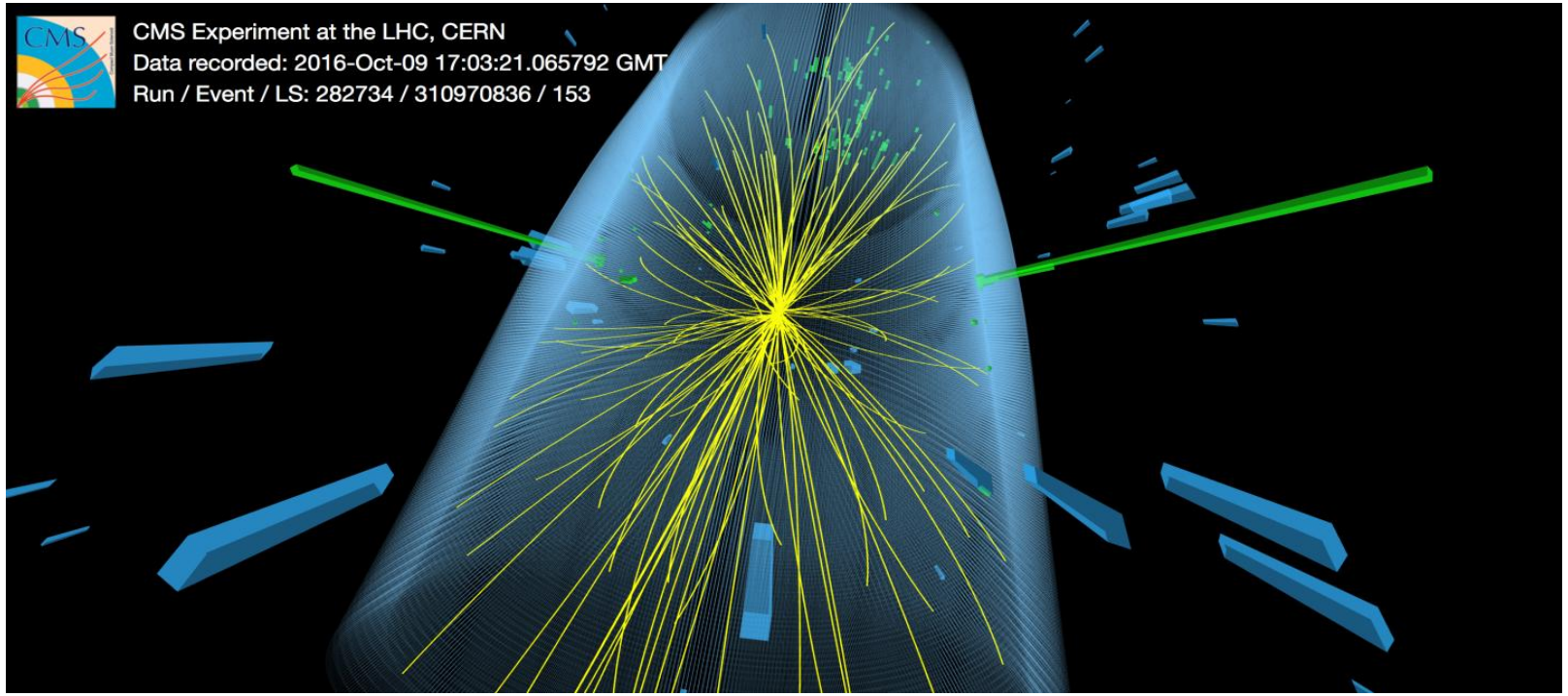


Andreas Crivellin

Universitat Autonoma de Barcelona &

ICREA

Indications for New Higgs Bosons

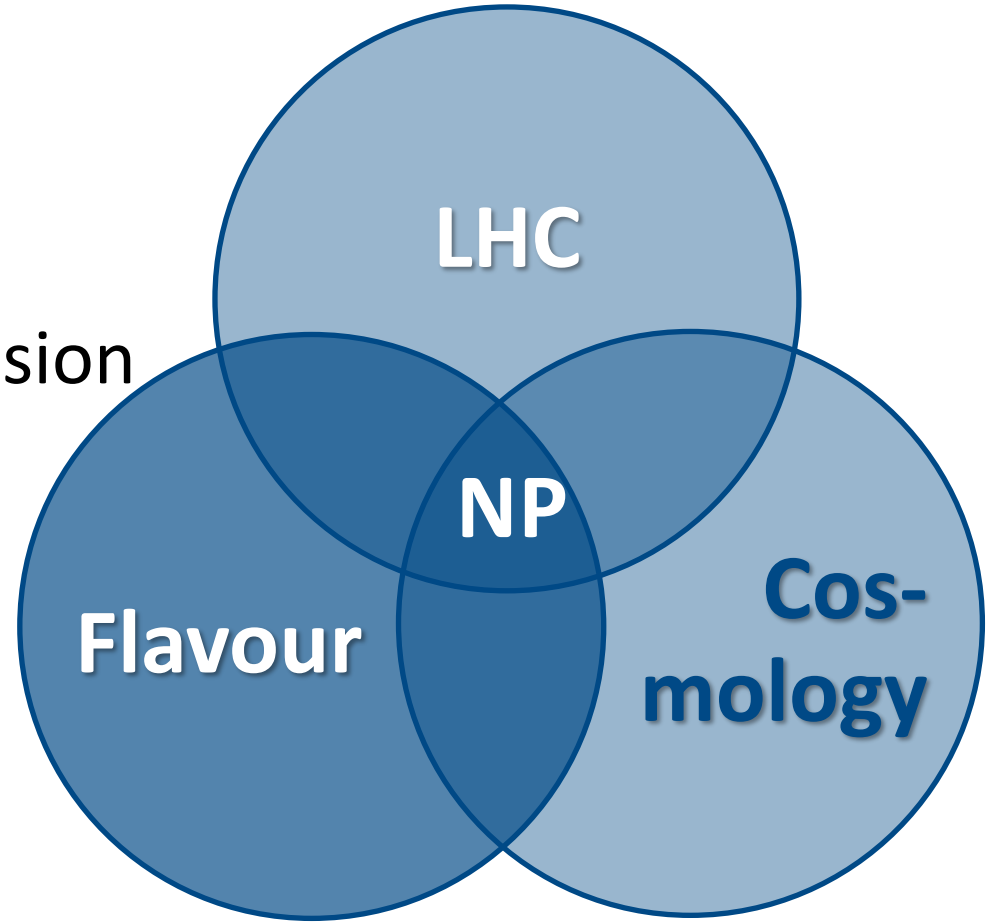
Cargese, 17.09.2026

Outline

- Introduction
  - Motivation for new Higgses
- Indirect indications
  - b→sll anomalies
  - R(D) & R(D*)
- Direct indictions:
  - 130 GeV excess in t →b(H^+→cb)
  - 95 GeV di-photon
  - 152 GeV di-photon
- Explanations

Searching for New Physics

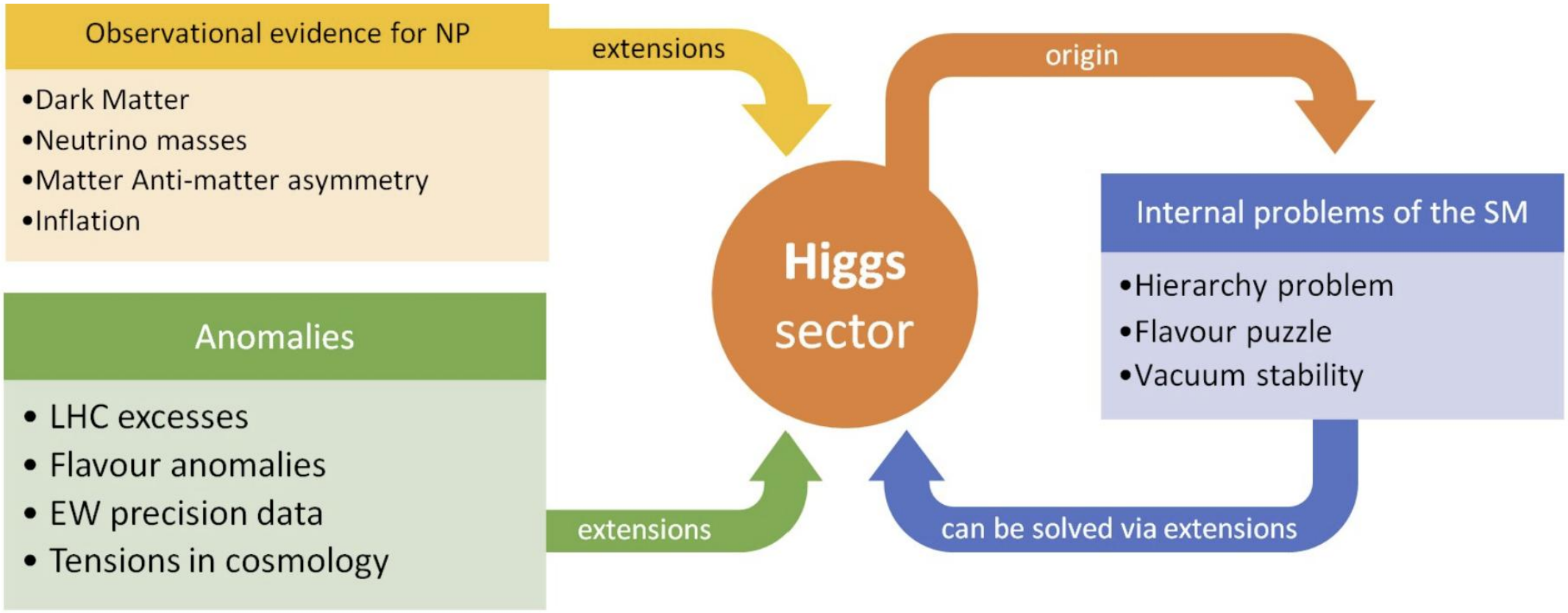
- Direct searches:
  - Dark Matter direct detection
  - Direct LHC searches for new particles
- Indirect searches: High statistics/precision searches for quantum effects of NP
  - Flavour
  - EW precision observables
  - Higgs signal strength
  - Lorentz violation, etc.



In this talk mainly flavour and LHC physics

Why new Higgses?

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

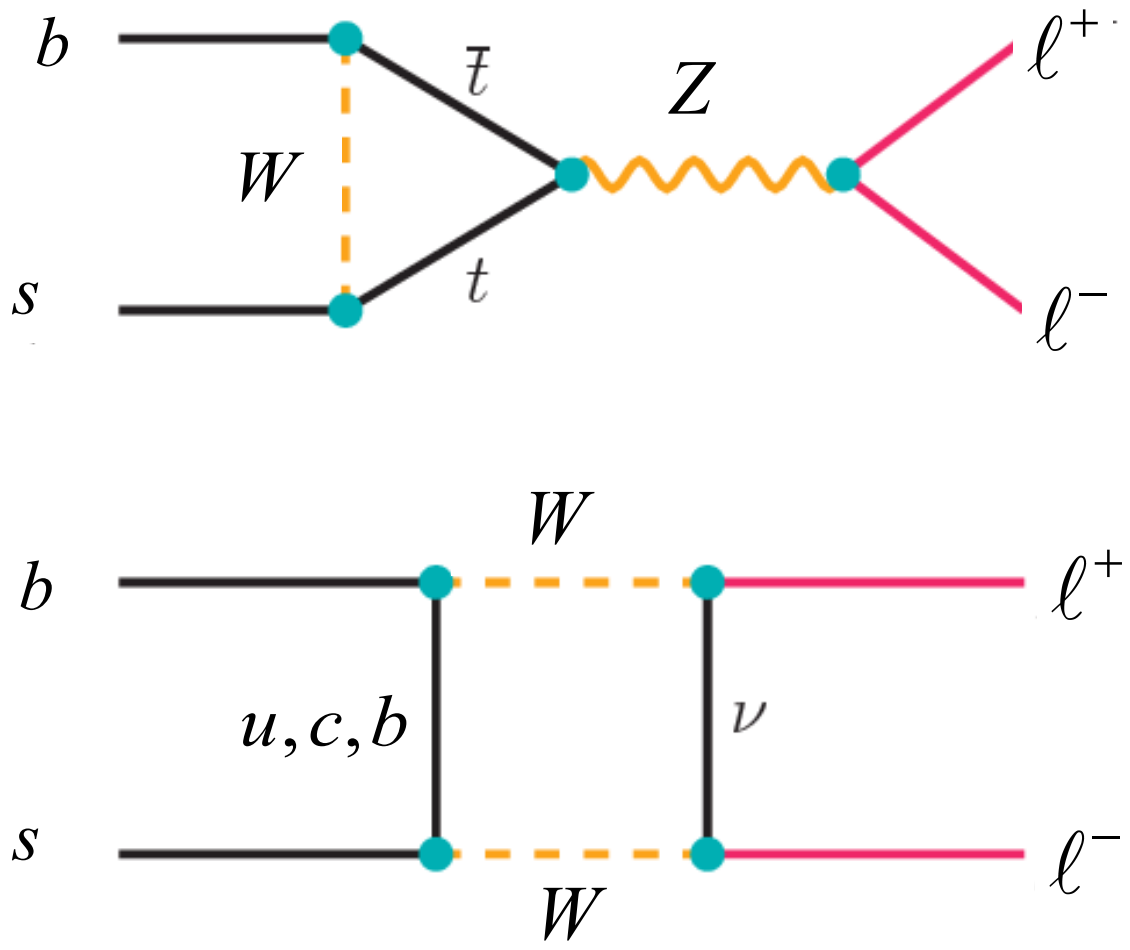


Higgs sector very promising place to expect new physics

$b \to s\mu^+\mu^-$ Processes

- Flavour Changing Neutral Current (FCNC)
- In the SM suppressed by
  - The CKM elements $V_{cb} \approx 0.04$
  - Electroweak scale
  - Loop-factor
- Wilson coefficients precisely known

