



Universität Hamburg

DER FORSCHUNG | DER LEHRE | DER BILDUNG



search for
single production of a vector-like T quark
decaying into a top quark and a Higgs boson



GEFÖRDERT VOM



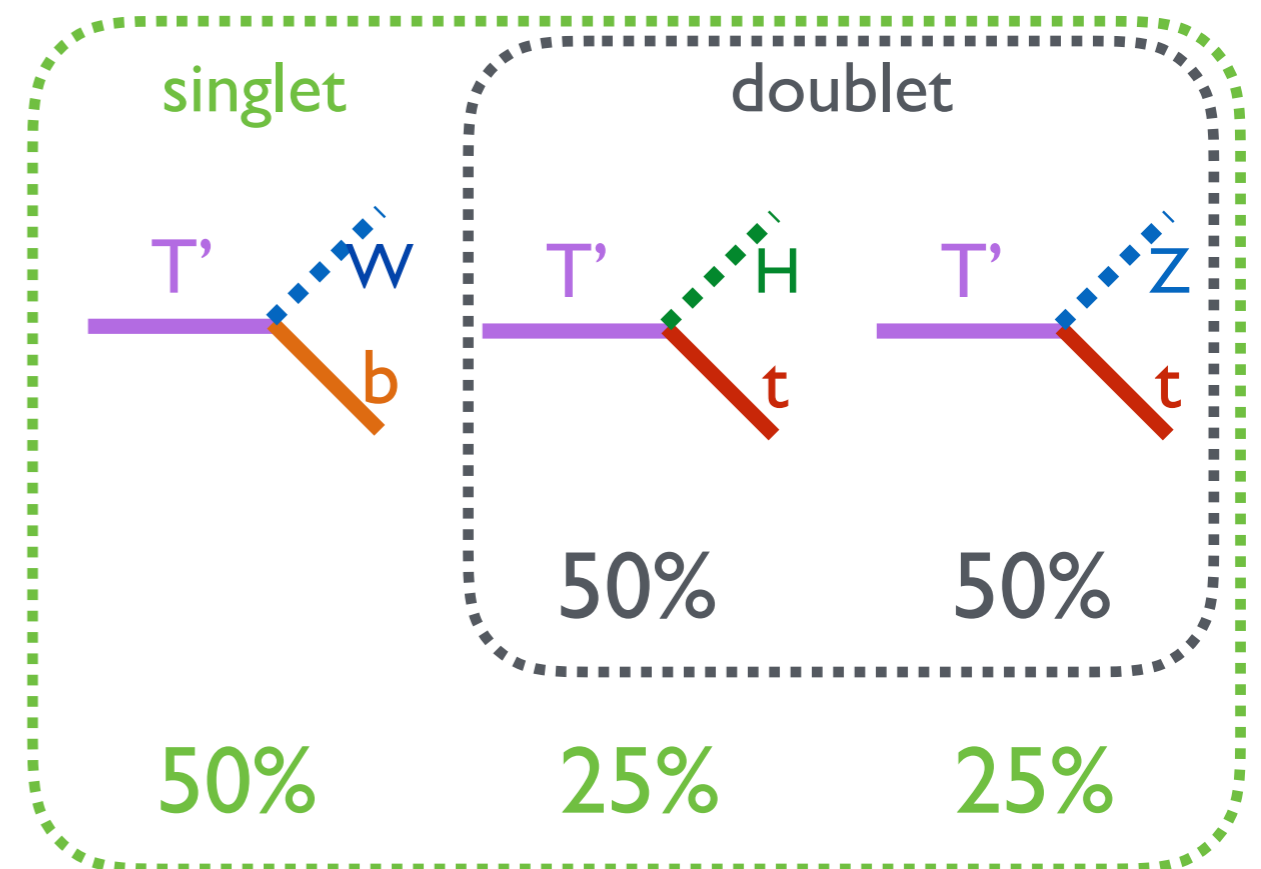
La Thuile 2017

2017 / 03 / 10

Heiner Tholen
for the CMS Collaboration

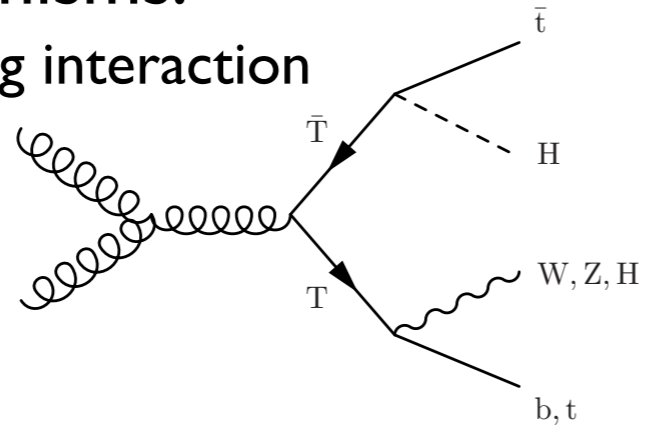
- **quarks!** colored, charged, spin 1/2
- **vector-like:** same coupling to lh and rh currents
=> mass terms without gauge inv. violation
- not constrained through Higgs boson measurements
(unlike chiral 4th-gen quarks)
- simplest colored extra-fermions allowed by data
- **but why??**
 - common in non-SUSY SM extensions
e.g. little Higgs, composite Higgs, warped/extra dimensions
 - stabilize the Higgs mass
 - solve the Hierarchy problem
- expected at TeV scale

simplified model BR's =>
[10.1007/JHEP12(2014)097]



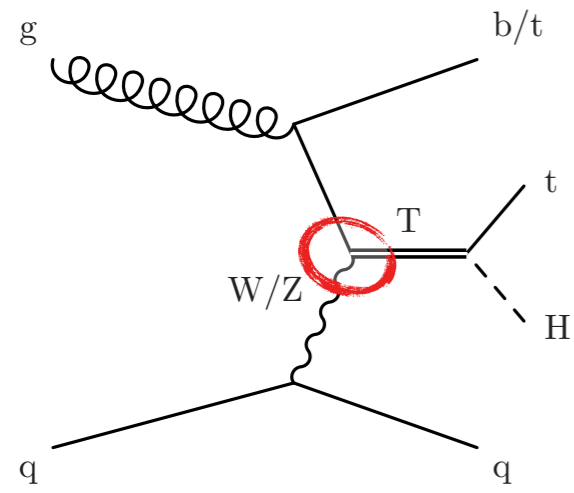
production mechanisms:

- 'pair' through strong interaction

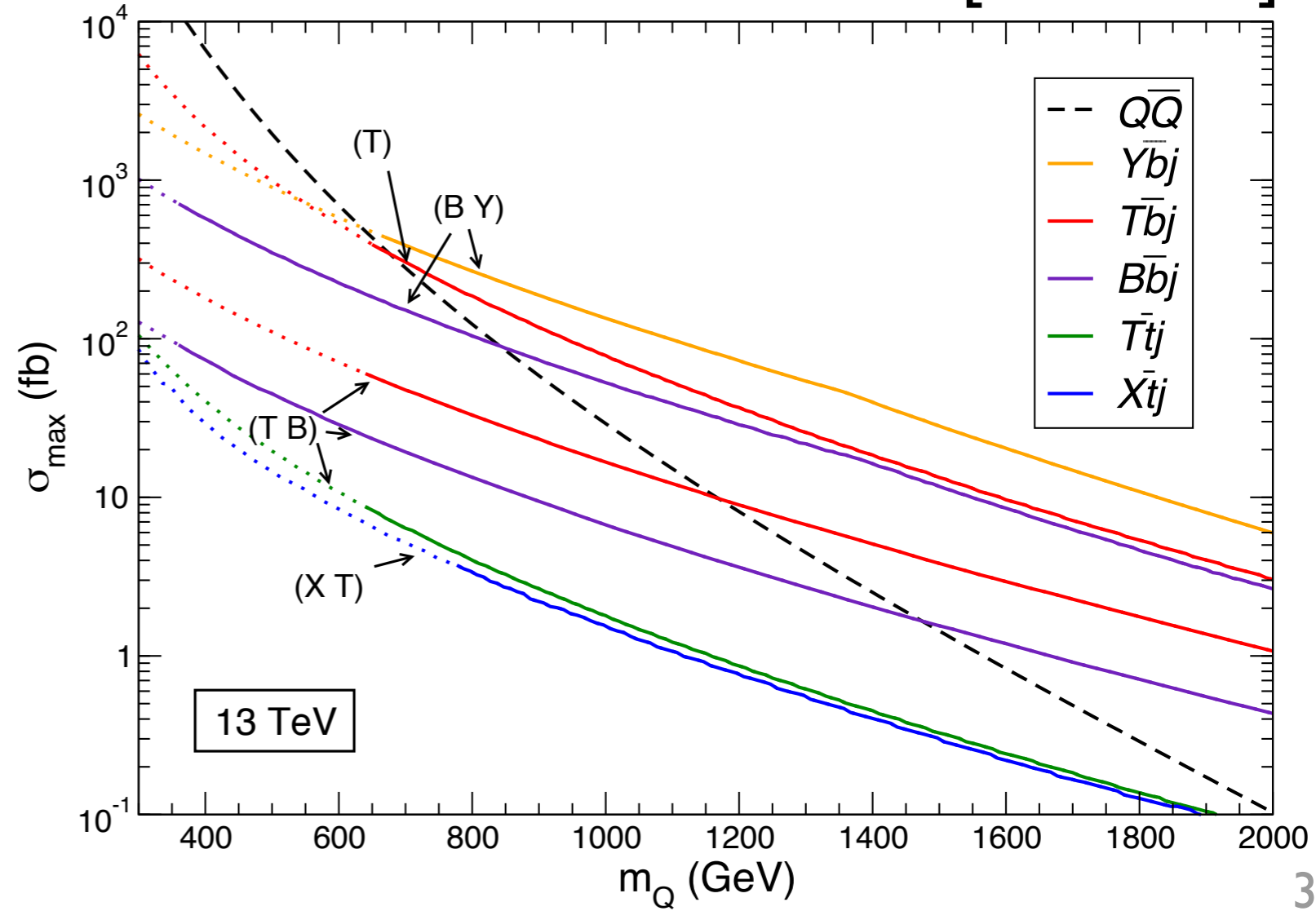


\Rightarrow T excluded between 600 and 1200 GeV dep. on decay mode

- 'single' through ewk (including arbitrary coupling modifier)



[1306.0572]

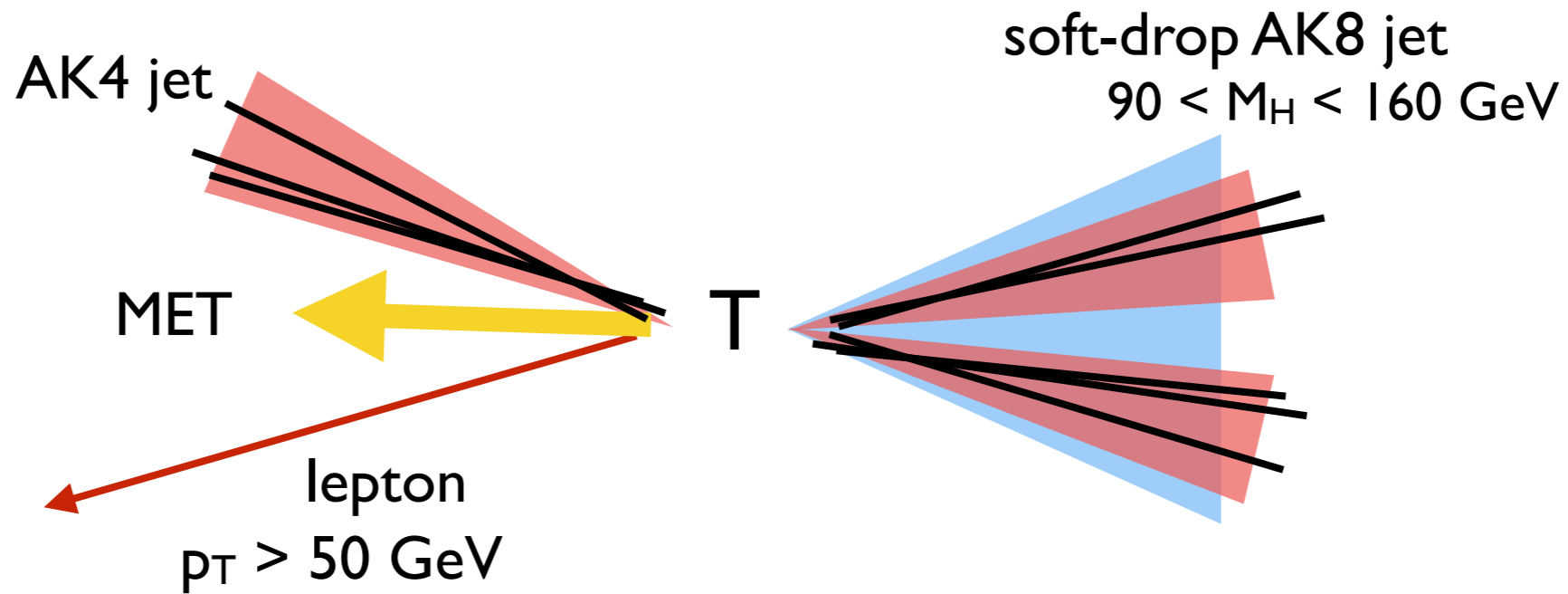
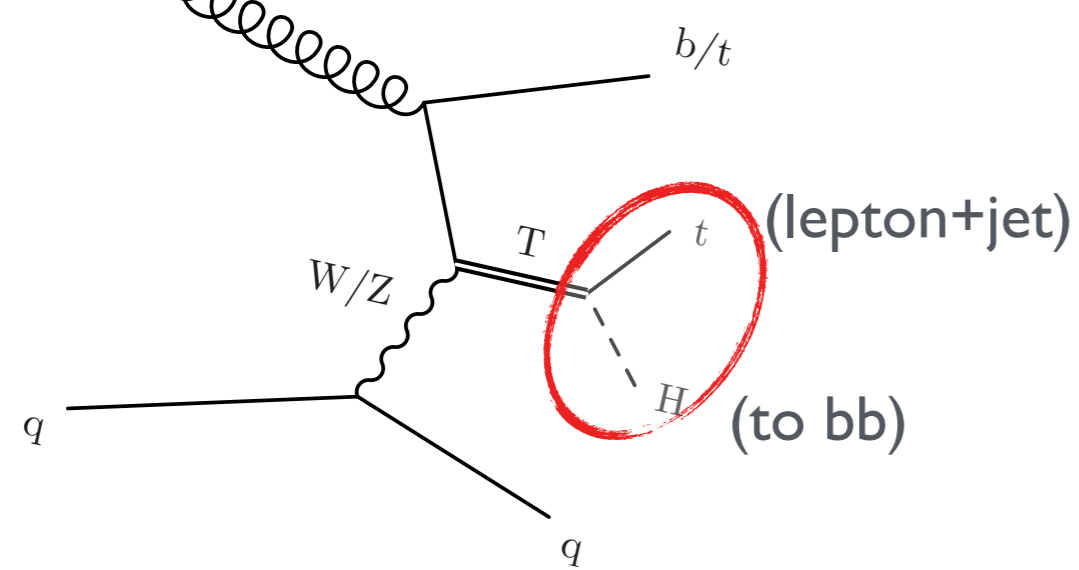


single T production

[1612.00999]

