
I FOUND THE HUGS BISON.
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The Discovery of the Second Higgs Boson

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DESY/zoom, 06/2023

Based on a collaboration with

T. Biekötter and G. Weiglein [arXiv:2306.03889]

LHC Seminar

Measurement of Higgs boson production and search for new resonances in final states with photons and Z bosons

by Chiara Arcangeletti (INFN e Laboratori Nazionali di Frascati (IT))

Tuesday 6 Jun 2023, 11:00 → 12:00 Europe/Zurich

500/1-001 - Main Auditorium (CERN)

New ATLAS result on the low-mass Higgs search in $pp \to \phi \to \gamma\gamma$

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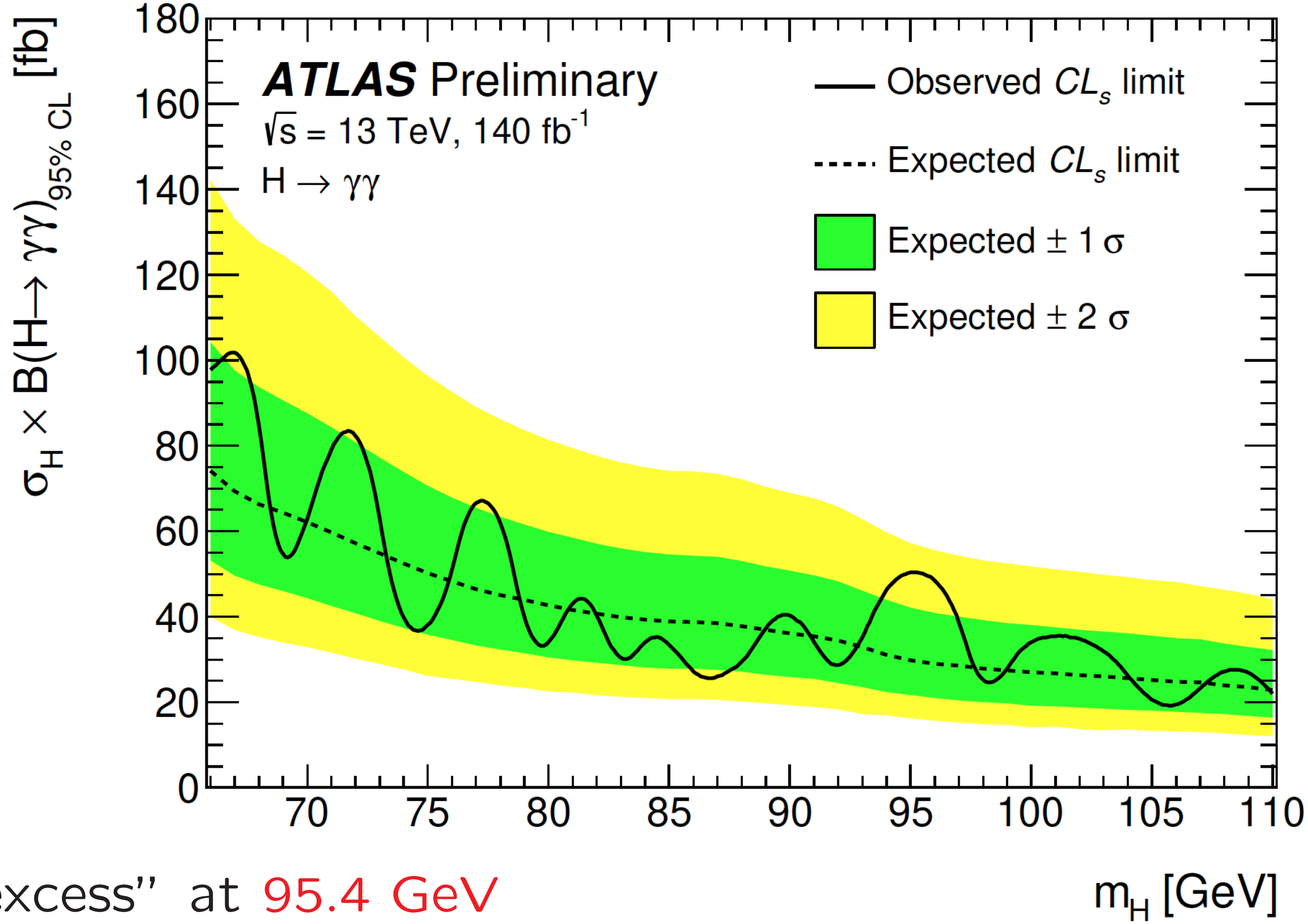
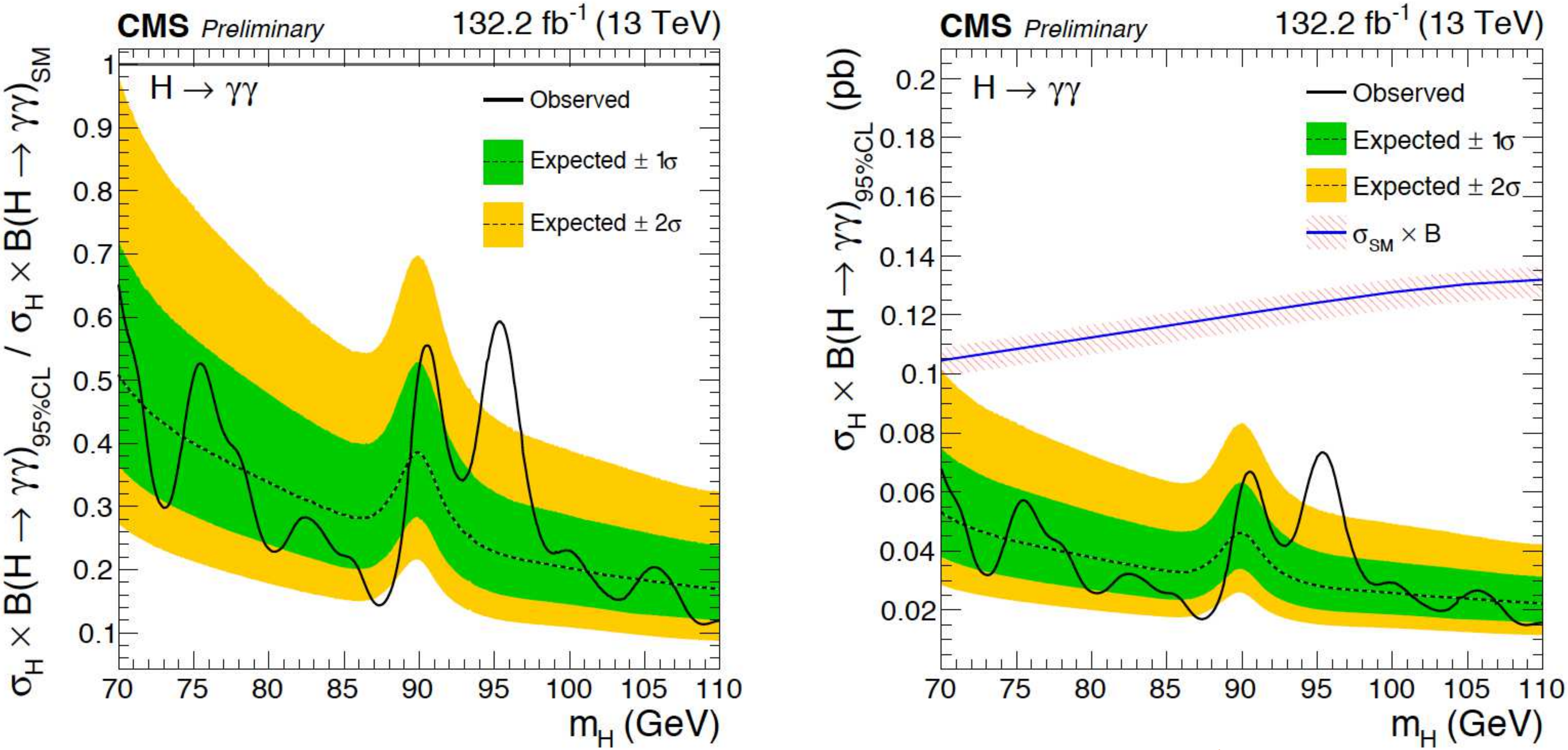
New ATLAS result on the low-mass Higgs search in $pp \to \phi \to \gamma\gamma$



$\Rightarrow$ higest "excess" at 95.4 GeV

Full Run 2 results from CMS: excess at 95.4 GeV [CMS '23]

