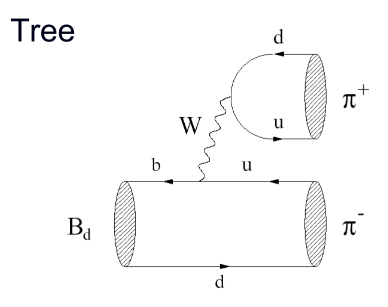
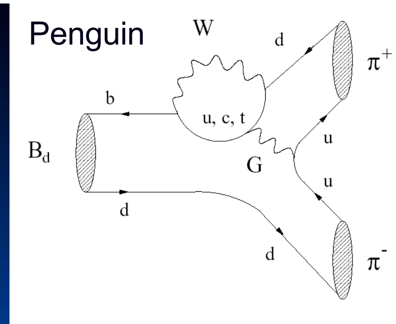
$B \to h^+h^-$ modes at CDF

G. Punzi
for the CDF collaboration

CKM workshop 2006
Nagoya, Japan



Outline



- CDF results with 1 fb^{-1} sample [hep-ex/0612018]

  (Updates previous results with 180pb-1 or 360pb-1)

  & PROSPECTS

- SCOPE: All modes into pairs of charged charmless hadrons:

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

- Better known modes:
  - $B^0 \rightarrow K^+\pi^-$
  - $B^0 \rightarrow \pi^+\pi^-$
  - $B^0_s \rightarrow K^+K^-$ (observed by CDF)

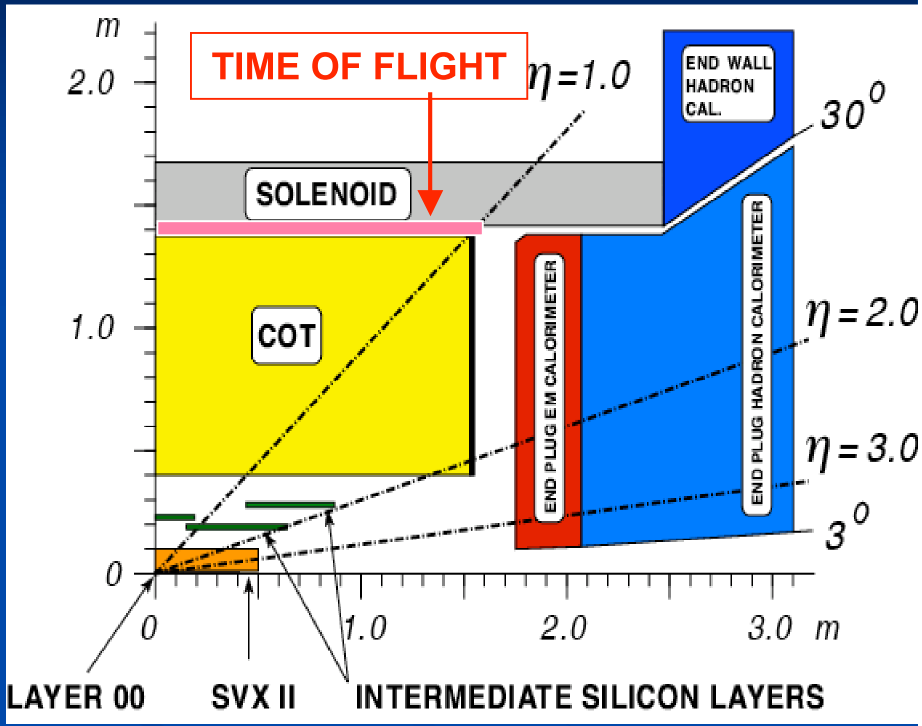
DCPV

- Rarer modes: NEW!
  - $B^0_s \rightarrow K^-\pi^+$
  - $B^0 \rightarrow K^+K^-$
  - $B^0_s \rightarrow \pi^+\pi^-$
  - $\Lambda_b \rightarrow pK$
  - $\Lambda_b \rightarrow p\pi$

All BR's are normalized to $B^0 \rightarrow K^+\pi^-$

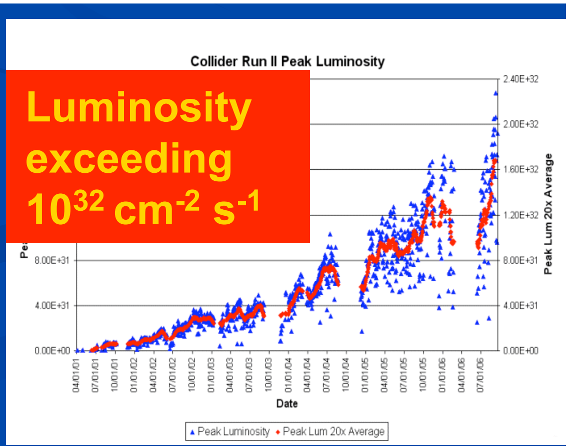
Important CDF features

- Central Drift chamber in B field
  - $\sigma(p_T)/p_T^{\,2} \sim 0.1\%\ \mathrm{GeV}^{-1}$
  - dE/dx measurement
- Silicon VerteX detector
  - I.P. resolution: 35μm@2GeV
- Time-of-Flight
  - Contol systematics from possible proton background asymmetry



- Tracking trigger:
  - XFT @L1: 2D tracks in COT, $p_T > 1.5$ GeV/c^2
  - SVT @L2: 2D tracks in COT+SVX $p_T > 2.0$ GeV/c^2
    - ☞ Impact parameter measurement
- Luminosity + X-sec + trigger ⇒ Current monthly rate of $B^0 \to h^+h^-$ > both Υ(4S) experiments

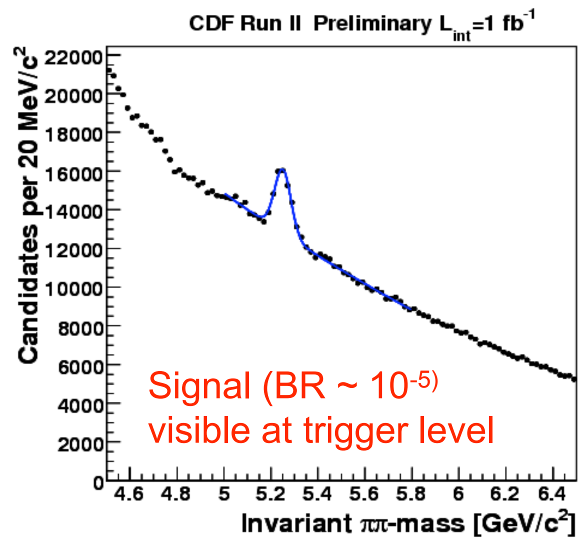
Already 1.7 fb-1 on tape, expect ~ 8 fb-1 by 2009



Sample selection

TRIGGER cuts

- Reject light-quark background
  - Two oppositely-charged tracks
  - Transverse opening angle [20°, 135°];
  - p_{T1} , p_{T2} > 2 GeV;
  - $p_{T1}+p_{T2}$ > 5.5 GeV.
- Long-lived candidate
  - Track impact parameters >100 μm;
  - Transverse decay length L> 200 μm;
- Reject multi-prongs and backgrounds
  - B impact parameter < 140 μm;



OFFLINE cuts

- Further observables:
  - 3D Vertex chi-square
  - Isolation:

$$I(B)= \frac{Pt(B)}{Pt(B) + \Sigma_{cone} Pt_i}$$

- Effective in reducing light-quark background, 85% efficient. (analog of event shape at e^+e^-)

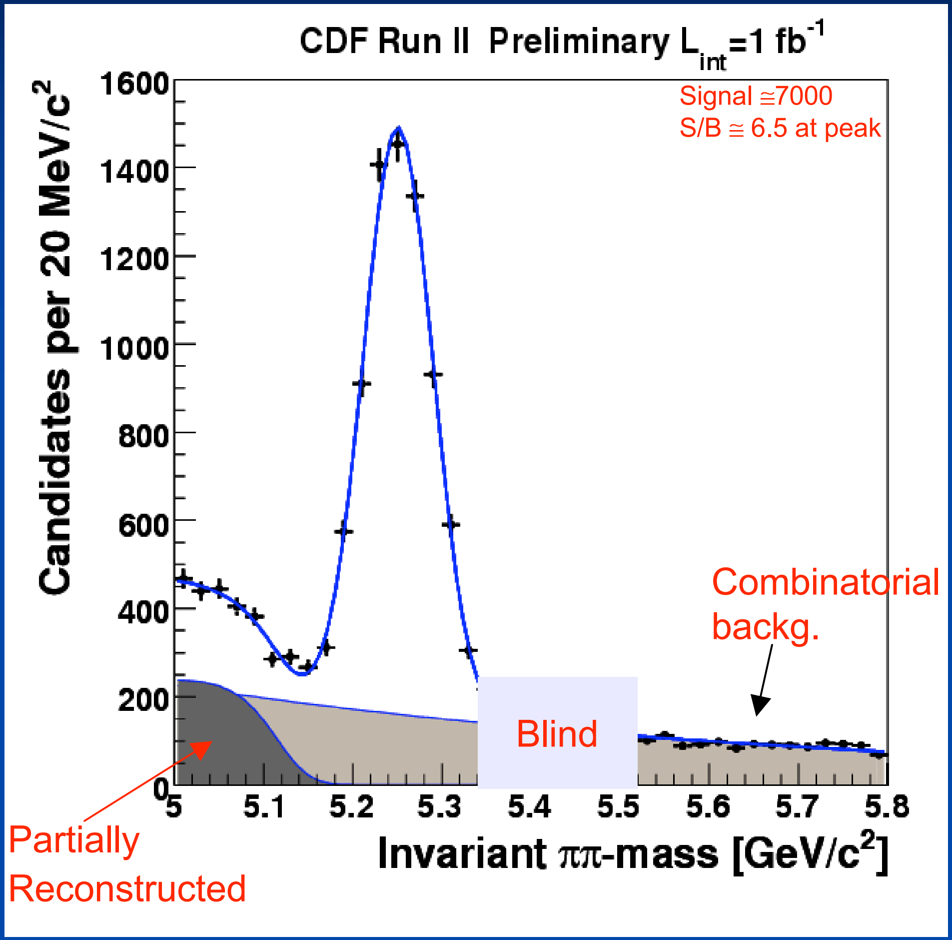
2 sets of cuts:

