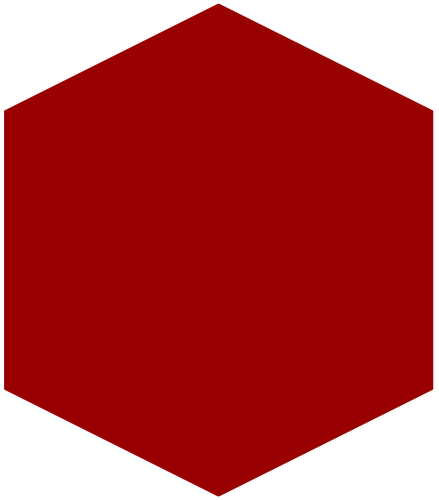


HIGGS - EXPERIMENTAL INTRODUCTION

PASQUALE MUSELLA - ETH ZURICH

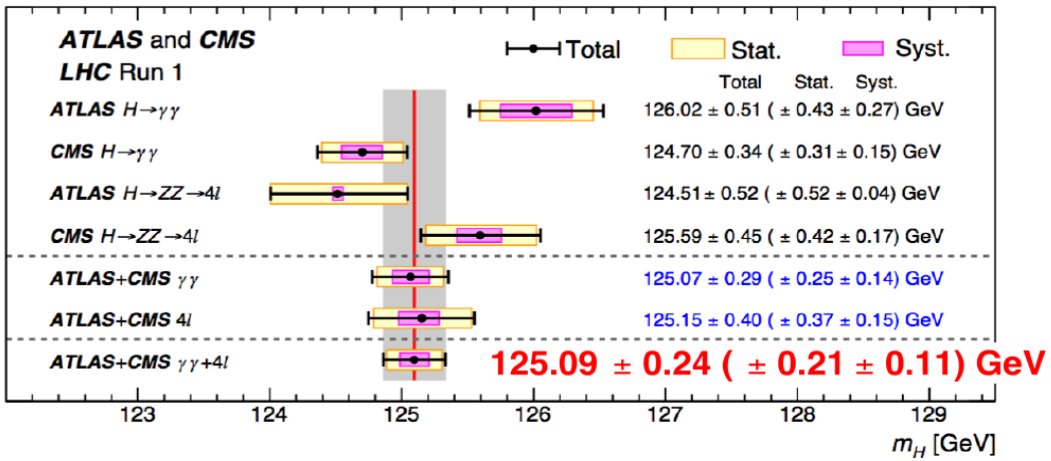
ETH Institute for
Particle Physics

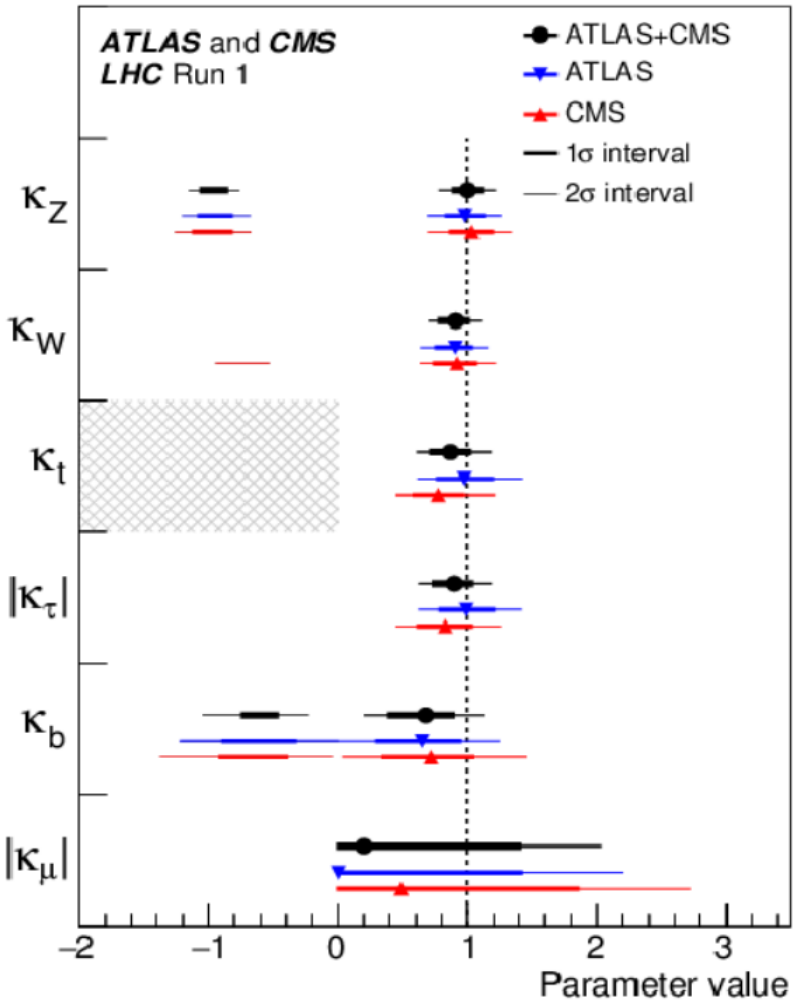
HIGGS: LHC RUN I LEGACY

A BEAUTIFUL DISCOVERY.

- MAIN PRODUCTION AND DECAY MODES MEASURED WITH ~20% UNCERTAINTIES BY EACH EXPERIMENT.

- COMBINED INTERPRETATION OF ALL MEASUREMENTS GIVES A PICTURE PICTURE

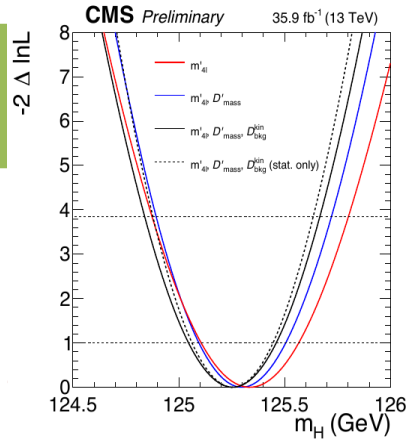


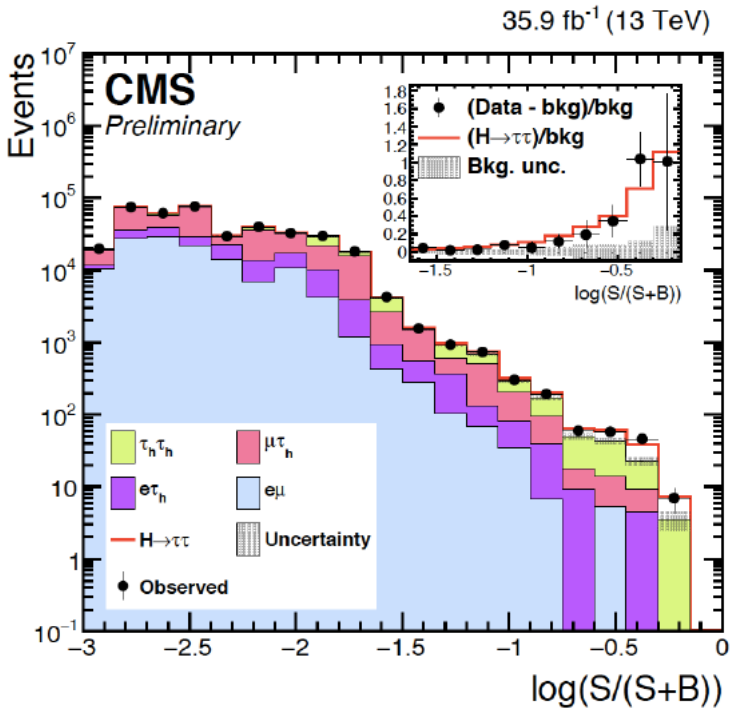


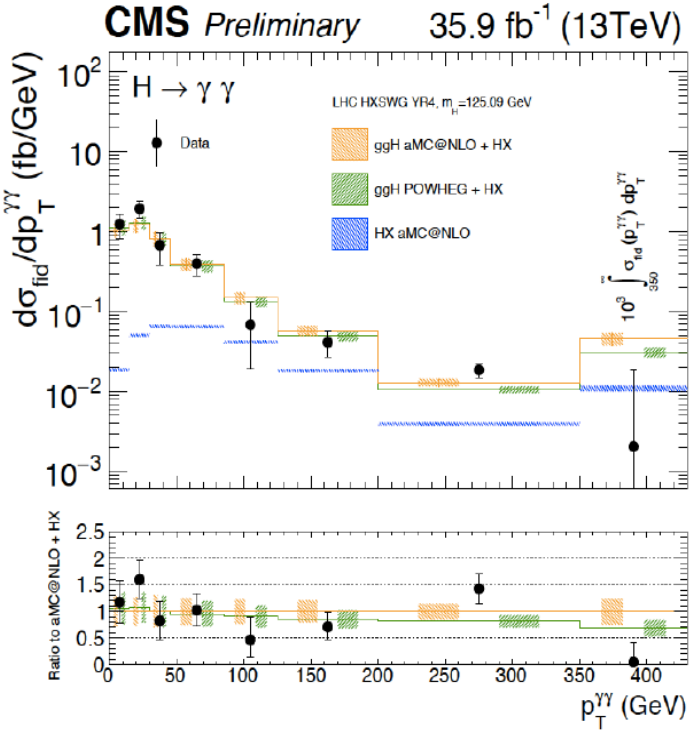
LHC RUN 2

ALREADY IMPROVING ON RUN I PRECISION

- HIGGS REDISCOVERED IN THE MAIN DECAY MODES.
- DATA ANALYZED BOTH IN TERMS OF OPTIMIZED SELECTION AND FIDUCIAL CROSS-SECTIONS.





