Missing the Forest for the Trees:
Experimental Perspectives on Searches for New Higgs Bosons

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SMU | Dedman College of Humanities & Sciences

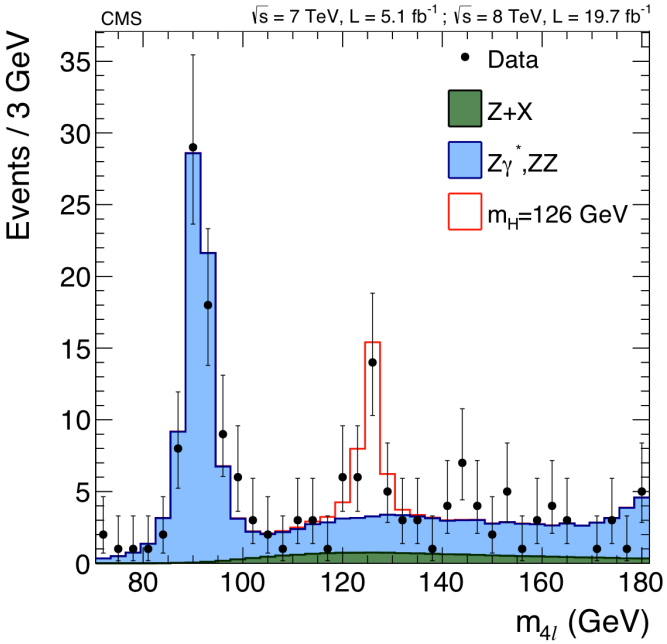
“Legal Disclaimer”

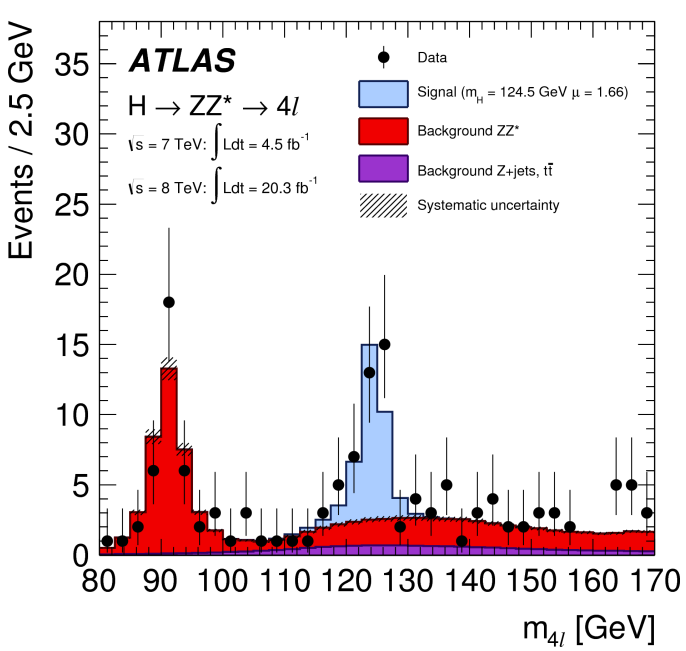
- Any views or opinions expressed are solely those of the author and do not necessarily represent those of the experimental collaborations mentioned in the talk or to which the speaker has any affiliation[*]. If you enjoy or dislike any remarks made by the speaker, then all praise or blame should be directed purely at the speaker.

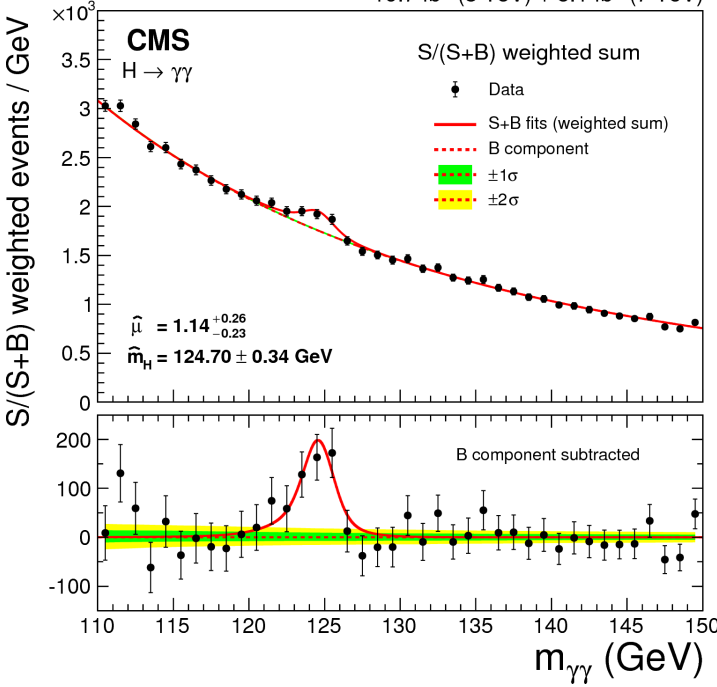
[*] While I am a member of the ATLAS Collaboration, any resemblance to an actual representative of the ATLAS Collaboration is purely coincidental.


