



CMS + PPS/TOTEM overview

Theo Chatzistavrou

Questions to carry through the talk



How well can we weight the top?
Reconstruct its decay and control the jet energy scale.



What is the shape of the Higgs potential?

Probe self-interactions with HH, and electroweak symmetry breaking with VBS.



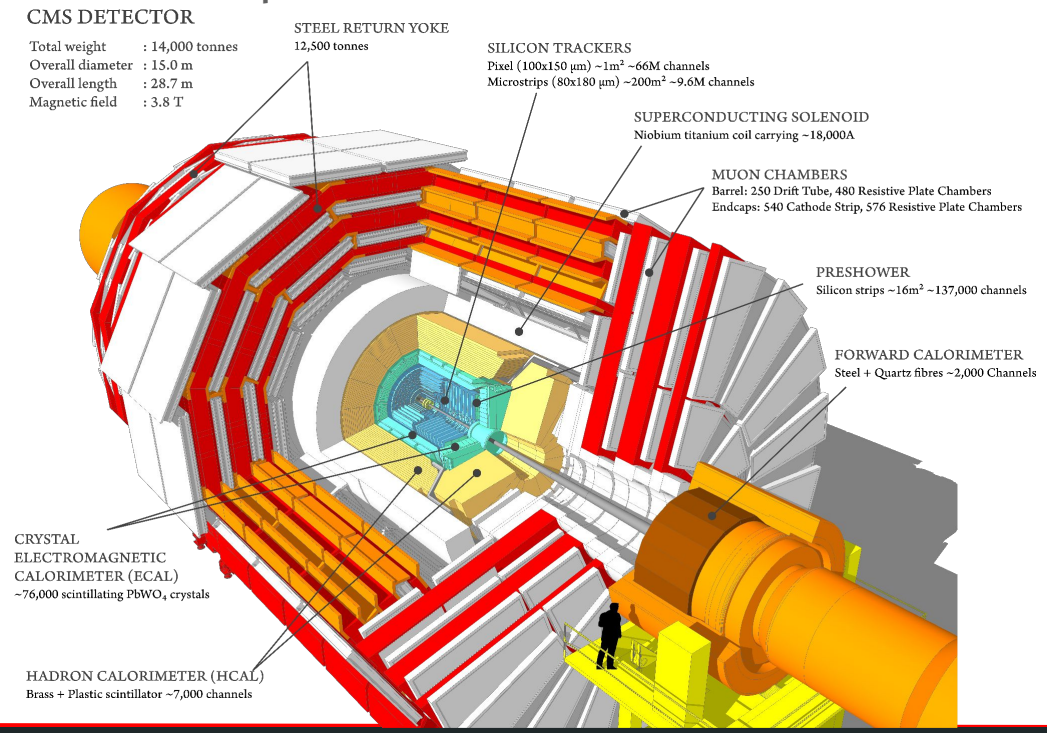
Did the proton survive?

Tag the outgoing proton and connect it to the hard collision.

First we need to keep the right events, and reconstruct them.

CMS Detector

CMS (Compact Muon Solenoid) Detector(s)



We don't see the particles but what they leave behind.

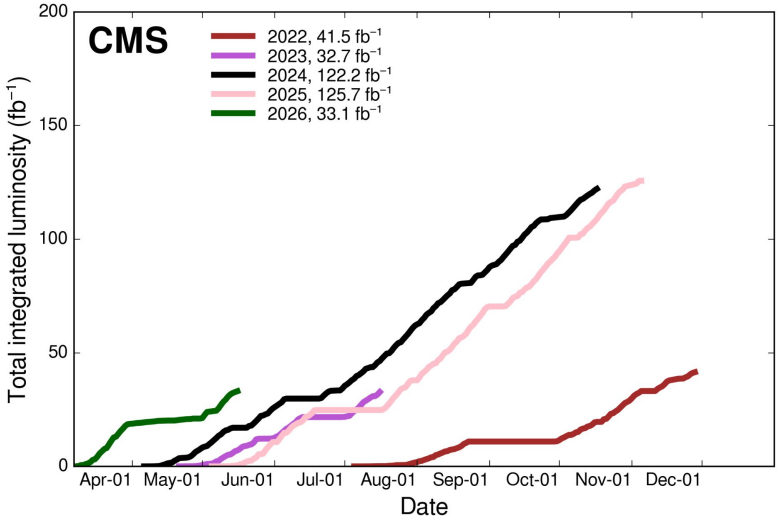
Tracks
Trajectories and displaced vertices.

Calorimeter deposits
Energy from photons and hadrons.

Muons
A clean outer-detector signature.

Particle flow combines the clues into particles, jets and missing transverse momentum.

Run3 delivered lots of data



[Public Luminosity plots]

355fb^{-1}

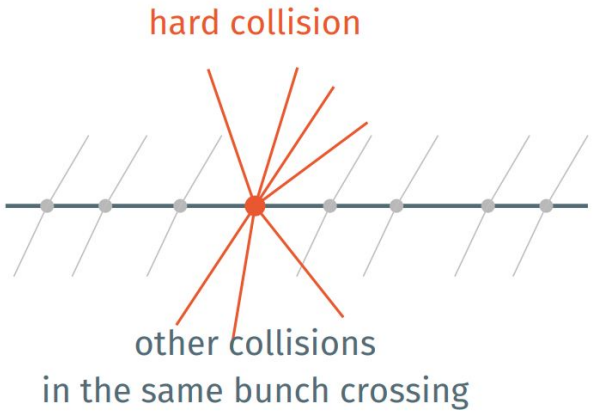
delivered in Run3

More than 320fb^{-1} recorded by CMS thanks to certification at small time intervals (lumisections) assisted by machine learning certification.

More data is only half the story.

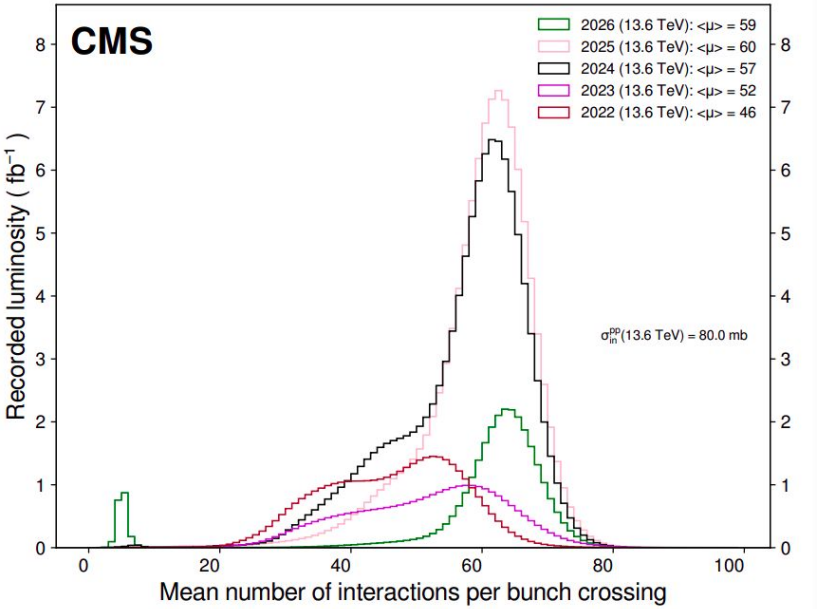
Analyses results shown today use a fraction 62-172fb^{-1}

