Rare B_s and D Decays With the DØ Detector

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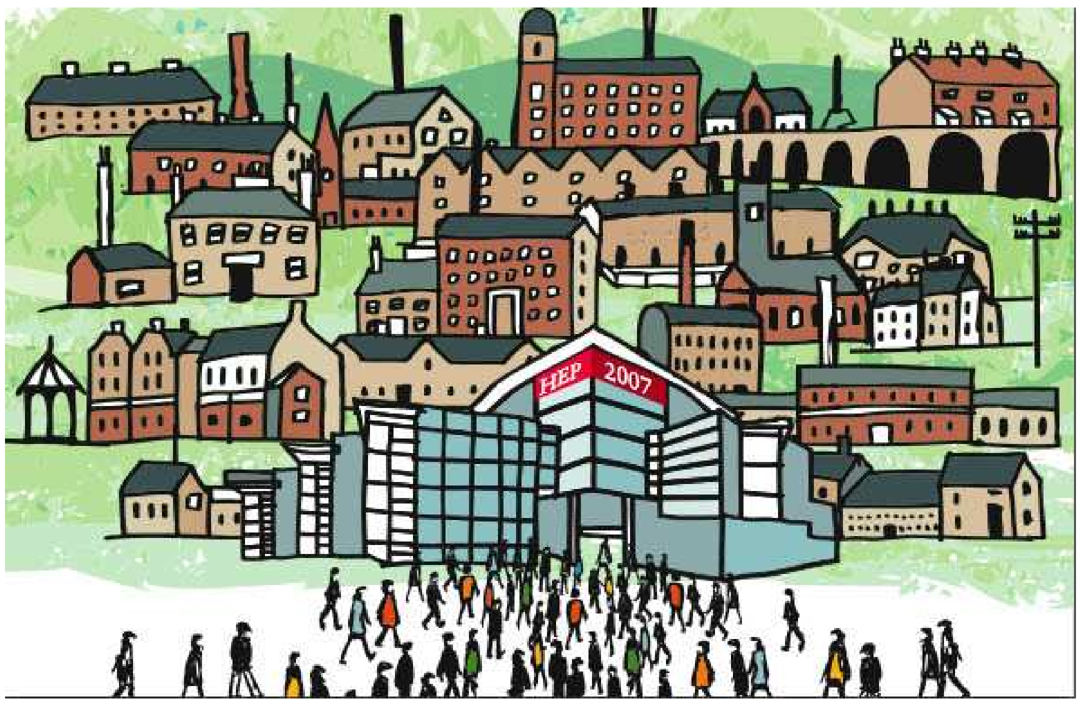
— For the DØ Collaboration —



Outline

- Two FCNC decay searches with the DØ detector are reported *(EPS'07 abstract n.390)*

  * $B_s \longrightarrow \mu^+\mu^-$ $\qquad b \rightarrow s$ (FCNC in the d-sector)

  * $D^\pm \rightarrow \pi^\pm\mu^+\mu^-$ $\qquad c \rightarrow u$ (FCNC in the u-sector)

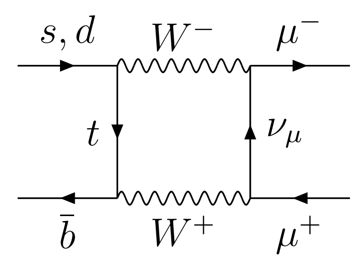
- Looking for sizeable *BR* enhancements, above SM expectations, due to new physics (*).

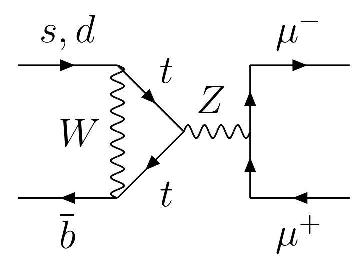
- In both cases, currently the most stringent limits.

(*) reminder: (FCNC)

  – Forbidden at tree level in the SM, must proceed via higher order WIs $\Longrightarrow$

