Results on Rare Decays and other CP Violation at the Tevatron

Paola Squillacioti
(Siena University & INFN Pisa)
for the CDF and DØ collaborations

Topics:

- Current status of the rare decay searches:
  - $B \to \mu\mu$
  - $B \to \mu\mu h$
  - $D \to \mu\mu h$
- $B \to hh$ results (decay rates and A_{CP})

The Tevatron

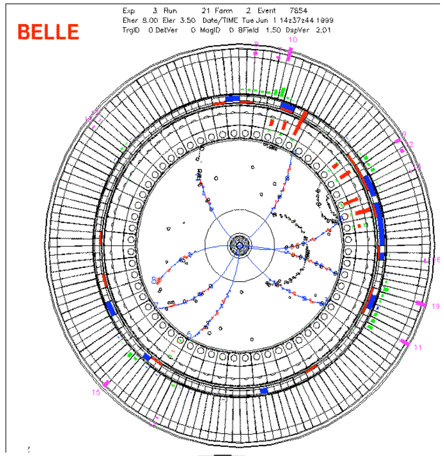
Tevatron is great for rare B and D decay searches:

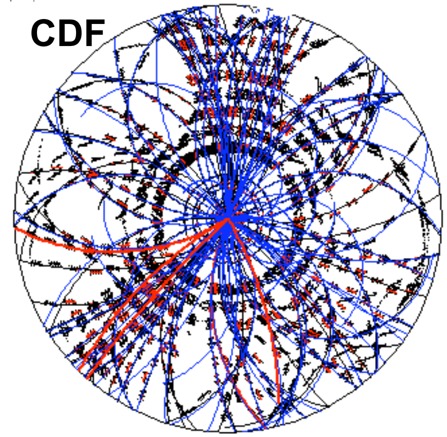
- Enormous *b* production cross section, x1000 times larger than e^+e^- B factories
- All B species are produced (B^0, B^+, B_s, Λ_b...)

But:

- The total inelastic x-section is a factor 10^3 larger than $\sigma(b\bar{b})$
- The BRs of rare b-hadron decays are $O(10^{-6})$ or lower

Therefore interesting events must be extracted from a high track multiplicity environment

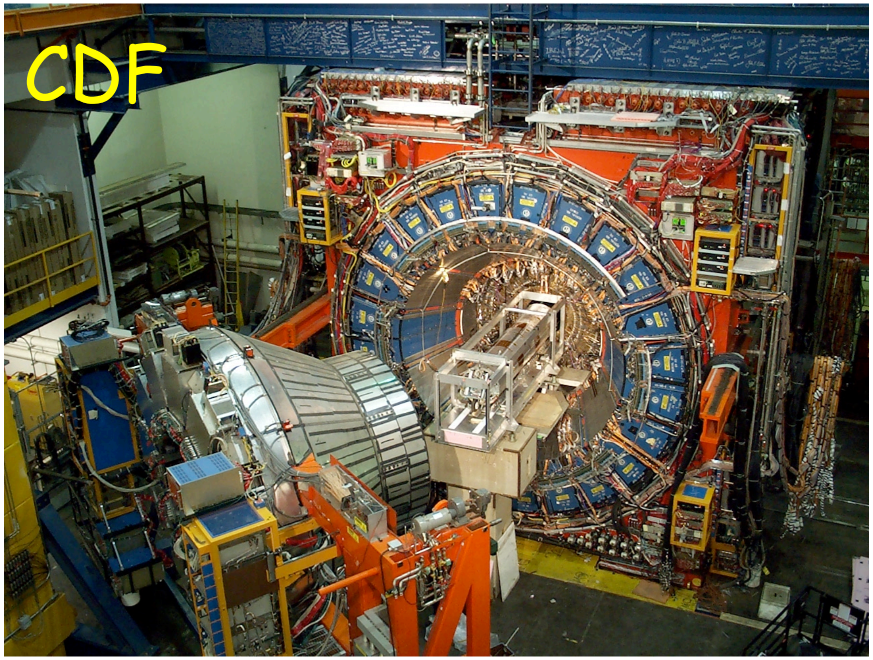


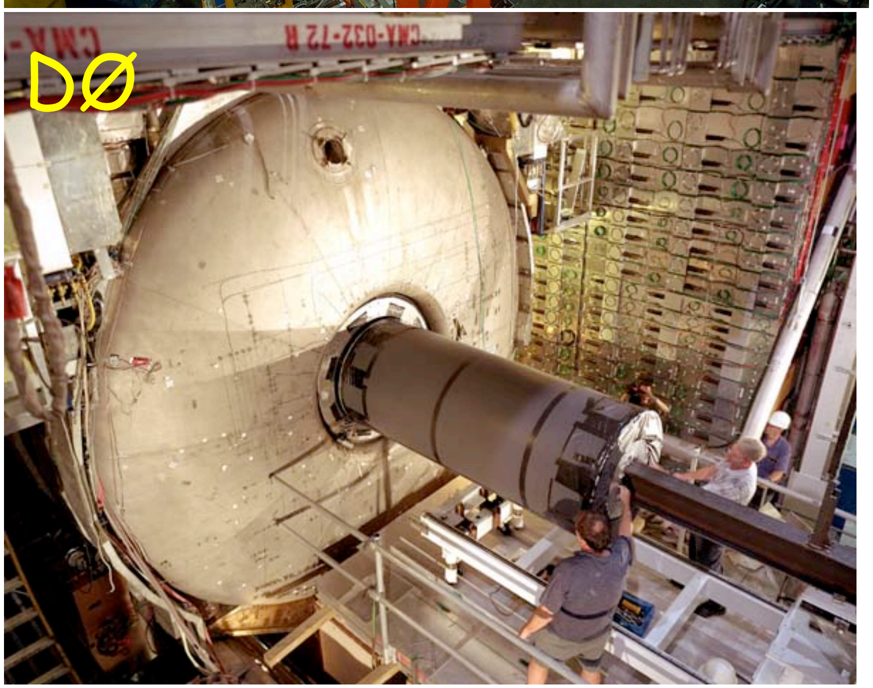


Detectors need to have:

- Very good tracking and vertex resolution
- Wide acceptance and good ID for electrons and muons
- Highly selective trigger

Analyses presented today use 0.450 to 2 fb^{-1} of data





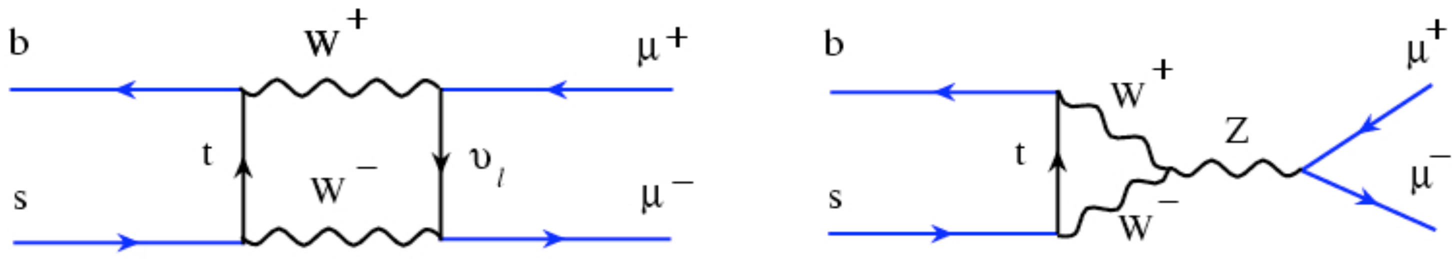
CDF and DØ detectors

- Good muon coverage and triggering
  - DØ: $|\eta| < 2.2$
  - CDF: $|\eta| < 1$
- Good momentum resolution, tracking:
  - CDF: $\sigma(M_B) \sim 25$ MeV/c^2
- Good vertexing
  - CDF: L00 (r_{inner}~1.4cm)
  - DØ: L0 upgrade (r_{inner}~1.6 cm)
- Particle ID
  - CDF: dE/dx and TOF

$B \rightarrow \mu^+\mu^-$ search at Tevatron

Motivation

- In the Standard Model, the FCNC decay of $B \rightarrow \mu^+\mu^-$ is heavily suppressed



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

(Buchalla & Buras)

- $B_d \rightarrow \mu^+\mu^-$ is further suppressed by CKM factor $(v_{td}/v_{ts})^2$
- SM prediction is below the sensitivity of current experiments (CDF+DØ): SM ⇒ Expect to see 0 events at the Tevatron
- SUSY scenarios (MSSM,RPV,mSUGRA) boost the BR by up to 100x

Any signal at the Tevatron would indicate new physics!!

Procedure

- Blind optimization using signal Monte Carlo sample and sideband data
- Normalize to the $B^+ \to J/\psi\, K^+$ mode

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

- Reconstruct normalization mode in the same data sample, applying same criteria $\Rightarrow$ reduce systematics, only ratio of efficiency matters
- Evaluate expected background, then "un-blind" the signal region and calculate BR or limit

Similar discriminating observables for the two experiments:
(Secondary vertex displacement, B pointing angle to the P.V., B isolation,…..)

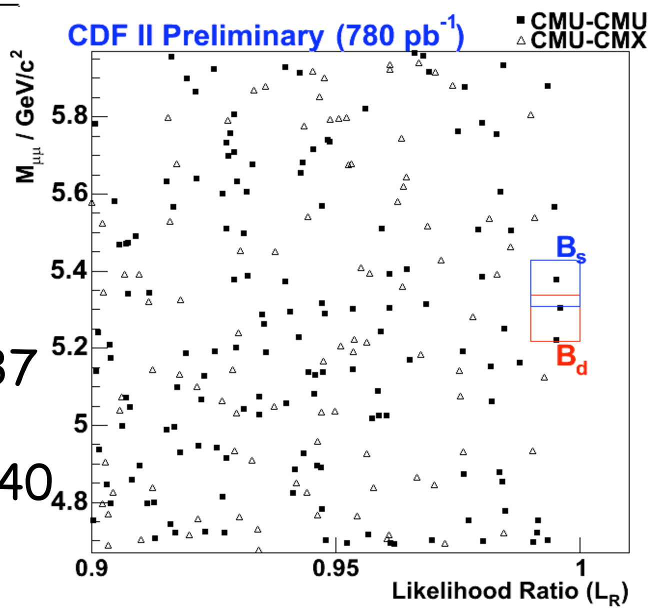
Similar methods for the search optimization:
- CDF: construct a lilkelihood ratio L_R with three discriminating observables and optimize L_R cut on the expected *a-priori* 90% C.L. limit
- DØ: construct a lilkelihood ratio L_R with six discriminating observables and optimize L_R cut on

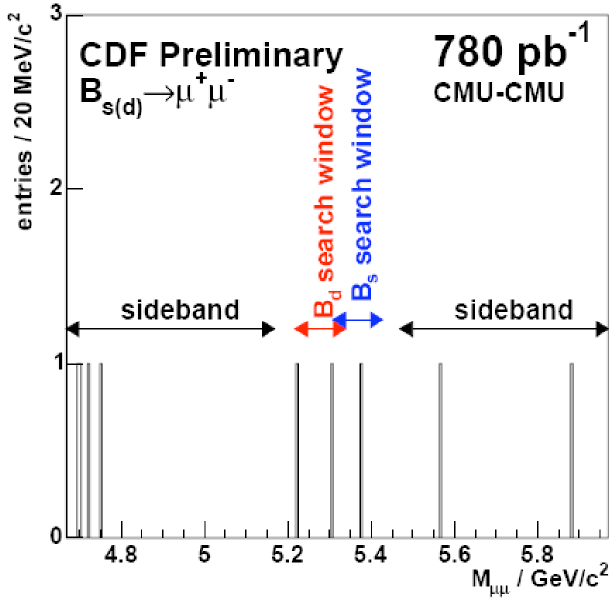
$$a): \frac{\varepsilon_{\mu\mu}}{\langle n_{\text{up.lim.}}(n_{\text{exp.back}})\rangle} \qquad b): \frac{\varepsilon_{\mu\mu}}{1+\sqrt{n_{back}}}$$