One collision of interest, dozens of neighbors



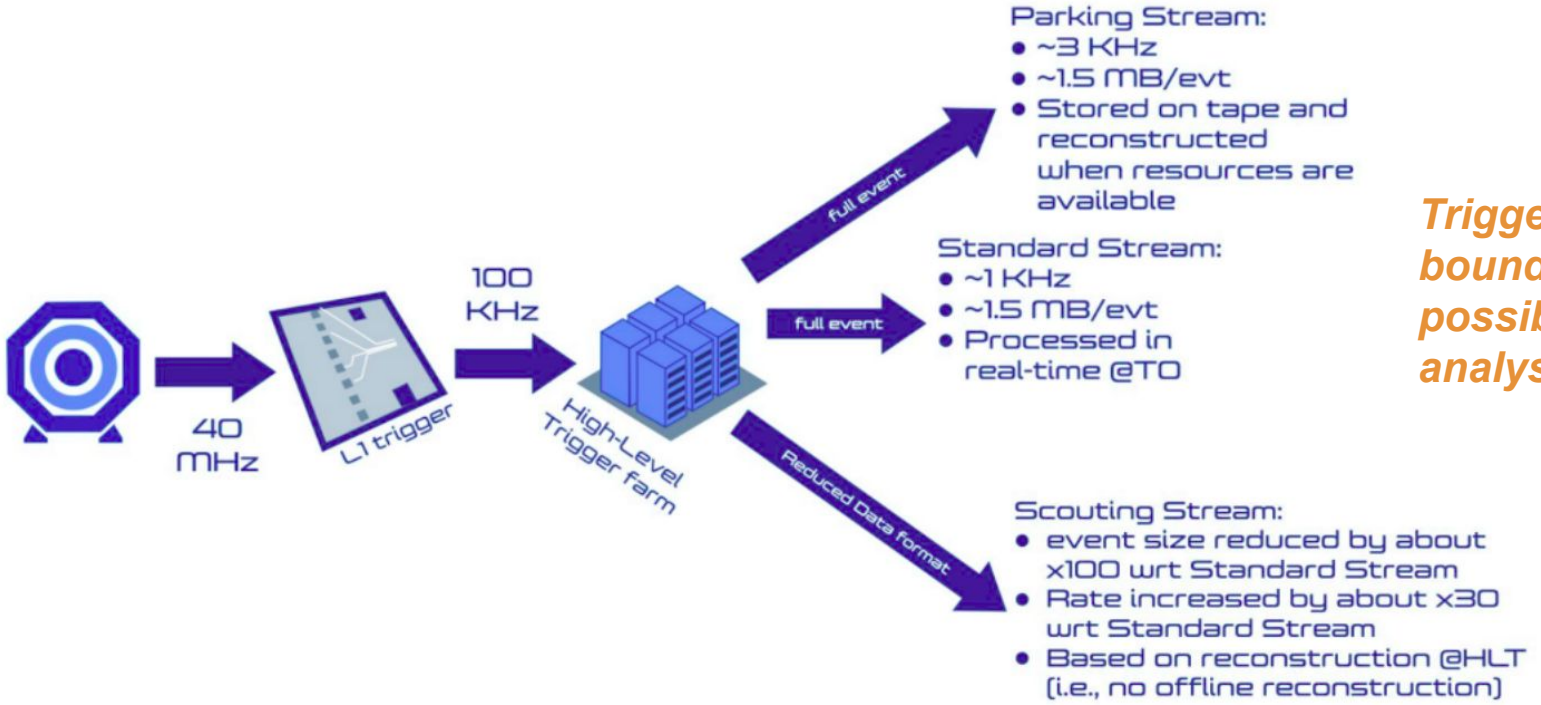
Which particles belong to our collision?

PUPPI uses tracking and local event structure to suppress pileup.



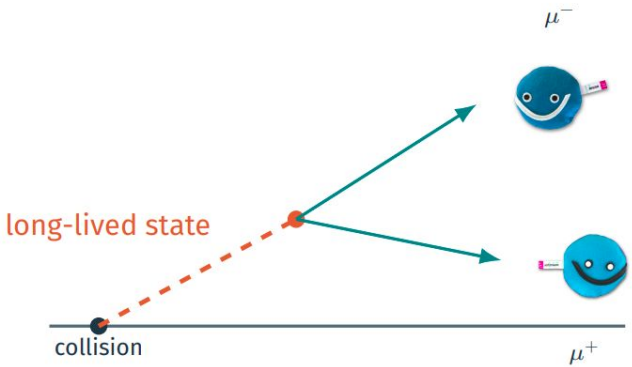
Public Luminosity plots

Trigger: Every analysis cut before we save the event



Trigger defines the boundary of possible physics analyses.

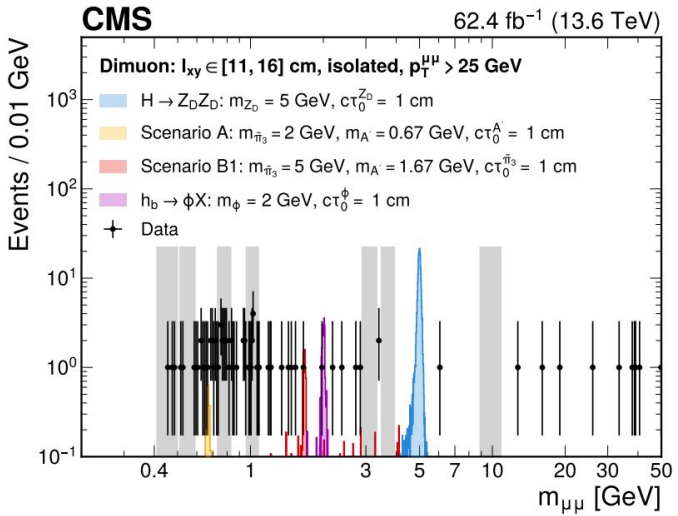
Scouting allows us to search late decays



small files softer muons

Low-threshold scouting retains **soft, displaced dimuons.**

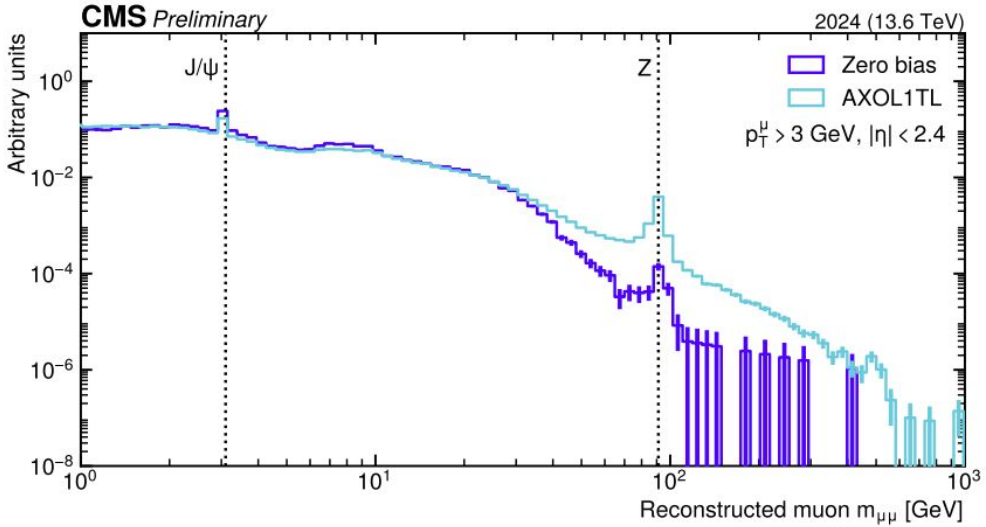
No excess. Limits constrain several LLP scenarios.



