Study of CP Violation at BABAR

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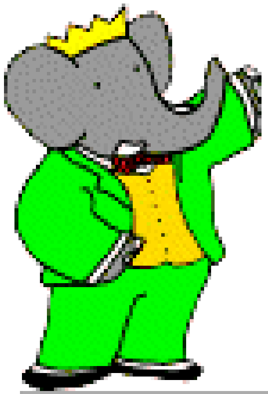
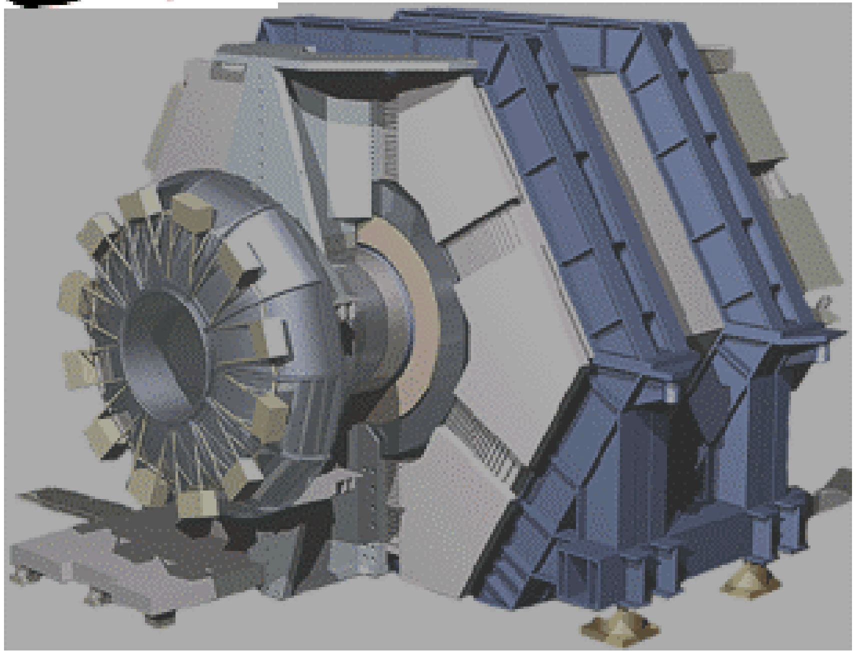
For the BABAR Collaboration





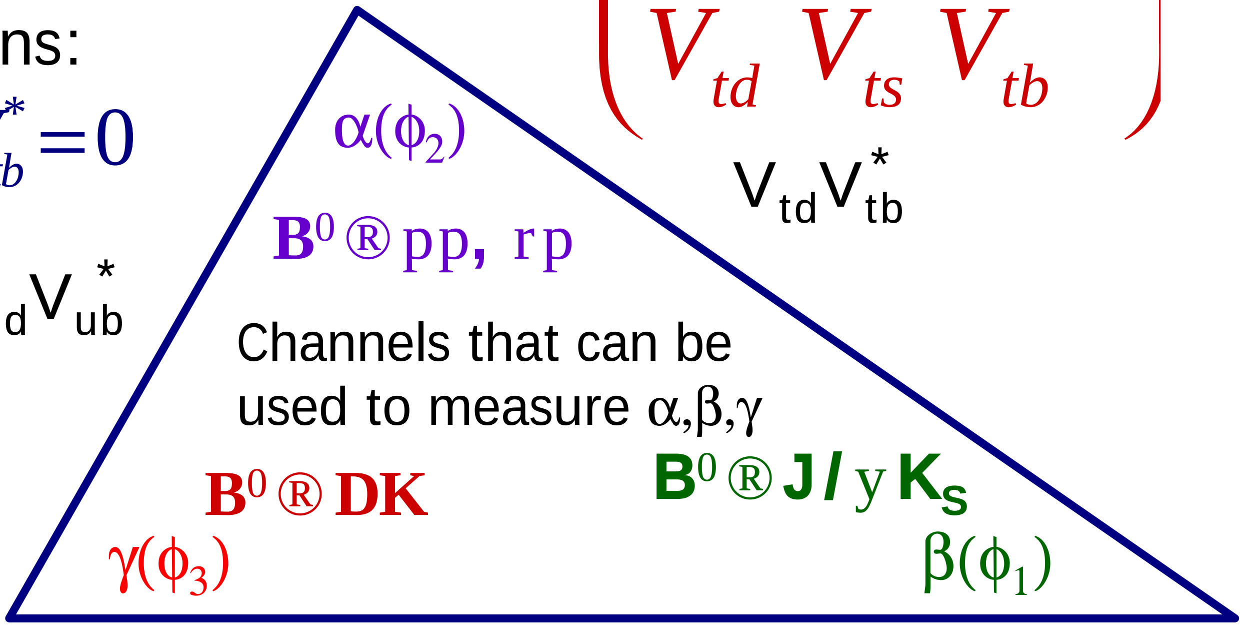
30th SLAC Summer Institute, August 5-16,2002

CKM matrix and Unitarity Triangle

- Coupling for $Q \rightarrow W^+ q$ is ~ V^*_{Qq}
- SM mechanism for *CP* violation is non-0 complex phase in V_{CKM}.
- Orthogonality of the 1st and 3rd columns:

$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

$$V_{ud}V^*_{ub} + V_{cd}V^*_{cb} + V_{td}V^*_{tb} = 0$$



$V_{td}V^*_{tb}$

$V_{ud}V^*_{ub}$

$V_{cd}V^*_{cb}$

$\alpha(\phi_2)$

B^0 ® pp, rp

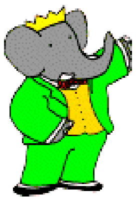
Channels that can be used to measure α,β,γ

B^0 ® DK

B^0 ® J/y K_S

$\gamma(\phi_3)$

$\beta(\phi_1)$



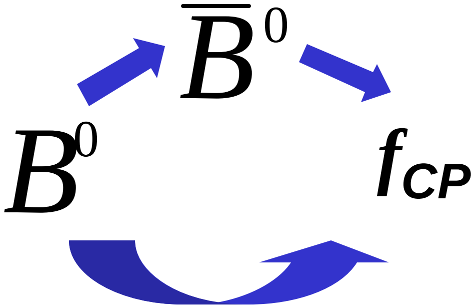
- Overconstrain the “Unitarity Triangle” → Test the SM

Three observable interference effects

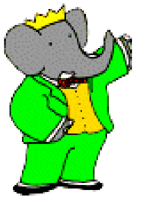
1. CP violation in mixing→ $|q/p| \neq 1$
2. (direct) CP violation in decay→ $|\bar{A}/A| \neq 1$
3. (indirect) CP violation in mixing and decay→ $Im\lambda \neq 0$

$$|B_{H,L}\rangle = p|B^0\rangle \pm q|\overline{B^0}\rangle$$

$$\lambda = \frac{q}{p} \cdot \frac{\bar{A}}{A}$$

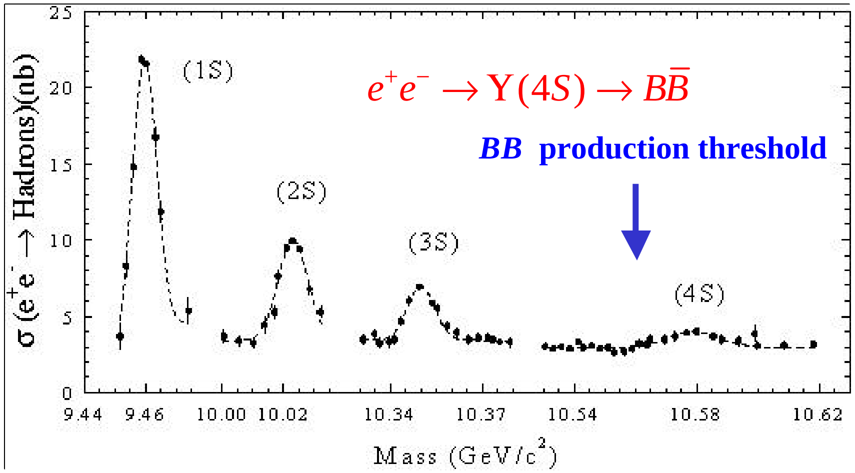


$$A = A(B \rightarrow f_{CP})$$
$$\bar{A} = A(\bar{B} \rightarrow f_{CP})$$



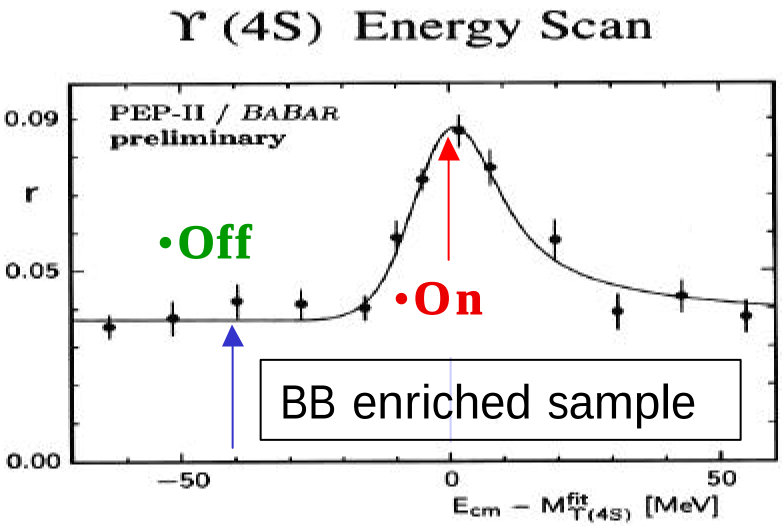
CP Physics at the *U(4S)*

- *BB* events are large fraction of the “physics” cross section (=1 nb)
- Coherent production of *B* meson pair (in L=1 state)
- **Need high luminosity to produce sufficient event samples**
- m(*U(4S)*) ~ 2*m(B)
  - Take advantage of known *B* momentum in COM.
- Spend ~12% of running time below *BB* threshold to generate *qq* “continuum” events (ie, background samples for CP analyses.



