Light Charged Higgs Discovery Potential of CMS in the $H^{\pm} \to \tau\nu$ Decay

A. Nikitenko,

Imperial College,

London

M. Hashemi,

IPM & Sharif Univ. of Tech.

Tehran

Outline:

- Signal and background identification
- Signal selection strategy
- Selection cuts and their efficiencies
- Systematic uncertainties
- Discovery contour

Signal:

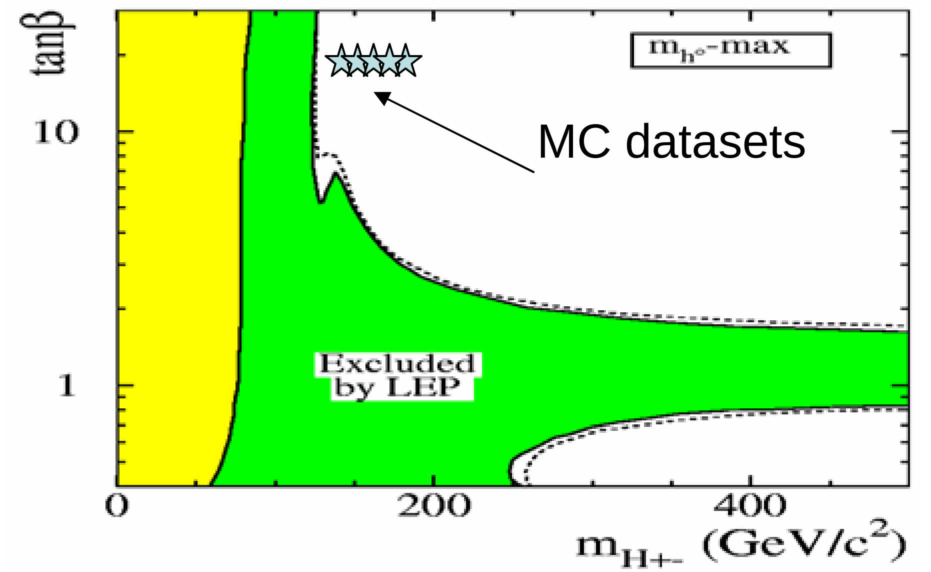
m(H+)<170GeV

$$gg \to t\bar{t} \to W^{\pm}H^{\mp}b\bar{b} \to \ell\,\nu\tau\nu\,b\bar{b}$$

$\ell = e \;\; or \;\; \mu$

m(H+)>=170GeV

$$gb \to tH^{\pm},\; gg \to tbH^{\pm}$$



CERN

Background:

$$pp \to t\bar{t} \to W^{+}W^{-}b\bar{b}\;,\; W^{+} \to \tau^{+}\nu_{\tau}\;,\; W^{-} \to \ell\,\nu$$

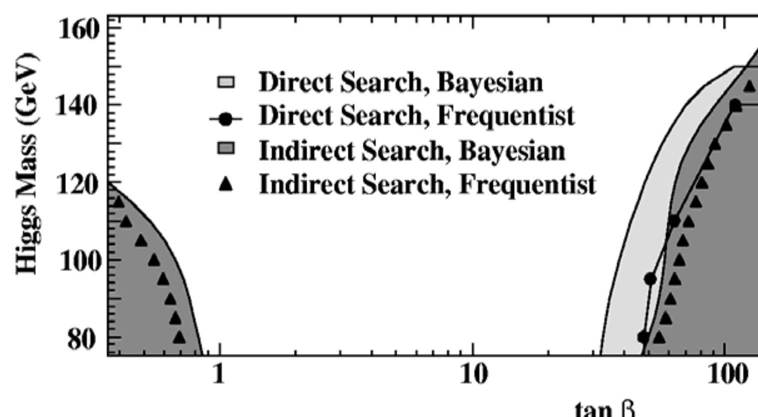
$$pp \to t\bar{t} \to W^{+}W^{-}b\bar{b}\;,\; W^{+} \to jj\;,\; W^{-} \to \ell\,\nu$$

$$pp \to t\bar{t} \to W^{+}W^{-}b\bar{b}\;,\; W^{+} \to \ell\,\nu\;,\; W^{-} \to \ell'\,\nu$$

$$W + 3\;jets\;,\; W \to \ell\,\nu$$

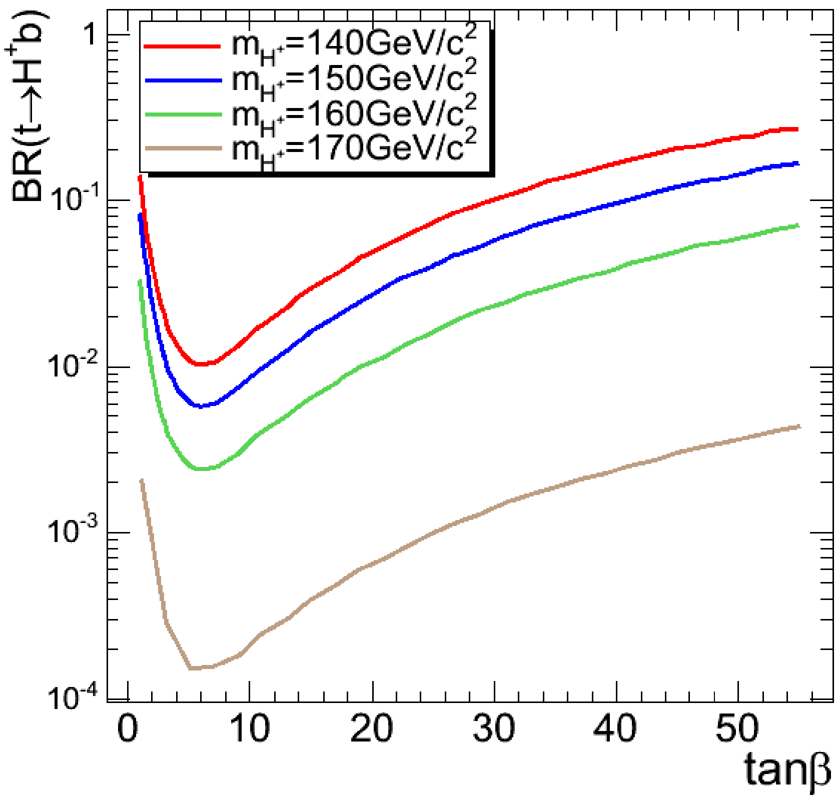
$$Wt\;,\; W_1 \to \ell\,\nu, W_2 \to \tau\nu \;\; or \;\; jj$$

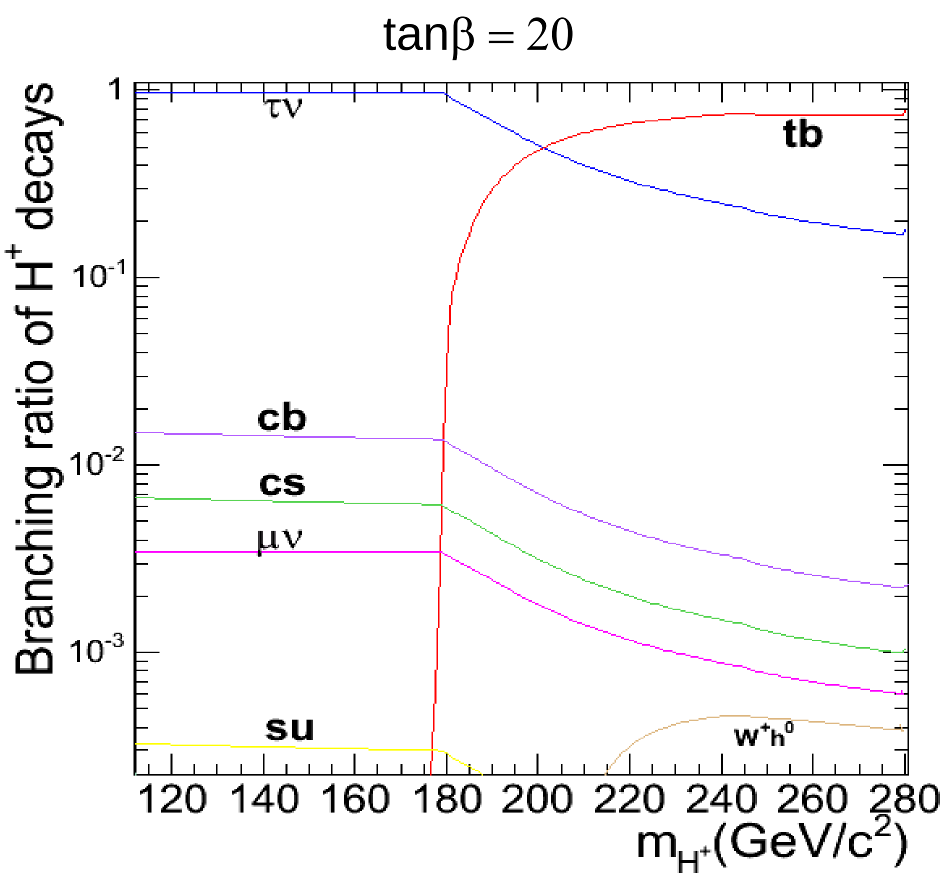
$$tq + t\bar{b}\;,\; t \to Wb \to \ell\,\nu b$$



