Higgs searches at CDF

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on behalf of the CDF collaboration

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Outline

The Tevatron and CDF

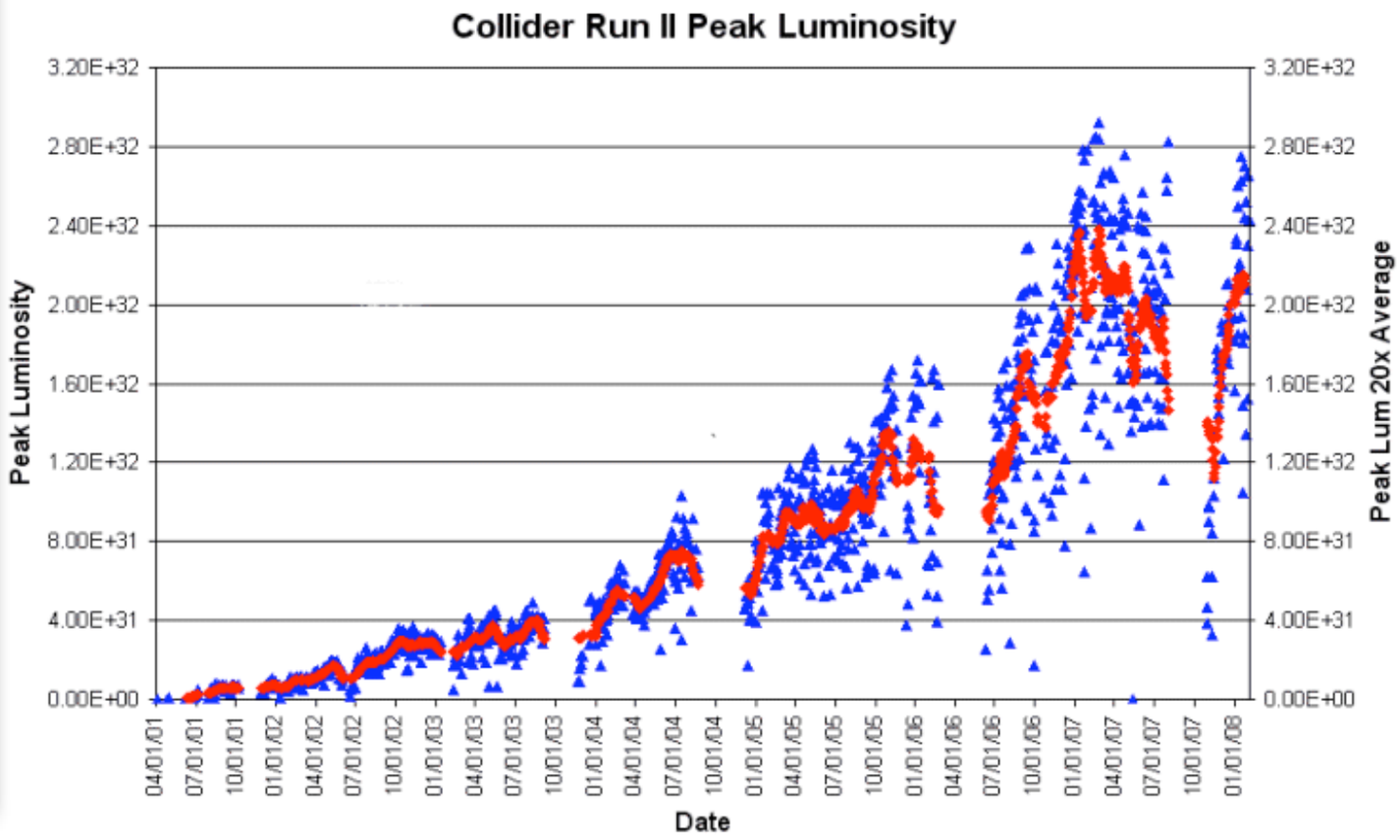
SM Higgs

MSSM Higgs

Conclusions

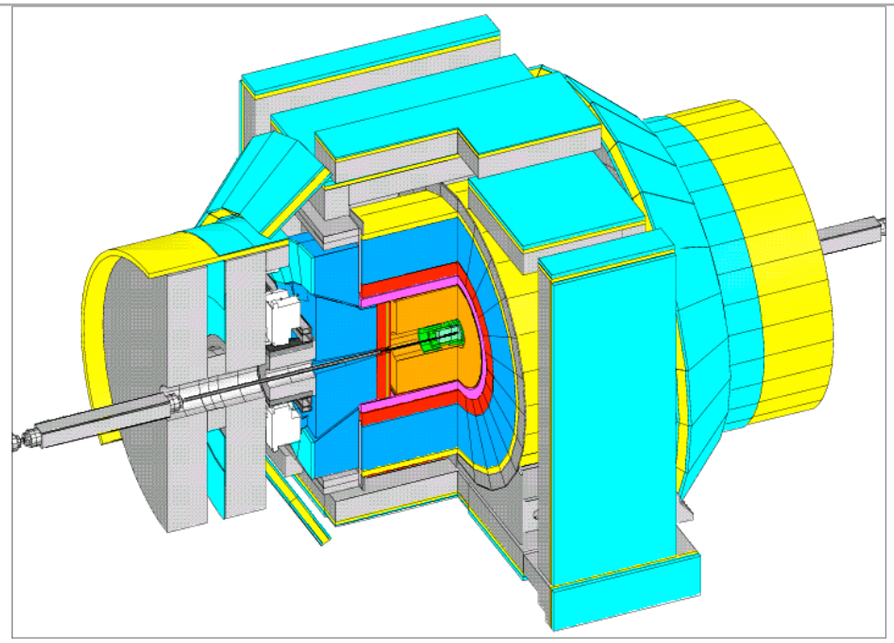
The Tevatron

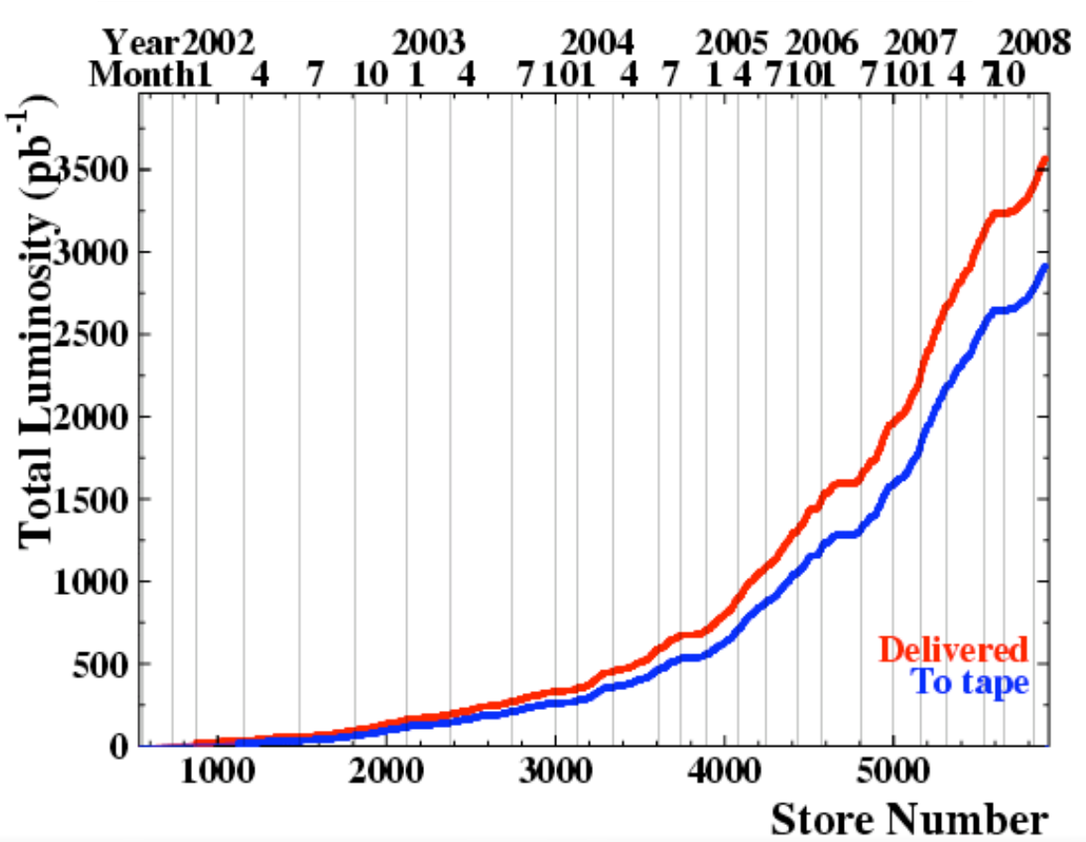
- $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV
- 36×36 bunches, 396 ns crossing period.
- Initial instantaneous luminosity record: **3×10^{32} cm^{-2}s^{-1}**
- Delivered luminosity > **3.2 fb^{-1}** since March 01, Run II



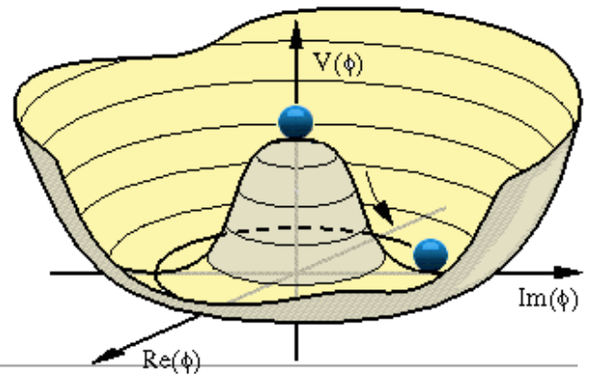
CDF Run II

- General purpose collider experiment. Usual structure:
  - silicon vertex detector: vtx finding
  - tracker: charged particles p_T
  - solenoid: 1.4 T field
  - calorimeter: electrons, taus, photons and jets
  - muon chambers: hits matched with tracks
- Almost 3 fb^{-1} of data on tape
- 85% data taking efficiency
- Results shown here: **1 - 2 fb^{-1}**

