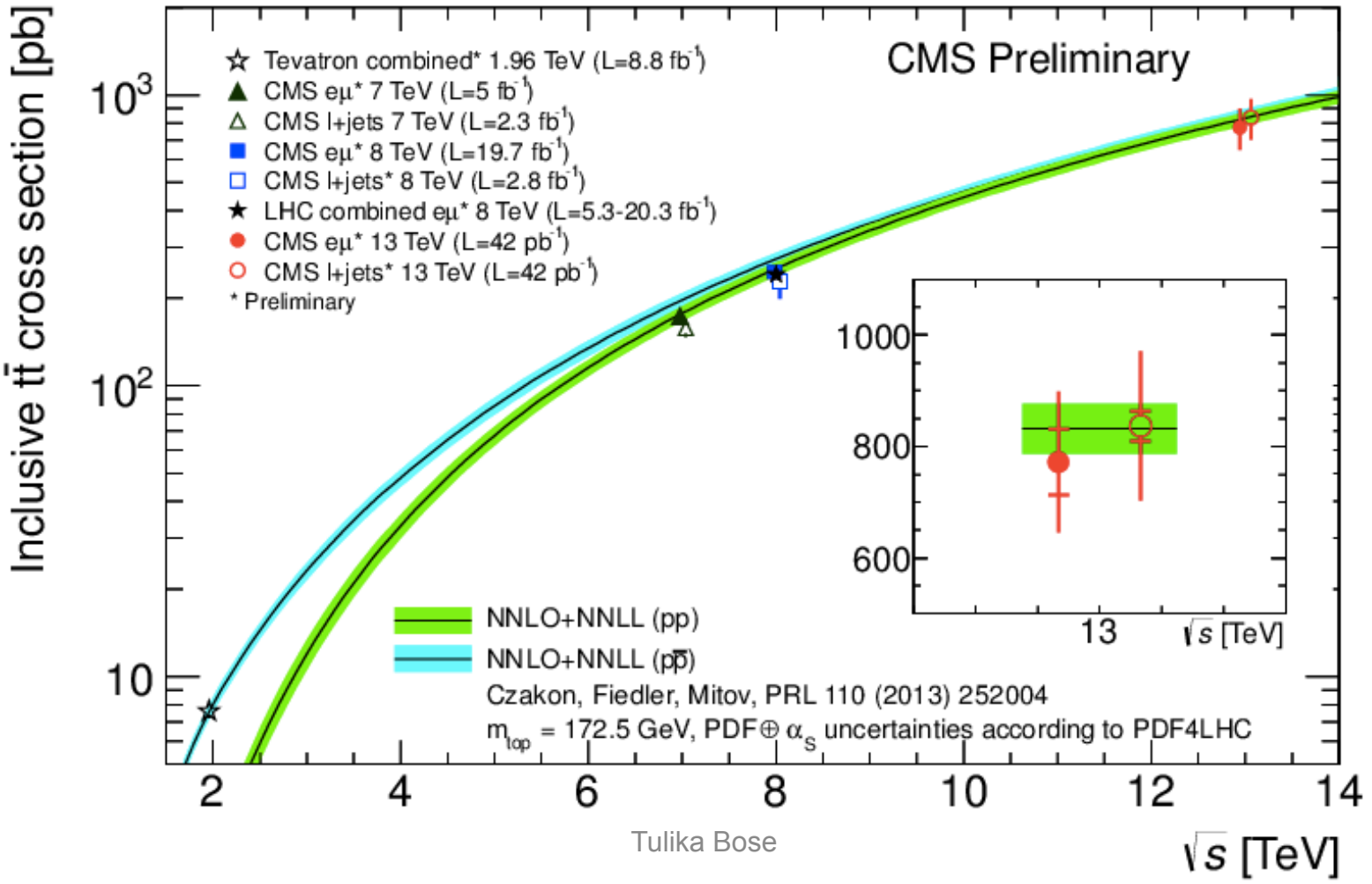
- Mid-rapidity: **EPOS LHC** and **PYTHIA8 CUETP8M1** consistent with data within systematic uncertainties
- Rapidity dependence better described by **EPOS LHC**
- Provides new constraints for tuning event generators

Submitted to PLB!
arXiv:1507.05915

ttbar inclusive cross section

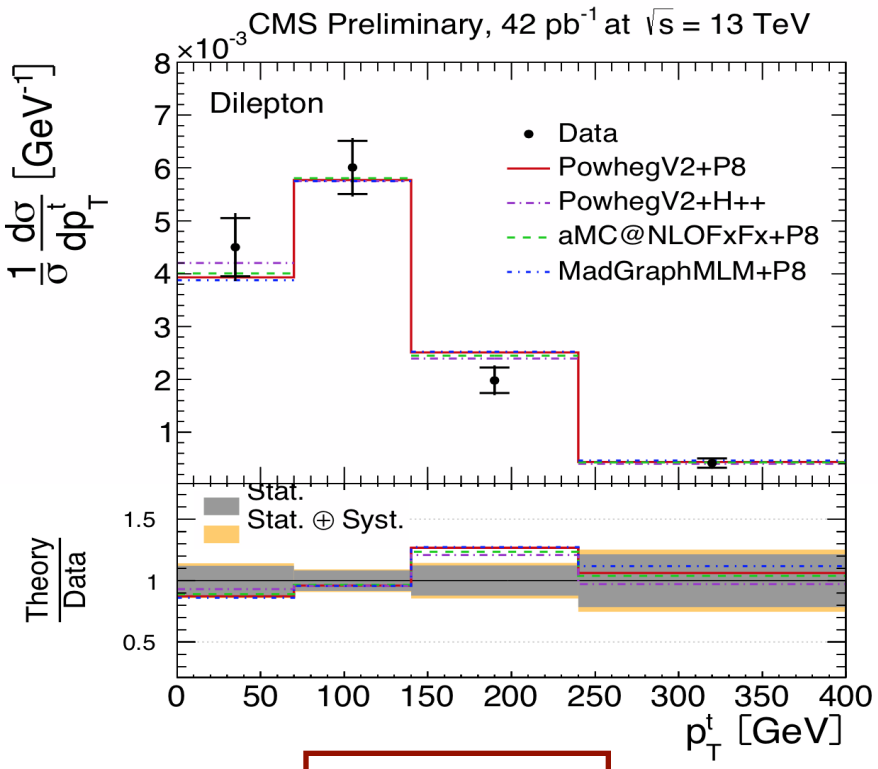
- Inclusive ttbar cross section @13 TeV measured:
  - eμ and semi-leptonic channels

