Search for $VH \rightarrow b\bar{b} + \not\!\!E_T$ at the Tevatron

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on behalf of the CDF and DØ collaborations

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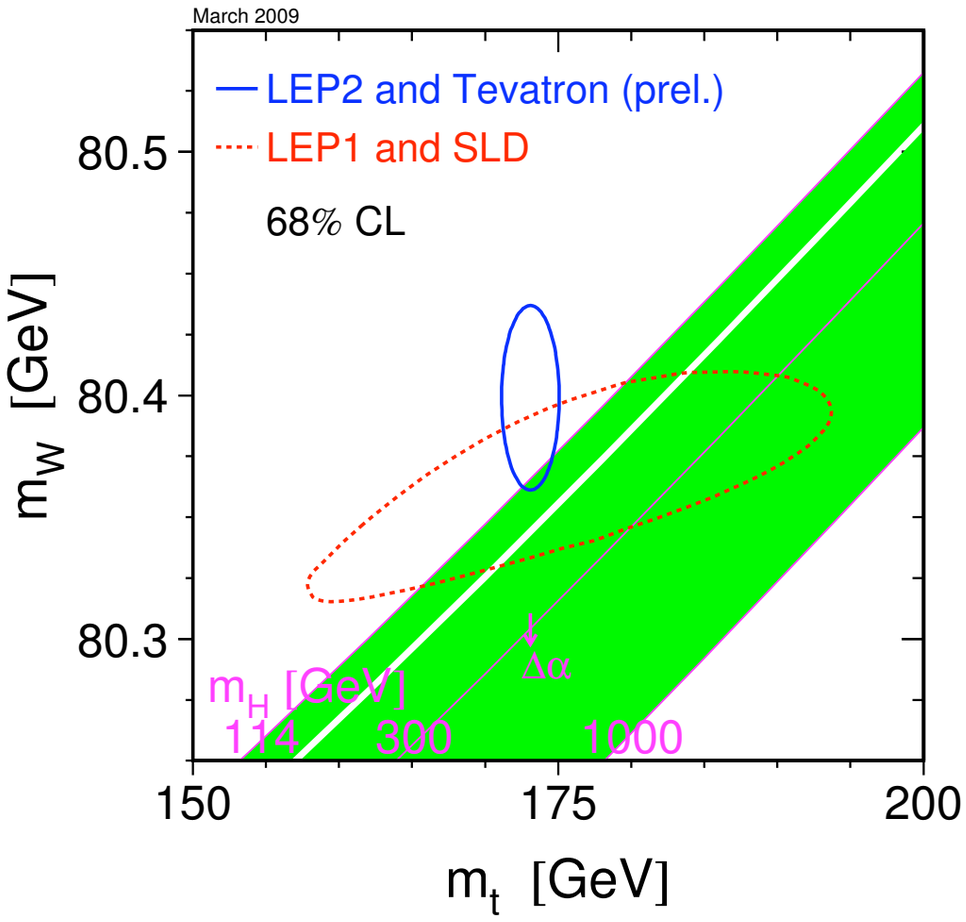
The quest for the Higgs

- SM has a broken symmetry
  - EWSB can be described by the Higgs mechanism
  - Prescribes observation of the Higgs boson
- Experimental evidence so far:
  - Direct searches at LEP exclude **m_H<114 GeV/c^2**
  - Direct searches at Tevatron exclude **160<m_H<170 GeV/c^2**
  - Indirect constraints from precision measurements (m_W and m_t) prefer low mass Higgs: **m_H<163 GeV/c^2**
- Efforts on low mass Higgs searches are key



