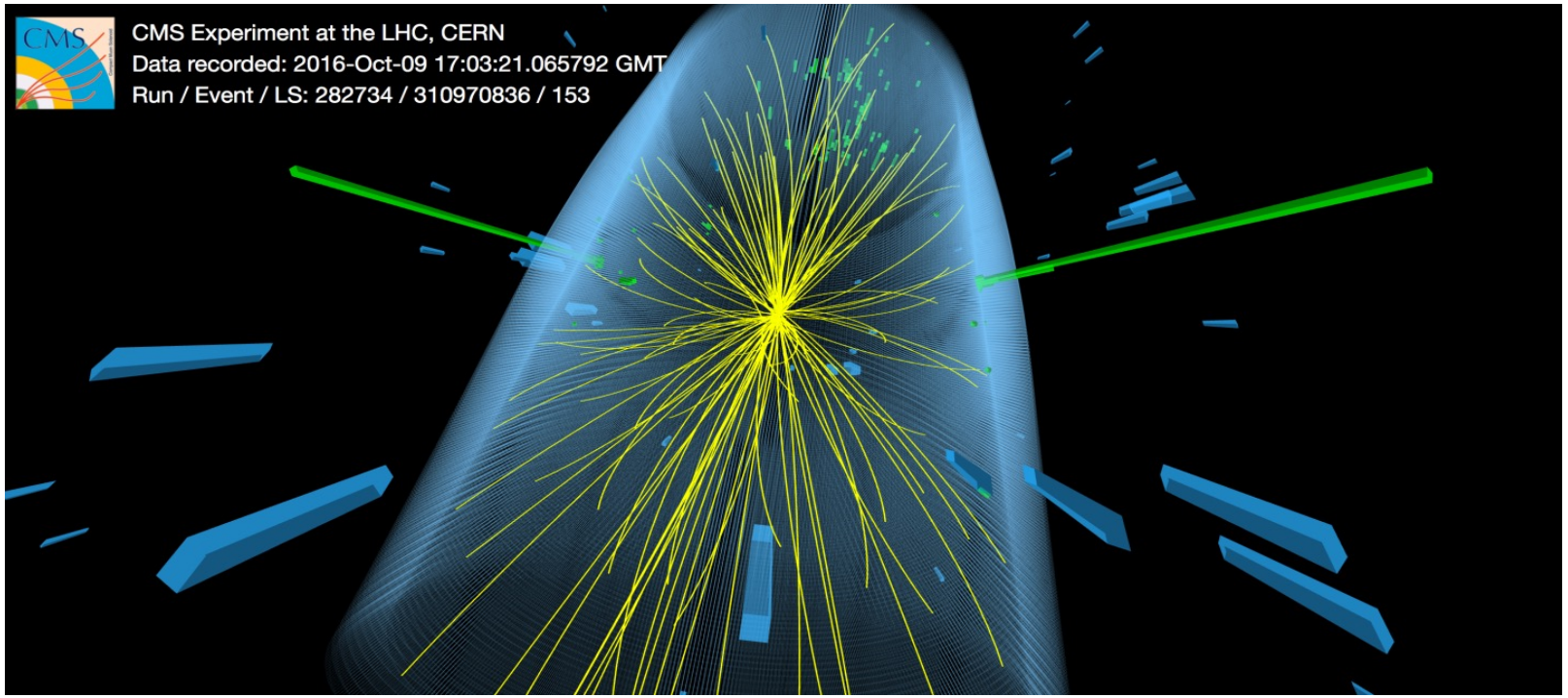
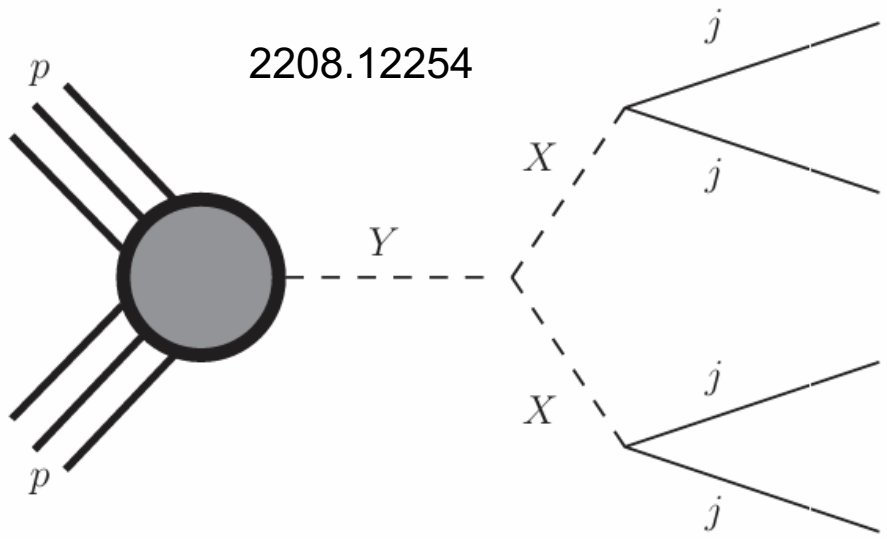


Andreas Crivellin

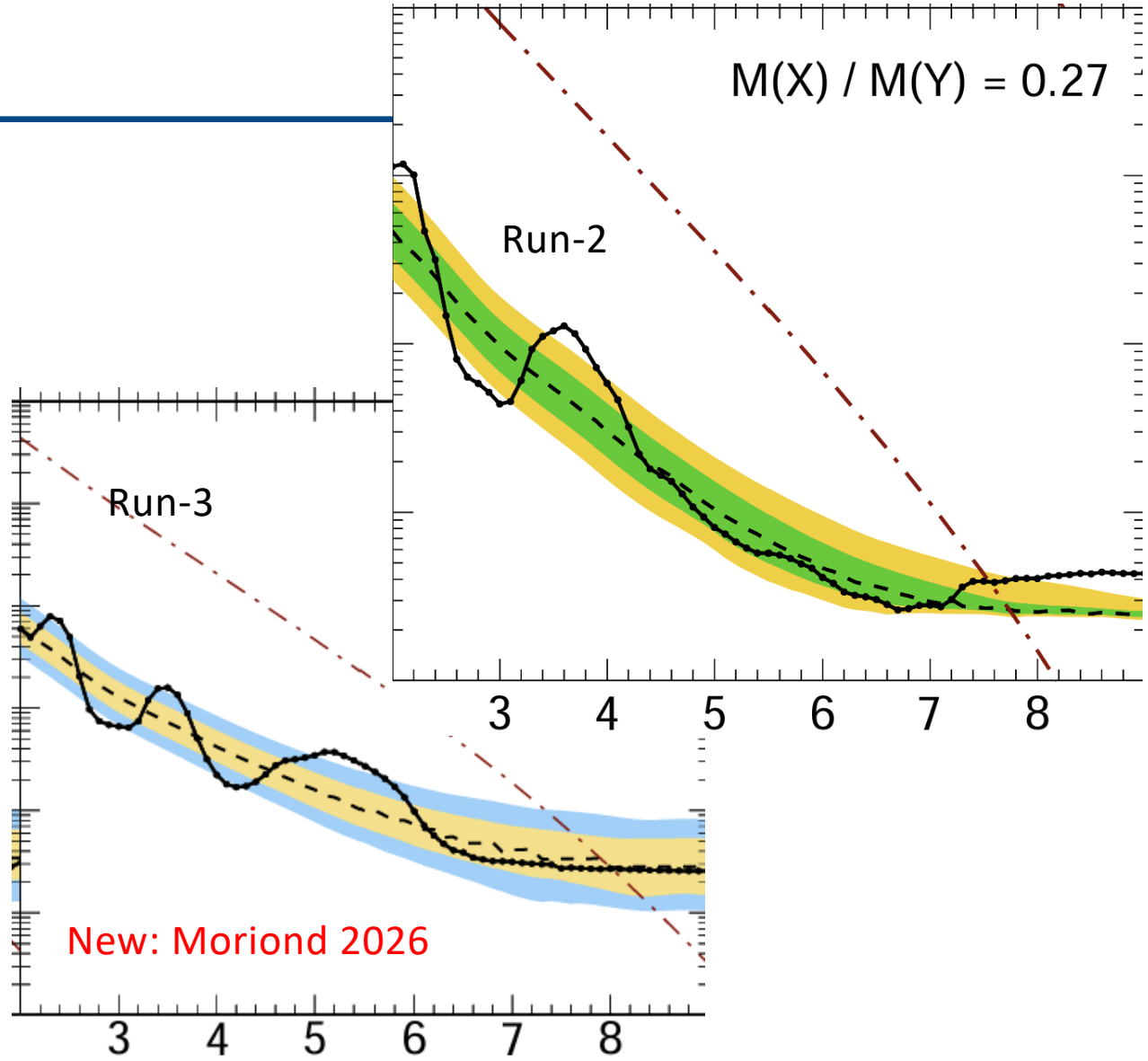
Update on Scalar Excesses

Moriond EW, La Thuile, 20.03.2026

Di-Di-jets and di-quarks



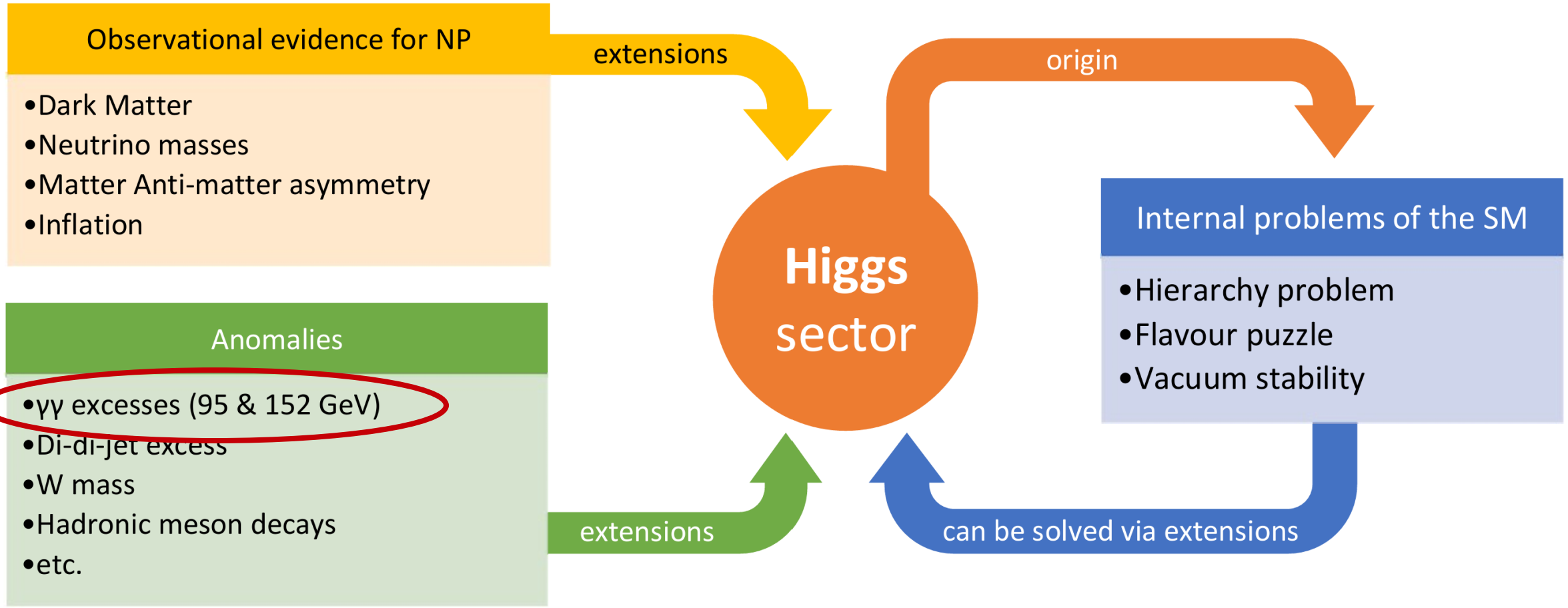
Scalar di-quarks can lead to resonant di-di-jet production



Run 2 and run 3 seem to be consistent at ~3.5TeV

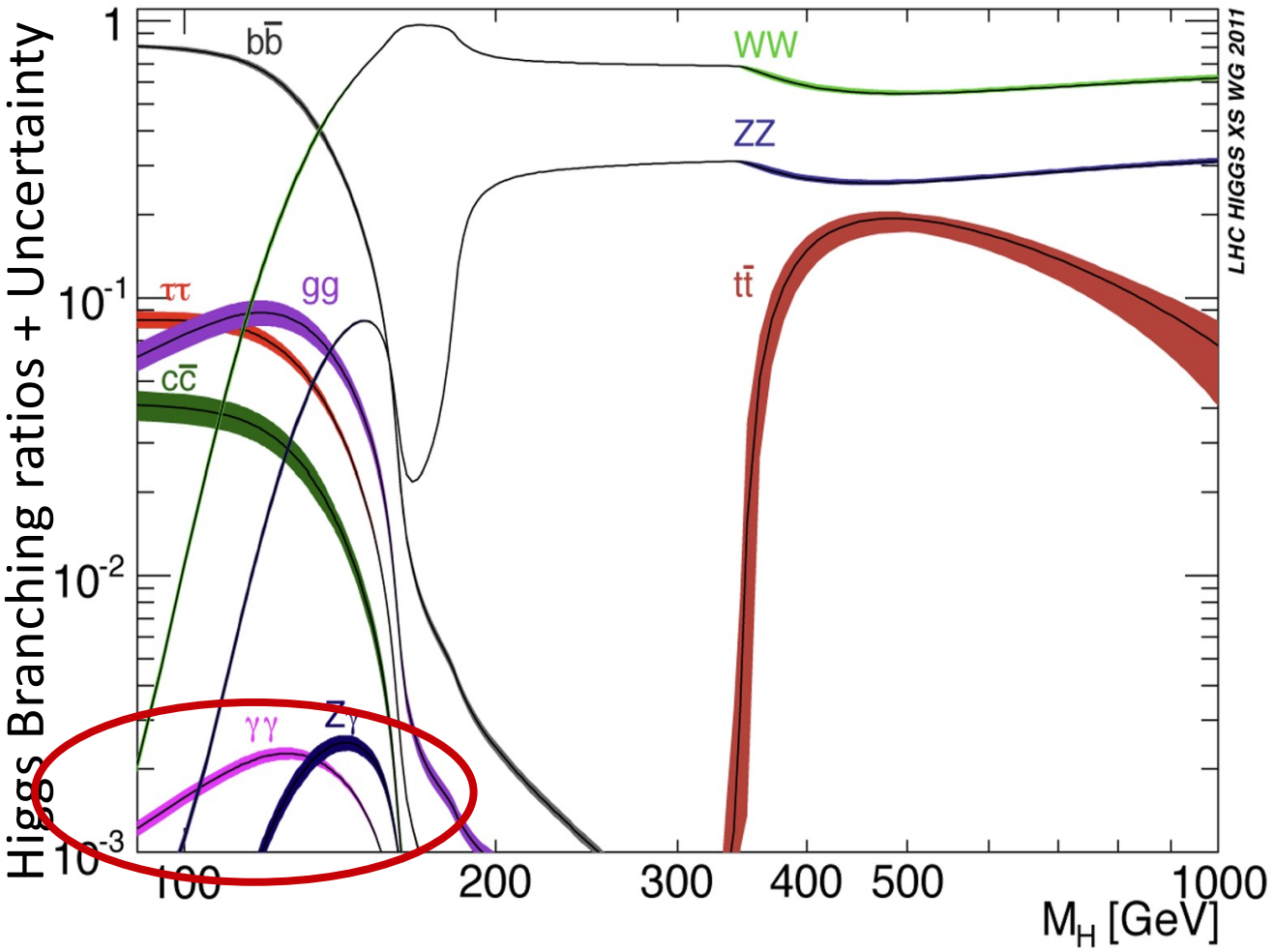
Why new Higgses?