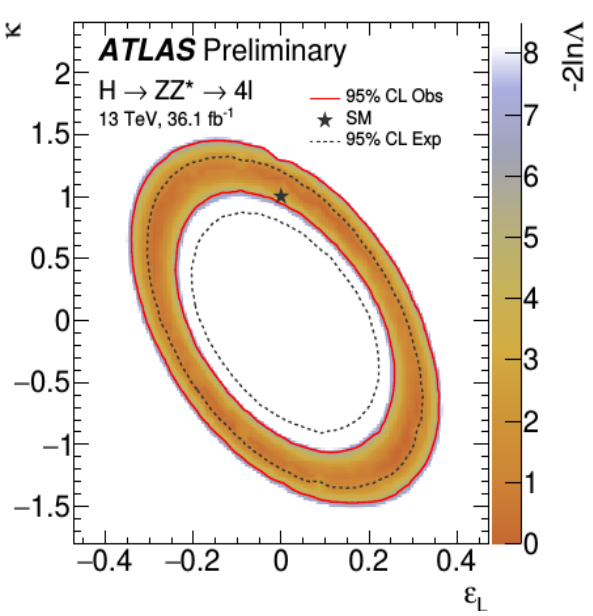


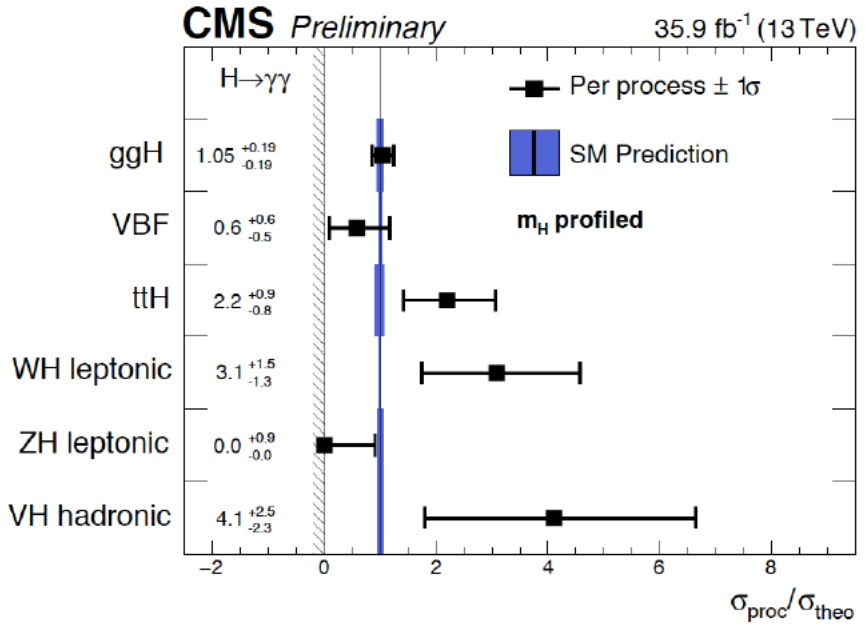
DATA INTERPRETATION

GOING BEYOND K-FRAMEWORK

- FOCUS IS SHIFTING TOWARDS DATA REPRESENTATION WITH LONGER-TERM VALIDITY
  - TEMPLATE / FIDUCIAL CROSS SECTIONS
  - PSEUDO-OBSERVABLES

- EFT-INTERPRETATIONS LESS POPULAR.

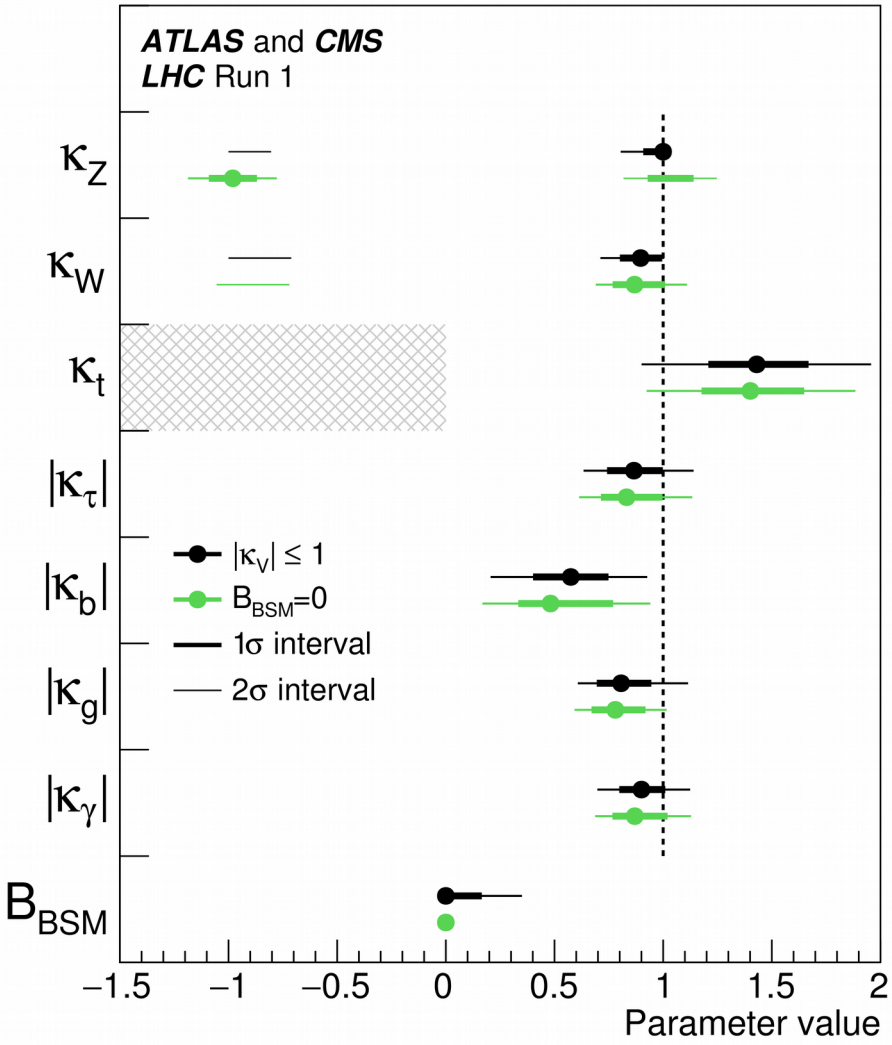




ROOM FOR BSM?

YES, STILL PLENTY.

SEARCH FOR H(125) NON-STANDARD PRODUCTION AND DECAYS, AND EXTRA STATES IS A BIG CHUNK OF THE PROGRAM.



A SMALL SURVEY

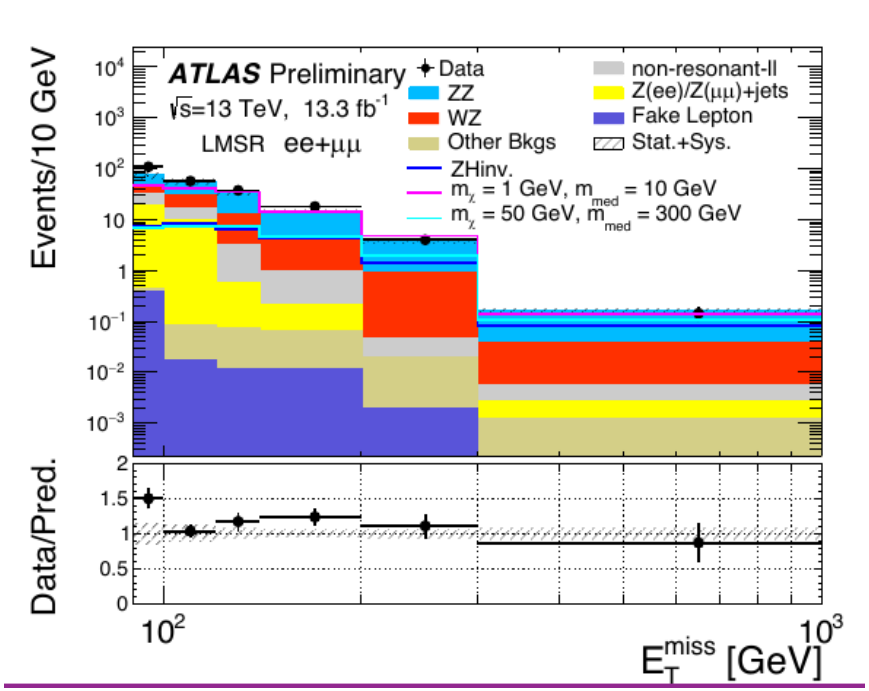
AIM	• I TRIED TO SUMMARIZE LHC RESULTS ON BSM ANALYSIS IN HIGGS PHYSICS
DISCLAIMER	• I TRIED TO BE EXTENSIVE, BUT MANY ANALYSES HAVE BEEN PERFORMED.
FOCUS	• EXOTIC DECAY MODES, SEARCHES FOR EXTRA RESONANCES.

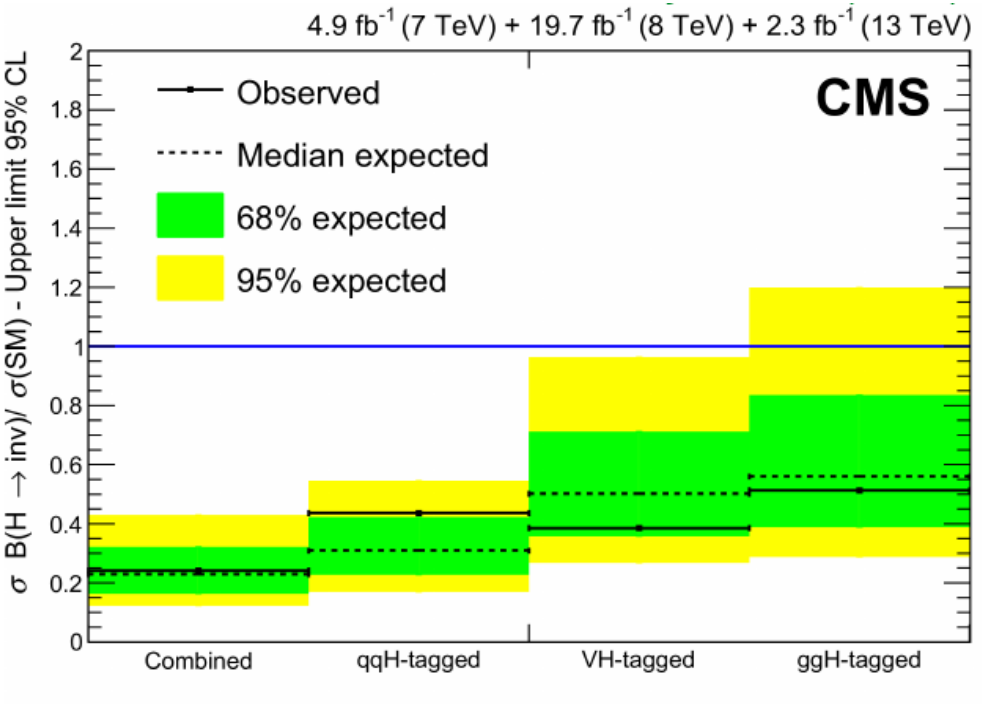
EXOTIC DECAYS

H → INV

- MOST "CLASSICAL" SEARCH FOR BSM EFFECT IN HIGGS DECAYS.
  - SEARCH FOR HIGGS DECAY TO WEAKLY INTERACTING PARTICLES.
  - SENSITIVITY DOMINATED BY VBF AND VH CHANNNELS.