  – New physics potentially competitive with SM

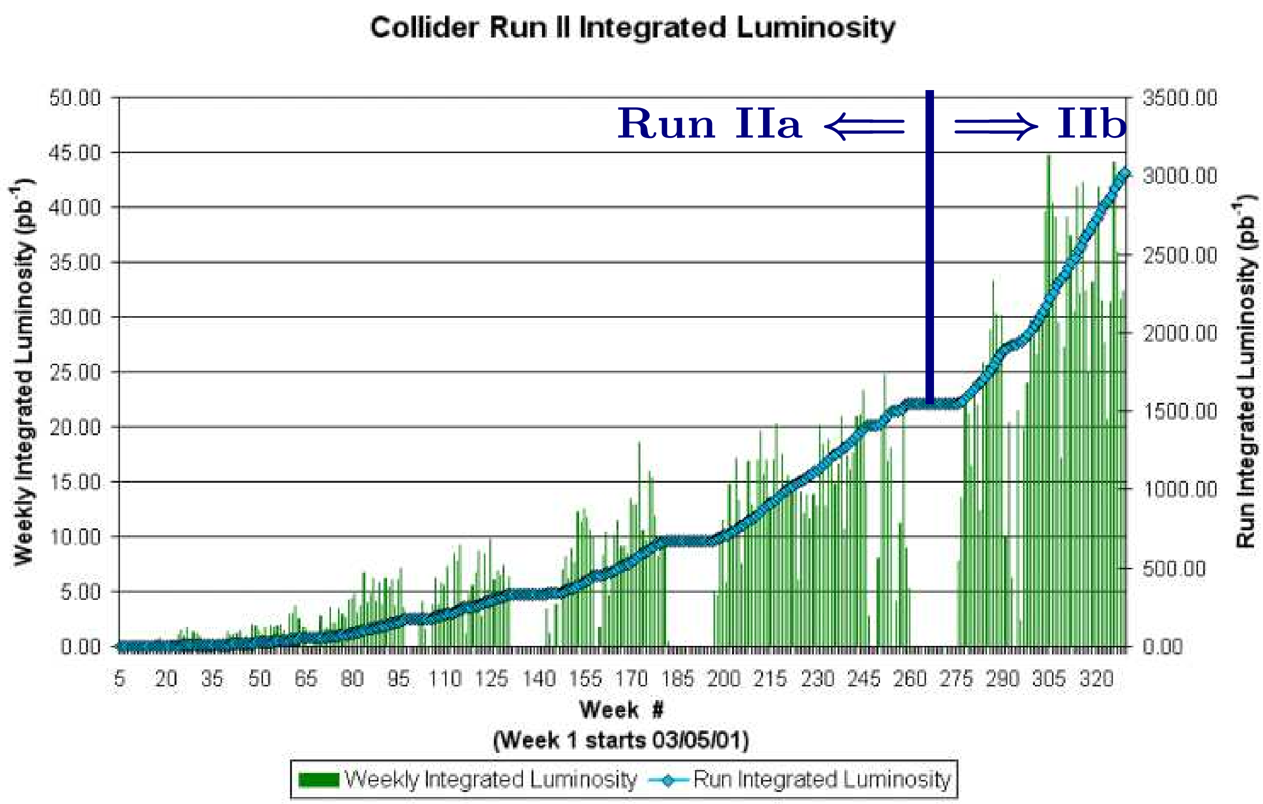




$+\cdots$

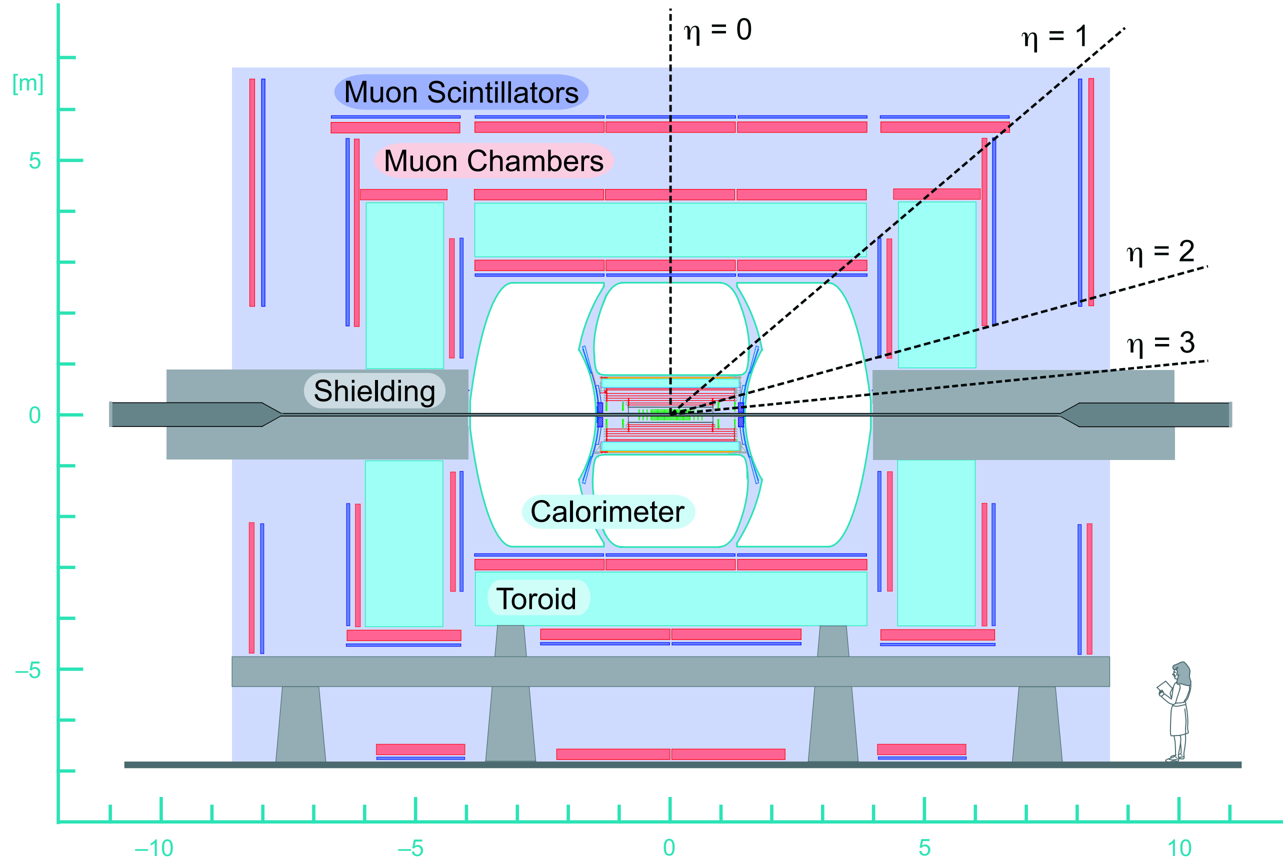
Tevatron RunII

Int.Lum	fb^{-1}
Delivered	3
DØ recorded	2.6
DØ analyses	2



TeV now delivering
$\sim 40 pb^{-1}$/week

The DØ Detector – TeV RunII



Central magnetic tracking volume is a RunII addition:

Si(4 double layers)

Sci-Fi(8 double layers)

SCond Solenoid (2T)

Compact ($R \approx 80cm$)

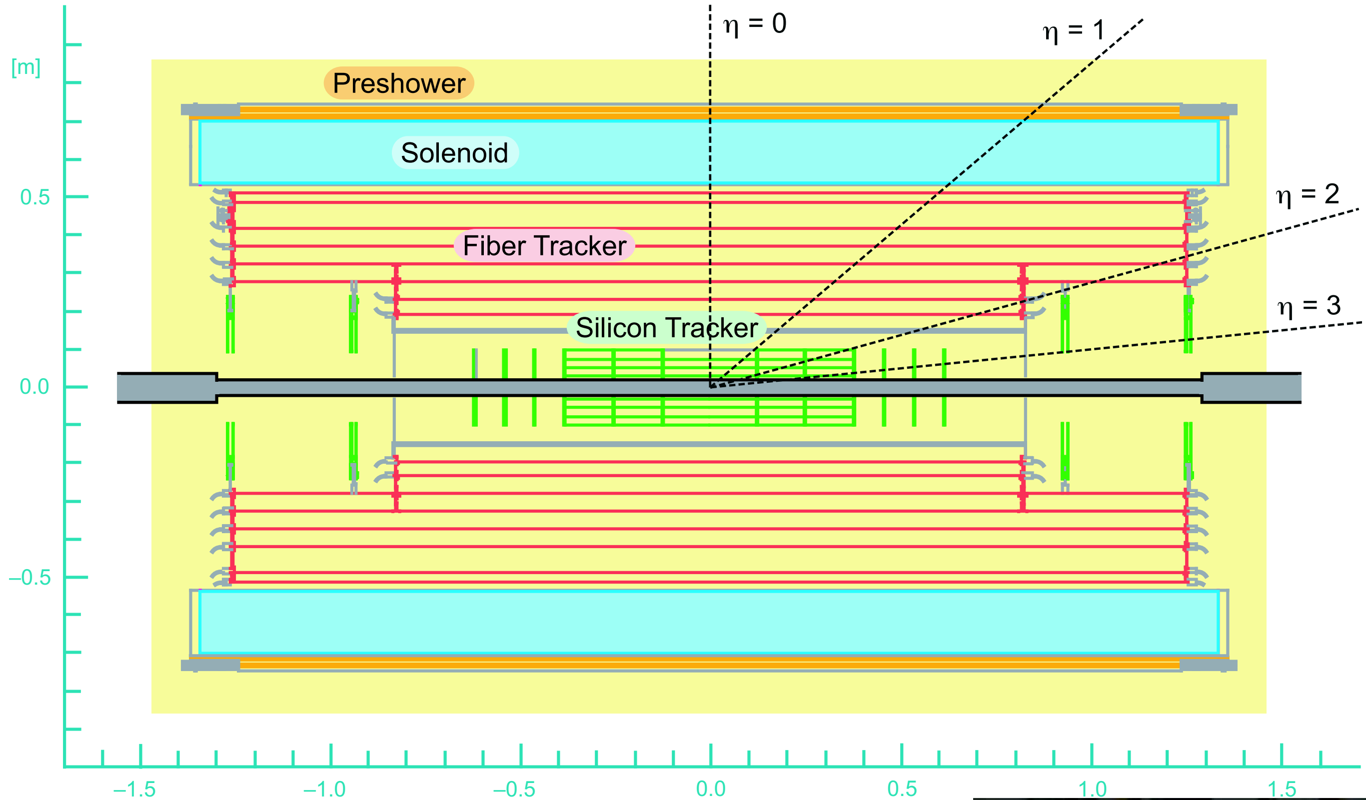
Special B-strengths:

- Muon-ID, muon triggers
- single-μ 70% pure at L1

Wide angle coverage:

- Muon chambers; $|\eta| < 2.0$
- Tracking volume; $|\eta| < 3.0$

The DØ Tracking Volume



RunIIb addition:

Silicon "Layer Ø"

carbon fiber support

$(r \approx 1.7cm)$

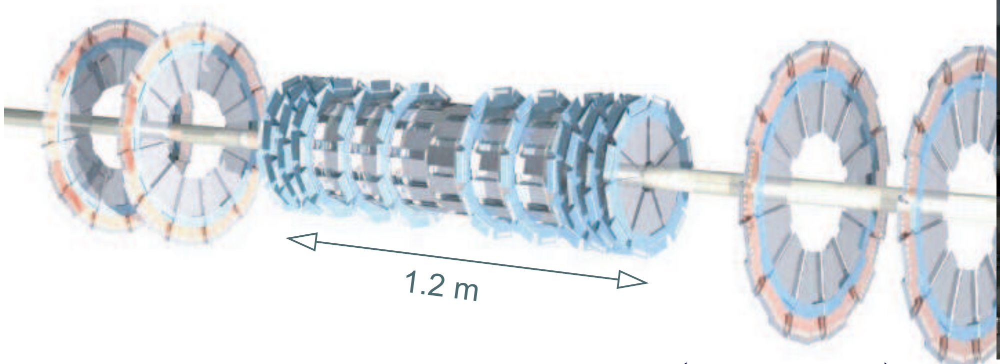
48 sensors (6ϕ- and

$8z$- segments)

$\sim$40-50% drop in track

DCA uncertainty

$\Downarrow$



Purely Leptonic B^0 Decays

S.M. predictions

source	decay	BR	
A.Buras, PLB 566, 115(2003)	$B_s \rightarrow \mu^+\mu^-$	$(3.42 \pm 0.54) \times 10^{-9}$	
	$B_d \rightarrow \mu^+\mu^-$	$(1.00 \pm 0.14) \times 10^{-10}$	(*)

errors dominated by non-perturbative hadronic uncertainties

(*) suppressed by an additional factor $|V_{ts}/V_{td}|^2 \sim 0.04$

Any signal within current experimental sensitivity indicates new physics...

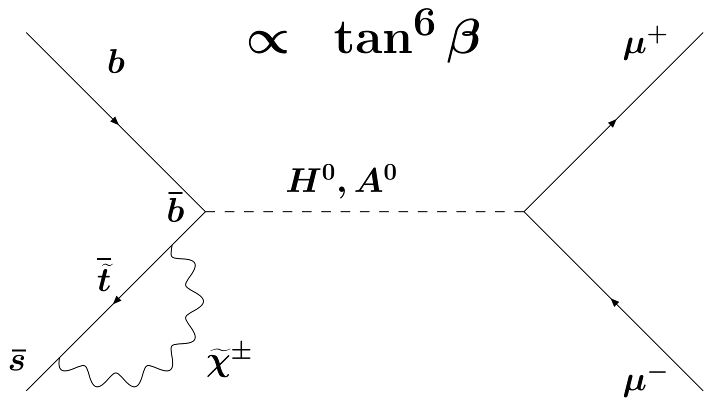
$B_s \rightarrow \mu^+\mu^-$ history with DØ

when	where	Int.Lum.	$BR <$(95% CL)
Fall 2004	PRL 94, 071802 (2005)	$240pb^{-1}$	5.0×10^{-7}
March 2005	4733-CONF	$300pb^{-1}$	3.7×10^{-7}
March 2006	5009-CONF	$700pb^{-1}$	2.3×10^{-7}
March 2007	5344-CONF	$2000pb^{-1}$	**this talk**

Beyond The Standard Model

(see e.g. *J.Ellis, K.A.Olive, V.C.Spanos;* hep-ph/0504196)

(Ex.I) Multiple Higgs Bosons (some low mass)

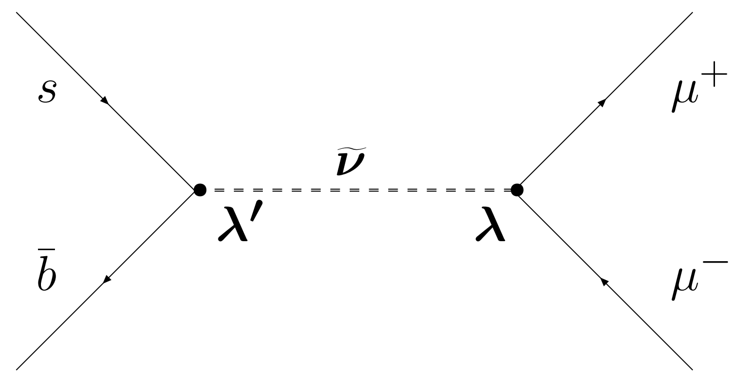


SUSY/MSSM

- neutral Higgs bosons
- and high $\tan\beta$

BR enhancements possible by up to 3 orders of mag.

(Ex.II) Non-standard Particles with Large Couplings to SM



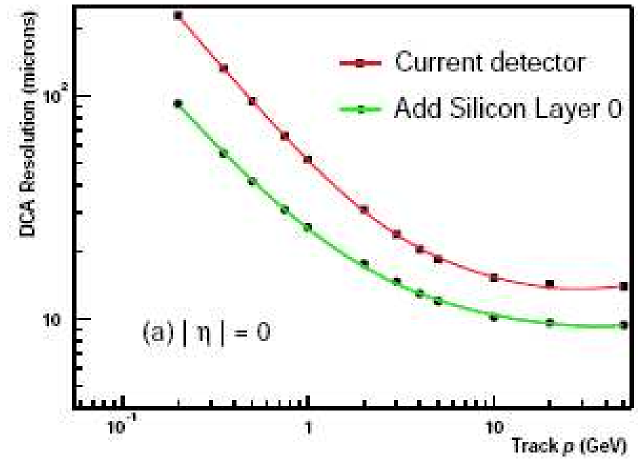
SUSY/RPV

- at tree level,
- irrespective of $\tan\beta$
- but depending on coupling consts

