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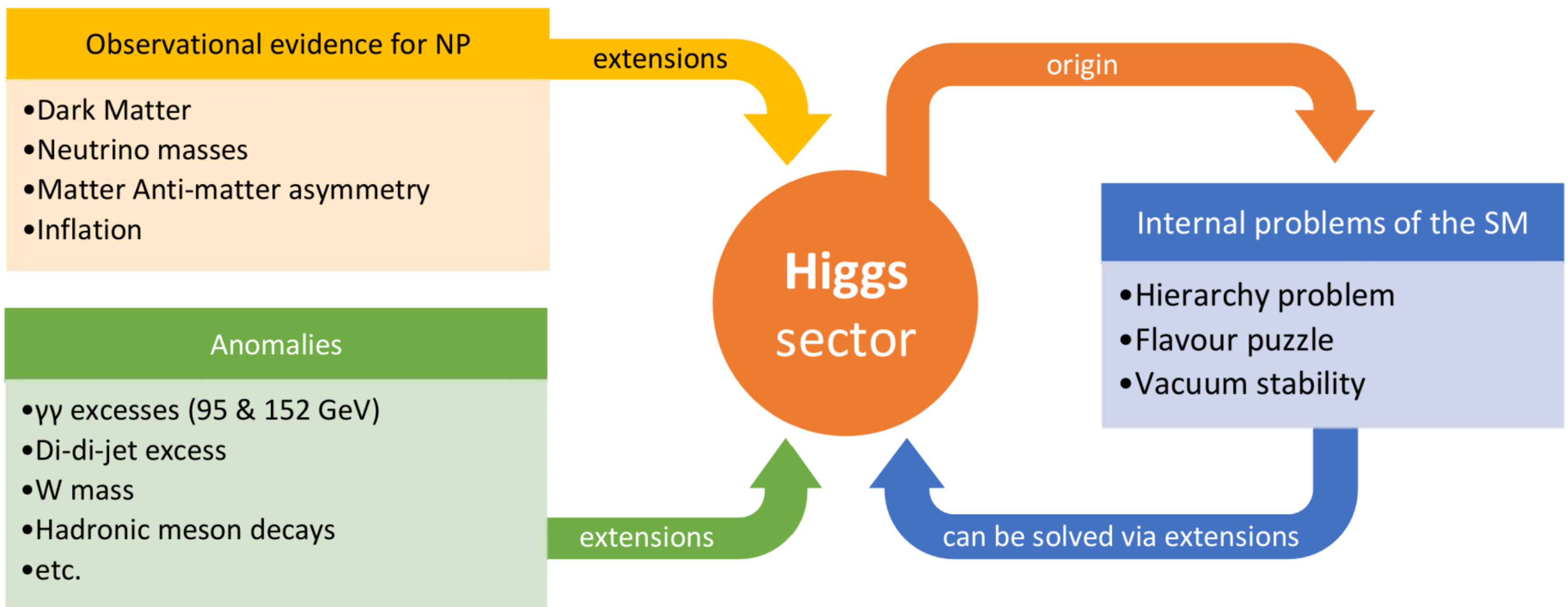
New Higgs Bosons at the EW Scale and Implications for CEPC

Guangzhou, 10.11.2025

Why new Higgses?

- No theoretical principle forbids new Higgses
- Nearly all top-down approached have new scalars



Higgs sector very promising place to expect NP

New Higgses at the Electroweak Scale

- Signatures of new Higgses expected to be sub-leading compared to the SM Higgs
  - SM-Higgs signal strength
  - EW precision measurements
- Large SM background
- Small p_T leads to low detector efficiencies
- Non-resonant signatures
  - $H \to tt$
  - $H \to WW$
  - $H^+ \to tb, WZ$

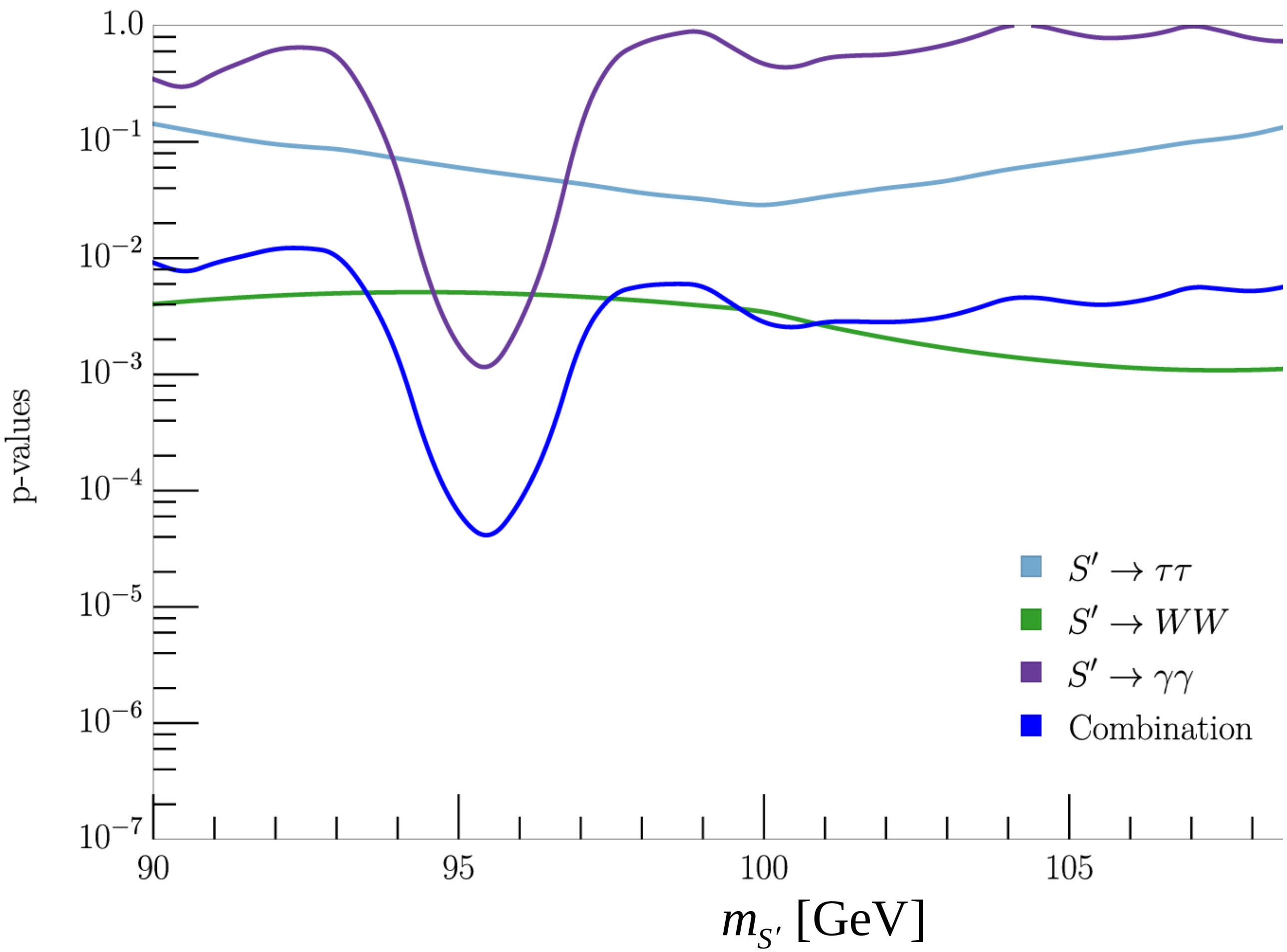
  are weakly constrained

EW scale Higgses could be hiding in the LHC data

95 GeV Combination

S. Bhattacharya, G. Coloretti, A. Crivellin, et al. arXiv:2306.17209

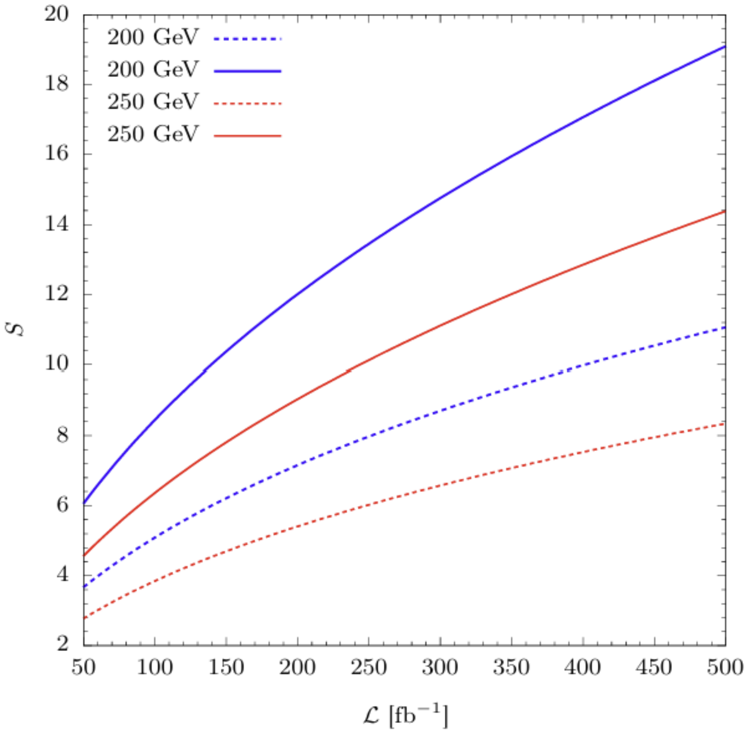
- LEP used to reduce the look-elsewhere effect



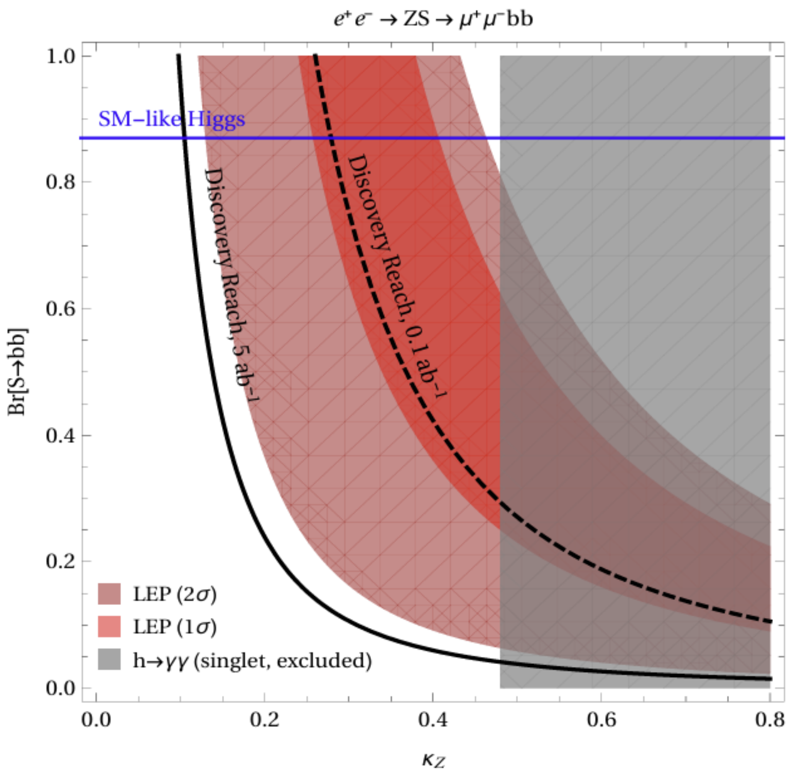
3.4σ global significance

Discovery potential

- 10% SM Higgs signal strength



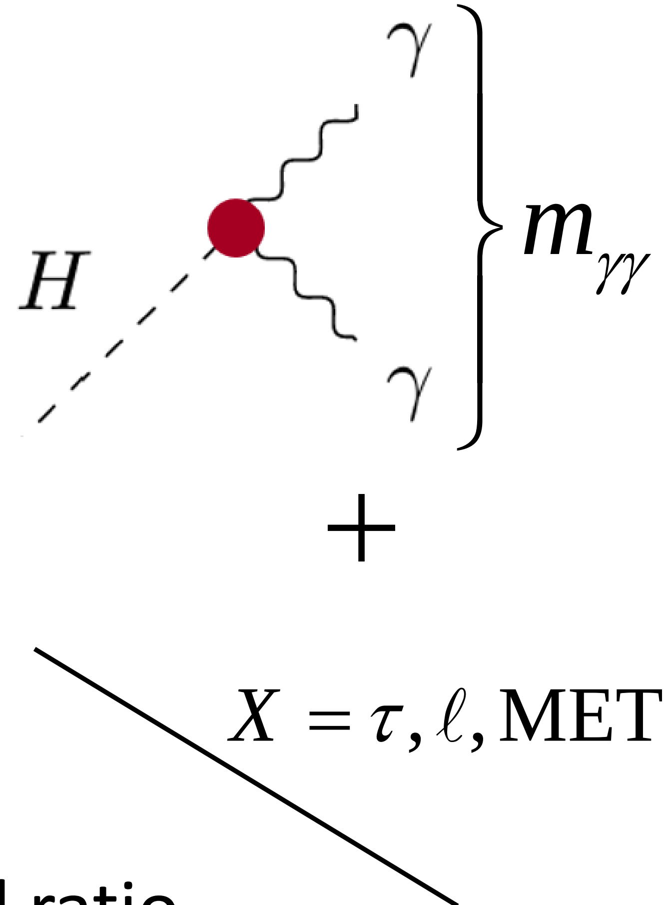
- Singlet case



Whole region preferred by LEP can be covered

Associated Production of New Higgses

- Associate production can be dominant for BSM Higgses
- Requirements of an additional signature "X" reduced the the background
- Better signal over background ratio