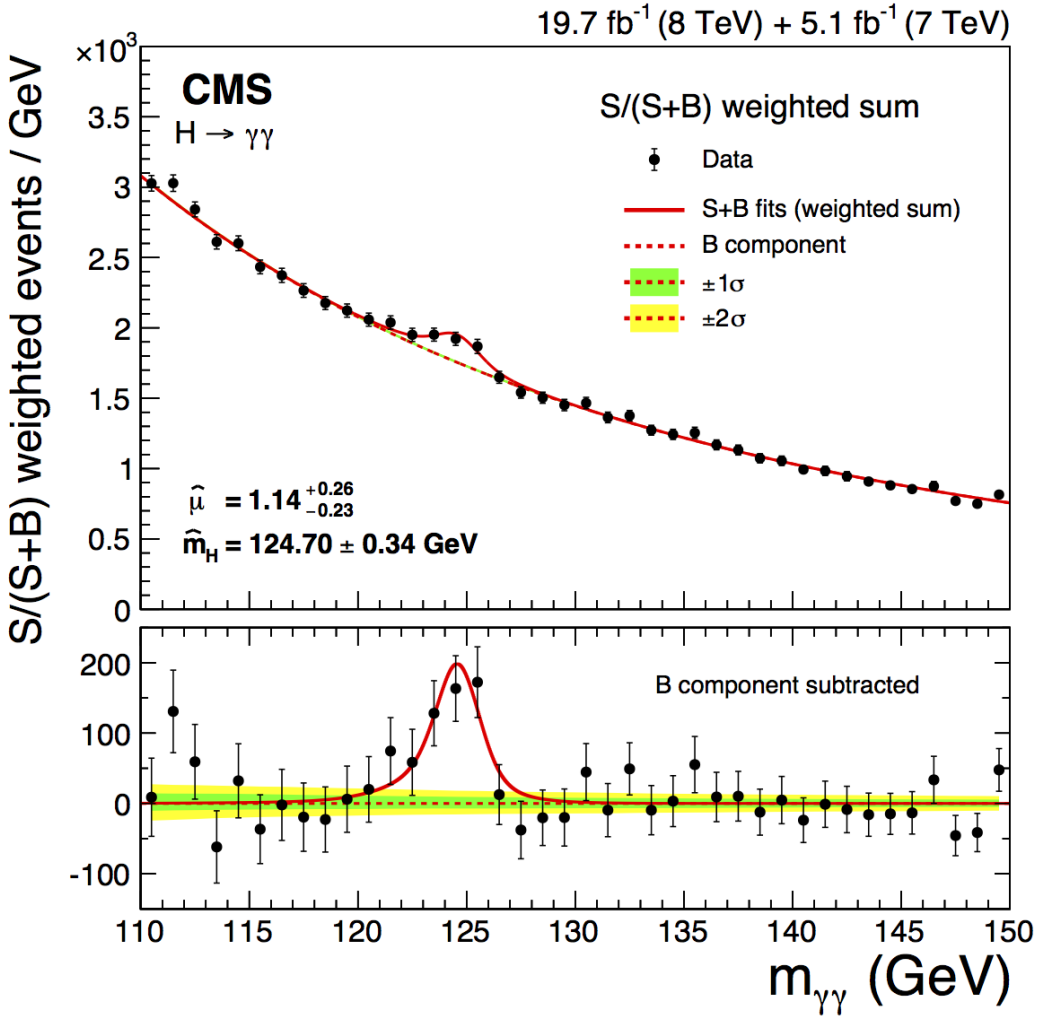
- Minimal realisation in the SM not protected by any symmetry principle



