Tevatron searches for charged and doubly-charged Higgs

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Talk Outline

- Several extensions to the SM predict additional Higgs Bosons
  - Charged Higgs (H^+)
  - Doubly charged Higgs (H^{++})
- Experimental searches at CDF and DØ
- Summary


```
if (SM Higgs) { Great! }
else if (SUSY) {
    switch (SUSY) {
        case MSSM :
            ...
            break;
        case Another one?
            ...
        ...
}
else {
    Choose your favorite model...
}
```

Charged Higgs Bosons

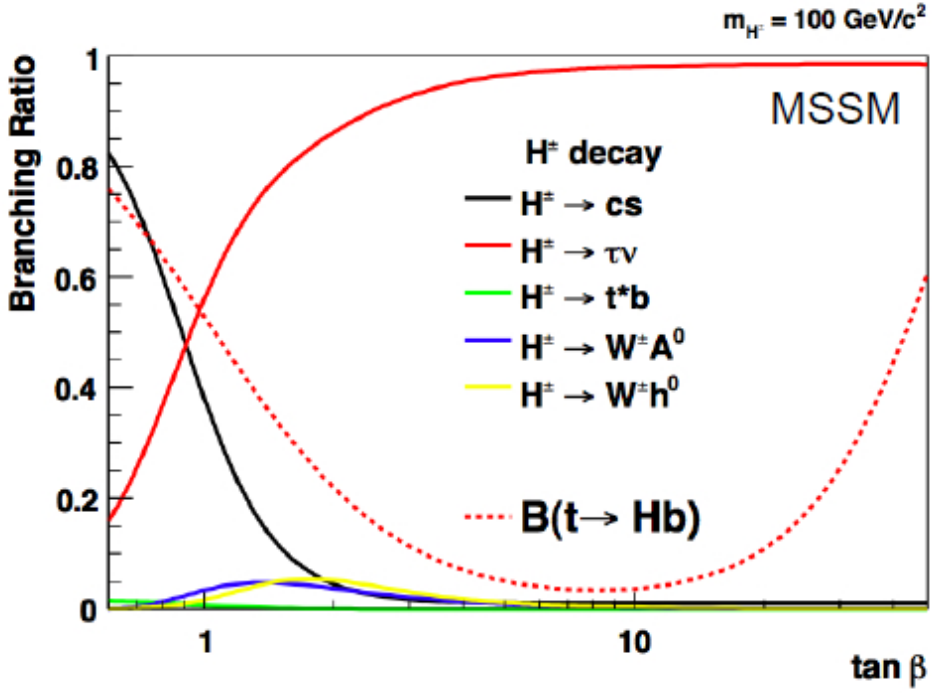
- Singly charged Higgs
  - Arise in models with two Higgs doublets - SUSY and some GUT
  - Different models to avoid FCNC
  - Typically depends on M_{H^+} and $\tan\beta$:
    either direct production $p\bar{p} \rightarrow H^+ \rightarrow t\bar{b}$ or
    top quark decays $p\bar{p} \rightarrow t\bar{t} \rightarrow (H^+ b)(W^- \bar{b})$
- Doubly charged Higgs
  - Exotic extensions of the Higgs sector (Left/Right symmetric models, Higgs triplet, Little Higgs)
  - Depend on $M_{H^{++}}$ and Higgs couplings
    direct production $p\bar{p} \rightarrow H^{++}H^{--} \rightarrow l^+l^+l^-l^-$

MSSM

MSSM Higgs sector needs 2 Higgs doublets which leads to 5 Higgs bosons ($h/H/A$, $H^{\pm}$)
At the tree level, two parameters $\tan\beta$ (v_u/v_d vev ratio) and $M_{H^{\pm}}$

