Charmless B decays at CDF

Beauty 2005

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B-Physics at Hadron Machines

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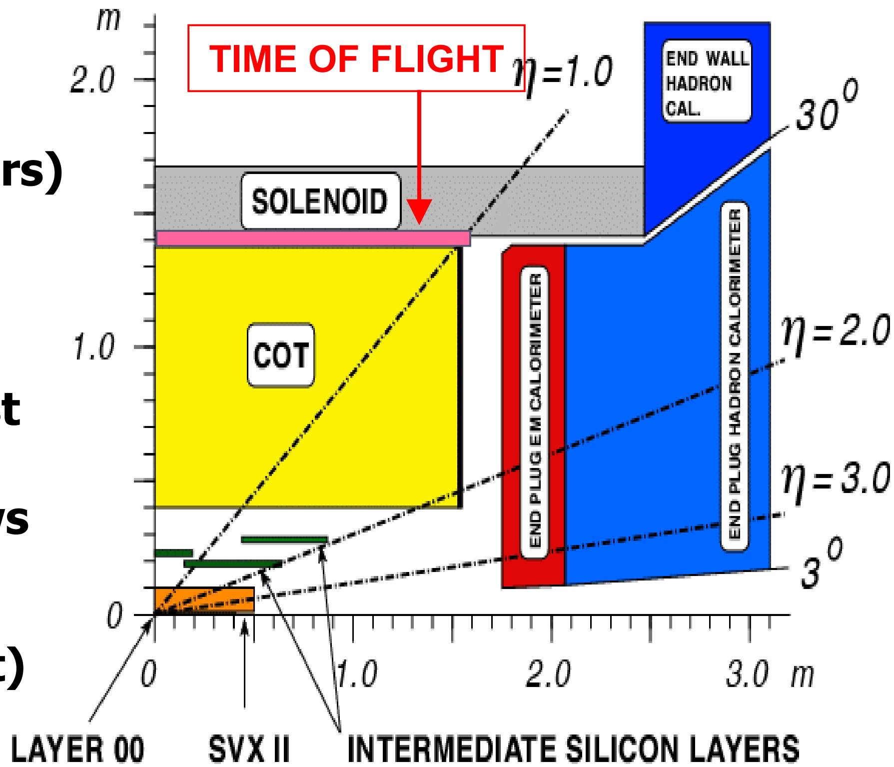
Charmless decays in hadronic machines

- Why hadronic machines ?
  - Large B_d, B_u yields (comparable with B-factories)
  - Additional access to B_s and Λ_b
- Charmless 2-body B decays are a laboratory for understanding the CKM matrix and looking for new physics.
  - $B \to PP$: BR and A_{CP} predictable and sensitive to CKM parameters (γ)
  - $B \to VV/PV$: Study polarization and CP violation
- Special interest:
  - $B_s \to K^+K^-$ & $B_d \to \pi^+\pi^-$: sensitive to γ [R. Fleischer, Phys. Lett. 459,306 (1999)]
  - $B_s \to K^+K^-$: CP-eigenstate with sizeable BR, sensitive to $\Delta\Gamma_s$.
  - Hint NP in ϕK_s (ICHEP04), if true, also visible in: $B_{d,u} \to \phi K^*$,$B_s \to \phi\phi$

In this talk L_{int}=180(360) pb^{-1} → TODAY about 700 pb^{-1} on tape

CDFII: the first hadronic experiment to study charmless B decays

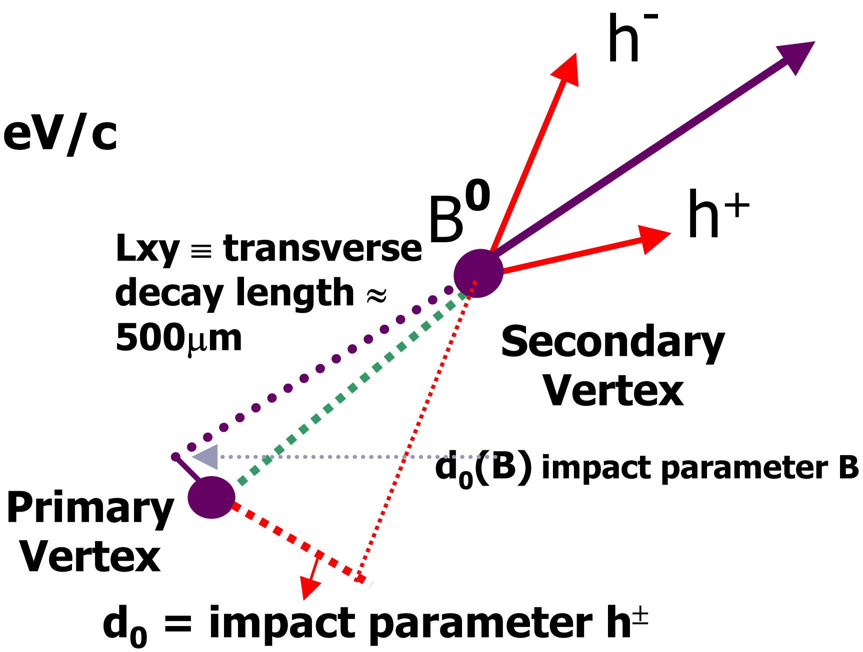
- Tracking:
  - **Central Drift chamber (COT)**
    96 layers, $\sigma(P_T)/P_T^2 \sim 0.1\%\ GeV^{-1}$
  - **Silicon Vertex detector (1+5+2 layers)**
    I.P. resolution 35 µm @2GeV
  - **PID from dE/dx+TOF**
- Trigger:
  - **Drift chamber tracks: eXtremely Fast Tracker (at L1)**
  - **Silicon Vertex Trigger (at L2): allows powerful triggers based on impact parameters and transverse B decay length (CDF first hadron experiment)**



See M. Dell'Orso's talk
"The SVT Trigger at CDF"

$B^0_{d,s} \to PP(\pi^+\pi^-, K^+\pi^-, K^+K^-)$ sample selection

- **Long lived B**
  → large track impact parameter and transverse B decay length
- **Trigger on track pairs with p_T>2 GeV/c and large impact parameters**
- **B pointing back to primary vertex**
  → small B impact parameter
- **Light quark background**
  → require B isolated (offline)



$$I(B)=\frac{P_T(B)}{P_T(B)+\sum_{cone}P_{Ti}}$$

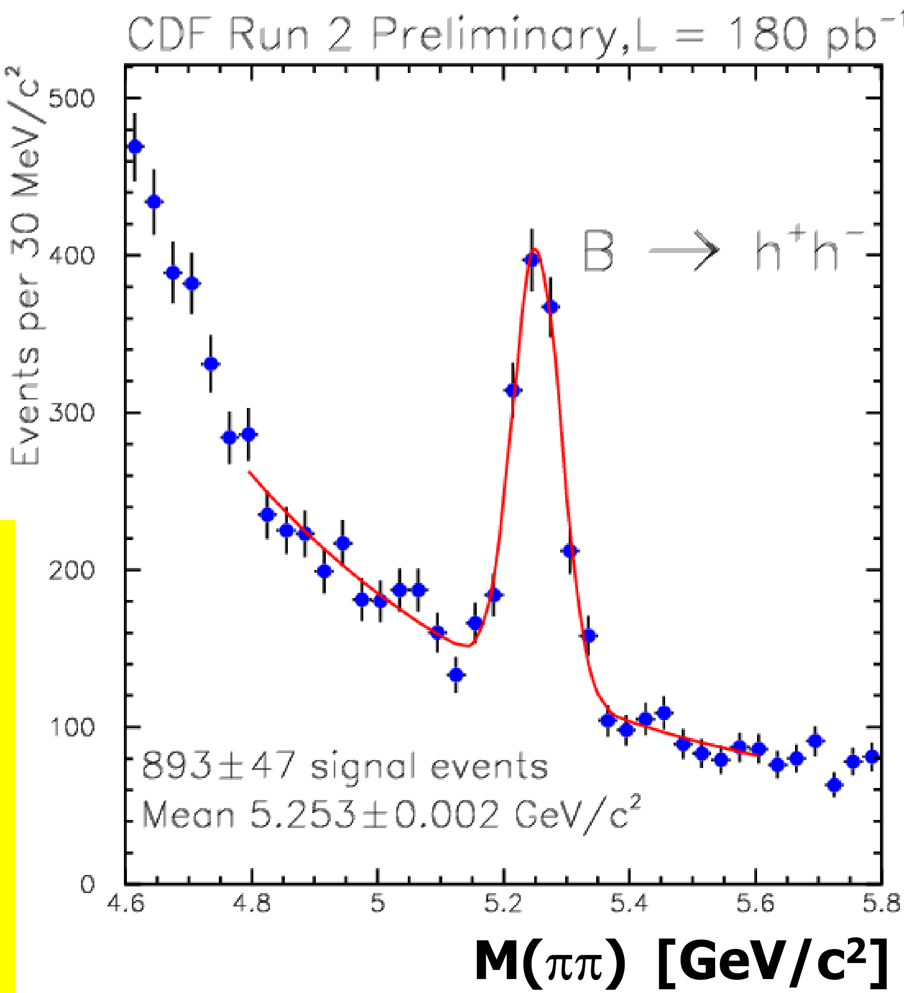
85% efficient on signal, reduces background by factor 4

All cuts simultaneously optimized for maximum S/sqrt(S+B) (S from MC, B from data sidebands) → Optimize resolution on BR/A_{CP} measurement

