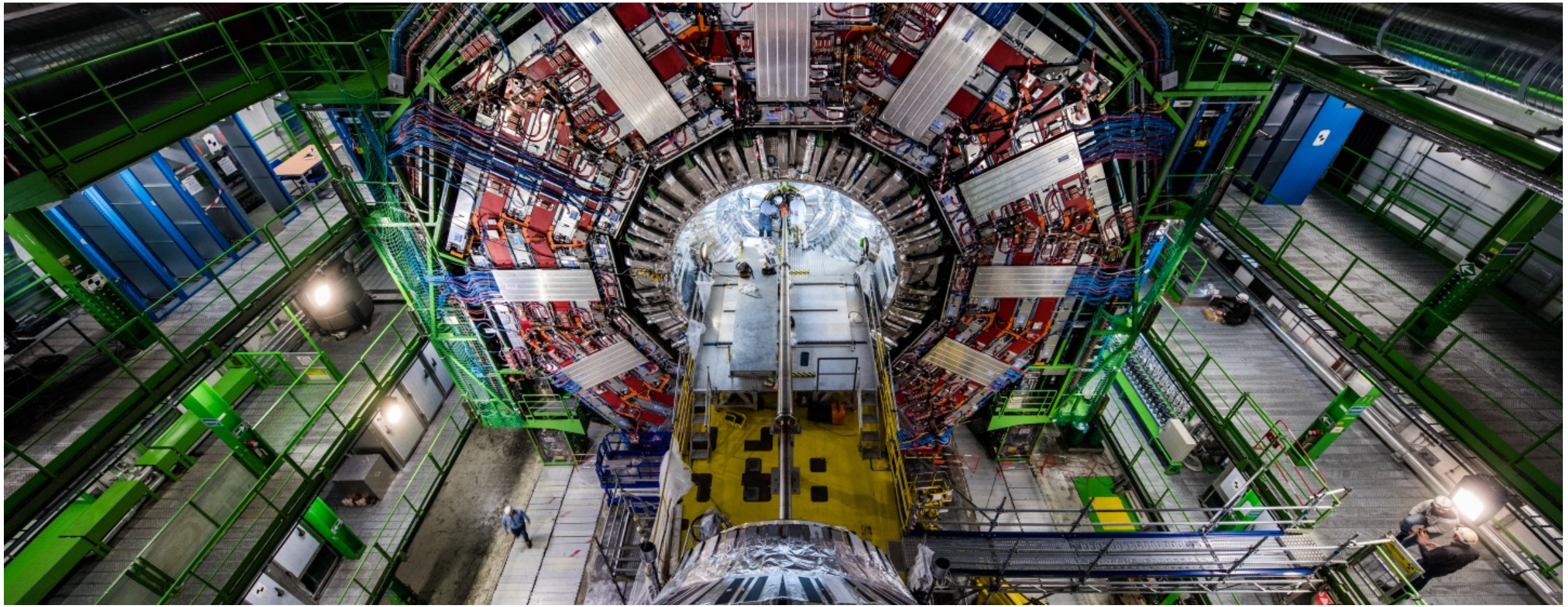


PPAP Meeting – CMS

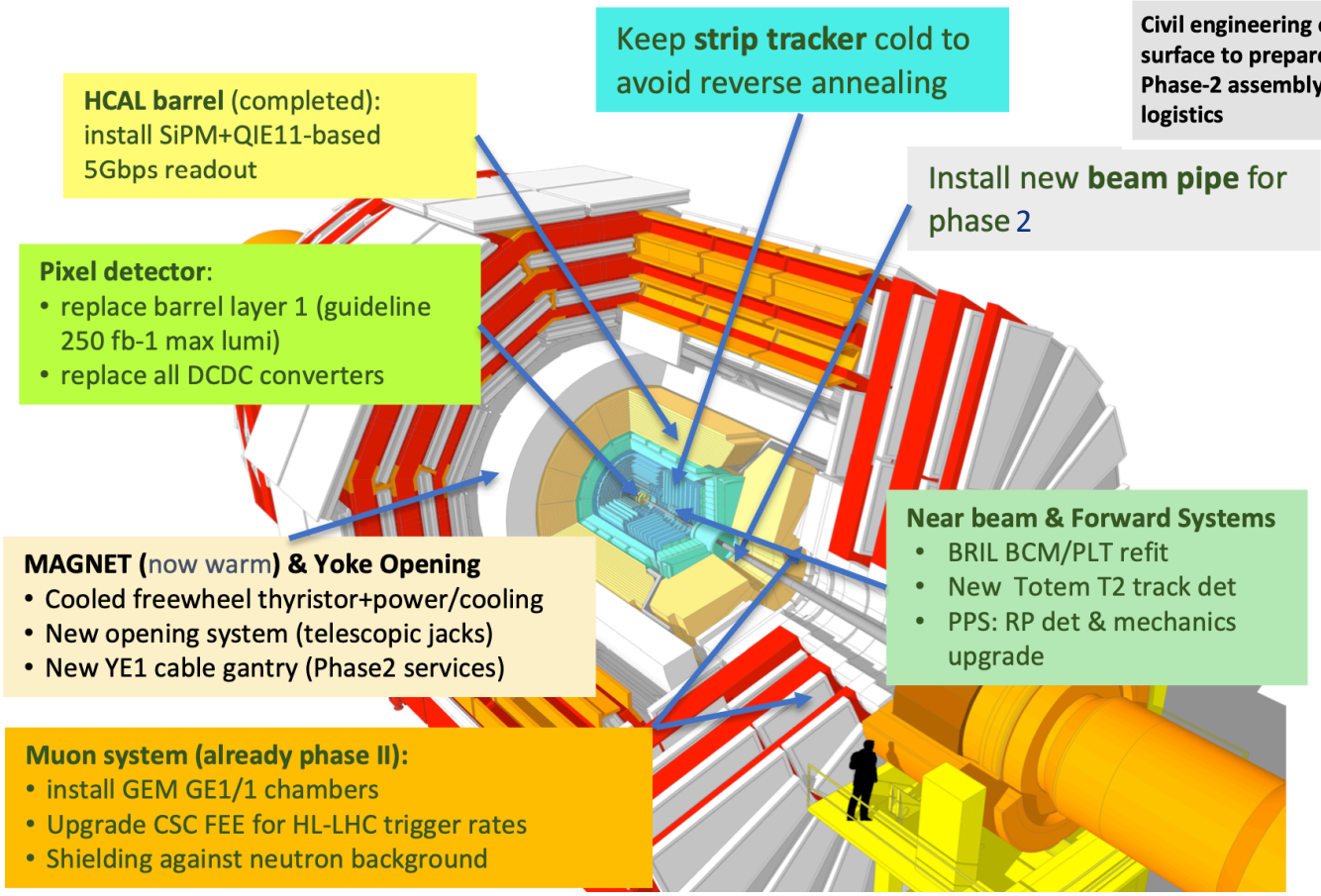
Emmanuel Olaiya (RAL) on behalf of the CMSUK collaboration

Science and Technology Facilities Council

Contents

- LS2 Activities
- LHC performance
- Run 3 Status
- Physics Analysis
- Upgrade

LS2 Activities



Muon activities in full swing.
Expect to complete by beginning of Dec:
- Install and commission new GEMs
- CSC cooling and front-end electronics
- DT repair, maintenance and shielding
- RPC gas leak & HV repair

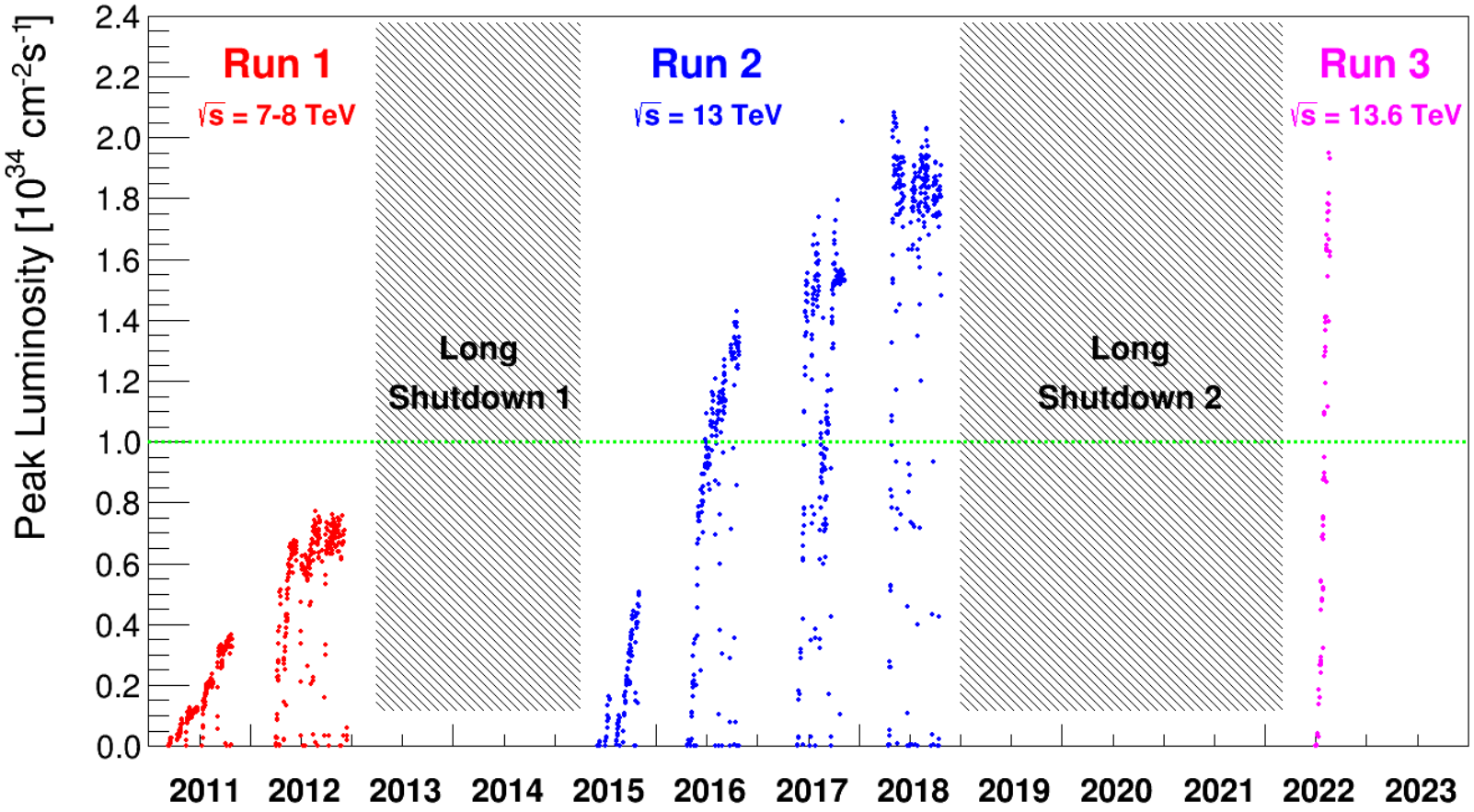
Next major activities (time ordered):
- forward shielding (part 1)
- beam pipe
- pixel installation (new L1)
- yoke closing
- forward shielding (part 2)

All LS2 activities completed successfully!

