Search for WH→lνbb at the Tevatron

DPF 2009

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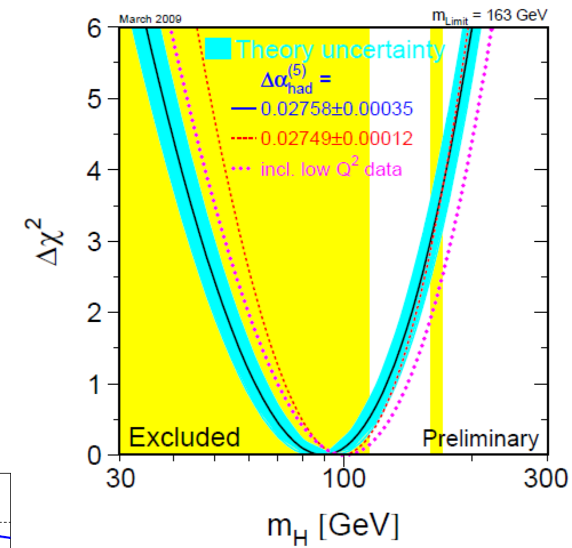
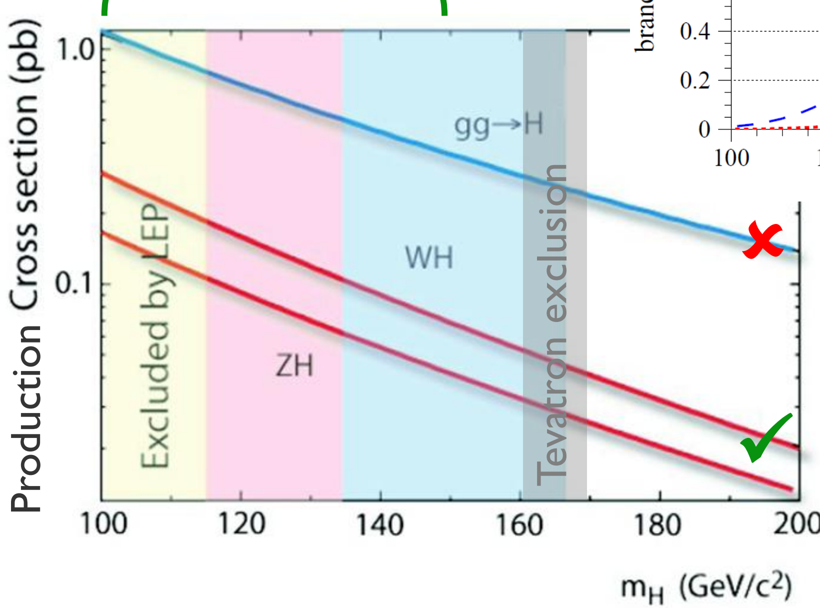
on behalf of the CDF and DØ collaborations

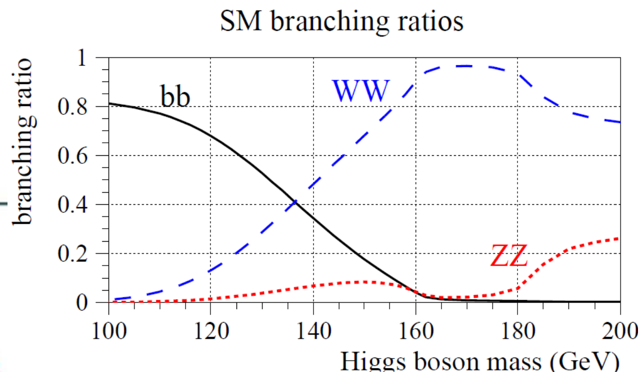
WH→lνbb and the low mass Higgs

- LEP excluded m_H<114.4 GeV, Tevatron currently excludes mass range 160 – 170 GeV
- Electroweak precision measurements constrain m_H
  - Fit favours low mass Higgs (m_H<163 GeV)
- At Tevatron, dominant Higgs production from gg, WH, ZH



WH→lνbb search focuses on this range





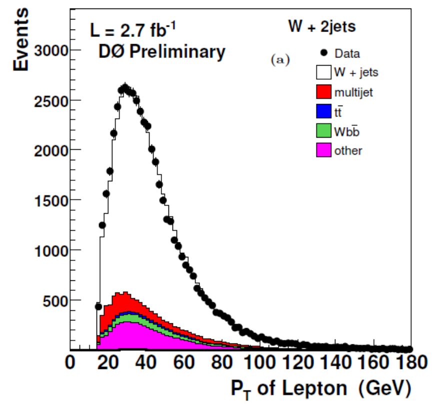
Low mass SM Higgs branching dominated by $b\bar{b}$

