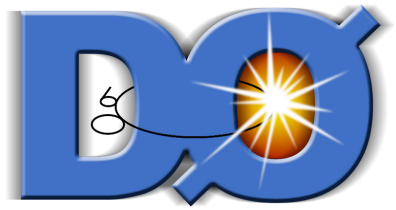

Combined CDF and DØ upper limits on MSSM Higgs boson production in $p\bar{p}$ collisions at 1.96 TeV

Louise Suter

For the DØ and CDF collaborations

DPF 2011

- The Tevatron
- Quick guide to the MSSM
- Object Identification
- Combinations
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    - Inputs
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    - Limits
  - DØ
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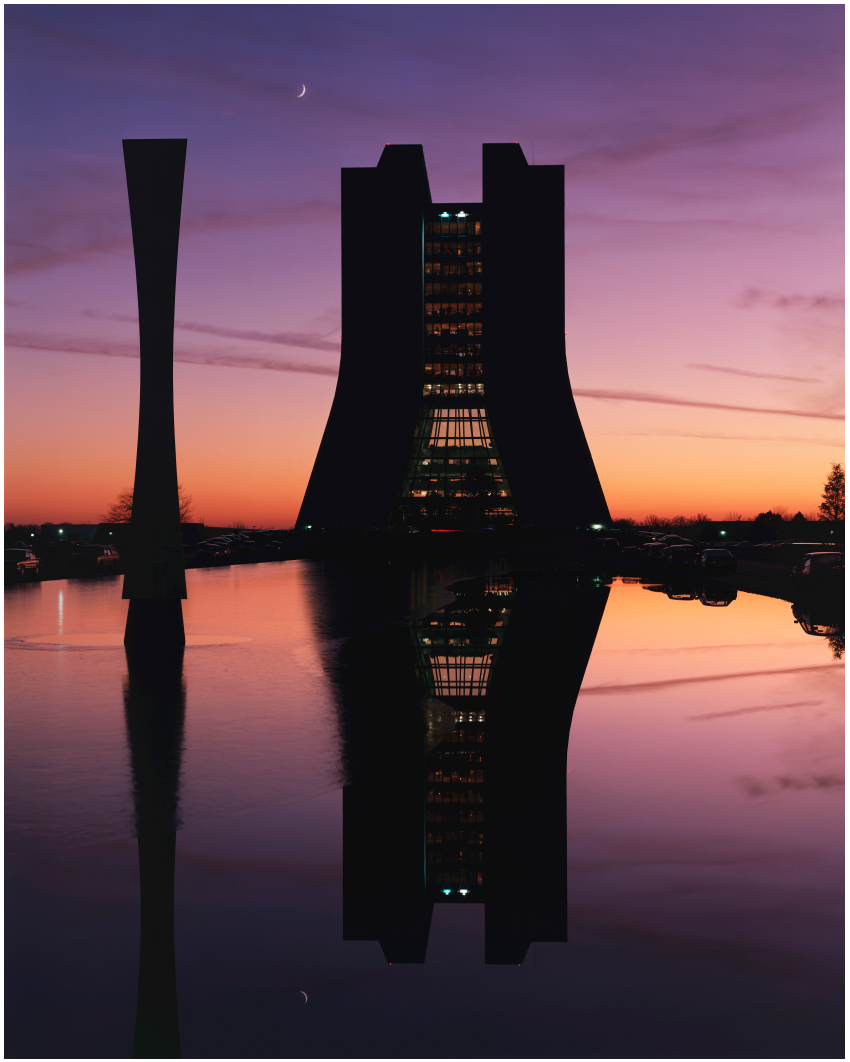
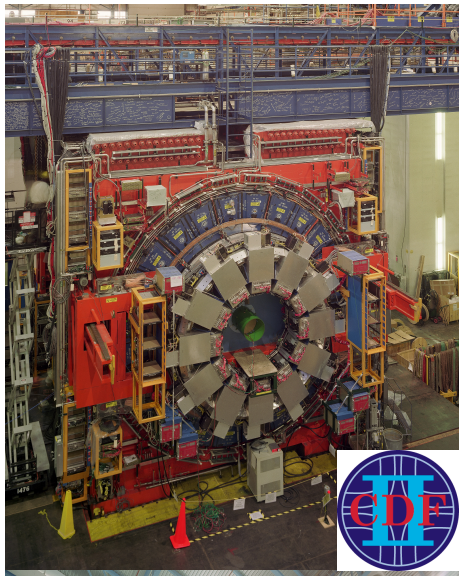


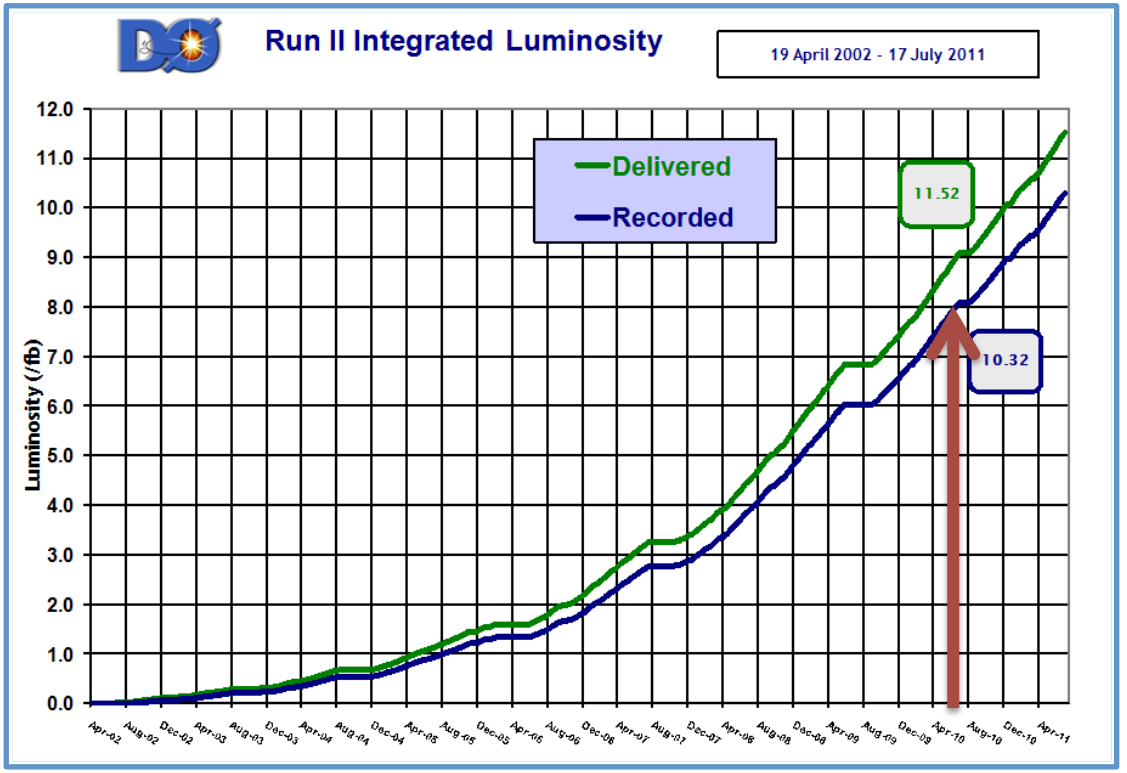
The Tevatron



Recorded: 10.3 fb^{-1}

Delivered: 11.5 fb^{-1}

Showing results with up to 7.3 fb^{-1}



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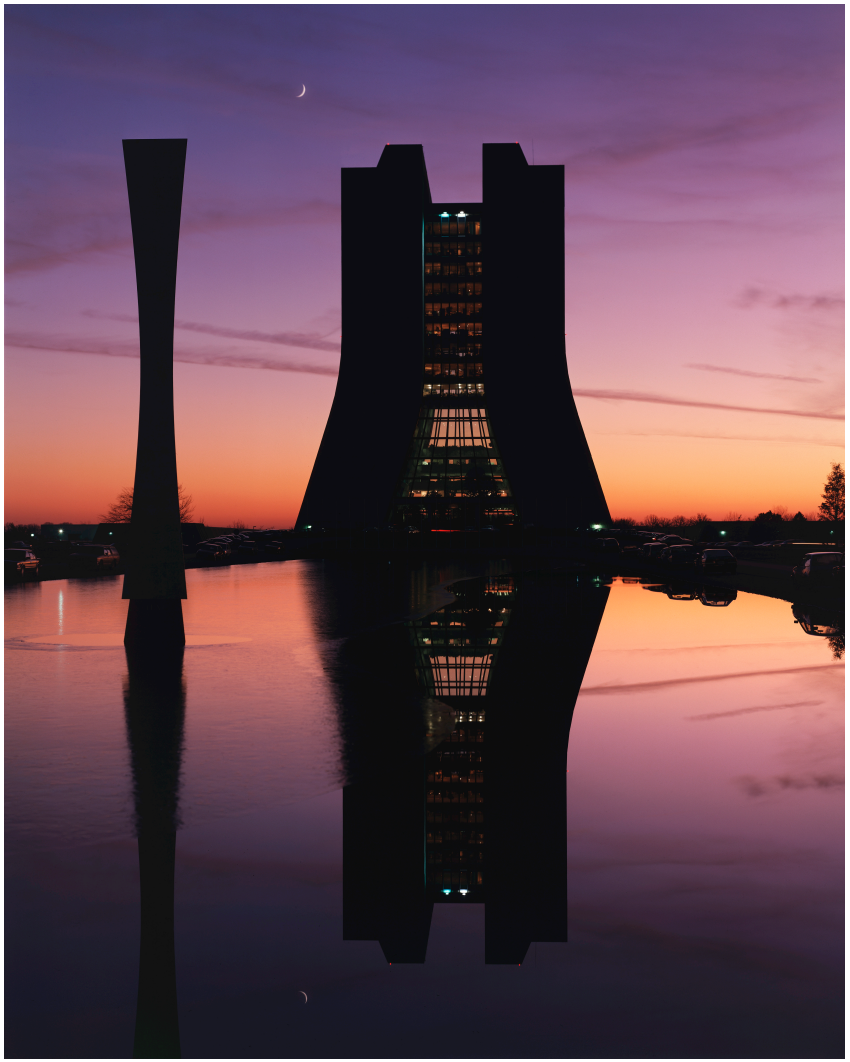


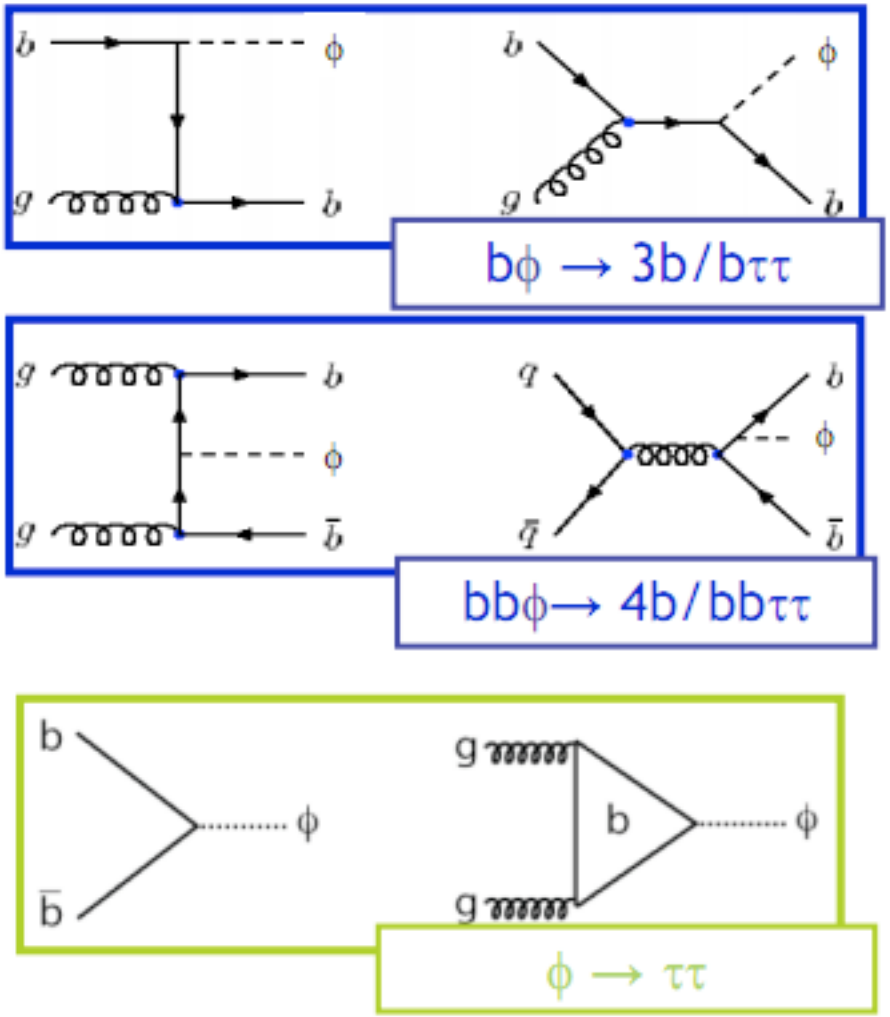
MSSM Higgs boson production

- Cover the 3 neutral Higgs ϕ = (h,H,A)
  - charged Higgs results covered in other talk

- Large tan β is preferred, leads to enhanced coupling to down type quarks and leptons

- Production/decay mechanism
  - $\phi b \rightarrow bbb$
  - $\phi b \rightarrow \tau\tau b$
  - $\phi \rightarrow \tau\tau$

- Branching Ratios
  - BR($\phi \rightarrow$ bb) ~ 90%
  - BR($\phi \rightarrow \tau\tau$) ~ 10%



SUSY Parameters

- Tree level MSSM Higgs sector described by two parameters
  1. M_A
  2. $\tan\beta = \langle H_u \rangle / \langle H_d \rangle$
- Radiate corrections introduce dependence on other parameters
- Limits set in model independent case
- Excluded in M_A ,$\tan\beta$ for two scenarios:

