

B pair production sensitivity

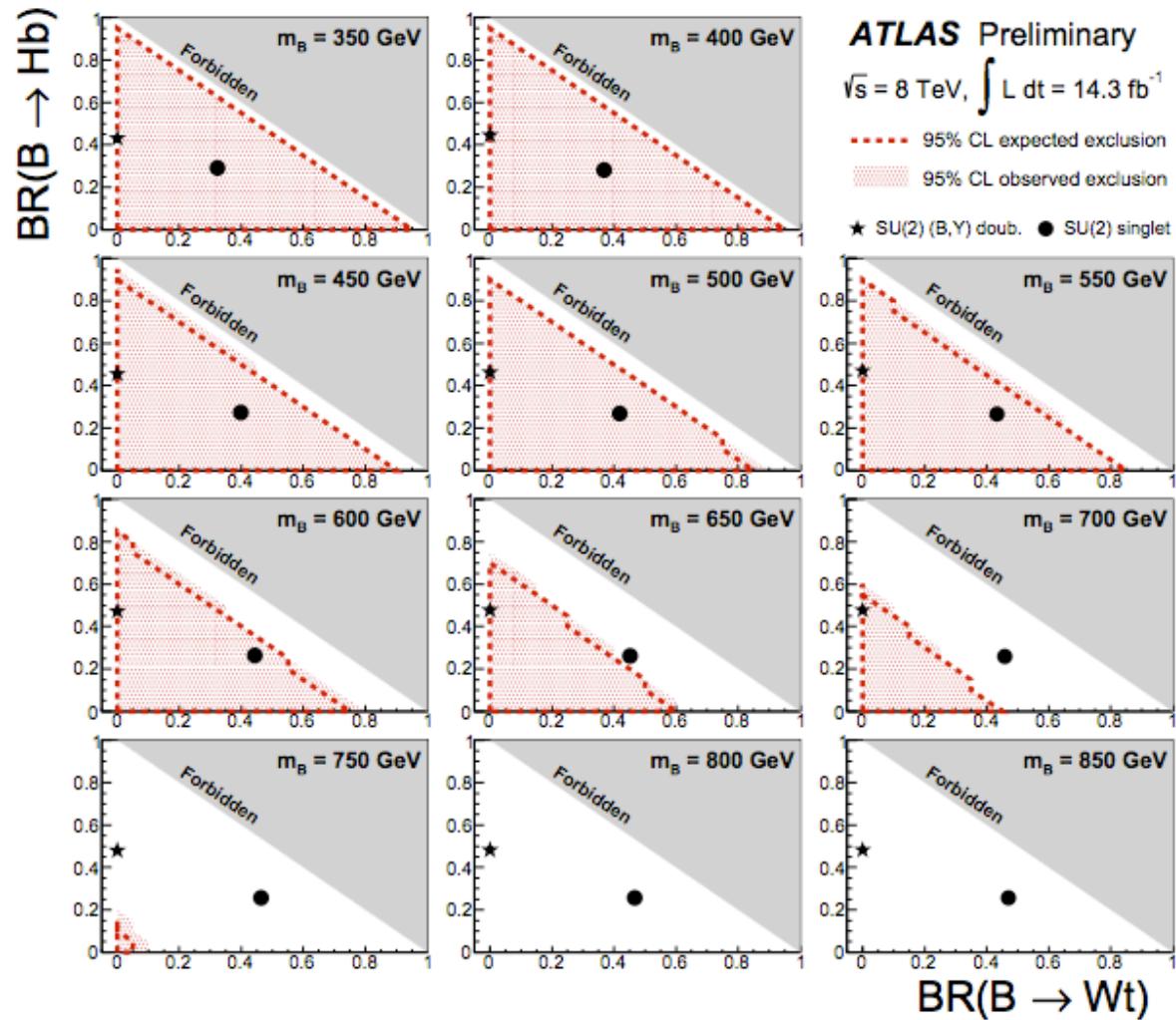
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Introduction

- Though chiral (i.e. SM-like) additional quark generations are disfavored by the measured Higgs cross section, “vector-like” heavy quark models remain viable
 - left- and right-handed “vector-like” quark components transform identically under SU(2)
 - can write gauge-invariant mass term without coupling to Higgs
 - many BSM models that address the hierarchy problem posit the existence of such quarks
 - “Natural” if mass is not too much larger than 1 TeV
- I am investigating sensitivity of future accelerators to pair-production of vector-like B (i.e. charge -1/3) quarks
 - using same-sign dilepton signature
 - two reference mass points (1000 and 1500 GeV)
 - considering all possible branching ratios to Wt , Zb , and Hb
 - 100% BR to Wt point can be used to assess sensitivity to chiral b'