$B^0_{d,s} \rightarrow PP(\pi^+\pi^-, K^+\pi^-, K^+K^-)$ selection cuts

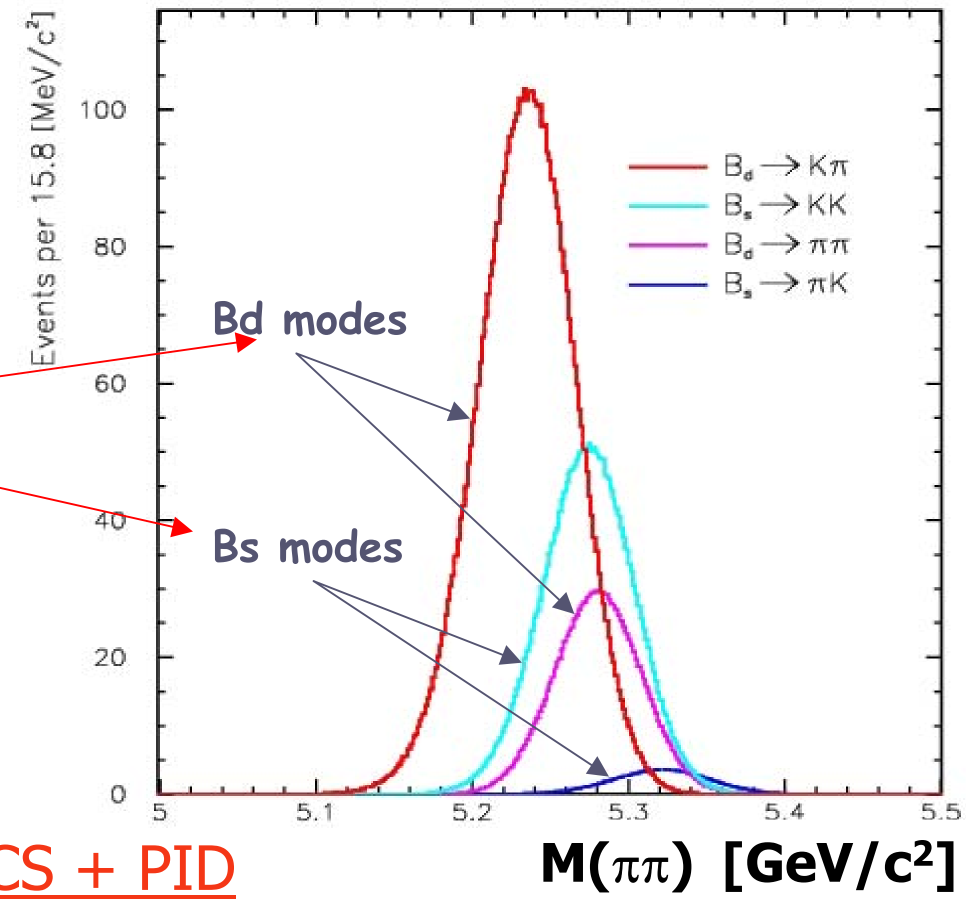
- **2 opposite charge tracks, p_{T1}, p_{T2} > 2.0 GeV/c**
- **$p_{T1} + p_{T2}$ > 5.5 GeV/c**
- **$20^o < \Delta\phi < 135^o$**
- **150 μm < $|d0_{1,2}|$ < 1 mm**
- **$|d0(B)|$ < 80 μm**
- **Lxy(B) > 300 μm**
- **Isolation(B) > 0.5**

Signal: 893 ± 47 events.
S/B > 2 at peak.
N.B. S/B ~10^{-8} at production.
The 4 major expected modes
$B_d \rightarrow \pi\pi$, $K\pi$, $B_s \rightarrow K\pi$, KK
overlap to form a single
unresolved bump.



Disentangling the $B^0_{d,s} \to h^+h^{-\prime}$ contributions

Simulated signals
(fractions as from theory)

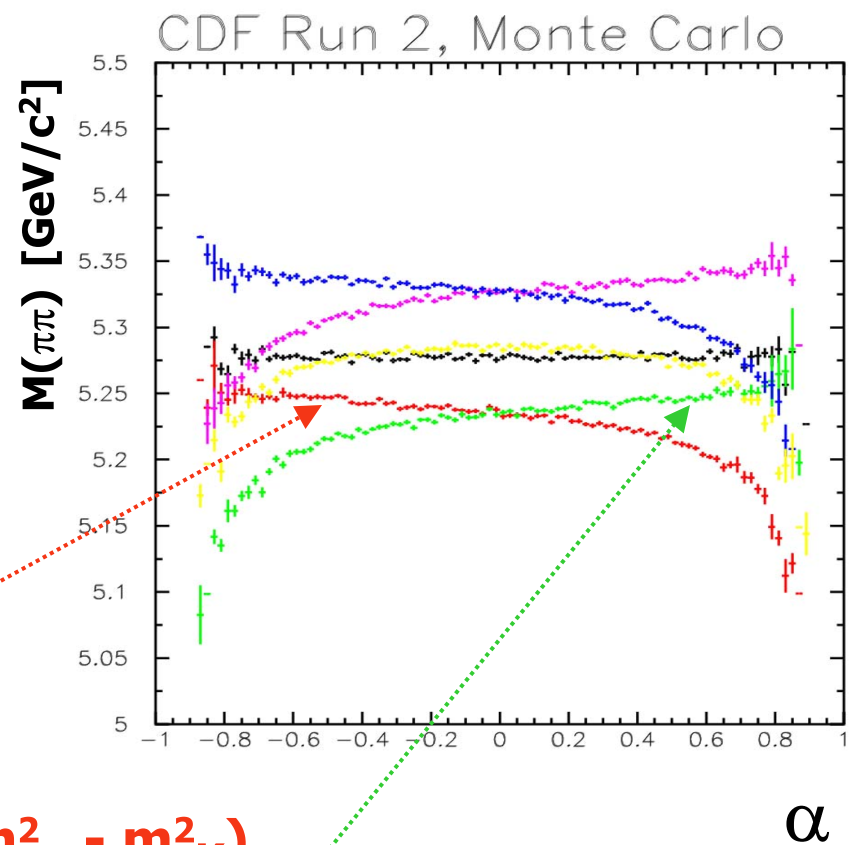


<u>COMBINE MASS + KINEMATICS + PID</u>
in an unbinned ML fit to extract the fraction of each component.

Separation from Kinematics

- Use $\pi\pi$-mass vs signed momentum imbalance.
- $\alpha = [1 - p_{min}/p_{max}] \times q_{min}$ discriminates amongst modes and between flavors for $K\pi$ decays.
- All 4 possible mass assignments depend on $(\alpha, M\pi\pi)$ which have all information.

- $\bar{B}_s \to K\pi$ (blue)
- $B_s \to K\pi$ (magenta)
- $\bar{B} \to K\pi$ (green)
- $B \to K\pi$ (red)
- $B_s \to KK$ (yellow)
- $B \to \pi\pi$ (black)



$B^0_d \to \pi K$ $(\alpha<0)$

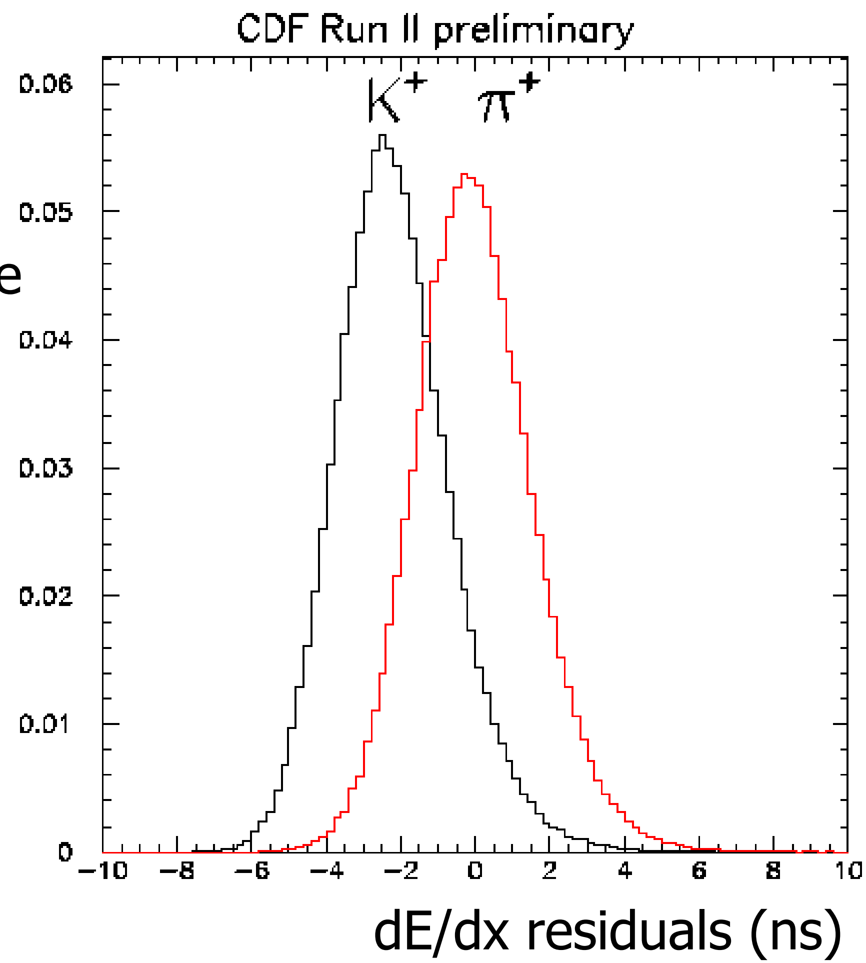
$M^2(\pi K) = M^2(B^0_d) + (2 + \alpha)(m^2_\pi - m^2_K)$

$\overline{B^0}_d \to \pi K$ $(\alpha>0)$

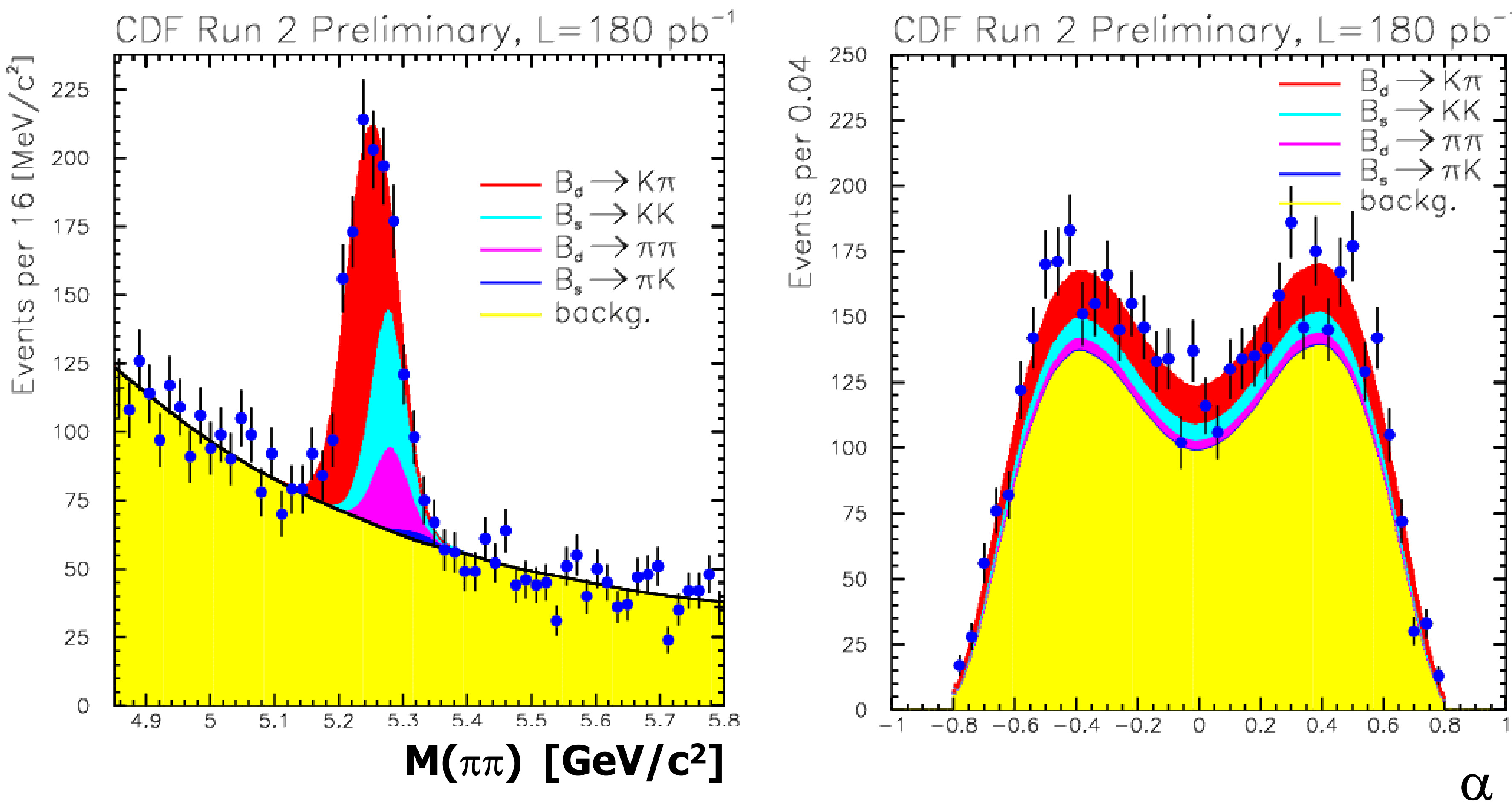
$M^2(\pi K) = M^2(B^0_d) + (2 - \alpha)(m^2_\pi - m^2_K)$