$e^+e^- \rightarrow \Upsilon(4S) \rightarrow B\bar{B}$

***BB* production threshold**

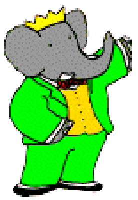


•Off

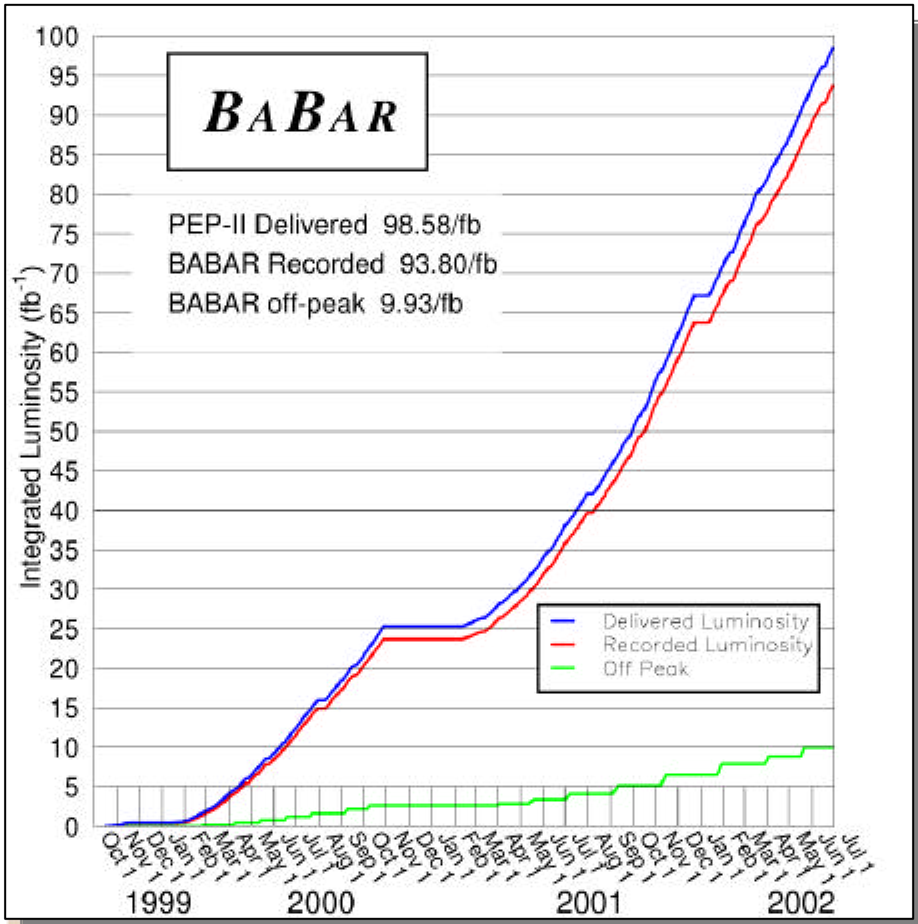
•On

BB enriched sample

Fantastic Pep II performance allows us to study CP violation



SLAC B Factory performance



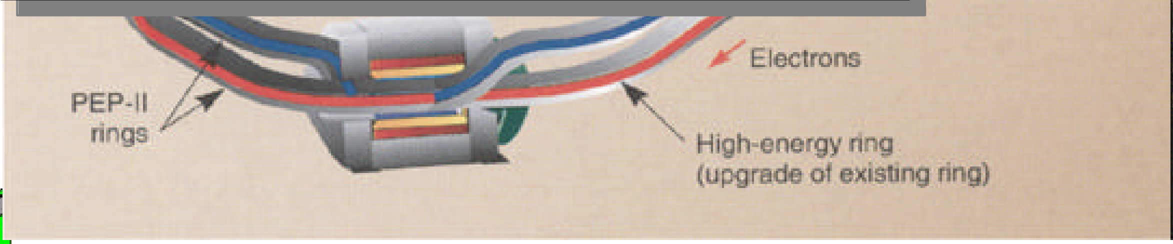
- **PEP-II top luminosity:**
  $4.60 \times 10^{33} cm^{-2}s^{-1}$
  (exceeded design goal 3.0×10^{33})
- **Best 24 hours: 308.8 pb^{-1}**

Total Luminosity:

• **PEP-II delivered**	**99 fb^{-1}**
• **BaBar recorded**	**94 fb^{-1}**

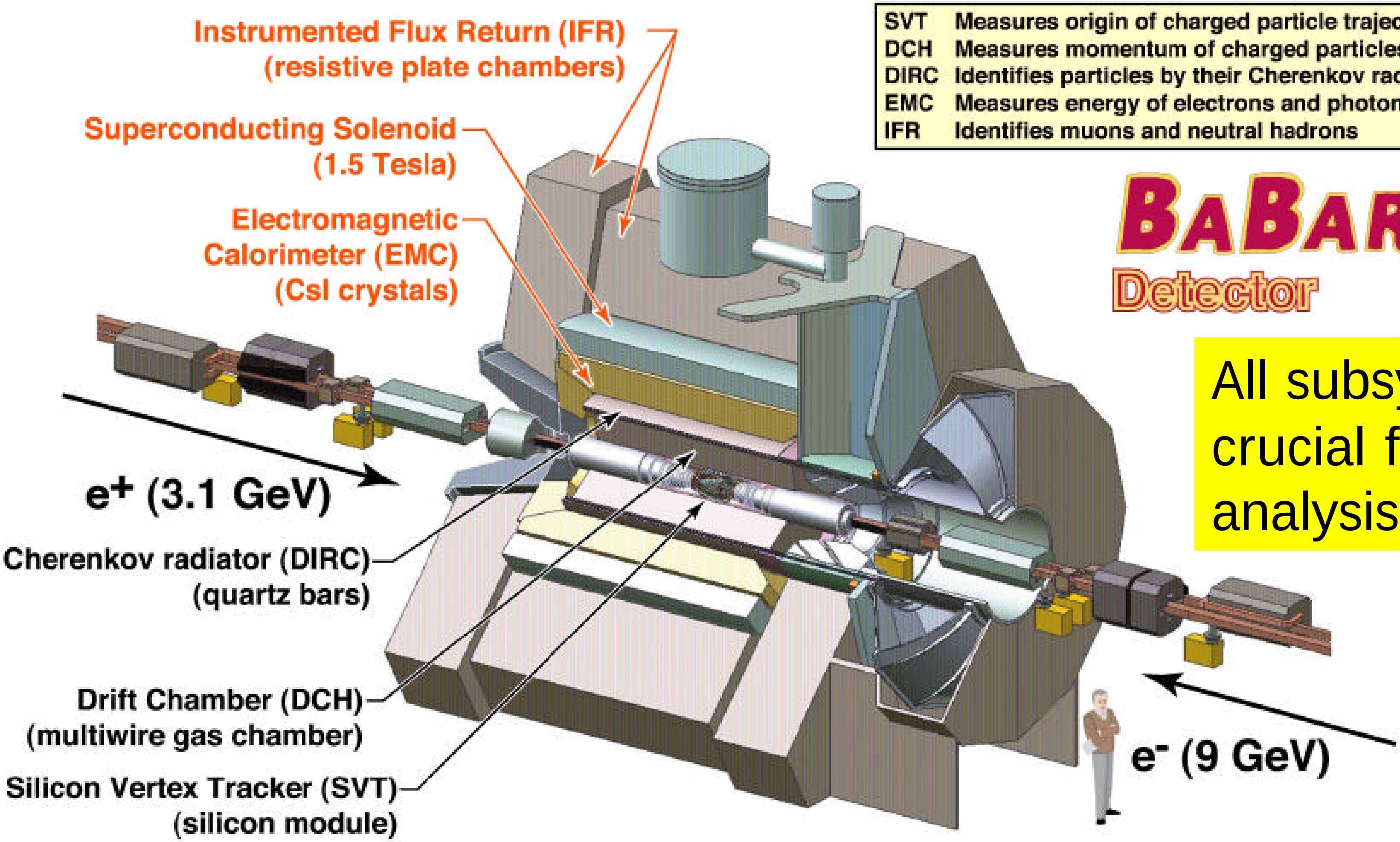
Most analyses in this talk:

On peak data	**81 fb^{-1}**
# of BB pairs	**88M**
Off peak data	**10 fb^{-1}**



BaBar Detector

SVT	Measures origin of charged particle trajectories
DCH	Measures momentum of charged particles
DIRC	Identifies particles by their Cherenkov radiation
EMC	Measures energy of electrons and photons
IFR	Identifies muons and neutral hadrons



All subsystems crucial for CP analysis

SVT: 97% efficiency, 15 μm z hit resolution (inner layers, perp. tracks)

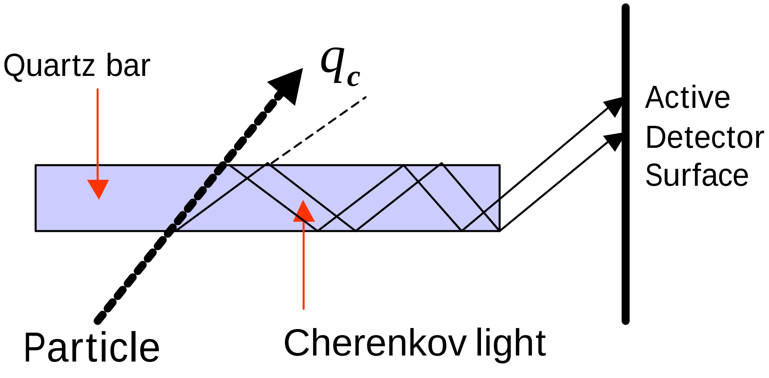
SVT+DCH: $\sigma(p_T)/p_T = 0.13\ \% \times p_T + 0.45\ \%$

DIRC: K-π separation 4.2 σ @ 3.0 GeV/c → 2.5 σ @ 4.0 GeV/c

EMC: $\sigma_E/E = 2.3\ \% \cdot E^{-1/4} \oplus 1.9\ \%$

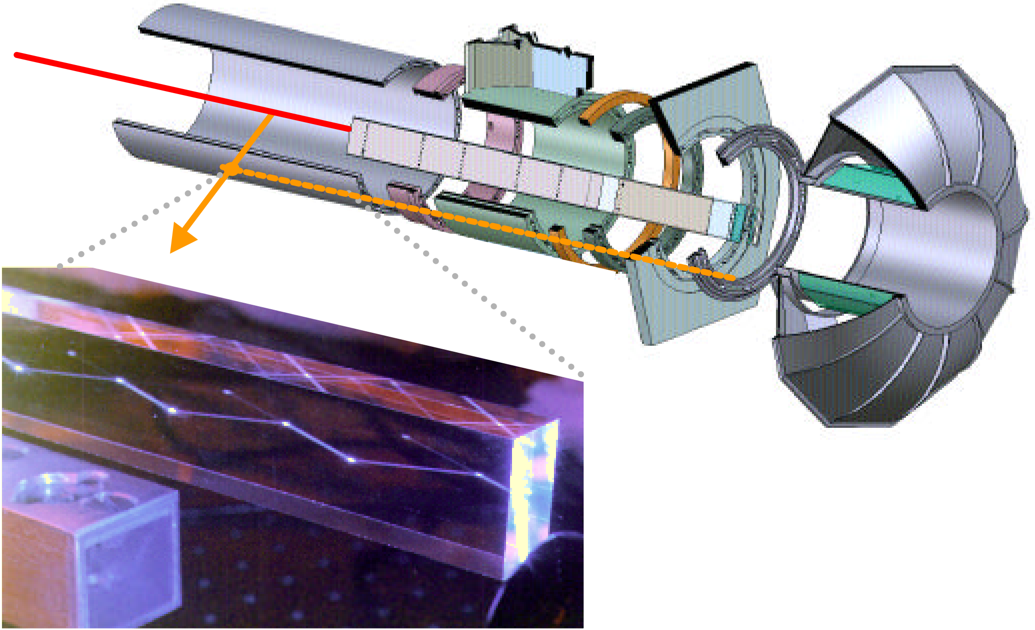
Detector of Internally Reflected Cherenkov Light (DIRC)