Parameter	m_h-max	no-mixing
μ	200 GeV	200 GeV
M_{SUSY}	1000 GeV	2000 GeV
X_t	2000 GeV	0 GeV
M_2	200 GeV	200 GeV
M_3	800 GeV	1600 GeV

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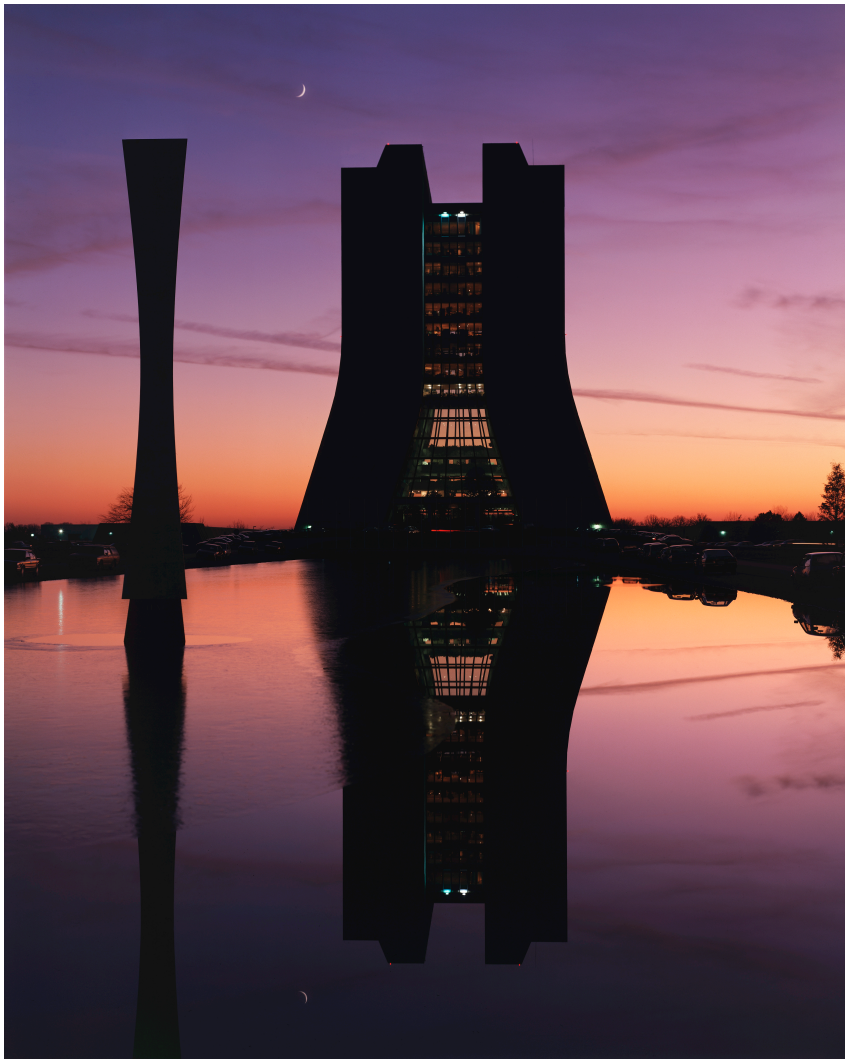
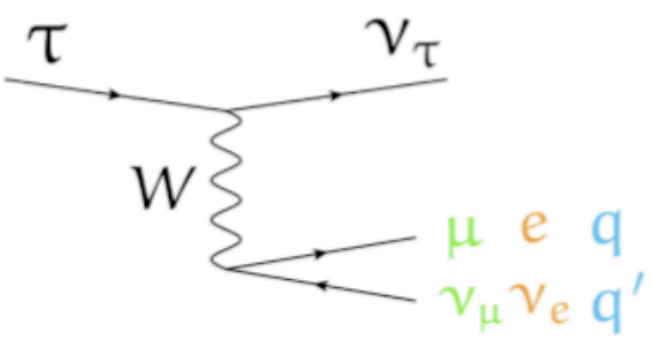
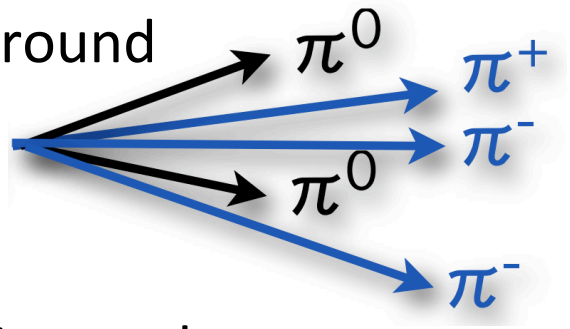


Object Identification: Taus

- Different tools for leptonic and hadronic tau decay



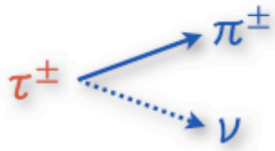
- μ,e use standard leptonic identification tools
- hadronic tau decay --- large jet background



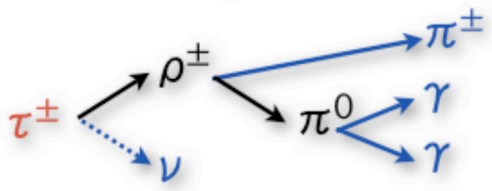
- D0 and CDF have specific identification tools

Object Identification: Taus

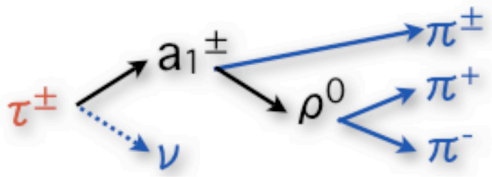
- Define 3 types due to decay products



1 Track
Calorimeter cluster

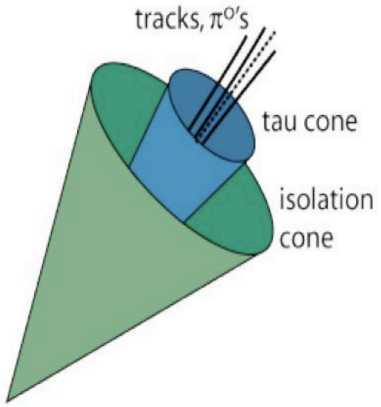


1 Track
Calorimeter cluster
> 0 EM sub-cluster



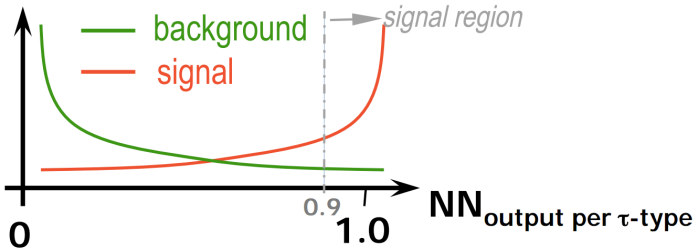
> 1 Track
Calorimeter cluster
> 0 EM sub-cluster

- Isolation cone



- Select 1 or 3 tracks in variable size and cone.

- Remove background with NN



Efficiency = 65% Fake rate = 2.5%
Efficiency = 50% Fake rate < 1%

Object Identification: b-jets

Use lifetime information – corrected for data MC differences

CDF: Secondary vertex reconstruction

NN increase purity

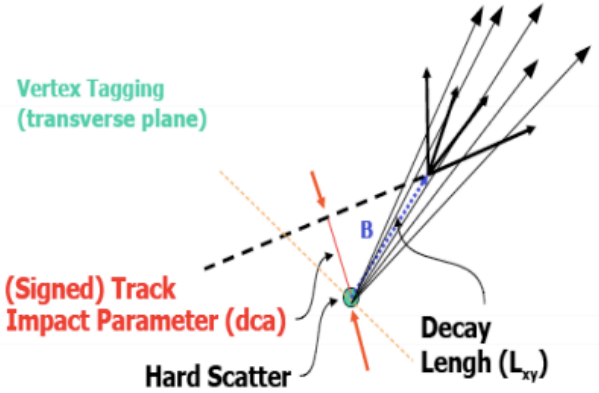
40% efficiency, 0.5% mis-tag

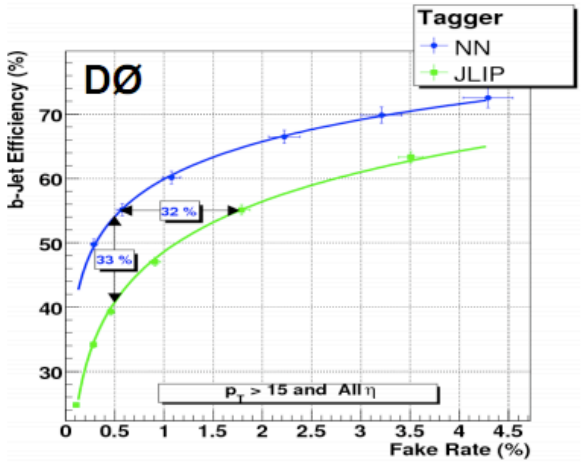
DØ: NN tagger

Secondary vertex and dca based inputs derived from basic b-tagging tools

High efficiency and purity

50% efficiency., 0.5% mis-tag





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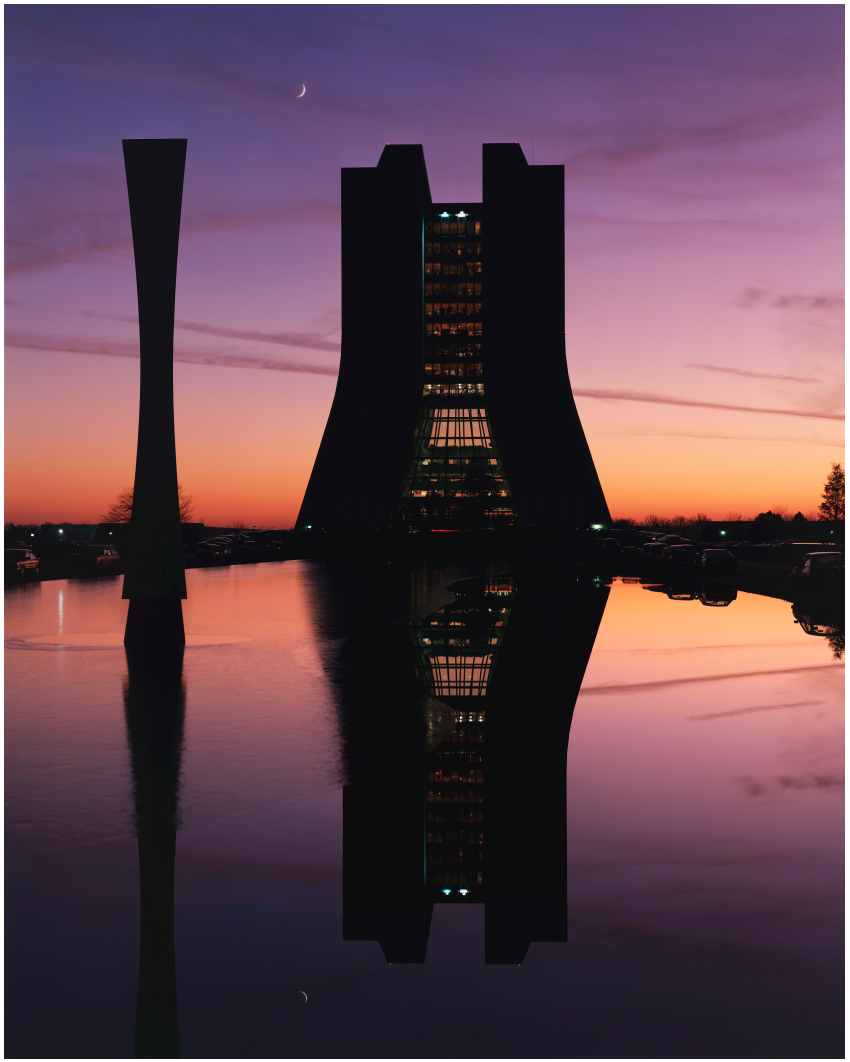


