Heavy Flavor Physics Results From the DØ Experiment

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(On behalf of the DØ Collaboration)

SUSY 2006
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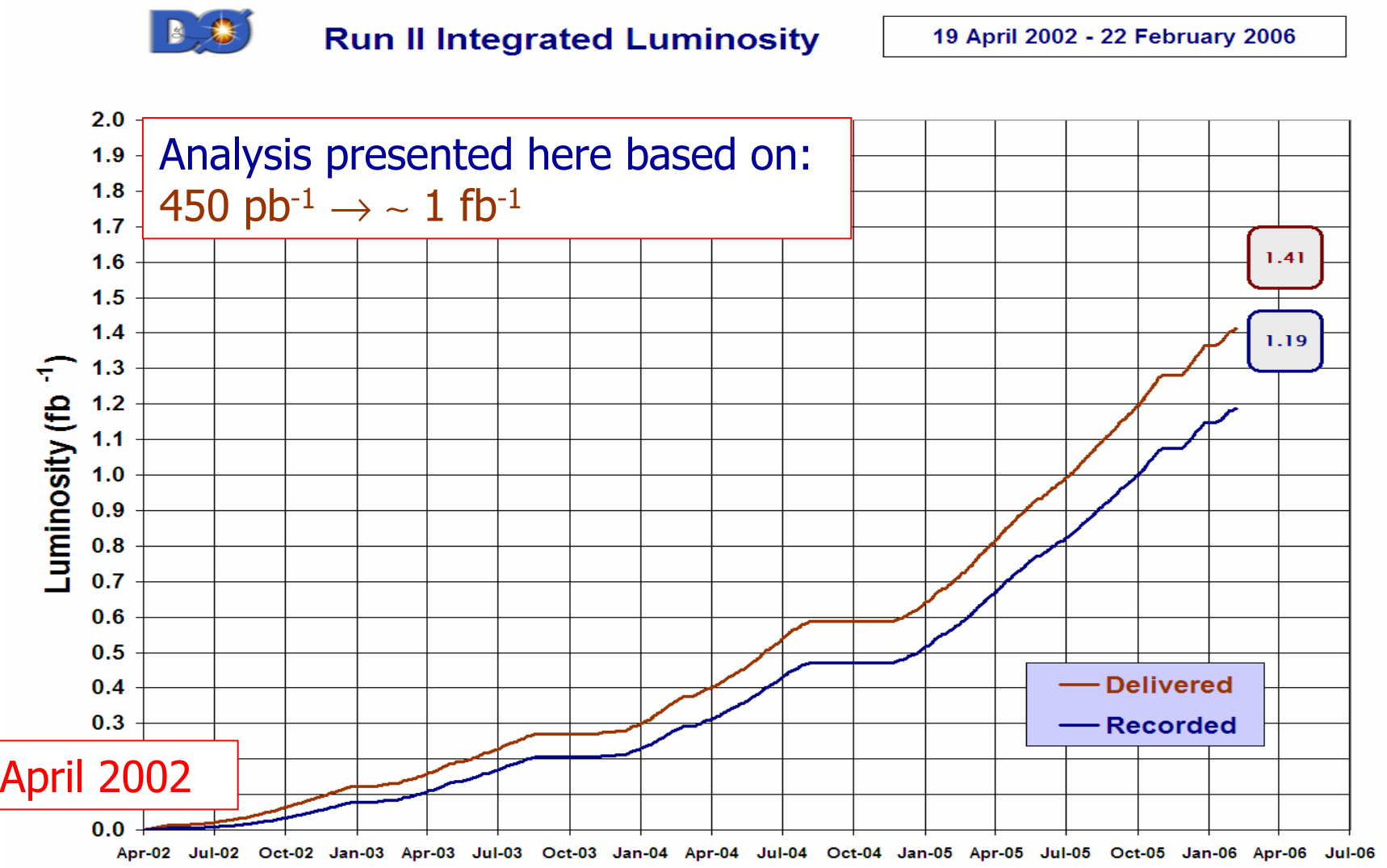
B physics program @ DØ

- Reconstruction of b hadrons in different decay modes and study of their properties,
- Measurement of the B_u, B_d, B_s and b baryons lifetimes,
- Study of exited B Mesons (B**),
- Measurement of the semileptonic branching fractions of B mesons to narrow D** states,
- Measurement of the lifetime difference in the B_s system,
- Searches for FCNC $B_s \to \mu^+\mu^-$ and $B_s \to \phi\mu^+\mu^-$ decays,
- FCNC charm decays and observation of $D^+_s \to \phi\pi^+ \to \pi^+\mu^+\mu^-$,
- B_d and B_s mixing,
- CPV in B^0 mixing,
- Search for $B_s \to D_s(2536)\mu\nu X$,
- Observation of the B_c meson and study of its properties,
- Observation of $B_s \to \psi(2s)\phi$ and a measurement, of $Br(B_s \to \psi(2s)\phi))/Br(B_s \to \psi(2s)\phi)$,
- Measurement of upsilon differential cross section,
- Observation and Properties of the X(3872) Decaying to $J/\psi\pi^+\pi^-$.

