Electroweak Physics and Higgs Boson Searches at DØ

Séminaire LAL, Orsay

23rd April 2007

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Introduction

– Standard model:

  ∗ Tested extensively at LEP, Tevatron, . . .

  ∗ Very successful !

  ∗ But: where is the Higgs ?

– How to find the Higgs:

  ∗ Precision electroweak studies

  ∗ Direct search

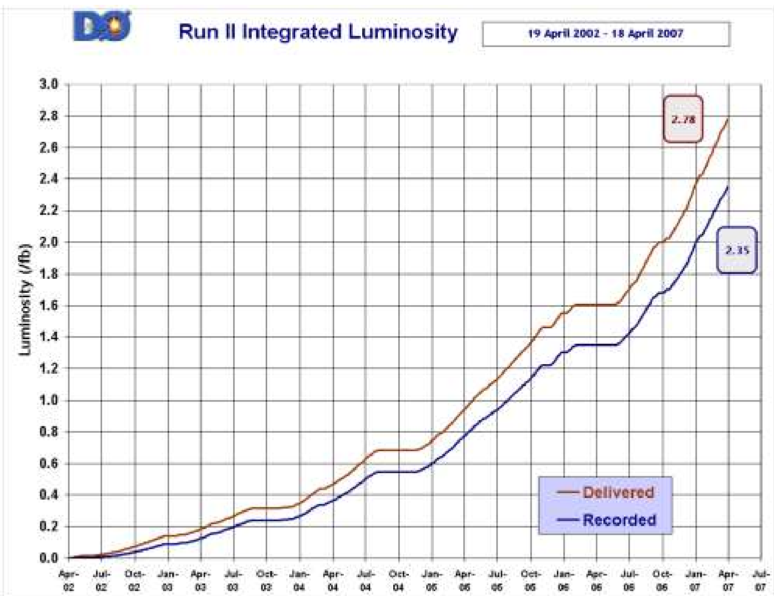
Outline

- Tevatron & DØ
- Electroweak topics:
  - Z boson p_{T} spectrum
  - Z boson rapidity distribution
  - W boson charge asymmetry
- Higgs search:
  - WH channel
  - Other channels, DØ combination
  - Future
- Conclusion

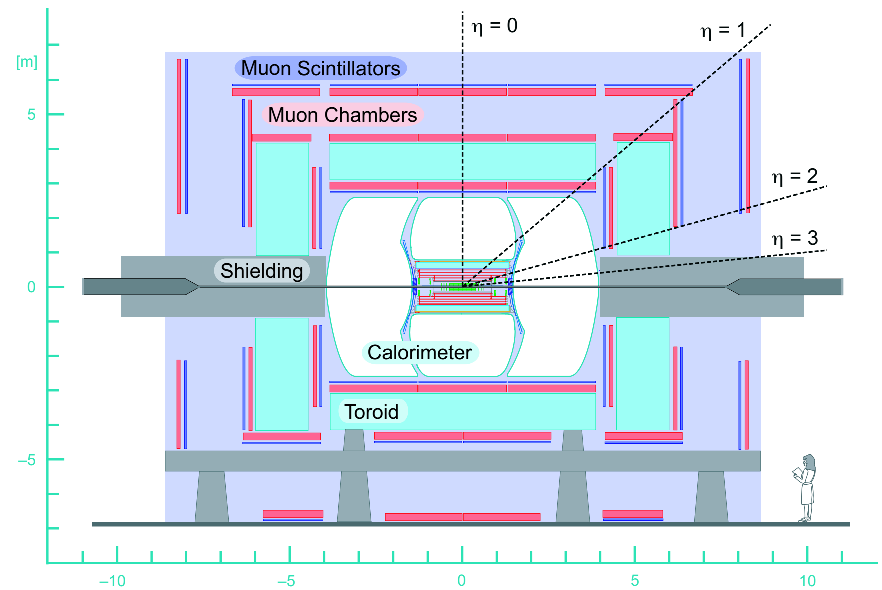
Tevatron & DØ

- $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV
- Up to now: $\int \mathcal{L}dt \simeq 2.8$ fb^{-1} delivered / experiment
- Good weeks: > 40 pb^{-1} per week
- Results shown in this talk: up to 1 fb^{-1}

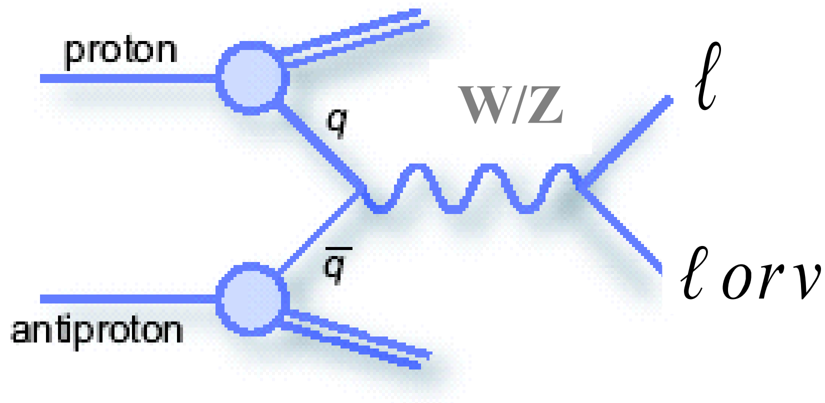
$\int \mathcal{L}dt$



DØ



W & Z Production at the Tevatron



– Test QCD at NNLO

– Probe PDF's

– W & Z production properties ($\rightarrow m_{\rm W}$ measurement)

– Benchmark for other measurements/searches

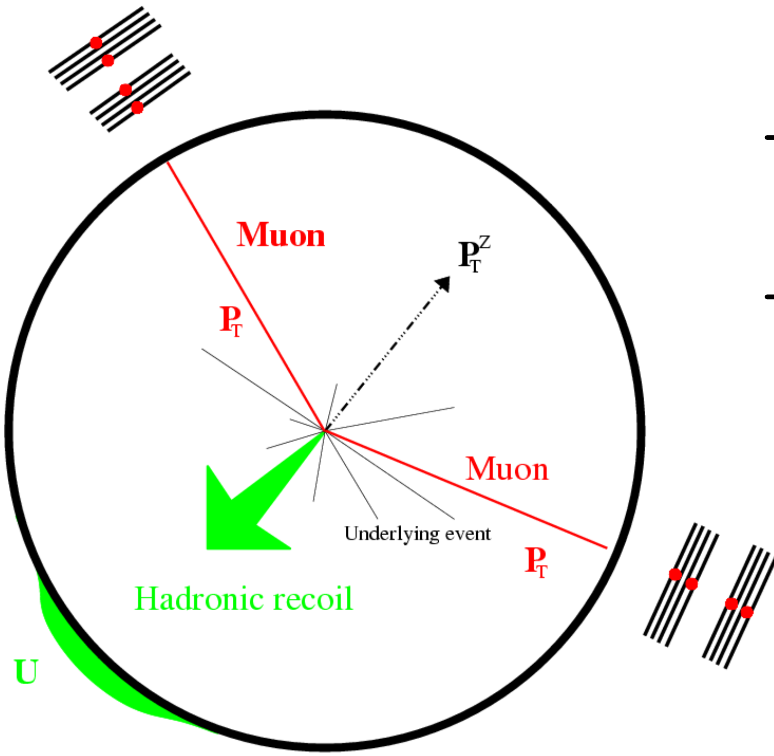
– Luminosity measurement ($\rightarrow$ LHC)

Hadronic decays very hard to select

Transverse Momentum of Z (→ee) Boson

- At lowest order, Z produced at rest
- Gluon radiation gives the Z a transverse boost
- Calculable:
  - ∗ High p_T: (N)NLO pQCD
  - ∗ Low p_T: pQCD and soft-gluon resummation, but still non-perturbative parameterization → RESBOS
  - ∗ Recent calculation: p_T shape broadens at small x
- Goal of measurement:
  - ∗ Verify theory predictions
  - ∗ Fix the non-perturbative parameters

Z Experimental Signature



- Two leptons, $p_T > 15 - 25$ GeV
- Background from:
  - c-, b-quark decays (μ: 0.5%)
  - Electron-like jets (e: 1%)
  - $Z \rightarrow \tau\tau$ ($< 0.5\%$)

Electrons identified by their showershape in the calorimeter

For each fb^{-1}, about 100k candidates

Experimental Challenges

– Measure selection efficiencies

  ∗ Use the data, tag-and-probe methods

– Understand electron energy measurement

  ∗ Use the Z peak itself

– Measure background contributions

  ∗ Use data to determine “QCD” background
  ∗ Use simulation to determine Z $\rightarrow \tau\tau$ etc.

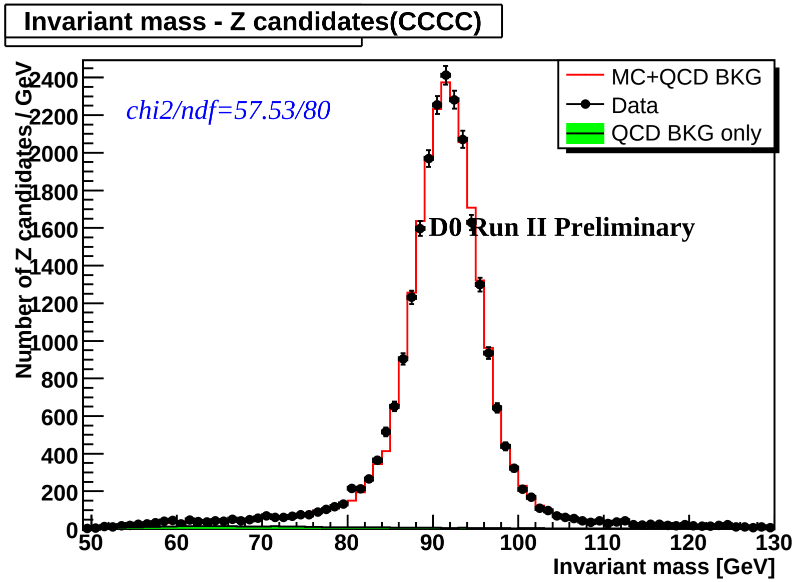
Experimental Challenges

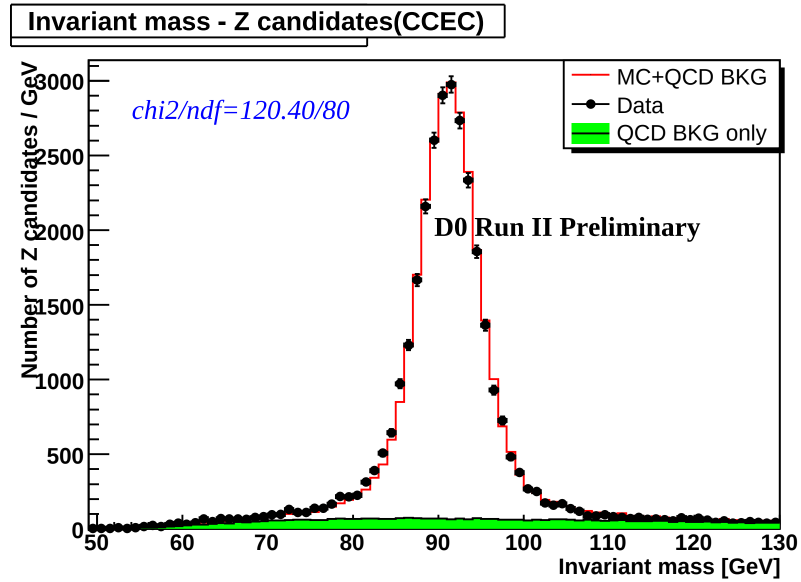
– Model everything in parameterized detector simulation

