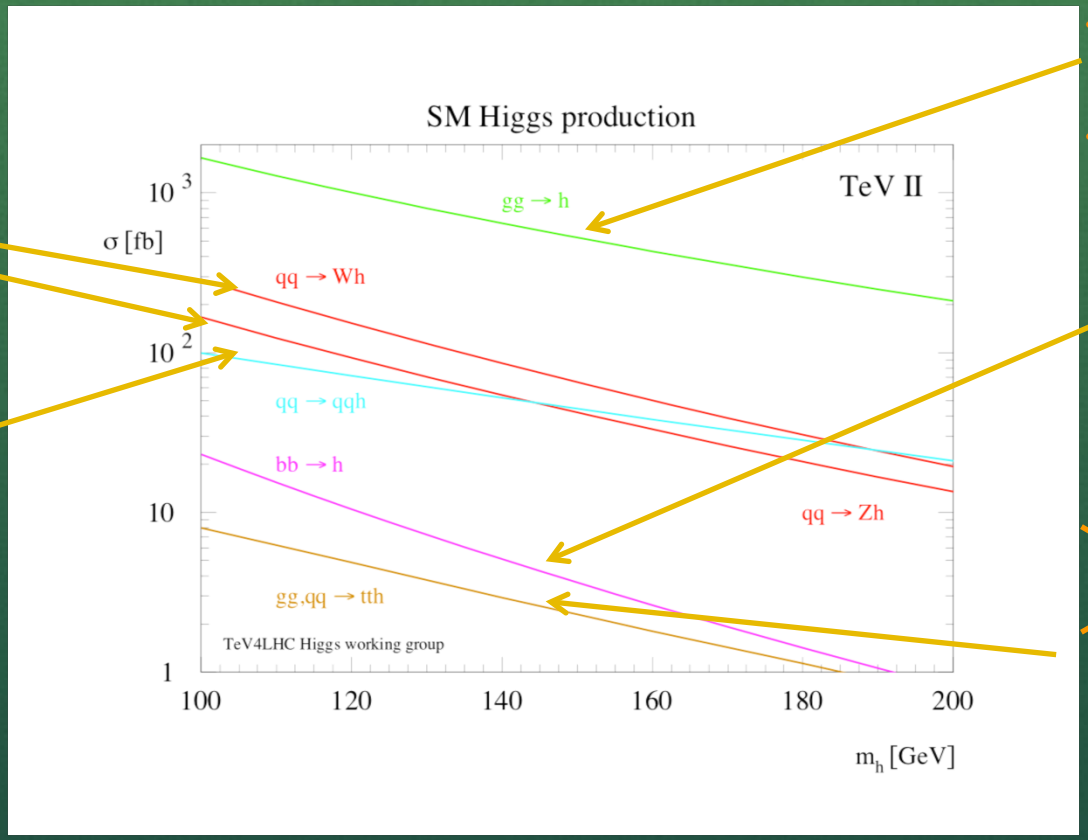
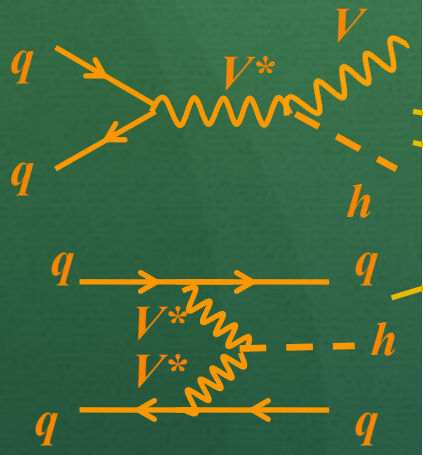
Tevatron BSM Higgs Results

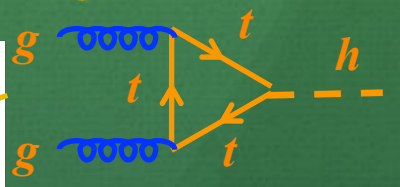
Peter Svoisky, University of Oklahoma, for the CDF and D0 collaborations

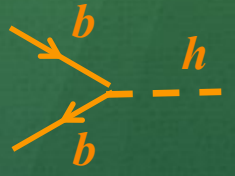
Higgs Cross Sections for the LHC, BNL, May 4

