Study of Heavy Mesons Rare Decays and B_c Mass and Lifetime at DØ

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on behalf of the DØ collaboration

Outline: DØ and the Tevatron

rare decays with FCNC:

- $B^0 \rightarrow \mu^+ \mu^-$
- $D^+ \rightarrow \mu^+ \mu^- \pi^+$

B_c properties:

- lifetime
- mass

conclusion

experimental environment

Run II (since 2001):

$\sqrt{s}$ = 1.96 TeV

lumi $\leq 3 \cdot 10^{32}$ cm^{-2}s^{-1}

>4.5 fb^{-1} recorded by DØ

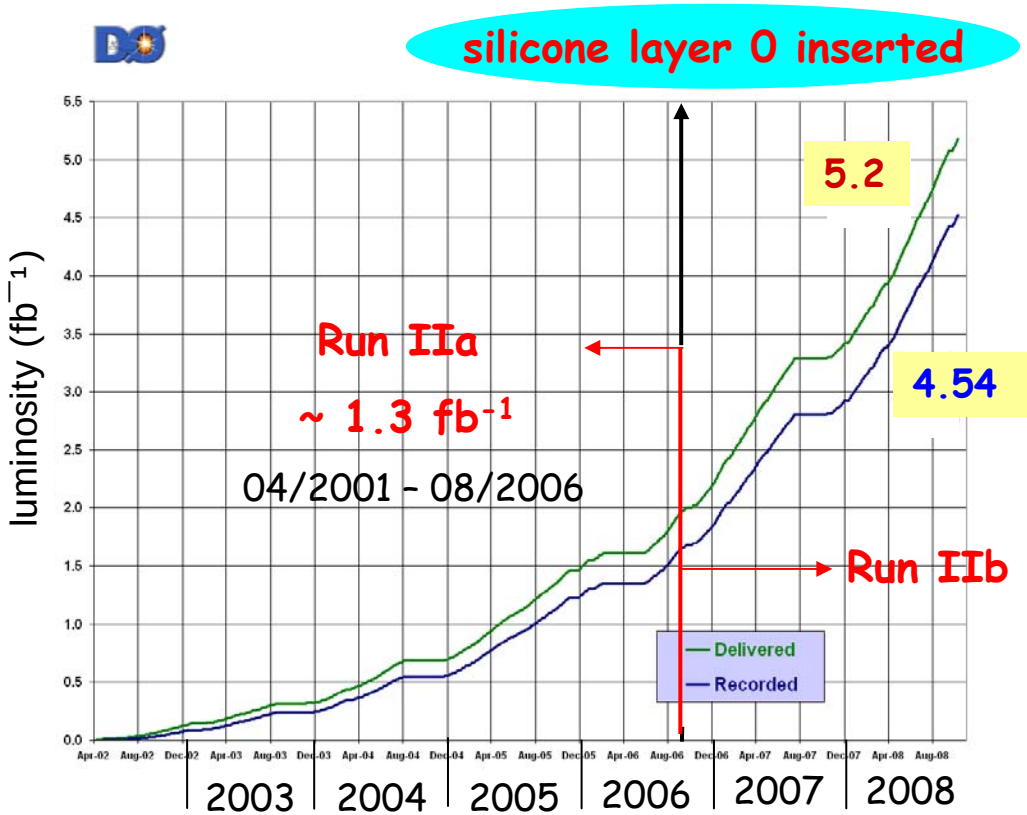
up to 2 fb^{-1} analysed here

Tevatron offers:

- unique opportunity to study B_s^0 and B_c mesons
- large $b\bar{b}$ and $c\bar{c}$ production rates
- high luminosity

But also:

- high track multiplicity environment ☞



good muon identification with **wide acceptance** in DØ → highly selective triggers

FCNC B and D decays

• FCNC processes have very low rate in S.M., whereas many Beyond S.M. theories predict enhancements

→ **sensitivity to new physics**.

• Some scenarios predict deviation from S.M. only in the up quark sector

→ motivate the study of **FCNC charm decays**.