Tevatron performance

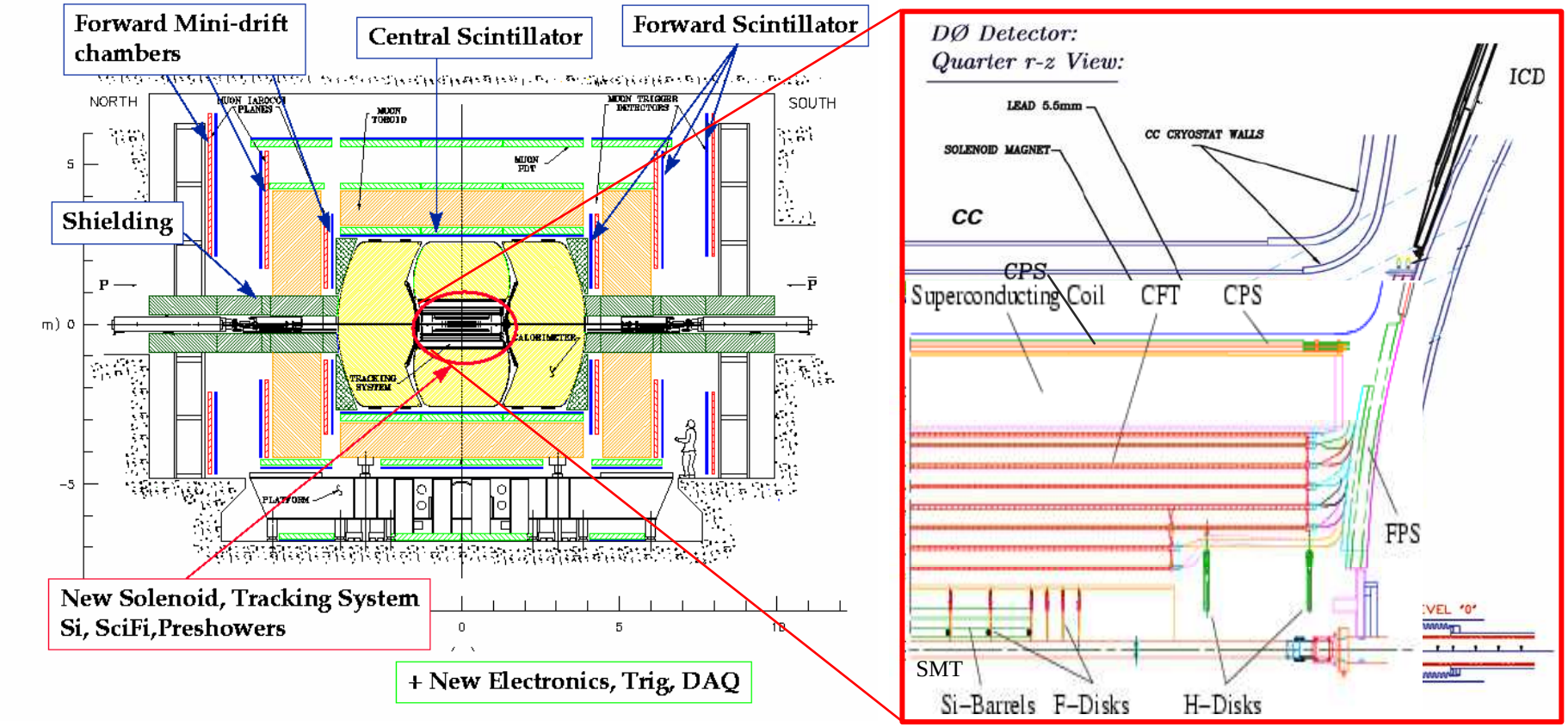


April 2002

October 2005

DØ detector

- Excellent coverage of Tracking and Muon Systems
- Forward muon system with |η|<2 and good shielding
- 4-layer Silicon and 16-layer Fiber Trackers in 2 T magnetic field

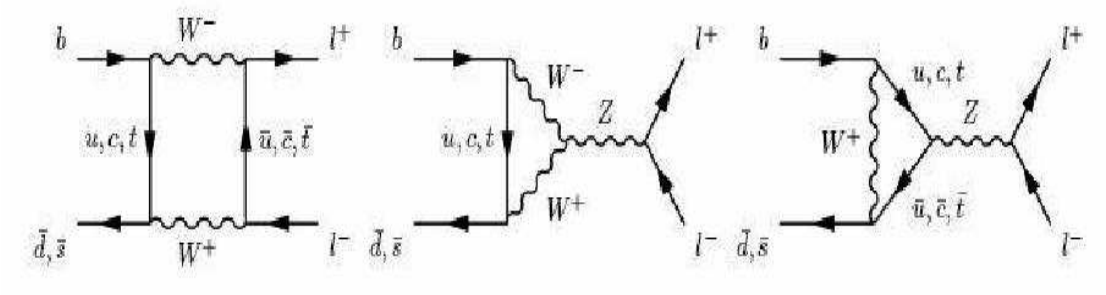


Search for FCNC in b and c decays

- FCNC processes are forbidden at the tree level in the Standard Model
  $\Rightarrow$ proceed via higher order penguin or box diagrams
  $\Rightarrow$ very small decay rates
  $\Rightarrow$ ideal testing ground for physics beyond the SM:
  Many extensions of the SM allow for FCNC contributions at tree level or via alternative penguin and/or box diagrams:
  $\Rightarrow$ FCNC decay rates enhanced with respect to SM expectations.
- In the d-quark sector FCNC decay rates receive large supersymmetric contributions generated, for instance, by Higgs penguin-like diagrams mediated by charginos and top-squarks:
  $\Rightarrow$ FCNC decay rates increased by orders of magnitude with respect to SM.
- In the u-quark sector several scenarios such as SUSY RPV or little Higgs models are expected to enhance the FCNC decay rates with respect to SM expectations.

$\Rightarrow$ Measuring or putting a limit on FCNC decay rates allows to constrain the parameters of the new phenomena models beyond the SM.

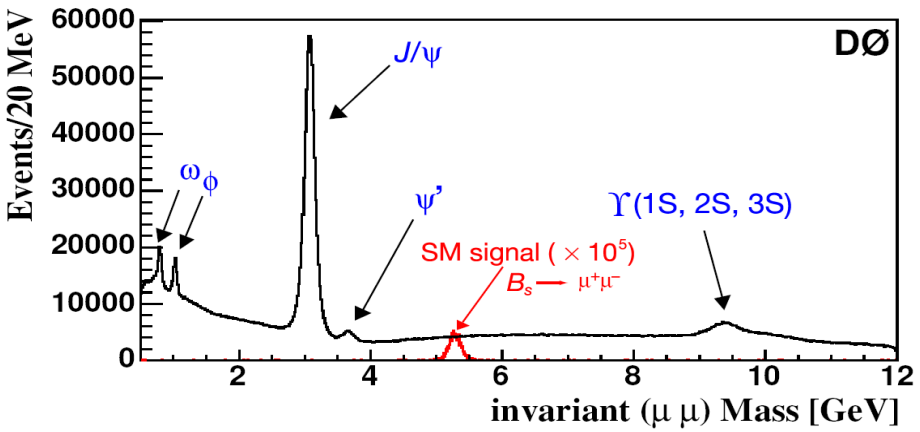
Search for FCNC decay $B_s \to \mu^+\mu^-$



Standard Model prediction:

	$BR(B_d \to l^+l^-)$	$BR(B_s \to l^+l^-)$
$l = e$	$(3.4 \pm 2.3) \cdot 10^{-15}$	$(8.0 \pm 3.5) \cdot 10^{-14}$
$l = \mu$	$(1.5 \pm 0.9) \cdot 10^{-10}$	$(3.4 \pm 0.5) \cdot 10^{-9}$
$l = \tau$	$(3.1 \pm 1.9) \cdot 10^{-8}$	$(7.4 \pm 1.9) \cdot 10^{-7}$

- Analysis based on 700 pb^{-1} (300 pb^{-1}+400 pb^{-1})

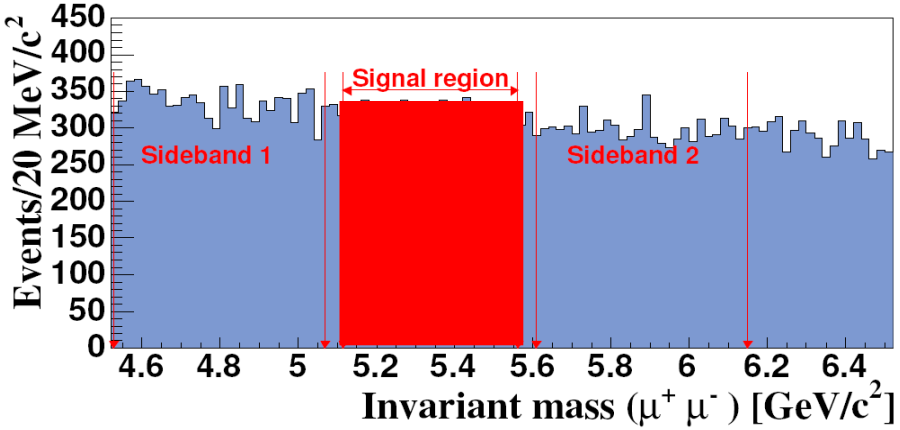


Potential sources of background:

- Drell-Yan $\mu^+\mu^-$ continium
- Sequential semileptonic $b \to c \to s$
- Double semileptonic $b\bar{b} \to \mu^+\mu^-$
- $b/c \to \mu^+\mu^- X$ + fakes
- fake+fake

Pre-selection cuts from triggered di-muon events sample:

- $4.5 < m_{\mu\mu} < 7.0$ GeV/c^2
- $p_T(\mu) > 2.5$ GeV/c and $|\eta(\mu)| < 2$
- $p_T(B_s) > 5$ GeV/c and good $\mu^+\mu^-$ vertex



Blinded signal region: $5.160 < m_{\mu\mu} < 5.520$ GeV/c^2
Side-bands for background determination.
Use $B^+ \to J/\psi\, K^+$ for normalization.

