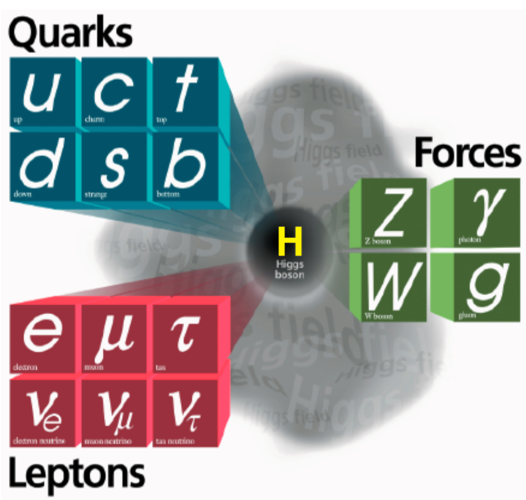
Low Mass SM Higgs Limits at The Tevatron

On behalf of the CDF and DØ Collaborations



Justin Keung
University of Toronto

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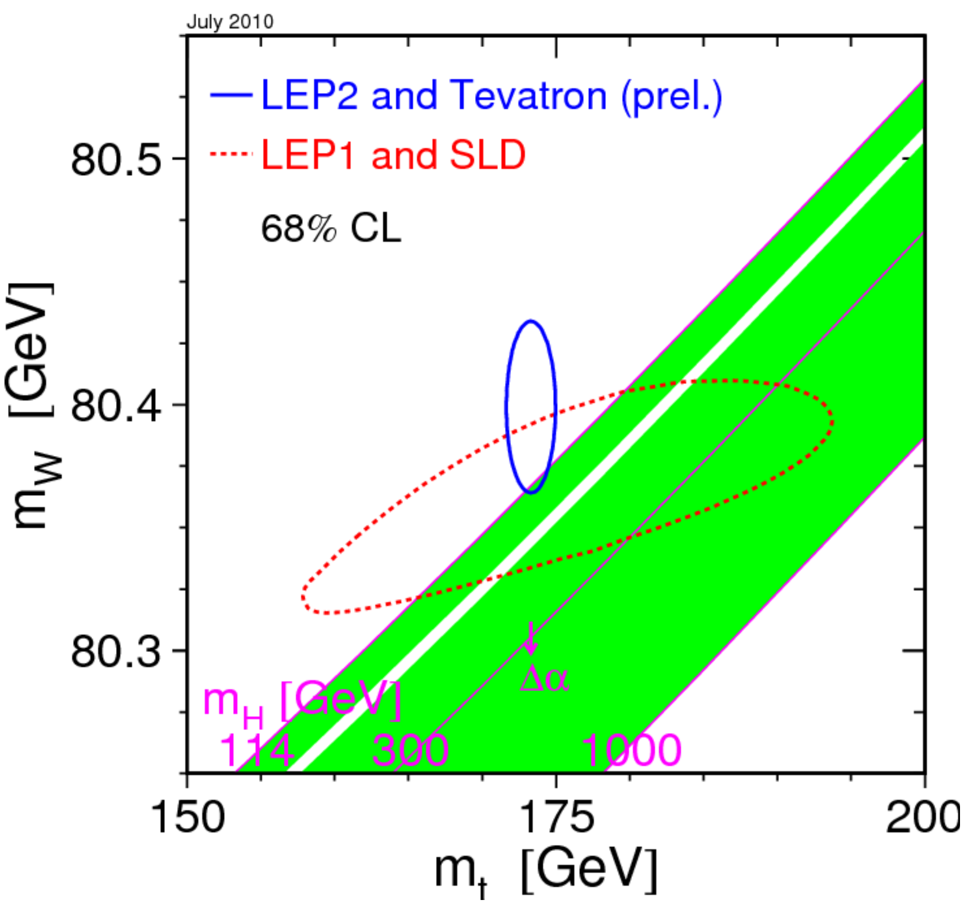
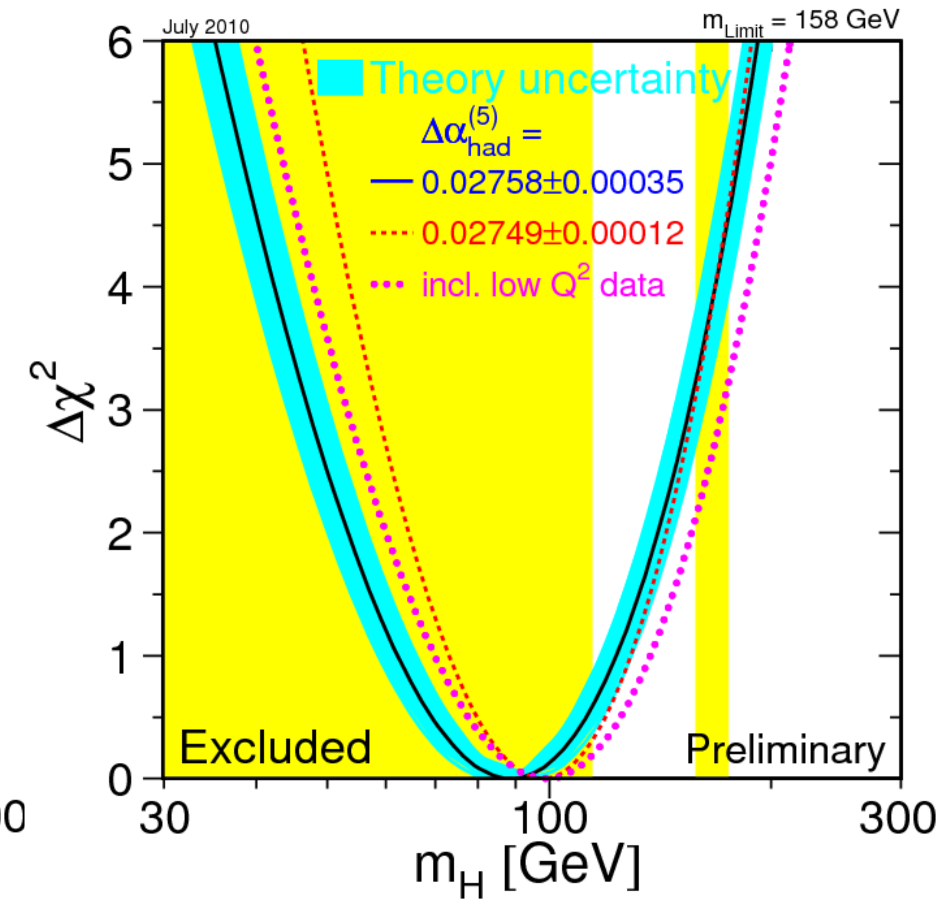
Hadron Collider Physics Symposium 2010

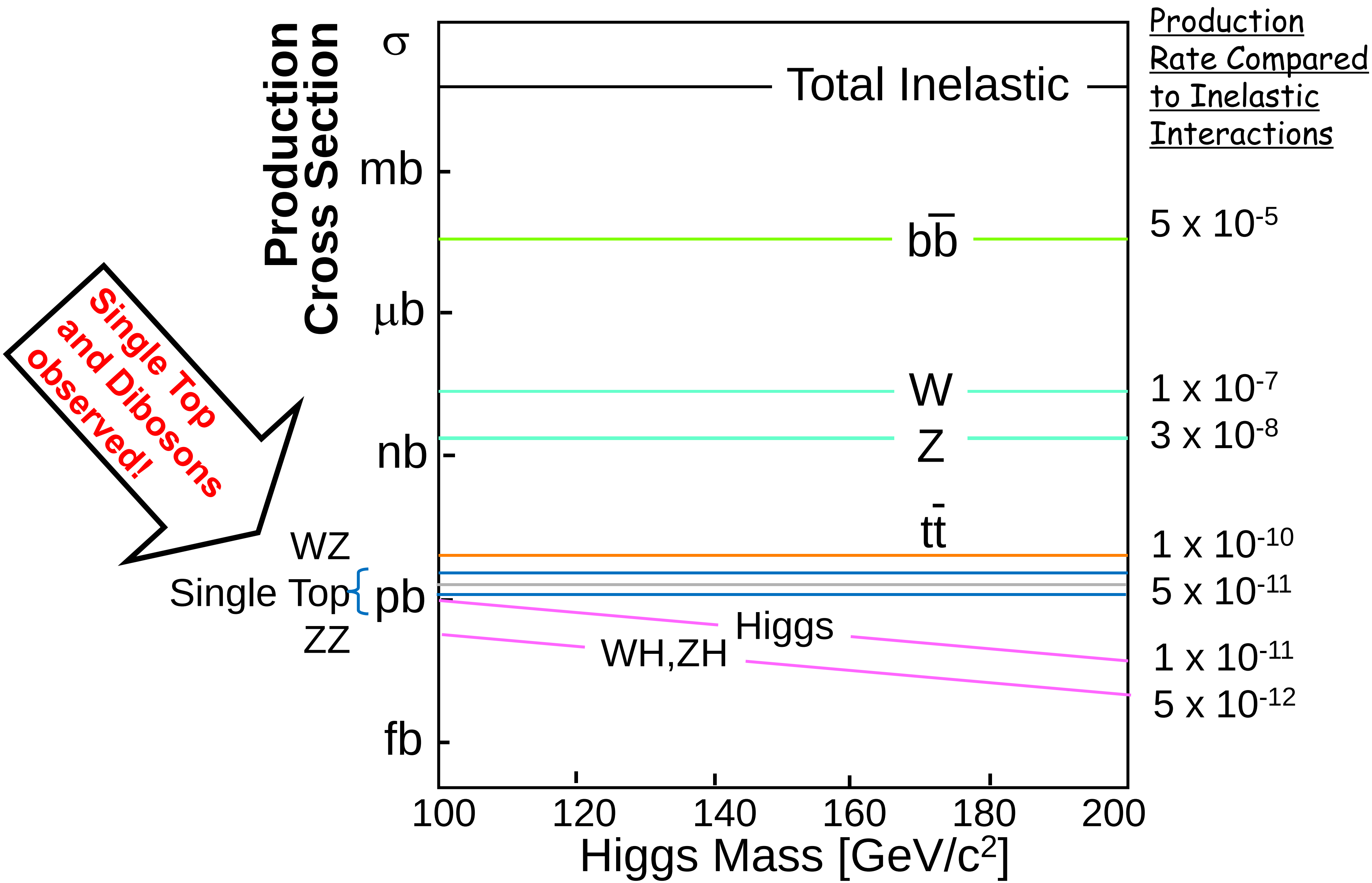
Present Knowledge

- The Higgs boson enters in Standard Model interactions via radiative corrections
  - Indirectly bound Higgs mass by precision m_W and m_{top} measurements
  - 95% CL m_H<158 GeV/c^2 (including LEP limits, 114<m_H<185 GeV/c^2)