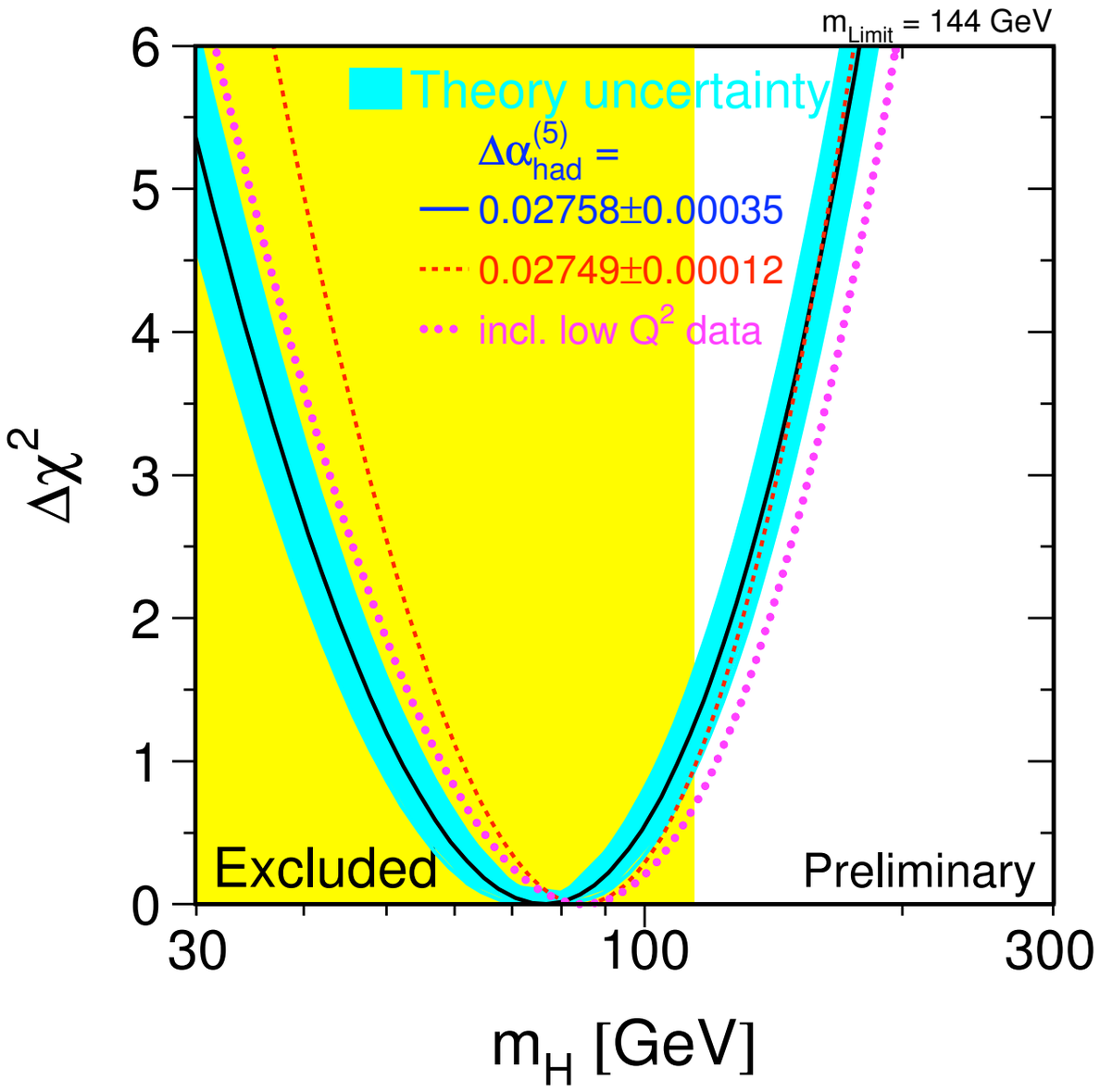


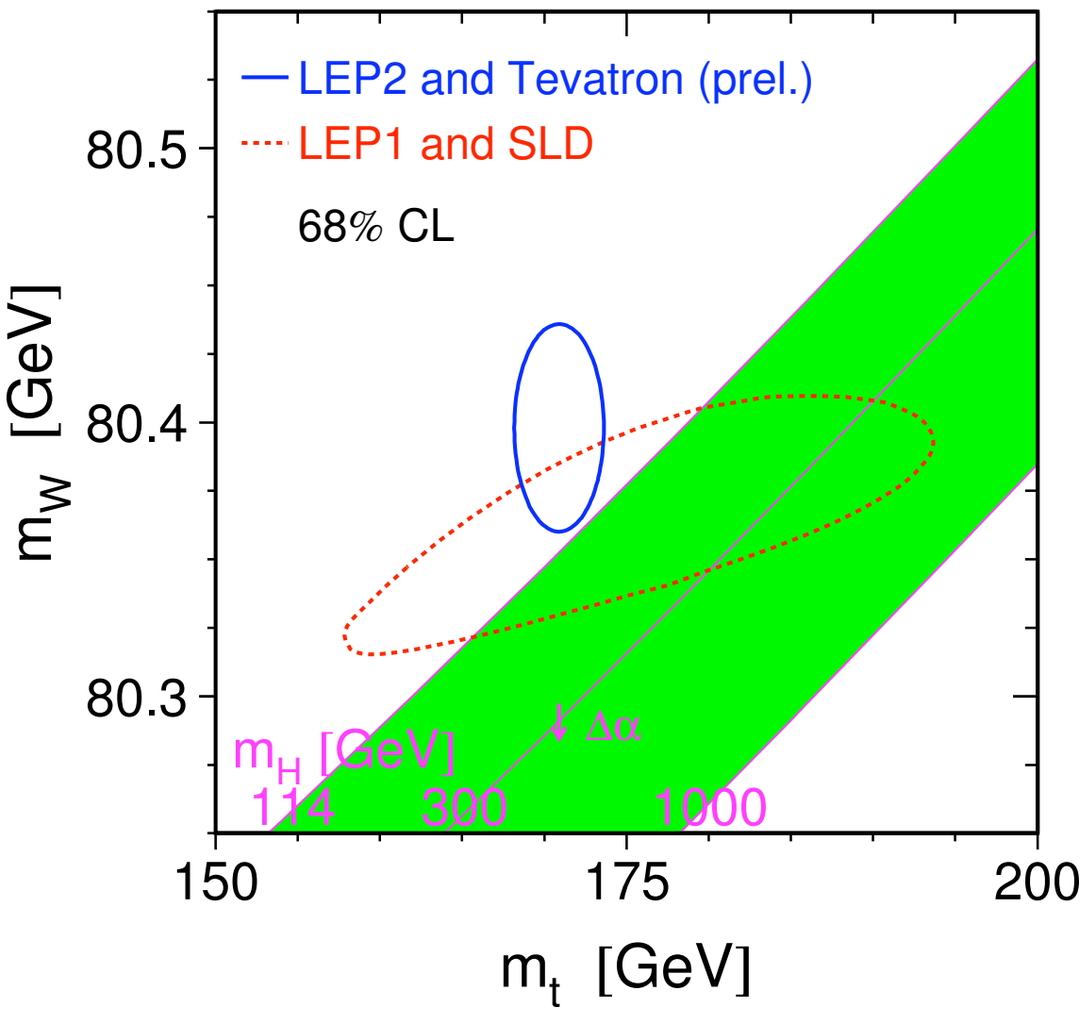


Standard Model Higgs Boson



- Direct Searches at LEP:
  M_H > 114.4 GeV @ 95% CL

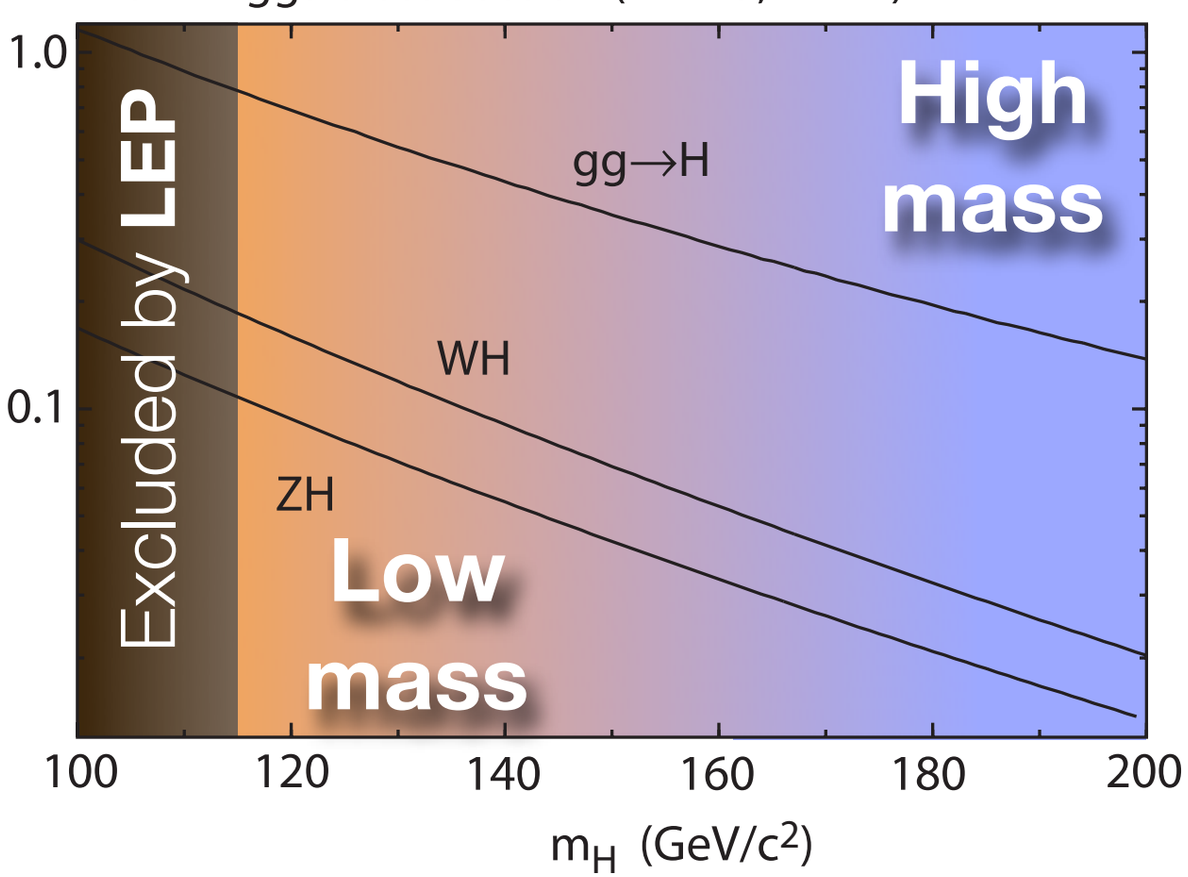




- Global fit with Tevatron's
  - **M^{top}= 170.9 ± 1.8 GeV** and
  - **M^W=80.398 ± 0.025 GeV**
- **$M_H = 76\ ^{+33}_{-24}$ GeV**
- **M_H < 144 GeV** @ 95 % CL

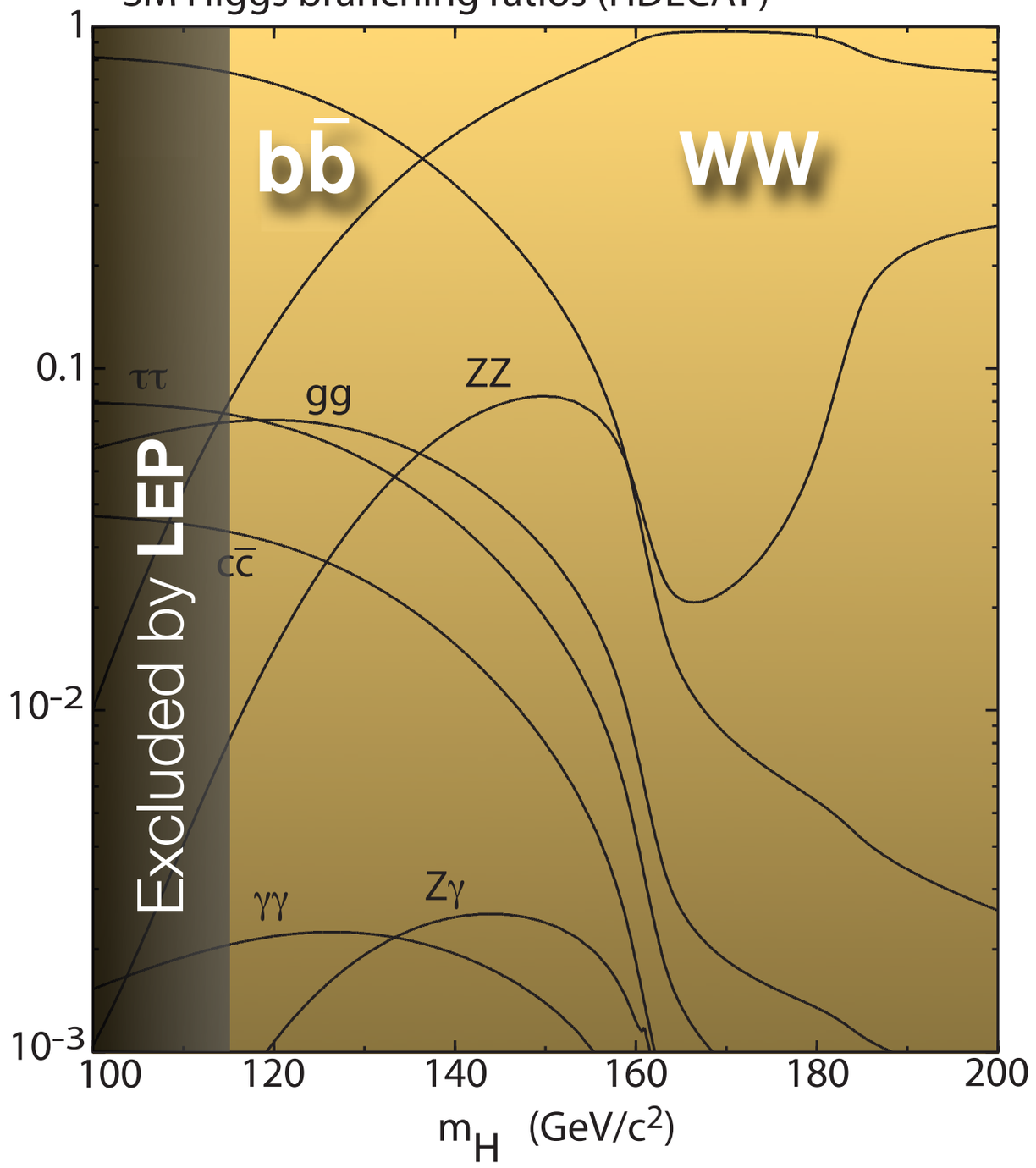
SM Higgs at the Tevatron

SM Higgs cross section (HIGLU, V2HV)



- Challenging search:
  - minute cross sections
  - difficult backgrounds
- If significant signal not found:
  - 95% CL exclusion limits

SM Higgs branching ratios (HDECAY)



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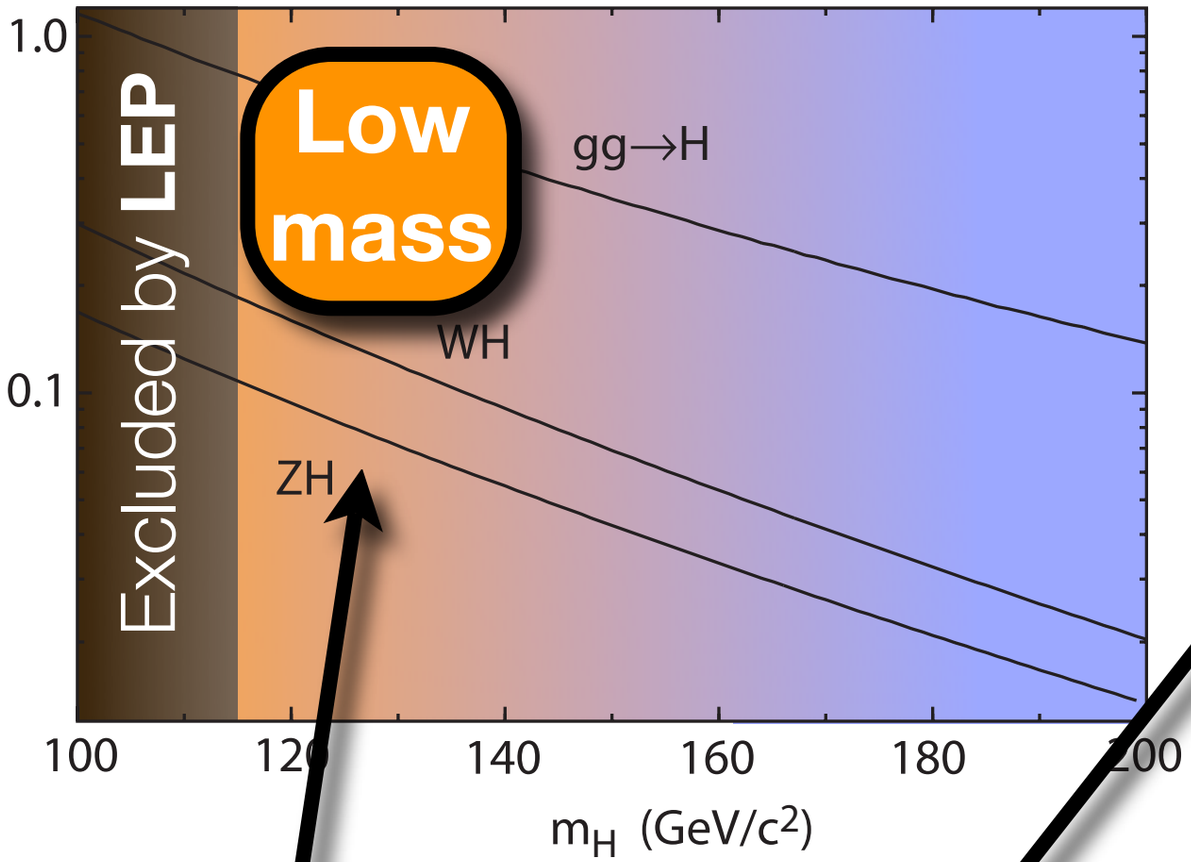
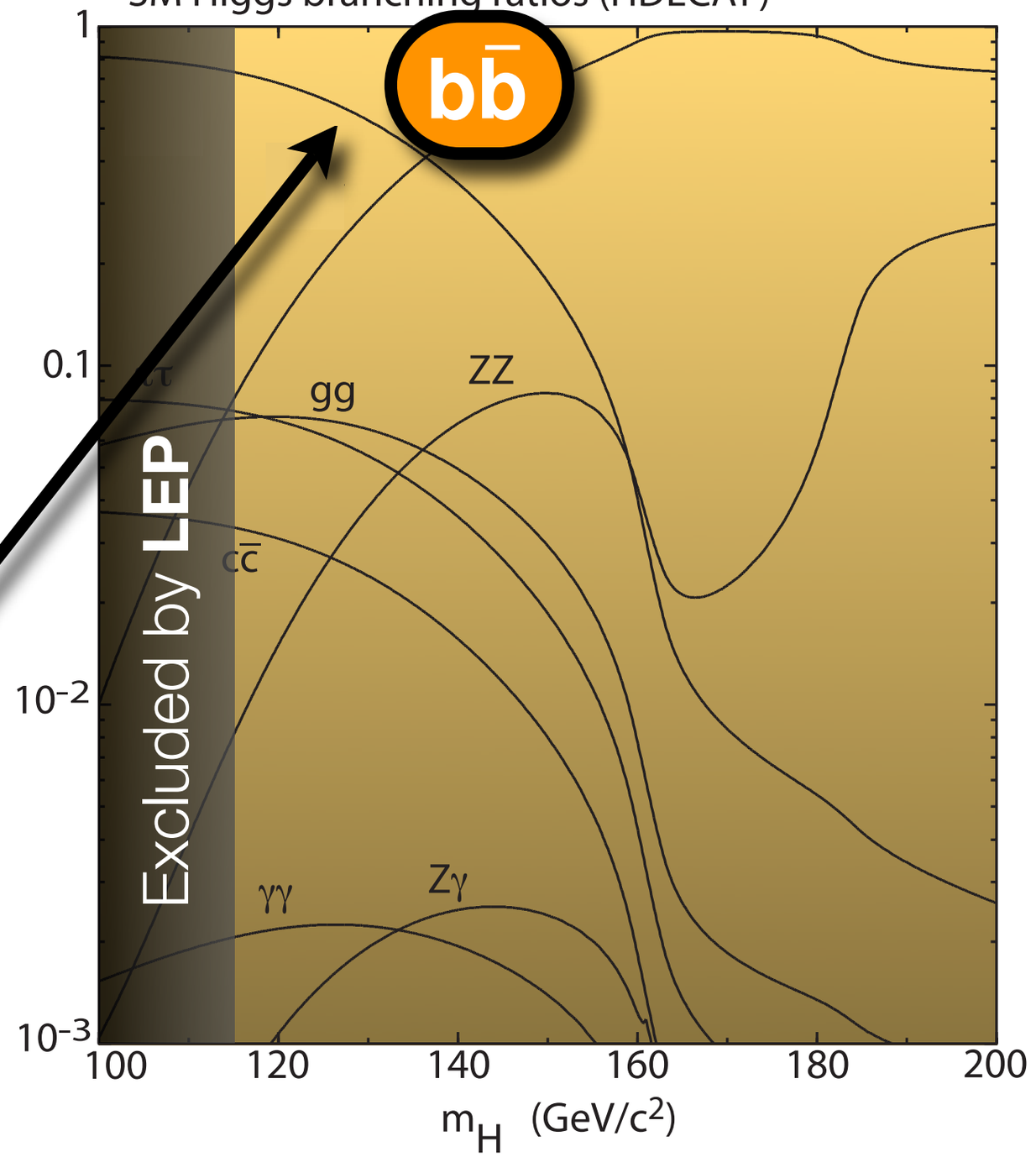


