Prospects for the Higgs Bosons at DØ

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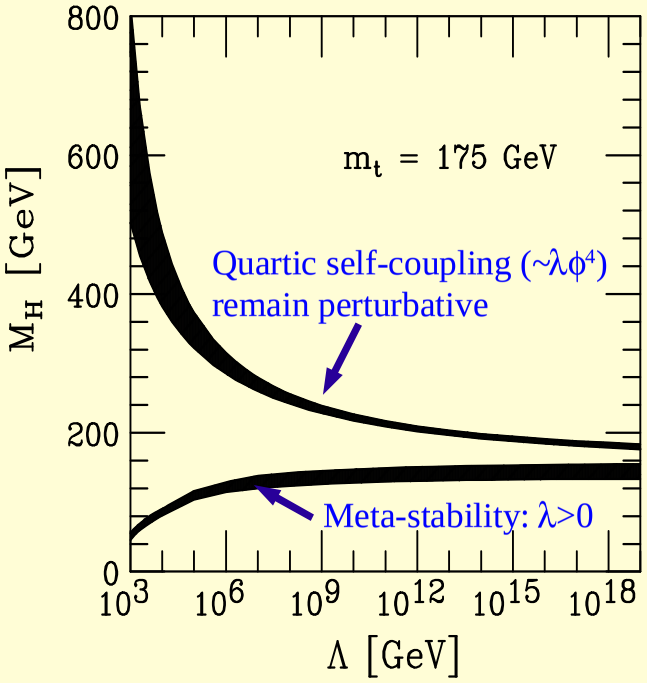
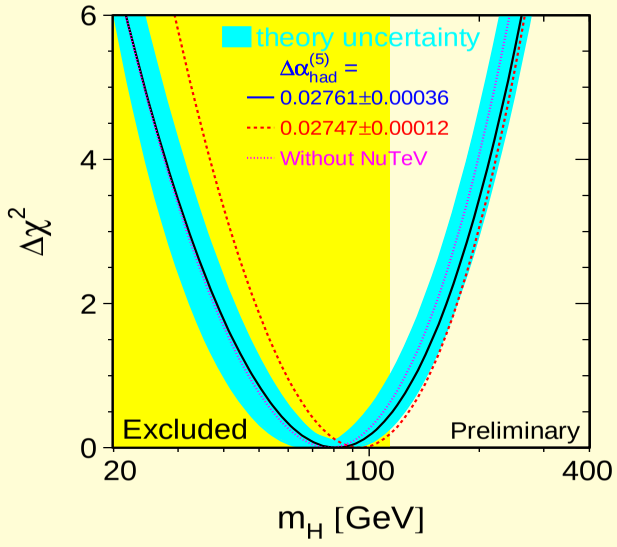
for the DØ Collaboration