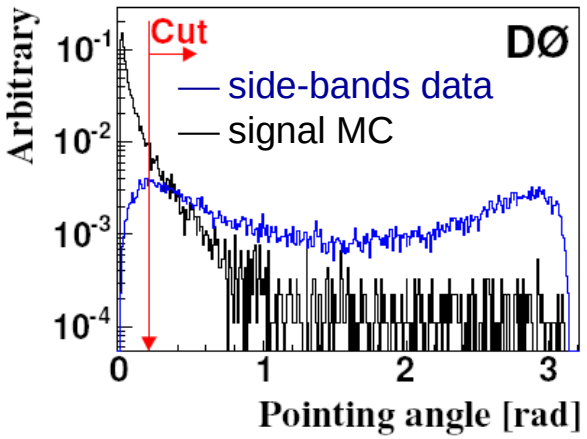
Cuts optimization

Optimization cuts on 3 discriminating variables:

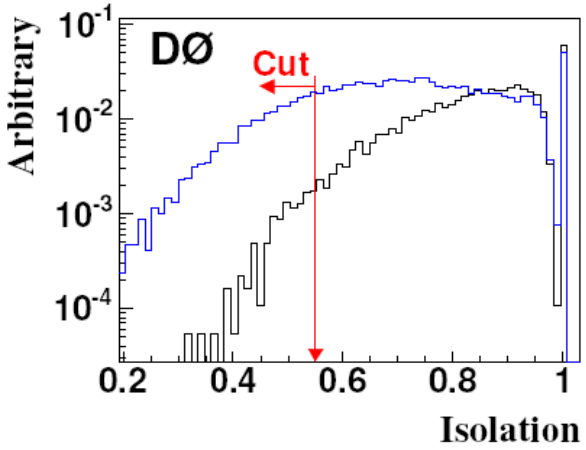
- Opening angle between the vertex direction and the muon pair momentum,
- Decay length significance ($L_{xy}/\sigma(L_{xy})$),
- Isolation of the B candidate: $\mathrm{Iso} = \frac{p_{B_s}}{p_{B_s} + \sum_{\mathrm{allTracks}\Delta R \leq 1} p}$ with $\Delta R = \sqrt{(\Delta\Phi)^2 + (\Delta\eta)^2} \leq 1$

- Use a random grid search to find the optimum cuts on the 3 discriminating variables, by optimizing the ratio: $P = \frac{\epsilon}{\frac{a}{2} + \sqrt{N_{Back}}}$ (G. Punzi, Phystat 2003, SLAC phys/0308063)

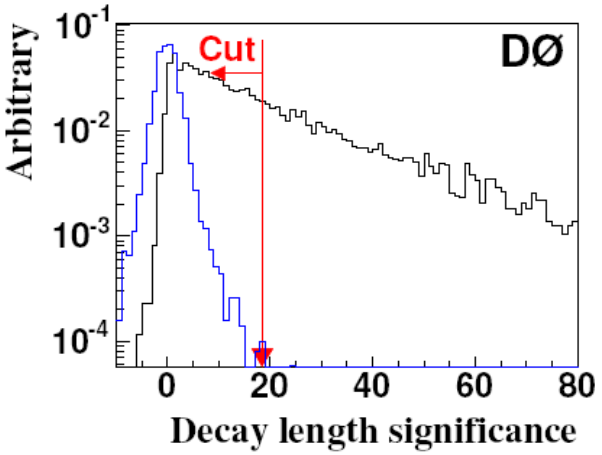
ε = reconstruction efficiency of signal MC.
N_{Back}= expected background in signal region extrapolated from sidebands.
a = number of sigmas corresponding to the confidence level at which the signal hypothesis is tested (a=2 → ~ 95% CL).



Pointing angle < 0.2 rad



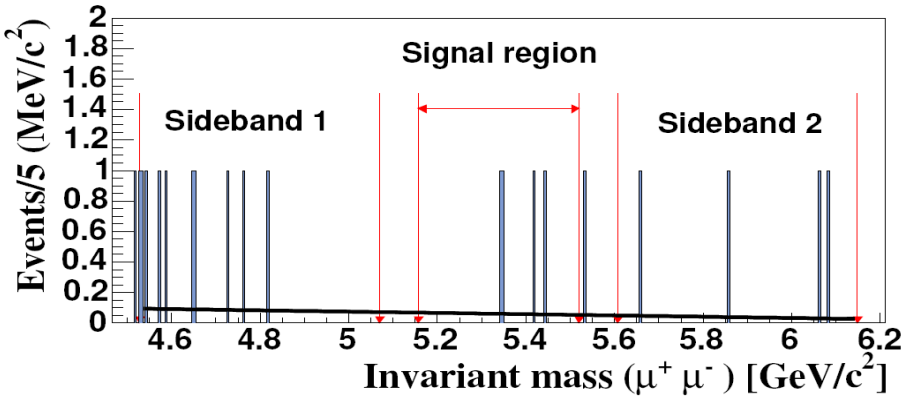
Isolation > 0.56



$L_{xy}/\sigma(L_{xy})$ >18.5

Results

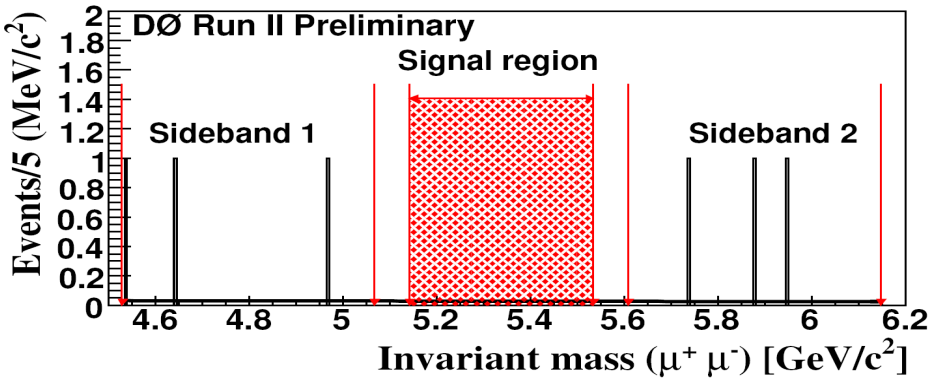
From the first 300 pb^{-1} we obtain:



Expected number of bkg evts in signal region: 4.3±1.2

Observed in signal region: 4

From additional 400 pb^{-1} we obtain:



Expected number of bkg evts in signal region: 2.2±0.7

$$Br(B_s \to \mu^+\mu^-) \le \frac{N_{UL}(n_{obs}, n_B)}{N_{B^\pm}} \cdot \frac{\varepsilon^{B^\pm}_{\mu\mu K}}{\varepsilon^{B_s}_{\mu\mu}} \cdot \frac{f_{b\to B^+}}{f_{b\to B_s}} \cdot \frac{Br(B^\pm \to J/\psi K^\pm) \times Br(J/\psi \to \mu^+\mu^-)}{1 + R \cdot \frac{\varepsilon^{Bd}_{\mu\mu}}{\varepsilon^{B_s}_{\mu\mu}} \cdot \frac{f_{b\to Bd}}{f_{b\to B_s}}}$$

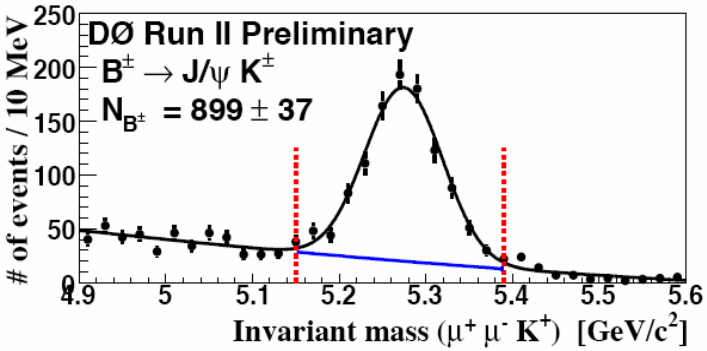
Fron 300 pb^{-1} we get:

$Br(B_s \to \mu^+\mu^-) < 3.7 \times 10^{-7}$ @ 95% CL

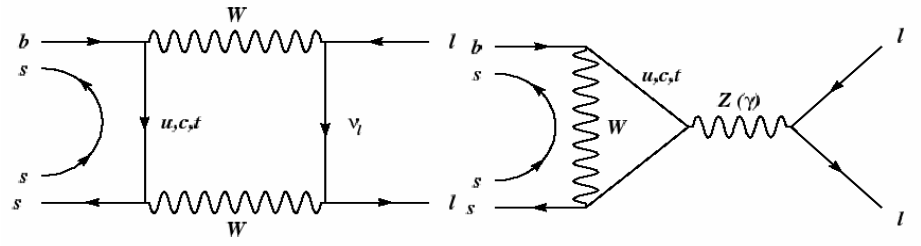
If we add the expected Br from the 400 pb^{-1} we obtain:

$\Rightarrow$ $Br(B_s \to \mu^+\mu^-) < 2.3 \times 10^{-7}$ @ 95% CL

to be compared to SM expectation: $Br(B_s \to \mu^+\mu^-) = 3.4 \times 10^{-9}$



Search for FCNC decay $B_s \to \phi \mu^+ \mu^-$



Standard Model prediction:

Br(Bs→ϕμ+μ-) ≈ 1.6 x 10^{-6}

30% uncertainty due to B→ϕ form factor

Analysis based on 450 pb^{-1}

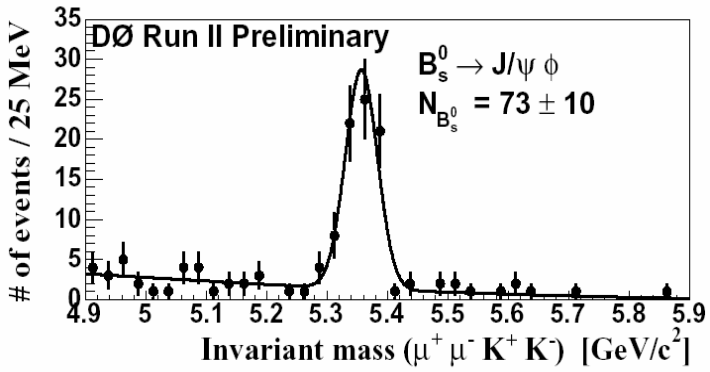
Analysis strategy similar to that used for the $B_s \to \mu^+ \mu^-$ analysis with the same signal/bkg discrimination variables and the same cuts optimization technique.

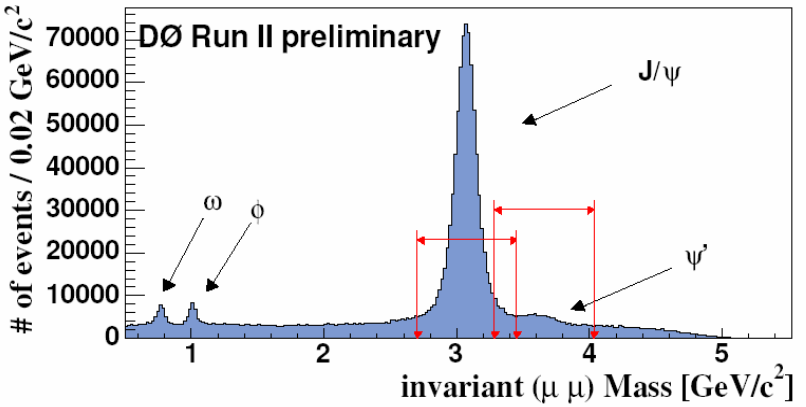
- Blind analysis
- Background modeled from sidebands
- Use resonant decay $B_s \to J/\psi\, \phi$ with same cuts for normalization.

- Di-muons candidates required to satisfy similar cuts as in $B_s \to \mu^+ \mu^-$

In addition:

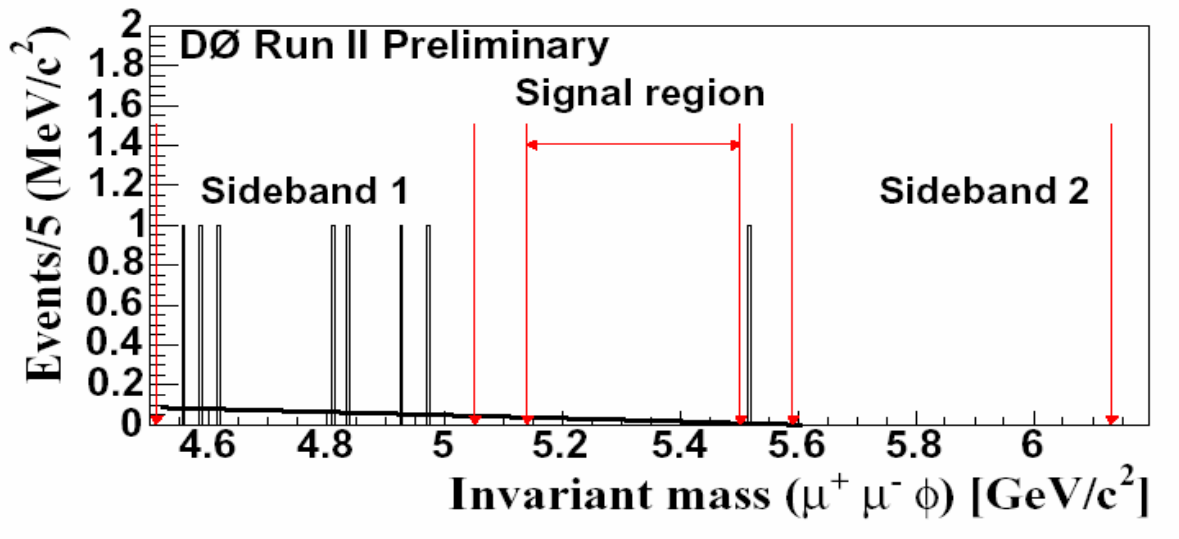
- cut on $0.5 < m_{\mu^+\mu^-} < 4.4$ GeV/c^2 excluding J/ψ and ψ'
- ϕ candidate reconstructed in the K^+K^- decay mode and is required to be within $1.008 \le m_{KK} \le 1.032$ GeV/c^2.