σ(gg→H→bb) ~ 2–0.1 pb vs. QCD σ(qq→bb) ~ 10^6 pb rules this out for low mass searches

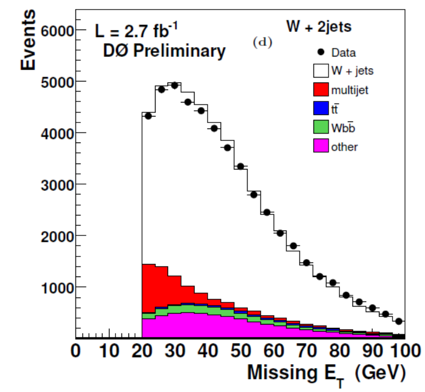
- **As such, best channel for low mass sensitivity WH→lνbb (and ZH)**

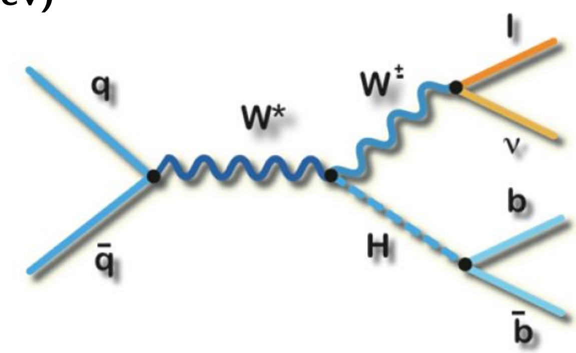
WH→lνbb selection

- **WH→lνbb signature:** one isolated high-p_T lepton, high MET and 2 b-jets



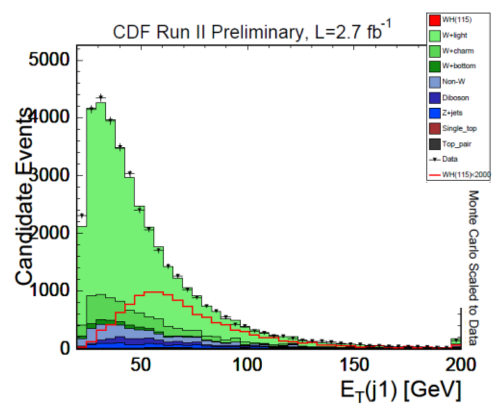
Two or more jets with p_T>20 GeV
(DØ additionally requires leading jet p_T>25 GeV)

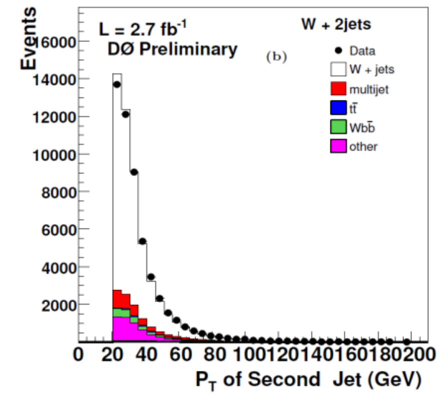




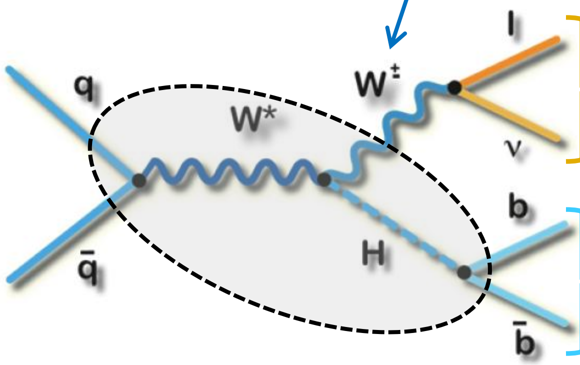
Single isolated lepton
CDF p_T>20 GeV :: DØ p_T>15 GeV

Missing transverse energy
CDF $\not{E}_T$>20 GeV (forward electron $\not{E}_T$>25 GeV)
DØ $\not{E}_T$>20 GeV (muon), $\not{E}_T$>25 GeV (electron)