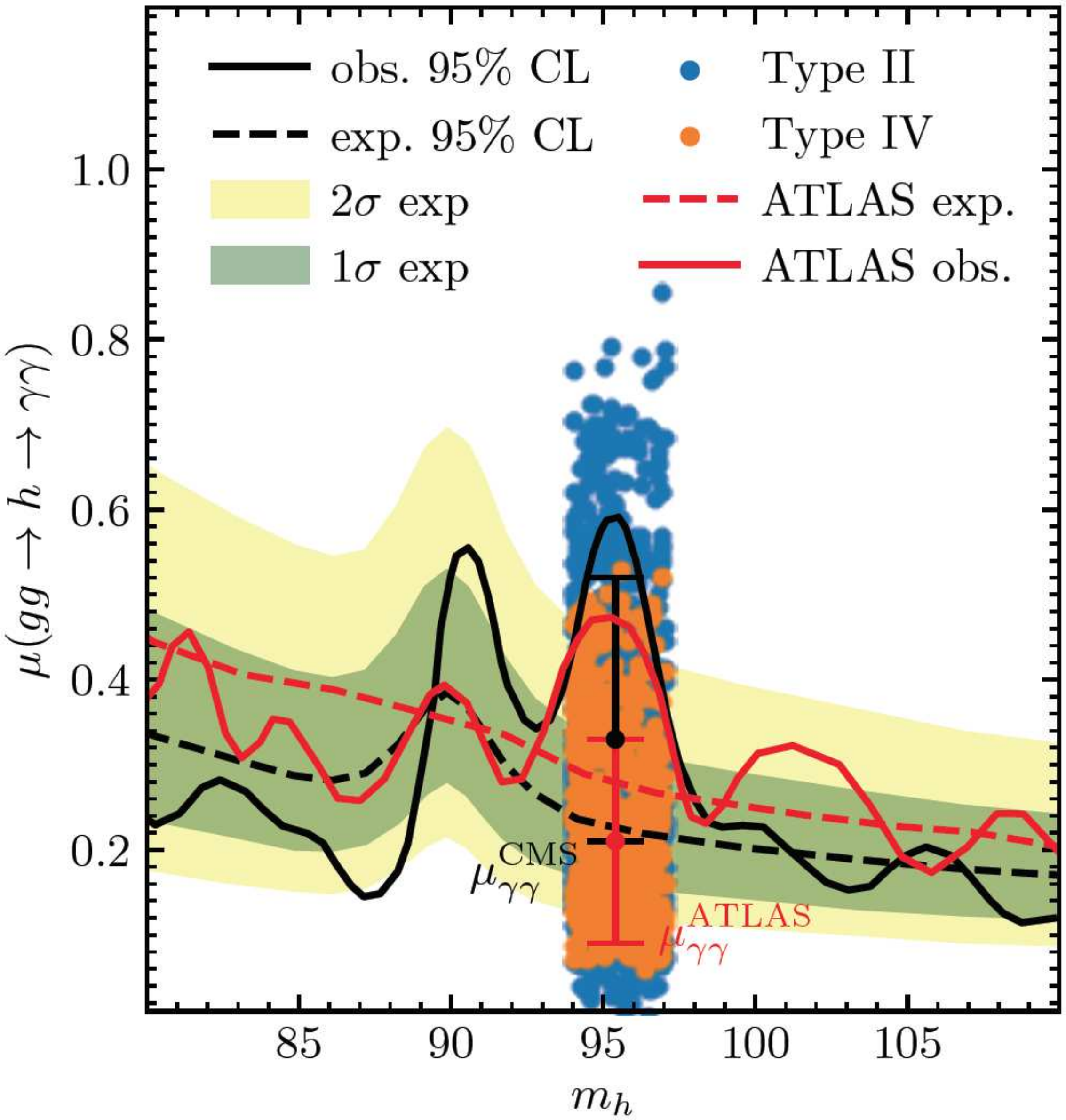


$$\mu_{\gamma\gamma}^{\text{CMS}} = [\sigma(gg \to h_{95}) \times \text{BR}(h_{95} \to \gamma\gamma)]_{\text{exp/SM}} = 0.33^{+0.19}_{-0.12}\ (2.9\,\sigma)$$

$$\mu_{\gamma\gamma}^{\text{ATLAS}} = 0.21 \pm 0.12\ (1.7\,\sigma)$$

New CMS/ATLAS comparison:

[*T. Biekötter, S.H., G. Weiglein '23*]



$\Rightarrow$ agreement between ATLAS and CMS!

