

Dalitz Plot Analyses of Charmless Hadronic B decays

Zhitang Yu

University of Wisconsin-Madison
On behalf of *BABAR* Collaboration

DPF 2004, August 26th – 31st, 2004
UC Riverside

- Motivation
- Analysis method
- Preliminary results
- Summary and outlook



Motivation

- Amplitude analyses of $B^0 \rightarrow K^+ \pi^- \pi^0$, $B^+ \rightarrow \pi^+ \pi^- \pi^+$, and $B^+ \rightarrow K^+ \pi^- \pi^+$ to take into account the interferences between intermediate states
 - Help to understand B decay mechanisms (strong & electroweak penguin contributions, strong phases etc.)
 - Search for unobserved rare decays

- Search for direct CP violation

Probe the CKM angle $\gamma \equiv \arg(-V_{ud} V_{ub}^* / V_{cd} V_{cb}^*)$
with measured decay rates and phases
using SU(3) flavor symmetry

Phys. Rev. D69, 034001 (2004);
Phys. Re. Lett. 26, 2720 (2001).

➤ Experimental challenge : small branching fraction against large background from continuum (u, d, s, c) production

Dalitz Plot Method

- For B decay to particles 1, 2, 3 with four momenta p_B, p_1, p_2, p_3 , respectively, the differential decay width reads

$$d\Gamma = \frac{1}{(2\pi)^3} \frac{|A_{total}|^2}{8m_B^3} dm_{12}^2 dm_{23}^2,$$

where $m_{12}^2 = s_{12} = (p_1+p_2)^2$, $m_{23}^2 = s_{23} = (p_2+p_3)^2$, and

$$A_{total} = a_{NR} e^{i\phi_{NR}} + \sum_i a_i e^{i\phi_i} A_i, \quad A_i = B_i(s) K_i(DP) F_{R,i}(s),$$

where $B_i(s)$ – Blatt-Weisskopf damping form factor;

$K_i(DP)$ – angular (spin-dependent) function;

$F_{R,i}(s)$ – *usually* a relativistic Breit-Wigner
with s -dependent width.

Similar formulation is implied for anti-B decay, with $\bar{a}_i, \bar{\phi}_i$ usually expected to be different from $a_i, \phi_i \rightarrow$ possible to probe γ

Dalitz Plot Method (2)

- Calculating the observables for the intermediate states (and nonresonant)
 - The fractions (f_i) and direct CP asymmetries (A_{CP}^i) are extracted as

$$f_i = \frac{\int (|a_i e^{i\phi_i} A_i|^2 + |\bar{a}_i e^{i\bar{\phi}_i} \bar{A}_i|^2) dm_{12}^2 dm_{23}^2}{\int (|A_{total}|^2 + |\bar{A}_{total}|^2) dm_{12}^2 dm_{23}^2},$$

$$A_{CP}^i = \frac{|\bar{a}_i|^2 - |a_i|^2}{|\bar{a}_i|^2 + |a_i|^2}$$

- The branching fractions (BF_i) and the inclusive BF_i^{incl} :

$$BF_i = f_i \cdot BF^{incl}, \quad BF^{incl} = \frac{N_{sig}}{\varepsilon N_{B\bar{B}}},$$

where N_{sig} - total signal yield observed in data,
 ε - the signal efficiency averaged over DP,
 $N_{B\bar{B}}$ - number of BB pairs produced

Analysis Procedure

Event selection:

- ✓ Quality cuts for tracks and neutrals
- ✓ Particle identification
- ✓ Continuum rejection using event shape variables (continuum is jet-like while B decay is isotropic)
- ✓ Kinematic signal identification with m_{ES} and ΔE .

$$m_{ES} = \sqrt{E_{beam}^2 - p_B^2}$$

$$E_{beam} = \frac{s - 2\vec{p}_{e^+e^-} \cdot \vec{p}_B}{2E_{e^+e^-}}$$

$$\Delta E = E_B^* - \sqrt{s} / 2$$

Maximum Likelihood Fit

to determine yields and amplitudes (magnitudes & phases) :

