
With financial support from the National Science Foundation and Department of Energy

Φαινό 2026

The 2026 Phenomenology Symposium

*An odyssey through particle physics and related encounters in astrophysics and cosmology*

University of Pittsburgh

May 11-13, 2026

indico.global/e/pheno26

# Searches for New Resonances with CMS

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On behalf of the CMS Collaboration

Pheno 2026

University of Pittsburgh, May 11-13, 2026

# Outline of this talk

- **CMS Resonance search landscape**

  From high-mass energy-frontier searches to low-mass trigger-frontier searches

- **High-mass resonance searches**

  Jets, leptons, MET, and diboson final states

- **Boosted and merged cascade decays**

  Dedicated reconstruction for collimated leptons and photons, jets

- **Low-mass resonance searches**

  Scouting, high-rate streams, and specialized triggers

- **Summary and outlook**

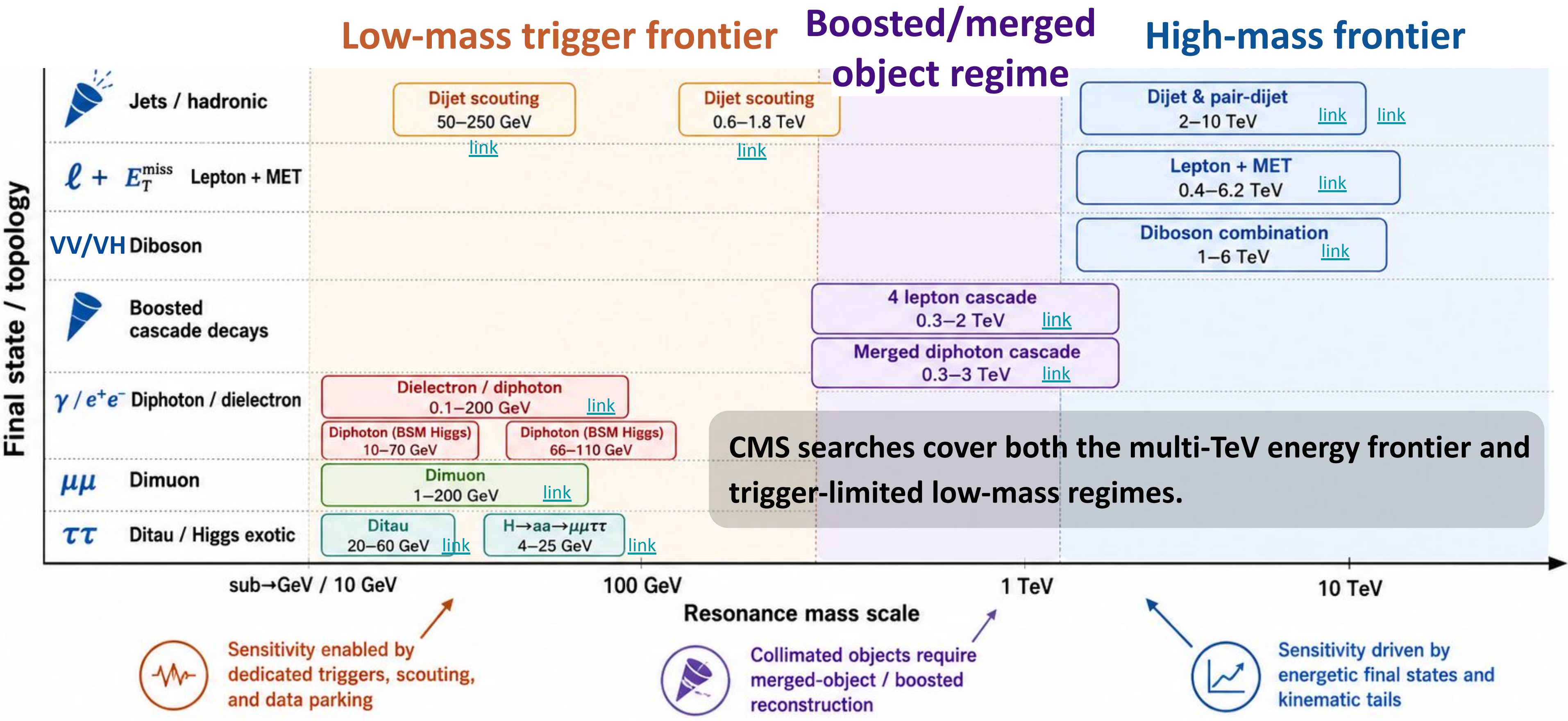
  Run 3 and future sensitivity improvements

CMS

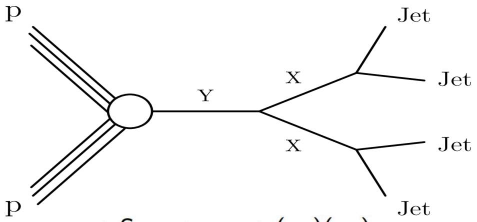
**Exotica results** Preliminary Publications

**B2G results** Preliminary Publications

# CMS resonance searches: Final state vs resonance mass map



# High-mass hadronic cascades: resolved 4-jet resonances

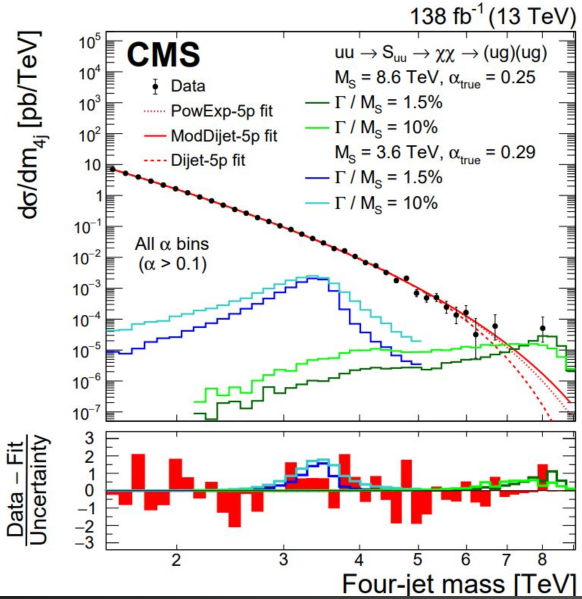



$uu \to S_{uu} \to \chi\chi \to (ug)(ug)$

$dd \to S_{dd} \to \omega\omega \to (dg)(dg)$

➔ **Pair-produced dijet resonances in a four-jet cascade topology**

Push CMS sensitivity to the **multi-TeV** scale by reconstructing resonant structures in both the **4-jet mass** and **paired-dijet masses**

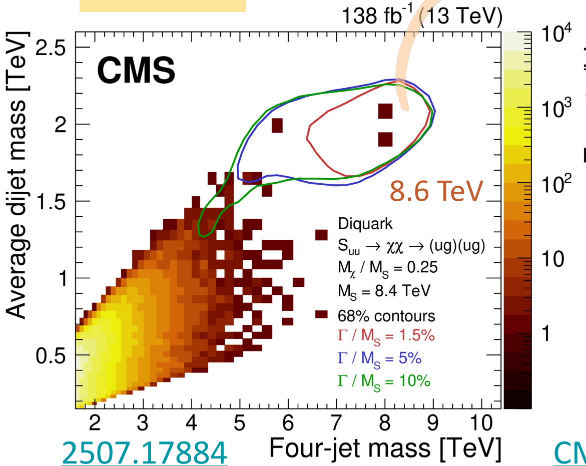



## $Y \to XX \to (jj)(jj)$

3.9σ local (1.6σ global)

Best-fit: $m_{4j}$ = 8.6 TeV, $m_{jj}$ = 2 TeV

**Run2**

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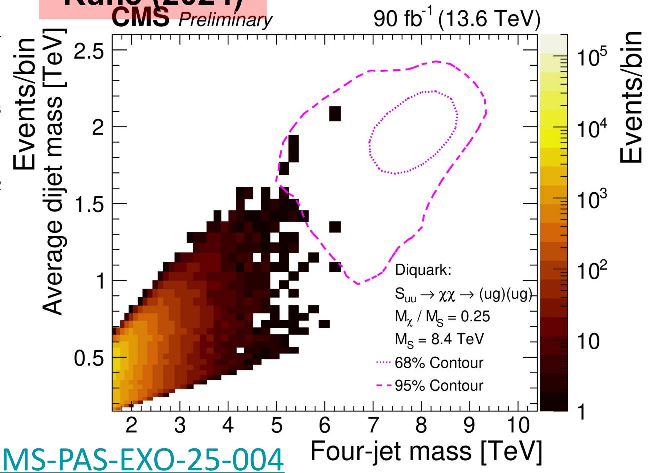
**Run3 (2024)**




CMS-PAS-EXO-25-004

# High-mass clean leptonic channel : W' → lν search

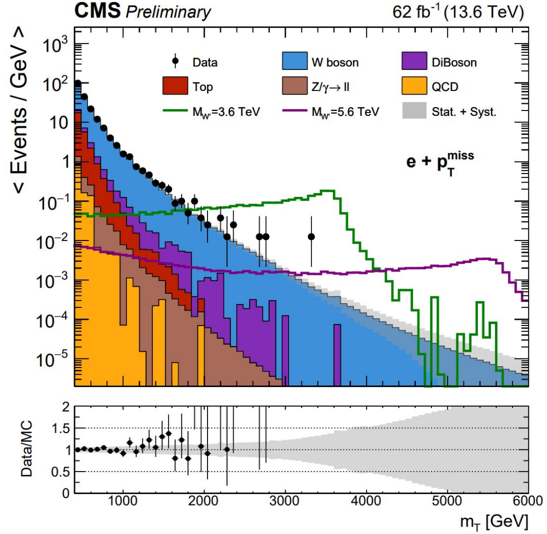
- ➔ Search for W' → lν, (l = e, μ) using the high-$m_T$ tail
- ➔ No significant deviation from the SM expectation
- ➔ SSM W' mass excluded up to ~6 TeV in Run 3
- ➔ Model-independent interpretation

➔ Improved Run 3 sensitivity

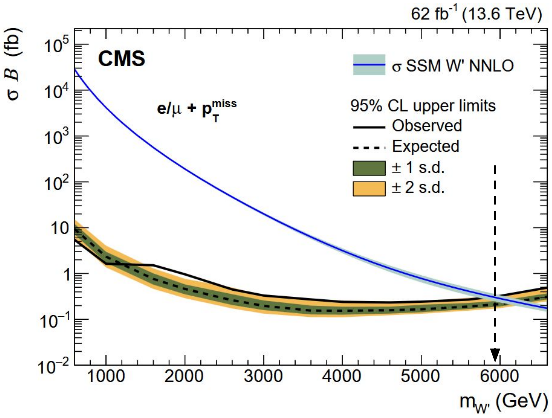
Higher center-of-mass energy √s

Lower trigger threshold for e-channel

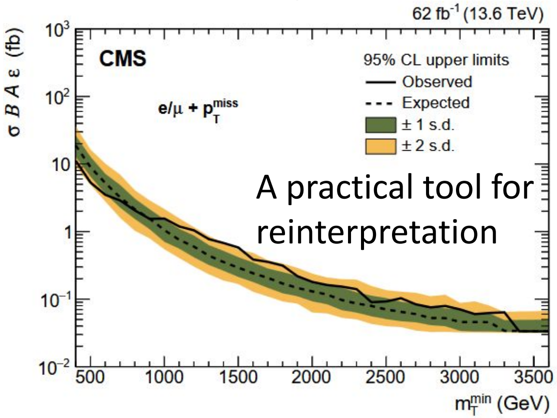
**Run3 (2022+2023)**




## SSM W' limit




## Model independent limit




A practical tool for reinterpretation

| Dataset | e Obs (Exp)[ TeV ] | $\mu$ Obs (Exp)[ TeV ] | $e + \mu$ Obs (Exp) [ TeV ] |
|---|---|---|---|
| 2022 + 2023 | 5.7 (5.9) | 5.6 (6.0) | 5.9 (6.2) |
| Run-2 result | 5.4 (5.3) | 5.6 (5.5) | 5.7 (5.6) |

