



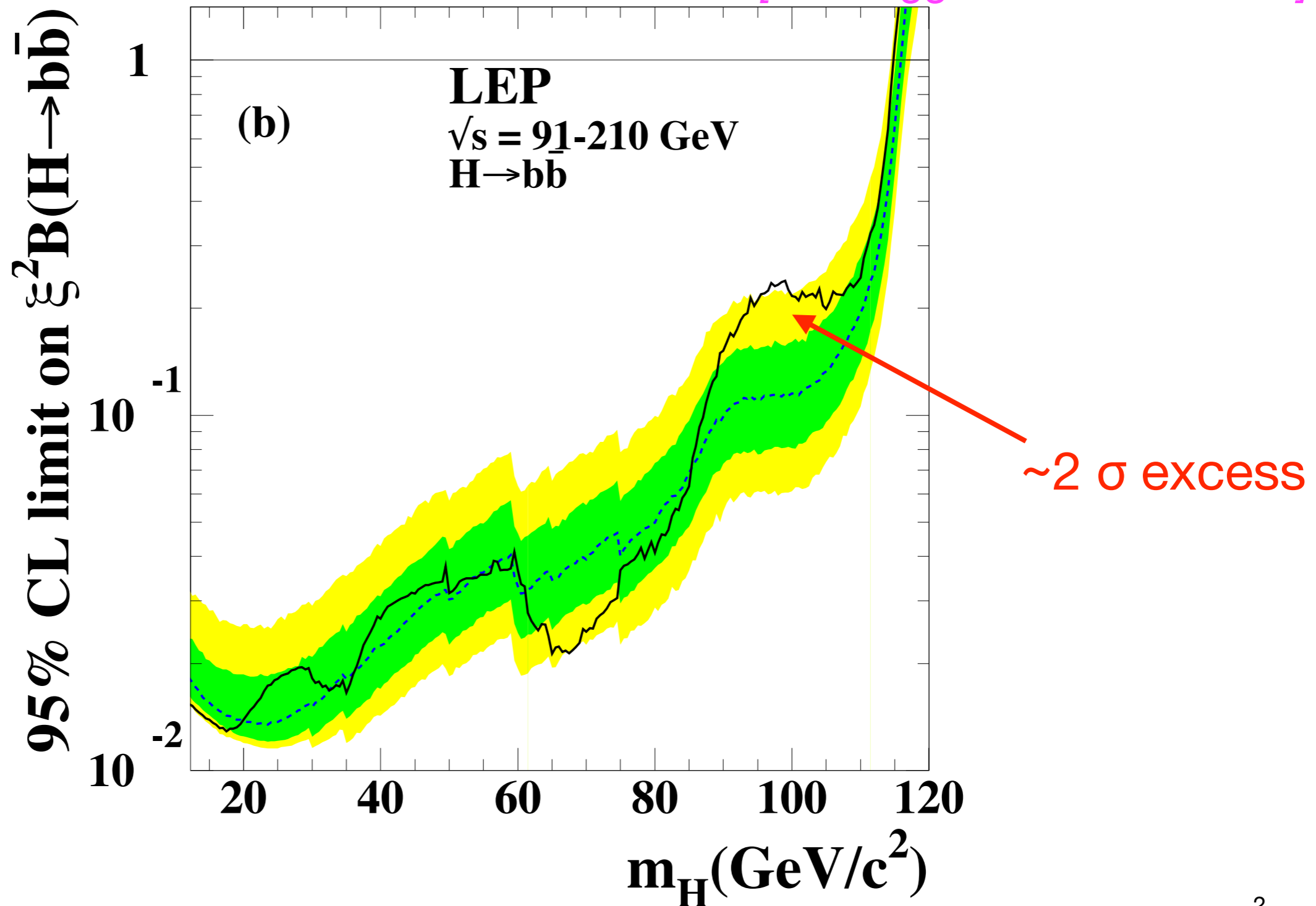
# A 95 GeV Higgs boson at $e^+e^-$ colliders

Georg Weiglein, DESY & UHH  
Tokyo, 07 / 2024

# Introduction

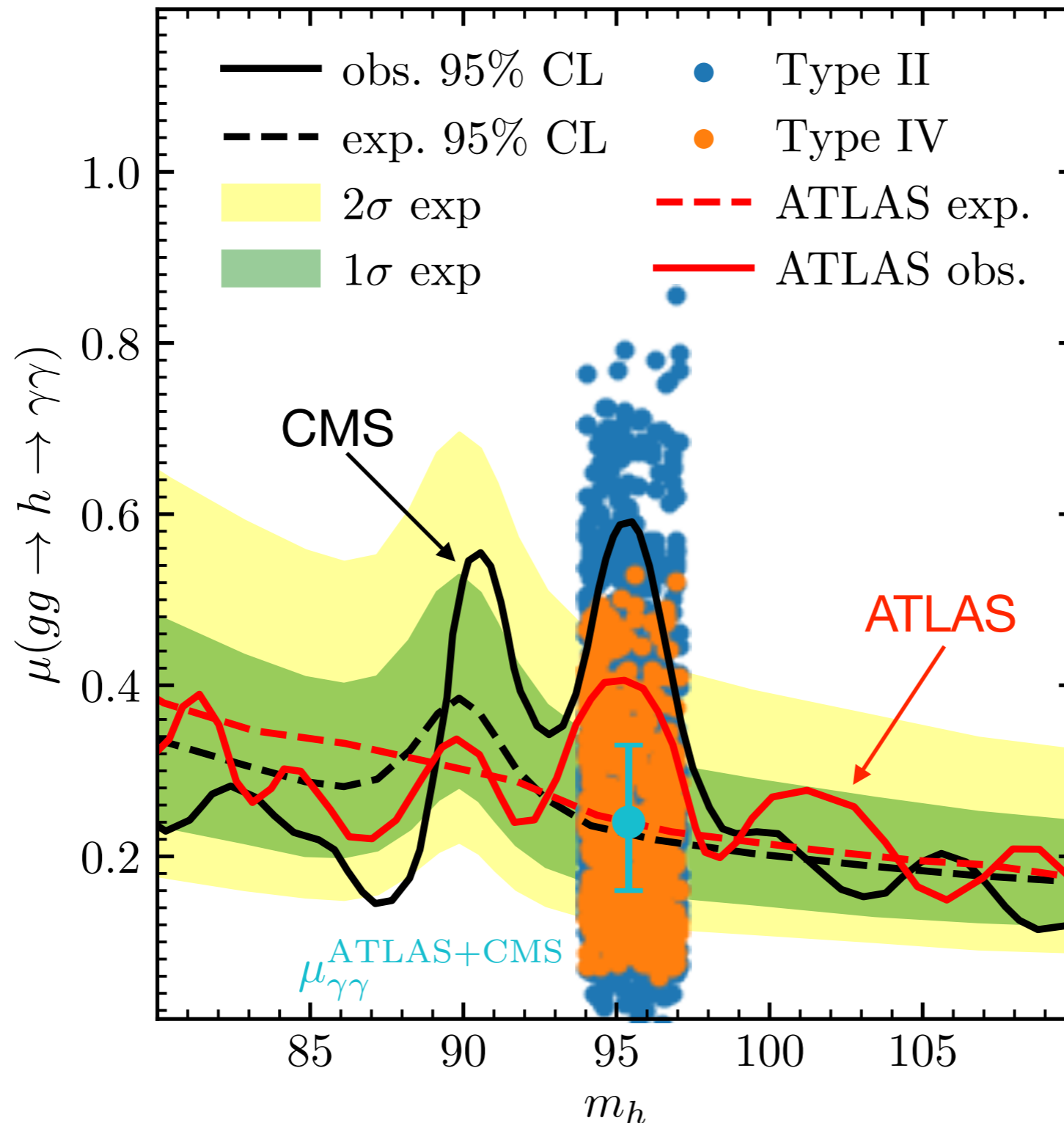
Low-mass Higgs searches at LEP,  $e^+e^- \rightarrow Zh, h \rightarrow b\bar{b}$

[LEP Higgs Combination '06]



# LHC: CMS + ATLAS excess in $\gamma\gamma$ channel at 95 GeV, interpretation in 2HDM + singlet (S2HDM)

CMS + ATLAS excess in  $\gamma\gamma$  channel at 95 GeV:

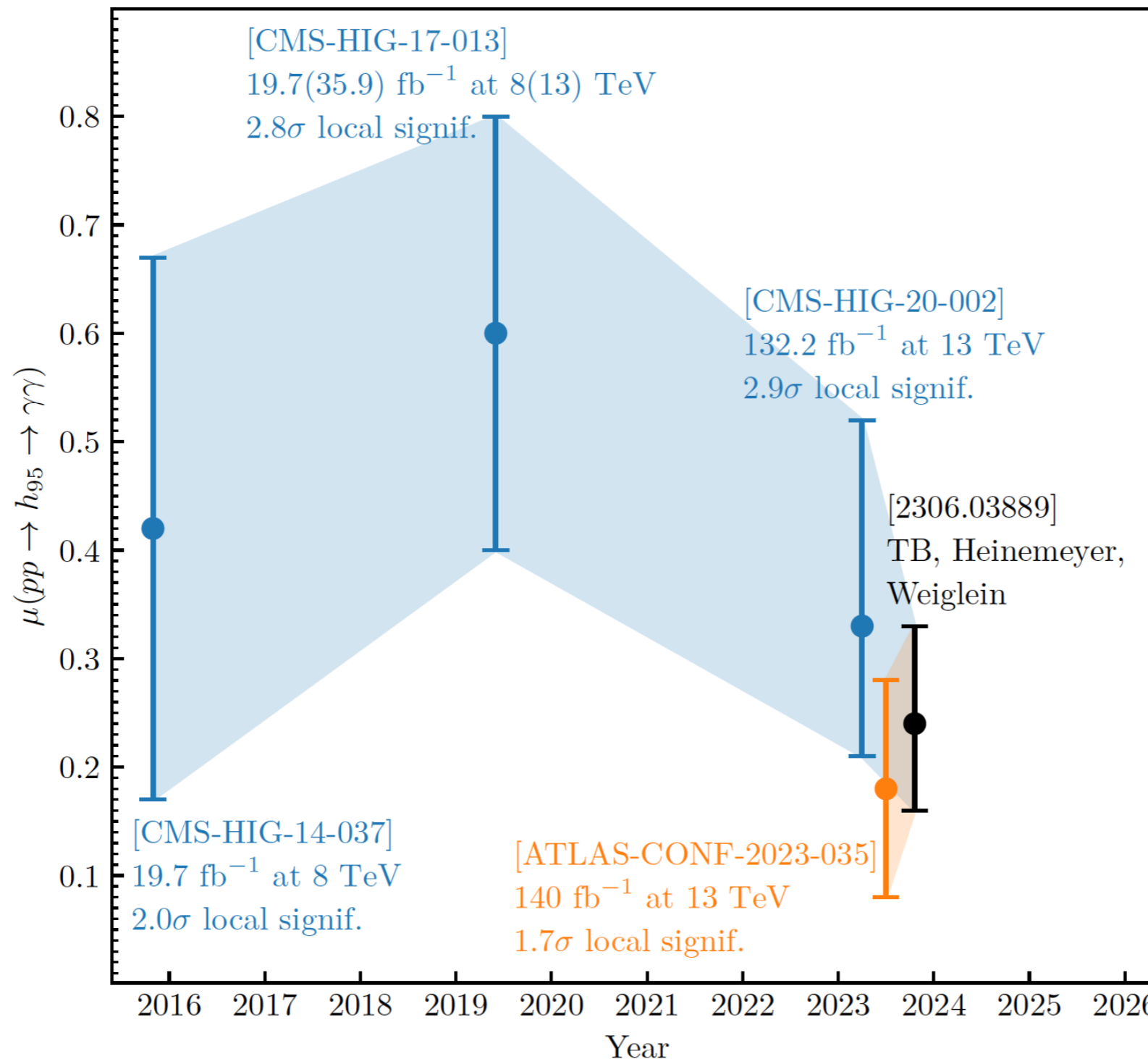


[T. Biekötter,  
S. Heinemeyer,  
G. W. '23]

Example interpretation:  
S2HDM,  
type II and IV

⇒ Good description in extended Higgs sectors with an additional doublet and a singlet

# Summary of the experimental results



[T. Biekötter,  
S. Heinemeyer,  
G. W. '23]

$$\mu_{\gamma\gamma}^{\text{ATLAS+CMS}} = 0.24^{+0.09}_{-0.08}$$

3.1σ

Implications for physics at an e<sup>+</sup>e<sup>-</sup> Higgs factory?

# Case 1: h95 as a CP-even BSM Higgs boson

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h95 is interpreted as **singlet-like CP-even state**, e.g. N2HDM, S2HDM, NMSSM, ... :

Singlet-like state h95 **mixes with h125**

**Significant ZZ h95 coupling**, allows possible explanation of LEP excess

Sizeable  $\gamma\gamma$  rate via suppression of bb h95 coupling

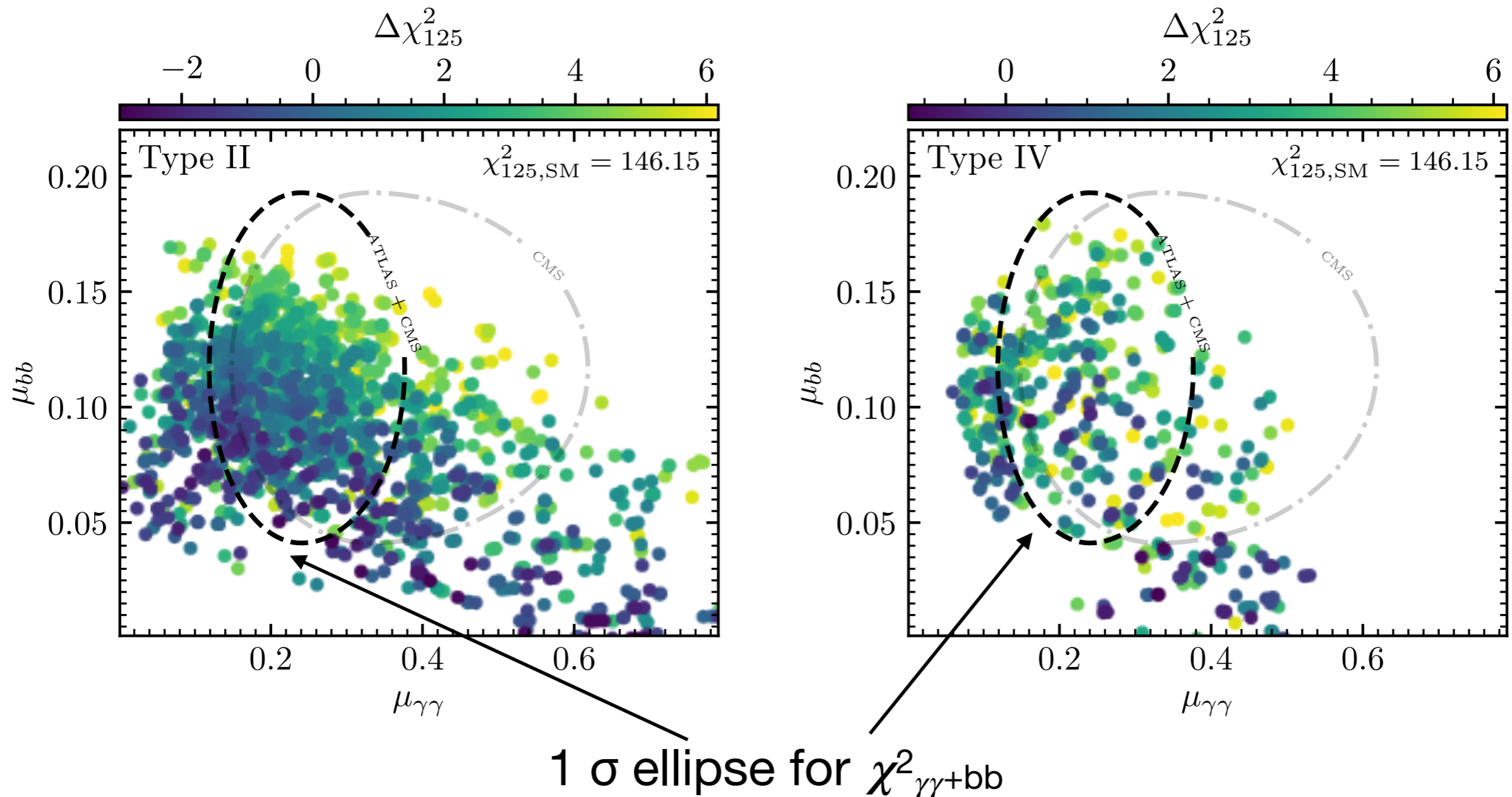
Note: SUSY interpretations of the LEP excess predict  $\mu_{\gamma\gamma} \approx 0.3!$

- Direct production at an  $e^+e^-$  Higgs factory in **Z h95** channel: detailed studies of the **properties of h95**
- Precision measurements of the **couplings of h125**
- Possible production of **additional Higgs bosons / BSM particles**

