$t\bar{t}H$ at CDF and at the LHC

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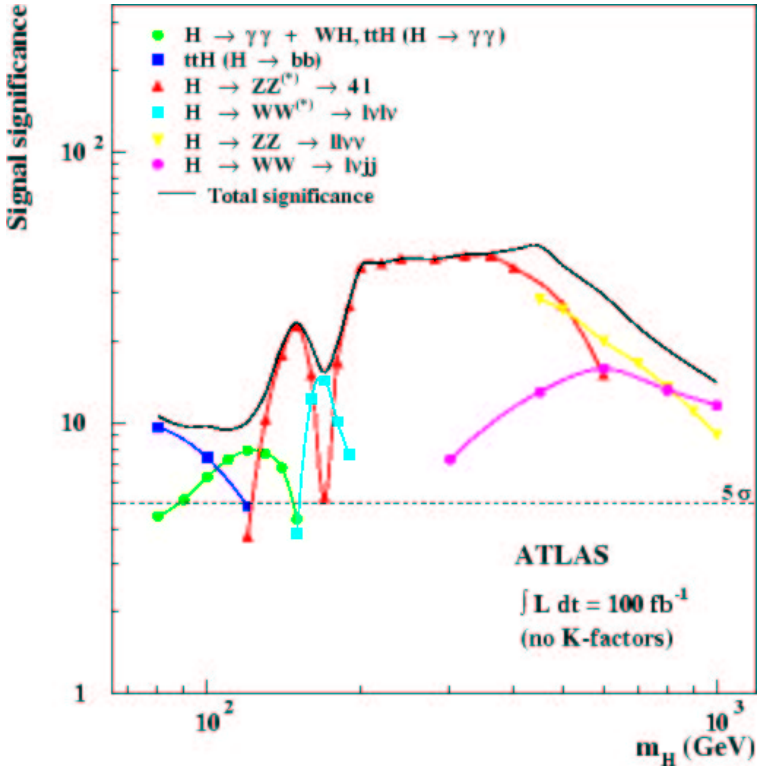
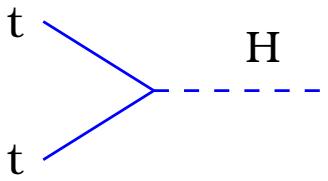
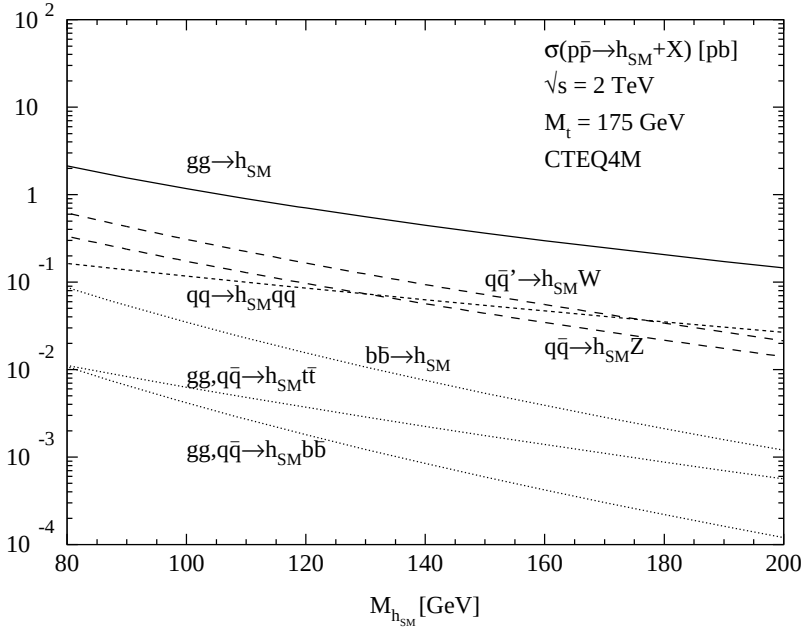
The $t\bar{t}H$ channel and ATLAS prospects