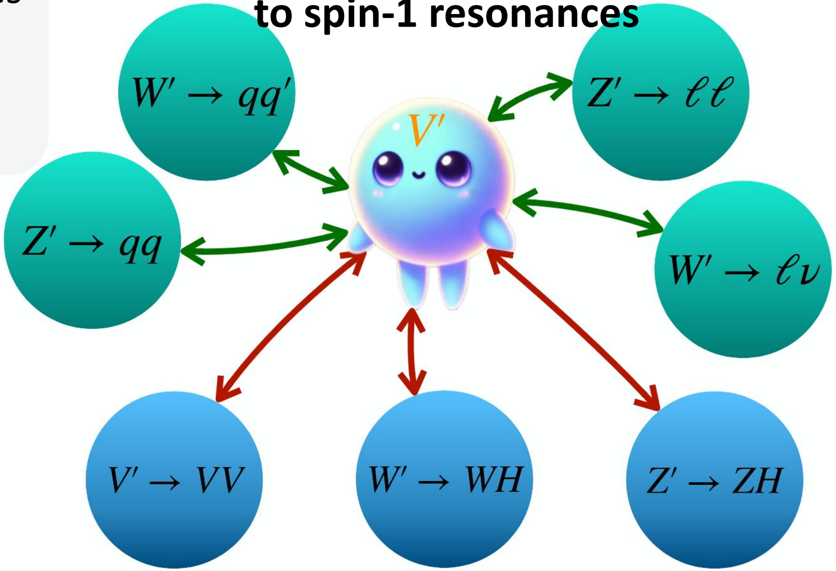
CMS-PAS_EXO-24-021

# A combined interpretation of High-mass spin-1 resonances

- ➔ Combination of 16 CMS searches for spin-1 resonances
- ➔ Covers V’ decays to leptons, quarks, and bosons
- ➔ Complementary sensitivity across coupling scenarios

| Channel | Prod. modes | $m_{V'}$ range [TeV] | Leptons | Jets |
|---|---|---|---|---|
| $Z' \to \tau^+\tau^-$ | DY | 0.5–4.0 | $\ell\tau_h$ or $2\tau_h$ | — |
| $Z' \to \ell^+\ell^-$ | DY | 0.8–5.5 | $2\ell$ | — |
| $W' \to \ell\bar{\nu}$ | DY | 0.8–6.0 | $1\ell$ | — |
| $W' \to \tau\bar{\nu}$ | DY | 0.8–6.0 | $1\tau_h$ | — |
| $V' \to q\bar{q}^{(\prime)}$ | DY | 1.8–8.7 | $0\ell$ | $jj$ |
| $W' \to t\bar{b}$ $(0\ell)$ | DY | 1.0–4.0 | $0\ell$ | $j^t j^b$ |
| $W' \to t\bar{b}$ $(1\ell)$ | DY | 2.0–6.0 | $1\ell$ | $j^b j^b$ |
| $Z' \to t\bar{t}$ $(1\ell)$ | DY | 0.8–5.0 | $1\ell$ | $j^t$or $jjj^b$ |
| $Z' \to ZH$ $(2\ell 2b)$ | DY + VBF | 0.8–5.0 | $2\ell$ | $j^{bb}$ |
| $Z' \to ZH$ $(2\nu 2b)$ | DY + VBF | 0.8–5.0 | $0\ell$ | $j^{bb}$ |
| $Z' \to ZH$ $(2\ell 2q)$ | DY | 1.2–6.0 | $2\ell$ | $j^H$ |
| $Z' \to ZH$ $(2\nu 2q)$ | DY | 1.2–6.0 | $0\ell$ | $j^H$ |
| $W' \to WZ$ $(2q2\ell)$ | DY | 0.6–2.0 | $2\ell$ | $j^V$or $jj$ |
| $W' \to WZ$ $(2q2\nu)$ | DY + VBF | 1.0–4.5 | $0\ell$ | $j^V$ |
| $V' \to WV/WH$ | DY + VBF | 1.0–4.5 | $1\ell$ | $j^V$ |
| $V' \to VV/VH$ | DY + VBF | 1.3–6.0 | $0\ell$ | $j^V j^V$ |

**Global CMS sensitivity to spin-1 resonances**




Interpretation in the **Heavy Vector Triplet framework**
Sensitivity depends on fermionic and bosonic couplings

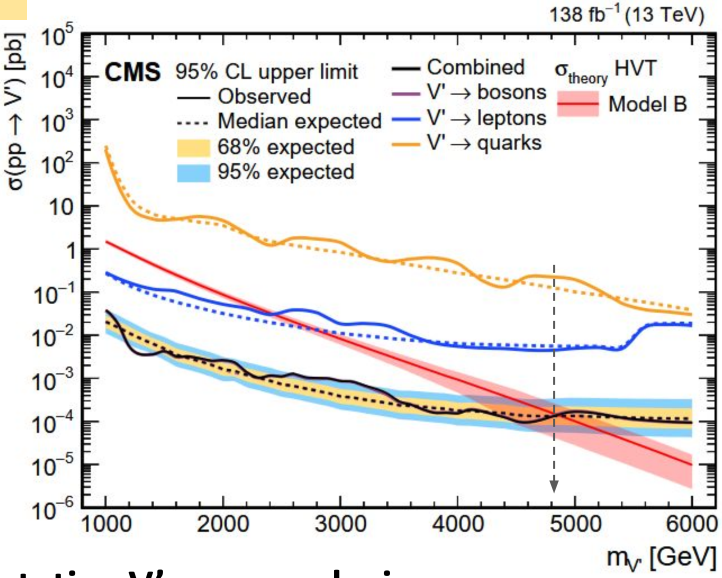
2601.12583

# Spin-1 combination: mass reach and coupling interpretation

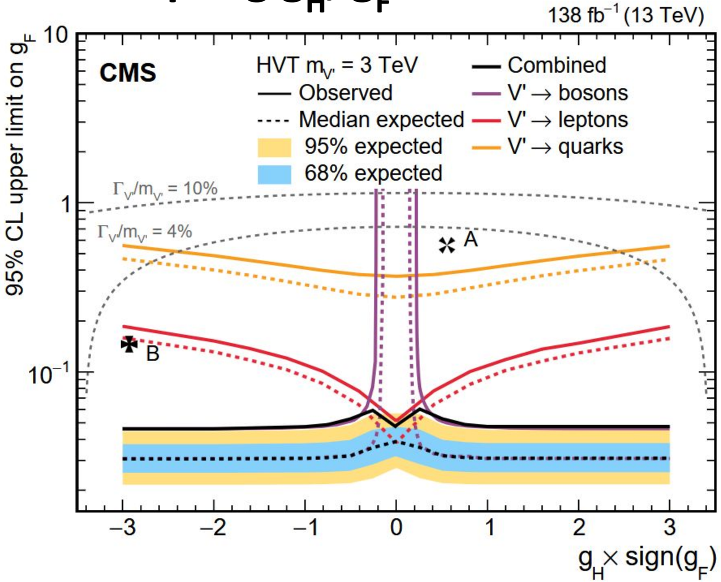
The combination constraints not only the **V’ mass,** but also the **coupling structure** of the new vector states.

**Run2**

## Broad mass scan




## Coupling $g_H$, $g_F$ scan




**Representative V’ mass exclusions:**

➔ Weakly coupled A model : M(V’) below ~5.5 TeV

➔ Strongly coupled B model: M(V’) below ~4.8 TeV

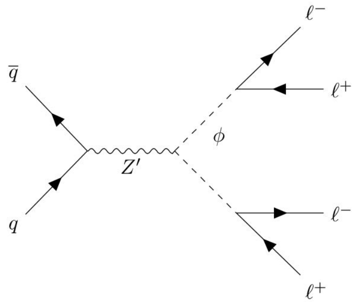
➔ VBF production C model : M(V’) below ~2.0 TeV

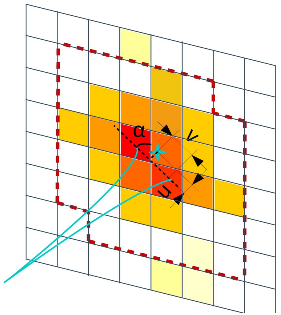
beyond the assumption of fermion universality ($g_{lep} = g_H = 0$)

Limit on $g_{1st\ 2nd\ quark}$ , $g_{3rd\ quark}$ (backup)

2601.12583

# Boosted cascade decays: collimated four-leptons

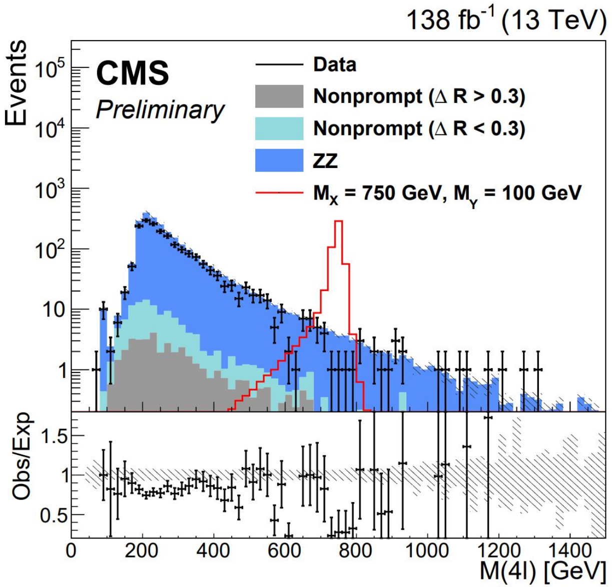


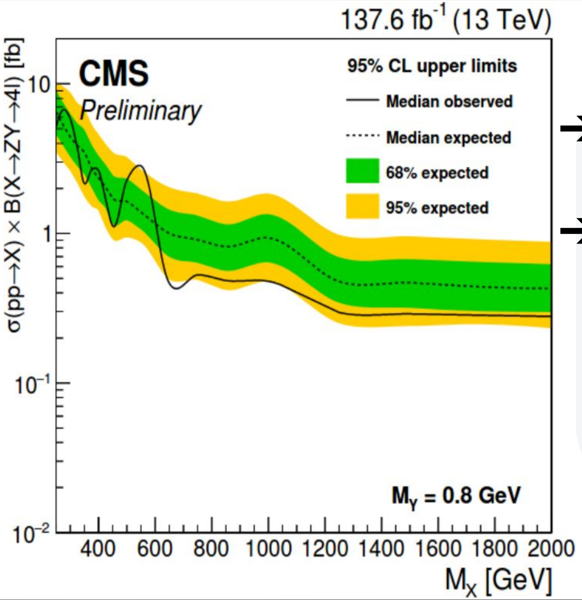



Light intermediate bosons can produce **highly collimated dileptons**, extending resonance searches to boosted four-lepton topologies.

- ➔ Targets X masses up to 2 TeV and Y masses down to sub-GeV
- ➔ Uses dedicated merged-electron reconstruction & identification
- ➔ Total 9 signal regions cover different boost regimes

**Run2**



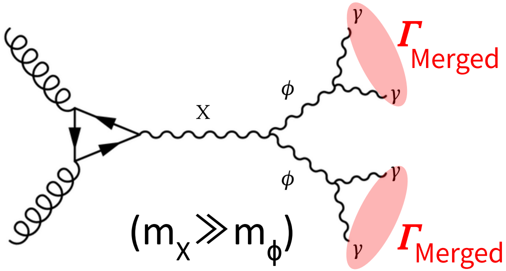

- ➔ No significant excess is found.
- ➔ largest deviation: 2.37σ (local), 1.85σ (global) at $M_X$= 550 GeV $M_Y$= 0.8 GeV.