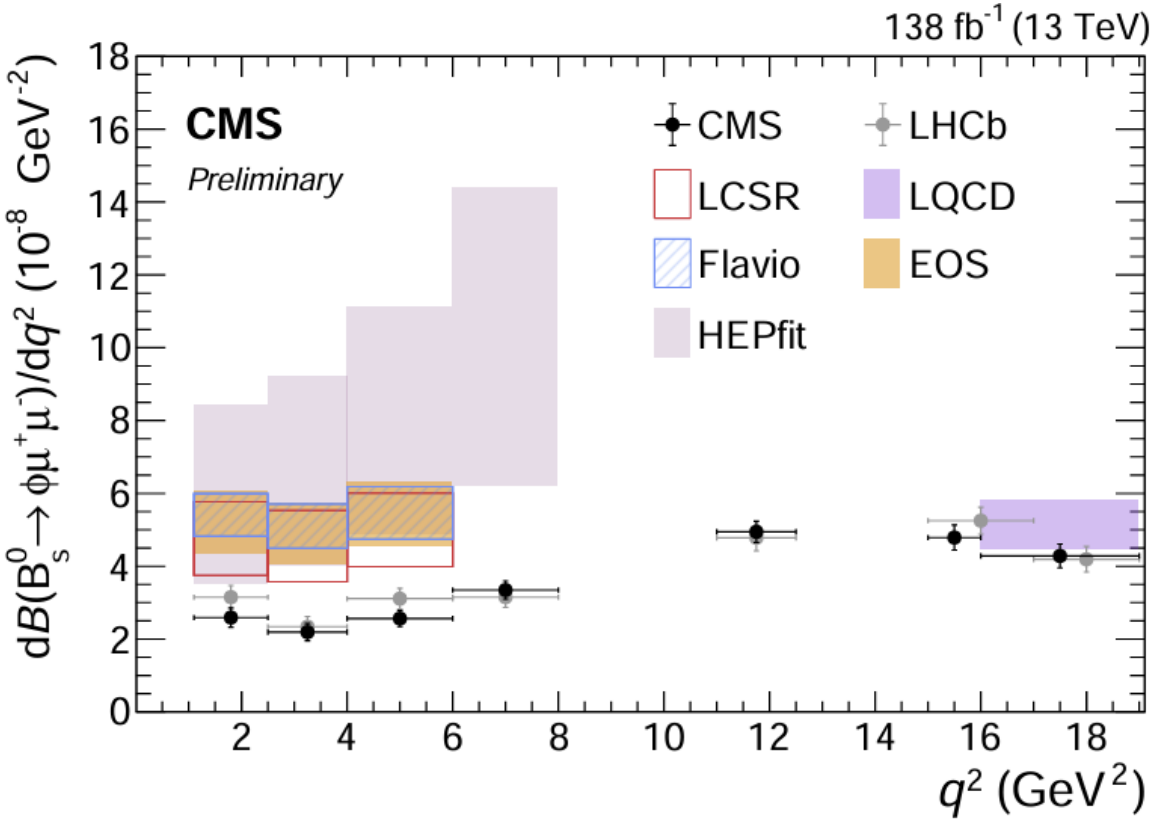
Bobeth et al. PRD, 2013



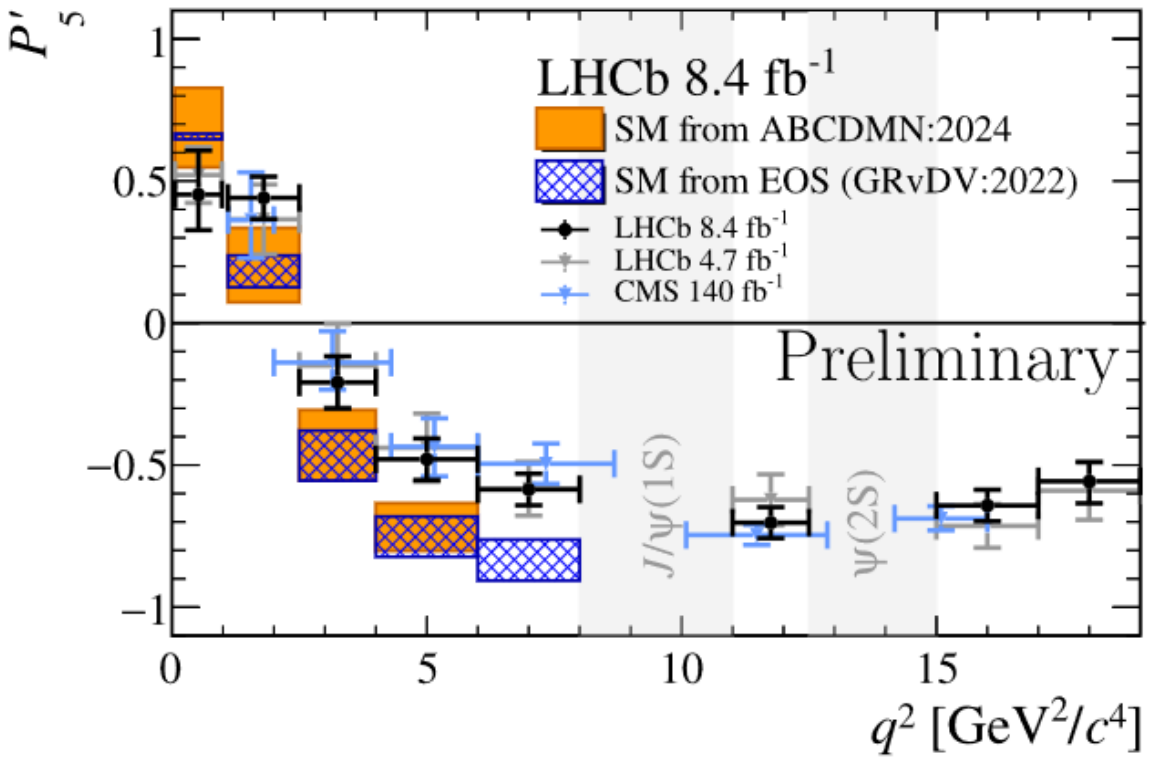
Rare processes; very sensitive to NP

$b \to s\mu^+\mu^-$ Processes

- Total Branching ratios $B_s \to \phi\mu^+\mu^-$ and $B \to K^{(*)}\mu^+\mu^-$



- Angular observables



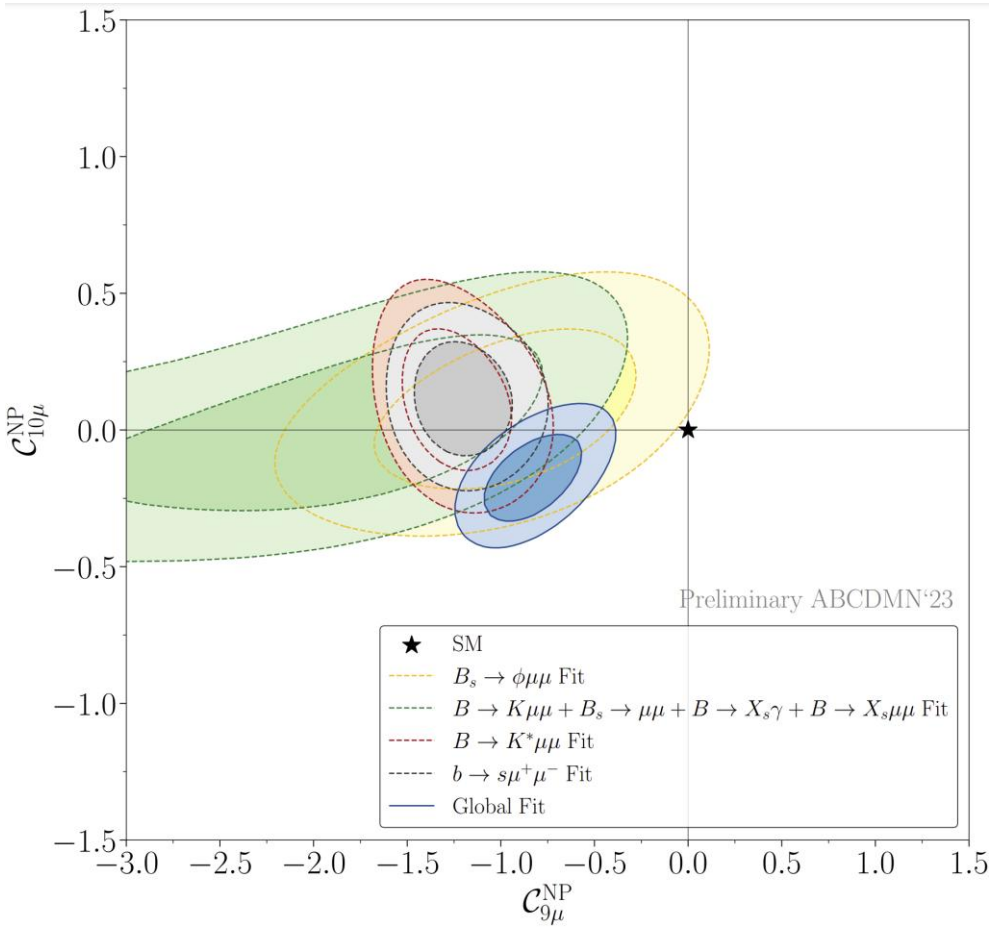
Consistent deficits of ≈20% w.r.t. the SM

Indirect hints for NP: $b \to s l^+ l^-$

- Perform global model independent fit to include all observables (≈150)
- Several NP hypothesis are significantly preferred over the SM hypothesis
- Study via effective interactions

$$O_9 = \bar{s}\gamma^\mu P_L b \bar{\ell}\gamma_\mu \ell$$

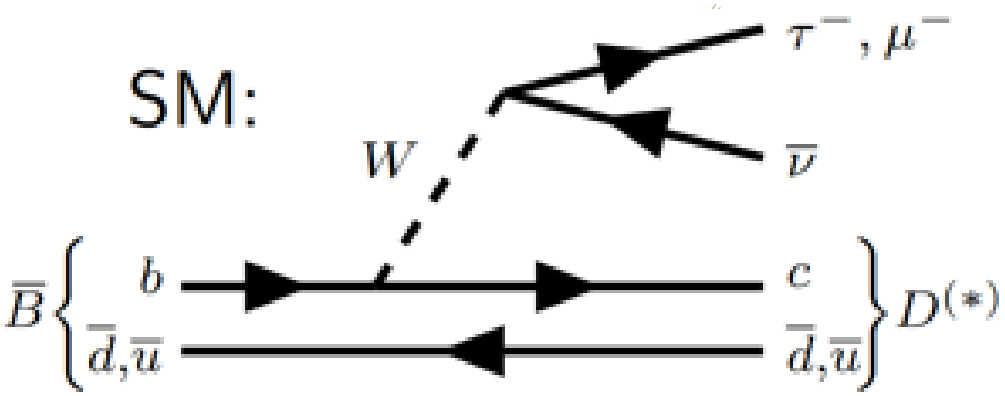
$$O_{10} = \bar{s}\gamma^\mu P_L b \bar{\ell}\gamma_\mu \gamma^5 \ell$$

