Report on the LHC re-start: Compact Muon Solenoid (CMS) experiment

Greg Rakness (FNAL)

CMS Commissioning and Run Coordinator

US CMS Ops Program – contact at CERN

HEPAP

Newport Beach, CA

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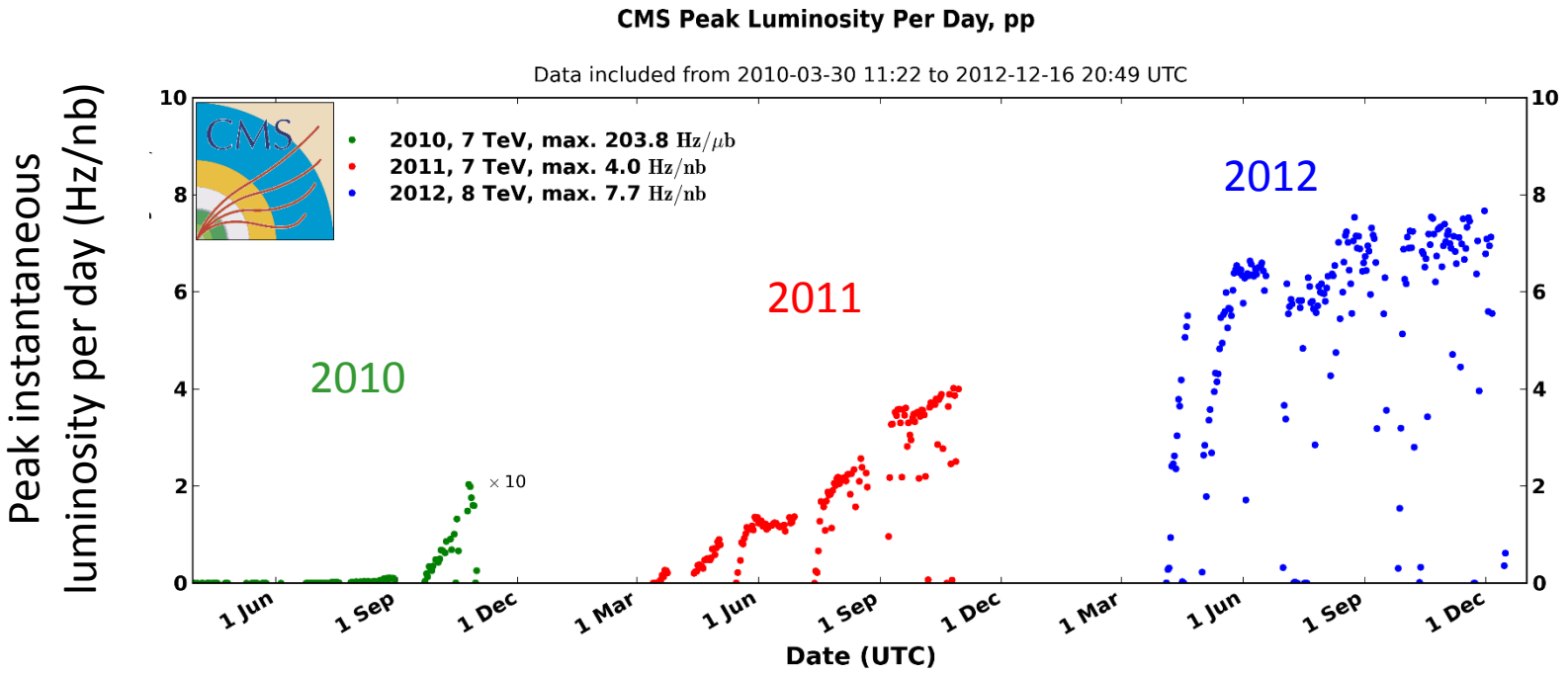
Outline

- LHC: expectations for Run-2
- CMS: work during Long Shutdown 1
- Successes & issues during 2015 running
- Plan for 2015-2016 Year-End Technical Stop

Run-1: instantaneous lumi evolution

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



Run-1 peak performance numbers

- Max. inst. lumi = $7.7 \times 10^{33}/cm^2/s$ (design = 1×10^{34})
- Number of bunches = 1380 (design ~ 2200)
- Bunch spacing = 50ns (design = 25ns)

From the point of view of peak instantaneous luminosity *per bunch*, LHC Run-1 **exceeded the specs by ~140%**

Changes from Run-1 → Run-2

From M. Solfaroli (CERN) at LHCC 23 Sept 2015 (https://indico.cern.ch/event/443017/)

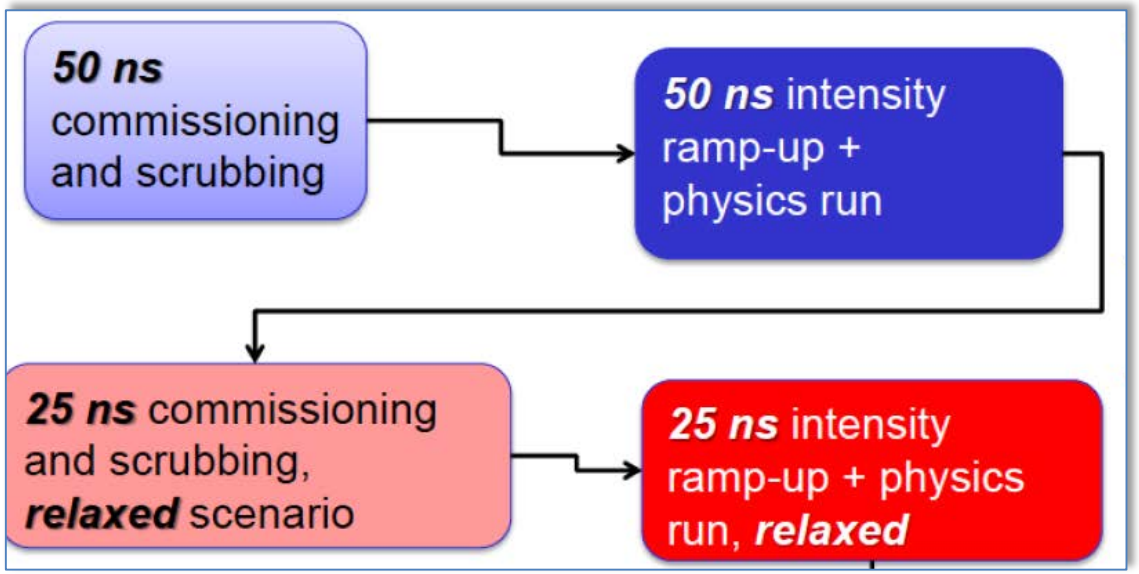
- 160% larger collision energy → $\sqrt{s}$=13 TeV
- 50% smaller bunch spacing → 25ns
- 200% larger number of bunches → 2800 bunches
- 200% larger pileup → 40 interactions/crossing
- 66% smaller β^* → 40cm
- 170-220% larger peak lumi→ (13-17)x10^{33}cm^{-2}s^{-1}