<https://arxiv.org/abs/1612.00999>

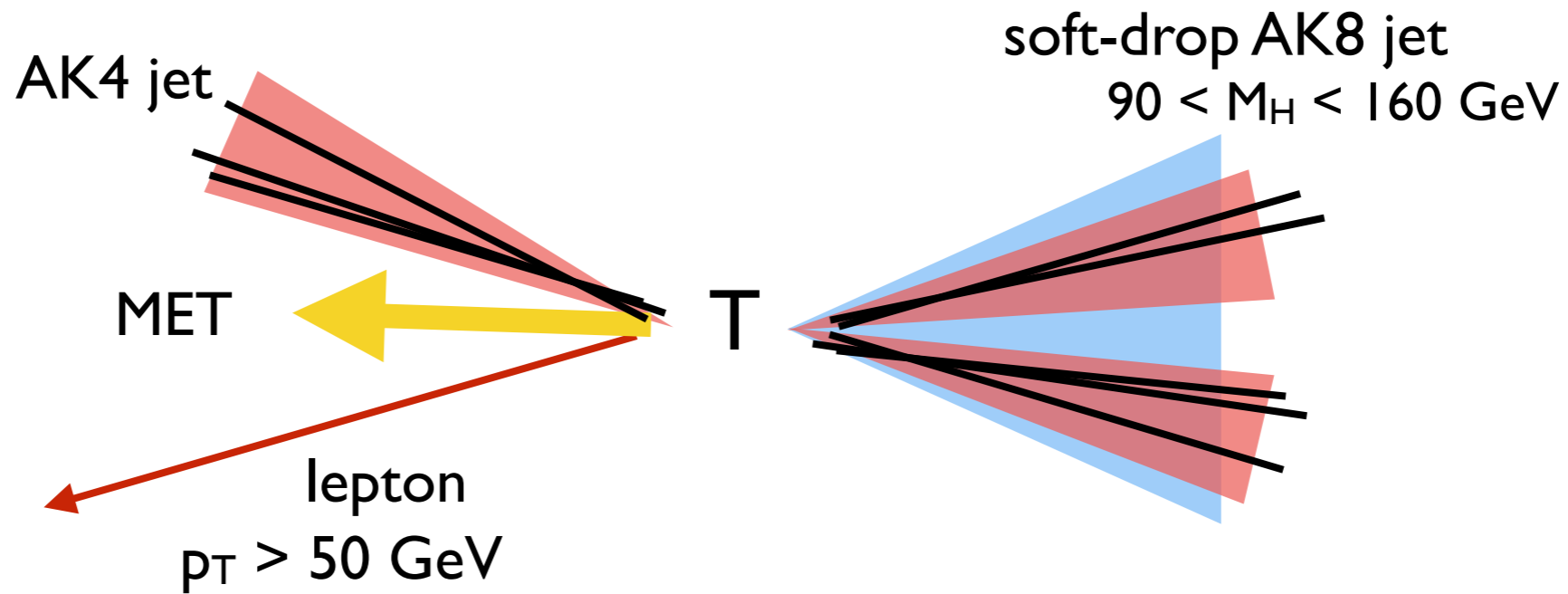
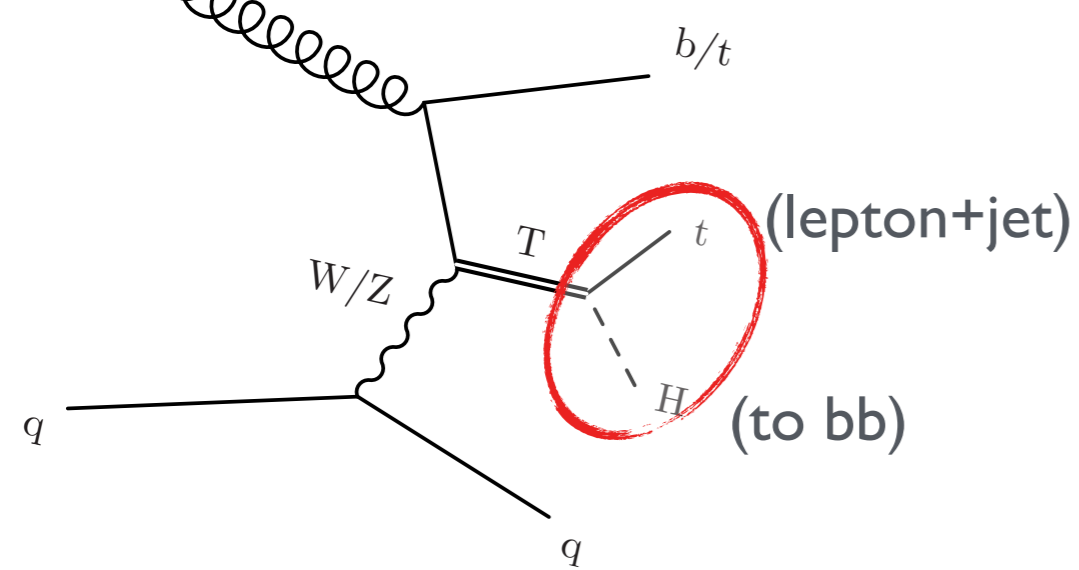
single T production



triggers with non-isolated leptons:

- electron $p_T > 45$ GeV, 2 jets $p_T > 200$ (50) GeV
- muon $p_T > 45$ GeV

single T production



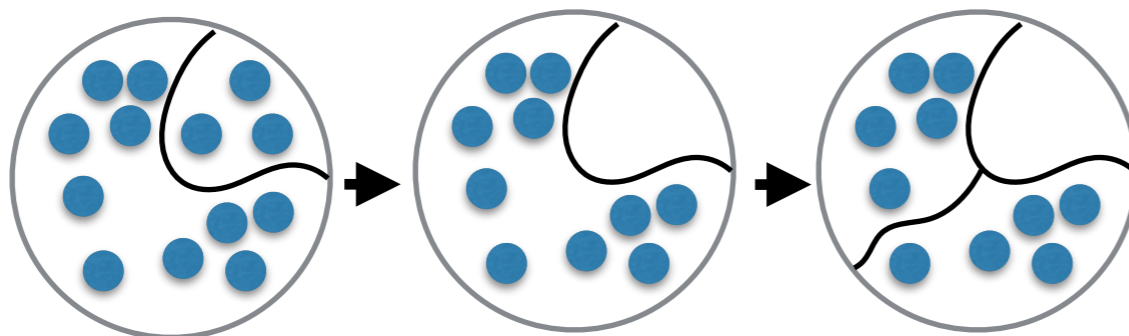
pick best combination by:

$$\chi^2 = \left(\frac{\Delta M_H}{\sigma_{M_H}} \right)^2 + \left(\frac{\Delta M_t}{\sigma_{M_t}} \right)^2 + \left(\frac{\Delta(dR(H,t))}{\sigma_{dR(H,t)}} \right)^2$$

soft drop groomer: iteratively removes subclusters not satisfying

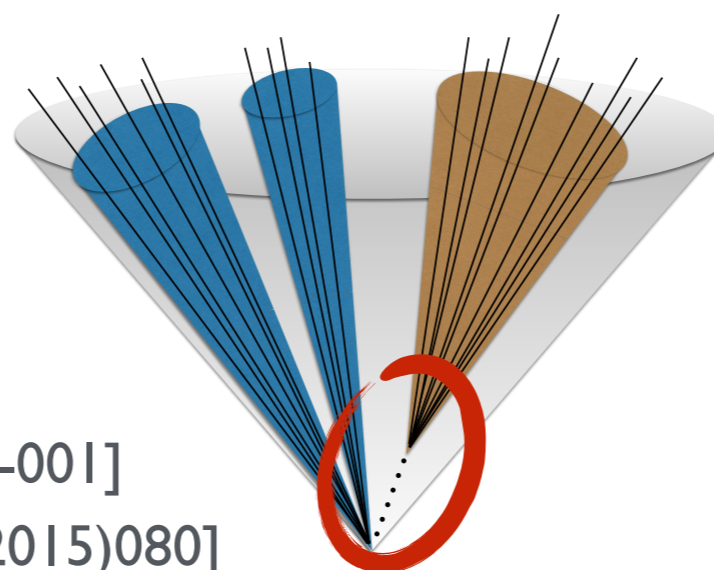
$$\frac{\min(p_{T1}, p_{T2})}{p_{T1} + p_{T2}} > z_{\text{cut}} \left(\frac{\Delta R_{12}}{R_0} \right)^\beta$$

Undo
clustering



[10.1007/JHEP05(2014)146]

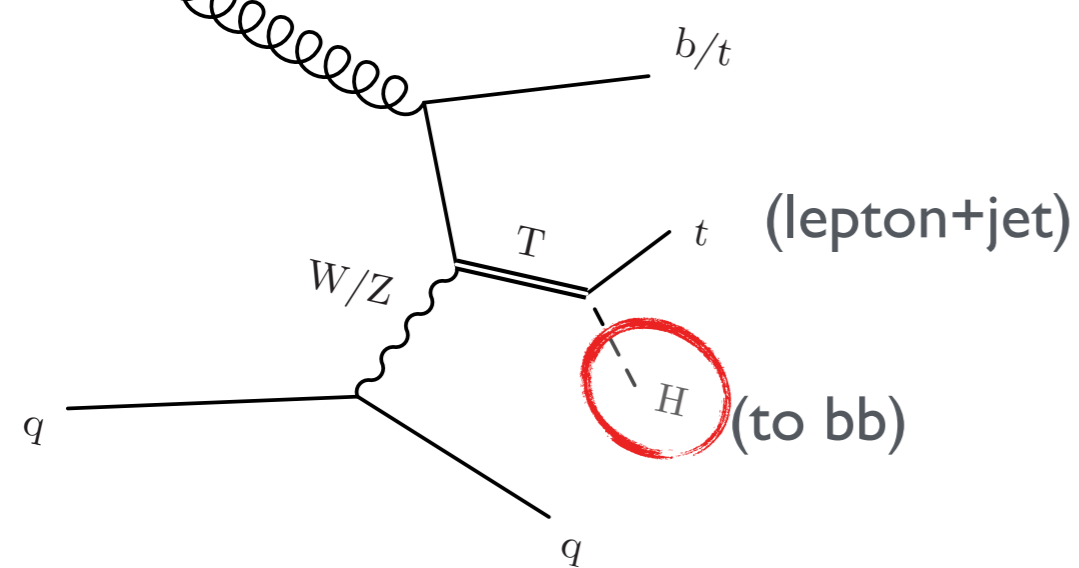
subject b tagging: apply b tagging directly to the subjects found by the groomer