- Introduction
- Review of the Results of SHW
- Studies at DØ
- Summary

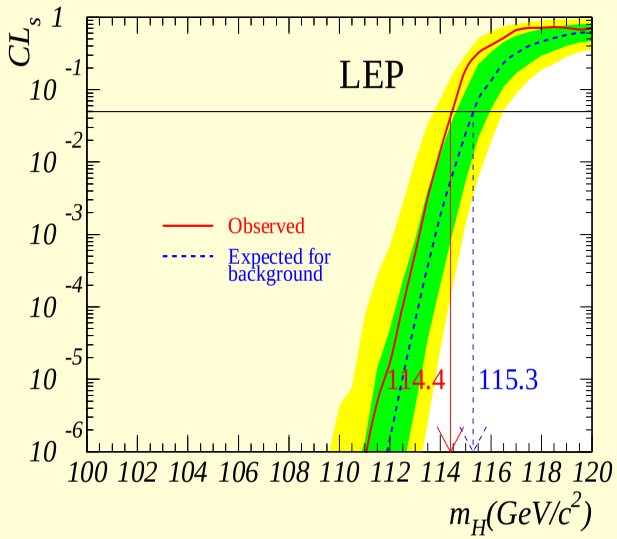
Preference for light mass Higgs

Theoretical bounds



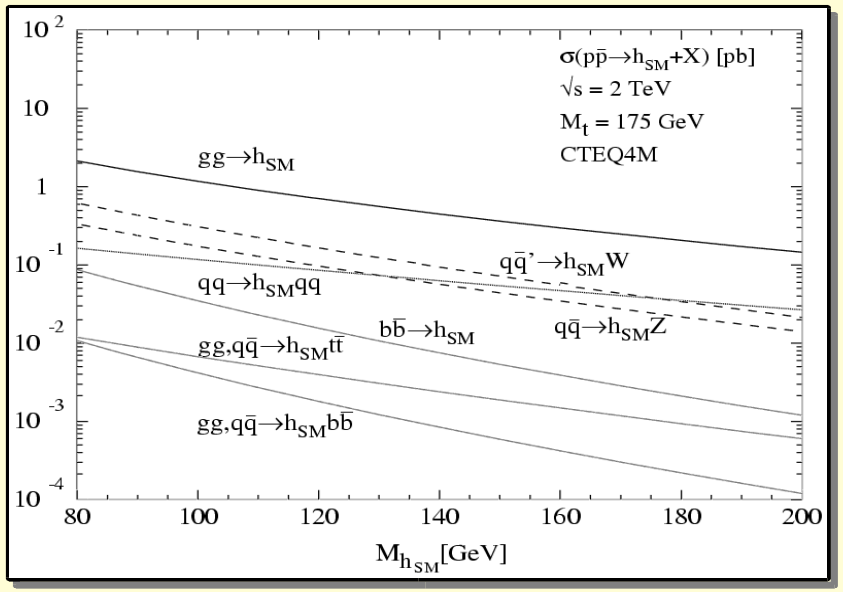


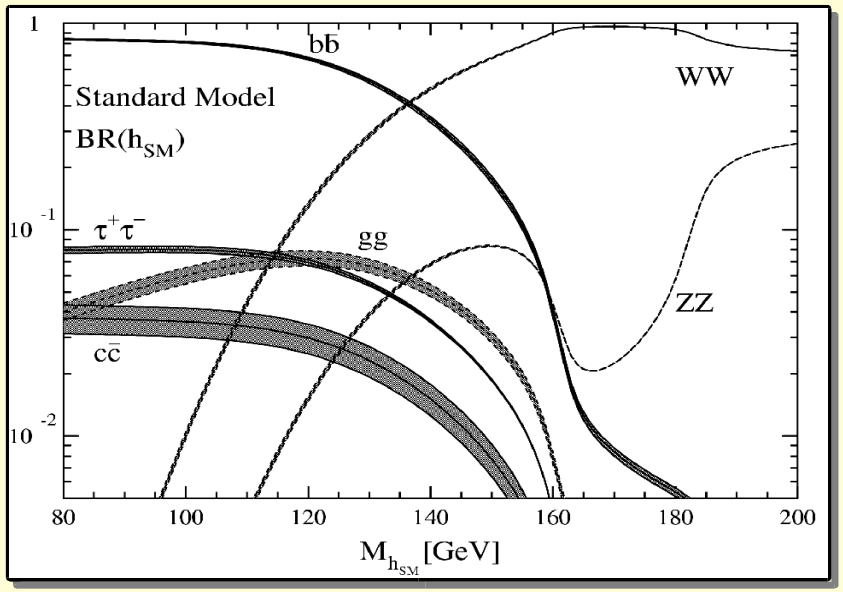
Indirect limit
M_H < 195 GeV
@ 95% CL



Direct search
MH>114.4 GeV
@ 95% CL

The Standard Model Higgs



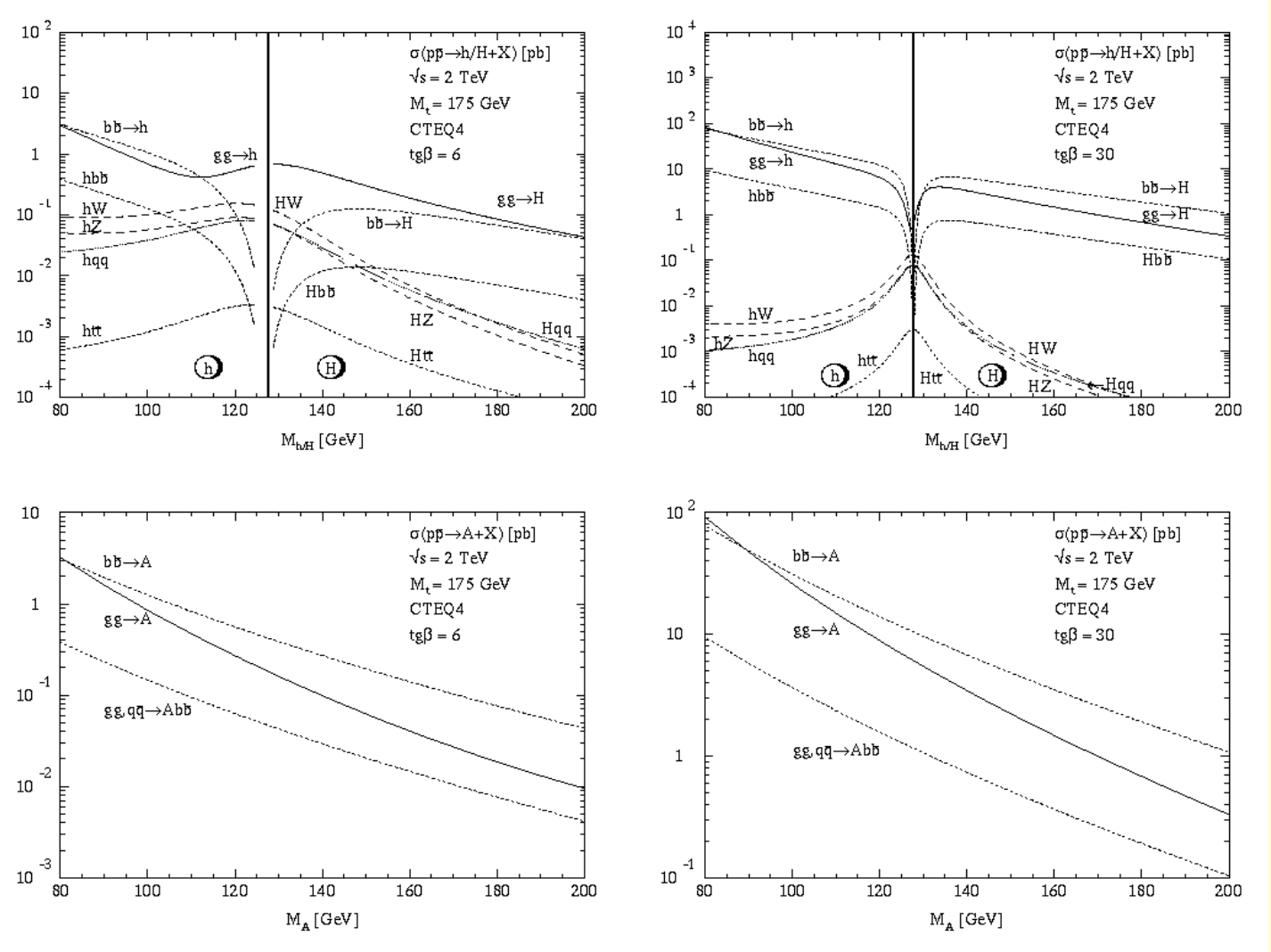


- Production
  - gg fusion
  - Associated production with W/Z
  - hqq
- Relevant decay modes
  - bb
  - WW
  - ZZ
  - ττ

Relevant Channels for SM Higgs

- gg fusion channel ✔
  - Largest production cross-section (0.5 ~ 1 pb^{-1})
  - Useful for high mass Higgs
- W/ZH associated production ✔
  - Accessible production cross-section (0.02~ 0.2 pb^{-1})
  - Good separation with background possible through good lepton identification
- Hqq ✗
  - Small production cross section (<0.01pb^{-1})
  - Background separation difficult

MSSM Higgs


σ(pp̄→h/H+X) [pb]
√s = 2 TeV
M_t = 175 GeV
CTEQ4
tgβ = 6
bb̄→h
gg→h
hbb̄
hW
hZ
hqq
htt̄
HW
bb̄→H
gg→H
Hbb̄
HZ
Hqq
Htt̄
h
H
M_h/H [GeV]
σ(pp̄→h/H+X) [pb]
√s = 2 TeV
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CTEQ4
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bb̄→h
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hbb̄
bb̄→H
gg→H
Hbb̄
hW
hZ
hqq
htt̄
Htt̄
HW
HZ
Hqq
h
H
M_h/H [GeV]
σ(pp̄→A+X) [pb]
√s = 2 TeV
M_t = 175 GeV
CTEQ4
tgβ = 6
bb̄→A
gg→A
gg,qq̄→Abb̄
M_A [GeV]
σ(pp̄→A+X) [pb]
√s = 2 TeV
M_t = 175 GeV
CTEQ4
tgβ = 30
bb̄→A
gg→A
gg,qq̄→Abb̄
M_A [GeV]

Relevant Channels for MSSM Higgs at the Tevatron

- SM channels
  - Interesting in the decoupling limit
  - SM results can be reinterpreted in the MSSM framework once the results are scaled to account for differences in couplings and branching fractions
- ϕbb
  - Large $\tan\beta$ can enhance coupling to b-quarks hence lead to increased production cross sections and decays to bb

General Comments

- Conclusions from SUSY-Higgs Workshop (SHW) in 2000 (hep-ph/0010338)
  - Due to lack of statistics, significant results cannot be obtained from a single channel unlike in LHC
  - Understanding the details of the cross-sections, kinematics of the signal and background along with precise knowledge of the performance of the detector is necessary
  - Advanced analysis techniques should be employed to make the most of the physics content in samples
  - It is critical to combine the results of CDF and DØ.

Assumptions

- Upgraded Tevatron

	Run 2A	Run 2B
Instantaneous $\mathcal{L}$	8.6×10^{31}	5.2×10^{32}
Weekly $\int \mathcal{L} dt$	17.3 pb^{-1}	105 pb^{-1}
$\int \mathcal{L} dt$	2.0 fb^{-1}	15 fb^{-1}
Bunch spacing	396 ns	132 ns
<# of interactions>	2.4	4.8

  - x20 the Run I integrated luminosity in Run 2A
  - Increase of energy: $\sqrt{s}$=1.8 TeV (Run 1) $\rightarrow$ $\sqrt{s}$=1.96 TeV

$WH \rightarrow l\nu bb$ (SHW)

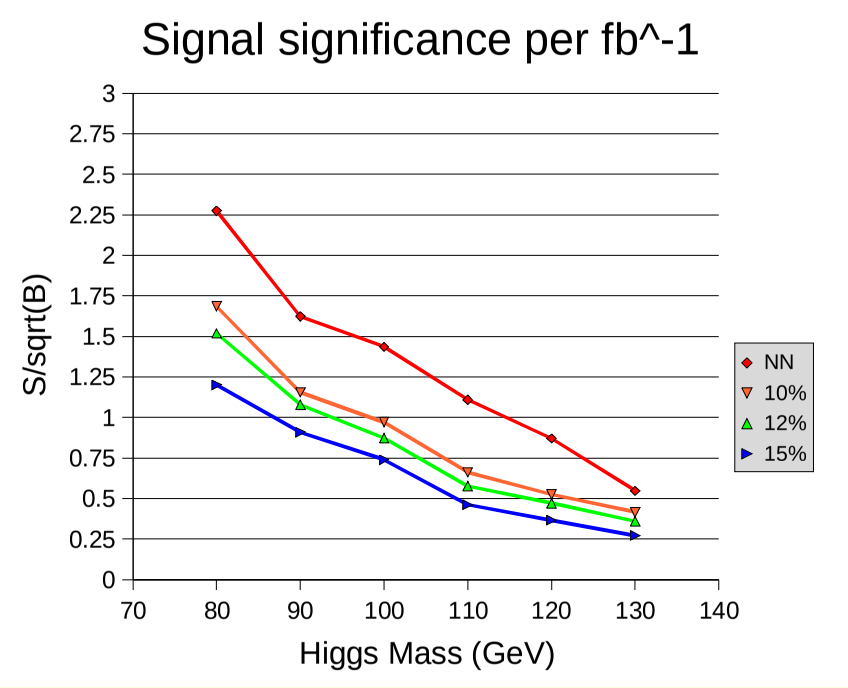
- Selection
  - Only one lepton
    - veto on additional leptons E_T>10 GeV
  - Primary lepton E_T>20 GeV
  - Missing E_T>20 GeV
  - Veto on extra jets- reject against tt-bar background
    - No extra jets with p_T>30 GeV and $|\eta|$<2.5
    - ≤1 extra jets with p_T<30 GeV and $|\eta|$<2.5
  - One tight and one loose b-tagged jets
  - 2σ mass window cut