Separation from PID (dE/dx)

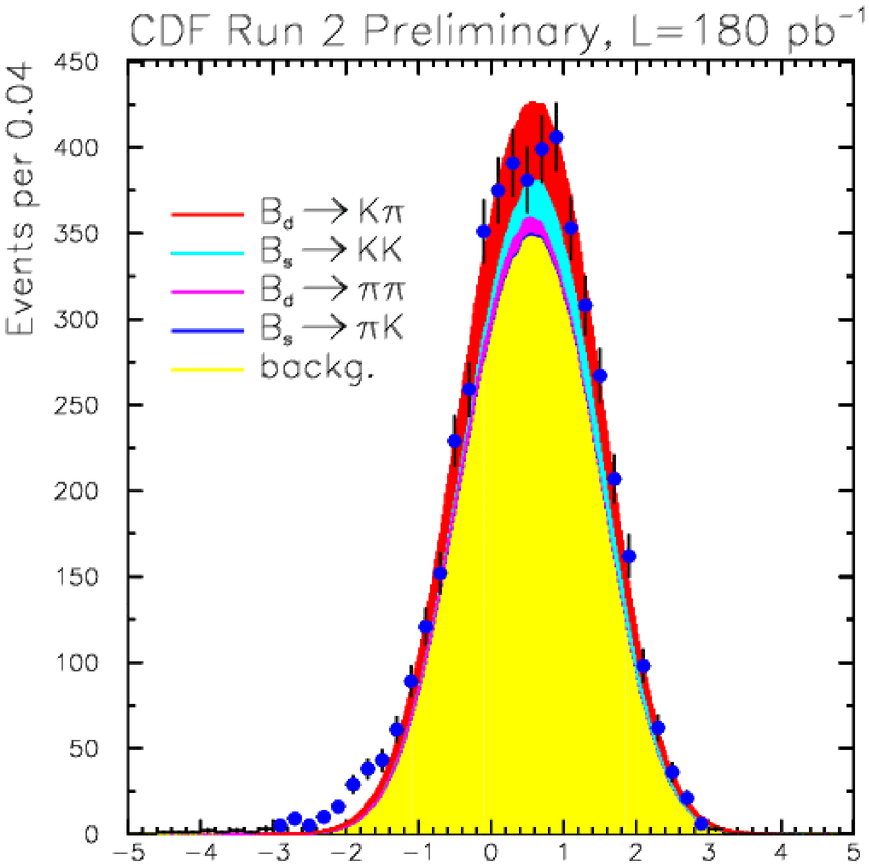
- K/π separation: 1.4σ @P_T>2 GeV/c
- Performance calibrated and separation measured on very pure K and π samples from huge $\mathbf{D^{*+} \rightarrow D^0}\pi^+$ sample collected by the SVT trigger. Calibration performed in the same momentum range as of the analysis tracks.
- Control of systematic errors: Residual gain/baseline fluctuations cause correlated fluctuations of tracks in same event. They have been measured and explicitly included in the fit.



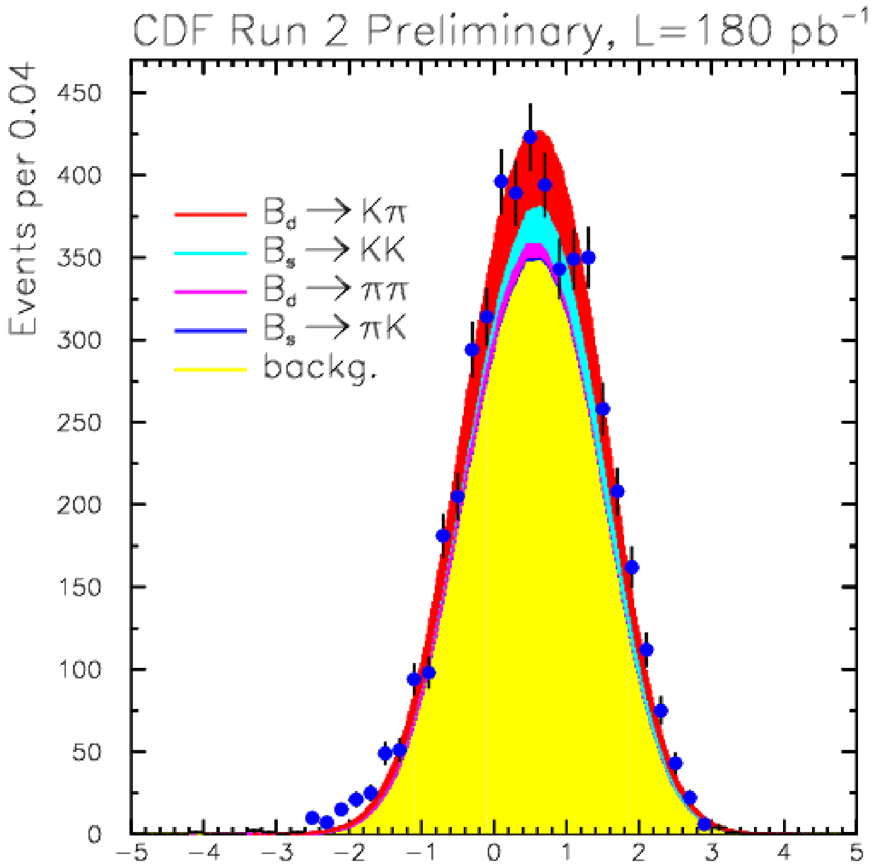
Fit projections (I)



Fit projections (II)



ID1



ID2

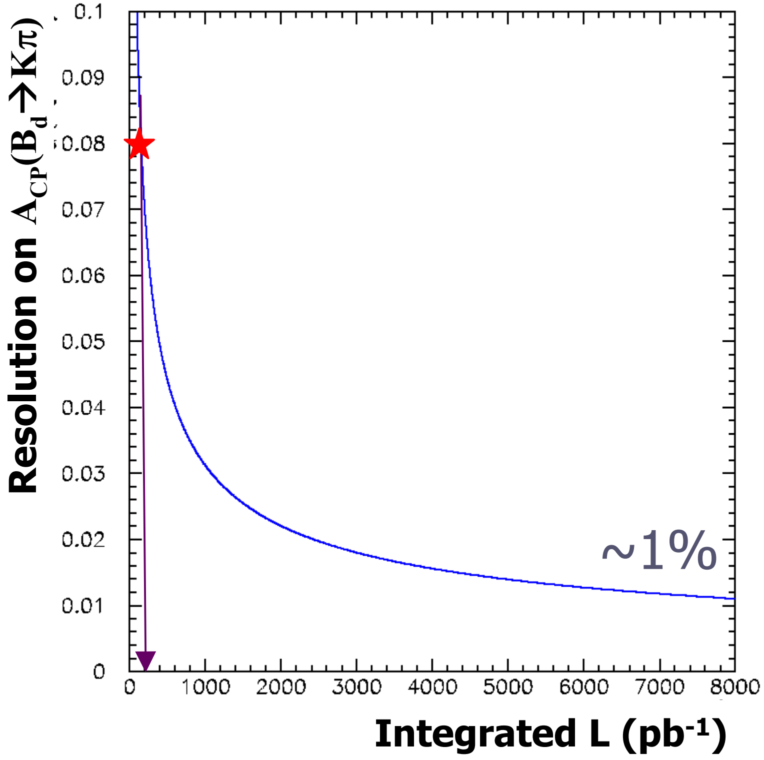
Results: B_d sector

$A_{CP}(B_d \rightarrow K\pi) = -0.04 \pm 0.08(stat.) \pm 0.01(sys.)$

BaBar: $A_{CP}(B_d \rightarrow K\pi) = -0.133 \pm 0.030(stat.) \pm 0.009(syst.)$

Belle: $A_{CP}(B_d \rightarrow K\pi) = -0.101 \pm 0.025(stat.) \pm 0.005(syst.)$

- **A_{CP} result compatible with B-factories**
- **Current sample being analyzed: x3 statistics ($B_d \rightarrow K\pi$ ~1600) expect A_{CP} at ~ 4.5% level**



Good cross check: **$BR(B_d \rightarrow \pi\pi)/BR(B_d \rightarrow K\pi) = 0.24 \pm 0.06(stat.) \pm 0.04(sys.)$**

HFAG w.a.:
$BR(B_d \rightarrow \pi\pi)/BR(B_d \rightarrow K\pi) = 0.246 \pm 0.025$

Results: B_s sector

$BR(B_s \to KK) = 0.50 \pm 0.08(stat.) \pm 0.09(sys.) \times BR(B_d \to K\pi) \times (f_d/f_s)$

Using PDG 2004 we obtain: $BR(B_s \to KK) = (34.3 \pm 5.5 \pm 5.2) \times 10^{-6}$

$BR(B_s \to K\pi)/BR(B_d \to K\pi) < 0.11 \times (f_d/f_s)$ @ 90%C.L.