$\Longrightarrow$ ***improvements in BR upper limits will constrain parameter space of such models***

$B_s \longrightarrow \mu^+\mu^-$

($2fb^{-1}$ update)



- DØ's 1st result using "RunIIb" (June'06) data
  - tracking aided by extra silicon "Layer Ø"

- Runs IIa and IIb treated as two different and independent analyses
  $\Longrightarrow$ COMBINED

- Data collection uses a set of dimuon triggers

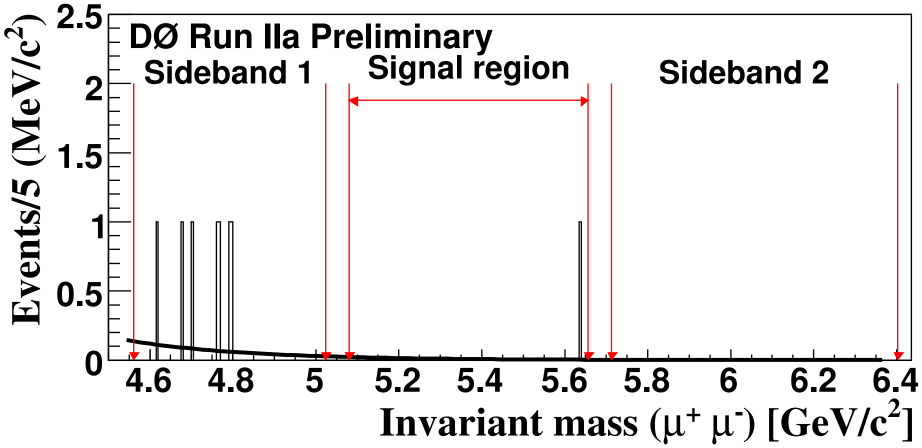
DØ Conf. Note 5344

- A two-step discrimination against other dimuon sources
  - (1) a pre-selection based on track quality, dimuon kinematics and isolation, pointing angle and impact parameters, dimuon vertex χ^2 and decay length significance
  - (2) further background reduction by using a discriminator LHR

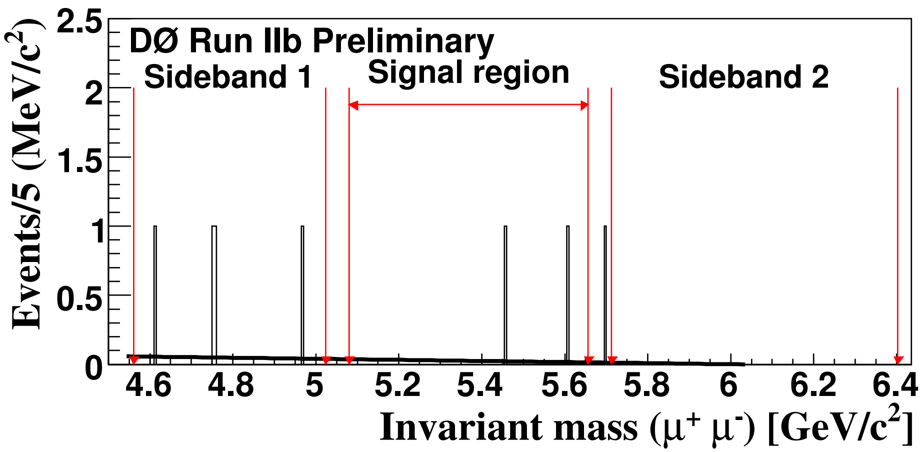
- The signal region is kept blinded throughout the selection process

Resulting Mass Distributions

- Run IIa
  - observe one event
  - expected backgnds
    - 0.8 ± 0.2 events (exponential interpolation)