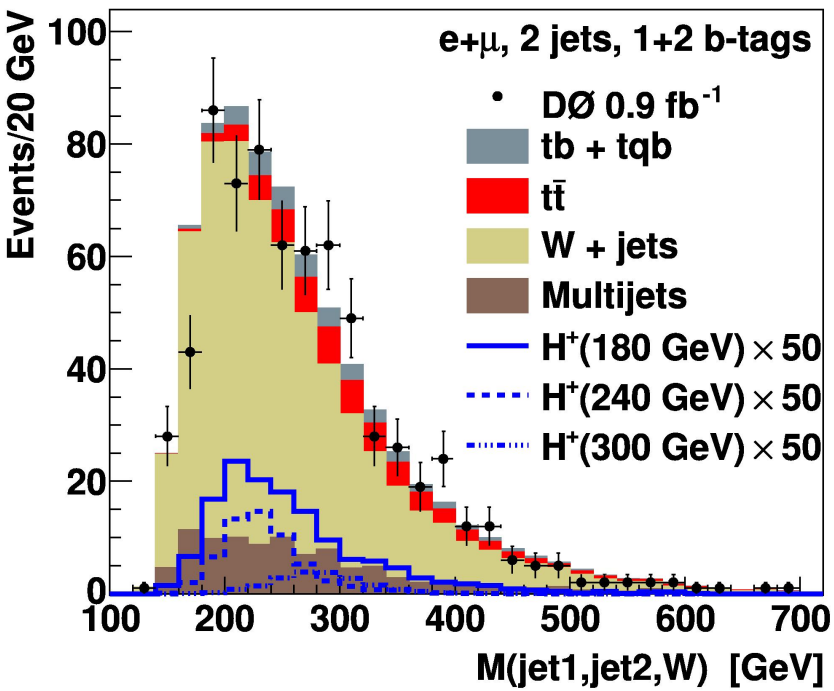
$\tan\beta$ controls the H^+ decay:

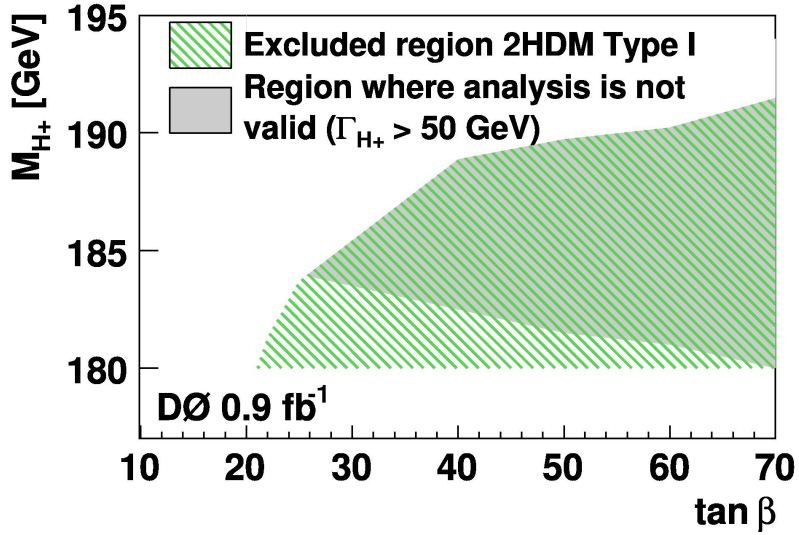
- $H^{\pm} \to \tau\nu$ (high $\tan\beta$)
- $H^{\pm} \to c\bar{s}$ (low $\tan\beta$)



$M_H > M_t$: Direct Production

Search for high mass $180 < M_H < 300\,\mathrm{GeV}$ Higgs boson reconstructed in $H^+ \to t\bar{b} \to W^+ b\bar{b} \to l^+ \nu b\bar{b}$ - selection similar to single top analysis.
Discriminating variable - the $M(t\bar{b})$ spectrum - $M(\mathrm{jet1}, \mathrm{jet2}, W)$
No evidence $\to$ limits in two-Higgs-double models (2HDMs)