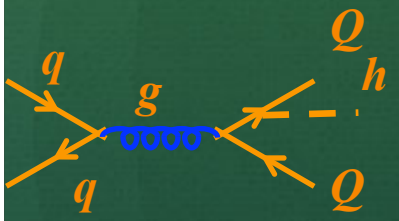
Standard Model Higgs

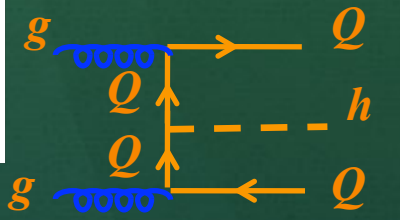










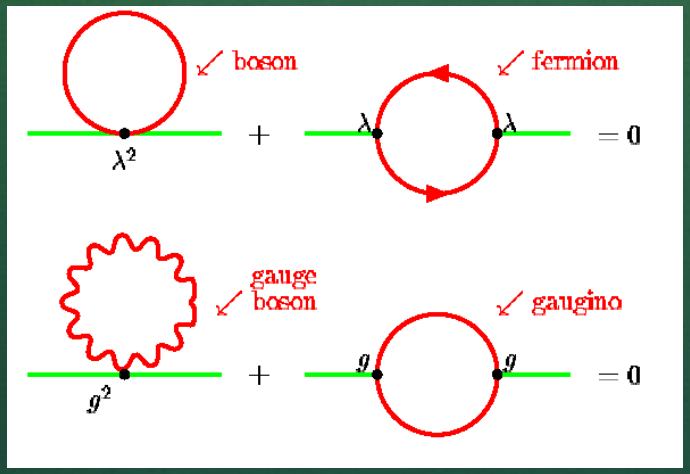


- 1 complex doublet
  - 1 scalar boson

Supersymmetry

$$m_h^2 = (m_h^2)_0 + cg^2\Lambda^2$$

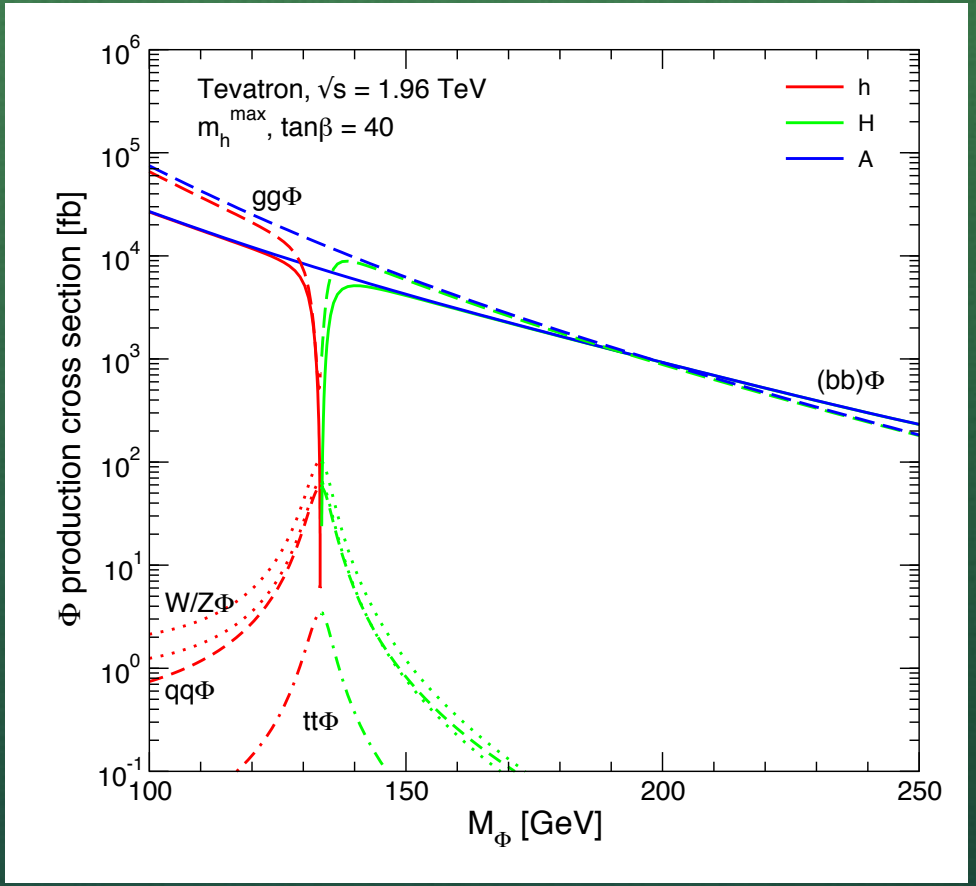
$$\Lambda \simeq \frac{m_h}{g} \sim O(1\ \text{TeV})$$



