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BSM Higgs Searches in Tau Final States at DØ

Les Rencontres de Physique de la Vallée d'Aoste

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For the DØ Collaboration

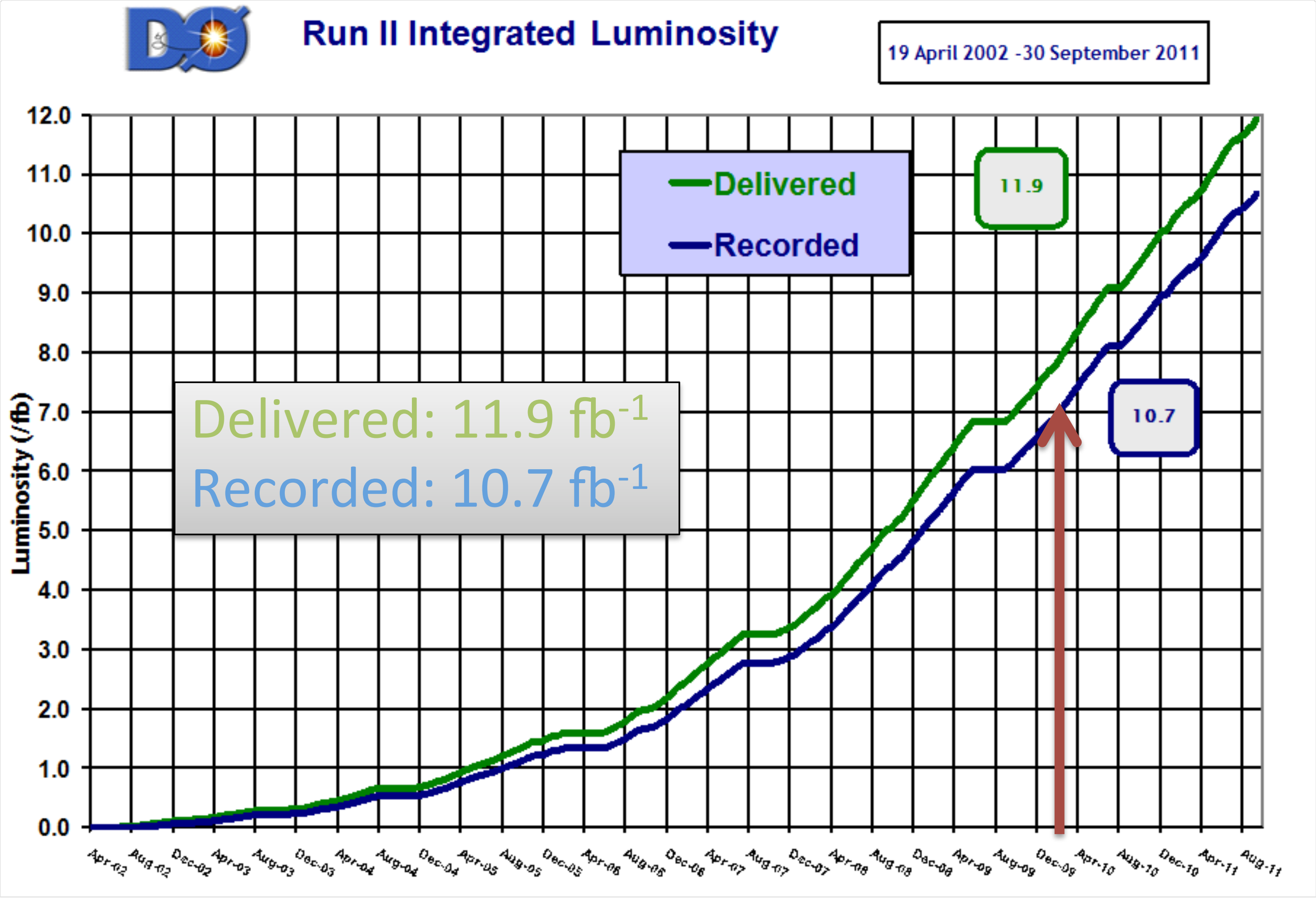
The Fermi National Accelerator Laboratory

