



CMS Results

From Current Constraints to the HL-LHC

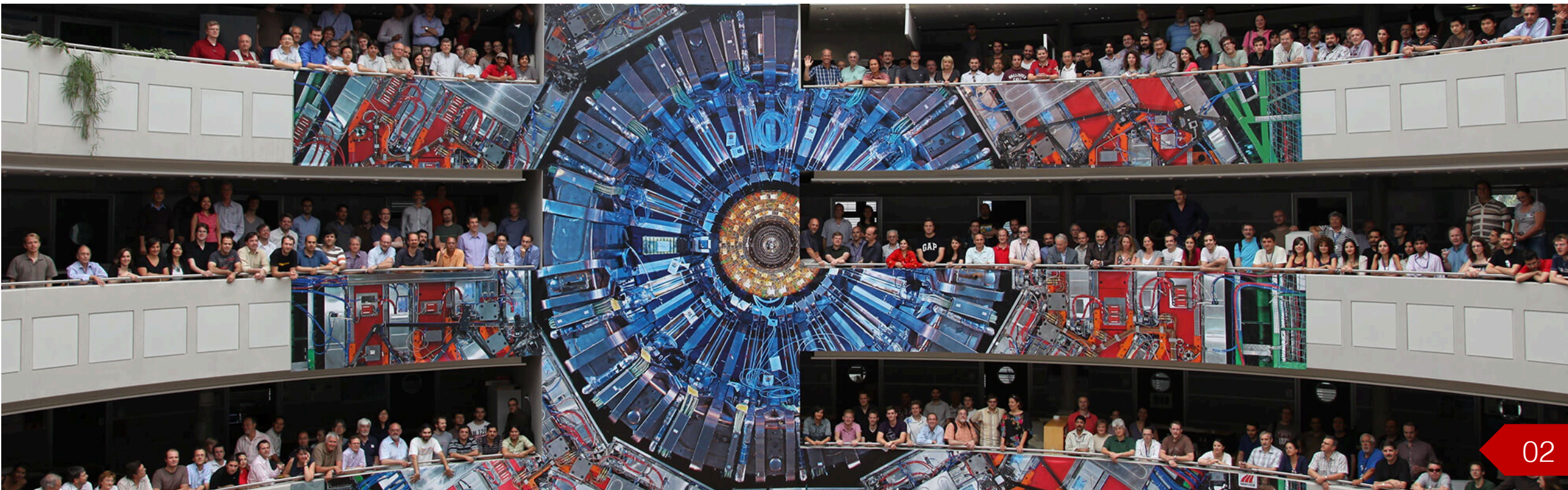
Cristina Oropeza Barrera

Universidad Iberoamericana Ciudad de México

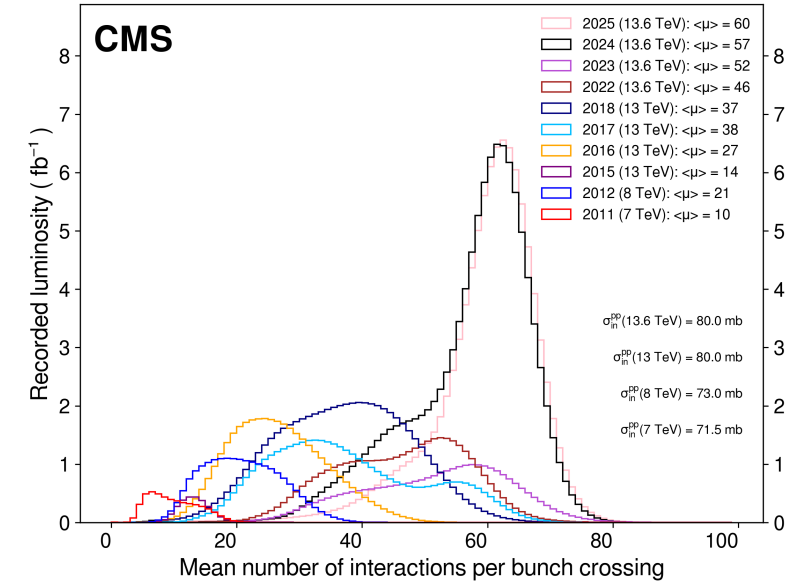
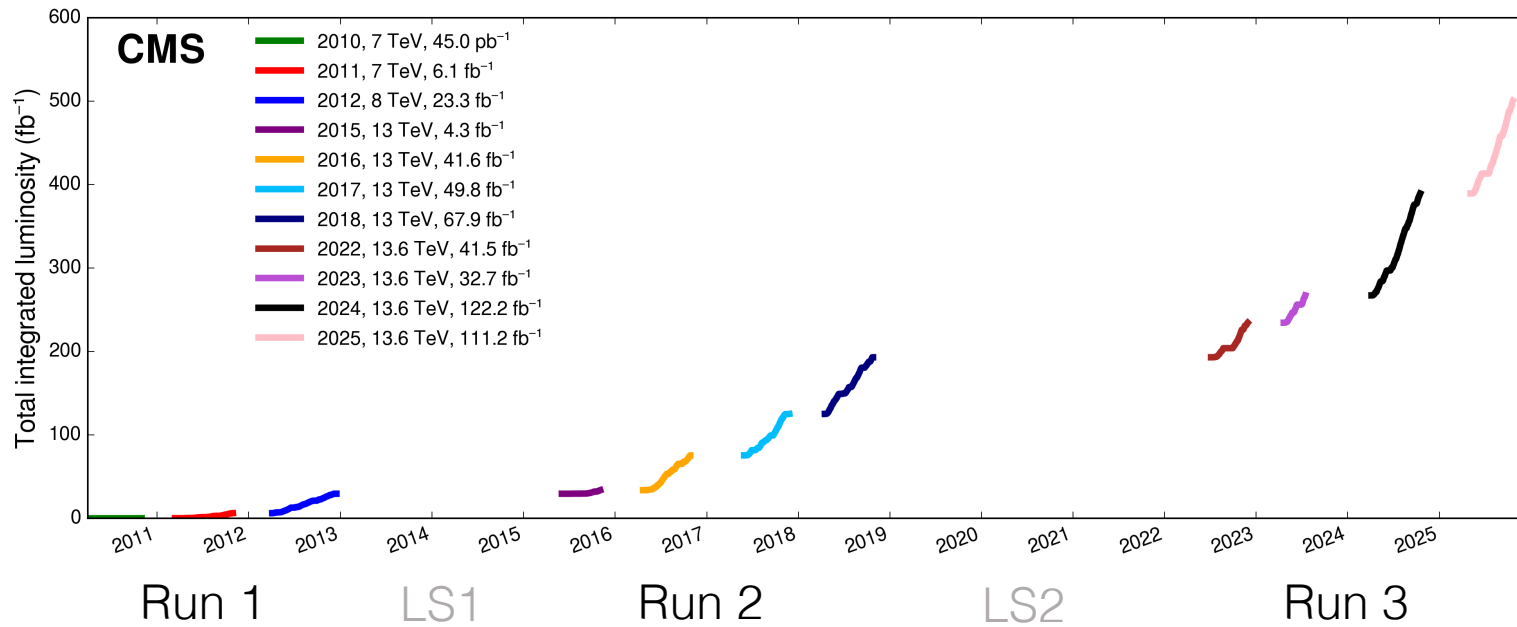


Outline

1. Where we are and where we are going
2. CMS Highlights
3. CMS Mexico Highlights



(Almost) Fifteen years in...



[Twiki](#)

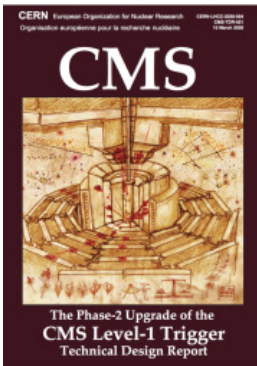
~500 fb^{-1} of pp collision data

Excellent detector performance and innovative approaches to technical challenges.

Rich and diverse physics program:

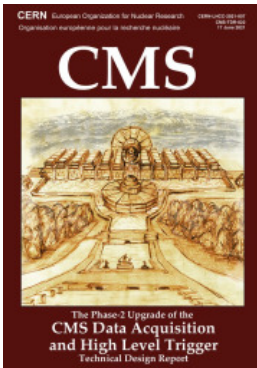
- Measurement of Higgs boson properties (couplings, signal strengths, cross sections).
- Study of the QGP.
- Precision SM measurements.
- Heavy flavor physics and ultra-rare decay modes.
- New physics searches.

The road ahead



L1-Trigger

Tracks in L1 at 40 MHz
Particle flow selection
750 kHz L1 output
40 MHz data scouting



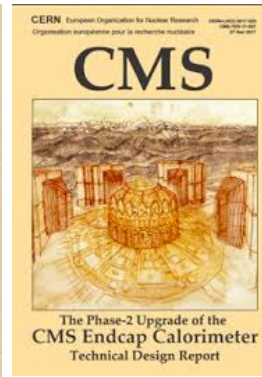
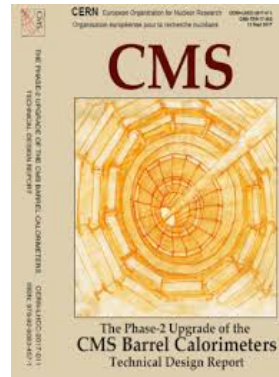
DAQ & HLT

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



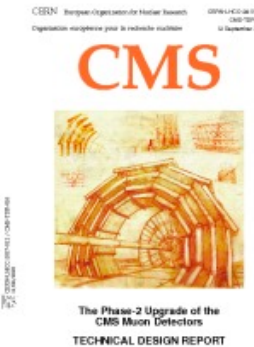
BRIL

Beam abort & timing
Beam-induced background
Bunch-by-bunch luminosity
Neutron and mixed-field
radiation monitors



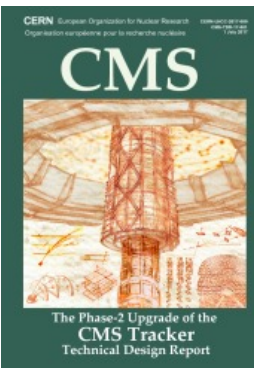
Barrel and Endcap calorimeters

ECAL crystal granularity readout at 40 MHz with precise timing for e/γ at 30 GeV.
ECAL and HCAL new BE boards
3D showers and precise timing
Si, Scint+SiPM in Pb/W-SS



