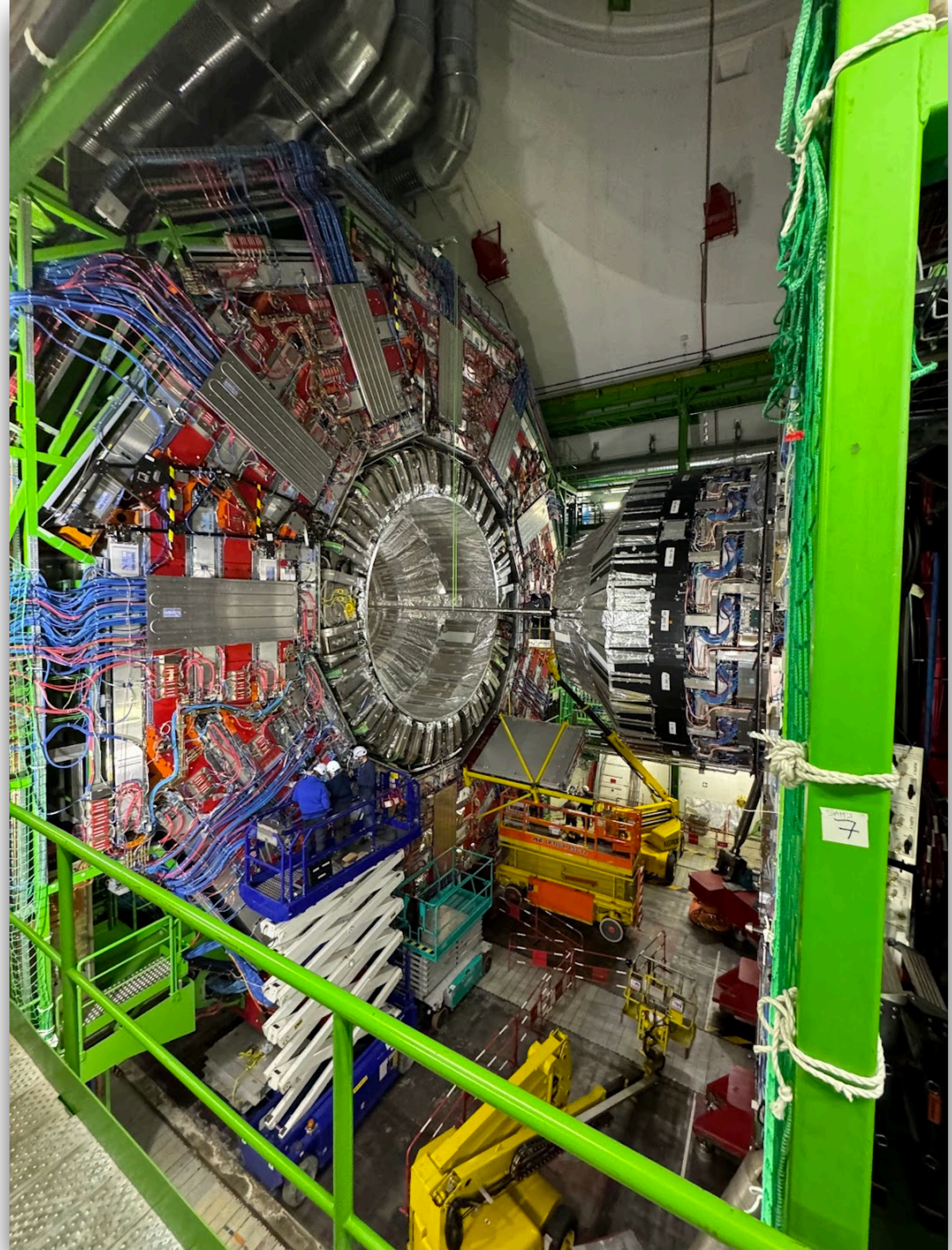
# CMS Report

Giulia Negro
for the CMS Collaboration

156th LHCC Open Session
*29 November 2023*



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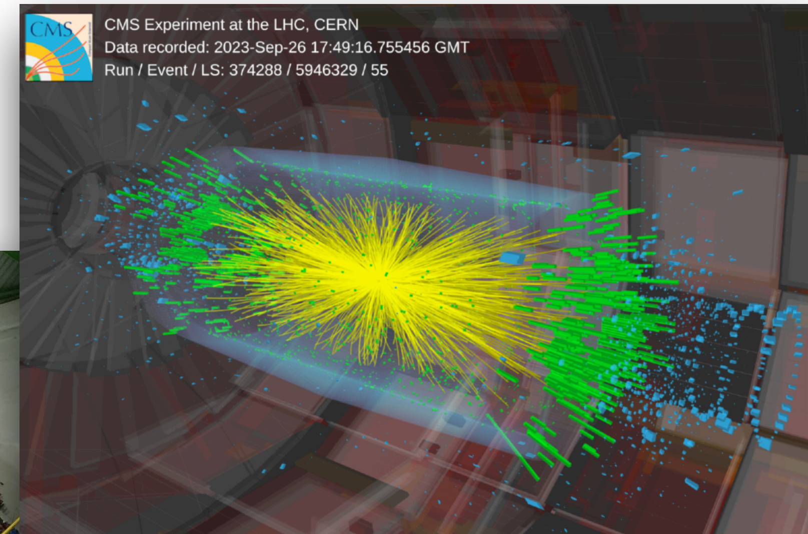
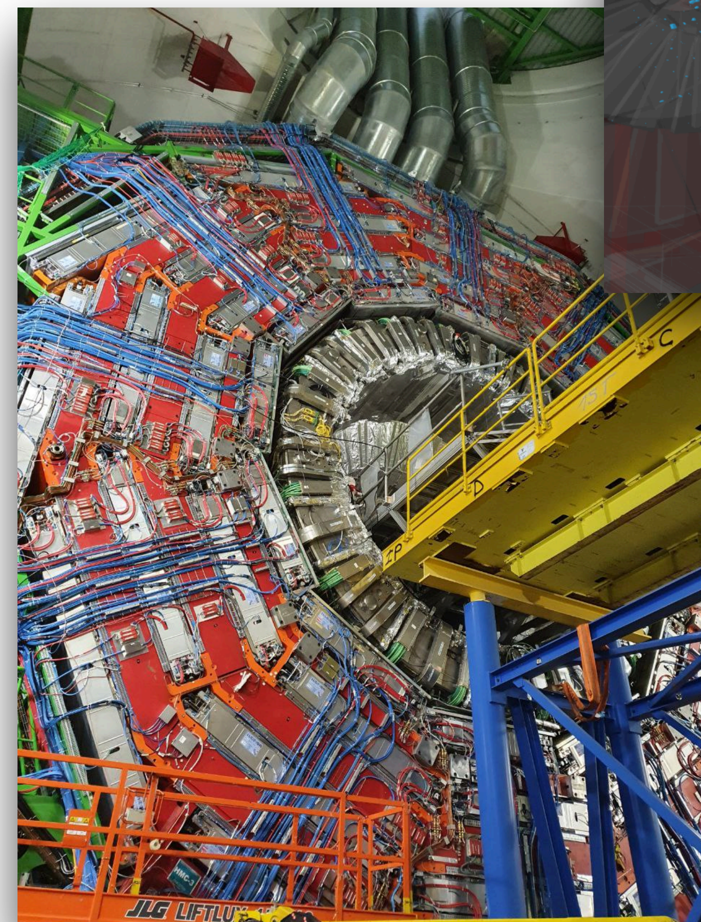
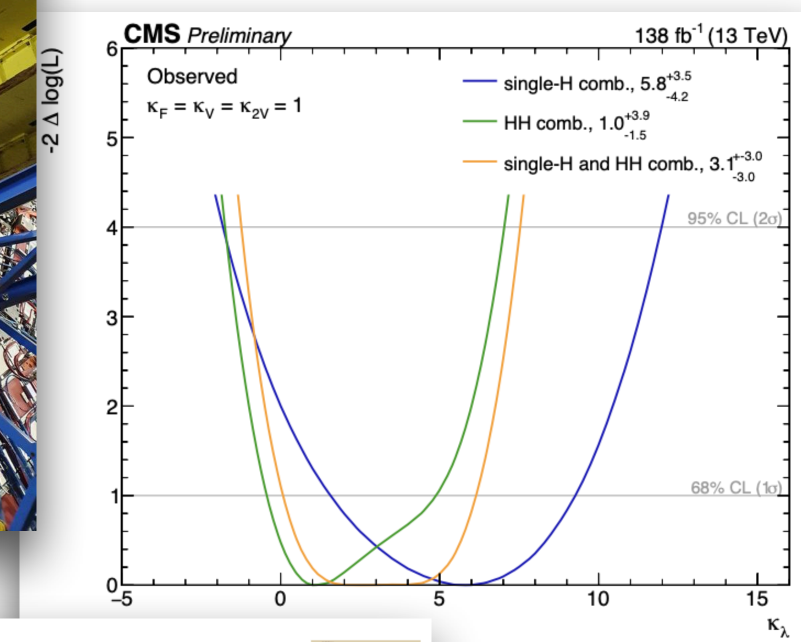
# Overview




Heavy Ion data-taking

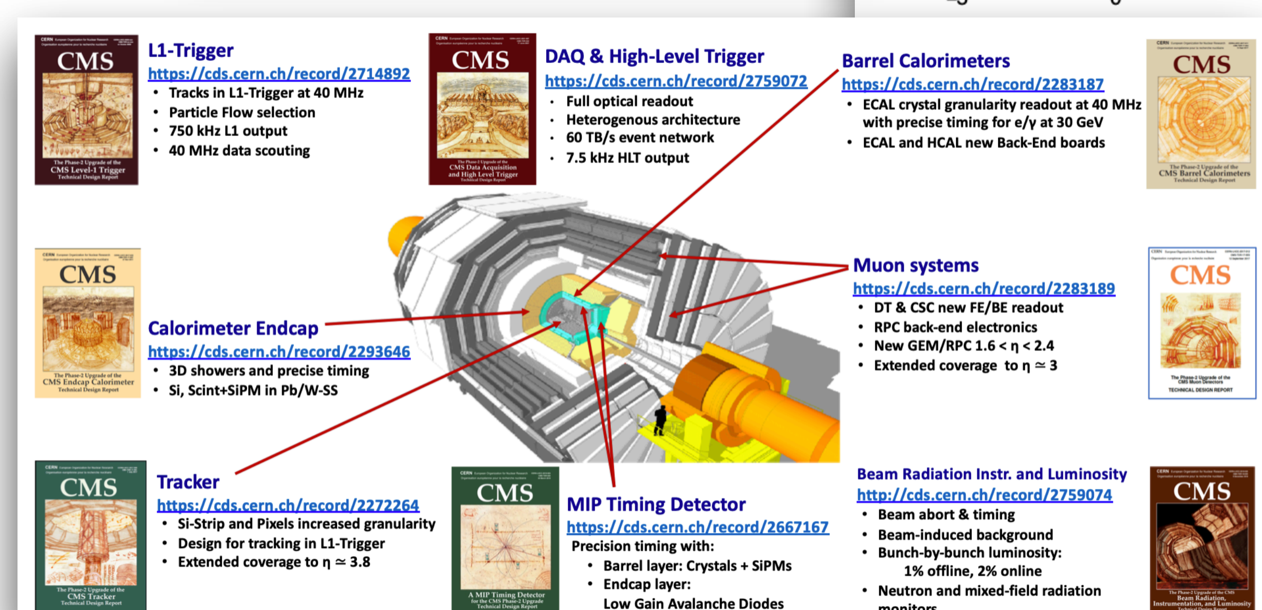
Status of detectors





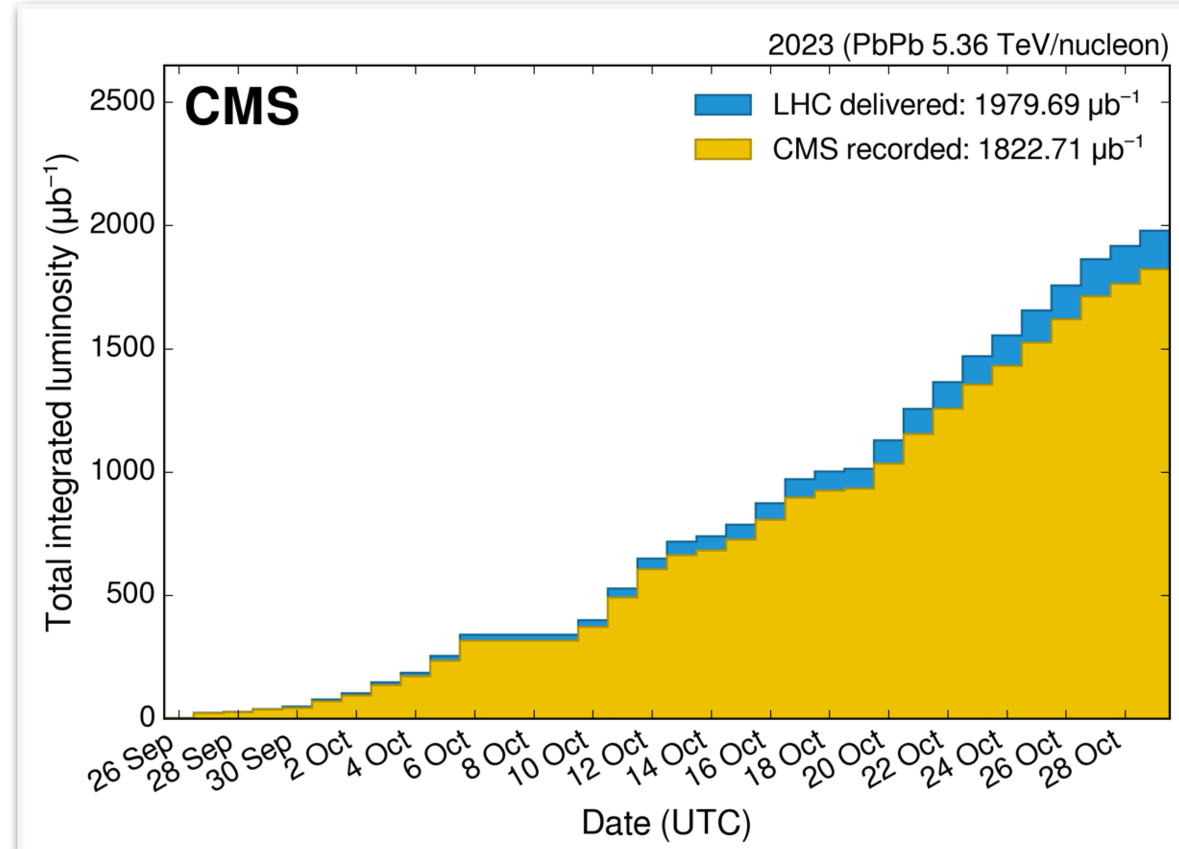

Physics analyses

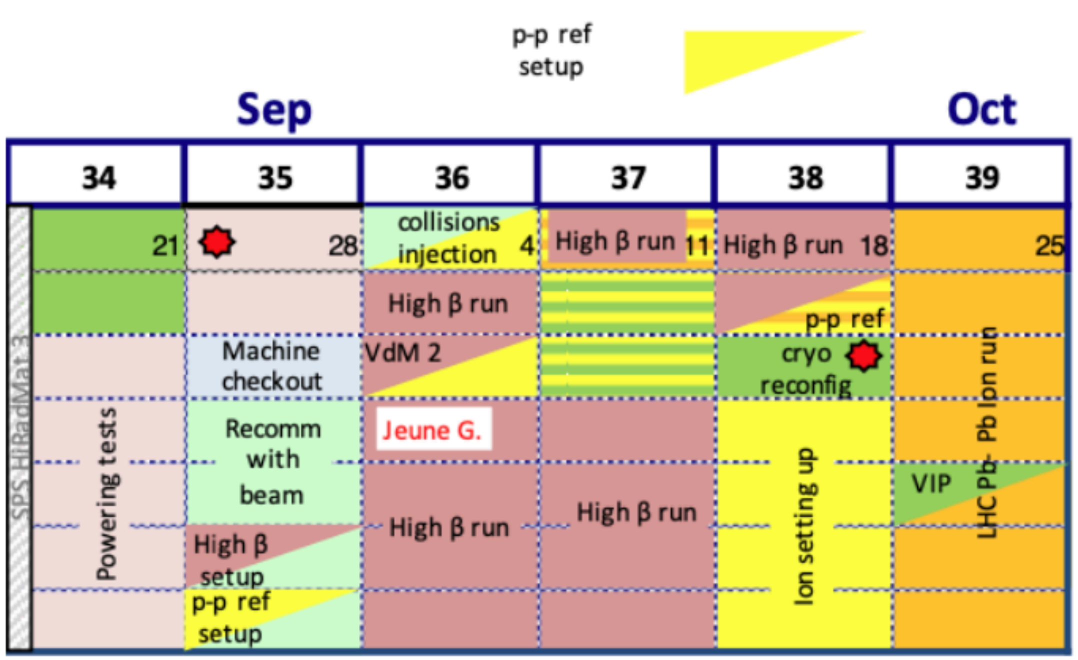
Phase 2 upgrade

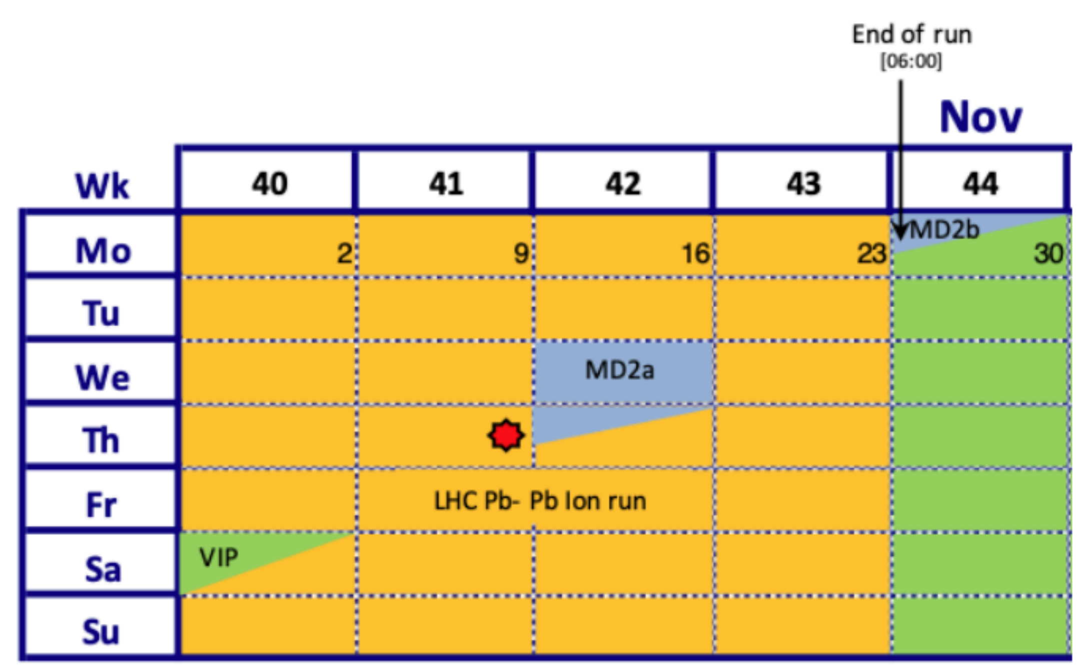


# Heavy Ion

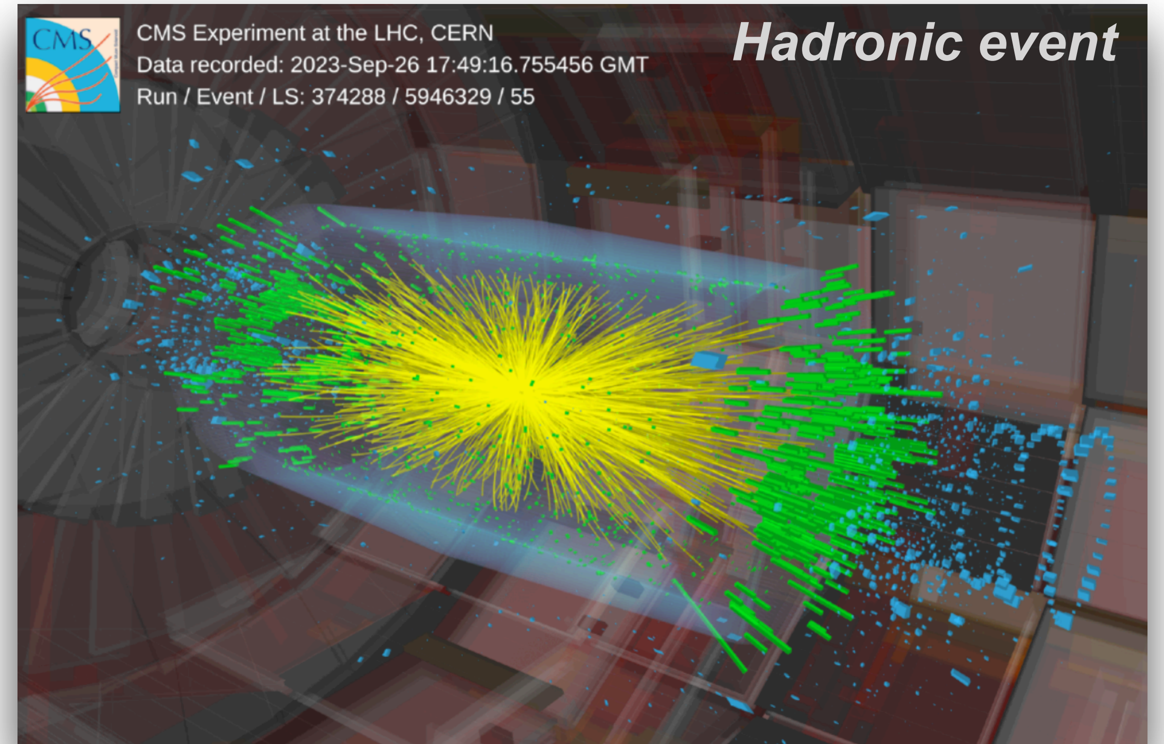
- **~5 weeks of PbPb data-taking @5.36 TeV in 2023**
  - ~1.98 nb$^{-1}$ delivered by LHC (1.8 nb$^{-1}$ in 2018)
  - ~1.82 nb$^{-1}$ recorded by CMS (1.7 nb$^{-1}$ in 1018)
  - efficiency by luminosity: ~91%
- **Smooth operation of the CMS detector**
- **Collected nearly all hadronic statistic**
  - ~17 billion Minimum Bias (MB) events
- **Also collected ~10 billion Ultra Peripheral Collisions (UPC) events**

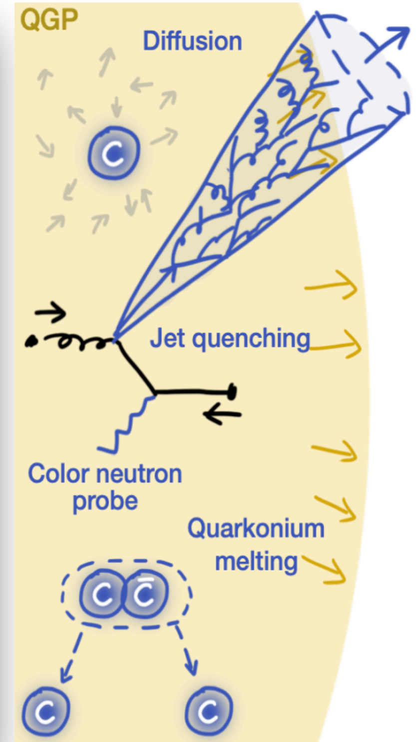


# Heavy Ion Physics



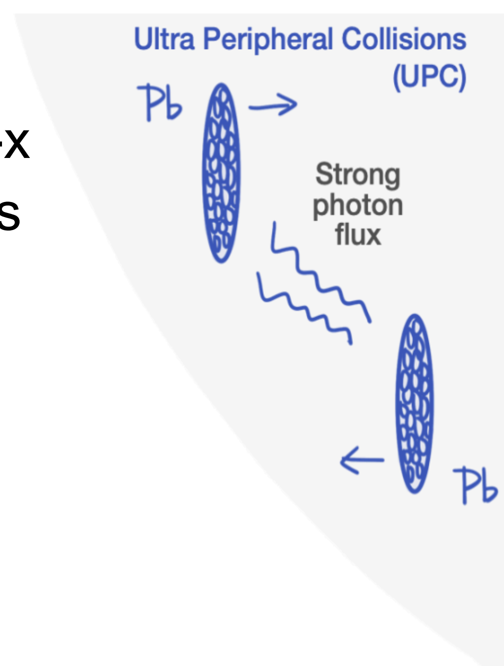



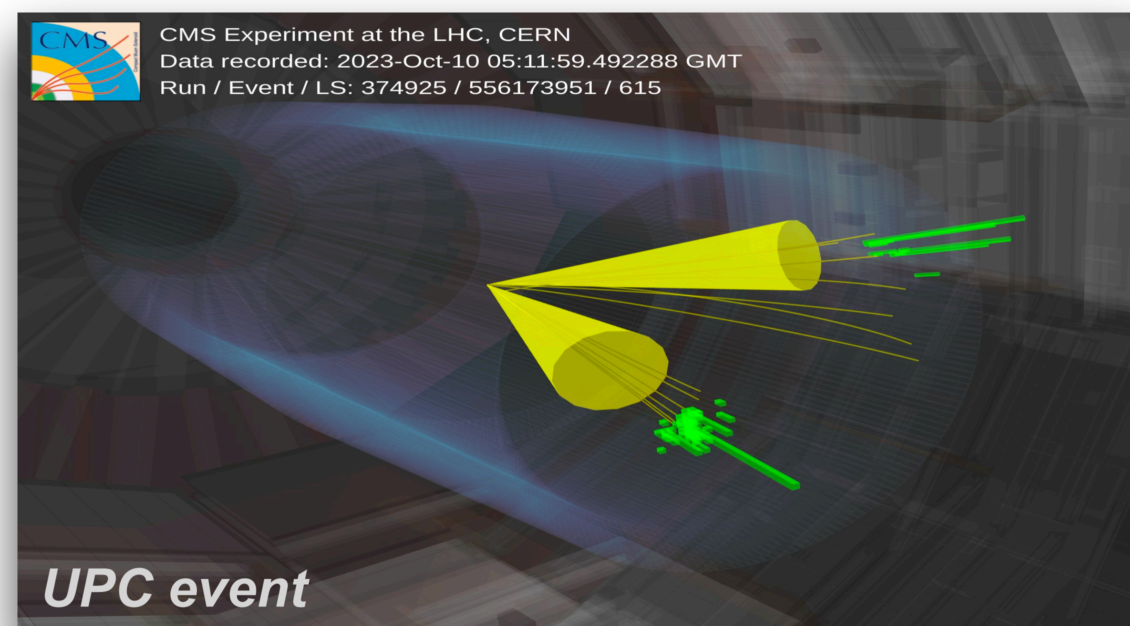

**Hadronic collisions: QGP studies**

- correlations and flow
- jet quenching
- quarkonia and open-heavy flavor production modifications
- EM probes to control nuclear effects