Tevatron collided protons and antiprotons from 1985 to 2011

2 general purpose detectors DØ and CDF

Over 10 fb^{-1} recorded

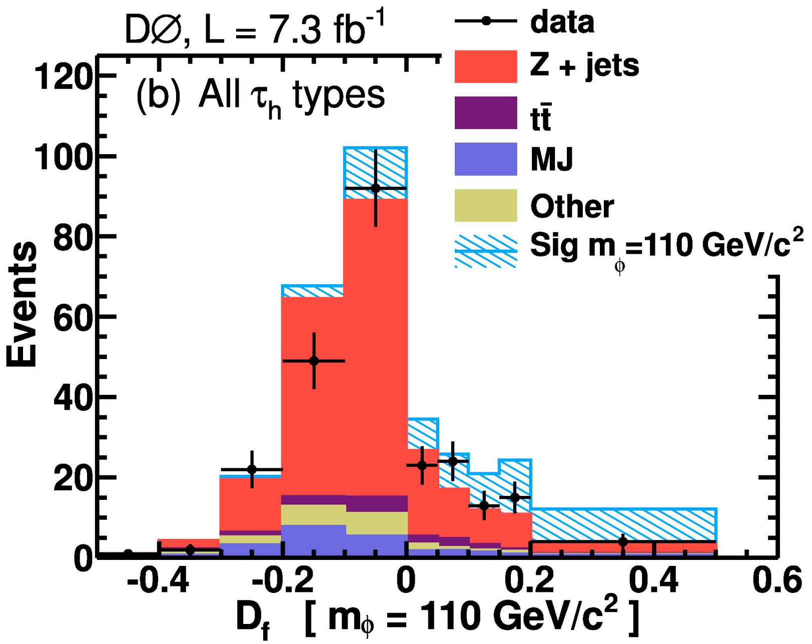
DØ luminosity



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

BSM Higgs with tau leptons

- Various BSM models predict tau decay modes to be important.
  - MSSM can have enhanced down-type coupling.
    BR(ϕ ➔ bb) ~ 90%
    BR(ϕ ➔ ττ) ~ 10%
  - NMSSM suggested to have very light pseudo-scalar Higgs then decays to tau avoiding the LEP limits.



- The results I am showing today is looking for a less well known Higgs, a doubly charged Higgs.

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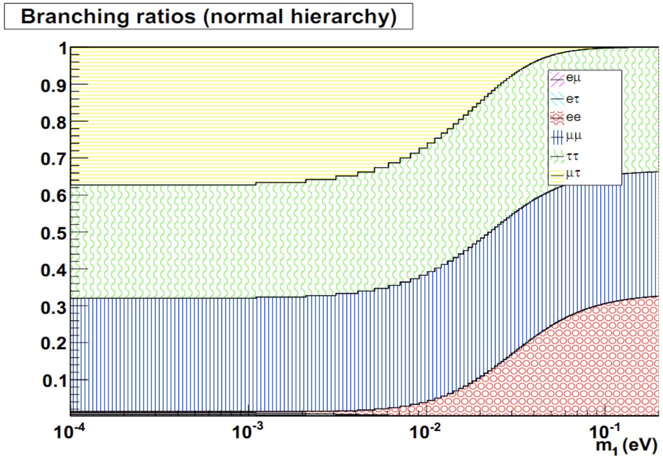
Higgs triplet models



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

Extensions to SM with a Higgs triplet result in a Higgs with double charge.

Left Right Symmetry models: Symmetry between left and right handed particles.

Predict both H_L^{++}, H_R^{++}

Cross section for right-handed Higgs is predicted to be about half that of left-handed.

See-Saw mechanism: Higgs triplet as a production mechanism of the neutrino masses.

