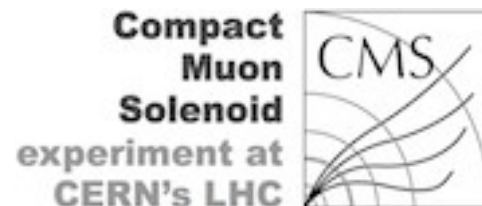


# Search for a vector like quark in the fully hadronic channel at CMS experiment

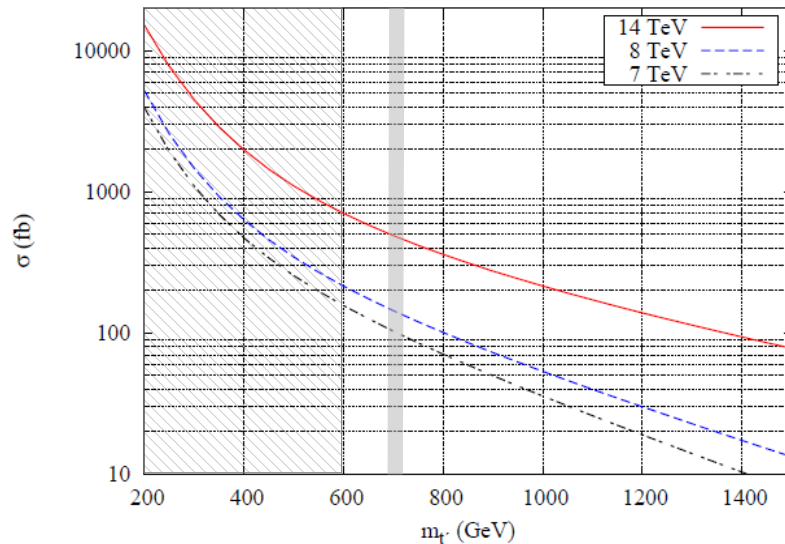
José David Ruiz Álvarez

Cargese  
July 2014

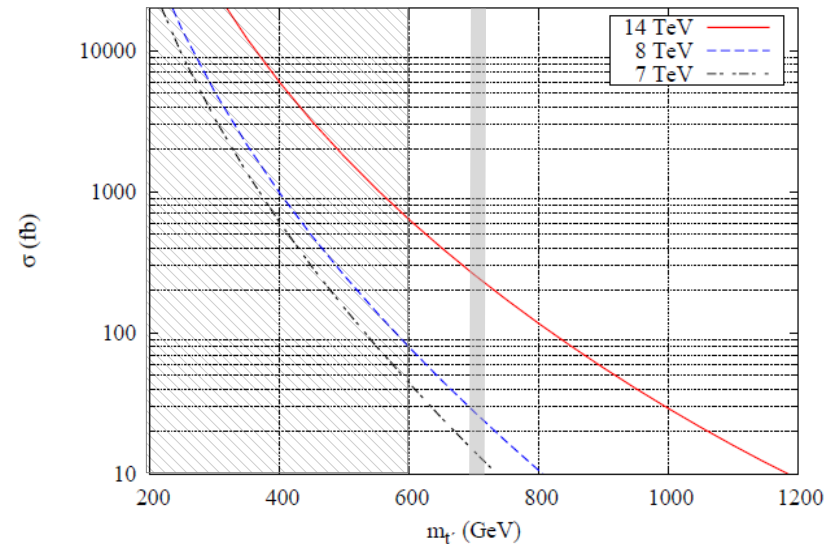


# T' production and decay

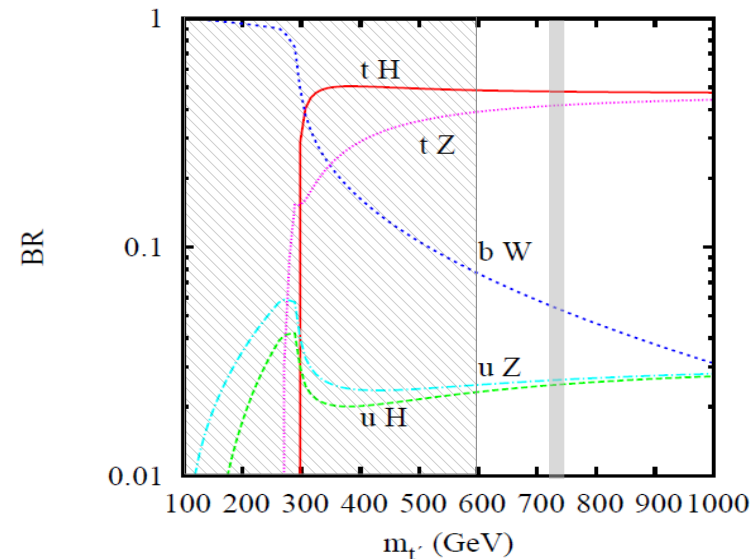
Single production



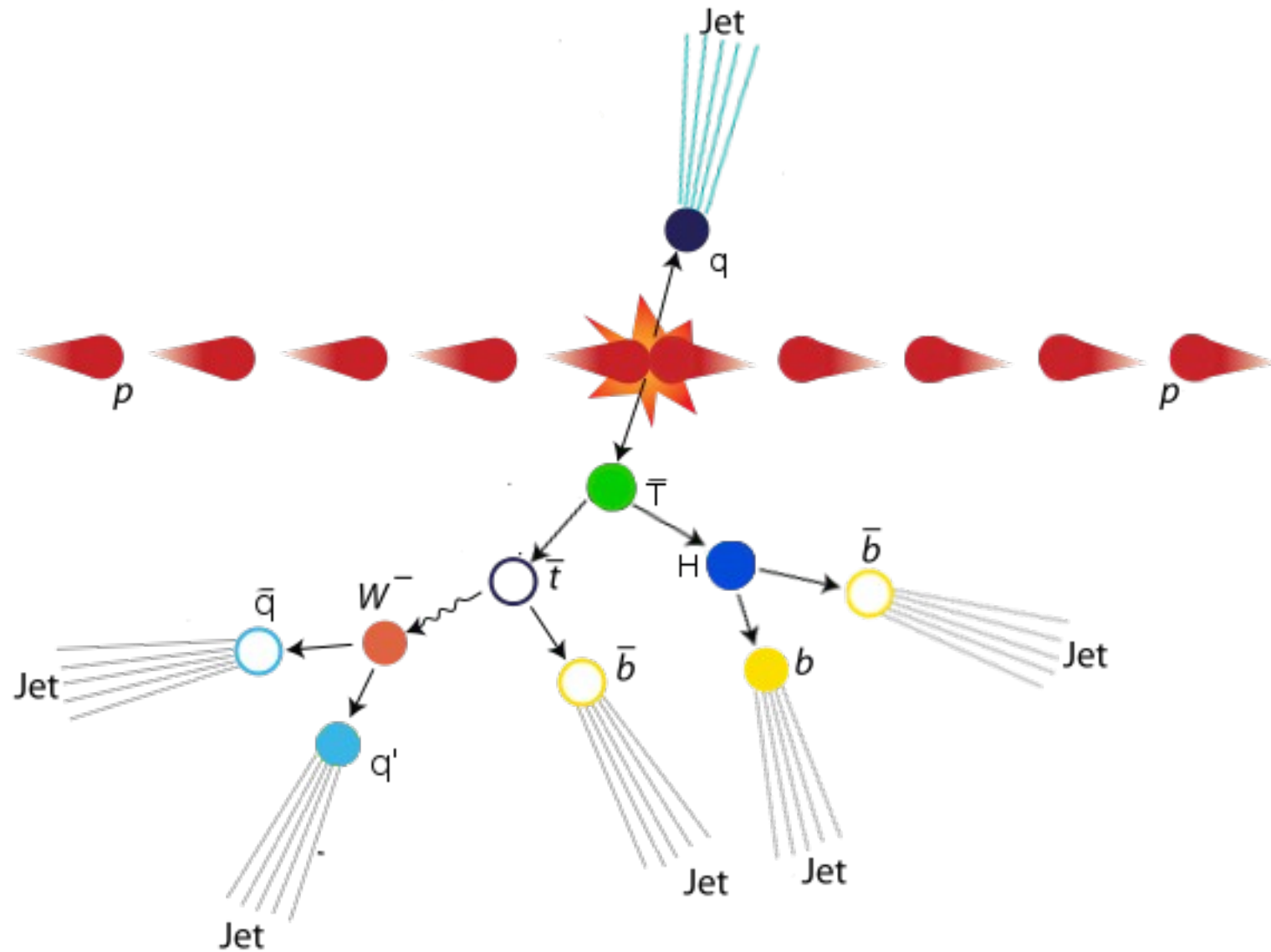
Pair production



→ Mixing with light quarks  
enhance the cross-section  
of production  
→  $m_{T'} > 300$  GeV,  
tH becomes the preferential  
decay channel



# Single $T'$ search



# Analysis strategy

- $20 \text{ fb}^{-1}$  @ 8 TeV  $\rightarrow$  Fully hadronic channel: Highest expected number of events for the signal [ $\sim 700$  events]  $\rightarrow$  Full mass reconstruction of  $T'$
- Background reduction: Higgs and top as handles.
- Event selection: Keep high efficiencies on signal.
- Cuts based on angular distributions  $\rightarrow$  Preservation from hadronization to fullsim

# Pre-Selection

Full hadronic final state with 3b's and 2j's (making W, Top, Higgs) + 1 accompanying jet

- Trigger: Dijet\_80\_Dijet\_60\_Dijet\_20
- Jet pt: 1<sup>st</sup> pt > 150 GeV, 2<sup>nd</sup> pt > 90 GeV, 3<sup>rd</sup> and 4<sup>th</sup> pt > 70 GeV, 5<sup>th</sup> and 6<sup>th</sup> pt > 30 GeV
- HT > 630 GeV
- ≥ 3 CSVM b-tag

