

A short plea for H(650)



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Work in preparation of the 2023 ECFA Workshop on Higgs/EW/Top factories
in Paestum (Salerno) / Italy from 11 - 13 October 2023



F. Richard IJCLab September 2023

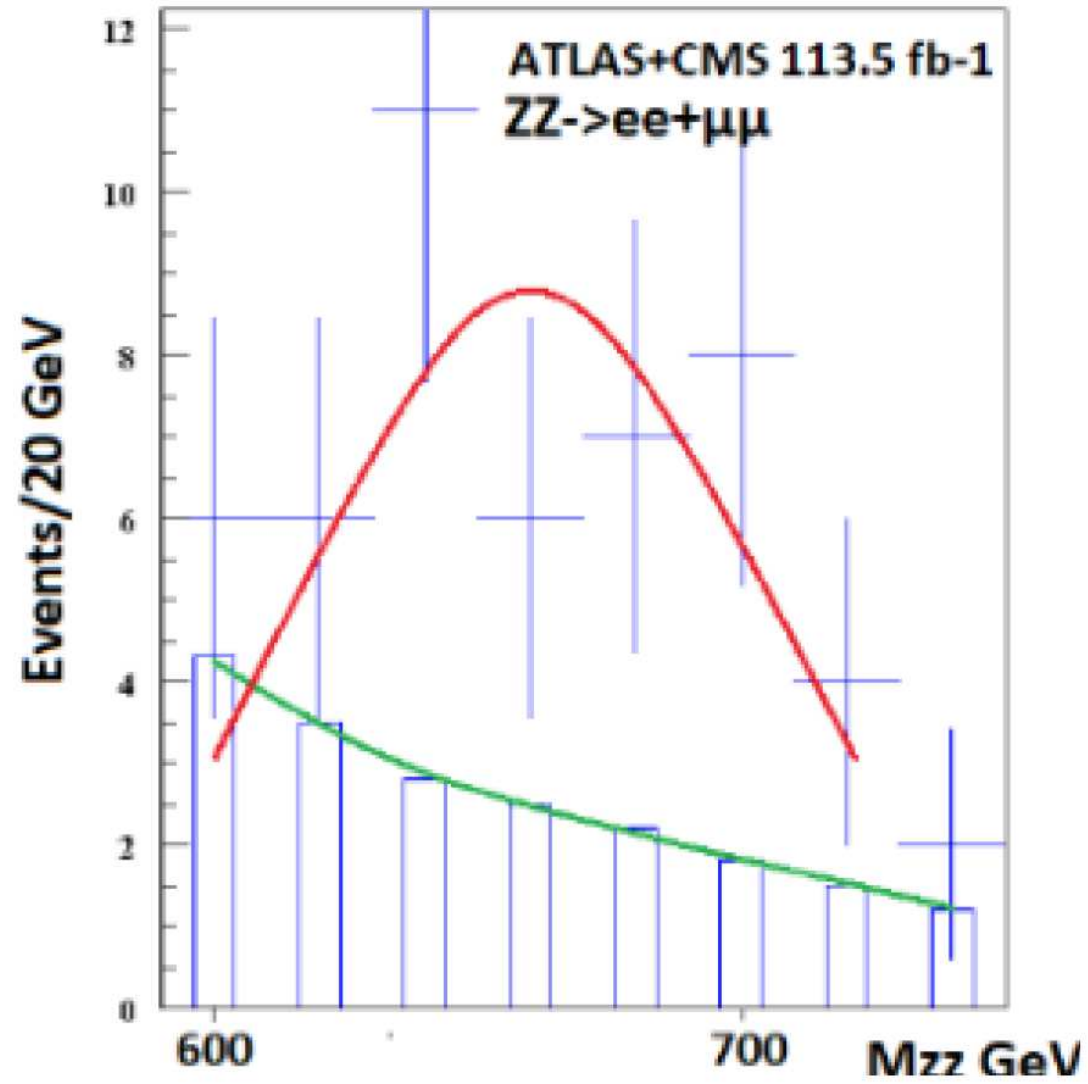
Introduction I

- With RUN2 data there has been growing evidence for a wide resonance with $M=650$ GeV and $\Gamma_{\text{tot}}=100$ GeV
- Seen in 3 modes ZZ, WW, $h(125)h'(95)$, each > 3.5 s.d.
- Historically this work started in 2018 [1806.04529](#) with the mode ZZ, confirmed by [2103.01918](#), then came WW [2104.04762](#) and $h(95)h(125)$
HIG-21-011
- Putting them together, one reaches **6 s.d. global** (Fisher method)
- Question: how to interpret this resonance in the context of existing phenomenology ?

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2

$h_{650} \rightarrow ZZ:$



$h_{650} \rightarrow WW$:

\Rightarrow what about ATLAS?