Higgs sector very promising place to expect new physics

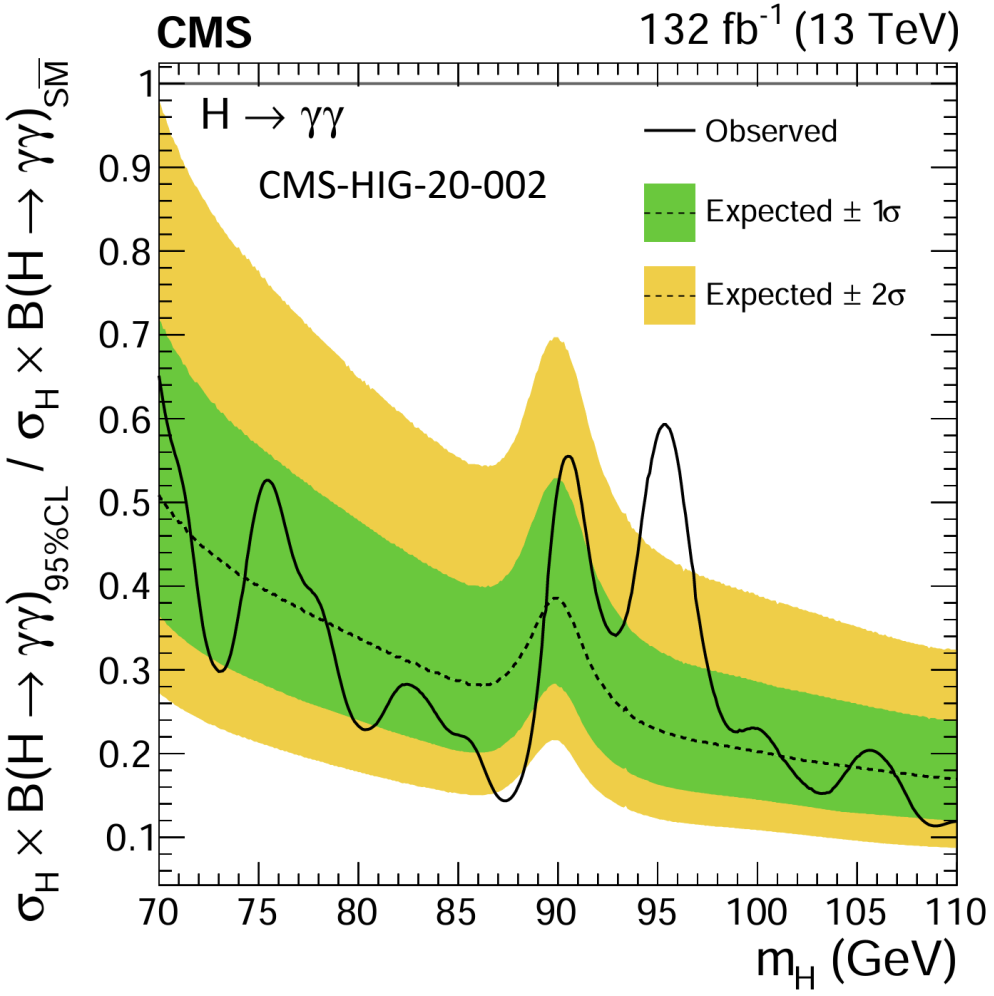
Higgses at the electroweak scale

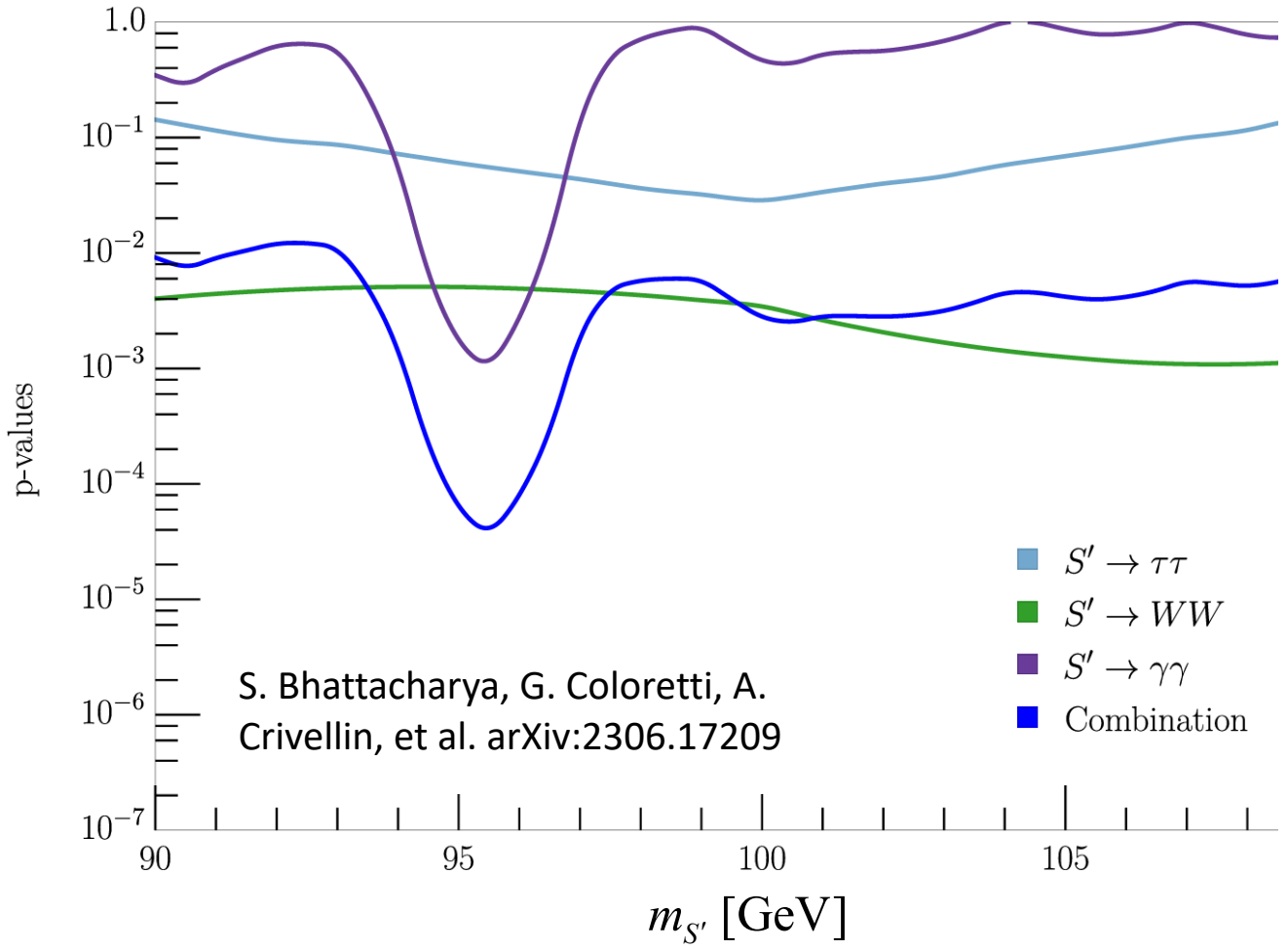




EW scale Higgses difficult to observe; di-photon natural discovery channel

Indications for a 95 GeV Higgs

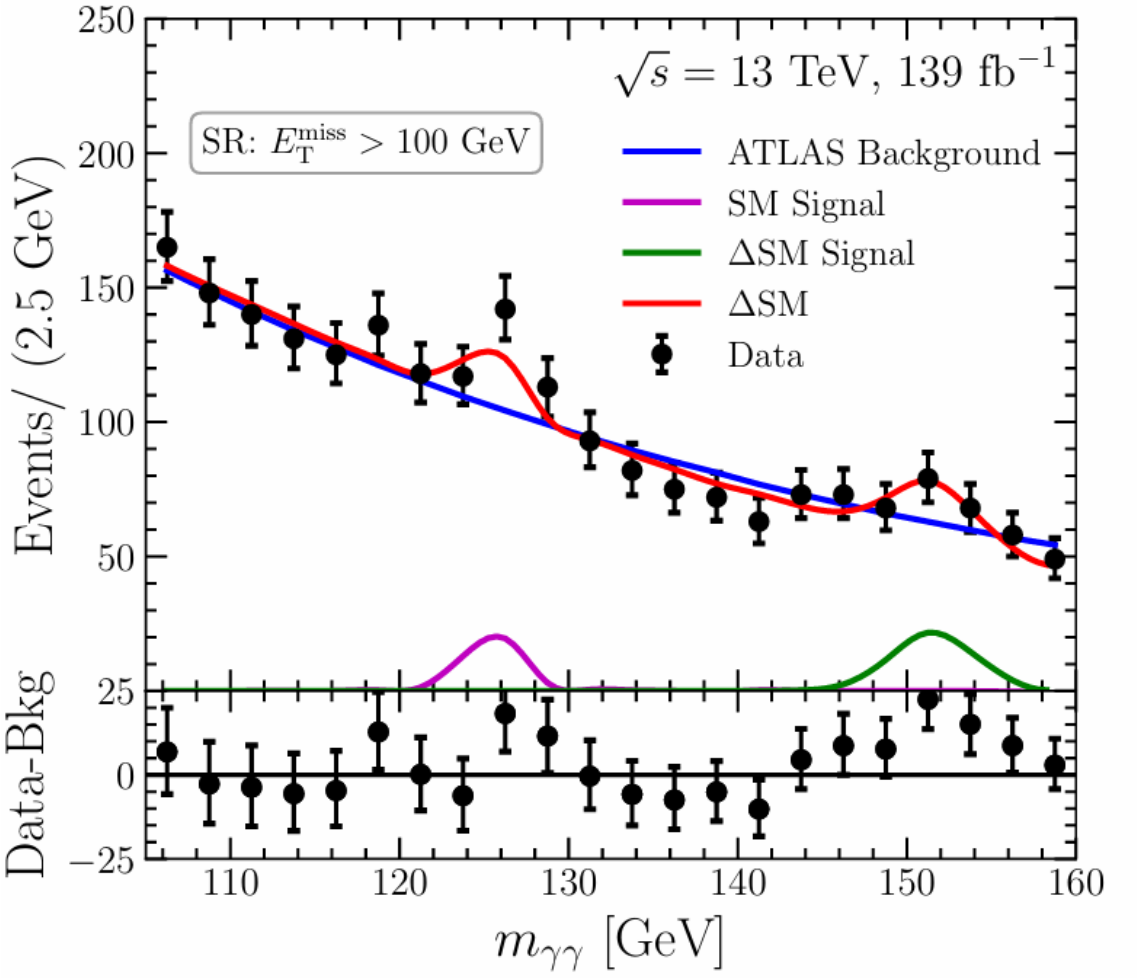


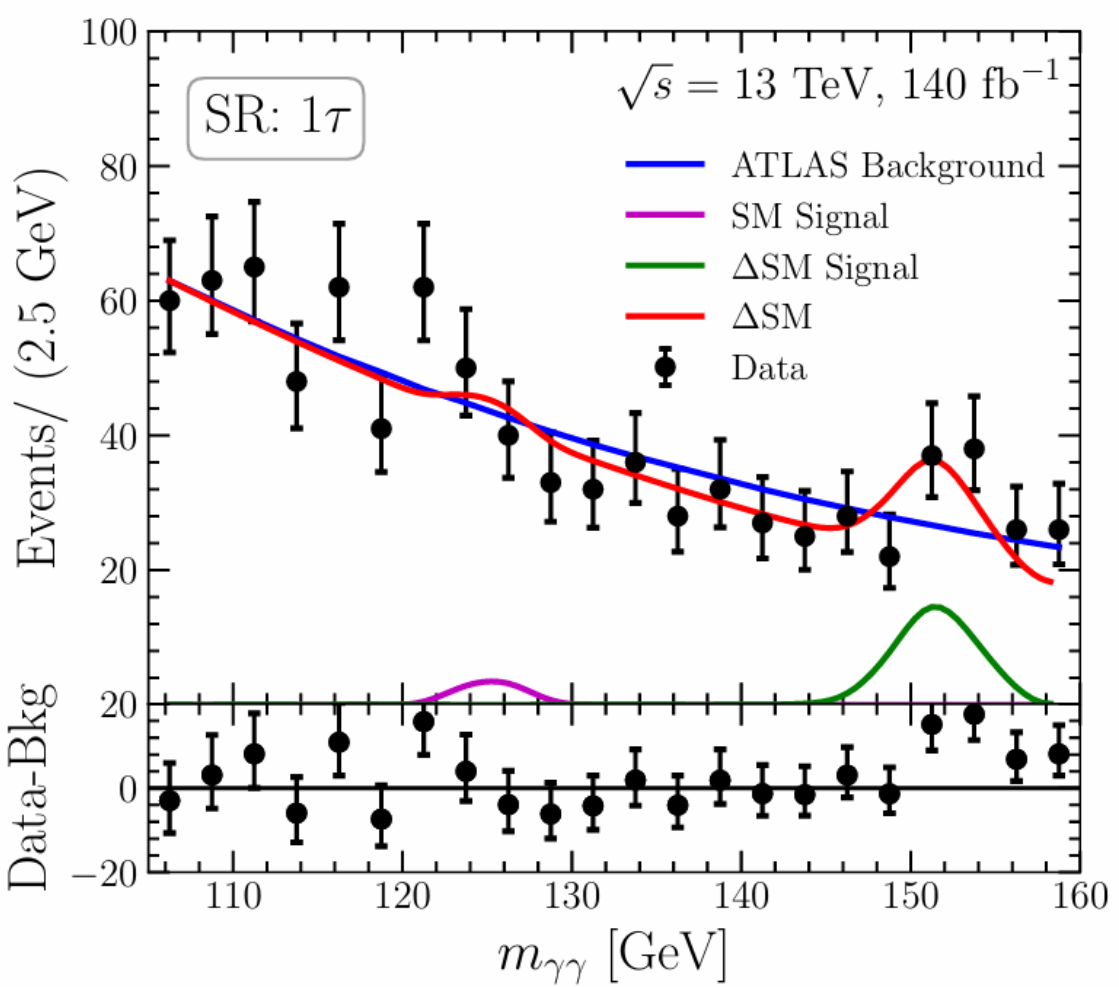


Di-photon channel supported by WW and ττ: 3.4σ global significance

152 GeV Scalar in Associated Production

JHEP 07 (2023) 176
ATLAS-CONF-2024-005



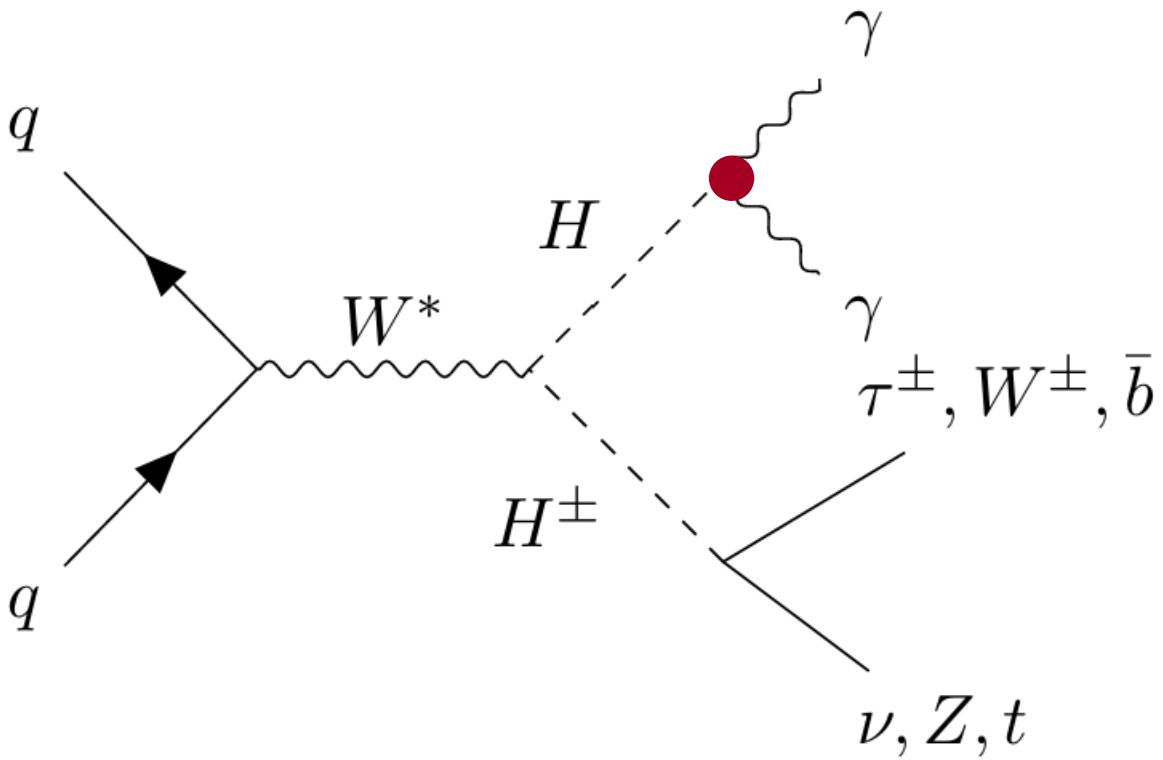


Associated production can enhance signal over background strength

Drell-Yan Production

- Looking at all 23 channels, we need:
- Two photons produced in association with
  - One lepton,
    but not two leptons
  - One tau,
    but not two taus
  - lb (≥1l+1b),
    but not t_{lep} (=1l+1b)
  - Moderate missing energy

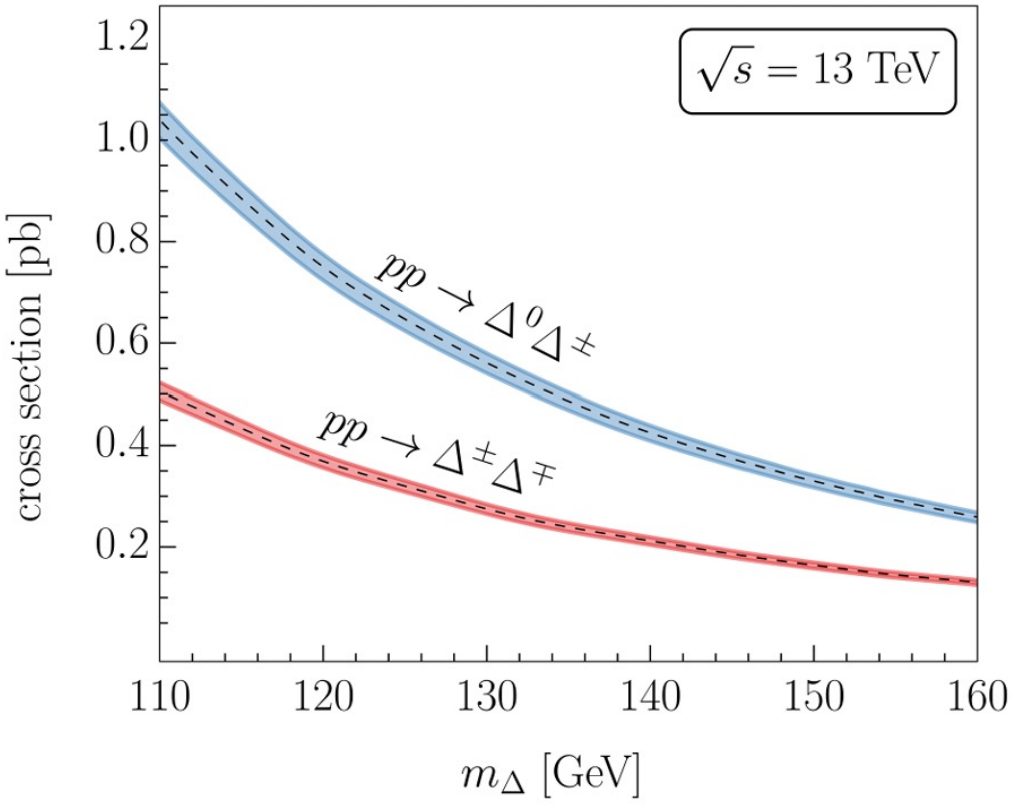
Drell Yan production of a charged and a neutral Higgs



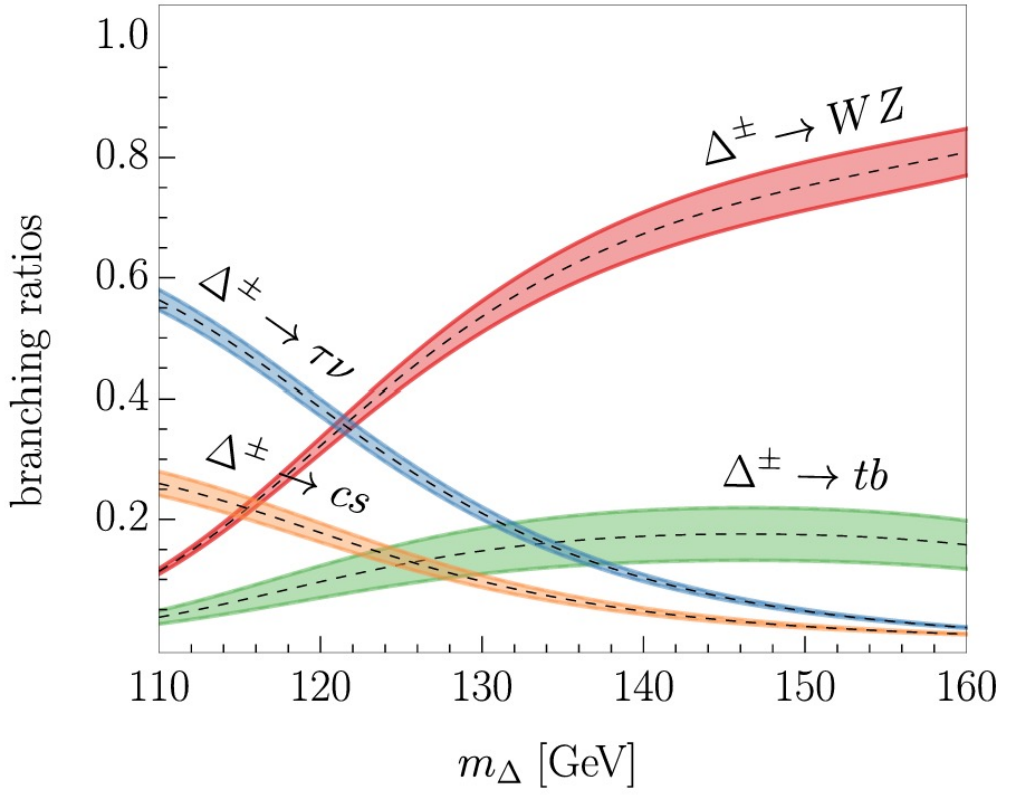
Drell-Yan production leads to the right signature

$SU(2)_L$ Triplet with Y=0 (ΔSM)

- Contains a charged and a neutral Higgs which are quasi-degenerate
- Production cross section known