"Priority for 2015 is to prepare 2016 as a 'physics production run' at 25ns" – M. Solfaroli (CERN)

Step-by-step approach

To bring up machine safely in 2015, LHC took it step-by-step

R. Bruce (CERN) at Chamonix '14 (http://indico.cern.ch/event/315665/)



1. "Scrub" to reduce e-cloud
2. $\sqrt{s}$=13 TeV with 50ns bunch spacing (as in Run-1)

3. Scrub to reduce e-cloud
4. Try 25ns bunch spacing
5. Increase # of bunches

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

Recall CMS plan: upgrade detector to match the LHC performance

- CMS "Phase-1" upgrade (2014-2019): handle increased pileup…
  - Add another layer of silicon tracking
  - Add processing power to the Level-1 trigger
  - Refine granularity of the hadron calorimeter

- Long-Shutdown 1 (2013-2014): complete and maintain detector; lay foundation for Phase-1…
  - Next page →

CMS work during Long Shutdown 1

- Data acquisition: new architecture, hardware, software
- Trigger Control and Distribution System: new (uTCA)
- Level-1 trigger: new calorimeter trigger (uTCA)
- Silicon pixels: new modules
- Silicon tracker: new lower temperature (–15°C)
- Electromagnetic calorimeter: new trigger optical links
- Hadronic calo: new SiPMs, back-end electronics (uTCA)
- Drift Tube chambers: new trigger electronics
- Resistive Plate Chambers: new chambers
- Cathode Strip Chambers: new chambers & electronics
- Beam Radiation Instr. and Luminosity: new detectors

Coming into 2015, CMS was a ~new detector

http://www.bbc.com/news/science-environment-32976838

3 June 2015: first “Stable Beams” (collisions) at $\sqrt{s}$=13 TeV

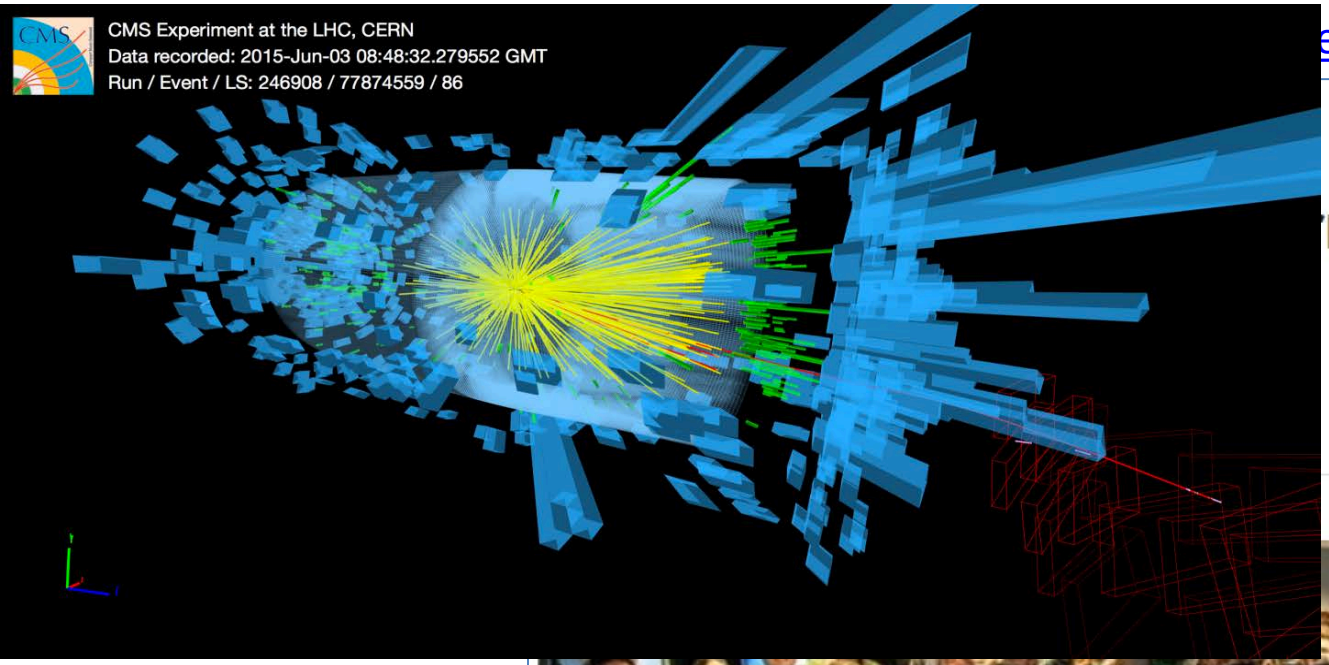
Science & Environment

Large Hadron Collider turns on 'data tap'