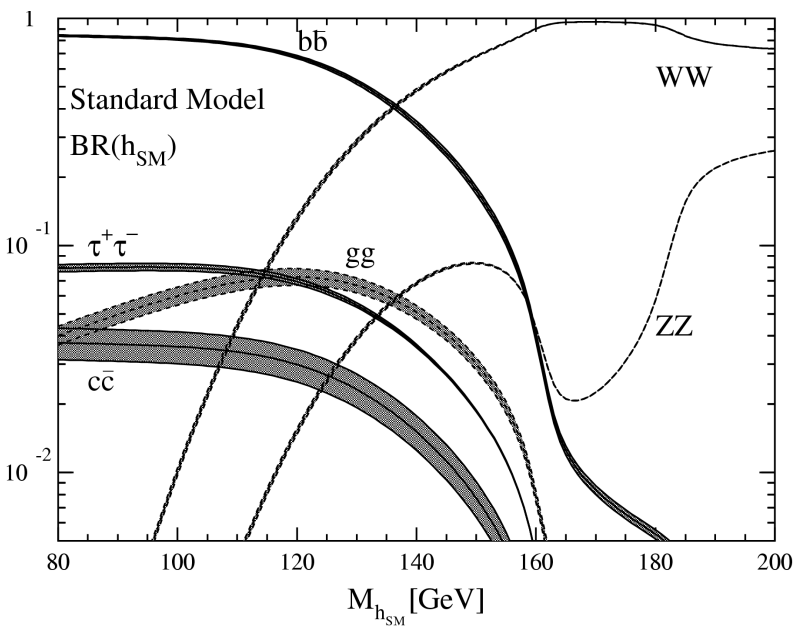




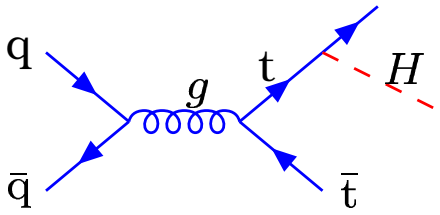
- $t\bar{t}H$ is plays a large role in the low mass Higgs range
- Dominant search channel to $m_H \sim 110$ GeV
- Plays a role out to $m_H \sim 125$ GeV
- Explores $H - t$ yukawa coupling at scale of EWSB
- Possible insights into mechanisms of particle mass generation

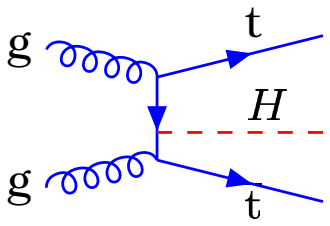
Higgs Production at the Tevatron and Decay

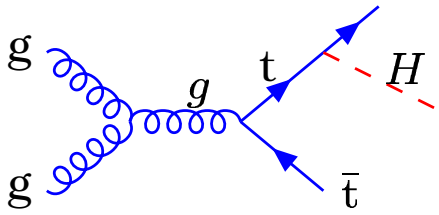




Leading Order Cross Sections for $t\bar{t}H$:





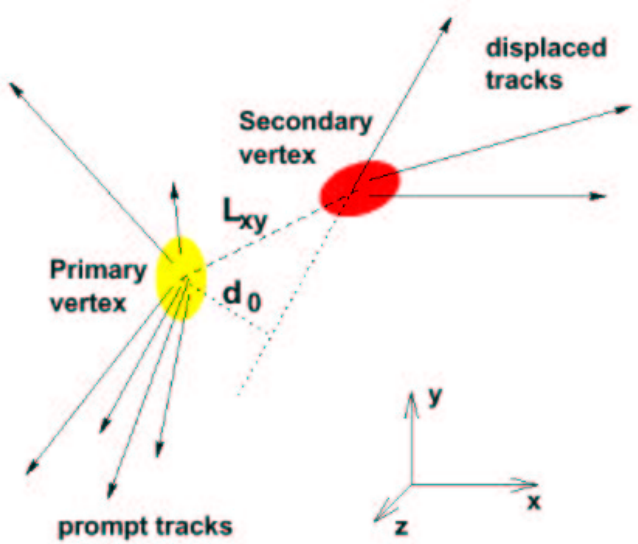


Event Selection for $t\bar{t}H$

For $m_H < 135$ GeV,
primary decay is $H \to b\bar{b}$

Look for signatures $W^+W^-b\bar{b}b\bar{b}$

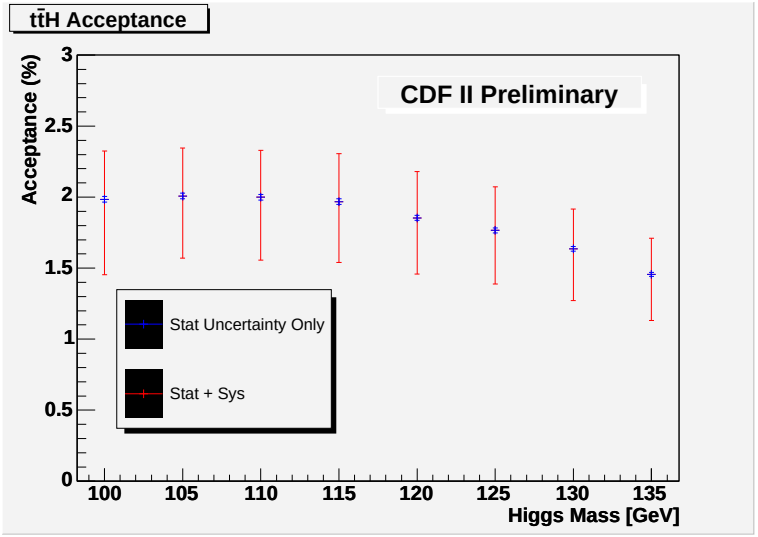
Event identification relies heavily on b-tagging

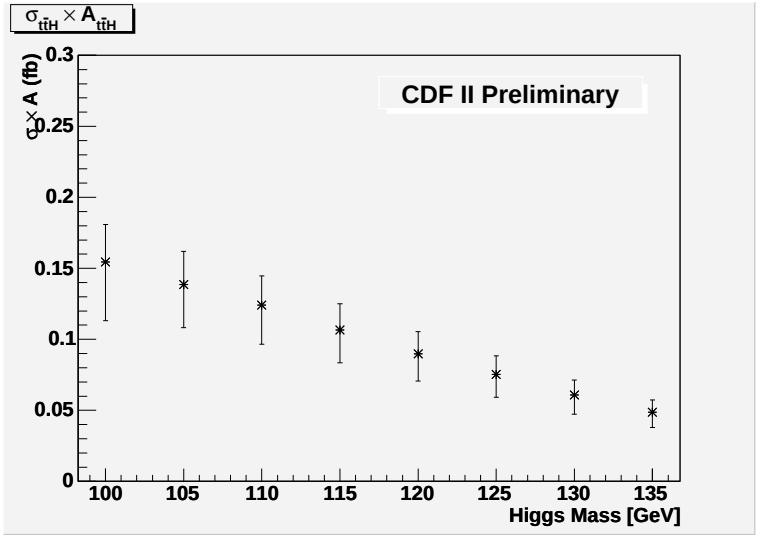


Event Selection:

- 1 identified electron or muon ($p_T > 20$ GeV)
- 4 or more jets ($E_T > 15$ GeV, $|\eta| < 2.0$)
- $\not\!\!E_T > 10$ GeV
- ≥ 3 jets that originate from Secondary Vertices

Detector Acceptance for $t\bar{t}H$





Acceptances calculated for inclusive $t\bar{t}H$ events

Systematic Uncertainties on the Acceptance

Source	Uncertainty (%)
Jet Energy Scale	1.3
PDF	0.5
ISR/FSR	5.9
MC Modelling	1.2
Lepton ID Efficiency	5.1
BTag Efficiency	17
MC Stats	1
Total	19

Backgrounds to worry about

Requiring 3 b-tags (secondary vertices) reduces backgrounds significantly

What backgrounds do we have to still evaluate? (CDF)

