Monte Carlo Studies of $p\bar{p} \to t\bar{t}H$ at CDF

Stan Lai

Outline:

- The Higgs Mechanism and EWSB
- Properties of the Higgs Boson
- The Channel $p\bar{p} \to t\bar{t}H$
- A look a $t\bar{t}H$ Simulation
- Conclusions and Outlook

Electroweak Symmetry Breaking and the Standard Model

The $SU(2)_L \times U(1)_Y$ Electroweak Lagrangian incorporates:

- Massless fermions
- Three massless $SU(2)$ and one massless $U(1)$ gauge bosons

EWSB introduced with 4 self-interacting scalar fields:

$\phi = \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix}$ with vacuum expectation value $\phi_0 = \sqrt{\frac{1}{2}} \begin{pmatrix} 0 \\ v \end{pmatrix}$

Via the Higgs mechanism, 3 degrees of freedom from scalar fields give mass to $W^\pm$ and Z^0 bosons

Remaining degree of freedom: The Higgs Boson

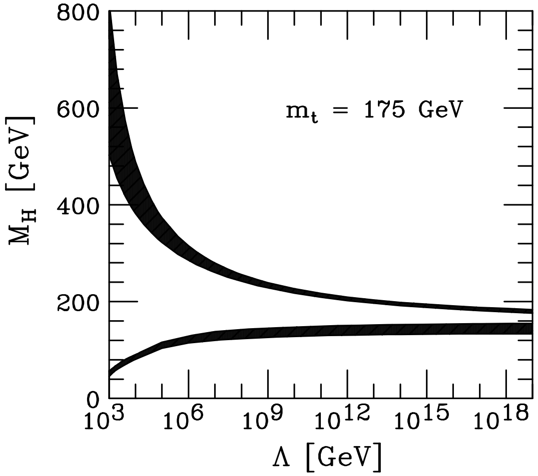
Fermions also gain mass through coupling with Higgs field.

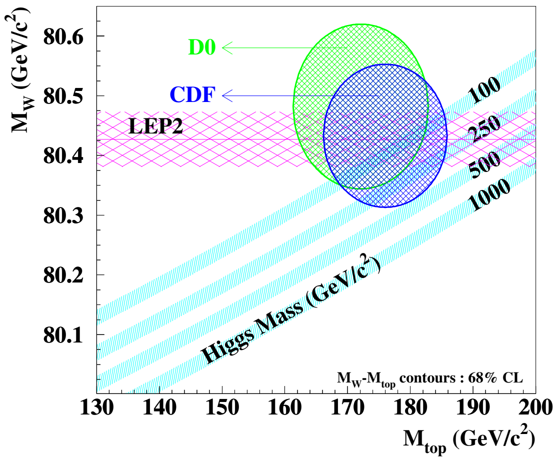
Higgs Mass is Sensitive to m_W, m_t and New Physics

No direct prediction of m_H in the Standard Model

Electroweak fits and sensitivity to new physics constrain m_H

(Direct searches also rule out $m_H < 114$ GeV at 95% C.L.)





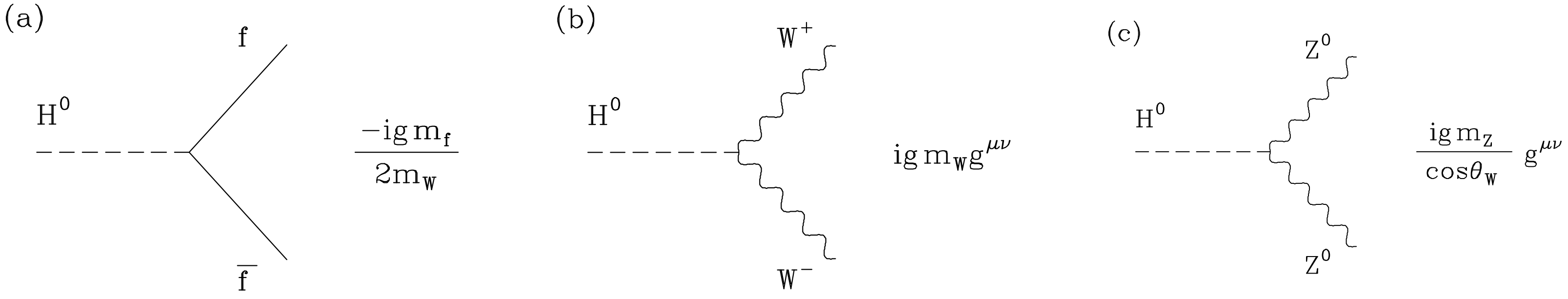
Upper bound on m_H: Higgs self-coupling becomes non-perturbative