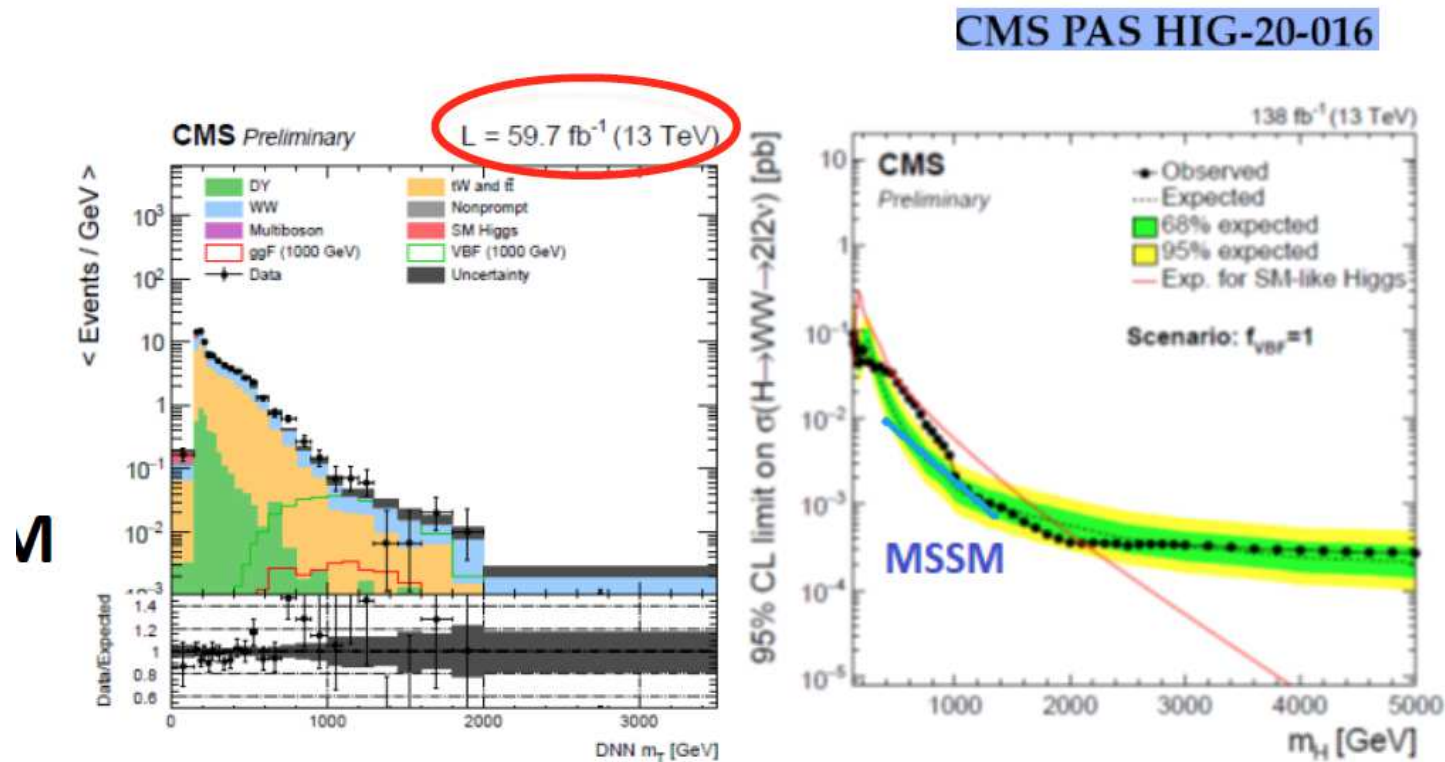
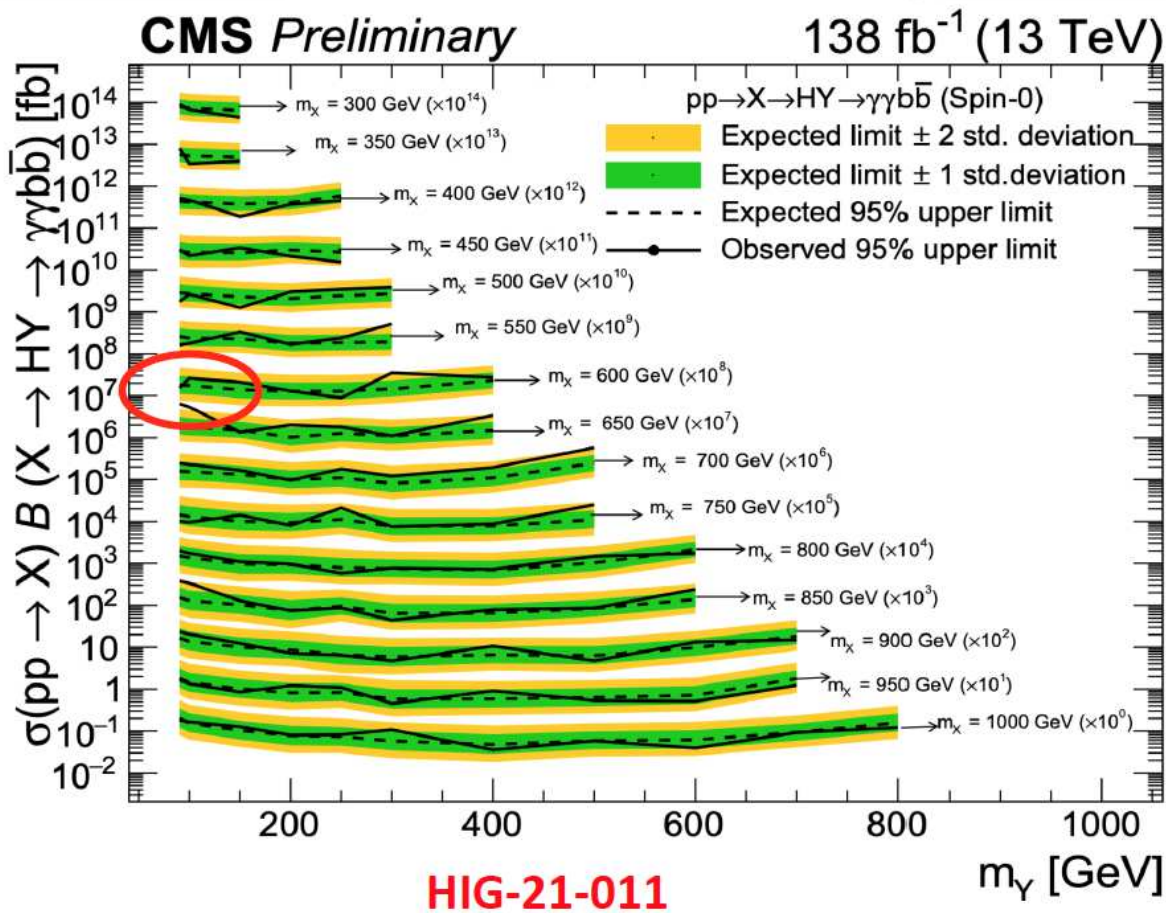
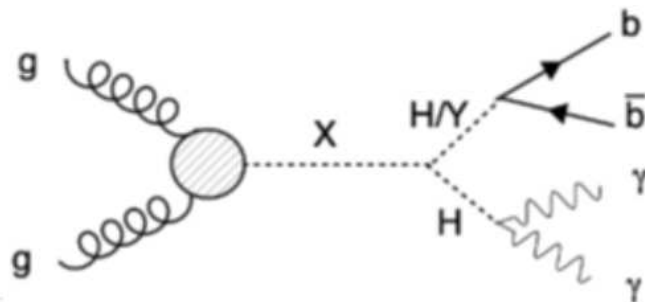


Table 3: Summary of the signal hypotheses with highest local significance for each f_{VBF} scenario. For each signal hypothesis the resonance mass, production cross sections, and the local and global significances are given.