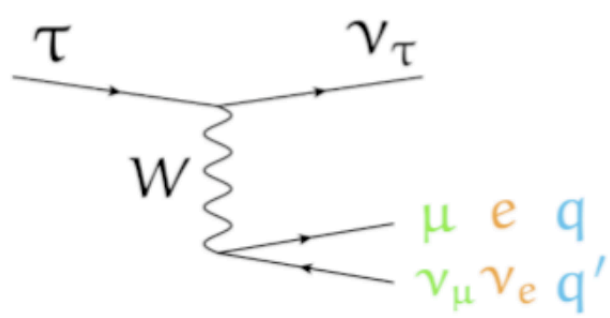
Predict equal BR to μμ,ττ,μτ for masses < 10meV and normal hierarchy of neutrino masses

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

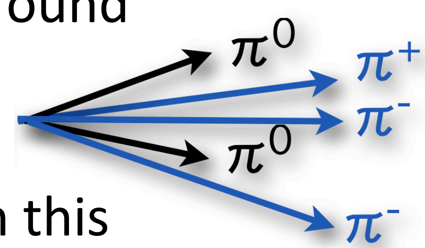
Predicts that tau decays dominate.

Object identification: Taus

- Tau lepton heaviest of leptons with M = 1777 MeV and lifetime of just 2.9×10^{-13} s, so one just sees it decay products.
- We use different tools for leptonic and hadronic tau decay



- For μ,e use standard leptonic identification tools
- Hadronic tau decay suffers from large jet background



- Specific identification tools created to deal with this

Object identification: Taus

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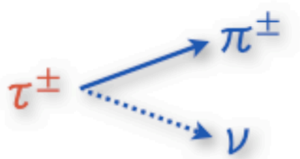
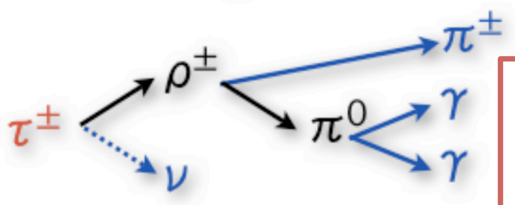
Define 3 types of hadronic taus

Type 1



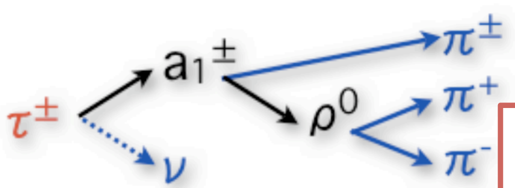
1 Track
Calorimeter cluster

Type 2



1 Track
Calorimeter cluster
> 0 EM sub-cluster

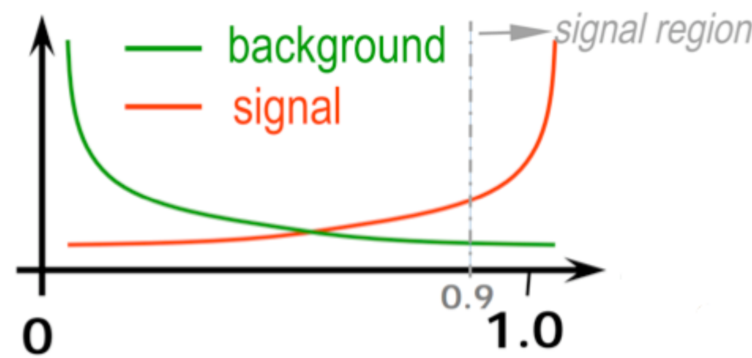
Type 3



> 1 Track
Calorimeter cluster
> 0 EM sub-cluster

Efficiency = 65% Fake rate = 2.5%

- Neutral Network trained for each type
- Trained on Z ➔ ττ to differentiate real taus from jets