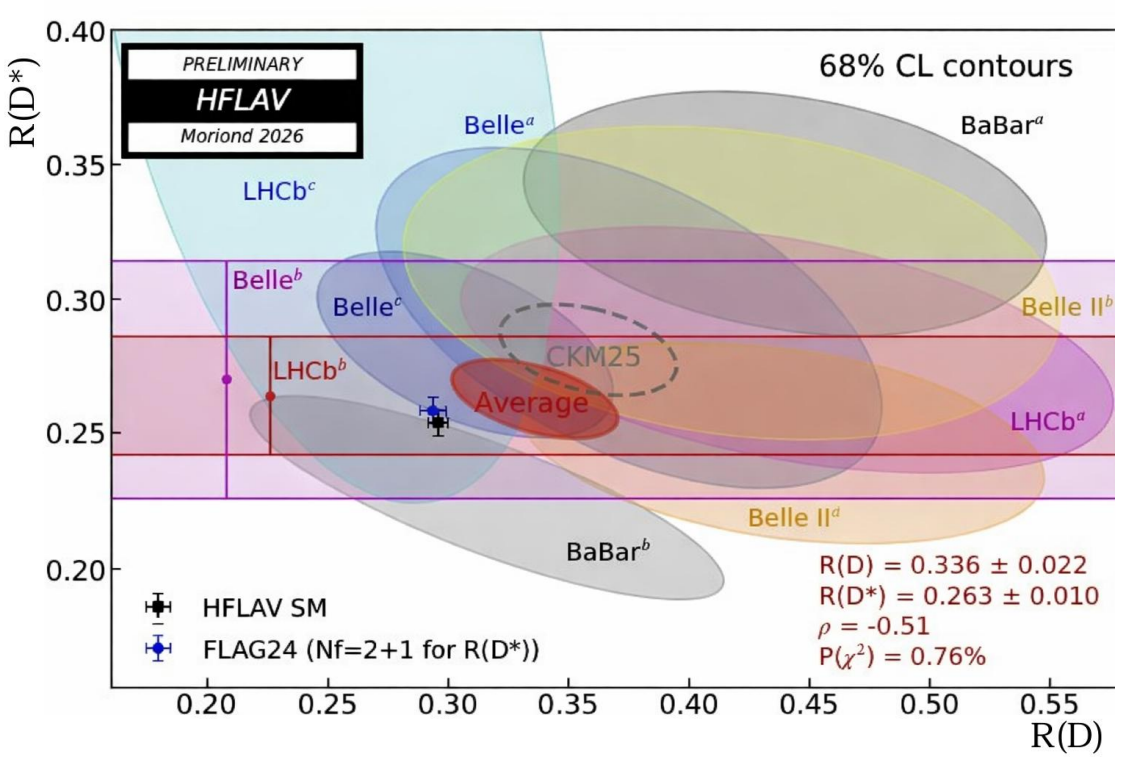


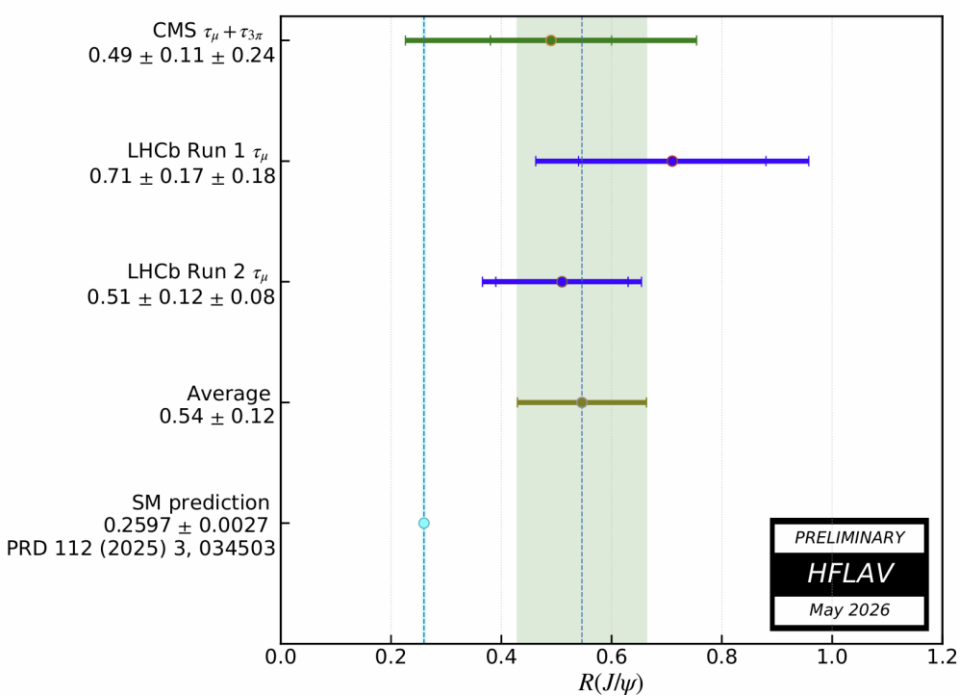
Fit is >7 σ better than the SM

b→cτν anomalies

- Tree-level in the SM
- Cannot be due to form factors



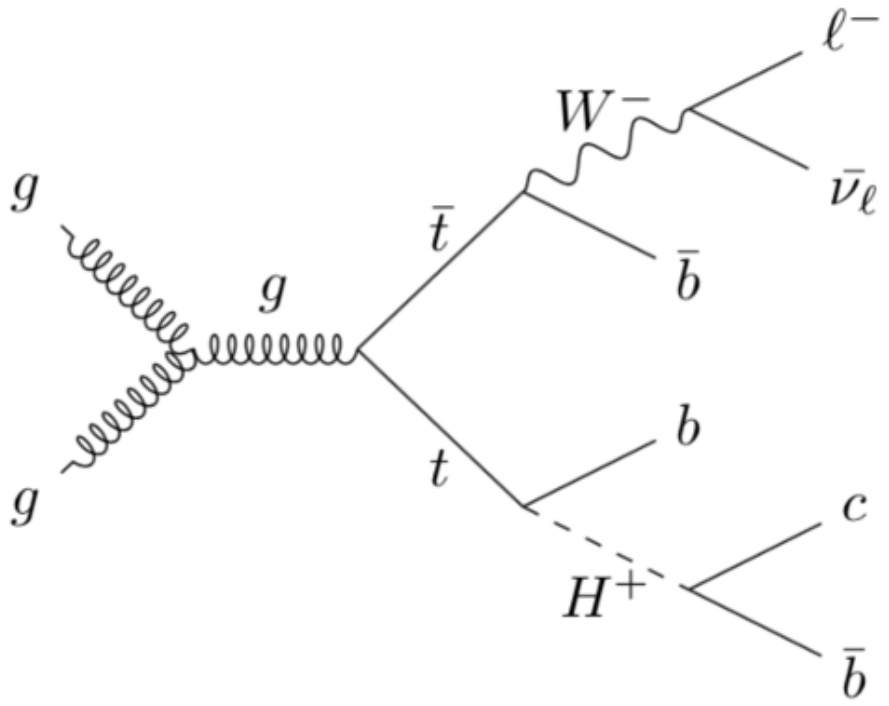


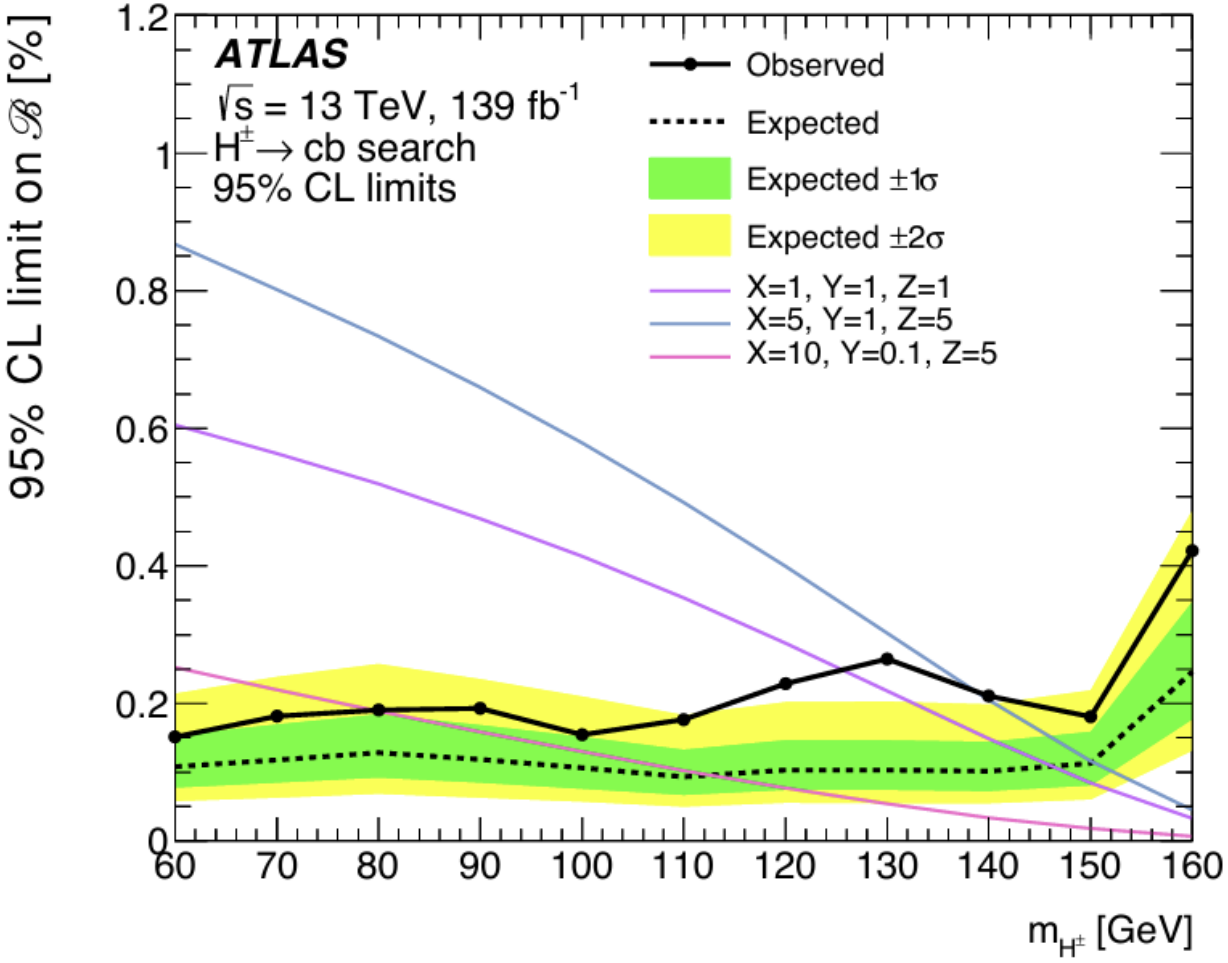


Indications for 10% new physics in the charged current

130 GeV Charged Higgs excess (ATLAS 2302.11739)

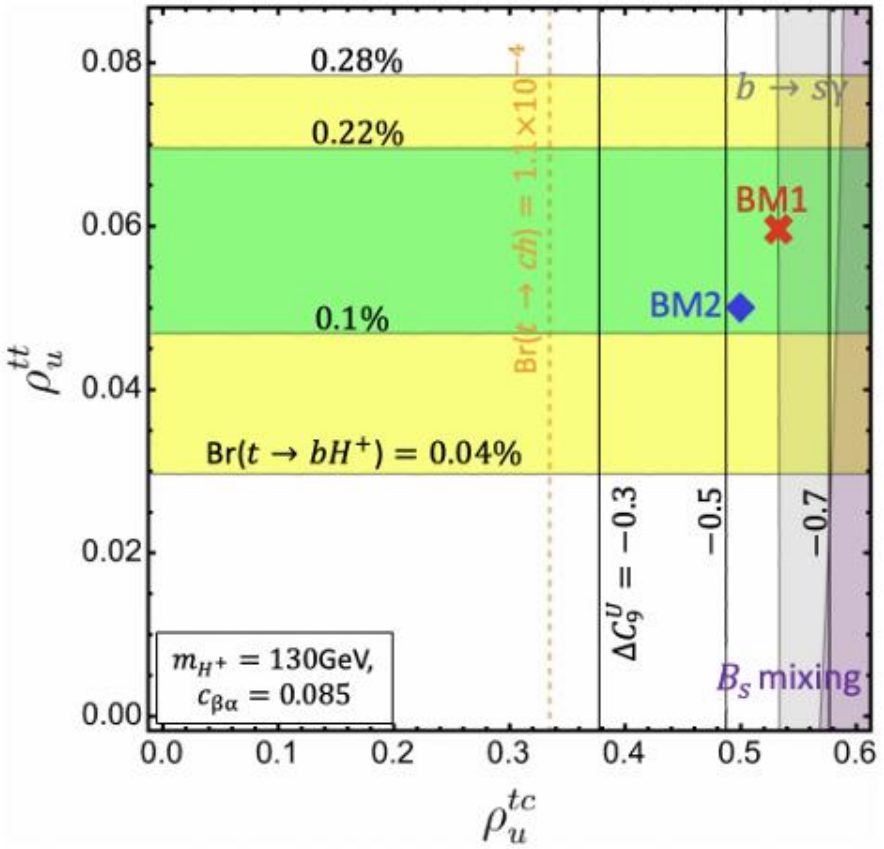
- $t \to (H^+ \to cb)b$
- Non-minimal couplings



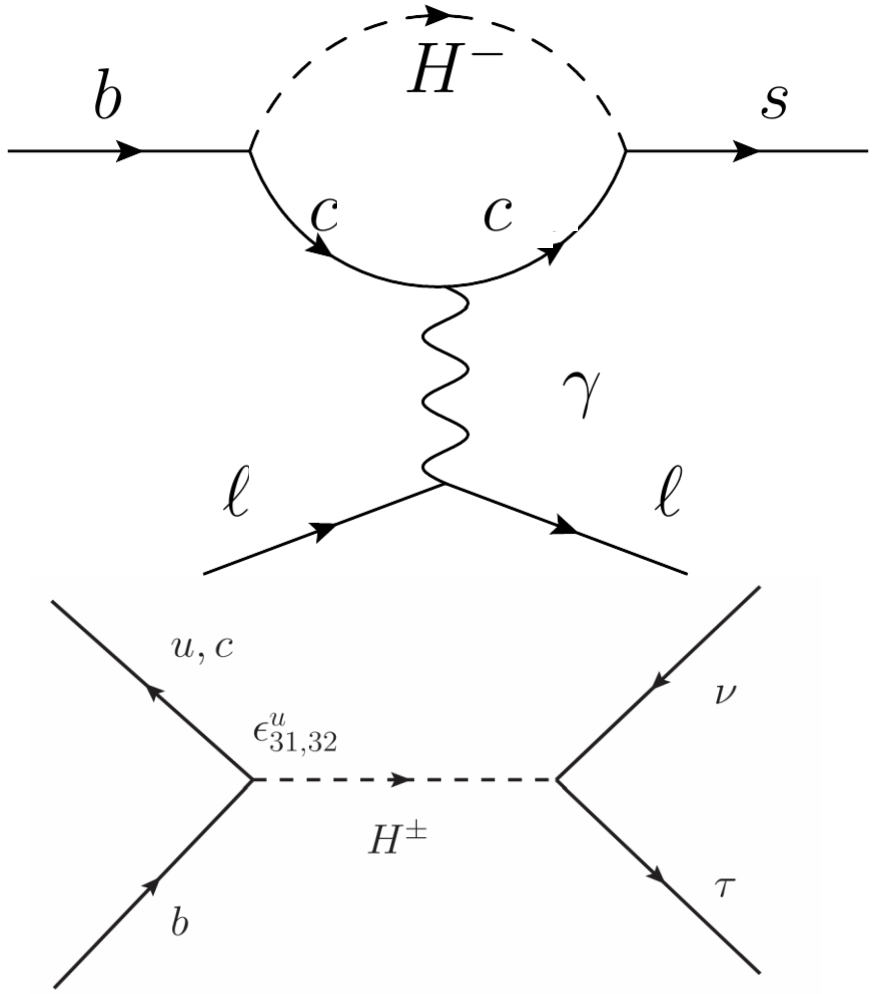


3σ (2.5 σ global) indication for a 130 GeV charged Higgs

Explaning the B anomalies with a charged Higgs

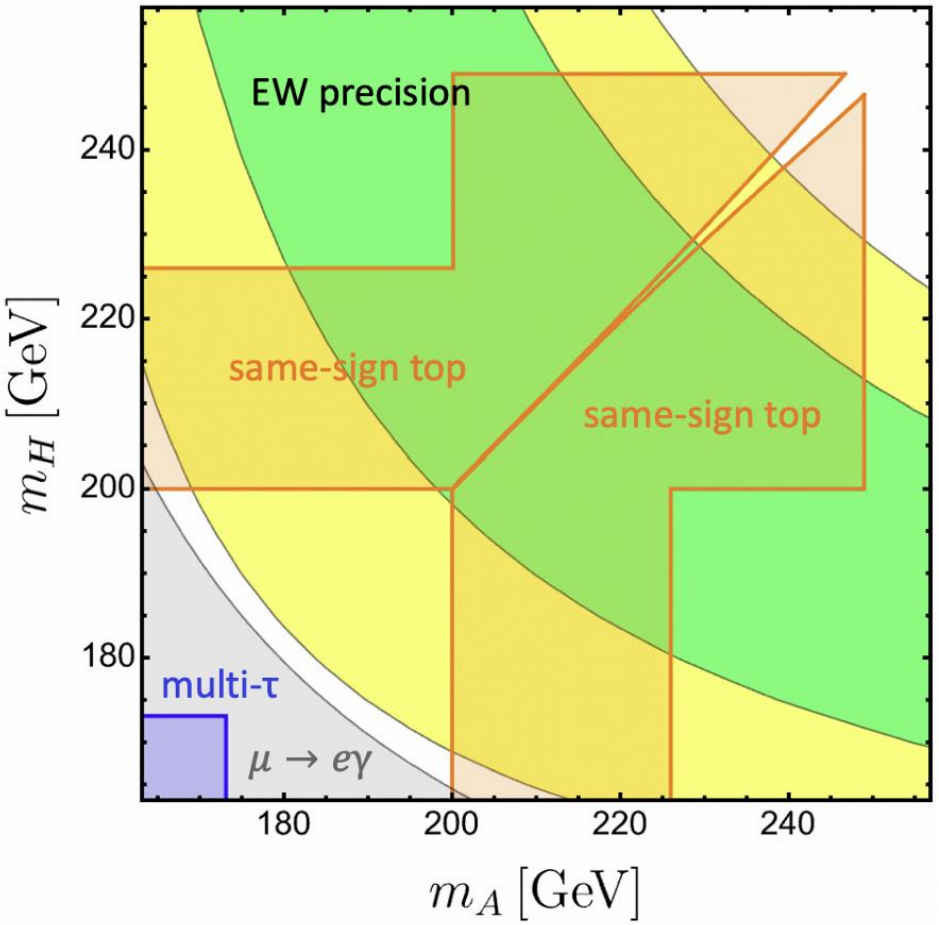


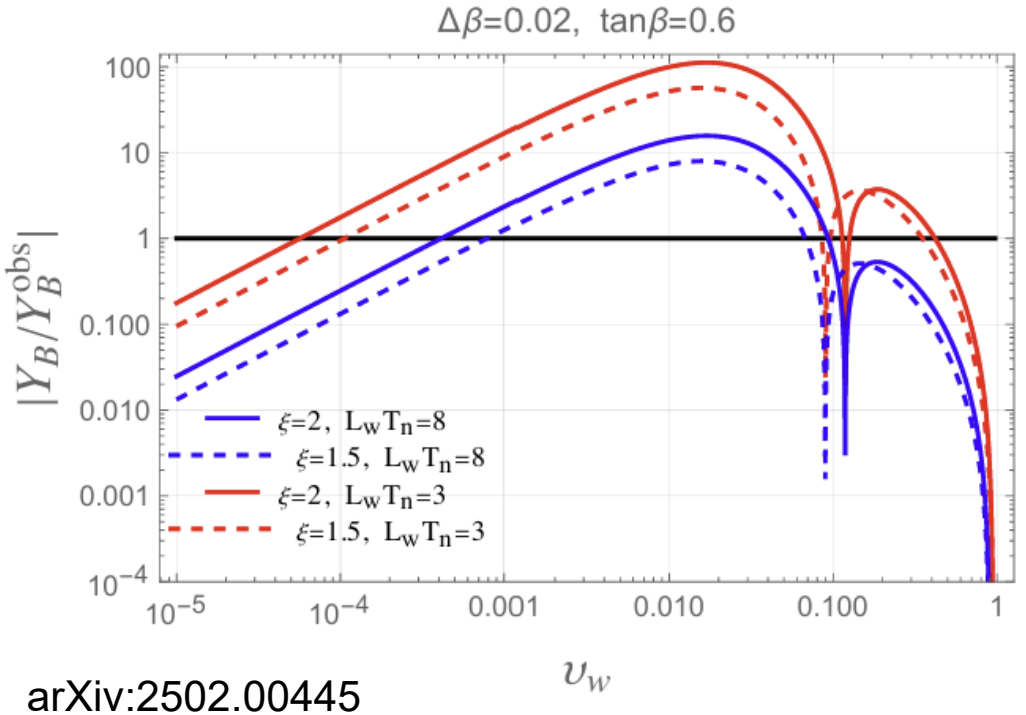
- Tree-level in b→cτυ
- Charm-loop in b→sll
- Charged Higgs mass fixed to 130 GeV
- Predicts t→ch