**UPC: $\gamma$N and $\gamma\gamma$ collisions**

- study gluon nuclear PDFs at low-x
- unique source of background-less jets at the LHC
- unique environment to study SM and BSM processes



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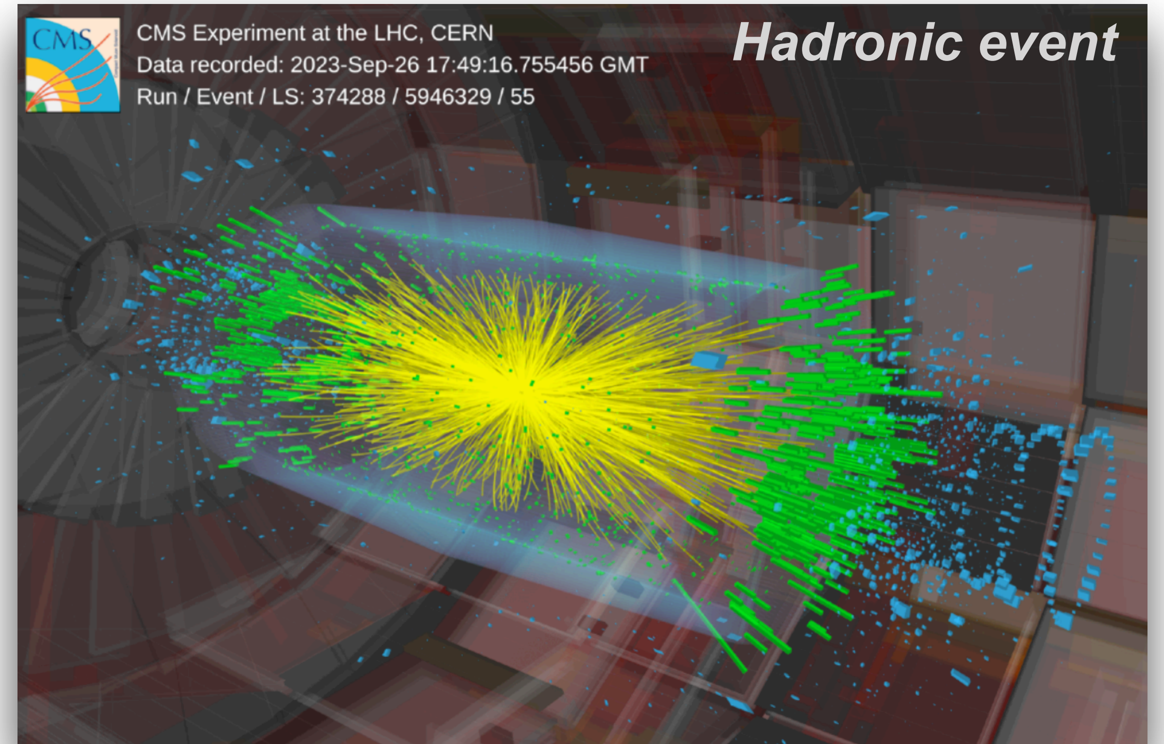


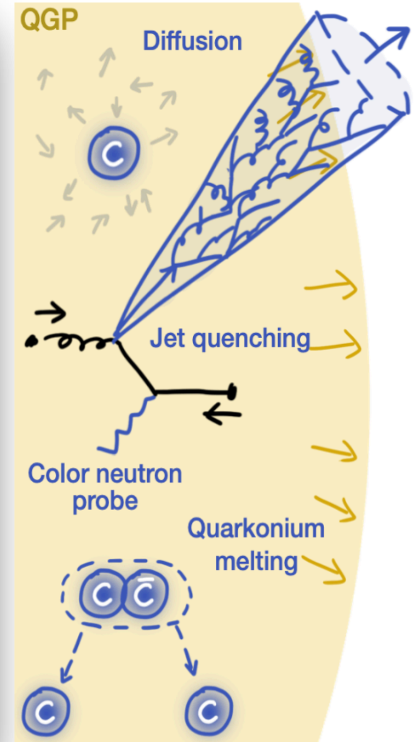


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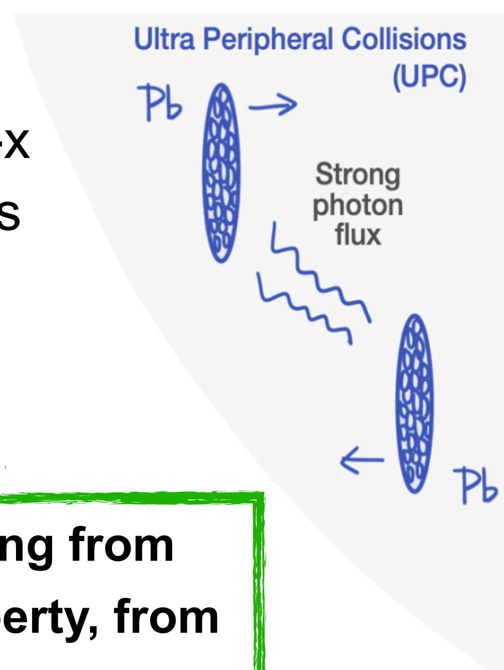
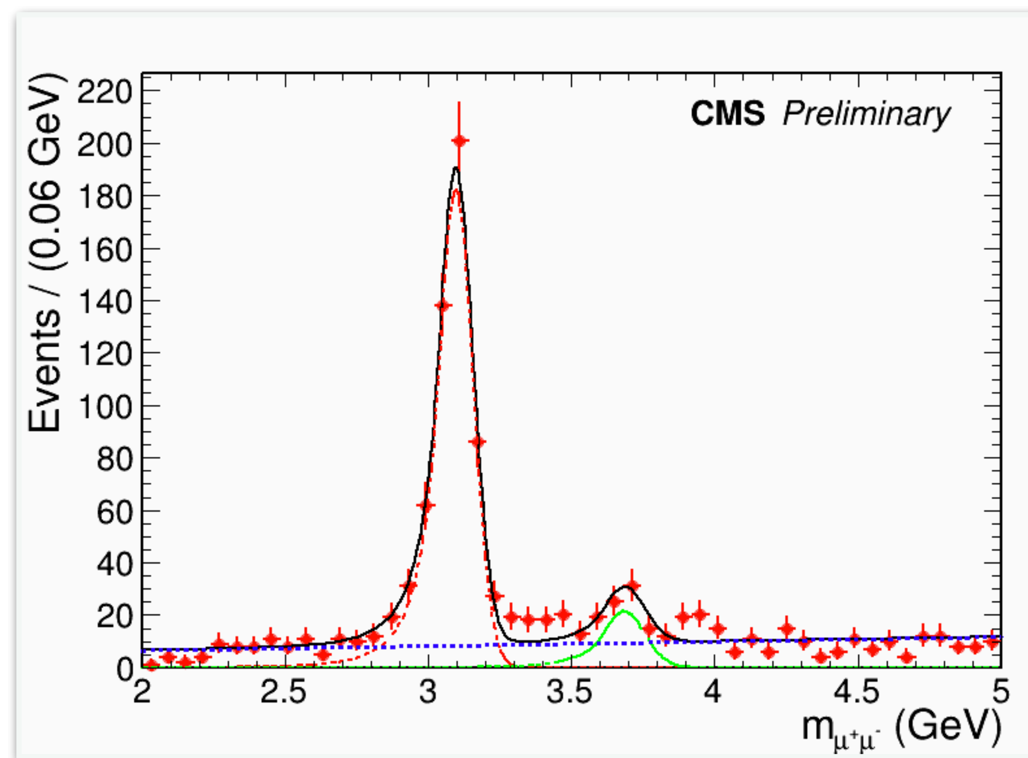


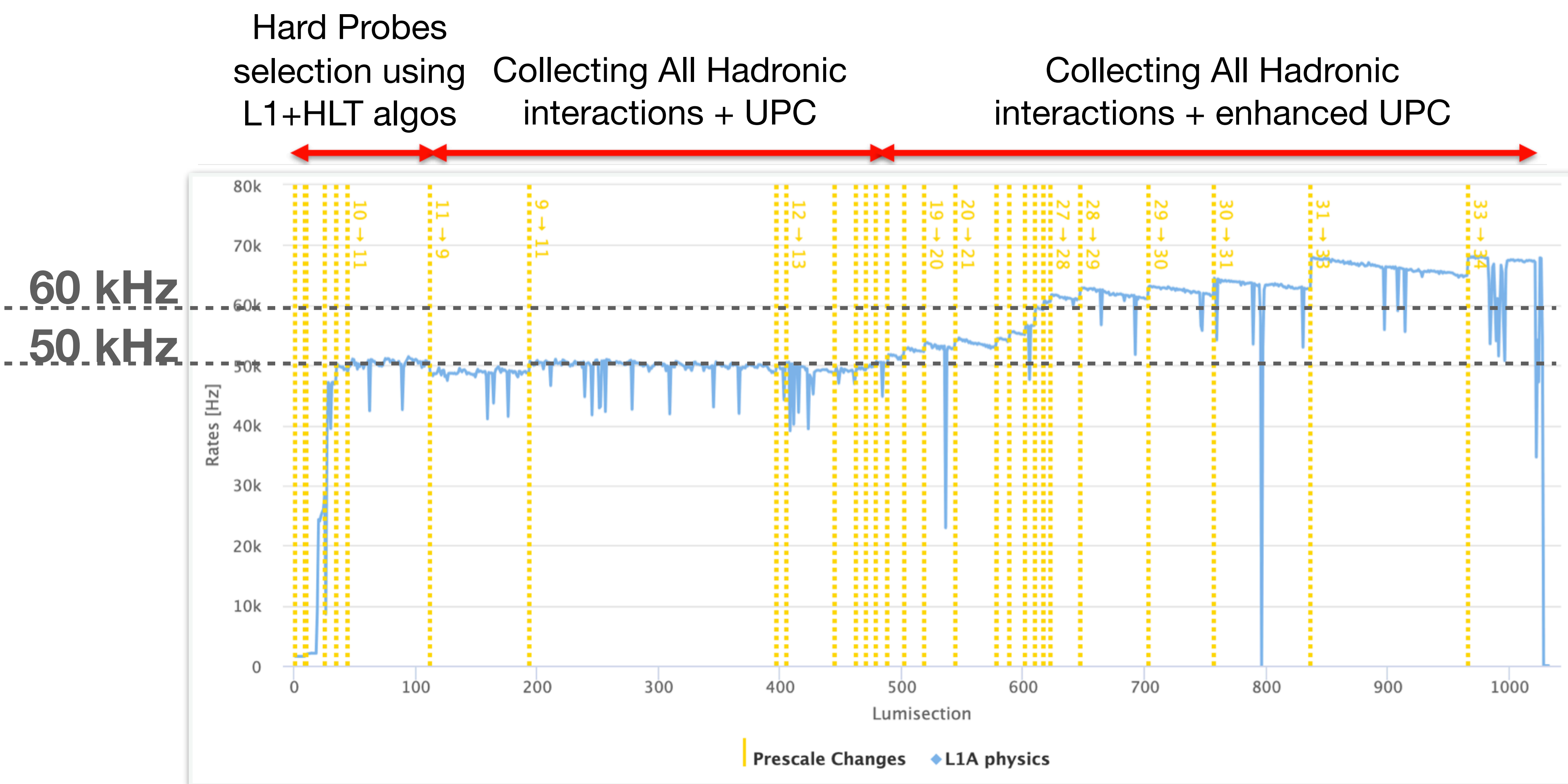

**Run 3 is crucial for progressing from observable to quantitative property, from phenomena to microscopic structure**

*Dimuon reconstruction in UPC events has good efficiency and resolution*




***Dimuon invariant mass***

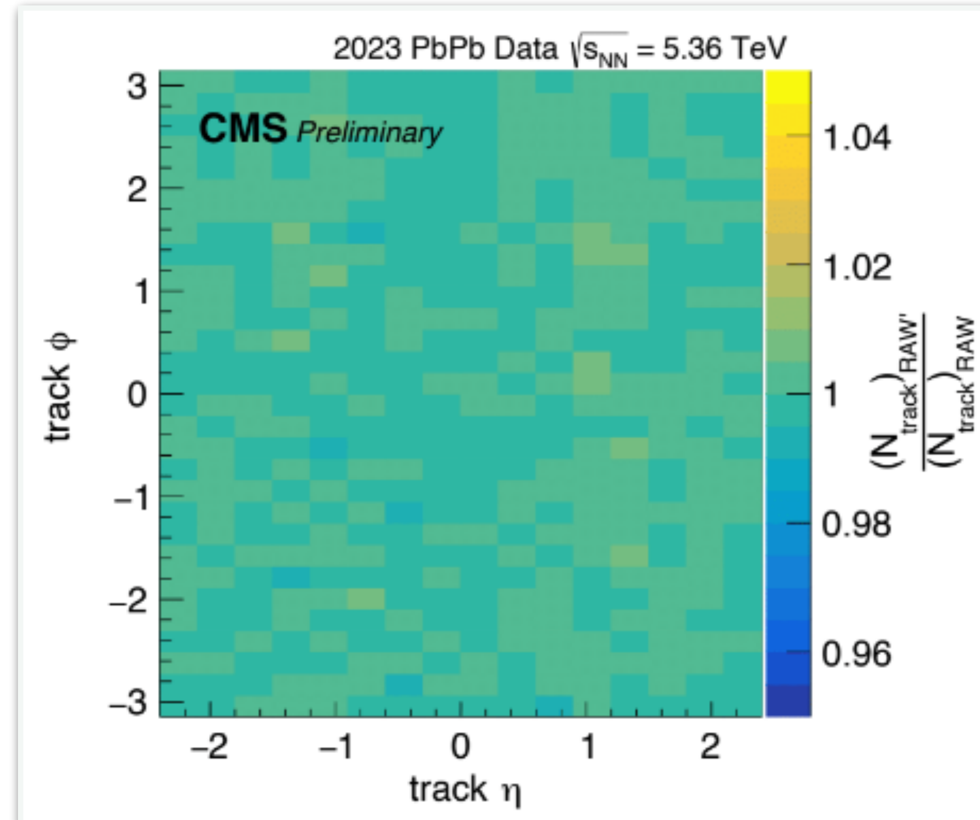
# Heavy Ion data-taking strategy




- **For the first time CMS has been run in PbPb collisions at a L1 trigger rate > 50 kHz** (vs 35 kHz in 2018) with less than 8% deadtime
  - up to 50 kHz at the beginning of the fill when recording large amounts of Minimum Bias data
  - > 60 kHz at the end of the fill when recording UPC
  - other physics triggers to catch rare events (high $p_T$ jets, muons, etc.)

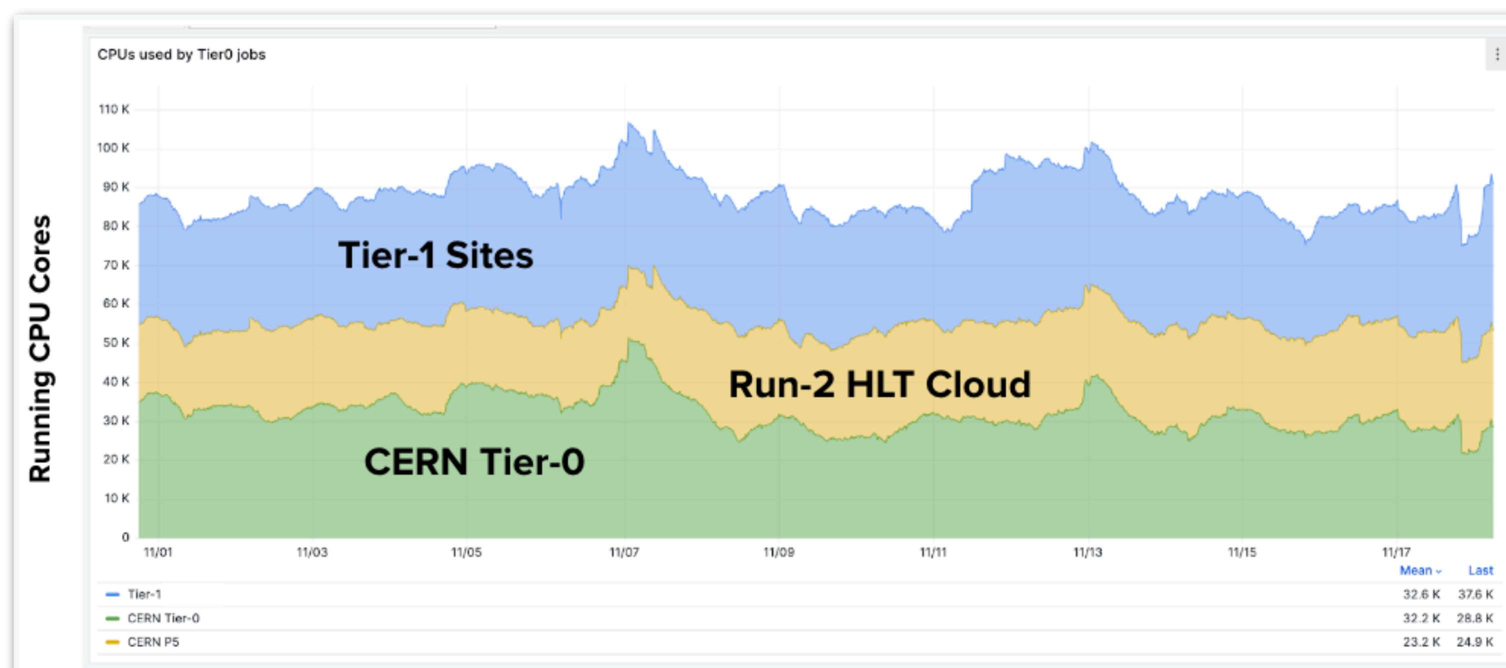
# HLT, DAQ, Computing in Heavy Ion

- Heavy Ion data taking can saturate DAQ transfer rate out of P5 → **data reduction necessary**
- **New data format RAW' at HLT validated this year**
    - processed "approximated" cluster information to reduce Tracker RAW data size
- **RAW' + HLT compression reduce data size by 54%**
    - no significant effects on physics performance



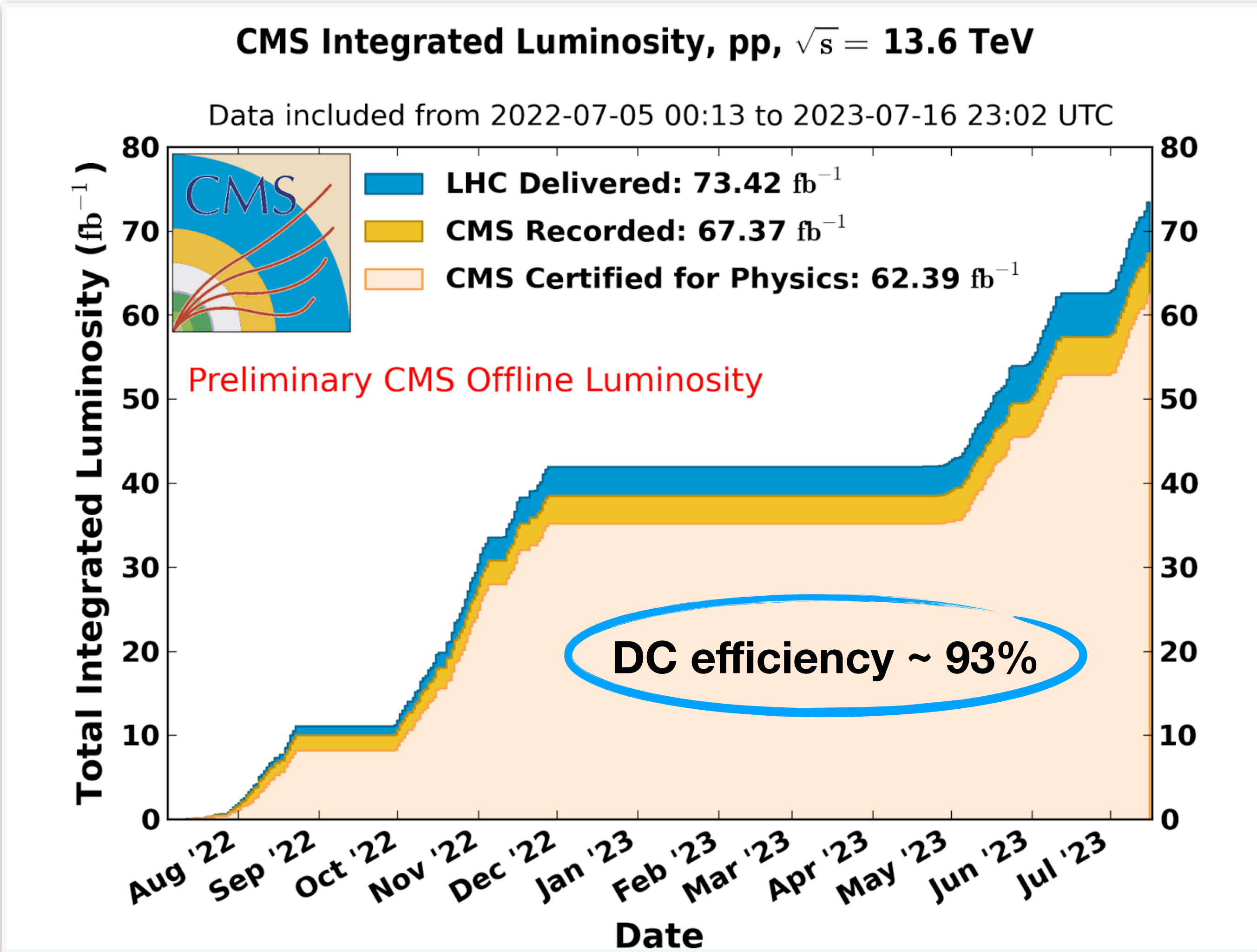

- DAQ system sustained **bandwidth of ~20 GB/s to disk** (vs 8.5 Gb/s in 2018)
- **CMS recorded up to 34 kHz of hadronic PbPb collisions to disk** (vs 8 kHz in 2018)

- Tier-0 and up to 5 Tier-1 sites used to **promptly reconstruct HI data**
- Tier-0 backlog of prompt-reco HI data has cleared in record time
    - **data available for physics analyses in short time**

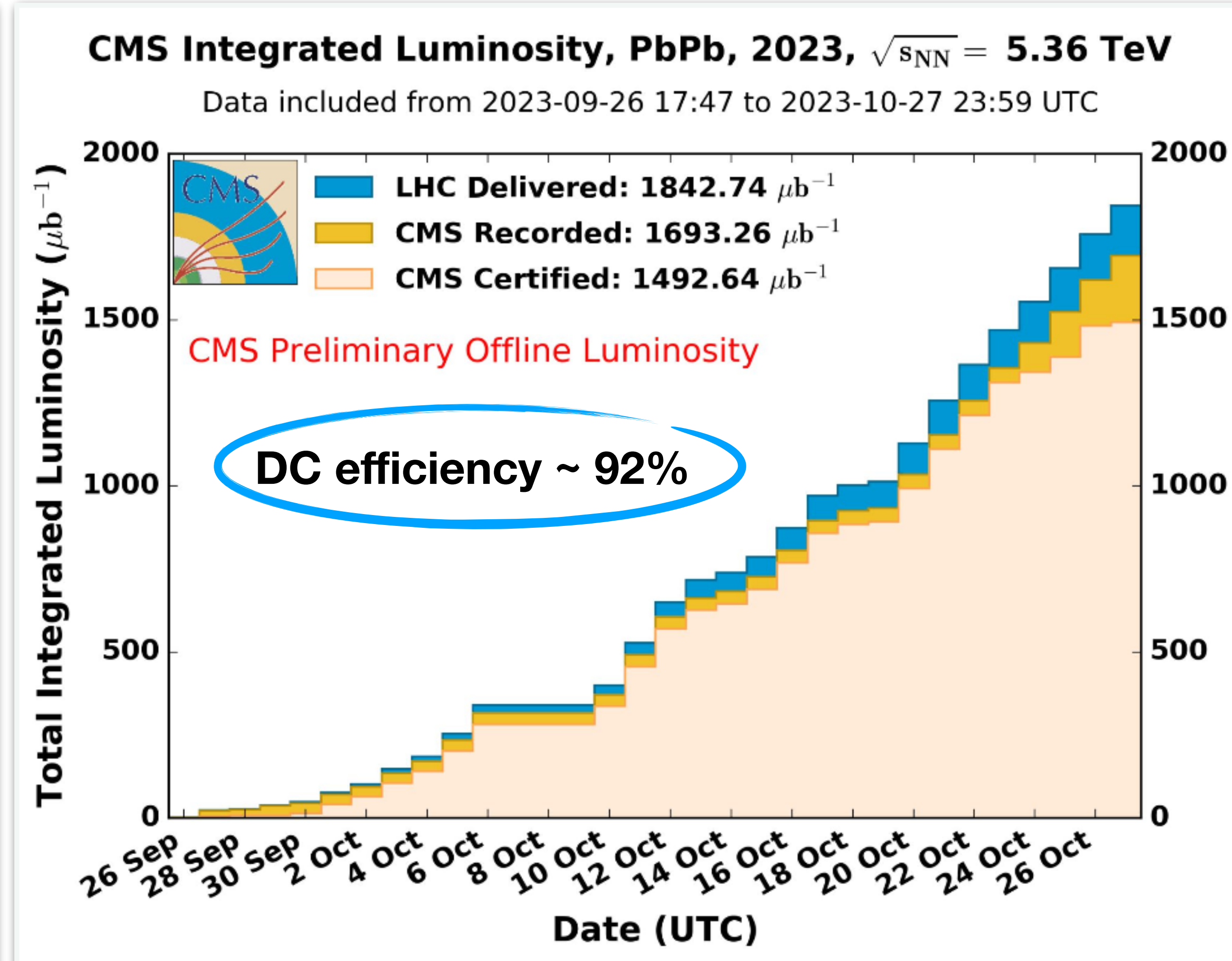


# Data certification

*Run 3 (2022+2023) pp collisions*




*2023 Heavy Ion collisions*




- **Smooth running of all detectors in both pp and Heavy Ion data-taking**
- Certified data recorded with all detectors