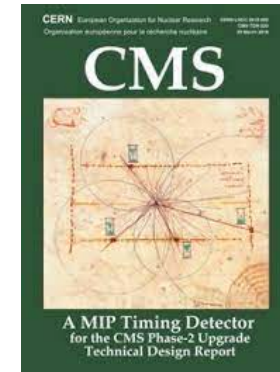
Muon system

DT & CSC new FE/BE readout
RPC BE electronics
New GEM/RPC in $1.6 < \eta < 2.4$
Extended coverage to η of 3



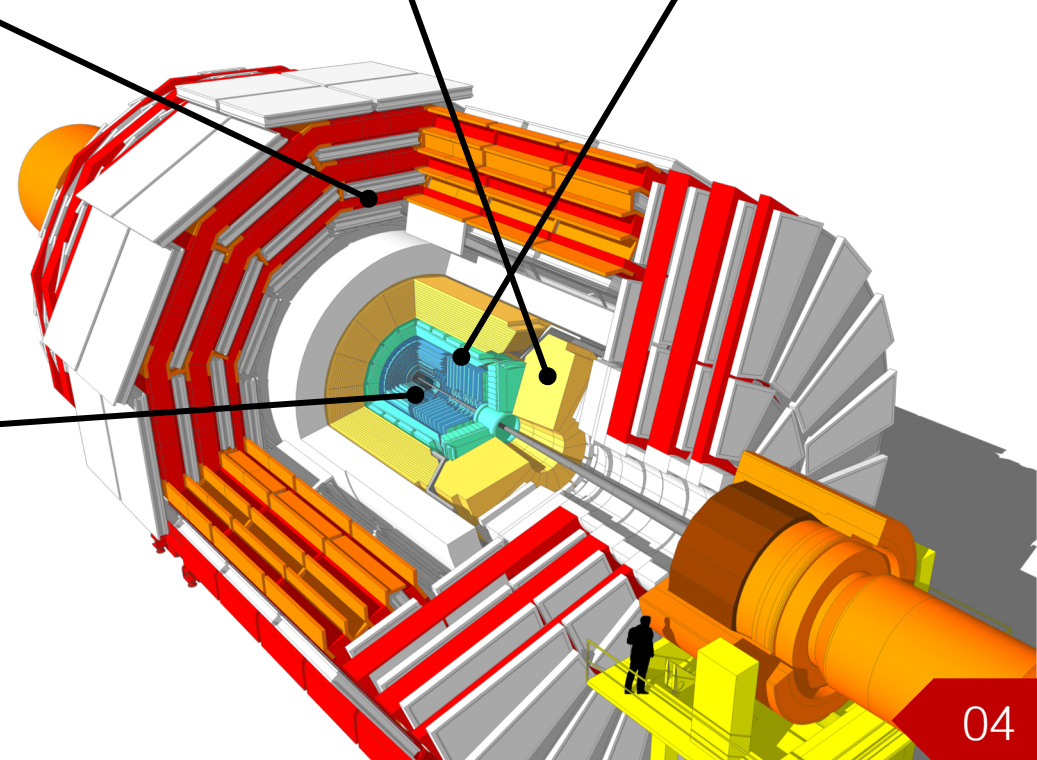
Tracker

Si-strip and pixels increased granularity
Design for tracking in L1 trigger
Extended coverage to η of 3.8



MIP Timing Detector

Precision timing with:
Barrel layer – Crystals and SiPMs
Endcap layer – low gain avalanche diodes

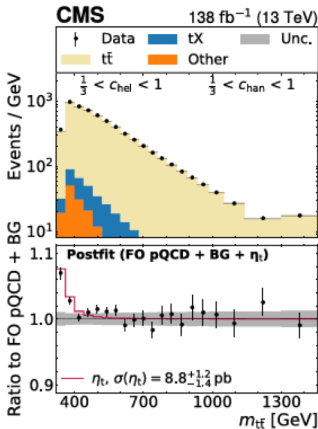


Highlights

OPEN ACCESS
IOP Publishing
Rep. Prog. Phys. 88 (2025) 087801 (25pp)
https://doi.org/10.1088/1361-6633/adf7d3

Observation of a pseudoscalar excess at the top quark pair production threshold

The CMS Collaboration
CERN, Geneva, Switzerland
E-mail: cms-publication-committee-chair@cern.ch
Received 28 March 2025, revised 23 July 2025
Accepted for publication 5 August 2025
Published 22 August 2025
Corresponding editor: Dr Lorna Brigham



[10.1088/1361-6633/adf7d3](https://doi.org/10.1088/1361-6633/adf7d3)

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)



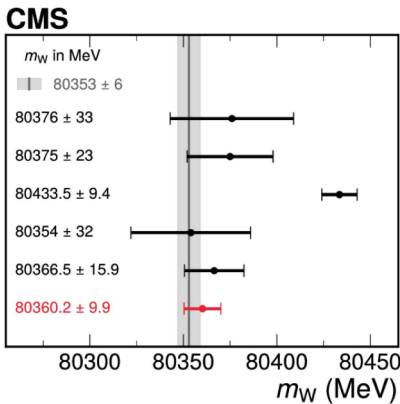
CMS-SMP-23-002

CERN-EP-2024-308
2024/12/19

High-precision measurement of the W boson mass with the CMS experiment at the LHC

The CMS Collaboration*

Electroweak fit
PRD 110 (2024) 030001
LEP combination
Phys. Rep. 532 (2013) 119
D0
PRL 108 (2012) 151804
CDF
Science 376 (2022) 6589
LHCb
JHEP 01 (2022) 036
ATLAS
arXiv:2403.15085
CMS
This work



[arXiv:2412.13872](https://arxiv.org/abs/2412.13872)

Available on the CERN CDS information server

CMS PAS HIG-21-018

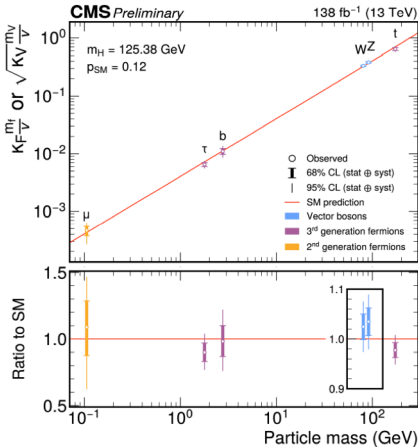
CMS Physics Analysis Summary

Contact: cms-pag-conveners-higgs@cern.ch

2025/04/11

Combined measurements and interpretations of Higgs boson production and decay at $\sqrt{s} = 13$ TeV

The CMS Collaboration



[CMS-PAS-HIG-21-018](https://arxiv.org/abs/2104.02804)

Mexico in CMS



Our highlights (1/2)



Physics Reports

Volume 1115, 17 April 2025, Pages 448-569



Dark sector searches with the CMS experiment

CMS Collaboration

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<https://doi.org/10.1016/j.physrep.2024.09.013>

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Dark matter



Physics Letters B

Volume 844, 10 September 2023, 137905



Two-particle azimuthal correlations in $\gamma\gamma$ interactions using pPb collisions at $\sqrt{s_{NN}} = 8.16$ TeV

The CMS Collaboration*

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<https://doi.org/10.1016/j.physletb.2023.137905>

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PUBLISHED FOR SISSA BY SPRINGER

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Model-independent search for pair production of new bosons decaying into muons in proton-proton collisions at $\sqrt{s} = 13$ TeV



The CMS collaboration

E-mail: cms-publication-committee-chair@cern.ch

ABSTRACT: The results of a model-independent search for the pair production of new bosons within a mass range of $0.21 < m < 60$ GeV, are presented. This study utilizes events with a four-muon final state. We use two data sets, comprising 41.5 fb^{-1} and 59.7 fb^{-1} of proton-proton collisions at $\sqrt{s} = 13$ TeV, recorded in 2017 and 2018 by the CMS experiment at the CERN LHC. The study of the 2018 data set includes a search for displaced signatures of a new boson within the proper decay length range of $0 < c\tau < 100$ mm. Our results are combined with a previous CMS result, based on 35.9 fb^{-1} of proton-proton collisions at $\sqrt{s} = 13$ TeV collected in 2016. No significant deviation from the expected background is observed. Results are presented in terms of a model-independent upper limit on the product of cross section, branching fraction, and acceptance. The findings are interpreted across various benchmark models, such as an axion-like particle model, a vector portal model, the next-to-minimal supersymmetric standard model, and a dark supersymmetric scenario, including those predicting a non-negligible proper decay length of the new boson. In all considered scenarios, substantial portions of the parameter space are excluded, expanding upon prior results.

KEYWORDS: Beyond Standard Model, Hadron-Hadron Scattering

ARXIV EPRINT: 2407.20425

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Article funded by SCOAP³.

[https://doi.org/10.1007/JHEP12\(2024\)172](https://doi.org/10.1007/JHEP12(2024)172)

PHYSICAL REVIEW LETTERS **134**, 111903 (2025)

Search for Nuclear Modifications of B^+ Meson Production in p -Pb Collisions at $\sqrt{s_{NN}} = 8.16$ TeV

A. Hayrapetyan *et al.**
(CMS Collaboration)

(Received 7 July 2024; revised 17 October 2024; accepted 31 January 2025; published 19 March 2025)

Nuclear medium effects on B^+ meson production are studied using the binary-collision scaled cross section ratio between events of different charged-particle multiplicities from proton-lead collisions. Data, collected by the CMS experiment in 2016 at a nucleon-nucleon center-of-mass energy of $\sqrt{s_{NN}} = 8.16$ TeV, corresponding to an integrated luminosity of 175 nb^{-1} , were used. The scaling factors in the ratio are determined using a novel approach based on the $Z \rightarrow \mu^-\mu^+$ cross sections measured in the same events. The scaled ratio for B^+ is consistent with unity for all event multiplicities, putting stringent constraints on nuclear modification for heavy flavor.

