Kinematic reconstruction of vector-like tops from fully hadronic events

Martin Stoll

based on

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[arXiv:1405.2677]

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motivation part 1: vector-like top partner

What are vector-like quarks?

The left- and right-handed components of a vector-like quark transform identically under the SM gauge group.

- $\mathcal{L} \ni -M\bar{\Psi}\Psi$ gauge-invariant mass term

What is "vector-like" about them?

Charged currents:

- SM chiral quarks:
  $J^{\mu+} = J_L^{\mu+} = \bar{u}\gamma^\mu(1-\gamma^5)d = V - A$
- vector-like quarks:
  $J^{\mu+} = J_L^{\mu+} + J_R^{\mu+} = \bar{u}\gamma^\mu d = V$

motivation part 1: vector-like top partner

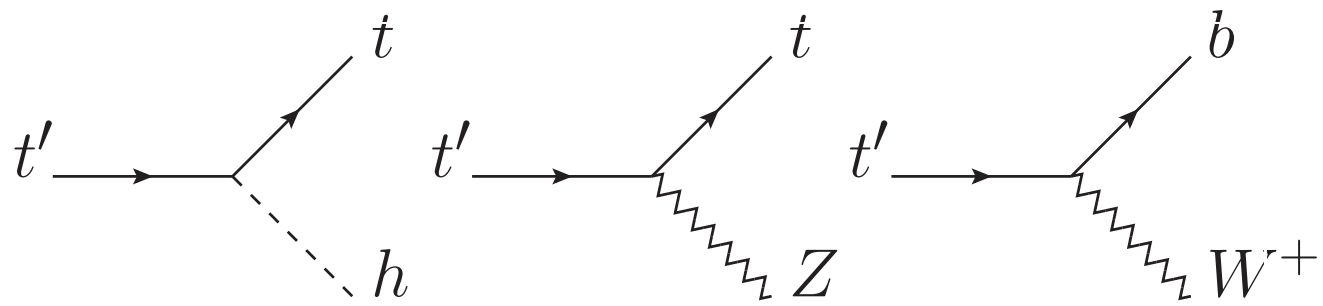
Where do they play a role?

- Little Higgs [N.Arkani-Hamed et al(2001)]
  - Higgs is pseudo-Nambu-Goldstone boson, no fine-tuning in m_h
- other composite Higgs models
- SUSY + vector-like matters [T.Moroi,Y.Okada(1992)]
  - vector-like top partner lifts m_h through loop corrections
- extra dimensions
- strongly interacting dynamics
- ...

motivation part 1: vector-like top partner

Vector-like top t'

- Yukawa couplings induce weak decay modes



- coloured fermion $\Rightarrow$ strong pair-production
- LHC searches: $m_{t'} > 700 \sim 800$ GeV [ATLAS(2013), CMS(2013)]

Benchmark point $pp \to t'\bar{t}'$, $\sqrt{s} = 14$ TeV , $\mathrm{BR}(t' \to th) = 1$

