Search for Rare b-Hadron Decays at CDF II

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for the CDF Collaboration

SUSY 07

Karlsruhe Institute of Technology

Covered in This Talk

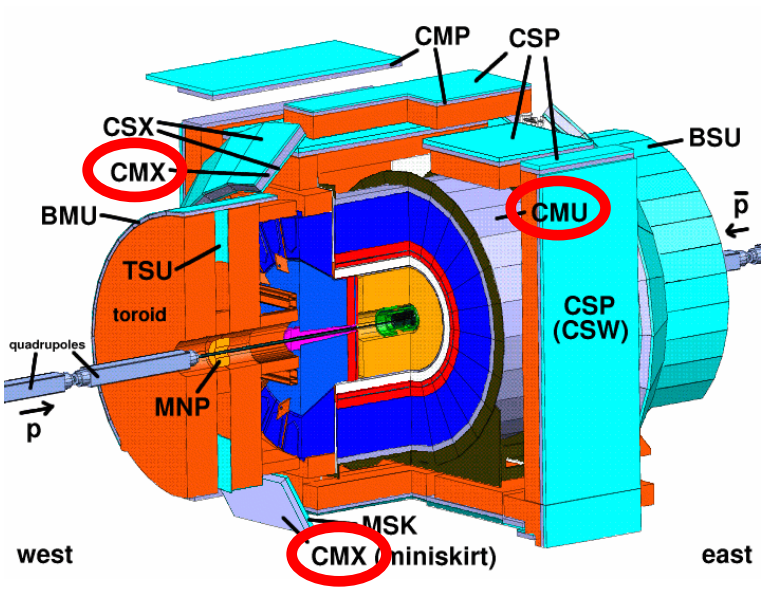
- $B_{s/d} \rightarrow \mu\mu$

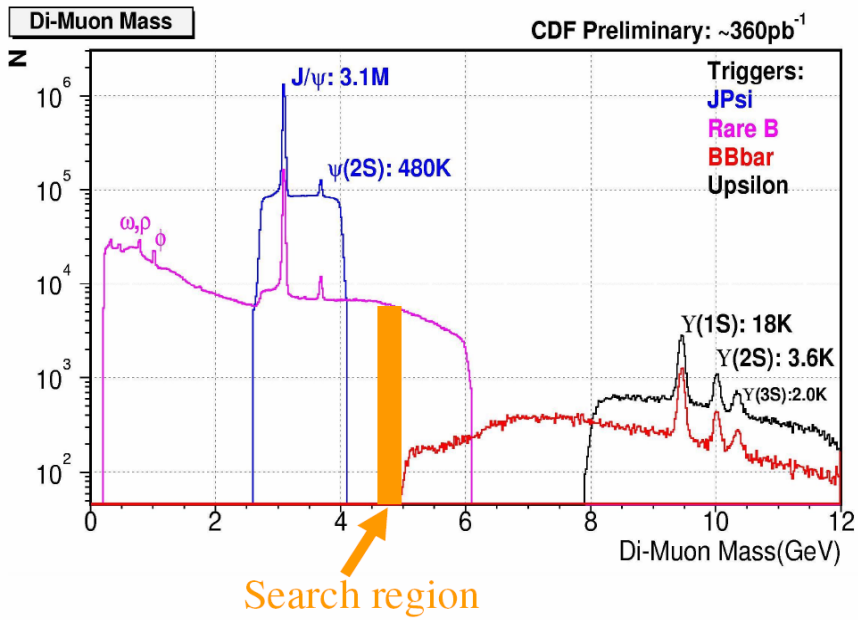
- $B \rightarrow \mu\mu\ h$
  - $B_u \rightarrow \mu\mu\ K$
  - $B_d \rightarrow \mu\mu\ K^*$
  - $B_s \rightarrow \mu\mu\ \phi$