2604.14236

# Boosted cascade decays: merged diphotons objects

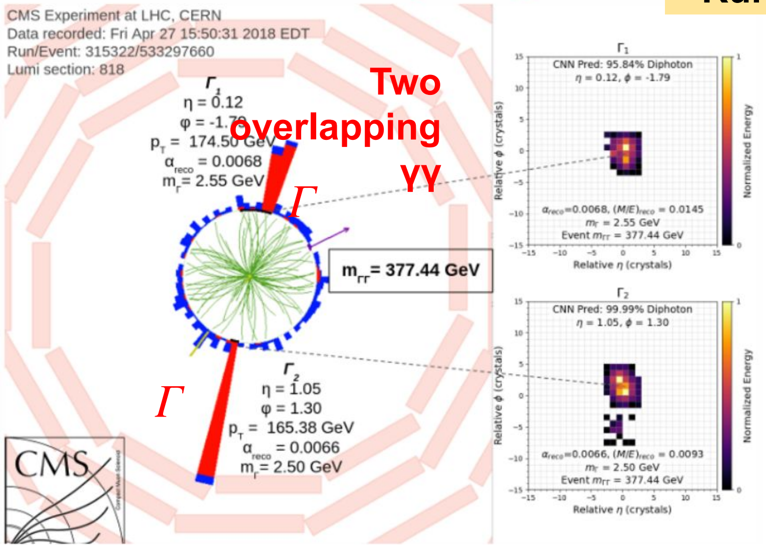
**X→ϕϕ → *ΓΓ* , where *Γ* = merged γγ**

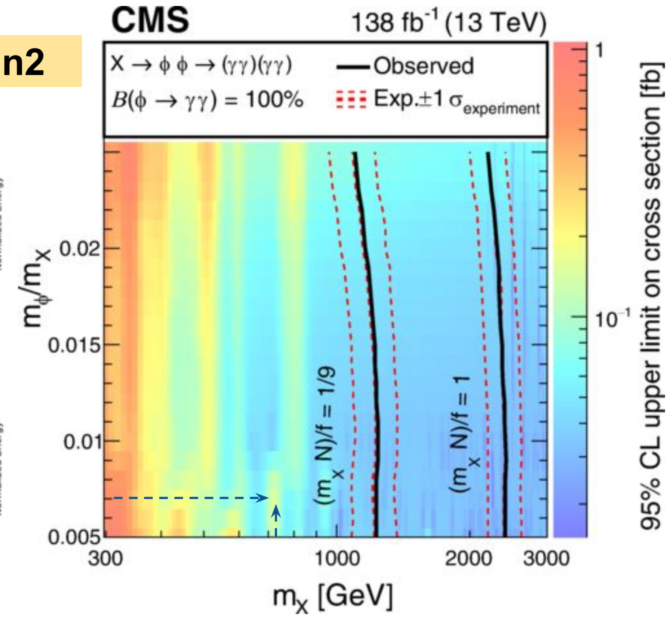
$0.3 < m_X < 3$ TeV and $0.5 < m_\phi / m_X < 2.5\,\%$




- ➔ CNN-based image recognition identifies merged 2γ objects
- ➔ Neural-network regression estimates the merged-object mass ($m_\Gamma$)
- ➔ Provides the most sensitive LHC constraints for this merged-2γ topology

**Run2**



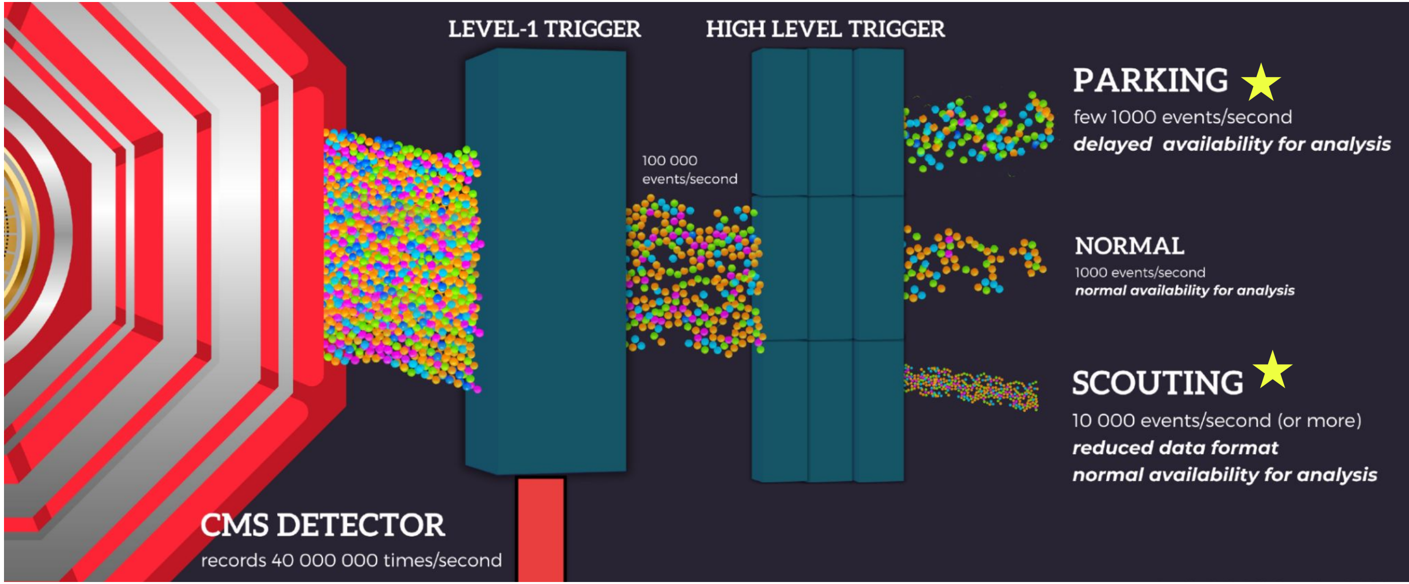

- ➔ No significant excess is found.
- ➔ largest deviation: 3.57σ (local), 1.07σ (global) at $M_X \approx 720$ GeV, $M_\phi \approx 5$ GeV.

PRL134(2025)041801

# Why low-mass resonance searches are challenging?

At low mass, sensitivity is often limited not by luminosity, but **by trigger thresholds, data rates, and object reconstruction.**

Phys. Rept. 1115 (2025) 678




## Why hard?

- ➔ **Softer** leptons, photons, and jets
- ➔ **Large SM rates** require high trigger thresholds
- ➔ **Bandwidth limits** full event storage
- ➔ **Boosted light states** produce **merged objects**

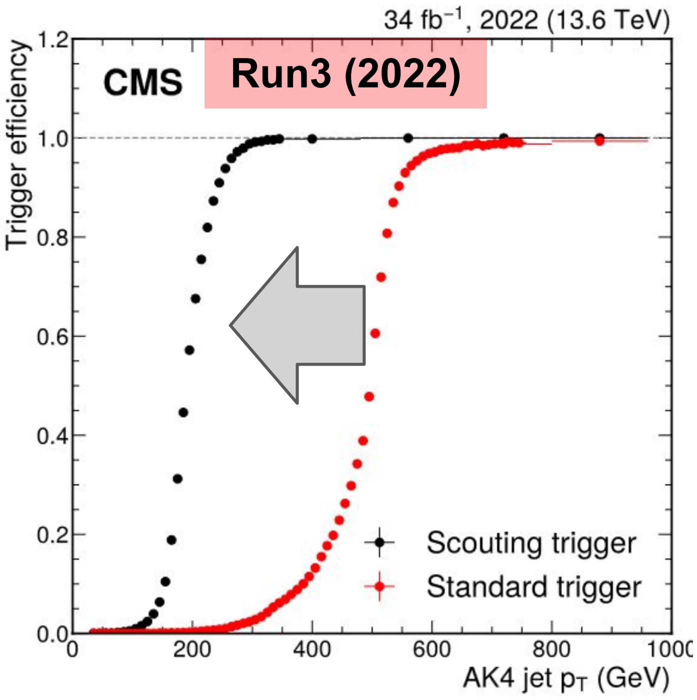
## CMS strategies

- ➔ Low-threshold dedicated triggers
- ➔ **Scouting**: reduced HLT-level event content
- ➔ **Parking:** delayed offline reconstruction
- ➔ **Specialized merged-object reconstruction**

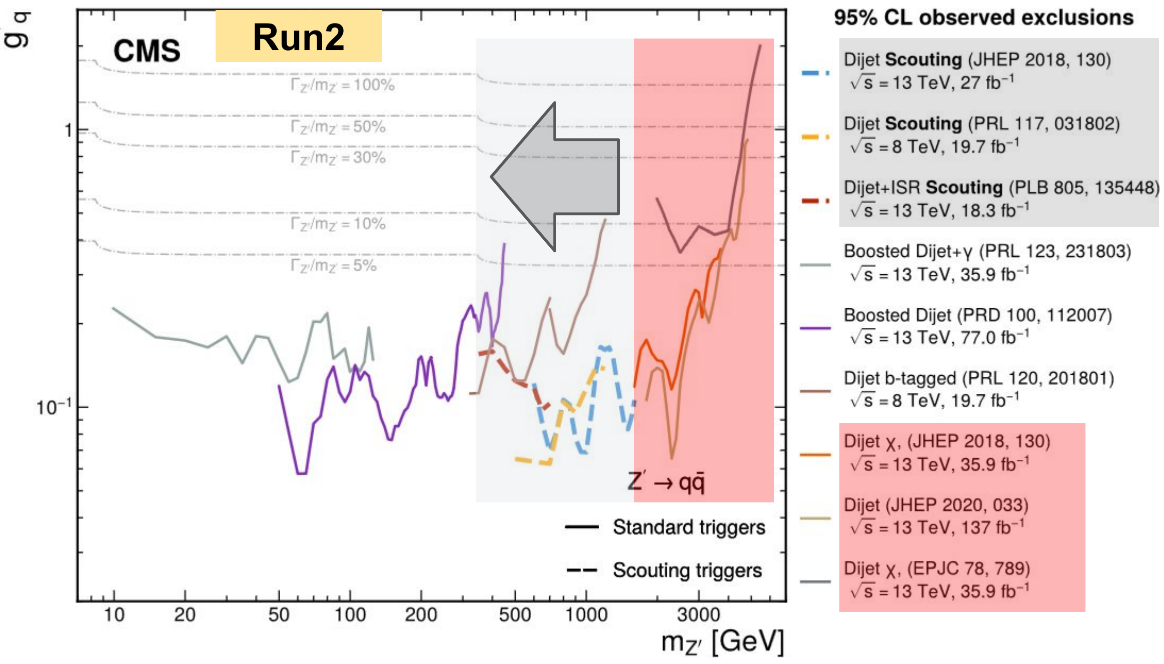
# Low-mass frontier: lowering thresholds with scouting

Scouting reduces the stored event content, enabling lower trigger thresholds & access to lighter resonances.