- RUN I LIMIT BR(INV) < ~25%
- RUN 2 ANALYSIS STILL LIMITED TO SOME CHANNELS / PARTIAL DATASETS.

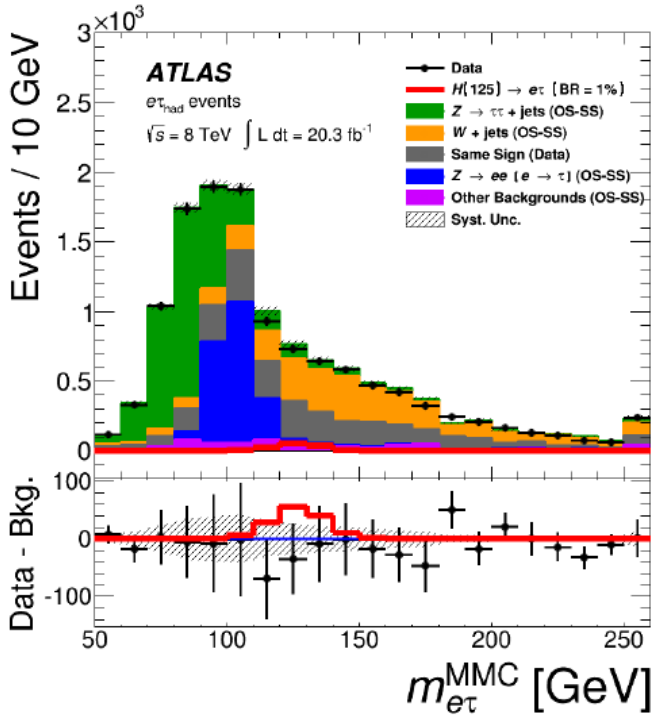


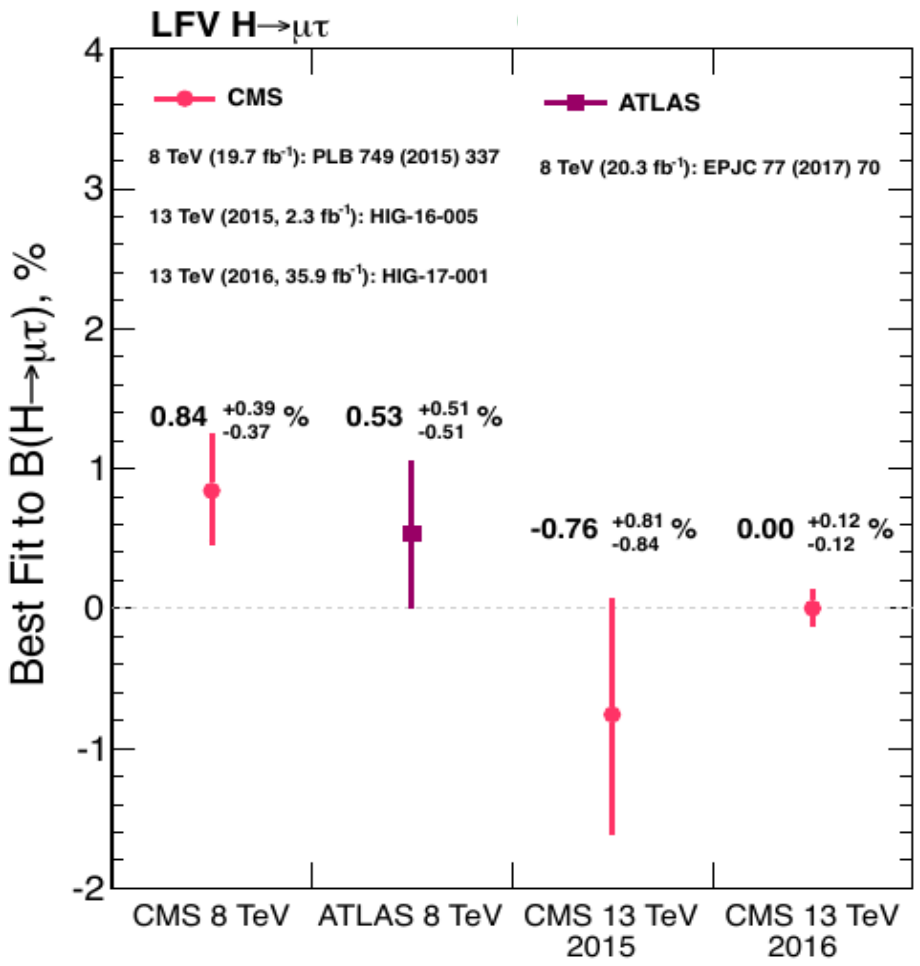


LEPTON-FLAVOUR VIOLATION

- SEARCH FOR LFV DECAYS OF THE HIGGS
  - H → E TAU
  - H → MU TAU
  - H → E MU

- SOME EXCITEMENT GENERATED BY RUN I RESULTS, BUT NOT CONFIRMED BY CMS RUN 2 DATA.

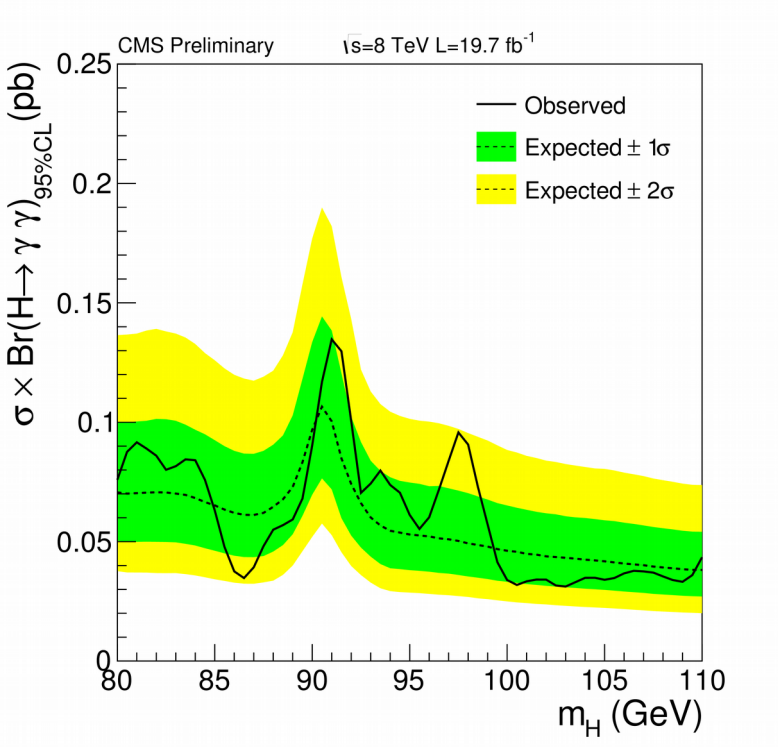


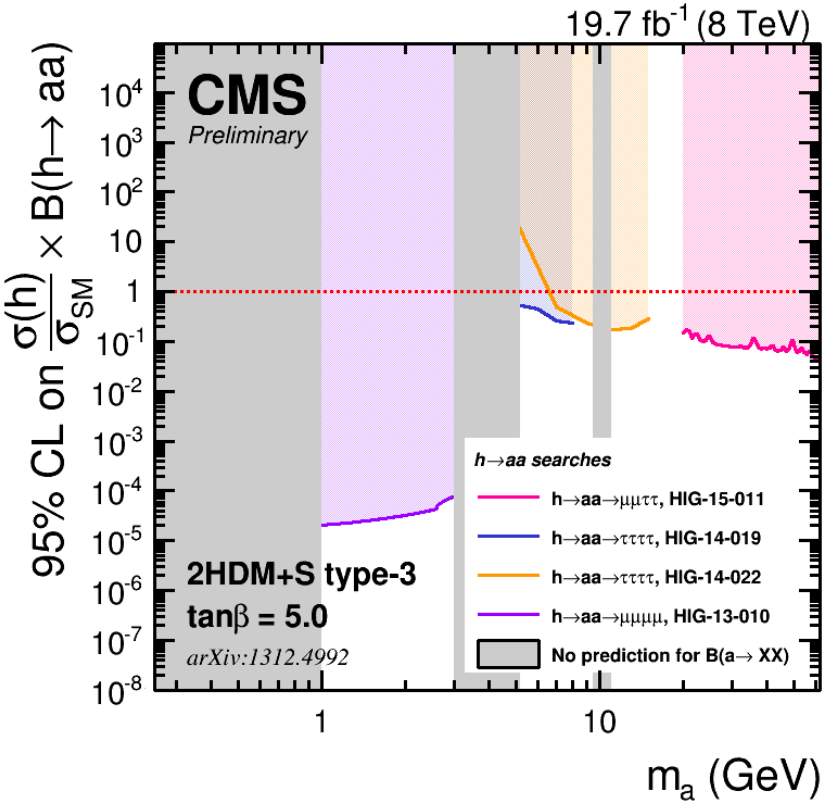


(DECAYS TO) NEW LIGHT BOSONS

- DIRECT SEARCH FOR LOW MASS RESONANCES VERY DIFFICULT AT THE LHC.
  - SEARCH FOR LOW-MASS SCALAR IN TWO PHOTONS IS ONE OF THE VERY FEW ANALYSIS GOING BELOW Z MASS.