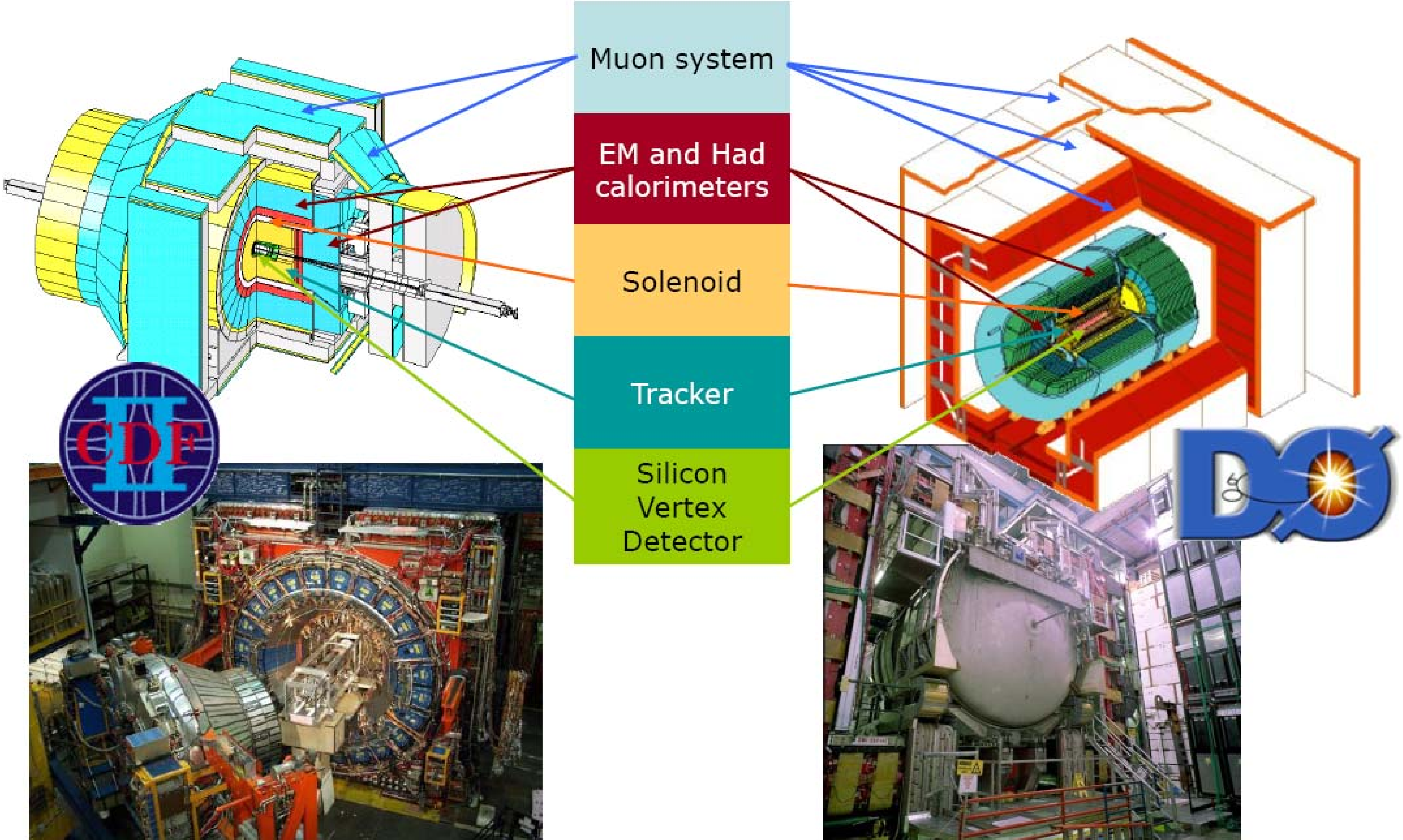


Road to the Higgs at the Tevatron

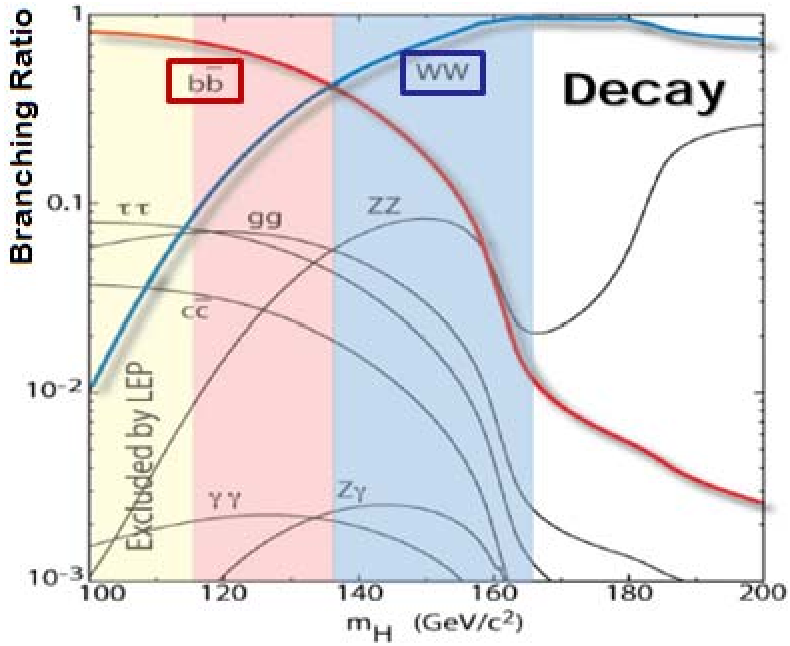


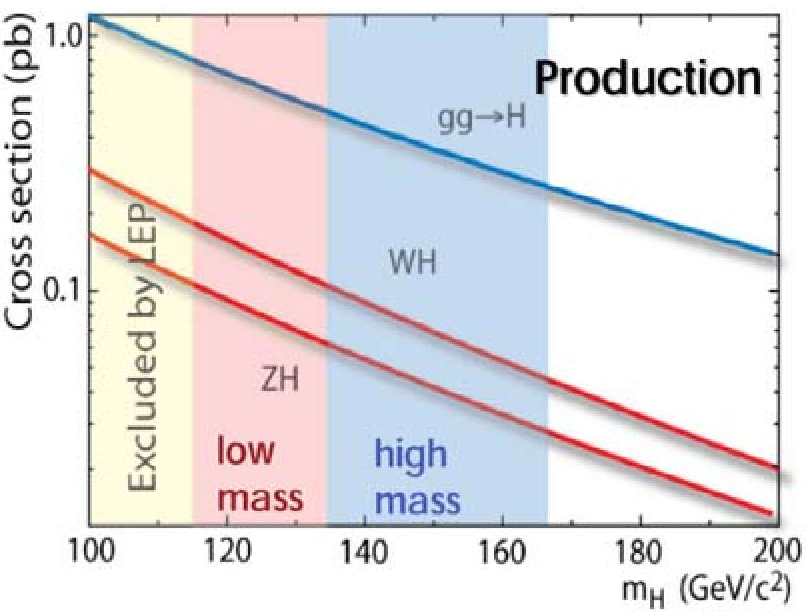
The Tevatron Experiments

- Multipurpose detectors
  - lepton ID, b-jet ID, jets and missing energy measurements



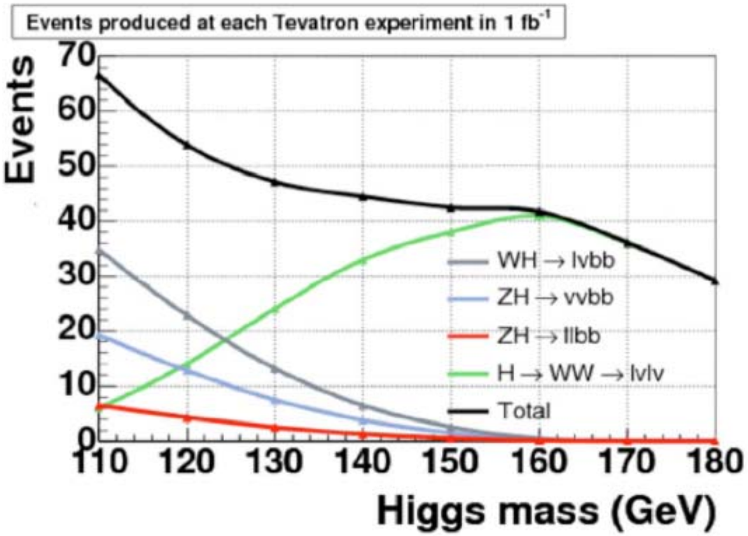
Searching for Higgs @Tevatron



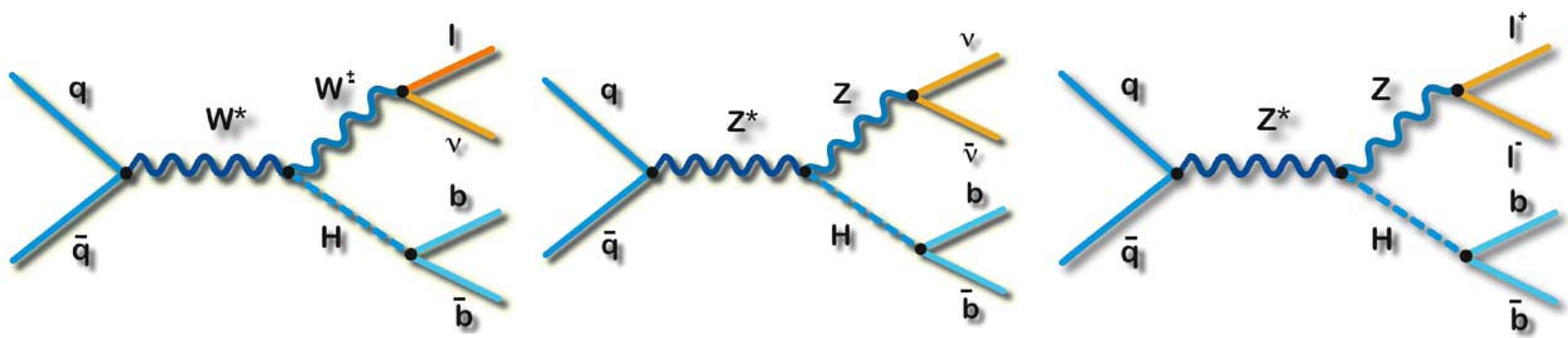


- Separate according to decays
- This talk: Low mass
  - ➢ m_H<135 GeV/c^2
- Decays dominated by H→bb
  - Identify Higgs by its b decays
- Direct production gg→H→bb has overwhelming QCD background
- Associated production WH/ZH, presence of the extra vector boson reduces backgrounds
  - Leptonic decay (into either electron or muon) gives a distinct signature for efficient triggering
  - MET reduces multijet background
- WH/ZH: Main low mass channels

Low Mass Channels



Prod+Decay Channel	events/fb @ 115 GeV/c²	events/fb @ 165 GeV/c²
WH→lvbb	28	0.1
ZH→vvbb	16	0.07
ZH →llbb	5	0.02
H→WW→lvlv	9	38
Total	58	38



