"Boost 2011" 25 May 2011

Boosted Higgs from New Physics

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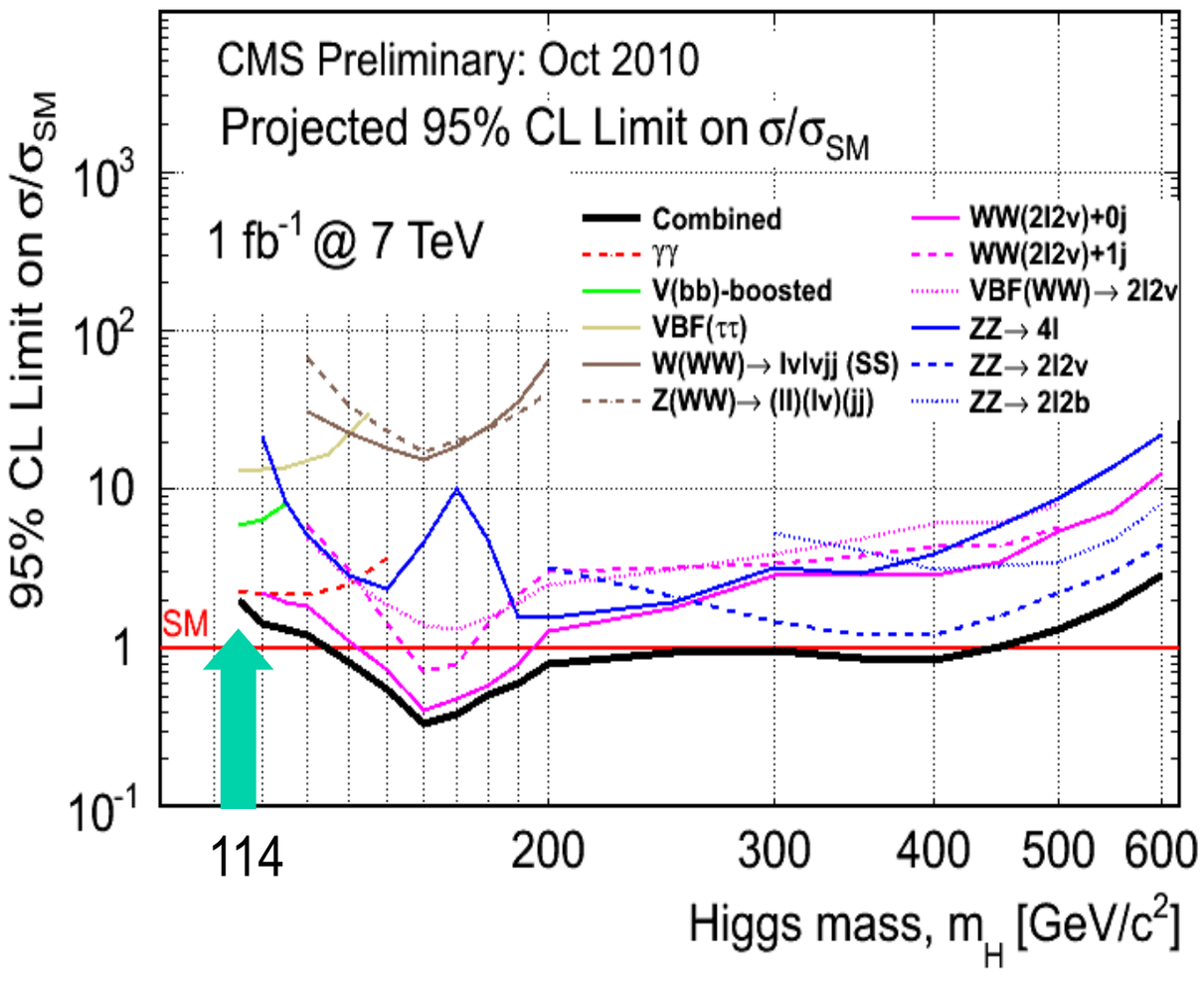
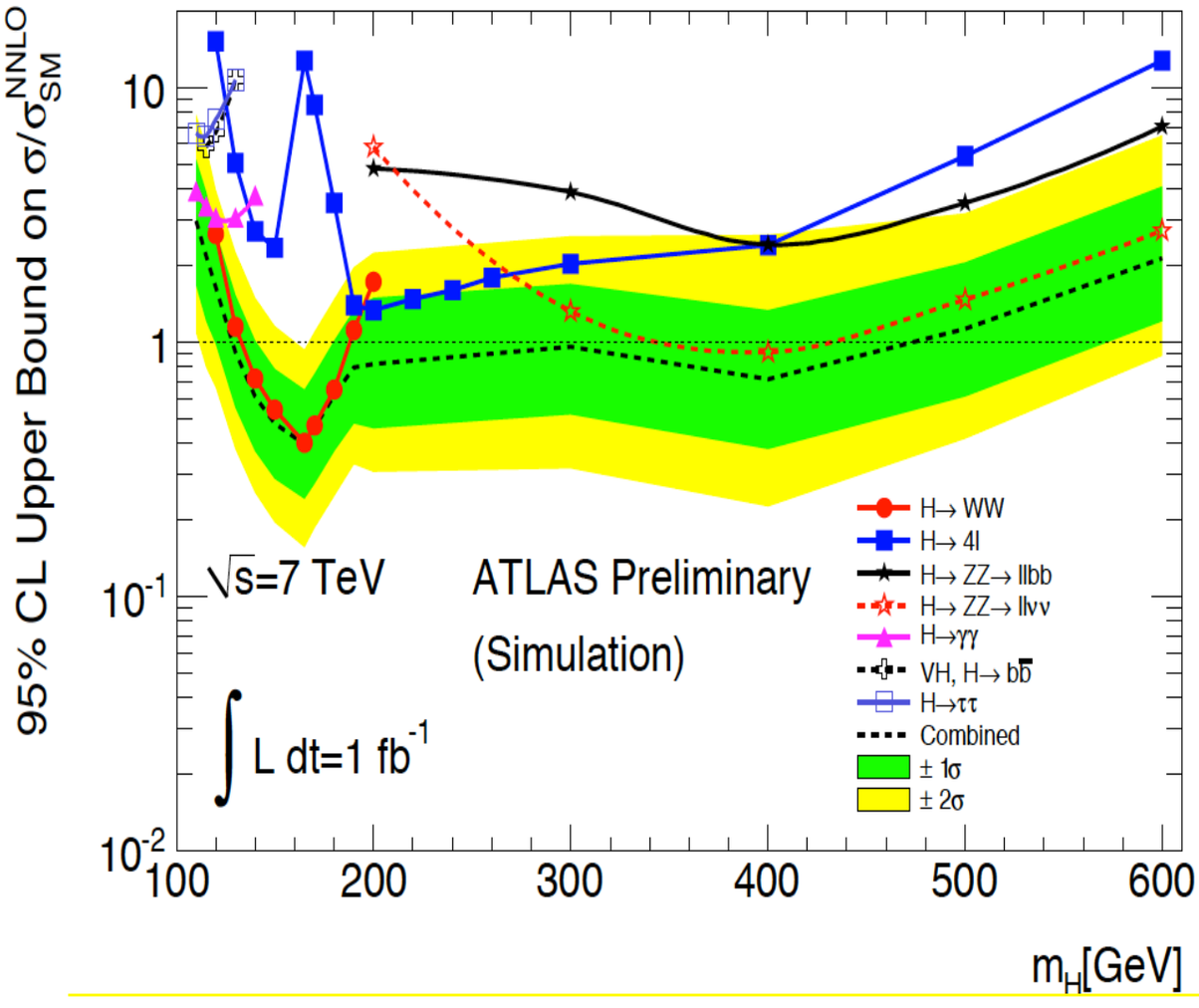
Fermilab & U Oregon

0912.4731, 1006.1656 (Martin, Roy, Spannowsky)
1012.2866, 110x.xxxx (Martin, Roy)