Fermilab

Branching Ratios





Branching ratio of top decay to charged Higgs depends on tanβ as well as $m_{(H+)}$

Branching ratio of charged Higgs decay to tau depends on m(H+), almost independent of tanβ

Signal and Background Cross sections

Process	$t\bar{t} \to H^{\pm}W^{\mp}bb$ $m_{(H^{\pm})}=140GeV$	$t\bar{t} \to H^{\pm}W^{\mp}bb$ $m_{(H^{\pm})}=150GeV$	$t\bar{t} \to H^{\pm}W^{\mp}bb$ $m_{(H^{\pm})}=160GeV$	$t\bar{t} \to H^{\pm}W^{\mp}bb$ $m_{(H^{\pm})}=170GeV$
Cross section x BR [pb]	10.70	5.06	1.83	0.16

Process	$gb \to tH^{\pm}$ $m_{(H^{\pm})}=170GeV$	$gg \to tbH^{\pm}$ $m_{(H^{\pm})}=170GeV$
Cross section x BR [pb]	0.14	0.3

Process	$t\bar{t} \to W^{\pm}W^{\mp}b\bar{b} \to \ell\nu_{\ell}\tau\nu_{\tau}b\bar{b}$	$t\bar{t} \to W^{\pm}W^{\mp}b\bar{b} \to \ell\nu_{\ell}\ell'\nu_{\ell'}b\bar{b}$	$t\bar{t} \to W^{\pm}W^{\mp}b\bar{b} \to \ell\nu_{\ell}jjb\bar{b}$	$W^{\pm}+3j$ $W^{\pm} \to \ell\nu_{\ell}$
Cross section x BR [pb]	25.8	39.7	245.6	840

Search strategy, selection chain

- ❑Search strategy is based on looking for excess of events over SM expectation :

$$\sigma = \frac{N_{obs.}^{MSSM} - N_{B}^{SM}}{\sqrt{N_{B}^{SM}}}$$

Signal events are reconstructed and identified as the following:

- ❑A single lepton should be in the event,
- ❑ >=3 jets are required with Et > 40GeV,
- ❑1 bjet is required with Et > 40GeV,
- ❑1 tau should be in the event,
- ❑Lepton charge+ tau charge=0
- ❑Missing Et >70GeV

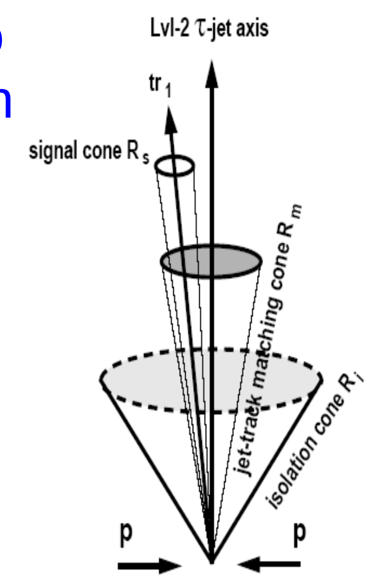
Offline tau selection

The hadronic decay of tau leptons is considered in this analysis, so we have a tau jet in the event which is identified offline as the following:

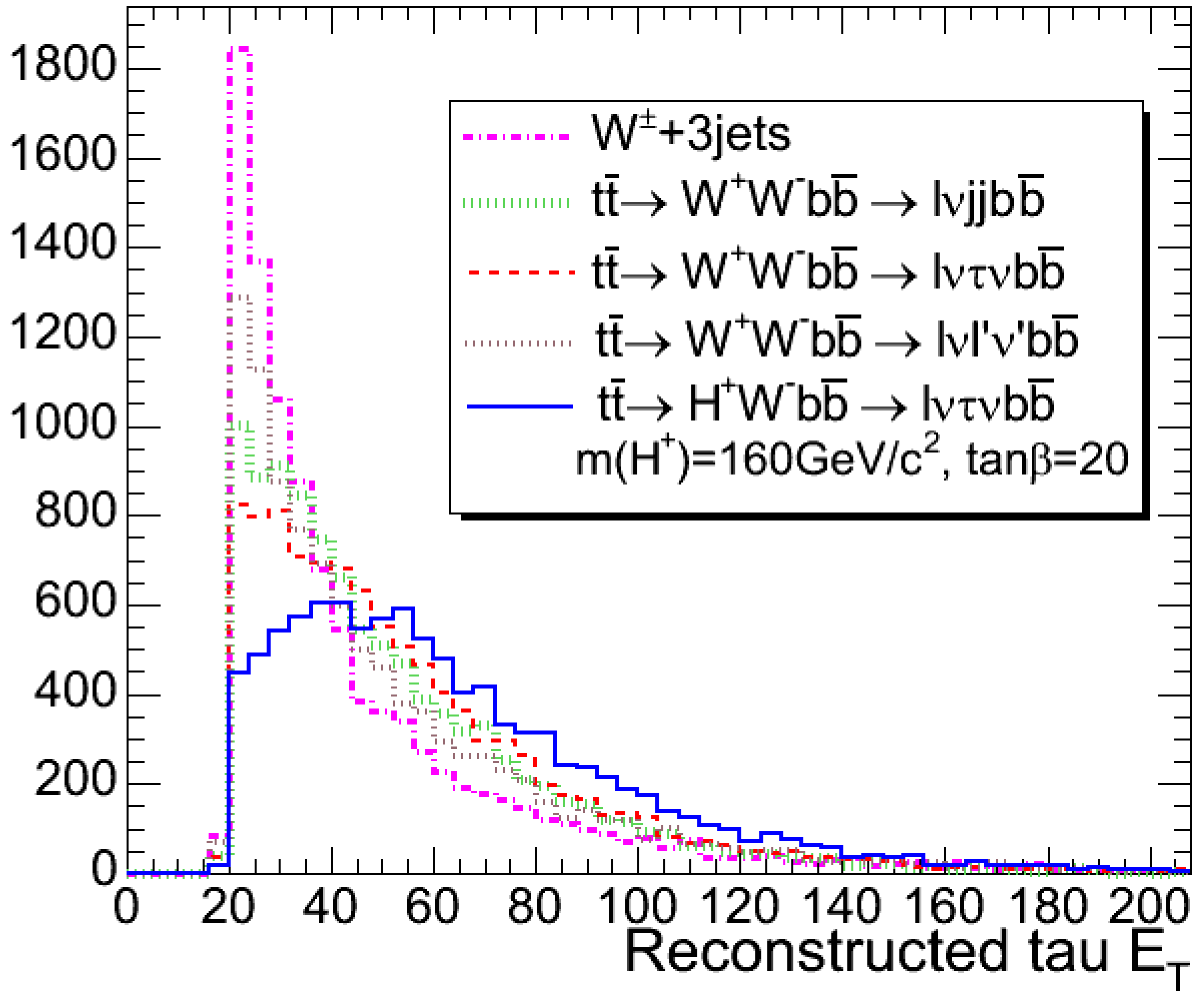
- L1 tau objects are reconstructed in each event, (up to 4 L1 tau)
- Regional jet reconstruction is done around the first and second L1 tau object direction, (Gives up to 2 jets)
- The first jet which satisfies the condition: Hottest HCAL tower Et>2GeV is used. This is to reduce the possibility of identifying electrons as tau jets.
- The jet Et requirement is applied as Et > 30 GeV