- H→WW→lvlv channel will be described in the High Mass Higgs presentation

Low Mass Higgs Search Strategy

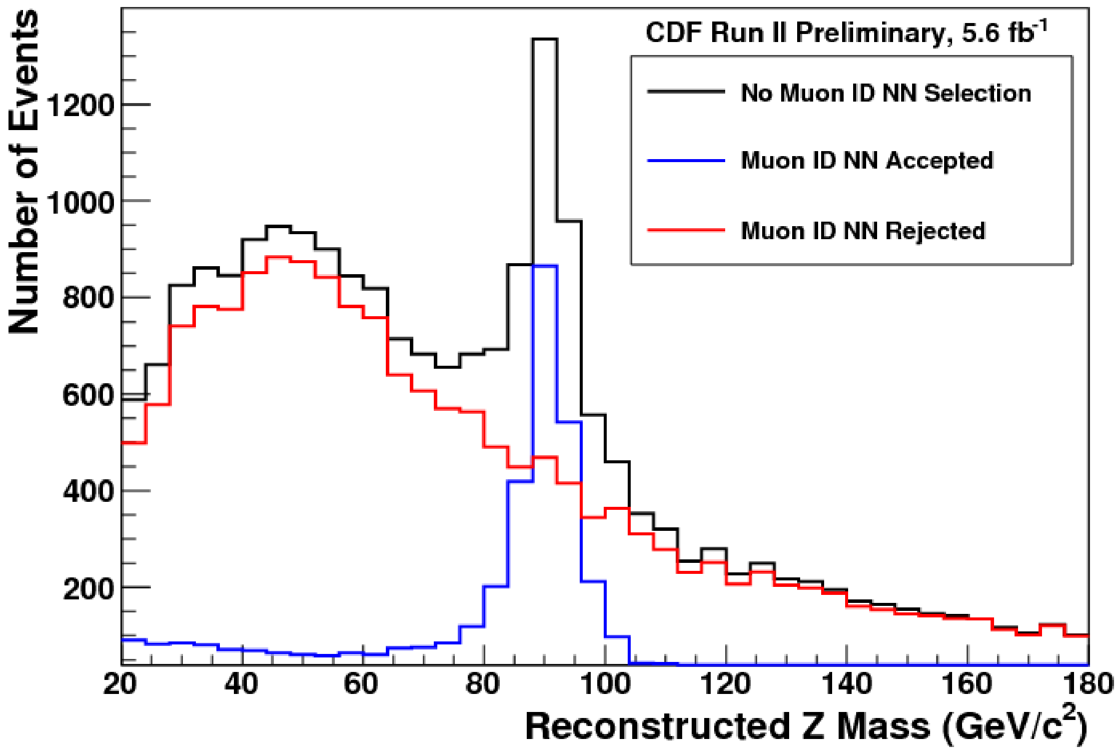
1. Maximize Signal Acceptance
   - Increase detector acceptance
   - Additional triggers, relaxed lepton ID

2. Reduce background through b-jet ID
   - "b-tagging" reduces up to ~95% of light and c-jet backgrounds

3. Multi-Variate (MV) signal/background discrimination
   - Simultaneously utilize the combined discriminating power of multiple quantities

1) Maximizing Signal Acceptance

- Example: ZH→llbb with small expected signal
- Loosen lepton selection to increase Z acceptance
  - Loose definition improves acceptance, with lots of additional BKG
  - MuonID NN removes most background while preserving signal
- Gain signal acceptance from extended lepton identification

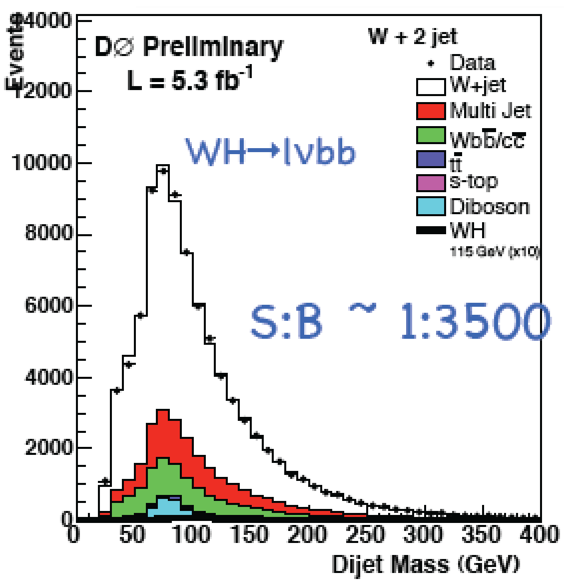


2) Reduce background through b-jet ID

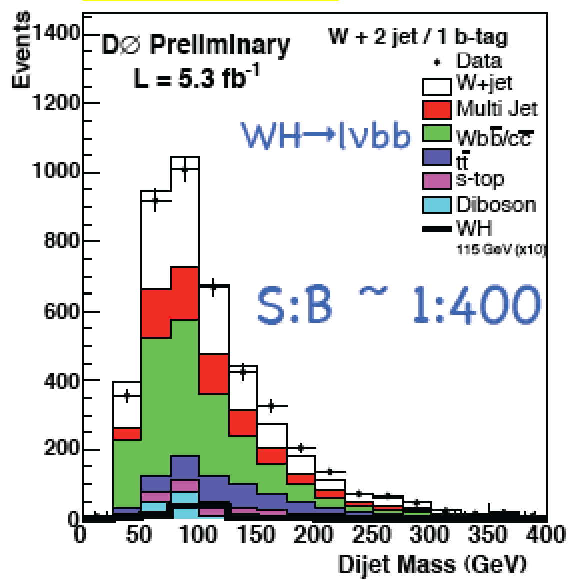
- Identification of b-jets improves the signal to background ratio

- Example WH→lvbb analysis benefits from b-jet ID
  – S:B improves with each b-jet ID'ed

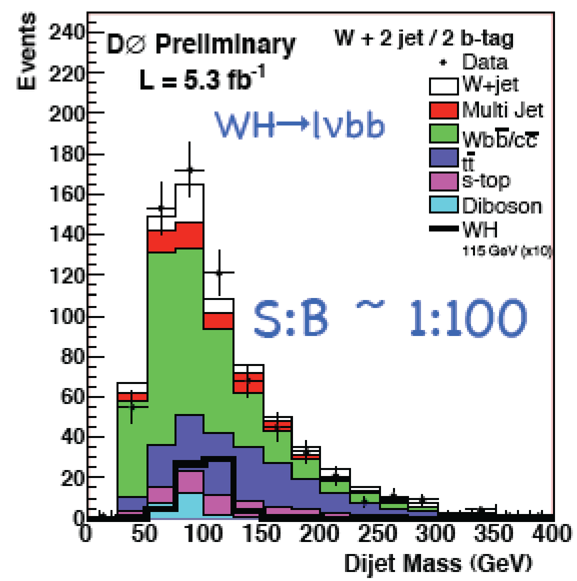
Zero b-jets identified



One b-jet identified



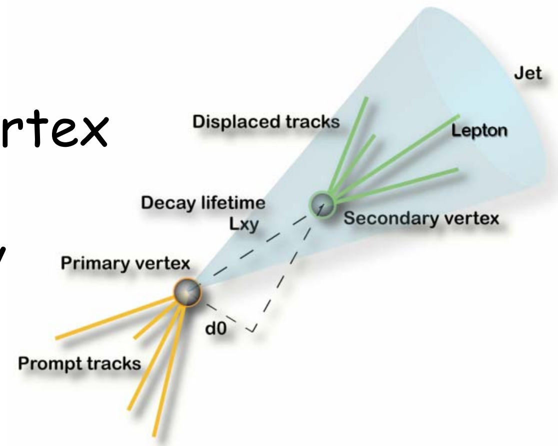
Two b-jets identified

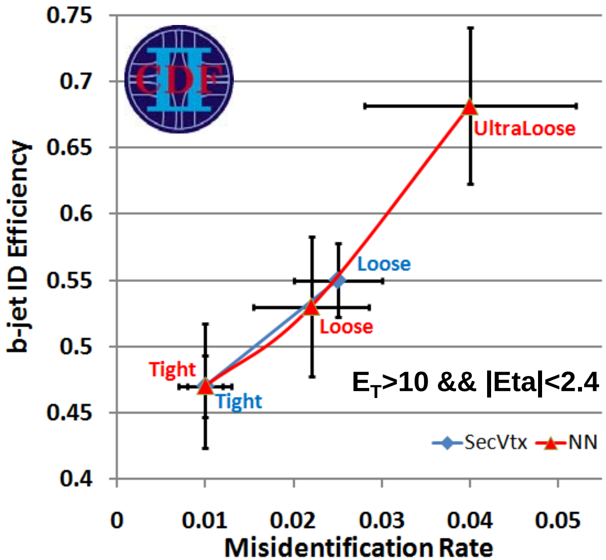


Advanced "b-tag" Algorithms

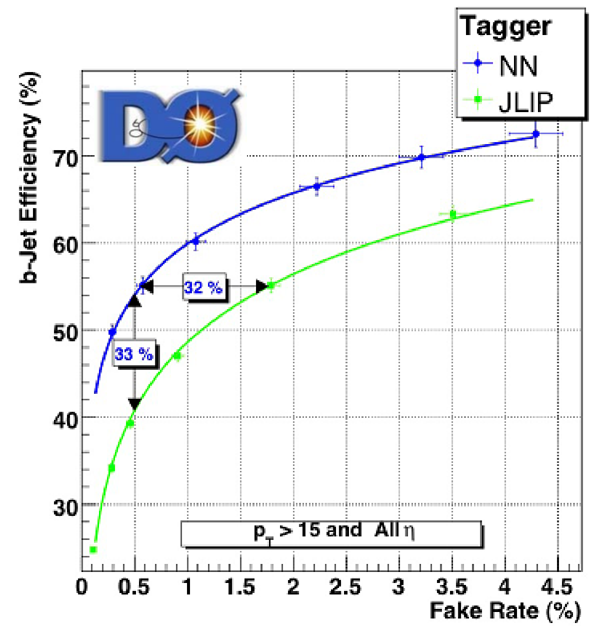
b-jet Features

- Displaced secondary vertex
- Displaced tracks
- Decays semileptonically





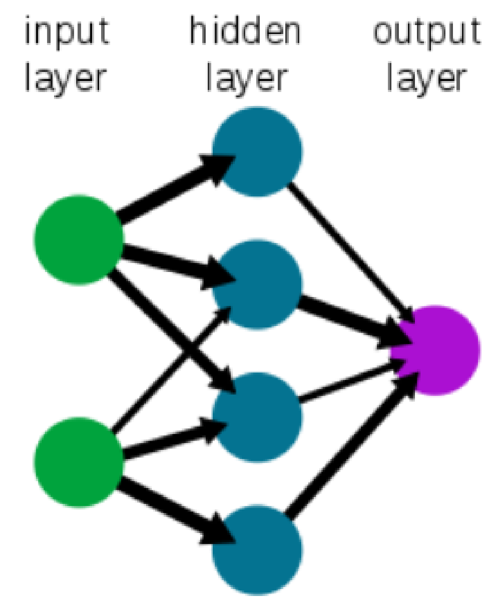
- Advanced "b-tag" algorithms use all information from jet
  - Improve efficiency while keeping misidentification rate low
- Important to improve b-jet identification efficiency to gain signal in the tagged samples
  - Double-tag channels have best S:B
  - If per-jet efficiency increases 10%, then the number of events with 2 identified b-jets increases 21%

