Rare Hadronic B Decays

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For the BaBar Collaboration

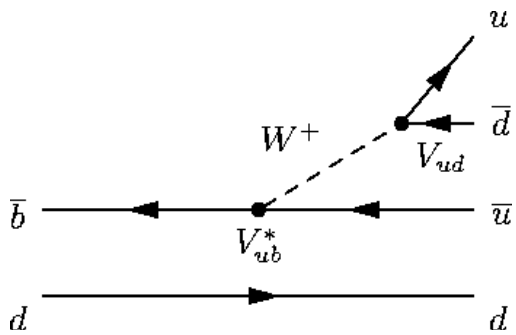
BABAR

Rare Hadronic B Decays

CKM suppressed: $|V_{ub}/V_{cb}| \approx \lambda$

$B \rightarrow \pi^+\pi^-, \pi^0\pi^0, B \rightarrow K\pi\pi, \pi\pi\pi, \rho\rho$

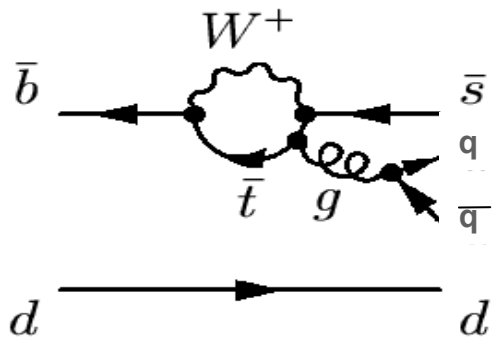
Br O(10^{-5}, 10^{-6})