Dimuon masses for decay vertices 11–16 cm from the beam line

[Search for long-lived particles decaying into muons using data scouting, 24 June 2026.]

Searching for anomalous events



Known resonances appear without training the trigger on them.

[Real-time unsupervised anomaly detection in CMS]

Keep the unusual

AXOL1TL: Level-1 objects.

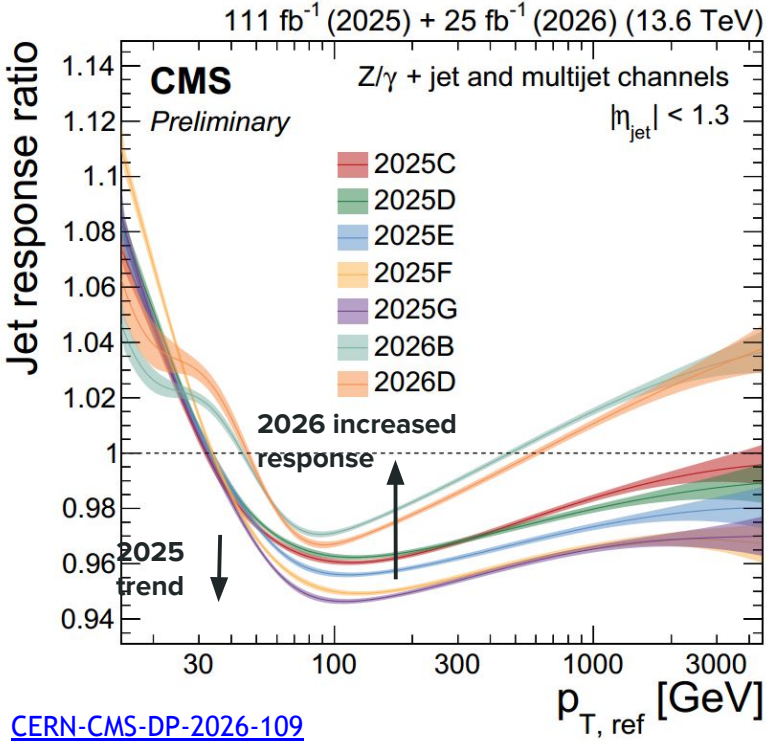
CICADA: calorimeter information.

Learn common patterns. Select high anomaly scores.

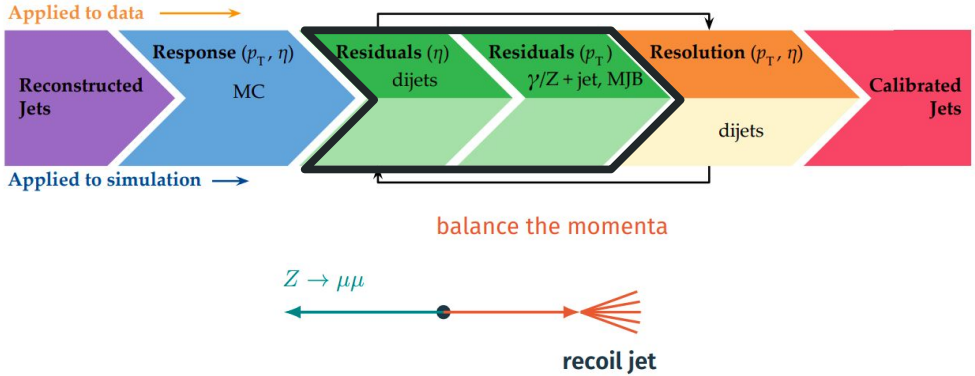
> 4 billion events selected for storage in 2024.

FPGA inference below 100 ns.

Fixing the jet energy scale



CERN-CMS-DP-2026-109



Eras of data-taking comparison in 2025/2026

During 2025 scale was falling probably due to tracking efficiency degradation

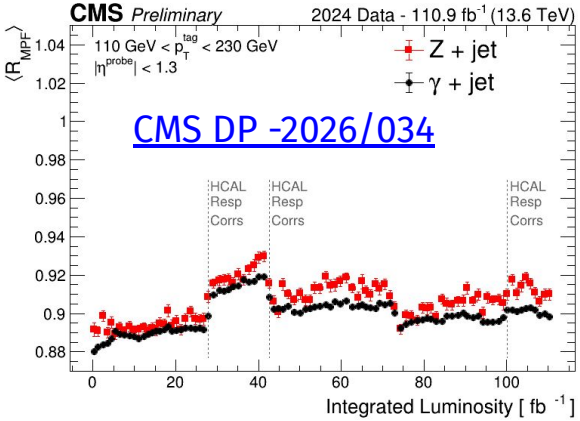
2026 increased scale from fixing HCAL response.

Smaller correction needed from fixing the underlying detector effects.

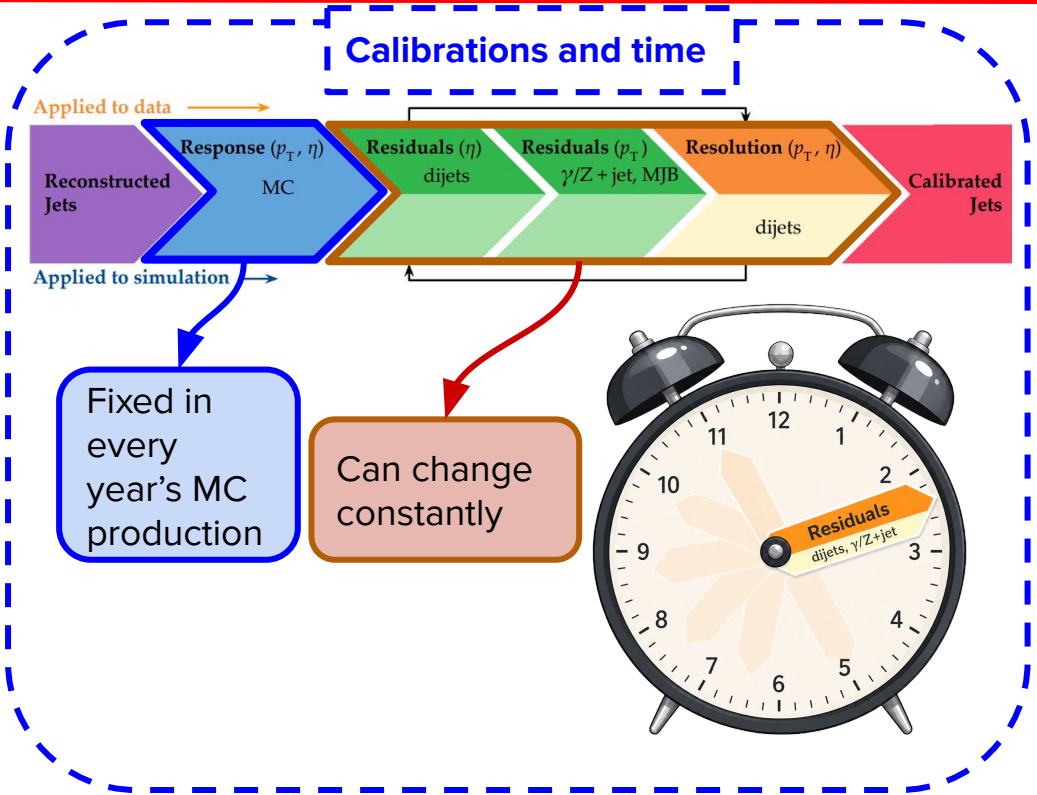
Fixing the jet energy scale.. constantly