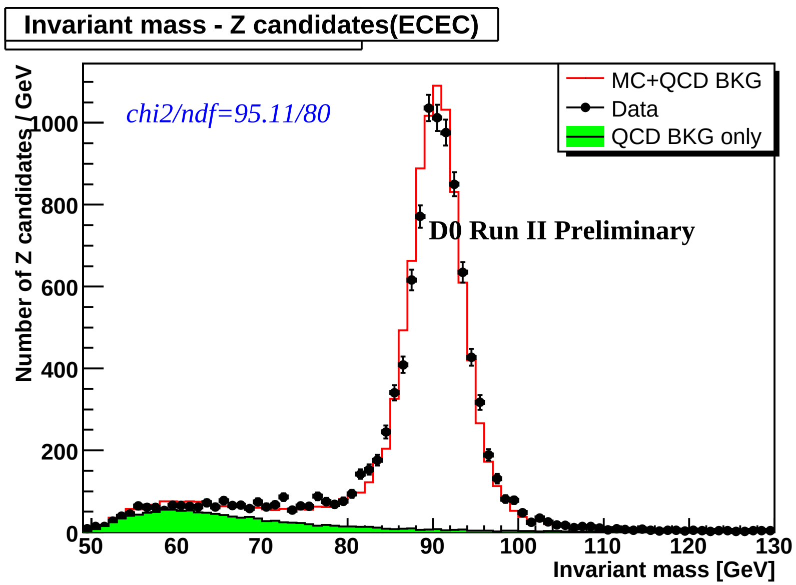
– Unfold momentum spectrum

$\Rightarrow$ Compare to predictions

Invariant Mass Distributions



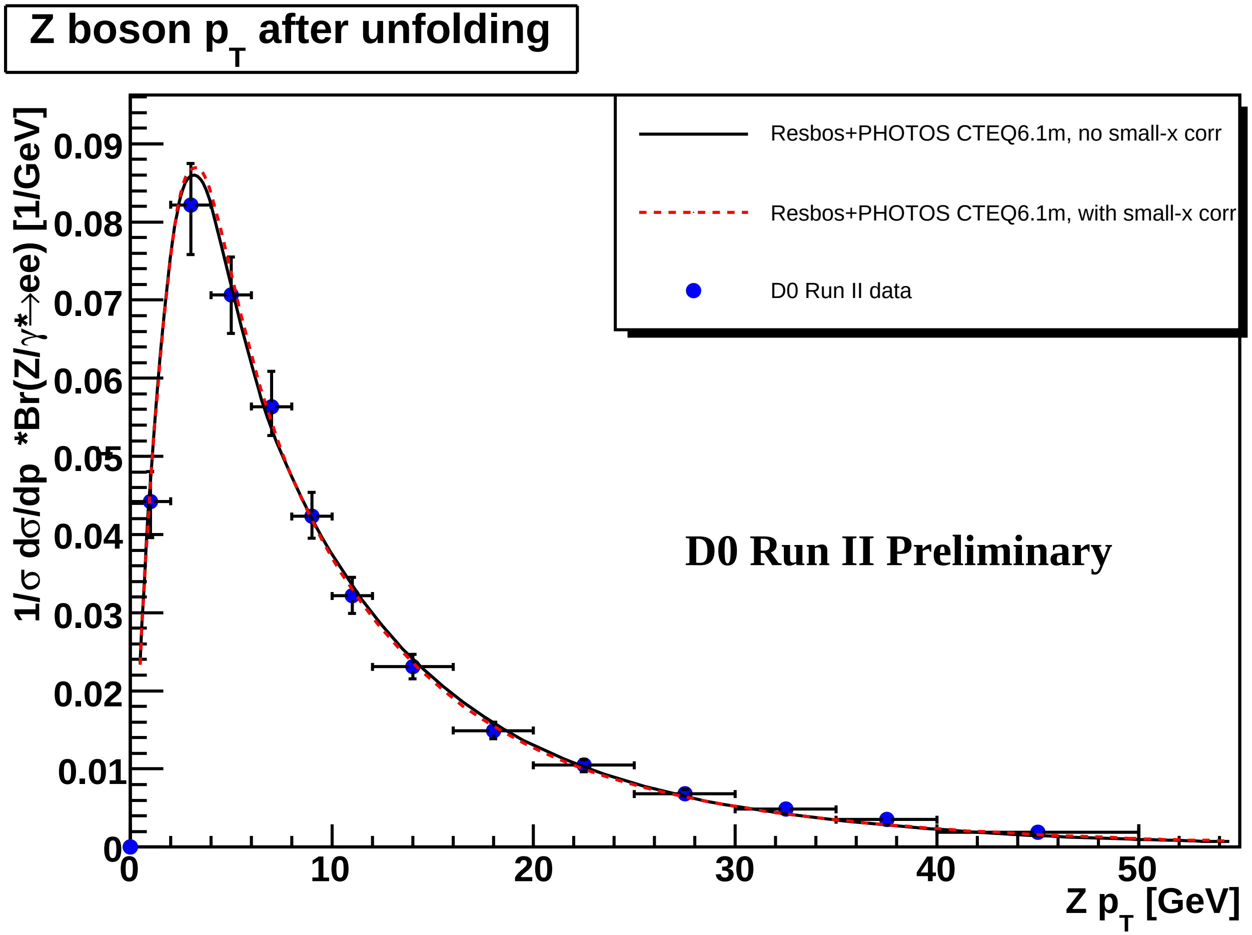




– Good agreement

– Small background ($70 < m_{\text{inv}} < 110$ GeV)

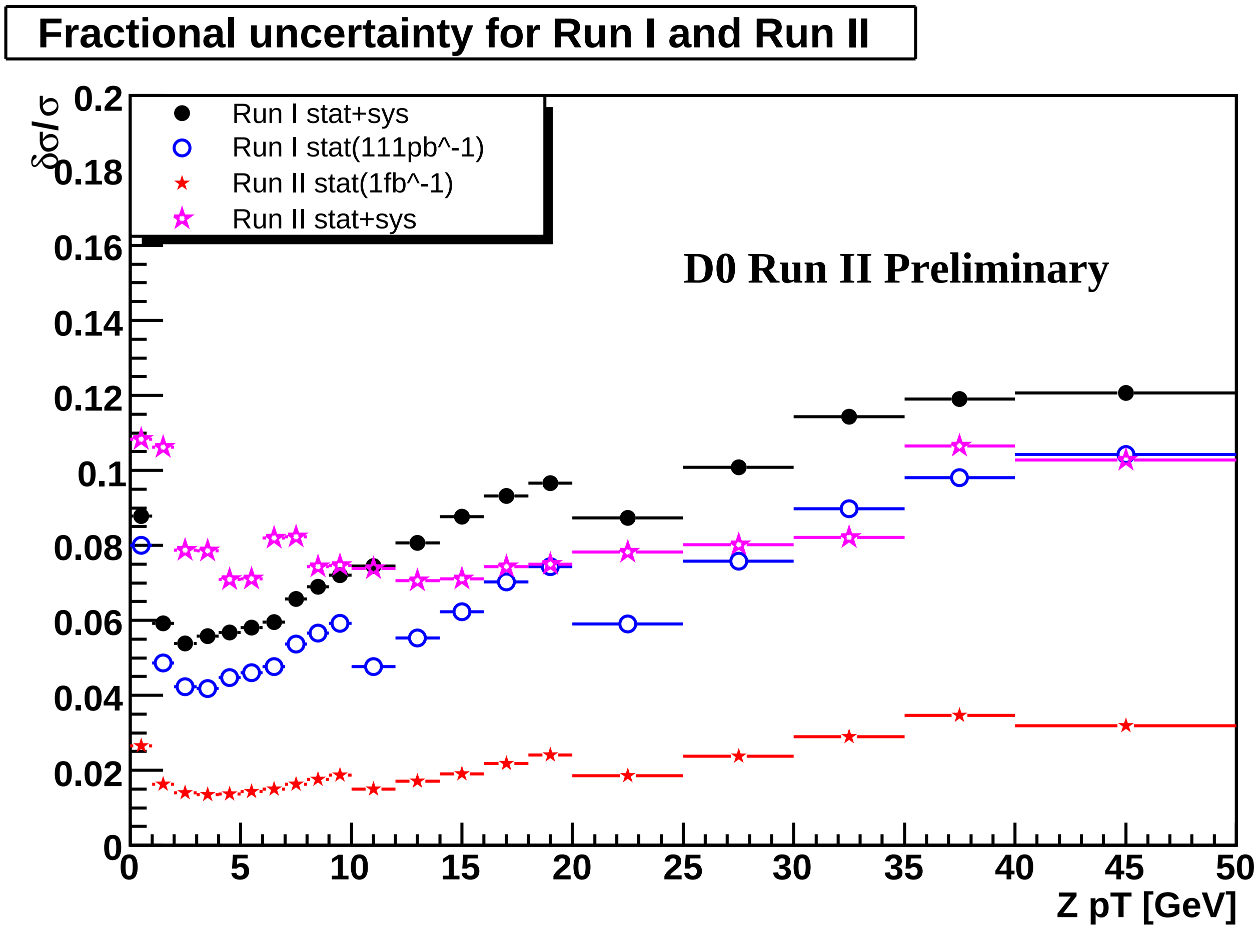
Transverse Momentum of Z Boson



– Good agreement with RESBOS

– No strong evidence for small-x behaviour

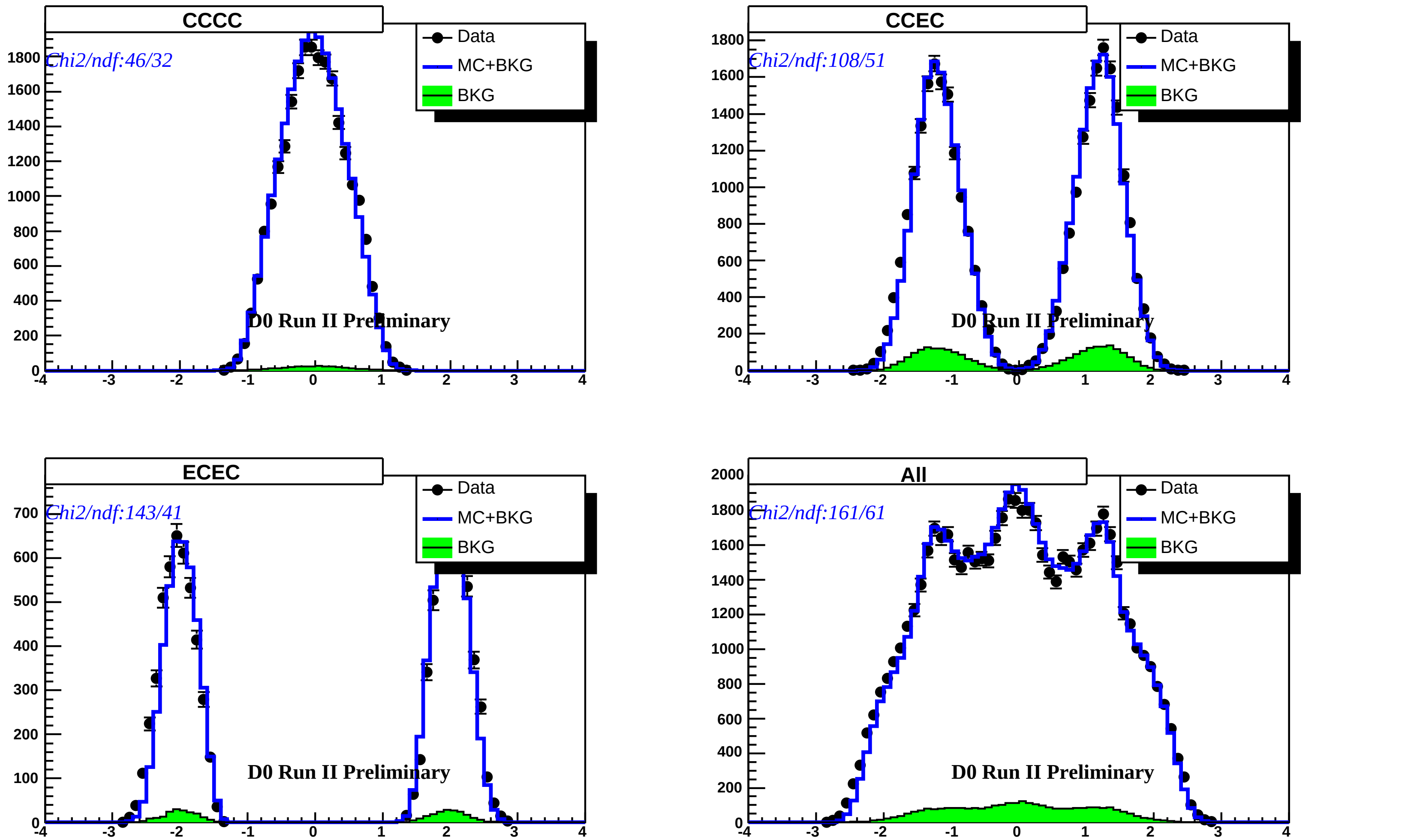
Transverse Momentum of Z Boson



– Statistics better than in Run I

– Systematics will be better soon. . .