→ Same optimal values

$B \to \mu\mu$ event yield after optimization

Thanks to the good mass resolution CDF can resolve $B_s \to \mu\mu$ from $B_d \to \mu\mu$





CDF (780 pb^{-1})

$B_s \to \mu\mu$

observe 1, expect 1.27 ± 0.37

$B_d \to \mu\mu$

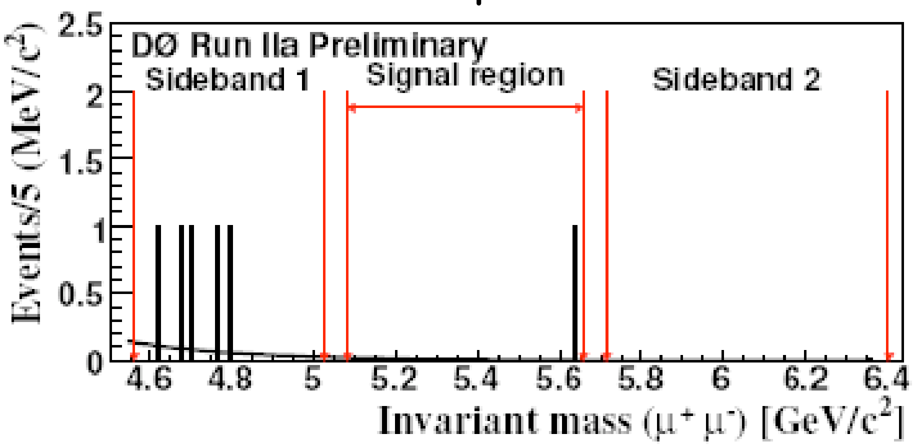
observe 2, expect 2.45 ± 0.40

DØ (2 fb^{-1})

$B_s \to \mu\mu$

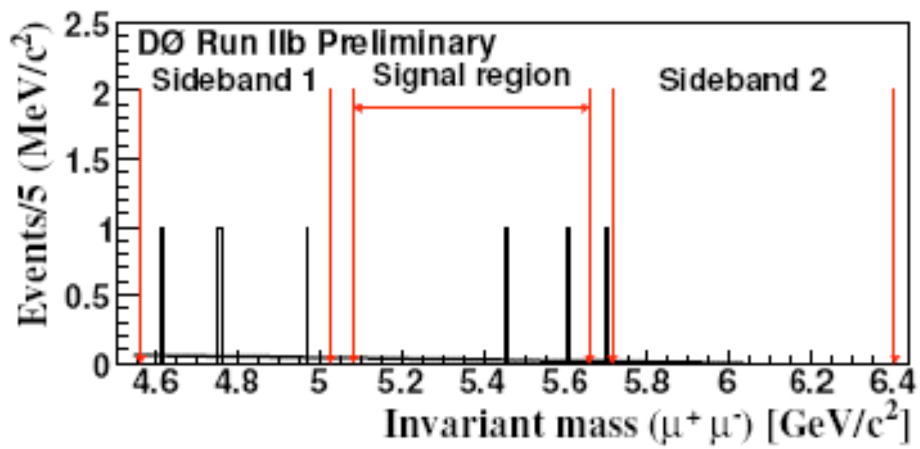
Run IIa (1250 pb^{-1})

observe 1, expect 0.8 ± 0.2



Run IIb (additional silicon layer, 750 pb^{-1})

observe 2, expect 1.5 ± 0.3



Results

- No signal found

- CDF B_s limit (780 pb^{-1})
  - $BR(B_s \rightarrow \mu^+\mu^-) < 8.0\ (10.0) \times 10^{-8}$ at 90% (95%) C.L.
  - $8.0 \times 10^{-8}/3.42 \times 10^{-9}$(SM) ~ 23

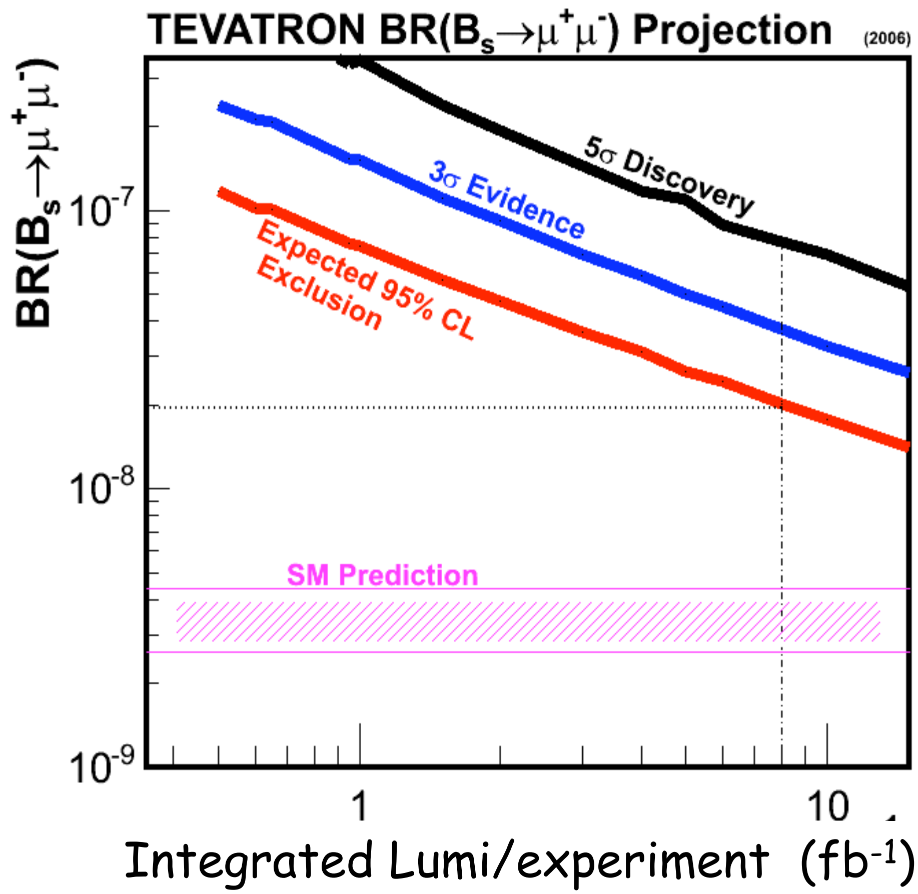
- DØ B_s limit (2 fb^{-1})
  - $BR(B_s \rightarrow \mu^+\mu^-) < 7.5\ (9.3) \times 10^{-8}$ at 90% (95%) C.L.
  - $7.5 \times 10^{-8}/3.42 \times 10^{-9}$(SM) ~ 22

- CDF B_d limit (780 pb^{-1})
  - $BR(B_d \rightarrow \mu^+\mu^-) < 2.3\ (3.0) \times 10^{-8}$ at 90% (95%) C.L.
  - $2.3 \times 10^{-8}/1.0 \times 10^{-10}$(SM) ~ 230
  - Compare Babar (hep-ex/0408096, 110 fb^{-1})
    - $BR(B_d \rightarrow \mu^+\mu^-) < 8.3 \times 10^{-8}$ at 90% C.L.
- Current upper limits probe BR 20 to 200 times higher than SM prediction

Tevatron Expected Reach

- Conservative projection based on sensitivity of current analysis
- Can exclude region of low 10^{-8} with full Run II statistics
- Significantly improved analysis will appear soon…

Any signal at the Tevatron would indicate new physics!!



$B \rightarrow \mu^+\mu^- h$ ($b \rightarrow s l^+ l^-$) decays at Tevatron

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$B_{u,d,s} \to \mu^+\mu^- K^+/K^*/\phi$

- Sensitive to New Physics (Asymmetry and decay rate)

- B^+ and B^0 observed at B-factories

  - $BR(B^+ \to \mu^+\mu^- K^+) = 0.34^{+0.19}_{-0.14} \times 10^{-6}$ (PDG 06)

  - $BR(B^0 \to \mu^+\mu^- K^*) = 1.22^{+0.38}_{-0.32} \times 10^{-6}$ (PDG 06)

- Re-establish signals in Tevatron data and "discover" the unseen $B_s \to \mu^+\mu^- \phi$ decay

  - predicted $BR(B_s \to \mu^+\mu^- \phi) = 16.1 \times 10^{-7}$

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

CDF new results with 920 pb^{-1}, search in all three modes
DØ published a $BR(B_s \to \mu^+\mu^- \phi)$ limit with 450 pb^{-1} (PRD 74, 031107(2006))

Procedure

- Experimental method similar to the $B_s \rightarrow \mu\mu$ analysis
- Normalize signal to analogous $B \rightarrow J/\psi\ h$ ($J/\psi \rightarrow \mu\mu$)

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

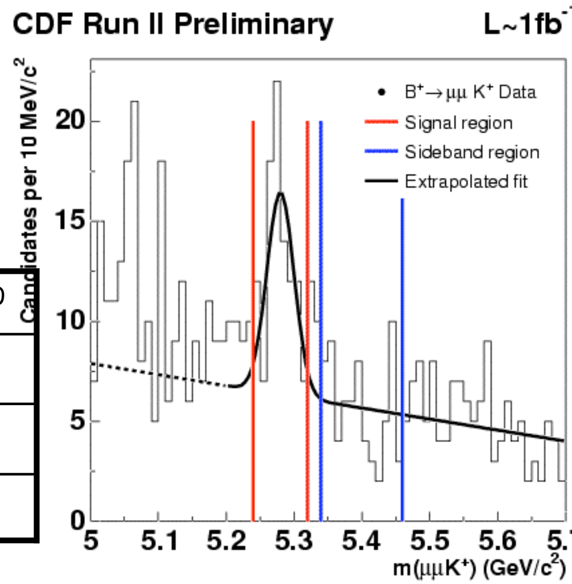
- Exclude J/ψ and ψ' regions in the ($\mu\mu$) invariant mass spectrum
- Blind optimization
- Sideband data for optimization and background estimate
- Monte Carlo and data for efficiency ratios with normalization modes

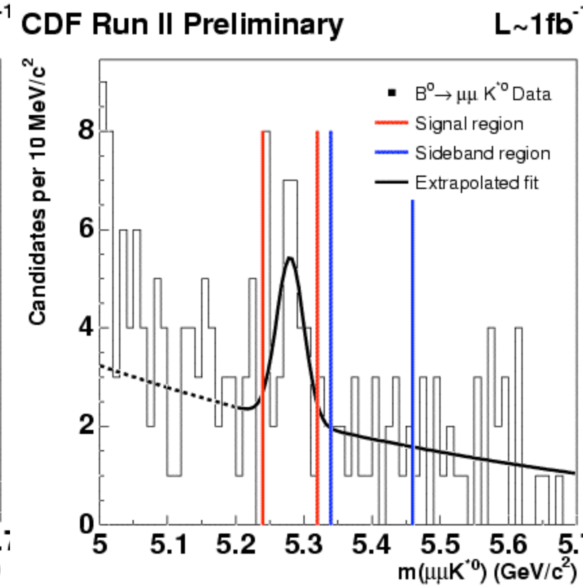
CDF optimizes $\frac{N_{sig}}{\sqrt{N_{sig} + N_{bkg}}}$ DØ optimizes $\frac{\varepsilon_{sig}}{1 + \sqrt{N_{bkg}}}$

