Higgs Searches at DØ

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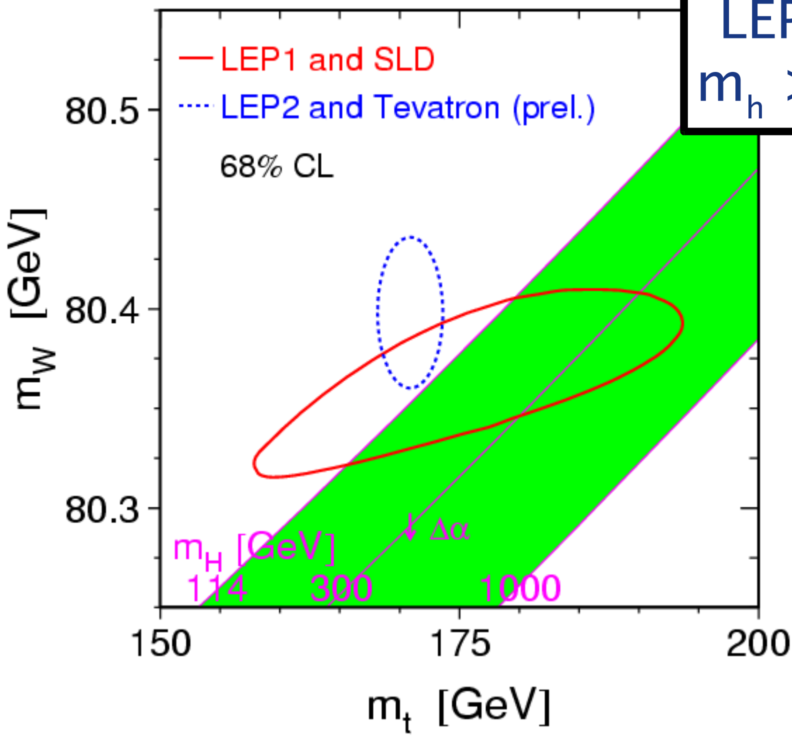
Introduction

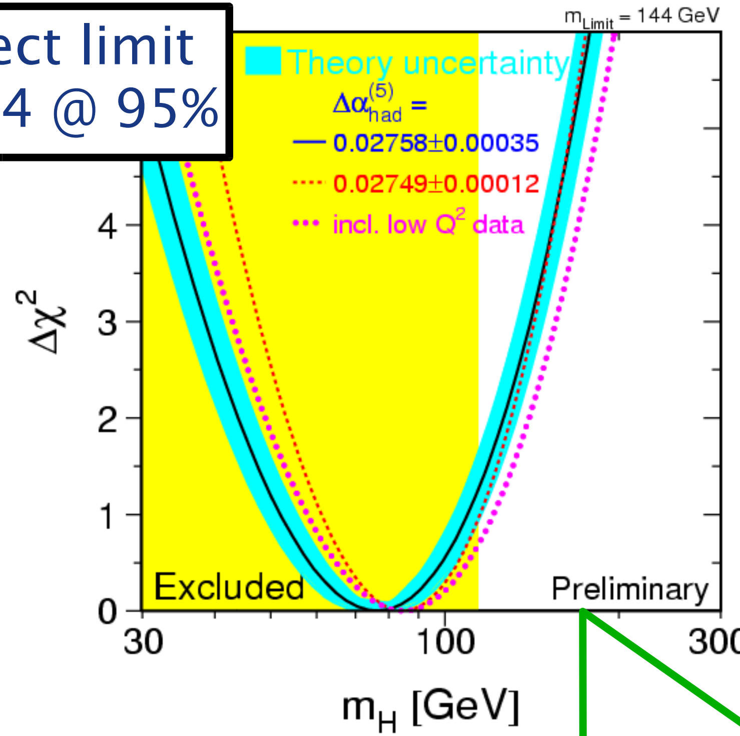
- The Higgs boson is needed in the Standard Model (SM) to achieve electroweak symmetry breaking.
- So far it has not been observed, but constraints exist on its mass.
- The Tevatron is the highest energy collider currently running – best place to search for the Higgs today.
- The Higgs does not have to be the one we predict in the SM, could be something more exotic.
- Will present the status of the SM Higgs boson searches at DØ and some of the searches for Higgs bosons beyond the SM.
  - Will concentrate on the most recent results.

Constraints on the SM Higgs Boson

- Use the W boson & top quark masses to constrain the Higgs mass:



LEP direct limit
$m_h > 114$ @ 95%

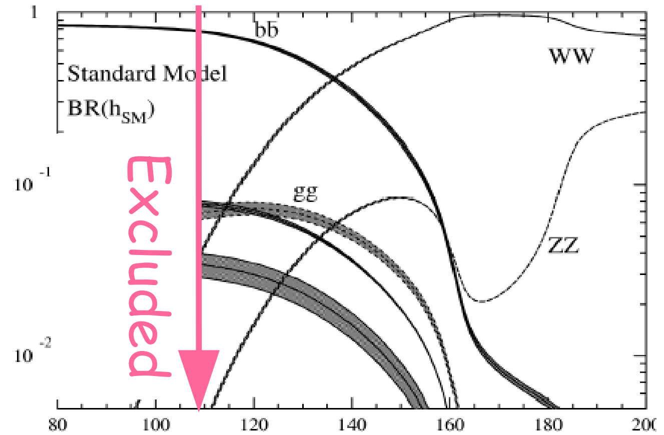


EW Fit gives $m_h < 144$ GeV
(182 GeV with LEP limit)

- If the SM Higgs boson exists then it should be light → Good news for Tevatron searches.