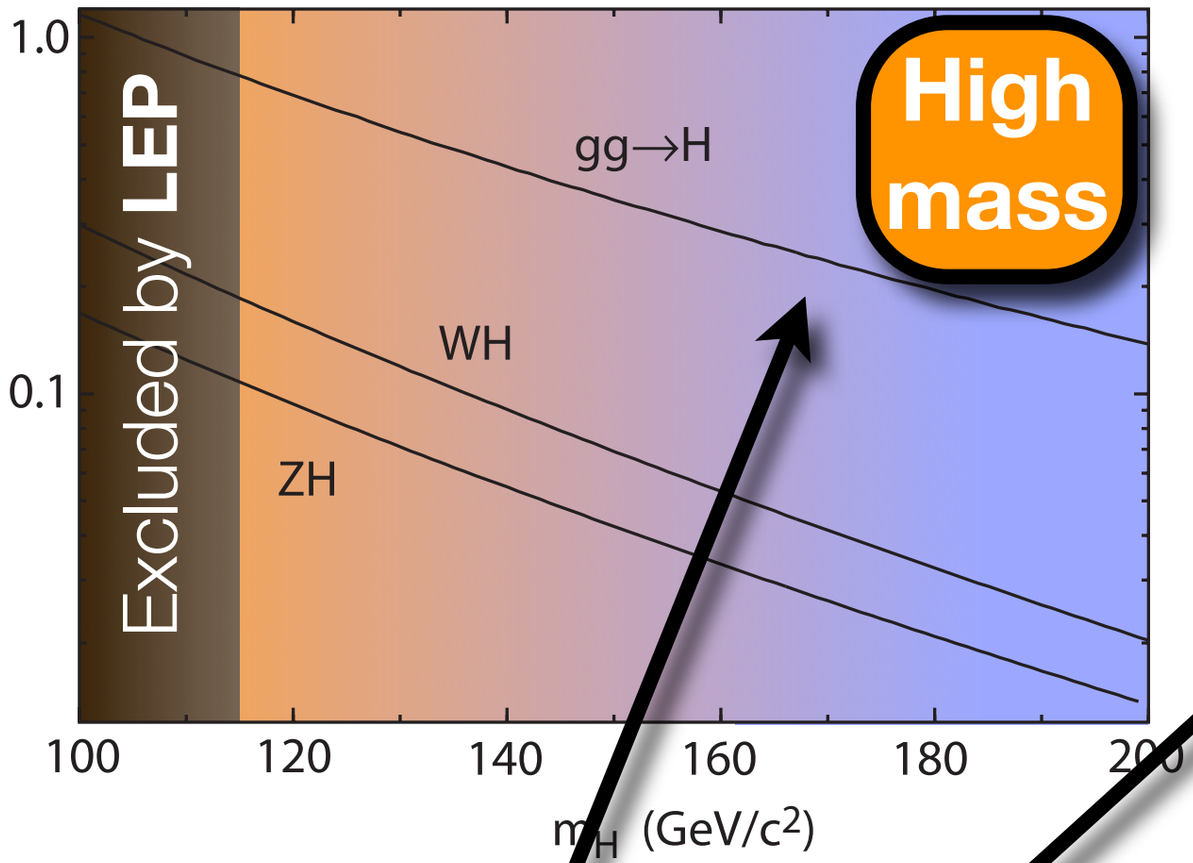
SM Higgs branching ratios (HDECAY)



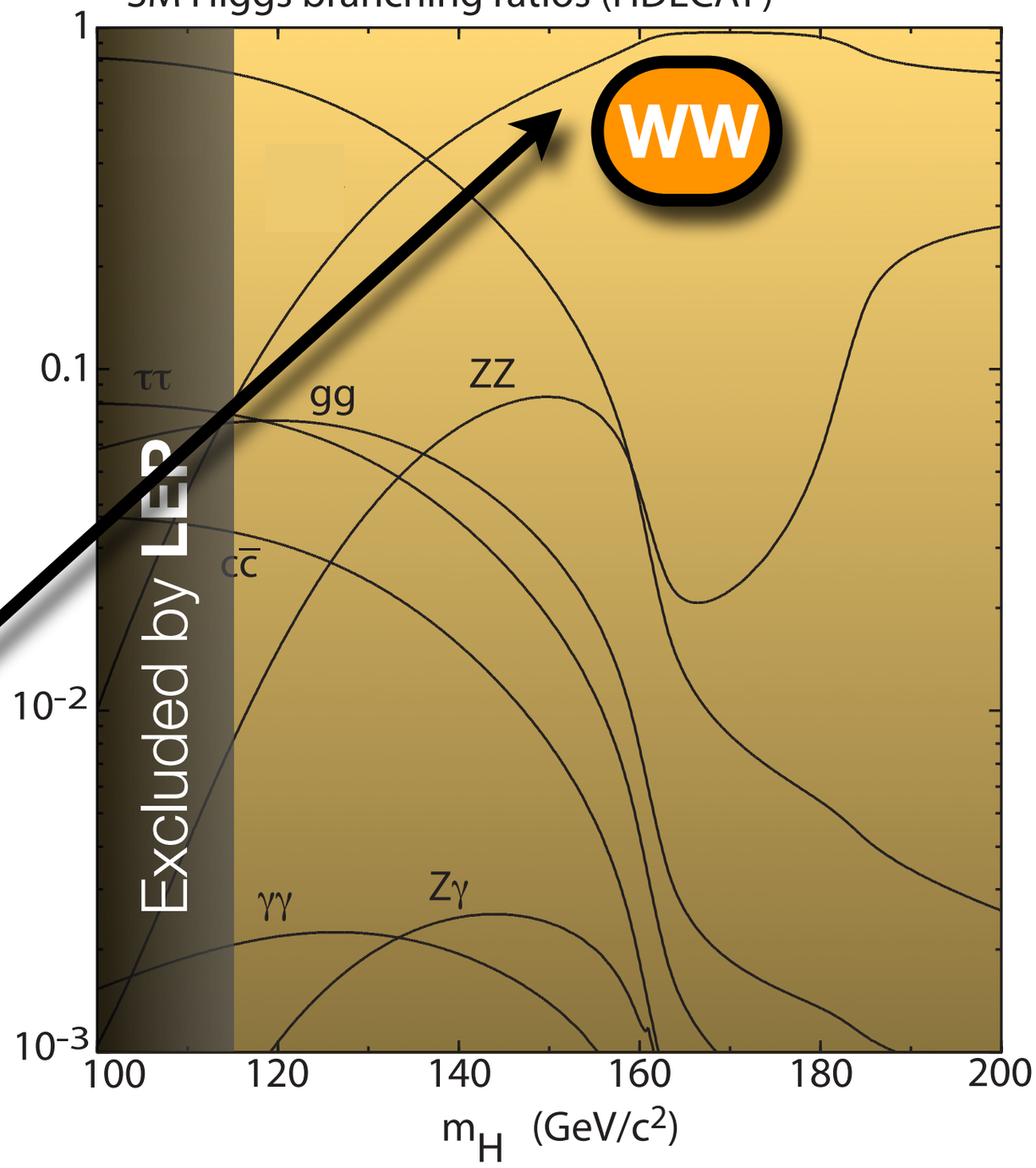
Low mass:
- ✦main decay $b\bar{b}$
- ✦associated production
- ✦trigger on lepton or E_T^{miss}

SM Higgs at the Tevatron

SM Higgs cross section (HIGLU, V2HV)



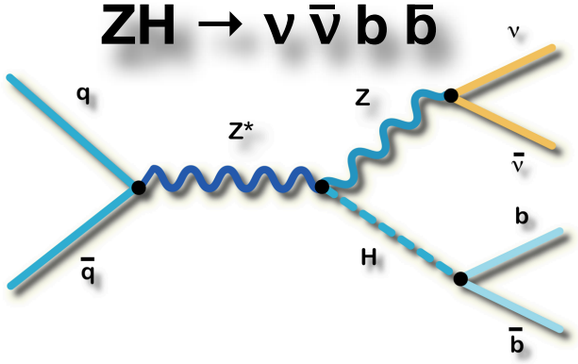
SM Higgs branching ratios (HDECAY)



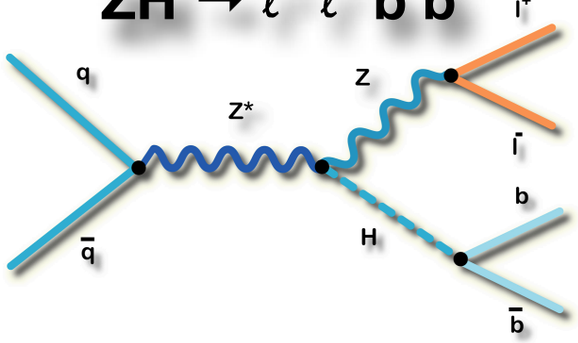
High mass:
- ✦direct production
- ✦main decay WW
- ✦trigger leptons from W

Different channels for the SM Higgs

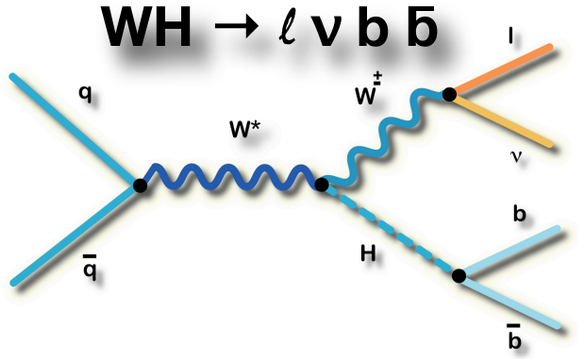
ZH → ν ν̄ b b̄



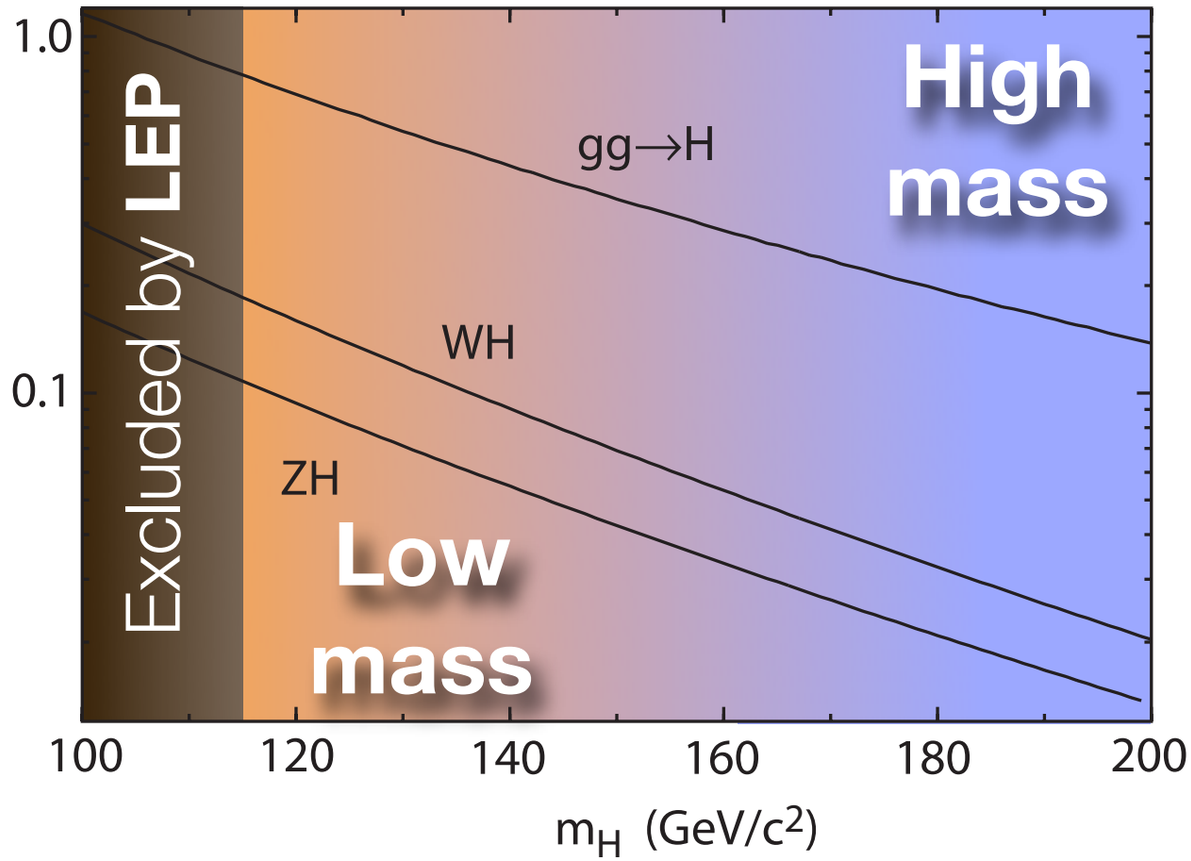
ZH → ℓ⁺ ℓ⁻ b b̄



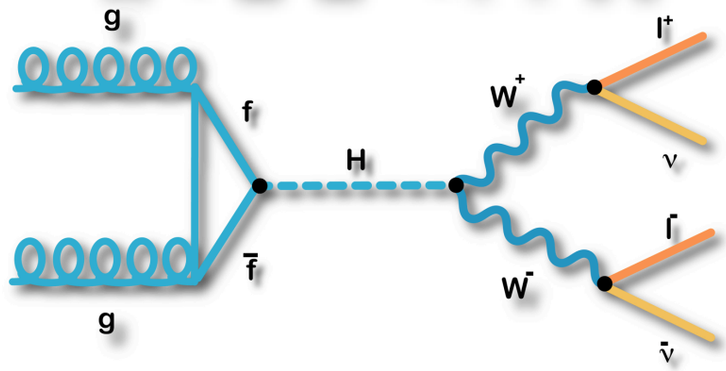
WH → ℓ ν b b̄



SM Higgs cross section (HIGLU, V2HV)