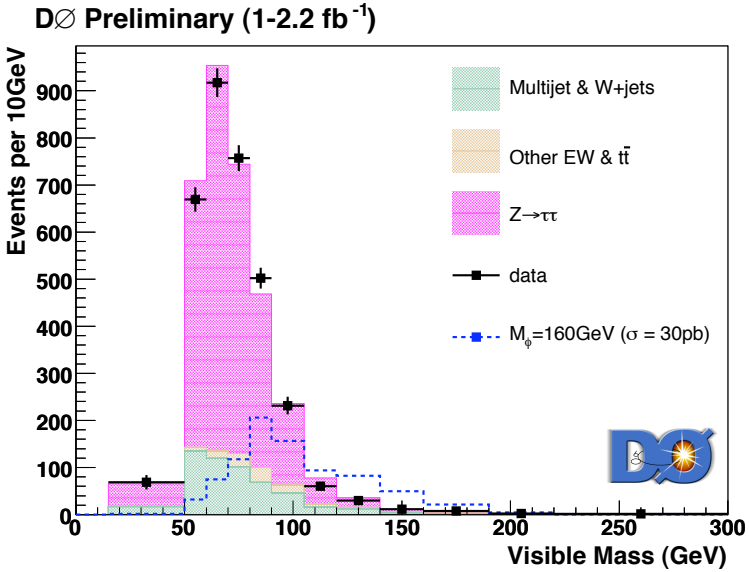
DØ and CDF Combination Inputs

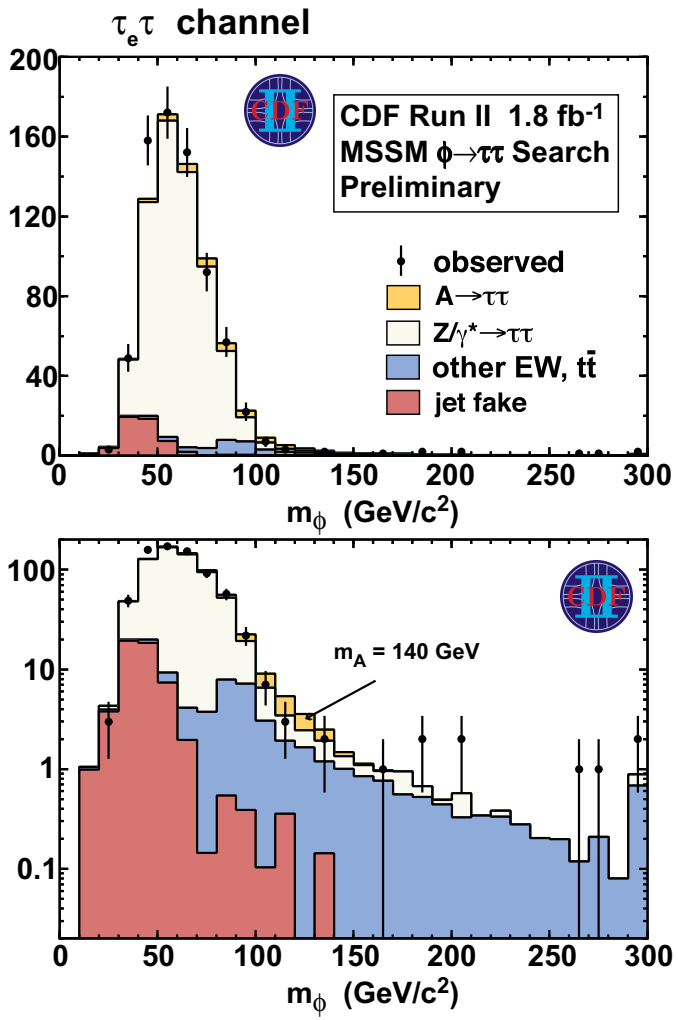
- Last updated in 2009
- Using up to 2.2 fb^{-1} integrated luminosity
- Using just $\phi \to \tau\tau$ decays

- DØ: $\phi \to \tau_\mu \tau_{had}$
  - 2.2fb^{-1} integrated luminosity
  - Released in 2008
  - combined with a DØ 1fb^{-1} covering $\phi \to \tau_e\tau_\mu, \tau_e\tau_{had}, \tau_\mu\tau_{had}$

- CDF: $\phi \to \tau_e\tau_\mu, \tau_e\tau_{had}, \tau_\mu\tau_{had},$
  - 1.8fb^{-1} integrated luminosity
  - Released in 2009

DØ and CDF Combination Inputs





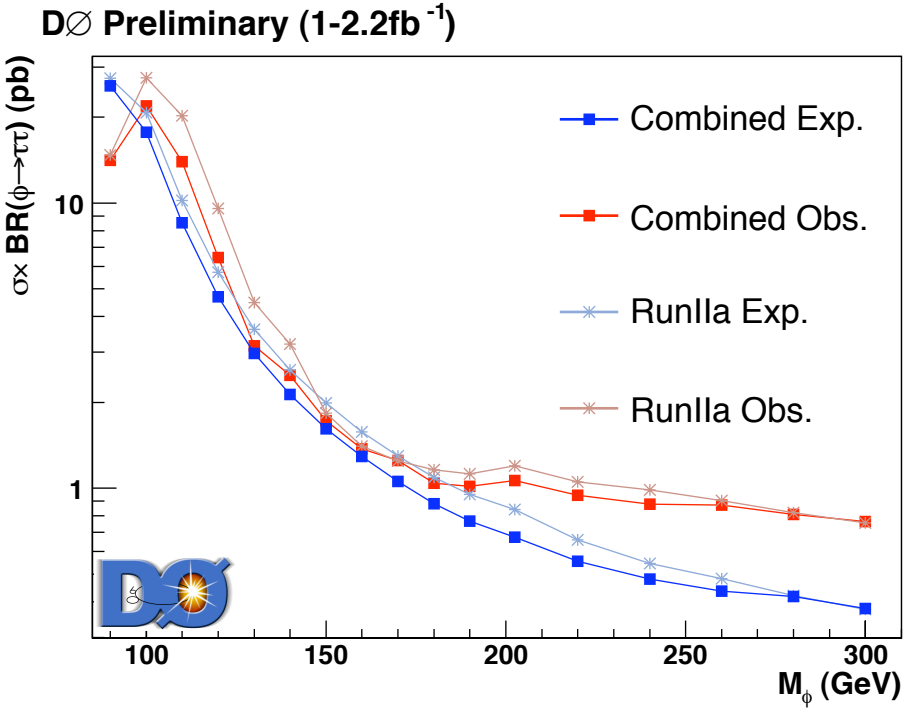
- Select two high P_t isolated leptons of opposite sign
- look for excess in

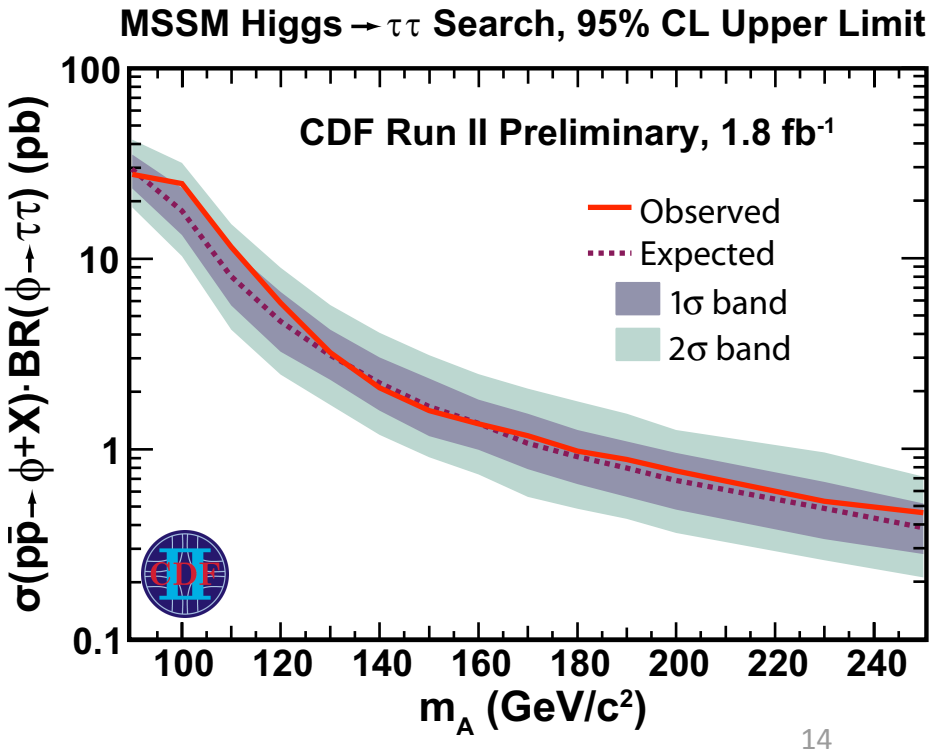
$$M_{vis} = \sqrt{(P_{\tau_1} + P_{\tau_2} + \not{P}_{\mathrm{T}})^2}$$

New 5.4 fb^{-1} DØ result now out

DØ and CDF Combination Inputs

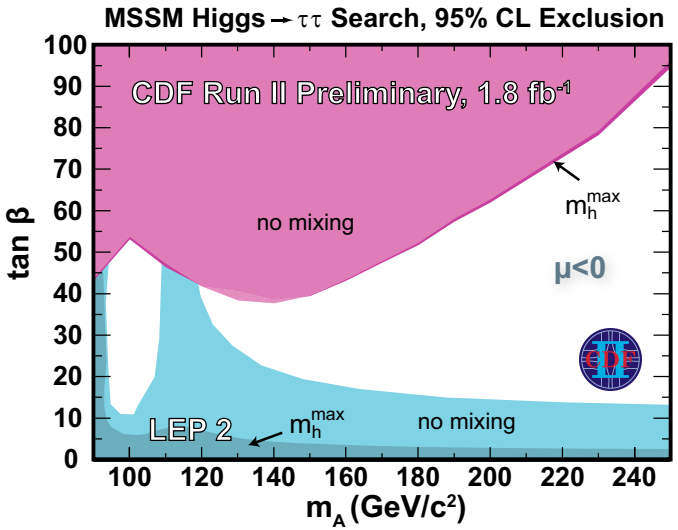
- Model Independent Limits
  - σ x BR(ϕ->ττ) at 95% CL level