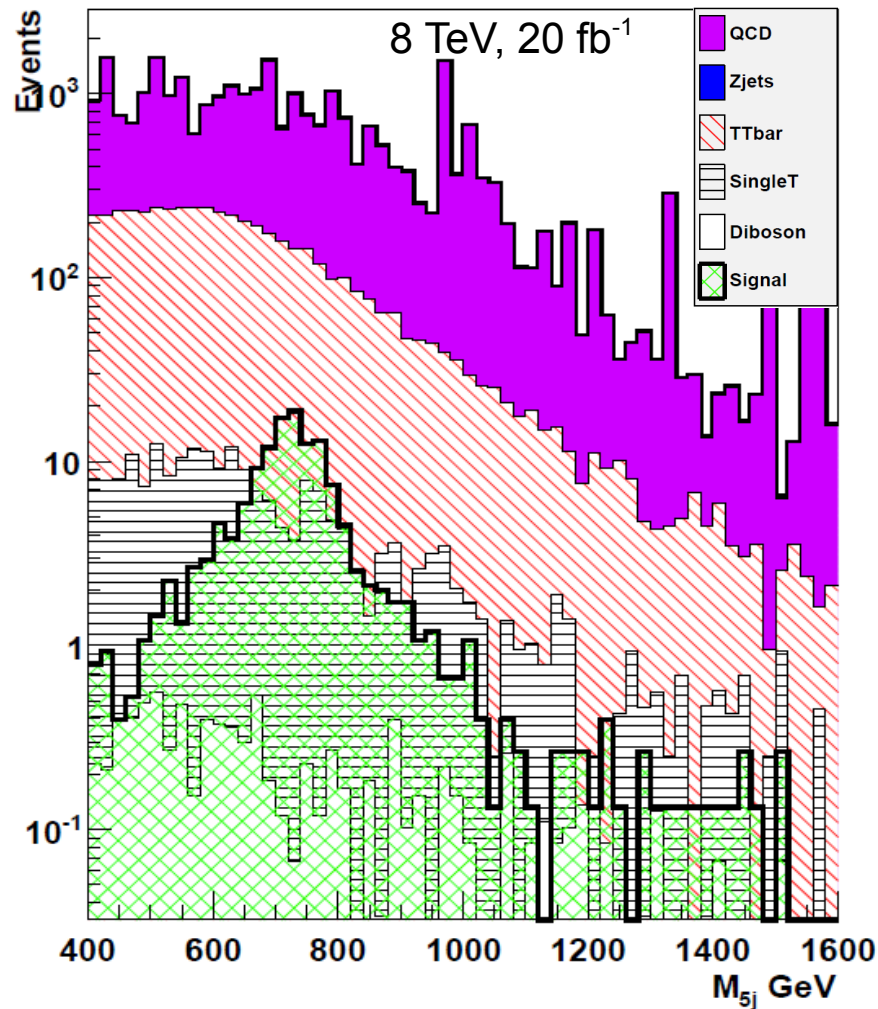
# Analysis selection

Based on Higgs, W and Top presence:

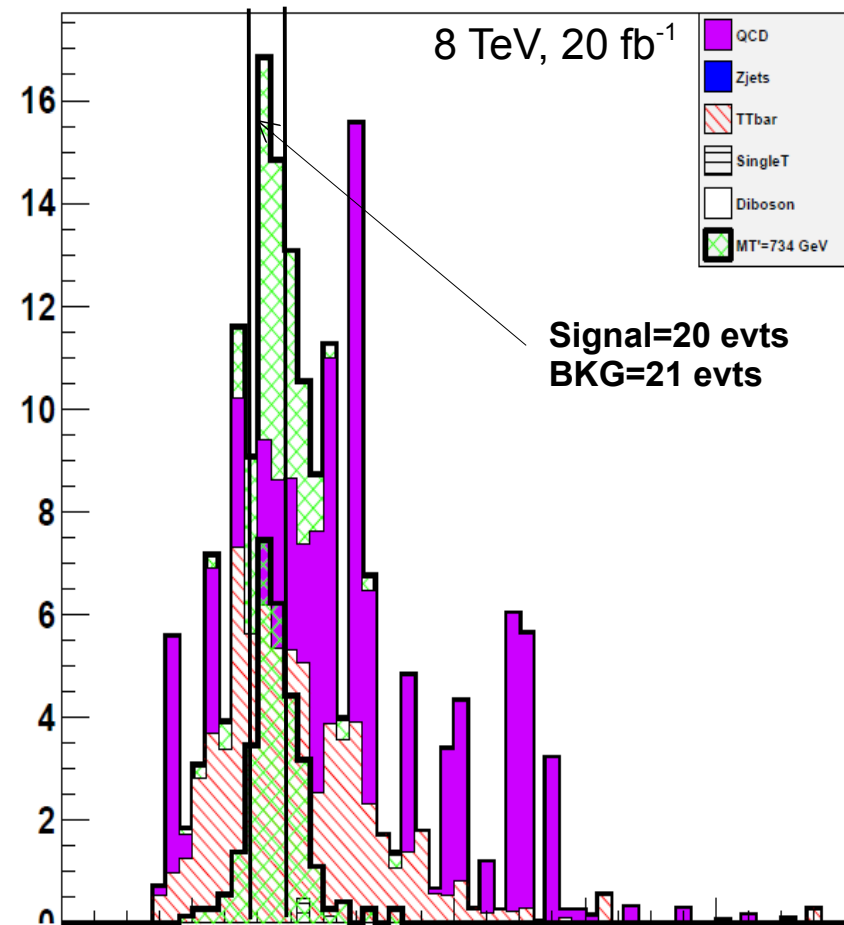
- Higgs selection:
  - $\Delta R(bb) < 1.2$
  - $110 \text{ GeV} < M(bb)H^{\text{reco}} < 140 \text{ GeV}$
- W selection:
  - $W^{\text{reco}} \Delta\phi(jj) < 2$
- Top selection:
  - $M \text{ Top}^{\text{[reco 2nd]}} < 140 \text{ GeV}$  and  $> 230 \text{ GeV}$
- Full Event selection:
  - $\text{Higgs}^{\text{reco}} pT > 200 \text{ GeV}$  and  $\text{Top}^{\text{reco}} pT > 200 \text{ GeV}$
  - $2.2 < \Delta R(W^{\text{reco}}H^{\text{reco}}) < 3.5$
  - $\text{Higgs} \Delta\phi(jj) < 1.2$  and  $\Delta\phi([W^{\text{reco}}, j]\text{Top}^{\text{reco}}) < 1.2$
  - $[(Pt(\text{Higgs}^{\text{reco}}) + Pt(\text{Top}^{\text{reco}})) / HT] > 0.65$
  - $0.3 < (M(\text{Higgs}^{\text{reco}}) + M(\text{Top}^{\text{reco}})) / M(\text{Tprime}^{\text{reco}}) < 0.5$

# Expected results from MC

## BASIC SELECTION



## AFTER FULL SELECTION



Stacked plots for backgrounds and signal, and signal superimposed for 5 jets invariant mass. Not good stats on QCD.

