SEARCHES FOR ADDITIONAL HIGGS BOSONS AND BSM DECAYS

YORAM ROZEN
ON BEHALF OF THE ATLAS AND CMS COLLABORATIONS

The Script

In the kingdom of the SM(@LHC) There is a king called Higgs.

But the kingdom only occupies part of the Westeros.

{The SM is only part of the story - it is a low energy approximation. We have evidence (m

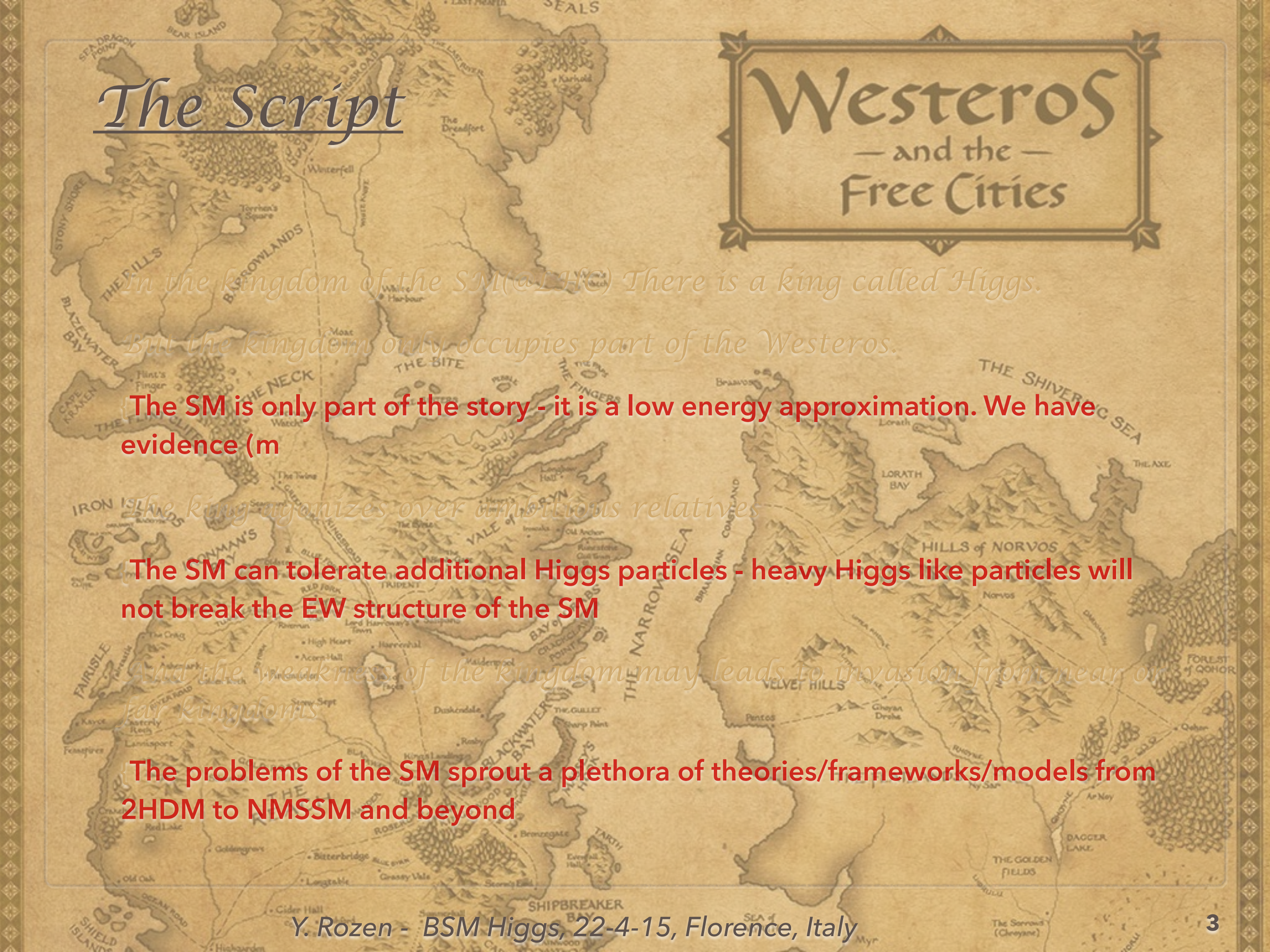
The king agonizes over ambitious relatives

{The SM can tolerate additional Higgs particles - heavy Higgs like particles will not break the EW structure of the SM}

And the weakness of the kingdom may leads to invasion from near or far kingdoms

{The problems of the SM sprout a plethora of theories/frameworks/models}

The Script



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The SM can tolerate additional Higgs particles - heavy Higgs like particles will not break the EW structure of the SM

And the weakness of the kingdom may leads to invasion from near or far kingdoms

The problems of the SM sprout a plethora of theories/frameworks/models from 2HDM to NMSSM and beyond

THIS TALK

- Additional (heavy) Higgs *SM tolerable*
- Di Higgs
- MSSM
- NMSSM
- LFV

} *BSM*

The full list*

Process	Category	CMS	ATLAS
H->WW	Heavy H	CMS-PAS-HIG-13-027	ATLAS-CONF-2013-067
H-> WW or ZZ	Heavy H	arXiv:1504.00936	arXiv:1503.01060
H-> γγ	Heavy H	CMS-PAS-HIG-14-006	Phys. Rev. Lett. 113, 171801
X→hh→γγbb	2HDM	CMS-PAS-HIG-13-032	Phys. Rev. Lett. 114, 081802 (2015)
H->hh	2HDM	arXiv:1410.2751	
H->bb	2HDM	arXiv:1302.2892	
MSSM Higgs to tautau	2HDM	arXiv:1408.3316 arXiv: 1104.1619	JHEP11(2014)056
A -> Zh -> llbb	2HDM	CMS-PAS-HIG-14-011	arXiv:1502.04478
A->Zh	2HDM	arXiv:1410.2751	
A->Zγ	2HDM	CMS-PAS-HIG-14-031	
H^+ -> taunu	2HDM	arXiv:1205.5736 CMS-PAS-HIG-14-020	arXiv:1412.6663; JHEP 1206 (2012) 039
H^+->tb	2HDM	CMS-PAS-HIG-13-026	
H^+ -> csbar	2HDM	CMS-PAS-HIG-13-035	Eur. Phys. J. C, 73 6 (2013) 2465
H^+ (lepton universality)	2HDM		JHEP03(2013)076
H^0->H^+W->hWW->	2HDM		Phys. Rev. D 89, 032002 (2014)
H → WW → eνμν	2HDM		ATLAS-CONF-2013-027
H^+->WZ	Htriplet		arXiv:1503.04233
H^{++}->WW	Htriplet	arXiv:1410.6315	
a -> mumu	NMSSM	arXiv:1206.63260	
h->bb+jets+MET	NMSSM	CMS-PAS-HIG-14-030	
h->γ+MET	NMSSM GMSB		ATLAS-CONF-2015-001
X -> HH -> 4 b	Mod. Ind. BSM	arXiv:1503.04114	ATLAS-CONF-2014-005
H -> tau mu	LFV	CMS-PAS-HIG-14-005	

** Published and most recent conference notes*

The full list

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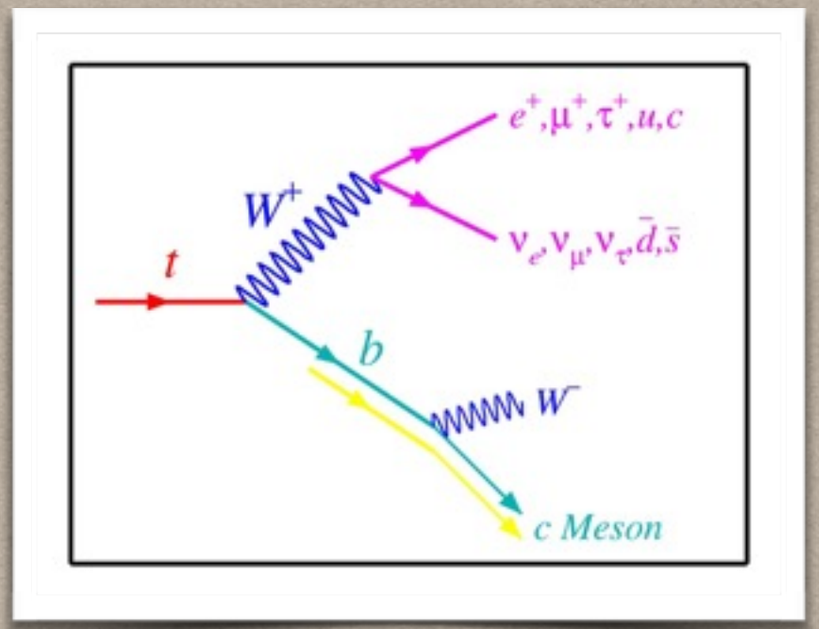
H -> tau mu	LFV	CMS-PAS-HIG-14-005	

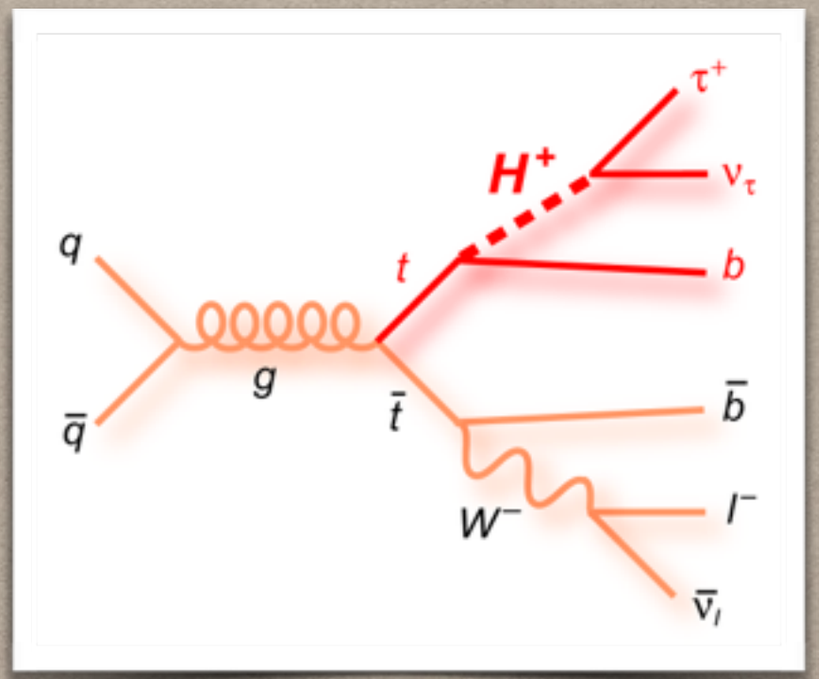
** Dozens of papers but with time limitations we'll focus only on two (but summarize more)*

H^+ SEARCH VIA LEPTON UNIVERSALITY

- In SM top decay, e,μ and τ are of equal abundance (universality)
  Nτ/Nμ= Nτ/Ne=1
  (ignoring eff, phase space)



- But assuming mass dependent coupling of the charged Higgs, taus are favored and the ratios Nτ/Nμ and Nτ/Ne differ from unity



- Limited to M(H)<M(t)

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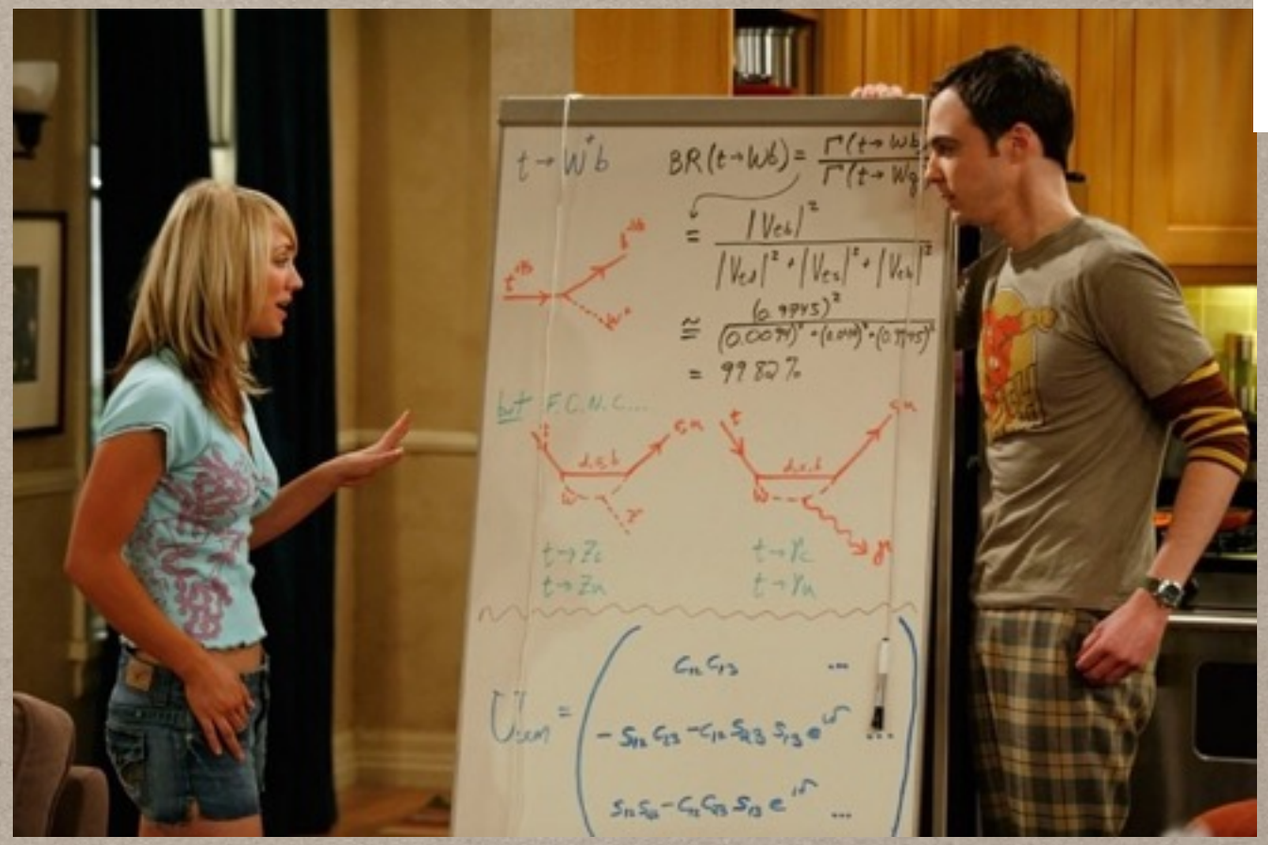