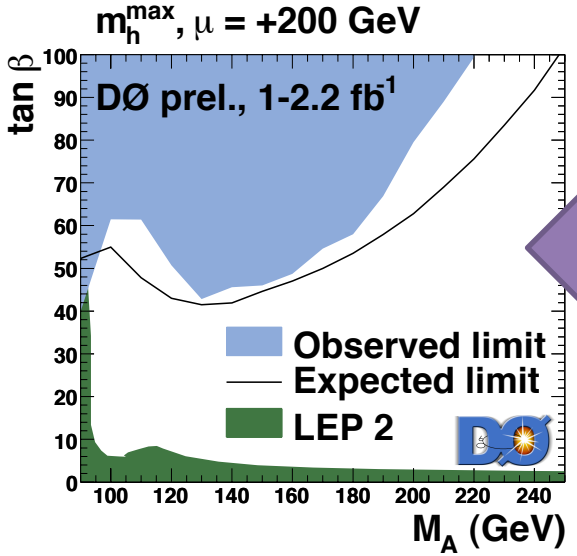




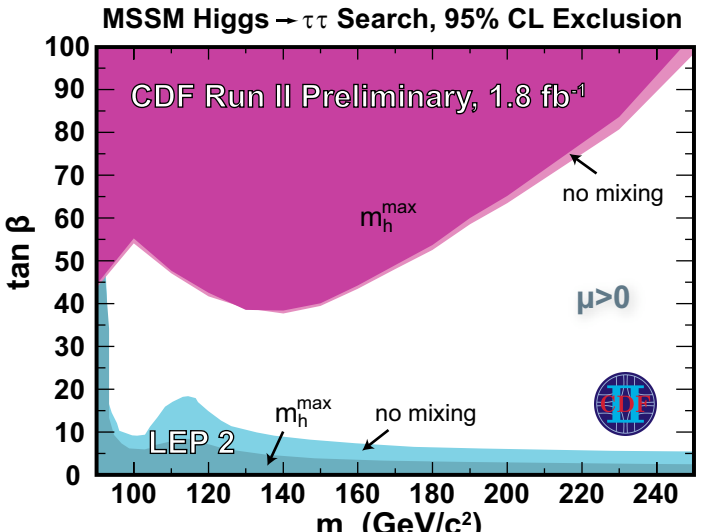
DØ and CDF Combination Inputs

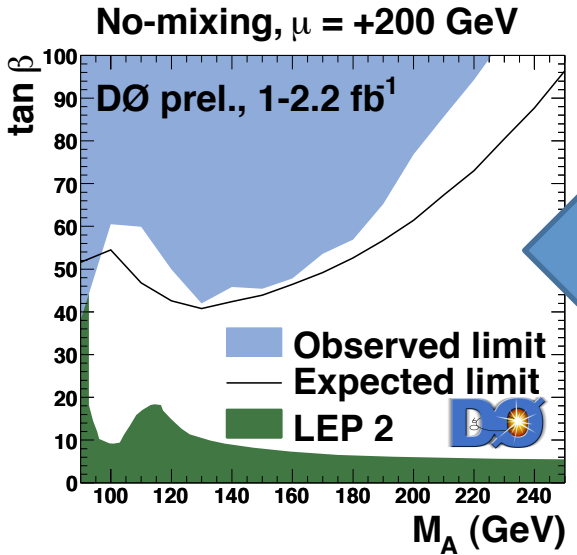
MSSM exclusions in M_A, tan β plane





m_h max

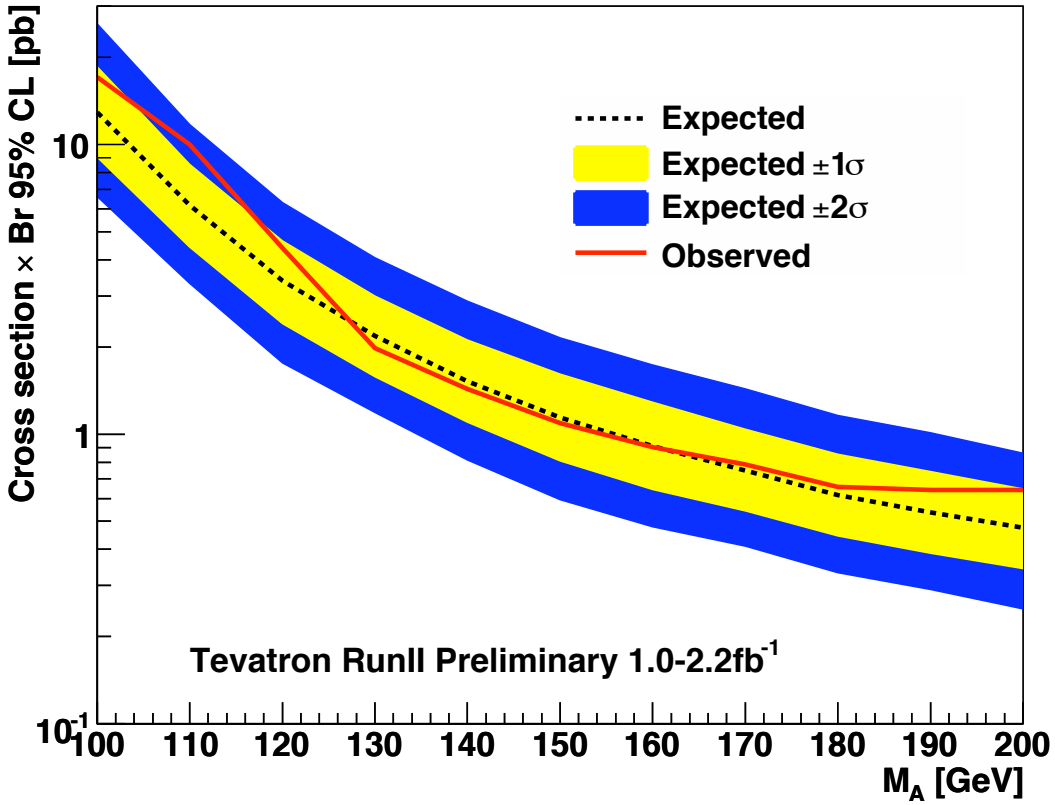




no mixing

DØ and CDF Combination Limits

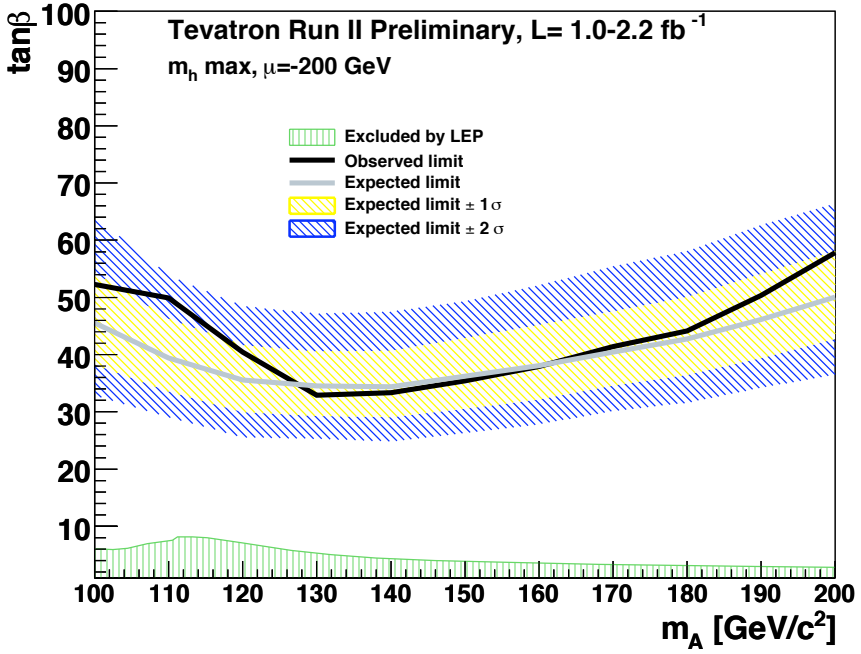
- Model Independent Limits
  - σ x BR(ϕ->ττ) at 95% CL level



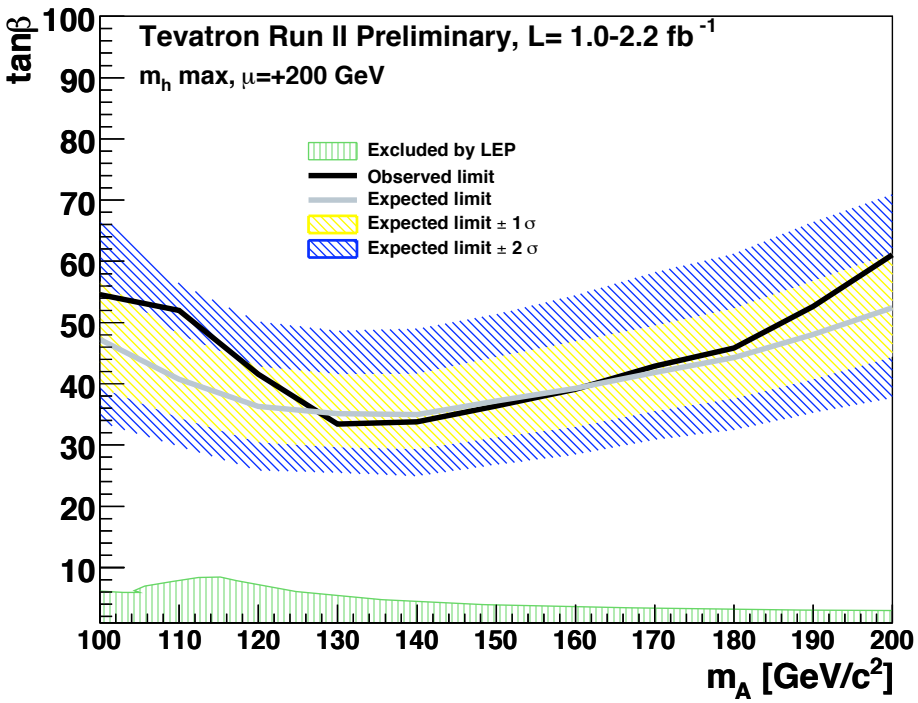
Limits in good agreement with expected, no significant excess seen.
Correlation of systematics between experiments taken into account.

DØ and CDF Combination Limits

m_h max



no mixing



Tan β width effects not expected to have large effect in this region

New combination out soon!

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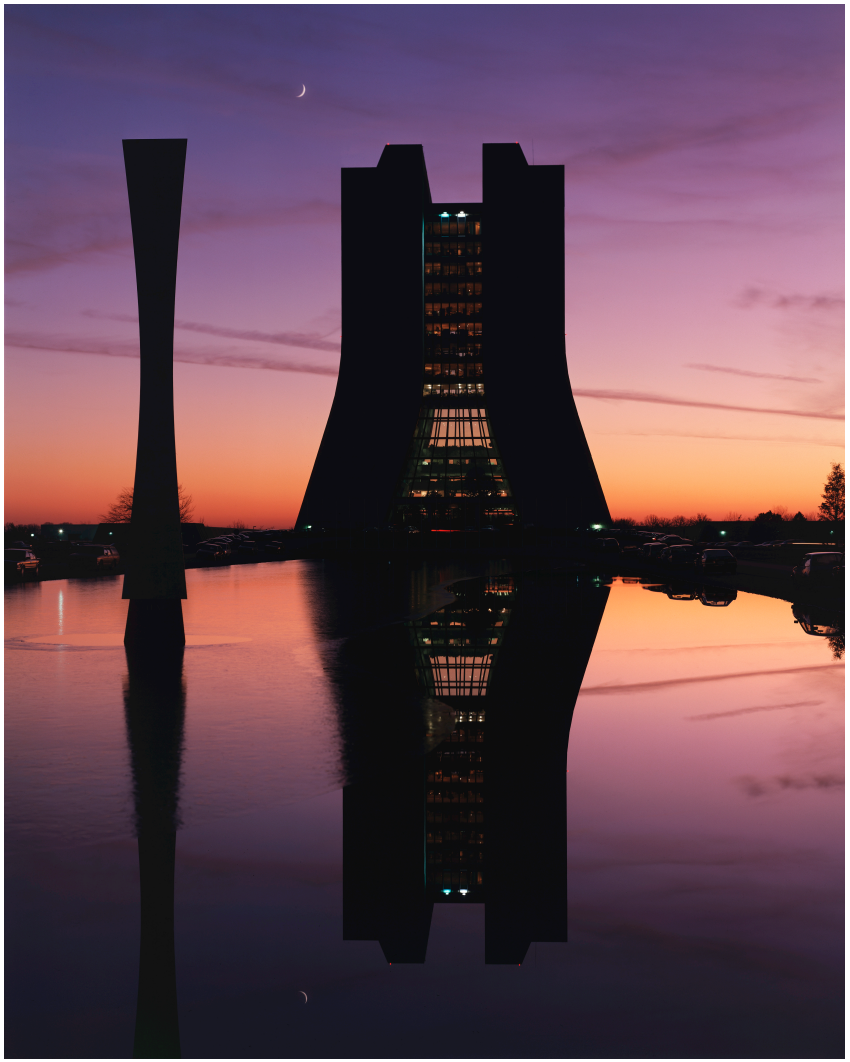


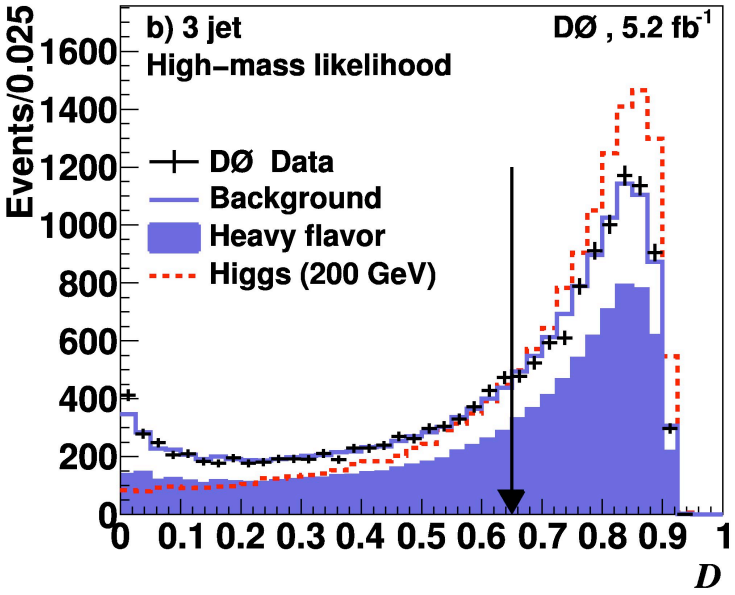
DØ Combination

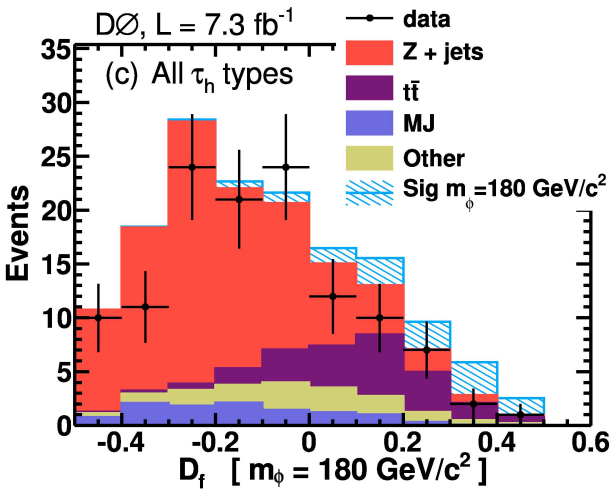
Limits set on production cross section of Higgs boson in association with one or more b quark

Combine two channels:

bϕ->bbb: 5.4fb^{-1} integrated luminosity

bϕ->bττ: 7.3fb^{-1} integrated luminosity



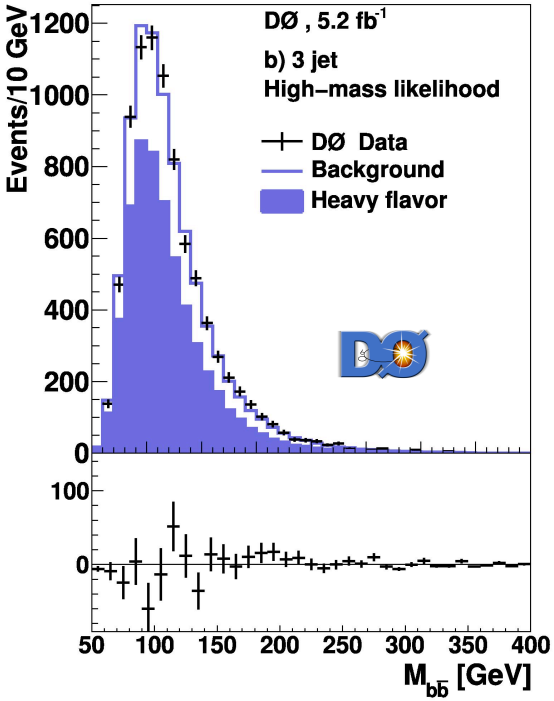


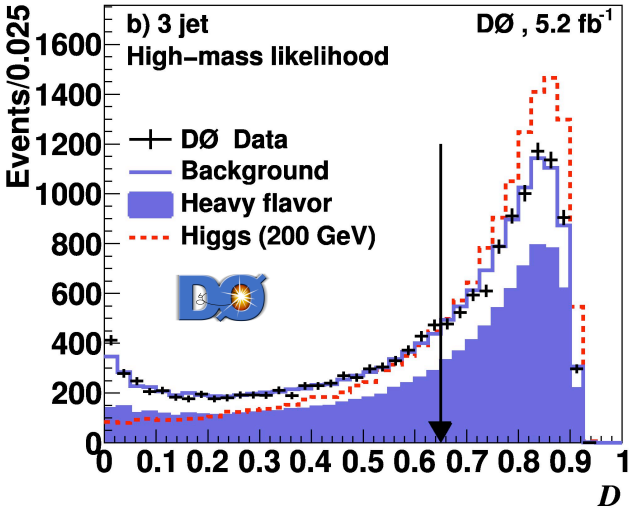
DØ Combination Inputs

bϕ -> bbb

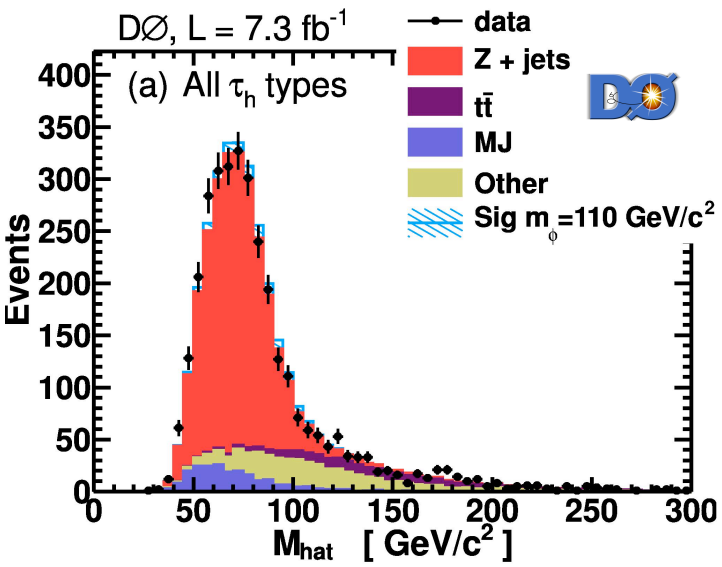
- Select 3 b-tagged jets
  - 3b jets greatly reduces background
- Background dominated multijet events
  - Predicted from data/MC
- Train discriminant to further separate signal
- Limits set using di-jet invariant mass