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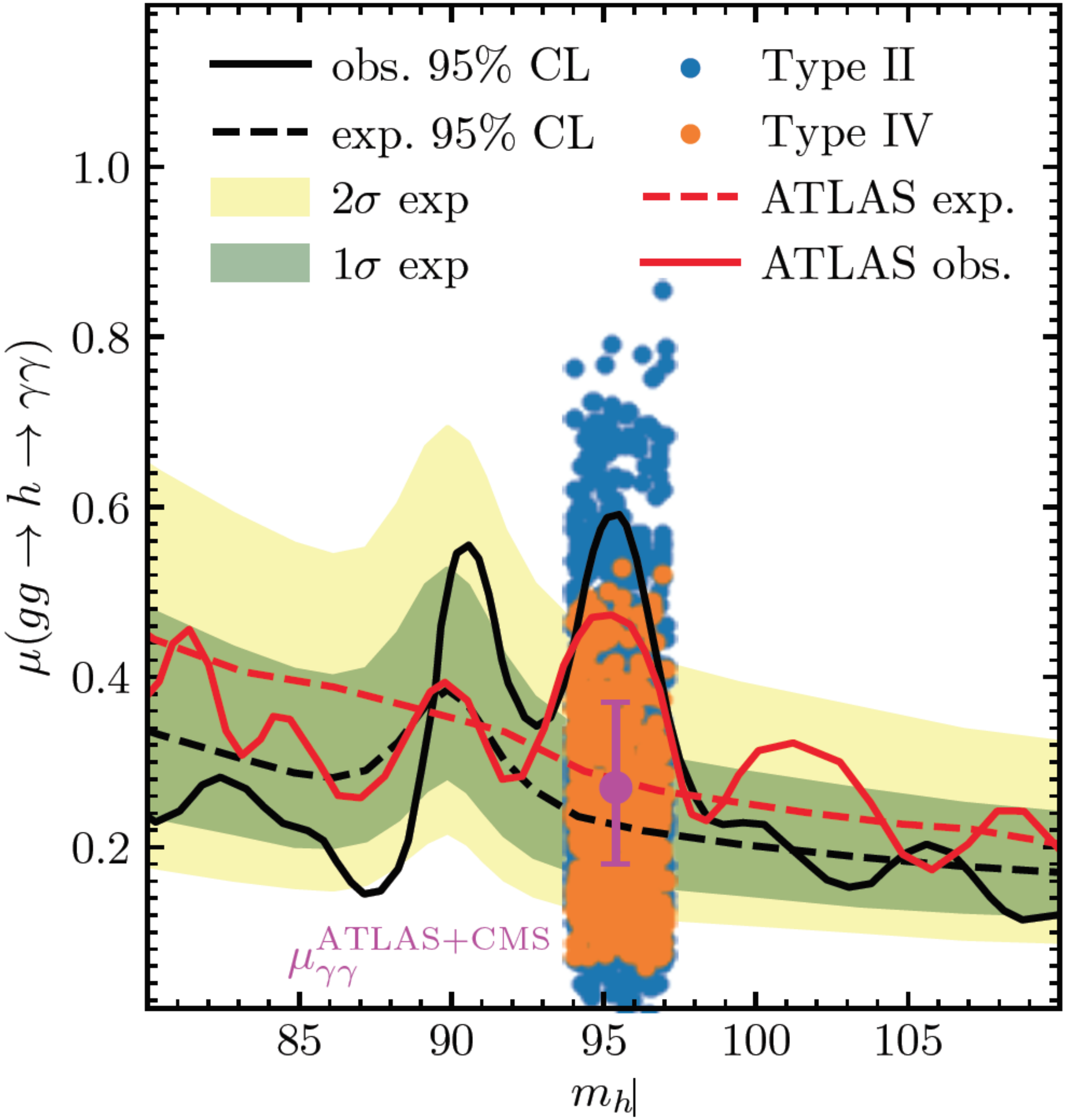
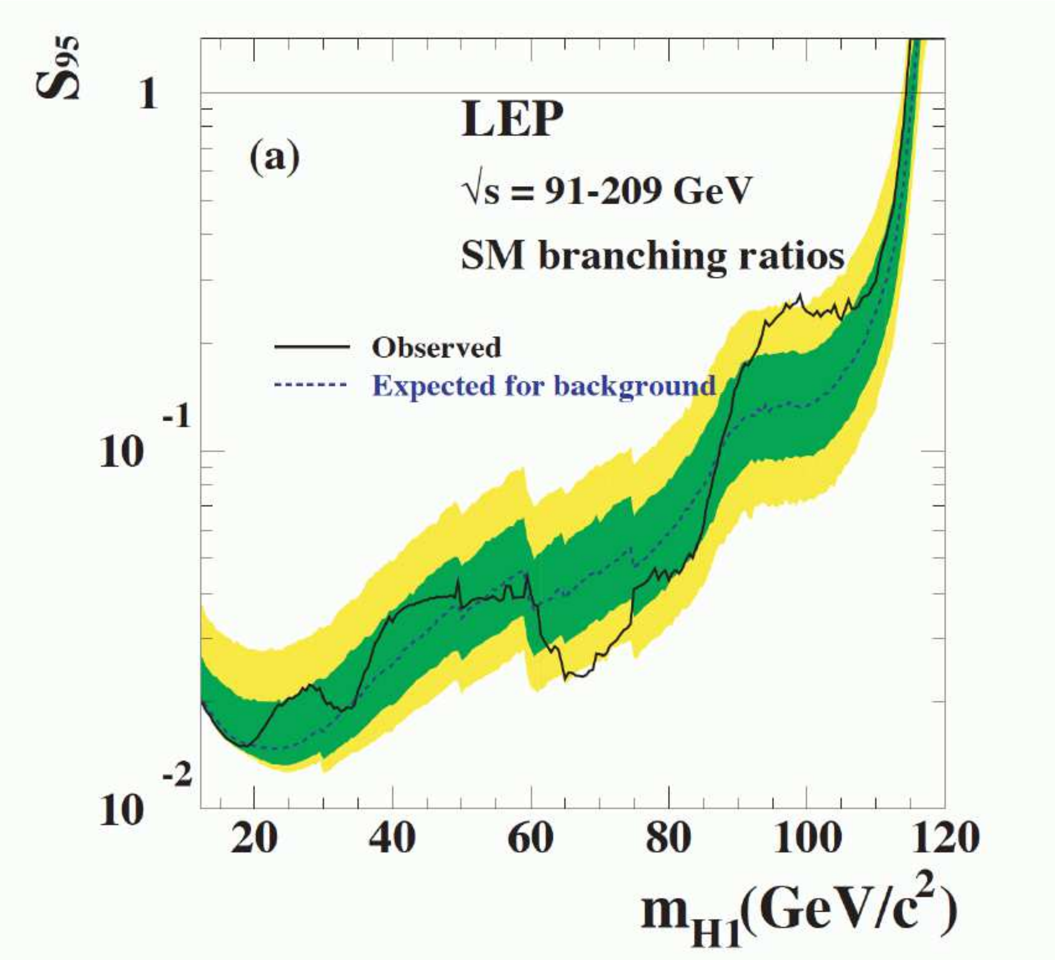