## Scouting vs standard trigger efficiency

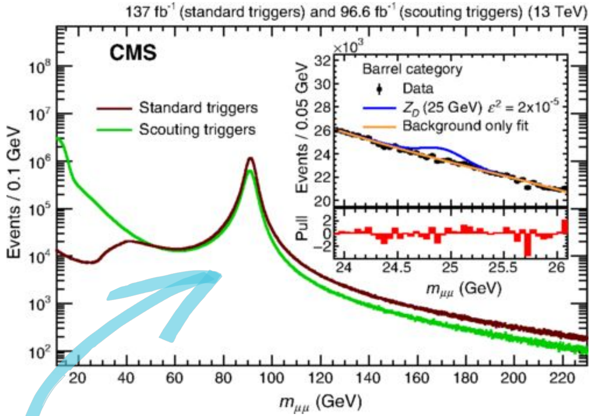



## Low-mass dijet resonances with scouting



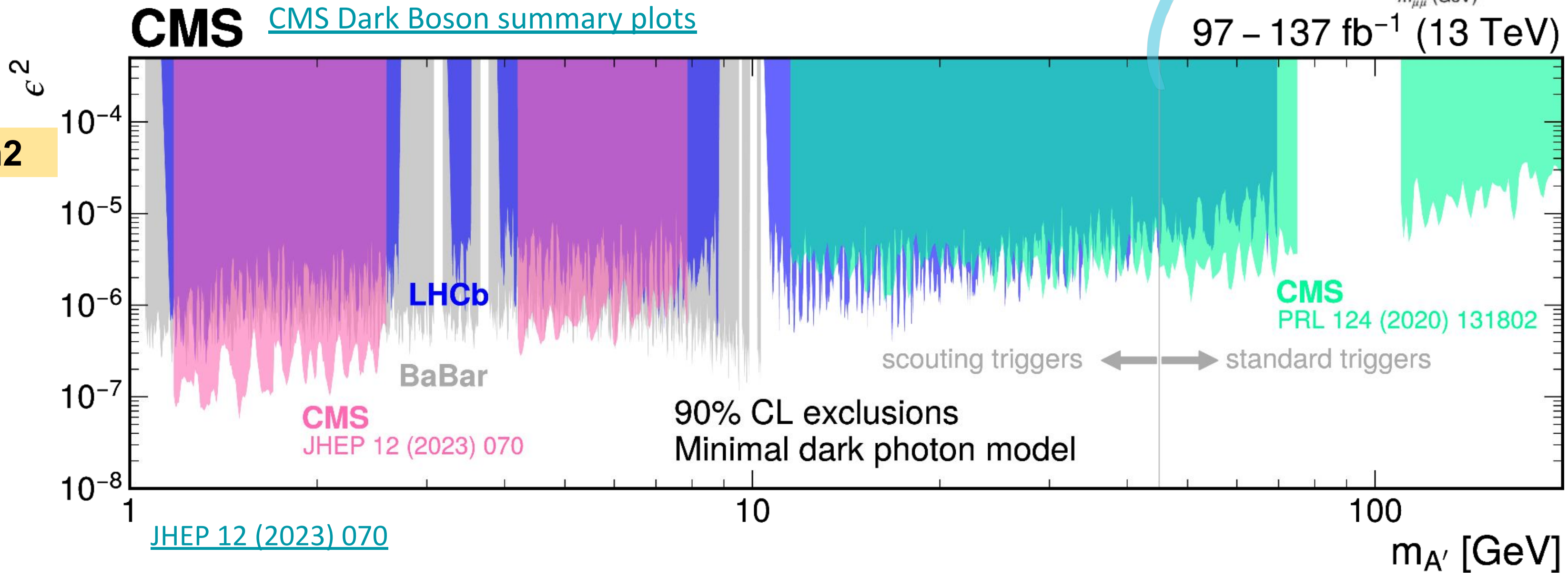
# Low-mass dimuon frontier: scouting

- ➔ Dimuon scouting enables μμ resonance searches in 1 – 200 GeV
- ➔ Scouting trigger record low-$p_T$ muons down to ~3 GeV
- ➔ Reduced event content extends sensitivity down to 1 GeV scale
- ➔ Strong constraints on dark photons and other light bosons




CMS Dark Boson summary plots

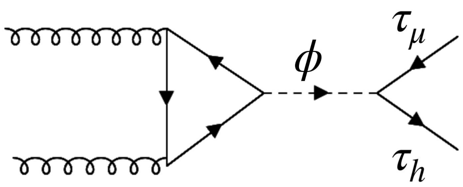
Run2

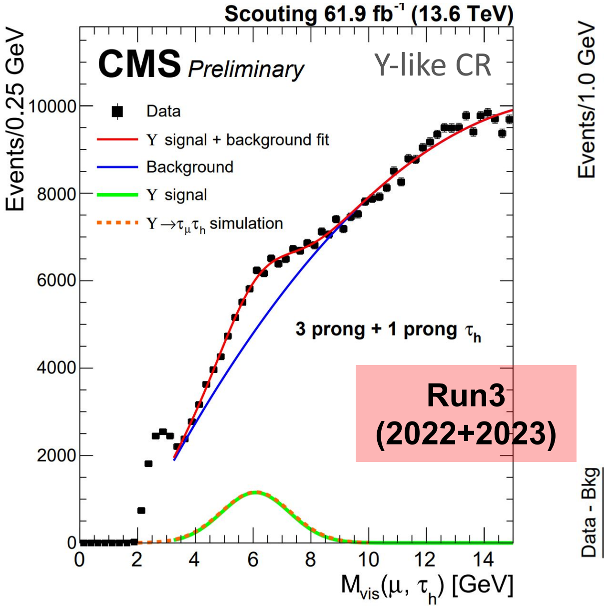


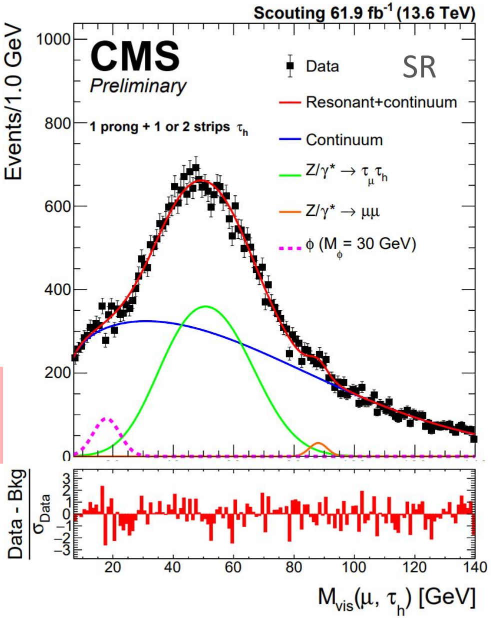

JHEP 12 (2023) 070

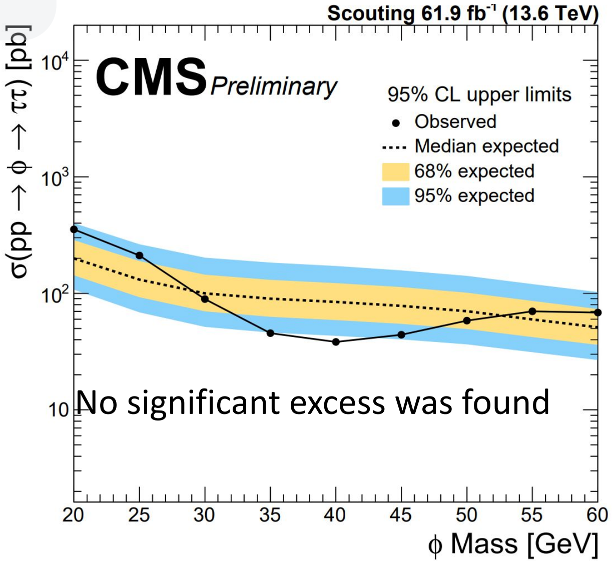
# Low-mass ditau frontier: scouting

- ➔ Inclusive $\tau_\mu\tau_h$ resonance search with 2022-2023 Scouting data
- ➔ EM- or hadronic-activity scouting triggers
- ➔ Key challenge : low-$p_T$ $\tau_h$ reconstruction ⇒ Scouting HPS, TauNet ID
- ➔ Open sensitivity to the 20-60 GeV mass range




**New collider constraints on $\tau_\mu\tau_h$**
in this low mass range

CMS-PAS-EXO-24-012

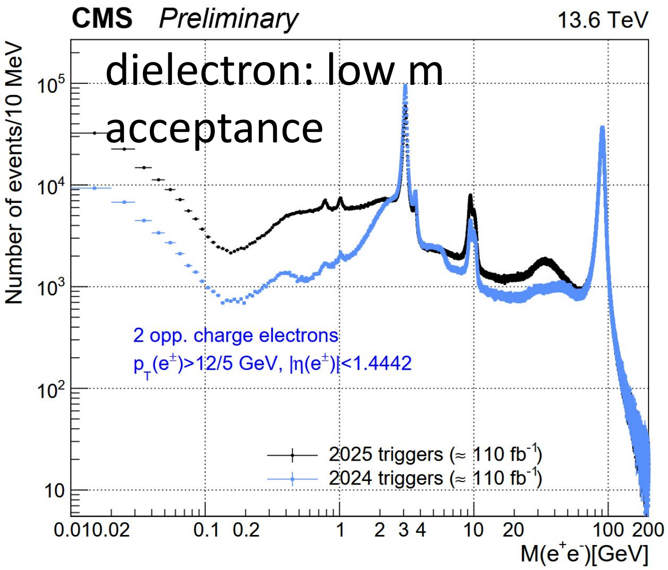
# Low-mass EM frontier: soft dielectron & diphoton final state

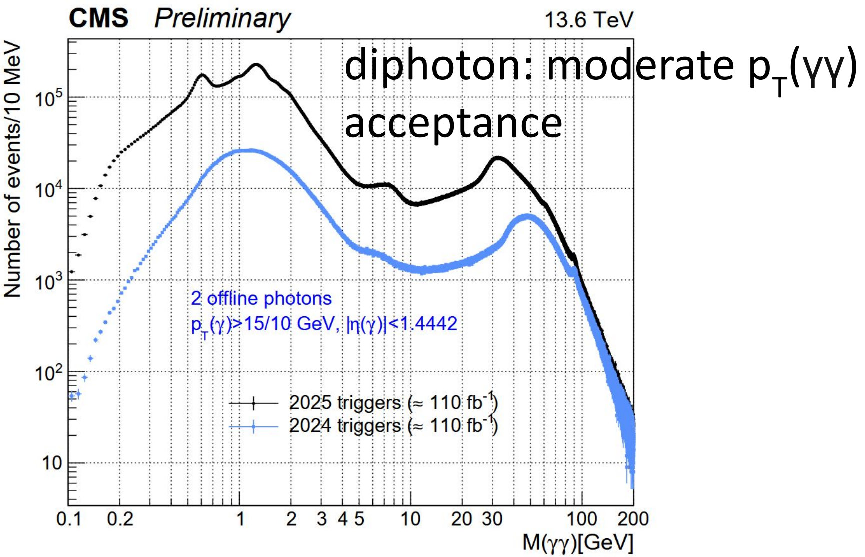
- ➔ New Run 3 EM-pair triggers target moderate-$E_T$ e/γs (~ 10–15 GeV)
- ➔ Designed for low-mass and boosted dielectron/diphoton topologies
- ➔ Extends acceptance below standard single-object trigger thresholds

| Trigger | Years | $E_T$ threshold(s) in 2025 (GeV) |
|---|---|---|
| Isolated dielectron | Since Run 1 | 25/12 |
| Non isolated dielectron | Since Run 1 | 25/25 |
| Isolated diphoton | Since Run 1 | 30/22 or 22/14 (barrel only) |
| Non isolated dielectron | Since Run 1 | 70/70 |
| Isolated single electron | Since Run 1 | 32 |
| Non isolated single electron | Since Run 1 | 115 |
| Non isolated single photon | Since Run 1 | 200 |
| Isolated single photon | Since 2018 | 40 (barrel only) |
| Non isolated low mass dielectron ($2 \lesssim M(ee) \lesssim 6$ GeV) | 2022-2024 | 6.5-11/6.5-11 GeV (barrel only) |
| New isolated dielectron/diphoton (custom isolation) | 2025 | ≈15/10 $p_T$ (barrel only) [1] |