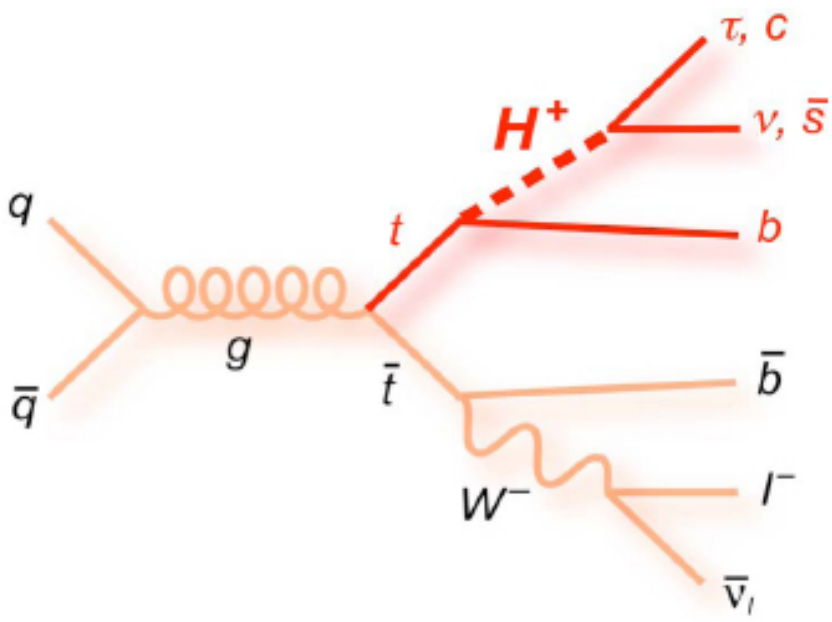


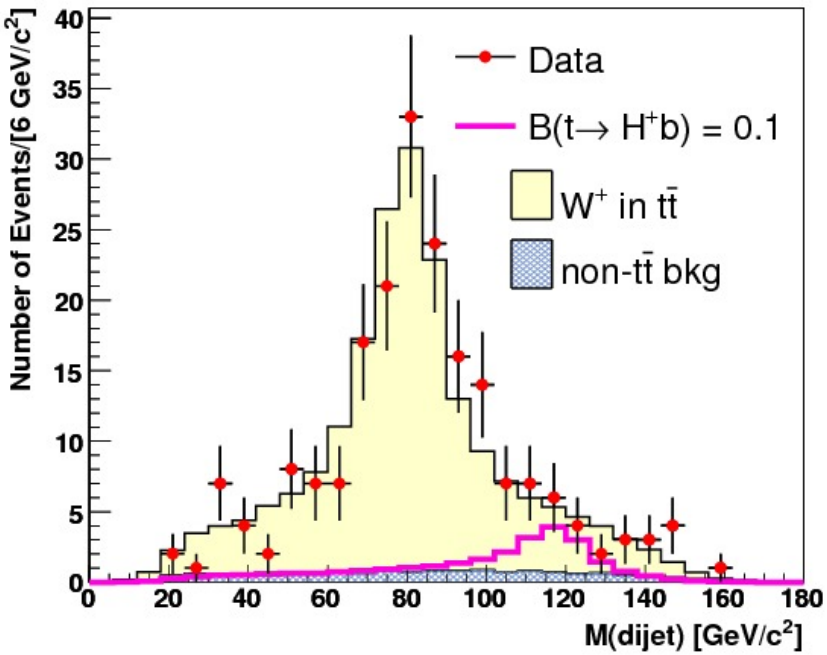


Phys. Rev. Lett. 102 , 191802 (2009)

$M_H < M_t$: Charged Higgs in Top Decay

Search for $H^{\pm}$ using top pair production:
CDF - in MSSM @low tan β - search for $H \rightarrow c\bar{s}$ second peak in the invariant mass of two light jets





