Search for Light SM Higgs at Tevatron

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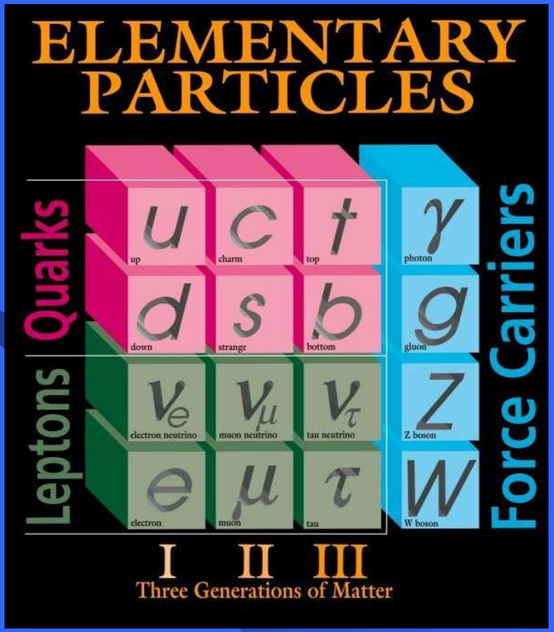
OutLine

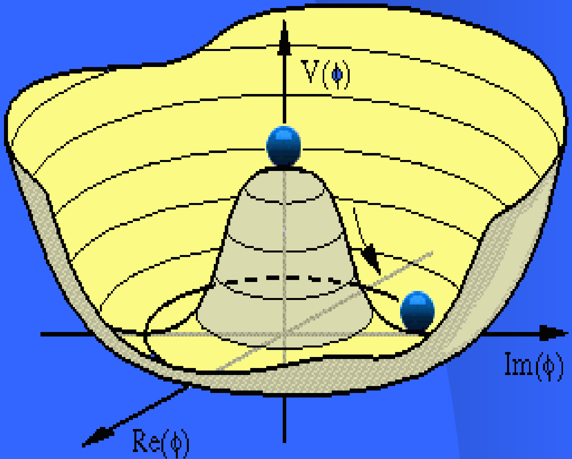
- Introduction
- SM Higgs Search Strategies and Challenges
- SM Results with up to $1.9fb^{-1}$
- Future Prospects
- Conclusion

Introduction

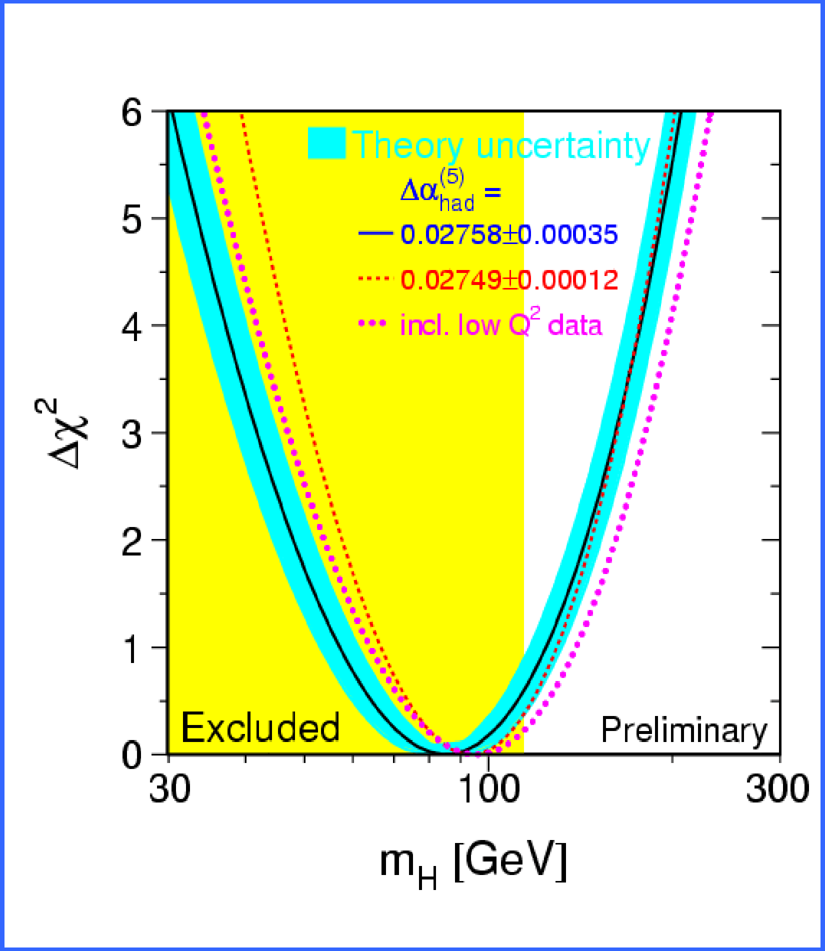
- The Standard Model describes nature well in terms of fundamental particles, but provides no explanation about the origin of masses.

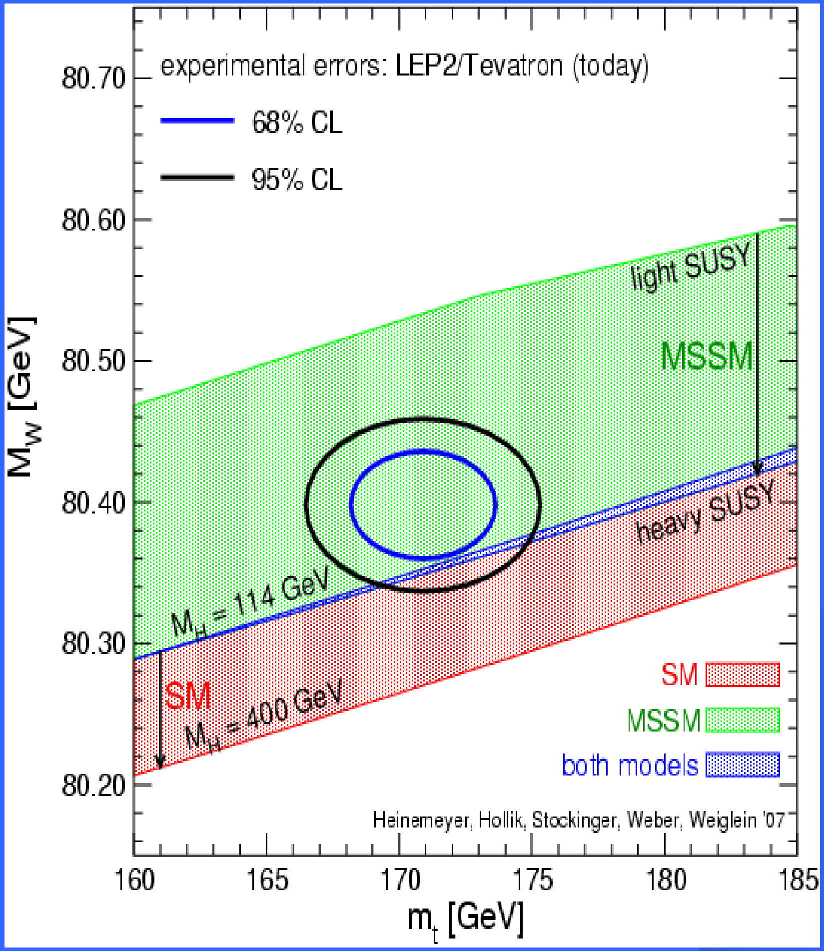


- The Higgs mechanism provides for EWSB and predicts the existence of Higgs boson, that has yet observed experimentally.
- Once the Higgs discovered there must be new physics to stabilize the Higgs boson mass, such as SUSY, extra-dimension, Little higgs …



What we know about the Higgs Boson





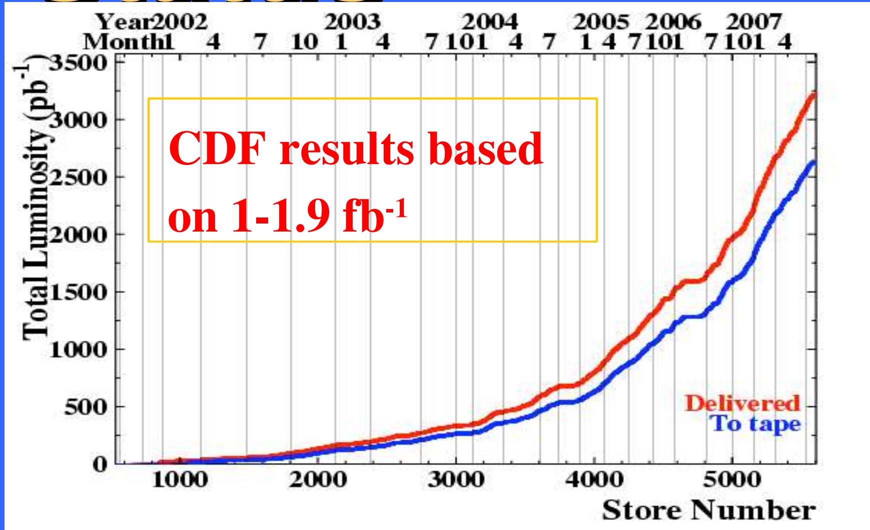
- **Direct Searches at LEP: excludes M_H<114.4 GeV at 95% C.L.**
- **Global fit give best fit of M_H= 76^{+33}_{-24} or <144 GeV at 95% C.L.**
- **The low-mass Higgs will be hard to reach with early LHC data.**

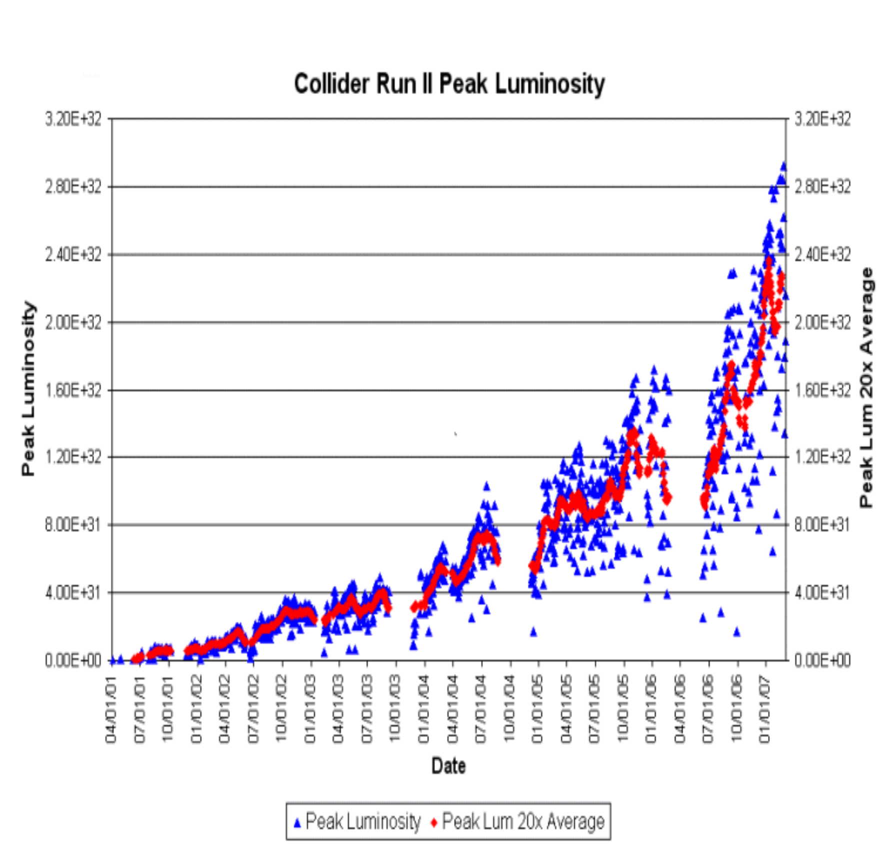
Tevatron Status

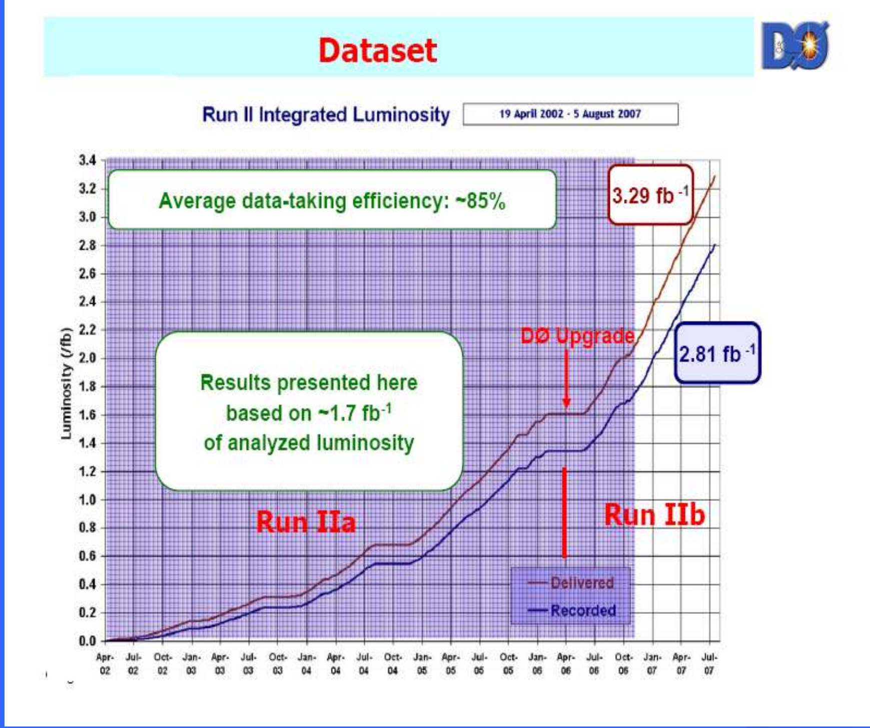
Tevatron has been doing great !

