Search for charged and doubly-charged Higgs Boson production at √s= 1.96 TeV

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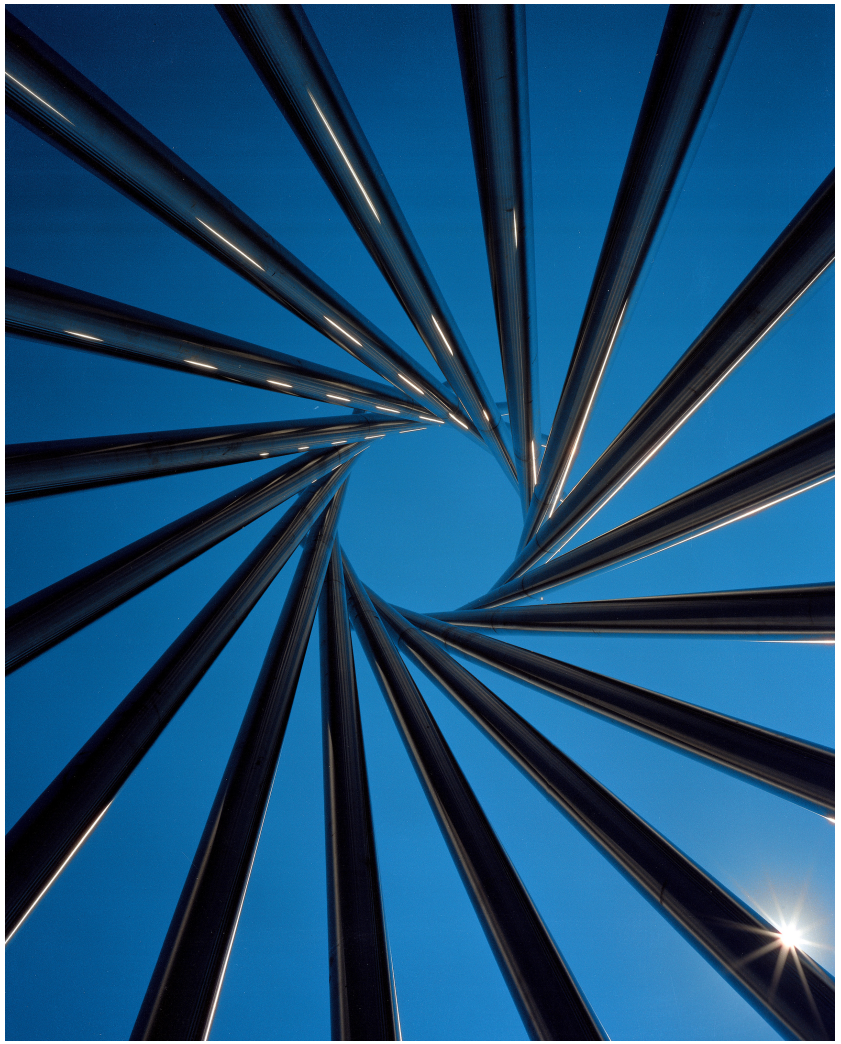
For the DØ and CDF collaborations

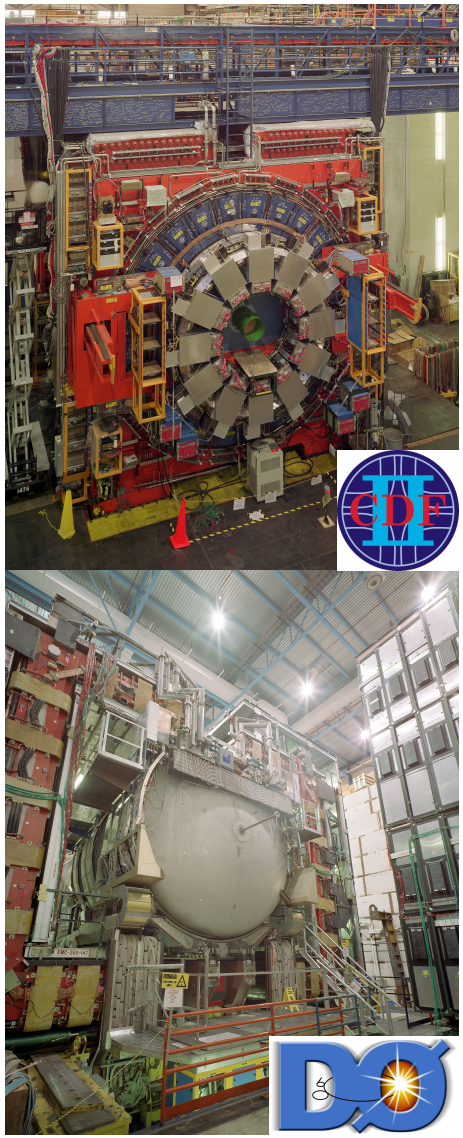
DPF 2011

MANCHESTER 1824
The University of Manchester

- The Tevatron
- Charged Higgs
  - Two Higgs Doublet Models
  - NMSSM
- Doubly Charged Higgs
  - Higgs Triplet Models
    - Left Right Symmetry
    - Little Higgs



