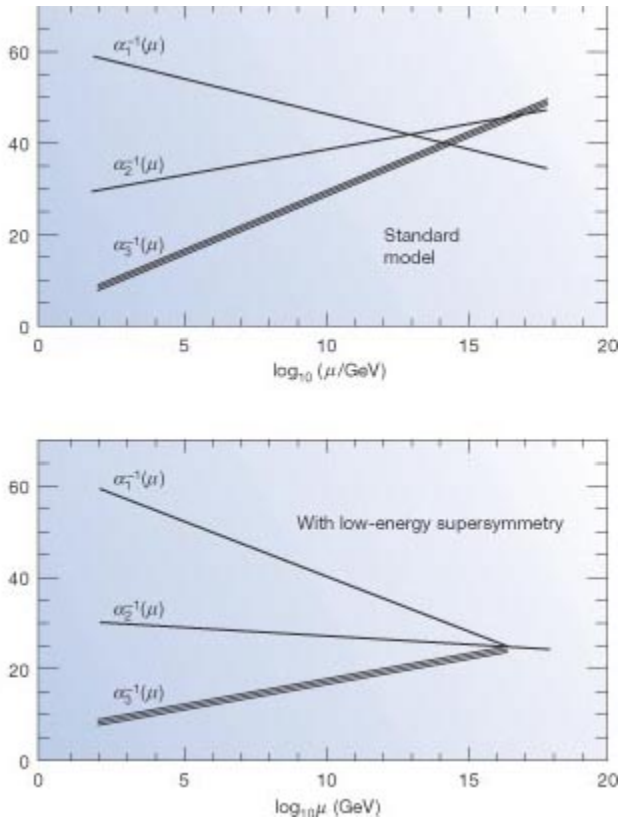
A search for gluino-mediated supersymmetry with Higgs bosons and missing energy in the final state

Frank Jensen

New Perspectives

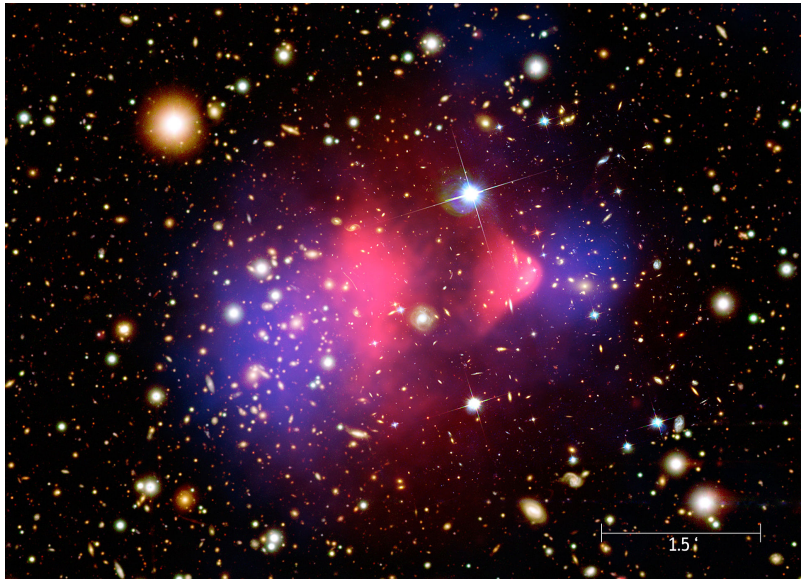
13 June 2016

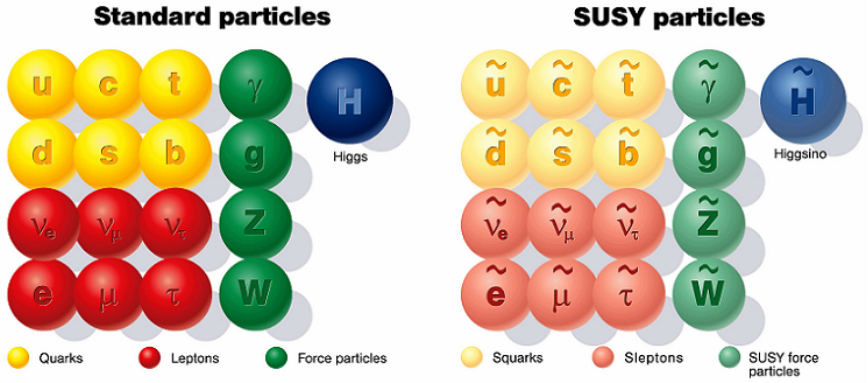
motivation



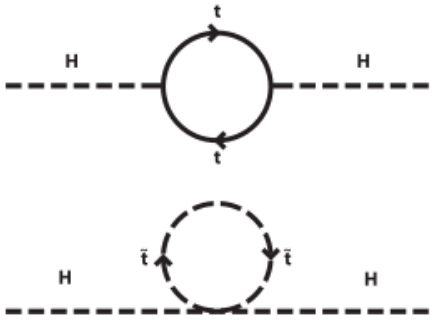
- Gauge coupling unification

- Provides a dark matter candidate





- Stabilize the Higgs boson mass



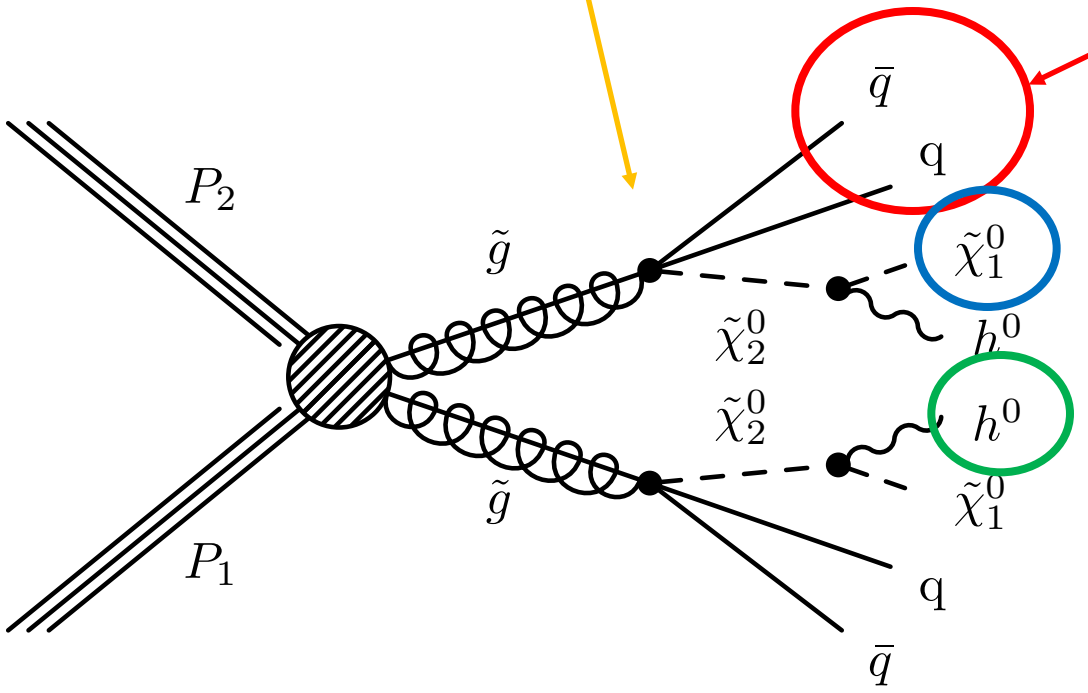
Supersymmetry (SUSY) provides an extension to the Standard Model which could help with various 'deficiencies'

model & event topology

interested in small mass differences between the gluino and NLSP - this leads to Higgs bosons with large p_T

quarks in the final state motivates using large jet multiplicity (NJets) events, and lots of hadronic energy (HT)

$$HT = \sum_{jets} p_T$$

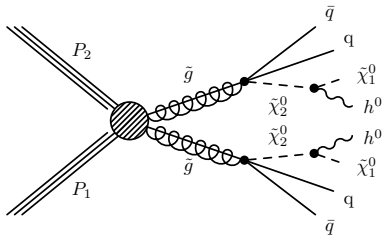


LSP escapes detection leading to momentum imbalance (MHT)

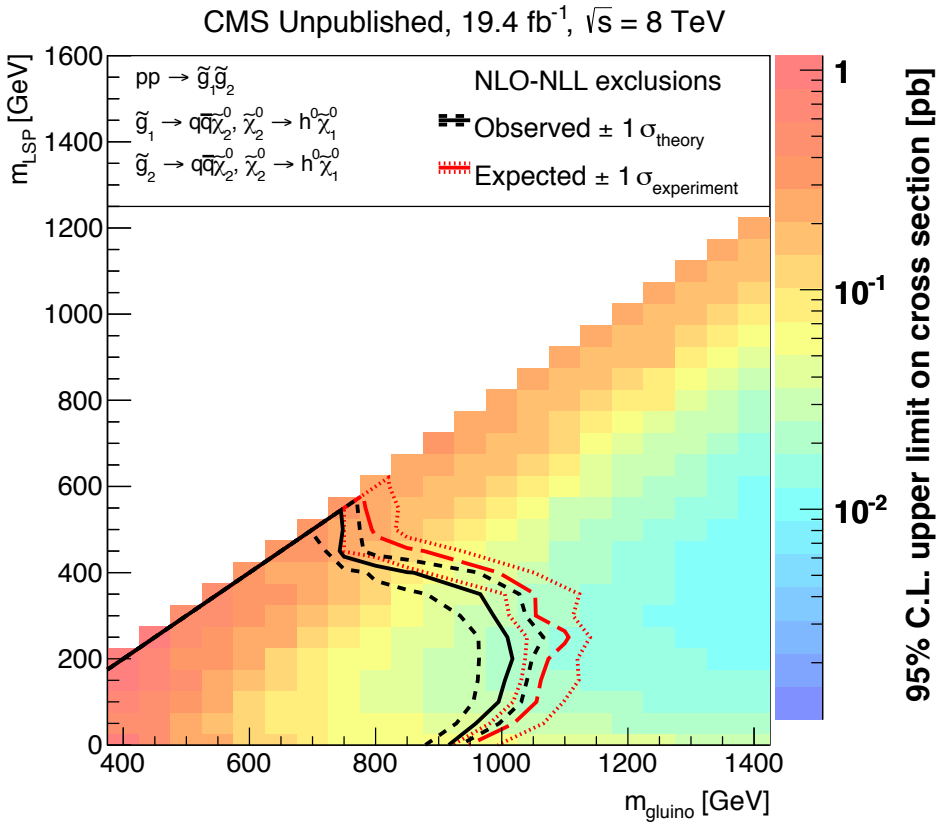
$$MHT = |-\sum_{jets} \vec{p_T}|$$

only consider Higgs → bbar decays (57% BR)