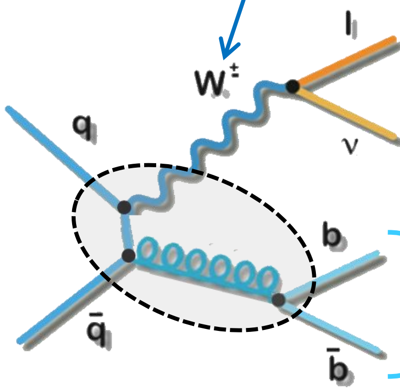




lνbb signal & background



HIGGS SIGNAL CHANNEL



W+JETS PRODUCTION

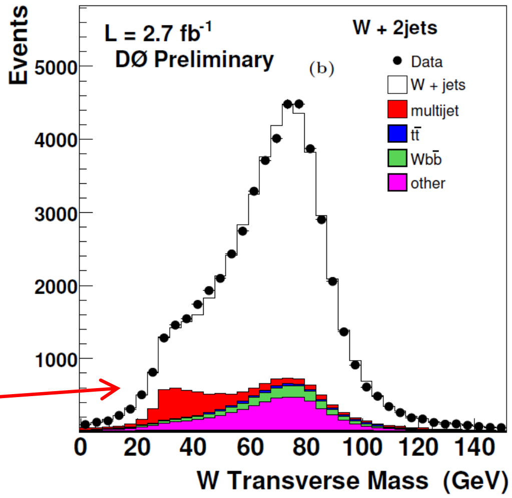
WH→lνbb signal has a number of distinctive features, but it is not alone!
Dominant background comes from W production in association with jets

Monte Carlo samples: hadronisation & showering with Pythia

- K-factors applied from MCFM for NLO normalisation of backgrounds
- Backgrounds are normalised to data where necessary in control samples

Instrumental background (multijet events) determined from multijet-enhanced data

Jet faking isolated electron or muon from semi-leptonic heavy quark decay appears isolated : can determine fake rate and contamination in signal region

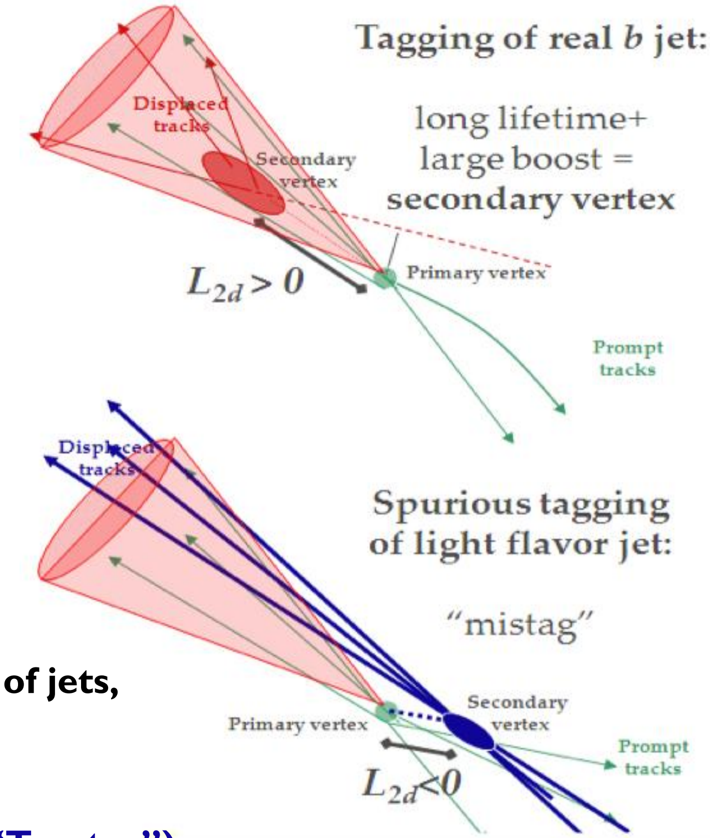


B-tagging for signal selection

Clearly crucial for analysis to be able to identify jet as b-jet

Can exploit B meson properties for b-tagging of jet

- **Long B-lifetime ~ 2 ps**
  - **Secondary vertex can be displaced mm in detector**
- **High charged particle multiplicity**
- **Larger vertex mass**
- **These, and topological properties used as algorithm/neural net inputs…**