Results from CDF on $B^0, B_s \rightarrow h^+h^-$' covered by M. Kreps

Trigger

- Di-muon trigger for rare B decays :
  two separate search channels
  - Central/central muons (CMU-CMU), CMU $|\eta|<0.6$
  - Central/forward muons (CMU-CMX),CMX $0.6<|\eta|<1$

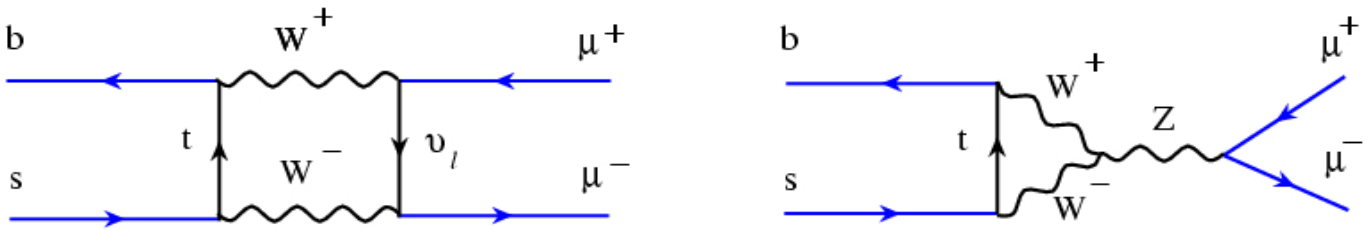




Search for $B_{s/d} \rightarrow \mu\mu$

Motivation:

- In the SM, $B \rightarrow \mu\mu$ heavily suppressed (need FCNC)



expectation: $BR(B_s \rightarrow \mu^+\mu^-) = (3.42 \pm 0.54) \times 10^{-9}$

A.J. Buras, Phys. Lett. B566, 115 (2003)

- $B_d \rightarrow \mu\mu$ further Cabbibo-suppressed
- Expect to see nothing, if something seen → new physics

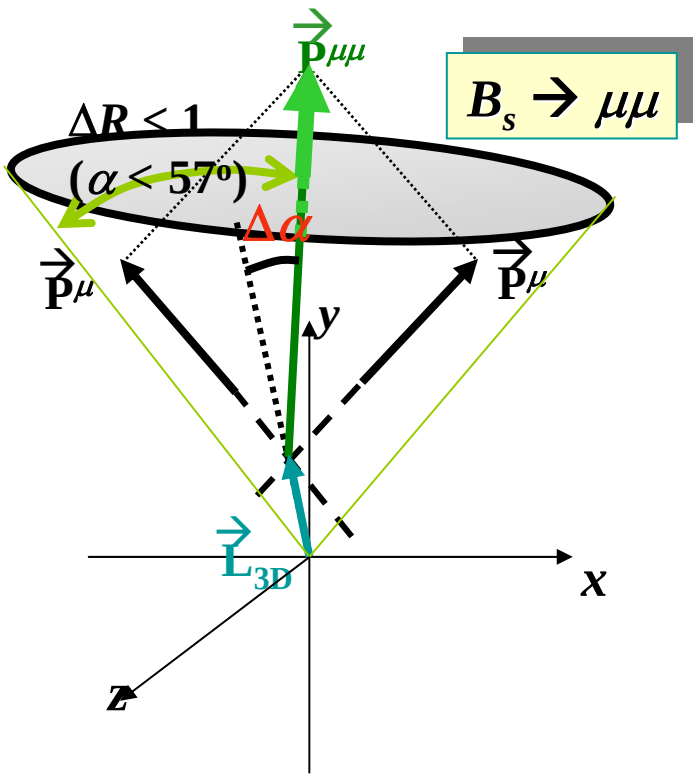
Search Methodology

1. Unbiased (blinded) selection optimization using
   - signal event sample: MC simulation
   - background sample: data sidebands
2. Normalize to well-known B $\rightarrow$ J/ψ K decay
   $\rightarrow$ cancellation of many systematic effects

$$\frac{BR(B_s \to \mu^+\mu^-)}{BR(B^+ \to J/\psi K^+)BR(J/\psi \to \mu^+\mu^-)} = \frac{N_{Bs}}{N_{B+}} \frac{\alpha_{B+} \cdot \varepsilon_{B+}^{total}}{\alpha_{Bs} \cdot \varepsilon_{Bs}^{total}} \frac{f_{b\to B+}}{f_{b\to Bs}}$$