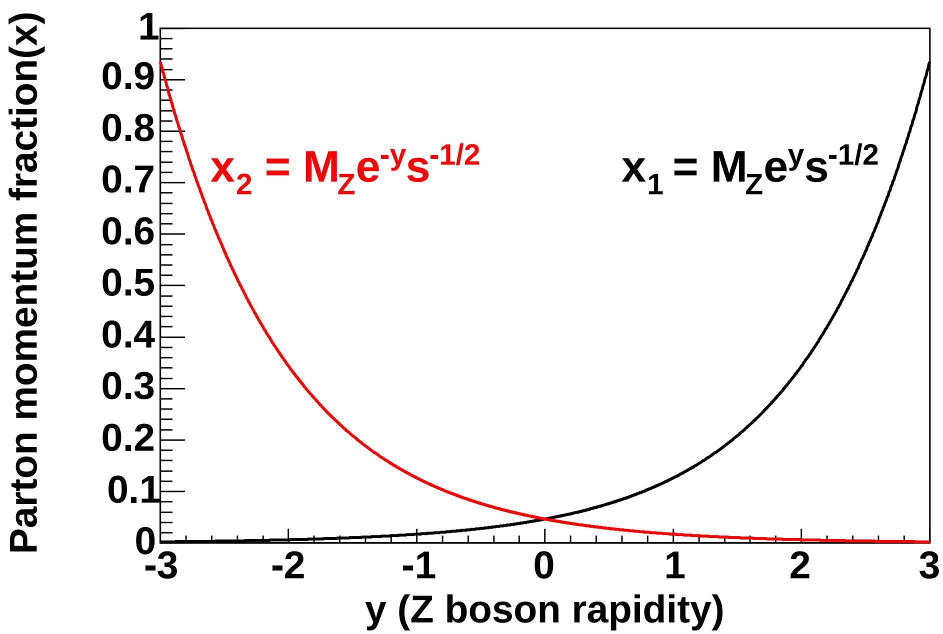
Z Transverse Momentum in Near Future



$\Rightarrow$ Split data in different y ($\sim x$) bins to test broadening

Rapidity of Z ($\rightarrow$ ee) Boson

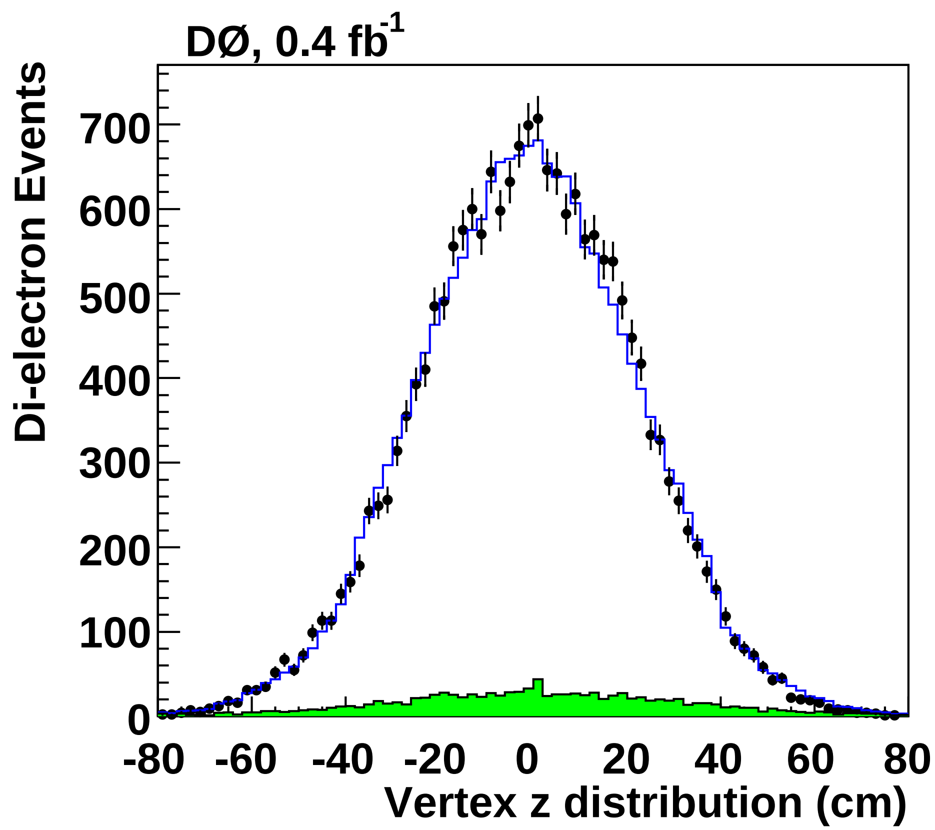
- Not well measured yet, in particular at large $|y|$ (> 1.5)
- Calculated at NNLO
- Sensitive to parton distribution functions in a region complementary to other measurements