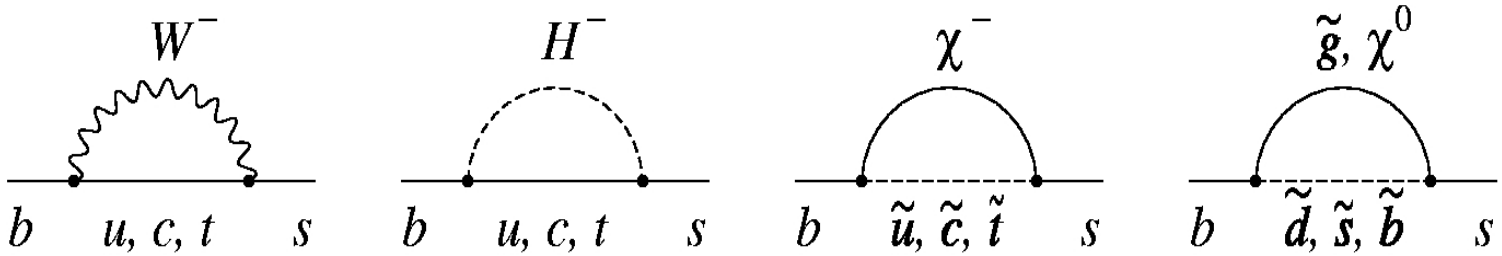


Leading order Penguin: $\alpha_s/4\pi$

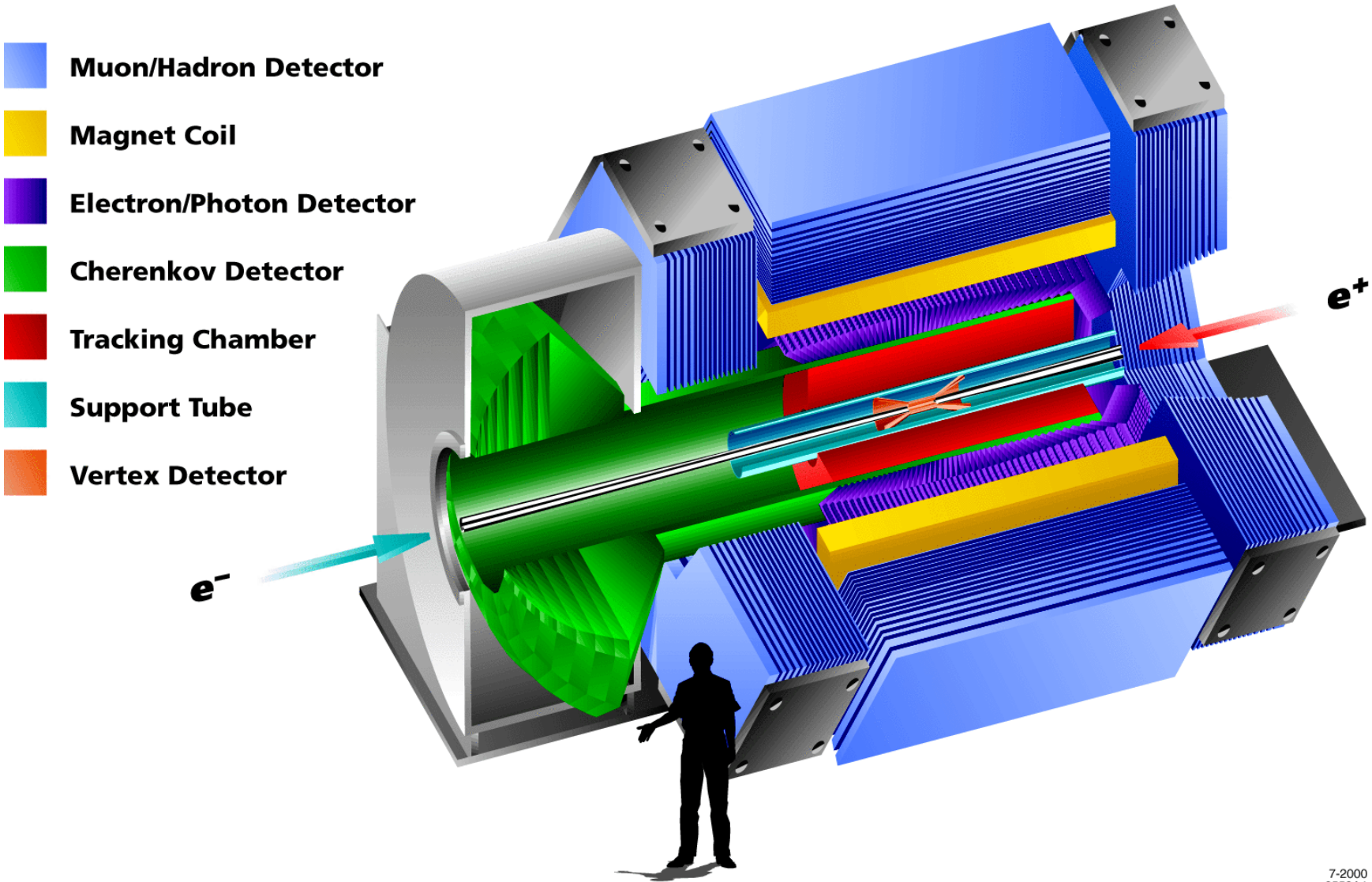
$B \rightarrow \Phi K, \eta K, \eta' K$

Br O(10^{-5}, 10^{-6})





The BaBar Detector



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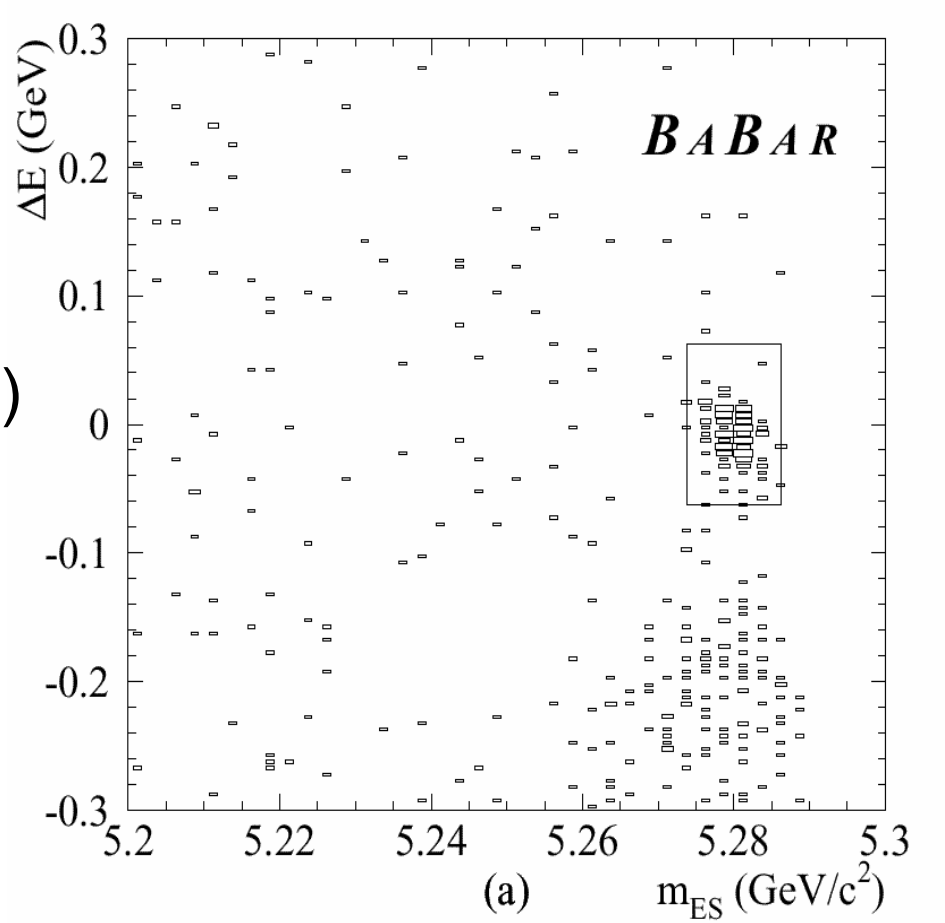
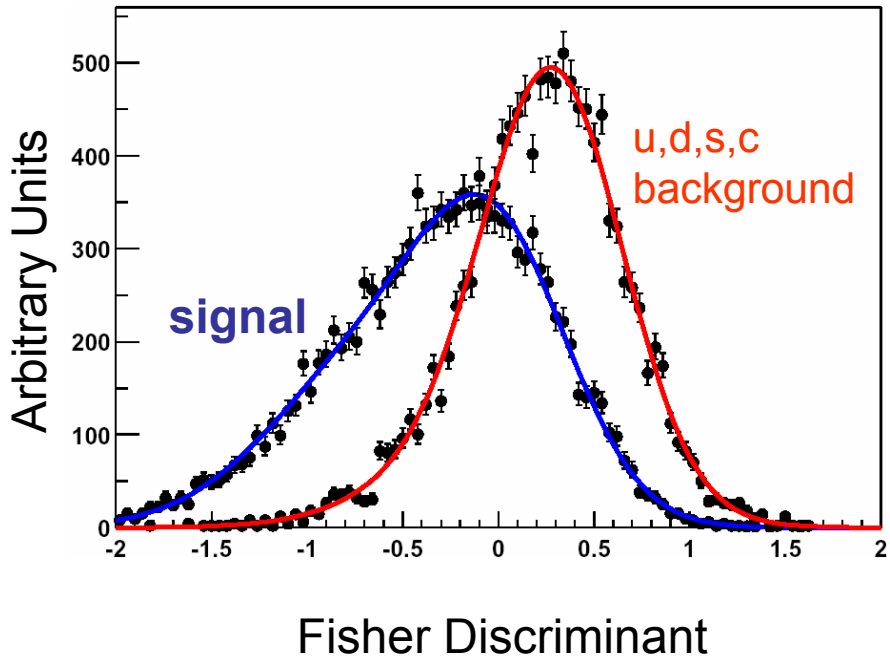
Common Analysis Techniques 1

