



Search for heavy top or bottom fermionic partners at CMS

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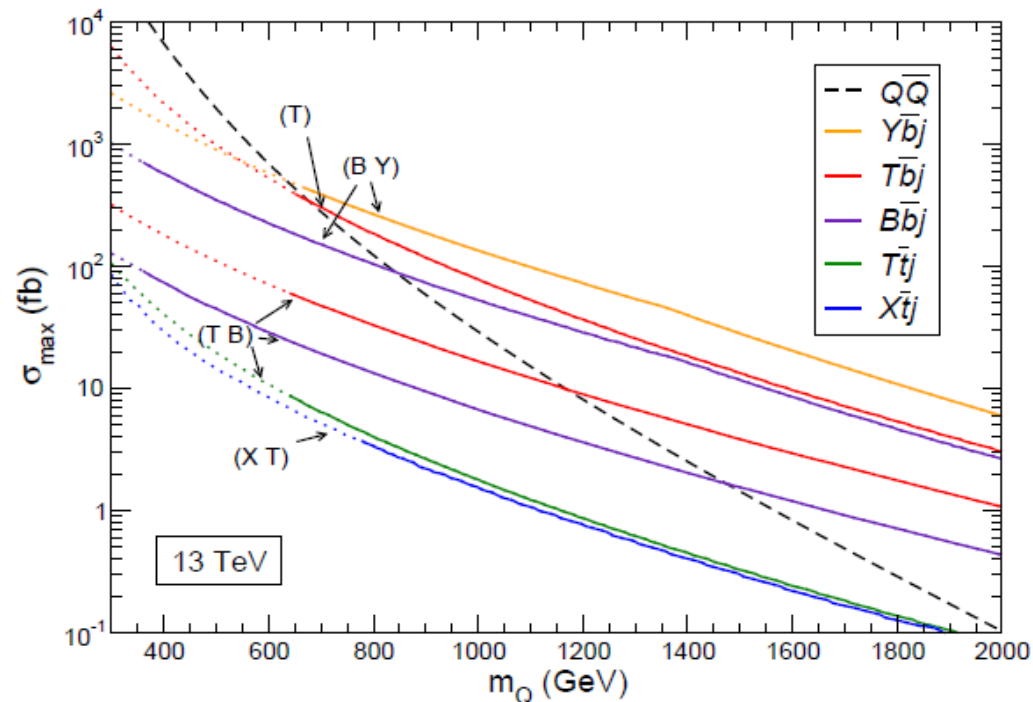
(On behalf of the CMS Collaboration)

Phenomenology 2016 Symposium

Heavy Fermionic Partner

10.1103/PhysRevD.88.094010

- Often called 'vector like quarks' - left & right handed couplings
- Not ruled out by Higgs
- Motivated by many theories
 - Composite Higgs
 - Little Higgs
 - Warped extra dimensions, ...
- Extension of the SM with a 4th quark generation
 - Preferred couplings t, b & W, H, Z
 - Different multiplets & particles possible
 - T(-2/3), B(+1/3), X(+5/3), Y(-4/3)

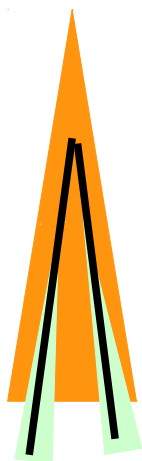


- Production Mechanism
 - Single \rightarrow Ewk
 - Pair \rightarrow QCD
- Very rich phenomenology

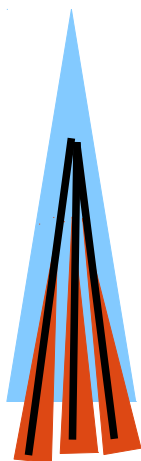
Jet-Tagging

- Jet-substructure one of the primary tools for heavy hadronic objects
 - Boosted objects reconstructed within wide jets
- Some examples: b-Tagging, t-Tagging, ...

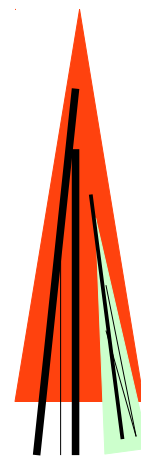
V-Tagging



t-Tagging



Subjet-b-Tagging



Typical Variables

- Groomed mass
- Number of subjets

Additional Cuts e.g.

- Nsubjettiness
- Subjet-b-tags

Subjets with CMS b-Tagging

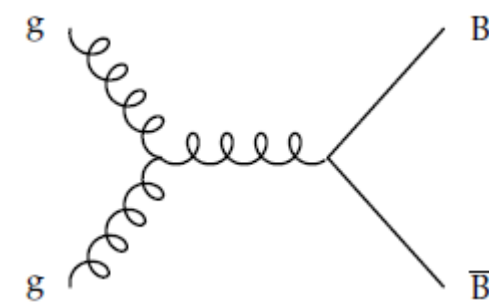
- Vertex reconstruction
- Lifetime
- Soft leptons ...