- VERY EXTENSIVE PROGRAM OF SEARCH FOR NEW SCALARS IN HIGGS DECAY.
  - $H \to AA \to 4$ FERMIONS

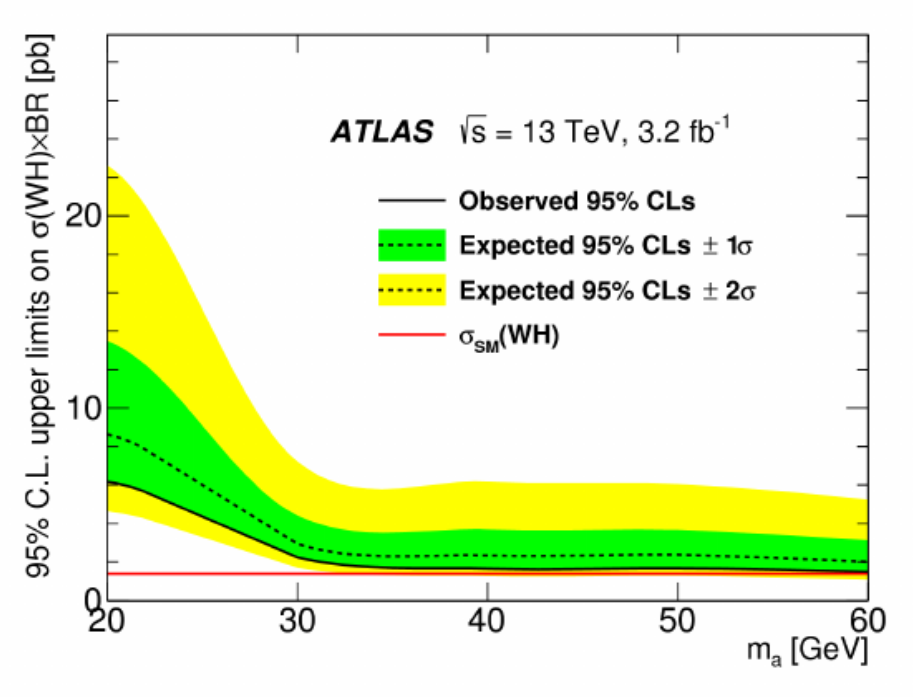


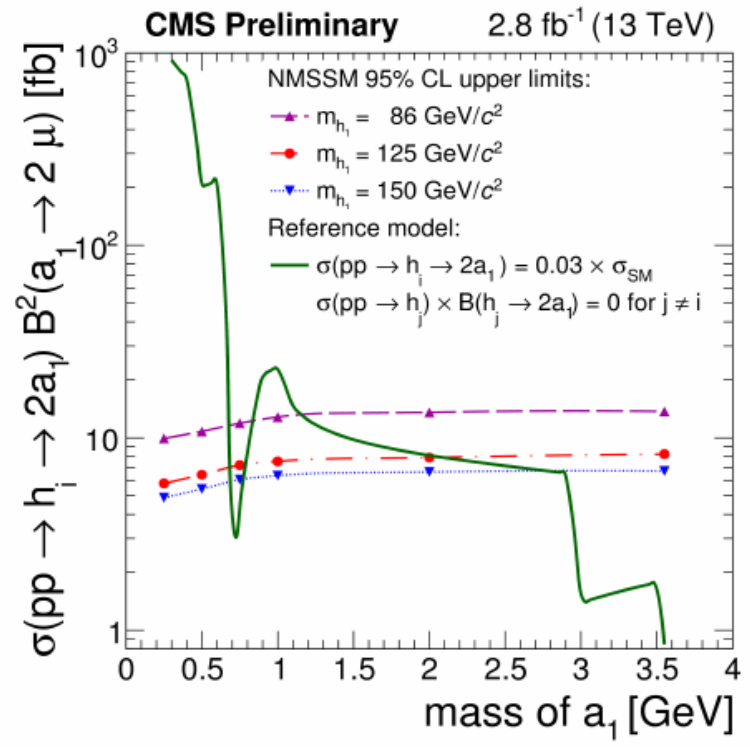


H → AA → 4F

- MANY CHANNELS BEING INVESTIGATED SINCE RUN I.
  - 4MU, 2MU 2TAU, 4TAU IN GLUON-FUSION

- RECENTLY ADDED 4B CHANNEL IN VH PRODUCTION.



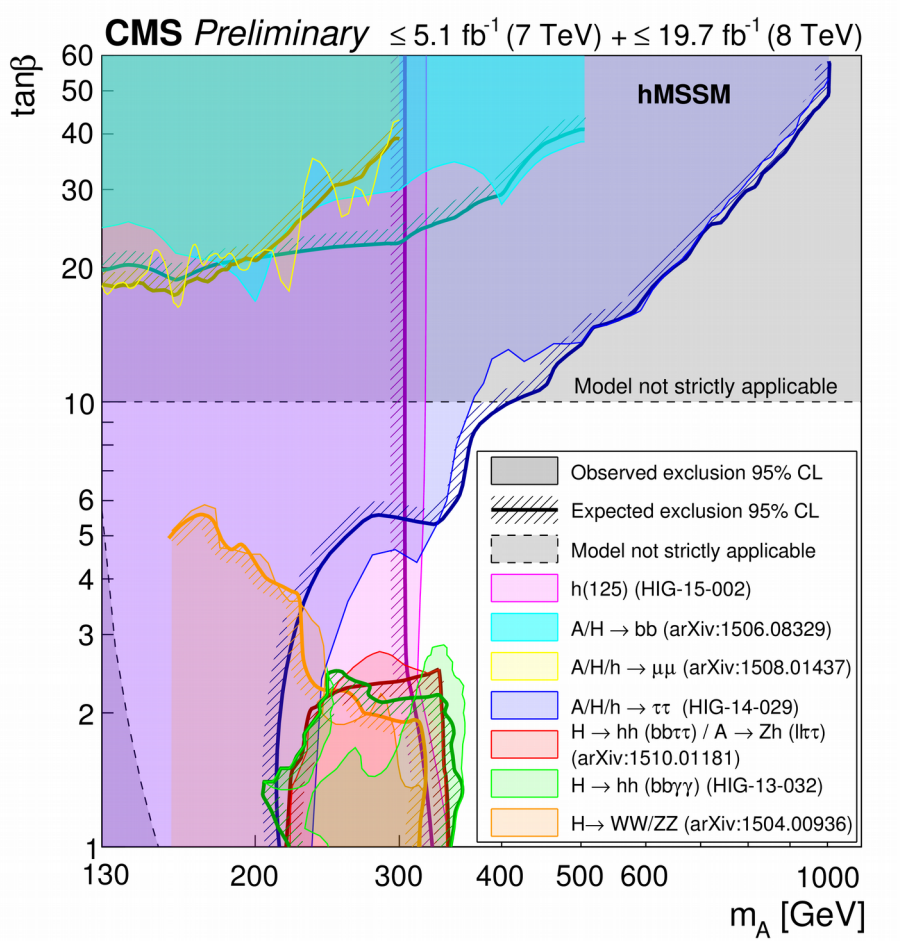


EXTRA MASSIVE SCALAR

A LARGE COLLECTION OF ANALYSES

- IS IT LARGE ENOUGH OR ARE THERE BLIND SPOTS?

- COMPLEMENTARITY WITH PRECISION HIGGS MEASUREMENTS.