# Excesses near 95 GeV at the LHC and at LEP

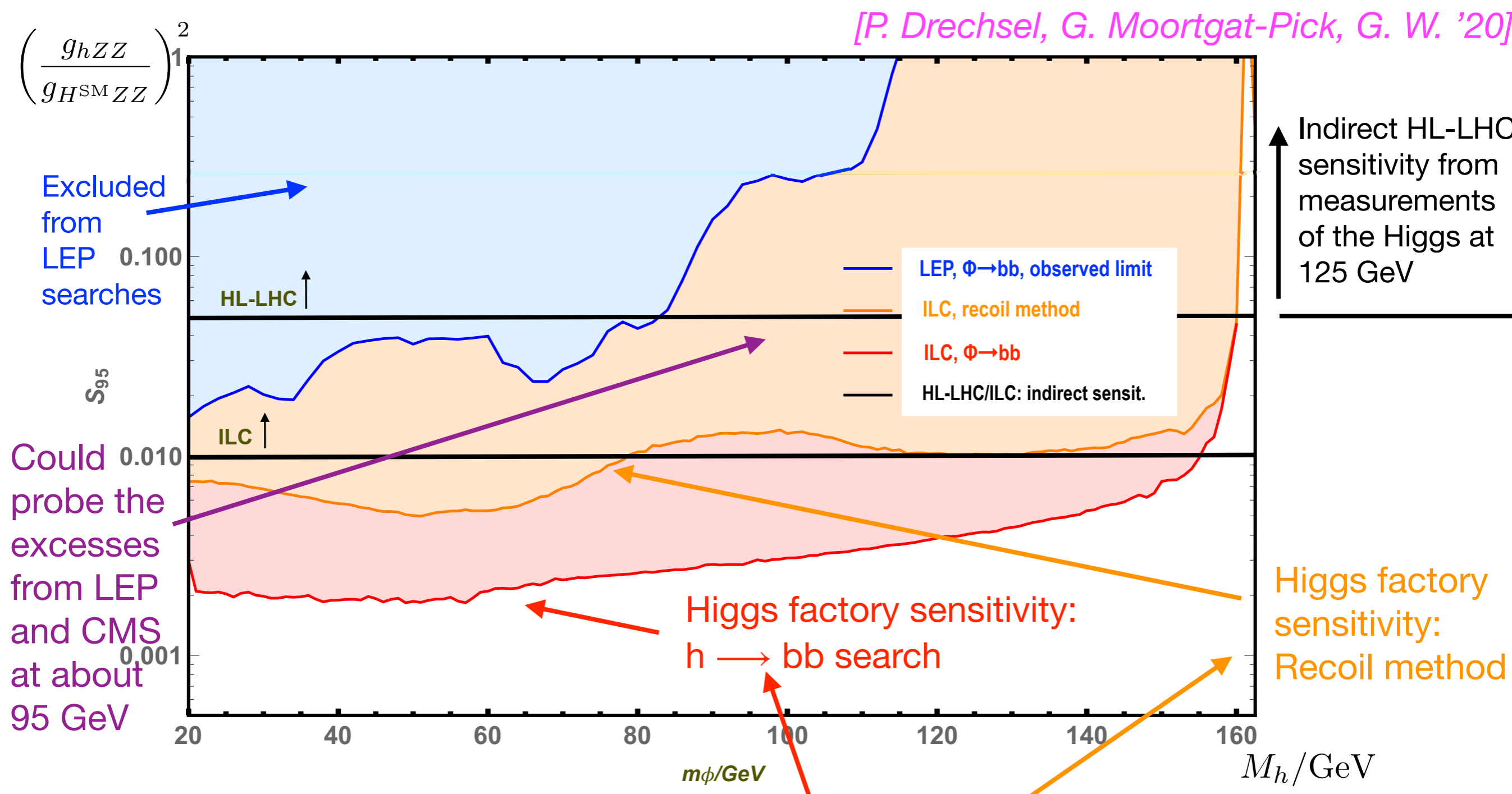
S2HDM, type II and IV:

[T. Biekötter, S. Heinemeyer, G. W. '23]



$\Rightarrow$  The LHC excess in the  $\gamma\gamma$  channel and the LEP excess in the bb channel can be described very well simultaneously!

# Higgs factory: discovery potential for a low-mass Higgs; Sensitivity at 250 GeV with 500 fb<sup>-1</sup>

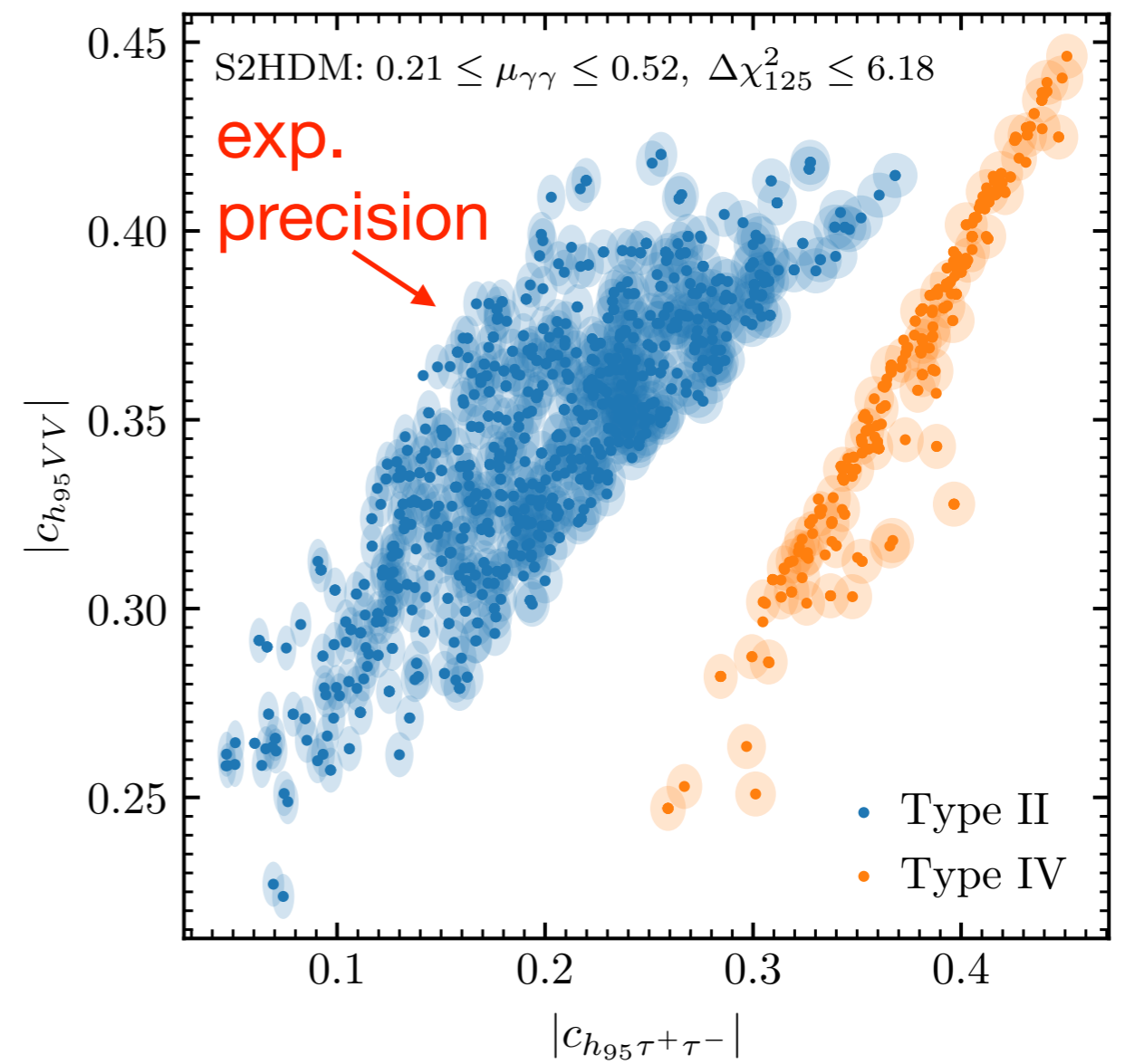
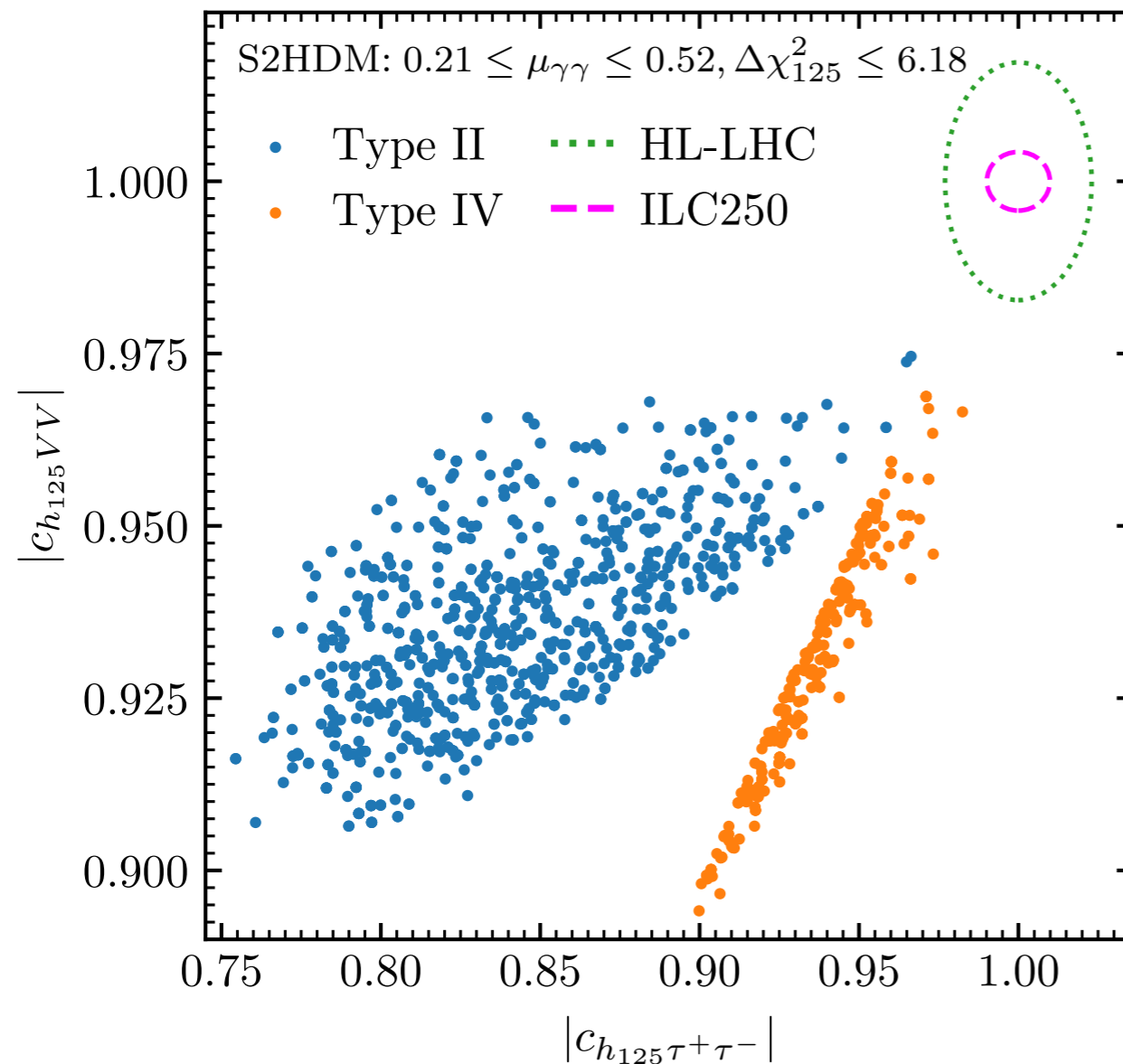