Combined explanation possible

Explaning the B anomalies with a charged Higgs



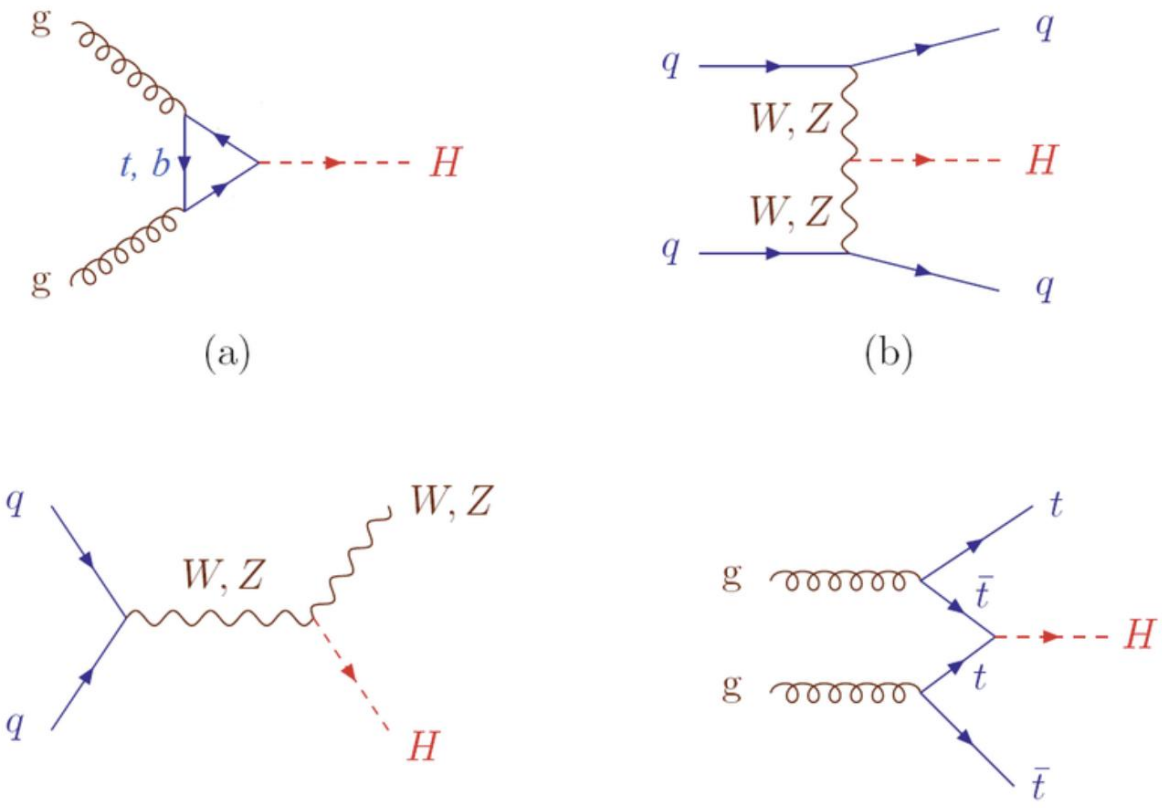


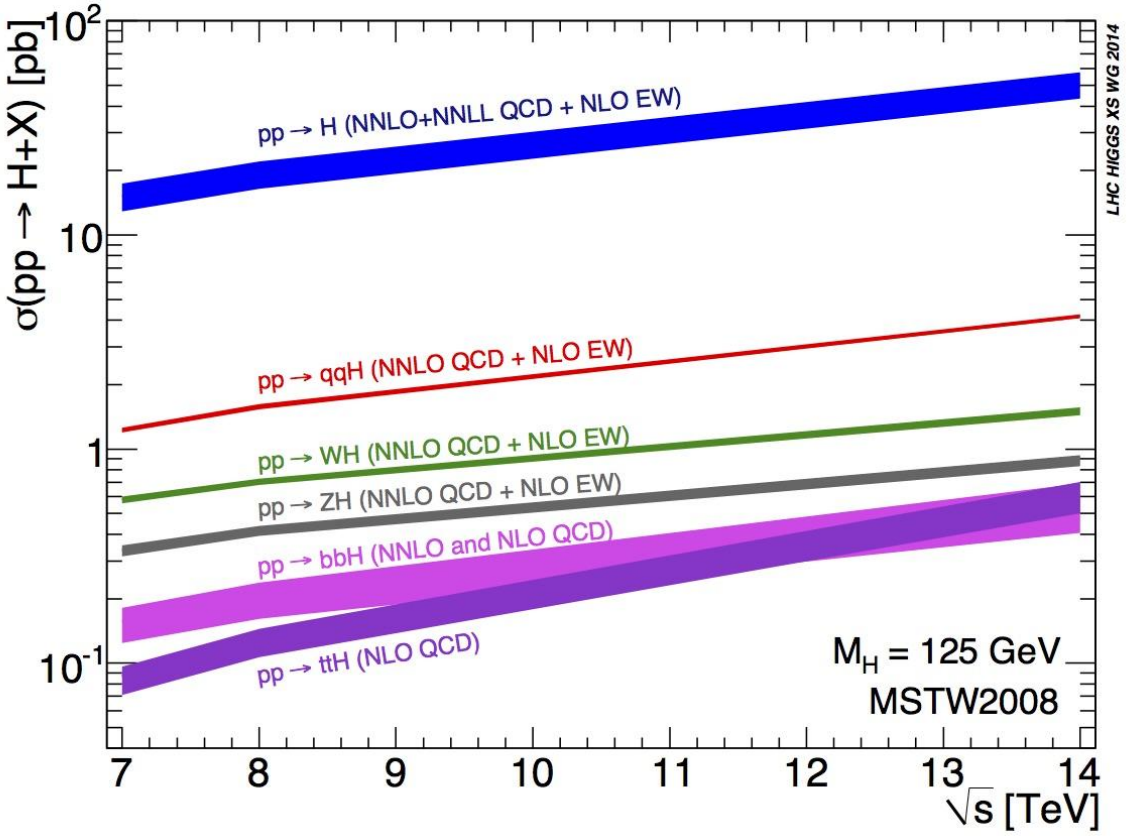
arXiv:2502.00445

FIG. 2. *Ratio* $|Y_B/Y_B^{\rm obs}|$ *as a function of* υ_w *with fixed values of the extra Yukawa couplings from the best fit point of the BM3 study of [17],* $y_{\mu\mu} = 0.001$, $y_{\mu\tau} = 0.01$, $y_{\tau\tau} = 0.05$, $\theta = 2.15$ *and* $c_{\beta-\alpha} = 0.01$.

LHC signatures and EW baryogenesis

Higgs production

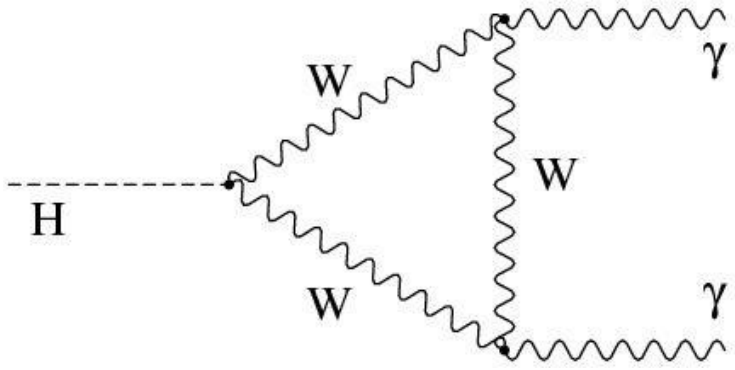


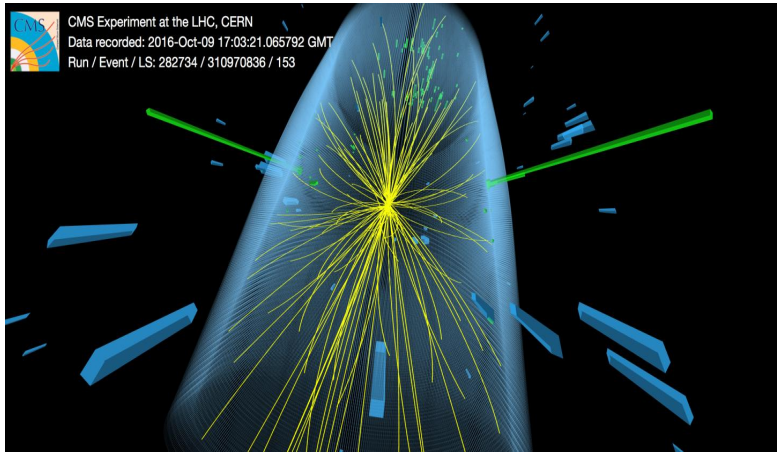


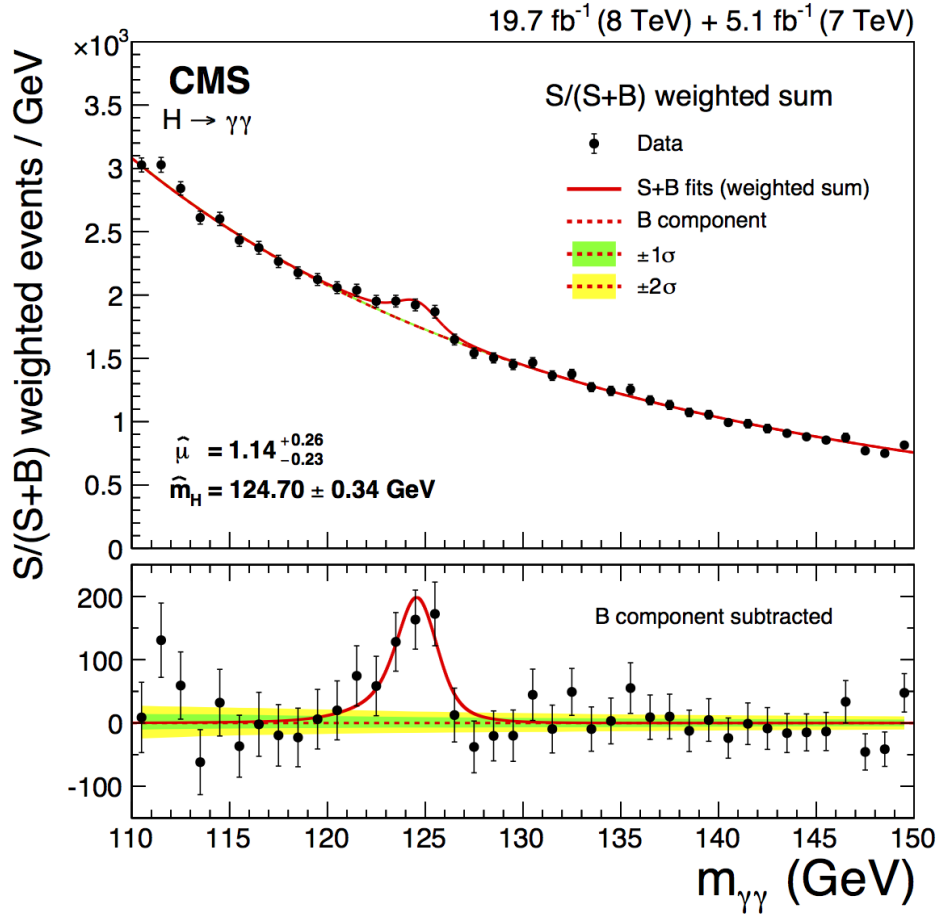
Gluon fusion dominant in the SM → inclusive searches most sensitive

