# Prospects for Higgs Searches at DØ

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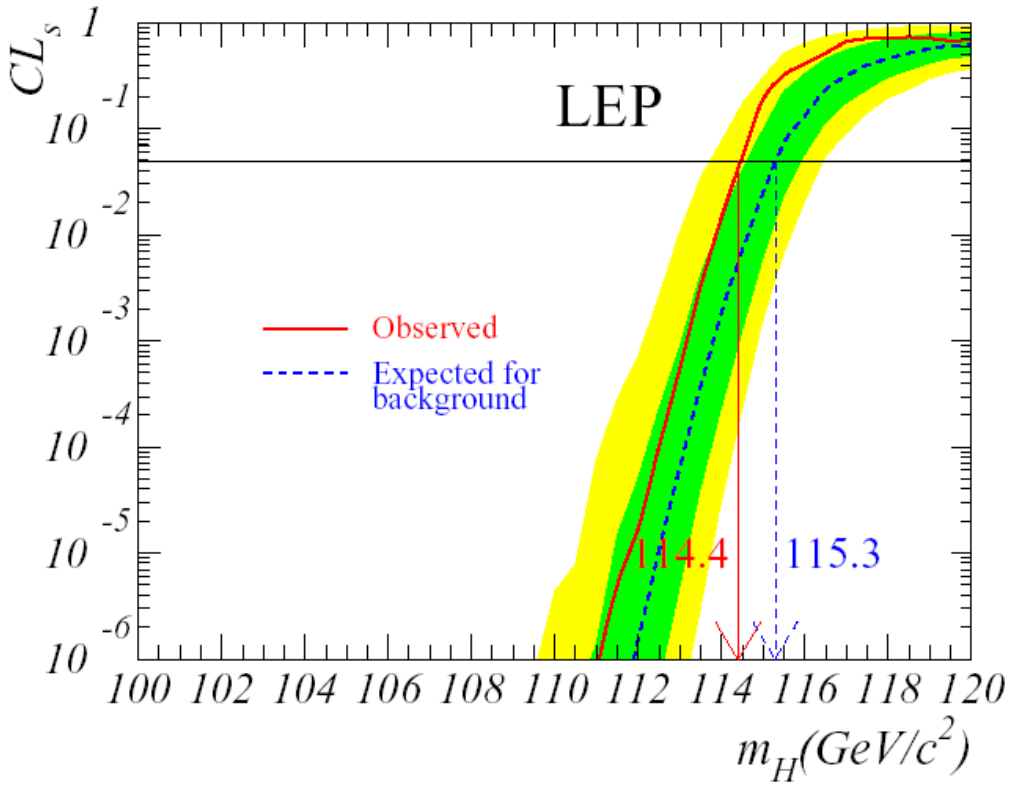
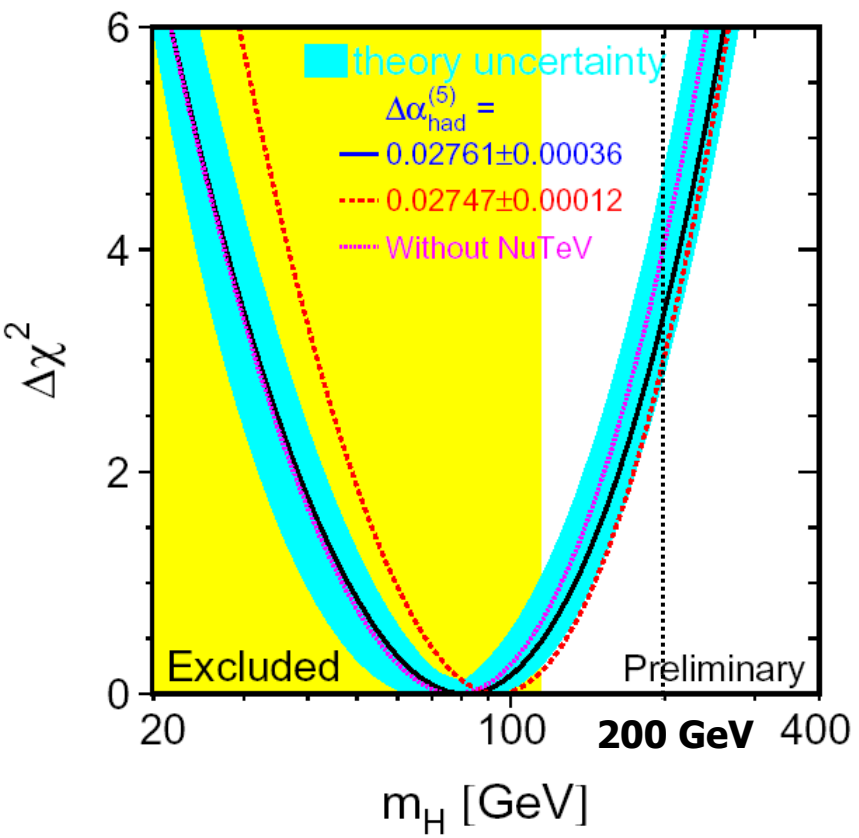
# Outline

- Introduction
- DØ Run II
- Run II Data
  - W + jets
  - Z + jets
  - H $\rightarrow$ WW
- Summary

# Introduction

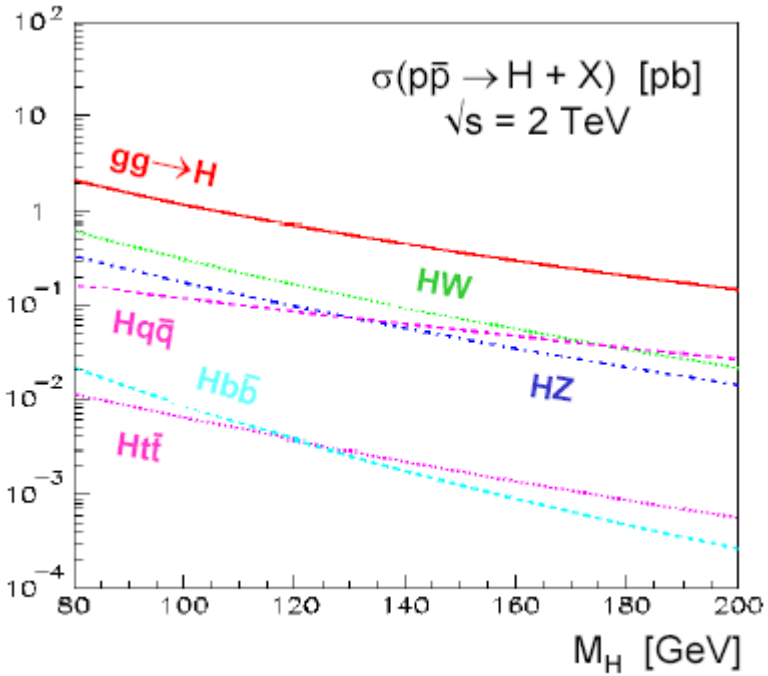
- Major goal of the Tevatron Run II is the search for Higgs bosons.
  - **Direct SM Higgs search at LEP:**
    **$m_H > 114.4$ GeV at 95% C.L.**
    **( hep-ex/0211058)**
  - **Indirect limit of the global SM fit:**
    **$m_H < 196$ GeV at 95% C.L.**
    **Fit minimum is at 85 GeV**
    **(hep-ex/0212036)**