- Loose: optimize for $A_{CP}(B^0 \to K^+\pi^-)$

  (good for all three "large modes")
- Tight: optimize for $B^0_s \to K^-\pi^+$

  (good for all "rare modes")

Offline signal (loose cuts)



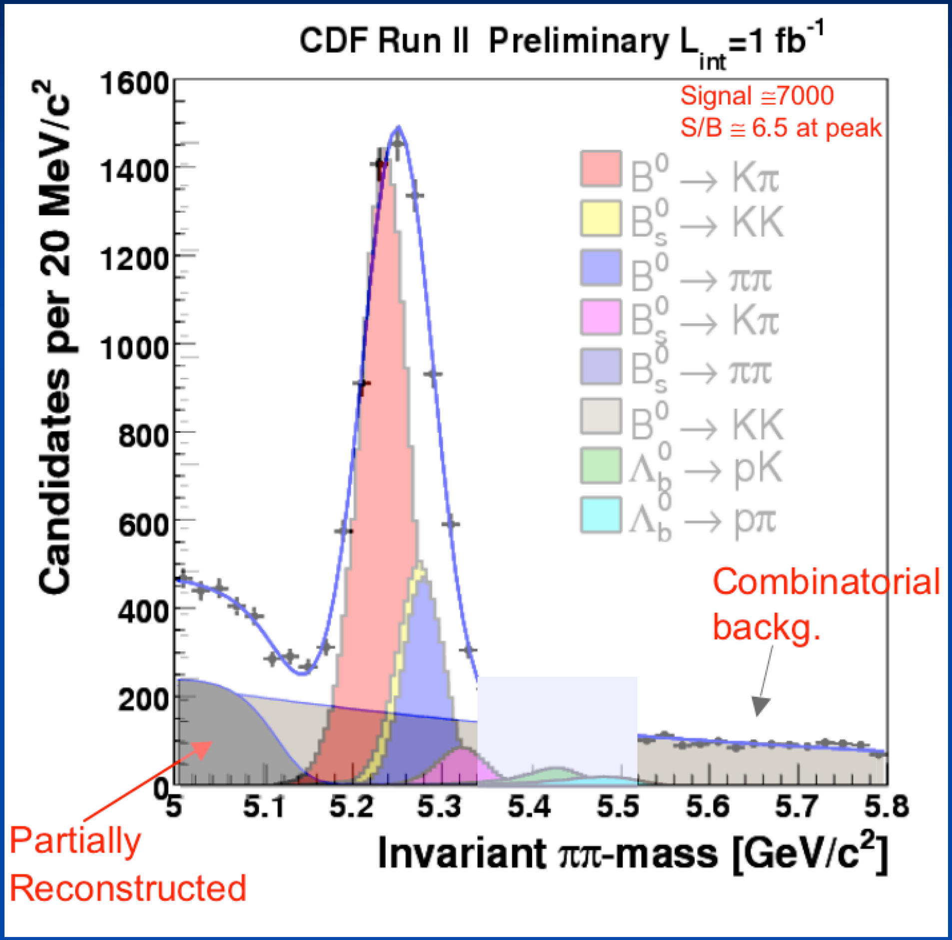
Despite good mass resolution (≅22 MeV/c²), individual modes overlap in a single peak (width ~35 MeV/c²)

Note that the use of a single mass assignment (ππ) 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).

Offline signal (loose cuts)



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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).

Separating channels

Unbinned ML fit based on 5 observables (kinematics+PID)

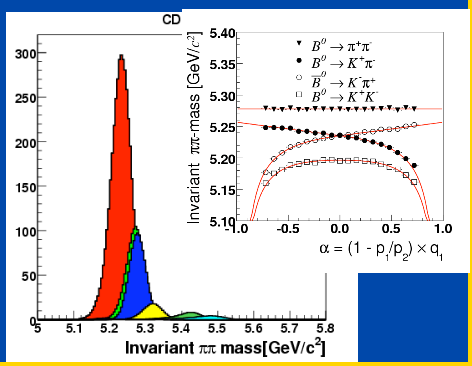
$$\mathcal{L}(\vec{\theta}) = \prod_{i=1}^{N} \mathcal{L}_i(\vec{\theta})$$

fraction of jth mode, to be determined by the fit

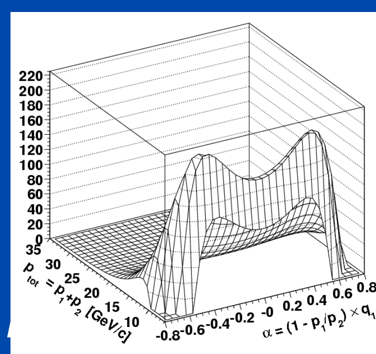
$$\mathcal{L}_i(\vec{\theta}) = (1-b)\sum f_j \mathcal{L}_j^{\text{sign}} + b\mathcal{L}^{\text{bckg}}$$

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

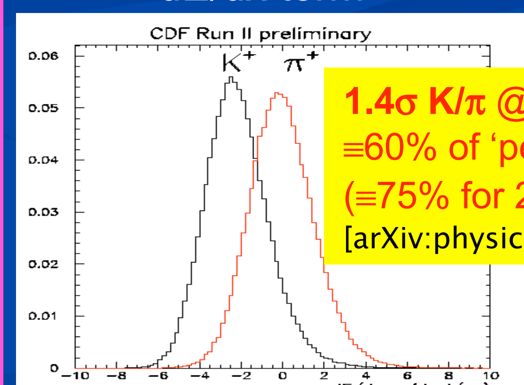
mass term



momentum term



dE/dx term

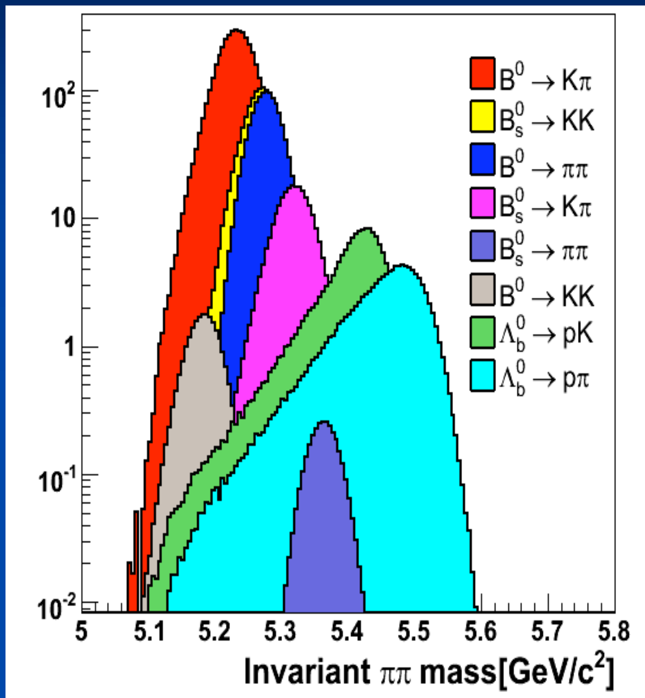


1.4σ K/π @p>2GeV
≡60% of ‘perfect’ PID
(≡75% for 2 particles)
[arXiv:physics/0611219]

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

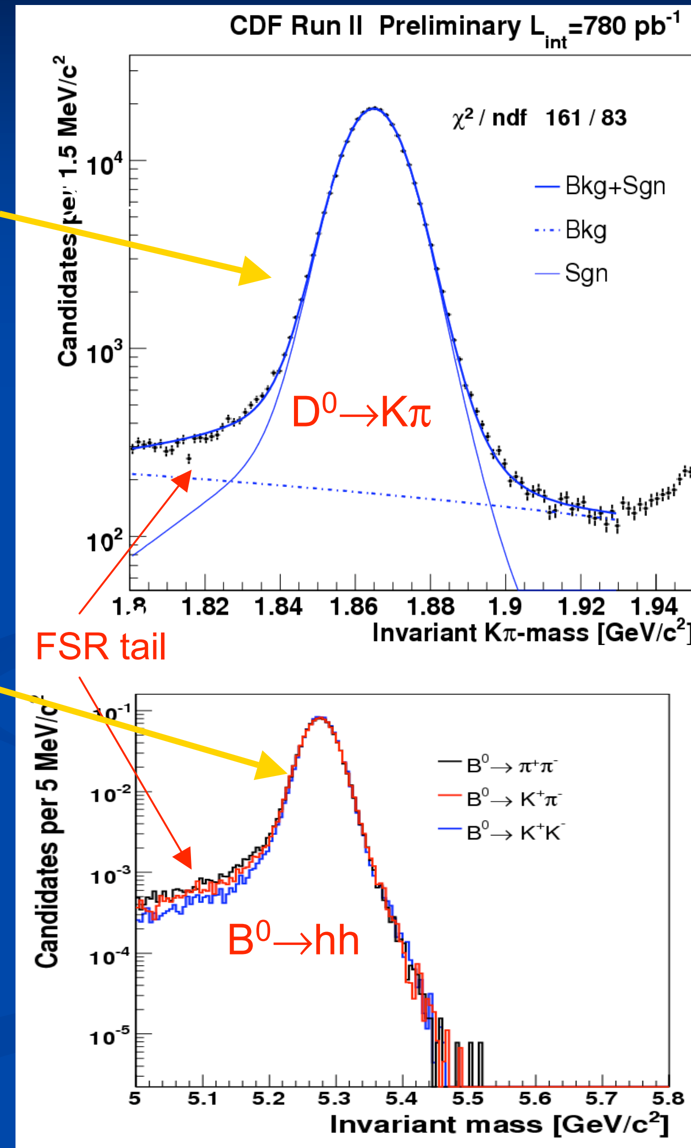
sign and bckg shapes
from $D^0 \to K^-\pi^+$