Record luminosity: ***2.90x10^{32}***

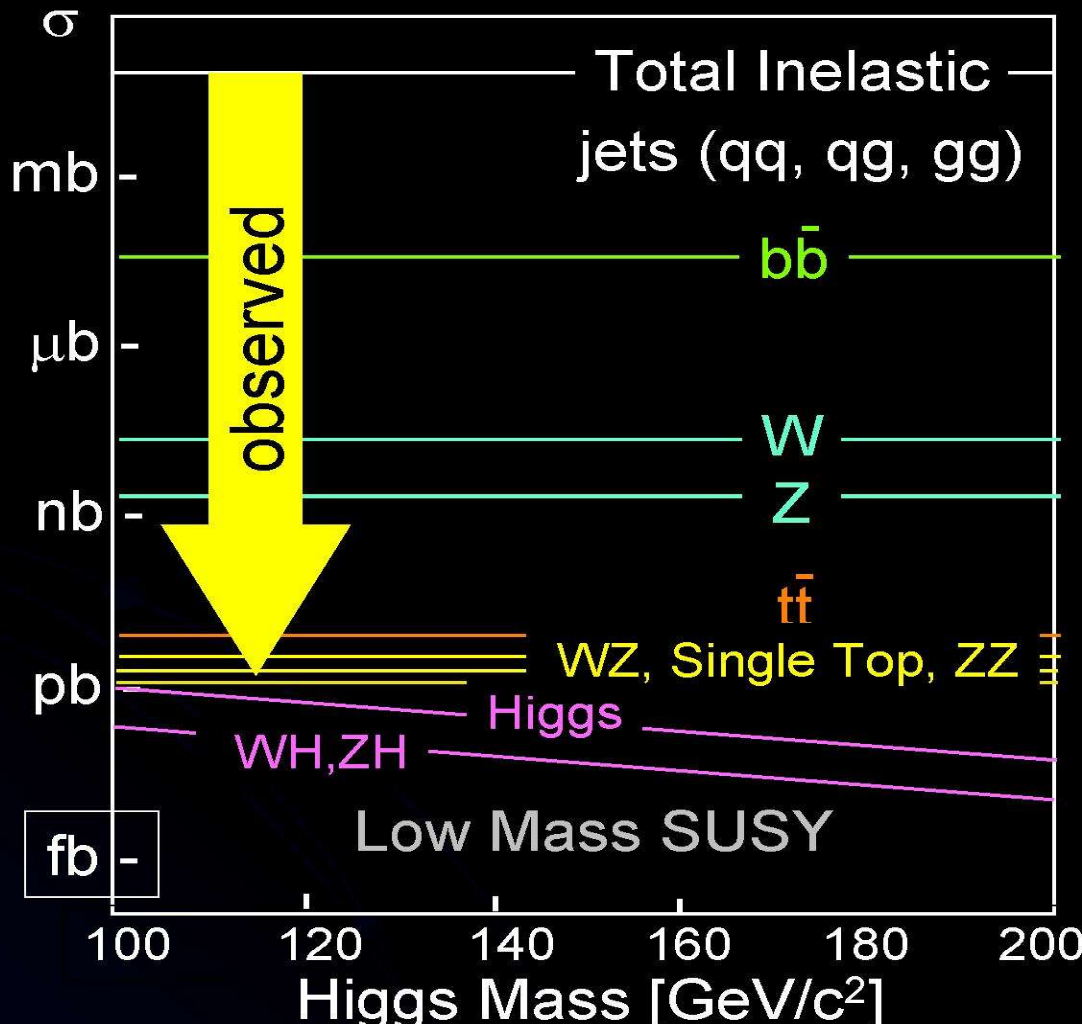
Delivered 3.2 fb^{-1} and 5-8 fb^{-1} by FY09, and more if running 2010







Road to Higgs and Beyond



B_s–B_s Oscillation,
Ξ_b Discovery +
Precision Meas.