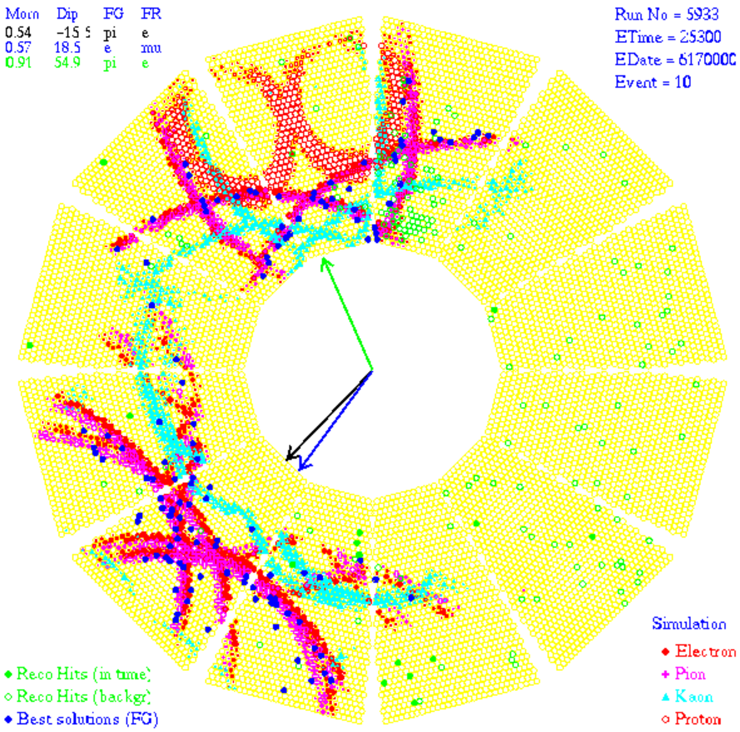
Measure angle of Cherenkov Cone in quartz



$$\cos\theta_c = 1/n\beta \quad p = m\beta\gamma$$

- Transmitted by internal reflection
- Detected by PMTs



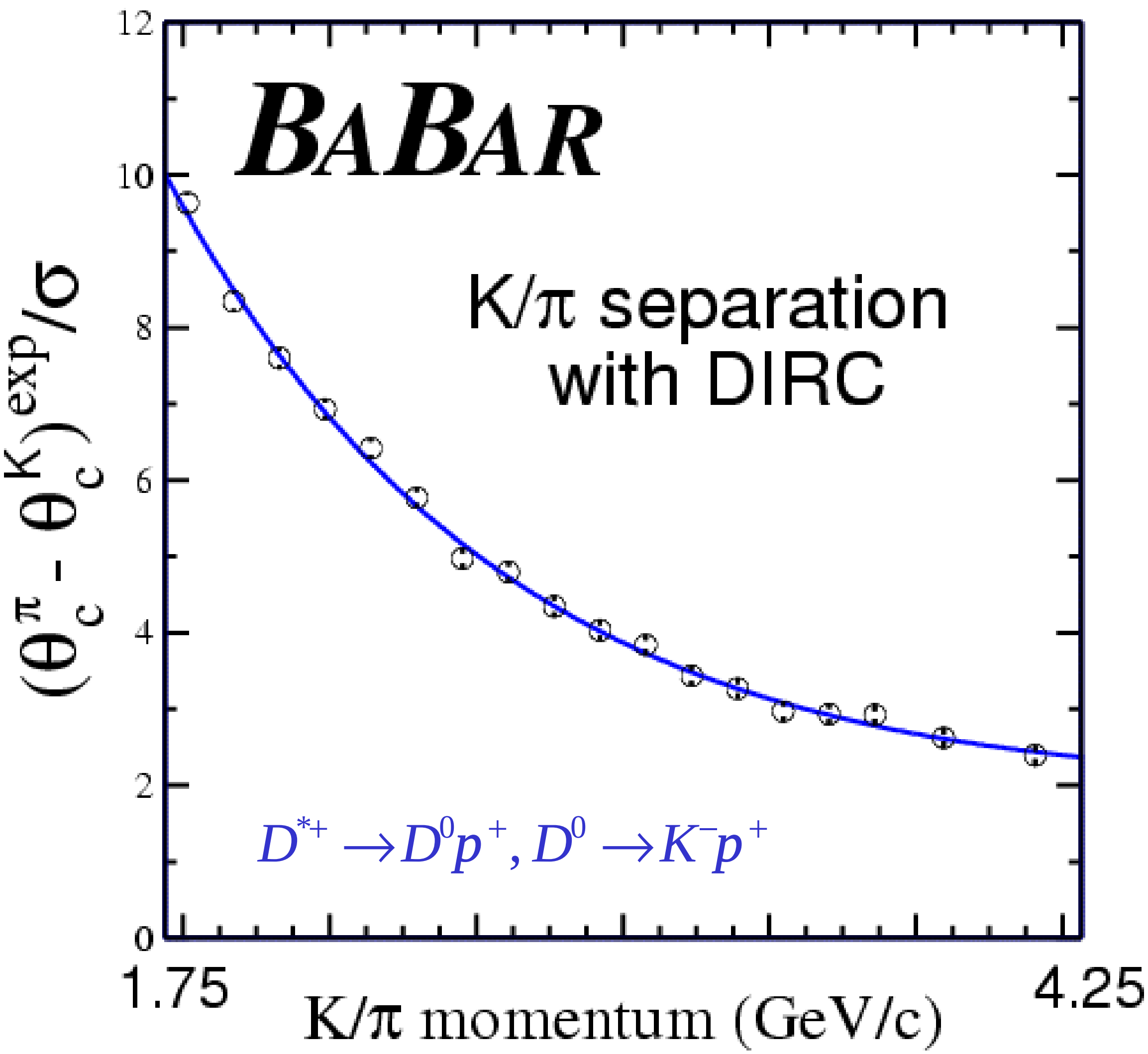


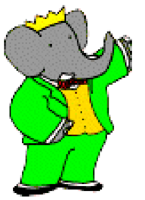
```
Mom   Dip    FG   FR
0.54  -15.5  pi   e
0.57  18.5   e    mu
0.91  54.9   pi   e
```

```
Run No = 5933
ETime = 25300
EDate = 6170000
Event = 10
```

K/π Separation with the DIRC

- Cherenkov angle θ_c resolution and K-π separation measured in data
- Excellent K-π separation up to kinematic endpoint for B decay products.
- Crucial for identification of charmless decays and for B flavor tagging.





Direct CPV: Interference of Decay Amplitudes

Time-independent *CP* observable:

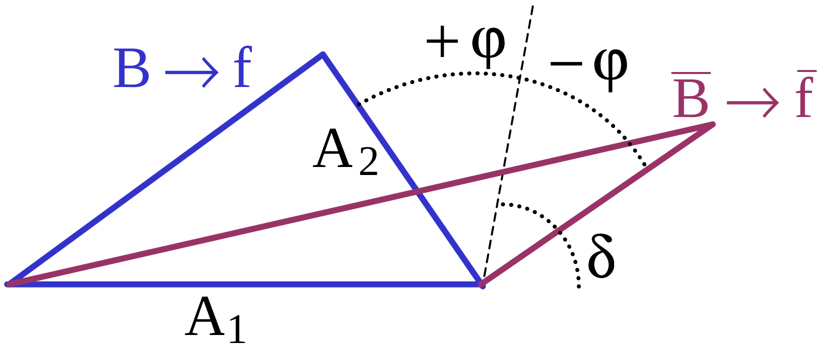
Partial
decay rate
asymmetry

$$A_{CP} = \frac{\Gamma(B \to f) - \Gamma(\overline{B} \to \overline{f})}{\Gamma(B \to f) + \Gamma(\overline{B} \to \overline{f})} \propto 2|A_1||A_2|\sin\delta \sin\varphi$$

2 amplitudes A_1 and A_2

Strong phase
difference

Weak phase
difference

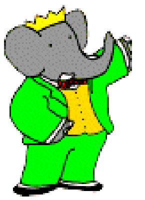


$\delta = 0$ or $\varphi = 0 \Rightarrow$ no CPV

For neutral modes, direct *CP* violation
competes with other types of
CP violation

- Large A_{CP} requires amplitudes of similar order
  - b→u: suppressed tree: charmless decays
    - large predicted A_{CP}
  - b→s: penguins: radiative decays
    - small predicted A_{CP}

- Understand penguins
- Access to α and γ
- New Physics in loops



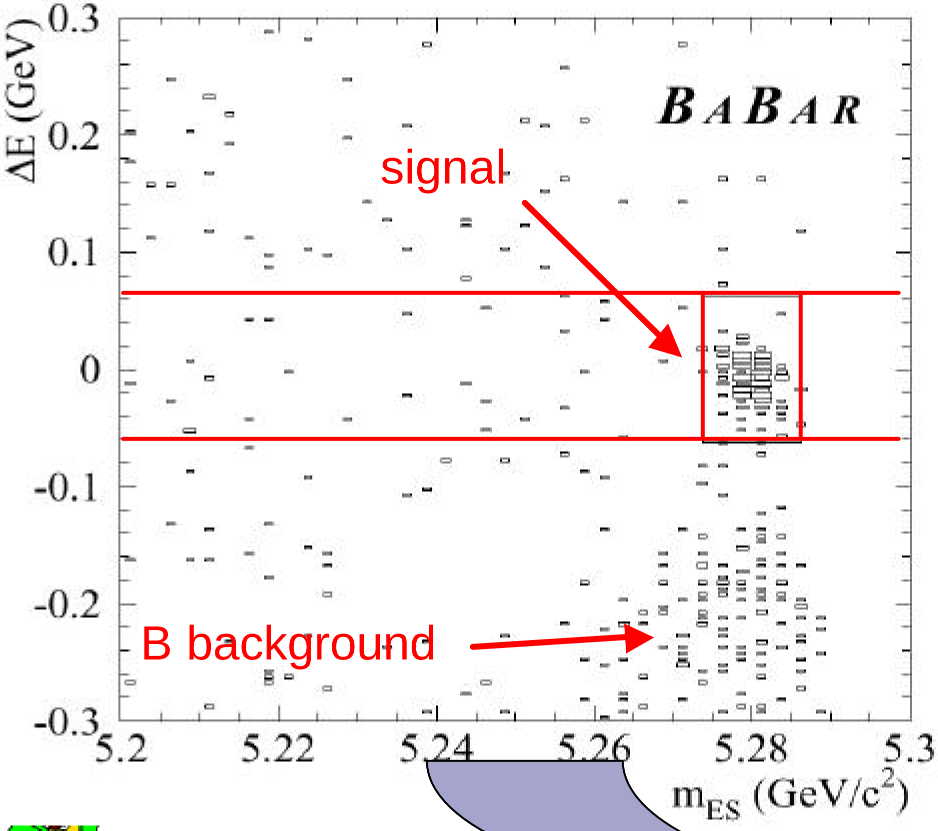
Event Selection for fully Reconstructed B mesons

Use known beam ($=E_B$) energy improve *E* and *p* conservation constraints

$$\Delta E = E_B - E^*_{beam}$$

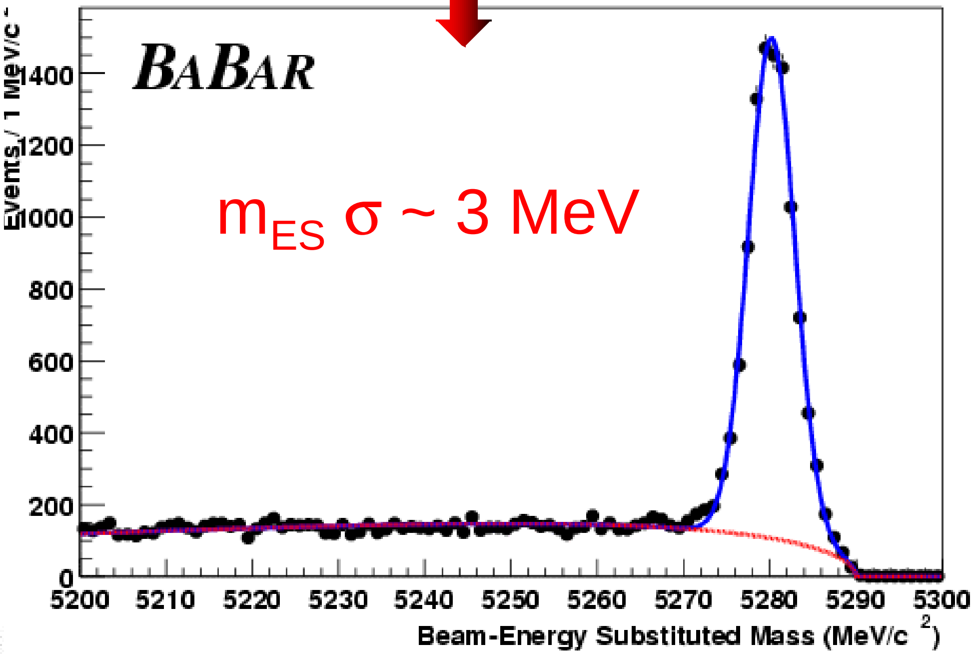
$$m_{ES} = \sqrt{(E^*_{beam})^2 - P_B^2}$$