Simple idea - counting.
Not shape comparison over the SM
-> Model independent

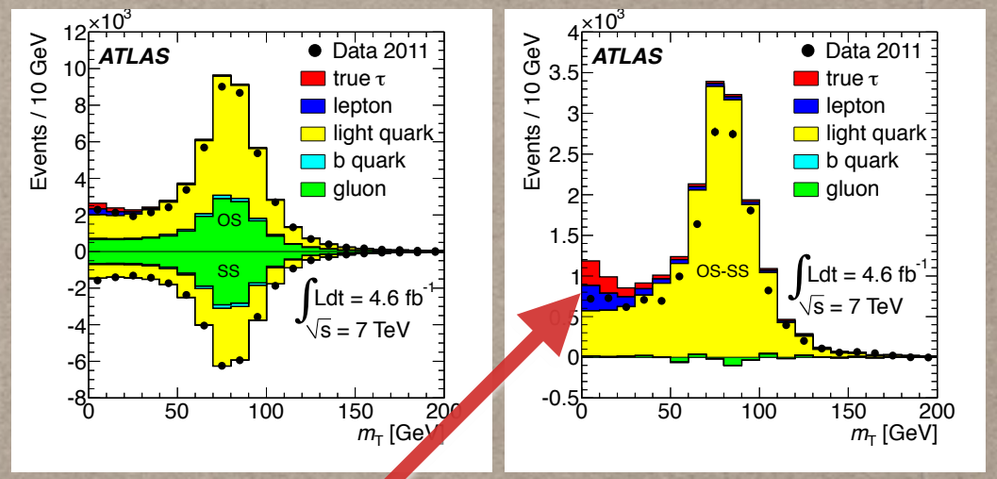
H^+ SEARCH VIA LEPTON UNIVERSALITY

- Defining the ratio $$R_t = \frac{\mathcal{B}(t\bar{t} \to b\bar{b} + l\tau_{had} + N\nu)}{\mathcal{B}(t\bar{t} \to b\bar{b} + ll' + N\nu)}$$

- Using leptonic decay (e, μ) for the "other" top
  - 1 e or μ above 25 GeV
  - >=2 jets of which 2 are b-tagged
  - 1 tau jet (no additional lepton) or 1 additional lepton
  - MET>40 GeV

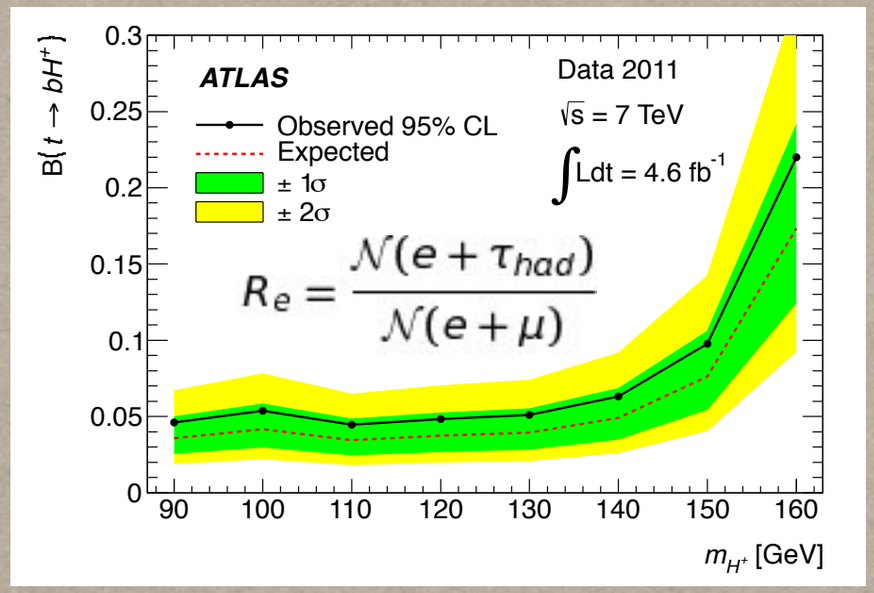
top enrichment

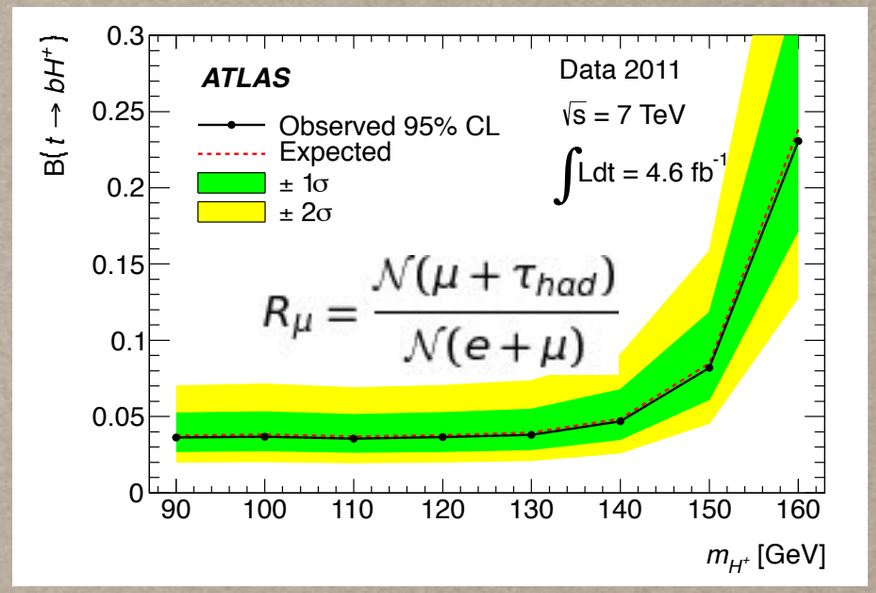
- Background:
  - mis-id e or μ (not originating from the top) - use tight/loose technique for weighting events
  - mis-id tau ~50% (mostly jets) - use data driven (OS-SS)



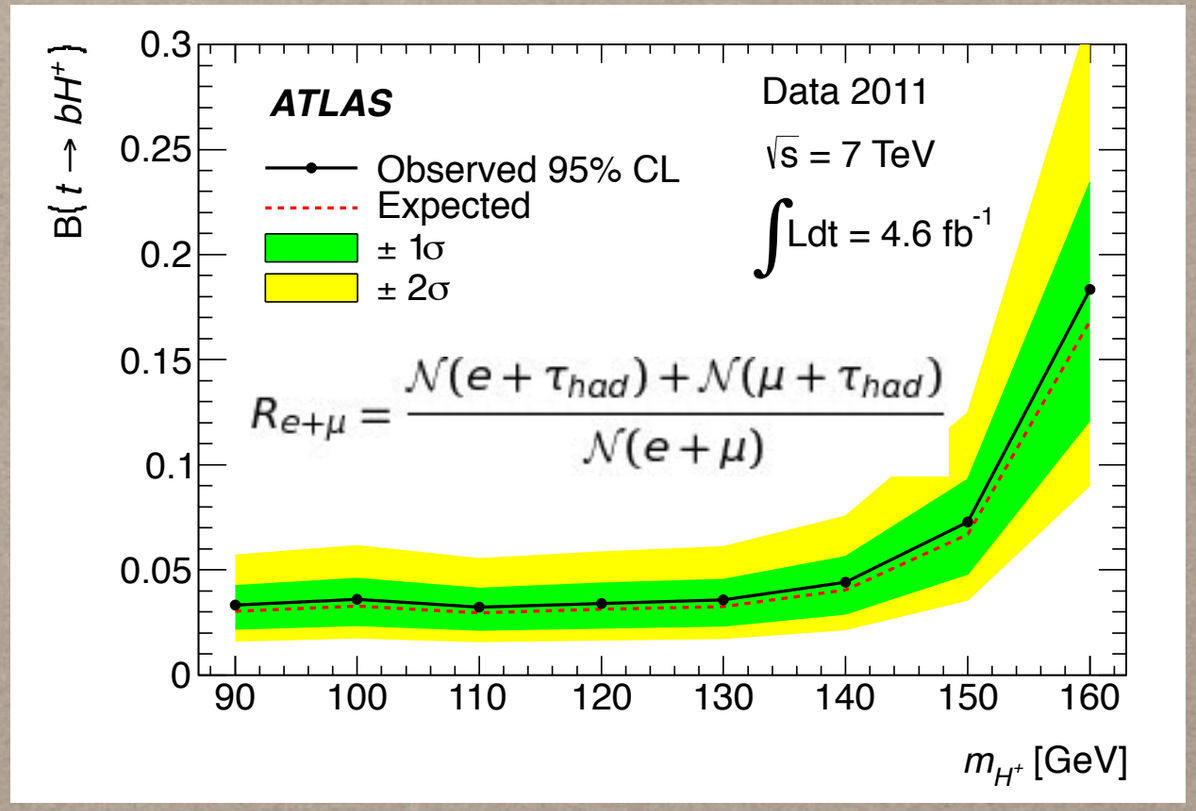
Z->ττ component removed with m_T cut

H^+ VIA LEPTON UNIVERSALITY - RESULTS





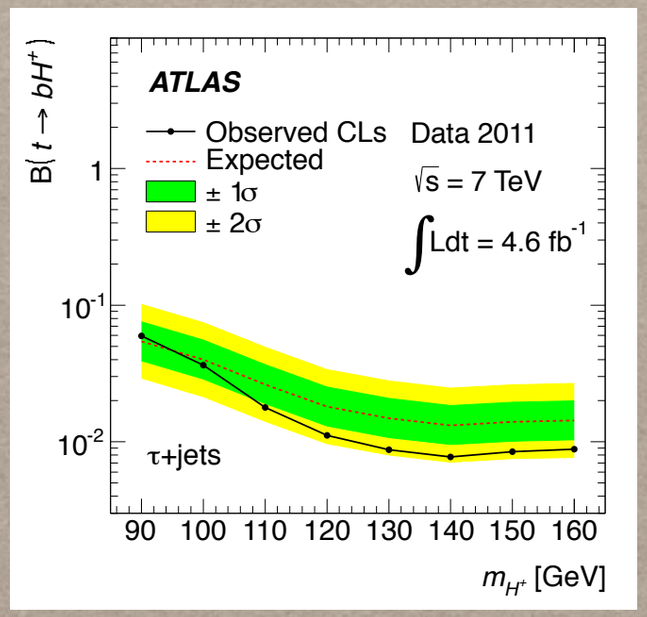
Assuming B(H^+->$\tau\nu$)=1 the Re and Rμ are directly related to B(t->bH)

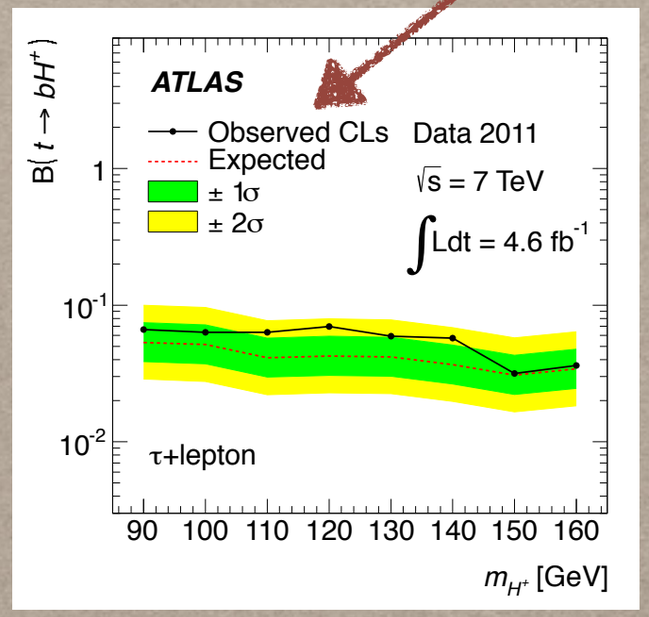


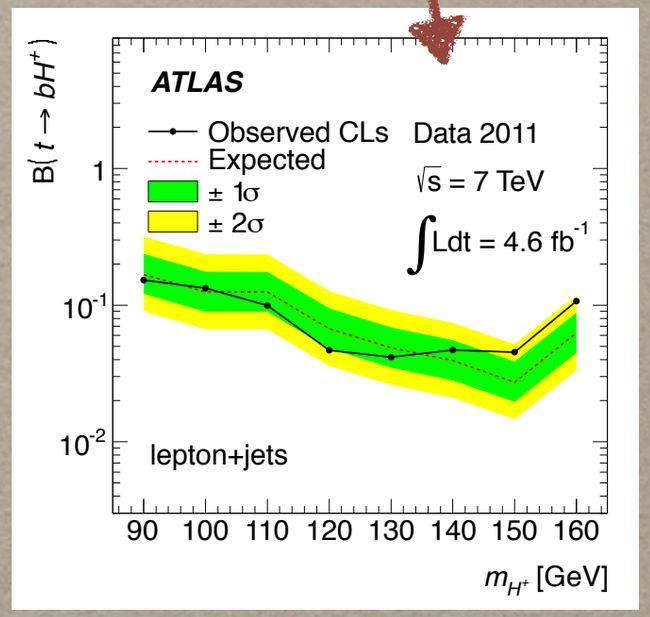
On The Same Topic - A Direct Search For H^+ Via τ