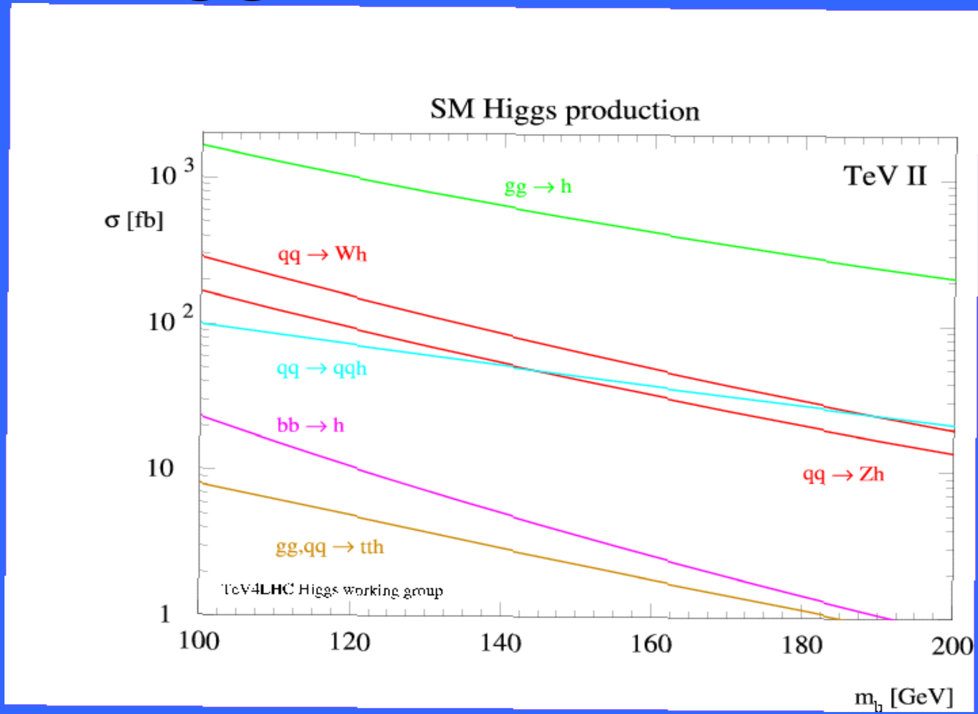
M_W ~0.05%

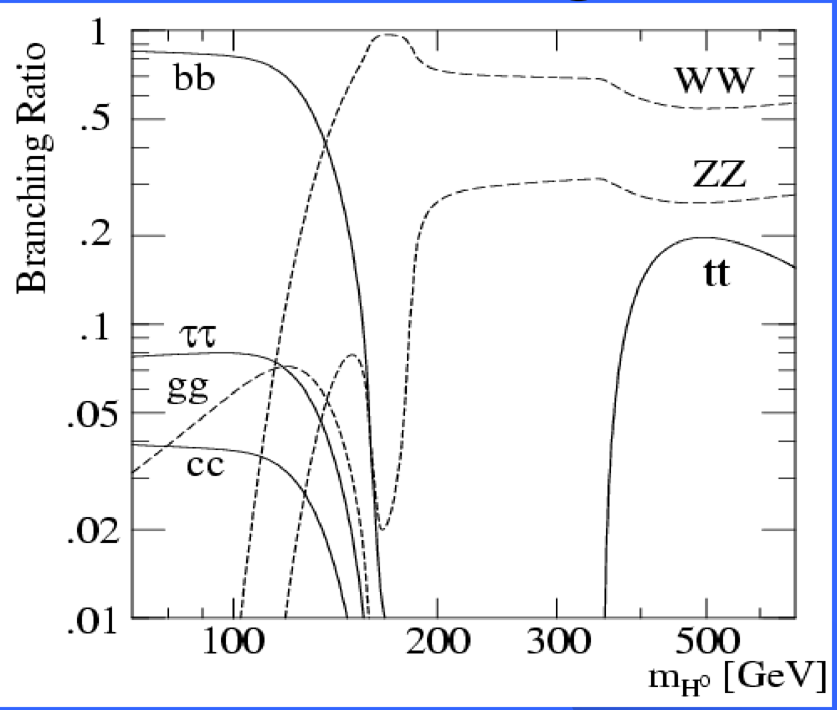
M_{top} ~1.2%

Observed WZ,
Evidence for ZZ
and Single Top

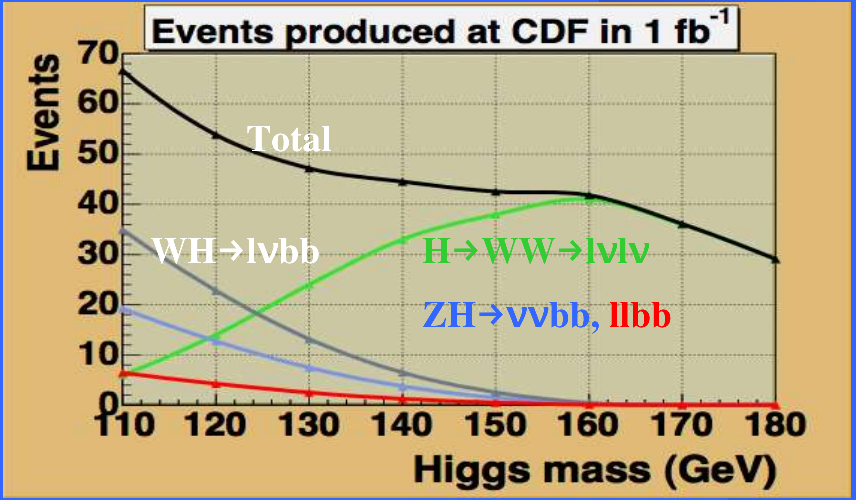
M_{Higgs} < ? GeV
at 95% CL

Higgs Production and Search Strategies

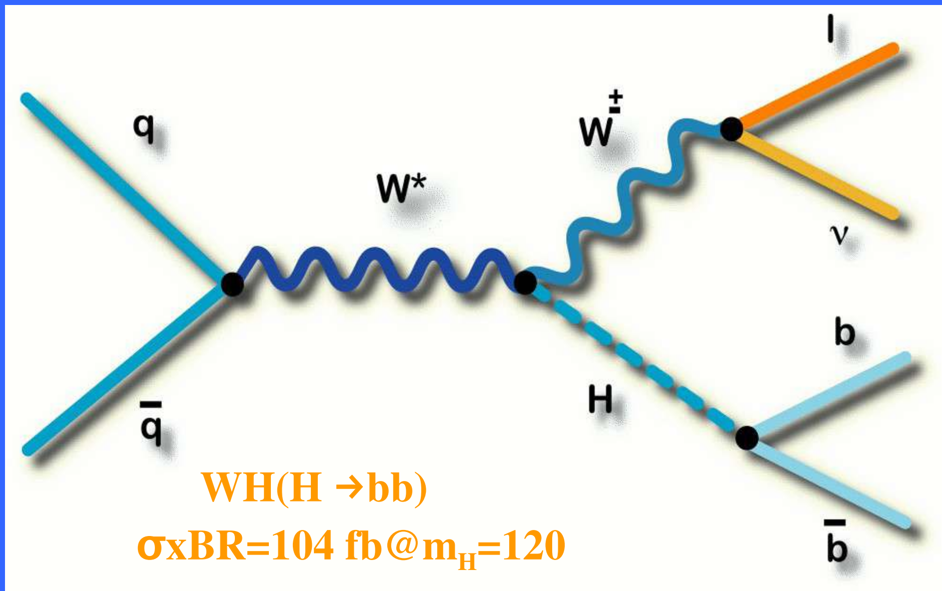


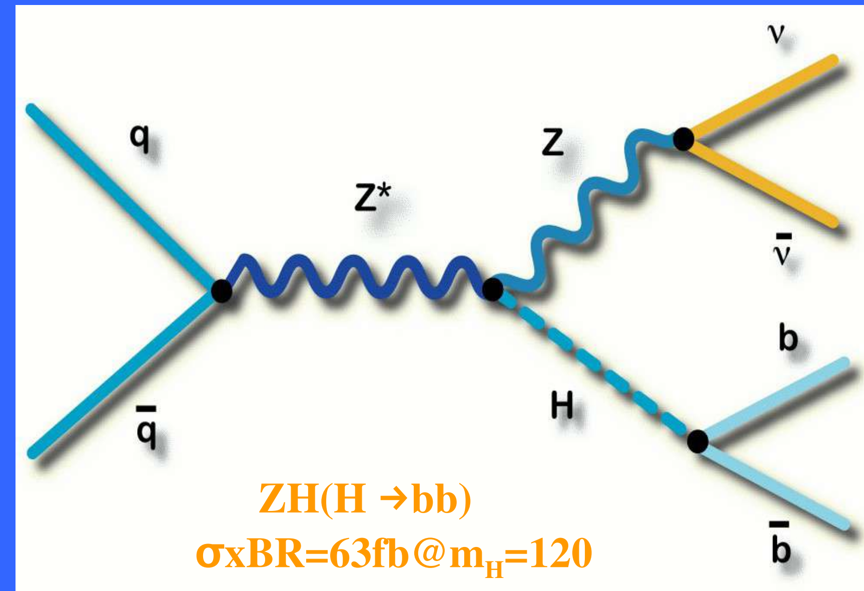


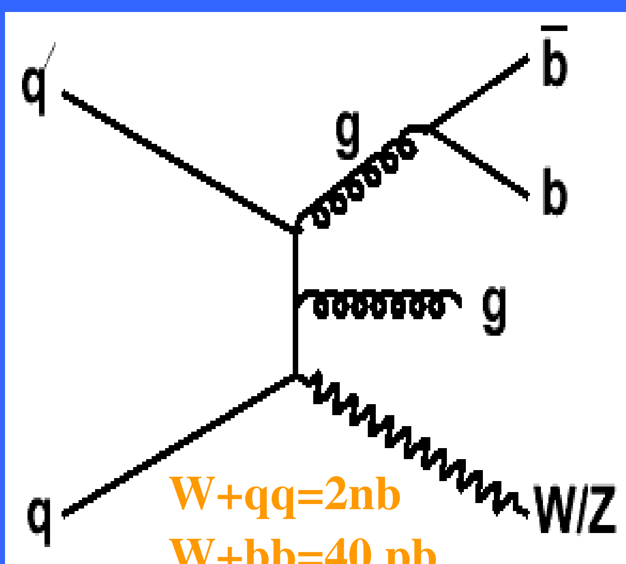
- M_H<135 GeV: H→bb
  - WH, ZH most accessible
  - Excellent b-tag and dijet mass
- M_H>135 GeV: H→WW*
  - See Next Talk

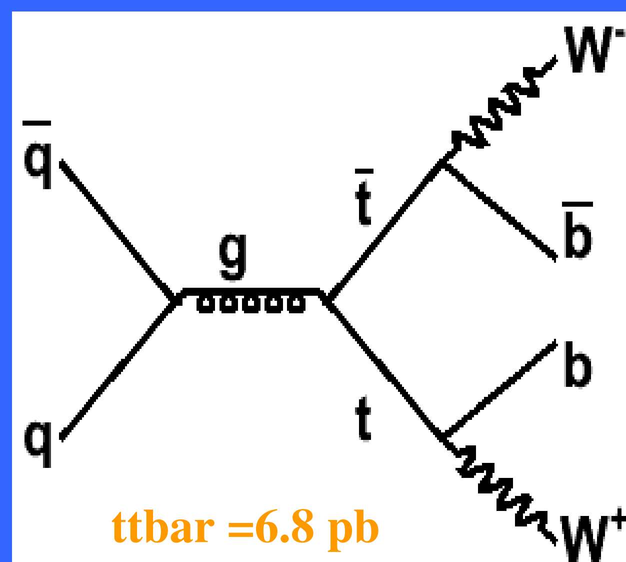


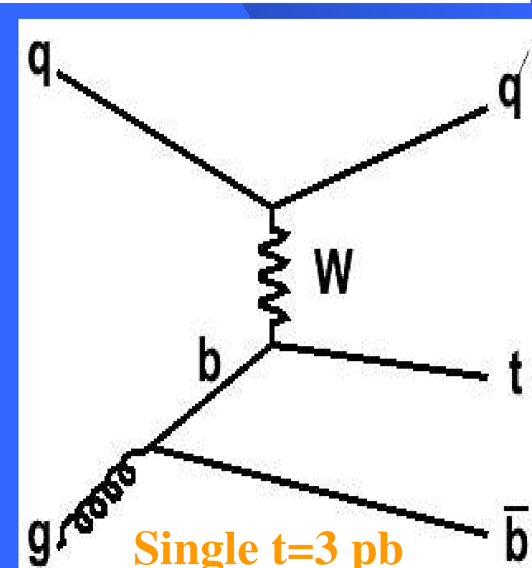
Signal and Background Rates









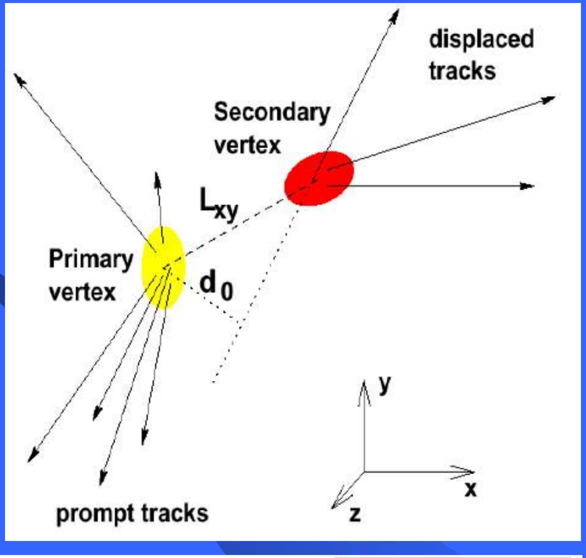


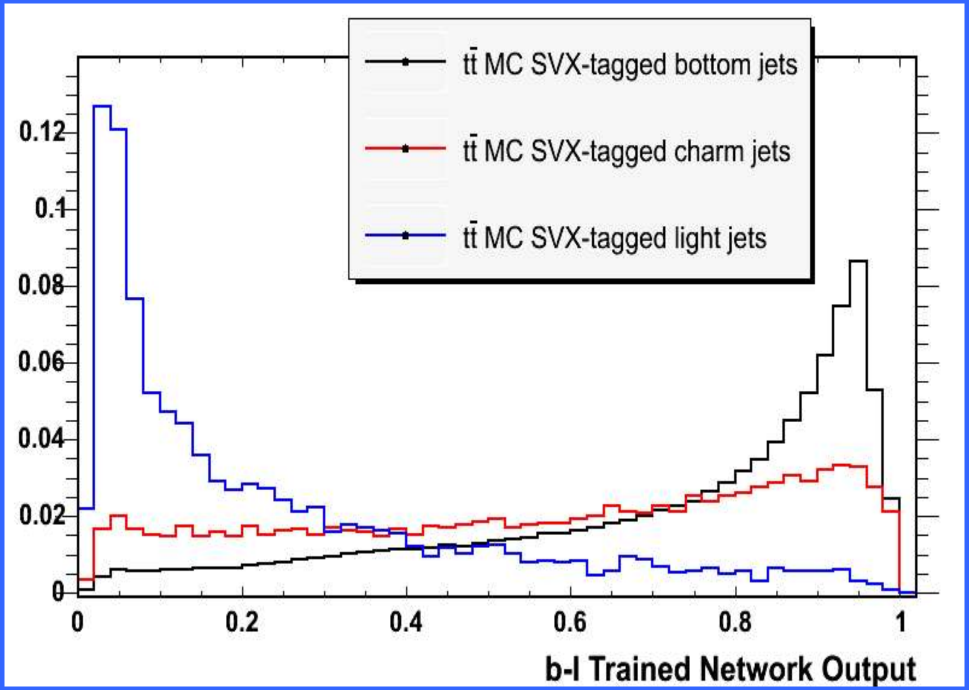
Analysis RoadMap

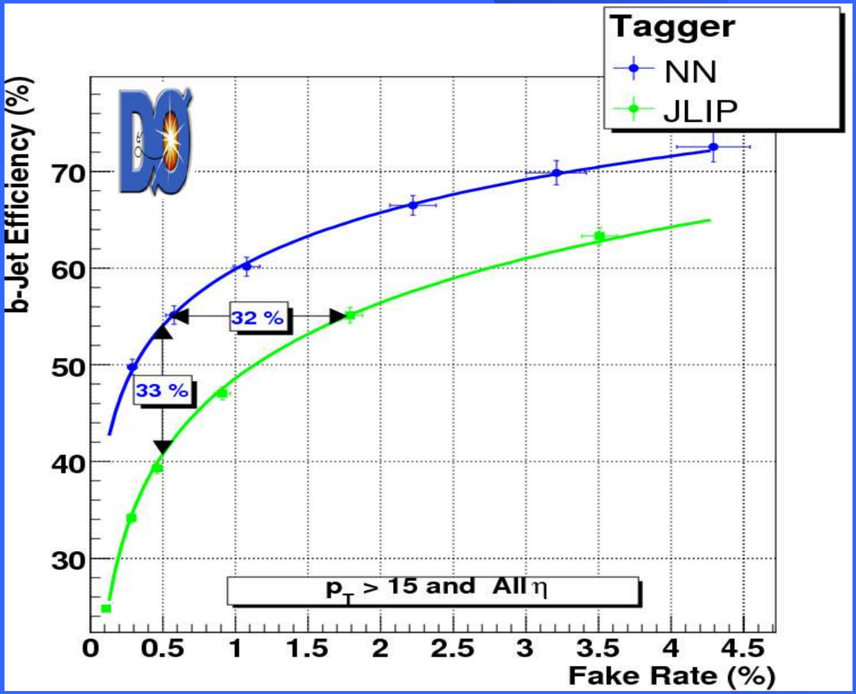
- Search for events consistent with:
  - WH→lνbb, ZH→llbb in Lepton +Jets
  - ZH→ννbb, WH→(ł)νbb in Missing Et +Jets
- Perform careful estimation of backgrounds:
  - W+jets, W+bbbar, W+ccbar, and Wc
  - Top production (single +pair) and Diboson
  - QCD multijet events
- Devise a discriminating variable to increase separation between signal and background (NN, ME) better than using m_{jj} only.
- Perform a likelihood fit to search for signal
- In absence of signal, set 95% limit on $\sigma\times BR$ vs m_H
- Low-mass Higgs is extremely challenge that requires great b tagging, mass resolution , bkgs understanding, and lots of data