CMS Results at 8 TeV

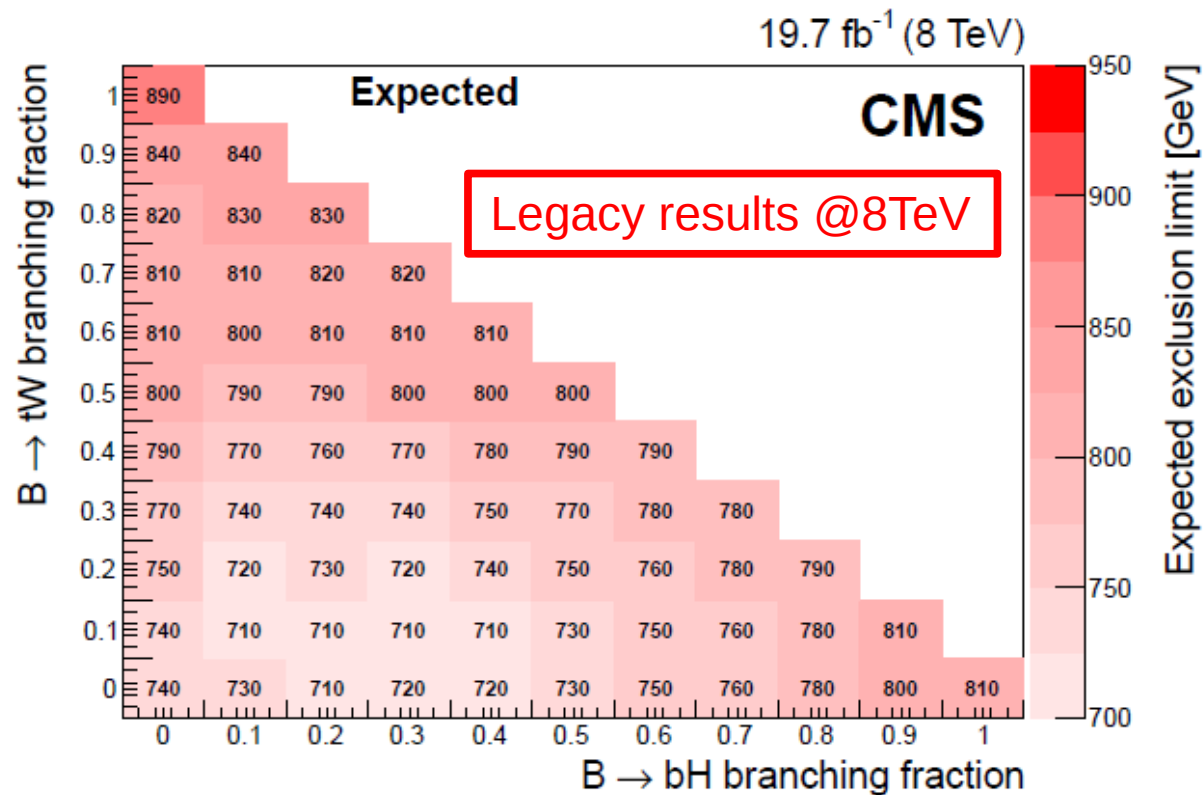
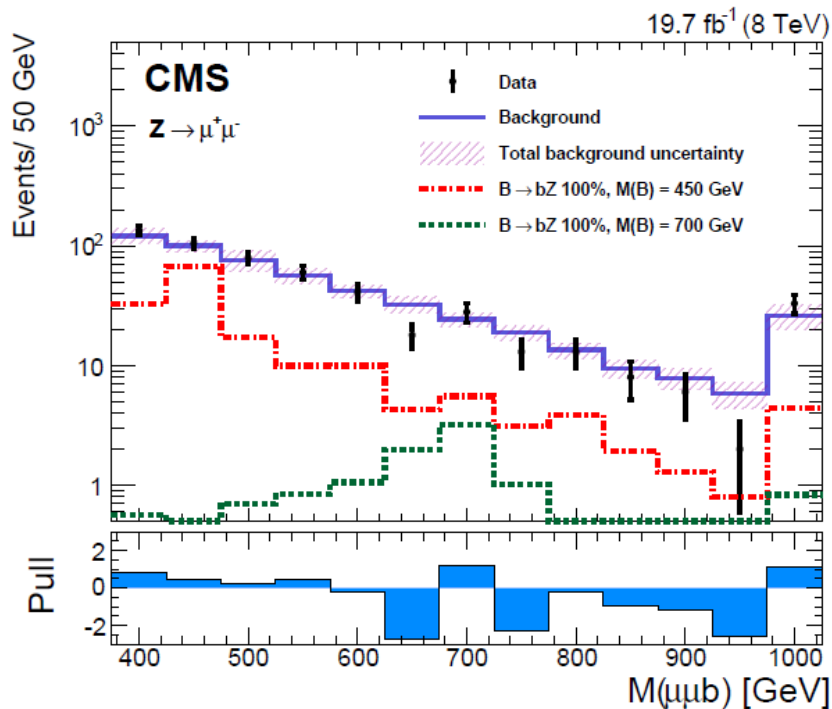
BB Search

arXiv:1507.07129



- In total 5 distinct hadronic and leptonic searches
 - Targeting all decay modes: bZ, bH, tW
- Discriminating variables H_T , S_T or $M(l\ell b)$
- Using V & b-tagging to categorize events

- Combination
 - Good sensitivity in all decay channels
 - Stringent limits around 800 GeV