Higgs 2011

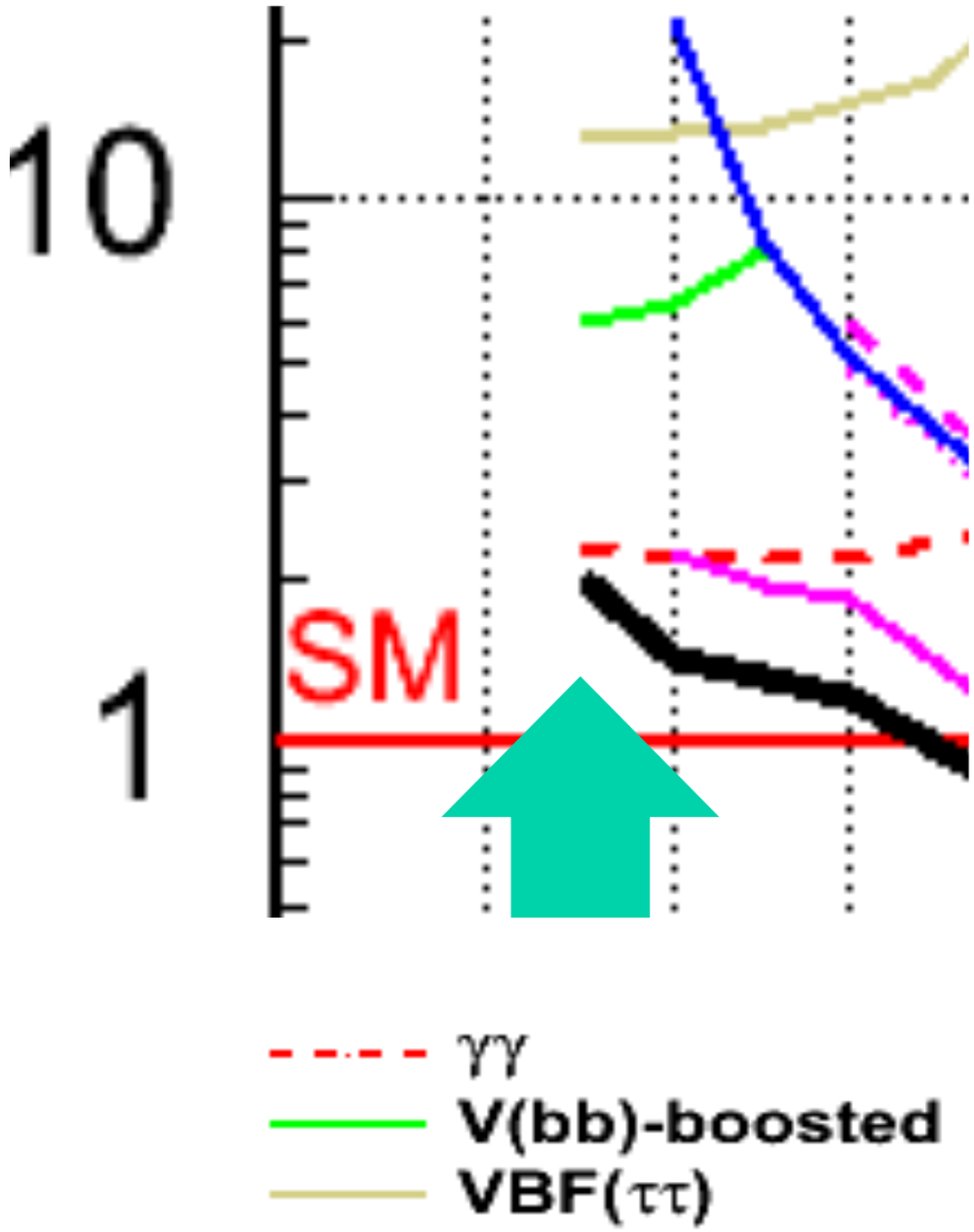


CMS Moriod 2011

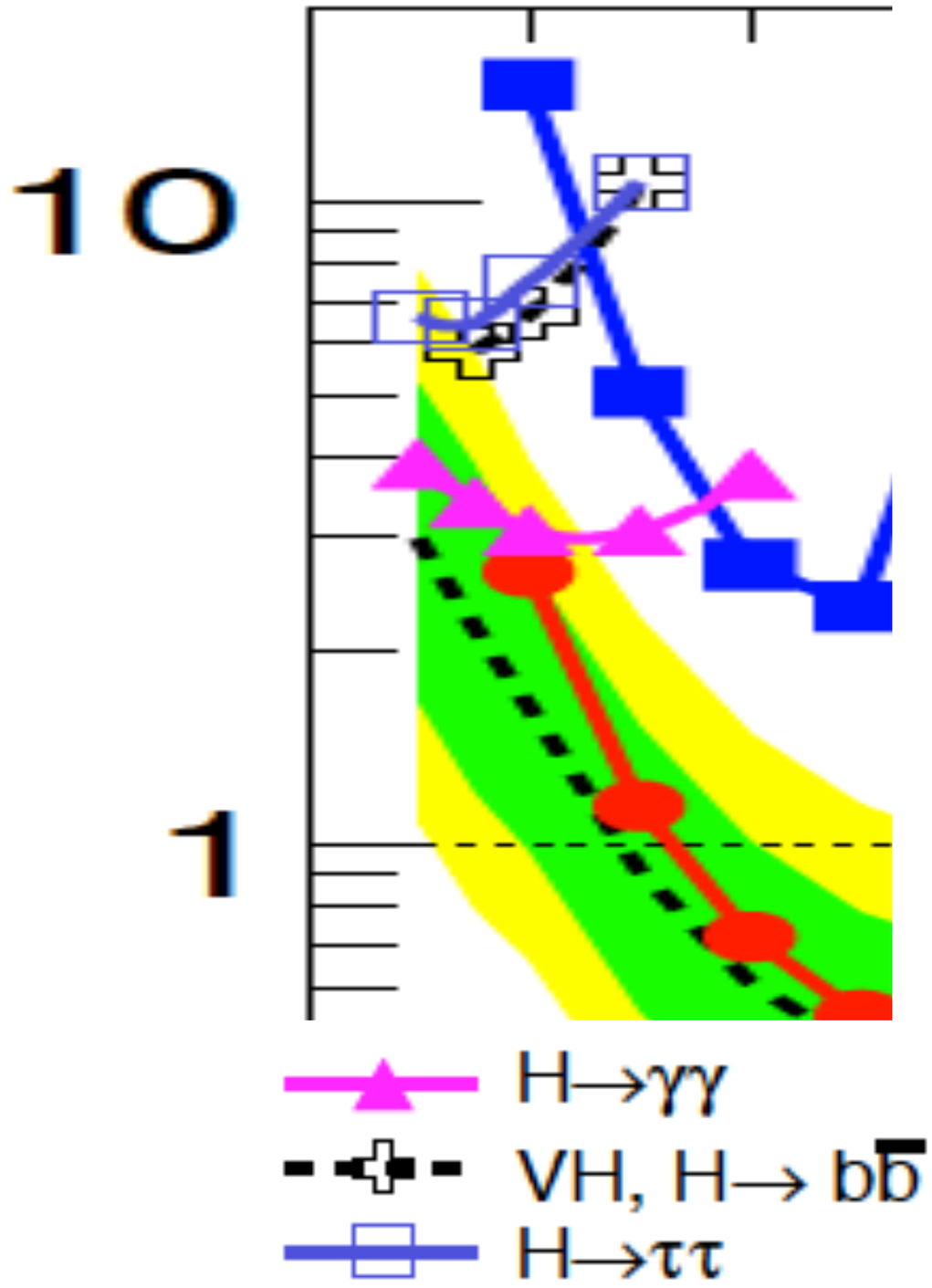


ATLAS Moriod 2011

Look closely...

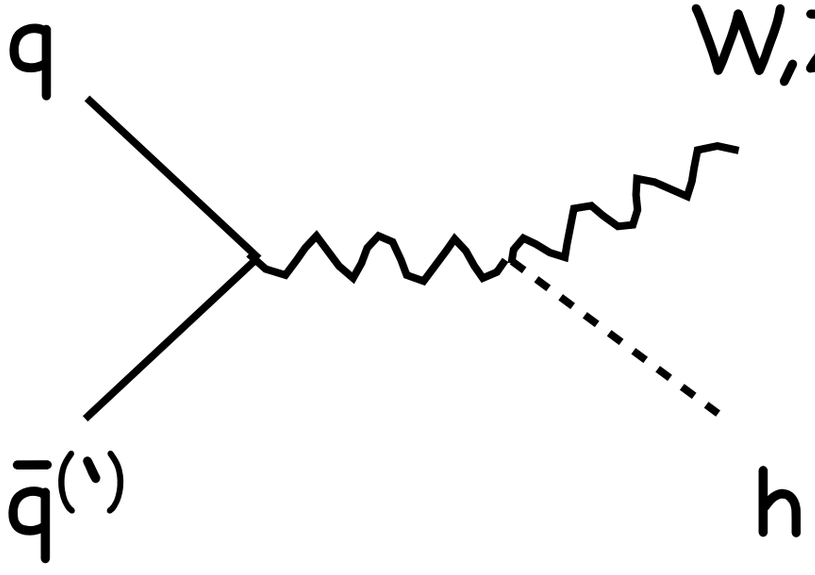


CMS Moriod 2011



ATLAS Moriod 2011

Boosted Higgsstrahlung



1) Leptonic decay of W/Z into llbb, lνbb, ννbb.

2) Boosted Higgs: pT(h) > 200 GeV

3) BDRS Higgs tagger

BDRS Higgs Tagger

ΔR = 1.2 fat jet with C/A

1) "mass drop"

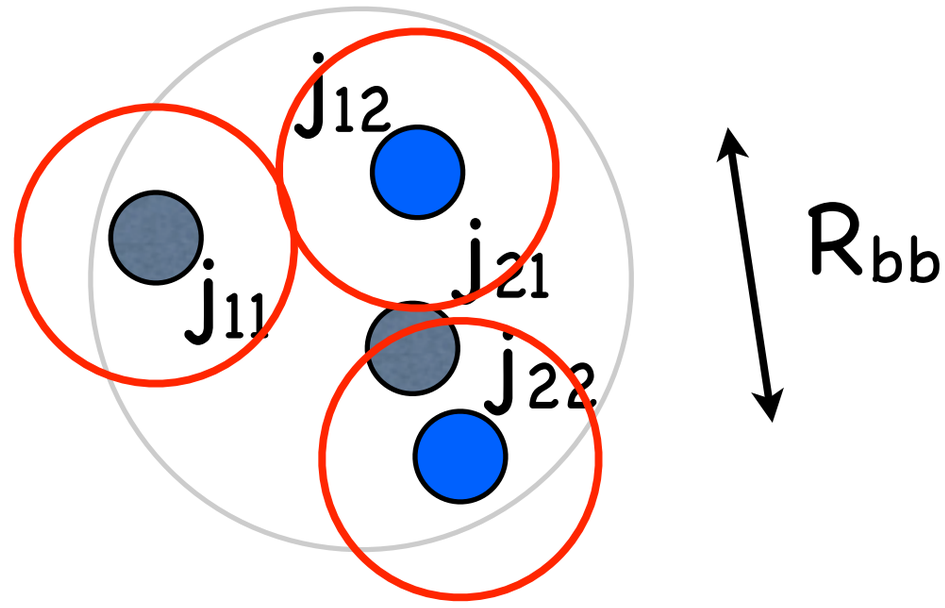
$m_{j1} < 0.68\, m_j$

2) "asymmetry"

$$y = \frac{\min\left(p_{t_{j1}}^2, p_{t_{j2}}^2\right)}{m_j^2} \Delta R_{j_1,j_2}^2 > (0.3)^2$$