[CMS-PAS-BTV-13-001]

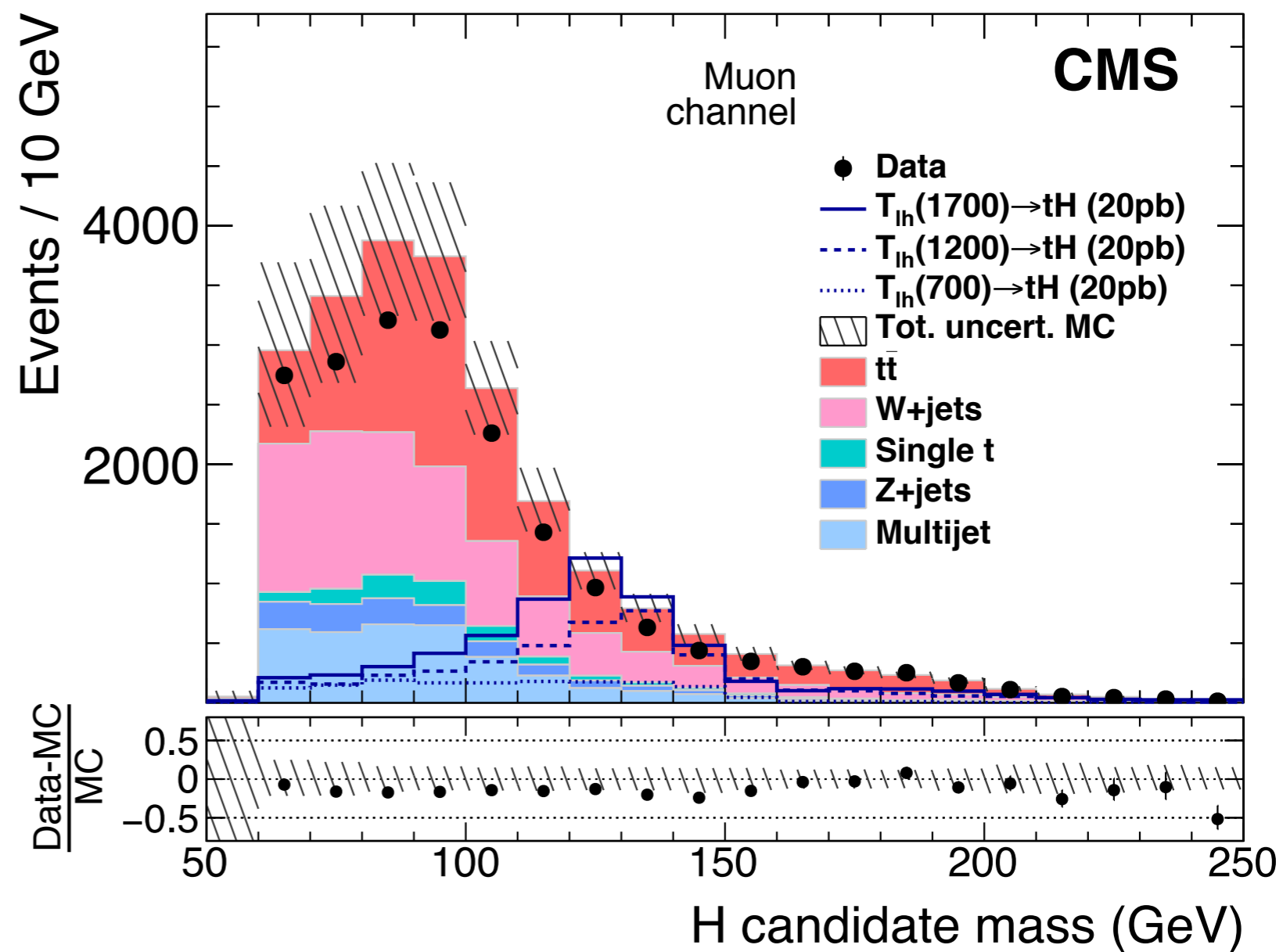
[10.1007/JHEP06(2015)080]

single T production

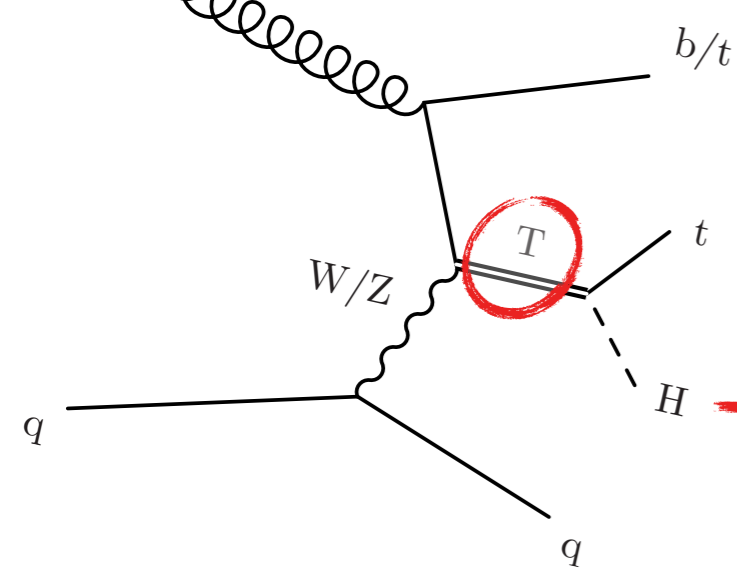


Higgs boson candidate mass

2.3 fb⁻¹ (13 TeV)



