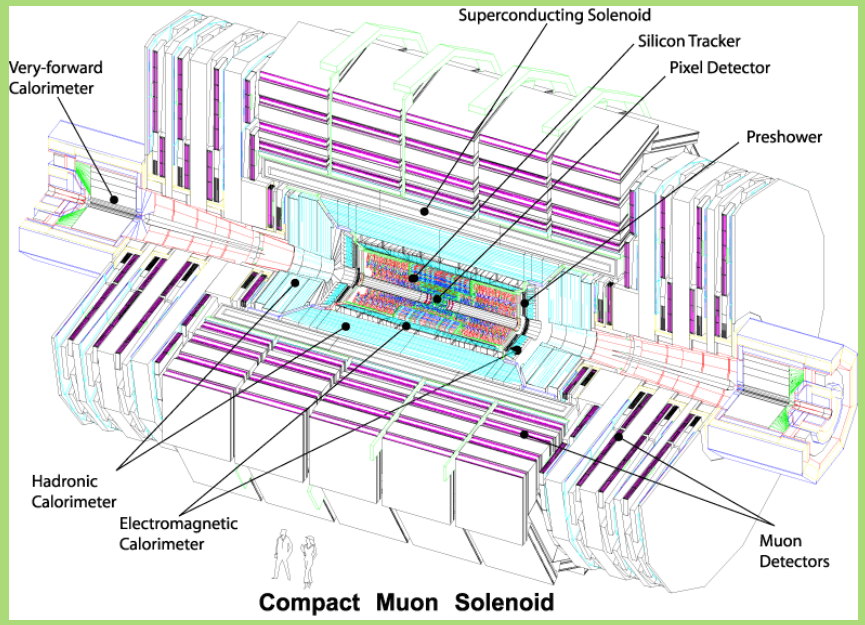
Search for a Fourth Generation t' Quark via Wb Decays into a Lepton Plus Jets Final State

C.M. Jenkins
Department of Physics University of South Alabama

for CMS

This work supported in part by DoE Grant DE-FG02-96ER4097

CMS Detector



- **Si Tracker**
- **EM Calorimeter**
- **Hadronic Calorimeter**
- **Muon Detection**
  - **21 m long, 15 m Diameter**
  - **3.8 T Solenoid**

- CMS is a multi-purpose detector located at the Large Hadron Collider (LHC) at CERN
- Currently observing 7 TeV center of mass pp collisions.
- Searching for
  - Higgs
  - SUSY
  - Compositeness
  - Extra dimensions
  - **Extensions to Standard Model**
  - etc.

Motivation

- Search for massive top-like quarks (t'): 4th Generation.
- Current number of generations set by $Z^o \rightarrow \nu\bar{\nu}$ width.
- Extra generations allowed if $m_{\nu(4)} > m_Z/2$
  - $m_{t'} - m_{b'} < m_W$
  - So $t' \rightarrow Wb$
  - This analysis is sensitive to chiral or vector t'.
- $pp \rightarrow t'\bar{t}' \rightarrow (Wb)(Wb) \rightarrow (l\ \nu\ b)\ (q\ \bar{q}\ b)$
  - $pp \rightarrow l\ \nu$ + 4 jets
    - Electron + 4 jets +MET final state: 537 pb^{-1}
    - Muon + 4 jets +MET final state: 821 pb^{-1}

CMS PAS EXO-11-051: http://cdsweb.cern.ch/record/1369546/files/EXO-11-051-pas.pdf
S Khalil, et al.:http://cdsagenda5.ictp.trieste.it/full_display.php?email=0&ida=a10168

Event Selection

- Number of good interaction vertices ≥ 1

- e + jets:
- P_T > 30, 35, 45 GeV
  - match trigger threshold
- $|\eta| < 2.1$

- μ + jets:
- P_T > 35 GeV
  - match trigger threshold
- $|\eta| < 2.5$

- Missing E_T > 20 GeV
- Number of Jets ≥ 4
- P_T for leading jets> 120, 90 GeV, 35 GeV, 35 GeV
- $|\eta| < 2.5$
- Lepton-jet separation: ΔR (l,jet) > 0.3

Event Yields (lumi)

- Observed and expected yields for standard model.

