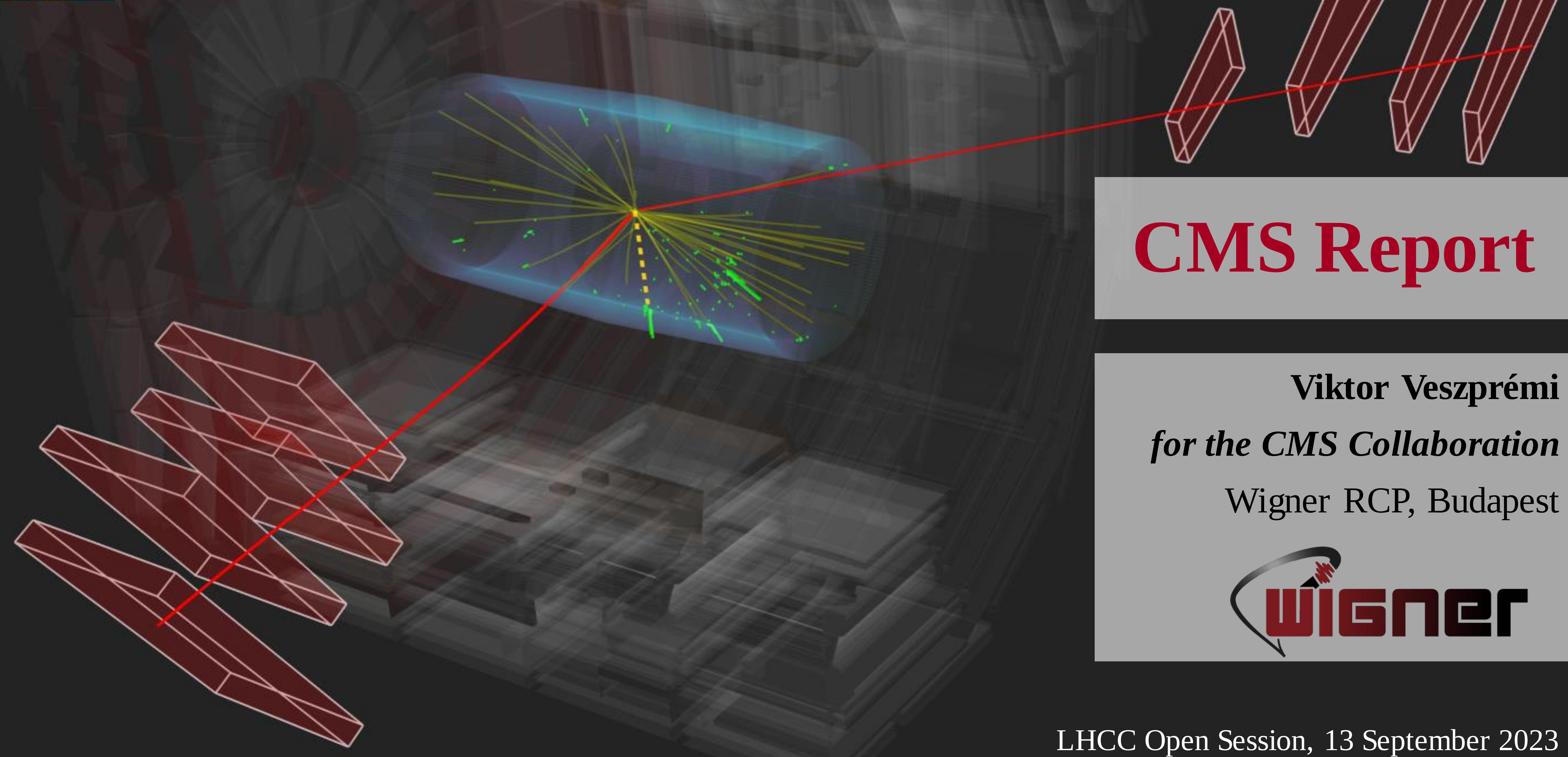
CMS Experiment at the LHC, CERN

Candidate event: Higgs boson decaying to a Z boson and a photon



CMS Report

Viktor Veszprémi

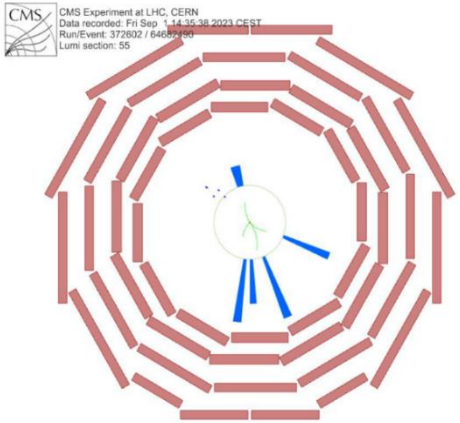
for the CMS Collaboration

Wigner RCP, Budapest

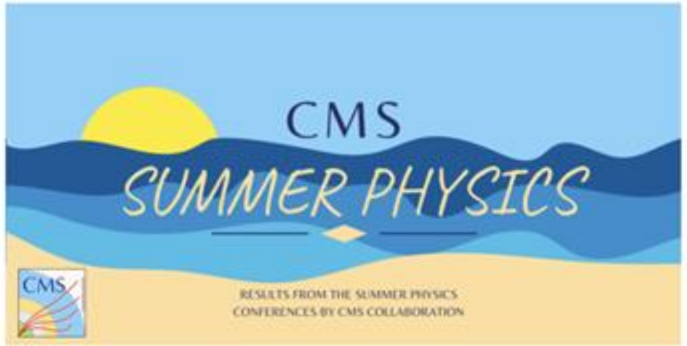
LHCC Open Session, 13 September 2023

Overview

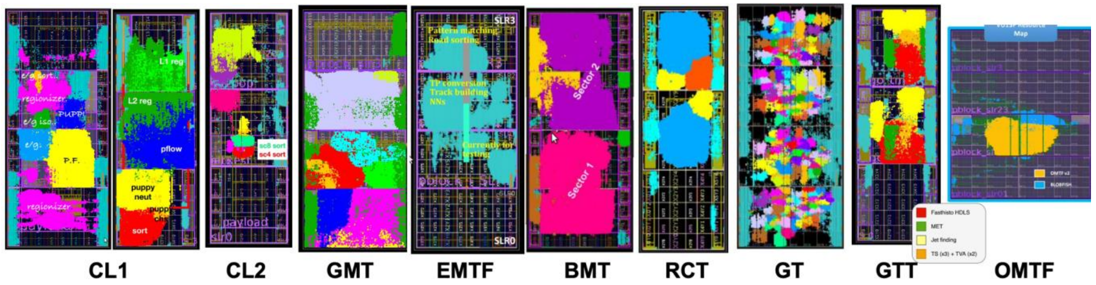
Run 3 data taking campaign



Physics analysis highlights

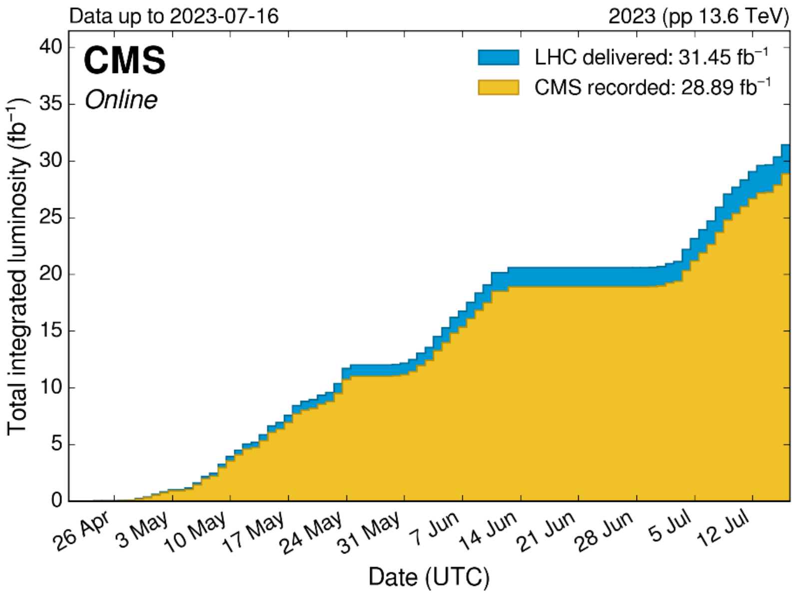


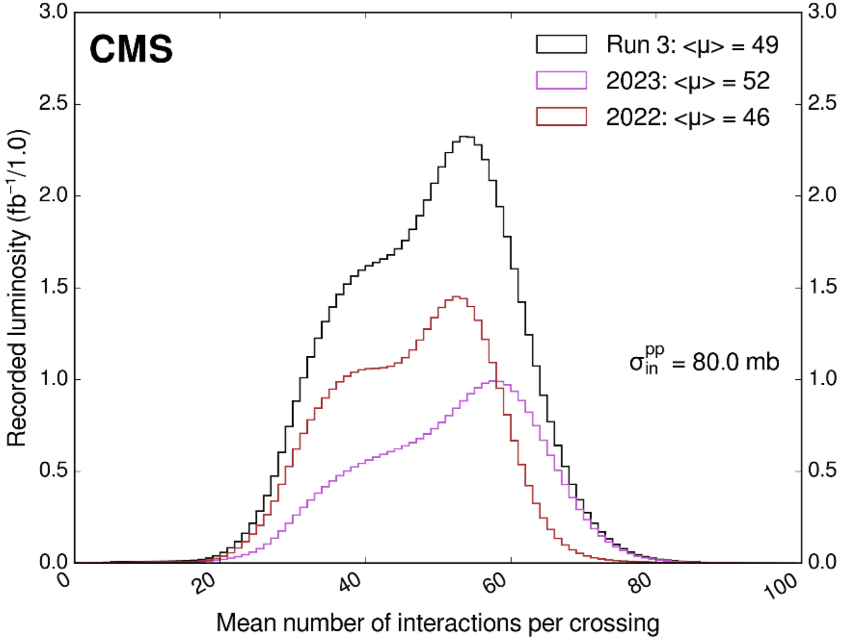
Phase 2 upgrade progress



Run 3 data taking

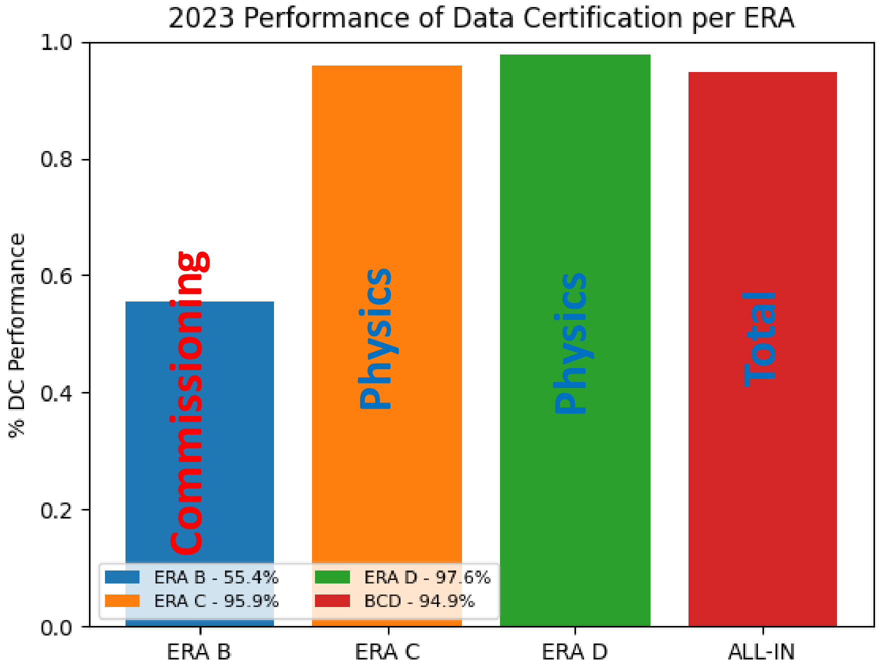
- **2023 proton runs**
  - 29 fb^{-1} recorded integrated luminosity
  - ~92% of data taking efficiency
  - Encountered no major problems
- **Reduced operation for a month after LHC incident on July 17**
- **CMS has been running well since restart**
  - detectors have been re-commissioned with cosmics and first stable proton collisions
  - High-beta* run with TOTEM detector this week
- **Preparation for pp reference run and HI run ongoing**
  - With priority to the integration and commissioning of a newly installed ZDC detector for the HI run

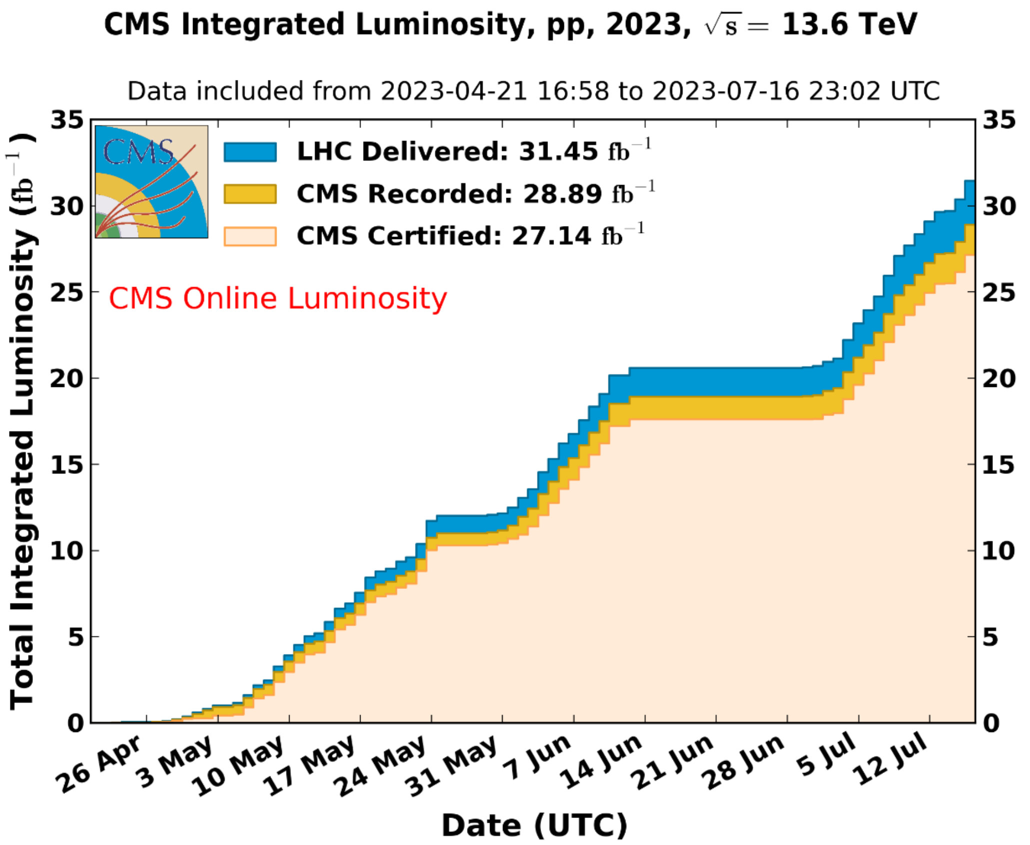




Data Certification

- 2023 data certification efficiency is 94%
- Lower efficiency in Spring due to detector/calibration optimization
- Smoother running during the last data-taking era