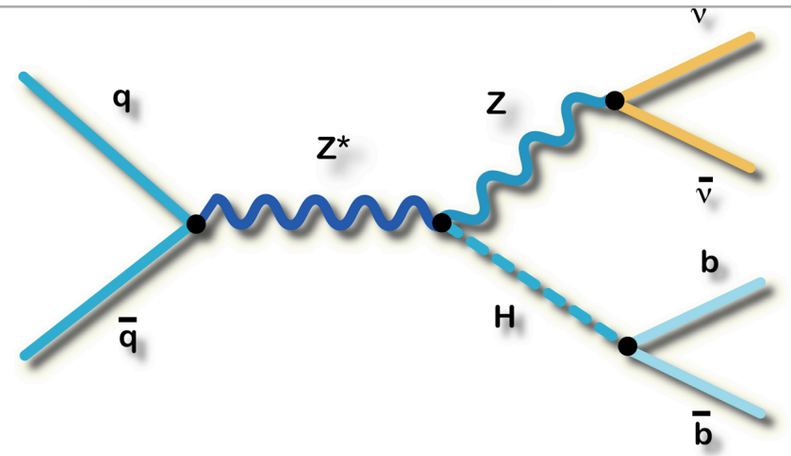
H → W⁺W⁻ → ℓ⁺ ℓ⁻ ν ν̄



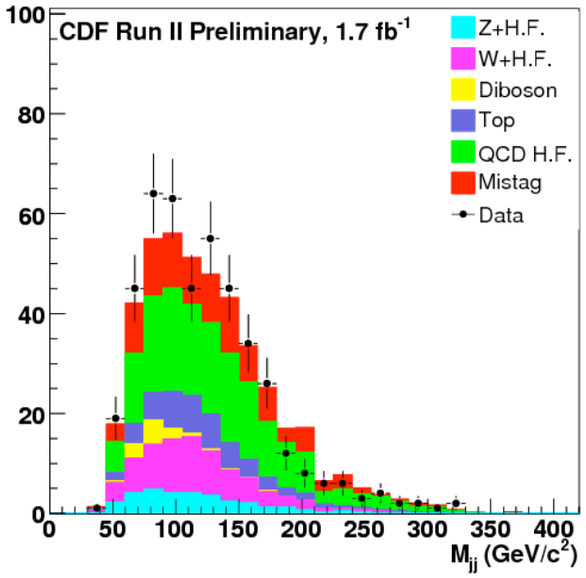
$ZH \to \nu\bar{\nu}\, b\bar{b}$

luminosity $1.7\ fb^{-1}$
exp limit@115GeV/SM 10
obs limit@115GeV/SM 20

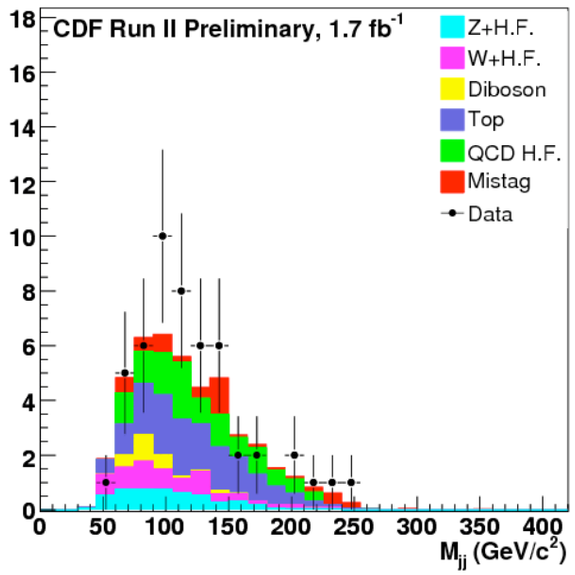
- Large E_T^{miss} and 2 jets (at least 1 b-tagged)
- Extra signal from WH (missing lepton)
- Main background: QCD, W+jets and top pairs



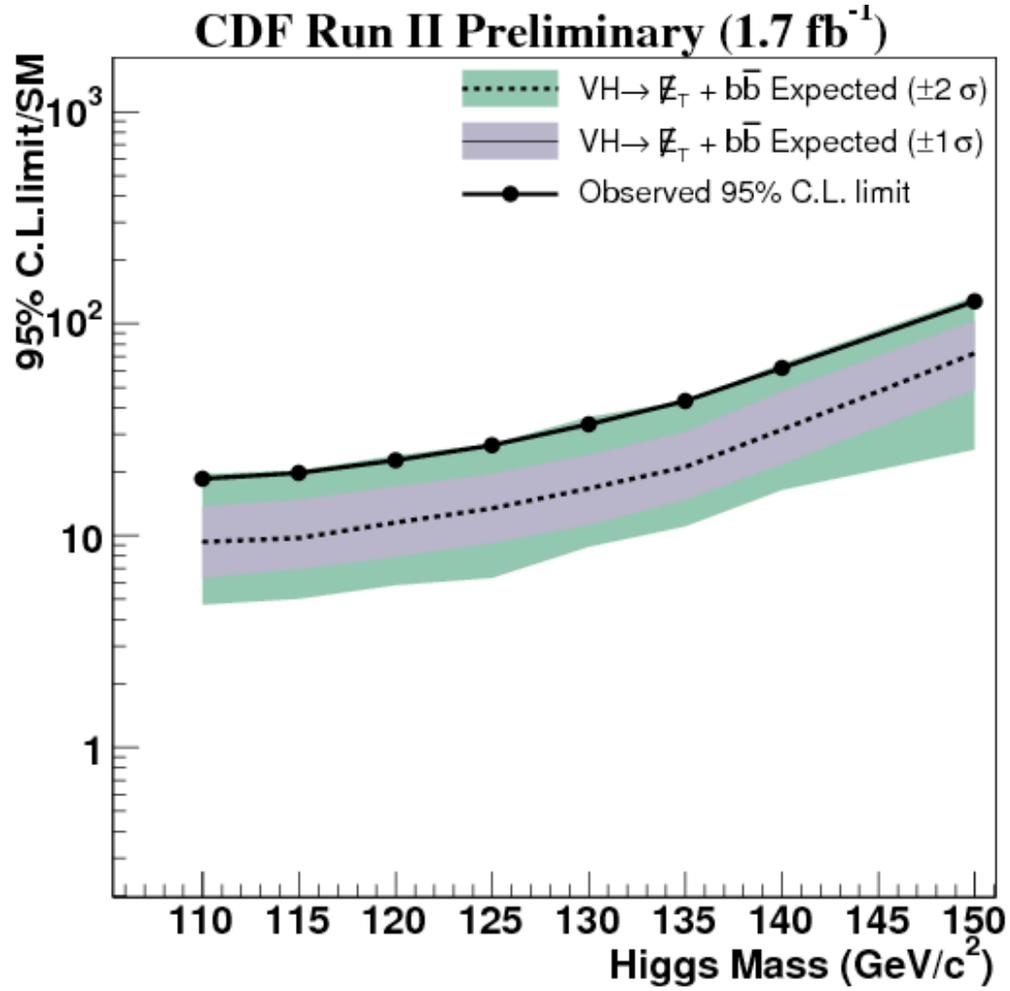
Dijet Mass, SR, Single Tight



Dijet Mass, SR, L+L



- Discriminant: di-jet mass
- 1-tag and 2-tags as different channels

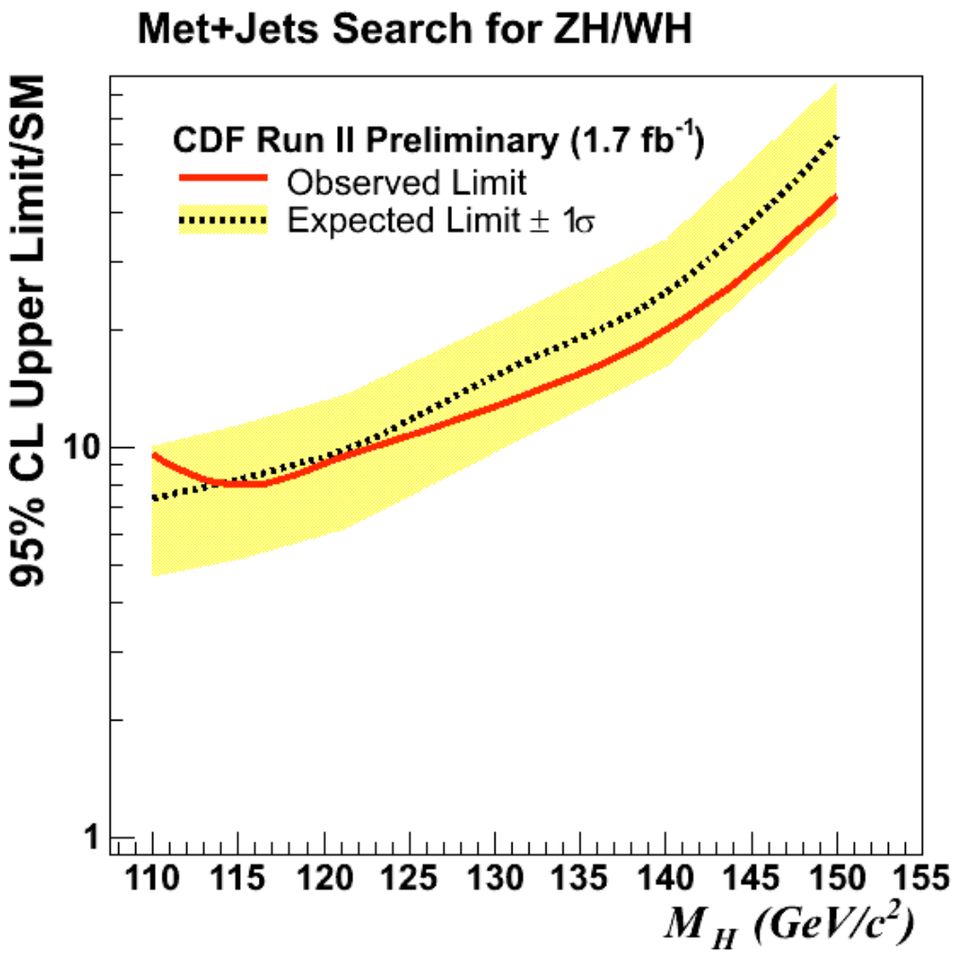


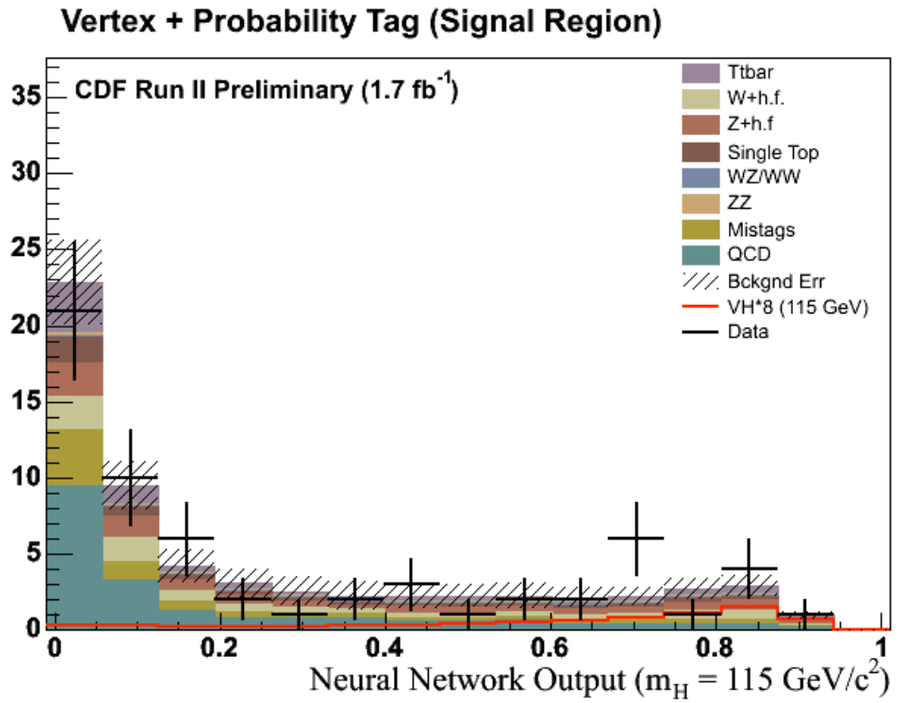
$ZH \to \nu\bar{\nu} b\bar{b}$ ...continued

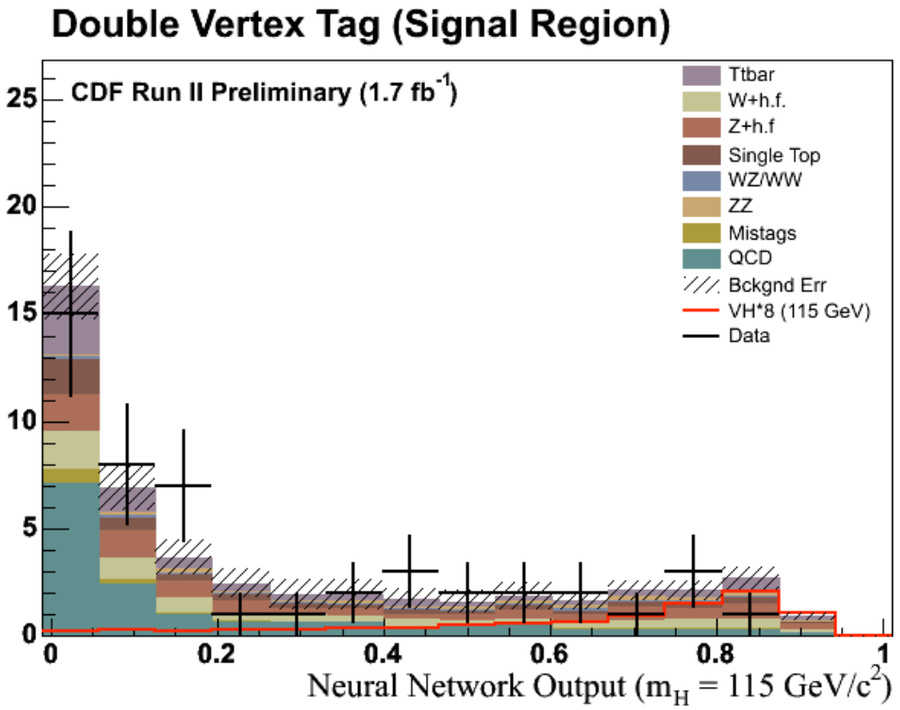
luminosity $1.7\ fb^{-1}$
exp limit@115GeV/SM 8
obs limit@115GeV/SM 7