Results

Expected number of bkg events (from side-bands) in signal region: 1.6 ± 0.4 events
Observe zero events in signal region:

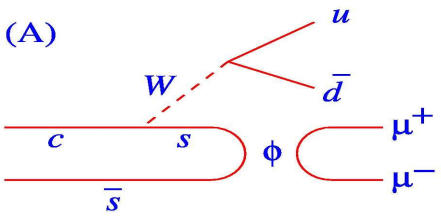


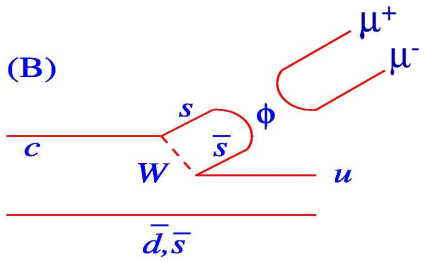
$$Br(B_s \to \phi\,\mu^+\,\mu^-) = \frac{N_{UL}(n_{obs}, n_{back})}{N_{Bs}} \times \frac{\varepsilon_{J/\psi\phi}}{\varepsilon_{\mu\mu\phi}} \times Br(B_s \to J/\psi\phi) \times Br(J/\psi \to \mu\mu)$$

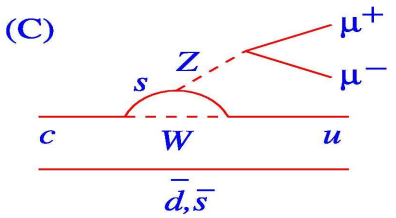
$\Rightarrow$ $Br(B_s \to \phi\,\mu^+\mu^-) < 4.1 \times 10^{-6}$ @ 95% CL

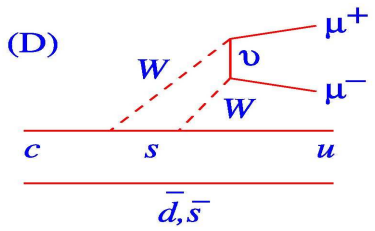
to be compared to SM expectation: $Br(B_s \to \phi\mu^+\mu^-) = 1.6 \times 10^{-6}$

Search for FCNC decay $D^+ \to \pi^+\mu^+\mu^-$









Resonant $\mu^+\mu^-$ final state

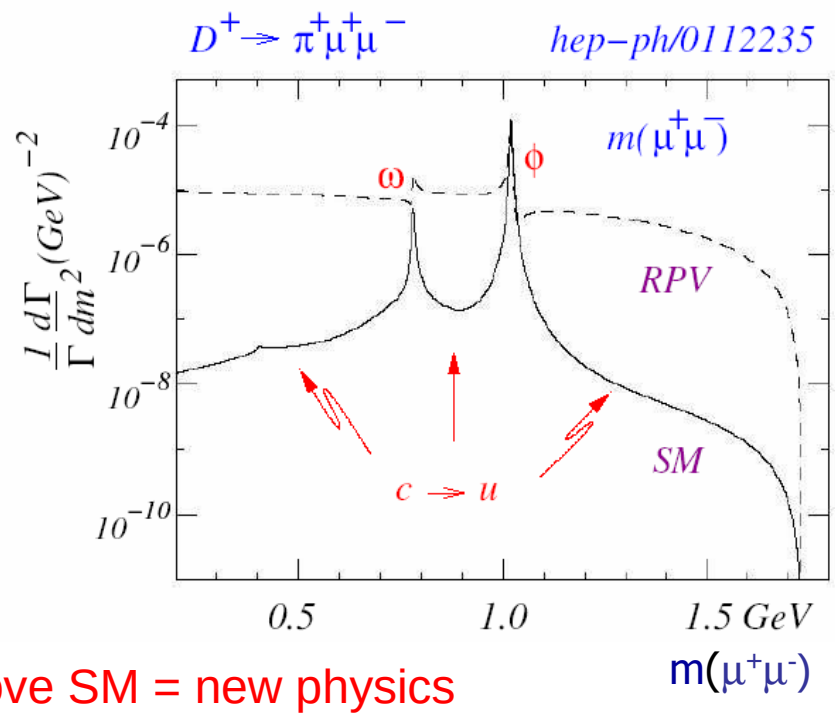
Non-resonant $\mu^+\mu^-$ final state

SM predictions for:

- long distance Br (A and B):
  $Br(D^+_s \to \pi^+\mu^+\mu^-) = 6.1\times10^{-6}$
  $Br(D^+ \to \pi^+\mu^+\mu^-) = 1.0\times10^{-6}$

$\Rightarrow$ essential to study $c \to u\, l^+ l^-$ transitions

- short distance FCNC Br (C and D):
  $Br(D^+_s \to \pi^+\mu^+\mu^-) = 0$
  $Br(D^+ \to \pi^+\mu^+\mu^-) = 9.4\times10^{-9}$

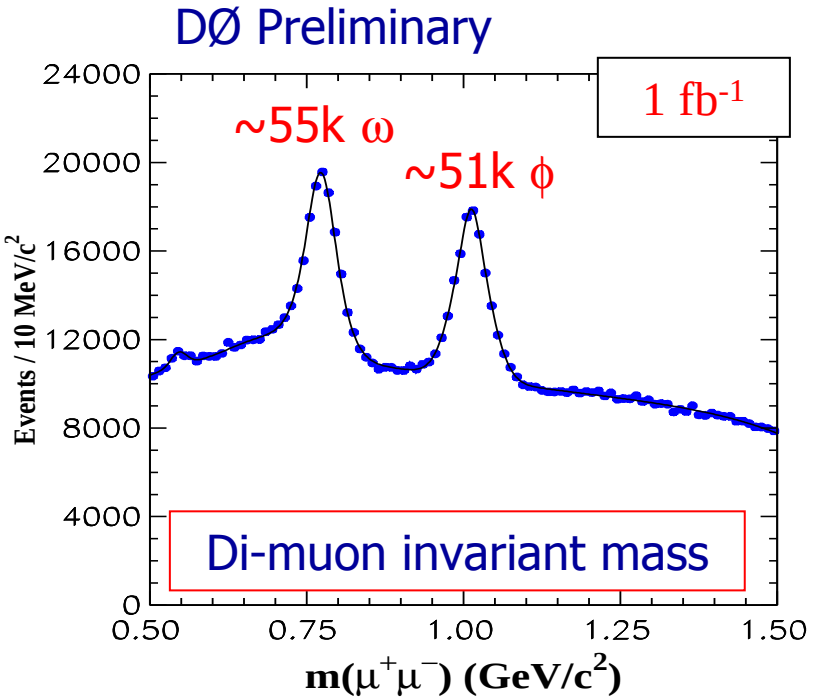


$\Rightarrow$ Observing non-resonant $\mu^+\mu^-$ final state above SM = new physics