Fit Config.	$B^0 \rightarrow K^+ \pi^- \pi^0$	$B^+ \rightarrow K^+ \pi^- \pi^+$, $B^+ \rightarrow \pi^+ \pi^- \pi^+$
Use m_{ES}	Yes	Yes (in first fit)
Use ΔE	Yes	No
Use DP	Yes	Yes (in second fit)
Direct CP	Yes	No ($\bar{a}_i = a_i, \bar{\phi}_i = \phi_i$)
Misreconstructed signal	Yes (with resolution)	No (<2%, ignored)

Preliminary Results

$$B^0 \rightarrow K^+ \pi^- \pi^0 : 213 \times 10^6 B\bar{B} \text{ pairs}$$

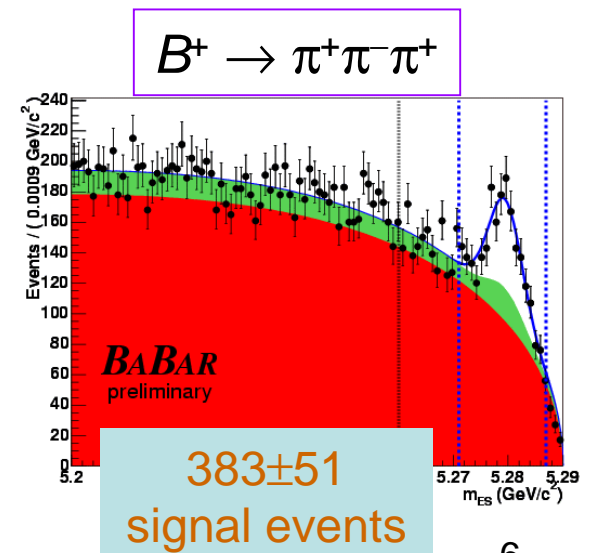
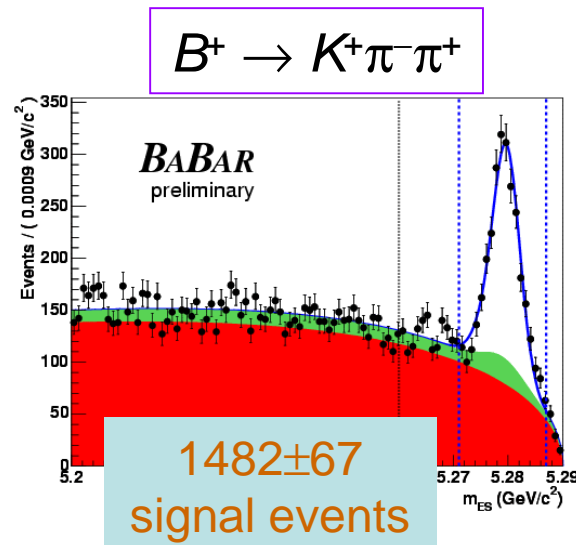
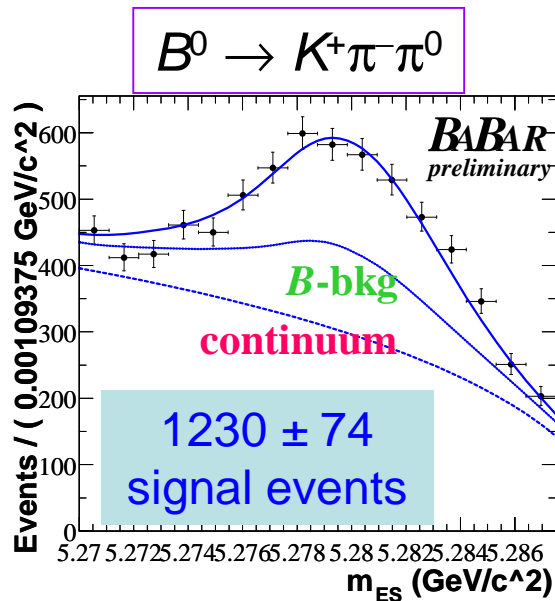
$$Br(B^0 \rightarrow K^+ \pi^- \pi^0) = (34.9 \pm 2.1 \pm 3.9) \times 10^{-6}$$

$$Br(B^0 \rightarrow \bar{D}^0 \pi^0) = (3.2 \pm 0.2 \pm 0.4) \times 10^{-4} \text{ (as crosscheck)}$$

$$B^+ \rightarrow K^+ \pi^- \pi^+, \pi^+ \pi^- \pi^+ : 182 \times 10^6 B\bar{B} \text{ pairs}$$

$$Br(B^+ \rightarrow K^+ \pi^- \pi^+) = (61.4 \pm 2.4 \pm 4.5) \times 10^{-6}$$

$$Br(B^+ \rightarrow \pi^+ \pi^- \pi^+) = (16.2 \pm 2.1 \pm 1.3) \times 10^{-6}$$



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

213x10⁶ $B\bar{B}$ pairs

- 6 components in the nominal fit: see table, with $\rho(770)^-$ fixed in fit
6 other resonances considered for systematic studies.
- Relativistic Breit-Wigner lineshapes usually used for resonances.