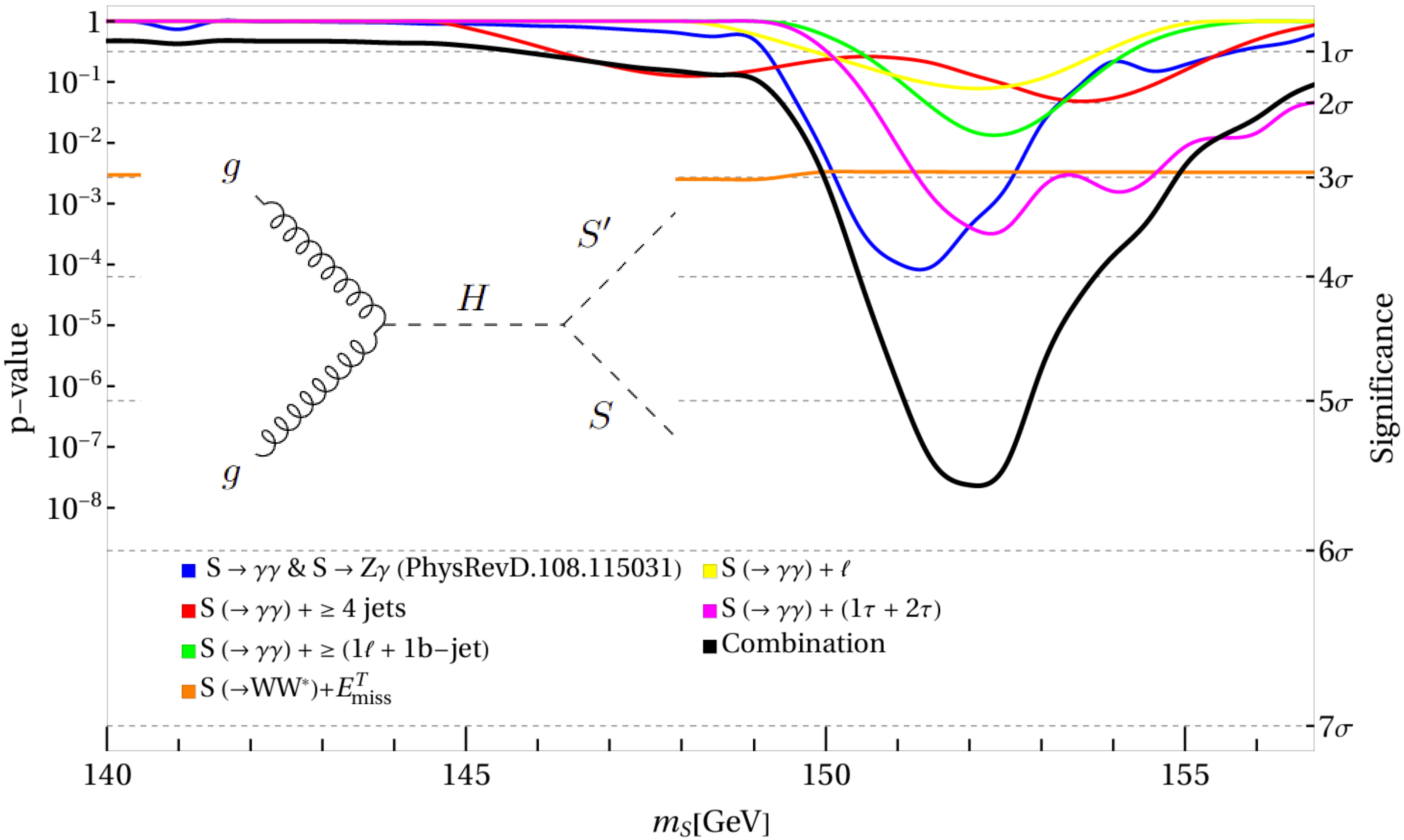


$$X = \tau, \ell, \text{MET}, \ldots$$

Can make a discovery of a EW scale Higgs possible

Hints for new Scalars at 152 GeV

- Combination within the simplified model
  H→SS* with S→WW, MET, γγ

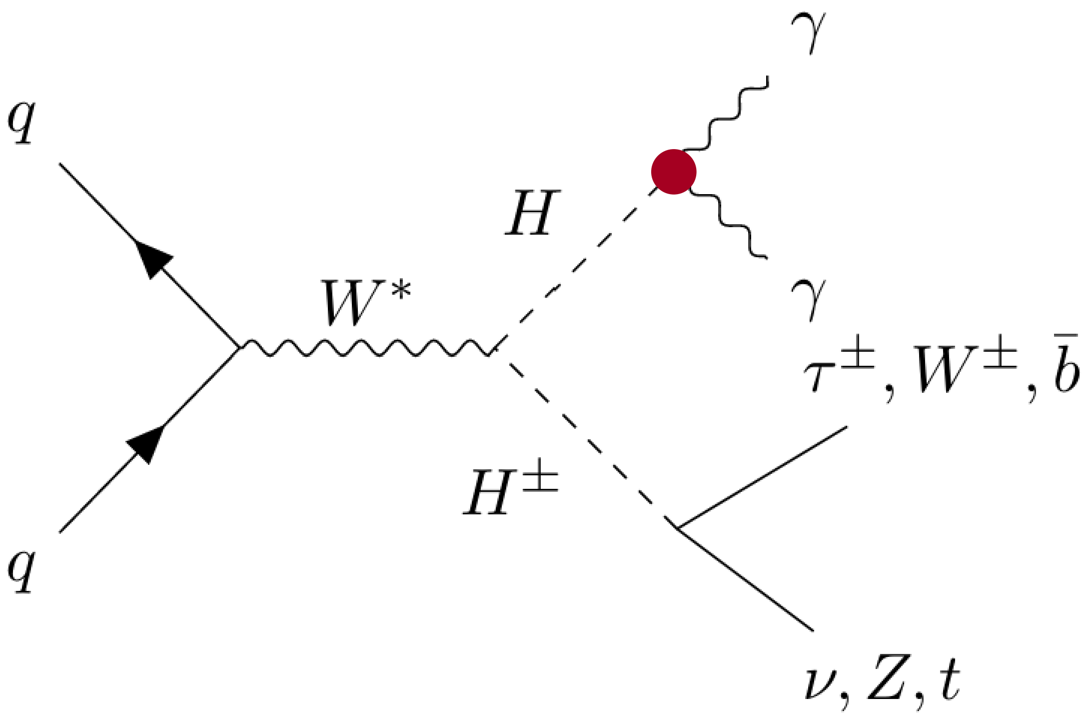


>5σ global significance for simplified model

Drell-Yan Production

- One leptons, but not two leptons
- One tau but not two taus
- lb but not t_{lep}
- Moderate MET

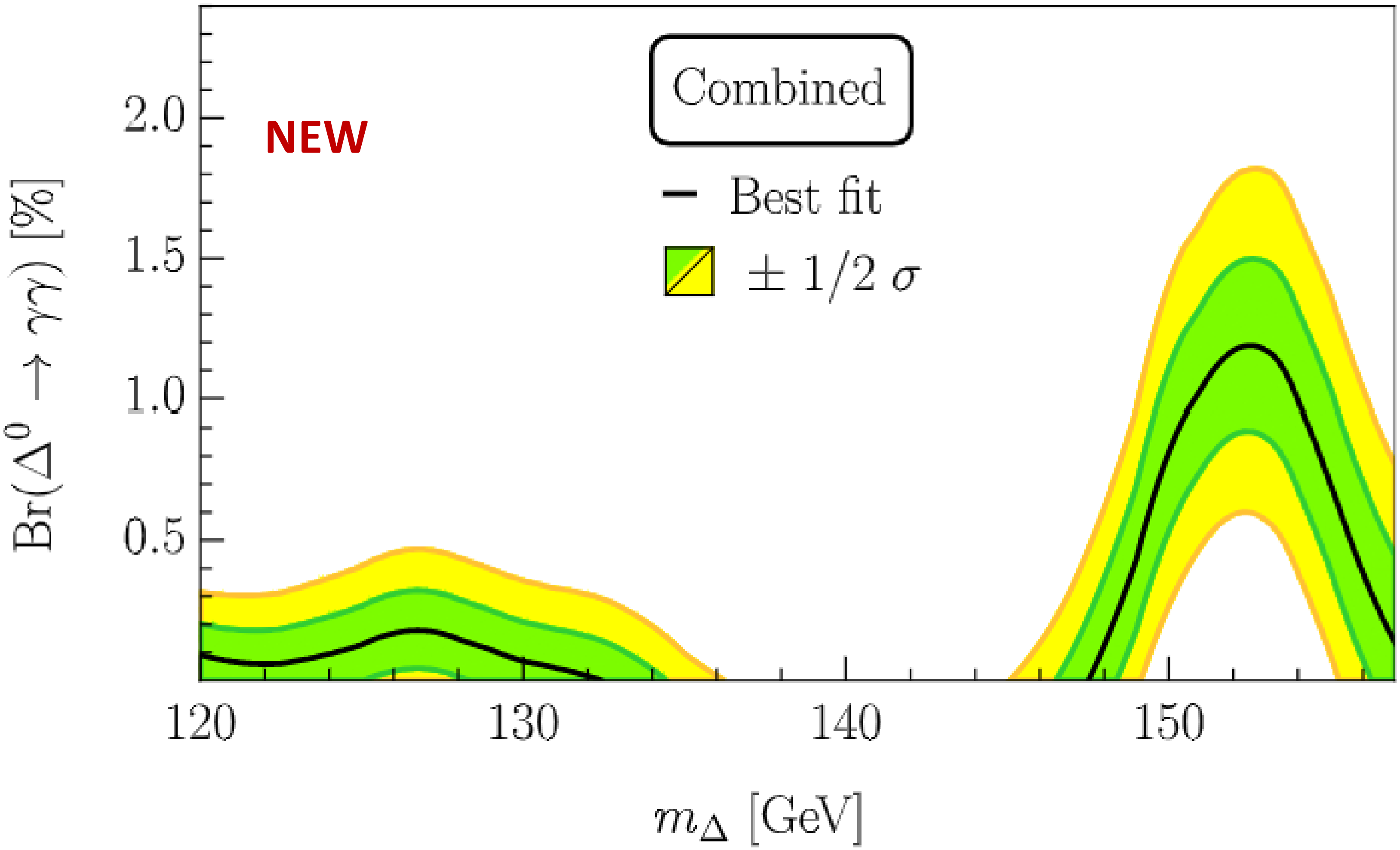
- DY production of charged and neutral Higgs