By Paul Rincon
Science editor, BBC News website

3 June 2015 | Science & Environment

The CMS experiment team celebrated when the first collisions occurred



e-environment-32976838

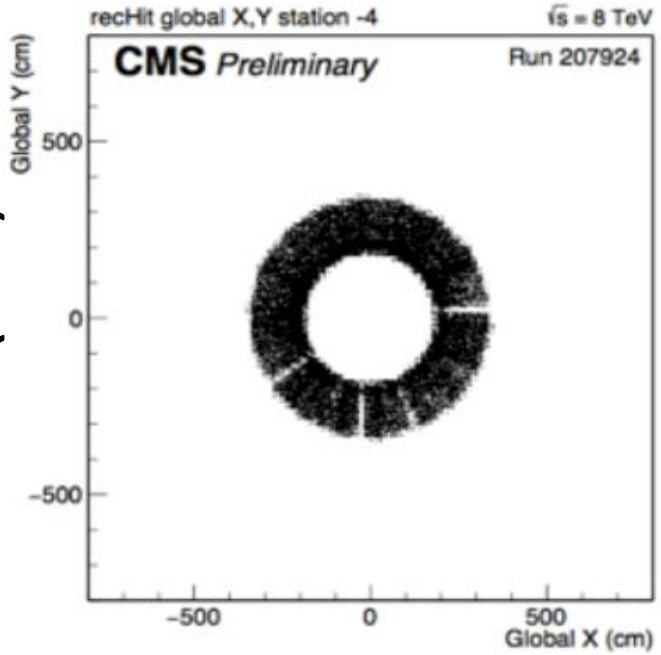
ns on 'data tap'

The CMS experiment team celebrated when the first collisions occurred

Appreciating the success of hard work

Examples of improvements for 2015 (1/4): new Cathode Strip Chambers

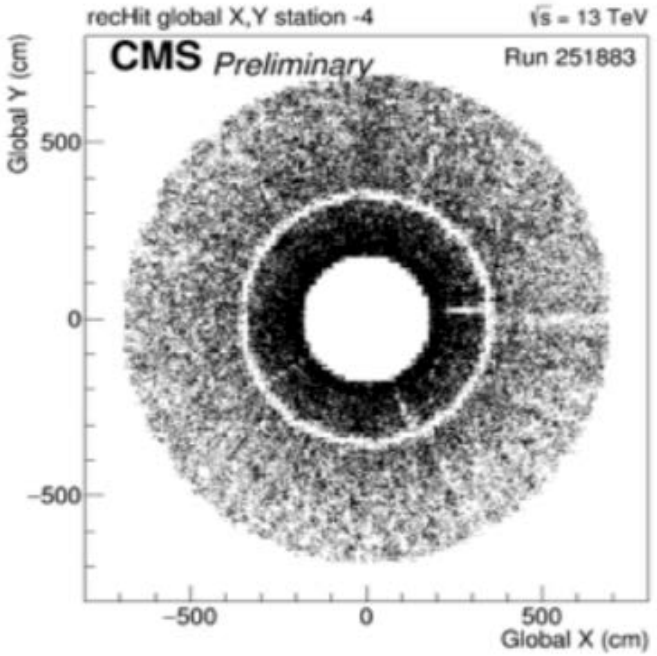
Run 1



Y (cm)

X (cm)

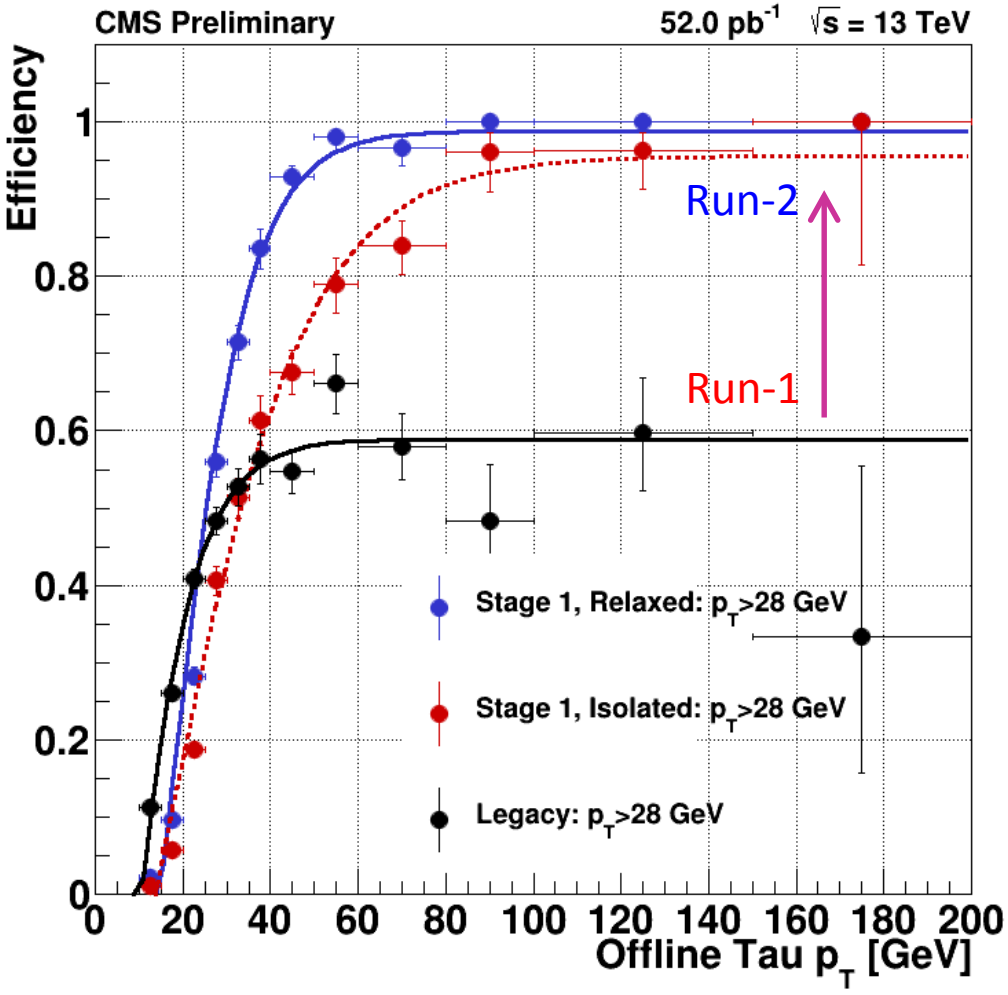
Run 2



X (cm)

Increased coverage from new chambers increases purity of triggers on high momentum muons