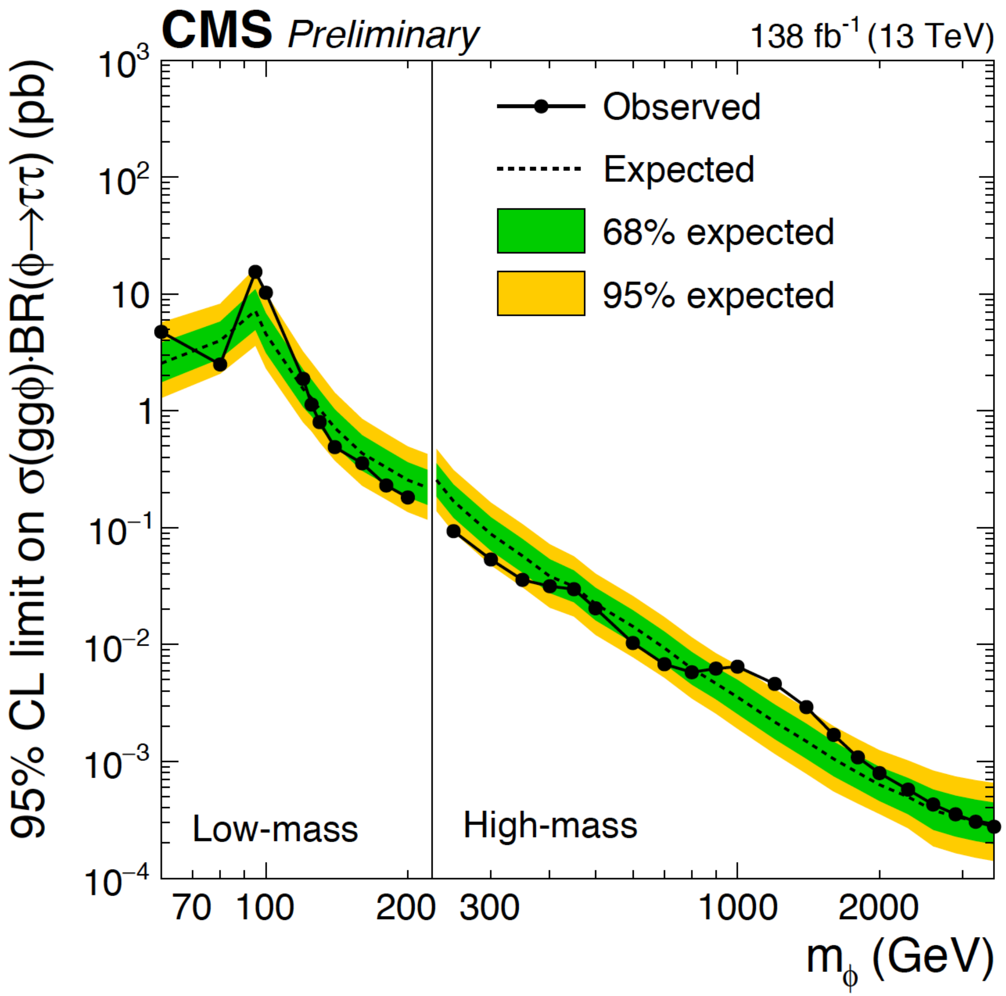
$\Rightarrow$ agreement between ATLAS and CMS!