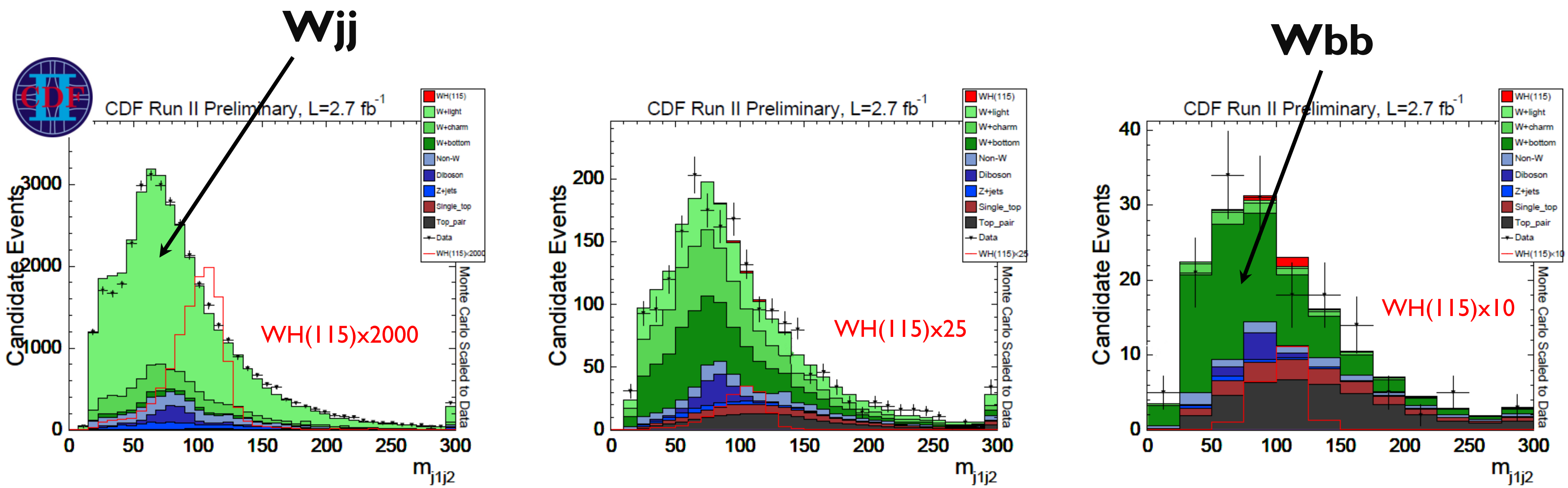
Once samples been b-tagged, can categorise not just by number of jets, but by number of b-tags (improved s/sqrt(b) discrimination):

- DØ: **Two orthogonal tag categories ("One tag" / "Two tag")**
- CDF: **Three orthogonal tag categories ("Single tag" / "Double tag" / "ST+JP")**

Results of b-tagging

Pre-tagged samples used for normalisation & validation of backgrounds – signal not visible

Orthogonal double loose and single tight samples separately studied to improve performance



Pre-tagged sample → **Single b-tag**

Pre-tagged sample → **Double b-tag**

Matrix element discriminants

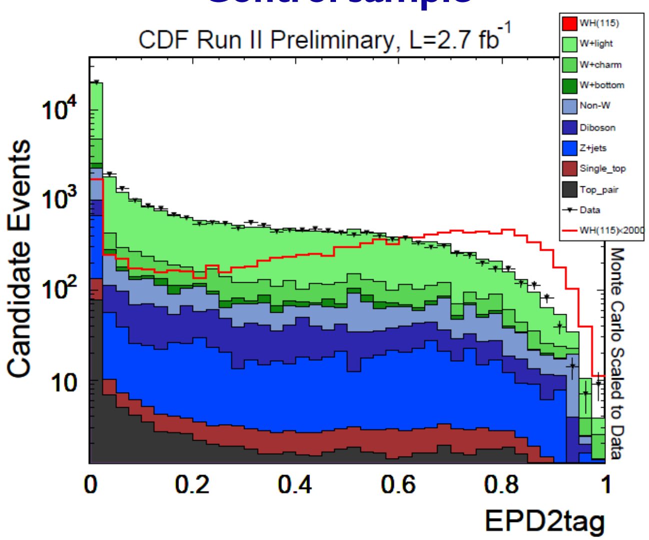
Both CDF and DØ use matrix element discriminants that take event kinematics as input

Gives a relative probability for an event to come from WH decay or background

$$P(x) = \frac{1}{\sigma}\int 2\pi^4 |M|^2 \frac{f(y_1)}{|E_{q_1}|}\frac{f(y_2)}{|E_{q_2}|} W(y,x) d\Phi_4 dE_{q_1} dE_{q_2}$$

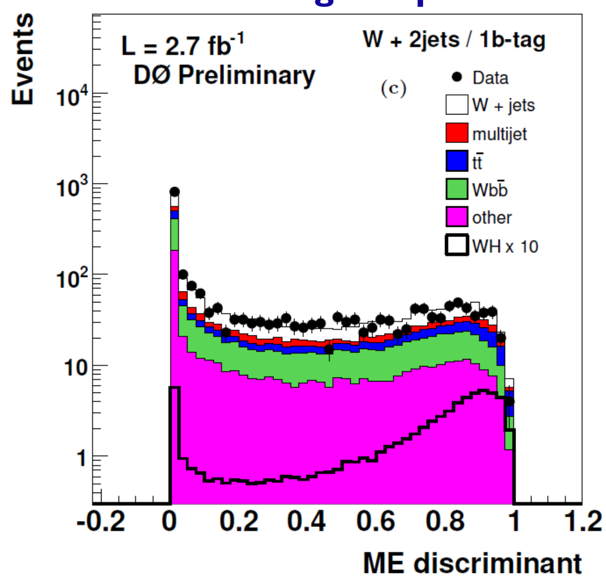
Matrix element — PDFs — Transfer function