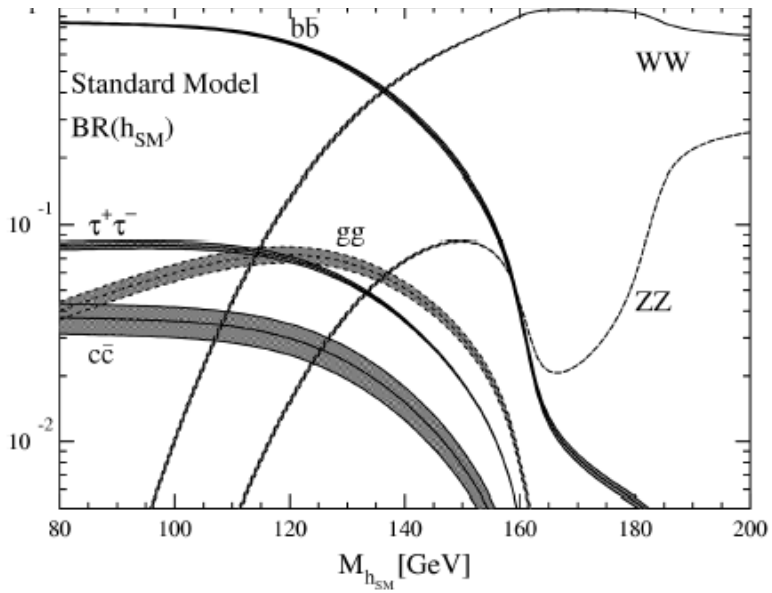


# Production Process & Decay Channel

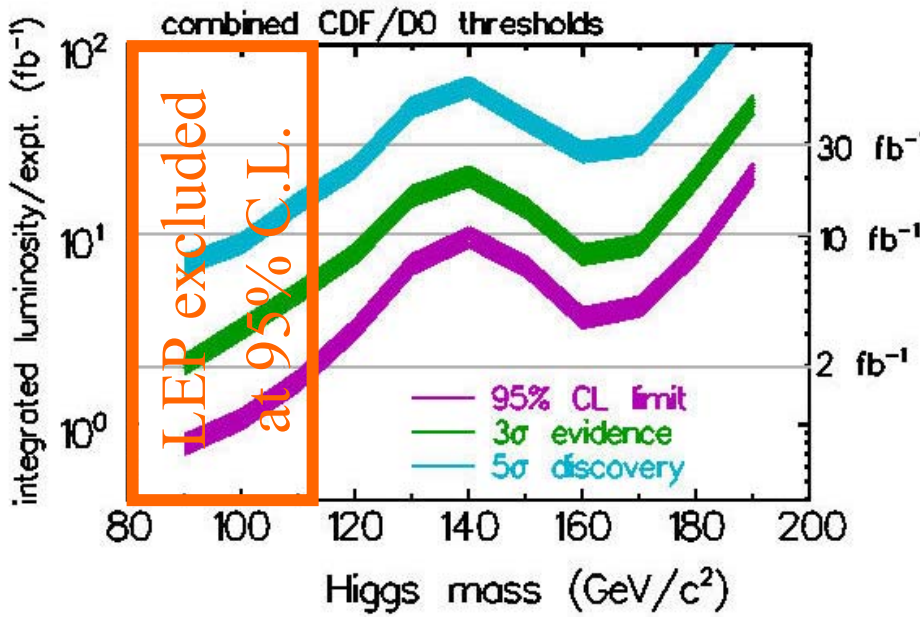
- $gg \rightarrow H$ … $\sigma(gg \rightarrow H) \sim 1$ pb
  - For masses below ~140 GeV,
    - ✗ Background hides $H \rightarrow bb$ signals
  - For higher masses; $m_H > 120$GeV,
    - ○ Combination with $H \rightarrow WW$ decay process can be useful
- HW, HZ … $\sigma(HW/HZ) \sim 0.1$ pb
  - ○ Leptonic decays of W/Z help background rejection
- Hqq … $\sigma(Hqq) \sim 0.1$ pb
  - ✗ Background too high
- Hbb … $\sigma(Hbb) \sim 5$ fb
  - ○ SM extensions may enhance $\phi b/bb$ ($\phi$ =h,H,A)



# Tevatron Higgs Working Group Study

- **The Higgs discovery potential for the Tevatron RunII has been evaluated.**
  - hep-ph/0010338
- **A joint effort of theorists and both experimental groups, CDF and DØ.**
- **Simulation performed using a parameterized fast detector simulation.**
- **Main conclusion :**
  - **Discovery at 3-5 σ can be made,**
    - **Combine all channels.**
    - **Combine the data from both experiments, CDF and DØ**
  - **Must improve understanding of signal and background processes and detector performance.**
    - **b-tagging, resolution of $M_{bb}$**
  - **Advanced analysis techniques are vital**
  - **Largest luminosity required to discover Higgs**




- **Results of studies with full simulations for selected signal process are consistent with SHWG expectations.**

# DØ Run II

- Tevatron Run II in progress
  - Collider energy : 1.8 TeV → 1.96 TeV
    → Higgs production cross section increases by 20~30%
  - Target Luminosity : 6 ~ 11 $fb^{-1}$ or more
  - Peak luminosity now better than Run I : 3.7 x $10^{31}$ $cm^{-1}$ $s^{-1}$
- DØ upgraded for Run II
  - New tracking system fully working well.
    → Important for b-tagging
  - D0 recorded over 80 $pb^{-1}$ with full detector
    (Operating at >85% efficiency)
- Analysis in this talk based on 30~50 $pb^{-1}$
  (Collected from August 2002 to January 2003)

# Current Activity

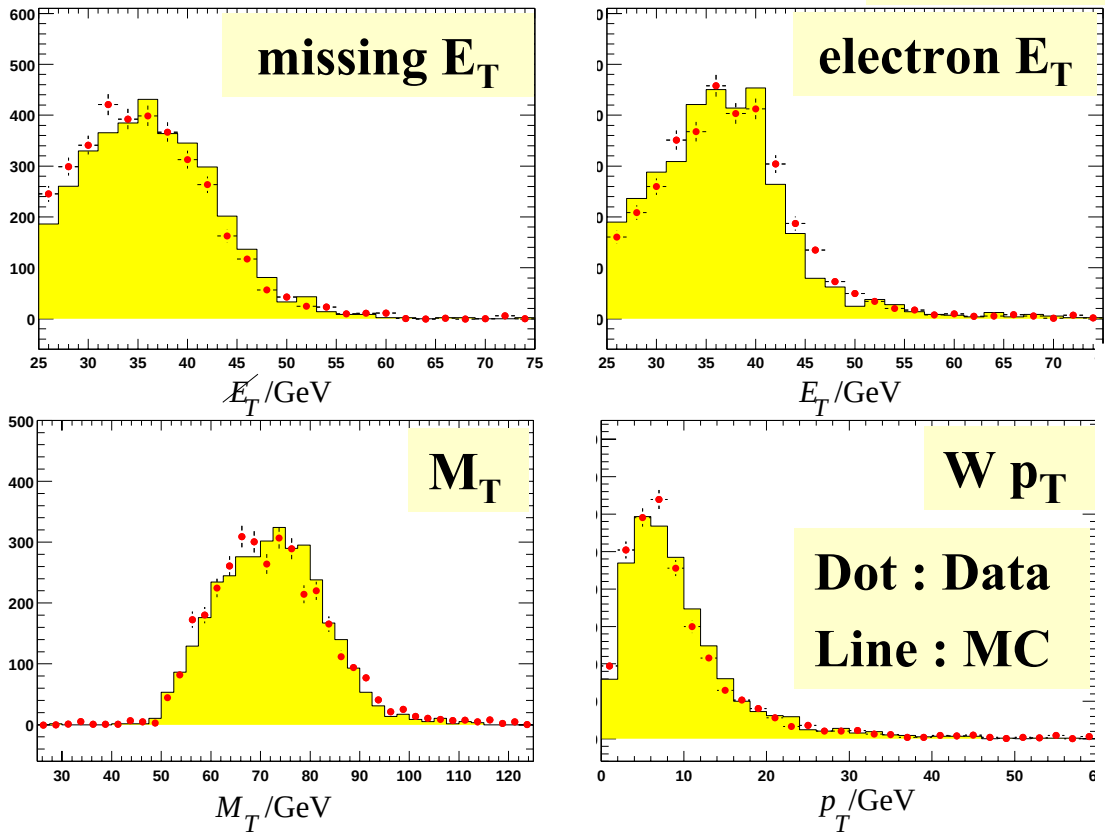
- Study of the W/Z(→lepton) + jets production
  - First step towards W/Z (→leptons) +H (→bb) measurement
  - The W/Z + b-jets can be related to W/Z+ jets properties
  - Try to understand major background source from W/Z + di-jets
- Search for $H \rightarrow WW^{(*)}$ ($\rightarrow ee\nu\nu/\mu\mu\nu\nu/e\mu\nu\nu$) decays
  - Lot of interesting physics in $WW^{(*)}$ production
  - Important to keep an eye