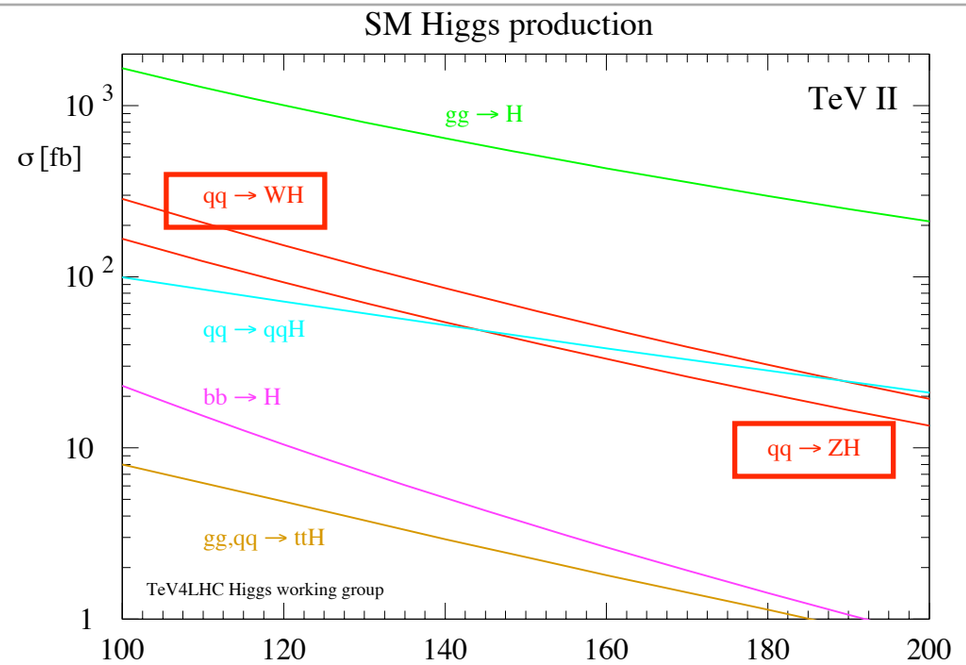
Low mass Higgs searches

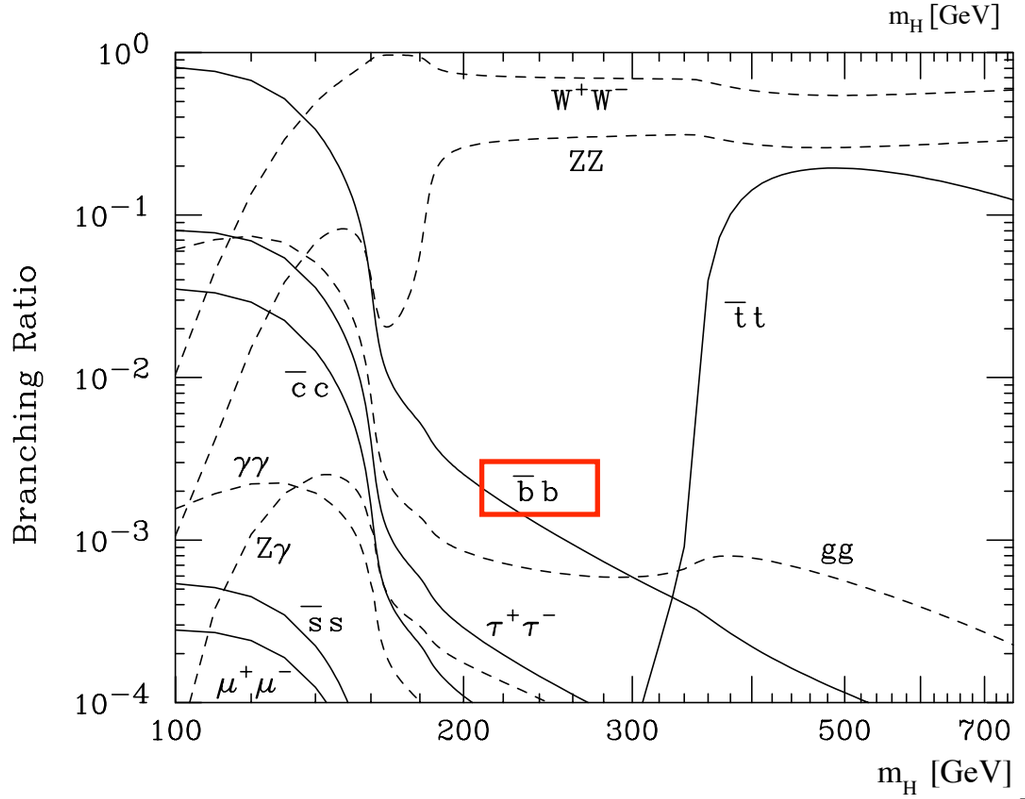
- Low mass SM Higgs production (m_H<135 GeV/c^2)
  - Decay dominated by $H \to b\bar{b}$
  - $gg \to H \to b\bar{b}$ difficult to see experimentally
- Rely on associated production, *WH* and *ZH*
  - Obvious choices: identified leptons
    - $WH \to l\nu b\bar{b}$
    - $ZH \to llb\bar{b}$

Previous two talks

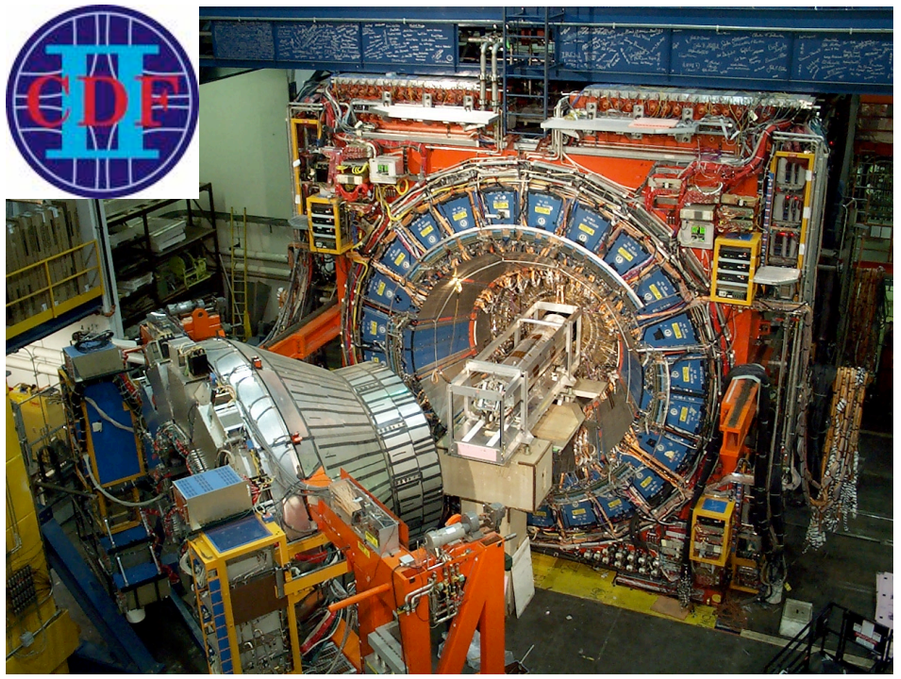
  - What's left: invisible leptons
    - $WH \to (l)\nu b\bar{b}$
    - $ZH \to \nu\nu b\bar{b}$