3) b-tag both subjets

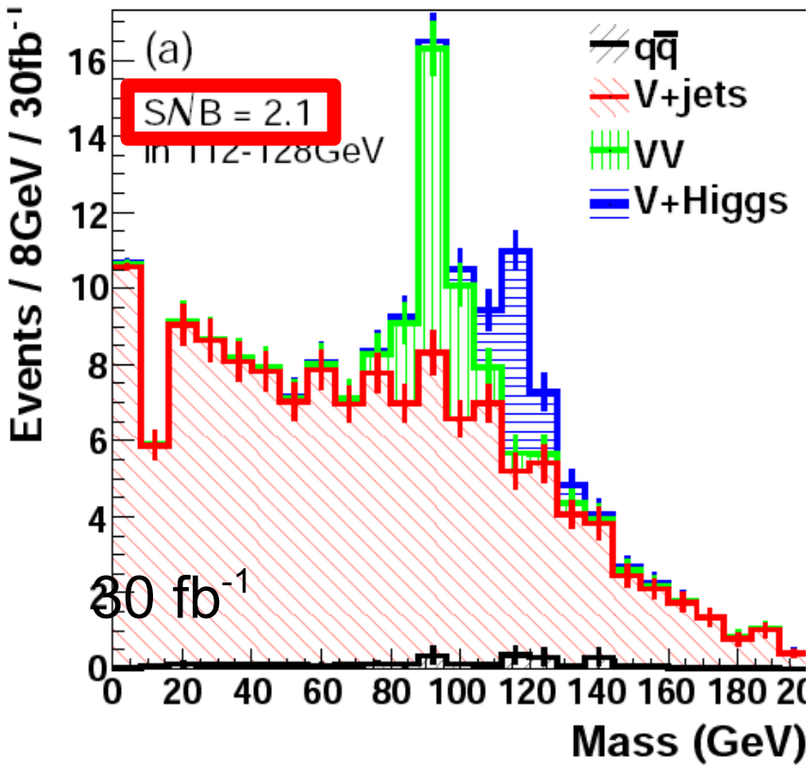
4) filter subjets



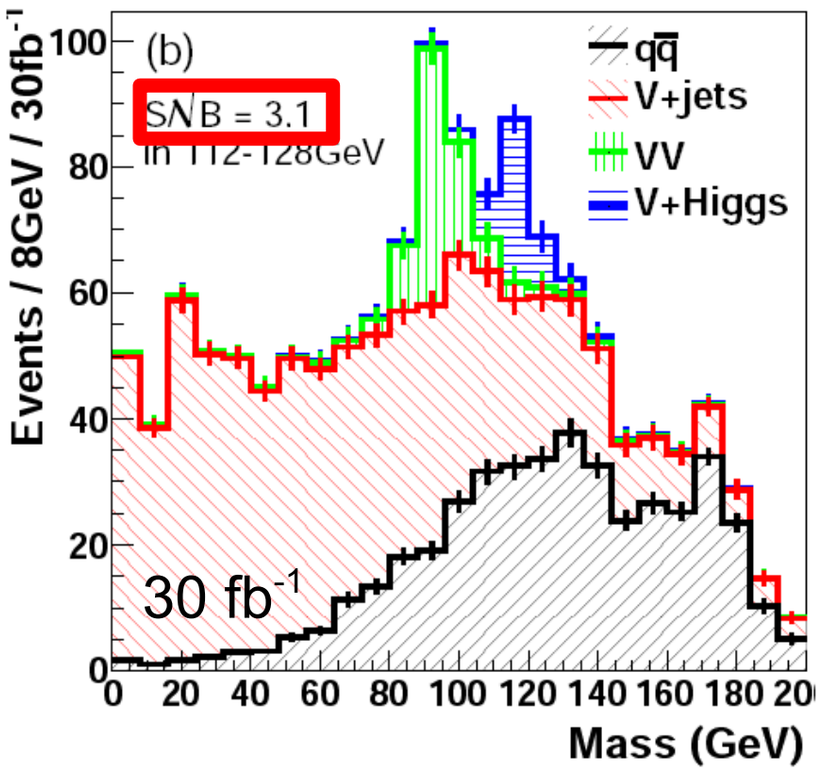
Higgs candidate mass -- 3 highest pT subjets
reclustered with $R_{j1,j2,j3} = \min(R_{bb}/2, 0.3)$

BDRS Result: 14 TeV; 30 fb^{-1}

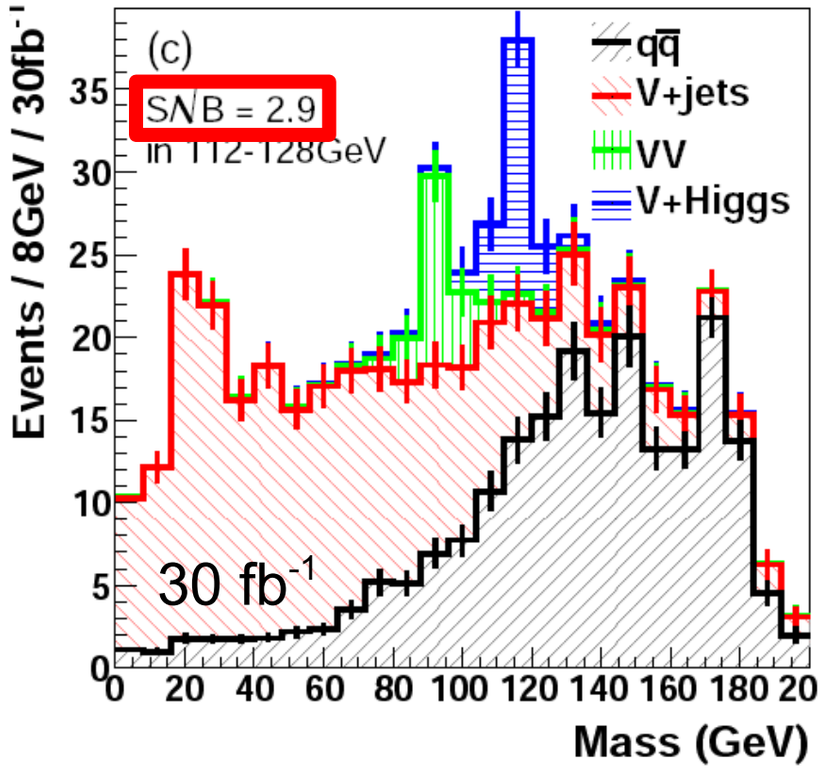
llbb



lνbb



ννbb



- LHC 14 TeV; 30 fb^{-1}; mh = 115 GeV
- HERWIG/JIMMY
  cross-checked with PYTHIA with "ATLAS tune"
- 60% b-tag; 2% mistag
- no smearing

BDRS 0802.2470

BDRS "Higgs tagger" is great!

Standard Model sucks.

h may not be < 125 GeV;
h pT boost > 200 GeV only 5% of σ;
V(->lep)h(->bb) S/B comparitively low*

*though still better than nothing!

New Physics

If new physics source of Higgs...

Production can be large
Boost can be larger
Signature can be more distinctive

While revealing Higgs <-> new physics connection.

Many Interesting Possibilities involving Higgs and/or SUSY

Butterworth et al hep-ph/0702150

Butterworth et al 0906.0728

Chen et al 1006.1151

Plehn et al 1006.2833, 1102.0557

Katz,Son,Tweedie 1011.4523

Bellazzini et al 1012.1316

Fan et al 1102.0302

Thaler,Thomas 1103.1631

...

new physics

Spectactular

Great

Promising

SUSY

(h always light in MSSM)

cascade ends
NLSP -> h $\tilde{g}$

cascade spits
h
in decays

top partners

(h could be light)

t' -> t h

new physics

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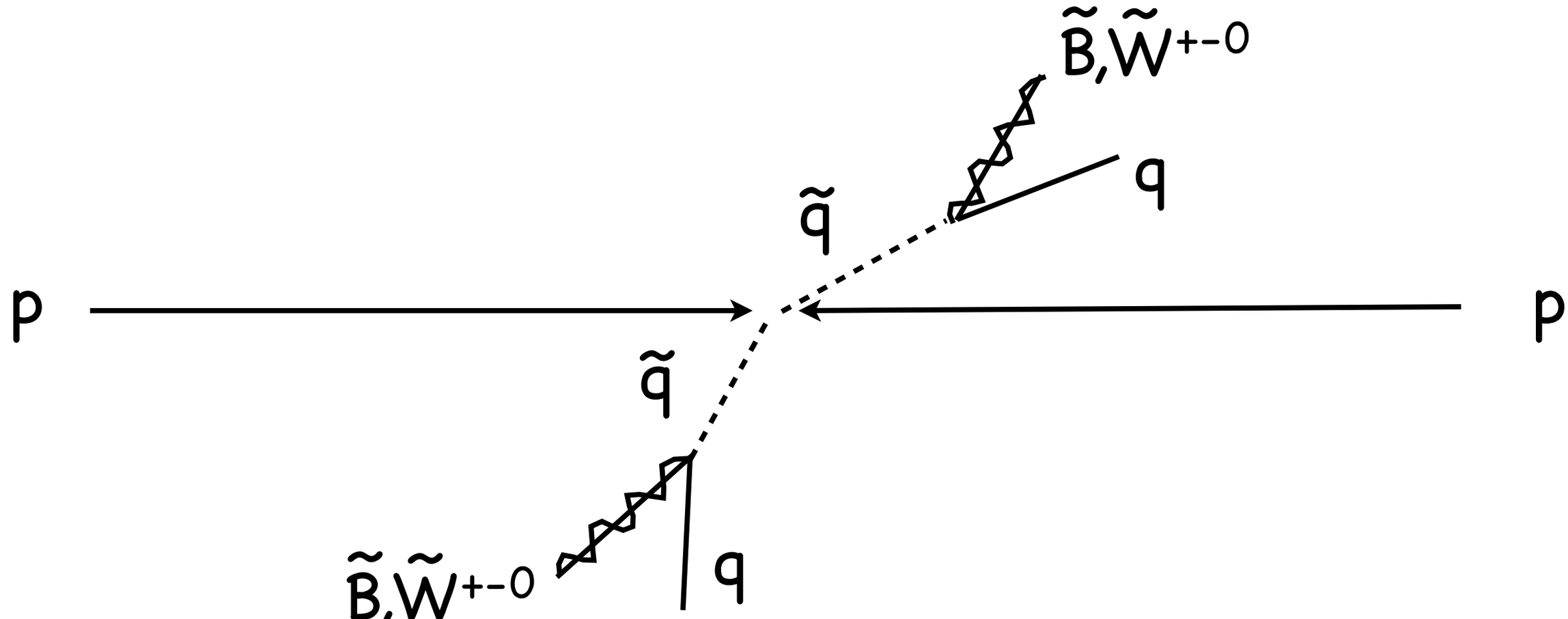
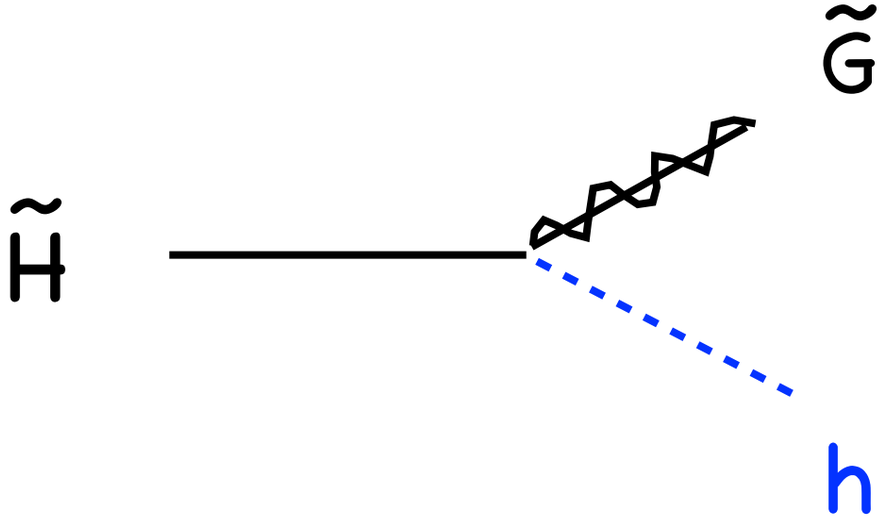
Squark Production to Gauginos

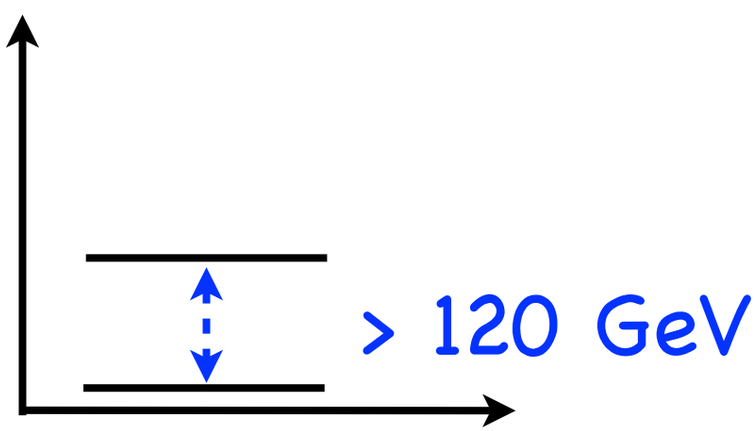


typical $\sigma(\text{squarks})_{14\ \text{TeV}} \approx$ several pb!