ΔE σ ~ 15-80 MeV; larger with neutrals



signal

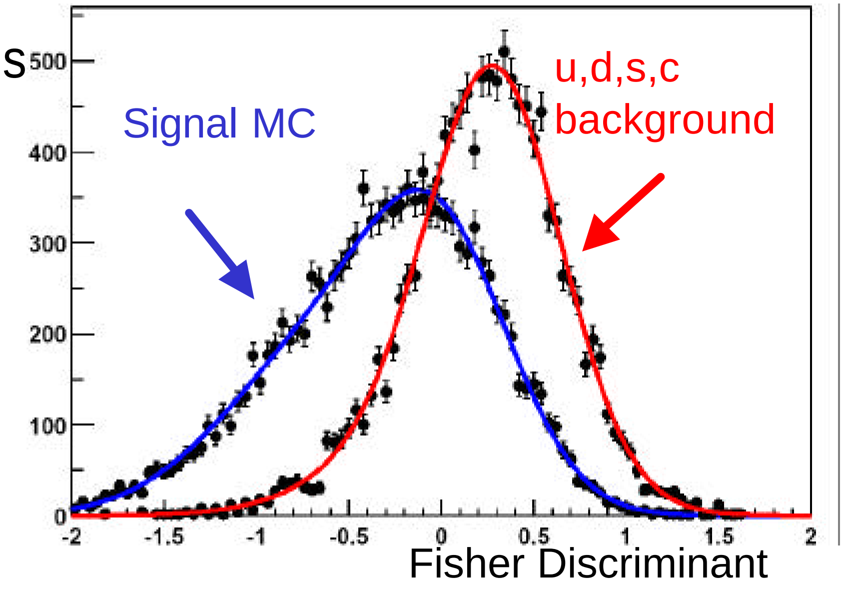
B background



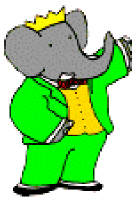
m_{ES} σ ~ 3 MeV

Overview of Charmless/Rare *B* Analyses

- Analysis issues:
  - BR ~ 10^{-5}-10^{-6} → need lots of data
  - Large background from $e^+e^- \rightarrow q\bar{q} \rightarrow$ background suppression
  - Modes with π^0 suffer backgrounds from other B decays
- Maximum likelihood (ML) fits to extract results
  - Kinematic and topological information separate signal from light-quark background
  - Particle ID to separate pions and kaons
- Beware of charge bias
  - detector: trigger, tracking; reconstruction
  - Event selection, particle ID, analysis



Arbitrary normalization



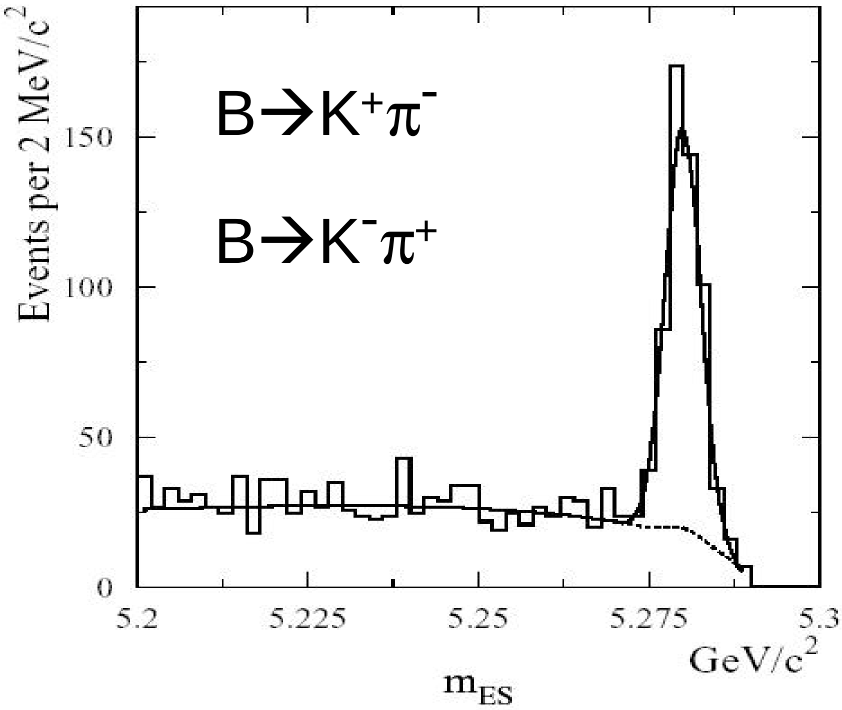
Two body Charmless *B* decays

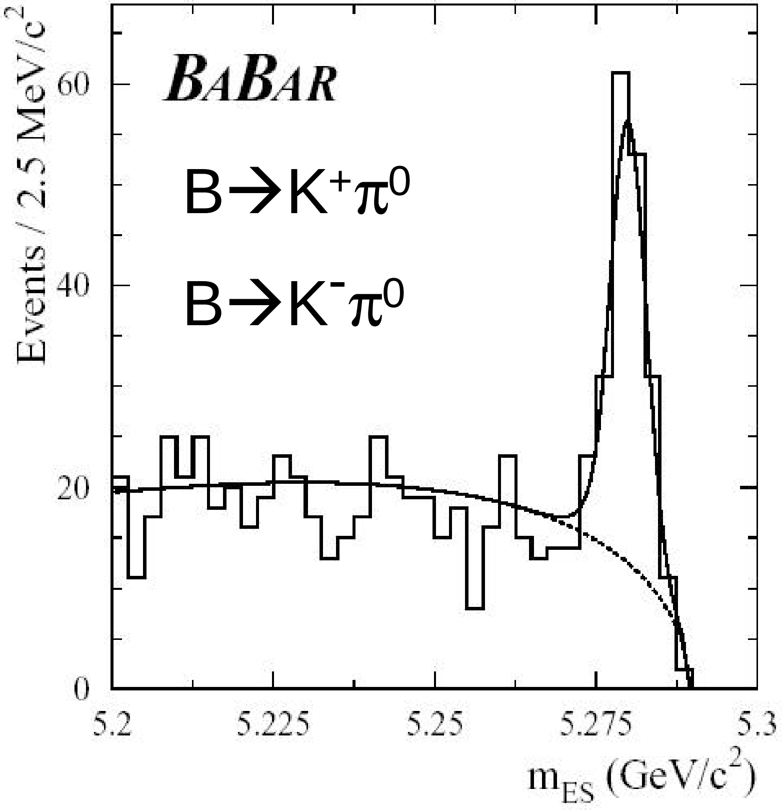
Sensitive to:

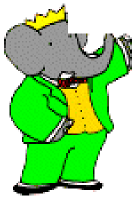
α eg. $B \rightarrow \pi^+\pi^-$, $\pi^+\pi^0$, $\pi^0\pi^0$ **see Paul Bloom's talk**

γ eg. $B \rightarrow K^+\pi^-$, $K^0\pi^+$ using Fleischer Mannel bound

A_{CP} can be sizeable







Plots have an optimised cut on likelihood ratio

Preliminary Results

New Results → $\sim 88\times10^6$ B pairs

$\sim 60\times10^6$ B pairs

hep-ex/0207065

$K^+\pi^-$: hep-ex/0207055(Sub. to PRL)

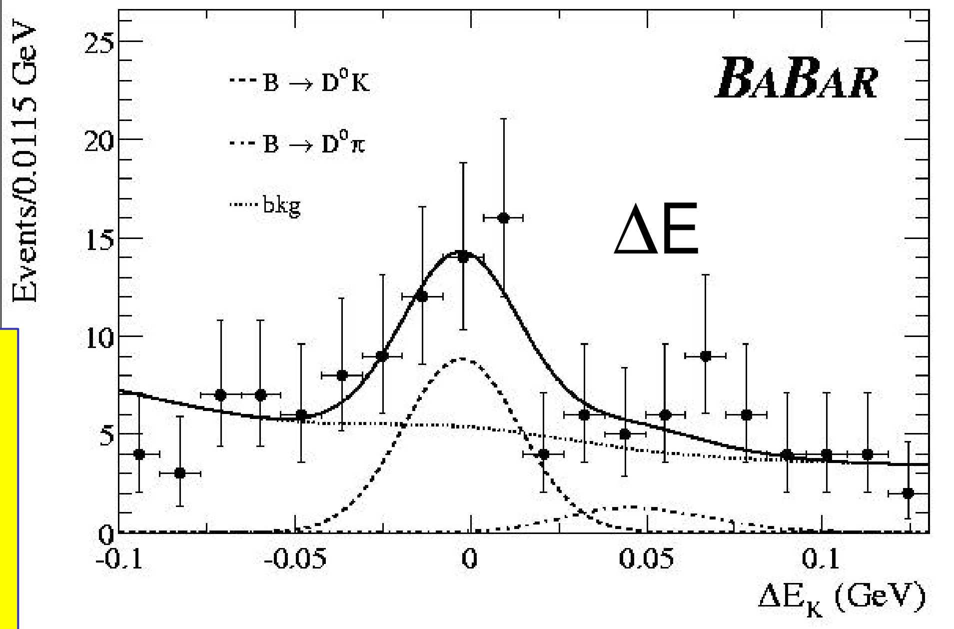
Mode	N(Events)	A_{CP}
$B^0\rightarrow K^+\pi^-$	$589 \pm 30 \pm 17$	$-0.102 \pm 0.050 \pm 0.016$
$B^+\rightarrow K^+\pi^0$	$239 \pm 22 \pm 6$	$-0.09 \pm 0.09 \pm 0.01$
$B^+\rightarrow \pi^+\pi^0$	$125 \pm^{23}_{21} \pm 10$	$-0.03 \pm 0.18 \pm 0.02$
$B^0\rightarrow K^0\pi^0$	$86 \pm 13 \pm 3$	$0.03 \pm 0.36 \pm 0.09$
$B^+\rightarrow K^0\pi^+$	$172 \pm 17 \pm 9$	$-0.17 \pm 0.10 \pm 0.02$

hep-ex/0206053

5% A_{CP} sensitivity in $B\rightarrow K^+ p^-$

Direct CPV: $B^- \to D^0_{(CP)}K^-$

$D^0 \to K^+K^-$

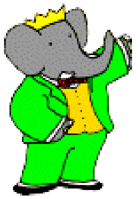


One ingredient to theoretically clean measurement of γ.
Experimentally very difficult [M. Gronau and D. Wyler, Phys. Lett **B265**, 172 (1991)]:

15.3 ± 5.6 B^+

21.7 ± 5.6 B^-

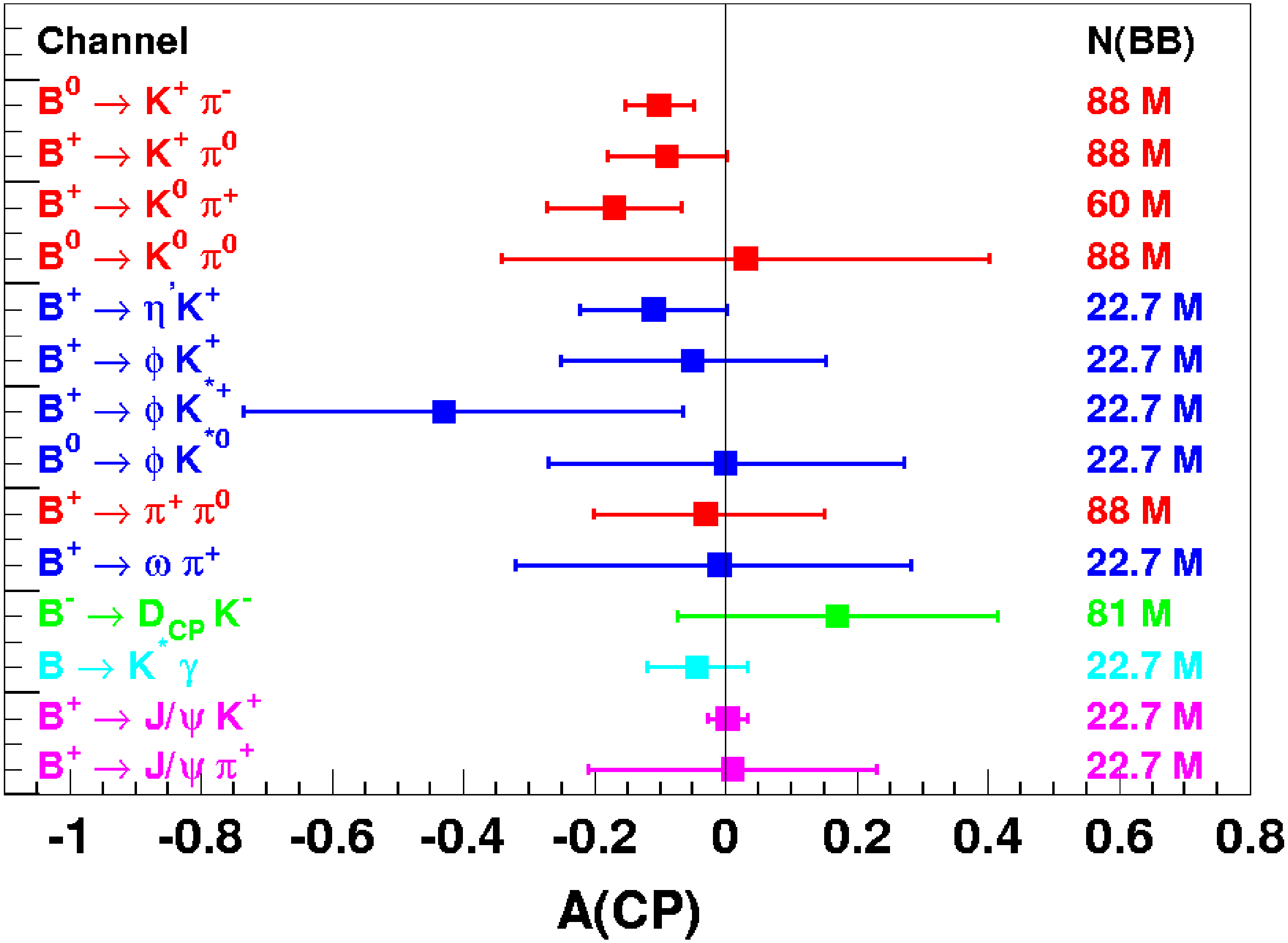
$$A_{CP} \equiv \frac{Br(B^- \to D^0_{CP}K^-) - Br(B^+ \to D^0_{CP}K^+)}{Br(B^- \to D^0_{CP}K^-) + Br(B^+ \to D^0_{CP}K^+)} = 0.17 \pm 0.23^{+0.09}_{-0.07}$$



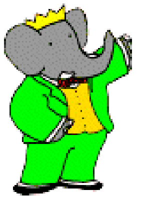
hep-ex/0207087

Preliminary

Summary of (time integrated) Direct CP results



- Details in: hep-ex/0207065, hep-ex/0206053, hep-ex/0207055, hep-ex/0207087, PRL88 101805, PRD65 091101, PRD65 051101.

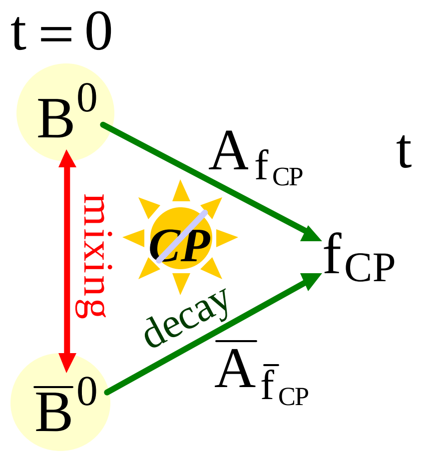


Formalism for CP from Interference

CP violation results from interference between decays with and without mixing

$$\lambda = \frac{q}{p} \cdot \frac{\overline{A}}{A}$$

Amplitude ratio



$$\boxed{\lambda_{f_{CP}} \neq \pm 1 \quad \Rightarrow \quad \mathrm{Prob}(\overline{B}^0_{phys}(t) \to f_{CP}) \neq \mathrm{Prob}(B^0_{phys}(t) \to f_{CP})}$$

Time-dependent *CP* Observable:

$$A_{f_{CP}}(t) = \frac{\Gamma(\overline{B}^0_{phys}(t) \to f_{CP}) - \Gamma(B^0_{phys}(t) \to f_{CP})}{\Gamma(\overline{B}^0_{phys}(t) \to f_{CP}) + \Gamma(B^0_{phys}(t) \to f_{CP})}$$

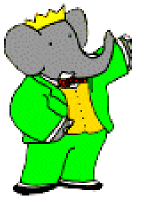
$$= C_{f_{CP}} \cdot \cos(\Delta m_{B_d} t) + S_{f_{CP}} \cdot \sin(\Delta m_{B_d} t)$$

cosine term

sine term

$$\boxed{\begin{aligned} C_{f_{CP}} &= \frac{1 - |\lambda_{f_{CP}}|^2}{1 + |\lambda_{f_{CP}}|^2} \\ S_{f_{CP}} &= \frac{\cdot 2\,\mathrm{Im}\lambda_{f_{CP}}}{1 + |\lambda_{f_{CP}}|^2} \end{aligned}}$$

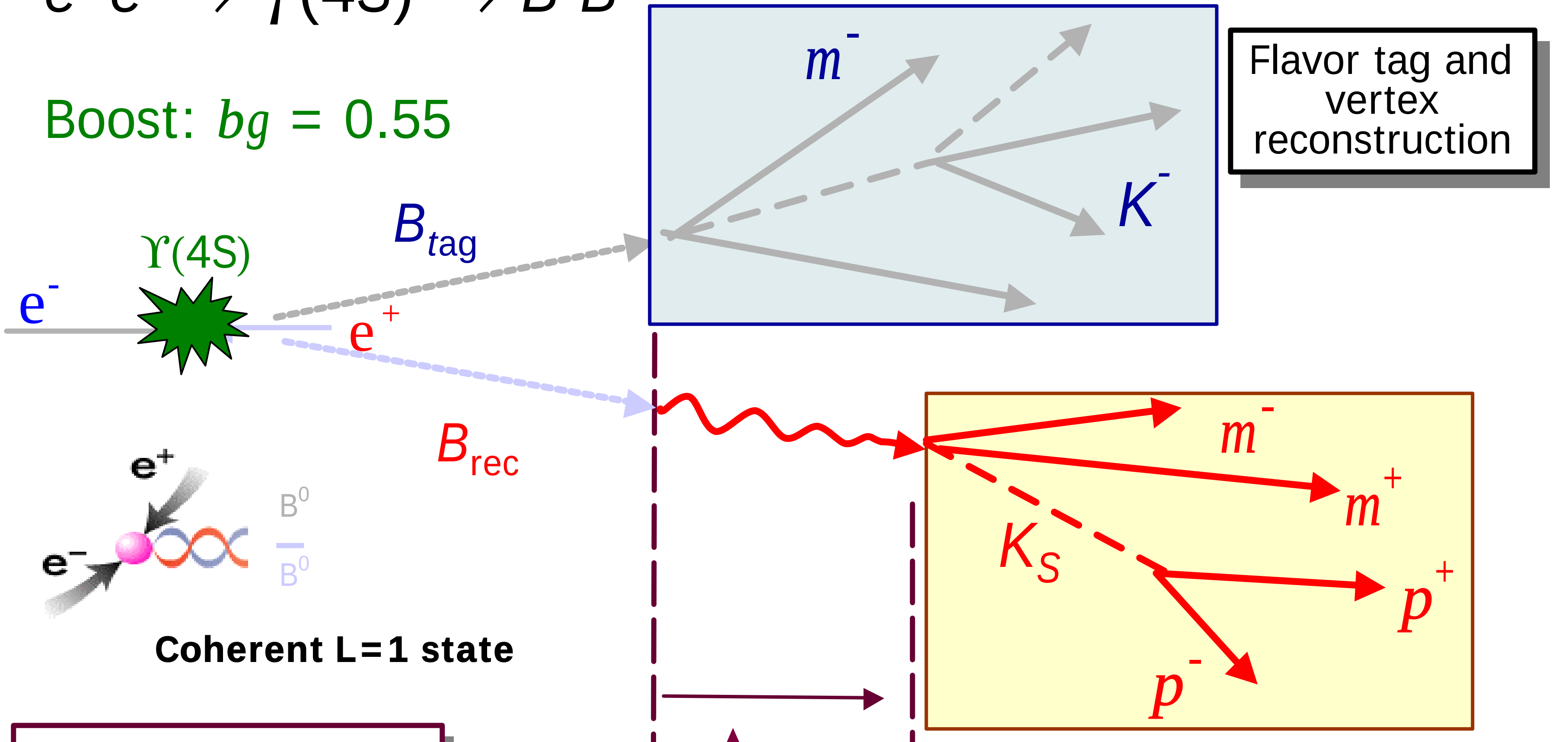
$(\Delta\Gamma = 0)$



Experimental technique at the ϒ(4S) resonance

$e^+e^- \rightarrow$ ¡$(4S) \rightarrow B\ \bar{B}$

Boost: $bg = 0.55$



Coherent L=1 state

Flavor tag and vertex reconstruction

Exclusive *B* meson and vertex reconstruction

Start the Clock

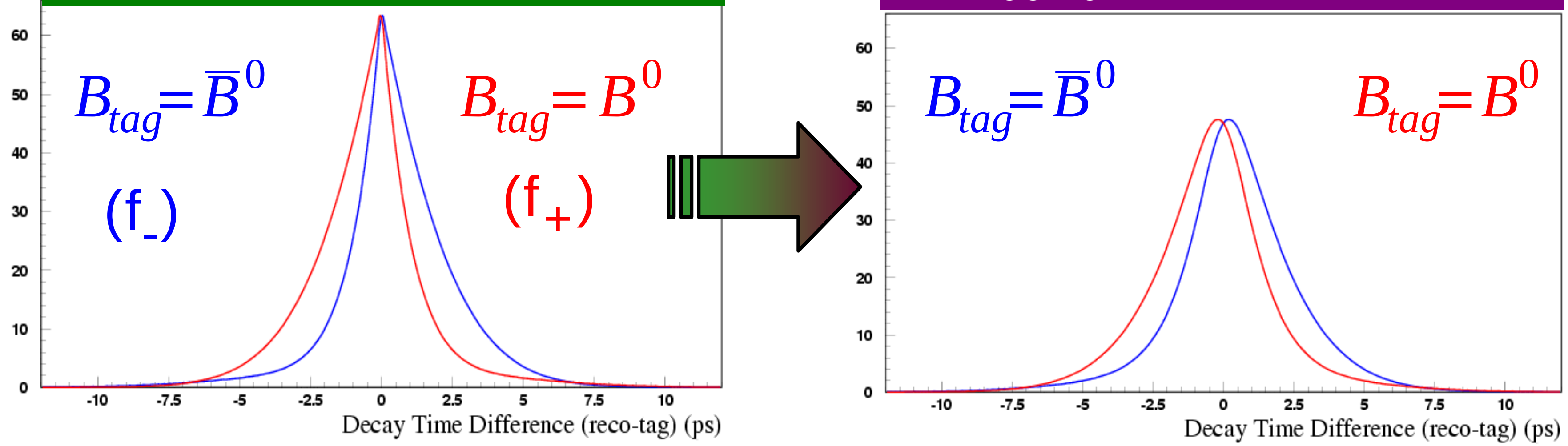
Stop the Clock

$$\Delta t \approx \frac{\Delta z}{\langle bg \rangle c}$$

Tagging errors and finite Δt resolution dilute the CP asymmetry

perfect
tagging & time resolution

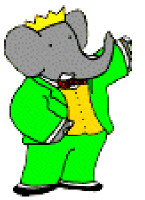
typical
mistagging & finite time resolution