past results



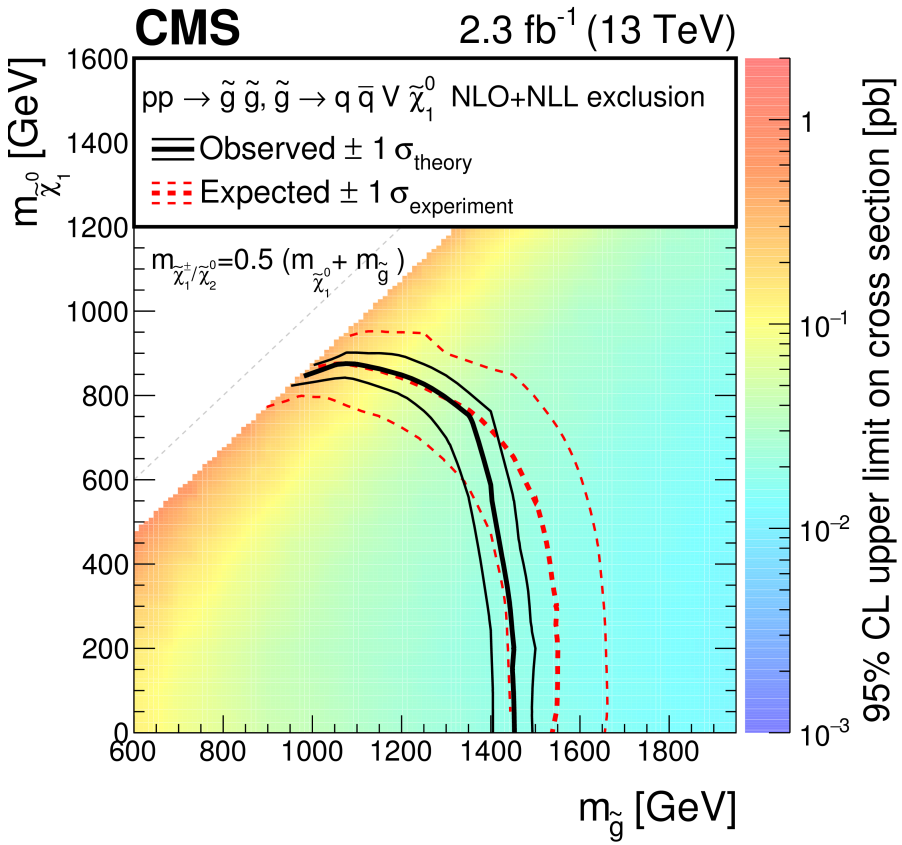
LSP

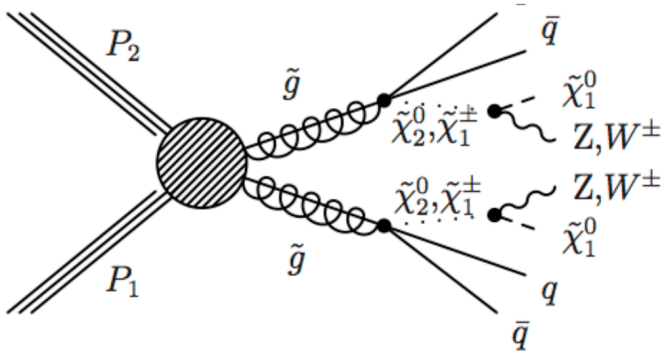


8 TeV results

more recent results
slightly different final states

LSP

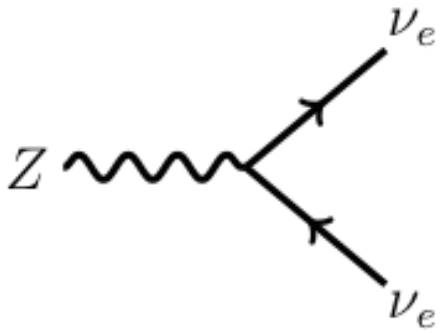




some standard backgrounds

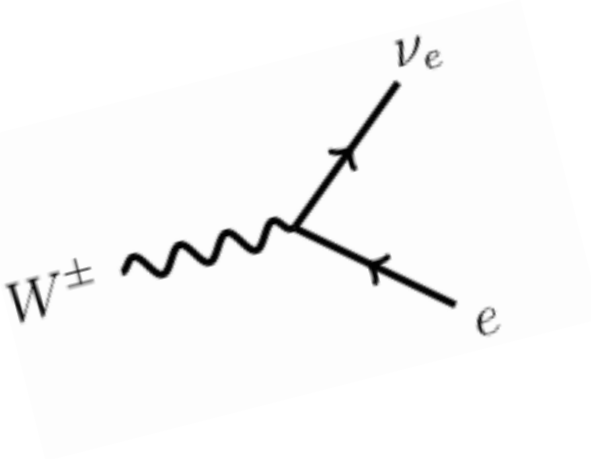
QCD

QCD processes which result in jet production become a background when a jet is mismeasured leading to a 'fake' contribution to MHT.



Z to invisible

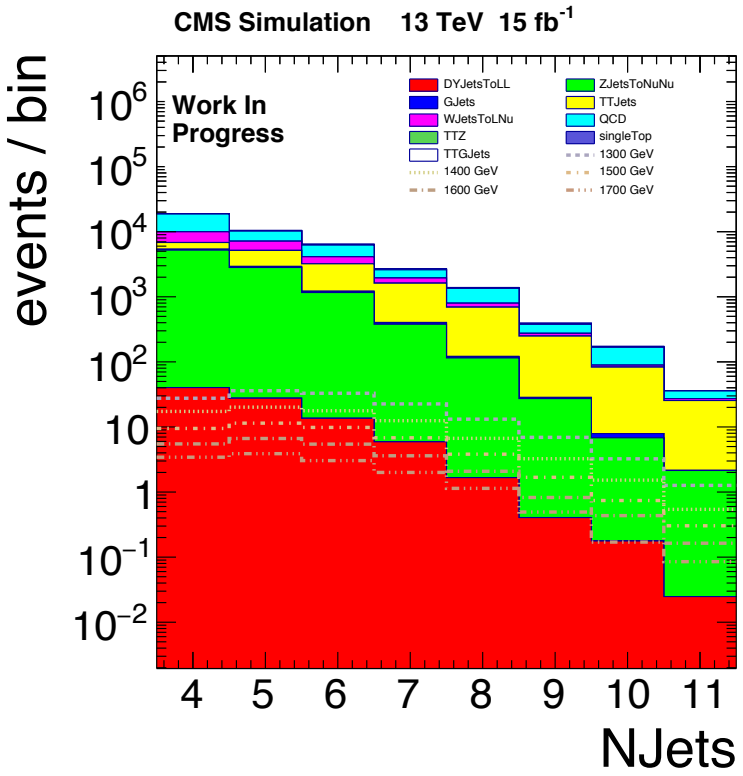
Decays of Z bosons to neutrinos provide a genuine source of MHT.

