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CMS Operations Update

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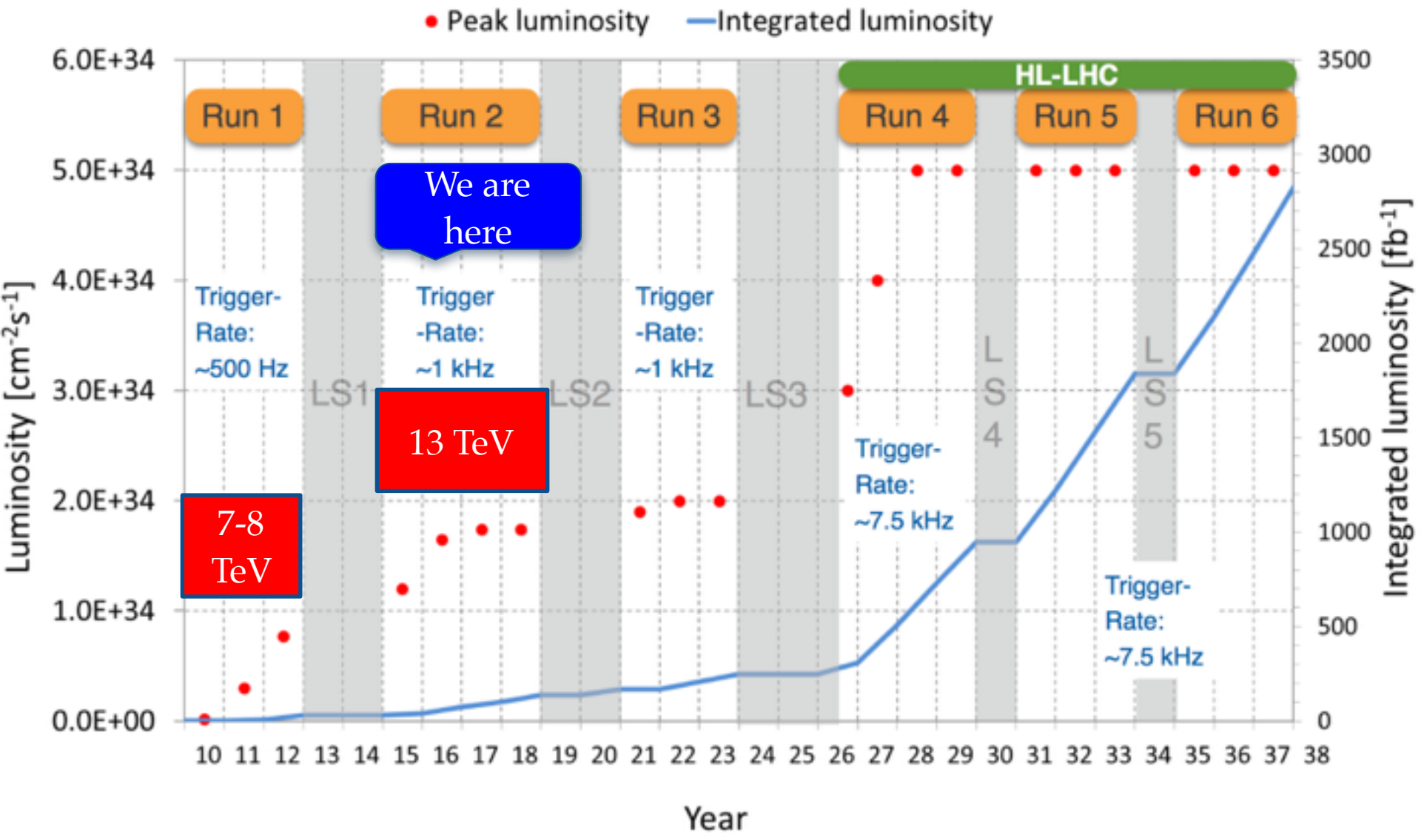
Fermilab PAC Meeting