- Kinematic Variables
  - $e^+e^- \rightarrow \Upsilon(4S) \rightarrow B\bar{B}$
  - $\Delta E = E^*_B - E^*_{beam}$
  - $M_{ES} = \sqrt{(E^{*2}_{beam} - p^{*2}_B)}$
  - ($*$ => CMS)
- For signal:
  - ΔE peaks at 0
  - M_{ES} peaks at the mass of the B



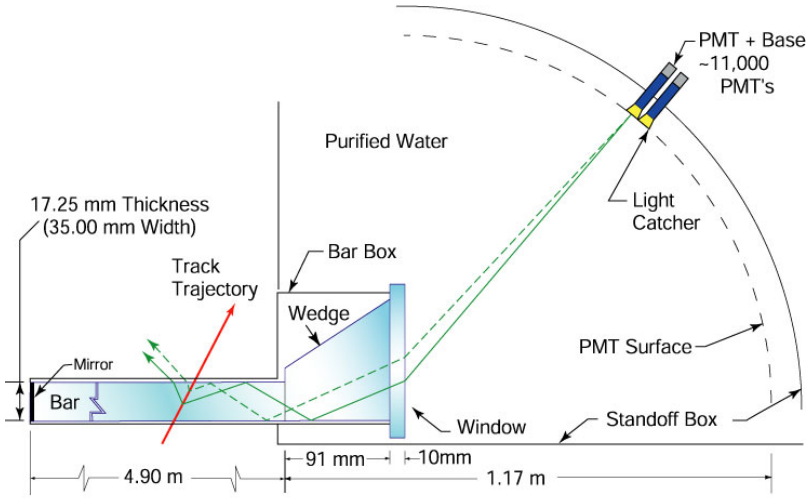
Common Analysis Techniques 2

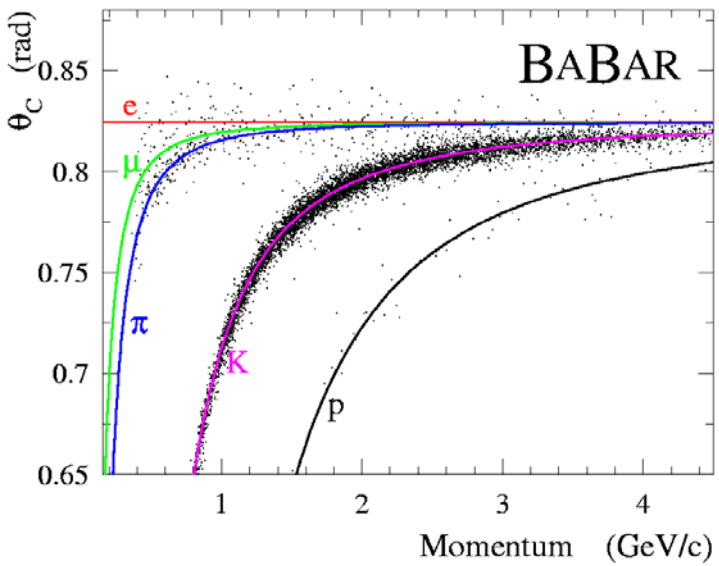
- Event Topology
  - Bs produced almost at rest in CM
  - BB decays isotropic
  - qq continuum jet like
  - Combine variables into Fisher or NN
- Luminosity
  - 82 fb-1
  - 88 times 10^6 $B\bar{B}$



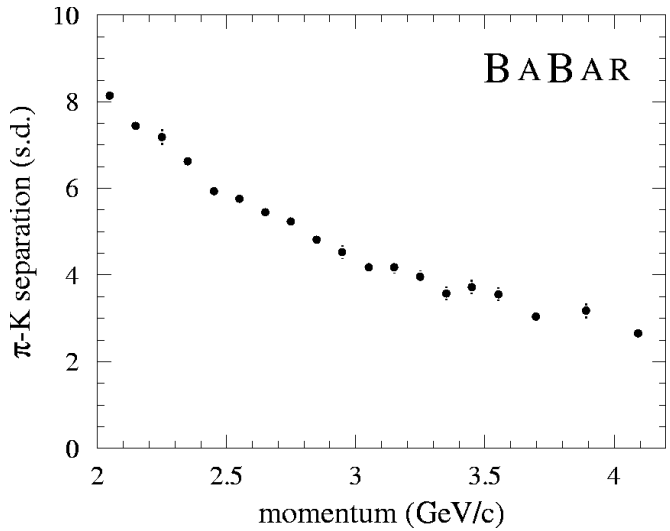
K/π separation: Detection of Internally Reflected Cherenkov