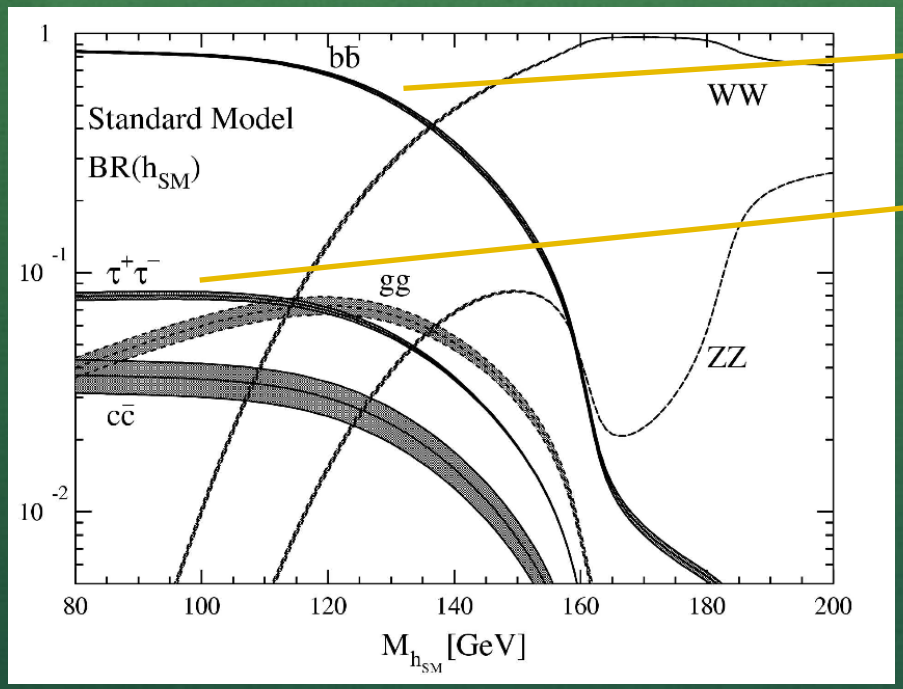
- Radiative corrections
  - Higgs self-coupling
    - Quadratic dependence on cut-off scale
- Supersymmetry
  - Superpartners
  - Higgs self-coupling
    - Logarithmic dependence on cut-off scale
    - Hierarchy problem lessens

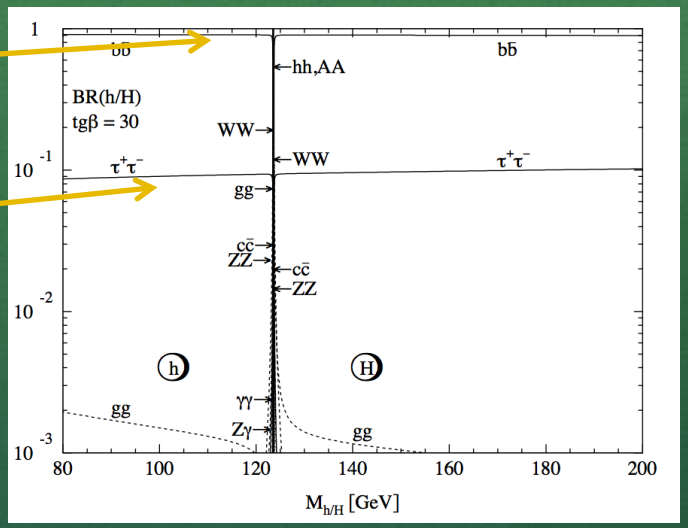
MSSM Higgs

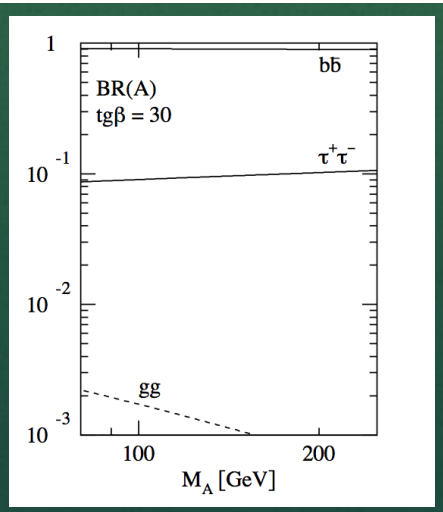
- 2 complex doublets
  - 5 scalar bosons: h, H, A, $H^{\pm}$
  - Bottom-type lepton coupling enhanced by $\sim v_u/v_d = \tan\beta$
  - Tree-level parameters: M_A, $\tan\beta$



Best channels to look for



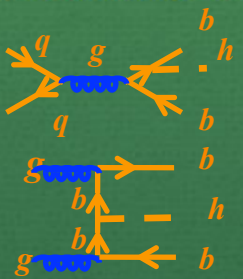




- Looking for h, H, A (ϕ) in
  - $\Phi \rightarrow bb$ (~90%, large QCD)
  - $\Phi \rightarrow \tau\ \tau$ (~9%, cleaner signature)

CDF ϕ b→bbb (2.2 fb^{-1})

- bg→bϕ XS from MCFM
  - p_T^{bjet}>15 GeV
  - CTEQ6.5M PDFs, uncertainty 4%
    - $\mu_R = \mu_F = (2m_b + m_H)/4$