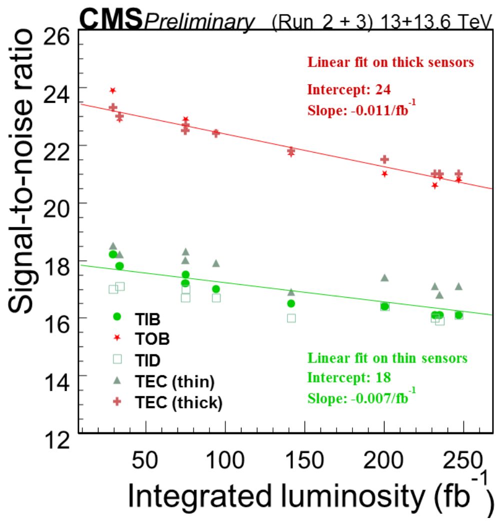


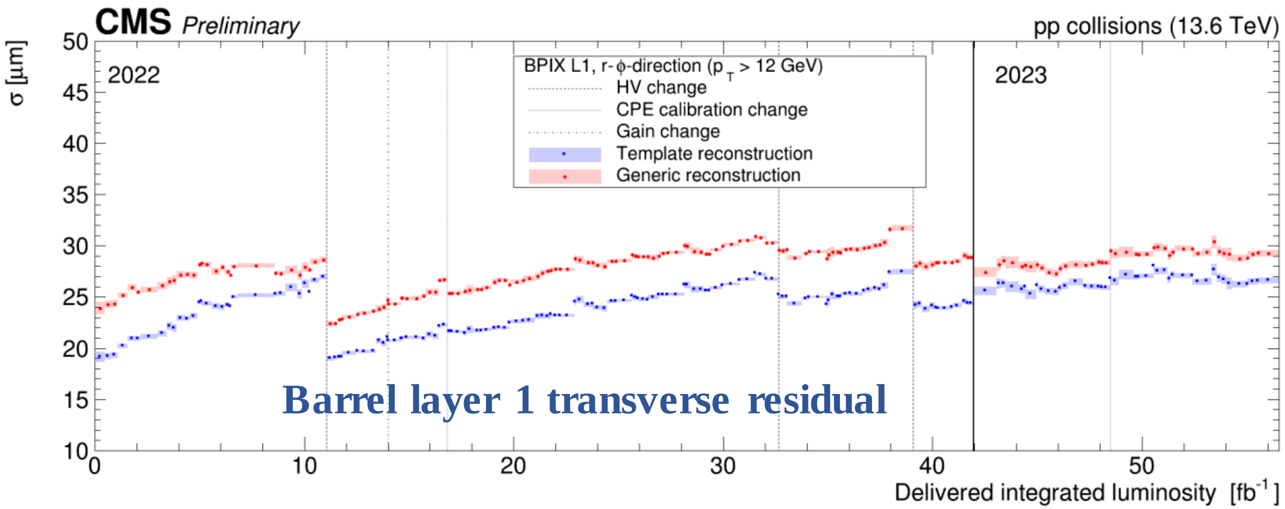
Certified data recorded with all detectors and reconstructed physics objects showing good performance

Tracker

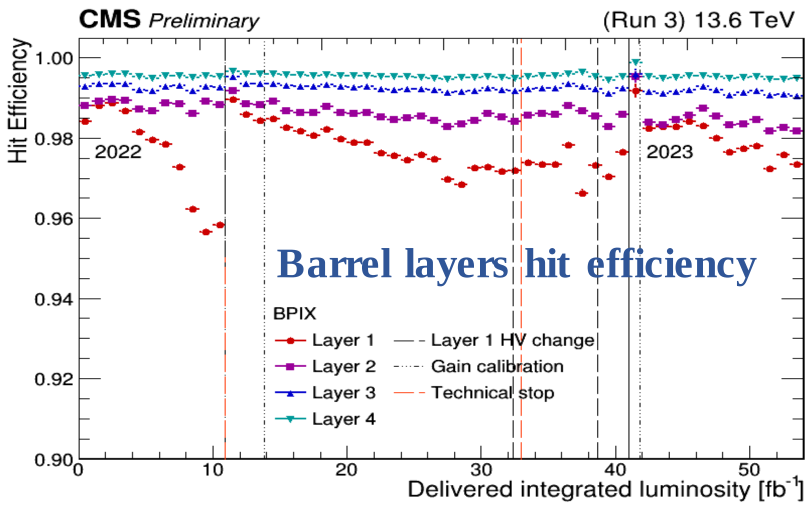
- **Strip detector**
  - Active fraction of Strip detector is stable
  - Performance keeps evolving along expected trend
- **Pixel detector:**
  - Lost 4-hit coverage in about 3% of the barrel area due to a hardware failure in the master clock tree of the outer two layers
  - Change in performance due to radiation damage in layer 1 slowed down as expected, uniform performance throughout 2023
  - Despite the larger average pileup in recent fills, the efficiency remained high
- **Smooth restart coming back from powered-down state over August**

Strip detector signal to noise ratio





Barrel layer 1 transverse residual



Barrel layers hit efficiency

Electromagnetic Calorimeter

- **ECAL ran smoothly up to LHC incident, coping well with demanding trigger rate & pileup**
  - Occasional downtime was caused by frequent SEUs in endcap and preshower, and problems with FEDs, which were promptly addressed

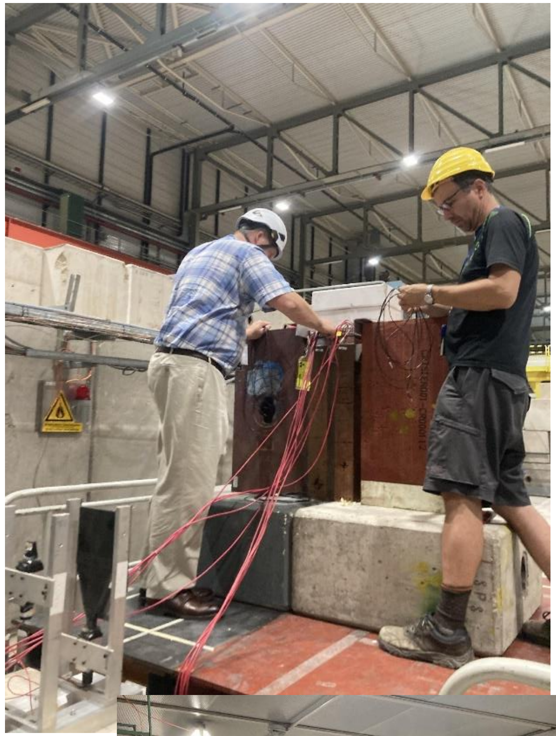
- **ECAL calibration campaign is on-going with an automated workflow**
  - Automation ran smoothly in 2022 and continues to operate well in 2023, with added workflows

- **Preparations for heavy ion running underway in collaboration with CMS heavy ion colleagues**

Hadronic Calorimeter

- **HCAL successful operation ongoing**
  - Detector in best condition, recently performed warm annealing of SiPMs
- **Preparation for the heavy-ion run**
  - ZDC test beam completed in August to study electromagnetic section of detector
  - Successful hardware integration of ZDC into CMS L1 trigger, a crucial step to ensure quality of 2023 HI data
- **Improved operations and quality of data**
  - Faster recovery from SEUs in the SiPM control board (BV upsets), automatic backend electronics resynchronization
  - Reconstruction and calibration: first depth- and η-dependent pulse-shape measurements

H4 test beam

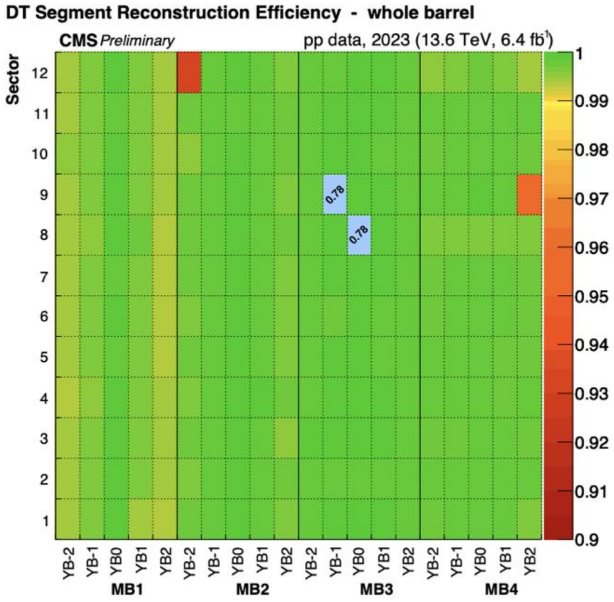


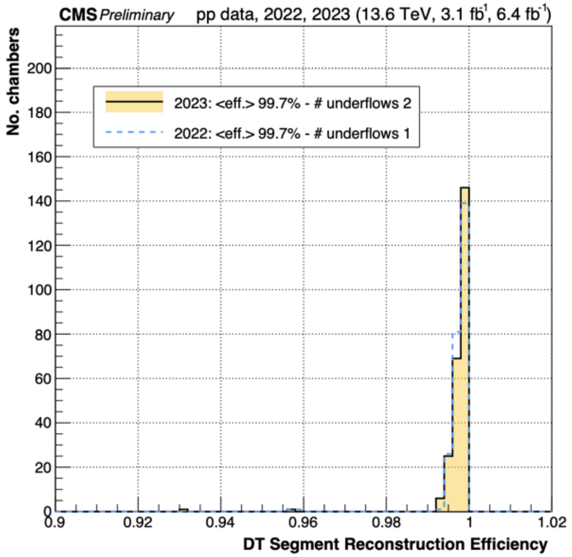
LHC Tunnel

H4 control room

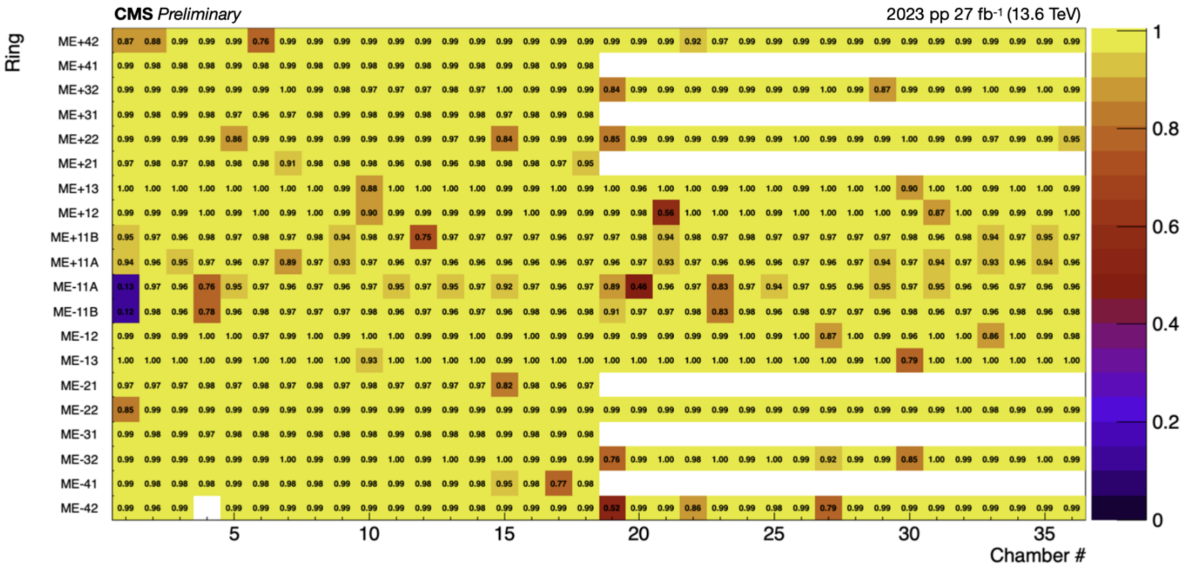
Muon System : DTs and CSCs

DT local reconstruction efficiency (left) is above 99% for all chambers, remaining consistent with 2022 (right)



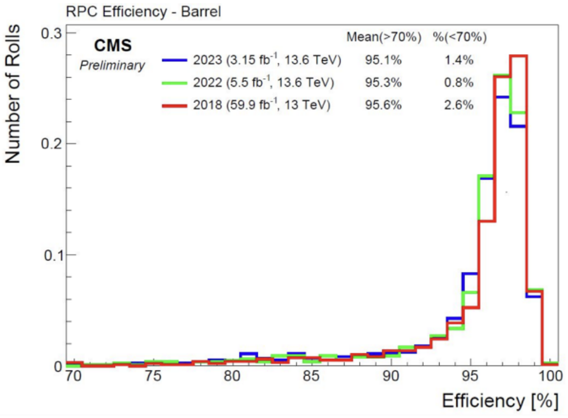


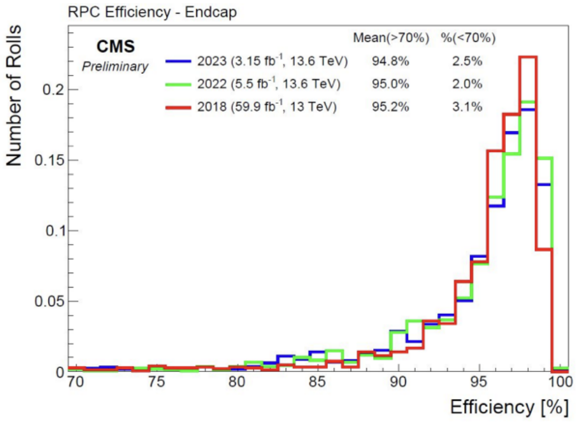
CSC Trigger Primitive Efficiency is close to 100% in more than 98% of the system



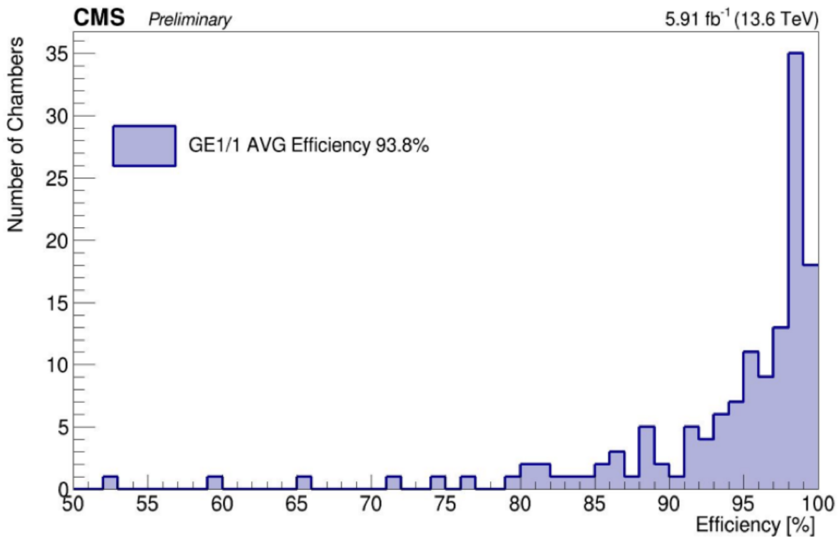
Muon System: RPCs and GEMs

RPC efficiency distribution in the Barrel (left) and Endcap regions (right) is stable compared to 2018 and 2022





- Optimized the **GEM** HV working point chamber by chamber to guarantee high efficiency and minimize discharge rate
- The **GEM** average efficiency for all good chambers is 93.8%. Chambers below 90% underperform due to known problems



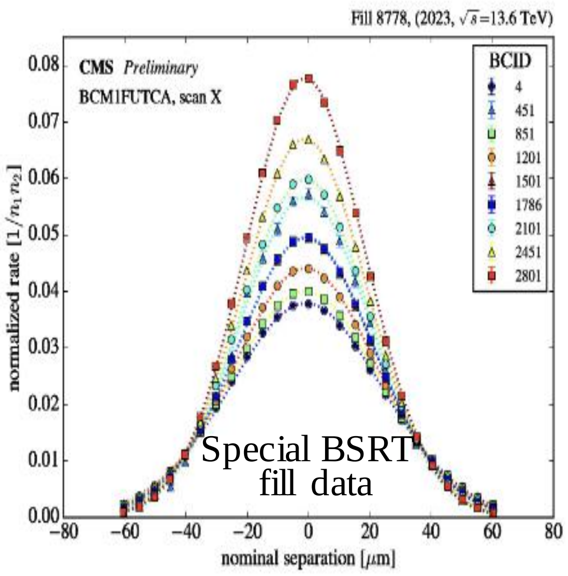
Beam Radiation, Instrumentation and Luminosity