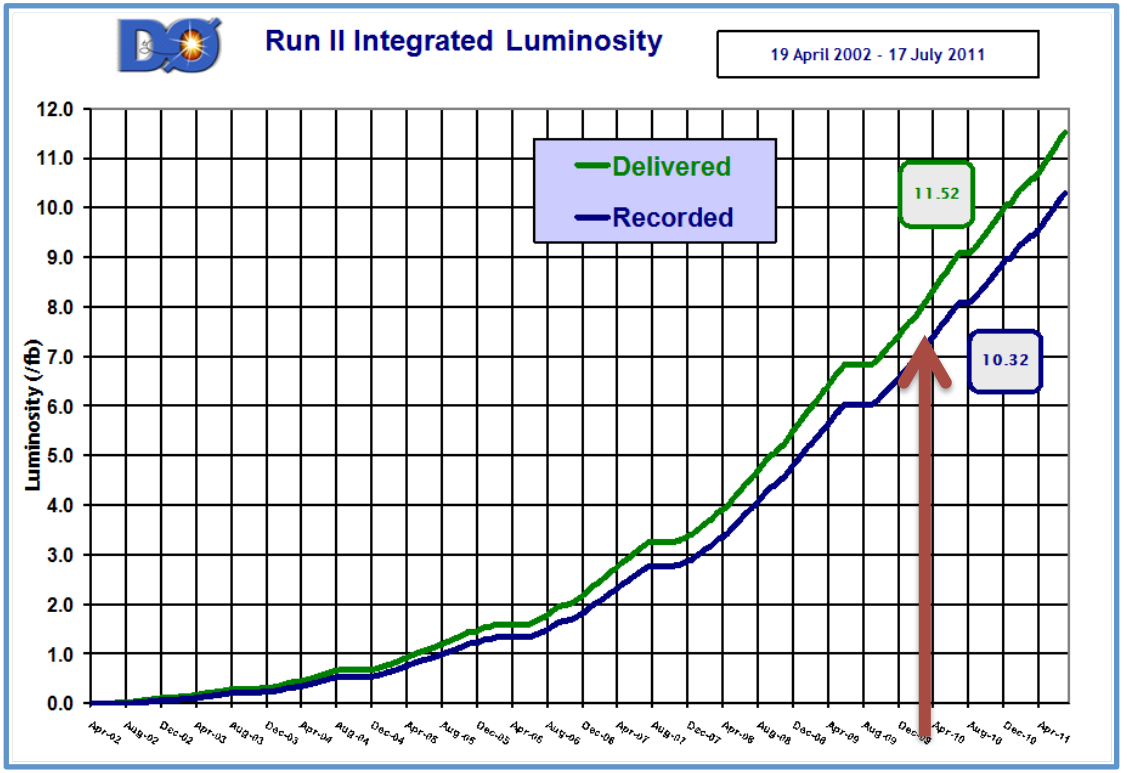
The Tevatron



Recorded: 10.3 fb^{-1}

Delivered: 11.5 fb^{-1}

Showing results with up to 7.0 fb^{-1}



Two Higgs Doublet Models

- Two Higgs doublet models (2HDM) have two Higgs doublets: H_u, H_d

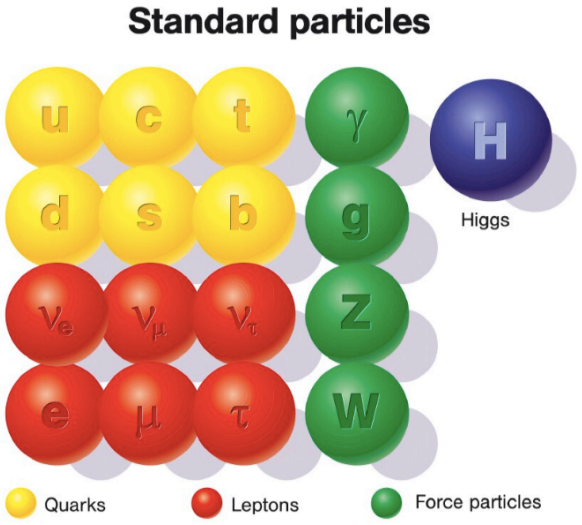
  After EW symmetry breaking:

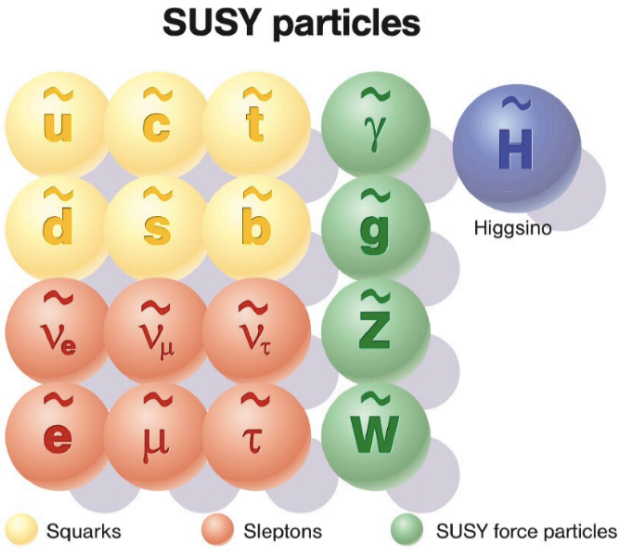
  - 5 Higgs: h, H, A, $H^{\pm}$

- Results shown relate to charged Higgs

- Decay depend on model and mass of the charged Higgs

- Relevant models include:
  - MSSM
  - CPX model
  - Leptophopic

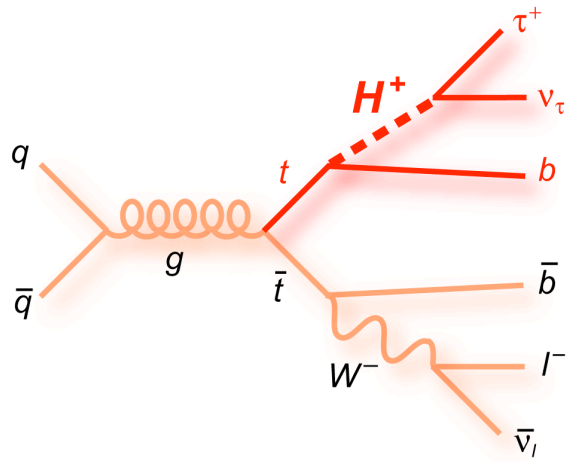




Two Higgs Doublet Models

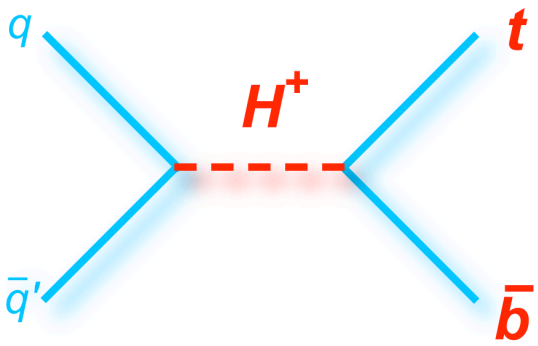
- $M_{H+} < M_{top} : t \rightarrow H^{\pm} b$

  - Decay depends on tan β
    - High tan β $H^+ \rightarrow c\bar{s}$
    - Small tan β $H^+ \rightarrow \tau\nu$