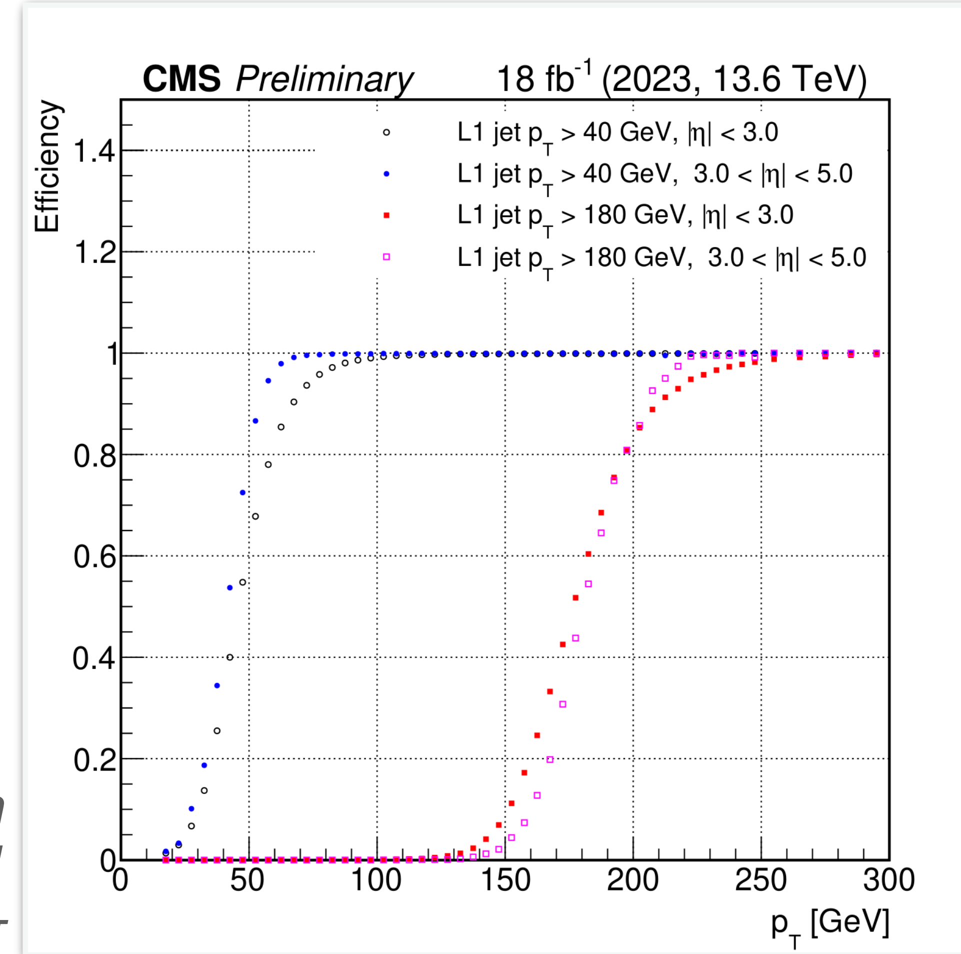
NB: this plot does not correspond to the whole period of HI data-taking, certification still ongoing

**2023 Heavy Ion Data Certification (DC):**

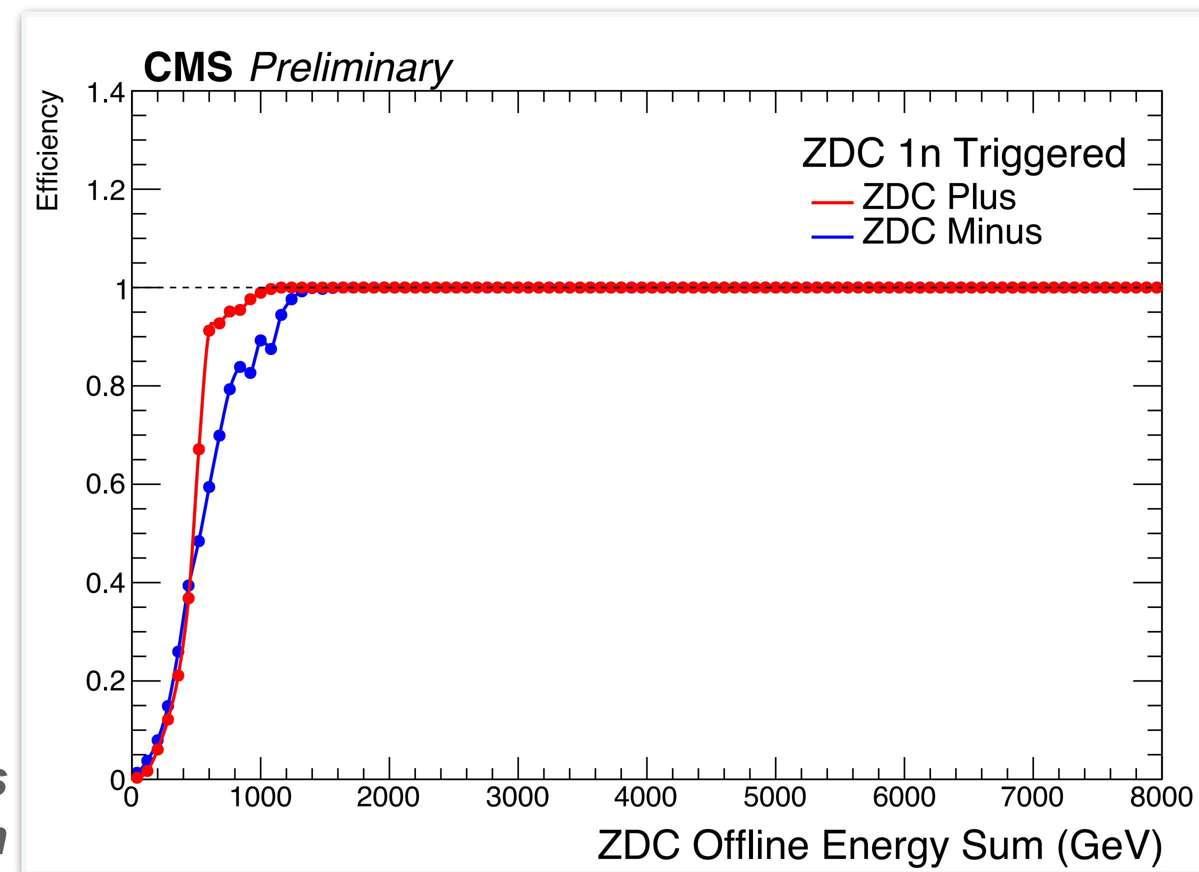
- DC efficiency in HI similar to pp data-taking
- DC certified/DC processed = 92.36%
- DC certified/Recorded = 88.16%

# Level-1 Trigger

- All L1T objects have **excellent 2023 performance**, improving w.r.t. 2022
- **Successful commissioning of neural network-based triggers**
  - muon $p_T$ regression
  - anomaly detection
- **Zero Degree Calorimeter (ZDC) trigger necessary to preserve PbPb Minimum Bias trigger**
  - commissioning finalized in time for physics data-taking
  - **good physics performance**
    - trigger efficiency > 95%




***L1 jet efficiency in 2023 for various L1 $E_T$ thresholds vs $p_T$***




***L1 efficiency vs ZDC energy sum***

EG/Tau: DP-2023-055

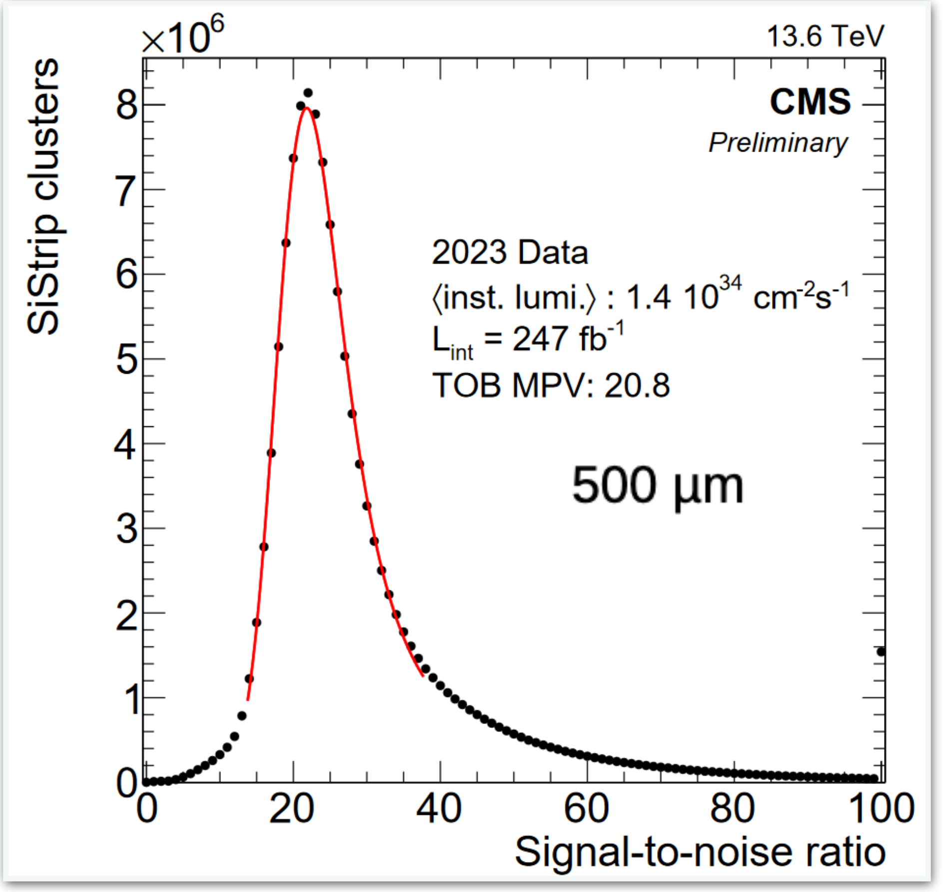
Jet/MET: DP-2023-054

Muon: DP-2023-057

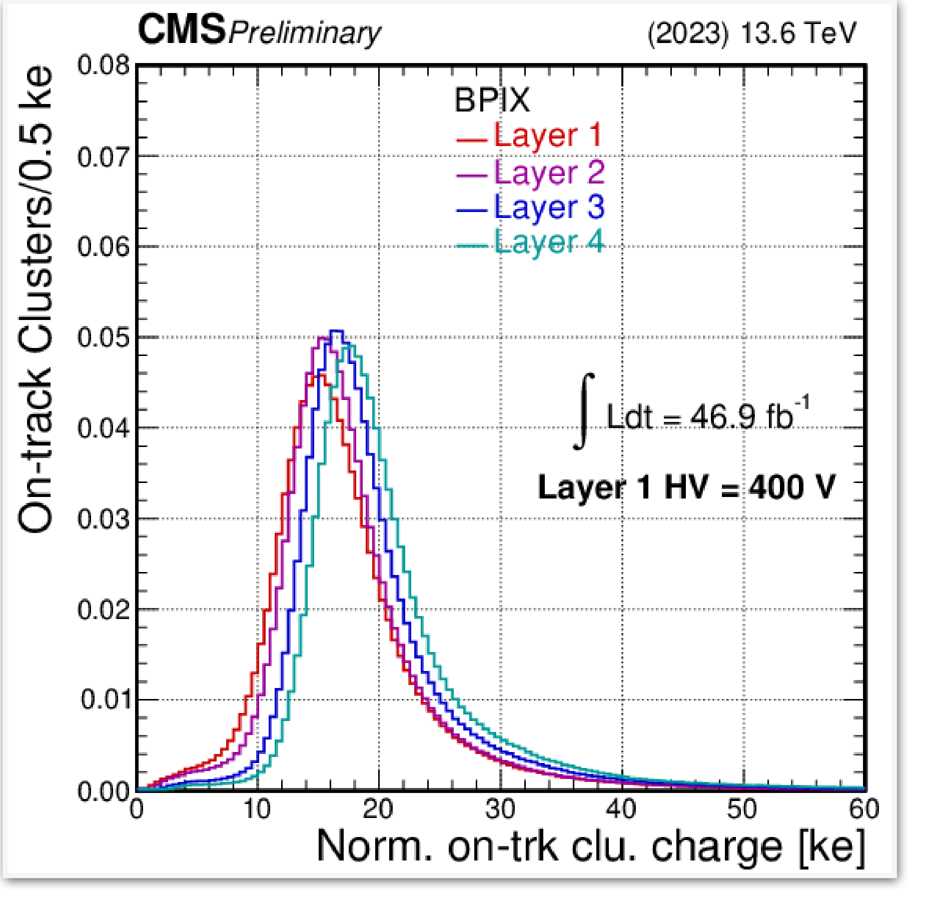
Displaced Muon: DP-2023-056

# Tracker

- **Strip Tracker**
  - **good detector fraction stable at 96%**
  - updated projections confirm estimates of signal to noise ratio of 14-18 after 500 $fb^{-1}$, well above specification of 10
- **Pixel detector**
  - **good detector fraction is 96% for BPIX, 98% for FPIX**
    - BPix lost ~3% due to HW failure in clock distribution in June
  - no indications of further issues with clock distribution
  - radiation effects are closely monitored and proceed as expected
- **Major alignment effort ongoing to provide optimal conditions after several magnet cycles**
- **Detectors will be kept cold during YETS**



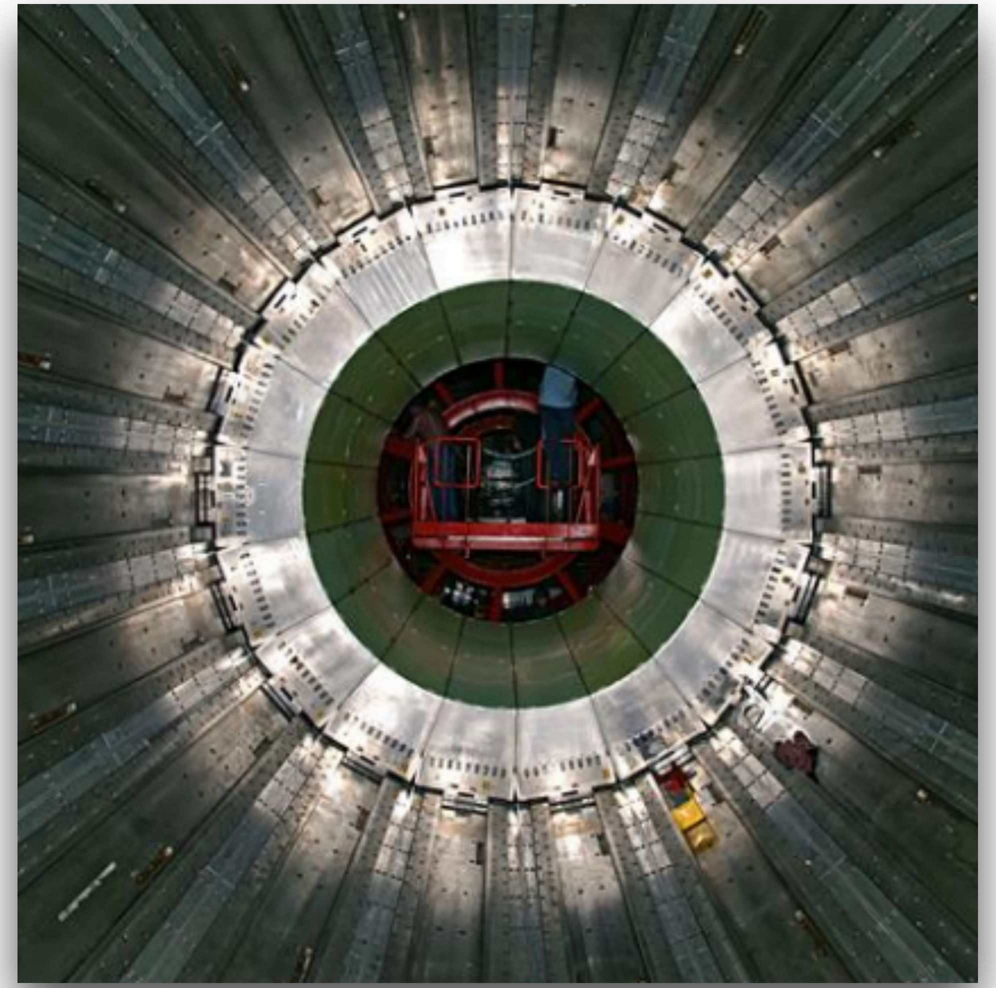

***Strip: signal to noise ratio***




***Pixel: cluster charge distribution***

# Electromagnetic calorimeter

- **Good performance of automated laser transparency updates**
  - transparency changes tracked more frequently (once per fill for L1T and HLT)
- **ECAL calibration campaign ongoing**
  - automation continues to operate well in 2023
- **Deployment of new timing calibrations and of almost all 2023 intercalibration constants**
  - work ongoing for last period of data-taking

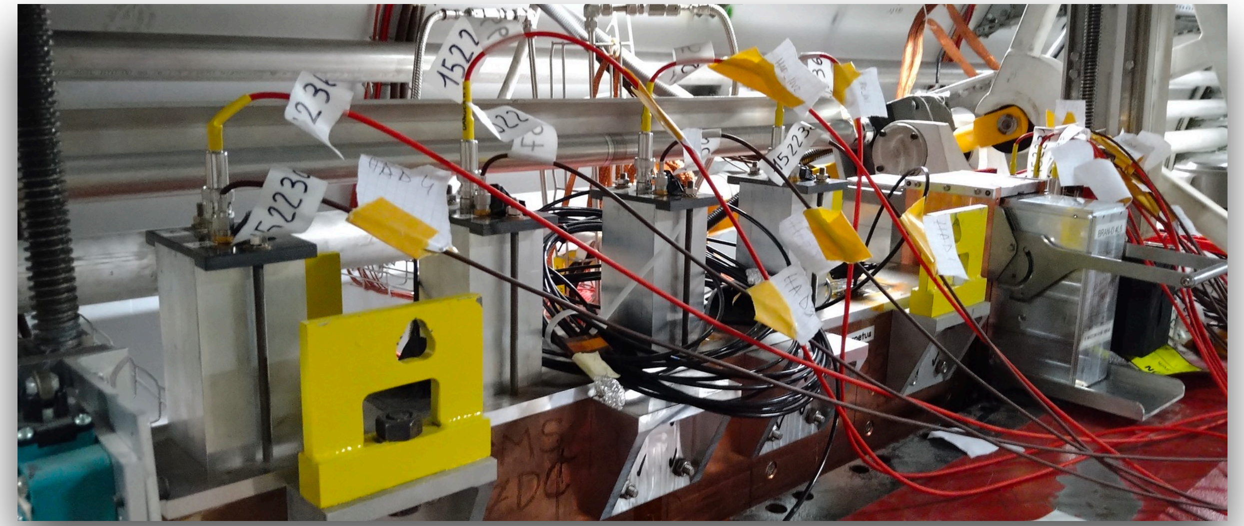


# Hadronic calorimeter

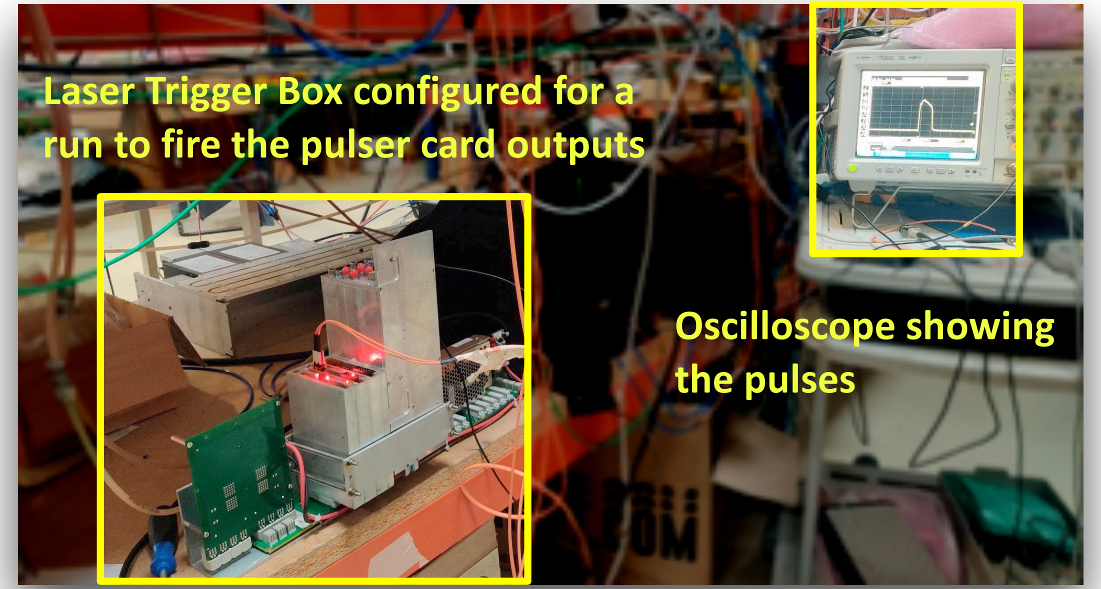
- **ZDC installed and commissioned very quickly**
  - integration in CMS L1 trigger crucial to satisfy requirements of Heavy Ion physics program

- **Guiding principle for 2023-2024 YETS: improve consistency and resilience**
  - automatic correction of misconfigurations caused by Single Event Upsets
  - control software and firmware updates implementing automatic recovery mechanisms

- **Further improvements for the rest of Run 3**
  - consolidation of hardware components
  - improvements to laser system
  - more automation in operations, calibration, and detector performance with machine-learning tools