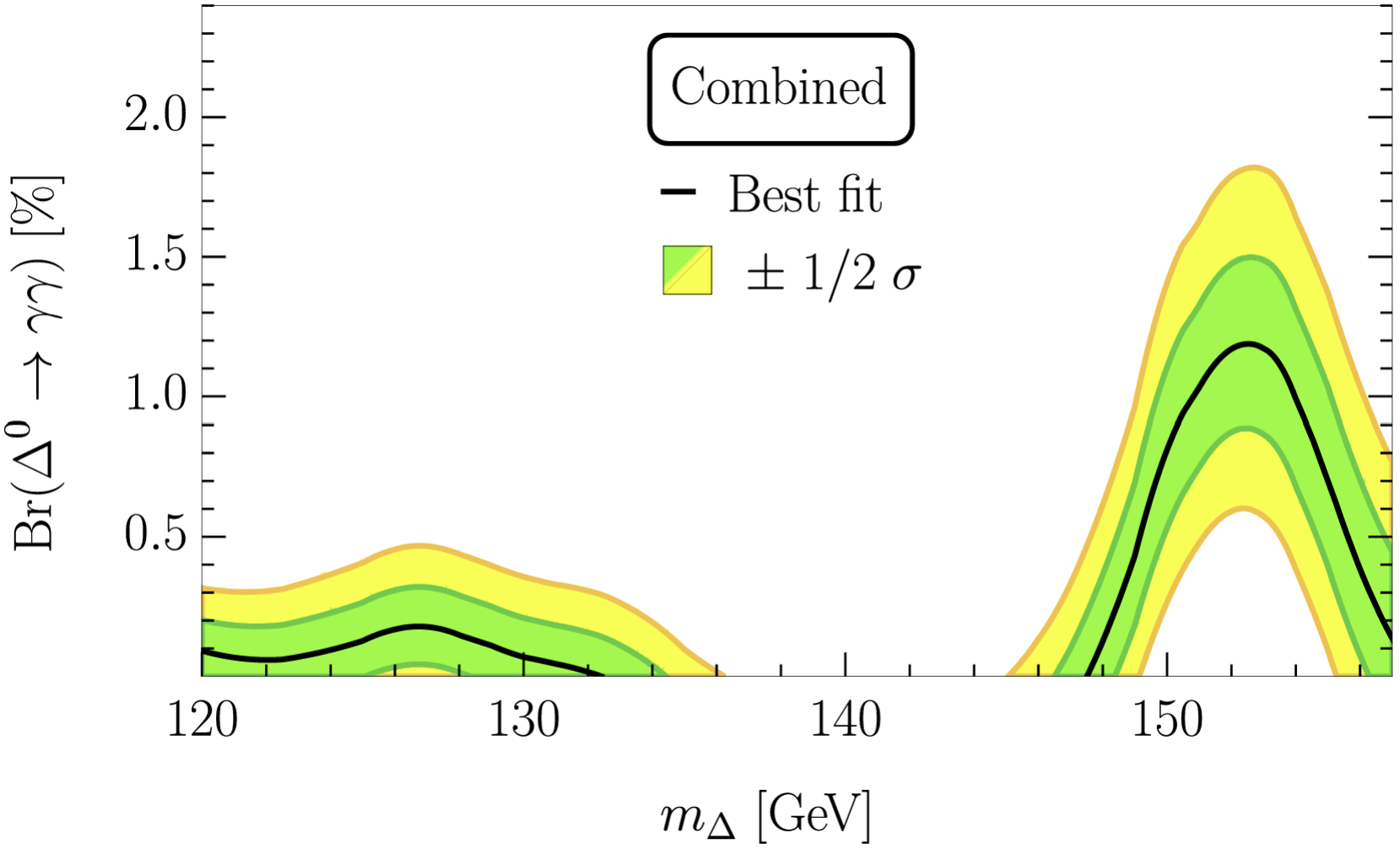
- Dependence on the vev cancels



Simple and very predictive model

Triplet Combination

S. Ashanujjaman, S. Banik, G. Coloretti, A.C., S. P. Maharathy,
B. Mellado, Chin.Phys.C 49 (2025) 5

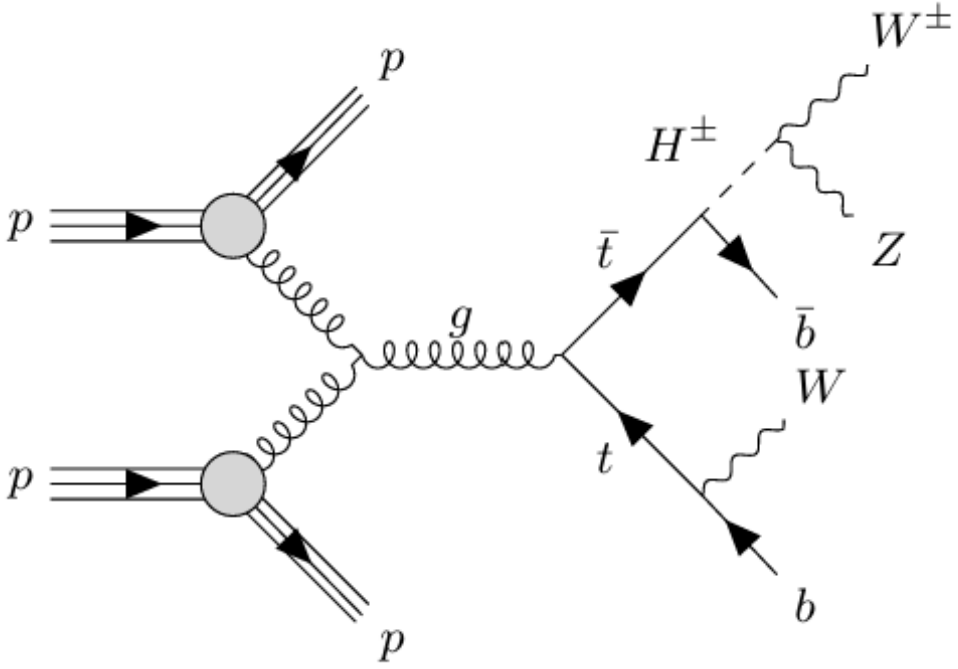


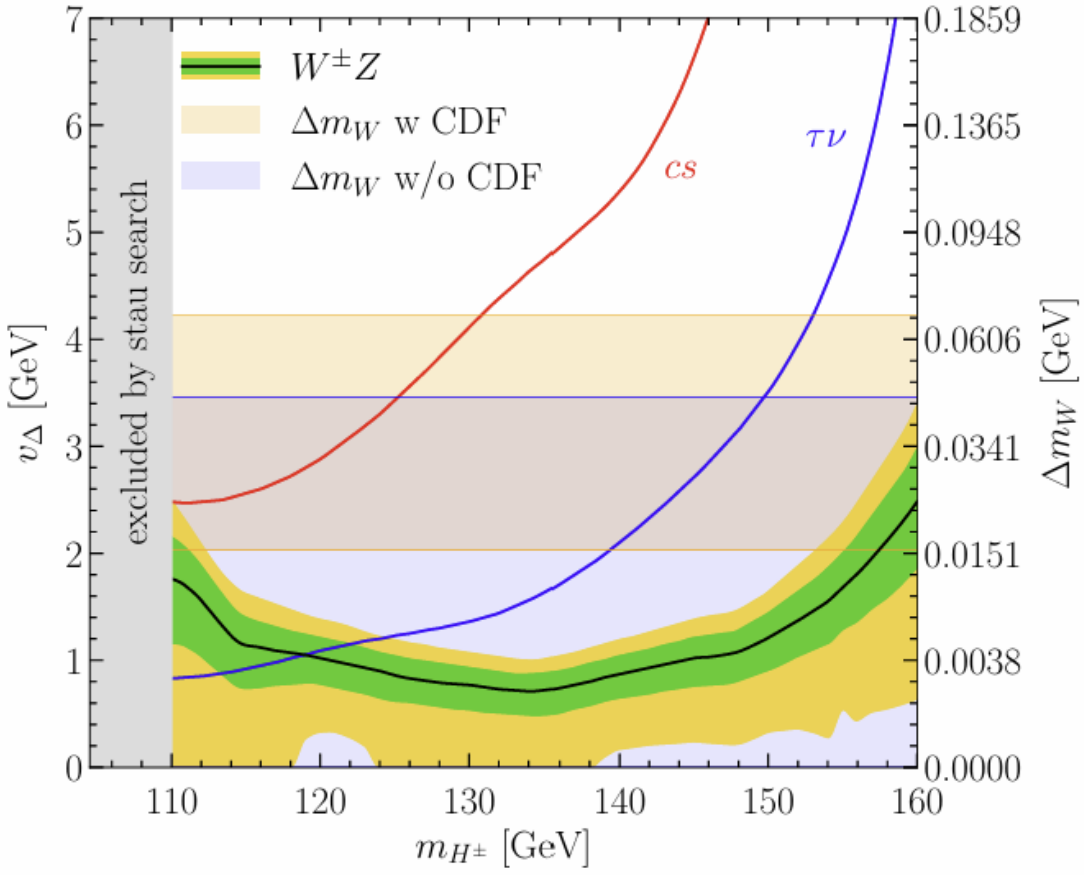
≈ 4σ significance at 152 GeV

Triplet Signature in Top-Quark Decays

S. Ashanujjaman, A.C., S. Maharathy, B. Mellado, 2509.07094

- Triplet with 152 GeV neutral Higgs predicts a charged Higgs production in top decays
- Resembles ttZ-like signal in the SM

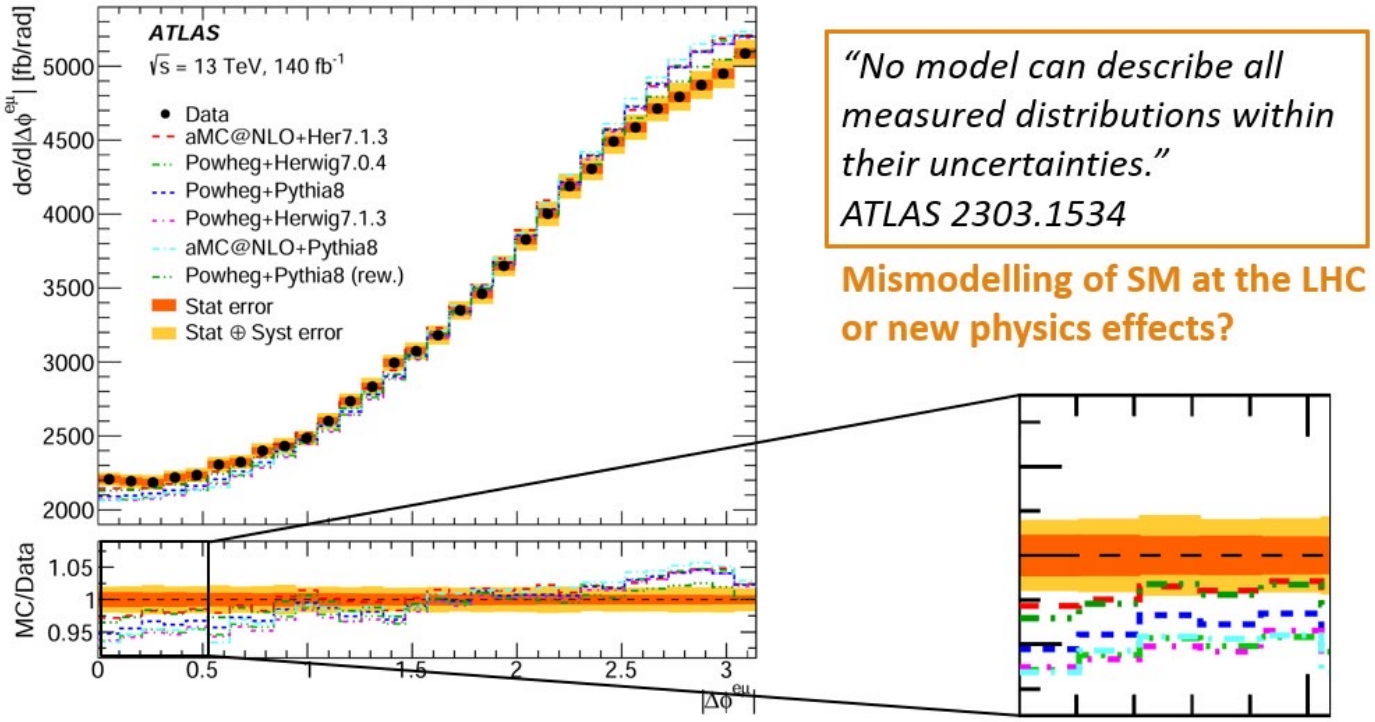




>2σ significance at ≈152 GeV, supporting evidence

Beyond the Triplet model

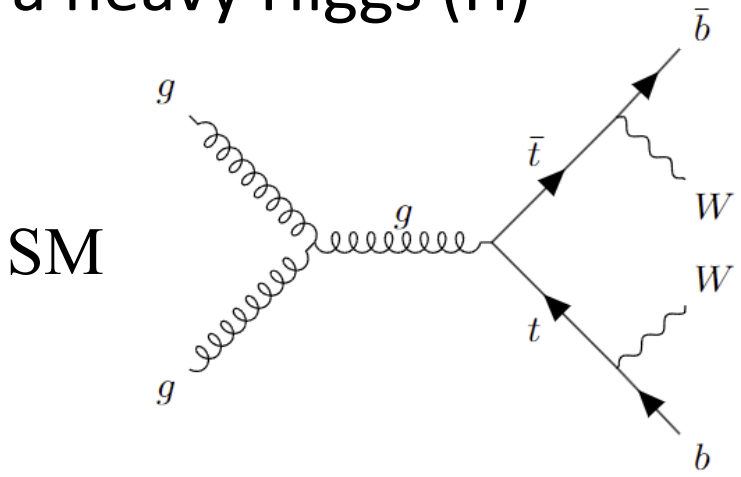
- Two Higgses (S and S’) produced from the decay of a heavy Higgs (H)
- 95 GeV (S’) naturally decays to bb
- 152 GeV triplet (S) dominantly decays to WW



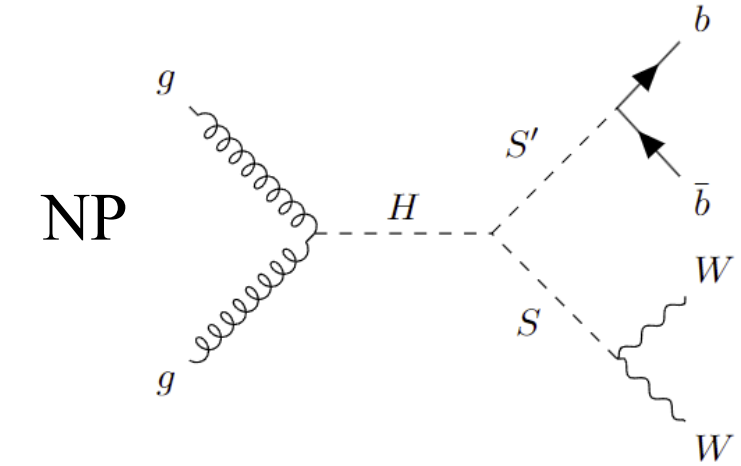
“No model can describe all measured distributions within their uncertainties.”
ATLAS 2303.1534

Mismodelling of SM at the LHC or new physics effects?

SM



NP



Can explain tensions in tt-differential distributions (>5σ)

Simplified Model: H→SS'→WWbb

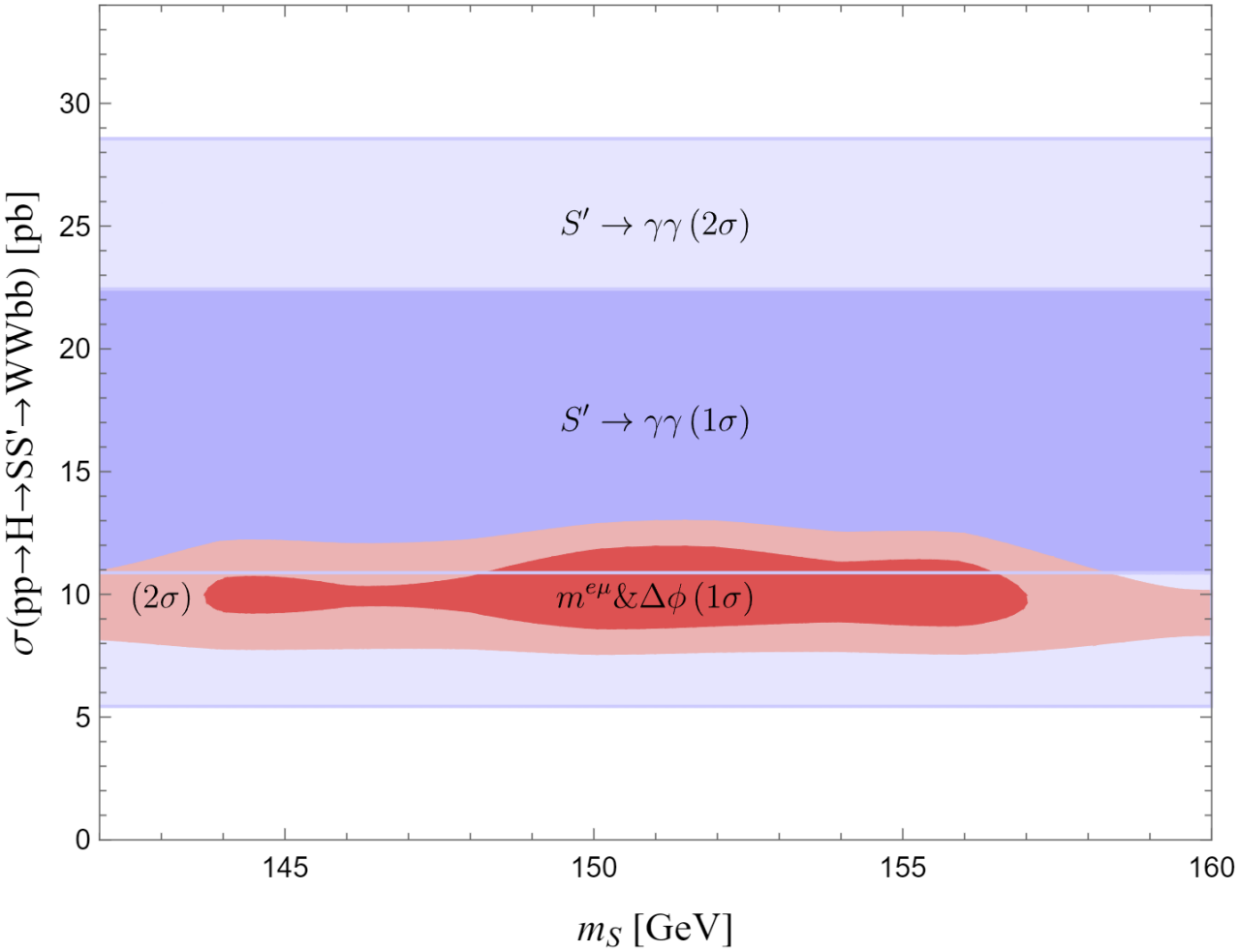
Monte Carlo	χ^2_{SM}	χ^2_{NP}	σ_{NP}	Sig.	m_S[GeV]
Powheg+Pyhtia8	213	102	9pb	10.5σ	$143-156$
aMC@NLO+Herwig7.1.3	102	68	5pb	5.8σ	$--$
aMC@NLO+Pythia8	291	163	10pb	11.3σ	148-157
Powheg+Herwig7.1.3	261	126	10pb	11.6σ	149-156
Powheg+Pythia8 (rew)	69	35	5pb	5.8σ	$--$
Powheg+Herwig7.0.4	294	126	12pb	13.0σ	149-156
Average	182	88	9pb	9.6σ	143-157

- Improvement of SM prediction imperative!

Agreement with data significantly improved (>5σ)

Is 95 GeV a singlet? Relation to 152 GeV?

- S’(95): Singlet decays dominantly to bb
- S(152): Triplet decays dominantly to WW
- Predicts resonant WWγγ(95GeV) signal
- CMS analysis B2G-24-010 finishes at 100 GeV

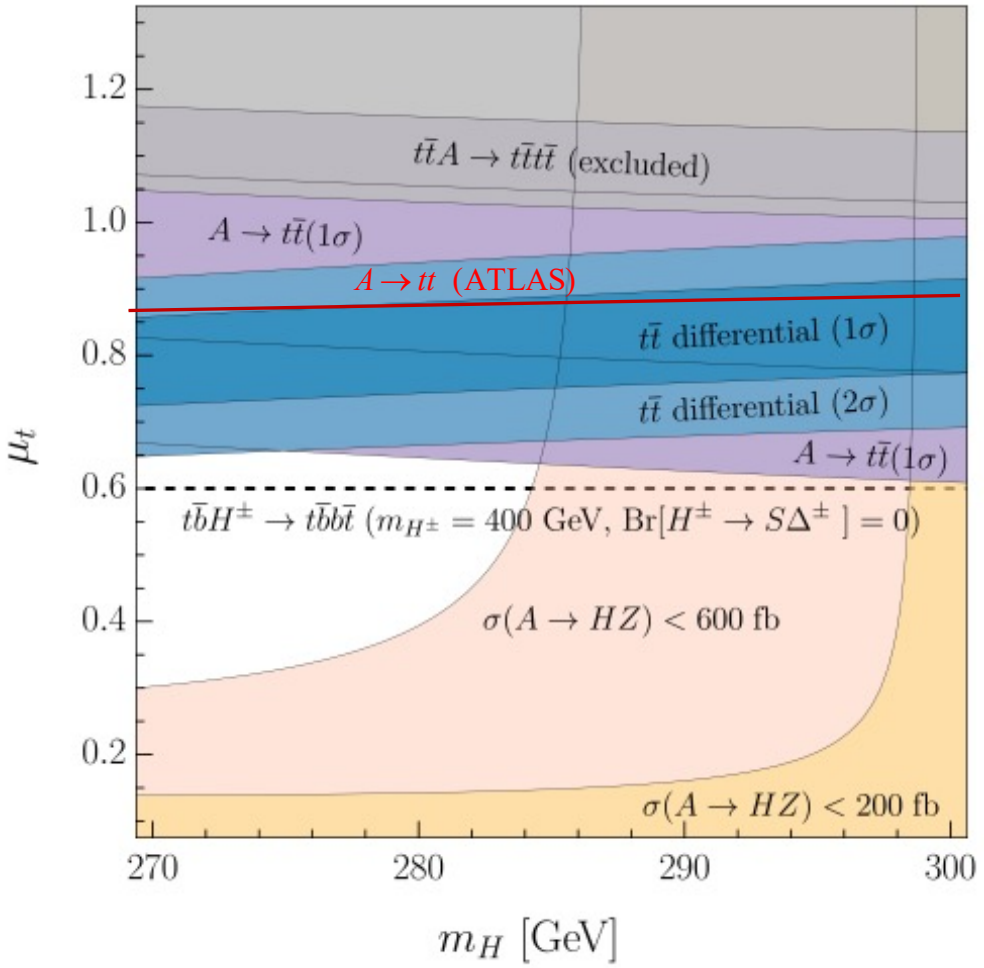


Consistent with 95 GeV γγ signal strength

Δ2HDMS and top-quark production

Field	$SU(2)_L$	$U(1)_Y$
ϕ_s	1	0
ϕ_2	2	1/2
ϕ_1	2	1/2
Δ	3	0

G. Coloretti, A.C. and B. Mellado, 2312.17314



Explains:

- Top-quark differential distributions Di-photon excesses
- Resonant top-quark production elevated 4-top cross section
- Strong two-step EW phase transition

R. Musolf et al: Phys.Rev.D 93 (2016) 015013

Combined explanation possible

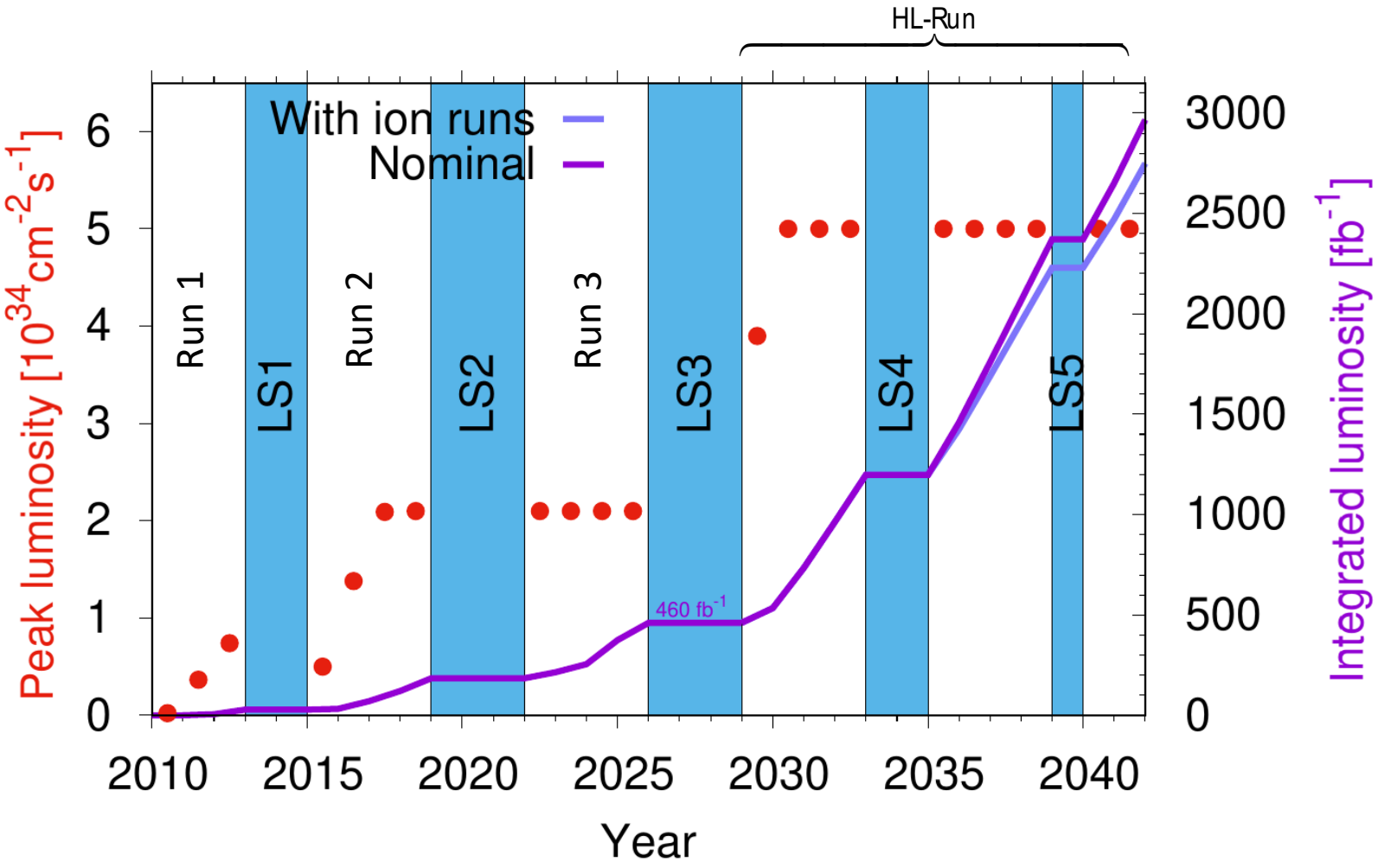
Conclusions

- Scalar sector especially interesting to search for NP
- EW scale Higgses might well be hiding in data
- Hints for narrow resonances at 95 GeV & 152 GeV
- 152 GeV could be a triplet ➡ ttZ-like signal
- Significant tensions in top quark differential distributions (>5σ)
- Can be explained via pp→H→SS' with masses consistent with the narrow resonances
- 95 GeV decays to dominantly to bb ➡ singlet?
- 152 GeV decays dominantly to WW ➡ triplet?
- Look for resonant WWbb and WWγγ signal

Most significant hints for new particles at the LHC

Prospects: LHC Run-3 and High-Luminosity LHC

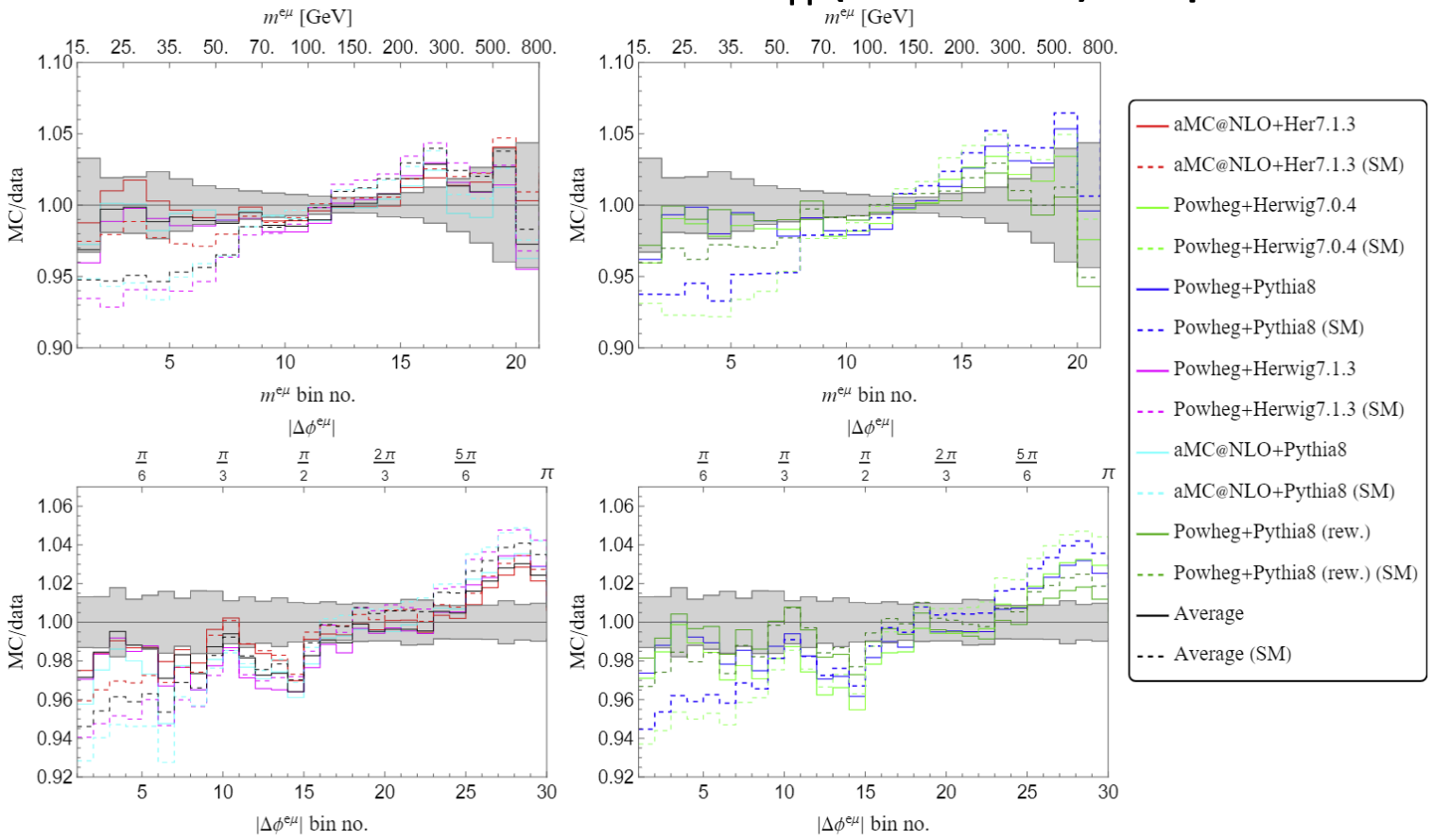
- EW-scale Higgs searches statistically limited
- LHC Run 3 more than doubles the dataset
- High-Luminosity LHC will even increase it by an order of magnitude



The next two decades will be a golden age for collider physics!

Simplified Model: H→SS'→WWbb 2308.07953

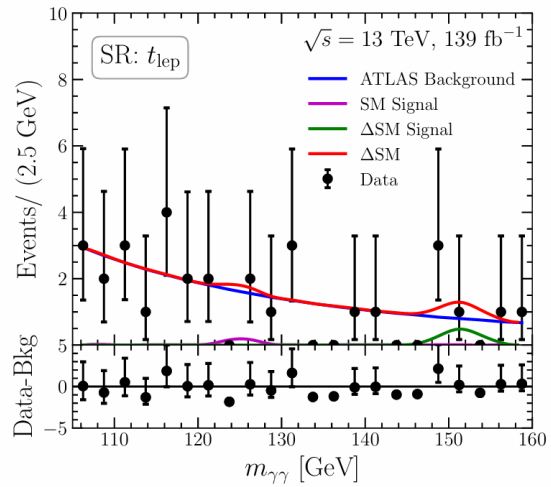
- Fix m_S=151.5GeV and $m_{S'}$=95GeV by the hints for narrow resonances. Weak m_H (270GeV) dependence.

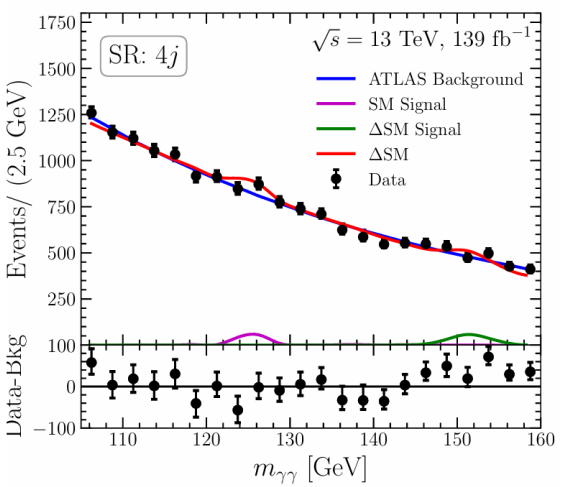


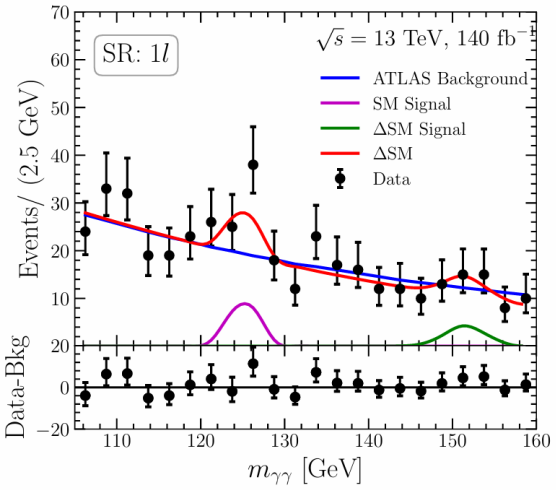
Deficit at large $\Delta\phi^{e\mu}$ & $m^{e\mu}$ explained as well