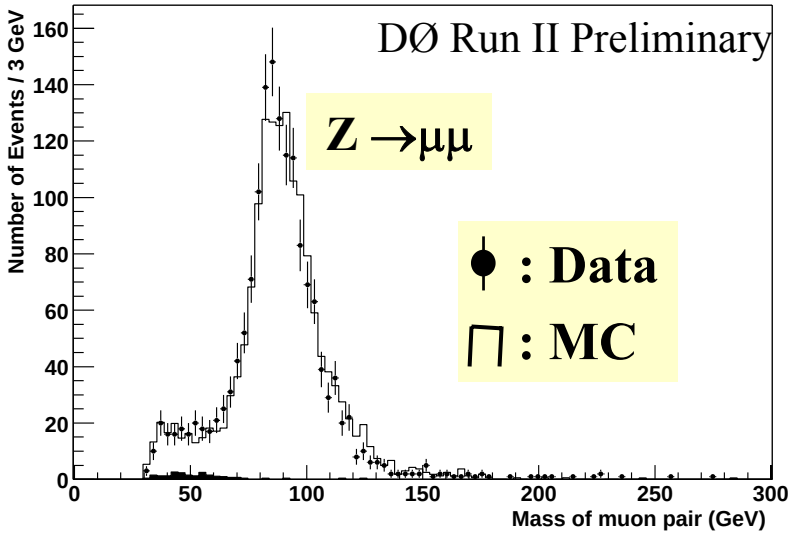
Others

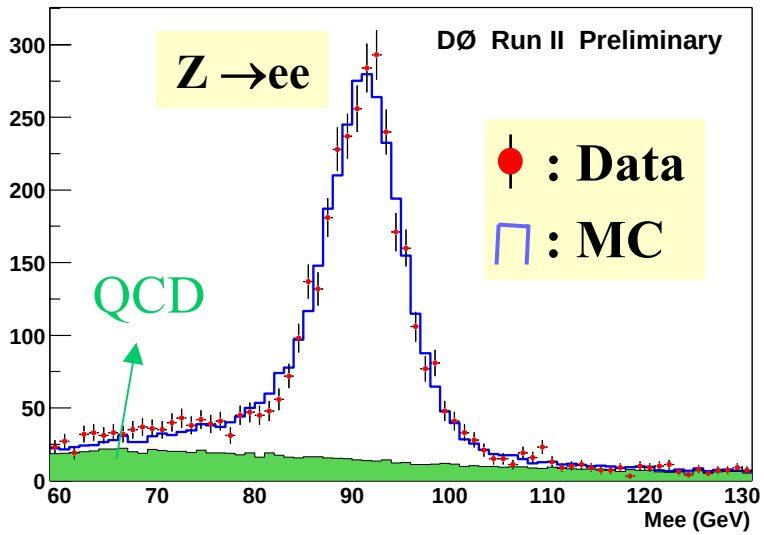
- Search for $H \rightarrow \gamma\gamma$ decays
- $WH(\rightarrow l^{\pm}\nu + bb)$
- $ZH(\rightarrow l^{+}l^{-}$ or $\nu\nu + bb)$
- $\phi b/bb$, $\phi \rightarrow bb/\tau\tau$ ($\phi$ = h, H, A ; SUSY Higgs)

# Object Identification

- W characteristics are represented by MC
- Clear mass peak of Z(ee) and Z(μμ)



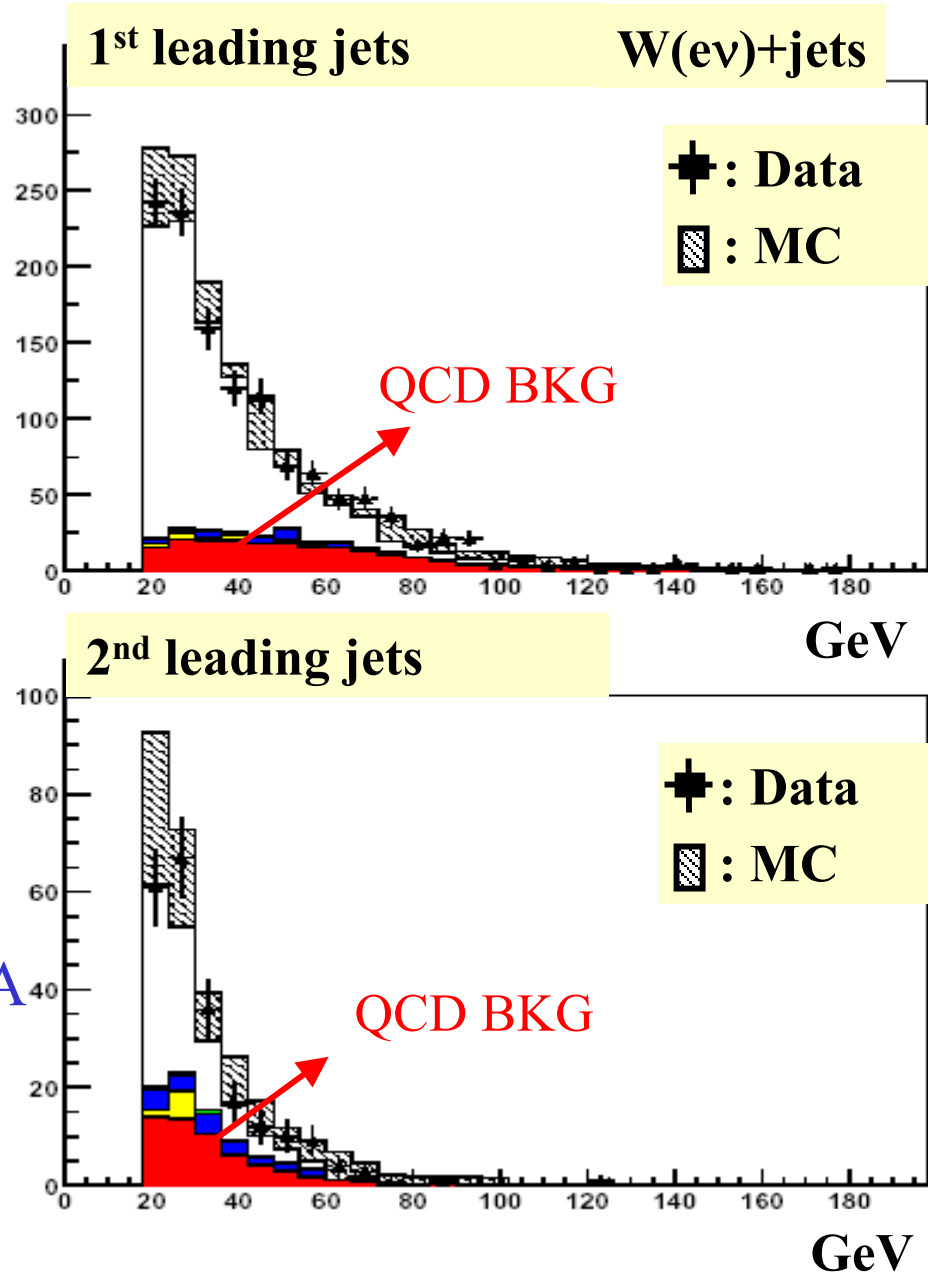



# W/Z + jets production

- First step towards W/Z ($\rightarrow$leptons) +H ($\rightarrow$bb) measurement.
- W/Z + b-jets properties can be related to W/Z + jets properties.
  - Major background source to Higgs searches
- Analysis utilized 35 $pb^{-1}$
- Data samples triggered by lepton
  - No bias for jets distribution.
- Basic Selection:
  - Isolated lepton and large $\not\!\!E_T$ (for W)
  - 2 high $p_T$ leptons and $m_{ll}$ consistent with $m_z$ (for Z)
  - Plus jets