Lower bound on m_H: Electroweak Minimum unstable

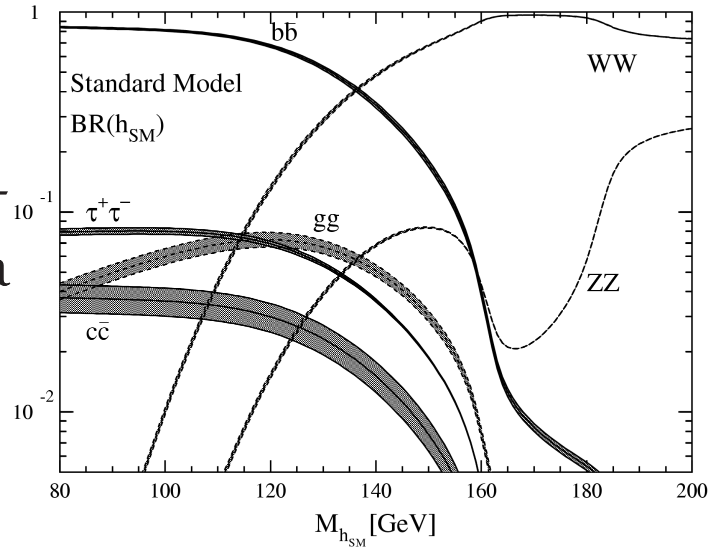
Constraints via m_W, m_t: Corrections to masses dependent logarithmically on m_H

Standard Model Higgs Couplings

Standard Model particles couple to Higgs with strength proportional to their mass