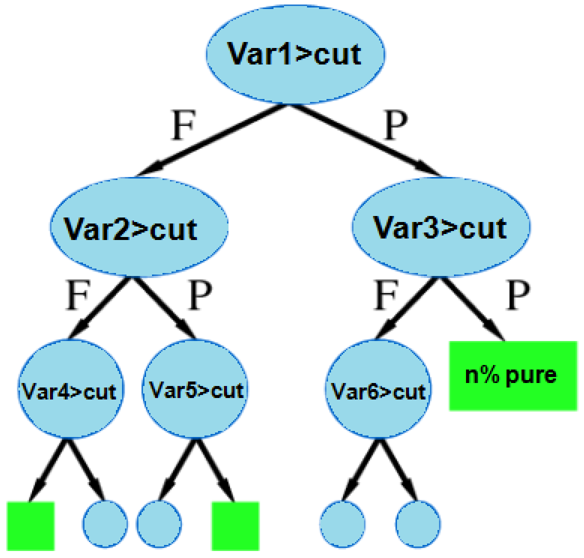


- MV: combine multiple discriminants into a stronger one
  - Improve analyses by ~20% with respect to leading two variables
  - Correlations useful
- Common MV Discriminants:
  - Artificial Neural Network (NN)
  - Boosted Decision Trees (BDT), Random Forests (RF)
  - Matrix Element Probabilities (ME)
  - ➢ They have similar performance

✓ Observed ~pb processes with MV tools
  - Single top, also WW,WZ (in lvqq final state)

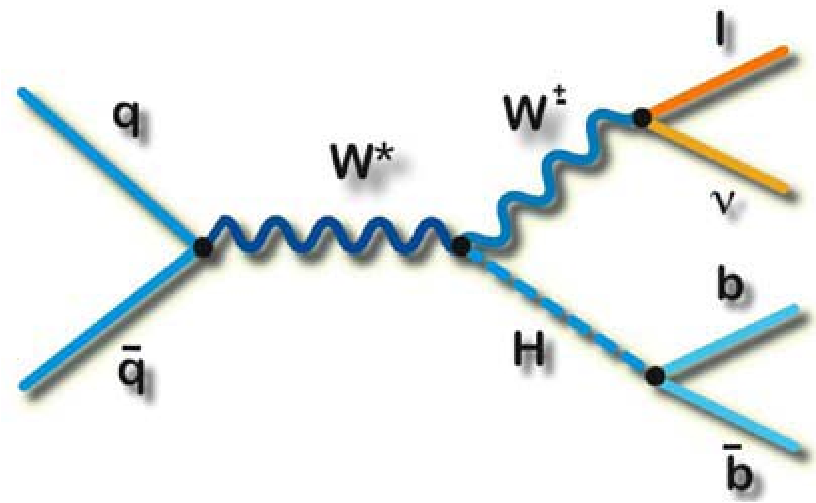
- Caveat: recently, our primary sensitivity gains don't come from MV
  - Mainly from improved signal acceptance





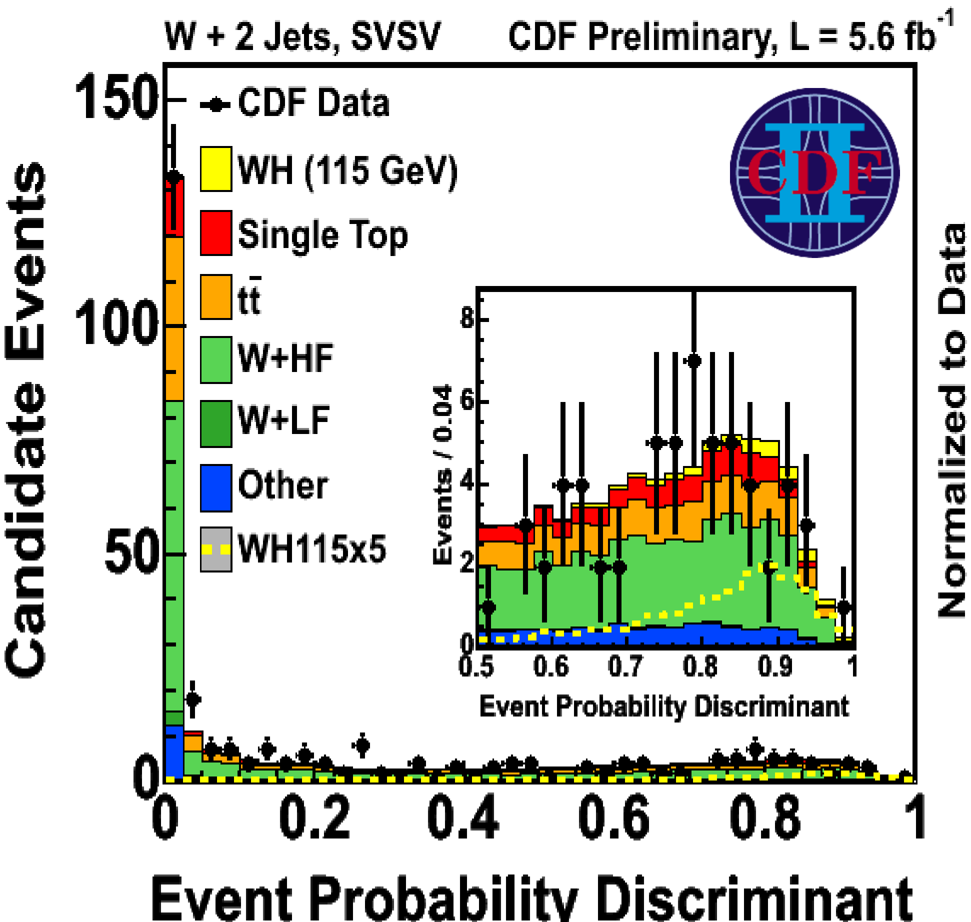
WH→lvbb

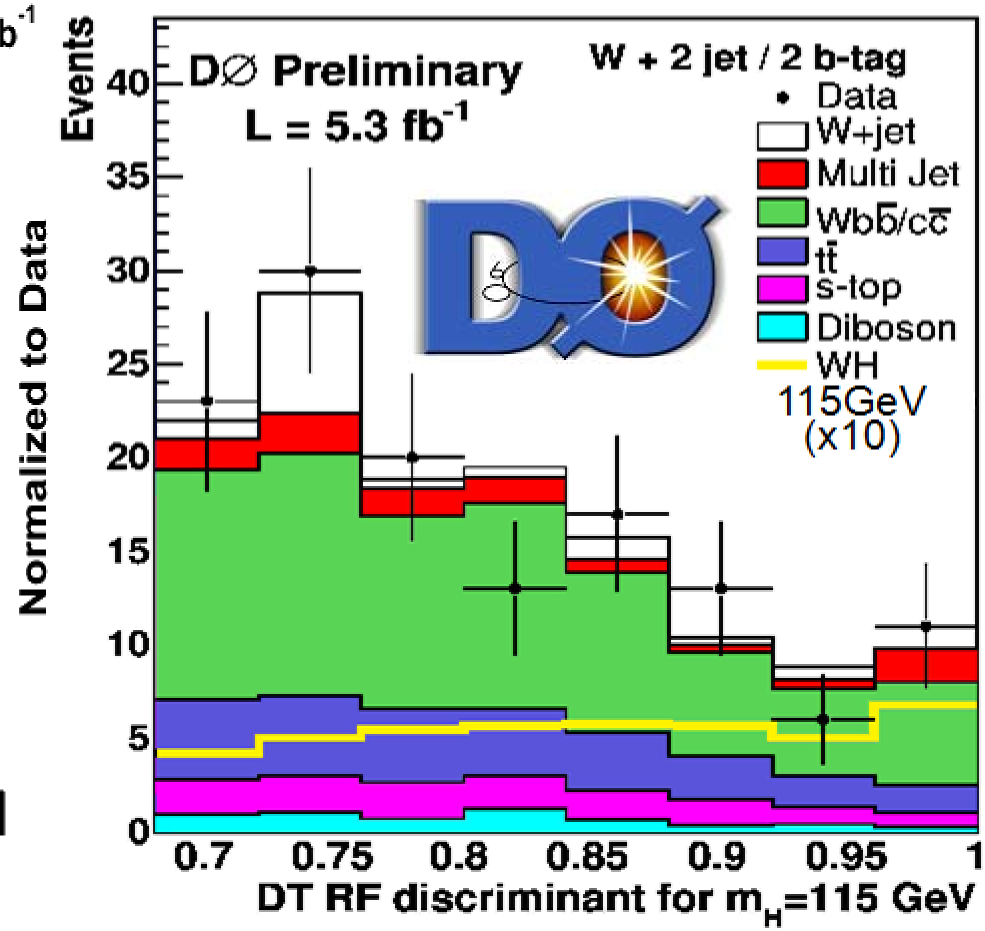
- Event Selection
  - 1 high P_T e or μ (>15GeV DØ, >20GeV CDF)
  - large missing transverse energy (>20GeV)
  - 2 or 3 jets (>20GeV), at least one with b-jet ID
- Main backgrounds
  - W + heavy-flavor jets
  - Mistags (light-flavor jets mis-ID'ed as b-jets)
  - QCD multi-jet (jet mis-ID'ed as lepton)
  - Top, dibosons



WH→lvbb

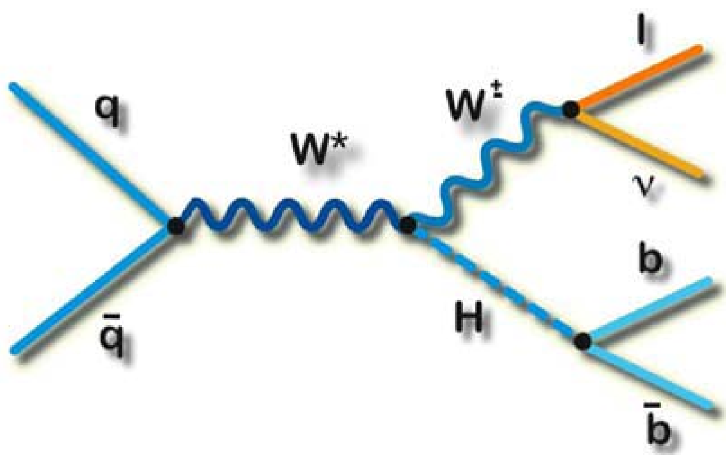
95% CL Limit for m_H=115 GeV/c²	Observed (Expected) [x σ_{SM}]	Comments
CDF Matrix Element 5.6 fb^{-1}	3.6 (3.5)	2 and 3-jets
CDF Neural Network 5.7 fb^{-1}	4.5 (3.5)	2-jets
DØ Random Forest 5.3 fb^{-1}	4.1 (4.8)	2 and 3-jets