B^+ and B^0 yield (CDF)

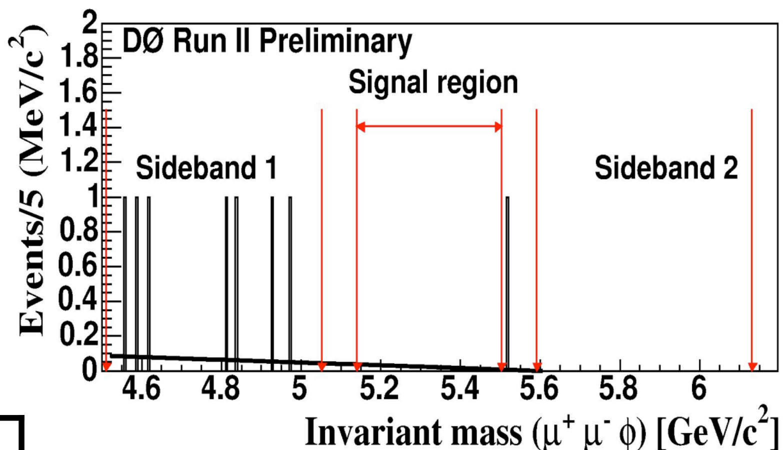
Fit shown only for illustration purpose

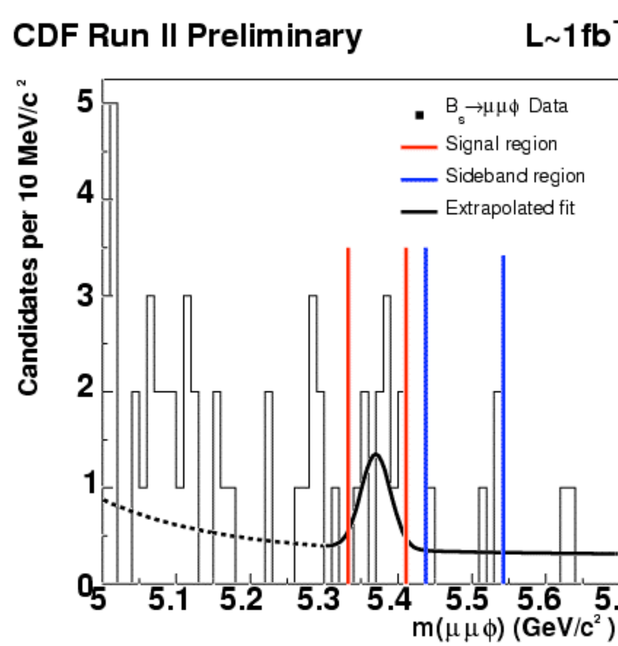
Mode	$B^+ \to \mu^+\mu^- K^+$	$B^0 \to \mu^+\mu^- K^{*0}$
$N_{sig.win.}$	90	35
N_{BG}	45.3 ± 5.8	16.5 ± 3.6
Significance	4.5	2.9





B_s yield





	DØ	CDF
Obs.	0	11
Exp.	1.6±0.6	3.5 ±1.5
pb^{-1}	450	920

2.4 σ significance

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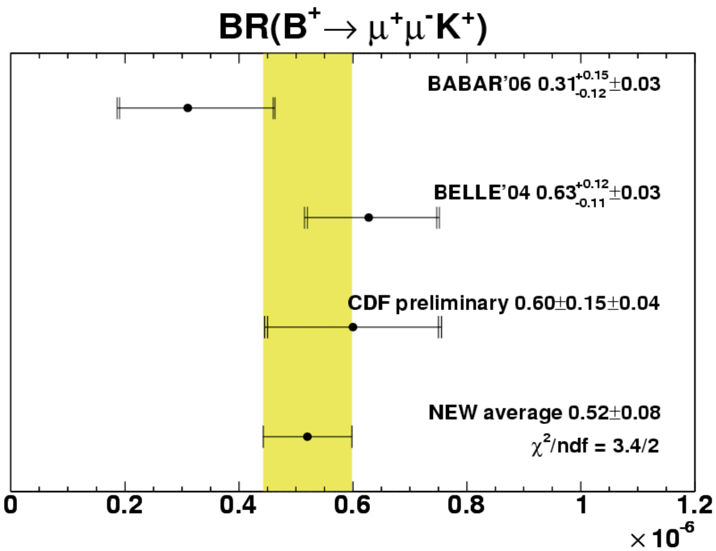
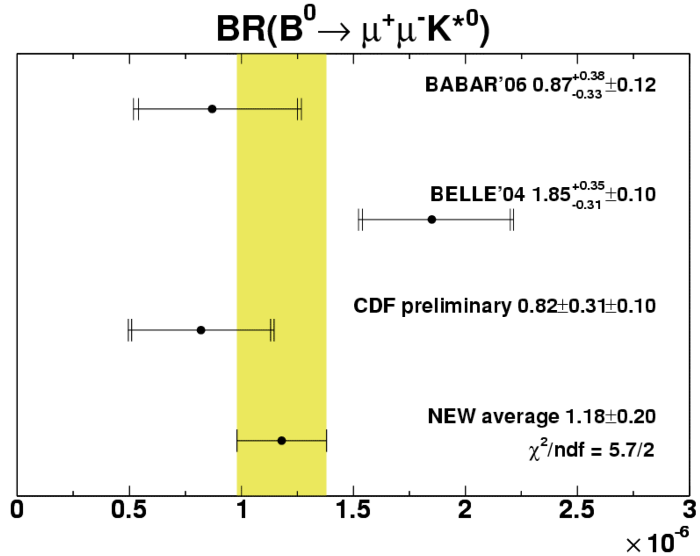
BR (B → μμh) result summary





- Good agreement and similar uncertainty for B-Factories & Tevatron:
  - Babar PRD 73, 092001 (2006) (208 fb-1: ~10 μμK+, ~15 μμK*0)
  - Belle hep-ex/0410006 (250 fb-1: ~40 μμK+, ~40 μμK*0)

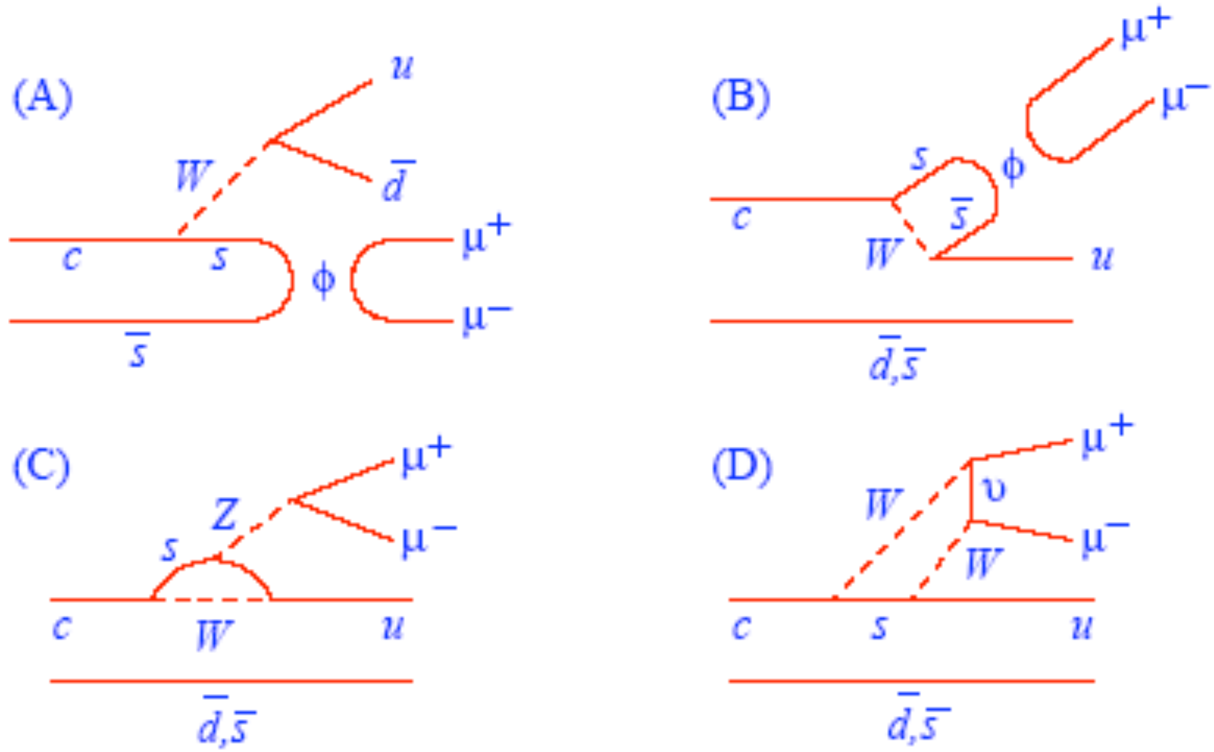
Tevatron results summary

- BR($B^+ \to \mu\mu K+$) = [0.60 ± 0.15(stat.) ± 0.04(sys.)]x10^{-6} CDF, 45 ev.
- BR($B^0 \to \mu\mu K^{*0}$) = [0.82 ± 0.31(stat.) ± 0.10(sys.)]x10^{-6} CDF, 45 ev.
- BR($B_s \to \mu\mu\phi$) < 2.4 x10^{-6} @ 90% C.L., CDF, 920 pb^{-1}, Bayesian approach
  = [1.16 ± 0.56(stat.) ± 0.42(sys.)]x10^{-6}
- BR($B_s \to \mu\mu\phi$) < 3.3 x 10^{-6} @ 90% C.L. DØ, 450 pb-1

$D^+ \rightarrow \pi^+\mu^+\mu^-$ decay at Tevatron

Motivation

- Non resonant $D^+ \rightarrow \mu^+\mu^-\pi^+$ is a good place to search for new physics in up-type FCNC, enhanced in SUSY R parity violation or little Higgs models
- Strategy: establish first resonant $D_s^+ \rightarrow \phi\pi^+ \rightarrow \mu^+\mu^-\pi^+$ and search then D^+ candidates in the continuum for non-resonant decay.



