BR & ACP of $B \rightarrow h^+h^-$
modes at CDF

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for the CDF collaboration

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Charmless $B$ decays are a great tool to explore CKM and possible NP

Single measurements hard to interpret: combination of multiple modes essential to understanding of data and comparison to theory

Tevatron access to all $b$-hadrons and large Luminosity is a great opportunity for extending the range of available measurements.

This talk: All modes into pairs of charged charmless hadrons:

$$(B_s / B^0 / \Lambda_b) \rightarrow h^+ h'^-$$  where $h = \pi, K$ (or $p$ for $\Lambda_b$)

Known modes (larger BR):
- $B^0 \rightarrow K^+ \pi^-$
- $B^0 \rightarrow \pi^+ \pi^-$
- $B^0_s \rightarrow K^+ K^-$ (observed by CDF)

Yet unobserved modes:
- $B^0_s \rightarrow K^- \pi^+$
- $B^0 \rightarrow K^+ K^-$
- $\Lambda_b \rightarrow pK$
- $B^0_s \rightarrow \pi^+ \pi^-$
- $\Lambda_b \rightarrow p\pi$

CDF results with 1 fb$^{-1}$ sample [CDF public note 8579]
(Updates previous results with 180pb-1 or 360pb-1)
**Important CDF features**

- Central Drift chamber in B field
  - \( \sigma(p_T)/p_T^2 \sim 0.1\% \text{ GeV}^{-1} \)
  - dE/dx measurement (encoded in hit width)
- Silicon VerteX detector
  - I.P. resolution: 35\( \mu \text{m} @ 2\text{GeV} \)
- Time-of-Flight
  - Control systematics from possible proton background asymmetry
- Tracking trigger:
  - XFT at L1: 2D tracks in COT, \( p_T > 1.5 \text{ GeV/c}^2 \)
  - SVT at L2: 2D tracks in COT+SVX \( p_T > 2.0 \text{ GeV/c}^2 \)
    - Impact parameter measurement
It all begins in the trigger

- **Reject light-quark background**
  - Two oppositely-charged tracks
  - Transverse opening angle \([20^\circ, 135^\circ]\);
  - \(p_T^{T_1}, p_T^{T_2} > 2 \text{ GeV}\);
  - \(p_T^{T_1} + p_T^{T_2} > 5.5 \text{ GeV}\).

- **Long-lived candidate**
  - Track impact parameters >100 \(\mu m\);
  - Transverse decay length \(L > 200 \mu m\);

- **Reject multi-prongs and backgrounds**
  - B impact parameter < 140 \(\mu m\);

\[ \sigma(d_0) \approx \text{offline:} \]
\[ 48 \mu m = 35 \ [\text{SVT}] \oplus 33 \ [\text{beam-spot}] \]
Signal with initial cuts

CDF Run II Preliminary $L_{\text{int}} = 1 \text{ fb}^{-1}$

~ 8500 events

$S/B \approx 0.7$ at the peak

Signal (BR $\sim 10^{-5}$) clearly visible with just trigger cuts confirmation

Further observable used for offline analysis:

- 3D Vertex chi-square
- Isolation:

$$I(B) = \frac{\text{Pt}(B)}{\text{Pt}(B) + \sum_{\text{cone}} \text{Pt}_i}$$

- Isolation effective in reducing light-quark background, 85% efficient on signal (analog of event shape at $e^+e^-$)
Choice of cuts

Cuts individually optimized by minimizing the expected statistical uncertainty on the quantity of interest. Its expression $\sigma(S,B)$ is determined from actual uncertainties observed in analysis of MC samples, and parameterized by an analytically-inspired model.

Signal yield $S$ is derived from MC simulation while the background $B$ is estimated from mass sidebands on data.

In practice, only 2 sets of cuts were needed:

- (1) optimize on $A_{CP}(B^0\to K^+\pi^-)$ => Loose cuts
  - good for all three “large modes” ($B^0\to K^+\pi^-$, $B^0\to \pi^+\pi^-$, $B^0_s\to K^+K^-$)
- (2) optimize on $B^0_s\to K^-\pi^+$ discovery/Limits [physics/0308063] => tight cuts
  - good for all “rare modes”

When compared with $S/\sqrt{(S+B)}$:

- $\sim 10\%$ better on $A_{CP}(B^0\to K^+\pi^-)$
- $\sim 27\%$ better on $BR(B^0_s\to K^-\pi^+)$
Offline signal (loose cuts)

Despite good mass resolution ($\approx 22$ MeV/c$^2$), individual modes overlap in a single peak (width $\approx 35$ MeV/c$^2$)

Note that the use of a single mass assignment ($\pi\pi$) causes overlap even with perfect resolution

Blinded region of unobserved modes: $B^0_s \rightarrow K\pi$, $B^0_s \rightarrow \pi\pi$, $\Lambda^0_b \rightarrow p\pi/pK$

Need to determine signal composition with a Likelihood fit, combining information from kinematics (mass and momenta) and particle ID (dE/dx).
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Need to determine signal composition with a Likelihood fit, combining information from kinematics (mass and momenta) and particle ID (dE/dx).
Different modes are somewhat separated in mass (~50 MeV between $B^0 \to K\pi i$ and $B_s \to K K$).