- $BR(B_s \to KK)$ measured with resolution 15%(stat)+15%(syst)
- $BR(B_s \to KK)/BR(B_d \to K\pi) = 1.85 \pm 0.4$ rather than ~1

  Consistent with U-spin breaking prediction from QCD sum rules [A.Khodjamirian et al., Phys.Rev D68(2003) 114007]

Systematic $B_{d,s} \to PP$

- Dominant systematics:
  - **dE/dx calibration**
  - **Isolation cut efficiency (measured from CDF samples of $Bs \to J/\psi\phi$, $Bs \to D_s\pi$, $Bd \to J/\psi\ K^{0*}$)**
- Both systematics are of *statistical* origin, and expected to go down with sample size

source	$\frac{f_s}{f_d} \cdot \frac{BR(B_s \to KK)}{BR(B_d \to K\pi)}$
background model	$^{+0.005}_{-0.005}$
mass resolution	$^{+0.001}_{-0.004}$
dE/dx correlation: RMS(s)	$^{+0.043}_{-0.031}$
dE/dx correlation: pdf(s)	$^{+0.002}_{-0.002}$
dE/dx tail	$^{+0.056}_{-0.056}$
dE/dx shift	$^{+0.001}_{-0.002}$
input masses	$^{+0.027}_{-0.028}$
B_d, B_s lifetime	$^{+0.004}_{-0.004}$
$\Delta\Gamma_s/\Gamma_s$ Standard Model	$^{+0.007}_{-0.006}$
MC statistics	$^{+0.004}_{-0.004}$
isolation efficiency	$^{+0.051}_{-0.051}$
charge asymmetry	-
XFT-bias correction	$^{+0.010}_{-0.007}$
$p_T(B)$ spectrum	$^{+0.007}_{-0.007}$
TOTAL	**± 0.09**

Theory: $B_s \to K^+K^-$ vs $B_d \to \pi^+\pi^-$

R.Fleisher hep-ph/0405091

Time dependent CP asymmetries

$$A_{cp}(t) = A_{cp}^{dir} \times \cos\Delta mt + A_{cp}^{mix} \times \sin\Delta mt$$

$$A_{cp}^{dir}(\pi^+\pi^-) = -\frac{2d\sin\theta\sin\gamma}{1-2d\cos\theta\cos\gamma+d^2}$$

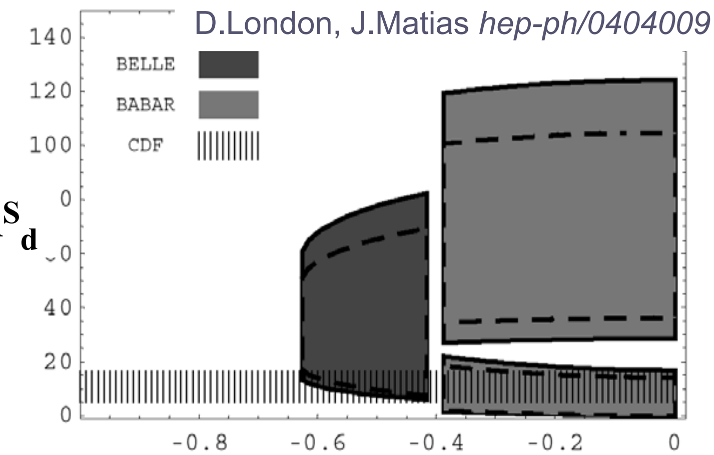
$$A_{cp}^{dir}(K^+K^-) = \frac{2d\frac{1-\lambda^2}{\lambda^2}\sin\theta\sin\gamma}{1+2d\frac{1-\lambda^2}{\lambda^2}\cos\theta\cos\gamma+(\frac{1-\lambda^2}{\lambda^2})^2 d^2}$$

$$A_{cp}^{mix}(K^+K^-) = \frac{\sin 2\gamma+2d\frac{1-\lambda^2}{\lambda^2}\cos\theta\sin\gamma}{1+2d\frac{1-\lambda^2}{\lambda^2}\cos\theta\cos\gamma+d^2(\frac{1-\lambda^2}{\lambda^2})^2}$$

$$A_{cp}^{mix}(\pi^+\pi^-) = \frac{\sin 2(\beta+\gamma)-2d\cos\theta\sin(2\beta+\gamma)+d^2\sin 2\beta}{1-2d\cos\theta\cos\gamma+d^2}$$

$$A_{cp}^{mix}(J/\psi K_s) = \sin 2\beta$$

Many observables related by U-spin relationship, determine angle γ and provide tests for NP



$$H = \left(\frac{1-\lambda^2}{\lambda^2}\right)\left(\frac{f_K}{f_\pi}\right)^2\left[\frac{BR(B_d \to \pi^+\pi^-)}{BR(B_d \to K^\pm\pi^\mp)}\right] = \frac{1-2d\cos\vartheta\cos\gamma+d^2}{\left(\frac{\lambda^2}{1-\lambda^2}\right)^2+2\left(\frac{\lambda^2}{1-\lambda^2}\right)d\cos\vartheta\cos\gamma+d^2}$$

$$R_d^s = \left[\frac{BR(B_s \to K^+K^-)}{BR(B_d \to \pi^+\pi^-)}\right] = \left(\frac{1-\lambda^2}{\lambda^2}\right)\left|\frac{C'}{C}\right|^2 \frac{\left(\frac{\lambda^2}{1-\lambda^2}\right)^2+2\left(\frac{\lambda^2}{1-\lambda^2}\right)d\cos\vartheta\cos\gamma+d^2}{1-2d\cos\vartheta\cos\gamma+d^2} F_{ps}$$

Phase space factor = 0.92

QCD sum rules: 1.76+0.15-0.17 (A.Khodyamirian et al., Phys.Rev D68 114007)

Branching Ratios

Limits on rare B_d, B_s modes

$BR(B_d \rightarrow KK)/BR(B_d \rightarrow K\pi) < 0.17$ @ 90% C.L.

$BR(B_s \rightarrow \pi\pi)/BR(B_s \rightarrow KK) < 0.10$ @ 90% C.L.

BR$\times 10^6$, Limits @90% CL

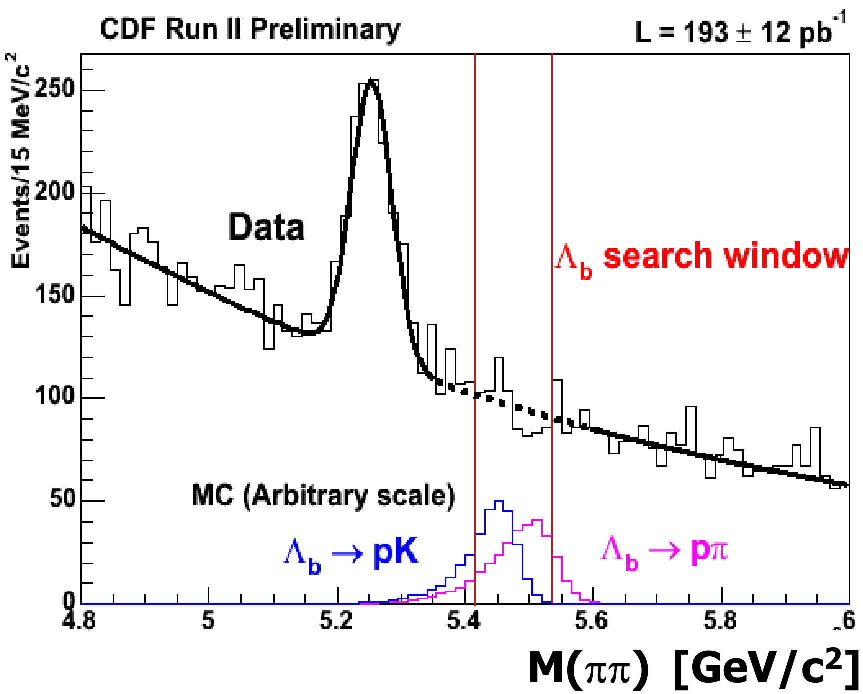
	CDF	PDG04	Expectations
$BR(B_d \rightarrow K^+K^-)$	**<3.1***	**< 0.6**	[0.01 - 0.2] [Beneke&Neubert] NP B675, 333(2003)
$BR(B_s \rightarrow \pi^+\pi^-)$	**<3.4****	**< 170**	0.42 ± 0.06 [Li et al. hep-ph/0404028] [0.03 - 0.16] [Beneke&Neubert]

*Based on $BR(B_d \rightarrow K^+\pi^-)$ from PDG2004
* *Assume equal lifetimes for KK and $\pi\pi$ modes

- Greatly improved limit on $B_s \rightarrow \pi^+\pi^-$
- $B_s \rightarrow \pi\pi$ and $B_d \rightarrow KK$: information on annihilation-type diagrams

Charmless Λ_b decays

- Use the same data to look to search for charmless Λ_b decays to ph^-
  - Large direct CP asymmetries expected
- Predictions:
  - $BR(\Lambda_b \to pK)$, $BR(\Lambda_b \to p\pi) \sim 10^{-6} - 2{*}10^{-6}$ [Mohanta, Phys. Rev. D63:074001, 2001]
- Current limits:
  - $BR(\Lambda_b \to pK) < 50\times10^{-6}$ @90% C.L.
  - $BR(\Lambda_b \to p\pi) < 50\times10^{-6}$ @90% C.L.