⇒ Higgs factory at 250 GeV will explore a large untested region!

# Prospects for coupling measurements of h125 and h95 at an e<sup>+</sup>e<sup>-</sup> Higgs factory

S2HDM, type II and IV:

[T. Biekötter, S. Heinemeyer, G. W. '23]



⇒ Precision measurements of the couplings of both h125 and h95  
High sensitivity to the realised physics scenario (Yukawa type, ...)



# Analysis in the Georgi-Machacek (GM) model

[T.-K. Chen, C.-W. Chiang, S. Heinemeyer, G. W. '23]

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One doublet and two triplet fields, custodial  $SU(2)_V$  symmetry preserved at tree level,  $\rho_{\text{tree}} = 1$

⇒ Higgs multiplets:

$H_5, H_3$ , two singlets:  $H_1$  (identified with h95),  $h$  (identified with h125)

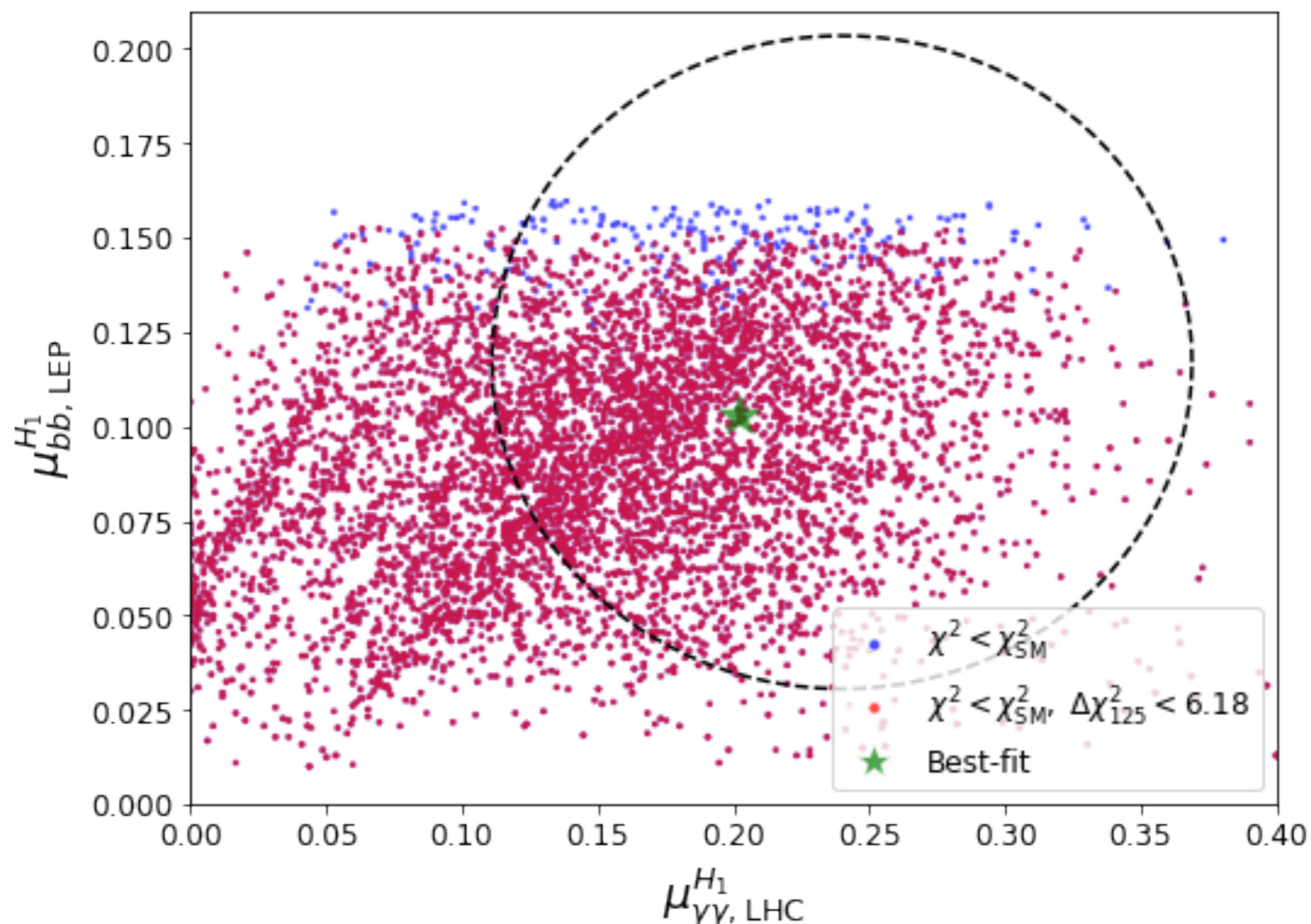
h95: possible enhancement of  $\gamma\gamma$  rate from loop of doubly-charged Higgs boson

GM model with h95: all BSM Higgs bosons at the electroweak scale

Analysis below: constraints from Higgs searches and properties of h125 taken into account via *HiggsTools* (contains *HiggsBounds* and *HiggsSignals*) [H. Bahl et al. '22]