WH→lνbb (SHW)

- Yield assuming 12% mass resolution

Higgs Mass	signal	total bkg	Wbb	WZ	tt-bar	single top
110	5	75.4	38	7.2	21	9.2
120	4	72	32	6	24	10
130	3	69.4	28	4.4	26	11

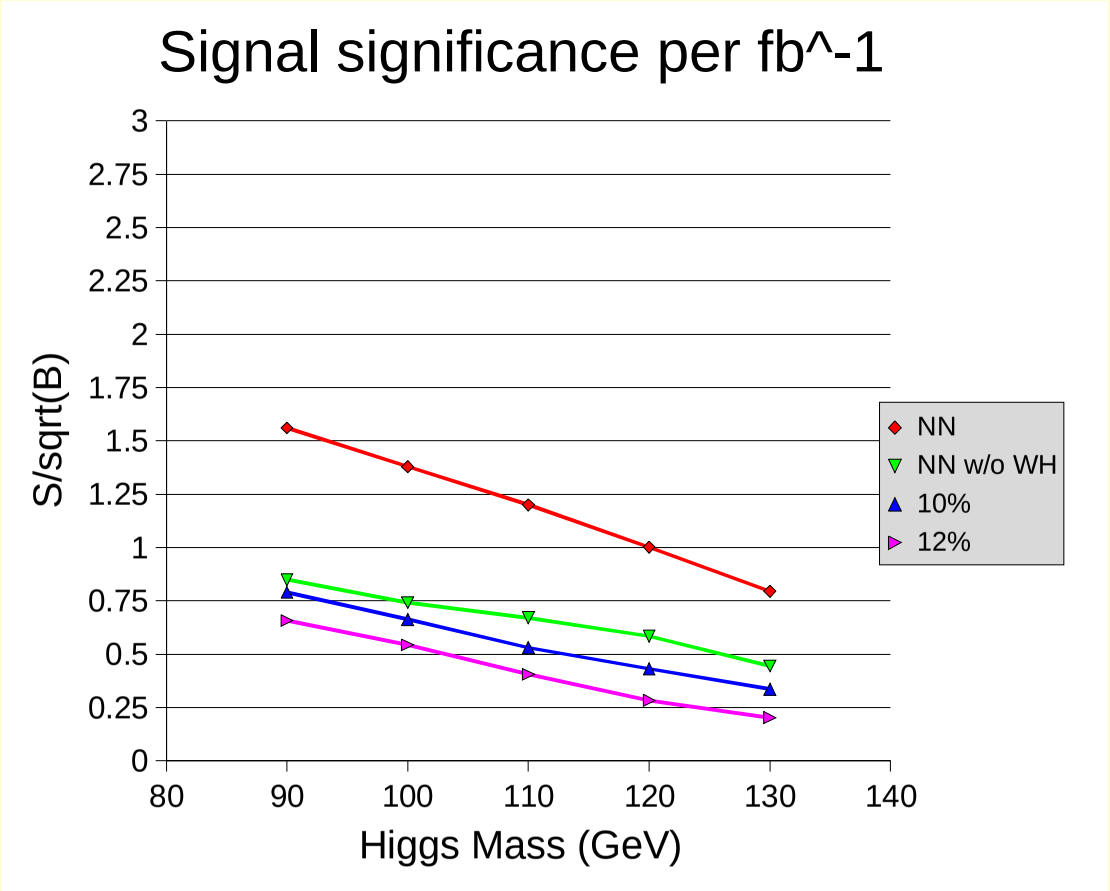
- Useful NN variables
  - E_T of b-jets
  - Dijet mass
  - H_T
  - ΔR of b-jets



$ZH \rightarrow \nu\nu bb$ (SHW)

- Selection
  - 2 b-jets
    - One tight and one loose
  - Missing E_T > 35 GeV
  - angle between missing E_T and closest jet $\delta\varphi$>0.5
  - Reject events with one or more isolated lepton
  - Scalar sum of hadronic energy H_T<175 GeV
- NN selection
  - Missing E_T > 20 GeV
  - 2 or more jets in the event with E_T>10 GeV, $|\eta|$<2

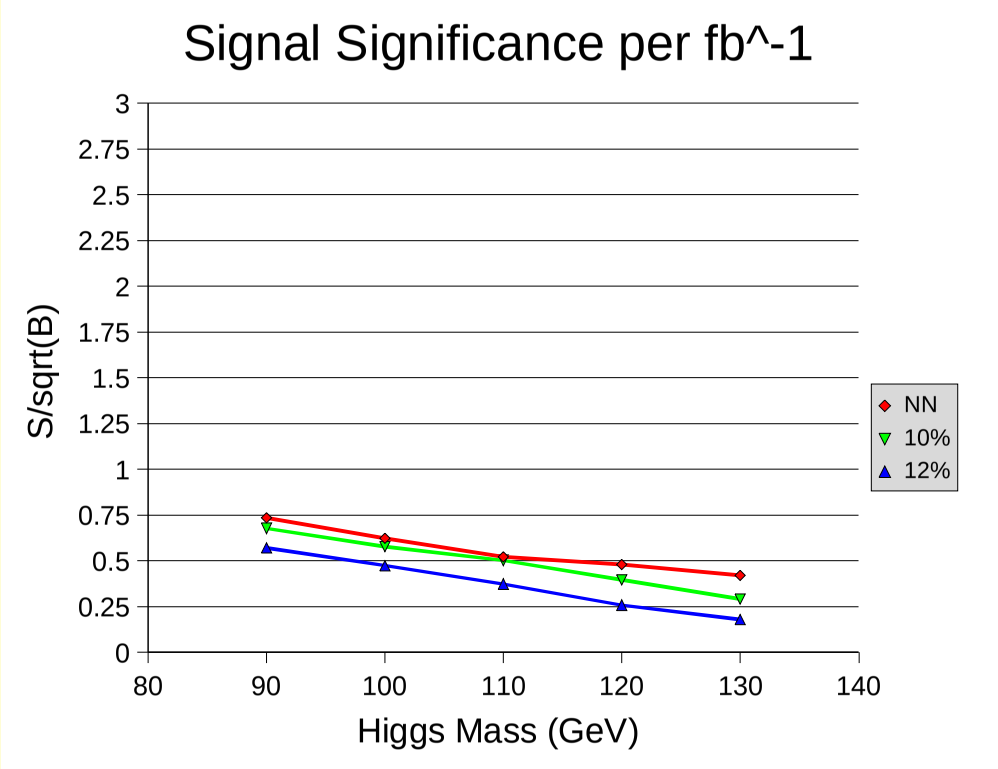
ZH→ννbb (SHW)



- Background: ZZ, WZ, Wbb and Zbb
  - No QCD bb-bar background included

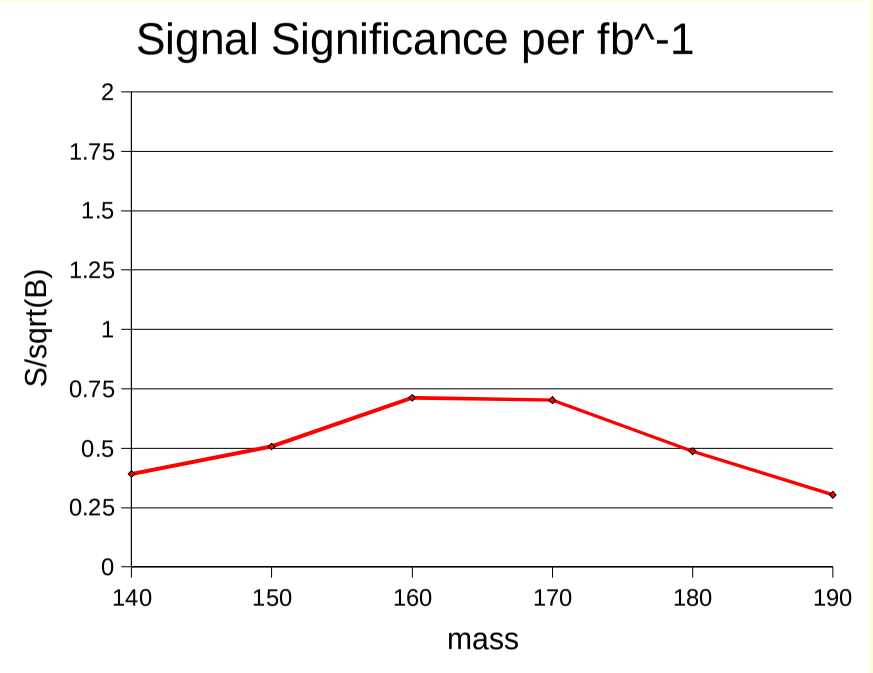
ZH→llbb (SHW)