Scenario	Mass [GeV]	ggF cross sec. [pb]	VBF cross sec. [pb]	Local signi. [σ]	Global signi. [σ]
SM f_{VBF}	800	0.16	0.057	3.2	1.7 ± 0.2
$f_{VBF} = 1$	650	0.0	0.16	3.8	2.6 ± 0.2
$f_{VBF} = 0$	950	0.19	0.0	2.6	0.4 ± 0.6
floating f_{VBF}	650	2.9×10^{-6}	0.16	3.8	2.4 ± 0.2

$h_{650} \rightarrow h_{125} h_{95} \rightarrow \gamma\gamma b\bar{b}$:

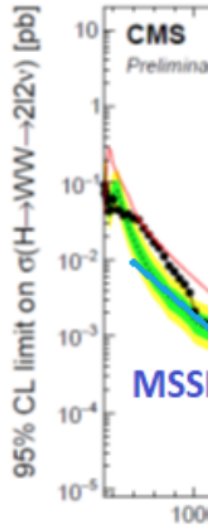
\Rightarrow what about ATLAS?



2

Model independent statement

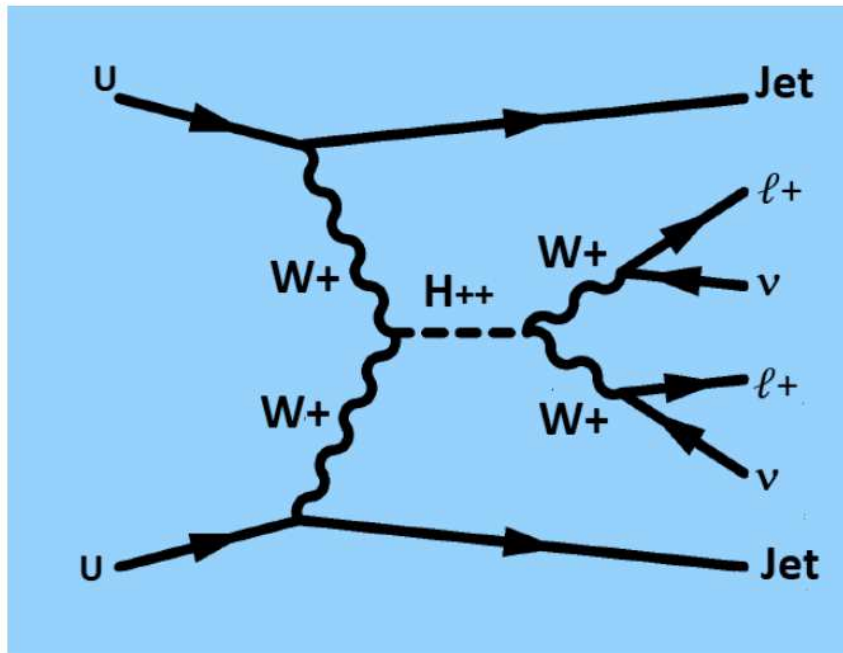
- Here I would like to emphasize a **model independent** aspect of this resonance: the fact that it couples to $W+W^-$ with \sim the same strength as $h(125)$ which breaks down a **unitarity sum rule (SR) due to Haber et al.** [Phys. Rev. D43, 904 \(1991\)](#)
- There is no remedy for this in 2HD+singlets while models with **triplets** offer the possibility of a compensation through an H^{++} (**u channel exchange** of opposite sign)
- One therefore predicts the appearance of $H^{++} \rightarrow W+W^+$ with a coupling $\sim H(600)W+W^-$
- This particle is ideally produced at LHC and can be cleanly seen in leptonic modes and can be reconstructed by the transverse mass method



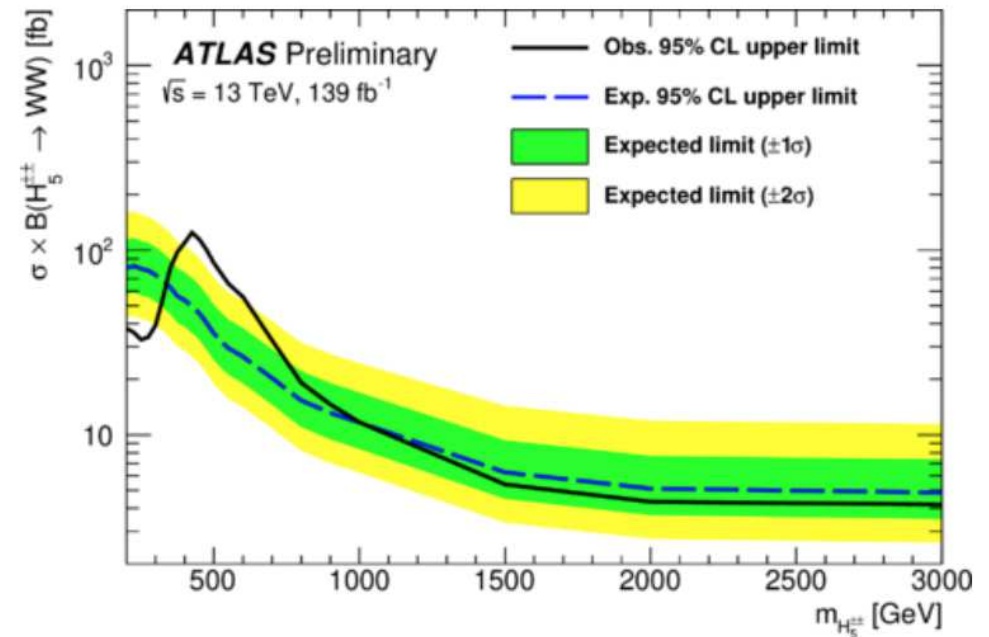
CMS

Hints from LHC

- Recently at the Belgrade ATLAS meeting: $H_{5}^{++}(450) \rightarrow W^{+}W^{+}$



- [ATLAS-CONF-2023-023/](#)
- 3.2 s.d. local, 2.5 s.d. global



Conclusions

- Growing confidence that **BSM physics** is – at last ! – showing up with strong synergy between H(650) and H⁺⁺(450) and H⁺(375)
- **Final consolidation** for H(650) should come soon from CMS with **ZZ**
- These observations can be accommodated in an extended version of GM
- As expected from e-GM, several other signals lying around, not discussed here
- Very rich prospects for HEP !
- Read our papers and a recent talk:

[2211.11723](#) , [2308.12180](#) and <https://indico.cern.ch/event/1253605/>

- Stay tuned !