- $M_{H+} > M_{top} : H^+ \rightarrow t\bar{b}$

  - Top decays as in Standard Model

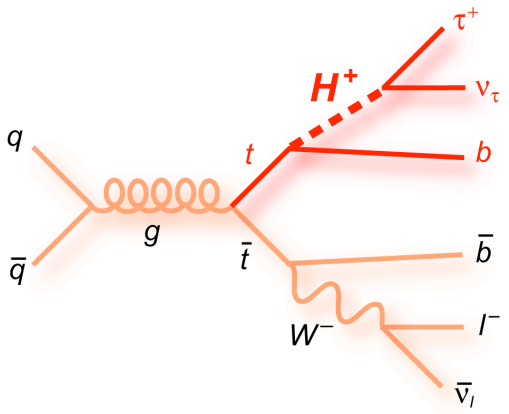


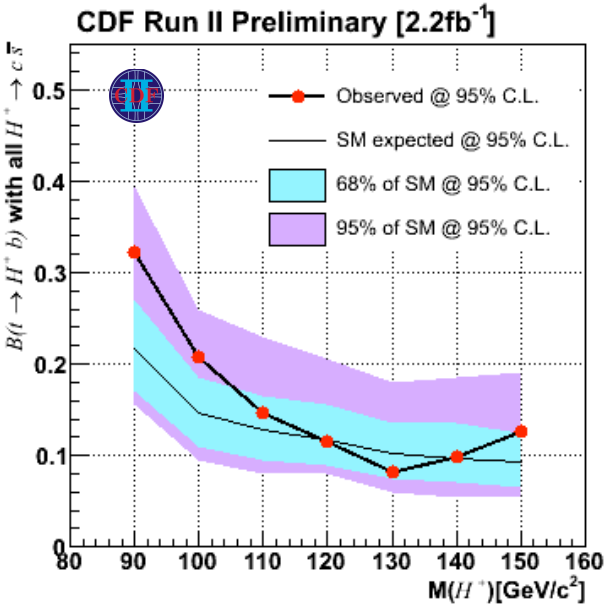
Tevatron Searches
Light Higgs

$t \rightarrow H^+ b$

- $BR(H^+ \rightarrow c\bar{s}) \approx 1$

  Leptophobic model
  CDF: 2.2 fb^{-1}
  DØ: 1.0 fb^{-1}



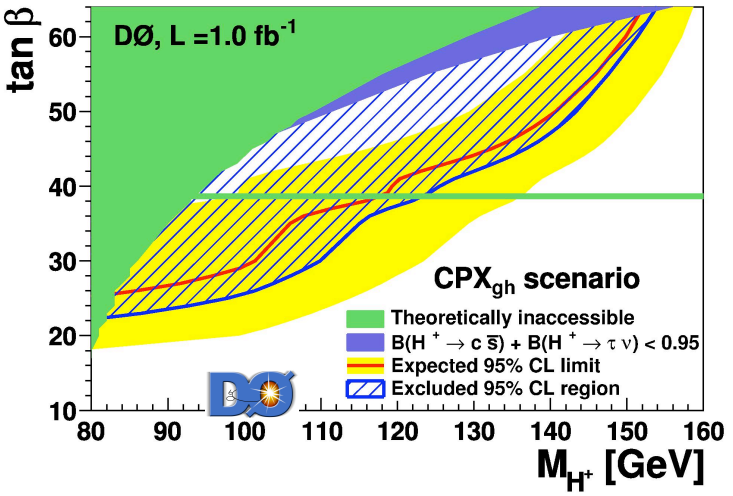


- $BR(H^+ \rightarrow \tau\nu) \approx 1$

  MSSM model
  DØ: 1 fb^{-1}

- $BR(H^+ \rightarrow c\bar{s}) + BR(H^+ \rightarrow \tau\nu) \approx 1$

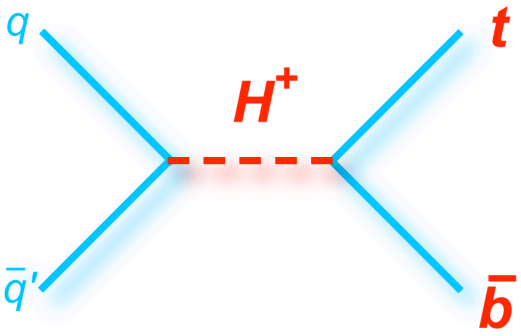
  CPX model
  DØ: 1 fb^{-1}



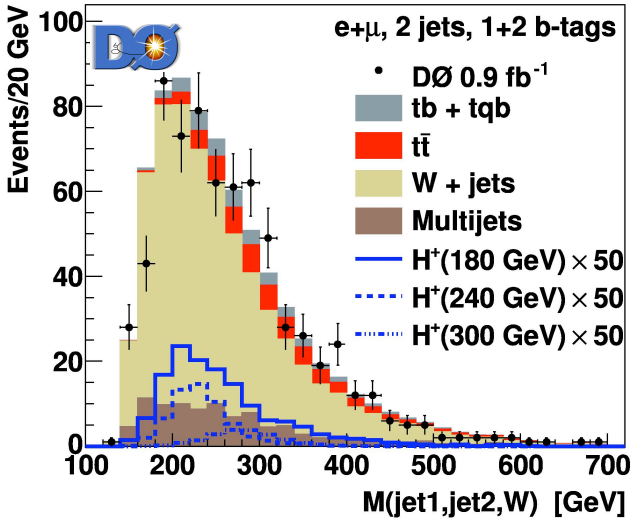
Tevatron Searches
Heavy Higgs

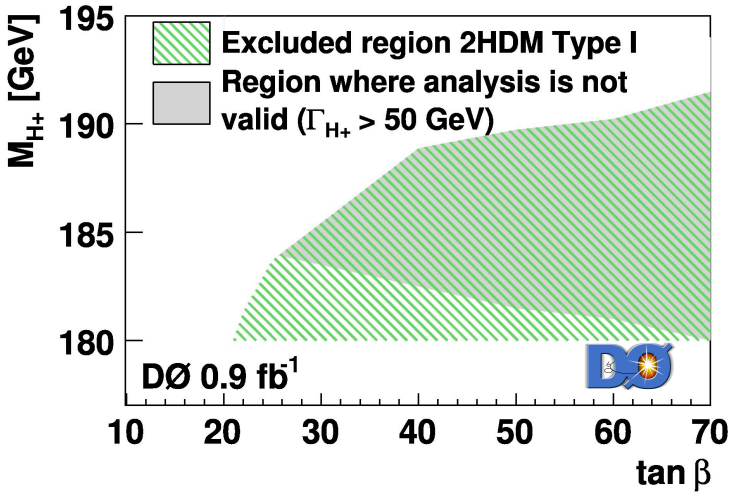
$H^+ \rightarrow t\bar{b}$

- Assume heavy $H^{\pm}$
  - $180 < M_{H^{\pm}} < 300$
- Same final state as $W^+ \rightarrow t\bar{b}$
- Set limits for various two Higgs doublet models



0.9 fb^{-1} of integrated luminosity





Extended 2HD Models: The NMSSM

- Extends MSSM by additional singlet Higgs, S
- After EW symmetry breaking have 7 Higgs bosons
  - $h, H, H_3, a, A, H^{\pm}$
- Several advantages over MSSM
  - For $m_a < 2m_b$ LEP limits can be avoided
  - Alleviates little hierarchy problem
  - Gives natural scale for μ parameter
- Higgs to Higgs decays can dominate

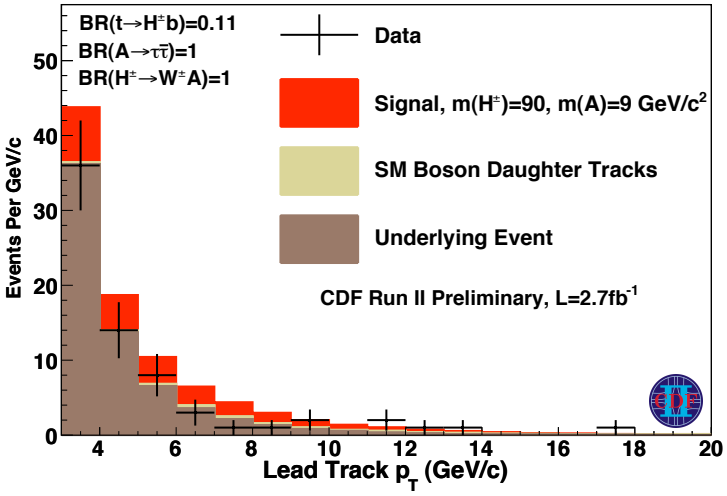
$$H^+ \rightarrow W^+ a$$

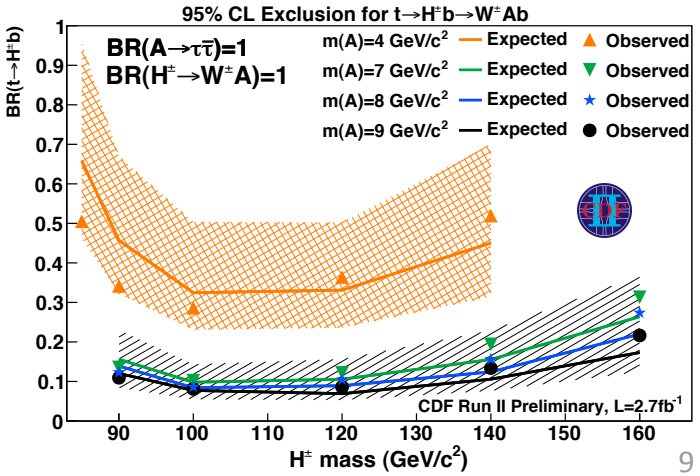
Tevatron Searches
NMSSM Higgs

$$t \rightarrow H^+ b \rightarrow W^{\pm} a b \rightarrow W^{\pm} \tau \bar{\tau} b$$