However, results depend on assumed mass resolution and details of the lineshape (rare modes confuse with the tails of larger modes).

Need good control of non-gaussian resolution tails and effects of Final State Radiation.
1. Accurate parameterization of *individual track parameters* resolution functions from full MC (including non-gaussian tails)
3. Generate mass lineshapes with a simple kinematical MC
4. Compare results with a huge sample of $D^0 \rightarrow K\pi$
   ⇒ perfect match, no tuning necessary ⇒ small systematics
5. Generate $B \rightarrow hh$ templates and use them in the Likelihood fit.
Kinematic variables:
\( p_{\text{min}} (p_{\text{max}}) \) is the 3D track momentum with \( p_{\text{min}} < p_{\text{max}} \)

1) \( M_{\pi\pi} \) invariant \( \pi\pi \)-mass
2) \( \alpha = (1-p_{\text{min}}/p_{\text{max}})q_{\text{min}} \) signed p-imbalance
3) \( p_{\text{tot}} = p_{\text{min}} + p_{\text{max}} \) scalar sum of 3-momenta

Each mode has an individual mass distribution \( p(M_{\pi\pi}) = G(M_{\pi\pi} - F(\alpha, p_{\text{tot}})) \)
This offers good discrimination amongst modes and between \( K^+\pi^- / K^-\pi^+ \).
Handle 3: $dE/dx$

Calibrate on pure K and $\pi$ samples from decay:
$D^{*+} \rightarrow D^0\pi^+ \rightarrow [K^-\pi^+]\pi^+$
(sign of $D^{*+}$ pion tags $D^0$ sign)

Useful quantity to plot (‘kaonness’):

$$ID(\text{track}) = \frac{\frac{dE}{dx}}{|\text{meas (track)}| - \frac{dE}{dx}|_{\exp-\pi}(\text{track})} - \frac{dE}{dx}|_{\exp-K}(\text{track}) - \frac{dE}{dx}|_{\exp-\pi}(\text{track})$$

$$<ID>(\text{pion}) = 0$$
$$<ID>(\text{kaon}) = 1$$

(independent of $p$)

$dE/dx$ carefully calibrated over tracking volume and time.
Detailed model includes tails, momentum dependence, two-track correlations

1.4$\sigma$ $K/\pi$ separation for $p>2 GeV$
achieve a statistical uncertainty on
separating classes of particles which
is just 60% worse than ‘perfect’ PID
Putting it all together

Unbinned ML fit based on 5 observables

\[ \mathcal{L}(\theta) = \prod_{i=1}^{N} \mathcal{L}_i(\theta) \]

\[ \mathcal{L}_i(\theta) = (1 - b) \sum_j f_j \mathcal{L}_{i,j}^{\text{sign}} + b \mathcal{L}_{i,bckg} \]

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

mass term
momentum term
PID term

fraction of \( j^{\text{th}} \) mode, to be determined by the fit

NB: Only measure relative BRs and normalize to \( B^0 \to K^+\pi^- \).
(Use HFAG06)
Loose cuts, raw fit results

CDF Run II Preliminary $L_{\text{int}}=1\ fb^{-1}$

Uncorrected fractions

- $B^0 \to K^+\pi^-$: 7% (16%)
- $B^0 \to K^+\pi^-$: 19% (26%)
- $B^0 \to K^+\pi^-$: 32%
- $B^0 \to \pi^+\pi^-$: ~7000 events total

- $B^0$ yields comparable to $e^+e^-$
- Large $B^0_s \to K^+K^-$ sample
- Good separation: compare to $\sqrt{N}$ below

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Fraction (σ/σ_{ideal})</th>
<th>Yield</th>
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<tr>
<td>$B^0 \to \pi^+\pi^-$ + c.c.</td>
<td>(0.160 ± 0.009)</td>
<td>1121 ± 63</td>
</tr>
<tr>
<td>$B^0 \to K^+\pi^-$ + c.c.</td>
<td>(0.577 ± 0.010)</td>
<td>4045 ± 84</td>
</tr>
<tr>
<td>$B^0 \to K^+K^-$ + c.c.</td>
<td>(0.186 ± 0.009)</td>
<td>1307 ± 64</td>
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</table>
Fit projections