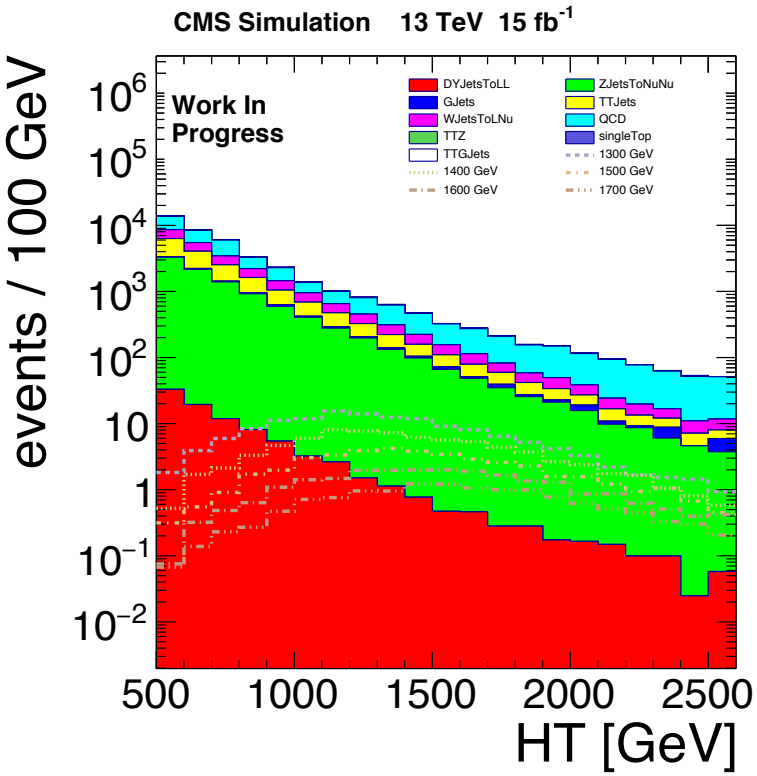


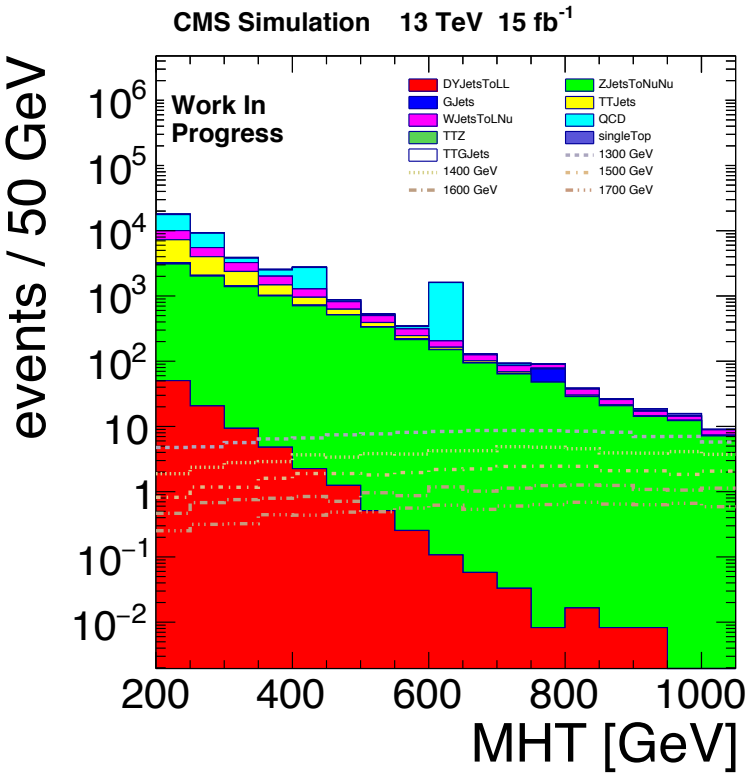
lost lepton

Semi-leptonic decays of W bosons become a background when the lepton is not properly identified and the neutrino escapes detection leaving a source of genuine MHT.

baseline selection





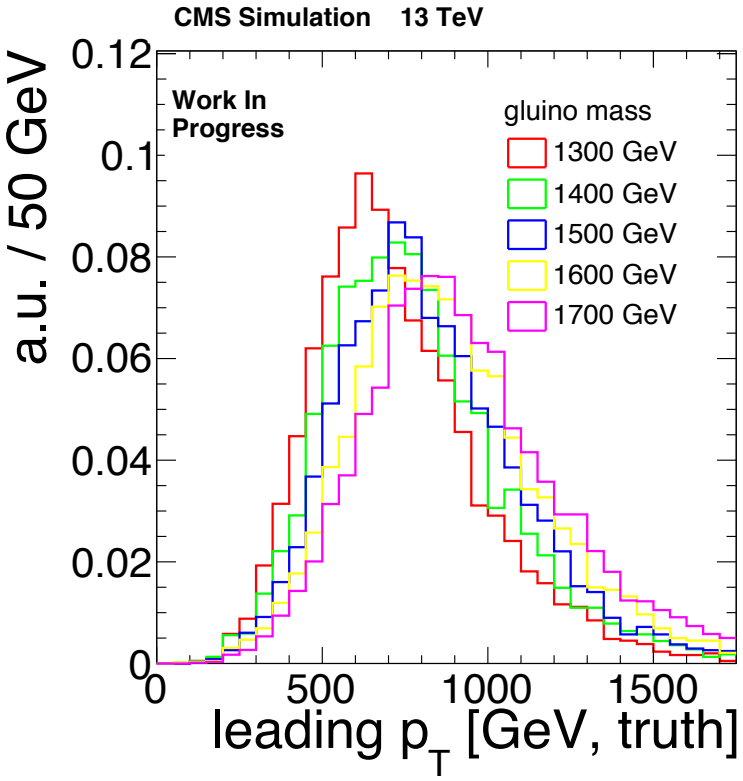


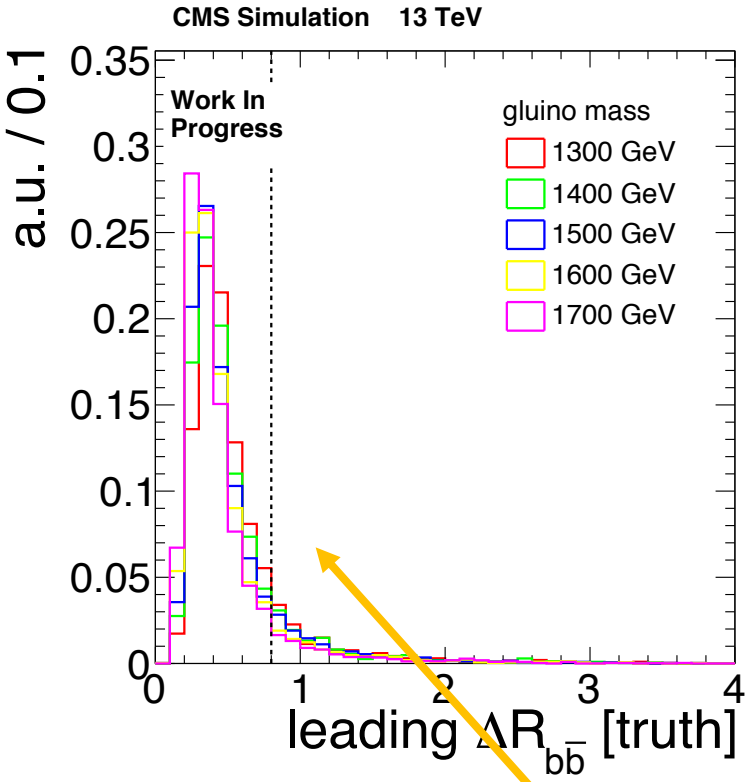
- no identified leptons
- HT > 500 GeV
- MHT > 200 GeV

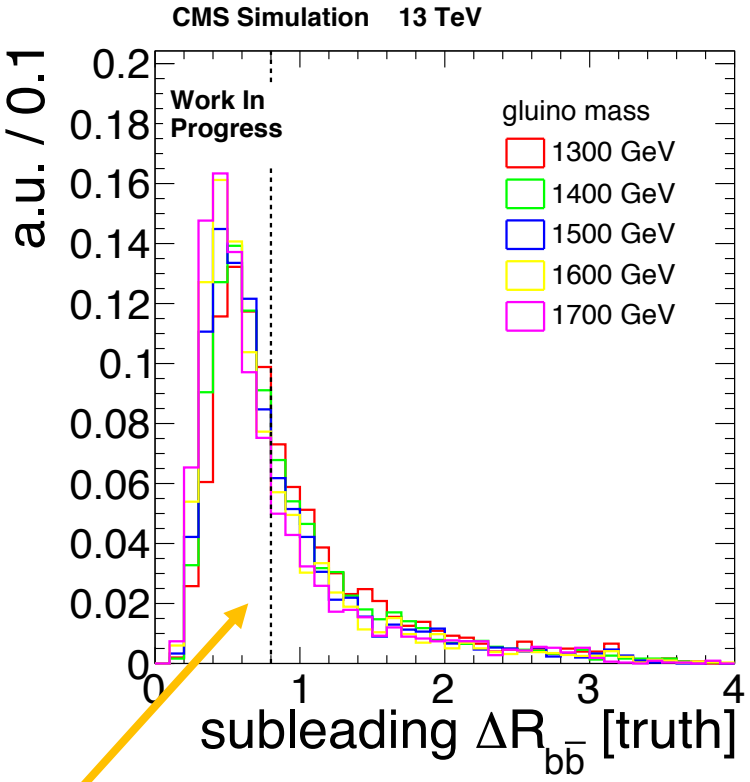
- NJets ≥ 4
- Δϕ > 0.5, 0.5, 0.3, 0.3
  - angle between MHT vector and 4 leading jets

selection criteria are ~65% efficient

a boosted Higgs







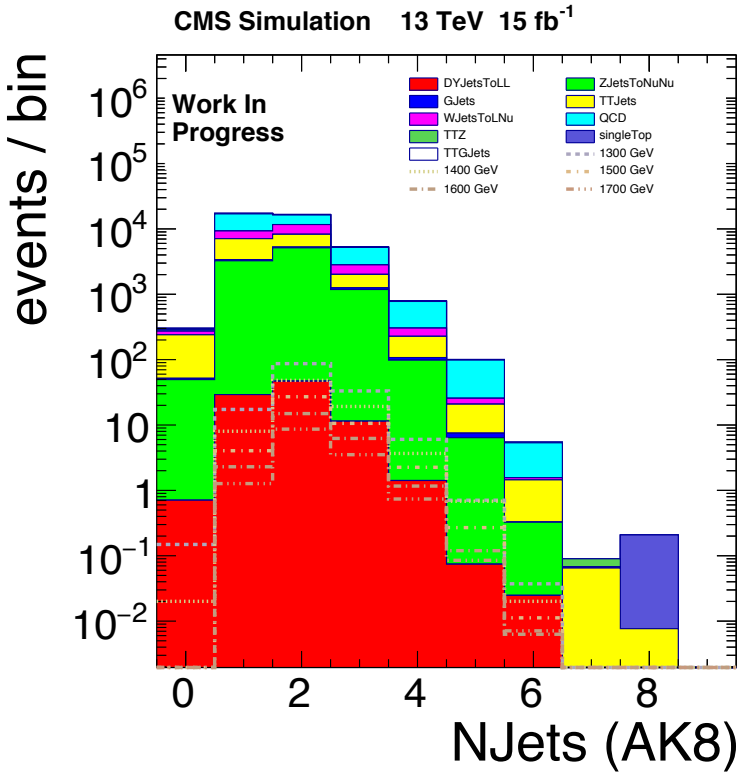
expect both b quarks to be contained inside one "fat jet" of cone size ΔR = 0.8