DOI: 10.1103/PhysRevLett.134.111903



Physics Reports

Volume 1115, 17 April 2025, Pages 570-677



Review of searches for vector-like quarks, vector-like leptons, and heavy neutral leptons in proton-proton collisions at $\sqrt{s}=13$ TeV at the CMS experiment

CMS Collaboration

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<https://doi.org/10.1016/j.physrep.2024.09.012>

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Vector-like quarks



B physics



Heavy ions



CMS PAS LUM-20-001

Contact: cms-pog-conveners-lum@cern.ch

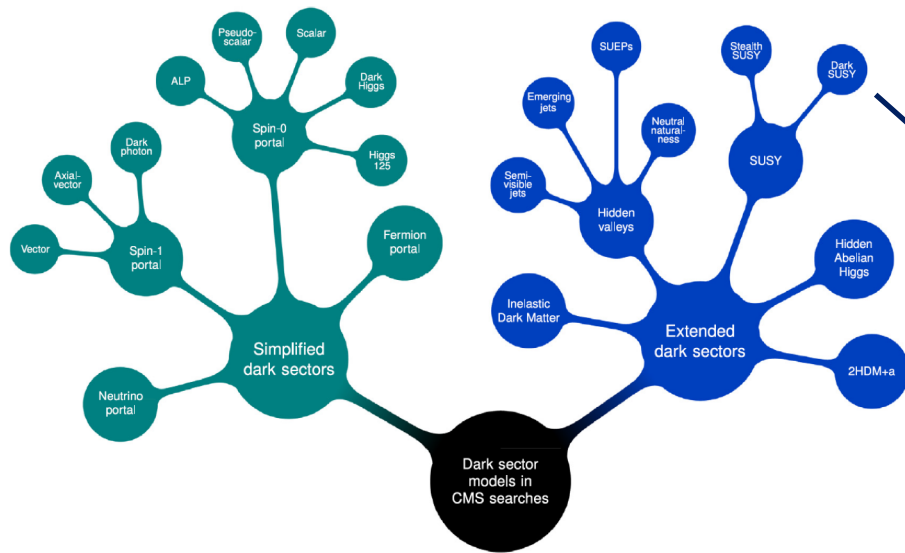
2025/08/23

The CMS Collaboration

Luminosity

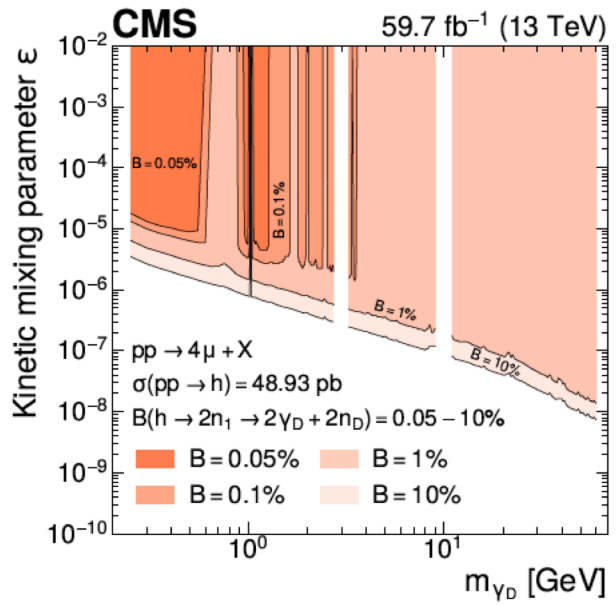
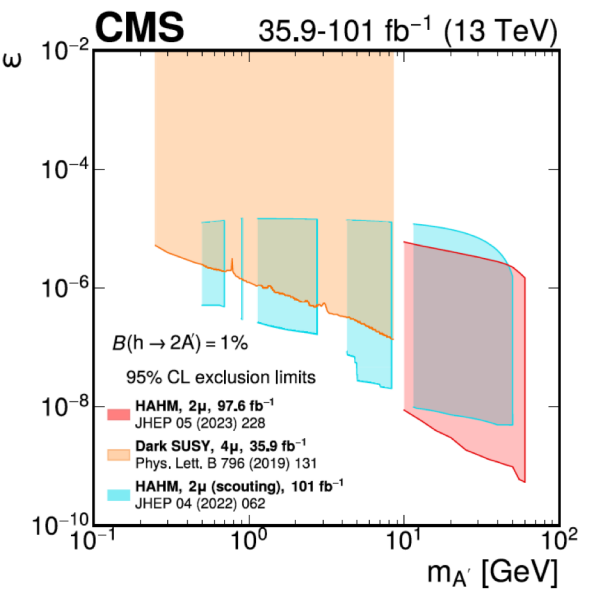
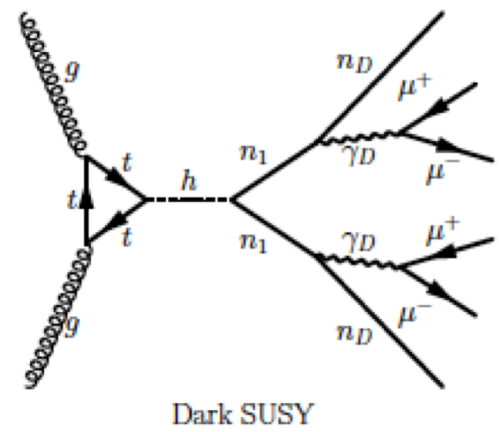


Dark matter searches



Model-independent search for the pair production of a new boson that decays into a pair of oppositely charged muons.

Model-independent limits and interpretation in terms of several models including: axion-like particle, dark photons signatures.

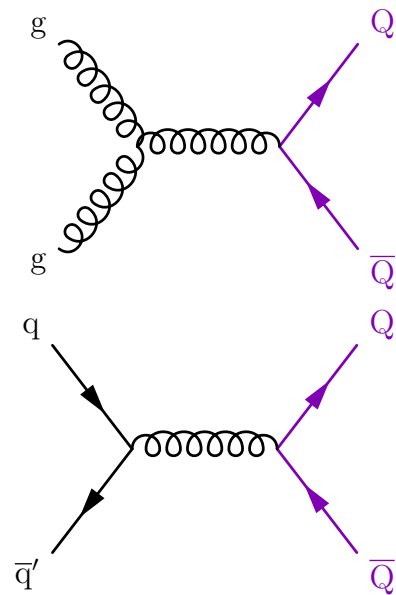


Interpretation results for extended dark sector in models including long living particles in the phase space defined by the kinetic mixing parameter and the mass of the new particle.

Vector-like quark searches (1/2)

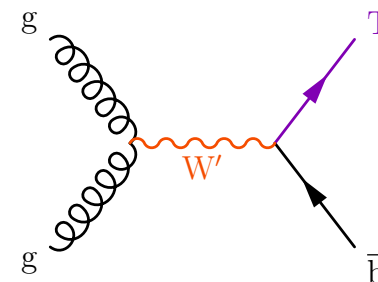
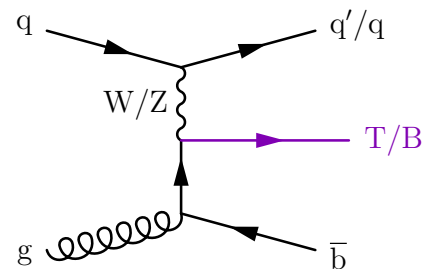
[10.1016/j.physrep.2024.09.012](https://doi.org/10.1016/j.physrep.2024.09.012)

- * They come up in many extensions to the SM to address the hierarchy and naturalness problems.
- * Their left- and right-handed components transform in the same way under the electroweak symmetry group.
- * Their masses do not arise from Yukawa couplings $\Rightarrow$ not constrained by Higgs cross-section measurements.
- * Flavours: T (+2/3), B (-1/3), $X_{5/3}$ (+5/3) and $Y_{4/3}$ (-4/3).
- * Generally assumed to decay into a 3rd generation SM quark and either a W, Z or Higgs boson.



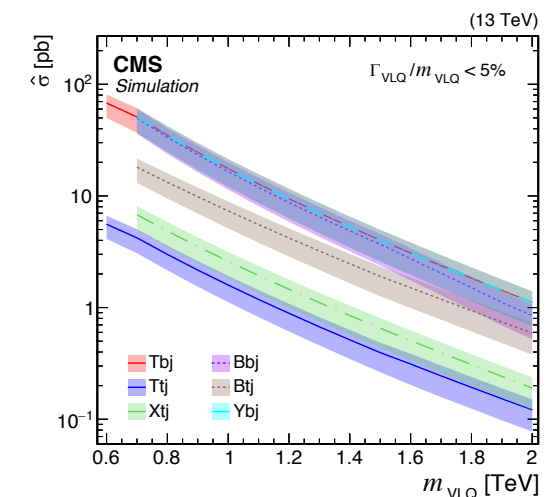
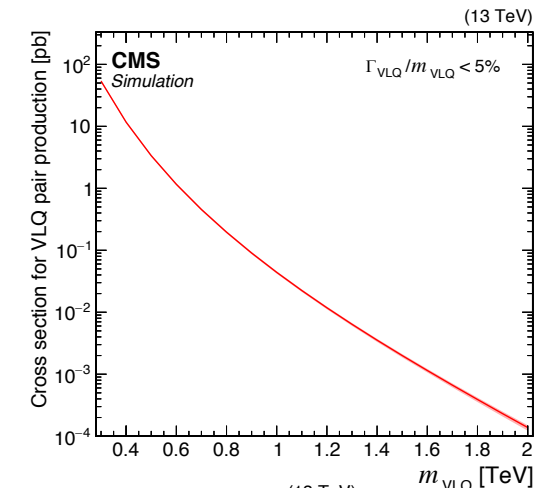
Pair production

Dominant at low masses



Single production

Model dependent (couplings)
Via EW processes or new interactions



Vector-like quark searches (2/2)