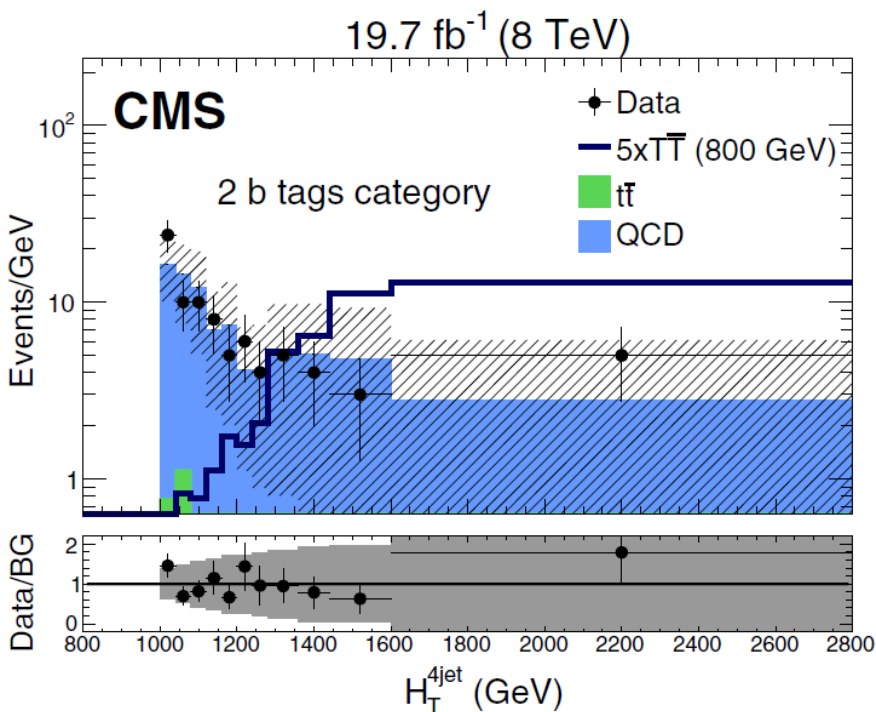


TT Search

doi:10.1103/PhysRevD.93.012003 & arXiv:1509.04177

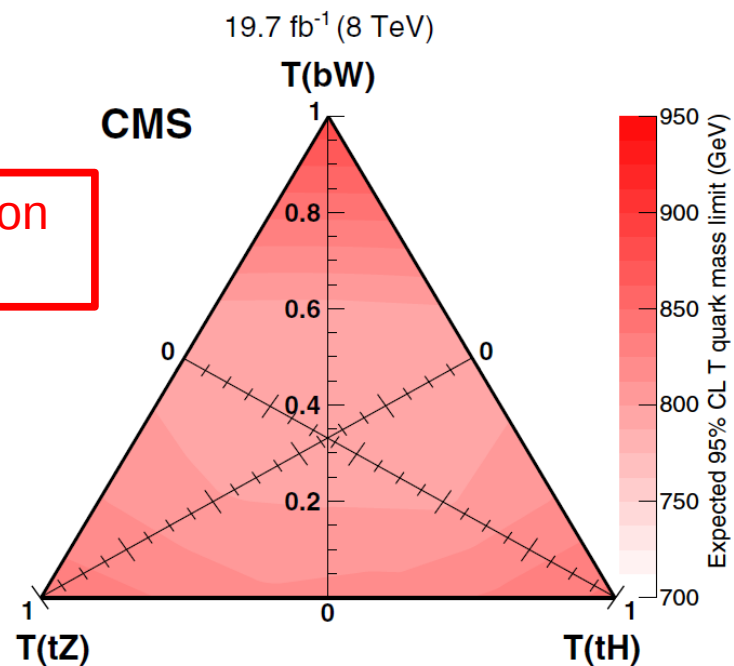


- In total 4 distinct searches
 - Targeting all decay modes: tZ, tH, bW
 - Leptonic, hadronic and decays into photons covered
- Discriminating variables H_T , S_T , H_{mass} or T_{mass}
- Using t, H & (sub-)b-tagging to categorize events
- Combination
 - All decay modes well covered
 - Limits around 800 GeV



Legacy combination @8TeV

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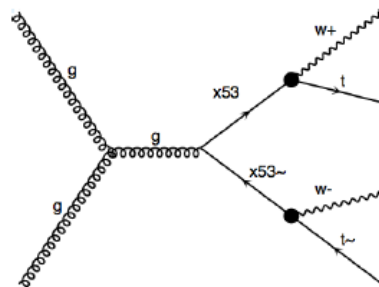


CMS results at 13 TeV

XX Search with same sign di-leptons

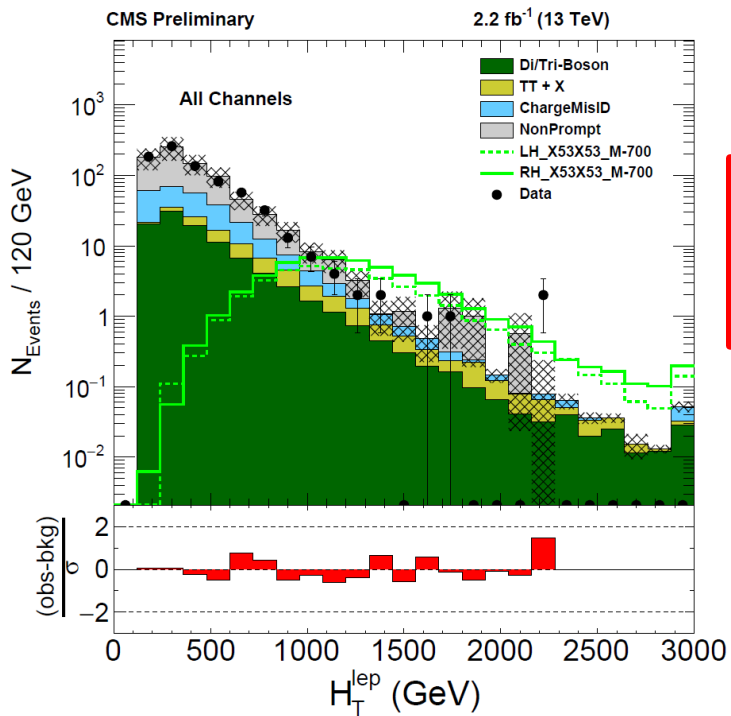
CMS PAS B2G-15-006

- Very clean channel with low SM-background
- 8 TeV limits of 800 GeV
- Require Σ jets + leptons > 4 and $S_T > 900$ GeV
- Veto Z-bosons
- Counting experiment
- Backgrounds
 - Most important: fake leptons estimated using a data-driven method
 - Charge mis-id leptons
 - Rare decays from MC e.g. WW, ZZ...

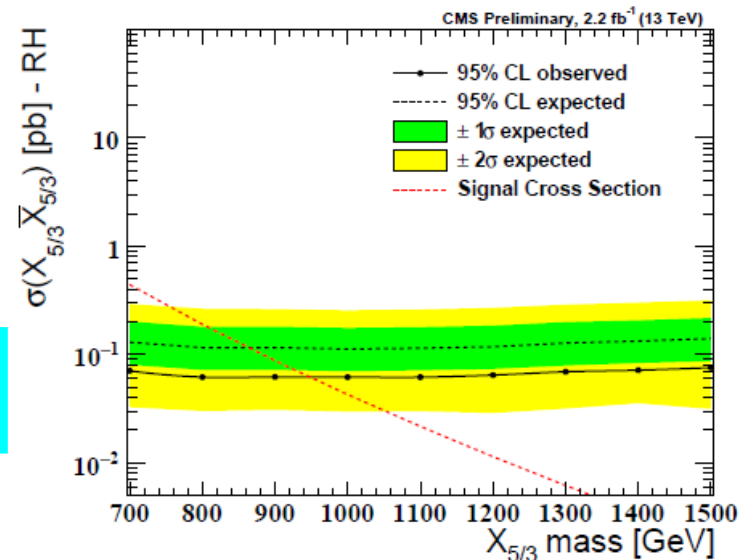


First LHC results in this channel @13TeV. Better than @8TeV.