5.2 fb^{-1} integrated luminosity

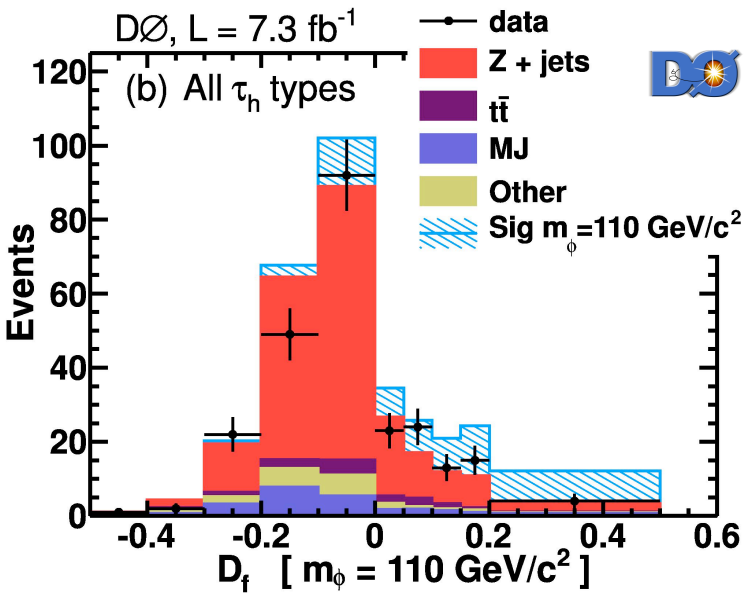




DØ Combination Inputs



bϕ -> bττ



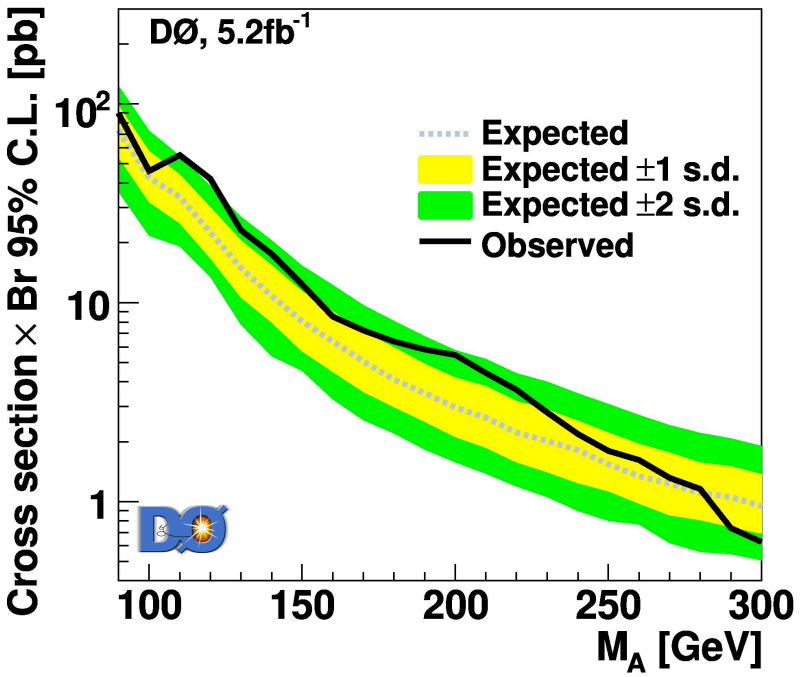
- Assume one tau decays hadronicly and one to a muon
- 7.3fb^{-1} integrated luminosity
- Builds on pervious 2.7fb^{-1} result
  - Improved systematic uncertainties
  - Improved trigger approach
- Combines discriminants D_{MJ}, D_{tt}, M_{hat}, NN_{bb} into likelihood

$$M_{hat} = \sqrt{(E^{\tau_\mu \tau_{had}} - p_z^{\tau_\mu \tau_{had}} + \not{P}_{\mathrm{T}})^2 + |\overrightarrow{p}_T^{\,\tau_{had}} + \overrightarrow{p}_T^{\,\tau_\mu} + \not{E}_{\mathrm{T}}|^2}$$

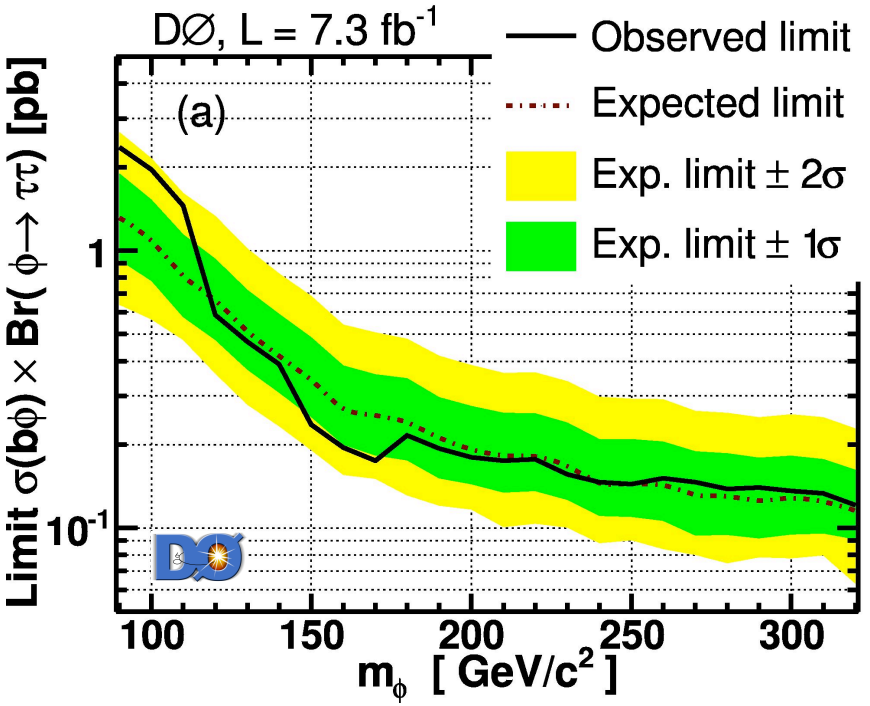
DØ Combination Inputs

- Model Independent Limits
  - σ x BR(ϕ->bb) or σ x BR(ϕ->ττ) at 95% CL level

bϕ➔ bbb



bϕ➔ bττ

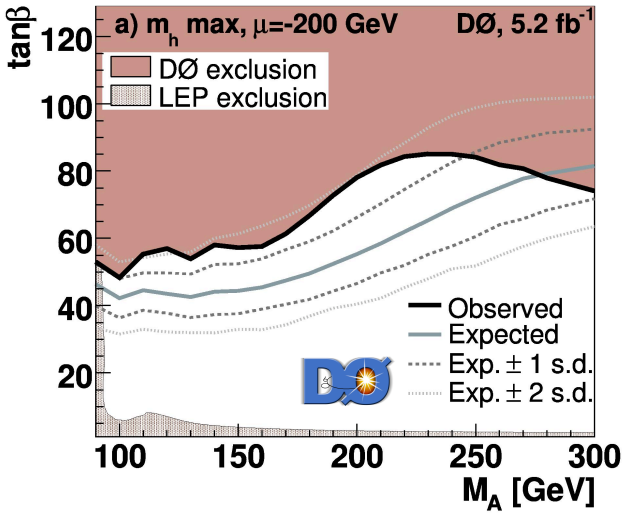


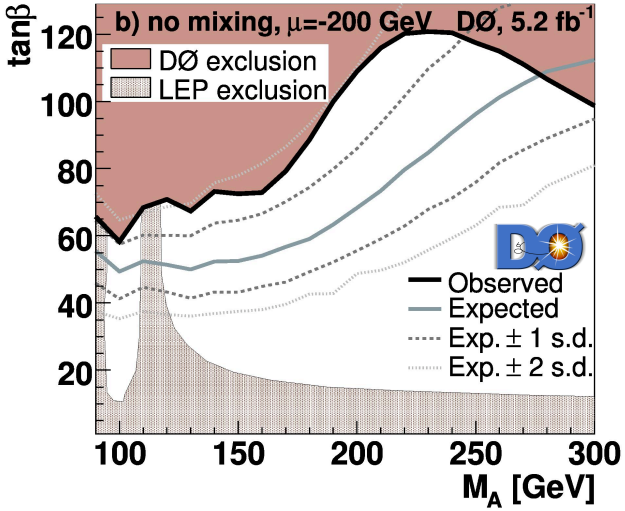
2.5 s.d. significance excess at 120 GeV in bϕ->bbb

DØ Combination Inputs

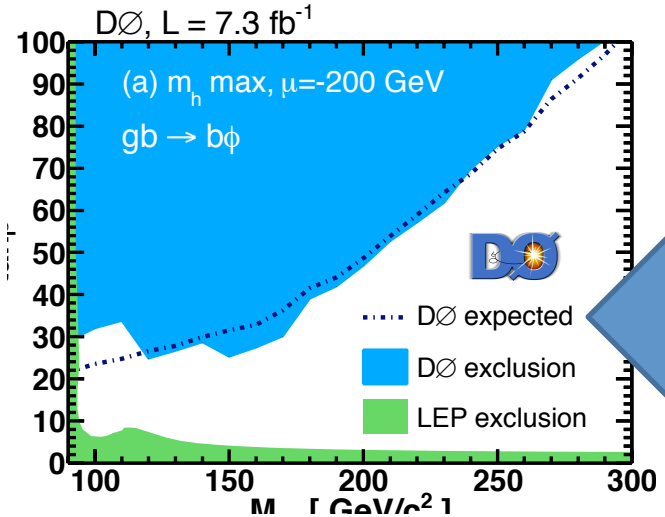
MSSM exclusions in M_A, tan β plane

bϕ➔ bbb

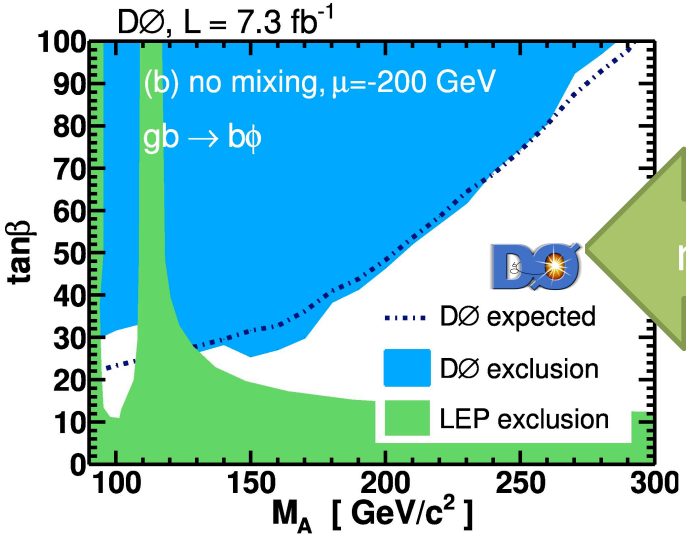




bϕ➔ bττ



m_h max

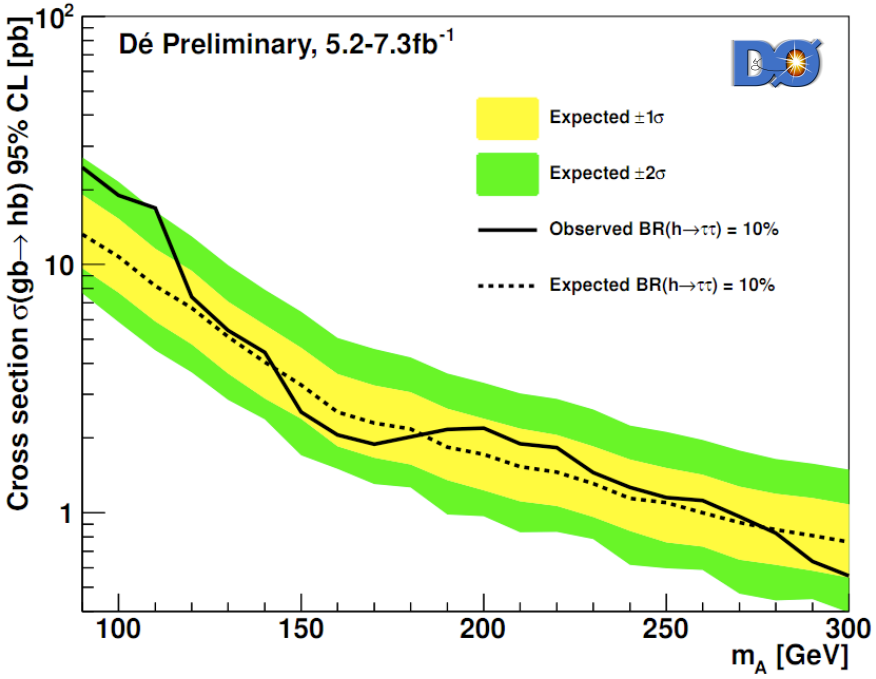


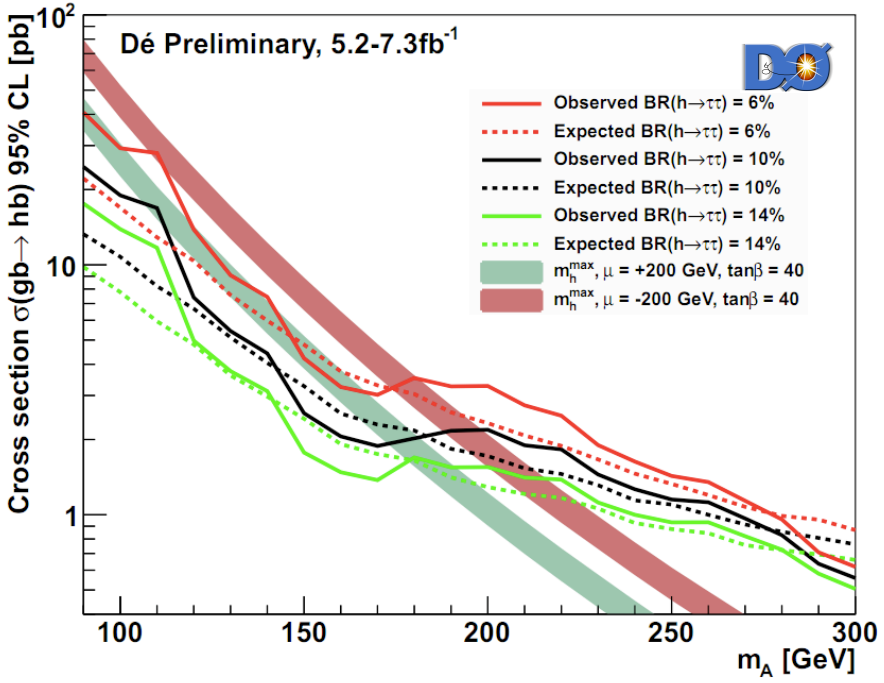
no mixing

DØ Combination Limits

Model Independent Limits

- Range 90 – 300 GeV
- BR(ϕ ->ττ) + BR(ϕ->bb) = 1
  - set for 3 values of BR(ϕ->ττ) = 6%, 10%, 14%