- NN for instrumental/QCD bg reduction (track charged-p_T^{miss} and other variables)
- QCD normalized to data
- 1-tag and 2-tags in different channels

- Neural Net for signal extraction

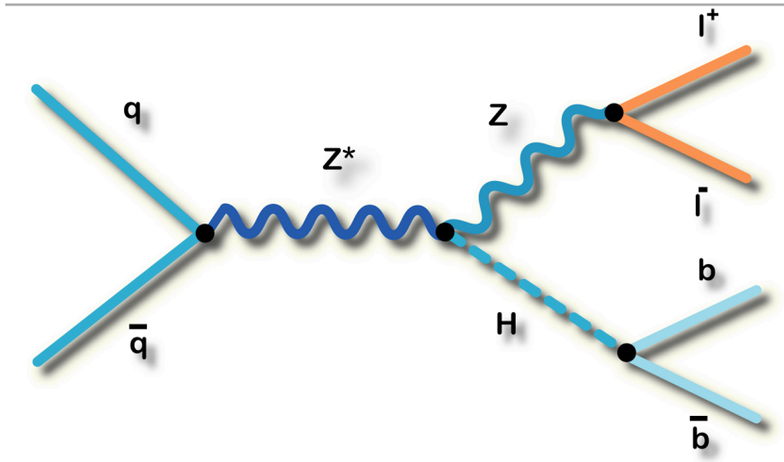






$ZH \rightarrow \ell^+ \ell^- b \bar{b}$

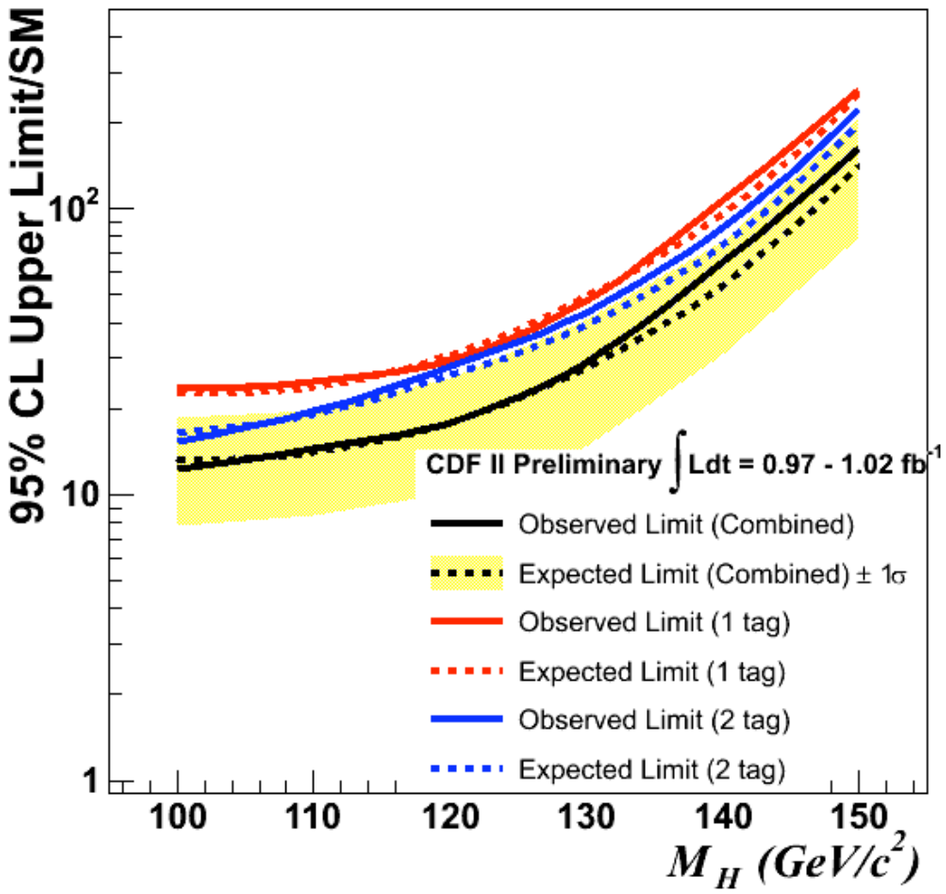
luminosity **1.0 fb^{-1}**
exp limit@115GeV/SM **16**
obs limit@115GeV/SM **16**

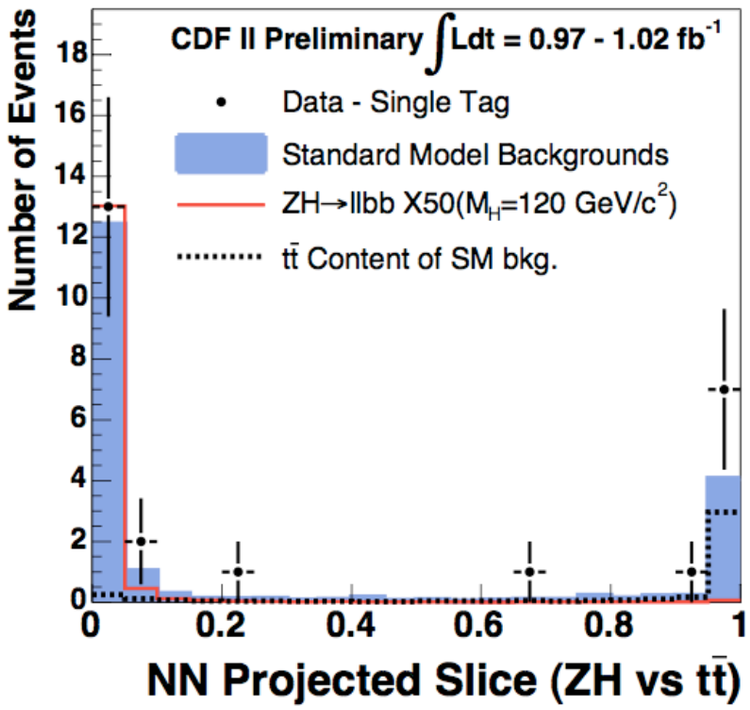


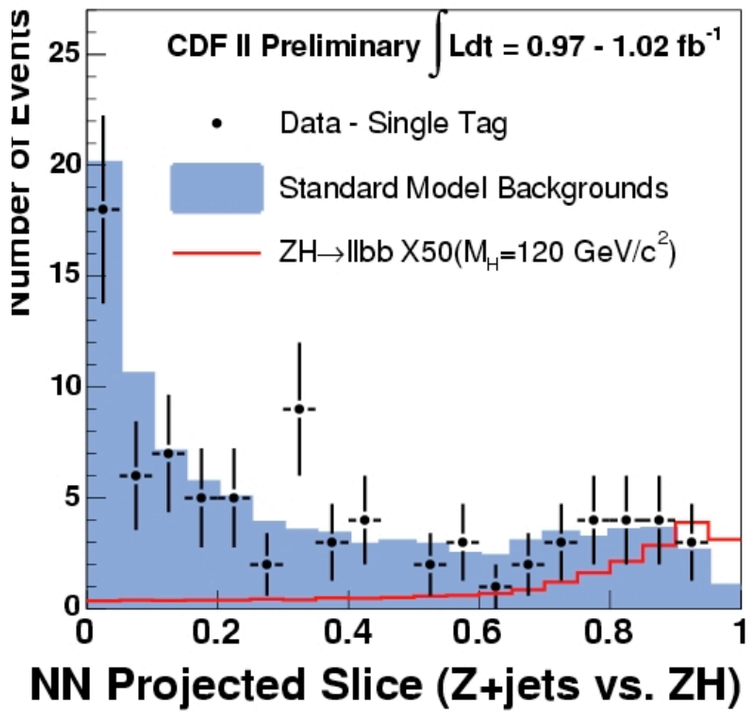
- Low event rate but clean signature
- 2 high p_T leptons, from Z
- 2 high E_T jets, with 1 or 2 b-tags

- Backgrounds: mainly Z+jets, also top pairs
- 2D Neural Network trained to separate ZH from backgrounds.
- Improve dijet mass resolution using measured E_T^{miss}.

Search for $ZH \rightarrow l^+l^-b\bar{b}$





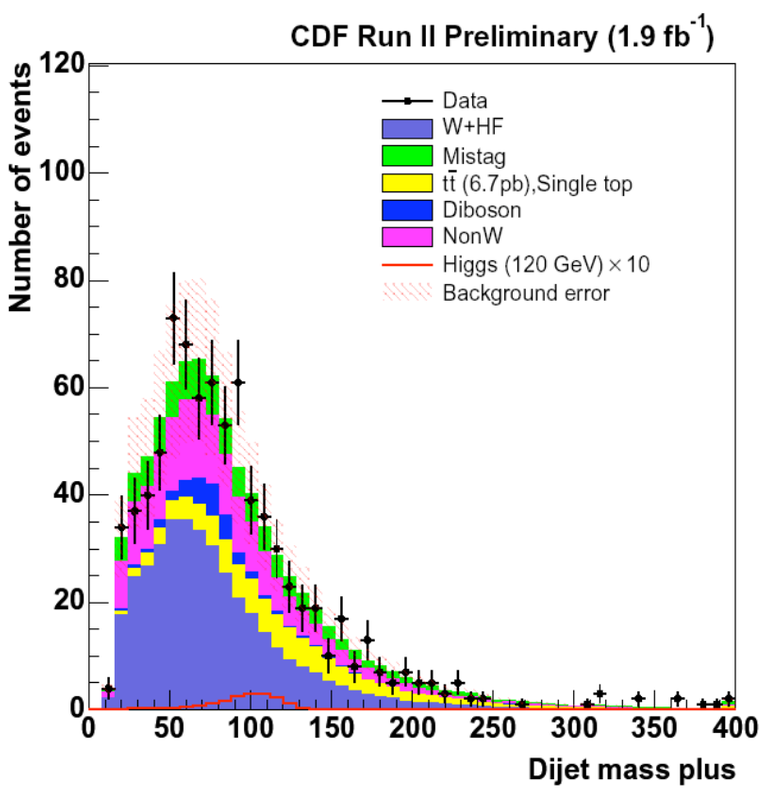


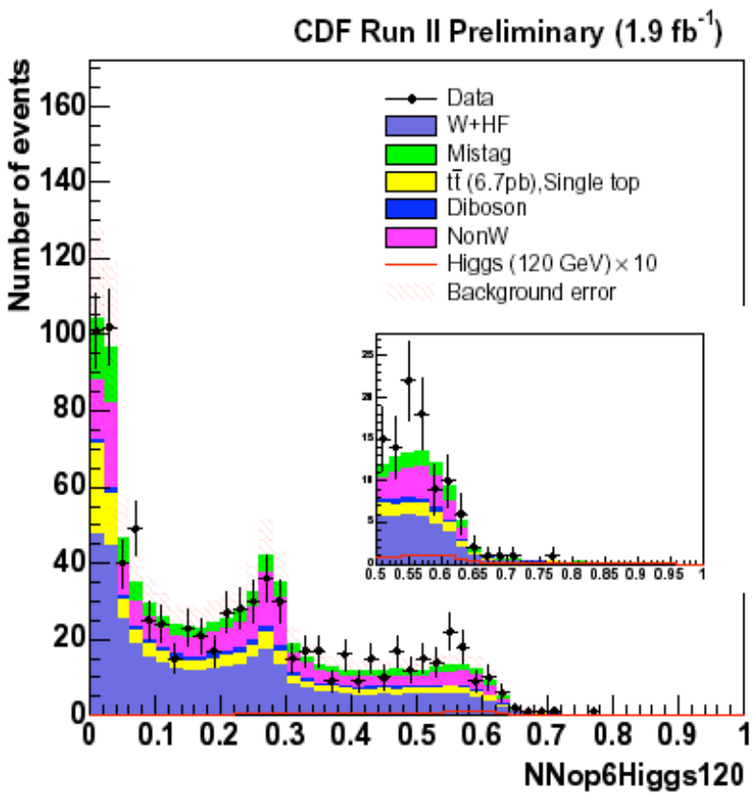
WH → ℓ ν b б

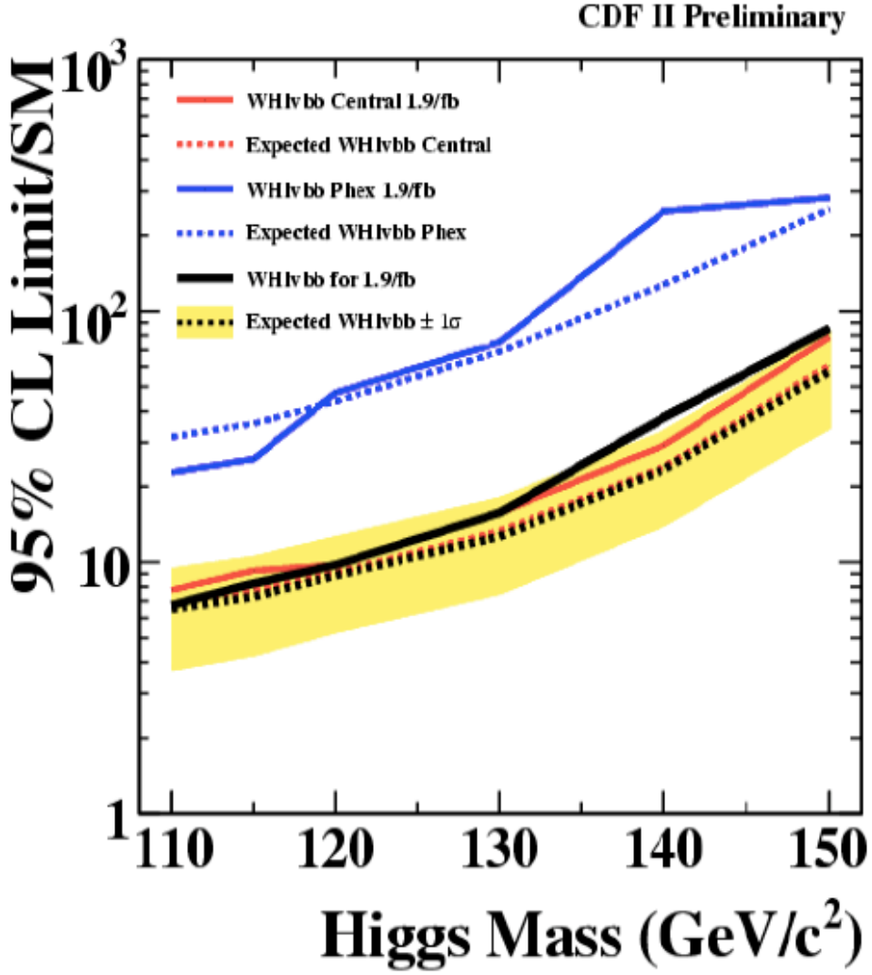
luminosity **1.9 fb^{-1}**

exp limit@115GeV/SM **7**

obs limit@115GeV/SM **8**

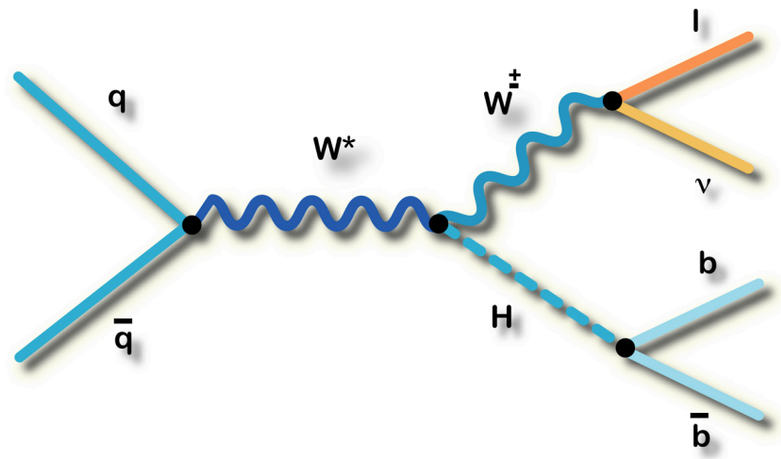






- Basic selection
  - high p_T lepton
  - 2 high E_T jets
  - large E_T^{miss}
  - 1 or 2 b-tags
- Signal discriminator: **NN** including dijet mass