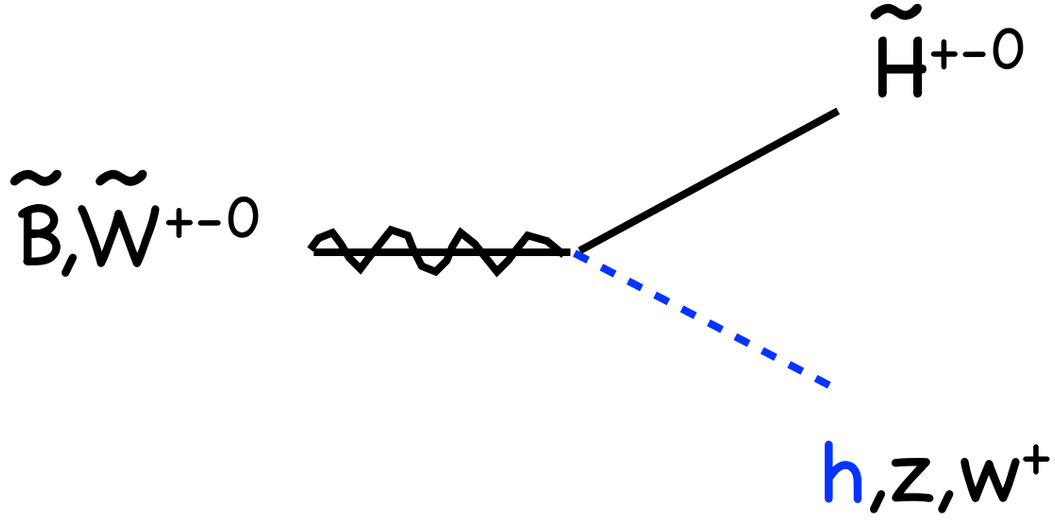
Superpartner Decay Channels to Higgs



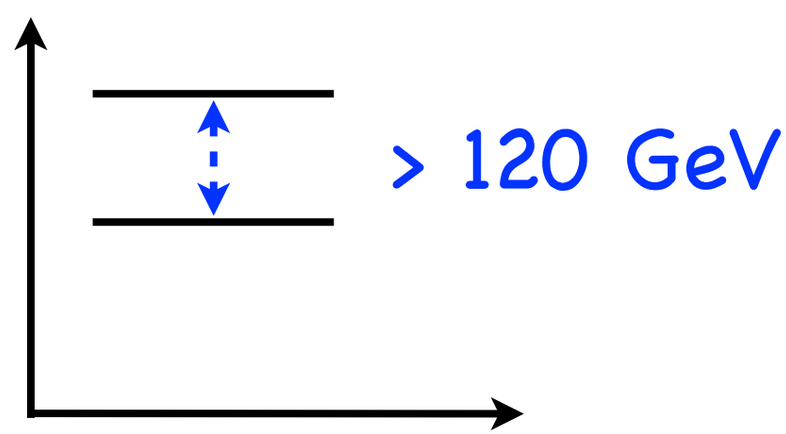
BR up to 50%*



*Thaler-Thomas can get 100%!



BR ≈ 25%**



**Automatic via Goldstone equivalence

Parameter Space

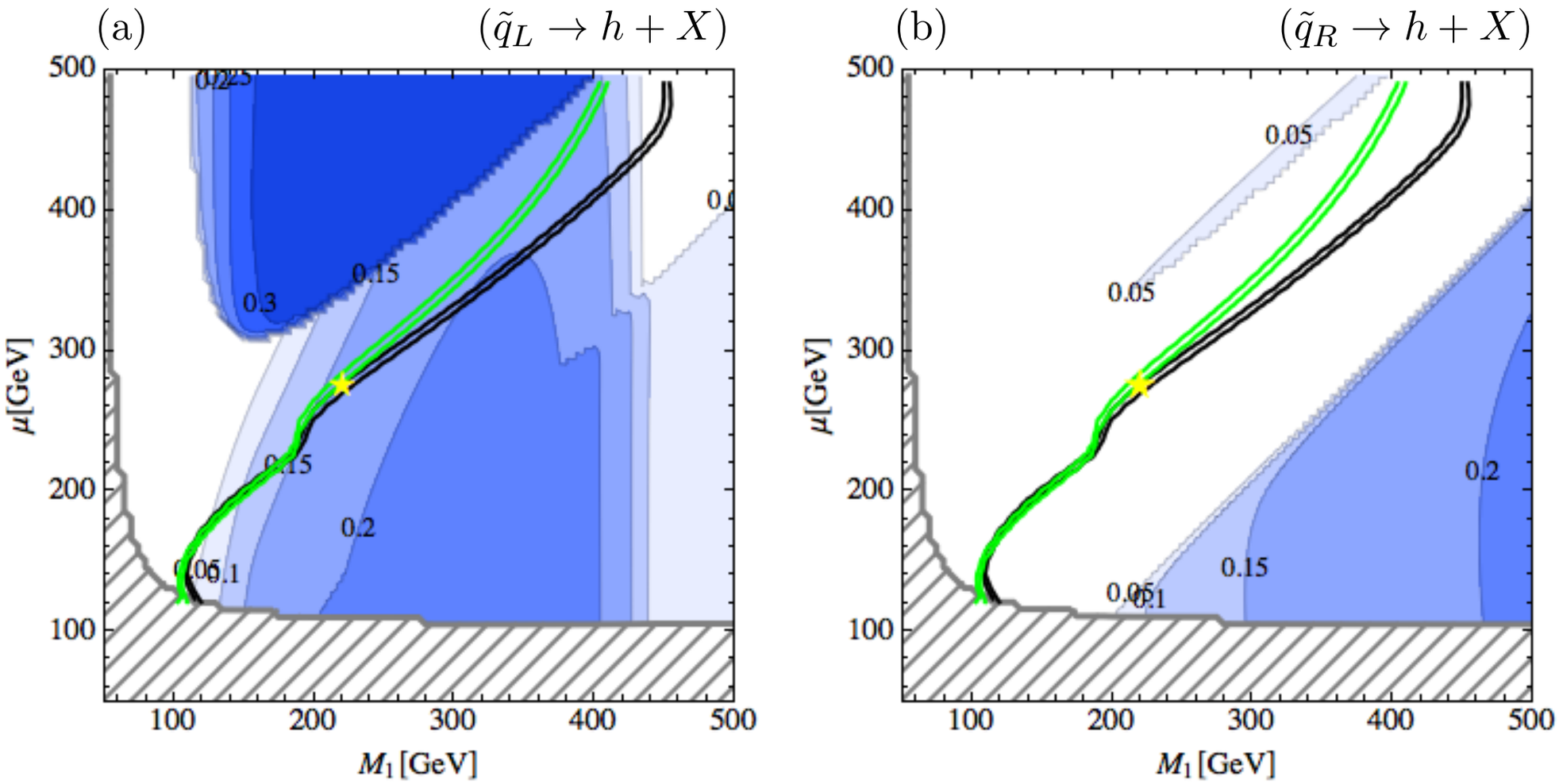


Figure 3: Probability for a Higgs boson in squark decay chains, for $M_A = 1000$ GeV. From lightest to darkest blue, the probabilities are 5%, 10%, 15%, 20%, 25%, 30%. The gray hatched area is excluded by LEP. Superimposed are the regions of correct relic density for $\tan\beta = 10$ (black) and $\tan\beta = 50$ (green). The constraints from dark matter direct detection are not shown. The yellow

Gori, Schwaller, Wagner 1103.4138

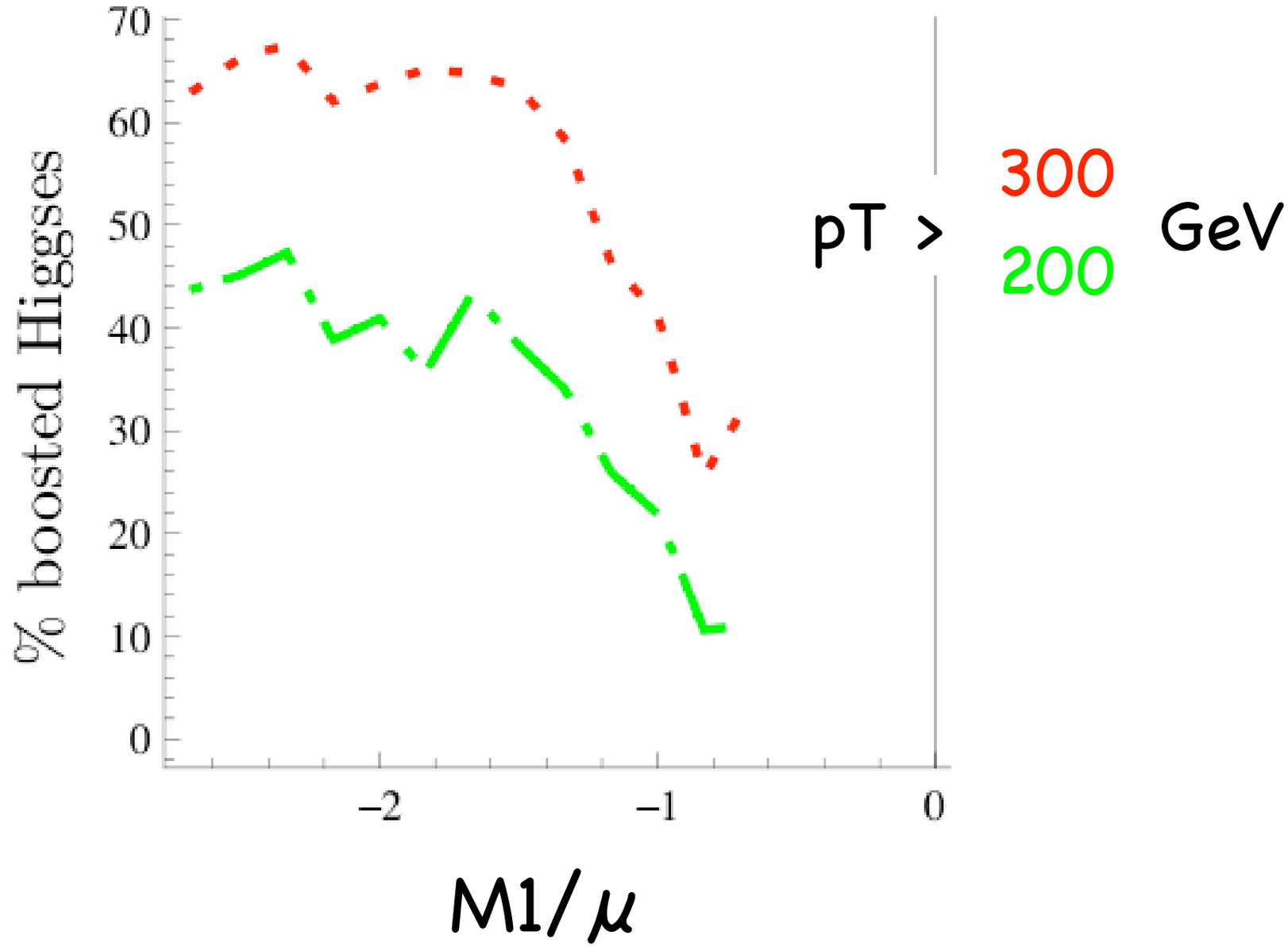
Boost

Example:

msq = 1 TeV

wino = 2 bino

μ = 150 GeV

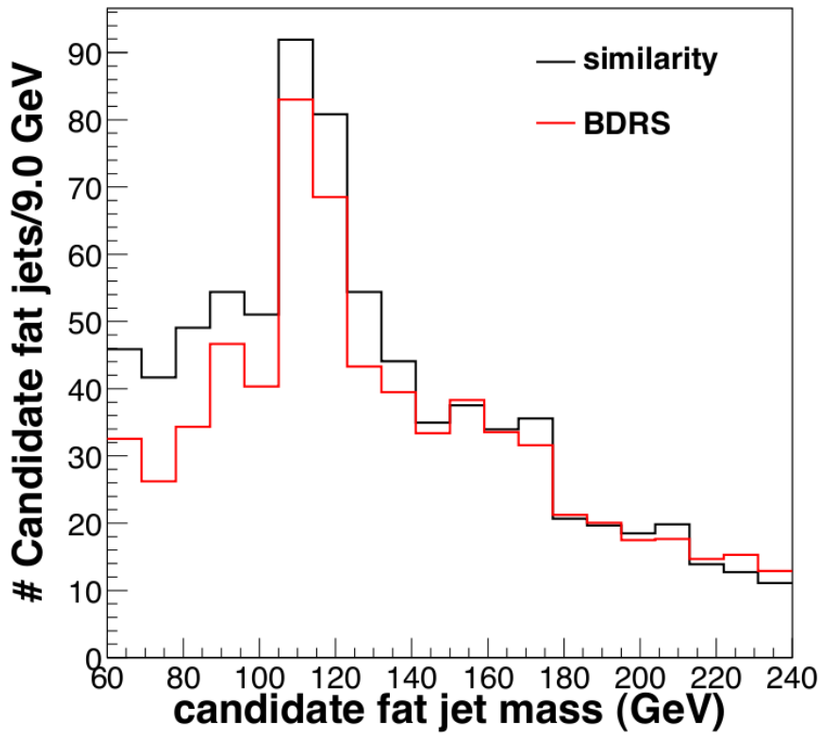


KMRS 1006.1656

Modest Improvment for Busy Events

At each stage of unclustering, calculate "similarity":

$$S_i = \frac{\min\left(p_{t_{j_1}}^2, p_{t_{j_2}}^2\right)}{\left(p_{t_{j_1}} + p_{t_{j_2}}\right)^2} \Delta R_{j_1 j_2}$$



KMRS 1006.1656

Choose 3 highest pT jets from stage which maximizes "S"

This helps improve the efficiency of finding the Higgs by ≈ 10-20% by not rejecting fat jets with stray b-tagged jet.

Simulation details...

Background: ALPGEN → PYTHIA6.4

Signal: SUSPECT2 → PYTHIA6.4

underlying event: ATLAS tune

- All final-state hadrons grouped into cells of size $(\Delta\eta \times \Delta\phi) = (0.1 \times 0.1)$
- Each cell is rescaled to be massless

this models detector response (Thaler, Wang '08)

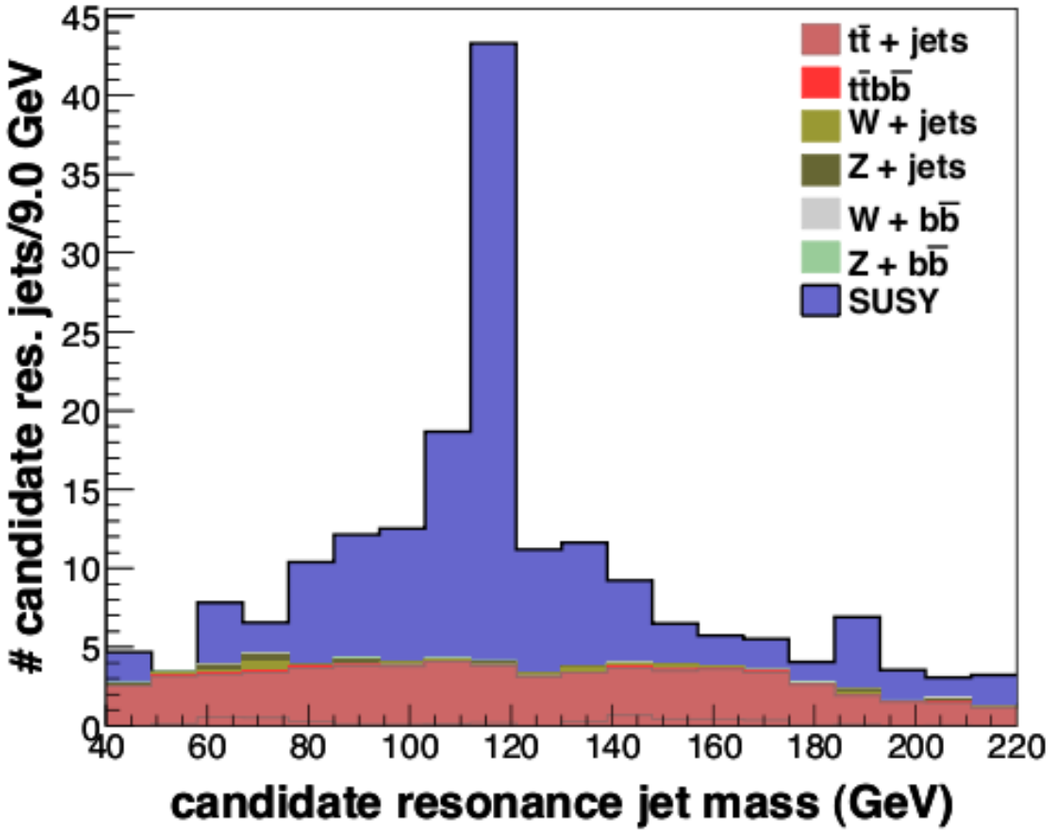
jet gymnastics performed using FastJet (hep-ph/0512210)