New Scalar with non-trivial SU(2) representation

Triplet Combination

S. Ashanujjaman, S. Banik, G. Coloretti, A.C. S. P. Maharathy, B. Mellado, 2404.14492

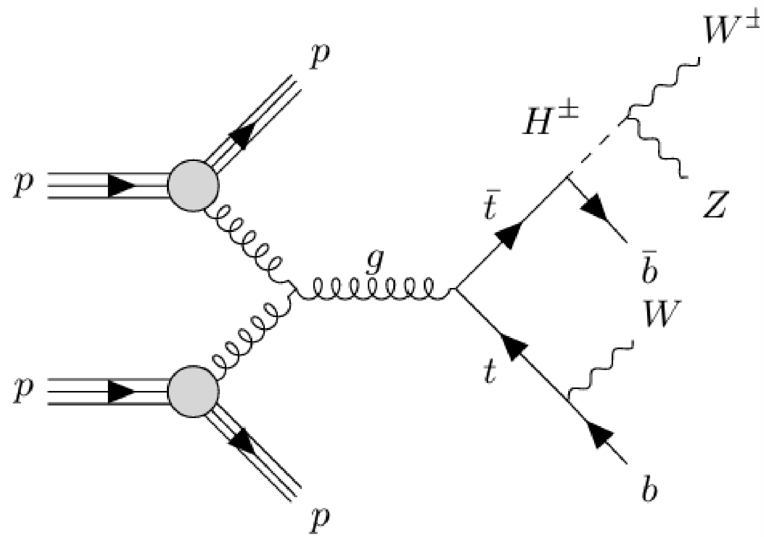


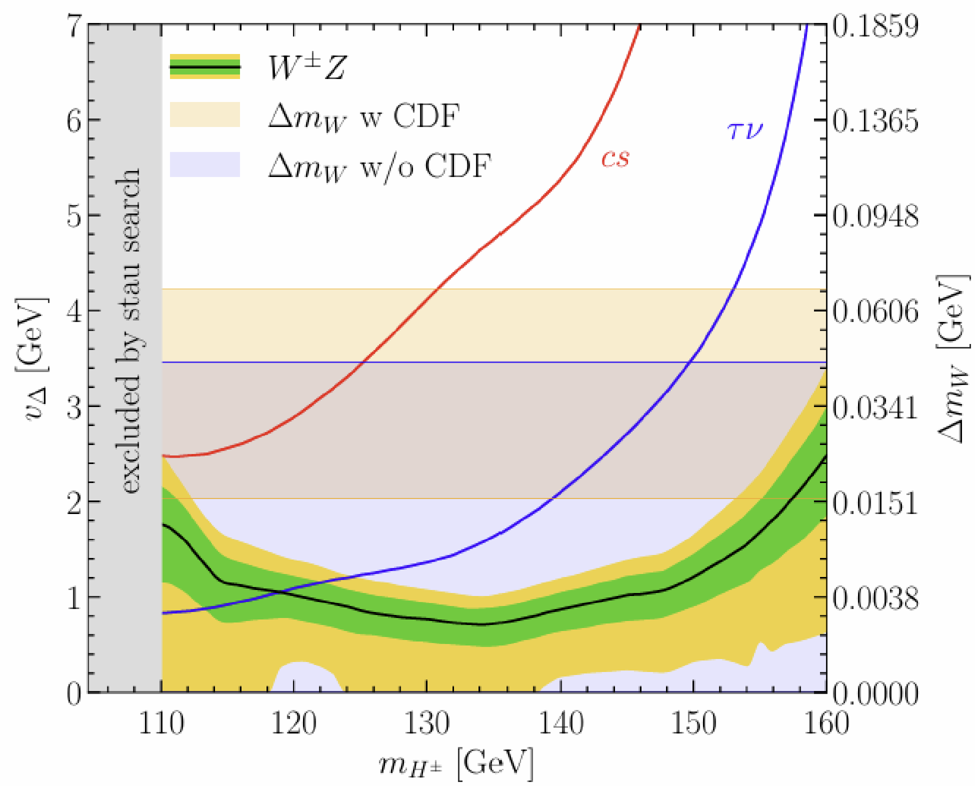
≈4σ excess at 152GeV

Triplet model

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

- Charged Higgs production in top decays
- Results in ttZ-like signal

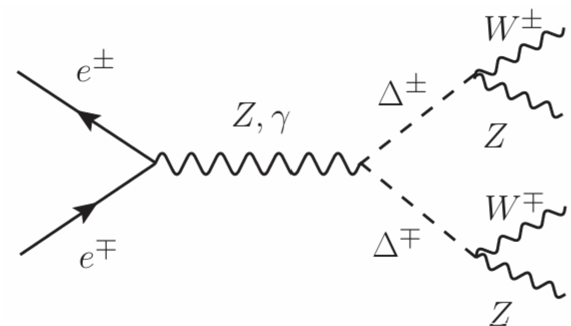


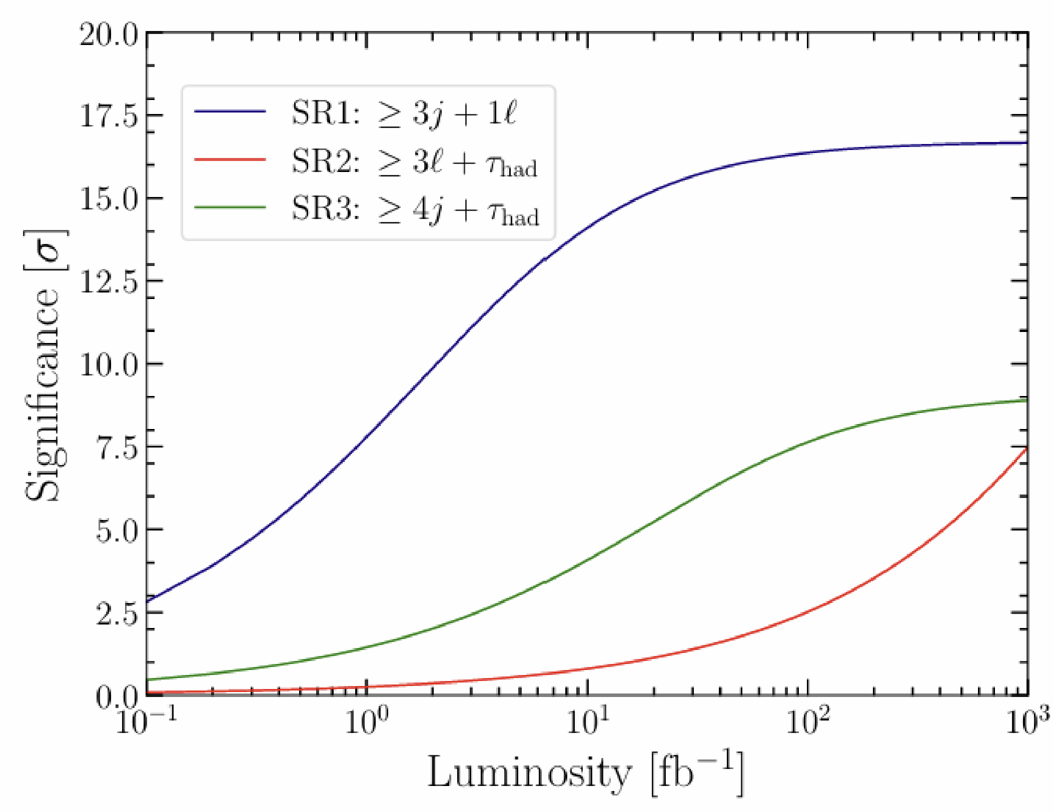


>2σ excess

Triplet CEPC Implications

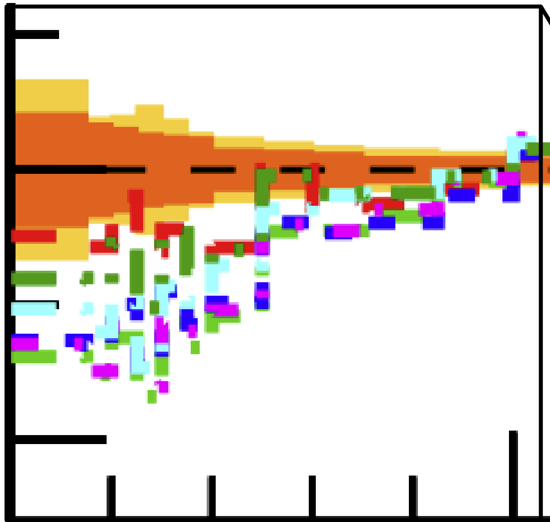
- W mass measurement (positive shift predicted)
- Multi-lepton signatures

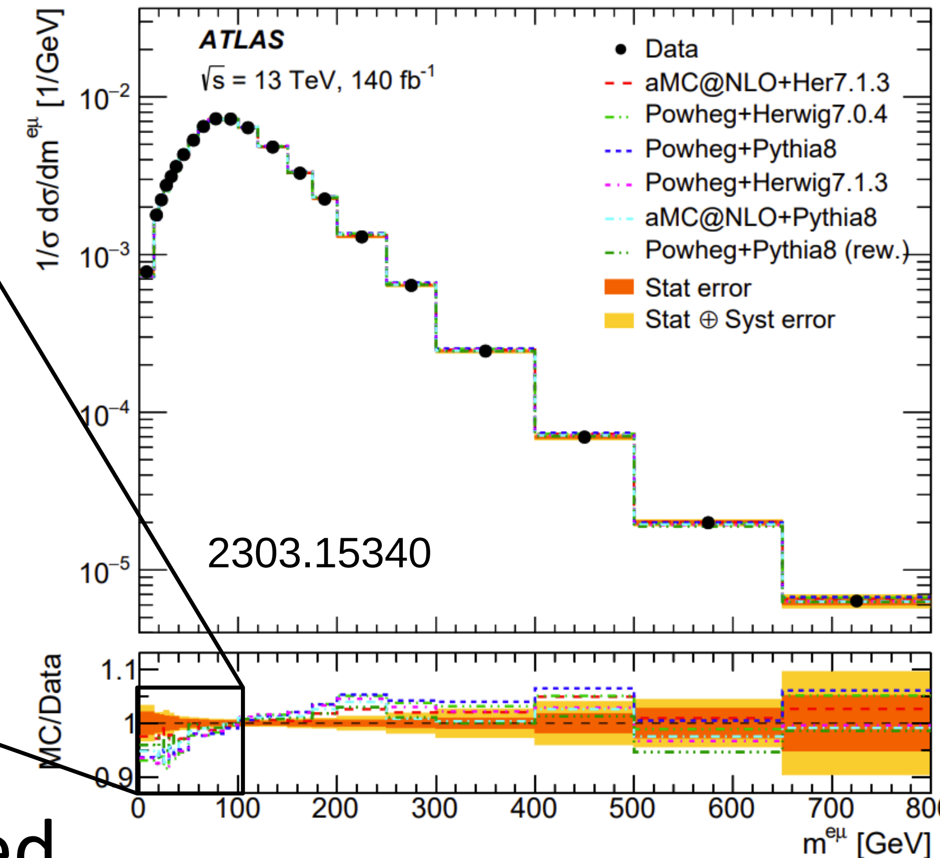




Discovery guaranteed!

Differential Top-Quark Distributions

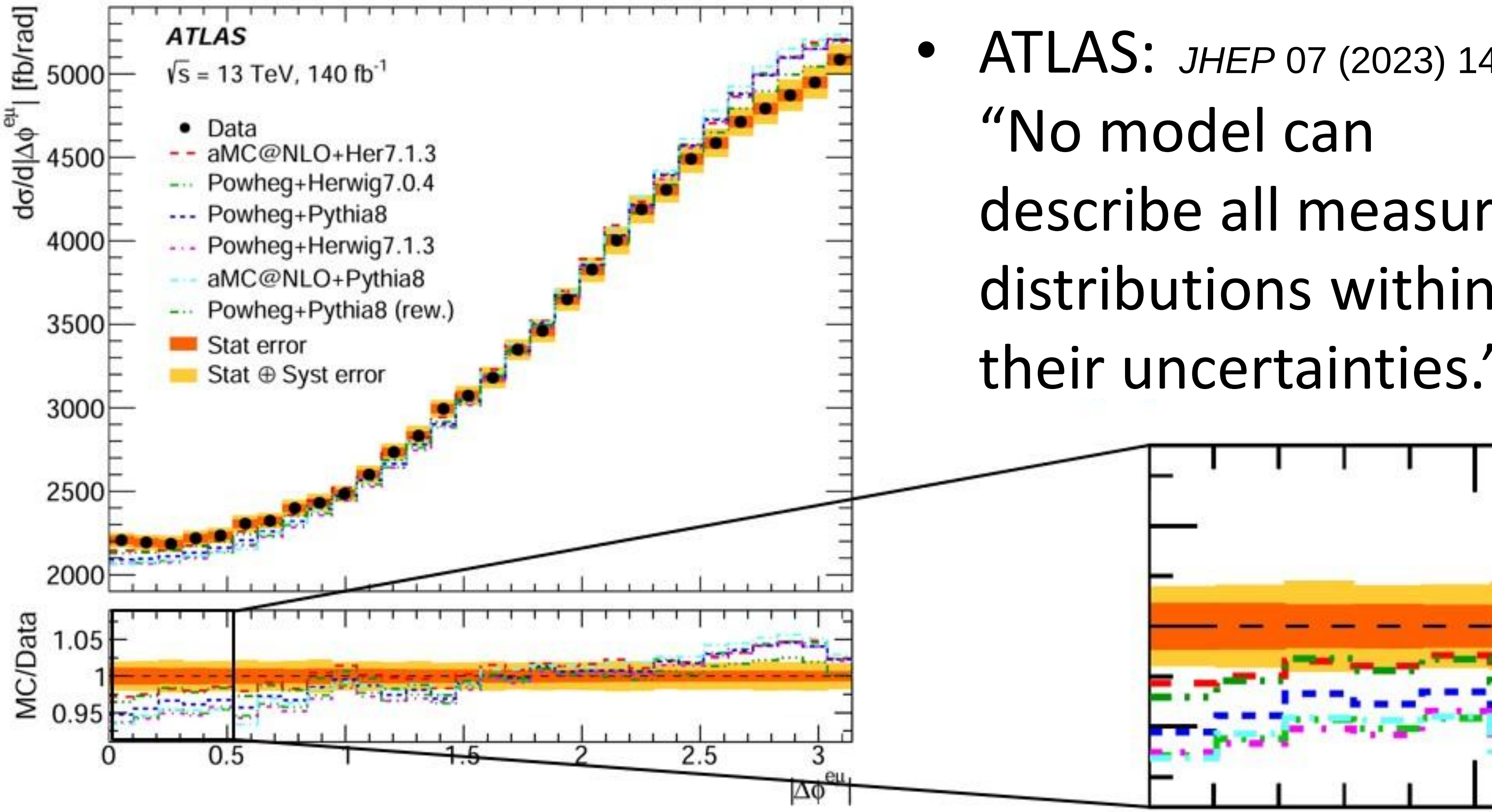




- ATLAS:
  "No model can describe all measured distributions within their uncertainties."