- **Photons produced in quartz bars**
- **Guided to end**
- **Detected outside of acceptance volume of detector**



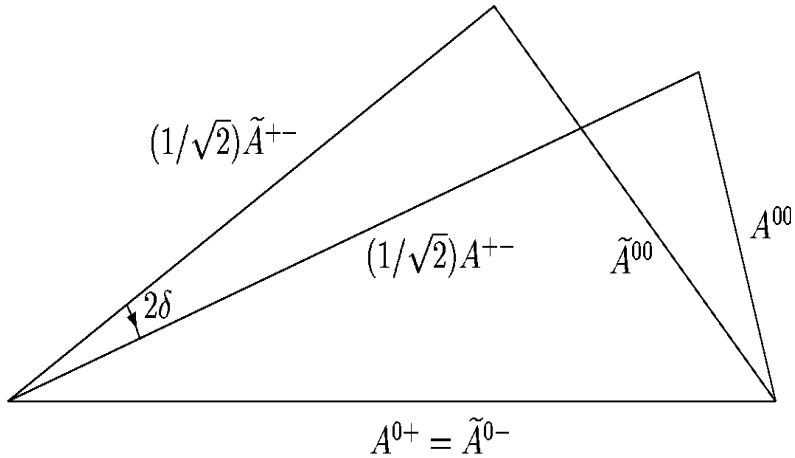


K/π separation 2.5σ at 4GeV/c



B→Pseudoscalar Pseudoscalar 1: B→ππ

- Isospin relation
- Analysis needed to relate time dependent CP asymmetry in $B^0 \to \pi^+\pi^-$ to α
- $B^0 \to \pi^0\pi^0$ is limiting factor



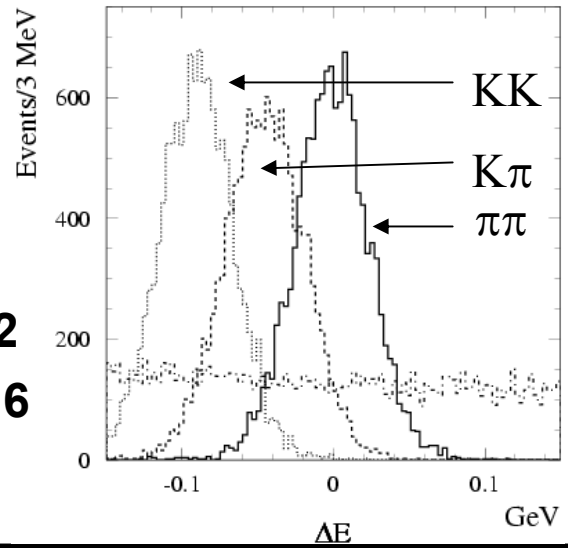
* hep-ex/0303028

* Phys.Rev.Lett. 89 (2002) 281802

Mode	**Event Yield**	**BR (10^{-6})**	**A_{CP}**	
$B^0 \to \pi^+\pi^-$*	**157±19**	**4.7 ±0.6 ±0.2**		Tree+Penguin+...
$B^+ \to \pi^+\pi^0$*	**125 ±22 ±10**	**$5.5\ ^{+1.0}_{-0.9} \pm 0.6$**	**$-0.03\ ^{+0.18}_{-0.17} \pm 0.02$**	Tree+……
$B^0 \to \pi^0\pi^0$*	**23 ±10**	**<3.6 (90% CL)**		Tree+Penguin+..

B→Pseudoscalar Pseudoscalar 2: B → Kπ, B → KK

- B → KK not yet observed
  - Br($B^0 \to K^+K^-$) <0.6 (90% CL)*
  - Br($B^+ \to K^+K^0$) <1.3 (90% CL) *
  - Br($B^0 \to K^0K^0$) <1.6 (90% CL) *