Higgs decays

- Higgs decay to photons a very sensitive channel

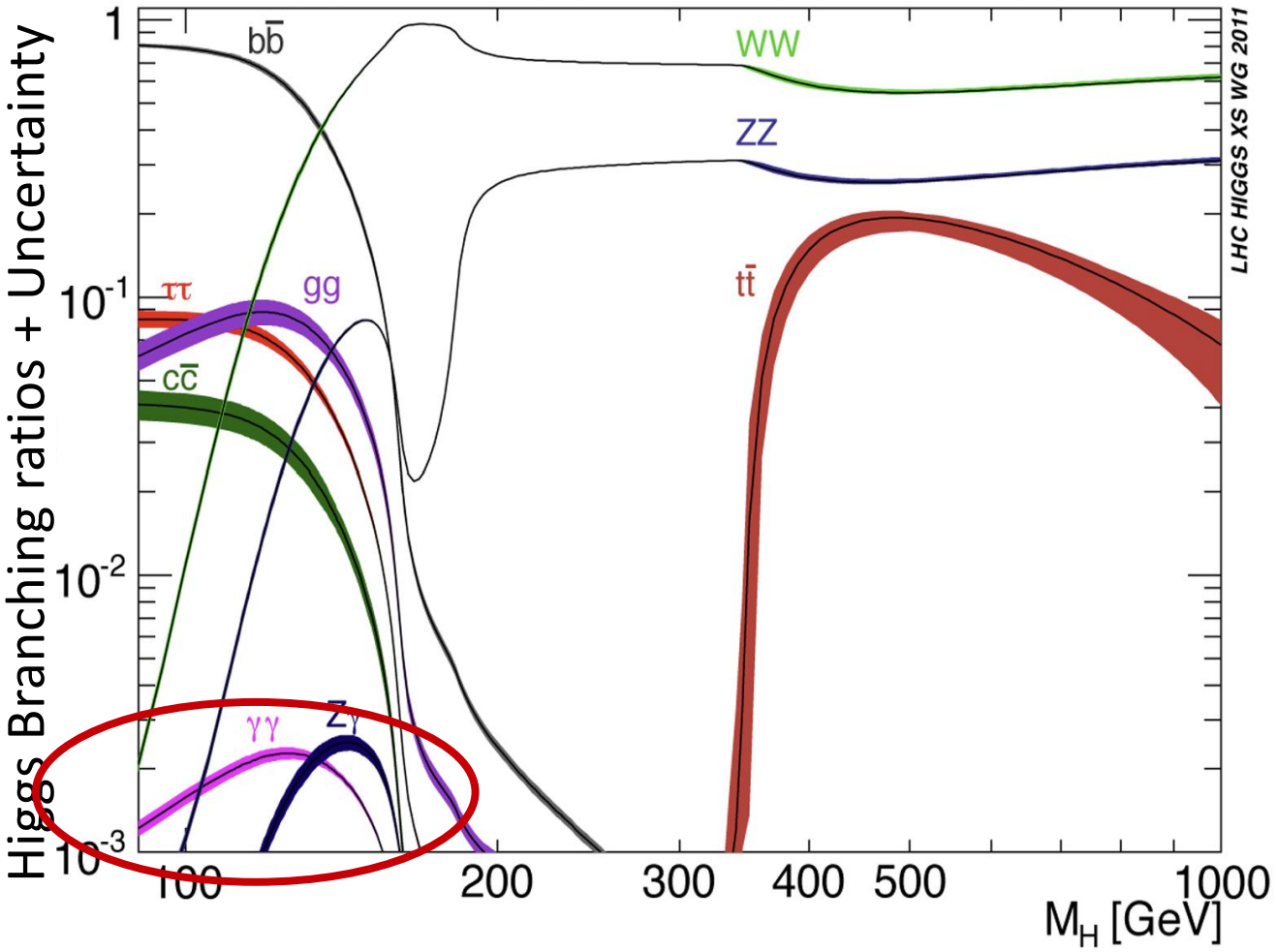


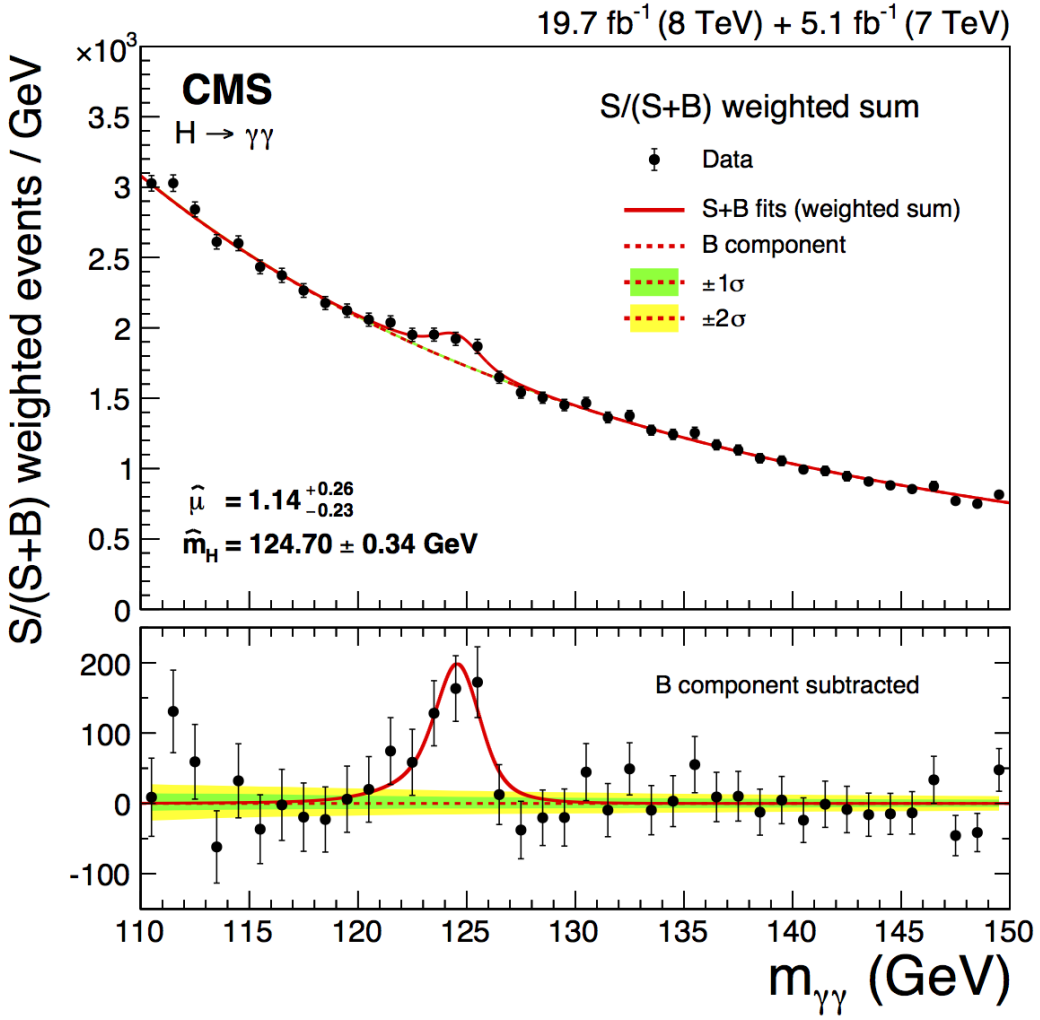




Very few events, many collisions needed

Higgses at the electroweak scale

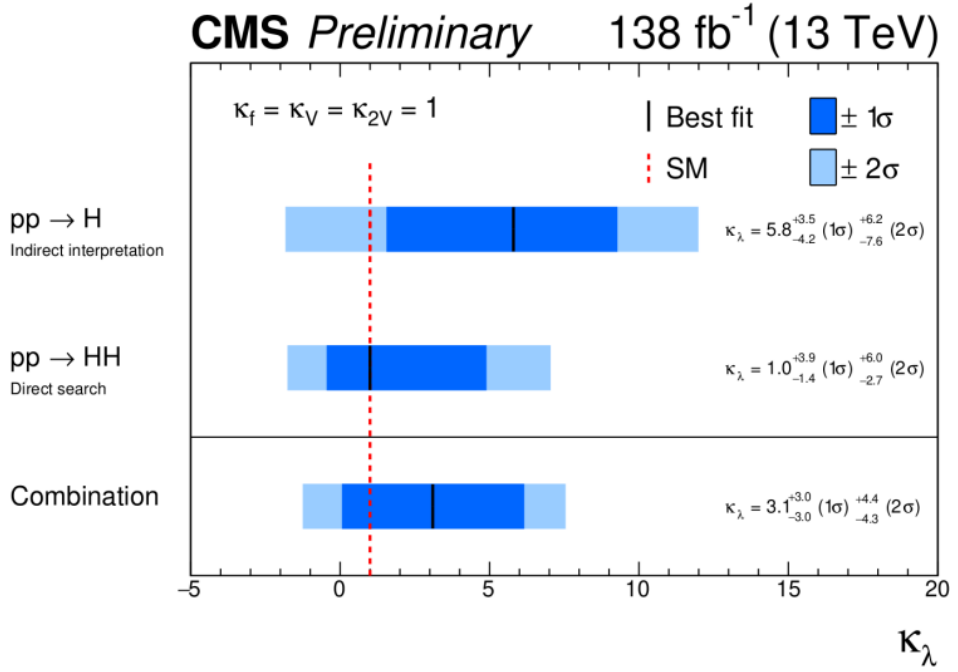


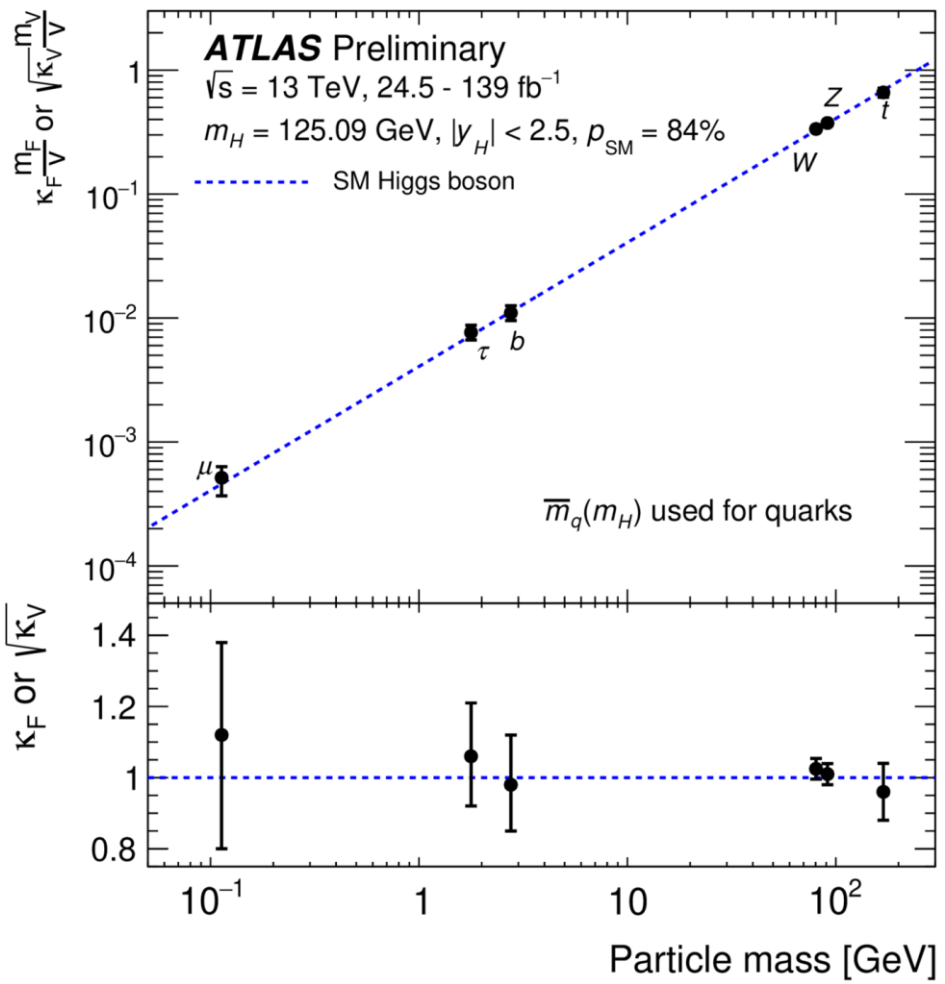


EW scale Higgses difficult to observe; di-photon natural discovery channel

Standard Model Higgs properties

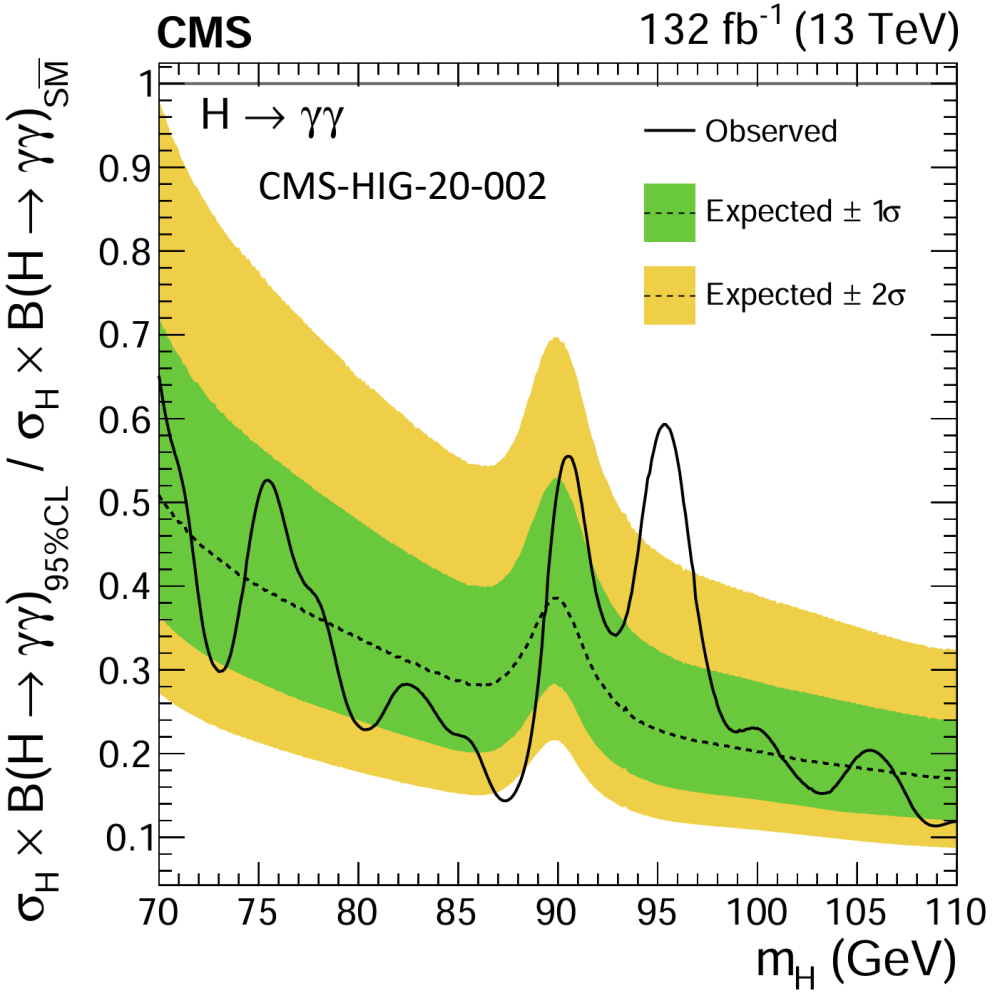
- Higgs decays as expected in the Standard Model (within errors)
- Self-couplings not well known