$$\Delta R = \sqrt{\Delta\eta^2 + \Delta\varphi^2}$$

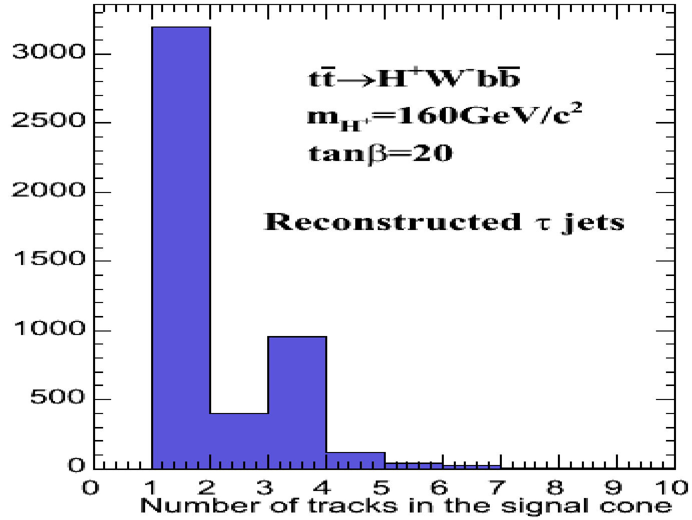
- Matching cone ΔR= 0.1 is defined around the jet direction to search for the leading track using regional track reconstruction
- Signal cone 0.07 is defined around the leading track
- Isolation cone 0.4 is defined around the leading track with p_T track>1.0GeV for tracker isolation requirement
- ECAL isolation is also applied as $\sum_{0.13<\Delta R<0.4} E_T < 5.6GeV$
- $p^{\text{leading track}} / E^{\text{Tau}} > 0.8$