Exceptions:

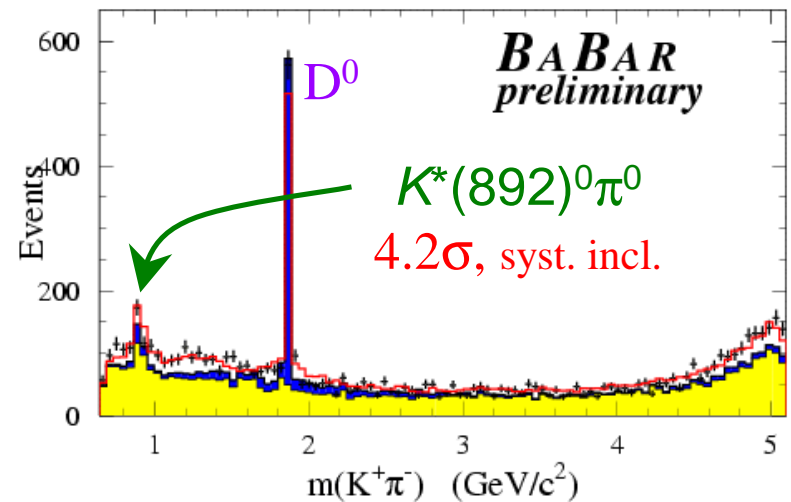
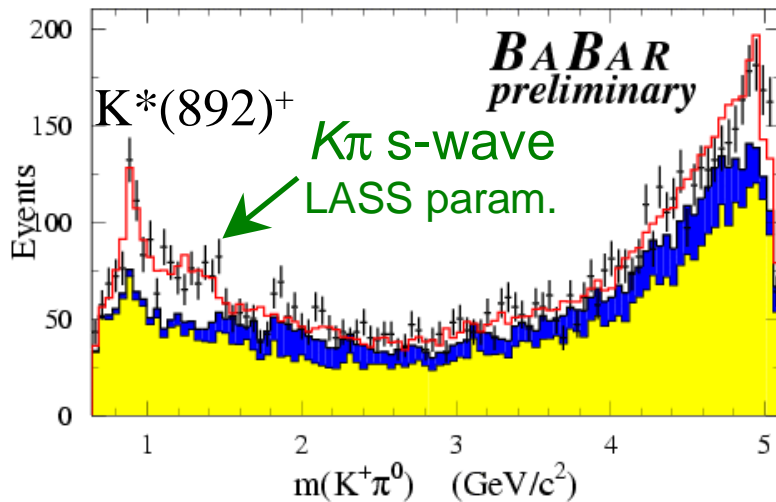
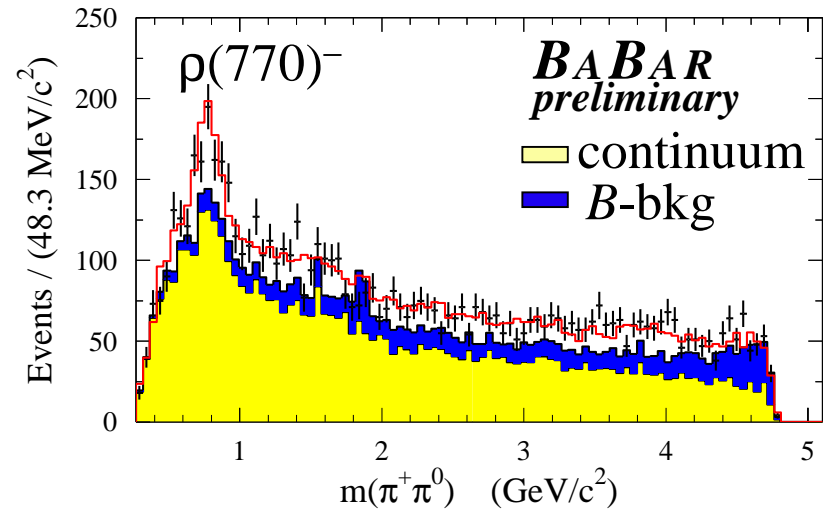
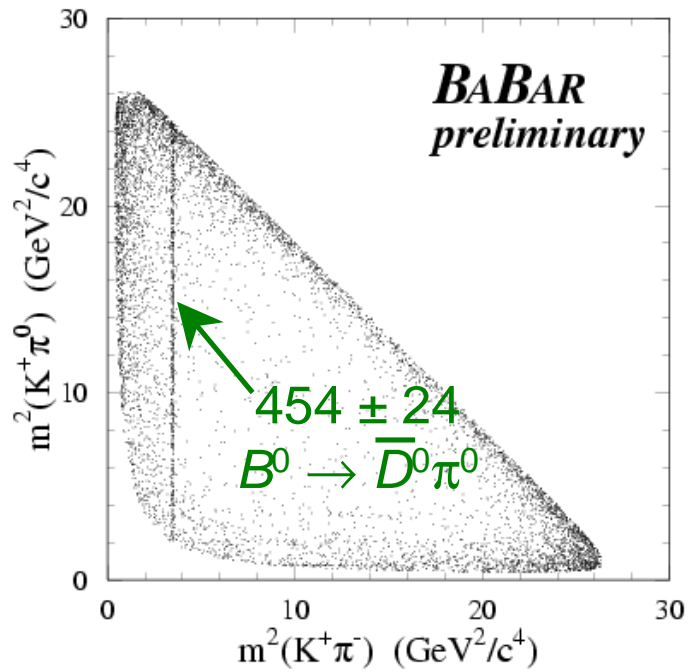
- $\rho(770)^-$ uses Gounaris-Sakurai [Phys. Rev. Lett. 21, 244 (1968)];
- $K\pi$ S-wave ($K_0^*(1430)$) uses LASS [Nucl. Phys. B 296, 493 (1988)].