Control sample



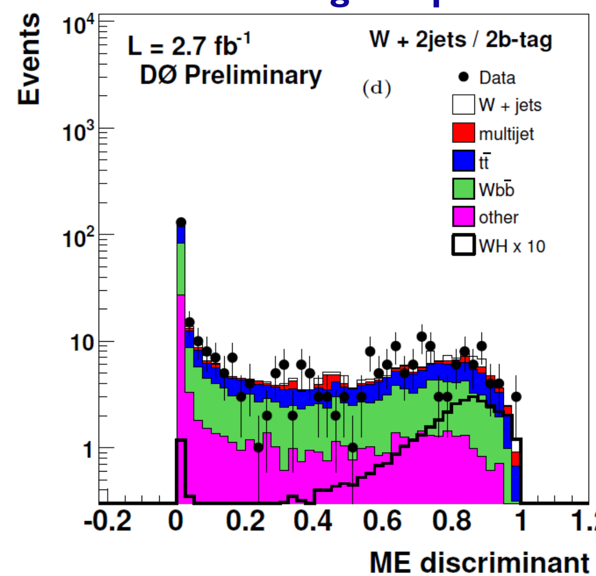
Background-like ← → **Signal-like**

One-tag sample



Background-like ← → **Signal-like**

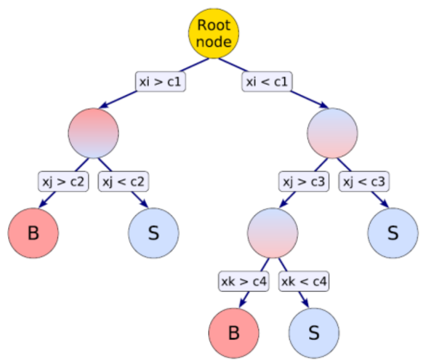
Two-tag sample



Background-like ← → **Signal-like**

Boosted decision tree

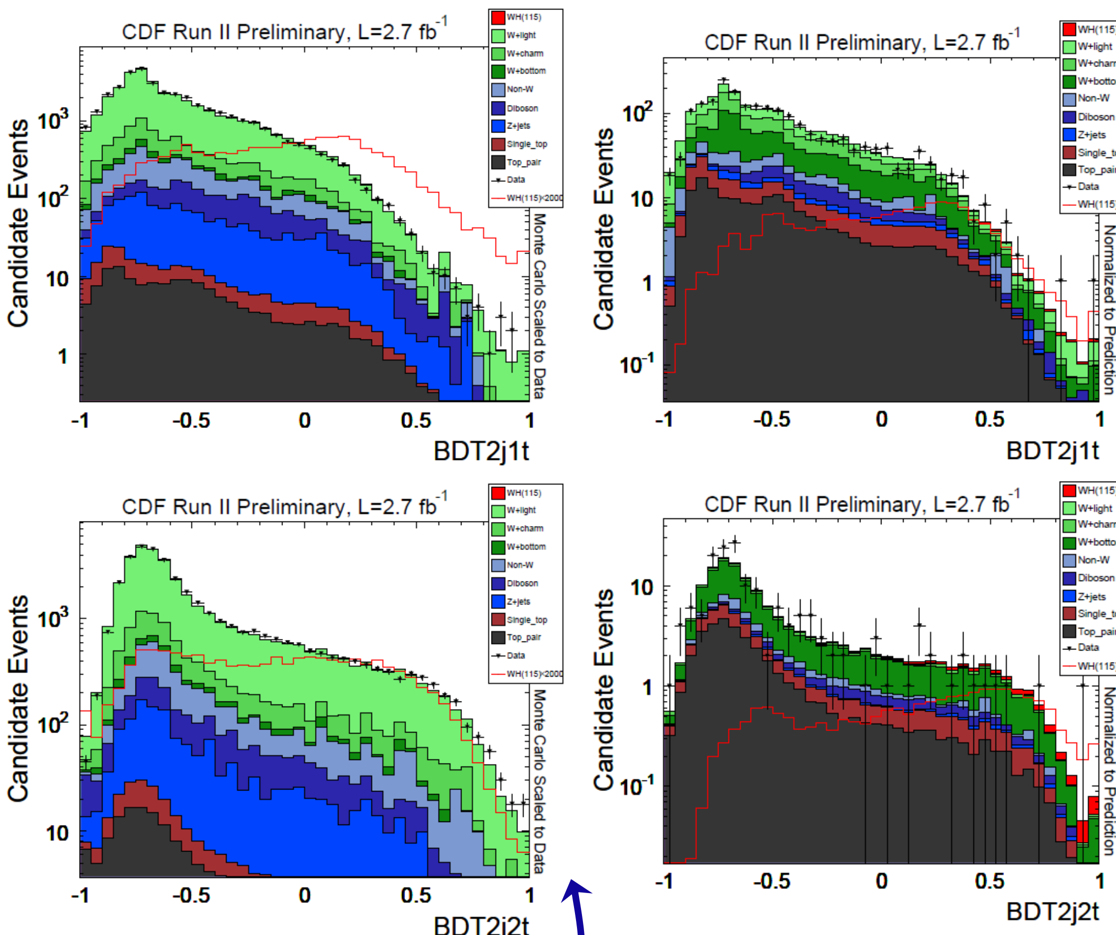
CDF additionally uses Boosted Decision Tree methods to further discriminate signal/background