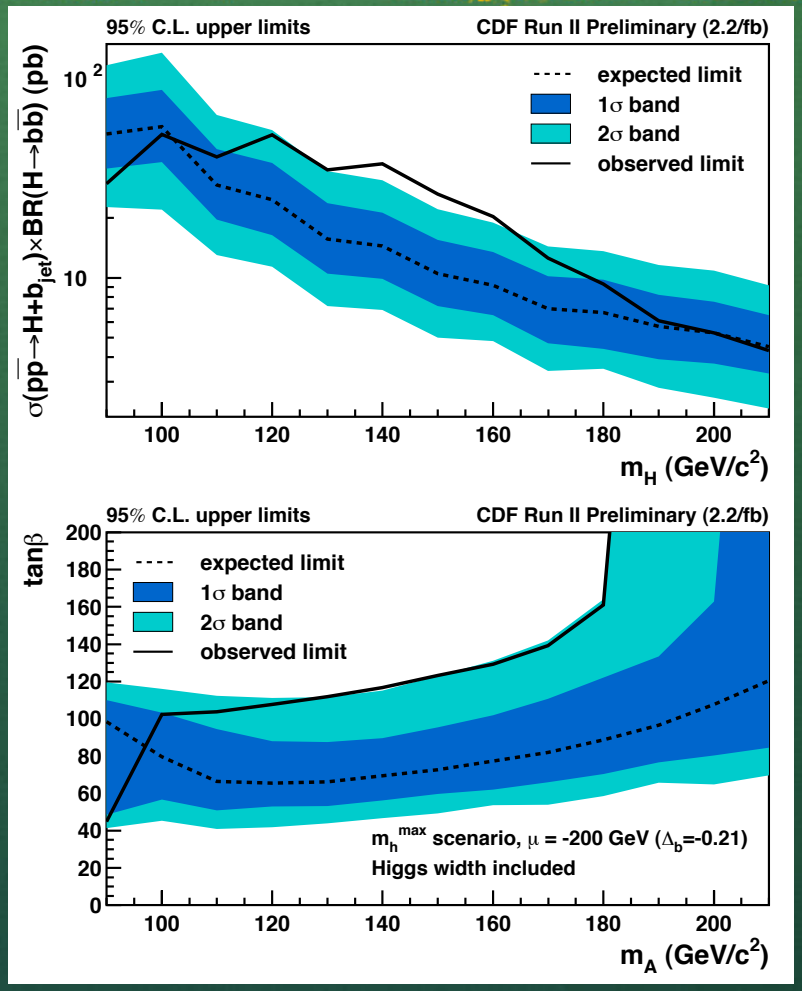
- Signal MC gg→bbH (MSUB=121 Pythia)
  - Remove hard FSR off the "beam-side" b-quark
  - B-jet η distribution broadened to match MCFM

- 3 b-tag MJ background from 2 b-tag events

- Convolve XS with Breit-Wigner, Γ_{bb} from FeynHiggs, dependent on Δ_b

$$\sigma(b\bar{b}\phi) \times BR(A \to b\bar{b}) \simeq 2\sigma(b\bar{b}\phi)_{SM} \frac{\tan^2\beta}{(1+\Delta_b)^2} \times \frac{9}{(1+\Delta_b)^2+9}$$

- Results: sensitive to region above tan $\beta \sim 60$ in m_h^{max}, μ =-200 GeV (Δ_b=-0.21)

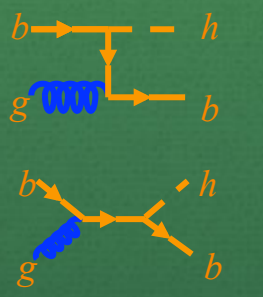


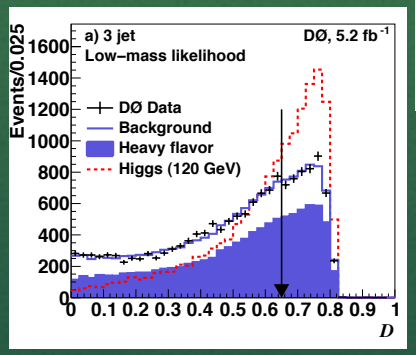
D0 ϕ b→bbb (5.2 fb^{-1})

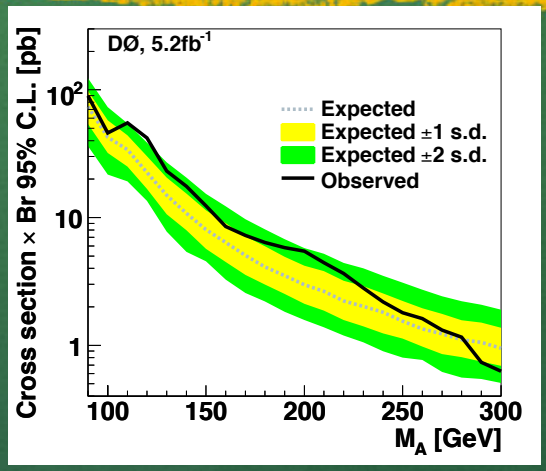
- Signal MC 5-flavor scheme (bg→bϕ)
  - CTEQ6L1, 10% uncertainty FS, 5%-13% PDFs
- Dedicated b-tagging trigger (60% eff)
- NN b-tagging algorithm (50% eff, 0.8% fake)
- 2 (low and high M_{bb}) likelihoods (D)
- MJ background from 2-tag