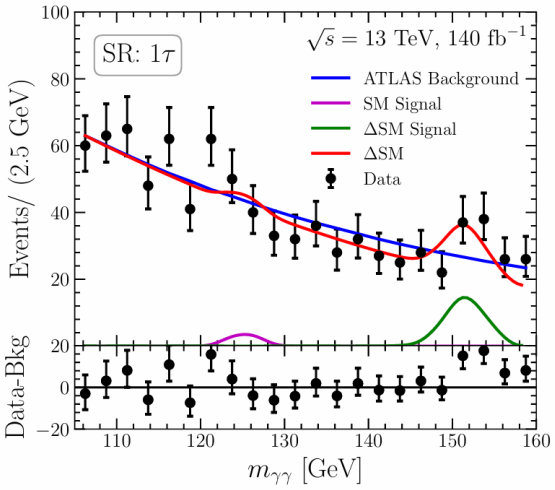
152 GeV Scalar in Associated Production

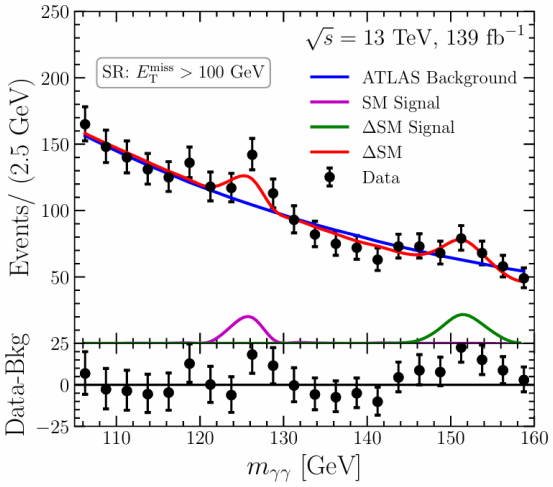
JHEP 07 (2023) 176
ATLAS-CONF-2024-005

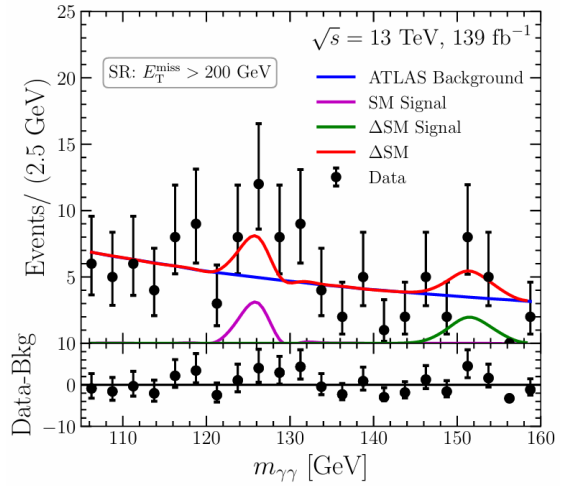


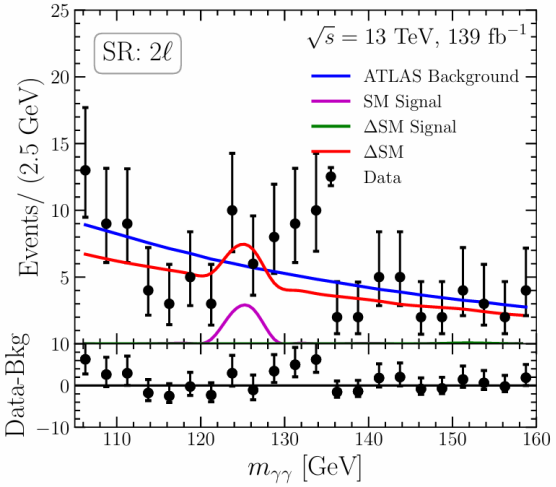


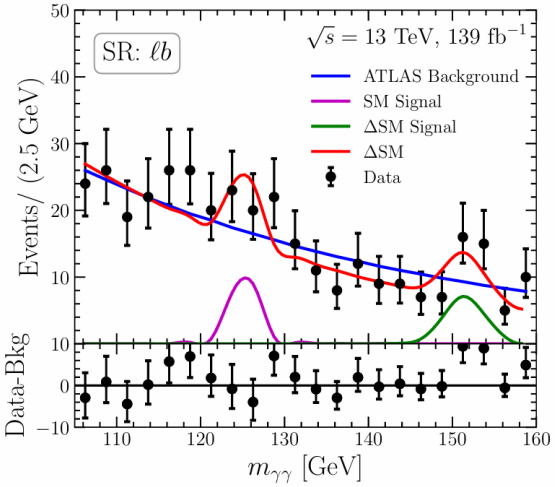












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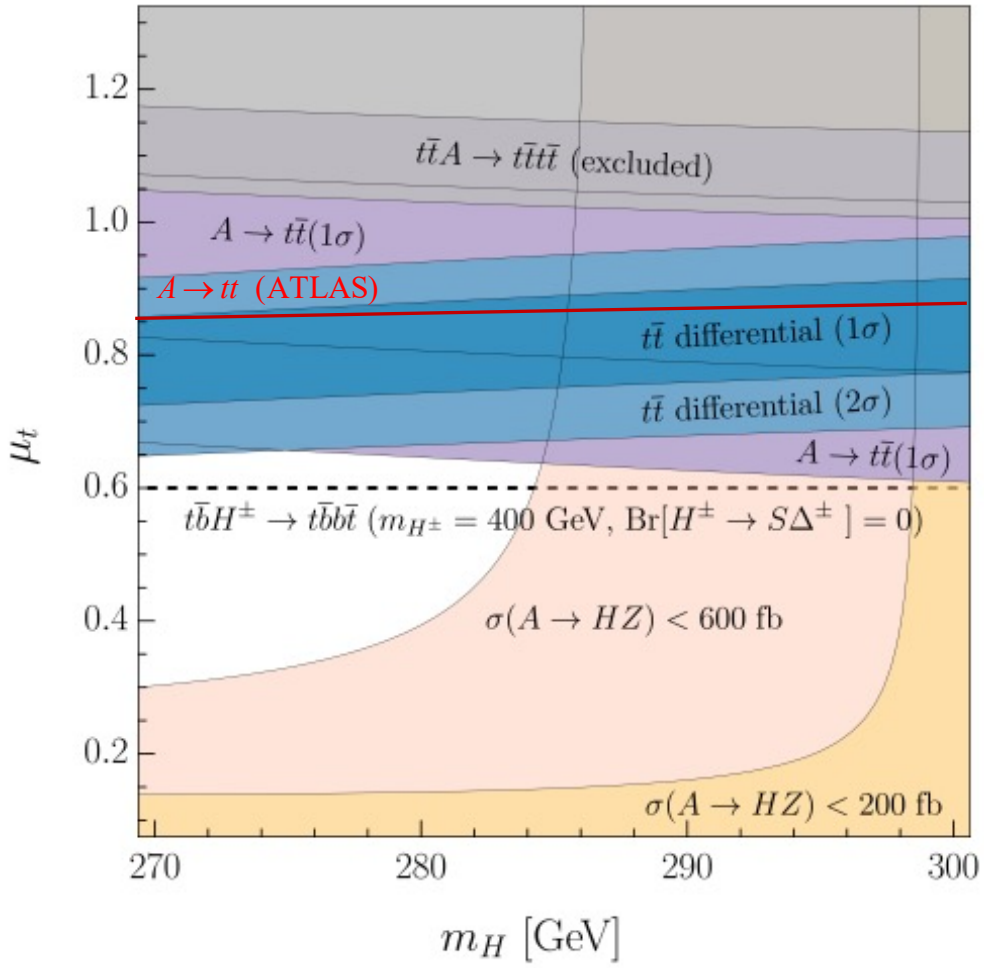
G. Coloretti, A.C. and B. Mellado, 2312.17314

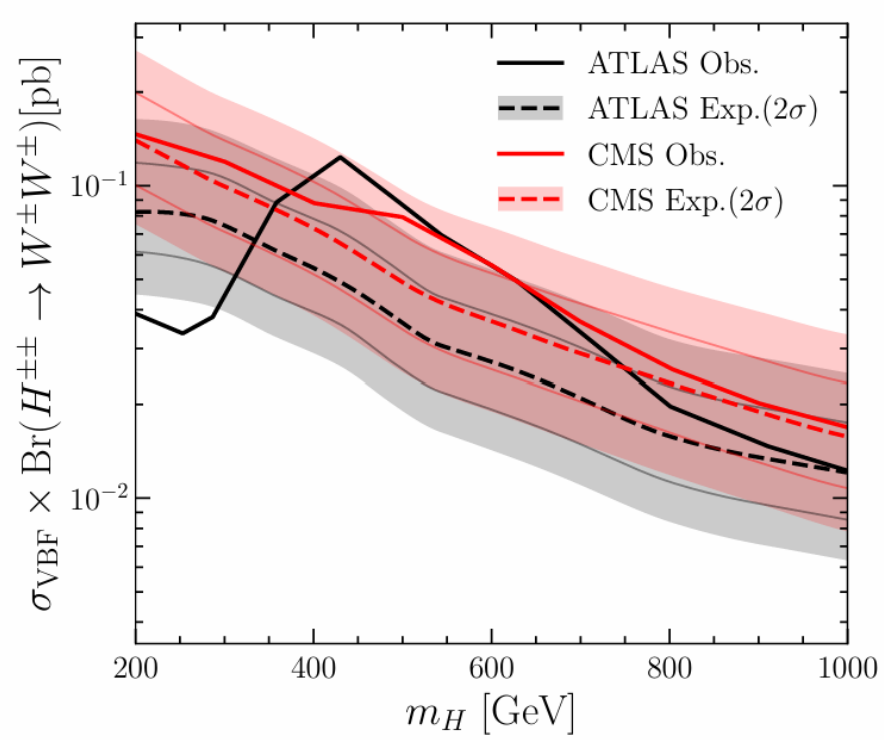


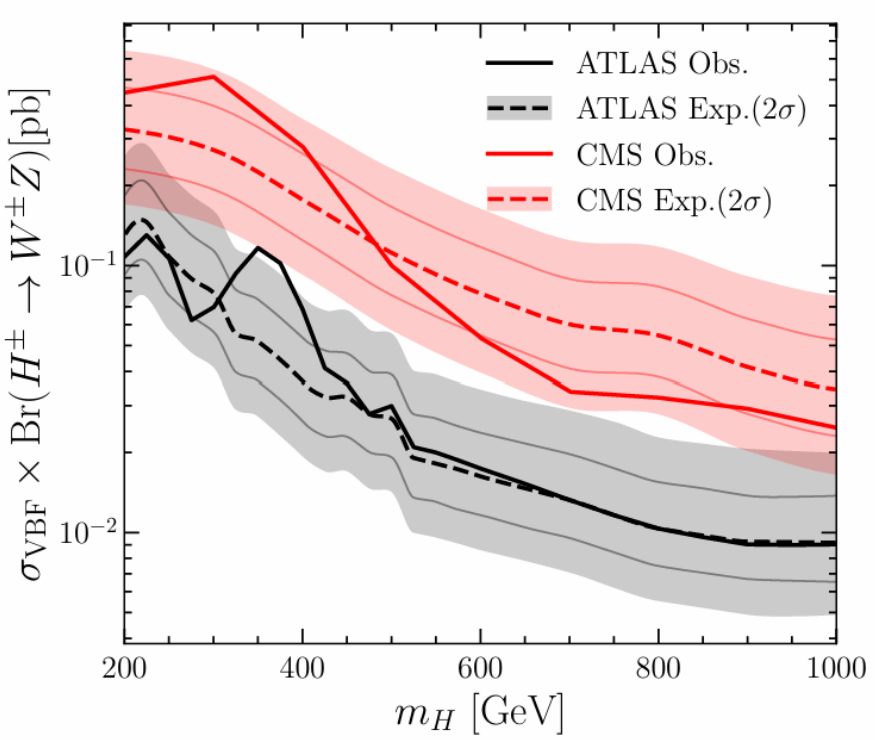
Combined explanation possible

VBF Di-Boson Excesses

2503.01974

- ATLAS excesses in same sign WW (450 GeV, 3.2σ) and ZW (375 GeV, 2.8σ) in vector-boson fusion
- CMS observes weaker-than expected limits





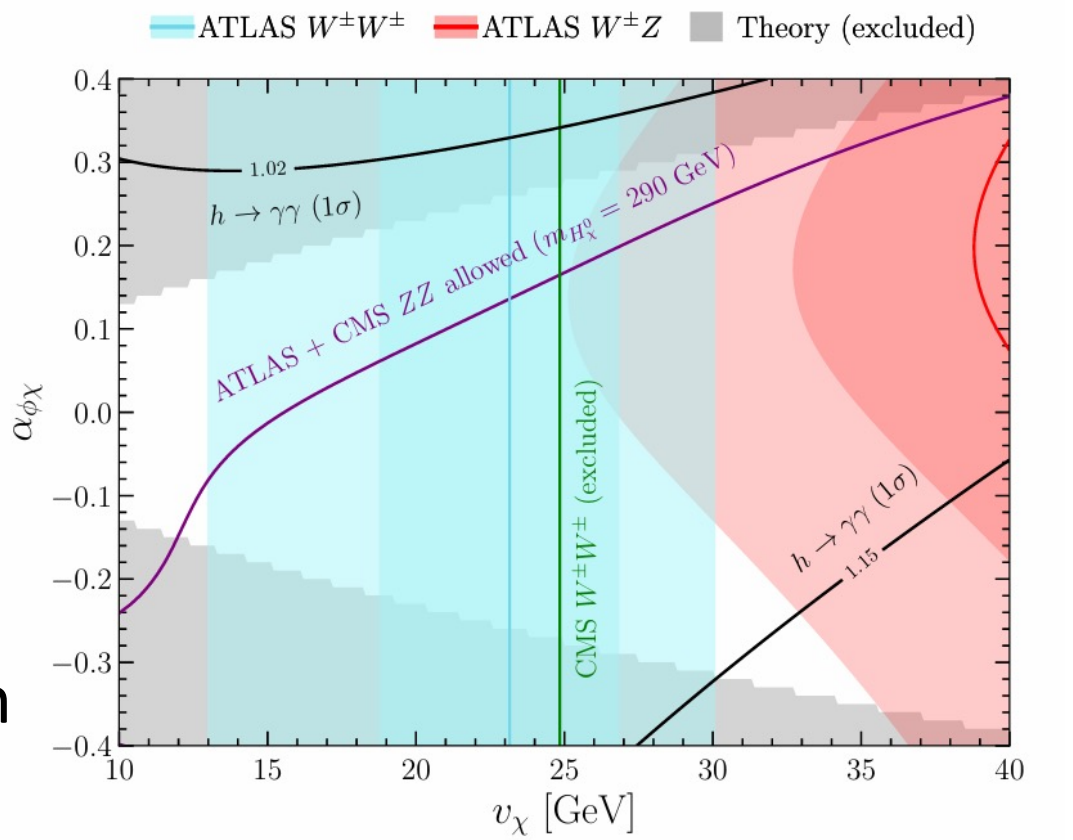
Tripelts with sizable vevs

Generic Georgi-Machacek Model

SM extend

- Y=0 triplet (ζ)
- Y=1 triplet (χ)
- Vevs of the triplet can be sizable due to cancellation in the W mass

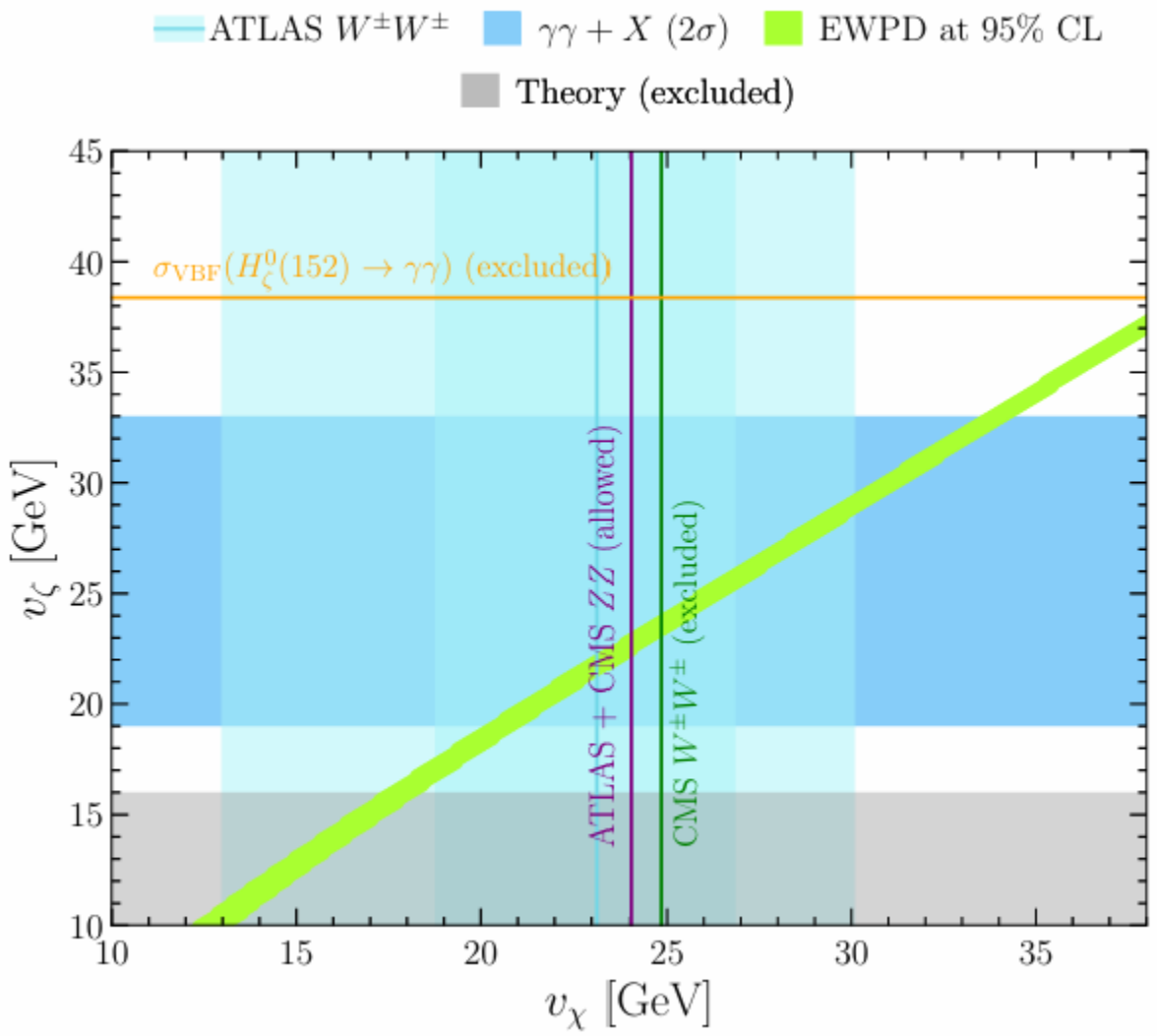
→ sizable vector-boson fusion cross section