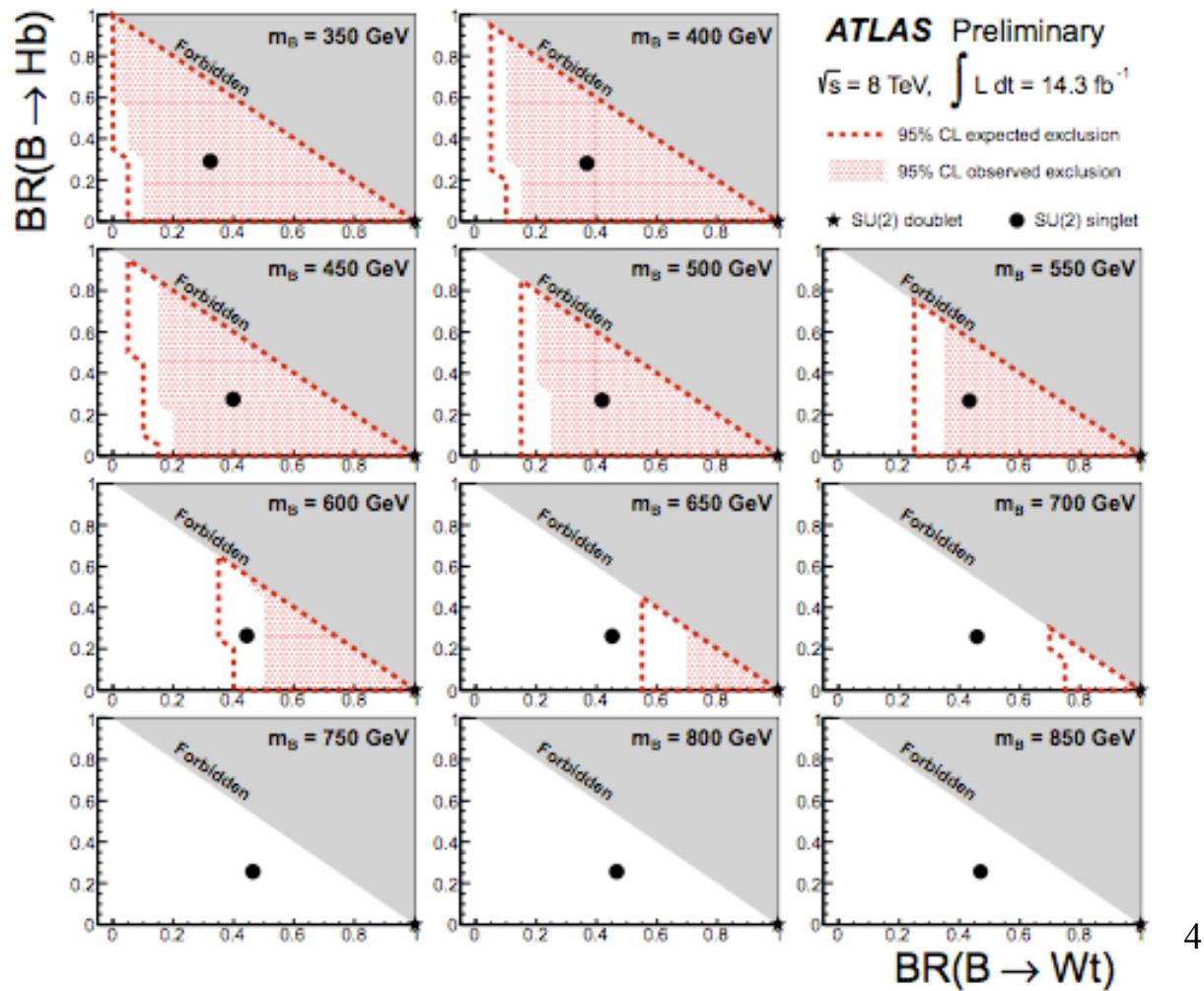
Current searches

- ATLAS, leptonic Z required in final state



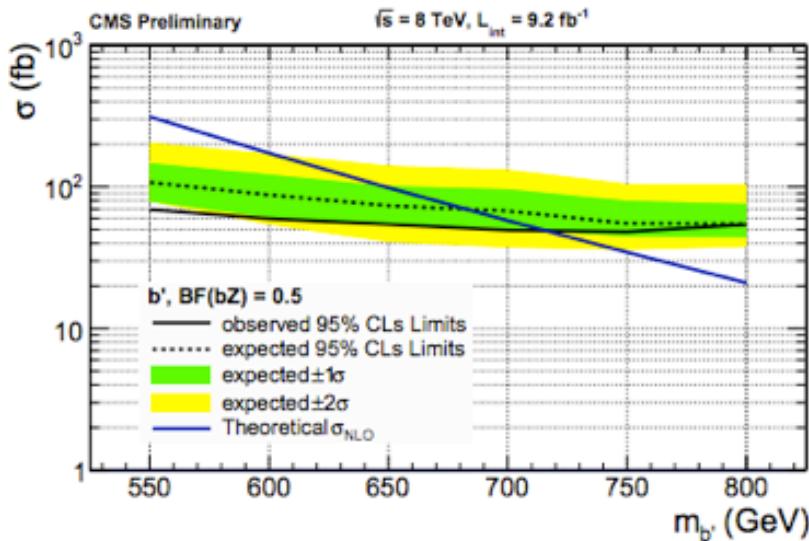
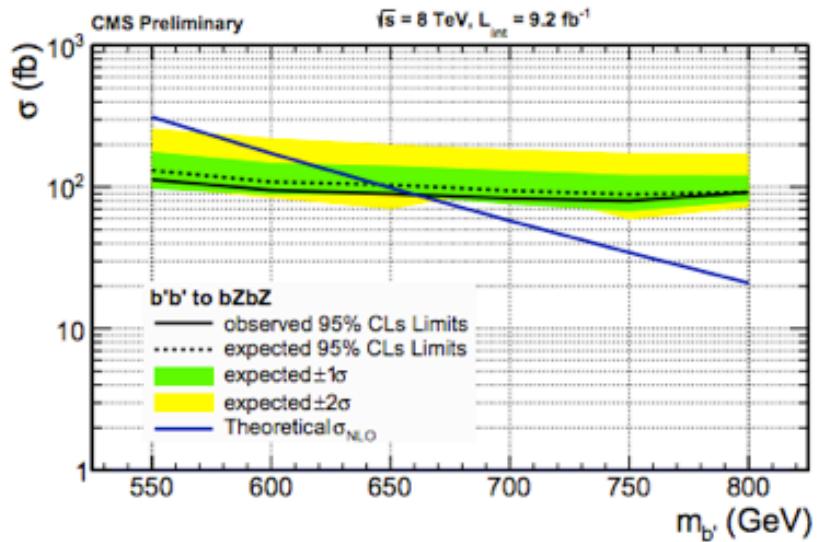
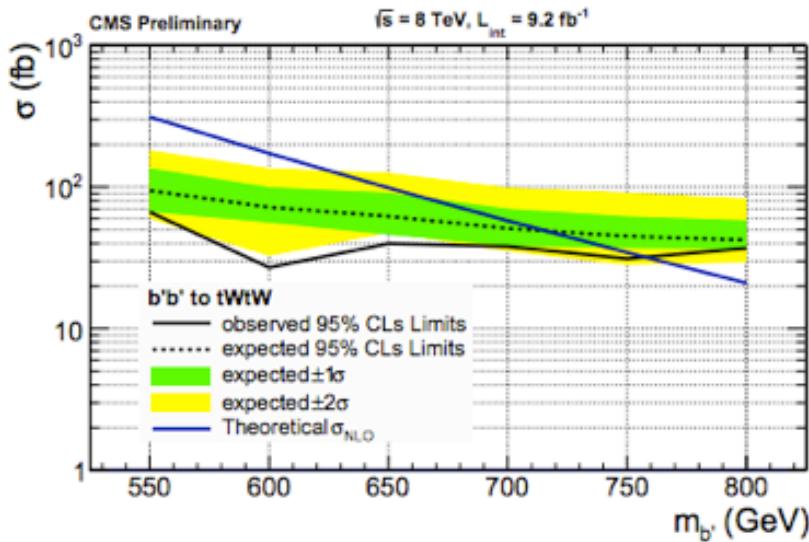
Current Searches

- ATLAS, same-sign dileptons (similar to my Snowmass study)



Current Searches

- CMS (three lepton final state)



Bottom line: currently not sensitive to $m_B > 750 \text{ GeV}$

Samples

- For now considering only the SM backgrounds:
 - ZZ , WZ , ttW , same-sign WW
 - for now am missing ttZ -- seems to have small statistics?
- Have generated signal samples using Madgraph 5/ Pythia 8/Delphes 3.0.9
- Cross sections (pb) (*= scaled from 13 TeV)