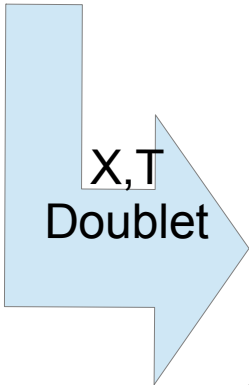
Backup slides



# Formalism

$$\begin{aligned}
 Q = 5/3 &\Rightarrow X \rightarrow W^+ u^i; \\
 Q = 2/3 &\Rightarrow T \rightarrow W^+ d^i, Zu^i, Hu^i; \\
 Q = -1/3 &\Rightarrow B \rightarrow W^- u^i, Zd^i, Hd^i; \\
 Q = -4/3 &\Rightarrow Y \rightarrow W^- d^i;
 \end{aligned}$$

$$\begin{aligned}
 \mathcal{L} = & \kappa_T \left\{ \sqrt{\frac{\zeta_i \xi_Z^T}{\Gamma_Z^0}} \frac{g}{2c_W} [\bar{T}_R Z_\mu \gamma^\mu u_R^i] \right\} - \kappa_T \left\{ \sqrt{\frac{\zeta_i \xi_H^T}{\Gamma_H^0}} \frac{M}{v} [\bar{T}_L H u_R^i] + \sqrt{\frac{\zeta_3 \xi_H^T}{\Gamma_H^0}} \frac{m_t}{v} [\bar{T}_R H t_L] \right\} \\
 & + \kappa_X \left\{ \sqrt{\frac{\zeta_i}{\Gamma_W^0}} \frac{g}{\sqrt{2}} [\bar{X}_R W_\mu^+ \gamma^\mu u_R^i] \right\} + h.c.
 \end{aligned} \tag{2.1}$$

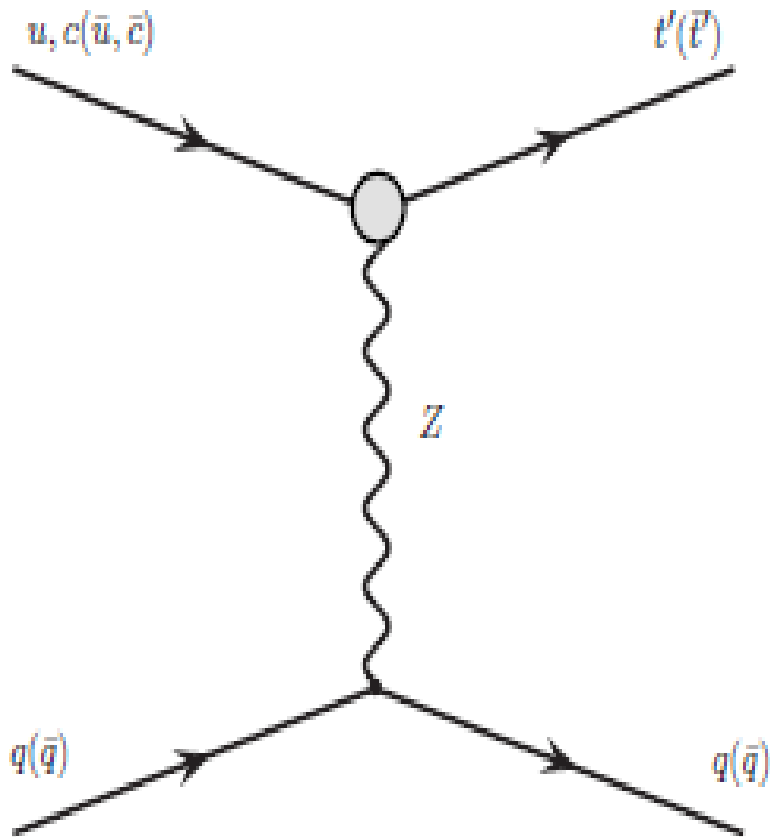


$$\begin{aligned}
 BR(T \rightarrow Zj) &= \frac{\zeta_{jet} \xi_Z^T}{1 + \zeta_3 \xi_H \delta_H}, & BR(T \rightarrow Zt) &= \frac{(1 - \zeta_{jet}) \xi_Z^T}{1 + \zeta_3 \xi_H \delta_H}, \\
 BR(T \rightarrow Hj) &= \frac{\zeta_{jet} (1 - \xi_Z^T)}{1 + \zeta_3 \xi_H \delta_H}, & BR(T \rightarrow Ht) &= \frac{(1 - \zeta_{jet}) (1 - \xi_Z^T) (1 + \delta_H)}{1 + \zeta_3 \xi_H \delta_H},
 \end{aligned}$$

$$BR(X \rightarrow W^+ j) = \zeta_{jet}, \quad BR(X \rightarrow W^+ t) = (1 - \zeta_{jet}).$$

- M. Buchkremer, **G. Cacciapaglia, A. Deandrea, L. Panizzi**. arXiv: 1305.4172
- **G. Cacciapaglia, A. Deandrea, L. Panizzi**, N. Gaur, D. Harada, Y. Okada. arXiv: 1108.63429<sub>9</sub>