*Zero Degree Calorimeter*

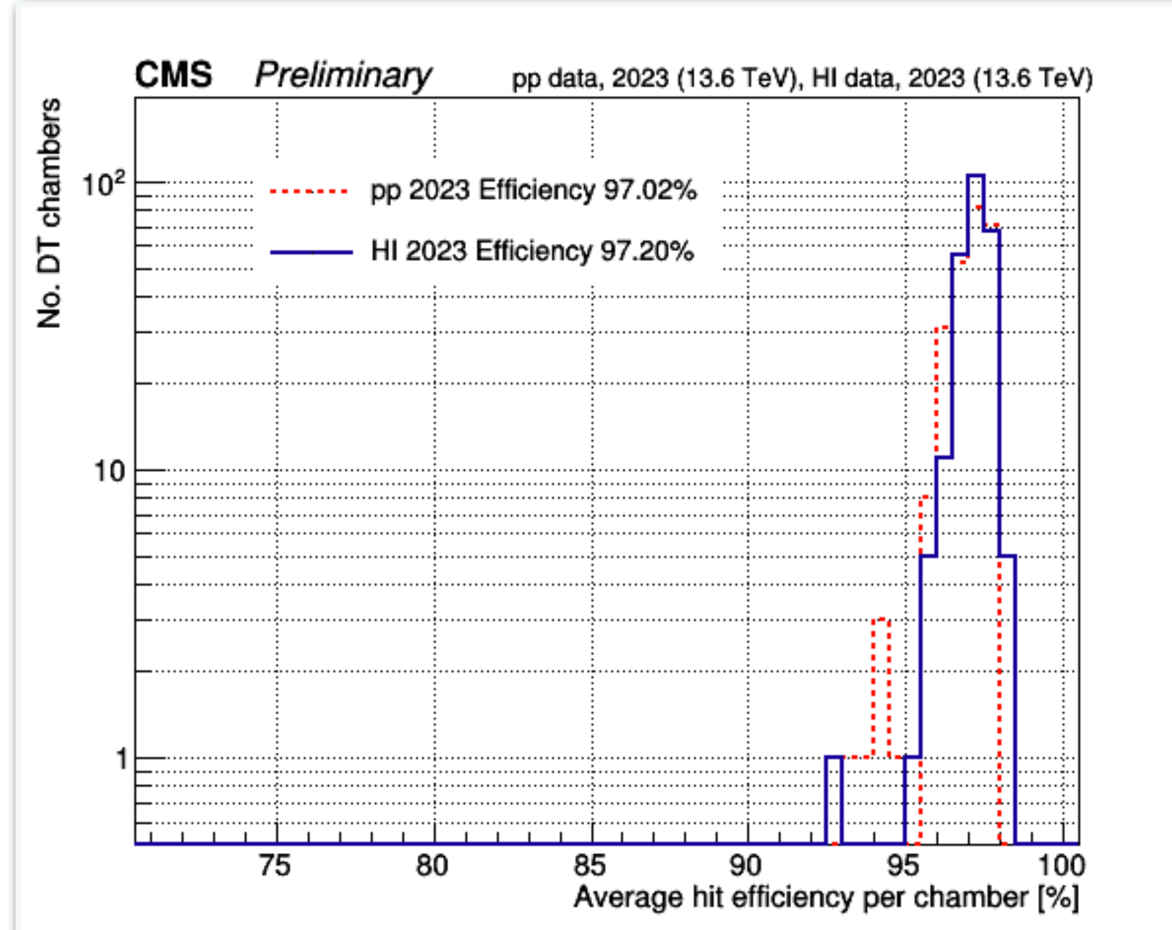



***HCAL 904 laboratory***

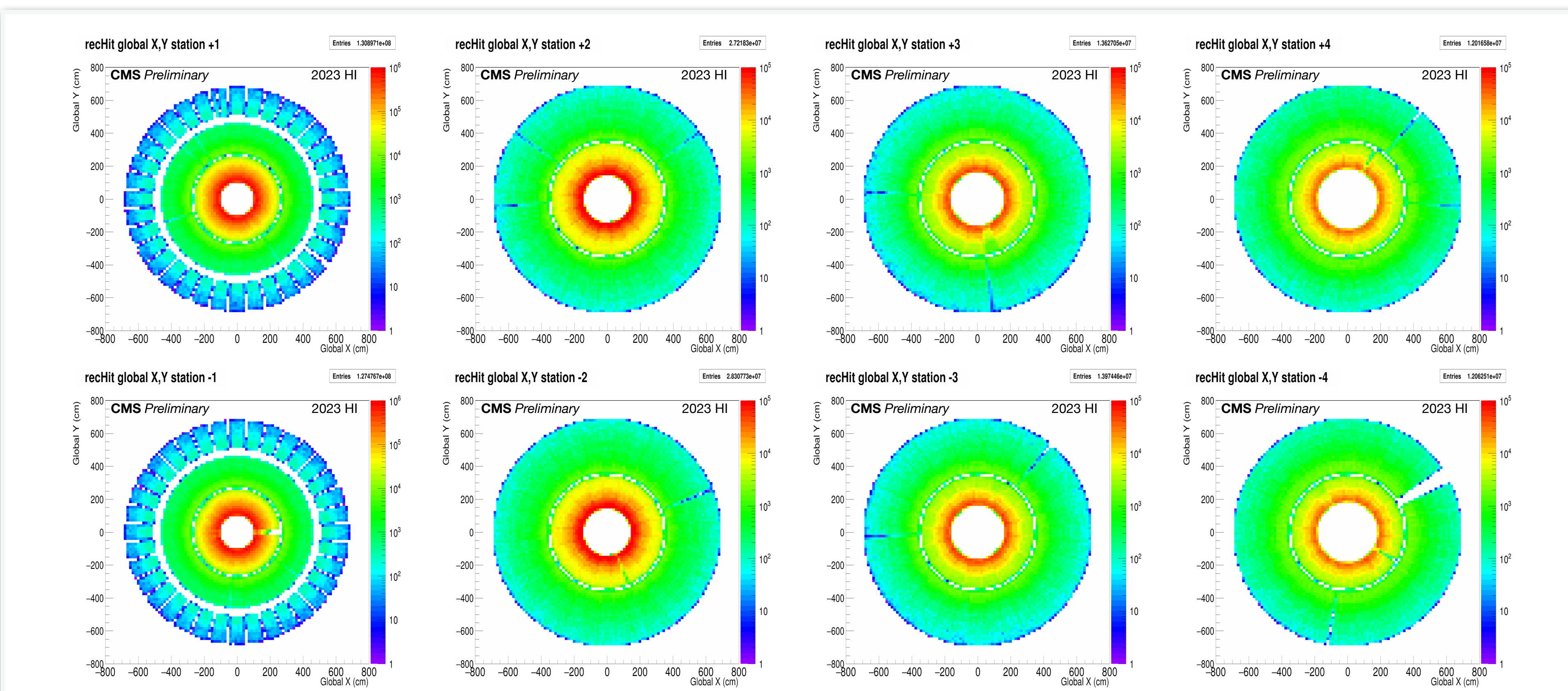
*Envisioning addition of trigger board to HCAL Calibration Laser to actively trigger the laser discharge, reducing its jitter from 100ns to 10ns*

# Muon system

- Small contribution to CMS downtime and luminosity loss
- **Good performance** also with 2023 HI data
- **GEM operated very well during its first HI run**




*DT chamber efficiency*




*CSC reconstructed hit position in HI data*

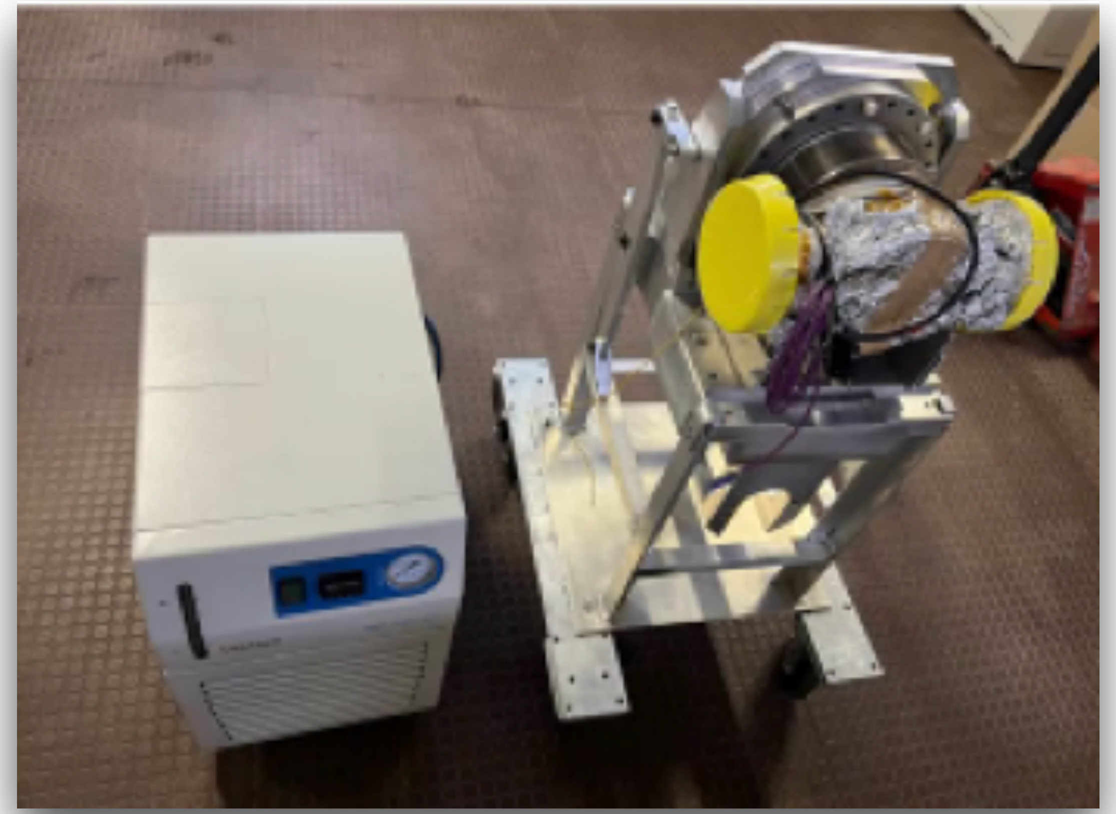
# Precision Proton Spectrometer

- **Successful high-luminosity 2023 pp running**

- **PPS Roman Pots were not inserted during the Heavy Ion run, as usual**

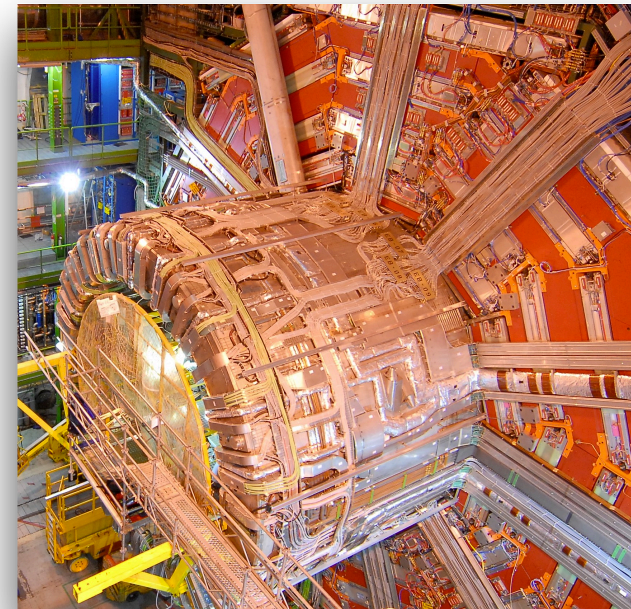
- **No major changes in detector configuration/LHC conditions expected for 2024**
  - exchange of 2 pixel detector packages to provide added redundancy
  - finish transition to automated prompt calibrations

- **Longer term:**
  - a Roman Pot + cooling test-stand has been setup to evaluate options for Run 4
  - a full scale Roman Pot station mockup including Fully Remote Alignment System moving tables is being assembled



***part of an air-based cooling system + 1 horizontal Roman Pot***

# CMS Run 3 detector paper

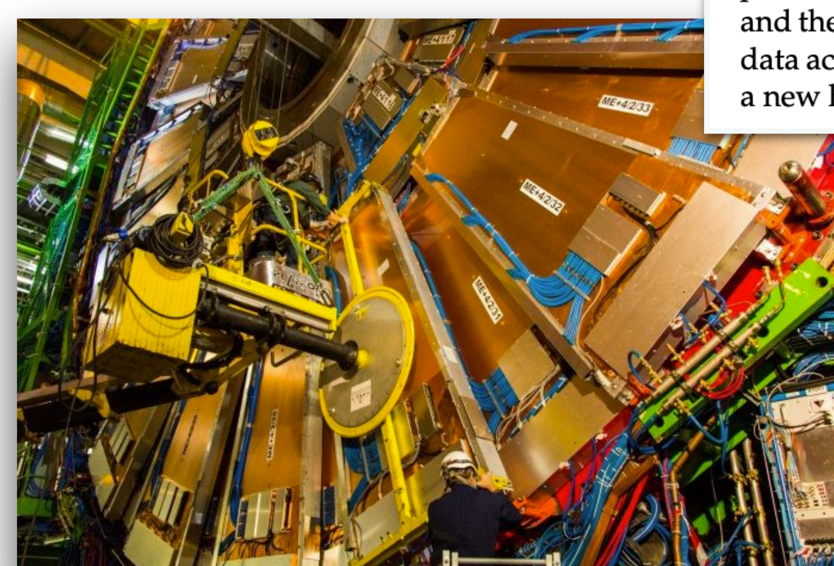


Development of the CMS detector for the CERN LHC Run 3

The CMS Collaboration*

**Abstract**

Since the initial data taking of the CERN LHC, the CMS experiment has undergone substantial upgrades and improvements. This paper discusses the CMS detector as it is configured for the third data-taking period of the CERN LHC, Run 3, which started in 2022. The entire silicon pixel tracking detector was replaced. A new powering system for the superconducting solenoid was installed. The electronics of the hadron calorimeter was upgraded. All the muon electronic systems were upgraded, and new muon detector stations were added, including a gas electron multiplier detector. The precision proton spectrometer was upgraded. The dedicated luminosity detectors and the beam loss monitor were refurbished. Substantial improvements to the trigger, data acquisition, software, and computing systems were also implemented, including a new hybrid CPU/GPU farm for the high-level trigger.



**Submitted to the Journal of Instrumentation**

https://arxiv.org/abs/2309.05466

# YETS 23-24 activities

*New Control Room*

- **Crucial period to advance on major activities**
- **Consolidate legacy detector systems**
  - hardware maintenance
  - new YE1 support for beam pipe
  - installation of new forward shielding
- **Maintain all major infrastructure to guarantee smooth end of Run3**
  - magnet controls & cryogenic system maintenance
  - laser system relocation
  - Control Room migration
- **Anticipate Phase 2 installations**, when possible, to prepare at best for LS3
  - $CO_2$ piping and infrastructure installation
  - new DAQ room, new buildings

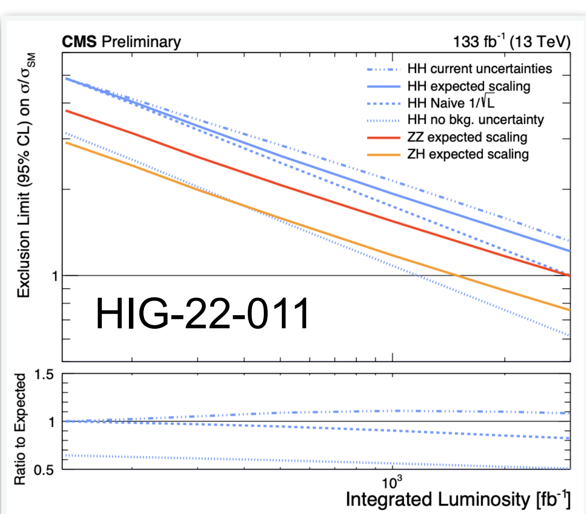
*New ECAL Laser Lab*

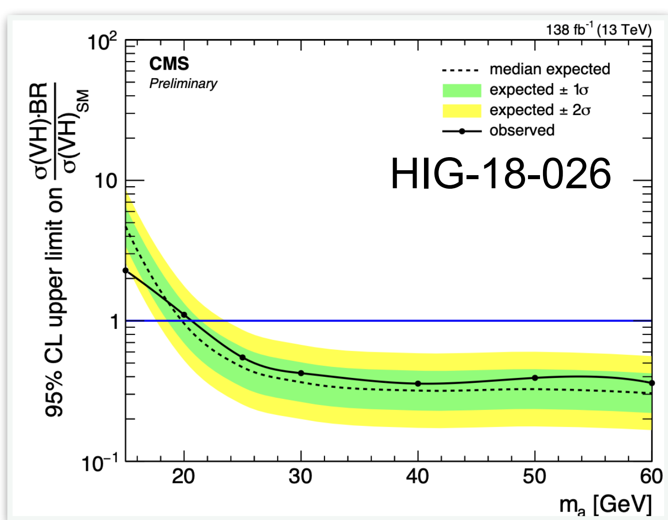
# Overview of recent physics results

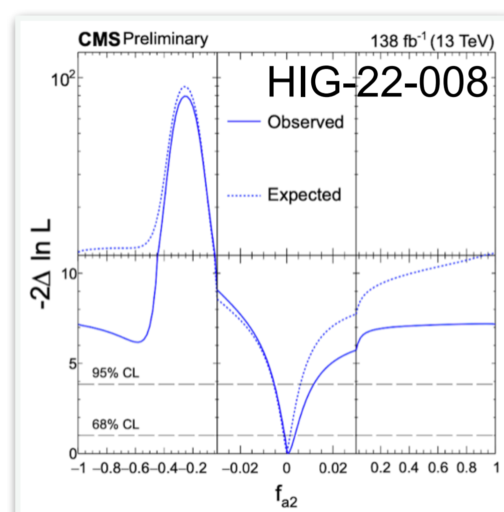
**8 analyses** (5 Higgs + 1 SUSY + 1 SMP + 1 TOP) **approved** since last LHCC, mostly for HIGGS23,
**+ 2 technical papers/notes**

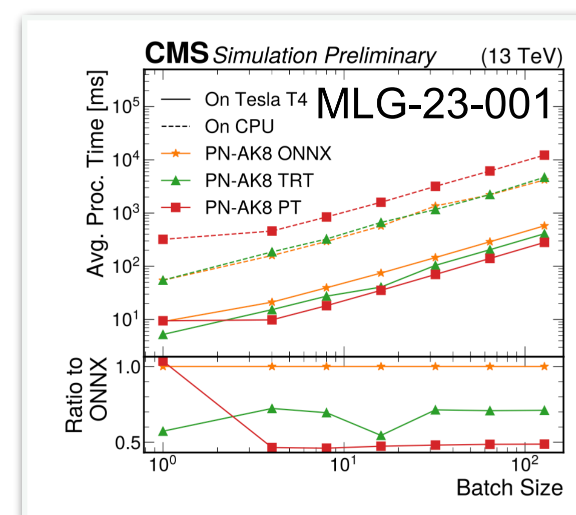
| | |
|---|---|
| **HIG-22-011** | Search for ZZ and ZH production in the four b-jet final state |
| **HIG-23-006** | H+HH combination |
| **SUS-23-007** | Search for Z* -> h/H A -> 4tau |
| **HIG-18-026** | H->2a->4b search in VH with full Run2 data |
| **TOP-22-002** | FCNC tHq with SS dileptons |
| **HIG-22-008** | Anomalous Couplings in H->WW |
| **MLG-23-001** | Portable Acceleration of CMS Mini-AOD Production with Coprocessors as a Service |
| **HIG-23-007** | Search for anomalous Higgs boson couplings in WH→ lνbb production through Vector Boson Scattering |
| **SMP-22-012** | Search for Z/H to a J/Psi or Psi' meson and a photon |
| **CMS-NOTE-2023-013** | Machine learning techniques for model-independent searches in dijet final states |

Only a few highlights in the next slides..
see here for more results!



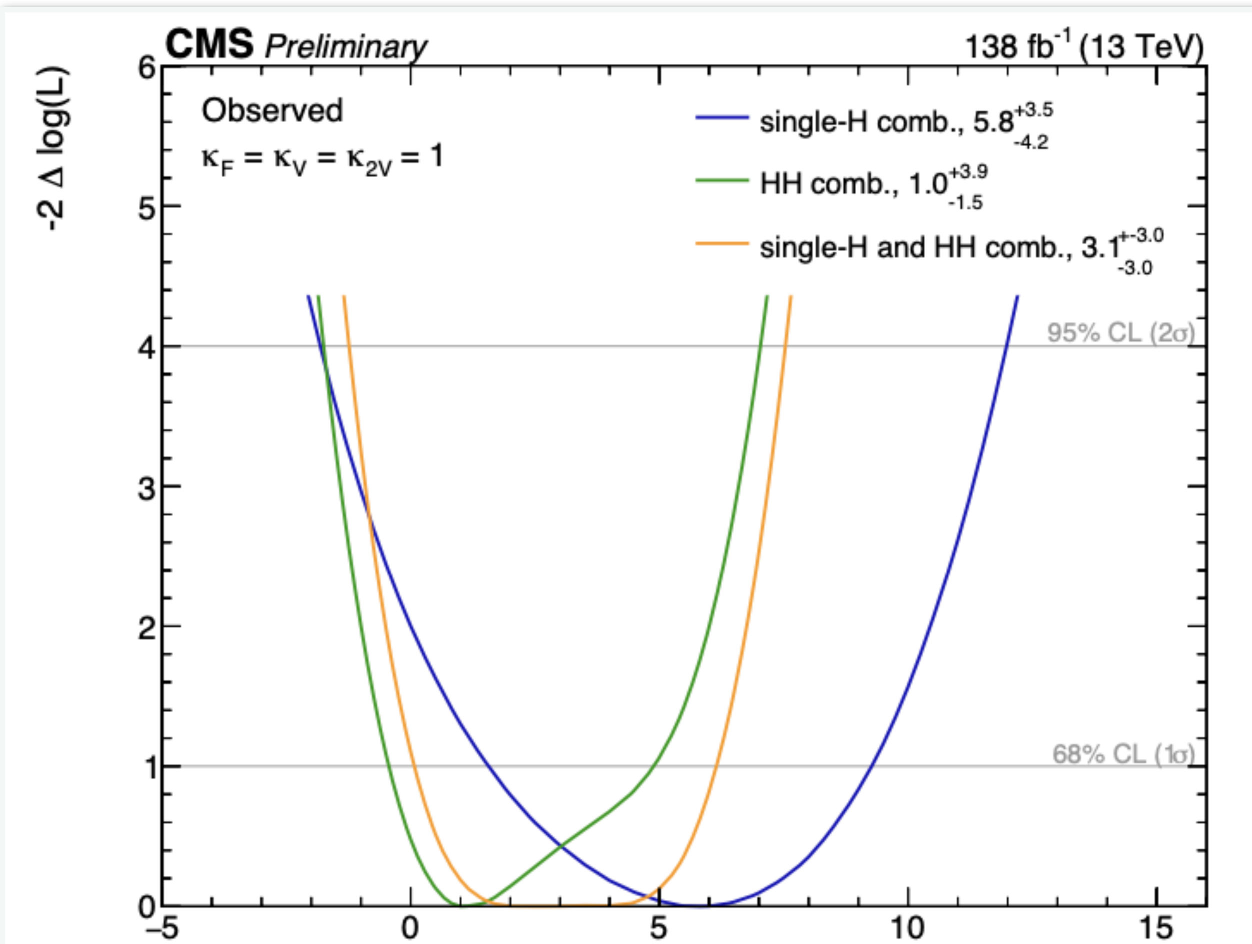



# Combination of H measurements and searches for HH to constrain $\lambda_{HHH}$

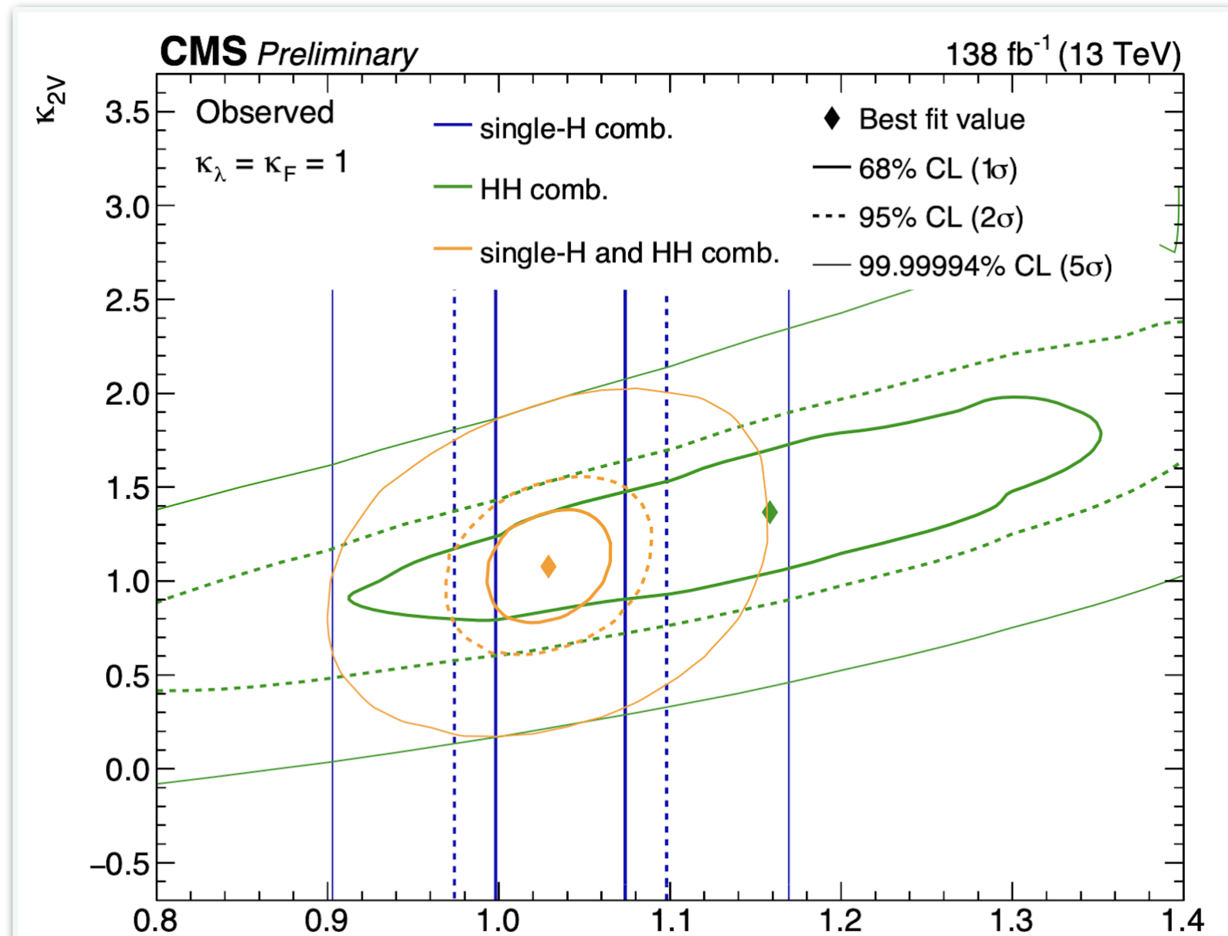
HIG-23-006

- 9 single-H analyses and 6 HH analyses combined, overlap removal studied in details
- **Inclusion of single-H channels improved constraints on Higgs boson trilinear self-coupling** $\lambda_{HHH}$ under more general assumptions on the Higgs boson couplings to fermions and vector bosons