Process	Cross section	e+jets events	μ+jets events
$\mathcal{L}$		537 pb^{-1}	821 pb^{-1}
Data		520	1054
$t\bar{t}$	158 pb	456 ± 91	907 ± 114
Single t	33 pb	14.5 ± 3.5	30 ± 6
W+jets	30 μb	33.3± 8.2	106 ± 25
Z+jets	2.9 μb	4.5 ± 1.2	2.6 ± 2.6
WW, WZ, ZZ	67 pb		2.1 ± 0.6
multijets		2.5 ± 1.2	5.7 ± 5.5
Total background		510 ± 103	1054 ± 145
CMS Preliminary			

- Efficiencies for t't̄' signals including branching ratio into lepton+jets final state.

Process	Cross Section	e+jets eff	μ+jets eff
$t'\bar{t}'$			
$m_{t'}$ = 350 GeV	3.20 pb	3.7 ± 0.4 %	4.5 ± 0.3 %
$m_{t'}$ = 400 GeV	1.41 pb	4.3 ± 0.4 %	5.2 ± 0.4 %
$m_{t'}$ = 450 GeV	0.66 pb	4.8 ± 0.4 %	5.6 ± 0.4 %
$m_{t'}$ = 500 GeV	0.33 pb	5.0 ± 0.4 %	5.8 ± 0.4 %
CMS Simulation			

- **Errors include uncertainties in the jet energy scale, lepton trigger selection, b-tagging, MC statistics.**
- **No uncertainties for cross section or integrated luminosity.**

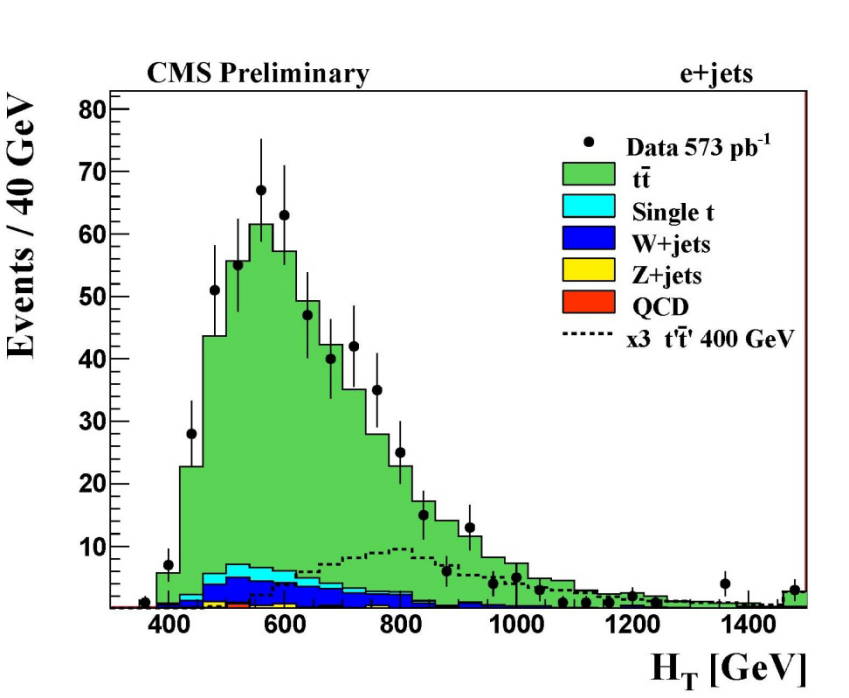
- **The background totals in agreement with observed number of events.**