# Pheno search design: Single $T'$



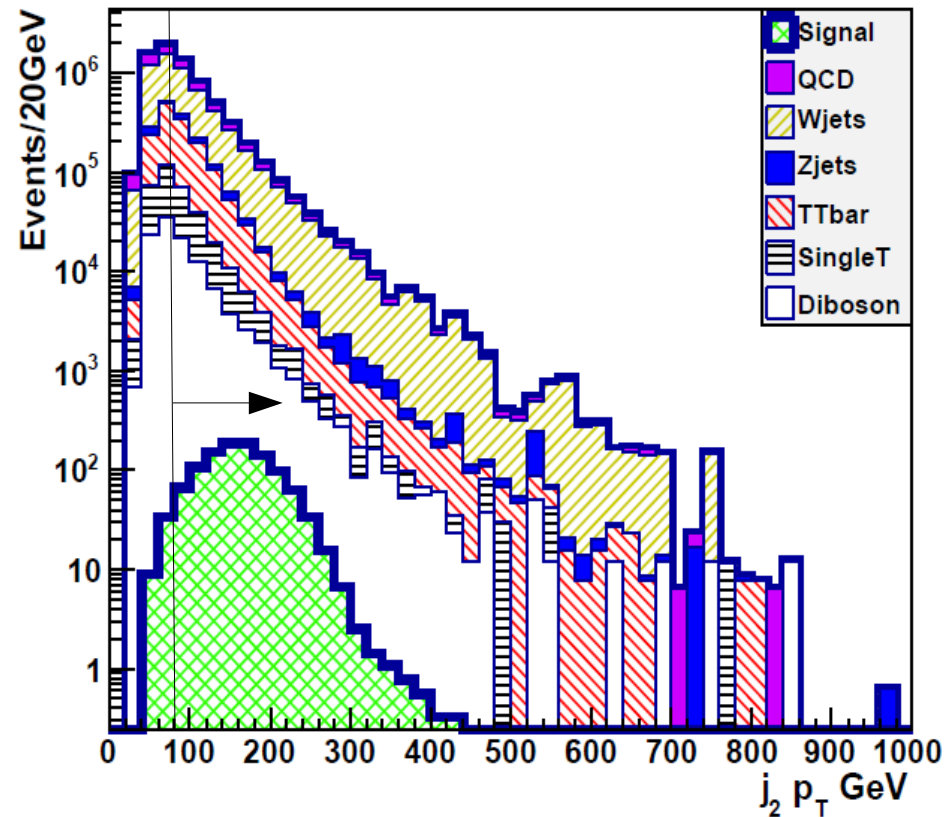
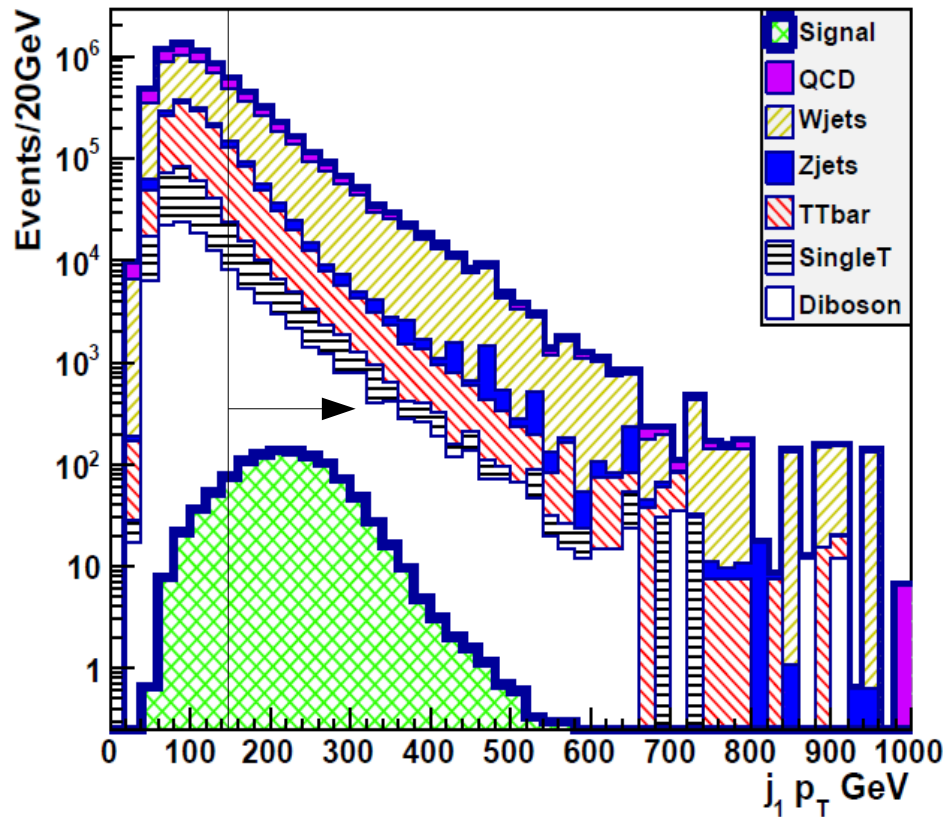
- $L=20\text{fb}^{-1}$ ,  $\text{xs}=150\text{fb}$  @8TeV  
 **$\text{BR}(T' \rightarrow t, H)=0.5$**   
 $m(T')=734.1$  GeV
- Jet association (below)
- Fully hadronic (5+1 jets)
- Final state:  
 $tH \rightarrow Wbb \rightarrow jjbb$

# Cut flow

	Description	BKG target
Cut 0	(~)Trigger (Dijet_80_Dijet_60)	
Cut 1	Leading jet $pt > 150$ GeV	QCD+TTbar
Cut 2	$HT > 630$ GeV [ $HT = \sum  j(pt) $ ]	TTbar+QCD
Cut 3	N b-tags $\geq 2$	Wjets
Cut 4	$\Delta R_{bb} < 1.8$	TTbar
Cut 5	$Higgs^{reco} (pt) > 200$ GeV and $top^{reco} (pt) > 300$ GeV	All
Cut 6	$2.2 < \Delta R_{(H^{reco}W^{reco})} < 3.5$	QCD+Wjets
Cut 7	$Higgs^{reco} (jets)$ with $\Delta\phi < 2.0$ and $\Delta\phi ([W^{reco}, j]^{Top}) < 3.3$	QCD
Cut 8	[Jets with $ \eta  < 2.5$ + Jets with ( $2 <  \eta $ and $ \eta  < 5$ )] $\leq 8$	TTbar
Cut 9	$W^{reco} (jets) \Delta\phi < 2.3$	All
Cut 10	$110 \text{ GeV} < M(bb)^H < 135 \text{ GeV}$	QCD+TTbar
Cut 11	Relative HT [ $(Pt(Higgs^{reco}) + Pt(Top^{reco}))/HT$ ] $> 0.65$	TTbar
Cut 12	Aplanarity $< 0.06$	TTbar