3. Apply cuts on search mode and normalization mode
4. Estimate Backgrounds
5. Unblind

Selection Procedure



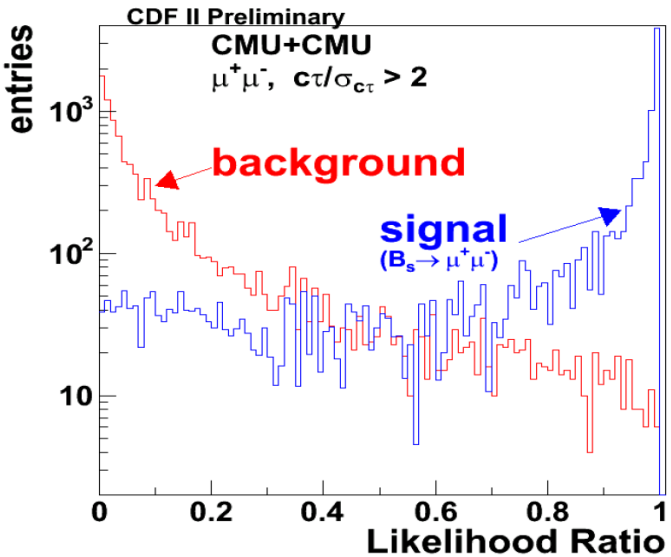
Form likelihood ratio from following discriminating variables:

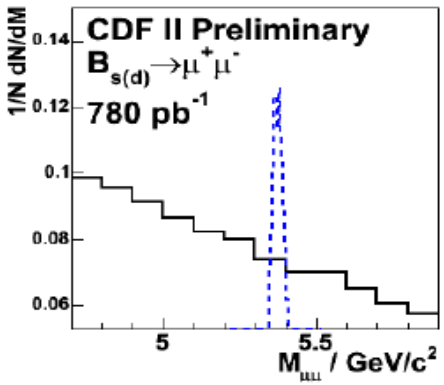
- displacement of reconstructed B vertex (long B lifetime) : λ
- isolation (expect B to be isolated)
- "pointing angle" between reconstructed B momentum and direction to primary vertex (should be small) : $\Delta\alpha$

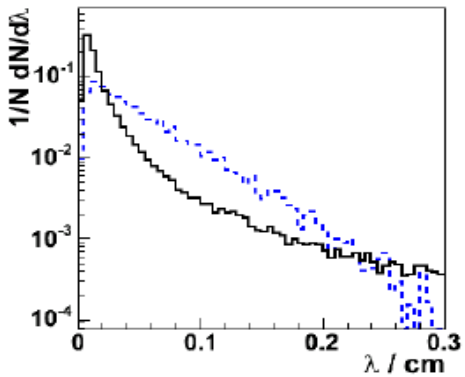
- Optimize on best limit with 90% C.L.