TOP-15-005
TOP-15-003

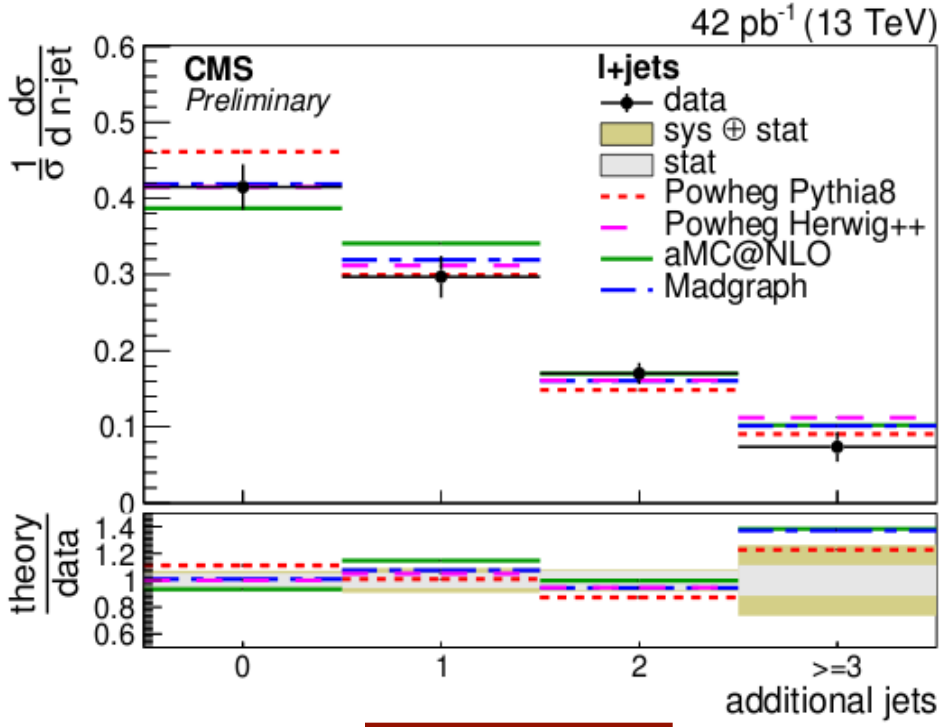


ttbar differential cross section

- ttbar differential cross sections at 13 TeV measured:
  - di-lepton (ee, eμ, μμ) and semi-leptonic channels
  - Good agreement with NLO MC within uncertainties