LHC Performance

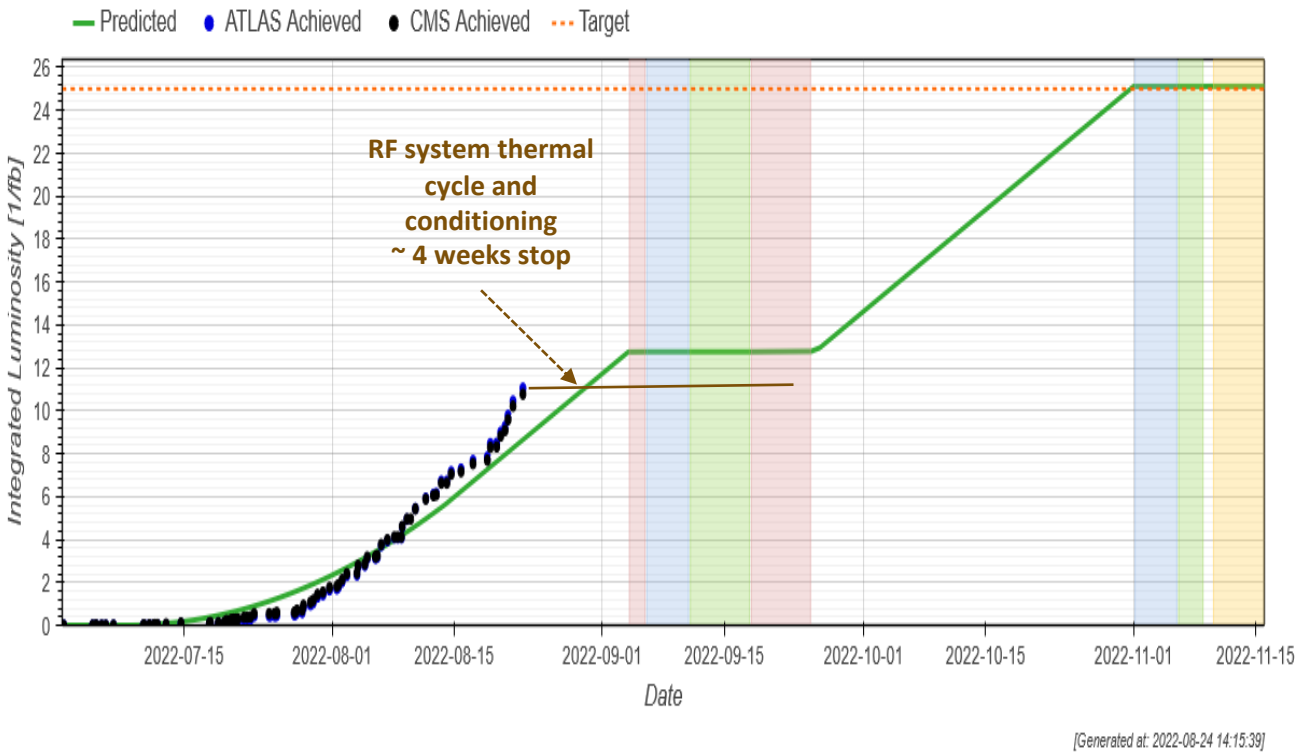
- With the experience of the previous two runs, the increase of peak luminosity over this short period was impressive after a LS – despite heat load limitations.

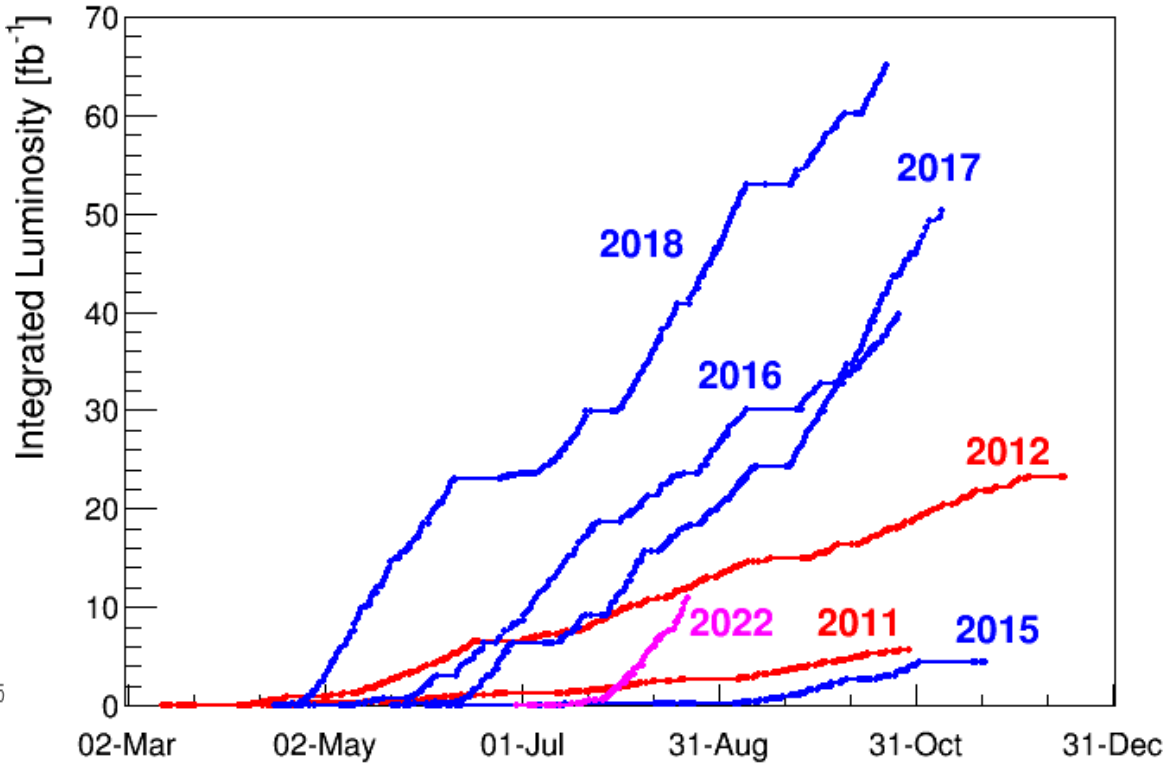
- Reflects the excellent understanding of how to control and to operate LHC.
- **Peak luminosity almost within target.** We need more protons now !



LHC Performance

- Luminosity production started to exceed the (conservative) planning for this run year before the beam stop.
- Latest slope close to the best Run 2 periods.





LHC Runtime

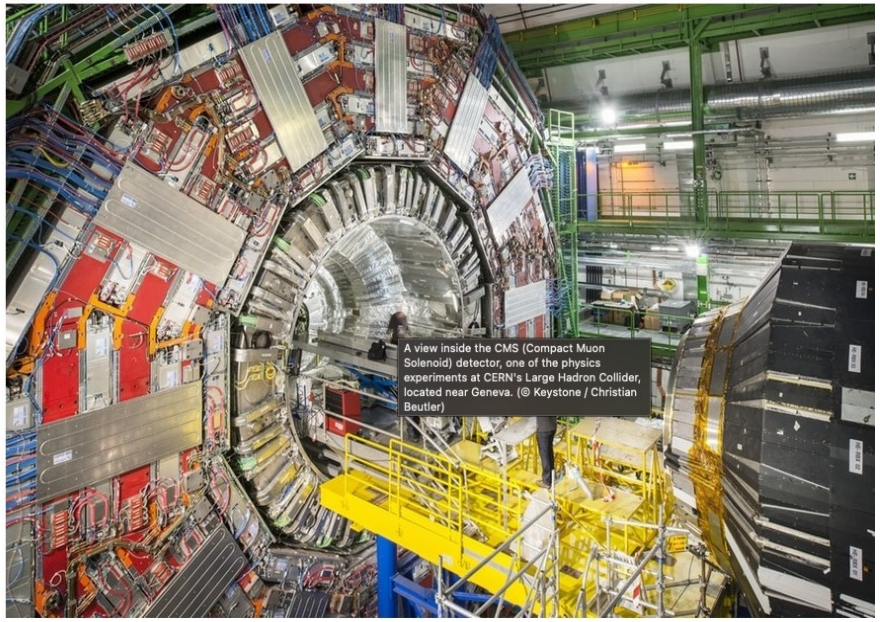
- LHC restart last Monday following the LHC incident on August 23 .
- There remains an unknown impact on the schedule related to the cost of electrical power - see recent articles in the WSJ and Science.
- **The 2022 Run will end 2 weeks early.** (No LHC running in December.)
    - Implications: the balance of HI vs pp running are under discussion.
- Decisions and details about the 2022/2023 run are expected in the coming days.

SWI swissinfo.ch

Science

Swiss perspectives in 10 languages

CERN drafts plans to idle accelerators due to Europe's energy crunch



A view inside the CMS (Compact Muon Solenoid) detector, one of the physics experiments at CERN's Large Hadron Collider, located near Geneva. (© Keystone / Christian Beutler)

Europe's energy crisis is threatening to slow fundamental particle physics experiments at the European Organization for Nuclear Research (CERN), located near Geneva, according to the Wall Street Journal (WSJ).

September 5, 2022 - 09:47

Schedule Update

In a response to the energy crisis the CERN directorate has decided to **bring forward the start of the YETS `22-23` by two weeks**

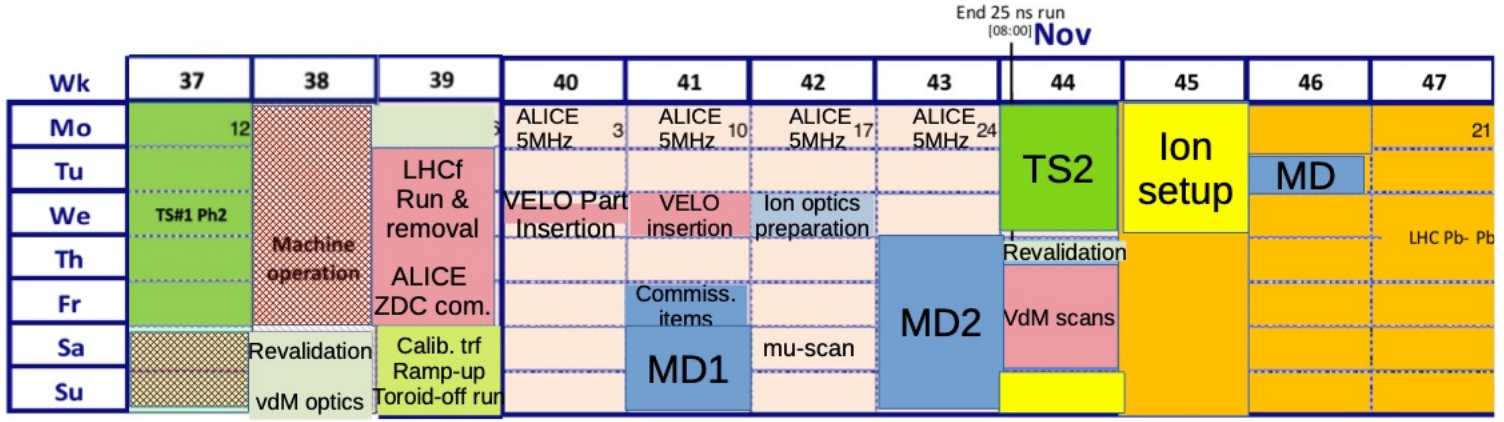
End of the run on **Monday 28th Nov**
~6am (exact time to be defined)

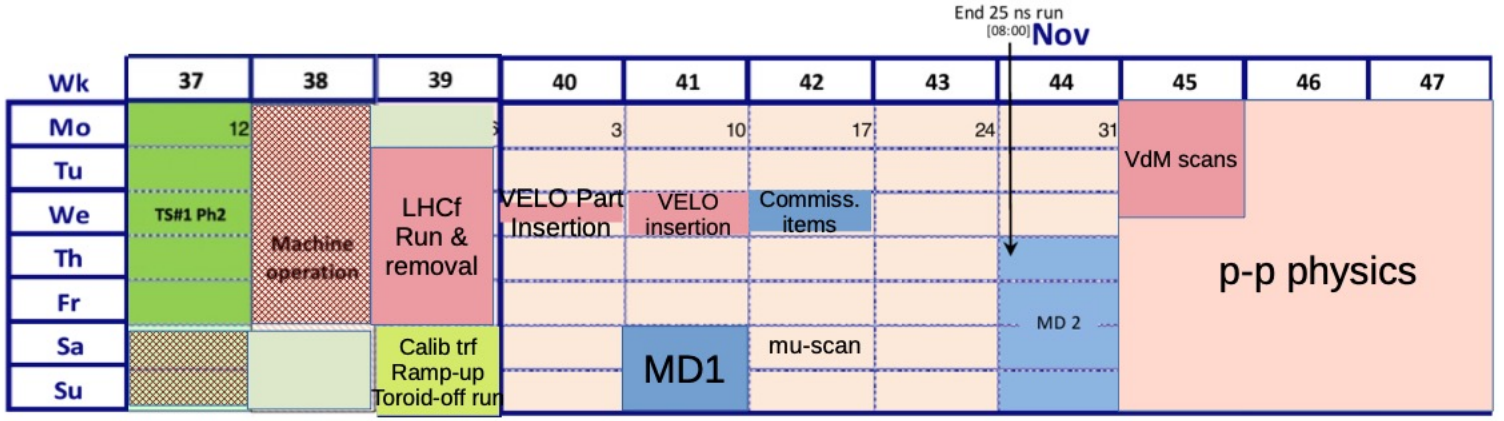
Two schedule options on the table:

- **A** including ION run
- **B** without ION run (in 2022)