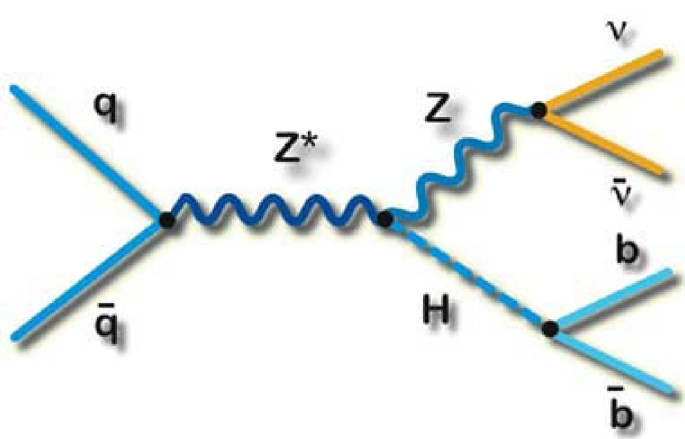




VH→MET bb

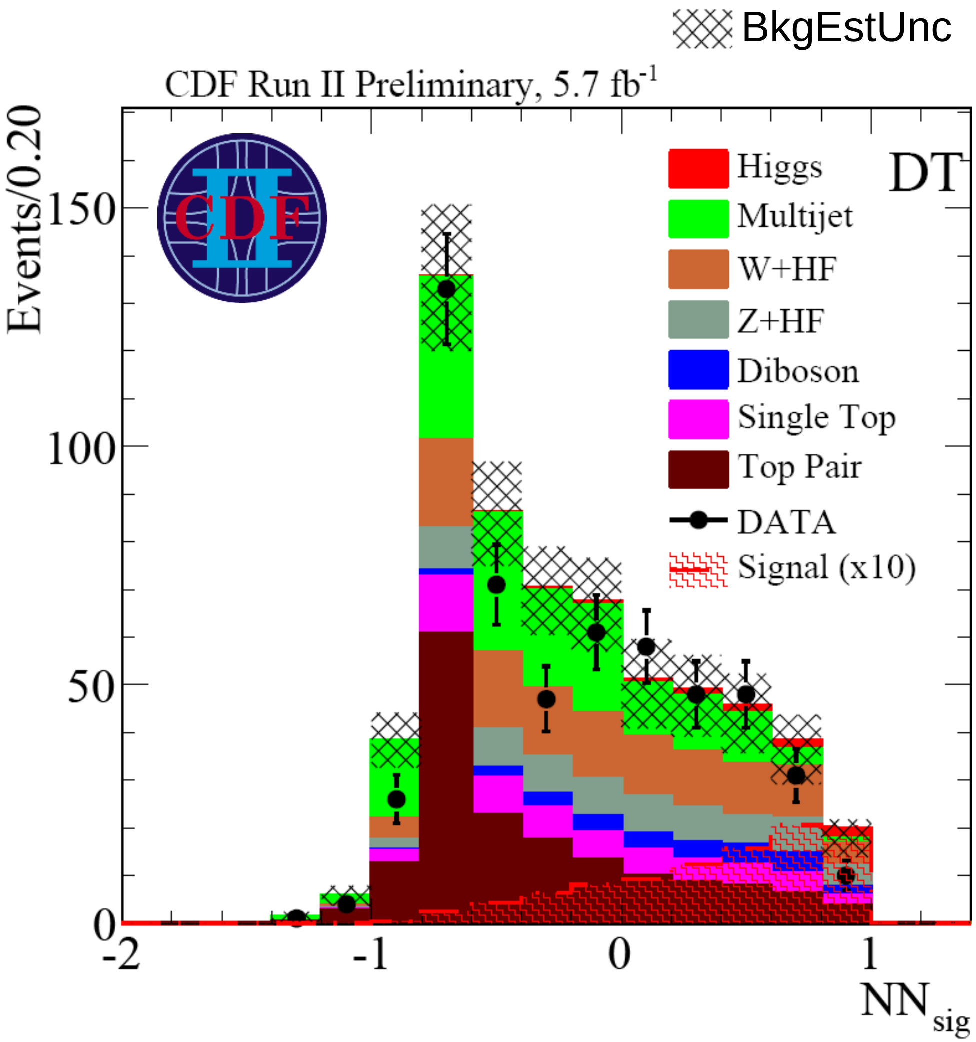
- Large signal statistics, but has large background from multi-jet processes
- Has signal contributions from:
  - ZH→vvbb, WH→(l)vbb (l not identified)
- <u>Event Selection</u>
  - large missing transverse energy (>40GeV DØ, >50GeV CDF)
  - 2 or 3 jets (>20GeV DØ, >35,25,15GeV CDF), ≥ one with b-jet ID
  - Exclude identified leptons, avoid overlap with other VH searches
- <u>Main Backgrounds</u>
  - QCD multijet (MET from Instrumental effects)
  - W/Z+jets, top, diboson (Real MET)

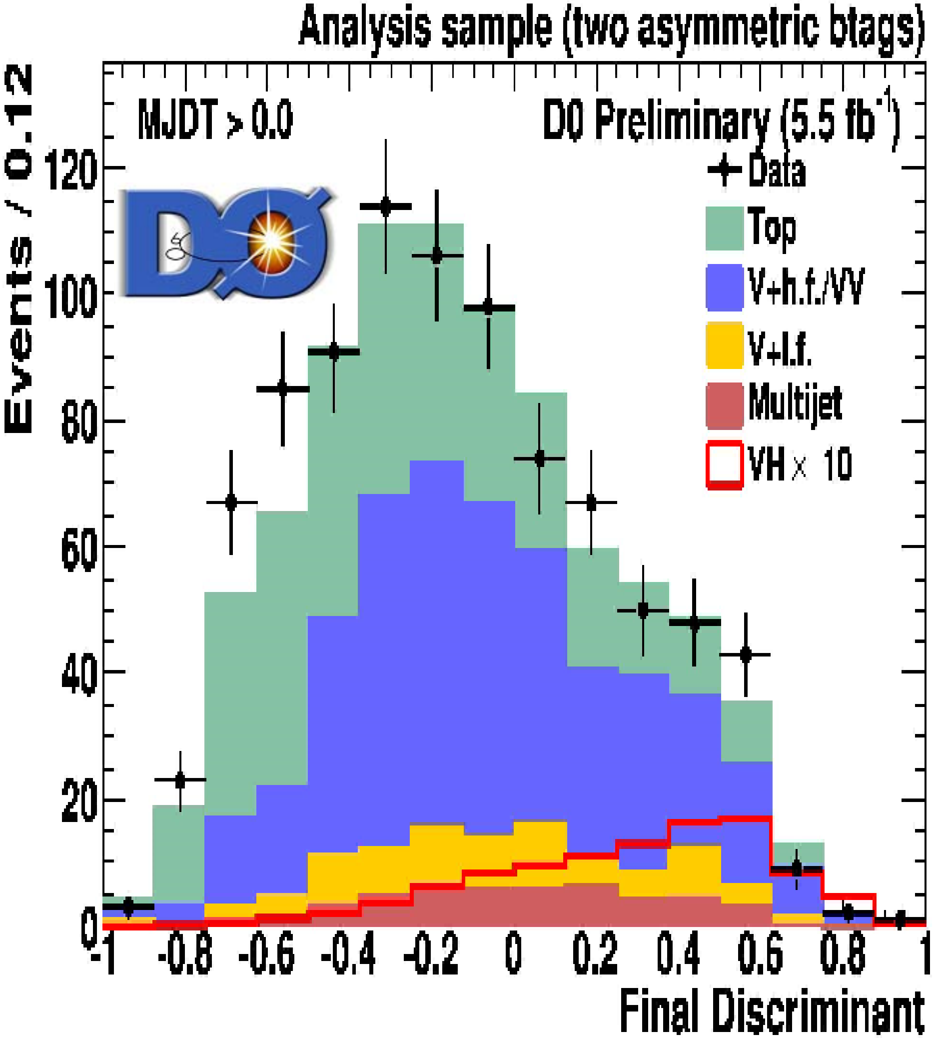




VH→MET bb

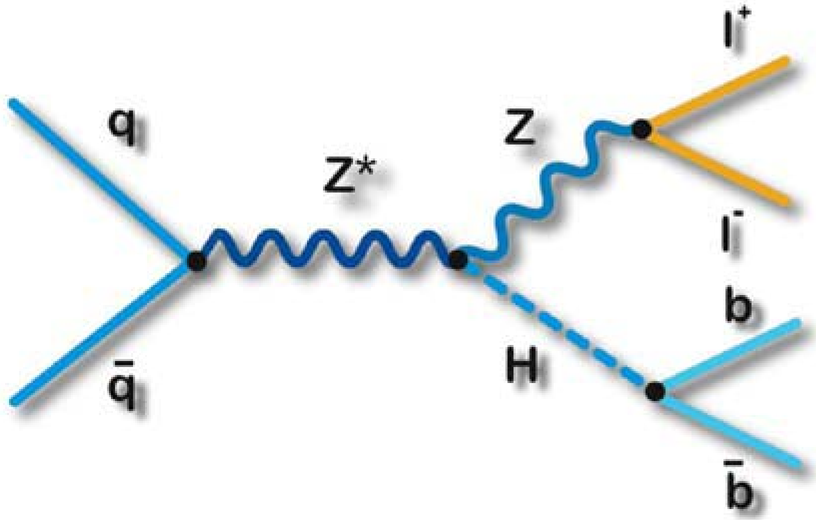
95% CL Limit for m_H=115 GeV/c^2	Observed (Expected) [x σ_{SM}]
CDF Neural Network 5.7 fb^{-1}	2.3 (4.0)
DØ Decision Tree 5.5 fb^{-1}	3.4 (4.2)