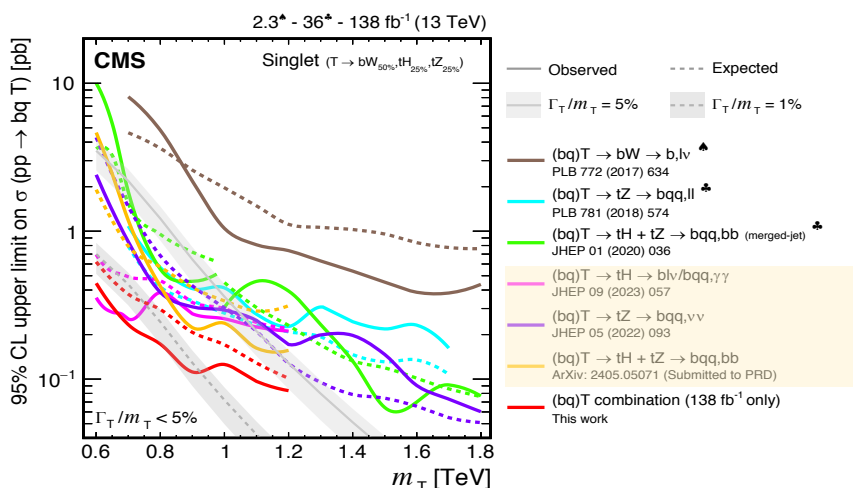
Combination of single T searches

* Decay modes considered:

$$tH \left\{ \begin{array}{l} H \rightarrow \gamma\gamma \\ H \rightarrow b\bar{b} \end{array} \right. \quad tZ \left\{ \begin{array}{l} Z \rightarrow \nu\nu \\ Z \rightarrow b\bar{b} \end{array} \right.$$

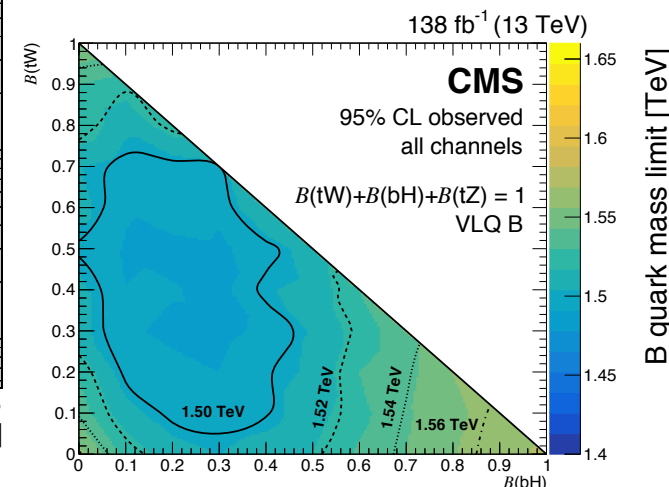
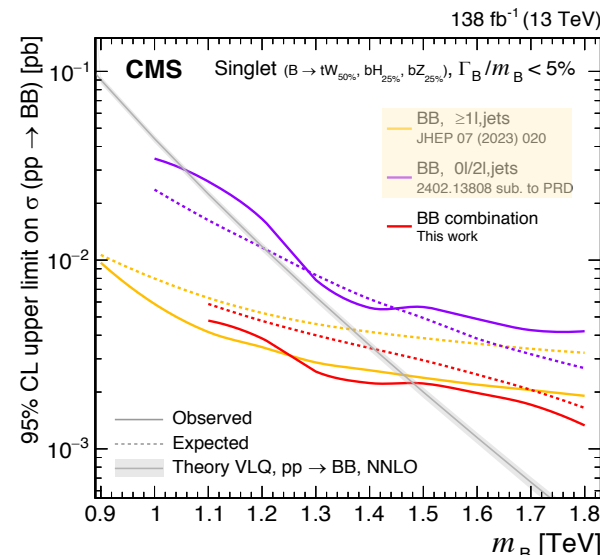
* Mutually exclusive final states $\Rightarrow$ statistically independent observations.

* Only NWA scenarios included in the combination.



The upper limits on the cross section as a function of m_T in a singlet scenario show that the combination significantly improves the sensitivity.

Combination of BB searches



* Mutually exclusive lepton selection criteria. Final states:

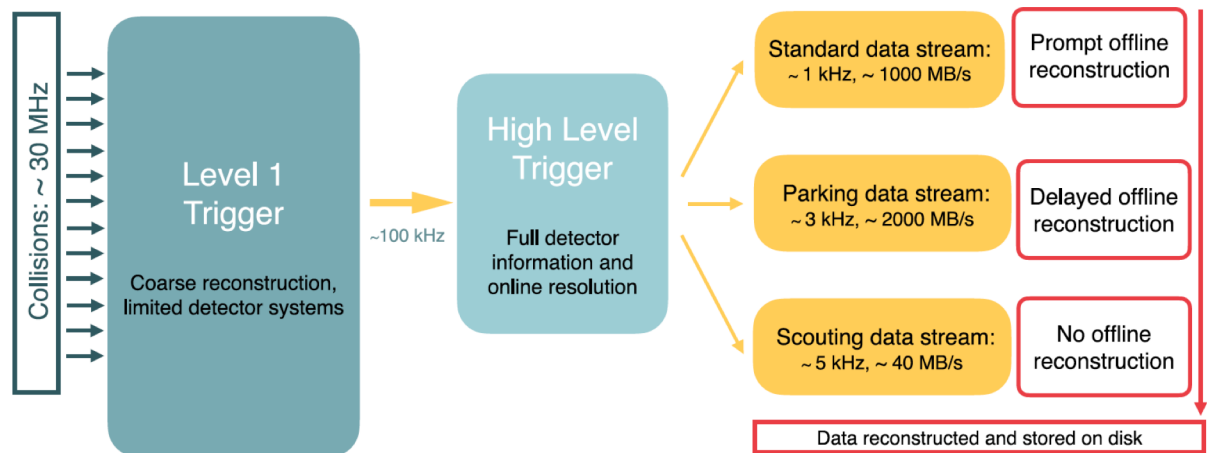
$$\left\{ \begin{array}{ll} \text{hadronic} & \text{same-sign dilepton} \\ \text{single-lepton} & \text{opposite-sign dilepton} \end{array} \right. \quad \text{multilepton}$$

* Depending on the assumed branching fraction is the gain in sensitivity from the combination.

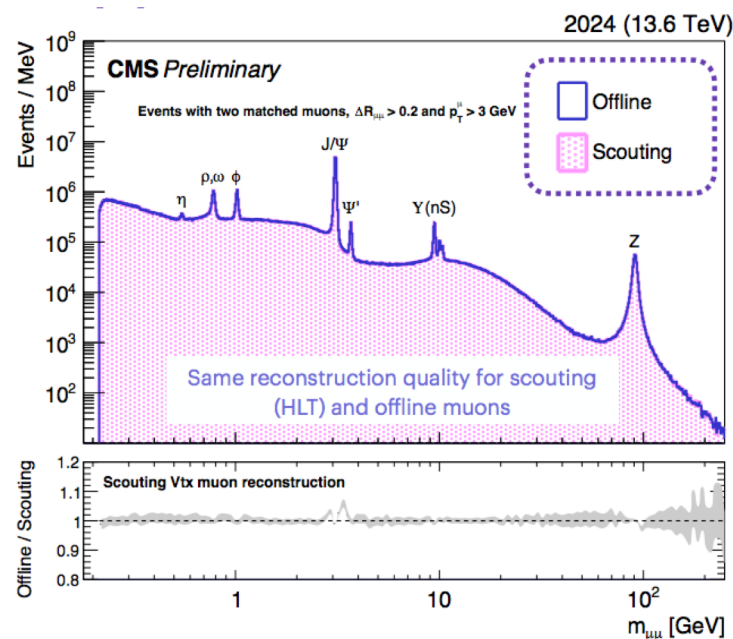
* BB production is excluded for masses below 1.49 TeV $\Rightarrow$ significant increase w.r.t. any of the individual searches.

Scouting & Parking

Data flow for a typical 2018 data-taking scenario



Parking: raw data are recorded and subsequently processed for analysis much later in time (between data-taking periods).