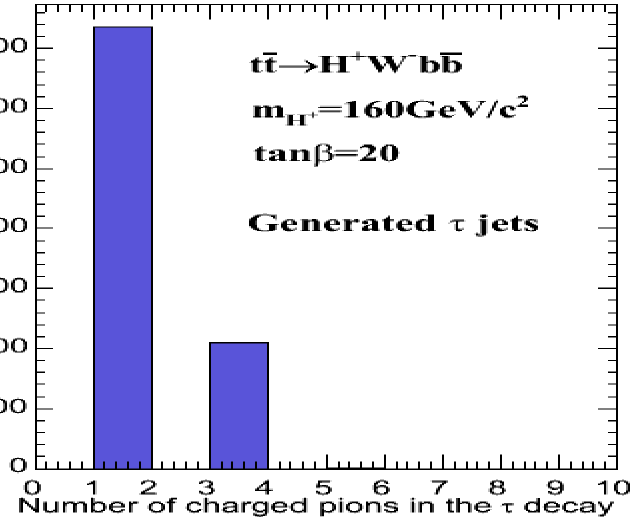


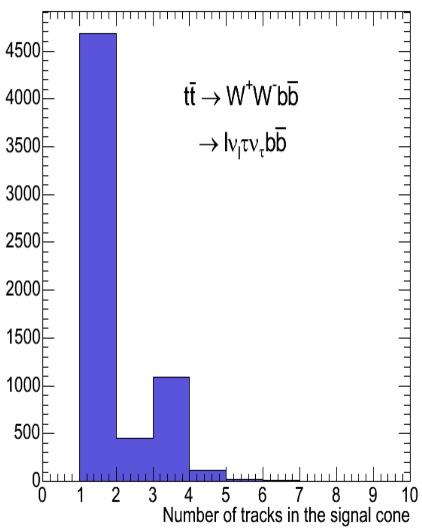
tau-jet transverse energy

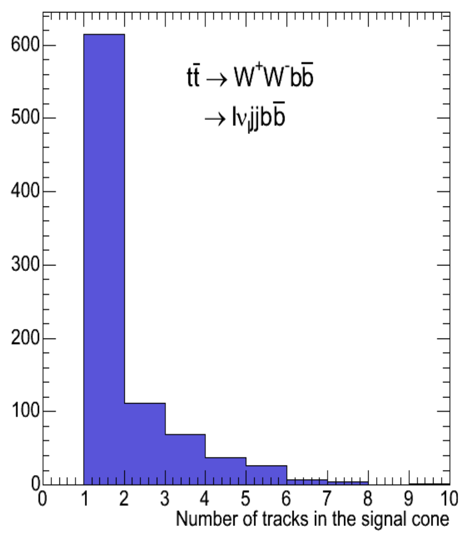


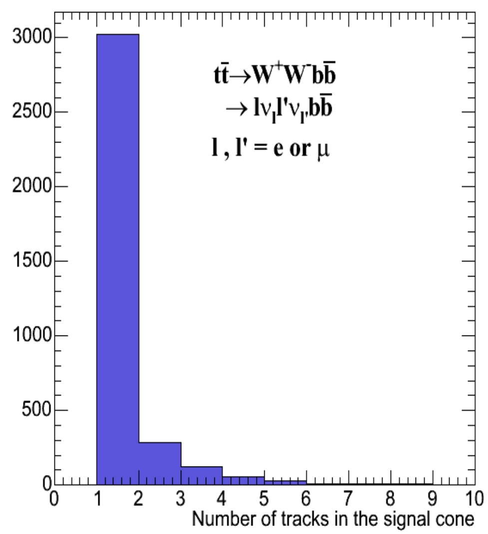
Offline tau selection

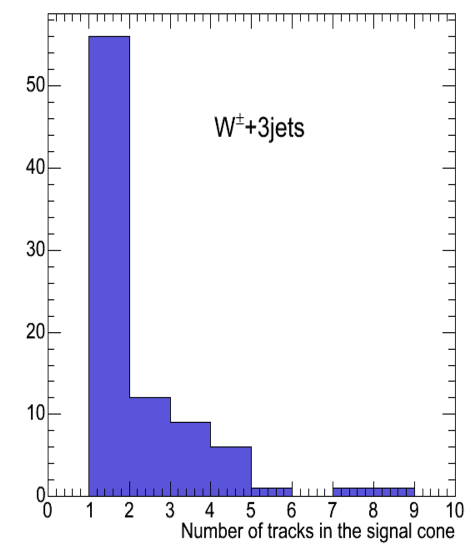






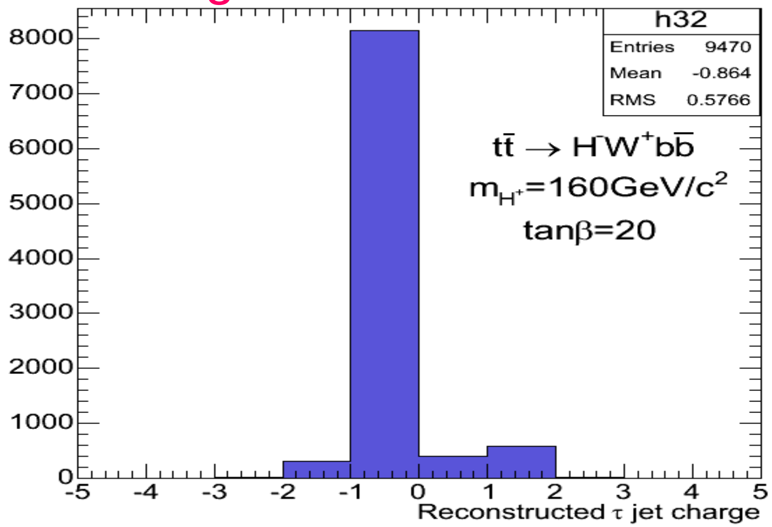


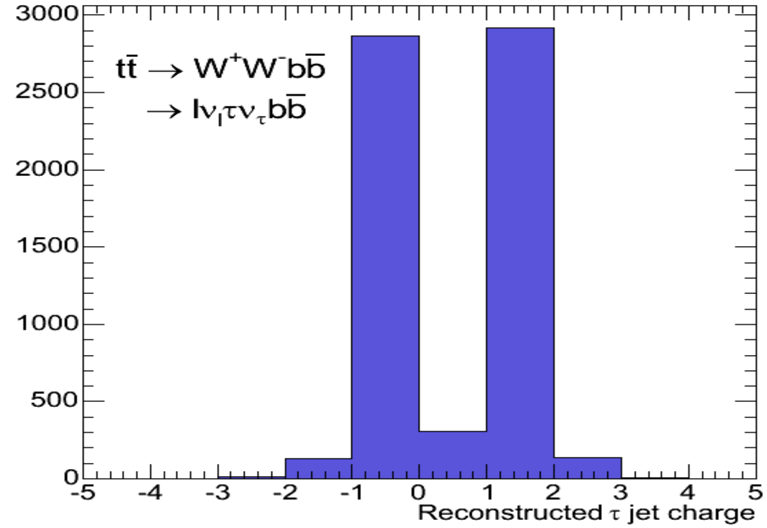


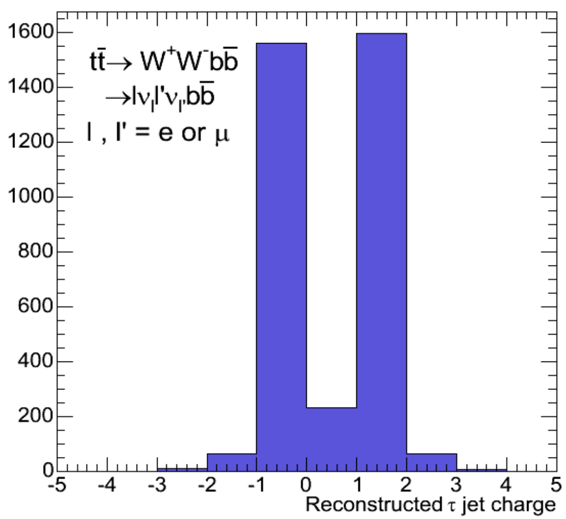


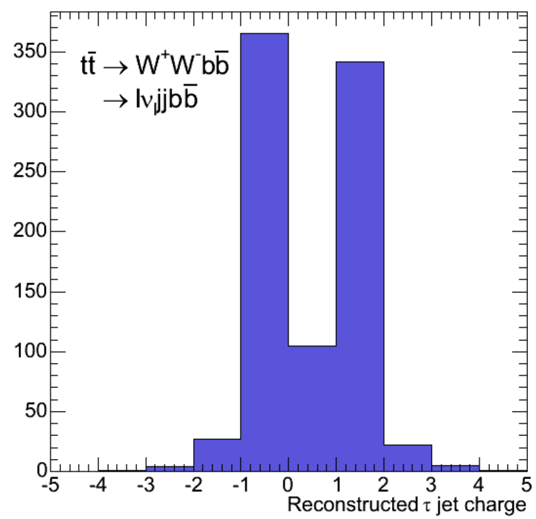
Offline tau selection

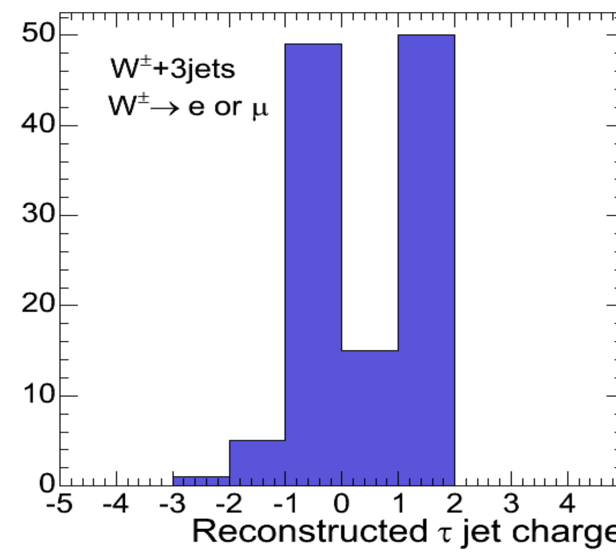
The tau charge is reconstructed by summing over the charge of tracks in the signal cone 0.07 :





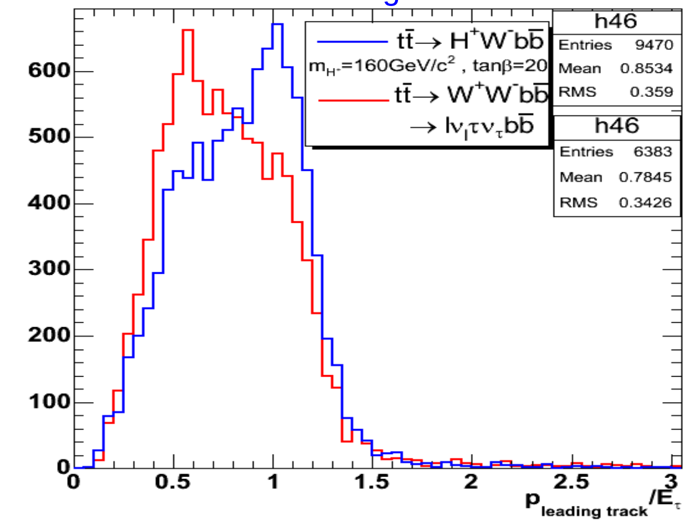


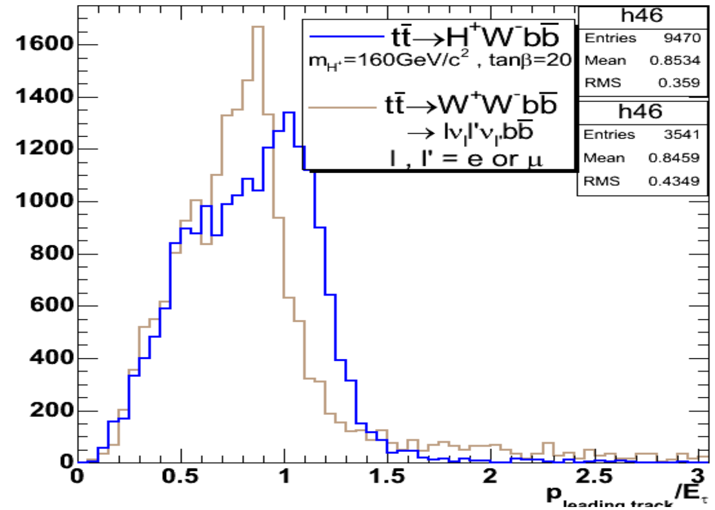


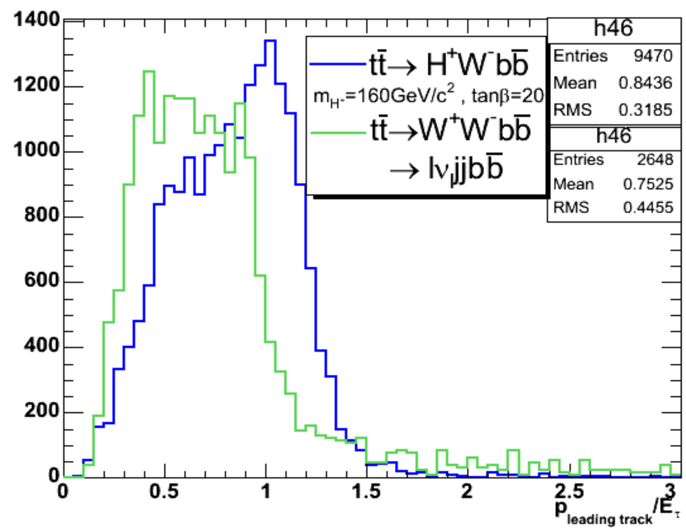


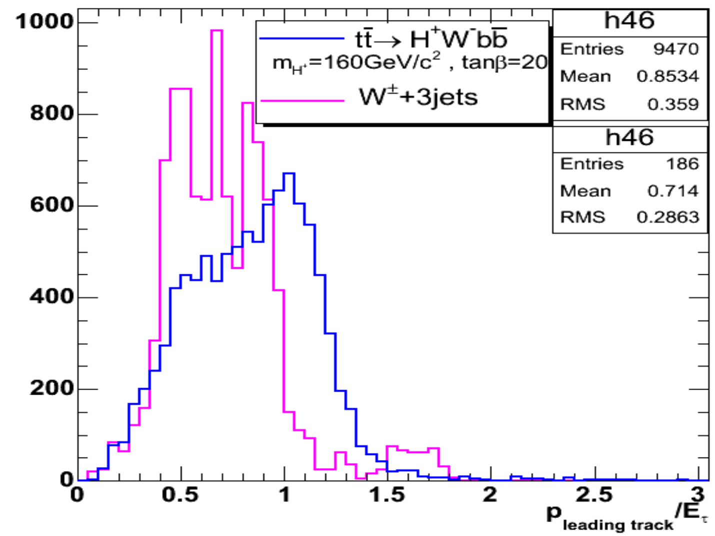
Offline tau selection

The cut on the leading track pt (leading track pt>20) is not applied because of applying the tau Et threshold which is 30GeV and the requirement $p_{\text{leading track}} / E_{Tau} > 0.8$:



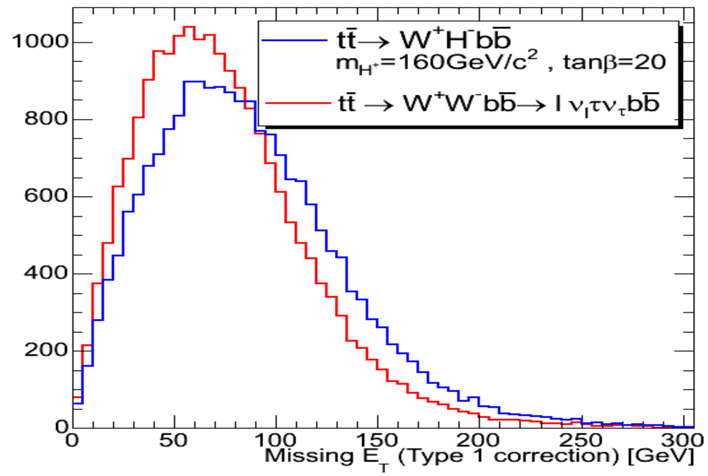


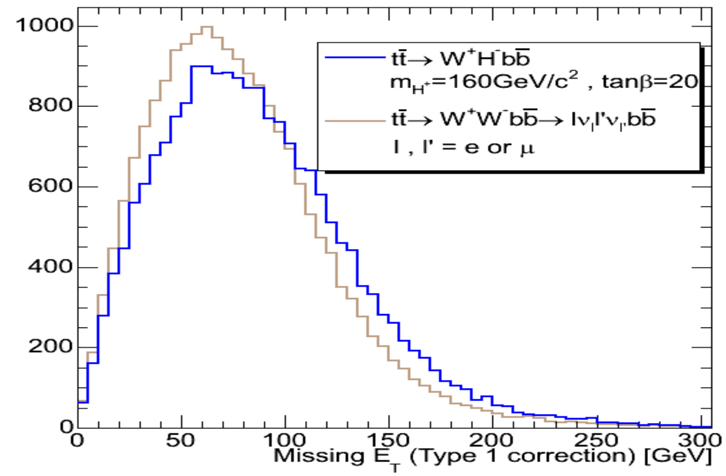


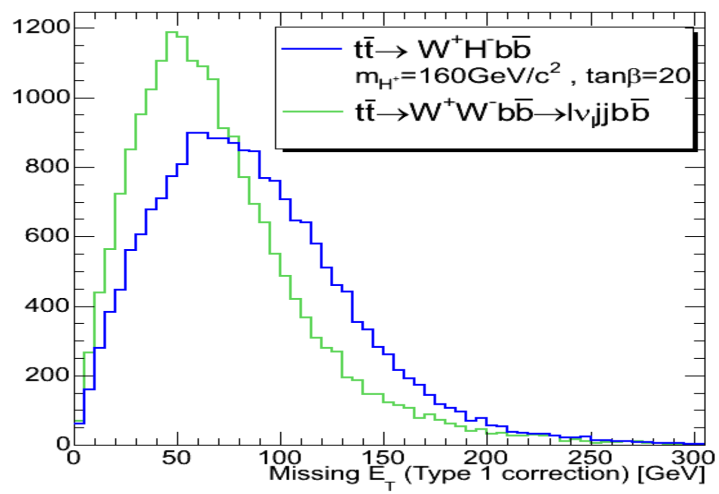


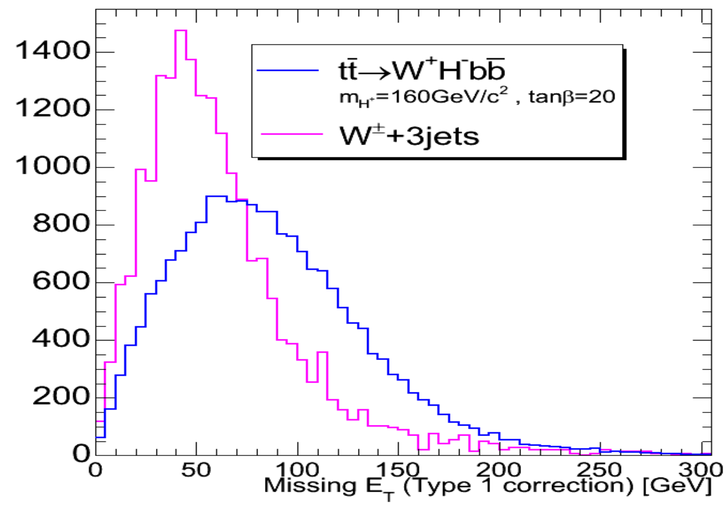
Missing Et distributions

- MET cut is set to 70 GeV which rejects the background events especially W+3j events.









Selection cuts and their efficiencies

Numbers are remaining cross sections after corresponding cuts, numbers in parantheses are relative efficiencies in percent

	$t\bar{t} \to H^{\pm}W^{+}bb$ $m_{(H^{\pm})} = 140GeV$	$t\bar{t} \to H^{\pm}W^{+}bb$ $m_{(H^{\pm})} = 150GeV$	$t\bar{t} \to H^{\pm}W^{+}bb$ $m_{(H^{\pm})} = 160GeV$
$\sigma \times BR[fb]$	10.7x10^3	5060.	1830.
L1+HLT	**5170.5(48.3)**	**2456.3(48.5)**	**888.9(48.6)**
>=3jets	**1889.7(36.5)**	**795.0(32.4)**	**264.3(29.7)**
>=1bjet	**1100.4(58.2)**	**427.4(53.8)**	**134.4(50.8)**
<2bjets	**880.5(80.0)**	**358.7(83.9)**	**121.9(90.7)**
Having L1 tau	**876.7(99.5)**	**357.9(99.7)**	**121.6(99.8)**
tau jet reconstruction	**873.0(99.6)**	**356.9(99.7)**	**121.4(99.8)**
Hottest HCAL tower Et>2GeV	**777.3(89.0)**	**315.0(88.3)**	**108.1(89.0)**
tau Et>30GeV	**728.7(93.7)**	**293.8(93.2)**	**101.3(93.7)**
Tracker isolation	**352.4(48.4)**	**151.7(51.6)**	**49.7(49.0)**
ECal isolation	**278.3(79.0)**	**126.1(83.1)**	**41.2(82.9)**
$p_{leading\ track}/E_{tau}>0.8$	**118.8(42.7)**	**57.8(45.8)**	**18.6(45.1)**
Q(l)+Q(tau)=0	**102.6(86.3)**	**48.7(84.3)**	**15.9(85.6)**
MET>70GeV	**58.8(57.3)**	**27.2(55.8)**	**9.4(59.4)**
Expected number of events after 10fb-1	**588**	**272**	**94**

Selection cuts and their efficiencies

	$t\bar{t} \to H^{\pm}W^{\mp}bb$ $m_{(H^{\pm})} = 170 GeV$	$gb \to tH^{\pm}$ $m_{(H^{\pm})} = 170 GeV$	$gg \to tbH^{\pm}$ $m_{(H^{\pm})} = 170 GeV$
$\sigma \times BR[fb]$	157.	140.	297.
L1+HLT	**78.0(49.7)**	**70.5(50.4)**	**146.8 (48.9)**
>=3jets	**23.2(29.7)**	**21.7 (30.7)**	**55.9 (38.0)**
>=1bjet	**11.6(50.2)**	**11.9 (54.7)**	**33.0 (59.1)**
<2bjets	**11.0(94.8)**	**10.2 (85.5)**	**26.7 (80.9)**
Having L1 tau	**11.0(99.8)**	**10.1 (99.6)**	**26.5 (99.4)**
tau jet reconstruction	**11.0(99.9)**	**10.1 (99.9)**	**26.3 (99.1)**
Hottest HCAL tower Et>2GeV	**9.7(88.3)**	**8.9 (88.6)**	**23.5 (89.2)**
tau Et>30GeV	**9.3(95.9)**	**8.6 (95.7)**	**22.5 (95.8)**
Tracker isolation	**4.8(51.6)**	**4.9 (57.7)**	**11.4 (50.7)**
ECal isolation	**4.2(86.6)**	**4.2 (85.1)**	**9.6 (84.2)**
$p_{leading\ track}/E_{tau}>0.8$	**1.7(40.6)**	**1.9 (44.6)**	**3.8 (39.8)**
Q(l)+Q(tau)=0	**1.5(86.4)**	**1.6 (86.0)**	**3.1 (82.3)**
MET>70GeV	**0.9(61.8)**	**1.0 (62.0)**	**1.7 (54.8)**
Expected number of events after 10fb-1	**9**	**10**	**17**