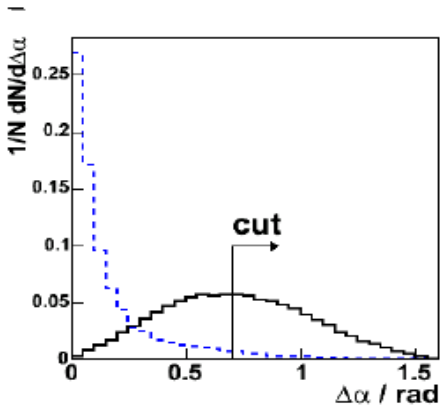
Likelihood Ratio

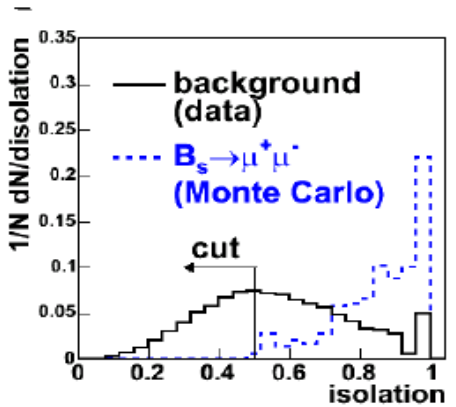
$$LR = \frac{\prod_i P_s(x_i)}{\prod_i P_s(x_i) + \prod_i P_b(x_i)}$$











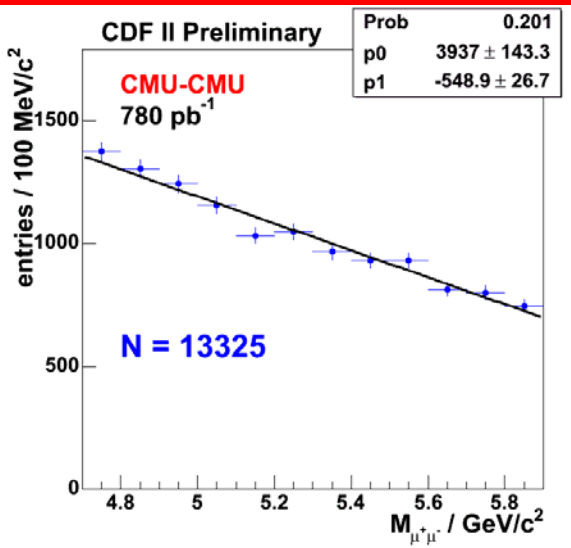
$B_{s/d} \rightarrow \mu\mu$ Backgrounds

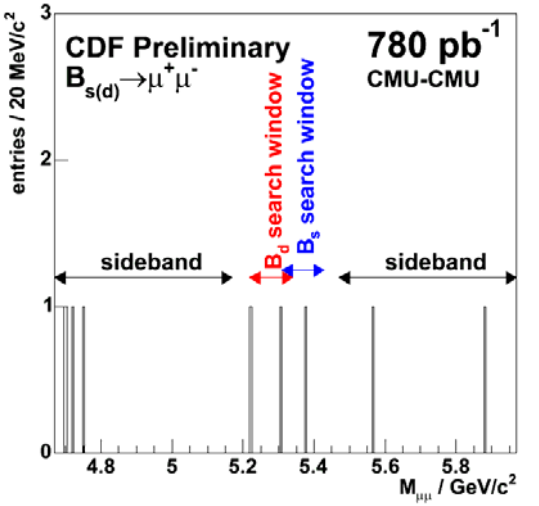
	B_s^0 Signal Window		B_d^0 Signal Window	
Bkg Source	CMU-CMU	CMU-CMX	CMU-CMU	CMU-CMX
Combinatoric	0.72 ± 0.29	0.36 ± 0.21	0.72 ± 0.29	0.36 ± 0.21
$B \rightarrow h^+h^-$	0.16 ± 0.06	0.03 ± 0.01	1.14 ± 0.16	0.23 ± 0.04
Total	0.88 ± 0.30	0.39 ± 0.21	1.86 ± 0.34	0.59 ± 0.21