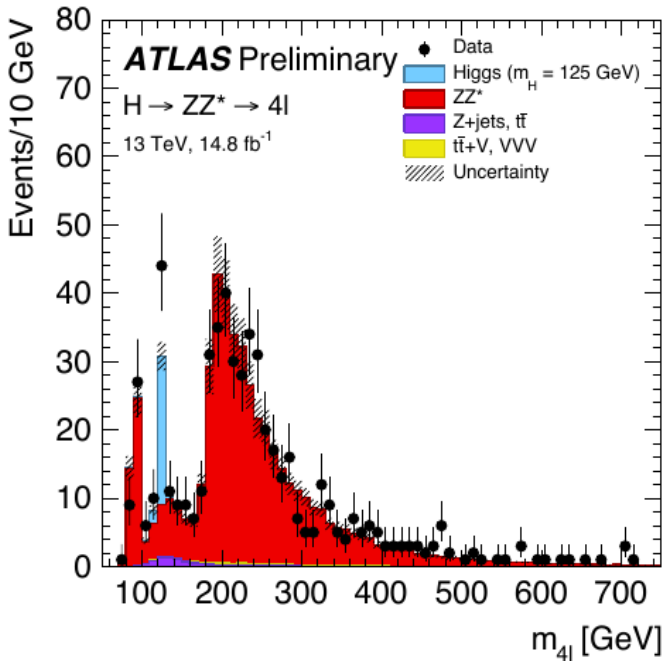


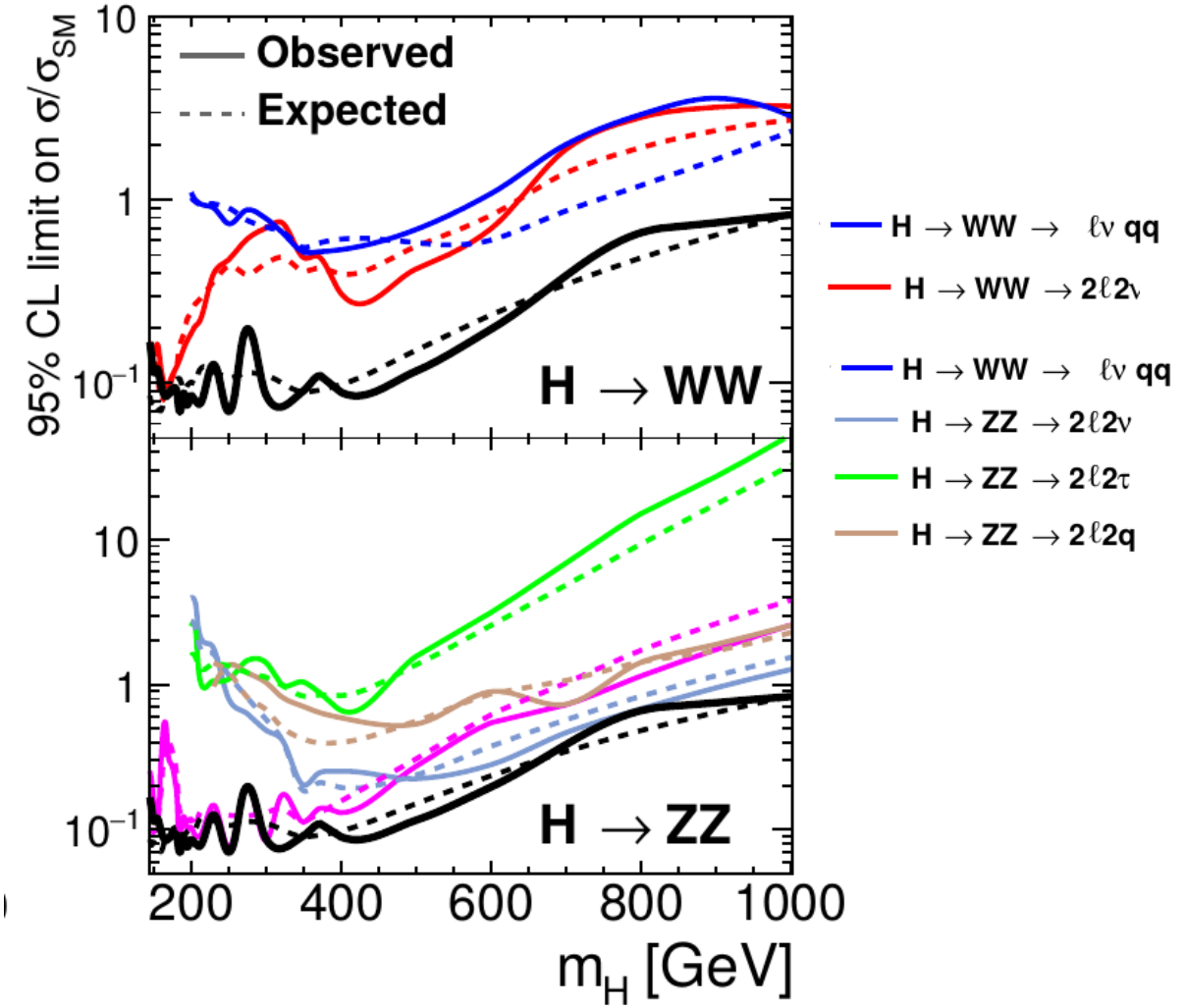
X → VV

- THIS IS A STANDARD.

- MANY DECAY CHANNELS EXPLOITED, EXPERIMENTALLY VERY CLEAN.

- RUN 2 DATA STILL BEING ANALYZED.



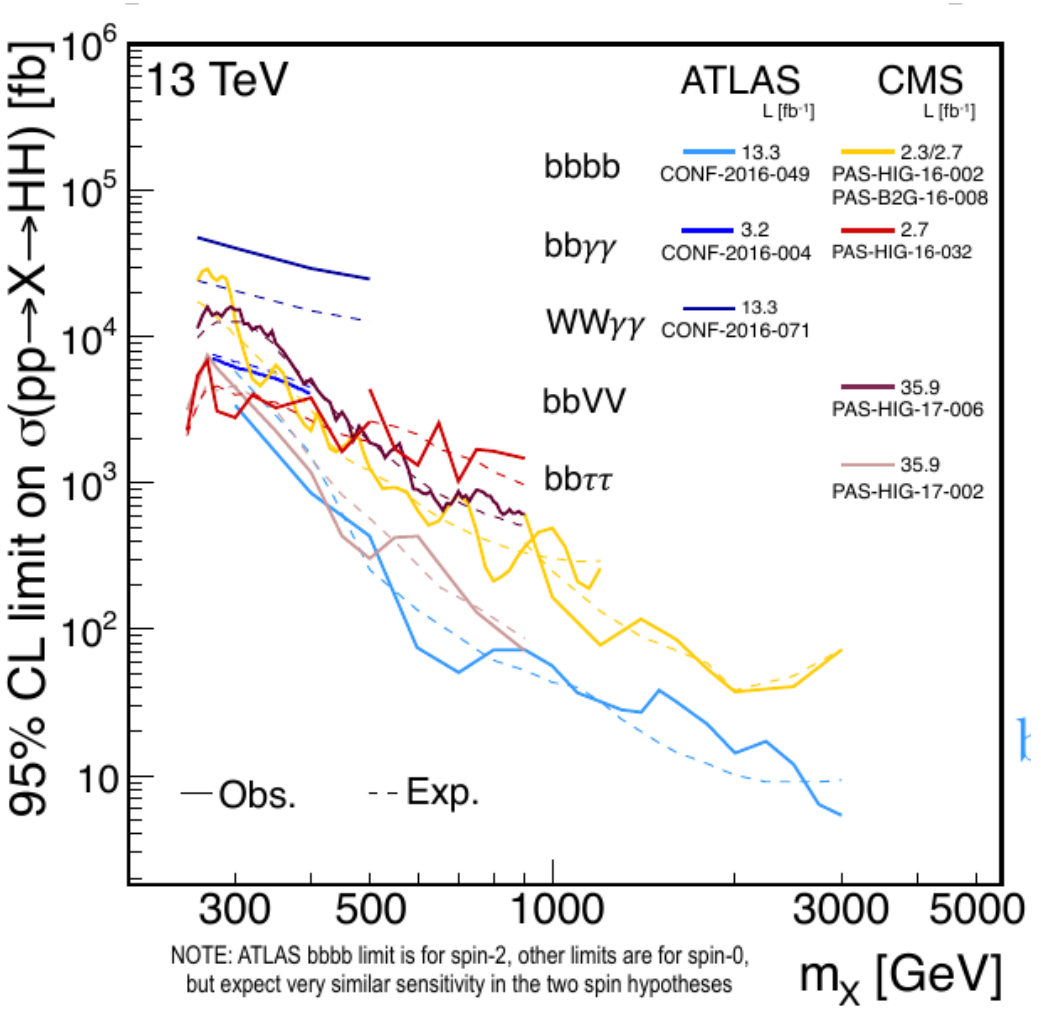


X → HH

- A WELL ESTABLISEHD EFFORT.

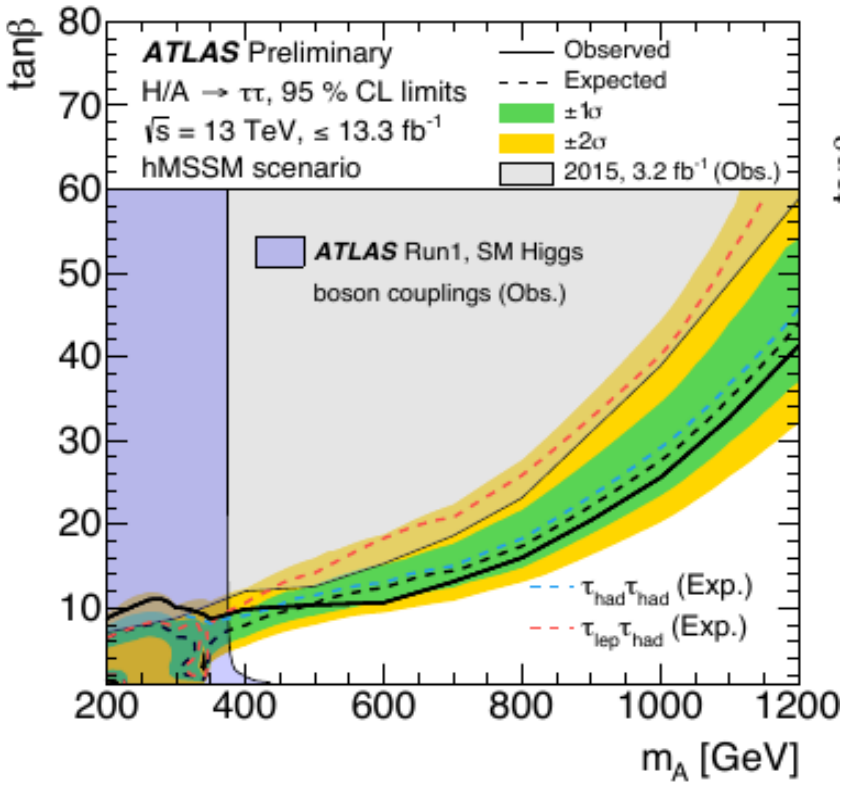
- MOST SENSITIVE CHANNELS
  - 2B 2GAMMA < 300GEV
  - 4B ABOVE.