A step for further improvement is to **automate the measurement of time dependent JECs (JEC4Prompt project).**

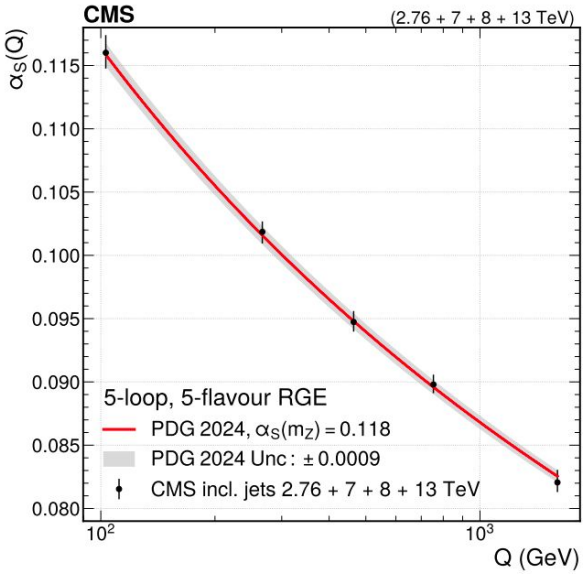
First results from the automation system running in real-time data show the detector changes are captured. Plan for HL-LHC.



CMS DP -2026/034



The jet spectrum becomes a QCD measurement



QCD weakens at high energy

Fit jet cross sections and HERA data jointly for αs and proton PDFs.

$$\alpha_s(m_Z) = 0.1176^{+0.0014}_{-0.0016}$$

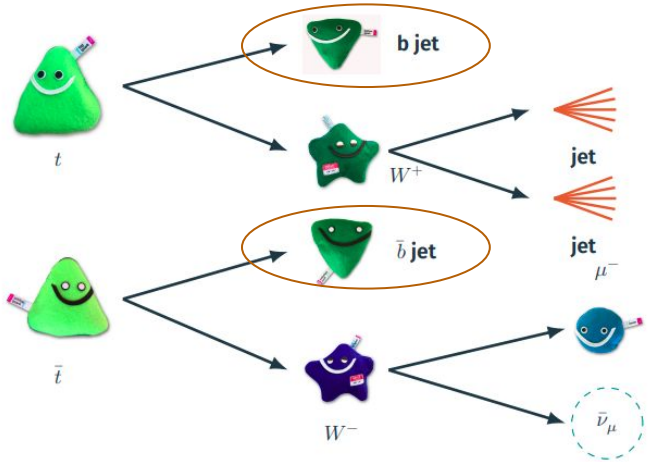
Running tested up to 1.6 TeV.

Experimental handle: the steeply falling spectrum makes the jet energy scale crucial.

Run 3: more reach with controlled response/resolution corrections

Determination of the strong coupling and its running from inclusive jet production, PLB 868 (2025) 139651

Use the jets to build the top

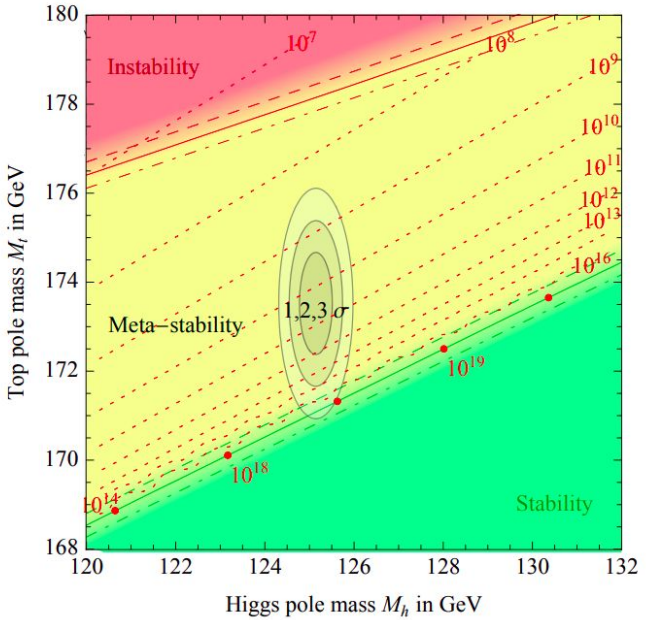


There is always a b-jet.

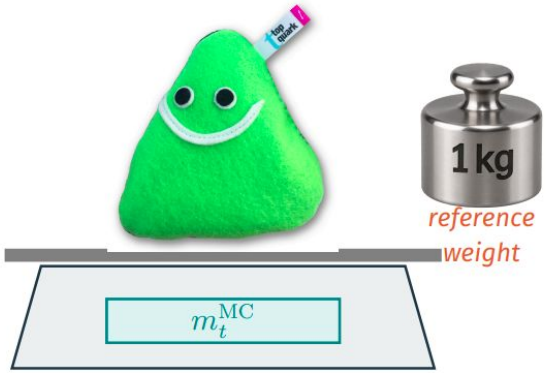
The Higgs quartic evolves with energy. Its evolution depends strongly on the top Yukawa interaction.

mt , mH and αs set key inputs to the Standard Model extrapolation.

Metastability can mean a lifetime far longer than the age of the Universe.



The top quark mass



What does the reference label mean?

$$m_t = 171.77 \pm 0.37\ \mathrm{GeV}$$

The scale has systematics Jet energy scale and resolution, b-jet response and pileup.

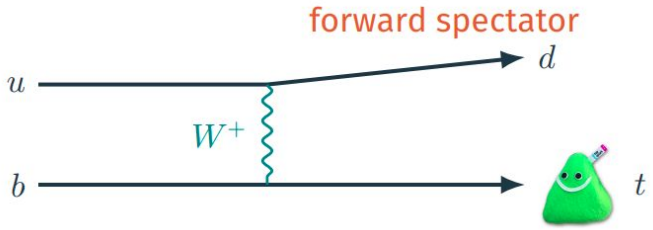
The decay is modelled Radiation, b fragmentation and colour reconnection alter the reconstructed mass.

Which mass are we measuring? The direct fit determines m_t^{MC}. Relating it to a pole or short-distance mass requires theory.

Interpretation is a separate issue

CMS top-mass benchmark, EPJC 83 (2023) 963; CMS mass review, Physics Reports 1115 (2025) 116–218.

Single top: Find the forward jet

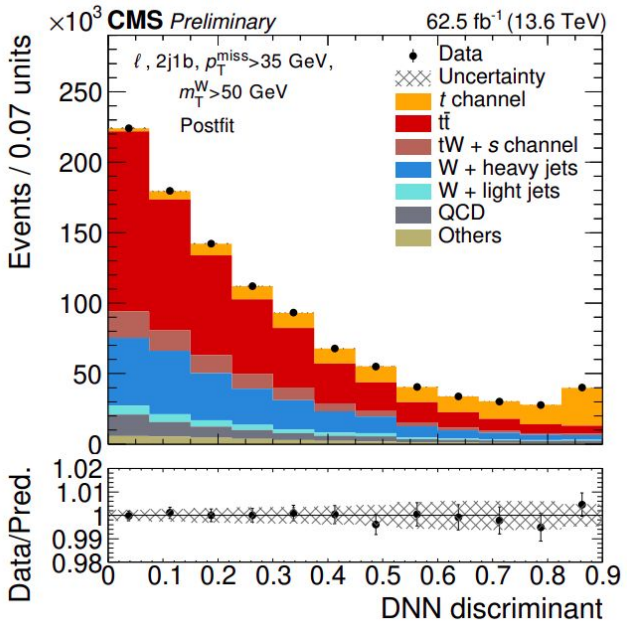


Selection: one isolated lepton, two jets, one b tag.

