Search for Associated Production of Z and Higgs Bosons in $\nu\bar{\nu}b\bar{b}$ Final States at DØ

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Introduction

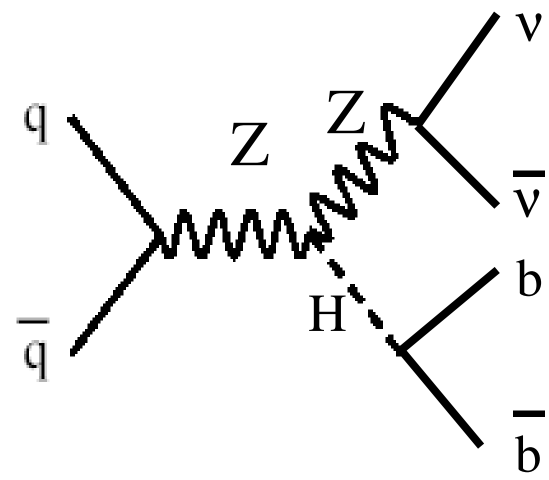
<u>Motivation</u>

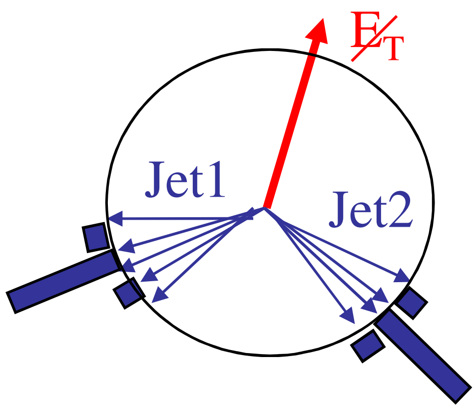
2 b-jets + missing E_T topology very sensitive:

$\sigma(qq \rightarrow ZH) \times Br(Z \rightarrow \nu\nu, H \rightarrow bb)$ ~0.015pb

(m_H=115GeV)

Also sensitive to $\sigma(qq \rightarrow WH) \times Br(W \rightarrow \not{l}\nu, H \rightarrow bb)$





<u>Characteristic Signal</u>

- Large missing E_T (calorimetry)
- 2 b-tagged jets with high p_T (tracking, b-tagging)
- Jets boosted (not back to back)
- Dijet mass of b-jets
- No isolated leptons

0.3 fb^{-1} result in PRL

1 fb^{-1} cuts-based result April 2007

neural net result November 2007

2 fb^{-1} preliminary result in February 2008

Analysis Outline

The signal is well defined but has significant background

Simulated SM background

Dominated by W+jets, Z+jets, top, and di-boson

Well defined: can be modeled but some irreducible

Instrumental background

Mainly QCD multi-jet events with mis-measured and fake jets

Generally low acceptance, but large cross-section

Estimate the magnitude and shape from data

Outline

1. Basic cuts
2. Neural net b-tagging
3. 2nd neural net for event selection

1. Basic Cuts

- **Using 0.93 fb^{-1} of data**

- **$\not{E}_T$ > 50 GeV**
- **2 jets with p_T > 20 GeV, $|\eta|<2.5$** signal topology

- **$\Delta\phi$(dijet) < 165°** rejects QCD di-jet events
- **Isolated EM and muon veto** rejects top, W/Z+jets
- **H_T < 240 GeV** rejects top

$\not{H}_T = |\Sigma p_T(\text{jets})|$
$\not{E}_T = |\Sigma E_T(\text{cal})|$
$\not{P}_T^{trk} = |\Sigma p_T(\text{tracks})|$
$\text{Asymmetry}(\not{E}_T,\not{H}_T) = (\not{E}_T-\not{H}_T)/(\not{E}_T+\not{H}_T)$