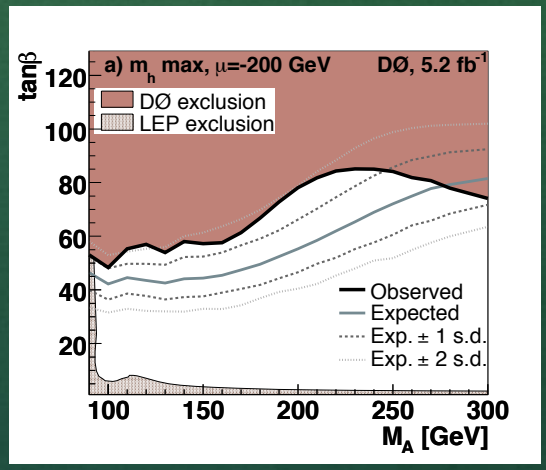
$$S^{pred}_{3Tag}(D, M_{b\bar{b}}) = \frac{S^{MC}_{3Tag}(D, M_{b\bar{b}})}{S^{MC}_{2Tag}(D, M_{b\bar{b}})} S^{data}_{2Tag}(D, M_{b\bar{b}})$$

- Width effects from FeynHiggs, XS from MCFM
- Results: exclude tan $\beta > 50$ in m_h^{max}, μ =-200 GeV at M_A=100 GeV





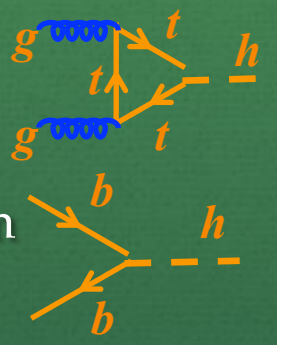


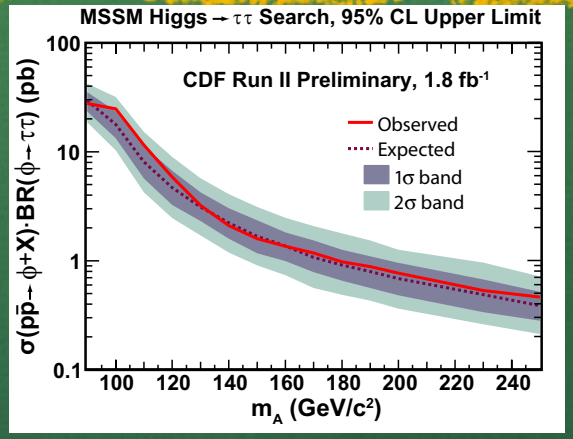


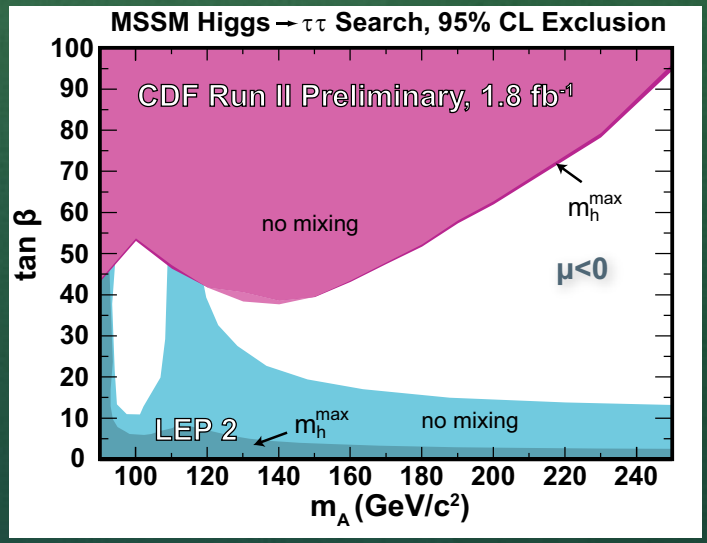
Phys. Lett. B **698**, 97 (2011)

CDF $\phi \rightarrow \tau\ \tau$ (1.8 fb^{-1})

- Signal MC generated with Pythia
  - 5.7% PDF uncertainty, CTEQ5L
- gg$\rightarrow \phi$ +X XS from HIGLU, bb$\rightarrow \phi$ +X from Harlander et al., PRD D68, 013001 (2003).
- Recorded with lepton+track and di-lepton triggers
- Isolated leptons (I_{iso}^{trk}<2 GeV), variable-size cone algorithm for τ_{had}
- QCD backgrounds from sidebands of lepton isolation or loose τ_{had} requirements
- W+jets cut with $p_\zeta^{\not{E}_T} > 0.6 p_\zeta^{vis} - 10$
- Results: excluded tan β >40 at M_A=140 GeV