	fraction(%)	phase ϕ	phase $\bar{\phi}$	A_{CP}
$\rho(770)K^+$	$24.6^{+3.6}_{-2.9} \pm 0.6$	0 (Fixed)	0 (Fixed)	$0.13^{+0.14}_{-0.17} \pm 0.04 \pm 0.13$
$K^*(892)^+\pi^-$	$10.4^{+2.1}_{-2.0} \pm 0.8$	138 ± 35	174 ± 42	$-0.25 \pm 0.17 \pm 0.02 \pm 0.02$
$K_0^*(1430)^+\pi^-$	$32.2 \pm 3.8 \pm 9.4$	115 ± 34	149 ± 35	$-0.07 \pm 0.12 \pm 0.06 \pm 0.05$
$K_0^*(1430)^0\pi^0$	$22.5 \pm 4.0 \pm 7.2$	-12 ± 40	8 ± 42	$-0.34 \pm 0.15 \pm 0.07 \pm 0.08$
$K^*(892)^0\pi^0$	$5.8^{+1.7}_{-1.5} \pm 0.6$	-160 ± 41	-144 ± 41	$-0.01^{+0.24}_{-0.22} \pm 0.07 \pm 0.11$
NR	$7.1^{+3.6}_{-2.9} \pm 0.1$	55 ± 28	79 ± 28	$-0.12^{+0.36}_{-0.37} \pm 0.20 \pm 0.07$