Using f_Λ/f_d=0.25±0.04:
$BR(\Lambda_b \to p\pi)+BR(\Lambda_b \to pK)<23\times10^{-6}$

Improved sensitivity in the future with proton PID from TOF+dE/dx

$B_s \rightarrow \phi\phi$(VV) sample selection

TRIGGER: very similar requirement to B→PP, based just on impact parameter

Blind analysis (expected a small yield)

Optimized cuts: lifetime,Vertex quality, impact parameter of B_s, transverse momentum of ϕ, impact parameter of ϕ daughter tracks

Signal search and BR measurement → maximize:

$$\frac{1}{S_{\min}} \propto \frac{\varepsilon(t)}{a/2+\sqrt{B(t)}} \quad ; \; a=3.$$

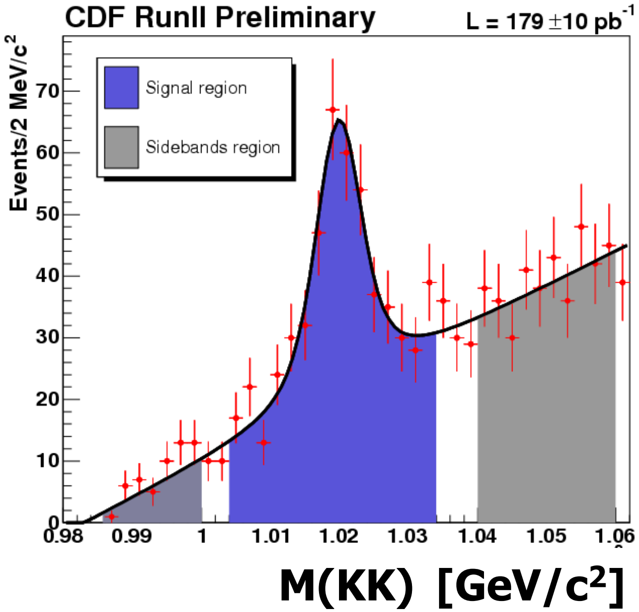
t=set of cuts

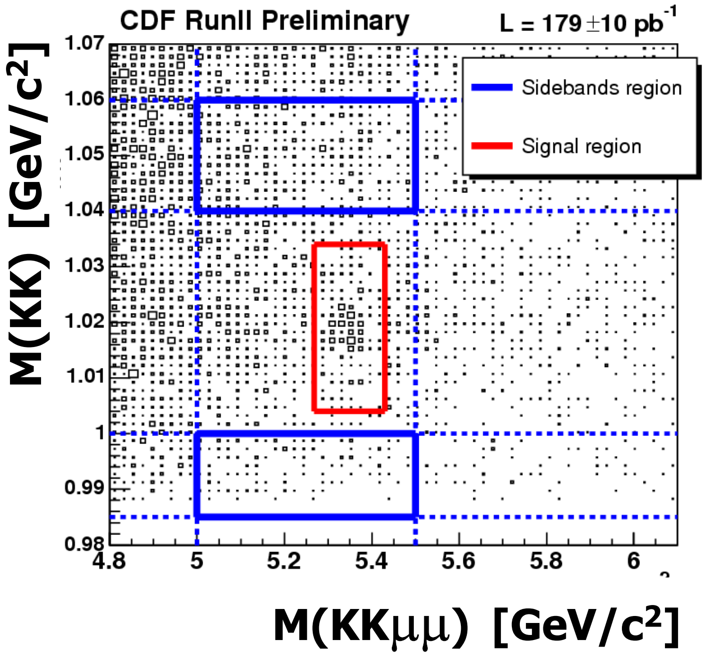
Where ε(t) is the signal efficiency from MC and B(t) is the expected background from sidebands extrapolation for the set t of selection cuts. For a=3 maximize the sensitivity region for a 3 sigma discovery with 99% C.L. [G.Punzi,hep-ph/0308063]

Nice feature:optimization independent of MC normalization

For the control sample $B_s \rightarrow J/\psi\phi$ maximize usual Significance = S(t)/sqrt(S(t)+B(t))

Optimization sample $B_s \rightarrow \phi\phi$

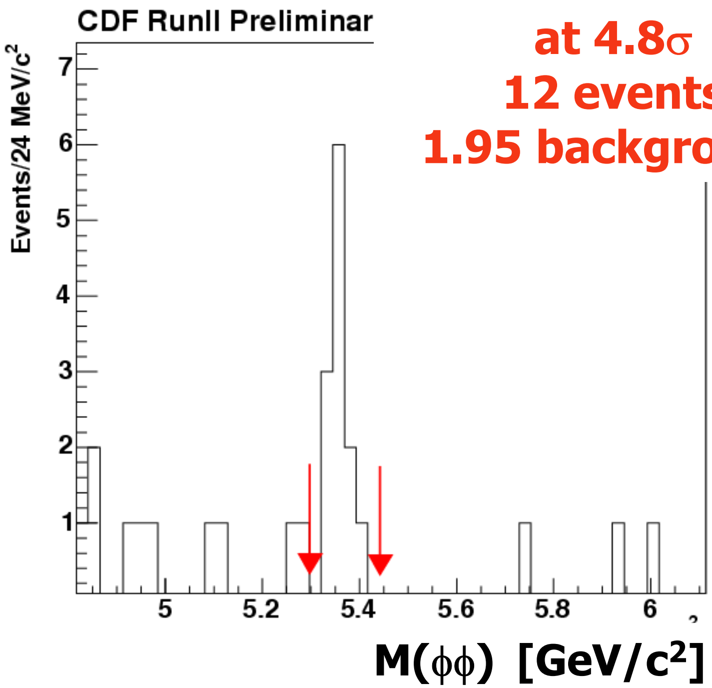




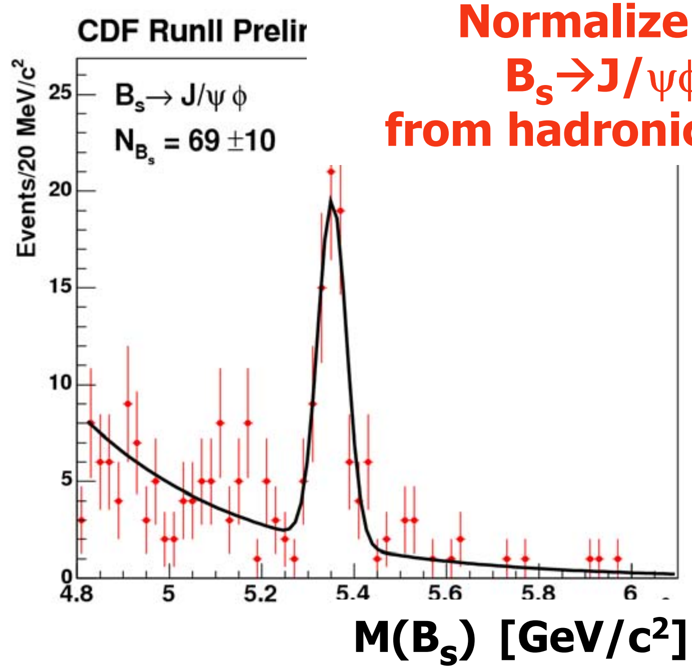
- Optimized set of cuts:
  - $L_{xy}(B) > 350\ \mu m$
  - $|d0(B)| < 80\ \mu m$
  - $\chi^2_{xy} < 10$
  - $p_T(\phi_1) > 2.5$ GeV/c
  - $|d0(\phi_1)| > 40\ \mu m$ $|d0(\phi_2)| > 110\ \mu m$

Decay	Signal region	Sideband
$J/\psi\ \phi$	$\|M_{\mu\mu}-M_{J/\psi}\|<50$ MeV/c^2 $\|M_{KK}-M_\phi\|<15$ MeV/c^2	$M_{KK} \in$ [0.985,1.0] U [1.04,1.06] GeV/c^2 $M_B \in$ [5.0,5.5] GeV/c^2
$\phi\ \phi$	$\|M_{KK}-M_\phi\|<15$ MeV/c^2 for both ϕ's	$M_{KK} \in$ [0.985,1.0] U [1.04,1.06] GeV/c^2 $M_B \in$ [4.9,6.0] GeV/c^2

BR($B_s \to \phi\phi$)



at 4.8σ
12 events
1.95 background



Normalize to
$B_s \to J/\psi\phi$
from hadronic data

$$\mathrm{BR}(\mathrm{B_s} \to \varphi\varphi) = \frac{\mathrm{N}(\mathrm{B_s} \to \varphi\varphi)}{\mathrm{N}(\mathrm{B_s} \to \psi\varphi)^{\mathrm{corr}}} \frac{\varepsilon(\psi\varphi)}{\varepsilon(\varphi\varphi)} \cdot \frac{BR(\mathrm{B_s} \to \psi\varphi).BR(J/\psi \to \mu^+\mu^-)}{BR(\varphi \to K^+K^-)}$$

From MC

From PDG *

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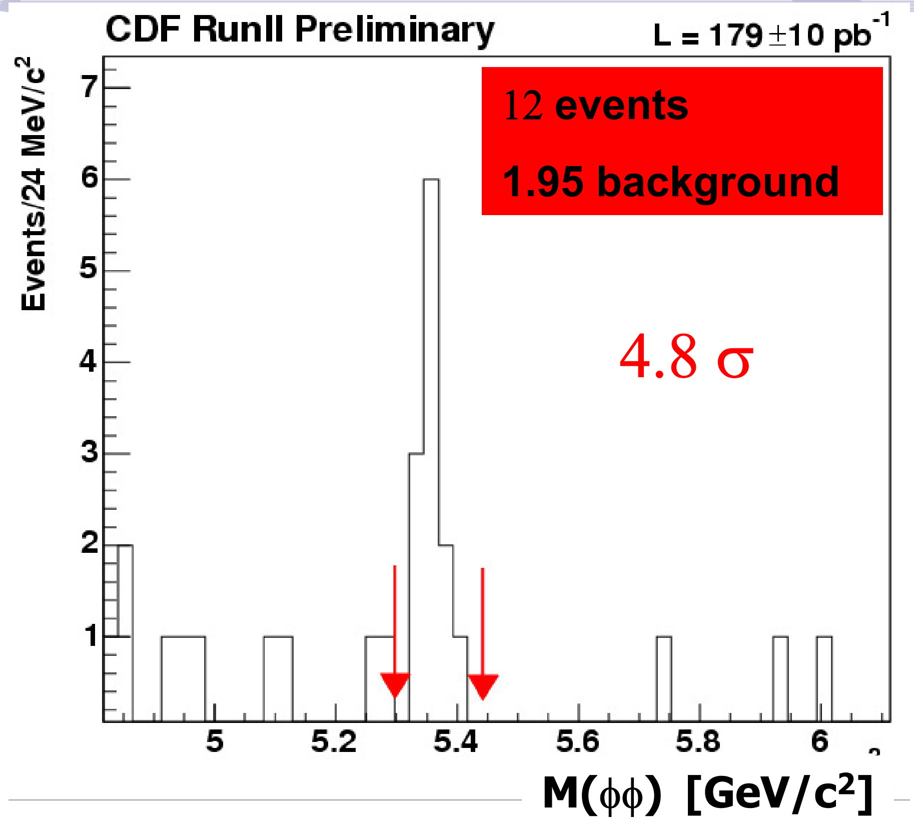
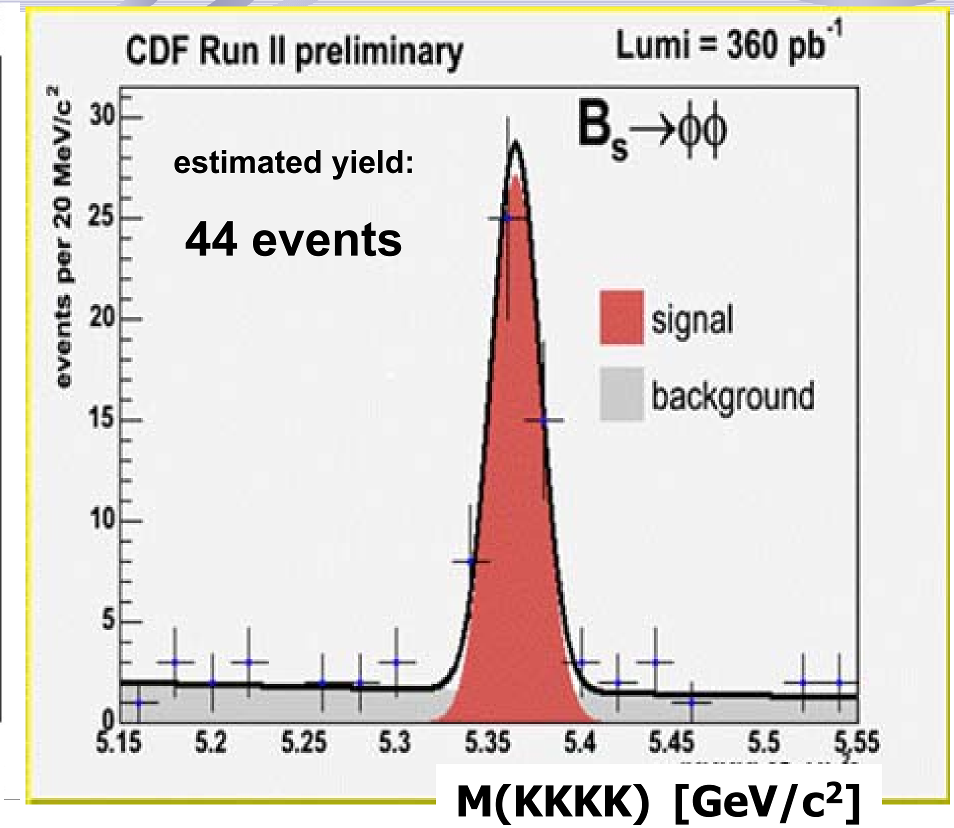
BR = (14 +6–5(stat.) ±2(syst.) ±5(BR)) ×10-6
(systematics dominated by BR of normalization mode)