Mass lineshape and FSR



1) TEST on $D^0 \to K^-\pi^+$

2) APPLY to $B \to h^-h^+$



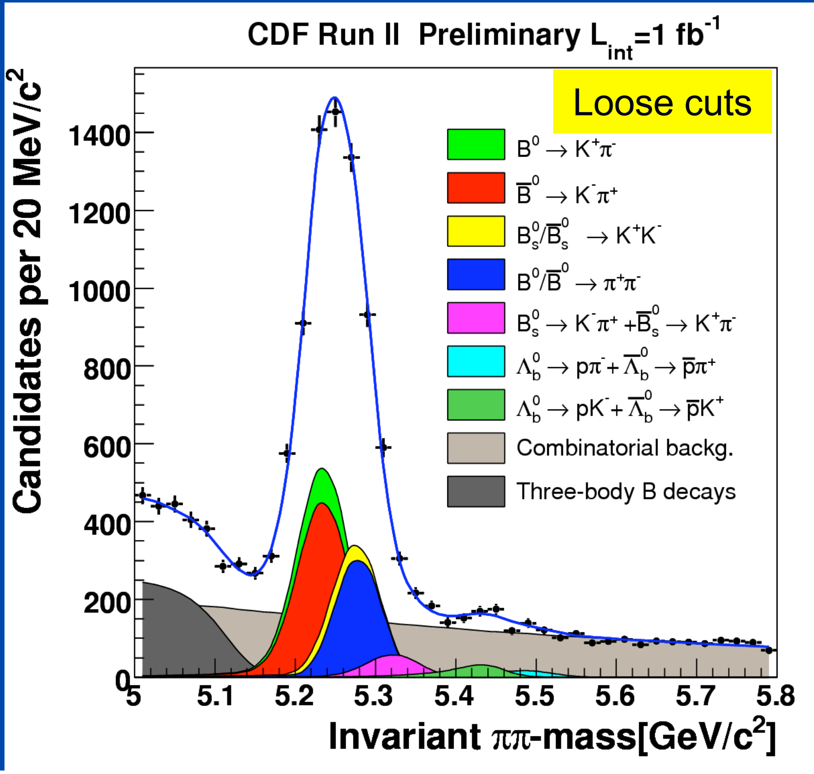
Results depend on assumed mass resolution and details of the lineshape (rare modes confuse with the tails of larger modes)

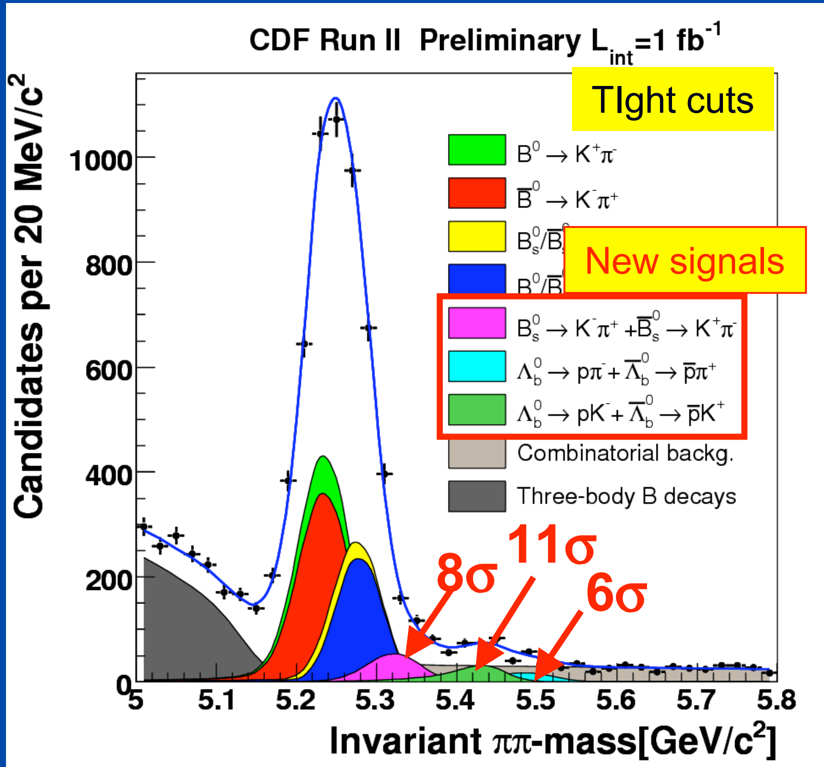
Need good control of non–gaussian resolution and effects of Final State Radiation

QED: [Baracchini,Isidori PL B633:309-313,2006]

$\to$ see E.Baracchini talk in this session

Raw fit results





parameter	fraction	yield	σ/σ_{ideal}
$B^0 \to \pi^+\pi^- + \text{c.c.}$	(0.160 ± 0.009)	1121 ± 63	1.8
$B^0 \to K^+\pi^- + \text{c.c.}$	(0.577 ± 0.010)	4045 ± 84	1.3
$B^0_s \to K^+K^- + \text{c.c.}$	(0.186 ± 0.009)	1307 ± 64	1.8

parameter	fraction	yield
$B^0_s \to K^-\pi^+ + \text{c.c.}$	(0.040 ± 0.006)	230 ± 34
$\Lambda^0_b \to p\pi^- + \text{c.c.}$	(0.019 ± 0.003)	110 ± 18
$\Lambda^0_b \to pK^- + \text{c.c.}$	(0.027 ± 0.003)	156 ± 20

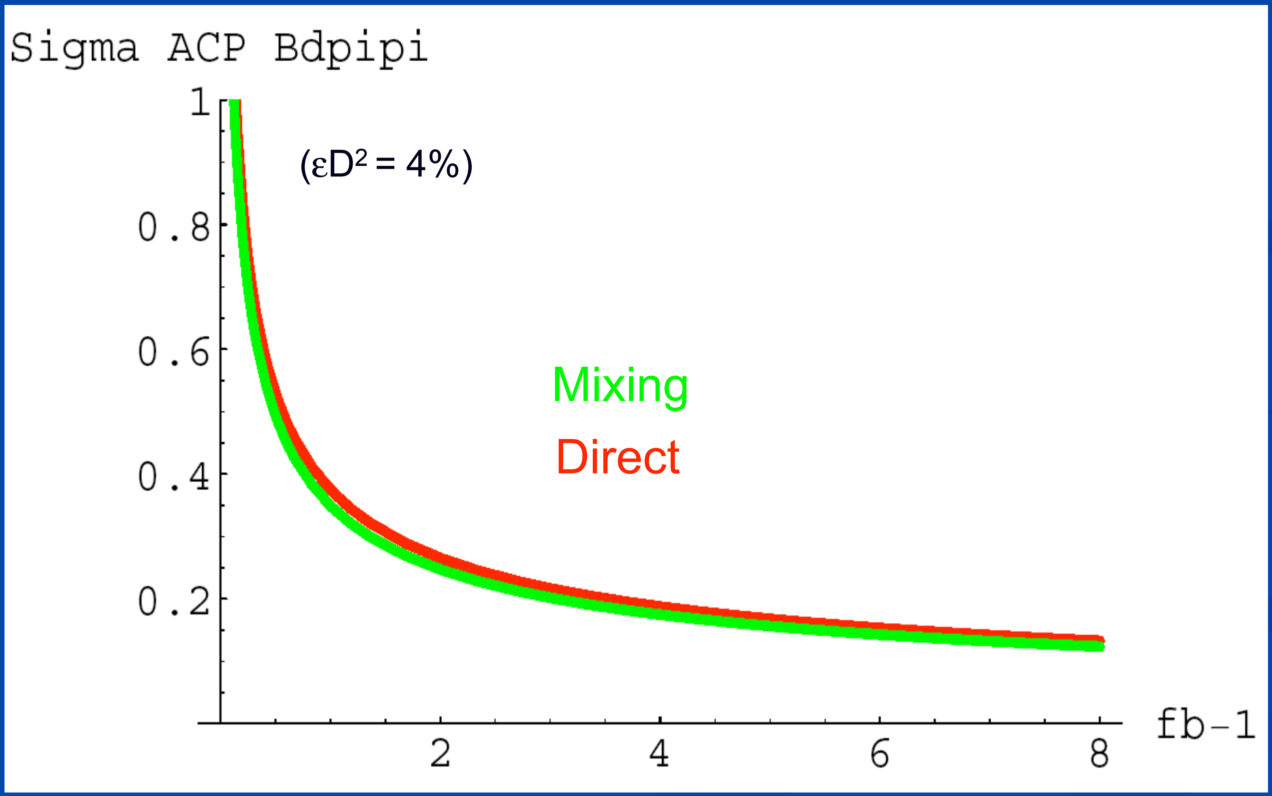
B^0 yields comparable to e^+e^-
Large $B^0_s \to K^+K^-$ sample

Good separation !
(compare to $\sqrt{N}$)

B_0 Results

$BR(B^0 \to \pi^+\pi^-)/BR(B^0 \to K^+\pi^-)$

$$\frac{BR(B^0 \to \pi^+\pi^-)}{BR(B^0 \to K^+\pi^-)} = 0.259 \pm 0.017\ (stat.) \pm 0.016\ (syst.)$$

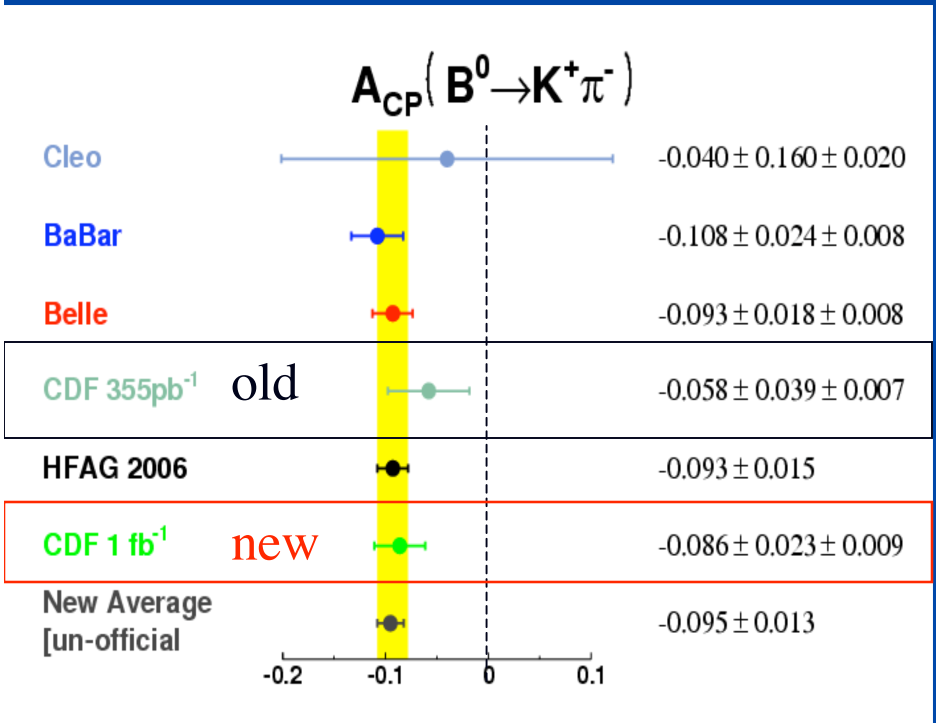


- A good crosscheck of the analysis, but also a precision measurement. systematic≅ statistics. Confirm previous results in a very different experimental setting
- Good perspectives for time-dependent A_{CP} measurements: expect similar resolution to current e+e- with full runII sample