Syst. dominated by ignoring 'minor' intermediate states

$B^0 \rightarrow K^+ \pi^- \pi^0$ Results

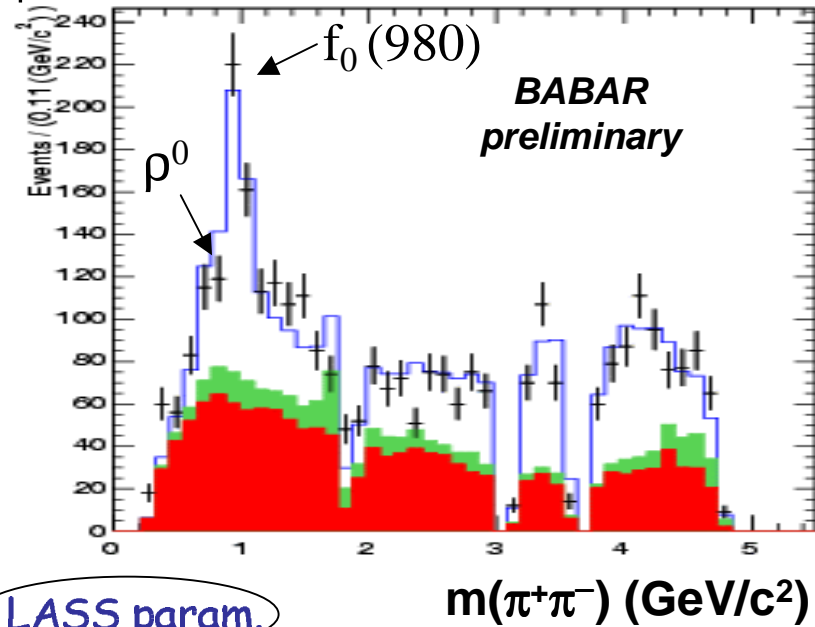
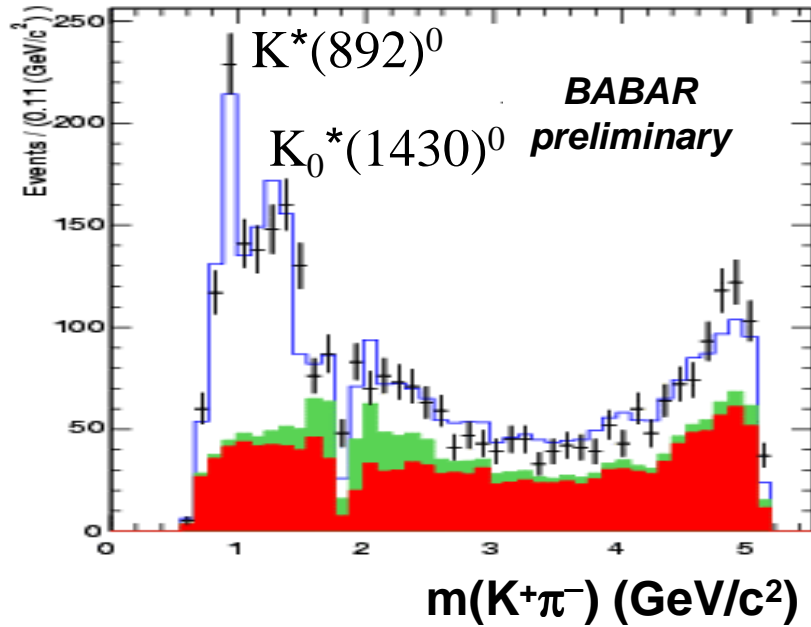
213x10⁶ $B\bar{B}$ pairs



$B^+ \rightarrow K^+ \pi^- \pi^+$

182x10⁶ $B\bar{B}$ pairs

Veto J/ψ , $\psi(2S)$, $D0$



LASS param.

	$K^*(892)^0 \pi^+$	$K_0^*(1430)^0 \pi^+$	$\rho(770)^0 K^+$
fraction(%)	$11.4 \pm 2.0 \pm 1.5$	$52.6 \pm 2.3 \pm 4.0$	$8.5 \pm 1.9 \pm 1.1$
Phase (°)	0 (Fixed)	$167.3 \pm 6.3 \pm 5.7$	$49 \pm 22 \pm 20$