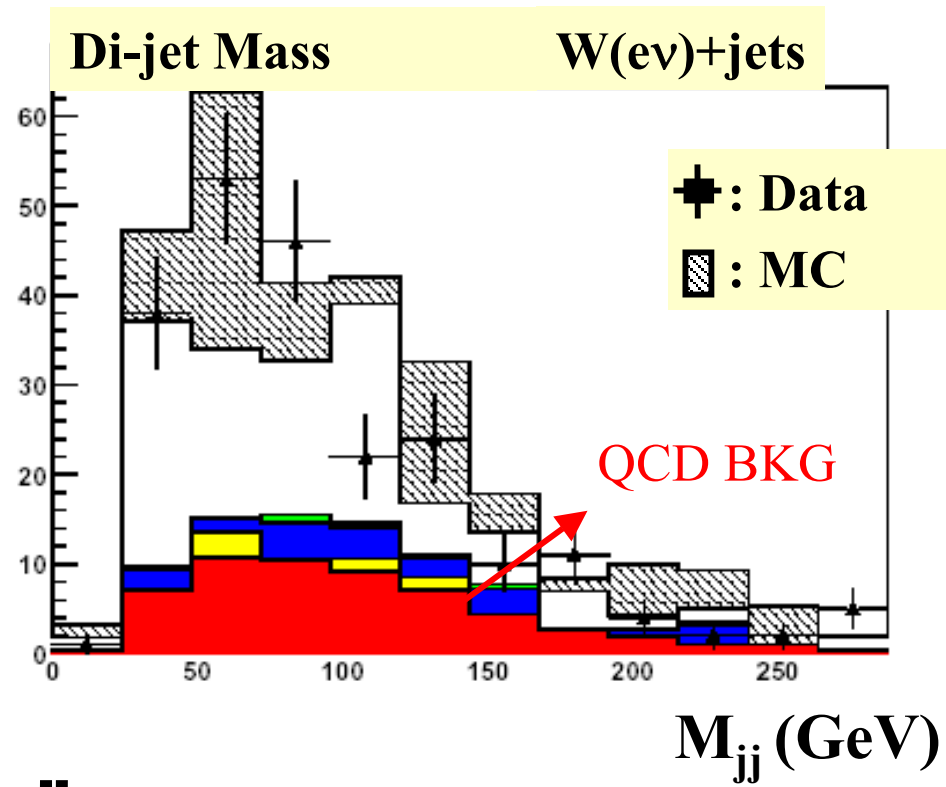
# W+jets production (1)

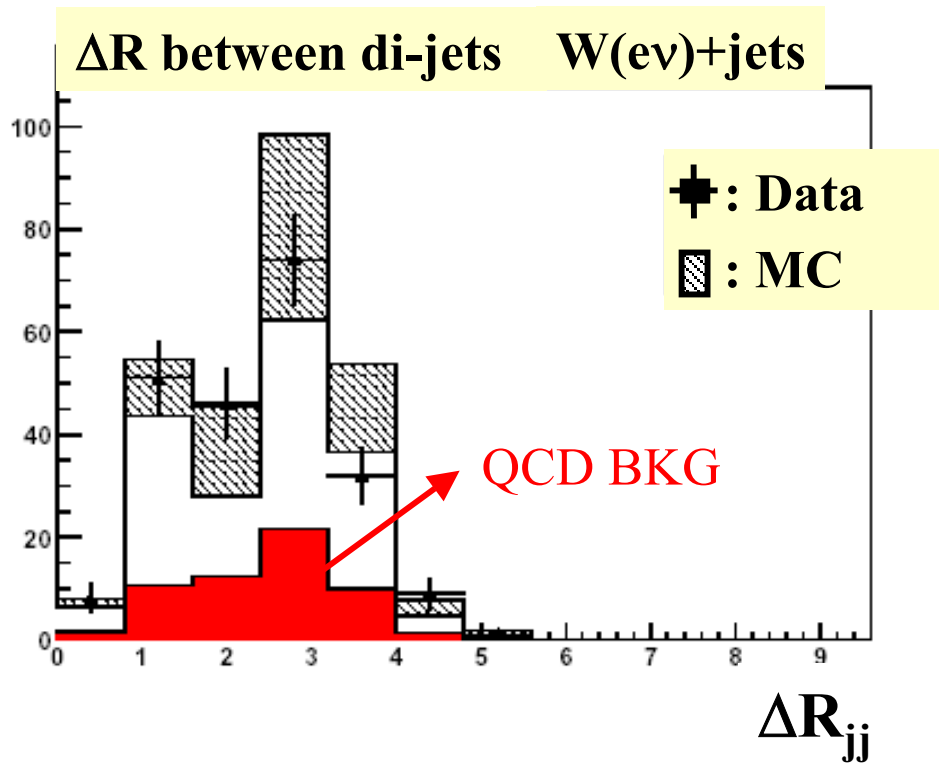
- Selection
  - W(→ eν)
    - Isolated e : $p_T$ > 20 GeV
    - $|\eta| < 0.8$
    - Missing $E_T$ > 25 GeV
  - W(→ μν)
    - Isolated μ : $p_T$ > 25 GeV
    - $|\eta| < 1.5$
    - missing $E_T$> 20 GeV
  - Jets
    - $p_T$ > 20 GeV
    - $|\eta| < 2.5$
- Compare PYTHIA MC with DATA
- Normalized by area
- Error includes stat. error and dominant syst. error from JES



# W+jets production (2)

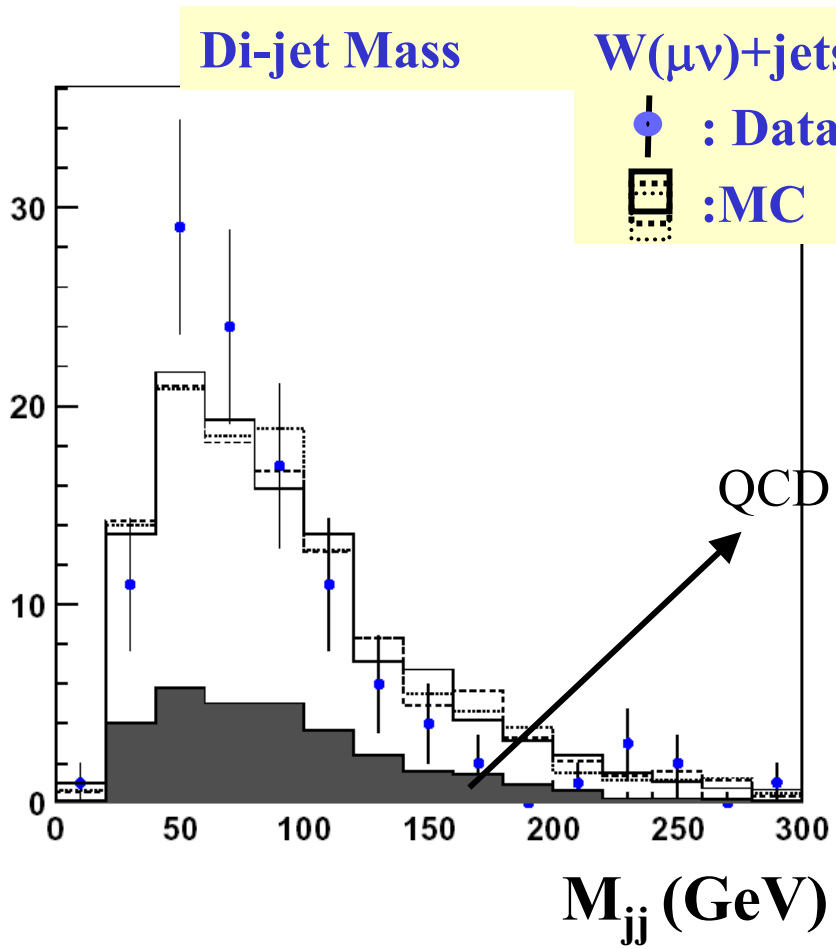
- Reconstructed di-jet mass and $\Delta R(=\sqrt{\Delta\phi^2 + \Delta\eta^2})$ between jets
  - MC reproduces jet distributions well
  - First step towards study of W(→leptons)H(→ bb) decay process