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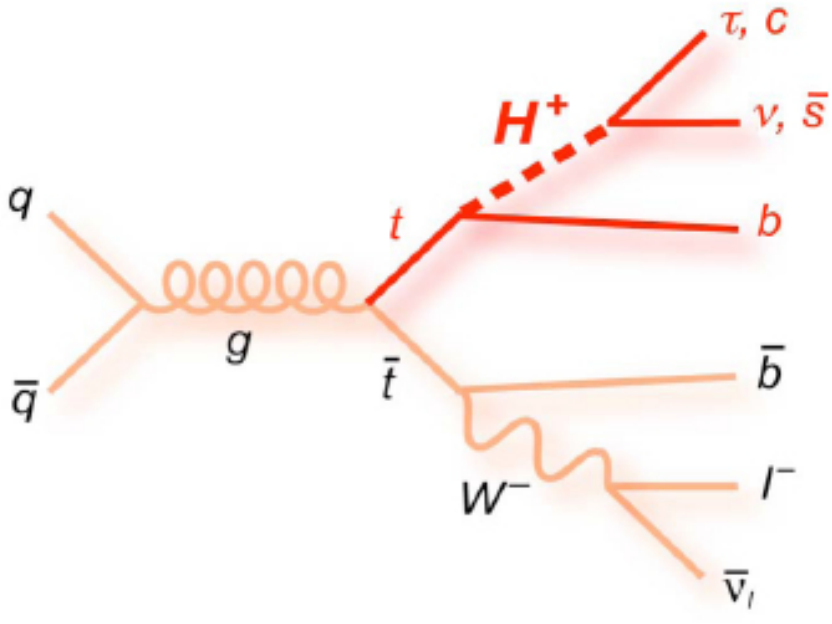
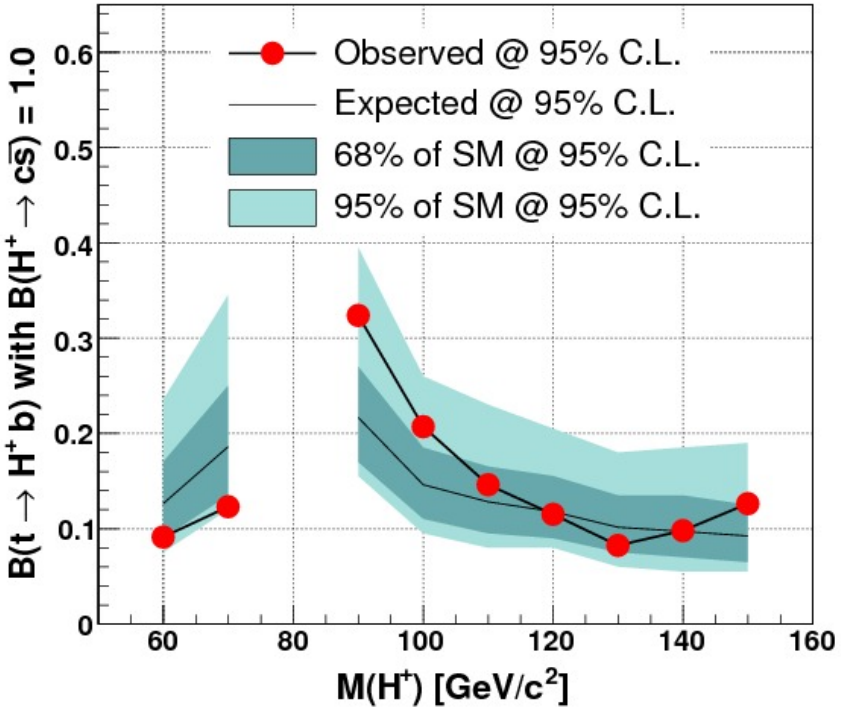
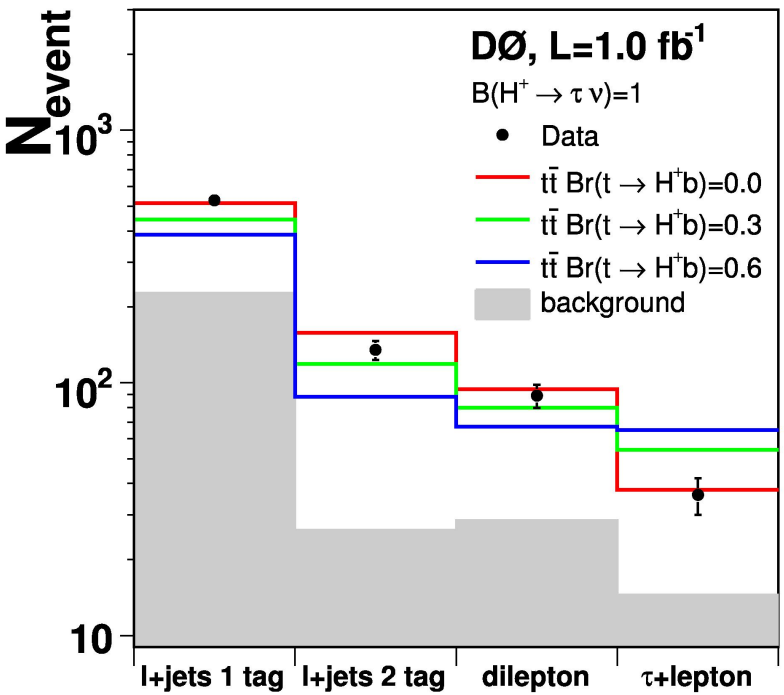