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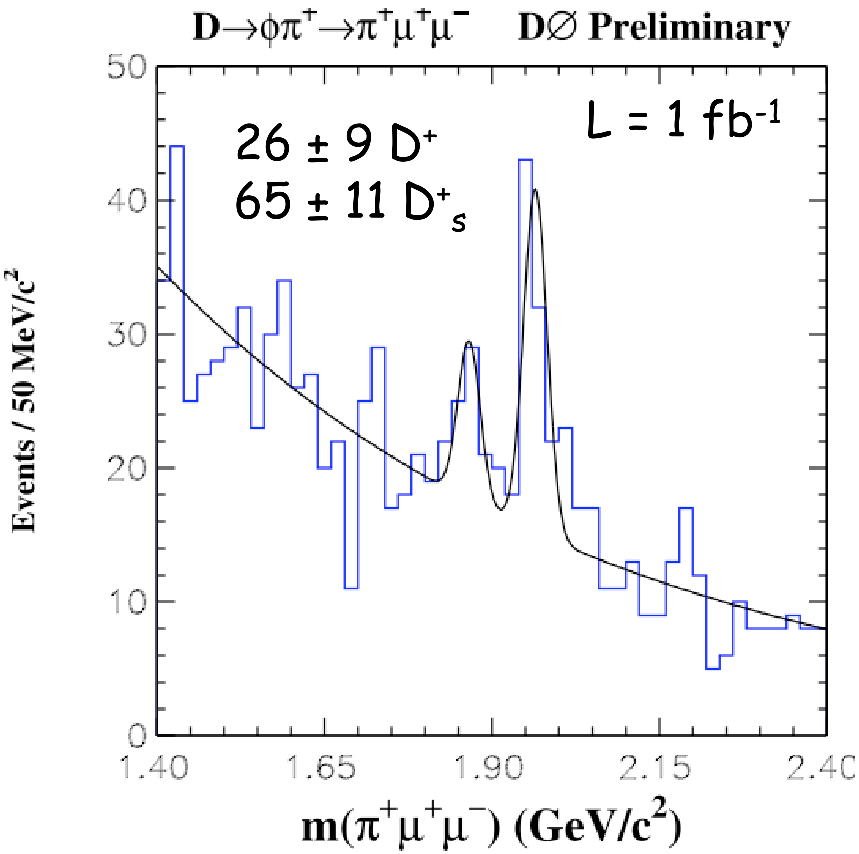
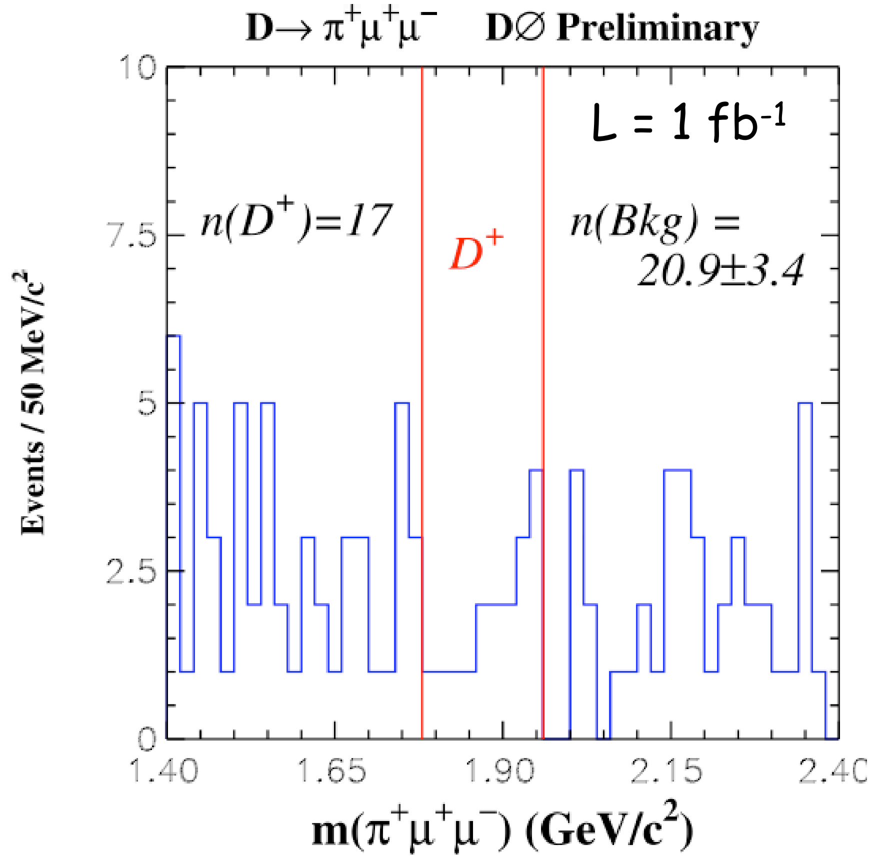
$D^+ \to \phi\pi^+ \quad \phi \to \mu^+\mu^-$



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

(ϕ mass window excluded)



$$\frac{BR(D^+ \to \phi\pi^+ \to \pi^+\mu^+\mu^-)}{BR(D_s^+ \to \phi\pi^+) \times BR(\phi \to \mu^+\mu^-)} = 0.17 \pm 0.07 \pm 0.05$$

$$BR(D^+ \to \phi\pi^+ \to \pi^+\mu^+\mu^-) = (1.75 \pm 0.7 \pm 0.5) \times 10^{-6}$$

Expected value is 1.77×10^{-6} from the product b.f.

$$\frac{BR(D^+ \to \pi^+\mu^+\mu^-)}{BR(D_s^+ \to \phi\pi^+) \times BR(\phi \to \mu^+\mu^-)} < 0.46 \;\; @90\%\ C.L.$$

$$BR(D^+ \to \pi^+\mu^+\mu^-) < 4.7 \times 10^{-6} \;\; @90\%\ C.L.$$

Most stringent limit to date in this modes

$B \rightarrow hh$ modes at Tevatron

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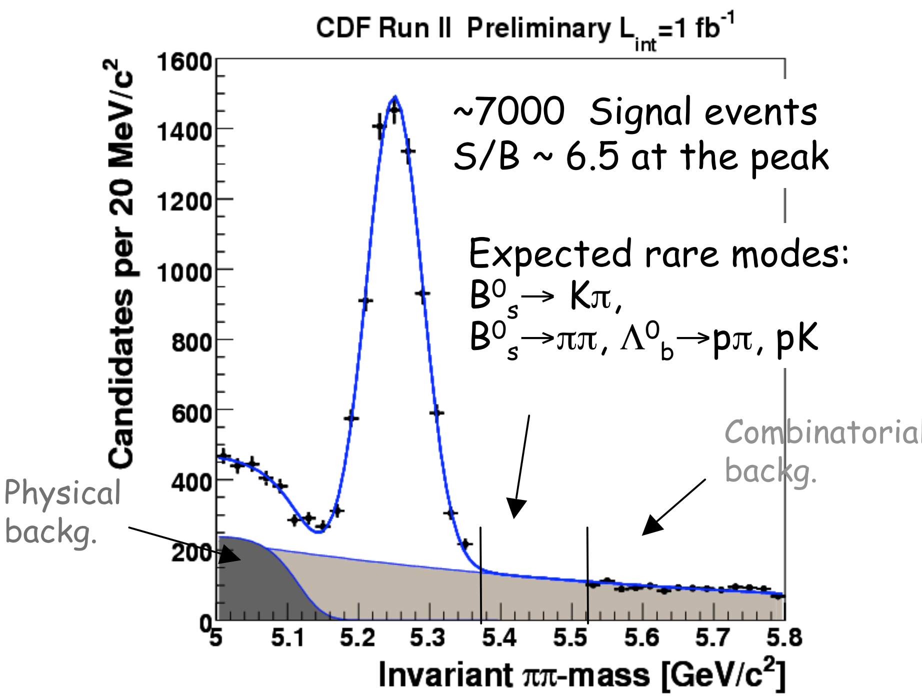
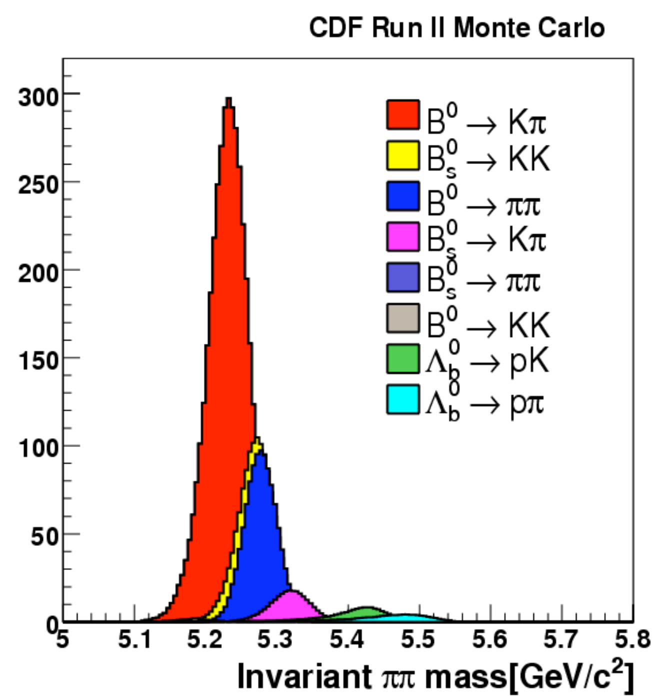
$B^0/B^0_s \to h^+h'^-$

- an useful tool for probing CKM
- sensitive to the New Physics contributions in the Penguin diagrams
- sensitive to New Physics effects via anomalies in A_{CP}





Despite excellent mass resolution (~22 MeV/c^2), modes overlap an unresolved peak, and PID resolution is insufficient for event-by-event separation.

Hence, fit signal composition with a Likelihood that combines information from kinematics (mass and momenta) and particle ID (dE/dx).

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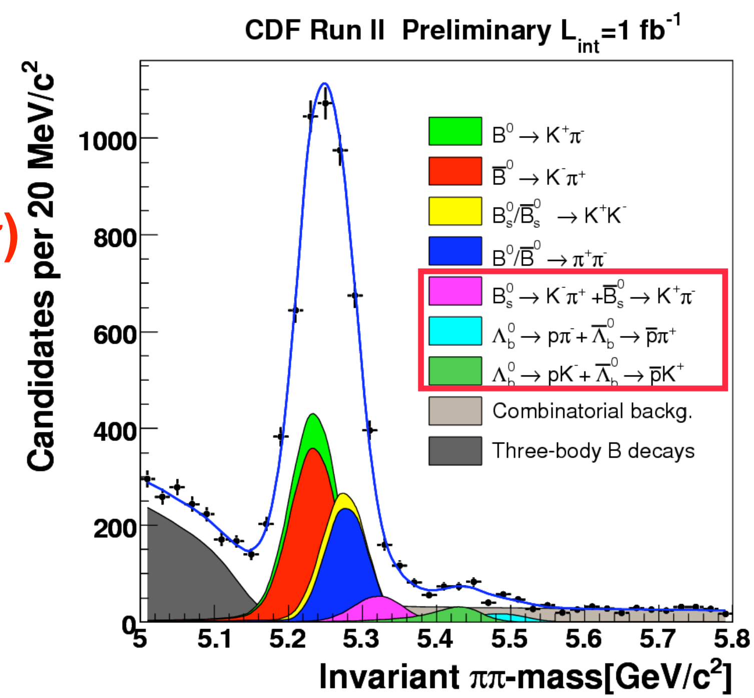
New rare modes observed

$$N_{raw}(B_s^0 \to K^- \pi^+) = 230 \pm 34(stat.) \pm 16(syst.)$$ **(8σ)**

$$N_{raw}(\Lambda_b^0 \to p\pi^-) = 110 \pm 18(stat.) \pm 16(syst.)$$ **(6σ)**

$$N_{raw}(\Lambda_b^0 \to pK^-) = 156 \pm 20(stat.) \pm 11(syst.)$$ **(11σ)**



$$\frac{BR(\Lambda_b^0 \to p\pi^-)}{BR(\Lambda_b^0 \to pK^-)} = 0.66 \pm 0.14(stat.) \pm 0.08(syst.)$$

In agreement with the theoretical expectation
(Phys.Rev.D63(2001)074001)

$$\frac{f_s}{f_d}\frac{BR(B_s^0 \to K^-\pi^+)}{BR(B^0 \to K^+\pi^-)} = 0.066 \pm 0.010(stat.) + 0.010(syst.)$$

using HFAG:

$$BR(B_s^0 \to K^-\pi^+) = (5.0 \pm 0.75(stat.) \pm 1.0(syst.)) \times 10^{-6}$$

In agreement with the latest theoretical expectation
(Phys.Rev.D74(2006)014003)