**Run3 (2024,2025)**

Run 3 trigger frontier



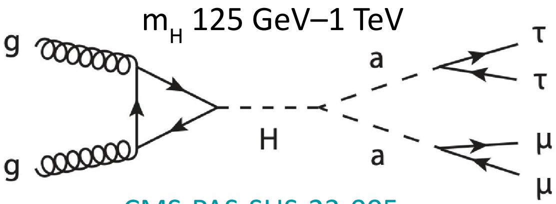




CMS DP-2026-001

# Exotic Higgs low-mass frontier: leptonic/tau channel

**$H \rightarrow aa \rightarrow \mu\mu\ \tau\tau = (\tau_h\tau_\mu), (\tau_h\tau_e), (\tau_h\tau_h), (\tau_e\tau_\mu)$**

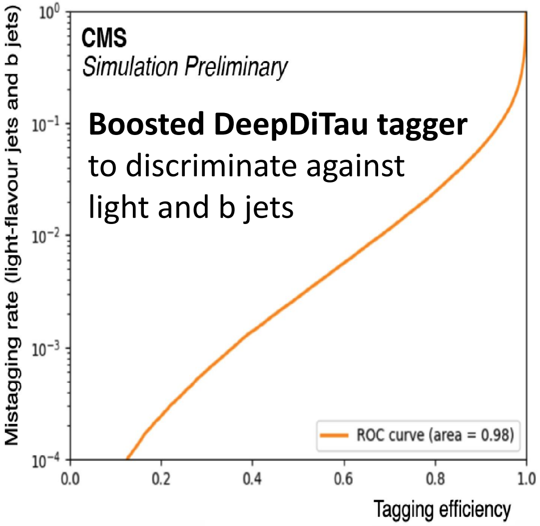
- ➔ A light pseudoscalar a → boosted/collimated μμ ττ pairs
- ➔ Key challenge : collimated ττ often fails standard τ reconstruction
- ➔ Dedicated di-τ reconstruction + DNN di-τ taggers recover efficiency



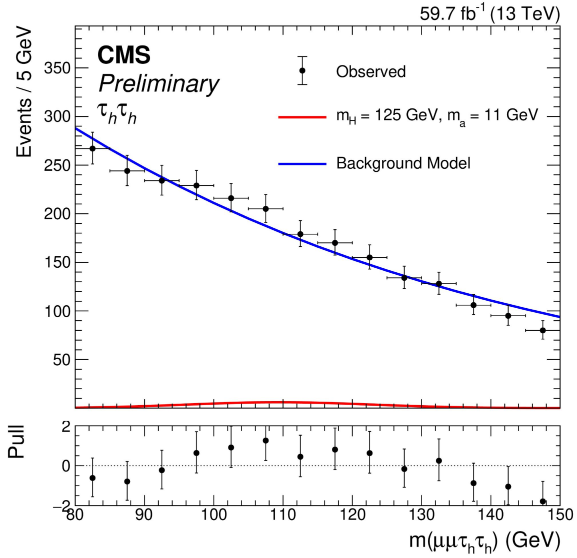

CMS-PAS-SUS-23-005

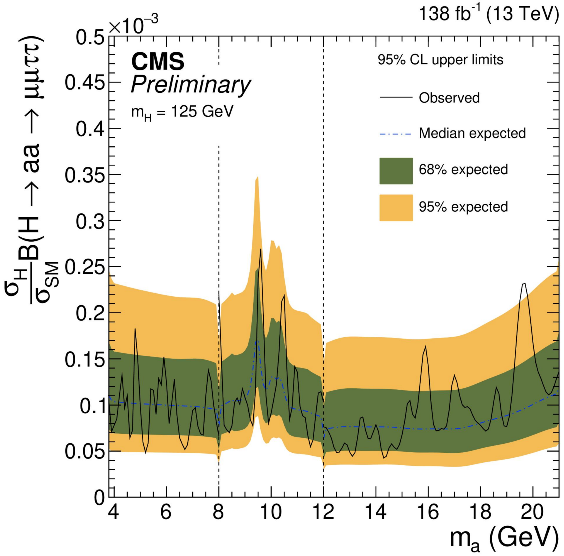
**Run2**

Open sensitivity to ma 3.6–50 GeV




**Boosted DeepDiTau tagger** to discriminate against light and b jets



# Summary and outlook

- CMS resonance searches span a wide range of final states and mass scales, from GeV-scale signatures to multi-TeV resonances.

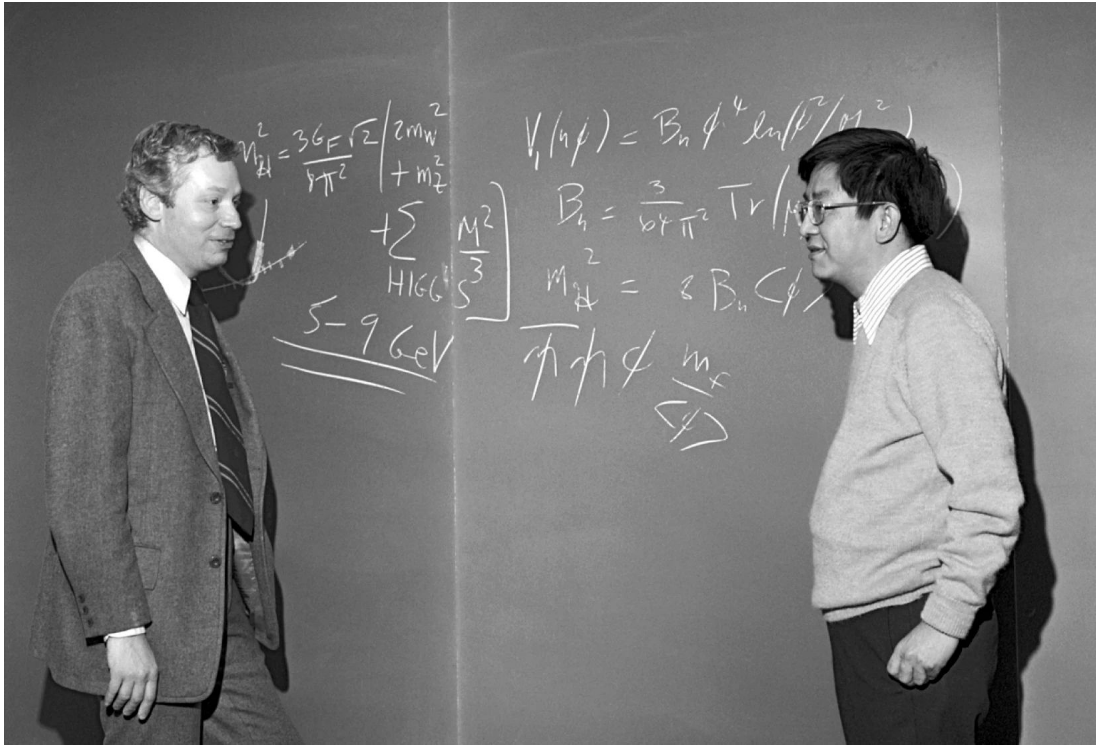
| Low-mass frontier | Boosted-object frontier | High-mass frontier |
|---|---|---|

- No significant evidence for new resonances has been observed so far; stringent limits are set across many BSM models and final states.
- With growing Run 3 dataset, including 2025 data, together with improved trigger and reconstruction techniques, will further expand the CMS resonance search reach.

# Backup slides


## Re-remembering

## Benjamin Whisoh Lee, promoter of gauge theories



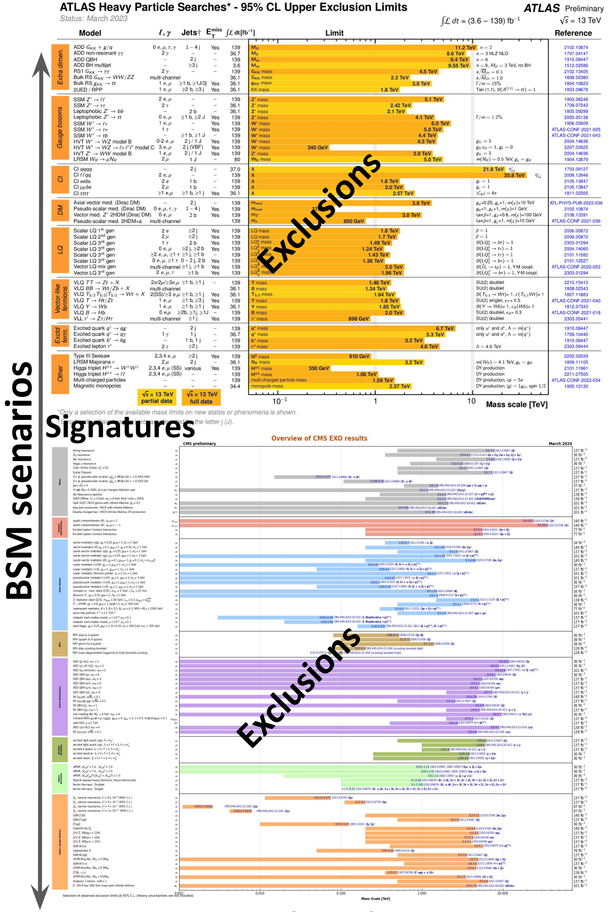
**Steven Weinberg and Ben Lee**, pictured at Fermilab, had a fruitful collaboration that produced an early calculation of the lower bound of heavy neutrinos' mass.

# BSM Searches at the LHC

- LHC is world's most powerful discovery machine
  - Hope to find hints of **BSM physics** and measurements as well

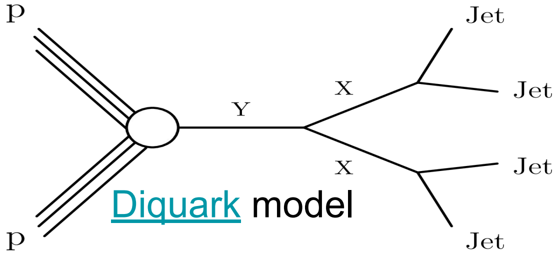
- Program driven by **BSM** and **experimental results**
  - Explaining unresolved mysteries in SM
    - Hierarchy problem, Unification, Dark matter, neutrino mass, Matter-antimatter asymmetry …
  - Strong hints from measurements
    - $\mu$ g-2, B-anomalies, direct detection of DM, cosmological constraints, neutrino oscillation …

- Program driven by **signatures in detector**
  - Trigger and reconstruction algorithm are important
  - Improving techniques (ML) to explore more exotic world
    - Allow us to test new signature, more sensitivity




**Physics reports (2025) ATLAS, CMS**
**Summary plots ATLAS, CMS-1,2,3**

# High-mass resolved hadronic resonances

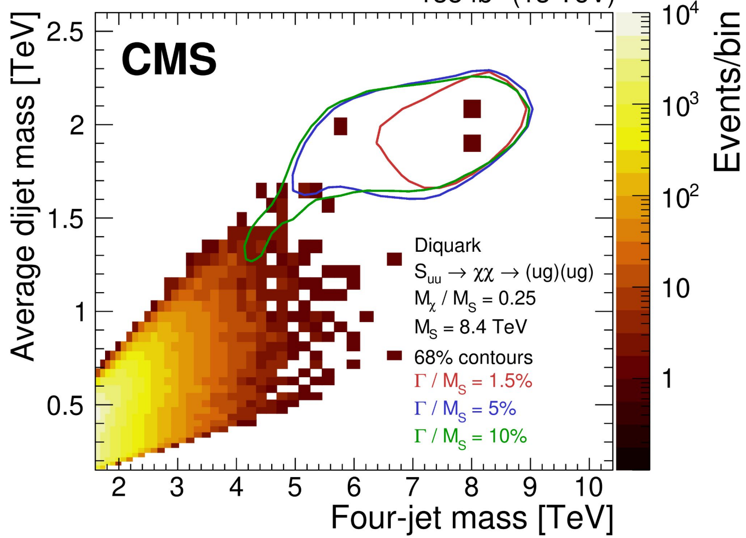


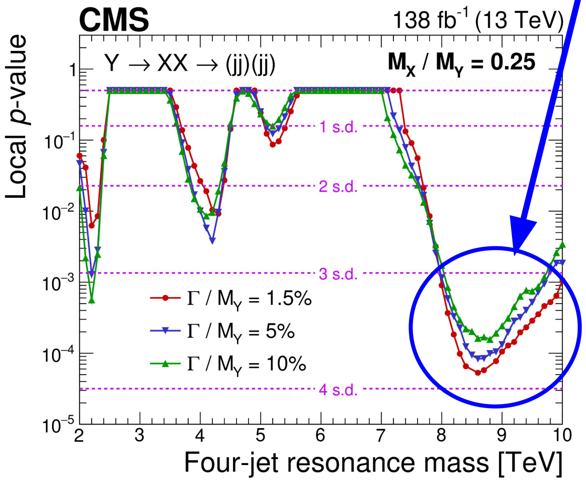

## Y→XX→(jj)(jj)

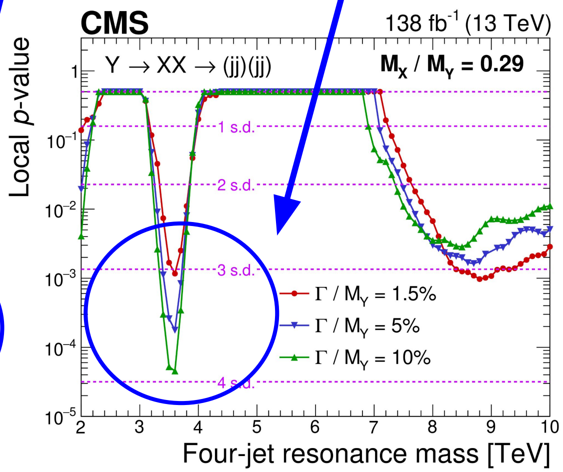
**At ($m_Y$, $m_X$) = (3.6, 1.04) TeV**
**⇒ 3.6σ (2.2σ) (only broad Y)**