STANDARD MODEL
GRAVITATION
WEAK
STRONG
ELECTROMAGNETISM

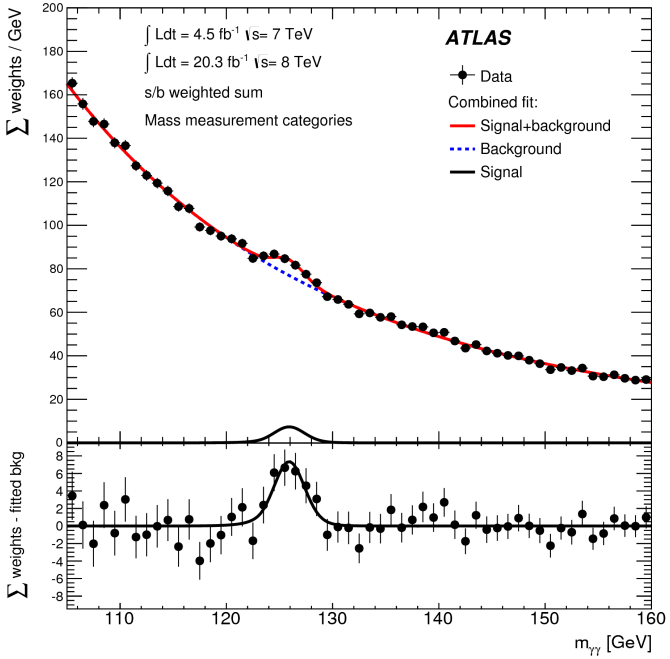

STANDARD MODEL
DARK MATTER
ARK ENERGY







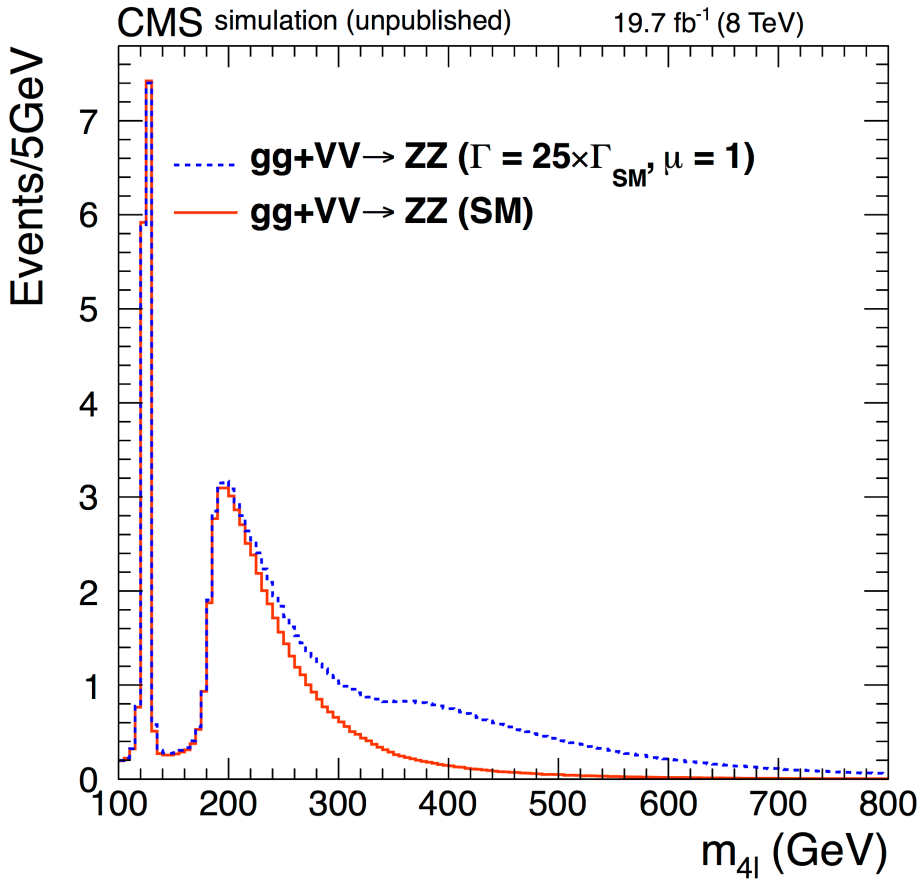
We've gone from discovery, to measurement, to "probe for new physics" in just 2 years. The Higgs boson offers an incredible new experimental tool.

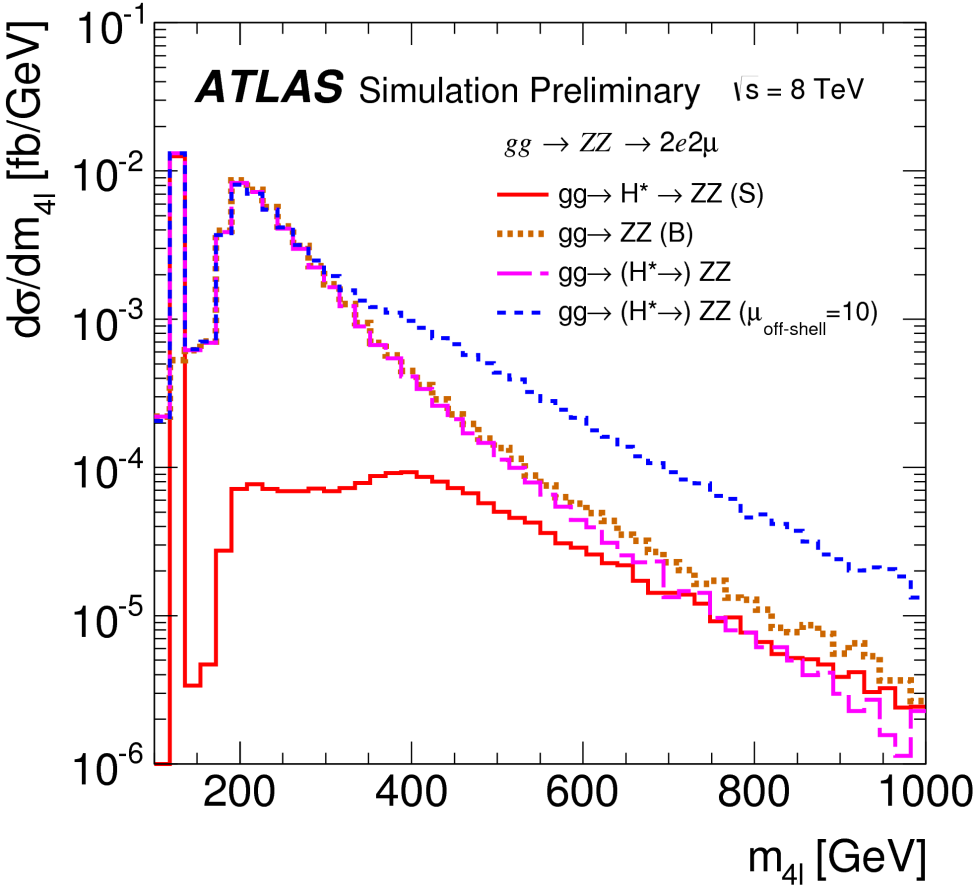


AN EXPERIMENTALIST'S CONCERN:

HOW DO WE STAY FOCUSED ON THE STANDARD MODEL AND ITS EXTENSIONS WHILE ALSO NOT MISSING THE NEXT BIG DISCOVERY?