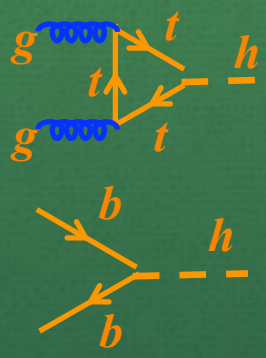


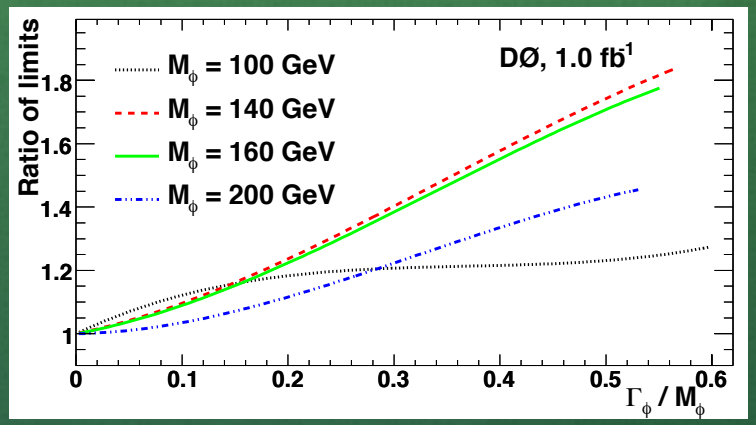


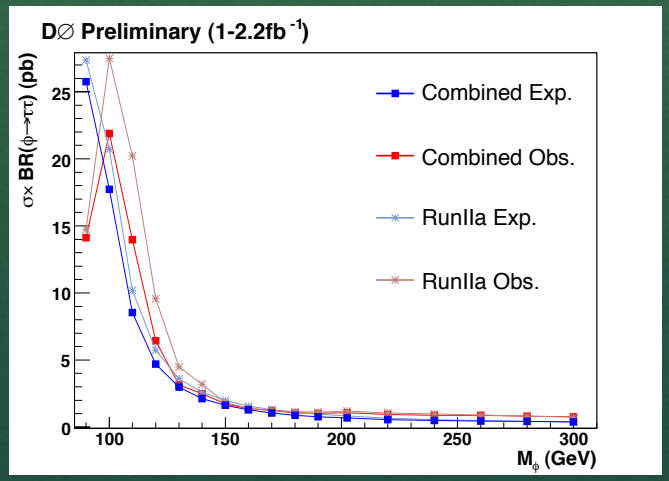
D0 $\phi \rightarrow \tau\ \tau$ (2.2 fb^{-1})

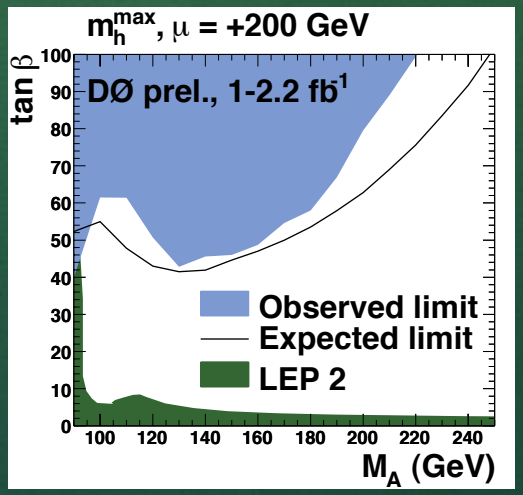
- Signal Pythia 6.329 $gg \rightarrow \phi \rightarrow \tau\ \tau$ only ($bb \rightarrow h$ acceptance similar, final normalization both)
  - PDF uncertainty 4%, Z/γ^* XS uncertainty 5%
  - Production XS, BR, width with FeynHiggs
- τ NN algorithm
- Limit calculation with CL_s

$$LLR = -2\ln\frac{p(data|S+B)}{p(data|B)}$$





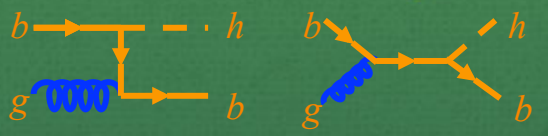


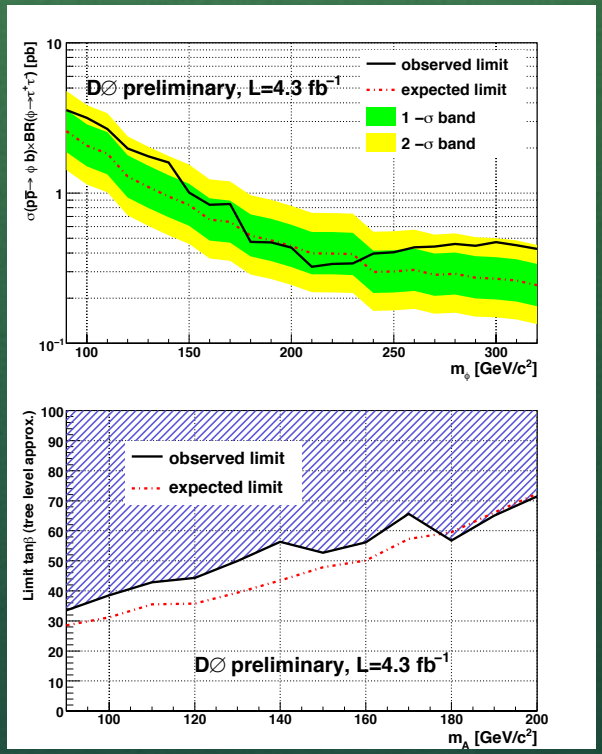


Phys. Rev. Lett. **101**, 071804 (2008)+1.2 fb^{-1}
D0 Note 5740

D0 ϕ b$\rightarrow \tau_{\mu} \tau_{had}$ b (4.3 fb^{-1})