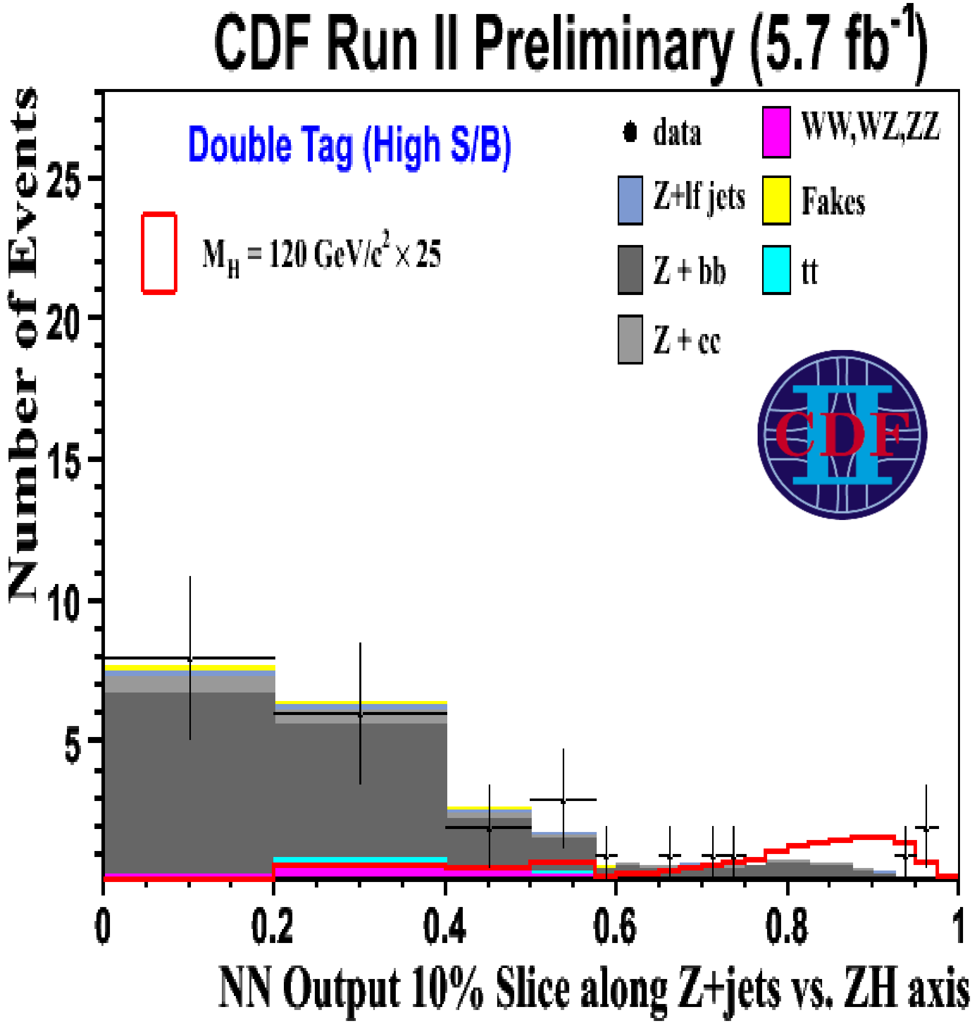
ZH→llbb

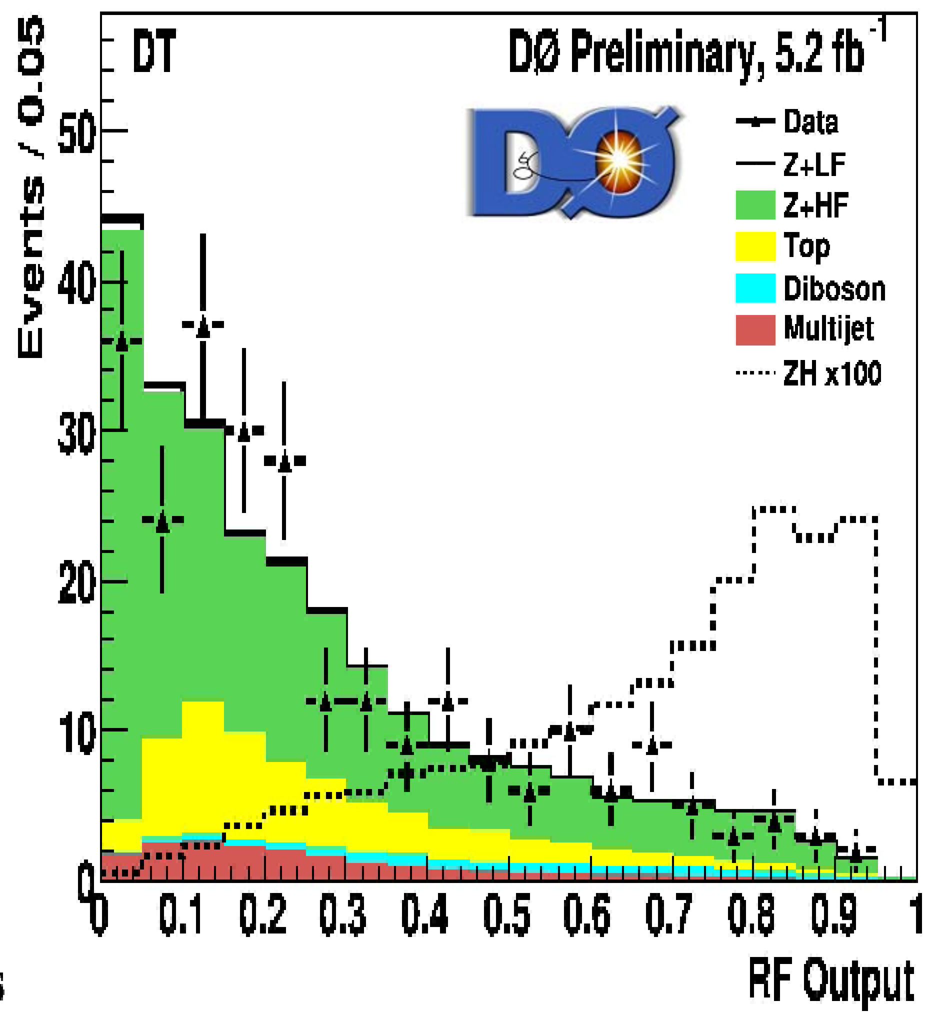
- Low signal statistics, but cleanest channel
  - Fully reconstructible final state, Z resonance
- <u>Event Selection</u>
  - Select Z candidate decaying into ee or μμ
  - 2 or 3 jets (>20,15GeV DØ, >25,15GeV CDF), >=1 with b-jet ID
- <u>Main Backgrounds</u>
  - Z+jets
  - Diboson, ttbar
- Reconstruction of Z resonance controls background rates, allowing for looser lepton selection requirements



ZH→llbb

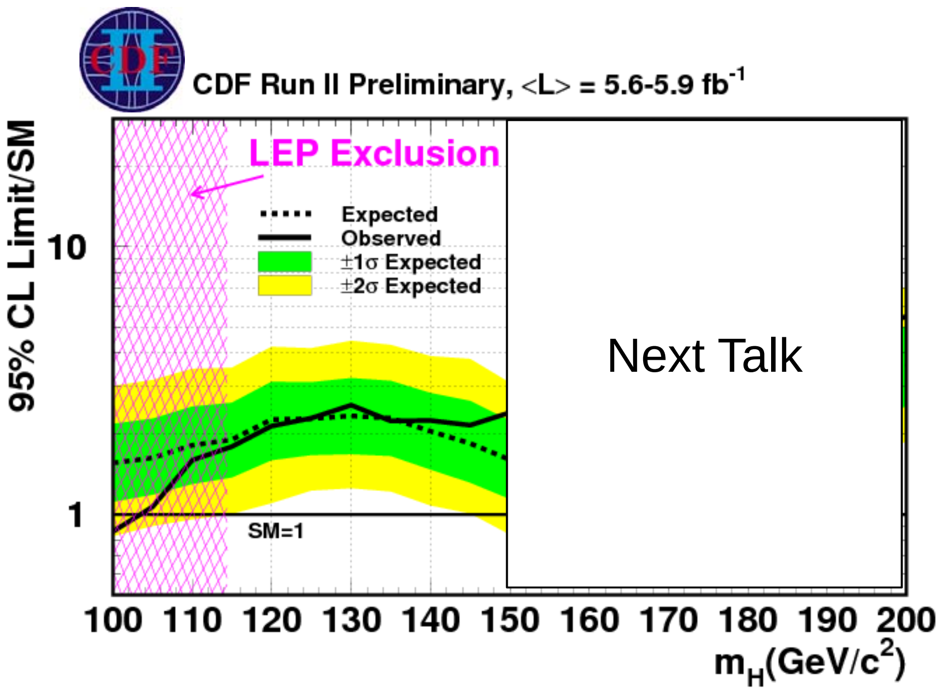
95% CL Limit for m_H=115 GeV/c²	Observed (Expected) [x σ_{SM}]
CDF Neural Network 5.7 fb^{-1}	6.0 (5.5)
DØ Random Forest 5.2 fb^{-1}	8.0 (5.7)

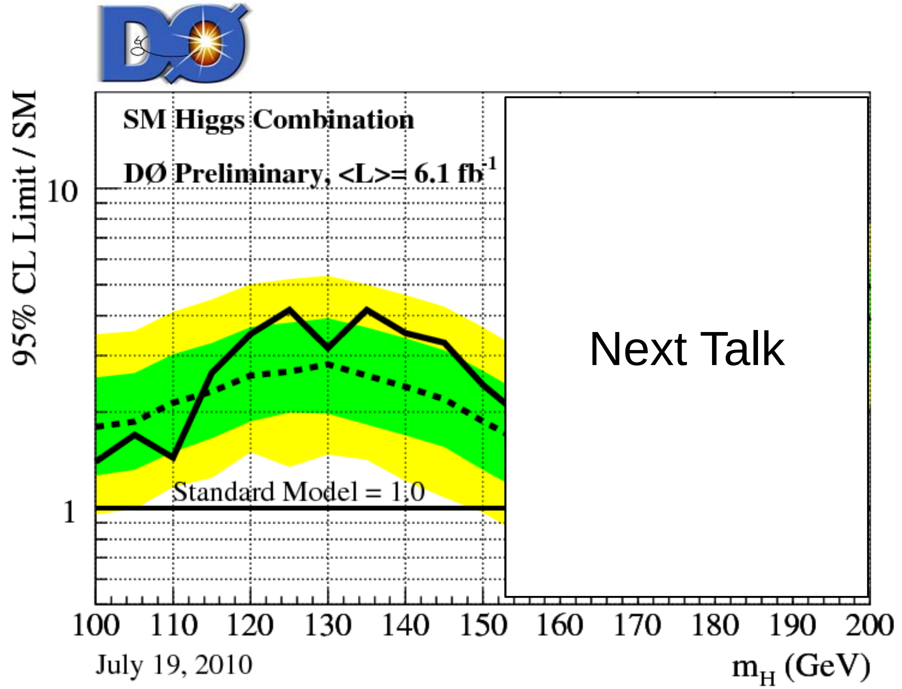




All Channels Combination

- With present dataset, no single channel has significant sensitivity to exclude the Low Mass Higgs
- Combine different channels to maximize sensitivity
  - The analysis were divided into mutually exclusive sub-categories