- The branching ratio of top to charged higgs may be as high as 40%
- NMSSM search for light psuedo-scalar Higgs
- Assume $m_a < 2m_b$
- Set limits on branching ratio $t \rightarrow H^{\pm} b$

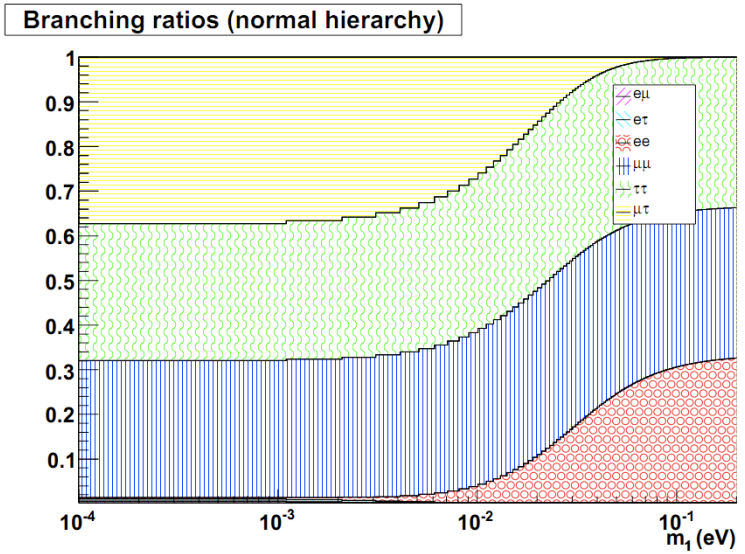
2.7 fb^{-1} of integrated luminosity





Higgs Triplet Models

- Introducing a Higgs Triplet produces a Higgs boson with a double charge, H^{++}
- Relevant Models:
  - Left Right Symmetry models:
    Symmetry between left and right handed particles.
    Predict both H_L^{++}, H_R^{++}



M. Kadastik, M. Raidal, and L. Rebane, Phys. Rev. D 77, 115023 (2008)

  - See-Saw mechanism
    Higgs triplet as a production mechanism of the neutrino masses.
    Predict equal BR to μμ,ττ,μτ for masses less than 10meV

  - (3-3-1) gauge symmetric models:
    Predict heavy exotic leptons and quarks providing anomaly cancellations.
    Predict that tau decays dominate.

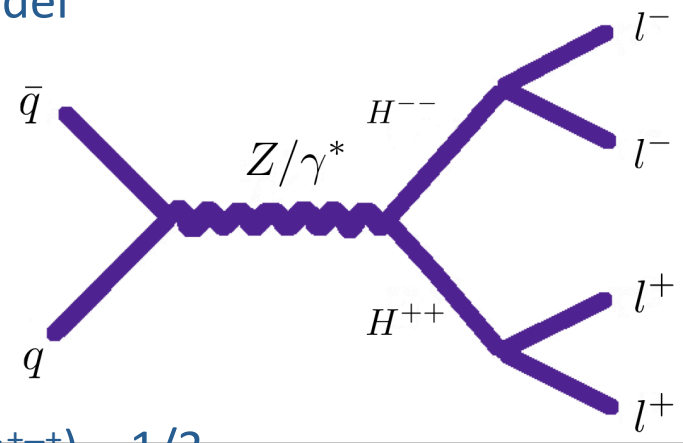
Tevatron Searches
Doubly Charged Higgs

New Result!

$$H^{++}H^{--} \rightarrow l^+l^+l^-l^-$$

$$l^+l^+ = \tau^+\tau^+, \mu^+\mu^+, \tau^+\mu^+$$

- Limits set for 4 model independent and one model specific final state.



1. BR(H^{++}-> $\tau^+\tau^+$) = 1
2. BR(H^{++}-> $\mu^+\tau^+$) = 1
3. BR(H^{++}-> $\mu^+\mu^+$) = 1
4. BR(H^{++}-> $\tau^+\tau^+$) + BR(H^{++}-> $\mu^+\mu^+$) = 1
5. BR(H^{++}-> $\tau^+\tau^+$) = BR(H^{++}-> $\mu^+\mu^+$) = BR(H^{++}->$\mu^+\tau^+$) = 1/3

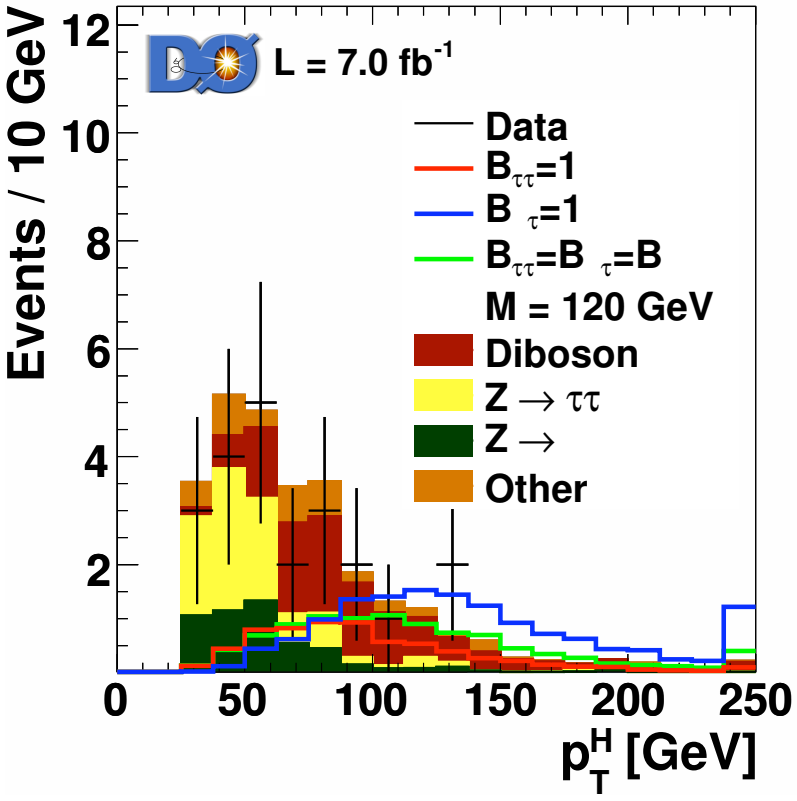
- For points 1 and first time this limits been set.
- Submitted to PRL

7.0 fb^{-1} of integrated luminosity

Tevatron Searches
Doubly Charged Higgs

New Result!