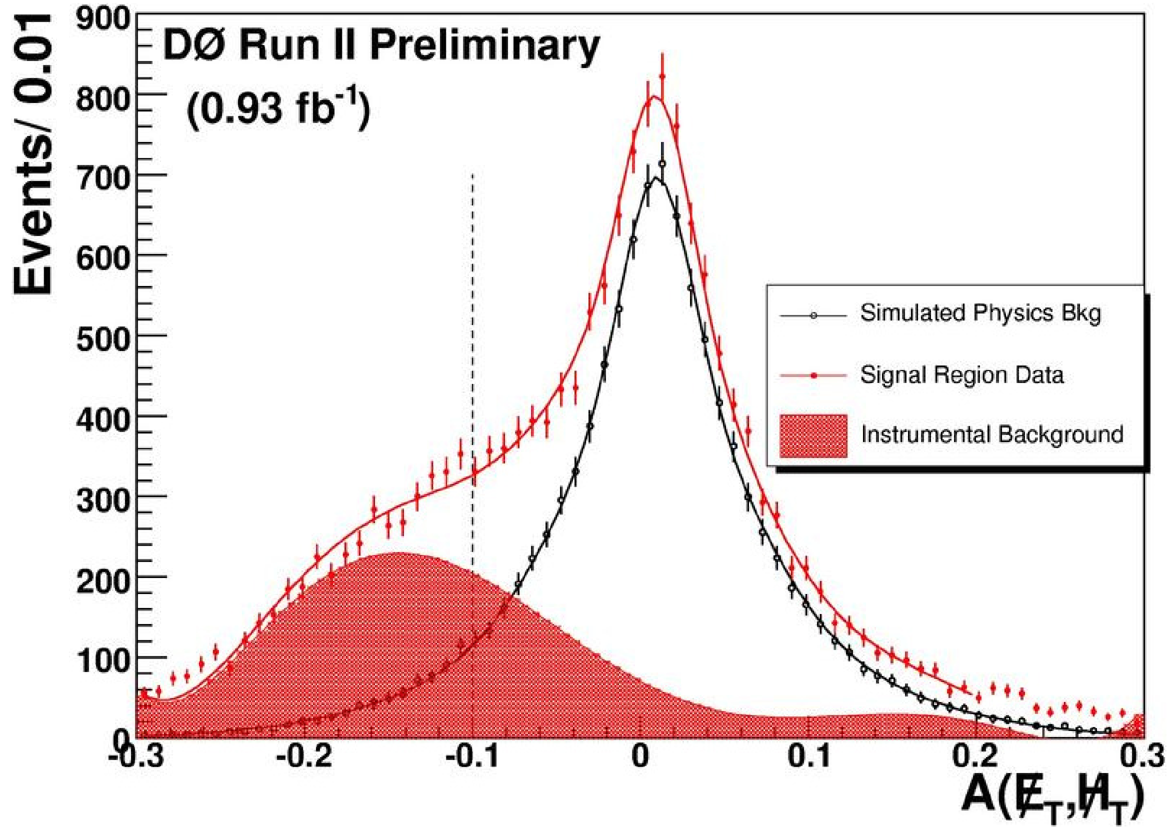
- **-0.1 < Asymmetry($\not{E}$T,$\not{H}$T) < 0.2** rejects instrumental background
- **$\Delta\phi(\not{E}_T, \not{P}_T trk)$ < 90°** for "signal" region
  > 90° for "sideband" region

