Search For a Low Mass Standard Model Higgs at the Fermilab Tevatron

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on behalf of the CDF and D0 collaborations

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Outline

- Talk will cover recent CDF & D0 low mass [M_H<135 GeV/c^2] SM Higgs results on H→bb
- Discuss search strategies for WH and ZH
- Latest results from CDF, D0, and Tevatron (H→bb) combination
- Prospects for the remainder of Run II and beyond...

For Additional Details and Latest Results

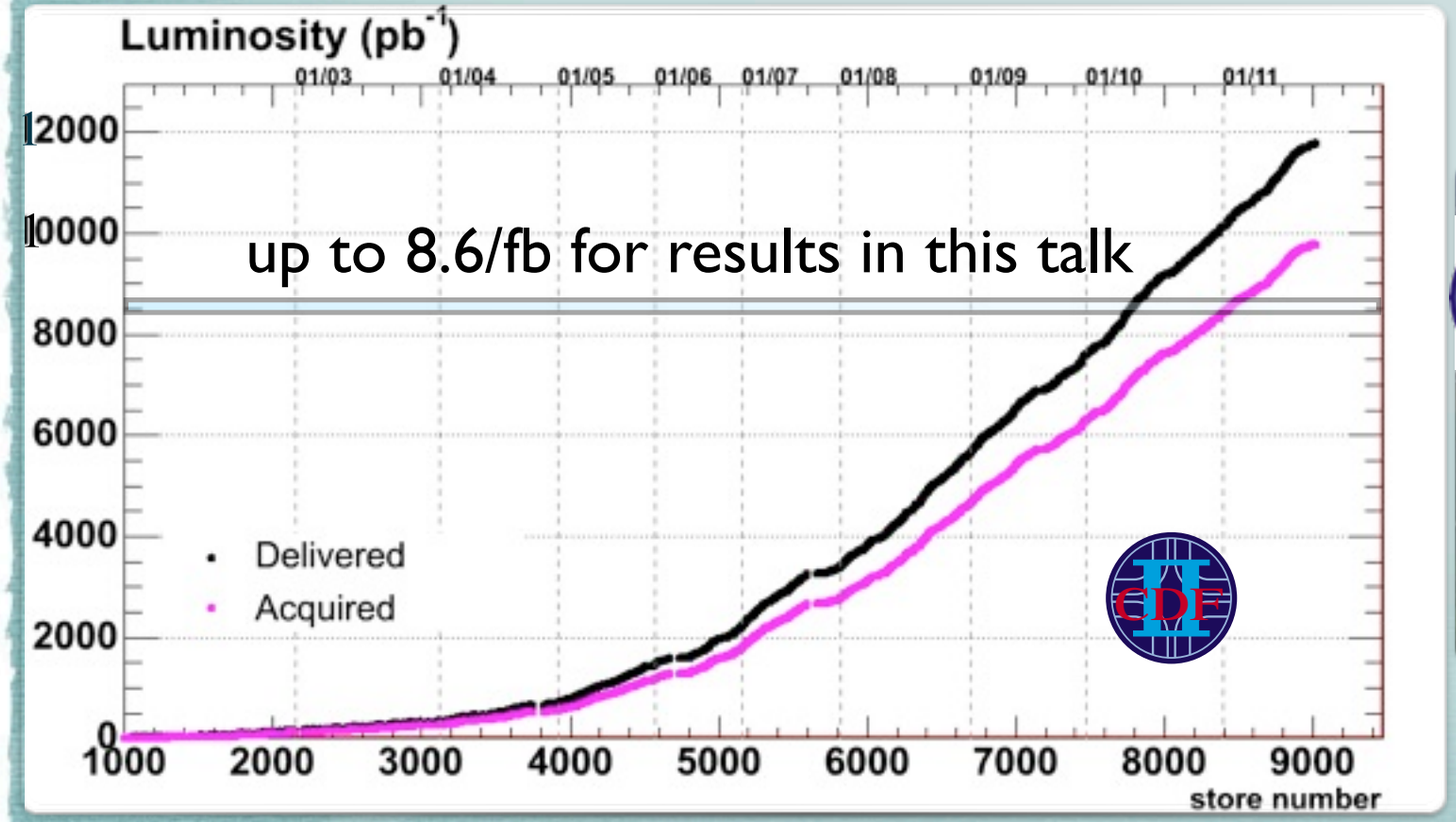
http://www-d0.fnal.gov/Run2Physics/WWW/results/higgs.htm
http://www-cdf.fnal.gov/physics/new/hdg/Results.html
http://tevnphwg.fnal.gov/results/SM_Higgs_Summer_11/

The Standard Model Higgs

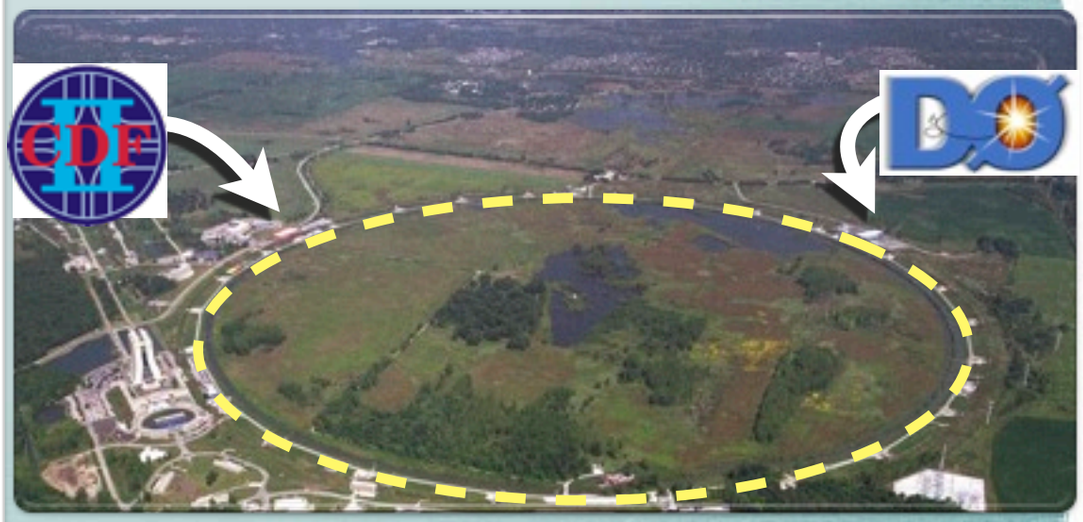
- Higgs mechanism is simplest way to achieve EWSB, generate W/Z masses and allow for fermions with mass
- Predicts a Higgs Boson of 'unspecified' mass M_H, whose existence has not been confirmed by experiment
- LEP experiments exclude values of M_H below 114.4 GeV/c^2 @ 95% CL, and with indirect constrains get $114 < M_H < 185$ GeV/c^2
- This mass range is accessible at the Tevatron and in recent years, Tevatron experiments have excluded values of $M_H \sim 165$ GeV/c^2
- The LHC experiments have recently excluded $M_H > 145$ GeV/c^2

The Tevatron

- pp collider $\sqrt{s}$ = 1.96 TeV
- ~12/fb delivered to each experiment so far
- Beam operations to end in September 2011
- Final datasets available to Higgs searches should total ~10/fb (per experiment)