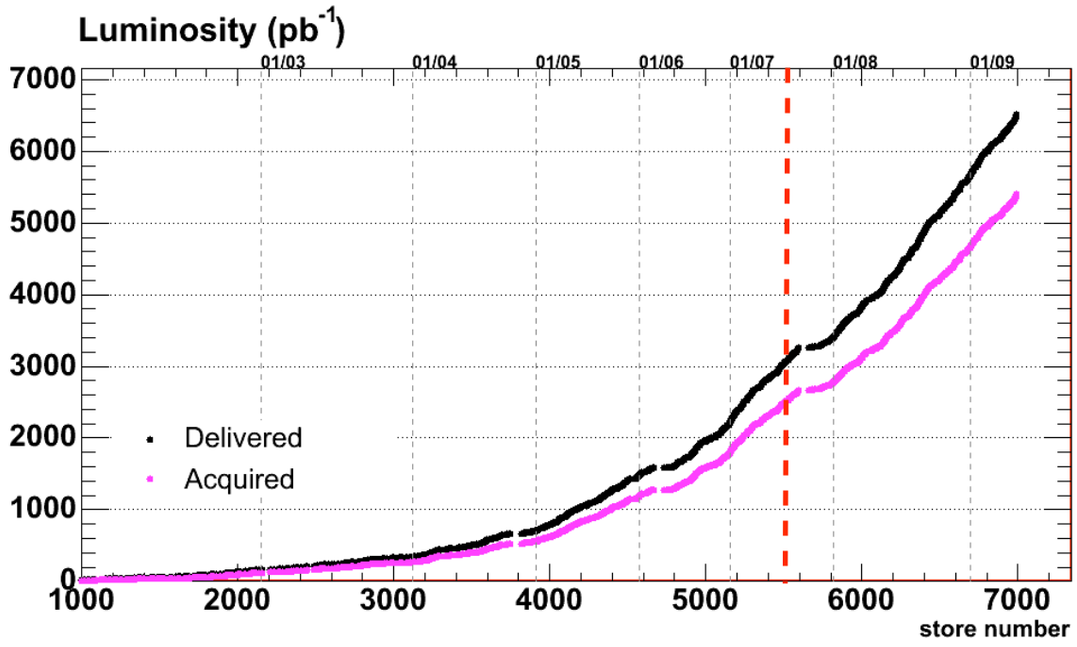
This talk

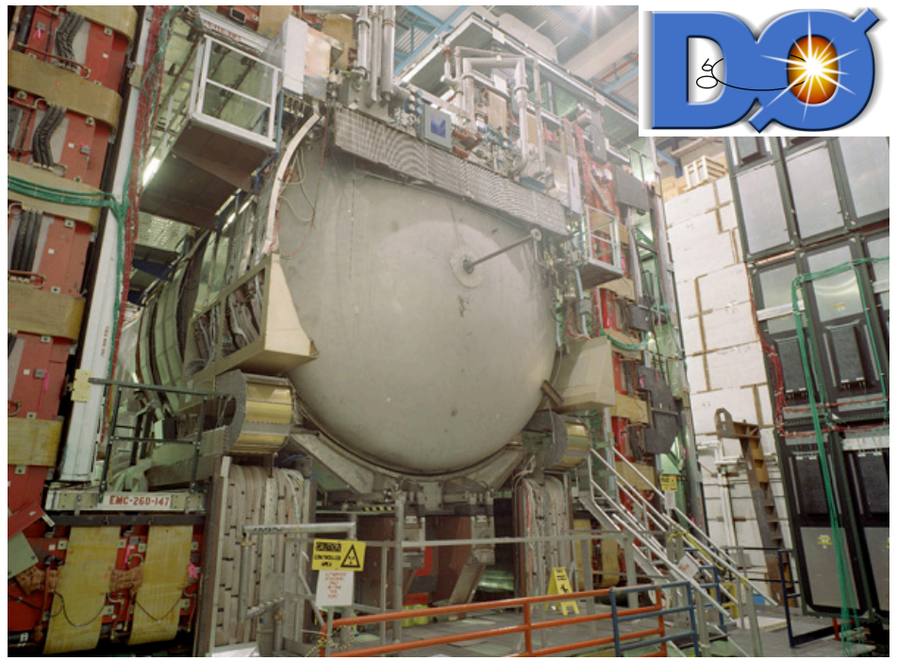




The experiments

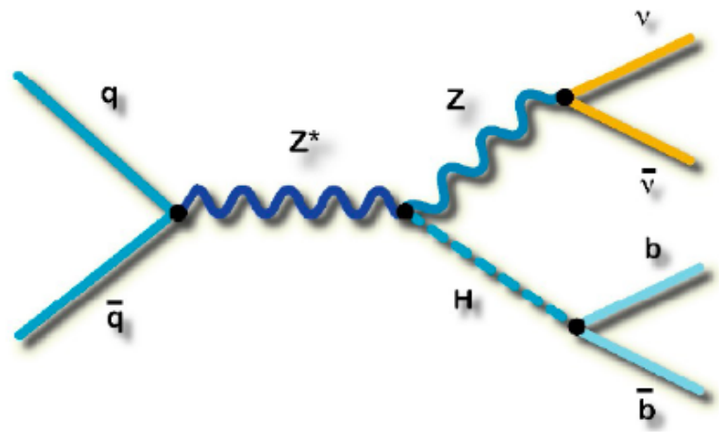






Analysis strategy

- Trigger on events with large missing E_T
- Select events with 2 or more jets
  - 3-jet events add sensitivity to $W \rightarrow \tau\nu$
- Exclude identified leptons
  - Ensures independent channel from other *VH* searches
- Backgrounds by source of missing E_T
  - Instrumental: QCD multijet
  - Real: W/Z+jets, top, diboson
- After preselection cuts, apply further cuts to reduce background
  - Identify b-jets (CDF: secondary vertex tags, DØ: neural network)
  - Identify QCD background (CDF: neural network)

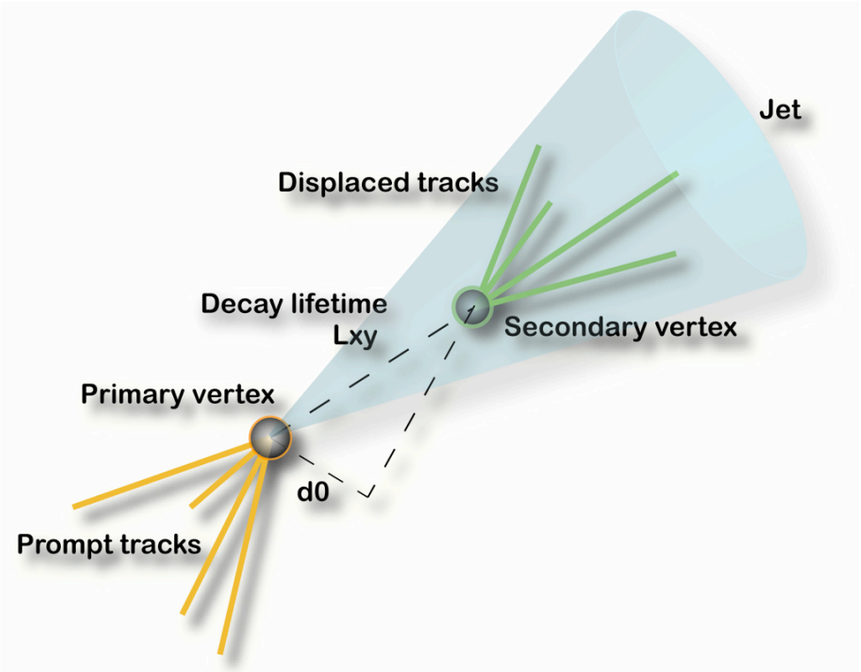


CDF preselection:
- Missing E_T>50 GeV
- 2 or 3 jets with E_T>25 GeV (>35 GeV for at least one jet)
- ΔR(jet1, jet2)>1.0

DØ preselection:
- Missing E_T>40 GeV
- 2 or 3 jets with E_T>20 GeV
- $\Delta\phi$(jet1, jet2)<165°

Identifying b-jets

- CDF- Two different secondary vertex tag algorithms: “SecVtx” (ST) and “JetProb” (JP)
  - 3 exclusive event categories depending on type of tags: ST+ST, ST+JP, ST
  - Most sensitivity from ST+ST category with single tags adding 10%
- DØ- Train neural net to identify b jets
  - Employ asymmetric cuts on tag output: one jet tagged at 73% efficiency, other at 48%
    - Found to provide best sensitivity to $H \to b\bar{b}$ signal