$\kappa_\lambda = \lambda_{HHH} / \lambda_{HHH}^{SM}$




*Profile likelihood scan of $\kappa_\lambda$*




*2D likelihood scan of $\kappa_V$ and $\kappa_{2V}$*

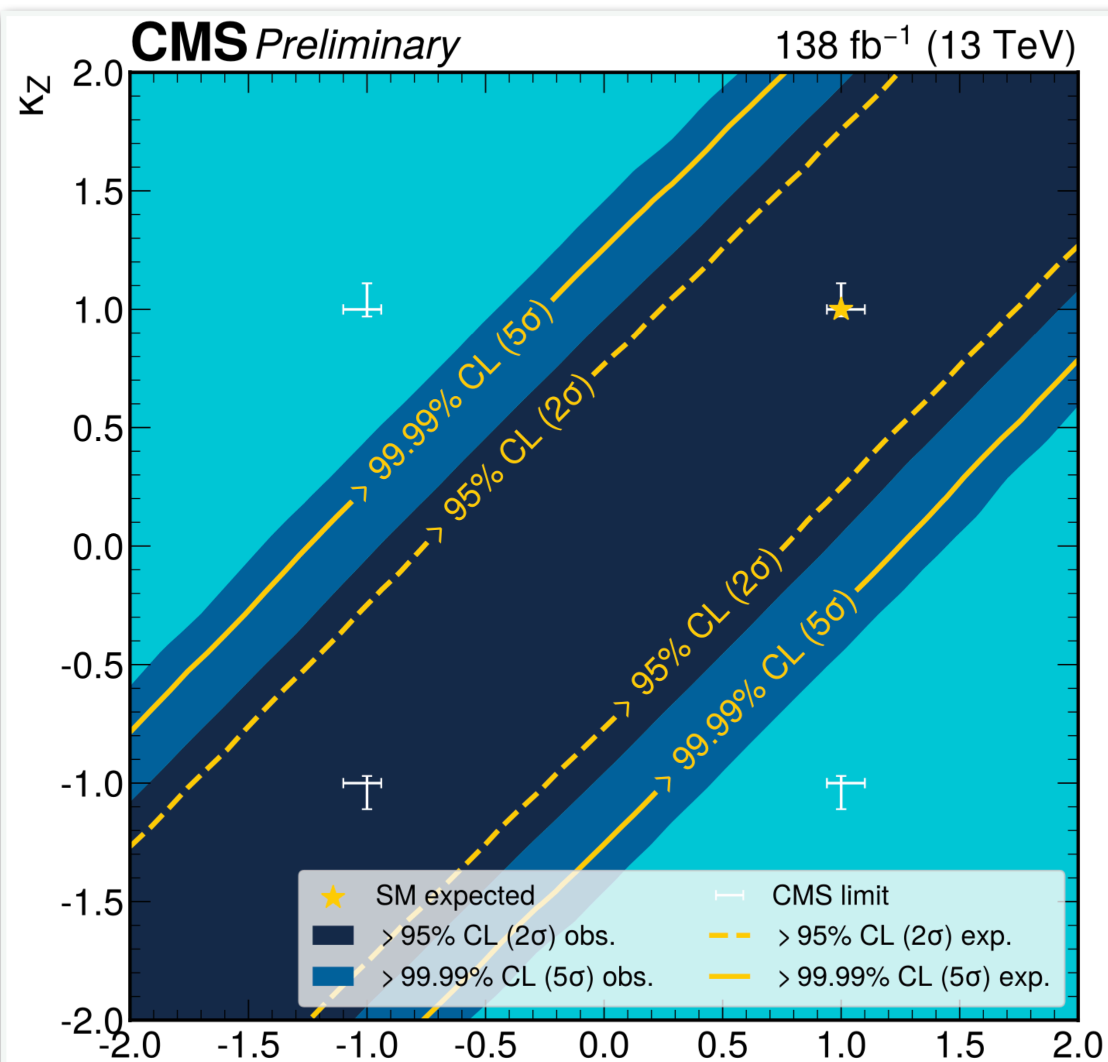
**First combination of single-H and HH channels at CMS !**

# Search for anomalous Higgs boson couplings in WH production through Vector Boson Scattering

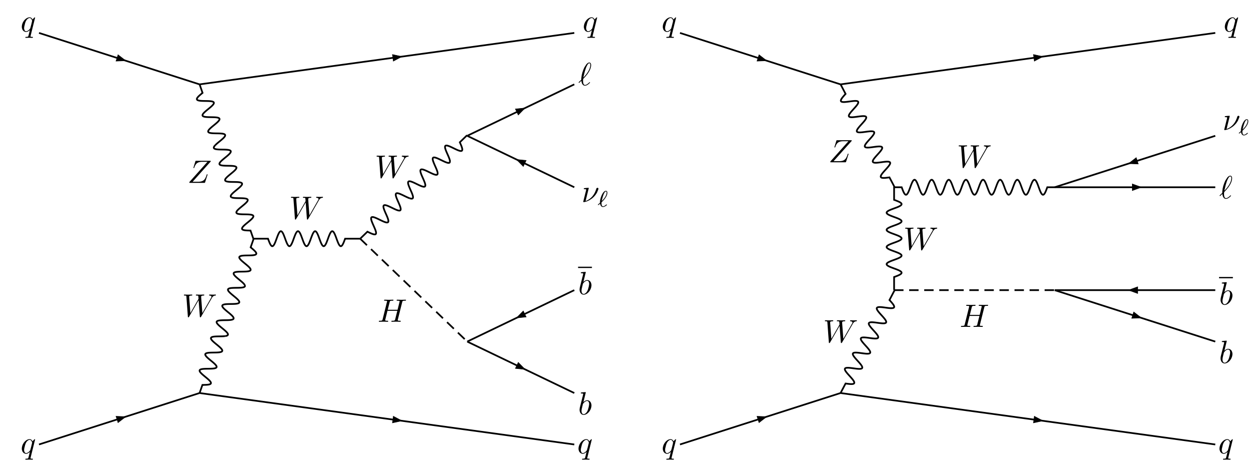
HIG-23-007

*Just released!*

- W leptonic decay and H decay into bb
- **Focus on boost topology**: H decay products are boosted and thus reconstructed as a single large-cone jet




***Exclusion significance in the $\kappa_W$-$\kappa_Z$ plane***



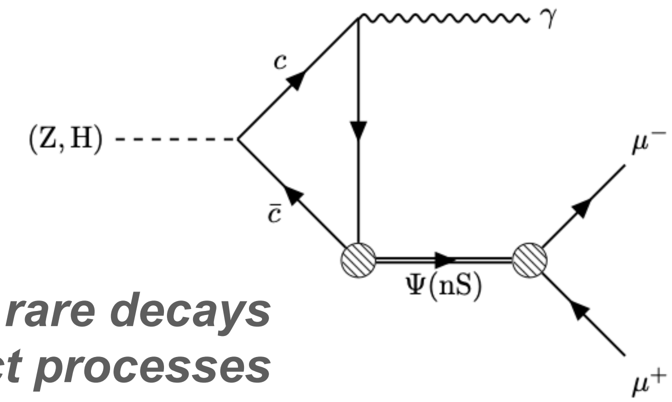
The interference between these diagrams generates a term in the cross section that is linear in both the WH ($\kappa_W$) and ZH ($\kappa_Z$) couplings

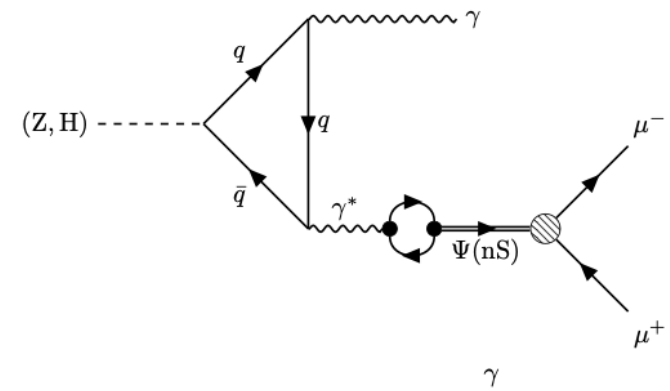
- **The BSM scenario where $\lambda_{WZ} = \kappa_W/\kappa_Z = -1$ is excluded** at a CL larger than 99.99%, with significance beyond 5 σ
- **All the opposite sign scenarios with $\kappa_W$ and $\kappa_Z$ values compatible with the current measurements are excluded** with a CL higher than 99.99%

# Search for $Z/H \to J/\Psi(\Psi')\,\gamma$

SMP-22-012

*Just released!*

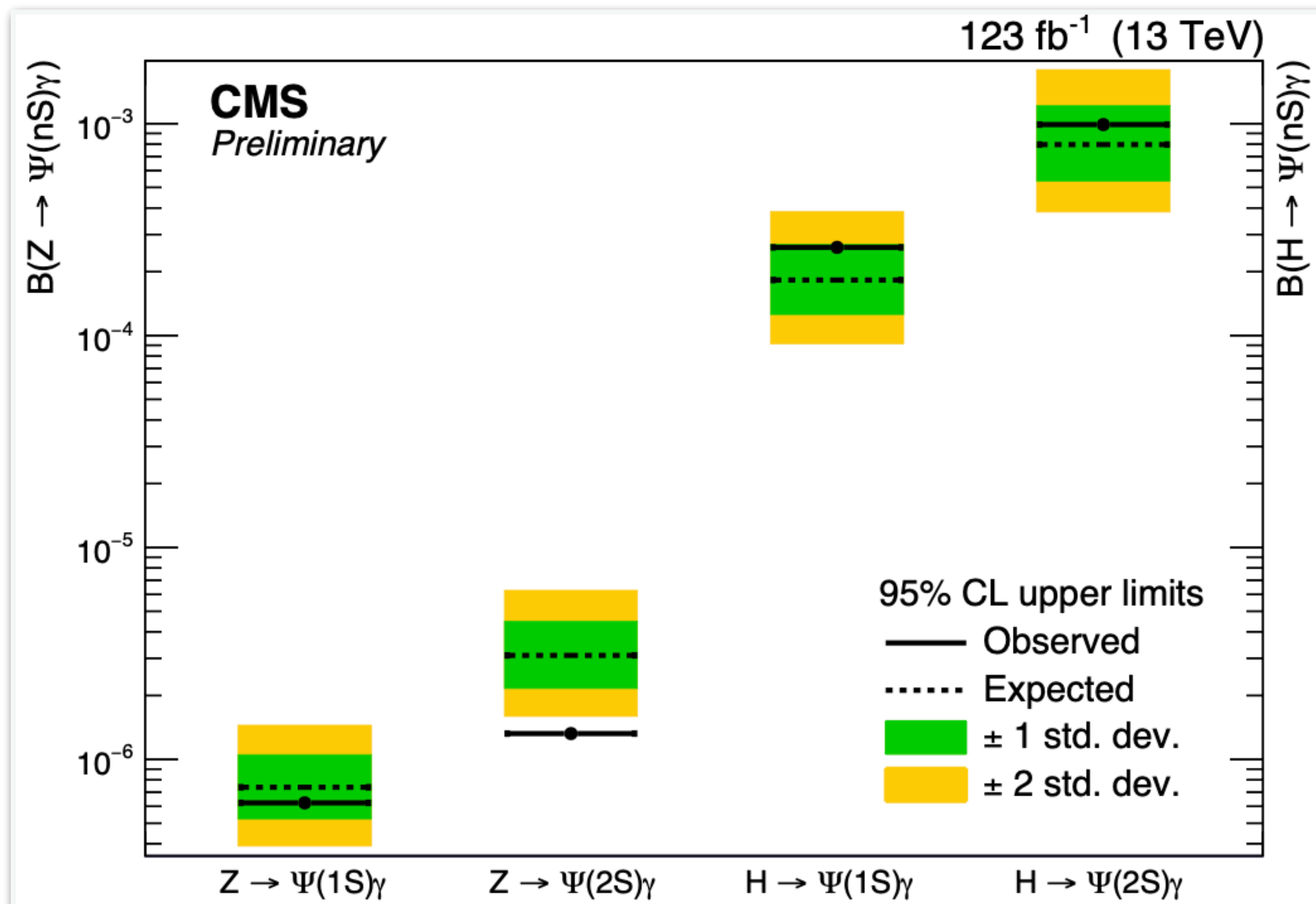



*LO Feynman diagrams of Z and H rare decays through direct and indirect processes*

- **No evidence for branching fractions to these rare decay channels larger than predicted in the SM is observed**
- **Interpretation of results to constrain ratio of Higgs boson coupling modifiers $\kappa_c/\kappa_\gamma$**
  - observed interval at 95% C.L.: $\kappa_c/\kappa_\gamma \in (-157, +199)$

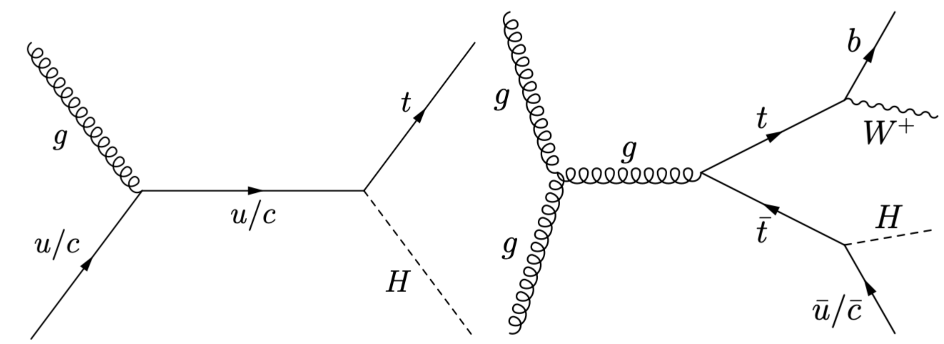
**Significant improvements w.r.t. 2016 analysis**




*Exclusion limits on the branching fraction*

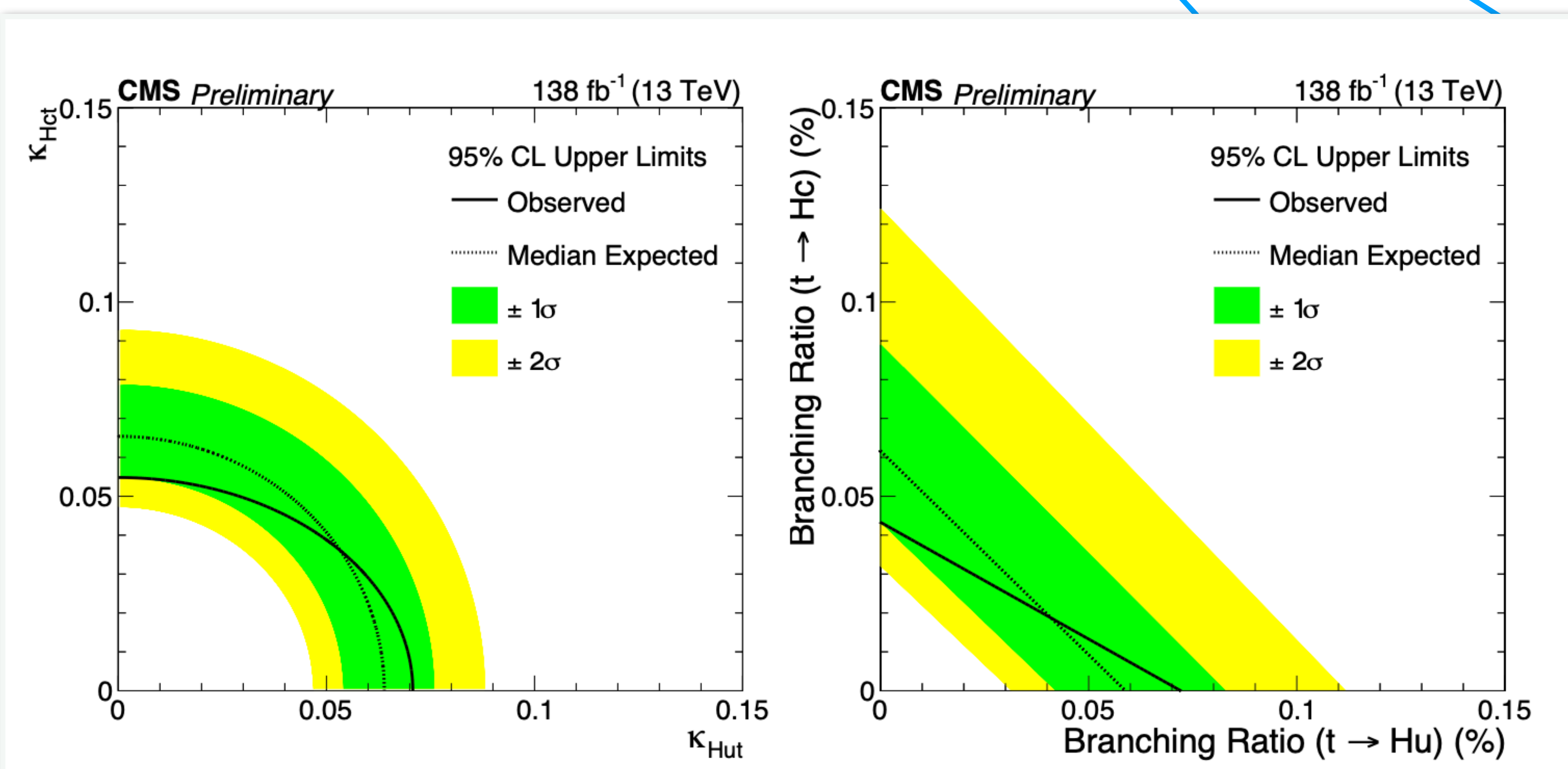
# Flavour Changing Neutral Currents in tHq

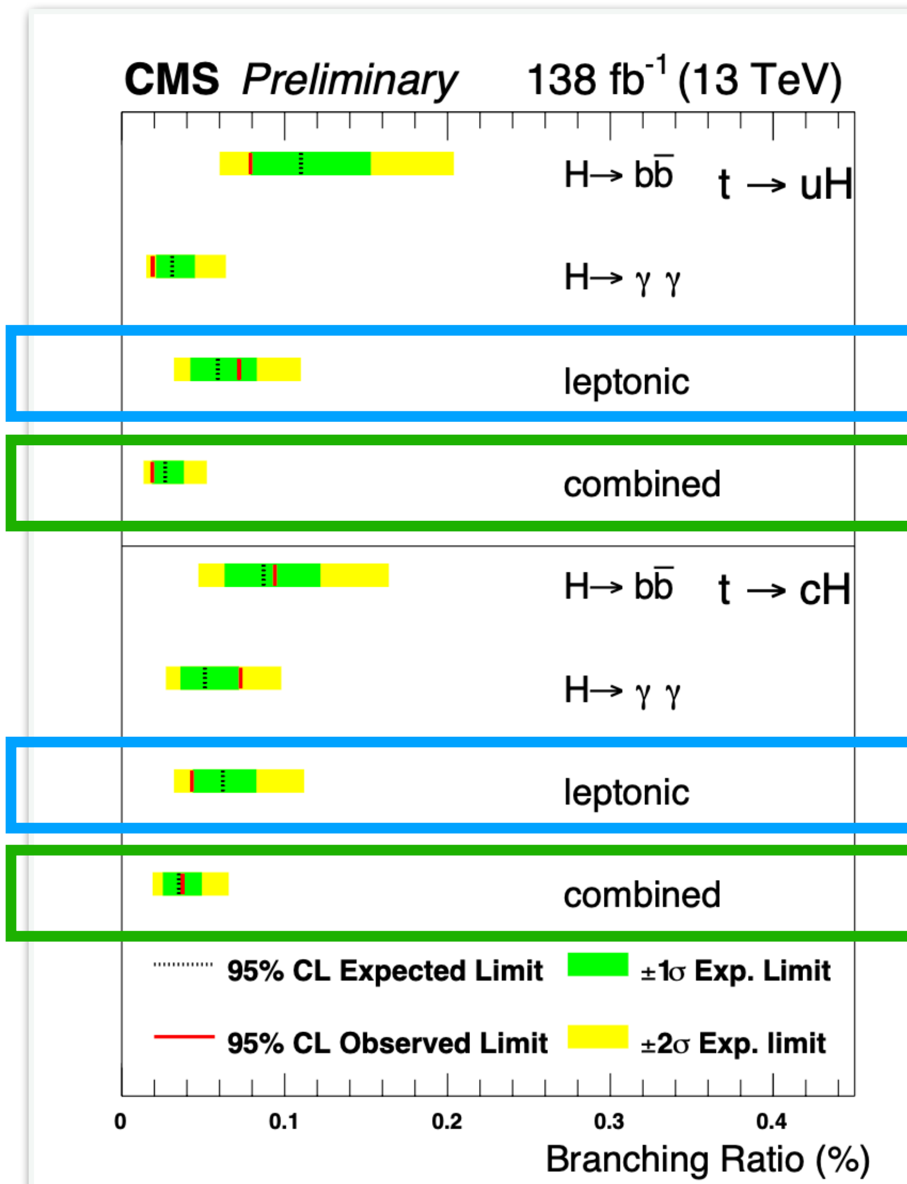
- Events containing a pair of leptons with the same-sign electric charge and at least one jet are considered




- **Observed (expected) 95% CL upper limits on branching ratio:**
  - 0.072% (0.059%) for B (t → Hu)
  - 0.043% (0.062%) for B(t → Hc)

- **Constraints on anomalous coupling strengths also derived**



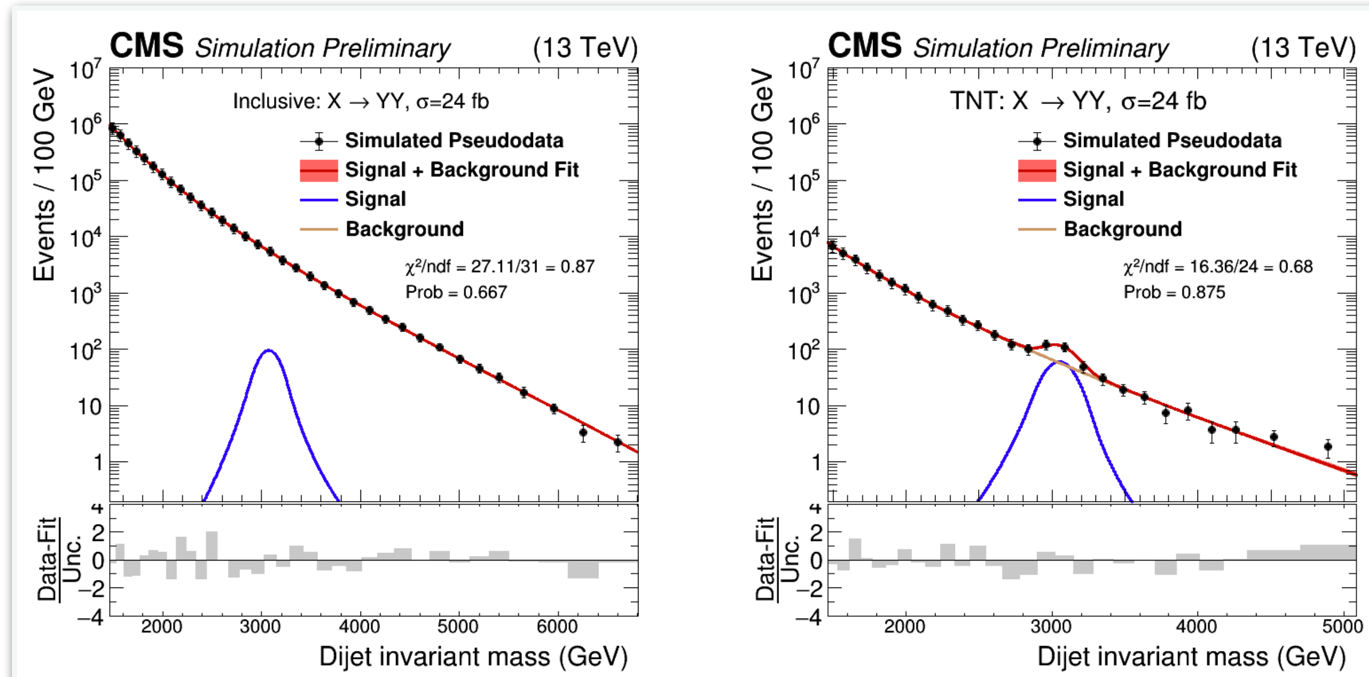



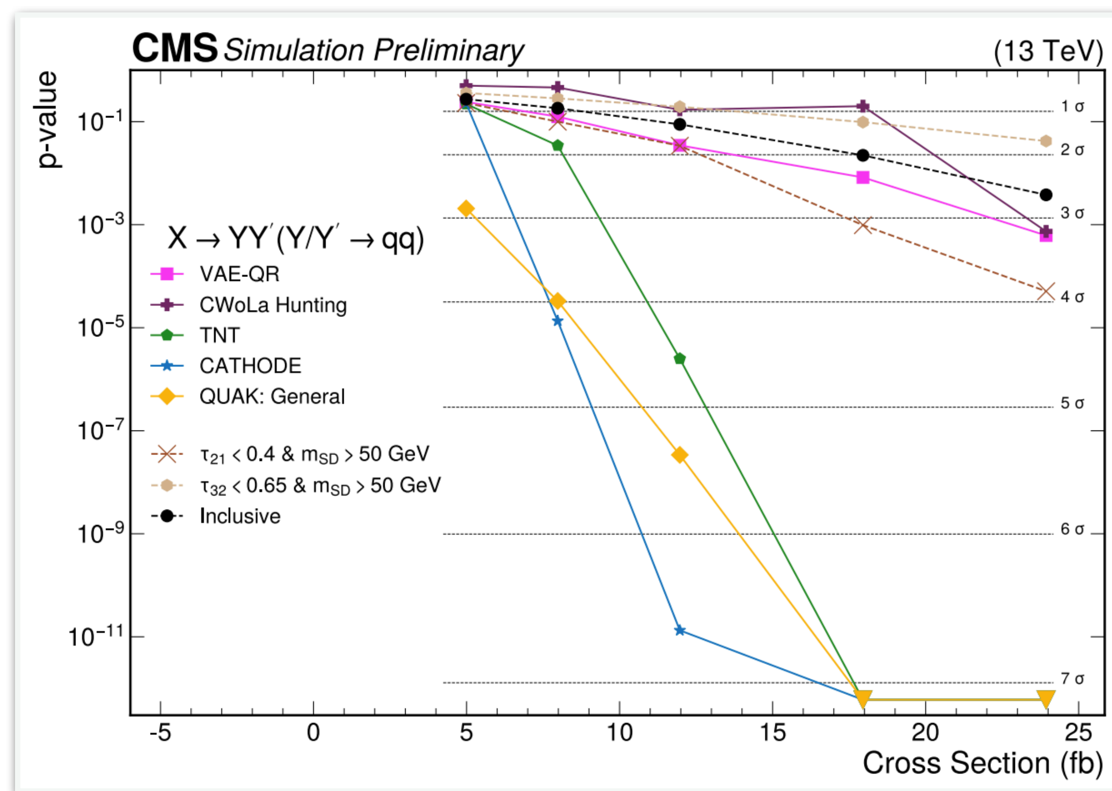

**Result of combination constitutes the best exclusion limits to date !**

# Machine learning techniques for model-independent searches in dijet final states

CMS-NOTE-2023-013

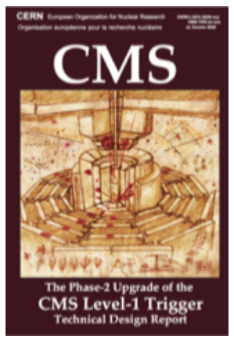
- **Investigated 5 unsupervised and semisupervised approaches to jet tagging**
- The aim is at pre-selecting a subset of dijet events with anomalous jet substructure and run a bump hunt, after removing overwhelming QCD background
- **Different approaches improve over inclusive dijet search**
- Different sensitivity to different models (complementarity of approaches)
- Analysis applying these methods to data is ongoing
- Dedicated data-driven method to measure efficiency for specific signal will be documented in dedicated paper