Many crosschecks:
- Gaussian fit pulls
- PID-less fit agrees with regular fit
- Free-mass-resolution fit agrees with standard fit
- Free-mass-scale fit agrees and returns mass shift
  \[ \delta = 0.2 \pm 0.6 \text{ MeV}/c^2 \]
Results for known modes
\[ \frac{BR(B^0 \to \pi^+\pi^-)}{BR(B^0 \to K^{+}\pi^-)} = 0.259 \pm 0.017 \text{ (stat.)} \pm 0.016 \text{ (syst.)} \]

\[ BR(B^0 \to \pi^+\pi^-) = (5.10 \pm 0.33 \text{ (stat.)} \pm 0.36 \text{ (syst.)}) \times 10^{-6} \]

- Precision measurements. systematic\text{\approx} statistics.
- Confirm previous results in a very different experimental setting
- Good yield, bright perspectives for time-dependent measurements: expect similar resolution to e+e- with full runII sample
Direct ACP ($B^0 \rightarrow K^+\pi^-$)

Large sample >4000 events allows measuring DCPV
Plot of $L(B^0)/[L(B^0)+L(\bar{B}^0)]$
shows good separation achieved between $B^0$ and $\bar{B}^0$
(mass, alpha, dE/dx)

Significant raw asymmetry, good resolution:

$$A_{CP} \bigg|_{raw} = \frac{N_{raw}(\bar{B}^0 \rightarrow K^-\pi^+)}{N_{raw}(\bar{B}^0 \rightarrow K^-\pi^+)} - \frac{N_{raw}(B^0 \rightarrow K^+\pi^-)}{N_{raw}(B^0 \rightarrow K^+\pi^-)} = -0.092 \pm 0.023$$
Correcting the raw $A_{CP}$

$$A_{CP}(B^0 \rightarrow K^+\pi^-) = \frac{N_{raw}(\bar{B}^0 \rightarrow K^-\pi^+)}{N_{raw}(\bar{B}^0 \rightarrow K^-\pi^+)} \cdot \frac{\epsilon(K^+\pi^-)}{\epsilon(K^-\pi^+)} - \frac{N_{raw}(B^0 \rightarrow K^+\pi^-)}{N_{raw}(B^0 \rightarrow K^+\pi^-)} \cdot \frac{\epsilon(K^+\pi^-)}{\epsilon(K^-\pi^+)}$$

Only the different $K^+/K^-$ interaction rate with material matters. $K^-$ has a larger hadronic cross section than $K^+$.

Huge sample of prompt $D^0 \rightarrow h^+h^-$ (15M).

*Kinematic* fit using the *same code* of the $B \rightarrow hh$ fit

Direct $A_{CP}(D^0 \rightarrow K\pi)$ very small:

⇒ extract from DATA correction for $\epsilon(K^-\pi^+)/\epsilon(K^+\pi^-)$ plus any other possible spurious asymmetries.

$$\frac{\epsilon(K^+\pi^-)}{\epsilon(K^-\pi^+)} = 1.0131 \pm 0.0028 \ (stat.).$$

Small (~0.6%) correction. Agrees with independent evaluation from CDF simulation.
Results on $A_{CP}(B^0 \rightarrow K^+\pi^-)$

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

- CDF agrees with $e^+e^-$ (3.5$\sigma$ effect)
- WA significance 6 $\sigma$ $\rightarrow$ 7 $\sigma$
- Discrepancy with $A_{CP}(B^+ \rightarrow K^+\pi^0)$ now up to 4.9 $\sigma$
- Whether this really means new physics has been subject to debate.
- CDF can help clarifying the issue by a much more robust test, based on $B_s \rightarrow K\pi$ (more on this shortly)
Systematics $A_{CP}(B^0 \rightarrow K^+\pi^-)$

- $dE/dx$ model ($\pm 0.0064$);
- Nominal $B$-meson masses ($\pm 0.005$);
- Global mass scale;
- Charge-asymmetries ($\pm 0.0014$);
- Background model ($\pm 0.003$).

Total systematic uncertainty is 0.9%, compare with 2.3% statistical.

Largest effect ($dE/dx$) also verified with additional crosscheck: measurement of $A_{CP}(D^0 \rightarrow K\pi)$ based on $dE/dx$-only. Discrepancy with the kinematic fit ($\approx 0.006$) within quoted systematics.