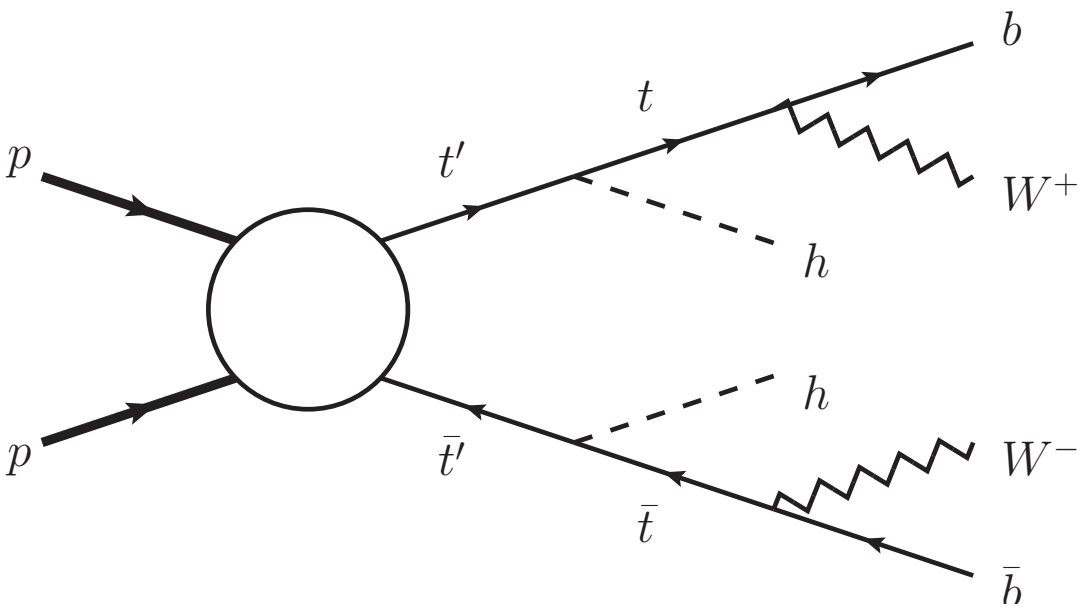
$$m'_t = 800 \text{ GeV}$$

$$900 \text{ GeV}$$

motivation part 2: hadronic final state

Most searches classify $t'\bar{t}'$ events by the number of leptons.

[ATLAS(2013),CMS(2013),K.Harigaya et al(2012), ...]