Selection cuts and their efficiencies

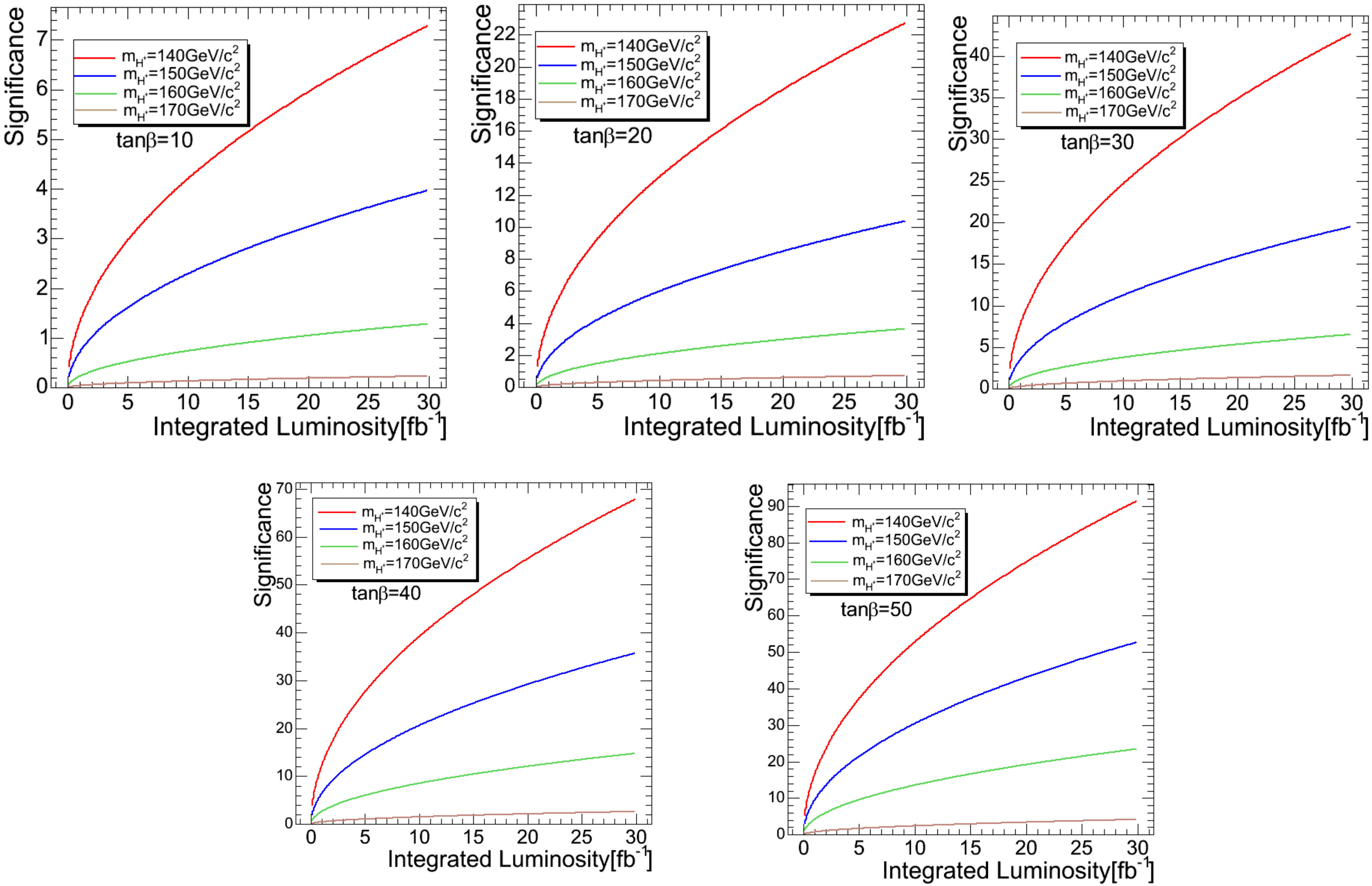
	$tt \to W^{\pm}W^{\mp}bb \to \ell\nu\tau\nu bb$	$tt \to W^{\pm}W^{\mp}bb \to \ell\nu\ell'\nu bb$	$t\bar{t} \to W^{\pm}W^{\mp}bb \to \ell\nu jjbb$	$W^{\pm} + 3\,jets$, $W^{\pm} \to \ell\nu$
$\sigma \times BR[fb]$	**25.8x10^3**	**39.8x10^3**	**245.6x10^3**	**840.x10^3**
L1+HLT	**12101.2(46.9)**	**28357.7(71.4)**	**98386.8(40.0)**	**279228 (33.2)**
>=3jets	**5105.2 (42.2)**	**11278.2(39.8)**	**66745.7 (67.8)**	**102248 (36.6)**
>=1bjet	**3393.9 (66.5)**	**7577.8 (67.2)**	**44879.8 (67.2)**	**18782.9(18.4)**
<2bjets	**2303.4 (67.8)**	**5221.9 (68.9)**	**29970.7 (66.8)**	**16254.7(86.5)**
Having L1 tau	**2285.1 (99.3)**	**5190.5 (99.4)**	**29596 (98.8)**	**15641.4(96.4)**
tau jet reconstruction	**2278.5 (99.7)**	**5180.5 (99.8)**	**29332.1 (99.1)**	**13912.3(88.9)**
Hottest HCAL tower Et>2GeV	**2013.0 (88.3)**	**3806.4 (73.5)**	**27534.4 (93.9)**	**11949.3(85.9)**
tau Et>30GeV	**1861.3 (92.5)**	**3441.1 (90.4)**	**25398.7 (92.2)**	**9352.9 (78.3)**
Tracker isolation	**712.7 (38.3)**	**947.3 (27.5)**	**6085.8 (24.0)**	**2682.0 (28.7)**
ECal isolation	**483.8 (67.9)**	**424.3 (44.8)**	**2449.2 (40.2)**	**1266.8 (47.2)**
$p_{leading\ track}/E_{tau}>0.8$	**146.0 (30.1)**	**159.6 (37.6)**	**453.5 (18.5)**	**222.5 (17.5)**
Q(l)+Q(tau)=0	**114.7 (78.5)**	**71.4 (44.7)**	**98.9 (21.8)**	**45.6 (20.5)**
MET>70GeV	**56.0 (48.8)**	**34.1 (47.7)**	**33.0 (33.3)**	**11.4 (25.0)**
Expected number of events after 10fb-1	**560**	**341**	**330**	**114**

The single top contribution is 66 events at 10fb^{-1} .