- Still in the m(H)<m(t) domain
- 3 analysis channels:

t->Wb	t->Hb; H->τ
Jets	Hadronic
Jets	Leptonic
Leptonic	Hadronic



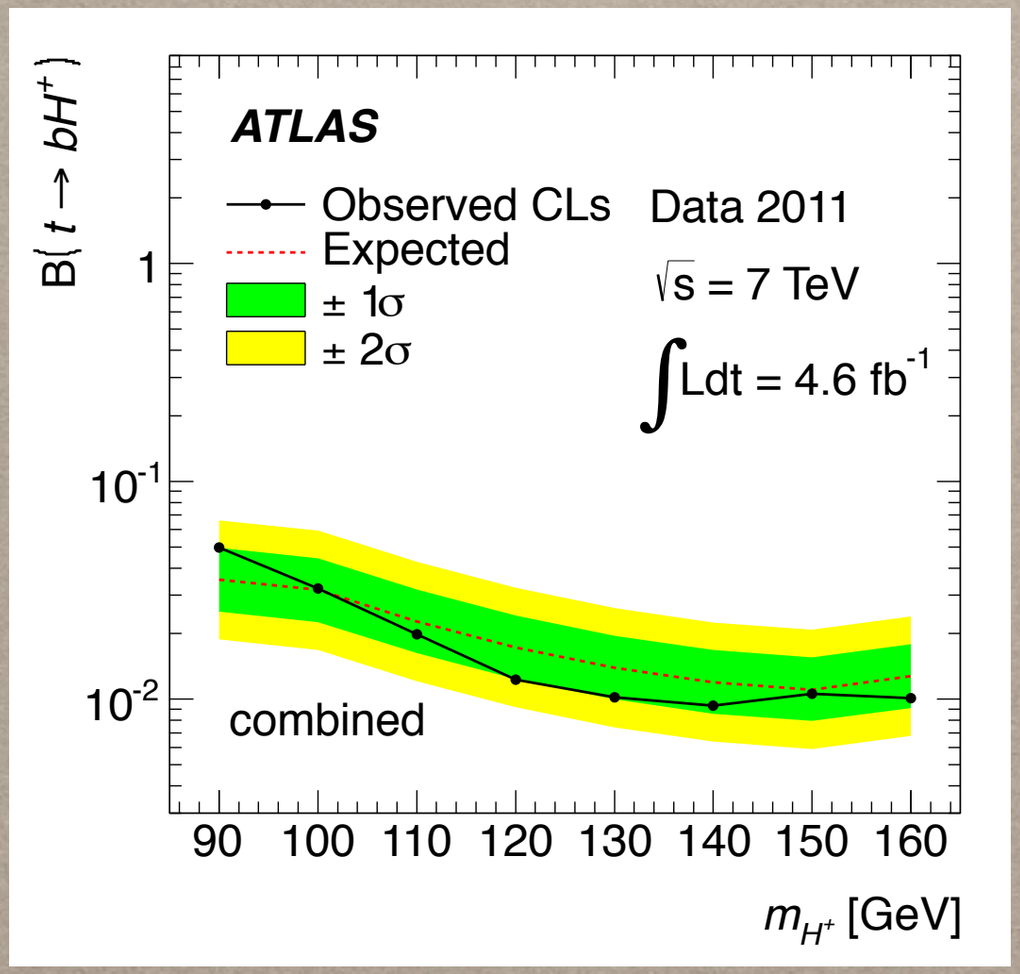




On The Same Topic - A Direct Search For H^+ Via τ (The Full Data Set)

- Still in the m(H)<m(t) domain
- 3 analysis channels:

t->Wb	t->Hb; H->τ
Jets	Hadronic
Jets	Leptonic
Leptonic	Hadronic



The full data set (but only in the hadronic mode is shown in the summary plots (S-17)

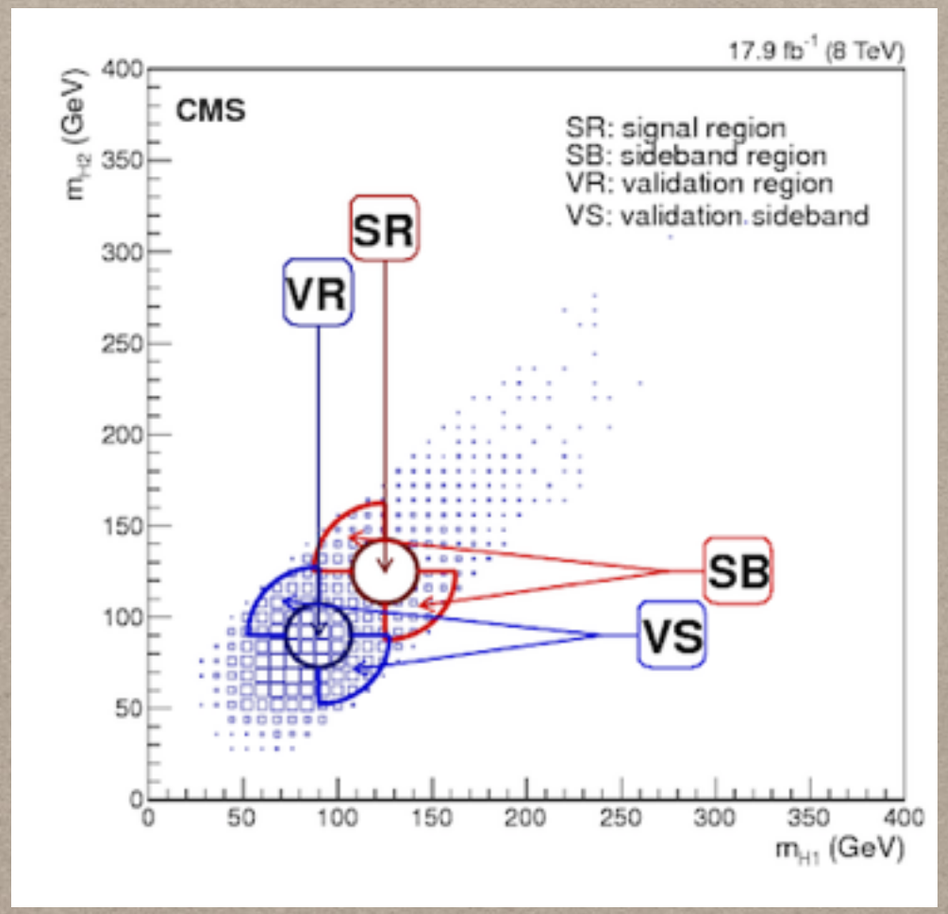
X->HH->bbbb

- While too small in the SM (~10 fb), Narrow width resonant production of higgs pair is possible in BSM (Radion or Kaluza-Klein graviton, 2HDM).
- Searching for SM higgs pair -> model independant.
- Using 2x(H->bb) (ATLAS also used H->bb,H->$\gamma\gamma$).
  - Two mass ranges: Low mass hypothesis (270-450 GeV) ; High mass hypothesis (450-1100 GeV)
- Main background: QCD multijet (~75%); tt (~25%)
- selection:
  - 4 b-tagged jets (2j: p_T>40,2j: p_T>90)
  - Mbb within 35 GeV of Higgs mass
  - collimated Higgs jets
  - One Higgs p_T at least 300 GeV

  } For High mass hypothesis (450-1100 GeV)
  - combined Higgs candidates deviation < 17.5 GeV

X->HH->bbbb

- Defining Signal, Sideband and Validation regions



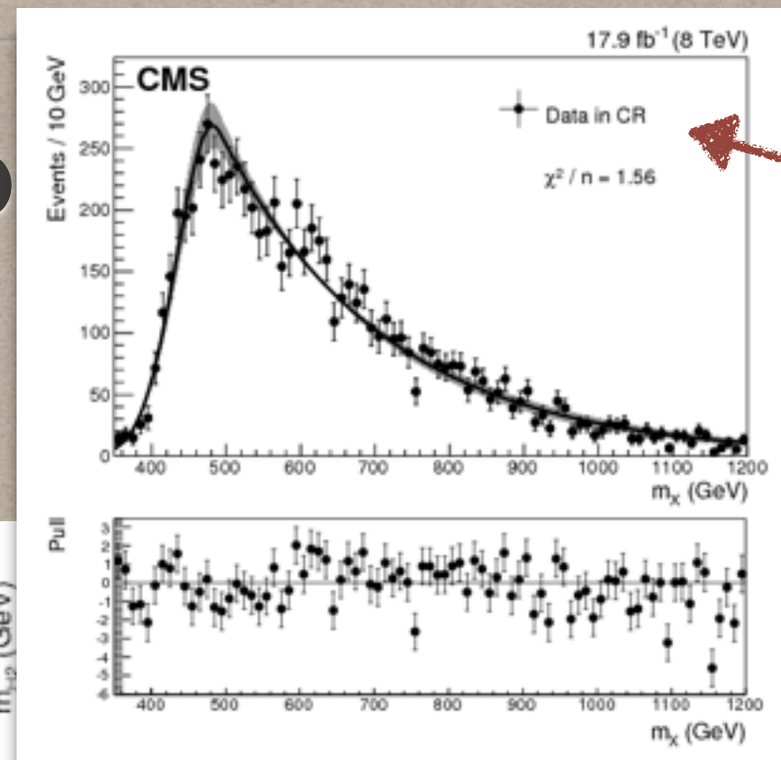
X->HH->bbb

GausExp param.