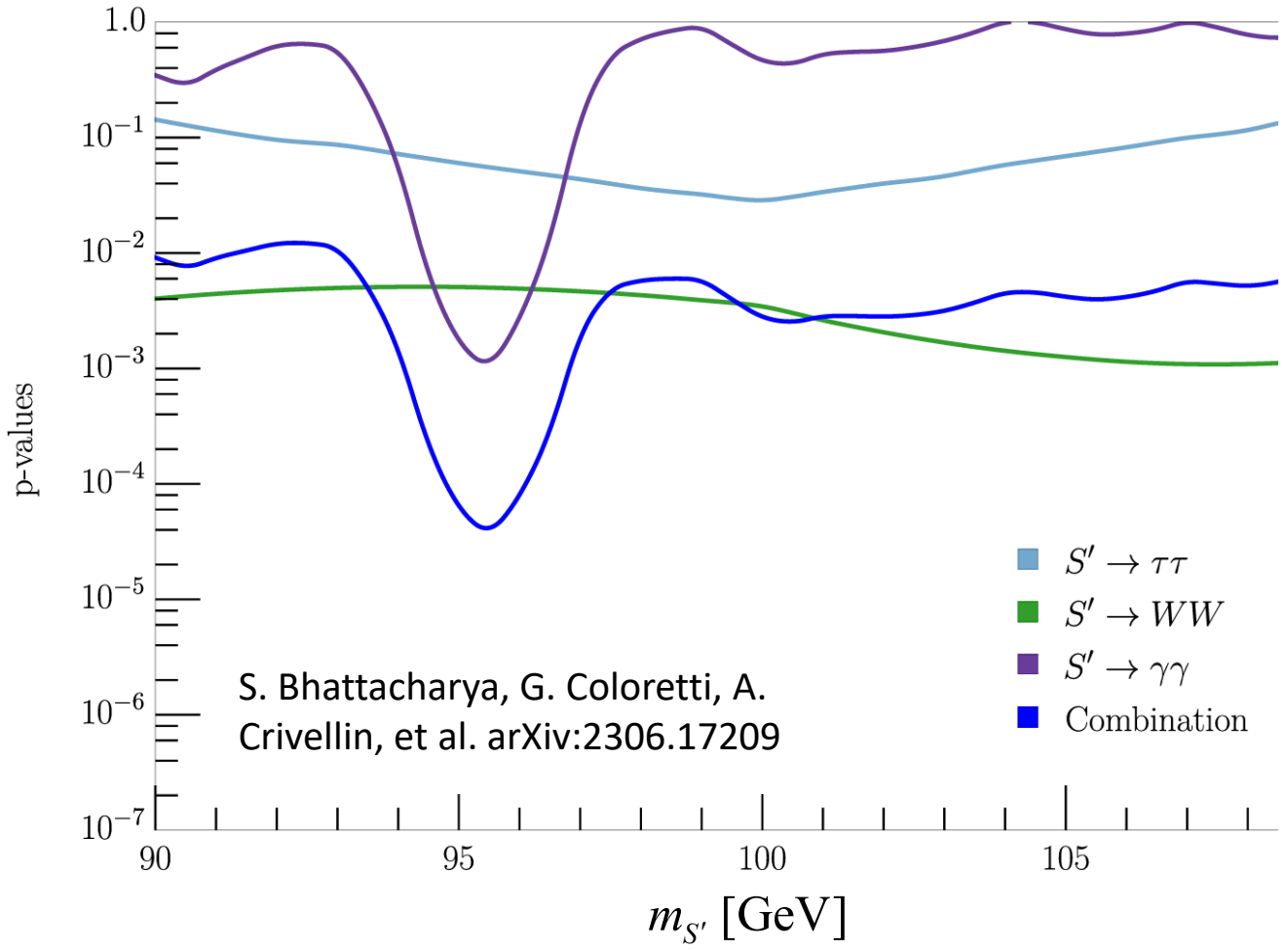




There can still be new Higgs bosons if they mix weakly with the SM Higgs

Indications for a 95 GeV Higgs

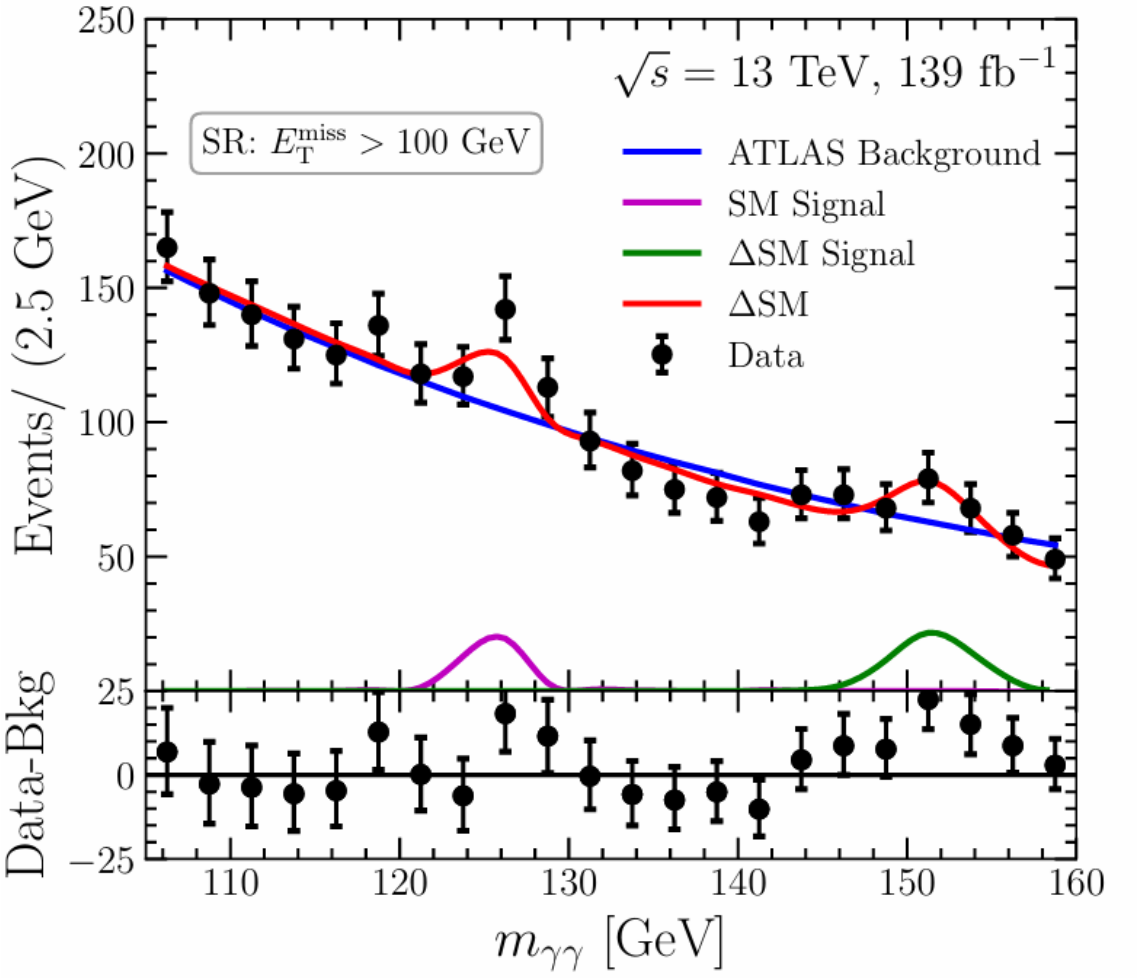


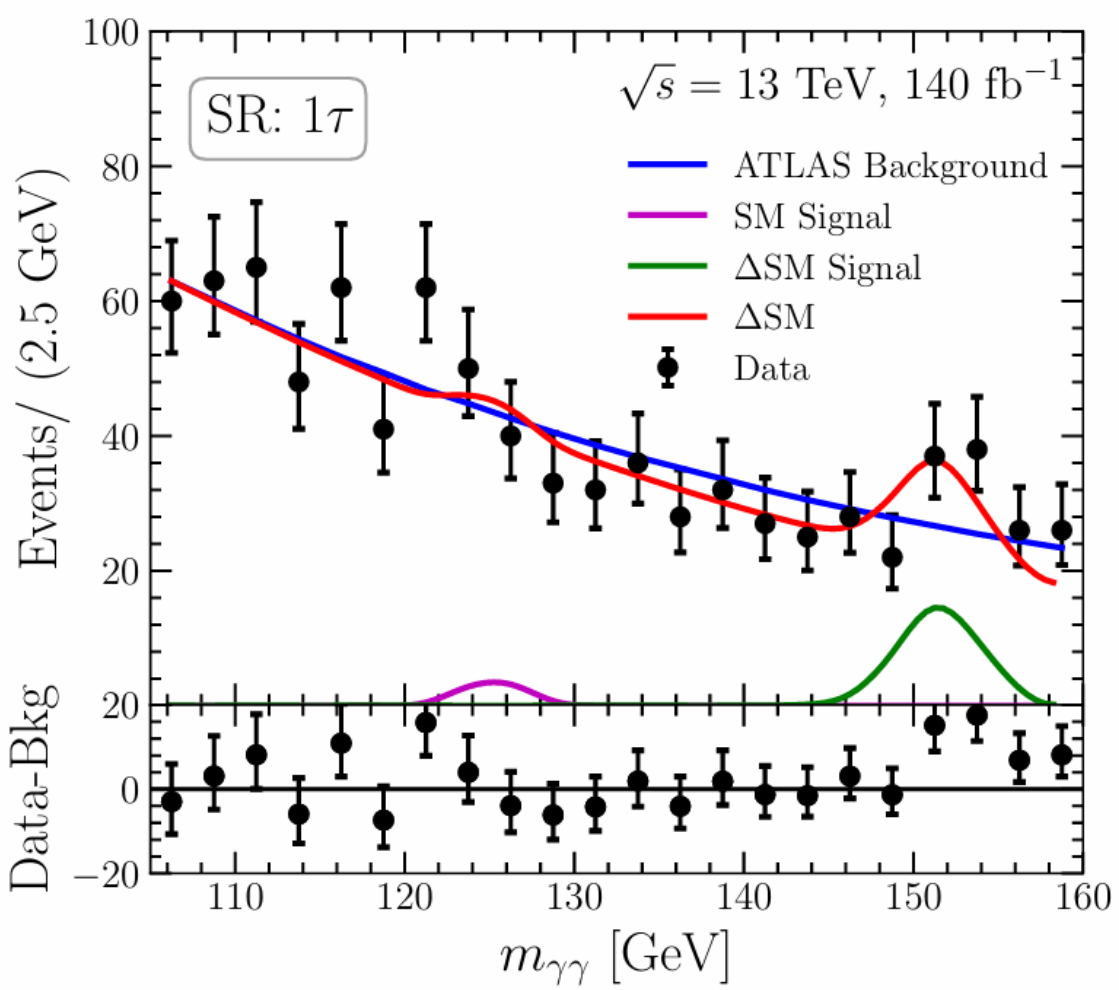


Di-photon channel supported by WW and ττ: 3.4σ global significance

152 GeV Scalar in Associated Production

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



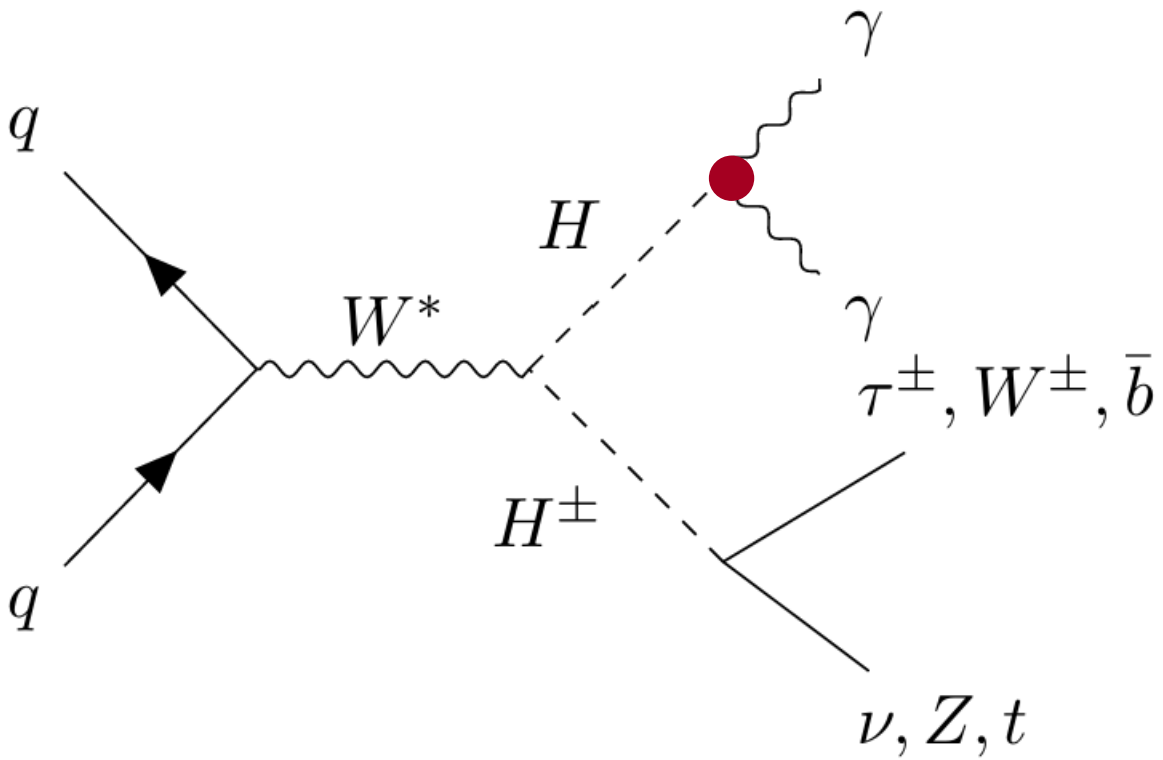


Associated production can enhance signal over background strength

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

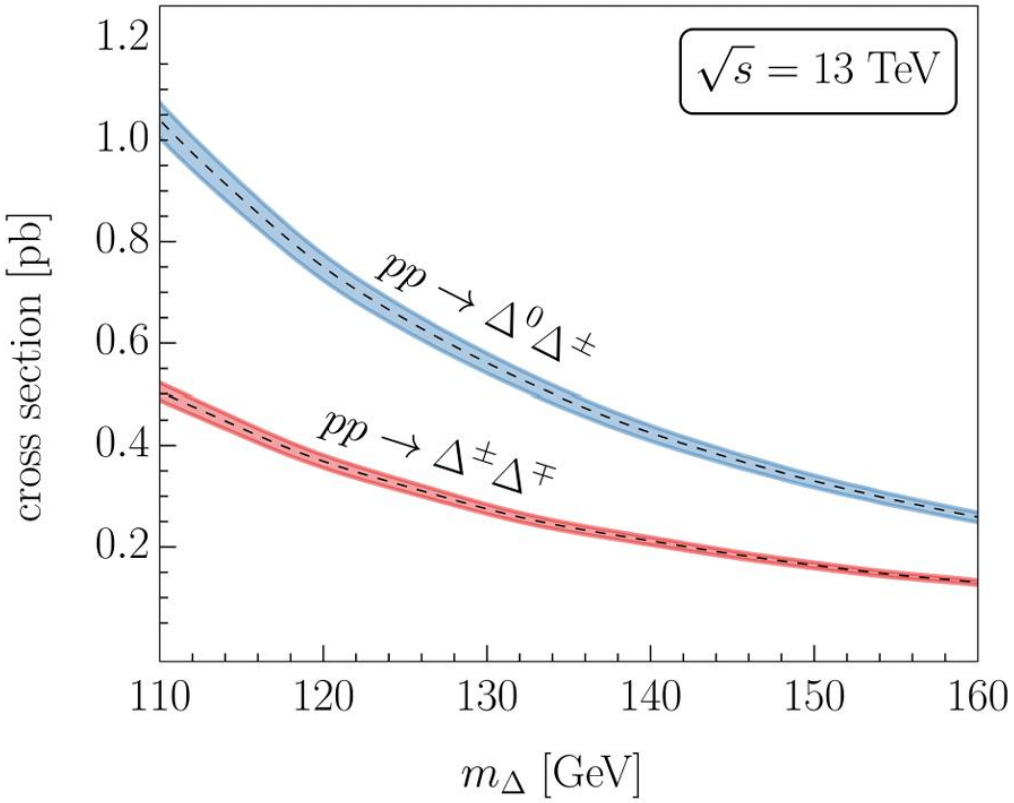
Drell Yan production of a charged and a neutral Higgs



