Recent results on B physics and prospects for Higgs Physics from DØ

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for the DØ Collaboration

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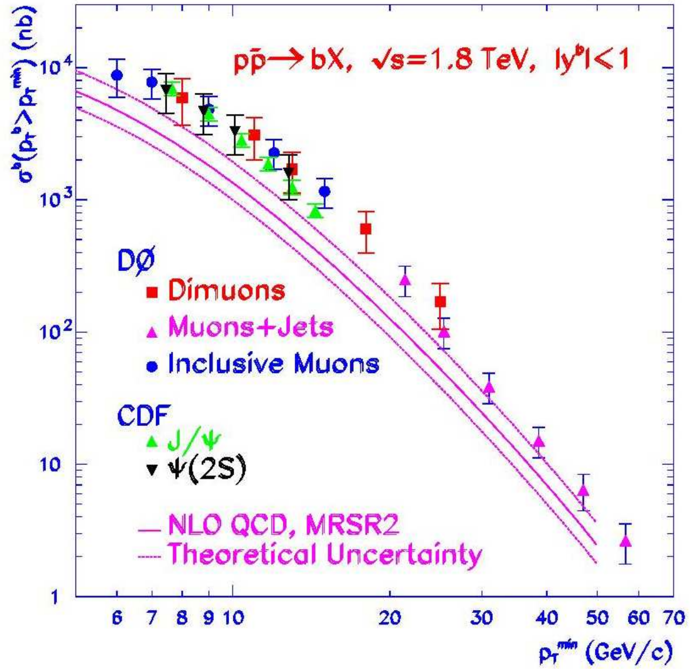
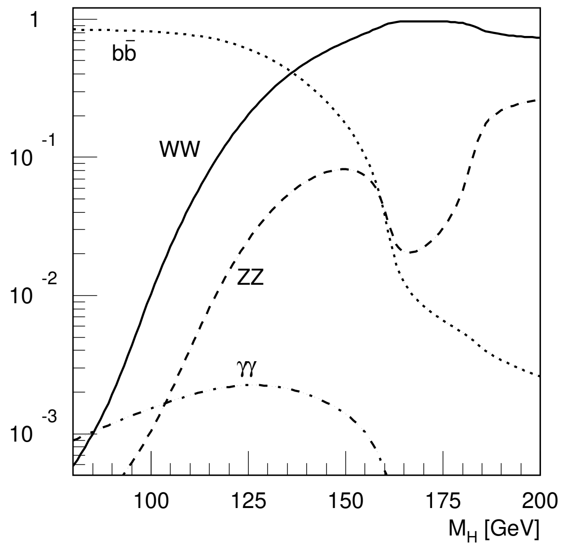
- Introduction
- The DØ Detector
- First results on B physics
- Prospects for Higgs physics
- Summary and outlook

Why study b–quarks and B Physics at the Tevatron



- Large production cross section
  - $\sigma(p\bar{p} \rightarrow b\bar{b}) \approx 150\mu b$ at $\sqrt{s} = 1.96$ TeV
  - $\sigma(e^+e^- \rightarrow b\bar{b}) \approx 7nb$ at Z^0
  - $\sigma(e^+e^- \rightarrow B\bar{B}) \approx 1nb$ at $\Upsilon(4S)$
- All species of $\mathrm{B}^0, \mathrm{B}_s^0, \mathrm{B}^+$ etc are produced



- b–quark identification crucial for Higgs physics
- Low mass Higgs boson decays basically into $b\bar{b}$ pairs
  - BR(H→ $b\bar{b}$) > 90% for M_H < 130 GeV

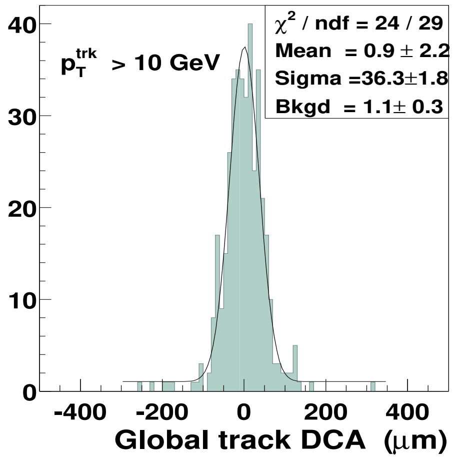
Tracking system

- Silicon Micro Tracker
- $\approx$ 800.000 readout channels
- Secondary vertex resolution: 80μm (r–z), 40 μm (r–ϕ)

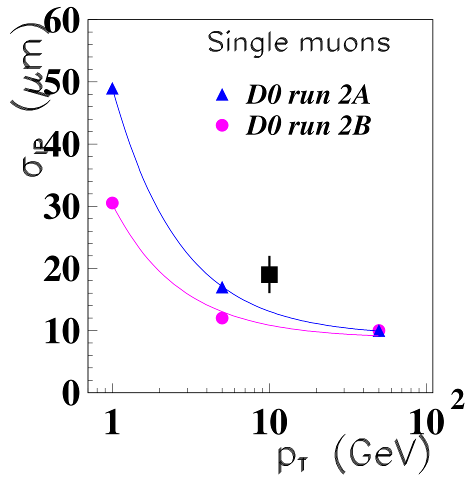
- Central Fiber Tracker
- Scintillator fibres
- Axial and stereo angle doublets: angle $\pm 3^\circ$