Analysis strategy

Analysis based on 1 fb^{-1}

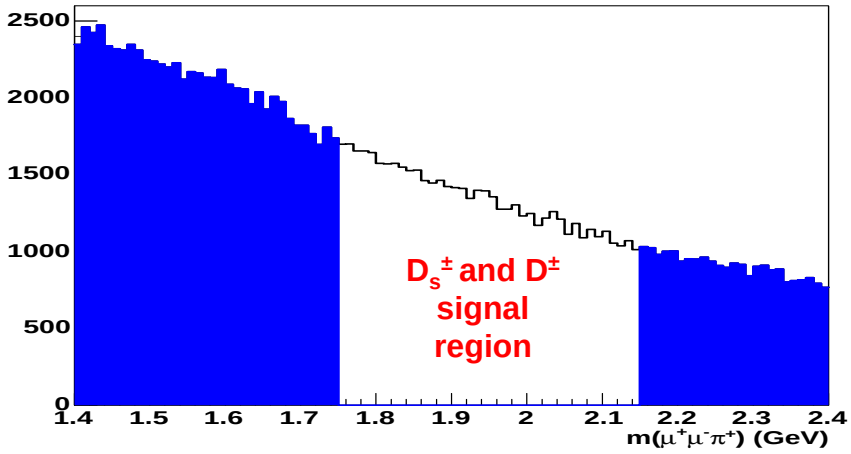
- Search for long distance decay channel: use golden $D^+_s \to \pi^+\phi(\to\mu^+\mu^-)$
- Once $D^+_s \to \pi^+\phi(\to\mu^+\mu^-)$ established, search for non-resonant $D^+ \to \pi^+\mu^+\mu^-$
- Start with low mass di-muon candidate, add track to it to form D candidate.
- Reduce background with lifetime and topological cuts.



- Pion track selection: should typically:
  - form good vtx with $\mu^+\mu^-$
  - has higher p_T
  - close to $\mu^+\mu^-$ (ΔR_π)

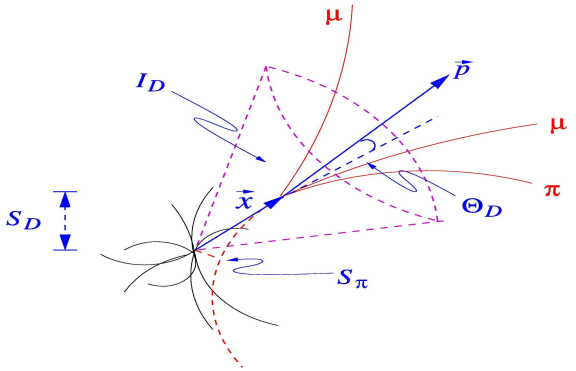
$\Rightarrow$ Choose to minimize:

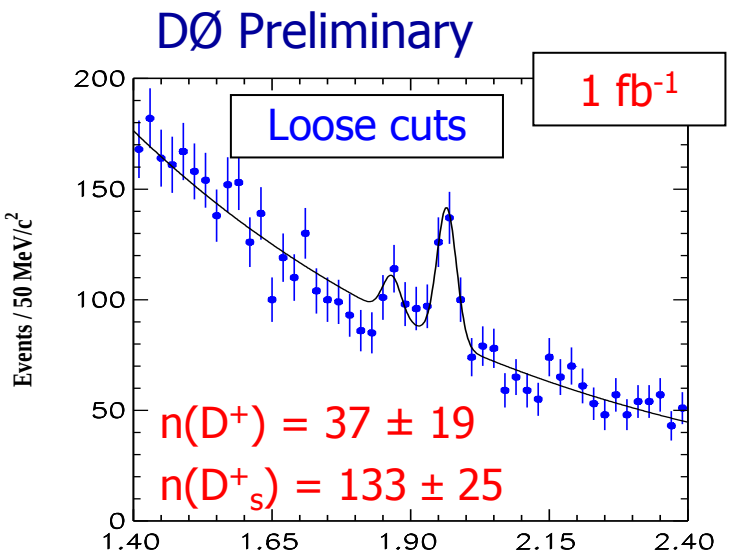
$$M = \chi^2_{vtx} + \left(1/p_T(\pi)\right)^2 + \Delta R^2_\pi$$

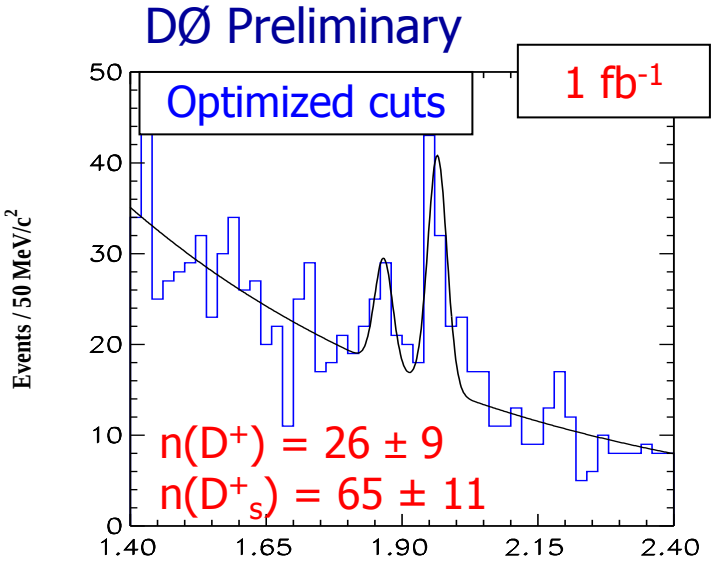


Background suppression

- Background suppression:
  - I_D : D isolation
  - S_D : D decay length significance
  - Θ_D: D collinearity angle
  - S_π : π impact parameter significance





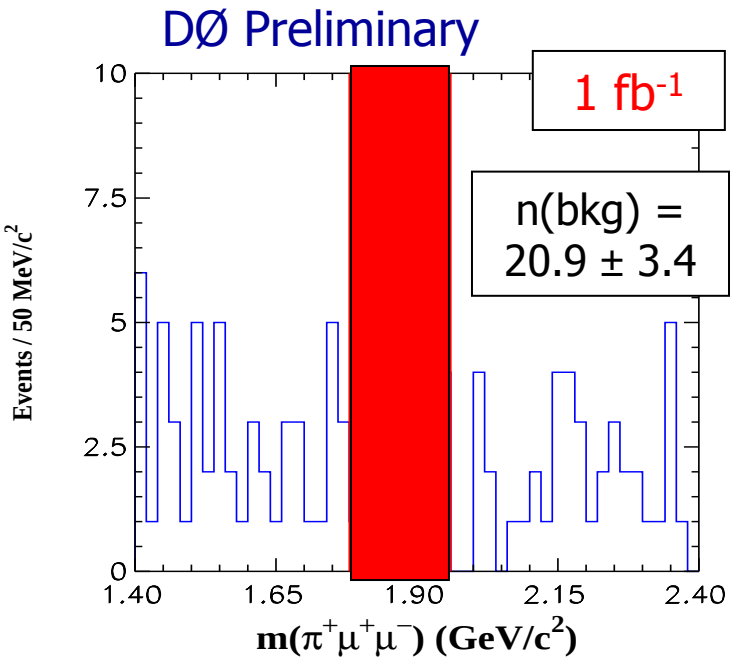


$m(\pi^+\mu^+\mu^-)$ GeV/c^2 for candidates with $0.96 < m(\mu^+\mu^-) < 1.06$ GeV/c^2