Examples of improvements for 2015 (2/4): "Stage-1" trigger upgrade

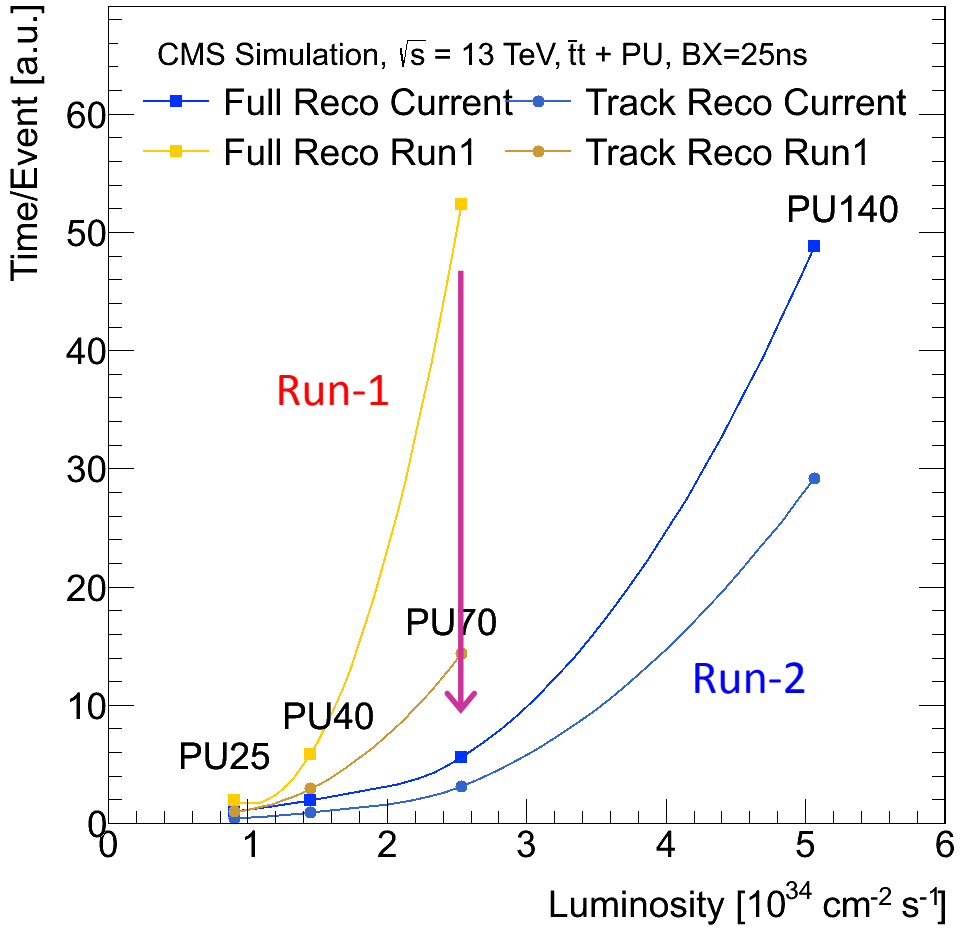


First stage of the CMS calorimeter trigger upgrade in use for 97% of the 2015 run

- 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

Examples of improvements for 2015 (3/4): event reconstruction

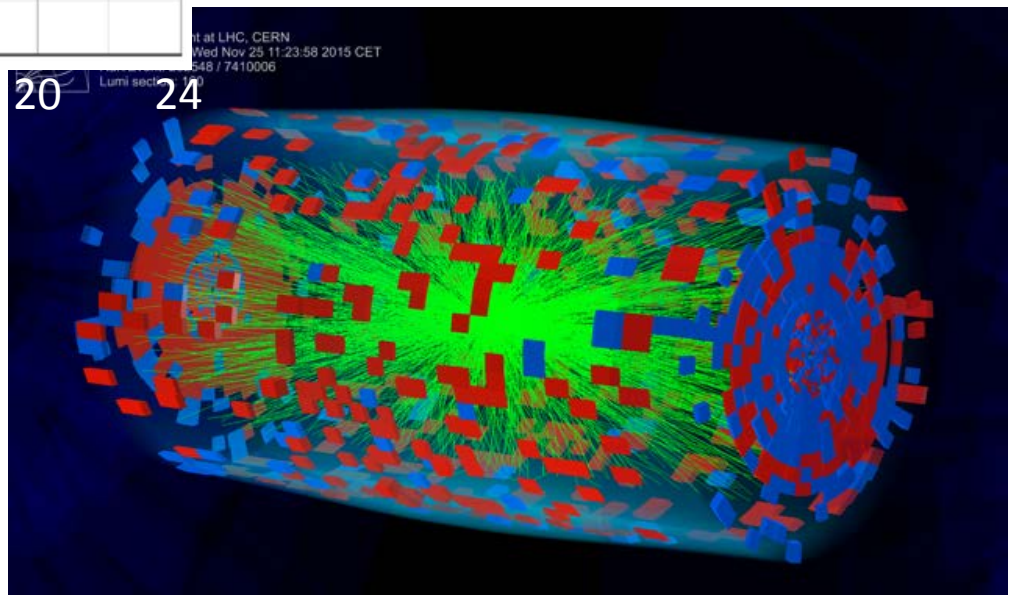


Updates to event reconstruction reduces processing time to manageable levels in a high pileup environment

Examples of improvements for 2015 (4/4): multi-threading framework

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

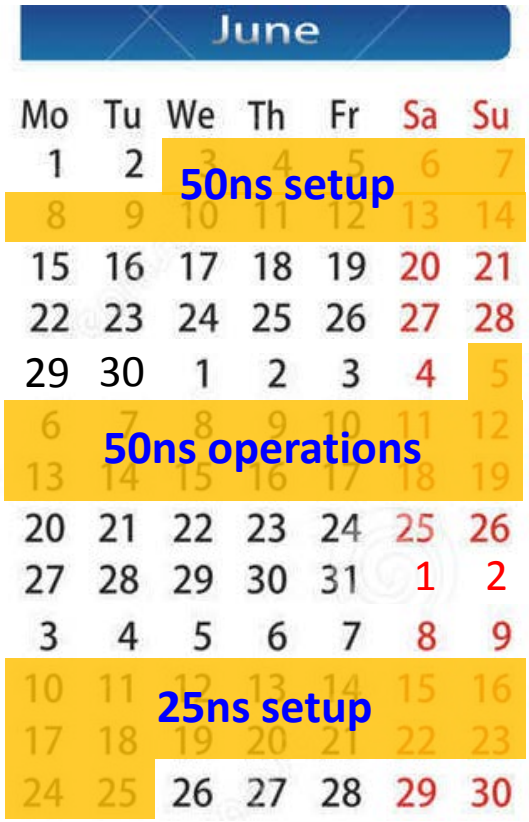
Important for Heavy Ion jobs targeted on central events →