# Leading jets pt

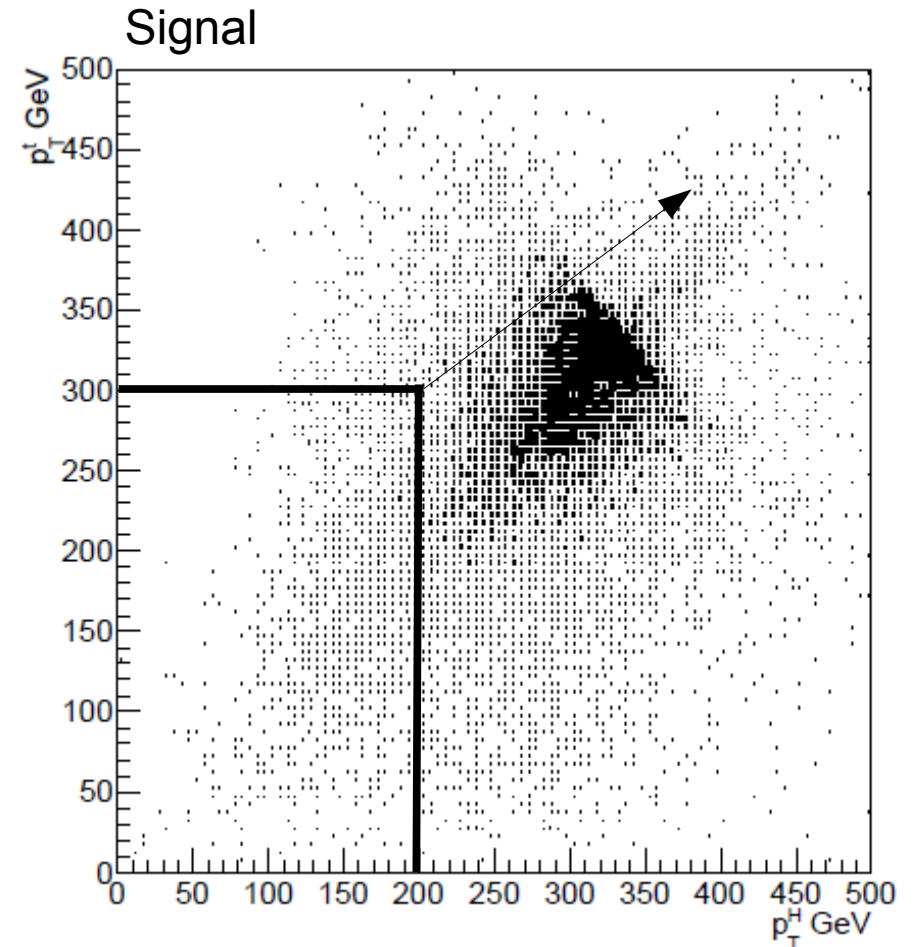
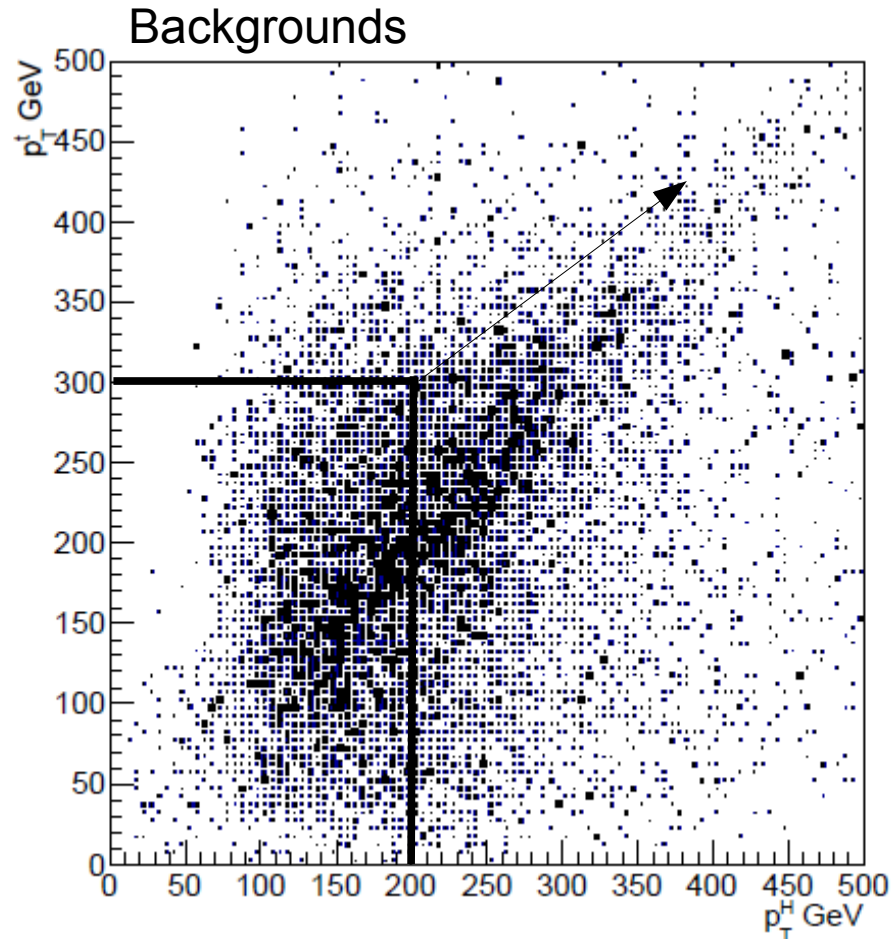
Pheno



Leading (left) and subleading (right) jet pt distribution for backgrounds (stacked and signal (superimposed). Higher pt jets in the signal.