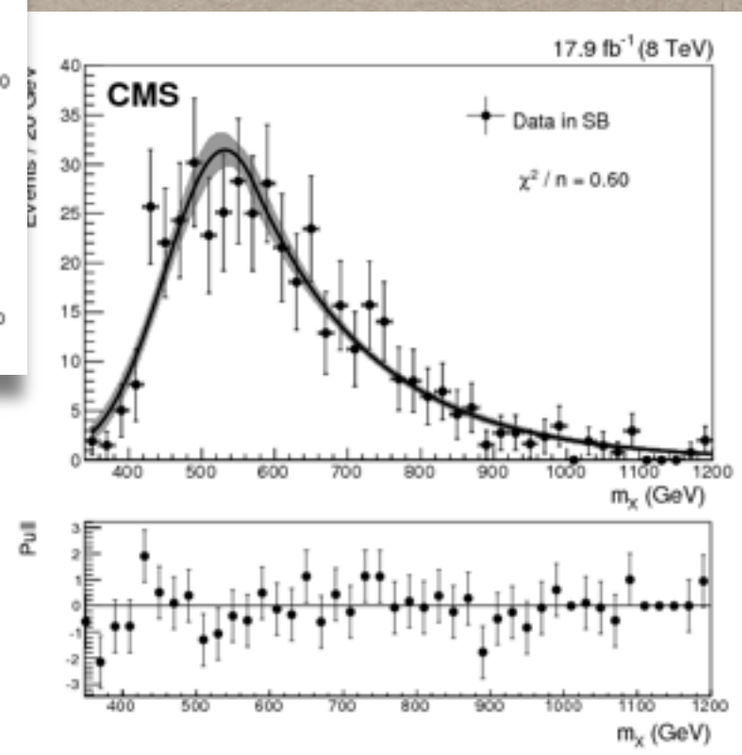
proven in SB and CR,

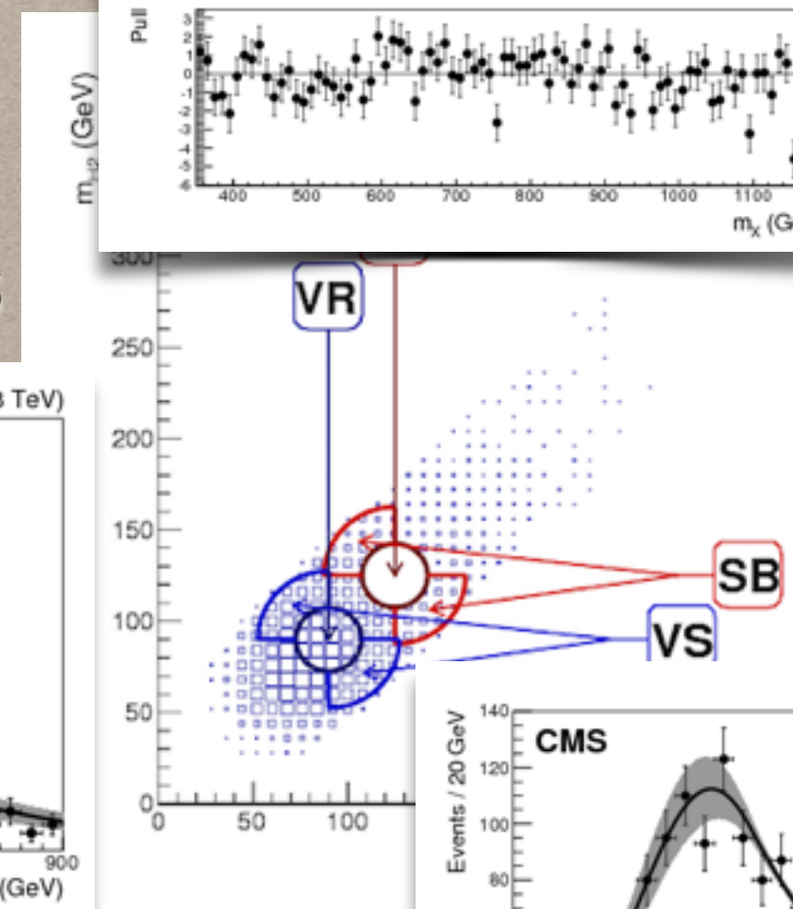
verified again in VR

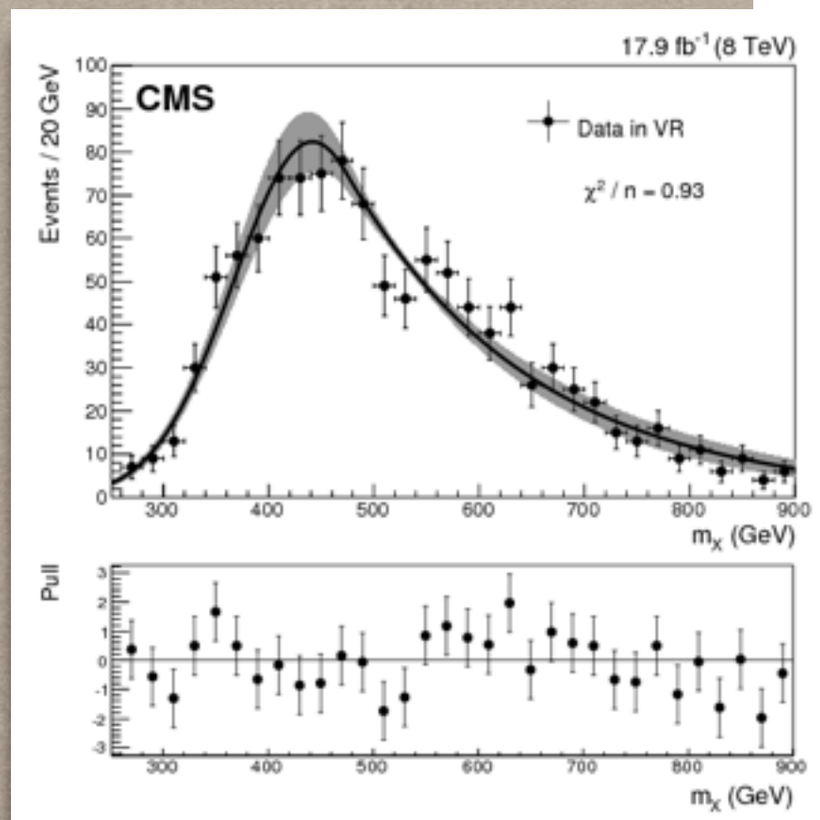
- Defining Signal Sideband and Validation regions

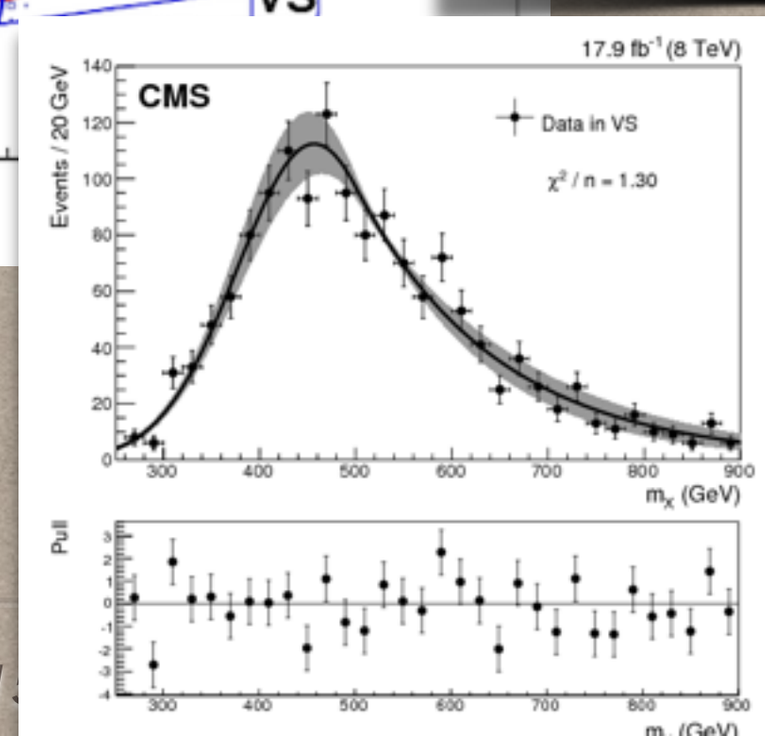


CR=SR 3b1~~b~~





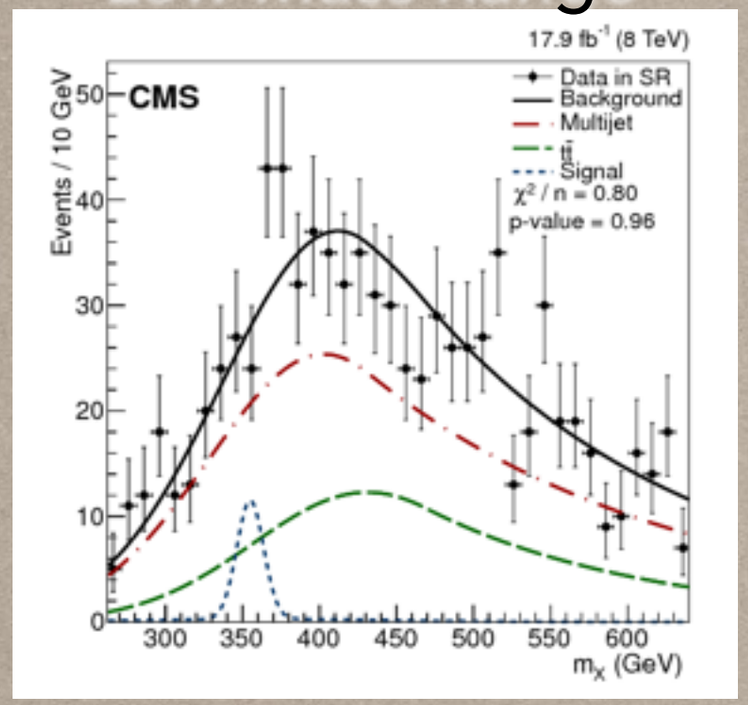




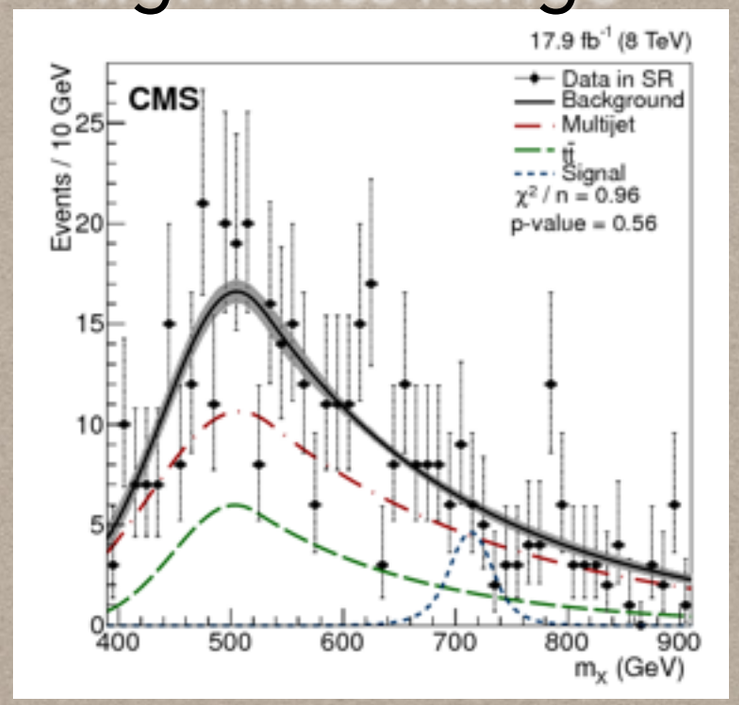
Plots are after tt BG subtraction(~25%)