Higgs Properties



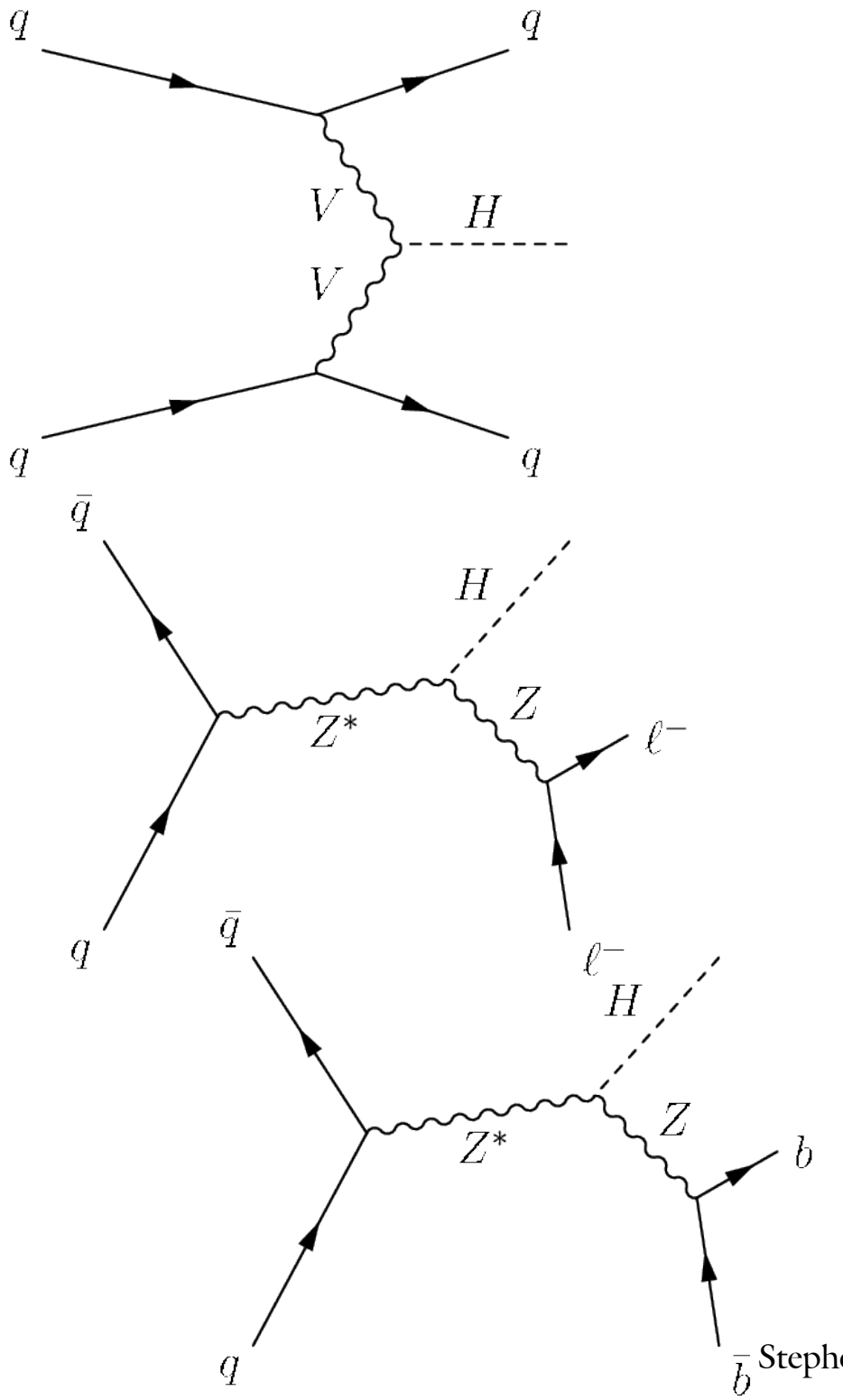


A measurement of the Higgs off-shell signal strength, $\mu_{\text{off-shell}}$, (and maybe then - even indirectly - an inference about its Natural Width) might tell us about its coupling to non-SM particles.

$\mu_{\text{off-shell}}$: challenges

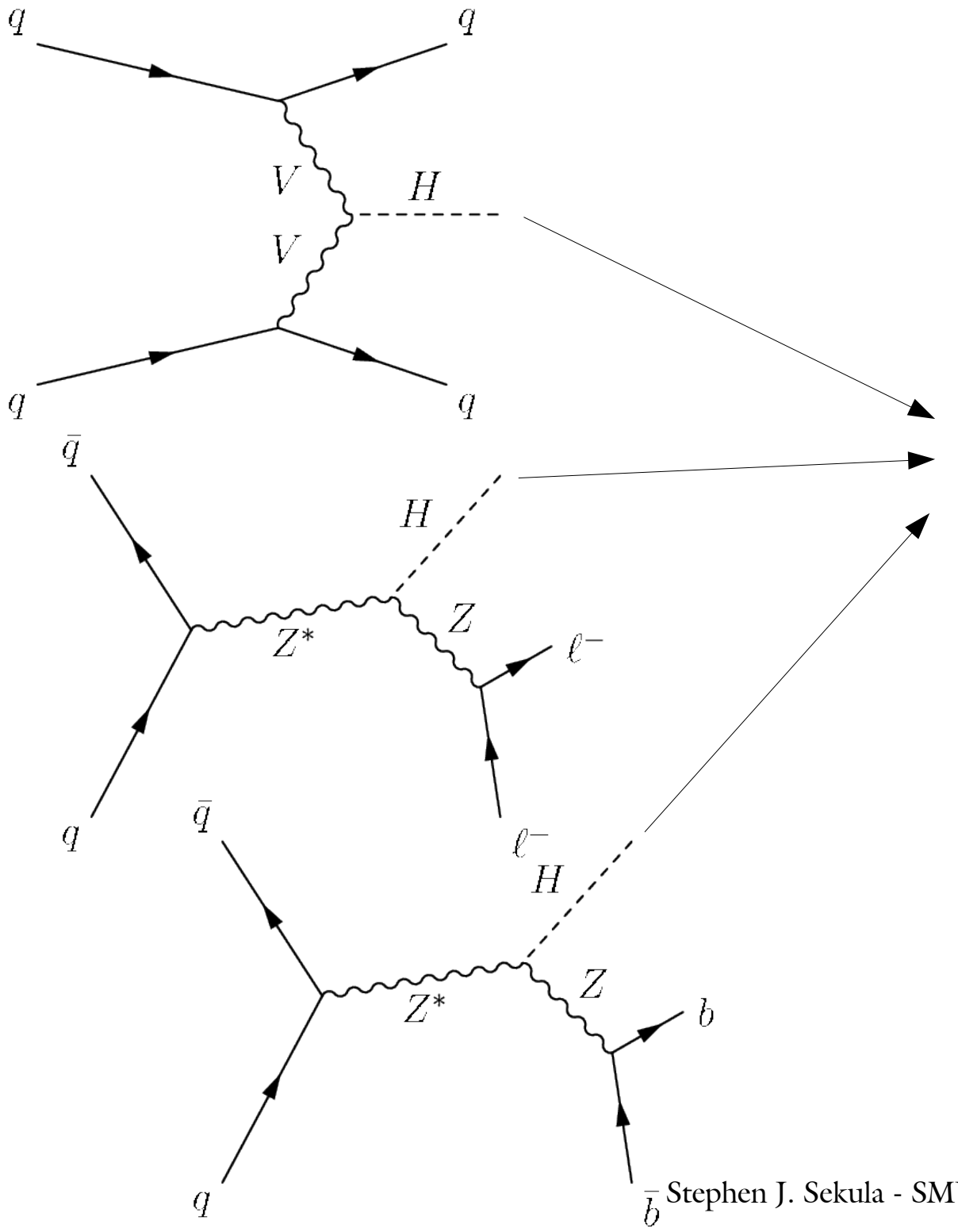
- Relies heavily on MC simulation of VV backgrounds
  - experiments interpret data in absence of knowledge of theoretical ratio of K-factors (N(N)LO/LO) for two processes R = K(gg→ZZ)/K(gg→H*→ZZ)
  - leading uncertainties are due to theoretical effects – QCD scale and PDFs.
  - there is momentum here toward a new leap in MC tools to take the next steps on this measurement in Runs 2 and 3 of the LHC.
- Here we have a key opportunity as a community to make important progress together.