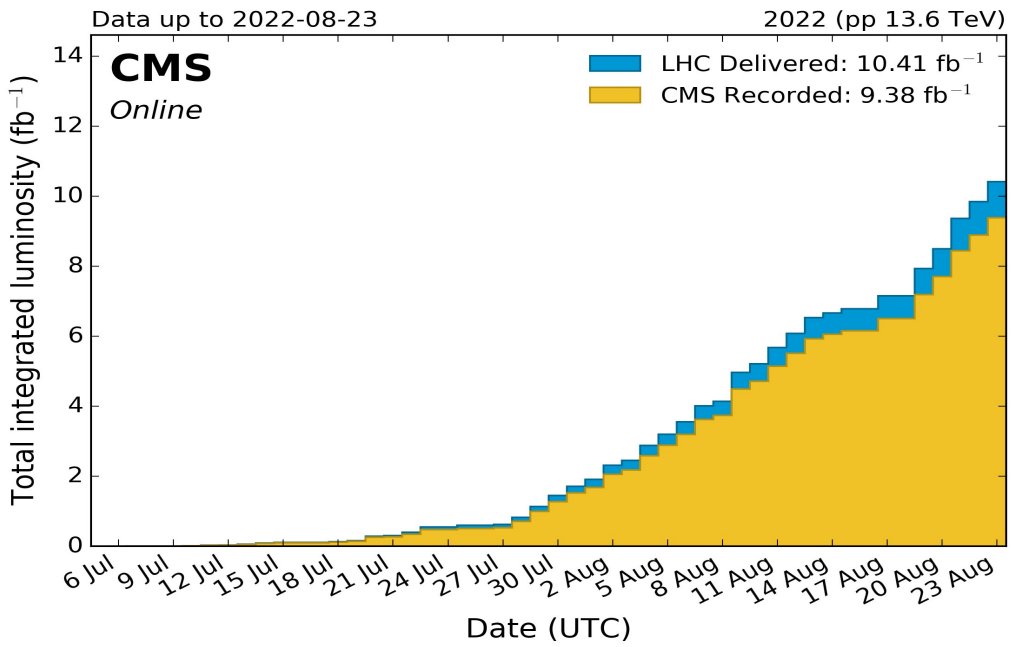
In addition, from October 15th EDF can request CERN to apply **large reductions in daytime power consumption** with one day notice.

- Switch off SPS, PS … for one day.

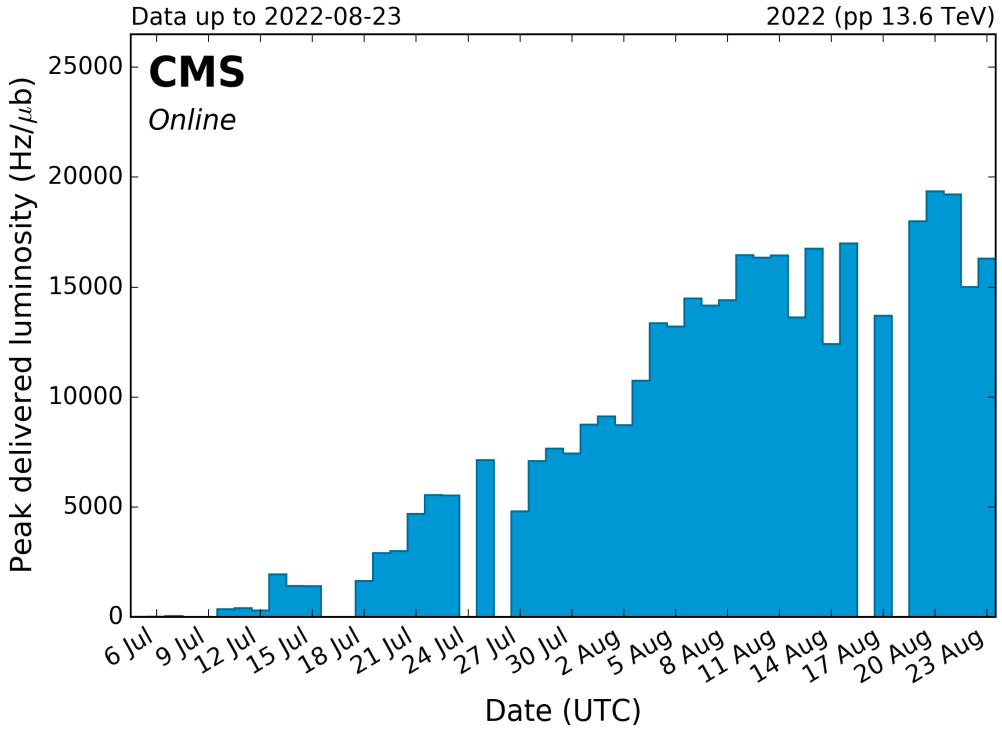




CMS Run 3 Status



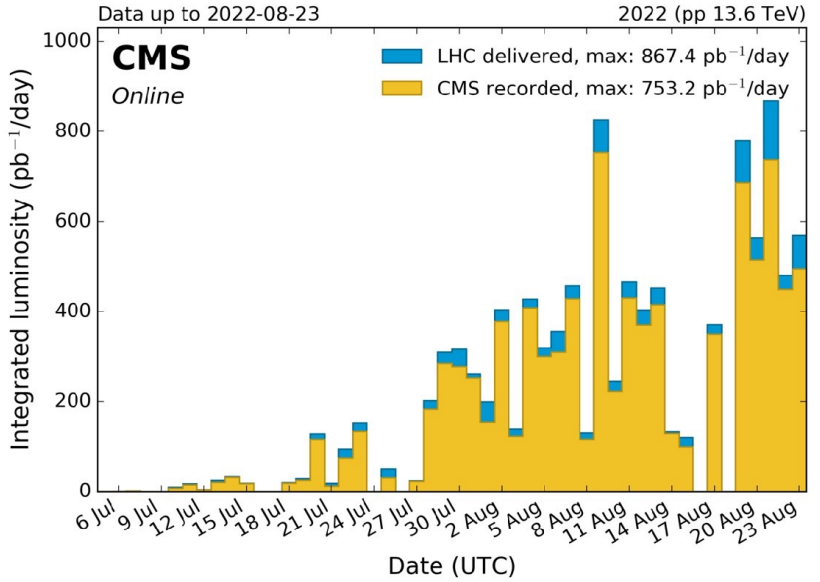
- Teething problems, most fixed promptly
- Running efficiency is good

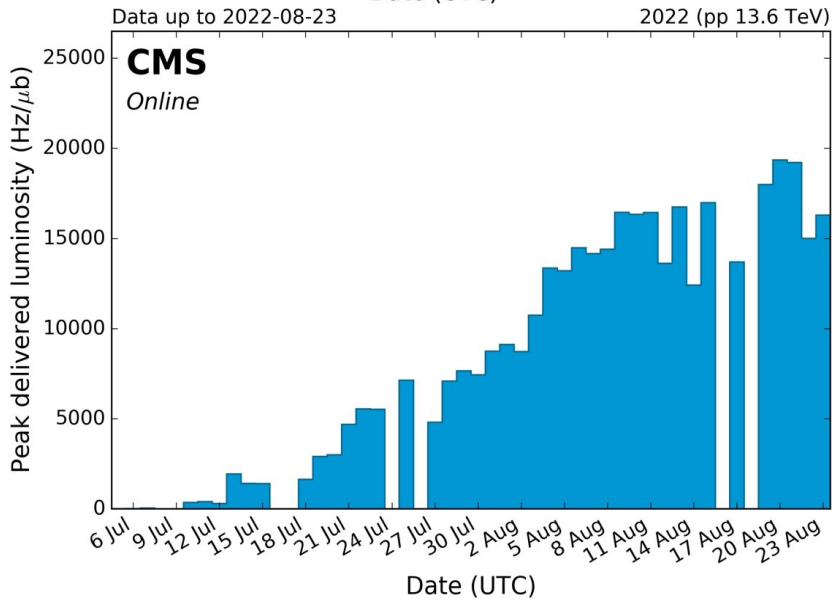


- Take home numbers:
  - Over 10 fb^{-1} delivered @13.6 TeV
  - 90.2% data taking efficiency

CMS Run 3 Status

- So far in 2022, LHC has delivered 10.8 fb-1 and CMS has collected 9.74 fb-1 up to now.
- The run was paused on August 23 due to an incident in the LHC which required a warm up to repair.
  - LHC beams started up again last Monday
  - CMS was running well at the time of the incident with some minor issues.
    - Water leak on the Endcap Calorimeter
    - UK experts were able to patch up the problem in order to continue data taking
    - It maybe the YETS before patch can become a fix

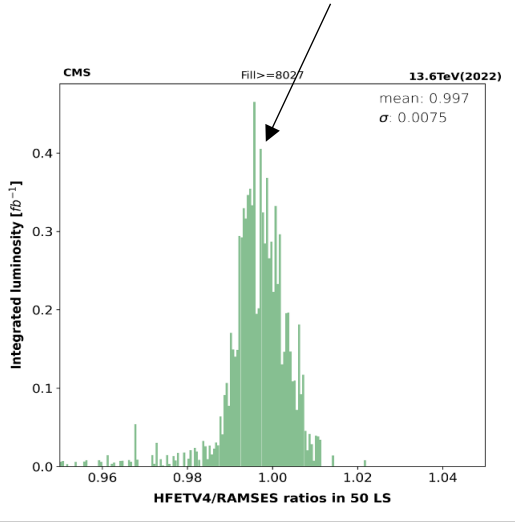


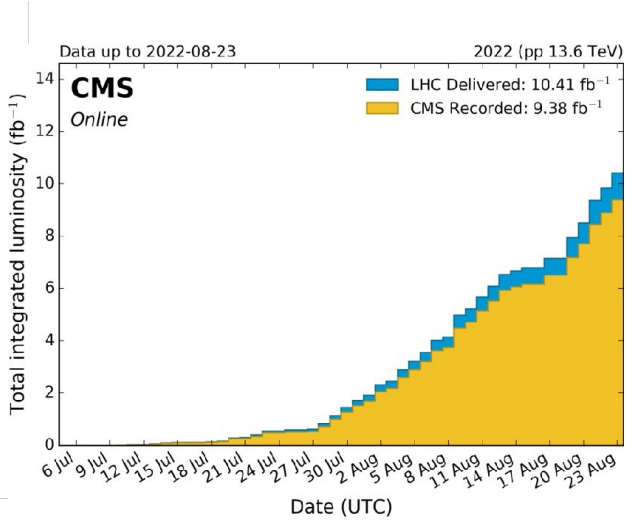


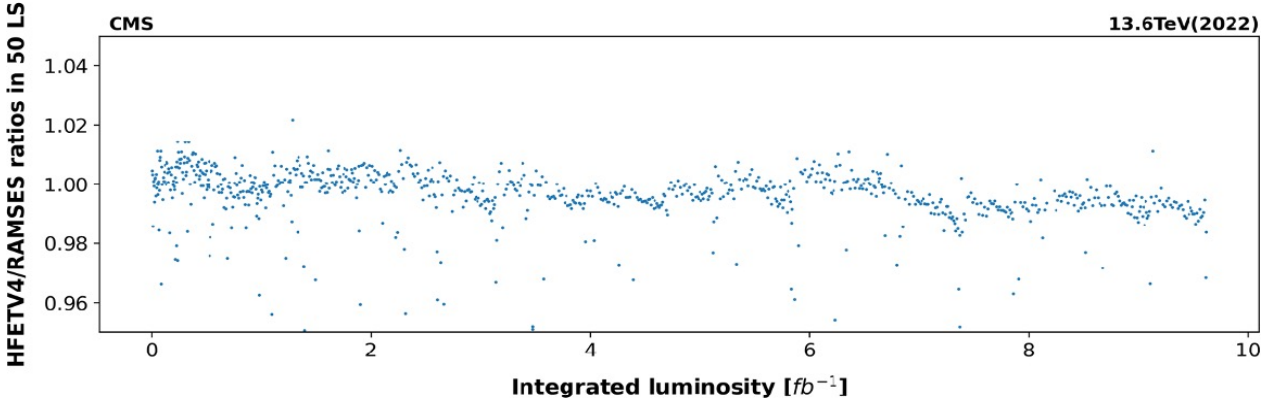
Beam monitoring and Luminosity

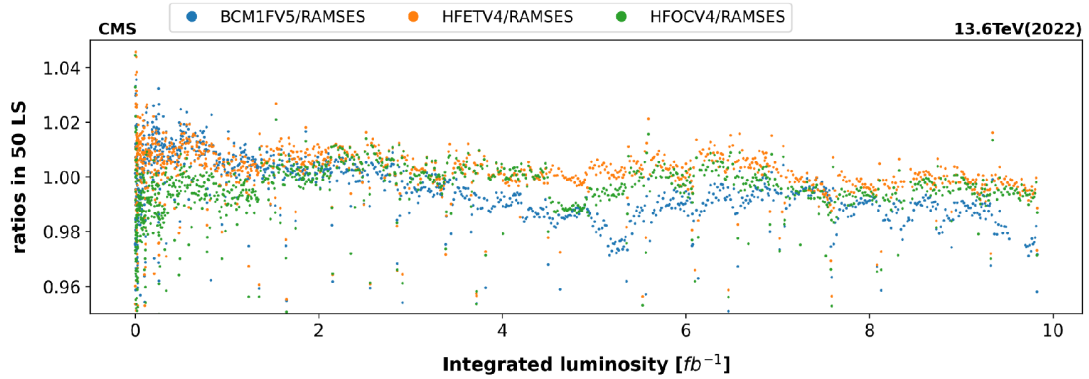
- Luminometers showing excellent performance
  - BCM1F, PLT, HFOC, HFET “calibrated” in emittance scans
  - RAMSES, DT cross calibrated
- Background and abort systems all operational
  - Great progress with BHM (Beam Halo Monitor)
- Awaiting a true VDM scan for better systematics