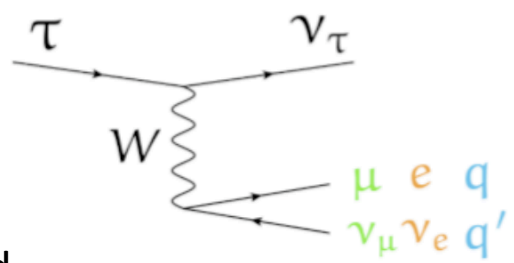
- Signal
  - Pick two highest P_T τ and highest P_T μ.
  - Unusual final state composition used to optimize selection
- Main Backgrounds
  - Z to ττ
  - Z to μμ
  - Diboson
- Data determined multijet background is negligible

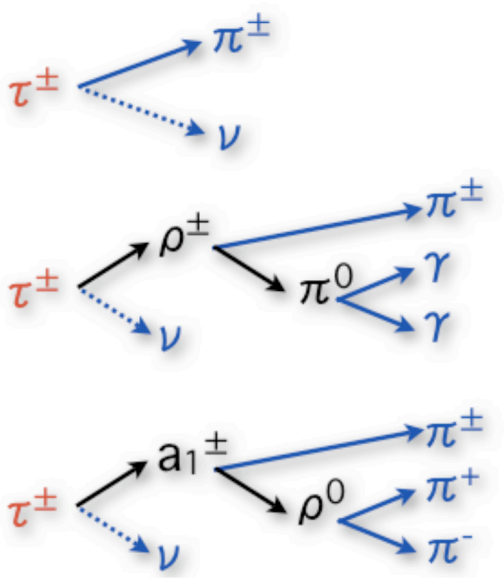


Tevatron Searches
Doubly Charged Higgs

New Result!

- Specific tools to deal with tau based final states. Split into leptonic and hadronic decays
- μ,e use standard leptonic identification tools
- For hadronic tau decay have large jet background

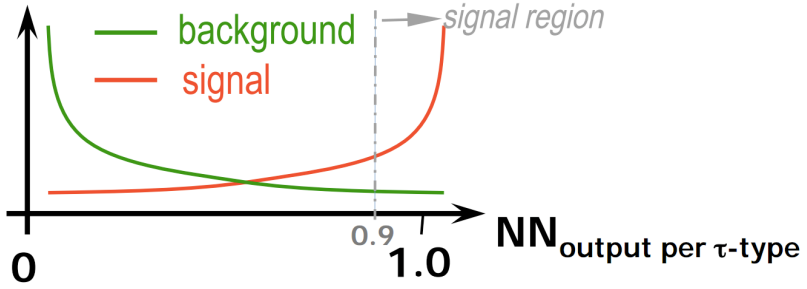




1 Track
Calorimeter cluster

1 Track
Calorimeter cluster
> 0 EM sub-cluster

> 1 Track
Calorimeter cluster
> 0 EM sub-cluster



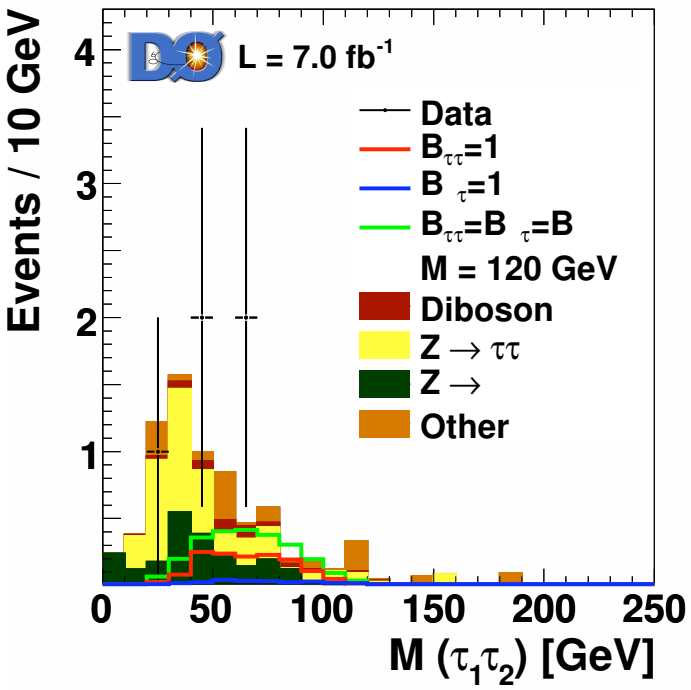
Efficiency = 65% Fake rate = 2.5%

Tevatron Searches
Doubly Charged Higgs

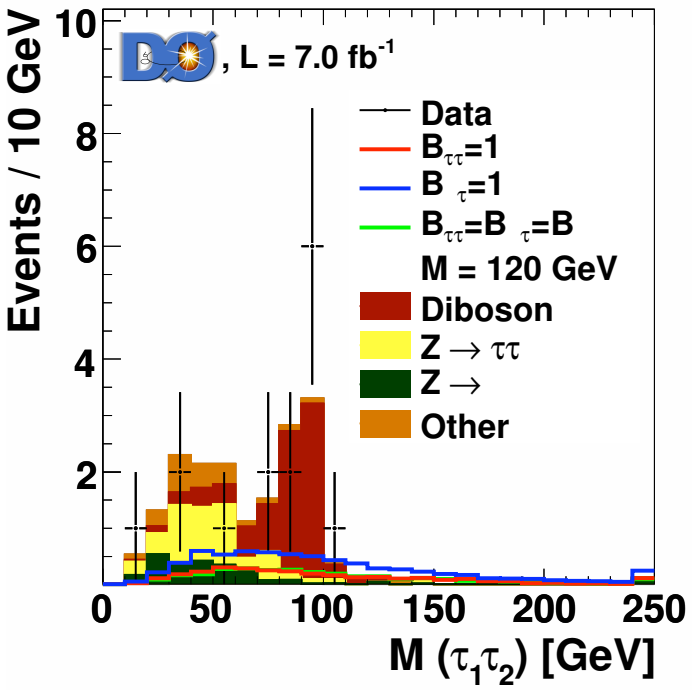
New Result!

Split into four sub samples based on charge and number of leptons to increase sensitivity to different final states.

$q_{\tau 1} = q_{\tau 2}$



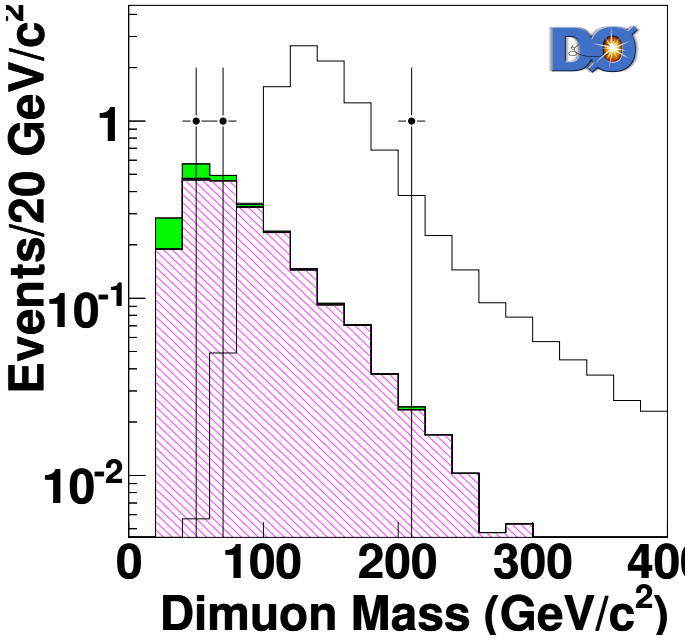
$q_{\tau 1} = -q_{\tau 2}$



Tevatron Searches
Doubly Charged Higgs

New Result!