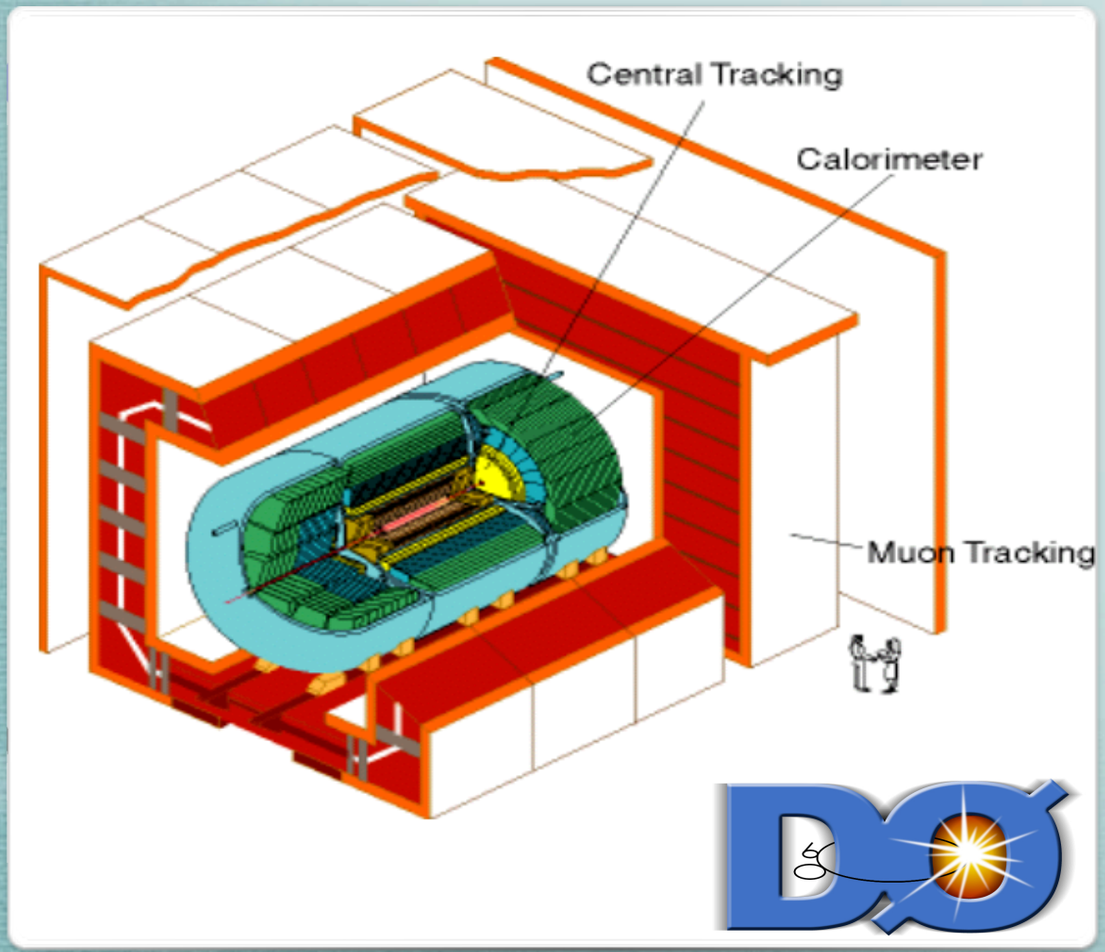


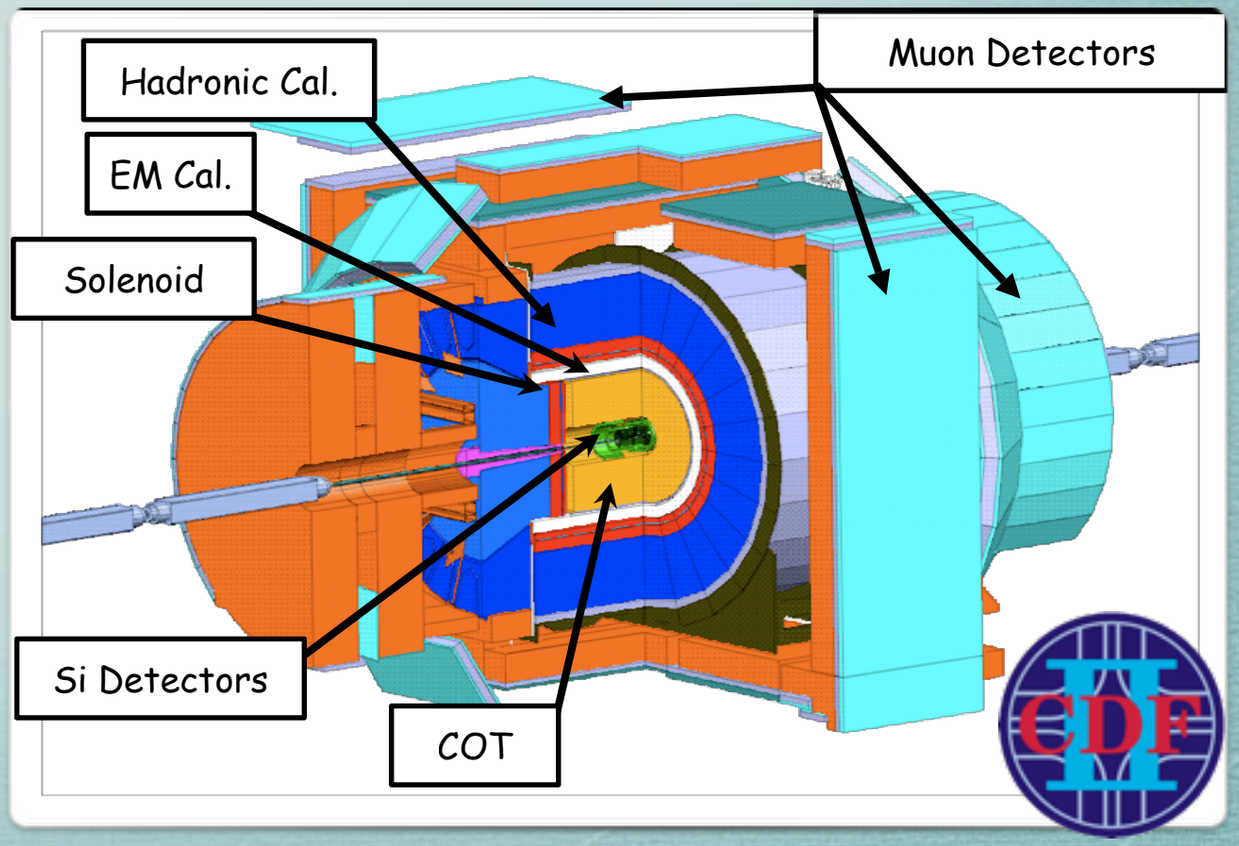
up to 8.6/fb for results in this talk



The Experiments

- D0 and CDF are general purpose detectors
- Silicon Vertex Detectors (critical for b-jet ID)
- Tracking Chambers (CDF Drift Chamber, D0 Fiber Tracker)
- Calorimeter + Muon Systems (jet, electron, tau, muon ID)
- Combined with muli-level 'trigger systems' to select events with topologies of interest (missing transverse energy, energetic jets/leptons)





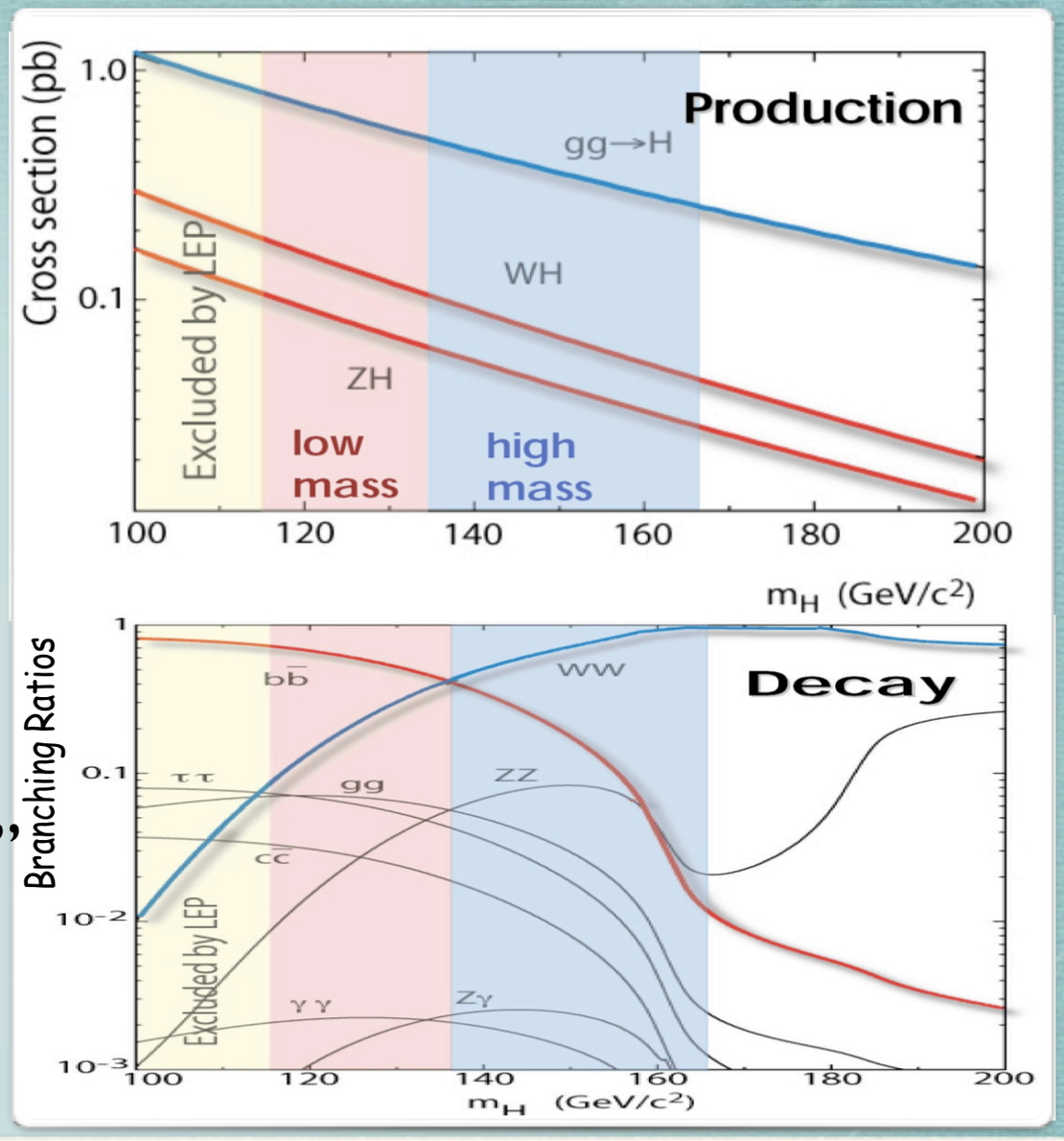
The SM Higgs @ The Tevatron

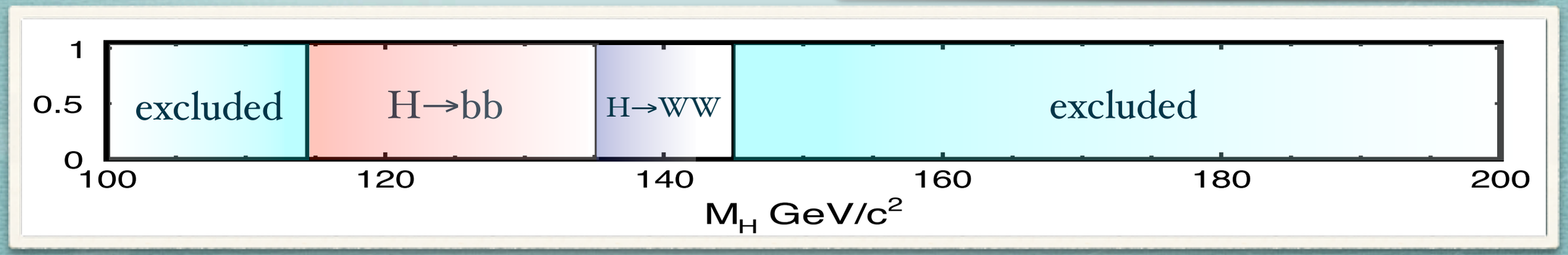
- Main production modes are :

  I. Gluon-gluon fusion (gg→H)
  II. Associated Production (ZH/WH)
  III. Vector Boson Fusion (qq→qqH)

- Dominant decay mode defines 2 search regimes :