SM Higgs Production & Decay Modes

- Two main production modes used at the Tevatron:
  - Gluon fusion $gg \rightarrow h$
  - Associated production $qq \rightarrow W/Z + h$
- Decay modes:
  - b quarks dominate at low mass
  - WW dominates at high mass
- Leads to the following analyses



Low Mass m_h ~< 135 GeV

$$q\bar{q} \rightarrow Wh \rightarrow l\nu\, b\bar{b},\ l = e, \mu$$

$$q\bar{q} \rightarrow Zh \rightarrow ll\, b\bar{b},\ l = e, \mu$$

$$q\bar{q} \rightarrow Zh \rightarrow \nu\nu\, b\bar{b},\ l = e, \mu$$

Intermediate Mass

$$q\bar{q} \rightarrow Wh \rightarrow WWW^*$$

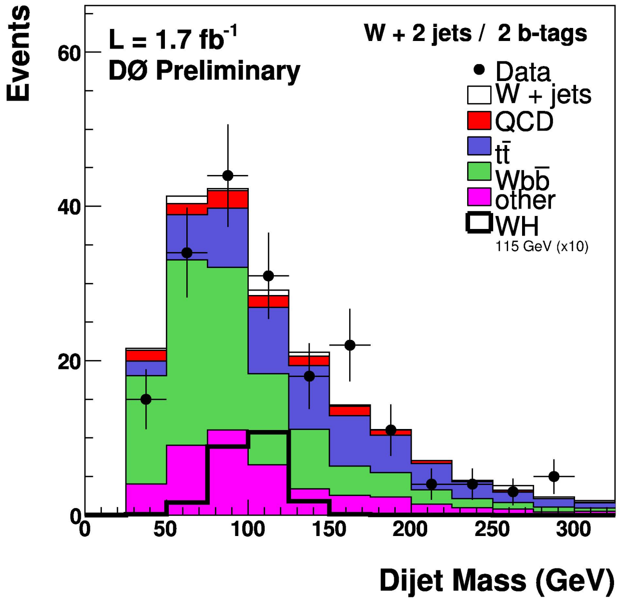
High Mass m_h ~> 135 GeV

$$gg \rightarrow h \rightarrow WW \rightarrow l\nu l\nu,\ l = e, \mu$$

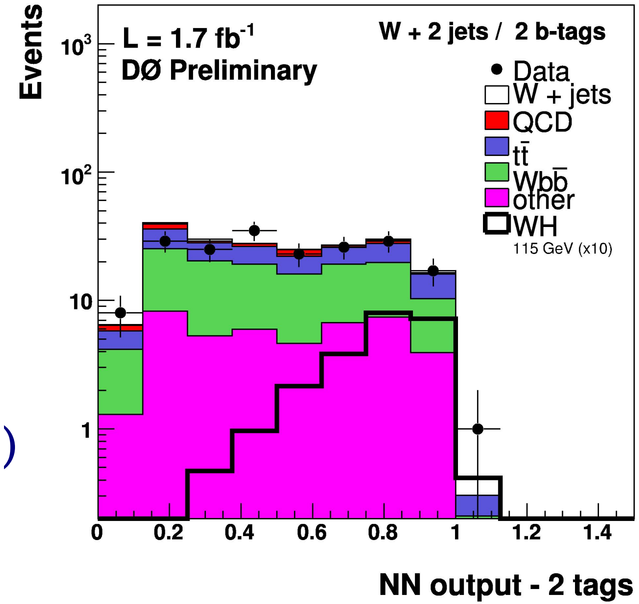
WH → lυ bb Search

1.7 fb^{-1} Aug 07

- Major backgrounds: W + jets, QCD multi-jet, top
- Basic selection: High p_T lepton + MET + jets
- Normalize & validate background with no b-tag requirement.
- Search for the Higgs in two orthogonal samples: double loose b-tag & single tight b-tag.