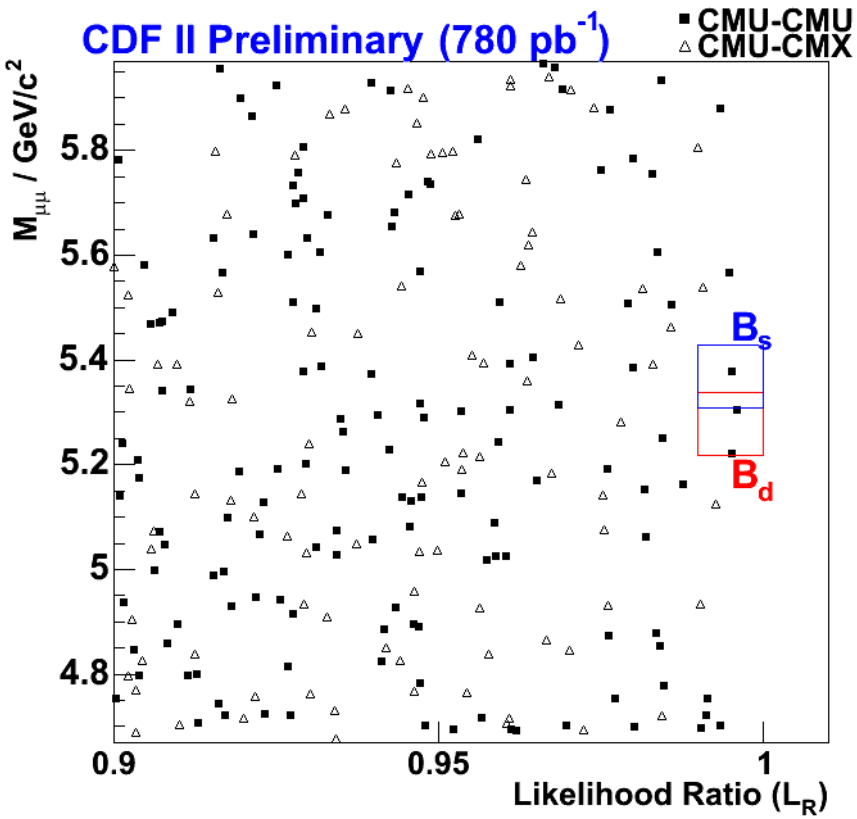
Estimate backgrounds from:

- sidebands (combinatoric)
- branching fractions $B \rightarrow h^+ h^-$ and fake rates

Apply Selection







- Observation in agreement with background expectation
- Set limits

Results

$$BR(B_s \to \mu^+\mu^-) < 1.0 \cdot 10^{-7} \; @ \; 95\% C.L.$$

World's best limit

$$BR(B_d \to \mu^+\mu^-) < 3.0 \cdot 10^{-8} \; @ \; 95\% C.L.$$

Search for B→μμh

- Non-resonant decays B → μμh via box or penguin diagrams
  - → new physics may be observable through interference with SM amplitudes

- Already observed (BaBar, Belle):
  - $B_u \rightarrow \mu\mu K$
  - $B_d \rightarrow \mu\mu K^*$

PRD 73, 092001 (2006)
PRL 96, 251801 (2006)

- Missing:
  - $B_s \rightarrow \mu\mu \phi$
  - prediction: $BR(B_s \rightarrow \mu\mu\phi)=1.6\times10^{-6}$

C.Q. Geng and C.C. Liu, J. Phys. G 29, 1103 (2003)

Search Methodology

- Similar method than for $B_s \to \mu\mu$
- Unbiased (blinded) selection optimization using
  - signal event sample: MC simulation
  - background sample: data sidebands
- Normalize to analogous resonant $B \to J/\psi\, h$ decay