  I. H→WW "high mass M_H>135 GeV"
  II. H→bb "low mass M_H <135 GeV"



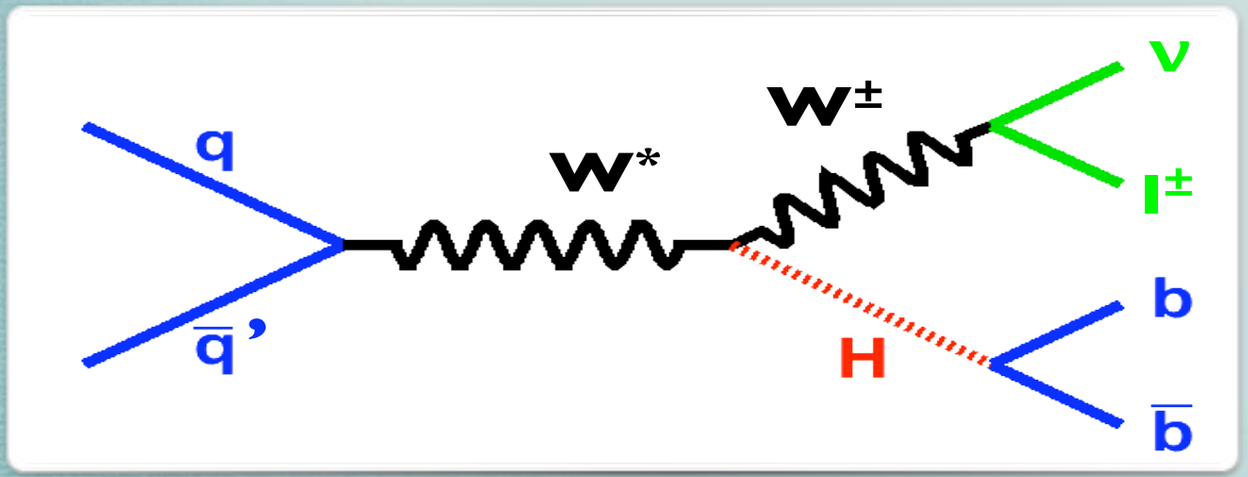


The Search Environment

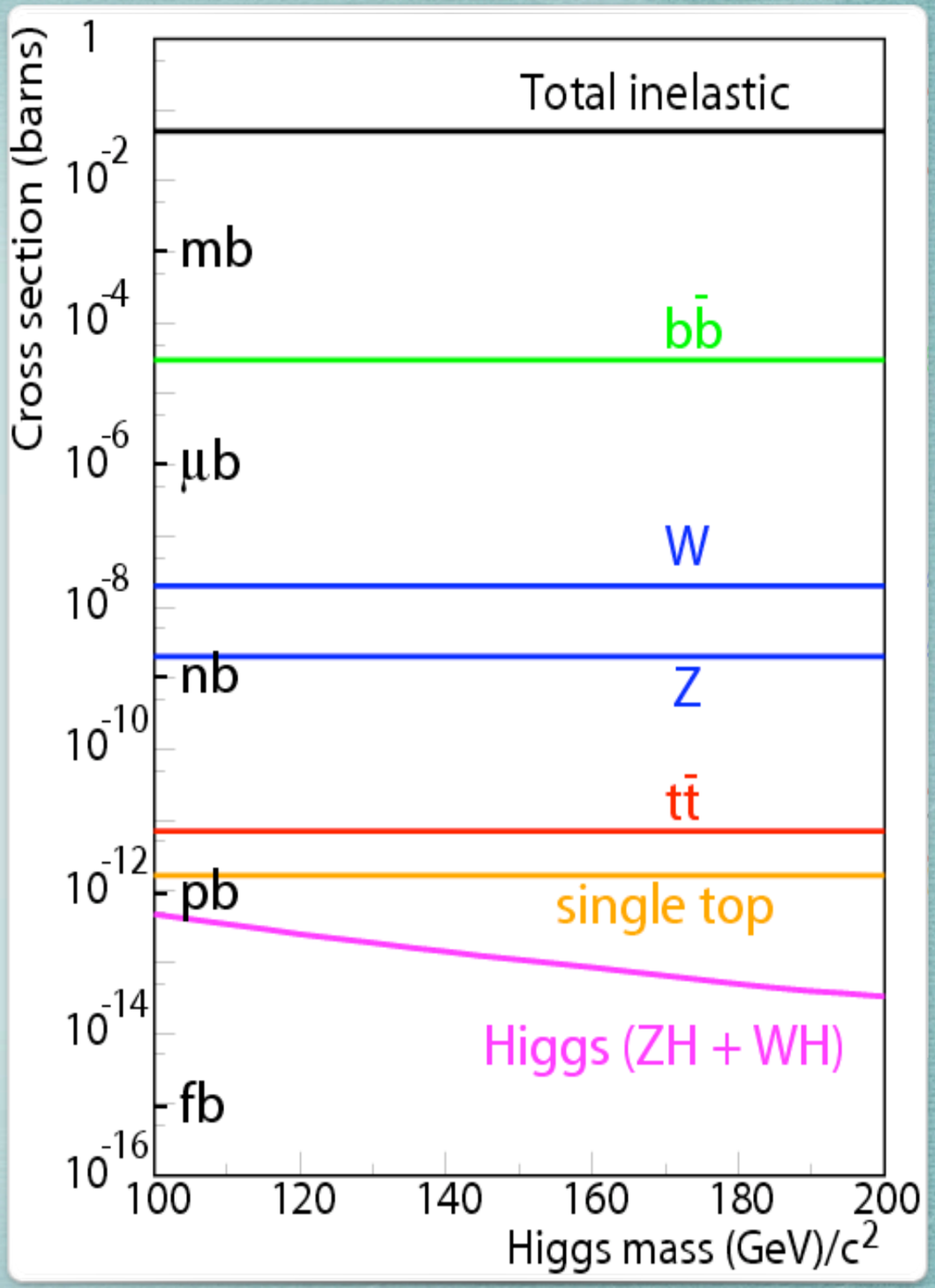
- Background rates many orders of magnitude higher than predicted SM Higgs rates

- The dominant process (gg→H→bb) is overwhelmed by multi-jet production

- Searches target Higgs production/decay modes with 'distinguishing' final states :

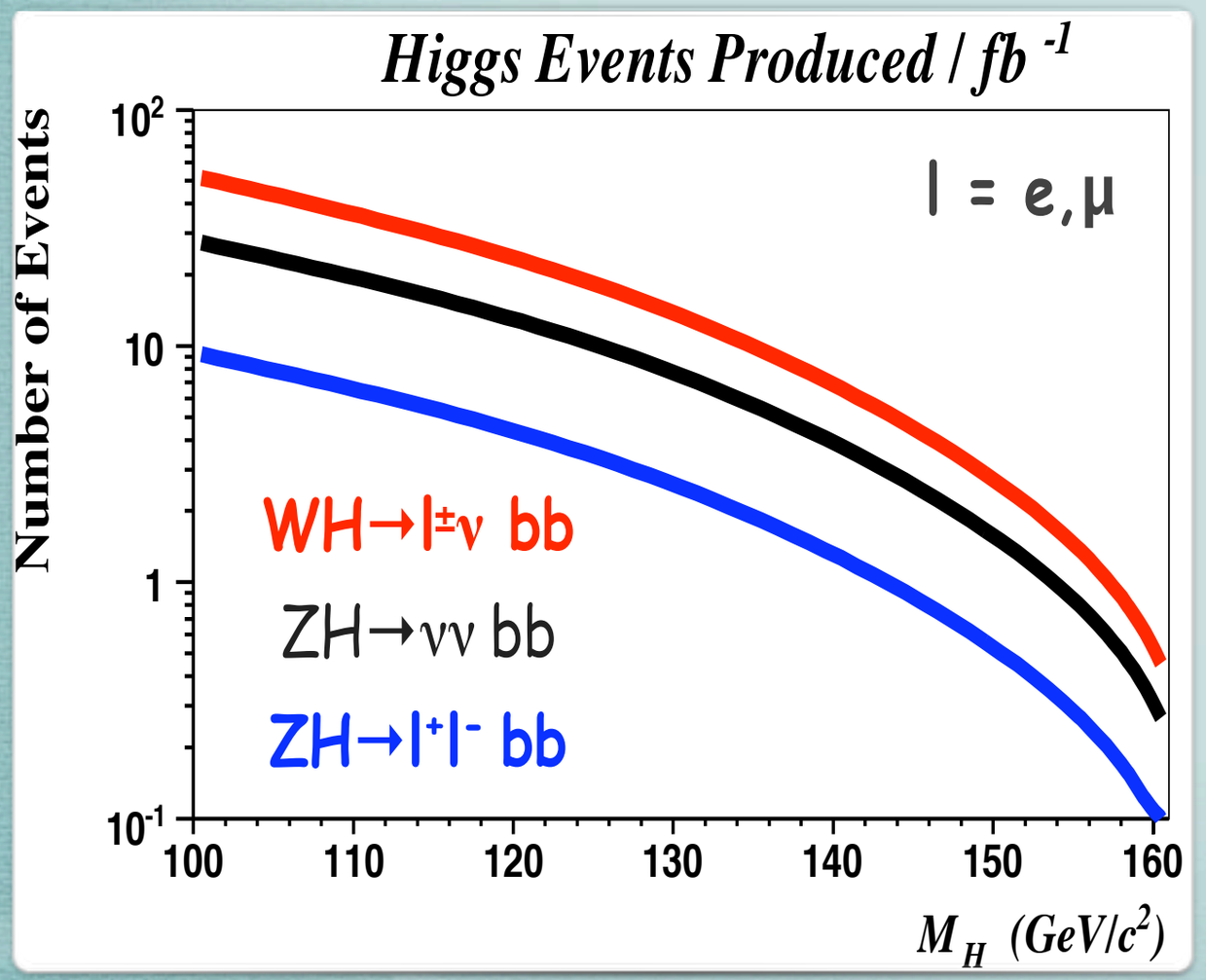


- Analysis methods proven successful in picking out signals as small as single top production (~pb)



The Target: bb + 0,1, or 2 leptons

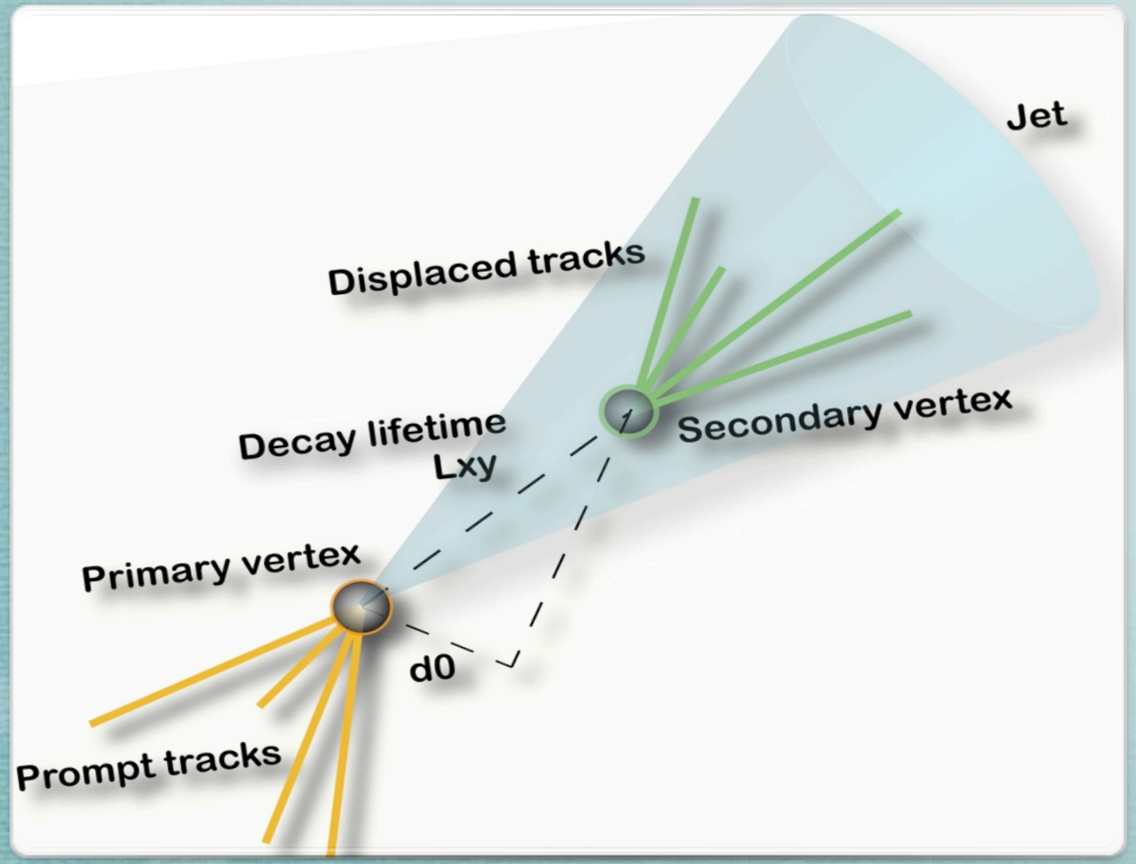
- For M_H < 135 GeV/c^2 searches focus on H→bb from ZH and WH production
- Search for the decay products of associated Z/W