RMS better than 1% over this entire Run3 sample

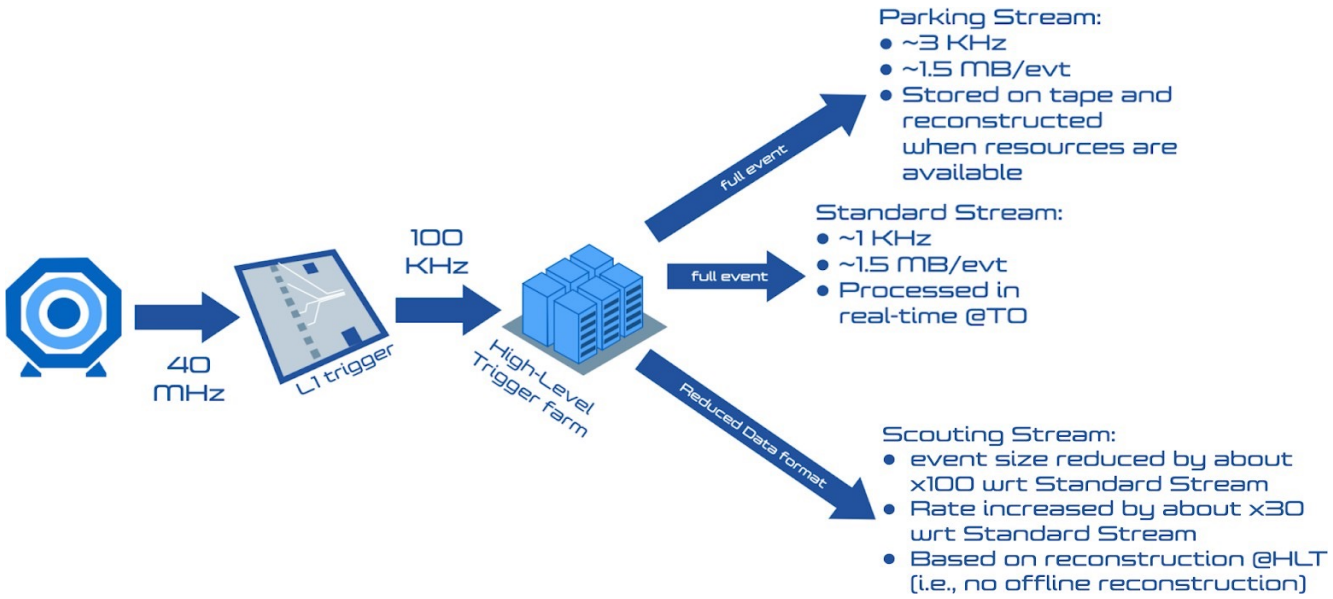




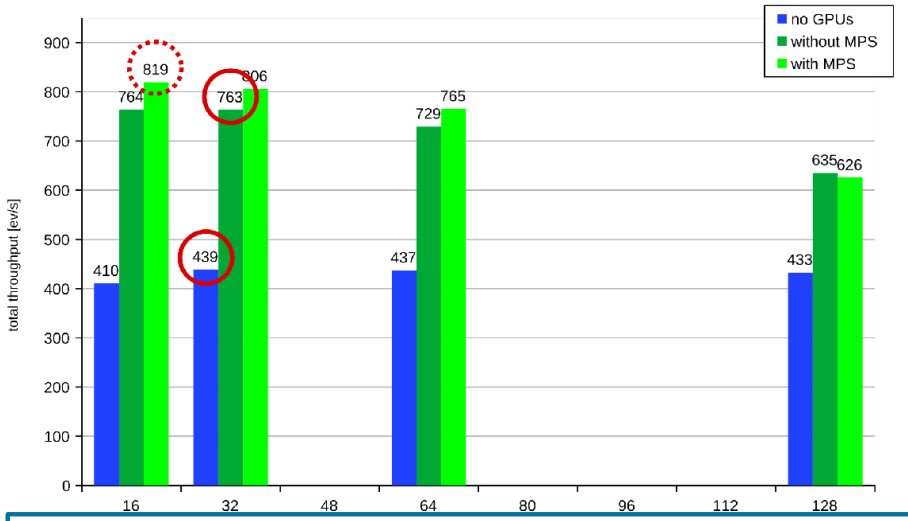




DAQ and Trigger



Running with 32 threads per job with GPU without MPS



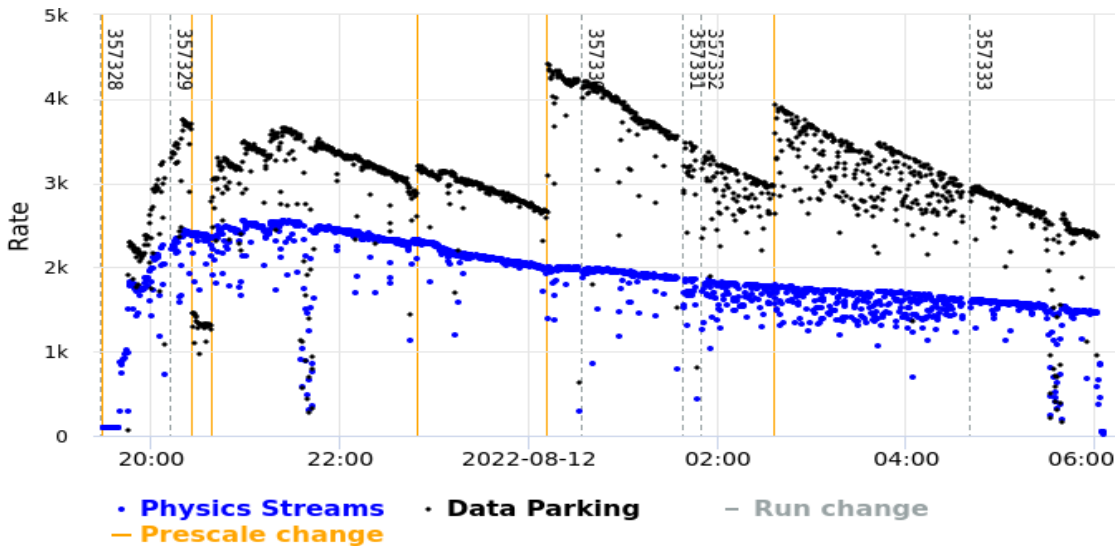
GPUs bringing ~40% offload, higher than the anticipated 25%

MPS: Multi-Process Service

- Level-1 Trigger highlights
  - New triggers: displaced/ delayed muons/jets, low E_T double E/γ for b-physics, …
- HLT highlights
  - GPU offload 40% of evt. processing Yields 70% increase in throughput
  - Consistent results CPU vs GPU
  - Graph Neural Network for jet tagging

Run 3 Data Processing

- So far *Standard* and *Parking* streams successfully promptly processed at the Tier-0
- Run 3 peak processing rates > 5 kHz
  - Approaching Run 4 rates



- Introduced new compression algorithm for RAW data:
  - LZMA replace Gzip thanks to ROOT
  - 10% smaller RAW event size

- Smooth transfers to tapes at the Tier-0 and Tier-1 sites:
  - Network and tape infrastructure are healthy
  - Tune the new data management system (RUCIO) for data taking.

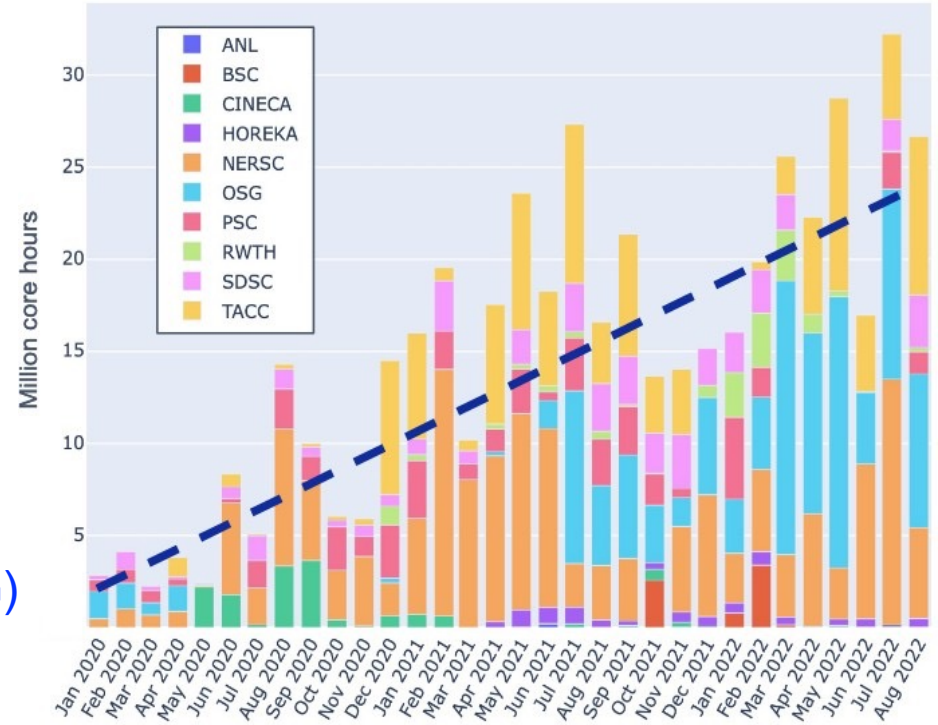
Successful prompt processing @ > 5 kHz, 10% smaller RAW events

Run 3 Data Processing

- Record CPU utilisation since May: 386K CPU cores average, peak: 466K

  Large contributions from HPCs, Run-2 HLT Cloud, and beyond-pledge contributions from our sites

- Excellent support and availability from all our sites
- Continuous growth of capacity used at HPCs
  - Transparent site extensions (e.g. RWTH, HOREKA, Marconi)
  - Allocations accessed through a service (e.g. HEPCloud, OSG)