Systematics can still decrease with larger calibration samples. Prospects for a runII CDF measurement with <1% uncertainty.
B_s
Conservative systematics at the moment, expect syst ≈ stat for final result

**Interesting comparison to predictions:**

- **Naively:** \( \text{BR}(B^0_s \rightarrow K^+K^-) \equiv \text{BR}(B^0 \rightarrow K^+\pi^-) \equiv 20 \cdot 10^{-6} \)
- **QCDF:** \( \text{BR} \approx 23-36 \cdot 10^{-6} \) [Beneke&Neubert NP B675, 333(2003)]
- **QCD sum rules predict large SU(3) breaking** \( \text{BR} \approx 35 \cdot 10^{-6} \)
  

- **More recently,** 1/mb corrections give lower values again: \( \text{BR}=(20\pm9) \cdot 10^{-6} \)
  
  [Descotes-Genon et al. PRL97, 061801, 2006]

**Further useful results expected from upcoming time-dependent measurements**
Search for new modes
Rare modes search (tight cuts)

CDF Run II  Preliminary $L_{int} = 1$ fb$^{-1}$

Candidates per 20 MeV/c$^2$

- $B^0 \rightarrow K^+\pi$
- $B^0 \rightarrow K^-\pi^+$
- $B^+_s/B^-_s \rightarrow K^+K^-$
- $B^{0}/\bar{B}^{0} \rightarrow \pi^+\pi^-$
- $B^0_s \rightarrow K^-\pi^+ + \bar{B}^0_s \rightarrow K^+\pi^-$
- $\Lambda^0 \rightarrow p\pi + \bar{\Lambda}^0 \rightarrow \bar{p}\pi^-$
- $\Lambda^0 \rightarrow pK + \bar{\Lambda}^0 \rightarrow \bar{p}K^+$
- Combinatorial backg.
- Three-body $B$ decays
First observation (8$\sigma$)

$$N_{\text{raw}}(B_s^0 \to K^-\pi^+) = 230 \pm 34 \text{ (stat.)} \pm 16 \text{ (syst.)}$$
BR(B_{s0} \rightarrow K^{-}\pi^{+})

\[
\frac{f_{s} \cdot BR(B_{s0}^{0} \rightarrow K^{-}\pi^{+})}{f_{d} \cdot BR(B^{0} \rightarrow K^{+}\pi^{-})} = 0.066 \pm 0.010 \ (\text{stat.}) \pm 0.010 \ (\text{syst.})
\]

\[
BR(B_{s0}^{0} \rightarrow K^{-}\pi^{+}) = (5.0 \pm 0.75 \ (\text{stat.}) \pm 1.0 \ (\text{syst.})) \times 10^{-6}
\]

Previous limit (CDF) < 5.4 @90% CL

SOME PREDICTIONS:

QCDF [7 \div 10] \cdot 10^{-6}
pQCD: [6 \div 10] \cdot 10^{-6}
[Yu, Li, Yu, PRD71: 074026 (2005)]
SCET: (4.9 \pm 1.8) \cdot 10^{-6}

Results agree with recent lower estimates

Large sensitivity to angle \alpha/\phi_{2}

Observation of this decay offers a unique opportunity of investigating the source of CP violation, and the reason for the discrepancy in $B^0$ vs $B^+$:

“Is observed direct CP violation in $B^0 \rightarrow K^+\pi^-$ due to new physics? Check standard Model prediction of equal violation in $B^0_s \rightarrow K^-\pi^+$”


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

This comparison of $B^0 \rightarrow K^+\pi^-$ and $B^0_s \rightarrow K^-\pi^+$ is a probe of NP in CP violation based on really minimal assumption. Currently unique to CDF.

$$\frac{A_{CP}(B_s \rightarrow K^-\pi^+)}{A_{CP}(B_d \rightarrow K^+\pi^-)} = \frac{BR(B_d \rightarrow K^+\pi^-)}{BR(B_s \rightarrow K^-\pi^+)}$$

From our measured low BR, expect large asymmetry $\approx 37\%$
DCPV $B^0_s \rightarrow K^-\pi^+$

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

$$|A(\bar{B}_d \rightarrow \pi^+K^-)|^2 - |A(B_d \rightarrow \pi^-K^+)|^2$$

$$= 0.84 \pm 0.42\text{ (stat.)} \pm 0.15\text{ (syst.)} \quad \text{(SM =1)}$$

First measurement of DCPV in the Bs
Sign and magnitude agree with SM predictions within errors
⇒ no evidence for exotic sources of CP violation (yet)

Exciting to pursue with more data
Even rarer modes:
Weak annihilation
Pure-annihilation modes

- All final-state quarks different from initial state quarks. ⇒ only via annihilation-type diagrams
- Not yet observed. Small BR, with large uncertainties.
- Depends on hard-to-predict hadronic parameters ⇒ large source of uncertainty in calculations.
- CDF can look for $B_s \rightarrow \pi^+ \pi^-$ in addition to $B_d \rightarrow K^+ K^-$, $B_s$ is expected larger by $x3$-$x4$.