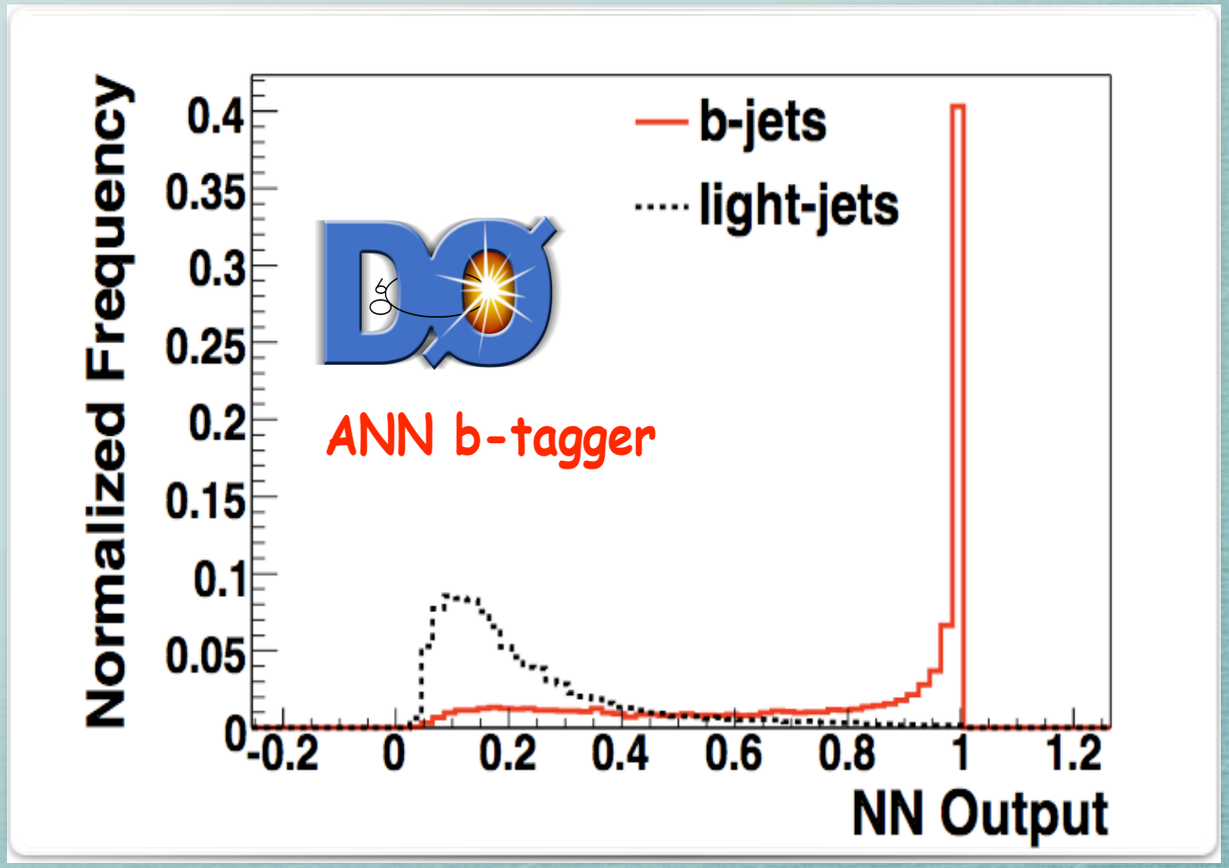


- Signal rates are low (~100 events/10^{14} collisions)
- Aim for maximum signal/ background
- Have developed several techniques to enhance sensitivity

b-jet Identification

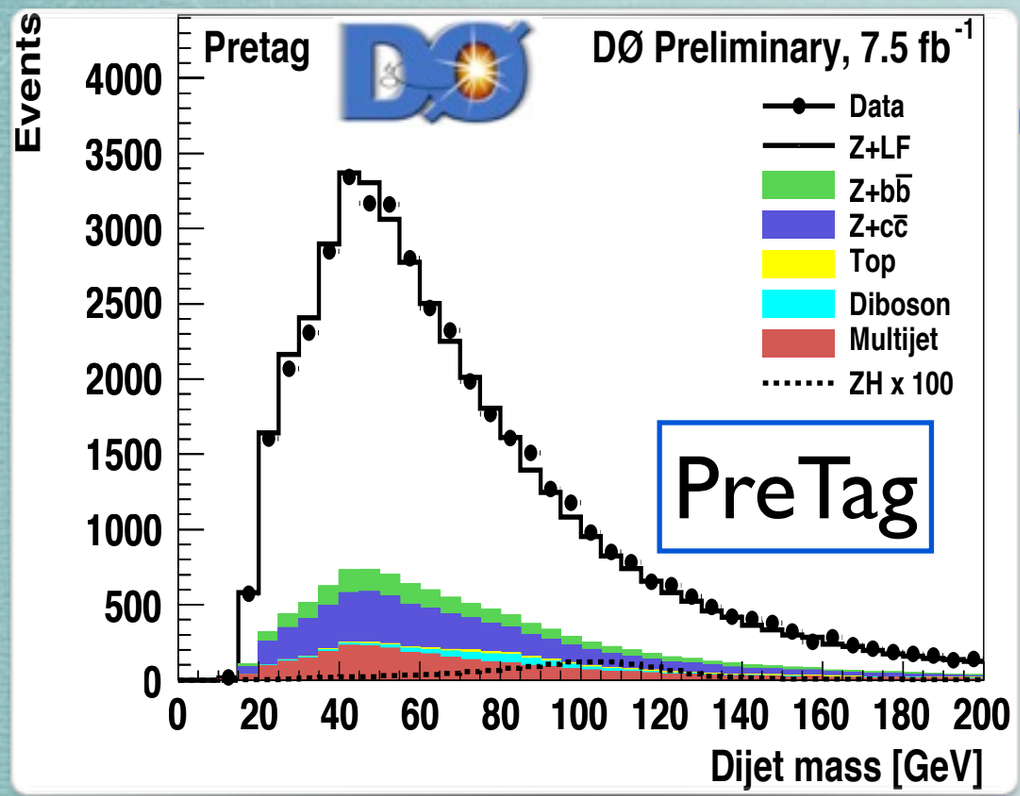
- Distinguish b-jets from c/light jets
- Most important analysis tool for low mass searches
- Various algorithms available @ CDF & D0 which exploit long lifetime of b to 'tag' jets
- Typically tag ~60% of b-jets with 1%≲ lf "mis-"tag rate



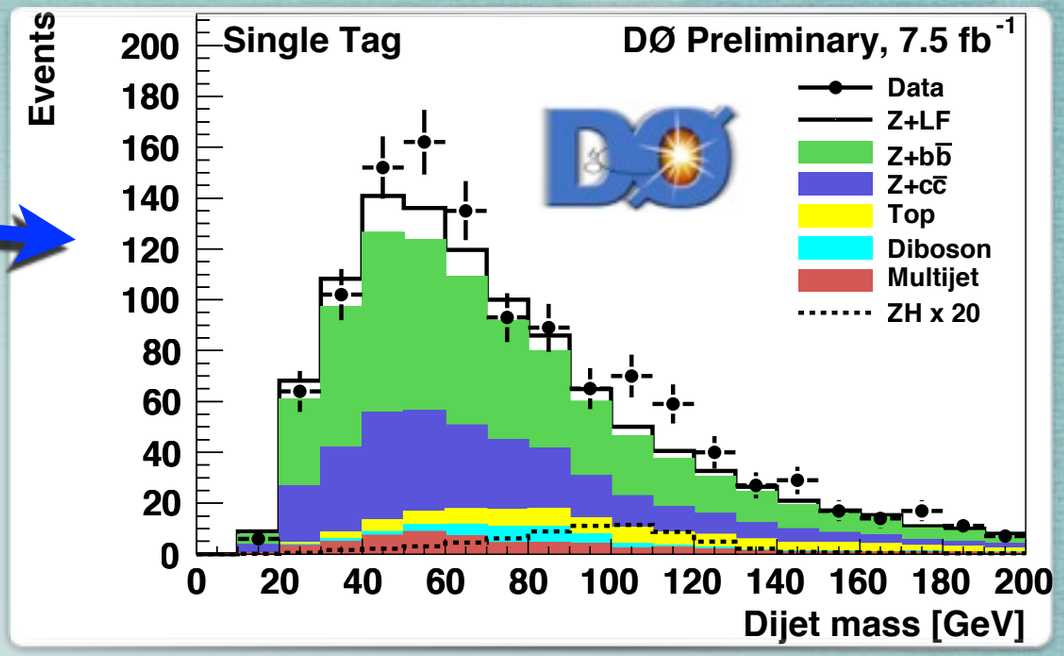


b-jet Identification

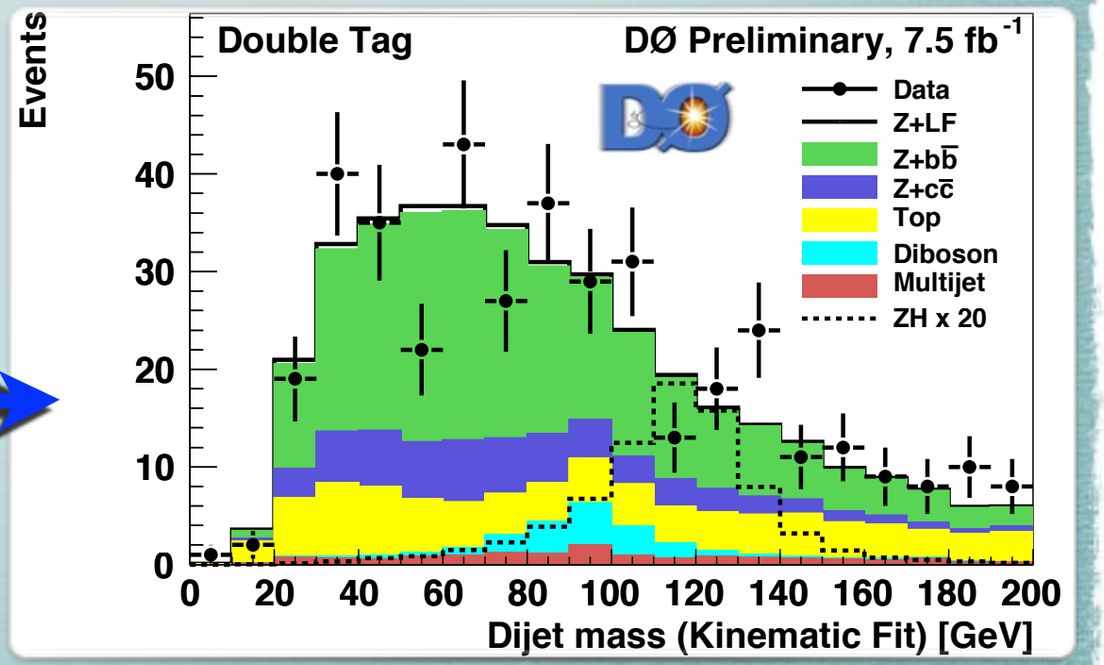
- b-tagging in ZH→llbb:



1 tag



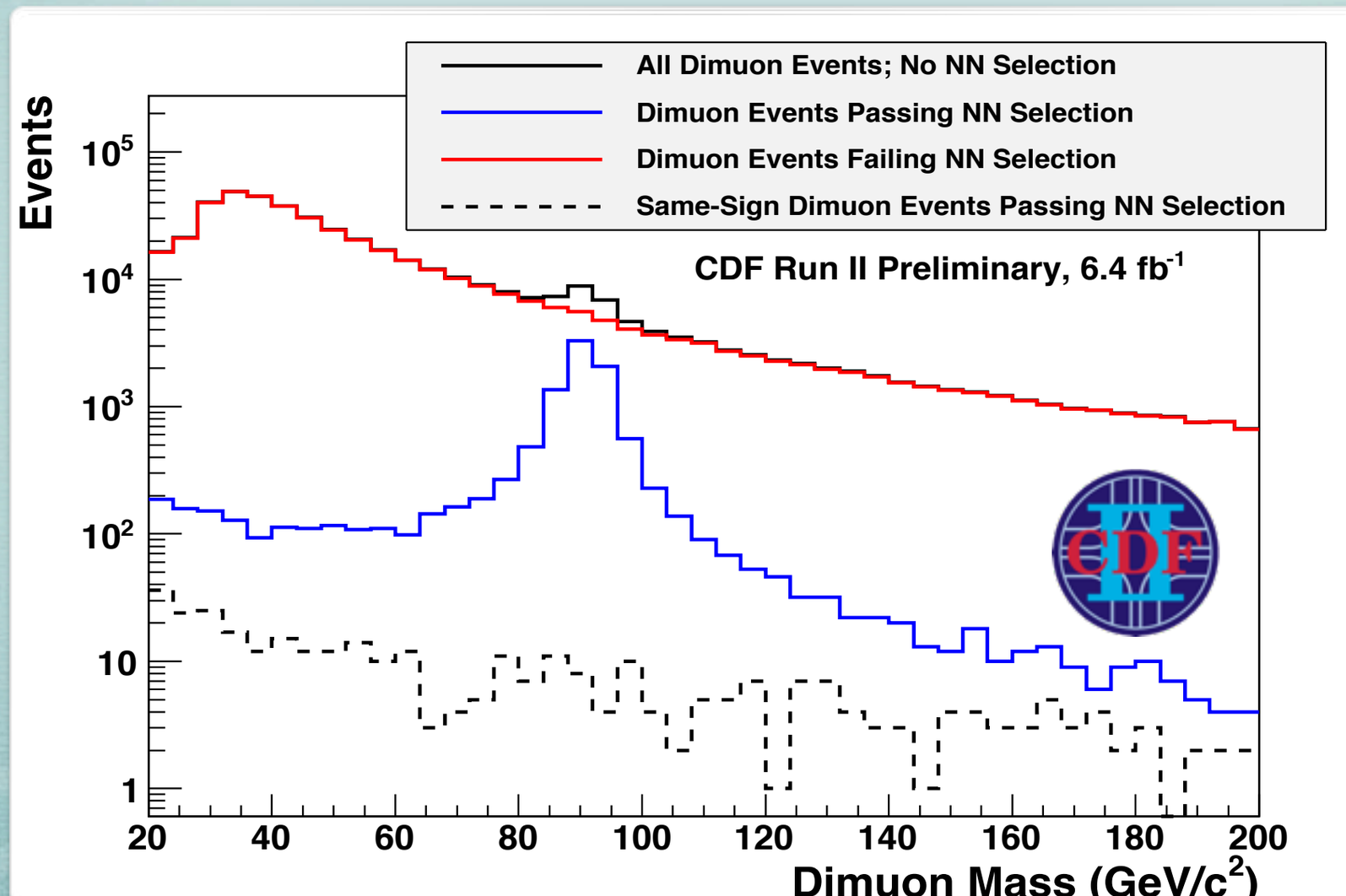
2 tags



- S/B @ Pretag ~ 1/3000
- S/B @ 1 Tag ~ 1/300
- S/B @ 2 Tag ~ 1/100

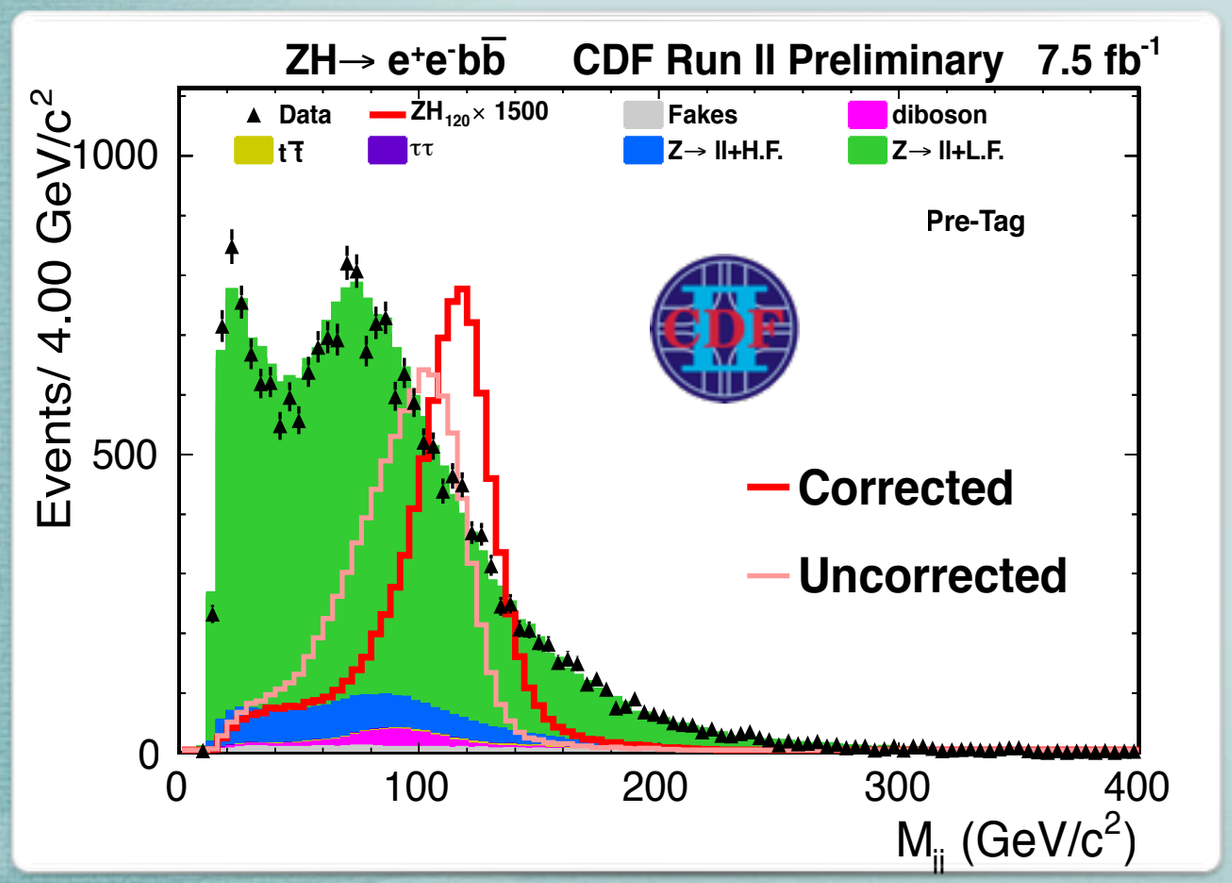
MultiVariate Lepton ID

- Several searches have replaced 'cut' based lepton identification with multivariate algorithms
- Neural Networks achieve ~10-20% lepton acceptance gains, and can reduce misidentification rates by a factor of 5



Specialized Jet Energy Corrections

- Dijet mass is typically among the most discriminating distributions for H→bb
- Improved jet energy resolution = improved sensitivity
- Tevatron searches employ both kinematic fits and multivariate energy corrections



- Multivariate corrections modify jet energies based on topological event properties (ΔΦ[jet,met])
- Have also successfully been employed to apply corrections specific to b-jets
- Kinematic fits are effective in llbb final state where jet and lepton systems can be balanced within known resolutions

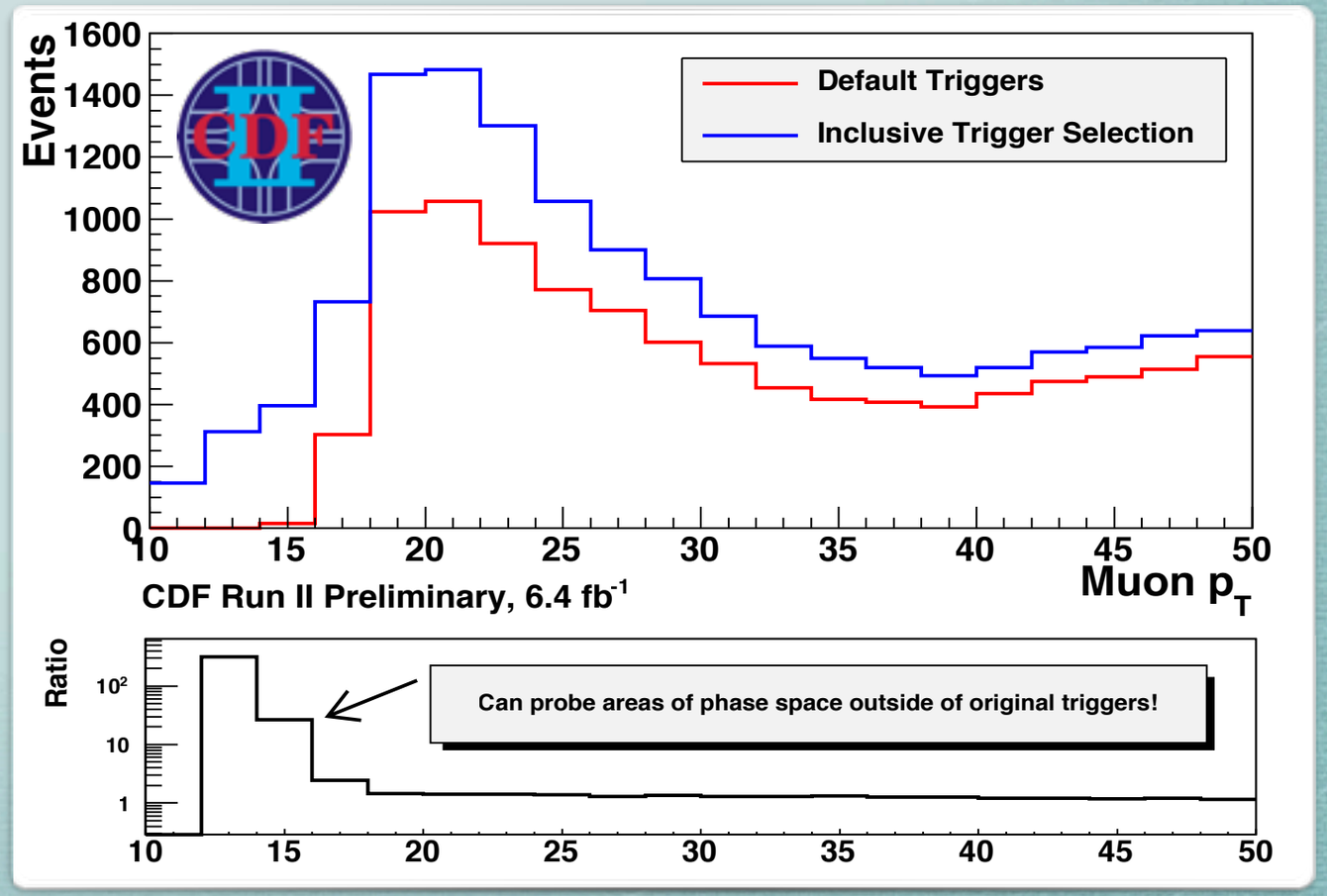
MultiVariate Trigger Emulation

- Response of an individual trigger selection depends on jet energies, missing E_T, etc.
- Past practice was to set event selection cuts above the trigger selection cuts