- Events split b-tagged groups
  - **1 tag + NN**
  - 2 tags
    - 2 tight
    - 1 tight +1 loose
- Extended acceptance for **electrons**

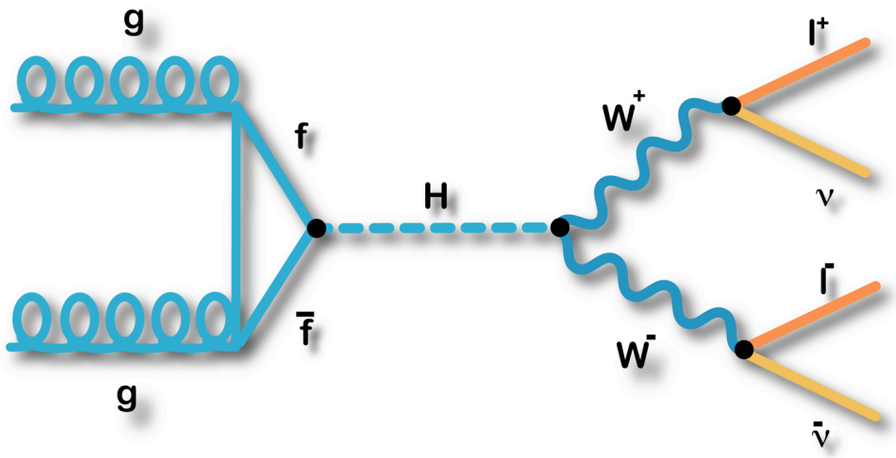


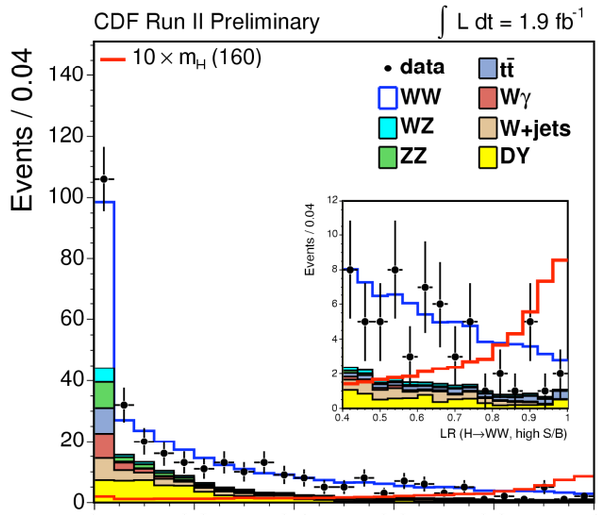
$H \rightarrow W^+W^- \rightarrow \ell^+ \ell^- \nu \bar{\nu}$

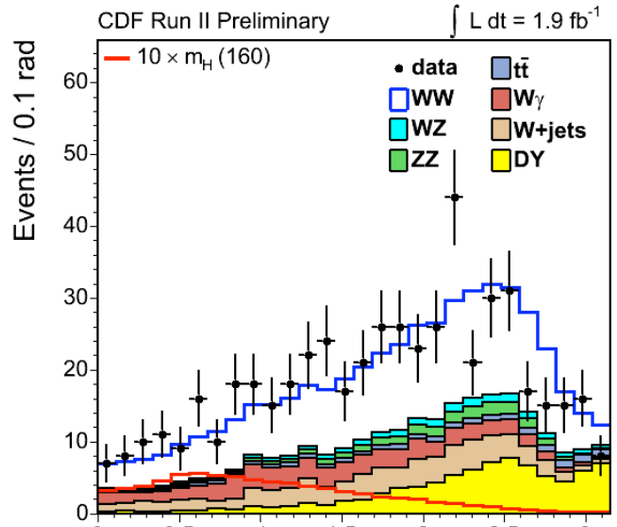
luminosity **1.9 fb^{-1}**

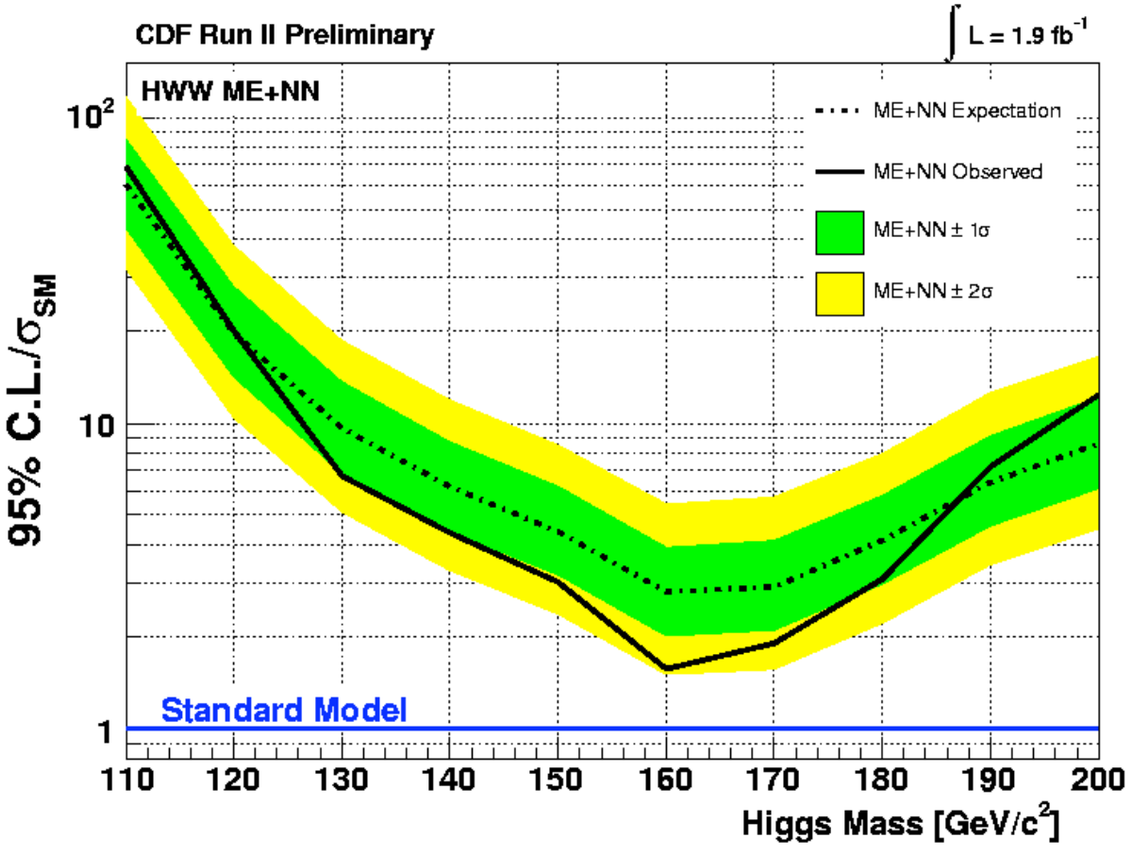
exp limit@160GeV/SM **3**

obs limit@160GeV/SM **1.6**







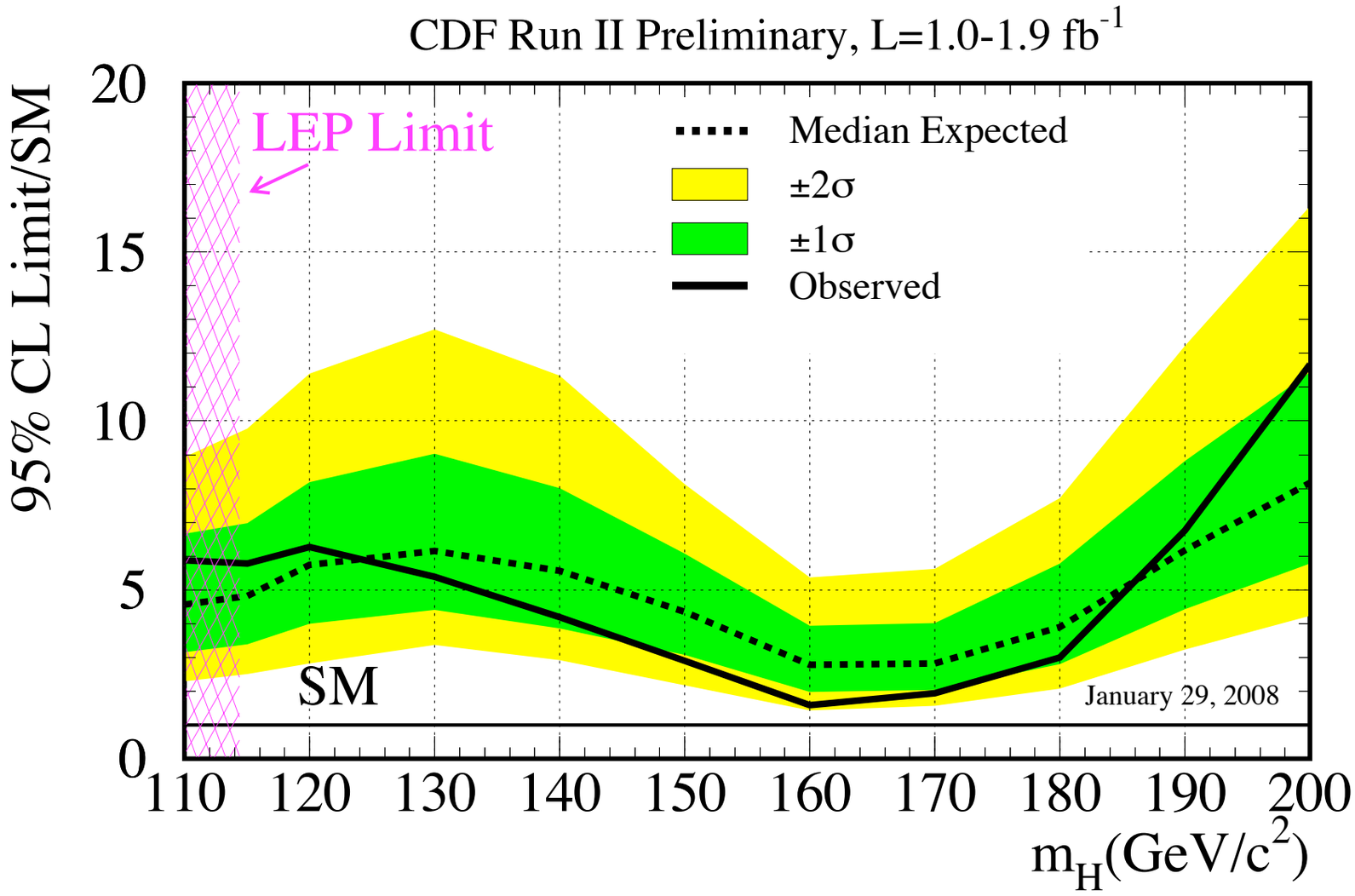


- Basic selection
  - 2 high p_T leptons
  - large E_T^{miss}
- Backgrounds
  - Drell-Yan
  - WW
- Increased lepton acceptance

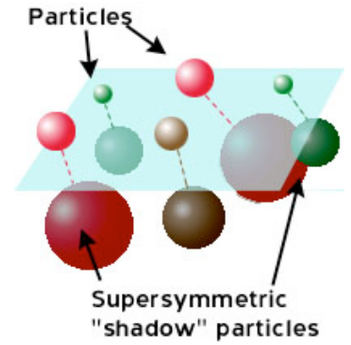
- Angle between leptons discriminates against backgrounds.
- New discriminant: Likelihood ratio, Matrix elements probabilities
- Final discriminant: **NN + ME** (NLO + LO)

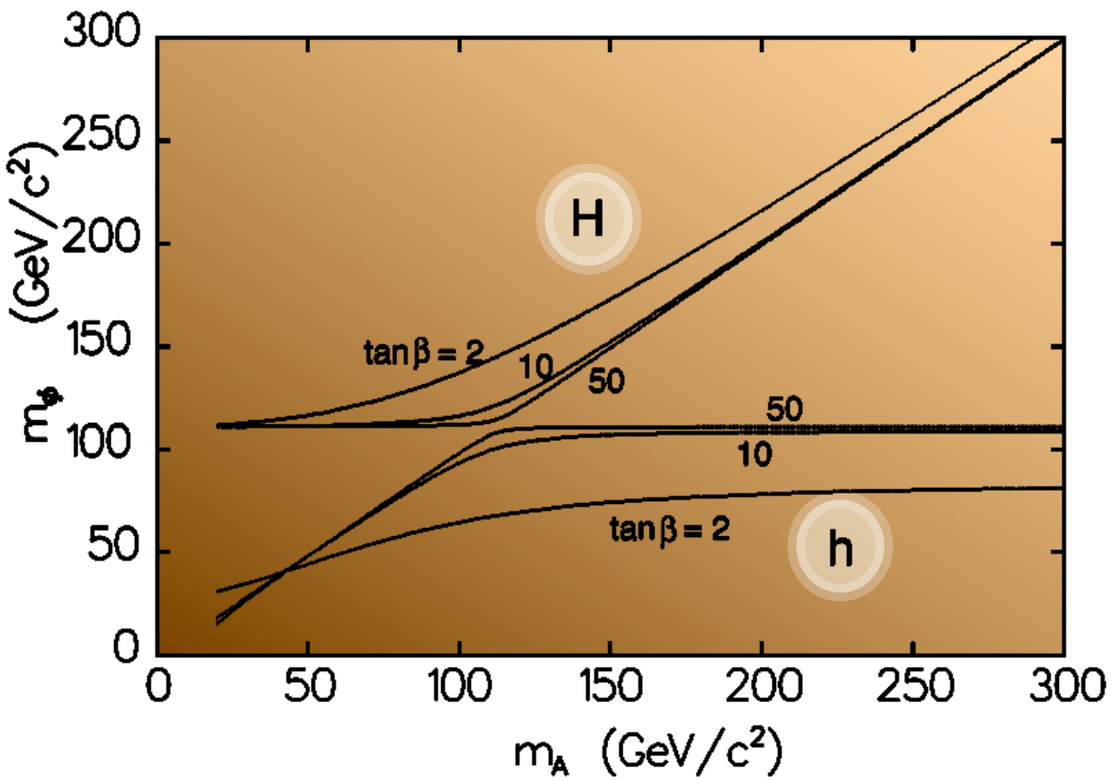
CDF SM Higgs Combined Result

- Analysis strategies:
  - **increase** signal acceptance
  - **reduce** backgrounds
  - **improve** discrimination (multivariate tech)
- Better sensitivity by combining different channels
- Latest result from the 4 channels in the previous slides combined