- To extract annihilation hadronic parameters, need BOTH measurements:

$$\frac{1}{\epsilon} \left[ \frac{\text{BR}(B_d \rightarrow K^+ K^-)}{\text{BR}(B_s \rightarrow \pi^+ \pi^-)} \right] \frac{\tau_{B_s}}{\tau_{B_d}} = \frac{1 + 2 \varphi_{PA} \cos \vartheta_{PA} \cos \gamma + \varphi_{PA}^2}{\epsilon^2 - 2 \epsilon \varphi_{PA} \cos \vartheta_{PA} \cos \gamma + \varphi_{PA}^2}$$

Results on $B^0_s \to \pi^+\pi^-$, $B^0 \to K^+K^-$

\[ BR(B^0 \to K^+K^-) = (0.39 \pm 0.16 \text{ (stat.)} \pm 0.12 \text{ (syst.)}) \times 10^{-6} (< 0.7 \cdot 10^{-6} \text{ @ 90\% CL}) \]

New WA: $0.16 \pm 0.11$ [speaker’s calculation]

Expectations: $[0.007 \div 0.08] \cdot 10^{-6}$
⇒ now in the region of interest

Best current limit
\[ <1.36 \cdot 10^{-6} \text{ @ 90\% CL} \]

Expectations: $[0.024 \div 0.16] \cdot 10^{-6}$ [Beneke&Neubert NP B675, 333(2003)]
$0.42 \pm 0.06 \cdot 10^{-6}$ [Li et al. hep-ph/0404028]

We have reached the interesting region for these channels. A signal may be just around the corner.
\[ \Lambda_0^b \rightarrow p\pi^- \text{ and } \Lambda_0^b \rightarrow pK^- \]

First observation, 6 $\sigma$

\[ N_{\text{raw}}(\Lambda_0^b \rightarrow pK^-) = 156 \pm 20 \text{ (stat.)} \pm 11 \text{ (syst.)} \]

\[ N_{\text{raw}}(\Lambda_0^b \rightarrow p\pi^-) = 110 \pm 18 \text{ (stat.)} \pm 16 \text{ (syst.)} \]

\[ \frac{BR(\Lambda_0^b \rightarrow p\pi^-)}{BR(\Lambda_0^b \rightarrow pK^-)} = 0.66 \pm 0.14 \text{ (stat.)} \pm 0.08 \text{ (syst.)} \]

See for the first time a charmless decay of a B barion

Ratio of BR in agreement with predictions (0.60-0.62)


Individual BR and ACP measurements in progress
Summary

- **First observation** of $B^0_s \rightarrow K^-\pi^+$ mode
- **First measurement** of DCPV in $B^0_s$:
  $A_{CP}(B^0_s \rightarrow K^-\pi^+)$ at $2.5\sigma$, in agreement with SM
- **First observation** of B-baryon modes $\Lambda_b \rightarrow pK / p\pi$
- Precision $A_{CP}(B^0 \rightarrow K^+\pi^-)$ confirms B-factories results.
  Increase significance of DCPV to $7\sigma$, and discrepancy with $B^+$ to $4.9\sigma$.
- Updated BR($B^0_s \rightarrow K^+K^-$) agrees with latest predictions, no indication of large U-spin breaking.
- Improved results on annihilation: $B^0 \rightarrow K^+K^- \quad B^0_s \rightarrow \pi^+\pi^-$

CDF has fresh new results in Charmless two-body decays of the $B^0$, plus unique results on $B^0_s$ and baryons.
Now ready to start time-dependent measurements ($B^0 \rightarrow \pi^+\pi^-, B^0_s \rightarrow K^+K^-$)
Many more results expected with progressing of RunII.
Backup
Separating $B^0_s \rightarrow K^+K^-$ from $B^0 \rightarrow \pi^+\pi^-$

PID separation $\pi\pi/KK \equiv 2\sigma$
Isolation cut efficiency

In order to normalize Bs Branching Fraction, need to know the relative efficiency.

The Isolation cut may affect Bs and B0 differently. Use data to measure it ( $p_T$ dependent )

Need low-$p_T$ samples: low edge of $p_T \sim 3$ GeV

Maximum Likelihood fit of yields in exclusive modes.

<table>
<thead>
<tr>
<th>$p_T(B) &lt; 6$</th>
<th>$\varepsilon_{Isol}(B_d)$</th>
<th>$\varepsilon_{Isol}(B_s)$</th>
<th>$\varepsilon_{Isol}(B_d)/\varepsilon_{Isol}(B_s)$</th>
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<tbody>
<tr>
<td>GeV/c</td>
<td></td>
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<tr>
<td>$p_T(B) &lt; 6$</td>
<td>57.5±9.7</td>
<td>70.1±14.6</td>
<td>0.82±0.22</td>
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<tr>
<td>6 &lt; $p_T(B)$ &lt; 10</td>
<td>84.6±2.4</td>
<td>84.8±5.7</td>
<td>1.00±0.08</td>
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<tr>
<td>$p_T(B) &gt; 10$</td>
<td>93.8±1.2</td>
<td>90.4±2.8</td>
<td>1.04±0.03</td>
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Cuts optimized for ACP(BdKpi)