**At ($m_Y$, $m_X$) = (8.6, 2.15) TeV**
**⇒ 3.9σ ~ 3.6σ (1.6~1.4σ) in narrow/broad Y**

**Run2**




2507.17884 (Run2)

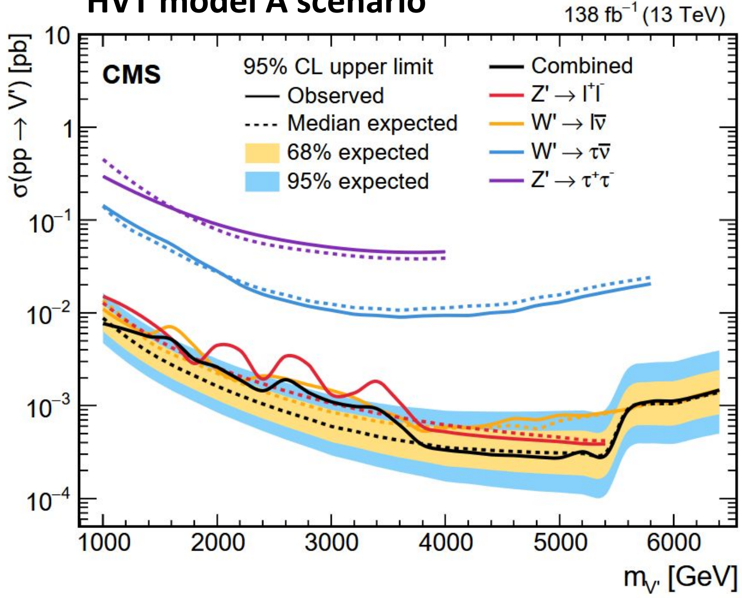
# High-mass diboson combination

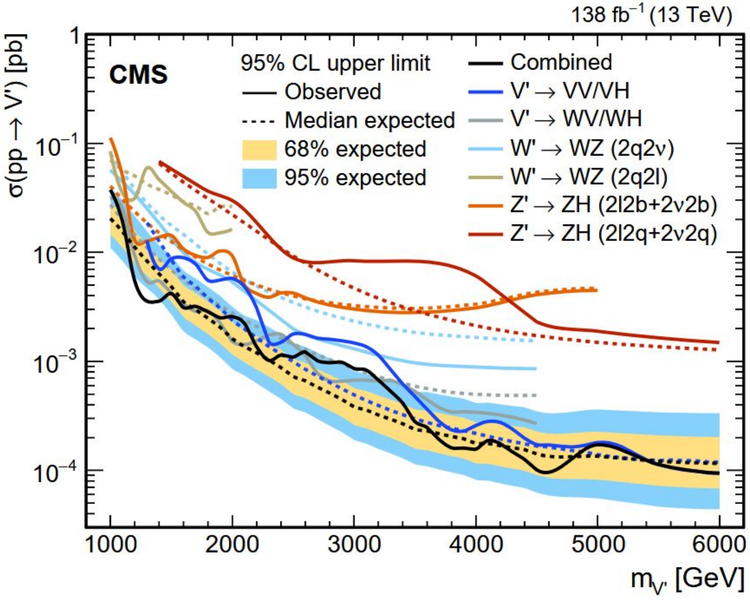
- HVT Scenarios
- Model A : gH = −0.56, gF = −0.55, and gV = 1
- Model B : gH = −2.93, gF = 0.15, and gV = 3
- Model C : gH = 1, 3, or 6 and gV = 1, and gF = 0