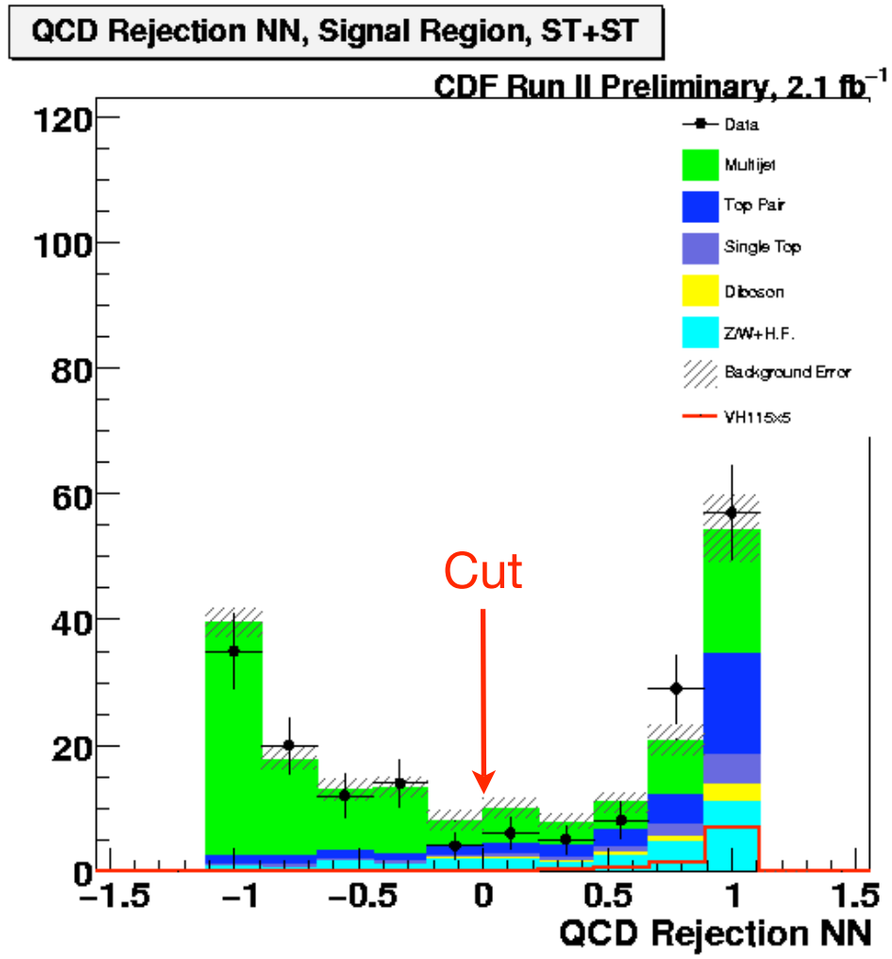


Background modeling

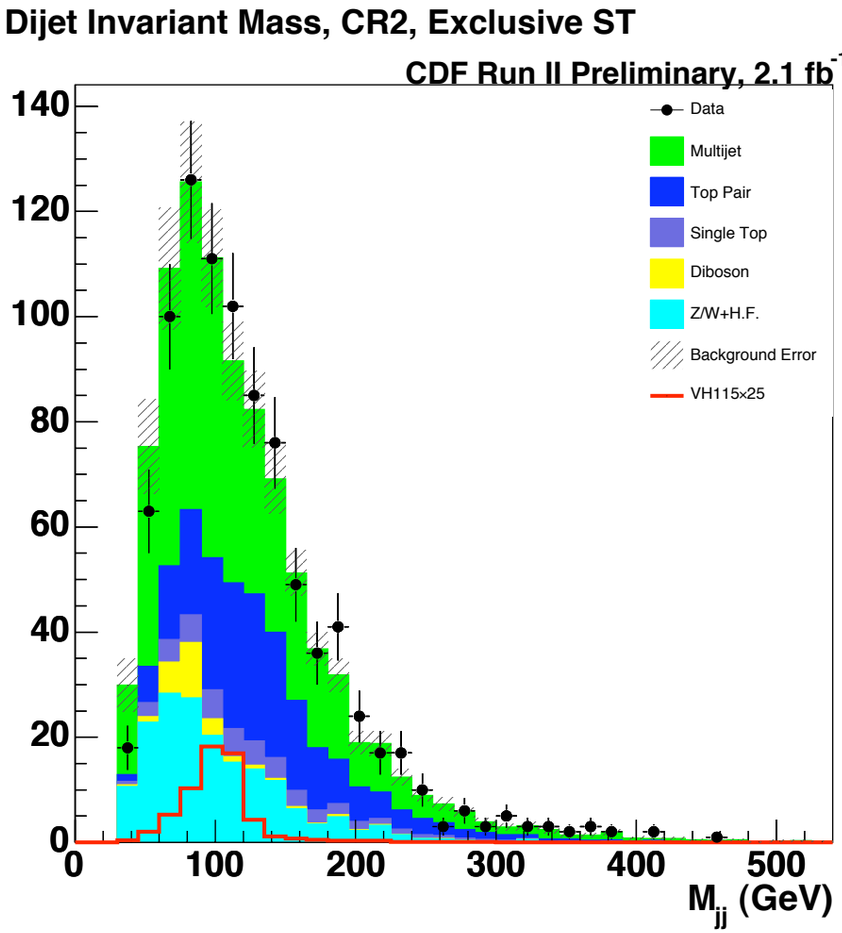
- After preselection, S/B~1/20,000 (1/3,500 after tagging)
- Easy: real missing E_T
  - Top, electroweak
  - Model using simulation
- Difficult: instrumental missing E_T
  - QCD multijet (increased dramatically by allowing 3-jet events)
  - Model using data
  - Important to determine probabilities of (mis)tagging a light flavor jet