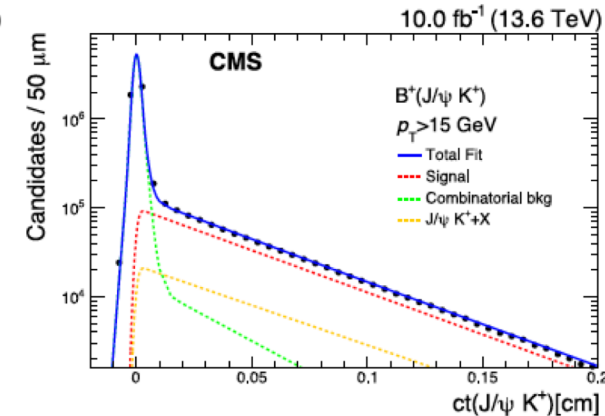
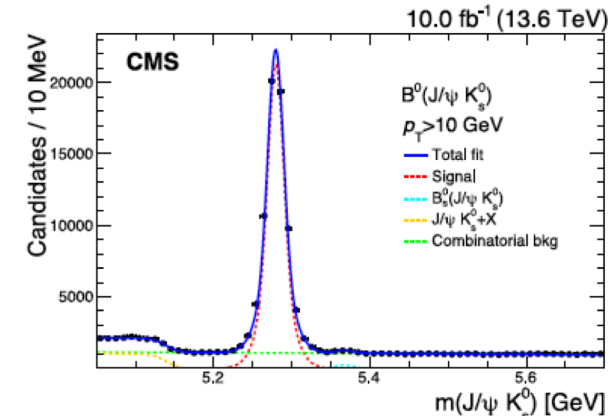
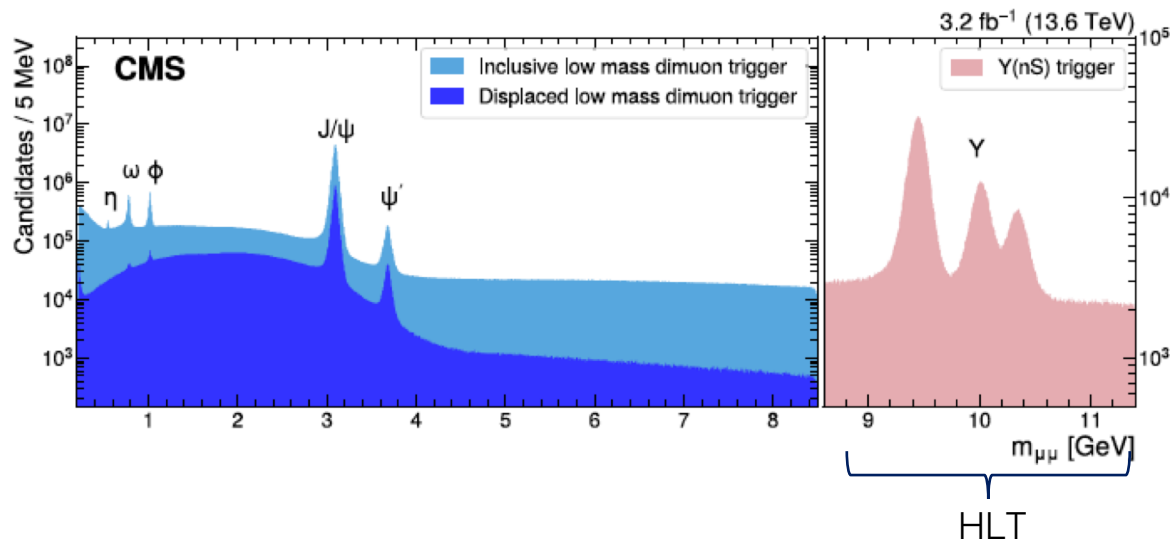
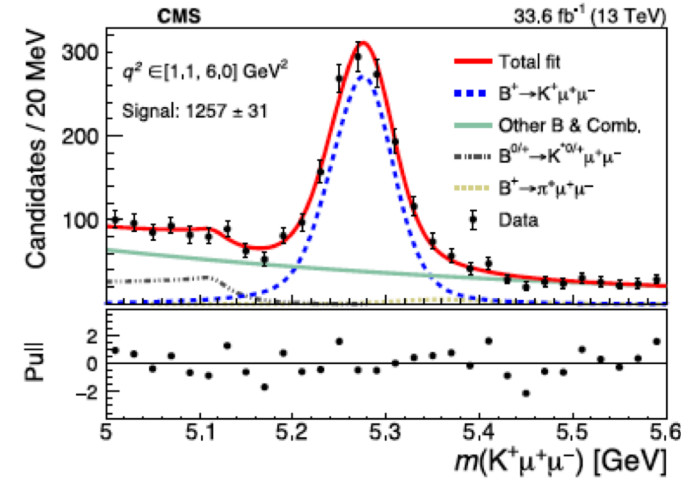
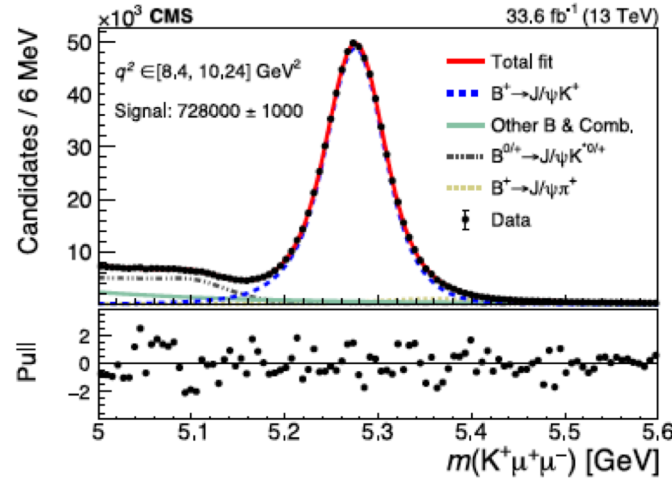


Scouting: Going beyond the designed trigger constraints by lowering thresholds. Record reduced information at high rates, opening up otherwise inaccessible low-mass phase space.

B physics in parking dataset

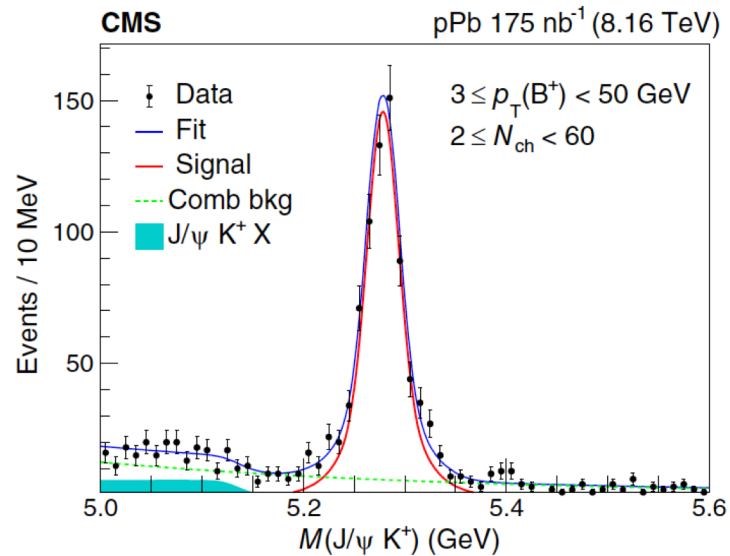
[10.1016/j.physrep.2024.09.006](https://doi.org/10.1016/j.physrep.2024.09.006)

The data set provides access to BSM models with low-mass states and/or very rare decays, a parameter space complementary to the one offered by data sets that serve the high- p_T searches typical at the LHC, and thus substantially extends the reach of the CMS physics program.



Flavour physics in Heavy Ions (1/2)

[10.1103/PhysRevLett.134.111903](https://arxiv.org/abs/10.1103/PhysRevLett.134.111903)

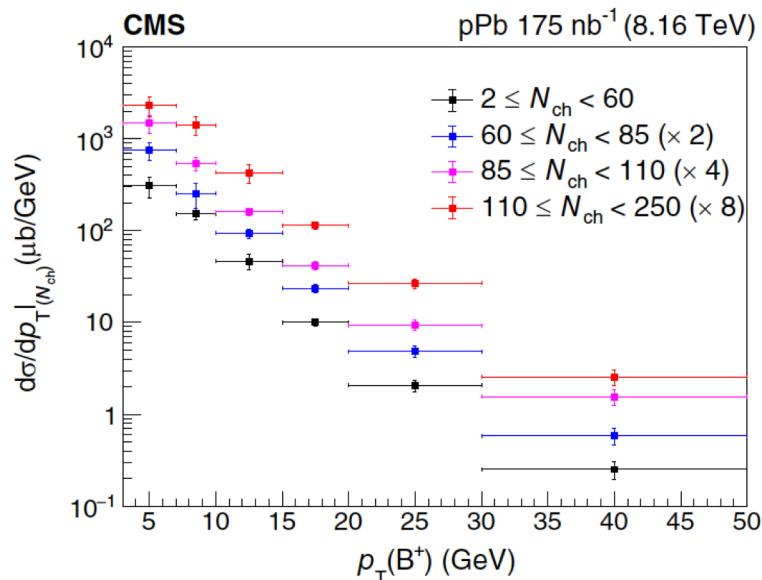


Heavy quarks are invaluable tools for studying QGP as they experience the entire lifetime of the medium, allowing them to probe the media properties throughout its evolution.

The analysis focuses on the measurement of the B⁺ differential cross section in pPb collisions, in the decay channel:

$$B^+ \rightarrow J/\psi K^+$$

Di-muon channel



The B⁺ cross section has been **measured for the first time in different bins of charged-particle multiplicity in pPb collisions**, revealing a rising trend in the B⁺ production with increasing charged-particle multiplicity.

Flavour physics in Heavy Ions (2/2)

[10.1103/PhysRevLett.134.111903](https://arxiv.org/abs/10.1103/PhysRevLett.134.111903)

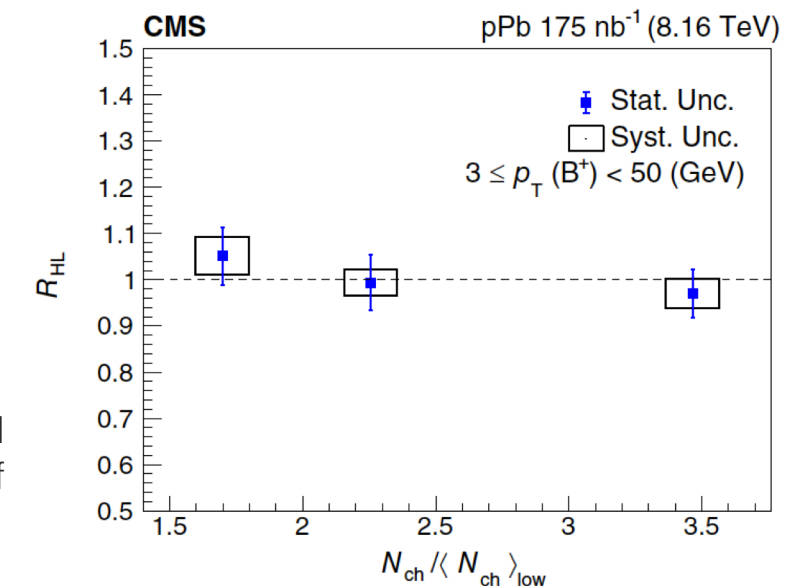
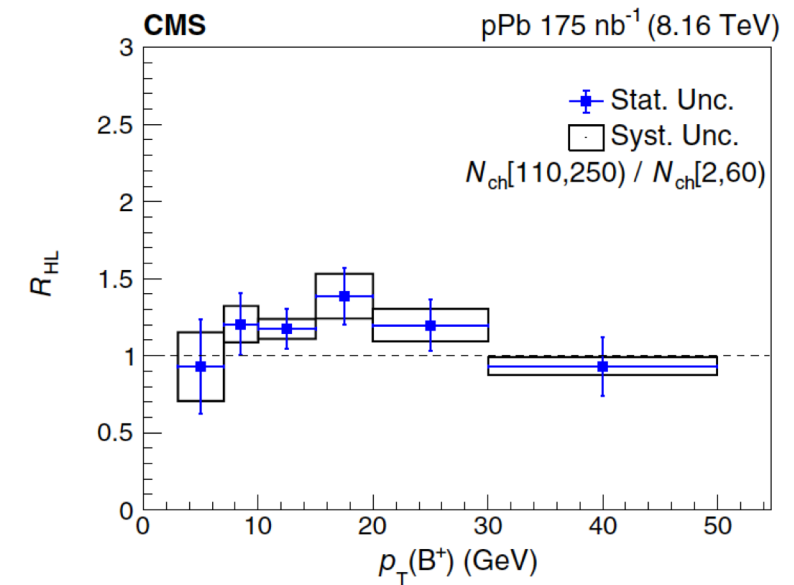
$$R_{\text{HL}} = \frac{\langle N_{\text{coll}} \rangle_{\text{low}} (d\sigma/dp_T)|_{\text{high}}}{\langle N_{\text{coll}} \rangle_{\text{high}} (d\sigma/dp_T)|_{\text{low}}}$$

This observable is defined as the ratio of cross sections for events at high multiplicity to those at low multiplicity, scaled by the corresponding number of binary collisions in two multiplicity bins.

$$R_{\text{HL}} = \frac{(d\sigma^{B^+}/dp_T)|_{\text{high}}}{(d\sigma^{B^+}/dp_T)|_{\text{low}}} \bigg/ \frac{(d\sigma^Z/dp_T)|_{\text{high}}}{(d\sigma^Z/dp_T)|_{\text{low}}}$$

The production of Z bosons is expected to scale with the number of binary collisions and be void of any final-state medium effects; thus, the ratio of Z boson cross sections can be used to determine the scaling factor.