Background Source	Method
Misidentification of b-jets	Mistag Matrix
QCD (fake lepton)	Lepton Isolation vs $\not\!\!E_T$
$t\bar{t}b\bar{b}$, $Wb\bar{b}b\bar{b}$	MC and normalize to Mistag backgrounds
$t\bar{t}Z$	Monte Carlo

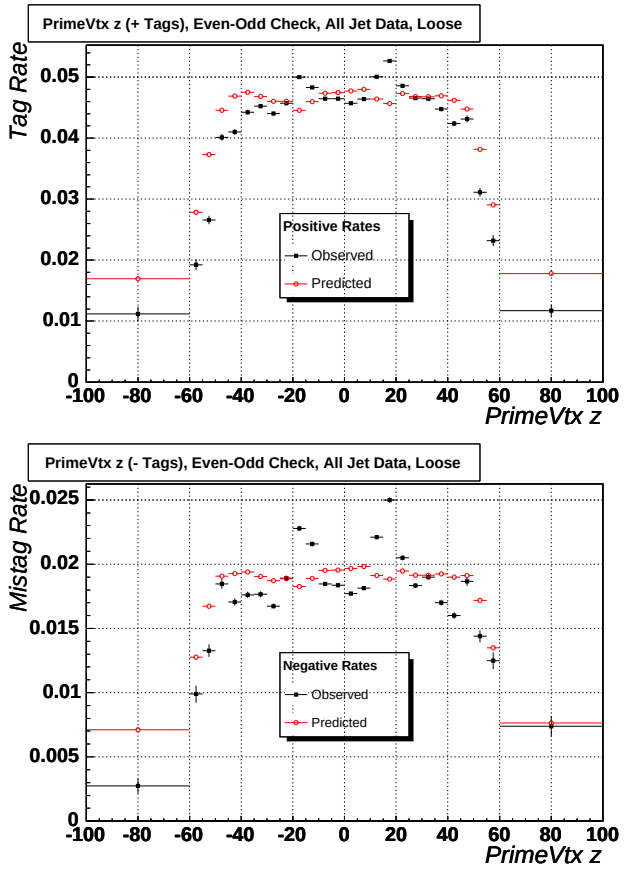
Misidentification of b-jets

Measure likelihood of mistag by forming secondary vertices with negative impact parameter tracks.

Use jet samples to construct probability of mistag as function of 5 variables:

- jet E_T
- jet η
- jet ϕ
- jet n_{tracks}
- event $\Sigma_{jet} E_T$

Matrix has a prediction uncertainty of 6%



Checks on Control Sample

Mistag Matrix used primarily for single fake tag predictions, but it works for multi-tags too!

Electrons	Predicted	Observed
$-$	881	879
$--$	2.94	3
$---$	0.01	0
$+-$	21.2	21
$+--$	0.16	0
$++-$	1.38	2

Muons	Predicted	Observed
$-$	298	279
$--$	1.24	2
$---$	0.007	0
$+-$	10.4	5
$+--$	0.12	0
$++-$	1.38	0

Signal sample mistag background (320 pb^{-1})

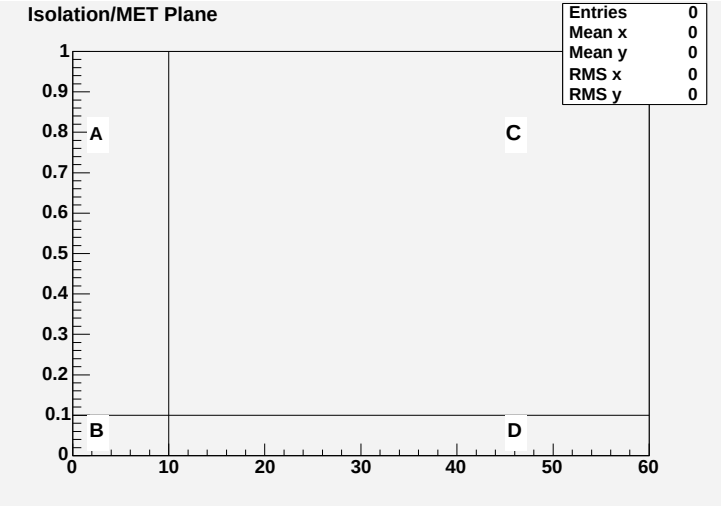
Electrons: 1.12 ± 0.17 , Muons: 1.56 ± 0.18 events