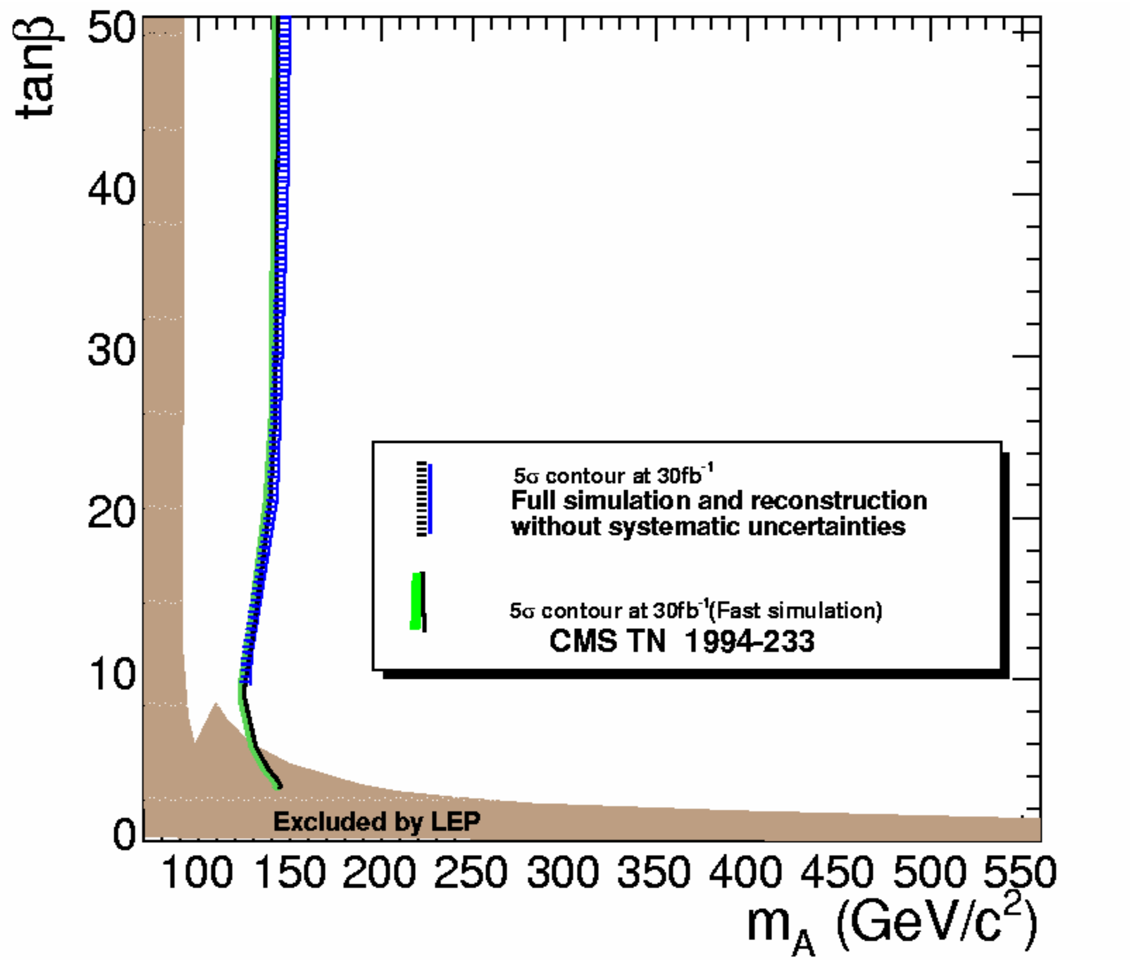
Significance versus integrated luminosity

(no systematics)

INSTITUTE FOR STUDIES IN THEORETICAL PHYSICS AND MATHEMATICS



With obtained final number of signal and background events, 5σ discovery contour for an integrated luminosity of $30fb^{-1}$ shows possible discovery at low luminosity up to $m(H^+)$=170GeV for $\tan\beta$ >20:



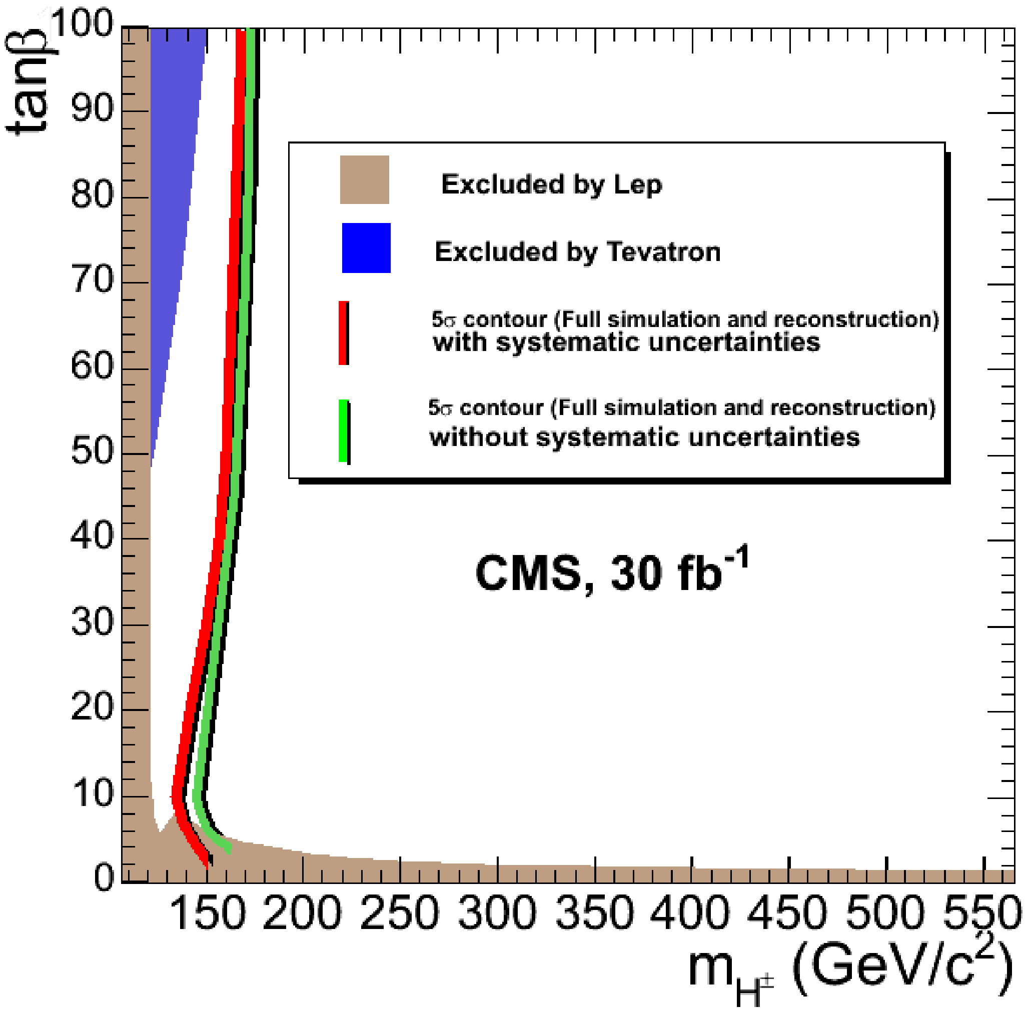
Estimations of the systematic uncertainties

The values that we have assumed for different sources of uncertainties are :

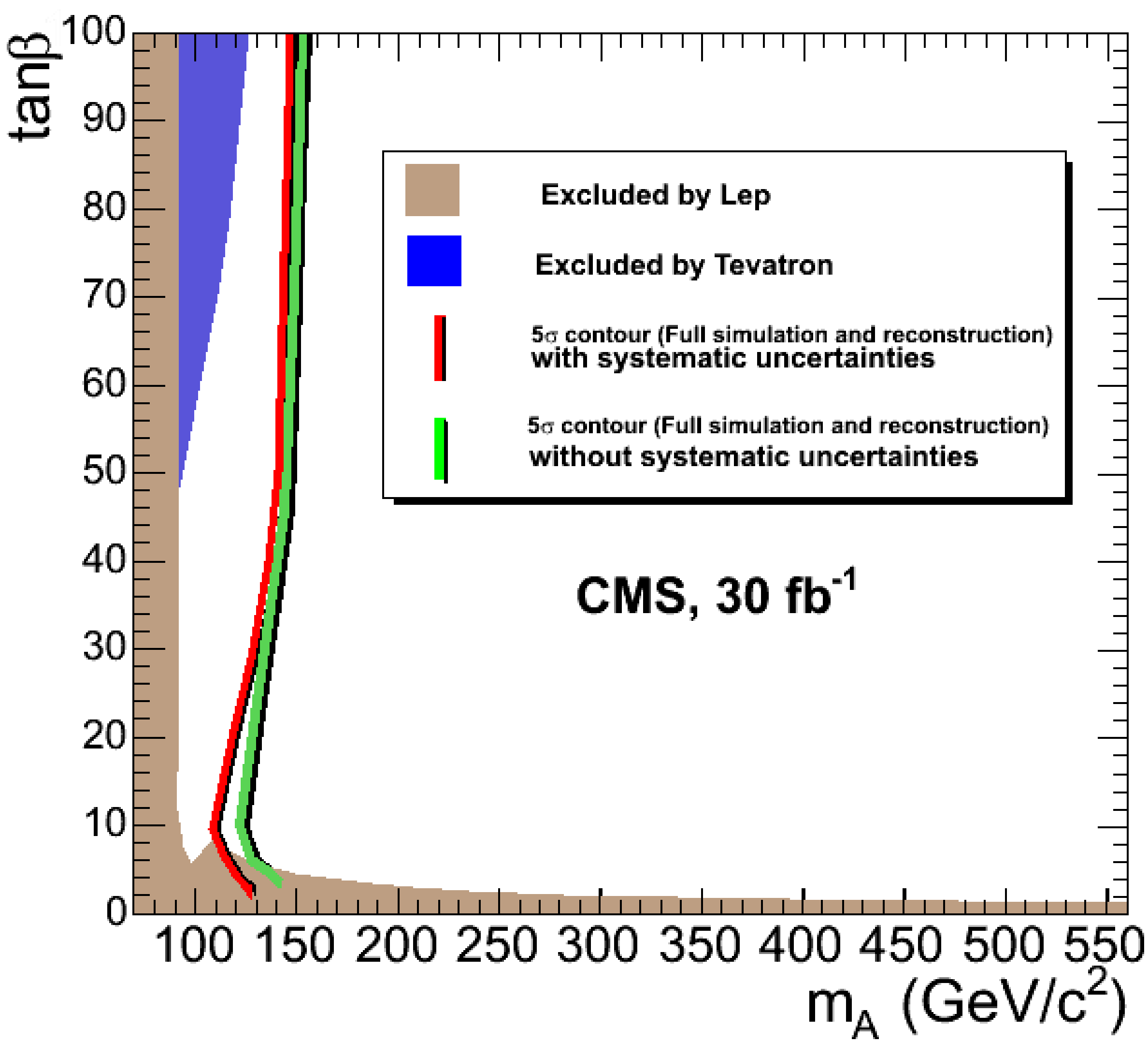
Scale uncertainty of ttbar cross section	2.5 %
PDF uncertainty of ttbar cross section	5 %
b-tagging	5 %
tau-tagging	4 %
Lepton identification	2 %
Jet energy scale	3 %
Mistagging a non-b-jet as a b-jet	5 %
Mistagging a jet as a tau-jet	2 %
Non-b-jet identification	5 %
Luminosity uncertainty	5 %