**and now it's time for something
completely different**



Discussion on “BSM Higgs Searches/Rare Higgs Decays”

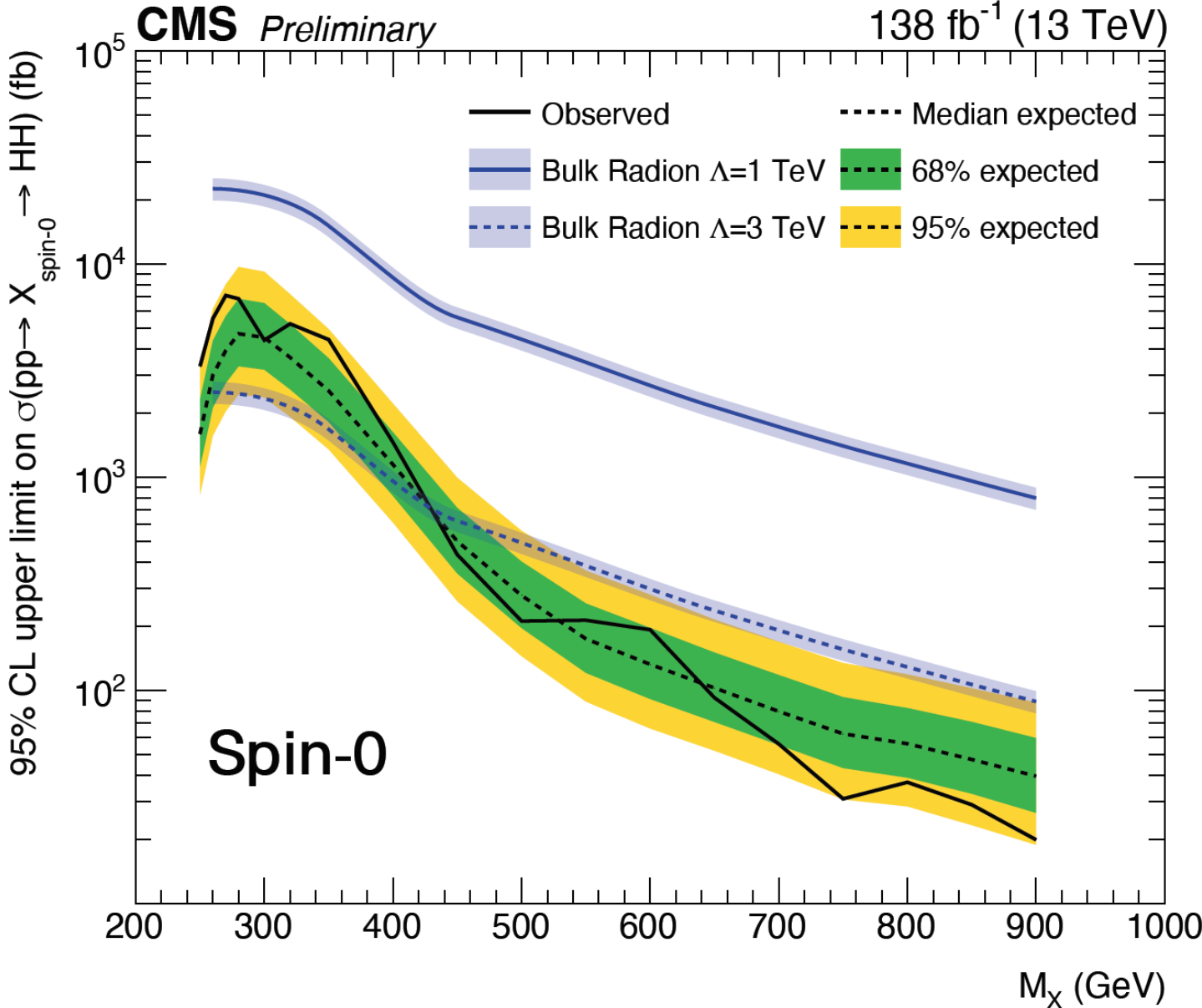
Sven Heinemeyer, IFT (CSIC, Madrid)

Paris, 09/2023

Talks:

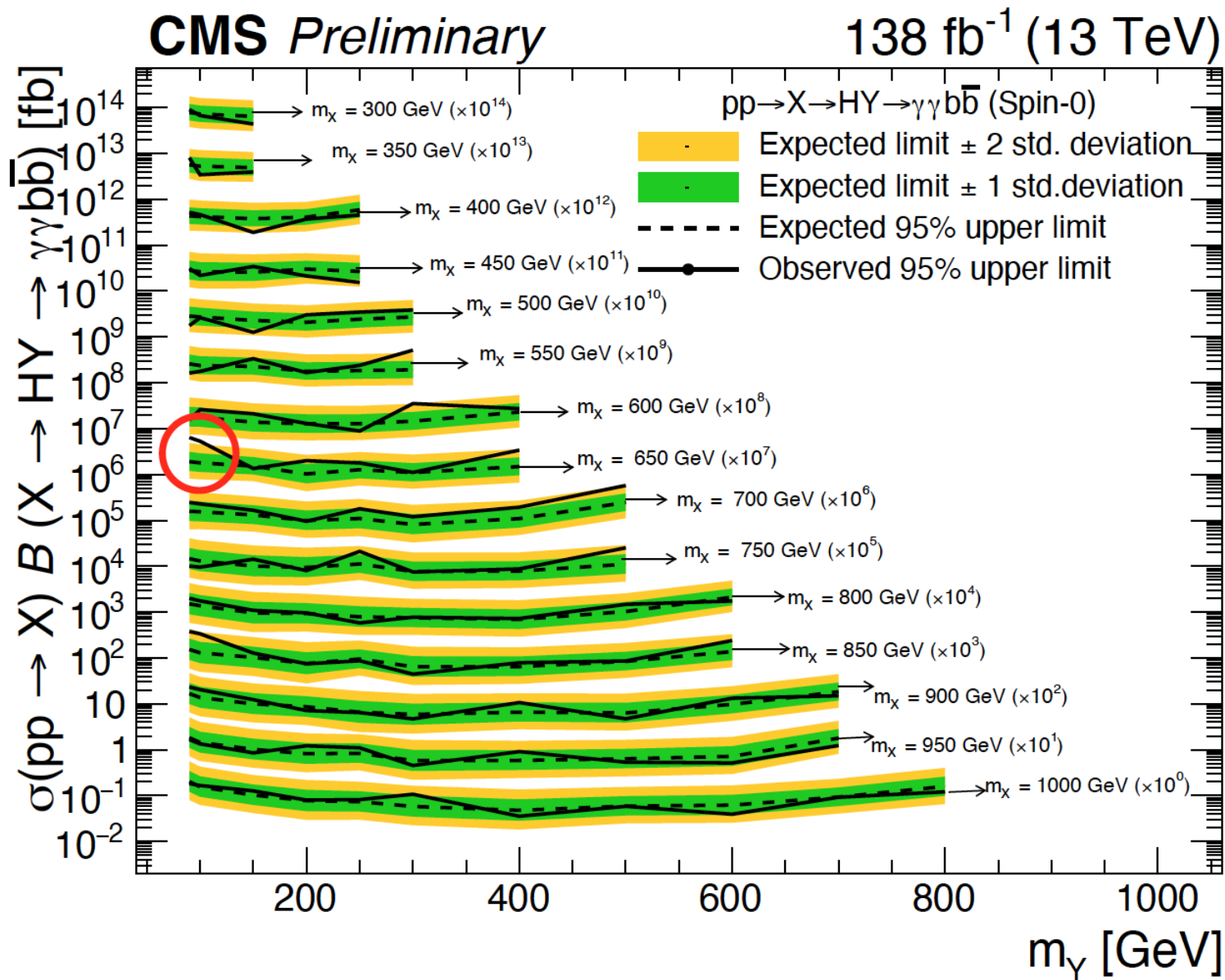
- Lerothodi Leeuw
 - Chayanit Asawatangtrakuldee
 - Michael Kwok Lam Chu
 - Jingyu Zhang
- ⇒ nearly no ATLAS – CMS comparison ... ⇒ not possible
- ⇒ just a few (personally biased) examples ...
- ⇒ interesting what is shown ...
- ⇒ even more revealing what is not shown!
- ⇒ one real excess was mentioned ...

Shown BSM limits, but not really helpful: $pp \rightarrow X \rightarrow h_{125}h_{125}$



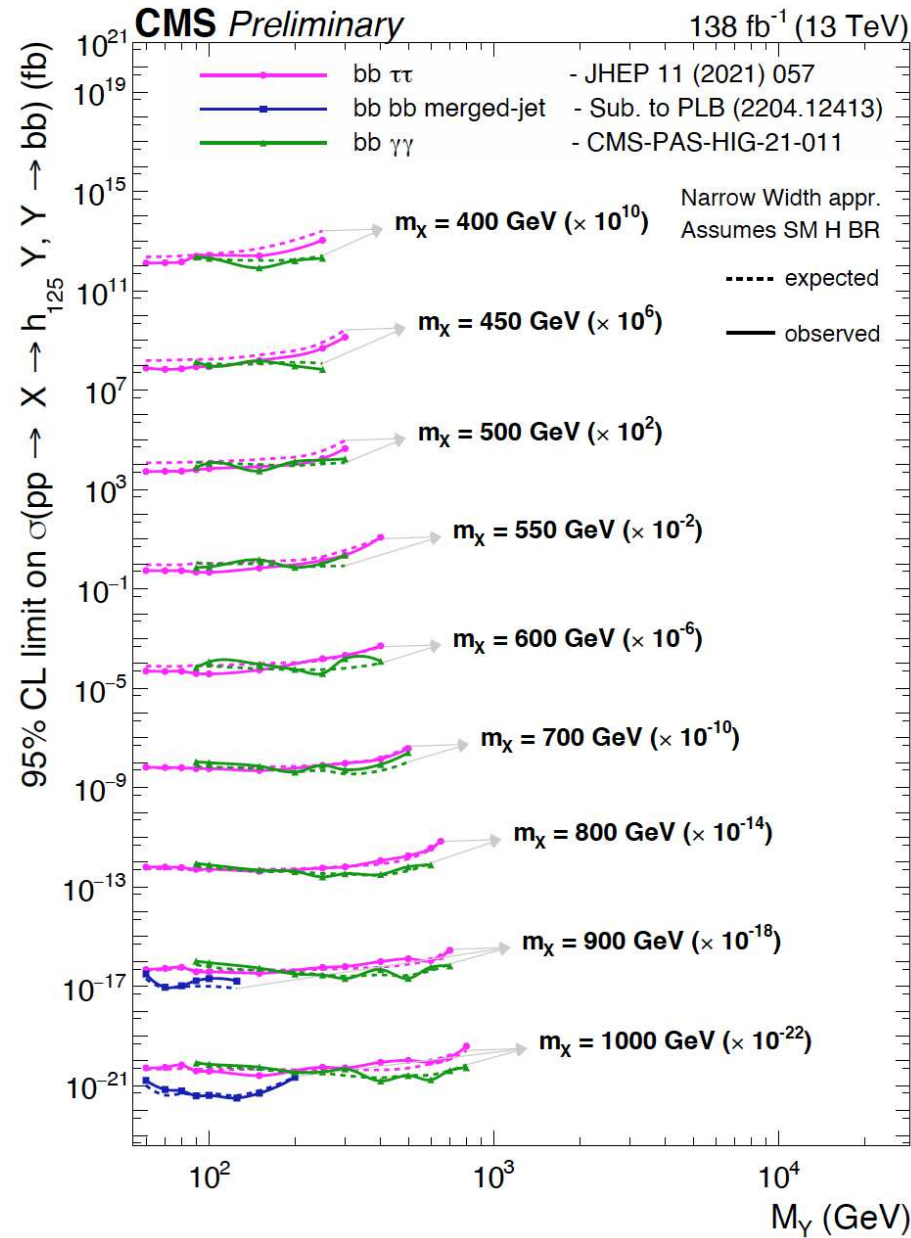
⇒ signal model knowingly wrong ...