single T production

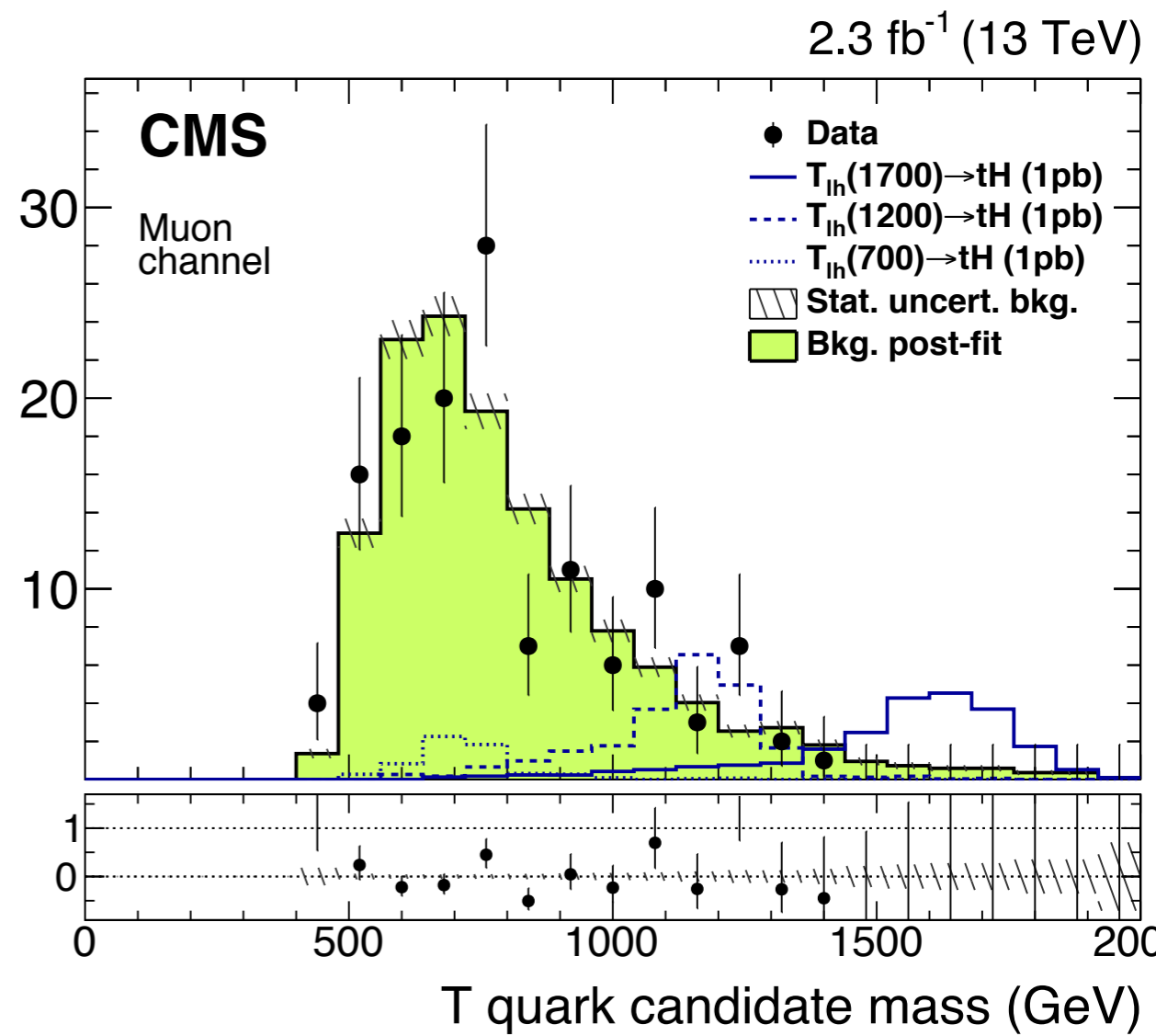


N subjet b tags

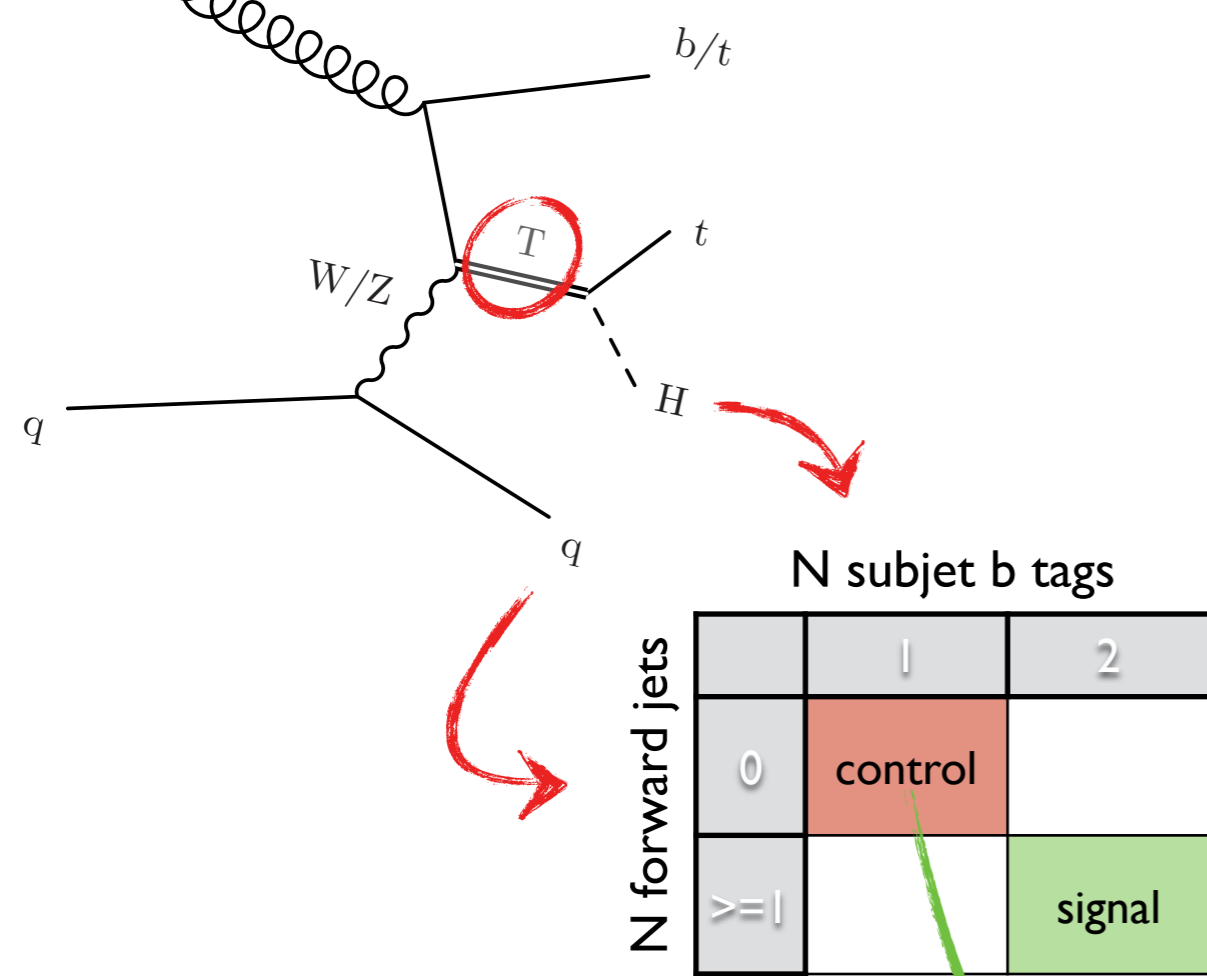
	1	2
0		
≥ 1		signal

N forward jets

Events / 80 GeV

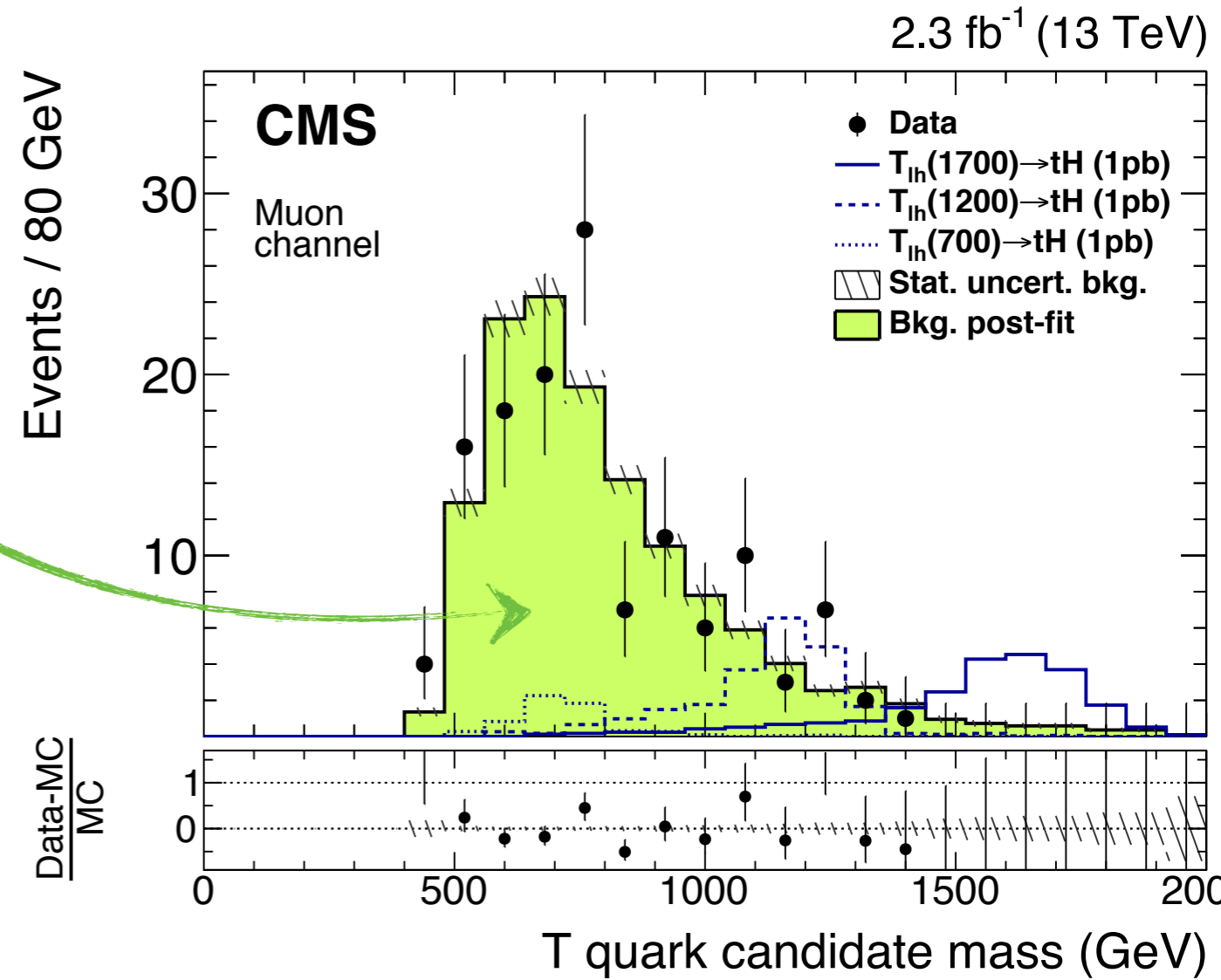


single T production

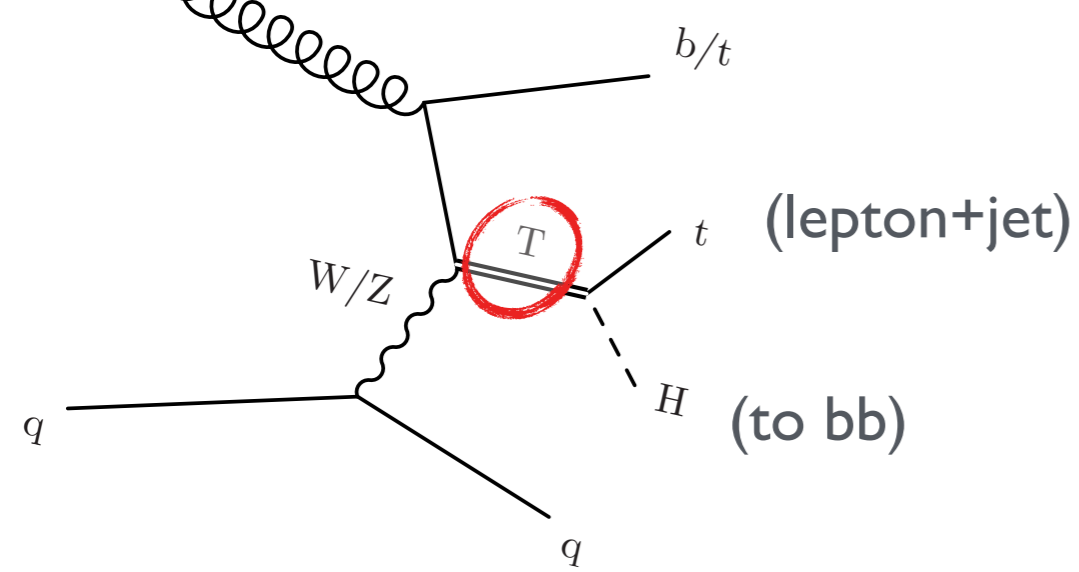


- **bkg. shape**
from control region in data
- **bkg. norm**
free floating in fit
- no excess observed