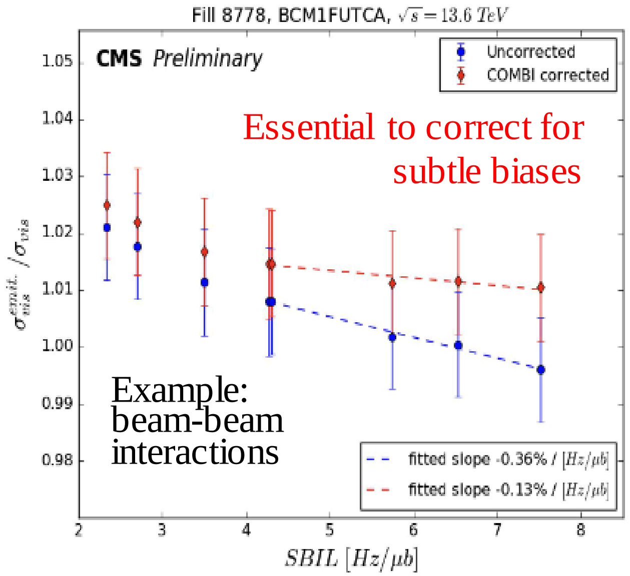
Many studies towards high precision luminosity

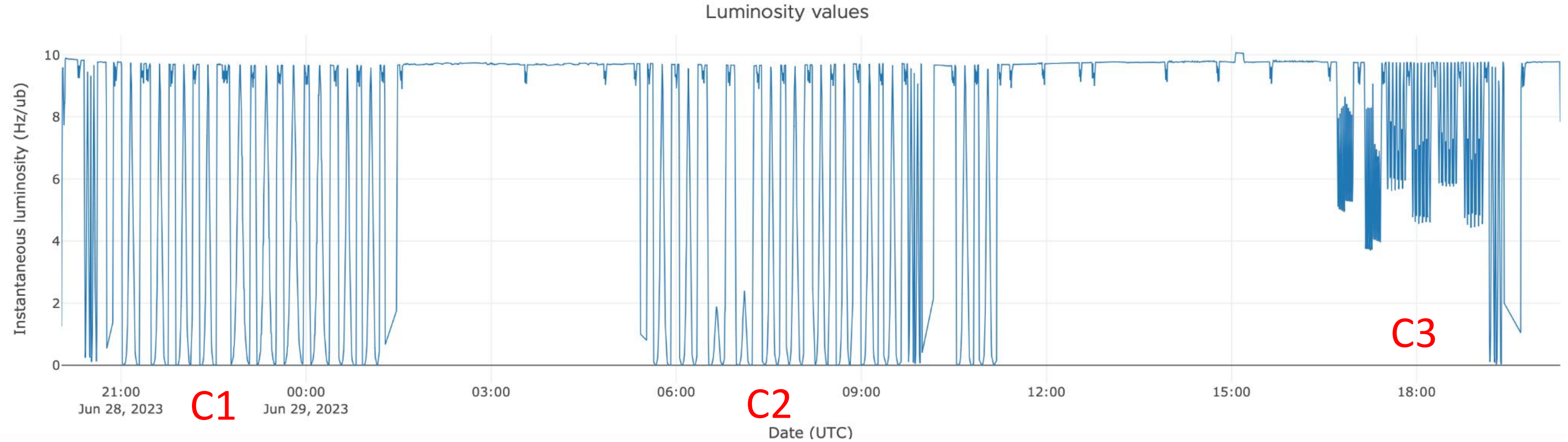
- Measurements performed on absolute linearity per luminometer

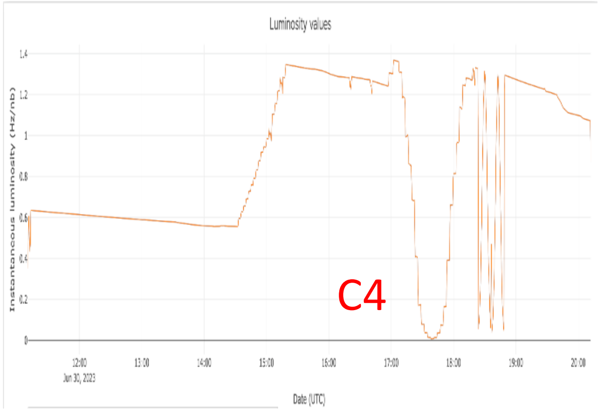
Excellent vdM data taken in 28 June – 4 July, work on the analysis ongoing

- C1&C2 to determine calibration for all 6 independent luminometers
- C3 to calibrate LHC steering magnets
- C4 to measure linearity



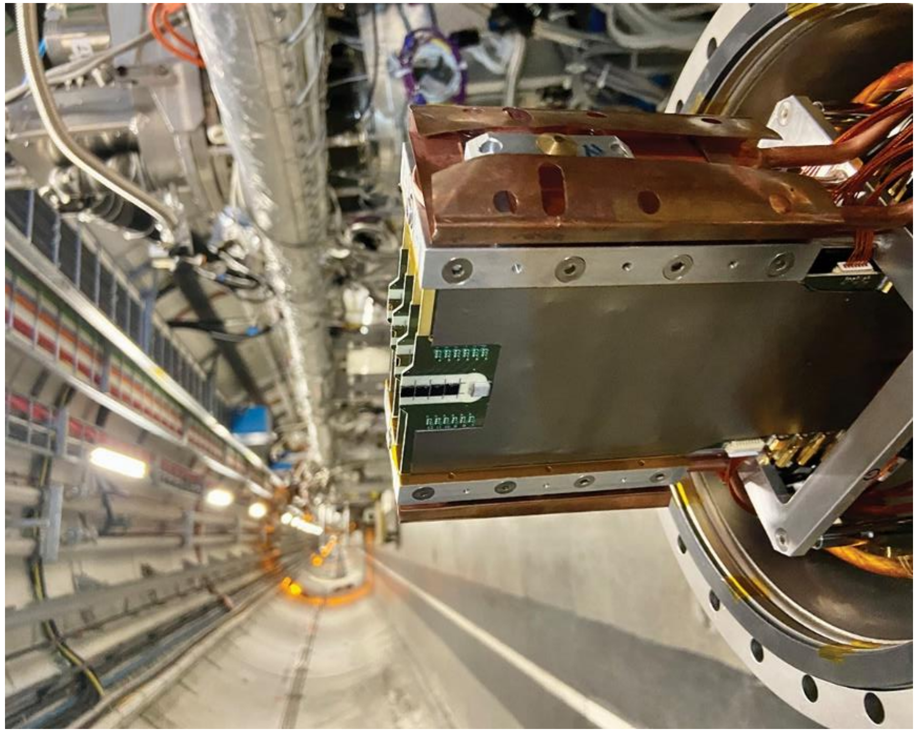






Precision Proton Spectrometer

- Expected correlation verified between proton times and vertex position in the two newly commissioned timing stations
- Improvements in DAQ allowed to sustain L1 trigger rates up to 110-120 kHz with negligible deadtime
- No limitations (e.g. cooling) imposed at maximum luminosities this year
- Roman Pots will not be used for the rest of 2023: pixel detectors will be active only for the high-beta* run, diamond timing detectors already extracted
- Delivering final calibrations for physics analyses with protons



L1 Trigger

Heavy Ion run preparations:

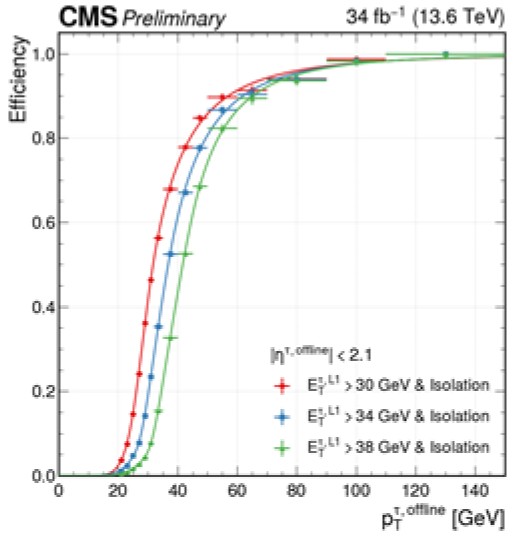
- ZDC is necessary to improve the HI minimum bias trigger
- HI menu containing ZDC-based trigger algorithms is ready
- Total latency of the ZDC trigger being within budget to be verified with collisions

L1 Algo Triggers

Bit	Name	Pre-DT Rate Before Prescale [Hz]	Pre-DT Rate After Prescale [Hz]	Post-DT Rate [Hz]
511	L1_ZDC512_OR	11245.50	112.46	112.28
510	L1_ZDC256_OR	11246.44	112.46	112.29
509	L1_ZDC0_OR	11620.26	116.20	115.98
508	L1_ZDC512_AND	11238.38	112.38	112.21
507	L1_ZDC256_AND	11244.87	112.45	112.27
506	L1_ZDC0_AND	11245.44	112.45	112.28
505	L1_ZDCM512	11238.38	112.38	112.21
504	L1_ZDCM256	11244.95	112.45	112.27
503	L1_ZDCM1	11273.89	112.74	112.56
502	L1_ZDCP512	11245.50	112.45	112.28
501	L1_ZDCP256	11246.37	112.46	112.28
500	L1_ZDCP1	11591.81	115.92	115.70

L1T performance in 2023:

- L1T objects have excellent performance improving on 2022 data taking performances: EG/Tau DP-2023-055, Jet/MET DP-2023-054, Muon DP-2023-057, Displaced Muon DP-2023-056
- Several improvements to data quality monitoring: full integration of L1 objects into the DQM data-processing workflow

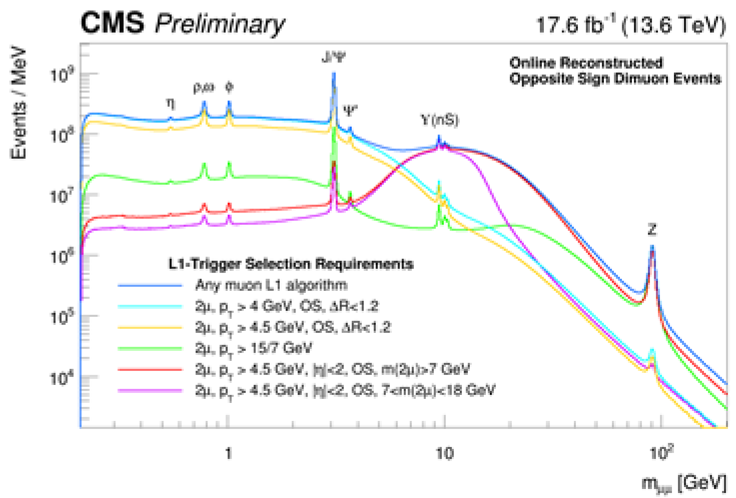


L1 isolated tau efficiency as a function of offline tau p_T

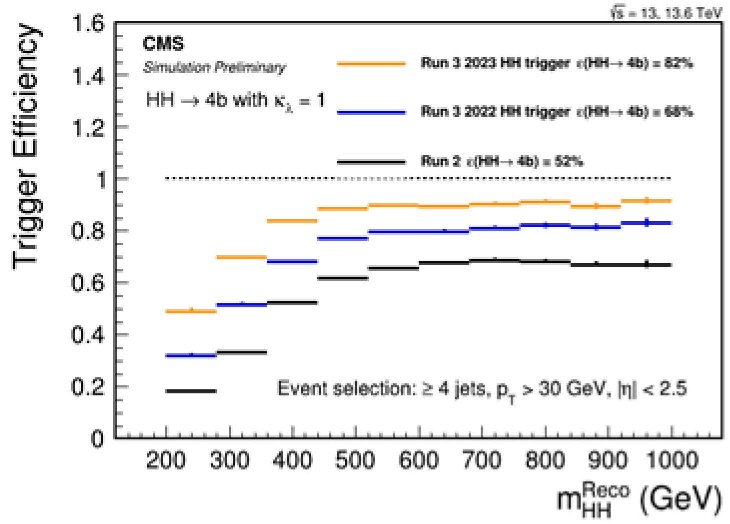
HLT

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

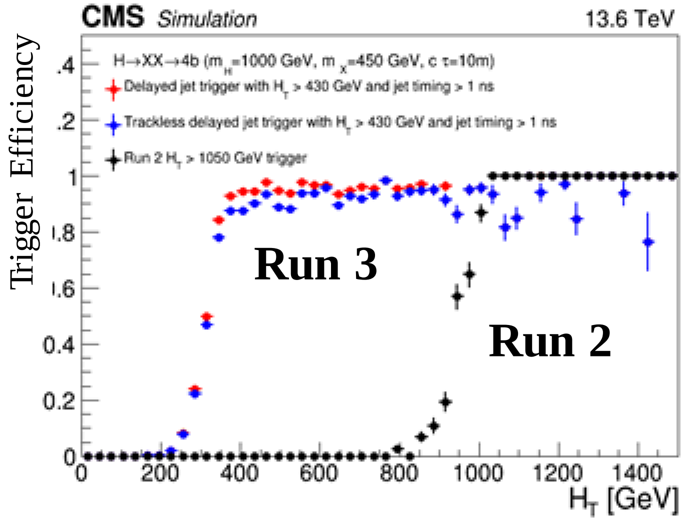
- **Good data taking quality in 2023 from trigger point of view, in challenging conditions (peak pileup ~64)**
  - 2023 target L1 rate 110 kHz, HLT output: ~2.5 kHz prompt, ~3.5 kHz parking, and ~25 kHz scouting
- **Enhancement of Scouting and Parking strategies in Run 3 in general**
  - New parking streams in 2023 dedicated to VBF, LLP, and HH



Muon Scouting: a modified version of the Particle Flow at HLT (based on pixel-only tracks) with pixel tracking on GPU allowed a higher L1 input rate



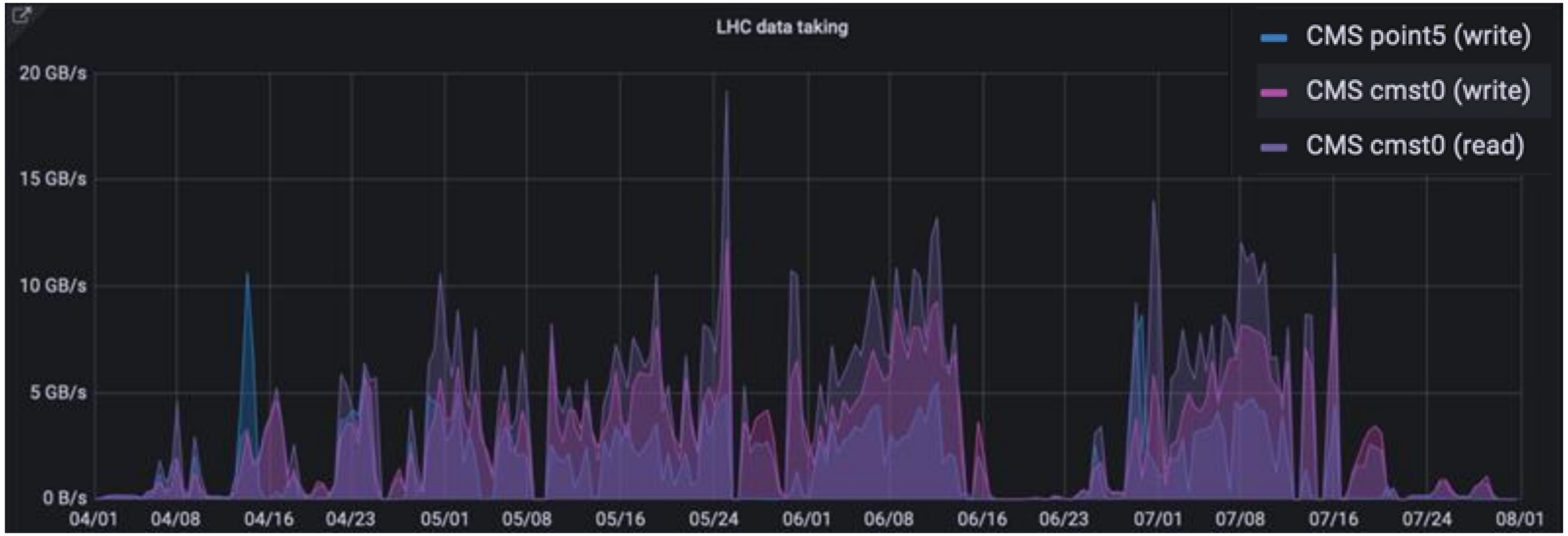
Better performance of ParticleNet tagging and lowered H_T cut (360 GeV to 280 GeV) at the L1 trigger lead to a higher trigger efficiency on the full spectrum of the m_{HH}