Apply Neural Network based on 7 kinematic variables



Limit

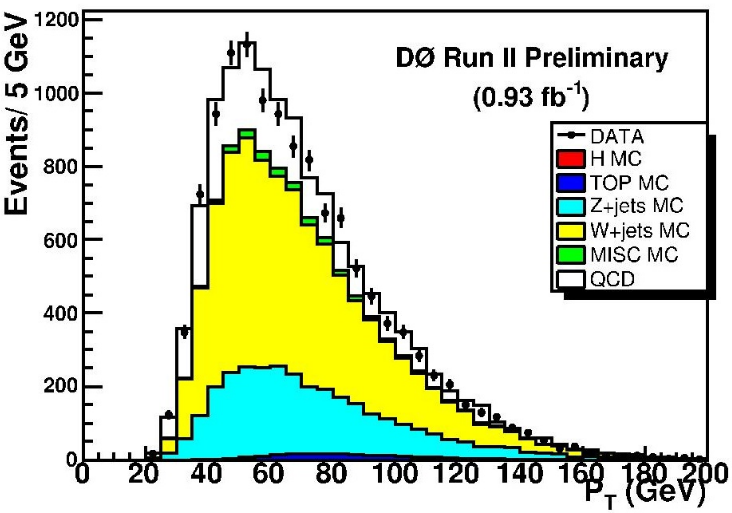
$\sigma_{95\%}/\sigma_{SM}$ = 9(exp), 11(obs) @ m_h = 115 GeV

ZH → υυ bb Search

0.9 fb^{-1} Nov 07

- Major backgrounds: W / Z + jets, QCD multi-jet, top.
- Select events with MET (> 50 GeV) + jets.
- Also search for Wh → *l*υ bb, where the lepton is not identified.
- Search for the Higgs in double b-tag selection, use 7 variable Neural Network (NN) as final variable.

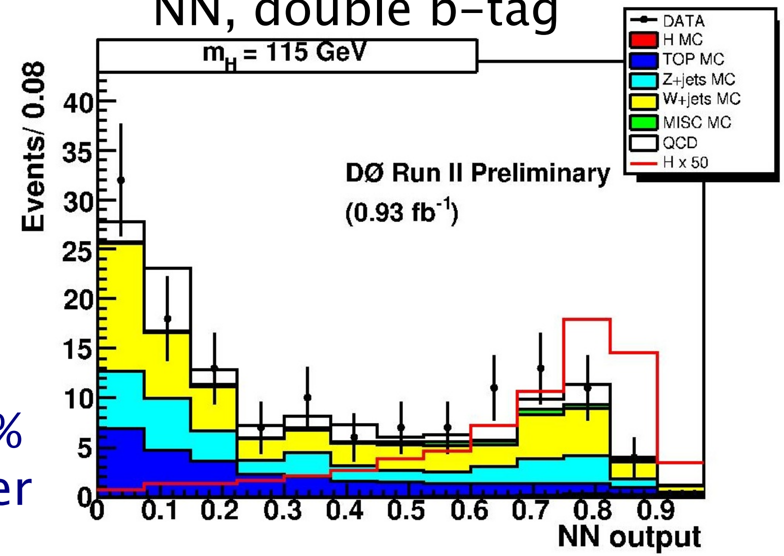
Lead jet p_T, before b-tag



Limit $\sigma_{95\%}/\sigma_{SM}$ = 12(exp), 13(obs) @ m_h = 115 GeV

NN gives 20–30% improvement over di-jet mass.