Uses ME discriminant as input along with additional variables:

- Signal probability / background probabilities
- Dijet mass
- Jet ET
- $\Delta\phi$ (jet, MET), $\Delta\phi$ (lepton, MET)
- Lepton p_T, η
- Scalar sum of transverse energies
- Lepton/jet cosine
- W transverse mass
- NN flavour separator
- Missing transverse energy

BDT optimised individually for the W+2jets-1tag & W+2jets-2tags signals



Signal x 2000 shown

Signal x 25 (10) shown

BDT validated in 2-jet no-tag sample for corresponding signal samples

Neural network discriminants at DØ

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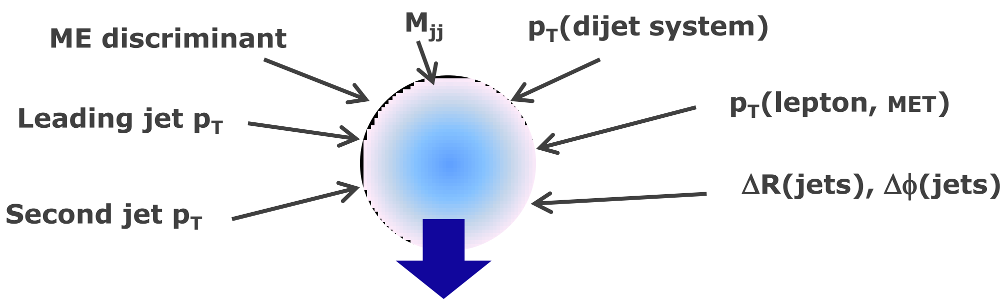
Like CDF's ME+BDT approach, DØ combines two approaches, using ME as input to Neural Net

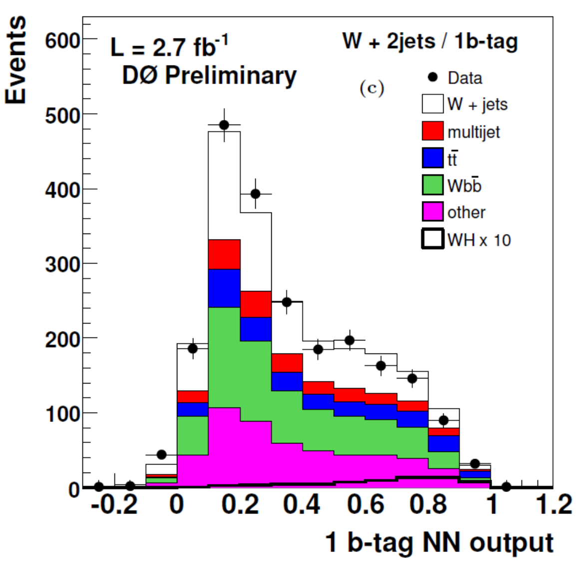
Using neural network allows for increased sensitivity to Higgs signal than distributions alone

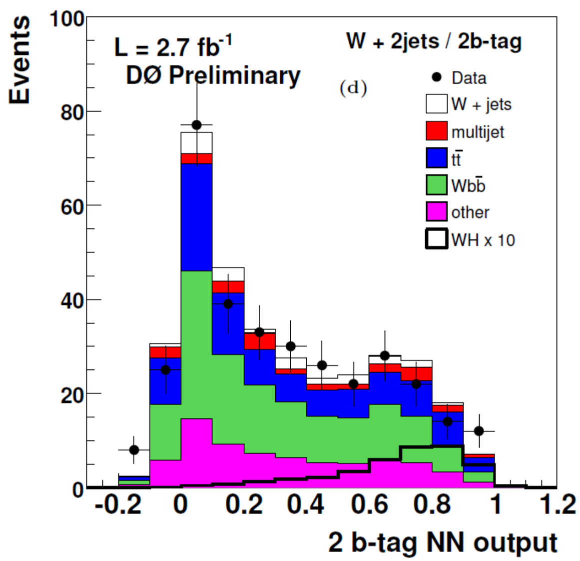
Gain 20% sensitivity over best discriminator (dijet mass) alone (2-jet bin)