Used to measure instrumental background

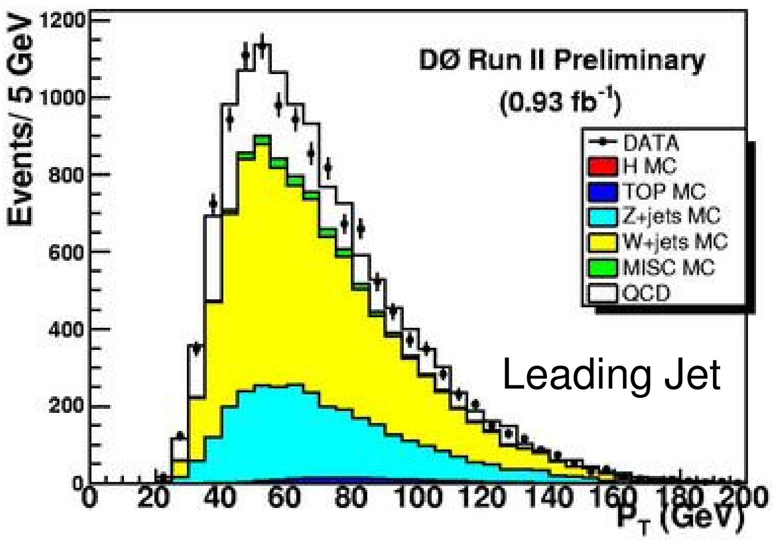
Instrumental Background Estimation

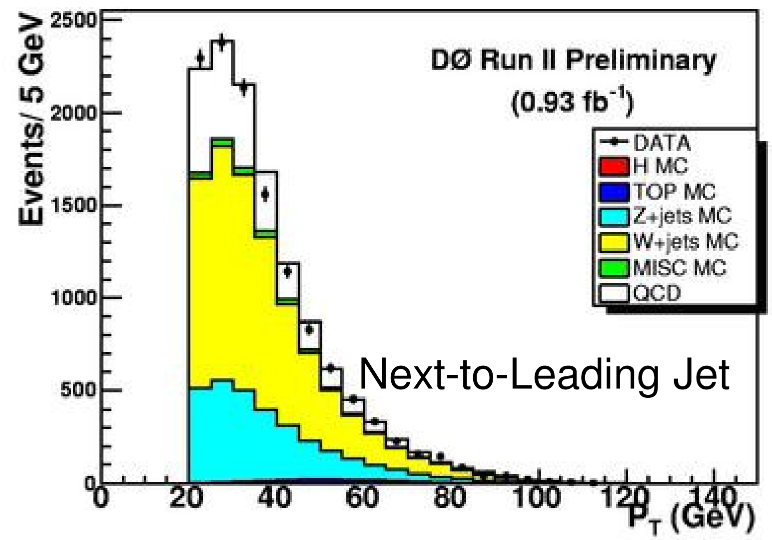
Use fit of Asymmetry($\not{E}_T$, $\not{H}_T$)

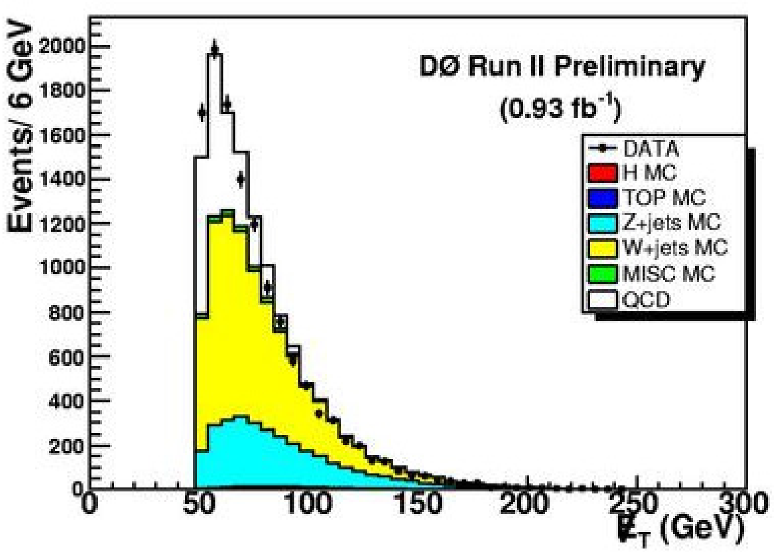
1. Simulated Physics background: Triple Gaussian fit to MC
2. Instrumental background: 6^{th} order polynomial in sideband region
3. Combined fit with fixed shapes to signal region for normalization