large p_T Higgs will decay with collimated b quarks

$$\Delta R^2 = \Delta\eta^2 + \Delta\phi^2$$

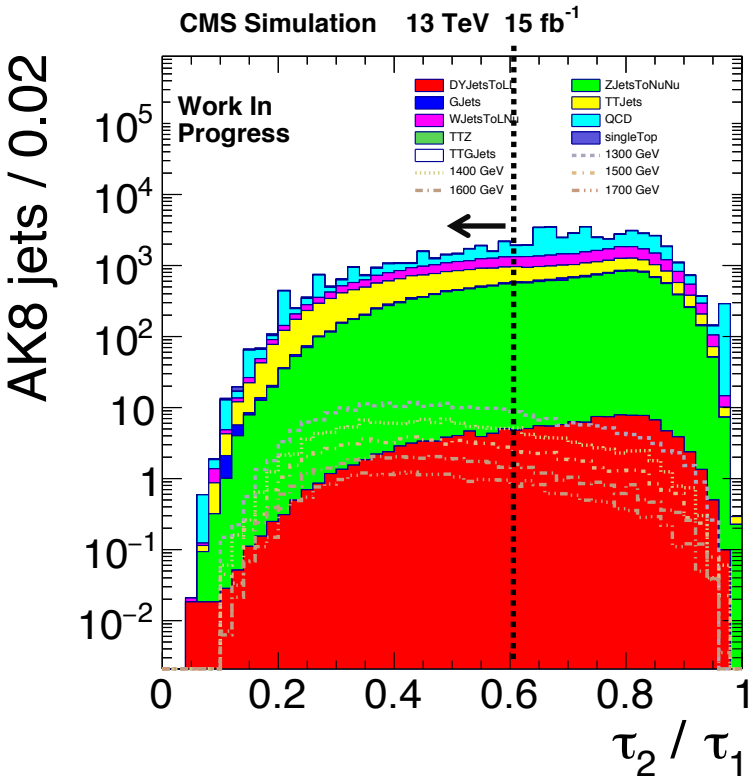
Higgs tagging

these distributions include the two leading jets in each event

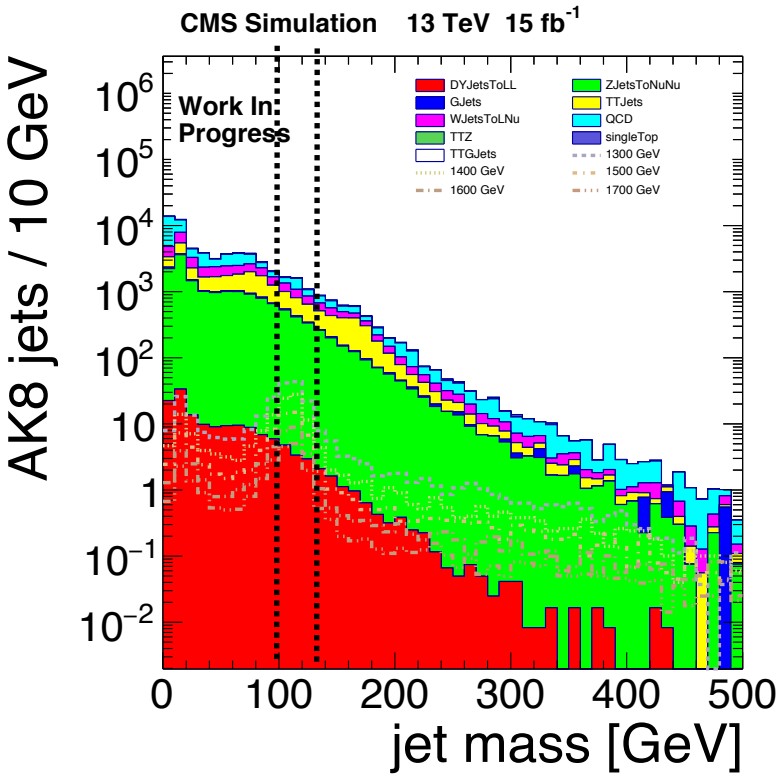


"AK8" jets

$p_T > 170$ GeV



more consistent with having 2 subjets than 1

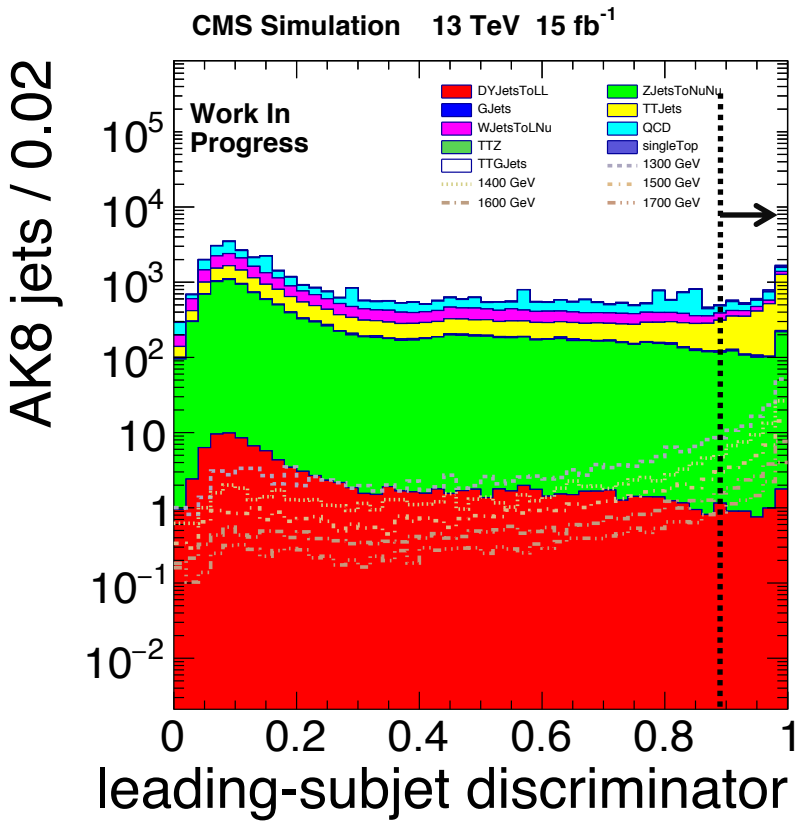


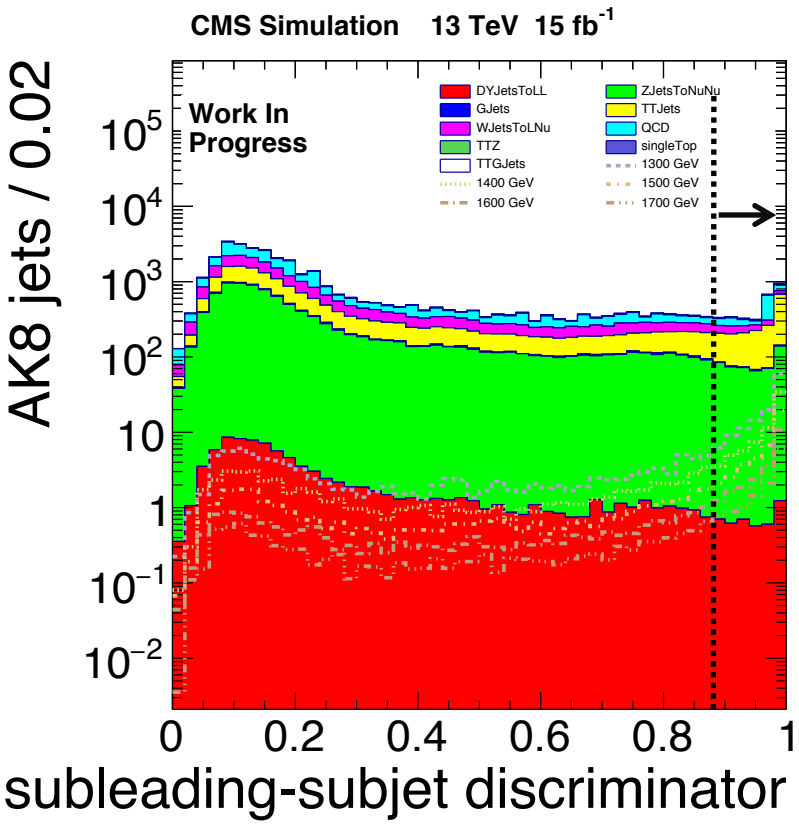
mass consistent with mass of Higgs boson

$$\tau_N = \frac{1}{d_0} \sum_k p_{T,k} \min\{\Delta R_{1,k}, \Delta R_{2,k}, \cdots, \Delta R_{N,k}\}$$

these distributions include the two leading jets in each event

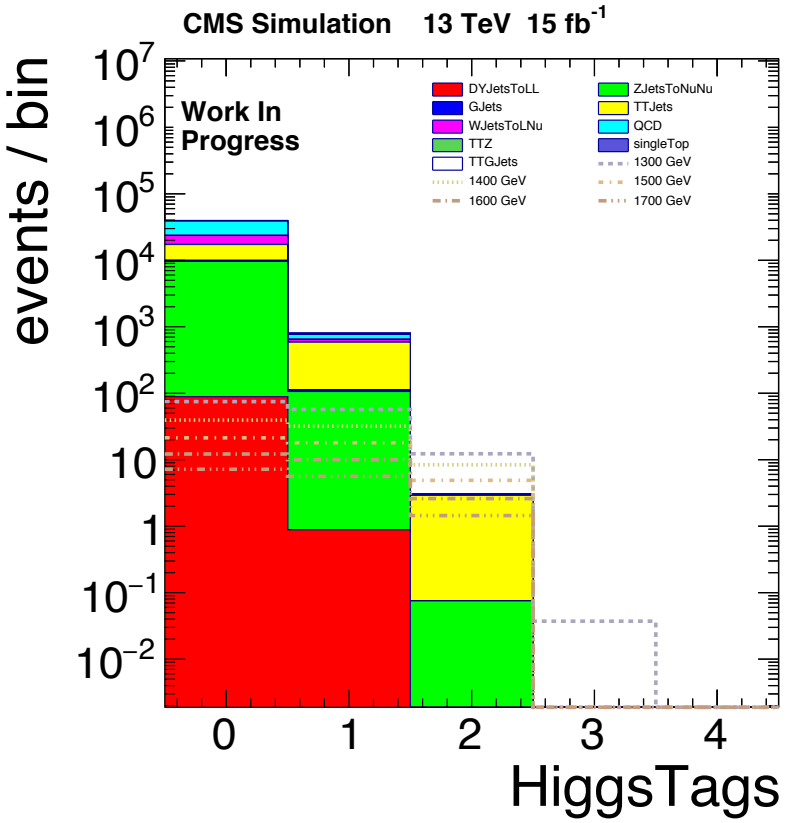
and the b-ness





MVA discriminator combines information about secondary vertex reconstruction, track impact parameters, & jet kinematics