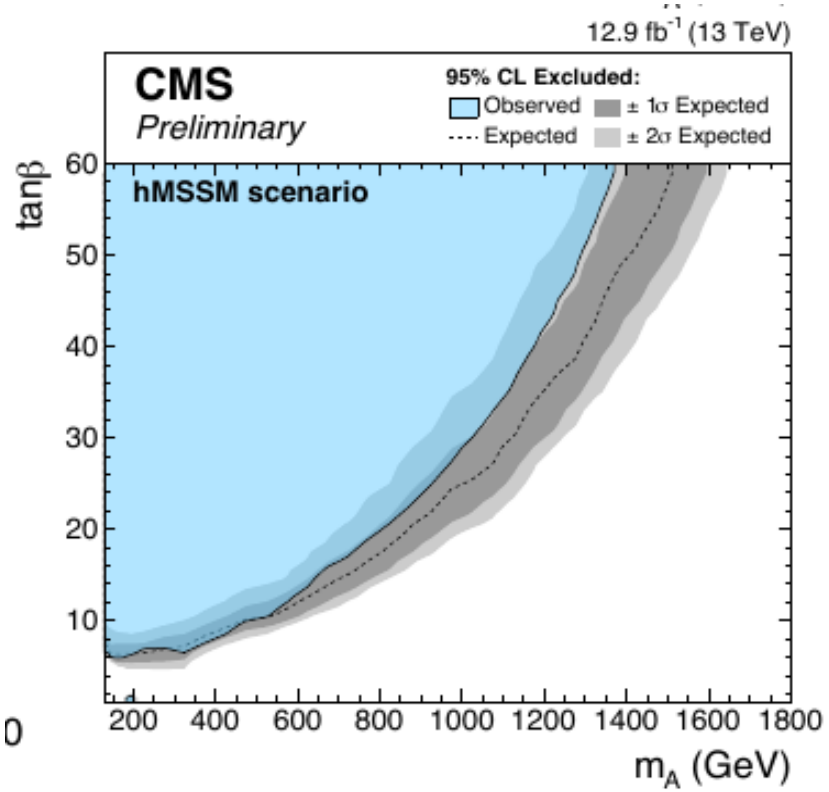
- CLOSELY RELATED TO SEARCH FOR NON-RESONANT HH PRODUCTION.



X → TAU TAU AND X → BBAR

- MSSM-MOTIVATED.
  - BBH AND GGF PRODUCTION MODES EXPLOITED.

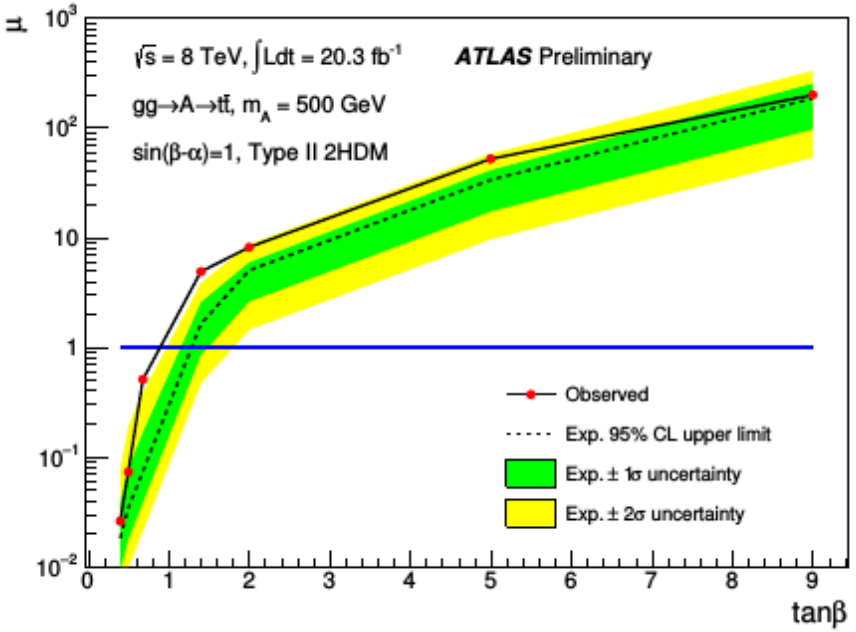


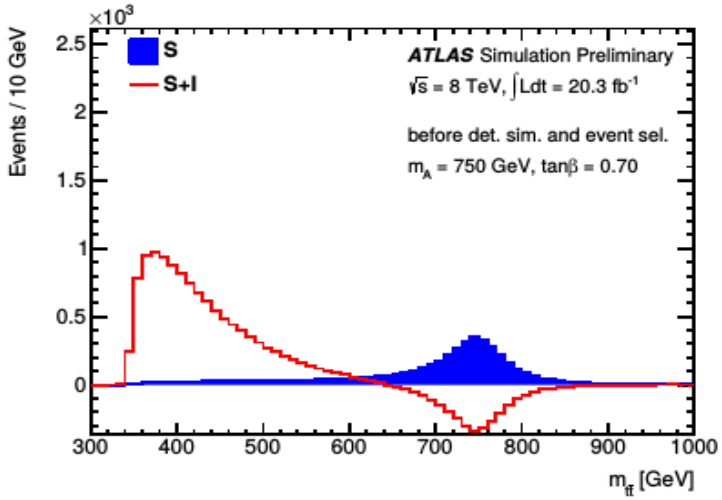


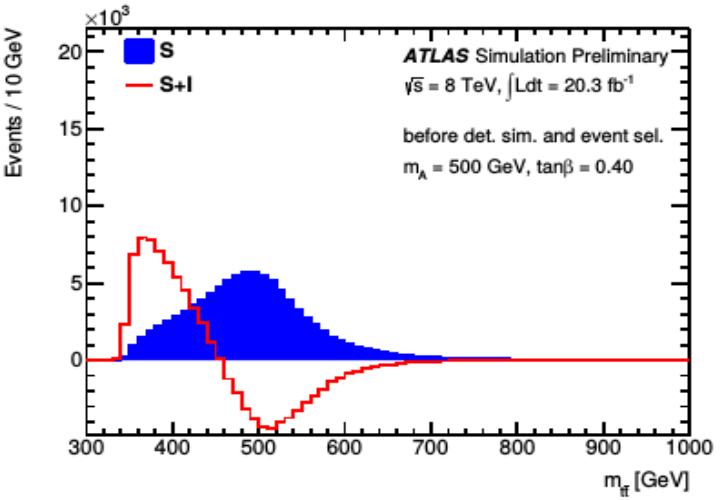
X → TTBAR

VERY CHALLENGING

- LARGE INTERFERENCE EFFECTS LIMIT SENSITIVITY SEVERELY.

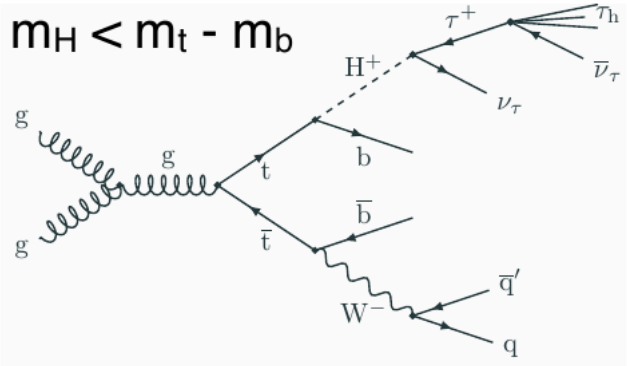


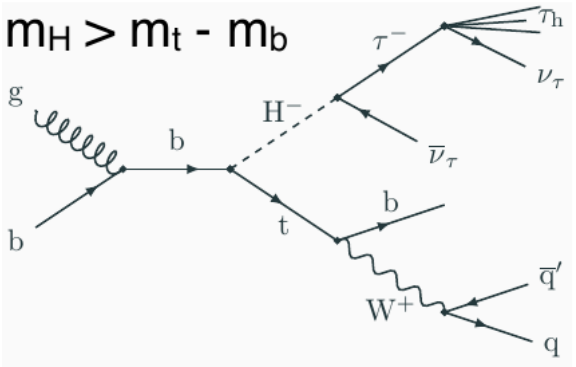




CHARGED HIGGSES

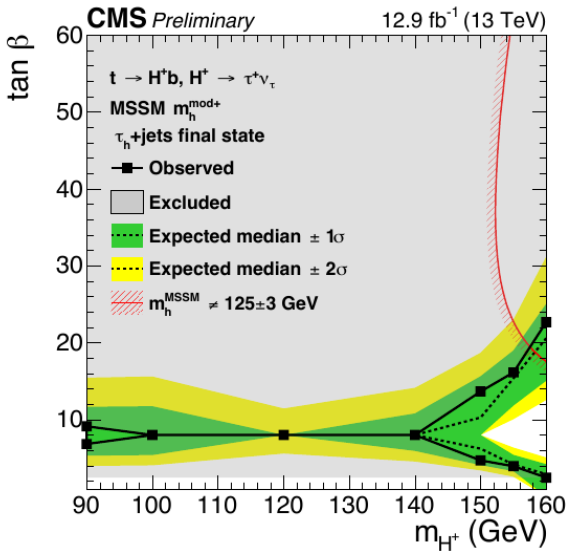
$H^{+-} \rightarrow$ TAU NU, $H^{+} \rightarrow$ CSBAR, CBBAR