# GM model, LHC and LEP excesses for h95

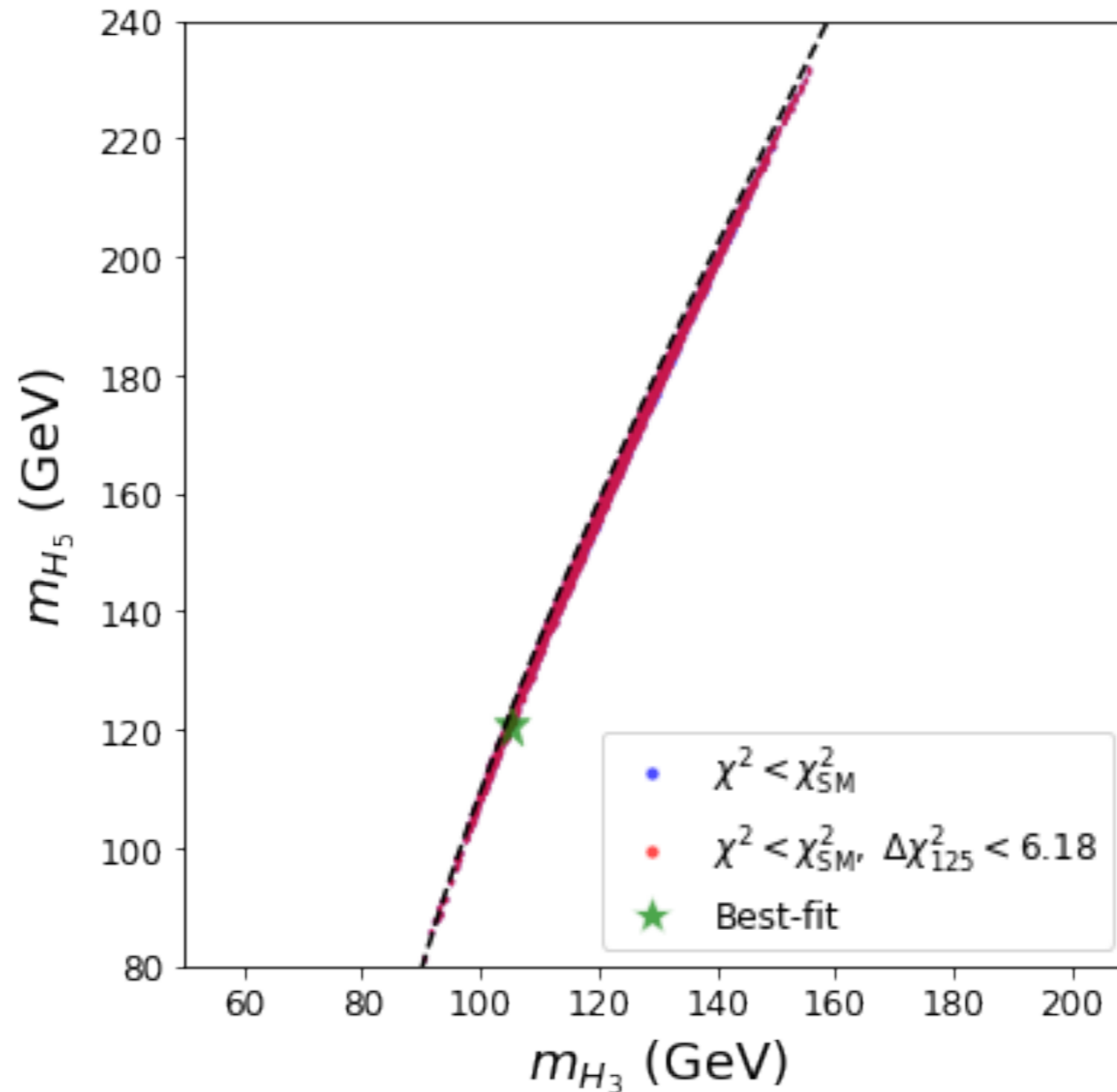
[T.-K. Chen, C.-W. Chiang, S. Heinemeyer, G. W. '23]



⇒ Simultaneous description of LHC excess in the  $\gamma\gamma$  channel and the LEP excess in the  $bb$  channel

# GM model with h95: quintet and triplet masses

[T.-K. Chen, C.-W. Chiang, S. Heinemeyer, G. W. '23]



⇒ Strong correlation between  $m_{H_3}$  and  $m_{H_5}$

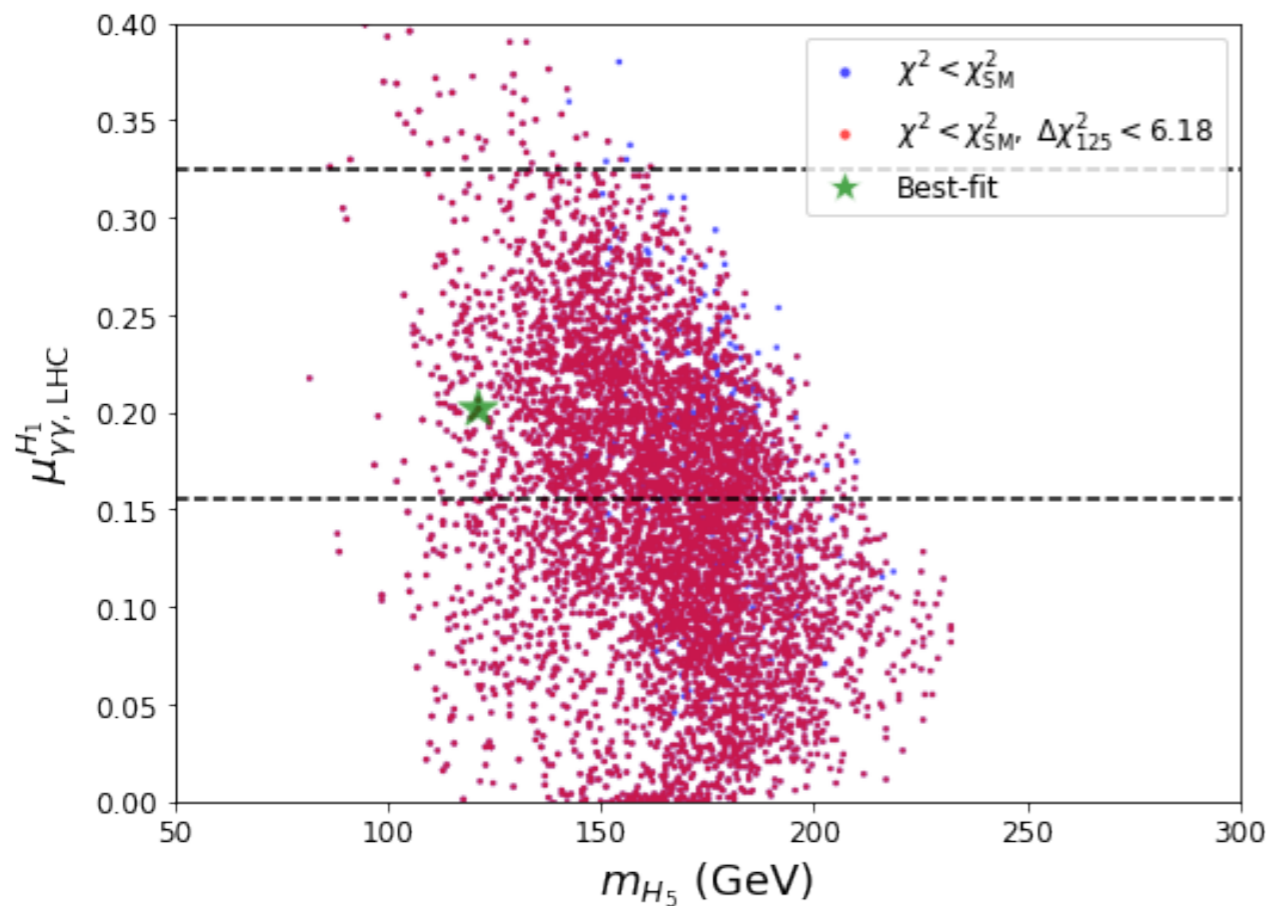
Scenario with h95 implies light BSM Higgs spectrum

# Impact of doubly-charged Higgs contribution on the $\gamma\gamma$ rate of h95

[T.-K. Chen, C.-W. Chiang, S. Heinemeyer, G. W. '23]