B-jet Identificaton (B-tagging)

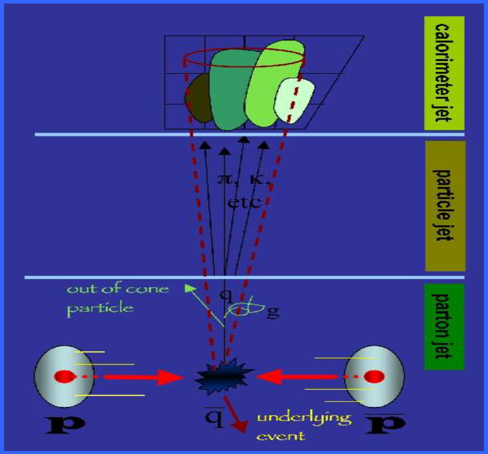
- **B-hadron are long-lived – search for displaced tracks/vertex inside the jet**
- **Combining existing taggers with neural network: to purify mistags or increase btag efficiency**



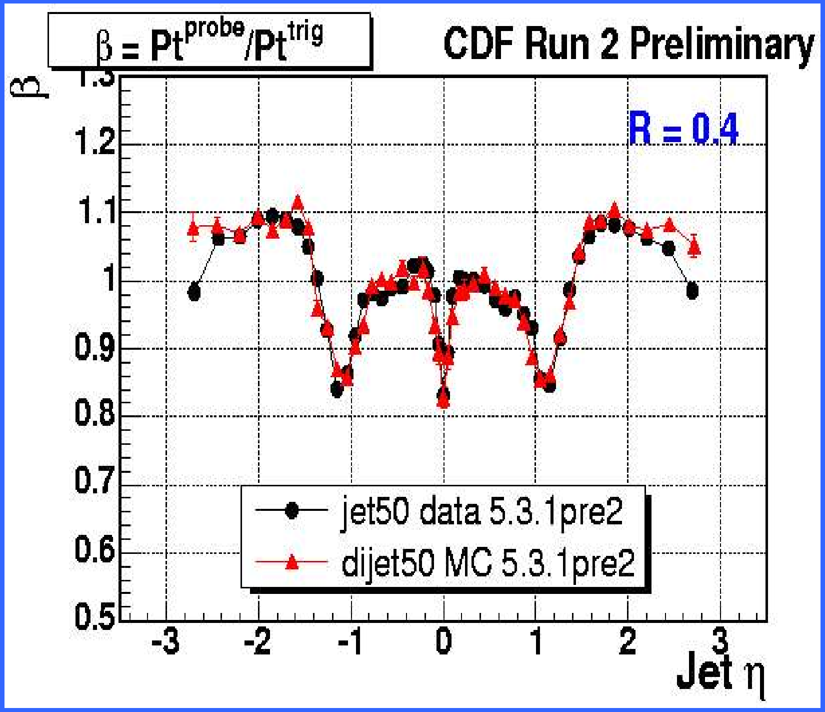


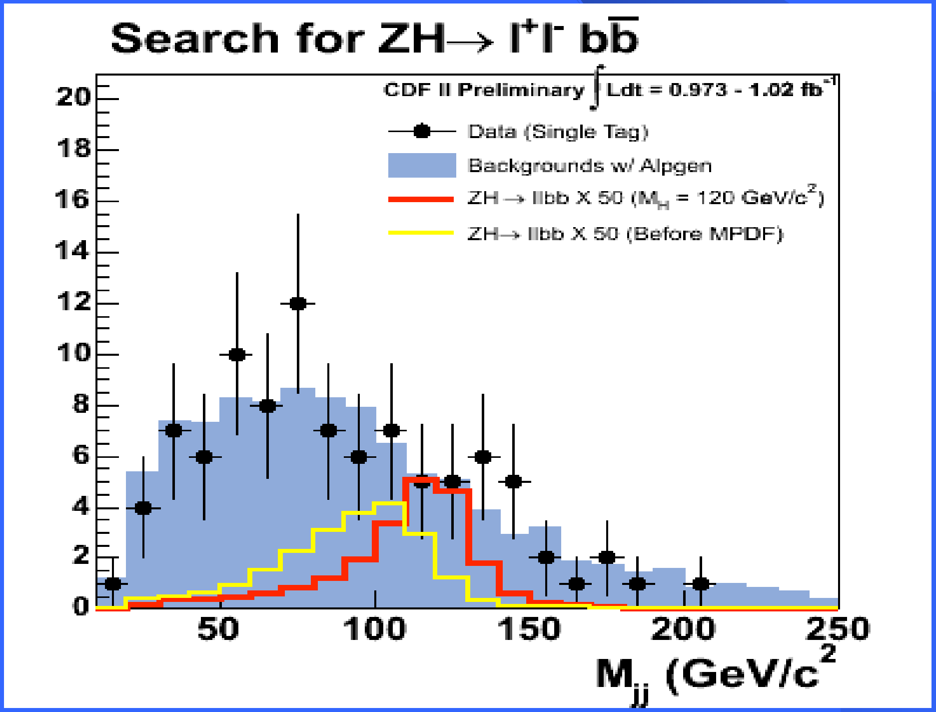


Jet Energy Correction



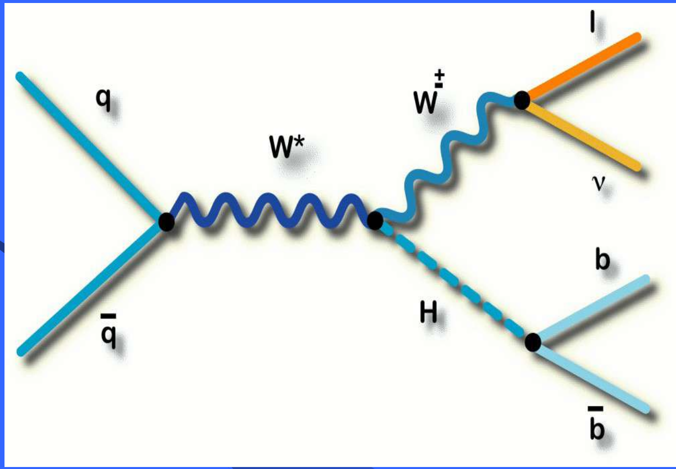
- Jet Et depends on the cal. response to hadrons: energy scale, non-linearity, out-cone, underlying activities.
- Need Calibration with data & improving MC modeling
- Particle flow, b-jet specific correction, and more advanced techniques would help…

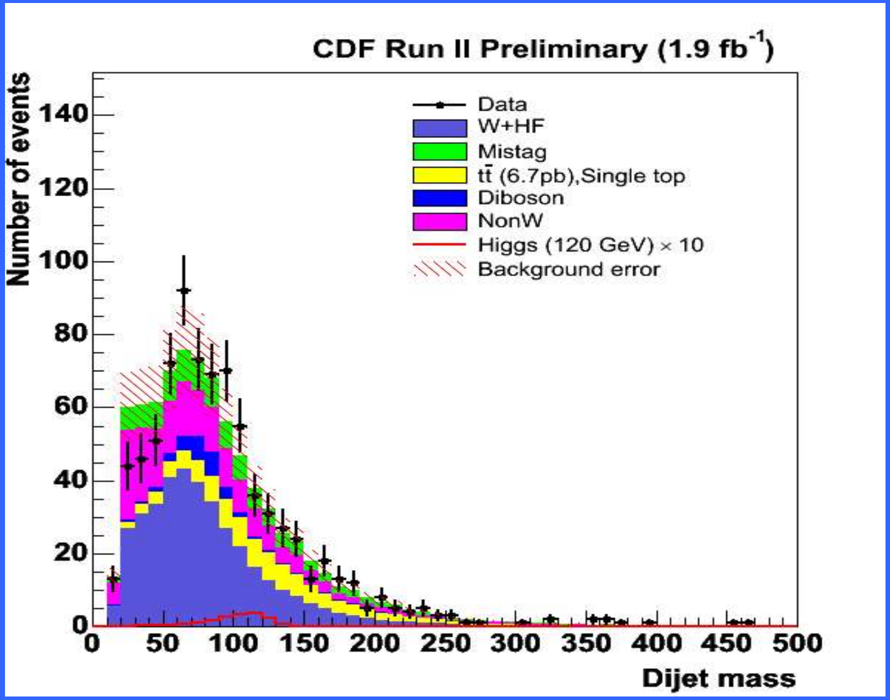


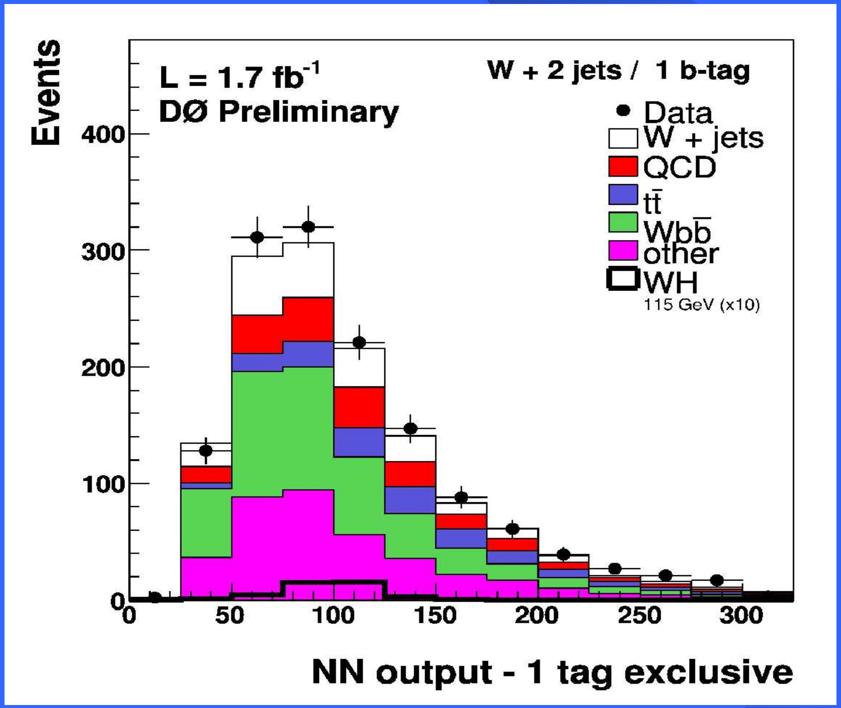


Search for WH→lνbb

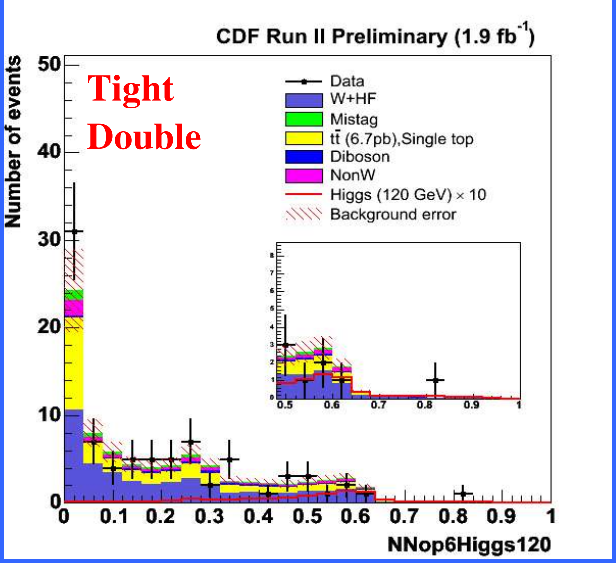
- Starting basic W+2jet selection
- Dividing events with 1 or 2 b-tags
- Data consistent with bkgs expectation
- Combing Mjj and other kinematics with NN to separate signal over bkgs