<table>
<thead>
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<th>variable</th>
<th>cut</th>
</tr>
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<tbody>
<tr>
<td># axial COT SL</td>
<td>$\geq 2$ (5 hits)</td>
</tr>
<tr>
<td># stereo COT SL</td>
<td>$\geq 2$ (5 hits)</td>
</tr>
<tr>
<td># $r-\phi$ SVX hits</td>
<td>$\geq 3$</td>
</tr>
<tr>
<td>tracking algorithm</td>
<td>sil. r-\phi and 90°z hits</td>
</tr>
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<td>$</td>
<td>\eta</td>
</tr>
<tr>
<td>$p_T$</td>
<td>$\geq 2$ GeV/c</td>
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<td>$p_T(1) + p_T(2)$</td>
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<td>$d_0(1) \cdot d_0(2)$</td>
<td>$&lt; 0$ cm$^2$</td>
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CDF Run II Preliminary $L_{\text{in}} = 1$ fb$^{-1}$

6509 $\pm$ 159 Signal events

$S/B \cong 6.5$ at the peak

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<td>\eta(B)</td>
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<td>$</td>
<td>d_0(B)</td>
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<tr>
<td>$L_{xy}(B)$</td>
<td>$\geq 300$ $\mu$m</td>
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<td>$\chi^2_{3D}(B)$</td>
<td>$\leq 7$</td>
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<tr>
<td>isolation $I_{R=1}$</td>
<td>$\geq 0.5$</td>
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Cuts optimized for rare modes

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<td>$q(1) \cdot q(2)$</td>
<td>$&lt; 0$</td>
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<tr>
<td>$\Delta \phi$</td>
<td>$\geq 20^\circ$</td>
</tr>
<tr>
<td>$\Delta \phi$</td>
<td>$\leq 135^\circ$</td>
</tr>
<tr>
<td>$</td>
<td>d_0</td>
</tr>
<tr>
<td>$</td>
<td>d_0</td>
</tr>
<tr>
<td>$d_0(1) \cdot d_0(2)$</td>
<td>$&lt; 0$ cm$^2$</td>
</tr>
</tbody>
</table>

CDF Run II Preliminary $L_{\text{int}} = 1$ fb$^{-1}$

4917 ± 209 Signal events
S/B ≃ 13 at the peak
ACP cuts: physical parameters

\[ A_{CP} = \frac{N(B^0 \rightarrow K^-\pi^+) - N(B^0 \rightarrow K^+\pi^-)}{N(B^0 \rightarrow K^-\pi^+) + N(B^0 \rightarrow K^+\pi^-)} = -0.086 \pm 0.023 \text{ (stat.)} \pm 0.009 \text{ (syst.)} \]

\[ \frac{BR(B^0 \rightarrow \pi^+\pi^-)}{BR(B^0 \rightarrow K^+\pi^-)} = 0.259 \pm 0.017 \text{ (stat.)} \pm 0.016 \text{ (syst.)} \]

\[ \frac{f_s \cdot BR(B^0_s \rightarrow K^+K^-)}{f_d \cdot BR(B^0 \rightarrow K^+\pi^-)} = 0.324 \pm 0.019 \text{ (stat.)} \pm 0.041 \text{ (syst.)} \]

With HFAG 2006:

\[ BR(B^0 \rightarrow \pi^+\pi^-) = (5.10 \pm 0.33 \text{ (stat.)} \pm 0.36 \text{ (syst.)}) \times 10^{-6} \]

\[ BR(B^0_s \rightarrow K^+K^-) = (24.4 \pm 1.4 \text{ (stat.)} \pm 4.6 \text{ (syst.)}) \times 10^{-6} \]
BsKpi cuts: physical parameters (1)

\[
A_{CP} = \frac{N(B_s^0 \to K^+\pi^-) - N(B_s^0 \to K^-\pi^+)}{N(B_s^0 \to K^+\pi^-) + N(B_s^0 \to K^-\pi^+)} = 0.39 \pm 0.15 \text{ (stat.)} \pm 0.08 \text{ (syst.)}
\]

\[
\frac{N(B^0 \to K^-\pi^+) - N(B^0 \to K^+\pi^-)}{N(B_s^0 \to K^+\pi^-) - N(B_s^0 \to K^-\pi^+)} = -3.21 \pm 1.60 \text{ (stat.)} \pm 0.39 \text{ (syst.)}
\]

\[
N_{raw}(B_s^0 \to K^-\pi^+) = 230 \pm 34 \text{ (stat.)} \pm 16 \text{ (syst.)}
\]