Some unforeseen obstacles in 2015

- Rare 3ns 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/automatic alarm/expert reaction
  - Data will require special handling for these cases

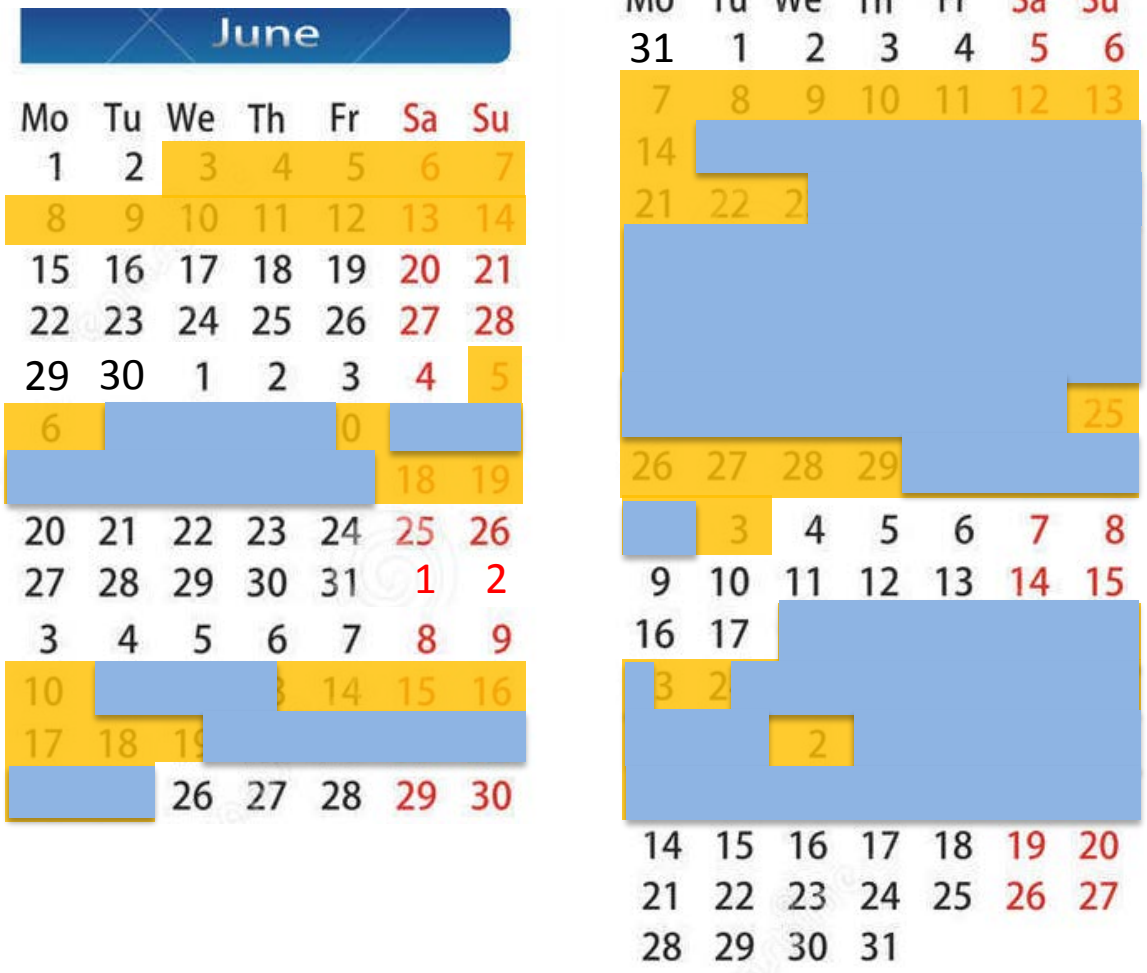
Another unforeseen obstacle in 2015



= LHC collisions

These are the times when CMS must be fully operational

Another unforeseen obstacle in 2015



= LHC collisions