New Physics pollution of this SM measurement?

Differential Top-Quark Distributions



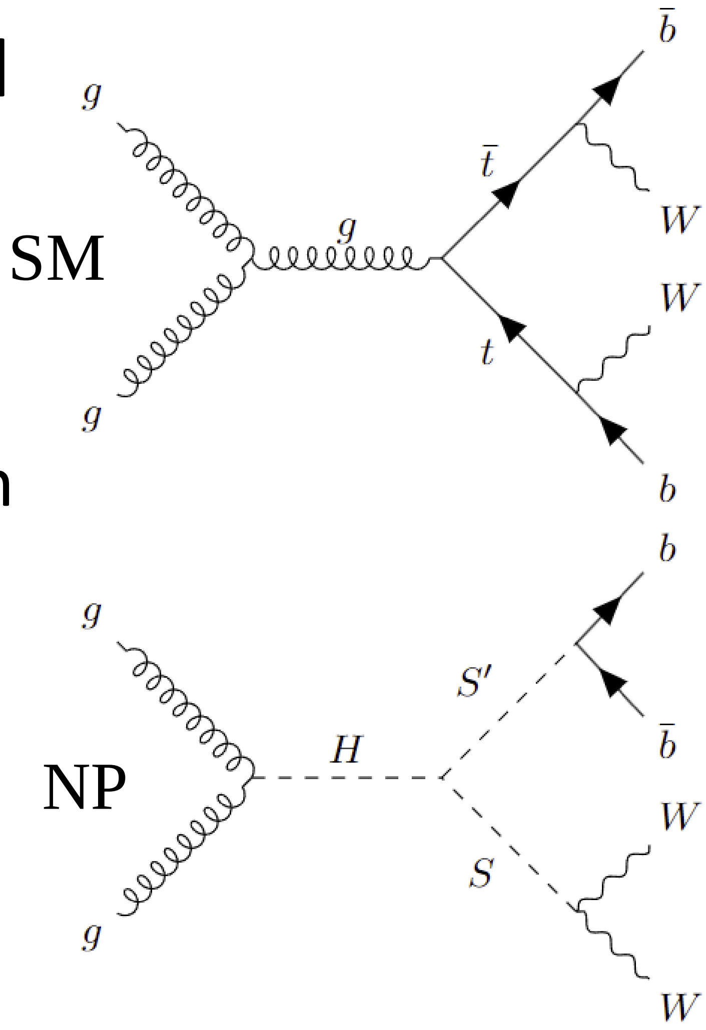
- ATLAS: *JHEP* 07 (2023) 141
  "No model can describe all measured distributions within their uncertainties."

- $\Delta\phi^{e\mu}$ angle between the leptons from the W decays

New Physics pollution of this SM measurement?

New Physics in Top-Quark Distributions

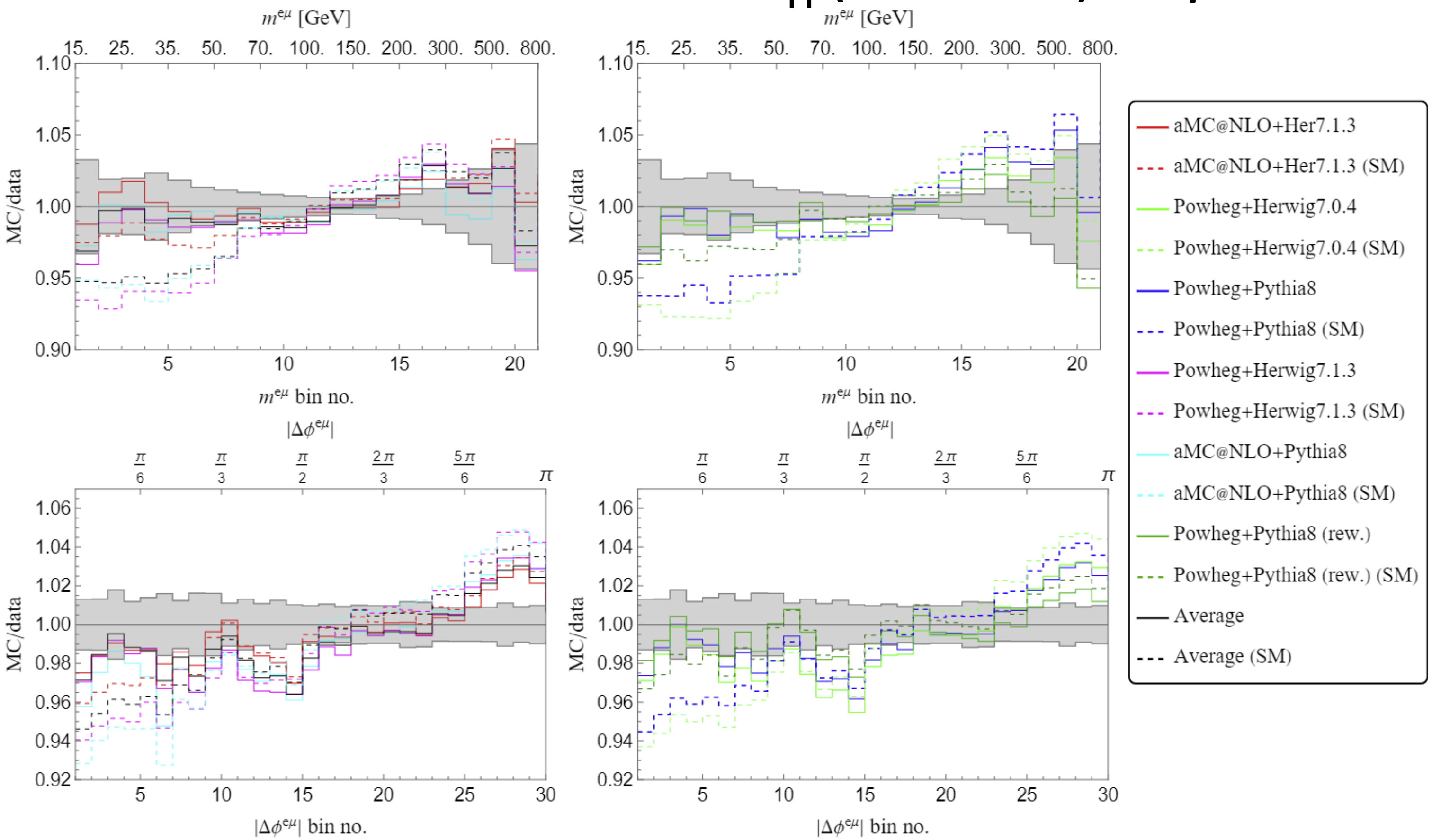
- ATLAS analysis normalized to the total cross section
  - only sensitive to the shape of NP
  - NP at small angels can explain deficit at large angles
- Associated production of new scalars decaying to WW and bb has a top-like signature



Related to the 95 GeV and 152 GeV hints?

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

Simplified Model: $H \to SS' \to WWbb$ 2308.07953

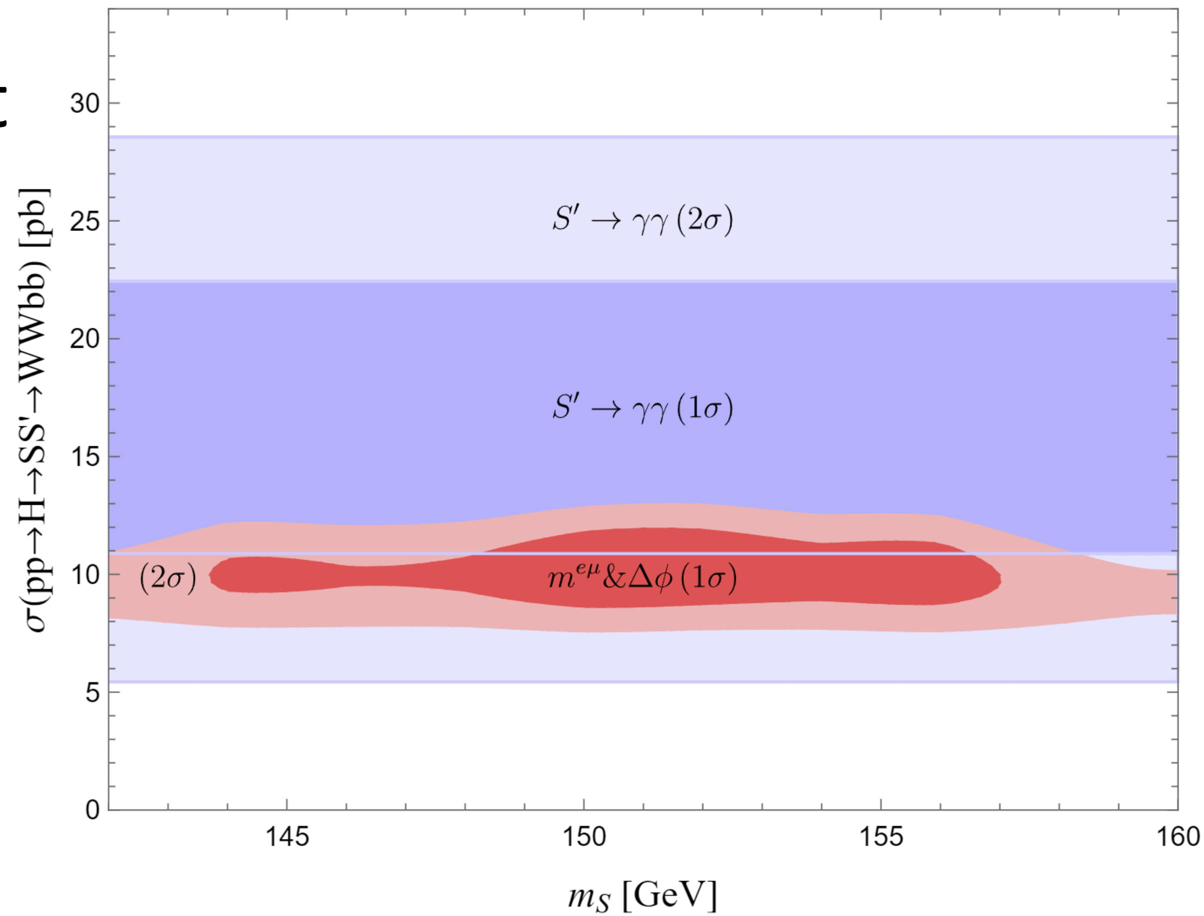
Monte Carlo	χ^2_{SM}	χ^2_{NP}	σ_{NP}	Sig.	m_S[GeV]
Powheg+Pyhtia8	213	102	9pb	10.5σ	$143-156$
aMC@NLO+Herwig7.1.3	102	68	5pb	5.8σ	$--$
aMC@NLO+Pythia8	291	163	10pb	11.3σ	148-157
Powheg+Herwig7.1.3	261	126	10pb	11.6σ	149-156
Powheg+Pythia8 (rew)	69	35	5pb	5.8σ	$--$
Powheg+Herwig7.0.4	294	126	12pb	13.0σ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