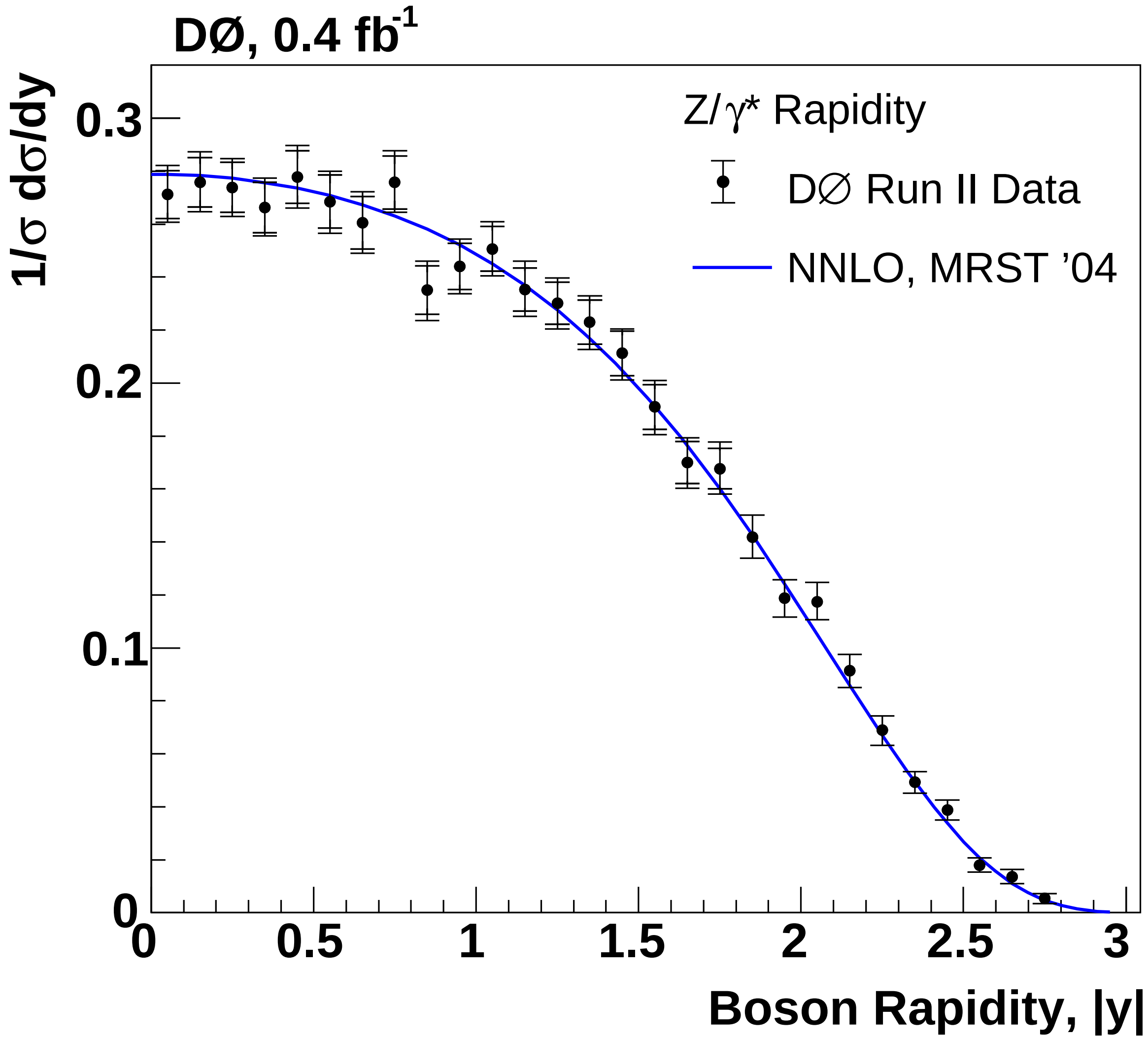
Experimental Procedure

– Procedure similar to that for $p_{\mathrm{T}}(\mathrm{Z})$ measurement

– In addition: longitudinal interaction region profile

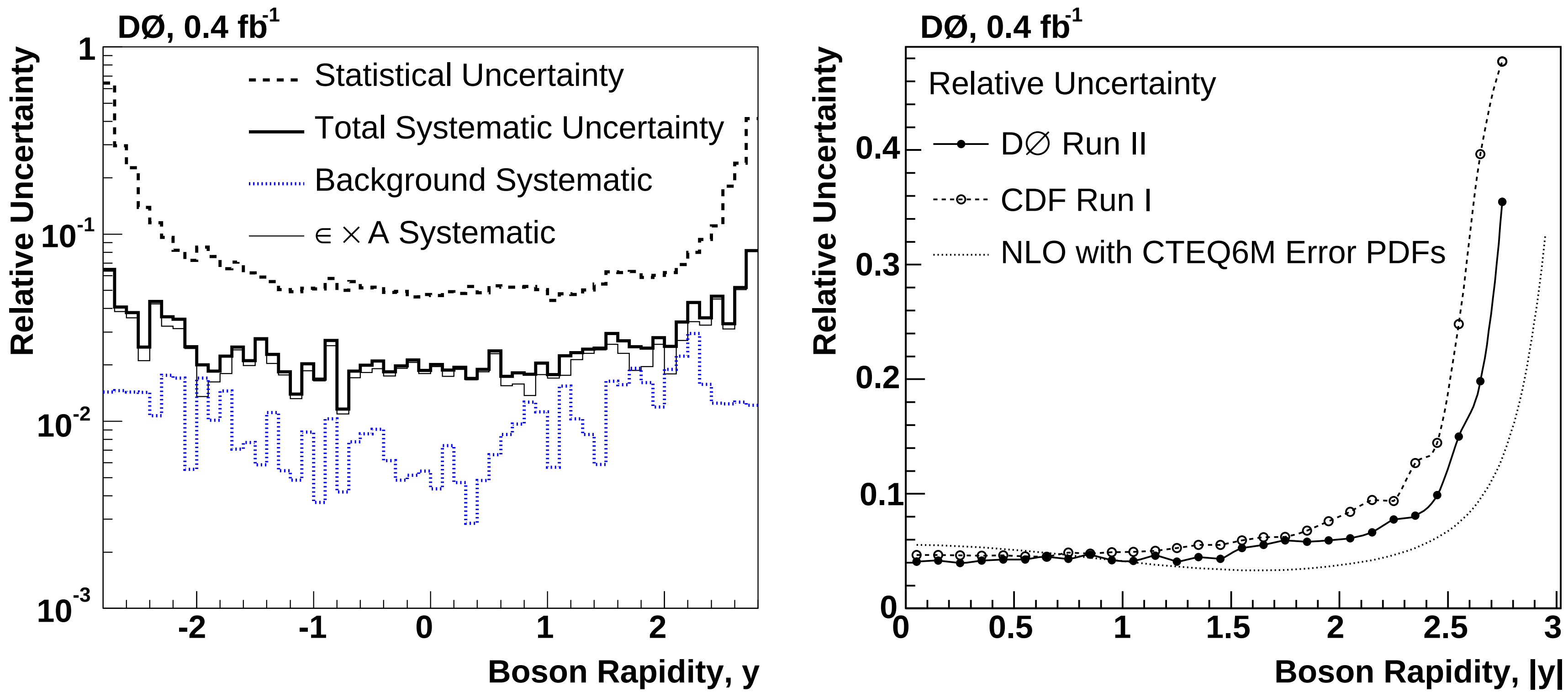


Rapidity of Z Boson



⇒ Excellent agreement with NNLO pQCD

Rapidity of Z Boson



– Statistics limited

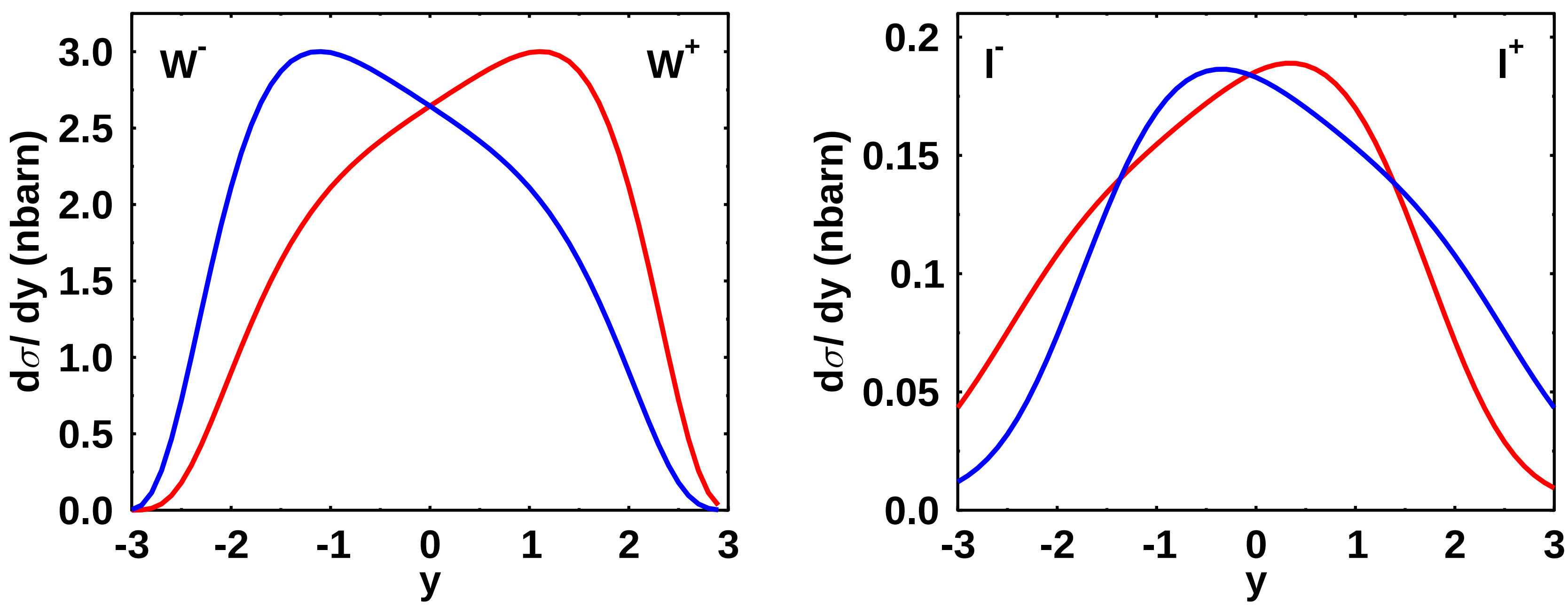
– In future: constrain PDF's

W Production Charge Asymmetry

– Proton's momentum fraction of u-quark > d-quark

⇒ $W^{+(-)}$ boosted in $p(\bar{p})$ direction ⇒ charge asymmetry

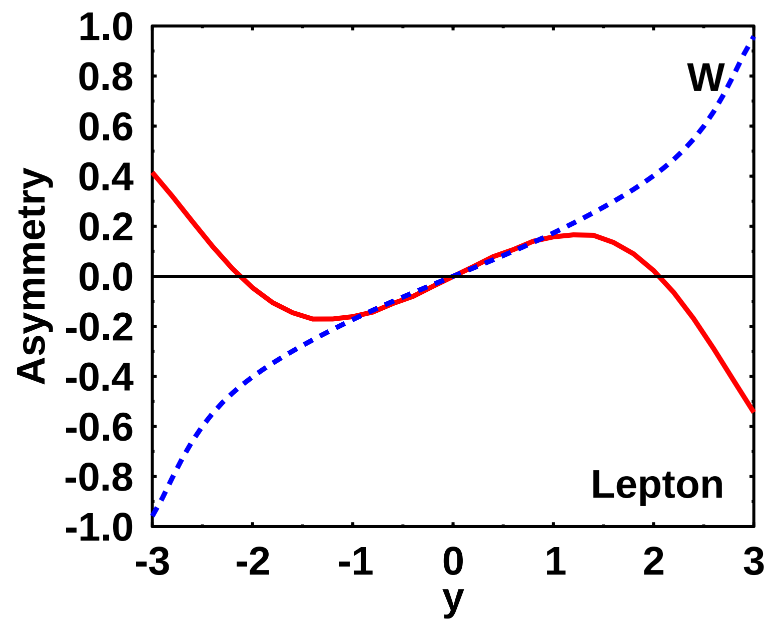
– Asymmetry partly preserved by decay-leptons



W Charge Asymmetry

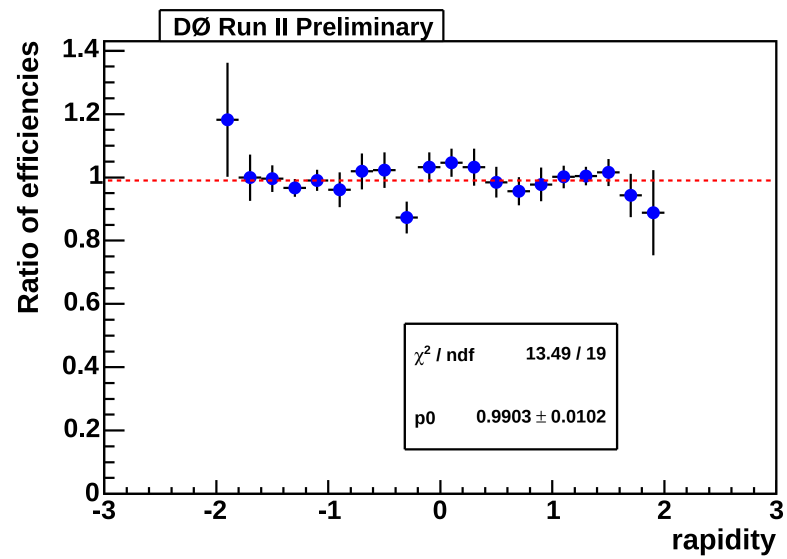
$$A = \frac{N^+(y) - N^-(y)}{N^+(y) + N^-(y)}$$

$\Rightarrow$ DØ probes (x, Q^2) not probed by, e.g., HERA

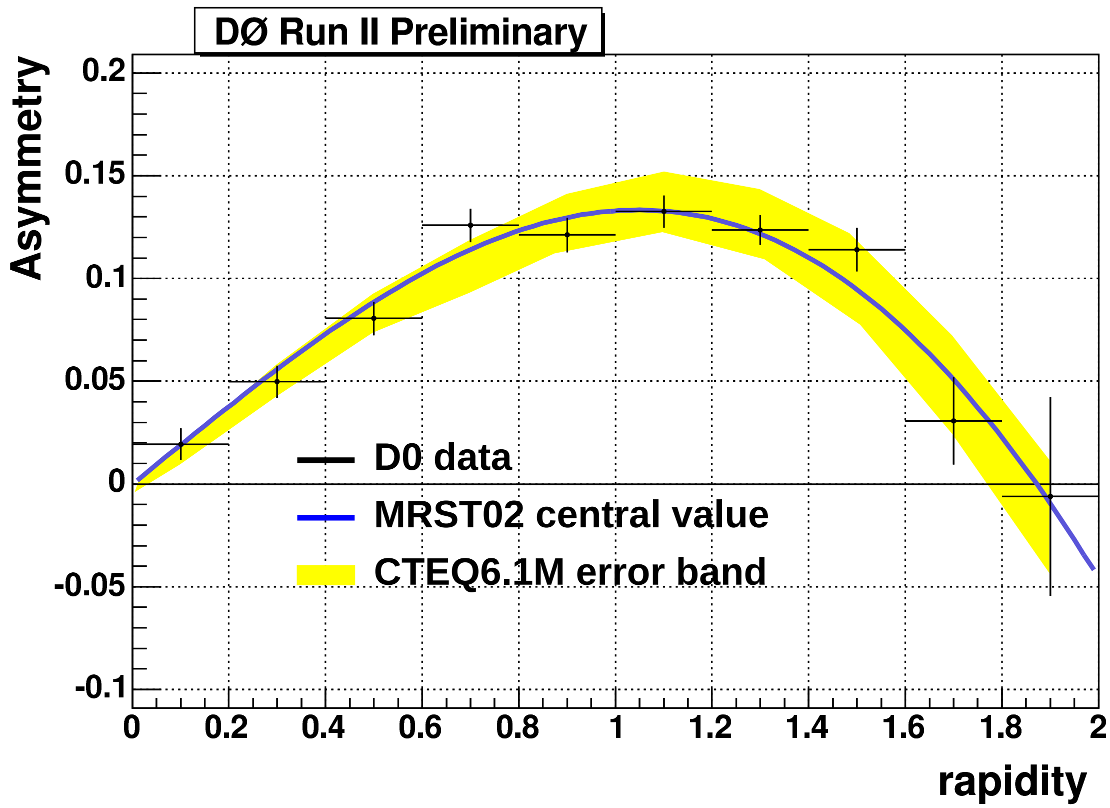


– Low charge mis-id rate: 0.01% (μ)

– Efficiencies charge independent



W ($\rightarrow \mu\nu$) Charge Asymmetry



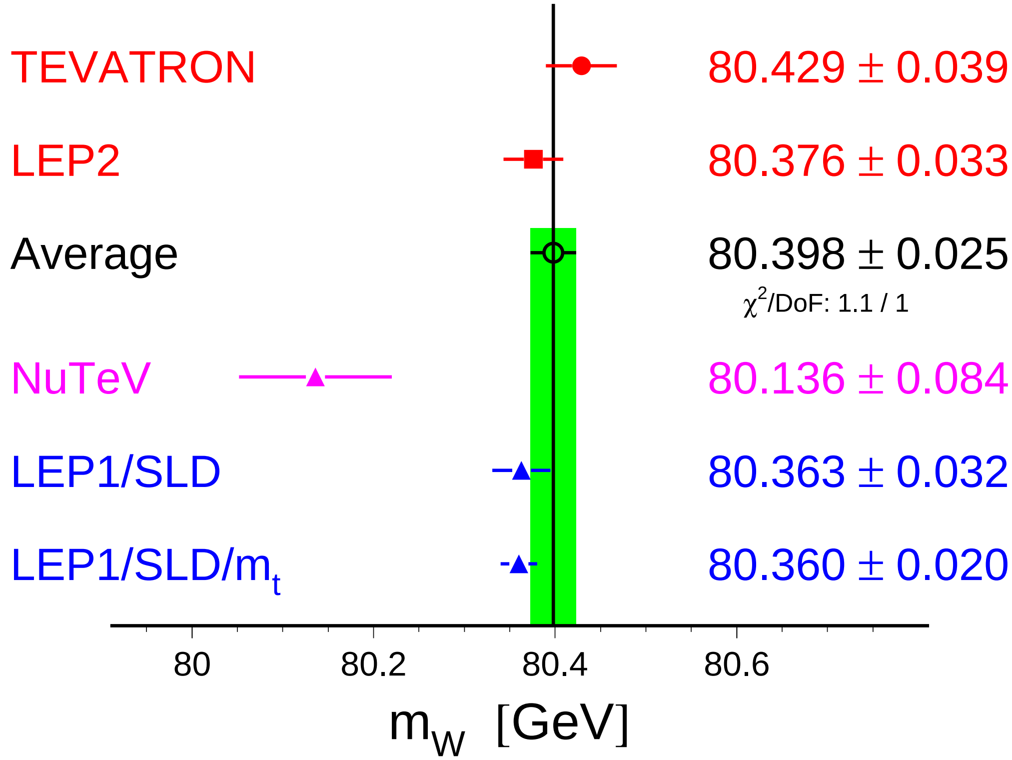
– Statistics dominated (230 pb^{-1})