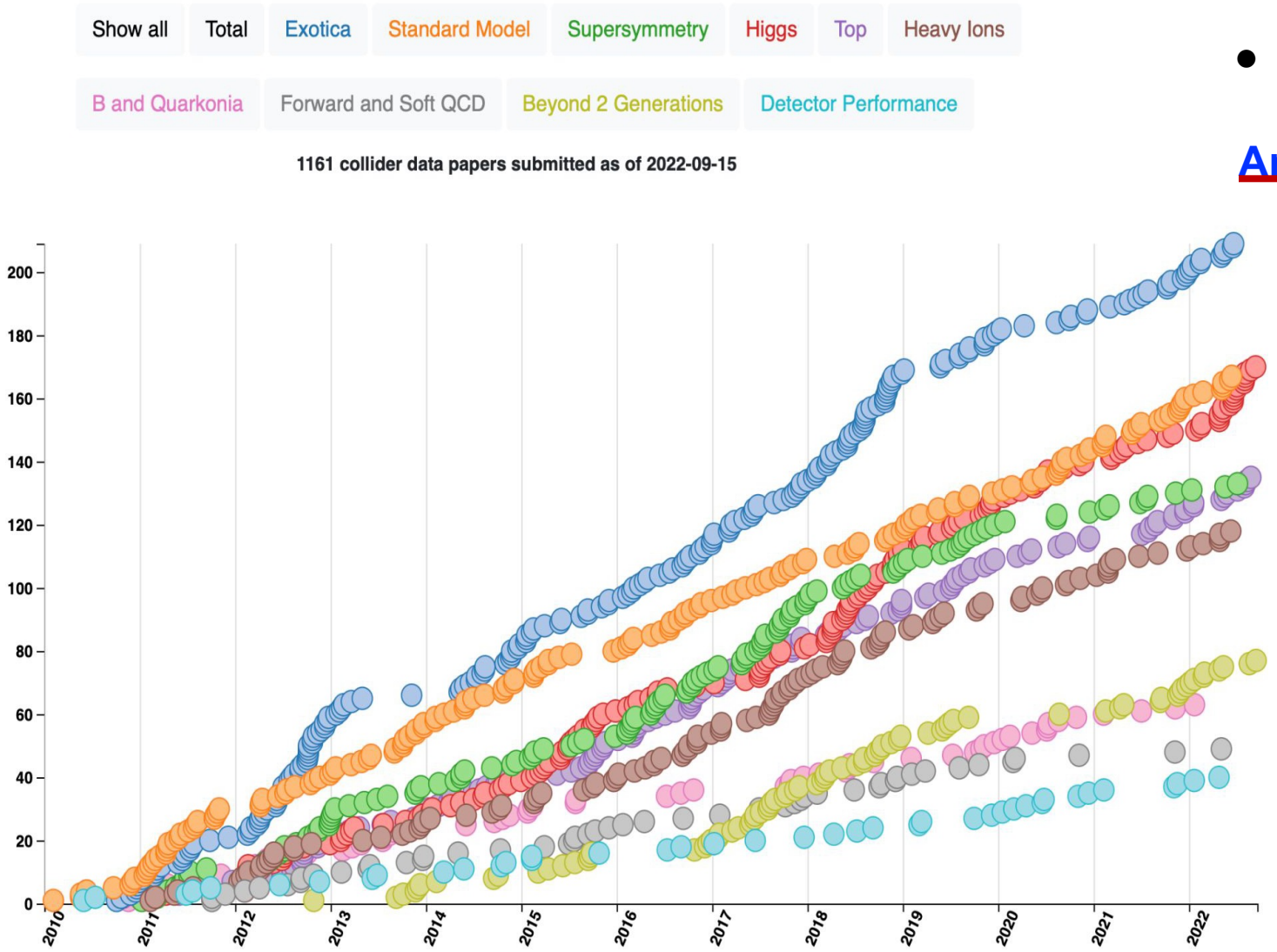


Record usage of compute capacity, usage of HPCs continues to grow.

War in Ukraine

- Impact of the war in Ukraine on computing
  - CMS is requesting additional resources from the collaboration
  - The UK have been able to provide additional, disk, tape and CPU
  - CMS is also making replicas of data based at Russian T1s
    - RAL has already produced its share of replicas
  - So far we can absorb the load!

CMS Publications



- **1161 papers** on collider data published or submitted to a journal

Analysis effort on two fronts:

- Run 2 data analysis not over (>100 analysis efforts ongoing)
- Run 3 early data analysis foresee ~100 analyses in the first couple of years
- First preliminary result with Run 3 data presented at TOP2022. More to come

Authorship Status

On July 28 and September 7 there were special CMS CB meetings to discuss authorship. CMS papers remain in a “suspended” state. There have been no publications since Feb 24th, the date of the military invasion of Ukraine by the Russian Federation), apart from an article in Nature published as “CMS Collaboration”. Currently 14 papers have been accepted and still pending at the journals. Many more (>40) have been submitted as CMS Collaboration pending the author list decision.

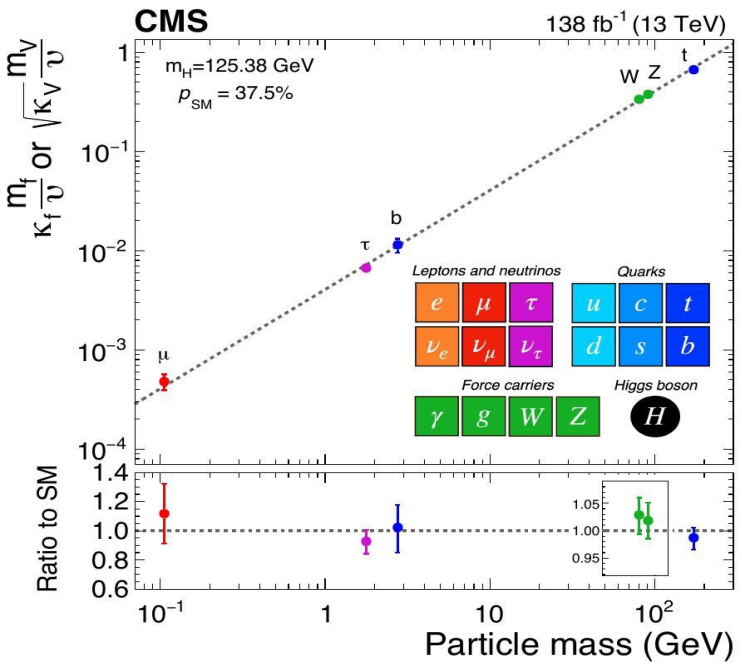
During August, the four LHC Spokespersons, in collaboration with the CB Chairs and in consultation with the CERN management, worked out a common document, with two proposals, and a procedure to reach a decision

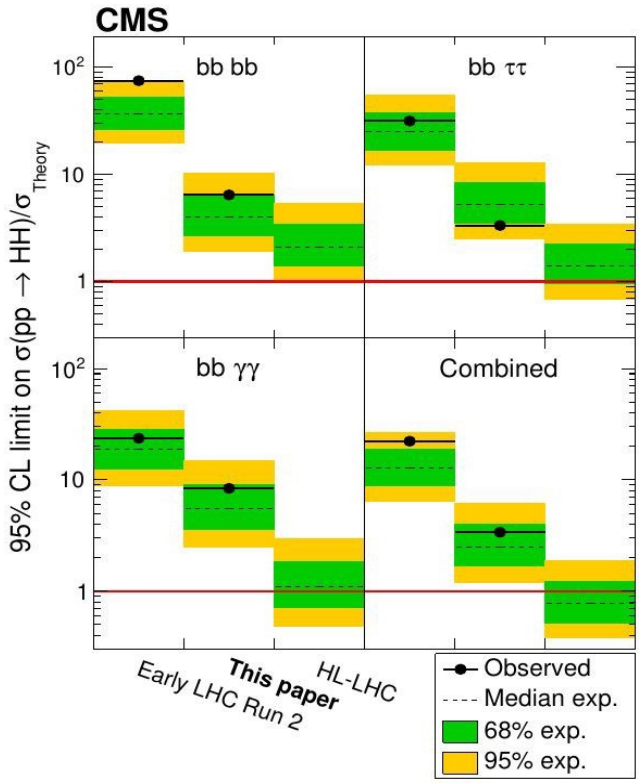
The joint document represents the output of a long process where different views are reflected with the ultimate aim to find a **common approach among all LHC collaborations**.

CMS strives to find a compromise that enables the entire collaboration to continue in the spirit and tradition of CMS and CERN.

Following polls (opinion votes) in all four collaborations, a single proposal will be formulated by the LHC Spokespersons and CB Chairs, and a formal vote on it is planned before the end of September (if possible).

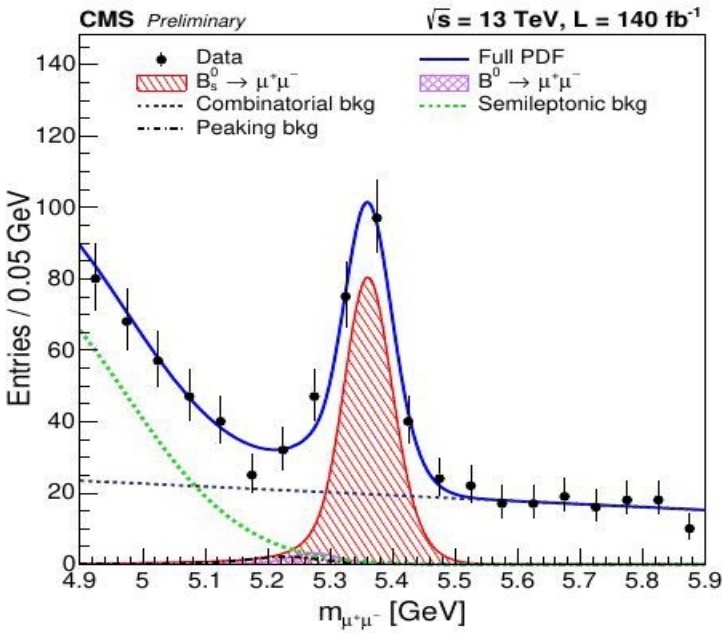
10 Year Celebration of Higgs Boson Discovery

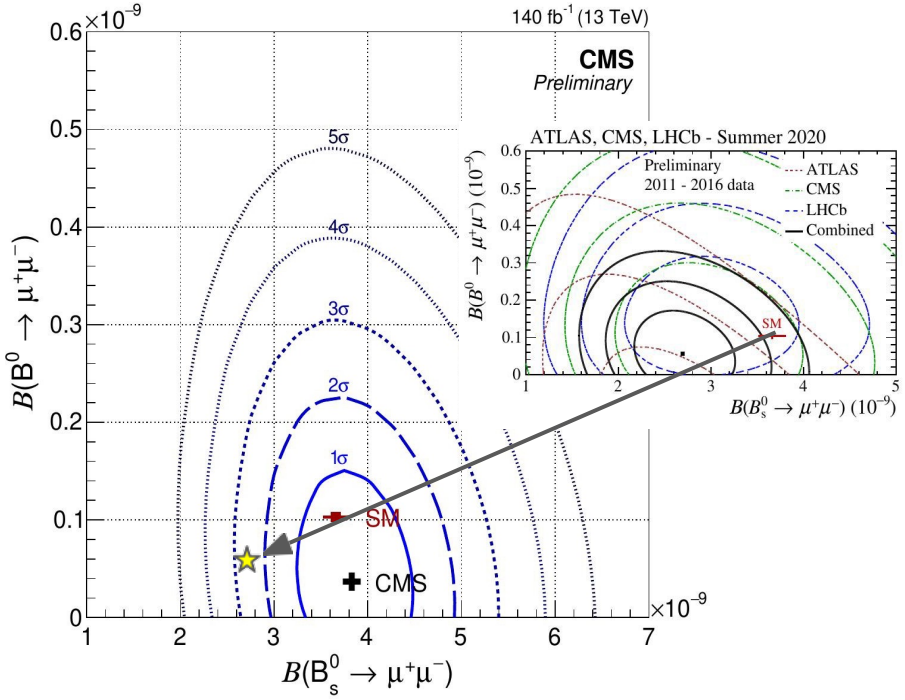


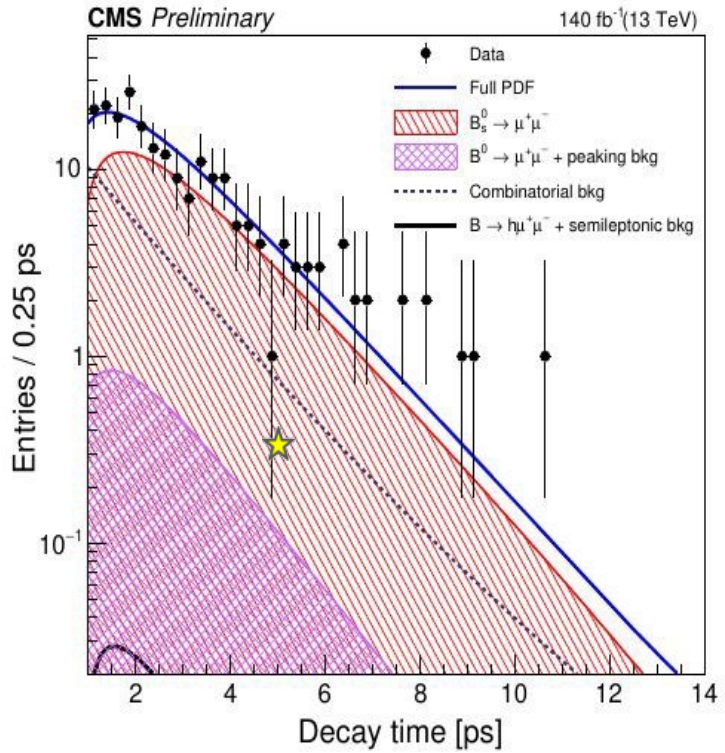


- Combination of multiple results fitting for *coupling modifiers*
- Combination of HH results for the three most sensitive channels (4b, 2b2τ, 2b2γ)
- All details in our Nature paper