Jan. 19, 2016

Large Hadron Collider



LHC Changes from Run 1 → Run 2

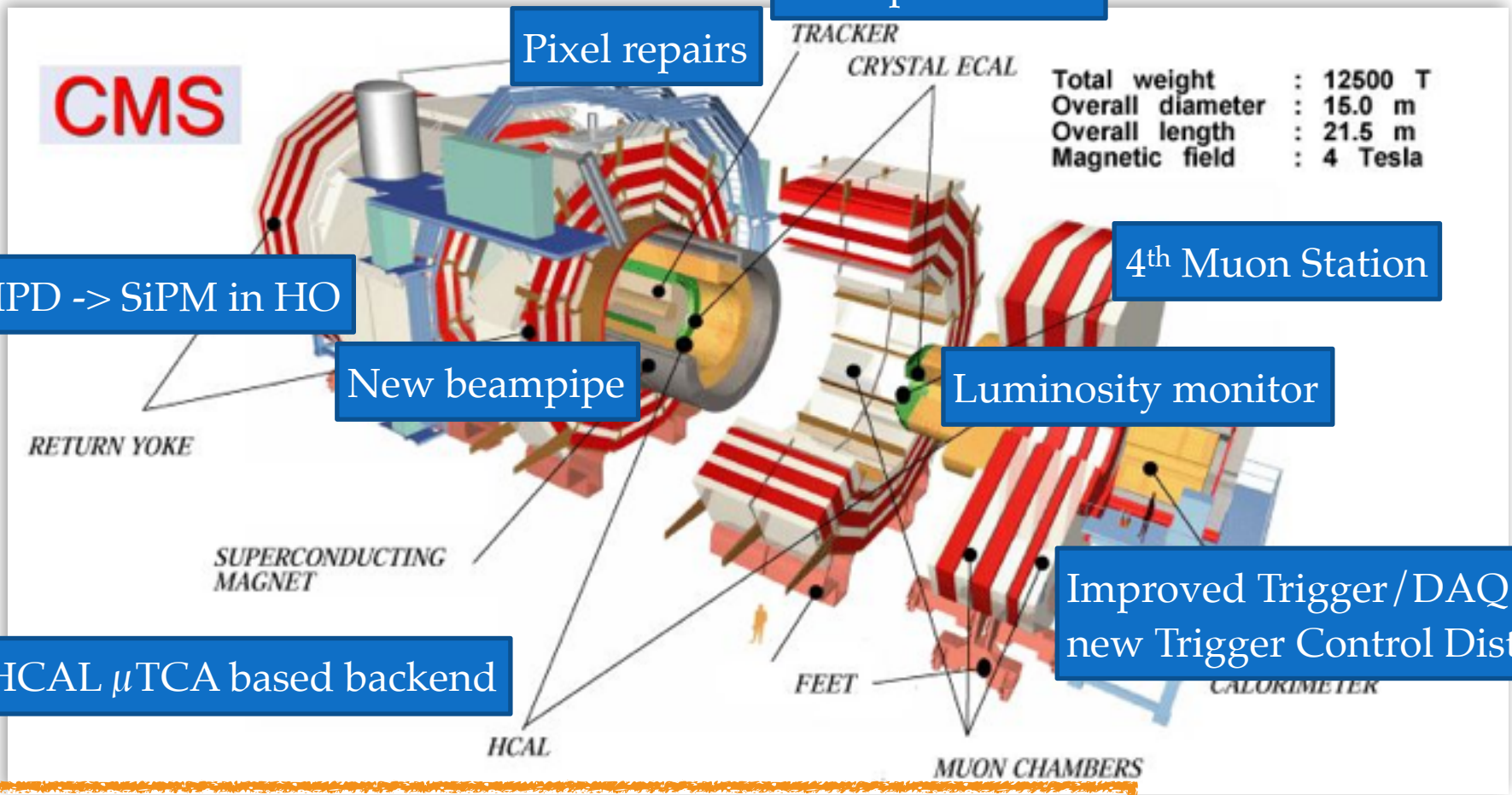
- **160%** larger collision energy → $\sqrt{s}$=13 TeV
- **50%** smaller bunch spacing → 25ns
- **200%** larger number of bunches → 2800 bunches
- **200%** larger pileup → 40 interactions/crossing
- **66%** smaller β^* → 40cm
- **170-220%** larger peak lumi → (13-17) x $10^{33}/cm^2/s$
  - From Matteo Solfaroli (CERN) at LHCC 23, Sept 2015 (https://indico.cern.ch/event/443017/)

"Priority for 2015 is to prepare 2016 as a 'physics production run' at 25ns"

- **50ns** recommissioning at 13 TeV, scrubbing, intensity ramp, brief physics run
- **25ns** commissioning, scrubbing, intensity ramp increasing # bunches, physics run

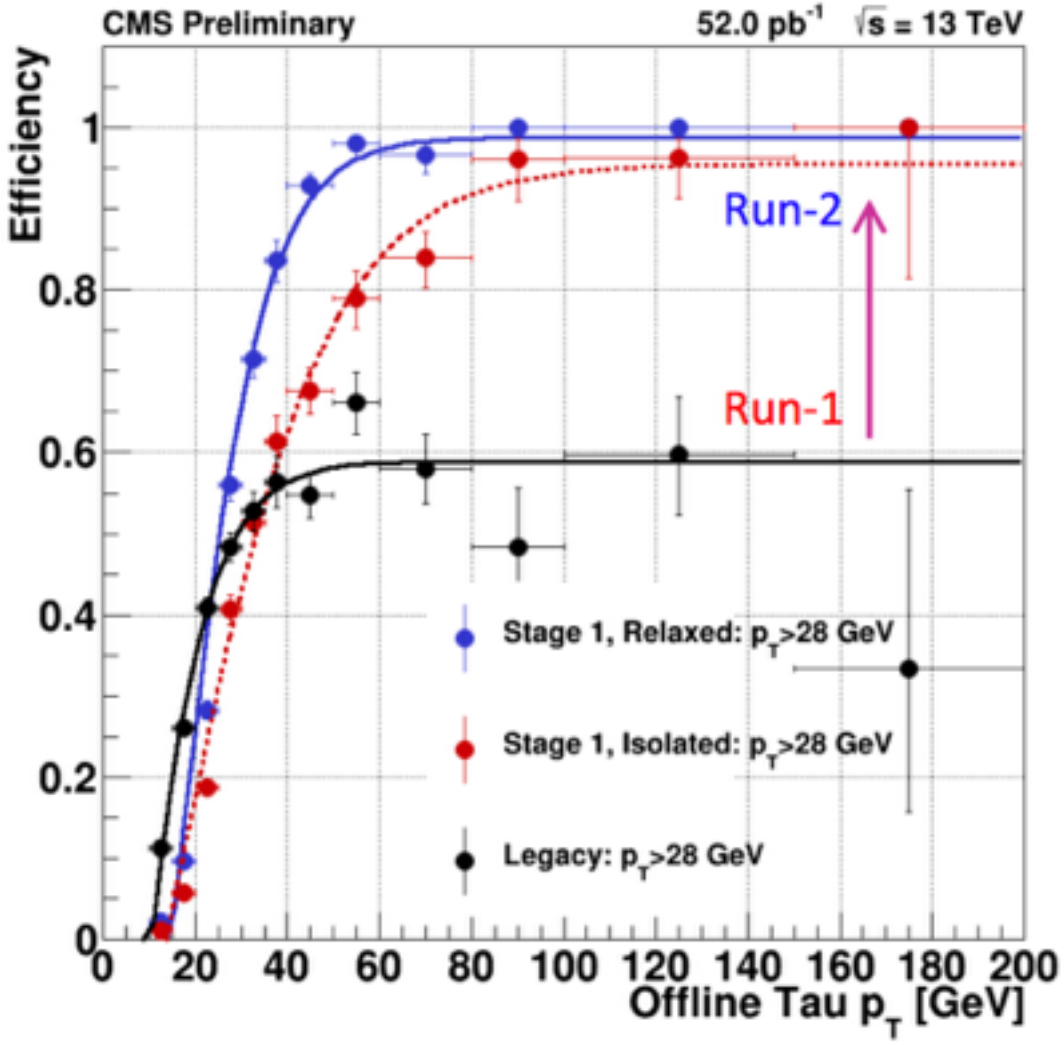
Variable running conditions made 2015 a dynamic year for LHC and for CMS