Excluded RH(LH)
X53 < 950 (910) GeV



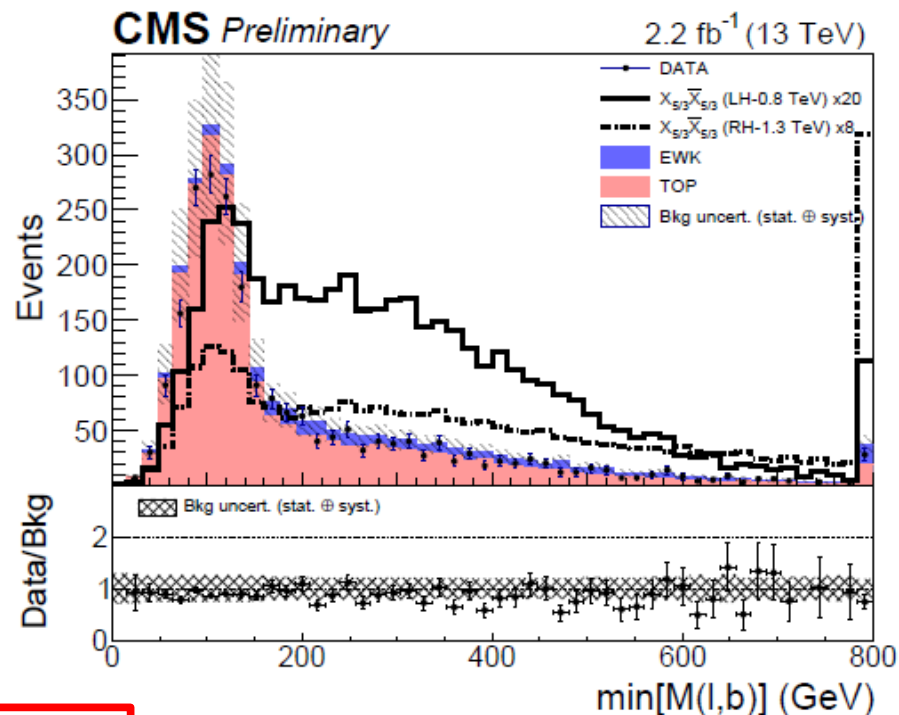
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XX Search in semi-leptonic Channel

CMS PAS B2G-15-006

- Selection:
 - 2 high p_T jets, 2 $>$ jets and $E_{T,miss} > 100$ GeV
- 8 signal categories
 - Lepton flavor e or μ
 - # b-Tags (1, 2+)
 - # W-Tags (0, 1+)



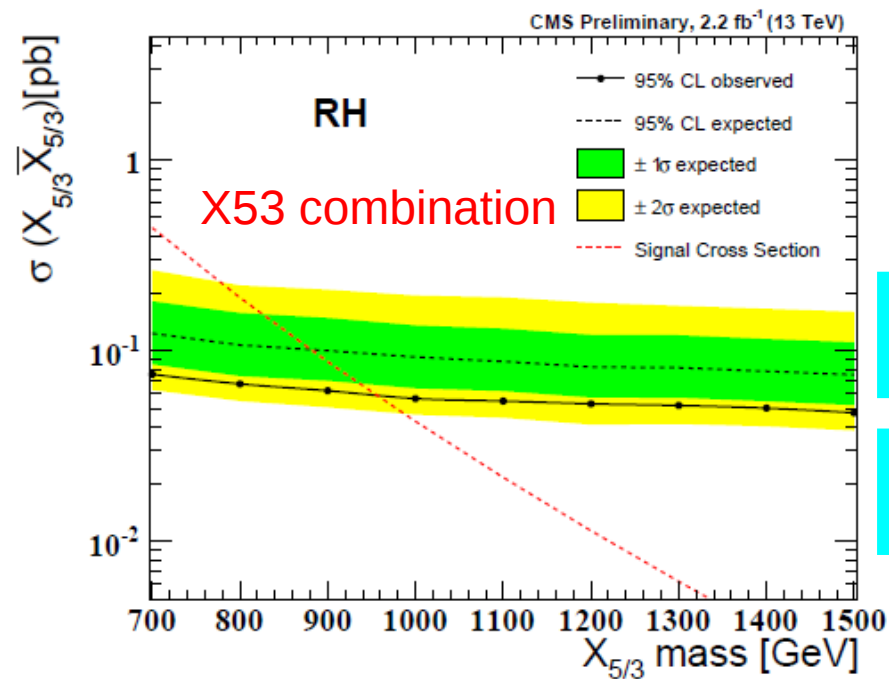
Newly explored channel at @13TeV

- Backgrounds
 - Top quarks with jets & V+jets
 - Based on MC
 - Controlled in sidebands
- Discriminating variable: $\min[M(l,b)]$

Excluded RH(LH)
 $X_{5/3} < 700$ (715) GeV

Combination
 $X_{5/3} < 960$ (940) GeV

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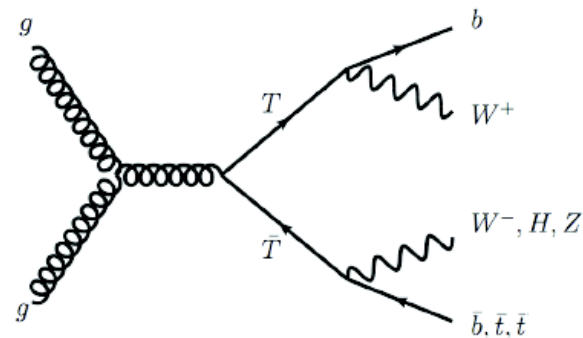


TT Search

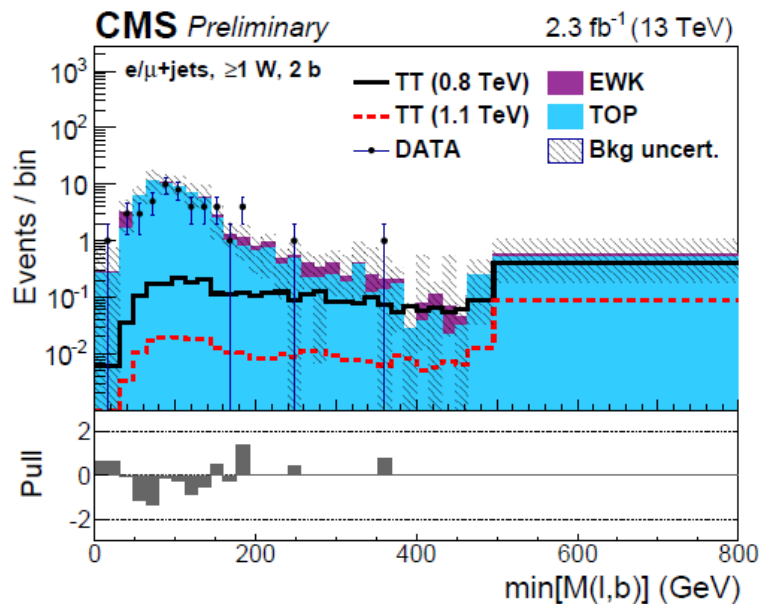
CMS PAS B2G-16-002



- Similar analysis strategy and selection to B2G-15-006
- 16 signal categories
 - Lepton flavor e or μ
 - # b-Tags (0,1,2,3+)
 - # W-Tags (0,1+)