- Selection
  - Two opposite signed leptons of the same flavor $P_T > 10$ GeV
  - $|M_Z - M_{ll}| < 10$ GeV
  - 2 b-tagged jets
  - $H_T < 175$ GeV
- Background
  - ZZ, Zbb, tt



H→WW→llνν (SHW)

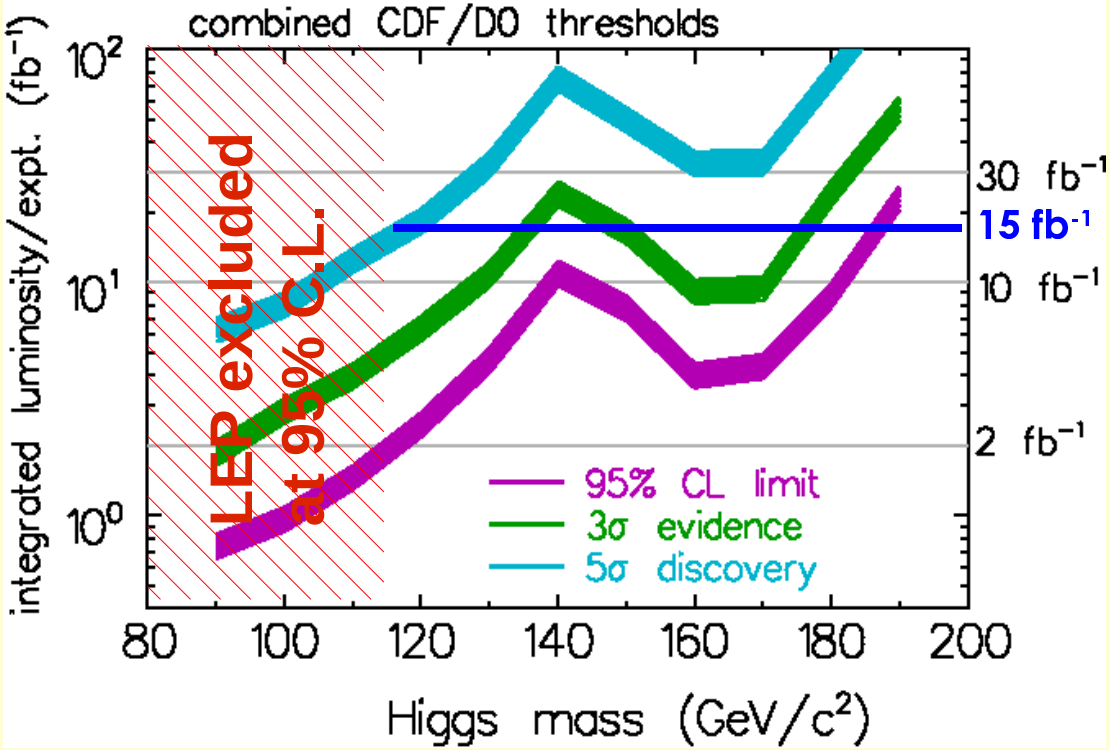
- Selection based on
  - lepton P_T, η
  - dilepton mass
  - dilepton opening angle
  - dR(lj)
  - missing E_T
- Likelihood analysis
  - polar angle of lepton w.r.t. beam axis
  - angle between dilepton and missing E_T



- Mass information can be obtained

$$M_C = \sqrt{P_T^2(ll) + m^2(ll)} + missing\ E_T$$

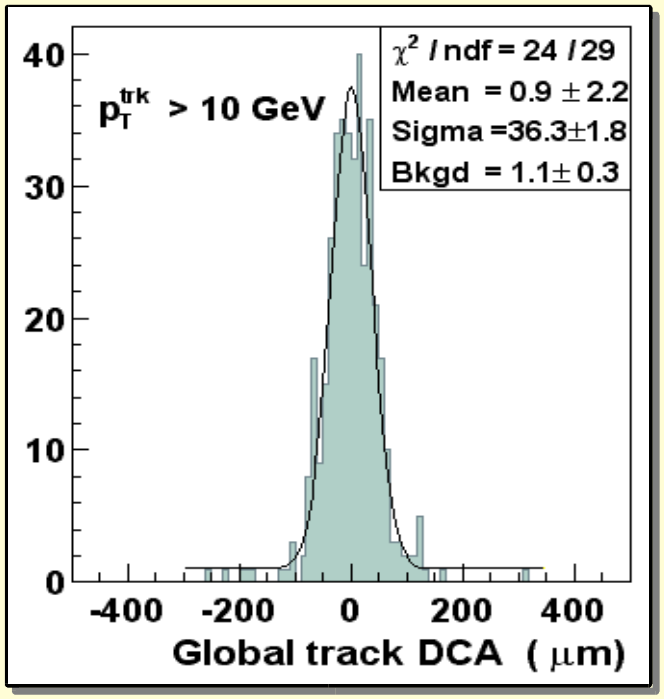
SM Higgs Searches at the Tevatron in Run 2

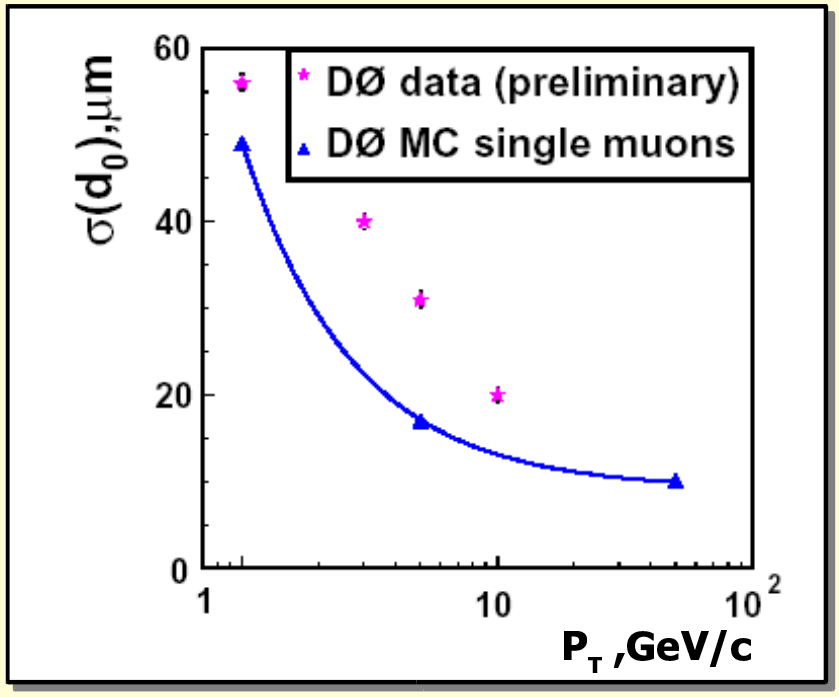


Both experiments are needed!