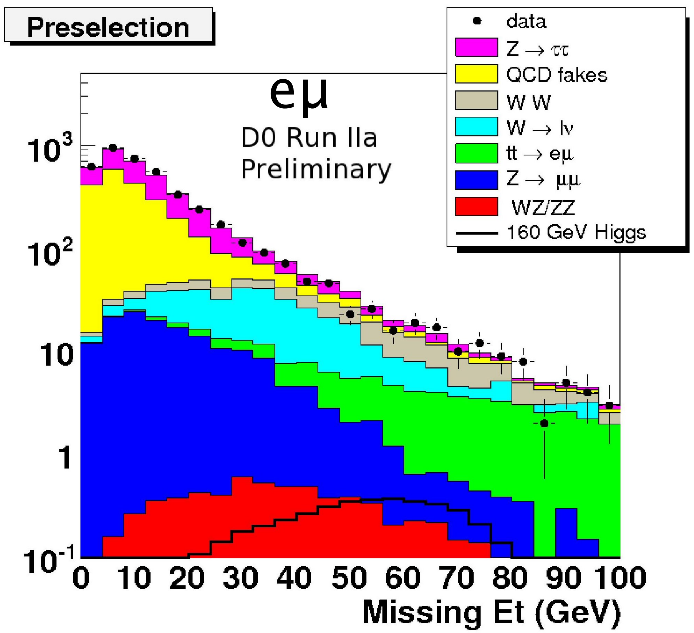
NN, double b-tag



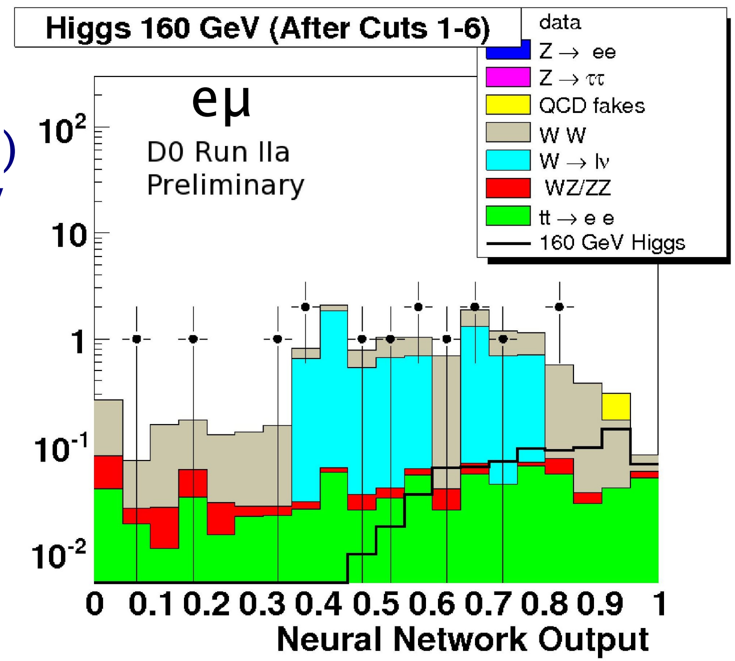
H → WW Search

1.7 fb^{-1} Nov 07

- Major backgrounds: Z, W + γ/jets, WW.
- Select events with two high p_T leptons & MET.
- Use mass dependent cuts to remove Z & W backgrounds.
- Cannot reconstruct Higgs mass → use NN for final variable.



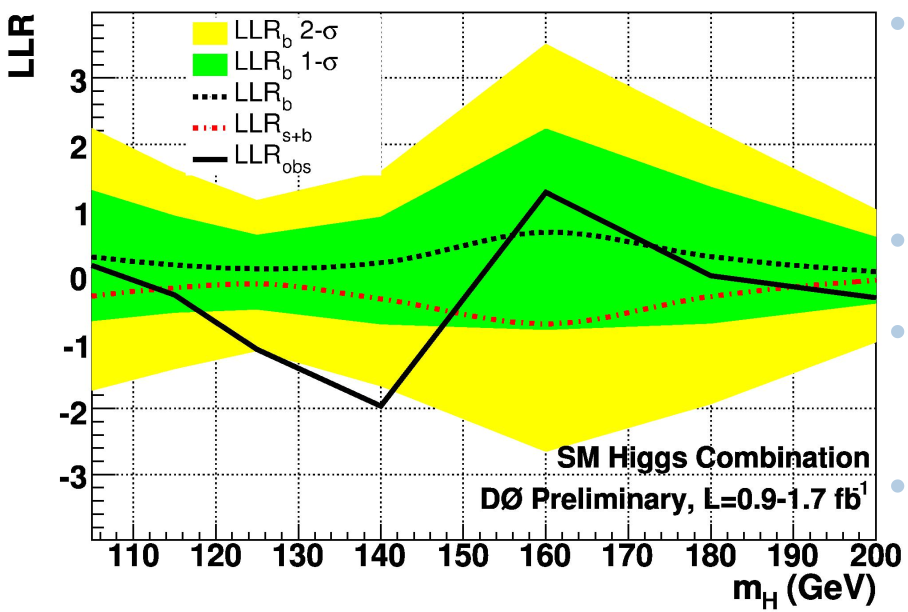
Limit $\sigma_{95\%}/\sigma_{SM}$ = 2.8(exp), 2.6(obs) @ m_h = 160 GeV



Combining Everything Together

0.9 - 1.7 fb^{-1}
Dec 07

- Get best sensitivity by combining all channels together.
- This is done with the CL_s technique. All systematics & appropriate correlations are included.
- Result is Log-Likelihood Ratio (LLR) distribution as a function of Higgs boson mass.