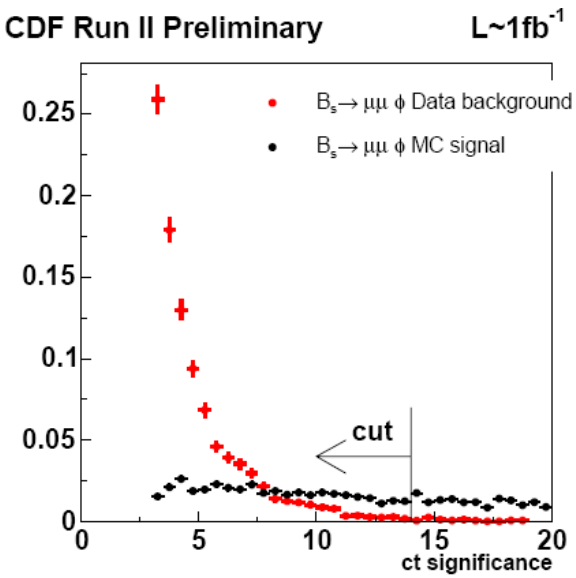
$$\frac{BR(B \to \mu^+\mu^- h)}{BR(B \to J/\psi h) \cdot BR(J/\psi \to \mu^+\mu^-)} = \frac{N_{\mu\mu h}}{N_{J/\Psi h}} \frac{\varepsilon^{total}_{J/\Psi h}}{\varepsilon^{total}_{\mu\mu h}}$$

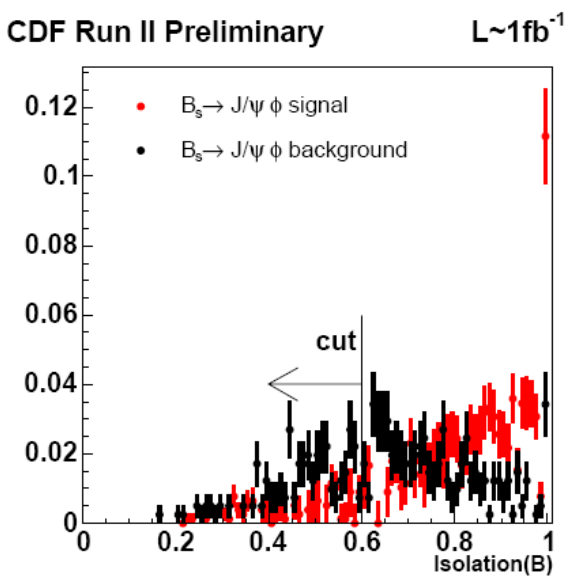
- Apply cuts on search mode and normalization mode
- Remove resonant $\mu\mu$ by cutting out J/ψ / $\psi(2S)$ mass ranges
- Unblind

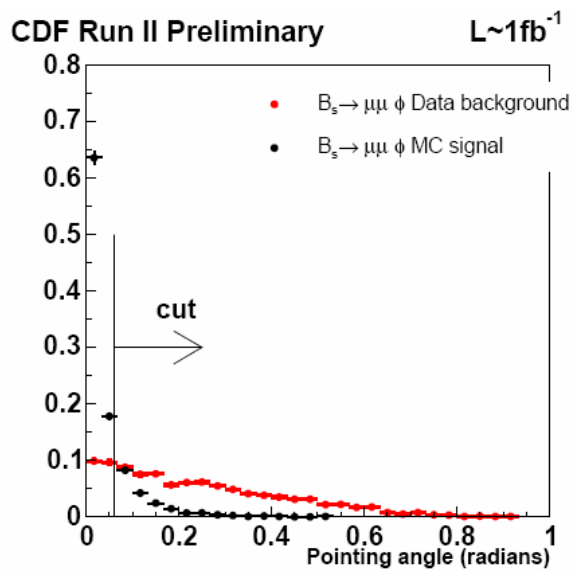
Selection Strategy

Optimize selection based on cuts on similar quantities as used for $B_s \rightarrow \mu\mu$ (decay length, isolation, pointing angle)