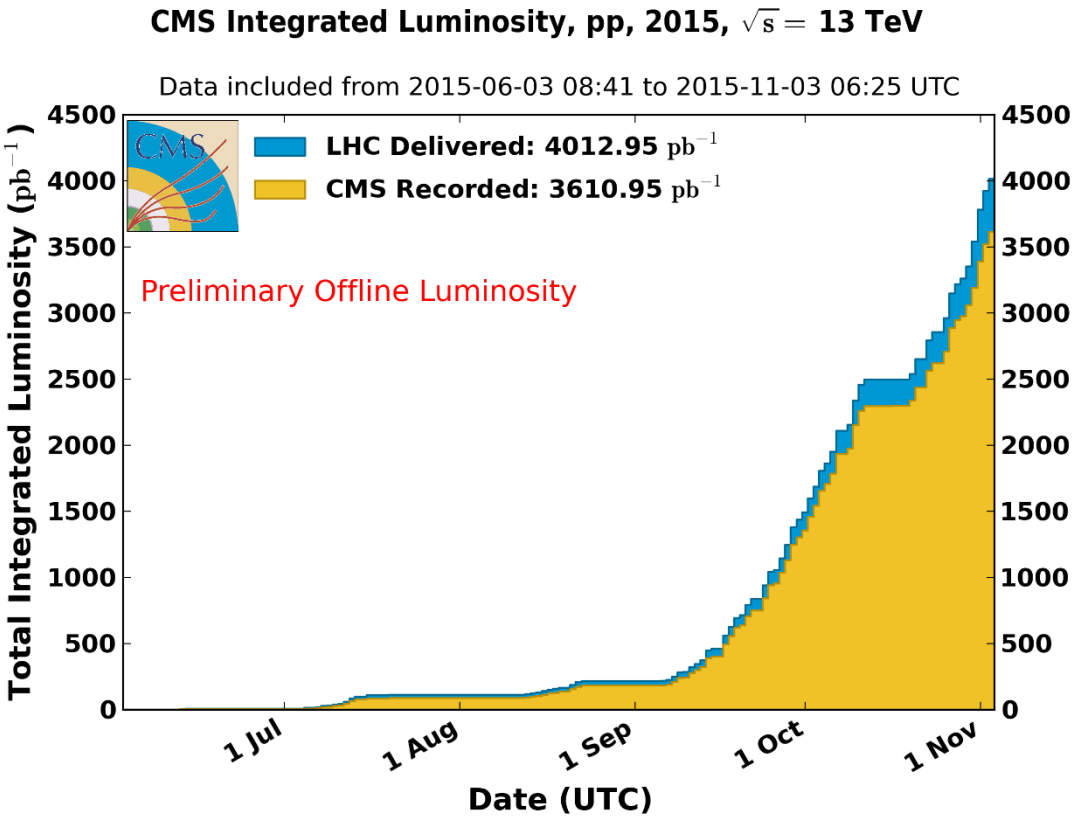
= CMS magnet B=3.8T

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

See talk by F. Bordry (CERN)

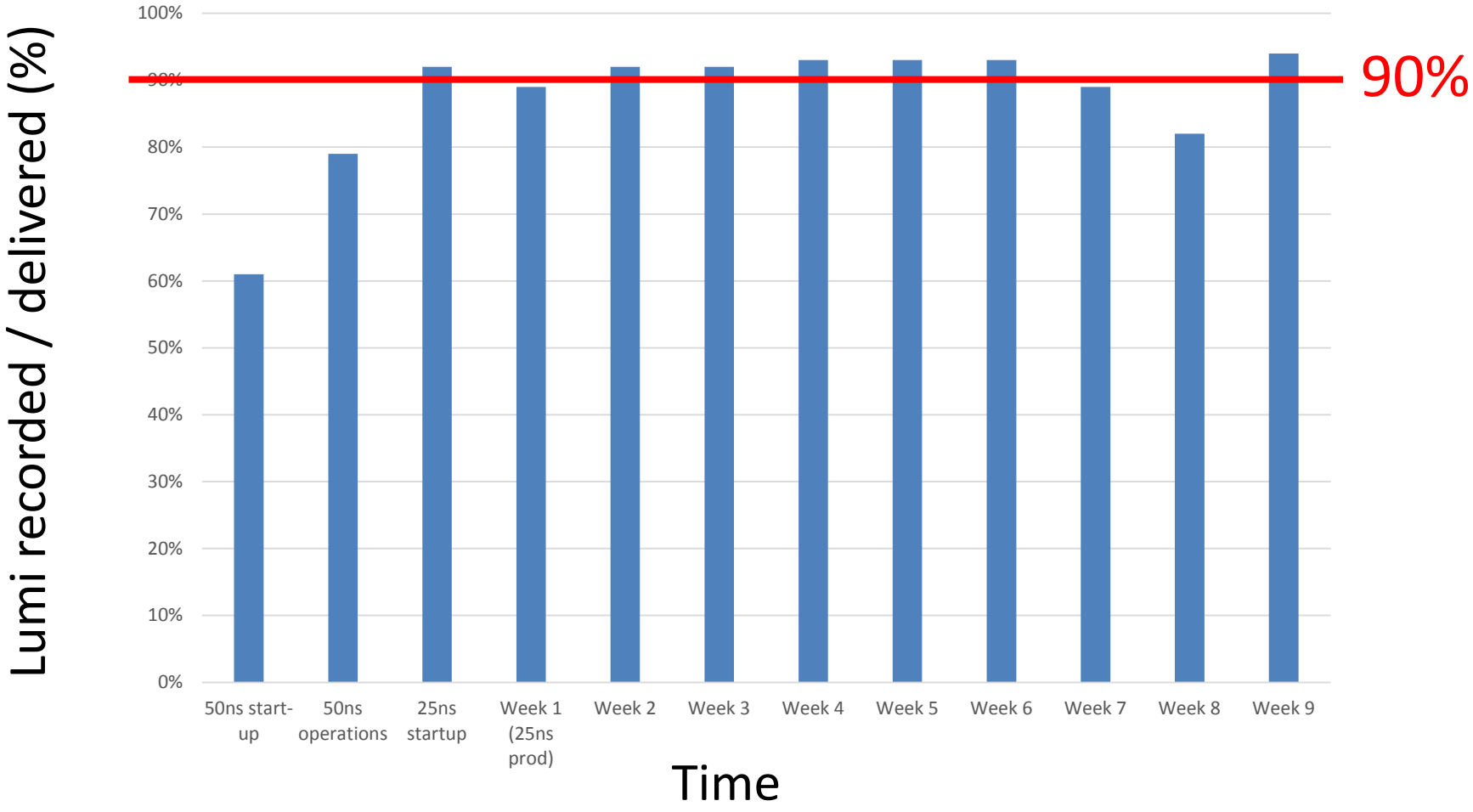
Integrated luminosity √s=13 TeV

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



B=3.8T: 3.0 fb^{-1} delivered, 2.8 fb^{-1} recorded (93%)
B≠3.8T: 1.0 fb^{-1} delivered, 0.8 fb^{-1} recorded (80%)