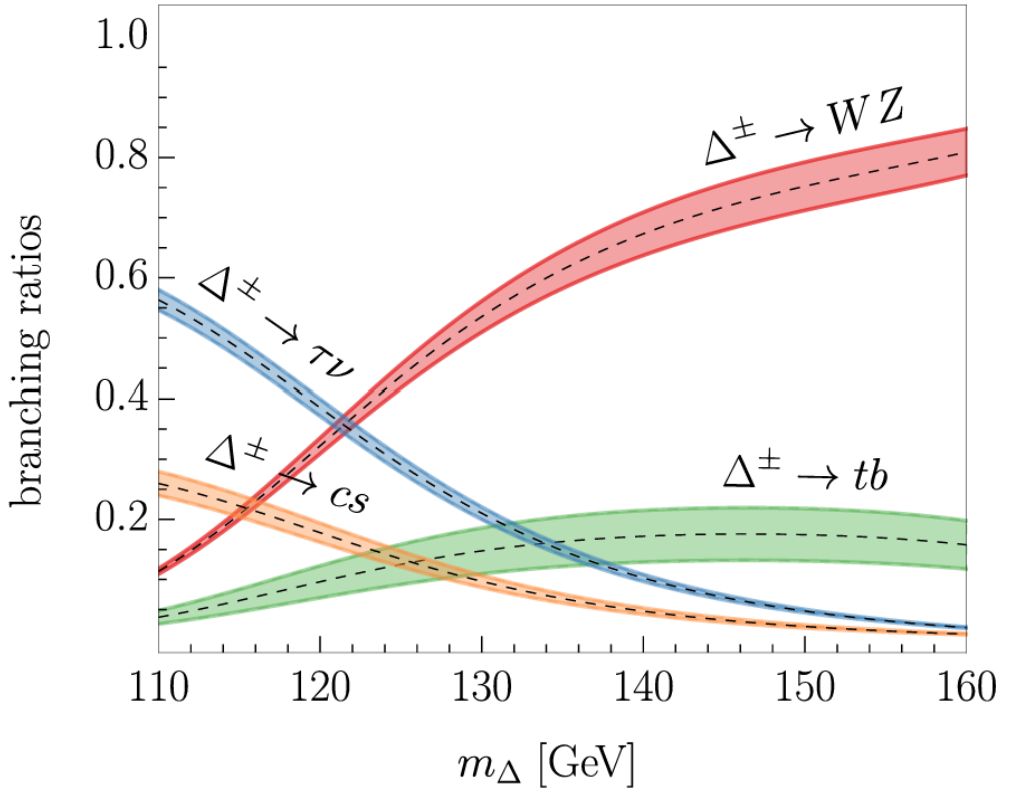
Drell-Yan production leads to the right signature

$SU(2)_L$ Triplet with Y=O (ΔSM)