Towards second generation analyses



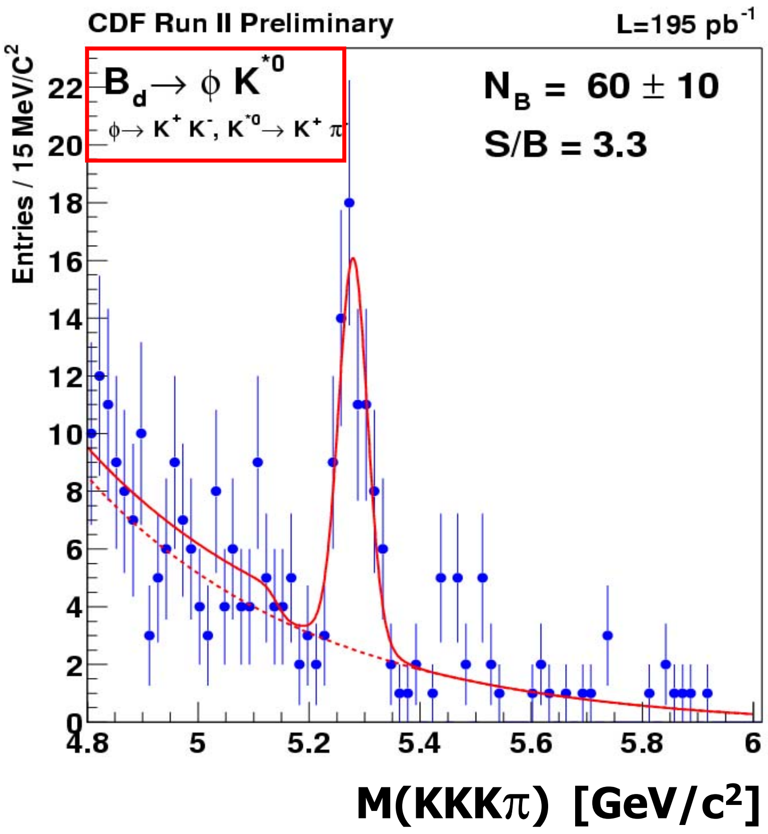


$B_s \to \phi\phi$ 12 events (180 pb^{-1}) → 44 events (360 pb^{-1})

Plan to perform polarization measurements

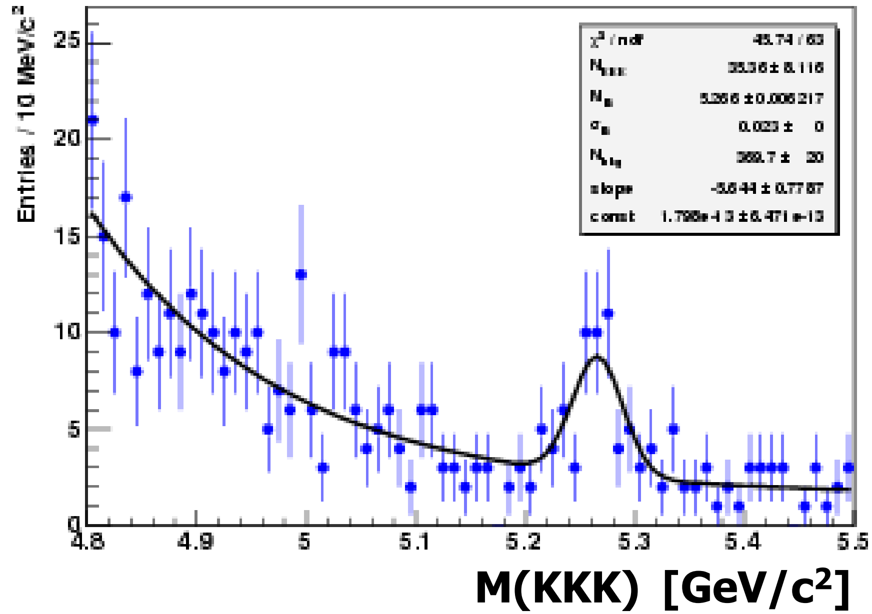
$B_d \rightarrow \phi K^{*0}$ (VV)

- Other interesting $B \rightarrow VV$ mode for polarization measurement.
- Selection similar to $B_s \rightarrow \phi\phi$
- CDF is implementing a dedicated trigger for displaced ϕ to improve yields.



$B^{\pm} \rightarrow \phi K^{\pm}$(VP)

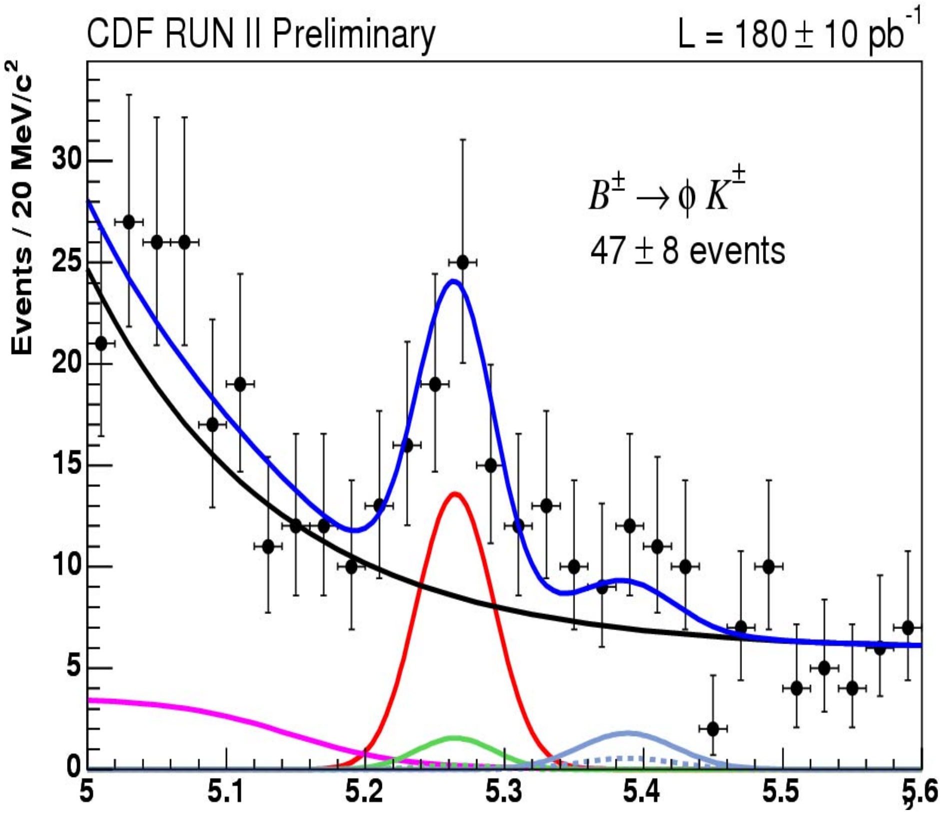
- Optimized set of cuts:
  - **$L_{xy}(B) > 350\ \mu m$**
  - **$|d0(B)| < 100\ \mu m$**
  - **$\chi^2_{xy} < 8$**
  - **$p_T(B) > 4.0$ GeV/c**
  - **$p_T(soft) > 1.3$ GeV/c**
  - **$|d0(soft)| > 120\ \mu m$**
  - **Isol(B) > 0.5**



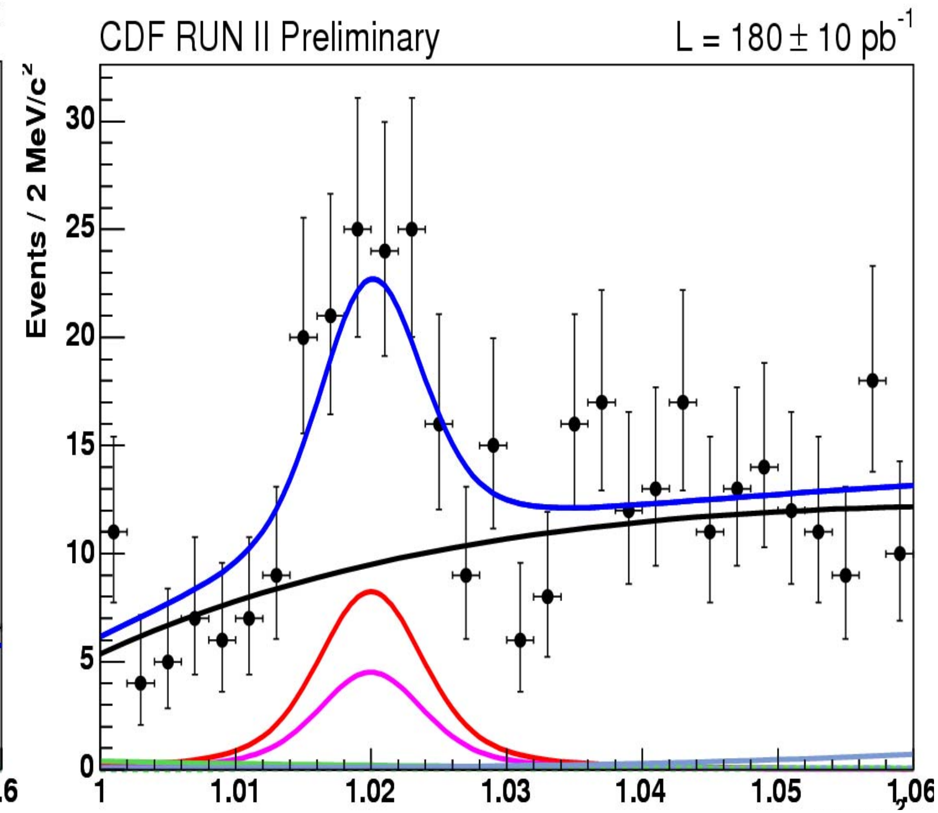
- Extended unbinned ML fit to:
  - **M_{KKK}**
  - **$M\phi$**
  - **Cosine of ϕ meson Helicity angle**
  - **dE/dx deviation from the expected value (pion hypothesis) for the lowest momentum trigger track.**