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

With HFAG 2006:

\[
BR(B_s^0 \to K^-\pi^+) = (5.0 \pm 0.75 \text{ (stat.)} \pm 1.0 \text{ (syst.)}) \times 10^{-6}
\]
BsKpi cuts: physical parameters (2)

\[ N_{\text{raw}}(B^0_s \rightarrow \pi^+\pi^-) = 26 \pm 16 \text{ (stat.)} \pm 14 \text{ (syst.)} \]

\[ N_{\text{raw}}(B^0 \rightarrow K^+K^-) = 61 \pm 25 \text{ (stat.)} \pm 35 \text{ (syst.)} \]

\[ \frac{f_s \cdot BR(B^0_s \rightarrow \pi^+\pi^-)}{f_d \cdot BR(B^0 \rightarrow K^+\pi^-)} = 0.007 \pm 0.004 \text{ (stat.)} \pm 0.005 \text{ (syst.)} \]

\[ \frac{BR(B^0 \rightarrow K^+K^-)}{BR(B^0 \rightarrow K^+\pi^-)} = 0.020 \pm 0.008 \text{ (stat.)} \pm 0.006 \text{ (syst.)} \]

With HFAG 2006:

\[ BR(B^0 \rightarrow K^+K^-) = (0.39 \pm 0.16 \text{ (stat.)} \pm 0.12 \text{ (syst.)}) \times 10^{-6} \]

\[ BR(B^0 \rightarrow K^+K^-) \in [0.1 - 0.7] \cdot 10^{-6} \text{ @ 90% C.L.} \]

\[ BR(B^0_s \rightarrow \pi^+\pi^-) = (0.53 \pm 0.31 \text{ (stat.)} \pm 0.40 \text{ (syst.)}) \times 10^{-6} \]

\[ BR(B^0_s \rightarrow \pi^+\pi^-) < 1.36 \cdot 10^{-6} \text{ @ 90% C.L.} \]
BsKpi cuts: physical parameters (3)

\[ N_{\text{raw}}(\Lambda_b^0 \to pK^-) = 156 \pm 20 \ (\text{stat.}) \pm 11 \ (\text{syst.}) \]

\[ N_{\text{raw}}(\Lambda_b^0 \to p\pi^-) = 110 \pm 18 \ (\text{stat.}) \pm 16 \ (\text{syst.}) \]

\[ \frac{BR(\Lambda_b^0 \to p\pi^-)}{BR(\Lambda_b^0 \to pK^-)} = 0.66 \pm 0.14 \ (\text{stat.}) \pm 0.08 \ (\text{syst.}) \]
## Systematics: $A_{CP}(B^{0} \rightarrow K^{+}\pi^{-})$

<table>
<thead>
<tr>
<th>source</th>
<th>shift wrt central fit</th>
</tr>
</thead>
<tbody>
<tr>
<td>mass scale</td>
<td>0.0004</td>
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<tr>
<td>asymmetric momentum-p.d.f</td>
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</tr>
<tr>
<td>dE/dx</td>
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<tr>
<td>input masses</td>
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<tr>
<td>combinatorial background model</td>
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<tr>
<td>momentum background model</td>
<td>0.0007</td>
</tr>
<tr>
<td>MC statistics</td>
<td>–</td>
</tr>
<tr>
<td>charge asymmetry</td>
<td>0.0014</td>
</tr>
<tr>
<td>$\Delta \Gamma_{s}/\Gamma_{s}$ Standard Model</td>
<td>–</td>
</tr>
<tr>
<td>lifetime</td>
<td>–</td>
</tr>
<tr>
<td>isolation efficiency</td>
<td>–</td>
</tr>
<tr>
<td>XFT-bias correction</td>
<td>–</td>
</tr>
<tr>
<td><strong>TOTAL (sum in quadrature)</strong></td>
<td><strong>0.009</strong></td>
</tr>
</tbody>
</table>
Systematics

$B^0 \rightarrow \pi^+\pi^-$ and $B^0_s \rightarrow K^+K^-$

\[
\begin{array}{c}
\frac{BR(B^0 \rightarrow \pi^+\pi^-)}{BR(B^0 \rightarrow K^+\pi^-)} \\
\frac{f_s \cdot BR(B^0_s \rightarrow K^+K^-)}{f_d \cdot BR(B^0 \rightarrow K^+\pi^-)}
\end{array}
\]