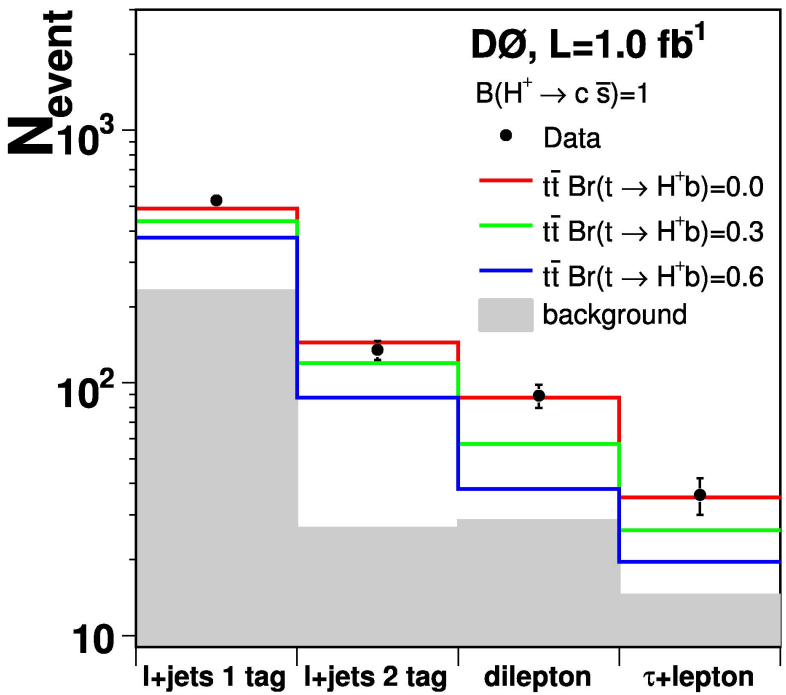


Phys. Rev. Lett. 103, 101803 (2009)

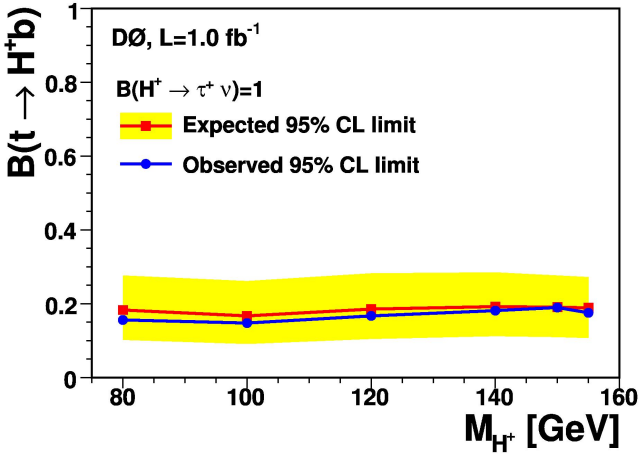
Charged Higgs in Top Decay

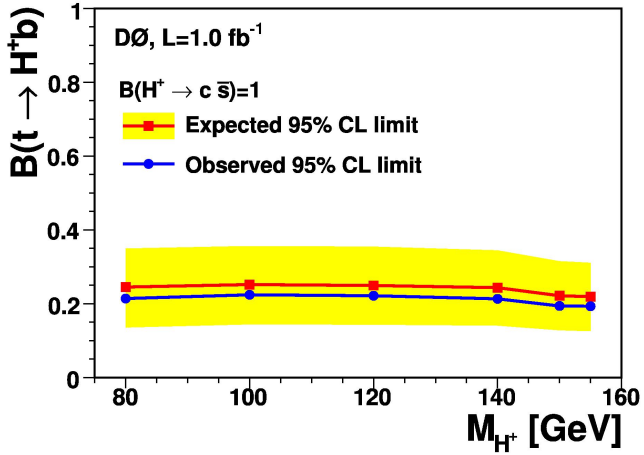
DØ: search for $H^{\pm}$ using top pair production, consider either purely tauonic or purely leptophobic decay
Maximum likelihood fit to the number of events