- Assumptions
  - good b-jet and lepton identification
  - Resolutions at least as good as Run 1
  - Trigger efficient at high luminosities

B-tagging



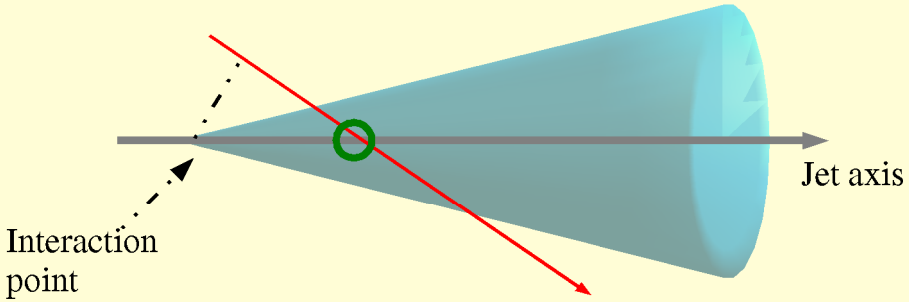


- Distance of closest approach with respect to the beam spot
- IP resolution of 20 μm
  - Beam width ~ 30 μm

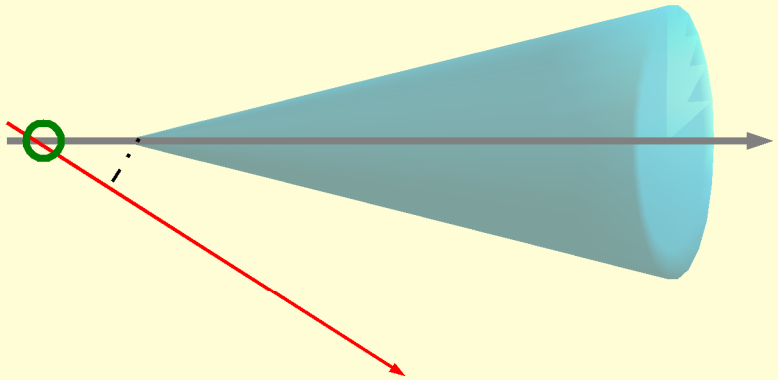
- Close to expectations
- further improvements expected from
  - Alignment
  - Understanding of SMT

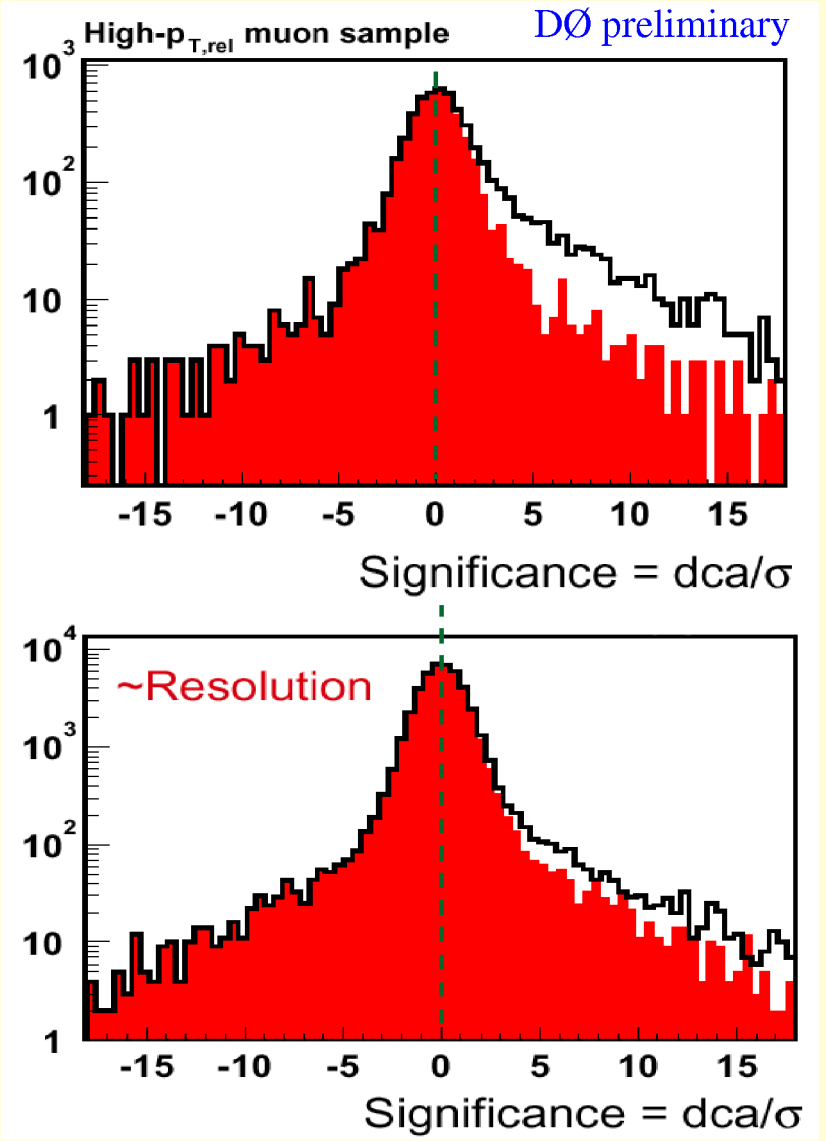
Impact Parameter b-tagging

- Positive signed impact parameter

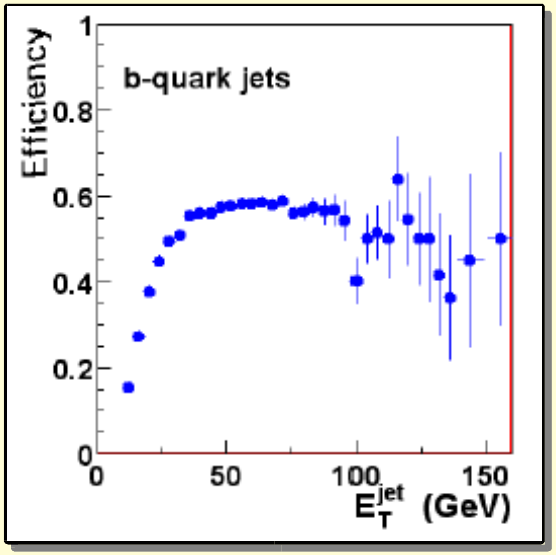


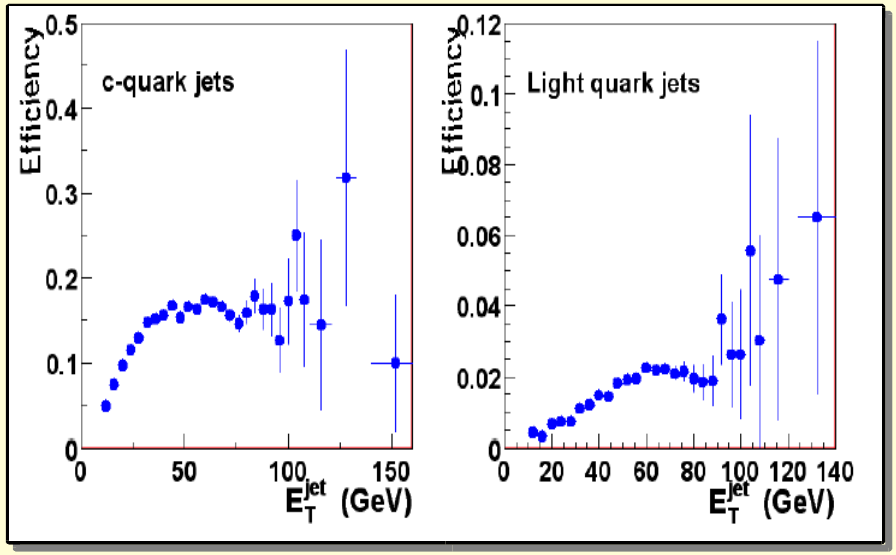
- Negative signed IP is due to resolution effects