Efficient data collection throughout 2015

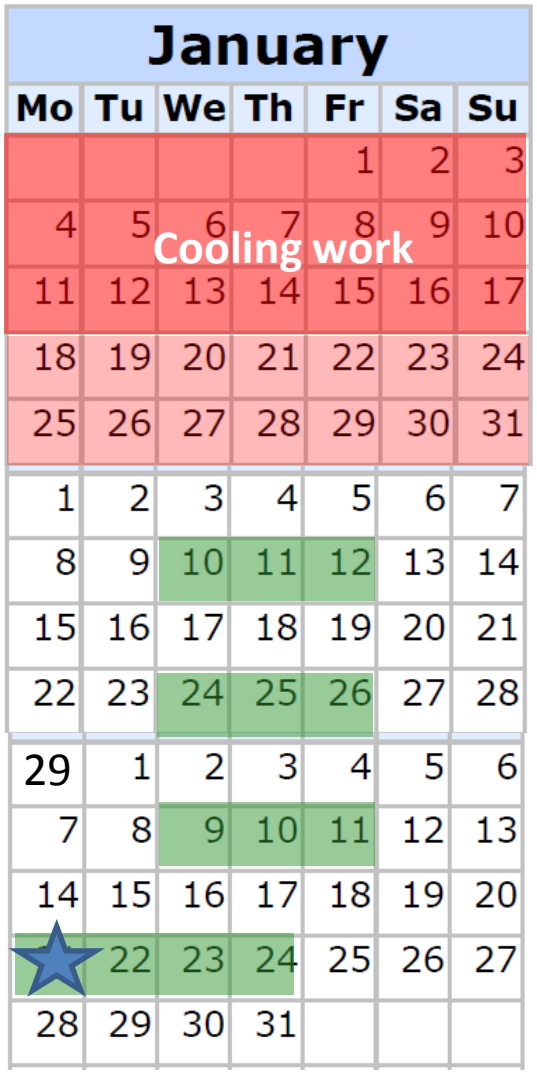


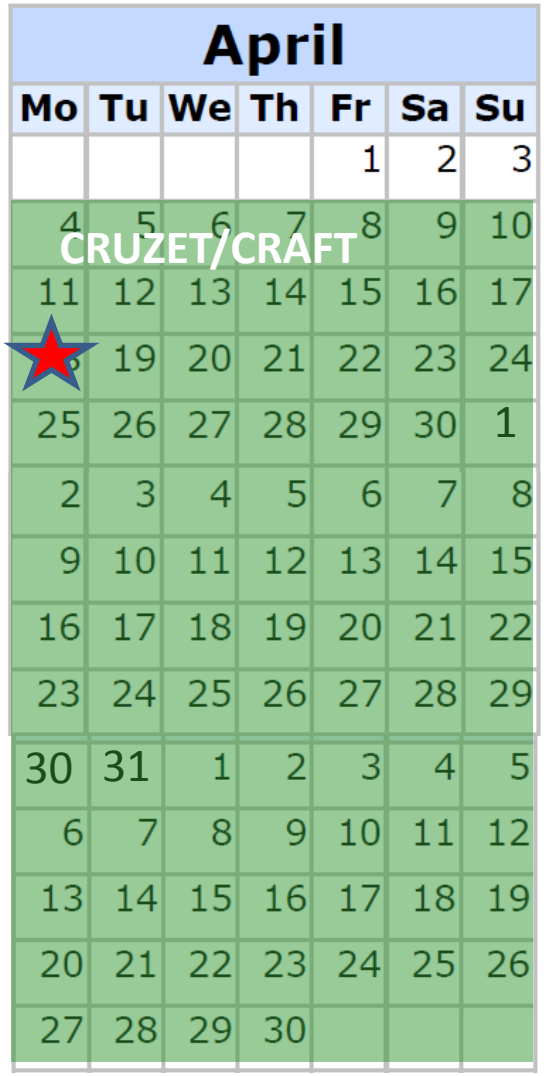
→ Steady state recording efficiency > 90% ←

Overview of CMS work plan during the 2015-2016 Year-End Technical Stop

- Clean cold box
  - See talk by F. Bordry (CERN)
- 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
- Set goal to minimize data lost at certification
  - Review data monitoring to catch problems online

CMS commissioning plan





= 1st beams in

= Stable Beams

(from latest LHC schedule as of 18 Nov 2015)

RED = cooling work

WHITE = local commissioning

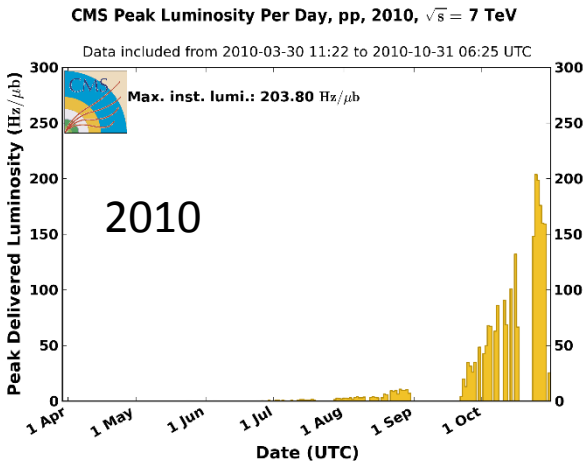
GREEN = "global" runs

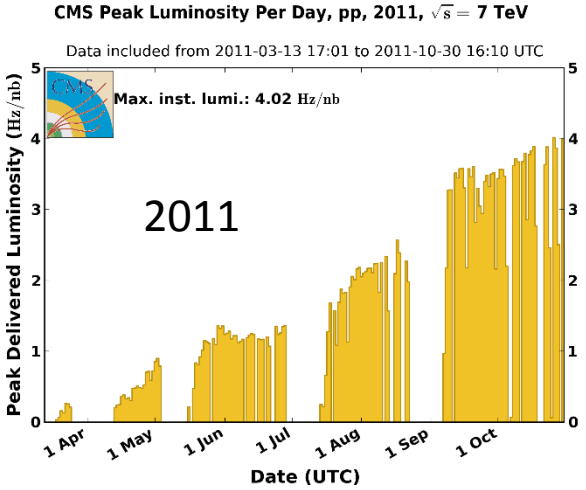
CMS commissioning plan: use mix with previously established track record of success…

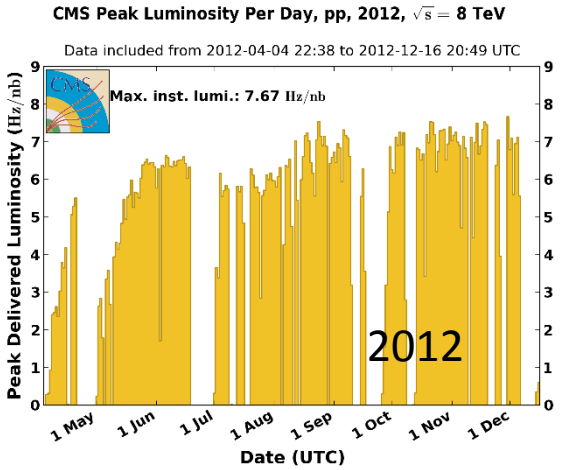
- Short "global" runs
- Interface tests (not shown)
- Extended running campaigns