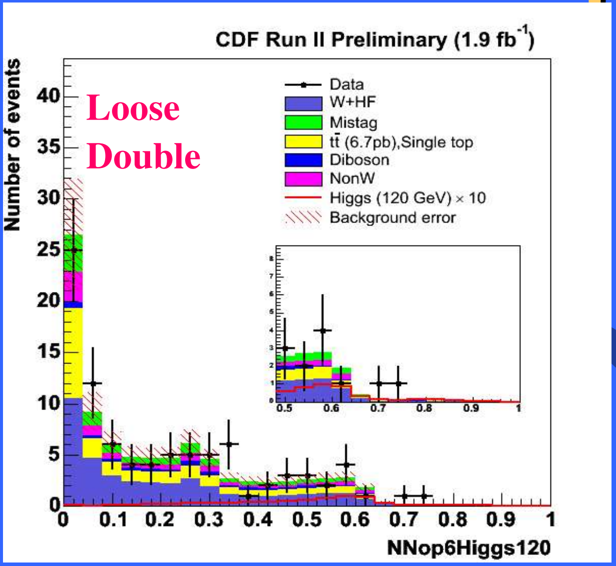


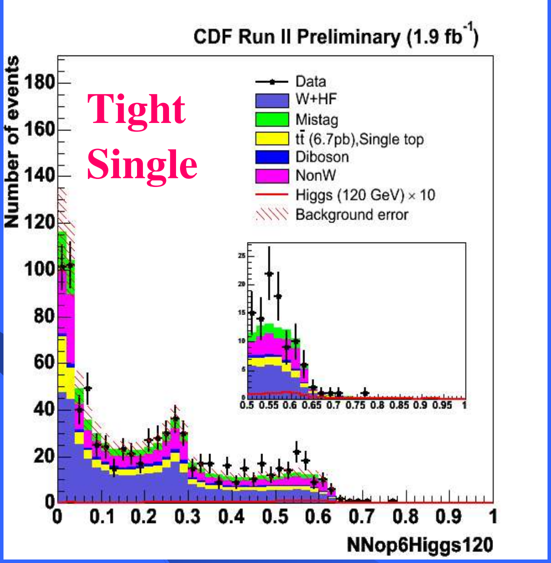


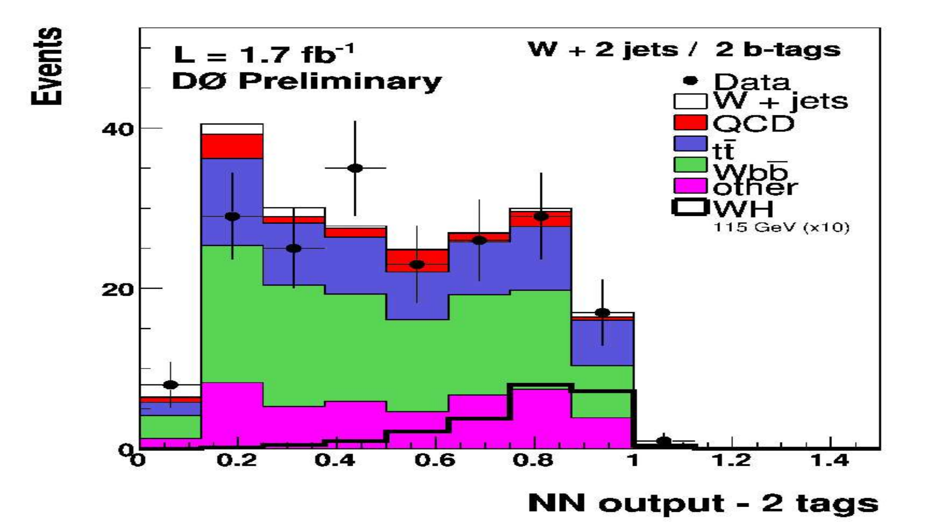


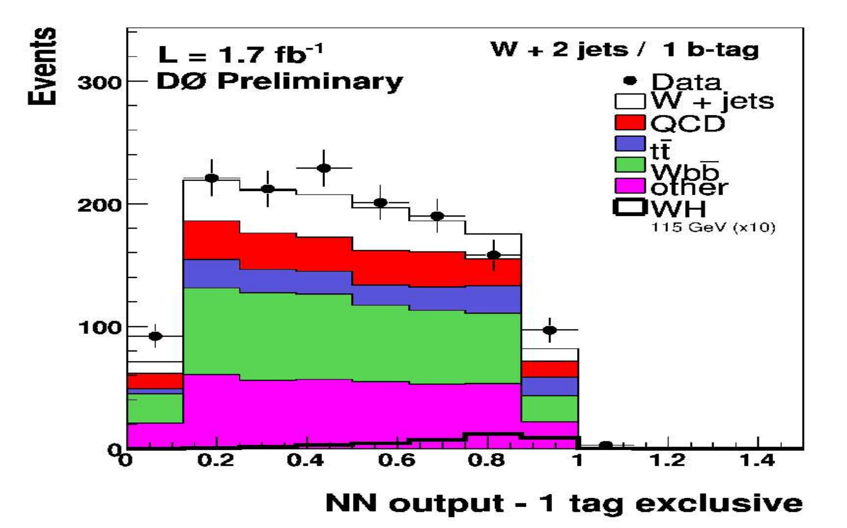
Neural Network Output





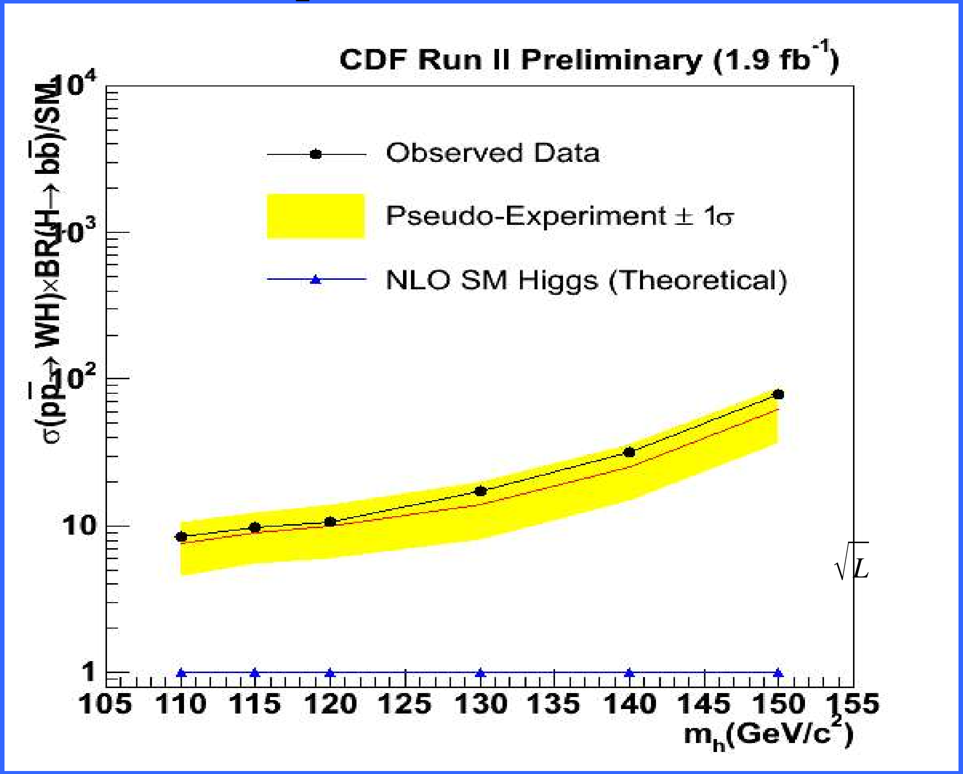


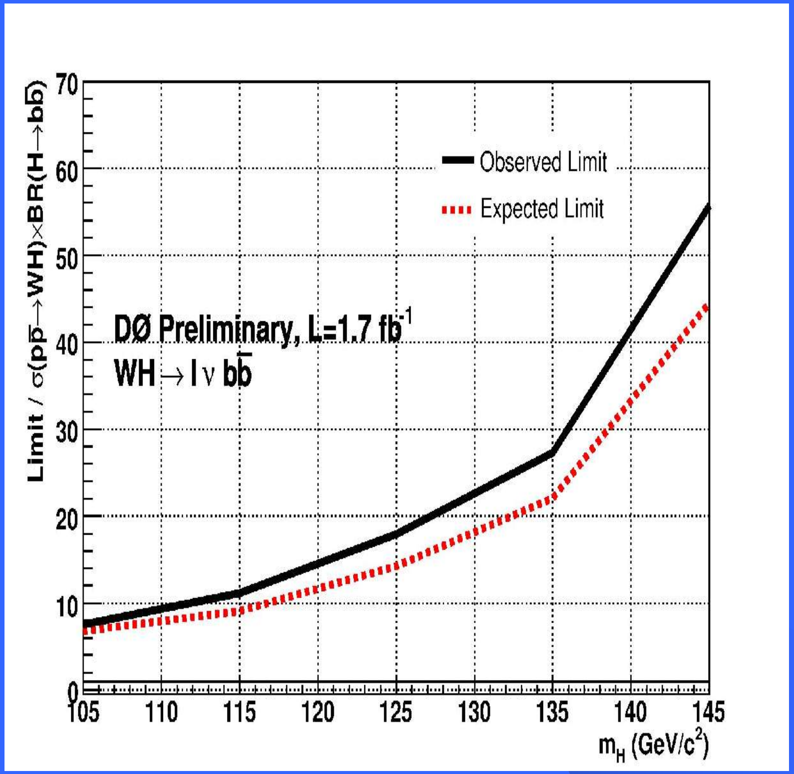




- Improves sensitivity by 10% over dijet mass alone
- Analysis refinement and optimization still ongoing

Expected and Observed Limits

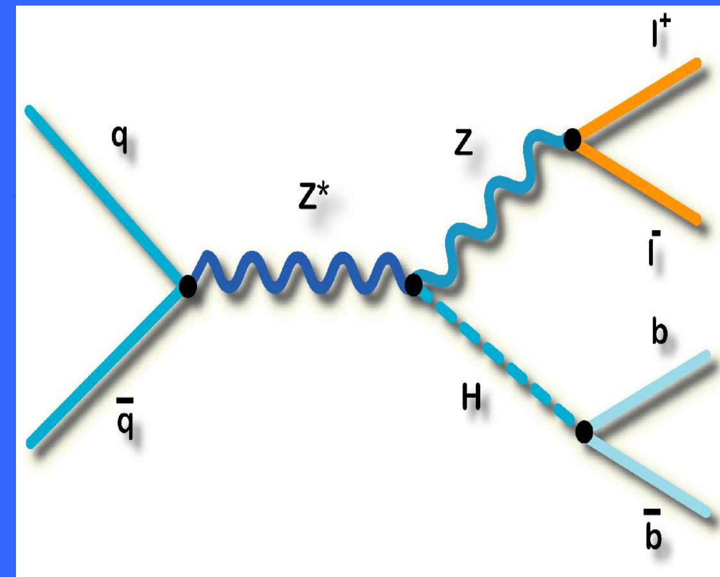


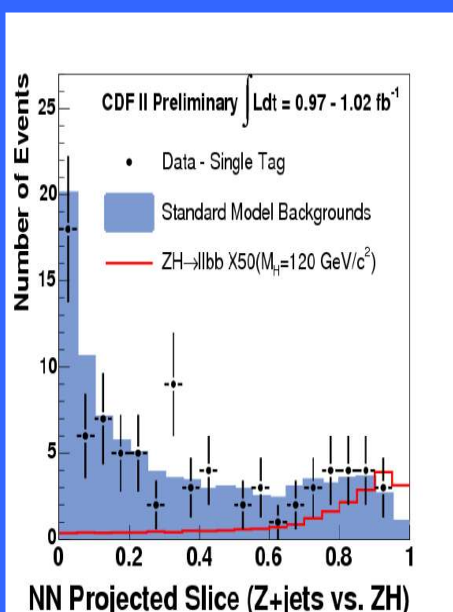


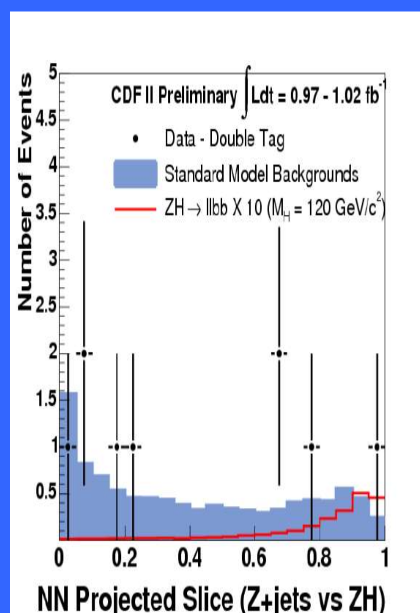
- Both Obs.(Exp.) limits are comparable: 9.7(8.9) for CDF and 11 (9) for D0 times SM at 115 GeV.
- Expected limits improved by 40% over sqrt(L) since summer 06
- Future improvements: extending lepton Id including tau's, btagging, and improving advanced analysis techniques …