Displaced Vertex B-tagging in Monte Carlo

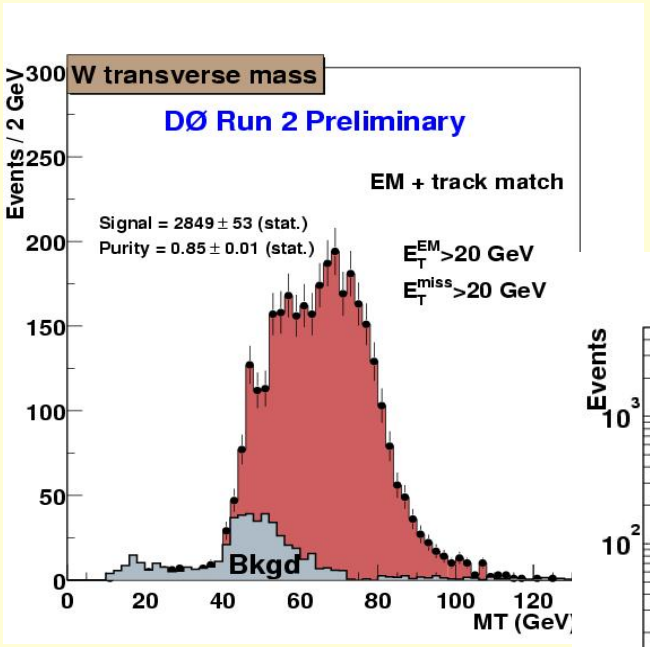


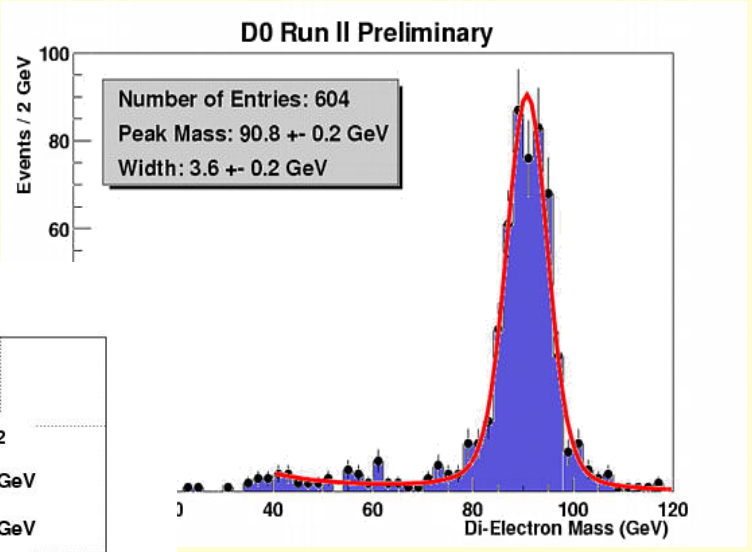


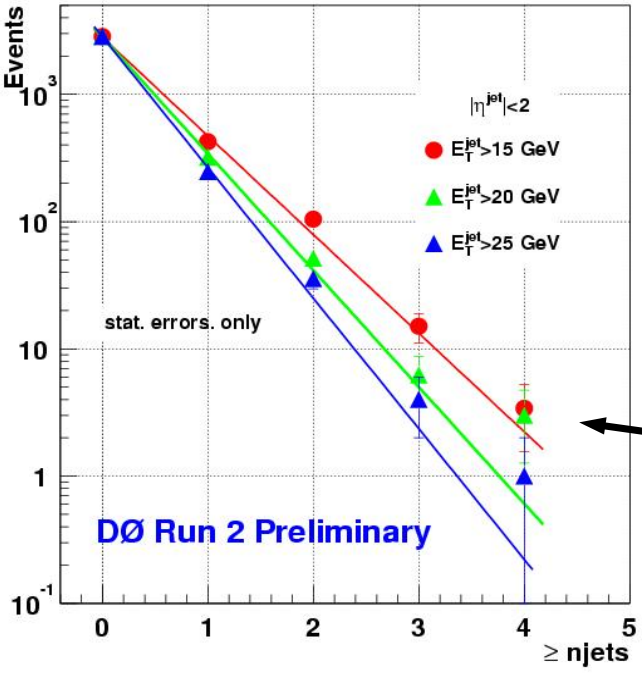
- Full simulation in highest luminosity condition for Run 2A
- Vertex decay length significance >3
- Close to the assumptions of the Higgs Workshop
- Expect improvement in light quark tagging by refinement in tracking algorithms and vertex selection

Electron Identification

- $W \rightarrow e\nu$
- $Z \rightarrow ee$



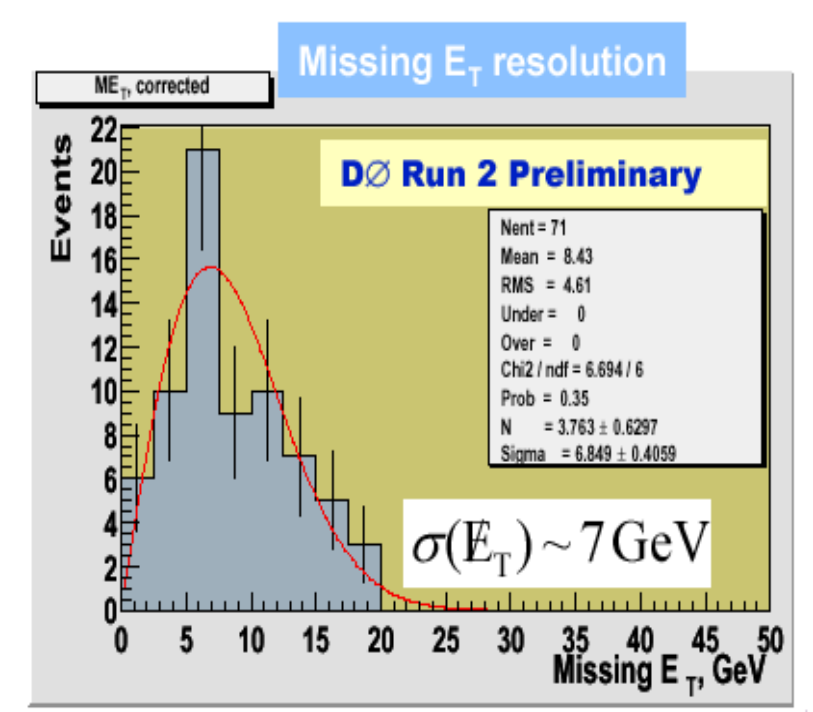




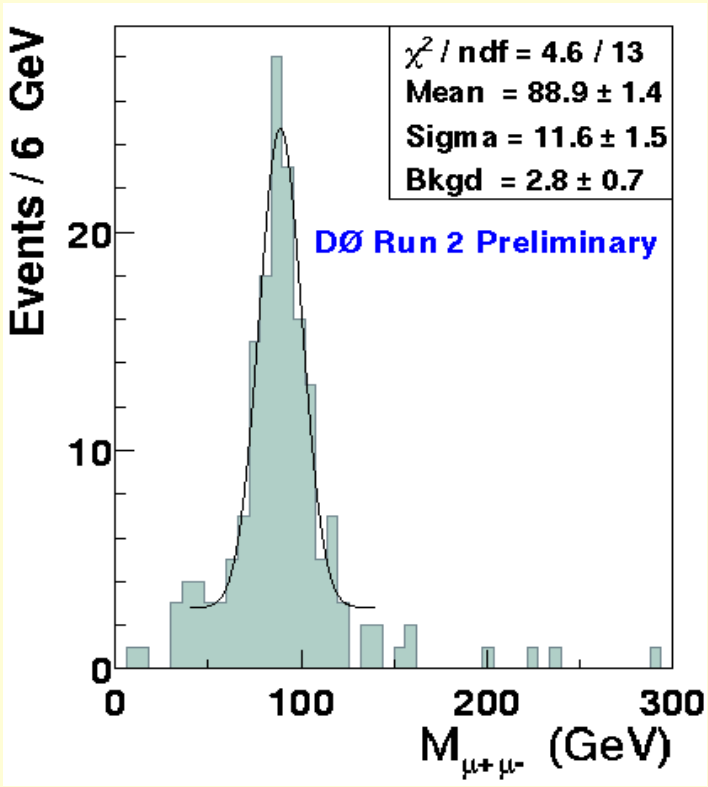
Inclusive # of jets in W events - Understanding the scaling behaviour is important

Other Objects

- Missing E_T

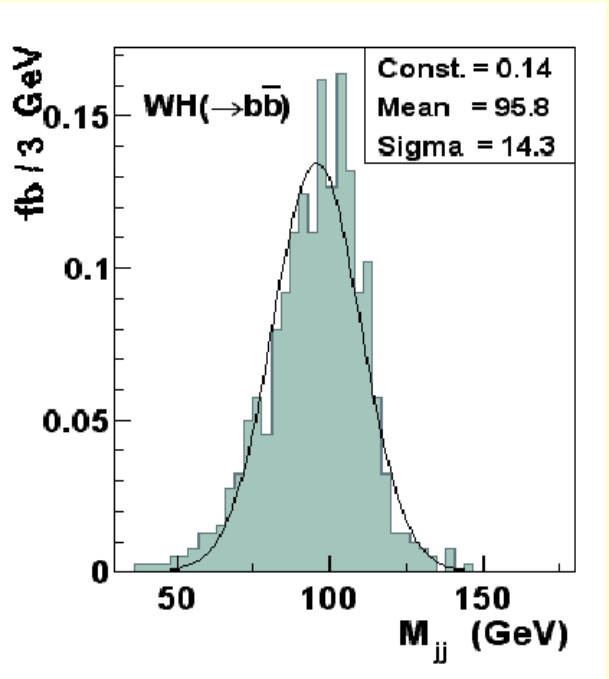


- Muon



WH (W→e/μ ν)