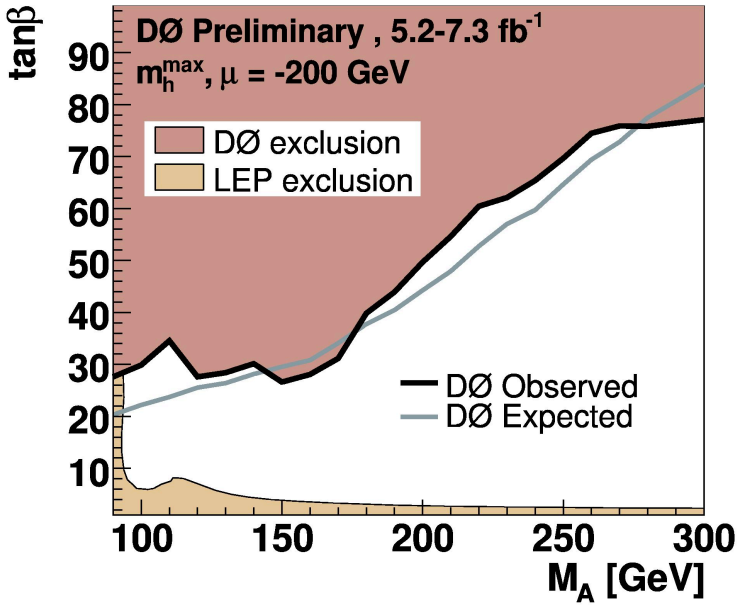


Best limits from the Tevatron on a SUSY Higgs

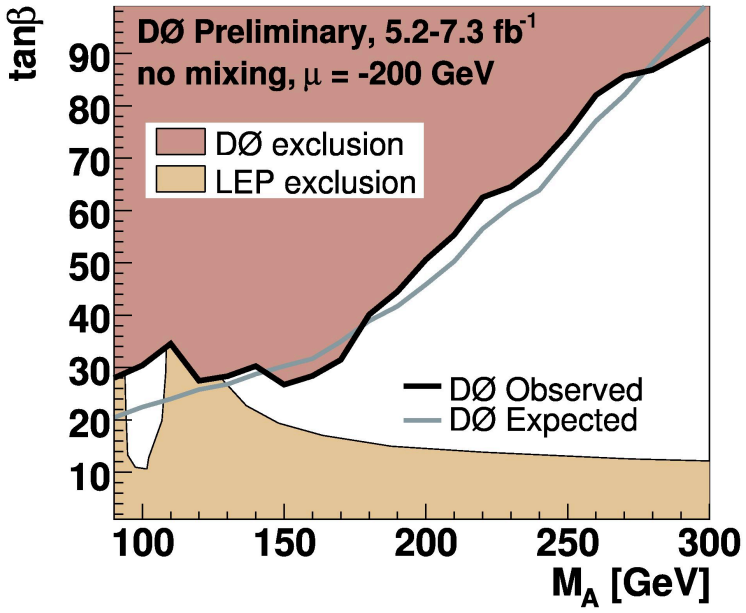
DØ Combination Limits

Interpreted in two MSSM scenarios

m_h max



no mixing



bbb channel remains the exclusive domain of Tevatron experiments

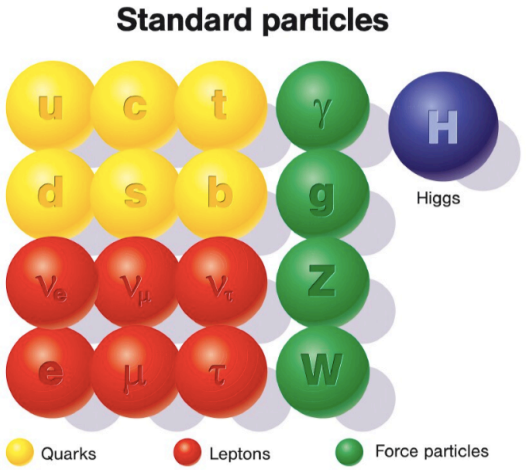
Conclusions

- Exciting new results out of the Tevatron
  - new results in
    - $\phi \rightarrow \tau\tau$
    - $b\phi \rightarrow bbb$
    - $b\phi \rightarrow b\tau\tau$
  - cover a wide range of channels using up to 7.3fb^{-1}
- DØ combination probing theoretically interesting regions.
- New DØ and CDF combination out soon!

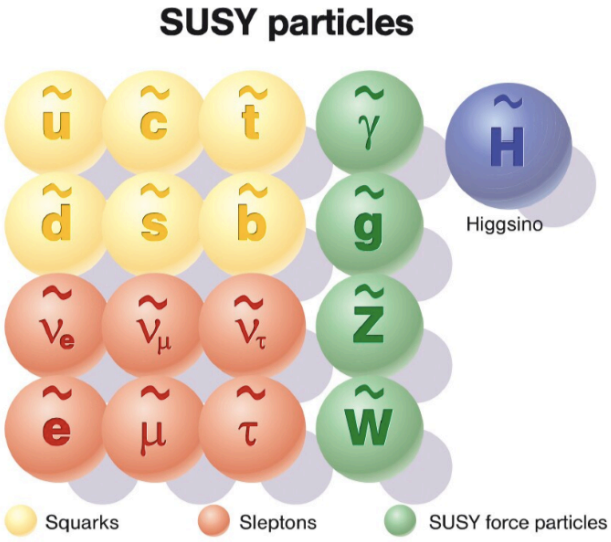
Back Up

SUSY

- Introduce symmetry between bosons and fermions
  - Solution to hierarchy problem
  - Dark matter candidate
  - GUT scale unification

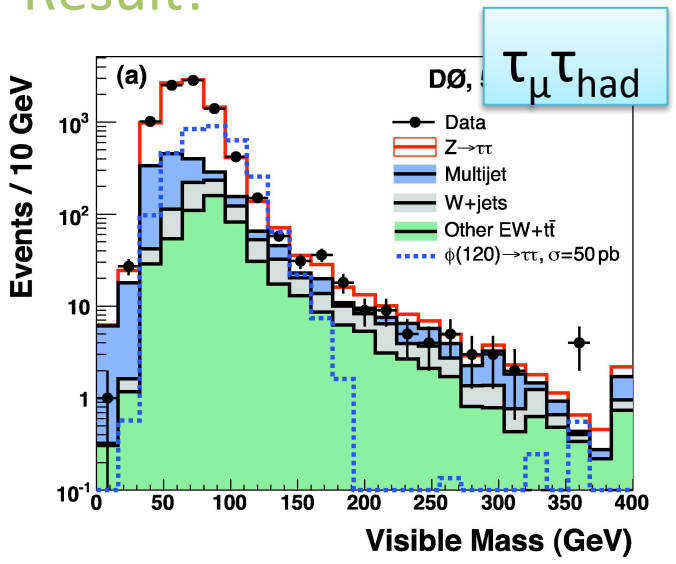


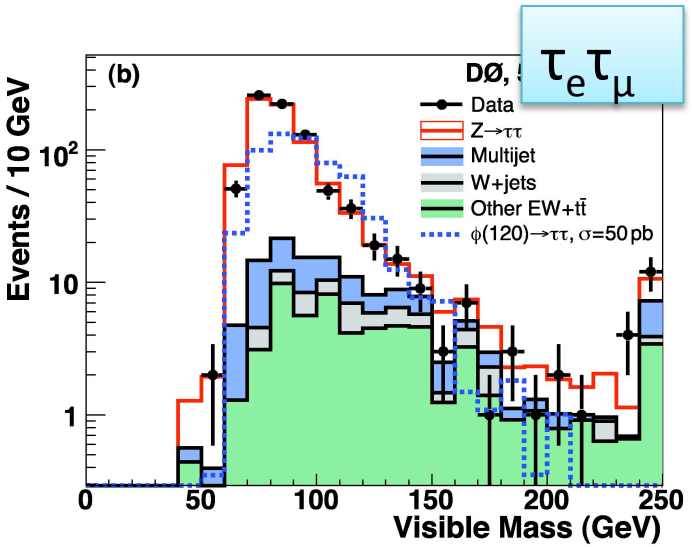
- Simplest form: MSSM
  - Two Higgs doublets: H_u, H_d
  - After EW symmetry breaking:
    5 Higgs Bosons h, H, A, H±



$\phi \rightarrow \tau\tau$

New Result!





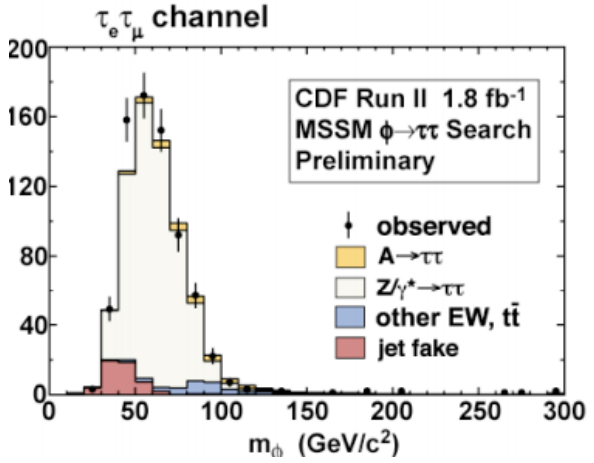
- Select two high P_t isolated leptons of opposite sign
- look for excess in

$$M_{vis} = \sqrt{(p_{\tau_h} + p_\mu + \not{P}_T)^2}$$

5.4 fb^{-1} integrated luminosity

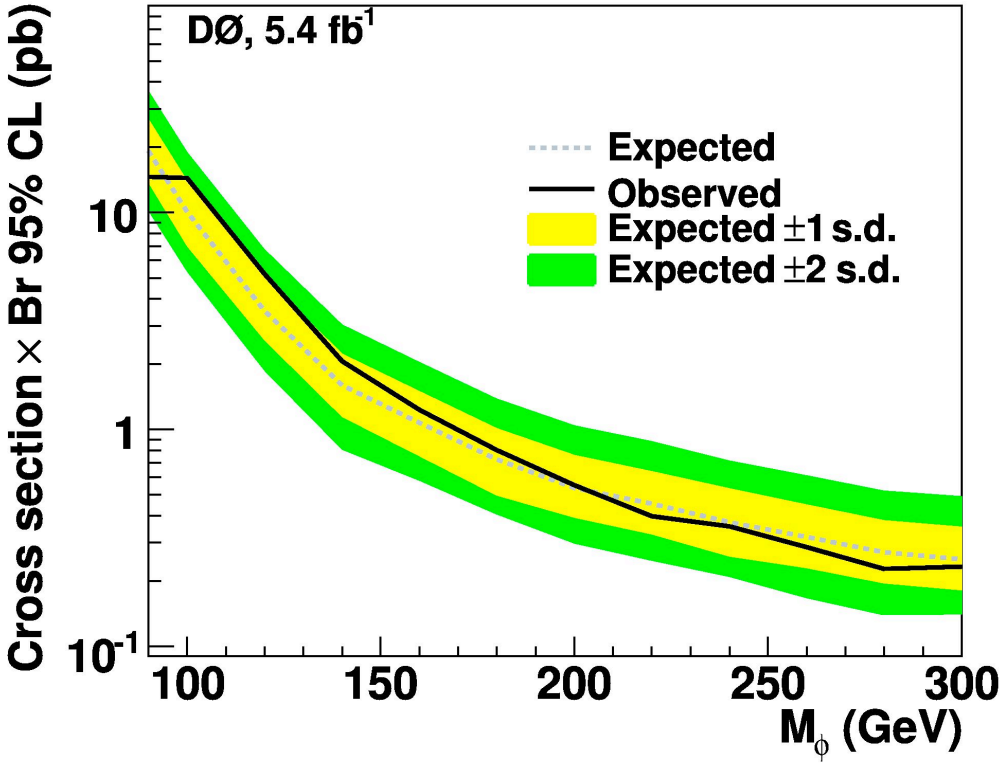
CDF: 1.8 fb-1

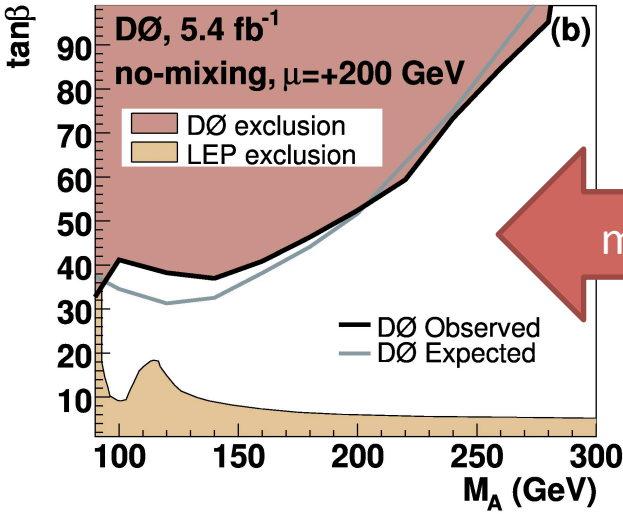
$\phi \rightarrow \tau_e\tau_\mu, \tau_e\tau_{had}, \tau_\mu\tau_{had}$