QCD Backgrounds

Standard Isol vs Met Technique:

$$\text{QCD}_D = \frac{N_B \times N_C}{N_A}$$

Assumes QCD events populate A:B in same ratio as C:D



We use the mistag matrix to predict the number of triple tag events in regions A, B, C (due to low event yields)

QCD contribution to signal region is negligible: $(4.1 \pm 0.7) \times 10^{-4}$ events (320 pb^{-1})

(This is $\simeq$ 100 lower than the signal rate)

First Glance at Other Backgrounds

Compute acceptance ratios of $t\bar{t}b\bar{b}$ to $t\bar{t}+jj$ and $t\bar{t}$ (MC)

Normalize background estimate to the mistag evaluation (data)

Topology	Acceptance (%)	Cross Section (fb)	Events per fb^{-1}
$t\bar{t}$	0.118	6700	7.9
$t\bar{t}+jj$	0.219	1000	2.19
$t\bar{t}b\bar{b}$	0.764	27	0.21

Ratio of event yields 0.021 (can normalize to mistag estimate)

Need to do the same exercise for W + jets events

Four b-jet tags?

Since dominant backgrounds come from misidentification of b-jets, should 4 b-tags be required?

Cuts sharply into signal at CDF, but with more data at LHC can afford stringent cuts

Assume $m_H = 115$ GeV

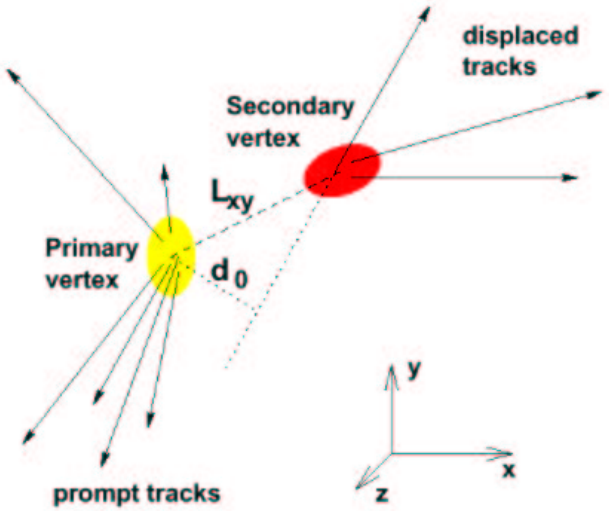
Tags Required	Signal/Mistag Background
3	0.0127
4	0.0256