Results on $A_{CP}(B^0 \to K^+\pi^-)$

3.5 σ

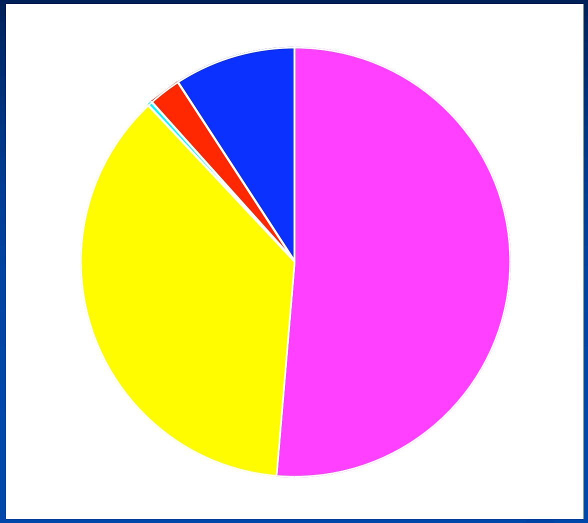
$$A_{CP} = \frac{N(\overline{B}^0 \to K^-\pi^+) - N(B^0 \to K^+\pi^-)}{N(\overline{B}^0 \to K^-\pi^+) + N(B^0 \to K^+\pi^-)} = -0.086 \pm 0.023\ (stat.) \pm 0.009\ (syst.)$$



- ✓Agrees with previous measurements (WA significance 6 σ →7 σ)
- ✓Discrepancy with $A_{CP}(B^+ \to K^+\pi^0)$ up to **4.9 σ** (whatever that means)
- ✓More robust SM test is the comparison with $A_{CP}(Bs \to K\pi)$ (see below)

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

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



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

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

Kinematic fit using *same code* of $B \to hh$ fit. Direct $A_{CP}(D^0 \to K\pi)$ very small:

$\Rightarrow$ extract from DATA correction for $\varepsilon(K^-\pi^+)/\varepsilon(K^+\pi^-)$ plus any spurious asymmetries.

Additional check: measurement of $A_{CP}(D^0 \to K\pi)$ based on dE/dx-only.

Discrepancy with the kinematic fit ($\cong$0.006) within quoted systematics.

Systematics can still decrease with larger calibration samples

Prospects for a runII CDF measurement with **<1% uncertainty**.

$\to$ see R. Fleischer talk in this session for connection with angle ϕ_3/γ

B_s Results

Updated BR($B^0_s \to K^+K^-$)

$$BR(B_s^0 \to K^+K^-) \quad = \quad (24.4 \pm 1.4\ (stat.) \pm 4.6\ (syst.)) \times 10^{-6}$$

Preliminary systematics at the moment, expect syst≅ stat for final result

Interesting comparison to predictions:

Naively : BR($B^0_s \to K^+K^-$) ≅ BR($B^0 \to K^+\pi^-$) ≅ $20 \cdot 10^{-6}$

QCDF : BR $23\text{-}36 \cdot 10^{-6}$ [Beneke&Neubert NP B675, 333(2003)]

QCD sum rules predict large SU(3) breaking BR ≅ $35 \cdot 10^{-6}$
[Khodjamirian et al. PRD68:114007, 2003; Buras et al, Nucl. Phys. B697, 133,2004]

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

Prospects for $A_{CP}(B^0_s \rightarrow K^+K^-)$

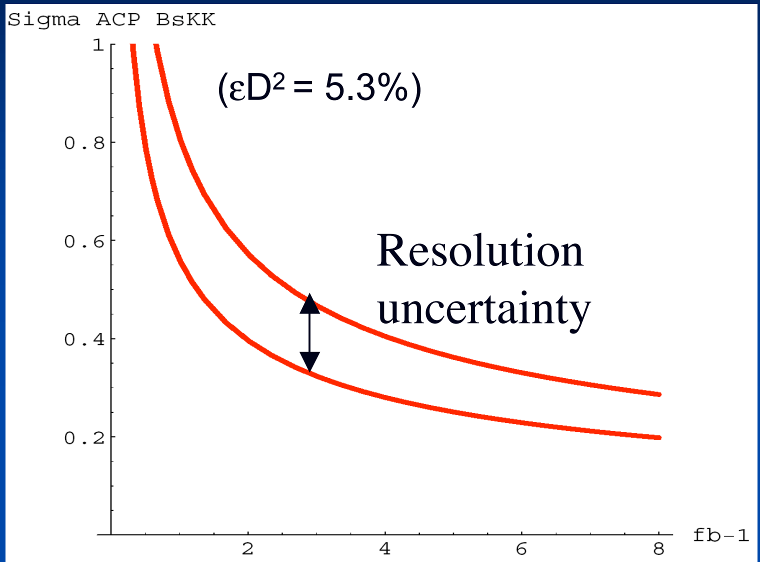
We now have all ingredients for a time-dependent ACP measurement

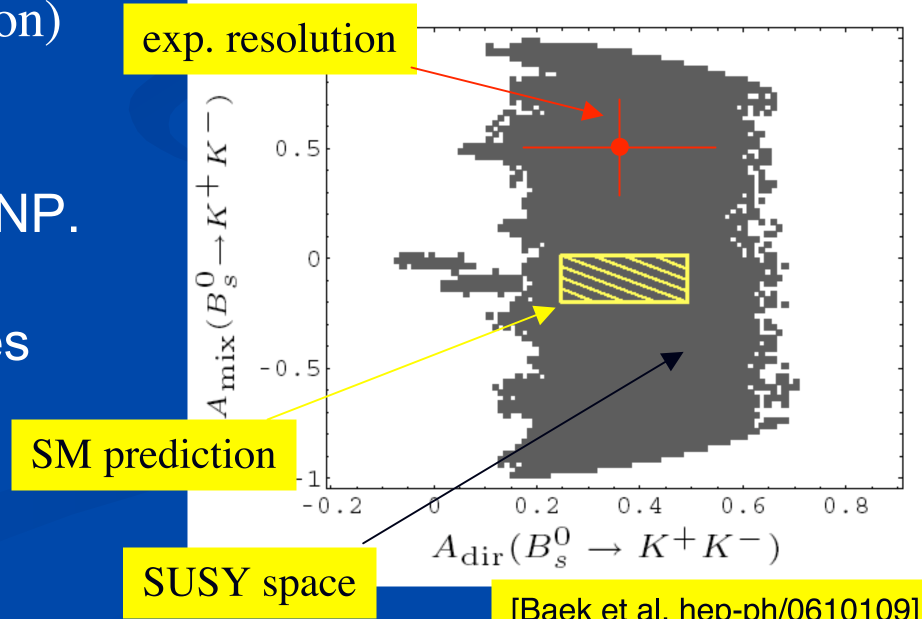
- Large samples (1300 ev/fb-1)
- Tag Dilutions calibrated, xs measured (→see F.Bedeschi,J.Kroll)

Can have $\sigma(A_{CP})$ ~0.2÷0.15 in runII (translate to sensitivity on γ ~ 10 deg.)

(→ see R. Fleischer in this session)

This resolution allows some tests for NP. See example at right, about possible impact of SUSY on these asymmetries





[Baek et al, hep-ph/0610109]

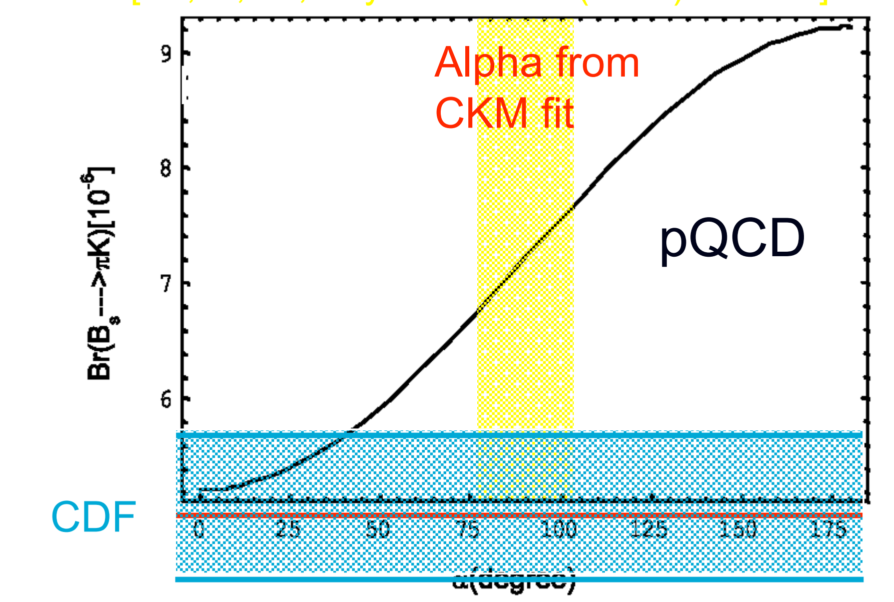
$BR(B^0_s \rightarrow K^-\pi^+)$ (NEW)

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

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

Previous limit (CDF) < 5.4 @90% CL

[Yu, Li, Lu, Phys.Rev. D71 (2005) 074026]



Large sensitivity to angle α/ϕ_2

[Gronau, Rosner, Phys. Lett. B 482, 71 (2000)]

[Yu, Li, Lu, Phys.Rev. D71 (2005) 074026]

SOME PREDICTIONS:

QCDF [7 ÷ 10] $\cdot 10^{-6}$

[Beneke&Neubert NP B675, 333(2003)]

pQCD: [6 ÷ 10]$\cdot 10^{-6}$

[Yu, Li, Lu, PRD71: 074026 (2005)]

SCET: $(4.9\pm1.8)\cdot 10^{-6}$

[Williamson,Zupan:PRD74(2006)014003]

Interesting dependence on CKM angles
Useful if it can be reliably predicted.