b-tagging: 60% efficiency, 2% fake rate

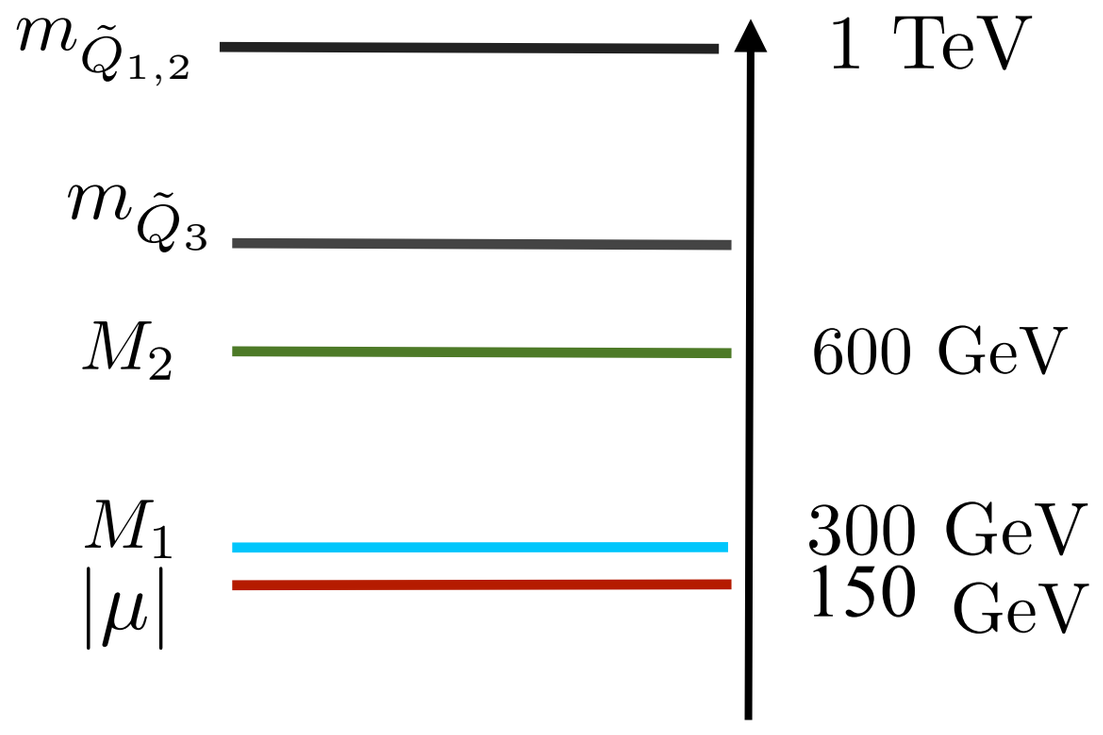
jet-photon fake rate: $.1\%$

Example 1: MSSM with Higgsino LSP

10 fb^{-1} @ 14 TeV



KMRS 1006.1656



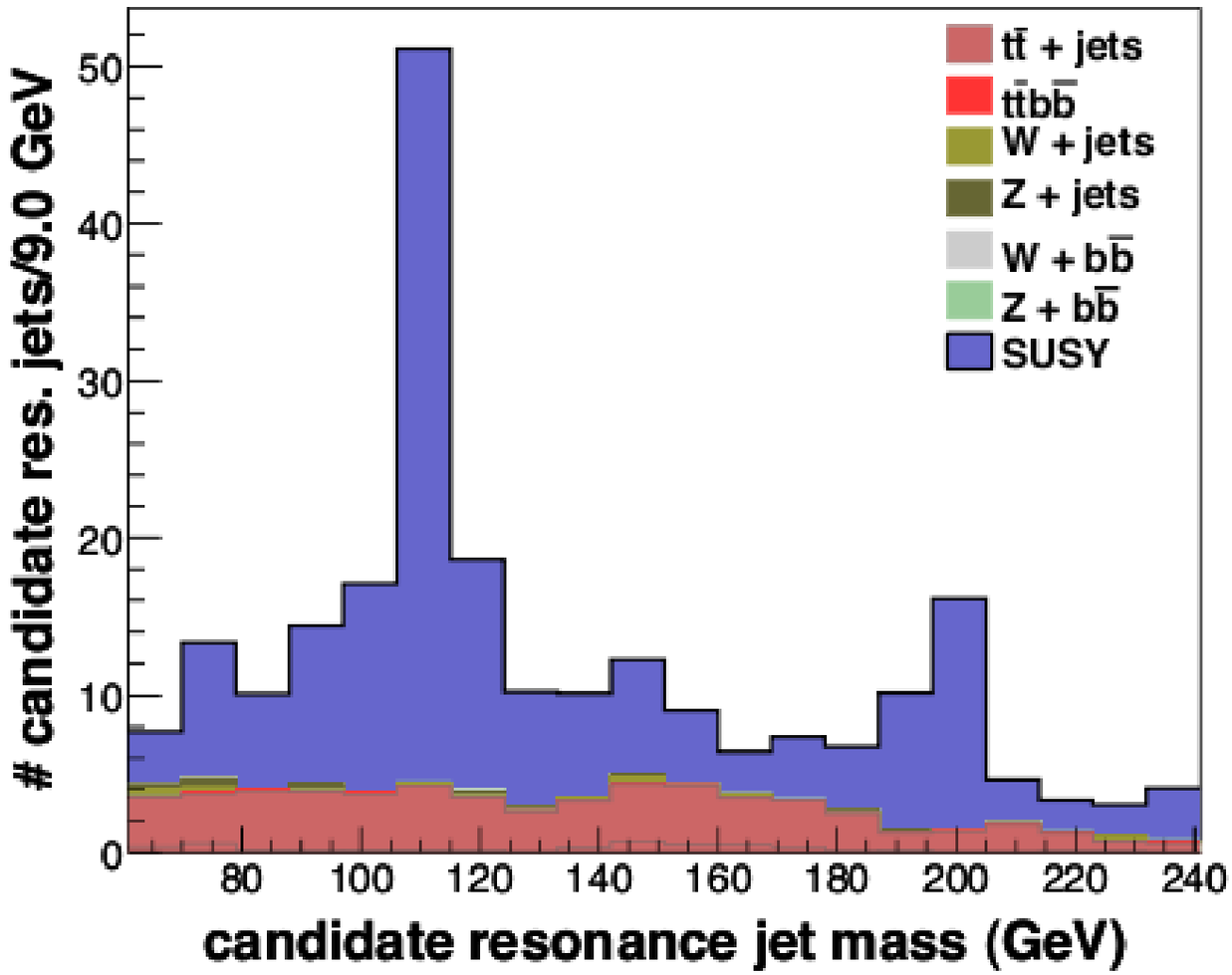
$$BR(\tilde{u}_L, \tilde{d}_L \to h + X) \sim 23\%$$
$$BR(\tilde{u}_R, \tilde{d}_R \to h + X) \sim 16\%$$

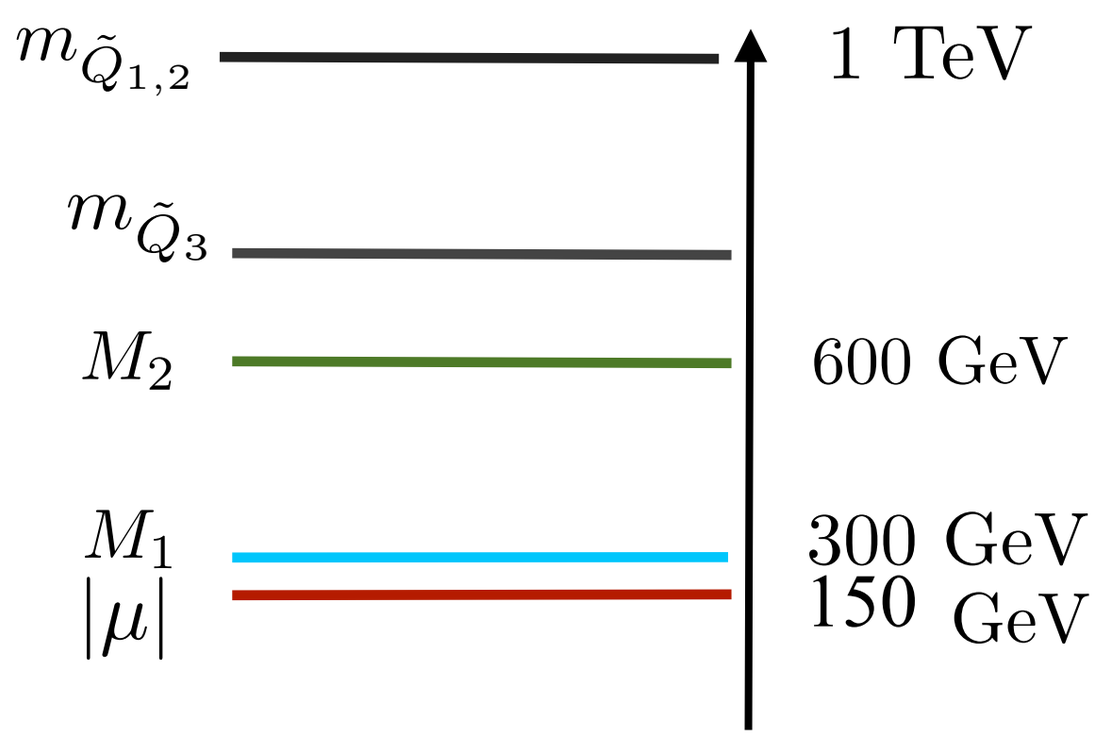
MET > 300 GeV, H_T > 1 TeV, 3+ jets,

no lepton, + 1 "tagged" Higgs

Example 2: MSSM with m_A = 200 GeV

10 fb^{-1} @ 14 TeV





KMRS 1006.1656

Could discover heavier A,H states!

new physics

Spectactular

Great

Promising

SUSY

(h always light in MSSM)

cascade ends
NLSP -> h $\tilde{g}$

cascade spits
h
in decays

top partners

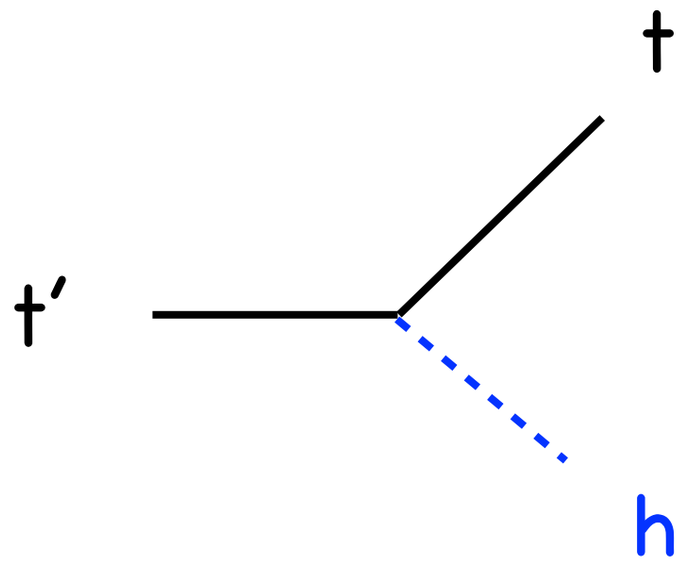
(h could be light)

t' -> t h

Top Partners

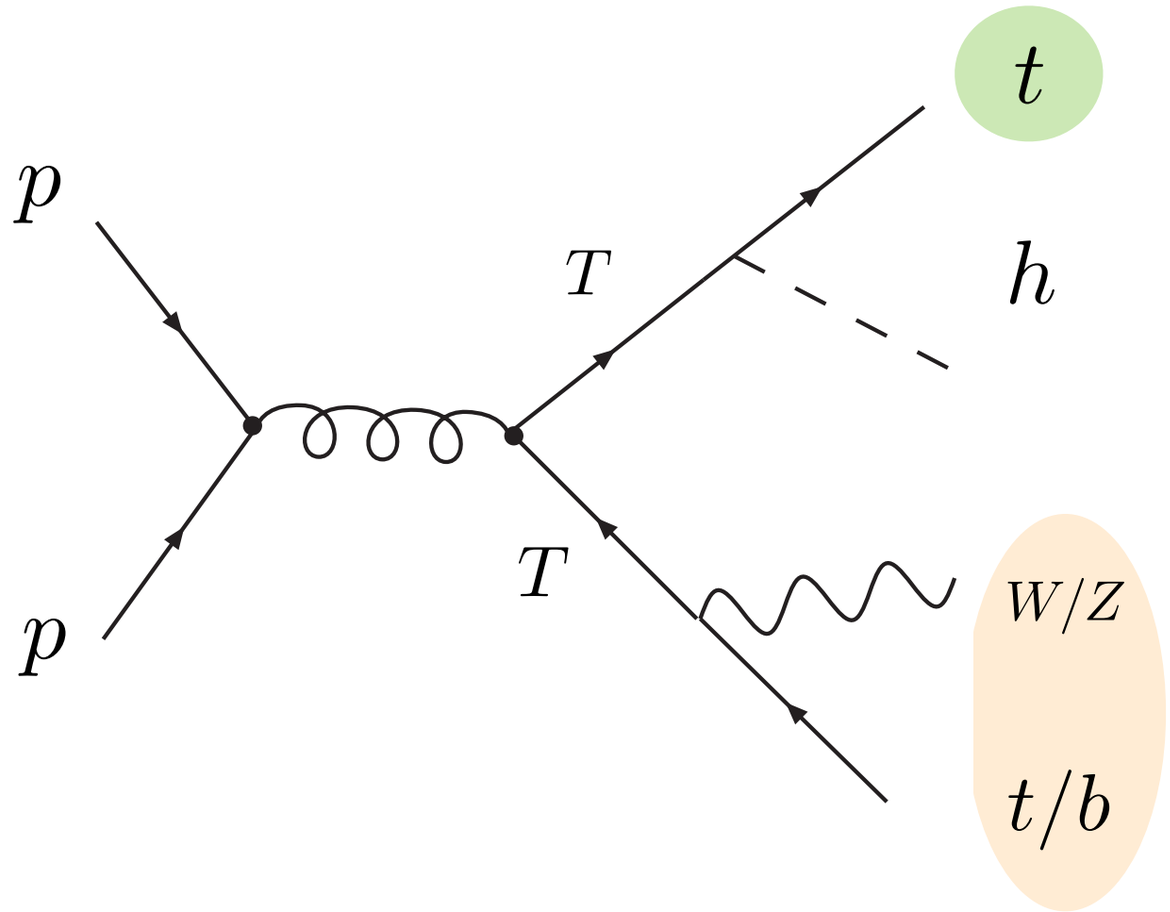
vector-like quarks with mixing through Higgs

(little Higgs models, top color with light h, ...)