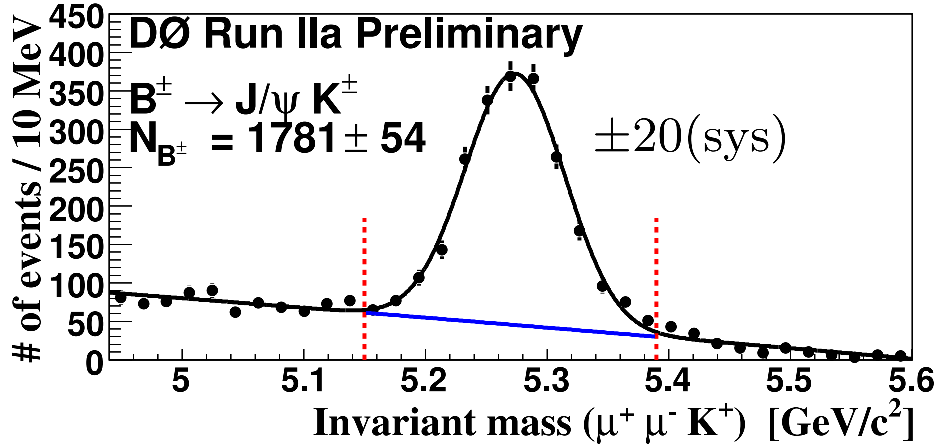


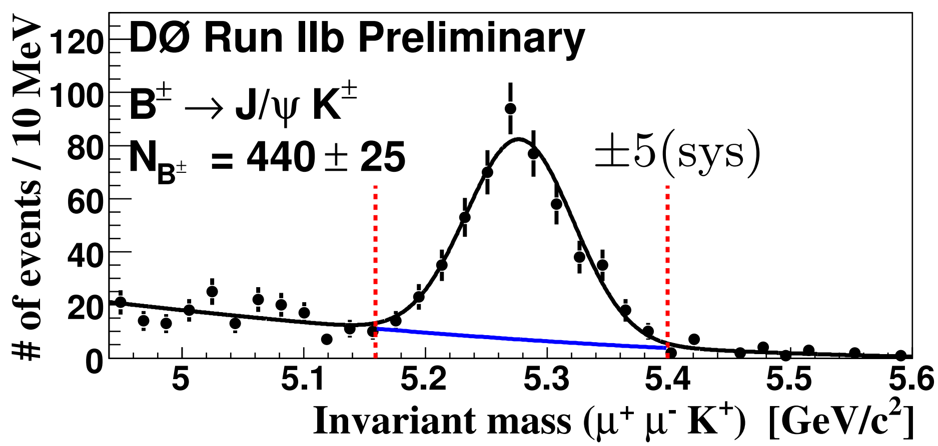
- Run IIb
  - observe two events
  - expected backgnds
    - 1.5 ± 0.5 events (combined linear and exponential interpolations)



Normalization Channel

- BR upper limit obtained w.r.to channel $B^{\pm} \to J/\psi\ K^{\pm}$
- same dimuon selection is applied to $J/\psi \to \mu^+\mu^-$
- efficiencies and uncertainties largely cancel
- additional K selection efficiencies determined from MC and data cross checks/corrections





BR Limit Calculation

$$\mathcal{B}(B_s \to \mu^+\mu^-) = \frac{N^{upper}_{limit}}{N_{B^\pm}} \times \left[\frac{\epsilon^K_{\mu^+\mu^-}}{\epsilon^{B_s}_{\mu^+\mu^-}}\right]_{MC} \times \left[\frac{b \to B^\pm}{b \to B_s}\right]_{PDG} \times \left[\begin{array}{c} \mathcal{B}(B^\pm \to J/\psi\; K^\pm) \\ \times \\ \mathcal{B}(J/\psi \to \mu^+\mu^-) \end{array}\right]_{PDG}$$

conservatively assumes no contribution from $B_d \to \mu^+\mu^-$ in search window

- Limits obtained in a (flat prior) Bayesian approach (see T.Hebbeker, L3 note 2633, Feb.2001)
- Assuming data counts follow Poisson probabilities
- All uncertainties on input fragmentation, BR's and observed $N(B^\pm)$ are propagated into an overall detection efficiency assumed gaussian.
- Uncertainties in $\mathcal{B}$ are dominated by background expectation estimates and the $b \to u/s$ fragmentation ratio (15%)

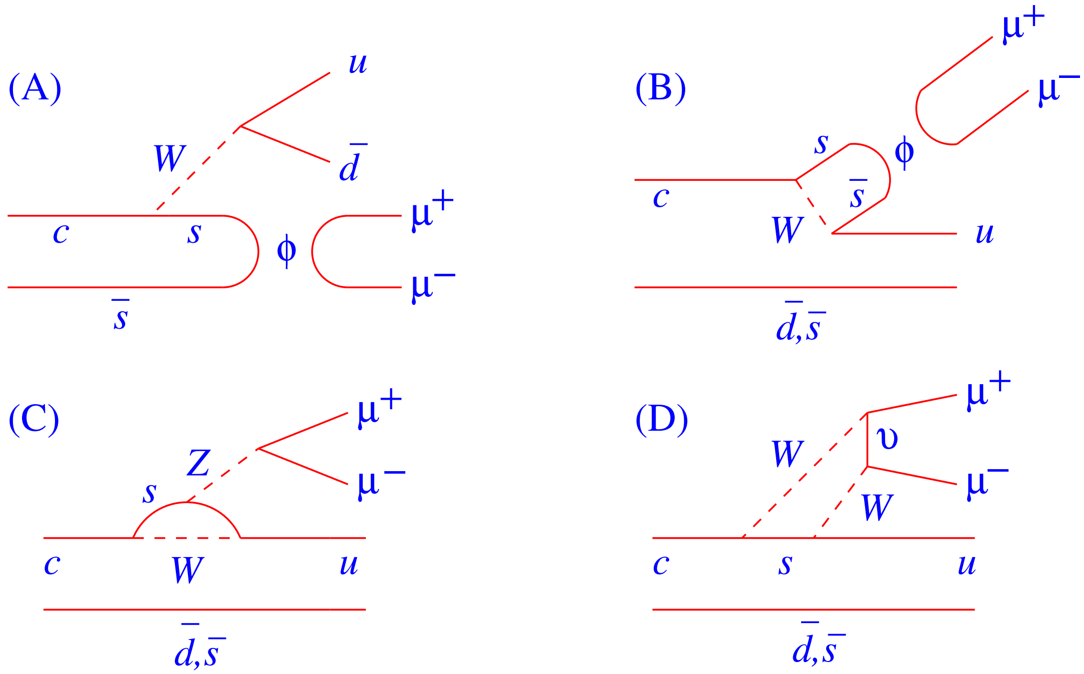
Results

Data sample	$\mathcal{B}(B_s \to \mu^+\mu^-) <$	
∼Int.Lum.(fb^{-1})	90% CL	95% CL
RunIIa (1.3)	7.9×10^{-8}	9.5×10^{-8}
RunIIb (0.6)	3.1×10^{-7}	4.0×10^{-7}
Combined (2)	7.5×10^{-8}	9.3×10^{-8}