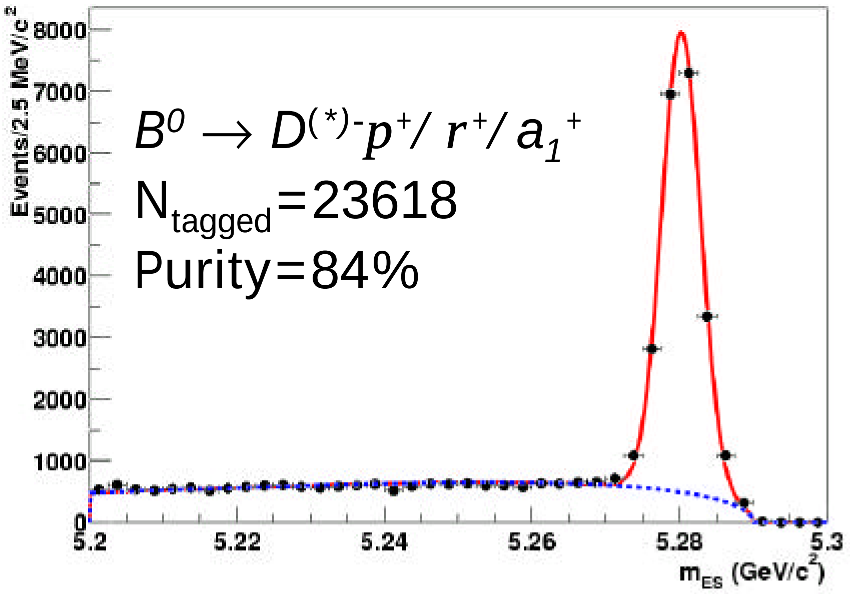
C=0

$$f_{\pm} = \left[1 \mp (1-2w) S_{f_{CP}} \sin(\Delta m \Delta t)\right] \times R$$

- Must determine mistag fraction w and Δt resolution function R in order to measure CP asymmetry.
- Fundamental assumption: w and R are the same for CP events and more plentiful B_{rec} modes. Measure from data with B^0-B^0 decays to flavor eigenstates.



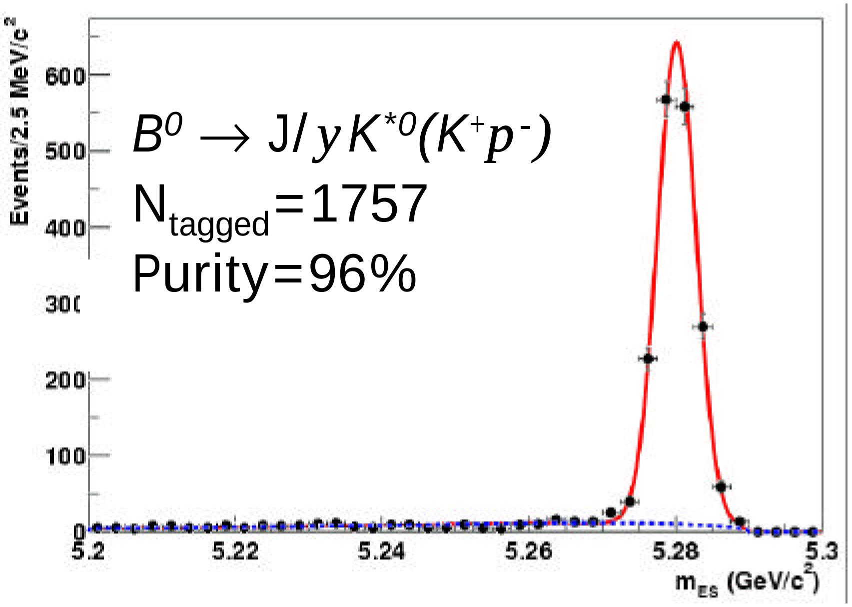
Use self-tagged B_{flav} sample to measure w and R



$B^0 \rightarrow D^{(*)-}p^+/\,r^+/\,a_1^+$

$N_{tagged}=23618$

Purity=84%



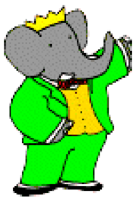
$B^0 \rightarrow J/y K^{*0}(K^+p^-)$

$N_{tagged}=1757$

Purity=96%

- High statistics, known decay time distribution:

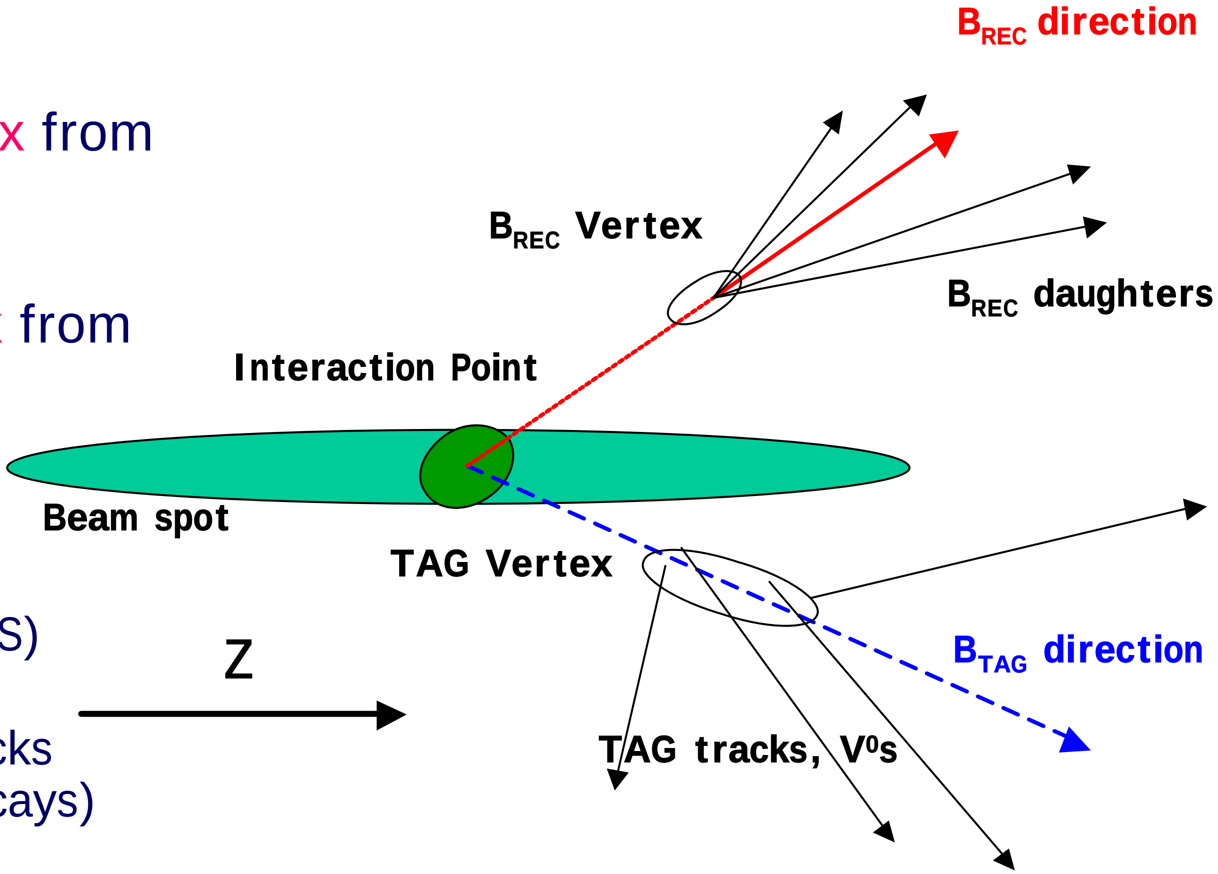
$$f_{\substack{\text{Unmixed}\\ \text{Mixed}}}(\Delta t)=\left\{\frac{e^{-|\Delta t|/t_B}}{4t_B}\left[1\pm(1-2w)\cos(\Delta m_d\Delta t)\right]\right\}\otimes R$$



B_{flav} sample is x10 size of CP sample

Vertex and Δt Reconstruction

- Reconstruct B_{rec} vertex from charged B_{rec} daughters
- Determine B_{Tag} vertex from
  - All charged tracks not in B_{rec}
  - Constrain with B_{rec} vertex, beam spot, and $\Upsilon(4S)$ momentum
  - Remove high χ^2 tracks (to reject charm decays)



B_{REC} direction

B_{REC} Vertex

B_{REC} daughters

Interaction Point

Beam spot

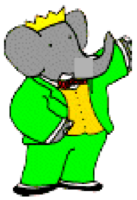
TAG Vertex

Z

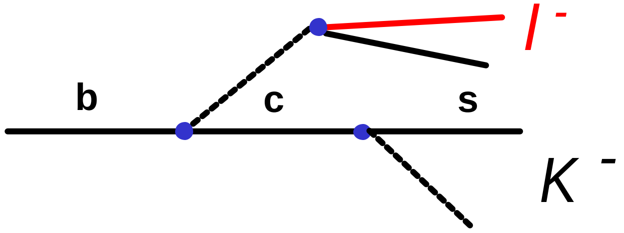
B_{TAG} direction

TAG tracks, V^0s

- High efficiency: 95%
- Average Δz resolution ~ 180 μm (dominated by B_{Tag}) (<|Δz|> ~ 260 μm)
- Δt resolution function measured from data



B Flavor tagging method



Exploit correlations between B flavor and its decay products to determine flavor of B_{tag}.

Using tracks with or without particle identification, and kinematic variables, a multilevel neural network assigns each event to one of five mutually-exclusive categories:

- Lepton tag: primary leptons from semileptonic decay
- Kaon1 tag: high quality kaons, correlated K^+ *and* p_s^- (from D^*)
- Kaon2 tag: lower quality kaons, p_s from D^*
- Inclusive tag: unidentified leptons, low quality K, p, l
- No tag: event is not used for CP analysis

New and improved tagging method

Tagging performance from B_{flav} sample

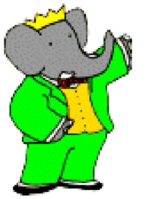
Measure of tagging performance Q:

$$Q=\varepsilon(1-2w)^2$$

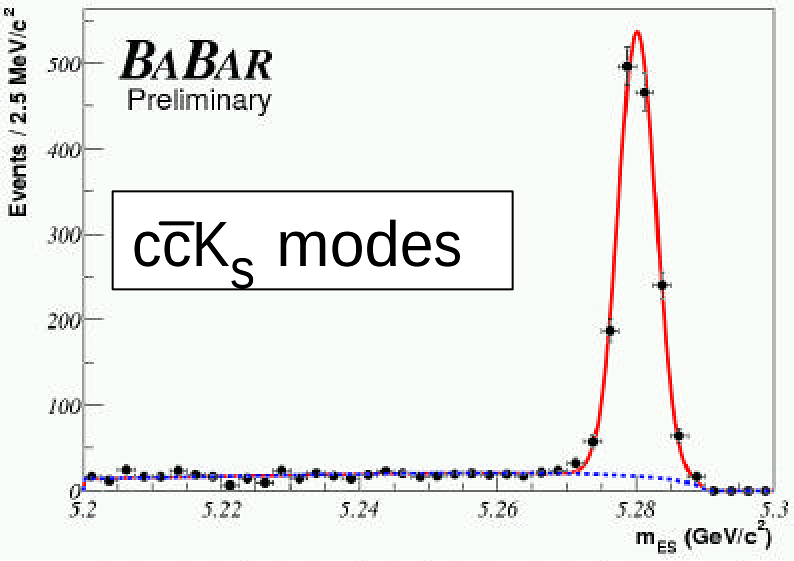
$$s\,(\sin 2b) \propto \frac{1}{\sqrt{Q}}$$

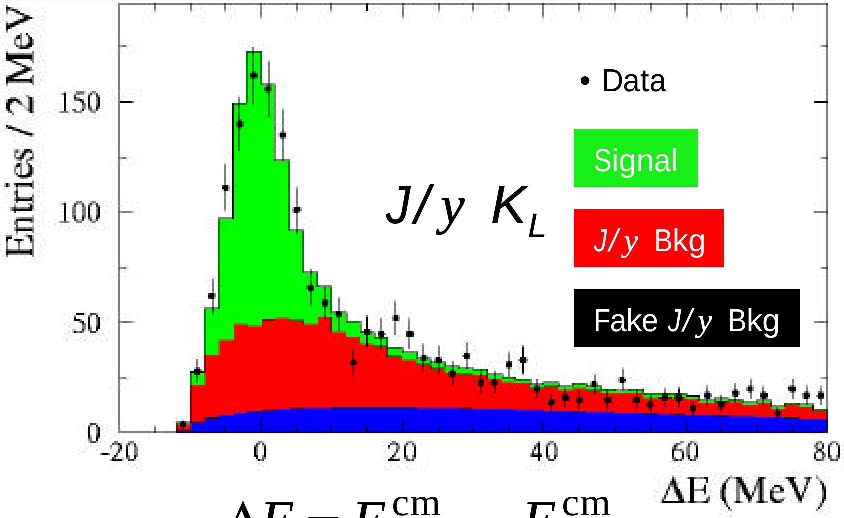
New tagging method increases Q by 7% compared to the method used in our previous result: PRL87 (Aug 01).