	14 TeV	33 TeV
$ZZ \rightarrow 4\ell$	0.115*	0.277
$WZ \rightarrow \ell\ell\ell\nu$	1.22*	3.46
$W^\pm W^\pm$	0.04*	0.16
ttW	0.62*	3.32
BB ($m_B = 1000$)	0.05	1.28
BB ($m_B = 1500$)	0.003	0.13

Selection

- Preselection:
 - jets, leptons, must have $\text{pt} > 25 \text{ GeV}$ and $|\eta| < 3.0$ (2.5)
 - require exactly one same-sign lepton pair
 - ≥ 2 jets, ≥ 1 of which has loose b-tag
 - veto leptons pairs in Z mass window
 - this is primarily to retain orthogonality to a Z-tag analysis, if one is done...

Optimization

- scan cuts in # of b-tagged jets, H_t, and MET to optimize significance, defined as

$$\frac{S}{\sqrt{S + B + \sigma_{\text{syst}}^2}}$$
 — systematic uncertainty

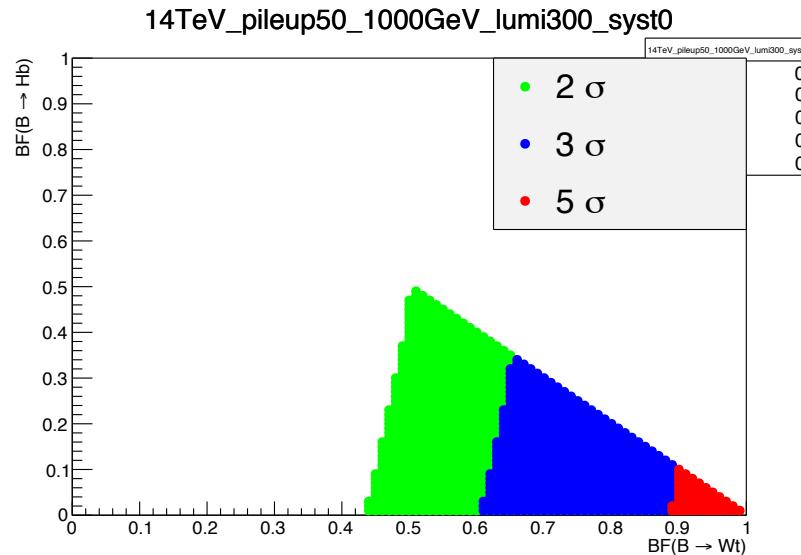
- Systematics have not been evaluated, but a few possible scenarios have been studied
 - varying size of systematics, expressed as a fraction of the background yield
- Branching ratios to Wt , Zb , and Hb are model-dependent
 - scan over possible values, and repeat optimization for each set

Estimate of sensitivity

- Optimized significance value is taken as estimate of search sensitivity
- Rough translation:
 - > 2 = exclusion
 - > 3 = evidence
 - > 5 = discovery

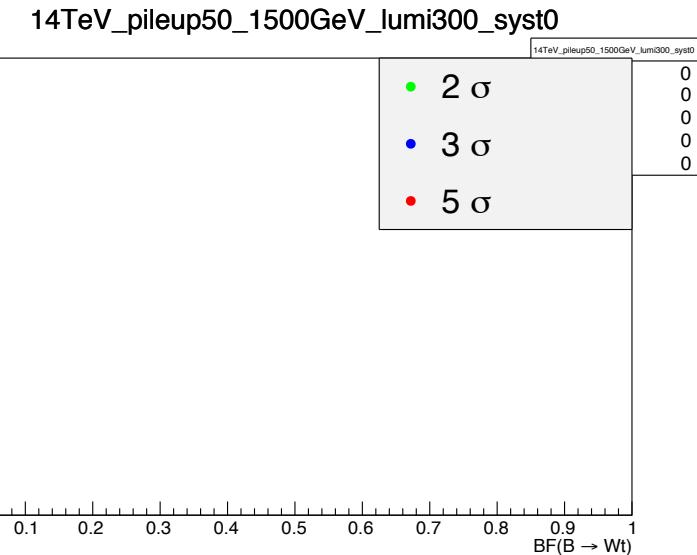
Sensitivity at 14 TeV (300 fb⁻¹, 50 pileup)