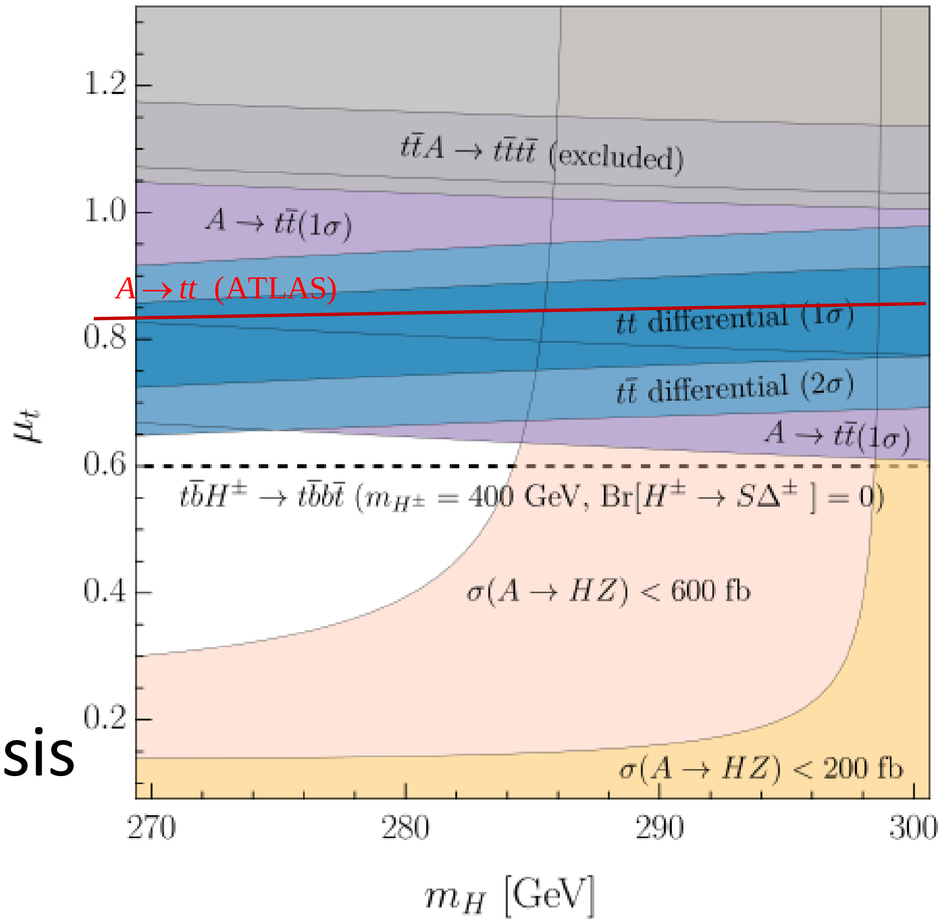


Consistent with 95 GeV γγ signal strength & a mass of S of 152 GeV

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
- Two-step EW Baryogenesis

S. Inoue, G. Ovanesyan and M. J. Ramsey-Musolf, 1508.05404

Combined explanation possible

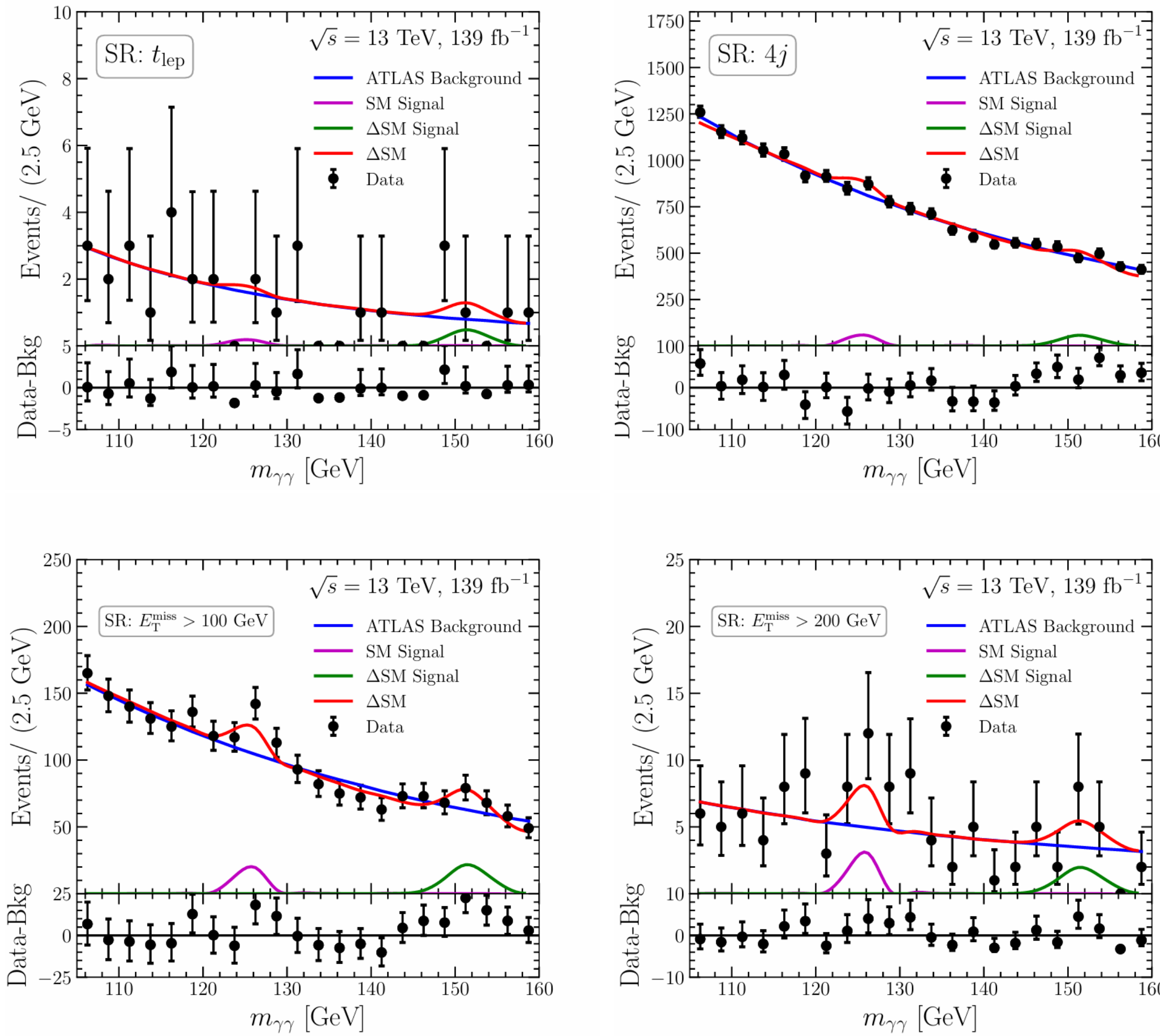
Conclusions

- Hints for narrow resonances at
  - 95 GeV
  - 152 GeV
- 152 GeV Triplet produced in top decays
  - ttZ-like signal
- H→SS'→WWbb can explain tensions in tt differential distribution
  - Mass of S consistent with 152 GeV
  - If S is a triplet and S' a singlet, right 95 GeV di-photon strength predicted

Fantastic Physics Case for CEPC

Hints for a 152 GeV scalar

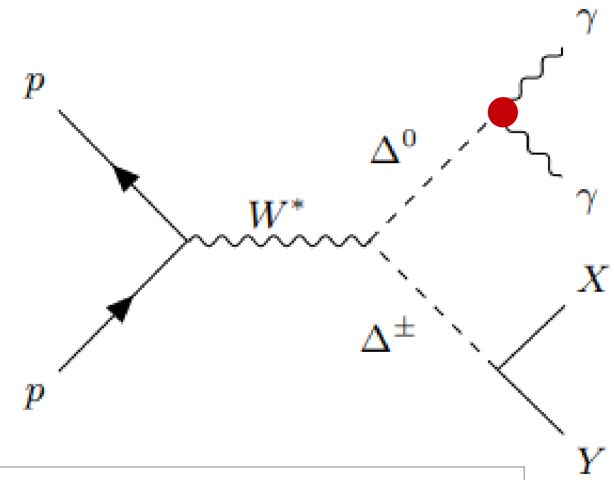
- Hints for a resonance decaying to photons in association with leptons missing energy and b-jets

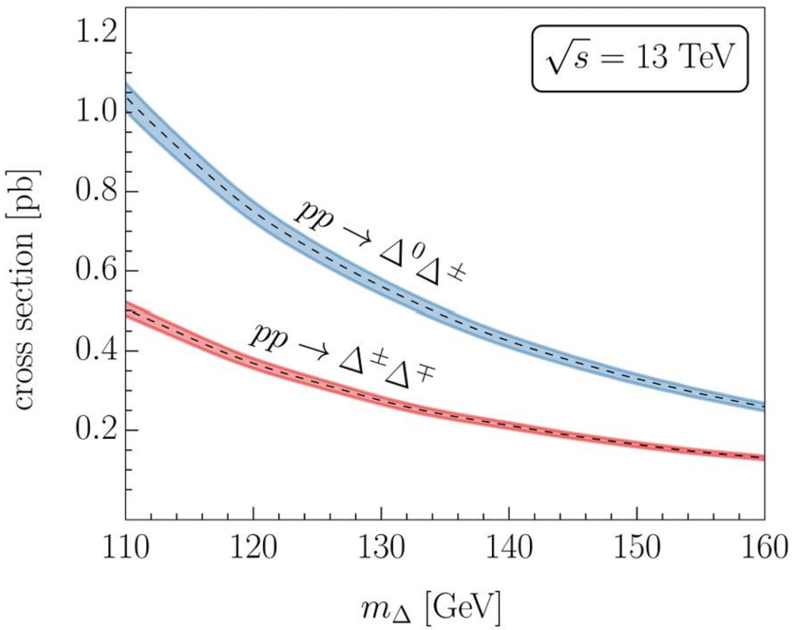


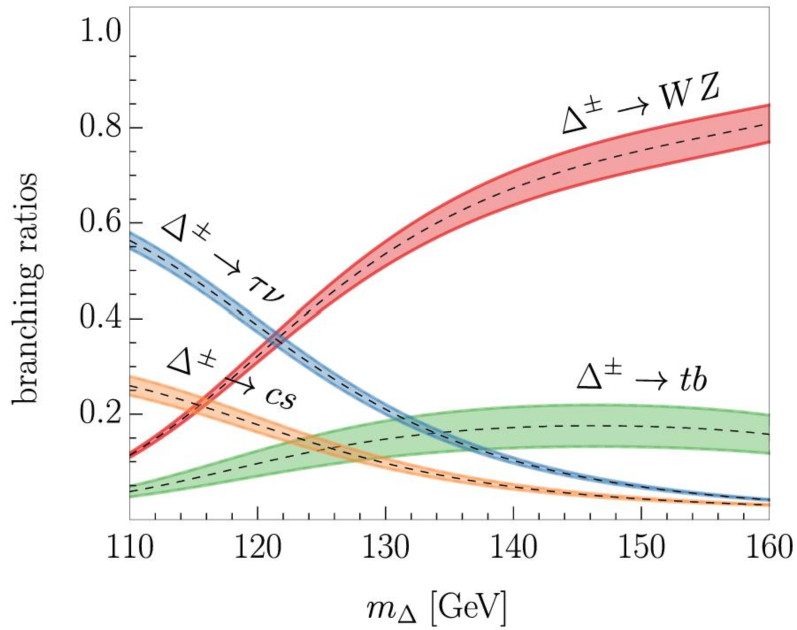
Dominant channels are γγ+X

Is the 152 GeV Higgs a Triplet (Δ)?

- Δ^0 decays dominantly to WW
- Positive shift in the W mass as preferred by the EW fit
- Quasi degenerate in mass