Detector performance

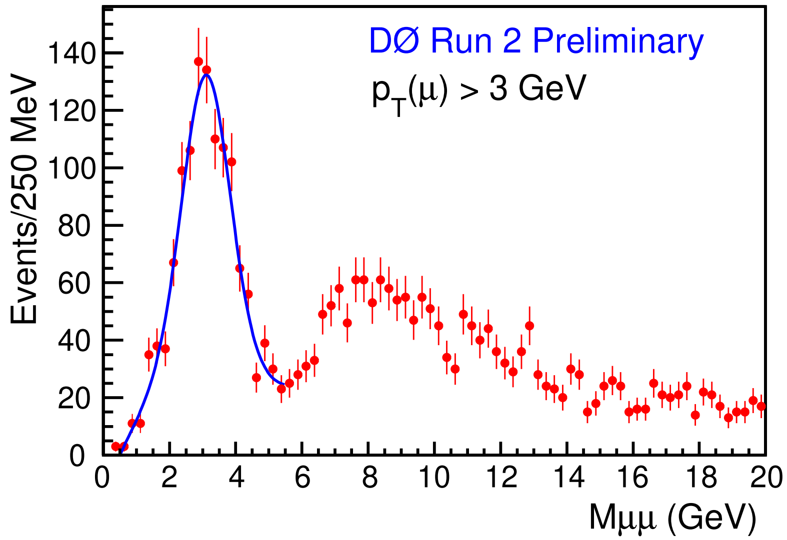
- Global track DCA



- Impact parameter resolution



- Width 36 μm, σ(beam) $= 30\mu$m
  $\Rightarrow \sigma = 20\ \mu$m



- Muon system only J/Ψ's

B and Higgs Physics program at DØ

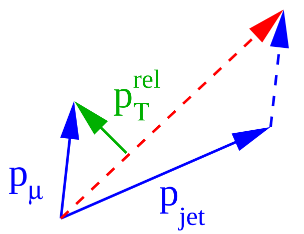
- Lifetime measurements
  - $b \rightarrow J/\Psi \Rightarrow$ Average B lifetime
  - $\Lambda_b^0 \rightarrow J/\Psi\Lambda^0 \Rightarrow \Lambda_b^0$ lifetime
  - $B_s^0 \rightarrow J/\Psi\phi \Rightarrow B_s^0$ lifetime and width
- $B^0 \rightarrow J/\Psi K_s^0 \Rightarrow \sin(2\beta)$ and CP violation
- $B_s \rightarrow D_s l X, B_s \rightarrow D_s(n\pi) \Rightarrow B_s^0$ mixing
- Cross sections and rare decays
- ..and much more I cannot talk about today

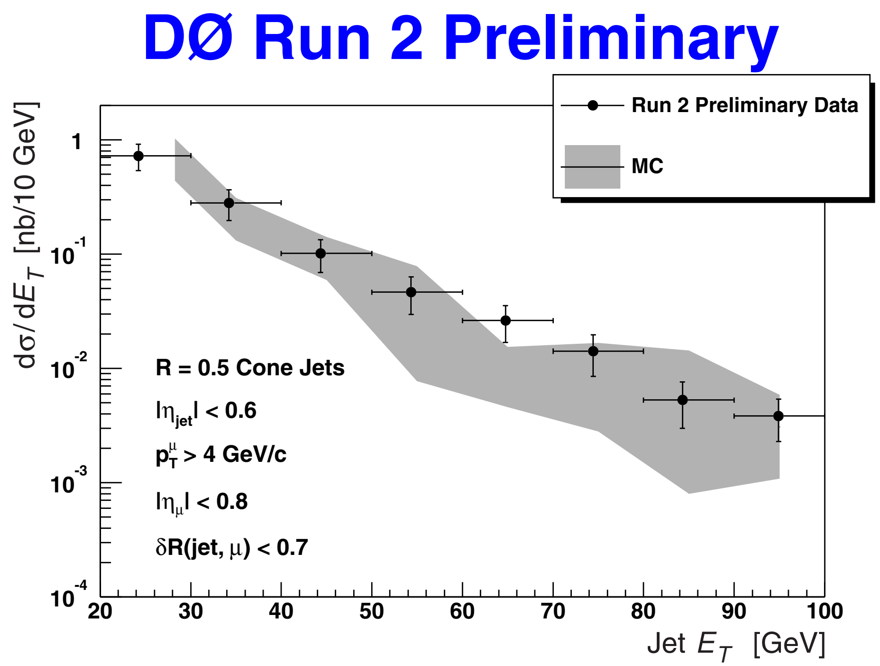
- Search for the standard model Higgs boson
  - $W/Z\ H \rightarrow b\bar{b} \Rightarrow$ Low mass Higgs $M_H < 140$ GeV
  - $H \rightarrow WW \Rightarrow$ Heavy mass Higgs $M_H > 140$ GeV
- Search for exotic Higgs models $\Rightarrow 4^{th}$ generation, fermiophobic

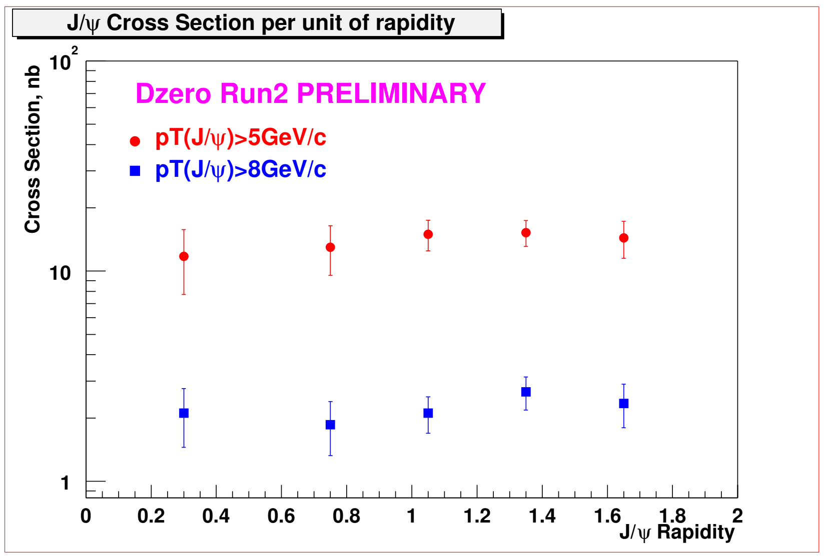
B and J/Ψ cross section

- b–quark production cross section
  - Start from μ+jets cross section
  - Get b–content from fit to the p_T^{rel} distribution