**Broad mass scan**

**V′ → leptons**

**HVT model A scenario**




**V′ → bosons**

**HVT model B scenario**

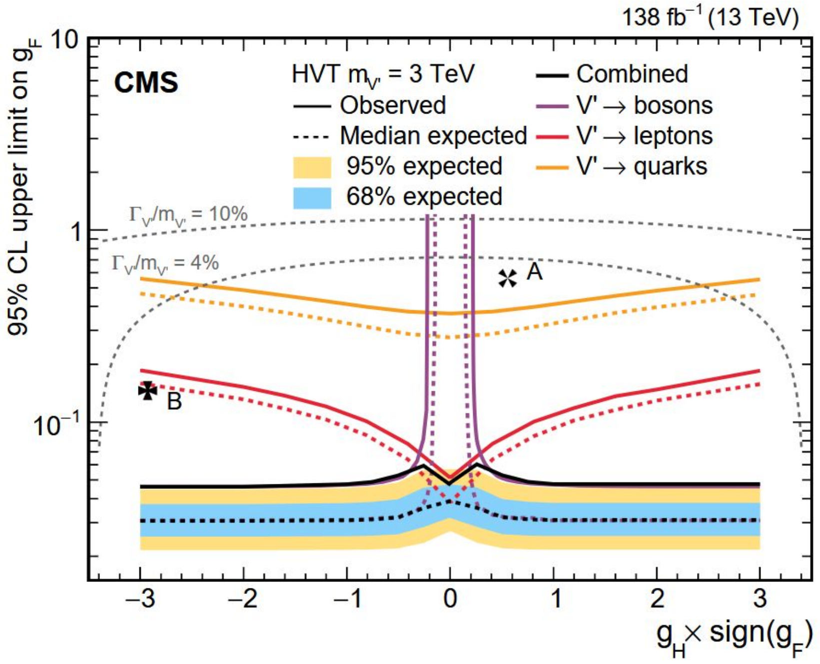
# High-mass diboson combination

2601.12583

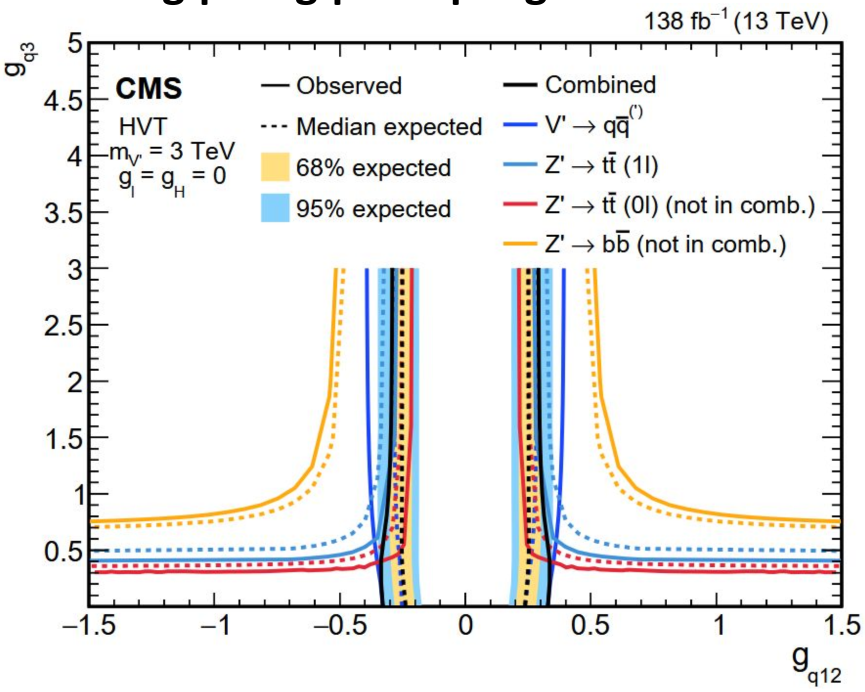
Run2 **Coupling scan**

**Beyond the assumption of fermion universality (gL = gH = 0)**

**gH - gF coupling**



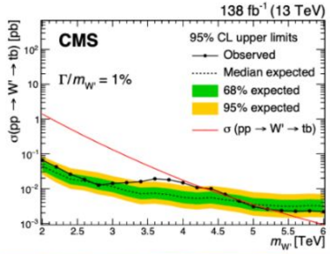

**gq12 - gq3 coupling**

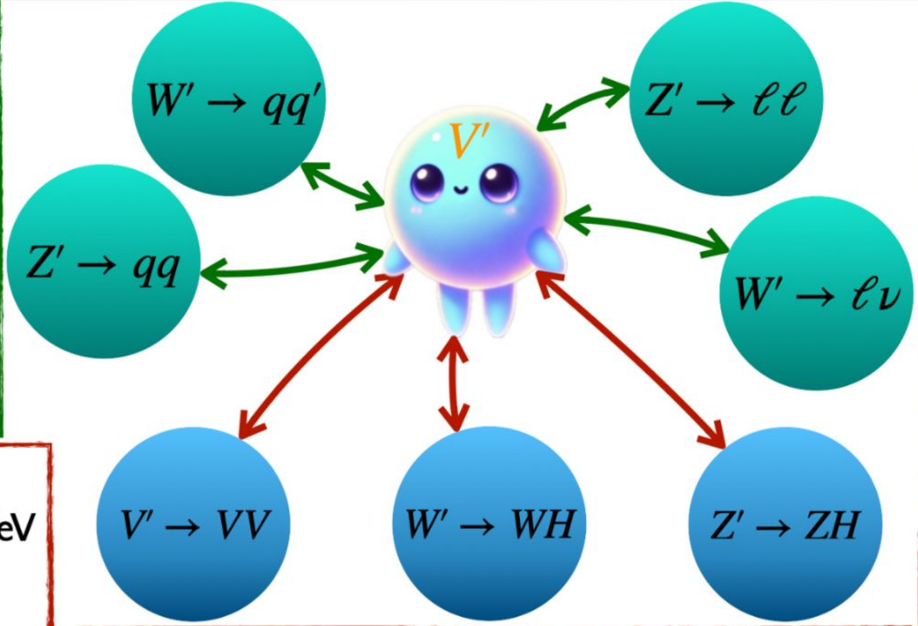



Different coupling to light and 3rd generation quarks

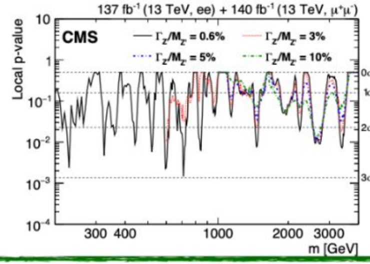
# High-mass diboson combination

$> 2\sigma$ local excess in
$W' \to tb$ at 3.4-4.4 TeV
for CMS-B2G-20-012

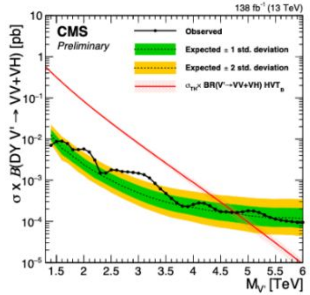


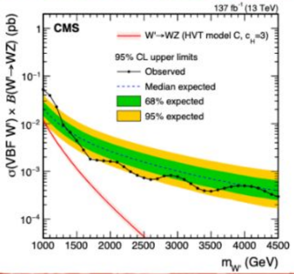




$> 2\sigma$ local excess in
$Z' \to \ell\ell$ at 2.7-3.4 TeV
for CMS-EXO-19-019



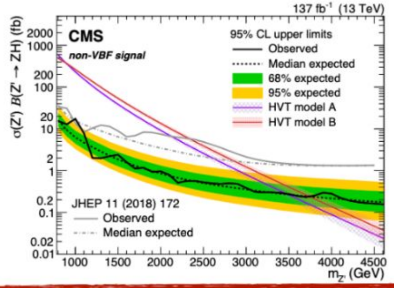

$> 3\sigma$ local excess in
$V' \to VV \to had$ at 2-3 TeV
for CMS-B2G-20-009




$> 2\sigma$ local excess in
$W' \to W(\ell\nu)V(qq)$ at 1TeV
for CMS-B2G-19-002

$> 2\sigma$ local excess in
$Z' \to Z(\nu\nu)H(bb)$ at 1TeV
for CMS-B2G-19-006

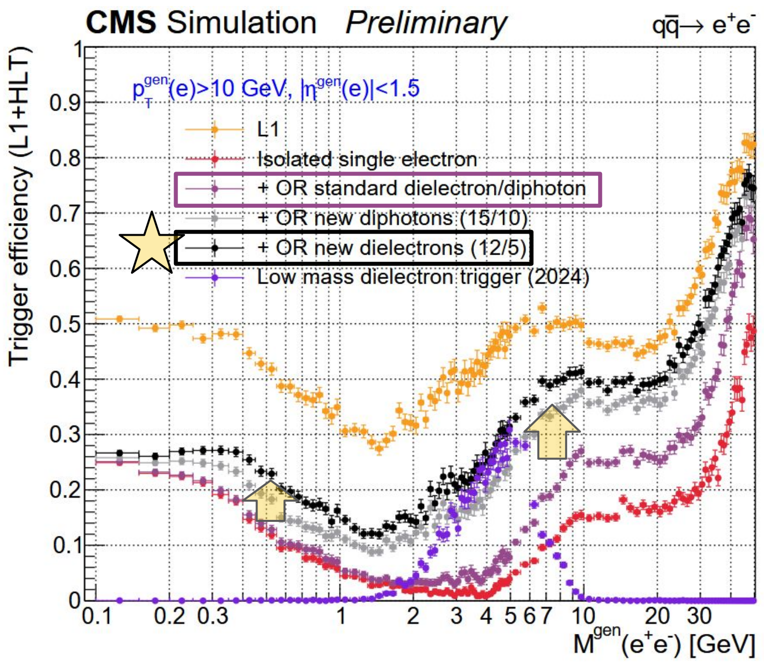


# Low-mass EM frontier :dielectron/diphoton trigger

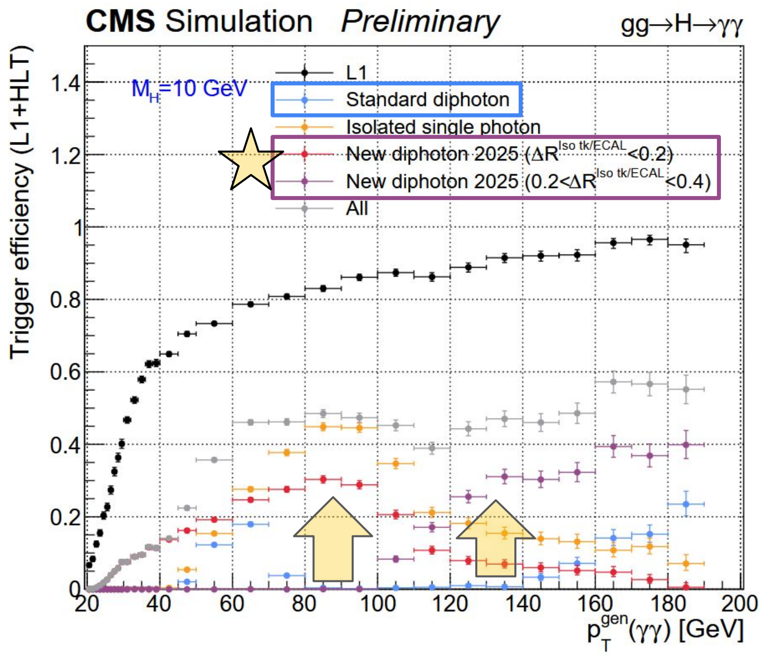
New dedicated low-threshold EM pairs triggers ($E_T$ ~ 10–15 GeV) extend CMS sensitivity to light resonances in dielectron and diphoton final states.

CMS DP-2026-001

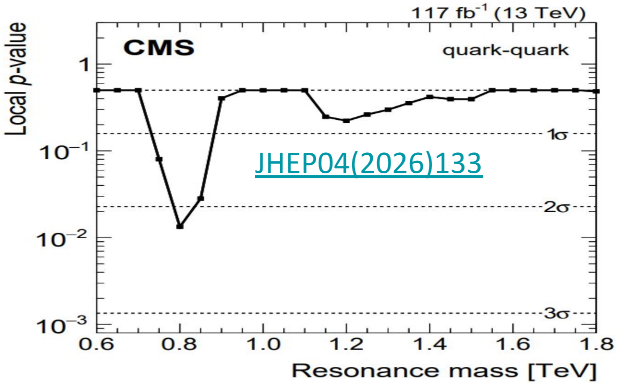
**Dielectron Trigger efficiency as a function of M(ee)**



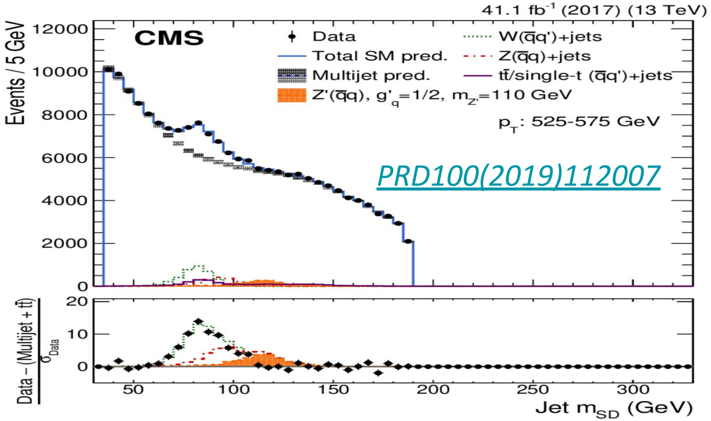

**Diphoton Trigger efficiency as a function of $p_T(\gamma\gamma)$**



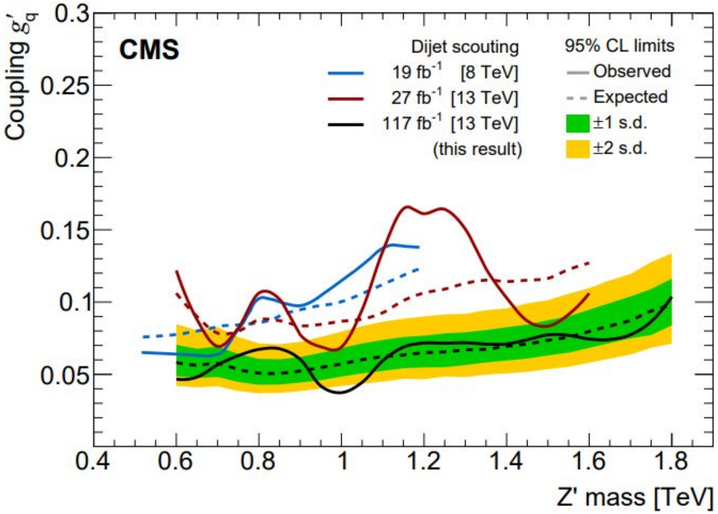
# Low-mass dijet resonances with scouting

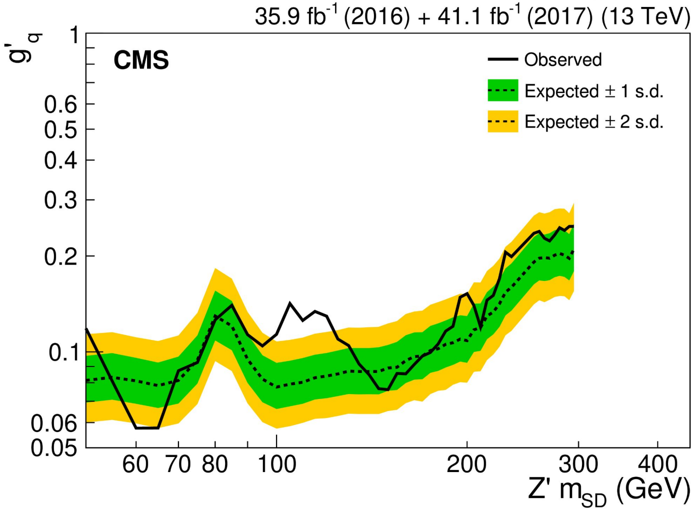



JHEP04(2026)133

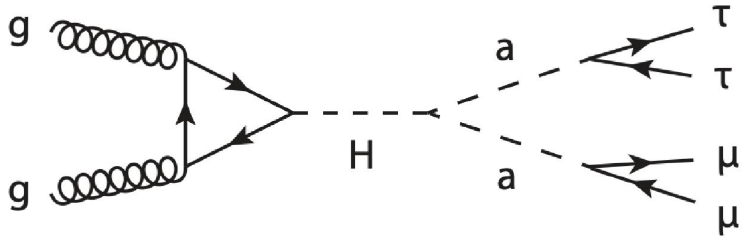



PRD100(2019)112007



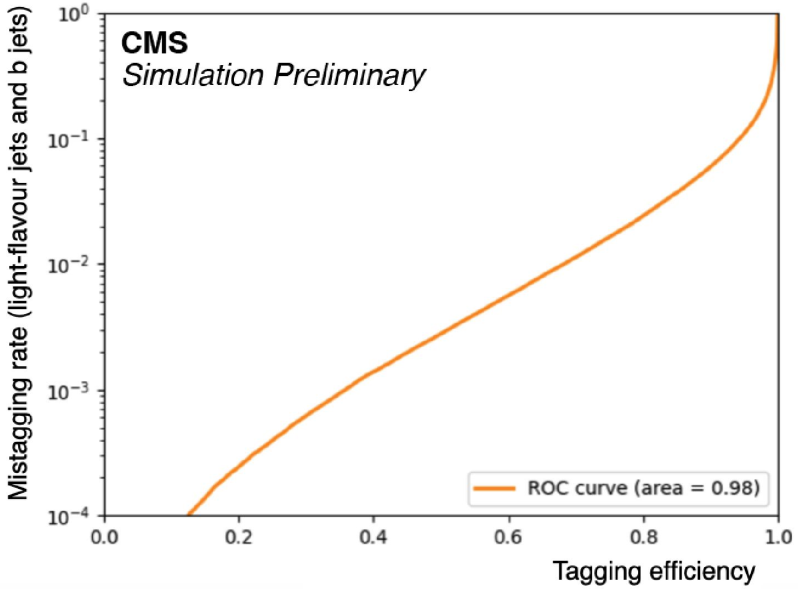



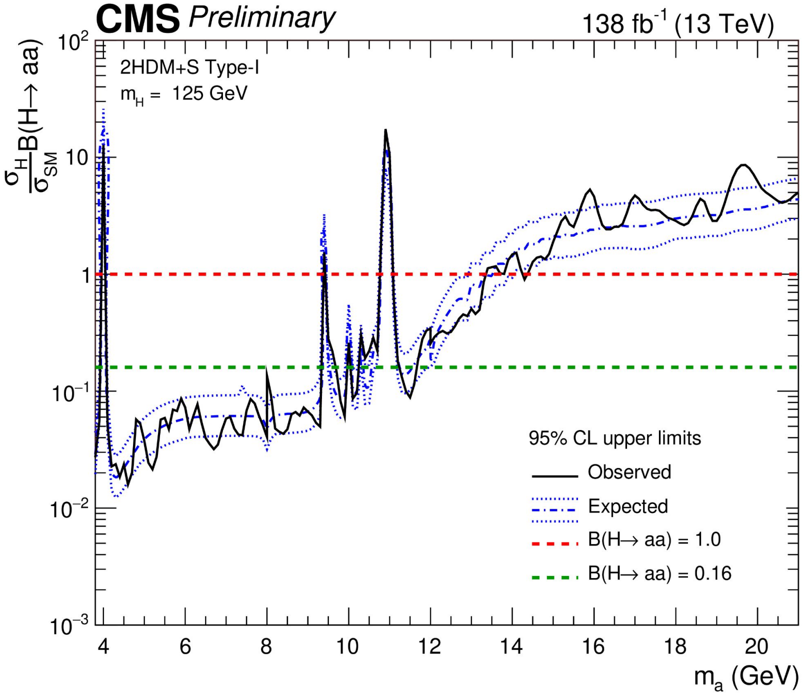
# Low-mass leptonic/tau frontier




[CMS-PAS-SUS-23-005](CMS-PAS-SUS-23-005)