DCPV $B^0_s \to K^- \pi^+$

Observation of this decay offers a unique opportunity of checking for the SM origin of direct CP violation, by means of a “sum rule”:

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

Proposed in [Gronau Rosner Phys.Rev. D71 (2005) 074019],
later shown to hold under much weaker assumptions, in a paper titled:
“Is observed direct CP violation in $B^0 \to K^+ \pi^-$ due to new physics ?
Check standard Model prediction of equal violation in $B^0_s \to K^- \pi^+$ ”
[Lipkin, Phys. Lett. B621:126, .2005]

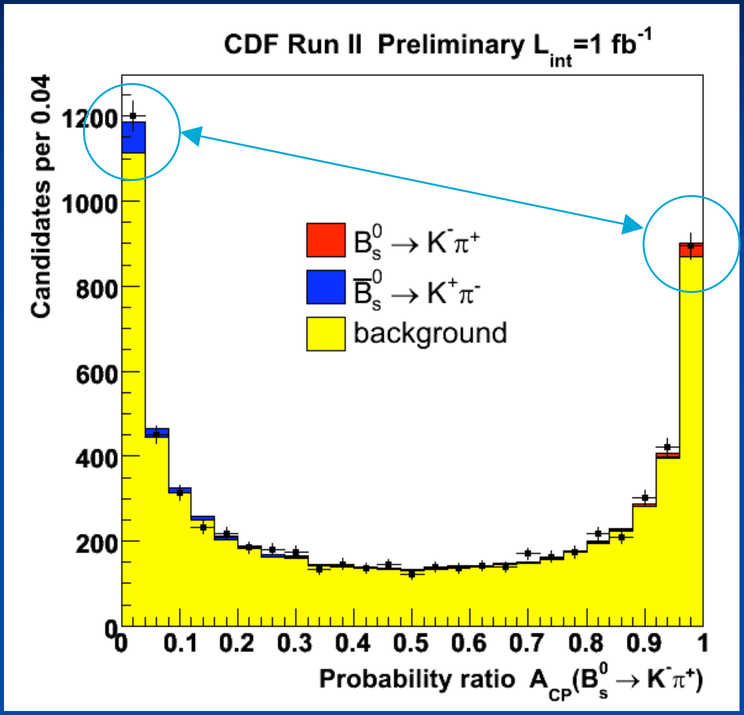
Currently unique to CDF. From our measured BR, we can predict DCPV using:

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

Low $BR(B^0_s \to K^+K^-)$ implies large asymmetry: DCPV≅ **37%**

Interesting case of large DCPV predicted under SM

Direct CPV in $B^0_s \to K^-\pi^+$



$$A_{CP} = 0.39 \pm 0.15\ (stat.) \pm 0.08\ (syst.)$$

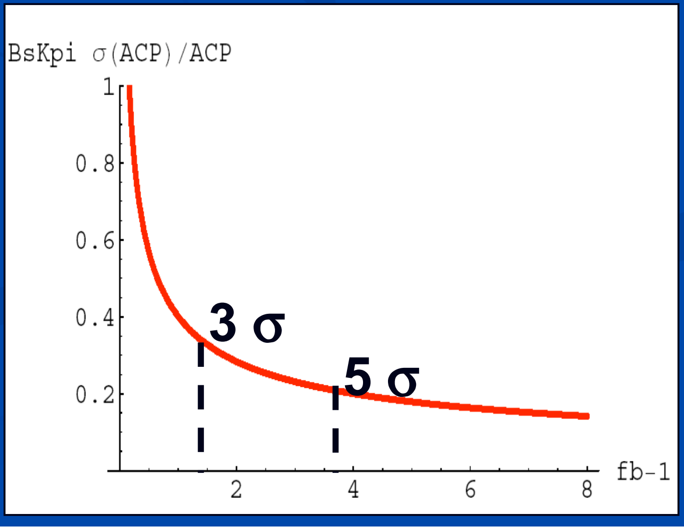
$$\frac{|A(\bar{B}_d \to \pi^+ K^-)|^2 - |A(B_d \to \pi^- K^+)|^2}{|A(B_s \to \pi^+ K^-)|^2 - |A(\bar{B}_s \to \pi^- K^+)|^2} =$$

= 0.84 ± 0.42(stat.) ± 0.15(syst.) (SM =1)

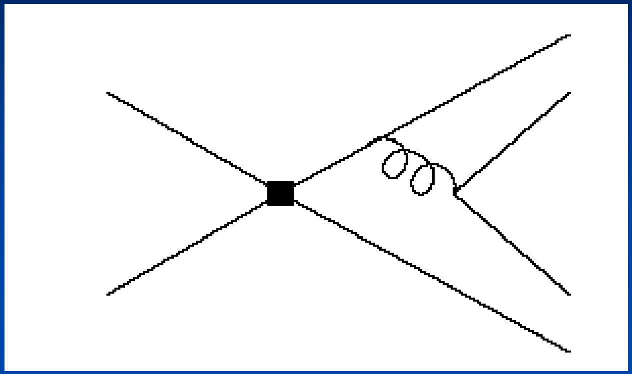
First measurement of DCPV in the Bs

Sign and magnitude agree with SM predictions within errors ⇒ no evidence for 'exotic' sources of CP violation (yet)

Exciting to pursue with more data



Pure-annihilation modes



- All final-state quarks different from initial state quarks. $\Rightarrow$ only via annihilation-type diagrams
- CDF is sensitive to $B_s \to \pi^+\pi^-$ in addition to the "traditional" $B_d \to K^+K^-$

  B_s expected x3-x4 larger - interesting candidate for this study

• To extract annihilation hadronic parameters, need BOTH measurements:

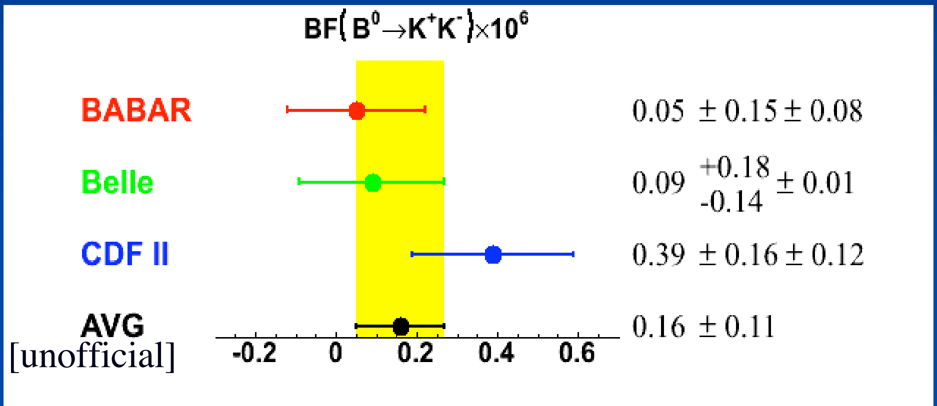
$$\frac{1}{\epsilon}\left[\frac{\mathrm{BR}(B_d \to K^+K^-)}{\mathrm{BR}(B_s \to \pi^+\pi^-)}\right]\frac{\tau_{B_s^0}}{\tau_{B_d^0}} = \frac{1 + 2\varrho_{\mathcal{PA}}\cos\vartheta_{\mathcal{PA}}\cos\gamma + \varrho_{\mathcal{PA}}^2}{\epsilon^2 - 2\epsilon\varrho_{\mathcal{PA}}\cos\vartheta_{\mathcal{PA}}\cos\gamma + \varrho_{\mathcal{PA}}^2}$$

[Buras et al., Nucl.Phys. B697 (2004) 133]

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

$$BR(B^0 \to K^+K^-) \quad = \quad (0.39 \pm 0.16\ (stat.) \pm 0.12\ (syst.)) \times 10^{-6}$$

($< 0.7 \cdot 10^{-6}$ @ 90% CL)



New WA : 0.16 ± 0.11 [speaker's calculation]

Expectations [0. 007 ÷ 0.08] $\cdot 10^{-6}$

[Beneke&Neubert NP B675, 333(2003)]

$\Rightarrow$ now in the region of interest

Current Best Limit

$$BR(B^0_s \to \pi^+\pi^-) \quad = \quad (0.53 \pm 0.31\ (stat.) \pm 0.40\ (syst.)) \times 10^{-6}$$

$<1.36 \cdot 10^{-6}$ @ 90% CL

Expectations: [0.024 ÷ 0.16] $\cdot 10^{-6}$ [Beneke&Neubert NP B675, 333(2003)]

0.42 ± 0.06 $\cdot 10^{-6}$ [Li et al. hep-ph/0404028]

We have reached the interesting region for these channels.
A signal might be just around the corner.

$\Lambda^0_b \to p\pi^-$ and $\Lambda^0_b \to pK^-$ (NEW)

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

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

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

Agrees with prediction: (0.60-0.62)

[Mohanta et al. Phys.Rev. D63 (2001) 074001]

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

BR and A_{CP} measurements in progress - expect LARGE A_{CP}.

Summary

- CDF is starting to deliver.
  First fb^{-1} in, several more to follow.
- Observed $B^0_s \to K^- \pi^+$ $\Lambda_b \to pK$, $\Lambda_b \to p\pi$ (previously $B^0_s \to K^- K^+$)
- Precision $A_{CP}(B^0 \to K^+\pi^-)$ confirms B-factories results.
  Expect final measurement below 1%
- First measurement of DCPV in B^0_s:
  SM prediction of large $A_{CP}(B^0_s \to K^-\pi^+)$ confirmed (for now)
- Updated $BR(B^0_s \to K^+K^-)$ does not show large U-spin breaking.
- Improved results on annihilation: $B^0 \to K^+K^-$ $B^0_s \to \pi^+\pi^-$
- Time-dependent measurements starting up.