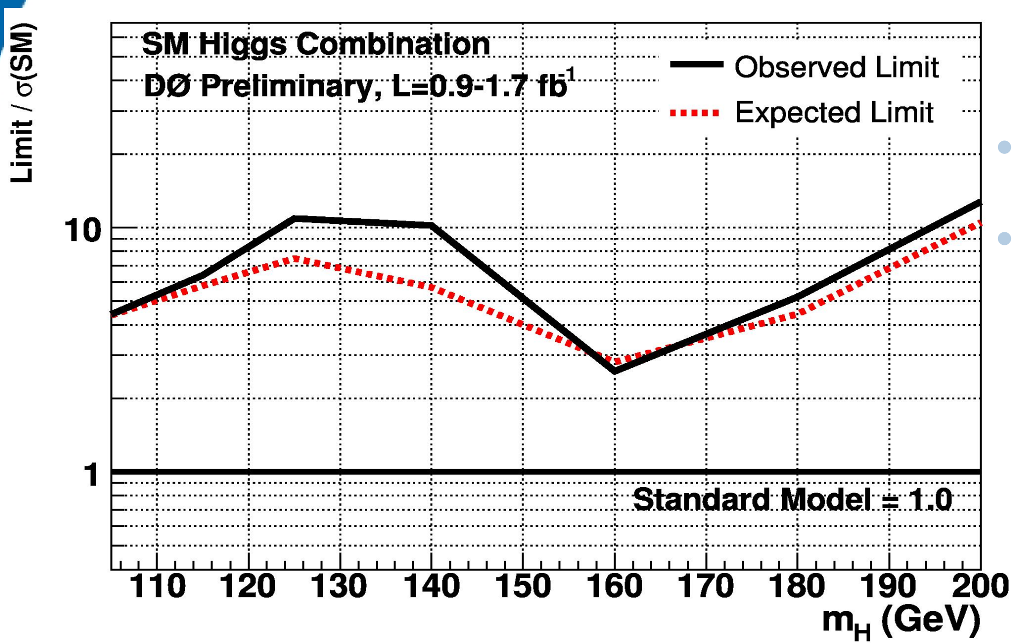


- $LLR_{b\ /\ s+b}$ – expectations in background & signal + background hypotheses.
- Bands show 1, 2σ variations of LLR_b
- Gap between LLR_b and LLR_{s+b} shows the sensitivity of the analysis.
- LLR_{obs} is the result in the D0 data.

Combining Everything Together

0.9 - 1.7 fb^{-1}
Dec 07

- Scale the signal to find the expected and observed limits.
- Express the limit as a ratio to the SM cross-section.
- Crossing 1 means we exclude the SM Higgs boson at 95% CL for that mass.



Limit $\sigma_{95\%} / \sigma_{SM}$ =

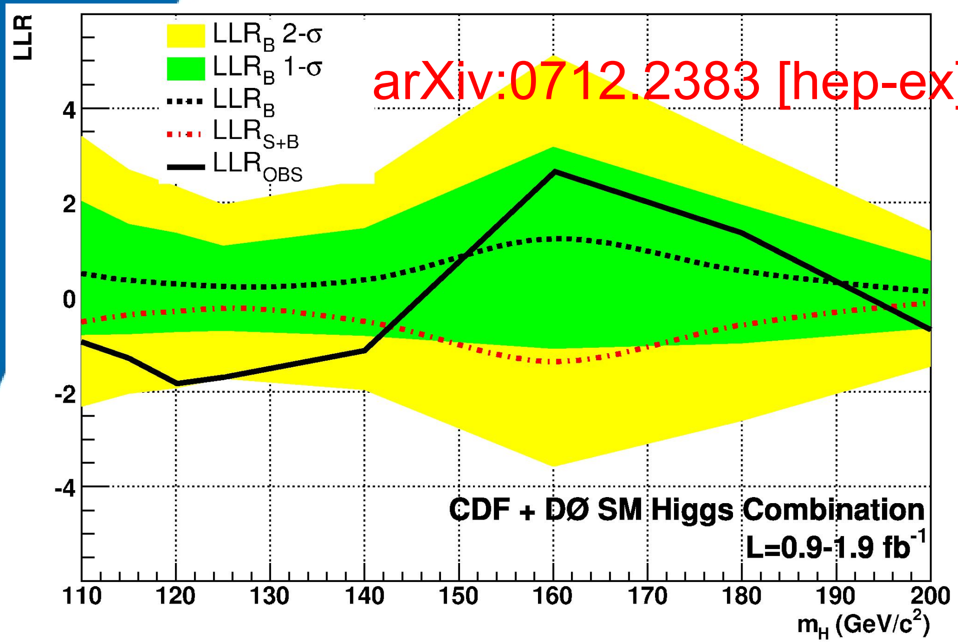
- 2.8(exp) 2.6(obs) @ m_h=160 GeV
- 5.8(exp) 6.4(obs) @ m_h=115 GeV