Only excess shown:



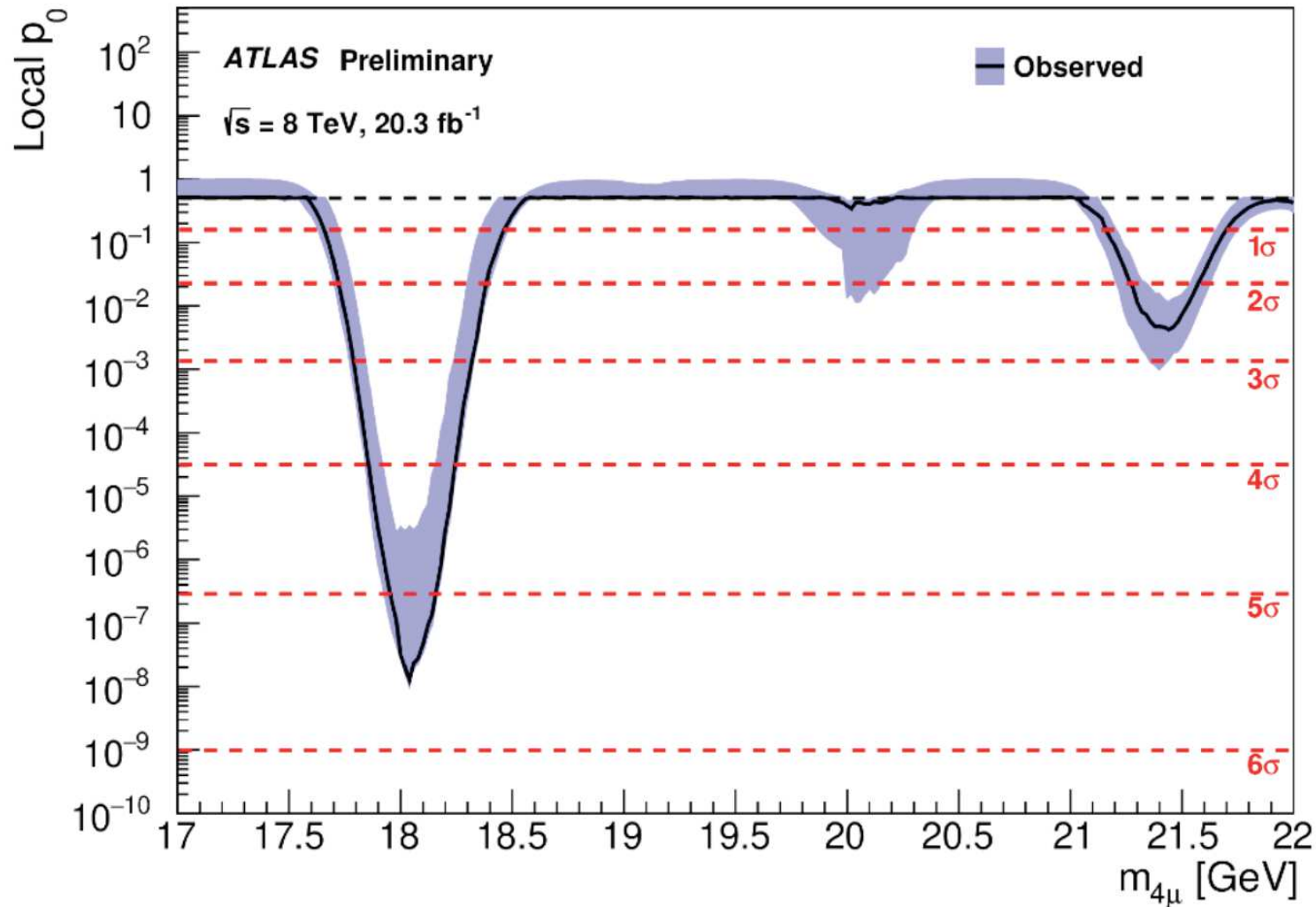
but ...

What about other channels? What about ATLAS?



⇒ no firm conclusion possible. Grrrr ...