Backup

ACP cuts: physical parameters

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

$$\frac{BR(B^0 \to \pi^+\pi^-)}{BR(B^0 \to K^+\pi^-)} = 0.259 \pm 0.017\ (stat.) \pm 0.016\ (syst.)$$

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With HFAG 2006:

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

$$BR(B_s^0 \to K^+K^-) = (24.4 \pm 1.4\ (stat.) \pm 4.6\ (syst.)) \times 10^{-6}$$

BsKpi cuts: physical parameters (1)

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

$$\frac{N(\overline{B}^0 \to K^-\pi^+) - N(B^0 \to K^+\pi^-)}{N(\overline{B}_s^0 \to K^+\pi^-) - N(B_s^0 \to K^-\pi^+)} = -3.21 \pm 1.60\ (stat.) \pm 0.39 (sys.)$$

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

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

With HFAG 2006:

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

BsKpi cuts: physical parameters (2)

$$N_{\text{raw}}(B_s^0 \to \pi^+\pi^-) = 26 \pm 16\ (stat.) \pm 14\ (syst.)$$

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

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

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

With HFAG 2006:

$$BR(B^0 \to K^+K^-) = (0.39 \pm 0.16\ (stat.) \pm 0.12\ (syst.)) \times 10^{-6}$$

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

$$BR(B_s^0 \to \pi^+\pi^-) = (0.53 \pm 0.31\ (stat.) \pm 0.40\ (syst.)) \times 10^{-6}$$

$$BR(B_s^0 \to \pi^+\pi^-) < 1.36 \cdot 10^{-6}\ @\ 90\%\ C.L.$$

BsKpi cuts: physical parameters (3)

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

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

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

$A_{CP}(B^0 \to K^+\pi^-)$ cuts: other fit parameters

Combinatorial background

parameter	value
f_{π^+} (combinatorial)	0.545 ± 0.017
f_{e^+} (combinatorial)	0.036 ± 0.005
f_p (combinatorial)	0.080 ± 0.025
f_{K^+} (combinatorial)	0.337 ± 0.031
f_{π^-} (combinatorial)	0.533 ± 0.018
f_{e^-} (combinatorial)	0.030 ± 0.005
$f_{\bar{p}}$ (combinatorial)	0.132 ± 0.027
f_{K^-} (combinatorial)	0.304 ± 0.033

$B \to$3body background

fraction of physics bckg (ARGUS norm.)	0.197 ± 0.016
ARGUS cut-off [GeV/c^2]	5.135 ± 0.001
ARGUS shape	8.467 ± 3.45
f_π (ARGUS)	0.728 ± 0.027
f_K (ARGUS)	0.272 ± 0.027
background fraction	0.481 ± 0.008
c_1 (background shape)	-1.221 ± 0.124

Significance Table

(Statistical + systematic)

raw yield ± stat. from fit on data

systematic error

mode	yield	TOY stat. ($f=0$)	syst.	Sign.(TOY stat.($f=0$) + syst.)
$B^0 \to K^+K^-$	61 ± 25	21	35	1.5σ
$B_s^0 \to \pi^+\pi^-$	26 ± 16	11	14	1.5σ
$B_s^0 \to K^-\pi^+$	230 ± 34	23	16	8.2σ
$\Lambda_b^0 \to p\pi^-$	110 ± 18	9	16	5.9σ
$\Lambda_b^0 \to pK^-$	156 ± 20	8	11	11.5σ

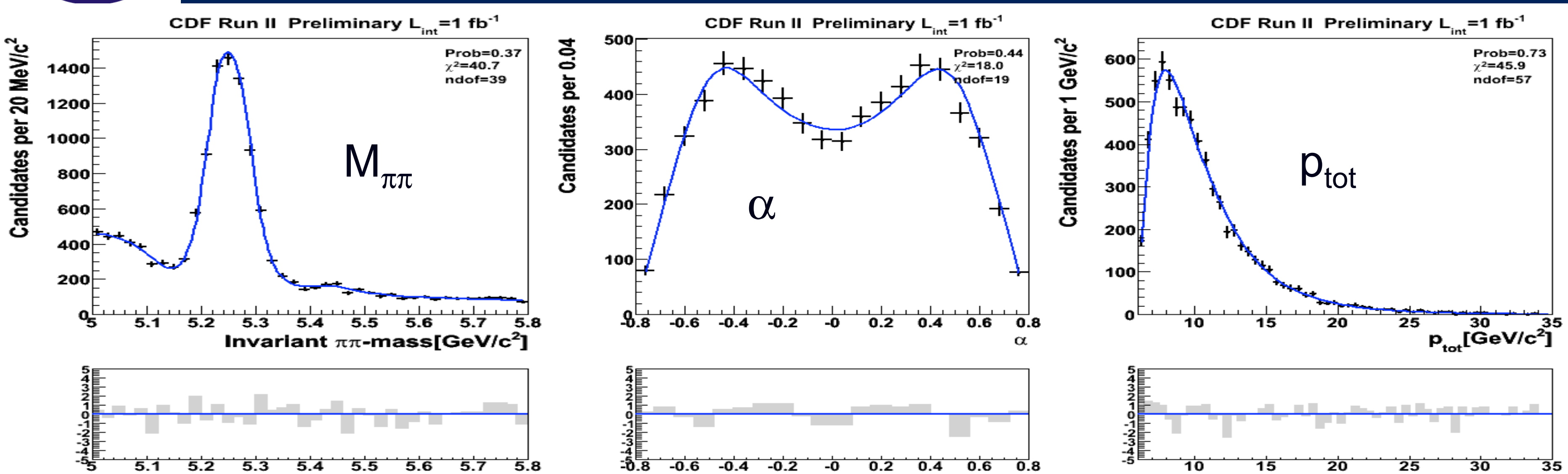
statistical uncertainty from pseudo experiments where the fractions of rare modes are fixed =0.

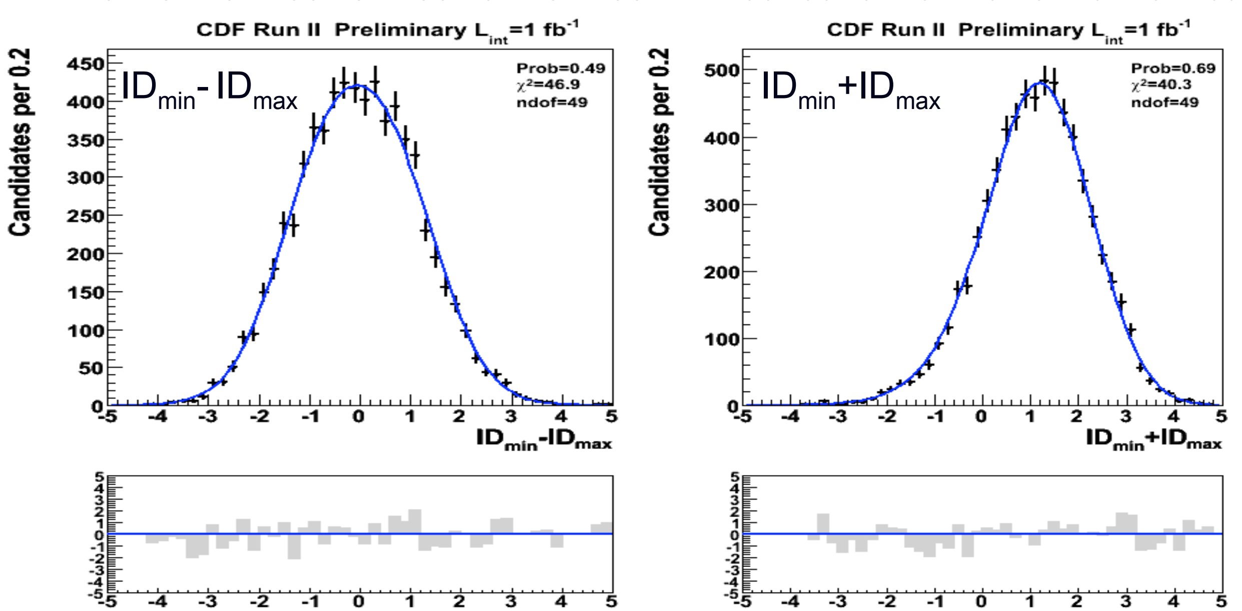
statistical error from the pseudo-experiment + systematic error. (Sum in quadrature).

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

source	shift wrt central fit
mass scale	0.0004
asymmetric momentum-p.d.f	0.0001
dE/dx	0.0064
input masses	0.0054
combinatorial background model	0.0027
momentum background model	0.0007
MC statistics	–
charge asymmetry	0.0014
$\Delta\Gamma_s/\Gamma_s$ Standard Model	–
lifetime	–
isolation efficiency	–
XFT-bias correction	–
TOTAL (sum in quadrature)	**0.009**

Fit projections





Many crosschecks:

-Gaussian fit pulls

-PID-less fit agrees with regular fit

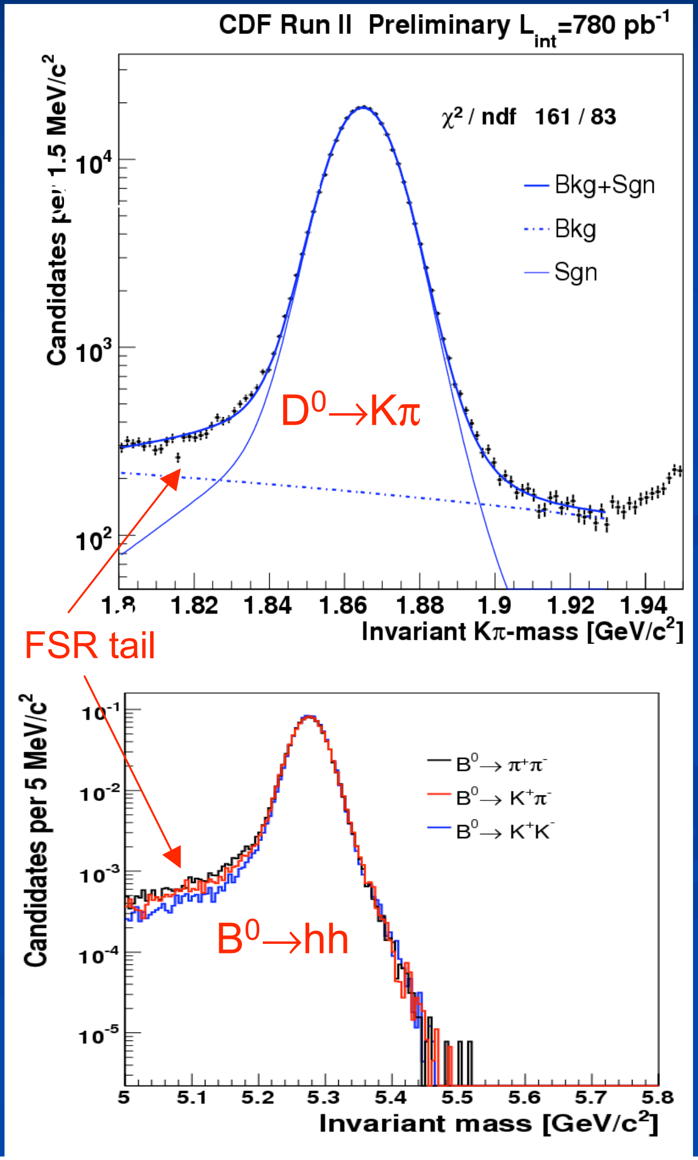
- Free-mass-resolution fit agrees with standard fit