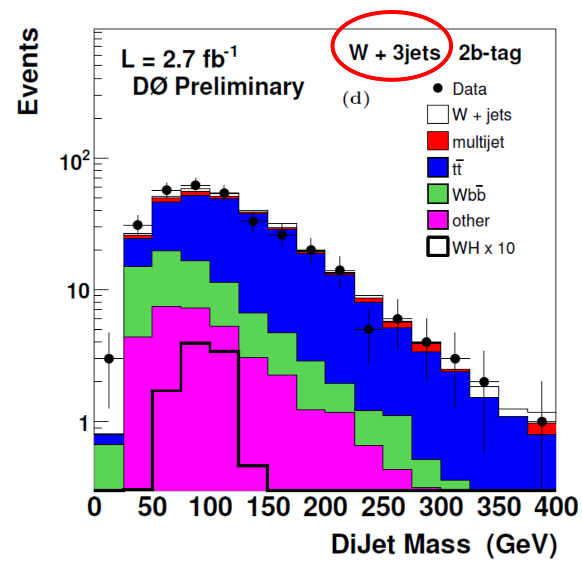
Most discriminating variable dijet mass used directly for W+3jet sample

NN out: Two-jet (1-tag/2-tag) samples



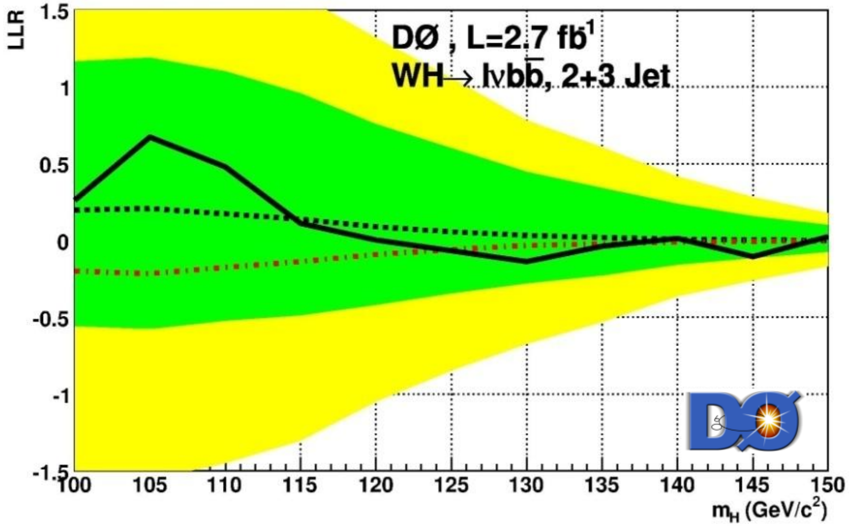


Dijet mass: Three-jet (2-tag) sample

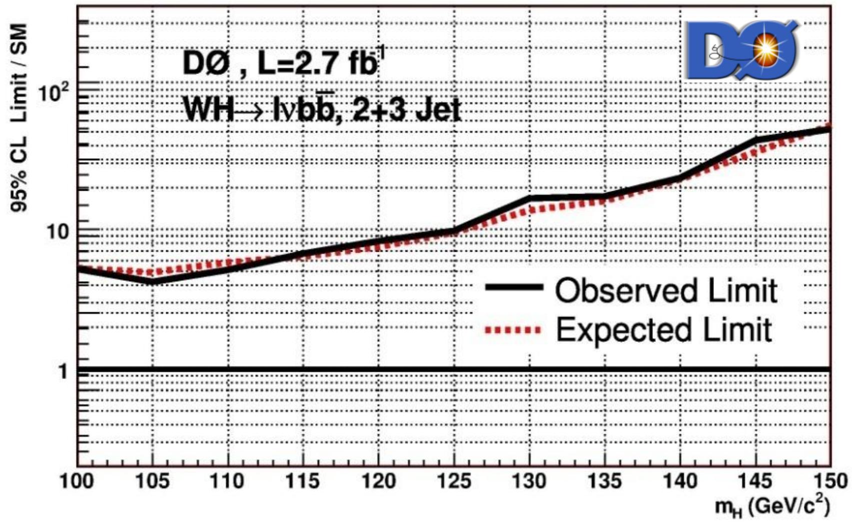


DØ combined WH→lνbb search results

DØ search combines **Neural Net** and **Matrix Element** discriminants & multiple jet bins