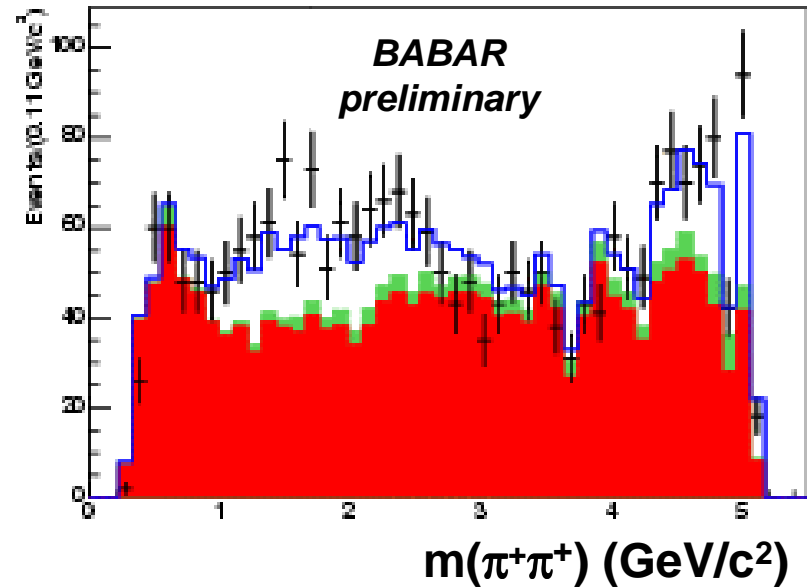
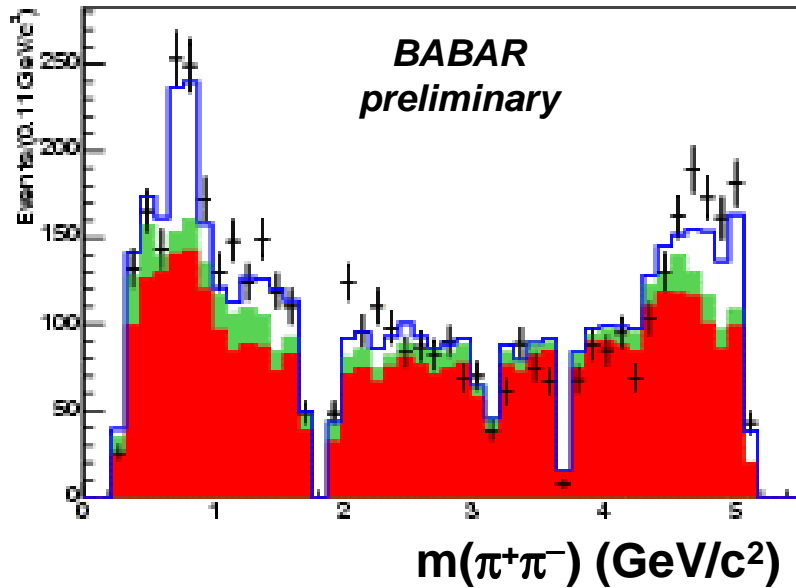
Flatte [Phys. Lett. B 63, 224 (1976)]

	$f_0(980) K^+$	$\chi_{c0} K^+$	NR
fraction(%)	$15.0 \pm 2.4 \pm 1.3$	$1.45 \pm 0.27 \pm 0.23$	$7.9 \pm 0.9 \pm 2.3$
Phase (°)	$-32 \pm 18 \pm 23$	$9 \pm 19 \pm 12$	$29 \pm 14 \pm 14$

Syst. dominated by: *bkg Dalitz plot param. & efficiency uncertainty*

$$B^+ \rightarrow \pi^+ \pi^- \pi^+$$

182x10⁶ $B\bar{B}$ pairs



	$\rho^0(770)\pi^+$	$\rho^0(1450)\pi^+$	$f_0(980)\pi^+$
fraction(%)	$58.2 \pm 2.9 \pm 6.0$	$13.6 \pm 2.8 \pm 2.0$	$2.0 \pm 1.3 \pm 2.8$
phase (°)	0 (Fixed)	$34 \pm 22 \pm 10$	$140 \pm 35 \pm 11$
	$f_2(1270)\pi^+$	NR	
fraction(%)	$14.3 \pm 2.0 \pm 1.8$	$4.2 \pm 2.0 \pm 1.4$	
phase (°)	$-154 \pm 20 \pm 10$	$35 \pm 32 \pm 11$	