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



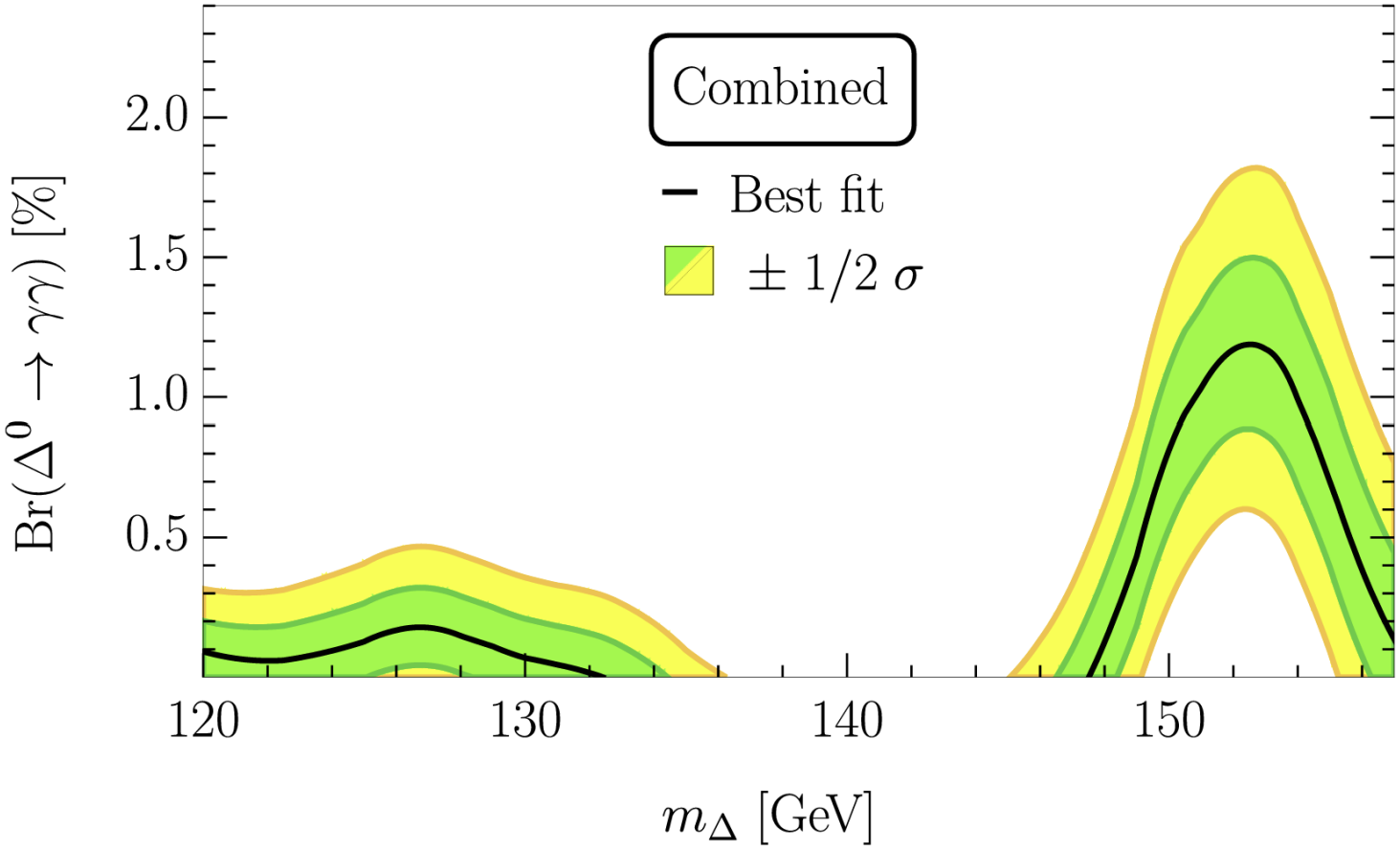
- Dependence on the vev cancels



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

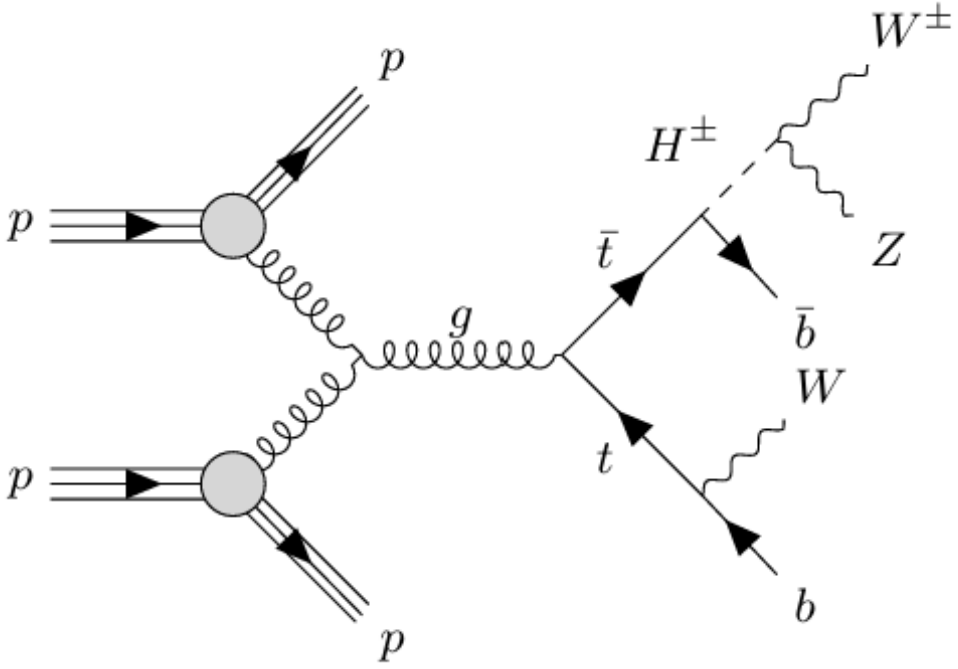


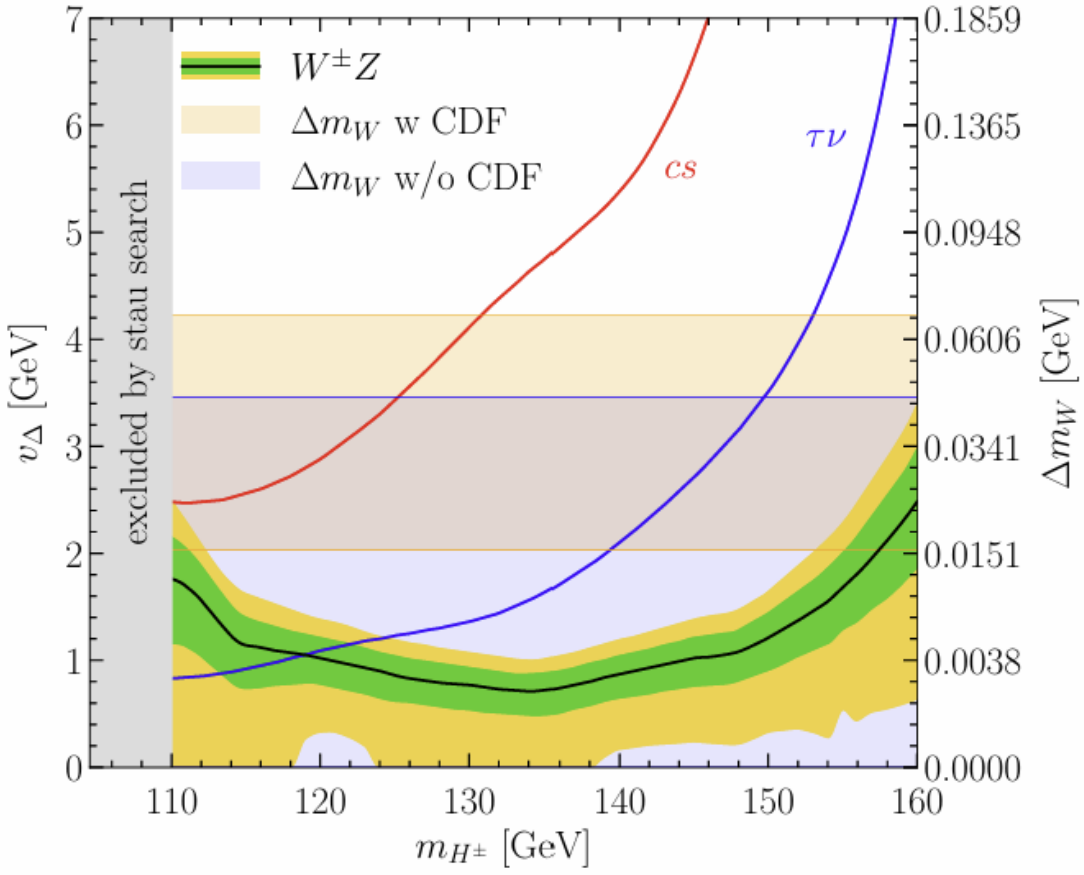
≈ 4σ significance at 152 GeV

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

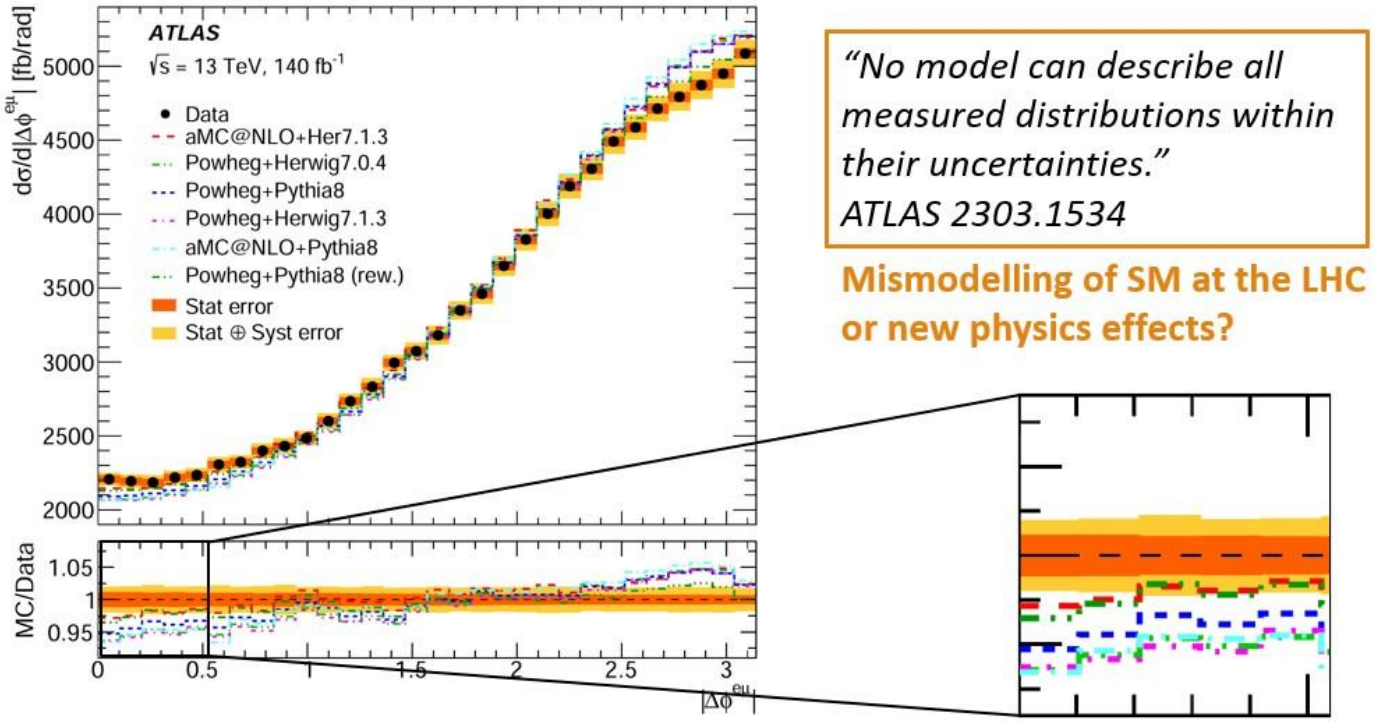




>2σ significance at ≈152 GeV, supporting evidence

Beyond the Triplet model

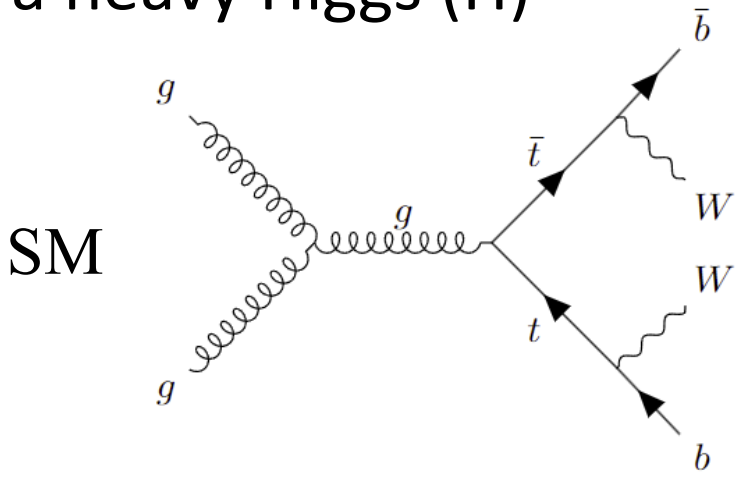
- Two Higgses (S and S') produced from the decay of a heavy Higgs (H)
- 95 GeV (S') naturally decays to bb
- 152 GeV triplet (S) dominantly decays to WW



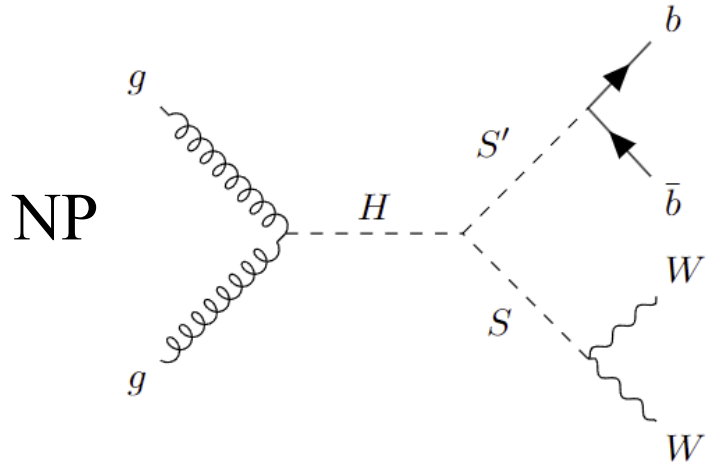
"No model can describe all measured distributions within their uncertainties."
ATLAS 2303.1534

Mismodelling of SM at the LHC or new physics effects?

SM

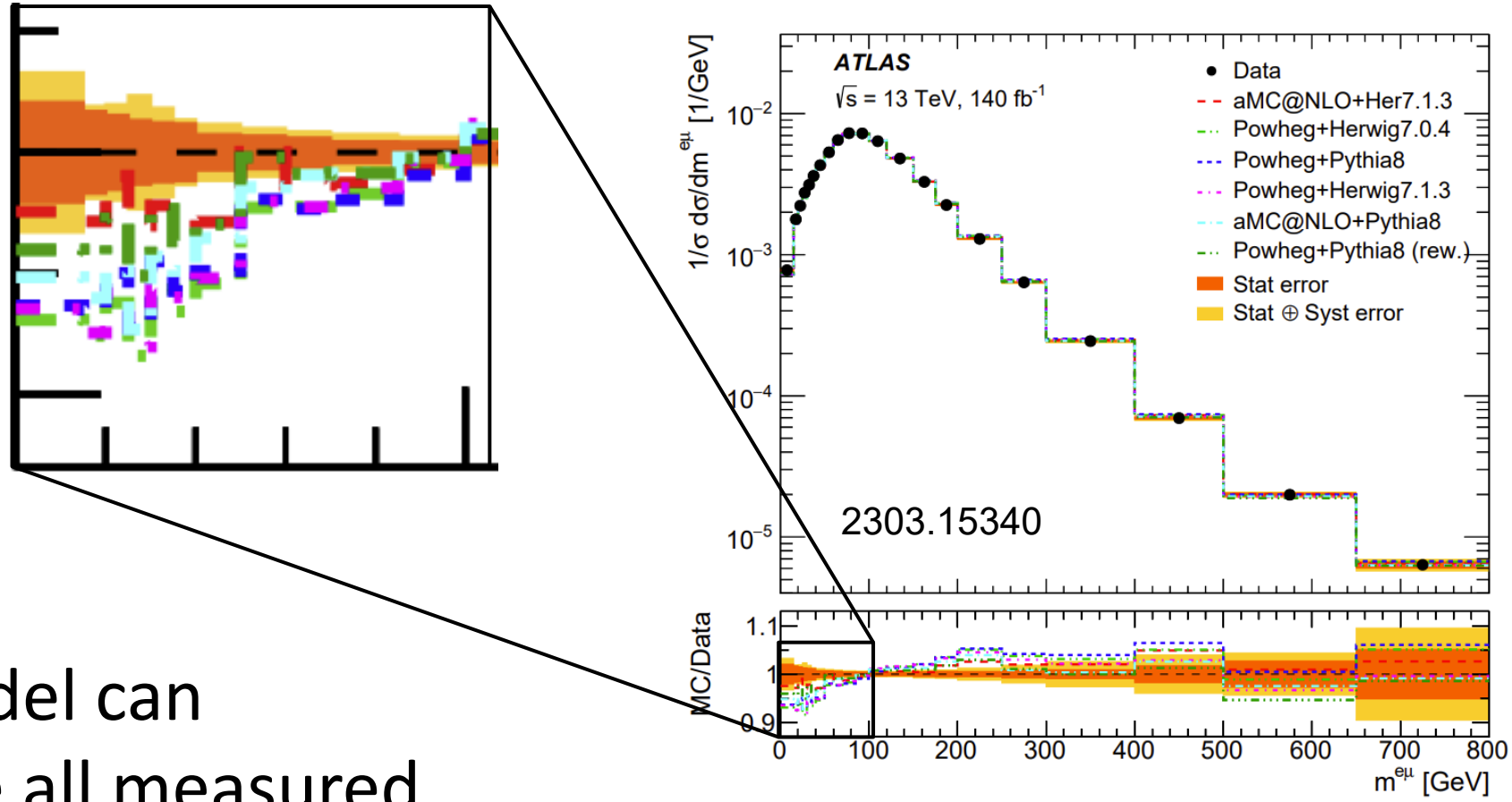


NP



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

Differential Top-Quark Distributions

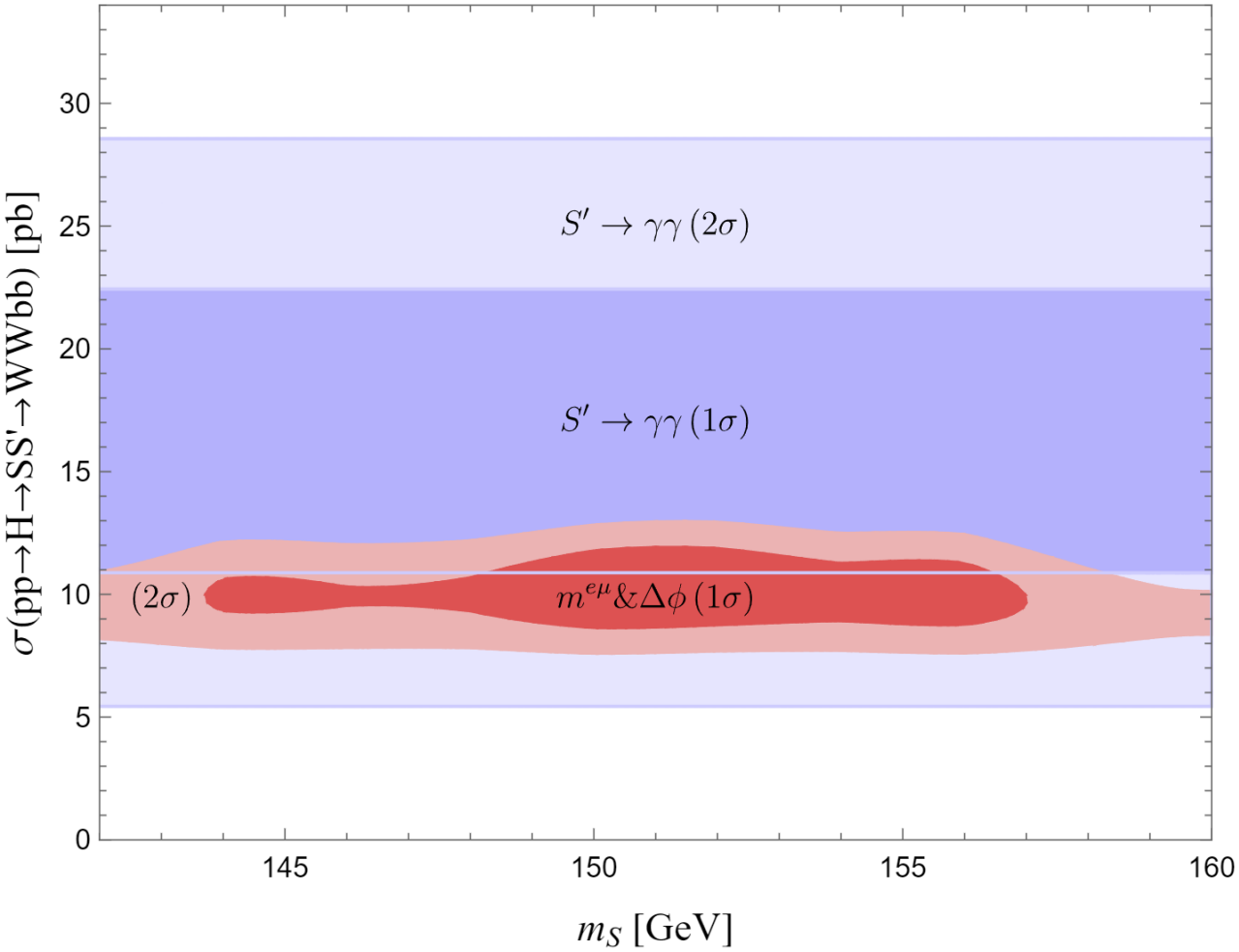


- ATLAS:
  "No model can describe all measured distributions within their uncertainties."

New Physics pollution of this SM measurement?

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

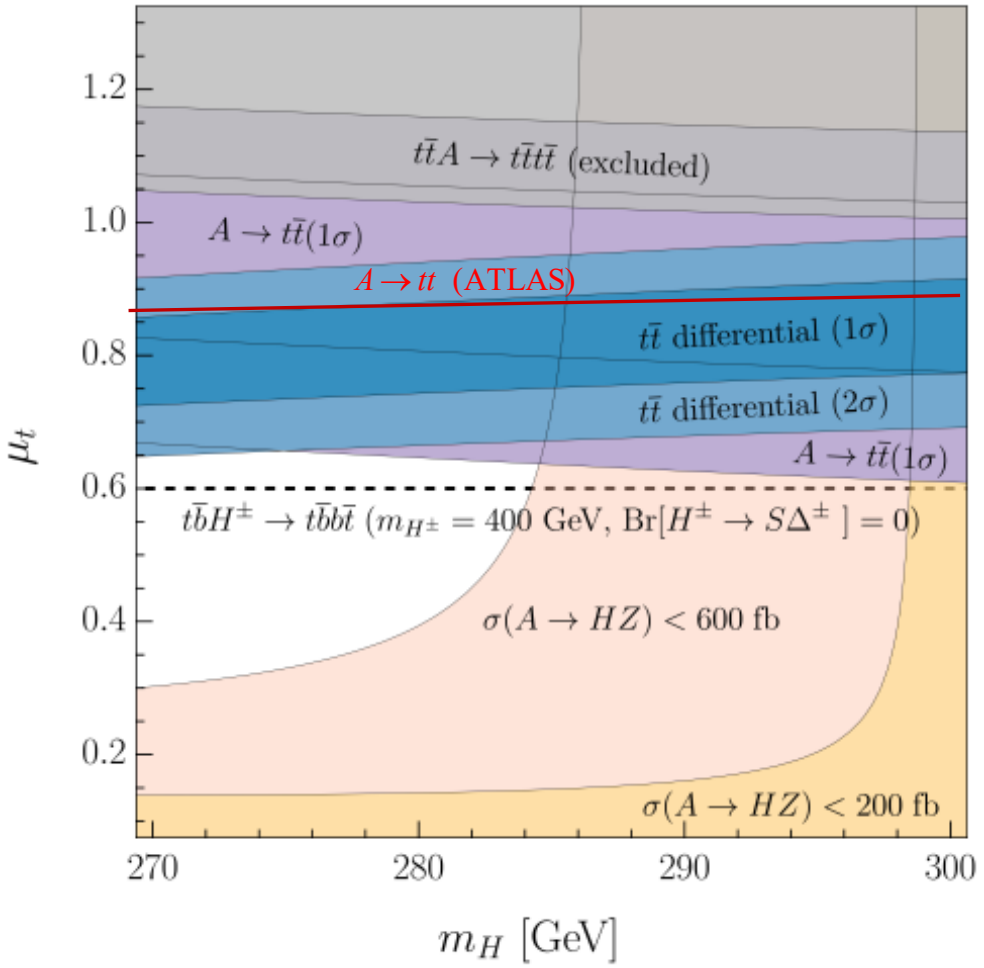
Field	$SU(2)_L$	$U(1)_Y$
ϕ_s	1	0
ϕ_2	2	1/2
ϕ_1	2	1/2
Δ	3	0

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

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



Combined explanation possible

Conclusions

- Intersting Hints for New Higgses at
  - 95 GeV
  - 152 GeV
  - 130 GeV (charged Higgs)
- Possible connections to
  - B anomalies
  - Top quark differential distributions
  - ttZ
  - Baryogenesis

LHC physics is not dead! Intersting indications for cosmology