  Ex: Missing E_T trigger level requirement of 30 GeV ⇒ analysis level cut @ 50 GeV

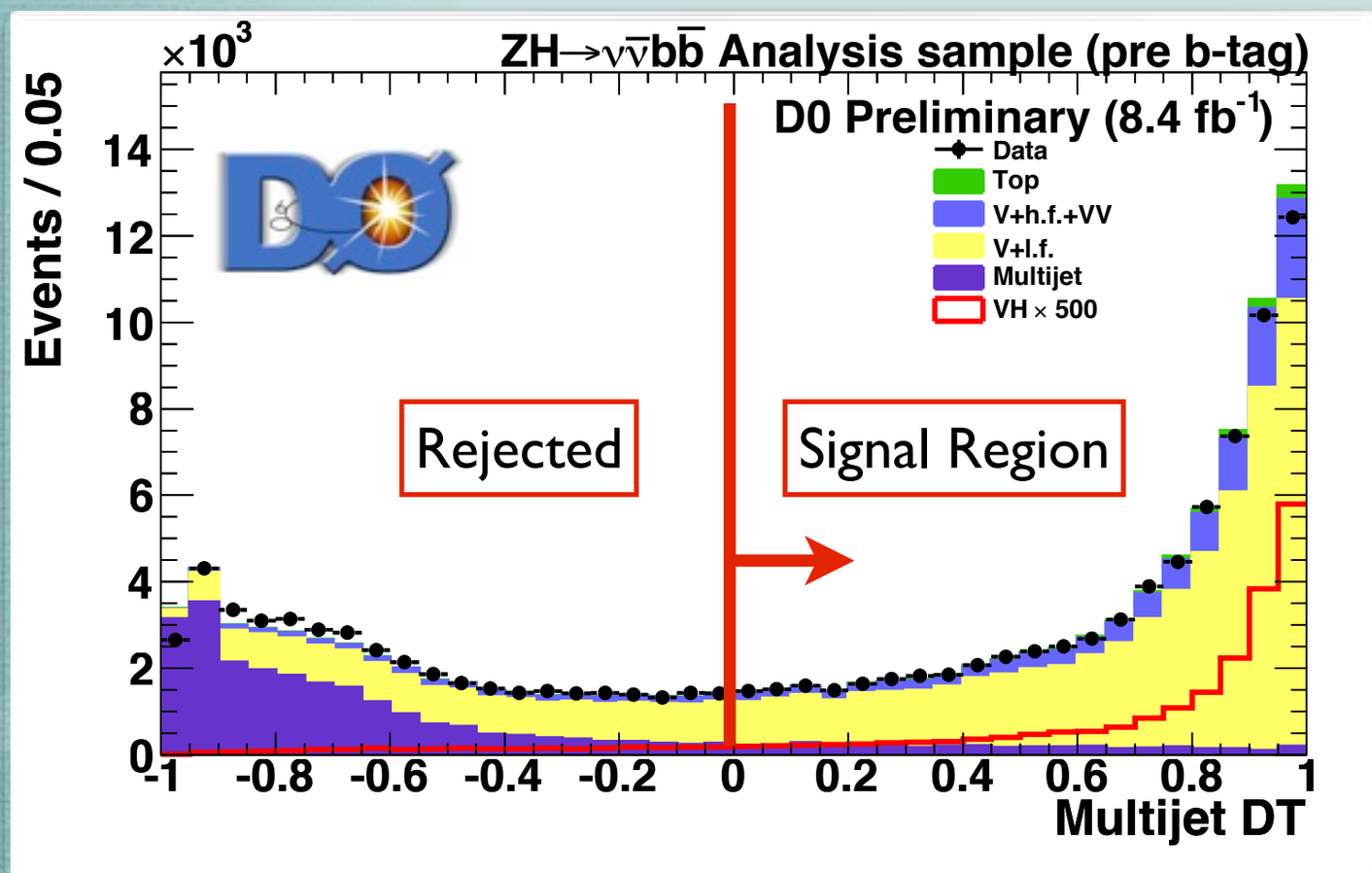
- By utilizing NN's for trigger response emulation, we are able effectively incorporate the combined response of multiple trigger selections in our data model

- Allows searches to combine several trigger selections
- Allows analysis-level cuts to be closer to the cuts at trigger level
- Gain signal acceptance including lower P_T leptons and events with less Missing E_T



0 leptons: VH→ννbb

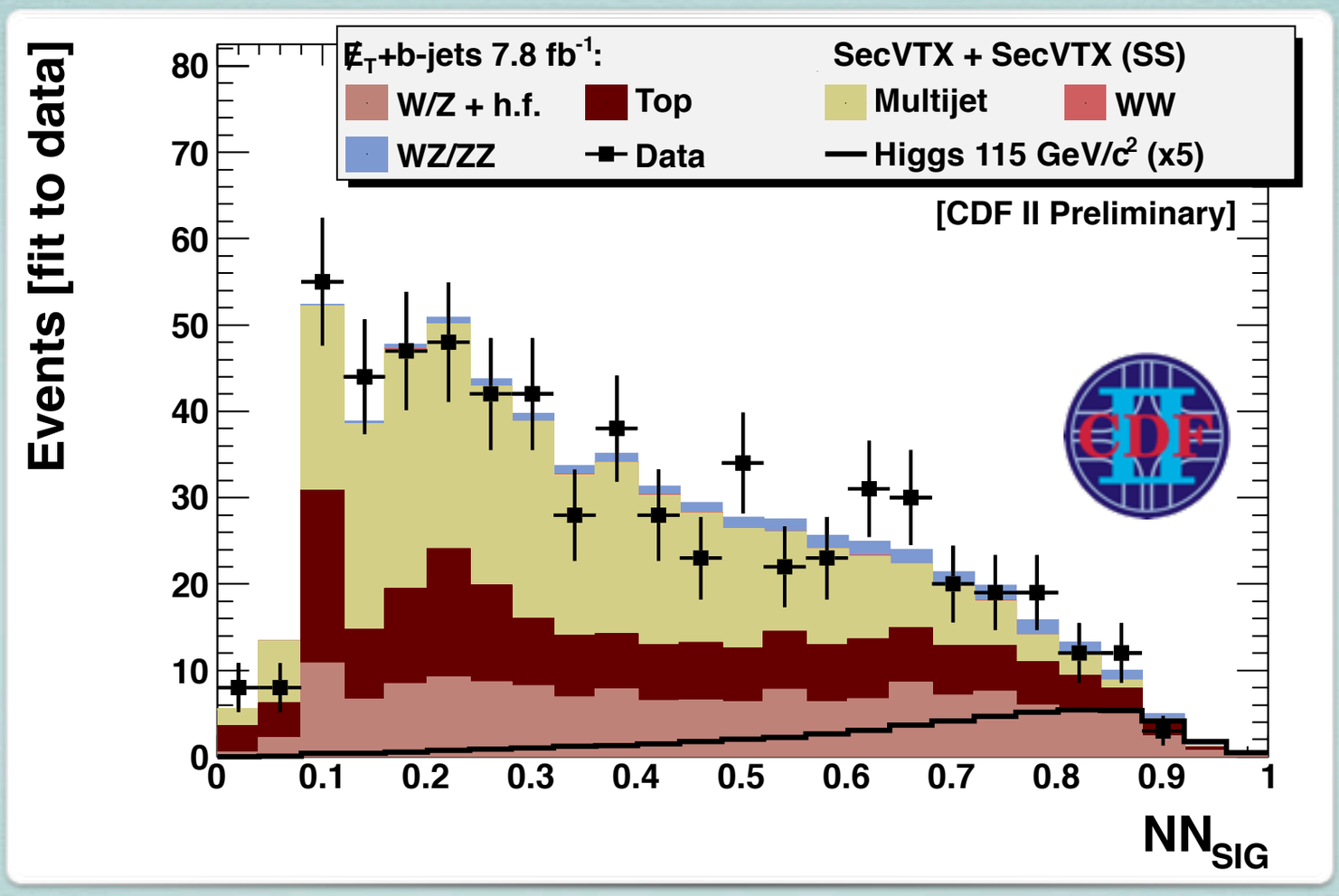
- Signal from Z→νν and W with a missed lepton
- Require energetic jets, significant missing transverse energy, and good separation between jets and missing E_T
- Multivariate technique to reduce multijet background :



- Multijet background is largely instrumental with large systematic uncertainties
- Decision Tree cut rejects ~90% of multijet background
- Retains ~84% of Higgs Signal

0 leptons: VH→ννbb

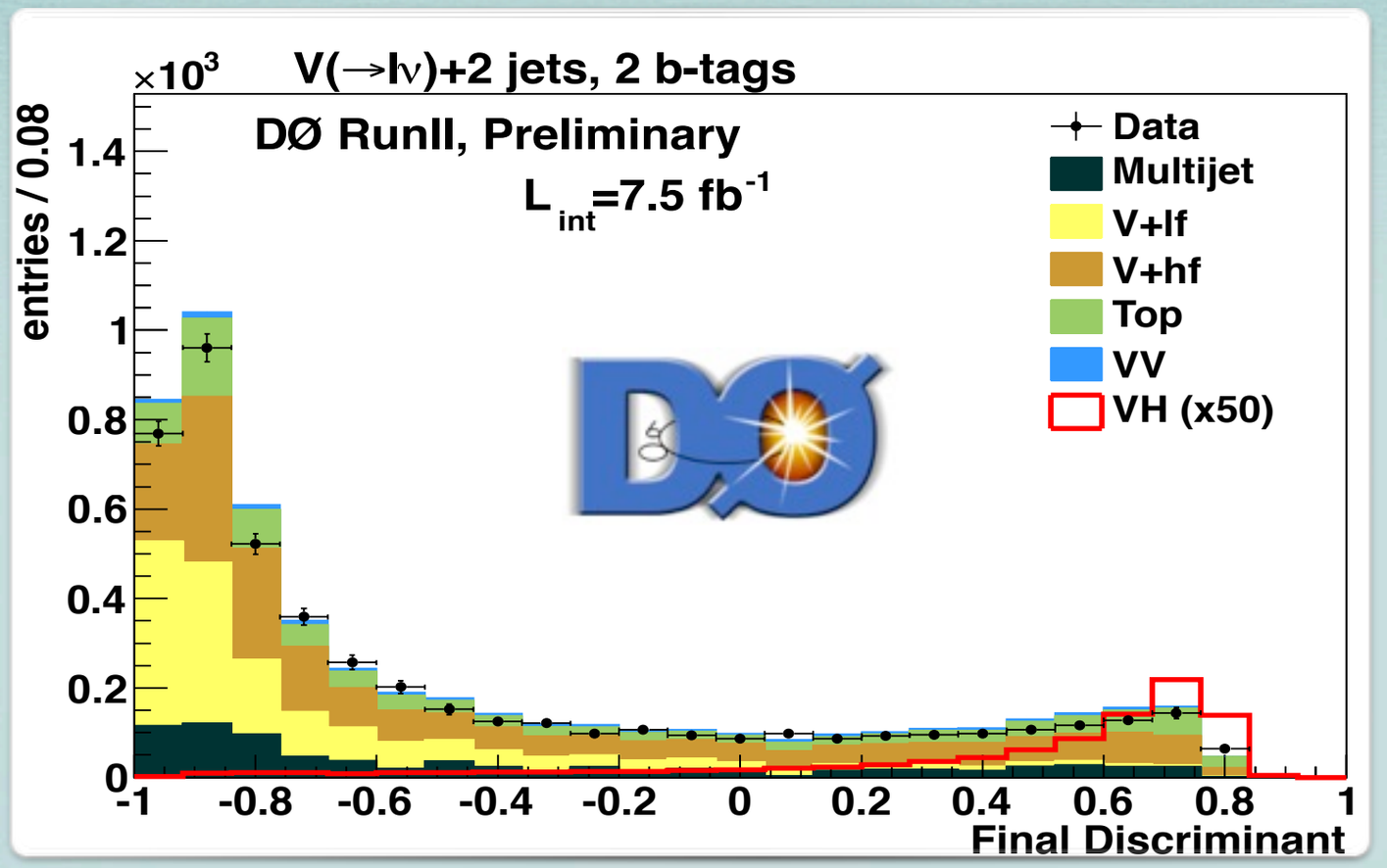
- Events surviving multijet rejection are processed by a second multivariate algorithm which aims to increase signal isolation