Fit a DNN discriminant. $\sigma(tq + \bar{t}q)$ = 223.1^{-}+9.3 −9.1 ± 1.2 pb
First uncertainty systematic, second statistical.

Top/antitop ratio: 1.67 ± 0.04 ± 0.02.

[Measurement of single-top t-channel production at 13.6 TeV.]



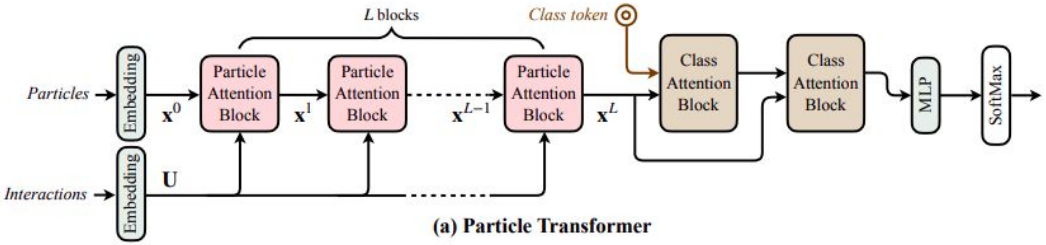
Postfit DNN distribution. The fit extracts the production rate.

What if the W makes a “b” and a “c”?

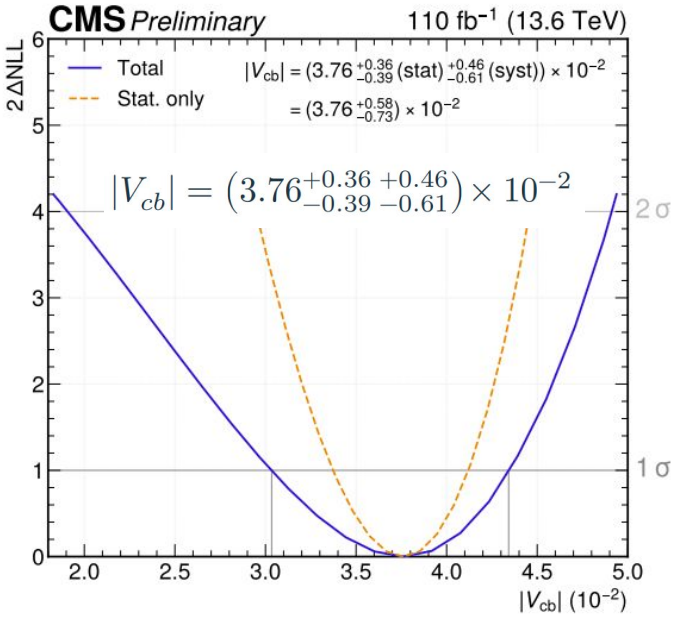
Top events are also a W factory

Look for $W \to cb$ in one top decay, with a lepton from the other W.

UParT identifies both b and c jets. An event transformer separates heavy-flavour backgrounds.



(a) Particle Transformer



[Measurement of the CKM matrix element |Vcb| using top-pair decays at 13.6 TeV.]

Total and statistical-only likelihood scans.
Complementary to B-hadron measurements

Near threshold slow top and anti-top

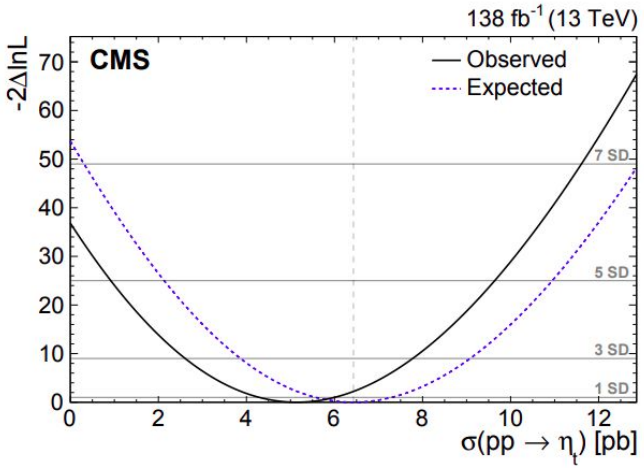
A slow top and antitop can interact

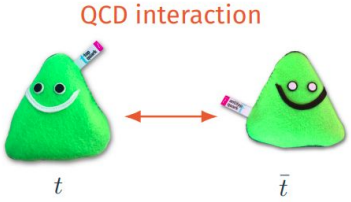
Near threshold, attractive QCD effects modify the rate and spin structure.

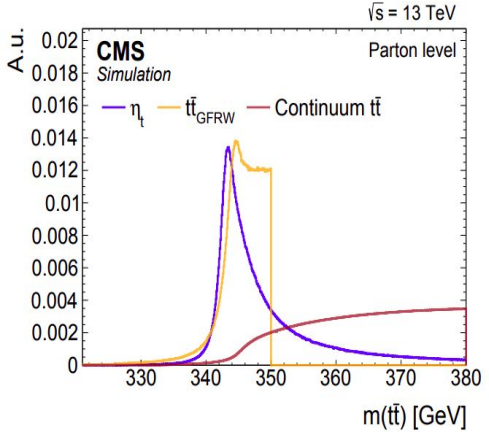
A lepton+jets analysis finds an excess consistent with a simplified pseudoscalar toponium model.

6.1σ significance

Fitted excess cross section: **5.1 ± 0.9 pb**



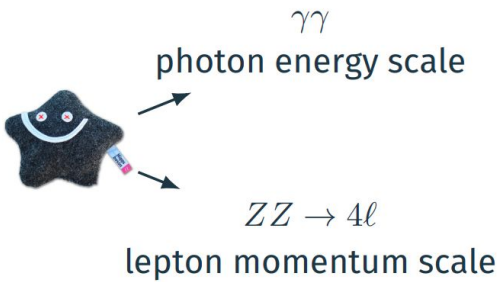




[CMS-TOP-25-002, Fig. 1(a) and Sec. 4; Fuks et al., EPJC 85 (2025) 157.]

Interpretation depends on the continuum and threshold modelling.

What about Higgs?

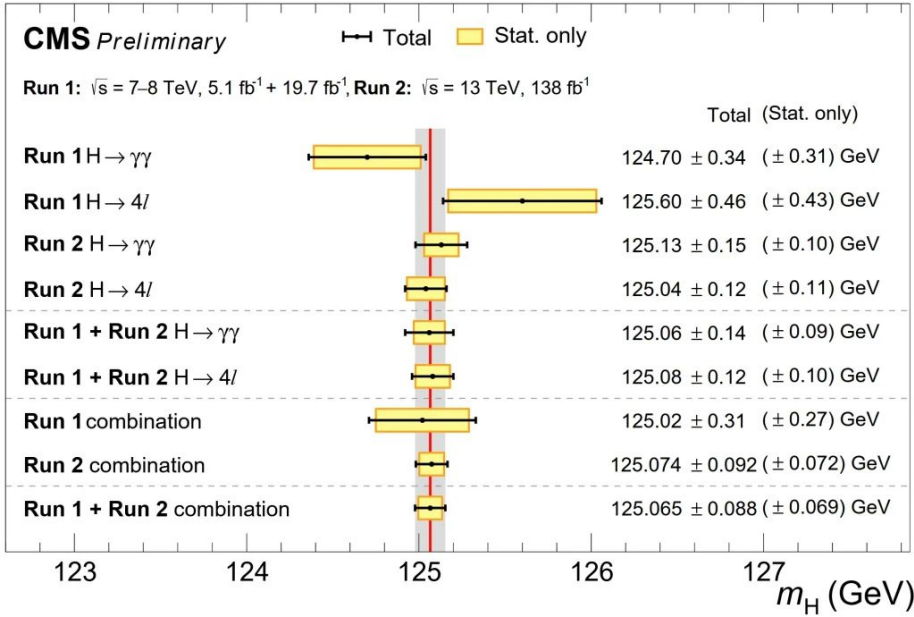


Different decay channels provide complementary precision measurements.