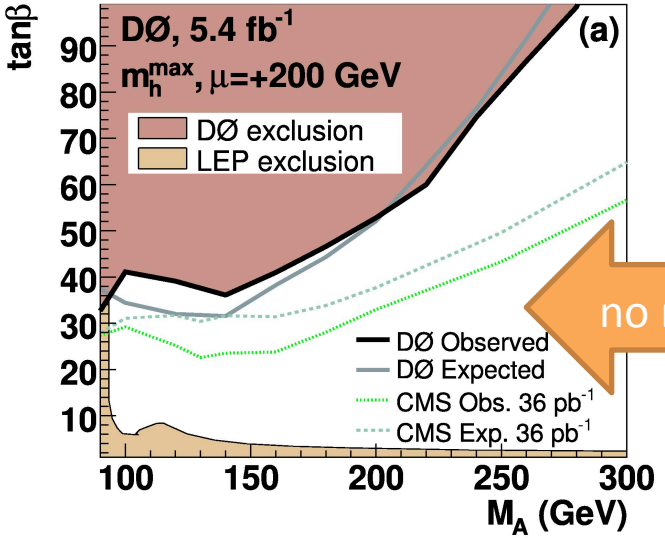
$\phi \rightarrow \tau\tau$

- Model Independent Limits
  - σ x BR(ϕ->ττ) at 95% CL level
  - M_a = 90 – 300 GeV



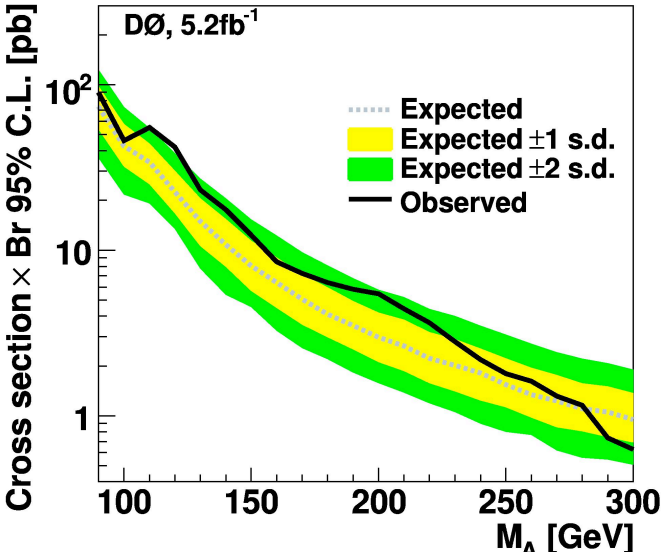


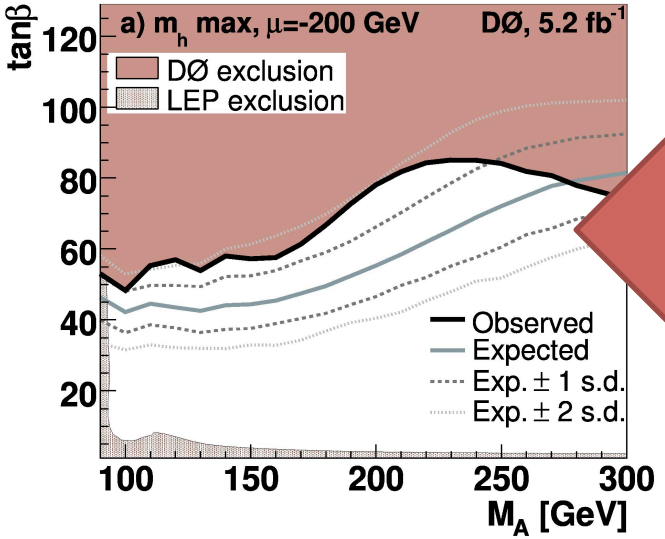
m_h max



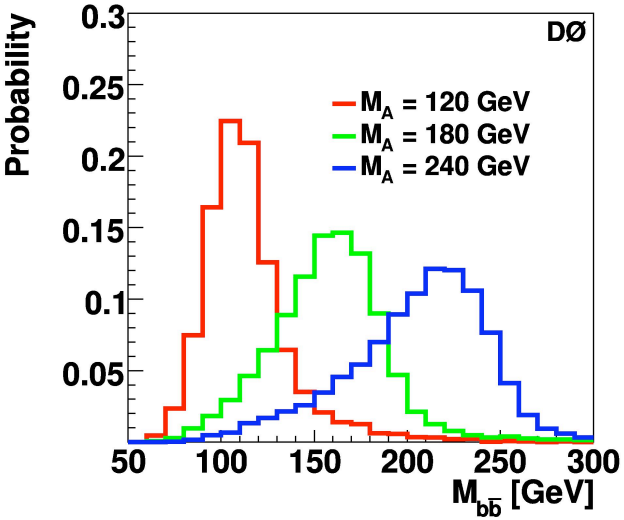
no mixing

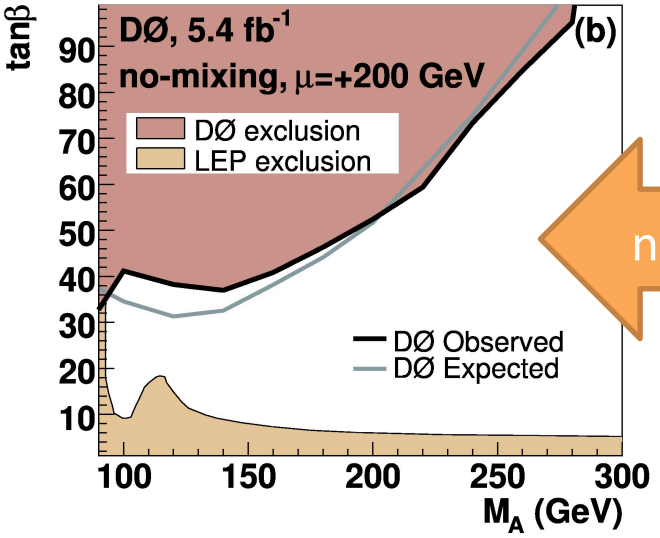
bh -> bbb





m_h max



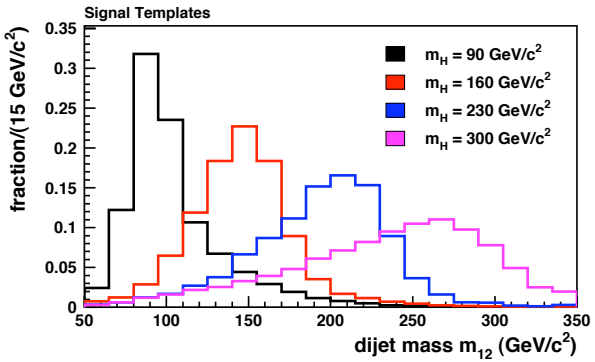


no mixing

bϕ➔ bbb

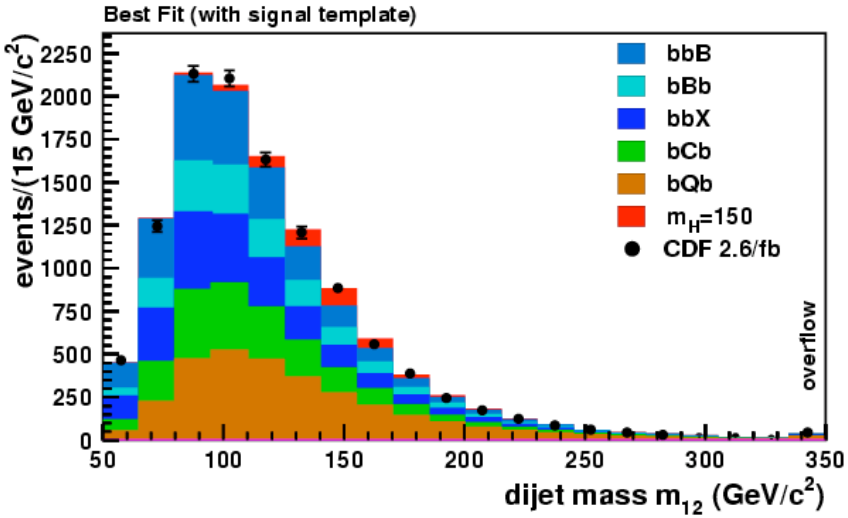
New Result!

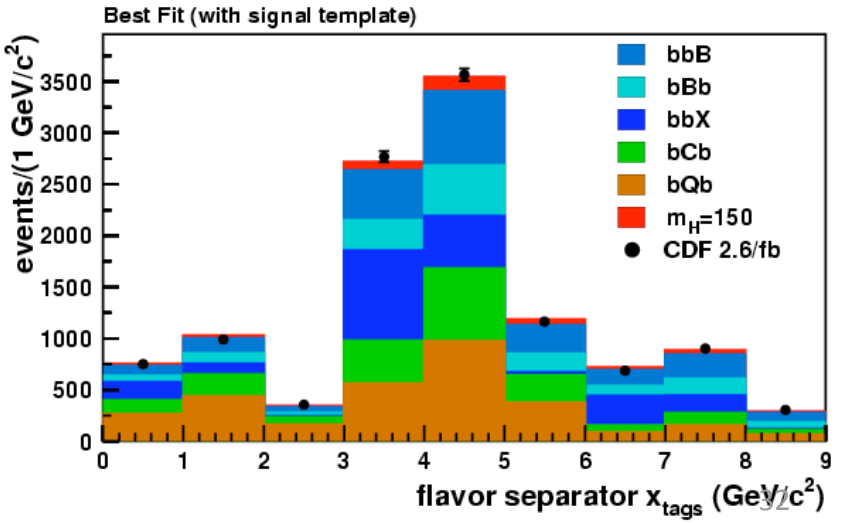
- Look in di-jet mass spectrum
- Select events 3 or more b-tagged jets



- background modeled data driven tech in double tagged events
- separate background and signal using 2D fit

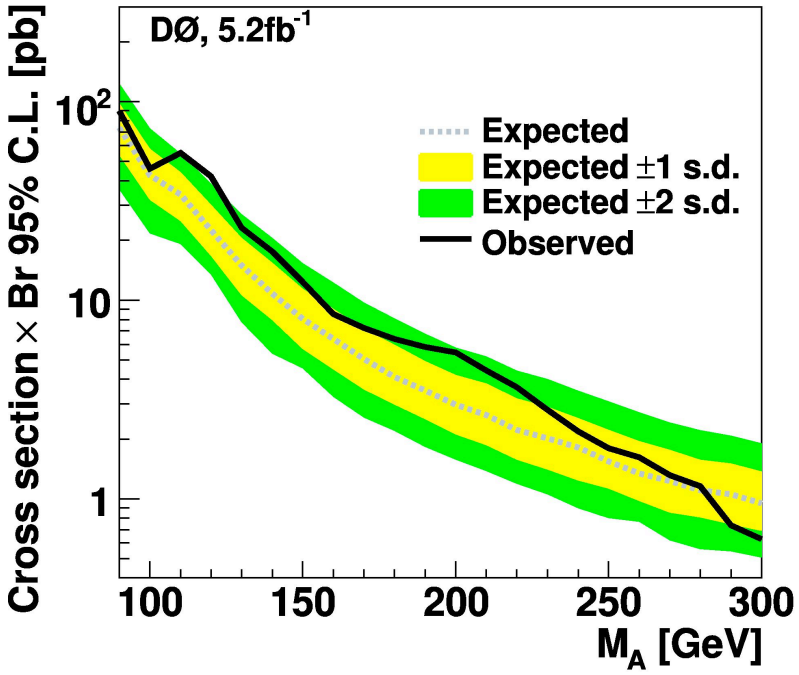
2.6 fb^{-1} integrated luminosity

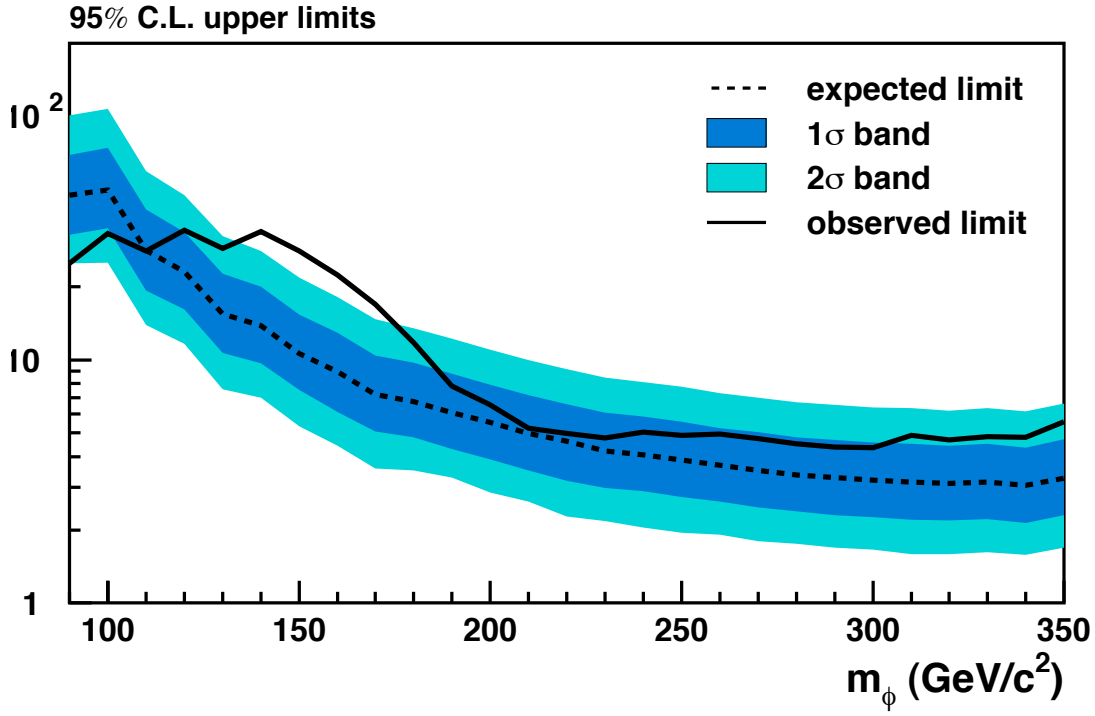




bϕ➔ bbb

- Model Independent Limits
  - σ x BR(ϕ->bb) at 95% CL level
  - M_a = 90 – 300 GeV