$B^0 \to \pi^+\pi^-$: 4.7 ±0.6 ±0.2

$B^0 \to \pi^+K^-$: 17.9 ±0.9 ±0.6

|Vtd/Vts| ~ λ

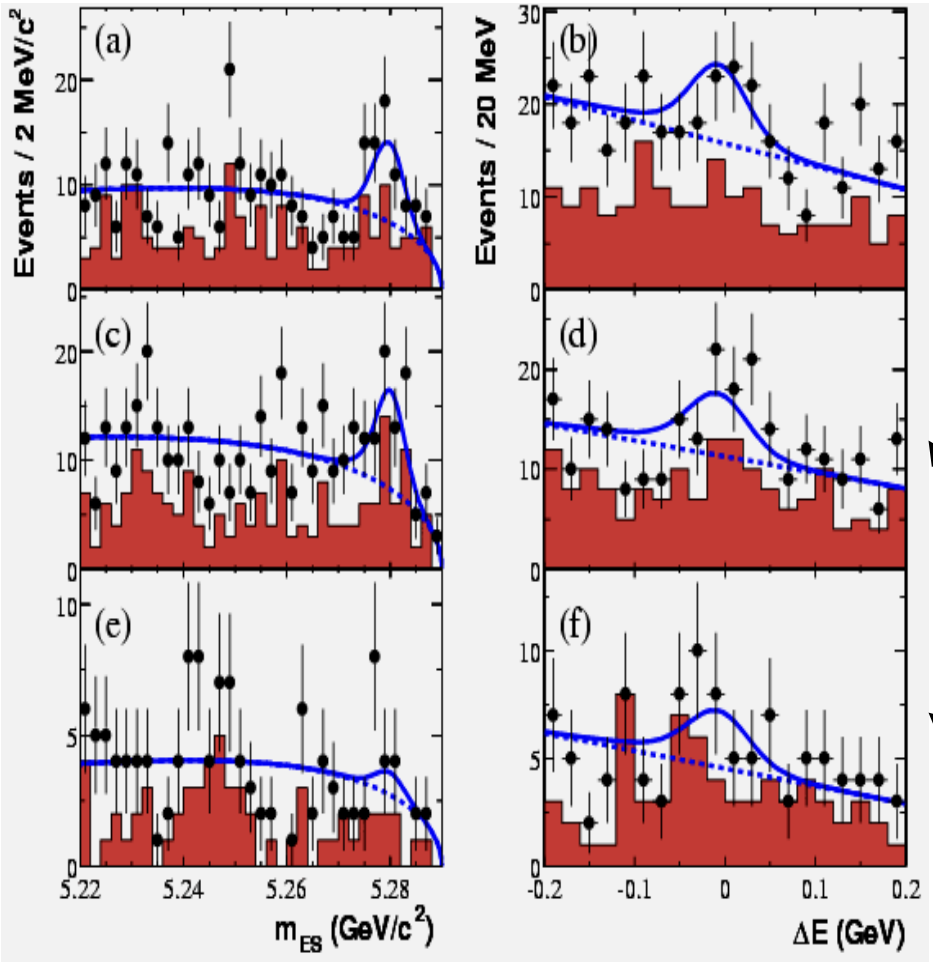
* Preliminary

* Phys.Rev.Lett. 89 (2002) 281802

Mode	Yield	BR (10^{-6})	A_{CP}	
$B^0 \to K^+\pi^-$ *	589±30	17.9 ±0.9 ±0.6	-0.102±0.050±0.016	Penguin+
$B^+ \to K^+\pi^0$ *	239 ±22 ±6	$12.8\ ^{+1.2}_{-1.0}$ ±1.0	-0.09 ±0.09 ±0.01	Penguin+
$B^0 \to K^0\pi^0$ *	86 ±13 ±3	10.4 ±1.5 ±0.8	0.03 ±0.36 ±0.09	$Tree_{(CS)}$+….
$B^+ \to K^0\pi^+$ *	172 ±17 ±9	17.5 ±1.8 ±1.3	-0.17 ±0.10 ±0.02	Penguin+…

B→Pseudoscalar Pseudoscalar 3: B→ηK, ηπ

hep-ex/0303039

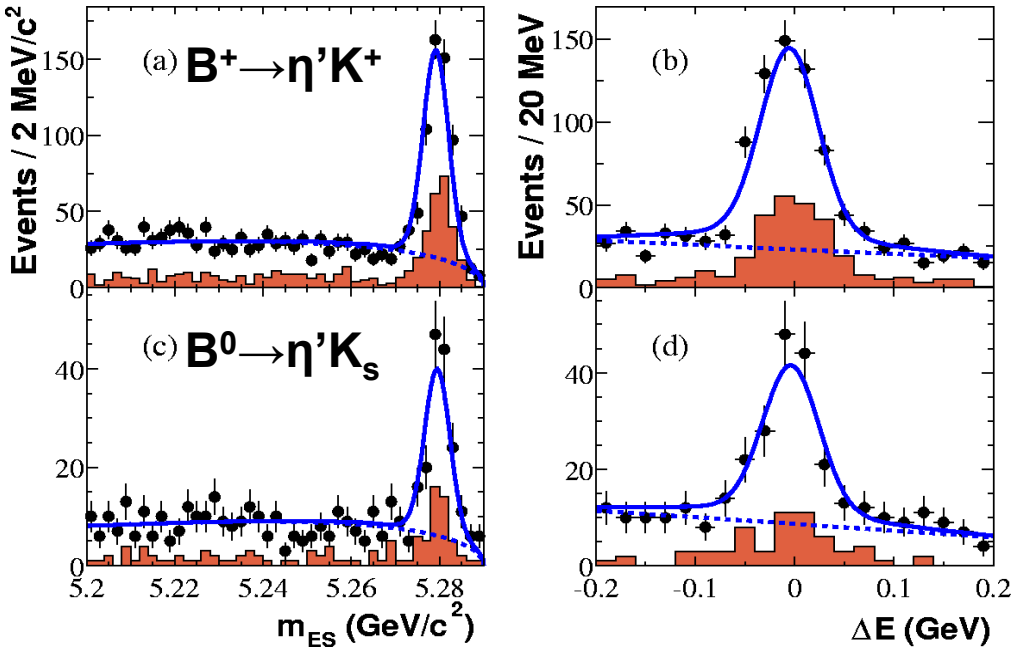


- Series of predictions for η(‘) K(*)
  - Br(B→ ηK)<<Br(B→ η’K) [1]
  - Inverted for ηK*
    - 1: H. J. Lipkin, Phys. Lett B 245,247
  - A_{CP} large ?
    - Chiang, Gronau, Rosner hep-ph/0306021

Mode		BR (10^{-6}) , A_{CP}
a)	$B^+ \to \eta K^+$	$2.8\ ^{+0.8}_{-0.7} \pm 0.2$
	A_{CP}	$0.32\ ^{+0.22}_{-0.18} \pm 0.01$
b)	$B^0 \to \eta K^0$	<4.6 (90% CL)
c)	$B^0 \to \eta \pi^+$	$4.2\ ^{+1.0}_{-0.9} \pm 0.3$
	A_{CP}	$0.51\ ^{+0.20}_{-0.18} \pm 0.01$

B→Pseudoscalar Pseudoscalar 4: B→η'K

- η'→ ηππ, $\rho^0\gamma$
- Br much higher than expected, ≈ 6 times Br(B→πK)
  - Intrinsic charm
  - Gluon fusion
  - (New Physics?)