$\mu_{\gamma\gamma} = 0.27^{+0.10}_{-0.09}$ (3.2 σ)

LEP: $e^+e^- \to Z\phi \to Zb\bar{b}$ $(2\,\sigma)$



CMS: $pp \to \phi \to \tau^+\tau^-$ $(2.4\,\sigma)$



$\Rightarrow$ no LEE (as theorist I am allowed to add naively)

$$\boxed{\Rightarrow \sim 4.6\,\sigma}$$

S2HDM: 2 Higgs doublets (complex) + 1 Higgs singlet (complex)

Three neutral $\mathcal{CP}$-even Higgses:

$$\begin{pmatrix} h_1 \\ h_2 \\ h_3 \end{pmatrix} = R \begin{pmatrix} \rho_1 \\ \rho_2 \\ \rho_S \end{pmatrix} , \quad R = \begin{pmatrix} c_{\alpha_1} c_{\alpha_2} & s_{\alpha_1} c_{\alpha_2} & s_{\alpha_2} \\ -(c_{\alpha_1} s_{\alpha_2} s_{\alpha_3} + s_{\alpha_1} c_{\alpha_3}) & c_{\alpha_1} c_{\alpha_3} - s_{\alpha_1} s_{\alpha_2} s_{\alpha_3} & c_{\alpha_2} s_{\alpha_3} \\ -c_{\alpha_1} s_{\alpha_2} c_{\alpha_3} + s_{\alpha_1} s_{\alpha_3} & -(c_{\alpha_1} s_{\alpha_3} + s_{\alpha_1} s_{\alpha_2} c_{\alpha_3}) & c_{\alpha_2} c_{\alpha_3} \end{pmatrix}$$

Coupling to fermions: (same pattern as in 2HDM)

	u-type ($c_{h_i tt}$)	d-type ($c_{h_i bb}$)	leptons ($c_{h_i \tau\tau}$)
type I	$\frac{R_{i2}}{s_\beta}$	$\frac{R_{i2}}{s_\beta}$	$\frac{R_{i2}}{s_\beta}$
type II	$\frac{R_{i2}}{s_\beta}$	$\frac{R_{i1}}{c_\beta}$	$\frac{R_{i1}}{c_\beta}$
type III (lepton-specific)	$\frac{R_{i2}}{s_\beta}$	$\frac{R_{i2}}{s_\beta}$	$\frac{R_{i1}}{c_\beta}$
type IV (flipped)	$\frac{R_{i2}}{s_\beta}$	$\frac{R_{i1}}{c_\beta}$	$\frac{R_{i2}}{s_\beta}$

"Physical" input parameters:

$$\alpha_{1,2,3} \,, \quad \tan\beta \,, \quad v \,, \quad v_S \,, \quad m_{h_{1,2,3}} \,, \quad m_A \,, \quad M_{H^\pm} \,, \quad m_\chi \,, \quad m_{12}^2$$

Needed to fit the two excesses: $m_{h_1} \sim 95$ GeV, $m_{h_2} \sim 125$ GeV

- $c^2_{h_1VV}$ strongly reduced for μ_{LEP}
- c_{h_1bb} reduced to enhance BR($h_1 \to \gamma\gamma$)
- c_{h_1tt} not reduced for μ_{CMS}
- $c_{h_1\tau\tau}$ possibly reduced to enhance BR($h_1 \to \gamma\gamma$)