"Goldstone region"
for m(t′) » m(t)
≈ 25% of time decay to h
≈ 75% of time to longitudinal W/Z

Higgs from Top Partners



always one top quark

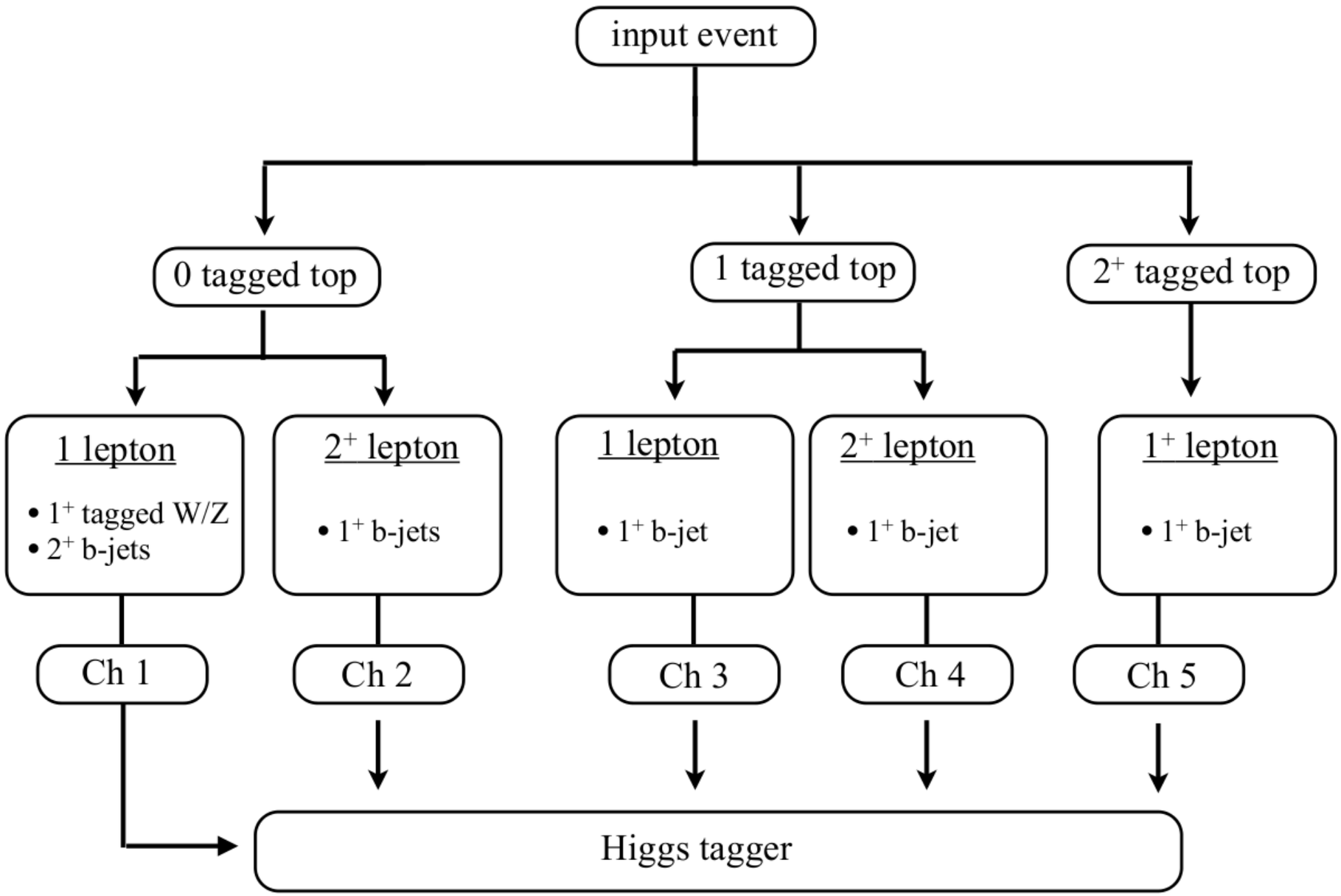
short cascade:
Higgs $p_T \sim M_T/2$
(vs. $\sim M_T/4$ for MSSM)

+ additional gauge boson/top

4^+ bs, many jets!

Unlike SUSY, require multiple "tags" involving the varied final states, including boosted top and boosted W tagging.

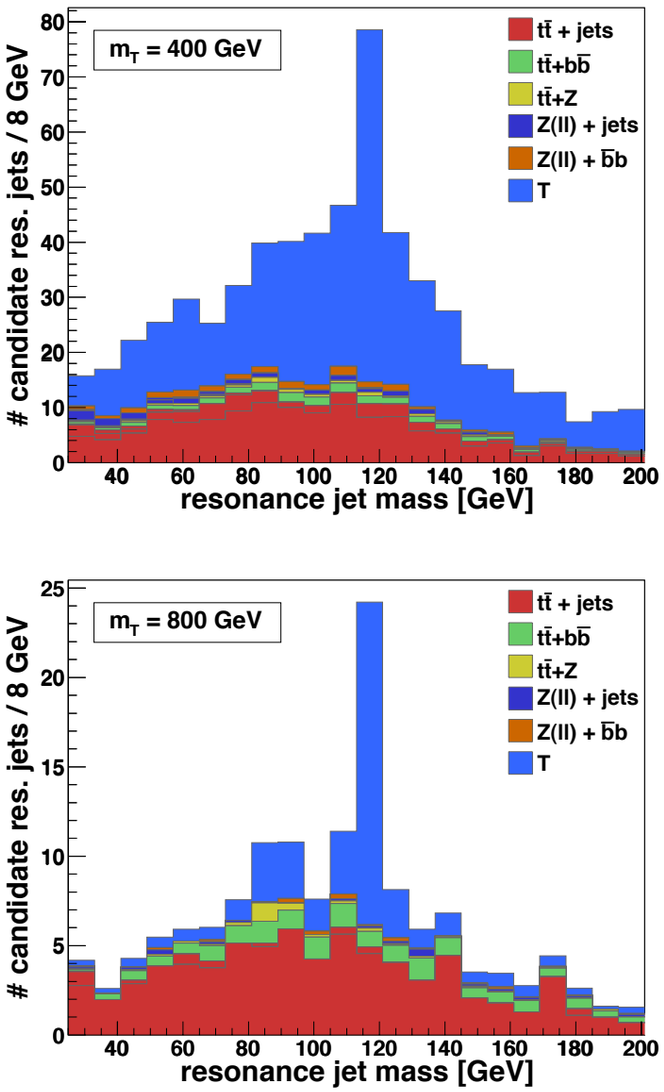
Exploit Boosted t,W (as well as h)

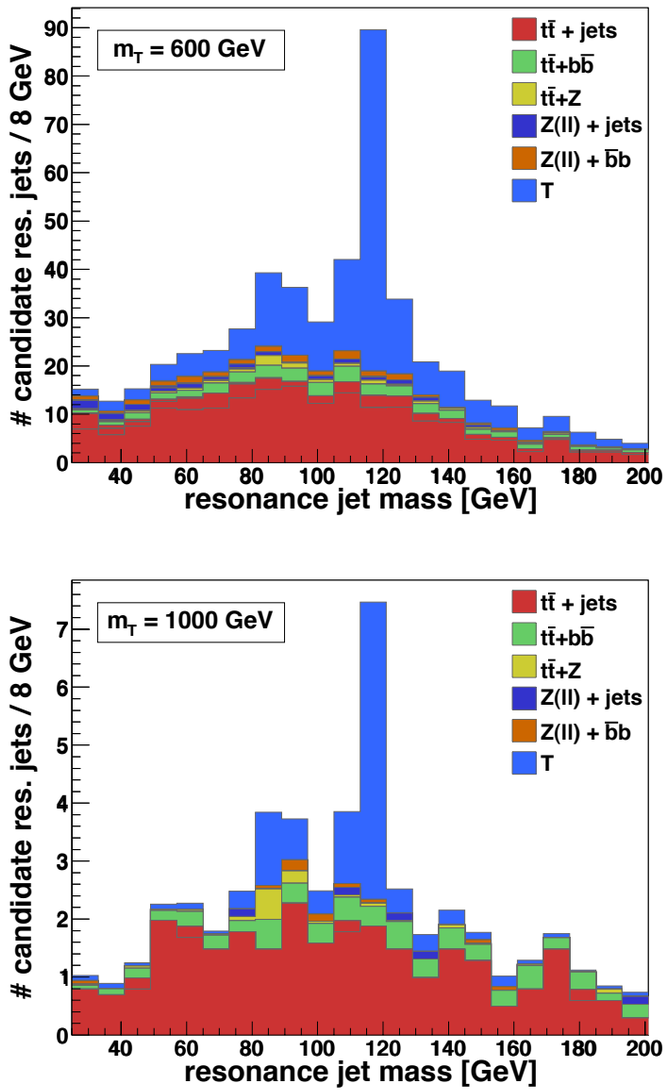


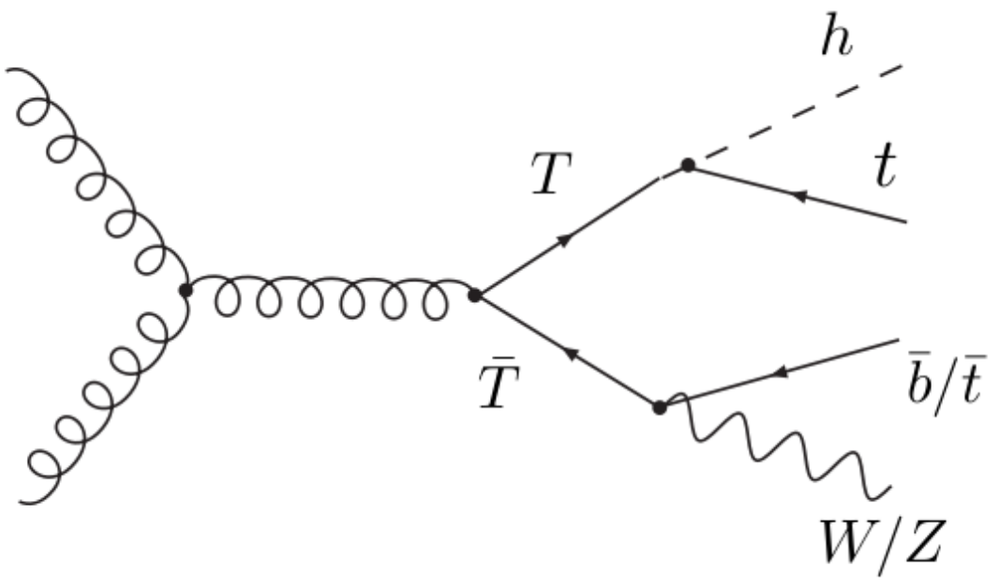
Different pathways better for different t' masses.