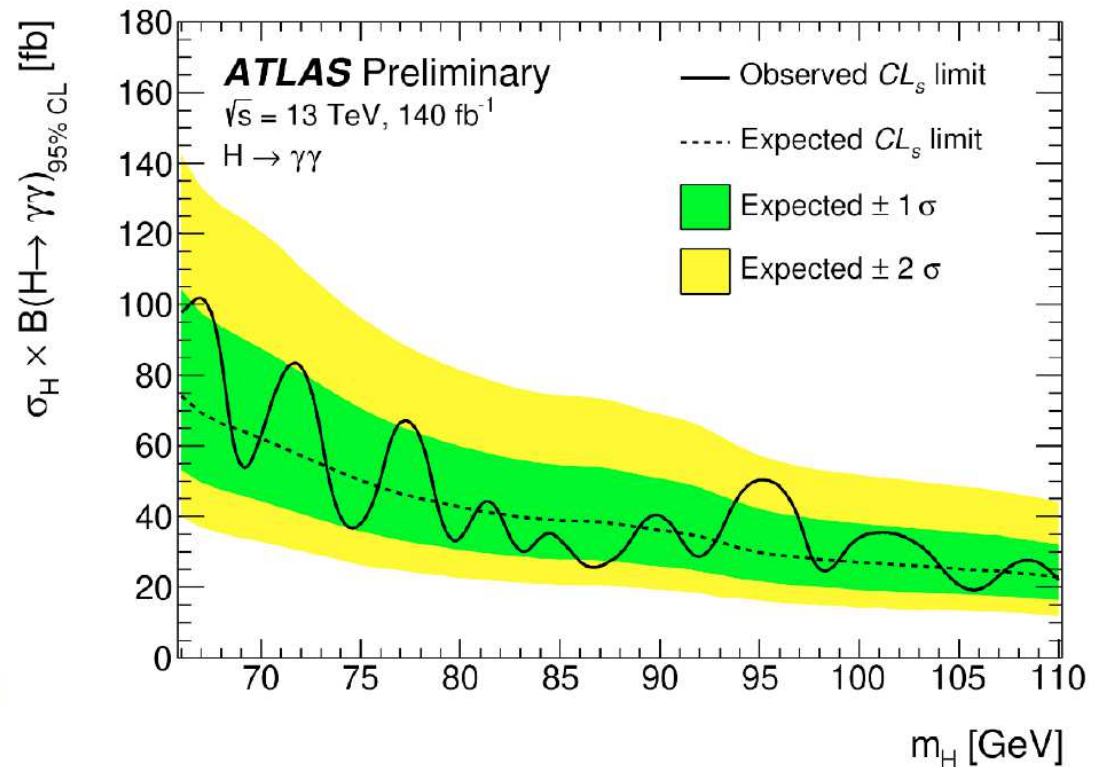
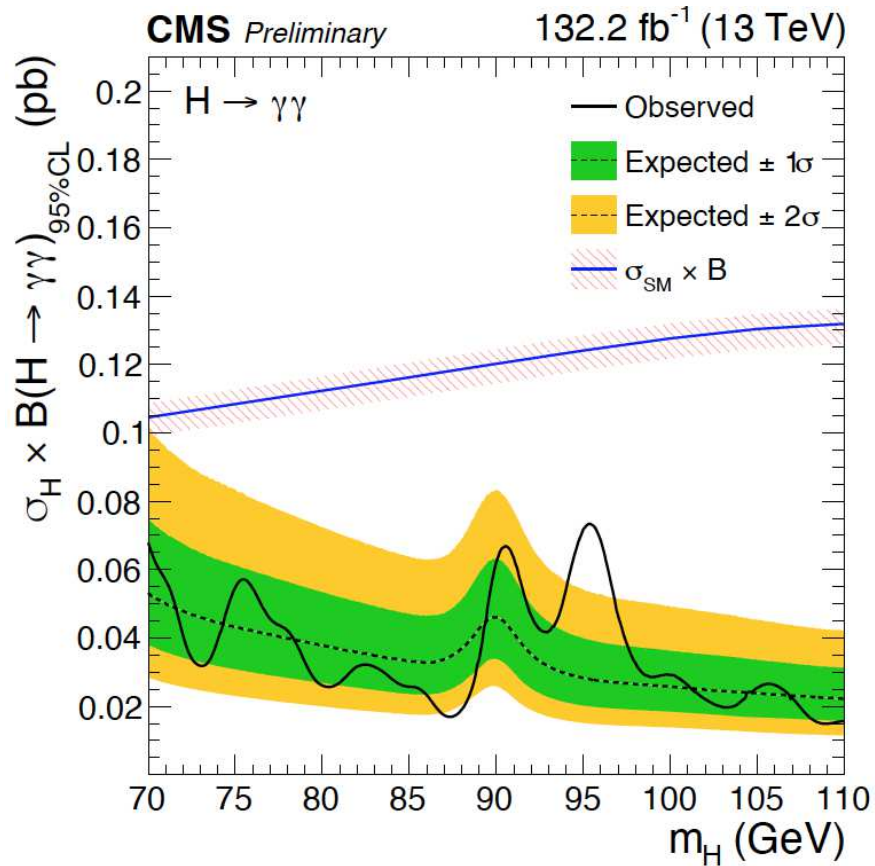
Not shown: $pp \rightarrow \phi_{18} \rightarrow \mu\mu \mu\mu$:



\Rightarrow global excess $> 5\sigma$

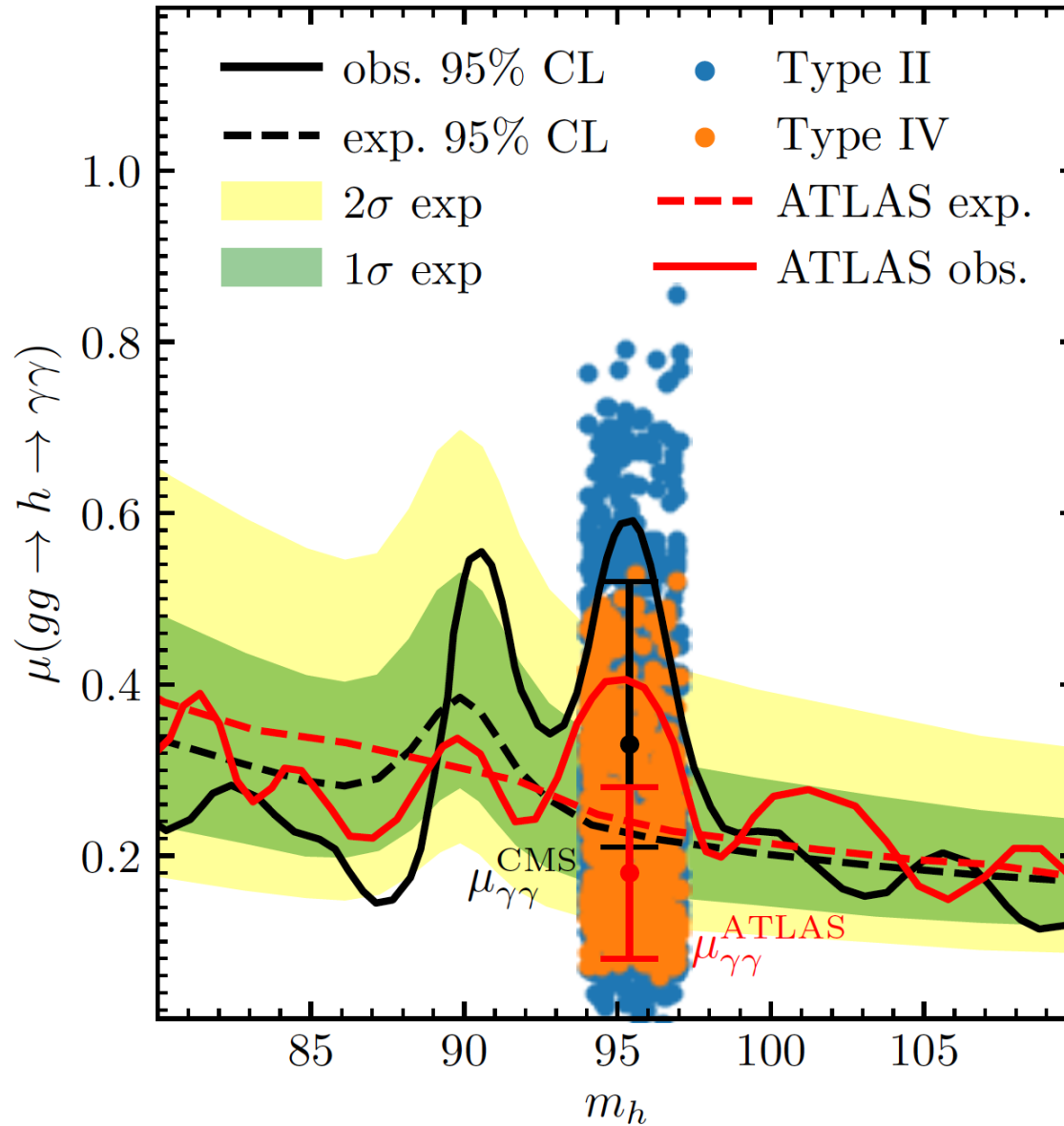
\Rightarrow usual reaction: wait for more data - under different conditions