TOP-15-010



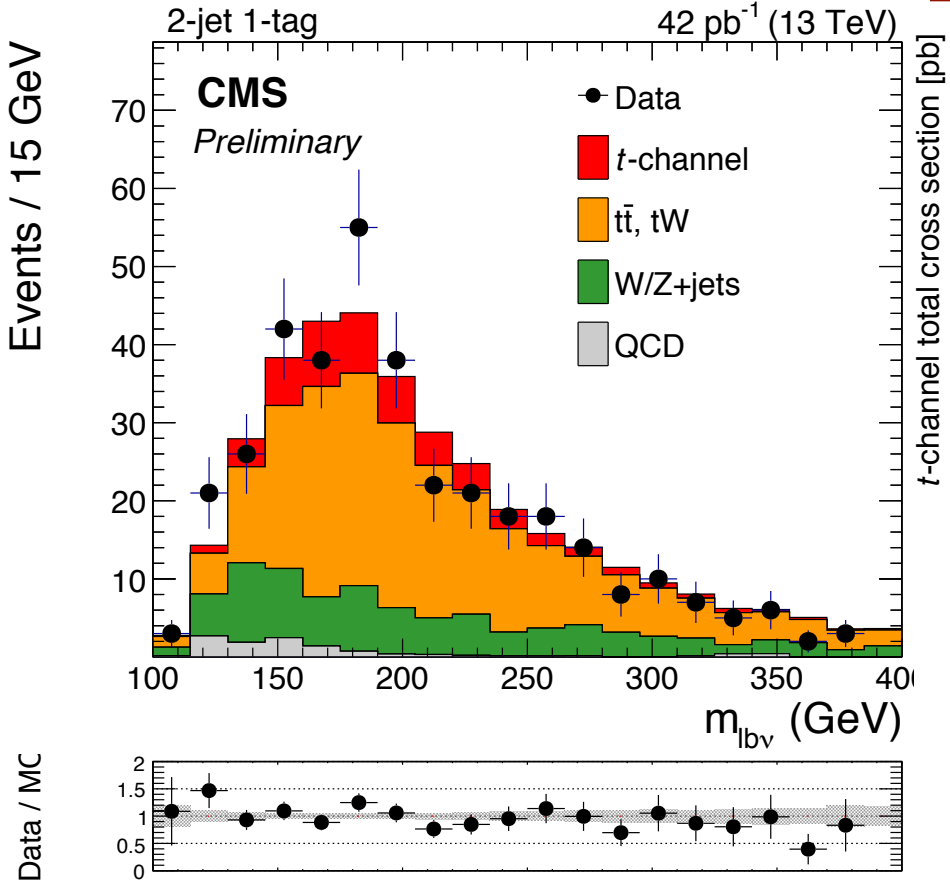
TOP-15-005

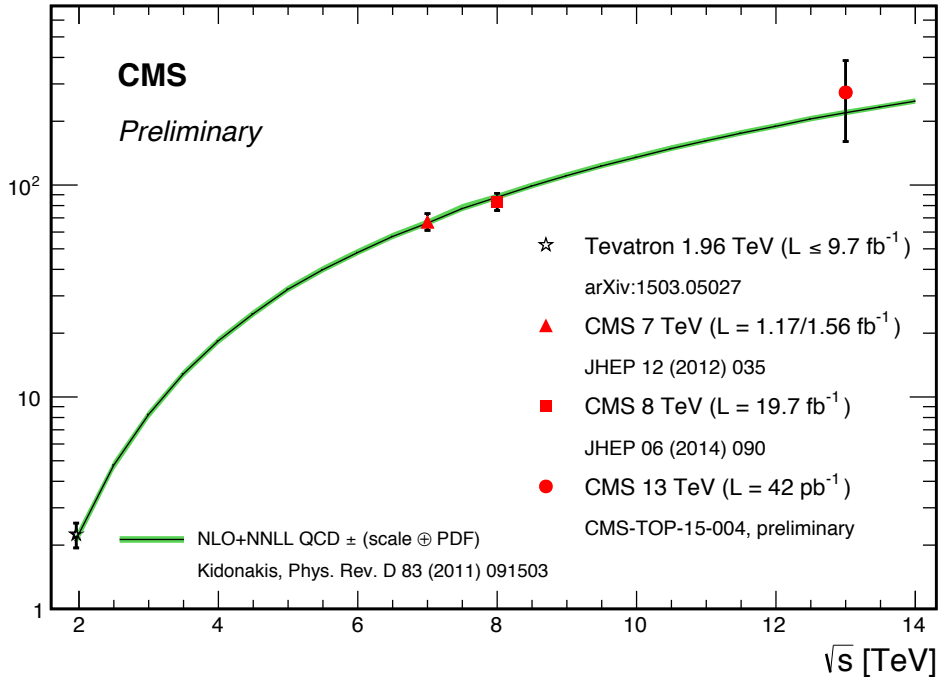
Single top cross section

t-channel single top cross section @13 TeV measured:

- μ + jet channel

$$\sigma_{t\text{-ch.}} = 274 \pm 98\,(\text{stat.}) \pm 52\,(\text{syst.}) \pm 33\,(\text{lumi.})\ \text{pb}$$