Flatte lineshape

No evidence of:
' σ ', χ_{c0} and $f_0(1370)$

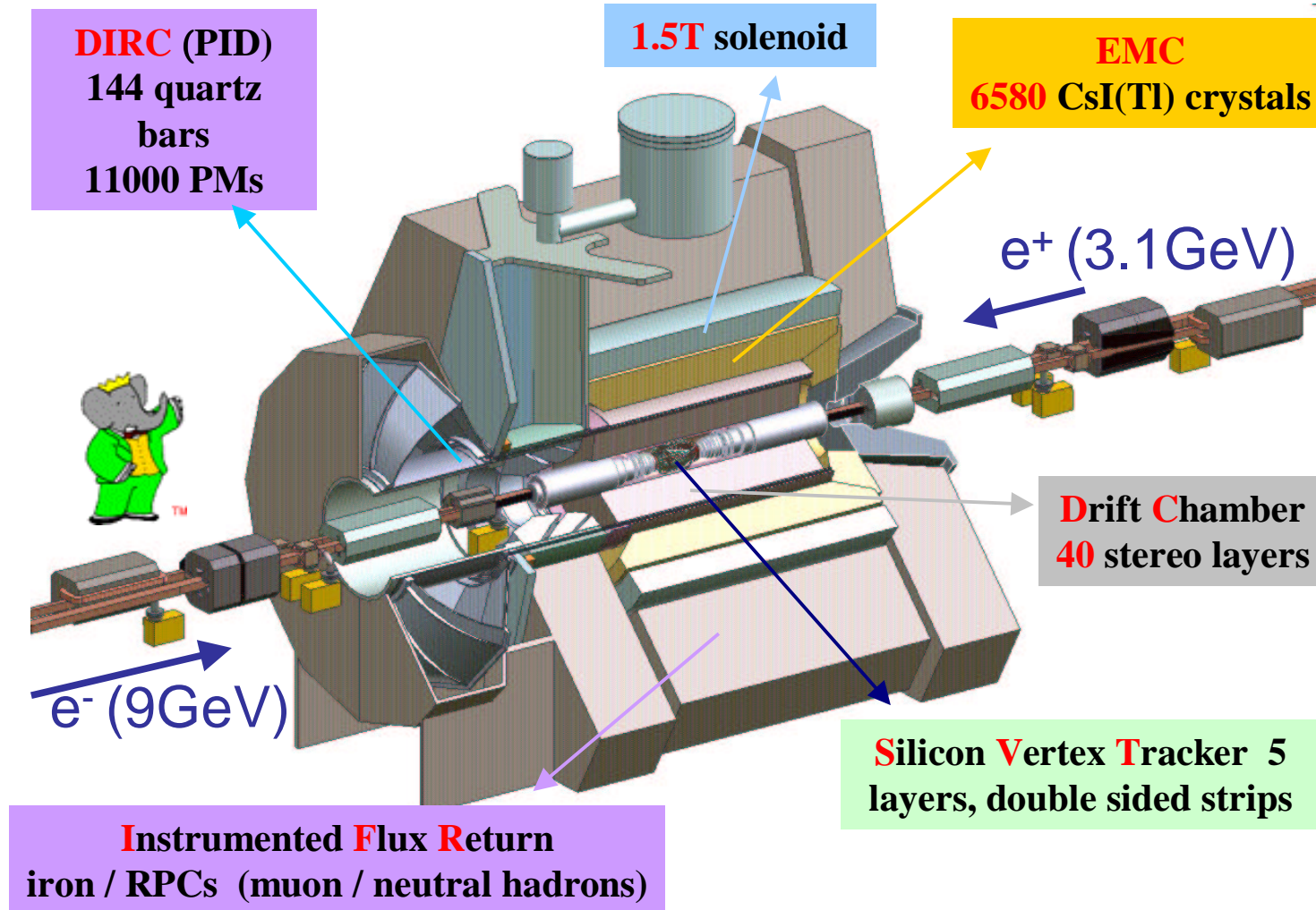
Syst. dominated by: *bkg Dalitz plot param. & efficiency uncertainty*¹⁰

Summary and outlook

- Charmless three body B decays move to the era of Dalitz plot analysis. Many branching fractions and A_{CP} have been measured simultaneously.
- All results are preliminary. For the previously measured intermediate modes, results are in agreement. We also see first evidences of
$$B^+ \rightarrow f_2(1270)\pi^+, B^0 \rightarrow K^*(892)^0\pi^0$$
- No direct CP violation is seen in $B^0 \rightarrow K^+\pi^-\pi^0$ decays.
- All results have been presented at ICHEP'04. Details can be found in
hep-ex/0408073 (for $B^0 \rightarrow K^+\pi^-\pi^0$)
hep-ex/0408032 (for $B^+ \rightarrow K^+\pi^-\pi^+, \pi^+\pi^-\pi^+$)
- Direct CP measurements will be performed for $K^+\pi^-\pi^+$ and $\pi^+\pi^-\pi^+$ modes in the near future
- Efforts will be made to probe the angle γ .

Backup slides

BaBar Detector



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