Delayed jet triggers utilize the ECAL timing information to identify jets produced by the decay of LLPs

Computing

- **Higher instantaneous luminosity than last year**
  - pileup of 62 during the levelling period
- Average input data rate to the Tier-0 of 4.7 GB/s and output of 6.5 GB/s in July before the end of the proton-proton run, **effectively doubling the 2022 rates.**
- By seamlessly extending the processing capacity of the Tier-0 into the Run 2 HLT Cloud resources when needed, CMS was able to promptly reconstruct the ~2.5 kHz rate from the HLT as well as the ~3.5kHz of parking data streams.
- Successfully (re)tested prompt reconstruction at the Tier-1's serving as a "safety valve"

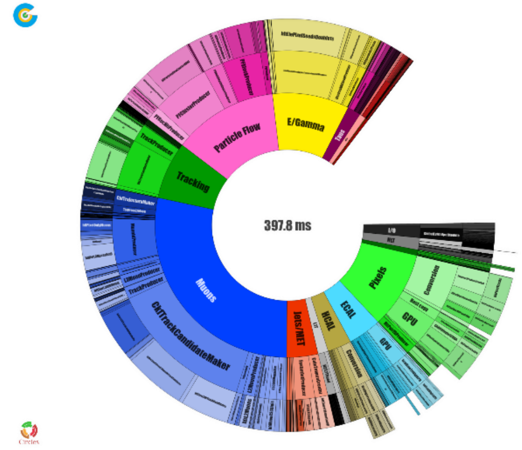


Offline Software

- **CMS worked with the developers of MadGraph to improve the I/O performance of the generator workflow:**
  - Optimized initialization step of the gridpacks by size reduction and by hosting it in read-only CVMFS, still in validation
- **Geant4 11 has been integrated into the currently open software release**
  - Better code performance
  - The physics performance is being assessed
- **Following the experience of online reconstruction at the HLT with offloading up to 40% processing to GPUs, goal is to be able offload 10% of the offline event reconstruction to GPUs by the end of the year**
- **Preparation for an eventual physics validation on ARM architecture, once sufficient resources become available**
  - Nightly integration builds on ARM for many years already

MadGraph

GEANT4
A SIMULATION TOOLKIT



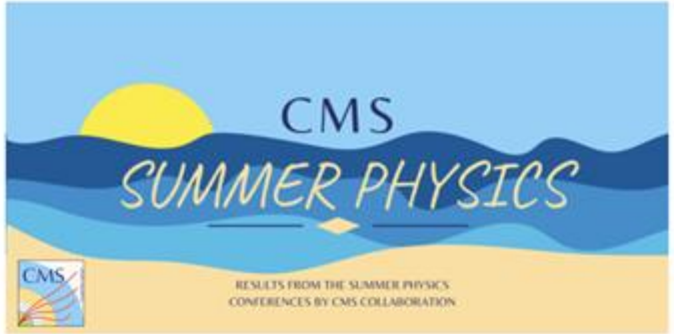
DP-2023-004

arm

Physics results

33 analyses :

- 2IS, 2LP, 5 BOOST, 18 EPS, 4QM



https://cms.cern/news/cms-summer-physics

https://indico.desy.de/event/34916/contributions/142207/

EXO	Search for neutral long-lived particles decaying in the muon system (DT, CSC and combination)	EXO-21-008
EXO	HNL decaying in the Muon System	EXO-22-017
EXO	multijet res using scouting	EXO-21-004
EXO	Leptoquarks (2nd gen)	EXO-21-019
EXO	NP w/ >1 displ. vertex and MET	EXO-22-020
EXO	Search for displaced dimuons - Run3 result **Run3**	EXO-23-014
HIG	Boosted H->tautau	HIG-21-017
HIG	H->bb boosted in VBF/ggF	HIG-21-020
HIG	ttH(bb)	HIG-19-011
HIG	Anomalous couplings in H->WW	HIG-22-008
HIG	Higgs mass/width in H->ZZ->4l	HIG-21-019
HIN	Two Particle Correlations in 13 TeV pp collisions	HIN-21-013
HIN	Net-charge fluctuations in PbPb collisions at 5.02 TeV	HIN-22-005
HIN	Measurement of the groomed jet radius and girth of jets recoiling from isolated photons in pp and PbPb ...	HIN-23-001
HIN	Measurement of f0(980) in pPb collisions at 8 TeV	HIN-20-002
HIN	Pseudorapidity distributions of charged hadrons in PbPb collisions at 5.36 TeV	HIN-23-007
HIN	Extracting the speed of sound in the strongly-interacting matter created in relativistic nuclear collisions	HIN-23-003
HIN	Differential multiplicity studies on B+ Production in pPb collisions at 8.16 TeV	HIN-22-001
HIN	B meson spectra in pp collisions and nuclear modification factors in PbPb at 5.02 TeV	HIN-21-014
MUO	Performance of CMS muon reconstruction in heavy-ion collisions	MUO-21-001
BTV	AK8 jet calibration for boosted X-> bb/cc	BTV-22-001
TOP	Search for extra Higgs bosons through same-sign top-quark production in association with an extra jet	TOP-22-010
SMP	Measurement of energy correlators inside jets	SMP-22-015
SMP	Nonres. exclusive production of charged had. pairs	SMP-21-004
SMP	W/Z at 5 & 13 TeV	SMP-20-004
SMP	Jet azimuth. corr. & alpha_s	SMP-22-005
SMP	Studies of Z-->4l	SMP-19-007
SMP	ss WW VBS (w/ tau)	SMP-22-008
SMP	W/Z at 13.6 TeV **Run3**	SMP-22-017
B2G	BB->bZbH dilepton + tWbH + combination	B2G-20-014
B2G	Single T->tH(bb), resolved all-hadronic channel, 5 jets with 3 b tags	B2G-19-001
BPH	RK	BPH-22-005
BPH	RJPsi leptonic	BPH-22-012

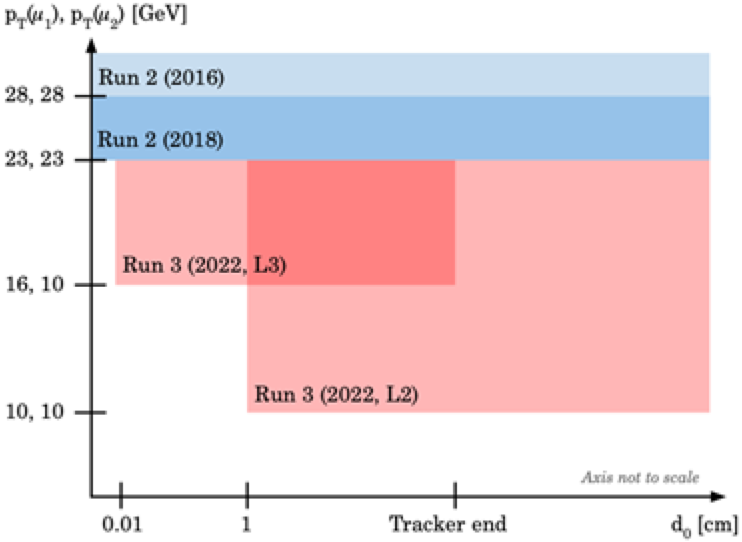
Search for Long Lived Particles

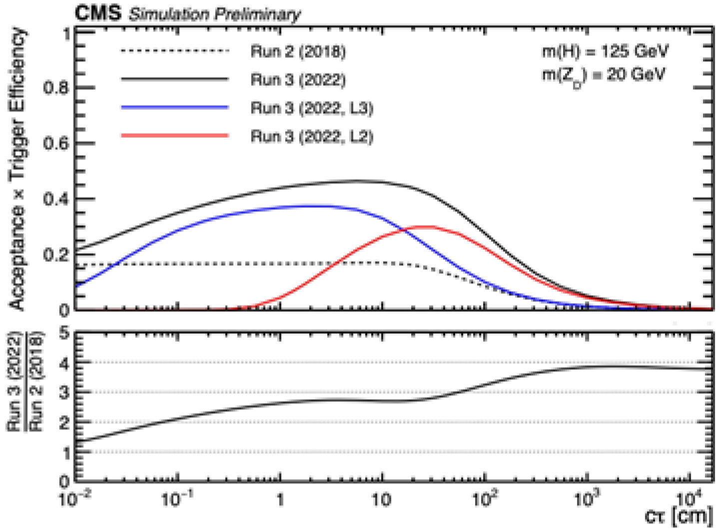
EXO-23-014

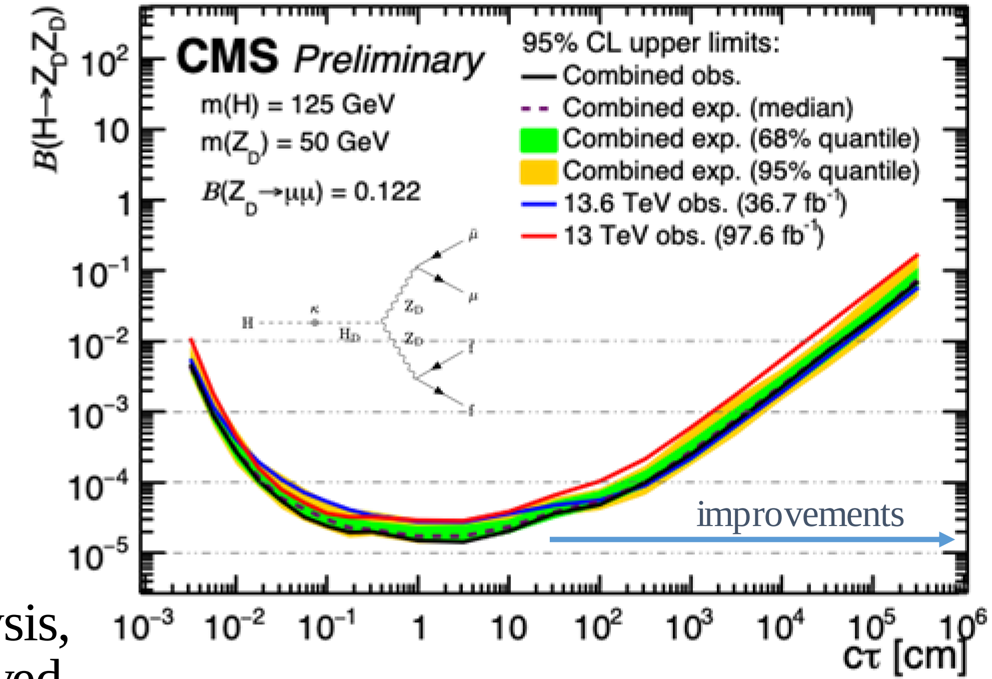
Run3

First Run 3 search for new physics:
inclusive search for long-lived exotic particles decaying to a pair of muons

- Using 36.7 fb^{-1} data taken in 2022, selecting muons originating from a common secondary vertex spatially separated from the primary interaction point by distances ranging from several hundred μm to several meters.







Substantial improvements in efficiency as compared to the Run 2 analysis, particularly at low masses and long lifetimes, mainly because of improved triggers for displaced muons and analysis refinements

Limits set for two benchmark models: the hidden Abelian Higgs model and SUSY

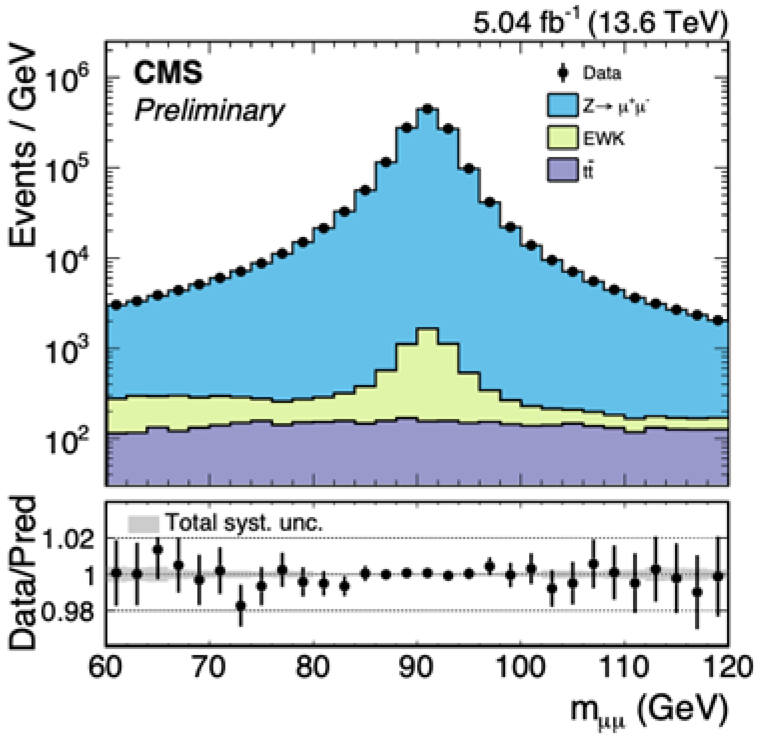
Z boson cross section @ 13.6 TeV

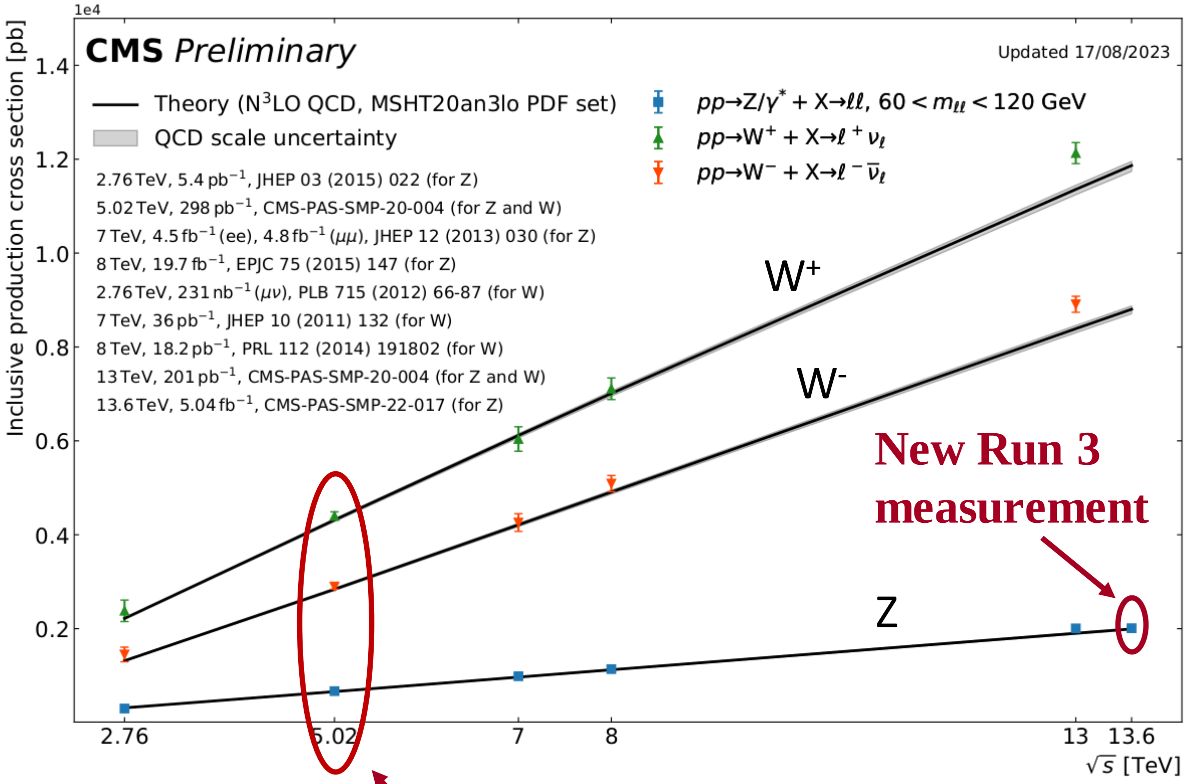
SMP-22-017

Run3

Measurement of the Z boson production cross section in proton-proton collisions at 13.6 TeV