Higgs Decays

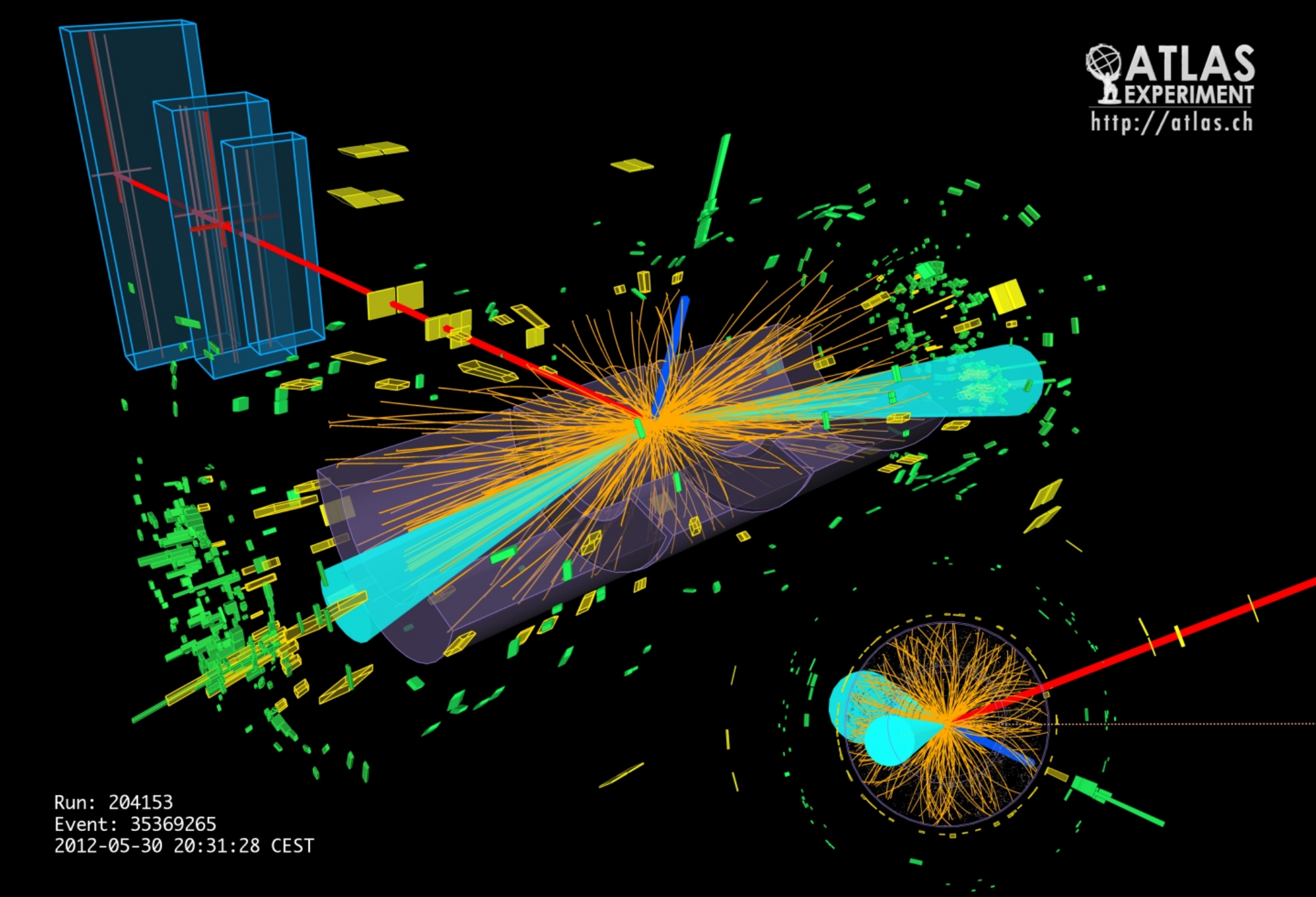


From an experimentalist's perspective, the ability to produce Higgs bosons at the LHC in a "tag and probe" fashion enables study of the Higgs decay with less bias than having to select exclusively on a Higgs final state.

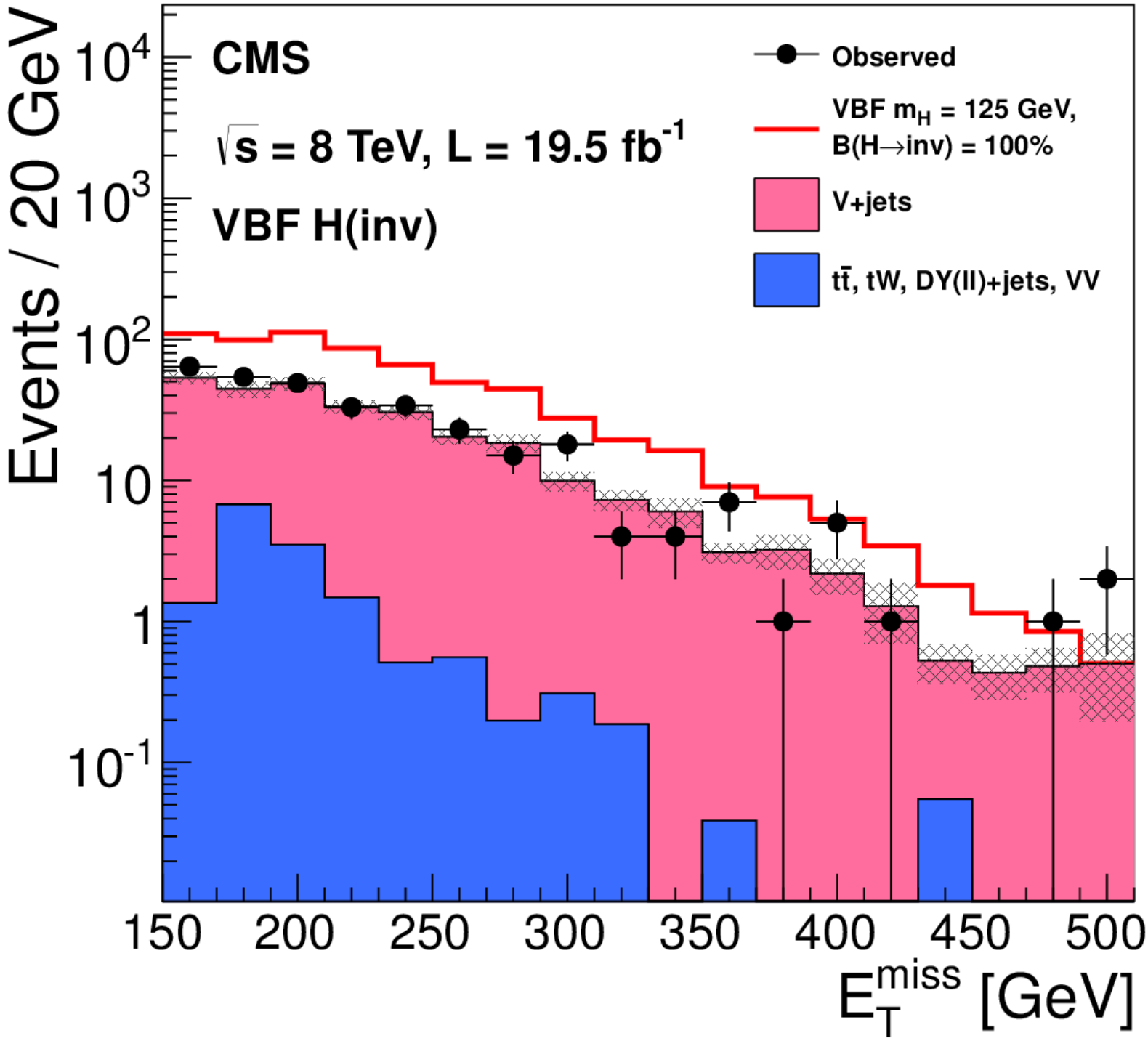
A "Higgs Boson Beam," if you will...