CMS detector for Run 2: Detector Improvements in LS1



Coming into the start of Run2, CMS was a ~new detector
Ready on 3 June 2015 for first collisions at √s=13 TeV

LS1 Improvements for 2015: example "Stage-1" Trigger

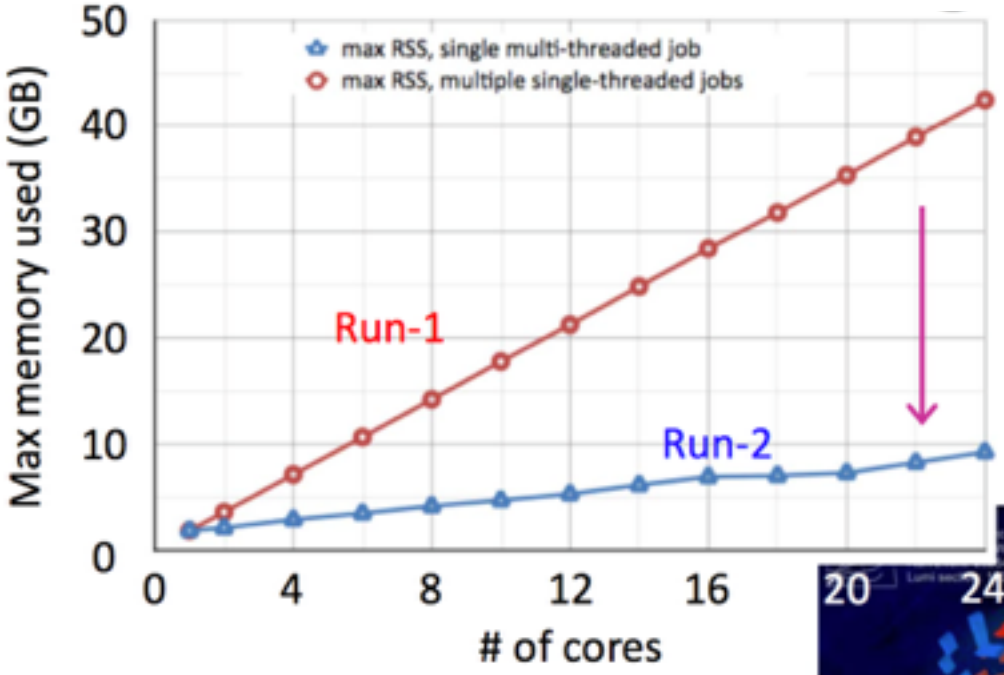


First stage of the CMS calorimeter trigger upgrade in use for 97% of the 2015 run

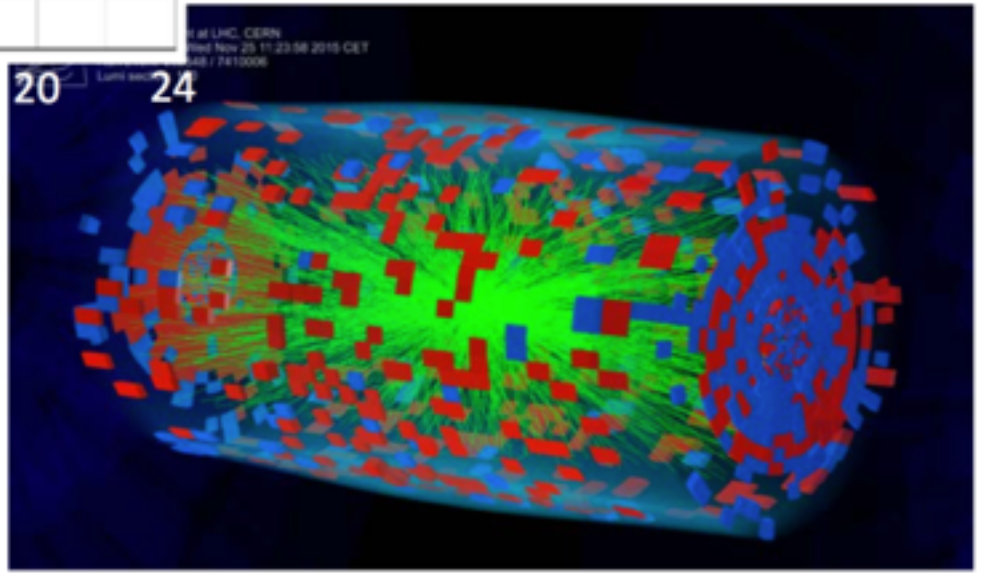
- Transition to the full trigger upgrade for the 2016 run
- Note: have regularly run with new trigger boards during 2015 collisions