– Already sensitive to PDF's

Precision EW & Higgs

- p_{T}(Z) model & PDF's important input to m_{W} measurement
  - * And to future LHC physics
- m_{W} together with $m_{\mathsf{top}} \Rightarrow m_{\mathsf{H}}$

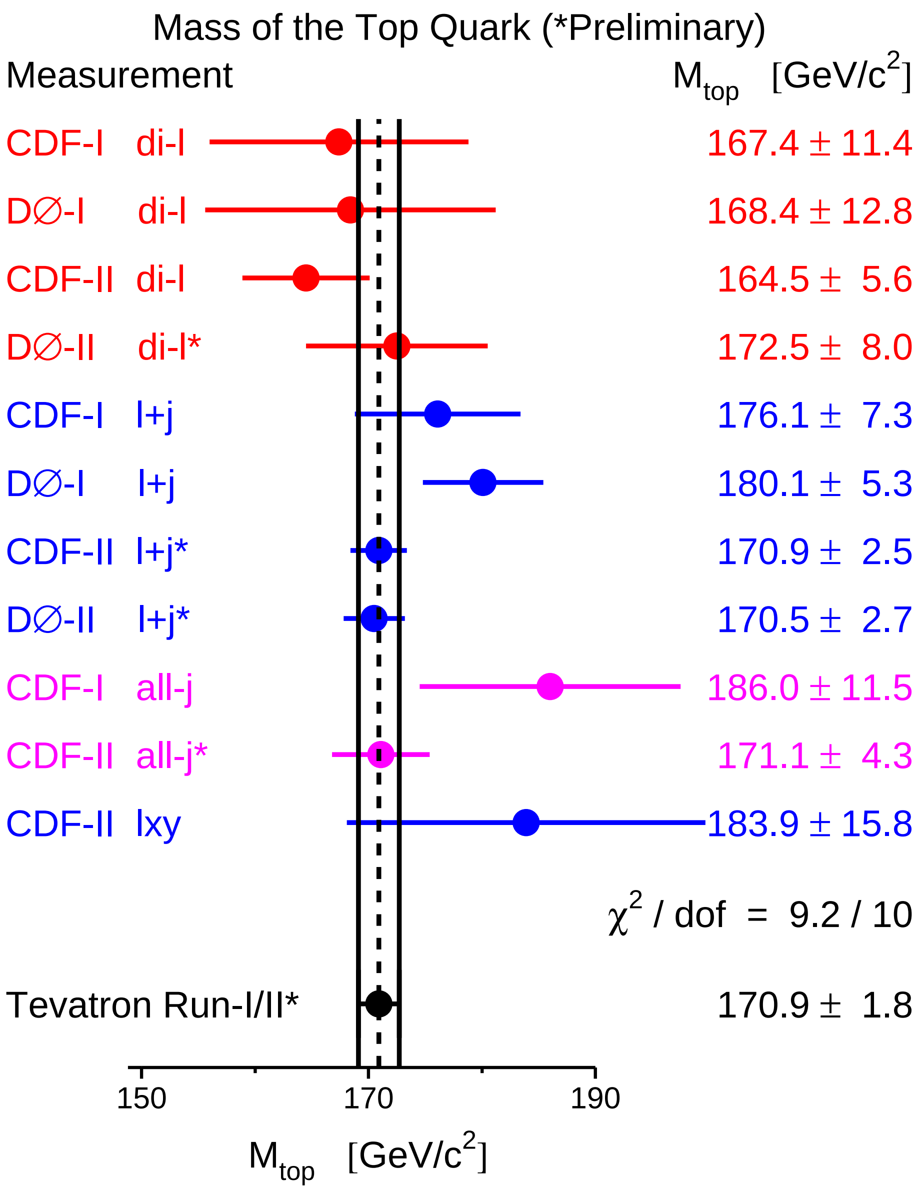
W Boson Mass



CDF Run II: $m_{\mathrm{W}} = 80.413 \pm 0.048$ GeV

$\Rightarrow m_{\mathrm{W}} = 80.398 \pm 0.025$ GeV (LEP & Tevatron combi)

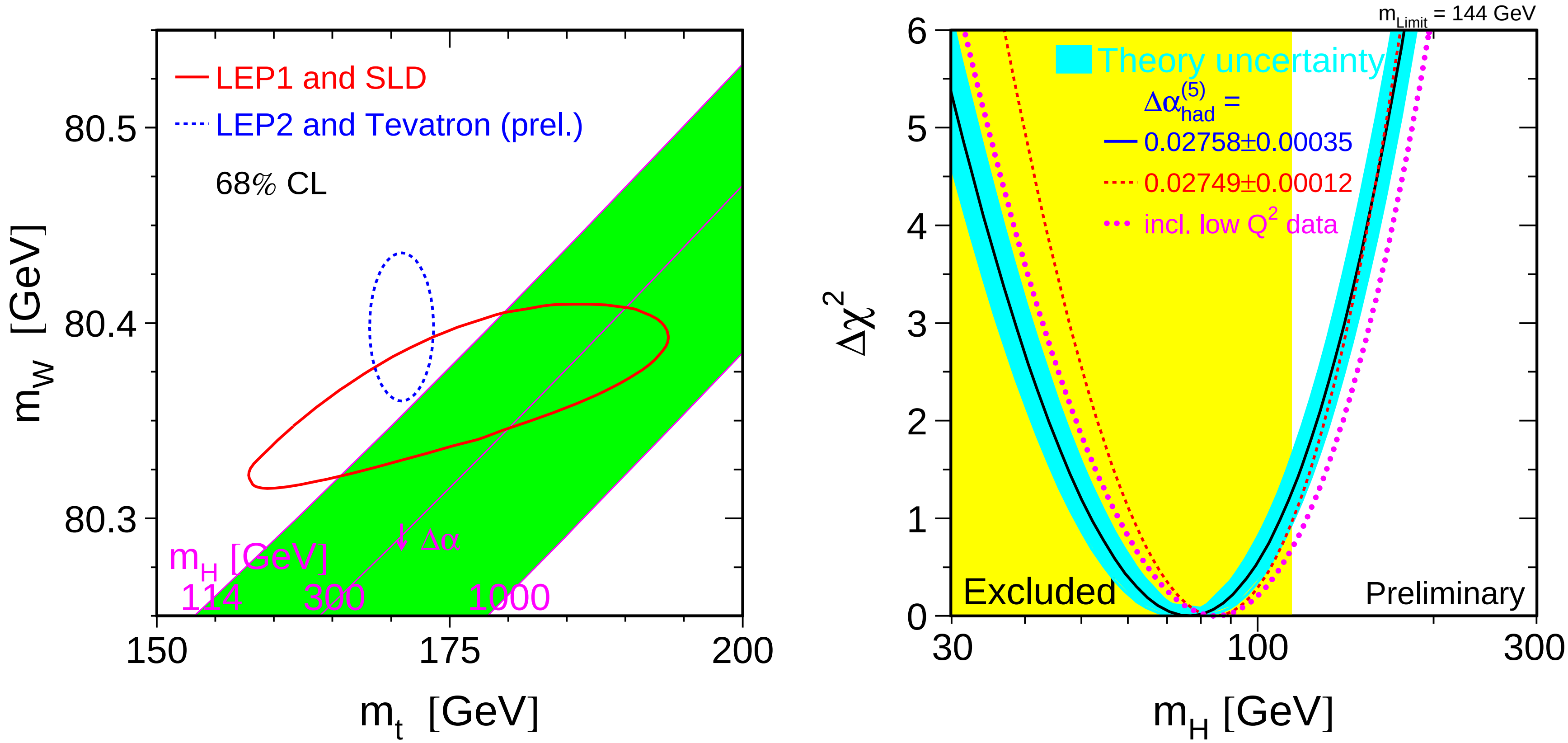
Top Quark Mass



$$m_{\text{top}} = 170.9 \pm 1.8 \text{ GeV}$$

(Tevatron combi)

Precision EW & Higgs

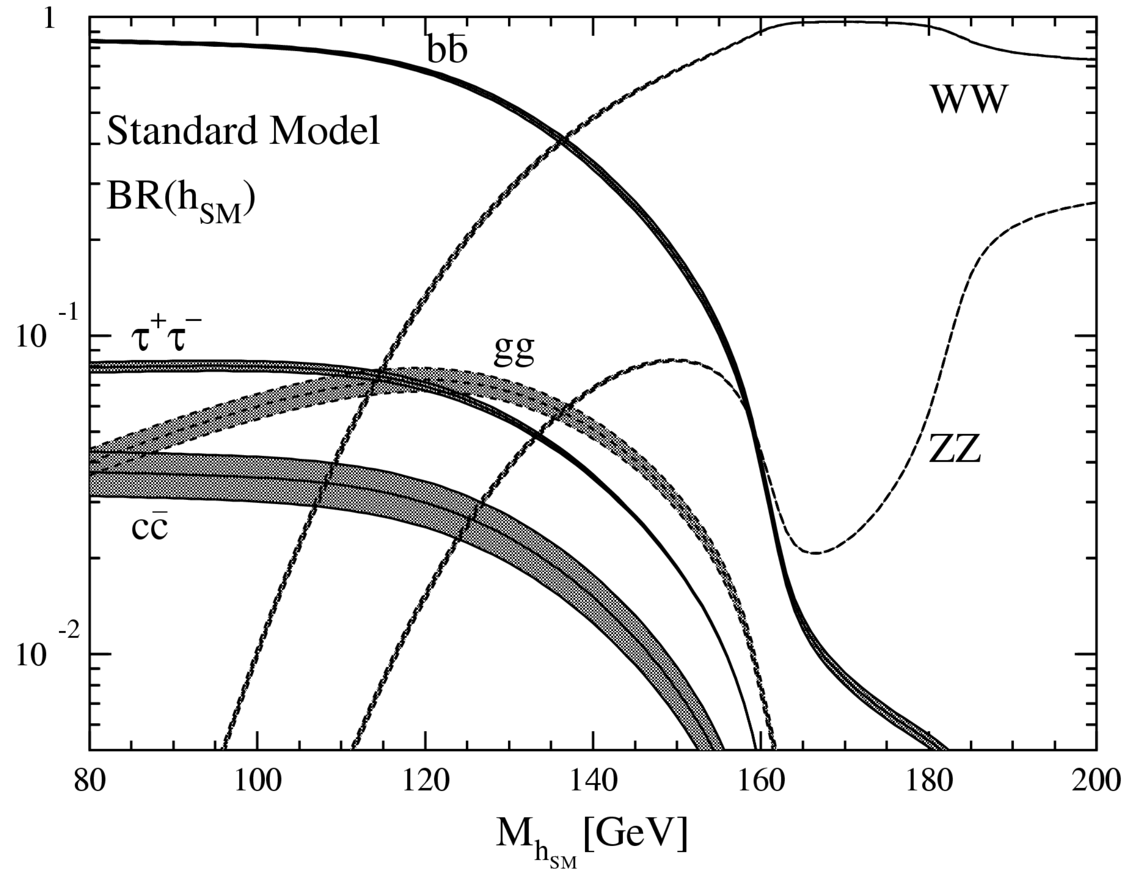


$m_{\mathrm{H}} = 76^{+33}_{-24}$ GeV

$m_{\mathrm{H}} < 144$ GeV at 95% CL

$\Rightarrow$ Within reach of the Tevatron!