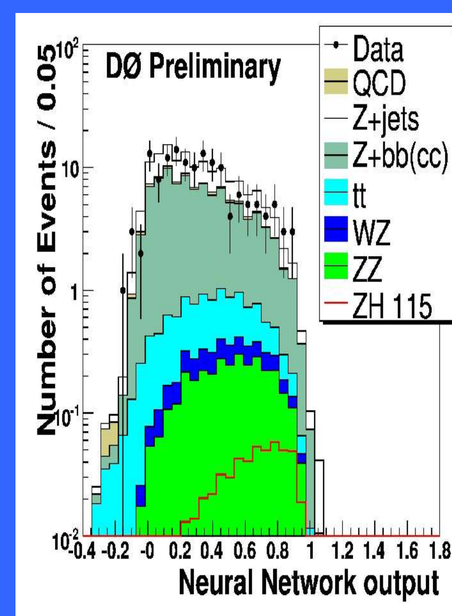
Search for ZH→llbb

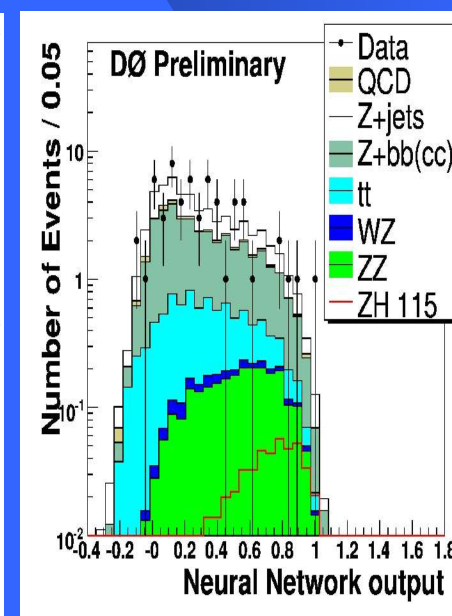
- Low event rate but clean signature
- Select two high Pt leptons from Z
- Z+2 jets with 1 or 2 b-tags
- Improve dijet mass resolution using measured missing Et.
- Neural Network trained to separate ZH from backgrounds.



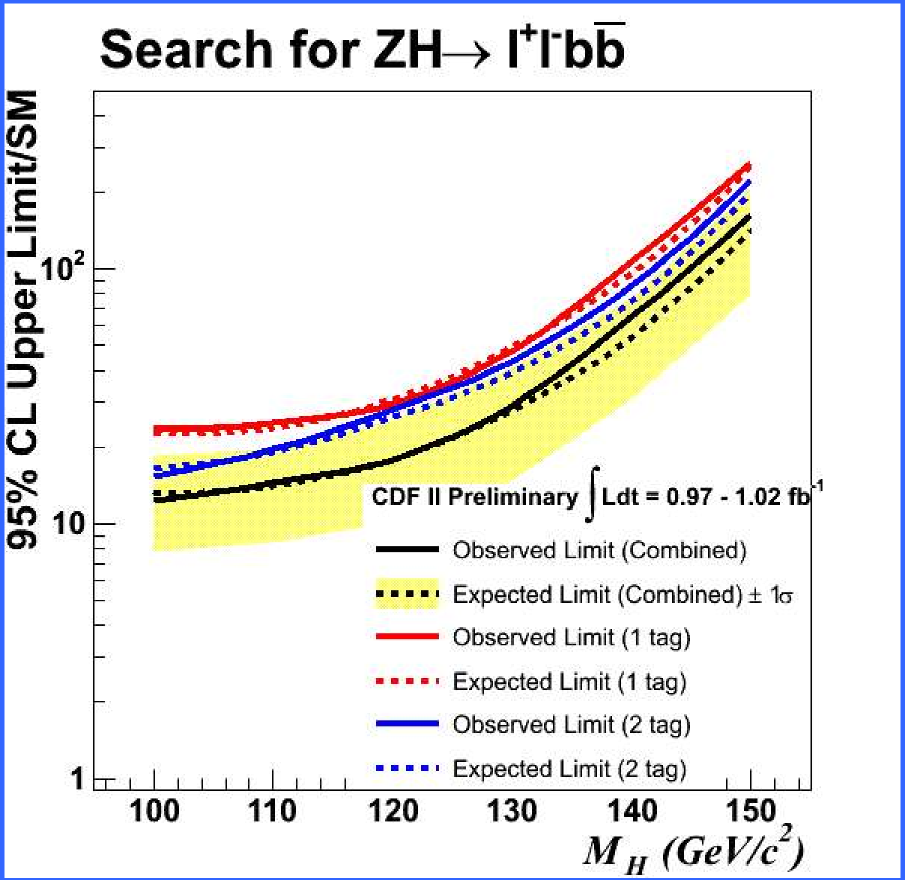


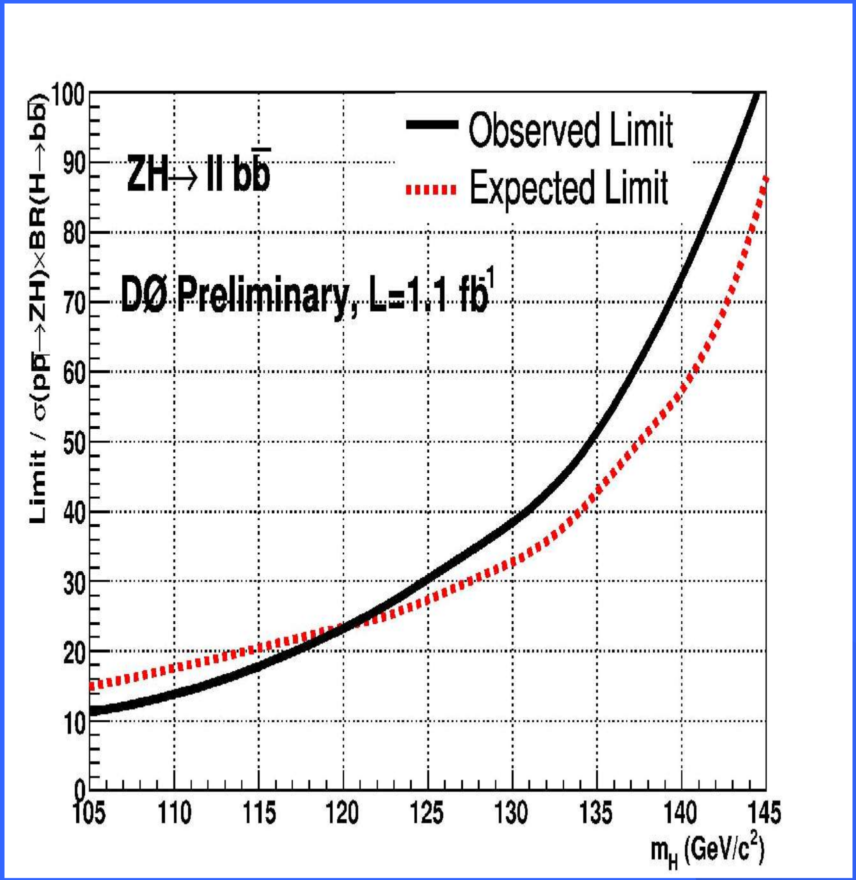






Search for ZH→llbb

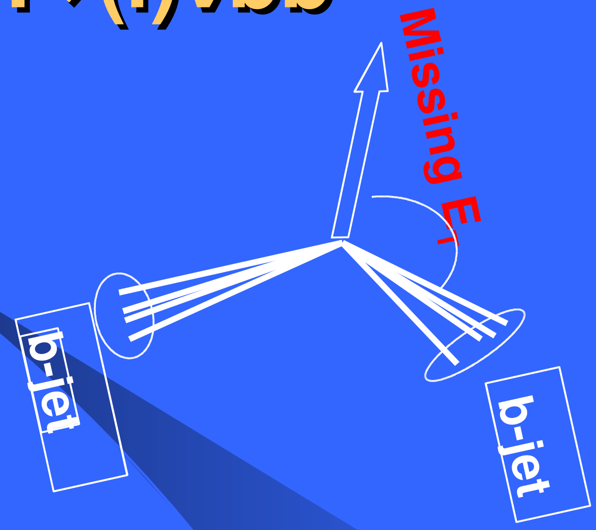


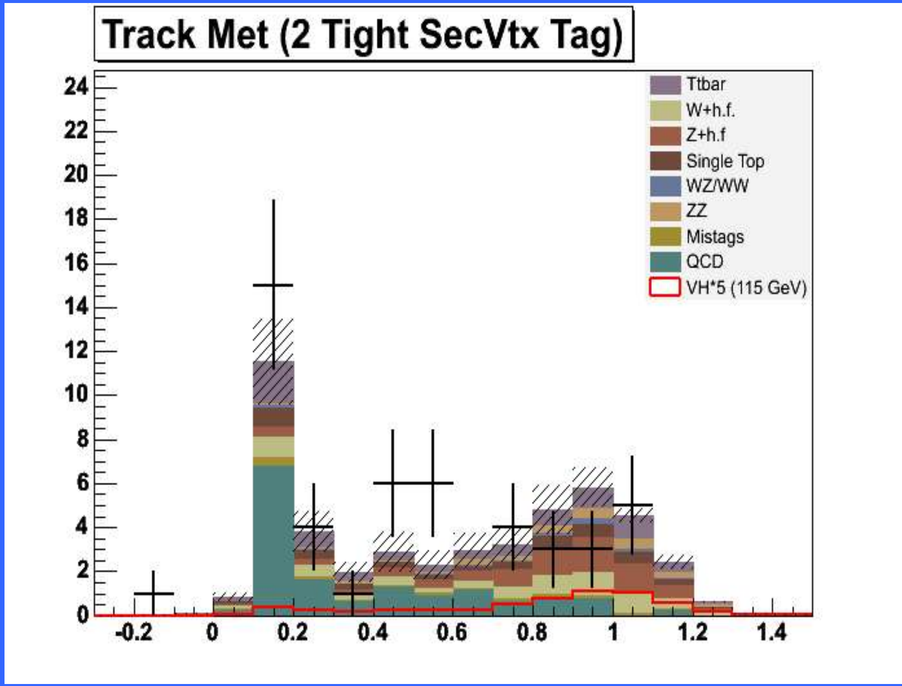


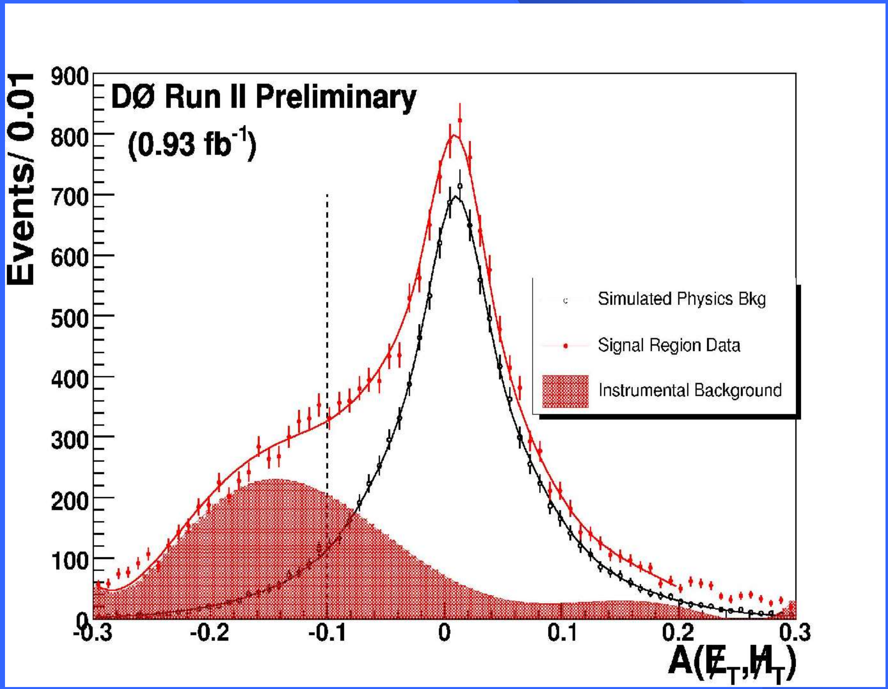
- CDF observed/expected limit is 16/16 x SM @ m_H =115 GeV
- D0 observed/expected limit is 18/20 x SM @ mH =115 GeV
- Future Improvements: update with more data, improving Z selection with loose lepton, optimizing b-tagging, and more …