Major improvement in τ trigger efficiency due to upgraded calo trigger

LS1 Improvements for 2015: example Software Framework



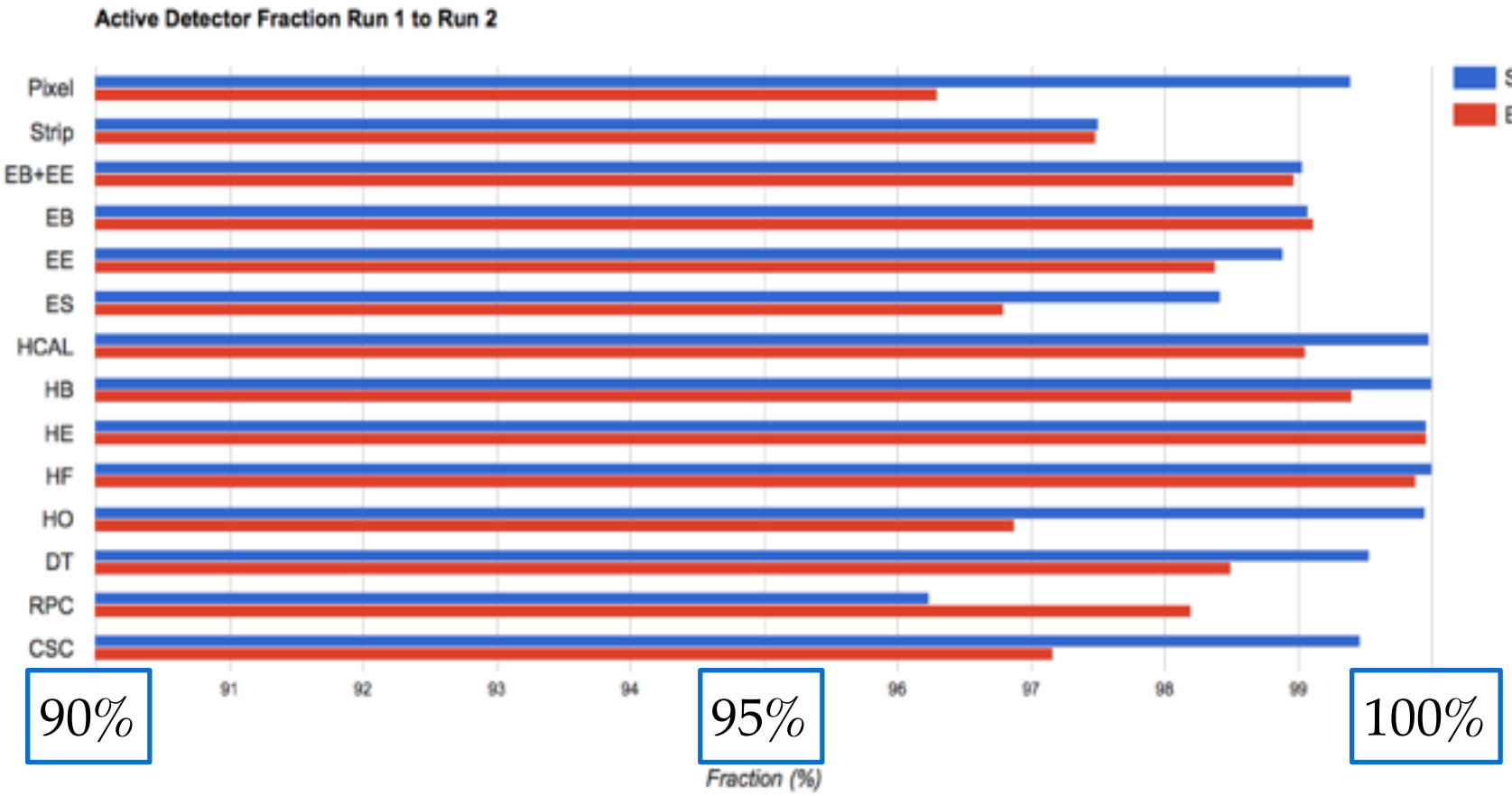
Updating to a multi-threaded framework reduces memory footprint needed to reconstruct events



Also, updates to event reconstruction reduced processing time to manageable levels in a high pileup environment

Excellent and stable performance of improved detector

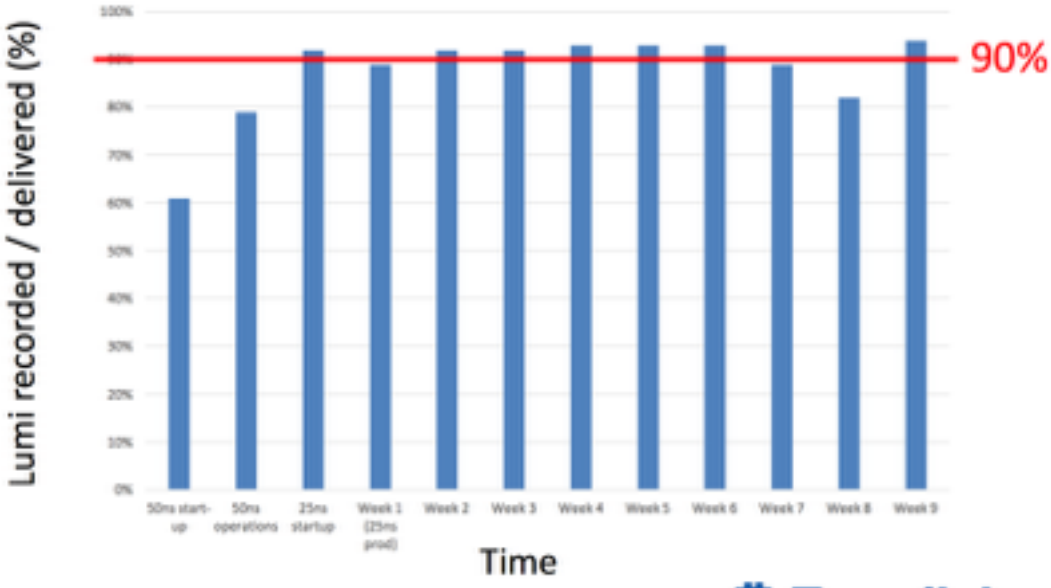
Fraction of active channels in Run-1 vs Run-2
Stayed stable during the year