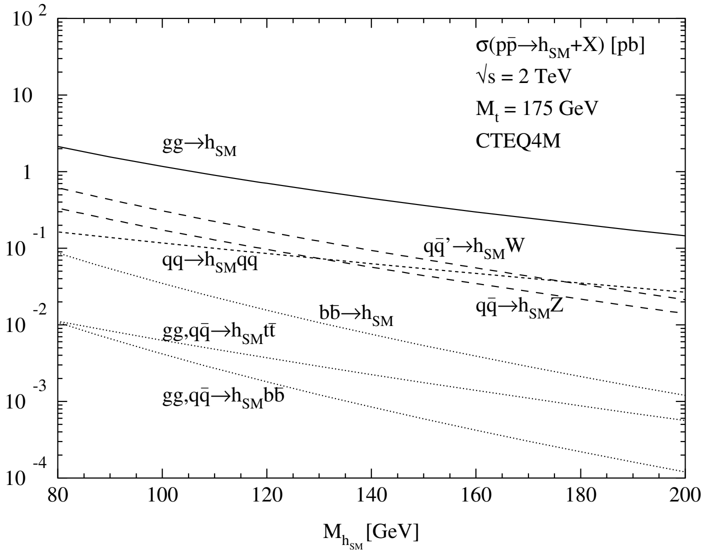


Branching ratios of Higgs decays can be predicted as a function of Higgs mass



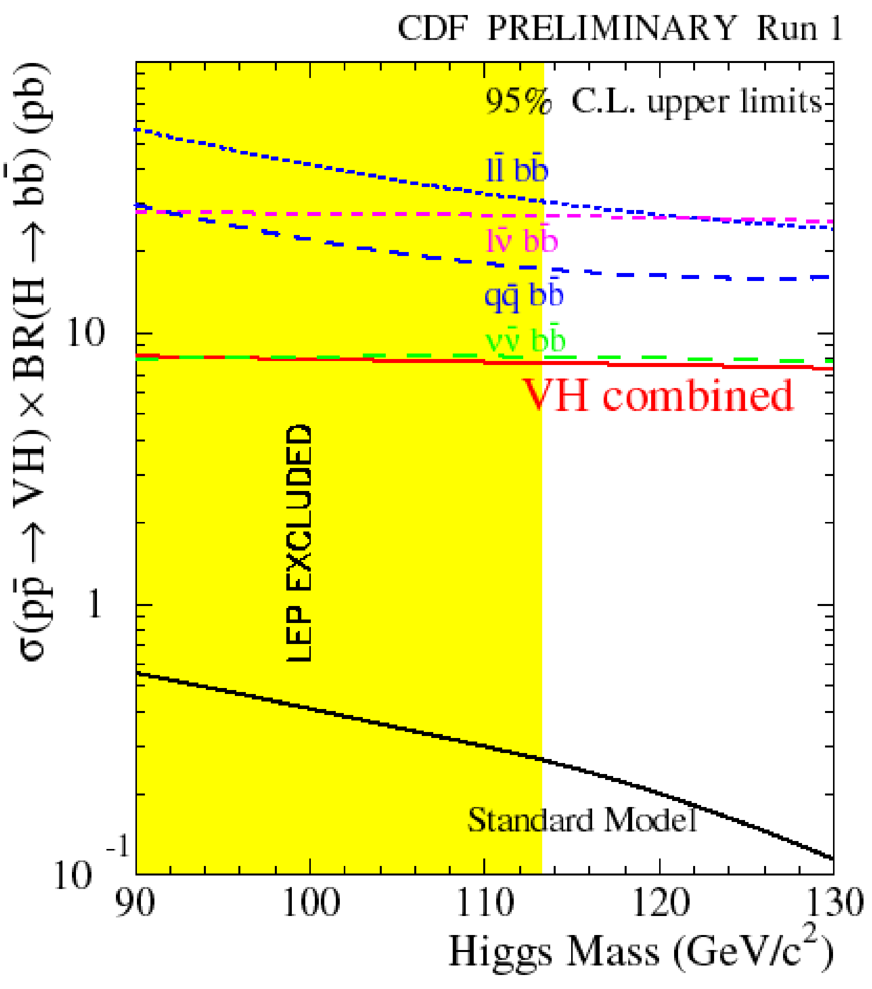
Higgs Production at the Tevatron

Production Cross Sections in $p\bar{p}$ Collisions at $E_{CM} = 2.0$ TeV



- Direct production $gg \to H \to b\bar{b}$ most copious channel, but swamped by QCD dijet background
- Promising channels involve associated production with $W^{\pm}, Z^0$
- The channel $t\bar{t}H$ worth investigating despite low cross section

Run I CDF Limit on Higgs Cross Section

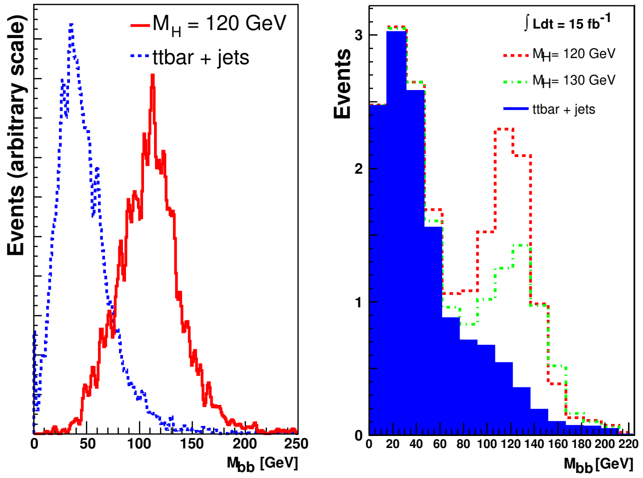


Primary Backgrounds $p\bar{p} \to t\bar{t}H$

Process	Cross Section (fb)	Process	Cross Section (fb)
$t\bar{t} + jj$	1030	$t\bar{t} + jj$	1030
$t\bar{t} + b\bar{b}$	27	$t\bar{t} + W$	17
$t\bar{t} + Z$	9.9	$t\bar{t} + Z$	8.9
$WZ + jj$	300		