Search for ZH→ννbb, WH→(ł)νbb

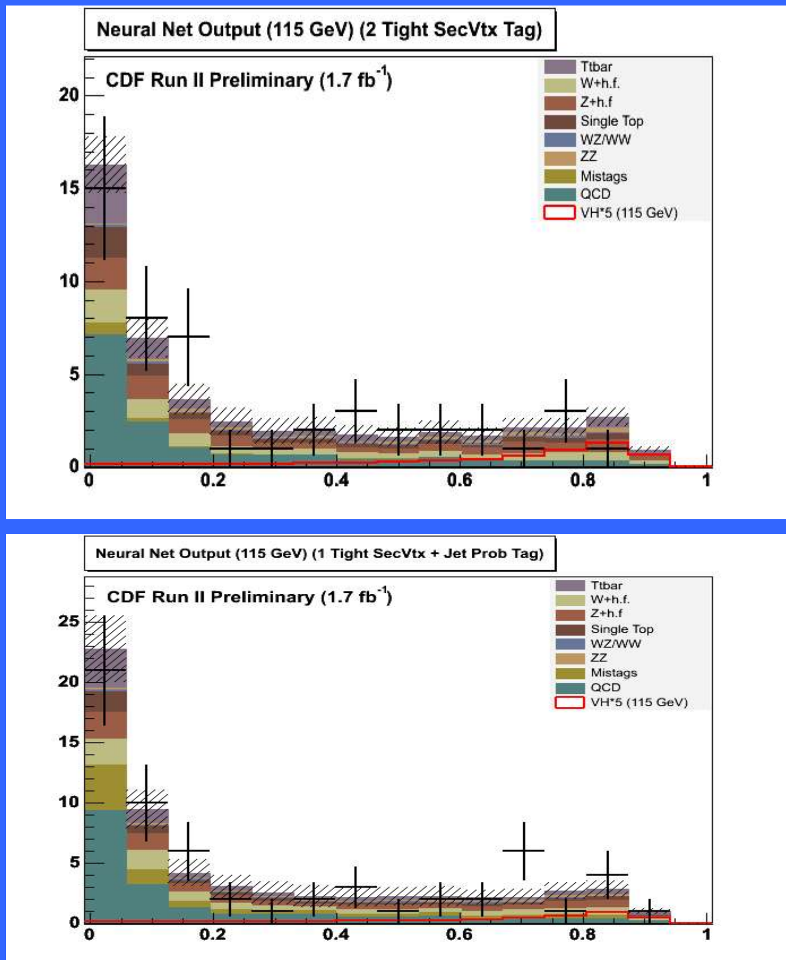
- Rely on large Met>50 GeV +2jet
- dφ(Et1, MET)>0.8
- Requiring 2 b-tags (tight and loose)
- Using a NN based on Track Met or asymmetry between Met and ΣEtjets to reduce instrumental backgrounds

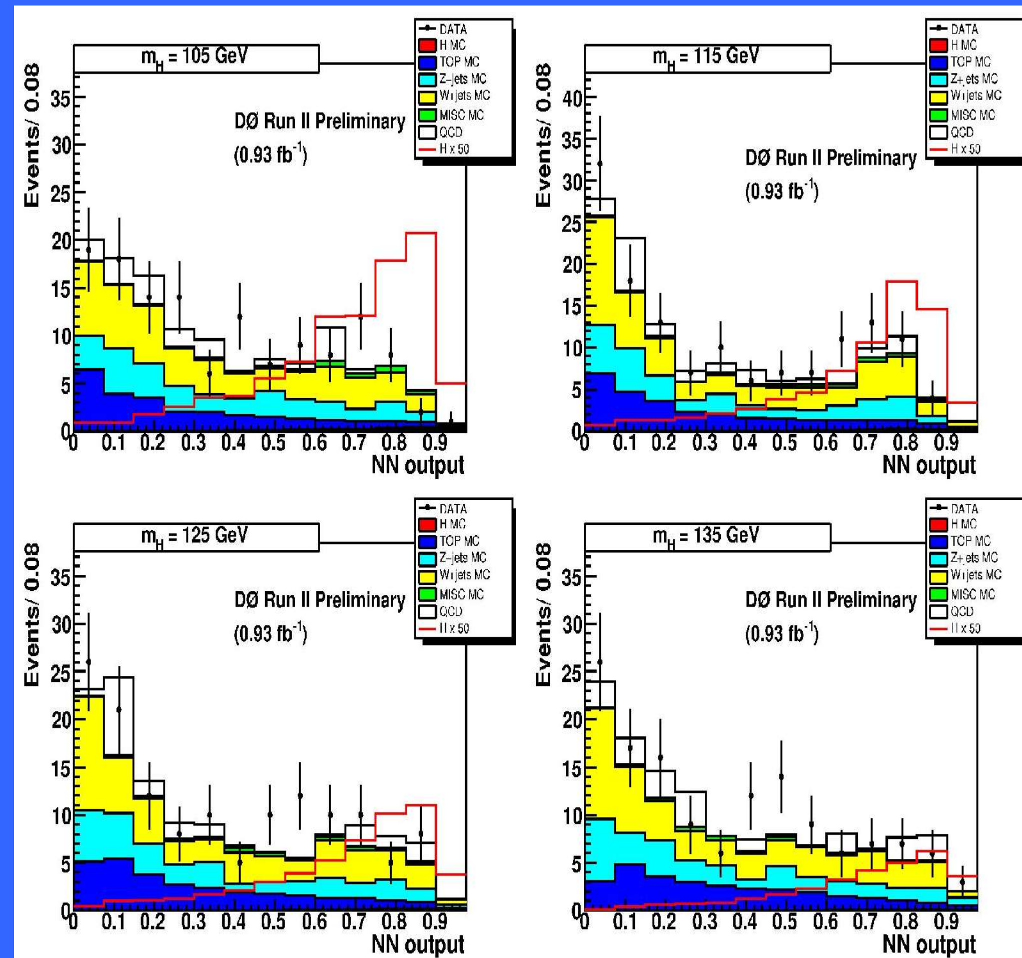






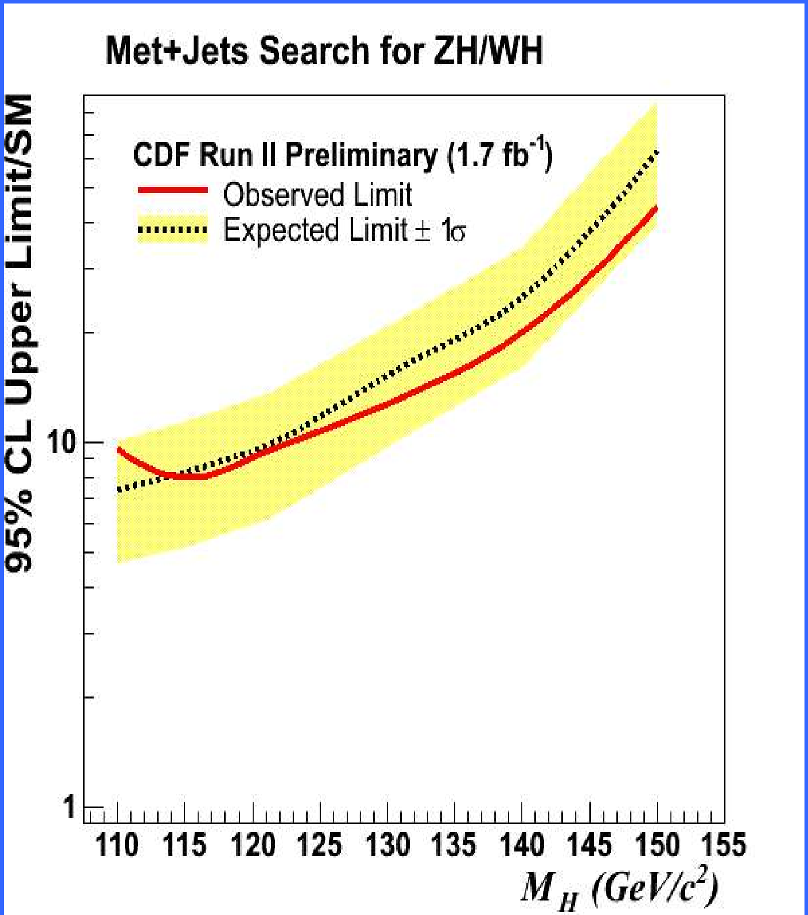
Final NN output for ZH→ννbb, WH→(ł)νbb

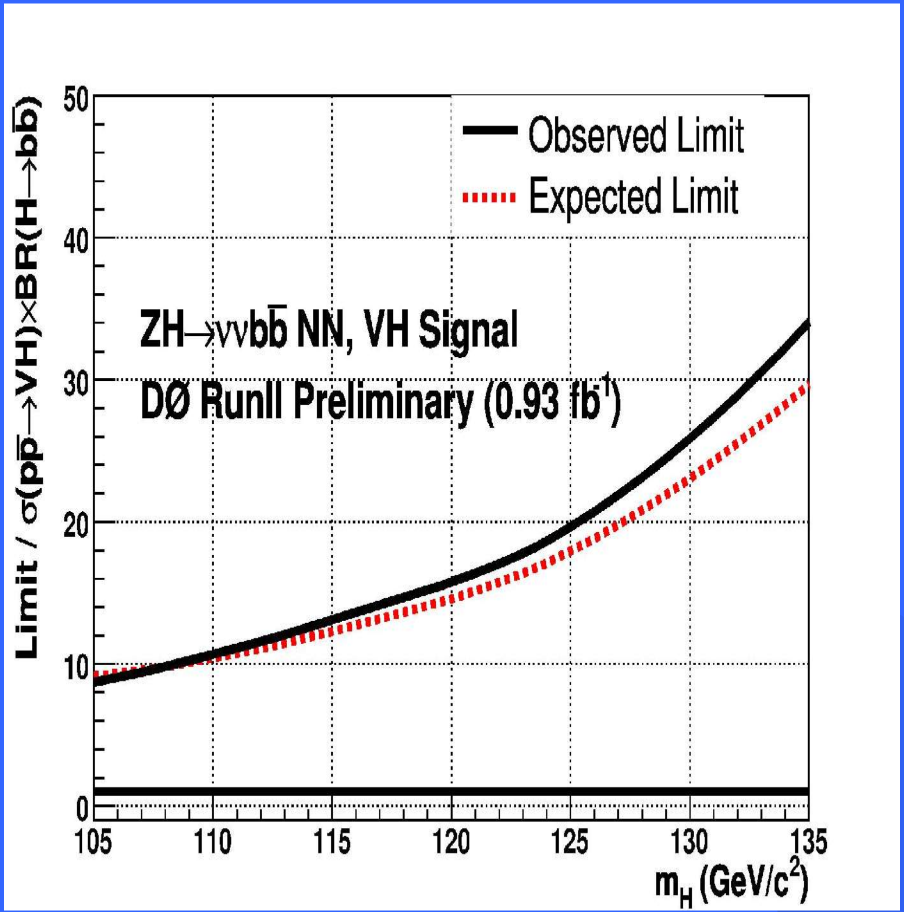




- Combining Mjj, track met, and other kinematic into final NN
- Expected limits improved by 20-30% over the previous analysis using the same data !