$\Rightarrow$ b–content $(21.5 \pm 4.3)\%$
for 20 GeV $< E_T <$ 25 GeV



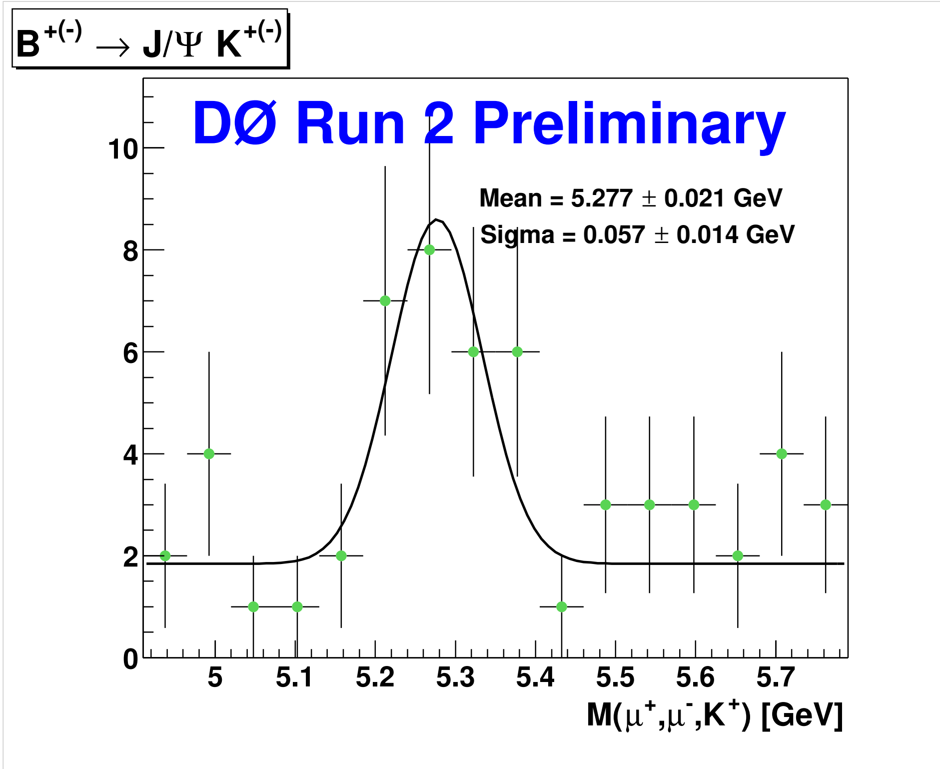




- Measurement of the J/Ψ cross section
  - Data corresponding to $\int \mathcal{L} dt = 5\ \mathrm{pb}^{-1}$
  - First measurement in this rapidity and E_{CM} region

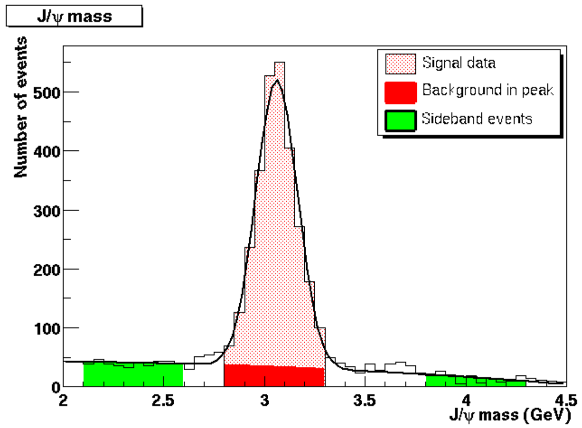
First look at B hadrons

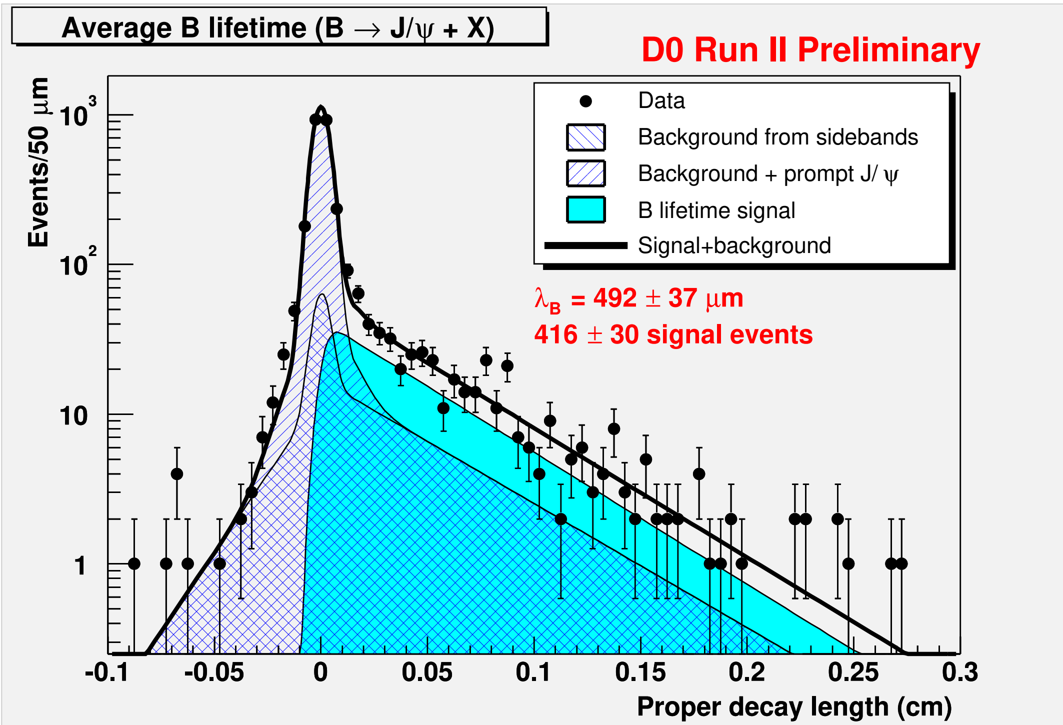
- Exclusive B reconstruction
  - First time at DØ
  - Data sample corresponding to $\int \mathcal{L}dt = 5\ \mathrm{pb}^{-1}$
- Reconstruct $J/\Psi \to \mu^+\mu^-$ vertex
  - Positive decay length
  - p_T(track)> 2 GeV
- B Vertex reconstruction
  - Decay length $> 120\ \mu m$
  - $p_T(B) > 10$ GeV
  - $\chi^2 < 10$
  - Colinearity angle $(\mathbf{p}\cdot\mathbf{l}) > 0.9$