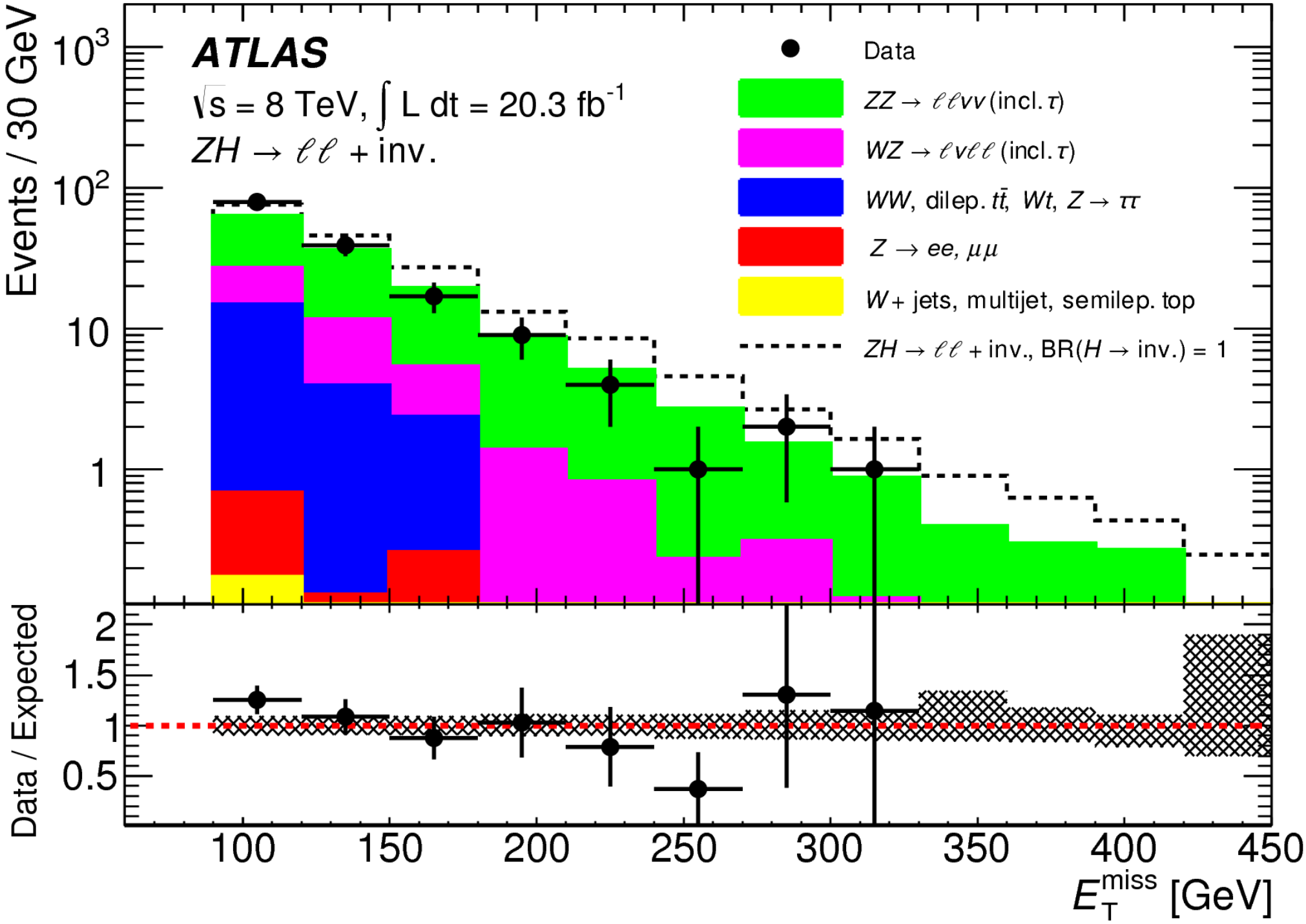


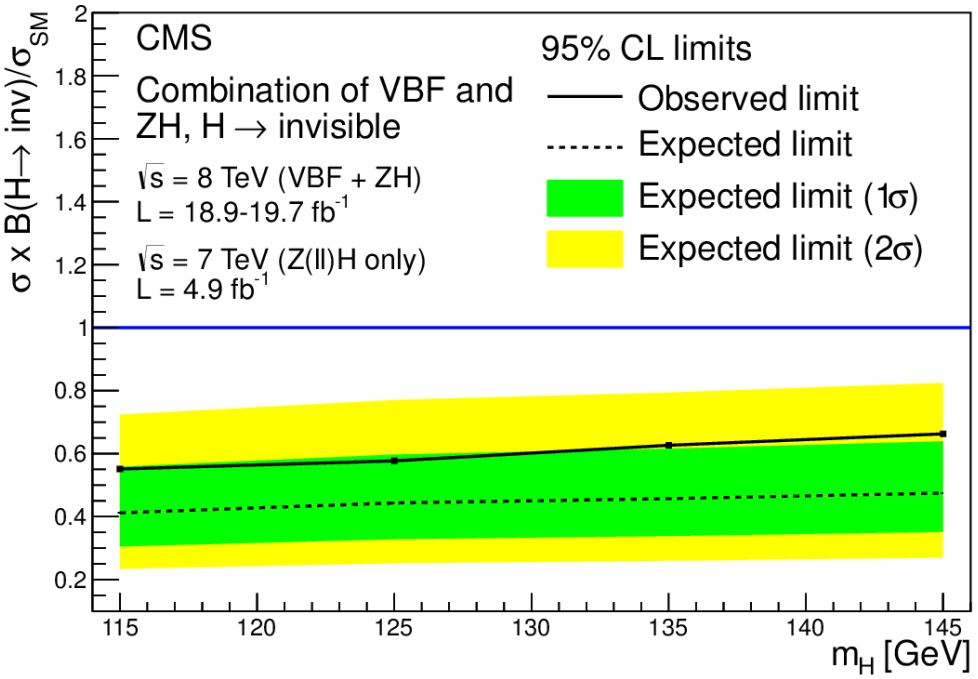
INVISIBLE
(UNDETECTABLE)
FINAL STATES

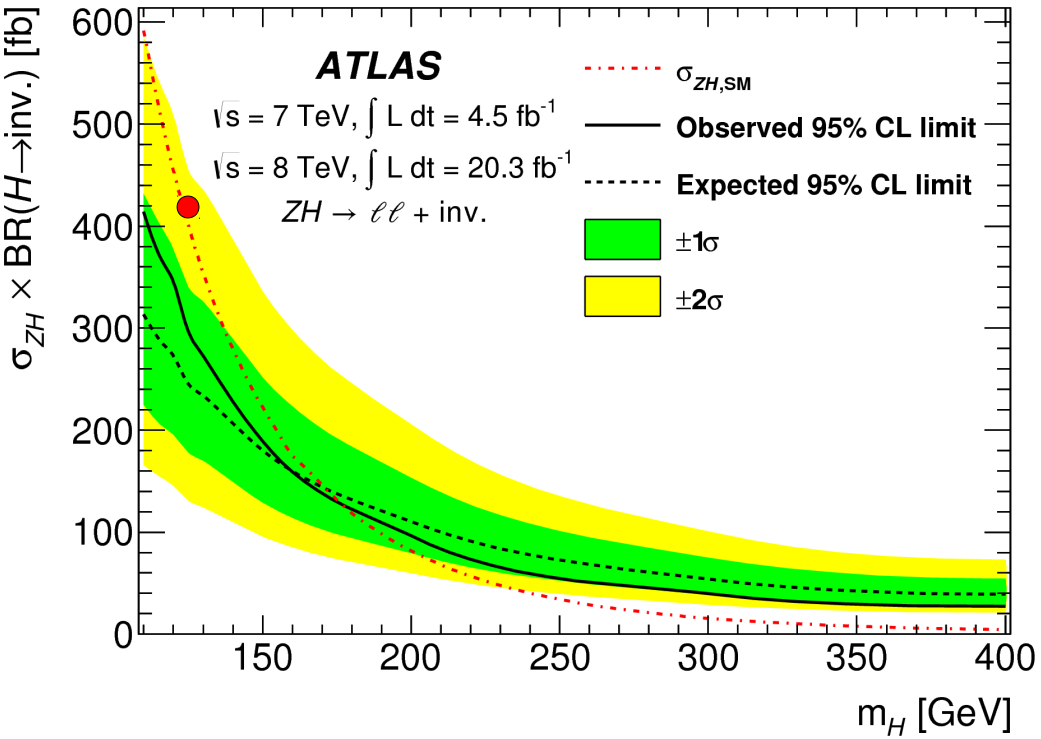


The VBF signature is really incredible at the LHC


CMS
√s = 8 TeV, L = 19.5 fb-1
VBF H(inv)
Observed
VBF mH = 125 GeV,
B(H→inv) = 100%
V+jets
tt̄, tW, DY(ll)+jets, VV
Events / 20 GeV
10^4
10^3
10^2
10
1
10^-1
150
200
250
300
350
400
450
500
E_T^miss [GeV]