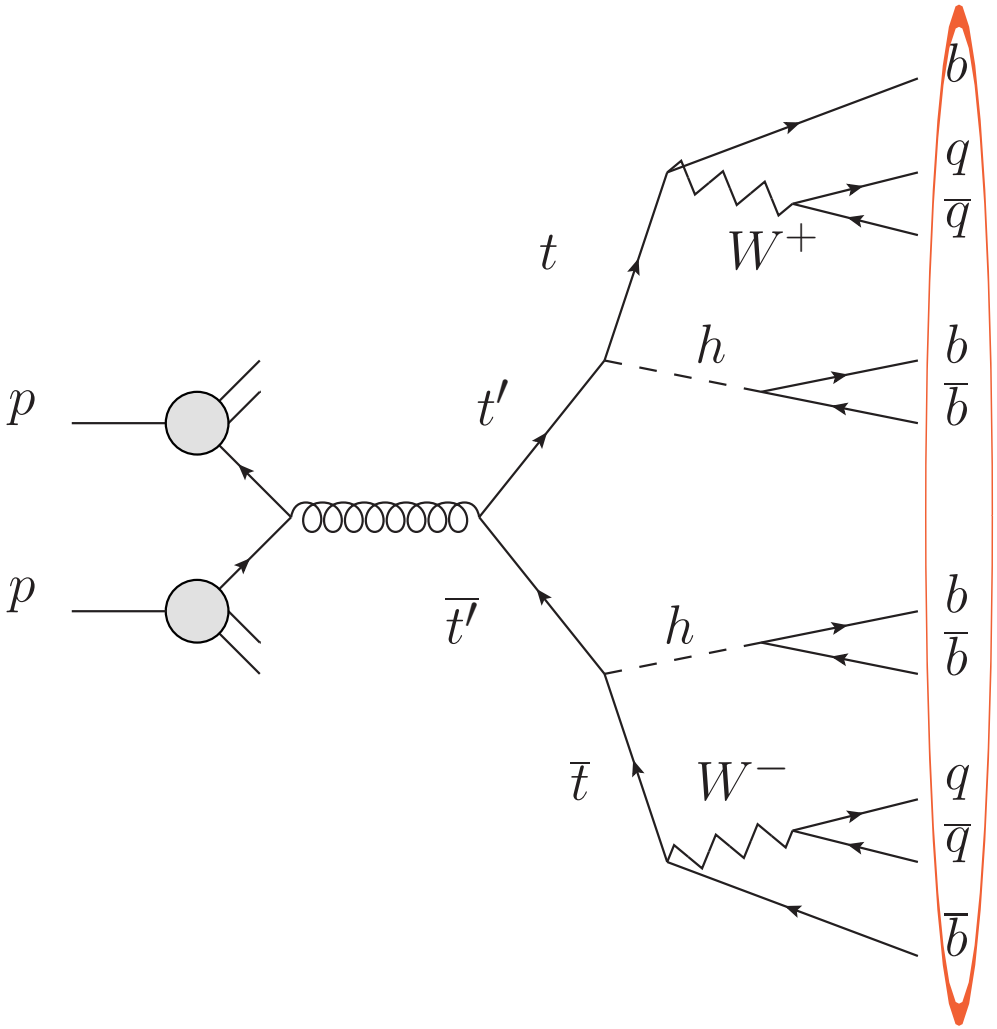


- 1 lepton
- opposite-sign dilepton
- same-sign dilepton
- 3, 4 leptons

But what about the 0-lepton multi-bottom channel?

motivation part 2: hadronic final state

aim: full reconstruction from fully hadronic events



+ larger branching ratio
  BR($W \to$ hadrons) = 68%
+ no $\not{E}_\perp$
+ can reconstruct t, h
+ $\to$ can reconstruct t'
  $\to$ measure $m_{t'}$
− large backgrounds
  (also pure QCD)

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overview: cuts

general

1. scalar transverse momentum $H_T \geq 1200$ GeV
2. multiple bottom tag $\#(b \text{ jets}) \geq 4$

tagging and reconstruction

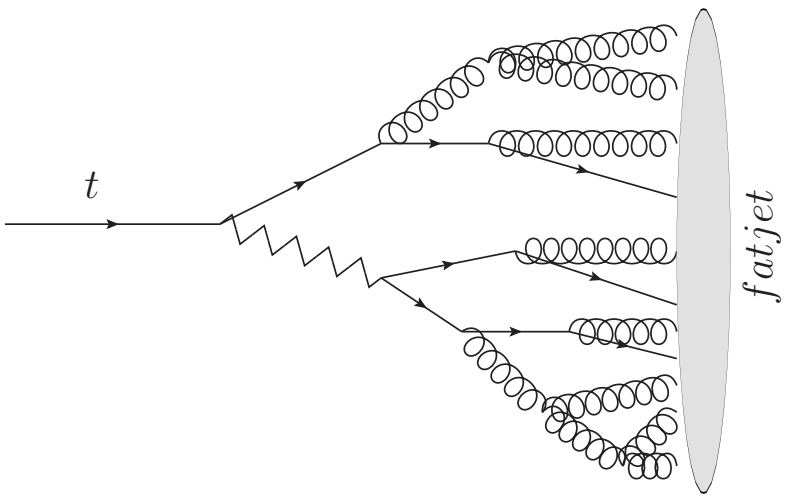
3. top tagging $\#t = 1$ or 2
4. Higgs tagging $\#h = 1$ or 2
5. reconstruct t'

relevant SM backgrounds

ttbb, tt, bbbb, tth

analysis tools

- multi-jet final state (signal has 10j)
- heavy t': boosted t, h, decay products collimated
- top decay $t \to bW \to bjj$ gives better handle against background than $h \to b\bar{b}$



strict top tag

HEPTopTagger [T.Plehn et al(2010)]

- find 3 subjets in fat jet
- good for $p_\perp(t) \gtrsim 200$ GeV
- low mistag rate

+ loose Higgs tag (from remaining fat jets) [J.M.Butterworth et al(2008)]

cut flow

LHC@14TeV, 100fb^{-1}

	800 GeV	900 GeV	BG*
σ_{NLO} [fb]	3.75	1.52	

number of events for *100fb*$^{-1}$

$H_T \geq 1200$ GeV	266	123	14800
$\#b \geq 4$	185	84.6	1560
$\#t = 1, \#h = 2$	25.0	11.3	10.3
$\#t = 2, \#h = 1$	13.0	5.7	5.8
any 3 *t* and *h*	38.0	17.0	16.1

*only ttbb, tt, bbbb, tth

mass reconstruction

Vector-like top mass: $m_{t'} \equiv M(t,h) = \sqrt{(p_t^\mu + p_h^\mu)^2}$

Example: have reconstructed t, h_1, h_2

Problem: $M(t,h_1)$ **or** $M(t,h_2)$

Idea: solve $\equiv M(t^1_{\text{miss}}, h_2)$ $\equiv M(t^2_{\text{miss}}, h_1)$