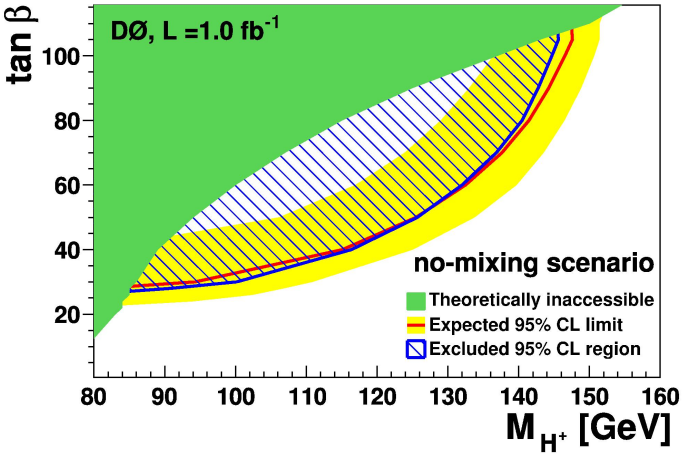


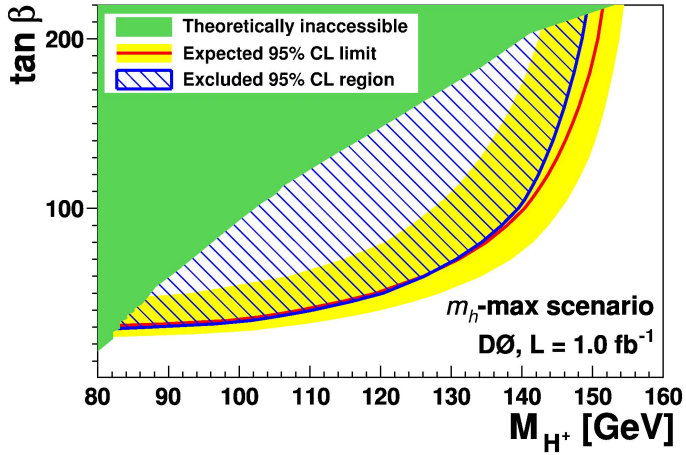
Charged Higgs in Top Decay - DØ Limits





We also extract limits assuming $B(H \to \tau\nu) + B(H \to c\bar{s}) = 1$: various CPX scenarios

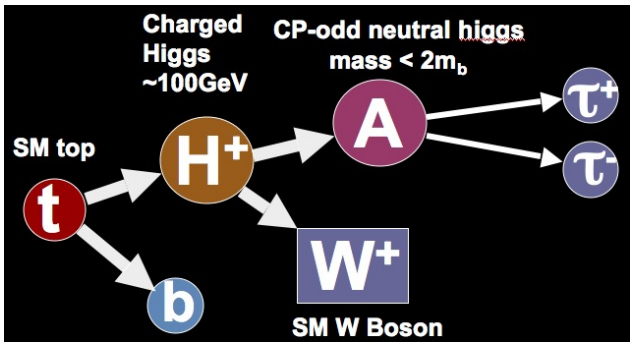




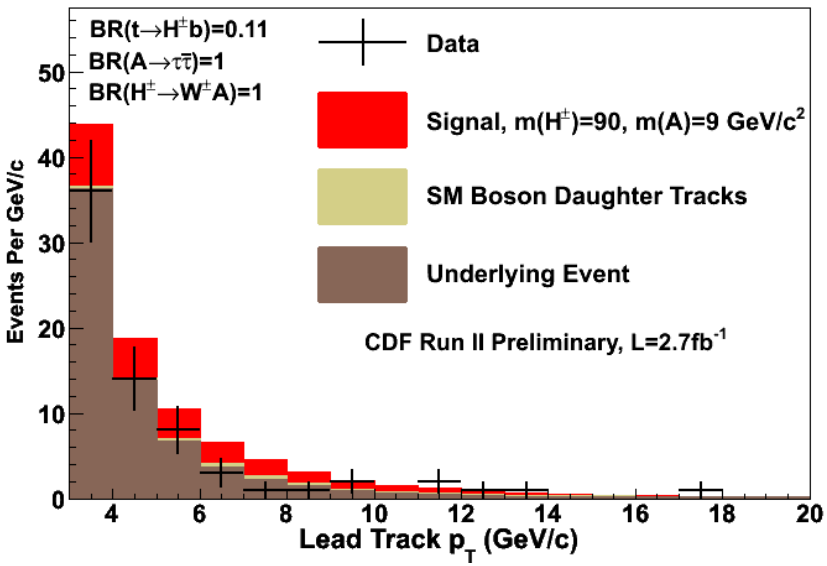
Phys. Lett. B 682, 278 (2009)

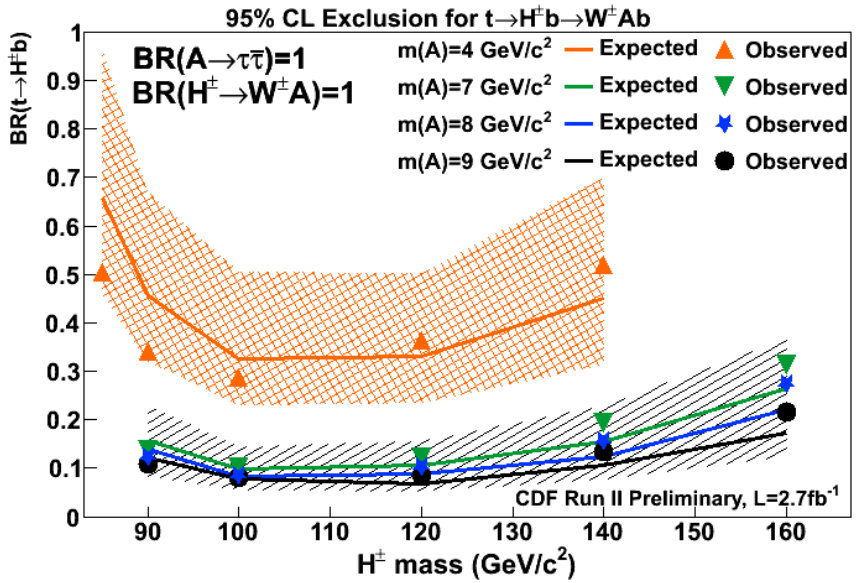
NMSSM

Includes additional CP-even and CP-odd neutral Higgs bosons and an additional neutralino - search H^+ if $M_A < 2M_b$