- Free-mass-scale fit agrees and returns mass shift

$$\delta = 0.2 \pm 0.6 \text{ MeV/c}^2$$

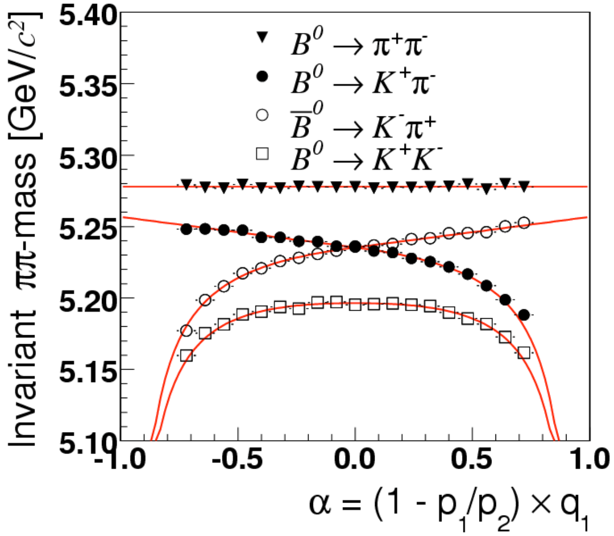
Calibrating Mass resolution and tails from the $D^0 \to K\pi$ peak

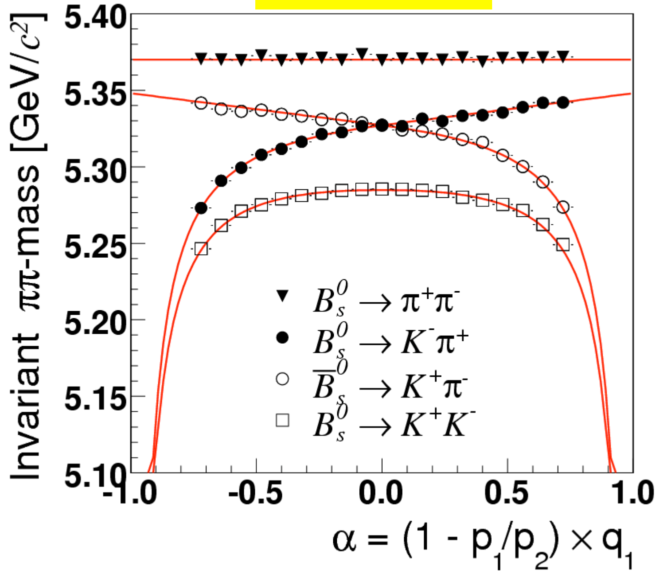
1. Accurate parameterization of *individual track parameters* resolution functions from full MC (including non-gaussian tails)
2. Add calculated QED radiation [Baracchini,Isidori PL B633:309-313,2006]
3. Generate mass lineshapes with a simple kinematical MC
4. Compare results with a huge sample of $D^0 \to K\pi$
   $\Rightarrow$ perfect match, no tuning necessary $\Rightarrow$ small systematics
5. Generate $B \to hh$ templates and use them in the Likelihood fit.

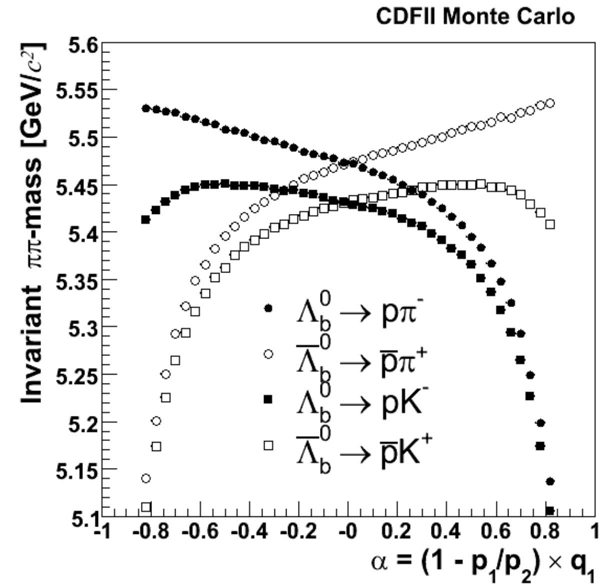


Handle 2: track momenta

CDF MC







Kinematic variables:

p_{min} (p_{max}) is the 3D track momentum with $p_{min} < p_{max}$

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

Each mode has an individual mass distribution $p(M_{\pi\pi}) = G(M_{\pi\pi} - F(\alpha , p_{tot}))$

This offers good discrimination amongst modes and between $K^+\pi^-$ / $K^-\pi^+$.

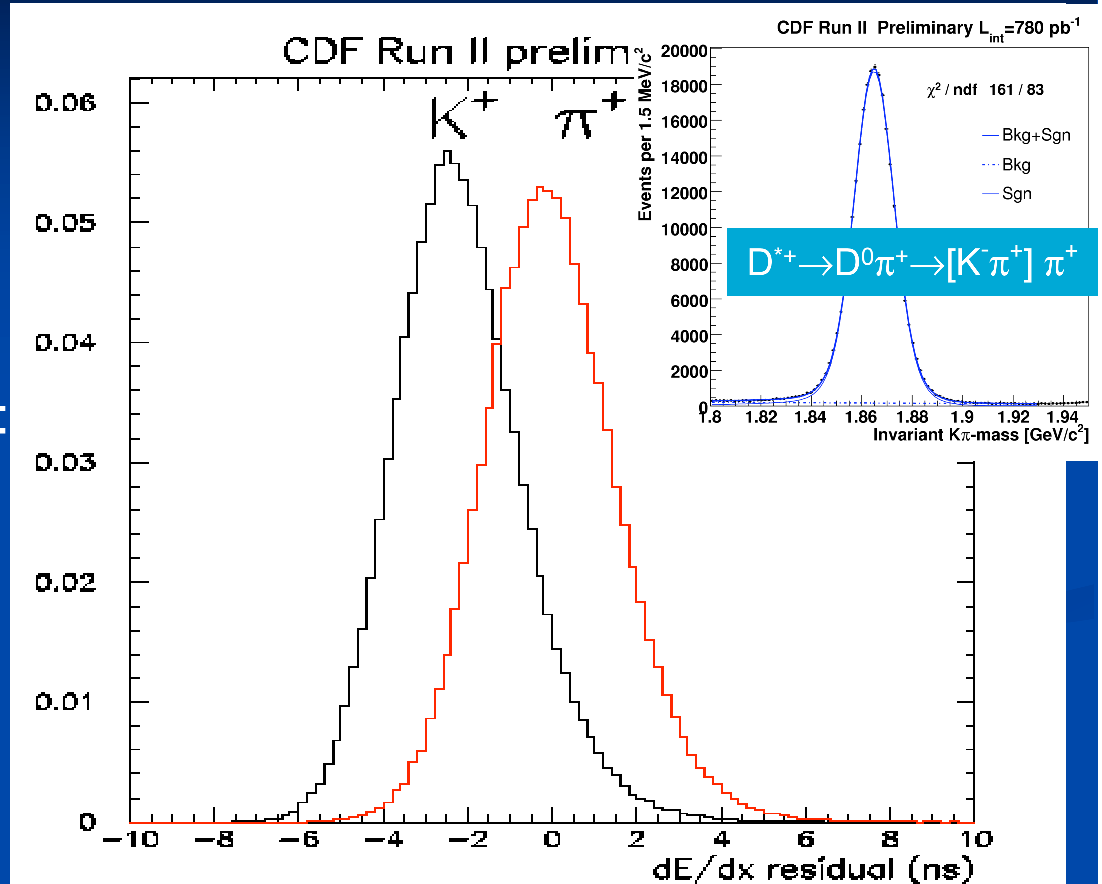
Handle 3: dE/dx

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

Useful quantity to plot ('kaonness'):

$$\mathrm{ID(track)} = \frac{\left.\frac{dE}{dx}\right|_{\mathrm{meas}}(\mathrm{track}) - \left.\frac{dE}{dx}\right|_{\mathrm{exp}-\pi}(\mathrm{track})}{\left.\frac{dE}{dx}\right|_{\mathrm{exp}-K}(\mathrm{track}) - \left.\frac{dE}{dx}\right|_{\mathrm{exp}-\pi}(\mathrm{track})}.$$