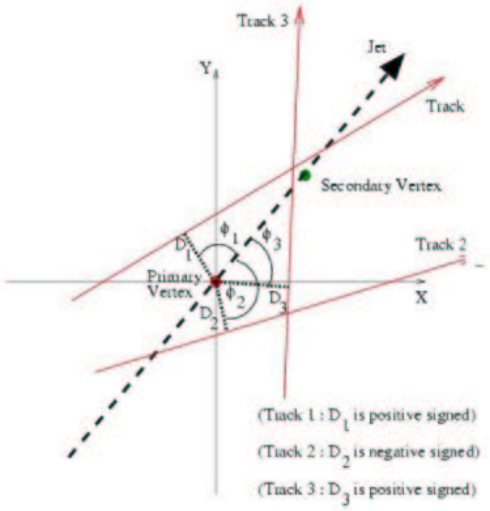
Signal falls by factor of ~ 5

Background falls by factor of ~ 11

Improvements to gain sensitivity

Combine tagging algorithms for greater b-tagging efficiency

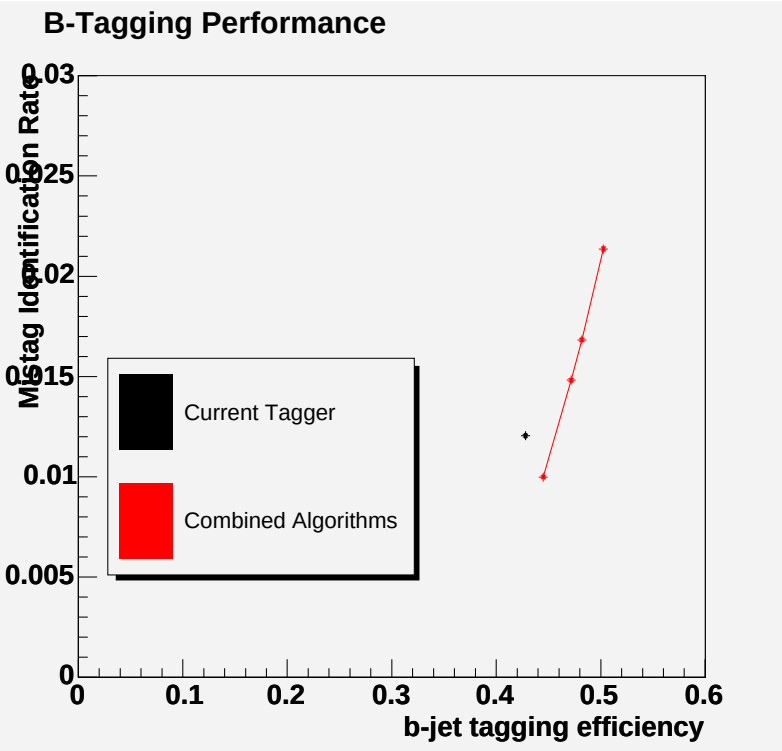


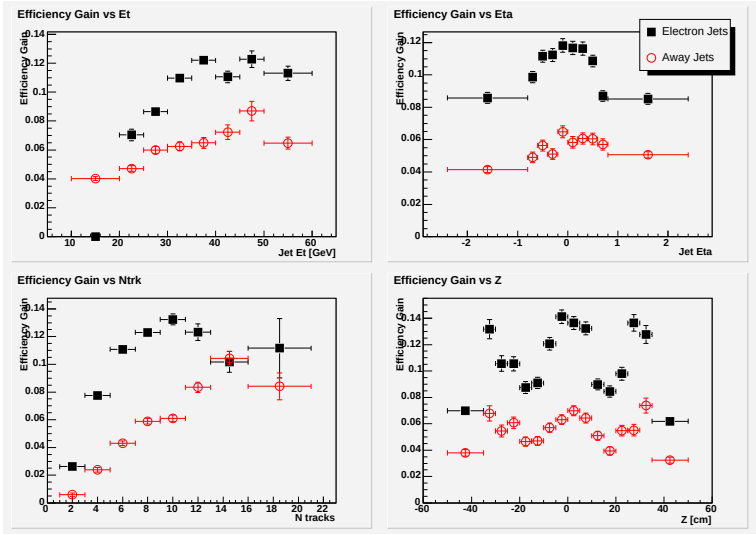


Use information from two b-tagging algorithms:

- SecVtx: Fits a displaced vertex using tracks with large impact parameters
- JetProb: Calculates probability a jet originates from a primary vertex using track impact parameter distributions

Improvements to gain sensitivity





Combining Taggers leads to better tagging performance

- b-tagging efficiency increases 5% per jet
- $t\bar{t}H$ event acceptance increases 15% per event
- Misidentification rate decreases 20% per jet

Summary

$t\bar{t}H$ at CDF

- Acceptances are of order 2% ($m_H = 115$ GeV)
- Event identification relies heavily on b-tagging
- Systematic Uncertainties dominated by uncertainty in b-tagging efficiency
- Misidenfication of b-jets dominates background
- b-tagging improvements a big win for this channel

$t\bar{t}H$ at LHC

- Higher cross-sections, luminosity make this an important search channel
- Tracking algorithms must be good to detect b-jets
- Requiring all 4 b-jets tagged may double S/B - reduce signal by factor of 5
- Interesting to explore the $t - H$ yukawa coupling at electroweak scale