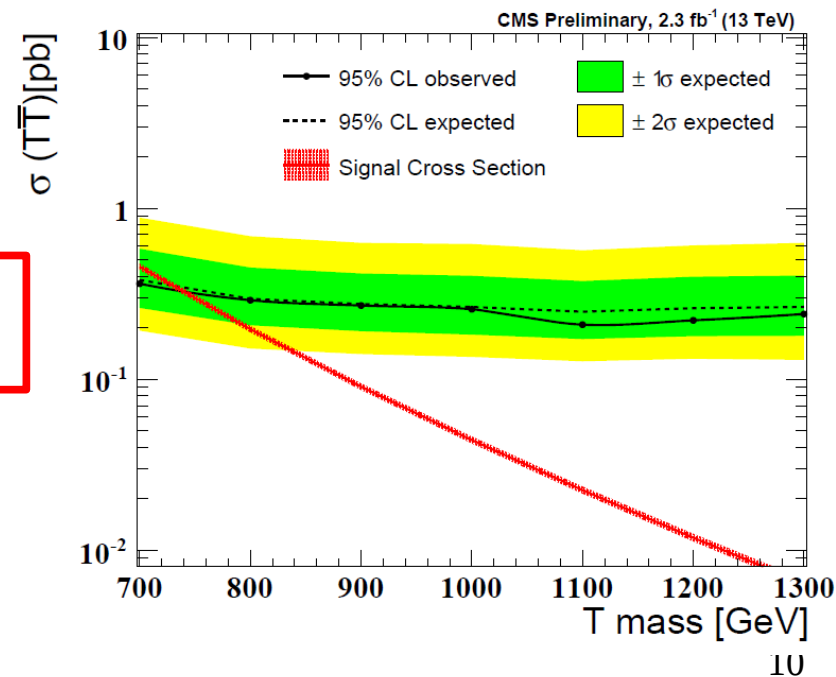
- Main discriminant: $\min[M(l,b)]$
- Benchmark point
 - BR of 50% bW, 25% tZ, tH



Already better
then @8TeV

T < 750 GeV

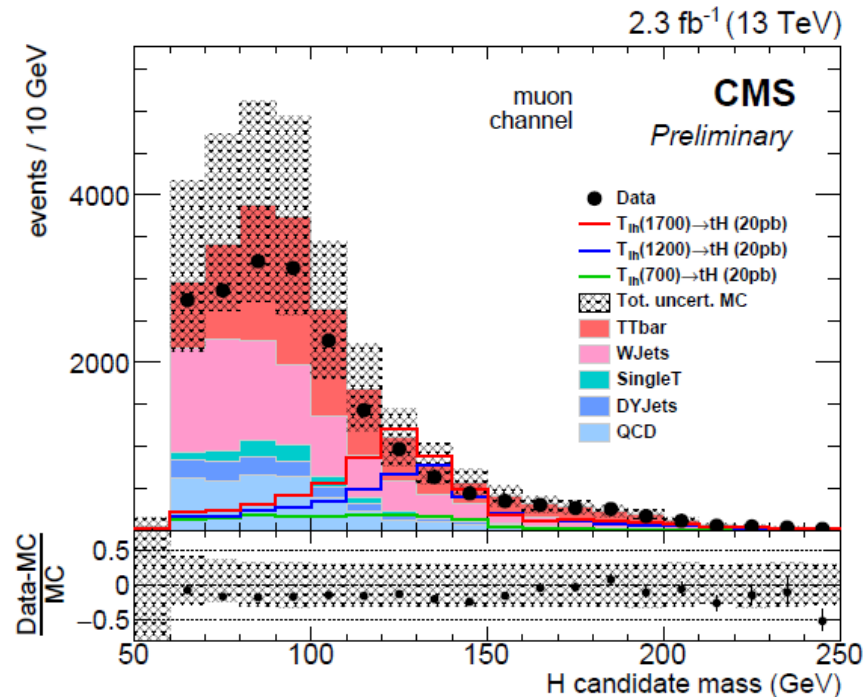
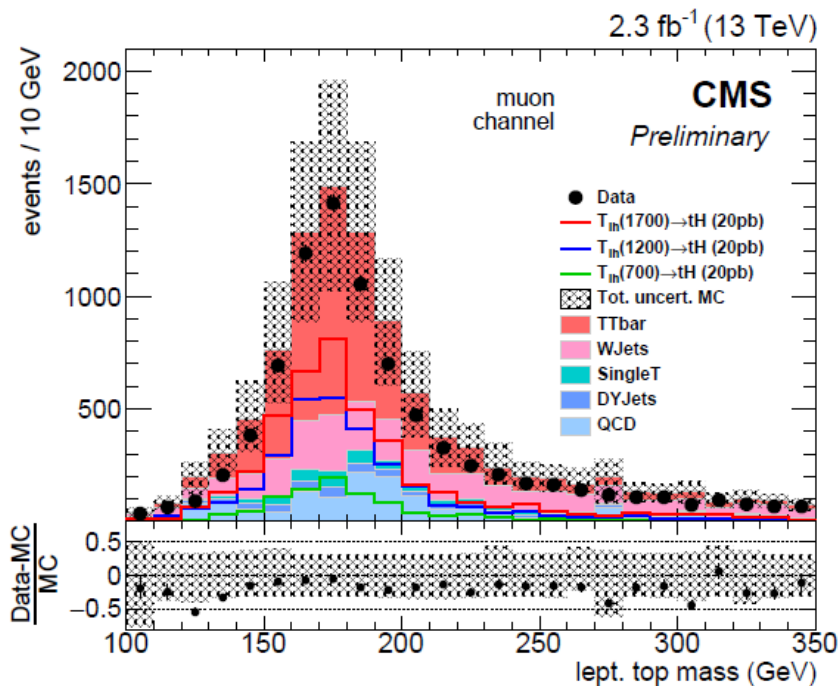
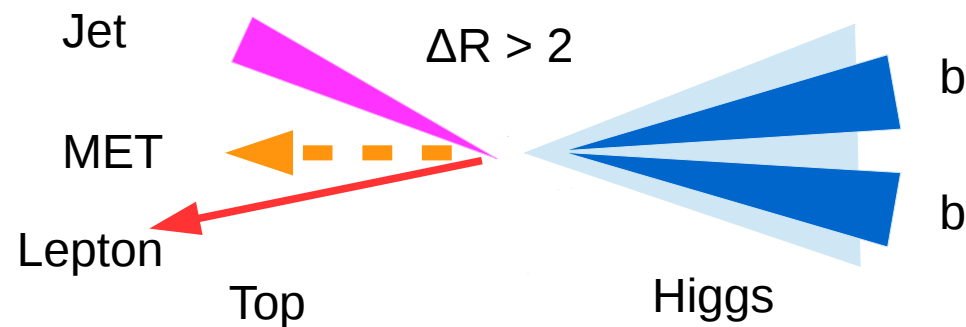
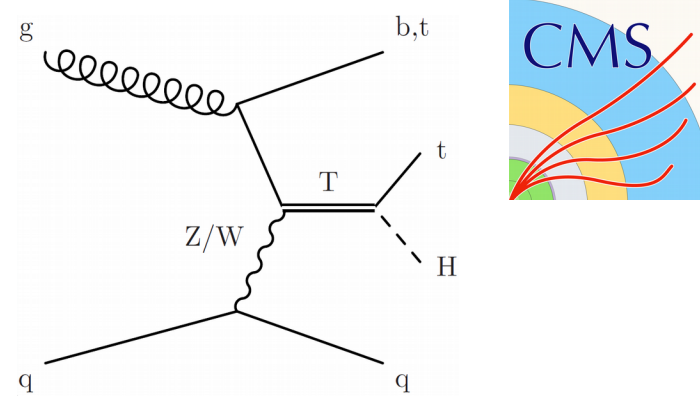
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Single Production: T Search