X->HH->bbbb - Results

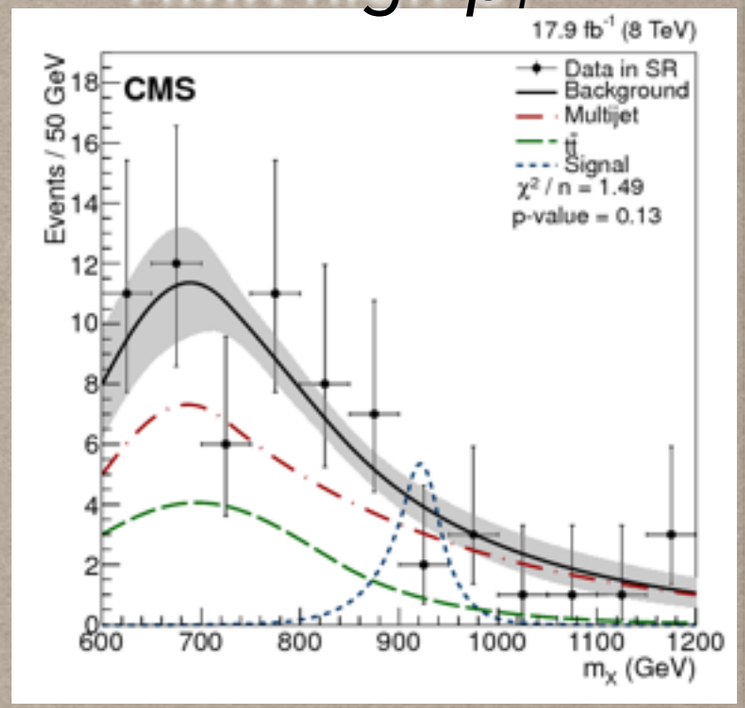
Low Mass Range



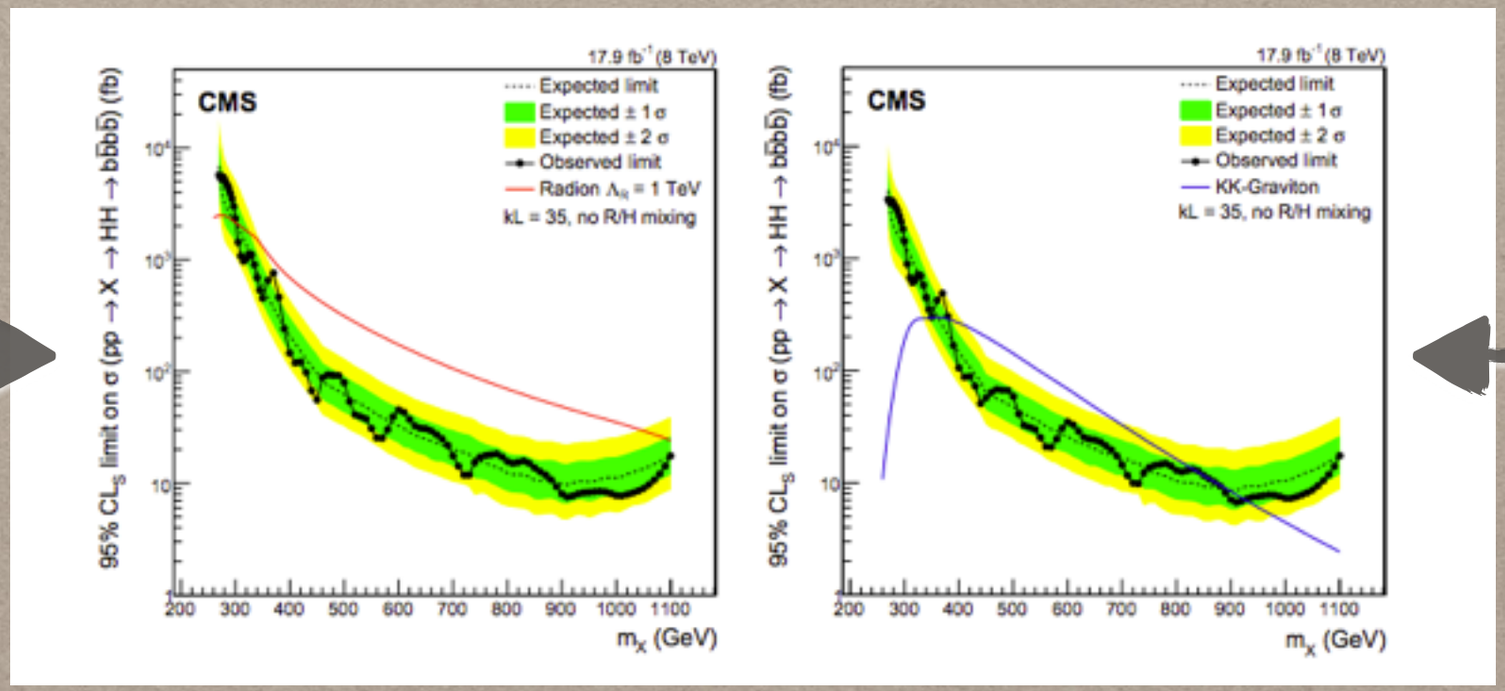
High Mass Range



HMR high p_T



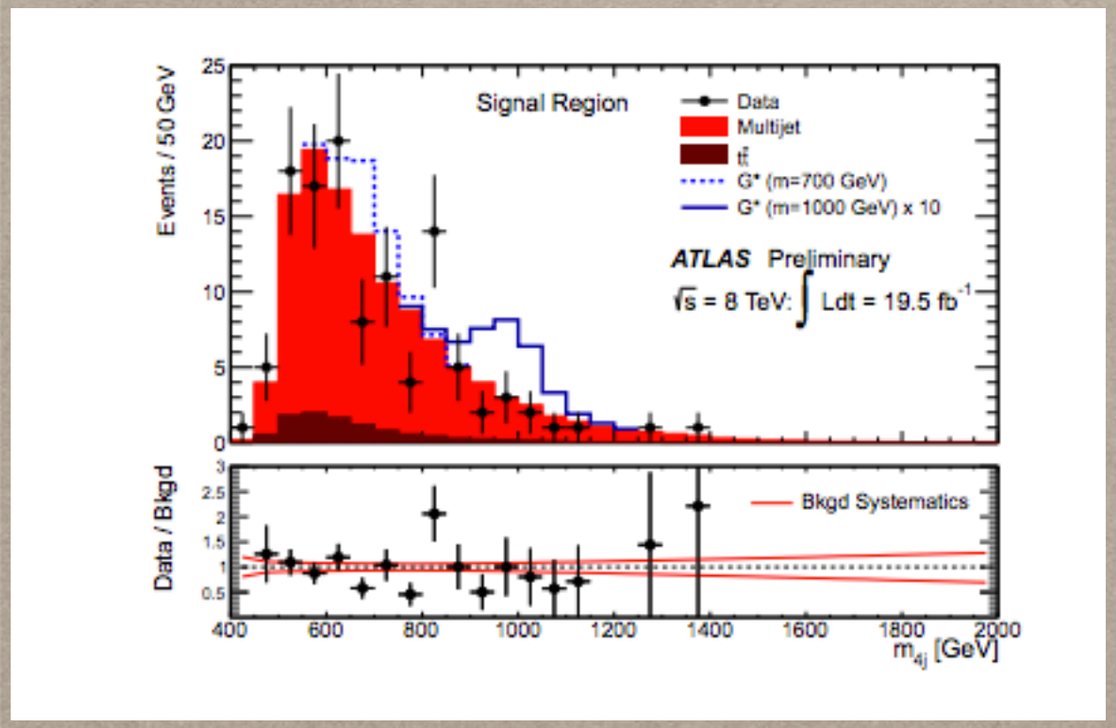
spin 0

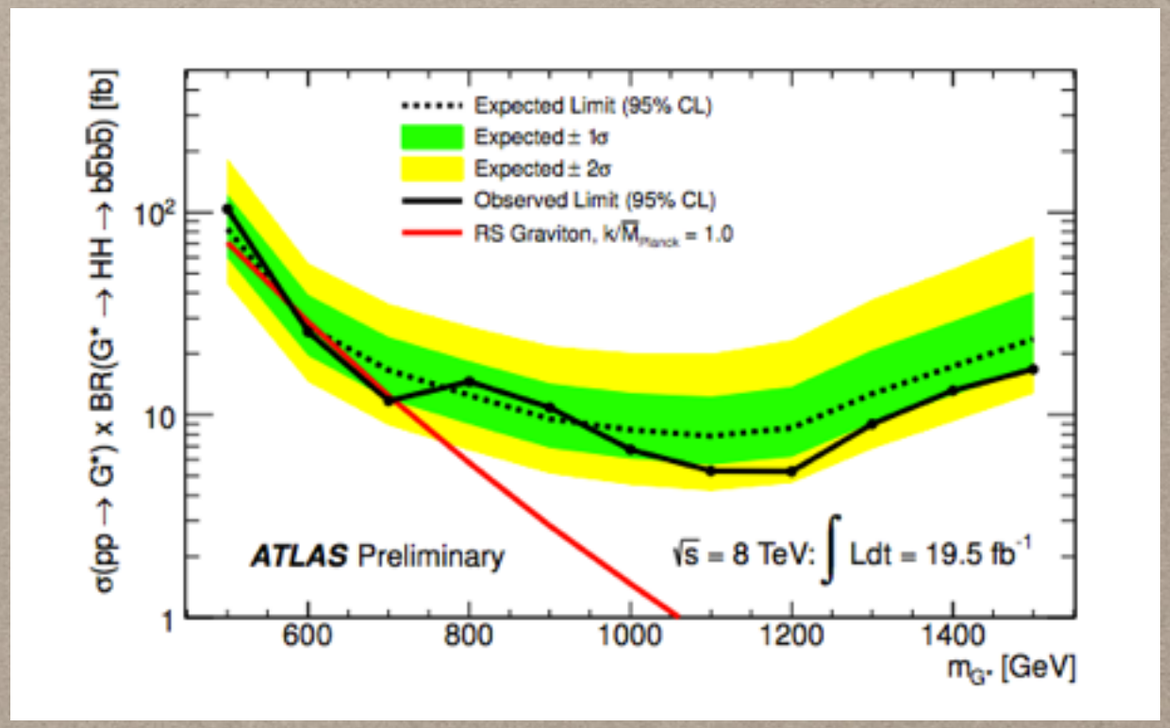


spin 2

X->HH->bbbb

- Similar analysis from ATLAS
- main difference: top rejection by using additional jets (W mass, top mass) -> different BG composition (~90% QCD; ~10% tt)





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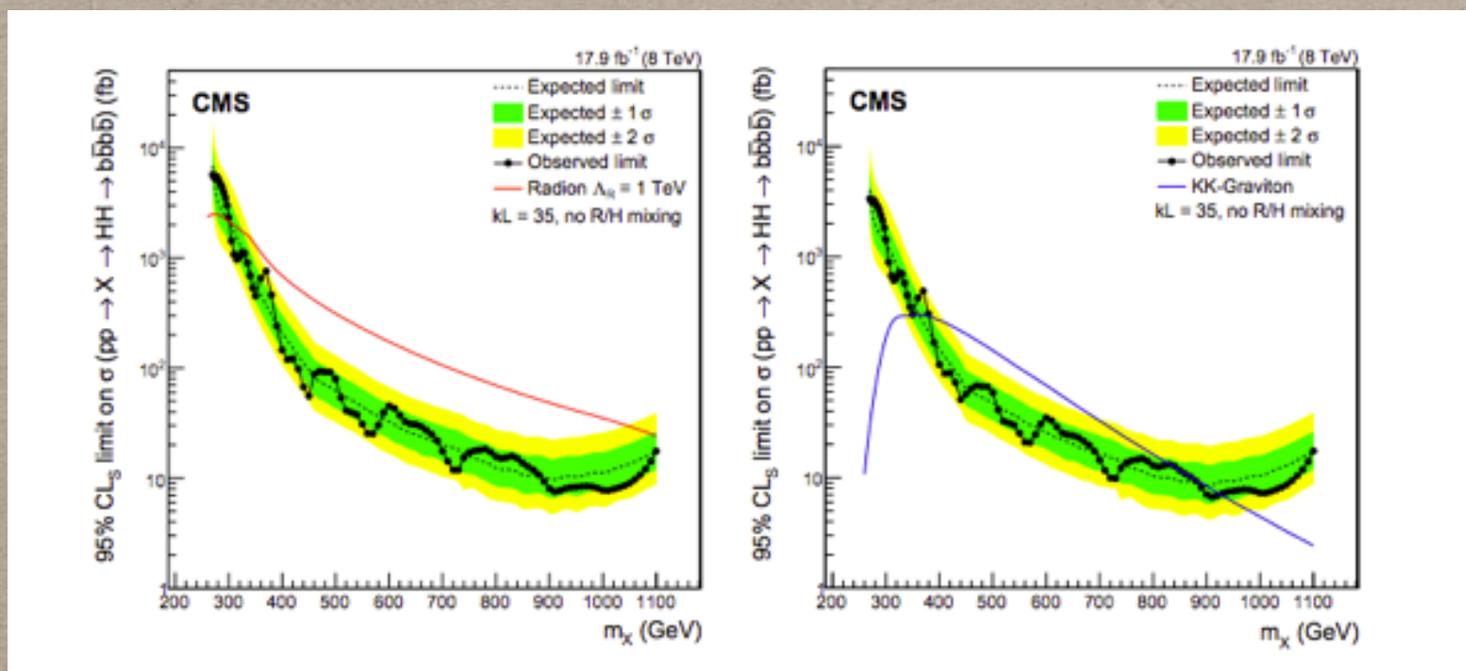
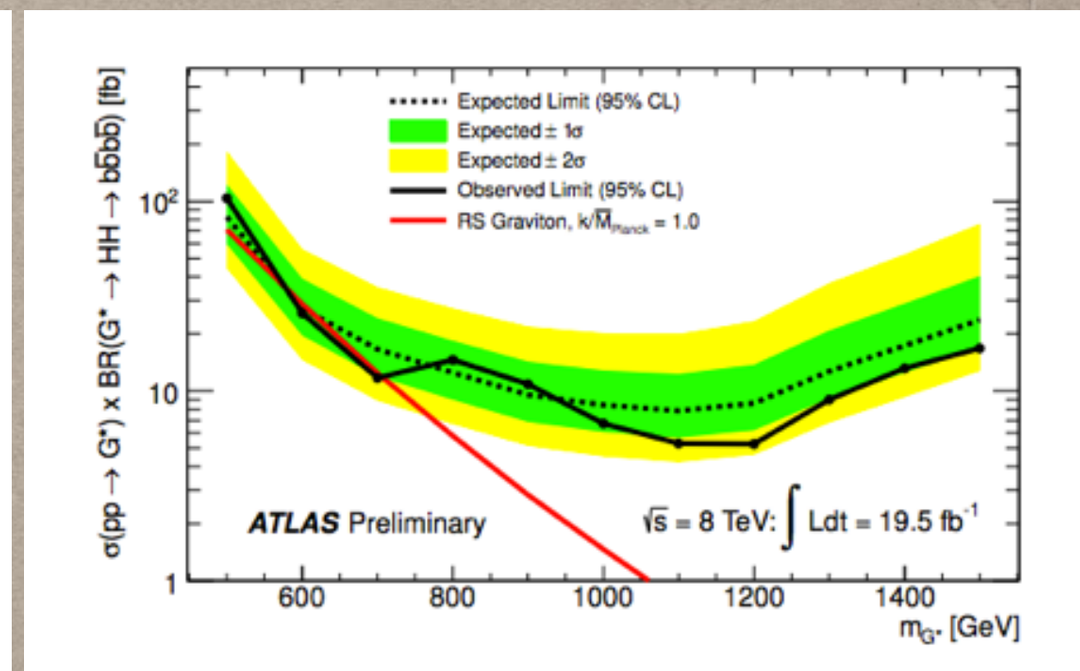
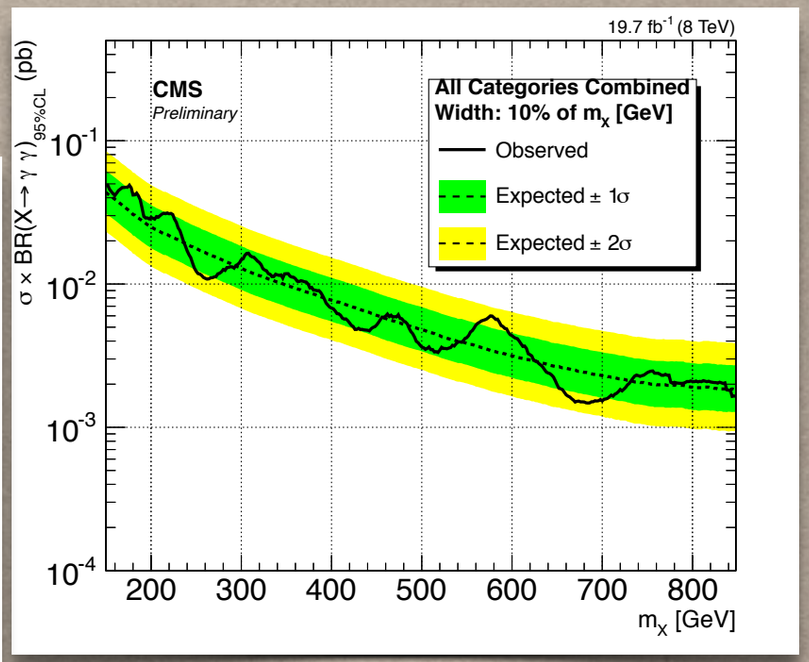




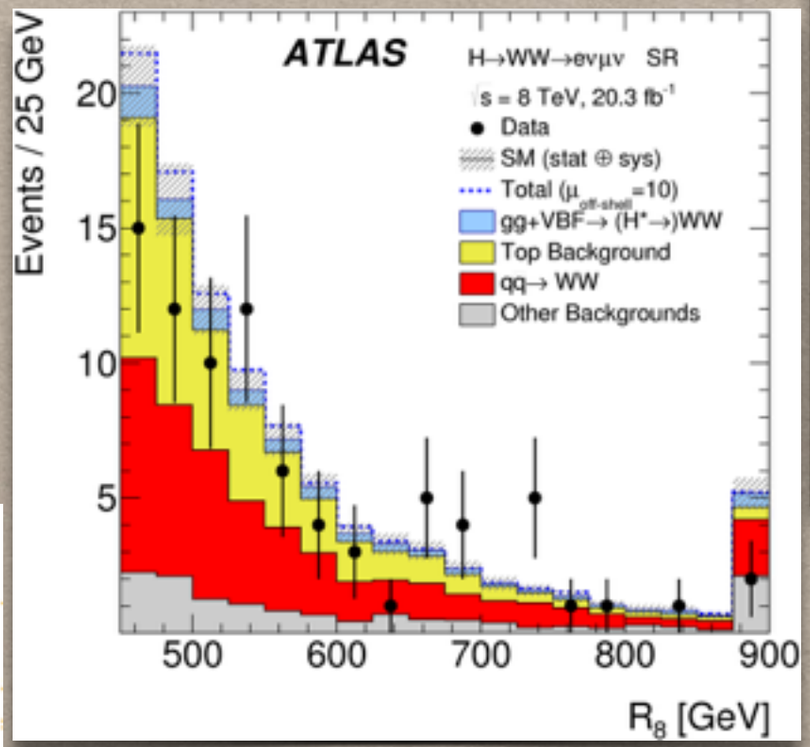
similar results (where comparable)