$$|V_{tb}| = 1.12 \pm 0.24\,(\text{exp.}) \pm 0.02\,(\text{theo.})$$

TOP-15-004

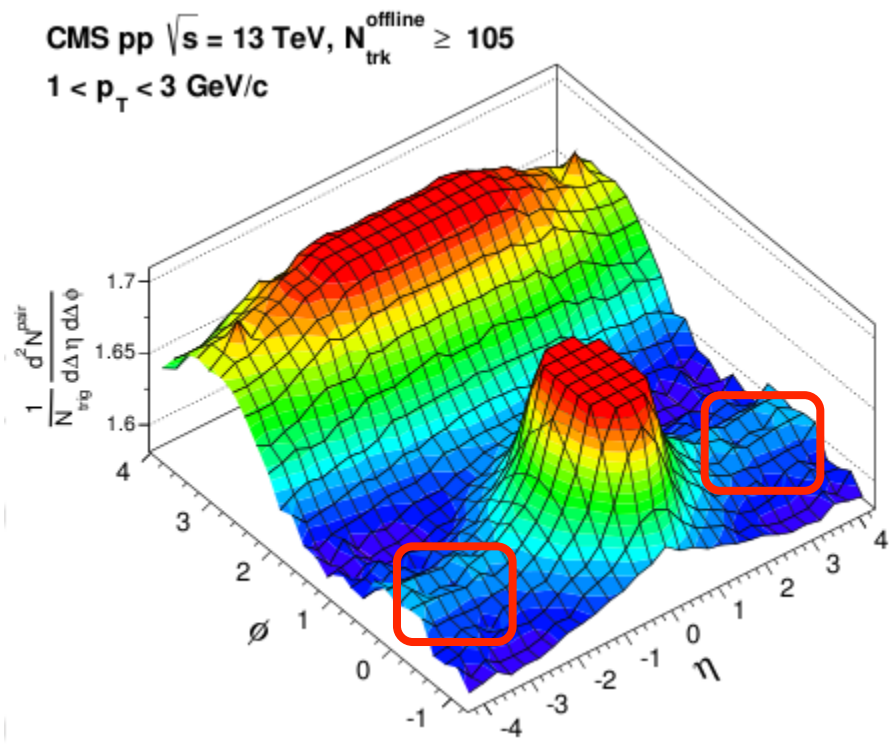
The ridge at 13 TeV

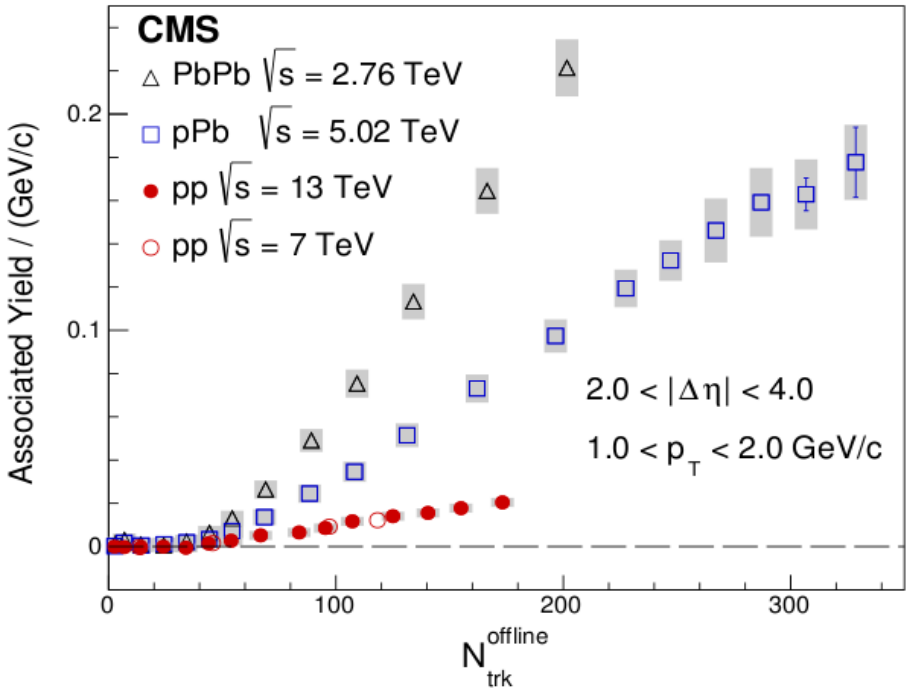
Two particle angular correlations for charged particles:

- Analysis similar to the one already performed at lower center-of-mass energies

FSQ-15-002

Effect confirmed at different energies and for different colliding beams





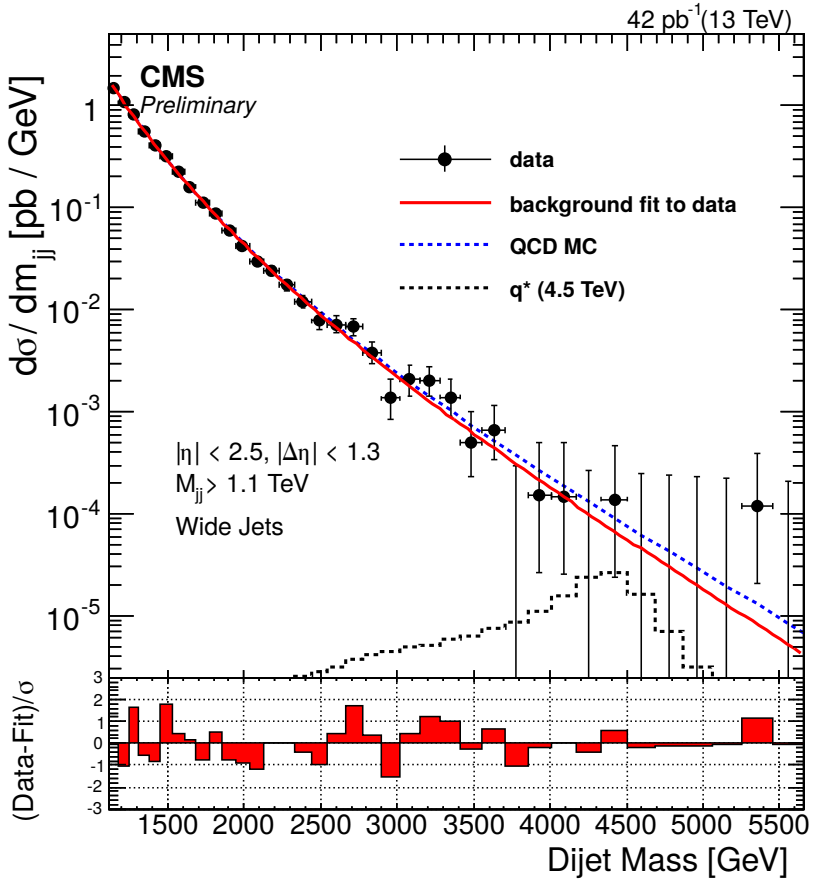
No energy dependence for pp

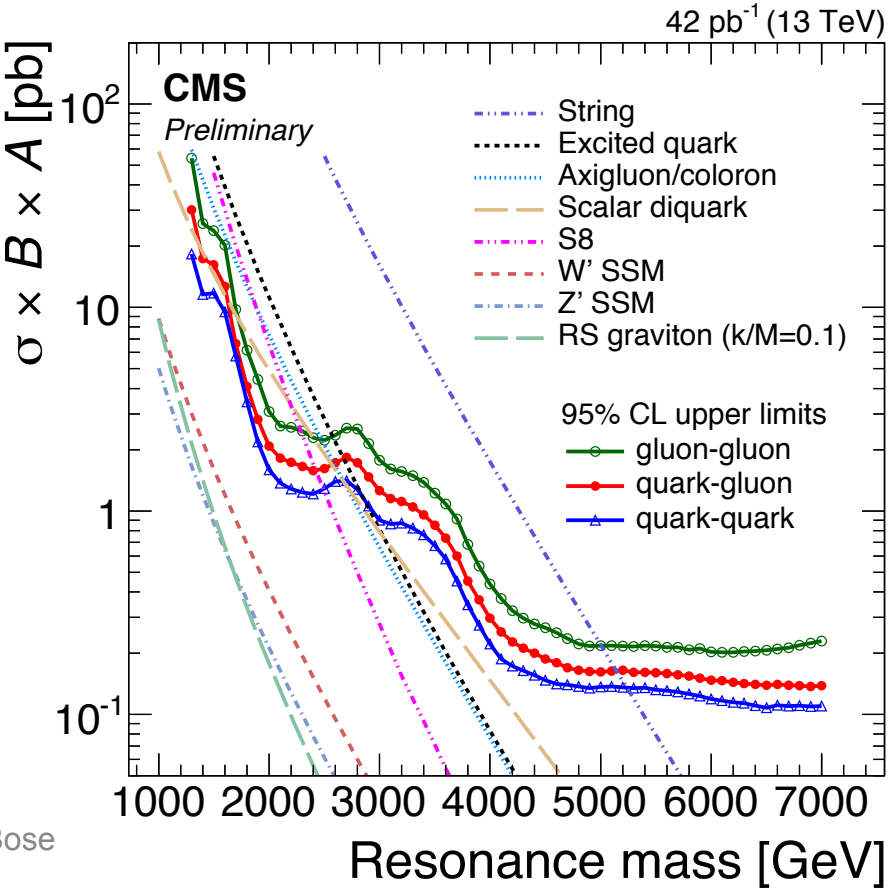
Di-jet resonance search

- Model independent search applicable to any model with narrow qq, qg, or gg resonances