- For BR($H^{++} \to \tau^+\tau^+$)+ BR($H^{++} \to \mu^+\mu^+$)=1 need a $H^{++} \to \mu^+\mu^+$ to combine with.
  - $1fb^{-1}$ DØ result.
    - At least 3 isolated muons
    - $\Delta\phi(\mu,\mu) < 2.5$ rad for at least one pair of muons
    - M(μ,μ) of leading muons used as discriminant
    - 3 candidate events with 2.3±0.2 background expected



Phys. Rev. Lett. **101**, 071803 (2008)

Original M(μ,μ) distribution used in limit setting procedure

Tevatron Searches
Doubly Charged Higgs

New Result!

$$BR(H^{++} \to \tau\tau) = 1$$

Limits:

$$M_L^{++} > 128 \text{ GeV}$$

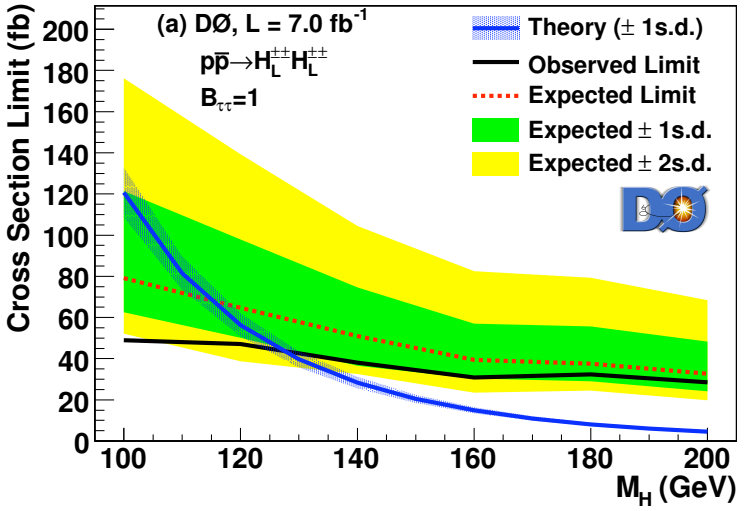
Right handed limit not set

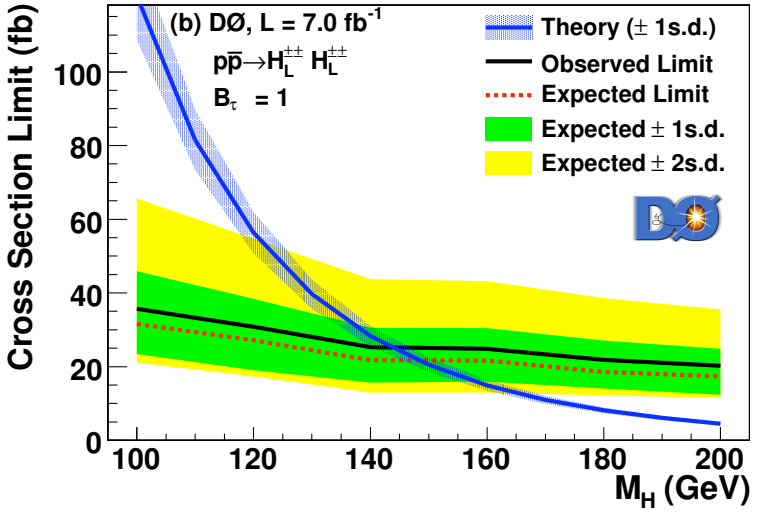
$$BR(H^{++} \to \mu\tau) = 1$$

Limits:

$$M_L^{++} > 144 \text{ GeV}$$

$$M_R^{++} > 113 \text{ GeV}$$





Tevatron Searches
Doubly Charged Higgs

New Result!

$$BR(H^{++} \to \tau\tau) \approx BR(H^{++} \to \mu\mu) \approx BR(H^{++} \to \mu\tau) \approx 1/3$$

Limits:

$$M_L^{++} > 138 \text{ GeV}$$

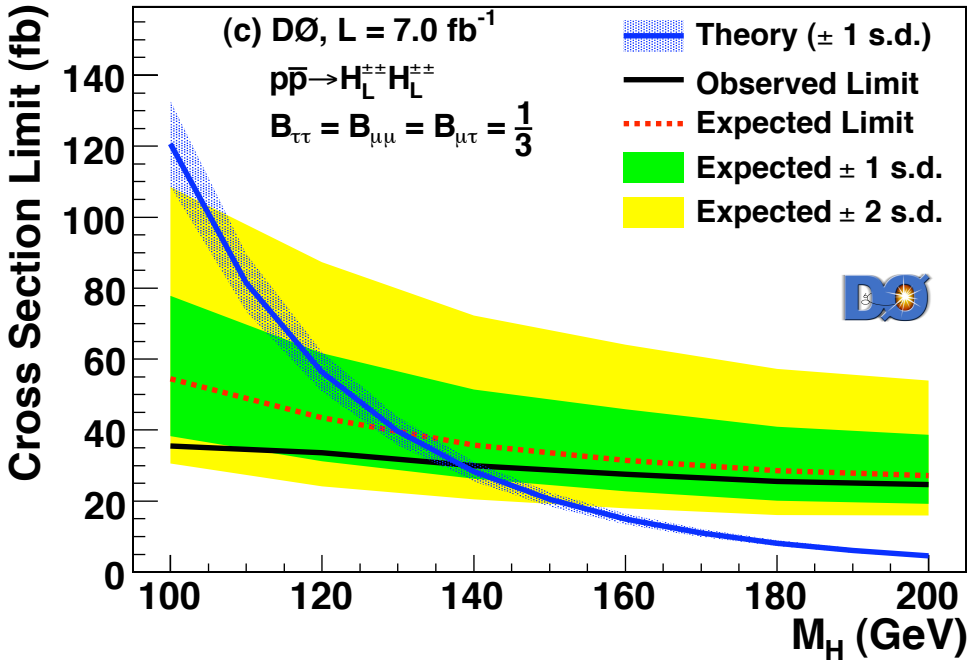
No right handed Higgs in this model

$$BR(H^{++} \to \mu\mu) = 1$$

Limits:

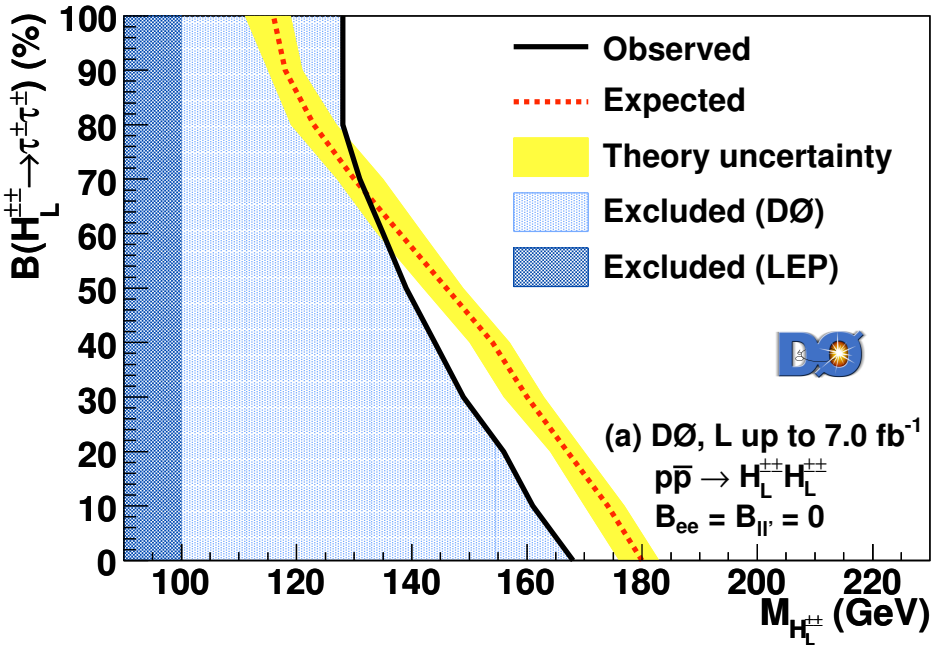
$$M_L^{++} > 168 \text{ GeV}$$

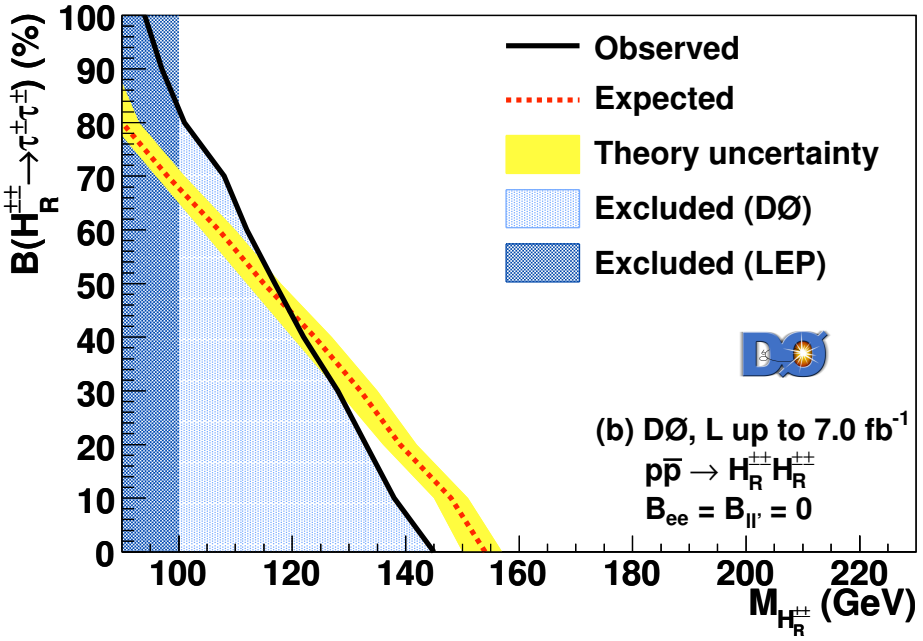
$$M_R^{++} > 145 \text{ GeV}$$



Tevatron Searches
Doubly Charged Higgs

New Result!





Set limits let for both left and right handed Higgs

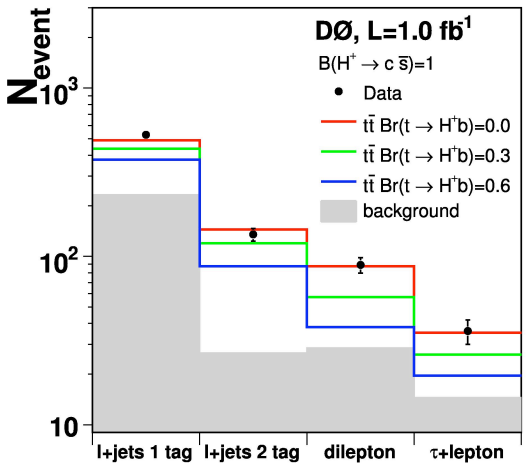
Predicted ross section H_R^{++} is approximately half cross section H_L^{++}

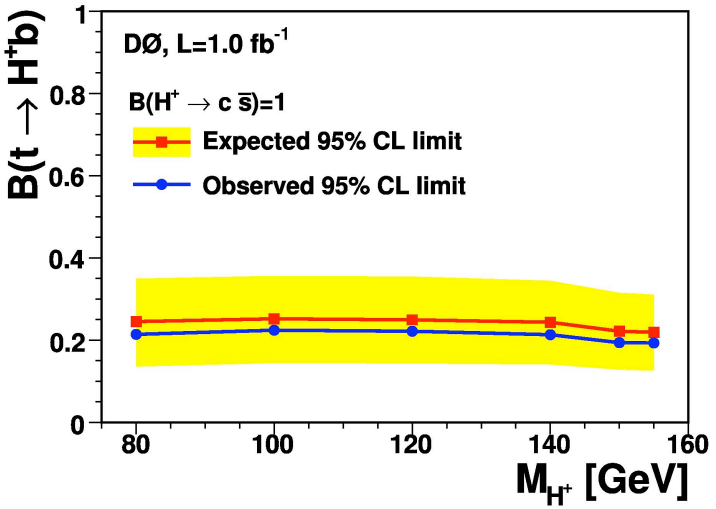
Conclusions

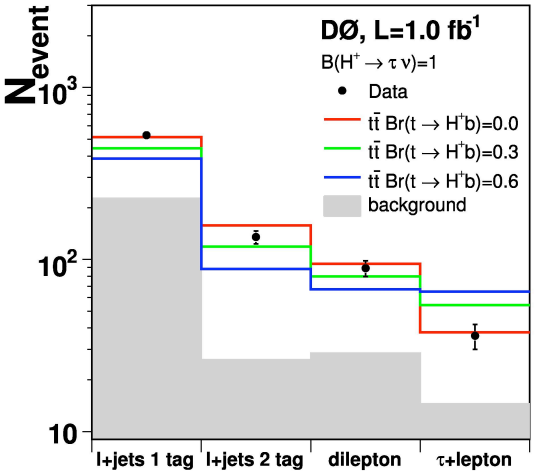
- DØ and CDF cover a wide range of charged and doubly charged Higgs channels.
- New results out this year and more expected.
- First and only limits on BR($H^{++} \rightarrow \tau\tau$) = 1