5σ discovery contour

Having Included all these terms of systematic and statistical uncertainties, the statistical significance of the signal is obtained for each point in the parameter space and for each integrated luminosity:



5σ discovery contour



Summary:

The possibility of light charged Higgs discovery was studied with full simulation and reconstruction of the CMS detector,

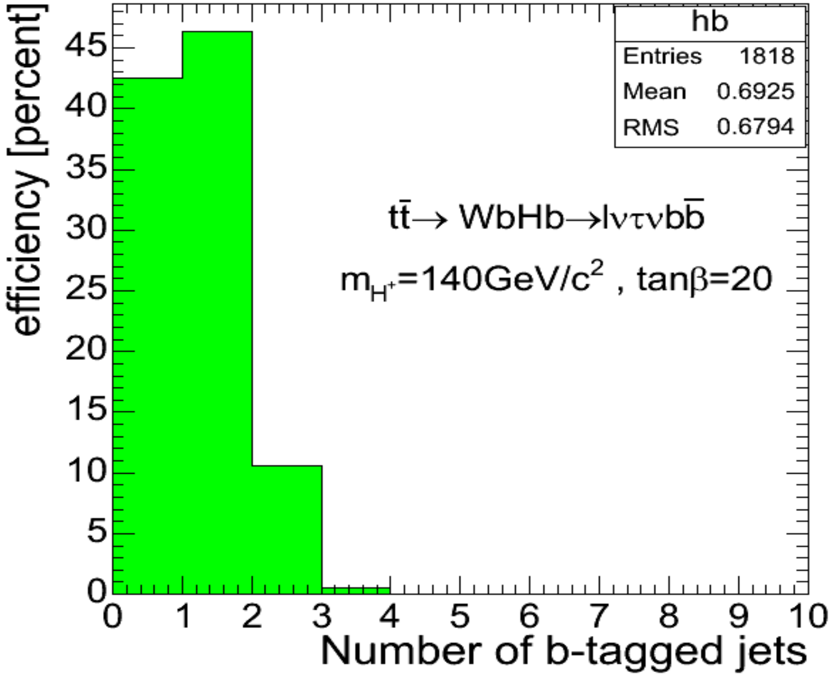
The search strategy was introduced and the significance was calculated in two different cases of without and with systematic uncertainties

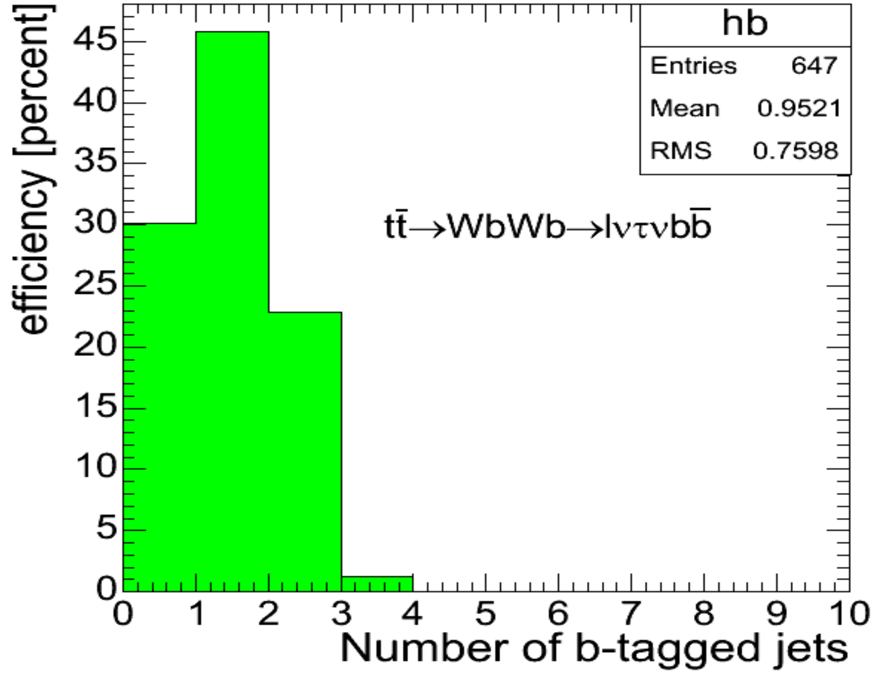
The 5 sigma discovery contour was obtained

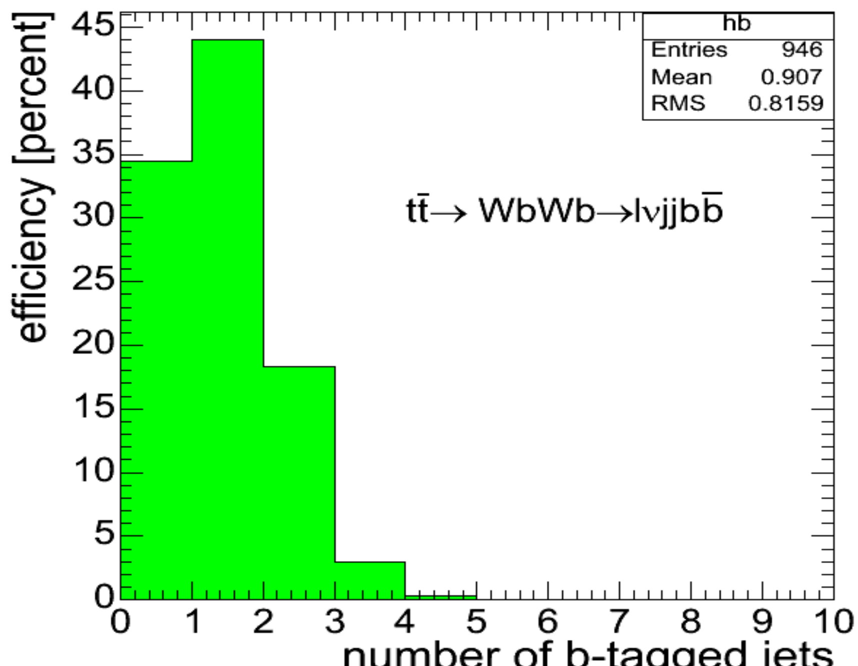
Conclusion:

The light charged Higgs can be discovered within the mass range of $125<m(H+)<170$GeV for high $\tan\beta$ values.

Backup


hb
Entries 1818
Mean 0.6925
RMS 0.6794
$t\bar{t} \to WbHb \to l\nu\tau\nu b\bar{b}$
$m_{H^{+}}=140GeV/c^{2}$, $\tan\beta=20$
efficiency [percent]
Number of b-tagged jets


hb
Entries 647
Mean 0.9521
RMS 0.7598
$t\bar{t} \to WbWb \to l\nu\tau\nu b\bar{b}$
efficiency [percent]
Number of b-tagged jets


hb
Entries 946
Mean 0.907
RMS 0.8159
$t\bar{t} \to WbWb \to l\nu jjb\bar{b}$
efficiency [percent]
number of b-tagged jets