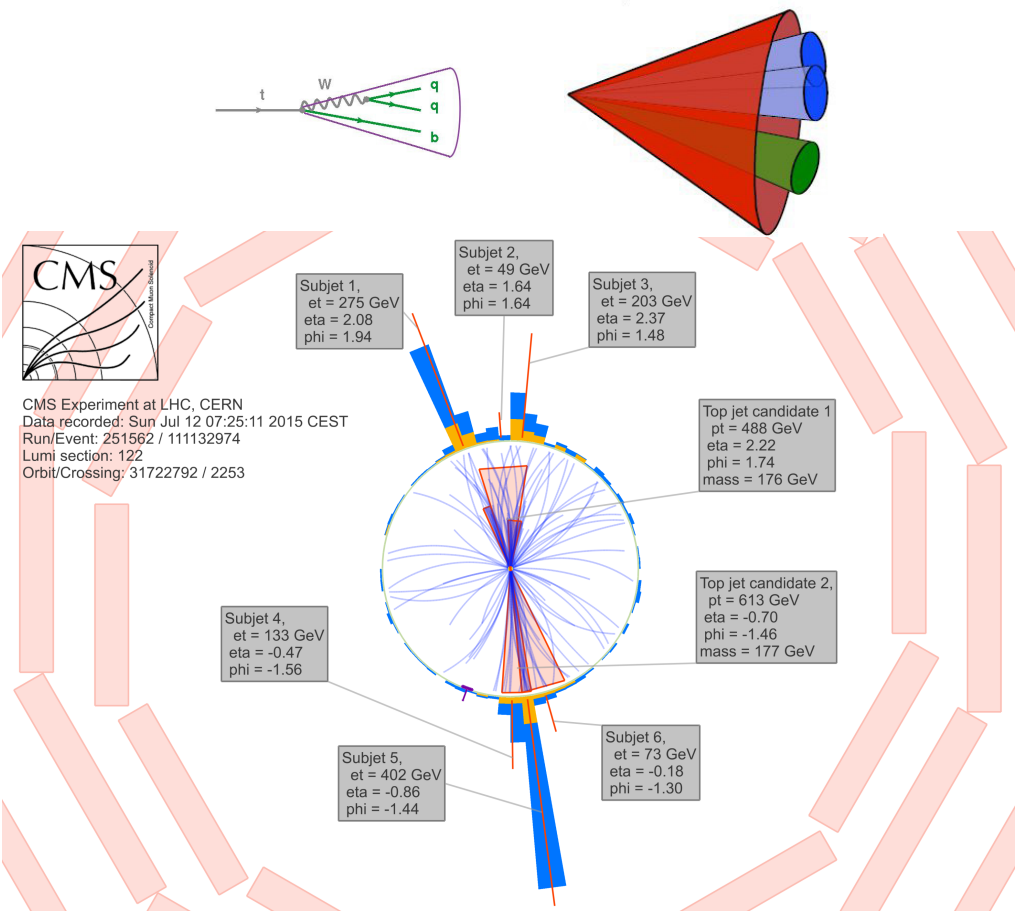
EXO-15-001

  - **We exclude string resonances with masses below 5.1 TeV**
  - **Surpass Run 1 limits for resonances above 5 TeV in general**