Full Run 2 result on $B_s \to \mu\mu$







- Updated results with **full Run-2 luminosity**
- Most precise single experiment measurement to date
  - Highly compatible with SM prediction
- Most precise measurement of lifetime

$$\mathcal{B}(\mathrm{B_s^0} \to \mu^+\mu^-) = \left[3.95^{+0.39}_{-0.37}\,(\mathrm{stat})\,^{+0.29}_{-0.24}\,(\mathrm{syst})\right] \times 10^{-9}$$

$$\tau = 1.83\,^{+0.23}_{-0.20}\,(\mathrm{stat})\,^{+0.03}_{-0.03}\,(\mathrm{syst})\ \mathrm{ps}$$

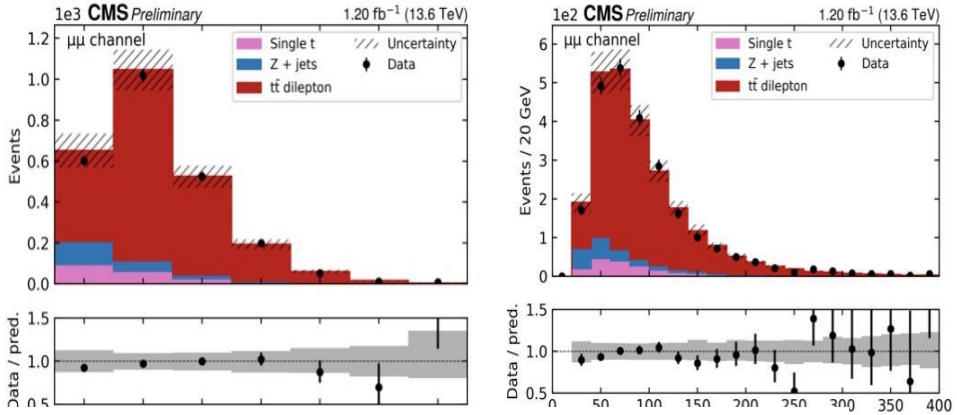
First Run 3 Result: tt cross section @13.6 TeV

First measurement of the top quark pair production cross section in proton-proton collisions at 13.6 TeV

Result presented at TOP2022 workshop

- Calibrated data/MC agreement directly on the measured dataset (trading systematic uncertainties for statistical ones)
- Validated method on Run 2 data (vs. data/MC correction factors used as input in standard analyses)
- Measurement in good agreement with the standard model prediction
- Aiming at publication soon
  - scale factors from POGs to improve precision

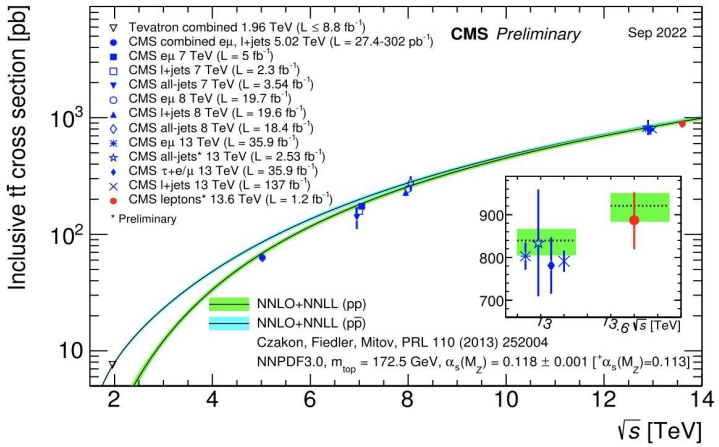
dimuon channel



Result

$\sigma_{tt} = 887\ (^{+43}_{-41}\ \text{(stat+syst)})\ (\pm 53\ \text{(lumi)})\ \text{pb}$

Consistent with SM theory prediction: 921^{+29}_{-37} pb



Upgrade for HL-LHC

L1-Trigger/HLT/DAQ

https://cds.cern.ch/record/2714892

https://cds.cern.ch/record/2283193

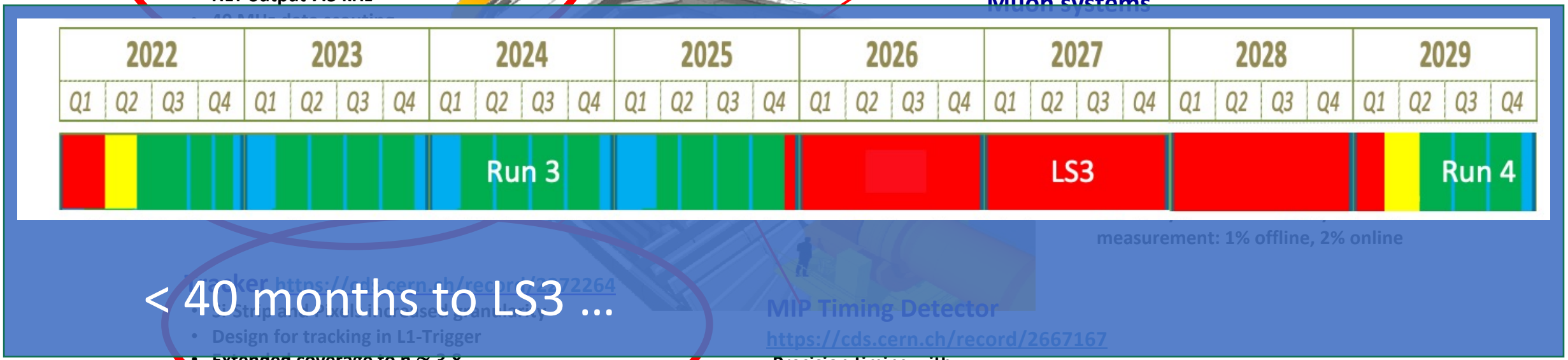
- Tracks in L1-Trigger at 40 MHz
- PFlow selection 750 kHz L1 output
- HLT output 7.5 kHz

Barrel Calorimeters

https://cds.cern.ch/record/2283187

- ECAL crystal granularity readout at 40 MHz with precise timing for e/γ at 30 GeV

  ECAL and HCAL new Back-End boards



Muon systems

measurement: 1% offline, 2% online

Tracker https://cds.cern.ch/record/2272264

- Design for tracking in L1-Trigger
- Extended coverage to η ≃ 3.8

MIP Timing Detector

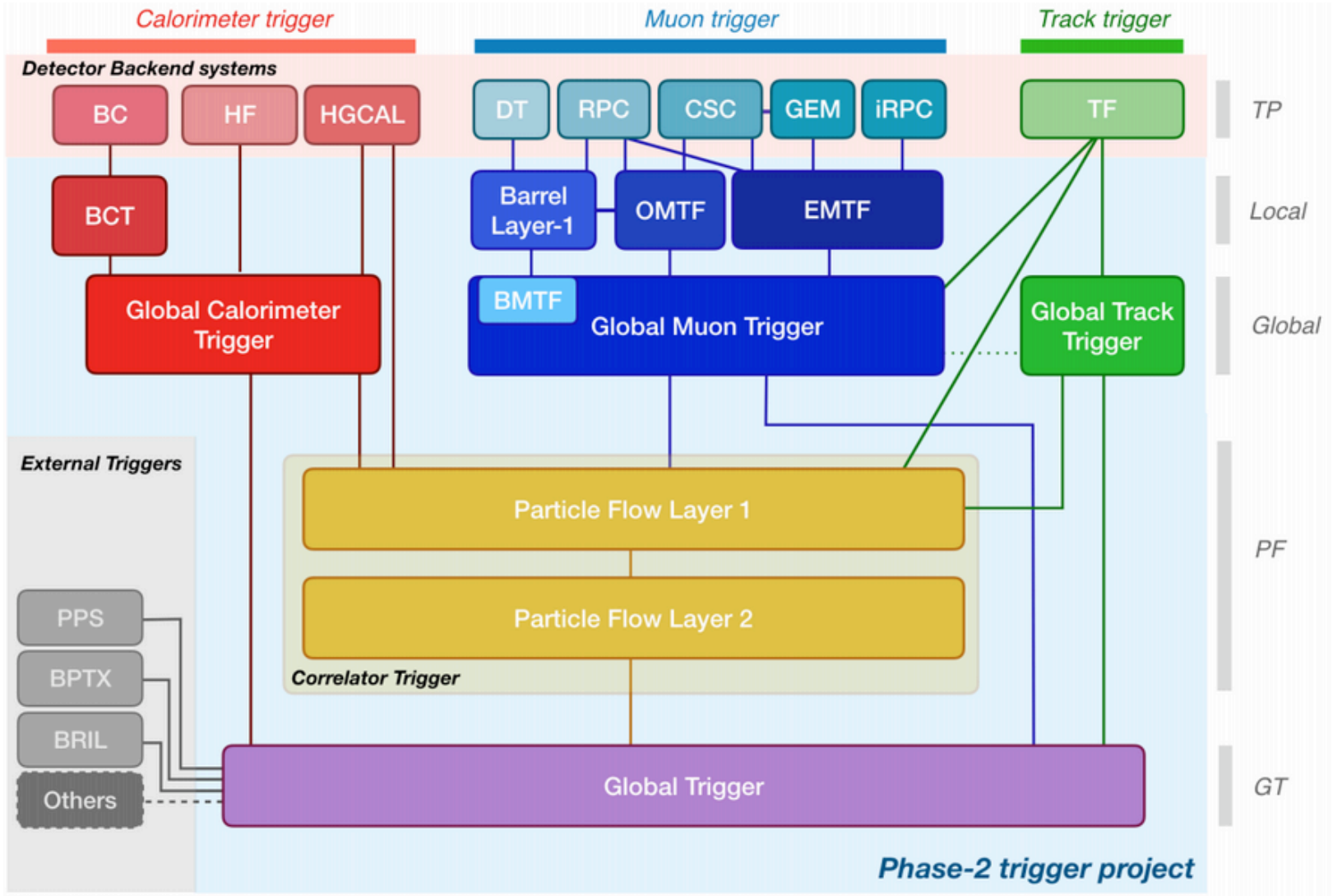
https://cds.cern.ch/record/2667167

Precision timing with:

- Barrel layer: Crystals + SiPMs
- Endcap layer: Low Gain Avalanche Diodes

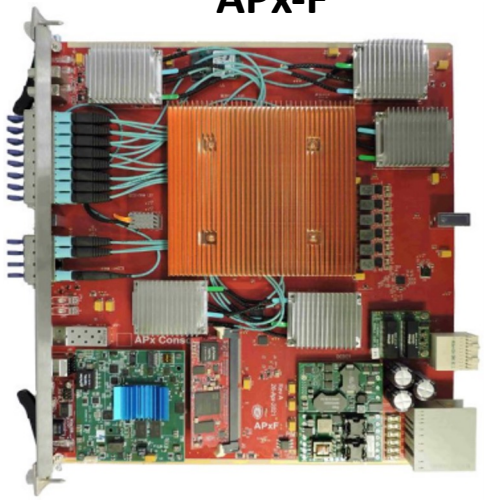
< 40 months to LS3 …

Phase 2 Trigger Overview



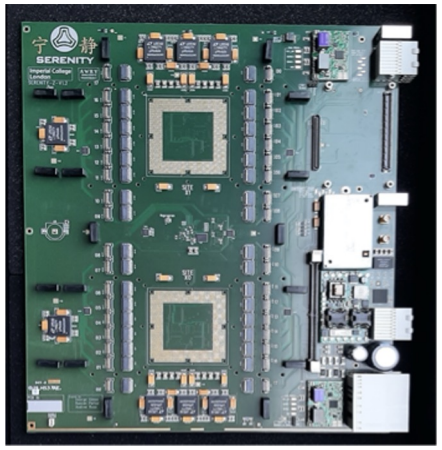
L1 Trigger

APx-F

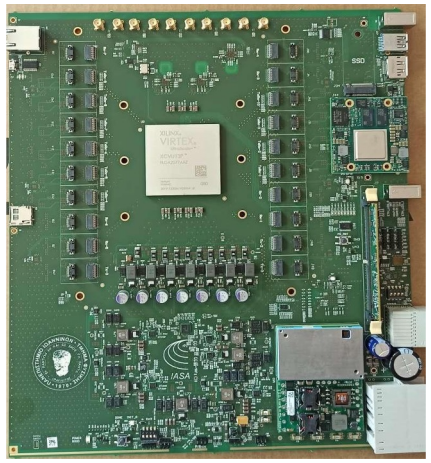


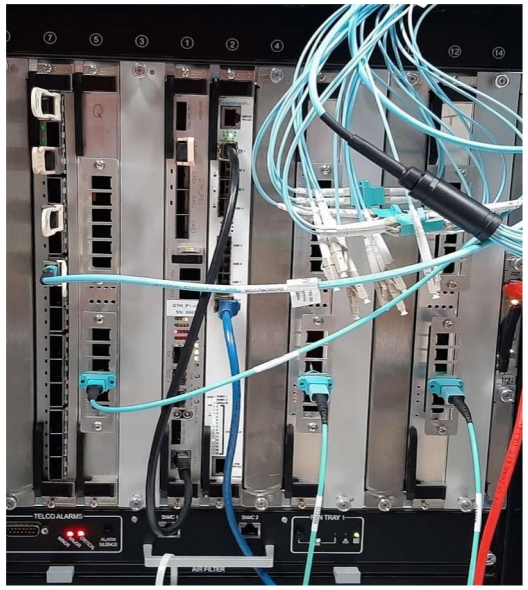
X2O

Serenity



BMT-L1



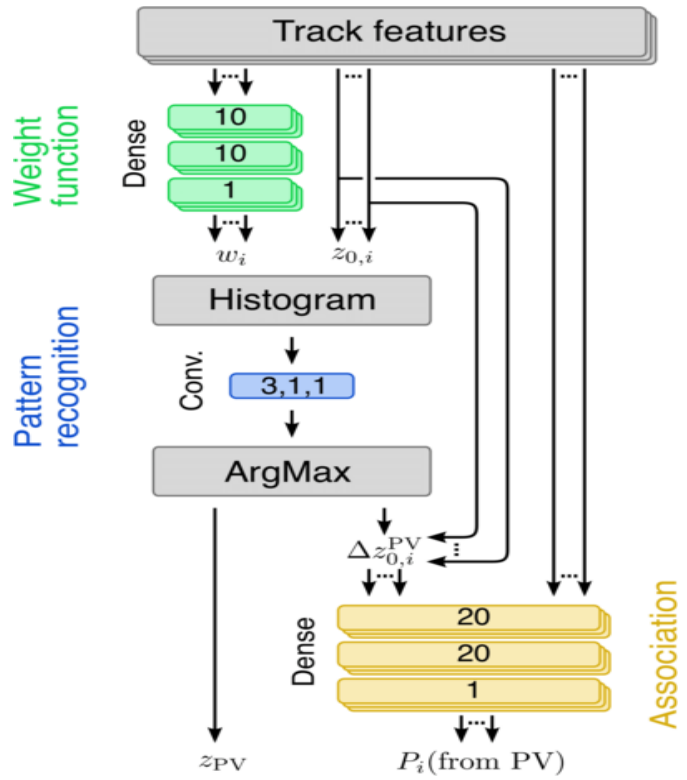


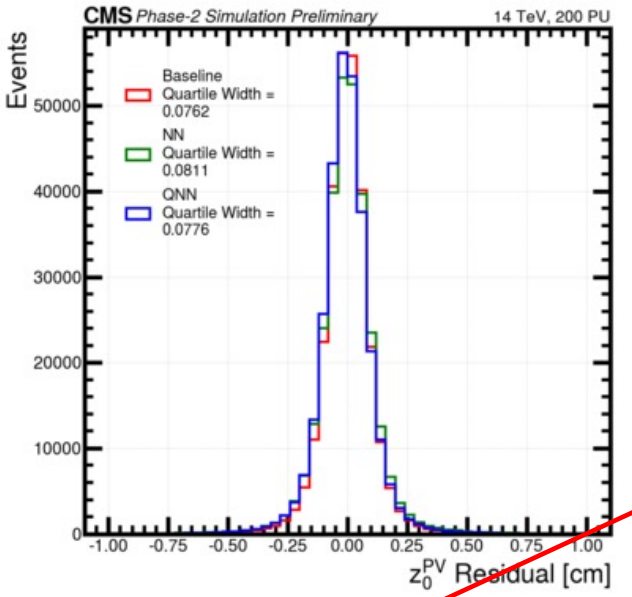
- 4 boards part of l1 trigger
- UK part of the Serenity consortium
- Serenity used for L1 Trigger, HGC and tracker
- **All pilot production hardware milestones reached for all families**
- Pre-production designs in progress

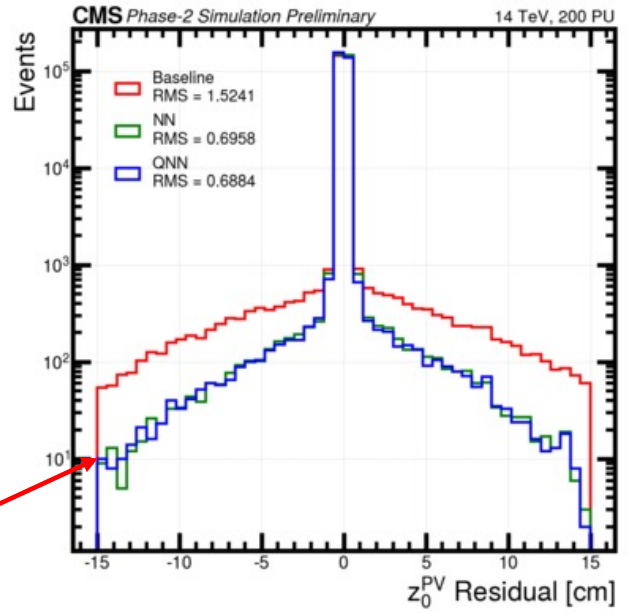
- First successful integration of Serenity and X2O
  - Common timing and synchronization
  - Data exchange performed with CMS Standard Protocol (CSP) successfully
  - No bit errors
- APx to be installed next
- BMT-L1 to be added after assembly of more boards

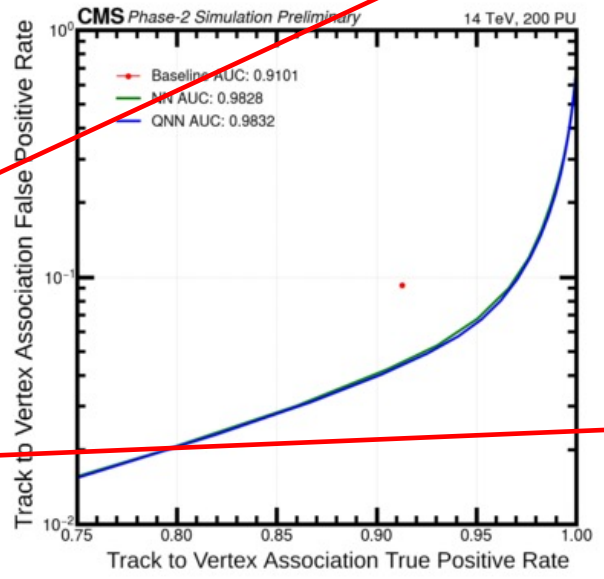
L1 Trigger Algorithms

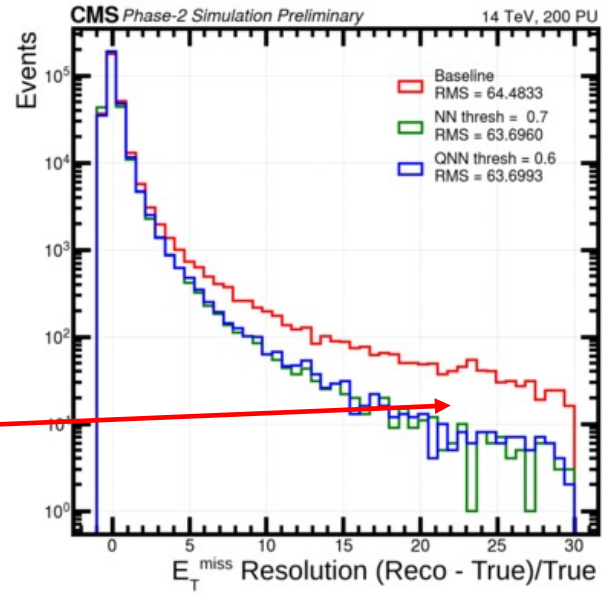
L1 Vertexing





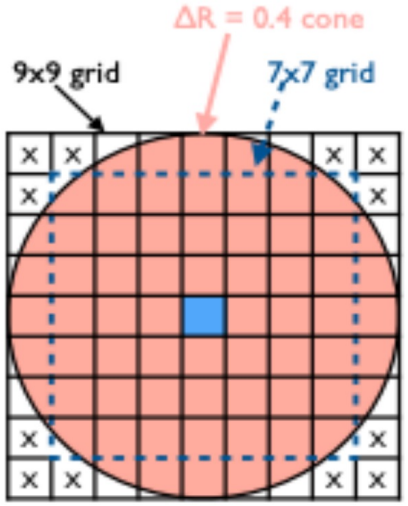




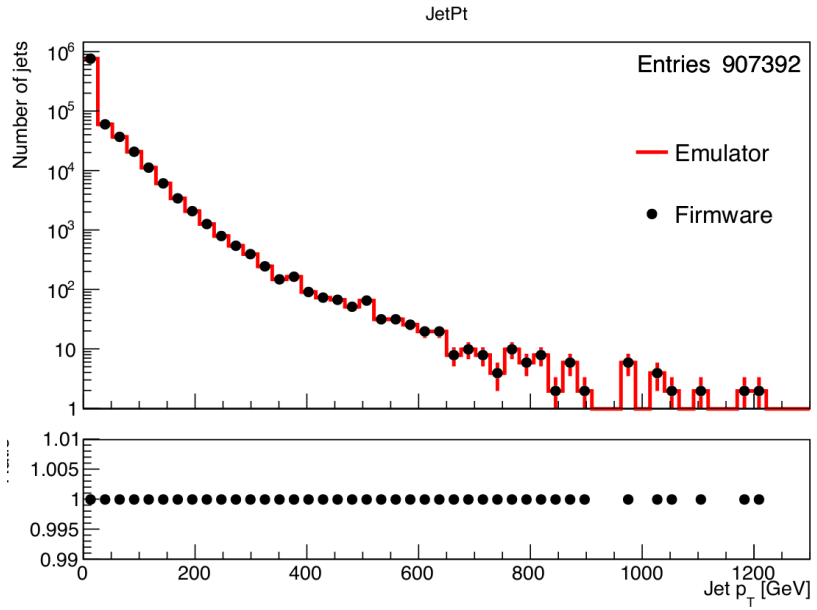


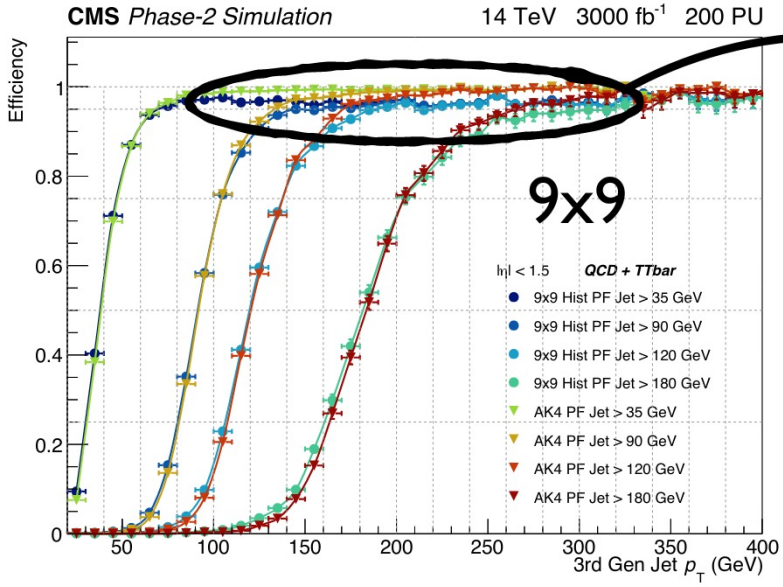
- Neural Network for vertex finding and track association implemented in a FPGA
- Improvement in tails