Obs. (Exp) 95% CL upper limits / SM @ M_H = 115 GeV/c^2		
Channel	CDF	DØ
VH→ννbb	2.3 (2.9) in 7.8 fb^{-1}	3.2 (4) in 8.4 fb^{-1}

1 lepton: WH→ ℓ νbb

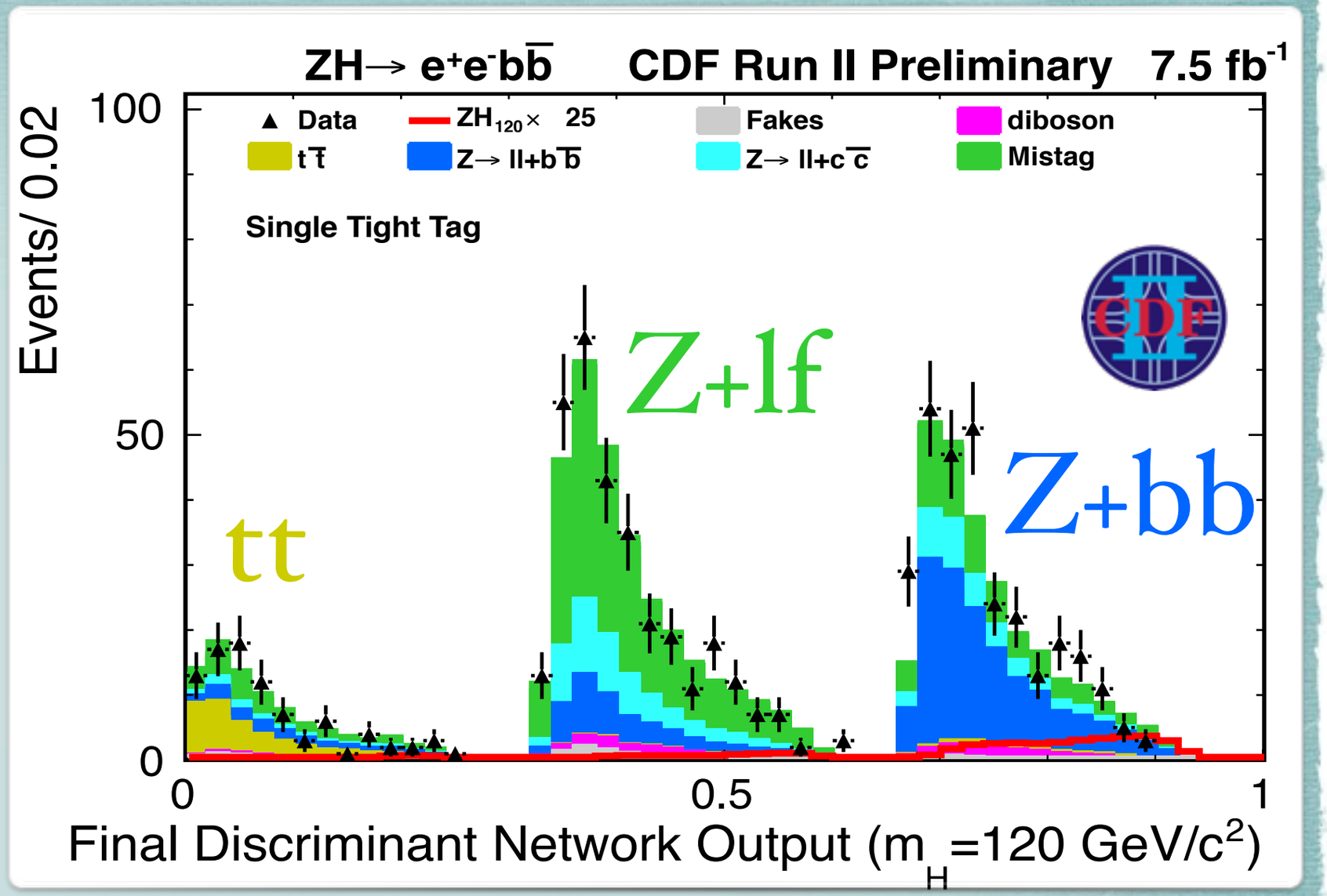
- Events contain exactly one lepton & significant missing E_T



Obs. (Exp) 95% CL upper limits / SM @ M_H = 115 GeV/c^2		
Channel	CDF II	DØ
$WH \to l^{\pm}\nu\, bb$	2.6 (2.7) in 7.5 fb^{-1}	4.9 (3.5) in 8.5 fb^{-1}

2 leptons: ZH→ $\ell^+\ell^-$ bb

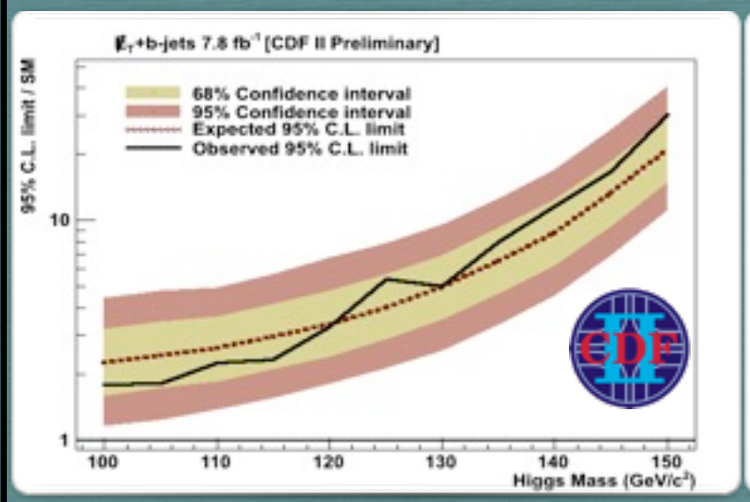
- Utilizes series of Neural Nets targeting tt, Z+lf, and Z+bb separately
- Final '3-region' discriminant formed by sorting events according to the individual NN scores

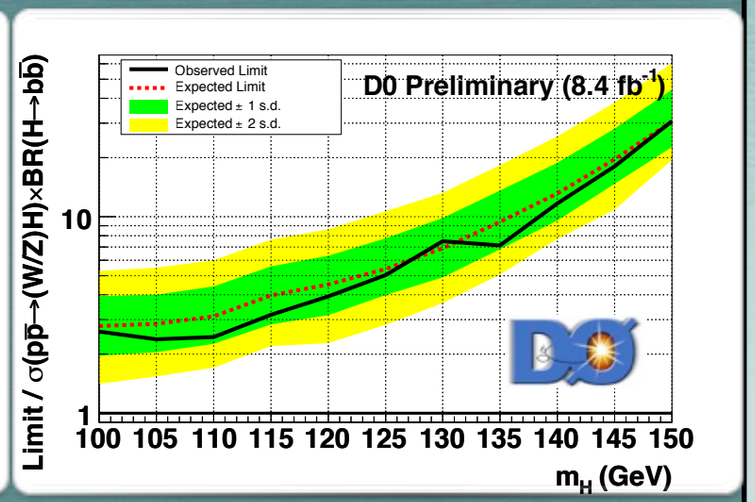


Obs. (Exp) 95% CL upper limits / SM @ M_H = 115 GeV/c^2		
Channel	CDF	DØ
ZH→llbb	4.8 (3.9) in 7.9 fb^{-1}	4.9 (4.8) in 8.6 fb^{-1}