$m_B = 1000 \text{ GeV}$

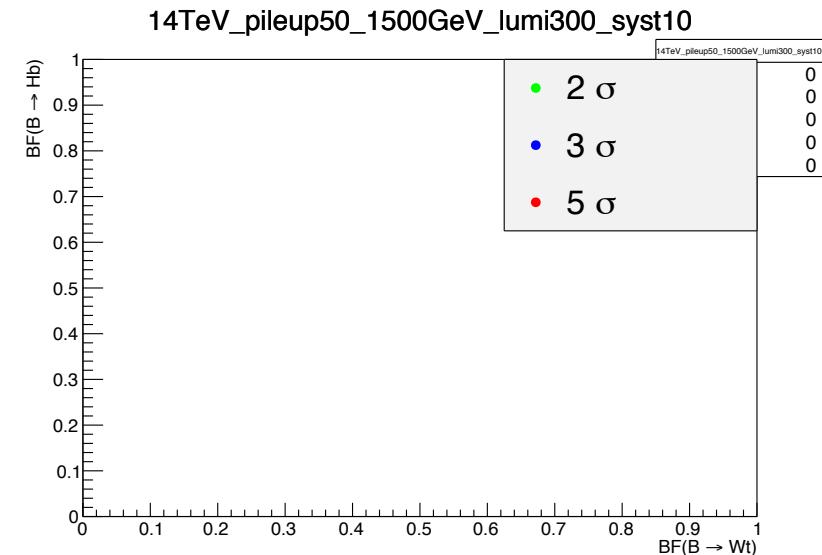
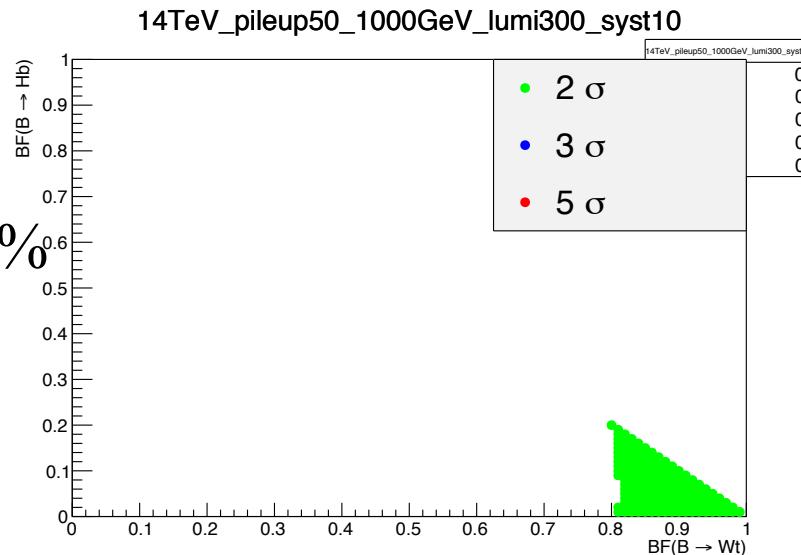