The τs from the A boson typically have low p_T, bad for efficient τ identification $\longrightarrow$ search instead for isolated low p_T track in lepton+ 3+ jets sample with b-tag and missing E_T.





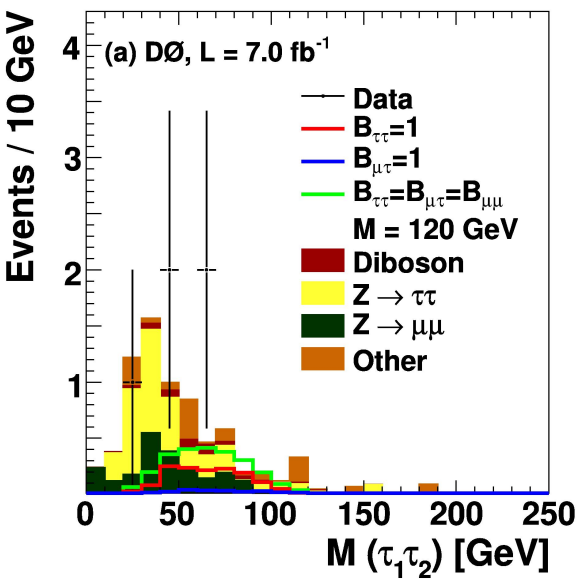
CDF Note 10104

Doubly Charged Higgs

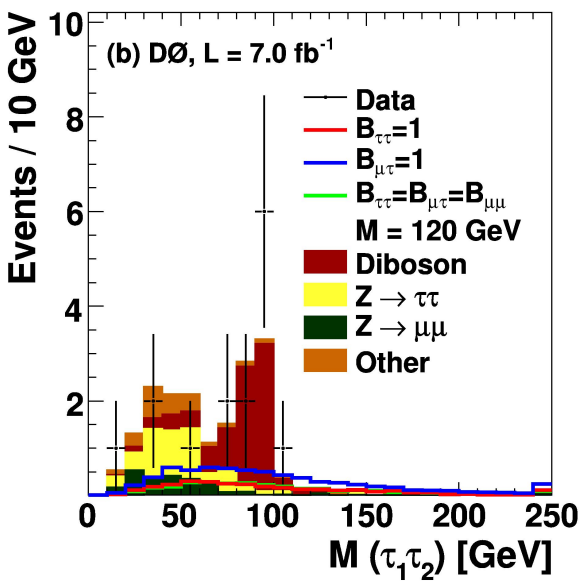
- Higgs triplet, $SU(3)_c \times SU(3)_L \times U(1)_Y$, Little Higgs, Left-Right symmetric models, ...
- Search for H^{++} in $q\bar{q} \rightarrow H^{++}H^{--}$ decaying through $H^{\pm\pm} \rightarrow \tau^{\pm}\tau^{\pm}, \mu^{\pm}\tau^{\pm}, \mu^{\pm}\mu^{\pm}$ (Preferred decay modes depend on a model)
- Select events with at least 1 muon and at least 2 hadronicaly decaying τ candidates, sum of charges $Q = \sum_{i=\mu,\tau_1,\tau_2} = \pm 1$

- Divide sample into 4 non-overlapping samples depending on the charges of the leptons:
  1. $N_\mu = 1, N_\tau = 2$ and $q_{\tau_1} = q_{\tau_2}$
  2. $N_\mu = 1, N_\tau = 2$ and $q_{\tau_1} = -q_{\tau_2}$
  3. $N_\tau = 3$
  4. $N_\mu = 2$
- Discriminating variables: for 1,2 $M(\tau_1, \tau_2)$, for 3,4 N_{evt}