• Run II results by DØ on rare B and D mesons decays **with two μ** in the final state:

- $B_s^0 \to \mu^+ \mu^- \phi$ not presented in this talk cf. PR D74, 031107 (2006)
- $B_s^0 \to \mu^+ \mu^-$

S.M. theory: $\mathcal{B}(B_s^0 \to \mu^+\mu^-) = (3.42 \pm 0.54) \cdot 10^{-9}$ A.J. Buras, PL B566, 115 (2003)

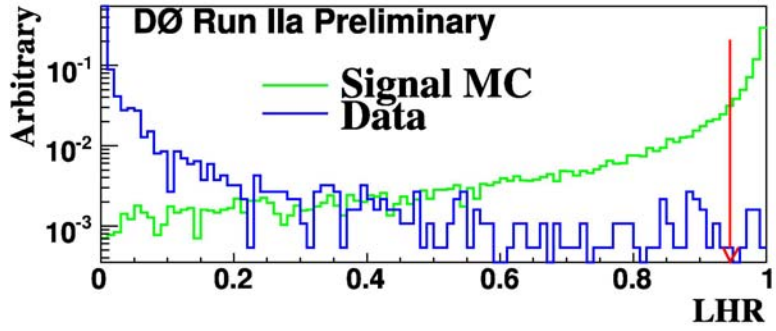
- $D^+ \to \mu^+ \mu^- \pi^+$ (short distance contribution)

S.M. theory: $\mathcal{B}(D^+ \to \mu^+\mu^-\pi^+) = 9.4 \cdot 10^{-9}$ S. Fajfer *et. al*, PR D64, 114009 (2001)

$B_s^0 \rightarrow \mu^+ \mu^-$ observed events

• sequential criteria + likelihood discriminant which combines 6 variables (i):

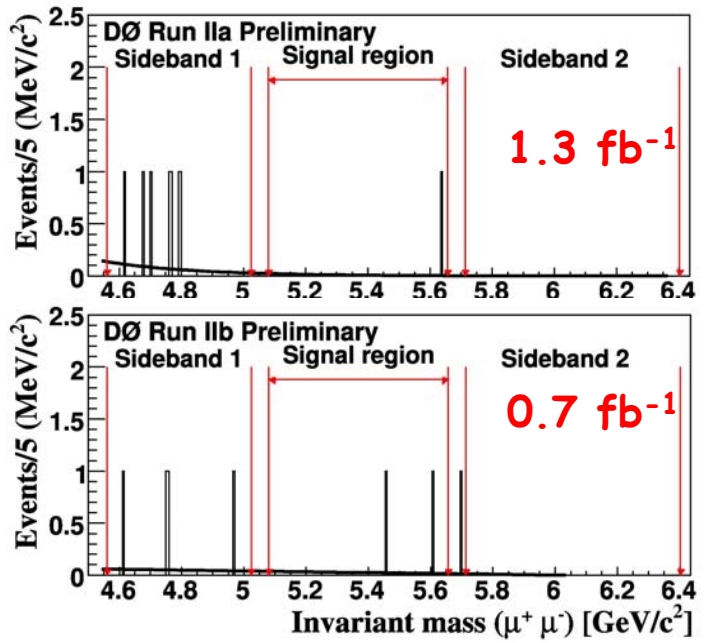
$$LHR = \frac{\Pi\, S_i(x)}{\Pi\, S_i(x) + \Pi\, B_i(x)}$$



• optimized cut on LHR.