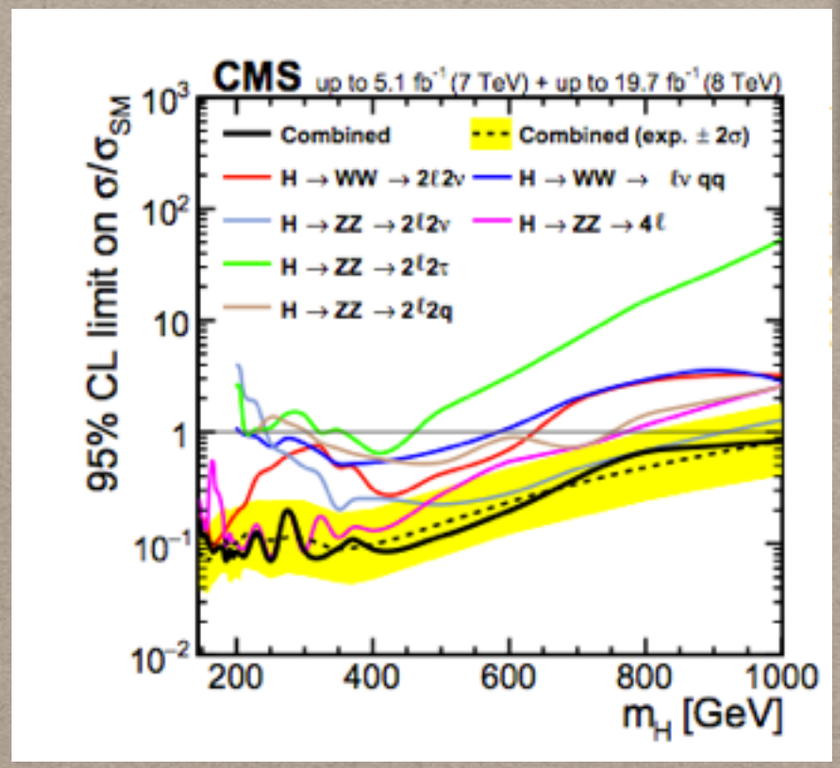
SUMMARY: HEAVY HIGGS

H->γγ from CMS



H->WW from ATLAS

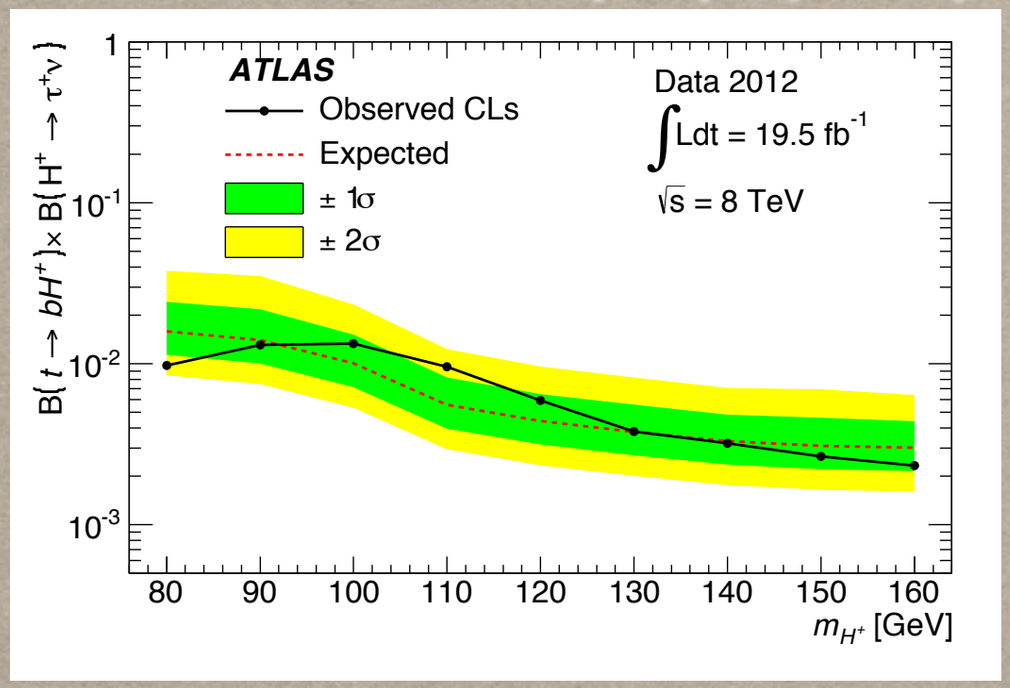


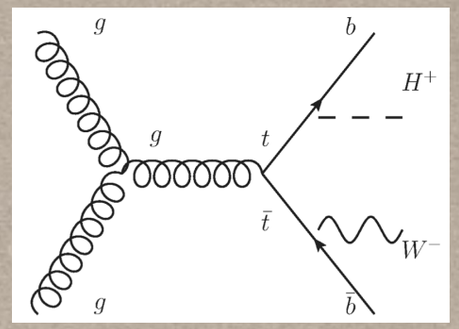


H->WW/ZZ from CMS

SUMMARY: H⁺

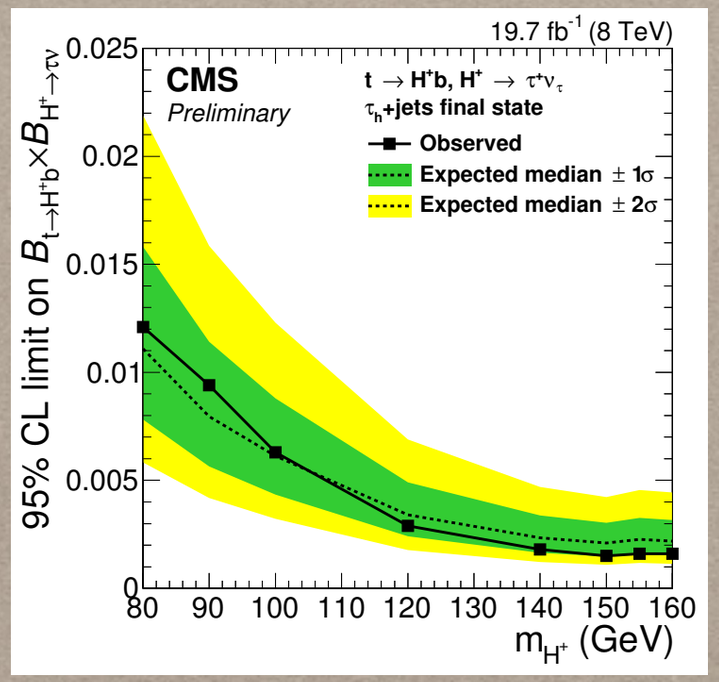
LIGHT H⁺ (M(H)<M(t))

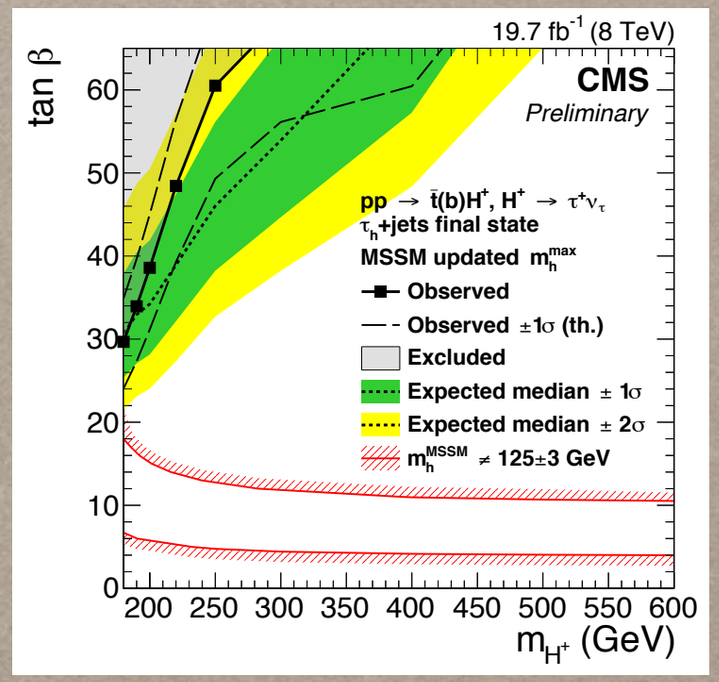




ATLAS hadronic tau

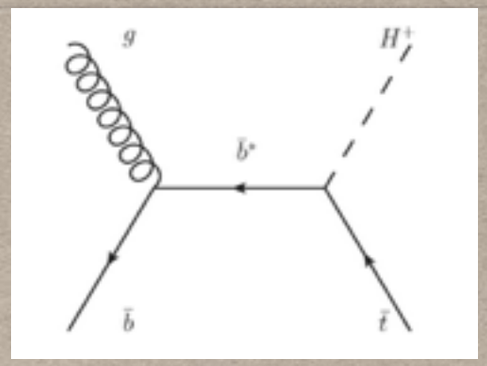
CMS hadronic

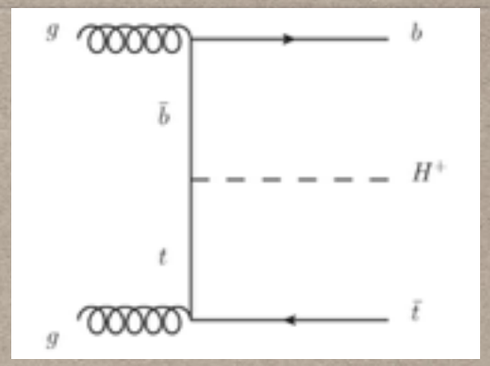


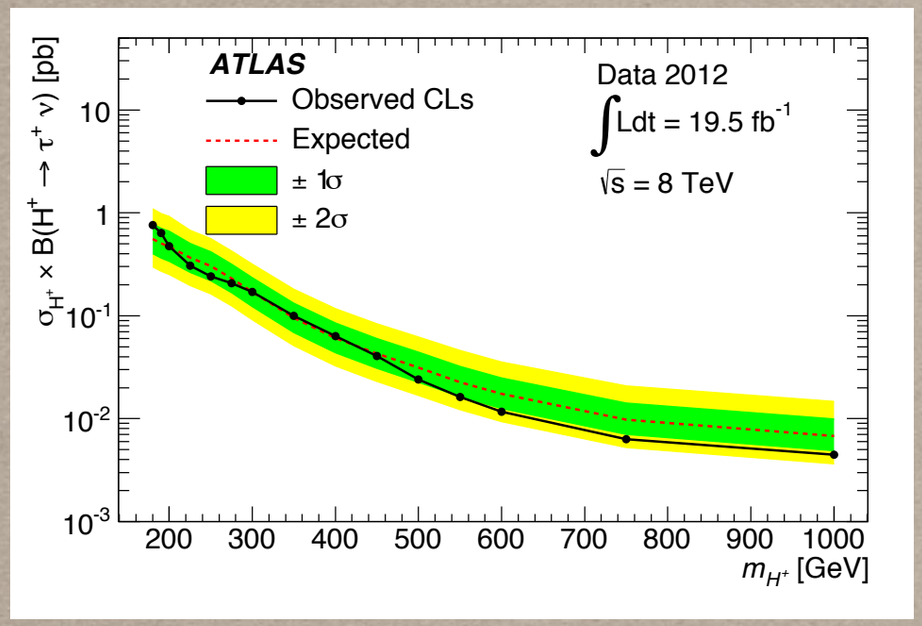


SUMMARY: H^+

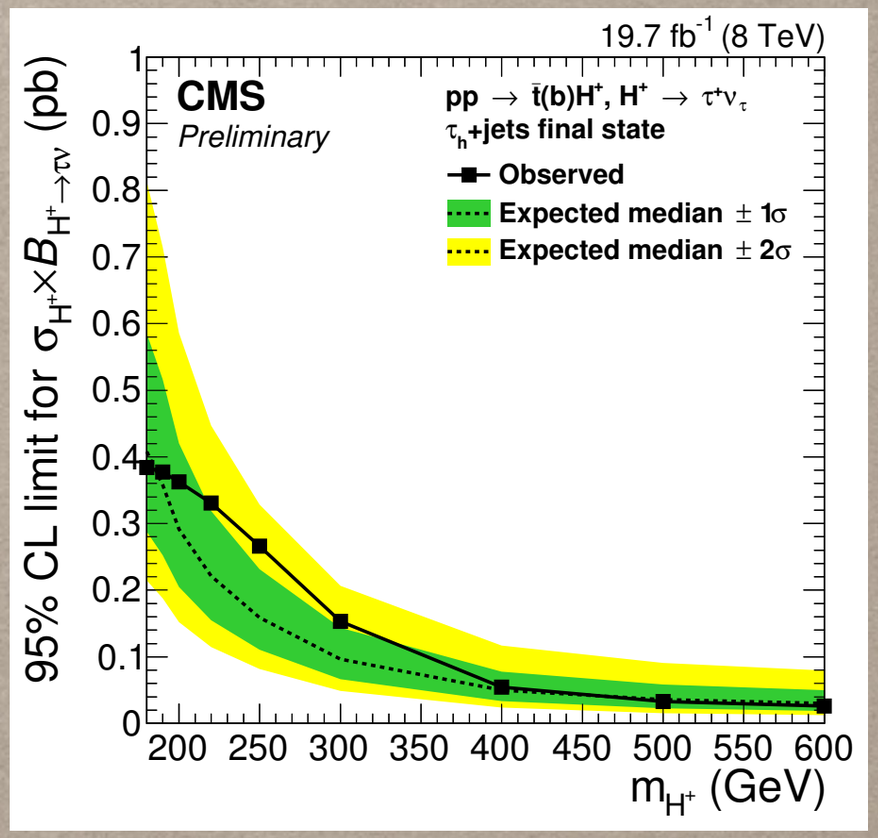
HEAVY H^+ (M(H)>M(t))