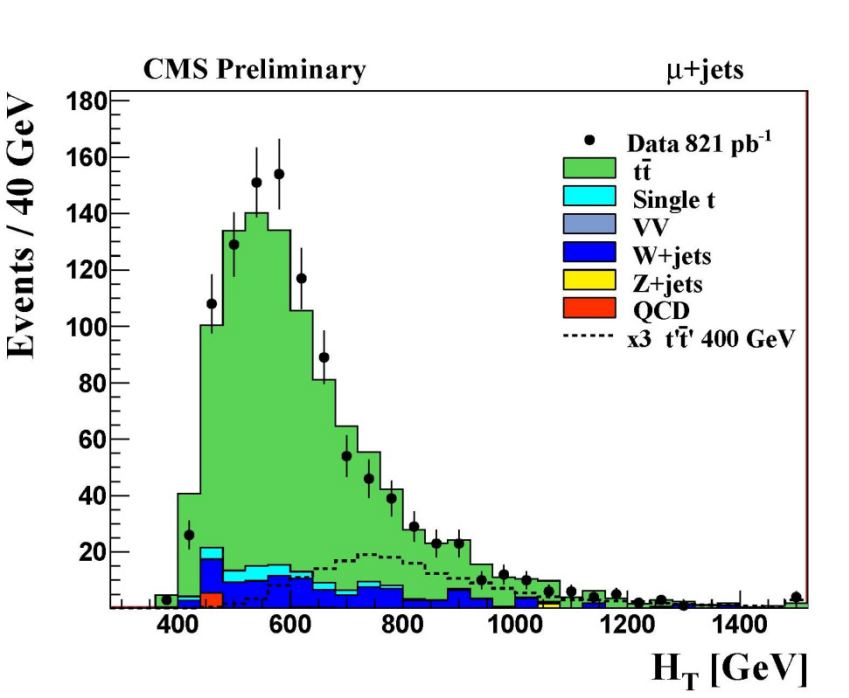
Scalar Transverse Energy

$$H_T = \sum P_T(Jets) + P_T(Lepton) + \not{E}_T$$

- H_T : scalar sum of transverse energy for e+jets
- Include backgrounds.
- Monte Carlo: $\sigma(t'\bar{t}')$ X 3 : $m_{t'}$ = 400 GeV (dotted line)

- H_T : scalar sum of transverse energy for μ+jets
- Include backgrounds
- Monte Carlo: $\sigma(t'\bar{t}')$ X 3: $m_{t'}$ = 400 GeV(dotted line)





Mass Reconstruction (m_{fit})

- Assign final state particles from decay to reconstructed objects
- Reconstructed objects: lepton, missing P_T, jets.
  - Constraints:
    - $m(l\nu) = M_W$,
    - $m(q\,\bar{q}) = M_W$
    - $m(l\nu b) = m(q\,\bar{q}\,b) = m_{fit}$
- Perform kinematic fit to improve mass resolution.

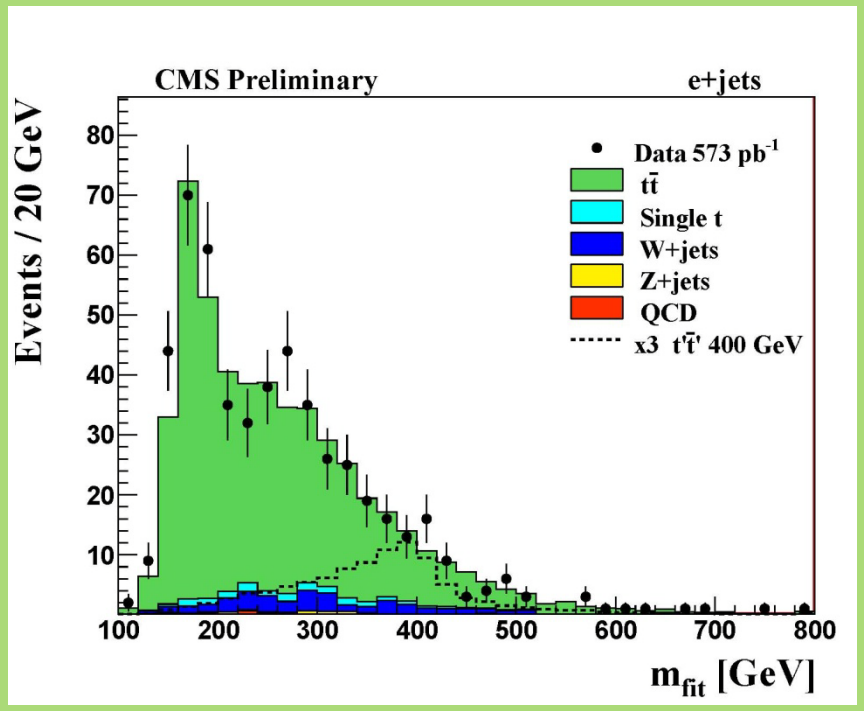
- **e + jets channel**
- Fit all 4 jet combinations from leading 5 jets
- Choose combination with smallest χ^2