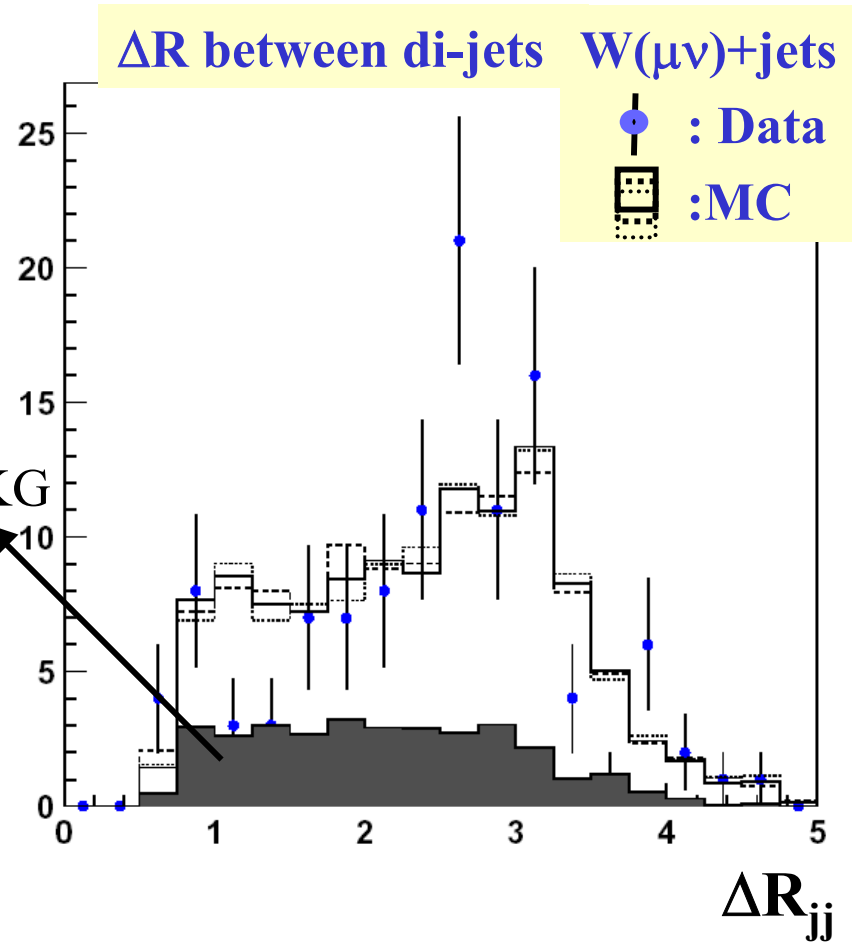



# W+jets production (3)

- Di-jet mass and $\Delta R_{jj}$ distribution for $W(\rightarrow \mu\nu)$ + jets event



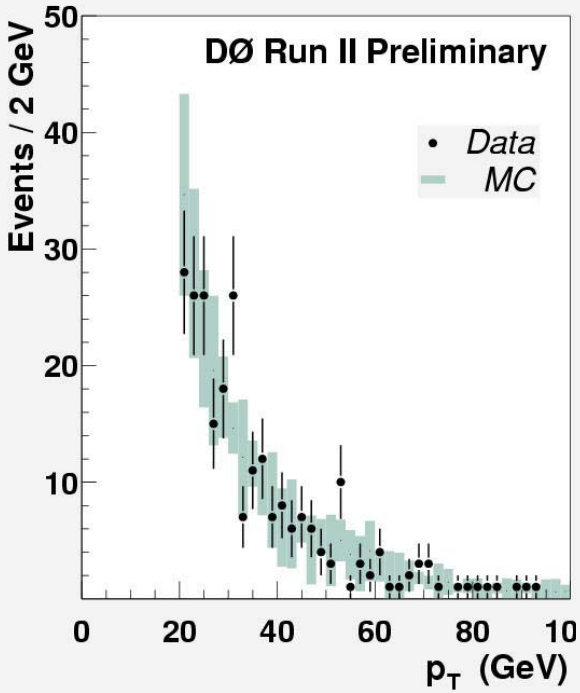

QCD BKG



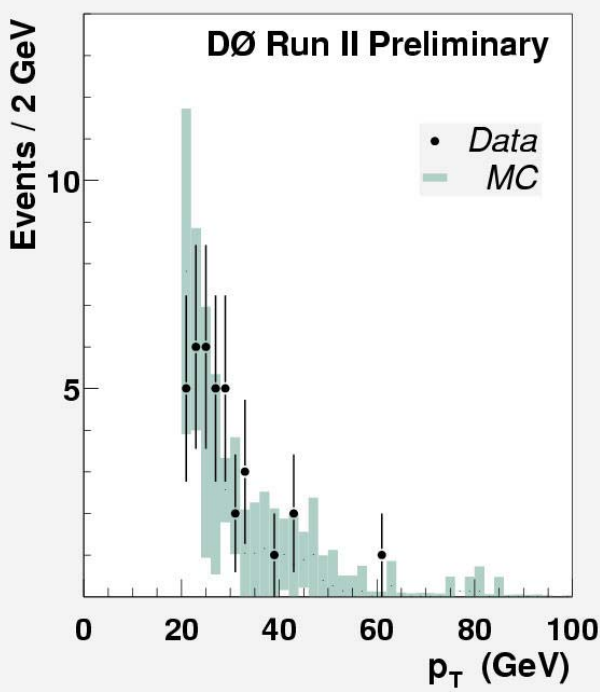
# Z+jets production (1)

- Selections
  - 2 electrons from Z(→ ee)
    - $p_T > 20$ GeV
    - $|\eta| < 2.3$
  - Jets
    - $p_T > 20$ GeV
    - $|\eta| < 2.5$
  - 2 muons from Z(→ μμ)
    - $p_T > 15$ GeV
    - $|\eta| < 2$
- Compare PYTHIA MC with DATA
- Normalized by area
- Error includes stat. error and dominant syst. error from JES

**1st leading jets**




**2nd leading jets**

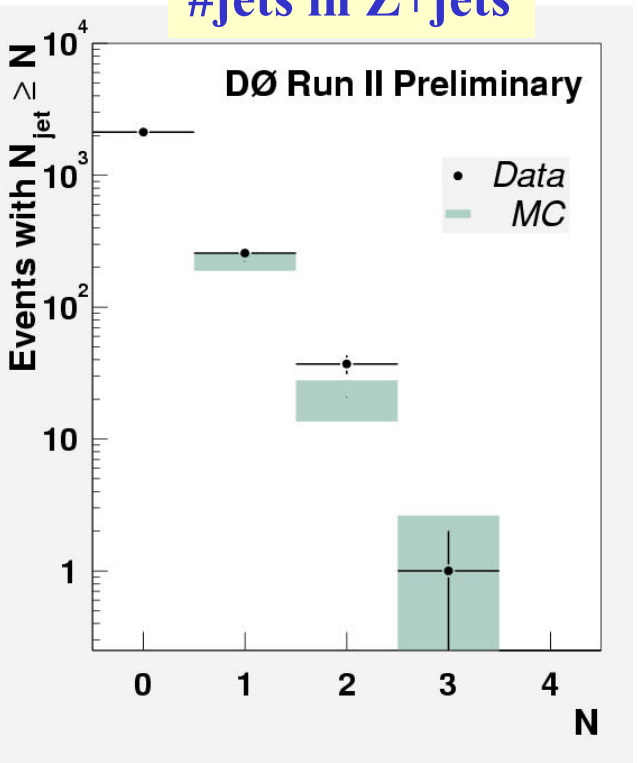



Combined Z(ee)+jets and Z(μμ)+jets

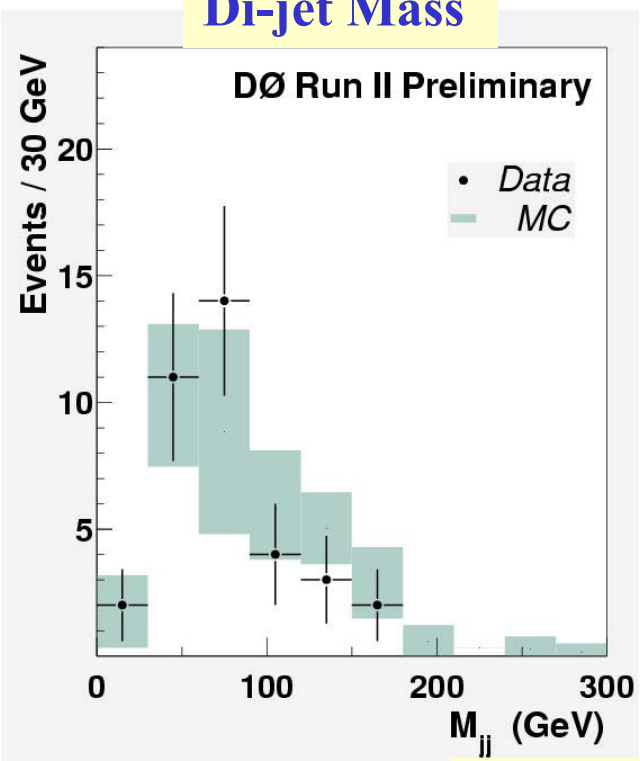
# Z+jets production (2)