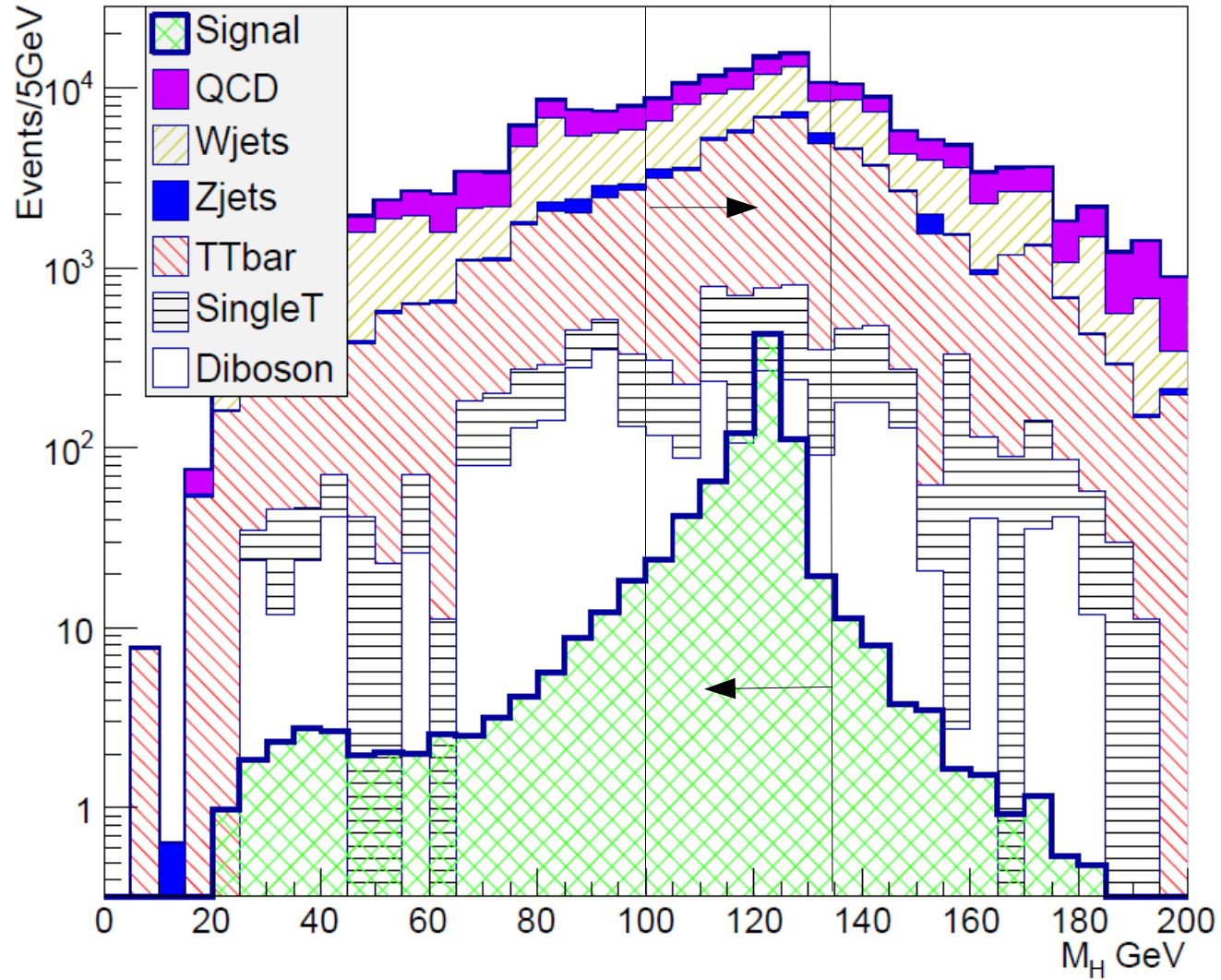
# Higgs - top pt

Pheno



2D plot for reconstructed Higgs pt (x-axis) and reconstructed top pt (y-axis) for background (left) and signal (right).