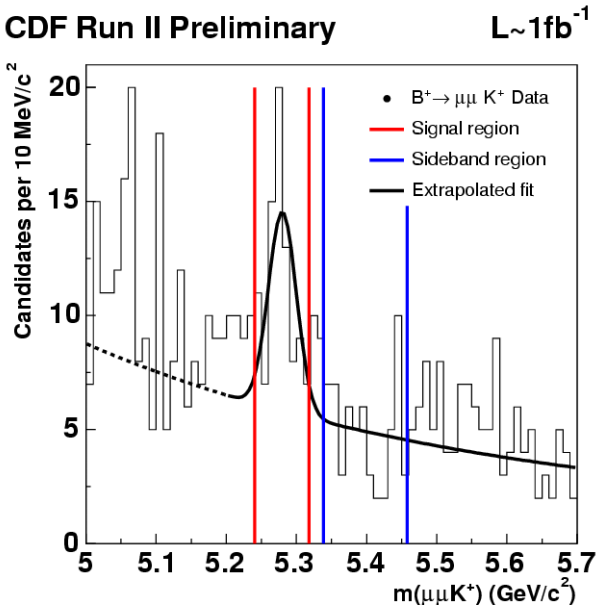
Optimize on best value for $\frac{S}{\sqrt{S+B}}$