CMS PAS B2G-15-008

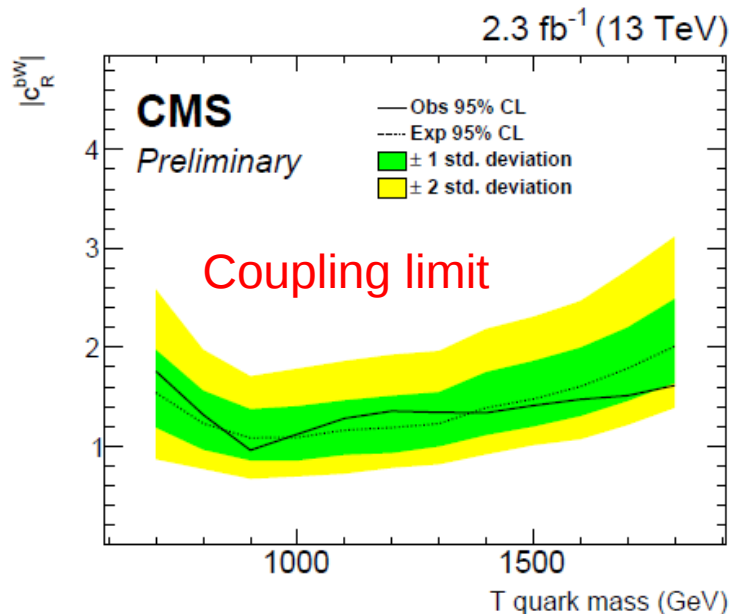
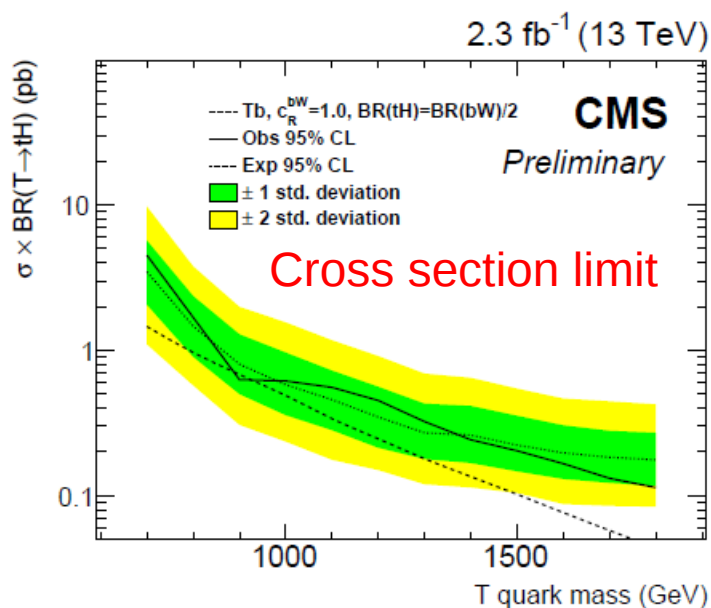
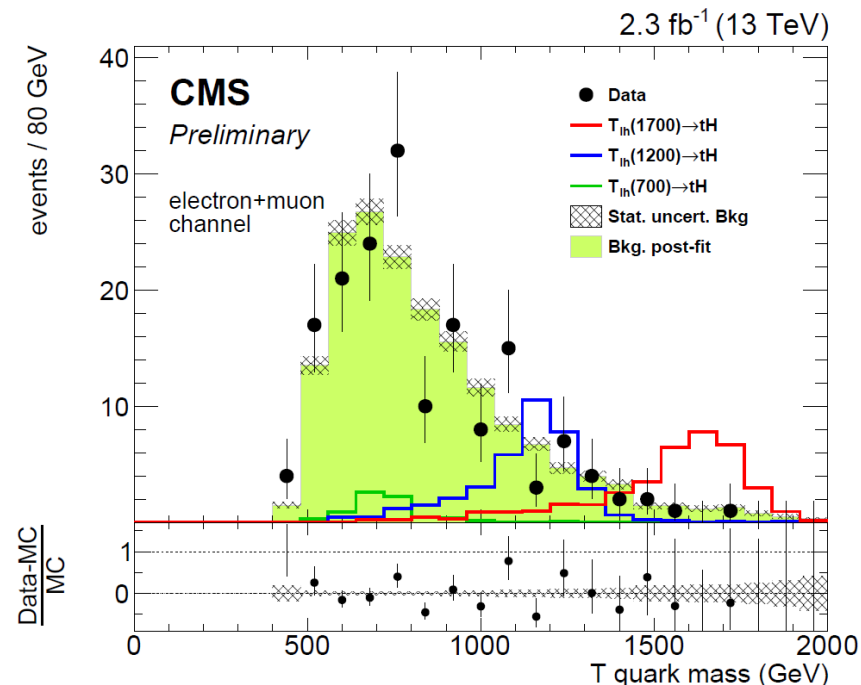
- First VLQ single production search in CMS
- Selection: $S_T > 400$ GeV, one lepton and jets ≥ 2
- Forward jet distinguished feature
- Optimized for leptonic top decay and boosted $H \rightarrow bb$
- Event reconstruction using Higgs-tagging