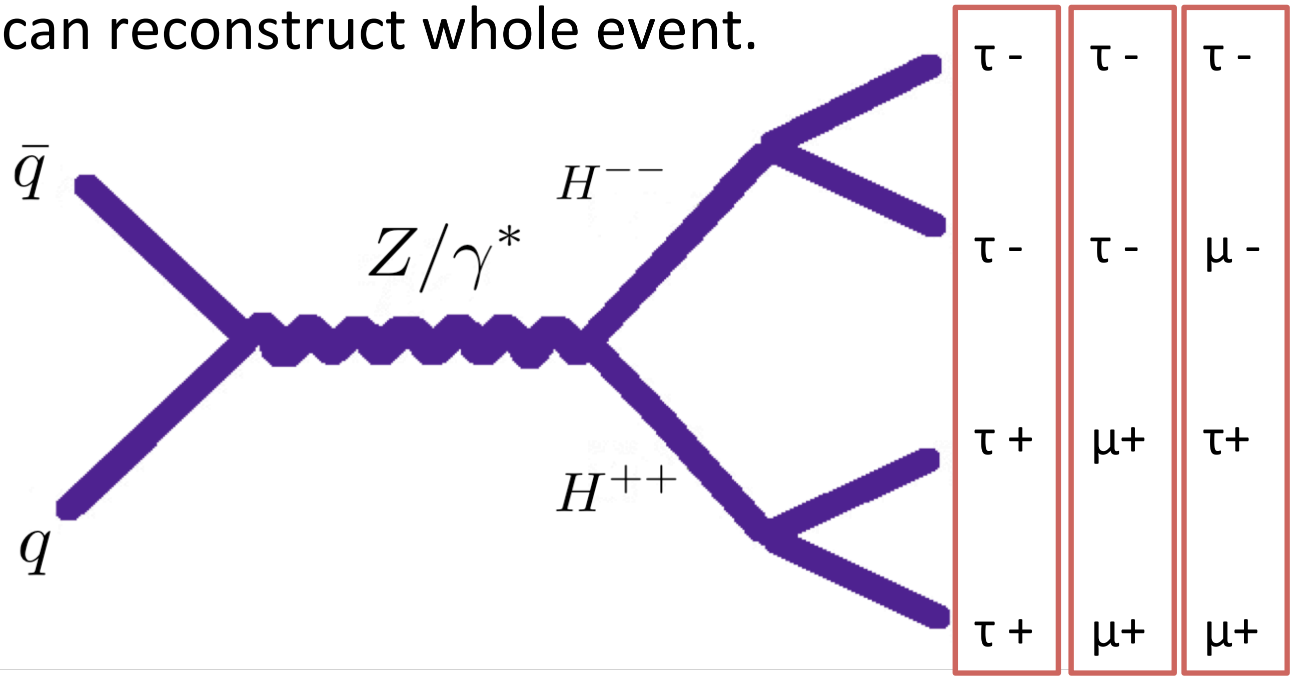
Doubly charged Higgs

- Look for pair produced H⁺⁺ decaying into tau and muon final states

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

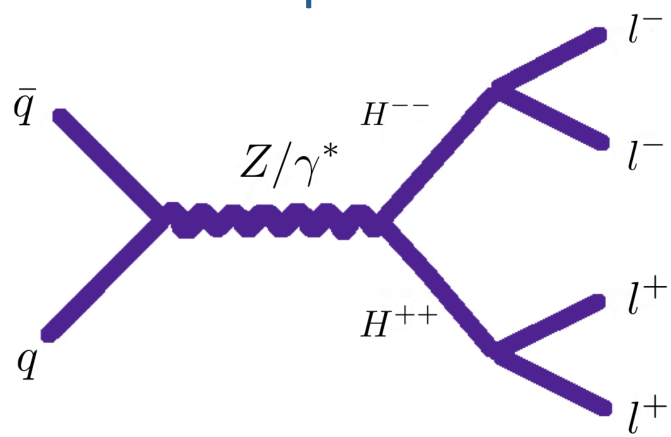
$$l^+l^+ = \tau^+\tau^+, \mu^+\mu^+, \tau^+\mu^+$$

- Flavor violating decay, but has advantage of no neutrinos so one can reconstruct whole event.



Model dependence of limits

- Not known how the H^{++} decays, dependent on model chosen.
- Limits set for 4 model independent and 1 model specific decay channels.