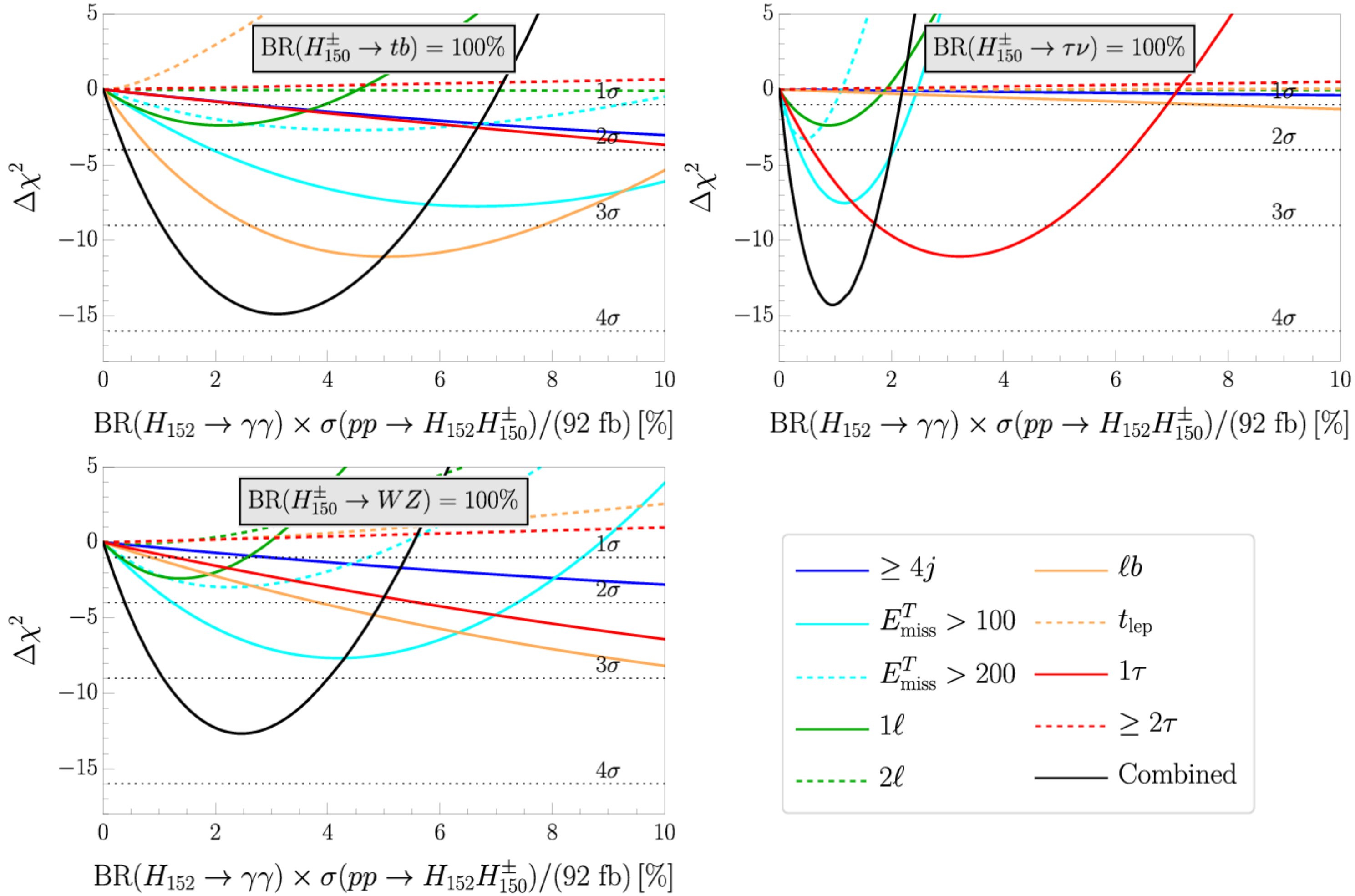




Drell-Yan production at the LHC

Simplifed Model Analysis

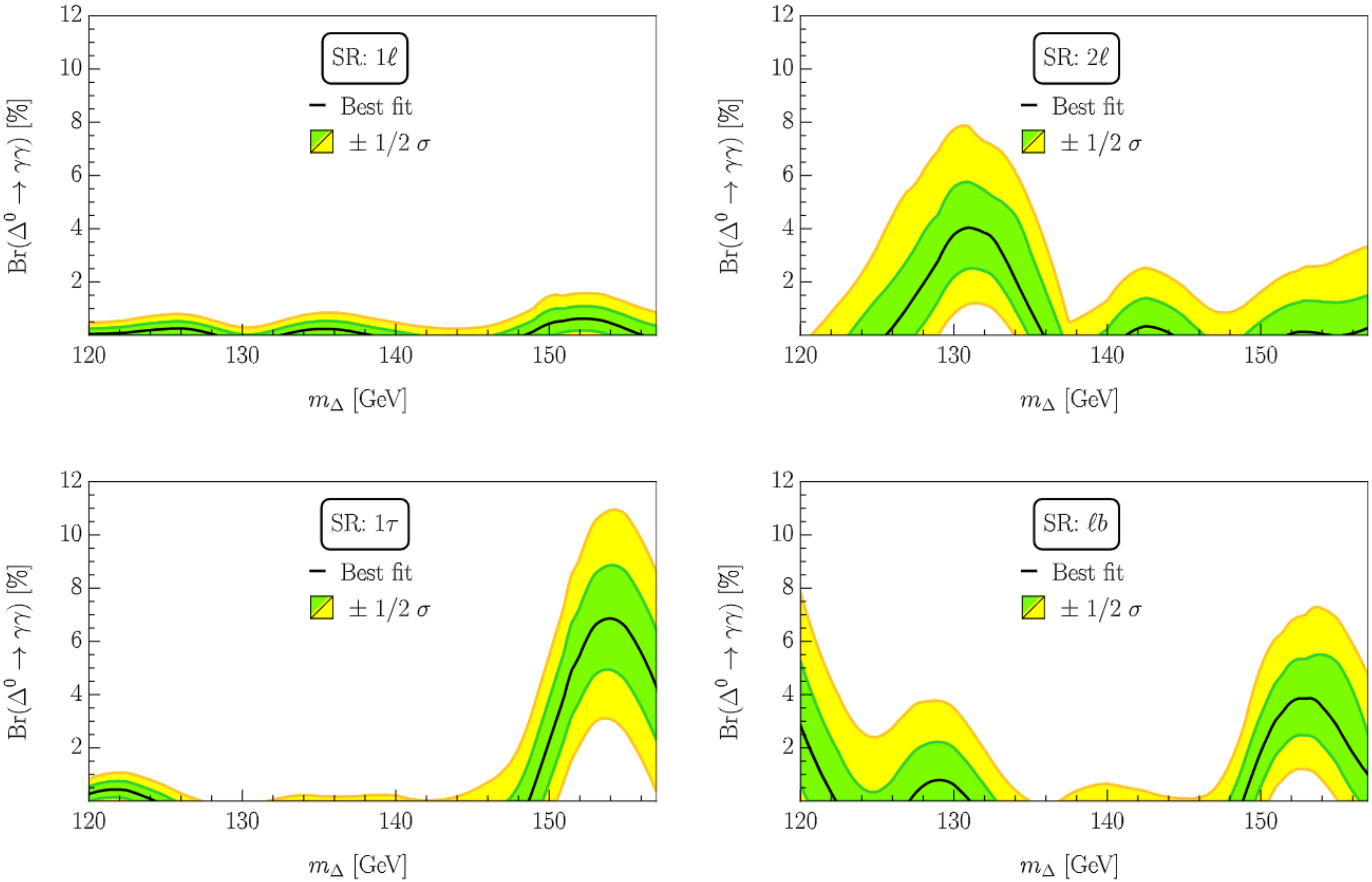
S. Banik, AC, 2407.06267



Triplet or Doublet?

h→γγ+X from ATLAS

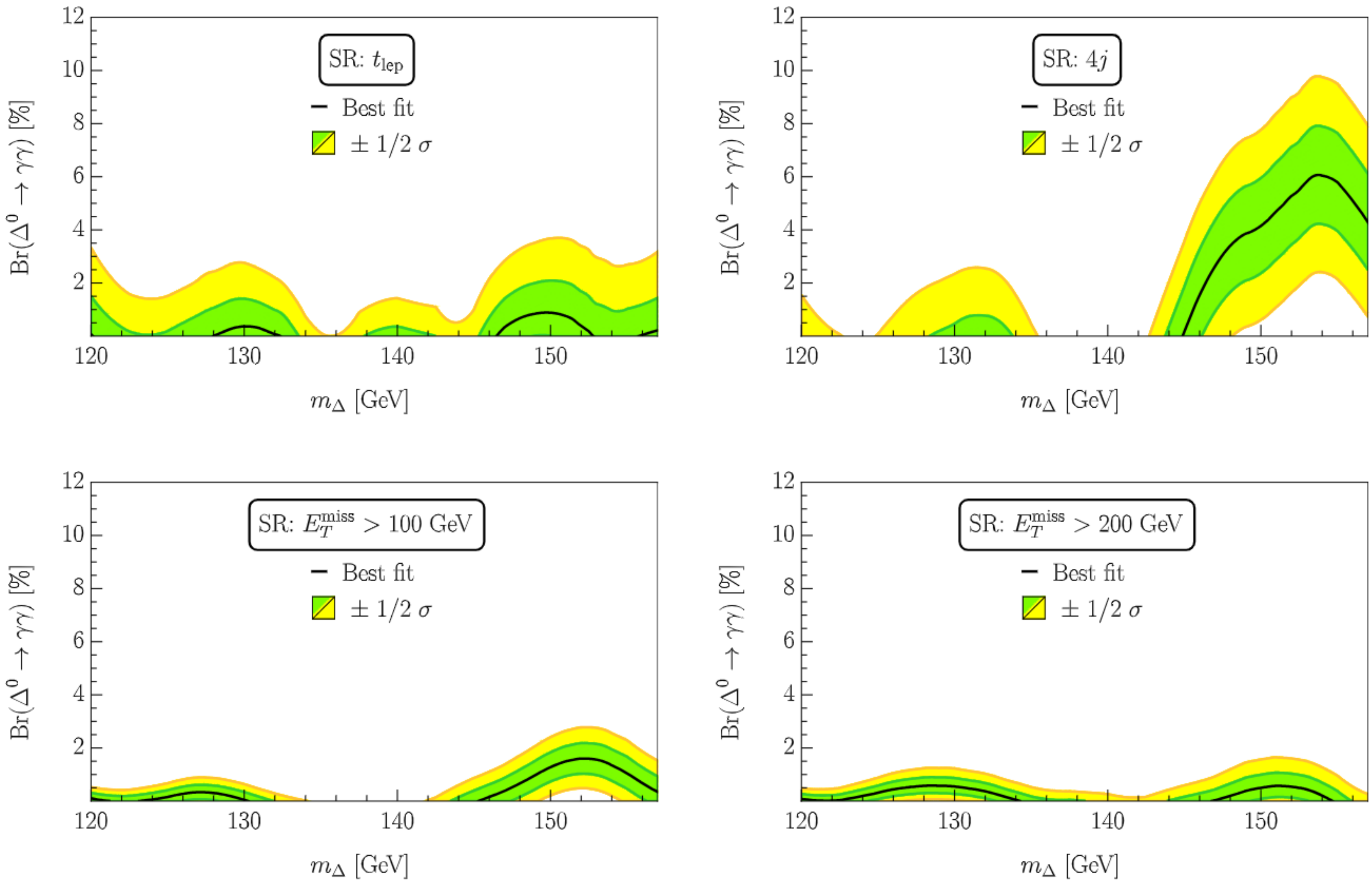
S. Ashanujjaman, S. Banik, G. Coloretti, A.C. S. P. Maharathy, B. Mellado, 2404.14492



Triplet consistently explains h→γγ+X excesses

h→γγ+X Channels

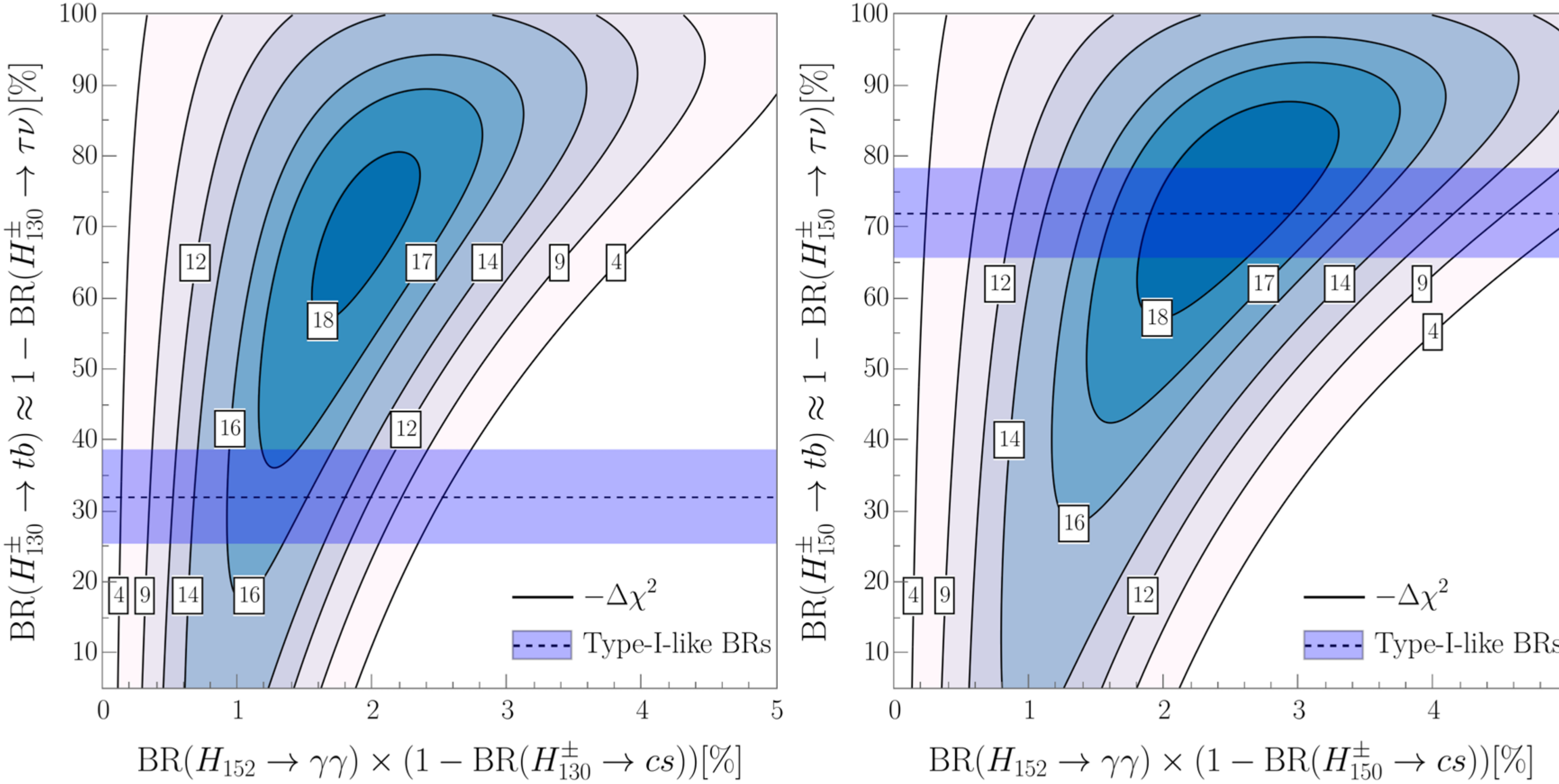
S. Ashanujjaman, S. Banik, G. Coloretti, A.C. S. P. Maharathy, B. Mellado, 2404.14492