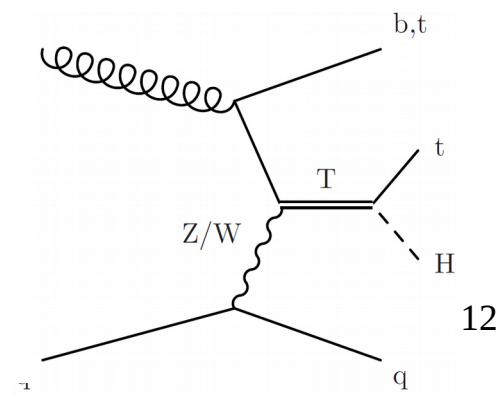
Single Production: T Search

CMS PAS B2G-15-008

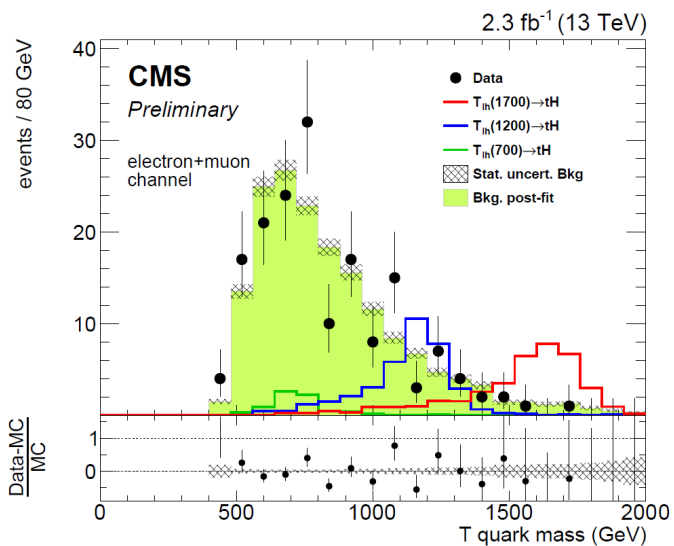
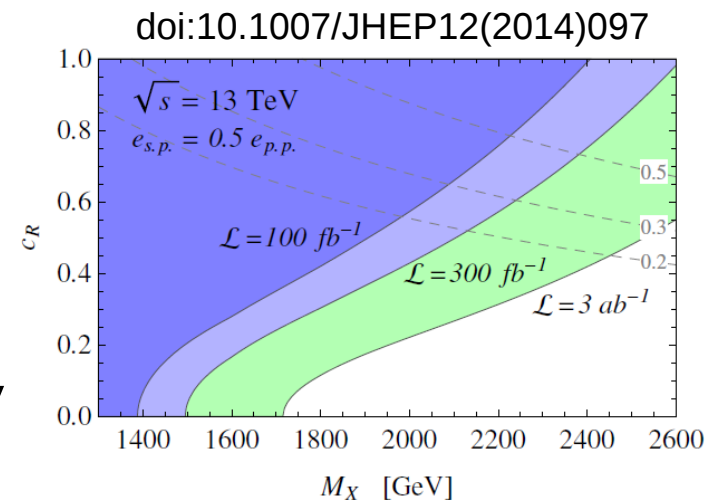
- Background estimated from data
 - Signal region: forward jet & 2 subjet-b-tags
 - Sideband: no forward jet & 1 subjet-b-tag
 - Main backgrounds W+jets & Top quarks
- No excess observed
 - Limits on cross section and T quark coupling



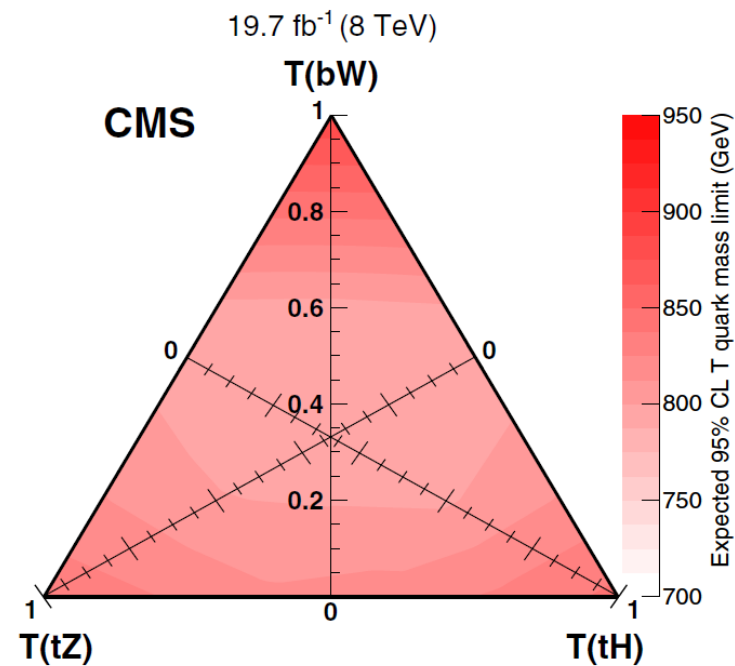
First LHC results for singly produced T quarks @13TeV.