- Generic version needed for different masses

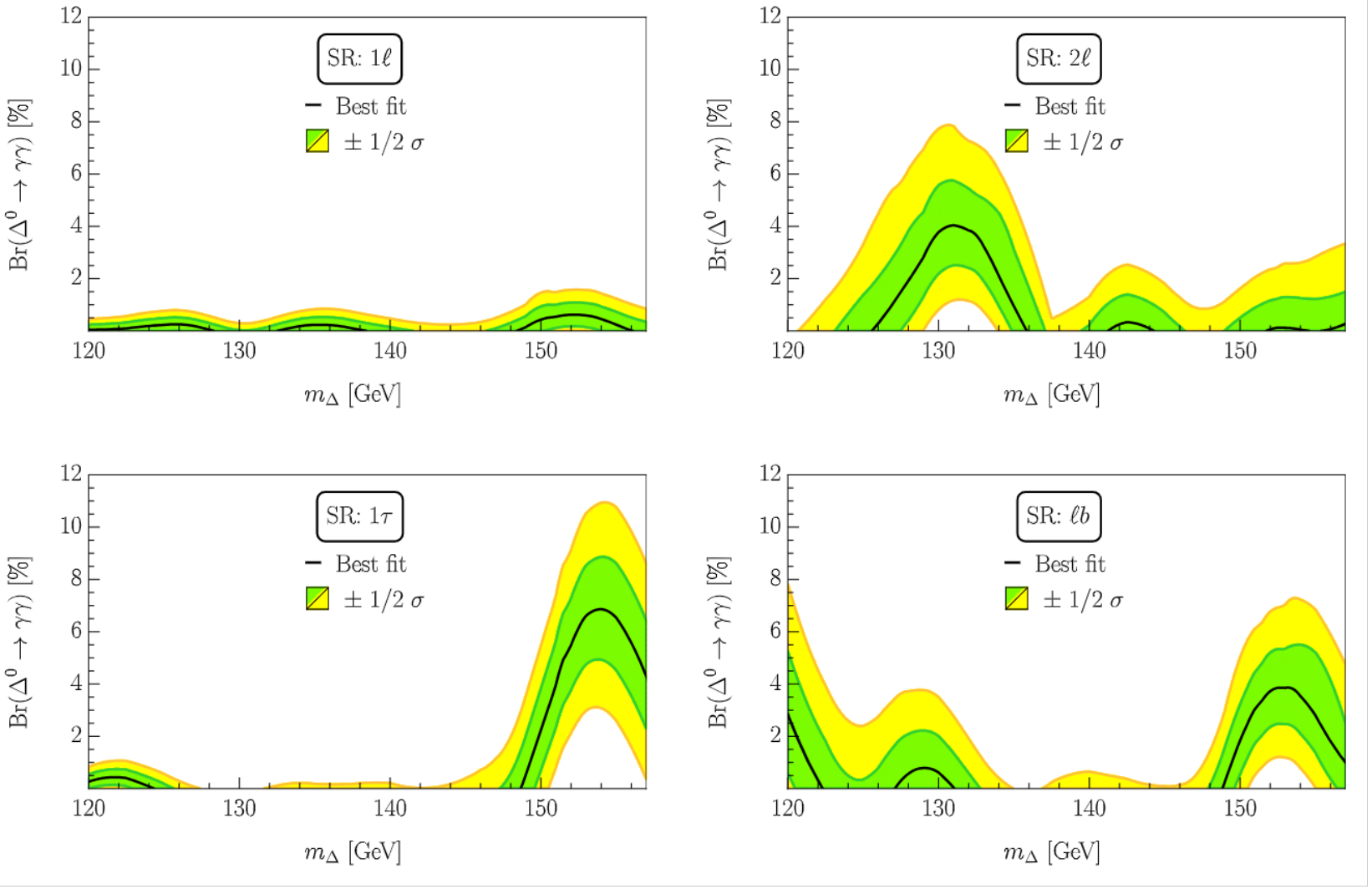
Y=1 Triplet in the GM model explain WW and ZW

Generic Georgi-Machacek Model



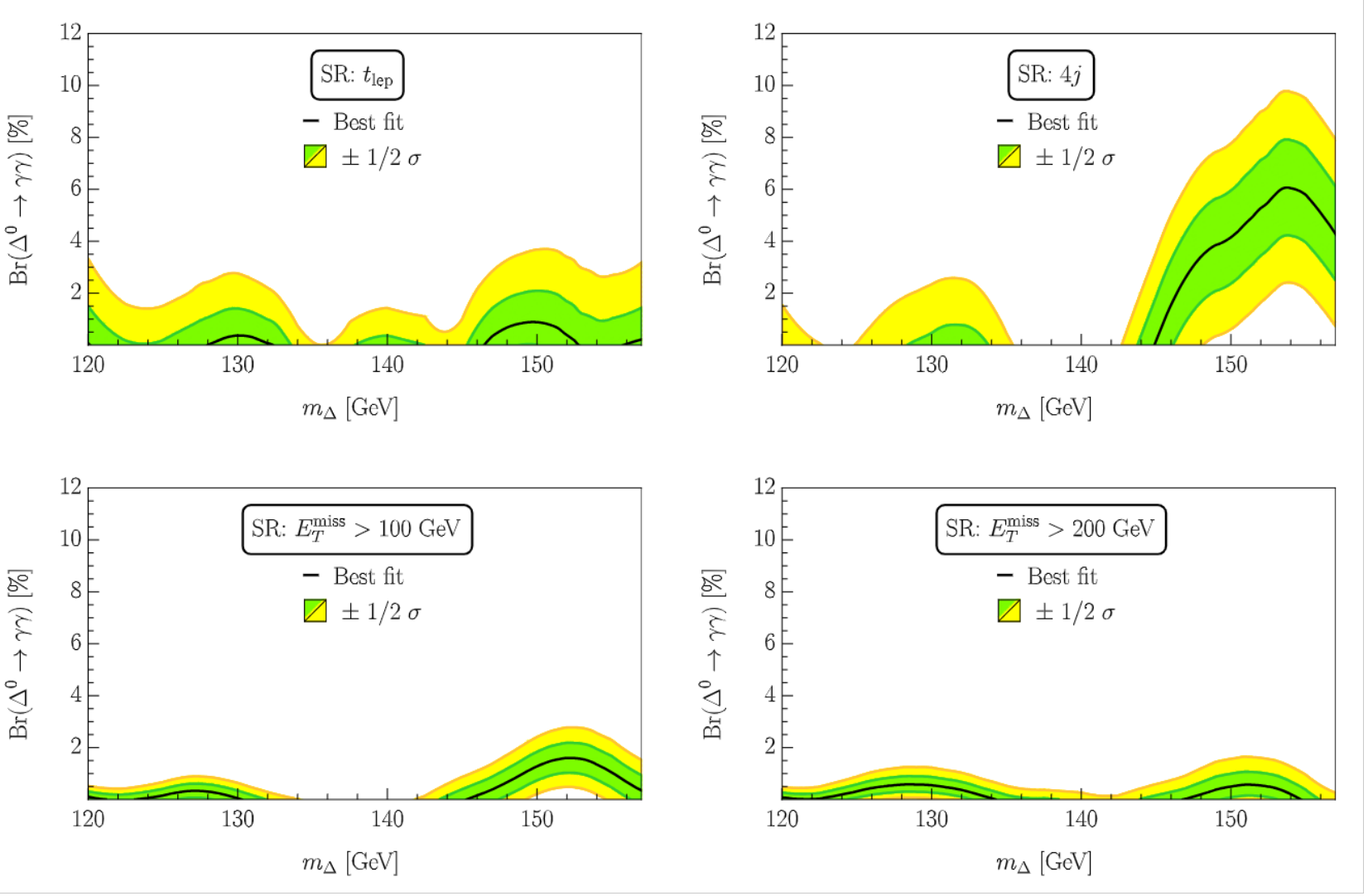
Y=1 can explain WW, ZW; Y=0 γγ (152)

h→γγ+X from ATLAS



Triplet consistently explains h→γγ+X excesses

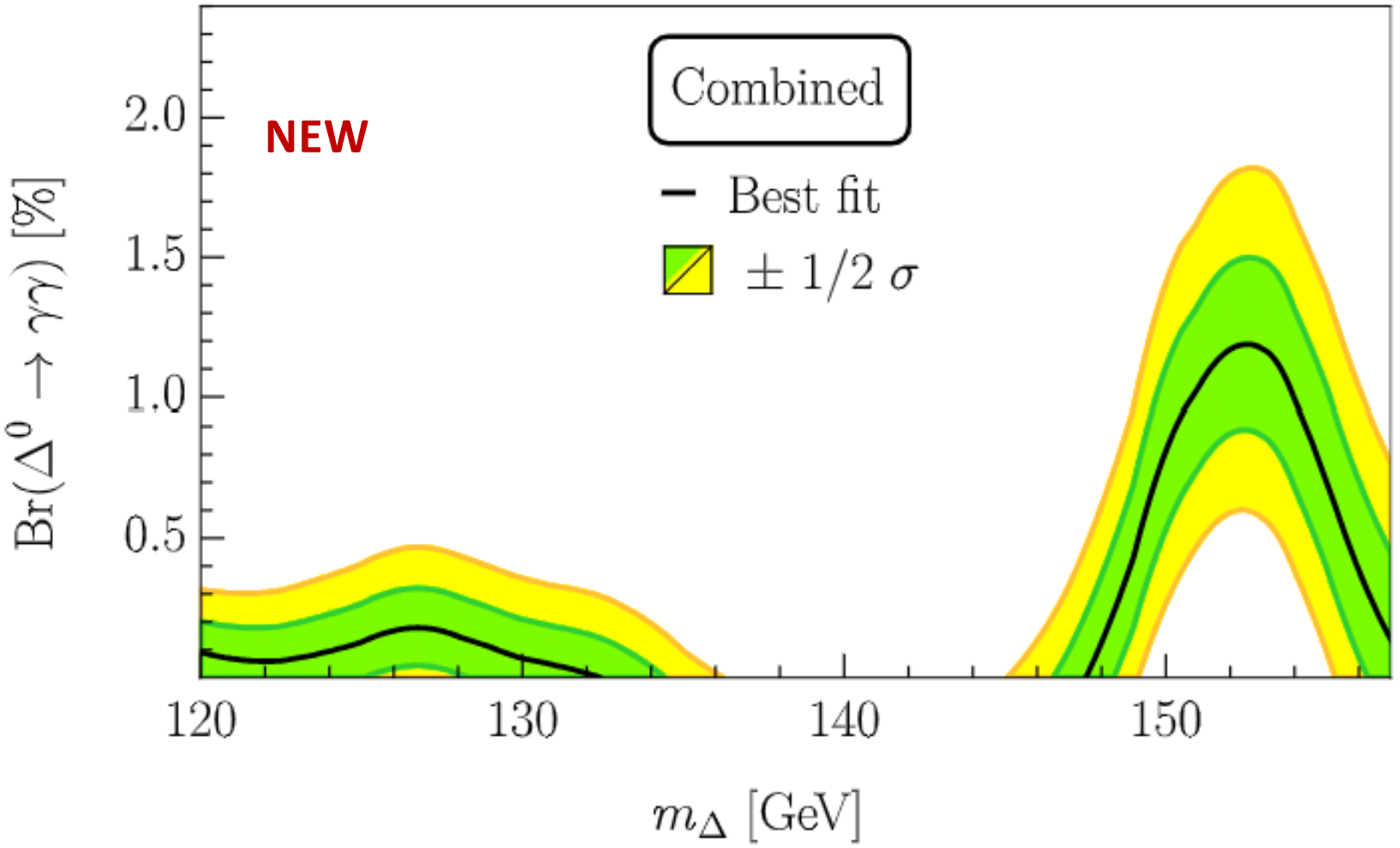
h→γγ+X Channels



Triplet consistently explains h→γγ+X excesses

Combination

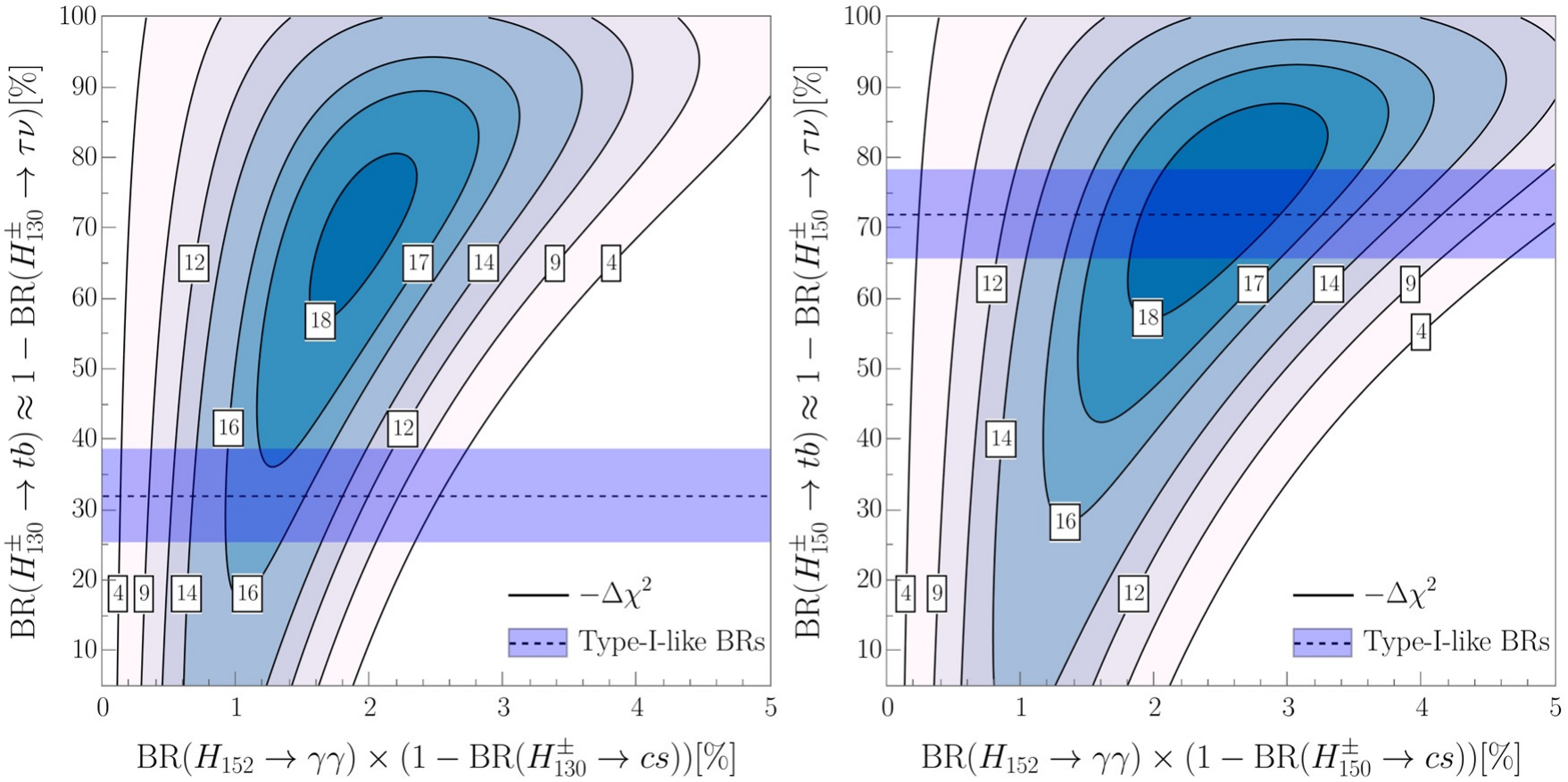
S. Ashanujjaman, S. Banik, G. Coloretti, A.C. S. P. Maharath
B. Mellado, 2404.1449_



4σ excess at 152GeV

Two-Higgs Doublet Model type-I

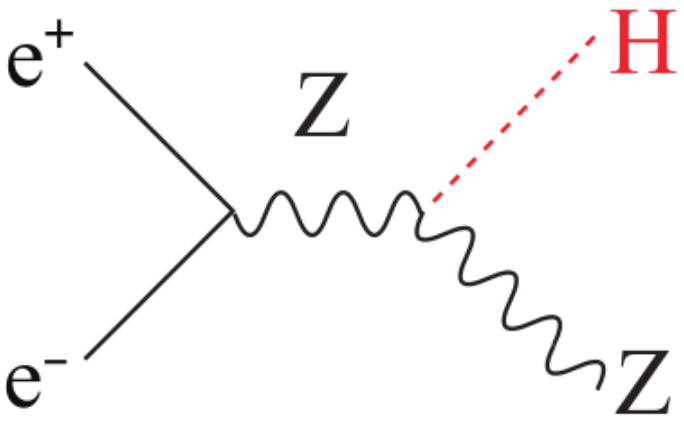
- $\mathrm{Br}\left(H^{\pm} \to WZ\right) = 0$ (at tree-level)