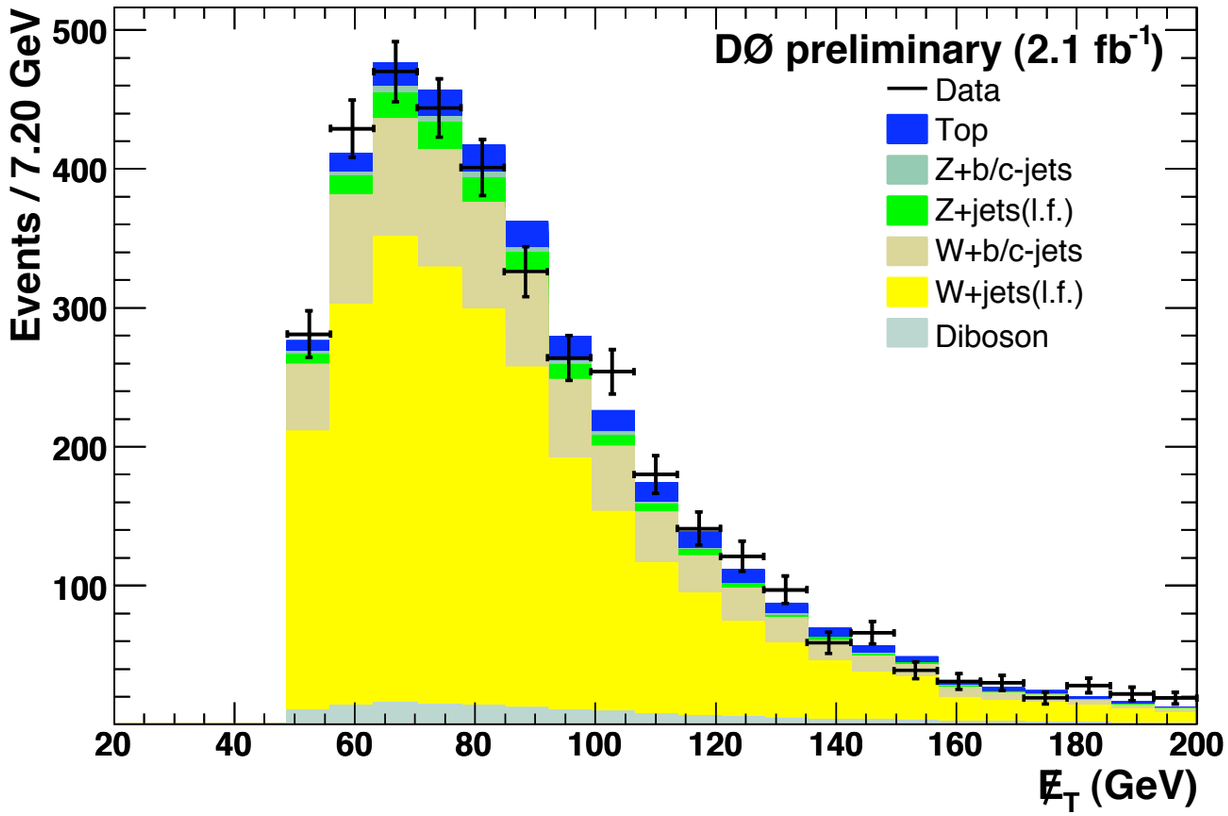
QCD rejection neural network

- Train neural network to separate multijet background from signal
- Exploit correlations amongst variables
  - Δφ(jets), ΔR(jets), missing E_T, etc.
- Train using simulated events
  - QCD with heavy flavor
  - 50/50 mixture of ZH and WH events
- Rejects 65% of multijet background at expense of only 5% of signal