**TNT**: Tag and Train
**VAE-QR**: Particle-based Variational Autoencoder

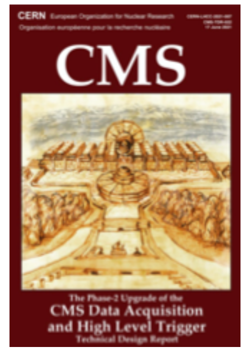
# The CMS Phase 2 Upgrade




## 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
- Heterogenous architecture
- 60 TB/s event network
- 7.5 kHz HLT output

## Barrel Calorimeters

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

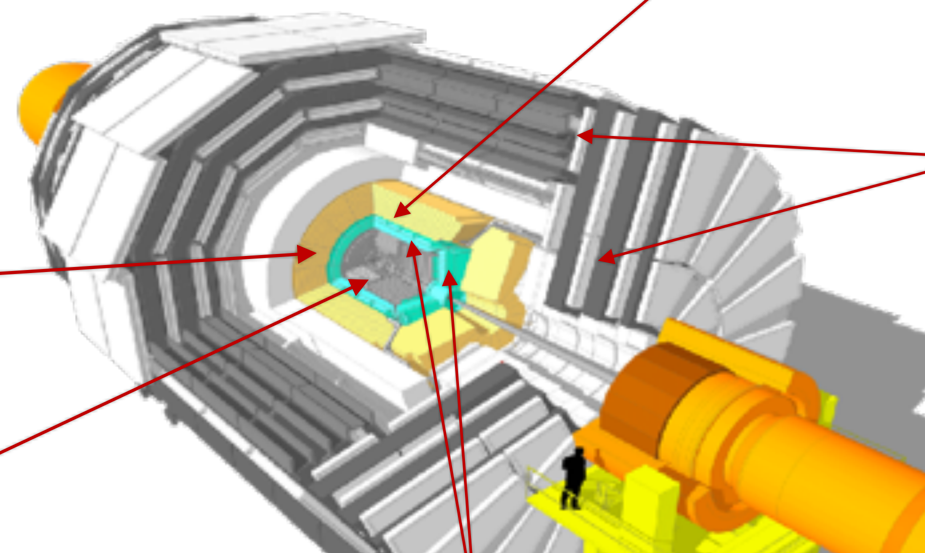
- ECAL crystal granularity readout at 40 MHz with precise timing for e/γ at 30 GeV
- ECAL and HCAL new Back-End boards



## Calorimeter Endcap

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

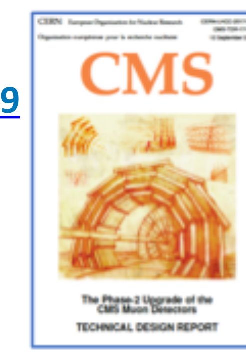
- 3D showers and precise timing
- Si, Scint+SiPM in Pb/W-SS



## Muon systems

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

- DT & CSC new FE/BE readout
- RPC back-end electronics
- New GEM/RPC 1.6 < η < 2.4
- Extended coverage to η ≃ 3

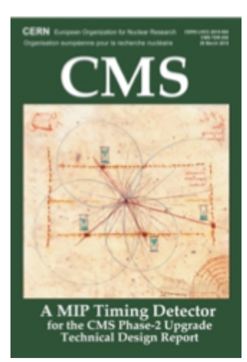




## Tracker

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

- Si-Strip and Pixels increased granularity
- 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

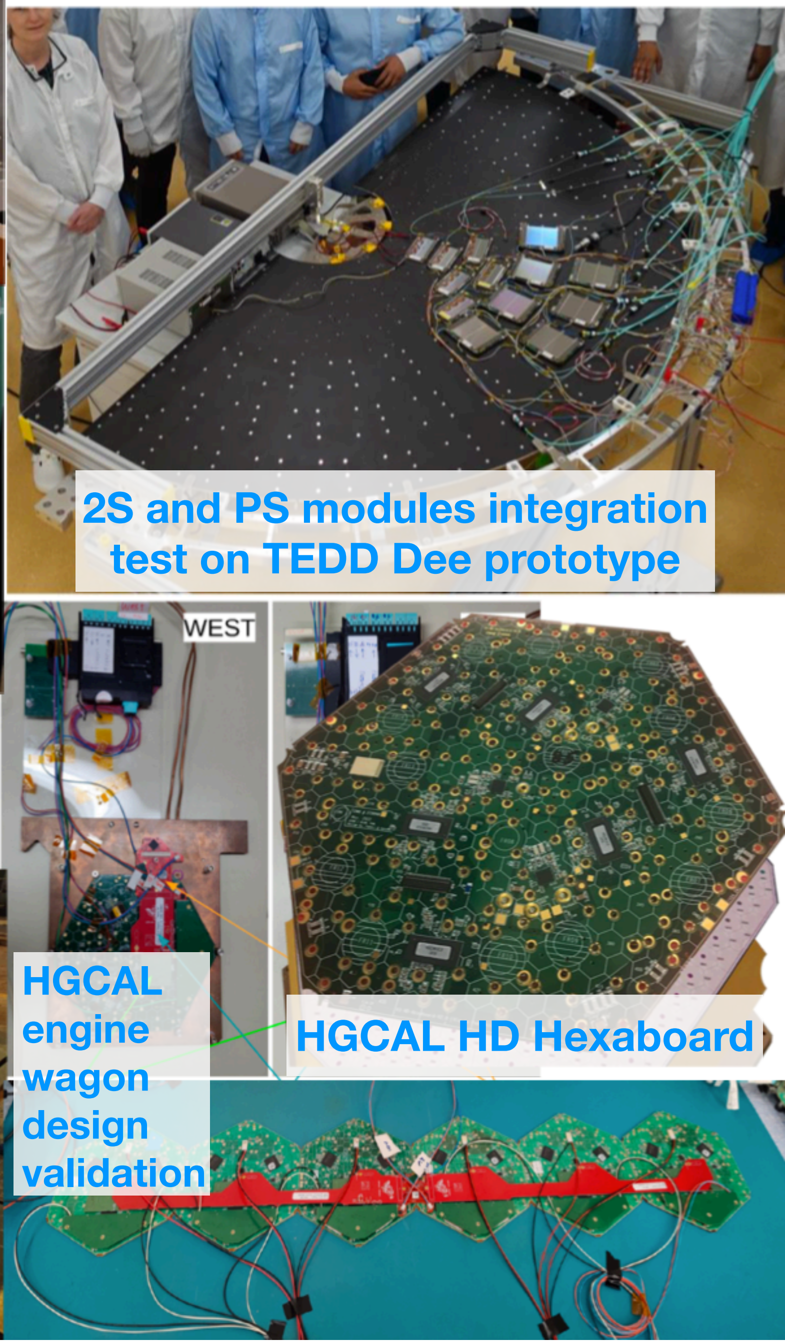
## Beam Radiation Instr. and Luminosity

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

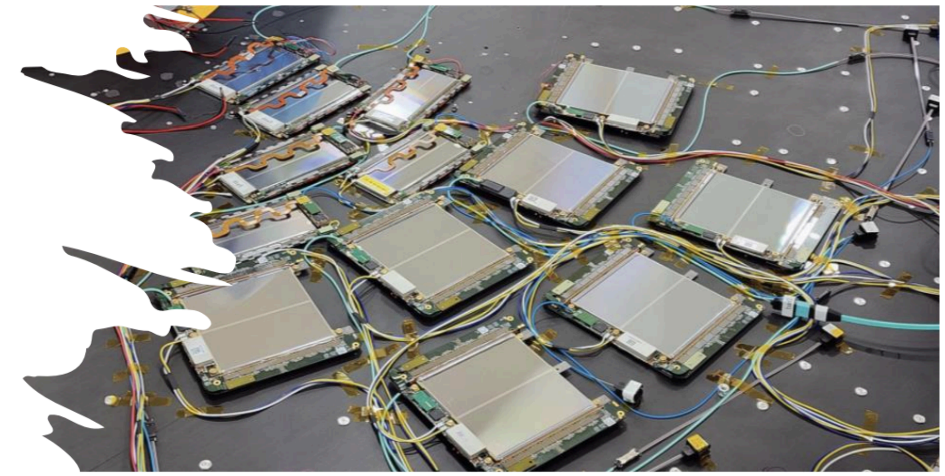
# The CMS Phase 2 Upgrade

*.. in pictures!*

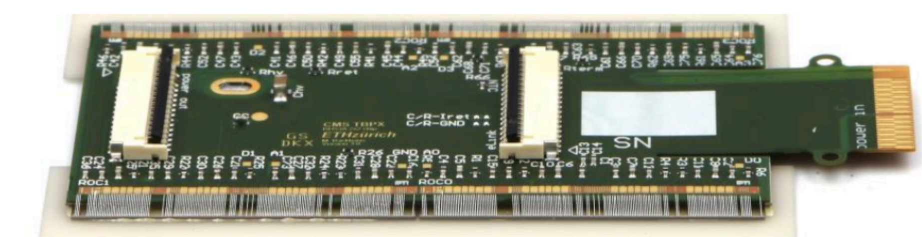



# Phase 2 Highlights in a nutshell

- **Tracker**
  - OT: excellent integration test (endcap, ladders)
  - OT: hybrid kickoff batch evaluated - all basic parameters, like noise excellent
  - OT: MaPSA pre-production started - two companies
  - IT: succesfully passed EDR
  - IT: final RD53 ASIC v12 - submitted
  - IT sensors: planar received; 3D ordered; Bump Bonding tender closed



*OT Modules*



*IT Module*

**IT** Inner Tracker aka Pixels; **OT** Outer Tracker
**EDR** Engineering Design Review – LHCC Step-III
**MaPSA** MacroPixel Sub-Assembly aka result of bump bonding
**MTD** MIP Timing Detector

# Phase 2 Highlights in a nutshell

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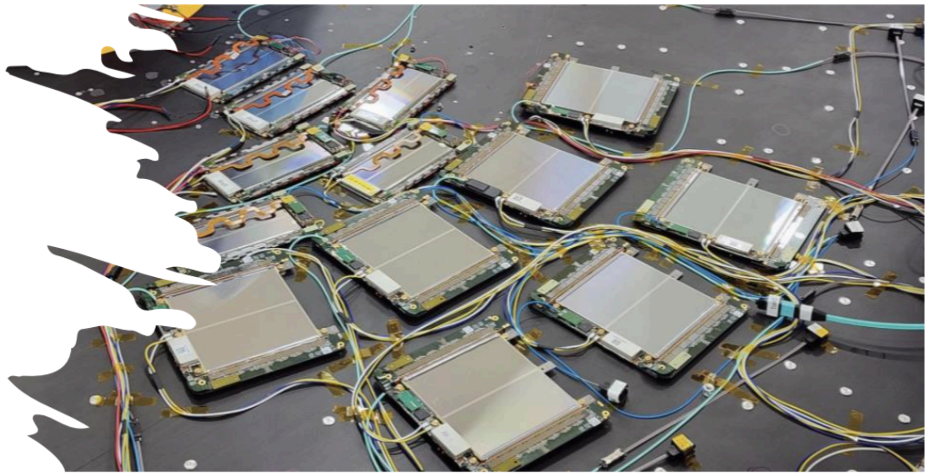
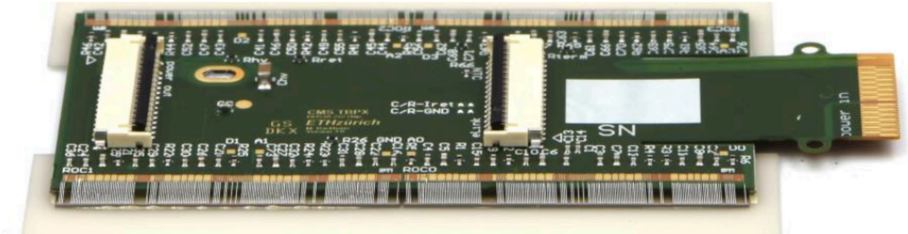
  - IT sensors: planar received; 3D ordered; Bump Bonding tender closed
- **MTD**
  - Barrel: successful EDR - ready for production; TDR timing resolution recovered - excellent
  - Endcap: successful Test beam of LGADs bump-bonded to ASIC - noise looks good
    - FE- ASIC (ETROC2) last prototype - full size, full functionality ASIC - looks good
- **Level-1 Trigger**
  - New SAMTEC Firefly12 optics received - looks good so far but further testing necessary

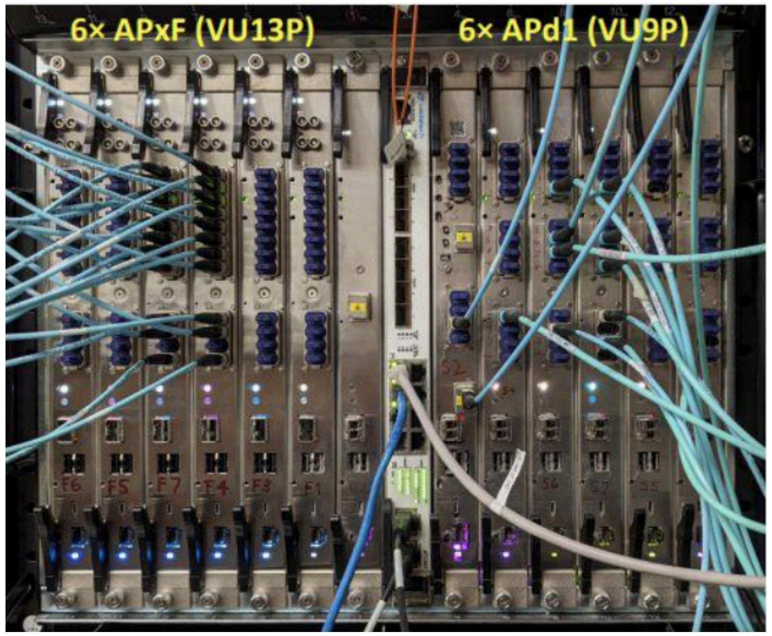
**IT** Inner Tracker aka Pixels; **OT** Outer Tracker
**EDR** Engineering Design Review – LHCC Step-III
**MaPSA** MacroPixel Sub-Assembly aka result of bump bonding
**MTD** MIP Timing Detector



*OT Modules*



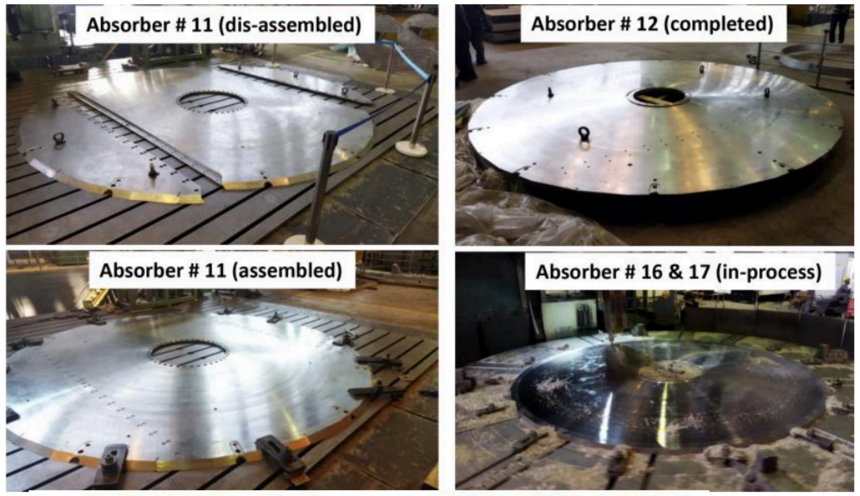
*IT Module*



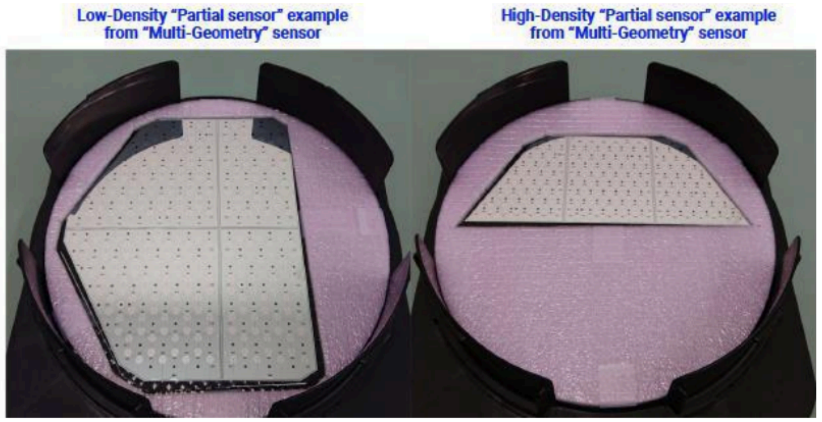

*L1T boards*

# Phase 2 Highlights in a nutshell

- **HGCAL**
  - Final layout optimisations finished improving S/N after radiation
  - ESR successfully passed
  - Silicon Sensors: low density - high quality; high density and 'partials' ordered
  - Final FE-ASIC (HGROC) received but *without BumpBonding balls* - back to the company
  - Final concentrator ECON ASICs on track to be submitted these days
  - Scintillator production started - machined/cast and moulded
  - Successful beam tests with full vertical Trigger and DAQ




***HGCAL absorber***




***HGCAL partial sensors***

**FBCM**: Fast Beam Condition Monitor
**ESR** Electronic System Review – LHCC Step-III

# Phase 2 Highlights in a nutshell

- **HGCAL**
  - Final layout optimisations finished improving S/N after radiation
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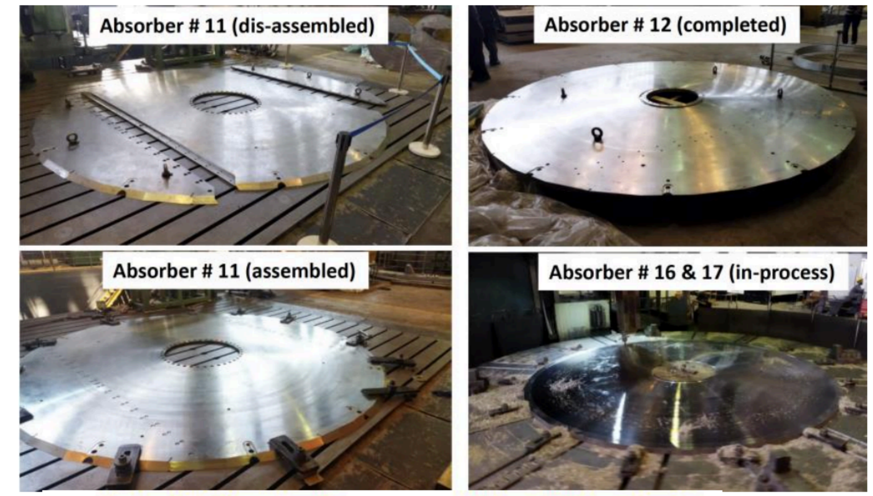
  - Successful beam tests with full vertical Trigger and DAQ

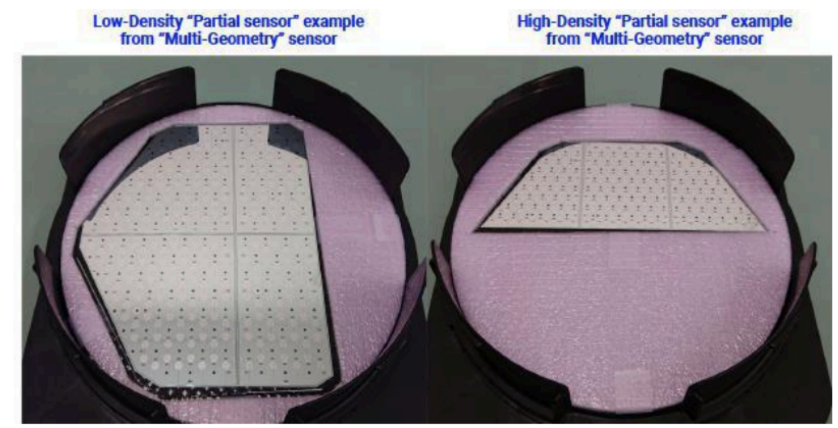
- **BRIL (Beam Radiation Instrumentation Luminosity)**
  - FBCM FE-ASIC (1st prototype) received - so far, all tests look good
  - Adapted Neutron Monitor strategy: Tetra Ball

- **Muons**
  - GEM ME0 foils - production started

- **Barrel CALO, DAQ progressing smoothly**

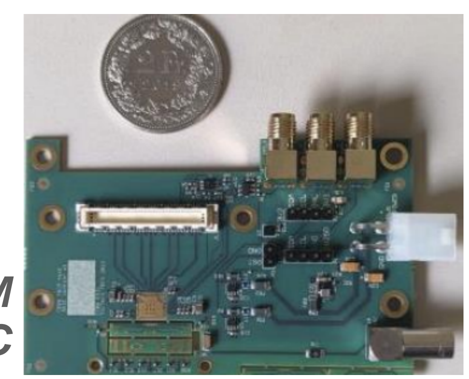


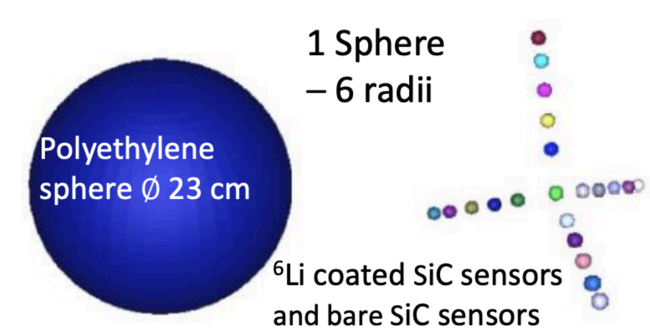

***HGCAL absorber***




***HGCAL partial sensors***

***FBCM ASIC***



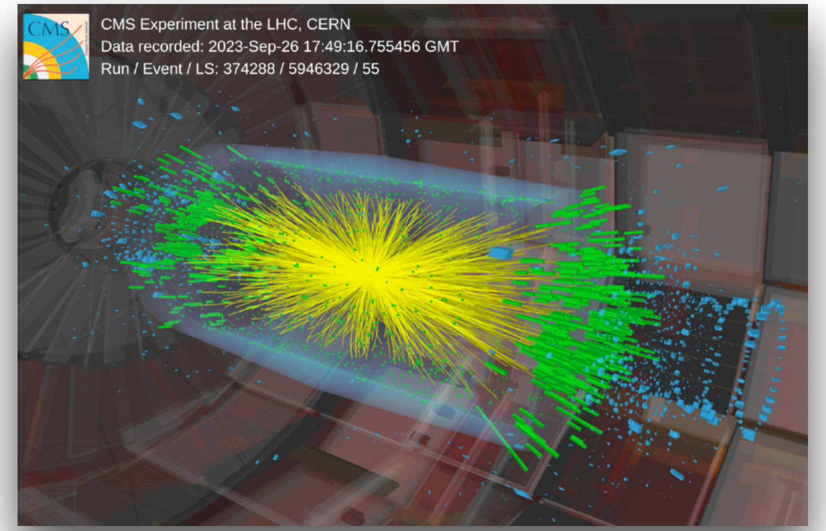



***Tetra Ball***

***BCAL Enfourneur: installation platform***

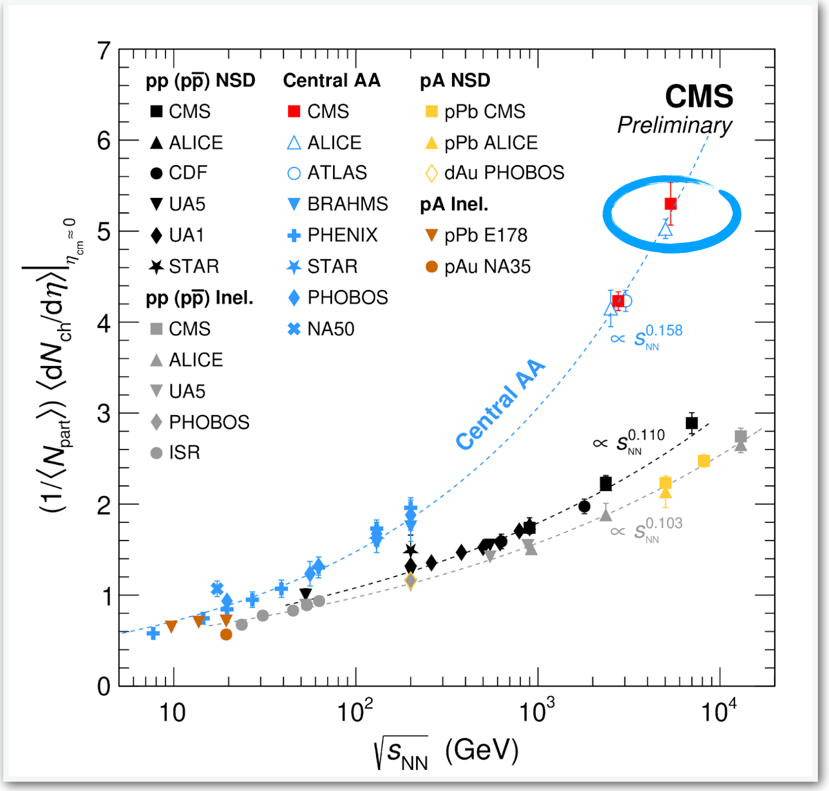
**FBCM**: Fast Beam Condition Monitor
**ESR** Electronic System Review – LHCC Step-III