The observed ratios are **consistent with unity** within uncertainties for all event selections studied, setting constraints on possible presence of medium effects in the B^+ meson production.



Particle correlations in UPC (1/2)

[10.1016/j.physletb.2023.137905](https://doi.org/10.1016/j.physletb.2023.137905)

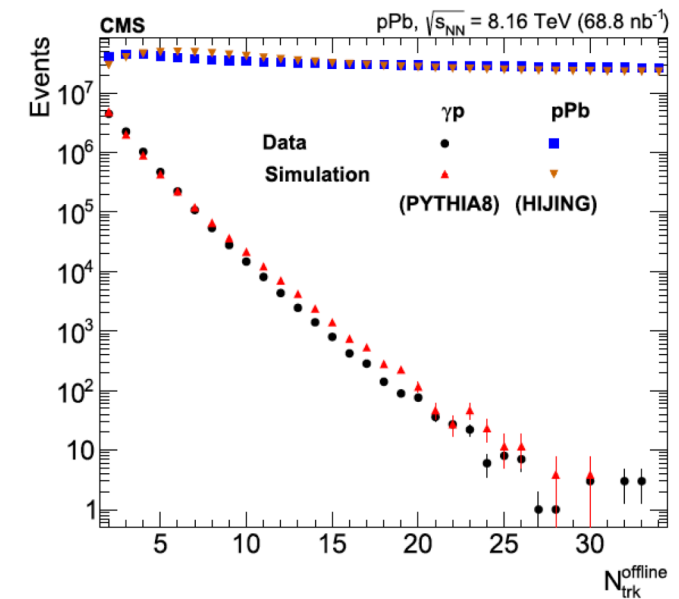
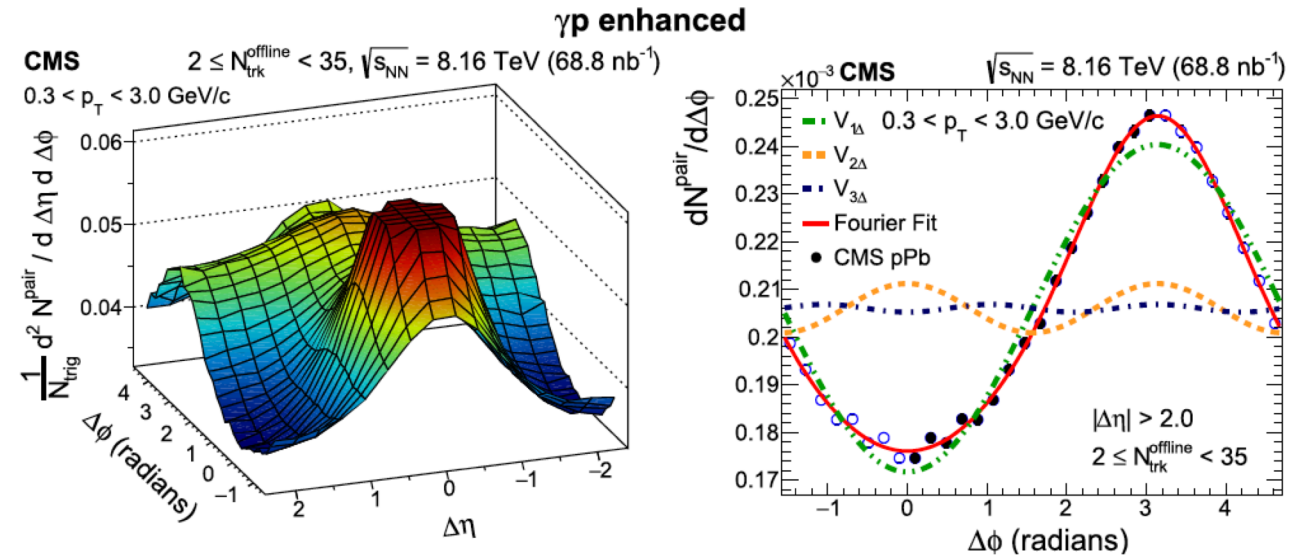
Search for collective effects in **γp events from ultra-peripheral collisions in pPb** => Measure azimuthal correlations between particles far apart in rapidity.

“Ridge” has been observed in pPb and high-multiplicity pp events, but so far not in smaller systems:
e⁺e⁻, ep, **γ Pb**

$$\frac{1}{N_{\text{trig}}} \frac{d^2 N^{\text{pair}}}{d\Delta\eta d\Delta\phi} = B(0,0) \frac{S(\Delta\eta, \Delta\phi)}{B(\Delta\eta, \Delta\phi)}$$

Unlike typical pPb collisions, which produce particles at both positive and negative rapidity, **γp** events are expected to be very asymmetric in the laboratory frame.
=> A rapidity gap is defined as a continuous region with low detector activity.

Two-particle azimuthal correlations can be characterized by their Fourier components ($V_{n\Delta}$).

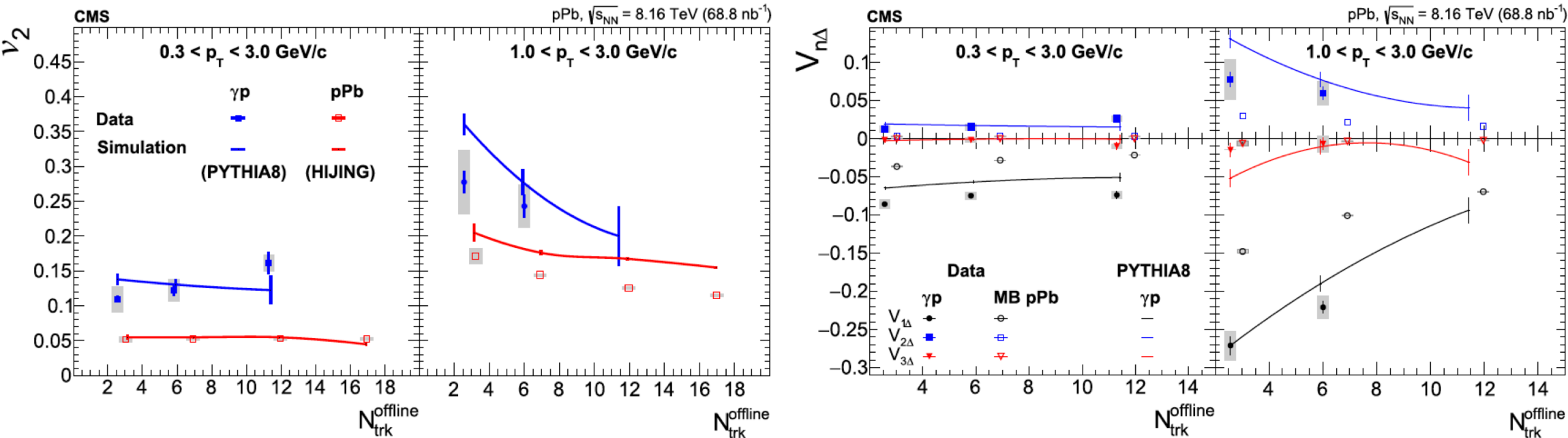


Particle correlations in UPC (2/2)

p_T range		$2 \leq N_{\text{trk}}^{\text{offline}} < 5$	$5 \leq N_{\text{trk}}^{\text{offline}} < 10$	$10 \leq N_{\text{trk}}^{\text{offline}} < 35$
$0.3 < p_T < 3.0 \text{ GeV/c}$	$V_{1\Delta}$	-0.086 ± 0.006	-0.075 ± 0.005	-0.074 ± 0.007
	$V_{2\Delta}$	0.012 ± 0.004	0.015 ± 0.004	0.026 ± 0.006
	$V_{3\Delta}$	-0.002 ± 0.001	-0.002 ± 0.004	-0.010 ± 0.006
$1.0 < p_T < 3.0 \text{ GeV/c}$		$2 \leq N_{\text{trk}}^{\text{offline}} < 5$	$5 \leq N_{\text{trk}}^{\text{offline}} < 35$	
	$V_{1\Delta}$	-0.271 ± 0.021	-0.221 ± 0.017	
	$V_{2\Delta}$	0.077 ± 0.027	0.059 ± 0.017	
	$V_{3\Delta}$	-0.015 ± 0.009	-0.007 ± 0.013	

In all p_T and multiplicity ranges, $V_{1\Delta}$ is negative, $V_{2\Delta}$ is positive with a smaller magnitude than $V_{1\Delta}$, and $V_{3\Delta}$ is consistent with zero. The magnitudes of both $V_{1\Delta}$ and $V_{2\Delta}$ increase with p_T .

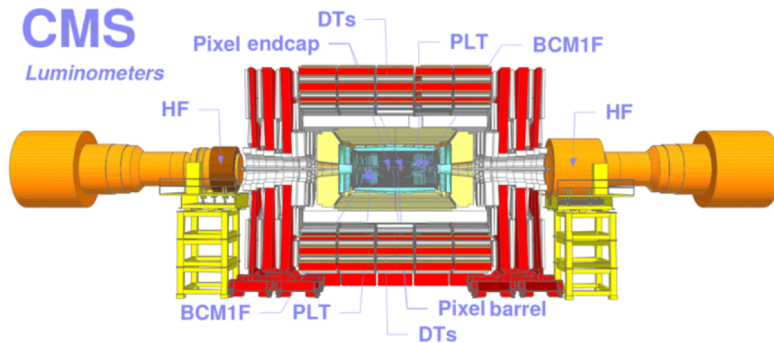
At a given p_T and track multiplicity, v_2 is larger for γp -enhanced events than for MB pPb interactions. Predictions from the Pythia8 model describe well the data within uncertainties. This suggests the data are dominated by noncollective effects.