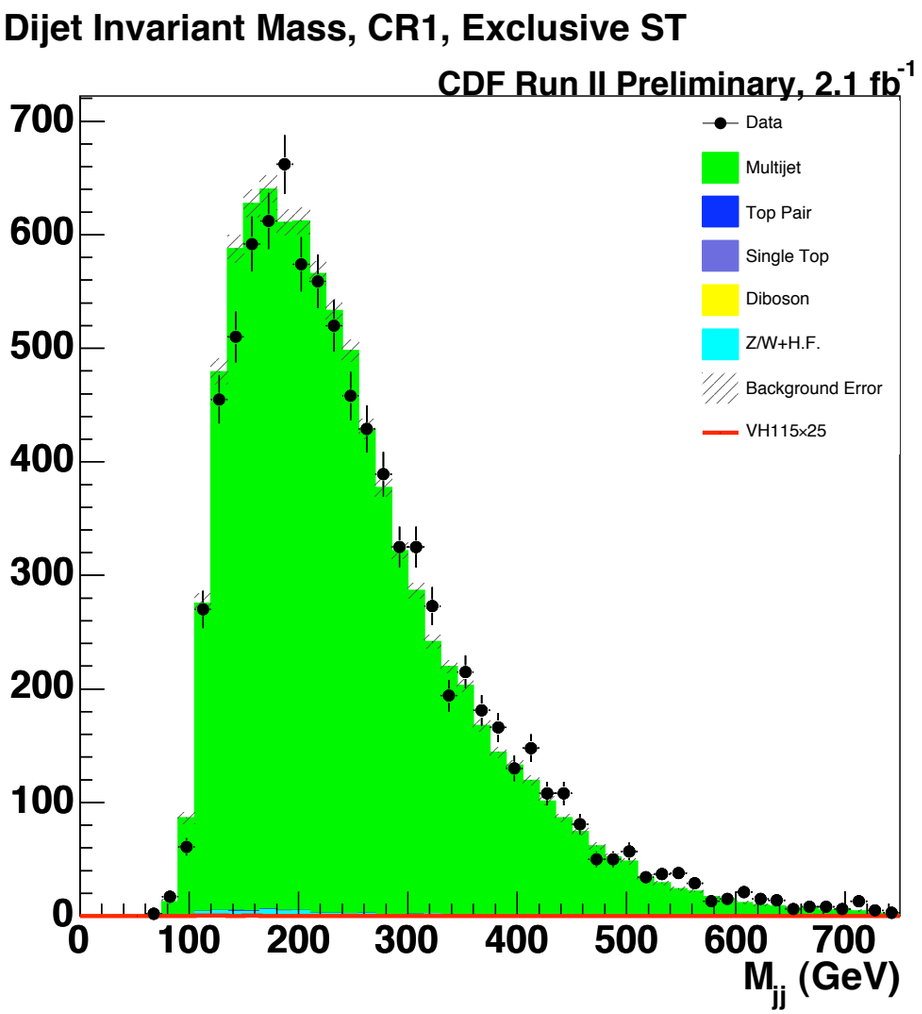
Control samples: electroweak

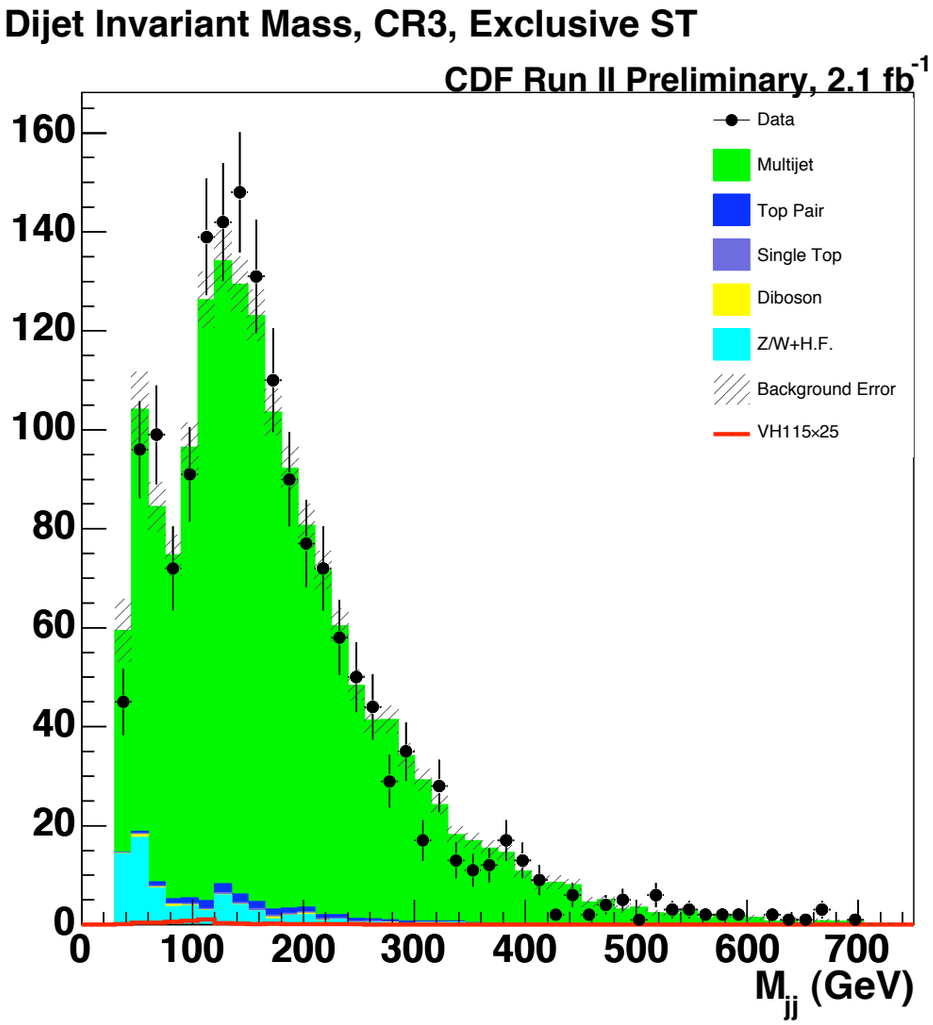




- Check background modeling in events primarily with real missing E_T
  - Require one identified lepton

Control samples: QCD





- Check background modeling in events primarily with instrumental missing E_T
- CDF: Two QCD control regions
  - "Signal-like" region includes events cut by QCD reduction NN

Final samples

CDF

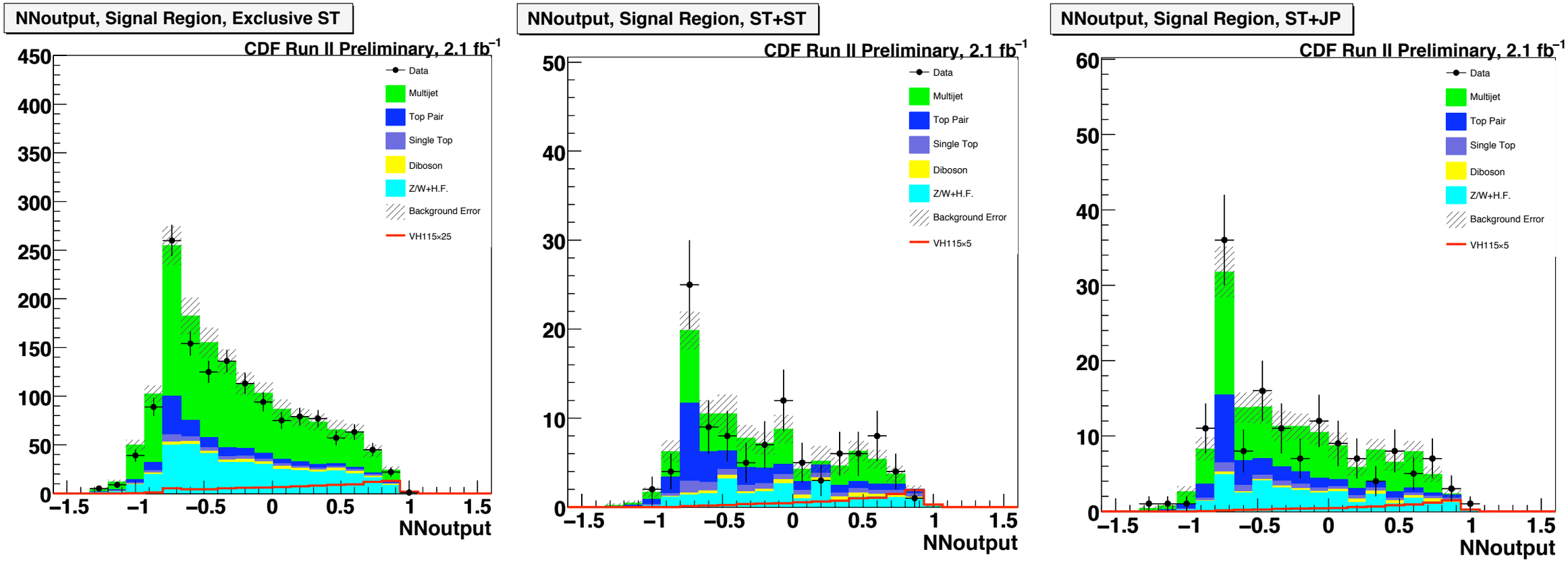
Process	ST	ST+ST	ST+JP
QCD+Mistags	941±44	42.1±8.7	78±11
Single top	43.2±7.9	8.5±1.7	7.2±1.5
Top pair	124±17	27.4±4.3	27.1±4.6
Diboson	35.6±6.8	4.9±1.2	4.3±1.1
W+h.f.	297±130	11.0±6.5	21±11
Z+h.f	107±46	10.8±5.0	11.3±5.2
Total Exp	1548±146	105±13	149±17
Observed	1443	105	148
$ZH \to \nu\nu b\bar{b}$	2.1	1.0	0.8
$WH \to (l)\nu b\bar{b}$	1.8	0.9	0.7
$ZH \to (l)(l)b\bar{b}$	0.09	0.04	0.03

DØ

Process	Events
W+jets	174.0
Z+jets	127.3
top	95.2
Diboson	12.5
QCD	33.8
HZ	2.12±0.01
HW	1.58±0.01
Total	442±1.1
Observed	439