Upper limits: $B^0_s \to \pi^+\pi^-$ and $B^0 \to K^+K^-$

$$\frac{f_s}{f_d}\frac{BR(B_s^0 \to \pi^+\pi^-)}{BR(B^0 \to K^+\pi^-)} = 0.007 \pm 0.004(stat.) \pm 0.005(syst.)$$

$$\frac{BR(B^0 \to K^+K^-)}{BR(B^0 \to K^+\pi^-)} = 0.020 \pm 0.008(stat.) \pm 0.006(syst.)$$

using HFAG:

$$BR(B^0 \to K^+K^-) = (0.39 \pm 0.16(stat.) \pm 0.12(syst)) \times 10^{-6}$$ **($< 0.7 \times 10^{-6}$ @ 90% C.L.)**

Expected $[0.01 - 0.2] \cdot 10^{-6}$ [Beneke&Neubert NP B675, 333(2003)]

$$BR(B_s^0 \to \pi^+\pi^-) = (0.53 \pm 0.31(stat.) \pm 0.40(syst)) \times 10^{-6}$$ **($< 1.36 \times 10^{-6}$ @ 90% C.L.)**

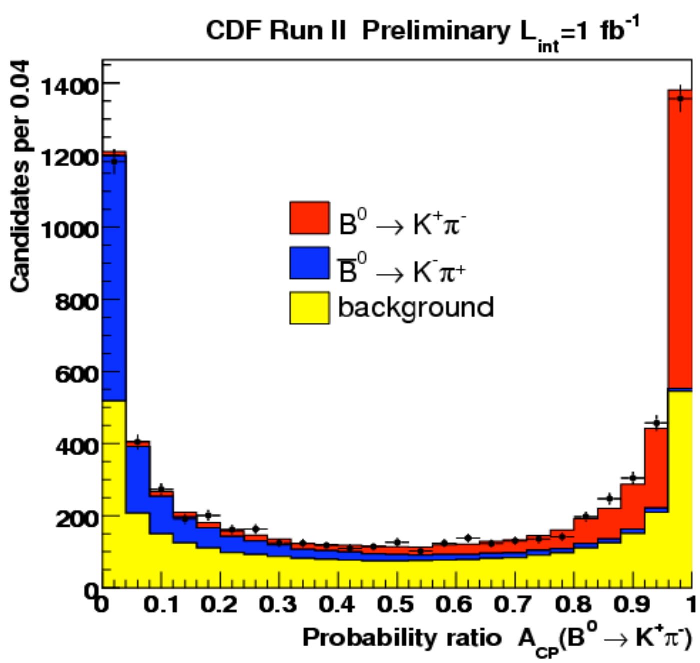
Expected: $[0.007 - 0.08] \cdot 10^{-6}$ [Beneke&Neuber t NP B675, 333(2003)]
Expected: $[0.42 \pm 0.06] \cdot 10^{-6}$ [Ying Li et al. hep-ph/0404028]

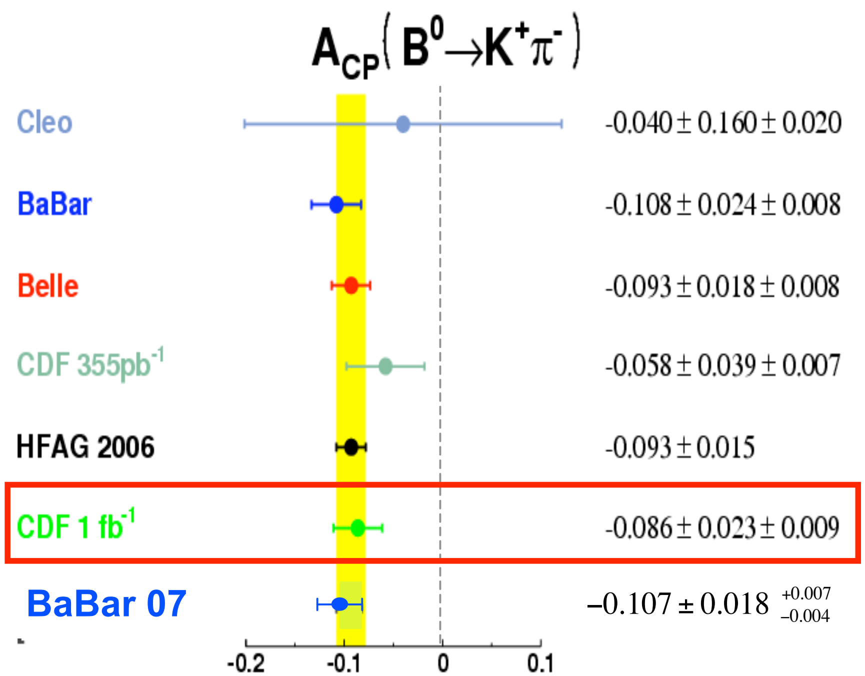
World's best upper limits for $B^0_s \to \pi^+\pi^-$ while same resolution of B-factories for $B^0 \to K^+K^-$. Both modes are annihilation-dominated decays and no observed yet them – they are hard to predict exactly.

New results on $A_{CP}(B^0 \to K^+\pi^-)$ with 1 fb^{-1}

$$A_{CP} = \frac{N(\overline{B}^0 \to K^-\pi^+) - N(B^0 \to K^+\pi^-)}{N(\overline{B}^0 \to K^-\pi^+) + N(B^0 \to K^+\pi^-)} = -0.086 \pm 0.023(stat.) \pm 0.009(syst.)$$

Plot of pdf(B^0)/[pdf(B^0)+pdf($\overline{B}^0$)] shows the good separation achieved between B^0 and $\overline{B}^0$ ($M_{\pi\pi}$, α, ptot, dE/dx)





- Tevatron and B-factories results agree
- More robust SM test is the comparison with $A_{CP}(B^0_s \to K^-\pi^+)$

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New results for the $B^0_s \to K^-\pi^+$ with 1 fb^{-1}

$$\frac{f_s}{f_d}\frac{BR(B^0_s \to K^-\pi^+)}{BR(B^0 \to K^+\pi^-)} = 0.066 \pm 0.010(stat.) \pm 0.010(syst.)$$

using HFAG: $BR(B^0_s \to K^-\pi^+) = (5.0 \pm 0.75(stat.) \pm 1.0(syst)) \times 10^{-6}$

Large SM expectation for this asymmetry ~0.37 (calculated with new measured BR).

$$A_{CP} = \frac{N(\overline{B}^0_s \to K^+\pi^-) - N(B^0_s \to K^-\pi^+)}{N(\overline{B}^0_s \to K^+\pi^-) + N(B^0_s \to K^-\pi^+)} = 0.39 \pm 0.15(stat.) \pm 0.08(syst.)$$

Compare rates and asymmetries of $B^0 \to K^+\pi^-$ and $B^0_s \to K^-\pi^+$ - unique to CDF - to probe New Physics with minimal assumption, just SM. [Lipkin, Phys. Lett. B621:126, .2005],[Gronau Rosner Phys.Rev. D71 (2005) 074019]. SM predict that:

$$\left|A(B_s \to \pi^+K^-)\right|^2 - \left|A(\overline{B}_s \to \pi^-K^+)\right|^2 = \left|A(\overline{B}_d \to \pi^+K^-)\right|^2 - \left|A(B_d \to \pi^-K^+)\right|^2$$

Using HFAG:

$$\frac{\left|A(\overline{B}_d \to \pi^+K^-)\right|^2 - \left|A(B_d \to \pi^-K^+)\right|^2}{\left|A(B_s \to \pi^+K^-)\right|^2 - \left|A(\overline{B}_s \to \pi^-K^+)\right|^2} = 0.84 \pm 0.42(stat.) \pm 0.15(syst.)$$

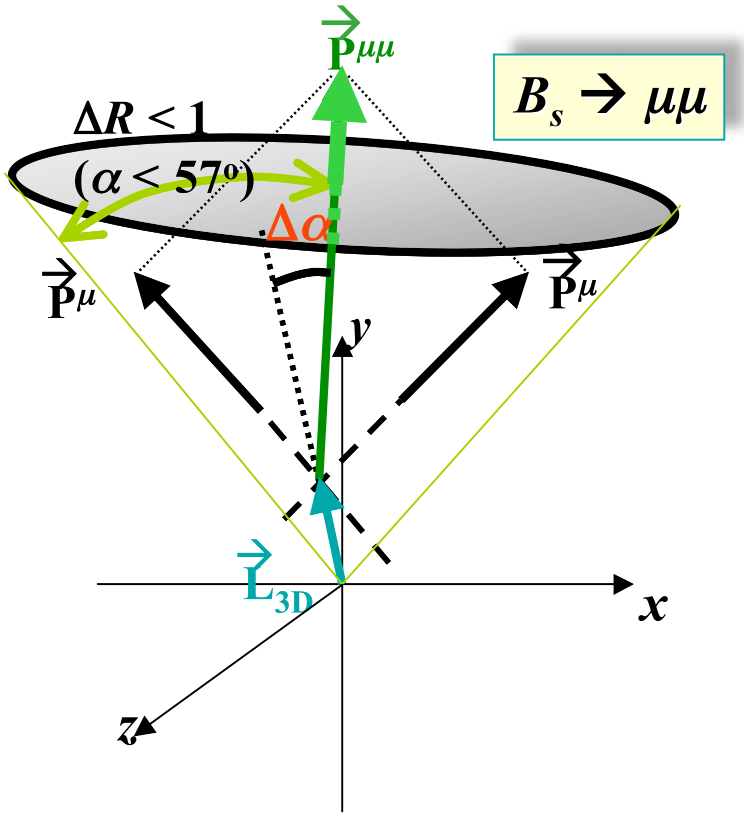
(=1 SM)

Conclusions

- Tevatron is demonstrated to be a good place to study B and D rare decays
  - $B \to \mu^+\mu^-$
    - Current values entering the 10^{-8} territory
    - First Tevatron result with 2 fb^{-1} from DØ
    - Any signal at Tevatron will be evidence of New Physics
  - $B \to \mu^+\mu^- h$
    - New solid $B \to \mu\mu K$ signals from CDF
    - A 2.4 σ excess in the $B_s \to \mu\mu\phi$ reported from CDF, upper limit close to SM prediction
  - $D \to \mu^+\mu^- h$
    - Best limit from DØ
  - $B \to h^+h'^-$
    - First observation of $B_s \to K^-\pi^+$, $\Lambda^0_b \to p\pi^-$, $\Lambda^0_b \to pK^-$
    - First measurement of DCPV in B_s: $A_{CP}(B_s \to K^-\pi^+)$ appears to be large in agreement with expectation
- Now, over 2 fb^{-1} on tape: more significantly improved results coming soon ($D \to \mu\mu$ analysis in progress)

BACKUP

Discriminating observables



- B vertex displacement:

CDF $\lambda = \dfrac{cL_{3D}M}{|\vec{p}(B)|}$

D0 L_{xy} / σ_{Lxy}

- Isolation (Iso):

$$Iso = \frac{p_T(B)}{p_T(B) + \sum_i p_T^i(\Delta R_i < 1)}$$

(fraction of p_T from $B \rightarrow \mu\mu$ within $\Delta R = (\Delta\eta^2 + \Delta\phi^2)^{1/2}$ cone of 1)

- "pointing ($\Delta\alpha$)":

$$\Delta\alpha = \angle(\vec{p}(B) - \vec{L}_{3D})$$

(angle between B_s momentum and decay axis)

Optimization

- CDF constructs a likelihood ratio using discriminating variables
  - 3D proper decay length λ
  - pointing angle $\Delta\alpha$
  - Isolation

- D0 constructs a likelihood ratio using six discriminating variables
  - 2D decay length significance
  - pointing angle $\Delta\alpha$
  - Isolation
  - B impact parameter
  - minimal muons impact parameter
  - χ^2 vertex probability

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

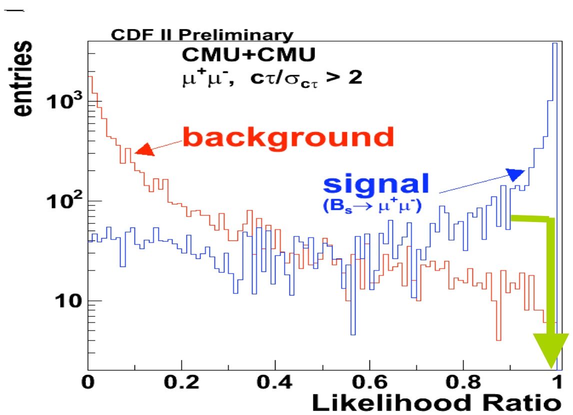
$P_{s/b}$ is the probability for a given sig/bkg to have a value of *x*, where *i* runs over all variables.