yields at 15 fb^{-1}



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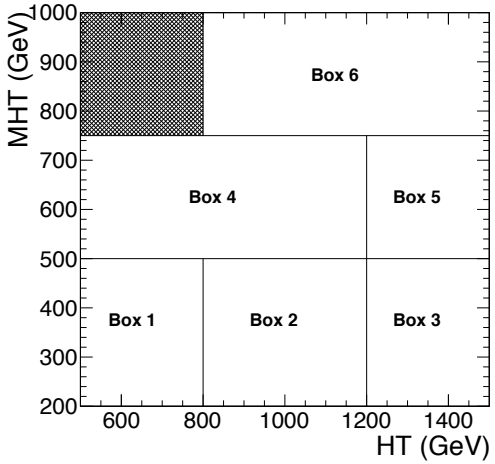

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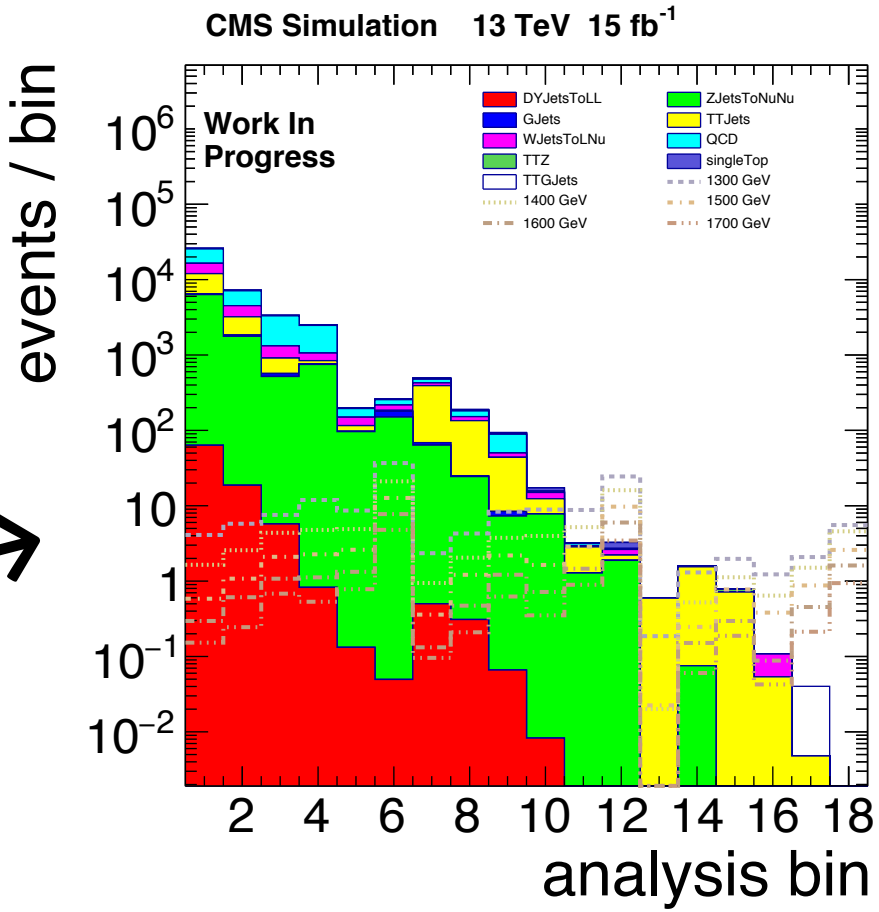


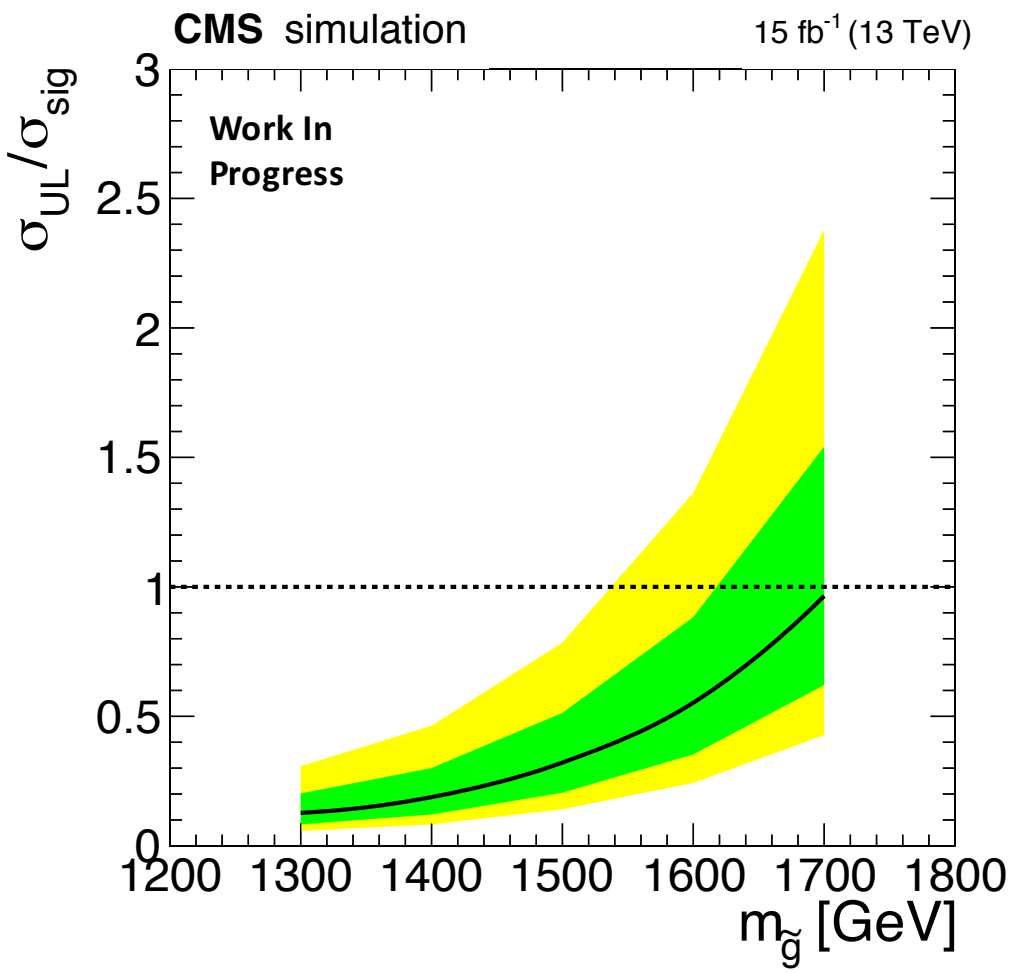
for the search:

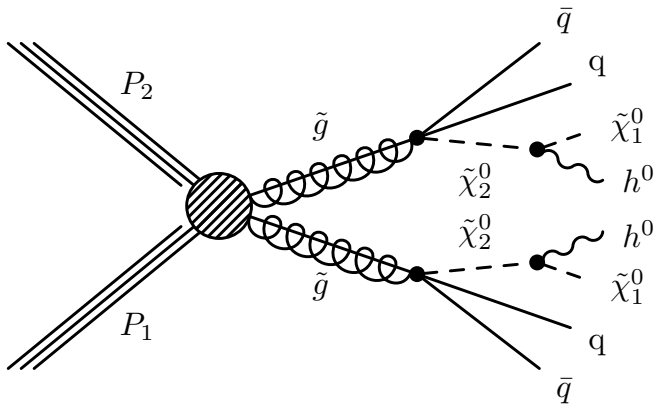
bin in the HT-MHT plane

crossed with the # of Higgs tagged jets = 0, 1, 2+

results...