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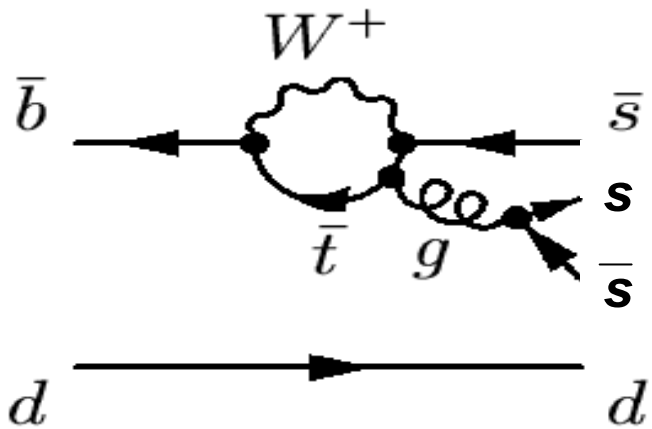
Mode	BR (10^{-6})	A_{CP}
$B^+\to\eta'K^+$	$76.9 \pm 3.5 \pm 4.4$	$0.037 \pm 0.045 \pm 0.011$
$B^0\to\eta'K^0$	$55.4 \pm 5.2 \pm 4.0$	

B→Pseudoscalar Vector 1: B→ΦK, Φπ

- Dominated by gluonic penguin
- Sensitive to new physics
- $B^+ \to \Phi\pi^+$ can constrain rescattering amplitudes in B→ΦK



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Mode	**BR (10^{-6})**	**A_{CP}**
$B^0 \to \Phi K^0$	**$7.6^{+1.3}_{-1.2} \pm 0.5$**	
$B^+ \to \Phi K^+$	**$10.0^{+0.9}_{-0.8} \pm 0.5$**	**$0.039 \pm 0.086 \pm 0.011$**
$B^+ \to \Phi\pi^+$	**<0.41 (90% CL)**	

B→Pseudoscalar Vector 2: B→ρπ, ρK, ωπ, ωK

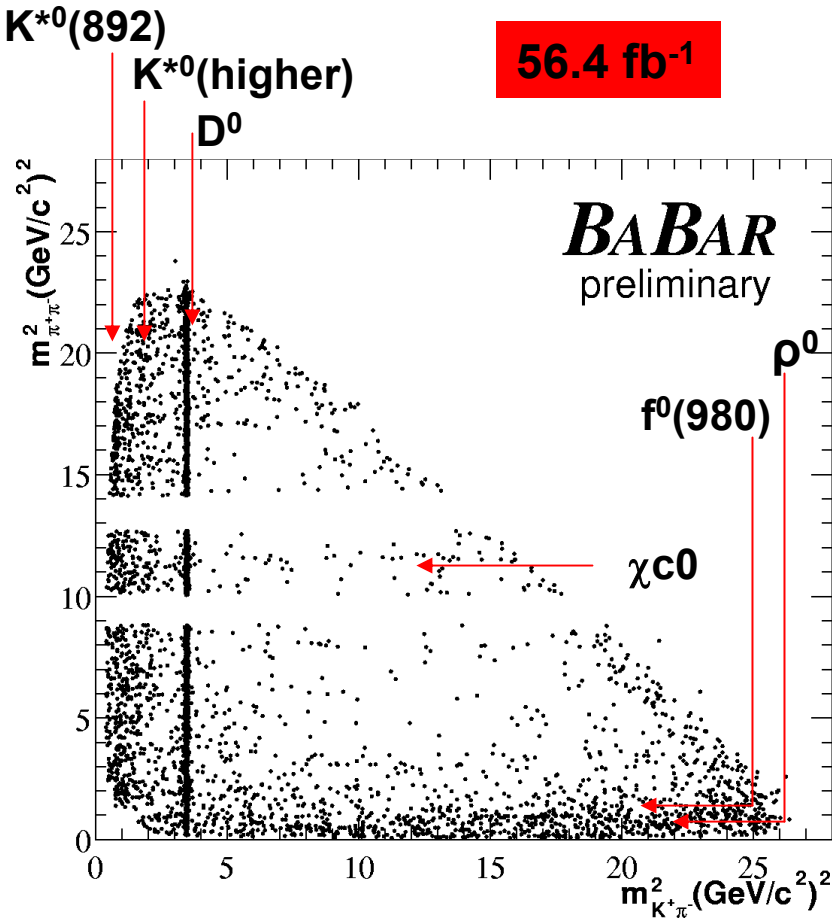
- Improved precision allows us to test Factorization models.