Triplet consistently explains h→γγ+X excesses

Two-Higgs Doublet Model type-I

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



Above 4σ, large Br needed

Large Br($H_{152}\to\gamma\gamma$) via Z_2 breaking in 2HDMs

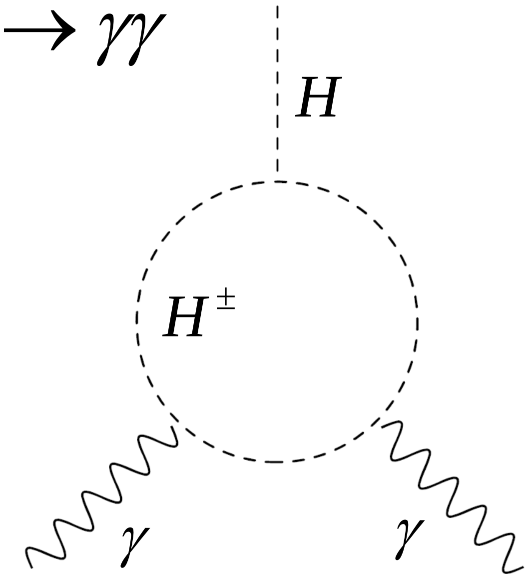
$$\lambda_6 H_1^\dagger H_1 H_2^\dagger H_1$$

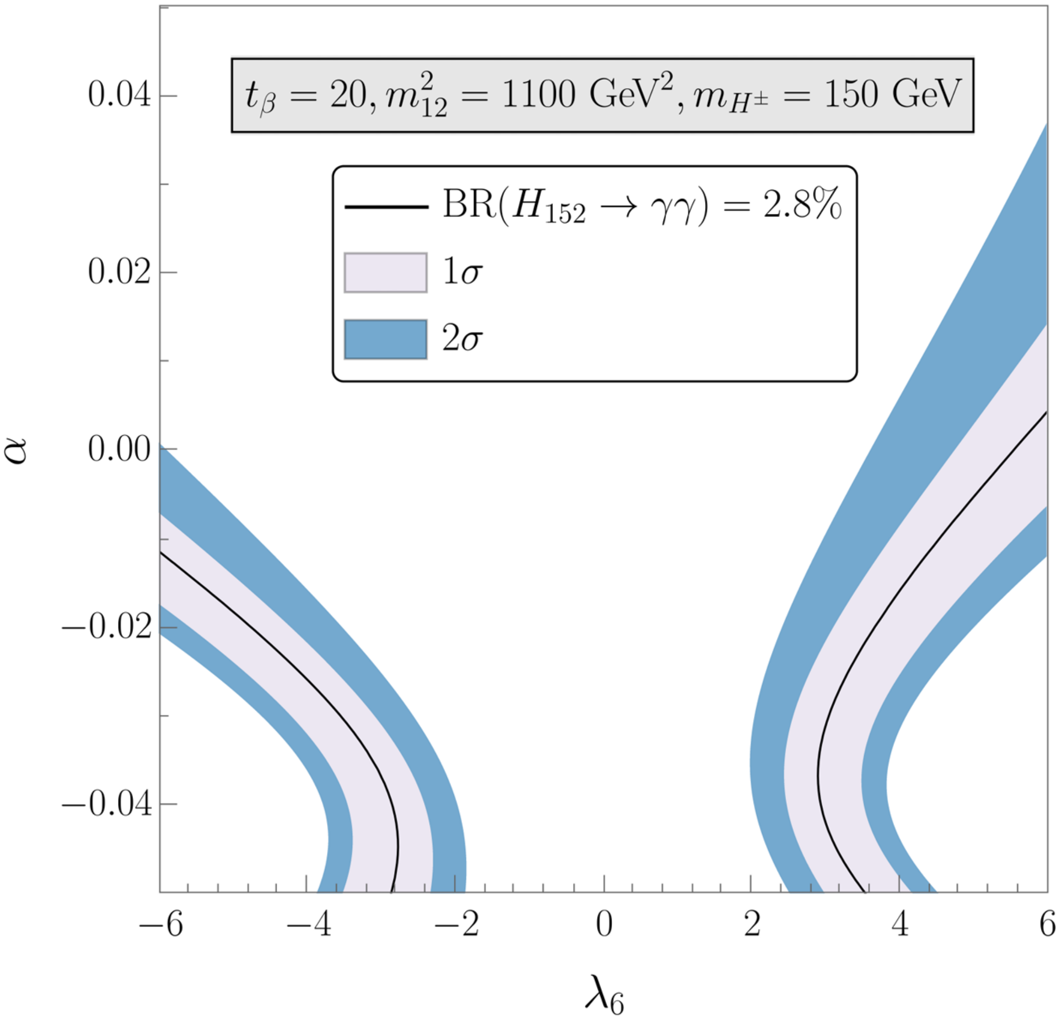
- Dominant effect in

$$H \to \gamma\gamma$$

but suppressed in

$$h \to \gamma\gamma$$





Consistent with vacuum stability, perturbativity

Conclusions

- Hints for narrow a narrow resonances at 152 GeV produced in association with
  - Tau Leptons
  - Light Leptons
  - Met
  - (b-)jets
- Drell-Yan production could explain this in a
  - Y=0 triplet
  - Y=1/2 doublet