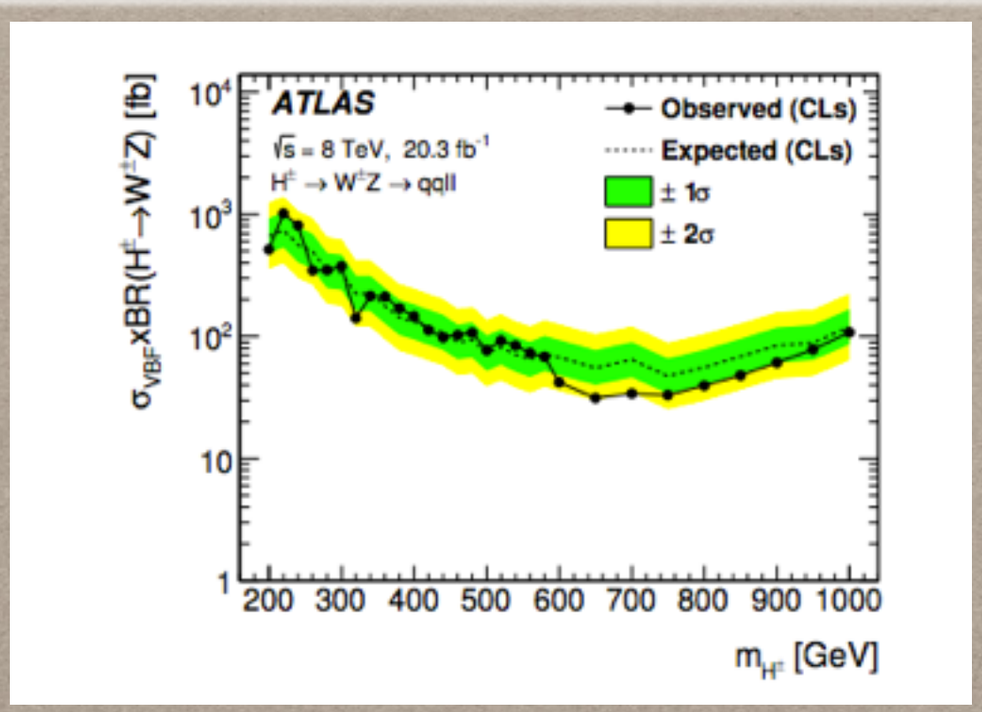




ATLAS hadronic tau



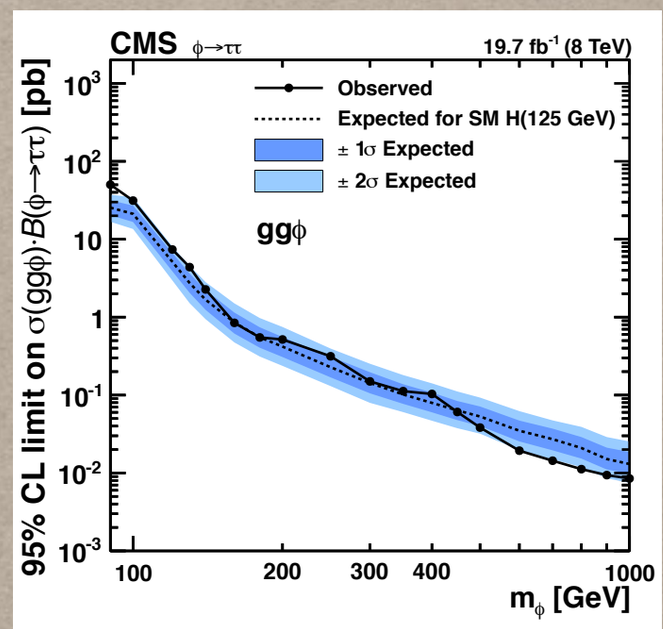
CMS hadronic

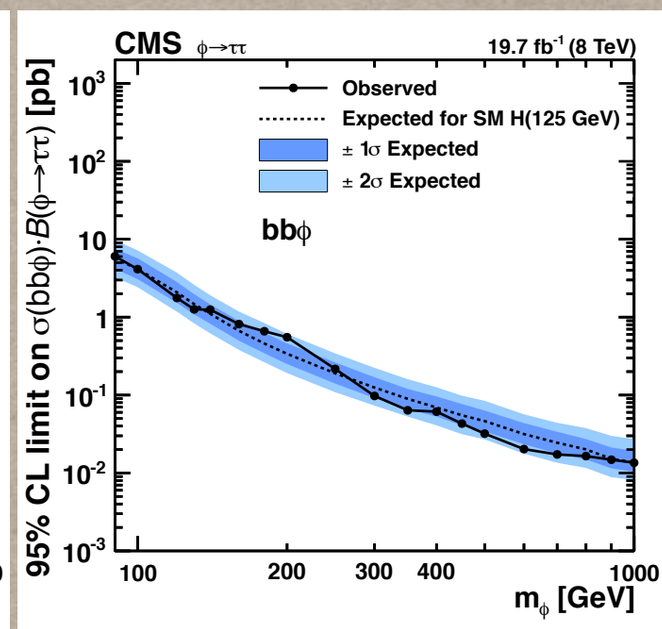


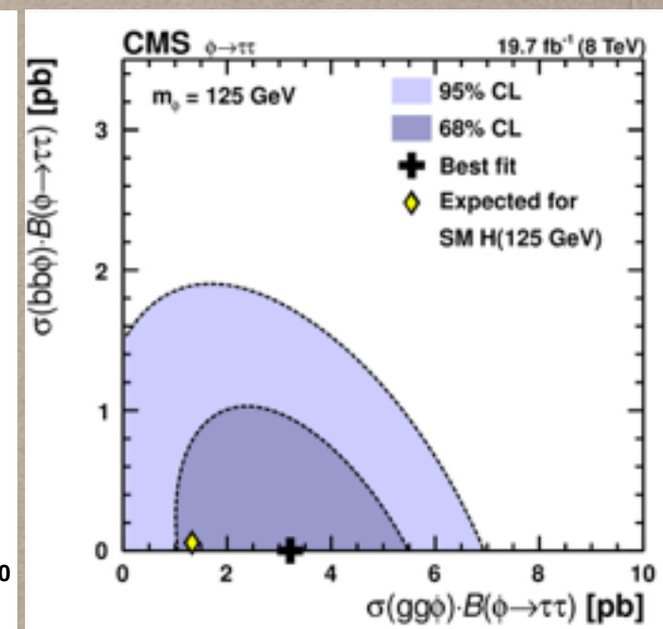
Fresh from ATLAS (a bit off topic but still a H^+ limit)

SUMMARY: 2HDM (Neutral states)

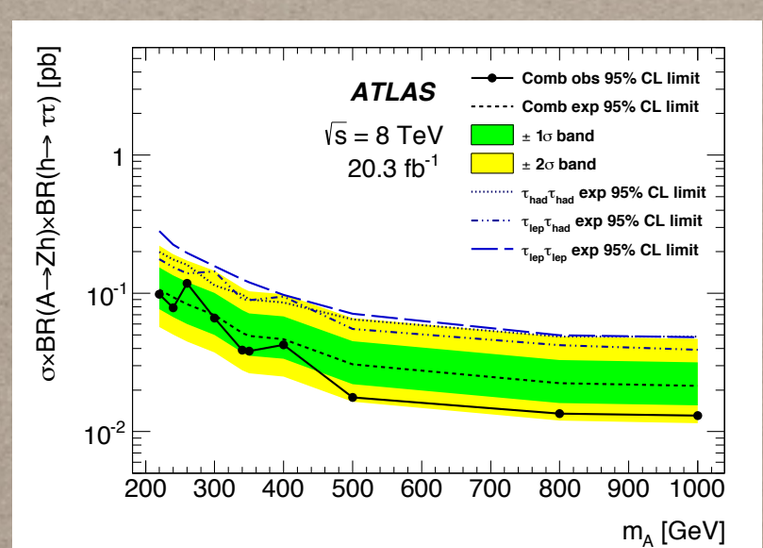
Neutral higgs like to $\tau\tau$ from CMS

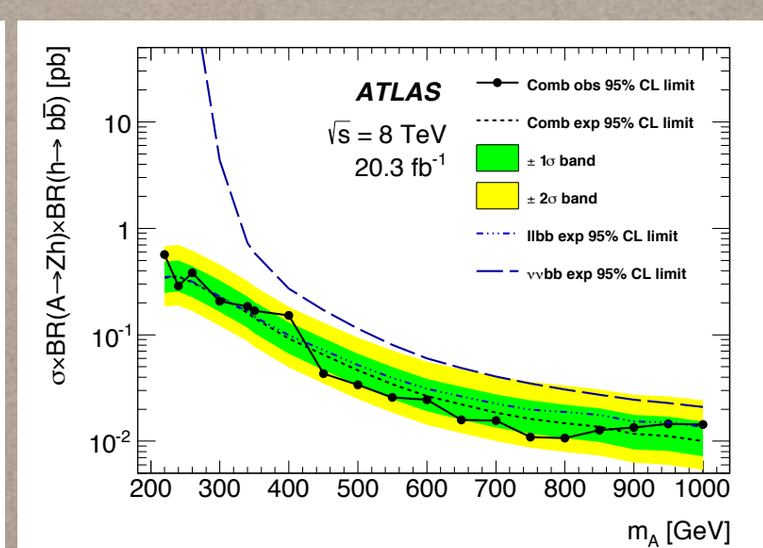


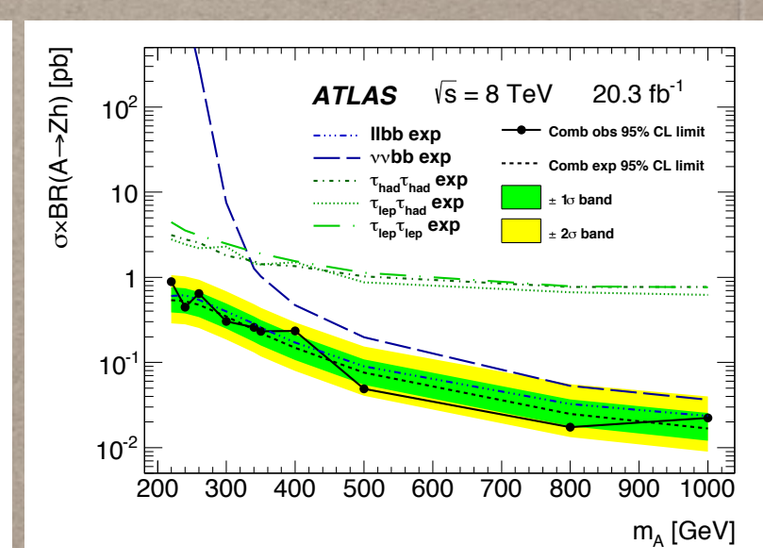




ATLAS A->Zh (h->bb,$\tau\tau$)

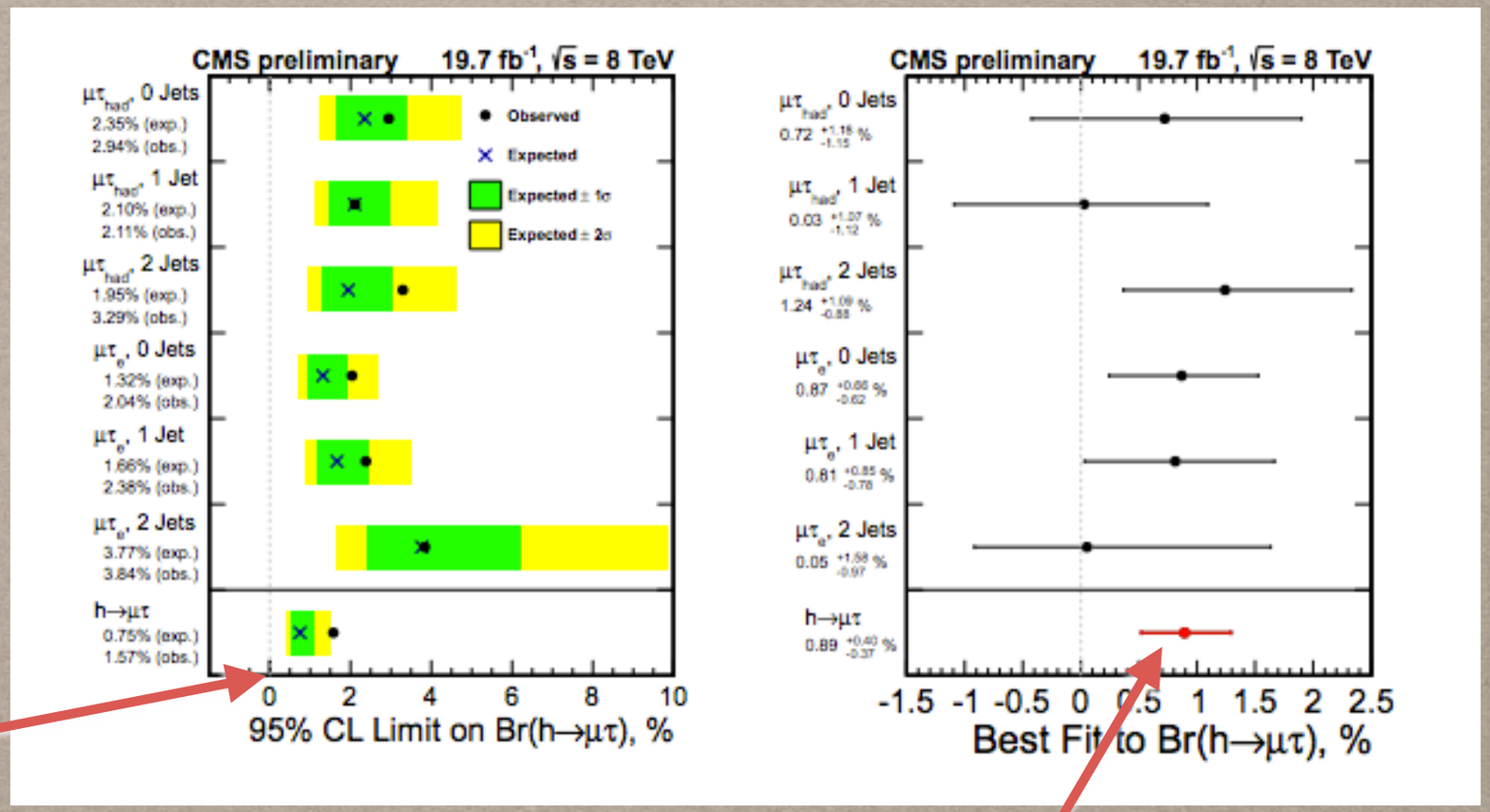






SUMMARY: LFV

- CMS h->$\mu\tau$
  - hadronic or electronic tau



0=SM value

X=Expected limit (no signal)