- Event characterised by
  - Isolated lepton
  - missing E_T
  - 2 b-jets
- Detailed studies using full simulation in progress
- e.g. M_H =115 GeV
  - Jet E_T > 15 GeV, |η|<2, both jets b-tagged
  - isolated e/μ, E_T >20 GeV, |η|<2.5
  - missing E_T >20 GeV



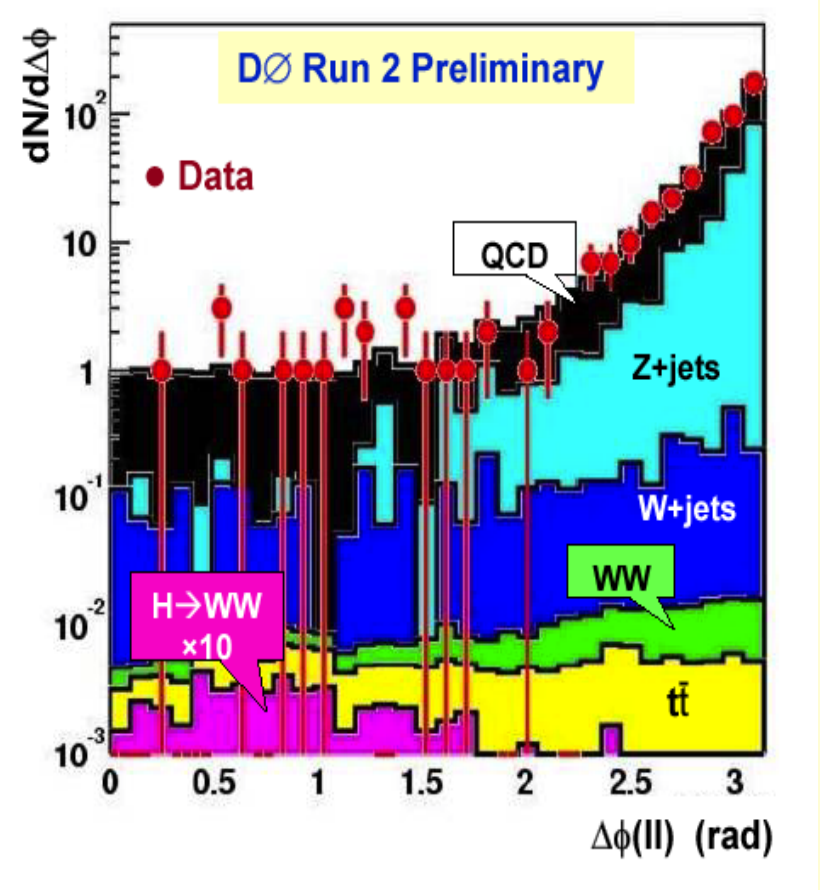
- Relative σ_M/M~15%
  - Calorimeter response correction only
  - Close to the SHW assumptions
- Yield is consistent with SHW of 4 events/fb^{-1}

ZH

- Signal acceptance (dilepton and neutrino channels) and rate estimations are based on detailed simulations
- Detailed background studies of QCD, tt-bar, ZZ, Zjj, Zbb and Zcc are underway
- Selection criteria similar to SHW
- Higgs mass resolution and expected number of events is similar to that of WH(bb) case and SHW estimations of 4.7 events/fb^{-1}

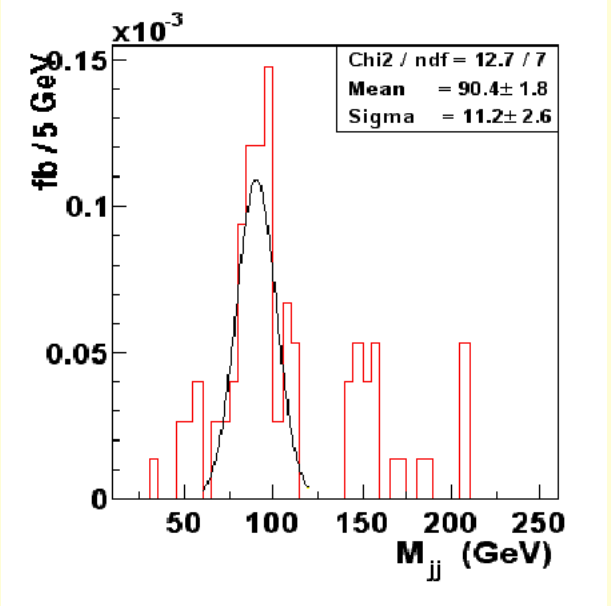
Understanding the Backgrounds to H→WW

- H→WW→eeνν
  - Mass reconstruction not possible
  - Since WW is a product of a spin 0 particle, one can employ variables sensitive to spin correlations
  - azimuthal opening angle is a powerful discriminating variable
  - After basic electron ID criteria



ϕbb Channel

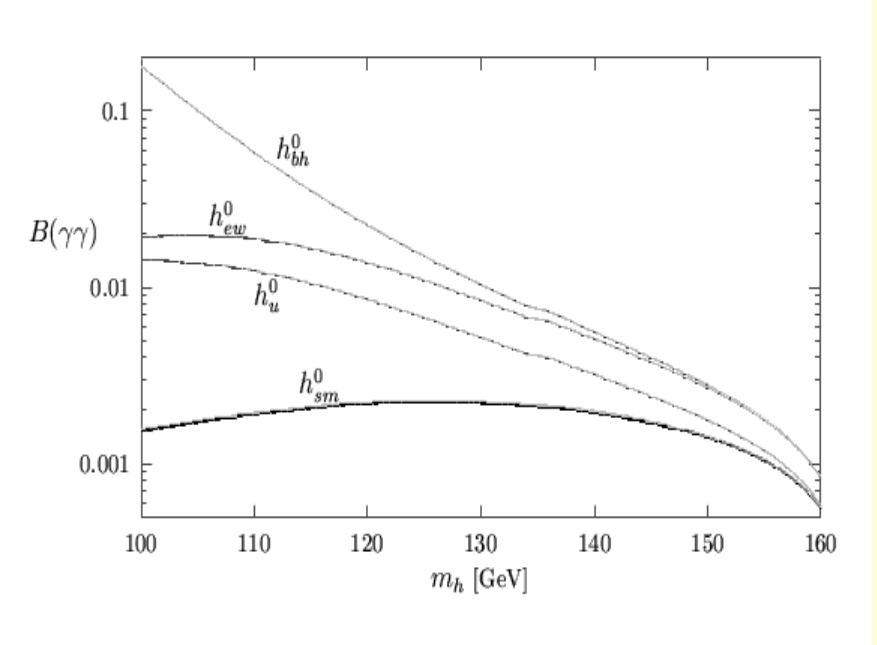
- Enhanced coupling of ϕbb by tan β
- 4 b-jet final state
- Backgrounds
  - Multijet, tt-bar, Zbb, Wbb
- For M_H=120 GeV
  - E_T(jet1)>55 GeV, E_T(jet2)>40 GeV, E_T(jet3/4)>30 GeV
  - 3 or more b-tags
- Consider all jet permutations
  - Normalized: $\sigma(\phi bb)$=3.7 fb



- 12% relative mass resolution

$H \rightarrow \gamma\gamma$

- Many theories beyond the SM predict much larger branching fractions due to suppressed coupling to
  - All fermions (fermiophobic, h_{bh})
  - All fermions but top (top color)
  - top and bottom quarks (h_{ew})
  - down-type fermions (h_u)