Not shown: the one “excess” seen by ATLAS and CMS:

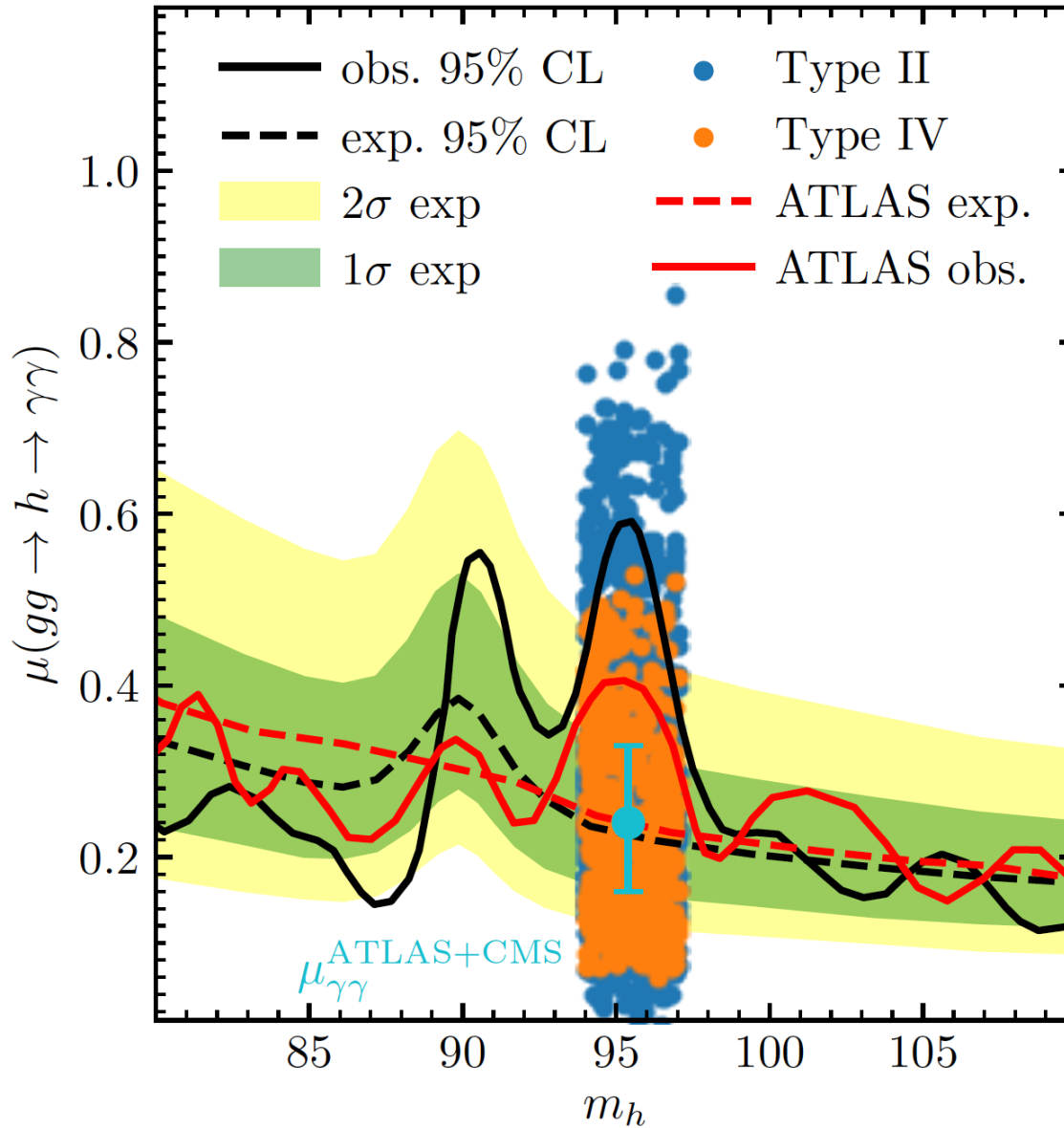


⇒ “excesses” seen at exactly the same mass!

⇒ “of course” no combination - by experimentalists



\Rightarrow agreement between ATLAS and CMS!



⇒ ATLAS and CMS: $\mu_{\gamma\gamma} = 0.24^{+0.09}_{-0.08}$ (3.1σ) - which is called "evidence"