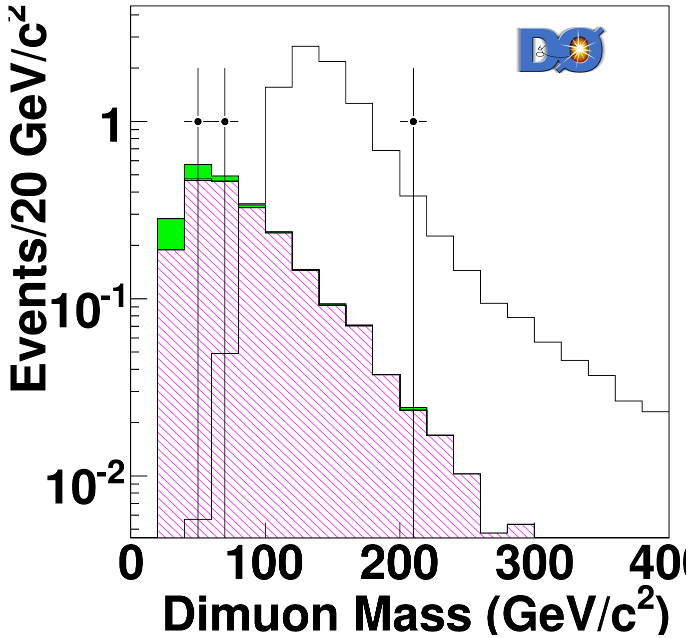


1. $B(H^{\pm\pm} \rightarrow \tau^\pm\tau^\pm) = 1$
2. $B(H^{\pm\pm} \rightarrow \mu^\pm\tau^\pm) = 1$
3. $B(H^{\pm\pm} \rightarrow \tau^\pm\tau^\pm) + BR(H^{\pm\pm} \rightarrow \mu^\pm\mu^\pm) = 1$
4. $B(H^{\pm\pm} \rightarrow \tau^\pm\tau^\pm) = BR(H^{\pm\pm} \rightarrow \mu^\pm\mu^\pm) = BR(H^{\pm\pm} \rightarrow \mu^\pm\tau^\pm) = 1/3$

- For points 1 and 3 this was the first time these limits had been set at a Hadron collider.

B($H^{++} \rightarrow \mu^+\mu^+$)=1 Combination

- For Points 3 and 4 we need a B($H^{++} \rightarrow \mu^+\mu^+$) =1 limit.
- Combine with 1fb^{-1} DØ result.
  - At least 3 isolated muons
  - M(μ,μ) of leading p_T muons used as discriminant
  - 3 candidate events with 2.3±0.2 background expected.