• **blinded** signal box

• expected background from extrapolation of **sidebands data**



Run IIa
- 0.8 ± 0.2 expected background
- 1 observed event

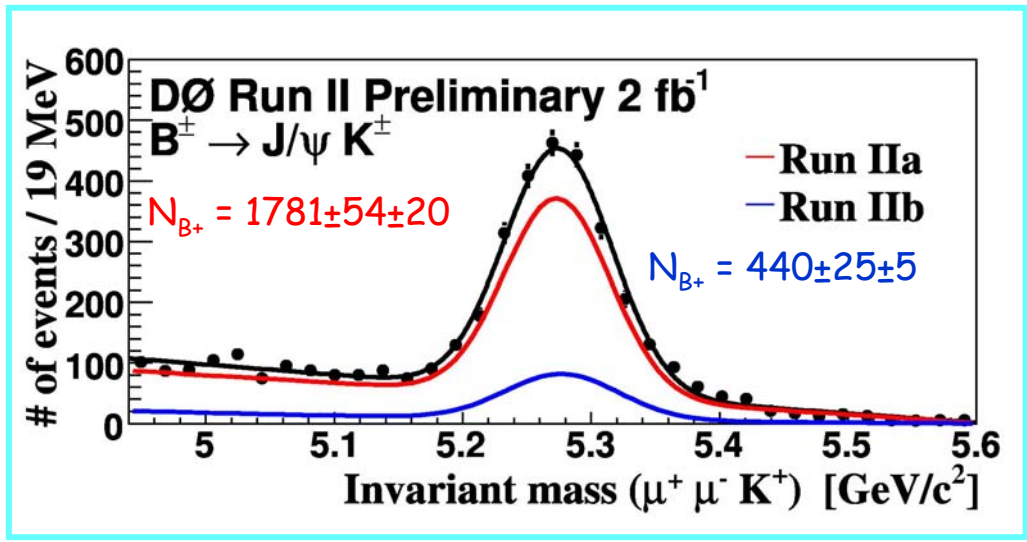
Run IIb
- 1.5 ± 0.3 expected background
- 2 observed events

$\mathcal{B}(B_s^0 \to \mu^+ \mu^-)$ limit

- selected events **compatible with background only** → limit extraction
- $\mathcal{B}(B_d \to \mu^+\mu^-)$ conservatively neglected (suppression factor $|V_{td}/V_{ts}|^2$ w.r.t. B_s^0)
- **normalization to $B^\pm \to J/\psi\, K^\pm$**

same kind of selection (some syst. cancellation) + high stat.:

$$\mathcal{B}(B_s^0 \to \mu\mu) \sim \frac{N(B^0 \to \mu\mu)}{N(B^+ \to \mu\mu K)} \frac{\varepsilon_{\mu\mu K}}{\varepsilon_{\mu\mu}} \frac{b \to B^+}{b \to B_s^0} \times \mathcal{B}(B^+ \to J/\psi K^+) \times \mathcal{B}(J/\psi \to \mu\mu)$$



- Bayesian limit:

$$\mathcal{B}(B_s \to \mu^+\mu^-) < 7.5 \cdot 10^{-8} \quad @\ 90\ \%\ C.L.$$

$D^+ \to \mu^+ \mu^- \pi^+$

Step 1: Search for $D^+_{(s)} \to \phi \pi^+ \to \pi^+\mu^+\mu^-$

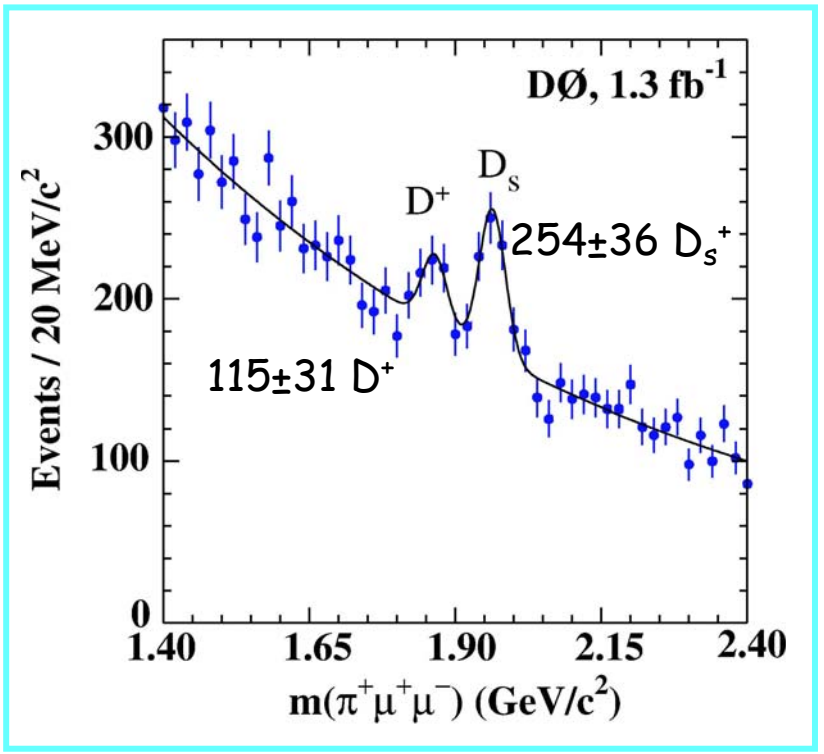
- First observation of $D_s^+ \to \phi\pi^+$ with $\phi \to \mu^+\mu^-$
- First evidence of $D^+ \to \phi\pi^+$ with $\phi \to \mu^+\mu^-$ (4.1σ)

$$\frac{n(D^+)}{n(D_s^+)} = \frac{f^+_{c\to D}\ f^s_p\ \varepsilon^+\ \mathcal{B}(D^+\to\phi\pi^+ \to \mu^+\mu^-\pi^+)}{f^s_{c\to D}\ f^+_p\ \varepsilon^s\ \mathcal{B}(D_s^+\to\phi\pi^+)\times\mathcal{B}(\phi\to \mu^+\mu^-)}$$

reconstruction efficiency for prompt and B→D:

$\varepsilon^+ = f^+_p\ \varepsilon^+_{prompt} + (1-f^+_p)\varepsilon^+_{B\to D}$

because no short distance contribution



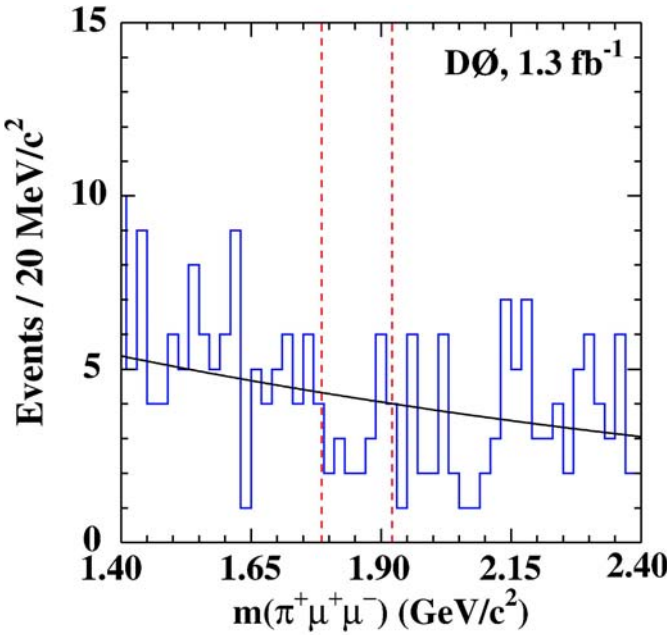
⇨ $\mathcal{B}(D^+\to \phi\pi^+ \to \mu^+\mu^-\pi^+) = (1.8 \pm 0.5\ (stat.)\ 0.6 \pm (syst.))\cdot 10^{-6}$

in good agreement with other measurements (CLEO, BaBar) and with $\mathcal{B}(D^+\to\phi\pi^+)\times\mathcal{B}(\phi\to \mu^+\mu^-)$