125.065 ± 0.088 GeV

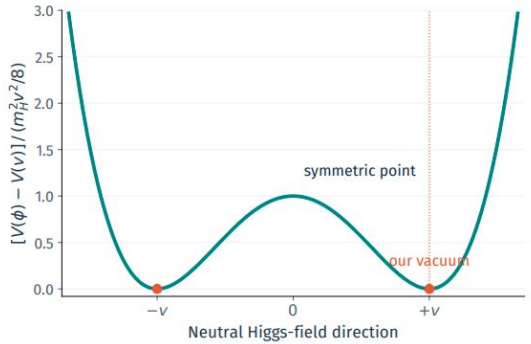
0.07% relative precision

Most precise Higgs mass measurement by a single experiment at the time of release.

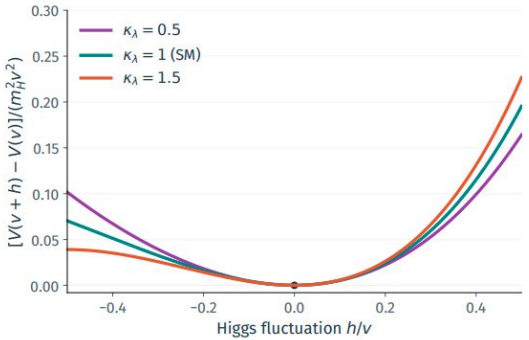


CMS-PAS-HIG-26-010; CMS physics briefing, 2 November 2026.

One Higgs tells us its mass. Two probe its self-interaction.



The field has a nonzero vacuum value v.



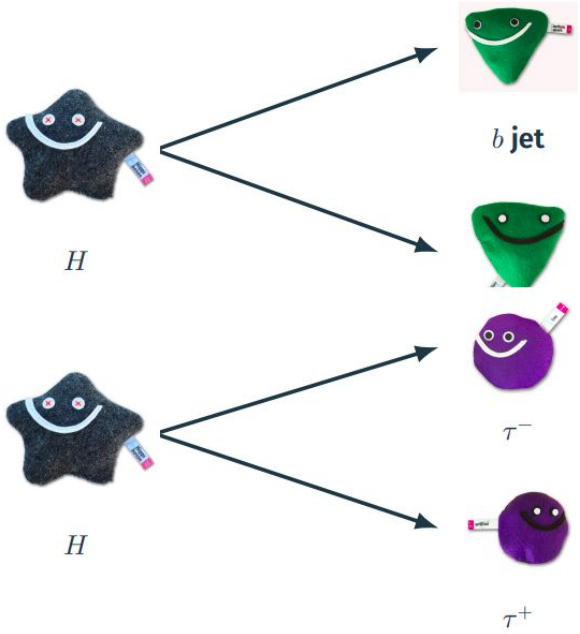
Changing the cubic term changes the local shape.

$$V(v+h) = \frac{m_H^2}{2}h^2 + \kappa_\lambda \frac{m_H^2}{2v}h^3 + \frac{m_H^2}{8v^2}h^4$$

The curvature is not the whole potential.

$\kappa_\lambda = \lambda_{HHH}/\lambda_{\text{SM}}$ HHH changes the cubic interaction.

Two Higgs. Two experimental jobs.



Two Higgs can decay to different mode.

Highest cross section HH➔bbbb.

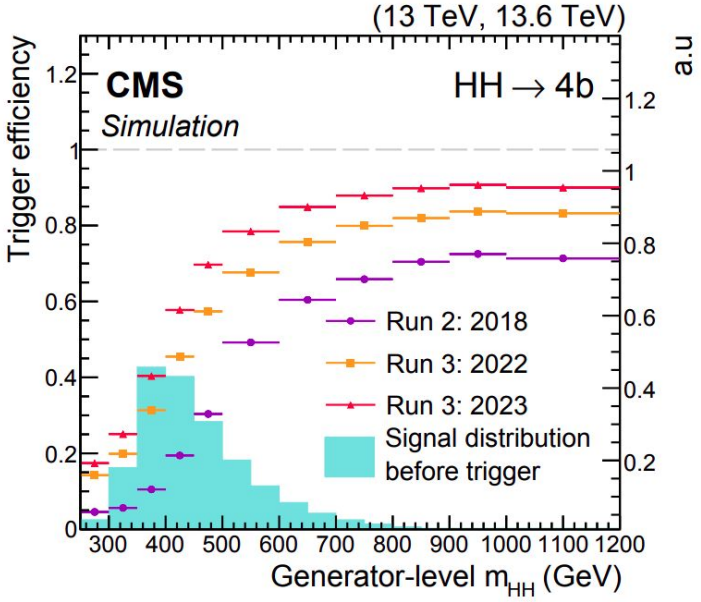
High cross section with cleaner topology HH ➔ bbττ

Experimental challenges in triggering, tagging and reconstruction.

Find the b jets Two b jets reconstruct one Higgs candidate. A

Account for the neutrinos Visible hadrons or leptons, plus neutrinos. Missing energy complicates the second Higgs candidate

Four b jets: the trigger gets a starring role



[Improved results on Higgs boson pair production in the 4b final state.]

Acceptance matters at low m_{HH}.

ParticleNet at HLT and dedicated HH triggers improve acceptance where much of the SM signal lies.

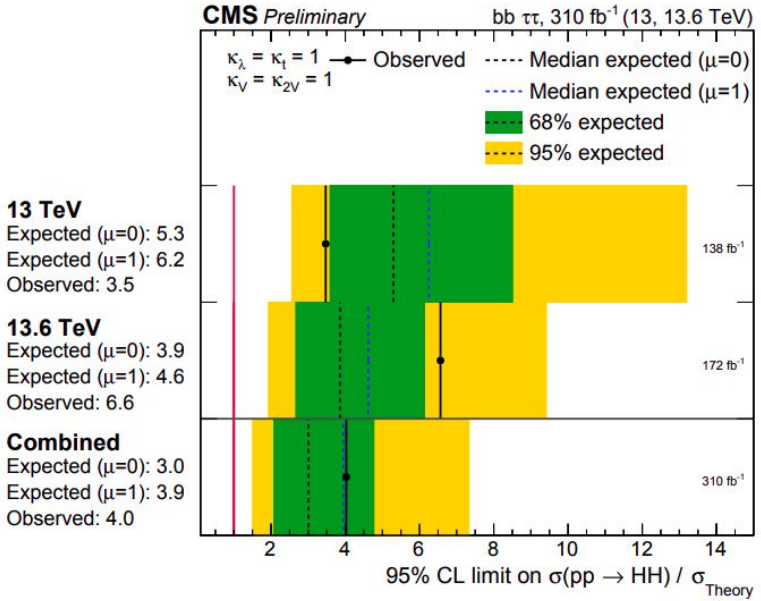
Resolved and merged topologies contribute.