Category	**Eff. (%)**	**Mistag (%)**	**Q=e(1-2w)² (%)**
Lepton	9.1 ± 0.2	3.3 ± 0.6	7.9 ± 0.3
Kaon1	16.7 ± 0.2	9.9 ± 0.7	10.7 ± 0.4
Kaon2	19.8 ± 0.3	20.9 ± 0.8	6.7 ± 0.4
Inclusive	20.0 ± 0.3	31.6 ± 0.9	2.7 ± 0.3
Total	**65.6 ± 0.5**		**28.1 ± 0.7**



sin2b golden sample: (c$\bar{c}$)K_S and (c$\bar{c}$)K_L



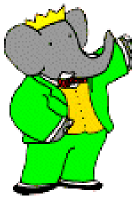


$$\Delta E = E^{cm}_{beam} - E^{cm}_{KL}$$

Sample	N_{tagged}	Purity
$J/y\ K_s(p^+p^-)$	974	97%
$J/y\ K_s(p^0p^0)$	170	89%
y (2S) K_s	150	97%
$c_{c1}\ K_s$	80	95%
$h_c\ K_s$	132	73%
Total h_{CP}**=-1**	1506	92%
$J/y\, K_L$	988	55%
$J/y\, K^{*0}$	147	81%
Total	2641	76%

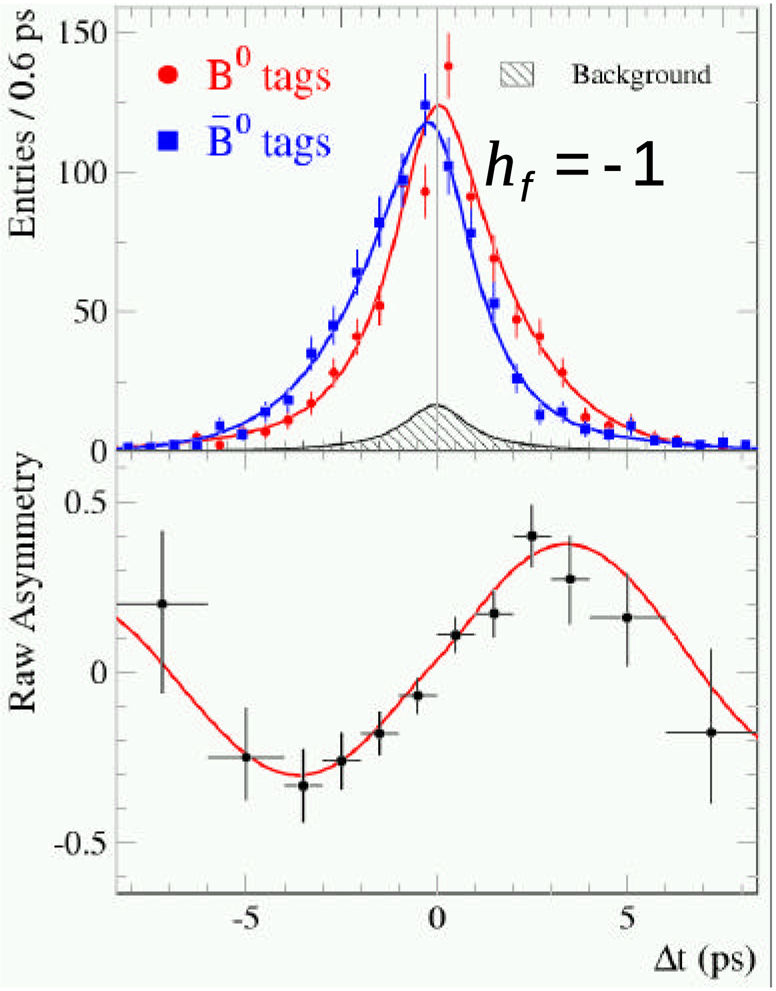
New

Cos coeff. = 0
Sin coeff. = -η_{CP}sin2β

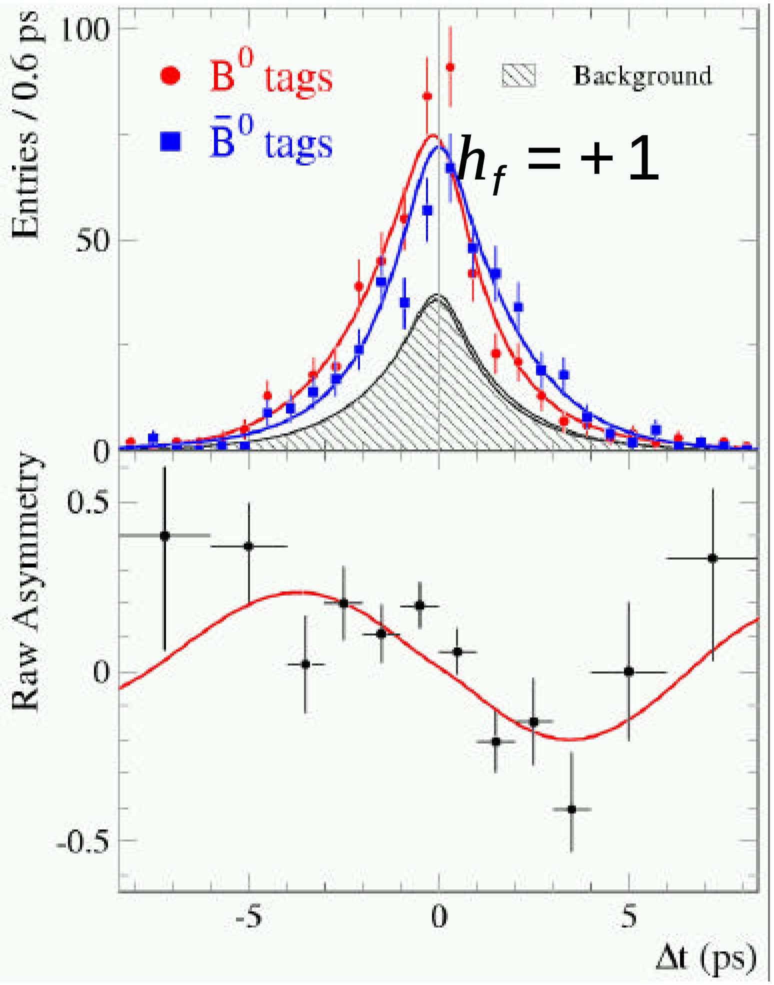


Theoretically “clean” and experimentally “easy” channels

Fit results



$\sin 2b = 0.755 \pm 0.074$

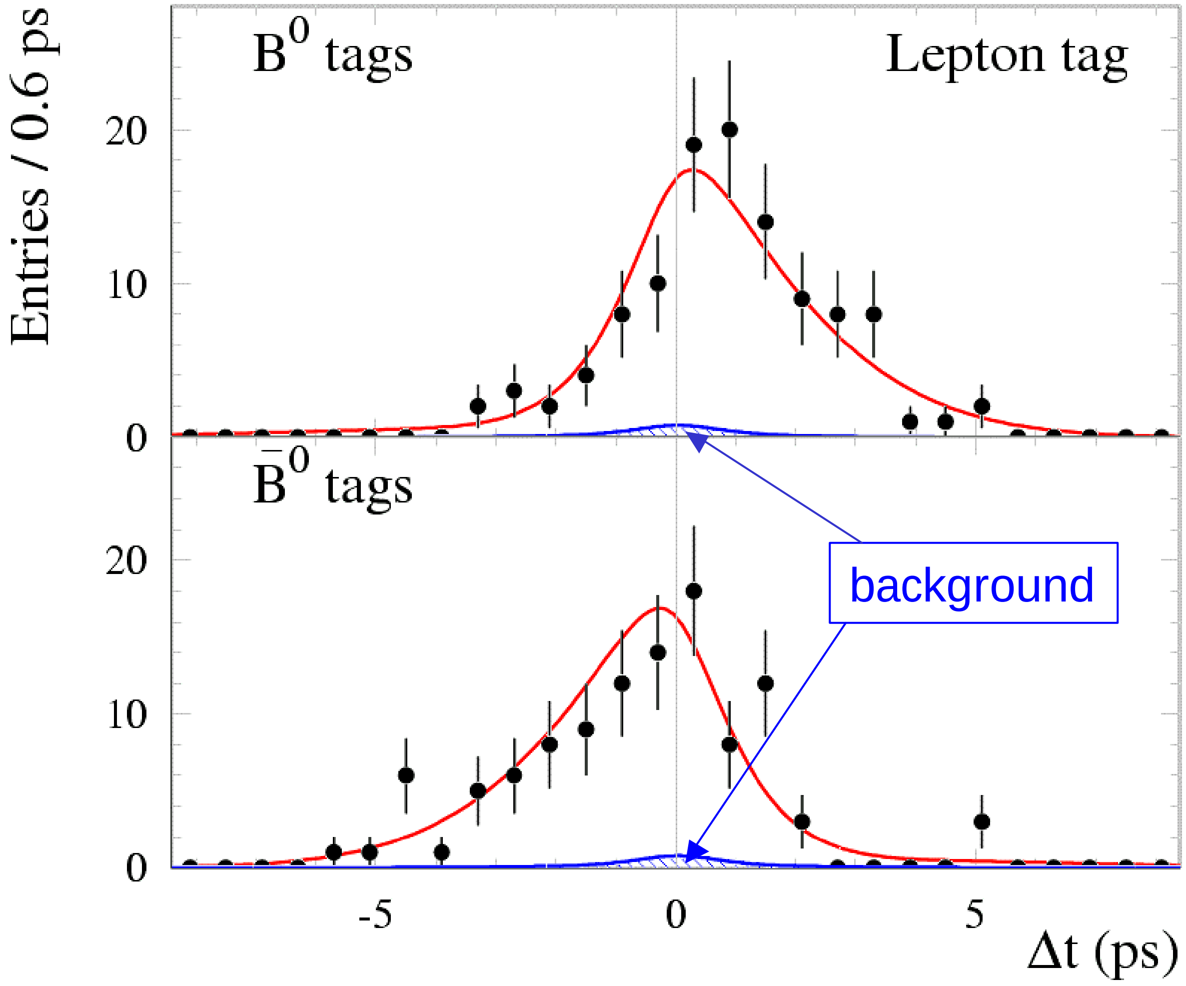


$\sin 2b = 0.723 \pm 0.158$

$\sin 2b$ = 0.741 ± 0.067 (stat) ± 0.033 (sys)

Preliminary

Golden modes with a lepton tag



The best of the best!