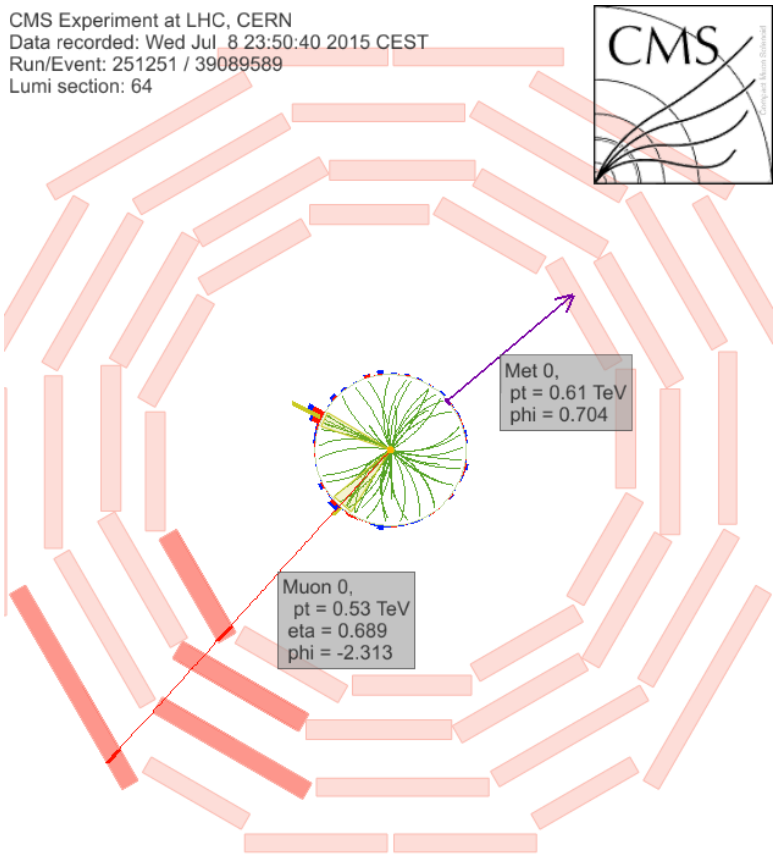




Looking forward to seeing more of these…



Boosted ttbar event
@ m_{ttbar}=2.5 TeV



Single muon + missing E_T
@ m_T = 1.1 TeV

Heavy Ion Run

Heavy Ion Preparations for Run 2

- CMS is getting ready for the first high luminosity Pb run in the LHC Ion program
  - L1 Calo Trigger upgrade hardware being commissioned for HI
  - Dedicated Tracker and Pixel firmware developed and commissioned
  - DAQ2 configuration parameters optimized for HI data taking available
  - Achieved ~10kHz detector readout rate for high occupancy HI events
  - Allows for highly selective trigger configurations for hard probes

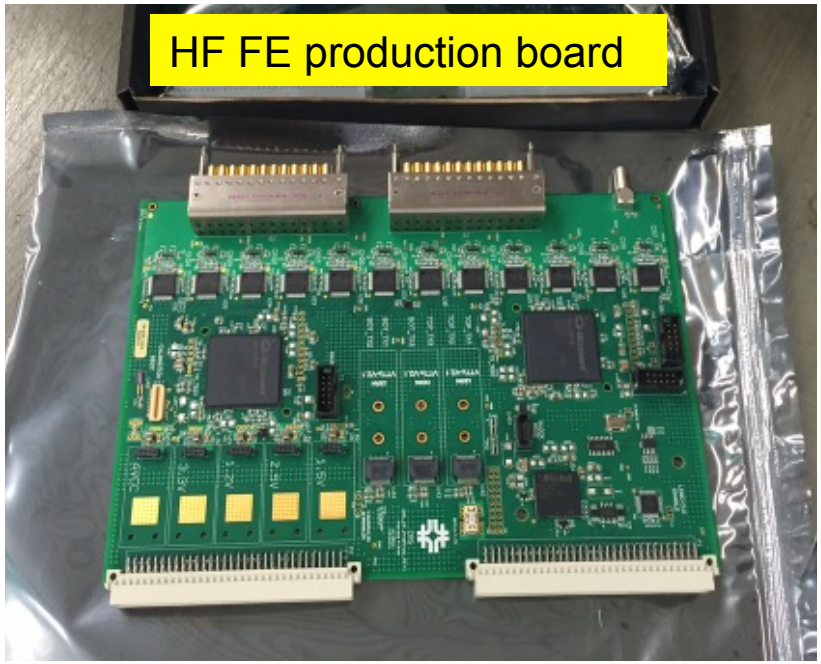
- All elements in place to fully exploit the high p_T reach of the high lumi (Ion) LHC
  - Z^0-jet, photon-jet correlations, TeV-scale jet quenching
  - Differential studies of path-length/system-size/flavor dependence
    - photon-jet correlations vs photon p_T, centrality, b-jets, charmonium and bottomium production
  - High integrated luminosity is essential
  - 5TeV pp reference data needed

- Our expectation/request for the Ion Run period:
  - ~1 nb^{-1} of 5.02 TeV PbPb data
  - ~40 pb^{-1} of 5.02 TeV pp reference data

Upgrades

Phase 1 Upgrades

- Phase I upgrades progressing well
  - L1 Trigger
  - HCAL Endcap (HE), HCAL Forward (HF) front-ends
  - New Pixel detector

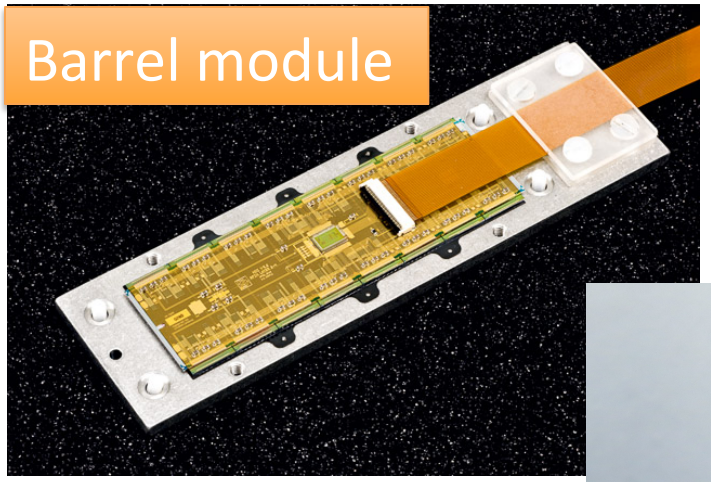


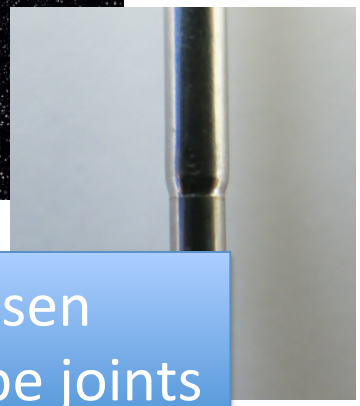
HCAL

- Phase1 HF Front-End (FE):
  - Production of QIE10 boards for HF FE upgrade completed.
    - Boards expected to arrive soon
  - Calibration/burn-in stand set up
- Phase1 HE Front-End:
  - Successful test-beam in H2
    - with prototype SiPM &QIE11 cards
  - Production Readiness Review in Nov-2015