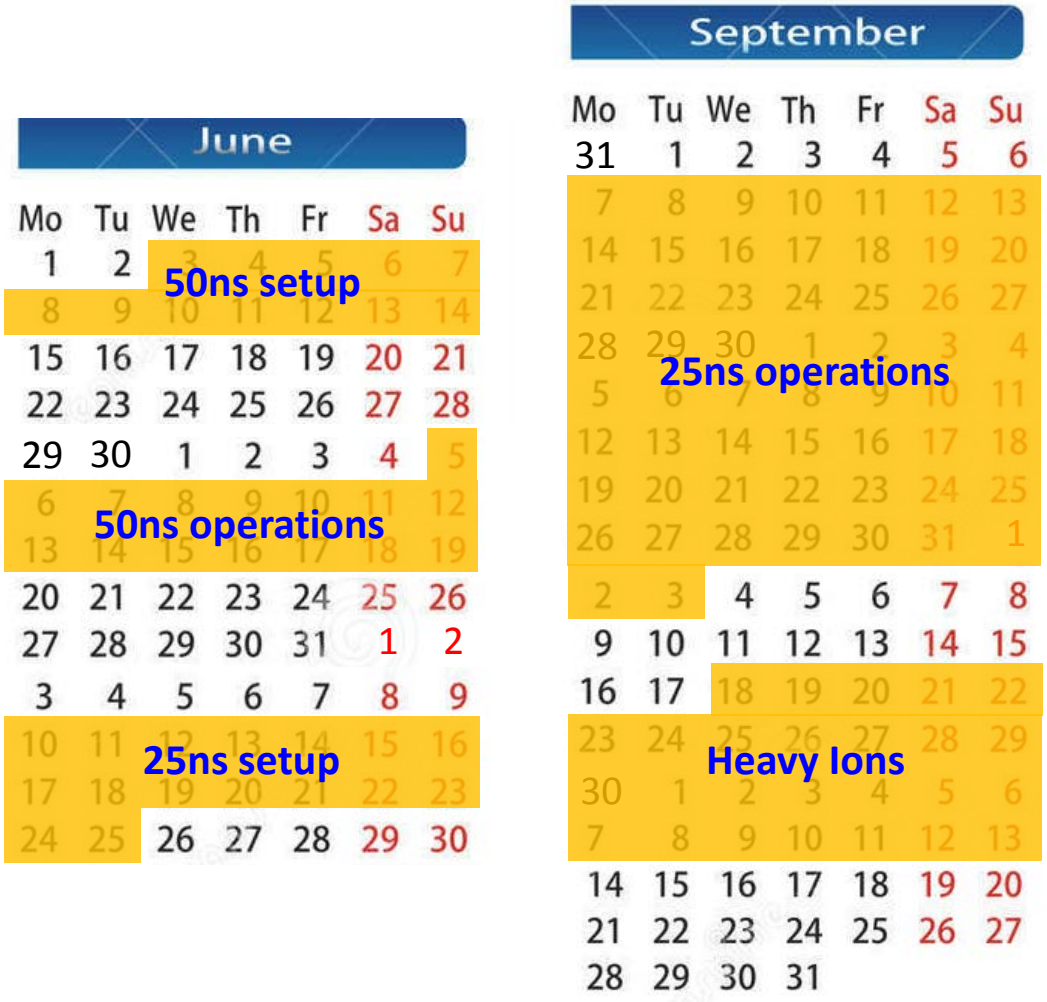
Some Operations Issues during 2015

- Rare 3 ns timing steps in clock tree
  - Fixed by resetting PLLs according to Xilinx specs
- Occasional trigger rate steps in calo optical links
  - Effect mitigated with automatic masking
  - Will not be an issue with 2016 trigger
- Rare link loss in forward Hadronic calo electronics
  - Effect minimized w/ autom. alarm/expert reaction
  - A significant amount of data requires special handling of MET