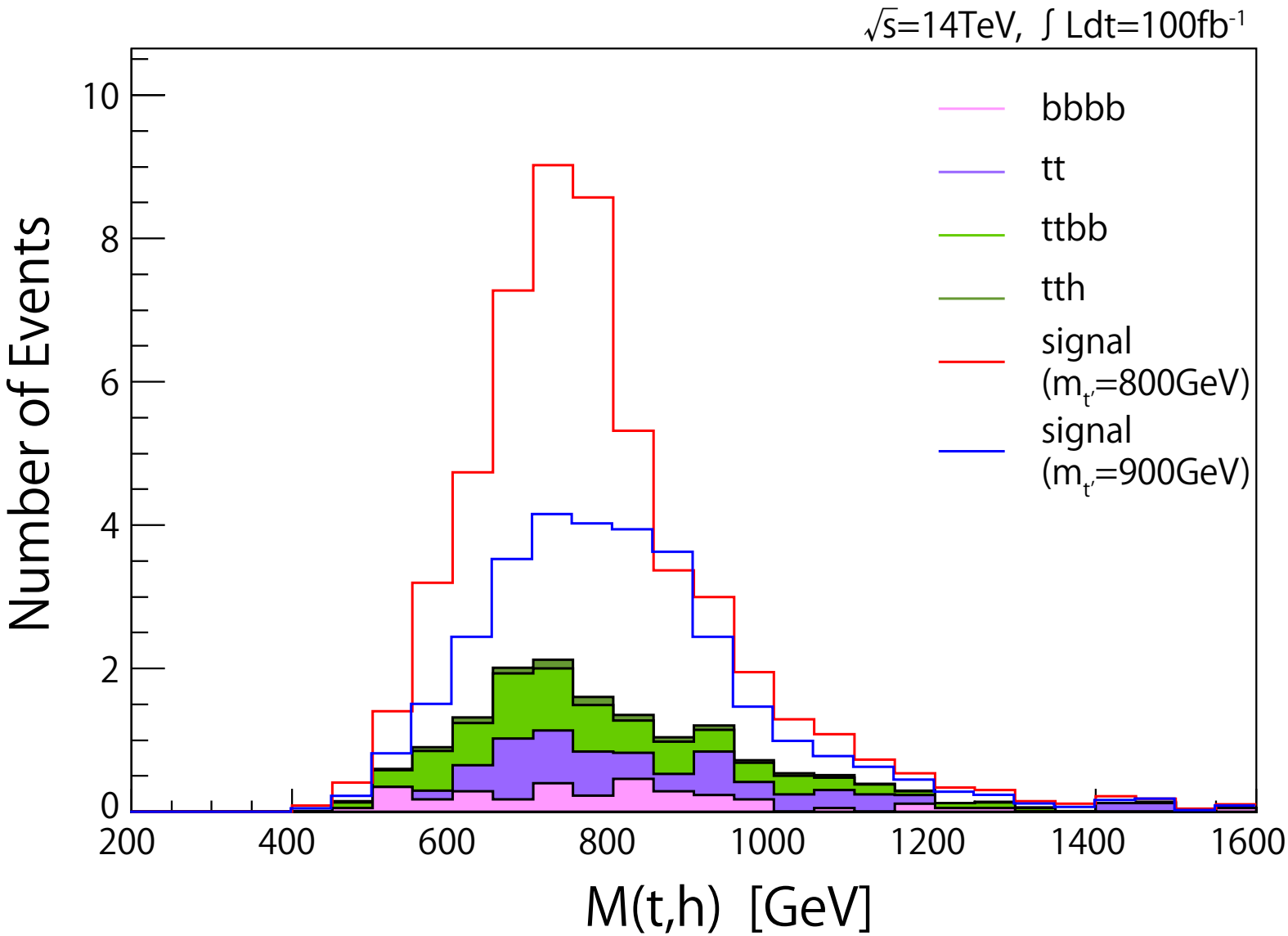
with

$$\sum \vec{p}_{\perp,i} = 0$$