<table>
<thead>
<tr>
<th>source</th>
<th>shift wrt central fit</th>
<th>shift wrt central fit</th>
</tr>
</thead>
<tbody>
<tr>
<td>mass scale</td>
<td>0.0036</td>
<td>0.0034</td>
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<tr>
<td>asymmetric momentum-p.d.f</td>
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<td>0.0030</td>
</tr>
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<td>dE/dx</td>
<td>0.0129</td>
<td>0.0107</td>
</tr>
<tr>
<td>input masses</td>
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<tr>
<td>combinatorial background model</td>
<td>0.0020</td>
<td>0.0020</td>
</tr>
<tr>
<td>momentum background model</td>
<td>0.0010</td>
<td>0.0060</td>
</tr>
<tr>
<td>MC statistics</td>
<td>0.0011</td>
<td>0.0012</td>
</tr>
<tr>
<td>charge asymmetry</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>$\Delta \Gamma_s/\Gamma_s$ Standard Model</td>
<td>–</td>
<td>0.0060</td>
</tr>
<tr>
<td>lifetime</td>
<td>–</td>
<td>0.0060</td>
</tr>
<tr>
<td>isolation efficiency</td>
<td>–</td>
<td>0.0370</td>
</tr>
<tr>
<td>XFT-bias correction</td>
<td>0.0050</td>
<td>0.0080</td>
</tr>
<tr>
<td>TOTAL (sum in quadrature)</td>
<td>0.0165</td>
<td>0.0413</td>
</tr>
</tbody>
</table>

Isolation efficiency $\varepsilon(B^0)/\varepsilon(B^0_s)$ from the data using 180 pb$^{-1}$
$A_{CP}(B^0 \rightarrow K^+\pi^-)$ cuts: other fit parameters

Combinatorial background

<table>
<thead>
<tr>
<th>parameter</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_{\pi^+}$ (combinatorial)</td>
<td>$0.545 \pm 0.017$</td>
</tr>
<tr>
<td>$f_{e^+}$ (combinatorial)</td>
<td>$0.036 \pm 0.005$</td>
</tr>
<tr>
<td>$f_{\pi^-}$ (combinatorial)</td>
<td>$0.080 \pm 0.025$</td>
</tr>
<tr>
<td>$f_{K^+}$ (combinatorial)</td>
<td>$0.337 \pm 0.031$</td>
</tr>
<tr>
<td>$f_{\pi^-}$ (combinatorial)</td>
<td>$0.533 \pm 0.018$</td>
</tr>
<tr>
<td>$f_{e^-}$ (combinatorial)</td>
<td>$0.030 \pm 0.005$</td>
</tr>
<tr>
<td>$f_{p}$ (combinatorial)</td>
<td>$0.132 \pm 0.027$</td>
</tr>
<tr>
<td>$f_{K^-}$ (combinatorial)</td>
<td>$0.304 \pm 0.033$</td>
</tr>
</tbody>
</table>

B$\rightarrow$3body background

- fraction of physics bckg (ARGUS norm.): $0.197 \pm 0.016$
- ARGUS cut-off [GeV/c$^2$]: $5.135 \pm 0.001$
- ARGUS shape: $8.467 \pm 3.45$
- $f_{\pi}$ (ARGUS): $0.728 \pm 0.027$
- $f_{K}$ (ARGUS): $0.272 \pm 0.027$
- background fraction: $0.481 \pm 0.008$
- $c_1$ (background shape): $-1.221 \pm 0.124$
### Significance Table

(Statistical + systematic)

<table>
<thead>
<tr>
<th>mode</th>
<th>yield</th>
<th>TOY stat. ($f = 0$)</th>
<th>syst.</th>
<th>Sign.($\text{TOY stat.} (f = 0) + \text{ syst.}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B^0 \to K^+ K^-$</td>
<td>$61 \pm 25$</td>
<td>21</td>
<td>35</td>
<td>$1.5\sigma$</td>
</tr>
<tr>
<td>$B^0_s \to \pi^+ \pi^-$</td>
<td>$26 \pm 16$</td>
<td>11</td>
<td>14</td>
<td>$1.5\sigma$</td>
</tr>
<tr>
<td>$B^0_s \to K^- \pi^+$</td>
<td>$230 \pm 34$</td>
<td>23</td>
<td>16</td>
<td>$8.2\sigma$</td>
</tr>
<tr>
<td>$\Lambda^0_b \to p\pi^-$</td>
<td>$110 \pm 18$</td>
<td>9</td>
<td>16</td>
<td>$5.9\sigma$</td>
</tr>
<tr>
<td>$\Lambda^0_b \to pK^-$</td>
<td>$156 \pm 20$</td>
<td>8</td>
<td>11</td>
<td>$11.5\sigma$</td>
</tr>
</tbody>
</table>

- **Raw yield ± stat.** from fit on data
- **Systematic error**
- **Statistical uncertainty** from pseudo-experiments where the fractions of rare modes are fixed =0.
- **Statistical error** from the pseudo-experiment + systematic error. (Sum in quadrature).
Prospects for $A_{CP}(B^0_s \rightarrow K^+K^-)$

The large available sample allows expecting $\sigma(A_{CP}) \sim 0.2$ with runII sample

This allows searches for new physics. See below a recent work quoting the present measurement about SUSY search.

[Baek et al, hep-ph/0610109]