$D^+ \to \mu^+ \mu^- \pi^+$

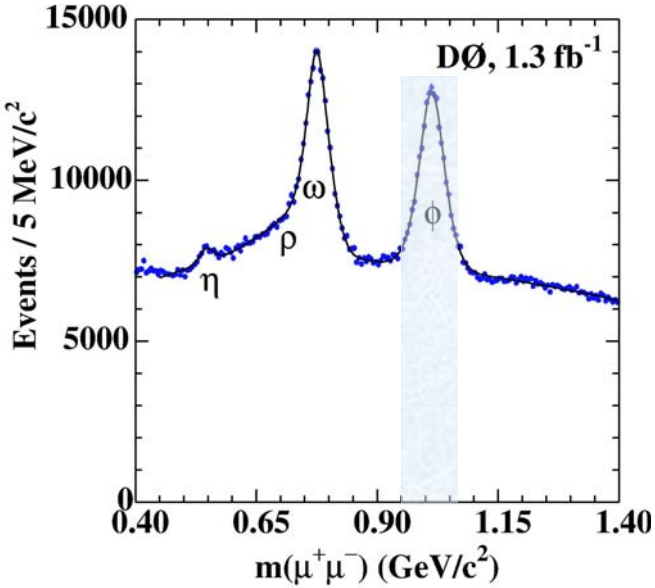
- **Step 2**: **Search for continuum production $D^+ \to \pi^+\mu^+\mu^-$**

by looking for an excess of D^+ candidates with $M(\mu^+\mu^-) \neq M\phi$ and re-optimized cuts



19 observed events

25.8 ± 4.6 expected background (sidebands extrapolation)



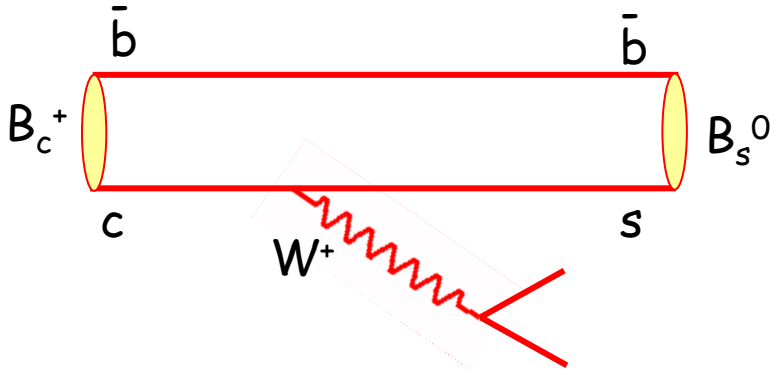
- Result normalized to $D^+ \to \phi\pi^+$ (to avoid uncertainties on D^+ production rates w.r.t. D_s^+)
- **Observed events compatible with bkg only**
- Bayesian limit extracted:

$\mathcal{B}(D^+ \to \mu^+\mu^-\pi^+) < 3.9 \cdot 10^{-6}$ 90% C.L.

B_c^+ properties

- observation at LEP and Tevatron Run I.
- two heavy quarks, that can each decay via W:

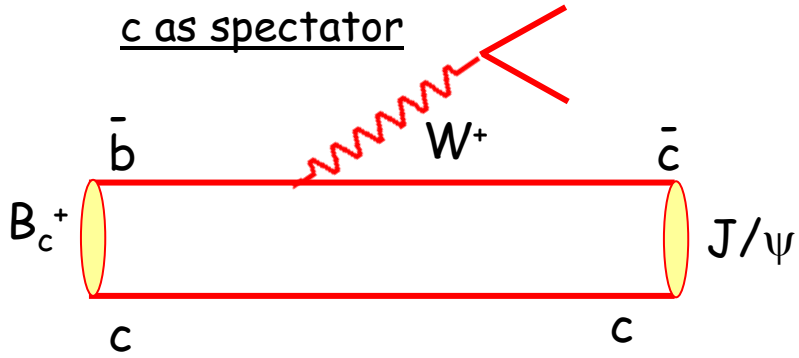
b as spectator



$B_c^+ \rightarrow B_s^0\ \pi^+$ or $B_s^0\ \mu^+\ \nu$

(unseen)

c as spectator



$B_c^+ \rightarrow J/\psi\ \pi^+$ or $J/\psi\ \mu^+\ \nu$

mass measurement
(no missing particles)

lifetime measurement
(high stat.)