Measurement of the B lifetime

- Same sample of $B^{\pm}$ as before
- Reconstruct J/Ψs with $p_T > 4$ GeV

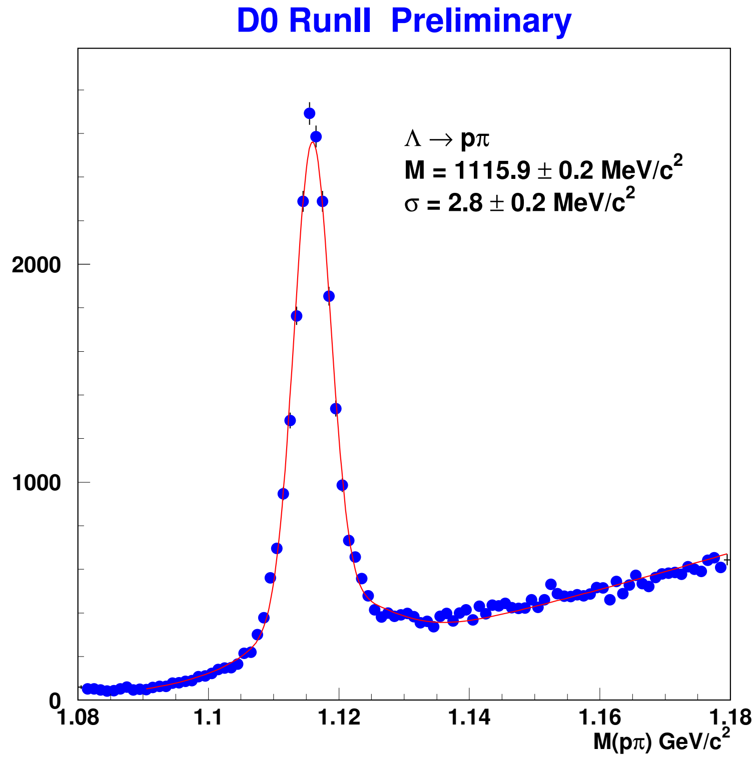




- 416 ± 30 signal events
- 2184 ± 47 prompt J/Ψ's
- B lifetime
  - $c\tau(B) = 492 \pm 37(\text{stat.})\mu m$
  - Compare to PDG value: $c\tau(B) = 469\mu m$

On the way to the Λ_b^0 lifetime

- Theoretical prediction $\tau(\Lambda_b^0)/\tau(B^0) = 0.9$
- Measurement from semileptonic mode is $\tau(\Lambda_b^0)/\tau(B^0) = 0.797 \pm 0.053$
  Problem in this mode, because neutrino is lost
- Use fully hadronic mode $\Lambda_b^0 \to J/\Psi\Lambda^0$
  $\Rightarrow BR(\Lambda_b^0 \to J/\Psi\Lambda^0) = 10^{-4}$
  $\Rightarrow$ Use leptonic J/Ψ decays to trigger and reconstruct $\Lambda^0 \to p\pi$



- $\Lambda^0 \to p\pi$ decay
  - Highest p_T track assigned proton mass
  - Reject events if $m(\pi\pi)$ is consistent with $m(K_s^0)$
- Look for these events in $J/\Psi \to \mu\mu$ events