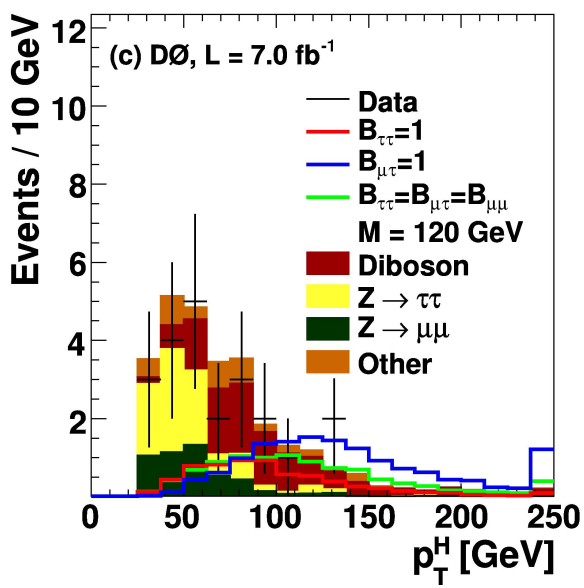
$q_{\tau_1} = q_{\tau_2}$



$q_{\tau_1} = -q_{\tau_2}$

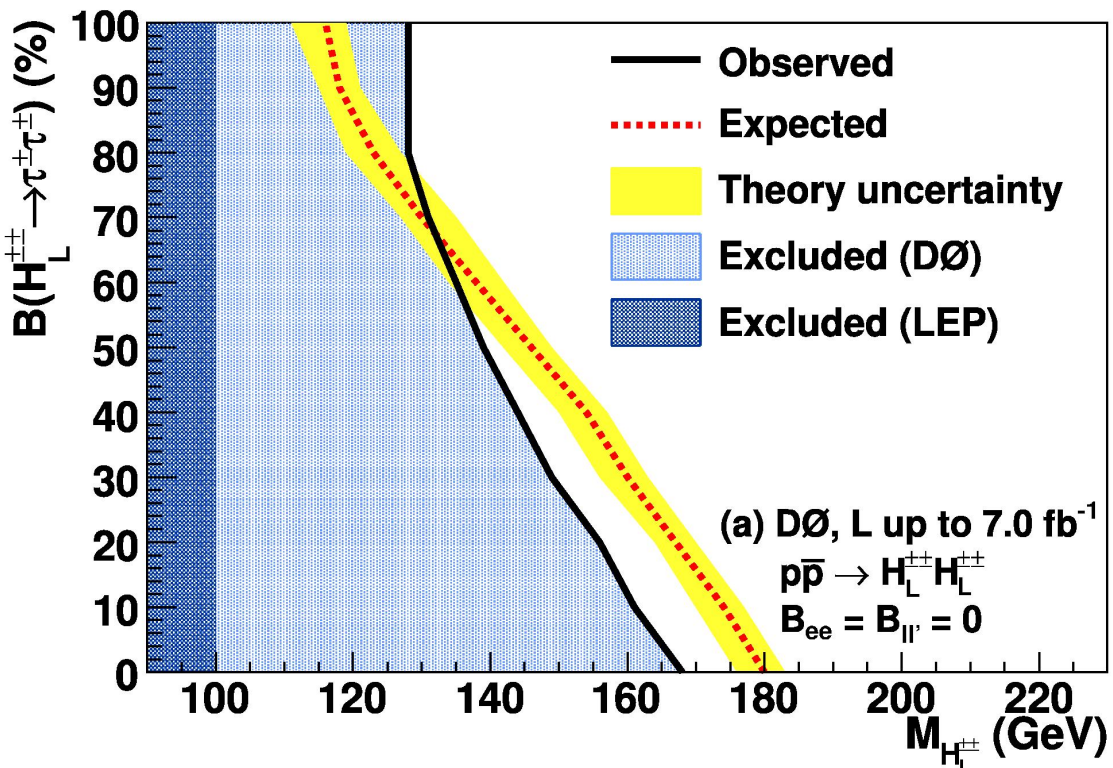


all 4 samples



Doubly Charged Higgs Limits

Branching fraction	obs (exp) limits
$B(H \to \tau\tau) = 1$	$M_{H_L^{++}} > 128(116)\,\mathrm{GeV}$
$B(H \to \mu\tau) = 1$	$M_{H_L^{++}} > 144(149)\,\mathrm{GeV}$
$B(H \to \tau\tau) = B(H \to \tau\mu) = B(H \to \mu\mu) = 1/3$	$M_{H_L^{++}} > 138(130)\,\mathrm{GeV}$
$B(H \to \tau\tau) + B(H \to \mu\mu) = 1$	below



arXiv:1106.4250, Submitted to Phys. Rev. Lett.

SUMMARY

- Charged Higgs boson is a clear sign of physics beyond the Standard Model
- No excess observed - set limits on singly and doubly charged Higgs boson production in various models
- Tevatron giving the baton to LHC now