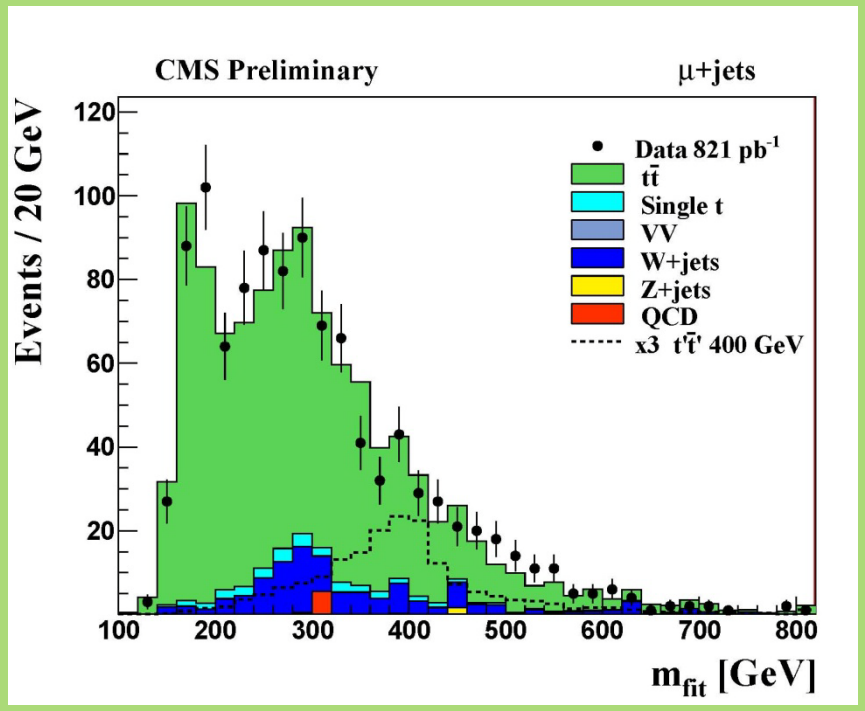
- **μ + jets channel**
- Fit leading 4 jets unless 5th leading jet is b tagged.
- Instead use 5th leading jet.

Reconstructed Mass

- e + jets data with backgrounds:
  - $t\bar{t}$, Single t , W + jets, Z + jets, QCD
- Monte Carlo: $\sigma(t'\bar{t}')$ X 3: $m_{t'} = 400$ GeV

- μ + jets data with backgrounds:
  - $t\bar{t}$, Single t , VV, W + jets, Z + jets, QCD
- Monte Carlo: $\sigma(t'\bar{t}')$ X 3: $m_{t'} = 400$ GeV