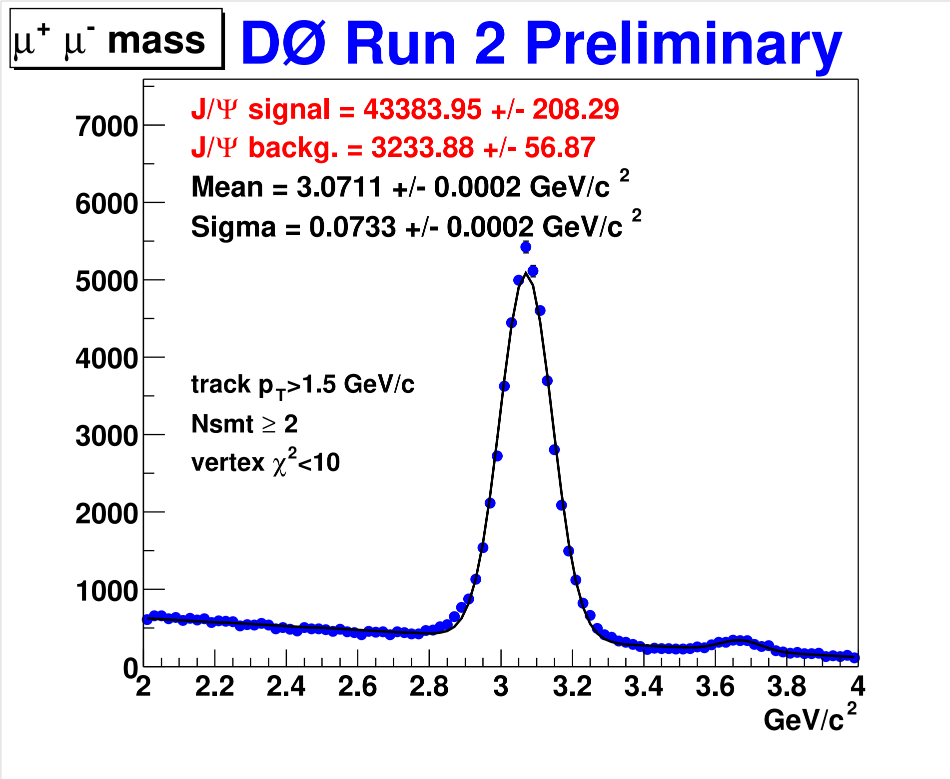
CP violation in the B system

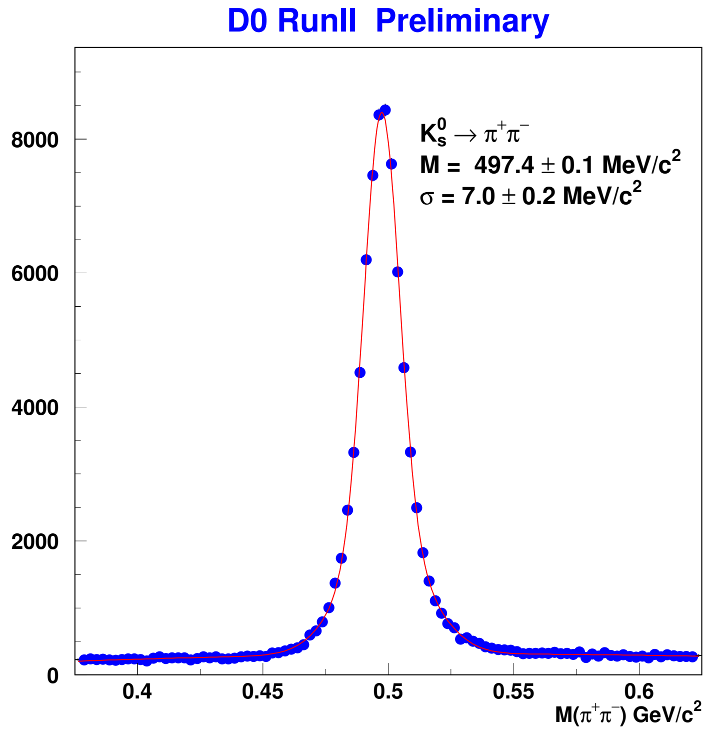
- Direct and mixed $\mathrm{B_d^0}$ decays yield same CP eigenstates
  - $\mathrm{A(B_d \to \bar{B}_d)} \sim m_t^2 V_{tb}^2 \approx |A| e^{i2\beta}$
  - $\mathrm{A(\bar{B}_d \to B_d)} \sim m_t^2 {V_{tb}^*}^2 \approx |A| e^{-i2\beta}$
- To measure $\sin(2\beta)$, reconstruct $\mathrm{B^0 \to J/\Psi K_s}$ decays
  - $\mathrm{A}_{CP}(t) = \frac{\Gamma(\mathrm{\bar{B}^0 \to J/\Psi K_s^0}) - \Gamma(\mathrm{B^0 \to J/\Psi K_s^0})}{\Gamma(\mathrm{\bar{B}^0 \to J/\Psi K_s^0}) + \Gamma(\mathrm{B^0 \to J/\Psi K_s^0})} = \sin(2\beta)\sin(\Delta m_d t)$
- Expectations for 2 $\mathrm{fb^{-1}}$:
  - Reconstruction of 30K – 40K $\mathrm{B^0 \to J/\Psi K_s^0}$ events
  - $\sigma(\sin(2\beta)) \approx 0.05$
    - ∗ Good muon acceptance and trigger thresholds
    - ∗ Forward tracking
    - ∗ Excellent flavour tagging
    - ∗ Trigger $\mathrm{J/\Psi \to e^+e^-}$

Towards the measurement of sin(2β)

- $J/\Psi \to \mu^+\mu^-$ selection
  - Two opposite sign muons matched to tracks
  - $p_T > 2$ GeV

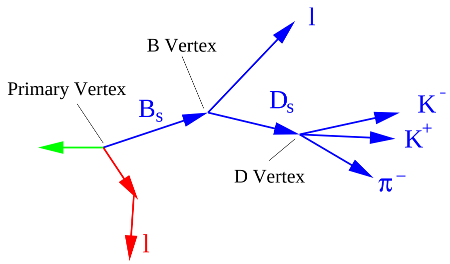
- $K^0_s \to \pi^+\pi^-$ selection
  - Two tracks with opposite sign
  - Large impact parameter significance

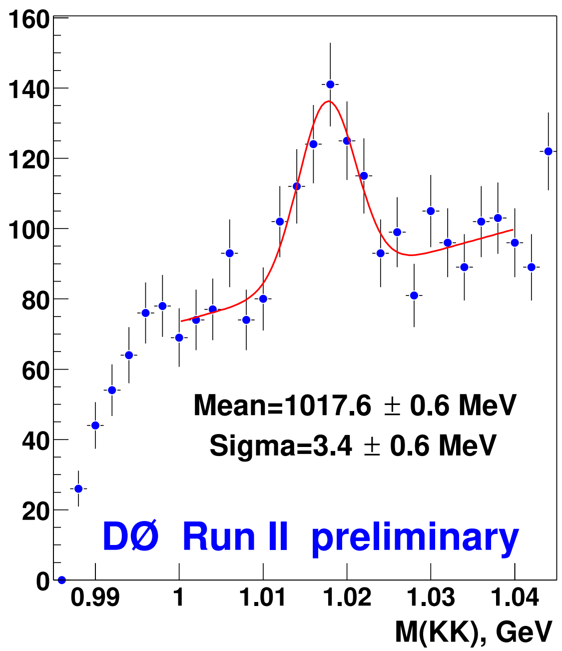




First steps in B_s mixing

- Semileptonic decay mode
  - $B_s \to D_s^- l^+ \nu X$ with $D_s^- \to \phi\pi^-$ and $\phi \to K^+K^-$
  - Trigger on di–leptons
  - Initial flavour tagged by charge of opposite side lepton
  - Final flavour tagging by same side lepton charge

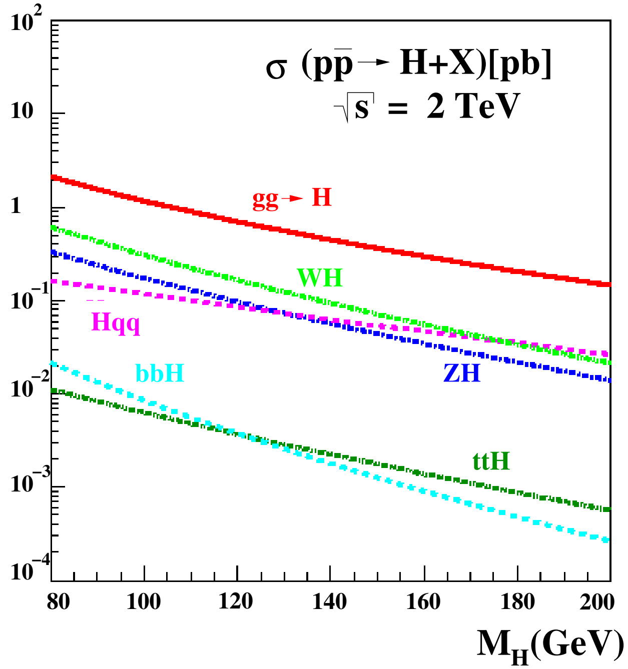




- Next steps
  - Reconstruct $D_s^- \to \phi\pi^-$ in events with leptons
  - Measure proper lifetime of B_s candidates
  - Unfortunately resolution limited by neutrino in the event
- Fully hadronic mode
  - Excellent lifetime measurement
  - Very hard to trigger
- Measurement possible up to $x_s \approx 30$

The hunt for the Higgs boson

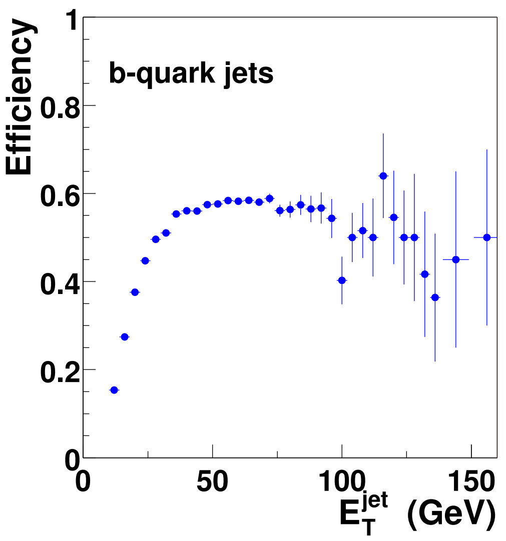
- Higgs production
  - Production cross section in the order of 0.1–2 pb
  - Main production process is gluon fusion
  - Associated production WH and ZH suppressed by an order of magnitude