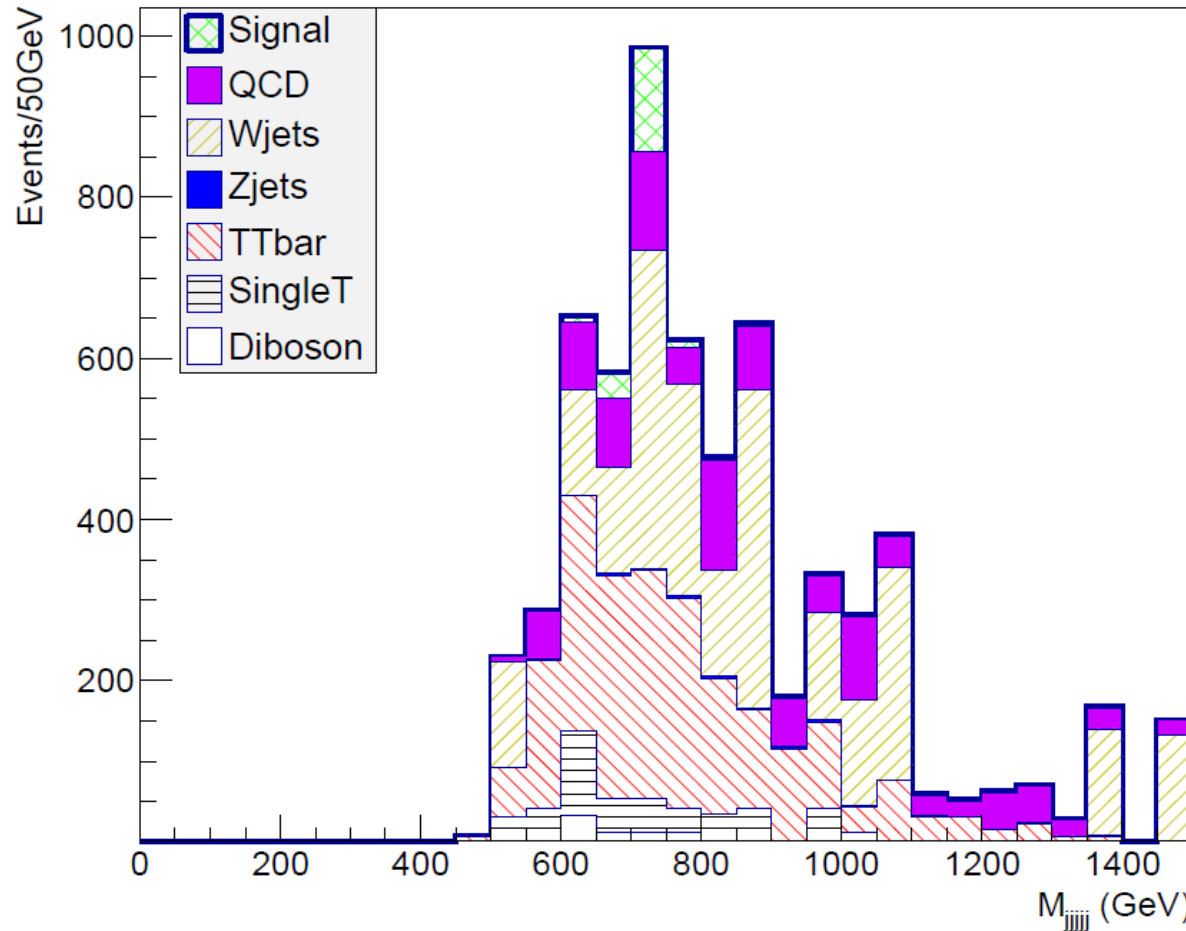
# Higgs mass



Higgs mass for backgrounds (stacked) and signal (superimposed).

# Five Jets Invariant Mass

Pheno

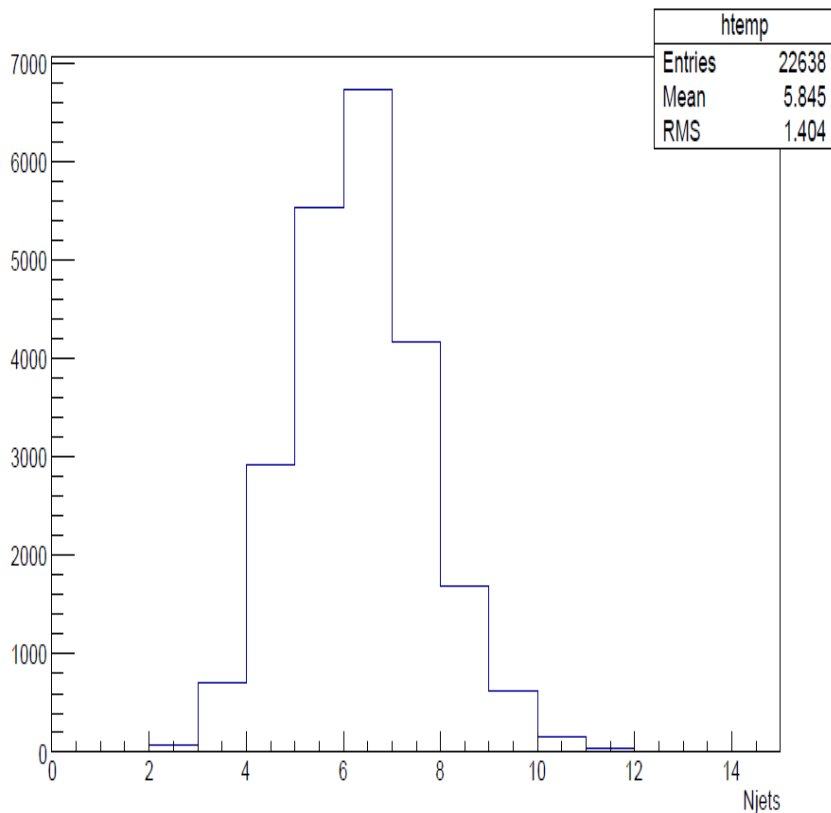


Five jets invariant mass for backgrounds and signal (stacked) after full event selection.

J. Ruiz-Alvarez et al.  
arXiv: 1401.5979

$$\frac{S}{\sqrt{S+B}} = 3.04 \pm 0.04, \quad \text{and} \quad \frac{S}{B} = 0.12 \pm 0.02$$

# Event selection – Jet association



- Only for jets inside the acceptance ( $pt > 30$  GeV,  $|\eta| < 2.5$ ).
  - Higgs reconstruction: From all pairs of b-tagged jets with  $\Delta R < 1.2$   
→ Choose pair with invariant mass closest to the Higgs.
  - W reconstruction: From all remaining pairs of jets within  $\Delta R < 3$   
→ Choose pair with invariant mass closest to the W.
  - Top reconstruction: From all possible triplets of jets with W jets and third b  
→ Choose triplet with invariant mass closest to the Top.
- 
- T' correctly tagged → 60% With respect to GEN events containing H, W and Top matched to RECO jets.