- Using 5.04 fb^{-1} data from 2022 with 2 identified muons





$$(\sigma_{tot}\mathcal{B})_{measured} = (2.010 \pm 0.001(stat) \pm 0.018(syst) \pm 0.046(lumi) \pm 0.007(theo))\ nb,$$
$$(\sigma_{tot}\mathcal{B})_{predicted} = (2.018 \pm 0.012(PDF)^{+0.018}_{-0.023}(scale))\ nb,$$

for the invariant dimuon mass in the range 60 to 120 GeV

Evidence of $f_0(980)$ quark-antiquark composition

via elliptic flow anisotropy measurement

HIN-20-002

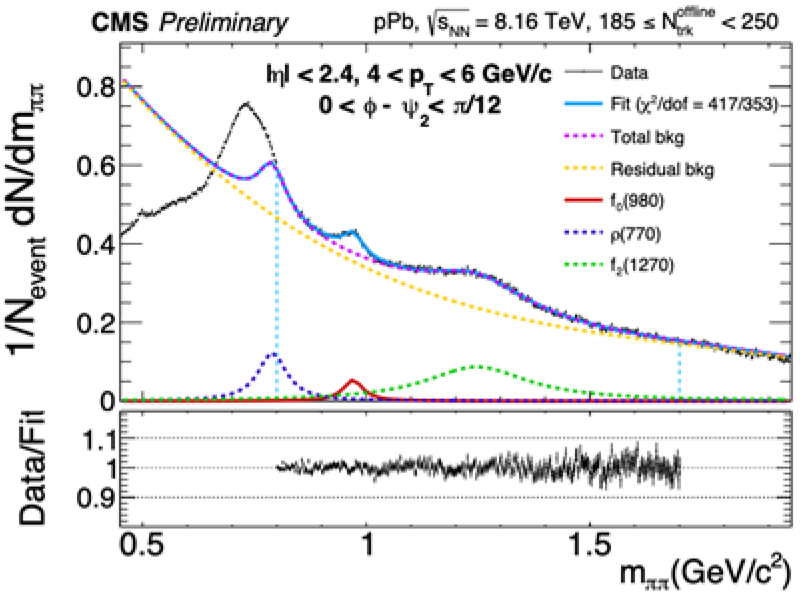
pPb data

- Discovered half century ago, the quark content of the $f_0(980)$ hadron has not been settled till now
- The elliptic flow (**v2**) anisotropy of hadrons formed in heavy ion collisions inherit those of the constituent quarks and scales with the number of constituents

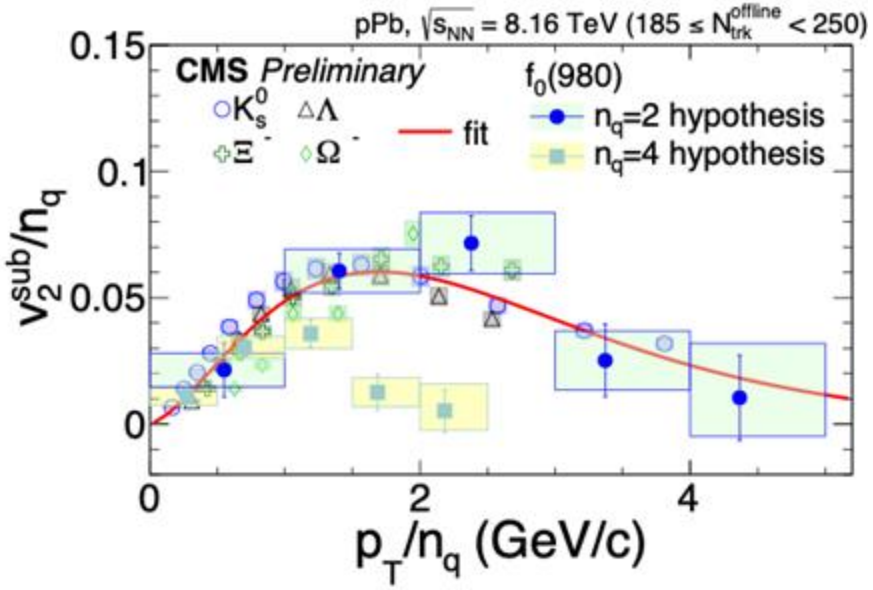
$$\frac{dN_h}{d\phi} \propto \left(\frac{dN_q}{d\phi}\right)^{n_q} \propto \left[1 + \sum_{n=1}^{\infty} 2v_{n,q} p_T^q \cos(n[\phi - \psi_n])\right]^{n_q}$$

$$v_n(p_T) = n_q v_{n,q}(p_T/n_q)$$

$f_0(980)$ is reconstructed via the invariant mass of its main decay channel ($\pi^+\pi^-$)



The number of constituents of $f_0(980)$ is **consistent with 2**

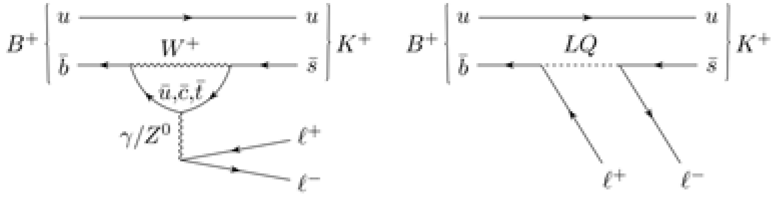


7.7 σ away from being a tetraquark state or KK molecule, or 6.3 σ (3.1 σ) if considering only restricted p_T range up to 8 GeV (6 GeV)

LFUV tests in $B^+ \to K^+ l^+ l^-$

BPH-22-005

- BSM can modify the branching ratio $B^+ \to K^+ \mu^+ \mu^-$ and $B^+ \to K^+ e^+ e^-$



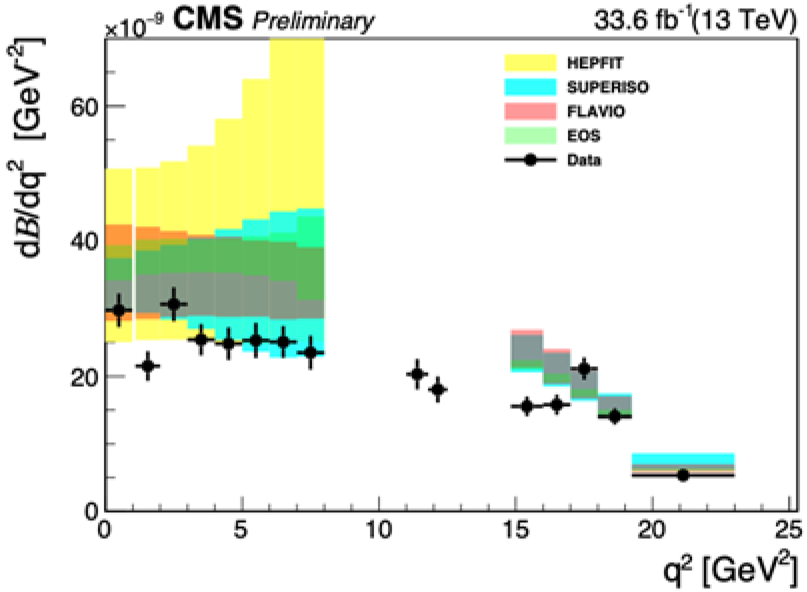
B-parking dataset (expanding CMS Physics Program)

taken with a special trigger and storage strategy that collected ~10^9 unbiased sample of B hadron decays during 2018

<u>Measure</u>:

- branching fraction of the $B^+ \to K^+ \mu^+ \mu^-$ decay in the low-q^2
  - comparable precision to the present world average
- differential BR of the $B^+ \to K^+ \mu^+ \mu^-$ decay in a **full q^2 range** →
- R(K) in the low, $1.1 < q^2 < 6.0$ GeV range:

$$\frac{\mathcal{B}(B^+ \to K^+ \mu^+ \mu^-)(q^2)}{\mathcal{B}(B^+ \to J/\psi(\mu^+ \mu^-) K^+)} \Big/ \frac{\mathcal{B}(B^+ \to K^+ e^+ e^-)(q^2)}{\mathcal{B}(B^+ \to J/\psi(e^+ e^-) K^+)}$$



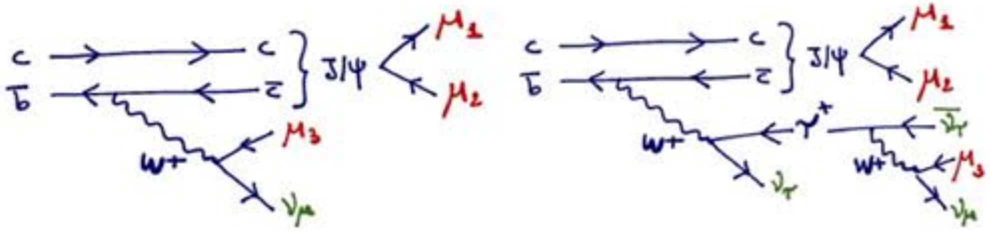
$$R(K) = 0.78^{+0.46}_{-0.23}\,(\text{stat})^{+0.09}_{-0.05}\,(\text{syst}) = 0.78^{+0.47}_{-0.23}$$

→ in agreements with the SM expectation within 1σ

LFUV tests in $B^+_c \to J/\psi\, \tau^+\, \nu_\tau$

BPH-22-012

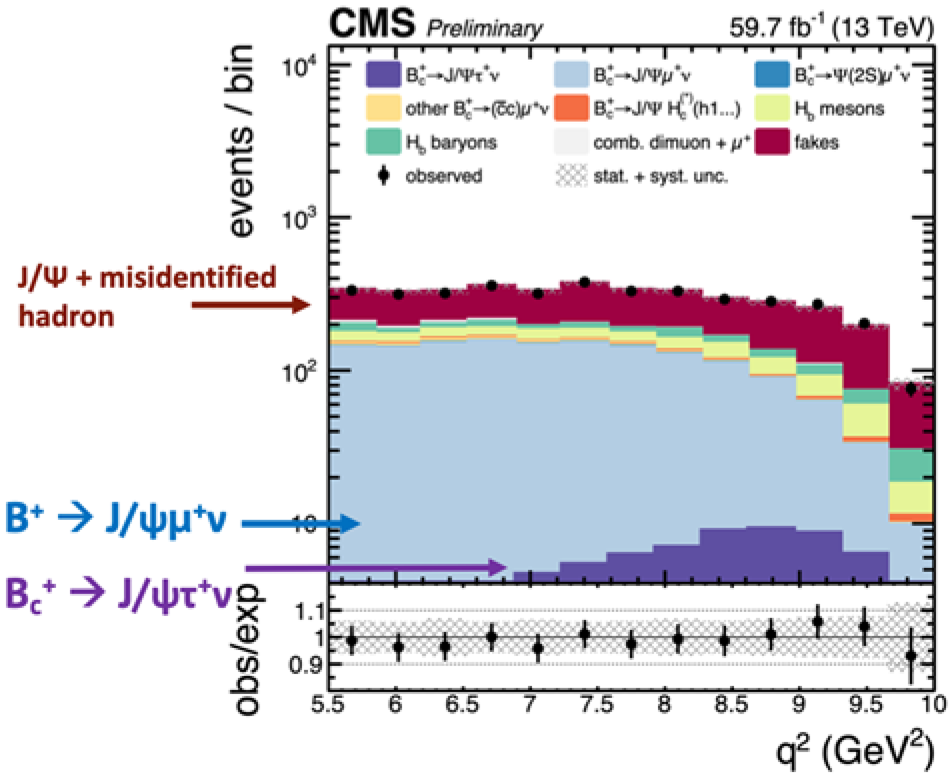
- BSM can modify the branching ratio $B^+_c \to J/\psi\, \tau^+\, \nu_\tau$ and $B^+_c \to J/\psi\, \mu^+\, \nu_\mu$



Measure:

- Ratio of branching fractions: $\mathrm{R}(J/\psi) = \dfrac{\mathcal{B}(\mathrm{B}_c^+ \to J/\psi\, \tau^+ \nu_\tau)}{\mathcal{B}(\mathrm{B}_c^+ \to J/\psi\, \mu^+ \nu_\mu)}$
- Considering only $J/\psi \to \mu^+\mu^-$ decays
  - Similar final state for signal processes (3 μ + νs)

    → disentangle exploiting:
    - large mass difference between τ and μ
    - presence of 3 ν versus 1 ν



Most important fake background: J/Ψ + misidentified hadron

From form factors (strong dependence on q^2)