Steady state recording efficiency > 90%



However: Big problems with CMS magnet cryo system

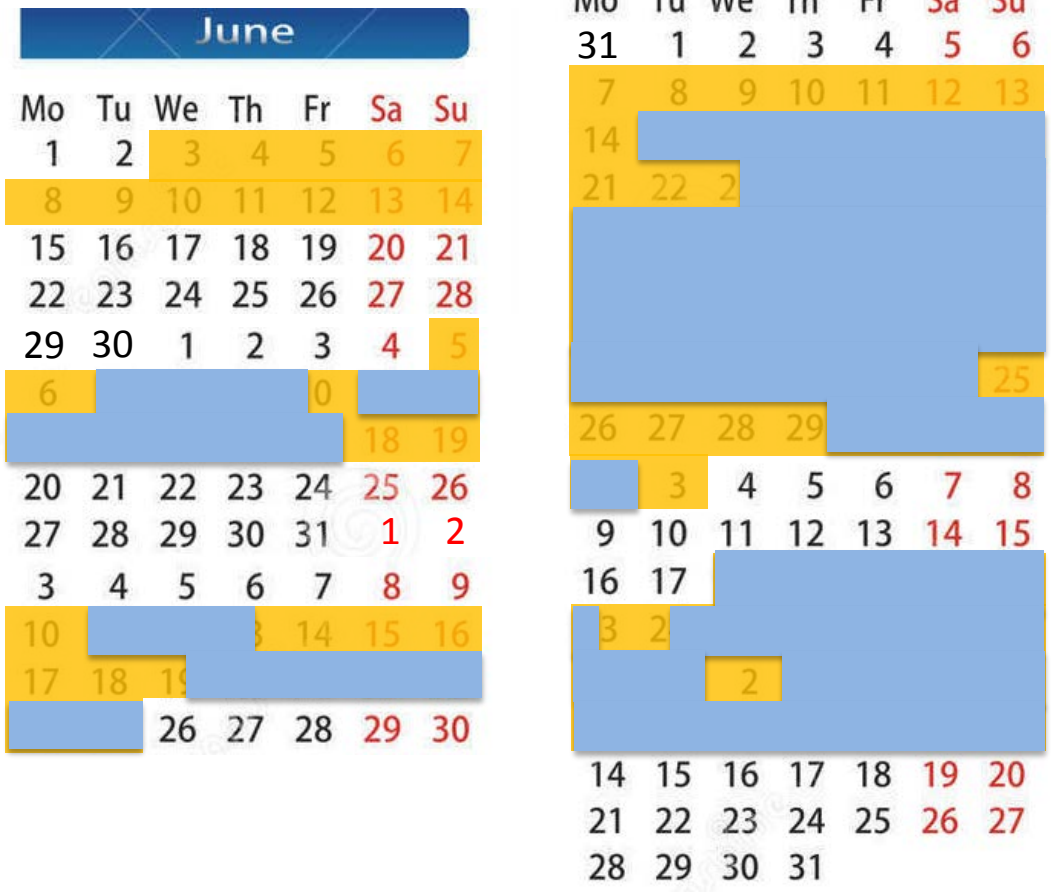


= LHC collisions

These are the times when CMS must be fully operational

However: Big problems with CMS magnet cryo system

- **only ¾ of 13 TeV luminosity recorded with magnetic field!**



= LHC collisions

= CMS magnet B=3.8T

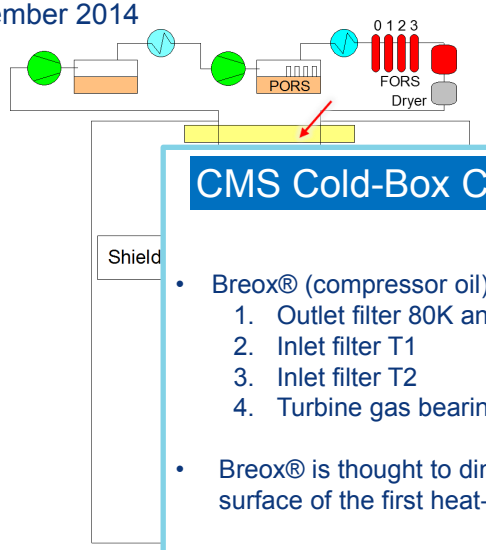
CERN cryo experts and CMS Technical Coordination worked extremely hard to maximize overlap of CMS magnet B=3.8T with LHC collisions

CMS Magnet Cryo Situation Summary

- from Frédérick Bordry's talk at HEPAP:

CMS Cold-Box Contamination: *Summary of events*

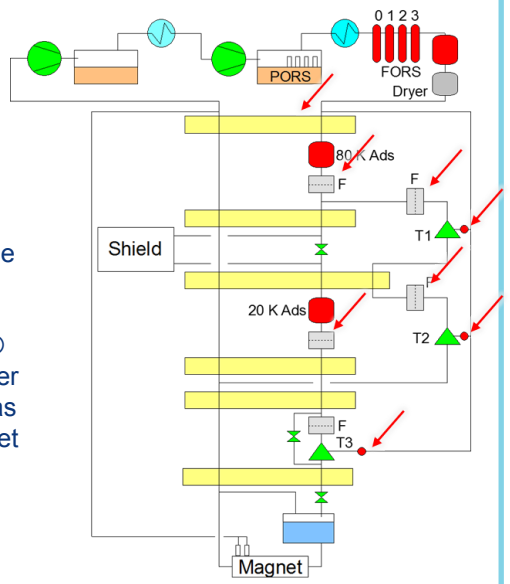
- CMS refrigerator has been re-started in November 2014 after the LS1 maintenance;
- Mid March first sign of contamination, at that moment blamed on air / water-pollution. ***Procedures applied: sub-system regenerated***.
- Beginning of May contamination identified at three different points. ***Procedures applied: System stopped, samples taken and complete regeneration***.
- After re-start of system almost **immediate contamination measured** at same points. Confirmed by result analysis of samples. ***Procedures applied: System stopped.***
- Analyse shows compressor oil (Breox®) milligram (mg) traces.



CMS Cold-Box Contamination: *What is causing these problems?*

- Breox® (compressor oil) was found on
  1. Outlet filter 80K and 20 K adsorbers
  2. Inlet filter T1
  3. Inlet filter T2
  4. Turbine gas bearing inlet filters
- Breox® is thought to diminish the heat exchange surface of the first heat-exchanger.

Normally a cold-box having suffered such a Breox® pollution is stopped to be cleaned. This was however impossible in the CMS case, and the installation was kept alive with regular 80K adsorber and turbine inlet filters regenerations. When judged necessary the turbine filters were exchanged for new ones.