95% CL rate limit: 4.4 (4.4)×SM
Observed (expected), Run 3 only.

At equal luminosity: > 2× better expected sensitivity (resolved).

Gain also includes offline tools.

bbττ: Run 3 is already doing heavy lifting



[Search for nonresonant HH production in the $bb\tau\tau$ final state, Fig. 7. 310fb−1 combined across two energies.]

More signal with better reconstruction.

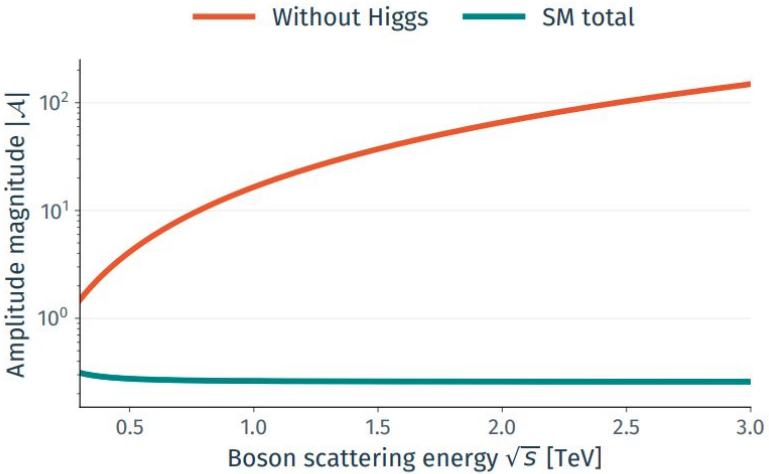
172 fb^{-1} in 2022–2024. Dedicated triggers and ML-based tools.

95% CL / SM	Obs.	Exp.
Run 3	6.6	3.9
Run 2 + 3	4.0	3.0

Combined coupling interval:

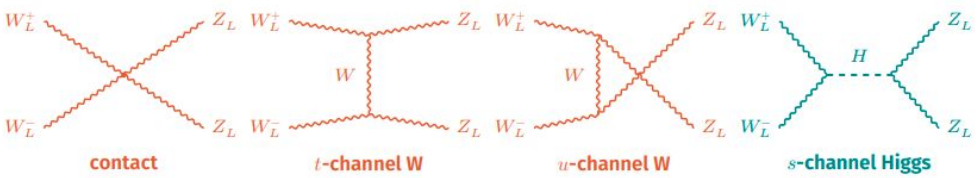
$-2.5 < \kappa_\lambda < 9.4$

The Higgs also keeps high-energy scattering in check



Longitudinal $W_L^+W_L^- \to Z_L Z_L$ at high energy.

$W_L^+W_L^- \to Z_L Z_L$



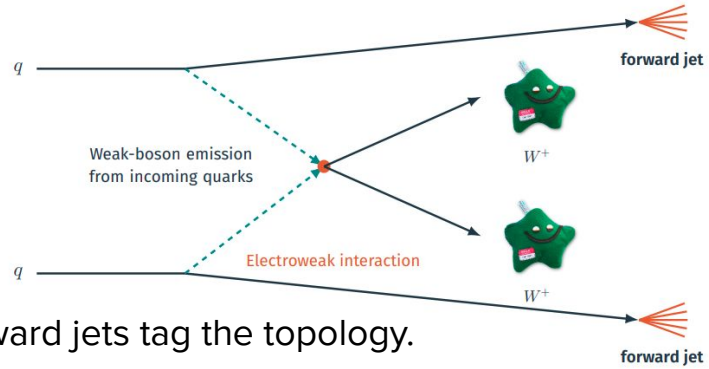
$$\mathcal{A} = \underbrace{\mathcal{A}_{\text{contact}} + \mathcal{A}_t + \mathcal{A}_u}_{\text{non-Higgs gauge sum}} + \mathcal{A}_H$$

$$|\mathcal{A}|^2 = |\mathcal{A}_{\text{gauge}}|^2 + |\mathcal{A}_H|^2 + \underbrace{2\,\text{Re}(\mathcal{A}_{\text{gauge}}\mathcal{A}_H^*)}_{\text{interference}}$$

The Higgs contribution cancels the leading energy growth of the gauge sum.

H. E. Logan : Peturbative unitarity lectures.

At CMS, VBS comes with two forward jets



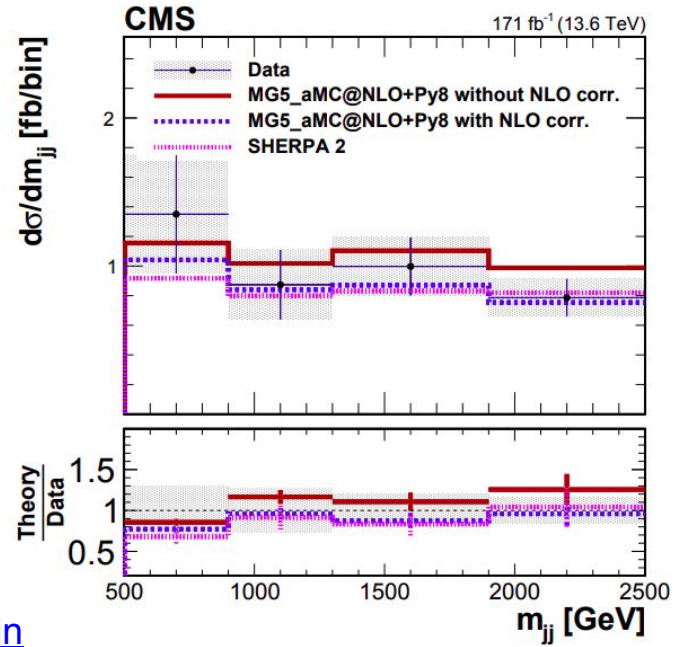
Two forward jets tag the topology.

Leptons identify the boson decays.

Same-sign WW and WZ electroweak production: each above 5σ.

Forward jets need careful calibration and pileup rejection.