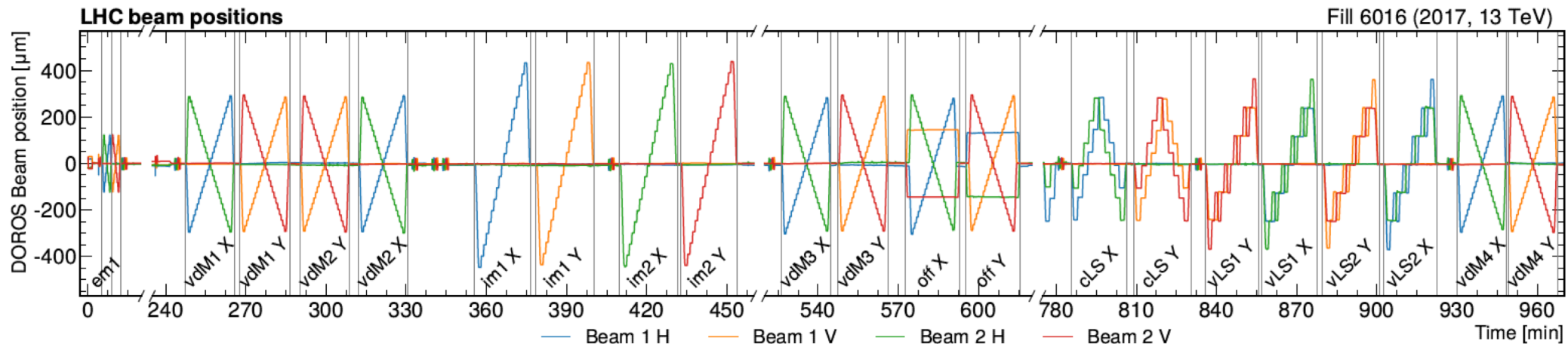
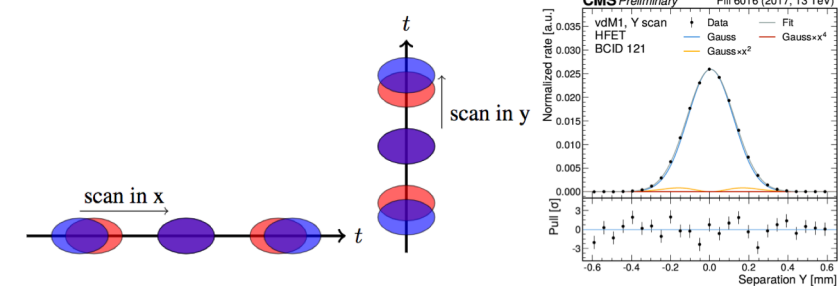
Run 2 luminosity measurement (1/2)

Instantaneous luminosity $\mathcal{L}(t)$ is defined as the number of collisions per unit area per unit time. It can be determined via:

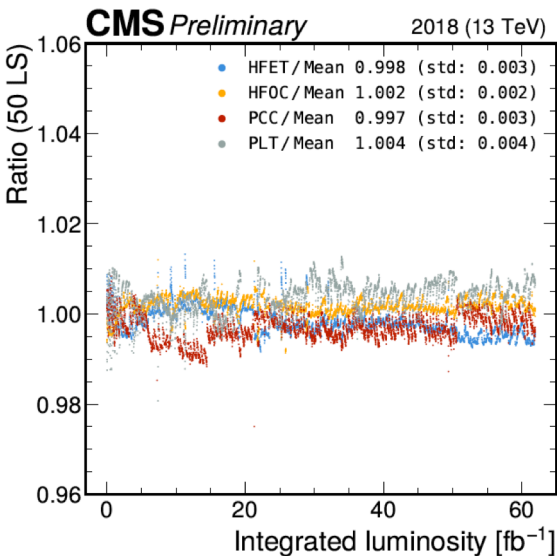
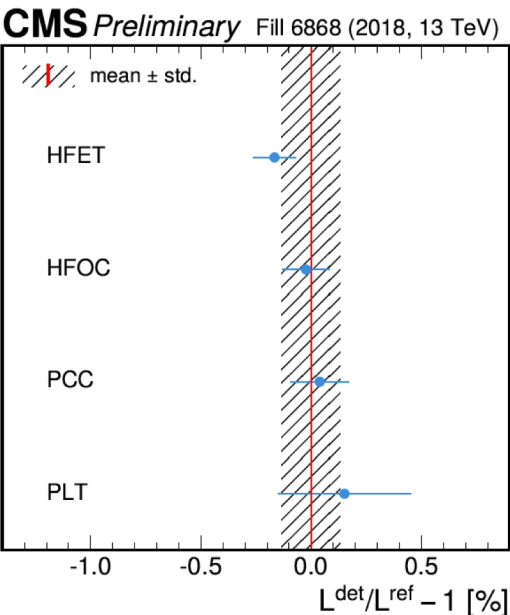
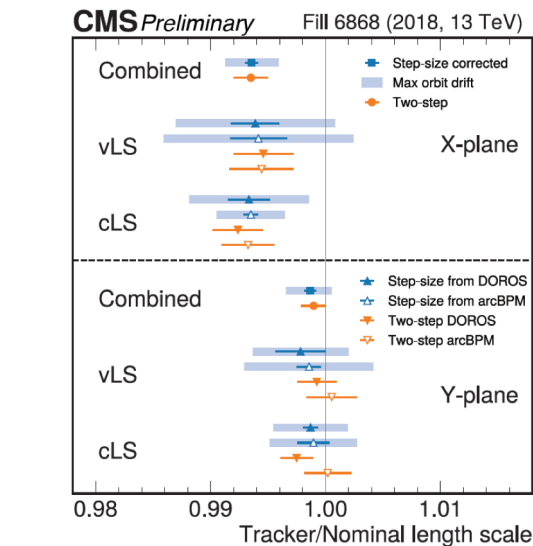
$$\mathcal{L}(t) = R(t) / \sigma_{\text{vis}}$$



$$\sigma_{\text{vis}} = 2\pi \frac{R(0,0)}{N_1 N_2} \Sigma_x \Sigma_y$$



Run 2 luminosity measurement (2/2)



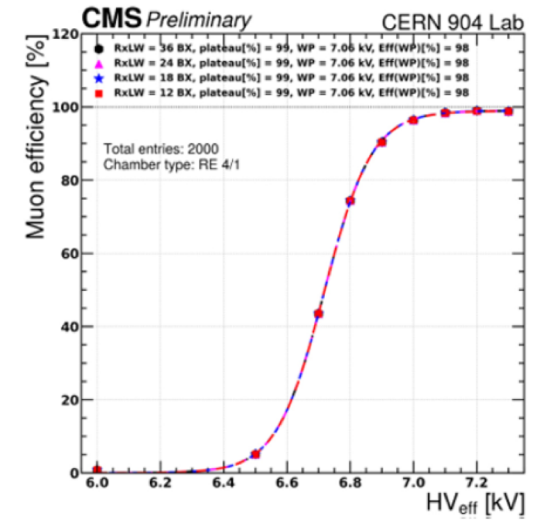
Source	2017 [%]	2018 [%]
<i>Normalization</i>		
Beam current normalization	0.2	0.2
Ghost and satellite charges	0.06	0.07
Beam-beam effects	0.29	0.30
Orbit drift	0.09	0.19
Length scale calibration	0.15	0.18
Transverse factorizability	0.33	0.36
Scan to scan variation	0.26	0.27
Bunch to bunch variation	0.1	0.1
Cross-detector consistency at vdM	0.17	0.14
<i>Integration</i>		
Cross-detector consistency per year	0.19	0.30
Linearity	0.51	0.42
Total normalization uncertainty	0.61	0.66
Total integration uncertainty	0.54	0.52
Total uncertainty	0.82	0.84

When combined with the 2015–2016 data sets at the same center-of-mass energy, the relative precision of the total integrated luminosity is **0.73%**, representing the most precise luminosity measurement ever achieved at bunched-beam hadron colliders.

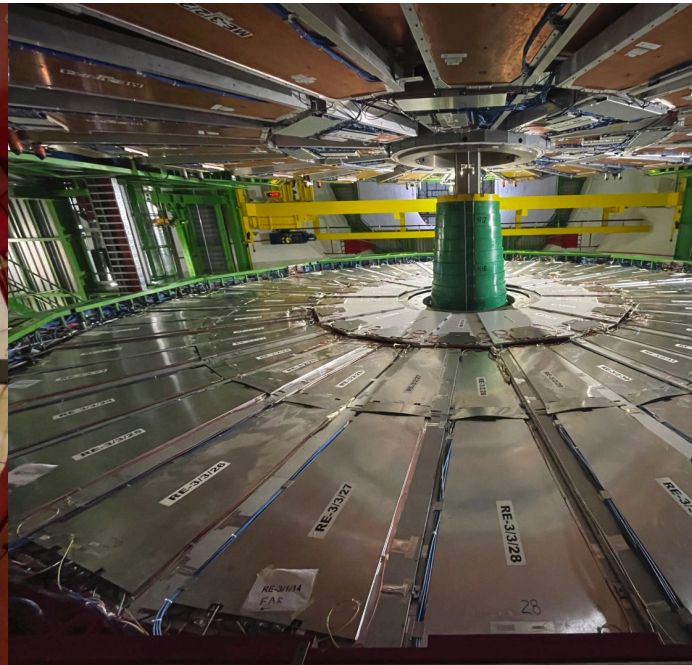
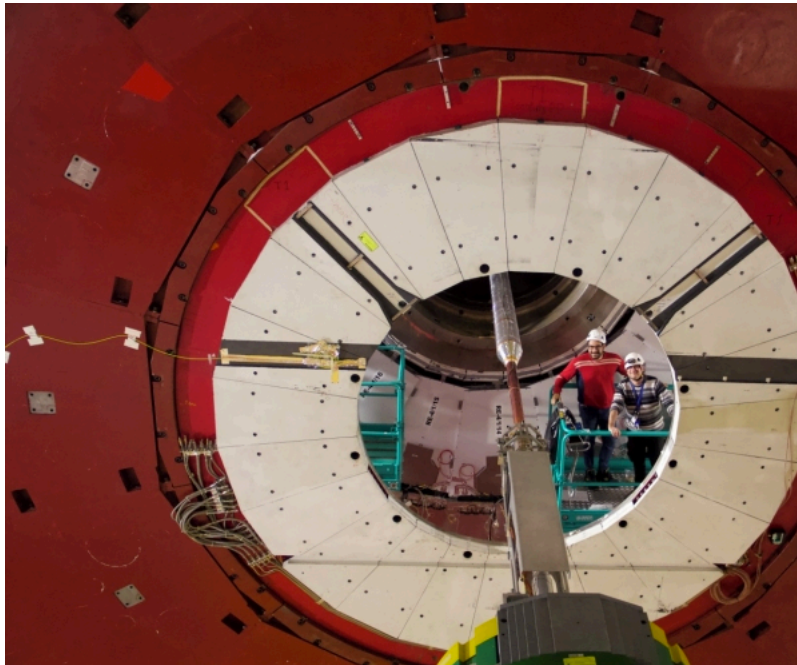
iRPC for Phase-2 (1/2)

[10.1016/j.nima.2025.170484](https://doi.org/10.1016/j.nima.2025.170484)

From construction...