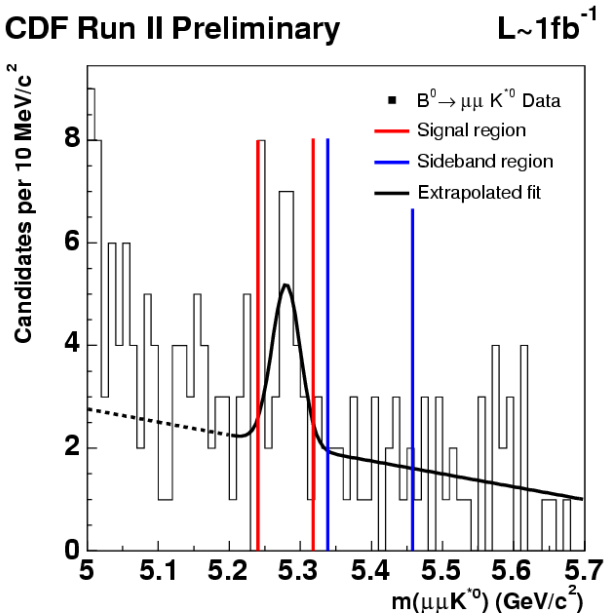


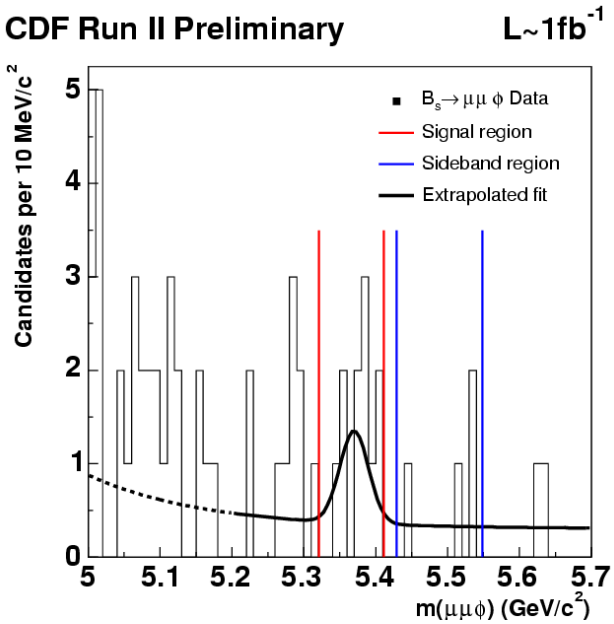




Observations





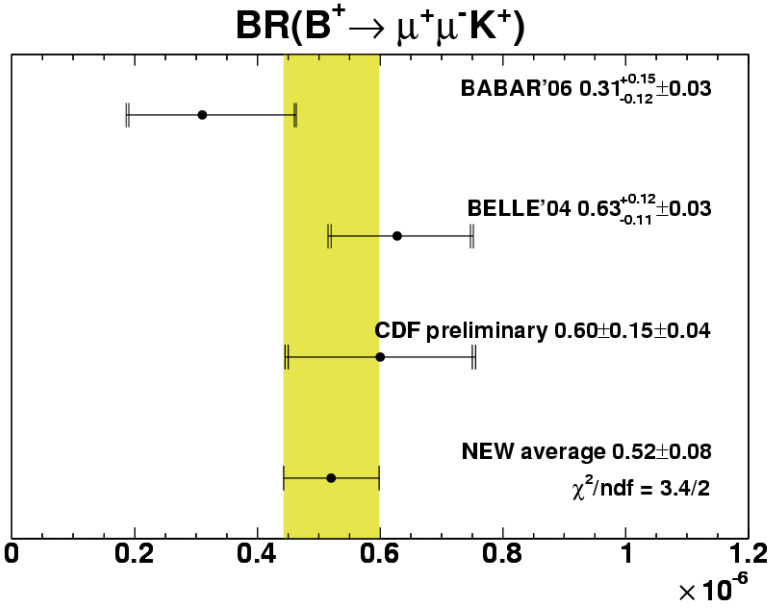


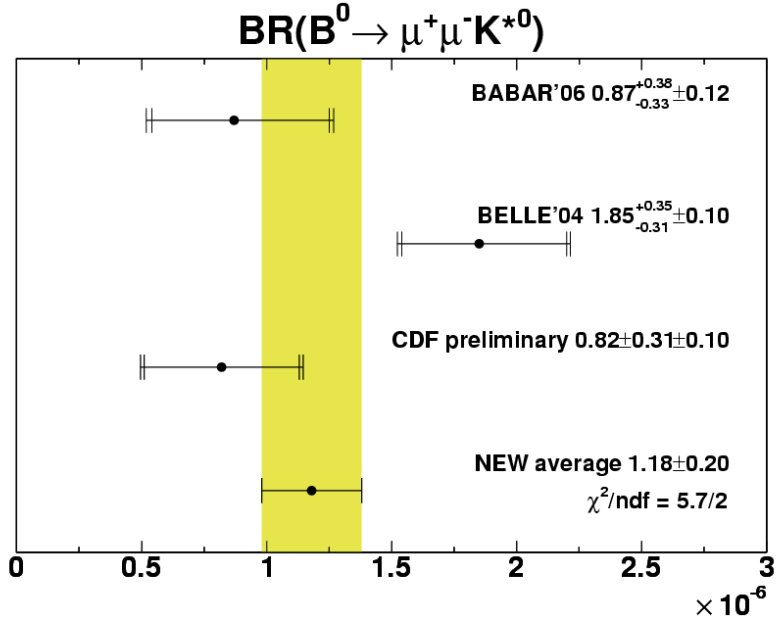
	$B_u \to \mu\mu\, K$	$B_d \to \mu\mu\, K^*$	$B_s \to \mu\mu\, \phi$
# events signal range	90	35	11
# estim. BG events	45.3 ± 5.8	16.5 ± 3.6	3.5 ± 1.5
Significance	4.5 σ	2.9 σ	2.4 σ

Results

$BR(B^+ \to \mu\mu\, K^+) = [0.60 \pm 0.15(stat.) \pm 0.04(syst.)] \times 10^{-6}$

$BR(B^0 \to \mu\mu\, K^*) = [0.82 \pm 0.31(stat.) \pm 0.10(syst.)] \times 10^{-6}$





$$\frac{BR(B_s \to \mu^+\mu^-\phi)}{BR(B_s \to J/\psi\phi)} < 2.61 \cdot 10^{-3} \,@\, 95\% C.L.$$

Summary & Outlook

- CDF set limits for $B_{s/d} \rightarrow \mu\mu$
  - currently probe the 10^{-8} level
  - limits severely constrain new physics models
  - growing dataset will allow deeper probing in the future
- CDF investigating $B \rightarrow \mu\mu$ h modes
  - results in agreement with those of b-factories
  - most stringent limit on $B_s \rightarrow \mu\mu\phi$
- More data – better results: watch out!