hep-ex/0303040

hep-ex/0207068

Mode	**BR (10^{-6})**	**A_{CP}**
$B^0 \to \rho^+\pi^-$ *	**$22.6 \pm 1.8 \pm 2.2$**	**$-0.18 \pm 0.08 \pm 0.03$**
$B^0 \to \rho^+K^-$ *	**$7.3\ ^{+1.3}_{-1.2} \pm 1.3$**	**$0.28 \pm 0.17 \pm 0.08$**
$B^0 \to \omega K^0$ *	**$5.3\ ^{+1.4}_{-1.2} \pm 0.5$**	
$B^+ \to \omega K^+$ *	**$5.0 \pm 1.0 \pm 0.4$**	**$-0.05 \pm 0.16 \pm 0.01$**
$B^+ \to \omega\pi^+$ *	**$5.4 \pm 1.0 \pm 0.5$**	**$0.04 \pm 0.17 \pm 0.01$**

B→Pseudoscalar Vector 3: B→Kππ



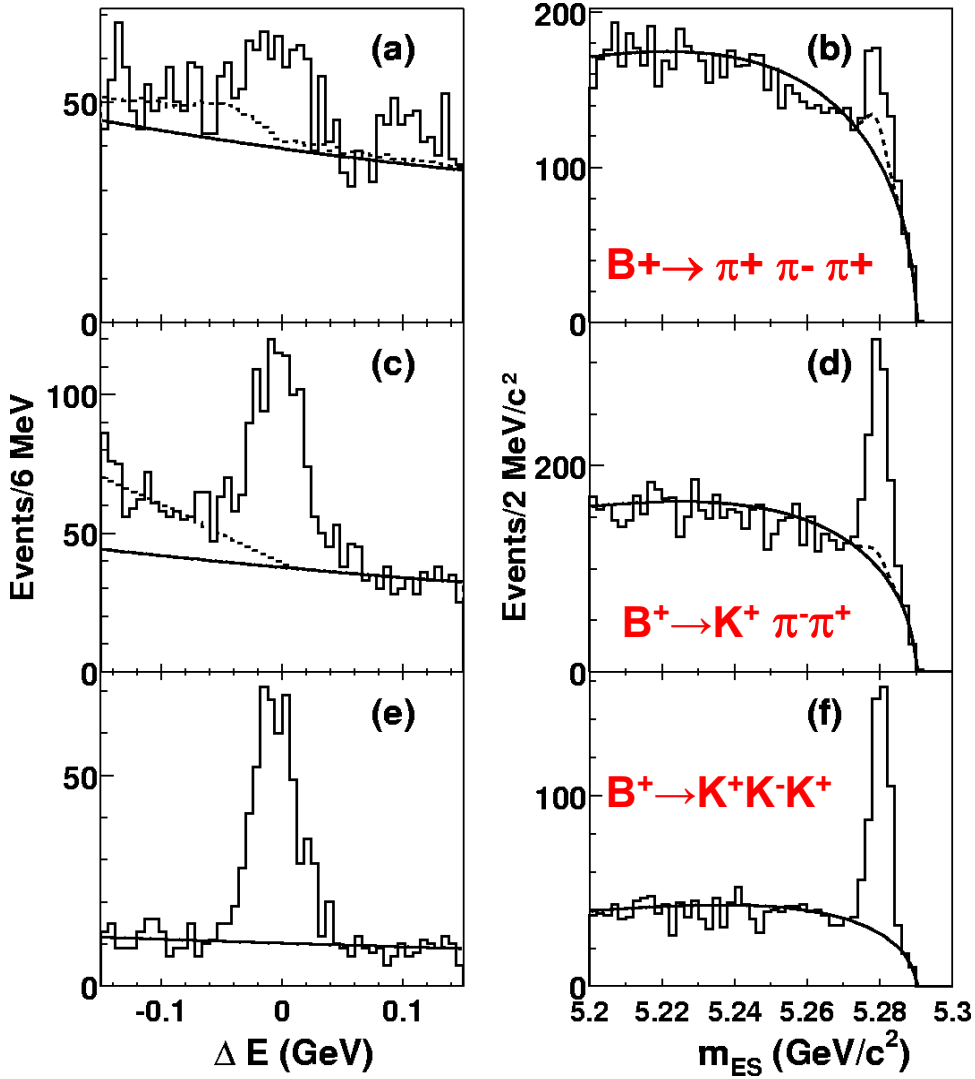
Submitted to PRL

Mode	Br (10^{-6})
B+ → K*0(892)π+, K*0→K+ π-	$10.3\pm1.2^{+1.0}_{-2.7}$
B+ → f0(980)K+, f0 →π+π	$9.2\pm1.2^{+2.1}_{-2.6}$
B+ → χc0 K+, χc0 →π+π	1.46±0.35±0.12
B+ → D0π+, D0 →K+ π-	184.6±3.2±9.7
B+→higher K*0π+, K*0→K+π-	$25.1\pm2.0+^{11.0}_{-5.7}$
B+ → ρ0(770)K+, ρ0 →π+π	< 6.2
B+ → K+ π- π+ (non resonant)	< 17
B+ → higher fK+, f →π+π	<12

$B^+ \to h^+ h^- h^+$ (h=K,π)