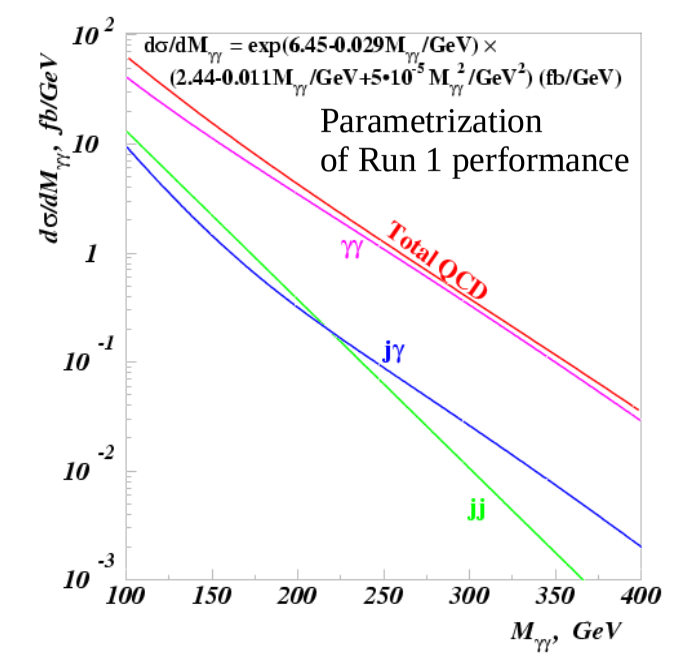


- Some models that employ large ED also predict enhanced di-photon rate
- One must be prepared for large $B(\gamma\gamma)$

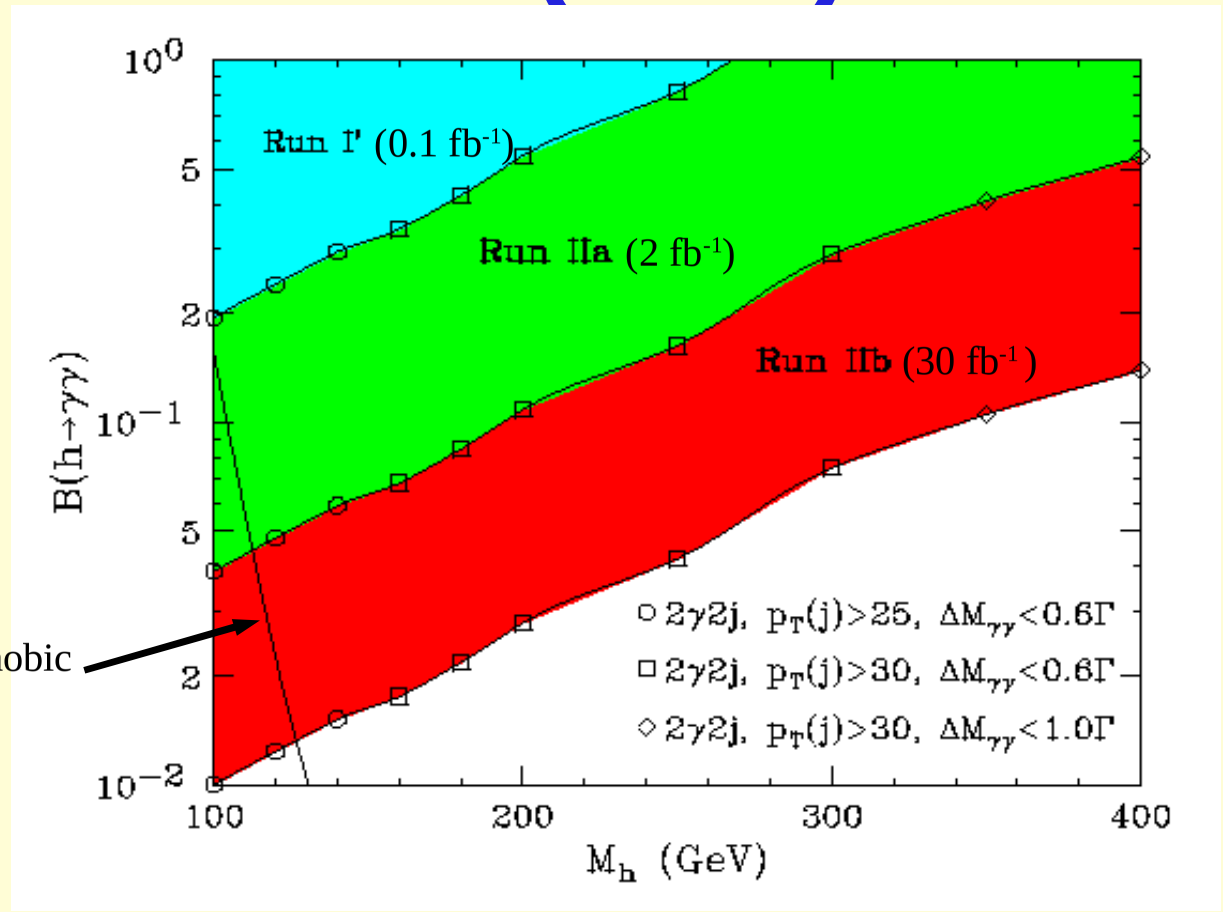
Diphoton Channel

- Fermiophobic
  - No production from gg fusion
- Top color
  - Can be produced by all leading diagrams
- No top,bottom coupling
  - similar to fermiophobic except reduced diphoton branching fraction due to charm and tau decays
- No down-type coupling
  - similar to top color but reduced rate

- Backgrounds
  - Z->ee with lost tracks
  - QCD
    - genuine diphoton production
    - jet mis-identified as photon



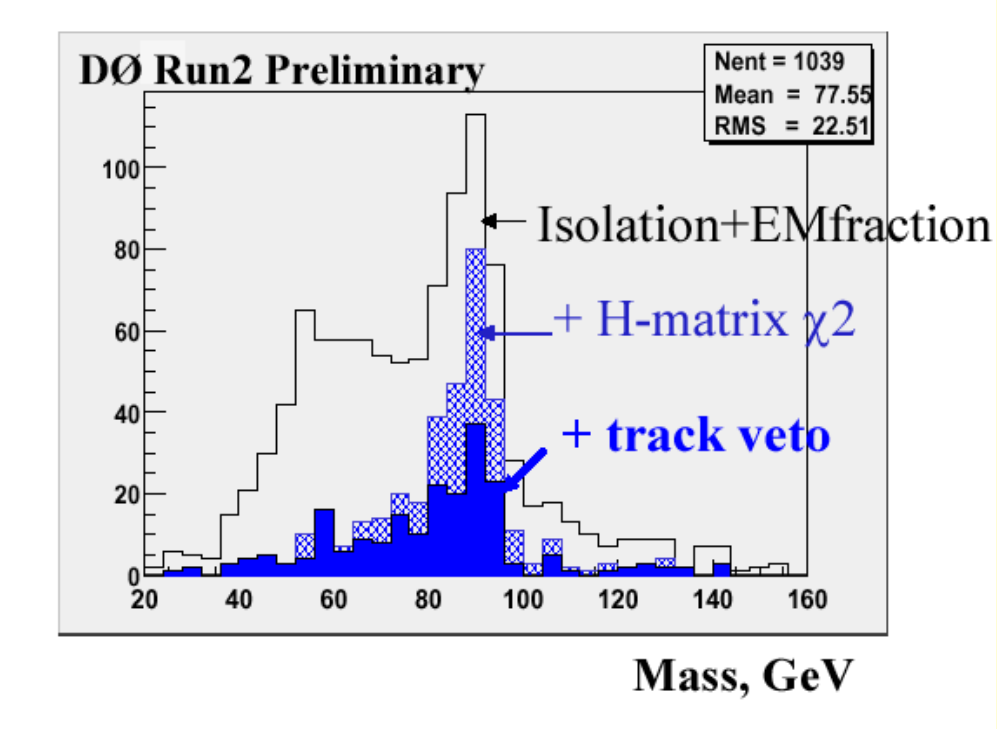
Reach of Diphoton Channel (SHW)



- Expect M_H >115 GeV @ 95 C.L in Run IIa for fermiophopic Higgs

Diphoton in Data

- First look at selected diphoton candidates in a small dataset with partial calibration (11/01~04/02)



- Work in progress to understand the backgrounds and reduce the photon mis-identification rate

Summary

- The detector is working well and we are taking physics data
- A lot of effort is being put in understanding our detector and incorporating our findings into the detailed simulations
- Final sensitivity studies will rely on our understanding of
  - bb mass resolution
  - b-tagging efficiency
  - missing E_T resolution
  - backgrounds