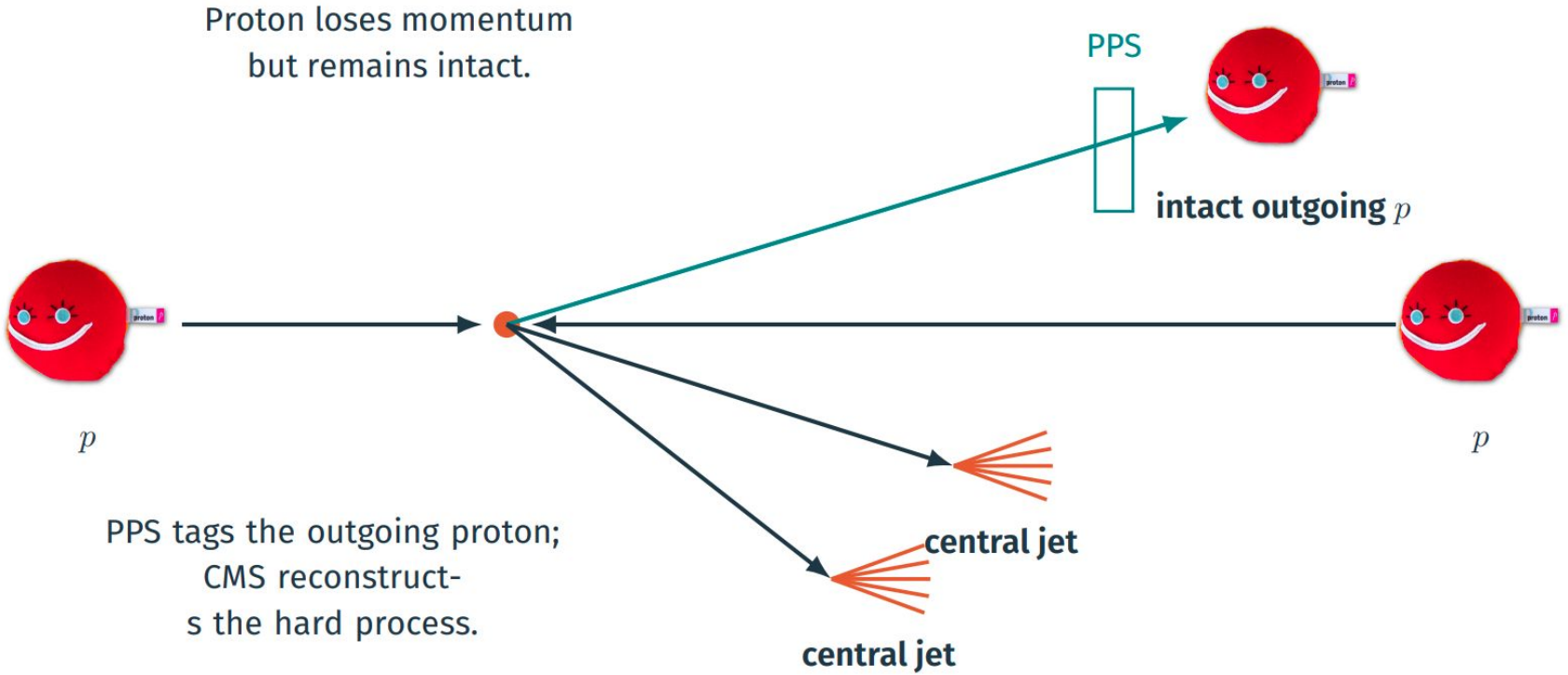
These measurements contain mixed polarizations.



[First VBS measurements in same-sign WW and WZ at 13.6 TeV]

Same-sign WW cross section versus dijet mass.

Meanwhile, one proton quietly leaves the scene



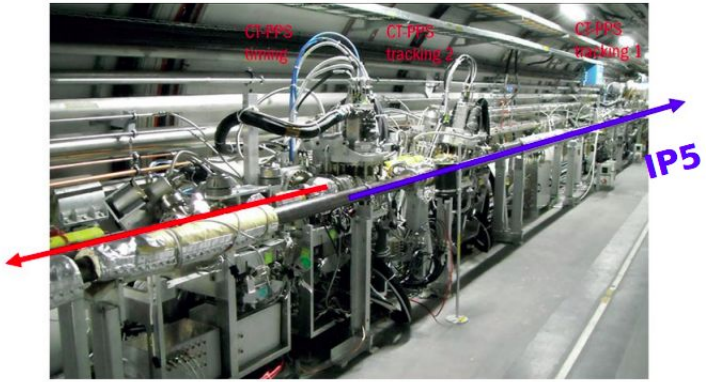
Proton Precision Spectrometer (PPS)

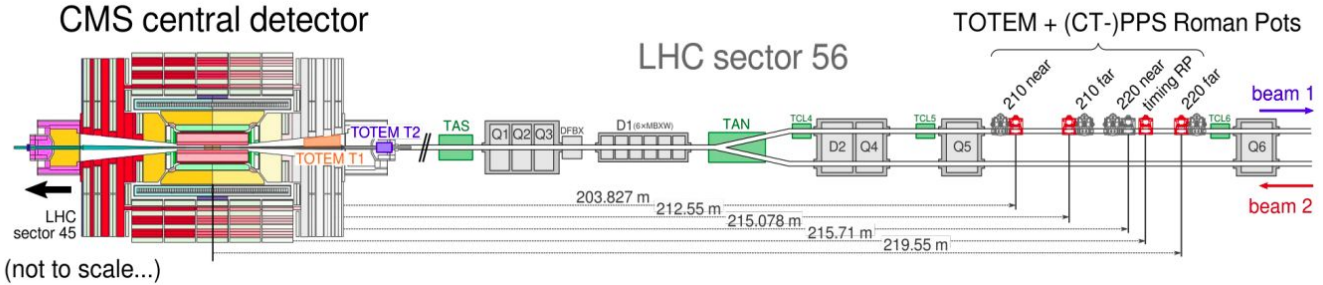
Built by combined TOTEM+CMS expertise

Operated in standard LHC runs since 2016

Located ~ 200m from CMS IP in both arms, equipped with tracking/timing detectors

A set of near-beam detectors that approach outgoing beam to a few mm



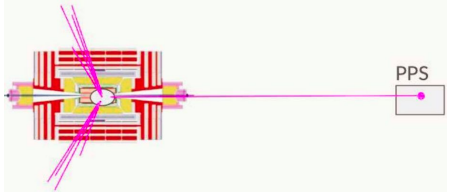


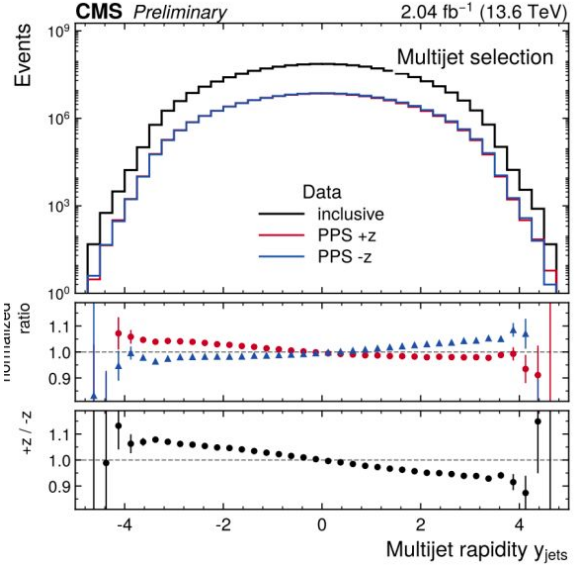
Diffractive jets, W & Z with forward protons

Study of diffractive events in low pileup data with CMS & PPS
➜ Uses 2fb-1 2026 low pileup run (μ approx. 5)

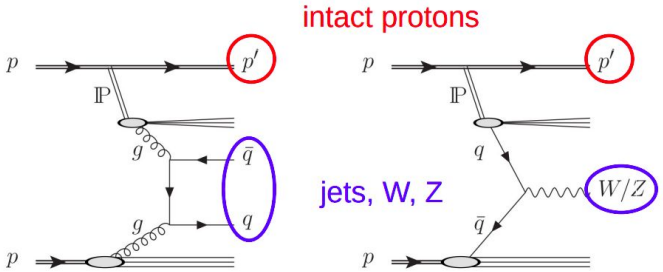
Correlate longitudinal boost of central system (jets, W, Z) with the tagged proton

Extract fraction of diffractive jets, W & Z:
~ 0.44% , ~ 1.0% , ~ 1.1%
➜ Differentially up to TeV scale





[CMS-PAS-SMP-26-015]



The physics starts long before the final fit



Top and QCD
Calibrated jets and flavour tags turn events into precision.



Higgs and VBS
HH acceptance and reconstruction. Forward jet control for VBS.



Forward physics PPS links protons to hard collisions.

Better events become better questions.

Helsinki's trigger, jet and analysis work connects with the whole chain.