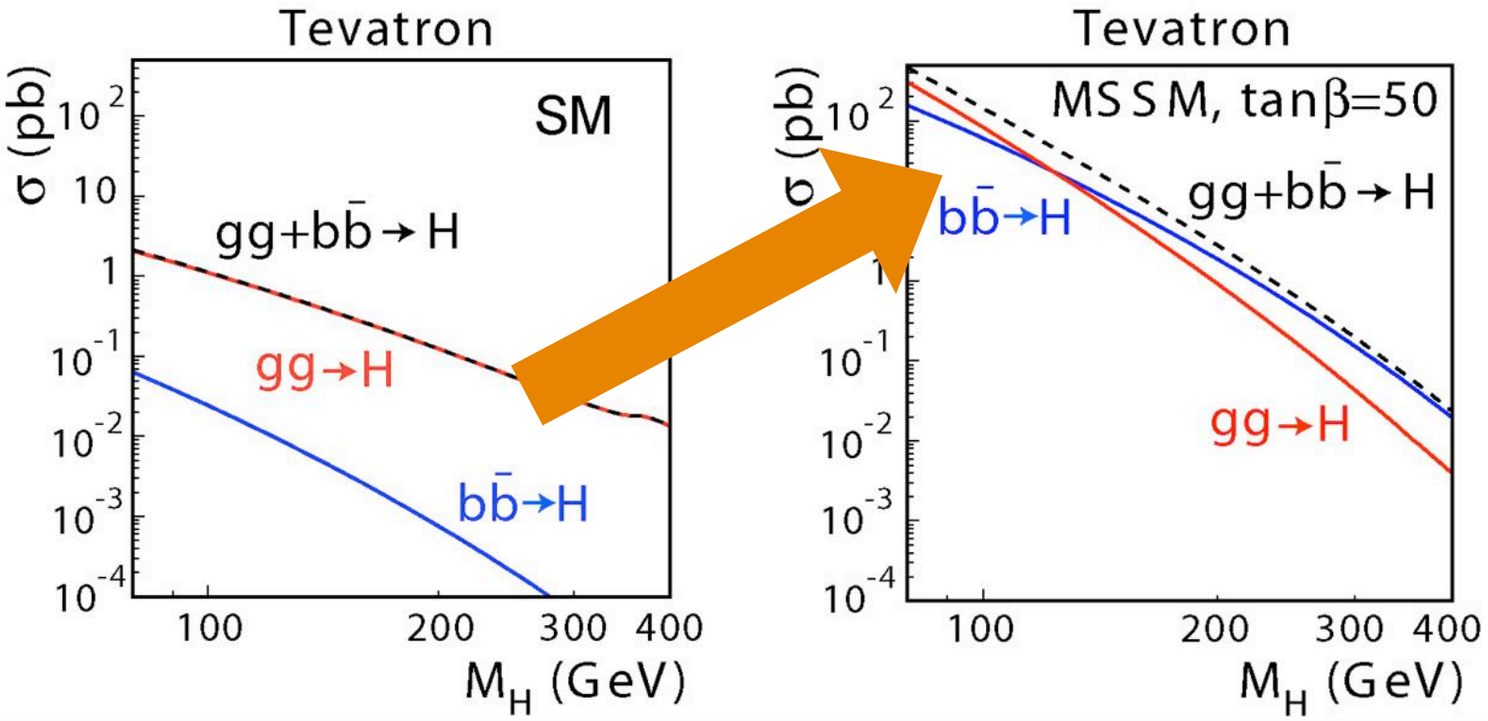
MSSM Higgs sector



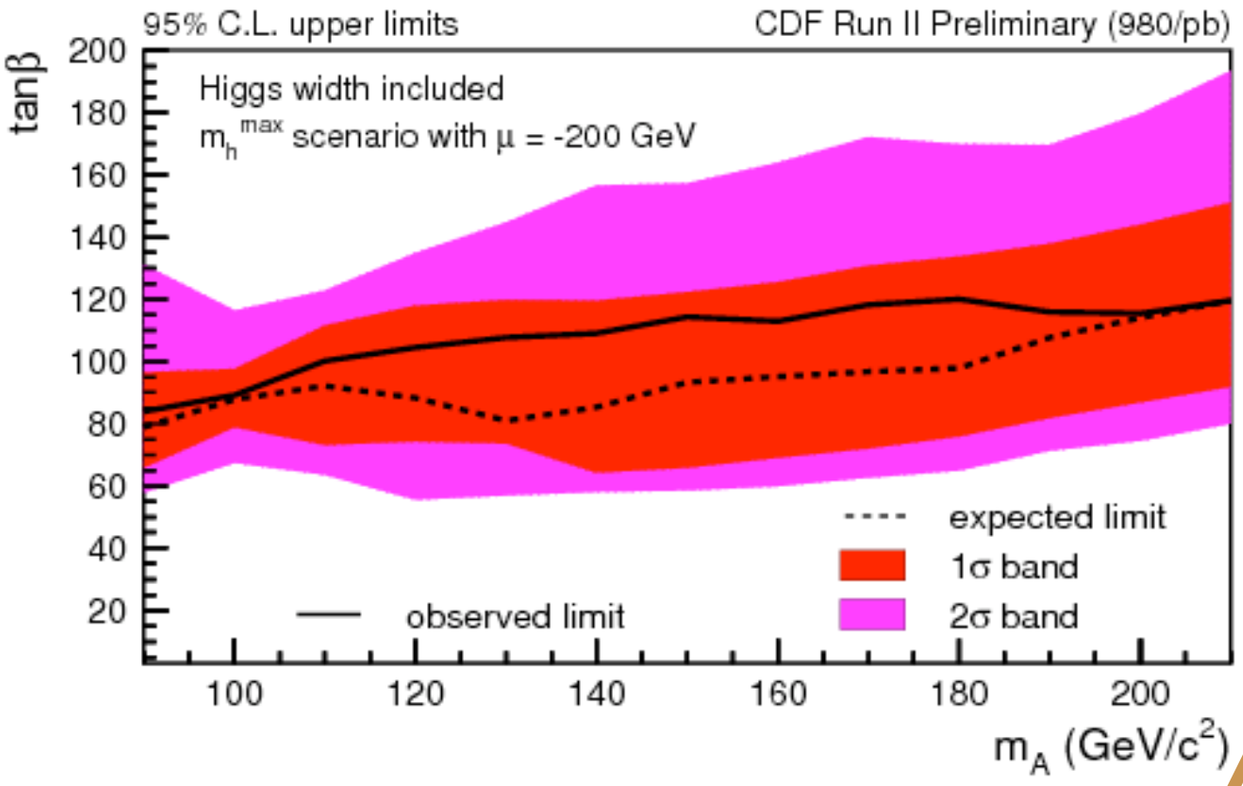


- MSSM is a SUSY model with **2 Higgs doublets**
- **5 Higgs bosons**: h, H, A, H^+ and H^-
- **2 neutrals** almost degenerate in mass
- **2 parameters**, **M_A** and **tanβ**, describe the MSSM Higgs sector.

- Production cross section enhanced by **~tan²β** with respect to SM Higgs
- Branching ratio neutral Higgs:
  - 8% **tau pairs**
  - 90% **b pairs**

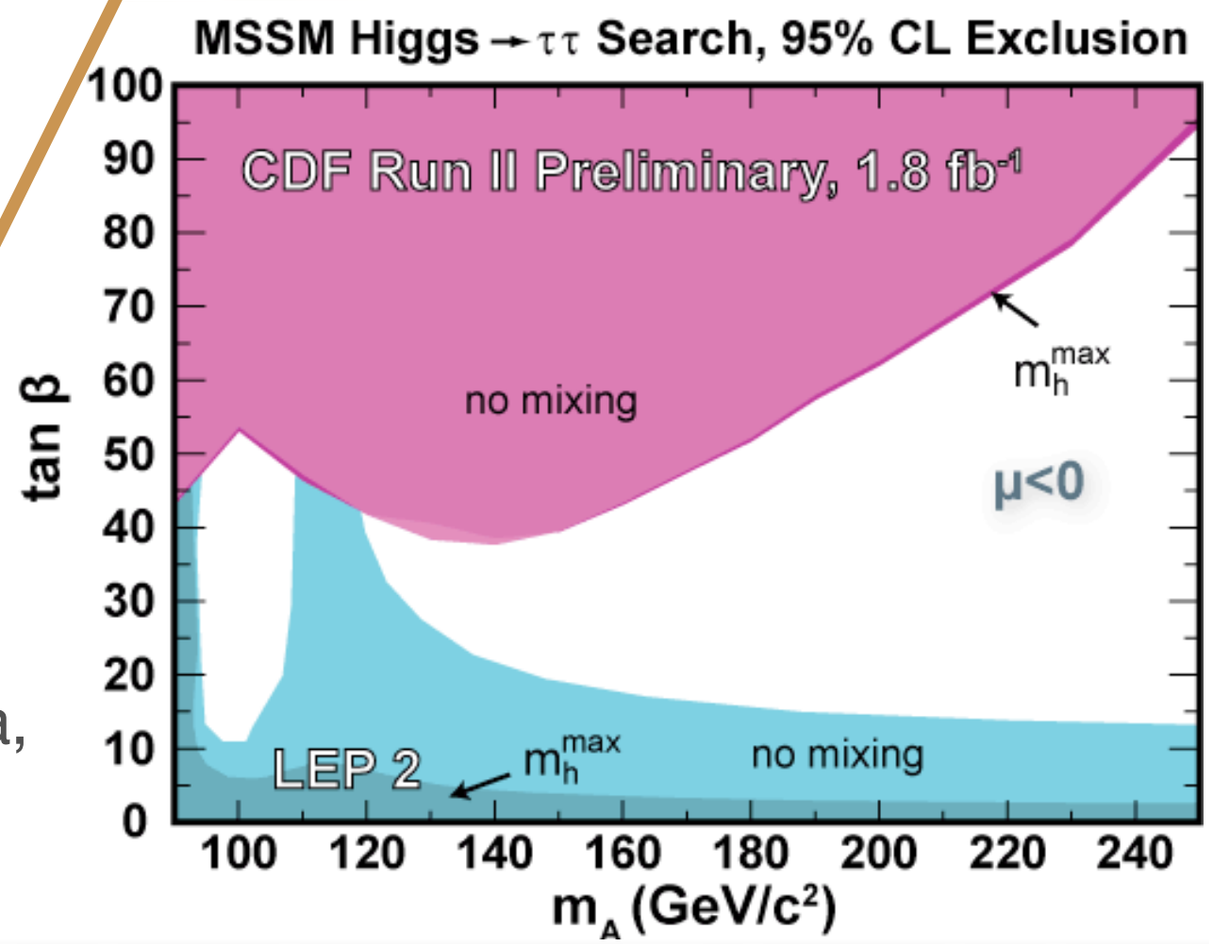


$b\bar{b} \to \phi \to b\bar{b}b(\bar{b})$ & $gg/b\bar{b} \to \phi \to \tau^+\tau^-$



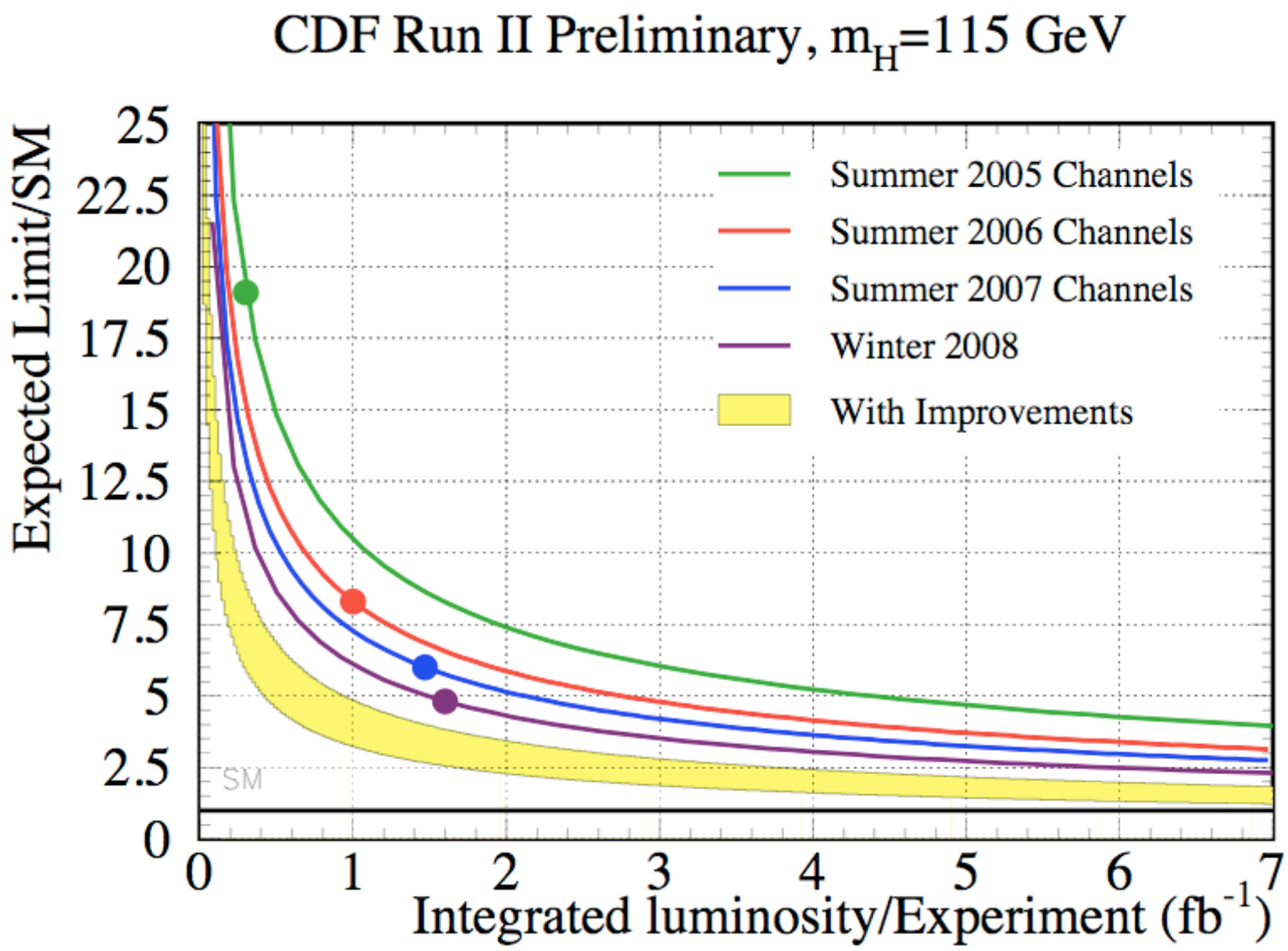
- $b\bar{b} \to \phi$+bjets production only:
  need extra b-jets in the event
- Selection
  - 3 tagged b-jets
- QCD backgrounds estimated from data
- Bg and signal templates fitted to data