- Note: early RunIIb had problems with newly installed tracking front end hardware (firmware, timing, threshold tuning)
  - some recoverable, some not (2 months)
  - these problems now understood and fixed
- Higher IIb efficiencies and lower uncertainties are to be recovered with the recent completion of the data reprocessing

FCNC Charm Decays

resonant,
Cabbibo
favored



resonant,
Cabbibo
suppressed

$[c \rightarrow u]$
penguin

$[c \rightarrow u]$
box

- **Example diagrams for $D^+_{(s)} \rightarrow \pi^+\mu^+\mu^-$ and/or $D^+_s \rightarrow K^+\mu^+\mu^-$**
- **Non-resonant penguin and box diagrams proceed via $\sum d, s, b$ internal loops and lead to strong GIM suppression**
- **DØ: search for $D^+ \rightarrow \pi^+\mu^+\mu^-$ in the continuum region of the dimuon invariant mass**

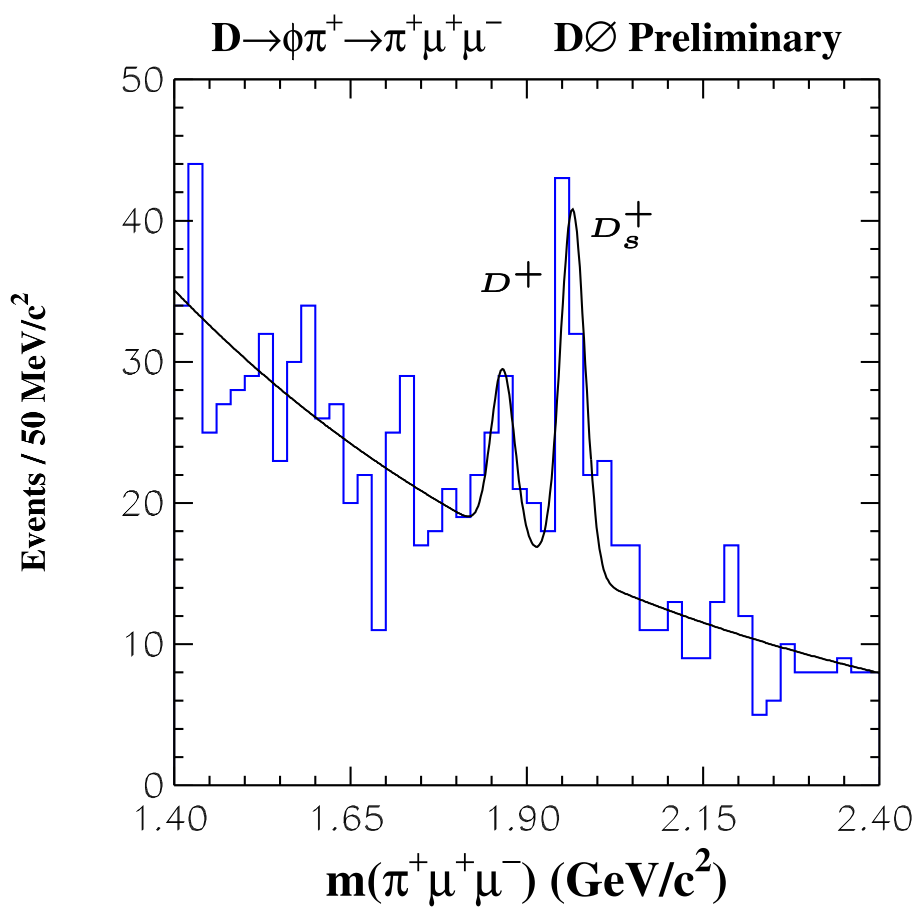
FCNC D-Decays

- General strategy:
  - **Step-1;** benchmark the resonant regions in $\mu^+\mu^-\pi$ spectrum. In particular, $D_s^+ \to \pi^+\mu^+\mu^-$ can only proceed via resonant mode $\Rightarrow \mathcal{BR}$ factorizes $(D_s \to \phi\pi) \times (\phi \to \mu\mu)$ $\Rightarrow$ used as normalization
  - **Step-2;** search for excess $D \to \pi\mu\mu$ in continuum regions of spectrum.

- Current status: $(\sim 1\ fb^{-1})$
  Observed (65±11) candidates
  * $D_s^\pm \to \phi\pi^\pm,\ \phi \to \mu^+\mu^- \quad \Rightarrow$

- Plus, evidence of the decay
  * $D^\pm \to \phi(\mu^+\mu^-)\ \pi^\pm \qquad (26 \pm 9)$
  * $3.1\ \sigma$ above background

    (from likelihood fits w/ and w/out the D^+)



FCNC D-Decays (cont.)