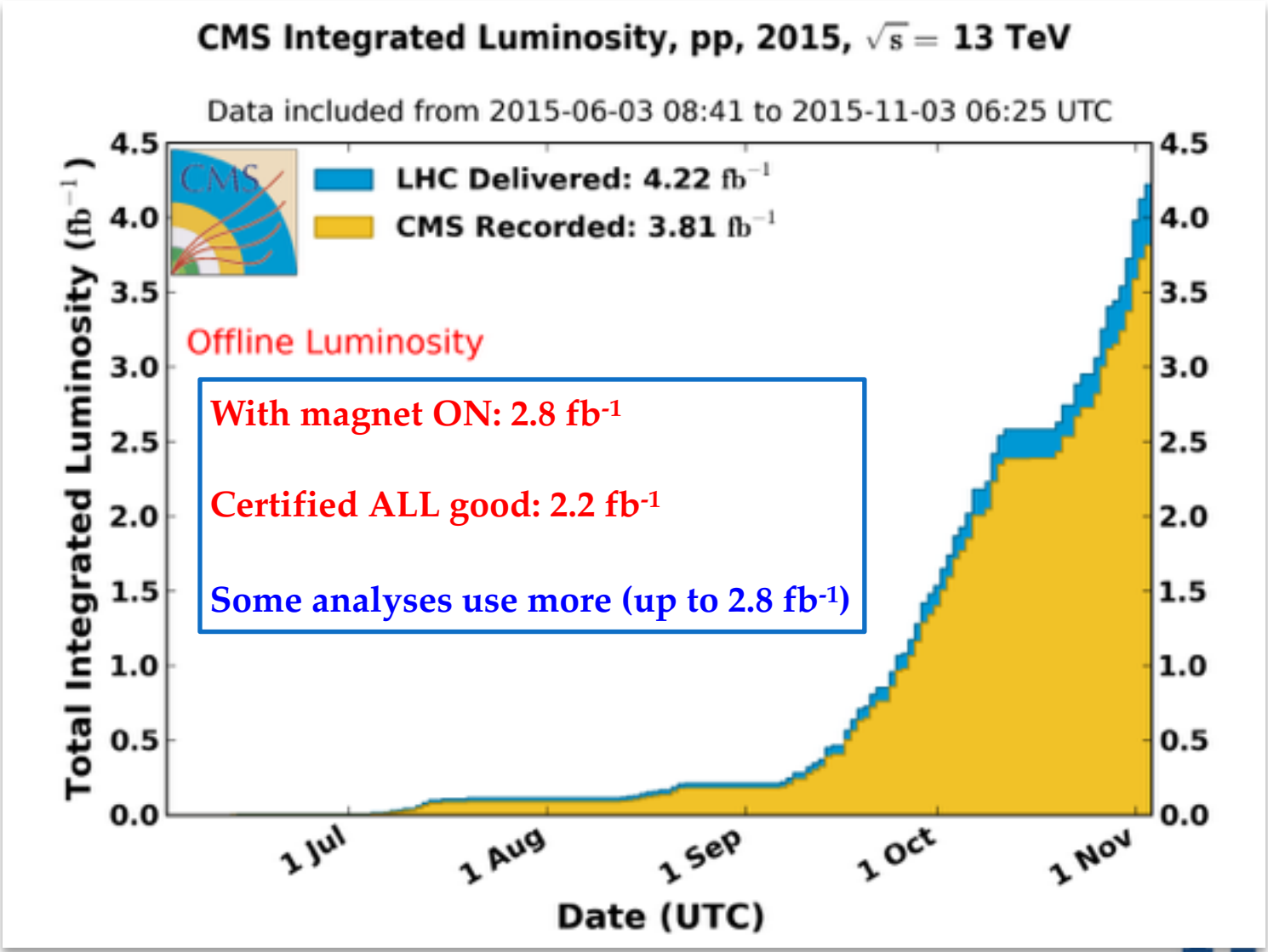
Of the integrated (p-p) luminosity delivered to CMS in 2015, about 73% of the data is taken under nominal field conditions;

Fermilab offered expert advice to CERN, and provided manpower to CMS to help with the magnet

“Consolidation” of the Cryo System during Technical Stop

- Work on the cold box started as soon as CERN re-opened on January 4 (some infrastructure preparation was done ahead of the shutdown)
- Opening of the “Cold Box”, inspection, exchange of adsorbers, repair of the leaky LN2 pre-cooler —> already done!
- Next: cleaning of the cold box circuits
  - defined procedure and cleaning medium compatible with cavern environment, to start in the next days.
- Installation of a new high-pressure line down to the CMS pit.
- Consolidation of the oil removal system:
  - New high-pressure primary oil separator, much larger capacity
  - New coalescers for the final oil removal system
- Repair of a bent cryo-valve on the 6000-l LHe buffer in the UX cavern (damaged during LS1)
- Additional boosting of the cryoplant with the connection of a 11’000-l LHe mobile reservoir (feasibility under study).

CMS Integrated Luminosity at 13 TeV



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CMS Run-2 results

- 33 public results based on 13 TeV data
- http://cms-results.web.cern.ch/cms-results/public-results/preliminary-results/LHC-Jamboree-2015.html

SUSY searches

Forward Physics and Small-x QCD
- Pseudorapidity Distributions of Charged Hadrons
- Two-Particle Correlations (the ``Ridge'')
- Underlying Event

QCD and EWK

Standard Model
- Inclusive Jet Production
- Inclusive W and Z Production
- Z+jets Differential Cross Section
- WZ Production Cross Section
- ZZ Production Cross Section

TOP

Heavy Flavours
- B Production Cross Section

Top Quark
- Inclusive $t\bar{t}$ Cross Section in Dileptons
- Inclusive and Differential $t\bar{t}$ Cross Sections in ℓ+jets
- Differential $t\bar{t}$ Cross Sections in Dileptons
- Differential $t\bar{t}$ Distributions as a Function of Event Variables
- Underlying Event Measurements in $t\bar{t}$+X Events
- Single Top-Quark Cross Section

Higgs signal regions remain blinded

125-GeV Higgs Boson
- Performance Studies

Search for Supersymmetry
- Supersymmetry in Multijet + Missing E_T
- Supersymmetry in All-Hadronic Using M_{T2}
- Supersymmetry in All-Hadronic Using α_T
- Supersymmetry in All-Hadronic Using Razor Variables
- Supersymmetry in One-Lepton Events Using Large Radius Jets
- Supersymmetry in Same-Sign Dilepton Events
- Supersymmetry in Opposite-Sign Dilepton Events