# Summary




- **Stable CMS operations during 2023 pp and Heavy Ion data taking**
- End of run was smooth, no major incidents on infrastructure
- Lots of work now ongoing during YETS to advance on major activities
- A lot of **interesting physics analyses and technical results** approved
- **Heavy Ion performance looks good**
  - *have a look at the LHCC posters session!*
- **First HI analysis at a record √sNN** (using 2022 data)
  - charged particle dN/dη in PbPb at 5.36 TeV
- **CMS Phase 2 Upgrade work proceeding well**

CMS-PAS-HIN-23-007




*.. in Jan/Feb 24 CERN courier !*

***Thanks to LHC***

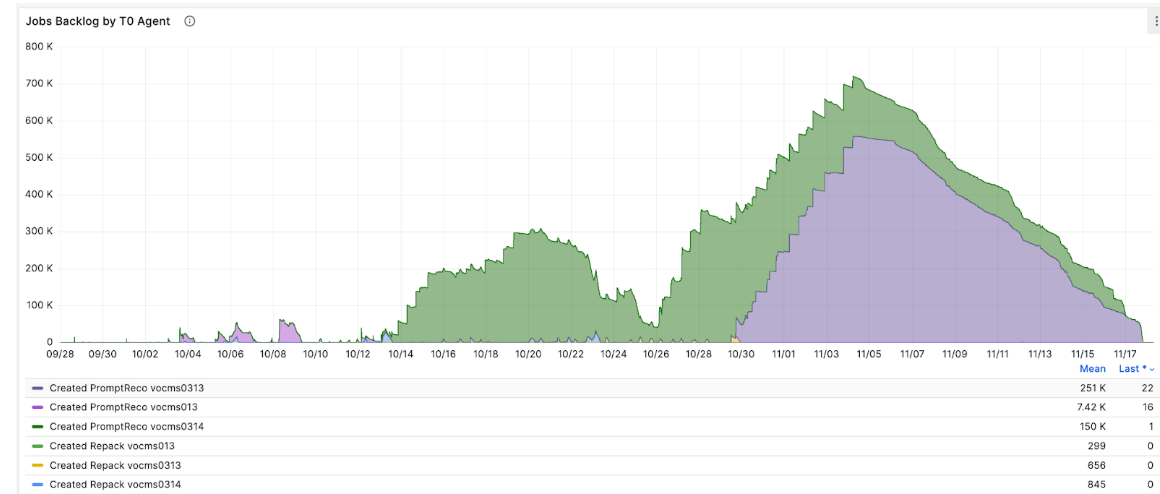
***for outstanding efforts in delivering***

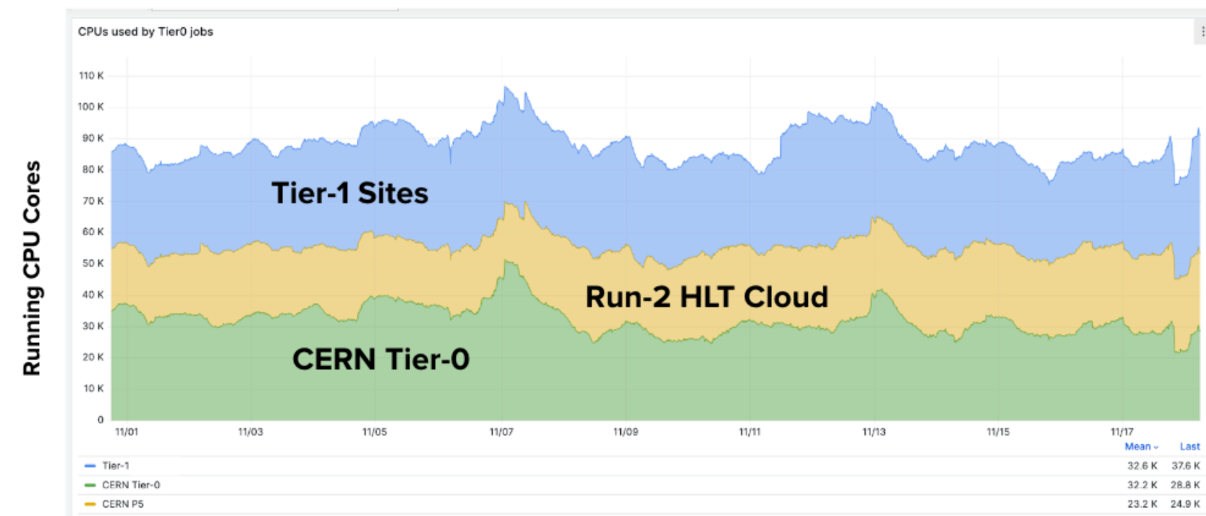
***Run 3 proton-proton and Heavy Ion data!***

# BACKUP

# Offline software & Computing

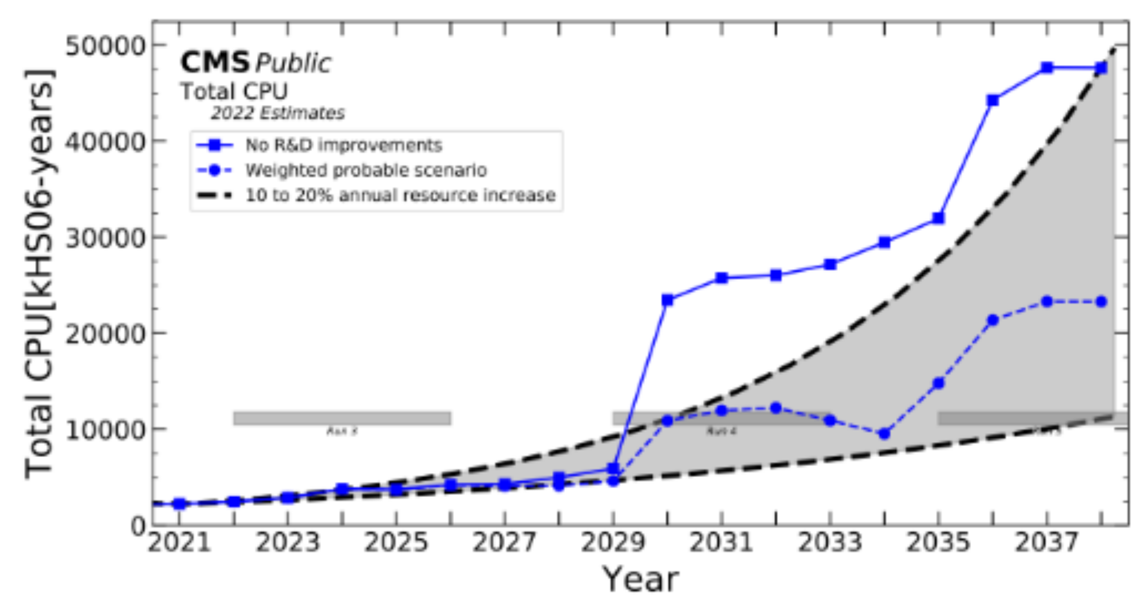
- **Data Taking Experience of the HI Run:**
  - Heavy Ion trigger designed to max out the DAQ bandwidth, backlog correlates with integrated lumi
  - no backlog for processes that have to finish within 48 hours
  - Tier-0 backlog of prompt-reco of the HI data has cleared in record time, a big success
  - Tier-0 processes were run at several Tier-1 sites at scale and the Run-2 HLT Cloud at P5
  - excellent performance of the distributed computing infrastructure, sites, and our operations teams!




- **Heavy Ion group requested a re-reconstruction of the UPC events (about 30% of the total events and 5% of the total by volume)**
  - goal is to greatly improve the low-pt reconstruction efficiencies of tracks and egamma objects

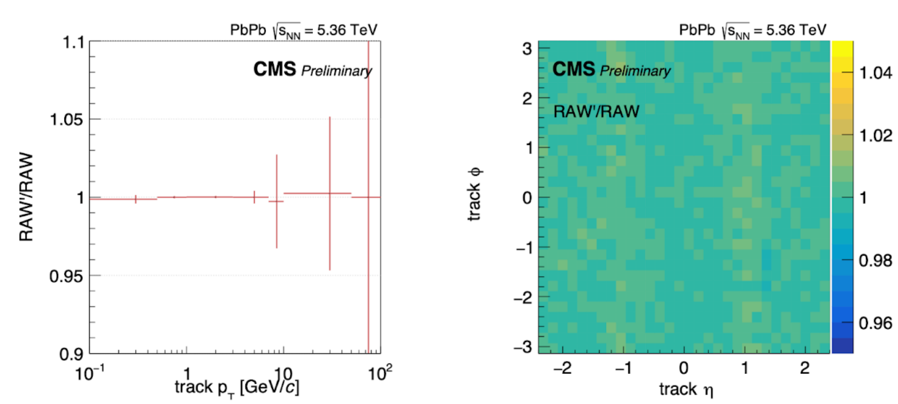
- **Increments in resource needs during LS3 expected to be relatively modest**
  - final 2025 resource request finalized in early 2024



# Data reduction - RAW’

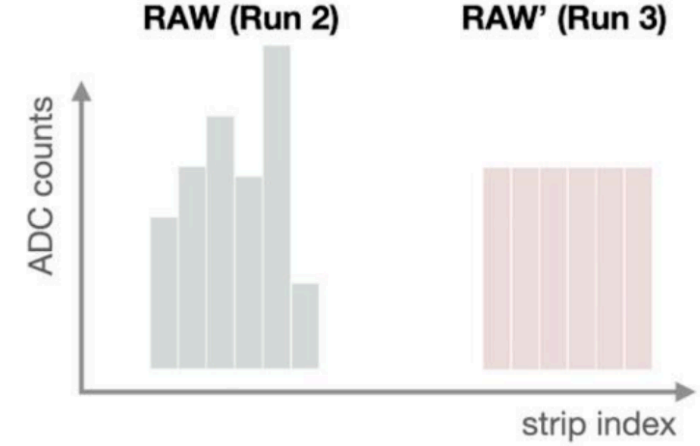
- Heavy Ion physics program limited by amount of DAQ data that can be transferred out of P5
- R&D to minimize the size of the RAW so that more events can be collected is necessary
- Strip tracker RAW data (~65% of PbPb event size) replaced with RAW’, processed “approximated” clusters information
- RAW’ in HLT validated and deployed this year
- Tracking good enough for HI analysis - promising approach for Run 3 strip detectors
- Reduces the size of the RAW by 40% and lossless compression can be applied on top of this approximation

**Tracks obtained with RAW and RAW’ cluster format**




Caption: Ratios of tracks’ $p_T$ (left), and η-φ (right) on the same event collection with RAW and RAW’ data format. An agreement better than 2% between RAW and RAW’ is observed throughout a wide $p_T$ range.

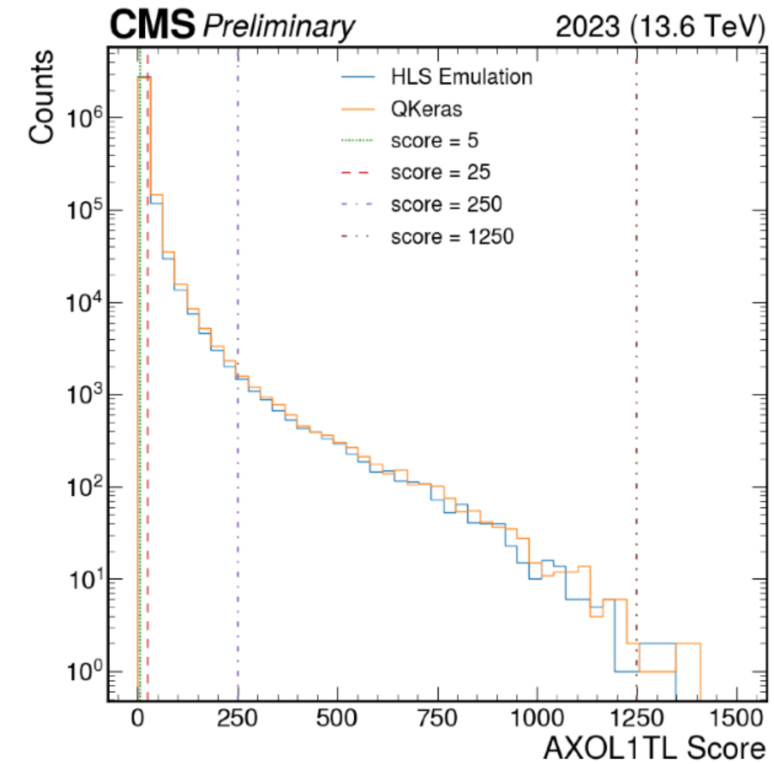
to be updated w/ more statistics



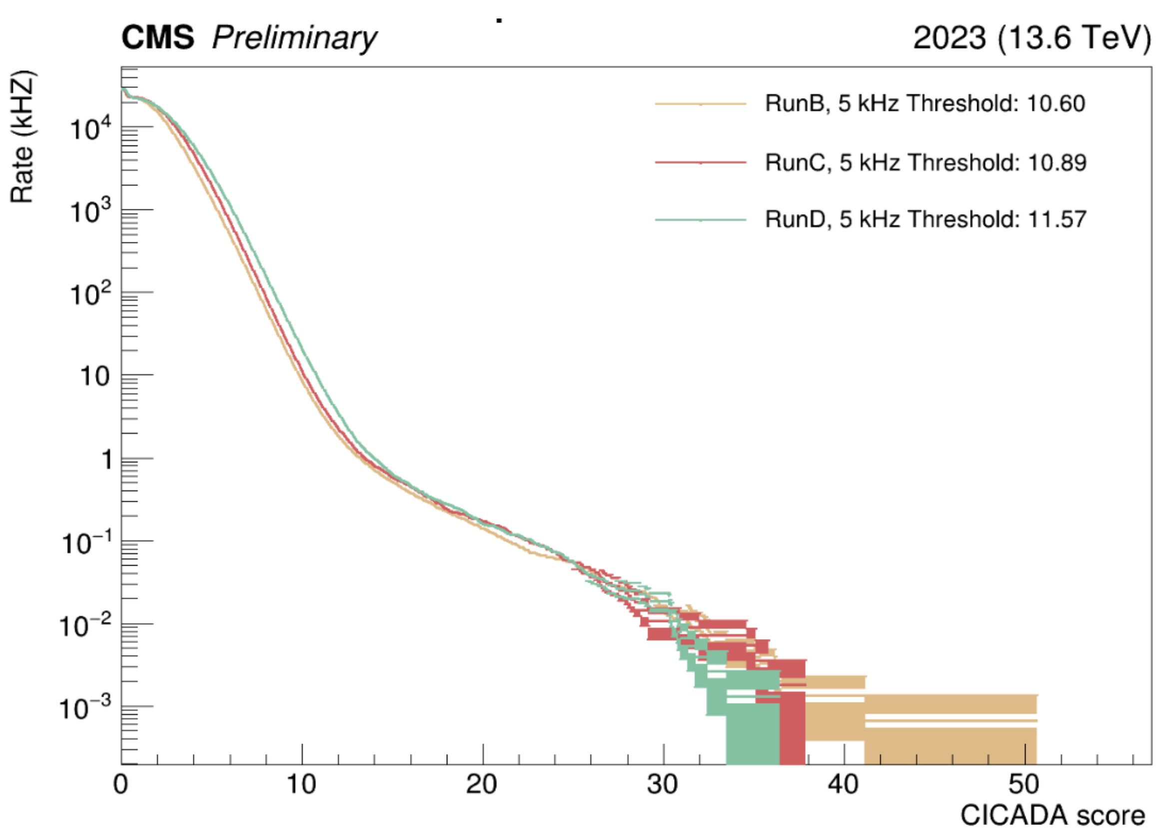

| SST cluster format | RAW | | | RAW’ | |
|---|---|---|---|---|---|
| Stored content | Strip index | | ADC counts (8-bit int) | Approximated cluster properties | |
| Example stored tracker data | First strip 123 (16-bit int) | | 75 | • Barycenter = 125.5 (10-bit int) (We store 10x barycenter as int)<br>• Size = 6 (6-bit int)<br>• Average charge = 100 (8-bit int)<br>• Cluster shape: (1-bit Boolean)<br>  • Saturated strip<br>  • Peak filter | [Event-basis] FED modules & readout error info |
| | (derived by first strip & ADC list) | 124 | 103 | | |
| | | 125 | 127 | | |
| | | 126 | 94 | | |
| | | 127 | 161 | | |
| | | 128 | 42 | | |
| Example total bits per cluster | 16 + 8*6 = 64 bits | | | 10 + 6 + 8 + 1*2 = 26 bits + smaller FED error contribution | |

# Anomaly detection with ML at L1

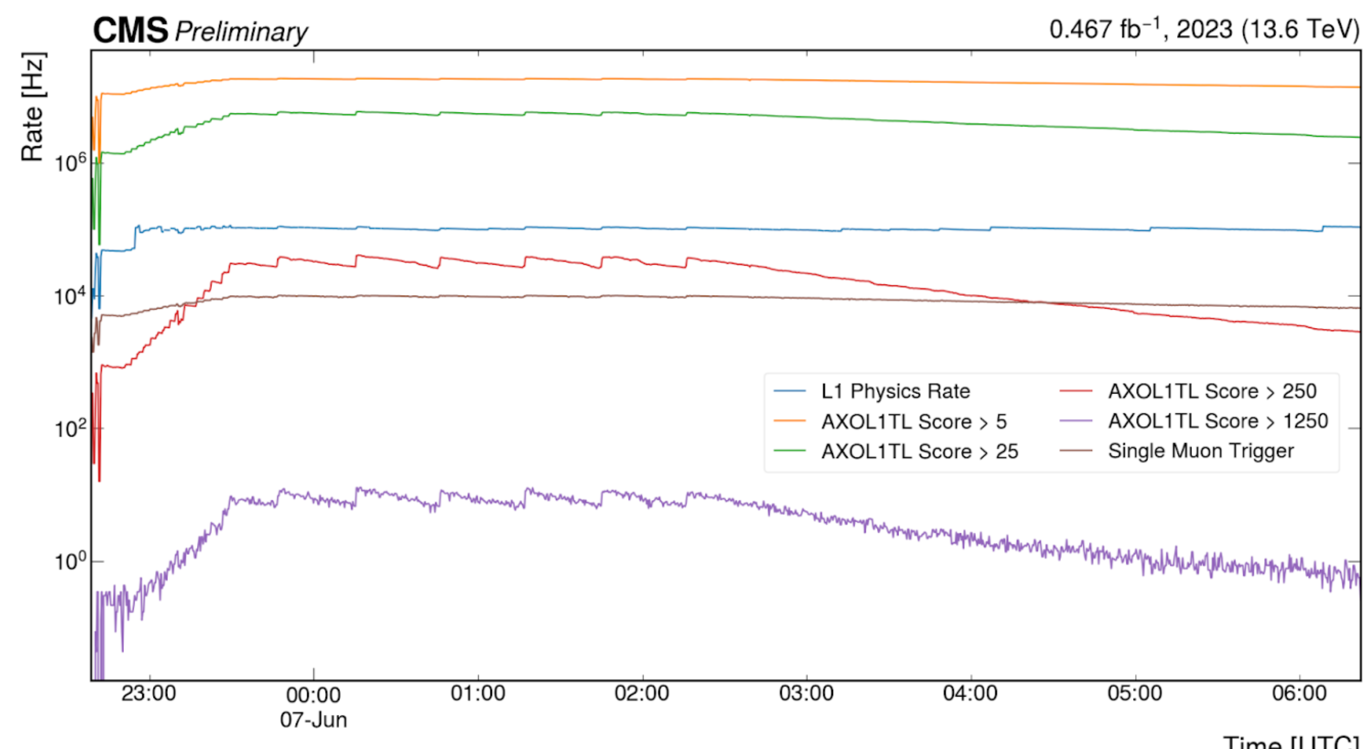
- **Active development of machine learning based anomaly detection triggers at L1**
  - AXOL1TL: DP-2023-079
    - Combines L1 objects (muons, EG, jets, MET) from μGT
    - Successfully running in μGT in 2023
  - CICADA: DP-2023-086
    - CNN auto encoder with calo $E_T$ deposits as inputs




***Anomaly score distributions***




***Rate from efficiencies obtained using scores as a threshold***




***Test crate rate monitoring time series***

# 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

- **Legacy lasers moved from old to new laser lab early November**
    - laser recommissioning going on smoothly
    - aiming to give green light for removal of old laser lab by end of November

- **New, more powerful green laser, is required to compensate for further radiation-induced transparency loss and increased attenuation from the relocation**
    - continue commissioning of new green laser in February 2024

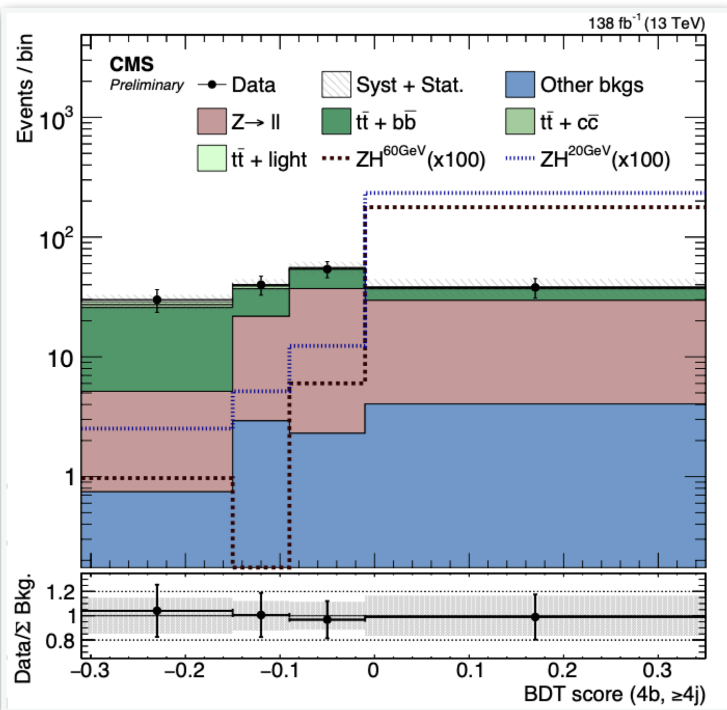



# Search for the decay of H to a pair of light pseudoscalar bosons in the bbbb final state

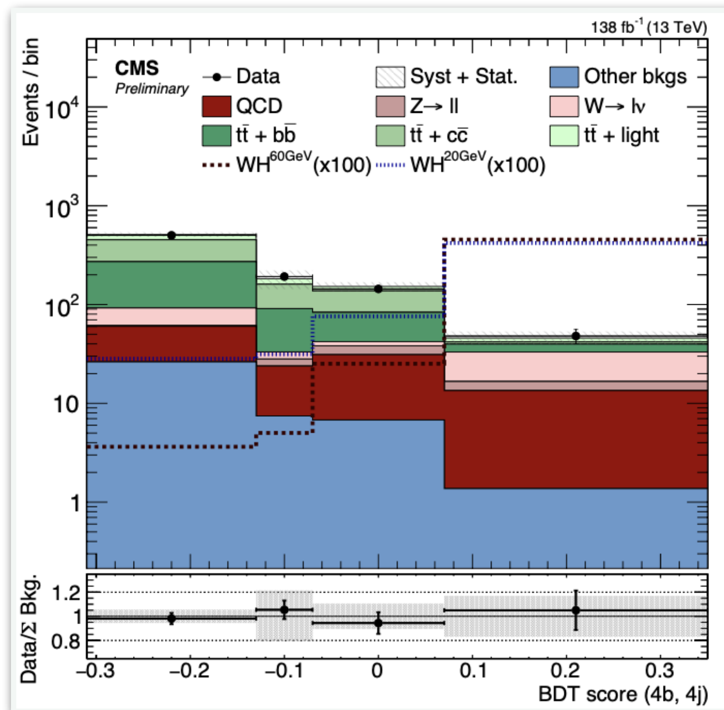
HIG-18-026

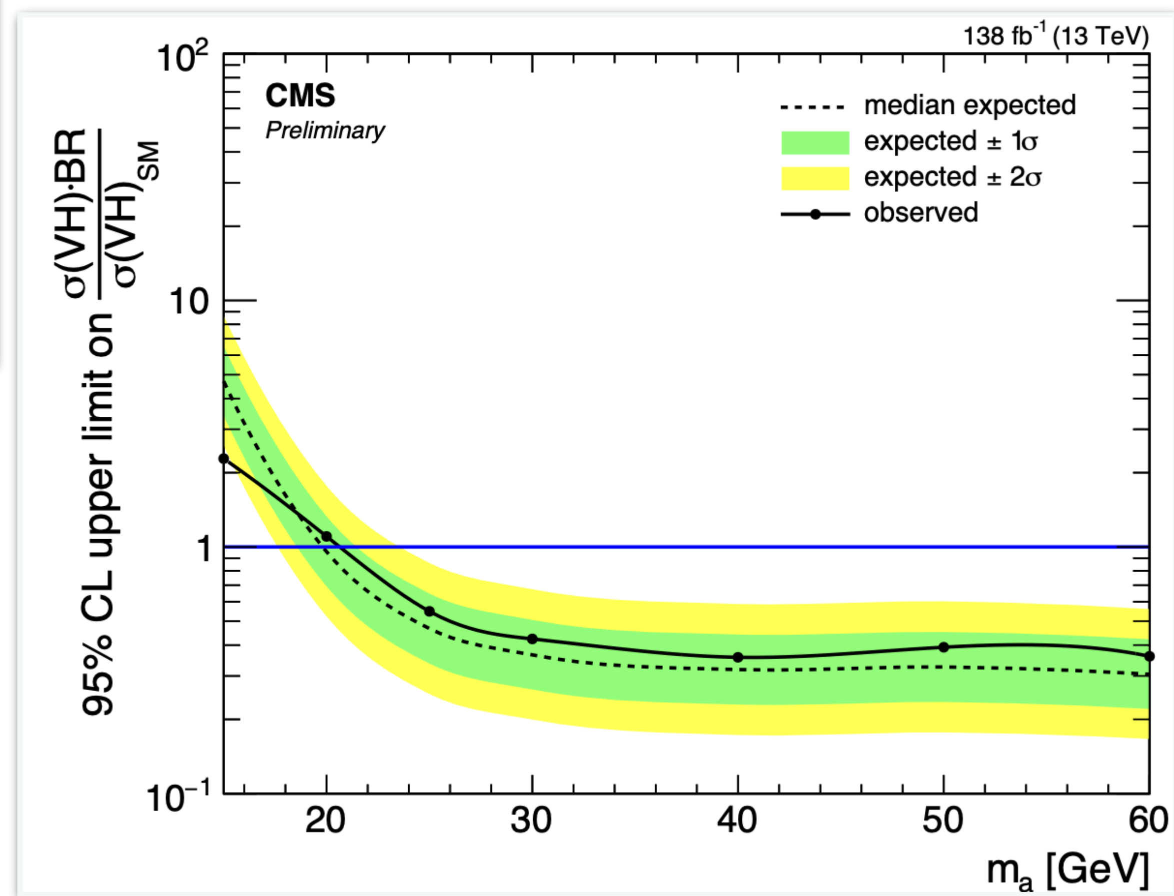
- Making use of the W and Z associated Higgs boson production to suppress the backgrounds