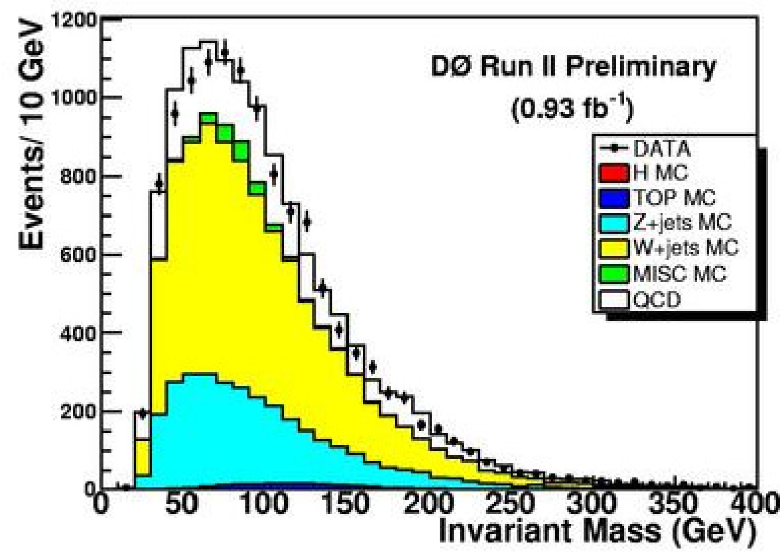


Pre *b*-tagging









2. Neural Net *b*-tagging

Combine various variables from track based b-tagging tools in a Neural Network

Train on MC, certify on data

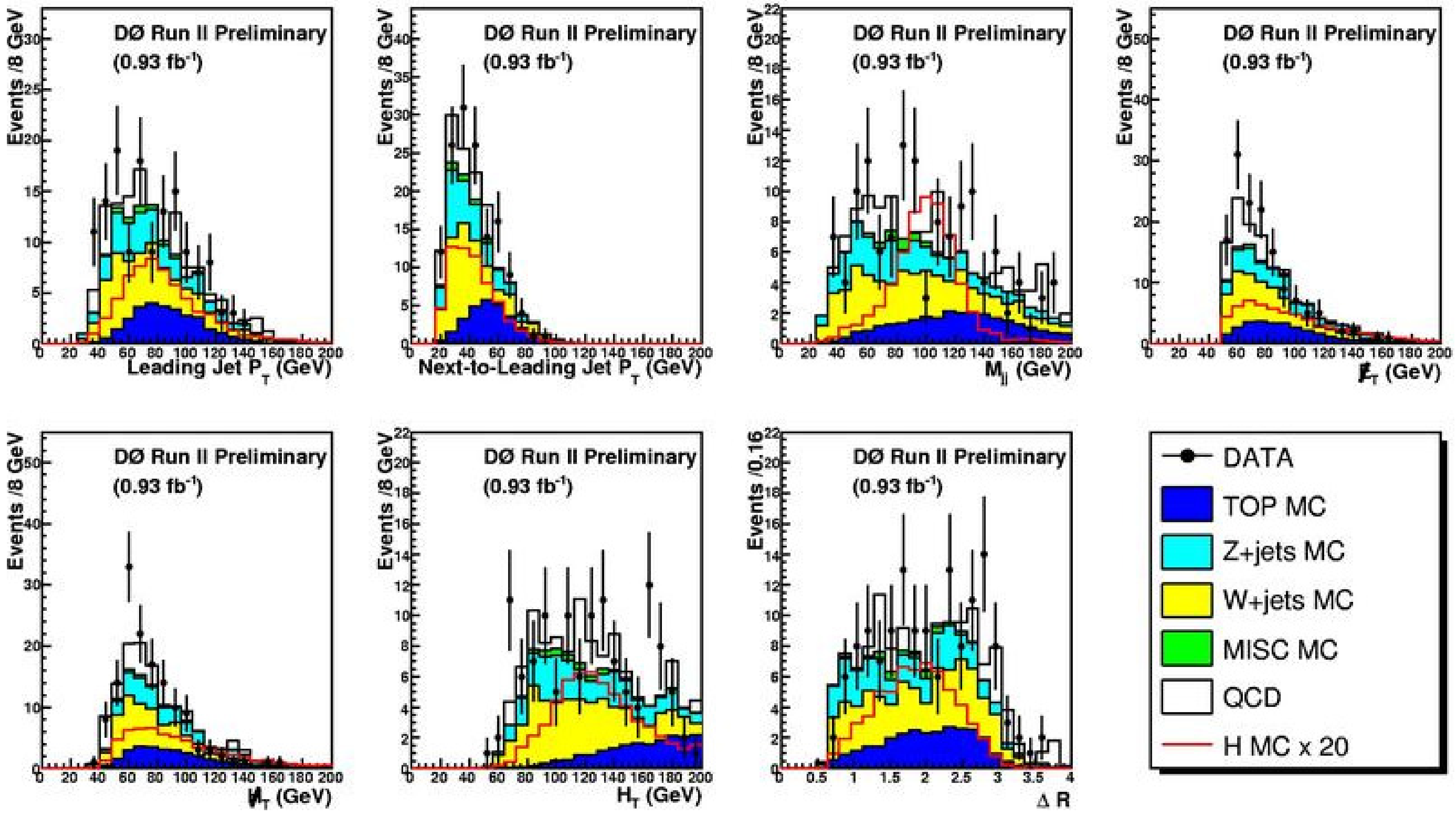
Increase efficiency by ~1/3 for same fake rate over best performing constituent tool