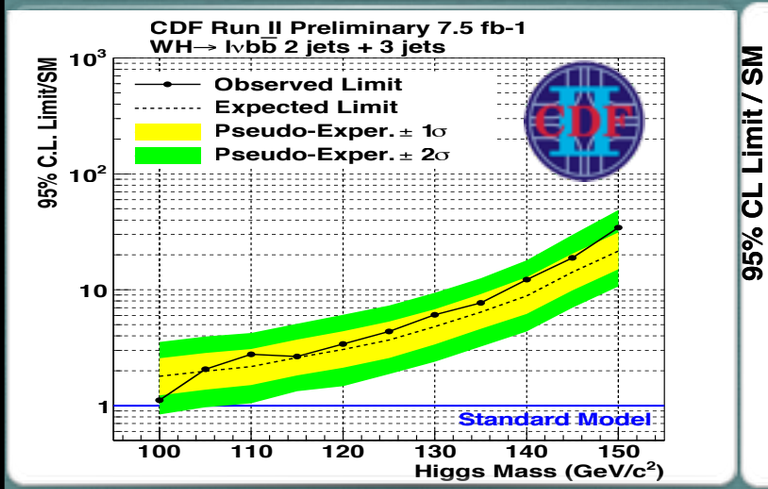
Tevatron Combination

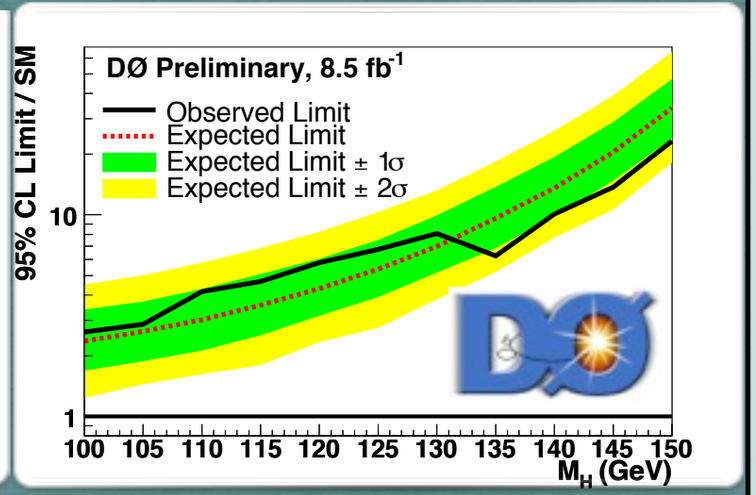
No Leptons



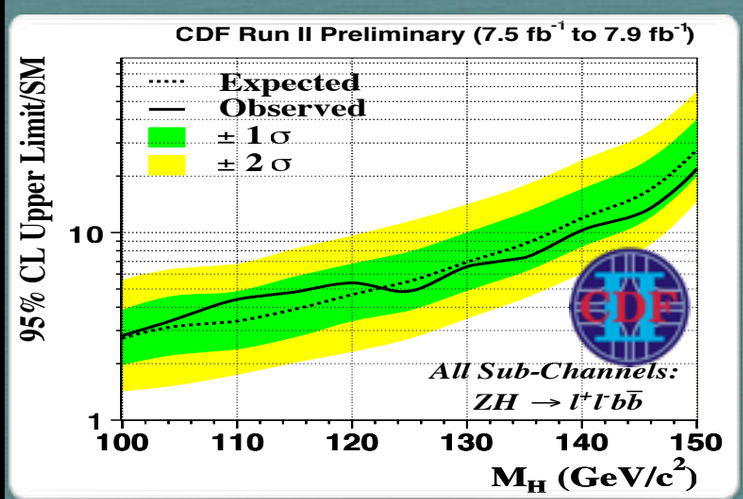


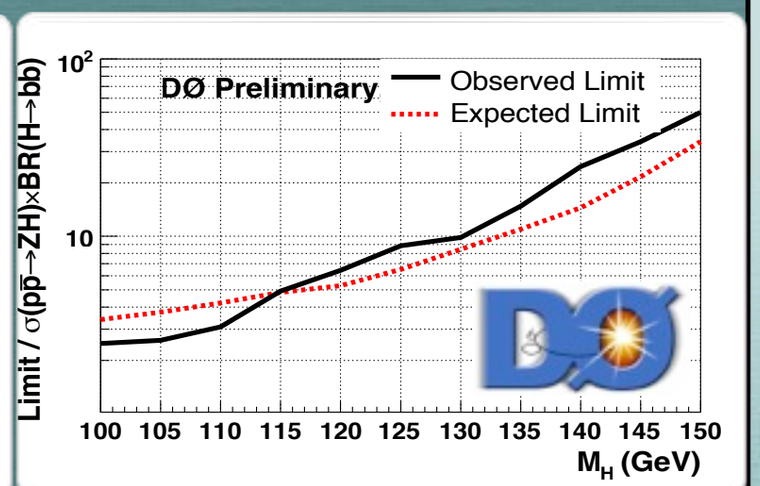
One Lepton





Two Leptons

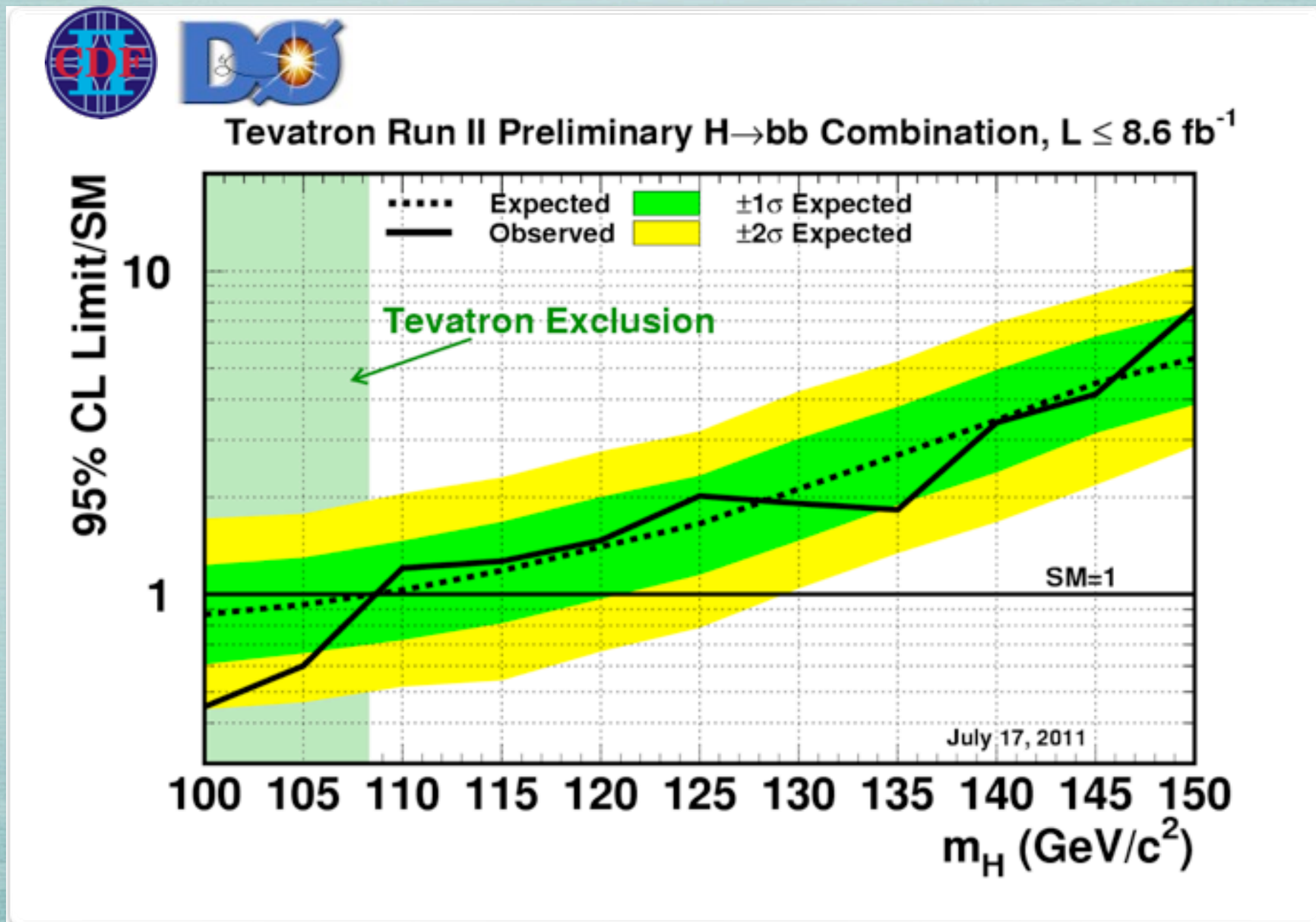


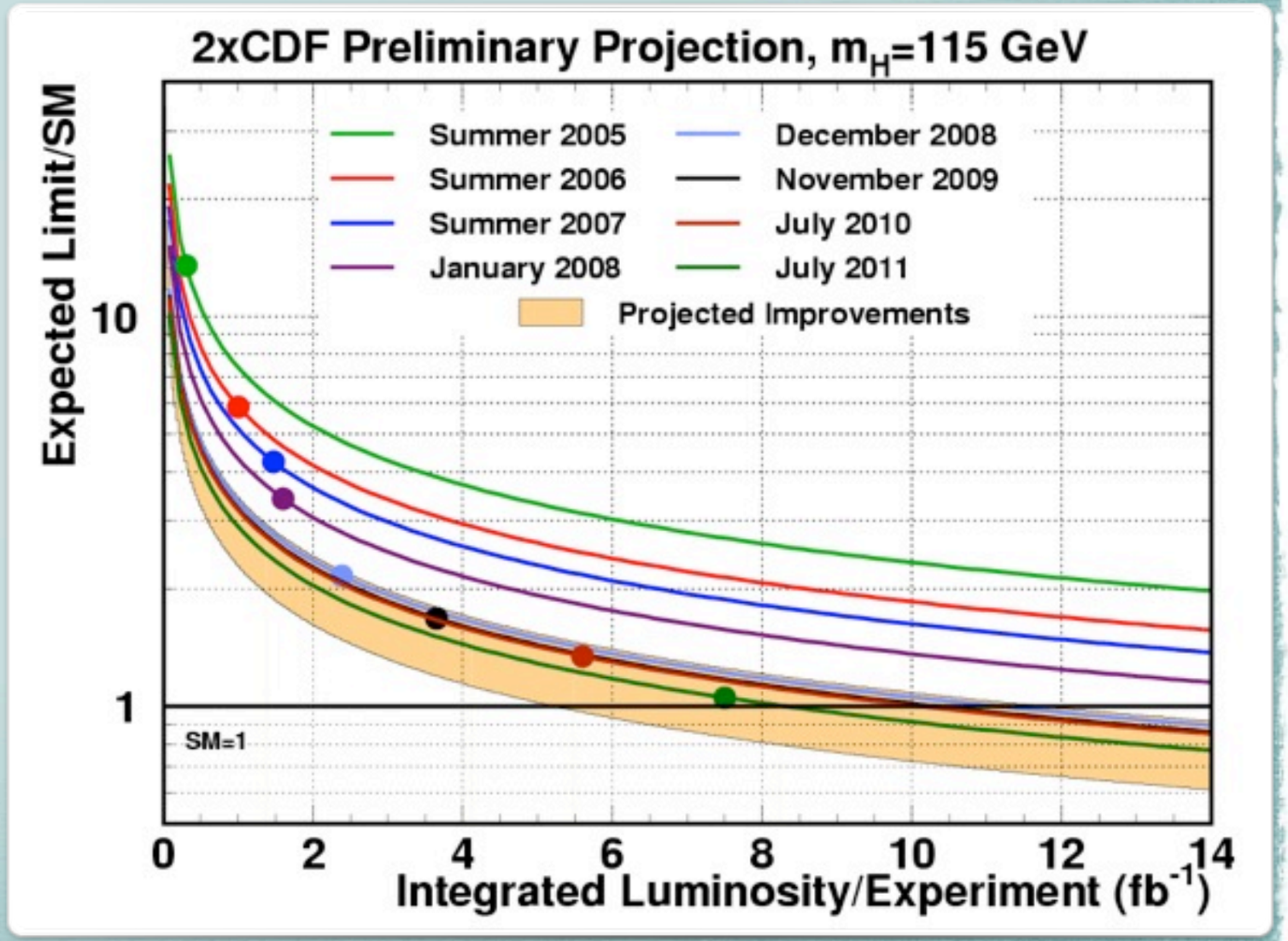


- Results from CDF and D0 searches are combined to produce Tevatron upper limits on SM Higgs rate
- Combination limits incorporate systematic uncertainties and account for correlations within and across experiments

Tevatron Combination

- 95% CL Upper limits on σ_H X BR(H→bb)
- Includes contributions from other channels (ttH, all-hadronic).



Conclusions

- ~1 month away from having complete Tevatron datasets
- CDF and D0 have steadily increased Higgs sensitivity through improved techniques
- Work underway to produce next results with final dataset!
- The Tevatron experiments are in a good position to make a statement on $H \rightarrow bb$.
- Thanks!