stat
only

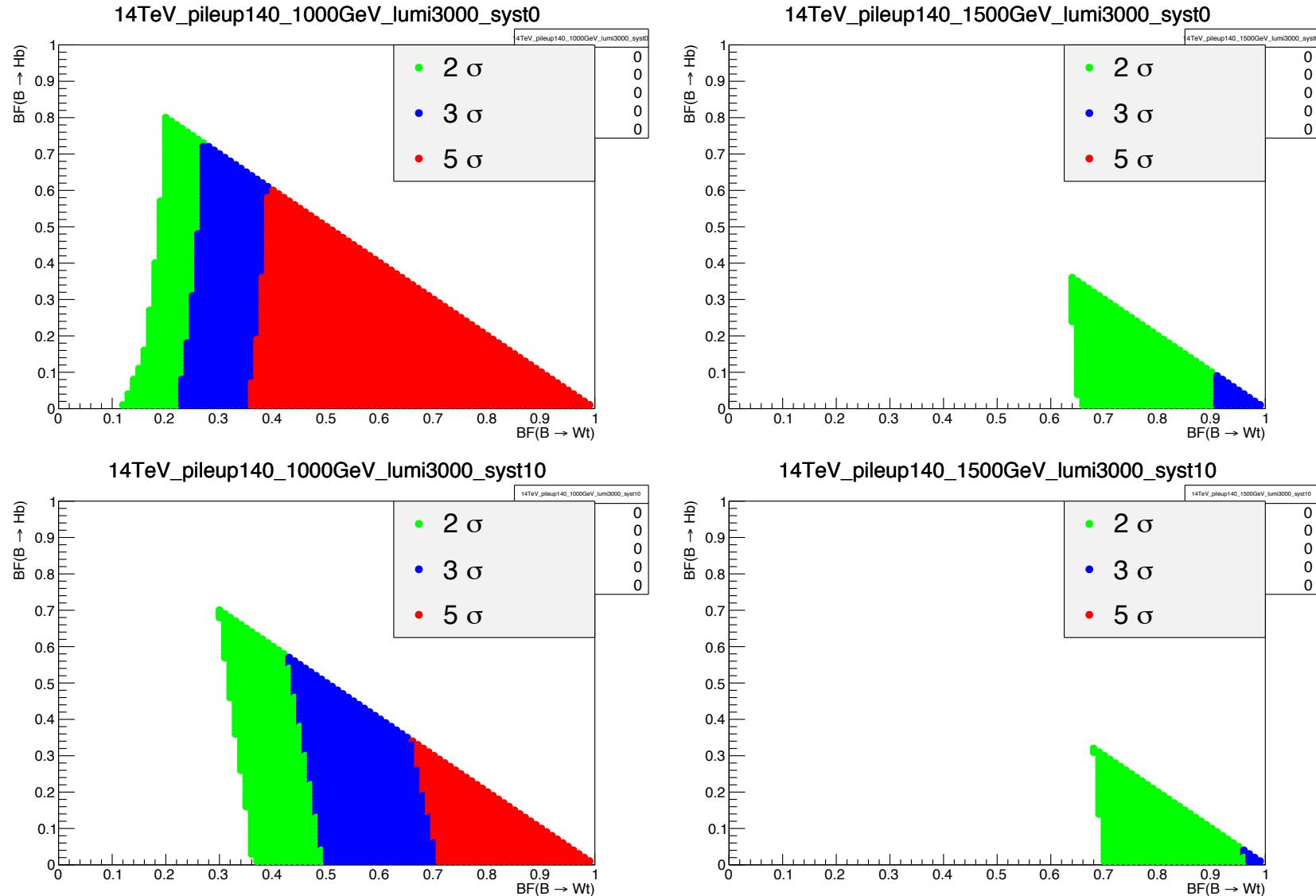
$m_B = 1500 \text{ GeV}$



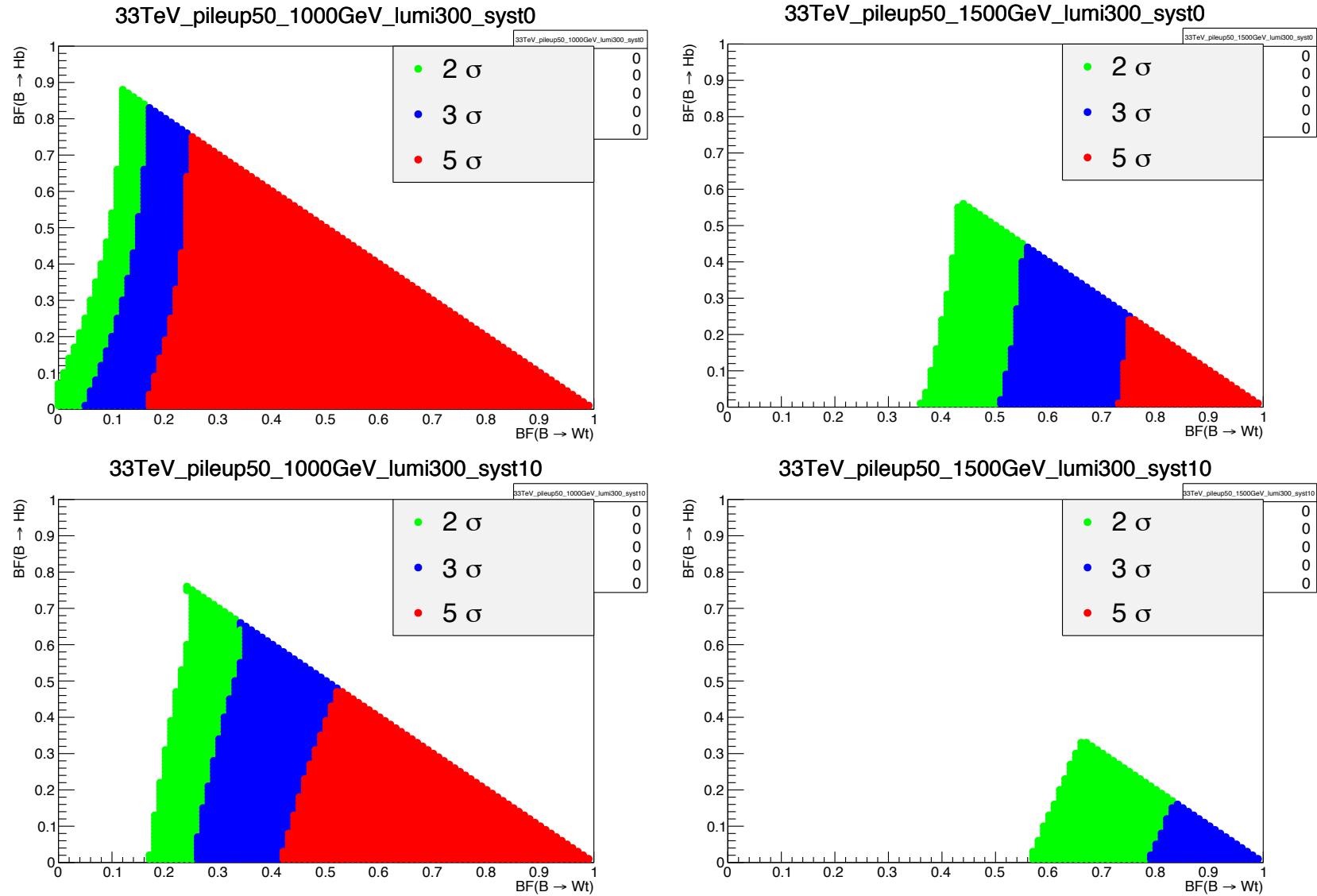