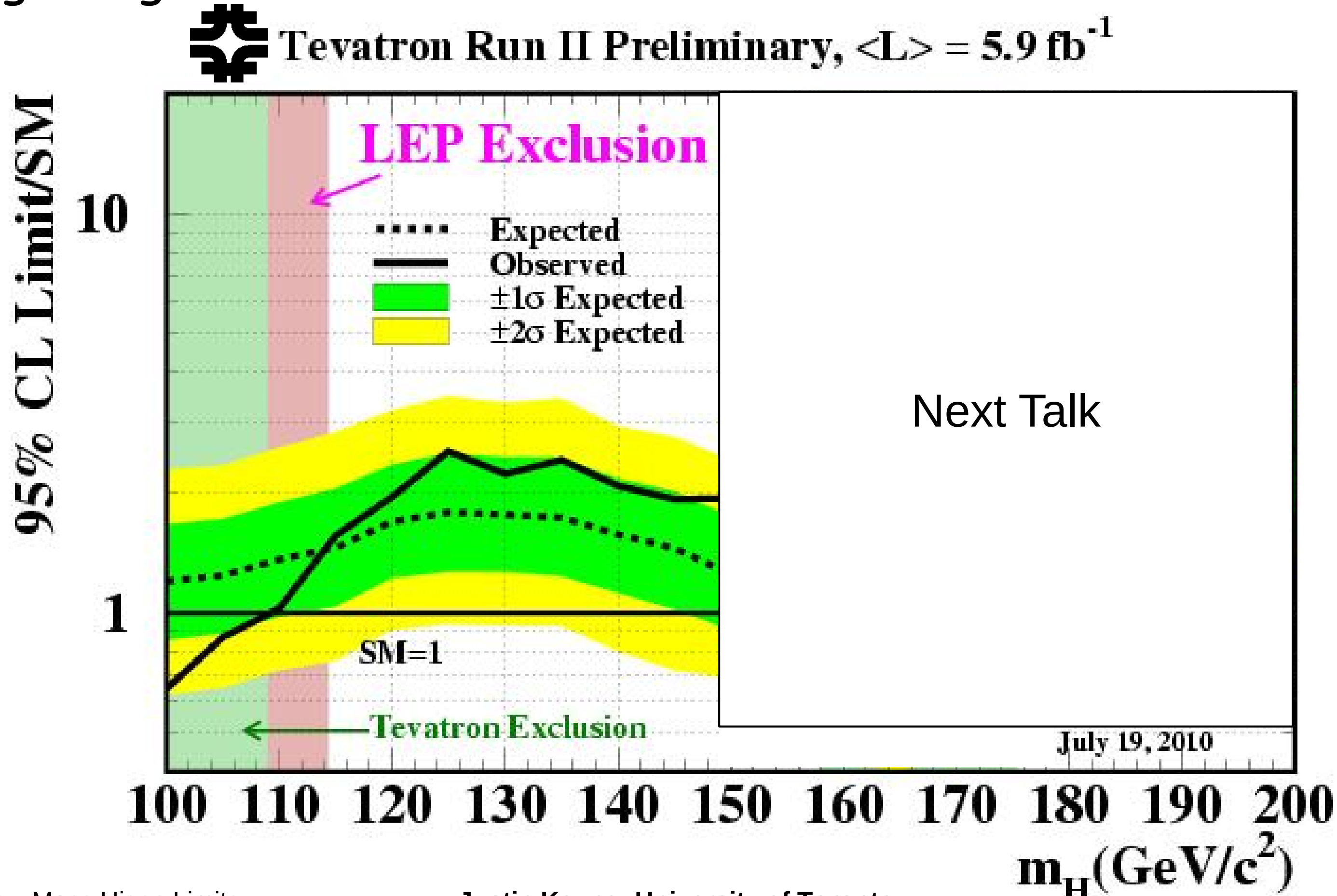




95% CL Limit for m_H=115 GeV/c^2	Observed (Expected) [x σ_{SM}]
CDF Combined	1.79 (1.90)
DØ Combined	2.65 (2.31)

CDF and DØ Combination

- Combine the results from the two Tevatron experiments
- Tevatron Combined
  - 95% CL limit for m_H=115 GeV/c^2: observe(expect) 1.56 (1.45) x σ_{SM}
  - Expected limit is 1.8 x σ_{SM} or below for entire low mass range
  - Beginning to exclude some masses below the direct LEP limits

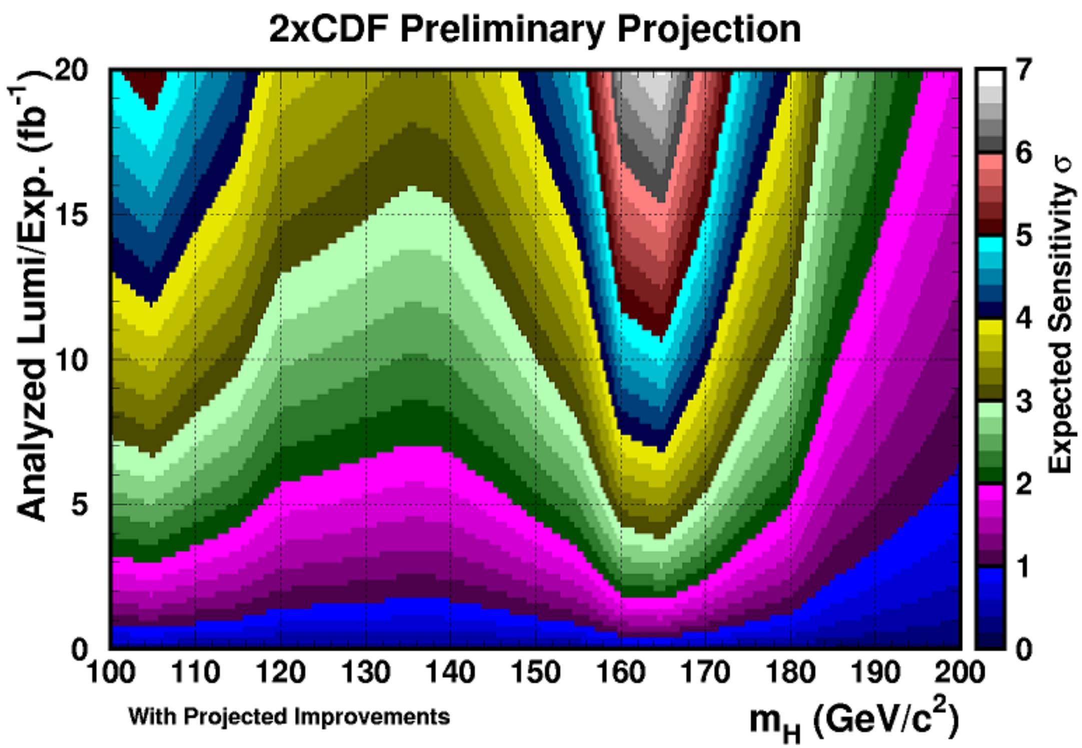


Outlook

- CDF and DØ each have about 8 fb^{-1} recorded, and is each projected to collect ~2 fb^{-1} more per year
- Tevatron will run at least one more year, can expect to have 10 fb^{-1} per experiment
- Can expect to achieve 3σ sensitivity at m_H=115 GeV/c^2

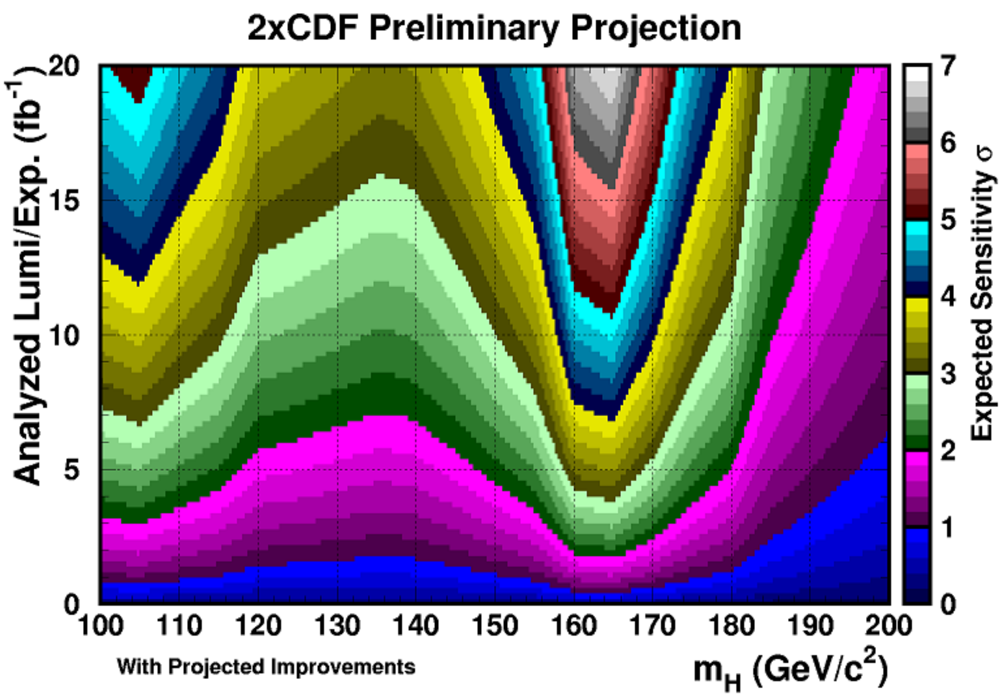
<u>Upcoming Improvements</u>

- migration of existing improvements across channels
- expanded e/μ selection
- final states with taus
- better b-tagging
- improved jet energy resolution



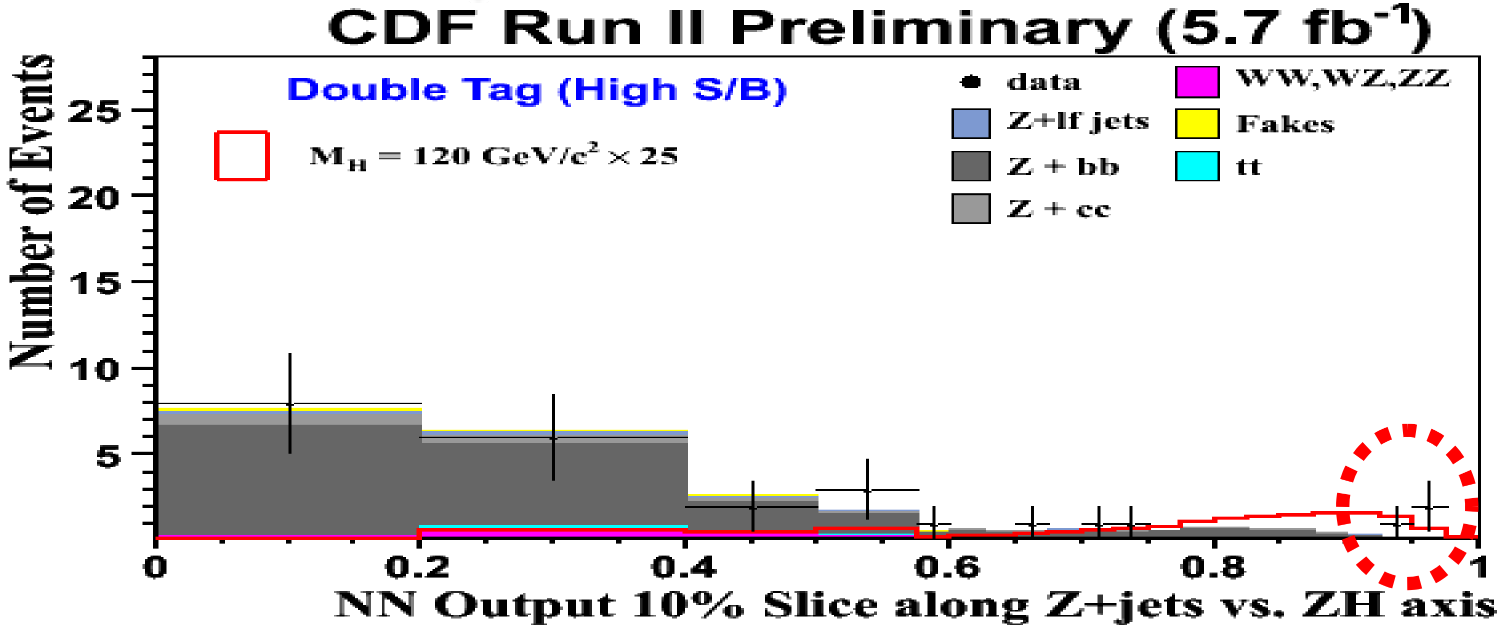
Conclusions

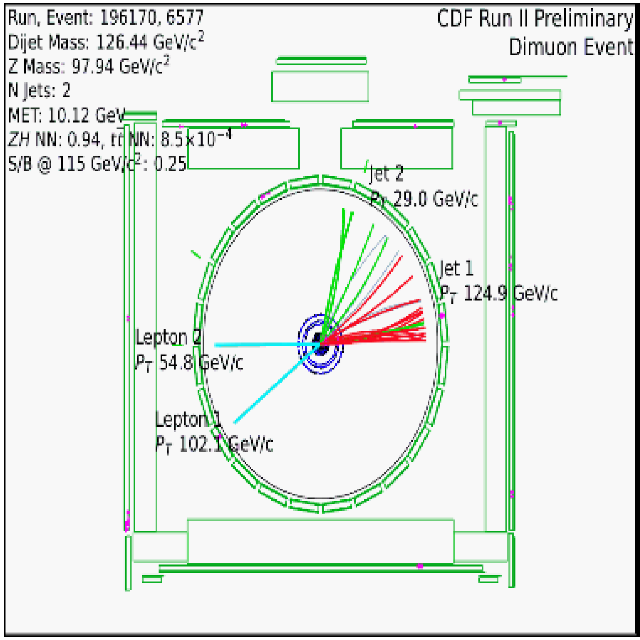
- CDF+DØ Combined 95% CL limit for m_H=115 GeV/c^2 is observed (expect) 1.56 (1.45) x σ_{SM}
- Tevatron is already excluding some masses below the direct LEP limits
- With projected improvements, Tevatron expects to be able to exclude SM Higgs (if it does not exist) over the entire mass range between 100 and 185 GeV/c^2