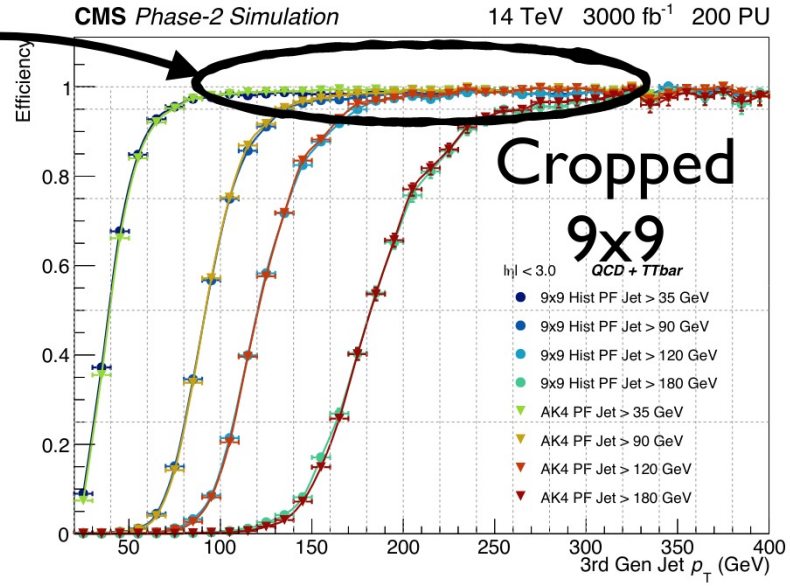
Layer 2 Jets/MET/MHT



- Seed Jets working well (Serenity, soon APx)
- Histogram algorithm updated to cropped jets



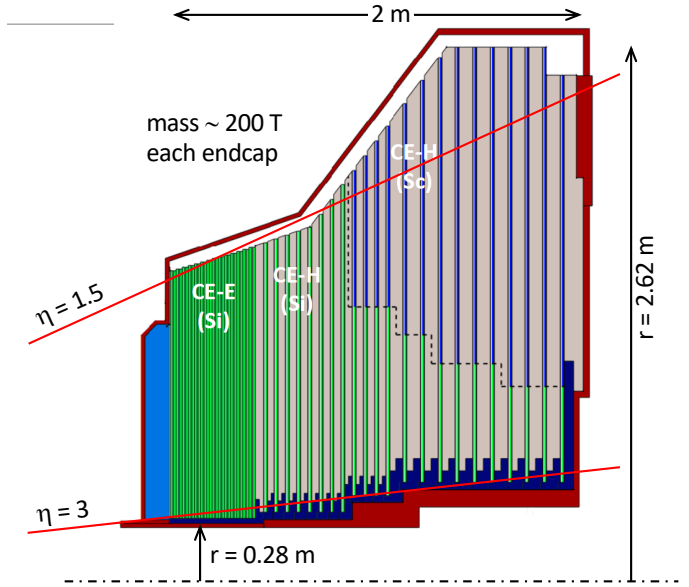




HGC

- Trigger primitive development and electronics, and simulation (UK)
- Firmware development and detector performance simulation underway

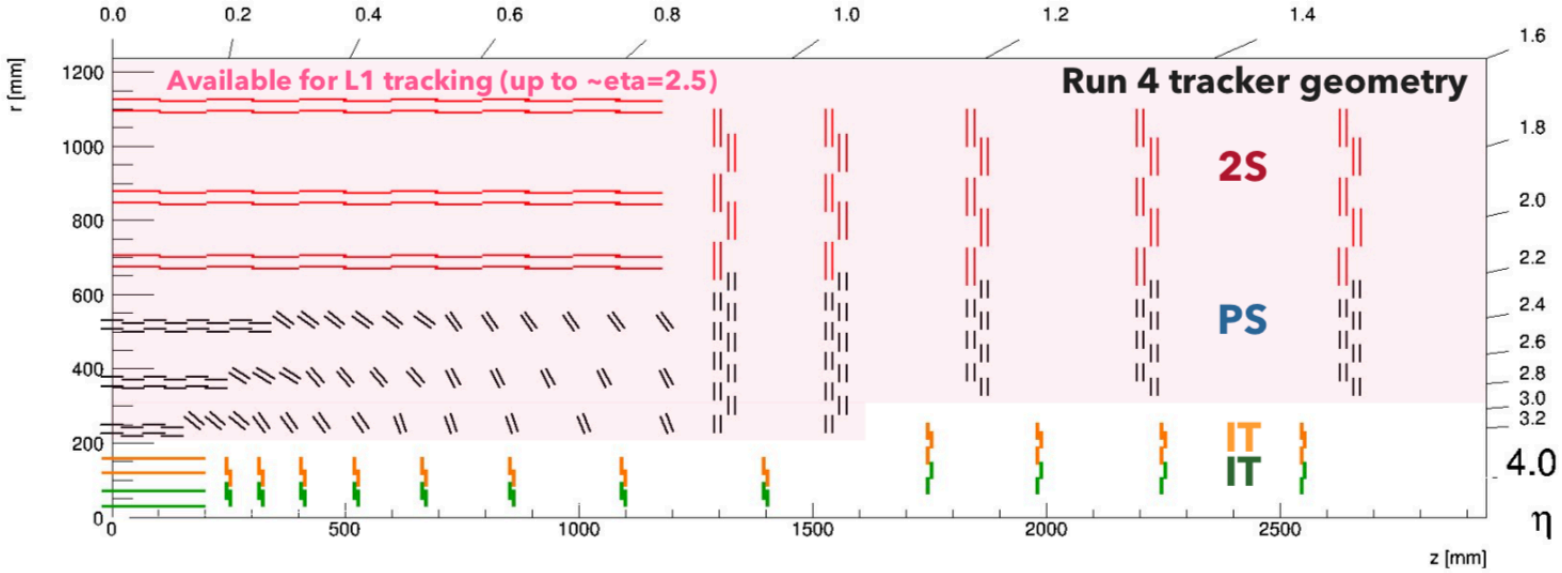
- Trigger version under test

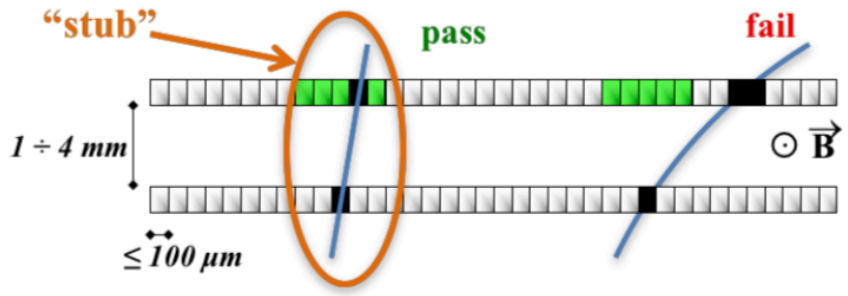


V3 system test chain at CERN, including
ROC → ECON-T-P1 → lpGBT → zcu102/Serenity

Communication tests with Serenity Board

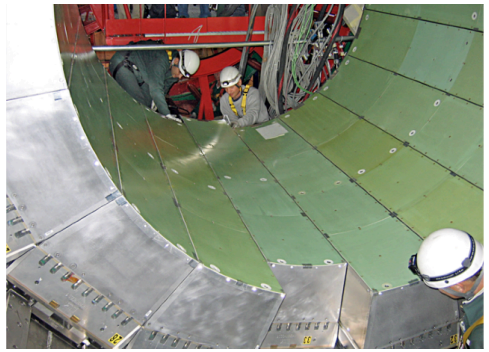
Tracker



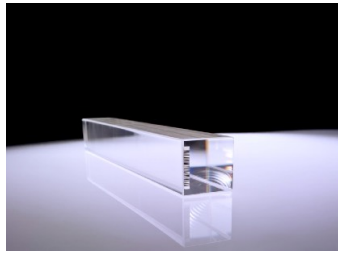


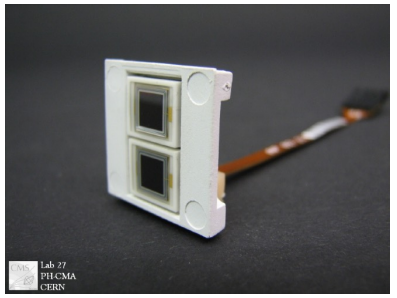
- Si tracker to be completely replaced.
- UK developed idea of "p_T" modules enabling use of tracks at L1.
- UK developed frontend ASIC (CBC)
- UK led development of all FPGA track reconstruction

ECAL Barrel



Keep crystals and APDs



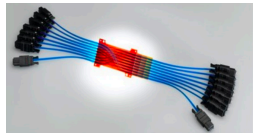


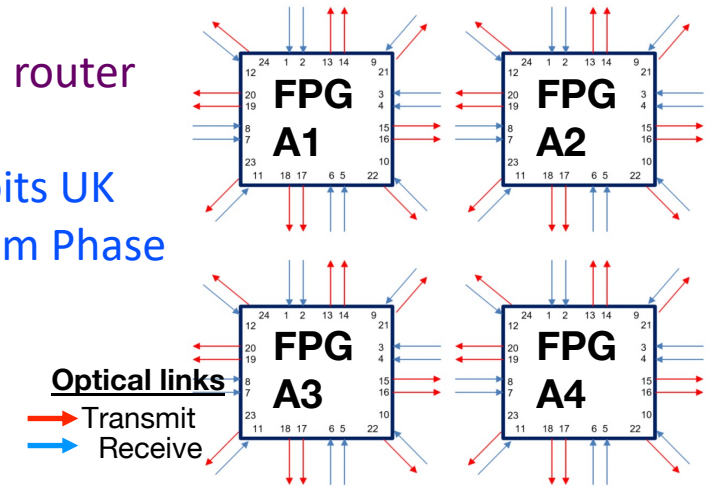
Replace all on and off detector readout

Trigger firmware/software (UK)

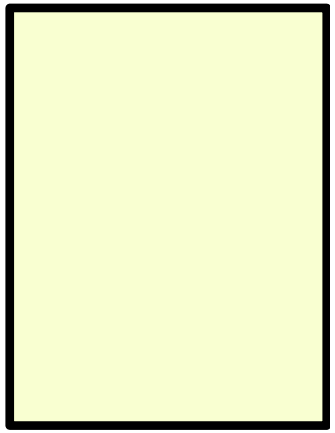
Optical Fibre router (UK)

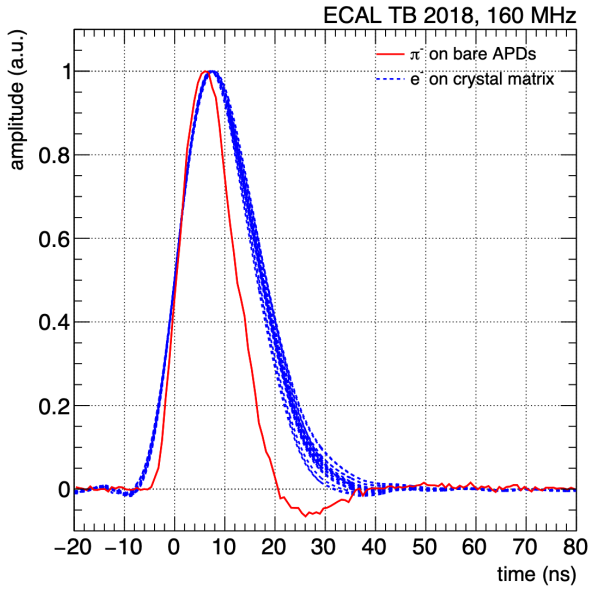
Design exploits UK expertise from Phase 1 upgrade





Link sharing between FPGAs





Looking Ahead

- Run 3 has started
  - CMS is in a position to take advantage of the luminosity the LHC is providing
  - Challenges have already arisen
- The situation in Ukraine has generated some challenges
  - We are rising to meet the challenges but the future is a little unclear
- Continue progression with upgrade work
  - Procurement of hardware
  - System development and realisation
  - Integration and commissioning
- Run 4
  - Will be a new detector. Commissioning will extend into running & operation and exploitation will require that effort levels remain similar to current levels

Summary

- LHC has provided a great start to Run 3
- CMS is in very good shape to exploit the high luminosity
  - Ecal issue shows the importance of having UK expertise available on hand to fix issues
  - The situation in Ukraine has thrown up some challenges
- CMS upgrade
  - Many projects transitioning from prototyping to preproduction
  - Previous worries still exist: supply chain issues, long lead times supply issues, war in Ukraine
- We look forward to future CMS results