Top partner production & decay:

10 fb^{-1} @ 14 TeV

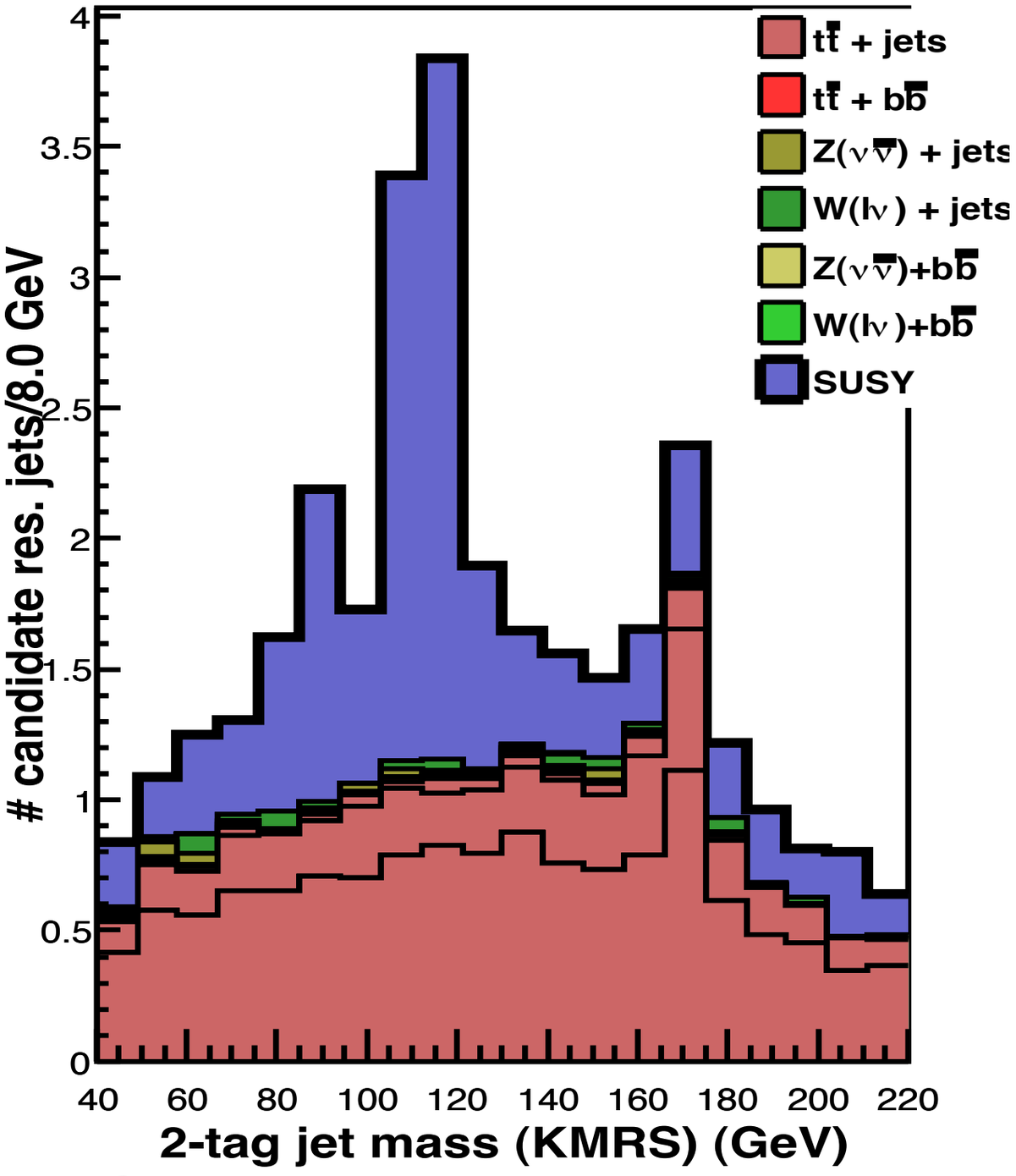






KMR 1012.2866

In preparation...SUSY @ 7 TeV, 1-2 fb^{-1}



KMR...

	Point 2
$m_{\tilde{Q}_{1,2}}$	800 GeV(L), 730 GeV(R)
$m_{\tilde{Q}_3}$	900 GeV
M_1	440 GeV
M_2	370 GeV
M_3	1 TeV
μ	260 GeV
LHC σ_{NLO}	0.68 pb
Tevatron σ_{NLO}	
Events at 40 pb^{-1}	~ 4
$BR(\tilde{Q}_{1,2} \to h + X)$	34%(R), 12%(L)

Summary

- BDRS Higgs tagger versitile tool to search for Higgs in new physics production/decay signals

- MSSM h ideal candidate; large rate from squark production; large boost from cascade decay. Could discover h faster than SM -- maybe this year!

Rethink m_A -tan(b) plane!!

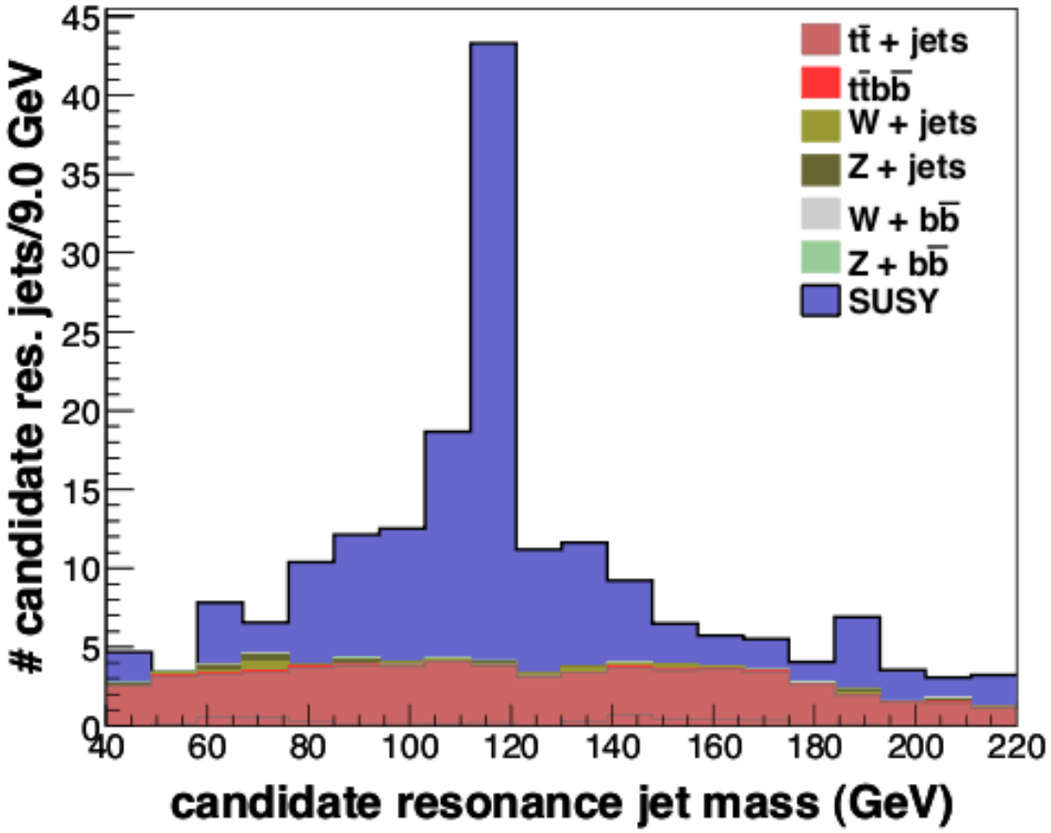
- Top-partners produced with large rate; large boost; large decay fraction into Higgs; can also help discover and measure top-partner properties.

New tools can dramatically improve
New Physics <-> Higgs connection

Extra

"What good is that fancy substructure?"

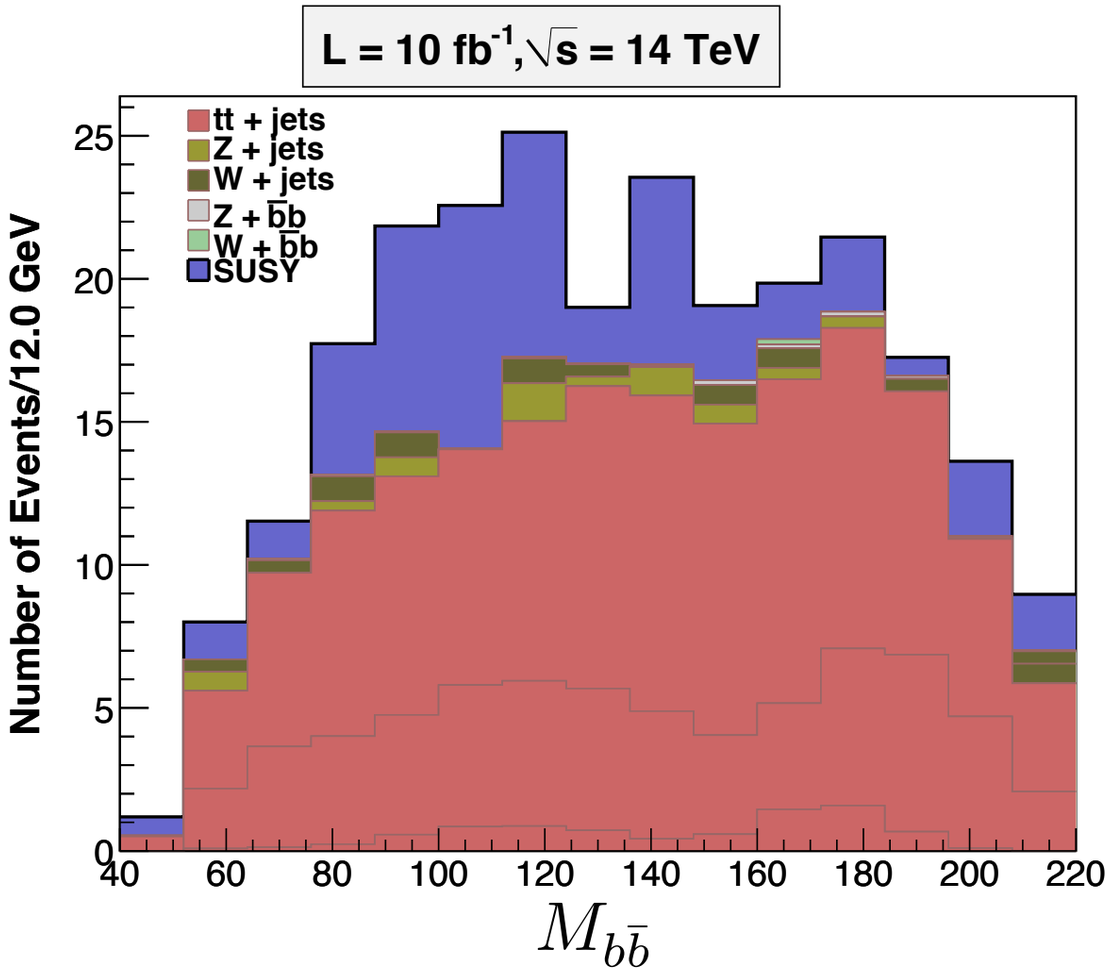
Comparison*: with substructure analysis vs. with PGS



$H_T > 1$ TeV, $\not{E}_T > 300$ GeV

3^+ high-p_T jets, no leptons

1 candidate Higgs



$H_T > 1$ TeV, $\not{E}_T > 300$ GeV

4^+ high $- p_T$ jets, no leptons

2^+ b-tags

(Stolen from A. Martin slides)

*not totally fair