⇨ predicted lifetime ~ 1/3 of other B-mesons (the shortest).

theory predictions: 0.47 ps → 0.59 ps

⇨ interesting QCD laboratory

B_c^+ lifetime

$B_c^+ \rightarrow J/\psi\ \mu^+\ \nu \rightarrow \mu^+\mu^-\mu^+\nu$

- Missing $\nu \rightarrow$ lifetime not measured but rather Visible Proper Decay Length:

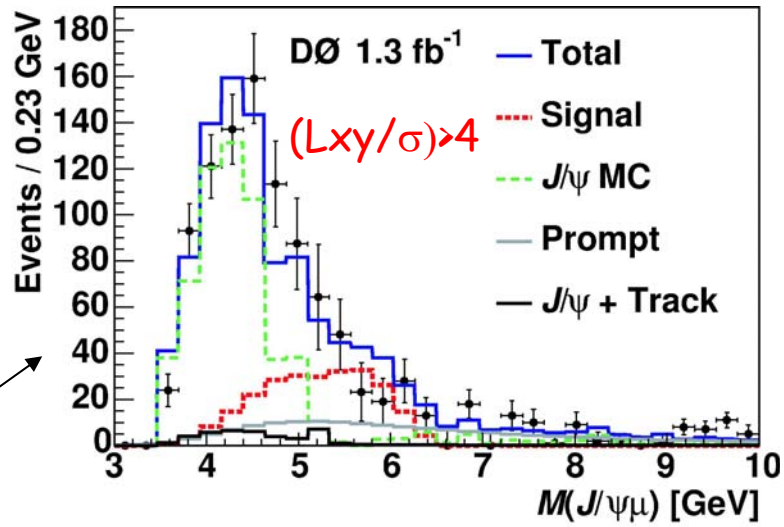
$$\text{VPDL} = \frac{c\tau}{K} \quad \text{with } L_{xy} = c\tau \frac{1}{M_{B_c^+}} \frac{p_T(J/\psi\ \mu)}{K}$$

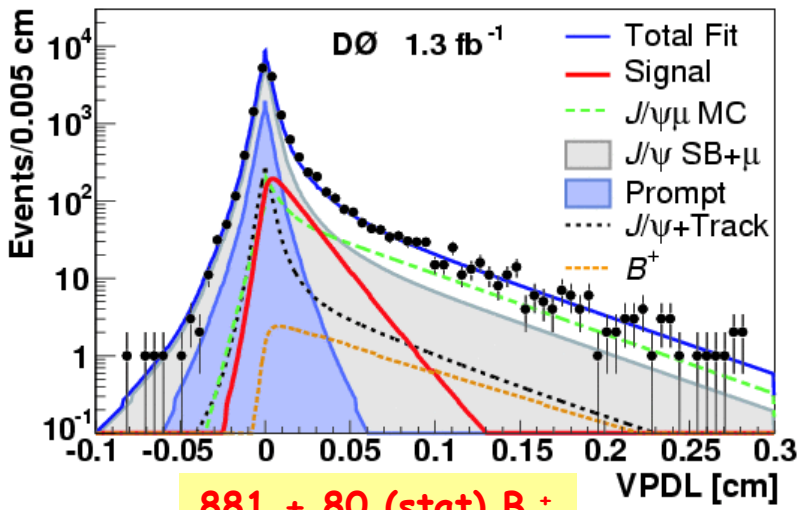
correction factor

- Background dominated. Signal established from **M(Jψ/μ) fit** after L_{xy} requirement and sample composition obtained .
- MC and data samples of signal and background used to model mass and decay length templates.
- Lifetime extracted from a **simultaneous mass+decay length likelihood fit**.