MC was produced with gluino masses of 1300, 1400, 1500, 1600, 1700 GeV
The NLSP mass is 50 GeV less than the gluino mass
The LSP mass is 1 GeV

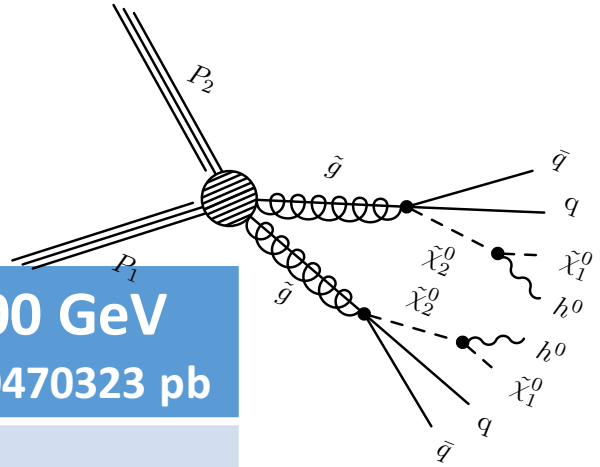




- With 15 fb^{-1} we should be able to exclude gluino masses up to about 1.7 TeV
- Much of the exclusion power comes from the bins with 2+ Higgs tags, large HT and large MHT
- Additional MC samples with higher gluino mass and/or different models can be used to further explore the SUSY parameter space

backup

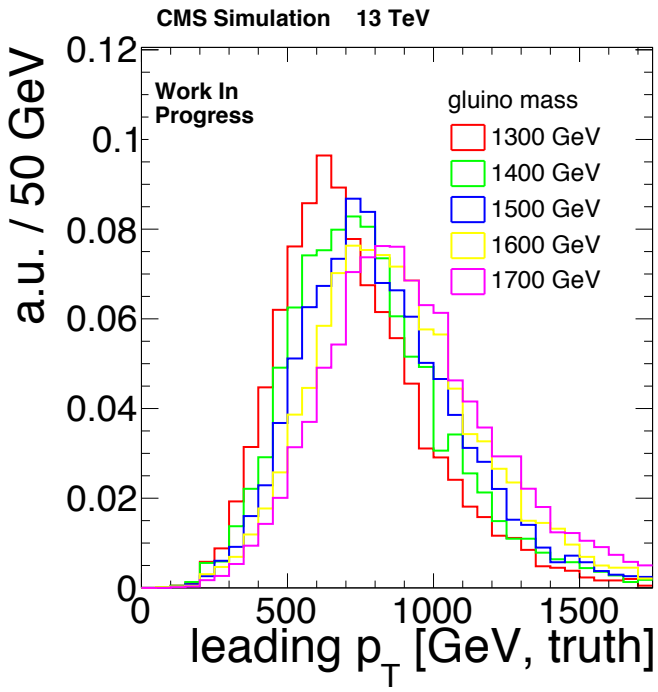
signal event yields @ 15 fb^{-1}

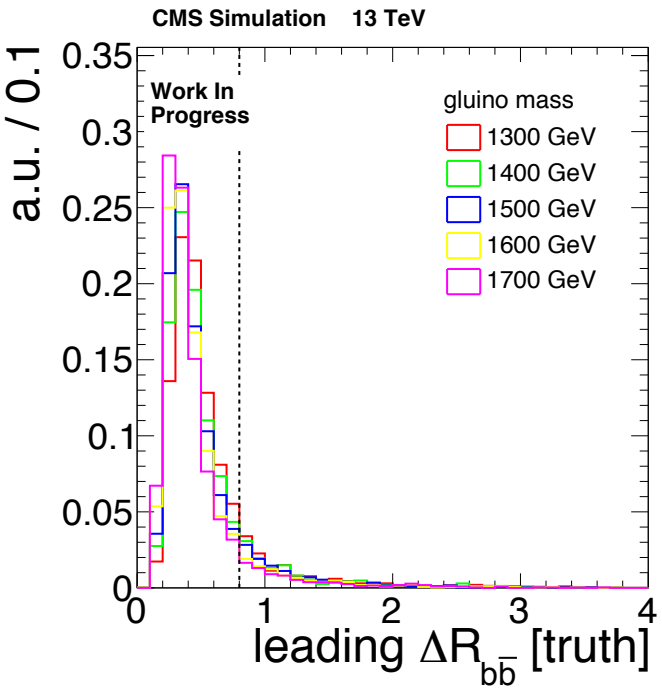


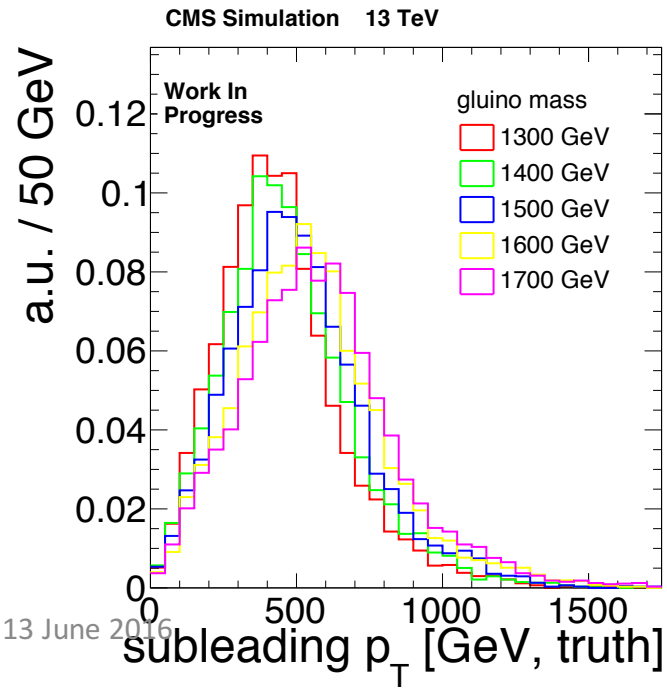
	1300 GeV 0.0460525 pb	1400 GeV 0.0252977 pb	1500 GeV 0.0141903 pb	1600 GeV 0.00810078 pb	1700 GeV 0.00470323 pb
start	**224**	**123**	**69**	**39**	**23**
+leptons	220 / 98%	121 / 98%	68 / 98%	39 / 98%	23 / 98%
+tracks	209 / 95%	115 / 95%	65 / 95%	37 / 96%	22 / 96%
+NJets	187 / 90%	102 / 89%	57 / 88%	32 / 86%	18 / 84%
+HT	186 / 99%	102 / 99%	56 / 100%	32 / 100%	18 / 100%
+MHT	173 / 93%	96 / 94%	54 / 95%	30 / 96%	17 / 96%
+DeltaPhi	**144** / 83%	**80** / 83%	**44** / 82%	**25** / 82%	**14** / 82%
net:	**64%**	**65%**	**64%**	**63%**	**62%**

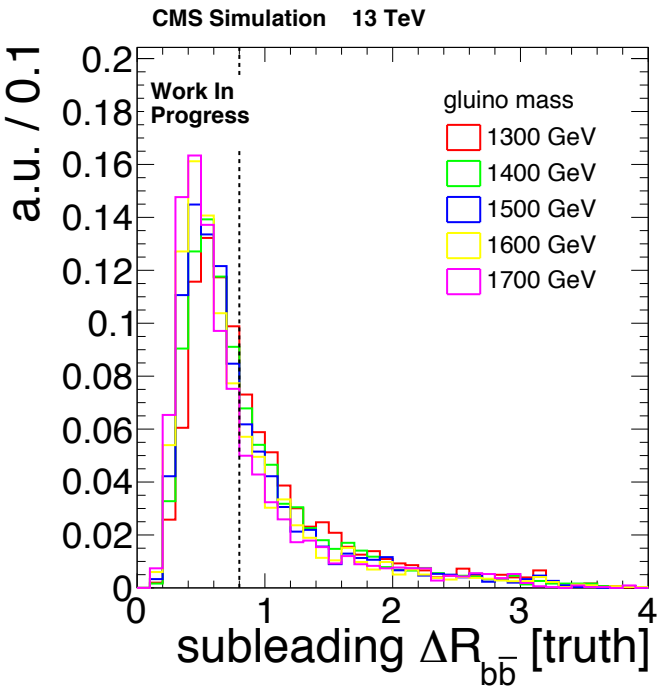
NLSP mass = gluino mass – 50 GeV
LSP mass = 1 GeV