The Channel $p\bar{p} \to t\bar{t}H$

- First look at $t\bar{t}H$ for Tevatron energies in Goldstein *et al.* PRL **86** 1694 (2001).
- For $m_H < 135$ GeV, signature given by $W^+W^-b\bar{b}b\bar{b}$.



- Advantage: Distinctive signature allows for better S/B ratio
- Disadvantage: Cross section $\sigma_{t\bar{t}H} = 4.8$ fb for $m_H = 120$ GeV

Monte Carlo Samples

Used CompHep V. 41.10 to generate 4000 events each:

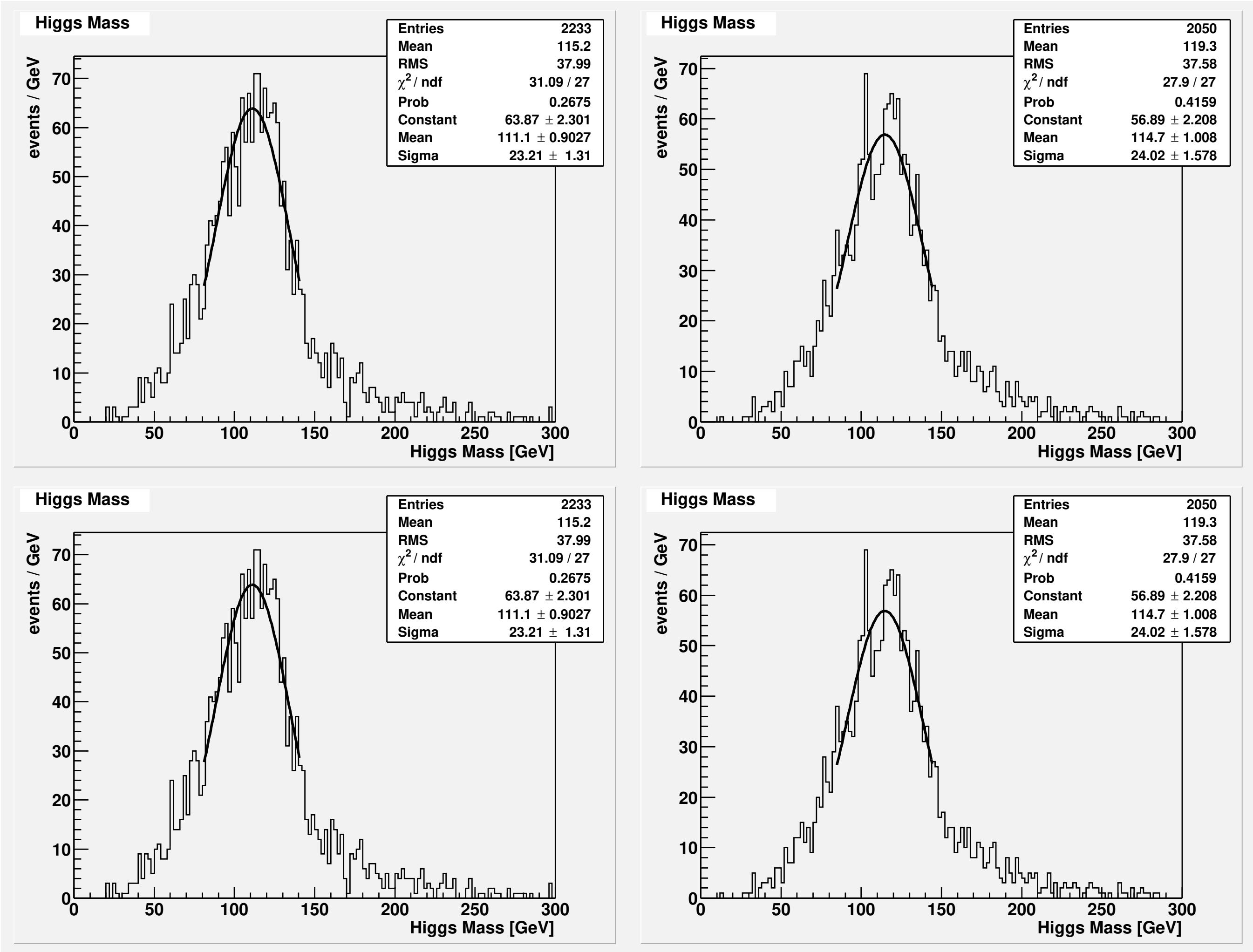
- $t\bar{t}H$ for $m_H = 110, 115, 120, 125$ GeV
- $t\bar{t}$, $t\bar{t}Z$, $t\bar{t}b\bar{b}$, $t\bar{t}c\bar{c}$