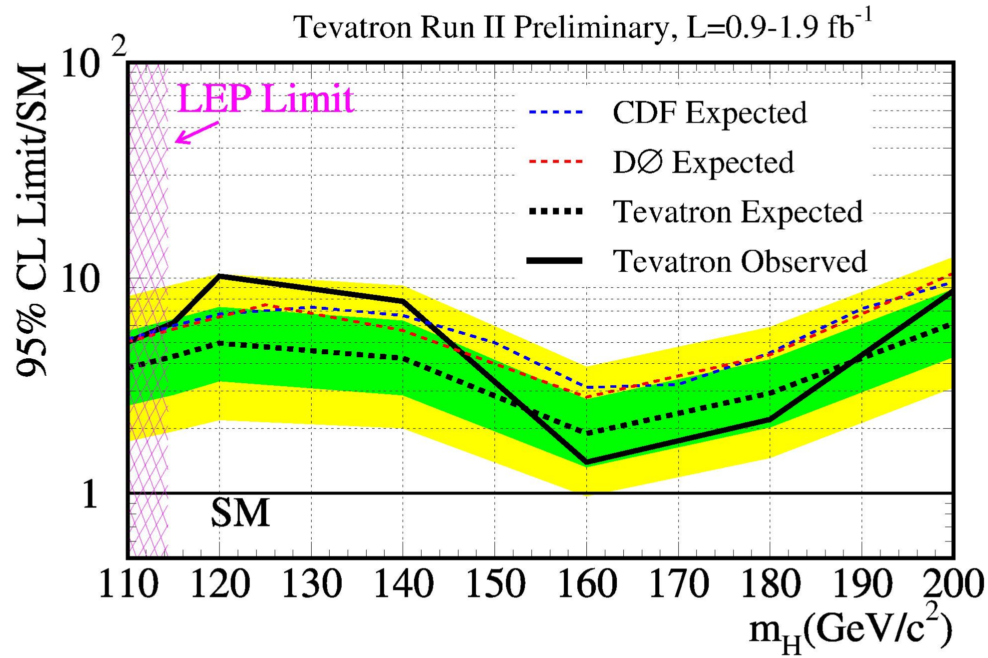
Combining Everything Together

0.9 – 1.9 fb^{-1}
Dec 07

- Finally, combine DØ & CDF results:

arXiv:0712.2383 [hep-ex]





Limit $\sigma_{95\%} / \sigma_{SM}$ =

- 1.9(exp) 1.4(obs) @ m_h=160 GeV, 4.3(exp) 6.2(obs) @ m_h=115 GeV

SM Higgs Summary & Outlook

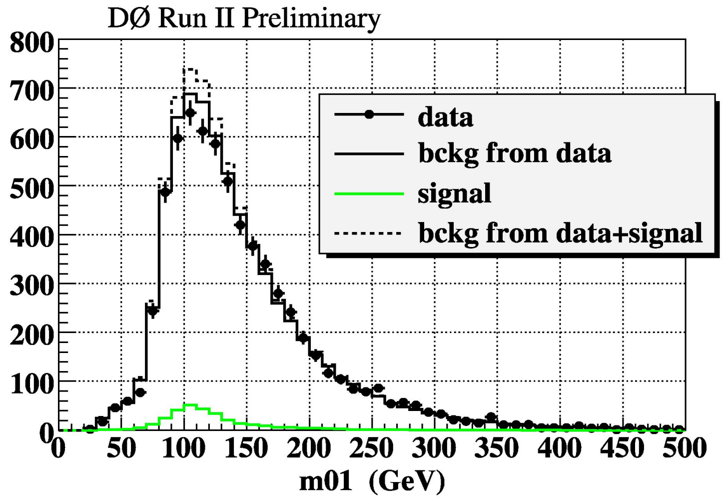
- SM Higgs boson searches are now approaching the SM – factor 1.4 away at m_h=160 GeV with 1.7–1.9 fb^{-1} of data.
- Already have 3 fb^{-1} on tape – expect 5–7 fb^{-1} by end 2010.
- But don't stand still, many improvements in the works:
  - Increase lepton acceptance
  - Improve di-jet mass resolution
  - Add more channels
  - Improved multi-variate techniques (matrix element)
  - Improve b-tagging (layer 0, semi-leptonic tagging)
- Exciting times ahead:
  - 2008 could see sensitivity @ m_h = 160 GeV (@ 95% CL)