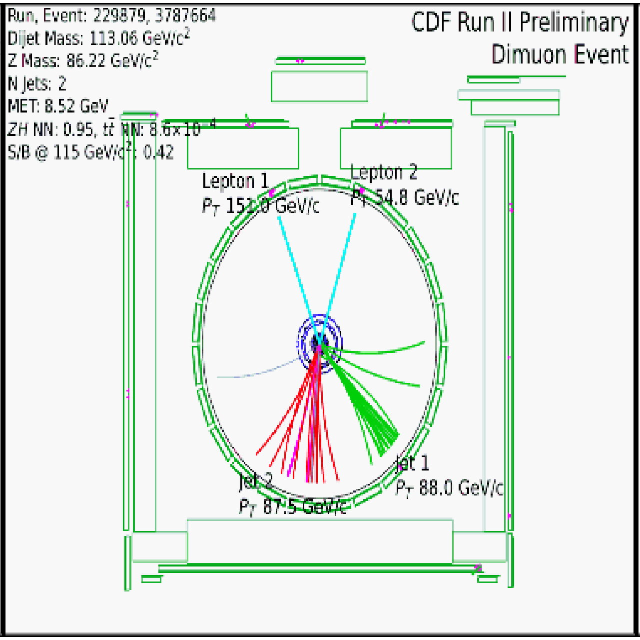


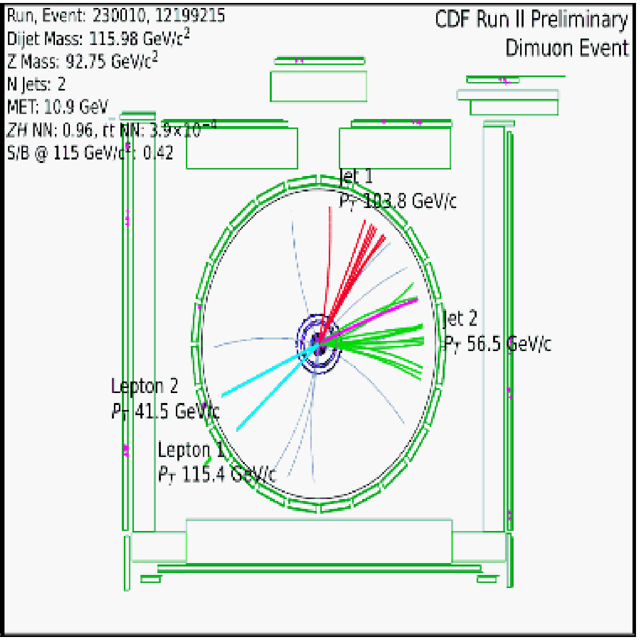
- With 15 fb^{-1} of data per experiment, expected sensitivity is above 3σ over the entire mass range!

Backup: Candidate ZH Events





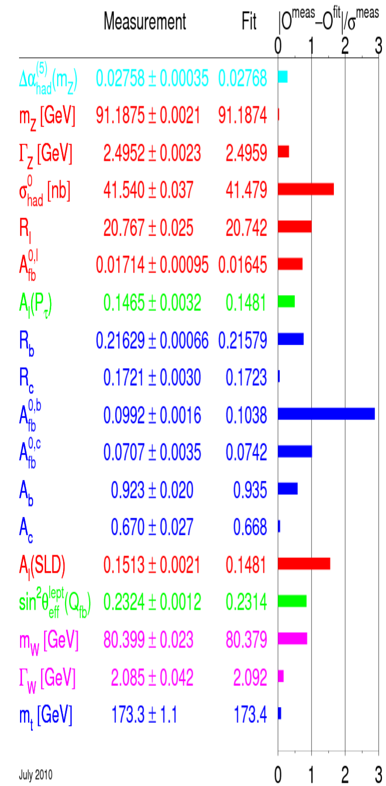


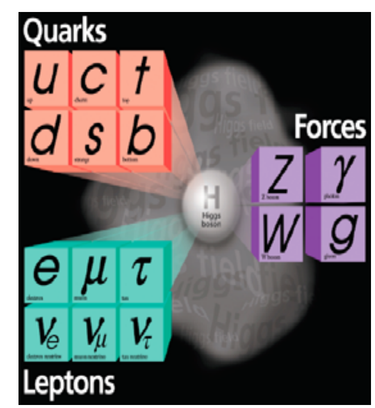


Backup: SM Higgs Motivations

- The Standard Model says that
  - Matter is made out of fermions (quarks and leptons)
  - Forces are mediated by bosons
- Its many predictions have been verified to incredible precision
- Shortcoming: cannot explain the different masses of the particles
- Proposal (Higgs et al): mass is not an intrinsic property of particles, but arises from their interaction with a yet unseen field
- Called the Higgs field, it interacts with particles via the Higgs boson

- Observing (or refuting the existence of) the Higgs boson is a very important test of the Standard Model

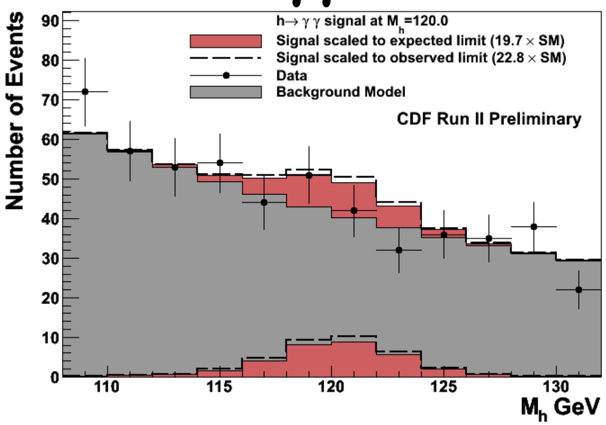


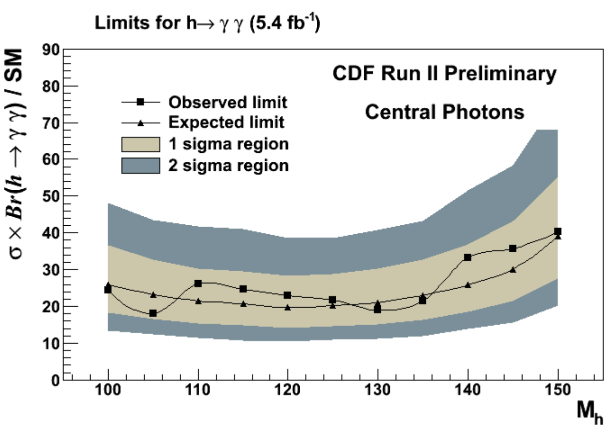


Backup: Selected Other Low Mass Higgs Channels

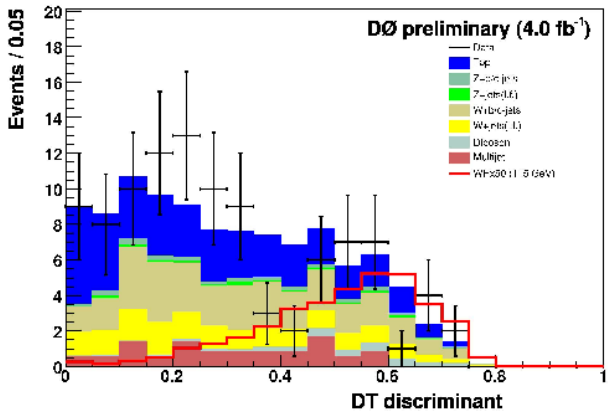
95% CL limit for m_H=115 GeV/c^2	Limit [x σ_{SM}]
CDF H→γγ Observed (Expected)	24 (20)
DØ H→γγ Observed (Expected)	16 (19)
DØ WH→τνbb Observed (Expected)	14 (22)
CDF VH→qqbb Observed (Expected)	9 (19)

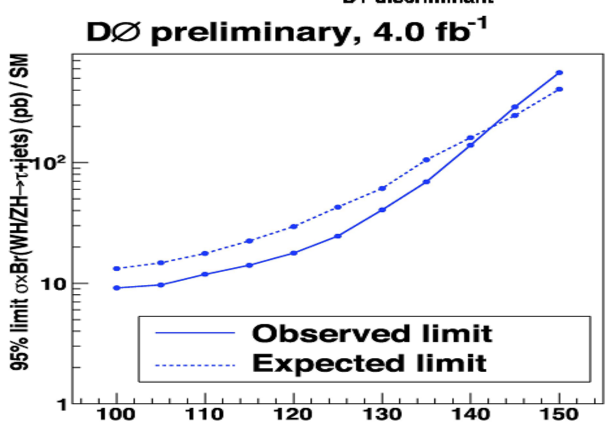
H→γγ



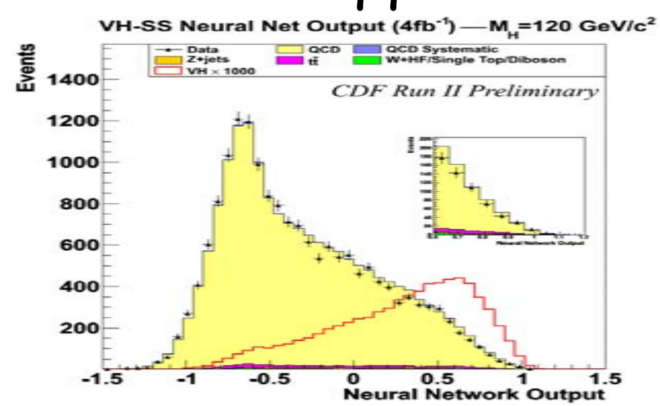


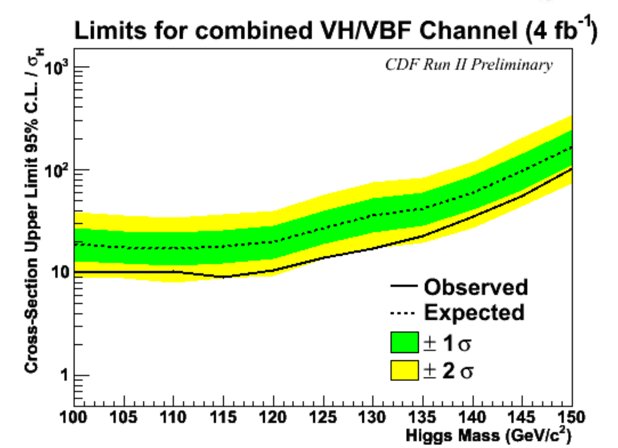
WH→τνbb





VH→qqbb





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