Require Tight-Loose *b*-tagged jets for optimum sensitivity

	Efficiency	**Mis-tag Rate**
Loose	~73%	~5%
Tight	~48%	~0.5%

3. Neural Net Event Selection

Input variables for 2^{nd} neural net after *b*-tagging:



3. NN Event Selection

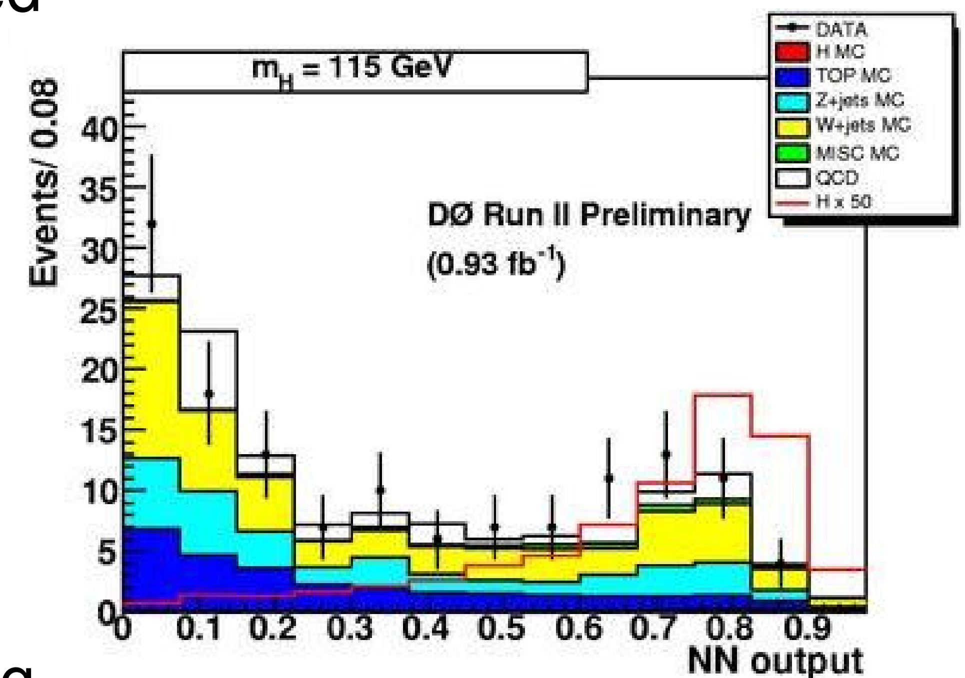
7 input variables

Training MC weighted with b-tag probability derived from dedicated sample

Using W/ZH signal MC.

One hidden layer (14 neurons)
Train over 200 epochs for each mass point

Separate training and limit-setting MC samples



Final Selection and Errors

Sample	No b-tag	Double b-tag
$ZH(m_H = 115\ GeV)$ $WH(m_H = 115\ GeV)$	2.46 1.75	0.88 ± 0.12 0.61 ± 0.08
$W + jets$ $\rightarrow Wbb$ $\rightarrow Wcc$	6750 397 1170	52.3 35.4 9.33
Zjj $Z \rightarrow \tau\tau$ $Z \rightarrow \nu\overline{\nu}$	 107 2130	 0.25 0.63
Zbb $Z \rightarrow \tau\tau$ $Z \rightarrow \nu\overline{\nu}$	 6.39 229	 0.63 24.9
Zcc $Z \rightarrow \tau\tau$ $Z \rightarrow \nu\overline{\nu}$	 12.8 467	 0.18 4.93
$t\overline{t}$ $Di - boson$	172 228	29.1 3.84
Total Physics Background Instrumental Background	10100 2560	117 ± 17 17.2 ± 3.4
Total Background	12700	134 ± 18
Observed Events	12500	140