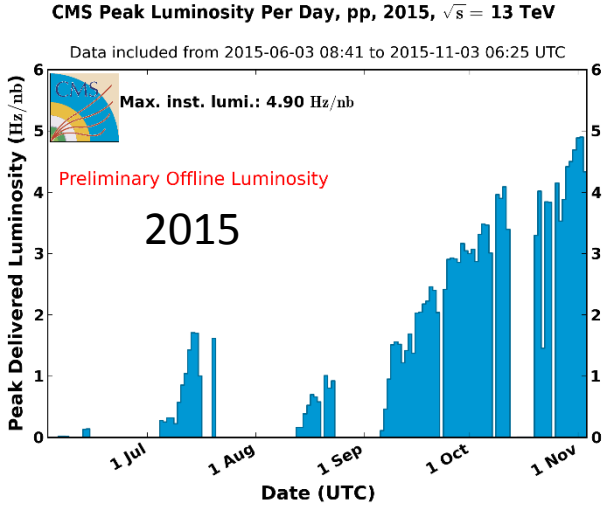
… to prepare for LHC collisions in 2016…

Expectations for 2016









2015 had a slow steady ramp-up similar to the 2011 ramp-up…

We are expecting that 2016 will be a production year as was 2012…

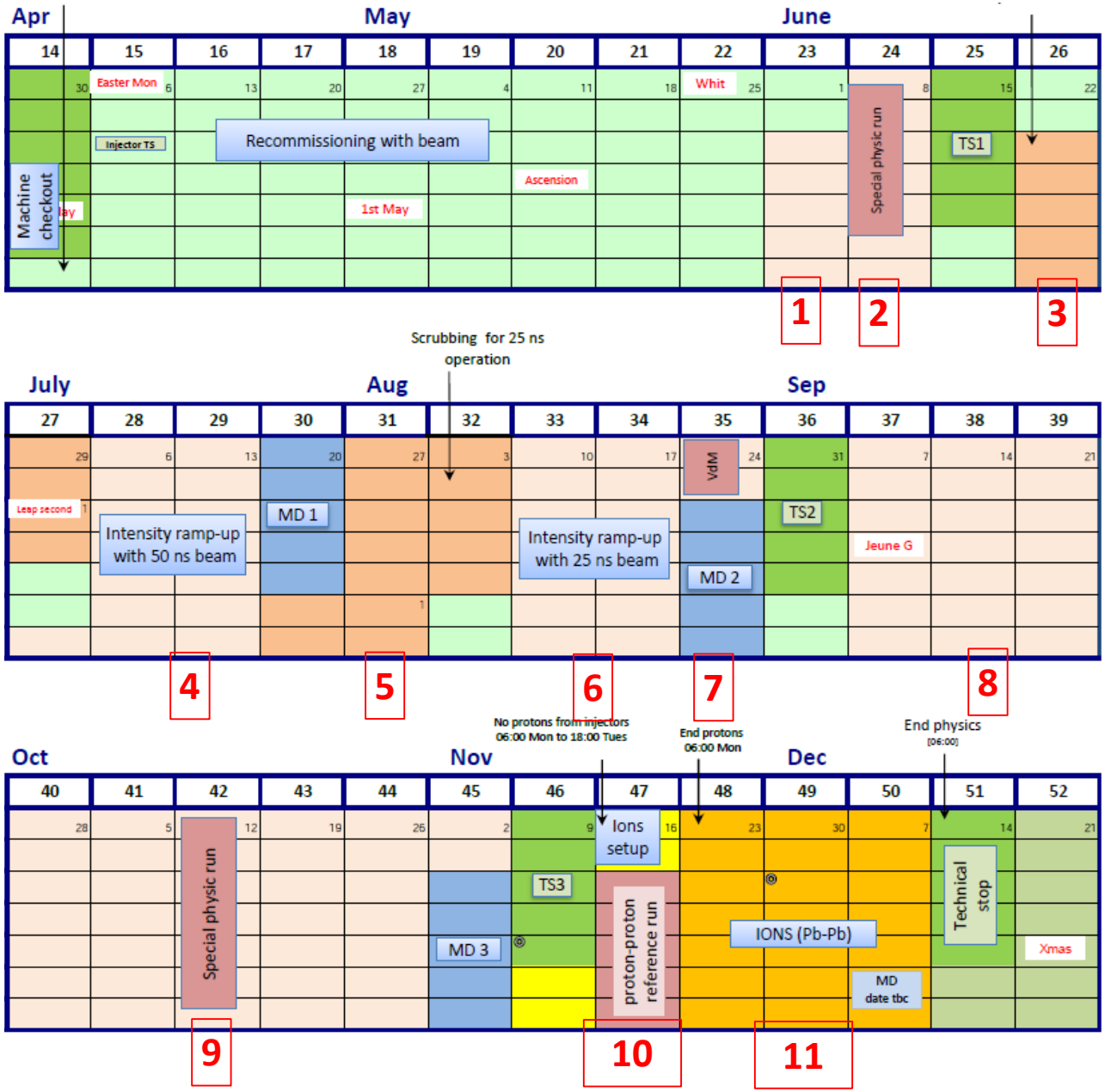
Summary

- LHC Run-2 promises higher luminosity and pileup
  - 2015 successfully laid the groundwork for these conditions
- CMS is on-track with its upgrade program
  - (Long-Shutdown 1 + 2015 run) made a solid step forward
- 2015 was a productive year of data collection
  - … including dealing with issues both expected and unexpected
- 2015-2016 Year-End Technical Stop will put CMS in a good position to reap the harvest from high intensity collisions

CMS is looking forward to LHC collisions in 2016

Backup

LHC schedule



1. Begin lumi ramp-up with 50ns bunch spacing
2. Low pileup (PU≈0.01-0.4)
3. Scrub for 50ns operation
4. Continue 50ns ramp-up
5. Scrub for 25ns operation
6. Lumi ramp-up @ 25ns
7. Van der Meer scan
8. Physics production with 25ns spacing
9. TOTEM run
10. pp “reference” run
11. Ion run

https://espace.cern.ch/be-dep/default.aspx