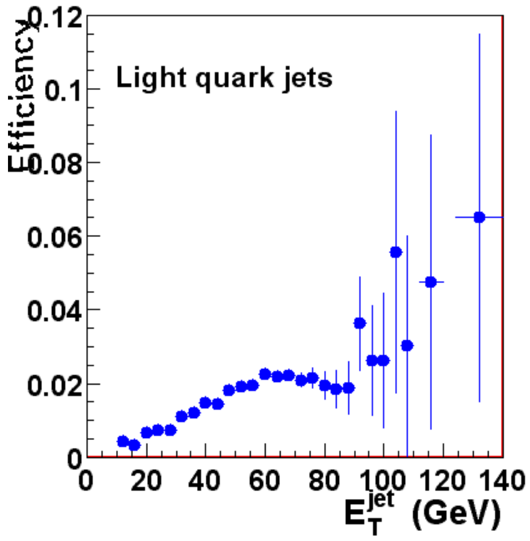


- Higgs decay
  - Low mass region $M_H < 140$ GeV: Decay into $b\bar{b}$ is dominant
    - Need additional lepton for trigger and to suppress backgrounds $\Rightarrow$ Associated Higgs production together with a Z/W boson
  - Above 140 GeV: Higgs decay mostly in WW pairs
  - Other intersting modes
    - $b\bar{b}H \rightarrow b\bar{b}b\bar{b} \Rightarrow$ SUSY
    - $H \rightarrow \gamma\gamma \Rightarrow$ Fermiophobic Higgs

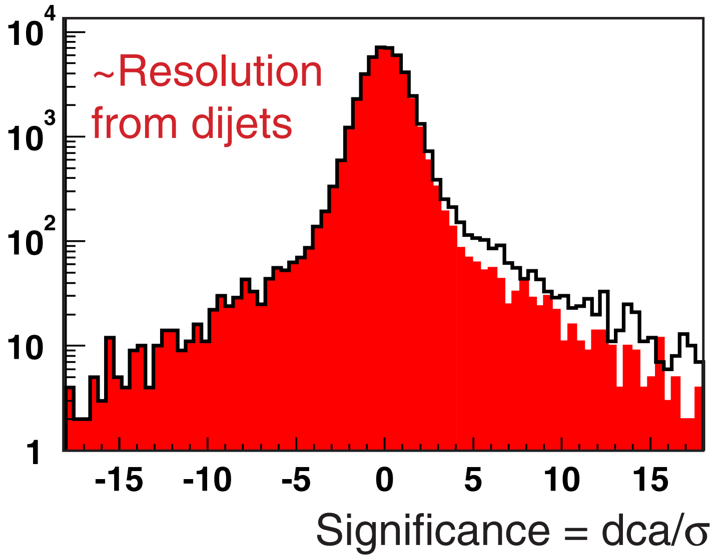
b–tagging

- b–tagging very crucial for the analysis to reject contributions from light quark
- Efficiency and fake rate is determined by the impact parameter resolution

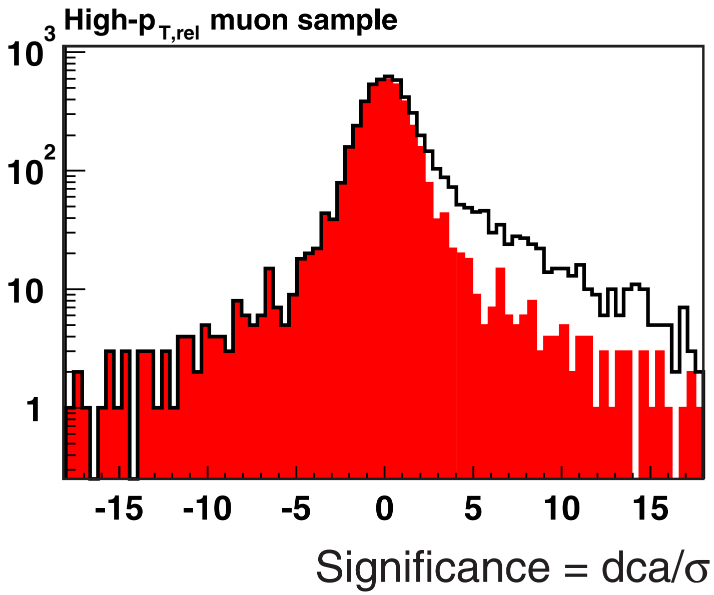




- b–tag efficiency is $\approx 60\%$
- c–quark mistag rate around 15%, at the few percent level for light quarks