*ZH production*




*WH production*



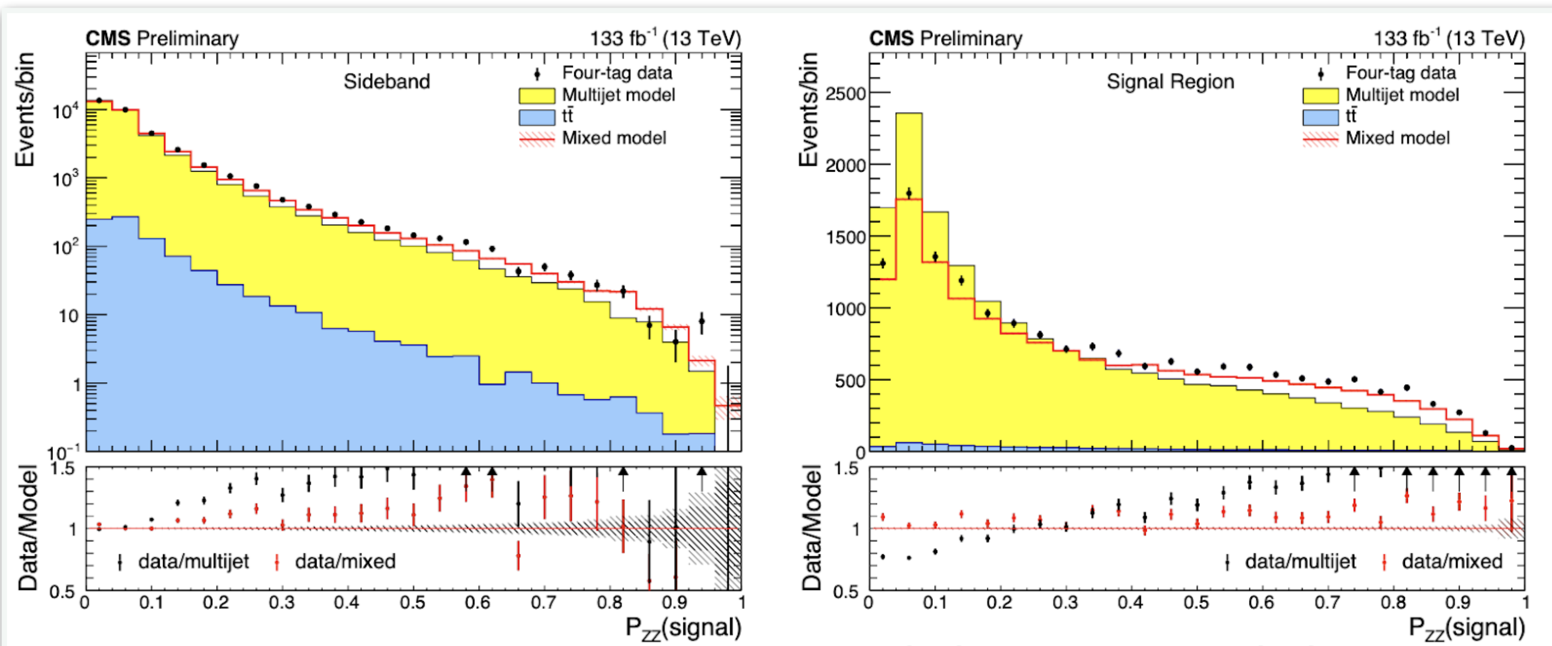




- The **first search in this channel** from CMS
  - ATLAS results were based on 2016-only data

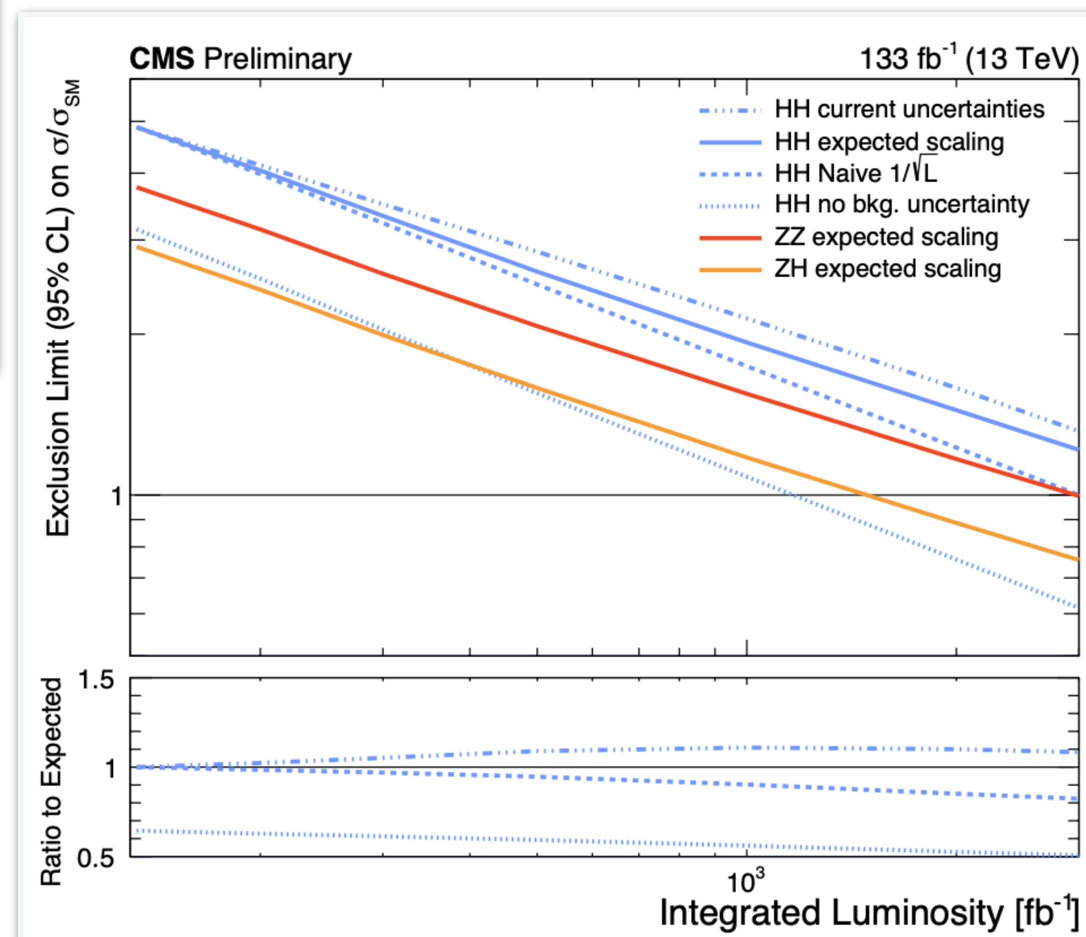
# Search for ZZ and ZH production in the four b-jet final state

HIG-22-011

- Several novel techniques for deriving and validating the data-driven background model for the HH→bbbb search: synthetic data sets from the hemisphere-mixing technique



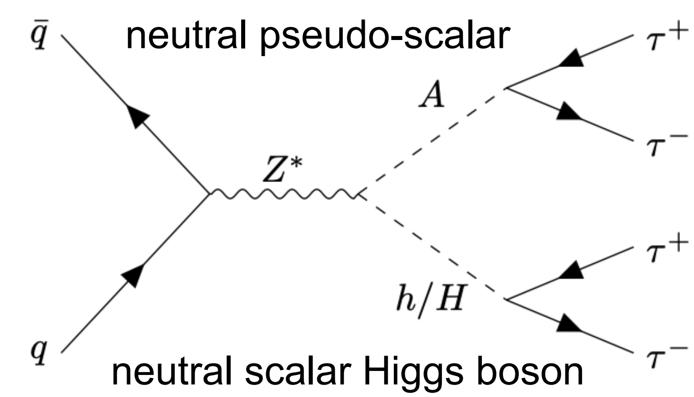

- Both the extrapolation uncertainty and variance of the background model is measured with a precision better than the statistical uncertainties of the four-tag data

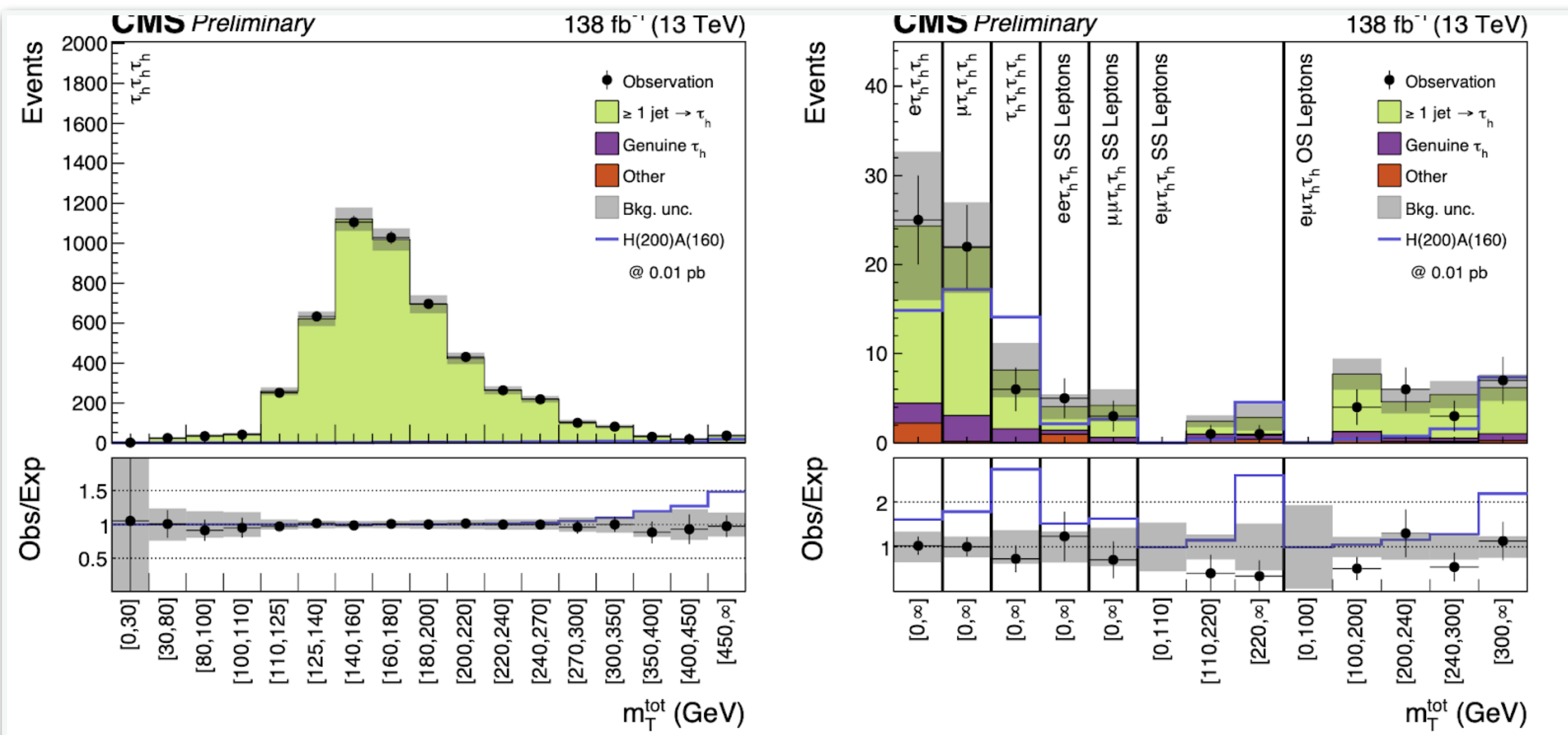


# Search for the production of two additional Higgs bosons from an off-shell Z boson

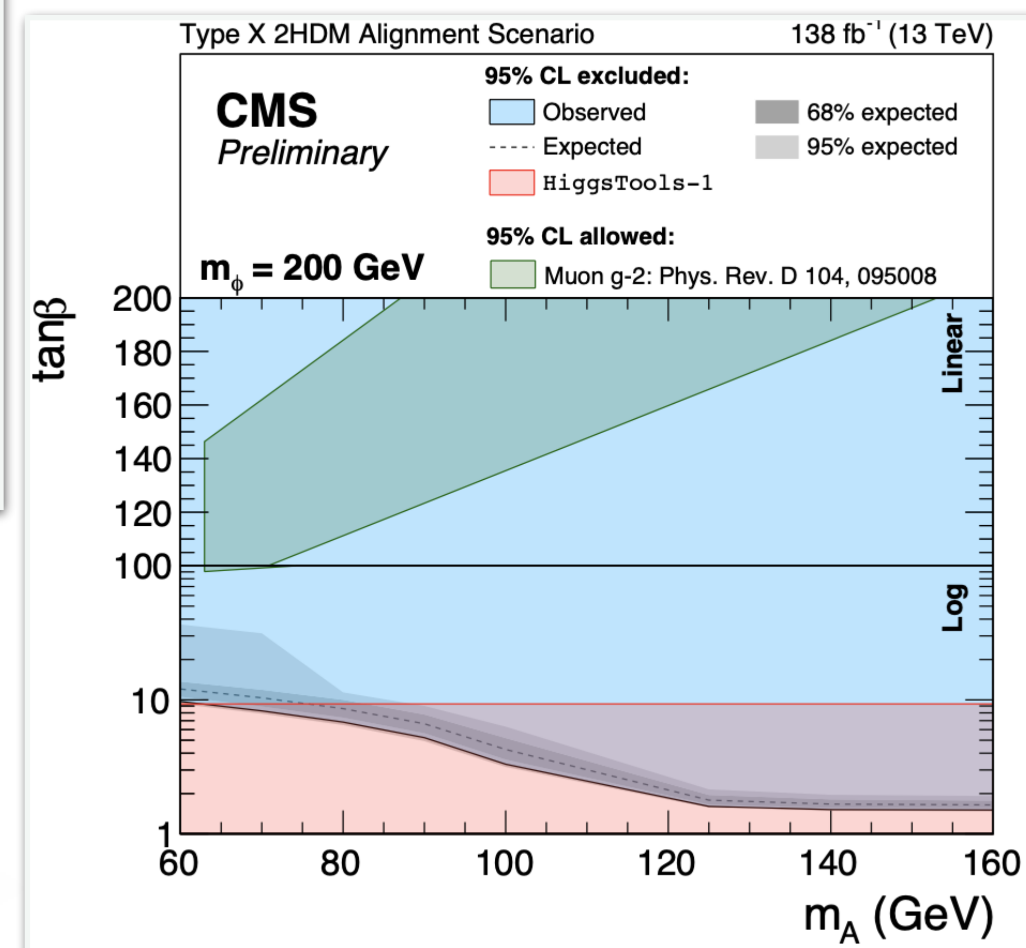
SUS-23-007

- Six $\tau\tau\tau\tau$ final states, accounting for ~87% of the branching fraction
- No deviation from Standard Model background is observed




***Distributions of discriminant variable after a background-only fit to data***

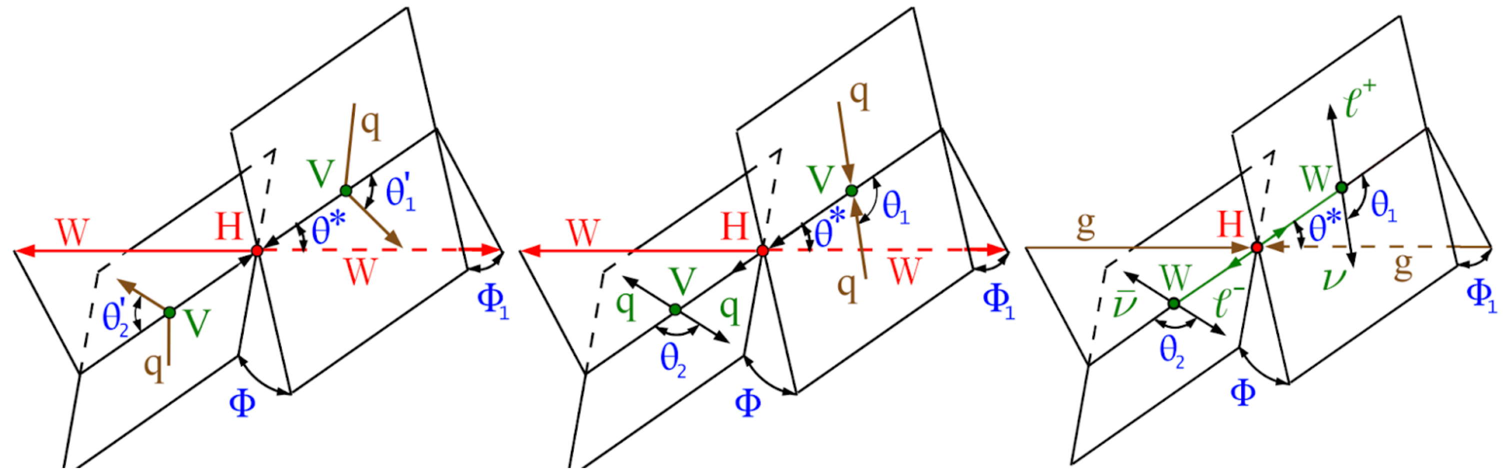



**These limits rule out the Type X 2HDM model as an explanation for the muon anomalous magnetic moment**

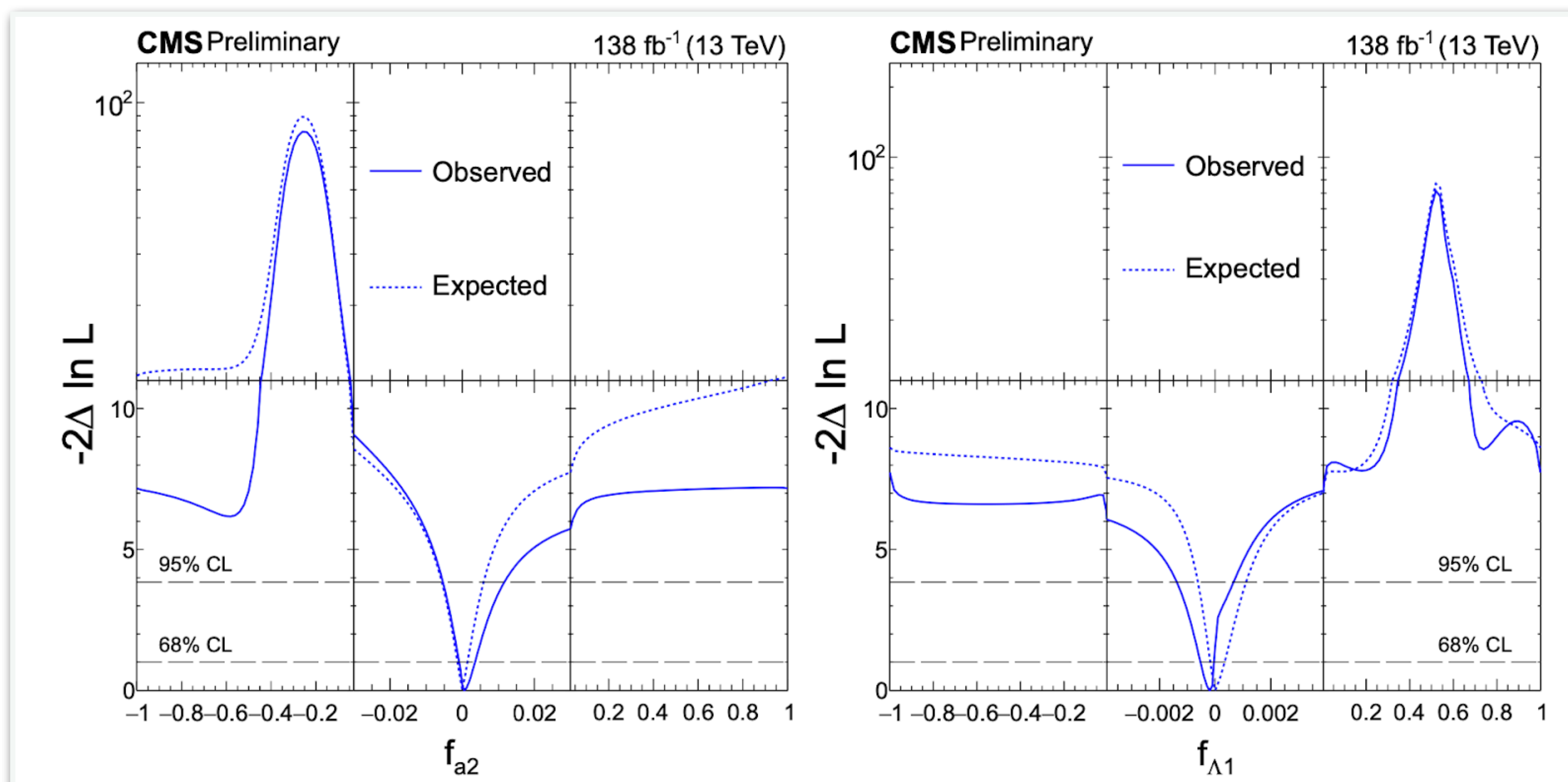
# Anomalous Couplings in H→WW

HIG-22-008

- Angular analysis of H→WW decays via matrix element method
- Studied different production mechanisms
- Probed fraction of anomalous couplings on top of SM matrix element contribution
- Result translated in bounds on Wilson coefficients in Warsaw basis




| Coupling | Observed | Expected |
|---|---|---|
| $c_{H\Box}$ | $-0.76^{+1.43}_{-3.43}$ | $0.0^{+1.37}_{-1.84}$ |
| $c_{HD}$ | $-0.12^{+0.93}_{-0.32}$ | $0.0^{+0.43}_{-0.30}$ |
| $c_{HW}$ | $0.08^{+0.43}_{-0.87}$ | $0.0^{+0.37}_{-0.48}$ |
| $c_{HWB}$ | $0.17^{+0.88}_{-1.79}$ | $0.0^{+0.77}_{-0.96}$ |
| $c_{HB}$ | $0.03^{+0.13}_{-0.26}$ | $0.0^{+0.11}_{-0.14}$ |
| $c_{H\tilde{W}}$ | $-0.26^{+0.67}_{-0.50}$ | $0.0^{+0.48}_{-0.52}$ |
| $c_{H\tilde{W}B}$ | $-0.54^{+1.37}_{-1.03}$ | $0.0^{+0.99}_{-1.07}$ |
| $c_{H\tilde{B}}$ | $-0.08^{+0.20}_{-0.15}$ | $0.0^{+0.15}_{-0.16}$ |



# Portable Acceleration of CMS Mini-AOD Production with Coprocessors as a Service

MLG-23-001

- Technical paper on using server for Machine learning inference when producing MiniAOD
  - shows how to run ML on accelerators (e.g. GPUs) even at CPU-only sites, by running inference through network
  - shows how to run ML inference locally by using a central server accessed asynchronously
  - PAS presented at FastML workshop in London
  - publication planned on CSBS (CWR just started)