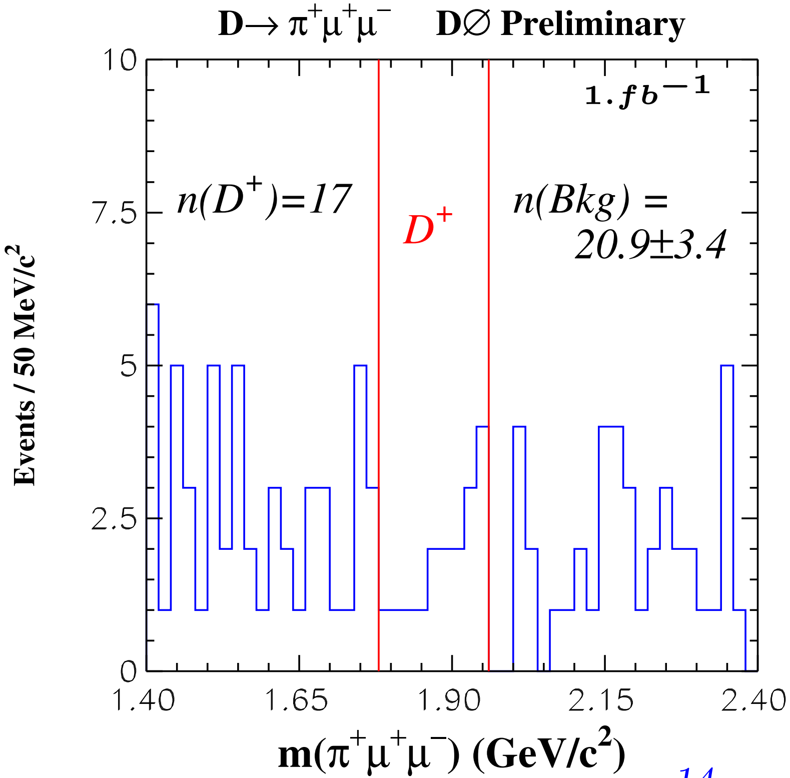
- **Step-1**

$\mathcal{B}(D^+ \to \phi\pi^+ \to \pi^+\mu^+\mu^-)$	$=$	$(1.8 \pm 0.7 \pm 0.5) \times 10^{-6}$

and can be compared with

$\mathcal{B}(D^+ \to \phi\pi^+) \times (\phi \to \mu^+\mu^-)$	$(1.86 \pm 0.26) \times 10^{-6}$
CLEO – PRL 95, 221802(2005)	$(2.7 \pm {}^{3.6}_{1.8} \pm 0.2) \times 10^{-6}$

- **Step-2** Search for continuum production of $D^+ \to \pi^+\mu^+\mu^-$
  - $m(\mu^+\mu^-) < 1.8\ GeV/c^2$ and $\pm 3\sigma$ excluded around $m(\phi)$
  - Selection reoptimized for 90% CL (Punzi: physics/0308063)
  - Expected backgrounds determined from sidebands



Results

- BR upper limit obtained w.r.to normalizing channel
  $D_s^+ \to \phi\pi^+ \to \pi^+\mu^+\mu^-$

$$\frac{\mathcal{B}(D^+ \to \pi^+\mu^+\mu^-)}{\mathcal{B}(D_s^+ \to \phi\pi^+) \times (\phi \to \mu^+\mu^-)} < 0.46 \quad (90\% CL)$$

- using the central values for the normalizing fractions,

$$\mathcal{B}(D^+ \to \pi^+\mu^+\mu^-) < 4.7 \times 10^{-6} \quad (90\% CL)$$

previous searches: **FOCUS(2003)** $< 8.8 \times 10^{-6}$ **CLEO(2005)** $< 7.4 \times 10^{-6}$ $(e^+e^-\pi^+)$
BaBar(2006) $< 24.4 \times 10^{-6}$

- This analysis currently under update: (with 30% more data)
  with a $\sim 4\sigma$ $D^+ \to \phi\pi^+ \to \pi^+\mu^+\mu^-$ signal now used as normalization to reduce uncertainties, notably in the D^+/D_s production fractions.

Conclusion

- Two new rare decay BR upper limits set by DØ

$$\mathcal{BR}(B_s^o \to \mu^+\mu^-) \ < \ 9.3 \times 10^{-8} \ \ (95\% CL)$$

$$\mathcal{BR}(D^+ \to \pi^+\mu^+\mu^-) \ < \ 4.7 \times 10^{-6} \ \ (90\% CL)$$

- In the $B_s \to \mu^+\mu^-$ case, the current CDF limit of

$$\mathcal{BR}(B_s^o \to \mu^+\mu^-) \ < \ 1.0 \times 10^{-7} \ \ (95\% CL, \ 780 fb^{-1})$$

has been combined with that from DØ to give

$$\boxed{\mathcal{BR}(B_s^o \to \mu^+\mu^-) \ < \ 5.8 \times 10^{-8} \ \ (95\% CL)}$$

Tevatron Combined
(thanks Matt Herndon)