GEN Higgs distributions



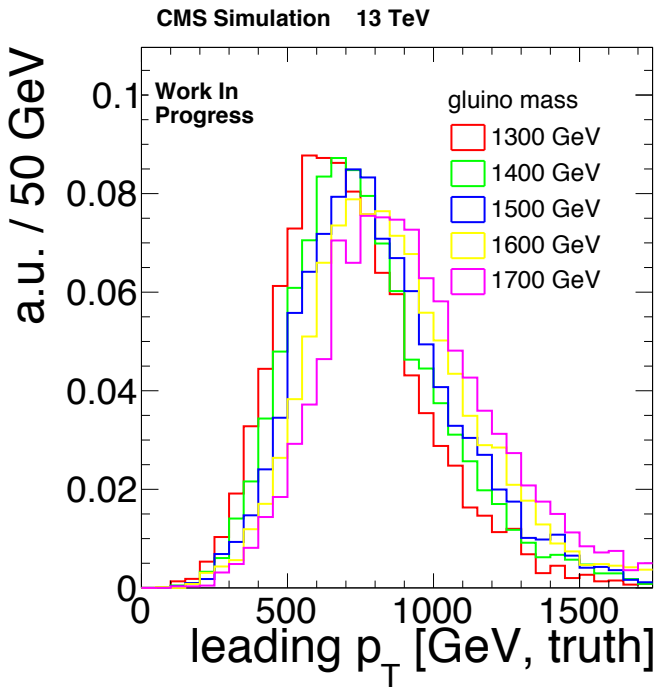


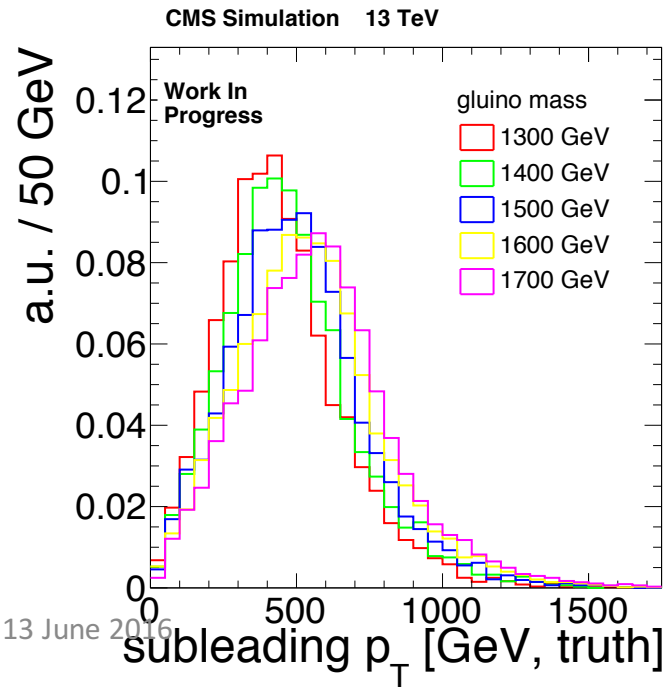




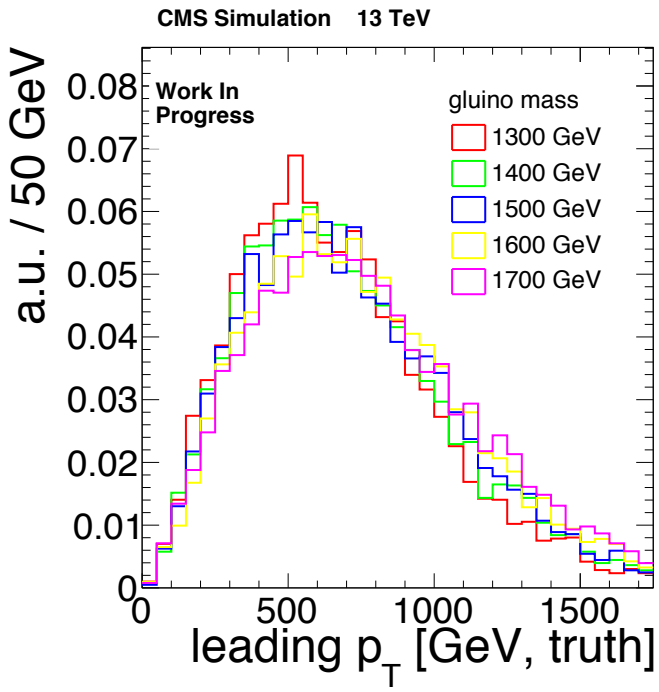
GEN SUSY distributions

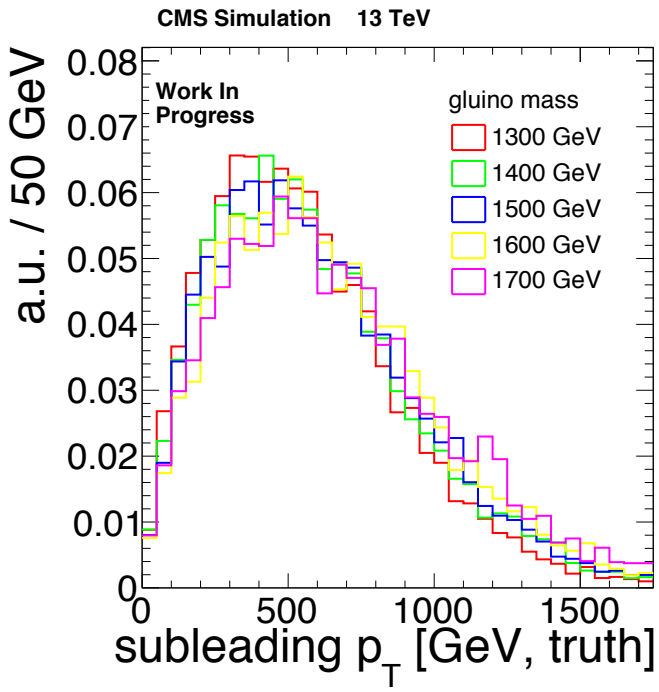
χ_1



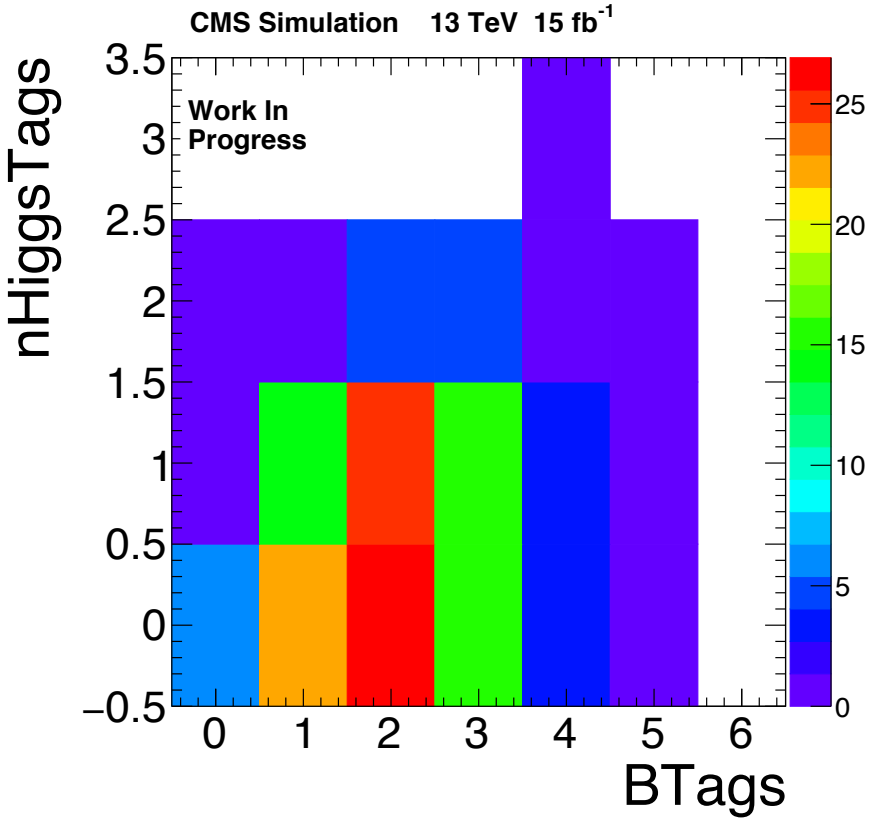


χ_2

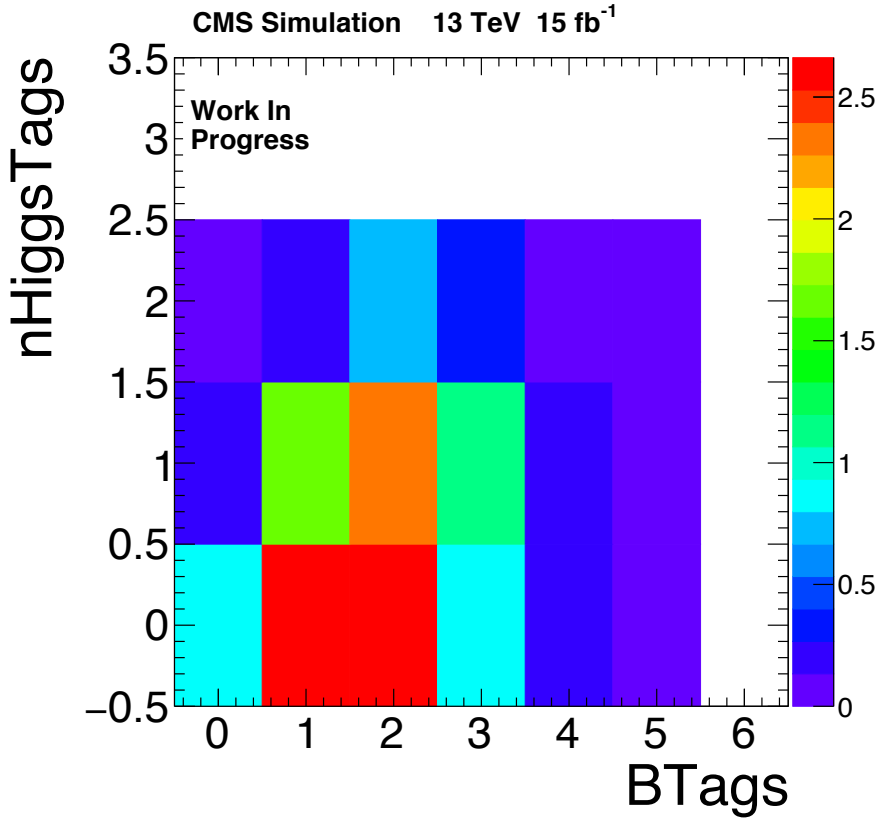




BTags / Higgs Tags



1300 GeV



1700 GeV

Sequential recombination algorithms

These are hierarchical clustering algorithms

Typically they work by calculating a **'distance'** between particles, and then recombine them pairwise according to a given order, until some condition is met (e.g. no particles are left, or the distance crosses a given threshold)

$$d_{ij} = \min(k_{ti}^{2p}, k_{tj}^{2p}) \frac{\Delta y^2 + \Delta\phi^2}{R^2} \qquad d_{iB} = k_{ti}^{2p}$$

If $d_{ij} < d_{iB}$ then merge them together

p = 1 k_t algorithm — S. Catani, Y. Dokshitzer, M. Seymour and B. Webber, Nucl. Phys. B406 (1993) 187; S.D. Ellis and D.E. Soper, Phys. Rev. D48 (1993) 3160

p = 0 Cambridge/Aachen algorithm — Y. Dokshitzer, G. Leder, S. Moretti and B. Webber, JHEP 08 (1997) 001; M. Wobisch and T. Wengler, hep-ph/9907280

p = -1 **anti-k_t algorithm** — MC, G. Salam and G. Soyez, arXiv:0802.1189

NB: in anti-kt pairs with a **hard** particle will cluster first: if no other hard particles are close by, the algorithm will give **perfect cones**