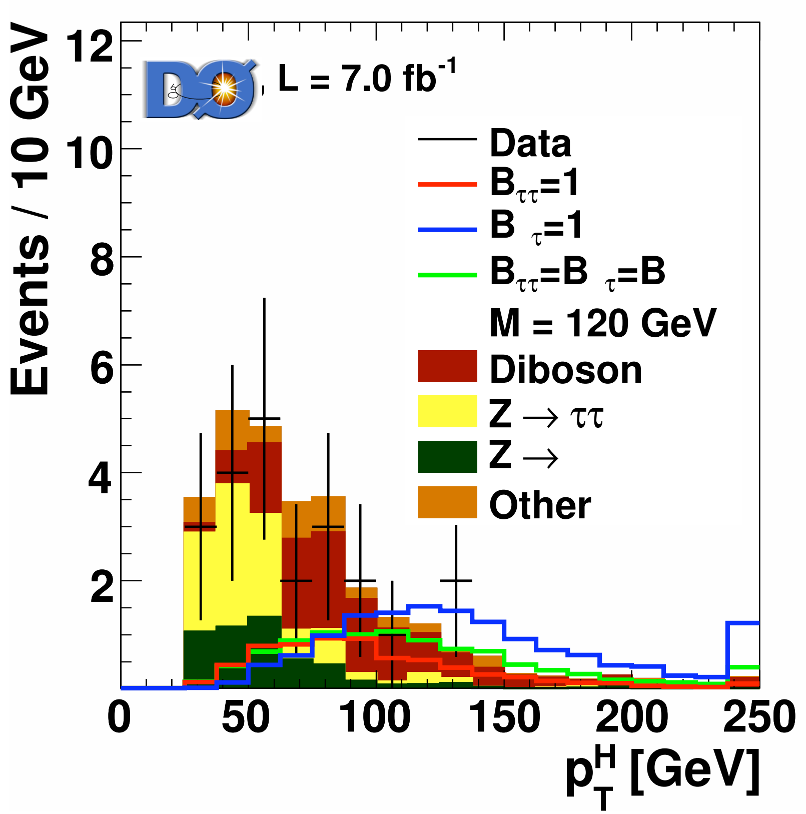


Phys. Rev. Lett. **101**, 071803 (2008)

The analysis selection

Selection

- Using 7.0 fb^{-1} of integrated luminosity
- Select the two taus with highest transverse momentum, $p_{T,}$ and the highest p_T muon.
- Neural Net, $NN_{\tau,}$ is used to discriminate taus from jets.
- Unusual final state composition used to optimize selection



P^H_T, Higgs P_T, calculated from selecting same sign pair from 3 final state objects

Main Backgrounds

- Z(➔ ττ) + jets
- Z (➔μμ) + jets
- Diboson (WZ, WW, ZZ)

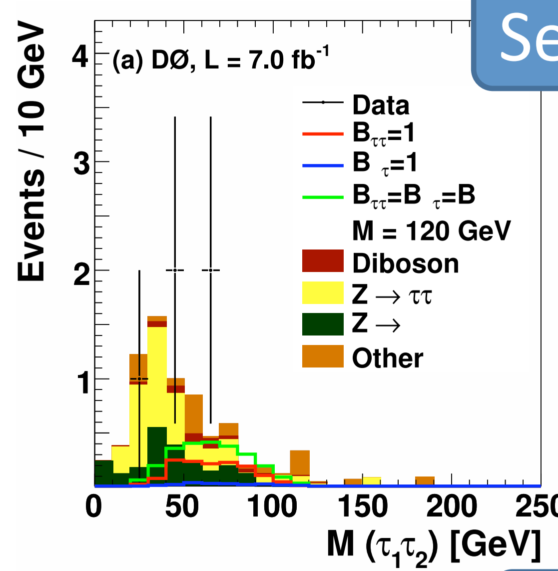
Final discriminants

Split into four sub samples
- based on charge and lepton multiplicity.

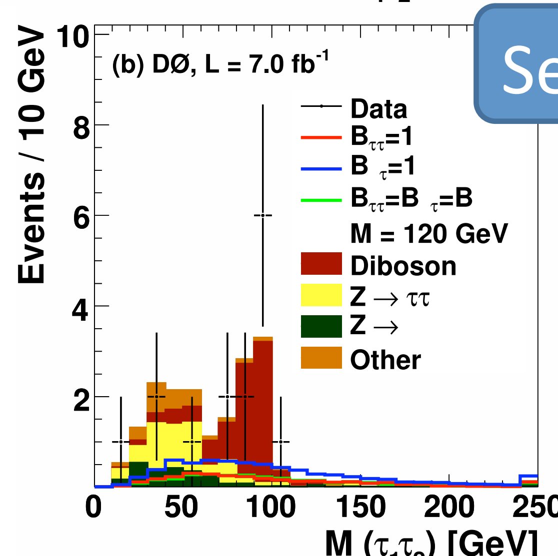
These are sensitive to different signals and have different background compositions