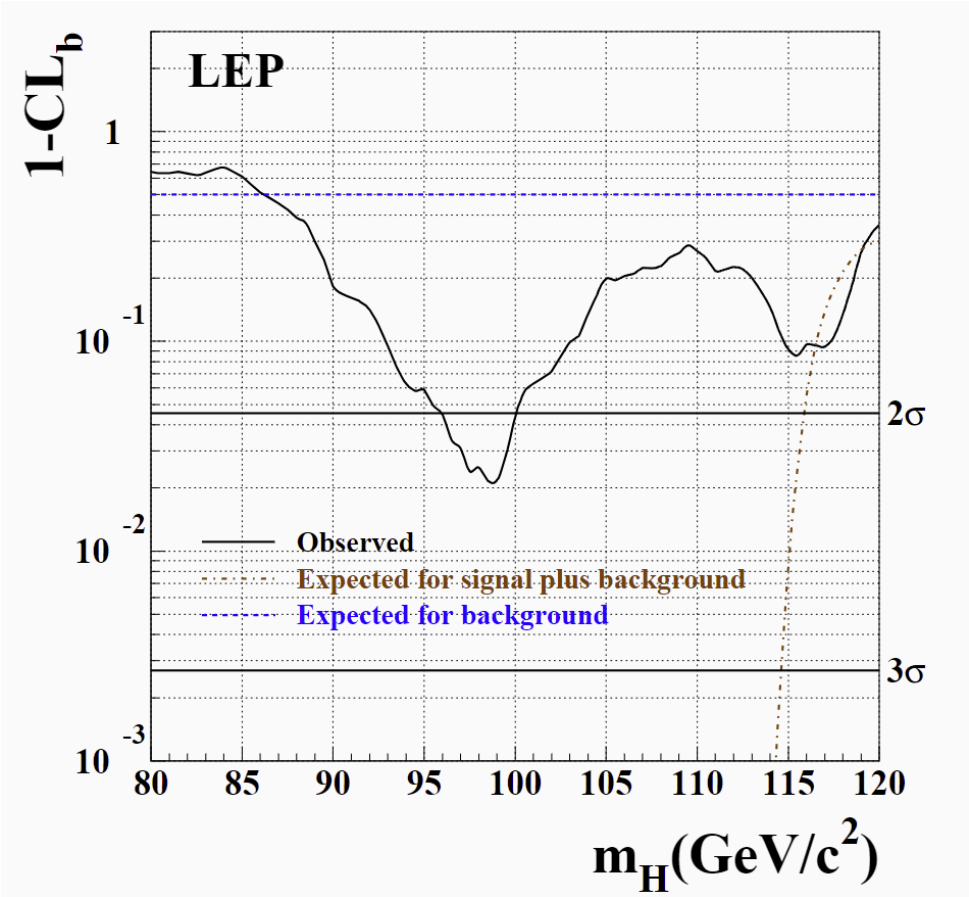
Above 4σ, large Br needed

Hints for a 95 GeV Higgs

- LEP: $e^+e^- \rightarrow Z^* \rightarrow Z(H \rightarrow bb)$



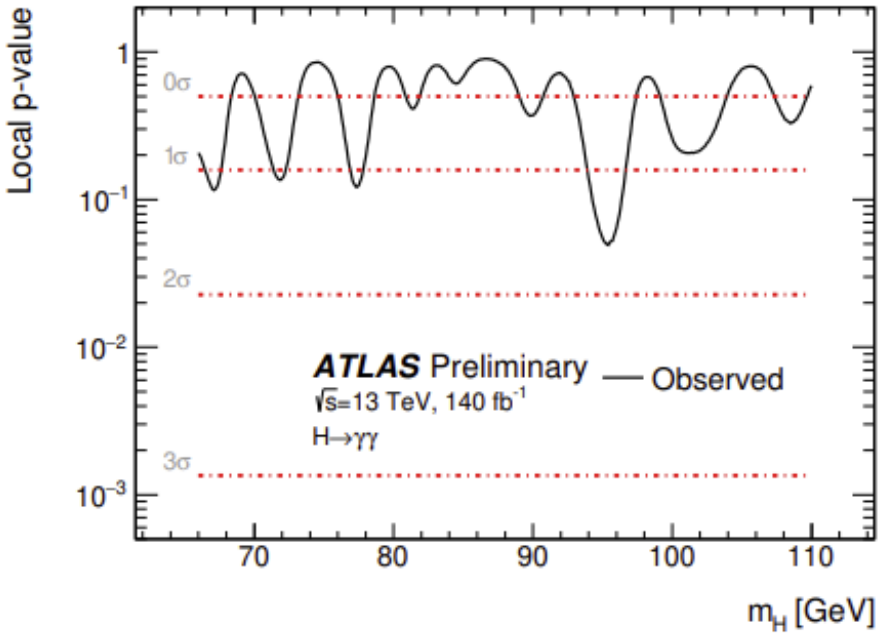
- Used the lower the search range

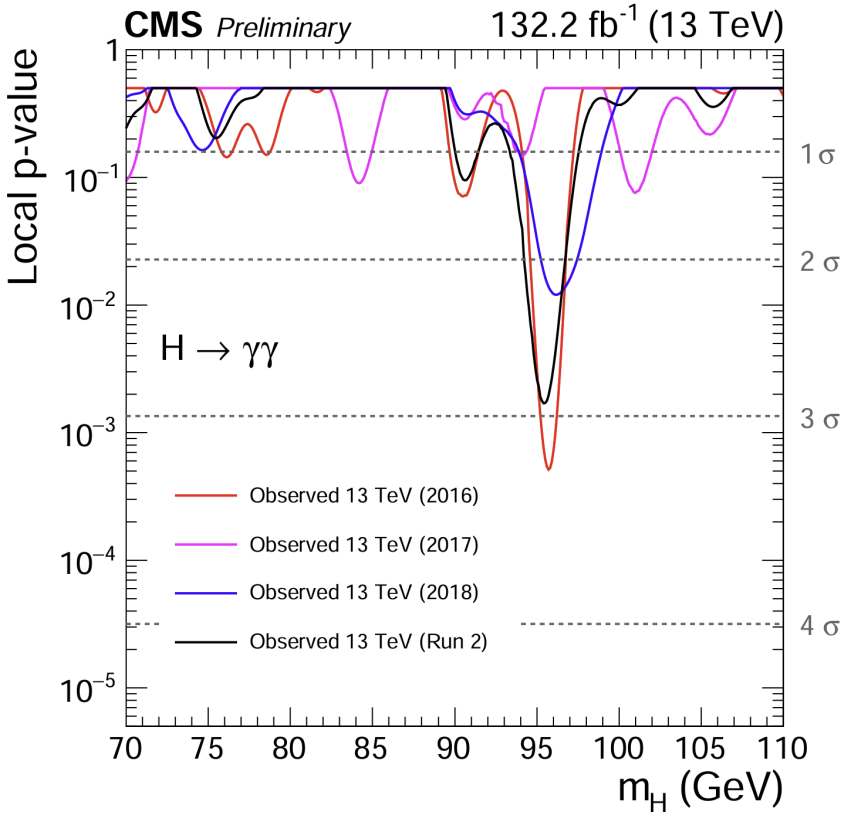


LEP excess compatible with 95 GeV

Hints for a 95 GeV Higgs

- ATLAS & CMS: γγ

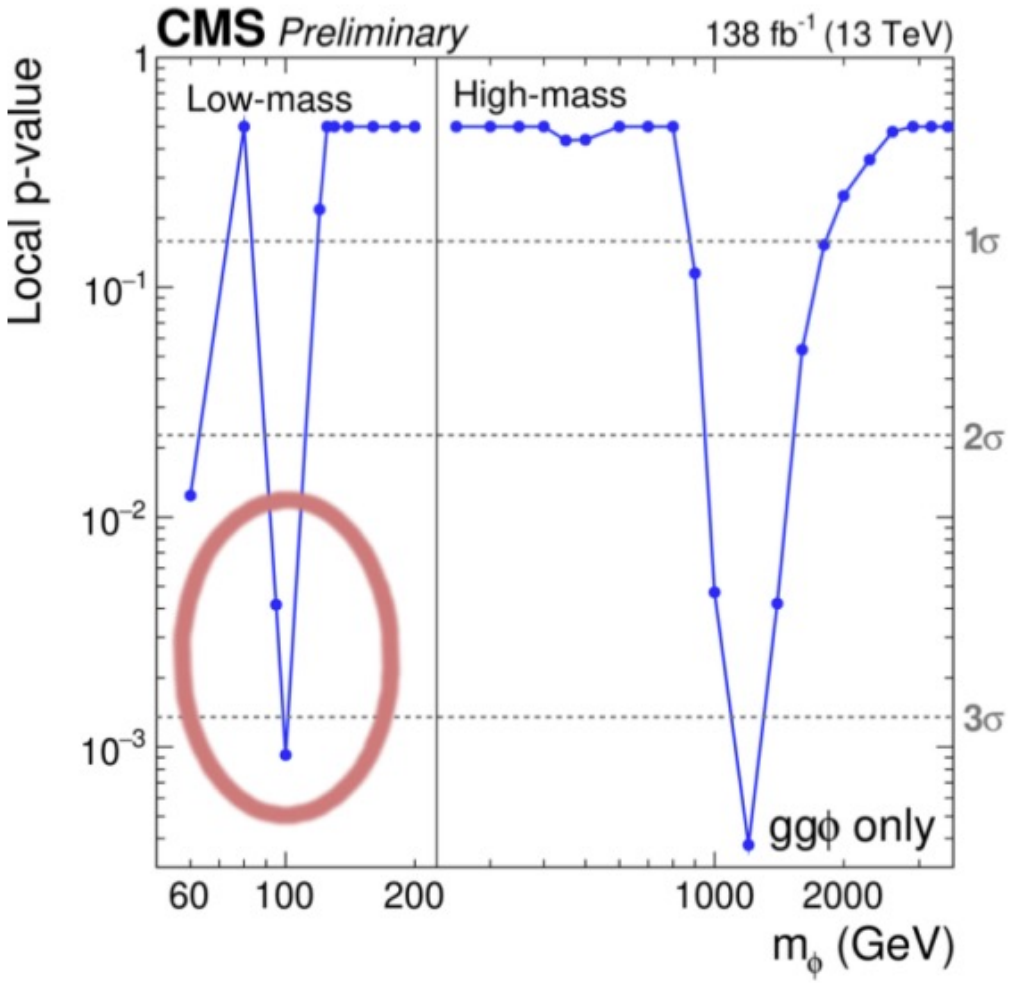




Nice agreement at 95 GeV

Hints for a 95 GeV Higgs

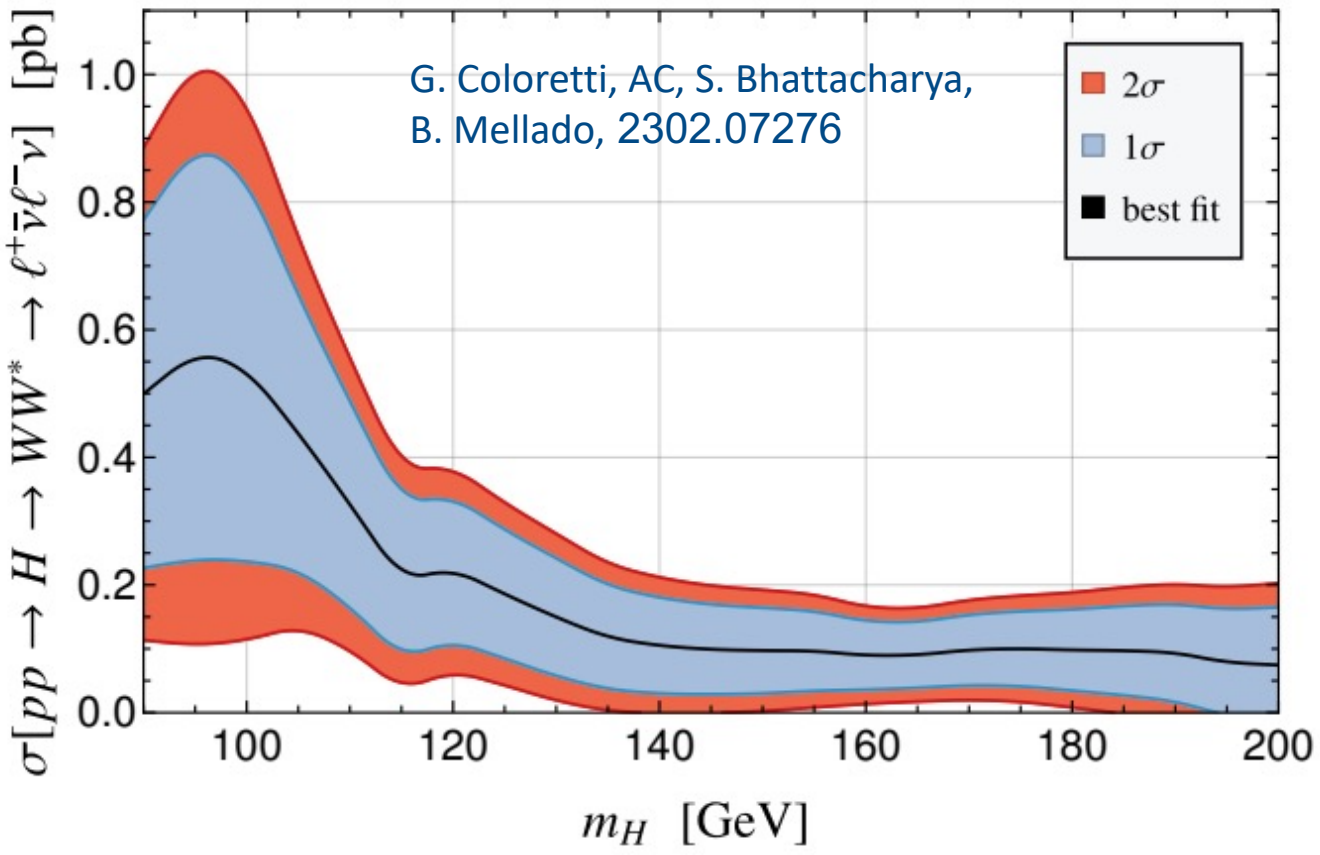
- CMS: ττ
- No dedicated ATLAS search
- No excess in the side-bands of the SM analysis



Reduced significance of <2σ

Low mass WW resonances searches

- ATLAS and CMS combination

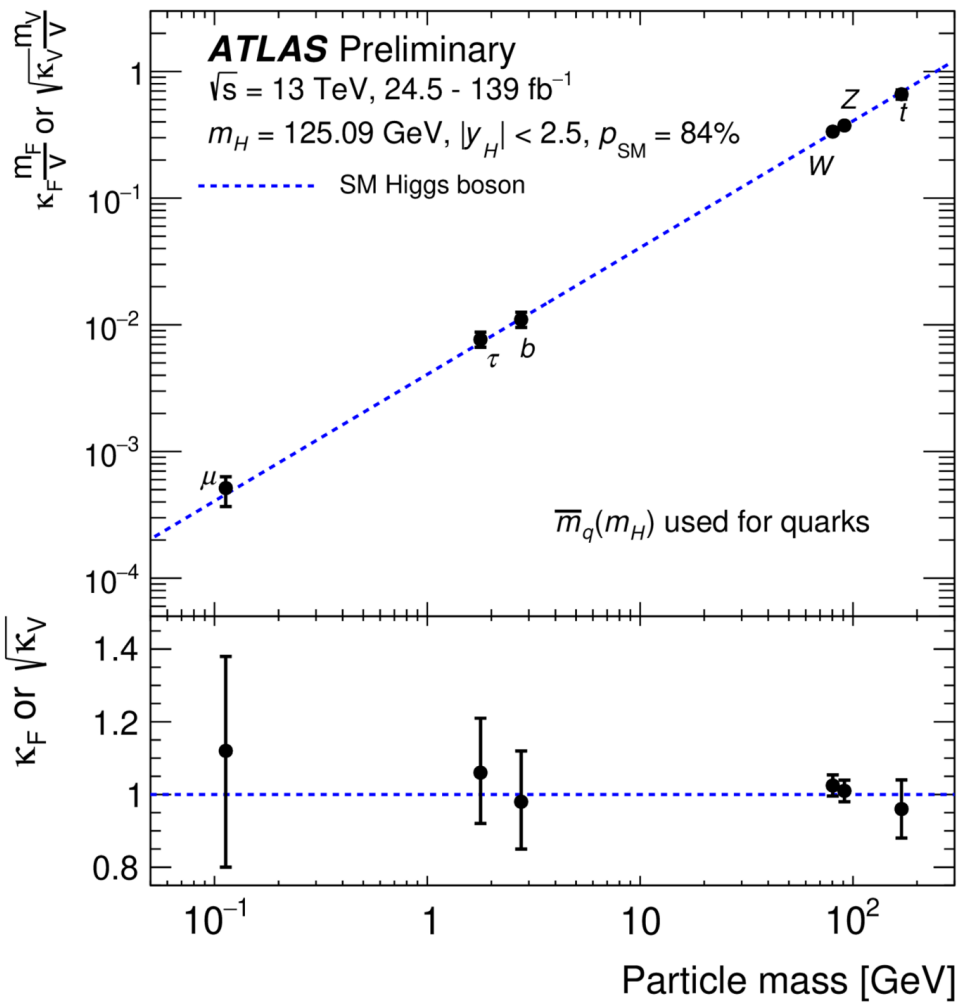


Transverse mass sensitive to additional missing energy from associated production

New physics effect preferred

The Higgs Boson in the Standard Model

- Higgs discovery in 2012, nearly 50 years after its prediction
- Only fundamental scalar in the SM
- Coupling strength is proportional to the masses of the particles
- Measurements agree with the SM predictions (within errors)
- EW precision tests work well (despite possible W-mass issue)



Is the 125 GeV Higgs the only (fundamental) scalar?

Multi-lepton anomalies