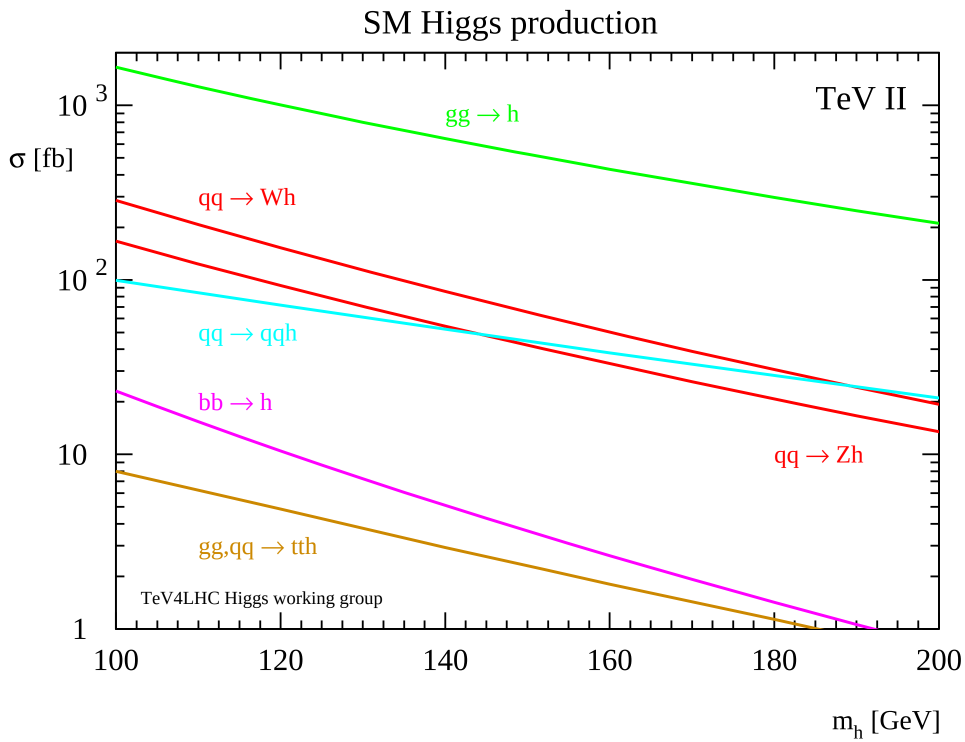
Higgs Decay



– Dominant decay modes:

- $b\bar{b}$ at low m_{H}
- WW at high m_{H}

Higgs Production at Tevatron



- Gluon fusion:
  - ∗ Experimentally only feasible at high m_{H} (H→WW)
- Associated production (WH, ZH)
  - ∗ "Golden channel" at low m_{H}

WH Basic Selection

– Trigger:

  * Single-lepton or lepton + jets
  * Add topological triggers in μ channel $\rightarrow \sim 100\%$ efficiency

– W selection:

  * High p_{T} lepton (e or μ)
  * Large $\not{E}_{\mathrm{T}}$ (undetected ν)

– "Higgs" selection:

  * Two or three high p_{T} jets

WH Backgrounds

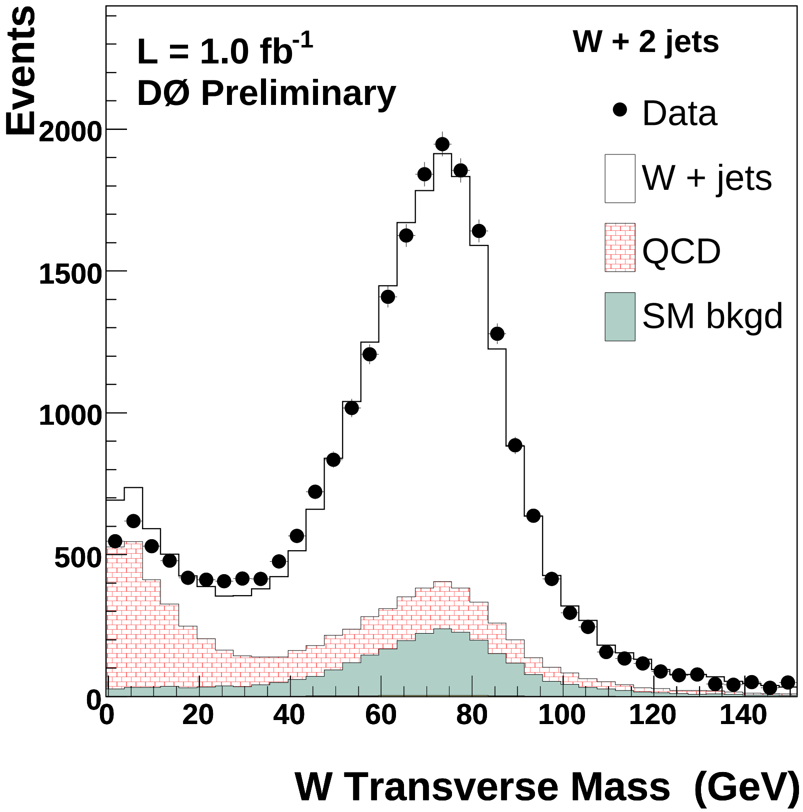
– Background sources:

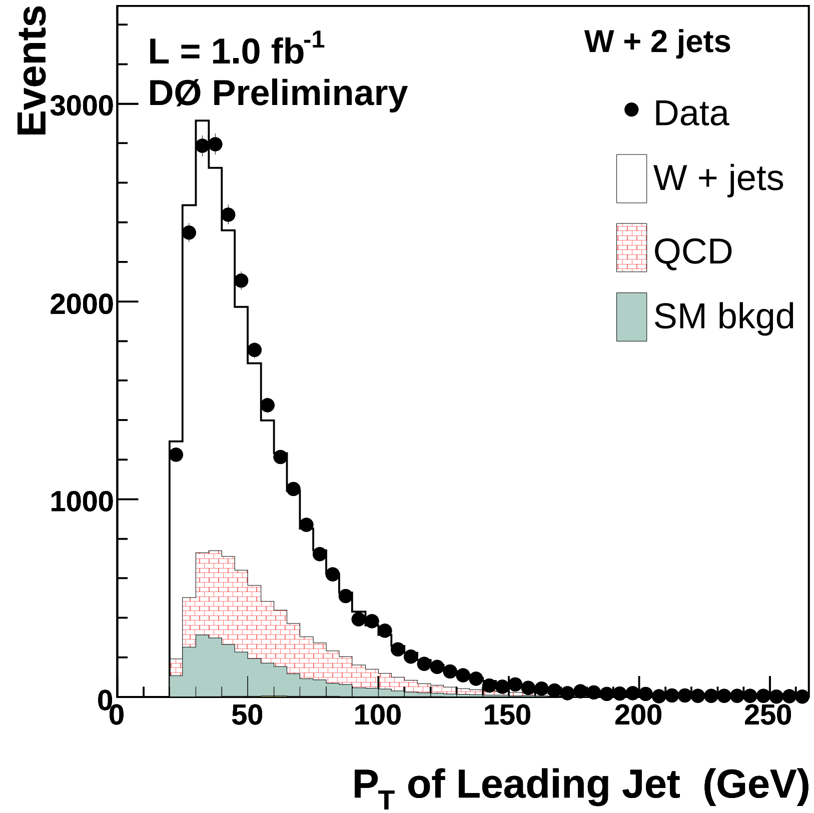
  * W with additional jets (including $Wb\bar{b}$)
  * $t\bar{t}$, single top
  * Multi-jet production with mis-ID of lepton or $\not{E}_T$
  * Di-EW-boson

⇒ Need to precisely model these !

  * Multi-jet directly from data
  * Others from simulation

After Basic Selection



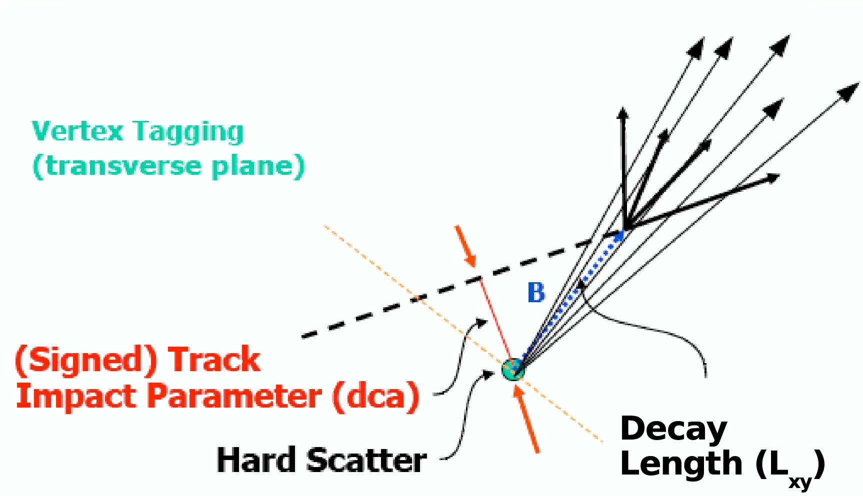


– Good agreement

– W with additional (non-b) jets dominant

b-Tagging

Exploit b-lifetime:



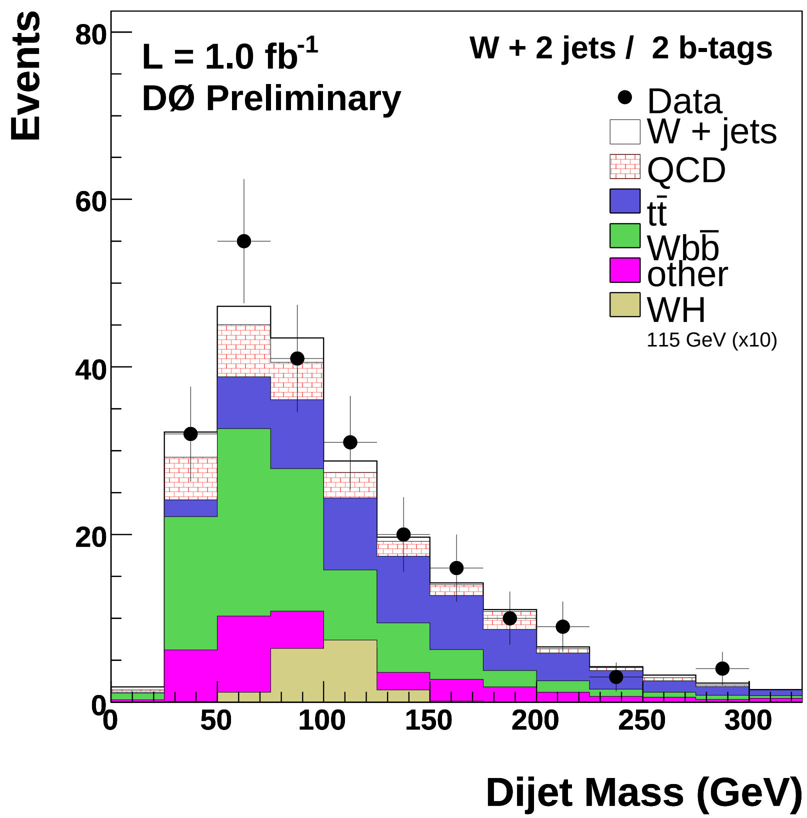
– Combine lifetime variables in a neural network:

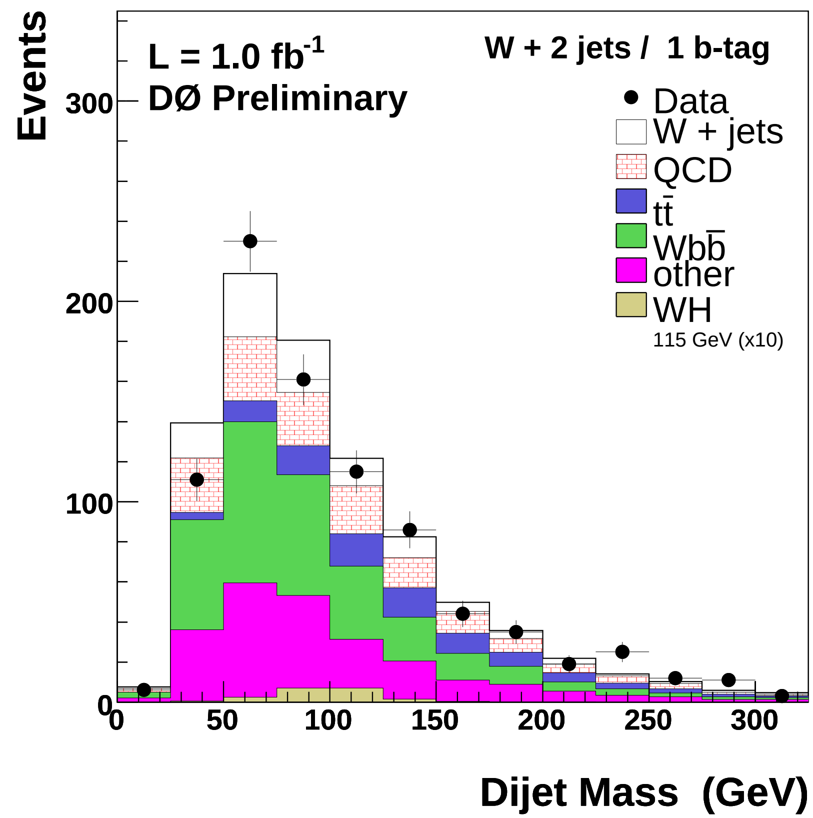
  * Vertex mass, decay length, impact parameter, . . .