- Background sources:
  - **$B^{\pm} \rightarrow f^0 K^{\pm}$**
  - **$B^{\pm} \rightarrow K^{*0} \pi^{\pm}$**
  - **$B_{u,d} \rightarrow \phi X$**
  - **combinatorial background**

B± → ϕK± projections (I)

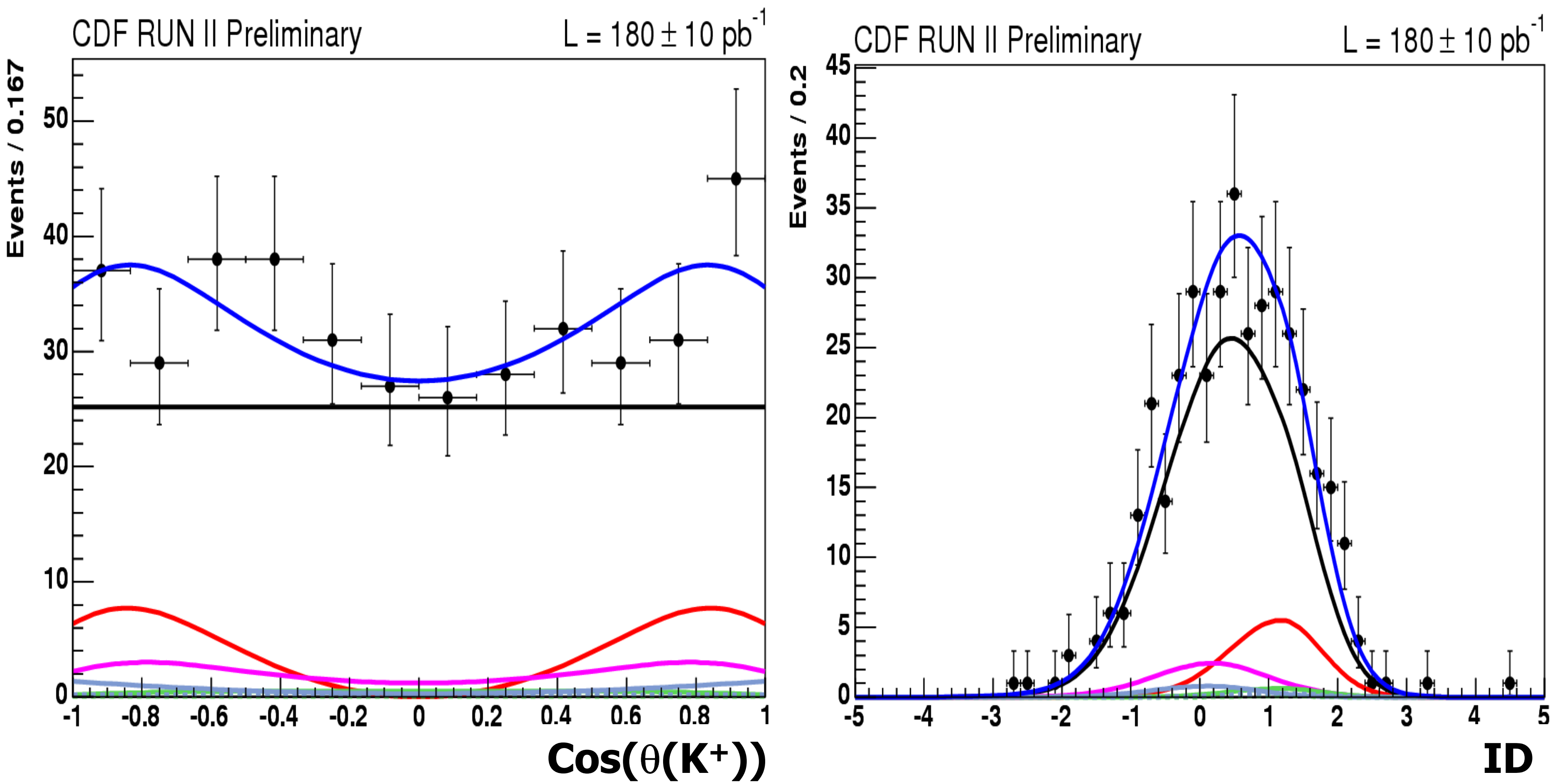


M(KKK) [GeV/c²]



M(KK) [GeV/c²]

B±→φK± projections (II)

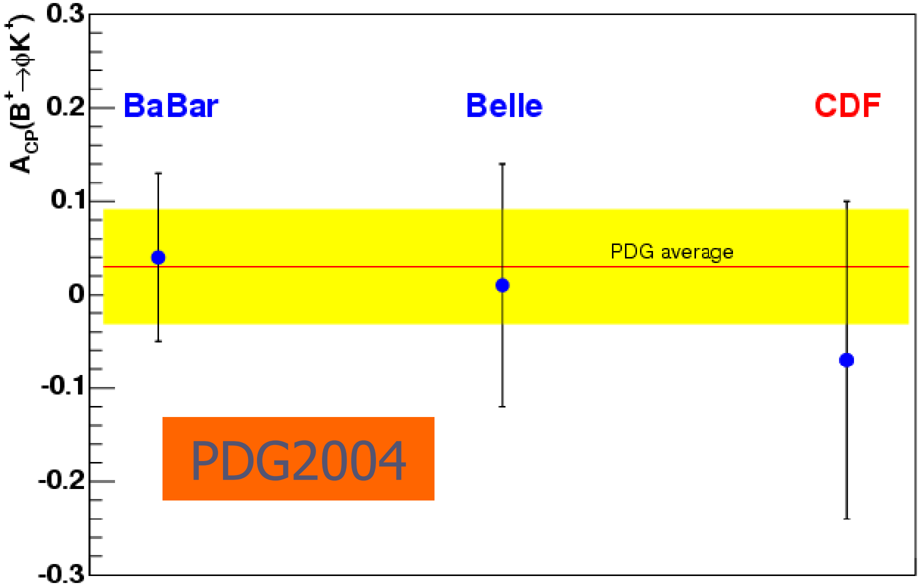


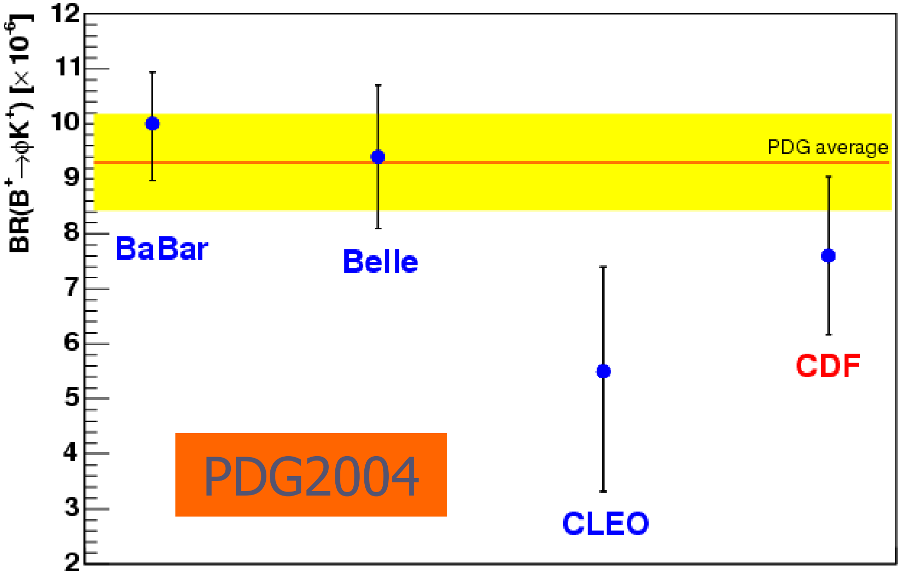
$B^{\pm}\rightarrow\phi K^{\pm}$ results

Normalize yield to $B^{\pm}\rightarrow J/\psi\ K^{\pm}$ to measure BR, similar technique as for $B_s\rightarrow\phi\phi$

$$BR(B^{\pm}\rightarrow\varphi K^{\pm}) = \left(7.6\pm1.3(stat.)\pm0.7(syst.)\right)\cdot10^{-6}$$

$$A_{CP}(B^{\pm}\rightarrow\varphi K^{\pm}) = \frac{\Gamma(B^{-}\rightarrow\varphi K^{-})-\Gamma(B^{+}\rightarrow\varphi K^{+})}{\Gamma(B^{-}\rightarrow\varphi K^{-})+\Gamma(B^{+}\rightarrow\varphi K^{+})} = -0.07\pm0.17(stat.)^{+0.03}_{-0.02}(syst.)$$





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Conclusions and Perspectives