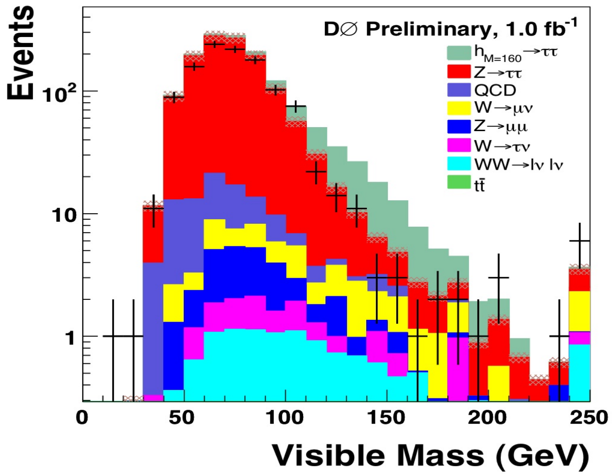
Beyond the SM - MSSM

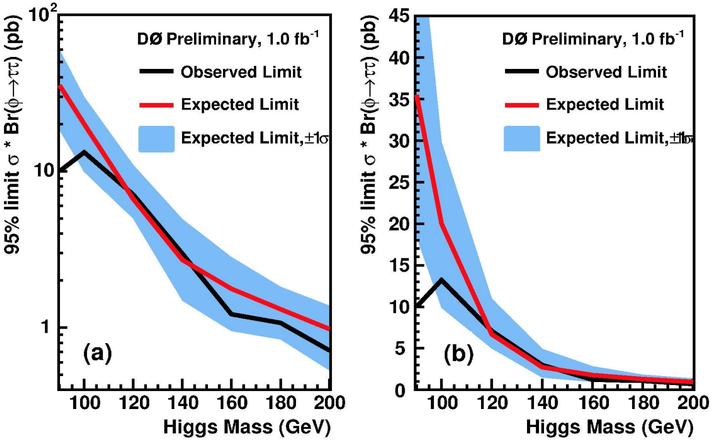
- MSSM has two Higgs doublets.
  - Leads to three neutral Higgs bosons, ϕ = h, H, A
- At tree level MSSM is fully specified by two parameters:
  - m_A – mass of CP odd neutral Higgs
  - $\tan\beta$ – ratio of the v.e.v of the two doublets.
- Higgs production is enhanced by ~ $\tan^2\beta$.
- Main decay modes are bb (~90%) and $\tau\tau$ (~10%).
- In the inclusive channel bb is swamped by mulitjet background, use $\phi\rightarrow\tau\tau$.
- However, bb decay is possible in $b\phi\rightarrow bbb$.
- Translate results into $\tan\beta$ – m_A plane.

Beyond the SM - MSSM

- Searches with 0.9 / 1.0 fb^{-1} in bbb / ττ modes:





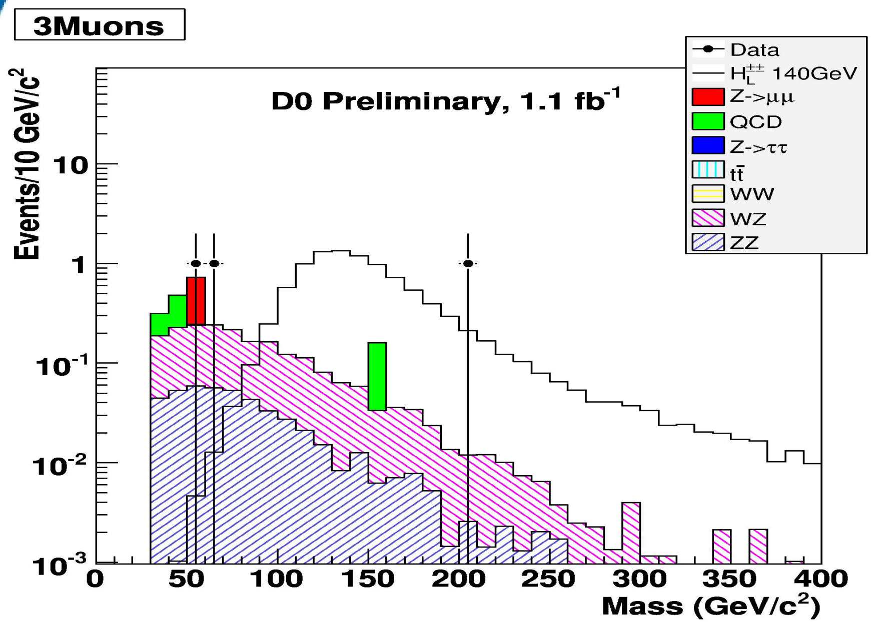


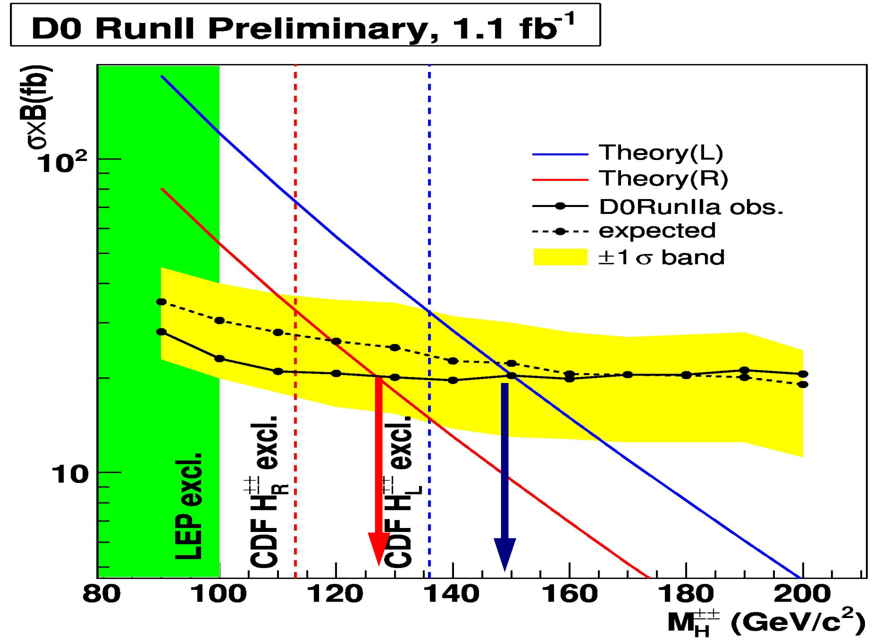
- No signal yet.
- Similar sensitivity at low mass.
- Have also analysed bh→bττ (only 0.3 fb^{-1}).
- Will also gain in sensitivity by combining all the channels.