In this tutorial, we explore AK4 and CA8

example: N-subjettiness

J. Thaler, K. Van Tilburg, arXiv:1011.2268

generalizing subjets…

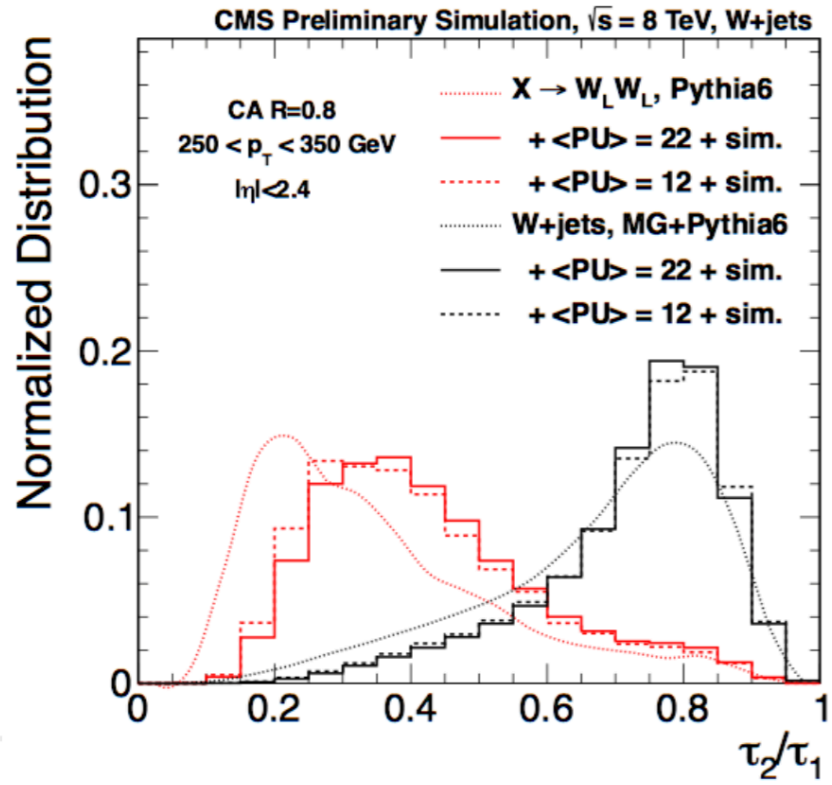
N-subjettiness: a measure of how consistent a jet is with having N subjets, τ_N

$$\tau_N = \frac{1}{d_0} \sum_k p_{T,k} \min \{\Delta R_{1,k}, \Delta R_{2,k}, \cdots, \Delta R_{N,k}\}$$

As $\tau_N \to 0$, jet is more consistent with having N subjets

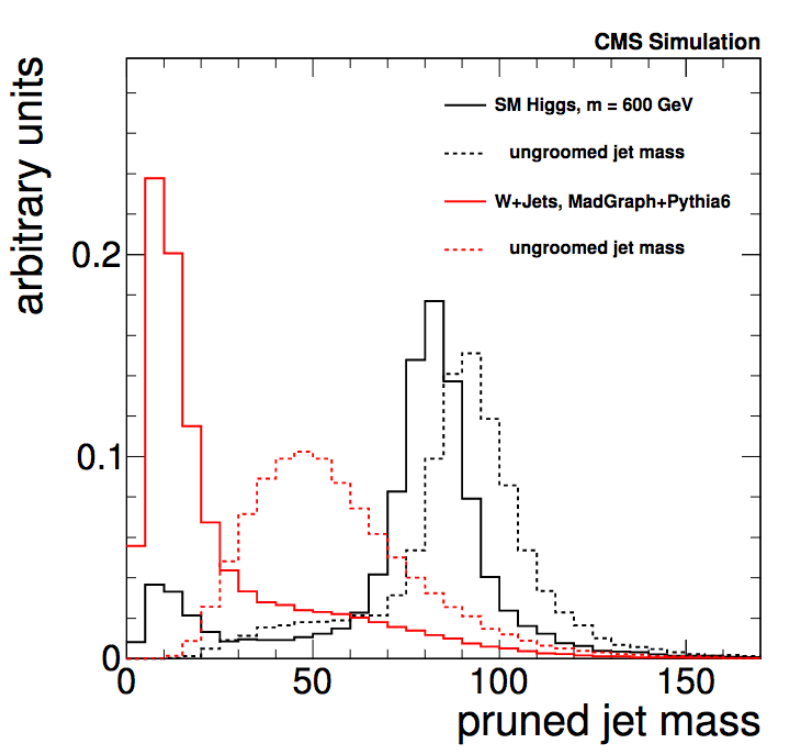
e.g. $\tau 2 \to 0$, more like a W jet
e.g. $\tau 1 \to 0$, more like a quark jet

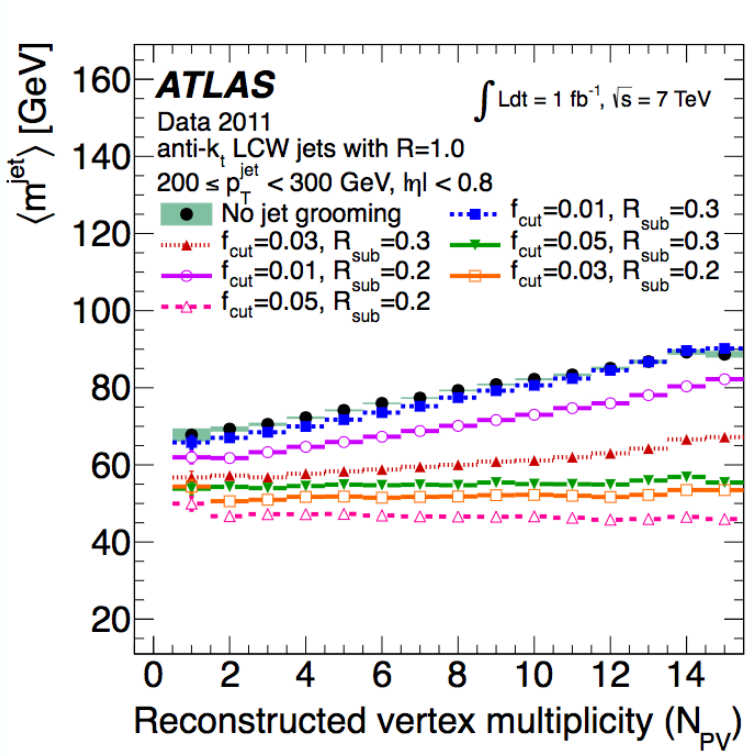
Ratios are typically used:
τ_2/τ_1 for separating **W jets** from **quark and gluon jets**



groomed mass

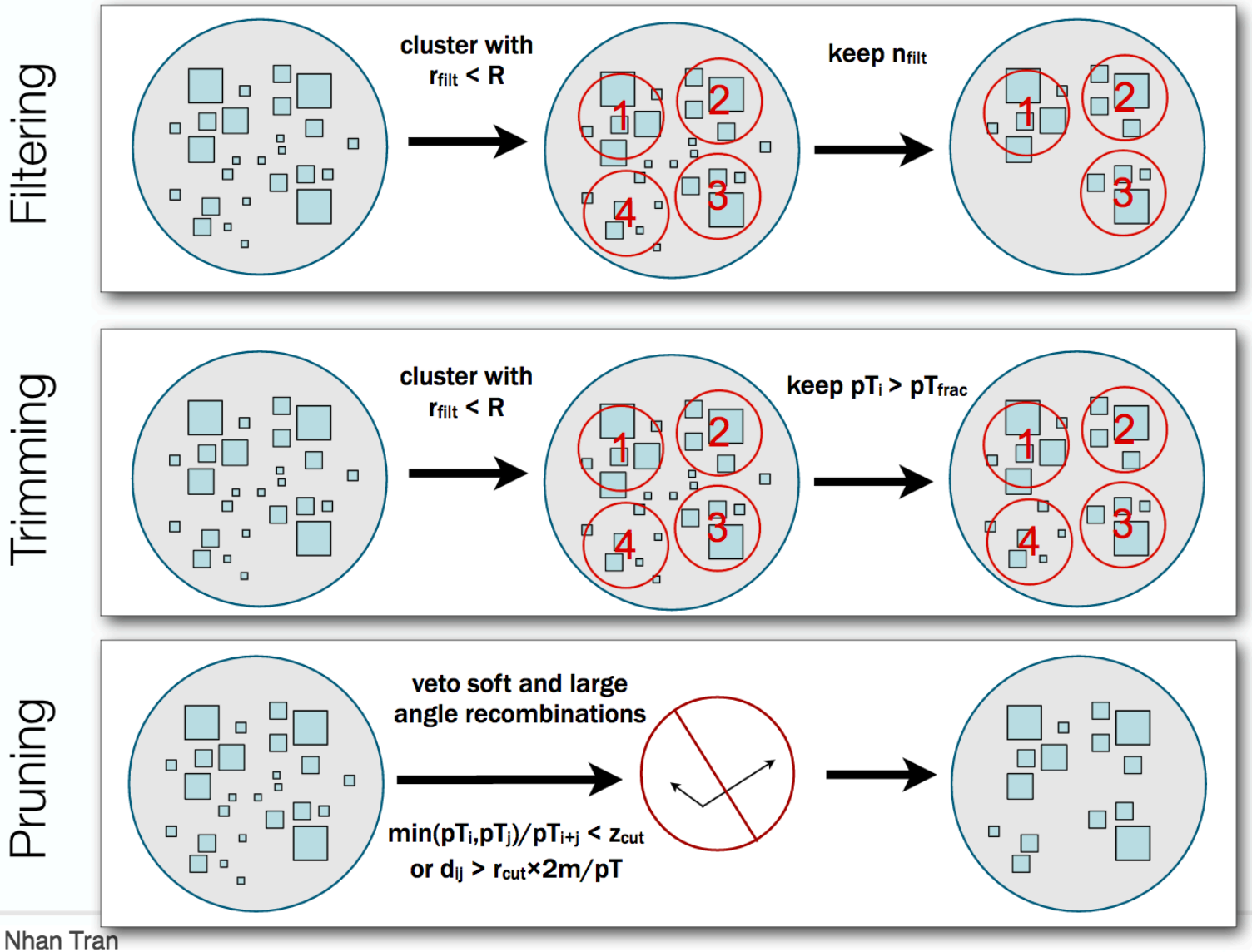
CMS-PAS-HIG-13-008
JHEP 1309 (2013) 076





Grooming tends to push the jet mass scale of the **background to lower values** while **preserving the hard scale of the heavy resonance**

Grooming techniques are also vital in **reducing the pileup dependence** of the jet mass

groomed mass

3 classic grooming cases…