Exotica searches

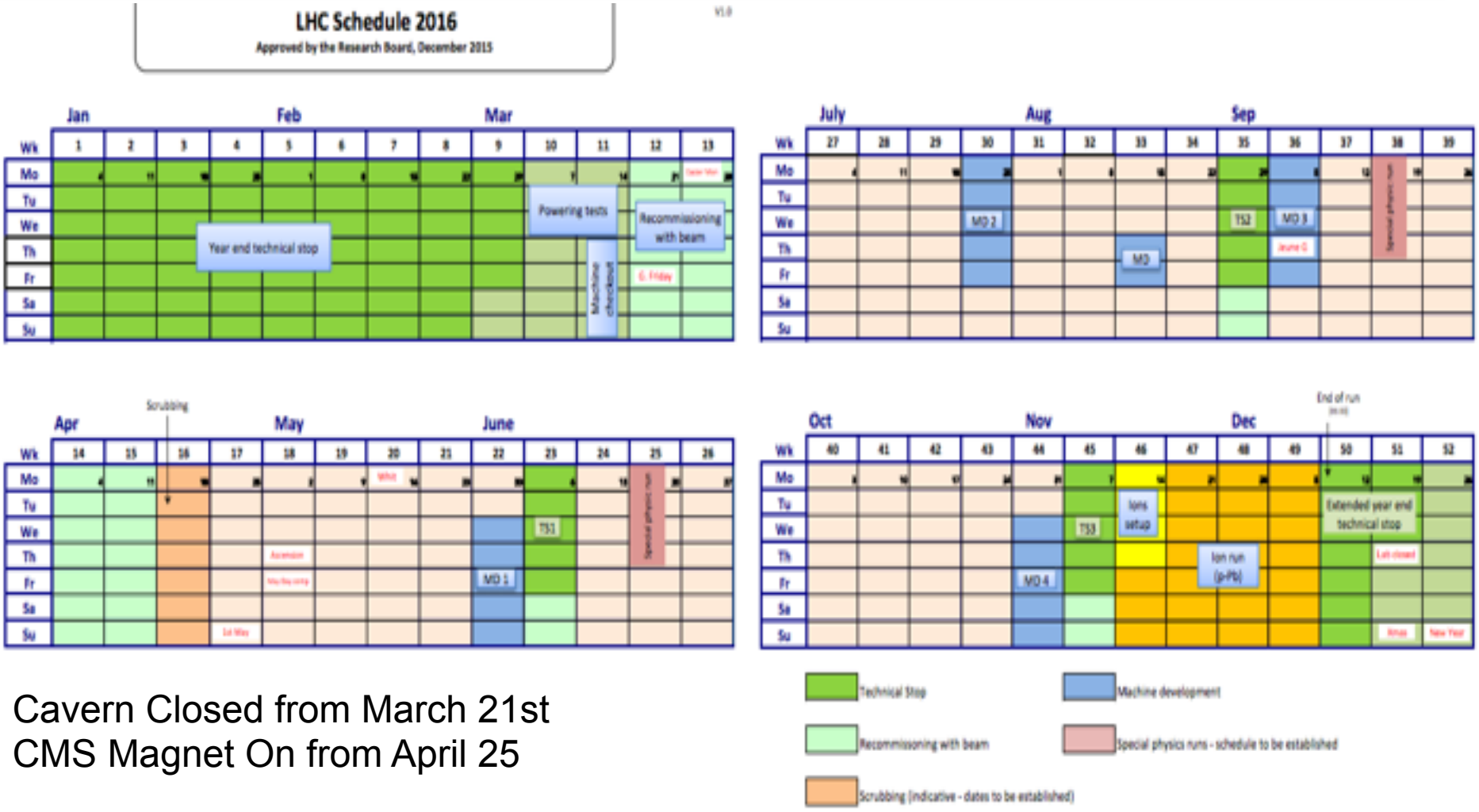
Search for Exotic Pheno
- Search for Resonan
- Search for Quark Compositness in Dijet Events
- Search for Z' in Dilepton Events
- Search for W' in Lepton+E_T^{miss} Events
- Search for Resonances in Diphoton Events
- Search for Resonances in Diboson Events
- Search for Dark Matter in Monojet Events
- Search for Quantum Black Holes
- Search for Heavy Stable Charged Particles

Search for Exotic Phenomena (Topologies with Heavy Quarks)
- Search for W' in tb Events
- Search for $X_{5/3}$ in SS Dilepton and Lepton+Jets Events

Program for 2016

- Technical Shutdown for CMS to Commission new items:
  - Trigger: on tight schedule (must be ready on day 1)
  - Hadronic Calorimeter: all electronics move to uTCA (coupled with Trigger)
  - Pixel: include new Pixel blade (for 2017) in 2016 running
  - Review data monitoring to catch problems online
- Prepare for extended technical stop in 2017 where major upgraded detectors get installed
- Details about LHC program are fairly established
  - 2016 will be a Luminosity production year aiming to deliver ~20 fb-1
    - There will be 2 weeks of special runs:
      VDM and VERY large β* (>2Km) run for TOTEM/ALFA
    - If the community will require a pPb run LHC wants to have it at the end of this year
  - Rapid intensity ramp up should be possible, at β* = 40cm
  - Nominal design luminosity $1x10^{34}/cm^2/s$ should be reached
    - (expectation to go up to ~$1.2x10^{34}$ in 2016)
- Run 2 goal of100/fb, and to reach 300/fb at the end of Run 3

LHC Schedule for 2016



Cavern Closed from March 21st
CMS Magnet On from April 25

- Chamonix workshop week of January 25

CMS Phase1 Upgrade Project — Barreling along

Hadron Calorimeter

Forward Front End
In Post-production Burn-in
Installation Dec 2016

Endcap/Barrel Front End
Successful Testbeam, Production Ensues
Installation Dec 2016/Jan 2019

Back End Readout
Installed, ~commisioned
→ Operations in 2016

Forward Pixel

Components
In Production
Feeds A&T

Assembly & Testing
Ramping Up
Installation Dec 2016

Pilot System
Installed, ~commisioned
→ Operations in 2016

L1 Trigger

Muon Trigger
Installed, commisioning
→ Operations in 2016

Calorimeter Trigger
Installed, ~commisioned
→ Operations in 2016

Successful DOE/NSF Review Oct 2015

- Upshot: Challenging Schedule! Keep up the hard work.

Summary

- In June 2015, for the start of Run2 collisions at 13 TeV, CMS was ready with improved detector and computing systems.
- Inefficiency of the magnet cryogenics system had a significant impact on the experiment, but were minimized through the hard work of the CERN cryo team.
- CMS took 2.8/fb data at 13 TeV, with magnetic field and good >90% efficiency.
- Repairs and improvements of magnet cryogenic systems are underway during the shutdown, and CMS magnet is expected to be ready for the start of 2016 data taking in April.
- Fermilab provides major contributions and leadership to CMS operations, including run coordination, the largest part of Tier-1 computing, software and detector maintenance.