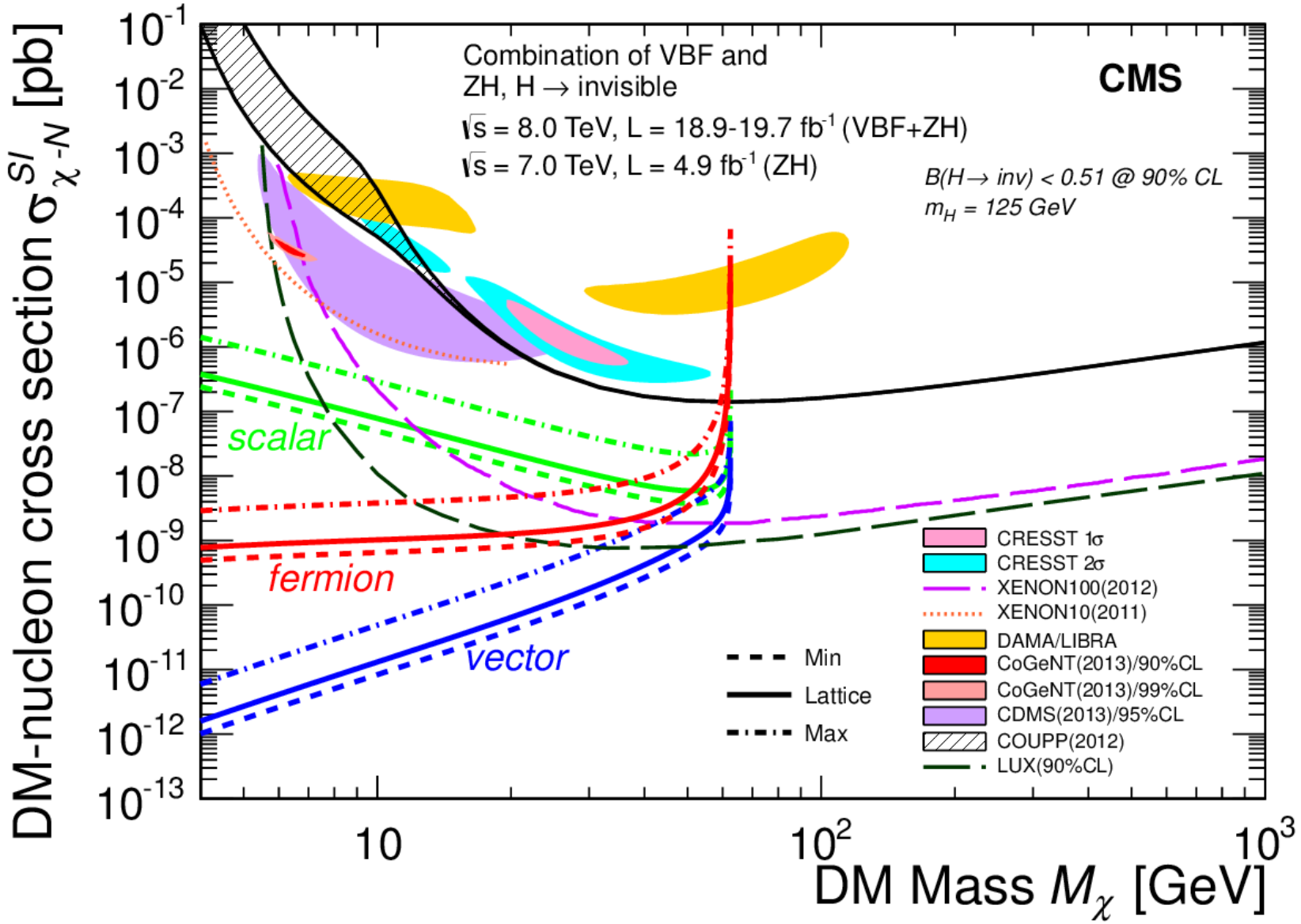

ATLAS
√s = 8 TeV, ∫ L dt = 20.3 fb-1
ZH → ℓℓ + inv.
Data
ZZ → ℓℓνν (incl. τ)
WZ → ℓνℓℓ (incl. τ)
WW, dilep. tt̄, Wt, Z → ττ
Z → ee, μμ
W + jets, multijet, semilep. top
ZH → ℓℓ + inv., BR(H → inv.) = 1
Events / 30 GeV
Data / Expected
E_T^miss [GeV]





ATLAS and CMS have probed invisible decay of the Higgs Boson down to the level of only ~50-60% of the total branching fraction of the Higgs.

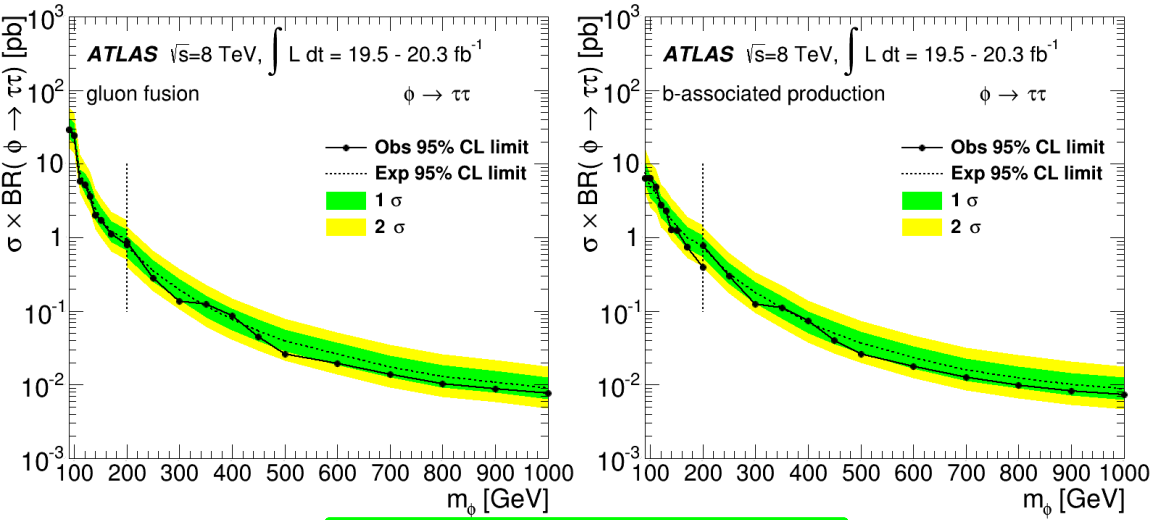
There is lots of space for discovery here.