	Decrease $c_{h_1 b\bar{b}}$	No decrease $c_{h_1 t\bar{t}}$	No enhancement $c_{h_1 \tau\bar{\tau}}$
type I	$(\frac{R_{12}}{s_\beta})$:-)	$(\frac{R_{12}}{s_\beta})$:-(	$(\frac{R_{12}}{s_\beta})$
type II	$(\frac{R_{11}}{c_\beta})$:-)	$(\frac{R_{12}}{s_\beta})$:-)	$(\frac{R_{11}}{c_\beta})$
type III	$(\frac{R_{12}}{s_\beta})$:-)	$(\frac{R_{12}}{s_\beta})$:-(	$(\frac{R_{11}}{c_\beta})$
type IV	$(\frac{R_{11}}{c_\beta})$:-)	$(\frac{R_{12}}{s_\beta})$:-)	$(\frac{R_{12}}{s_\beta})$

Type II and IV: c_{h_1bb} and c_{h_1tt} independent

Type II vs. IV: $c_{h_1\tau\tau}$ can be suppressed or enhanced

$\Rightarrow$ only type II and IV can fit CMS and LEP excesses

S2HDM type II vs. type IV

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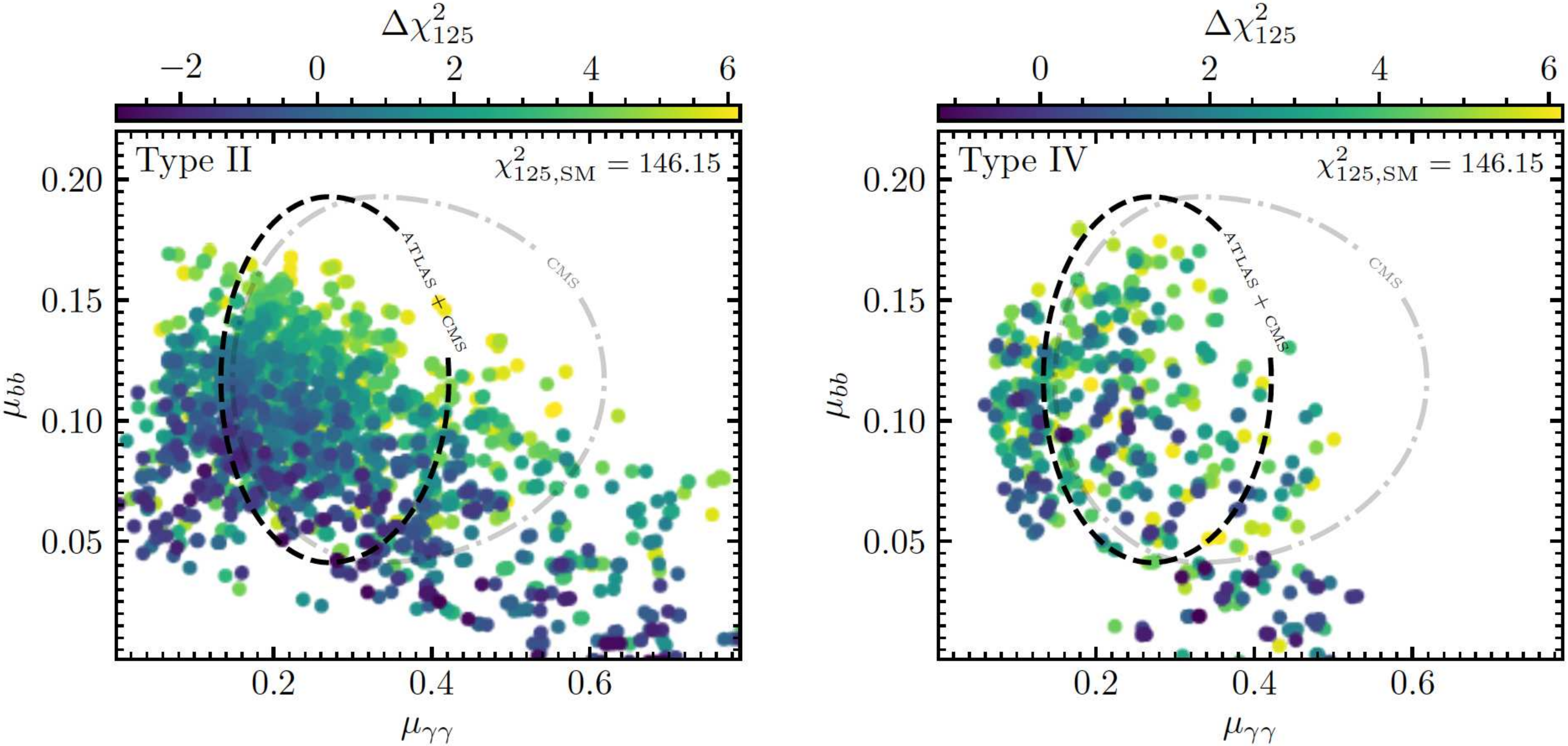