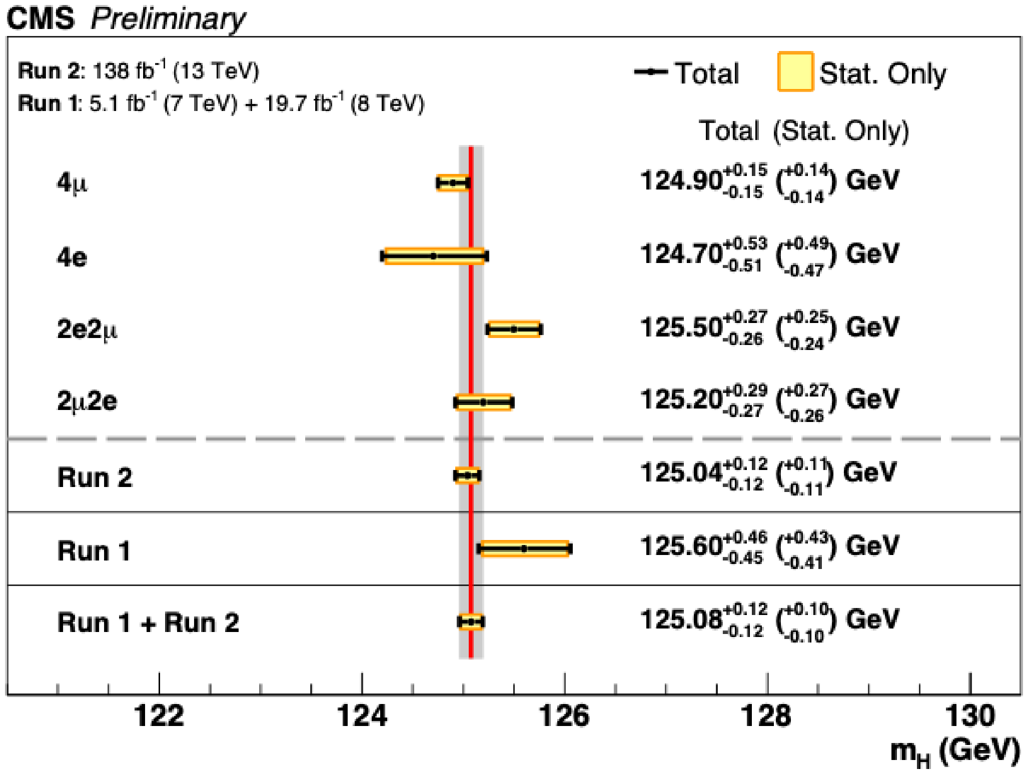
$$\mathrm{R}(J/\psi) = 0.17^{+0.18}_{-0.17}\,(\mathrm{stat.})^{+0.21}_{-0.22}\,(\mathrm{syst.})^{+0.19}_{-0.18}\,(\mathrm{theo.}) = 0.17 \pm 0.33$$

in agreement with the SM expectation within 0.3σ

Higgs boson mass and width measurements

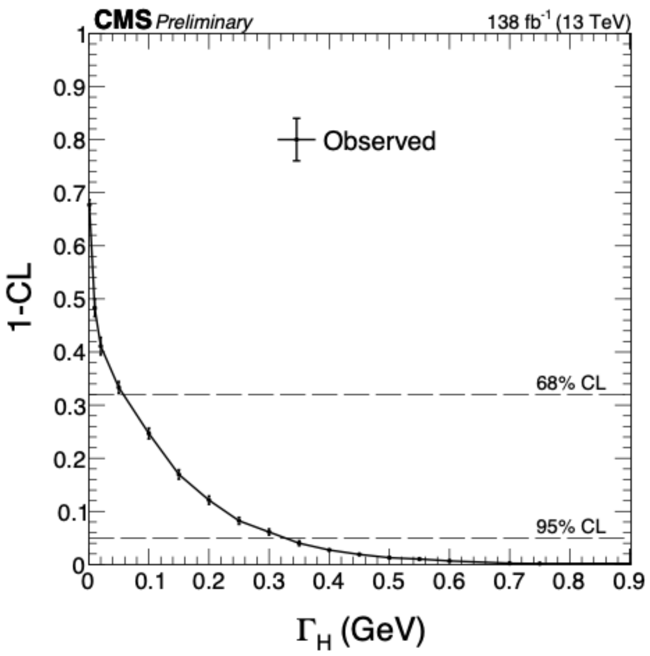
HIG-21-019

H → 4ℓ decay channel using the full Run2 LHC dataset



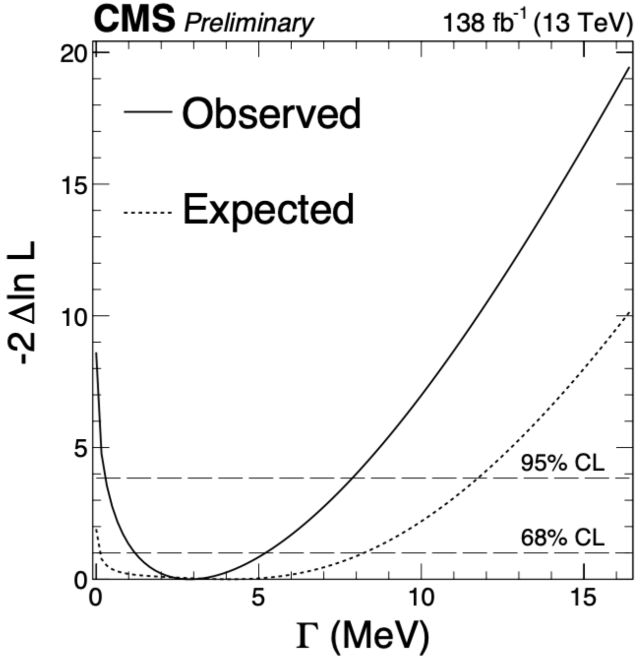
$m_H = 125.08 \pm 0.10\ (\text{stat}) \pm 0.05\ (\text{syst})$ GeV

Most precise single channel measurement to date!



On-shell Higgs width

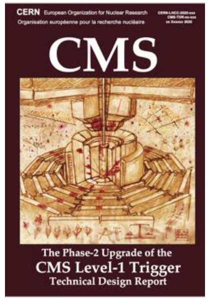
95% CL upper limit:
0.33 GeV obs. (0.75 exp.)



Off-shell Higgs width

Extracted width:
$\Gamma_H = 2.9^{+2.3}_{-1.7}$ MeV
Consistent with SM and confirms previous results

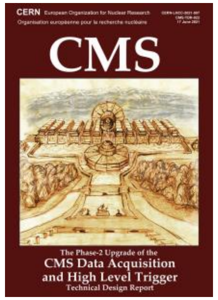
The CMS Phase 2 Upgrade



L1-Trigger

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

- Tracks in L1-Trigger at 40 MHz
- Particle Flow selection
- 750 kHz L1 output
- 40 MHz data scouting



DAQ & High-Level Trigger

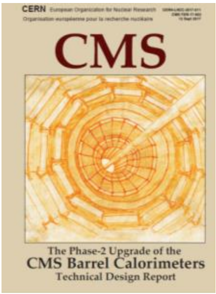
https://cds.cern.ch/record/2759072

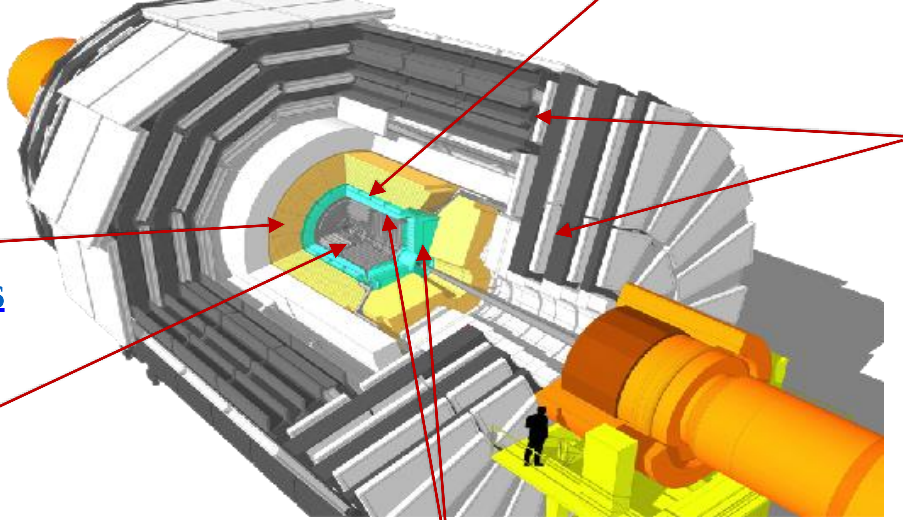
- Full optical readout
- Heterogeneous architecture
- 60 TB/s event network
- 7.5 kHz HLT output

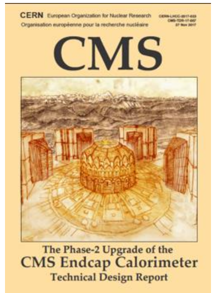
Barrel Calorimeters

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







Calorimeter Endcap

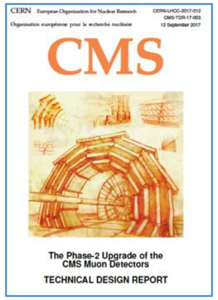
https://cds.cern.ch/record/2293646

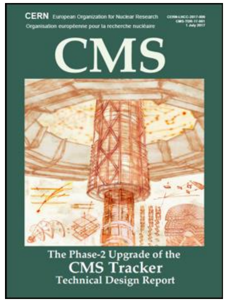
- 3D showers and precise timing
- Si, Scint+SiPM in Pb/W-SS

Muon systems

https://cds.cern.ch/record/2283189

- DT & CSC new FE/BE readout
- RPC back-end electronics
- New GEM/RPC $1.6 < \eta < 2.4$
- Extended coverage to $\eta \simeq 3$

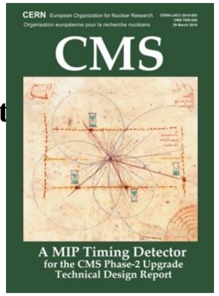




Tracker

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

- Si-Strip and Pixels increased granularit
- Design for tracking in L1-Trigger
- Extended coverage to $\eta \simeq 3.8$



MIP Timing Detector

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

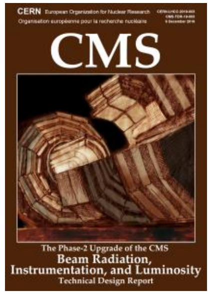
Precision timing with:

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

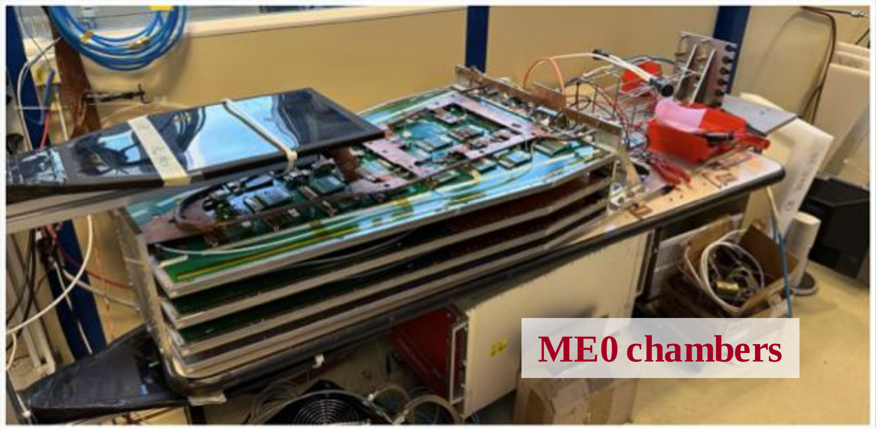
Beam Radiation Instr. and Luminosity

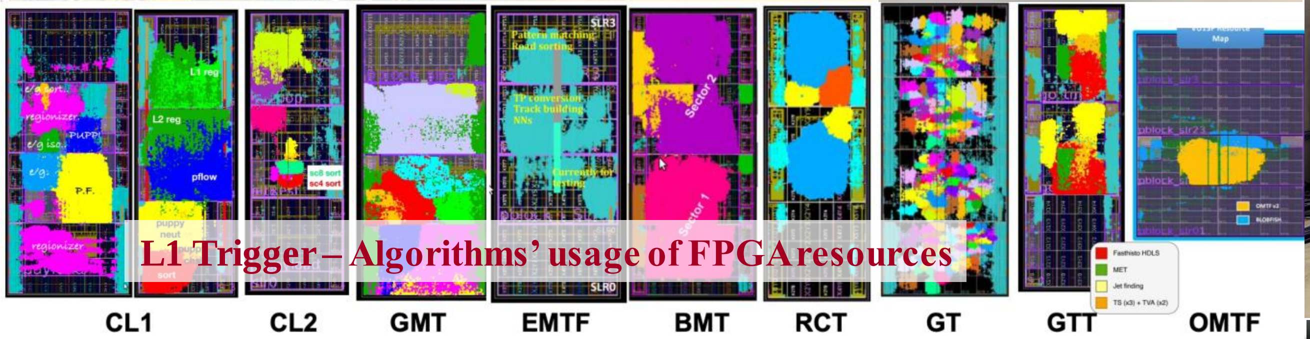
http://cds.cern.ch/record/2759074

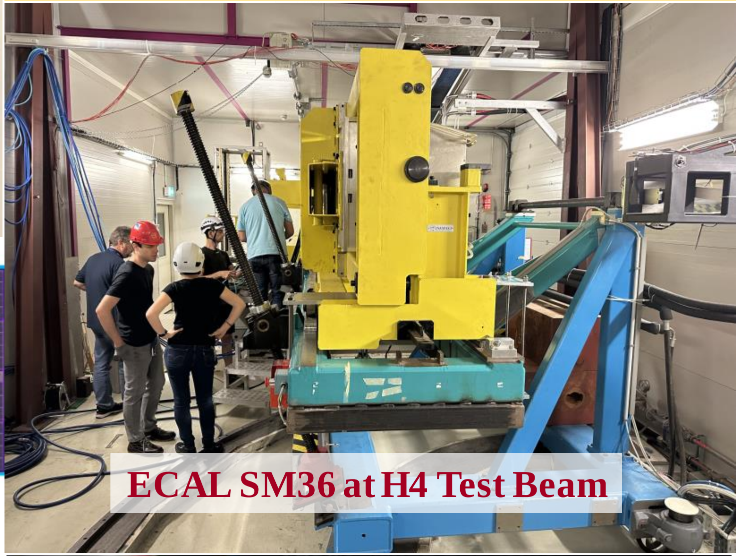
- Beam abort & timing
- Beam-induced background
- Bunch-by-bunch luminosity:
  1% offline, 2% online
- Neutron and mixed-field radiation monitors