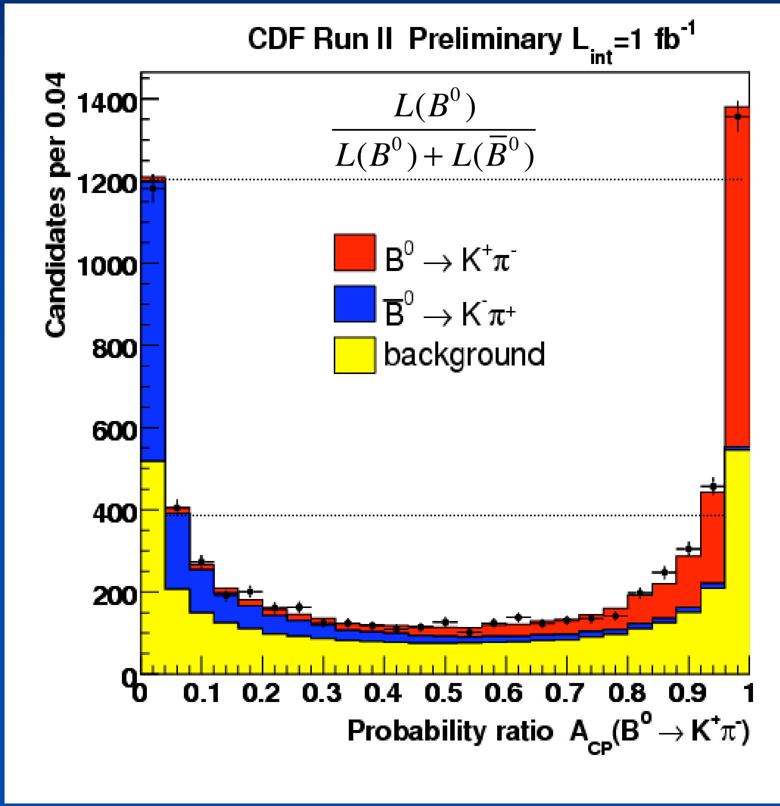
<ID>(pion) = 0
<ID>(kaon) = 1
(independent of p)



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

1.4σ K/π separation for p>2GeV achieve a statistical uncertainty on separating classes of particles which is just 60% worse than 'perfect' PID

Direct ACP ($B^0 \to K^+\pi^-$)



Large sample >4000 events allows measuring DCPV

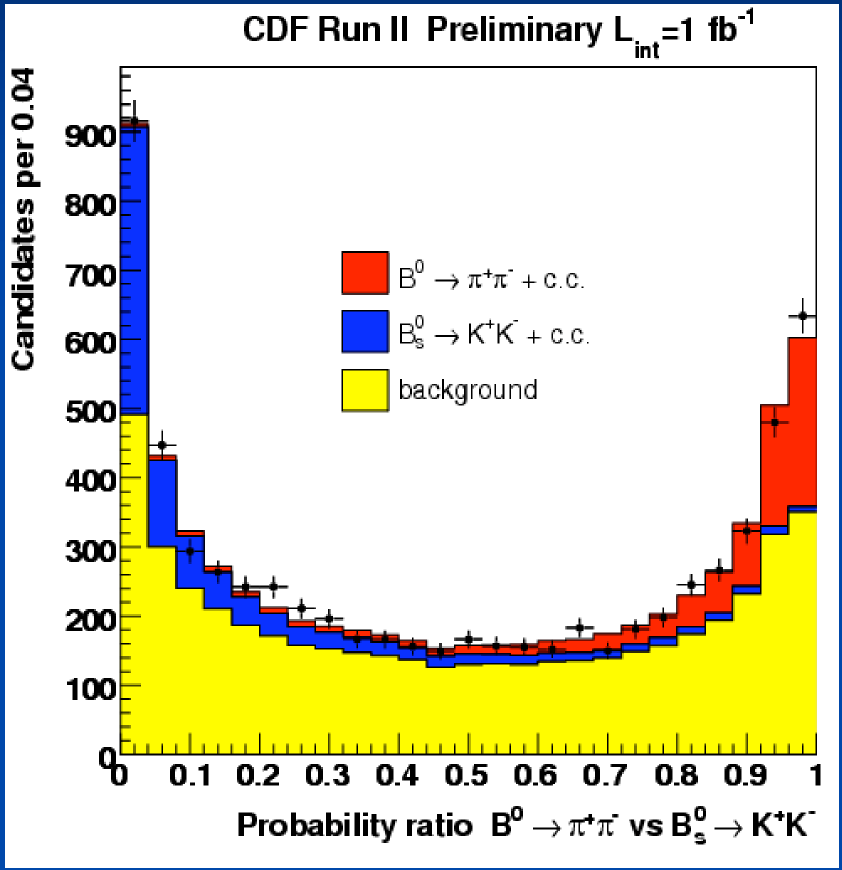
Plot of $L(B^0)/[L(B^0)+L(\bar{B}^0)]$ shows good separation achieved between B^0 and $\bar{B}^0$ (mass, alpha, dE/dx)

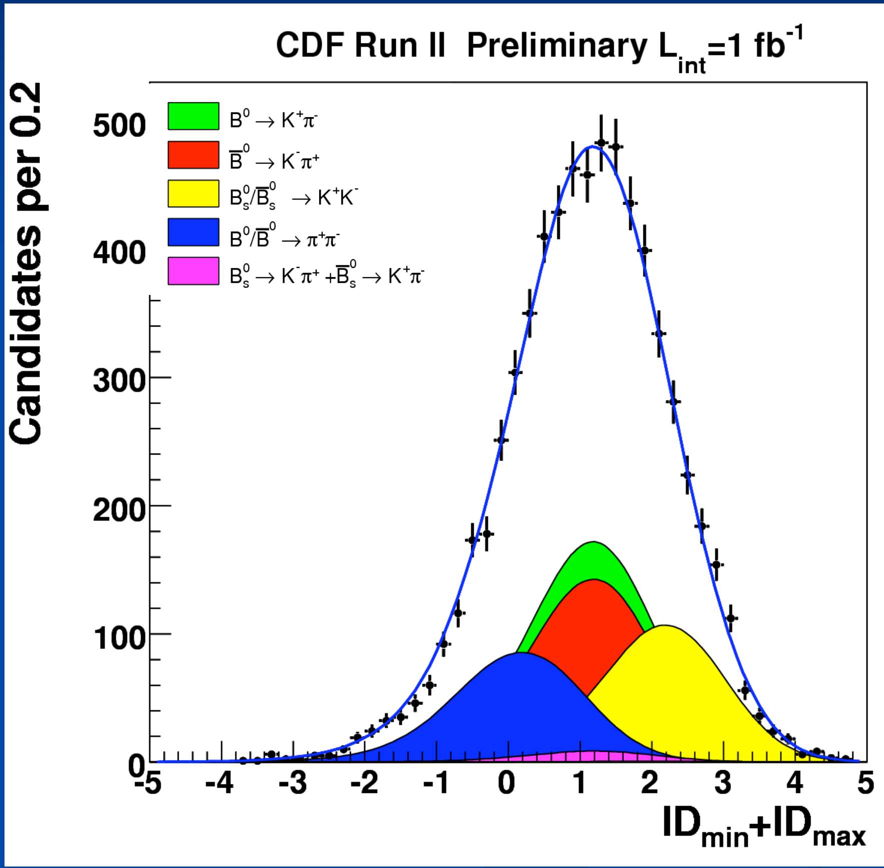
Significant raw asymmetry, good resolution:

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

Separating $B^0_s \to K^+K^-$ from $B^0 \to \pi^+\pi^-$

PID separation $\pi\pi/KK \cong 2\sigma$





Isolation cut efficiency

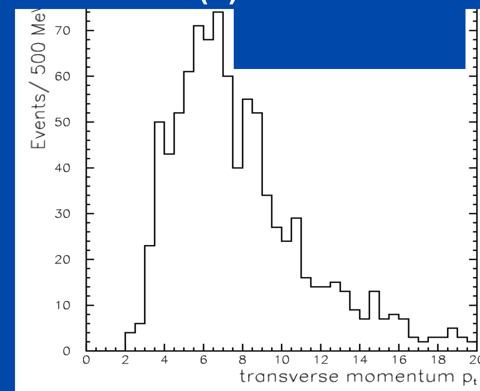
In order to normalize Bs Branching Fraction, need to know the relative efficiency.

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

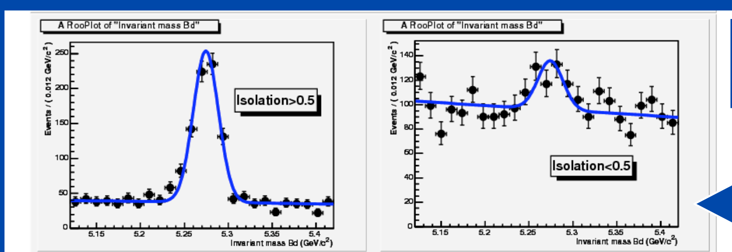
Need low-p_T samples: low edge of $p_T \sim 3$ GeV

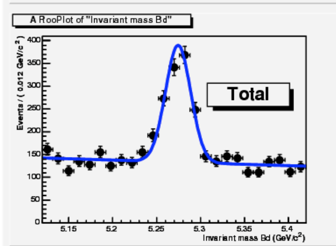
Maximum Likelihood fit of yields in exclusive modes.

$p_T(B^0_{(s)} \rightarrow h^+h'^-)$

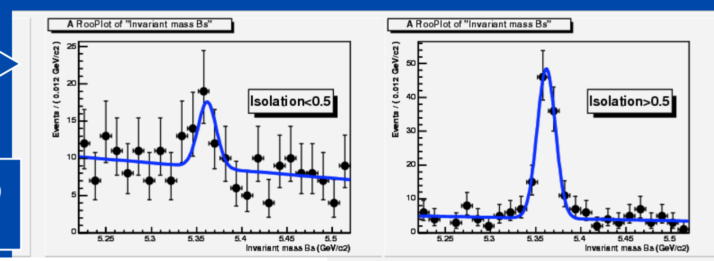


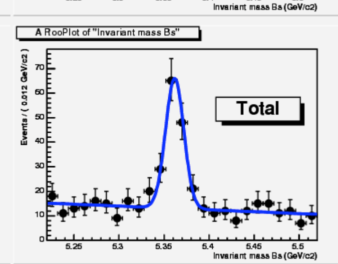
$B^0 \rightarrow J/\psi K^{*0}$





$B^0_s \rightarrow J/\psi\phi$





GeV/c	$\epsilon_{Iso}(B_d)$	$\epsilon_{Iso}(B_s)$	$\epsilon_{Iso}(B_d)/\epsilon_{Iso}(B_s)$
$p_T(B) < 6$	57.5±9.7	70.1±14.6	0.82±0.22
$6 < p_T(B) < 10$	84.6±2.4	84.8±5.7	1.00±0.08
$p_T(B) > 10$	93.8±1.2	90.4±2.8	1.04±0.03