No excess observed, set 95% confidence limit (modified frequentist) using Log-Likelihood Ratio (LLR) test statistic



Benchmark observed limit:

m_H = 115 GeV at 6.7 x σ(SM)

(expected 6.4)

CDF combined WH→lνbb search results

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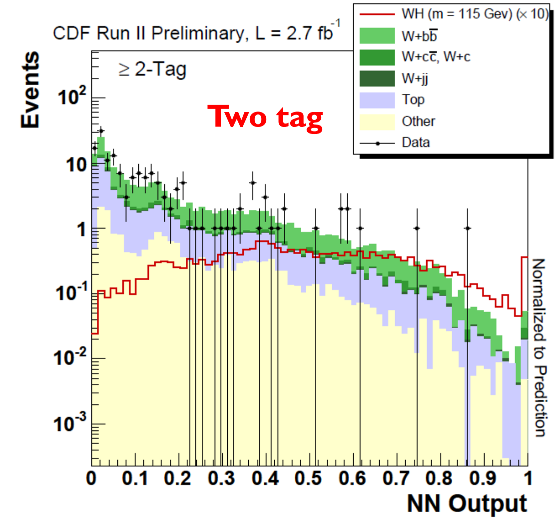
CDF has two separate analyses:

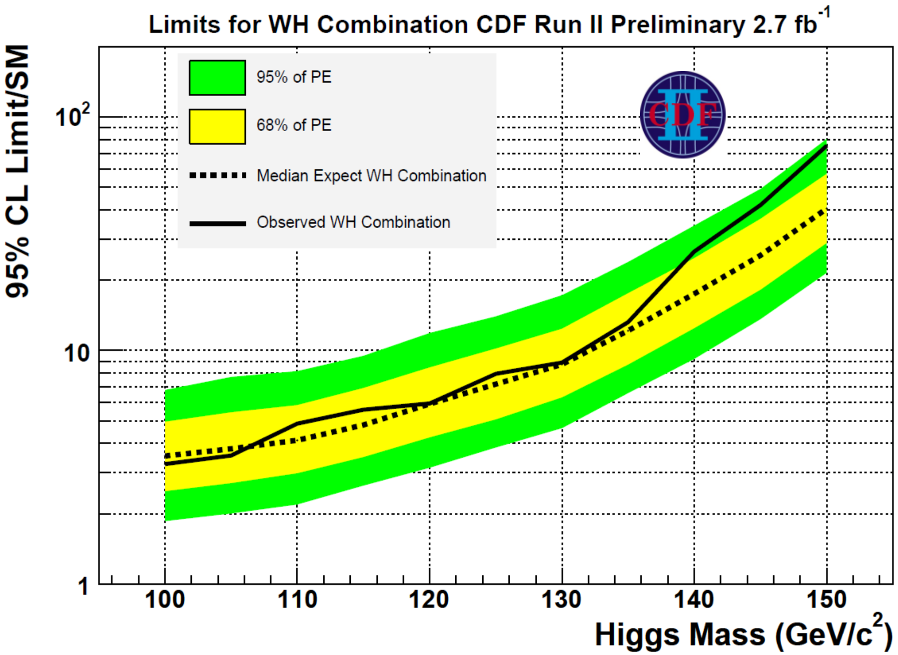
1. **Neural network approach**
2. **Matrix-Element + Boosted Decision Tree**



Combination of these two analyses then performed using second neural network

Although BDT+ME / NN use same inputs, not fully correlated! (15% gain in limit)

Again, no excess observed so set limits…



Benchmark observed limit:

m_H = 115 GeV at 5.6 x σ(SM)

(expected 4.8)

Outlook

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- Tevatron performing excellently, integrated luminosity continues to increase faster than ever
- $WH \rightarrow l\nu bb$ is most sensitive search channel at low mass
- Both CDF and DØ analyses continue to improve & optimise techniques, and of course add more data! [Aiming towards 10 fb^{-1}]
- Gaining efficiency from better ID and looser selections
- Our understanding of backgrounds continues to improve (W/Z+jets...)

Expect further improvements in Tevatron reach in the near future!

Results at m_H=115 GeV benchmark: 95% CL limit / σ(SM)

Analysis	Lumi. (fb^{-1})	Exp. limit	Obs. limit
CDF BDT+ME & NN (combined)	2.7	4.8	5.6
DØ NN+ME	2.7	6.4	6.7