- Number of jets in Z + jets final states
- Reconstructed di-jet mass and $\Delta R(=\sqrt{\Delta\phi^2+\Delta\eta^2})$ between jets
  - MC describes jet distributions well
  - First step towards Z(→leptons)H(→ bb) study

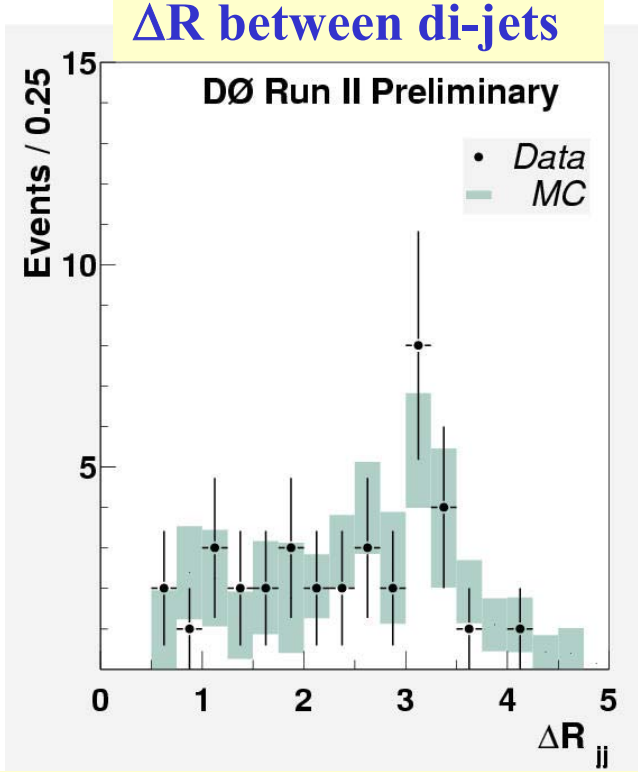
**#jets in Z+jets**




**Di-jet Mass**




**ΔR between di-jets**

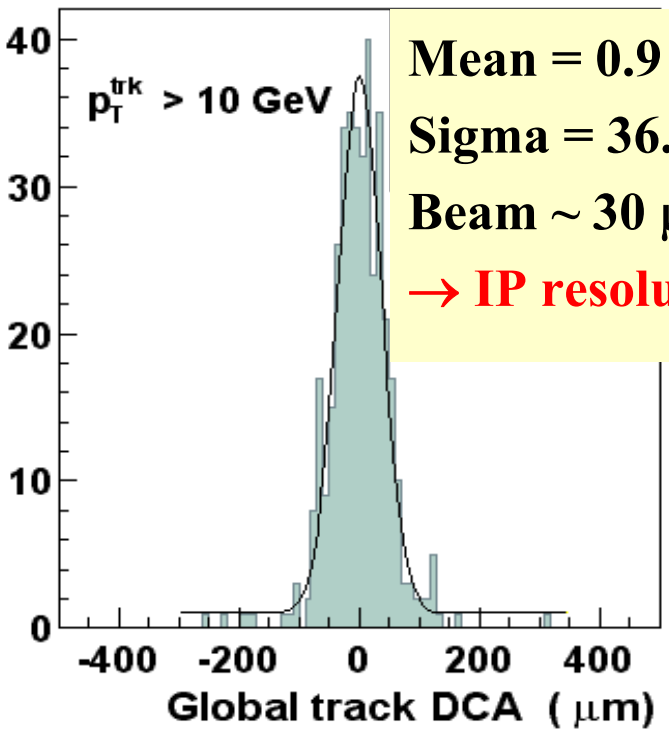



Combined Z(ee)+jets and Z(μμ)+jets

# b-tagging (1)

- Next step in searches for Higgs would be b-jet identification
- Crucial to keep signal efficiency high and suppress non-b jets
- b-tagging efficiency determined by Impact Parameter (IP) resolution
- Measured IP resolution after 1st pass in SMT alignment

• **IP resolution**



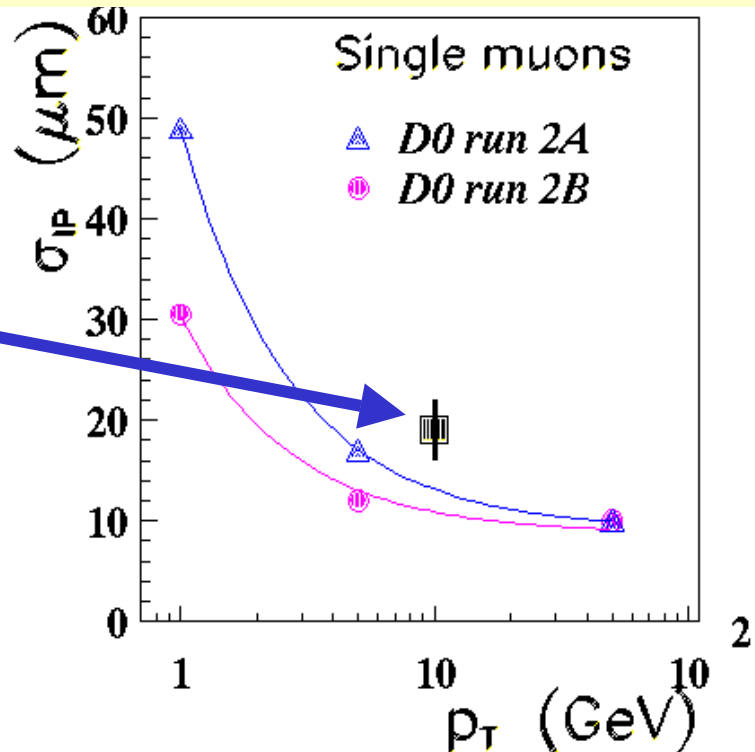

**Mean = 0.9 ± 2.2 μm**

**Sigma = 36.3 ± 1.8 μm**

**Beam ~ 30 μm**

**→ IP resolution ~ 20 μm**

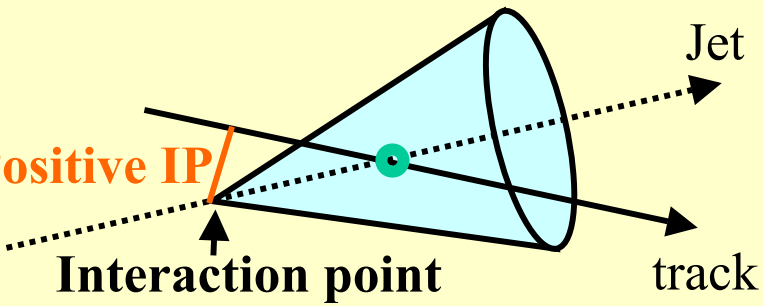
• **IP resolution as the function of $P_T$**



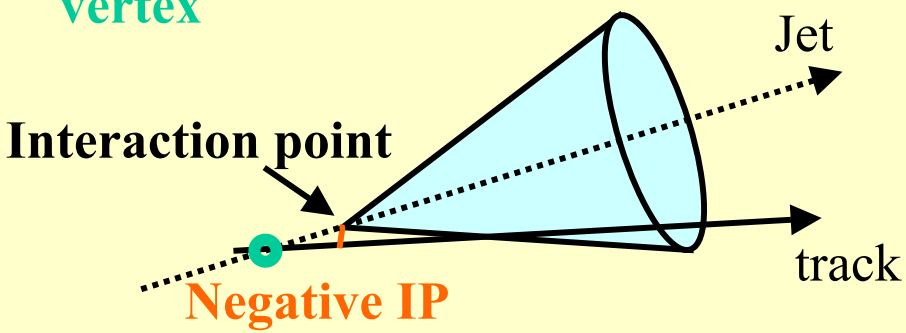
# b-tagging (2)