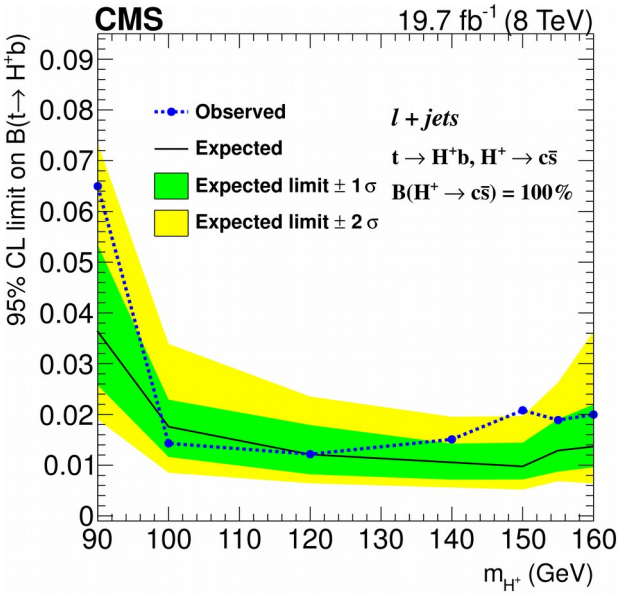


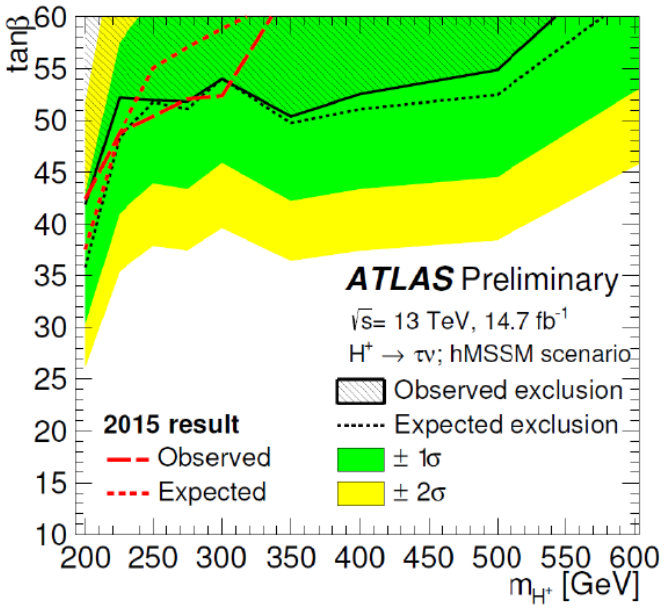


H+- → TAU NU, H+ → CSBAR, CBBAR

ONLY SEARCHED FOR H+- → TAU NU

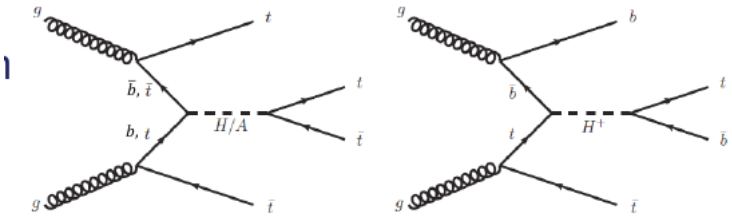


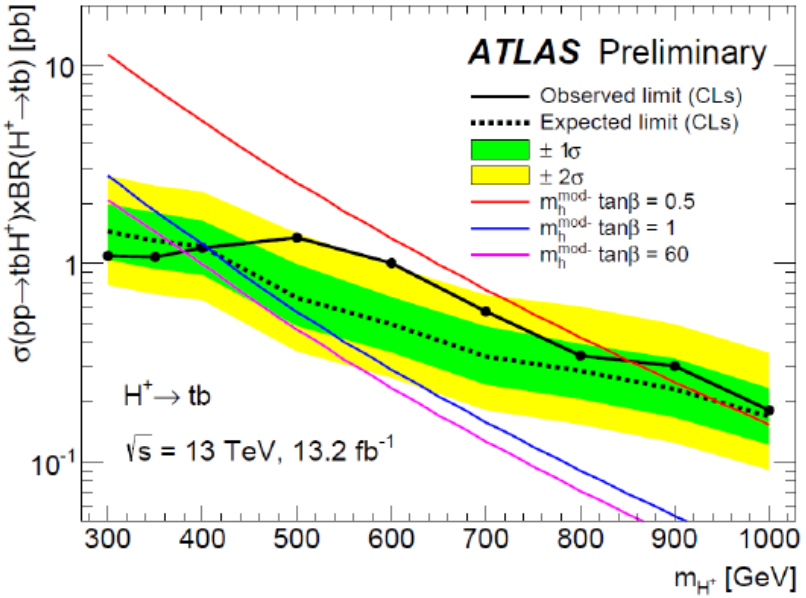


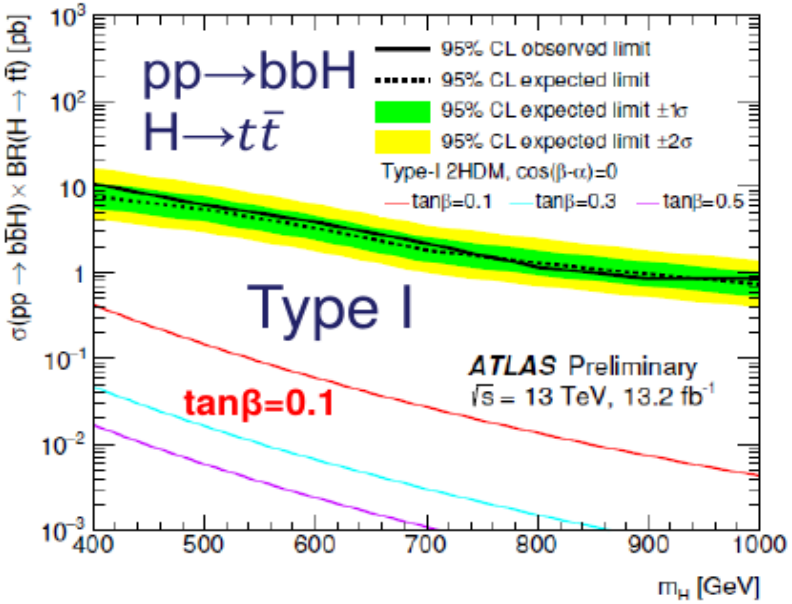


$H^+ \rightarrow T\,B$

SEARCHING FOR INCLUSIVE AND ASSOCIATED PRODUCTION WITH HEAVY FLAVOURS.

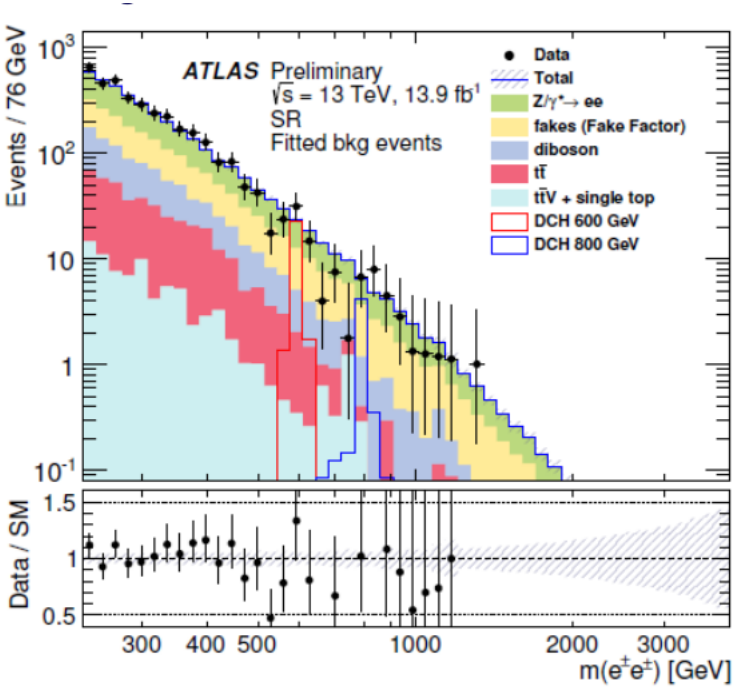


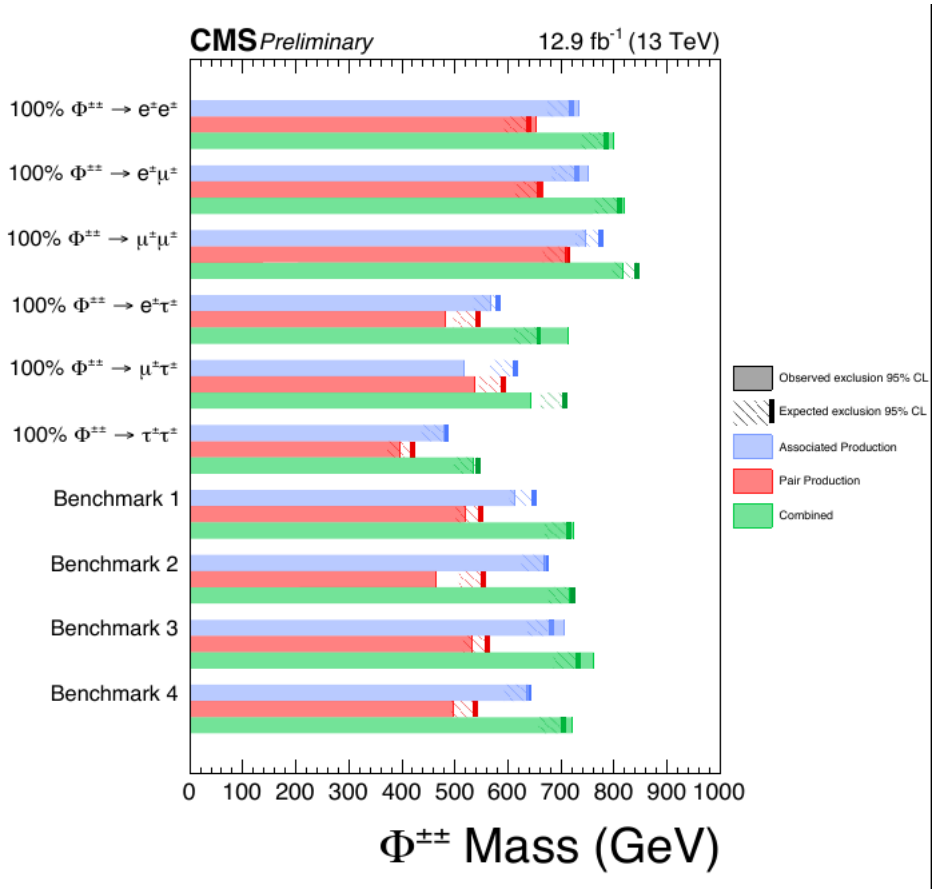




$H^{++--} \rightarrow L^{+-} L^{+-}$

SEARCH FOR SAME SIGN LEPTON RESONANCE.





SUMMARY

H(125)

- HEADING TO PRECISION
- FOCUS SHOULD BE ON INTEPRETATION AND CONRNERSE OF PHASE-SPACE.