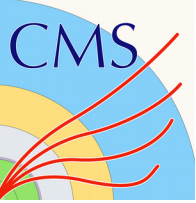


- CMS is searching for fermionic partners
- Broad search program for a rich phenomenology
- First results for single production at 13 TeV at CMS
- Results at 13 TeV with 2015 dataset already outperforming 8 TeV data



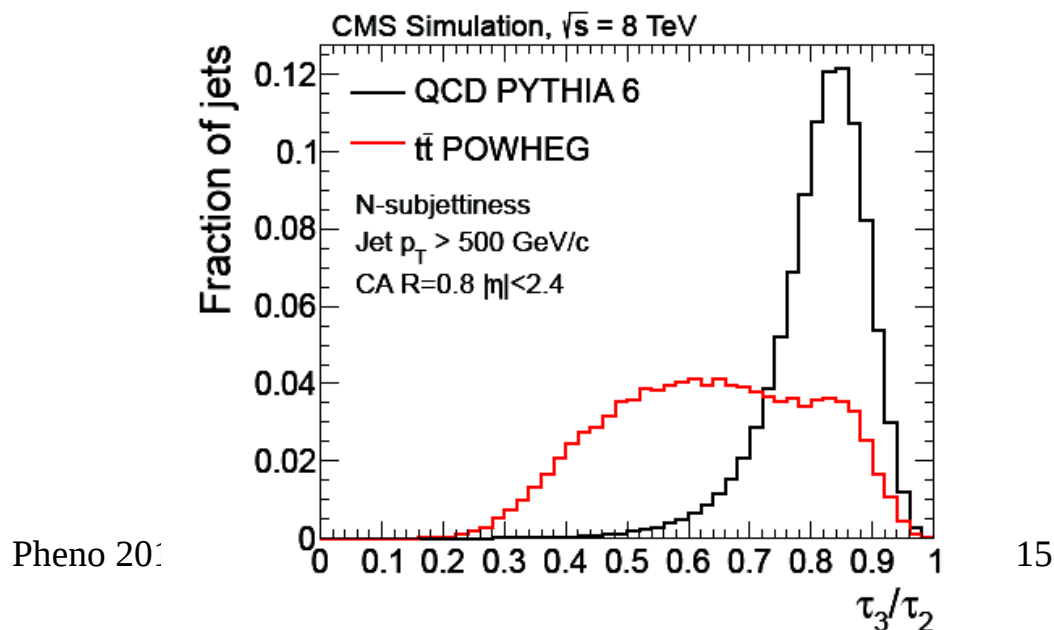
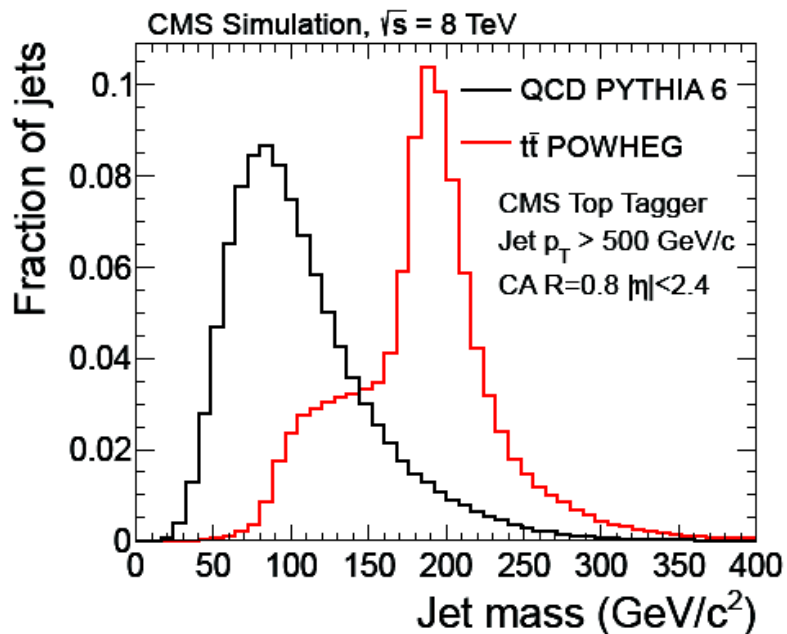
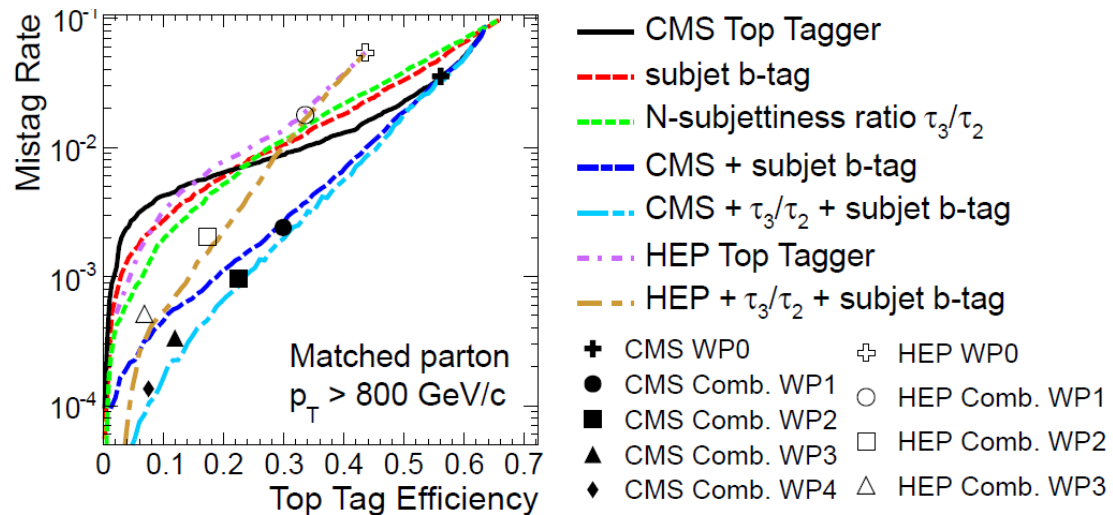
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Backup

- Performance curve for different t-tagging algorithms
- Example of t-tagging variables for the CMS Top Tagger
 - Mass of the Jet
 - NSubjettiness





TT

CMS PAS B2G-16-002



- 95% confidence limits on the T quark mass for different branching ratio, constrained to $B(T \rightarrow bW) + B(T \rightarrow tH) + B(T \rightarrow tZ) = 1$

B(T → bW)	B(T → tH)	B(T → tZ)	Expected [GeV]	Observed [GeV]
0.50	0.25	0.25	743	750
1.00	0.00	0.00	853	876
0.80	0.20	0.00	812	824
0.80	0.00	0.20	808	828
0.60	0.40	0.00	778	780
0.60	0.20	0.20	772	778
0.60	0.00	0.40	768	774
0.40	0.60	0.00	727	731
0.40	0.40	0.20	707	714
0.40	0.20	0.40	< 700	< 700
0.40	0.00	0.60	< 700	< 700
0.20	any	any	< 700	< 700
0.00	any	any	< 700	< 700