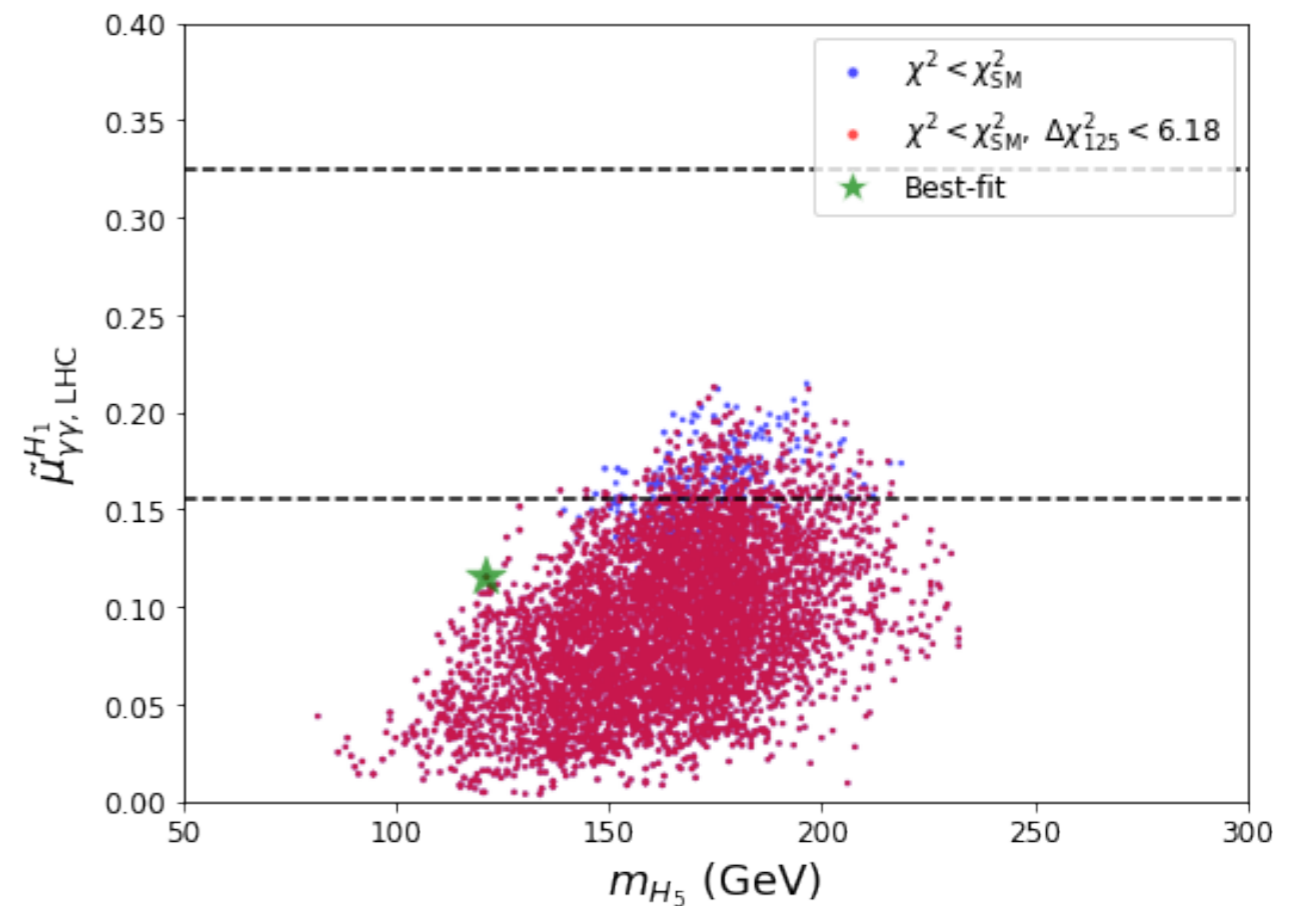
Doubly-charged Higgs contribution

included:



(a)

omitted:



(b)

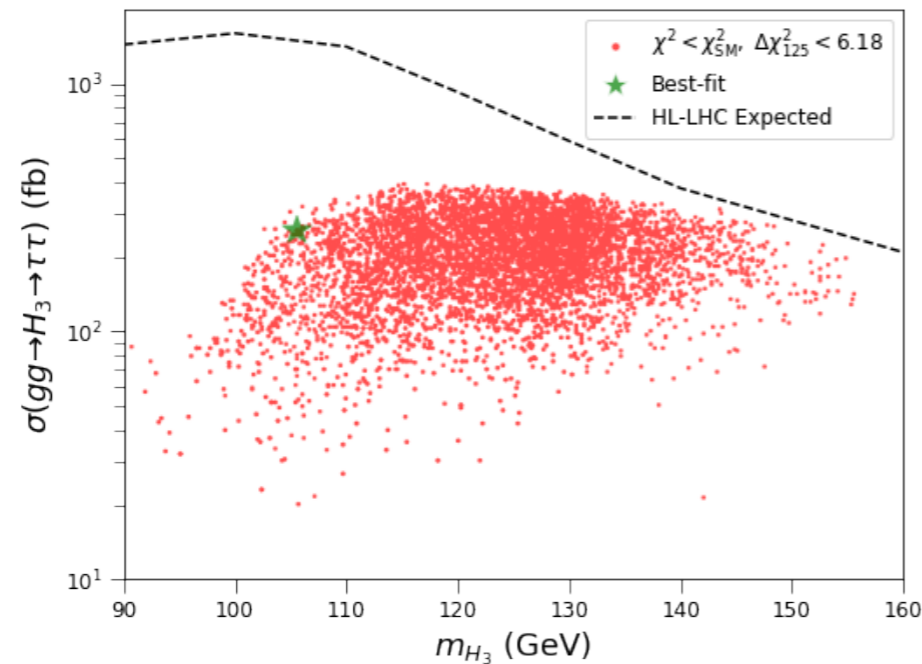
⇒ Doubly-charged Higgs contribution yields significant enhancement of the  $\gamma\gamma$  rate of h95

Motivates LHC search for light doubly-charged Higgs

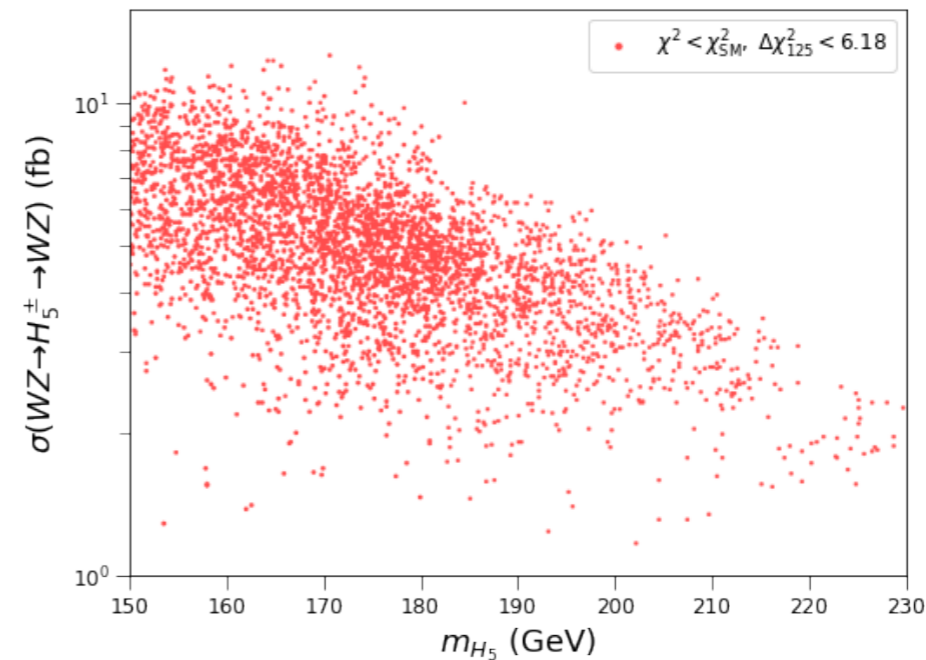
[see S. Ashanujjaman, K. Ghosh, R. Sahu '23]

# Production cross sections at the HL-LHC

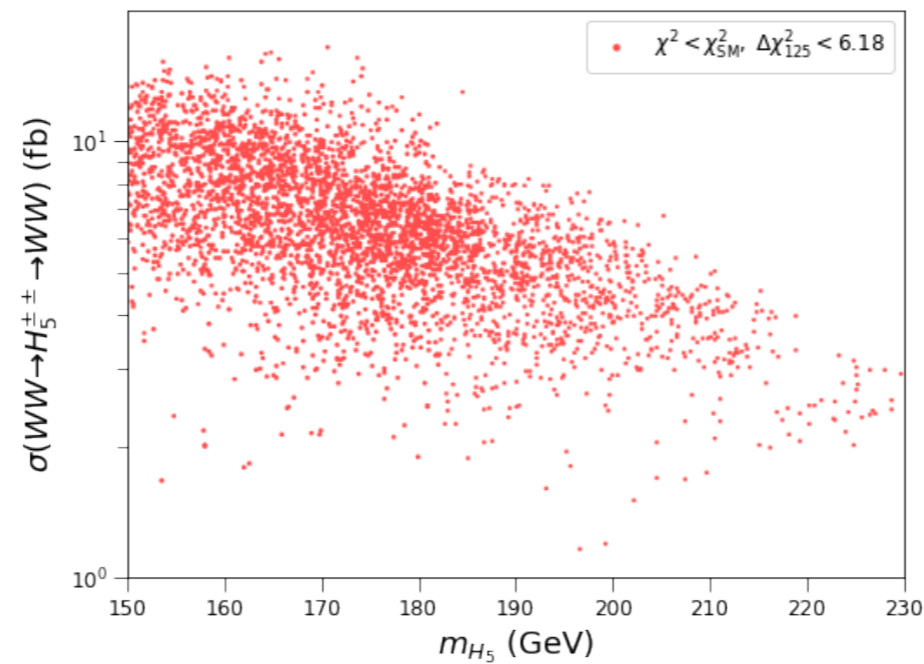
[T.-K. Chen, C.-W. Chiang, S. Heinemeyer, G. W. '23]



(a)



(b)