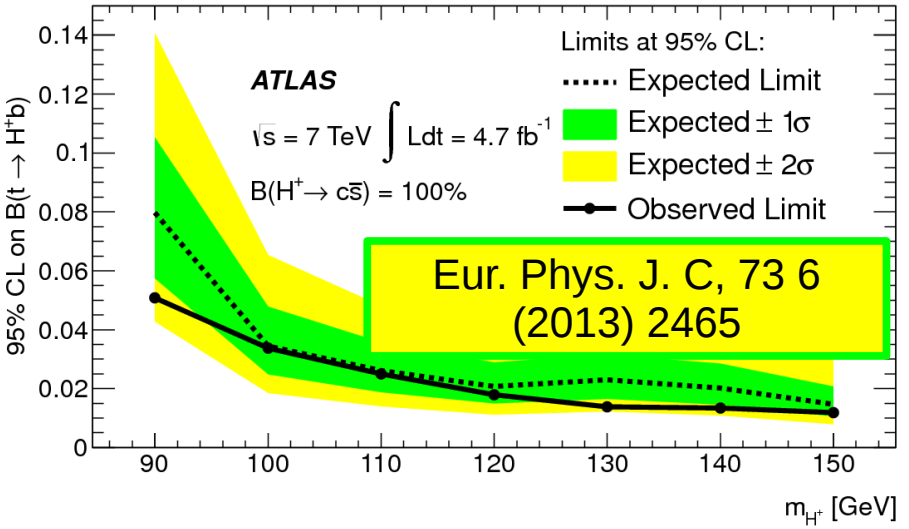
A comment: while interpreting the "model-independent" cross sections in a model-dependent context is nice, don't over-interpret the impact of LHC H → invisible searches on the direct-detection dark matter effort. You have to make a lot of guesses about the dark sector to do this.


This sequoia is one of many at Chatsworth House in the UK – not in the US, where you would naively expect them to be...!