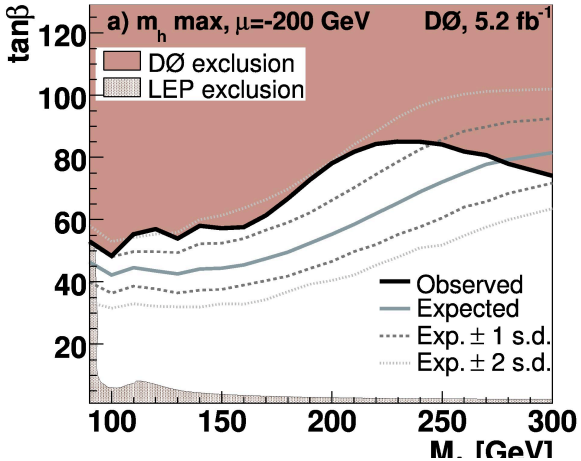


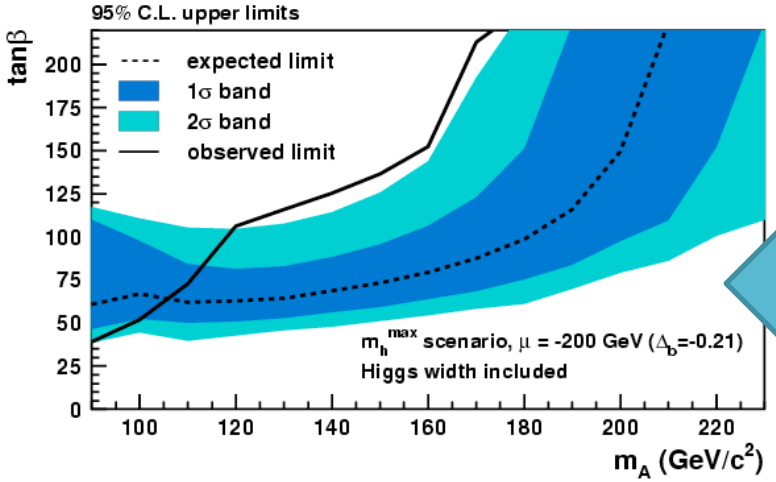


D0: 2.5 s.d. significance excess at 120 GeV
CDF: > 2 sigma discrepancy 130-150 GeV

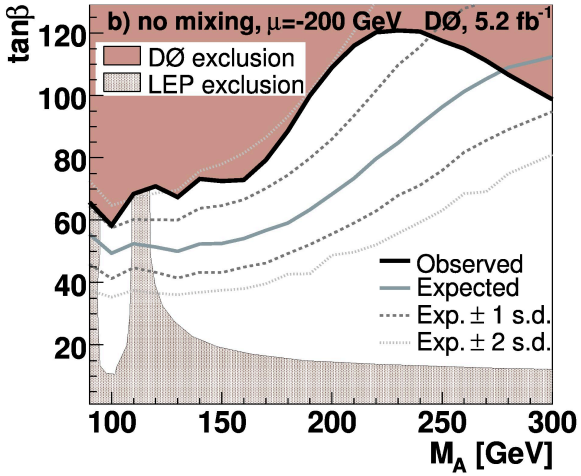
bϕ➔ bbb

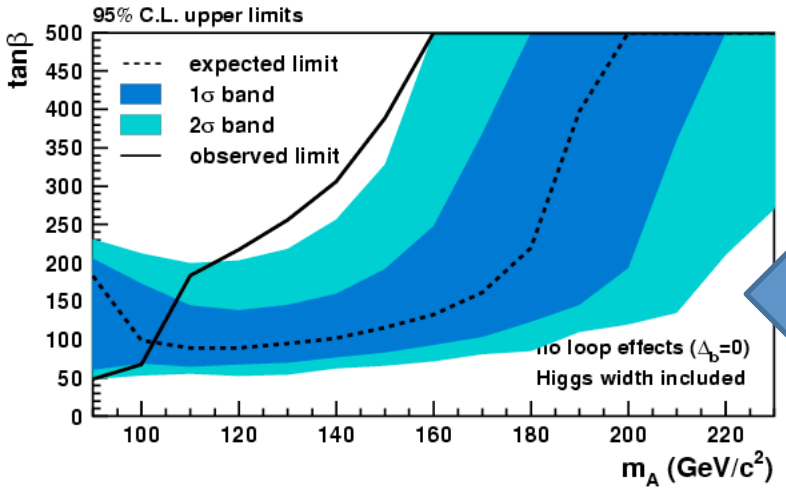
MSSM exclusions in $M_{A,}$ tan β plane





m_h max





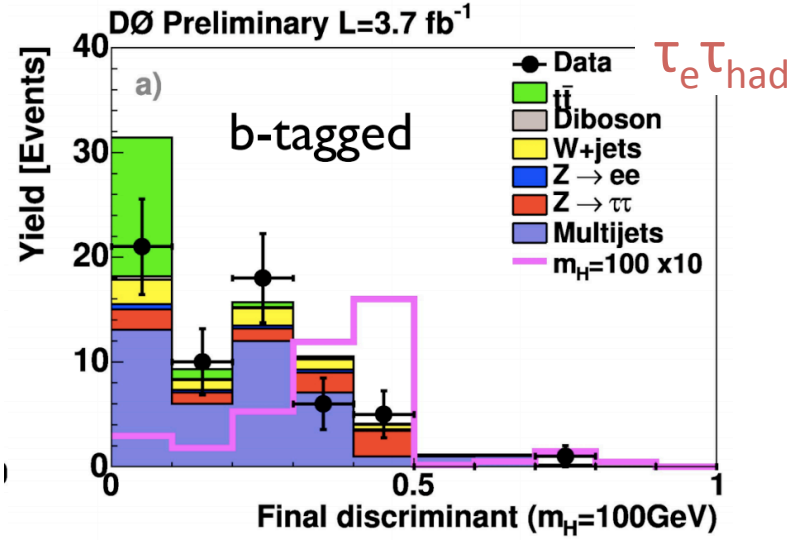
no mixing

bϕ➔ bττ

New Result!

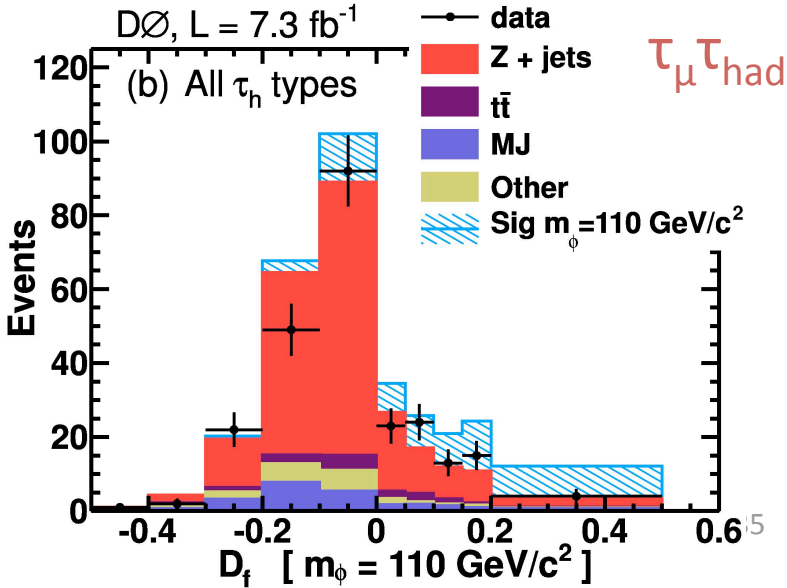
BR(ϕ->ττ) ~ 10%

- h-> $\tau_e\tau_{had}$: 3.7fb^{-1} integrated luminosity
  - Specific discriminants for main backgrounds D_{MJ}, D_{tt}



Even Newer Result!

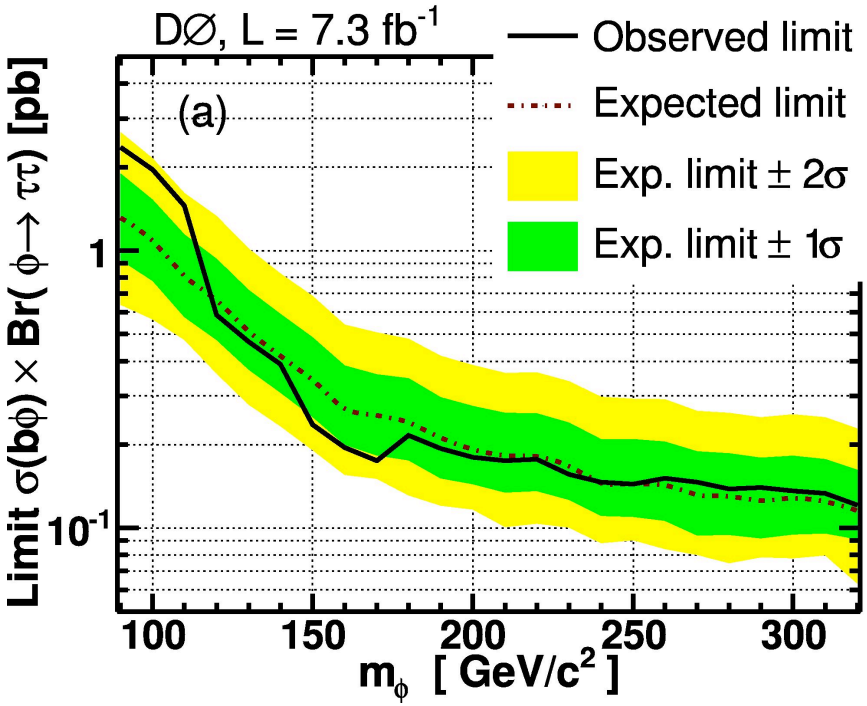
- h-> $\tau_\mu\tau_{had}$: 7.3fb^{-1} integrated luminosity
  - Improved systematic uncertainties
  - Improved trigger approach
  - Combined D_{MJ}, D_{tt}, M_{hat}, N_{bb} into likelihood

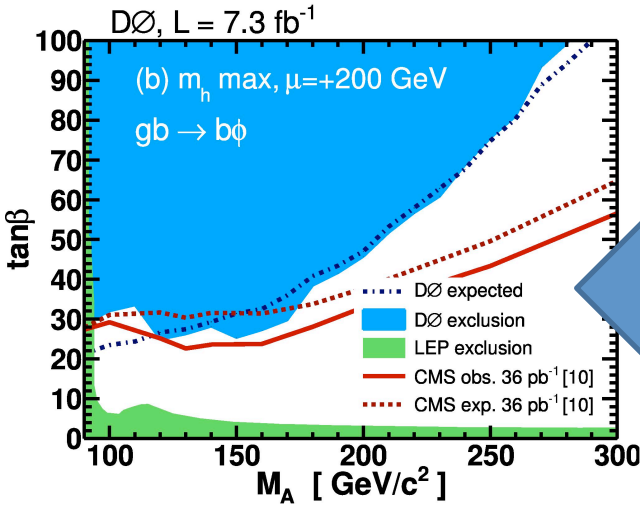


bϕ➔ bττ

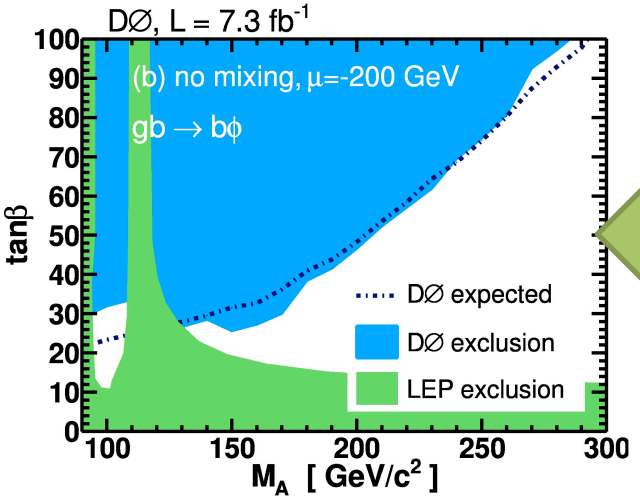
New Result!

- Model Independant Limits
  - σ x BR(ϕ->ττ) at 95% CL level
  - M_a = 90 – 300 GeV





mh max



no mixing

DØ and CDF Combination Systematics

Dominant effects

- DØ – object Id, Trigger, luminosity, signal acceptance
- CDF – object Id, luminosity, signal acceptance

- Correlated systematics
  - luminosity, tt and diboson production cross sections
- Uncorrelated systematics
  - multijet determination
  - calibration of fake rate, unvetoed ->ee conversions, b-tagging efficiency, mistag rates.