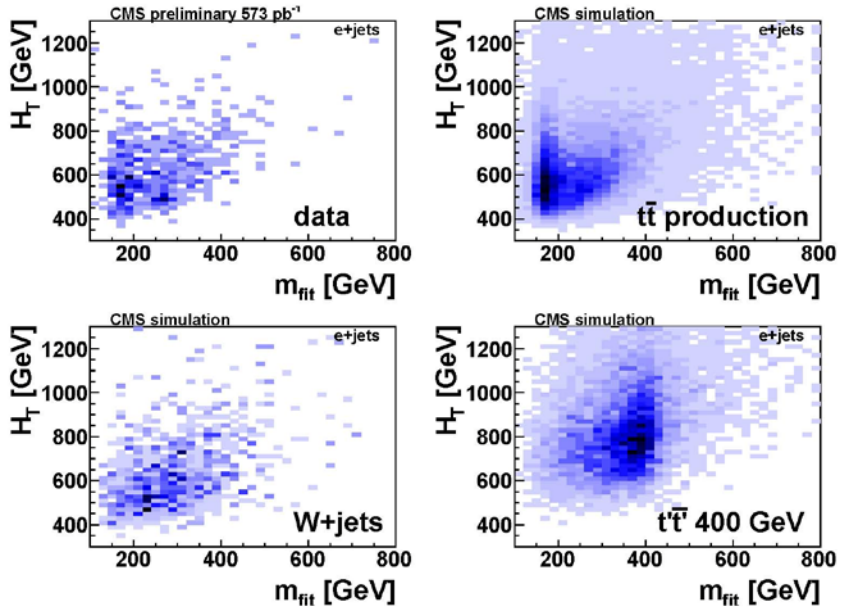




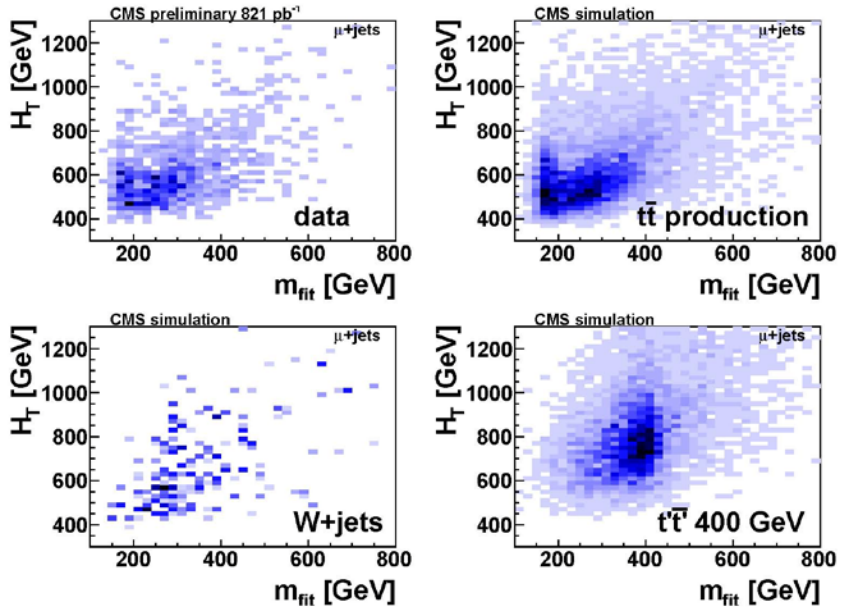
Isolate $t\bar{t}$ and W + Jet Background

- $t\bar{t}$ background irreducible from $t'\bar{t}'$ events.
- Mass difference of t and t' produce different kinematical distributions.
- Statistical separation of $t\bar{t}$ background.
- Also isolate events $t'\bar{t}'$ from W+jets background.
- Plot scalar transverse energy (H_T) vs. fitted mass (m_{fit}).

H_T vs. reconstructed mass for e + jets



H_T vs. reconstructed mass for μ + jets



Systematic Uncertainties

- $\sigma_{t\bar{t}}$= 158 pb ± 11%
- Number of electroweak background events
  - W+jets constrained to 1.5 times predicted value.
  - Other processes constrained to predicted values
  - 50% uncertainty to the sum of all electroweak backgrounds
- α_{jes} – jet energy scale calibration:
  - Affects H_T vs m_{fit} distributions
  - determined from jet-energy scale ± standard deviation.
  - Distributions for other values of α_{jes} determined from vertical morphing of H_T vs m_{fit} distributions
- ε_e: selection efficiency of e+jets events: 3%
- ε_μ: selection efficiency of μ+jets events: 3%
- ε_b: b-tagging efficiency: 5% in yield of $t\bar{t}$ and $t't'\bar{}$ events.
- $\mathcal{L}_{int}$ = ± 6%

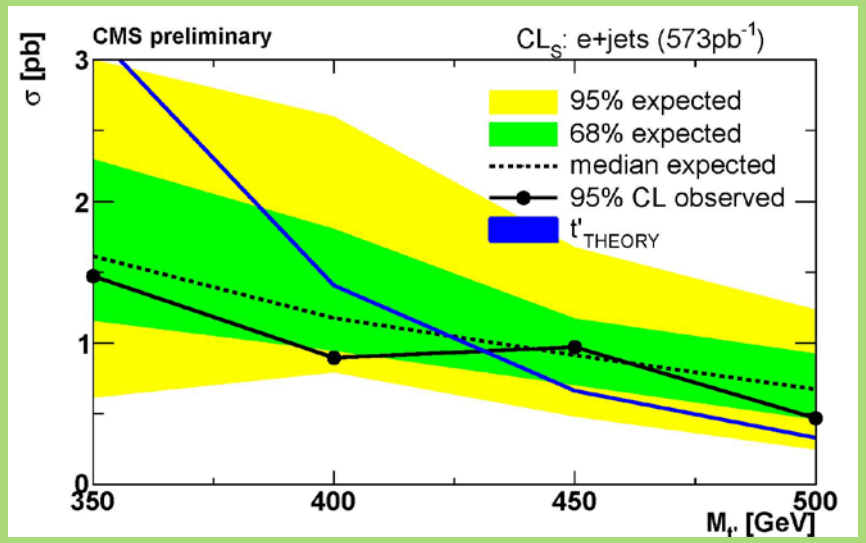
Systematic uncertainties small.