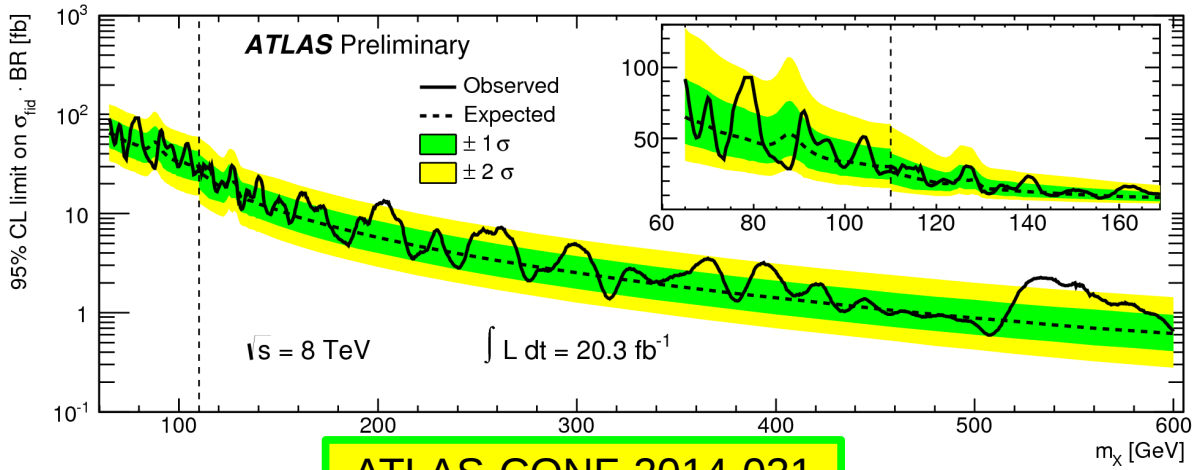
Searches for Additional Higgs Bosons



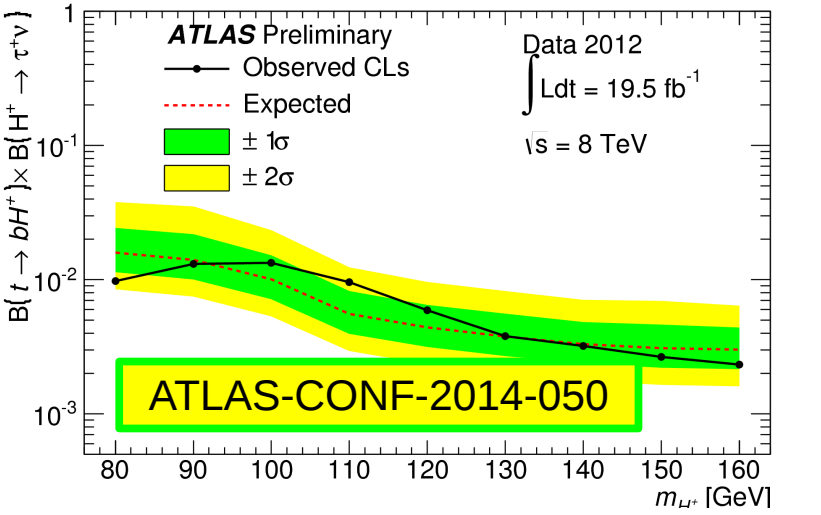
CMS-HIGG-2013-31



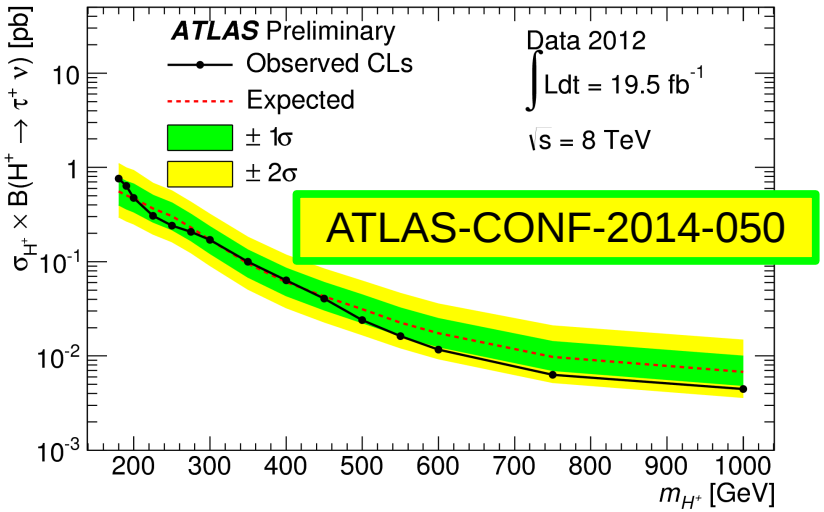
Eur. Phys. J. C, 73 6 (2013) 2465



ATLAS-CONF-2014-031

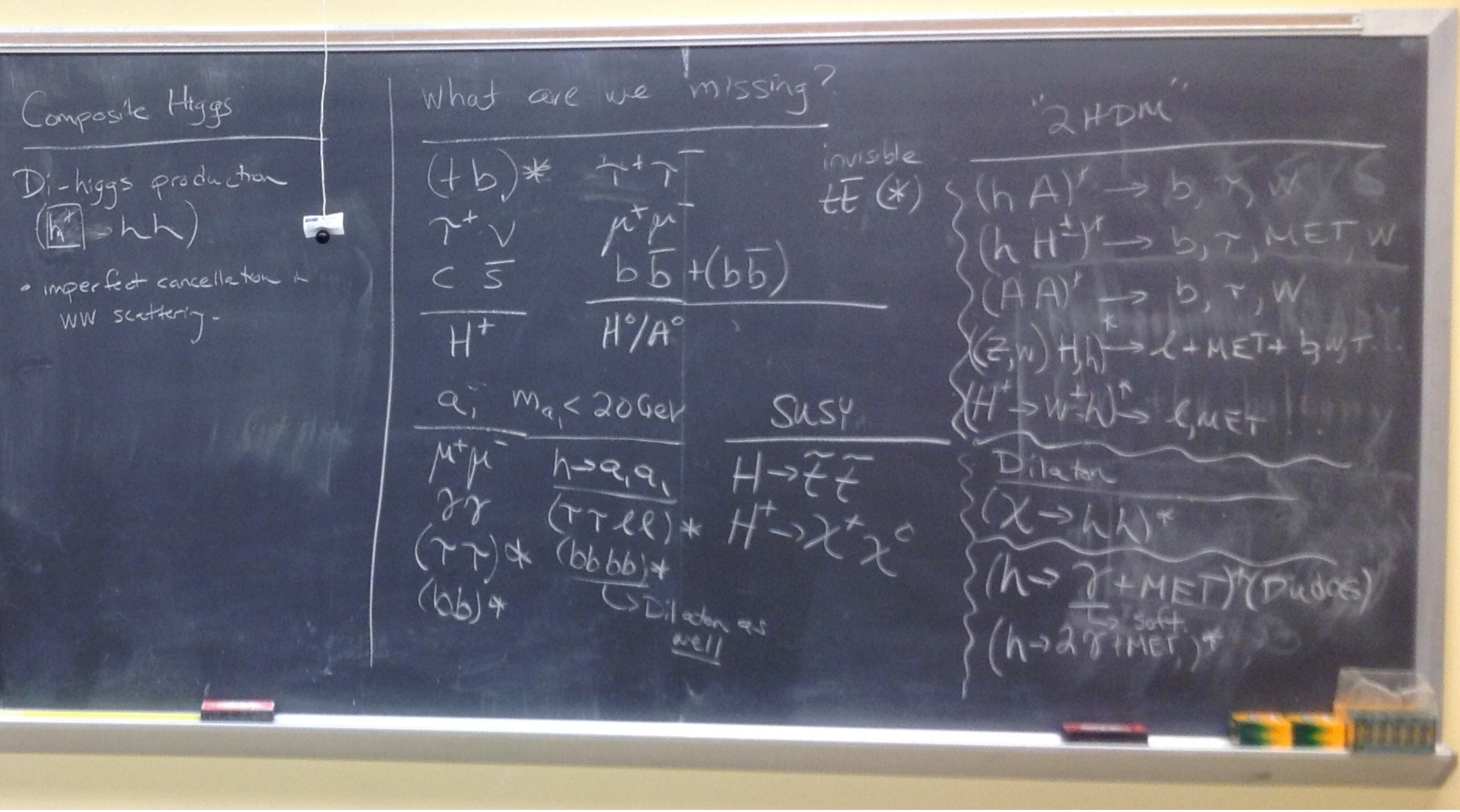


ATLAS-CONF-2014-050

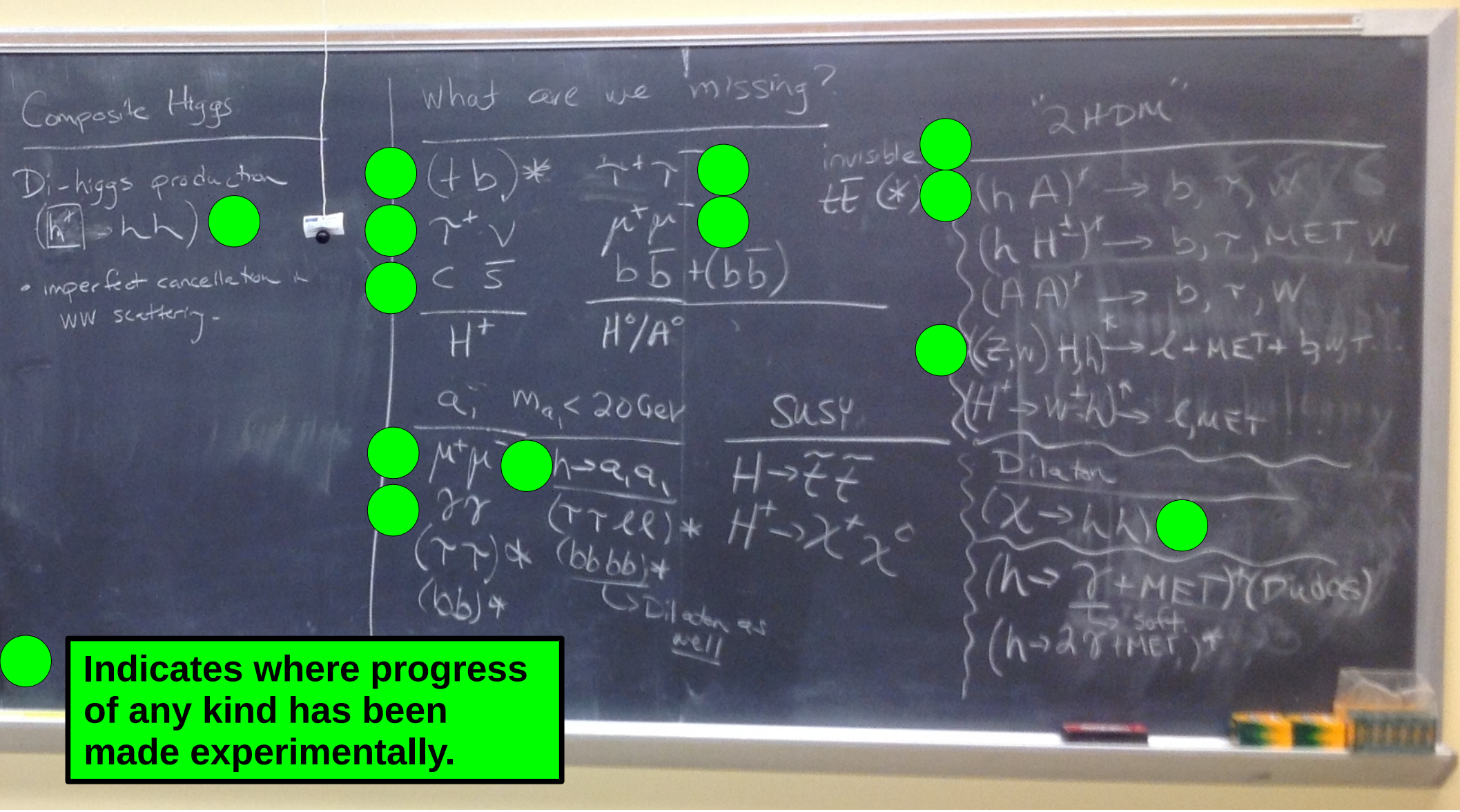


ATLAS-CONF-2014-050

ATLAS and CMS have made many searches for new scalars (Higgs-like states) using guidance from beyond-the-SM (BSM) models...



Blackboard record of ~hour-long discussion on what the community perceived as "not being done yet" at the LHC in April, 2013. From the UC Davis workshop, "The LHC Higgs Signal: Characterization, Interpretation and BSM Model Implications"



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Future Experimental Tools

Tools - Outlook

- General experimental improvements
  - Everything has to be redone and the Higgs “rediscovered” in Run 2 – this should be an incredible period of development and improvement – triggers, reconstruction, identification, ...
- Boosted object reconstruction/tagging
  - developed by both collaborations in Run 1 – experimental necessities for ≥Run 2
- VBF and VH for “Higgs Beams”
  - Once signals in these channels are firmly discovered, it would made sense to “assume the premise” and select on the VBF jets or V-boson in order to study Higgs decays

Outlook and Comments

Summary

- Run 1 yielded an incredible new experimental tool: the (first? only?) Higgs Boson
  - Run 2 and beyond will become the period of full exploitation of the tool for searches beyond the Standard Model
- Questions for discussion
  - What is the experimental community missing? What aren't we doing that we should be doing?
  - What are the theory pieces that could be better clarified by experiment (or otherwise) and fed back into the searches and measurements?