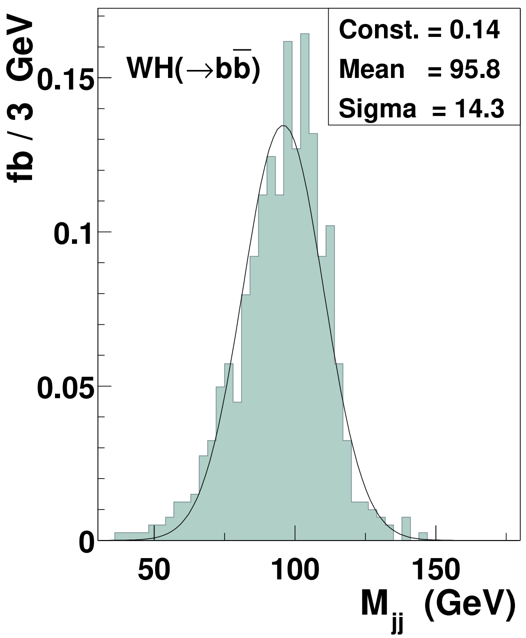


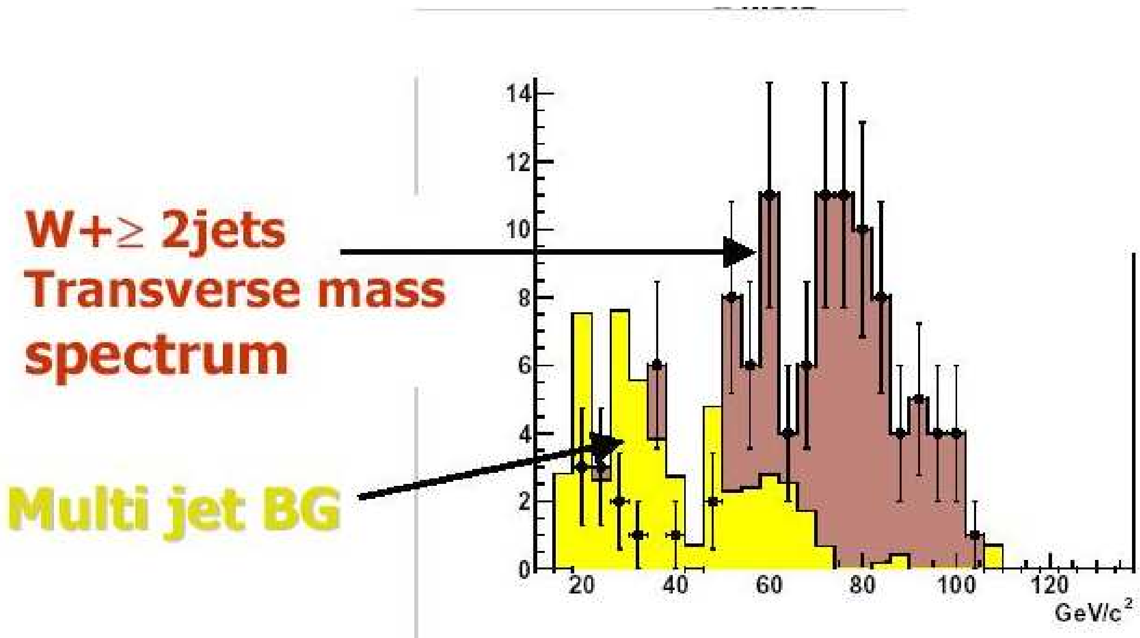
DØ Run 2 Preliminary



Associated production

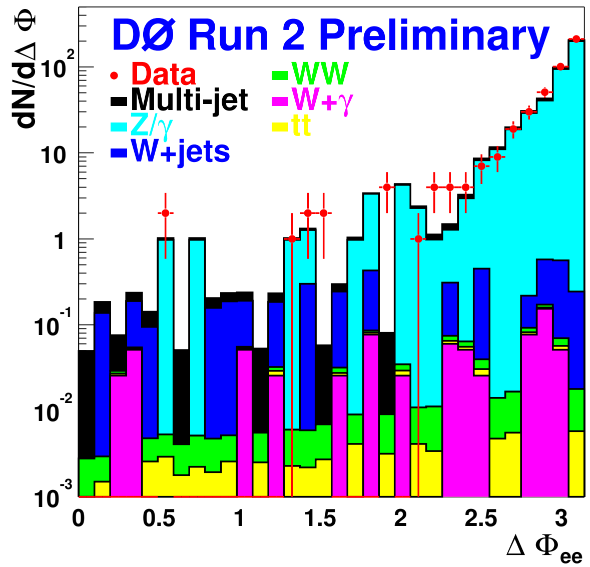
- Final state characterized by
  - One or two leptons from the decay of the vector boson
  - Two b–jets from the Higgs decay
  - Missing transverse energy
- Major backgrounds are W/Z+2jets events
  - Good understanding of invariant di–jet mass necessary
- To reconstruct the Higgs a good di–jet mass resolution is necessary

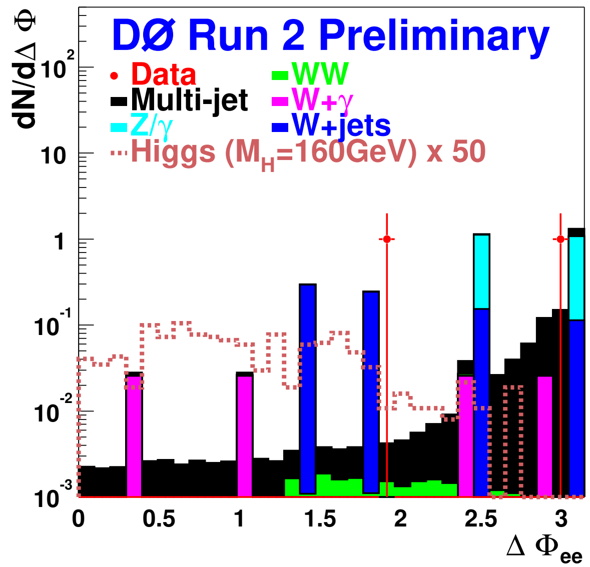




H→WW→$l\nu l\nu$

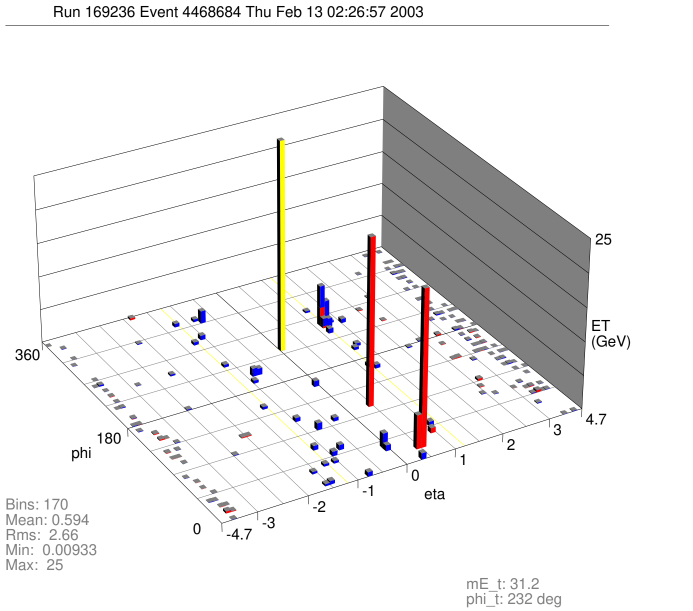
- Final state characterized by
  - Two leptons from the decay of the W bosons
  - large missing transverse energy
- Major backgrounds are WW, $t\bar{t}$, W+jets, QCD
  - Use spin correlations to suppress most part of the backgrounds
- Standard Model Higgs is still some steps away
- In the near future expect limits on exotic models with enhanced cross sections
  - 4^{th} generation model
  - Fermiophobic Higgs, topccolor model