Systematic Error	Value (%)
Luminosity	6.1
Trigger	5
Jet ID	5
b-tagging	7
Total Physics Background	6-18
Instrumental Background	20

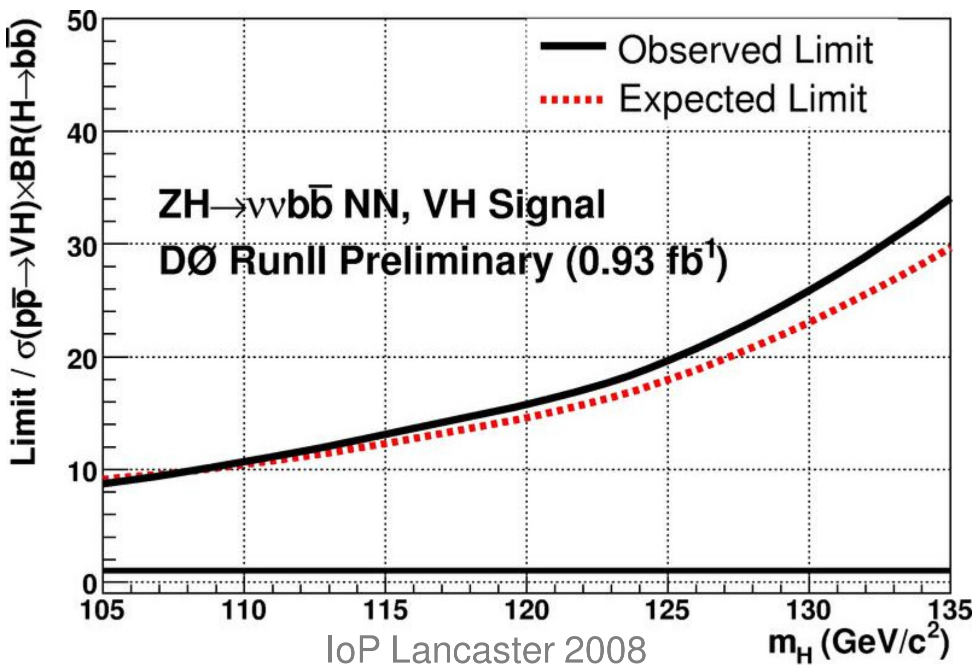
Shape dependent systematics included

Limits

Modified frequentist CLs approach:

Compare background-only (B) and signal-plus-background (S+B) hypotheses

Higgs Mass (GeV)	$m_H = 105$	$m_H = 115$	$m_H = 125$	$m_H = 135$
$ZH(H \to bb)$ Expected Limit (pb)	1.6	1.5	1.4	1.2
$ZH(H \to bb)$ Observed Limit (pb)	1.5	1.5	1.4	1.3
$WH(H \to bb)$ Expected Limit (pb)	4.8	4.3	3.8	3.6
$WH(H \to bb)$ Observed Limit (pb)	4.4	5.0	4.4	4.2
$VH(H \to bb)$ Expected Limit (pb)	2.8	2.5	2.3	2.0
$VH(H \to bb)$ Observed Limit (pb)	2.6	2.7	2.5	2.3