2.5 σ

p-value=0.007

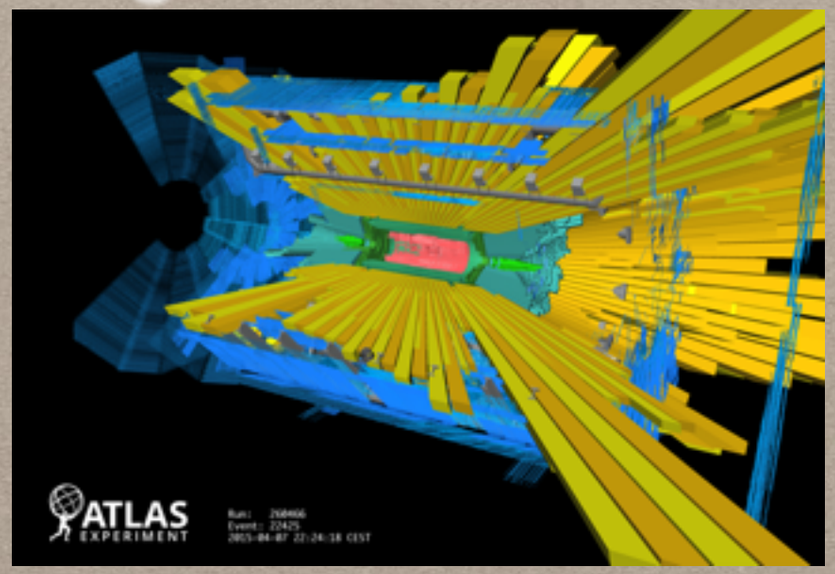
CONCLUSION:

- Many ATLAS and CMS BSM searches

  -> No discovery yet

- Heavy Higgs (SM like) also searched - nothing here as well

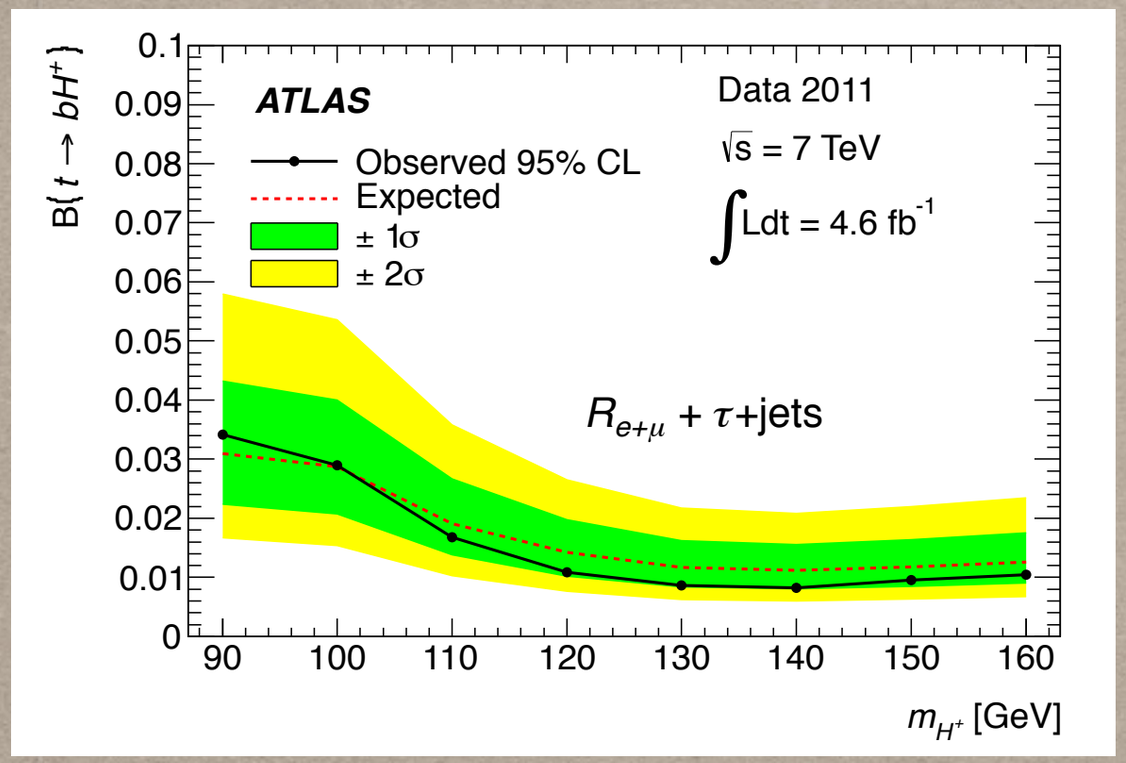
- Eagerly waiting for RUNII with many hopes for BSM physics.

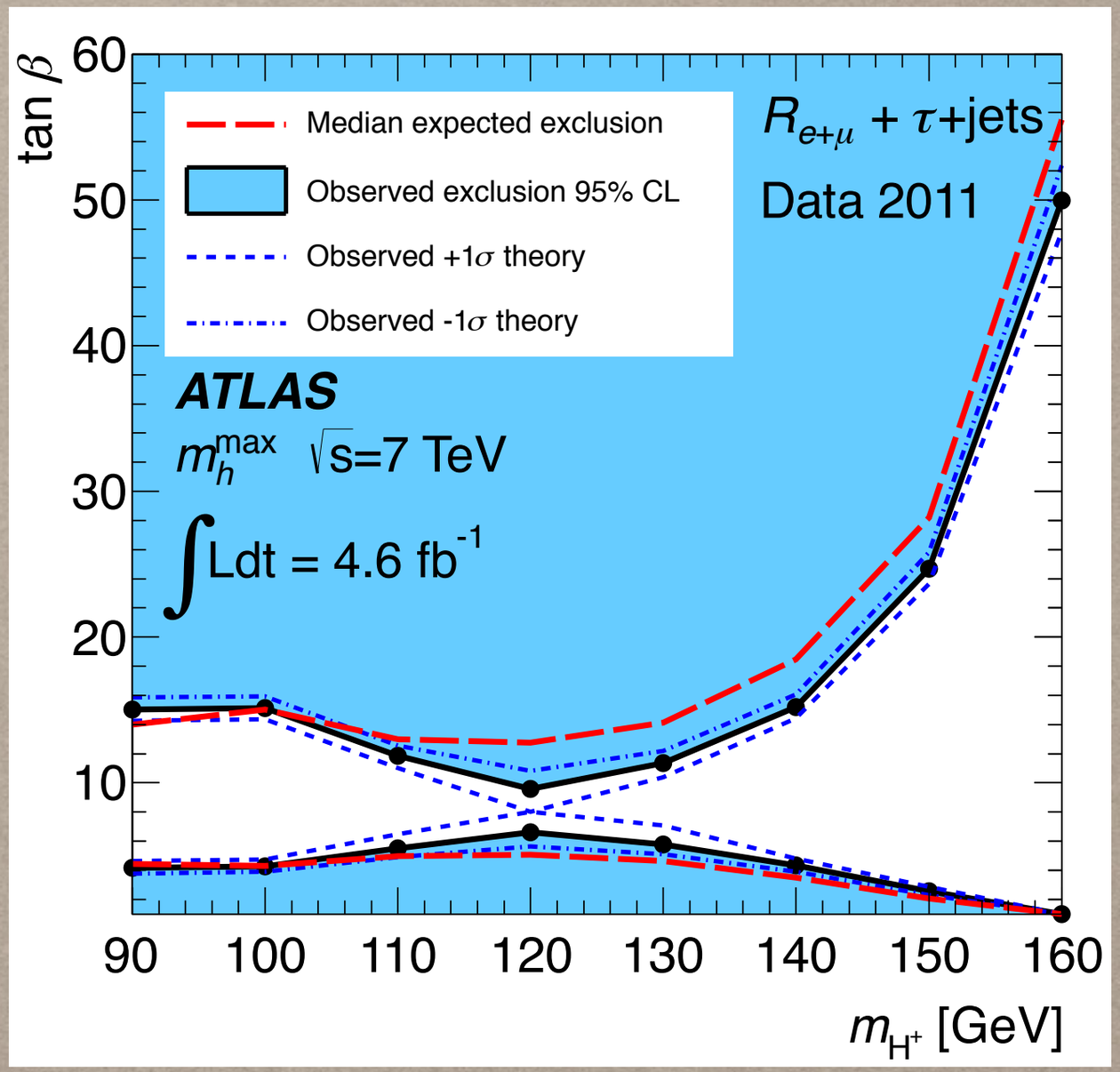


First beam splash from Run 2

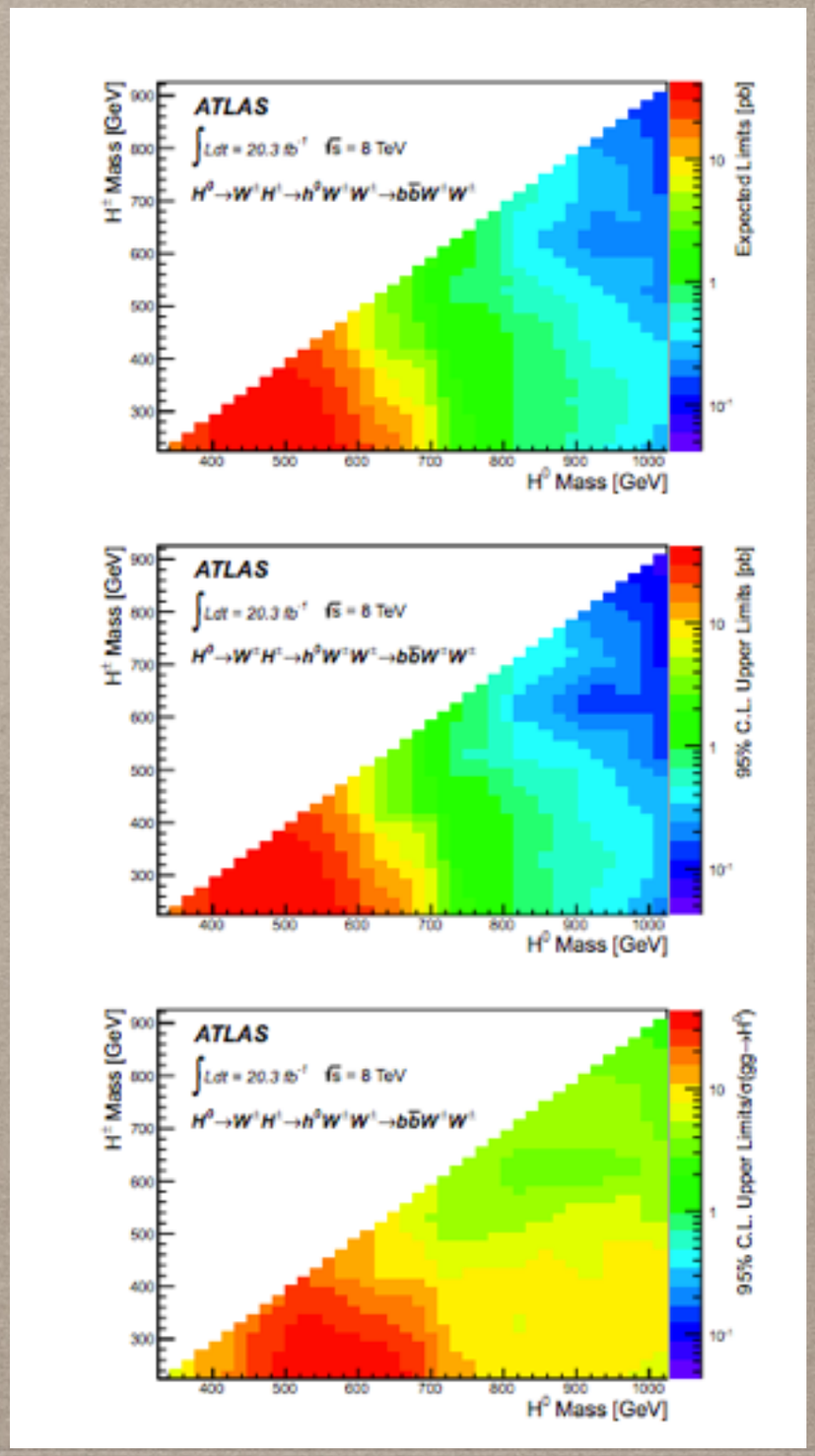
Backup slides

RATIO METHOD AND τ+JETS COMBINATION





ATLAS CASCADE H^0->W^-H^+->hWW->bbWW



EXOTIC DECAYS OF HIGGS