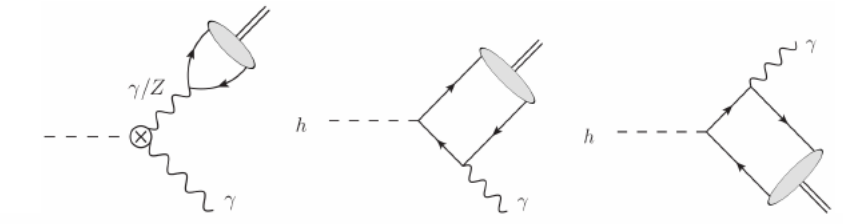
HIGGS SECTOR EXENSIONS

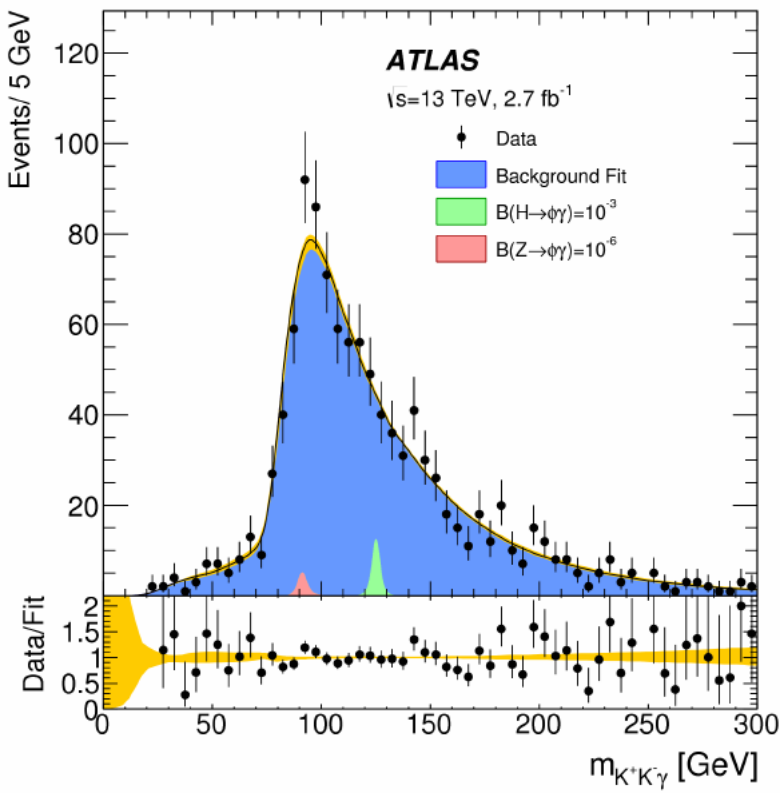
- MANY TOPICS COVERED.
- WHAT ARE WE MISSING?
- WHERE SHOULD WE IMPROVE?

BACKUP

H → PHI GAMMA

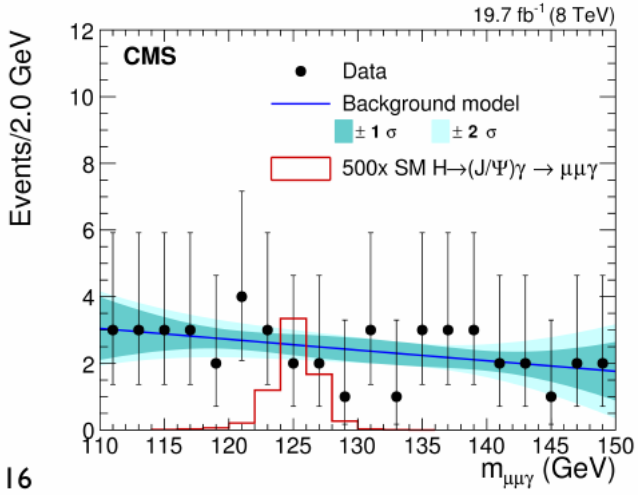
- Reconstruct $\phi \rightarrow K^+K^-$
  - BR($\phi \rightarrow K^+K^-$)=49%
- Two high-pT (20, 15 GeV) isolated collinear tracks ($\Delta R<0.05$, $m_{KK} \sim m_\phi$) recoiling against γ ($p_T > 35$ GeV)
- Dedicated trigger (~78% efficiency wrt. offline selection)
  - First limits on these rare exclusive processes (~600/700 times the expected SM branching fraction)





H → PSI,J/PSI GAMMA

- ATLAS perform a search using the same method as for H→Φγ search
  - BR(H→J/ψγ) <0.15%
  - BR(H→Υ(1S,2S,3S)γ) <(0.13%,0.19%,0.13%)
- CMS performed the search using low di-lepton mass very similar to the H→Zγ analysis but with $m_{ll} < 20$ GeV
  - BR(H→γ*γ) $< 6.7 \times BR_{SM}(H \to \gamma^*\gamma)$
  - BR(H→J/ψγ) <0.15%



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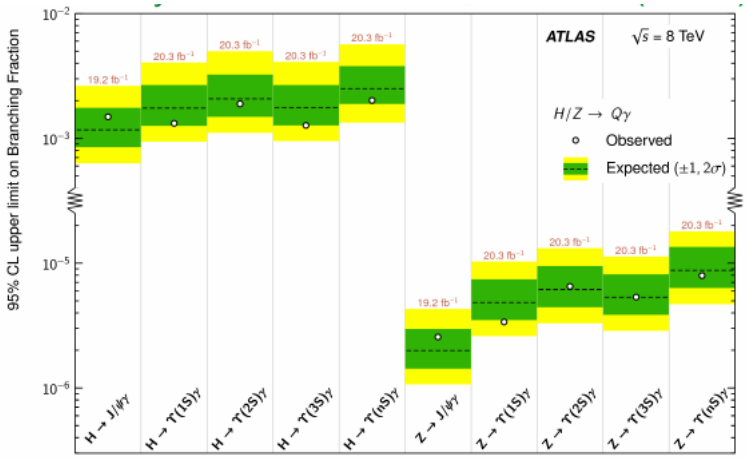

H → MU MU

- ATLAS Run 2
  - m_H= 125 GeV, 95% CL upper limits < 3.0 (3.1) observed (expected) x SM prediction
- ATLAS Run 1 + Run 2
  - < 2.8 (2.9) observed (expected) x SM prediction.

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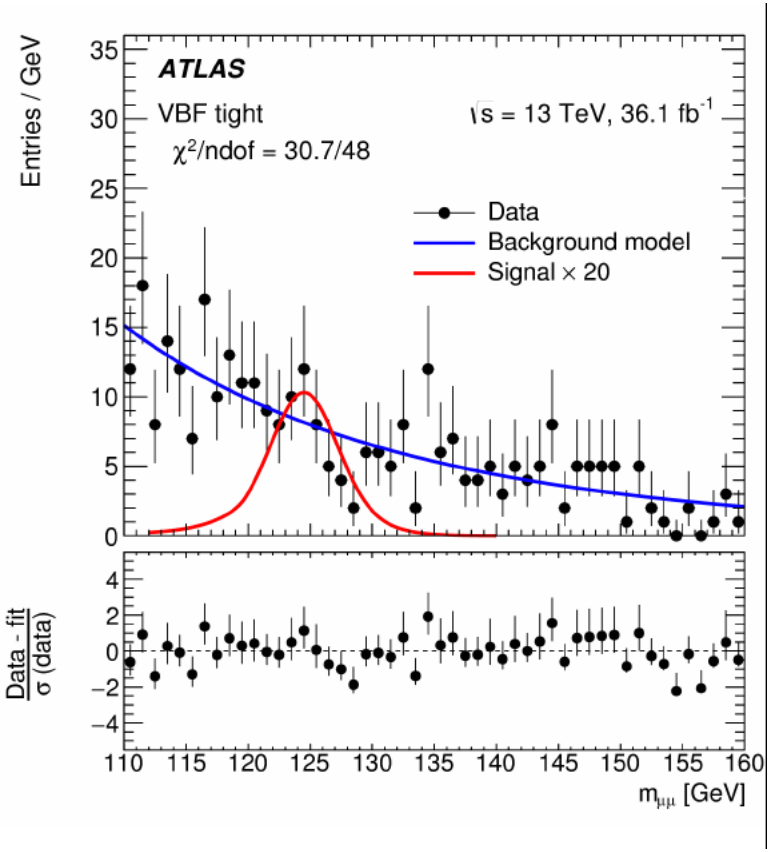
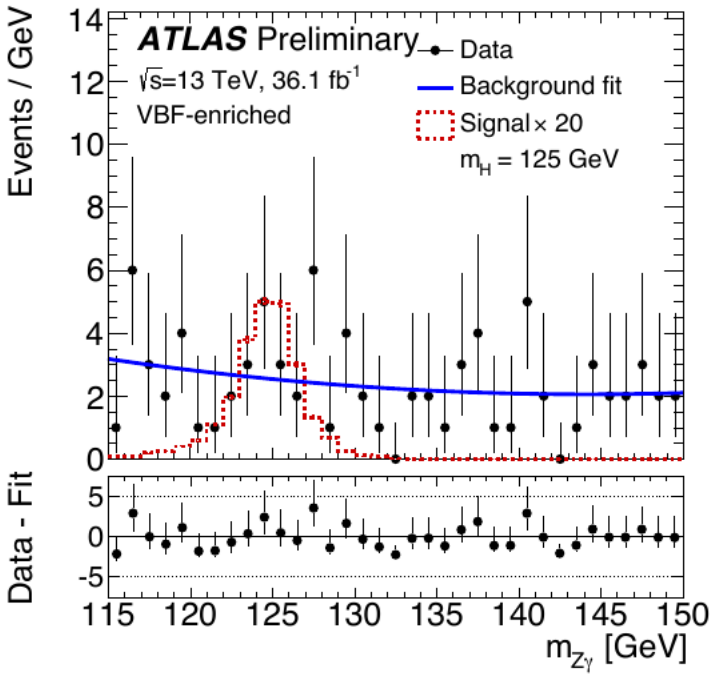
- CMS Run 1: H→μμ
  - m_H = 125 GeV, 95% CL upper limits < 7.4 (6.5) x σ_{SM} observed (expected)
- CMS Run 1: H→ee
  - m_H = 125 GeV, 95% CL upper limits σ(H)xBR<0.041 (0.052) pb observed (expected)
  - BR<0.0019 or ~3.7x10^5 x SM BR



H → Z GAMMA



95% CL Upper limit	Expected without Higgs boson decays	Expected with SM Higgs boson	Observed
$\sigma \cdot BR / (\sigma \cdot BR)_{SM}$	4.4	5.2	6.6