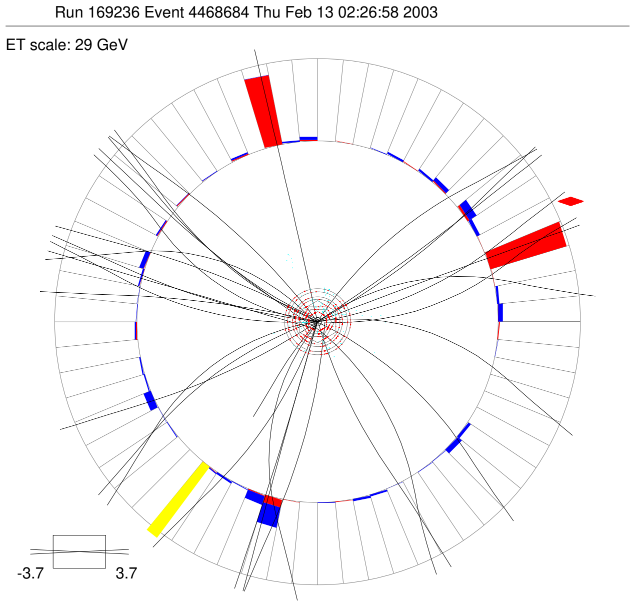


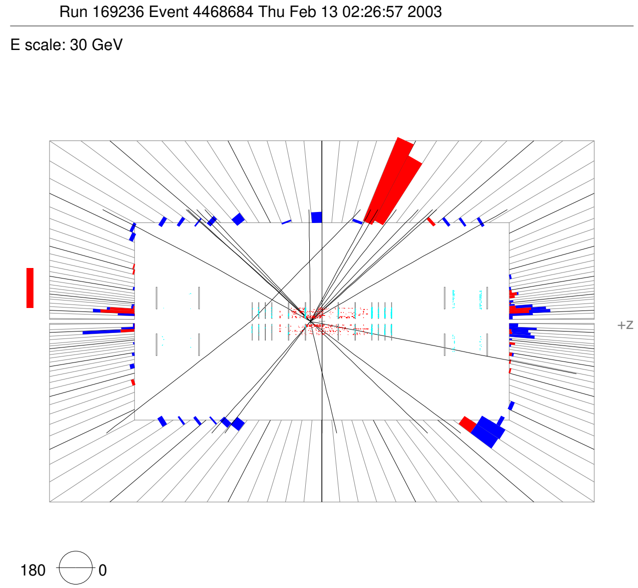


Event display

- One di-electron+$\not\!\!E_T$ event with small electron opening angle
  - $p_T = 31.1$ GeV
  - $p_T = 27.3$ GeV
  - $\not\!\!E_T = 31.2$ GeV
  - $m_T = 106.8$ GeV
  - $m_{ee} = 36.1$ GeV

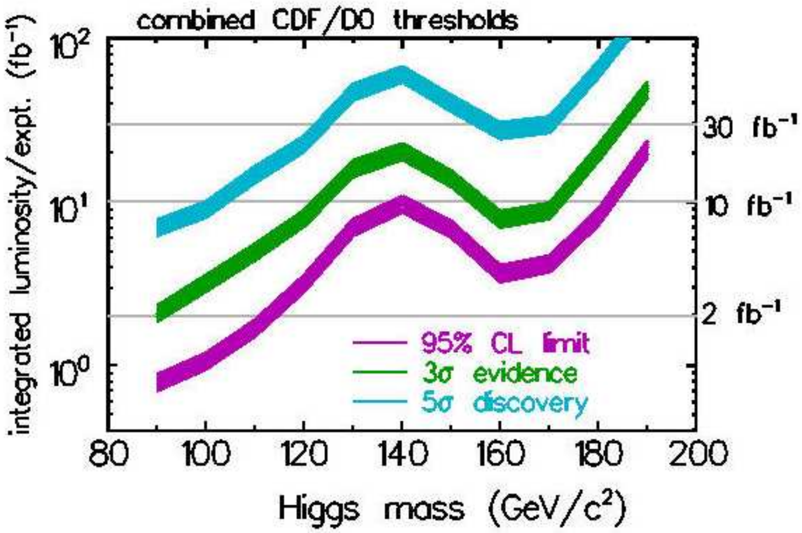






Result of Higgs studies

- Final result of the Tevatron Higgs Working Group report
  - Integrated luminosity required by each experiment to either exclude the Higgs at 95% CL or make a 3 or 5 σ discovery



- Main conclusion
  - No single channel guarantees the discovery of the Higgs
  - All different channels must be combined
  - For a heavy Higgs also both experiments CDF and DØ must be combined
  - 95% CL exclusion with an integrated luminosity of 10 fb^{-1} possible up to Higgs masses of 140 GeV

Summary and Outlook

- DØ has produced its first results in B physics
- Expect more interesting results with
  - the new L1 central track trigger online
  - increasing integrated luminosity
- With 2 fb^{-1} DØ will able to
  - measure B_s mixing in hadronic and semileptonic decay modes
  - measure $\sin(2\beta)$ with an accuracy of 0.05
  - measure lifetime of different B hadrons
  - measure rare decays, cross sections...
- In the next few years DØ can verify if there is a low mass Higgs
- In the near future expect significant impact on non–standard Higgs searches

Flavour tagging

- Tagging efficiency $\epsilon = N_{tag}/N_{tot}$
- Dilution $D = (N_R - N_W)/(N_R + N_W)$
- Tag quality is given by $\epsilon \cdot D^2$
- Expectations from DØ
  - Same side tag $\Rightarrow$ 2.0
  - Soft lepton tag $\Rightarrow$ 3.1
  - Jet Charge tag $\Rightarrow$ 4.7
  - Combination $\Rightarrow$ 9.8
- Use $B^{\pm} \rightarrow J/\Psi K^{\pm}$ events to calibrate flavour tagging algorithm

B_s mixing

- Weak eigentstates $\neq$ mass eigenstates
- $\Delta m_s = m(B^0{}_{heavy} - B^0{}_{light}) \sim |V_{tb} \cdot V_{ts}|^2$
- $P_{mix}(t) = \frac{1}{2}(1 - \cos(\Delta m_s t))$
- Mixing parameters
  - $x_s = \Delta m_s / \Gamma_s$
  - $\Delta\Gamma_s$
- Standard model predictions from global fit
  - $20 < x_s < 30.8$