- CDF optimize L_R cut on the expected a-priori 90% C.L. limit.
L_R > 0.99 is the optimal value

- D0 optimize L_R on

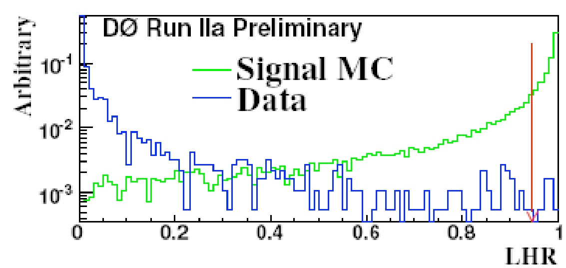
$$\begin{cases} a): \dfrac{\varepsilon_{\mu\mu}}{\langle n_{\text{up.lim.}}(n_{\text{exp.back}})\rangle} \\ b): \dfrac{\varepsilon_{\mu\mu}}{1+\sqrt{n_{back}}} \end{cases}$$

Same optimal values

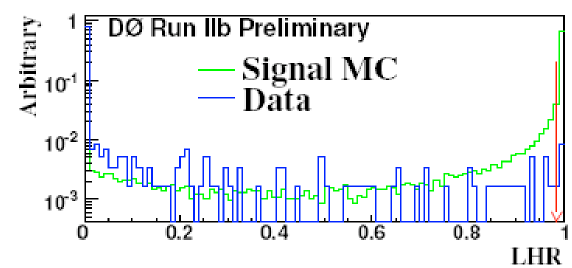


Pa

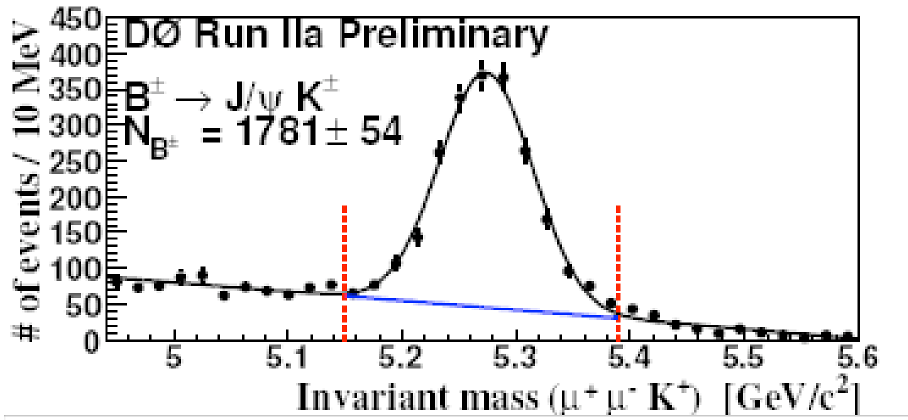
Run IIa L_R > 0.946

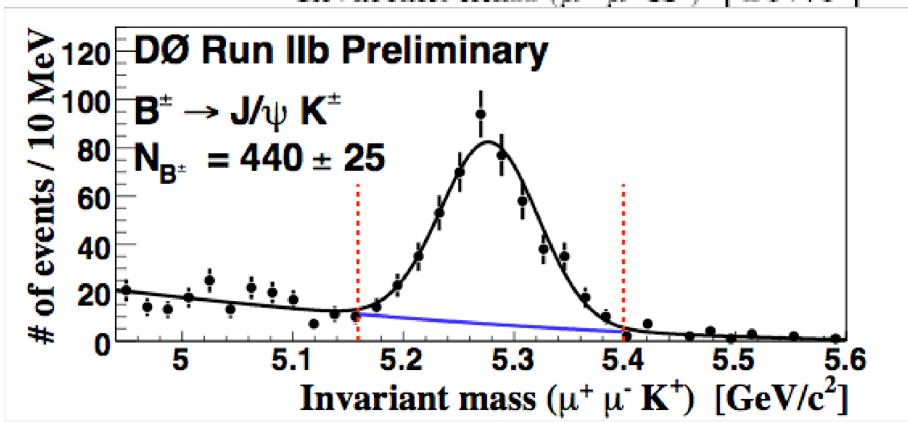


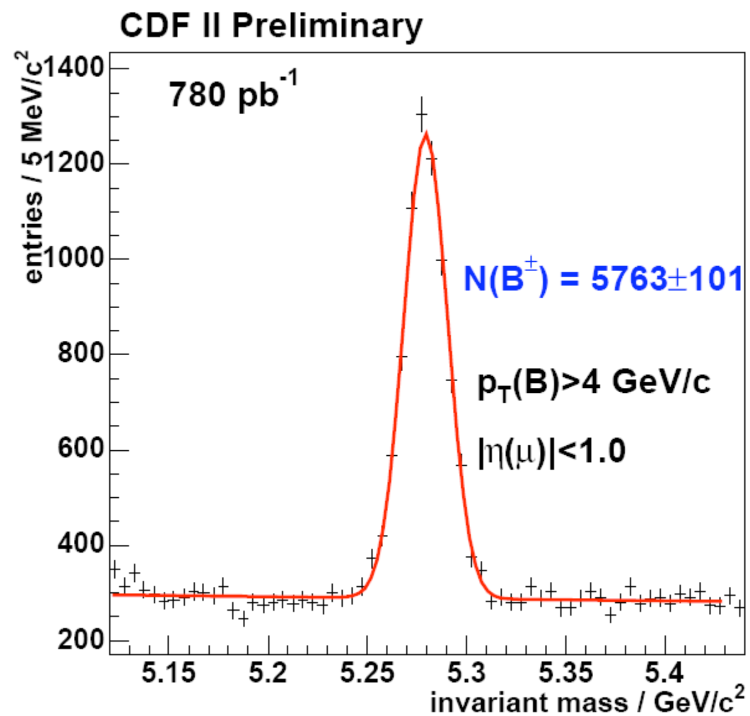
Run IIb L_R > 0.986



Normalization: $B^+ \to J/\psi\ K^+$







- Need $B^+ \to J/\psi\ K^+$ yield to extract limits
- CDF (780 pb^{-1}) : 4200 (CMU-CMU) + 1550 (CMU-CMX)
- D0 (2 fb^{-1}): 1781 (Run IIa) + 440 (Run IIb)

Background estimation

Combinatorics: Extrapolated background from side-bands to signal region assume linear shape

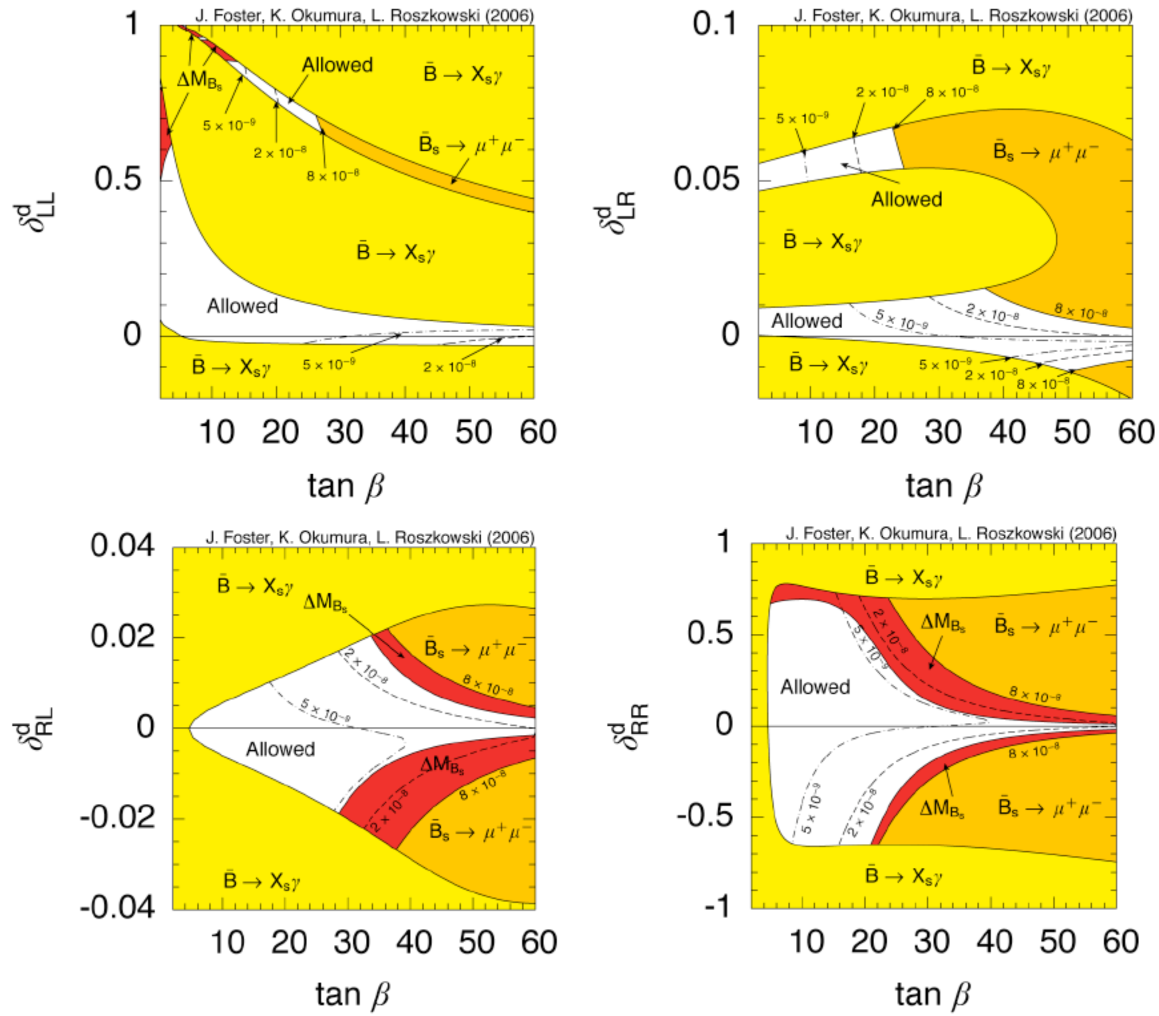
CDF signal region is also contaminated by $B \to h^+h^-$
(e.g. $B \to K^+K^-$, $K^+\pi^-$, $\pi^+ \pi^-$)
- $K, \pi \to$ muon fake rates measured from data
- Convolute fake rates with expected $Br(B \to h^+h^-)$ to estimate #
- Total bkg = combinatoric + ($B \to hh$)

	B_s Signal Window		B_d 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
$B \to h^+h^-$	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