$$\tau(B_c^{\pm}) = 0.448\ ^{+0.038}_{-0.036}\ \text{(stat.)}$$

$$\pm\ 0.032\ \text{(syst.)}\ \text{ps}$$





881 ± 80 (stat) B_c^+

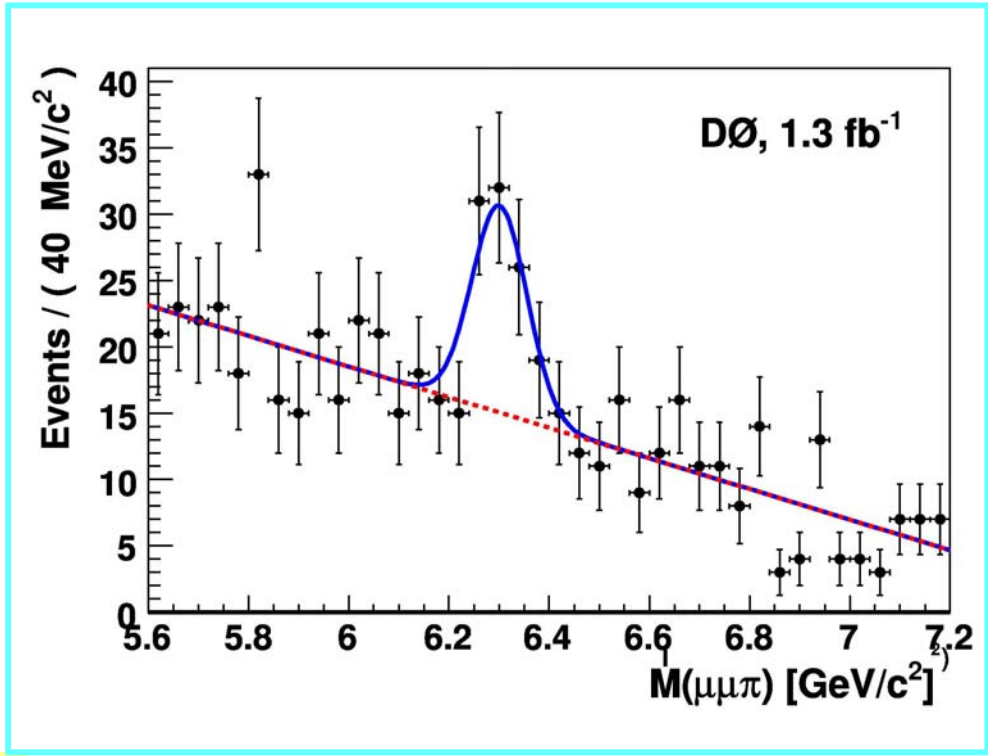
B_c^+ mass

$B_c^+ \rightarrow J/\psi\ \pi^+ \rightarrow \mu^+\ \mu^-\ \pi^+$

- Selection criteria:
1) controlled with $B^+ \rightarrow J/\psi\ K^+$ in data
2) further optimized with simulated B_c^+

- Result of an unbinned maximum likelihood fit:

54 ± 12 fully reconstructed B_c^+
(significance 5.2σ)



$M(B_c^{\pm}) = 6300 \pm 14$ (stat.)
± 5 (syst.) MeV/c^2

PRL 101:012001 (2008)

- Various theoretical predictions, the most recent one: $M(B_c^{\pm}) = 6304 \pm 12\ ^{+18}_{-0}$ MeV/c^2
I.F. Allison *et al.*, PRL 94:172001 (2005)

- This sample (+ increased stat.) may be now used to study branching ratios.

Conclusion

• Rare B and D decays studies:

- complement direct searches for new phenomena.

- DØ observe no evidence for new physics and set limits that are among the most stringent to date.

Any signal at Tevatron before the end of the Run II would be an evidence of new physics.

• Very good performance from the Tevatron:

- up to 2 fb^{-1} analysed in the measurements shown here.

- more than **4.5 fb^{-1} already stored**.

Some analyses still limited by stat, and statistics also allows systematics improvements.

⇨ **further significant reduction of theoretical parameter space can be expected as more date are included.**