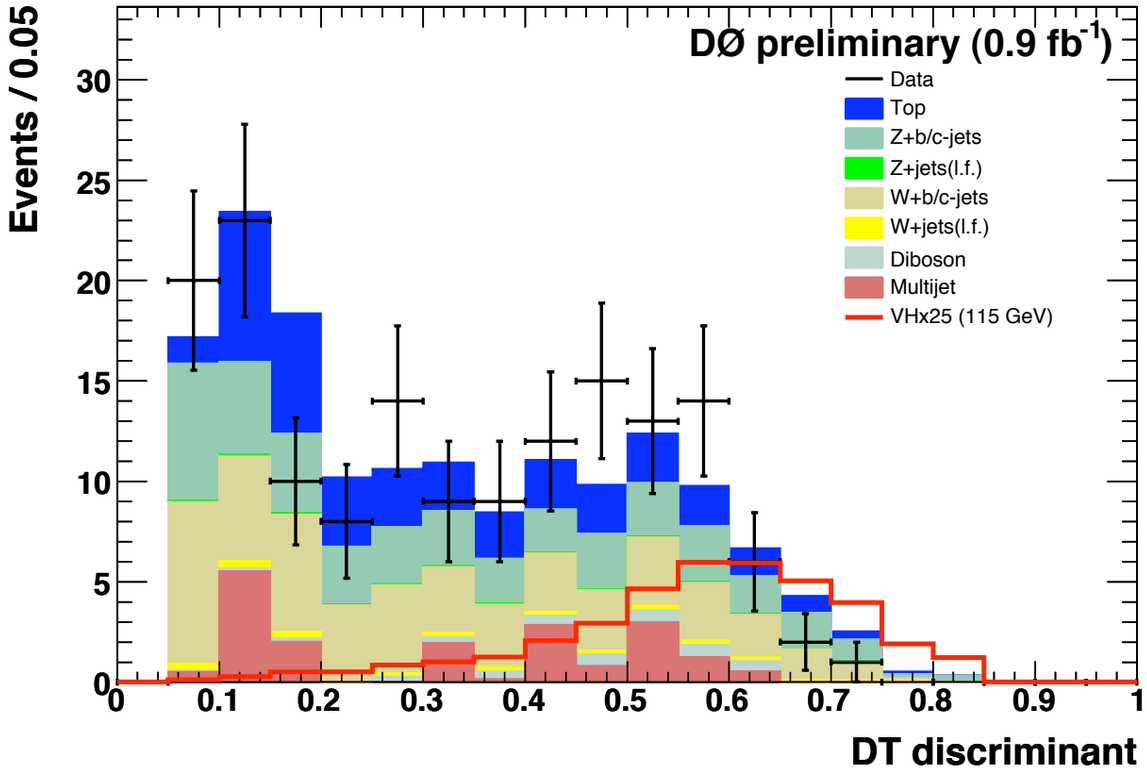
Signal expectation shown for m_H=115 GeV/c^2

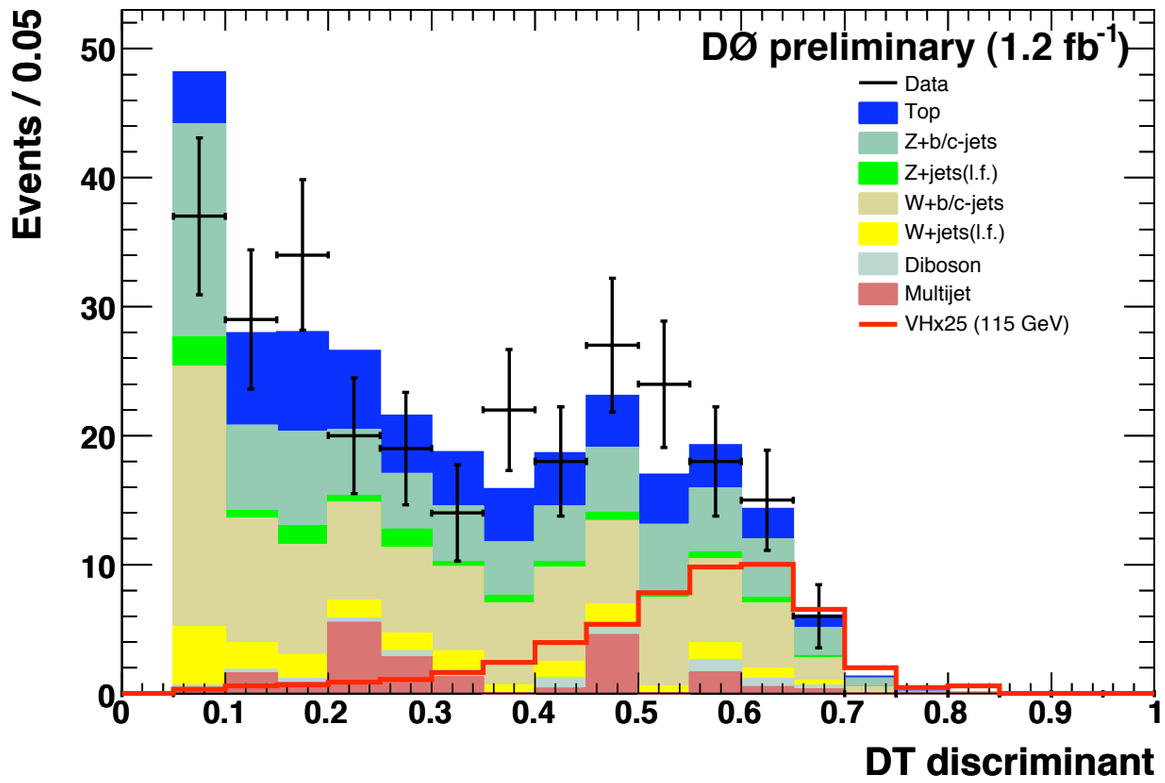
Final discriminant: CDF



- Train neural networks to discriminate signal from background
  - Separate NNs for 2-jet and 3-jet events