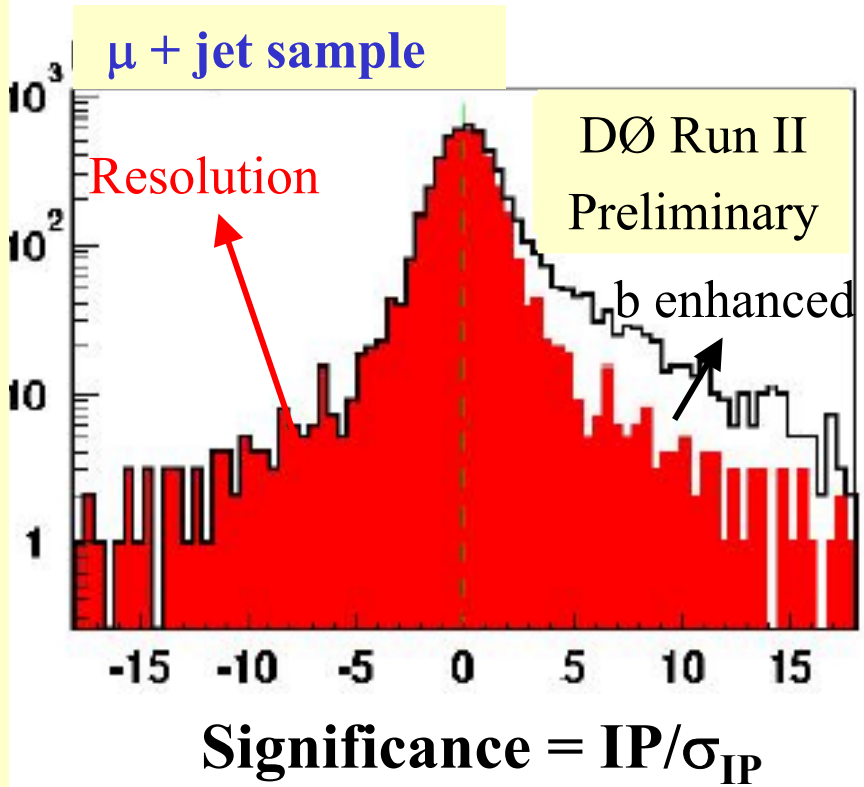
- b-tagging explores IP significance method
- Lepton from semileptonic decay of b is very useful

• **Impact Parameter > 0**
→ **track crosses jet axis after primary vertex**




• **Impact Parameter < 0**
→**track crosses jet axis before primary vertex**




**Significance = IP/$\sigma_{IP}$**

# $H \rightarrow WW^{(*)} \rightarrow l^+l^-\nu\bar{\nu}$ decays

- Lot of interesting physics in WW production
  - SM Higgs at high mass region ($m_H \geq 120$ GeV)
  - 4th fermion family enhances SM Higgs cross section (factor ~8.5 for $m_H$=100 – 200 GeV)
  - Fermiophobic/Topcolor Higgs
  - (Br(H $\rightarrow$WW)>98% for $m_H > 100$ GeV)
  - Non Higgs-related … Tri-linear couplings, New Phenomena
- Look at ee/μμ/eμ plus missing $E_T$ events
- Backgrounds include $Z/\gamma^*$, WW, $t\bar{t}$, W/Z+jets, QCD
- Cannot directly reconstruct mass
  - Transverse mass ($m_T$) computed using $m_{ll}$ and $\not\!\!E_T$
- Opening angle between leptons ($\Delta\Phi_{ll}$) is useful discriminating variable
  - Two leptons from Higgs tend to move in parallel (small $\Delta\Phi_{ll}$) , due to spin correlations in H$\rightarrow$WW decay products
  - Leptons from $Z/\gamma^*$ , multijets are emitted back to back (large $\Delta\Phi_{ll}$)

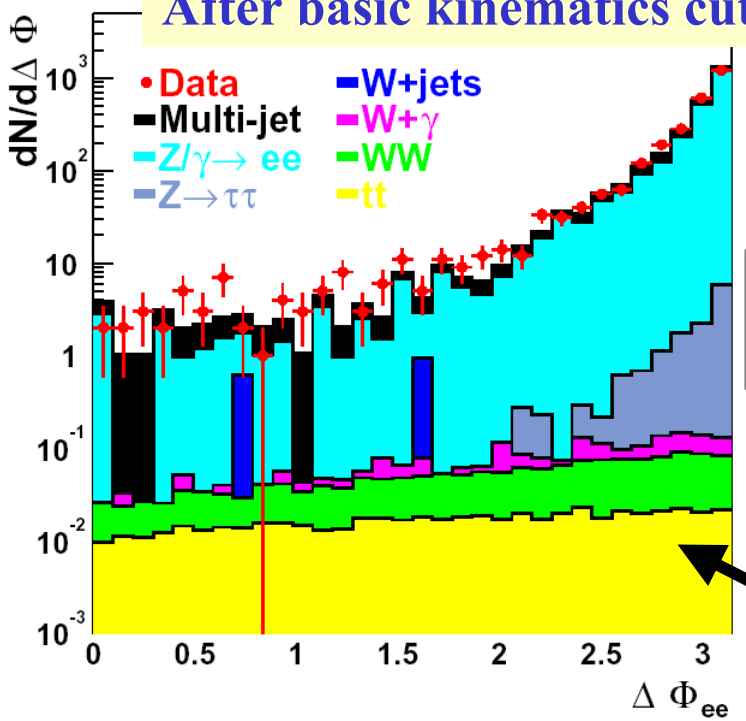
# $H \rightarrow WW^{(*)} \rightarrow e^+e^-\nu\bar{\nu}$ final states

**L=44.5 pb$^{-1}$**
**Selection optimized for $m_H = 120$ GeV**

| | Expected background | DATA |
|---|---|---|
| Lepton ID, $p_T$>10, 20 GeV | 2748 ± 42 ± 245 | 2753 |
| $m_{ee} < m_H/2$ | 264 ± 18.6 ± 4.3 | 262 |
| $\not\!\!E_T > 20$ GeV | 12.3 ± 2.5 ± 0.7 | 11 |
| $m_T < m_H + 20$ GeV | 3.6 ± 1.4 ± 0.2 | 1 |
| $\Delta\Phi_{ee} < 2.0$ | 0.7 ± 1.4 ± 0.1 | 0 |