syst
 $= 10\%$



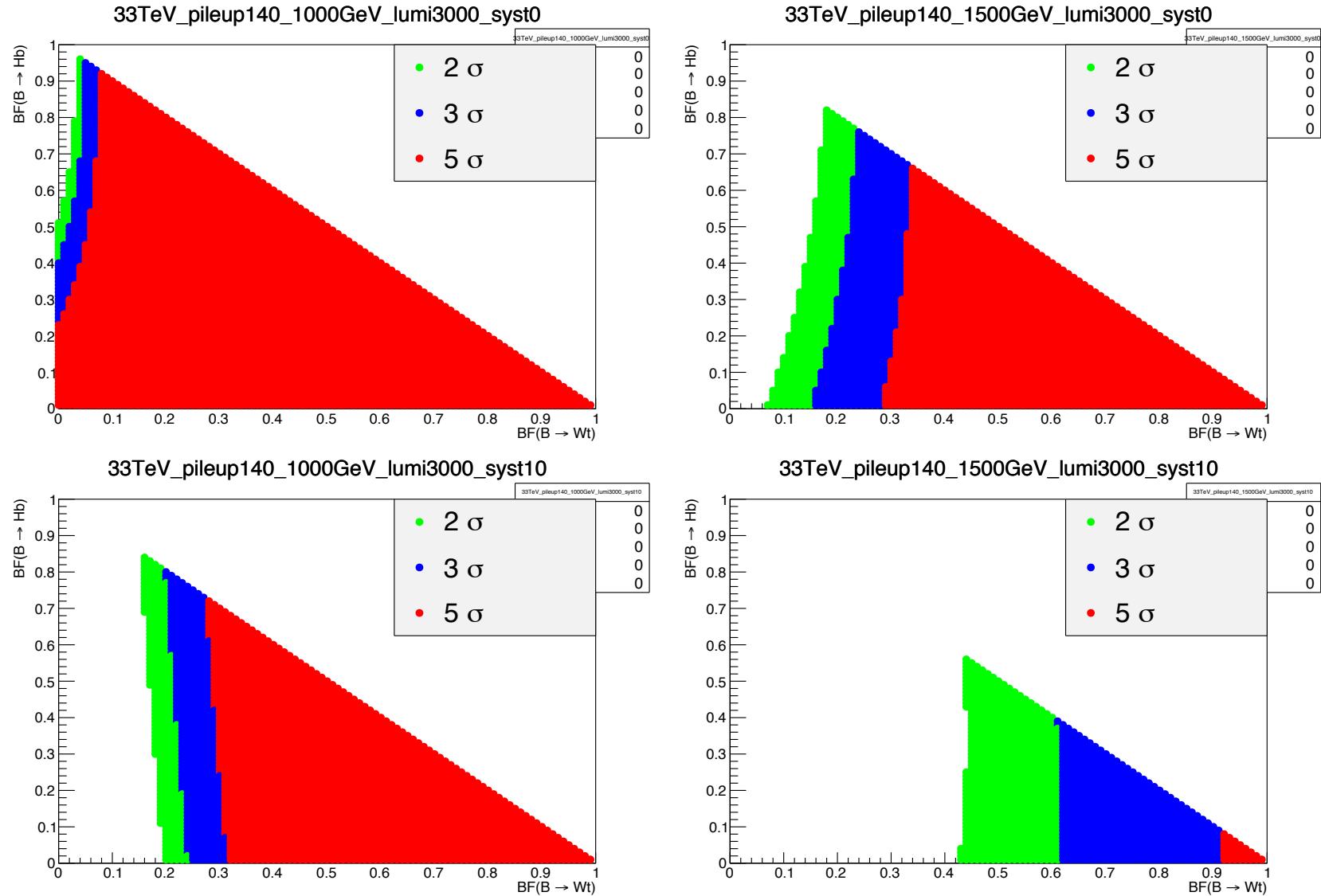
Sensitivity at 14 TeV (3 ab⁻¹, 140 pileup)