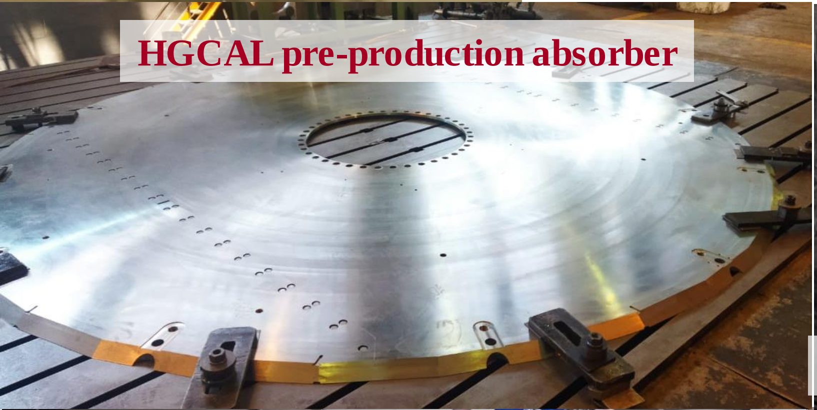


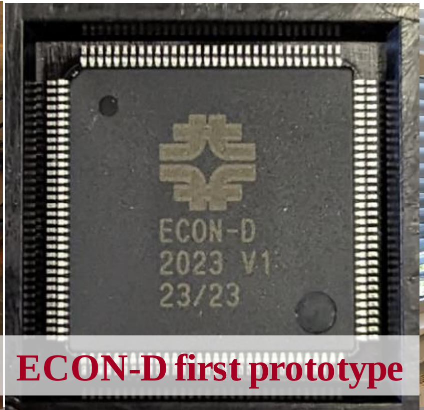
CMS Phase 2 in Pictures

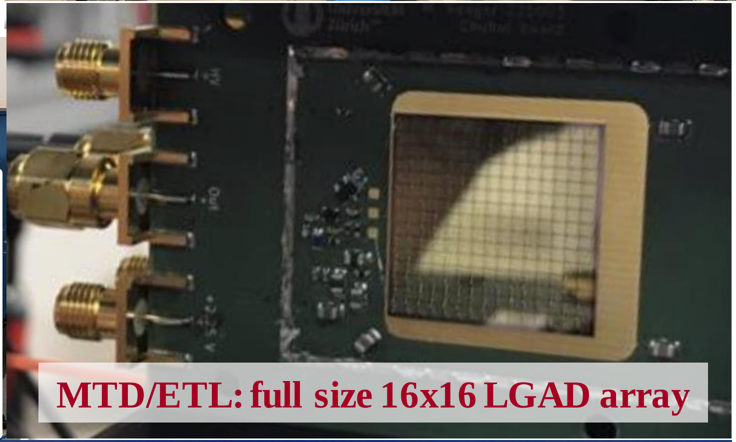


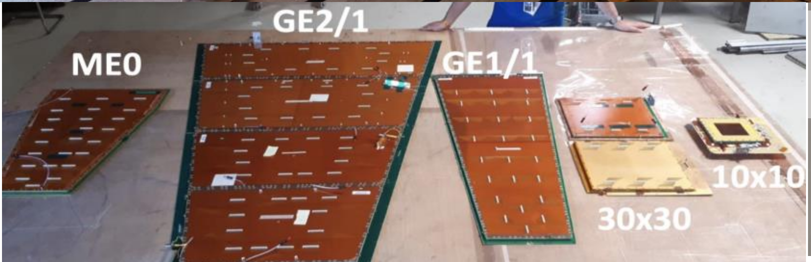


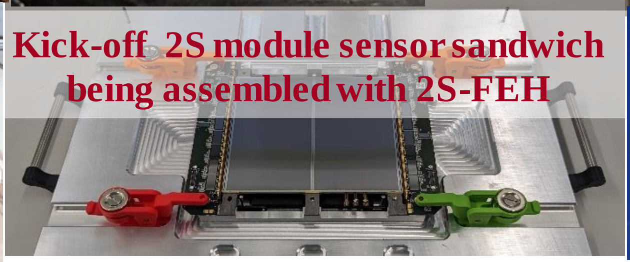


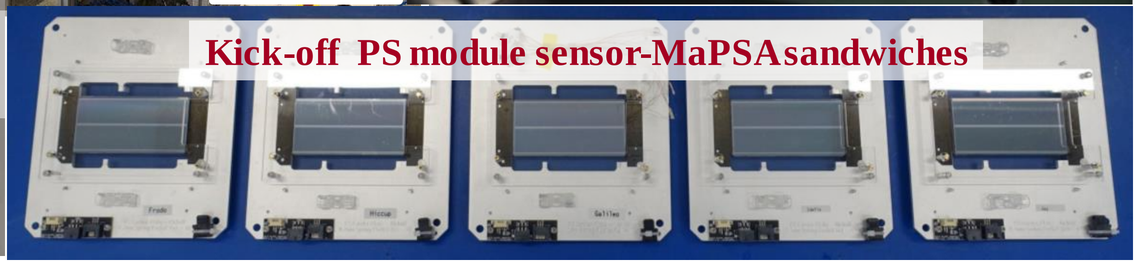




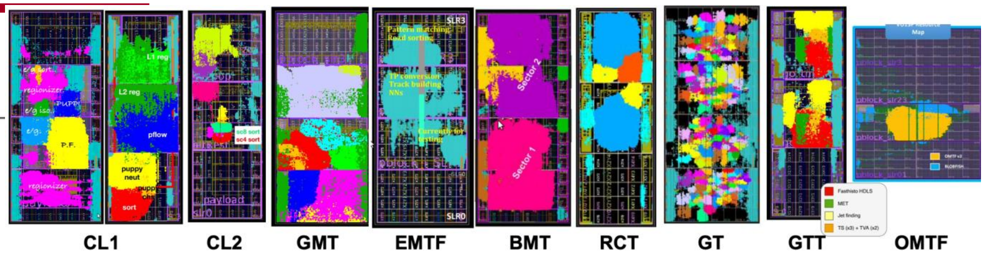


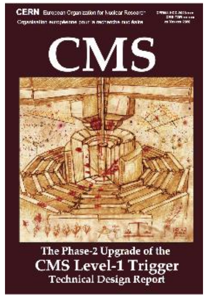


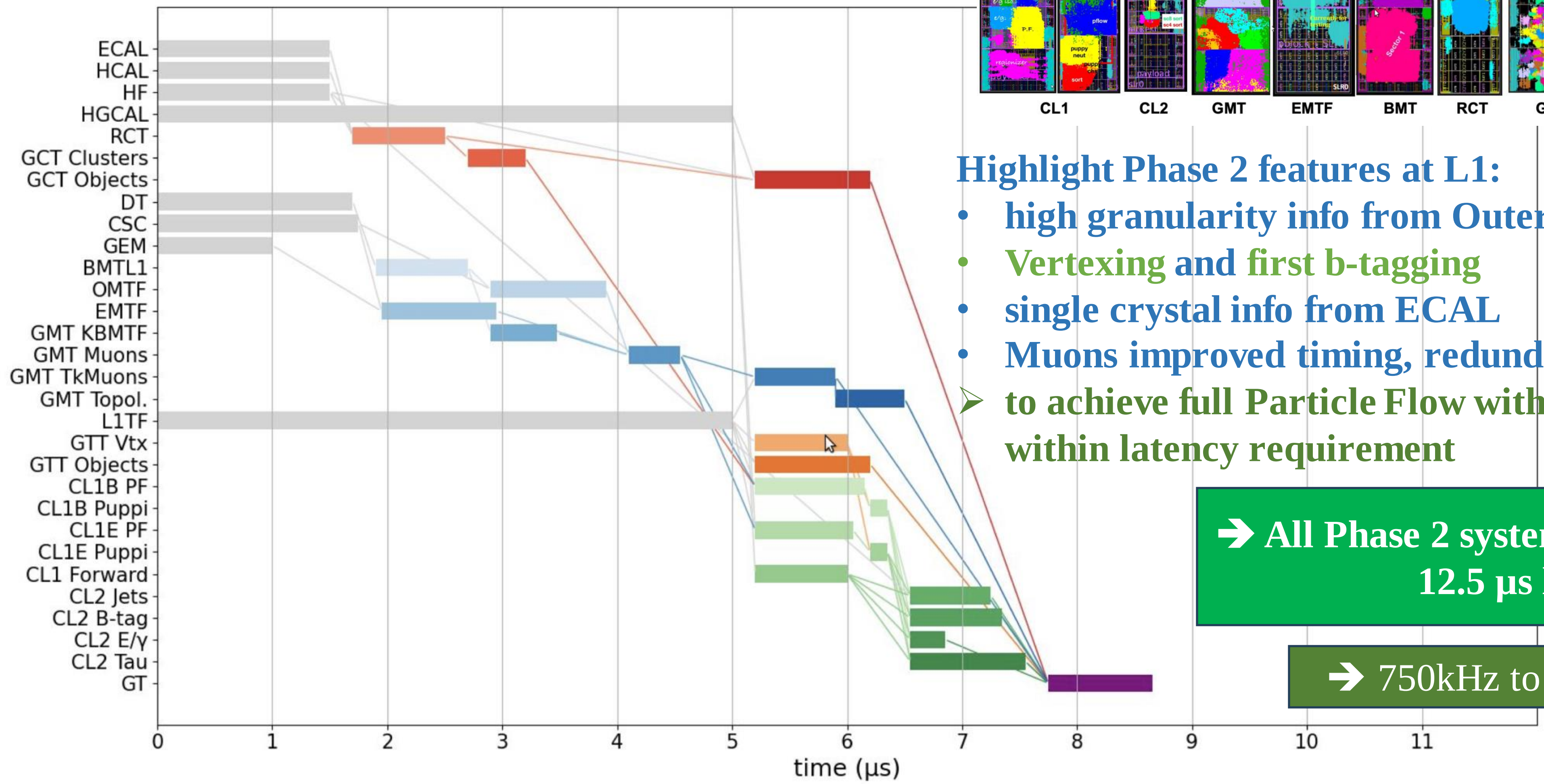




Story of the month: Level-1 Trigger excellent progress







Highlight Phase 2 features at L1:

- **high granularity info from Outer Tracker and HGCAL**
- **Vertexing and first b-tagging**
- **single crystal info from ECAL**
- **Muons improved timing, redundancy and extended coverage**
- ➢ **to achieve full Particle Flow with PU mitigation within latency requirement**

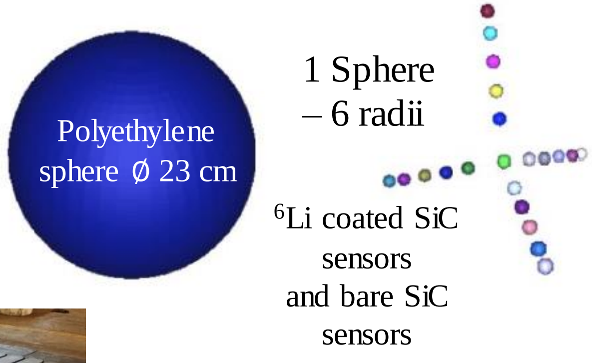
➔ All Phase 2 systems compatible with 12.5 μs latency

➔ 750kHz to High Level Trigger

Level-1 Trigger latency – preliminary, based on algos in **firmware in test systems**

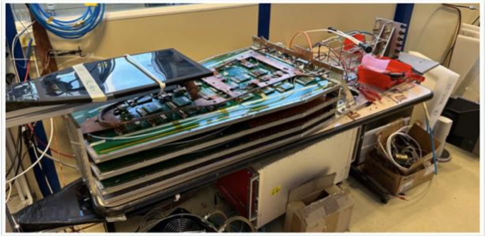
CMS Phase 2 Highlights

- **Successful Fraunhofer project schedule-“speed-up”**
- **BRIL**
  - FBCM FE-ASIC (1st prototype) back from foundry imminently
  - Adapted Neutron Monitor strategy – now Tetra Ball as Bonner Sphere



- **Tracker**
  - OT: hybrid kickoff most of batch received
  - OT: MaPSA pre-production started
  - IT: ready for EDR in October
  - IT: Final RD53 ASIC v12 – timing closure achieved - verification almost finished

- **HGCAL**
  - Silicon Sensors - low density sensors in pre-production - high quality
  - SiPM and Scintillator PRR passed
  - Submitted final FE-ASIC HGROC delayed at companies; ECON ASICs on track
  - CE-H - machining completed of first full, final absorber disk
- **Muons**:
  - First ME0 prototype stack successfully tested with muons and with high background at GIF++



- **MTD**
  - Ready for BTL EDR in September
    - FE-ASICS back; LYSO pre-production; SiPM tendering finished
  - ETL : Test beam verification of LGADs bump-bonded to ETROC2 imminent
- **L1T, BCAL, DAQ progressing smoothly**

FBCM: Fast Beam Condition Monitor
EDR Engineerign Design Review – LHCC Step-III
PRR Procurement Readiness Review
MaPSA MacroPixel Sub-Assembly

Summary and Outlook

- Run 3 data taking was challenging for both the average pileup and sustained operation at record high pileup
  - All detectors as well as trigger and offline reconstruction coped well
  - Pushed the L1 and HLT output rates and the Tier-0 processing rates to unprecedented values

- Building on the experiences from last year, data-taking was smooth and efficient this year

- Improved physics reach by exploiting new triggers in both L1 and at HLT

- Several new results in physics from Run 2 shown in the Summer conferences, still some in the pipeline. Run 3 results also started to appear profiting from the trigger enhancements

- The Phase 2 projects are making good progress moving from prototyping to production

Backup

Tracker

Layers 3 & 4 of BPix- Sector 7 have lost QPLL lock

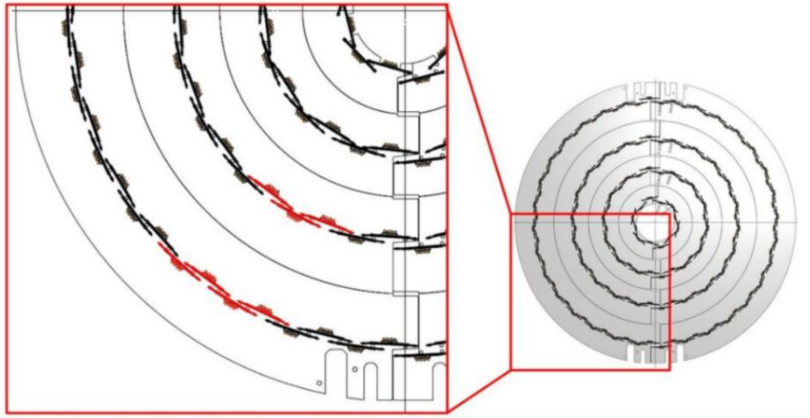
- Occurred shortly before the LHC magnet incident
- Recovery attempts have been unsuccessful
- 27 associated modules have been masked, corresponding to a region spanning ~24º in φ

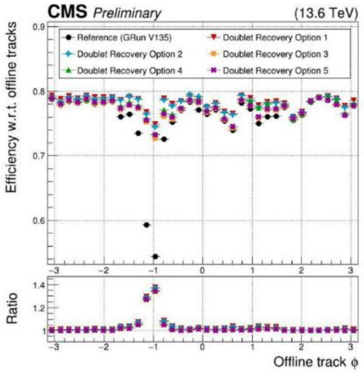
Tracking Impact

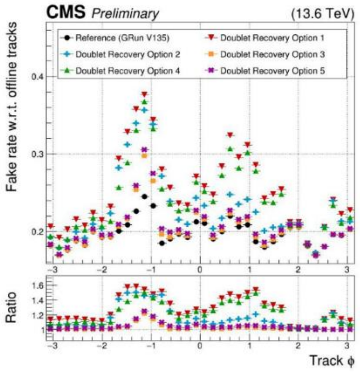
- HLT : mitigation is crucial
    - Efficiency partially recovered via pixel doublets used to seed an additional tracking iteration
    - Fake rate contained by using doublets from which no triplets can be constructed
- Offline : no further mitigation without increasing fake rates
    - Offline efficiency in the φ-region will be comparable to the online, ~80%

We presently do not intend to access

- Thus far no indication of a growing problem
- Access carries inherent risk, requiring the removal of Fpix, BRIL, services, etc.
- Would be a major intervention and would impact CMS plans for YETS
- We will continue to monitor the situation closely