- Signal 5-flavor scheme (bg$\rightarrow$bϕ)
  - Normalized to NLO with MCFM, CTEQ6L1 PDFs
    - Weighed p_T, η of the FS b-quark distribution
  - TAUOLA for τ, EVTGEN for b-quark decays
  - 4% Z production XS, 20% Z+b(c), 11% ttbar XS uncertainty
- Recorded with single μ triggers (60% eff)
- τ NN, NN b-tag ($D_{lead\text{-}b}$)
- MJ background from 2 methods: μ isolation fake rates and τ NN fake rates from sideband regions in data control samples
- Discriminant $D_f = (D_{t\bar{t}} \times D_{MJ} \times D_{lead-b})^{\frac{1}{3}}$
- E ID 8%, lumi 6.1%, τ ID 7%, JER 5% uncertainty, 20-50% MJ+W+jets evaluation uncertainty

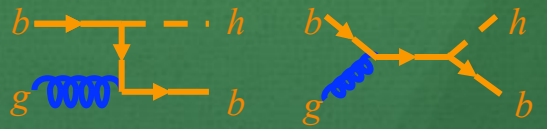


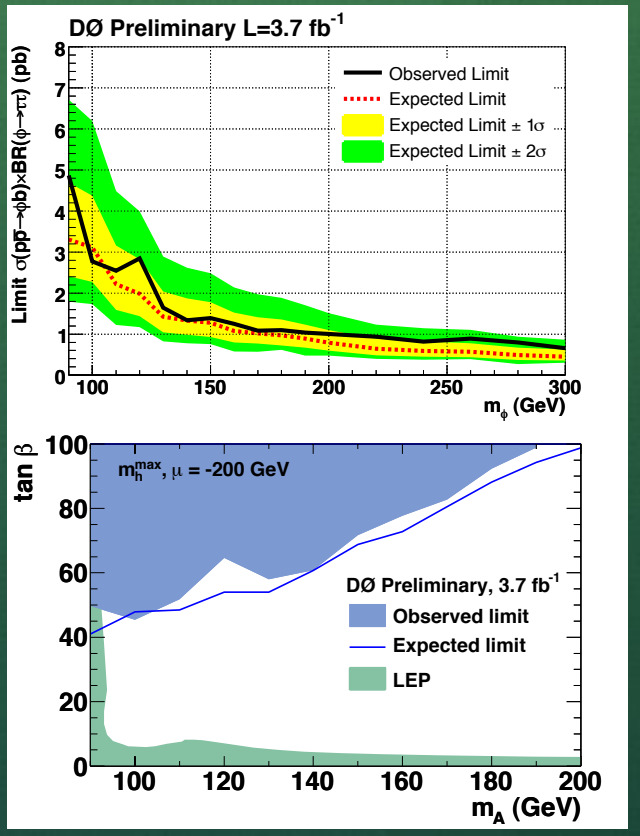


Phys. Rev. Lett. **104**, 151801 (2010)+1.6 fb^{-1}, D0 Note 6083, updates expected soon

D0 $\phi b \rightarrow \tau_e \tau_{had} b$ (3.7 fb^{-1})

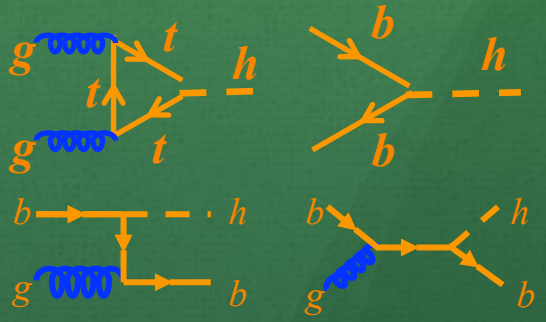
- Signal 5-flavor scheme ($bg \rightarrow b\phi$)
  - +2-5% Z production XS, 30% Z+b(c), 11% ttbar, 6% diboson XS uncertainty
  - 10-33% MJ uncertainty
- Recorded with single electron triggers, 5% uncertainty
- τ NN, NNe, NN b-tag, NN_{top}
- MJ background from SS events (MC subtracted) 0.3< τ NN<0.8 sideband
- Combined likelihood $\frac{LL_{MJ}+10}{20} \times NN_{top}$
- EM ID 8%, lumi 6.1%, τ ID 7% uncertainty