⇒ High b-tagging efficiency:

  * "Tight": 48% at 0.5% fake rate
  * "Loose": 70% at 4.5% fake rate

After b-Tagging





– Treat double-Loose tag & single-Tight tag exclusively

$\Rightarrow$ Good agreement, $Wb\bar{b}$ dominant

After Double-b-Tagging

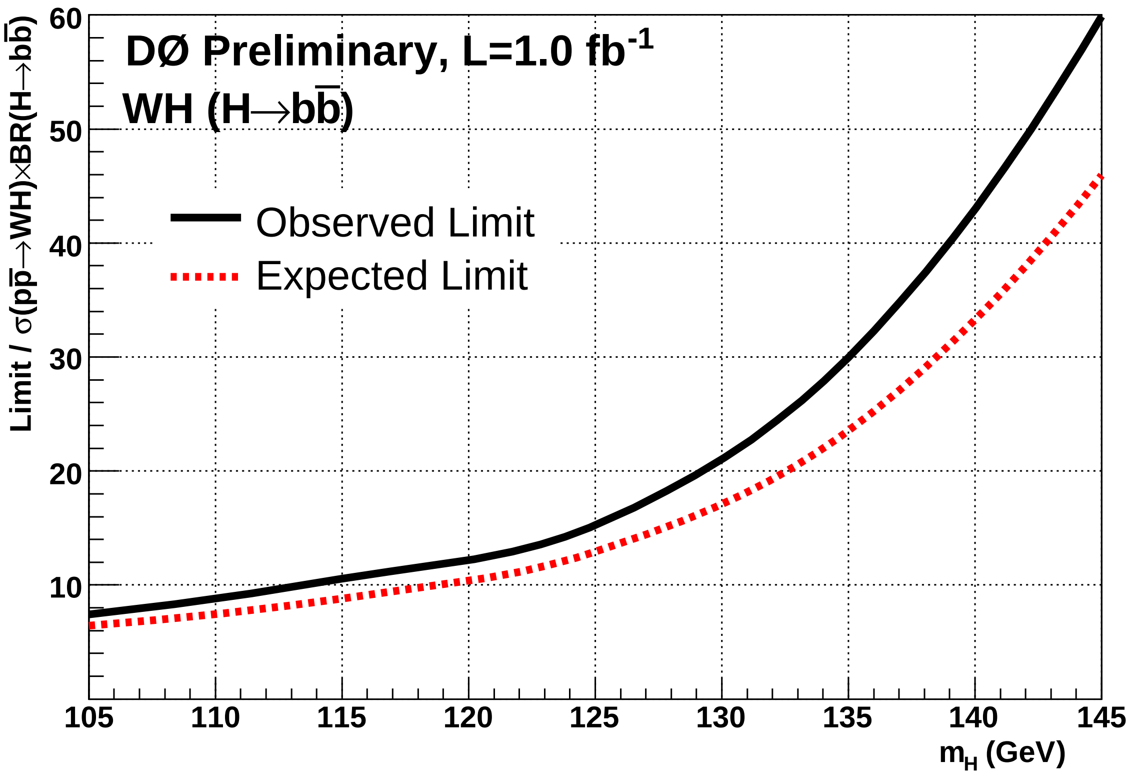
WH	1.67 ± 0.32
$Wb\bar{b}$	81.4 ± 23.1
$t\bar{t}$	54.4 ± 14.5
W+jets (light,c)	35.8 ± 11.9
Multijet	26.0 ± 8.0
Single top	14.9 ± 3.4
WZ	7.0 ± 1.24
Total	219.6 ± 31.0
Observed	222

$\Rightarrow$ No significant excess. . .

In the Absence of Signal

– Combine four WH channels and set cross section limits

  * Single & double b-tag
  * Electron & μ channel



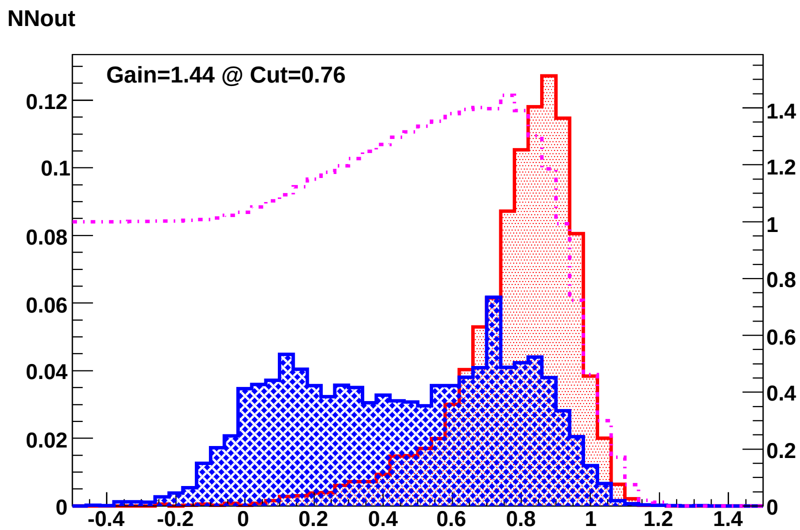
Future: WH Neural Network Selection

– "Cut-based" analysis not always optimal

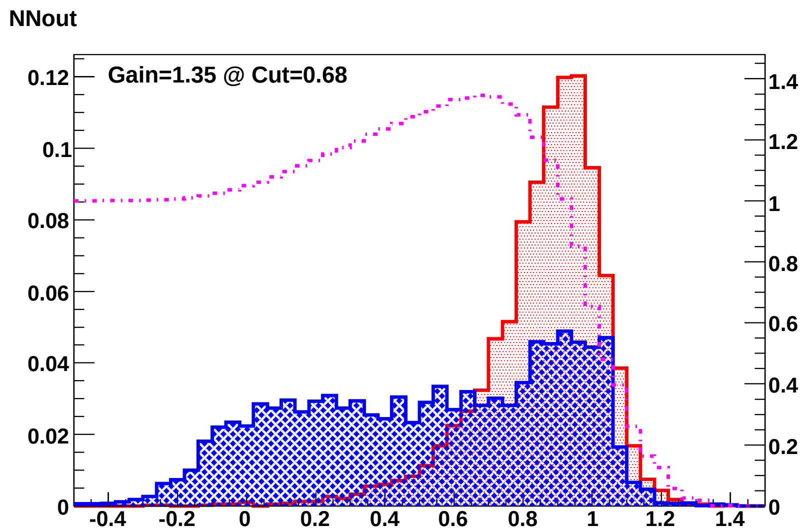
⇒ Combine all kinematic information in a neural network

– Train separate neural networks against major backgrounds; apply to all events

Using $Wb\bar{b}$ Network. . .



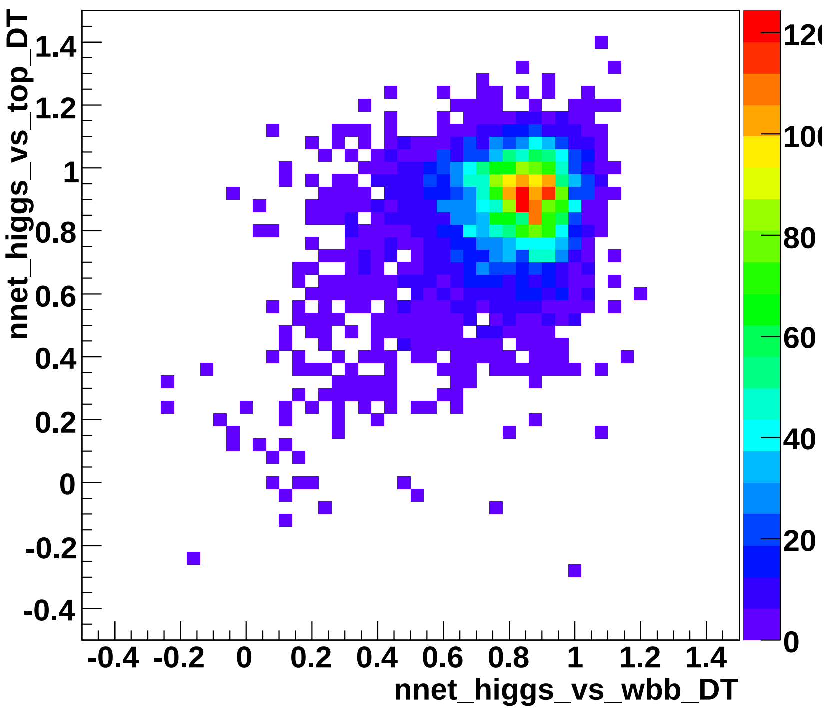
Using top Network. . .



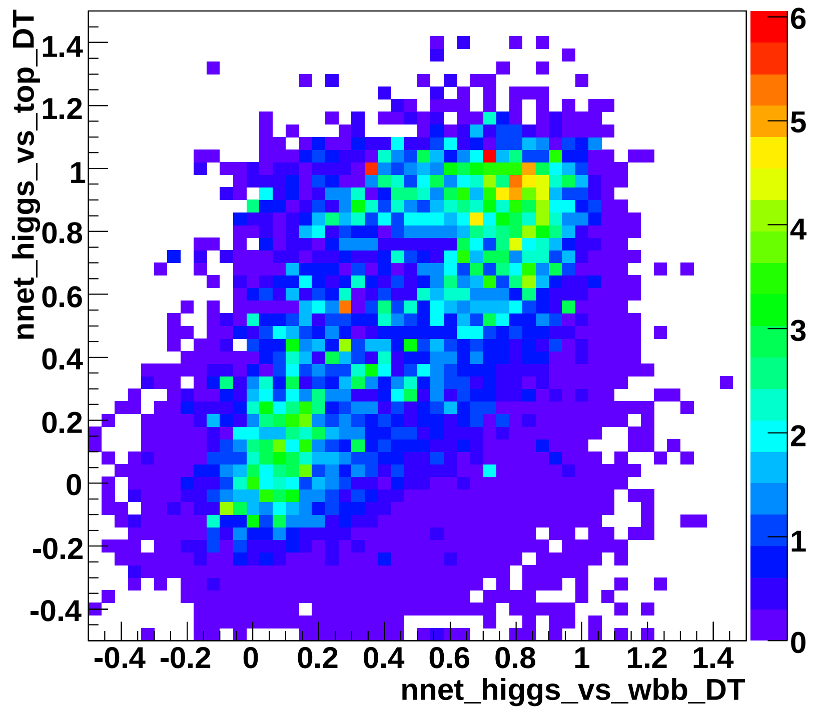
WH Neural Network Selection

Apply $Wb\bar{b}$ and top neural network to all events:

Higgs



Background

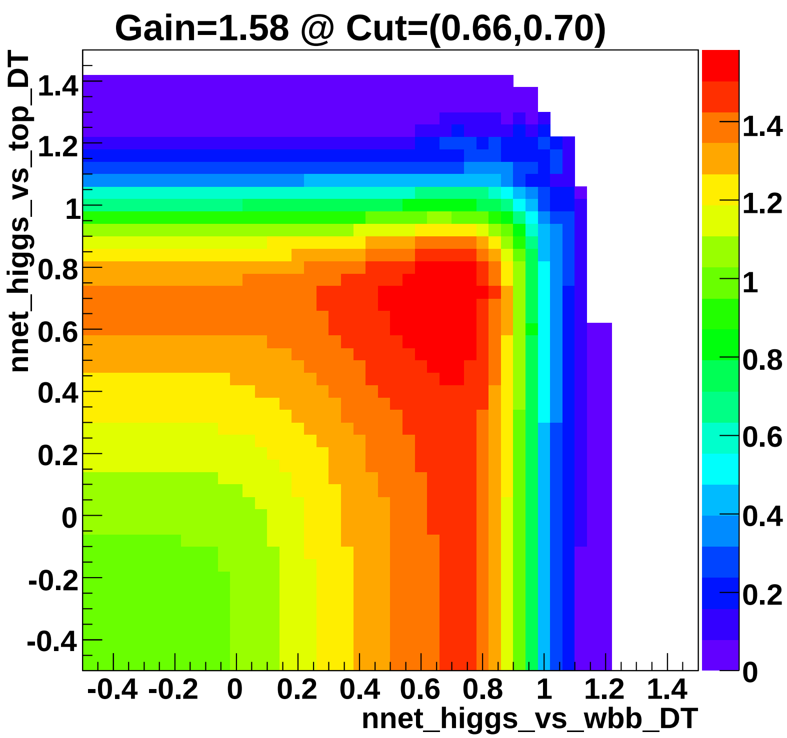


$\Rightarrow$ Some separation

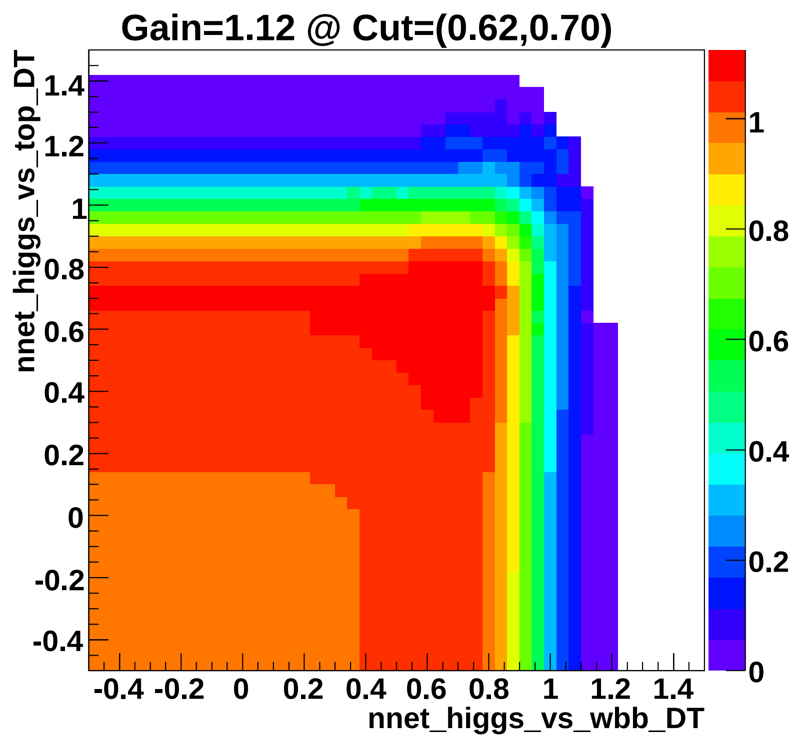
WH Neural Network Selection

Significance gain:

On all events

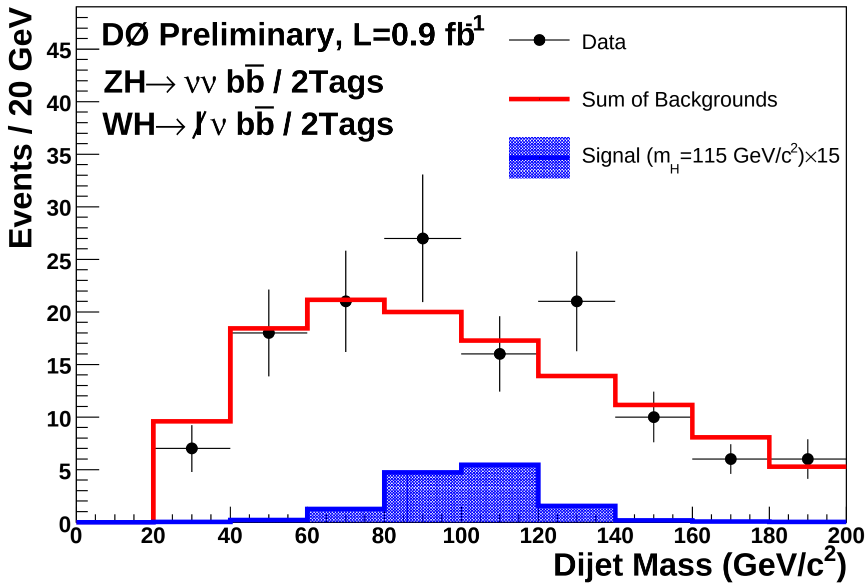


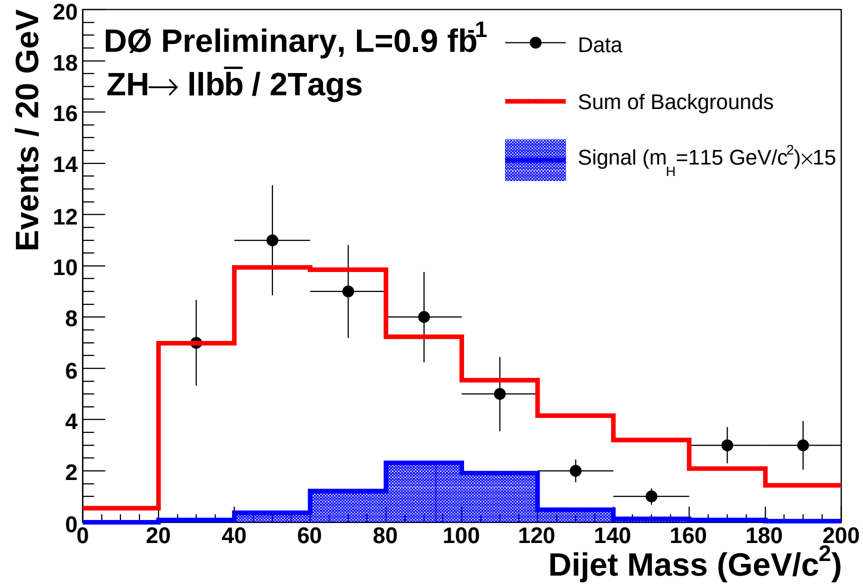
On events inside $m_{b\bar{b}}$ window

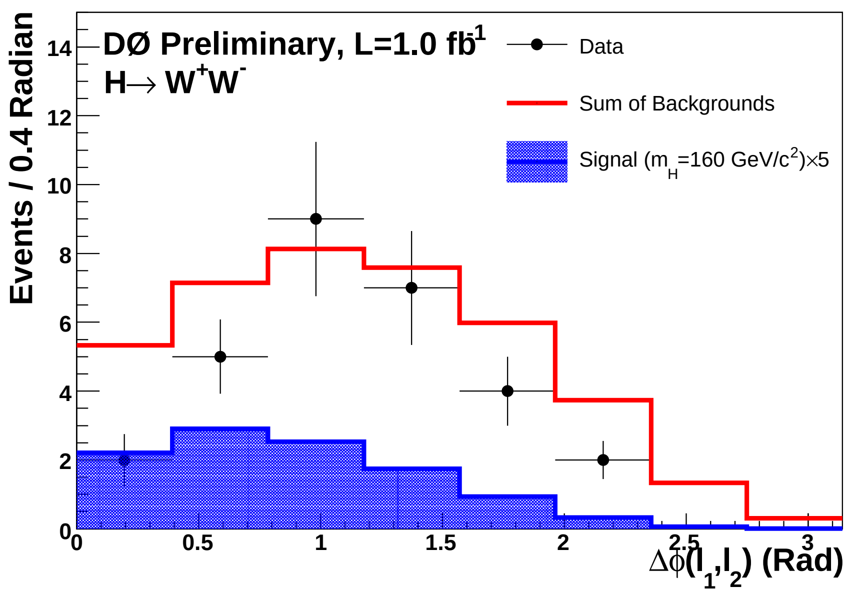


$\Rightarrow$ Work in progress. . .

Other Higgs Search Channels

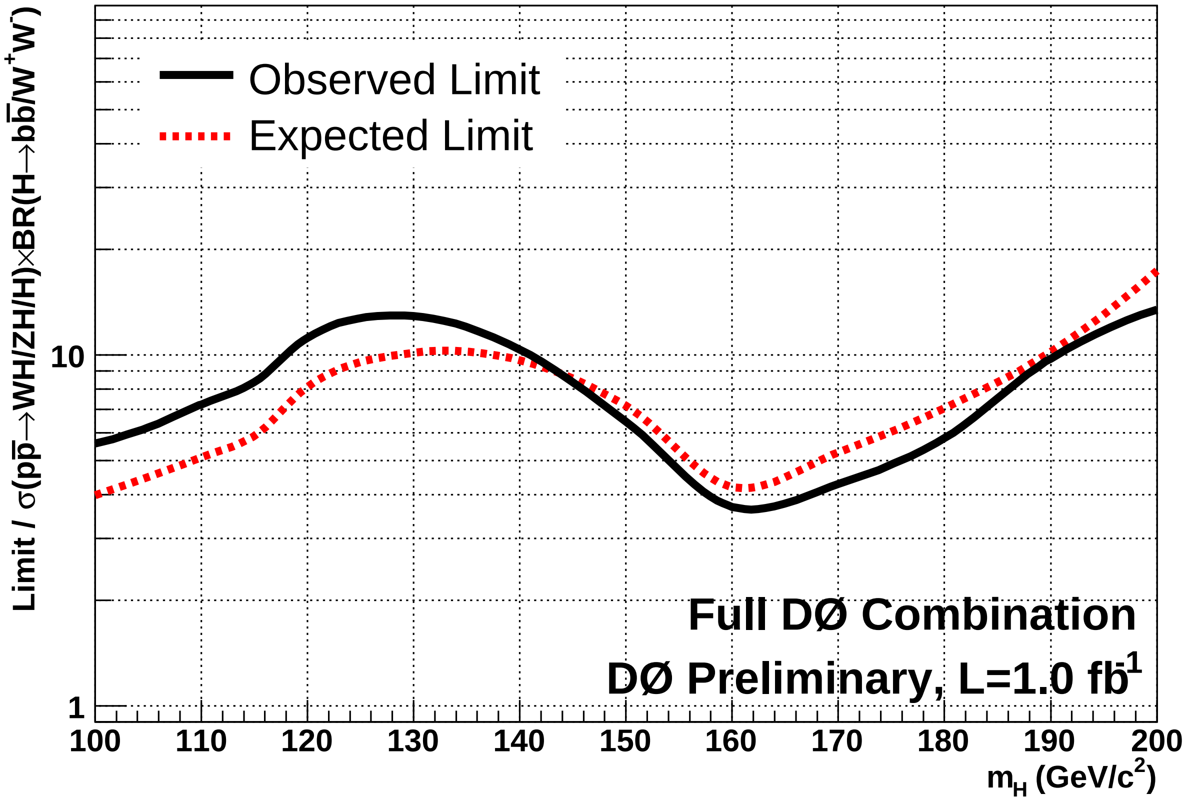






$\Rightarrow$ No excess. . .

DØ Combined Cross Section Limit



– No m_{H} exclusion yet, but

∗ At $m_{\mathrm{H}} = 115$ GeV: factor ~ 8.4 (obs.), ~ 5.9 (exp.)

∗ At $m_{\mathrm{H}} = 160$ GeV: factor ~ 3.7 (obs.), ~ 4.2 (exp.)

Future Prospects

– More $\int \mathcal{L}\mathrm{d}t$, up to $\sim$ 8 fb^{-1} by end 2009

– SMT Layer 0

– Be smarter with b-tagging

– Include more decay channels:

  * Hadronic τ decays
  * Hadronic W decays in H$\rightarrow$WW
  * WH $\rightarrow$ WWW
  * ZH single b-tag

– Reduce systematic uncertainties

– Improve di-jet mass resolution

Future Prospects

	$\int \mathcal{L}dt$ Gain	σ-factor 115 GeV	σ-factor 160 GeV
$\int \mathcal{L}dt = 1$ fb^{-1}	-	5.9	4.2
$\int \mathcal{L}dt = 2$ fb^{-1}	2	4.2	3.0
b-Tagging	2	3.0	3.0
Multivar. techn.	1.7	2.3	2.3
Mass resolution	1.5	1.8	2.3
New channels	1.3/1.5	1.6	1.9
Systematics	1.2	1.5	1.7

$\Rightarrow$ Need 4.5 fb^{-1} ($m_{\mathrm{H}} = 115$ GeV), 6 fb^{-1} ($m_{\mathrm{H}} = 160$ GeV)

Also add CDF. . .

Conclusions

– Standard model still going strong

– Tevatron is providing important additional tests and constraints

– Higgs not found yet, but getting close