Fragmentation done by Pythia 6.2

CDF Simulation and Reconstruction using RunMC V.11

Ntuple created using TopFind

A Look at $b\bar{b}$ Invariant Mass Resolution



Preliminary Selection Criteria

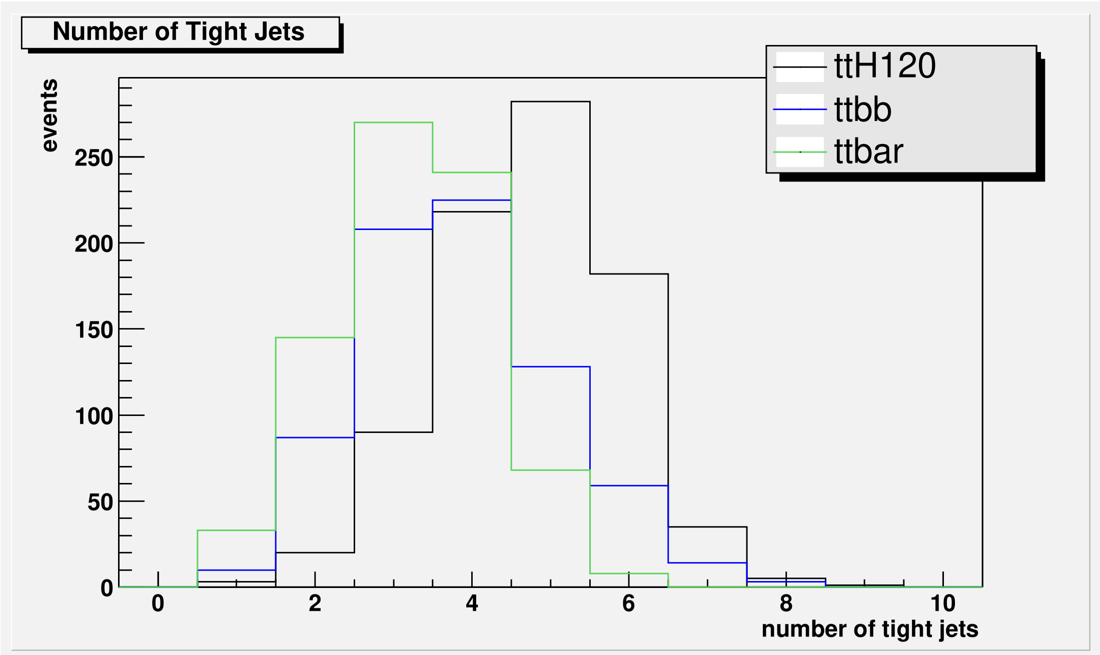
Start with some naïve criteria:

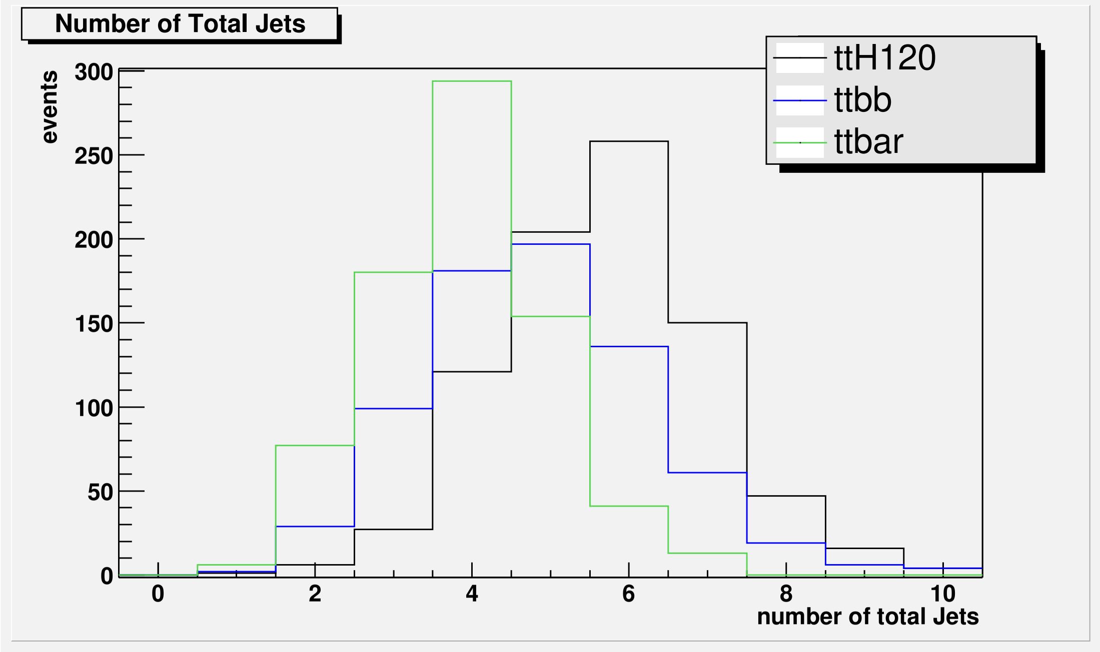
- 1 tight lepton
- $\not{E}_T > 15$ GeV
- # of tight jets between 5 and 8 or # of total jets between 6 and 9

Look at quantities such as:

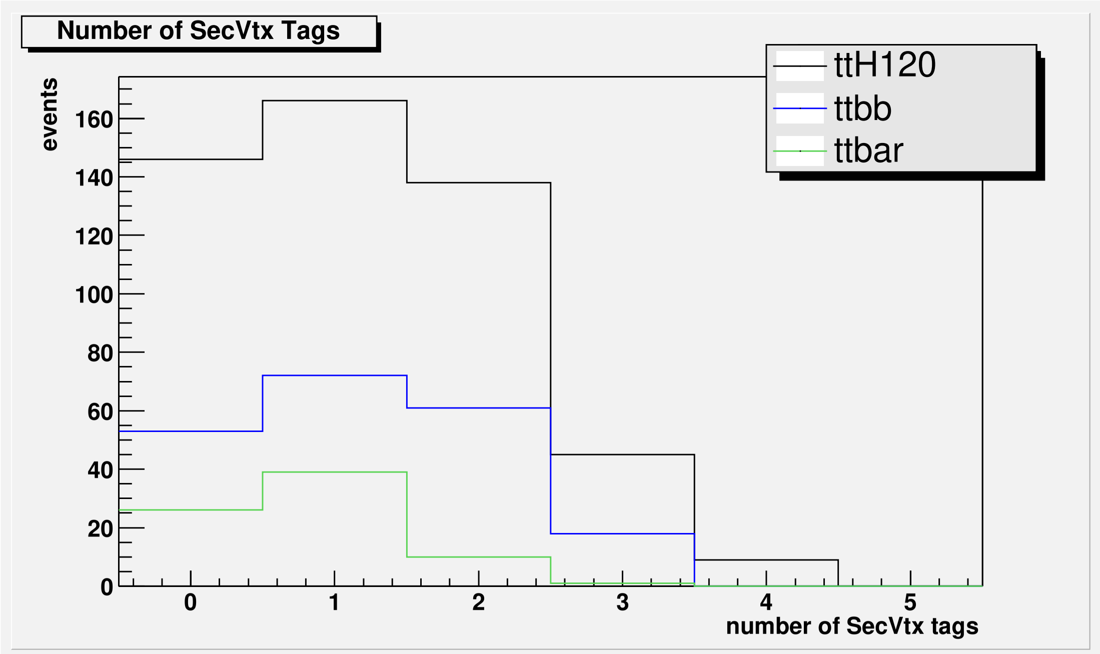
- jet multiplicity
- total jet transverse energy J_T
- tag multiplicity
- $b\bar{b}$ invariant mass