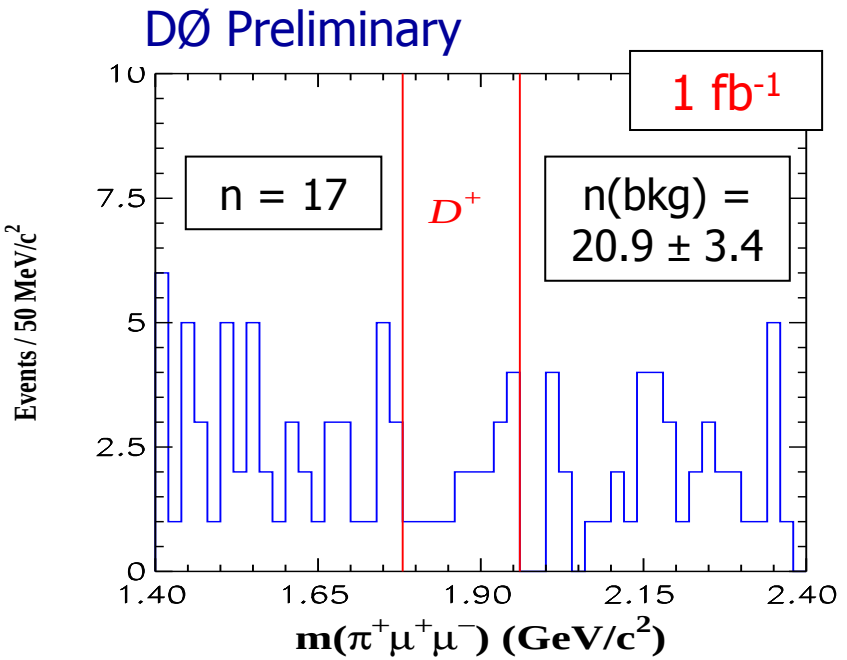
$\Rightarrow Br(D^+ \rightarrow \pi^+\phi \rightarrow \pi^+\mu^+\mu^-) = (1.75 \pm 0.70 \pm 0.50) \times 10^{-6}$

CLEO-c: $(2.7\ ^{+3.6}_{-1.8} \pm 0.2) \times 10^{-6}$

Result for non-resonant $D^+ \to \pi^+\mu^+\mu^-$



$0.2 < m(\mu^+\mu^-) < 0.96$ GeV/c^2
$1.06 < m(\mu^+\mu^-) < 1.76$ GeV/c^2



$0.2 < m(\mu^+\mu^-) < 0.96$ GeV/c^2
$1.06 < m(\mu^+\mu^-) < 1.76$ GeV/c^2

Branching fraction limit for non-resonant $D^+ \to \pi^+\mu^+\mu^-$:

$Br(D^+ \to \pi^+\mu^+\mu^-) < 4.7 \times 10^{-6}$ @ 90% CL $\Rightarrow$ New limit on second generation RPV couplings:

$$\bar{\lambda}_{22k}\bar{\lambda}_{21k} < 0.002$$

CLEO-c($\pi^+e^+e^-$): $< 7.4 \times 10^{-6}$ @ 90% CL
FOCUS: $< 8.8 \times 10^{-6}$ @ 90% CL

Summary

- A searches for FCNC b-decays and c-decays have been presented
  $\Rightarrow$ important to constrain models beyond SM.

- For the purely leptonic decay $B_s \to \mu^+\mu^-$ a search based on $700 pb^{-1}$ leads to an expected upper limit:
  $Br(B_s \to \mu^+\mu^-) < 2.3 \times 10^{-7}$ @ 95% CL (SM prediction $\approx (3.4 \pm 0.5) \times 10^{-9}$)

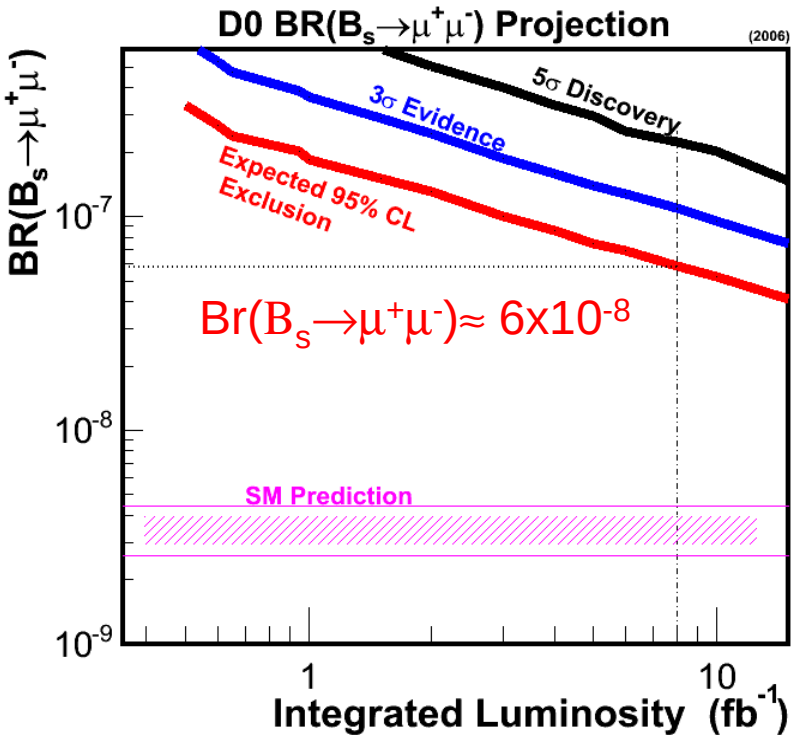
- For $B_s \to \phi\, \mu^+\mu^-$ decay we obtain (with $450 pb^{-1}$):
  $Br(B_s \to \phi\, \mu^+\mu^-) < 4.1 \times 10^{-6}$ @ 95% CL (SM prediction $\approx 1.6 \times 10^{-6}$)

- First D0 observation of the benchmark channel $D^{\pm}_s \to \phi\, \pi^{\pm} \to \mu^+\mu^-\, \pi^{\pm}$
  $\Rightarrow$ first step towards a charm FCNC c-decays studies
  with $1 fb^{-1}$ we measured:
  - $Br(D^+ \to \pi^+\phi \to \pi^+\mu^+\mu^-) = (1.75 \pm 0.70 \pm 0.50) \times 10^{-6}$
  - $Br(D^+ \to \pi^+\mu^+\mu^-) < 4.7 \times 10^{-6}$ @ 90% (SM prediction $\approx 9.4 \times 10^{-9}$)