Challenge: reconstruction of the boosted $\tau\tau$
- lepton removal technique
- Boosted DeepDiTau tagger (to discriminate against light and b jets)



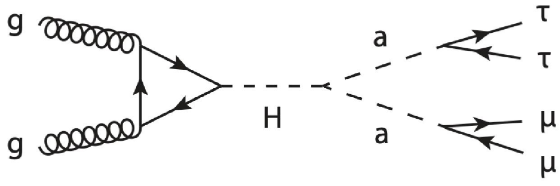
# Exotic Higgs low-mass leptonic/tau frontier

**H → aa → μμ ττ = $(\tau_h\tau_\mu)$, $(\tau_h\tau_e)$, $(\tau_h\tau_h)$, $(\tau_e\tau_\mu)$**

➔ Light pseudoscalar a → highly boosted/collimated lepton pairs

➔ Key Challenge : collimated ττ often fails standard τ reconstruction

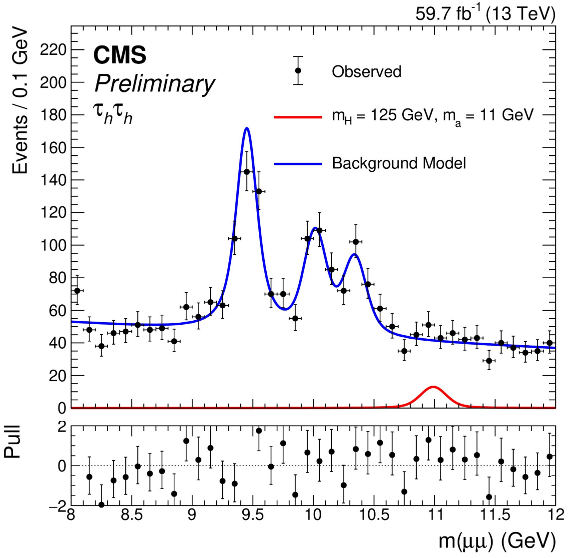
➔ Dedicated di-τ reconstruction + DNN di-τ taggers recover efficiency

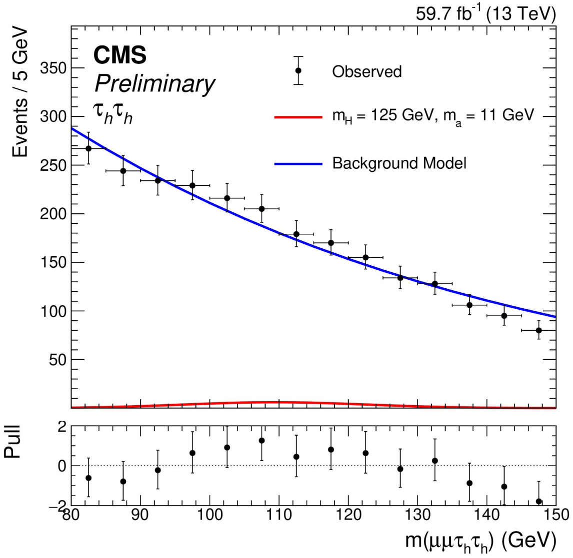


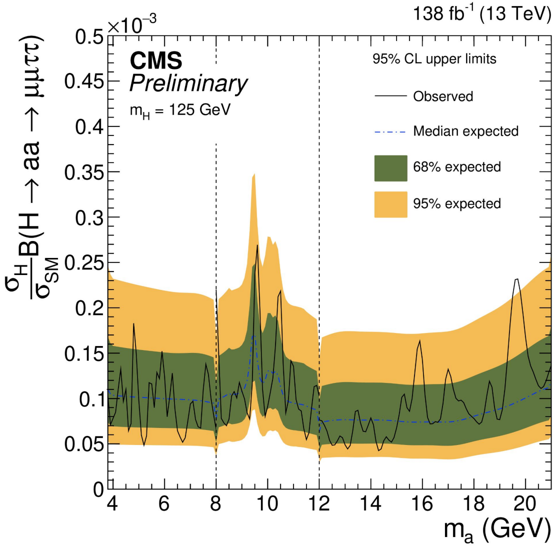

CMS-PAS-SUS-23-005

**Run2**

Open sensitivity to 3.6–50 GeV

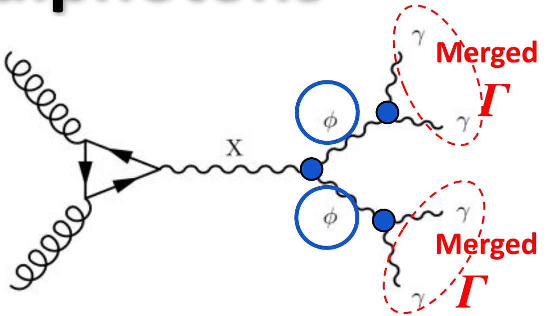


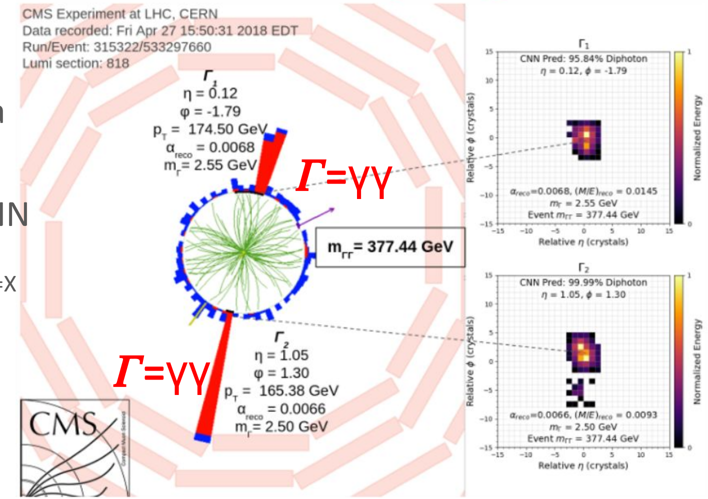
# Boosted cascade decays II: merged diphotons

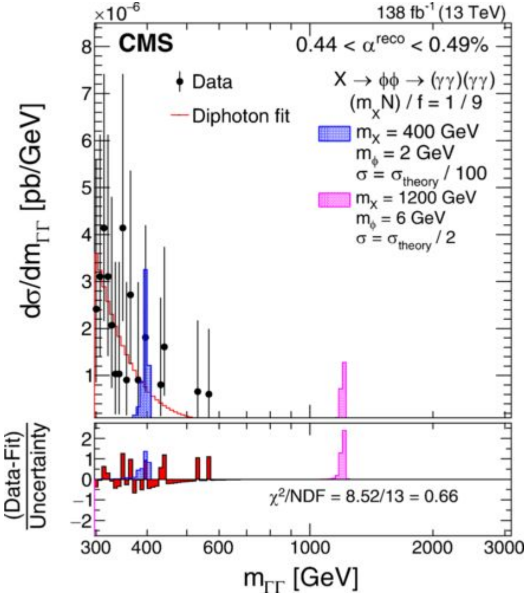
- **Dataset and Signatures**
  - 2016–2018 pp at 13 TeV, $\mathcal{L}$ ~ 138 $fb^{-1}$
  - Signal: BSM $X \to \phi\phi \to \gamma\gamma\gamma\gamma$ ($m_X >> m_\phi$) in the extended Higgs Sector
    Highly boosted $\phi\phi \to$ pairs of **fully merged diphoton, $\Gamma\Gamma$**
  - $m_X$ = 300–3000 GeV and $\alpha_{reco} = m_\phi/m_X$ = 0.5–2.5%
  - Probes ALP $\phi$ mass **1.5–75 GeV** range




- **Analysis Strategy**
  - Merged 2γ clusters ($\Gamma$) identified via ECAL Energy deposits using CNN
  - ALP mass ($m_\Gamma$) form by Regression NN
  - Discriminator: Di-Cluster mass, $m_{\Gamma\Gamma=X}$

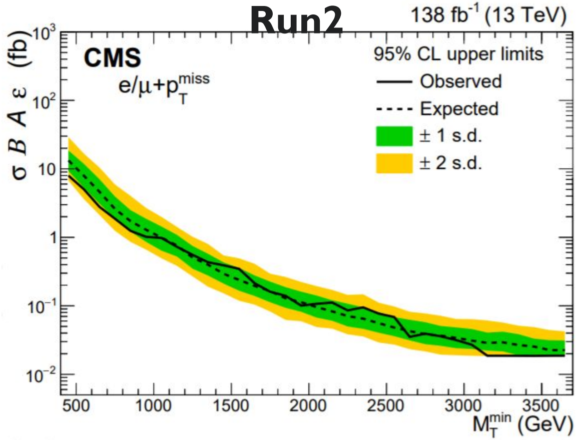
ECAL cluster image recognition



# W’ Search; Model-independent limit

**e+μ combined channel**
**Run2**

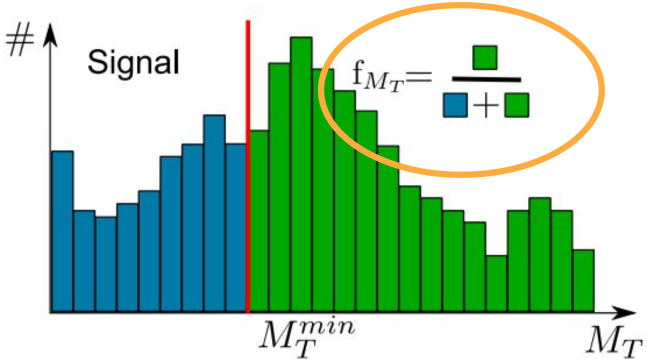



## Model Independent limit in Run2

Using a single bin counting experiment ($M_T^{min}$ to infinity).

Limit set on the **σ x B** and experimental effects (acceptance **A** x efficiency **ε**

This can be used to test new physics model with ℓ+$p_T^{miss}$ signature




$$[\sigma\mathcal{B}\mathcal{A}\epsilon]_{\mathrm{excl}}(M_{\mathrm{T}}^{\mathrm{min}}) = \frac{[\sigma\mathcal{B}\mathcal{A}\epsilon]_{\mathrm{MI}}(M_{\mathrm{T}}^{\mathrm{min}})}{f_{M_{\mathrm{T}}}(M_{\mathrm{T}}^{\mathrm{min}})}$$

exclude when

$(\sigma BA\varepsilon)_{\text{BSM theory}} > (\sigma BA\varepsilon)_{\text{excl}}$