Beyond the SM

1.1 fb^{-1}
Aug 07

- More exotic searches: Doubly charged Higgs, $H^{++}H^{--} \rightarrow \mu^+\mu^+\mu^-\mu^-$
- Search for three muons, small SM background from diboson events.
- Use di-muon invariant mass of like-sign muons to set limits.





Summary & Outlook

- Sensitivity of Standard Model Higgs boson searches continues to improve, so far we continue to exceed $\sqrt{L}$.
- Combination procedures in place & tested.
- Sensitivity around m_h = 160 GeV is possible this year.
- Low mass is a little further off, but this region is also tough for the LHC.
- No signals found in the BSM Higgs boson searches yet, continue to look in the larger dataset.
- Expect new results at the upcoming Winter conferences.

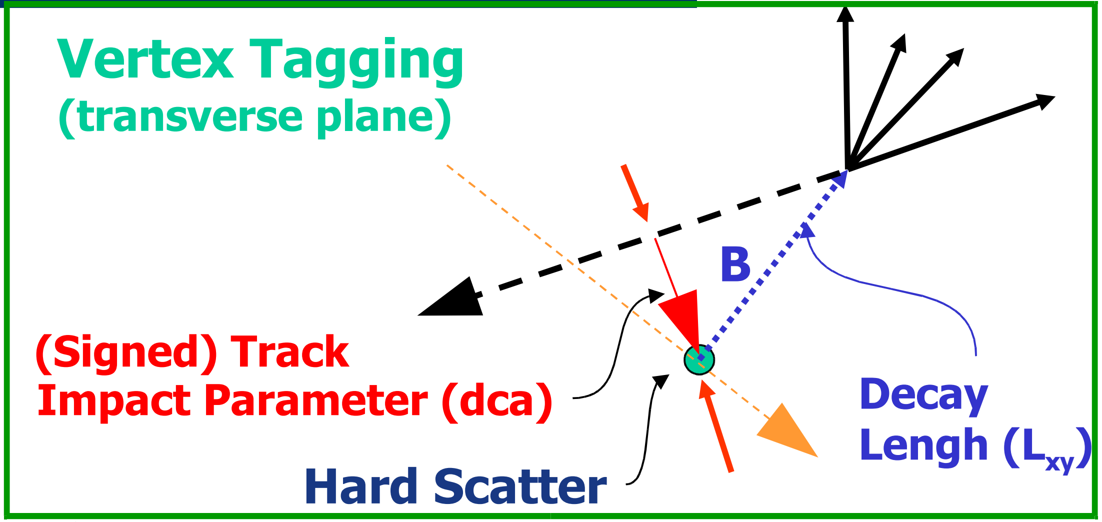
Backup

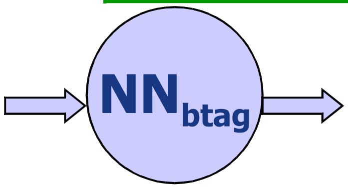
NN b-tagging

All Higgs analyses uses Neural Network b-tagging algorithm.

Combines:

- vertex mass
- vertex number of tracks
- vertex decay length significance
- chi2/DOF of vertex
- number of vertices
- two methods of combined track impact parameter significances

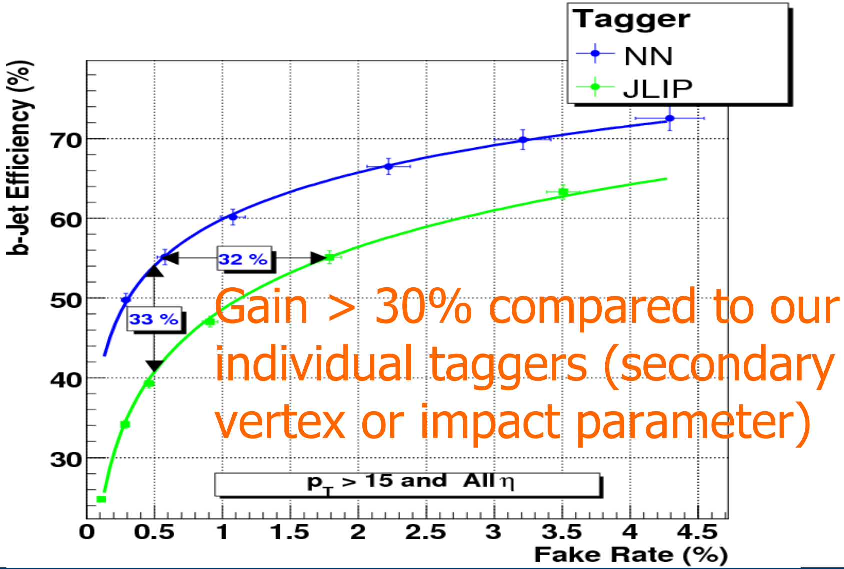




→ Large improvement compared to the individual taggers:

Loose→ 72% b-tagging eff.
6% mistag

Tight → 50% b-tagging eff.
0.3% mistag



Gain > 30% compared to our individual taggers (secondary vertex or impact parameter)