Impact on New Physics

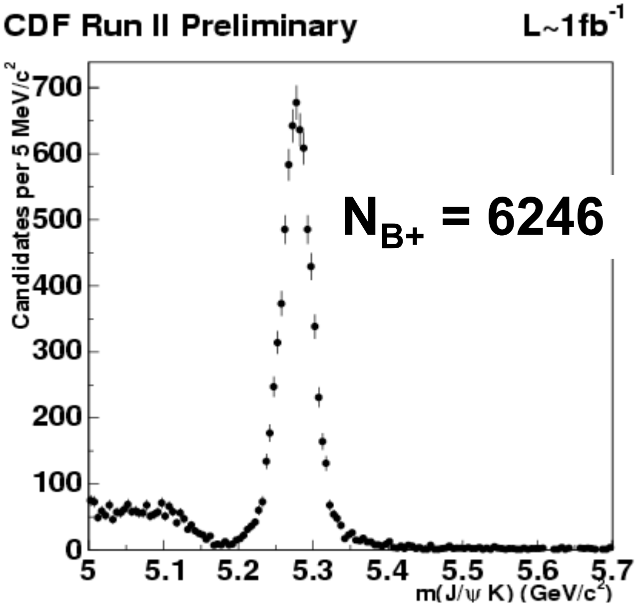
- Current constraints from Δm_s and $B_s \to \mu\mu$ are differently effective in the new physics parameter phase space

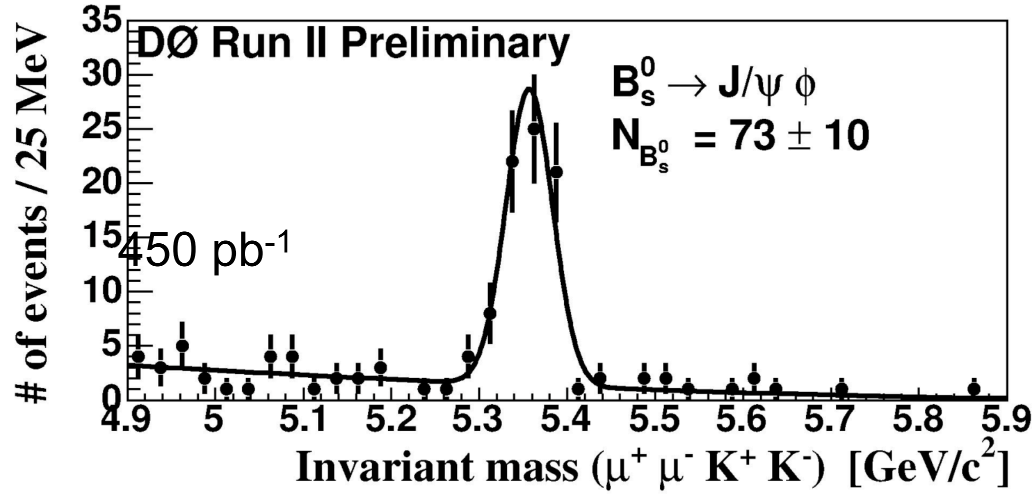
- Improved limits on $B_s \to \mu\mu$ can further constraint SUSY at large tanβ

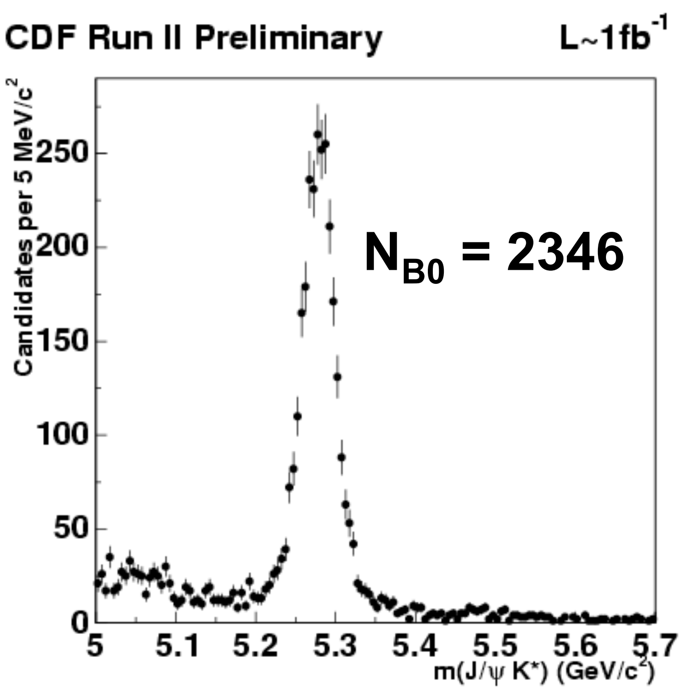


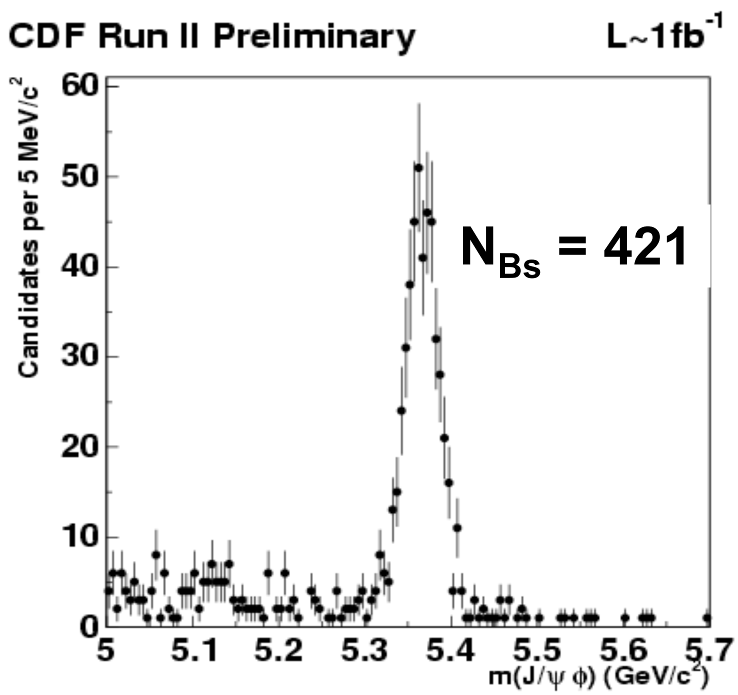
Foster,Okumura,Roszkowski
Phys.Lett. B641 (2006) 452

Normalization modes

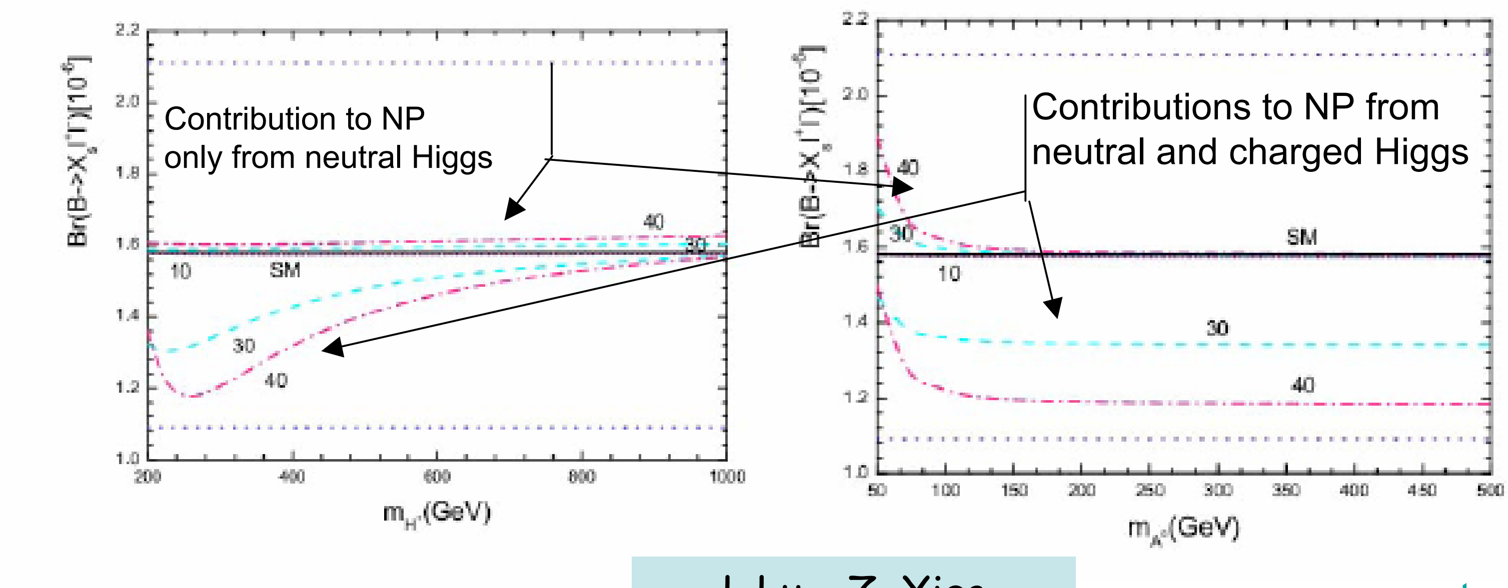








Impact on New Physics

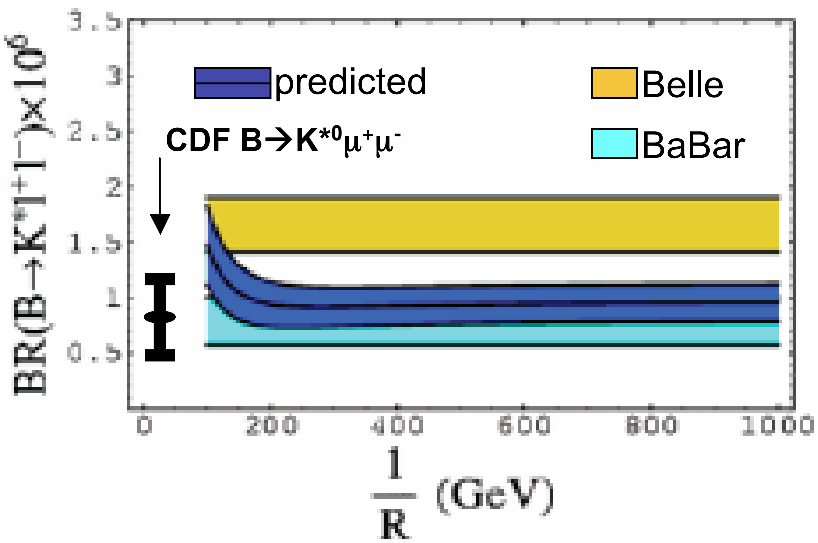


BR(B→X_sl+l-)
B-Factories
average:
$(1.60 \pm 0.51)\times10^{-6}$

Tevatron can contribute to squeeze the error

L.Lu – Z. Xiao
(hep-ph/0611252v2)