1. N(μ)= 1, N(τ) = 2, q(τ1) = q(τ2)
2. N(μ) = 1, N(τ) = 2, q(τ1) = - q(τ2)
3. N(μ) = 2, N(τ) = 2
4. N(μ) = 1, N(τ) =3

Set 1



Set 2

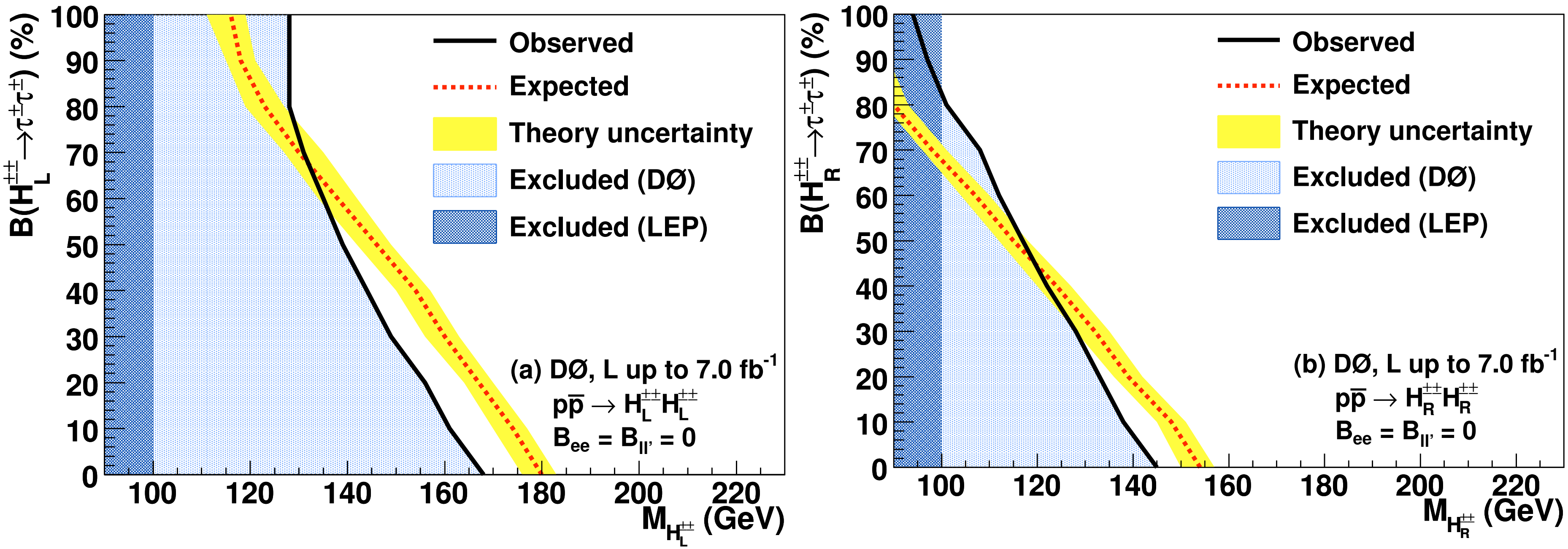


Doubly charged Higgs limits

Decay	$H_L^{\pm\pm}$ (GeV)		$H_R^{\pm\pm}$ (GeV)	
	expected	observed	expected	observed
$\mathcal{B}(H^{\pm\pm} \to \tau^{\pm}\tau^{\pm}) = 1$	116	128	no limit set	
$\mathcal{B}(H^{\pm\pm} \to \mu^{\pm}\tau^{\pm}) = 1$	149	144	119	113
Equal $\mathcal{B}$ into $\tau^{\pm}\tau^{\pm}, \mu^{\pm}\mu^{\pm}, \mu^{\pm}\tau^{\pm}$	130	138	no $H_R^{\pm\pm}$ in model	
$\mathcal{B}(H^{\pm\pm} \to \mu^{\pm}\mu^{\pm}) = 1$	180	168	154	145

Set limits let for both left and right handed Higgs
Predicted cross section for H_R^{++} is about half cross section for H_L^{++}

Doubly charged Higgs limits



Set limits let for both left and right handed Higgs

Predicted cross section for H_R^{++} is about half cross section for H_L^{++}

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Summary

- Results were presented on a recent search for pair produced doubly charged Higgs decaying to muons and tau leptons at DØ.
  - Phys.Rev.Lett. 108 (2012) 021801
- Limits set for three model independent benchmark points and one model specific one.
- Results were combined with a previous 1fb^{-1} result from DØ to produce limits at additional benchmark points.
- First time limits set for 100% BR to a tau final state at a Hadron collider.