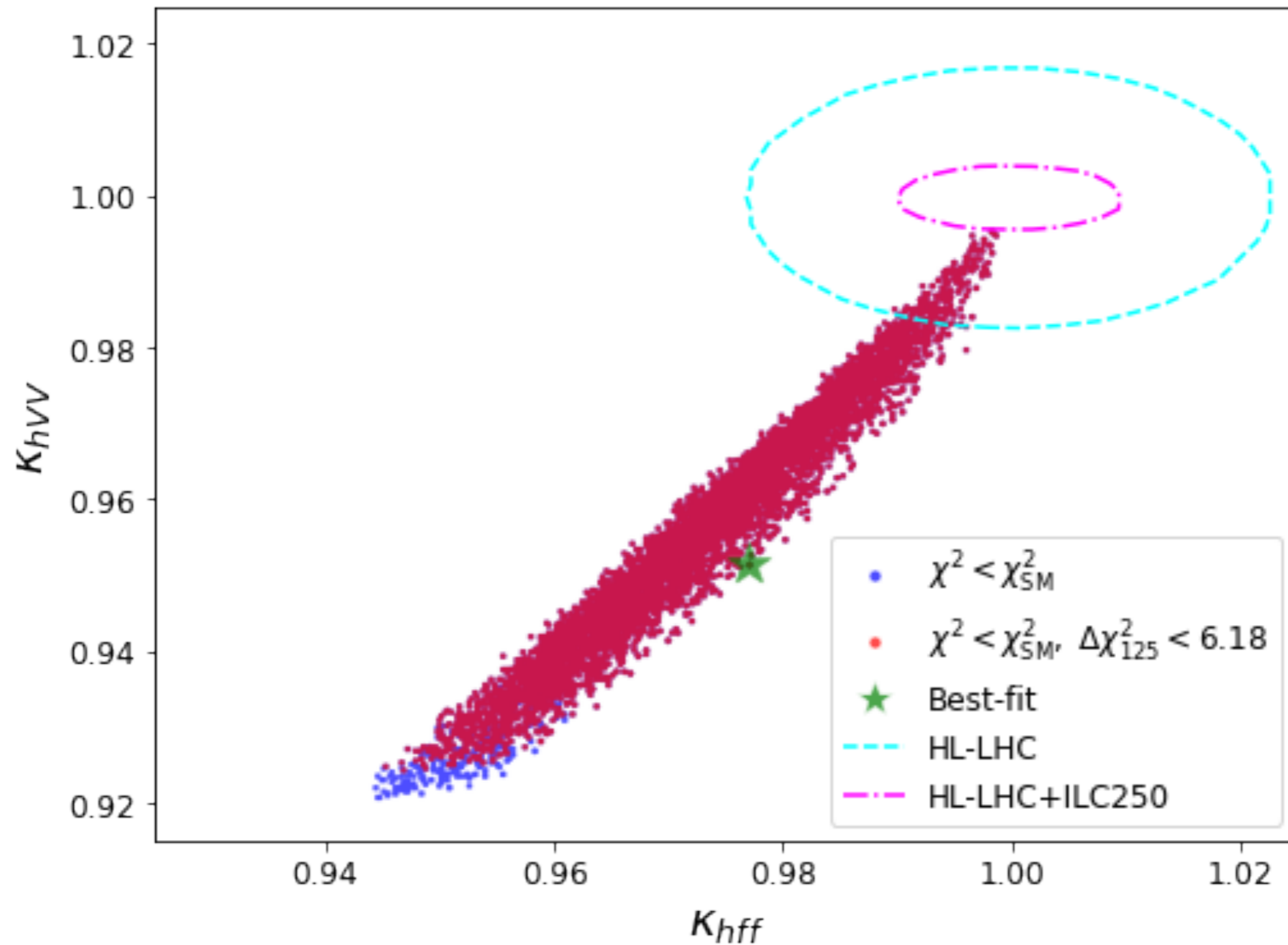


(c)

$\Rightarrow H_3 \rightarrow \tau\tau$  below projected HL-LHC sensitivity, no projections so far for displayed charged Higgs and doubly charged Higgs channels

# Impact of the coupling measurements of h125

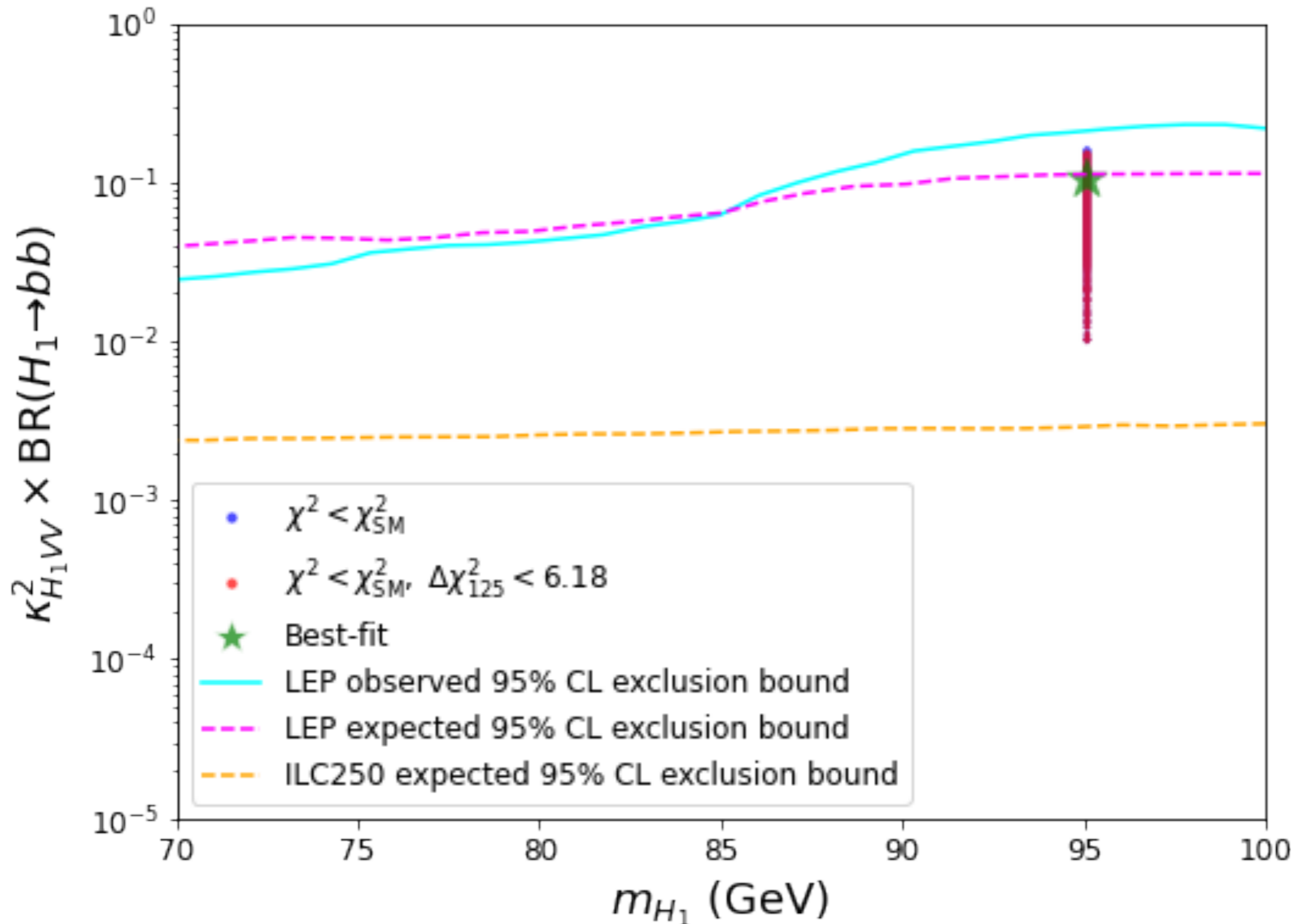
[T.-K. Chen, C.-W. Chiang, S. Heinemeyer, G. W. '23]



⇒ Significant improvement at Higgs factory, but coupling measurements of h125 may remain inconclusive