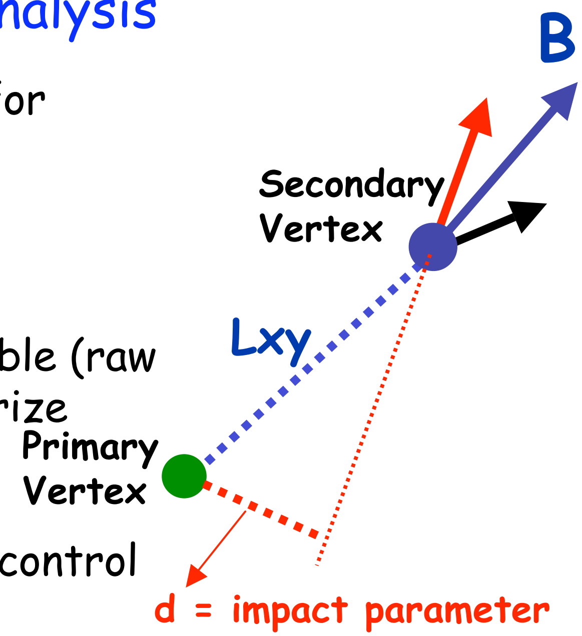
tanβ = 30
tanβ = 40



A special NP scenario:
one universal extra dimension

F.De Fazio
hep-ph/0610208

Strategy for the $B^0_{(s)} \to h^+h'^-$ analysis

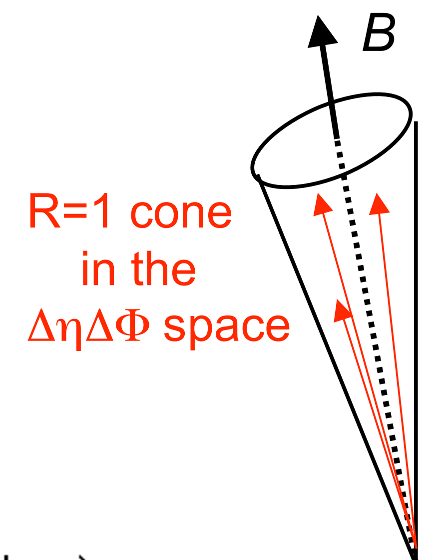


• Fully exploit the selection power of the CDF L2 SVT trigger for opposite charge track pairs originated form a displaced vertex (a 8500 events $B^0_{(s)} \to h^+h'^-$ signal just after trigger selection)

• Tighten trigger cuts in the offline optimization procedure by minimizing the expected uncertainty on each individual observable (raw asymmetry, event yield); analytical functions used to parameterize signal and background in the pseudo-experiments

• Add the isolation cut (efficiency measured in the $B^+ \to J/\psi\ K^+$ control sample)

$$I_{R=1}(B) = \frac{p_T(B)}{p_T(B) + \sum_i p_T(i)}$$



• Evaluate the sample composition with an unbinned Likelihood fit combining kinematics and PID

• Normalize to the most abundant $B^0 \to K^+\pi^-$ mode for BRs

$$BR(B_s \to h^+h'^-) = \frac{N(B_s \to h^+h'^-)}{N(B^0 \to K^+\pi^-)} \times \frac{f_b}{f_s} \times \frac{\varepsilon^{tot}_{B^0 \to K^+\pi^-}}{\varepsilon^{tot}_{Bs \to h^+h'^-}} \times BR(B^0 \to K^+\pi^-)$$

• Only different K+/K- interactions with material matter for correcting ACP

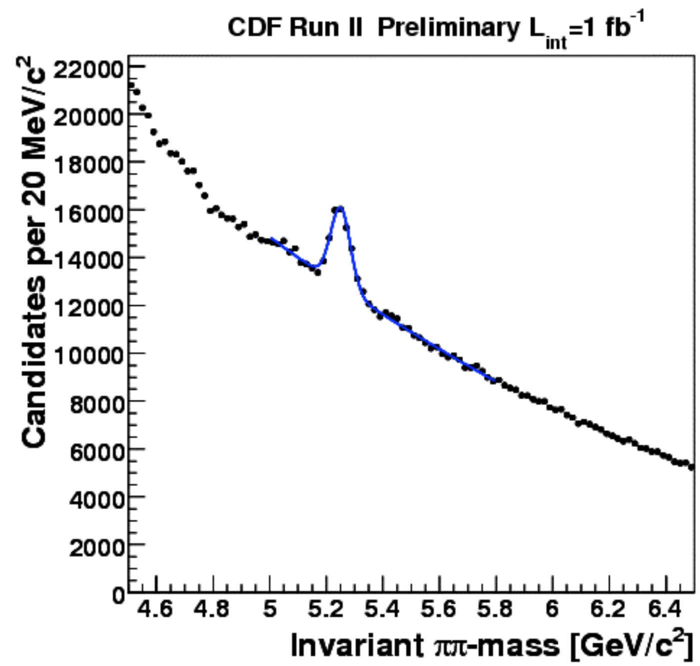
$$A_{CP}(B^0 \to K^+\pi^-) = \frac{N_{raw}(\overline{B}^0 \to K^-\pi^+) \cdot \frac{\varepsilon(K^+\pi^-)}{\varepsilon(K^-\pi^+)} - N_{raw}(B^0 \to K^+\pi^-)}{N_{raw}(\overline{B}^0 \to K^-\pi^+) \cdot \frac{\varepsilon(K^+\pi^-)}{\varepsilon(K^-\pi^+)} + N_{raw}(B^0 \to K^+\pi^-)}$$

ππ invariant mass: offline confirmation of the trigger selection

Signal (BR ~ 10^{-5}) visible with just offline trigger cuts confirmation:

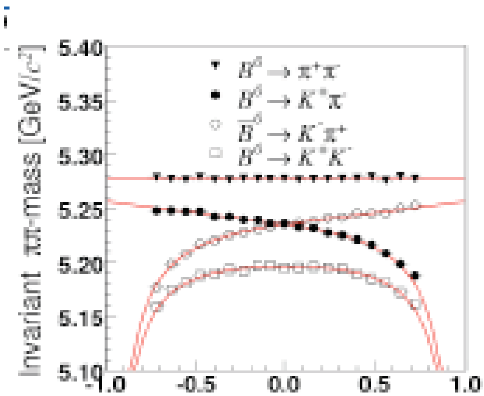
L2 trigger selection

variable	cut
# axial COT SL	≥ 2(5 hits)
# stereo COT SL	≥ 2(5 hits)
# $r-\phi$ SVXII hits	≥ 3
tracking algorithm	sil. r-ϕ and 90°z hits
$\mid \eta \mid$	≤ 1
p_T	≥ 2 GeV/c
$p_T(1) + p_T(2)$	≥ 5.5 GeV/c
$q(1) \cdot q(2)$	< 0
$\Delta\phi$	$\geq 20°$
$\Delta\phi$	$\leq 135°$
$\mid d_0 \mid$	$\geq 100\ \mu m$
$\mid d_0 \mid$	≤ 1 mm
$d_0(1) \cdot d_0(2)$	$< 0\ cm^2$



a bump of ~ 14500 events with S/B ≈ 0.2 (at peak) in ππ-invariant mass

Separating decays modes



$\alpha = (1 - p_1 / p_2) \times q_1$

Un-binned ML fit using 5 observables (M_{pp}, p_{tot}, α, ID_1, ID_2)

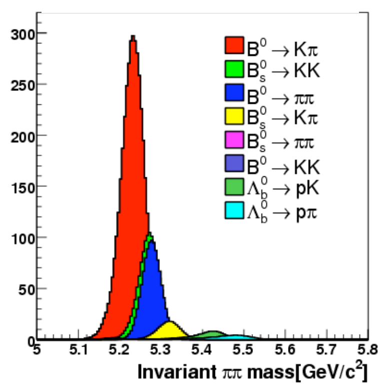
$$\mathscr{L}(\vec{\theta}) = \prod_{i=1}^{N} \mathscr{L}_i(\vec{\theta})$$

fraction of j[th] mode, to be determined by the fit

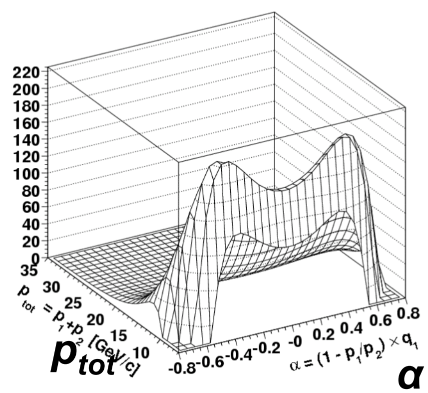
$$\mathscr{L}_i(\vec{\theta}) = (1-b)\sum f_j \mathscr{L}_j^{\text{sign}} + b\mathscr{L}^{\text{bckg}}$$

$$pdf_j^{\text{m}}(m_{\pi\pi}|\alpha, p_{tot}; \vec{\theta}) \cdot pdf_j^{\text{p}}(\alpha, p_{tot}; \vec{\theta}) \cdot pdf_j^{\text{PID}}(\text{ID}_1, \text{ID}_2 | p_{tot}, \alpha; \vec{\theta})$$

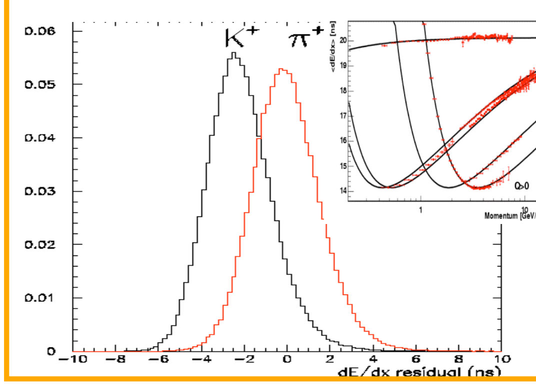
mass term



momentum term



PID term (dE/dx)

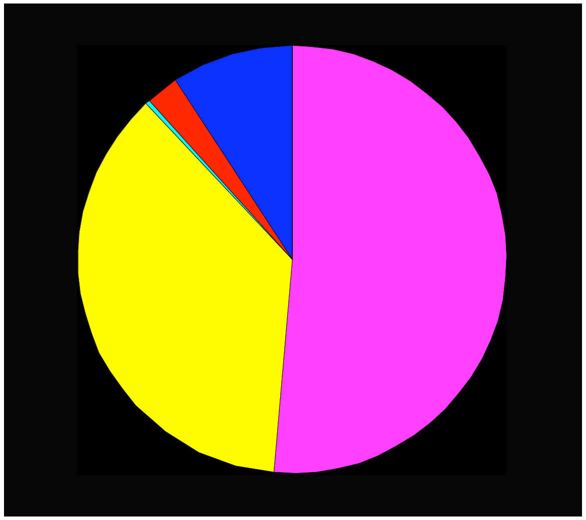


Signal shapes: from MC and analytic formula
Background shapes: from data sidebands

sign and bckg shapes
from $D^0 \to K^- \pi^+$

Systematics $A_{CP}(B^0 \rightarrow K^+\pi^-)$

- dE/dx model (±0.0064);
- nominal *B*-meson masses input to the fit (±0.005);
- global scale of masses;
- charge-asymmetries (±0.001);
- combinatorial background model (±0.003).



Total systematic uncertainty is 0.9%, smaller than the 2.3% statistical uncertainty. Although the accurate dE/dx calibration/parameterization uses the huge data sample of tagged $D^0 \rightarrow K^-\pi^+$ the dominant systematics is due to the dE/dx.

$B \to h^+h^-$: prospects for RunII

- Until the beginning of the planned Y(5S) run at Belle and the beginning of LHCb (at least fall 2008) only CDF has
  simultaneous access to B^0_s , B^0_d (plus B-baryons)
- $A_{CP}(B^0 \to K\pi)$ at ≈ 1% and $A_{CP}(B^0_s \to K\pi)$ at ≈ 5%
- High precision measurements for all BRs
  - Opportunity to observe annihilation modes $B^0 \to KK$, $B^0_s \to \pi\pi$
  - Measurements of BR/A_{CP} $\Lambda^0_b \to pK/p\pi$
- Time-dependent $A_{CP}(t)$ for $B^0 \to \pi\pi$, $B^0_s \to KK$, all ingredients are ready $\Delta m_s, \epsilon D^2 \approx 4\%$