Sensitivity at 33 TeV (300 fb^{-1} , 50 pileup)



Sensitivity at 33 TeV (3 ab⁻¹, 140 pileup)



Details and observations

- Same-sign lepton signature is most sensitive to Wt decays
- Estimated S and B for 100% Wt BR, 1000 GeV B:

Energy	14 TeV			
Systematics	0		10% of bkg estimate	
Pileup	50	140	50	140
Lum (fb^{-1})	300	3000	300	3000
ttW	1683	14.8K	128	89
WZ	217	1653	0	0
ZZ	2.6	89	0	0
$W^\pm W^\pm$	39	514	1.6	29
Tot. Bkg.	1943	17.1K	130	118
BB (1000 GeV)	274	2.8K	50	167

- Estimated S and B for 100% Wt BR, 1500 GeV B:

Energy	14 TeV			
Systematics	0		10% of bkg estimate	
Pileup	50	140	50	140
Lum (fb^{-1})	300	3000	300	3000
ttW	3.0	0	3.0	0
WZ	0	0	0	0
ZZ	0	0	0	0
$W^\pm W^\pm$	0	27	0	27
Tot. Bkg.	3.0	27	3.0	27
BB (1500 GeV)	1.8	24	1.8	24

- Estimated S and B for 100% Wt BR, 1000 GeV B:

Energy	33 TeV			
Systematics	0		10% of bkg estimate	
Pileup	50	140	50	140
Lum (fb^{-1})	300	3000	300	3000
ttW	33.3K	344K	240	571
WZ	3332	23.9K	7.9	0
ZZ	31.4	394	0	0
$W^\pm W^\pm$	2338	28.0K	4.1	0
Tot. Bkg.	39.1K	396K	252	571
BB (1000 GeV)	9113	123K	471	3202

- Estimated S and B for 100% Wt BR, 1500 GeV B:

Energy	33 TeV			
	0		10% of bkg estimate	
Systematics				
Pileup	50	140	50	140
Lum (fb^{-1})	300	3000	300	3000
$t\bar{t}W$	10.9 K	29.1K	120	571
WZ	1123	2140	0	0
ZZ	11	17	0	0
$W^\pm W^\pm$	1000	4193	3.1	0
Tot. Bkg.	13.1 K	35.5K	123	571
BB (1500 GeV)	952	5527	75	359

Limitations

- In many ways the current study is too optimistic
 - no backgrounds from fake leptons, or leptons with mis-measured charge
 - no real evaluation of systematics
 - and there's the missing $t\bar{t}Z$ background
- But is also too pessimistic, given the limited time available
 - “cut & count” with square cuts on a few variables
 - a “real” analysis would certainly use some type of MVA to maximize S/B discrimination
 - yield at low MVA values could be used to constrain backgrounds
- Naive hope is that these compromises roughly balance out

Next steps

- There are several possible steps to take between now and Minneapolis:
 - I will have time for some, but not all, of them
- Adding detector-related backgrounds
 - estimated using H_t -binned single-lepton and Z samples
- Looking into additional final states
 - e.g. requiring a Z in the final state
- More realistic estimate of sensitivity
 - e.g. CL_s
 - but given large statistics at future accelerators, Gaussian approximation is probably not too bad
- Other accelerator scenarios
 - 100 TeV?