Jet Multiplicity





SecVtx Tags



Number of SecVtx Tags
events
ttH120
ttbb
ttbar
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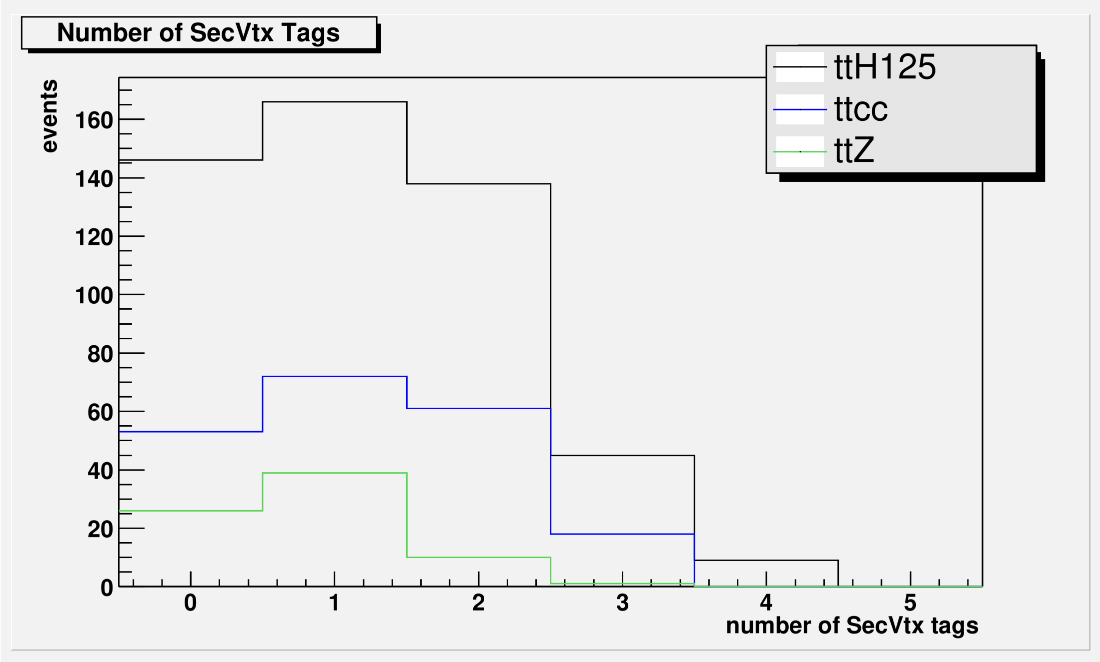
40
60
80
100
120
140
160
0
1
2
3
4
5
number of SecVtx tags



Number of SecVtx Tags
events
ttH125
ttcc
ttZ
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40
60
80
100
120
140
160
0
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2
3
4
5
number of SecVtx tags