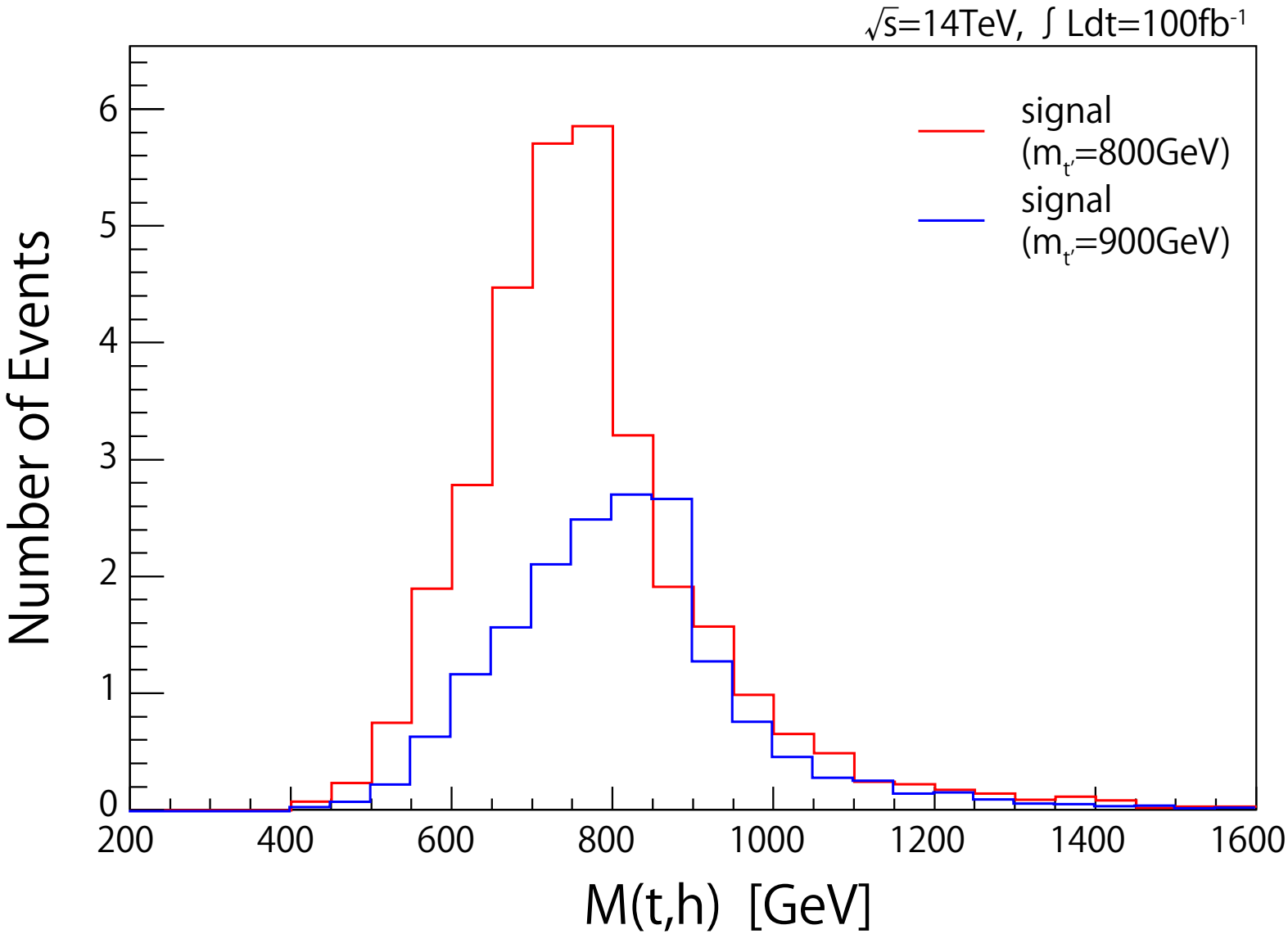
$$\left(p^\mu_{t_{\text{miss}}}\right)^2 = m_t^2$$