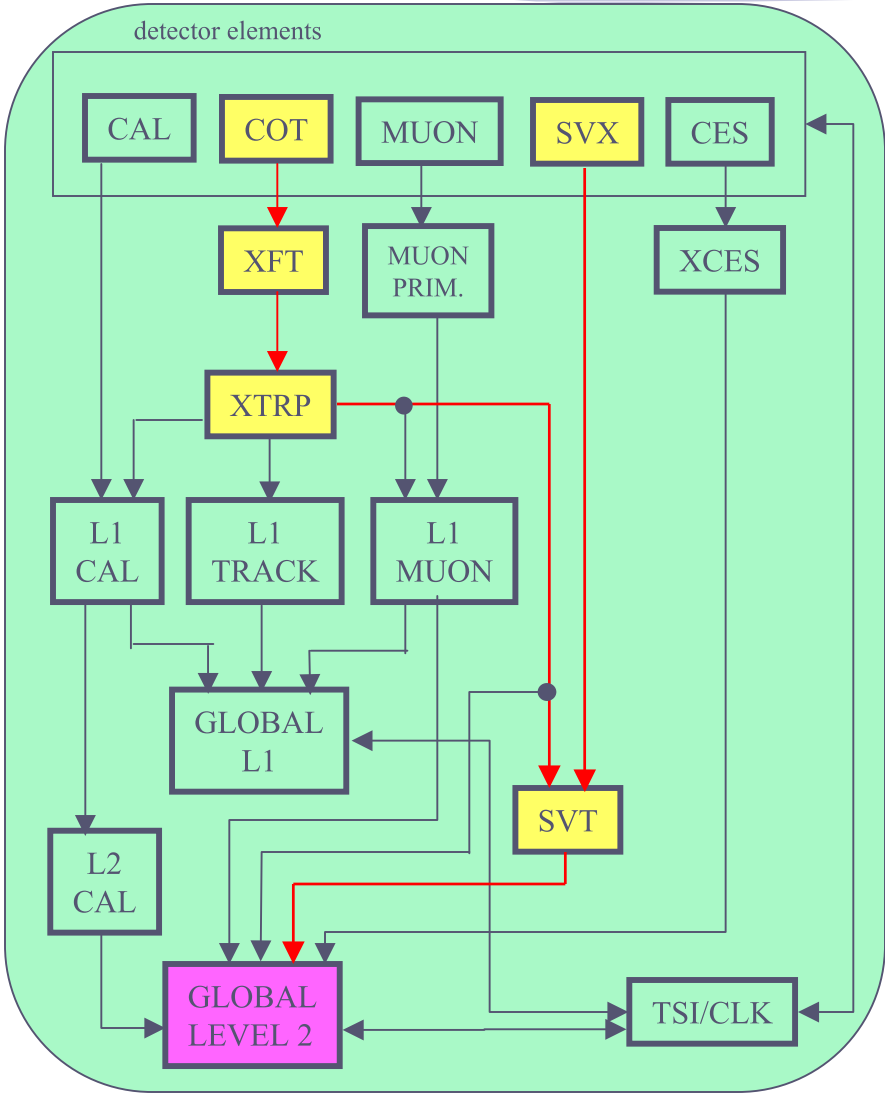
- Charmless 2-body B decays are reality to CDFII – now increasingly important with Tevatron higher luminosity and Trigger upgrade.
- For a long time unique results on B_s and Λ_b modes:
  $B_s \rightarrow KK$, $B_s \rightarrow K\pi$, $B_s \rightarrow \pi\pi$, $B_s \rightarrow \phi\phi$, $\Lambda_b \rightarrow p\pi$, $\Lambda_b \rightarrow pK$
- Now better tracking and PID and x2 luminosity.
- Much more to come:
  - Precision $BR(B_s \rightarrow KK)$, $B_s \rightarrow KK$ lifetime $\rightarrow \Delta\Gamma_s$
  - $B_s \rightarrow K\pi$ BR and direct A_{CP}
  - Precision $A_{CP}(B_d \rightarrow K\pi)$ (full Run II statistics 1%)
  - Measure "untagged" quantities with $B_s \rightarrow \phi\phi$ events
- Tagged time-dependent measurements further ahead: $A_{CP}(t)$ parameters for $B_d \rightarrow \pi\pi$ and $B_s \rightarrow KK$.

BACKUP

CDFII the first hadronic experiment to study charmless B decays

- **Tracking:**
  - Central Drift chamber 96 layers (COT) $\sigma(P_T)/P_T^{\,2} \sim 0.1\%\ GeV^{-1}$
  - Silicon Vertex detector (1+5+2 layers) I.P. resolution 35μm@2GeV
  - PID from dE/dx+TOF
- **Trigger:**
  - eXtremely Fast Tracker (at L1): trigger on drift chamber tracks (axial view only)
  - Silicon Vertex Trigger (at L2): Allows **powerful triggers based on impact parameters and transverse B decay length, (unique to CDF)**

See M. Dell'Orso's talk "The SVT Trigger at CDF"



$B_{d,s}$→PP analytic equations

B mesone	$\mathcal{M}^2(\alpha) = \mathcal{M}(\alpha < 0)$
$B_d \to \pi\pi$	$M^2_{B_d^0}$
$B_d^0 \to \pi K$	$M^2_{B_d^0} + (2+\alpha)(m_\pi^2 - m_K^2)$
$\overline{B}_d^0 \to K\pi$	$M^2_{B_d^0} + (1 + \frac{1}{1+\alpha})(m_\pi^2 - m_K^2)$
$\overline{B}_s^0 \to \pi K$	$M^2_{B_s^0} + (2+\alpha)(m_\pi^2 - m_K^2)$
$B_s^0 \to K\pi$	$M^2_{B_s^0} + (1 + \frac{1}{1+\alpha})(m_\pi^2 - m_K^2)$
$B_s \to KK$	$M^2_{B_s^0} + (3 + \alpha + \frac{1}{1+\alpha})(m_\pi^2 - m_K^2)$

B mesone	$\mathcal{M}^2(\alpha) = \mathcal{M}^2(\alpha > 0)$
$B_d \to \pi\pi$	$M^2_{B_d^0}$
$\overline{B}_d^0 \to \pi K$	$M^2_{B_d^0} + (2-\alpha)(m_\pi^2 - m_K^2)$
$B_d^0 \to K\pi$	$M^2_{B_d^0} + (1 + \frac{1}{1-\alpha})(m_\pi^2 - m_K^2)$
$B_s^0 \to \pi K$	$M^2_{B_s^0} + (2-\alpha)(m_\pi^2 - m_K^2)$
$\overline{B}_s^0 \to K\pi$	$M^2_{B_s^0} + (1 + \frac{1}{1-\alpha})(m_\pi^2 - m_K^2)$
$B_s \to KK$	$M^2_{B_s^0} + (3 - \alpha + \frac{1}{1-\alpha})(m_\pi^2 - m_K^2)$

Systematic $B_{d,s} \to PP$

source	$\frac{f_s}{f_d} \cdot \frac{BR(B_s \to KK)}{BR(B_d \to K\pi)}$	$A_{CP}(B_d \to K\pi)$	$\frac{BR(B_d \to \pi\pi)}{BR(B_d \to K\pi)}$	$\frac{f_d}{f_s} \cdot \frac{BR(B_d \to \pi\pi)}{BR(B_s \to KK)}$
mass resolution	$^{+0.001}_{-0.004}$	$^{+0.001}_{-0.001}$	$^{+0.001}_{-0.002}$	$^{+0.001}_{-0.001}$
dE/dx **correlation: RMS(s)**	$^{+0.043}_{-0.031}$	$^{+0.002}_{-0.002}$	$^{+0.034}_{-0.025}$	$^{+0.029}_{-0.017}$
dE/dx **correlation:** *pdf* **(s)**	$^{+0.002}_{-0.002}$	$^{+0.002}_{-0.002}$	$^{+0.000}_{-0.000}$	$^{+0.002}_{-0.002}$
dE/dx **tail**	$^{+0.056}_{-0.056}$	$^{+0.003}_{-0.003}$	$^{+0.020}_{-0.020}$	$^{+0.017}_{-0.017}$
dE/dx **shift**	$^{+0.001}_{-0.002}$	$^{+0.001}_{-0.001}$	$^{+0.001}_{-0.003}$	$^{+0.017}_{-0.005}$
input masses	$^{+0.027}_{-0.028}$	$^{+0.003}_{-0.003}$	$^{+0.009}_{-0.010}$	$^{+0.009}_{-0.010}$
background model	$^{+0.005}_{-0.005}$	$^{+0.002}_{-0.002}$	$^{+0.003}_{-0.003}$	$^{+0.000}_{-0.000}$
lifetime	$^{+0.004}_{-0.004}$	-	-	$^{+0.004}_{-0.004}$
isolation efficiency	$^{+0.051}_{-0.051}$	-	-	$^{+0.050}_{-0.050}$
MC statistics	$^{+0.004}_{-0.004}$	$^{+0.001}_{-0.001}(*)$	$^{+0.003}_{-0.003}$	$^{+0.006}_{-0.006}$
charge asymmetry	-	$^{+0.002}_{-0.002}$	-	-
XFT-bias correction	$^{+0.010}_{-0.007}$	-	$^{+0.004}_{-0.004}$	$^{+0.015}_{-0.010}$
$p_T(B)$ **spectrum**	$^{+0.007}_{-0.007}$	-	-	$^{+0.007}_{-0.007}$
$\Delta\Gamma_s/\Gamma_s$ **Standard Model**	$^{+0.007}_{-0.006}$	-	-	$^{+0.006}_{-0.006}$
TOTAL	± 0.09	± 0.01	± 0.04	± 0.07

Systematics of $B_s \to \phi\phi$

- Systematic error dominated by normalization mode BR uncertainty and already similar in size to the statistical error
- Theory uncertainty on polarization very conservative (vary longitudinal fraction in 20 % to 80% range as suggested by A. Kagan)
- $\Delta\Gamma_s$ uncertainty based on the preferred theory value of: $\Delta\Gamma_s/\Gamma_s = 0.12 \pm 0.06$
- BR is rather on the low side respect to QCDF (2.5 σ) 1.4 vs 3.7 E-5

Source	Relative error on BR
Trigger efficiency	3.3 %
$J/\psi\phi$ yield and efficiency	8.4%
Background subtraction	5.4%
$B_s \to \phi\phi$ polarization	3.8%
$B_s \to J/\psi\phi$ polarization	1.4%
$\Delta\Gamma_s$ uncertainty	0.6%
J/ψ and ϕ BR	2.1%
Sub Total	11 %
BR($J/\psi\phi$)	35%
Total	37%

BR($B^\pm \to \phi K^\pm$) syst. uncertainties

- Systematic error on BR dominated by fit uncertainty and acceptance correction, largely below statistical uncertainty
- A_{CP} systematic is largely statistical in nature, intrinsic systematic below 0.01
- Comparable to B-factory experiments

Source	Relative error on BR
Trigger efficiency	3.3 %
$J/\psi K$ yield and efficiency	4.0%
Efficiency Ratio	3.6%
$B^\pm \to \varphi K^\pm$ fit syst.	3.0%
J/ψ and ϕ BR	2.1%
$B^\pm \to \varphi K^\pm$ BR	0.4%
Total	7.4 %

Source	error on Acp
$B^\pm \to \varphi K^\pm$ fit syst.	+0.034 -0.020
Charge asymmetry	±0.005