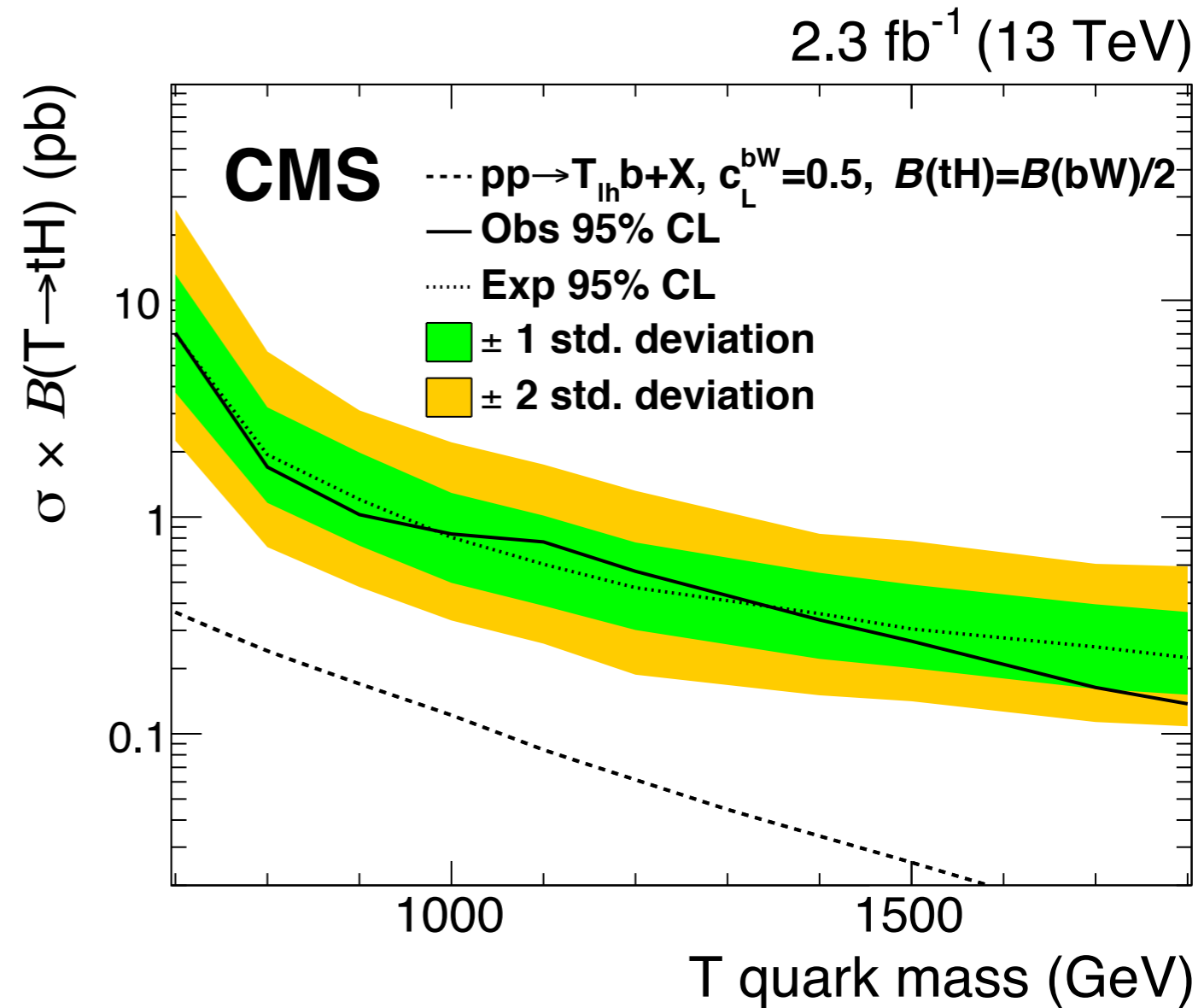
shape from data



single T production



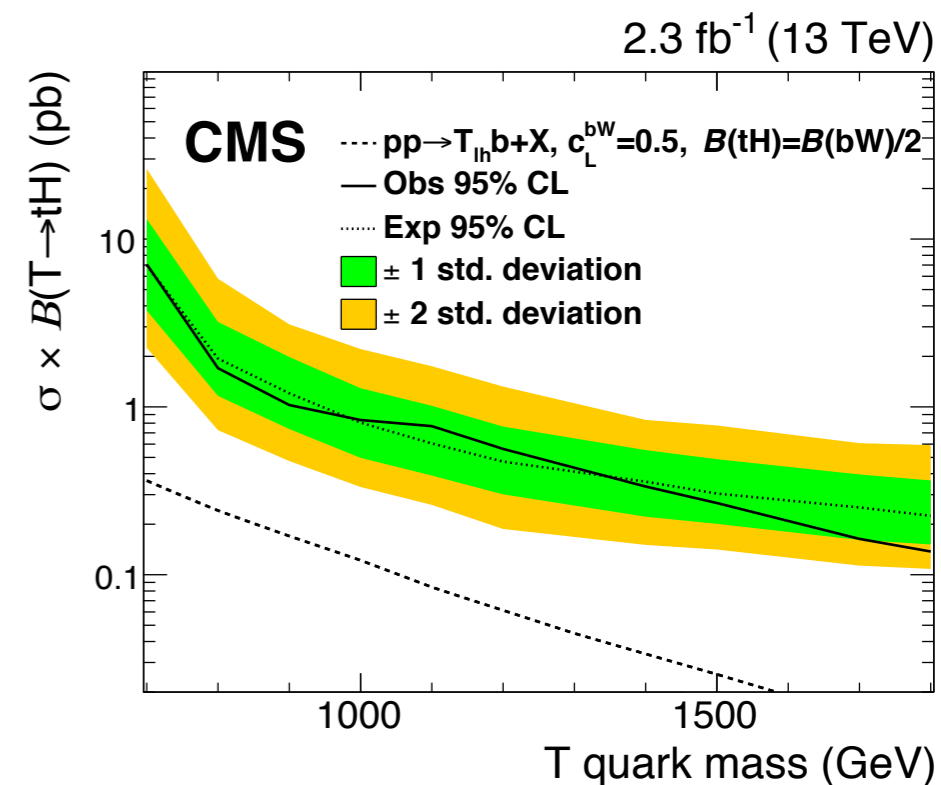
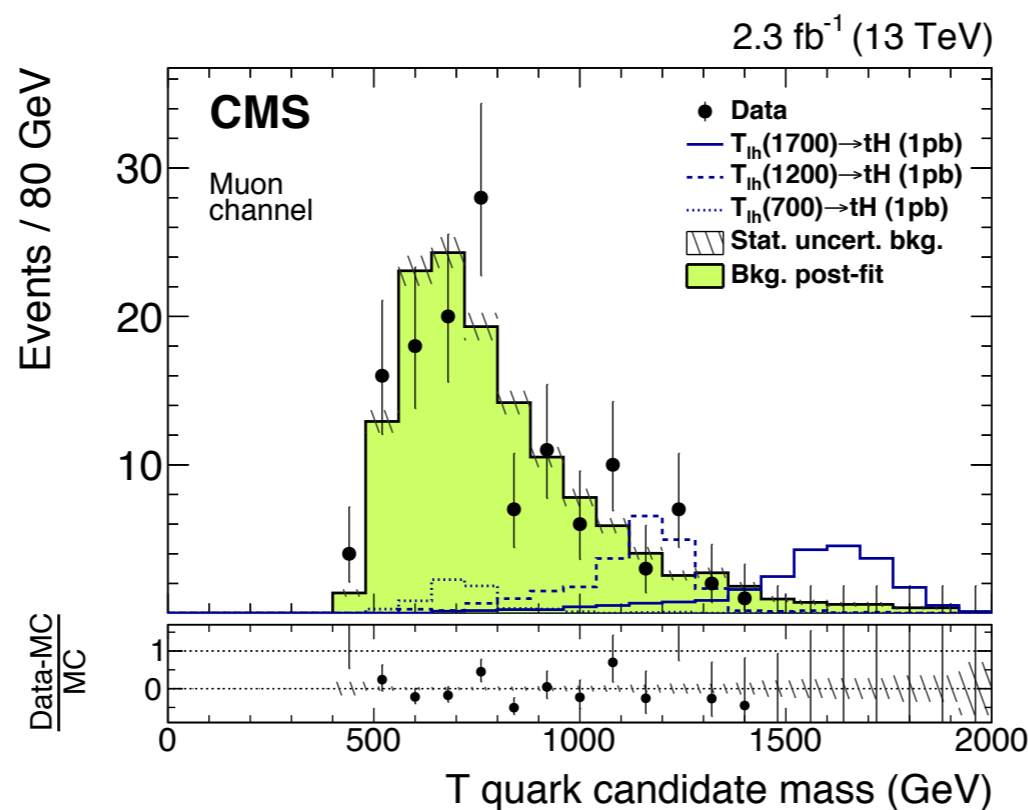
- 95% CL cross section incl. $BR(T \Rightarrow tH)$
- using bayesian inference
- coupling modifier $c = 0.5$
- more data needed to probe simplified model



summary

- **vector-like quarks**
 - appear in non-SUSY SM extensions that
 - stabilize the Higgs mass / solve hierarchy problem
- **not constrained** through Higgs measurements
- VLQ search
 - T single production
 - <https://arxiv.org/abs/1612.00999>
- exiting times are ahead!
 - VLQ's are expected to be at the TeV scale