If both are kinematically allowed, choose the less extreme one (smaller rapidity of t_{miss}).

combined signal region: 2t1h + 1t2h



signal only: sharp edges



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last slide

Summary

- vector-like top searches affect a large class of models
- fully hadronic channels are an alternative
- a direct mass measurement is possible

looking forward to LHC RUN II

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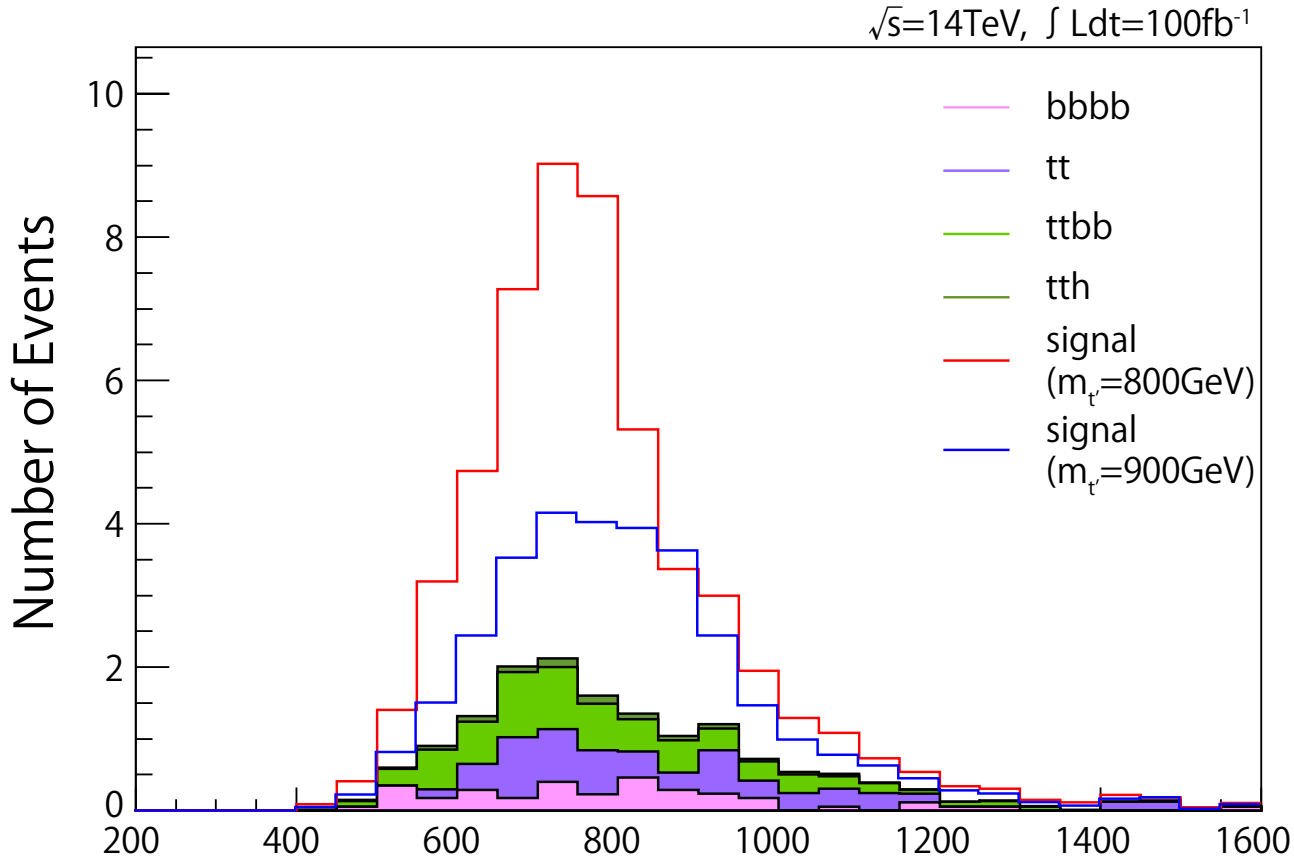

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