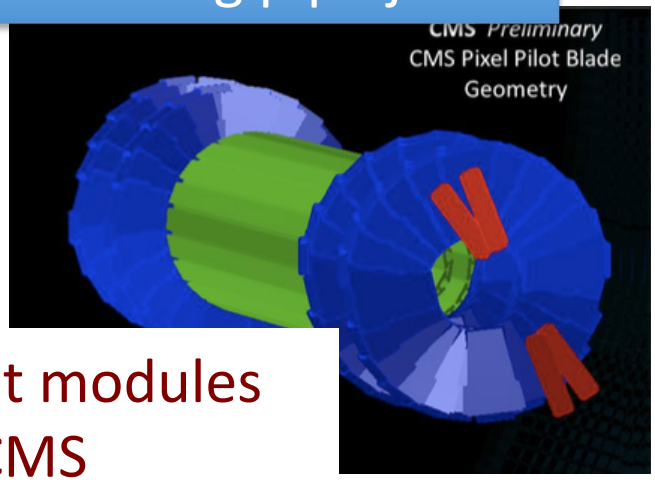
Pixel Phase 1 Upgrade

- Barrel module production is ramping up: more than 14% of the modules produced
  - Forward disk module production to be started soon
- Mechanics and service cylinders
  - All details sorted out
  - First final pieces ready
- Eight pilot modules installed in CMS have been calibrated and joined the global run: looking forward to collecting collision data
- On track for installation in YETS 2016/2017





Laser welding chosen for the cooling pipe joints



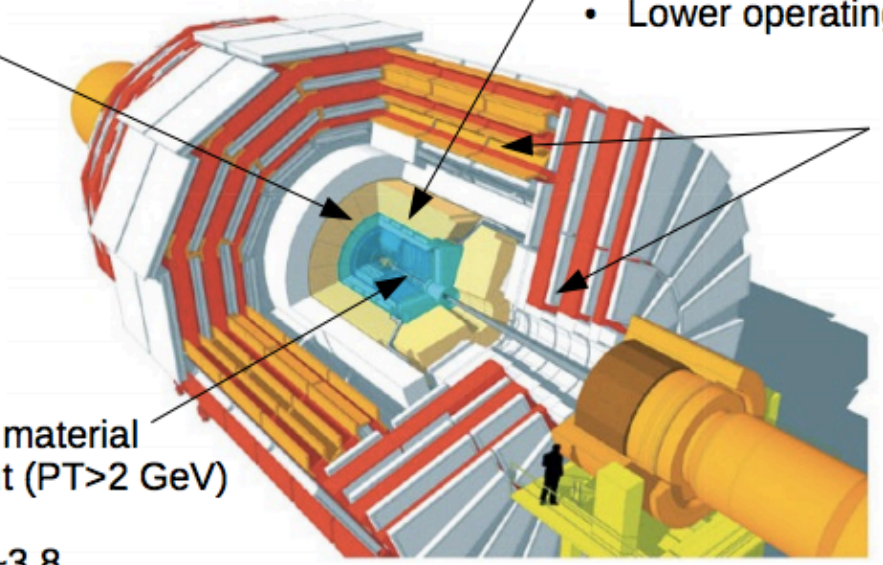
Pilot modules in CMS

Phase 2 Upgrades

- Technical Proposal submitted: https://cds.cern.ch/record/2020886
- Finalized Scope document (under scrutiny of LHCC)

New Endcap Calorimeter
- Radiation Tolerant
- High Granularity
- 3D capability

Barrel Calorimeter
- Replace FE/BE electronics
- Lower operating temperature(8°)



Muon system
- Replace DT/CSC FE/BE electronics
- Complete RPC coverage In region 1.5<η<2.4
- Muon tagging with GEMs for 2.4<η<3.0

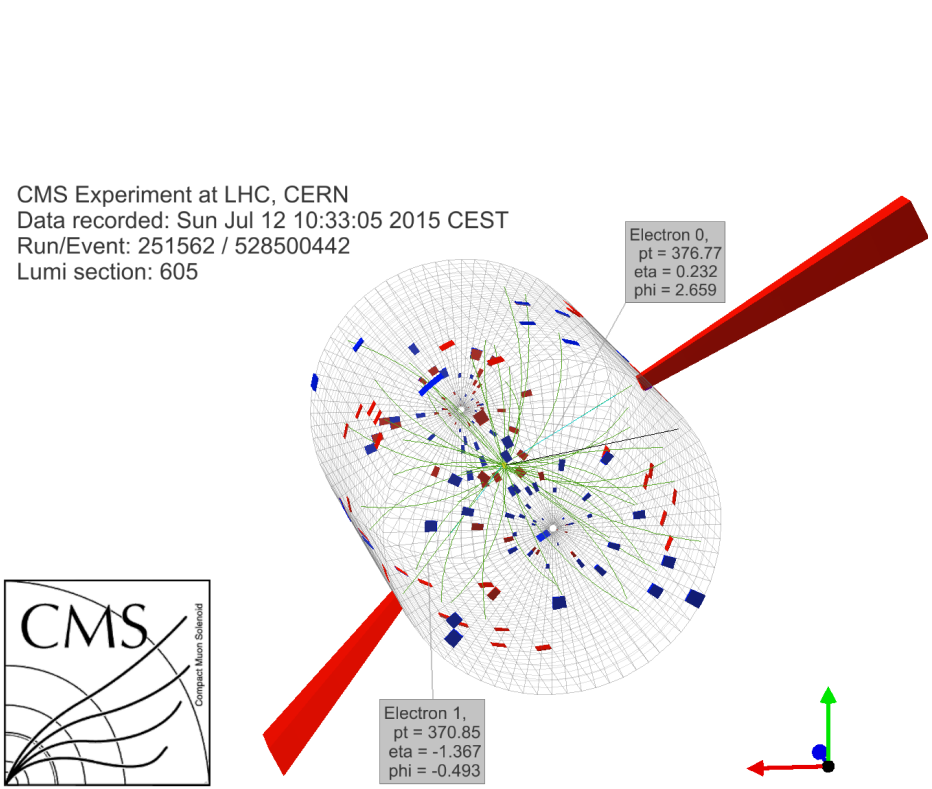
New Tracker
- Radiation tolerant – less material
- 40 MHz selective readout (PT>2 GeV) for track trigger
- Extend to coverage of η~3.8