 - the large sample of data from 2016 will provide much increased sensitivity

} submitted to PLB



backup

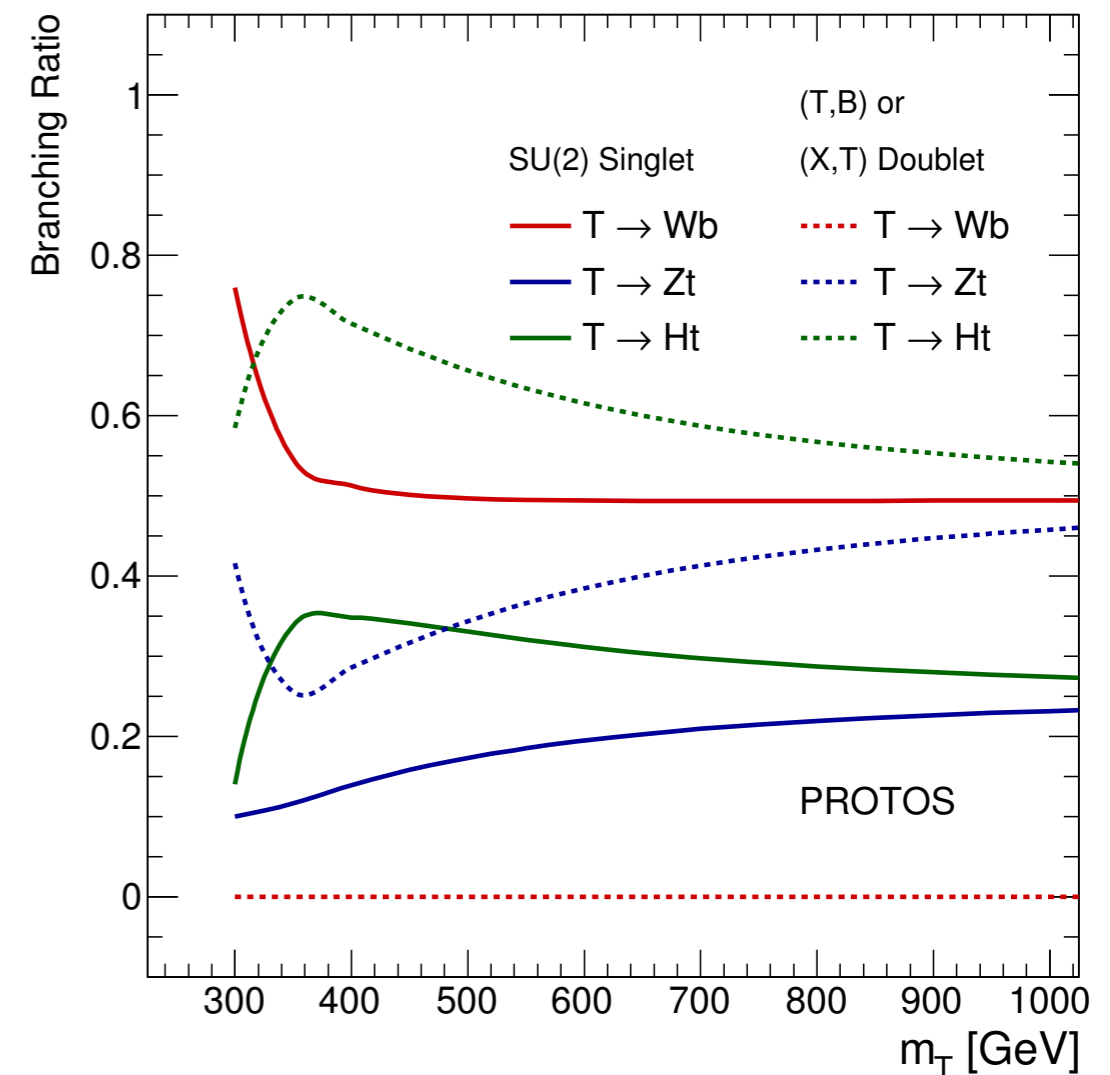
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Singlets	Doublets	Triplets	Notation:
$\mathbf{1}_{2/3} = T$	$\mathbf{2}_{1/6} = \begin{pmatrix} T \\ B \end{pmatrix}$	$\mathbf{3}_{2/3} = \begin{pmatrix} X \\ T \\ B \end{pmatrix}$	$\text{Isospin}_{\text{Hypercharge}}$ $T \rightarrow +2/3$ $B \rightarrow -1/3$ $X \rightarrow +5/3$ $Y \rightarrow -4/3$
$\mathbf{1}_{-1/3} = B$	$\mathbf{2}_{7/6} = \begin{pmatrix} X \\ T \end{pmatrix}$	$\mathbf{3}_{-1/3} = \begin{pmatrix} T \\ B \\ Y \end{pmatrix}$	
	$\mathbf{2}_{-5/6} = \begin{pmatrix} B \\ Y \end{pmatrix}$		