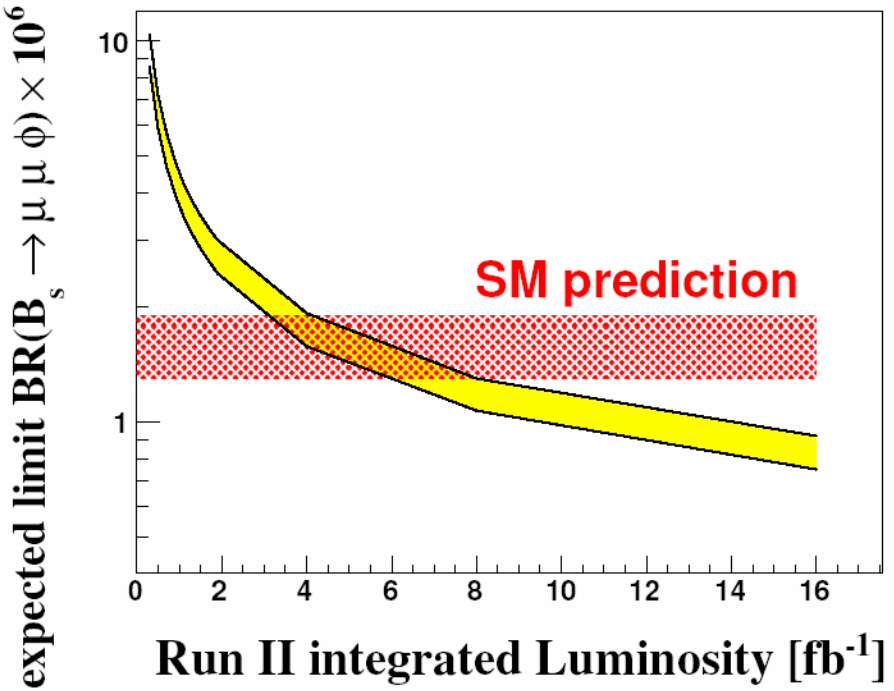
Backup slides

Expected limits for $B_s \to \mu^+\mu^-$ and $B_s \to \phi\mu^+\mu^-$

DØ projection for Br($B_s \to \mu^+\mu^-$)



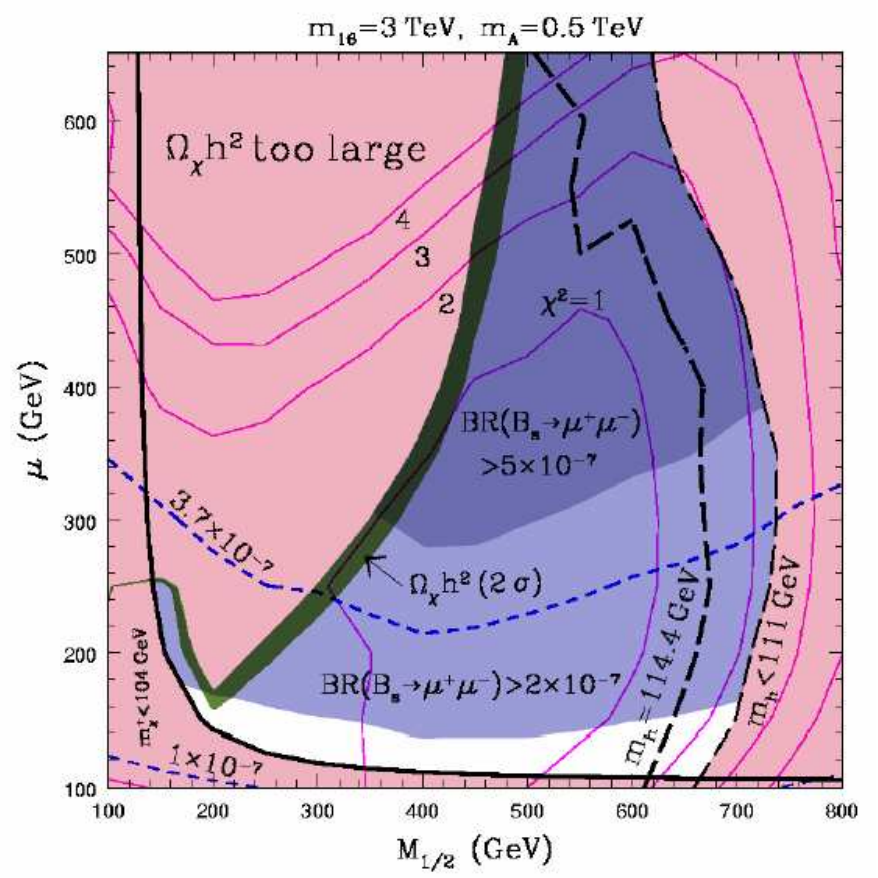
expected limit at 95% C.L. for $B_s \to \phi\ \mu^+\mu^-$



- Assume bkg scales linearly with luminosity.
- Bkg uncertainty is scaled down as sqrt(luminosity).

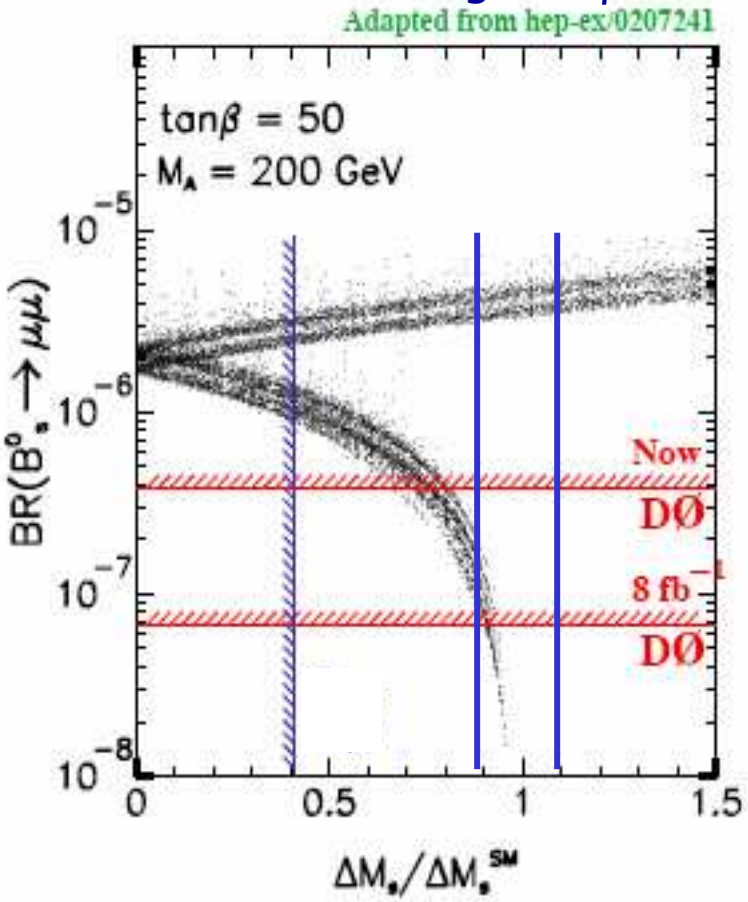
$B_s \to \mu^+\mu^-$ in SO(10) and MSSM

R. Dermisek et al. hep-ph/0507233



Contours of constant Br($B_s \to \mu^+\mu^-$)

MSSM with large tanβ



Random Search Grid