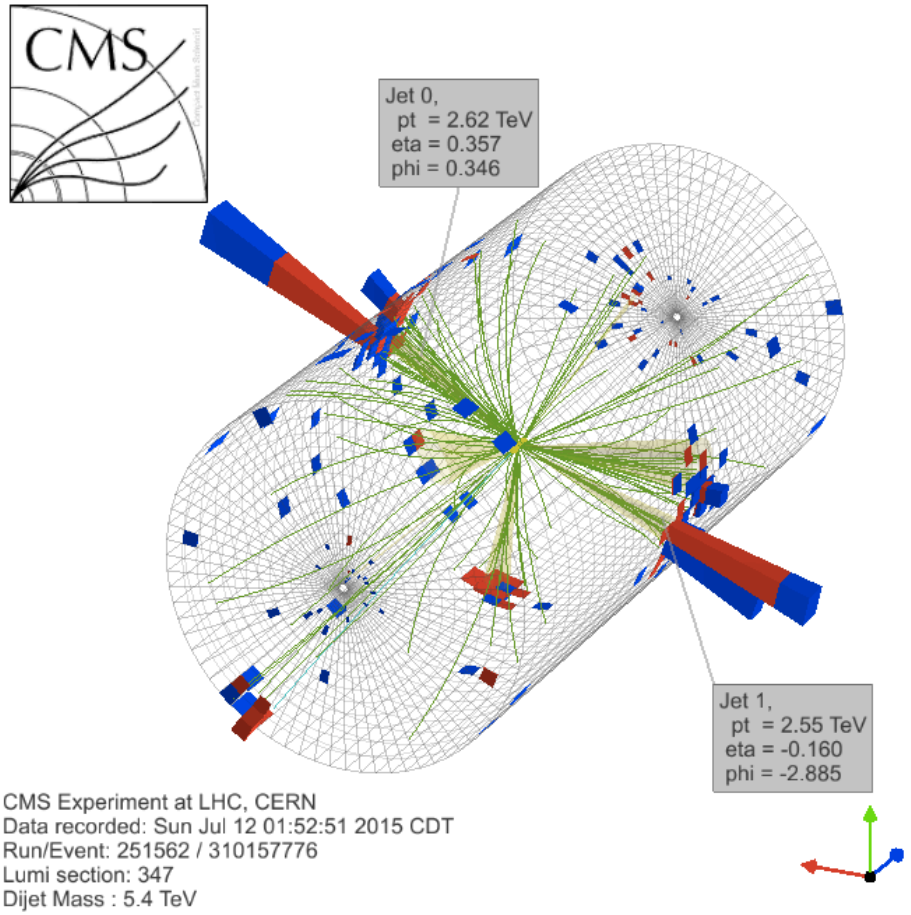
Trigger/HLT/DAQ
- L1 Track Trigger
- L1 Trigger: 12.5 μs latency, 750 kHz output
- HLT output of 7.5 kHz

Summary & Conclusions

- CMS is successfully taking good quality data with high efficiency during Run 2
  - Improved detectors, trigger and data-acquisition
- Computing and software algorithms much improved for Run 2
  - Event reconstruction robust against 25ns pile-up conditions
  - Multithreading already deployed offline; online is next
- Phase 1 and Phase 2 upgrades are progressing well
- Run 2 Physics is in full swing!
  - First Run 2 physics results/publications available!
  - Many more on their way…

Discoveries awaiting us ?

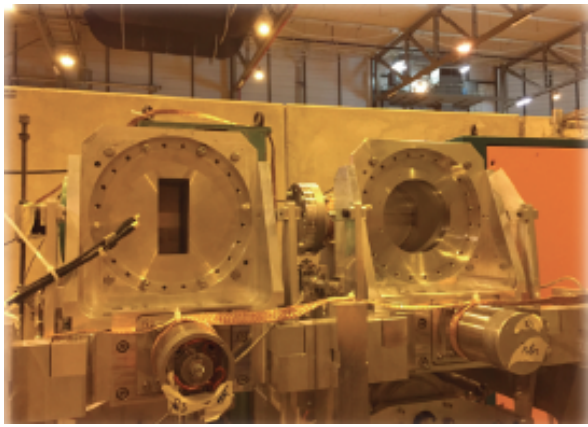




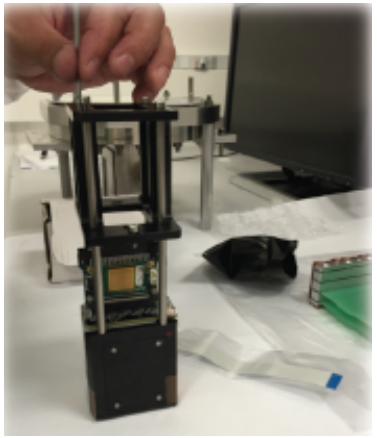
Backup

CT-PPS

- Tests of Roman Pots insertions at 0.8m beta star are proceeding according to the plans
  - Pots inserted at each intensity step up to 1.9 x 10^{33} cm^{-2} s^{-1} . No problems so far: BLMs, temperatures and vacuum ok.
  - Extrapolation to 10^{34}: no problem expected .
- Timing detectors tested with 180 GeV protons in the H8/SPS beam
  - Two final Quartic modules and one Gastof prototype, equipped with the NINO frontends and connected to HPTDC boards.
- Tracking 3-D pixel sensors tested with PSI46dig ROCs in Fermilab beam.
  - Data is now being analyzed.



Roman pots in the H8 beam line



Quartic module with NINO frontend