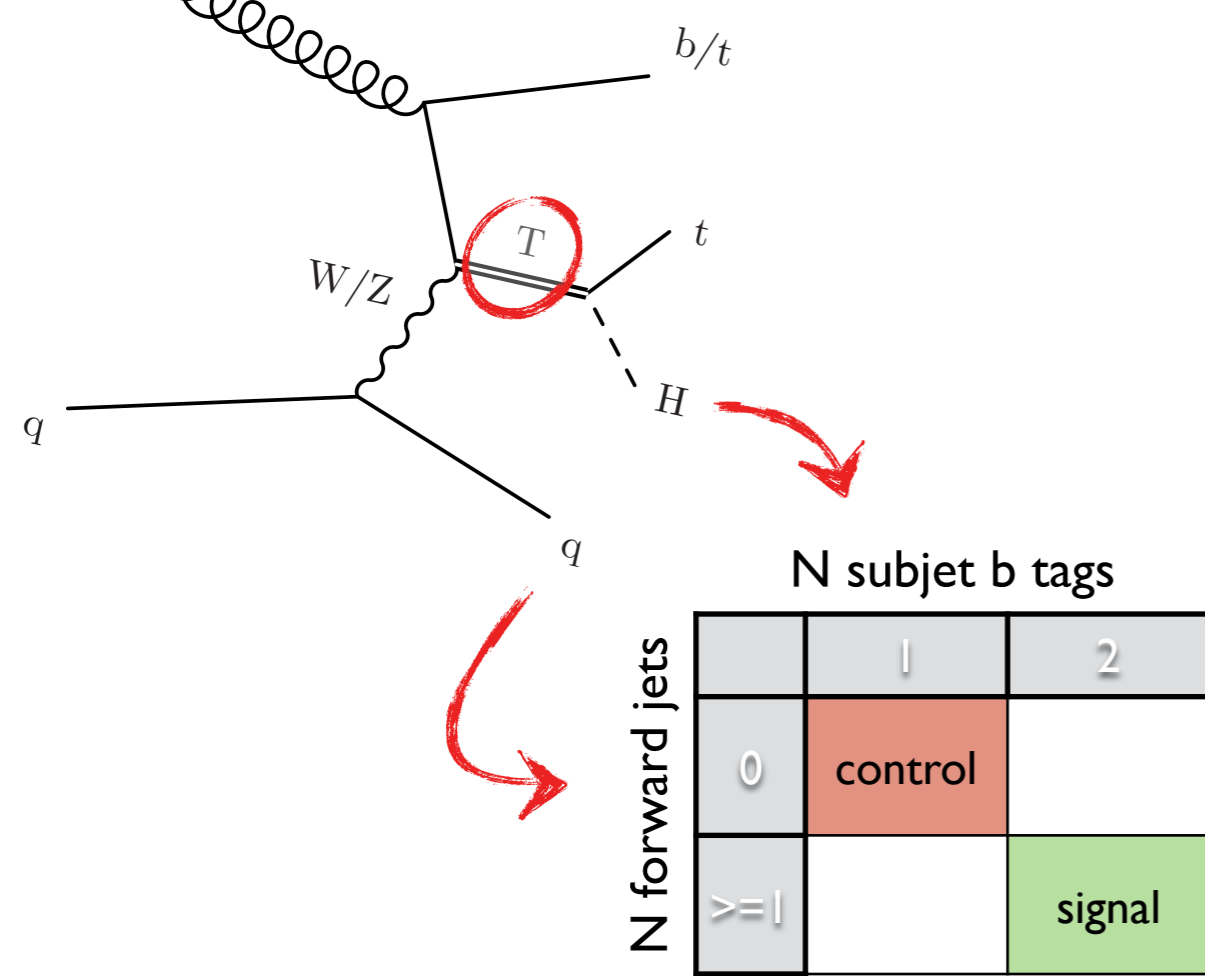
} charge Electric

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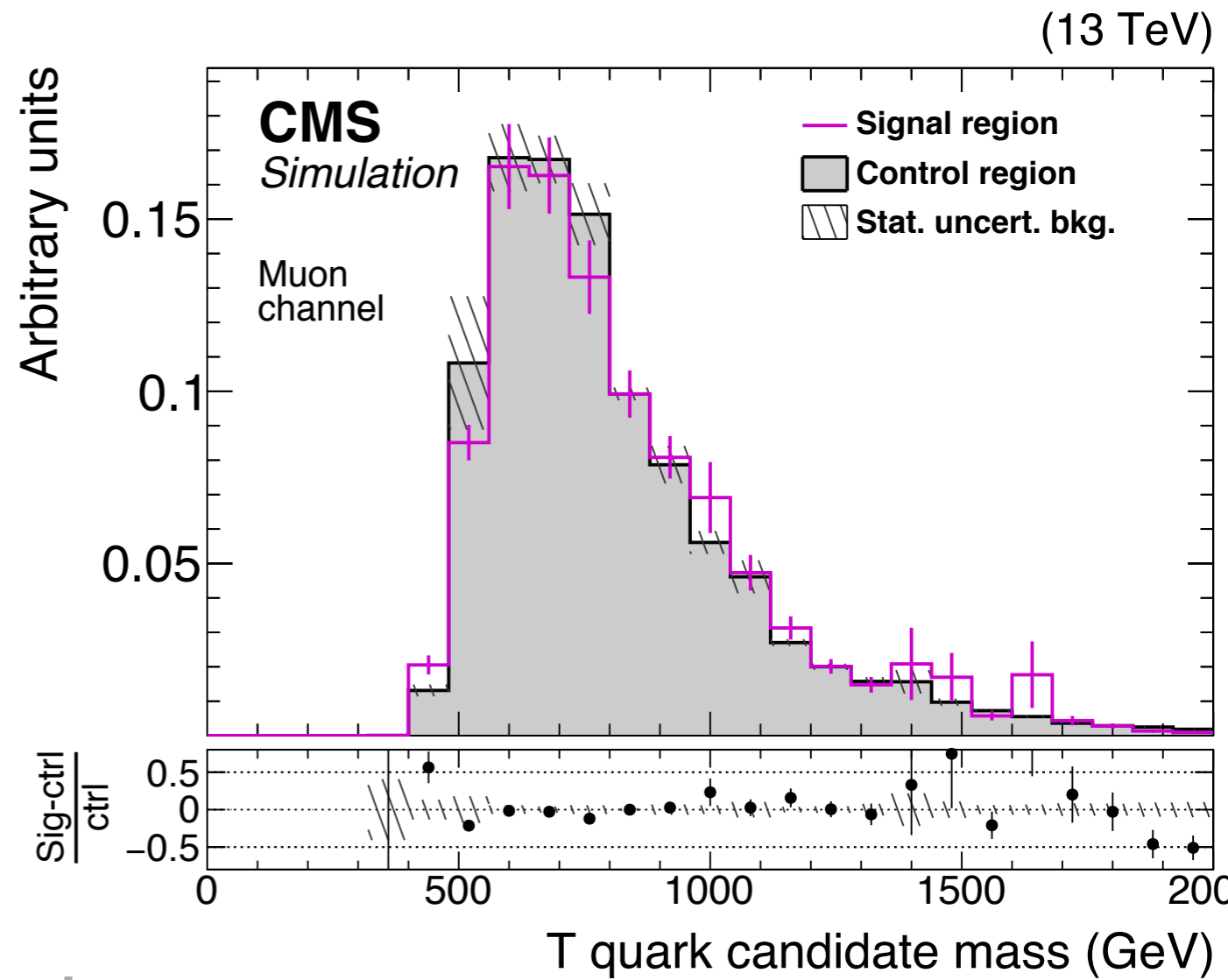
[JHEP 08 (2015) 105]



single T production



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closure test