# h95 production at an $e^+e^-$ Higgs factory

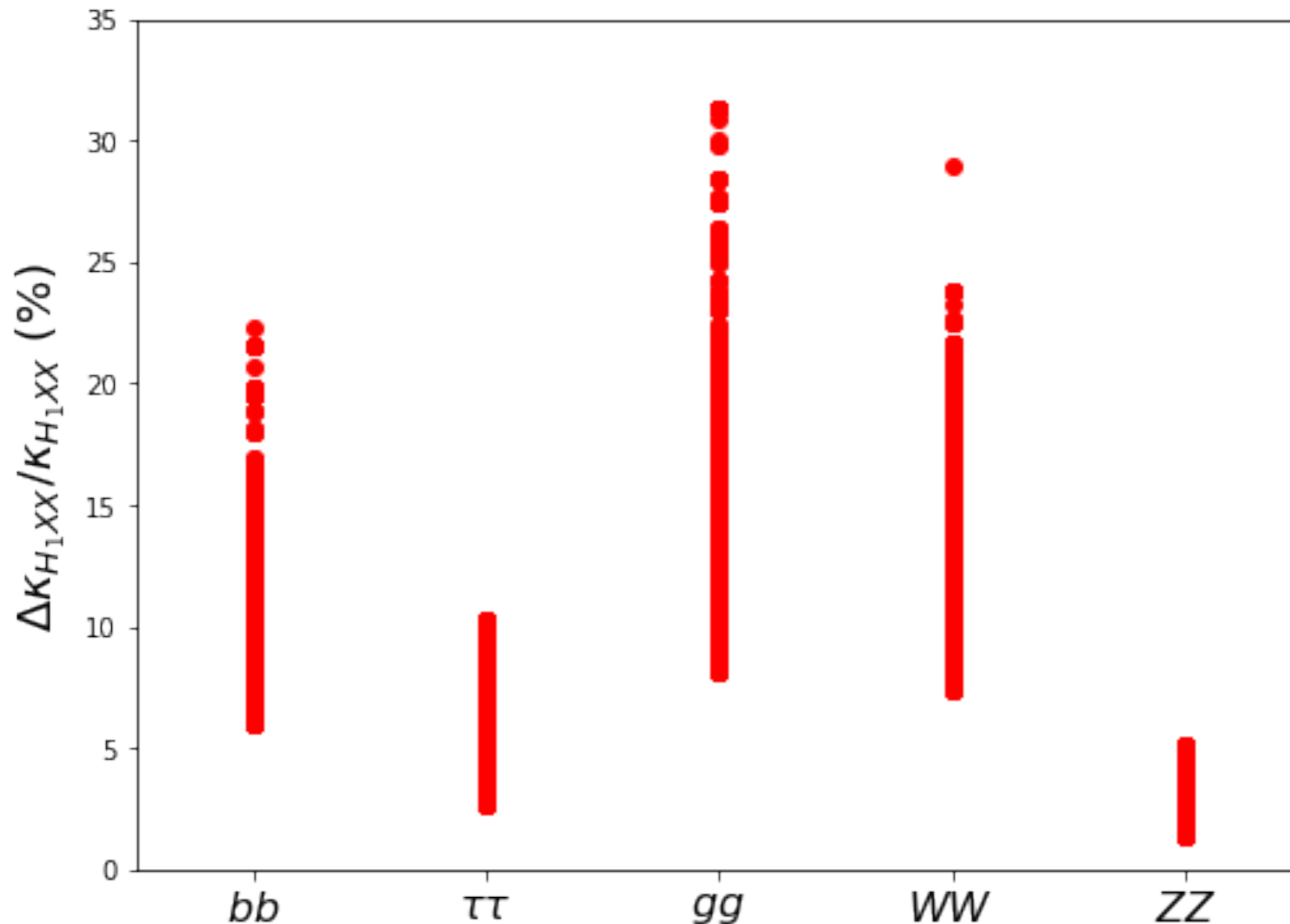
[T.-K. Chen, C.-W. Chiang, S. Heinemeyer, G. W. '23]



⇒ Production of h95 in GM model accessible at  $e^+e^-$  Higgs factory

# Prospects for coupling measurements of h95

[T.-K. Chen, C.-W. Chiang, S. Heinemeyer, G. W. '23]



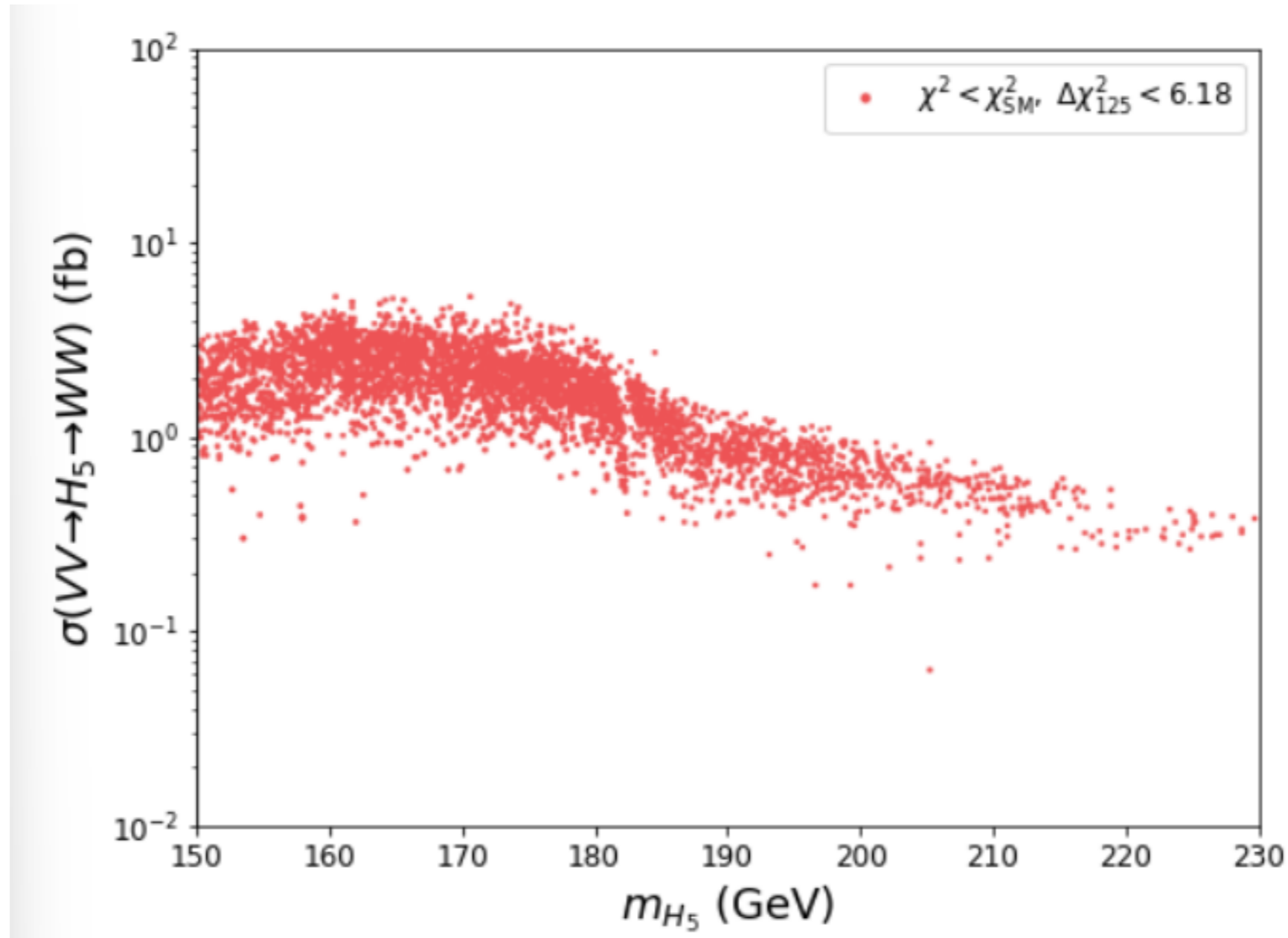
⇒ Accuracies at 1–30% level at Higgs factory, will be important for distinction between different model realisations of h95



# Could the GM model with h95 explain a possible excess at 151 GeV? [T.-K. Chen, C.-W. Chiang, S. Heinemeyer, G. W. '24]

Recent claim of possible excess at 151 GeV

[A. Crivellin et al. '24] [S. Ashanujjaman et al. '24] [...]



⇒ Interpretation of possible excess at 151 GeV does not work in the GM model with h95

# Case 2: h95 as a CP-odd Higgs boson

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Possible scenario where h95 explains only the LHC excess in the  $\gamma\gamma$  channel: CP-odd Higgs boson at 95 GeV

LHC excess in the  $\gamma\gamma$  channel: expect sizeable coupling of h95 to top quarks

Prospects at  $e^+e^-$  colliders?

$e^+e^- \rightarrow t t h95$ ,  $e^+e^- \rightarrow Z h95 h95$  (via intermediate h125), ...

⇒ Need higher c.m. energy (about 500 GeV for  $t t h95$  final state) and high luminosity

# Conclusions

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CMS + ATLAS excess in  $\gamma\gamma$  channel at 95 GeV:

well described in extended Higgs sectors with at least an additional doublet and a singlet; significant ZZ h95 coupling; simultaneous description of LEP excess possible

Higgs factory at 250 GeV: Z h95 production; coupling measurements of h125 and h95

Specific example: GM model; enhancement of  $\gamma\gamma$  rate from loop contribution of doubly charged Higgs boson; spectrum of light BSM Higgs bosons; possible HL-LHC potential in low-mass Higgs searches (neutral, charged, doubly-charged)

Interpretation of h95 in terms of CP-odd Higgs boson: study at Higgs factory would most likely require higher c.m. energies

# Backup

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# Low-mass Higgs searches at the LHC

Excesses in searches for light additional Higgs bosons:

[CMS Collaboration '18, 19, 22]