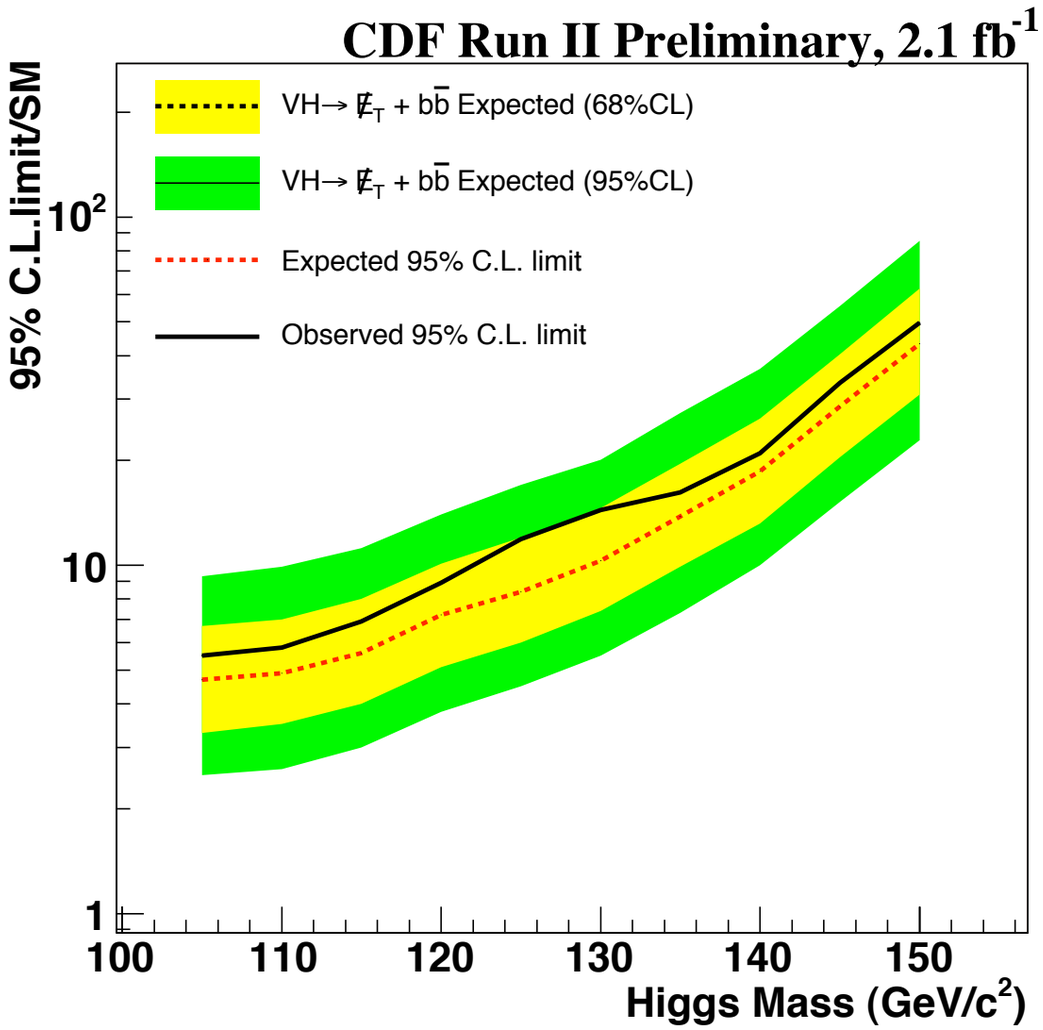
Final discriminant: DØ

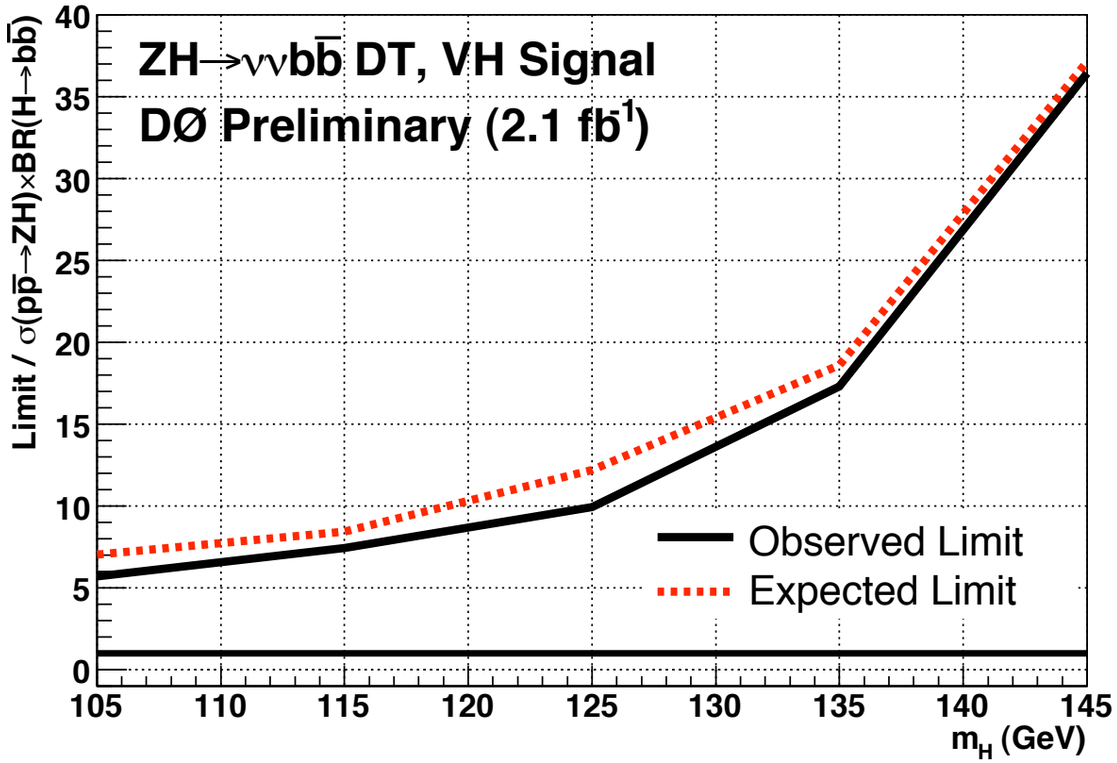




- Boosted decision tree used to discriminate signal from background
  - Retained DT with larger weight to misclassified events
- Separate DTs trained for Run 2a and Run 2b datasets

Results





Observed (expected) limit For m_H=115 GeV/c^2

CDF: 6.9 (5.6)×σ_{SM}

DØ: 7.5 (8.4)×σ_{SM}

Conclusion

- Both CDF and DØ have completed searches for low mass Higgs events without identified leptons in 2.1 fb^{-1} of data
  - CDF: A factor of ~2 improvement over method used in previous publication [PRL **100**, 211801 (2008)]
- New analyses are on the way
  - Considerably more data already available
  - Trigger and b-tagging improvements
- Low mass Higgs search are one of the highest priorities at the Tevatron
  - Much more difficult experimentally at LHC energies