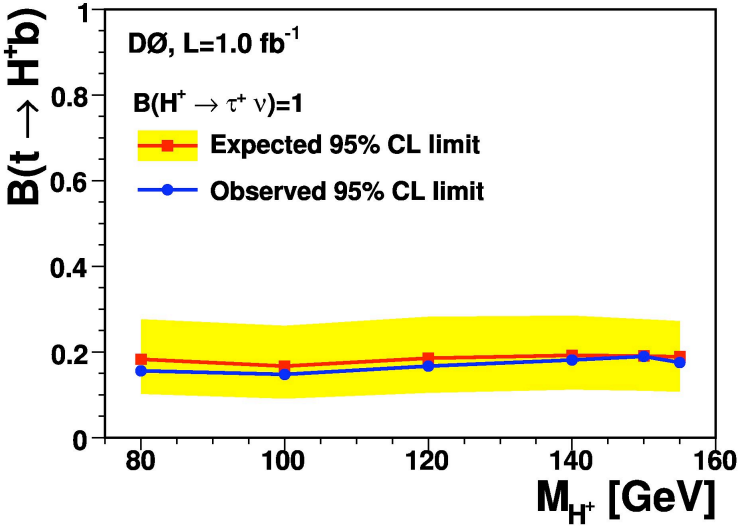
Back Up

Tevatron Searches









Tevatron Searches

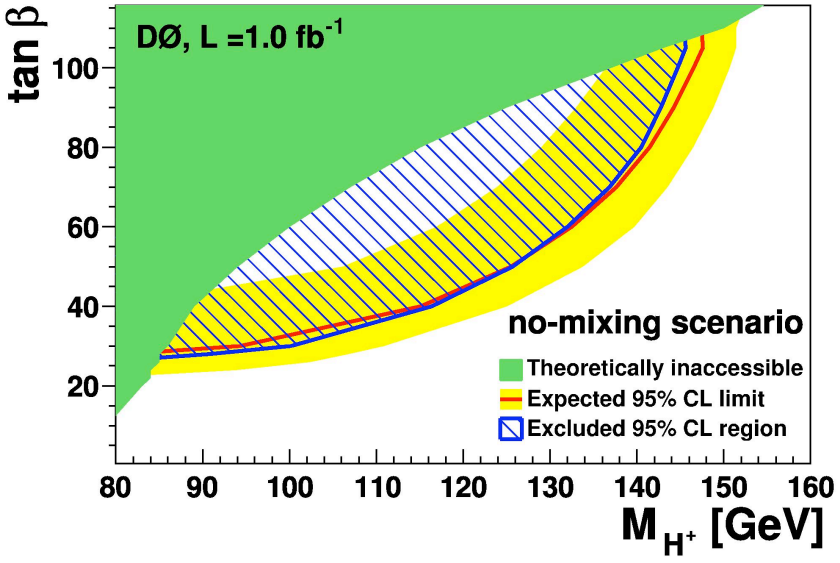
Tauonic MSSM models

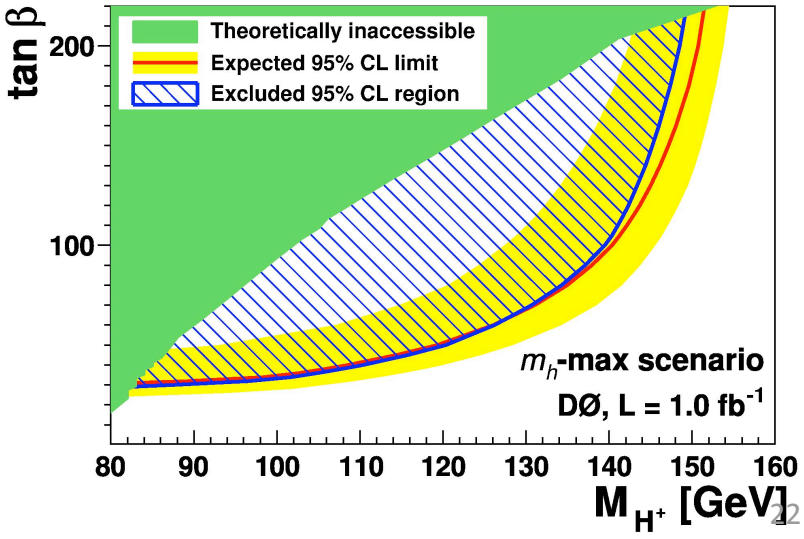
$$H^+ \rightarrow \tau\nu$$

M_h max: stop mixing parameter set to $2M_{susy}$

no-mixing: stop mixing parameter set to zero

parameter	CPX_{gh}	m_h-max	no-mixing
μ	2000	200	200
M_{SUSY}	500	1000	2000
A	$1000 \cdot \exp(i\pi/2)$		
X_t		2000	0
M_2	200	200	200
M_3	$1000 \cdot \exp(i\pi)$	800	1600





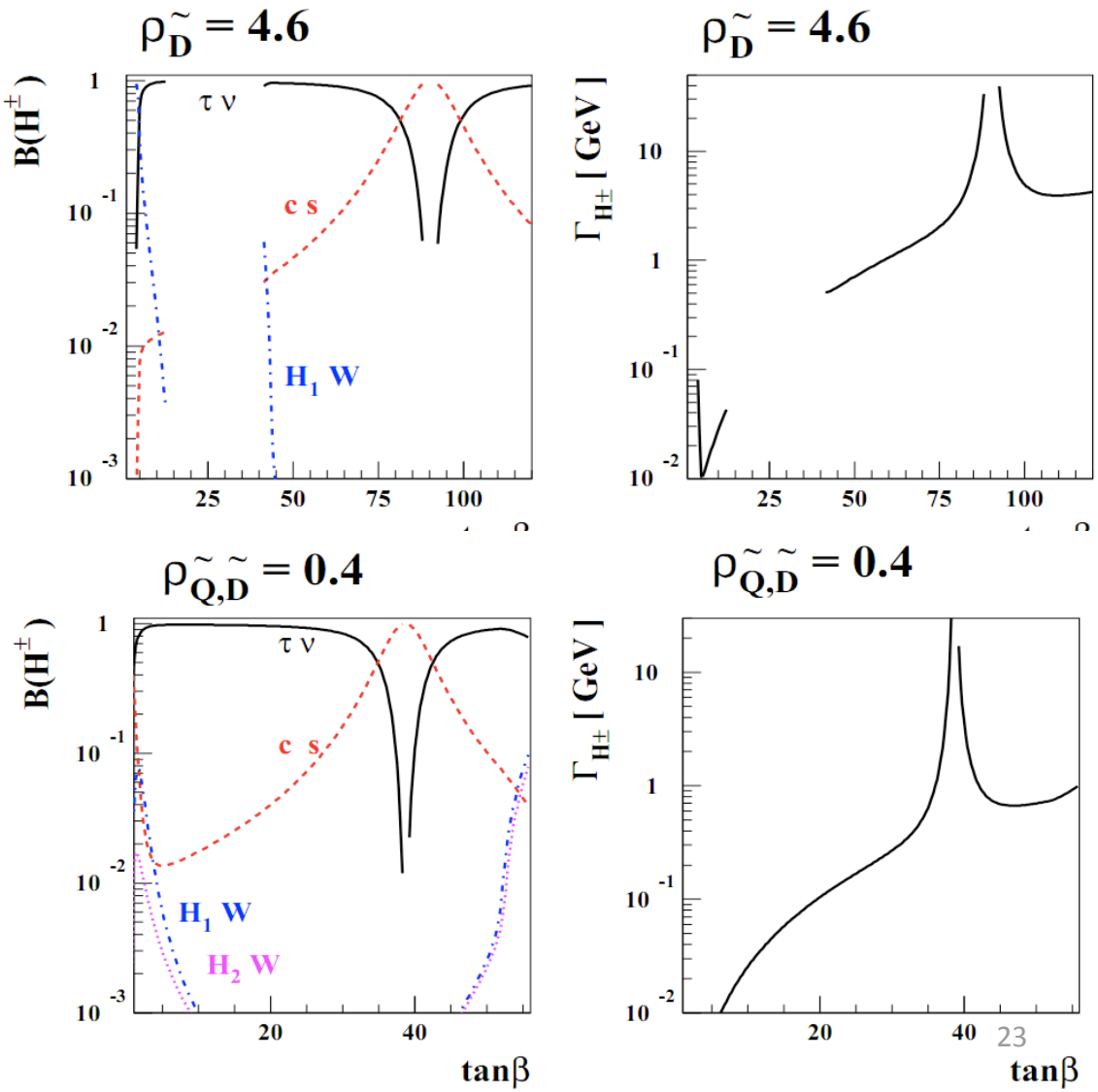
Tevatron Searches

CPX model:
Strangephilic Higgs bosons
– enhance s couplings

$$BR(H^+ \to c\bar{s}) + BR(H^+ \to \tau\nu) \approx 1$$

L scenario:
$\rho_D > 1$

S scenario:
$\rho_D < 1$



J. S. Lee, Y. Peters
, A. Pilaftsis and C. Schwanenberger,
arXiv:0909.1749 [hep-ph]