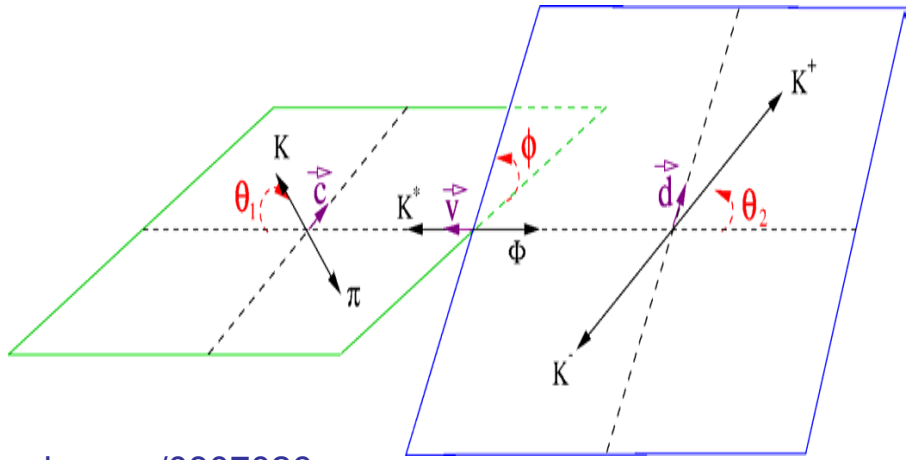
Mode	Br (10^{-6}) , A_{CP}
$B^+ \to \pi^+ \pi^- \pi^+$	10.9 ± 3.3 ± 1.6,
A_{CP}	-0.39 ± 0.33 ± 0.12
$B^+ \to K^+ \pi^- \pi^+$	59.1 ± 3.8 ± 3.2
A_{CP}	0.01 ± 0.07 ± 0.03
$B^+ \to K^+ K^- K^+$	29.6 ± 2.1 ± 1.6
A_{CP}	0.02 ± 0.07 ± 0.03
$B^+ \to K^+ K^- \pi^+$	< 6.3
$B^+ \to K^- \pi^+ \pi^+$	< 1.8
$B^+ \to K^+ K^+ \pi^-$	< 1.3

hep-ex/0304006



B→Vector Vector 2: B→ ρρ, ρK*

- Form triple product from decay angles
- Form 2 new asymmetries:
  - A_{tp}, decay rate asymmetry between (triple product times charge) + and –
  - A_{sp}, decay rate asymmetry between triple product + and –



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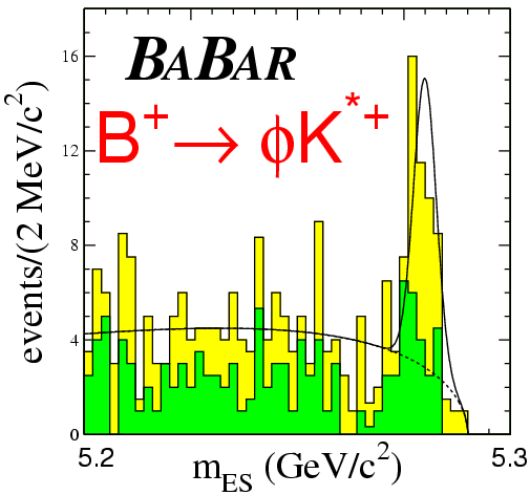
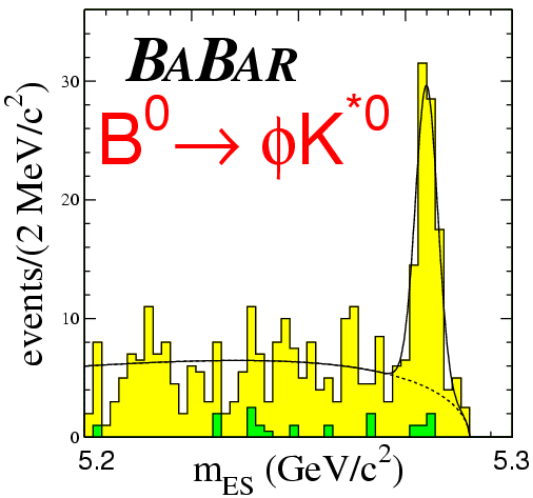
Mode	Br (10^{-6})	Polarization	A_{CP}	A_{TP}, A_{SP}
$B^+ \to \rho^+\rho^0$	$22.5^{+5.7}_{-5.4} \pm 5.8$	$0.97 \pm ^{+0.08}_{-0.07} \pm 0.04$	$0.04 \pm 0.12 \pm 0.02$	$0.09 \pm 0.24 \pm 0.04$, $-0.23 \pm 0.24 \pm 0.04$
$B^0 \to \rho^0\rho^0$	<2.1(90%CL)			
$B^+ \to \rho^0 K^{*+}$	$10.2^{+2.9}_{-2.5} \pm 2.3$	$0.96^{+0.04}_{-0.15} \pm 0.04$	$0.20^{+0.32}_{-0.29} \pm 0.04$	$0.03 \pm 0.29 \pm 0.03$ $-0.23^{+0.24}_{-0.33} \pm 0.04$

B→Vector Vector 1: B→ΦK*

- B→ΦK* gluonic penguin dominated
- Used with B→ΦK for time dependant CP after polarization measured.





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Mode	Br (10^{-6})	Polarization	A_{CP}	A_{TP}, A_{SP}
$B^0 \to \Phi K^{*0}$	$11.1^{+1.3}_{-1.2} \pm 0.8$	0.65±0.07±0.02	0.04±0.12±0.02	-0.02±0.18±0.03 -0.04±0.18±0.03
$B^+ \to \Phi K^{*+}$	$12.1^{+2.1}_{-1.9} \pm 1.1$	0.46±0.12±0.03	0.16±0.17±0.03	0.06±0.12±0.02 0.07±0.12±0.02

Overview

- Search for $B^0 \rightarrow \pi^0\pi^0$ continues
- $B \rightarrow \eta' K$ remains interestingly high
- Precision has reached the point where we can test factorization models
- Several modes here offer potential to reveal new physics