Search for ZH→ννbb and WH→(ł)νbb



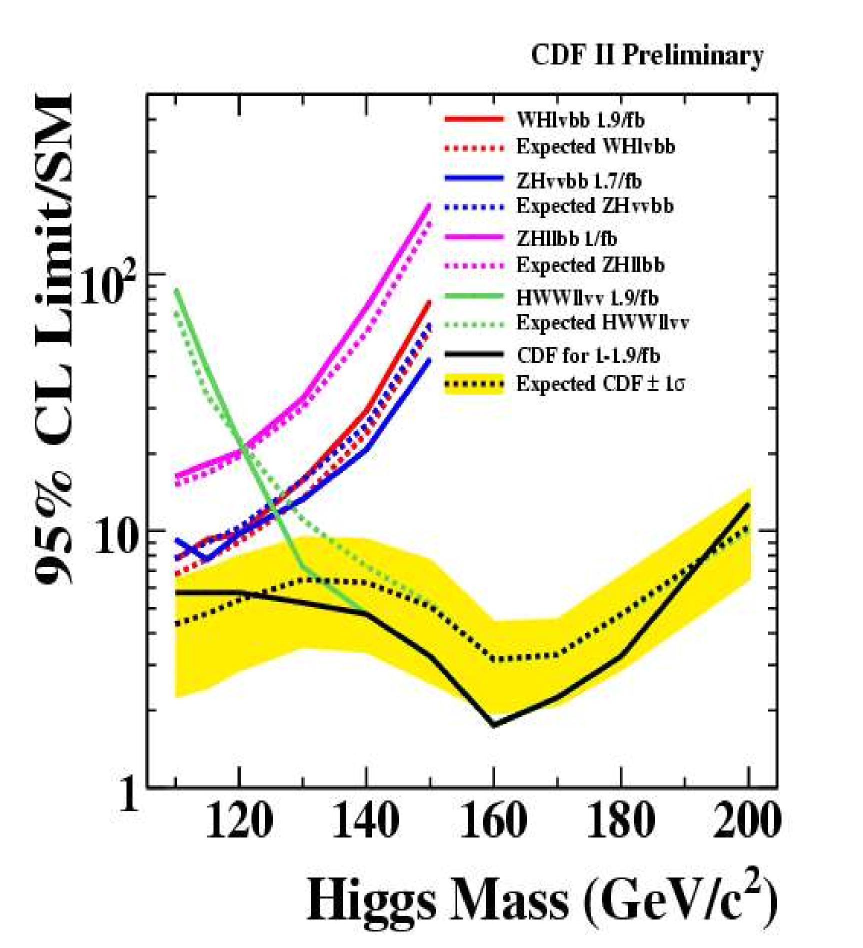


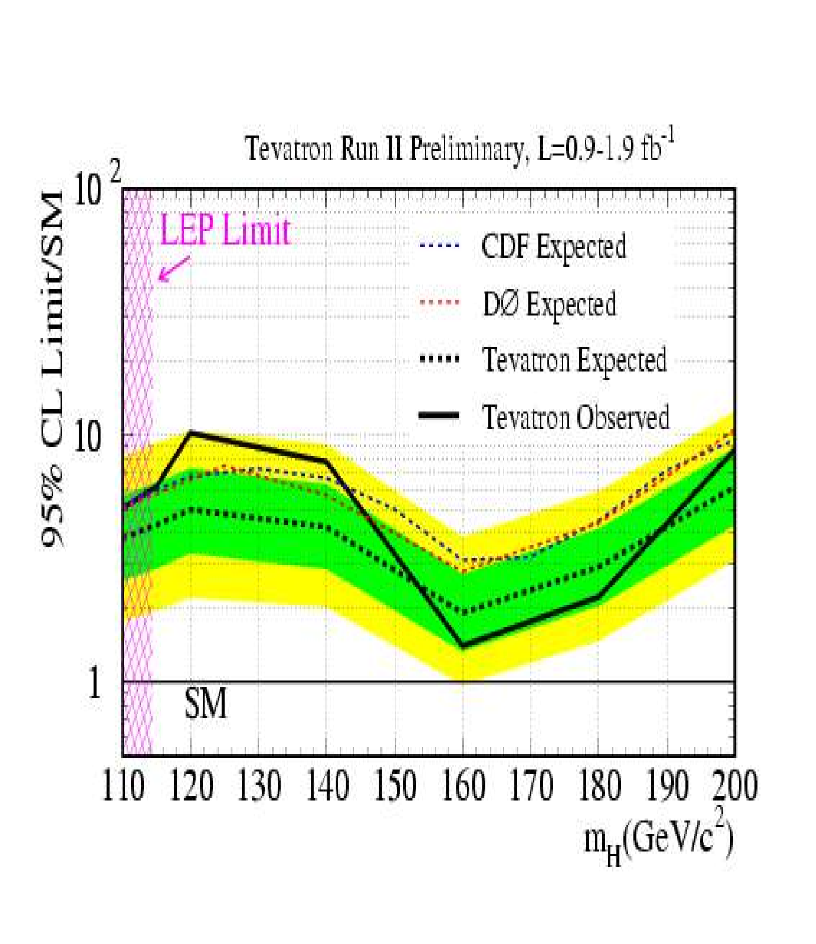
- CDF observed/expected limit is 8/8.3 x SM @ m_H =115 GeV
- D0 observed/expected limit is 13/12 x SM @ mH =115 GeV
- Future improvements: using single tag and improving the trigger

Combination Procedures

- Normalized to SM rate, we can combine σ×Br/SM statistically to improve the final result.
- Use Bayesian and Frequentist approaches:
  - Bayesian: $$L(R,\vec{s},\vec{b}|\vec{n},\vec{\theta}) = \prod_{i=1}^{Nc} \prod_{j=1}^{Nbins} \mu_{ij}^{nij} e^{-\mu_{ij}} / n_{ij}! \times \prod_{k=1}^{n} e^{-\theta_k^2/2}$$
  - Frequentist (CLs): $$LLR_n = 2\sum_{i=1}^{N} (s_i - n_i Log(1 + \frac{s_i}{b_i}))$$
  - All systematics treated as nuisance parameters with truncated Gaussian constrain
- If the excess is significant after combination, do more checks to make sure not statistic fluctuation.
- If no excess, set 95% CL upper limit vs m_H

Combination of CDF and Tevatron Limits





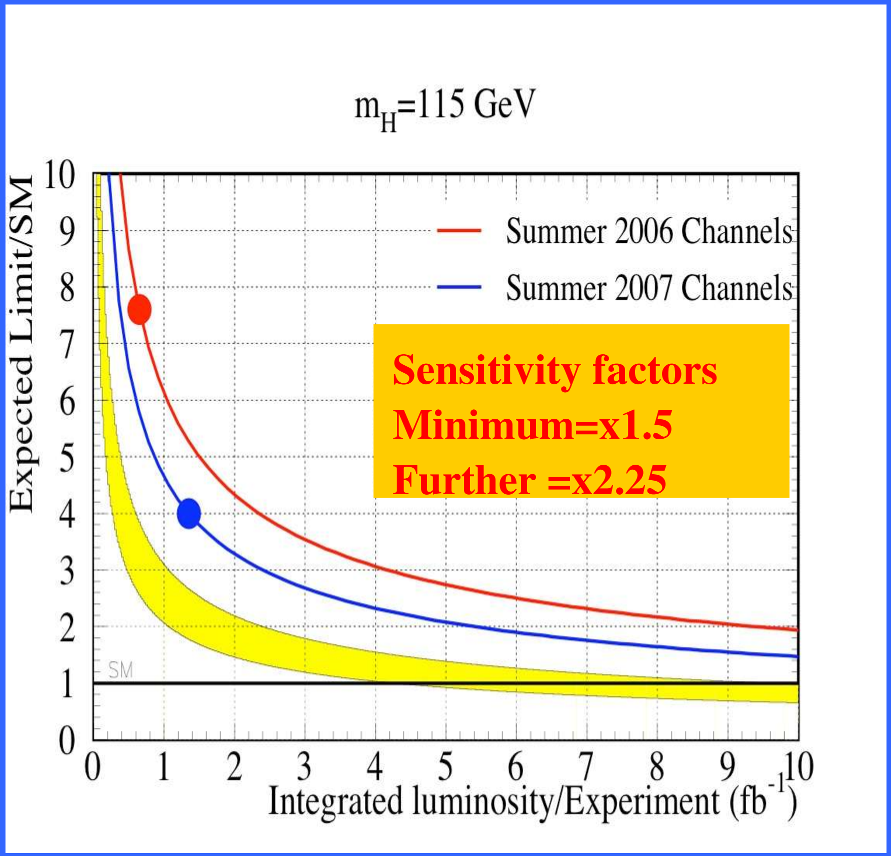
- ❑ CDF improved by 30% over LP07 and set the observed (expected) limits of 5.8 (4.8) at 95% CL @ mh=115 GeV.
- ❑ The combined CDF and D0 limit will be updated soon …

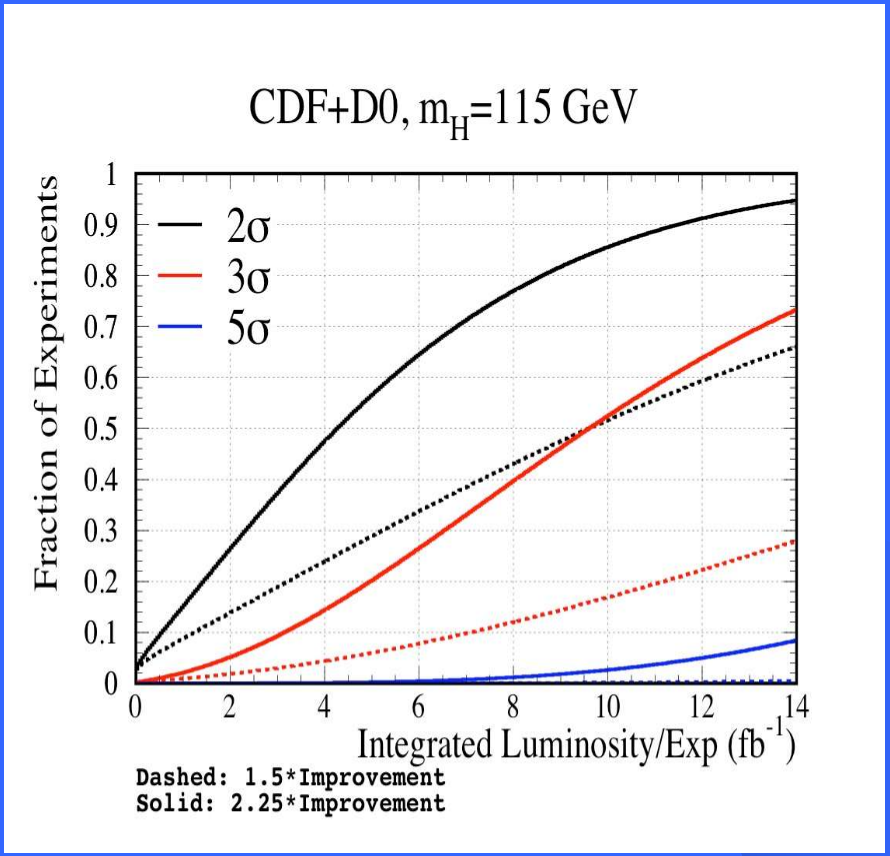
Conclusions

- We are closing in sensitivity towards less than 5 times SM Higgs @ mh=115 GeV
- There is no magic bullet, 10% effects matter most and no stone is left unturned.
- Both CDF and D0 have improved the sensitivity by 40% over the gaining of luminosity since summer 06 and expect the trend will continue in next two years.
- A factor of 2 improvement over the current analysis by 2010 will put the Tevatron within a reach of 3 σ evidence for Higgs mass at 115 GeV
- This is very exciting time for Higgs search at Tevatron

BACKUP Slides

Tevatron Achievable Sensitivity





- CDF+D0 combined and same improvement assumed
- Curves scaled by 1/sqrt(L) with analysable luminosity
- There is a good chance to see 3σ evidence of Higgs …