- Both production mechanisms
- Selection
  - 1 leptonic tau (e or mu)
  - 1 hadronic or leptonic tau
- QCD background estimated from data, EWK with MC
- Bg and signal templates fitted to data



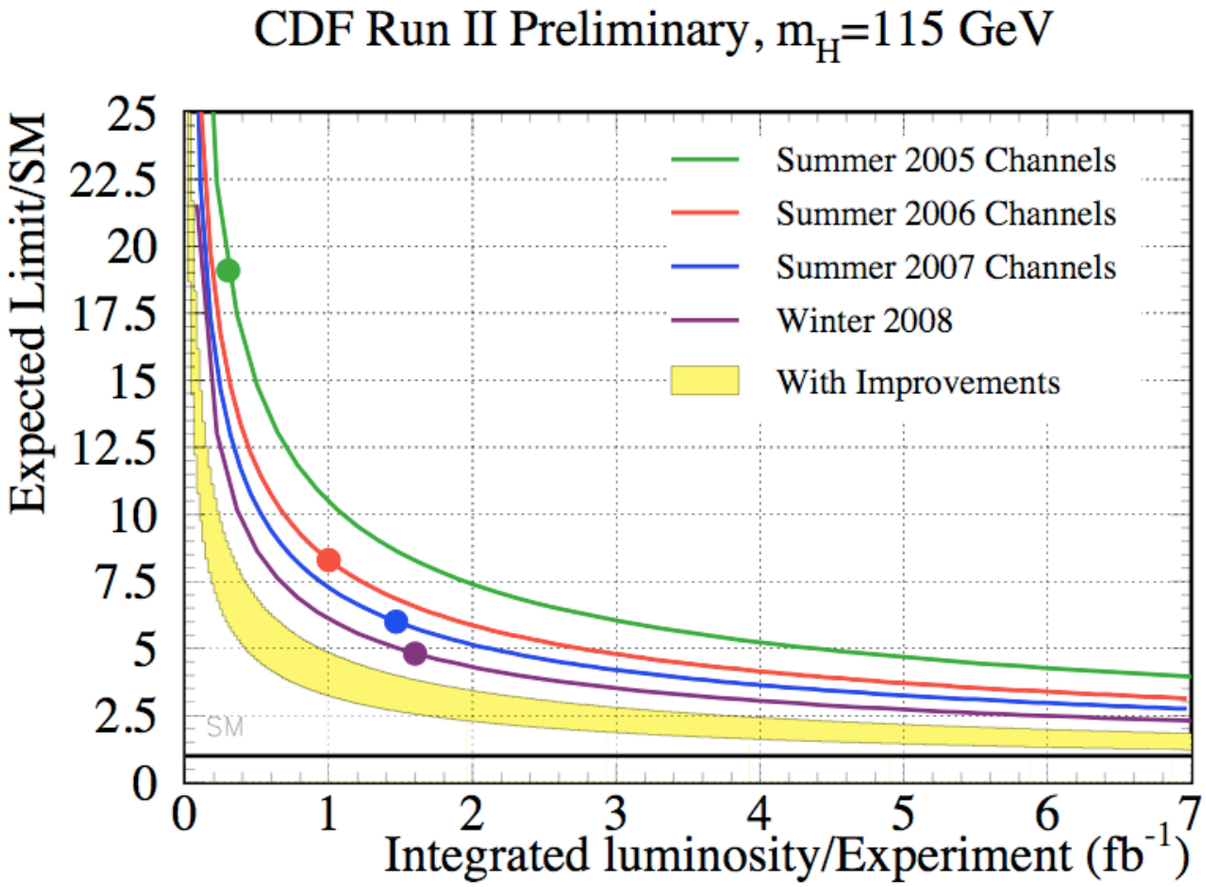
Conclusions

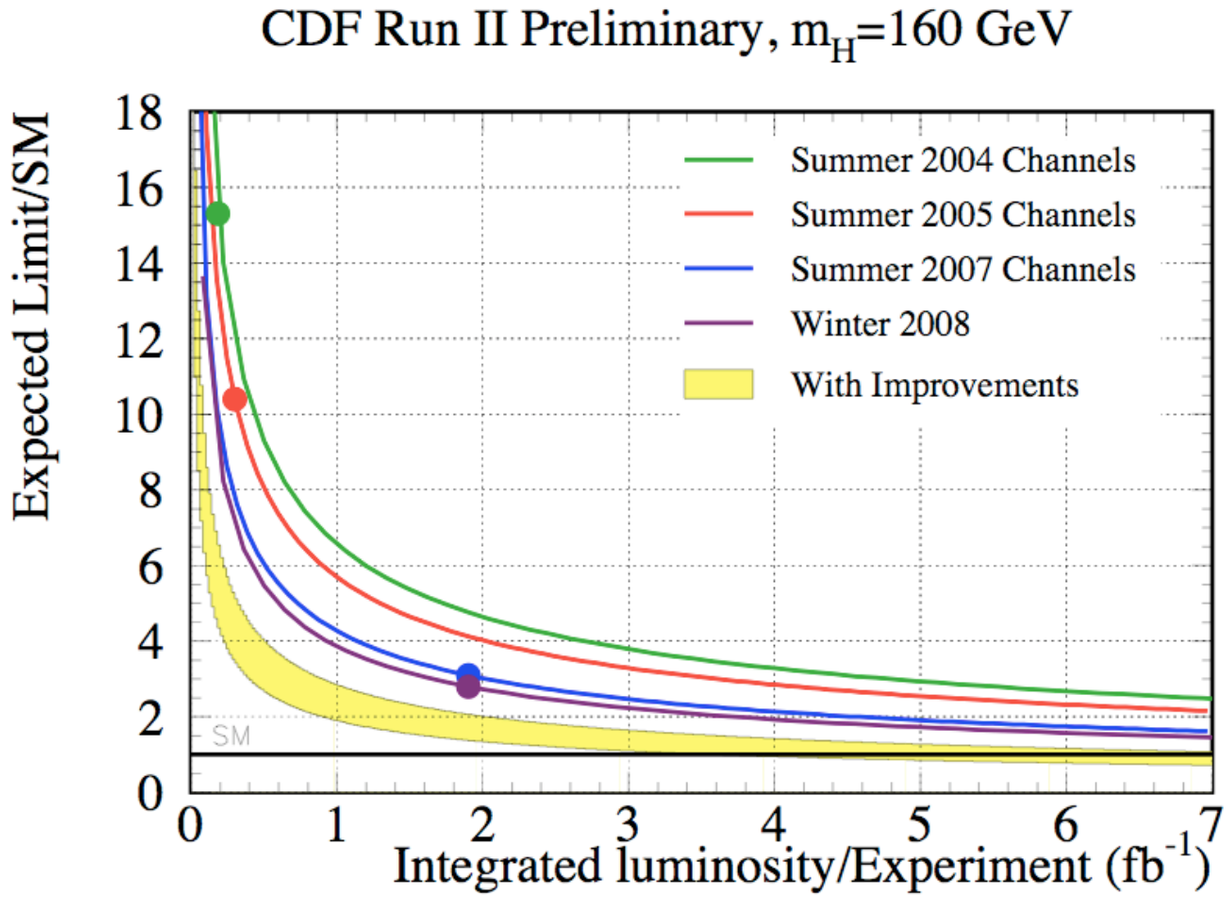
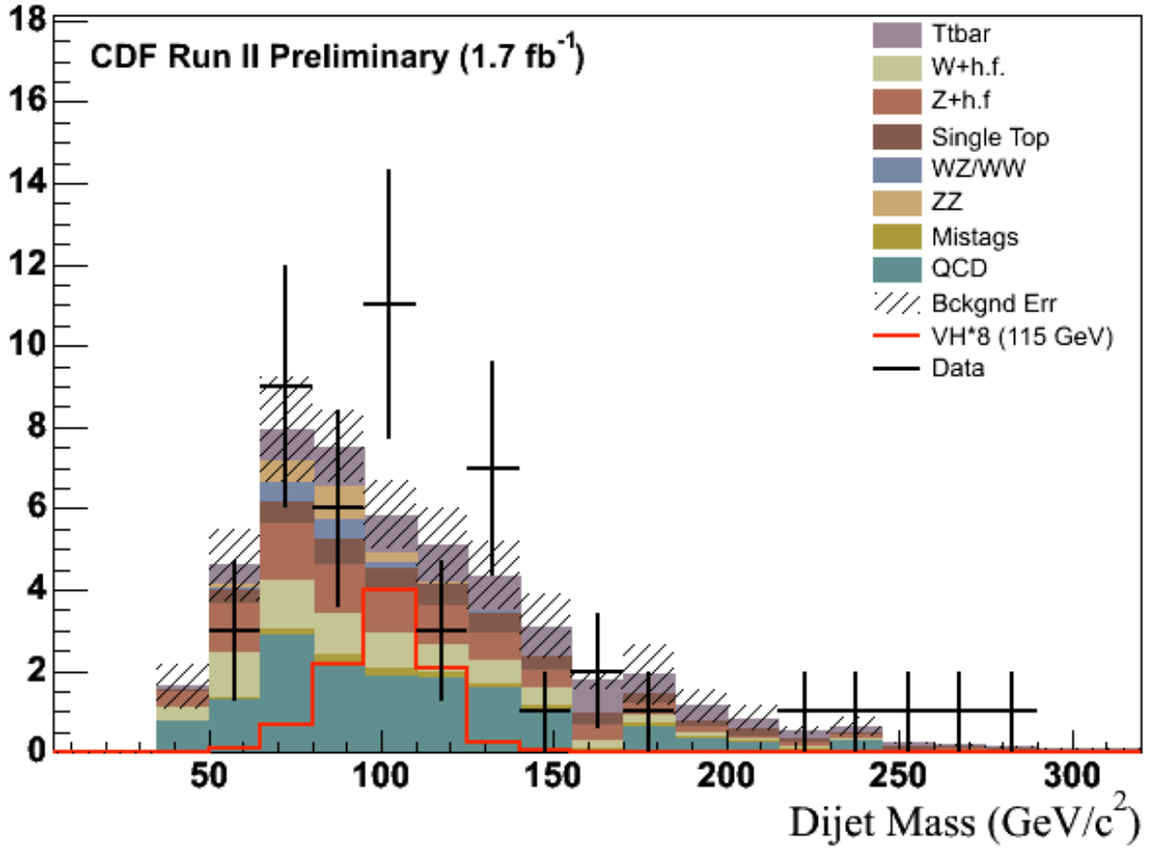
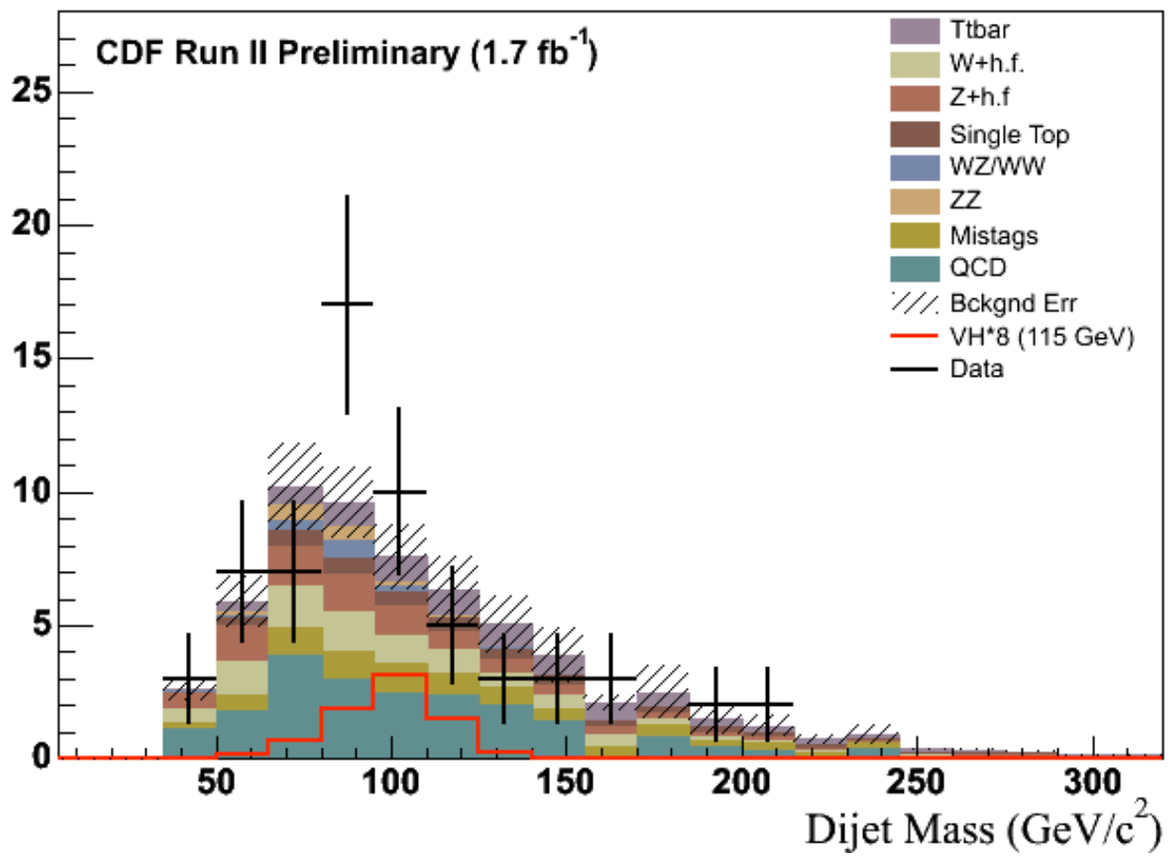
- **New results** with up to ~**2 fb^{-1}**. One more fb^{-1} already on tape!
- **No evidence** for signal found yet
- Current 95% CL **exclusion limits** on SM Higgs production
  - **5 times** SM Higgs σ at low mass
  - **2 times** at high mass
- Very **active Higgs program** @ **CDF**
  - **Advanced techniques** (NN, ME) provided improvements. Still room for more upgrades
  - **Increased sensitivity** with larger lepton acceptances.
- **More results coming soon!!!**



Backup

Higgs sensitivity improvements





Dijet mass, NN input, ZH → ν ν̄ b b̄