Color coding: χ^2_{125} from HiggsSignals

$\Rightarrow$ both type II and IV can fit the $\gamma\gamma$ and bb excesses

S2HDM type II vs. type IV

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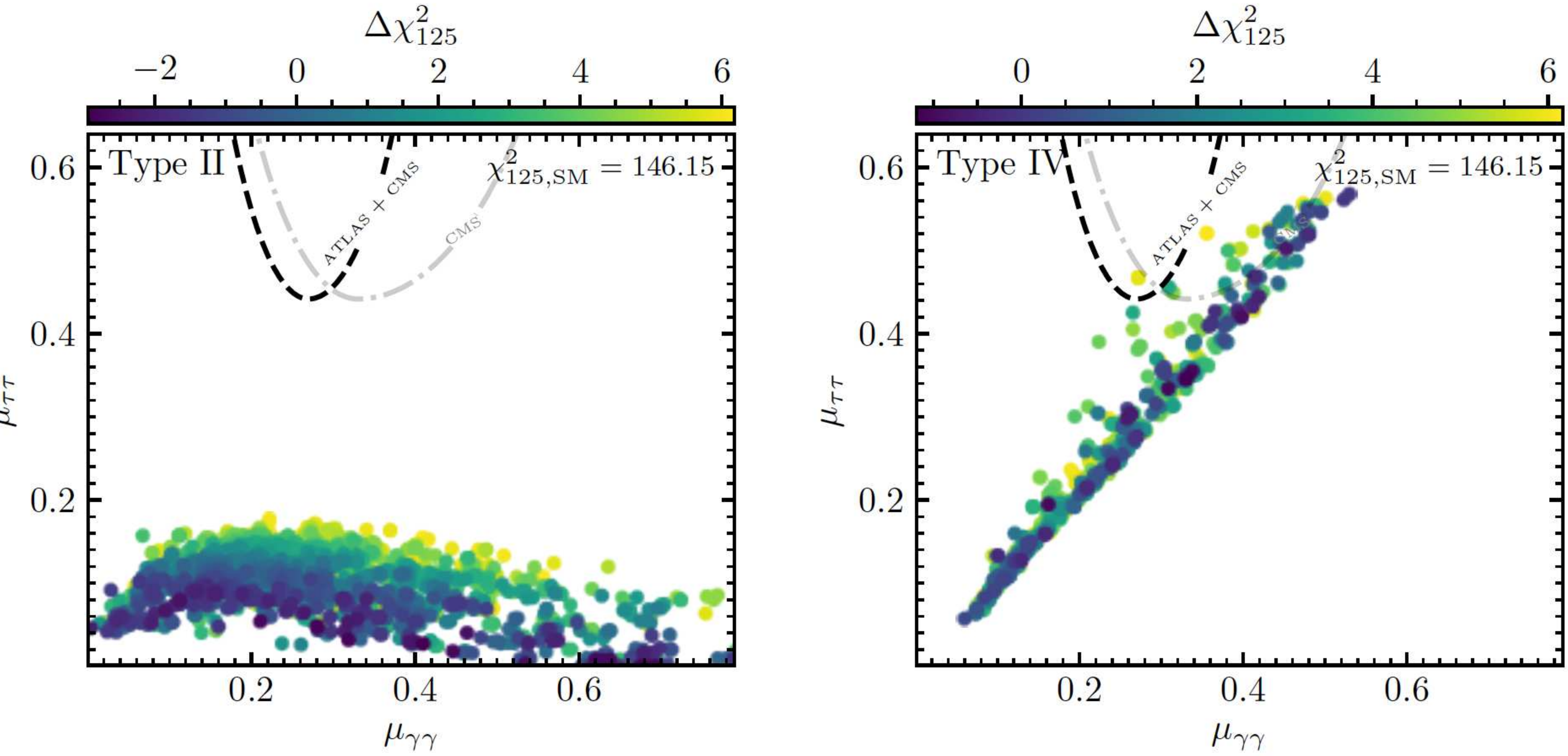

Color coding: χ^2_{125} from HiggsSignals

$\Rightarrow$ only type IV can fit marginally the $\gamma\gamma$ and $\tau\tau$ excesses


Further Questions?