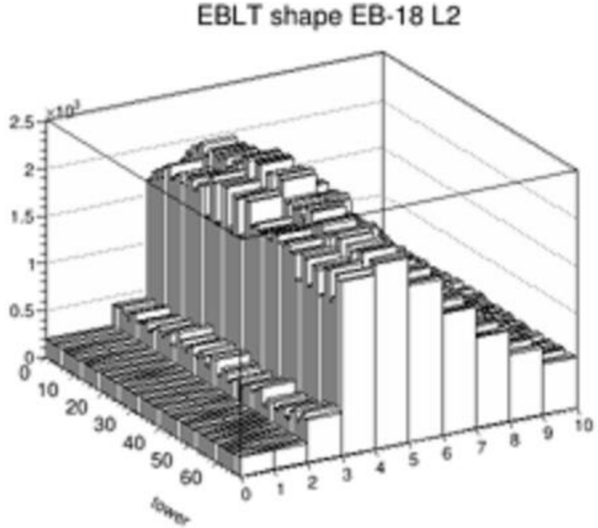


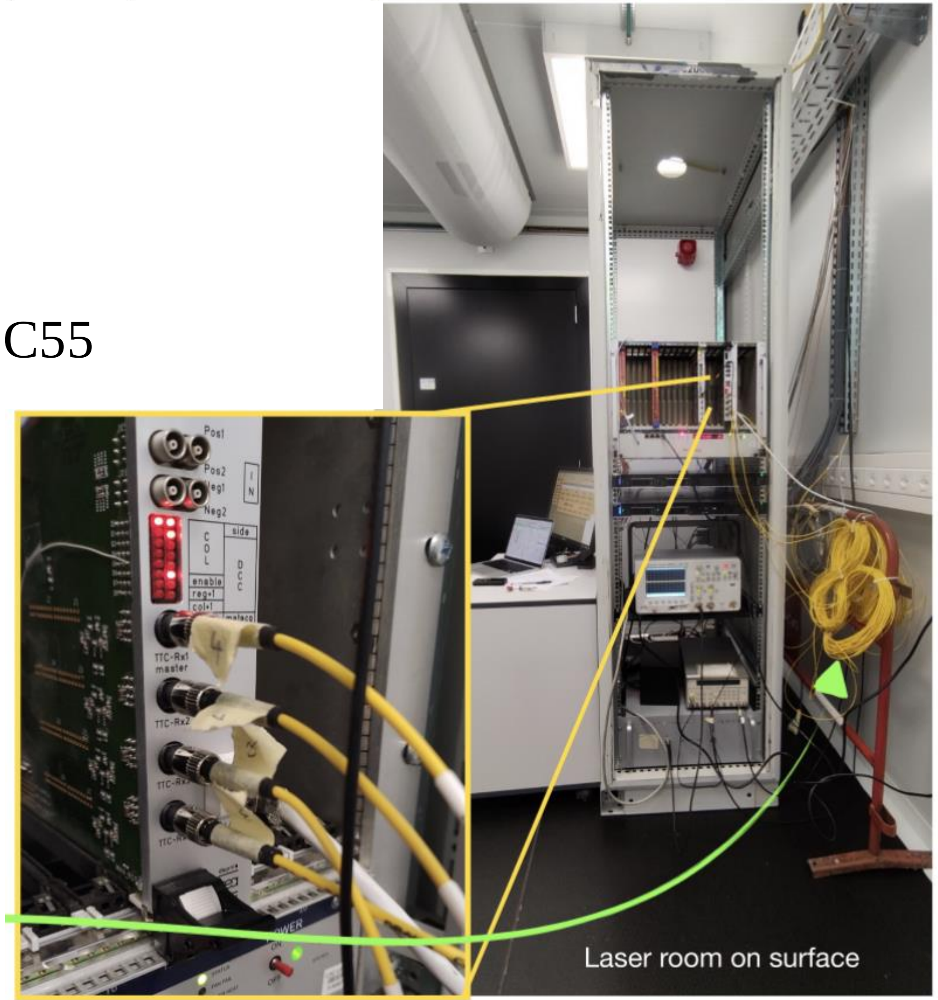




ECAL Laser Lab Relocation

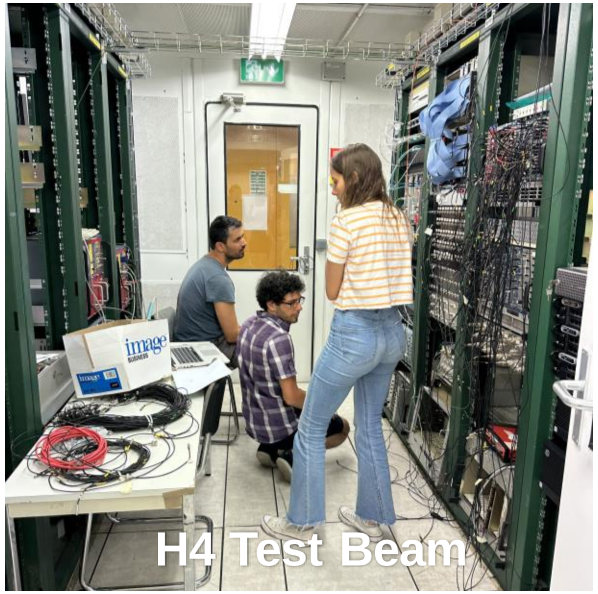
- **Installation of the CO_2 cooling plant for HL-LHC requires relocation of the ECAL laser lab**
- Laser system is essential to precisely monitor radiation damage that affects crystal transparency
- **Pilot Run took place during June Technical Stop**
  - All trigger fibers have been tested and work
  - Laser pulse shape from surface compatible with shape from USC55
  - Identified and addressed issues with temperature and humidity stability in the new lab
- **New, more powerful green laser, is currently being commissioned**
  - Required to compensate for further radiation-induced transparency loss and increased attenuation from the relocation

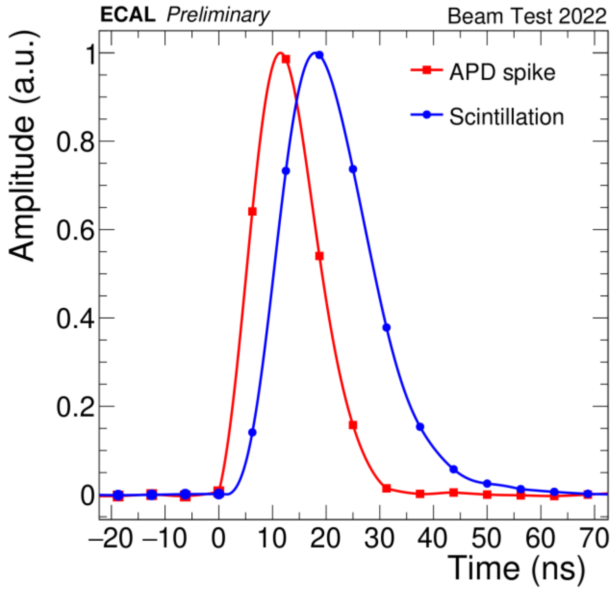




ECAL Upgrade

- **ASICs Status:** CATIA (preamplifier) & LiTE-DTU (digitization, compression, and transmission) have been submitted; CATIA wafers are now at CERN
- **Front-End:** v3.3 passed all functional tests, minor improvements identified for production version
- **Irradiation tests at CERN CHARM Facility (4 – 26 July):** full readout tower irradiated at high fluences to study SEU rates and APD dark current evolution
- **H4 Test Beam Campaign (19 July – 2 Aug):** spare SM36 equipped with new electronics for 9 readout towers (each with 25 channels), including new CATIA and 2 BCPs; tested full readout while collecting data for timing alignment, timing resolution, and energy resolution; analysis of data from 2022 and 2023 test beams on-going

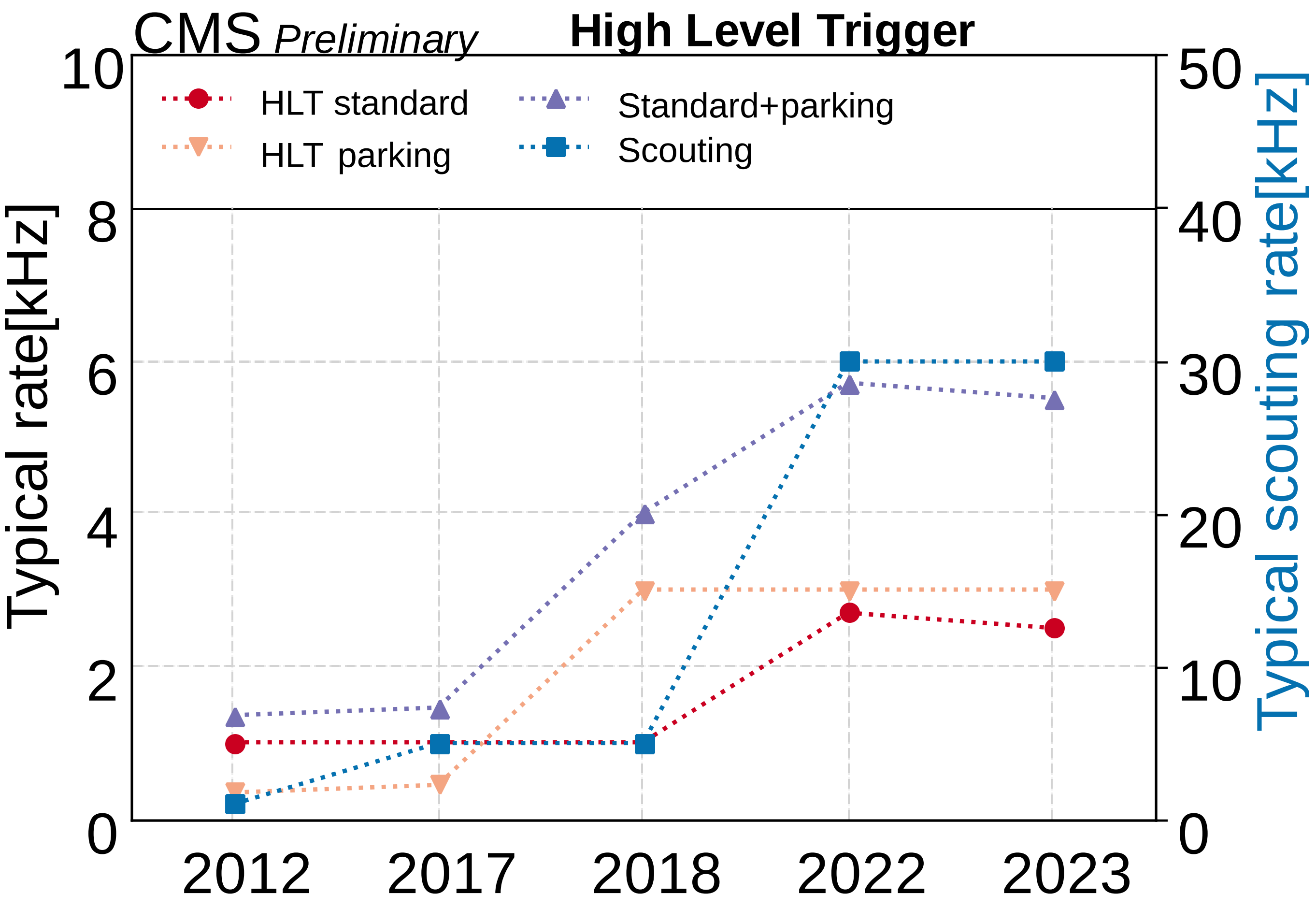




CMS trigger in Run 3

L1 Trigger:

- Enhanced menus for higher PU than Run 3 nominal (50)
- Extended trigger capabilities for specific physics topics: $B_s \to \mu\mu$, $\tau \to 3\mu$, $HH \to 4b$, $W \to 3\pi$, VBF, long-lived particles (with HCAL timing)



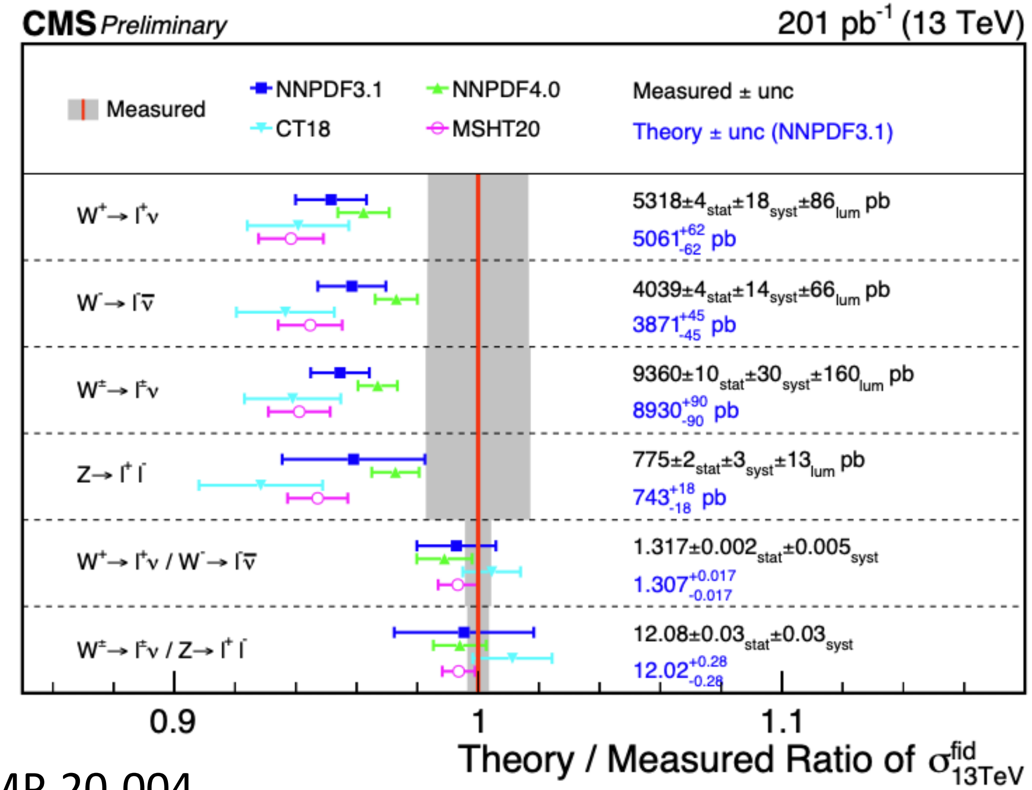
Z boson cross section @ 13.6 TeV

SMP-22-017

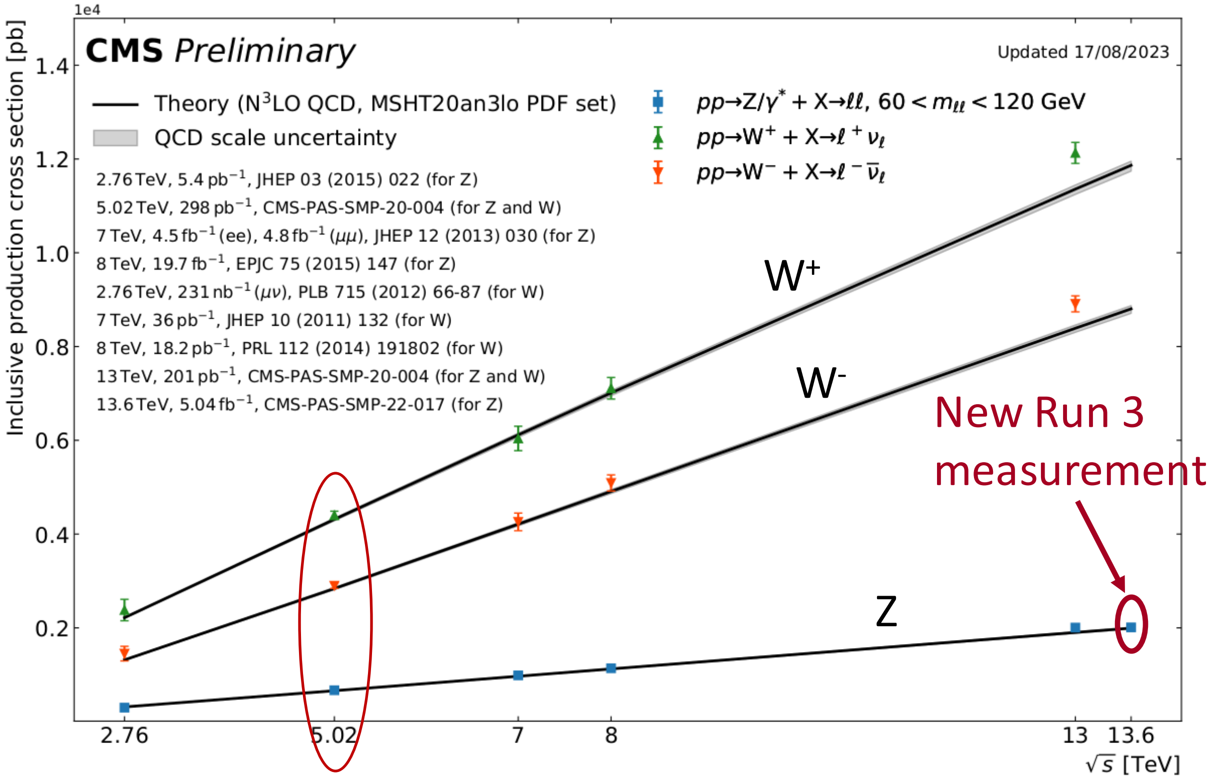
Run3

Measurement of the Z boson production cross section in proton-proton collisions at 13.6 TeV

Figure 5: Comparisons of the fiducial cross sections and cross section ratios between measurements and the theoretical calculations from DYTURBO with different PDF sets at 13 TeV. The uncertainties in the theoretical predictions include the statistical uncertainty, and the PDF, α_s, and renormalization and factorization scale uncertainties. The measured values and theoretical predictions (DYTURBO with NNPDF 3.1 as the example) are also shown in the right part of the plot.



SMP-20-004



New Run 3 measurement

Also new from Summer 23 results