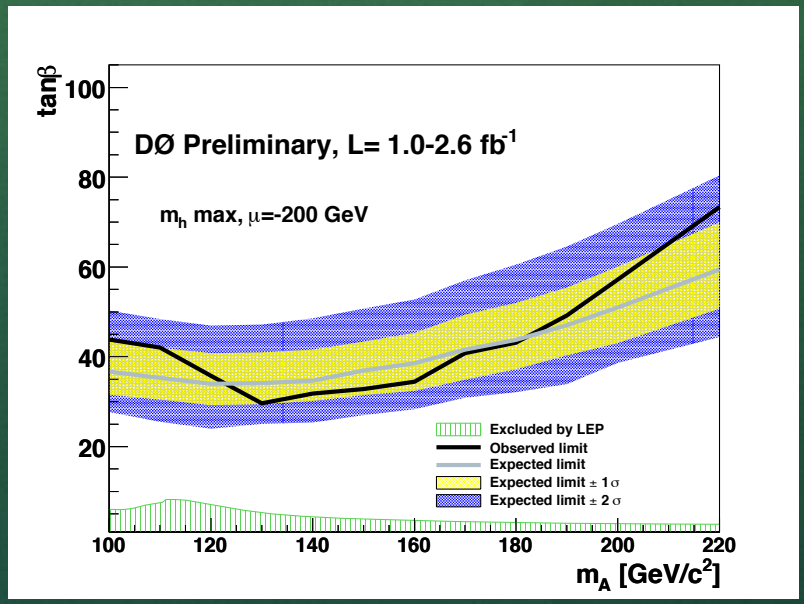




D0 $\phi \rightarrow \tau\ \tau$ (2.2 fb^{-1}) + ϕ b$\rightarrow \tau_{\mu}\ \tau_{had}$ b (1.2 fb^{-1}) + ϕ b$\rightarrow$bbb (2.6 fb^{-1})

- $gg \rightarrow \phi \rightarrow \tau\ \tau$
  - M_{vis} used for discriminants
  - Backgrounds: ALPGEN+PYTHIA Z/ γ*(NNLO), W, VV(NLO), tt(COMPHEP+PYTHIA, NLO)
- $gb \rightarrow \phi$ b (5 flavor scheme)
  - ϕ b$\rightarrow \tau\ \tau$ b recorded with μ and τ triggers (previously to 4.3 fb^{-1} result)
    - XS from FeynHiggs
    - 1 D discriminant out of N_{top} and QCD likelihood
  - ϕ b$\rightarrow$bbb special IP trigger
    - XS from MCFM
    - M_{bb} as discriminant
- Combination benchmark scenarios from FeynHiggs
- Leading systematics τ ID 4-10%, b-tagging 6-10%(signal), MJ background modeling 4-47%

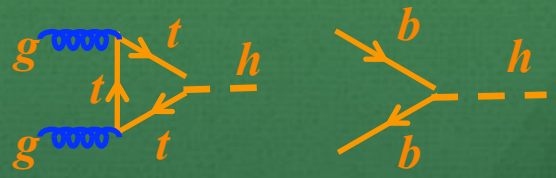


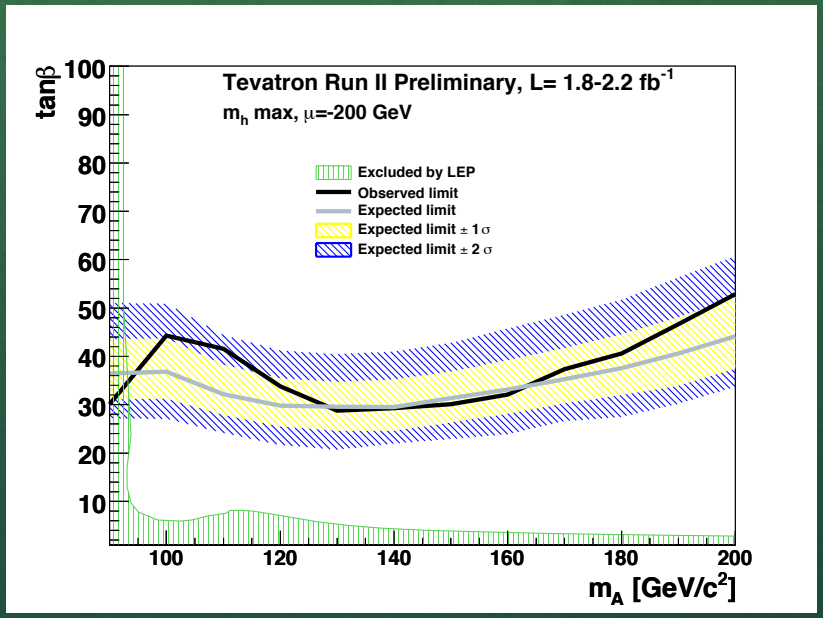


D0 Note 5935

CDF $\phi \rightarrow \tau\ \tau$ (1.8 fb^{-1})+D0 $\phi \rightarrow \tau\ \tau$ (2.2 fb^{-1})

- Signal MC CTEQ5L (CDF), CTEQ6L (D0)
  - CDF simulated both gg$\rightarrow\phi$ and bb$\rightarrow\phi$, D0 gg$\rightarrow\phi$ only
  - Z/ γ^* normalized to NNLO
- Bayesian and CL_s approaches used for combination
  - Similar results (within 10%)
  - Flat prior in the Bayesian method





D0 Note 6036

Conclusions

- Both Tevatron experiments cover most significant channels in MSSM Higgs boson search
- Combinations are made by D0 including both $\tau\ \tau$ and bb decay channels excluding tan β >35 at M_A=130 GeV
- CDF and D0 $\tau\ \tau$ combination excludes tan β >30 at M_A=130 GeV in m_h^{max}, μ =-200 GeV scenario
- Updates with larger datasets (up to 8 fb^{-1}) are expected soon