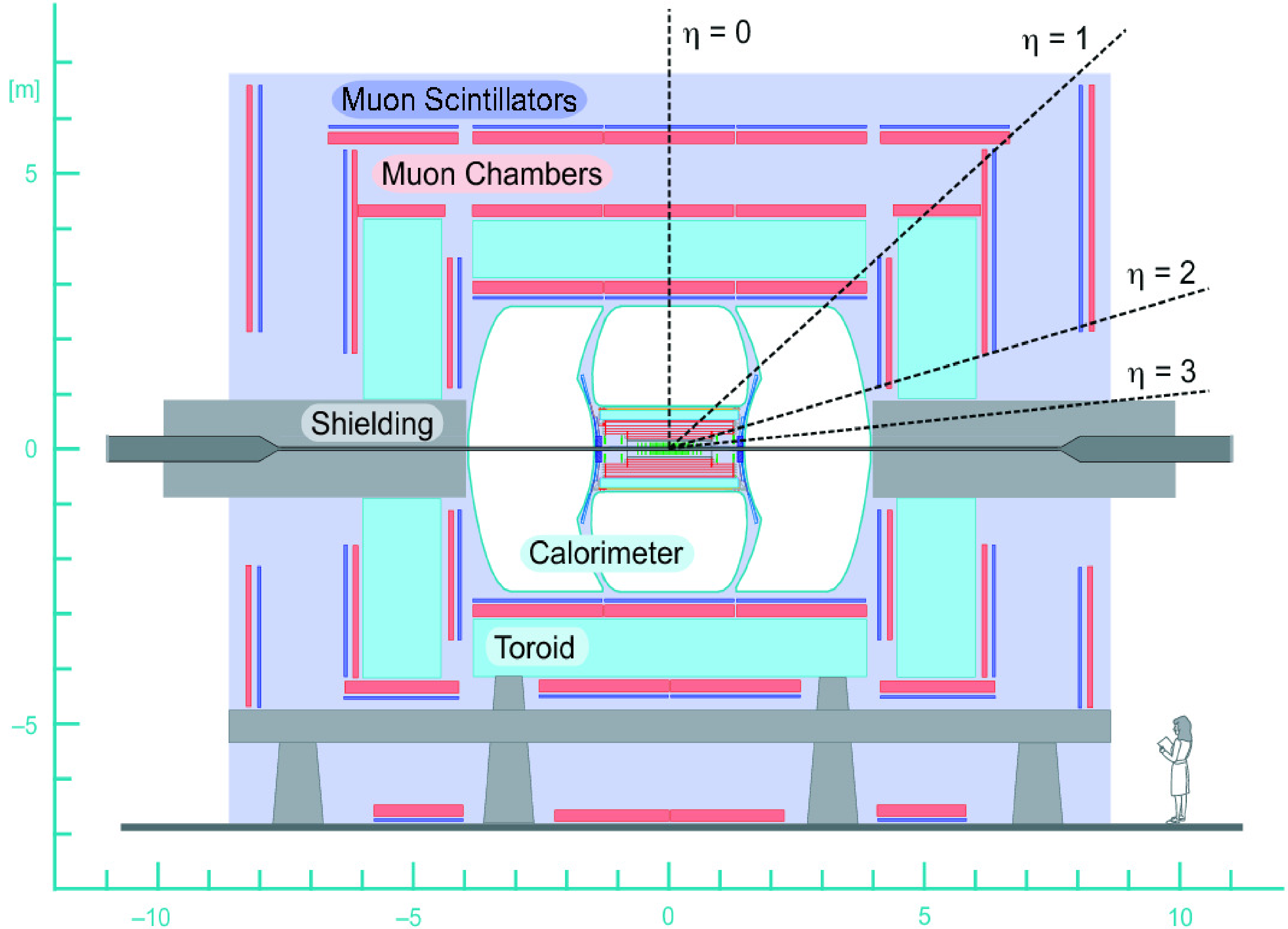
Summary

- Searched for SM Higgs boson in 0.93 fb^{-1} at $\sqrt{s}$ =1.96 TeV
- Analyzed 2 b-jet + missing E_T topology
- Sensitive to ZH→vvbb and WH→lvbb with unidentified lepton
- Utilized 2 neural networks for b-tagging and event selection
- No deviation from SM expectation observed
- Set upper limits on SM VH cross-section

References

- DØ 0.26 fb^{-1}result published in PRL; hep-ex/0607022
- RunIIa Preliminary result (0.93 fb^{-1}) in April 2007; DØ Note 5306-CONF
- Updated in November 2007 with Neural Net classifier;DØ Note 5506-CONF
- 2.1 fb^{-1} RunIIb Preliminary Result in February 2008; DØ Note 5586-CONF
- NN b-tagging Algorithm; FERMILAB-THESIS-2006-43
- Profile Likelihood Systematic Error Treatment; FERMILAB-TM-2386-E

The DØ Detector



Uranium/ Liquid-Argon Calorimeter

Tracking

Silicon Microstrip Tracker (SMT)

Central Fibre Tracker (CFT)

Limit Setting Method

Modified frequentist CLs approach:

Background only (b) and signal plus background (s+b) hypotheses compared to data using Poisson likelihoods.

Probability density function obtained by Gaussian smearing.

Systematic uncertainties included in likelihood ('profile likelihood')

Background constrained by maximising profile likelihood ('sideband fitting').