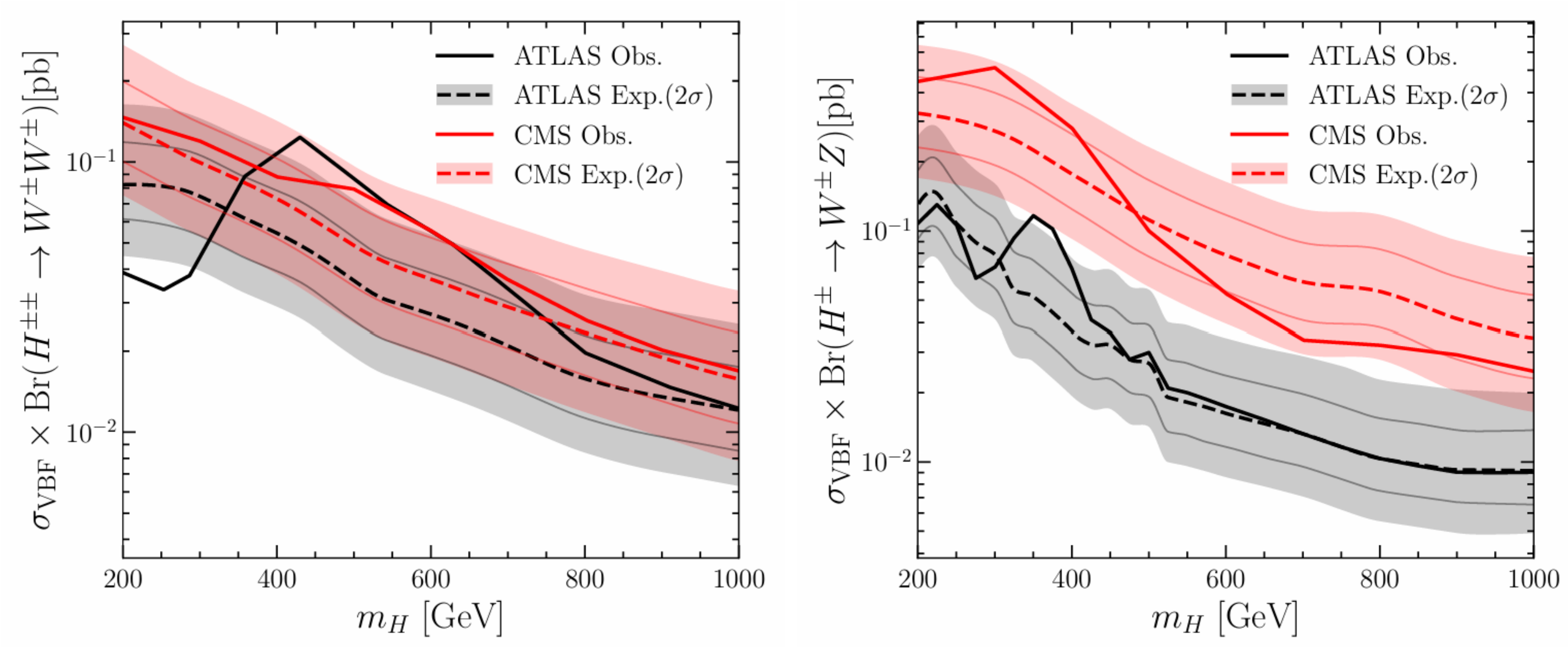
  model

Most significant hints for a new particle at the LHC

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



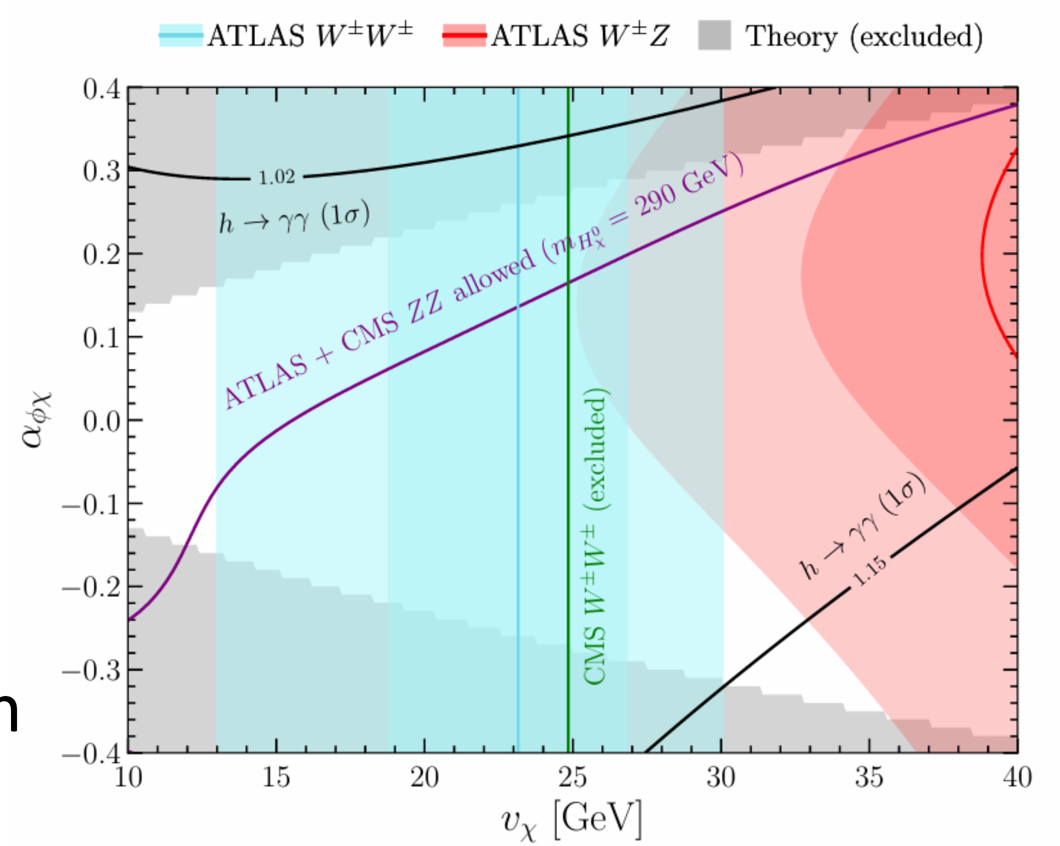
Tripelts with sizable vevs

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

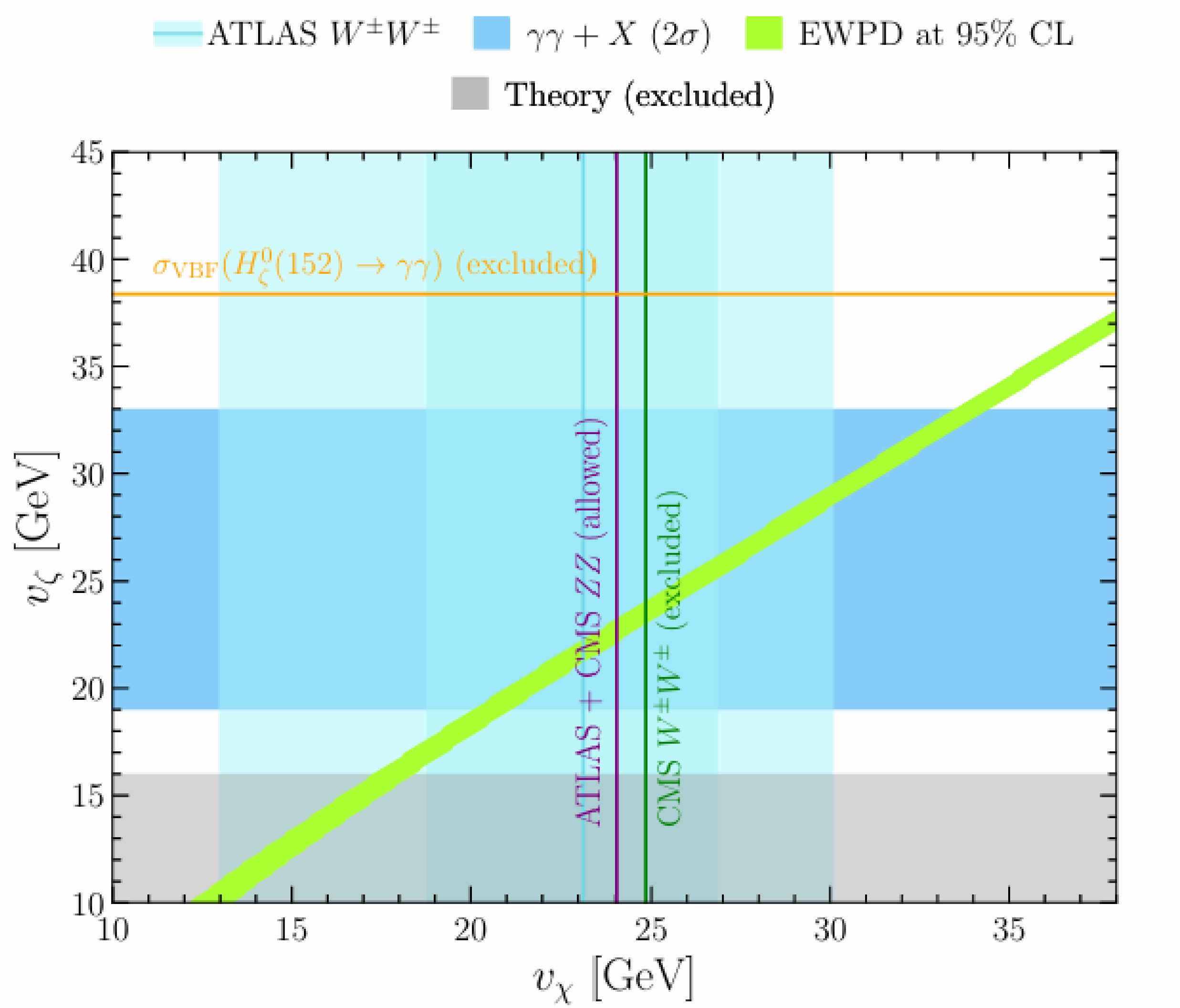
  ➡ sizable vector-boson fusion cross section



- Generic version needed for different masses

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

Generic Georgi-Machacek Model

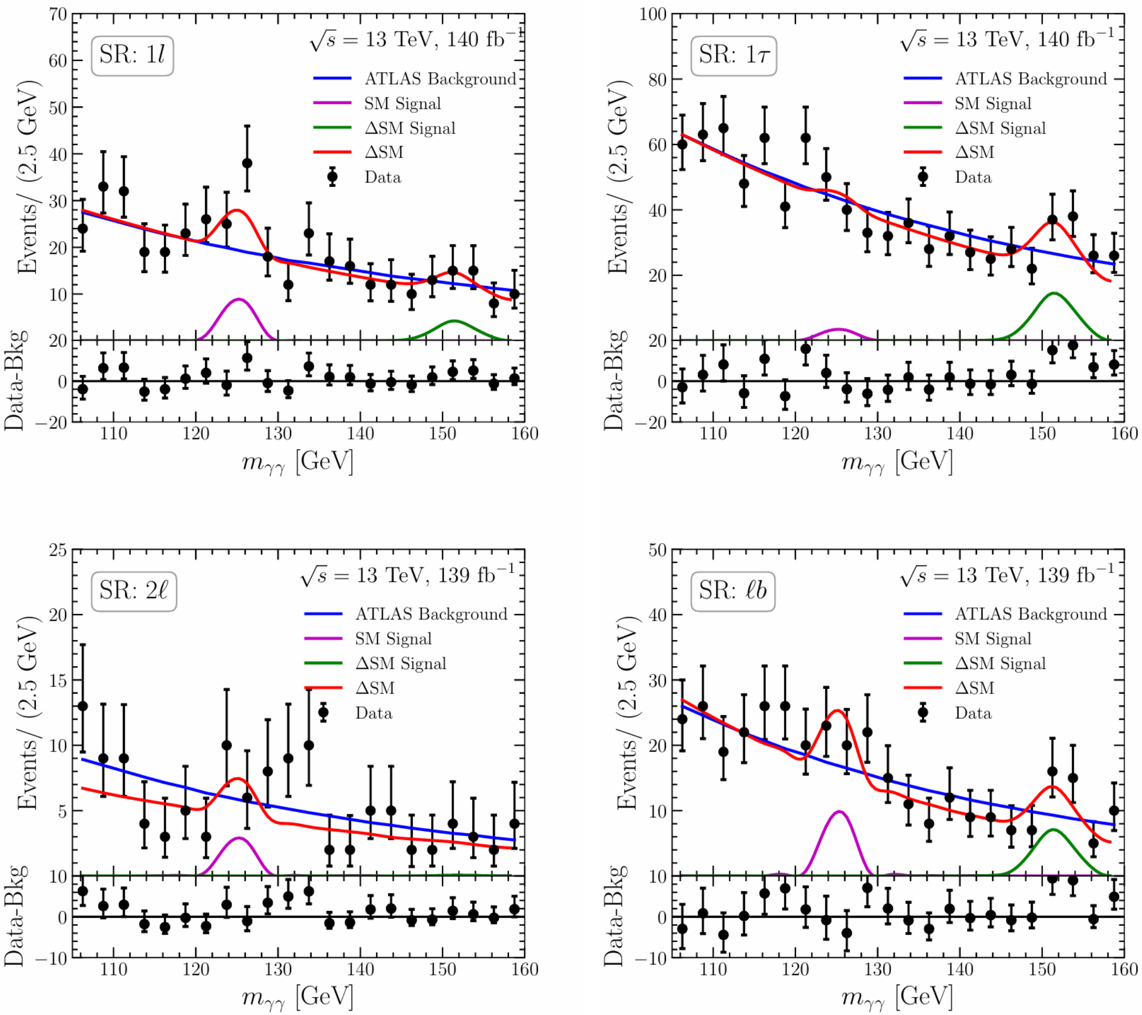


Y=1 can explain WW, ZW; Y=0 γγ (152)

Hints for a 152 GeV scalar

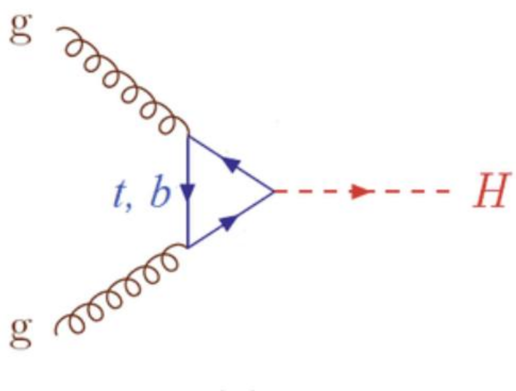
JHEP 07 (2023) 176
ATLAS-CONF-2024-005

- Hints for a resonance decaying to photons in association with leptons missing energy and b-jets

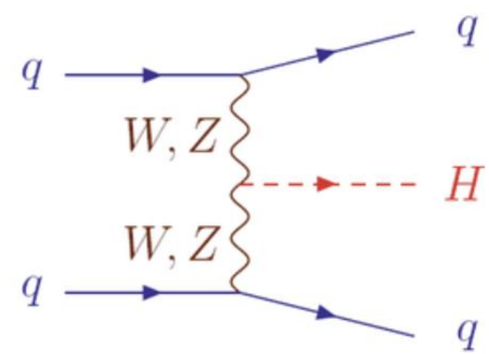


Dominant channels are γγ+X

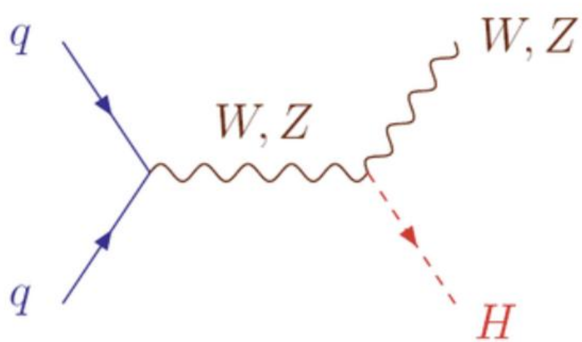
Higgs production in the SM



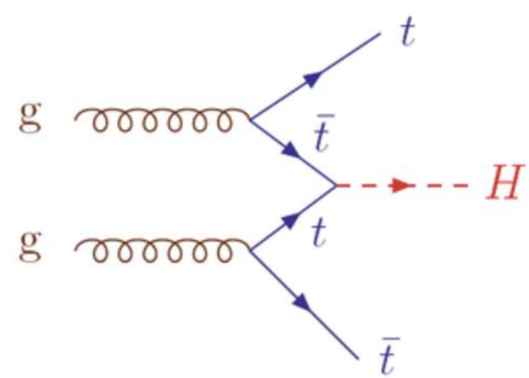
Gluon fusion (H)



Vector boson fusion (Hqq)



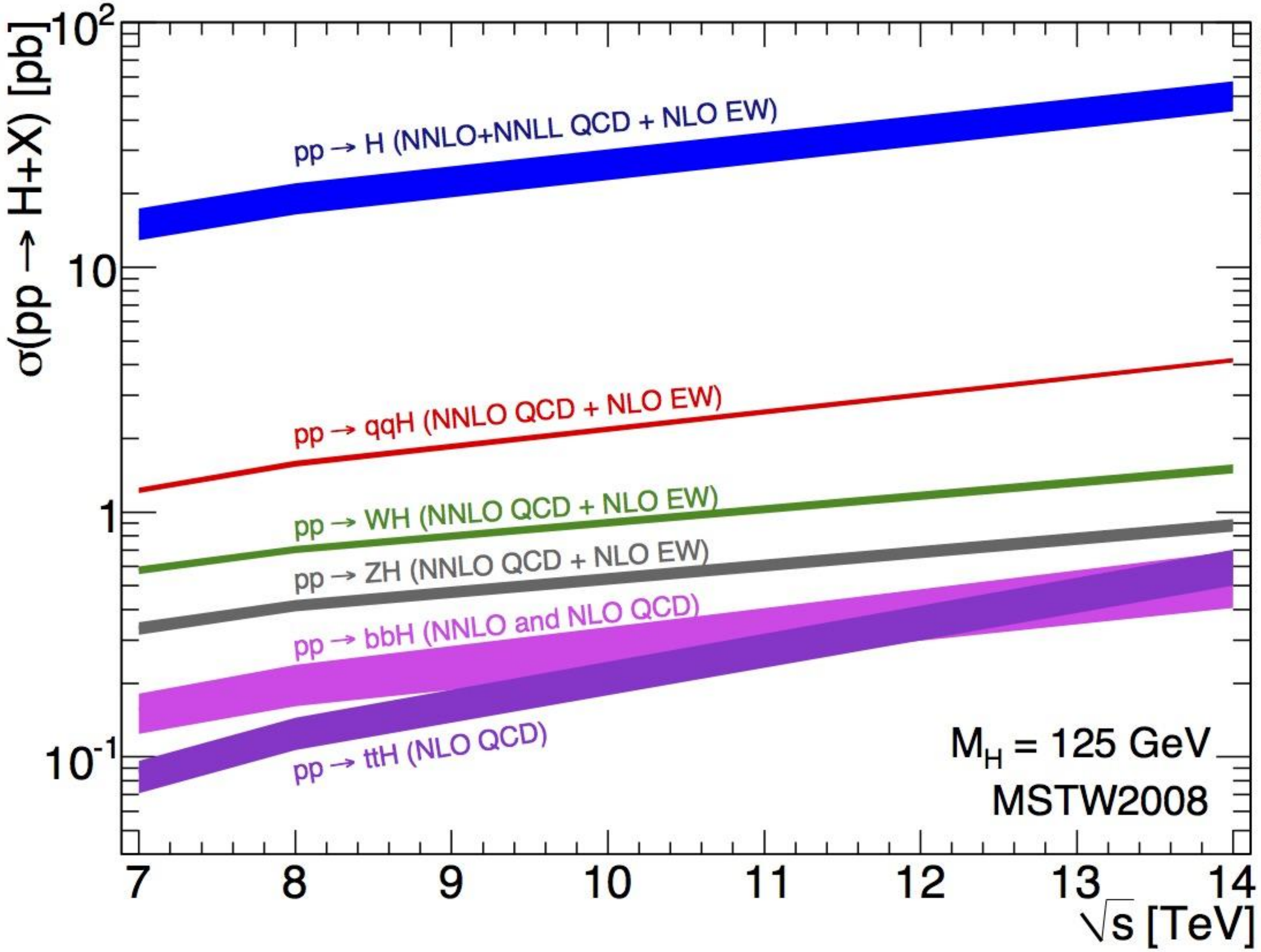
Higgs strahlung (ZH, WH)



top associated production (ttH)

Gluon fusion is not an associated production channel

Higgs production in the SM



Gluon fusion dominant for SM-like Higgs