$\varepsilon_{signal} = \sim 8\%$

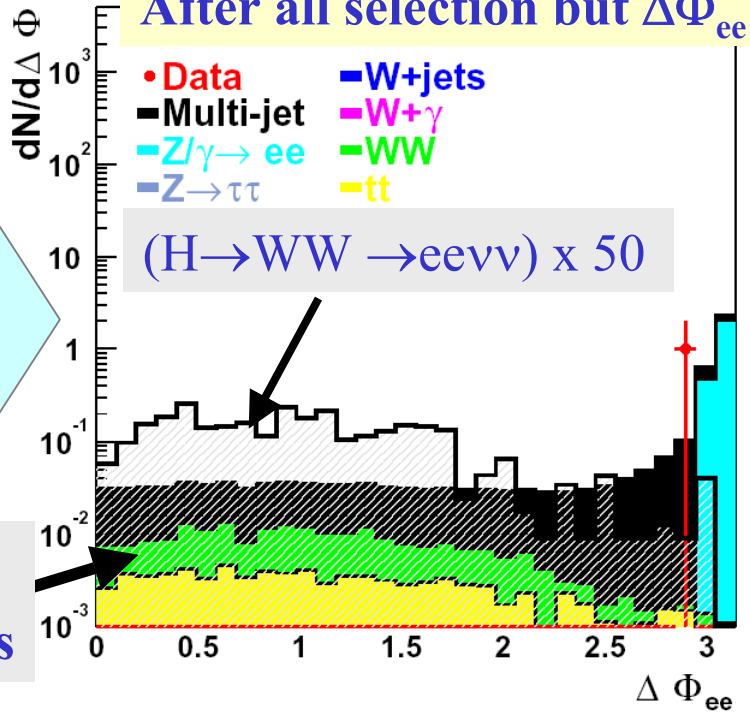
**After basic kinematics cuts**




**Event Selection**

**Expected Backgrounds**

**After all selection but $\Delta\Phi_{ee}$**

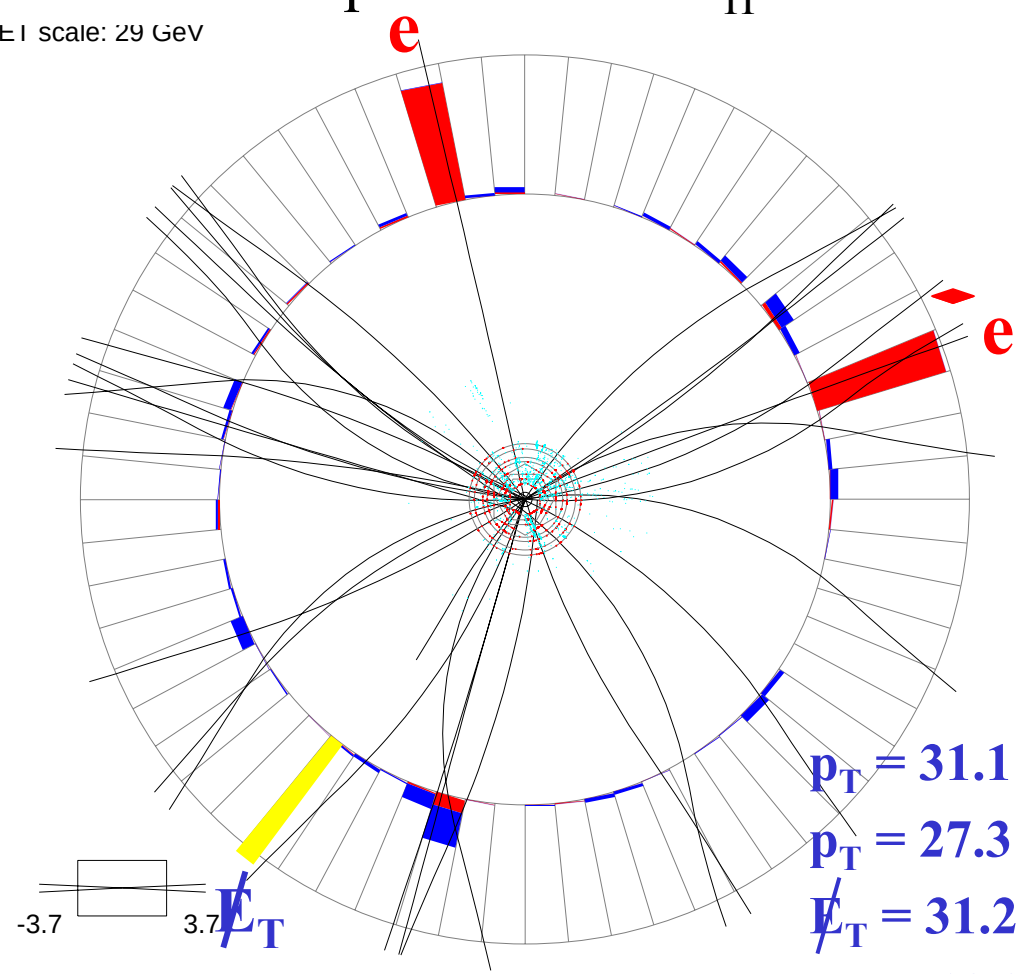


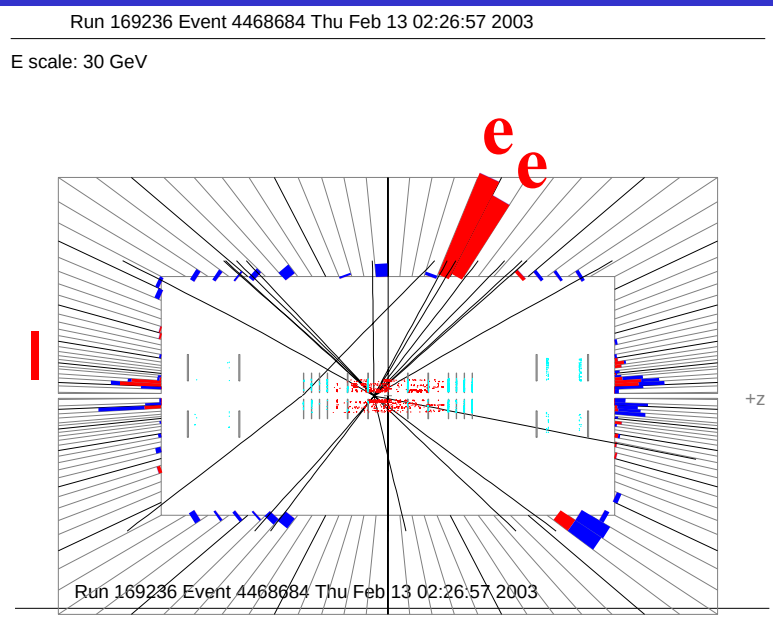
# $H \rightarrow WW^{(*)} \rightarrow e\mu\nu\nu$ final states

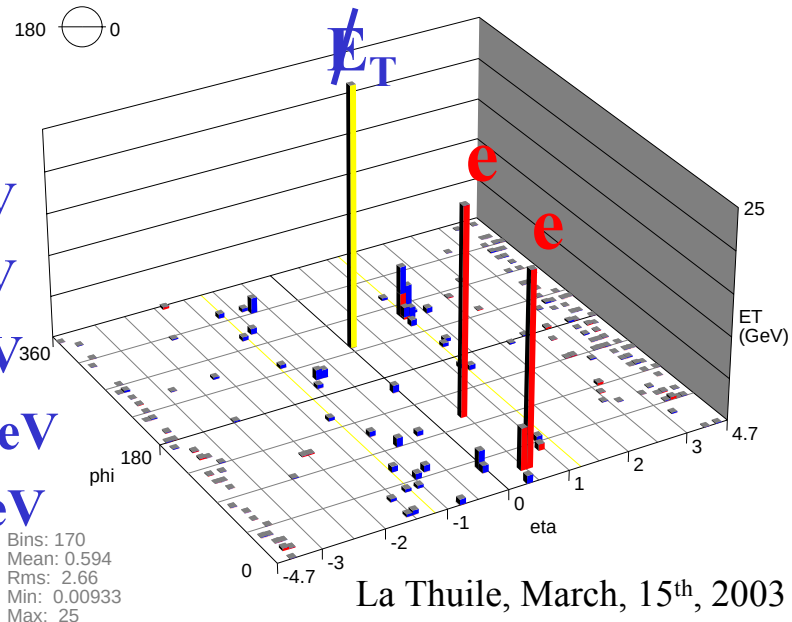
| | Expected background | DATA |
|---|---|---|
| Lepton ID, $p_T$>10, 20 GeV | $22 \pm 2.1 \pm 2.2$ | 22 |
| $E_T > 20$ GeV | $3.1 \pm 1.7 \pm 0.1$ | 4 |
| $\Delta\phi(E_T,\text{jets})>0.5$, $\lvert E_T+p_T\rvert>50$ GeV | $1.4 \pm 1.5 \pm 0.1$ | 2 |
| $\Delta\Phi_{e\mu} < 2.0$ | $0.9 \pm 1.5 \pm 0.1$ | 1 |

# Candidate of $H \rightarrow WW^{(*)} \rightarrow e^+e^-\nu\bar{\nu}$

## Selection optimized for $m_H$=160GeV




$p_T$ = 31.1 GeV

$p_T$ = 27.3 GeV

$\not\!\!E_T$ = 31.2 GeV

$m_T$ = 106.8 GeV

$M_{ee}$ = 36.1 GeV

$\Delta\Phi_{ee}$=1.43

# Summary

- DØ is taking physics quality data.
- Background to Higgs production are under study.
  - W+jets
  - Z+jets
  - WW
- More to come in the near future!!