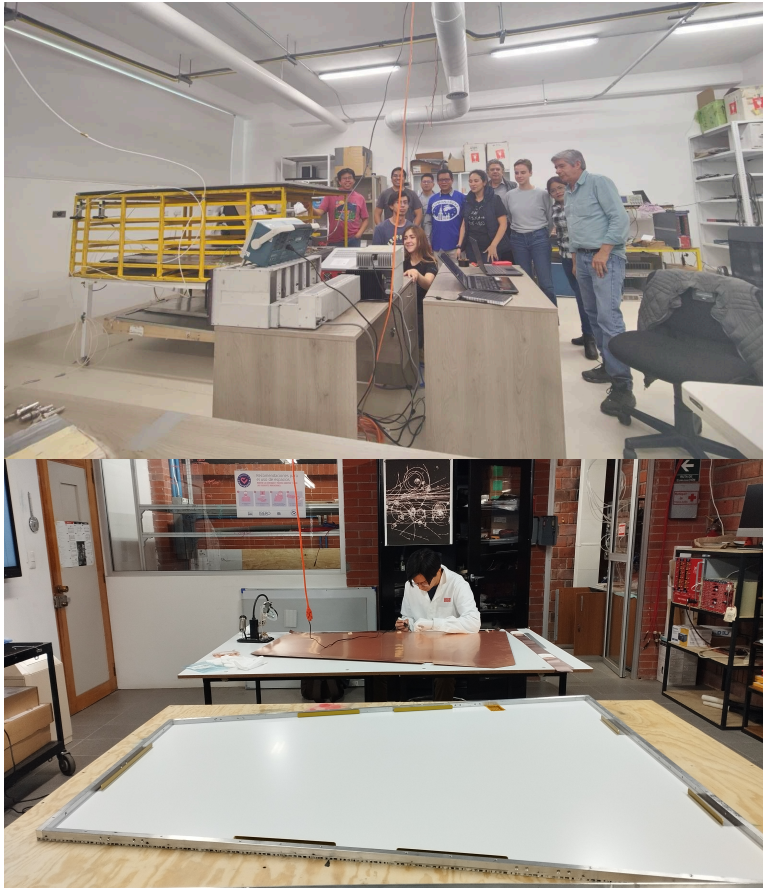


To installation!



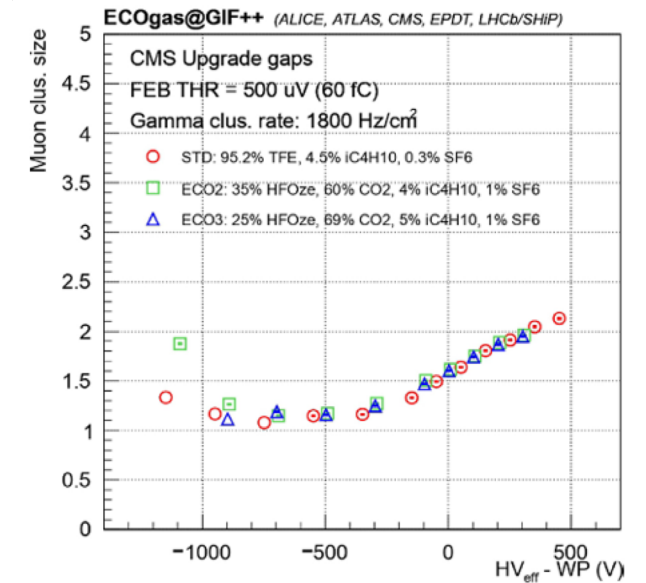
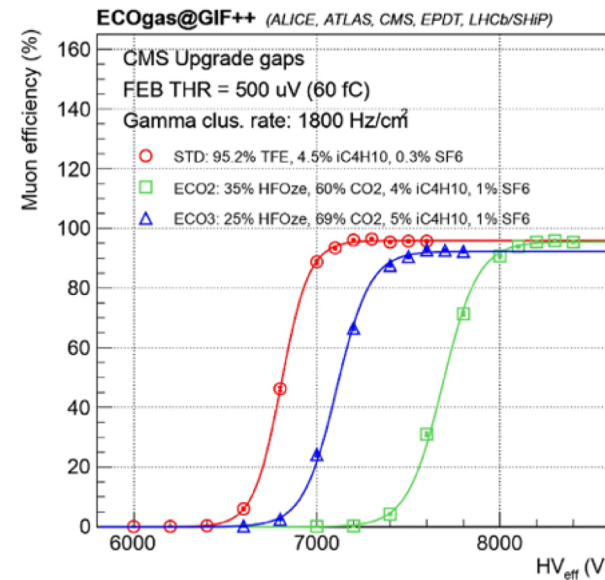
iRPC for Phase-2 (2/2)

[10.1016/j.nima.2024.169510](https://doi.org/10.1016/j.nima.2024.169510)



Mexican RPC Labs
(BUAP, IBERO)

Other studies

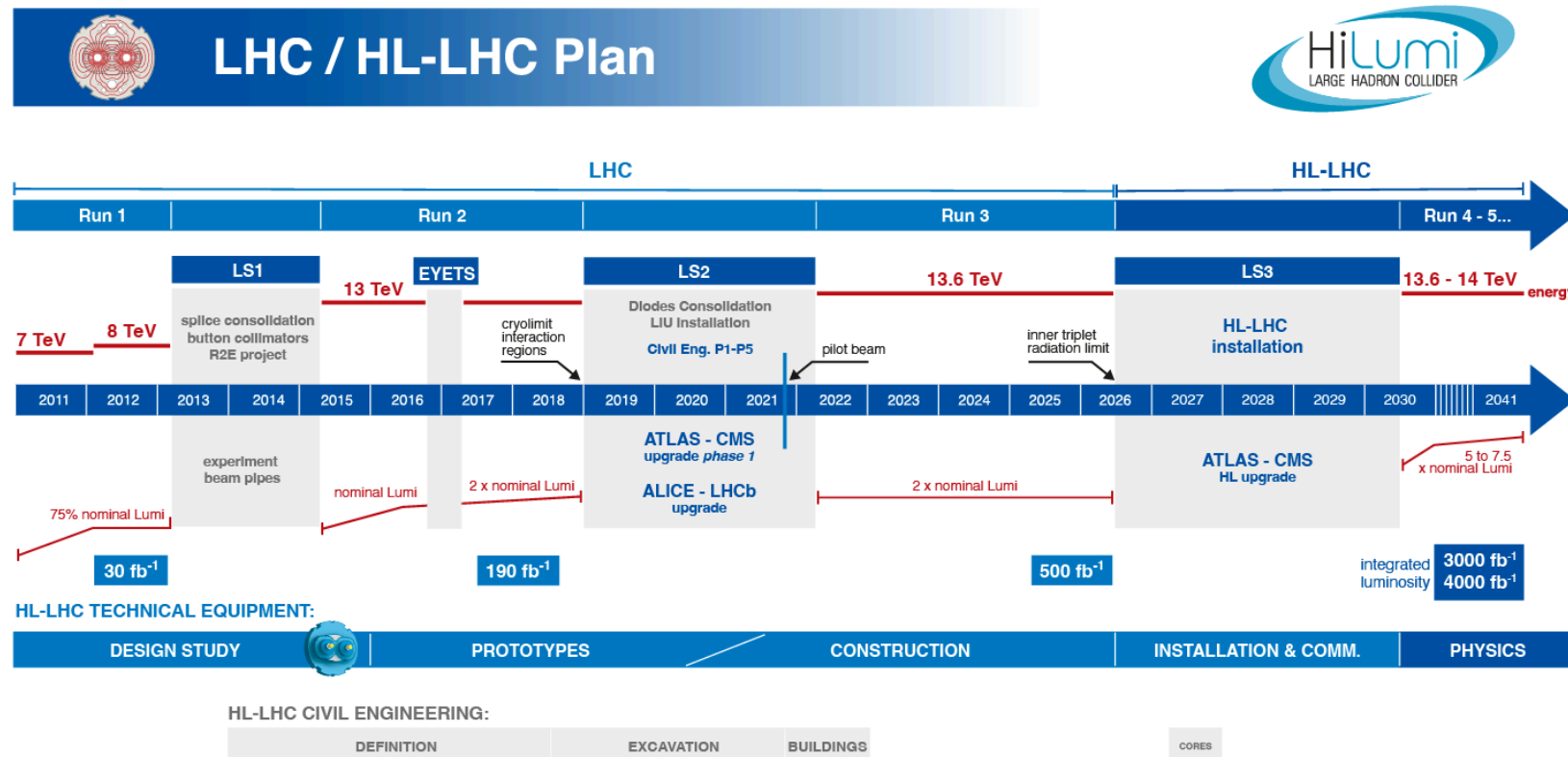


The performance of an iRPC-like detector using eco-friendly gas mixtures was compatible with the standard operational performance.



Summary

- * Excellent performance of machine & experiment has led to a plethora of nice physics results. Today only a handful were shown, totally biased based on personal interests.
- * The Mexican community in CMS plays a leading role both in physics analysis and in operation/performance.
- * We are almost halfway through the LHC adventure, but there is still plenty to do.



Backup