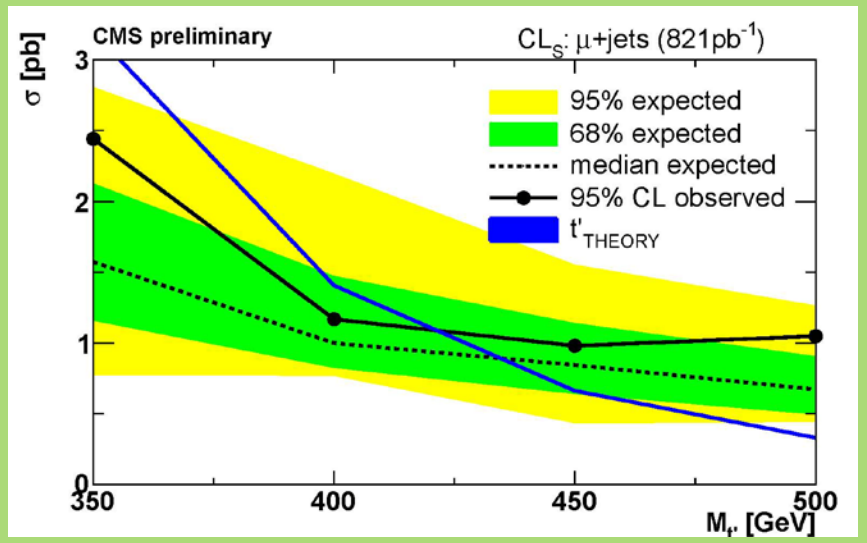
Limits for t' $\bar{t}$' Production

- Use CL_s method to establish the limit on the t' cross section.
- Probability calculated for likelihood L larger than observed likelihood L_{obs}
  - Generated 1000 pseudo experiments with background: probability: CL_b
  - Generated 1000 pseudo experiments with background and t' $\bar{t}$' signal with cross section σ: probability: CL_{s+b}

$$CL_s = \frac{CL_{s+b}}{CL_b} = 0.05$$

- e + jets: 573 pb^{-1}
- Exclude: $m_{t'} < 430$ GeV
- μ + jets: 821 pb^{-1}
- Exclude $m_{t'} < 420$ GeV





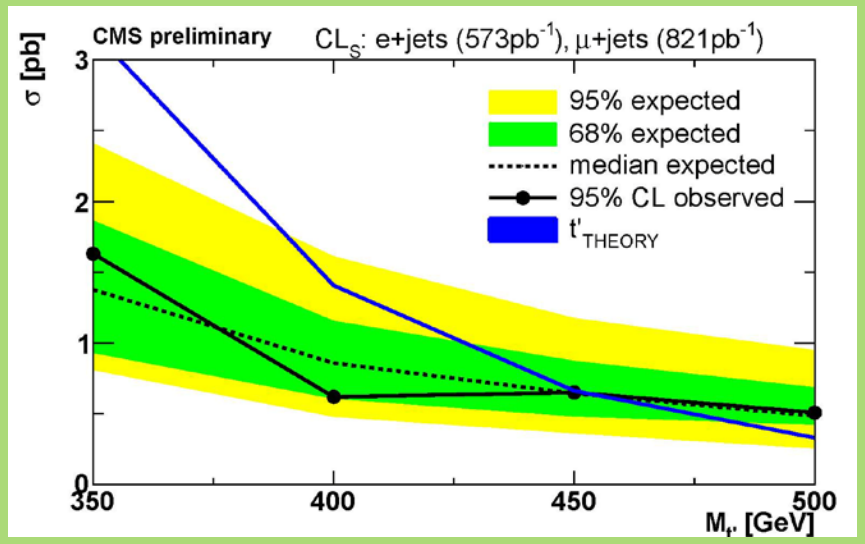
CMS PAS EXO-11-051: http://cdsweb.cern.ch/record/1369546/files/EXO-11-051-pas.pdf

Conclusions

Combined channels

t'$\bar{t}$'→WbWb→lν+4 jet

Exclude $m_{t'} < 450$ GeV (95 CL)



Future Plans

- Collect and analyze more data.
- CMS current delivered luminosity is 5 fb^{-1}.
- Search for other signals
  - b'→Wt Search
  - Third generation leptoquark.
  - Other searches.

CMS PAS EXO-11-051: http://cdsweb.cern.ch/record/1369546/files/EXO-11-051-pas.pdf