Ntagged = 220

Purity = 98%

Mistag fraction 3.3%

$\sigma_{\Delta t}$ 20% better than other tag categories

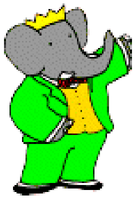
sin2*b* = 0.79 ± 0.11

Consistent results across mode, data sample, tagging category

Sources of Systematic Error

	σ(sin2*b*)
Description of background events	0.017
CP content of background components	
Background shape uncertainties	
Composition and content of $J/y\ K_L$ background	0.015
Δt resolution and detector effects	0.017
Silicon detector alignment uncertainty	
Dt resolution model	
Mistag differences between B_{CP} and B_{flav} samples	0.012
Fit bias correction	0.010
Fixed lifetime and oscillation frequency	0.005
TOTAL	0.033

Steadily reducing systematic error: July 2002 = 0.033
July 2001 = 0.05



Search for non-Standard Model effects in $(c\bar{c})K_S$

- If another amplitude (new physics) contributes a different phase, then

$$\left|\lambda_{f_{CP}}\right| \neq 1 \qquad \left(C_f \neq 1\right)$$

$(\Delta\Gamma=0)$

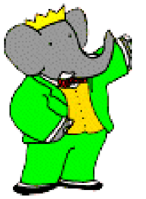
- Fit $|l_f|$ and S_f using the $(c\bar{c})K_s$ modes

$$|\, l_f \,| = 0.948 \pm 0.051\ (\text{stat}) \pm 0.017\ (\text{syst})$$

$$S_f = 0.759 \pm 0.074\ (\text{stat}) \pm 0.032\ (\text{syst})$$

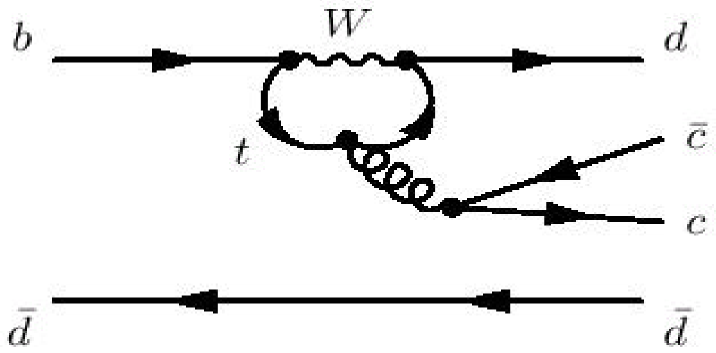
$$|\lambda| = \left|\frac{\bar{A}}{A}\right|$$

Consistent with the Standard Model expectation of $|l_f|=1$ and nominal fit sin2b = 0.755 ± 0.074 for $(c\bar{c})K_s$ modes alone.



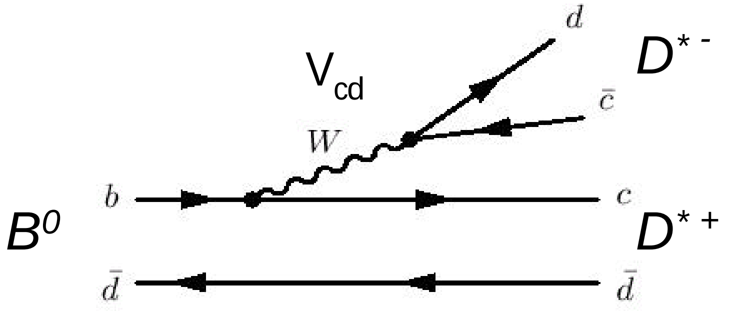
Other modes with $A_{CP}(\Delta t)$ proportional to sin2*b*

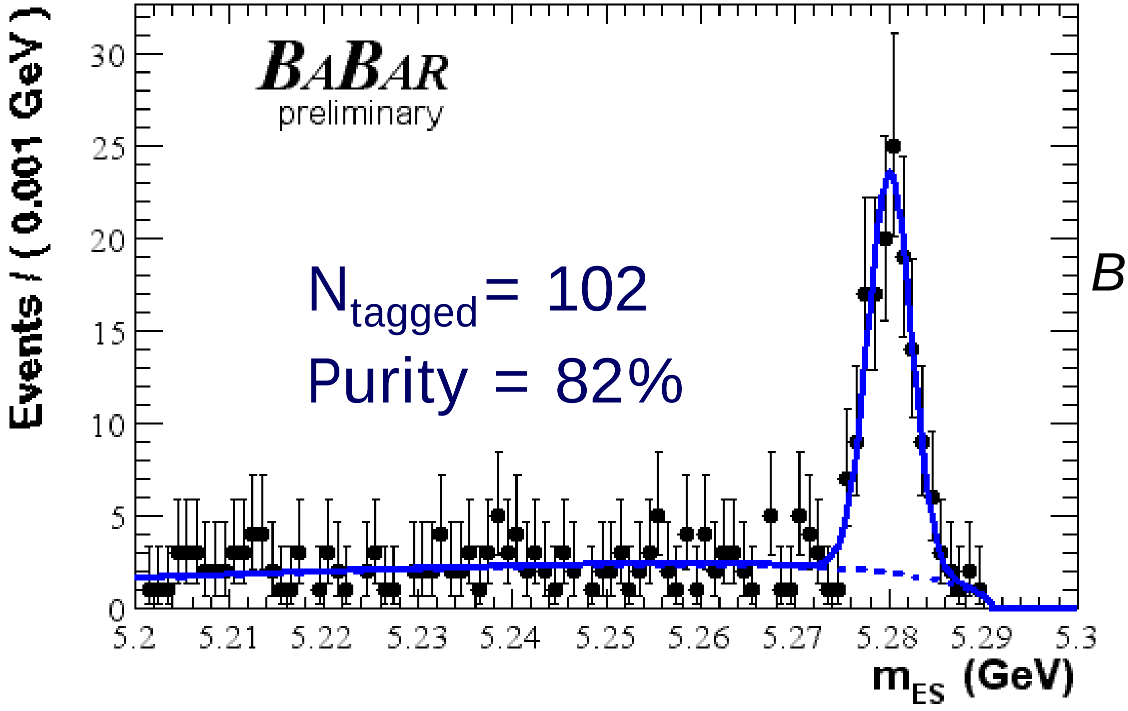
- Compare with “golden” measurements to test consistency of CKM picture
- Differences = Penguin “pollution” or New Physics



(b → c$\bar{c}$d) mode $B^0 \to D^{*+}D^{*-}$

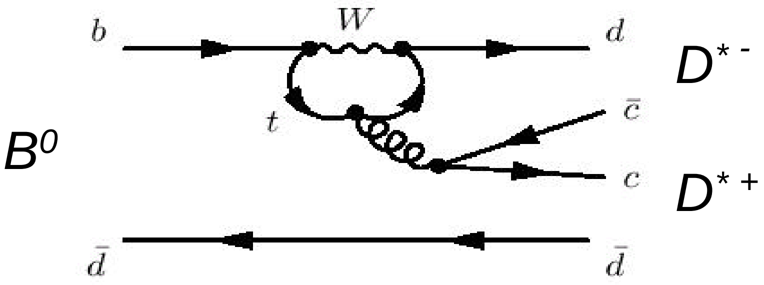
- Tree level weak phase same as b → c$\bar{c}$s
- Penguin contribution unknown:
    - expected to be small (< 0.1*Tree)
- Not a CP eigenstate, mixture of CP even (L=0,2) and CP odd (L=1)
    - Resolve using angular analysis





N_{tagged}= 102

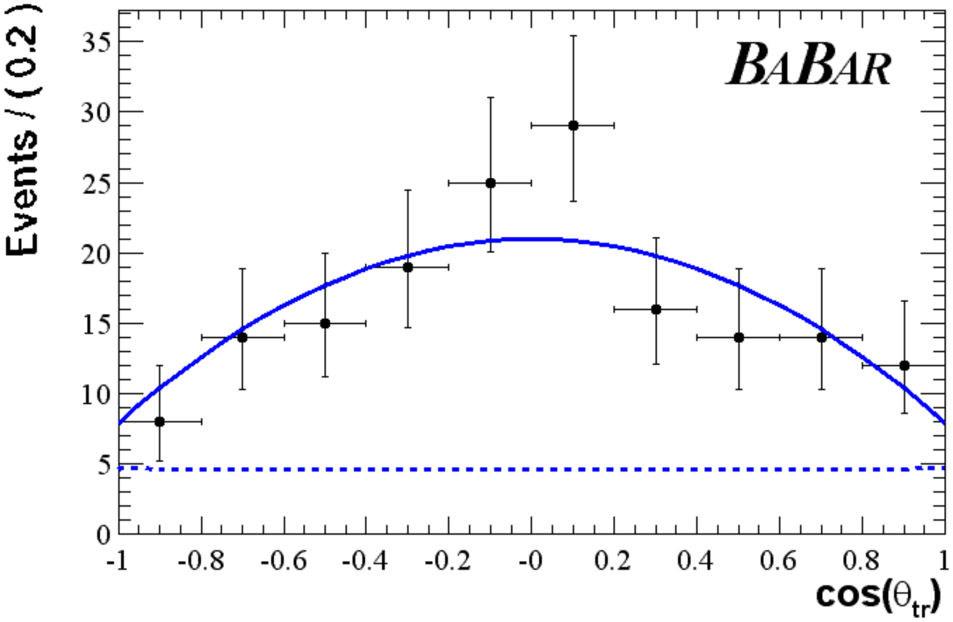
Purity = 82%

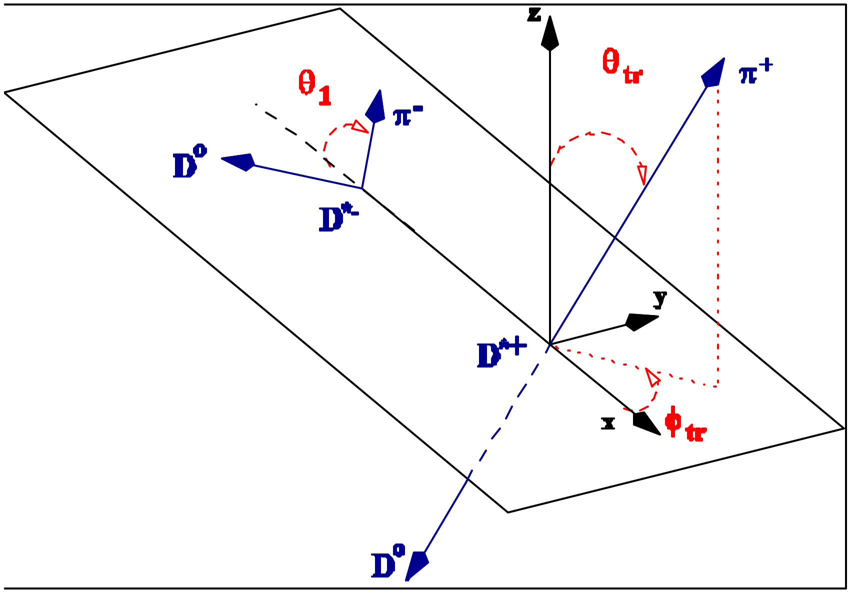


CP composition of $B^0 \to D^{*+}D^{*-}$

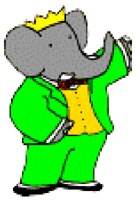
- Measure CP odd fraction:

$$R_\perp = 0.07 \pm 0.06\ \text{(stat)} \pm 0.03\ \text{(syst)}$$



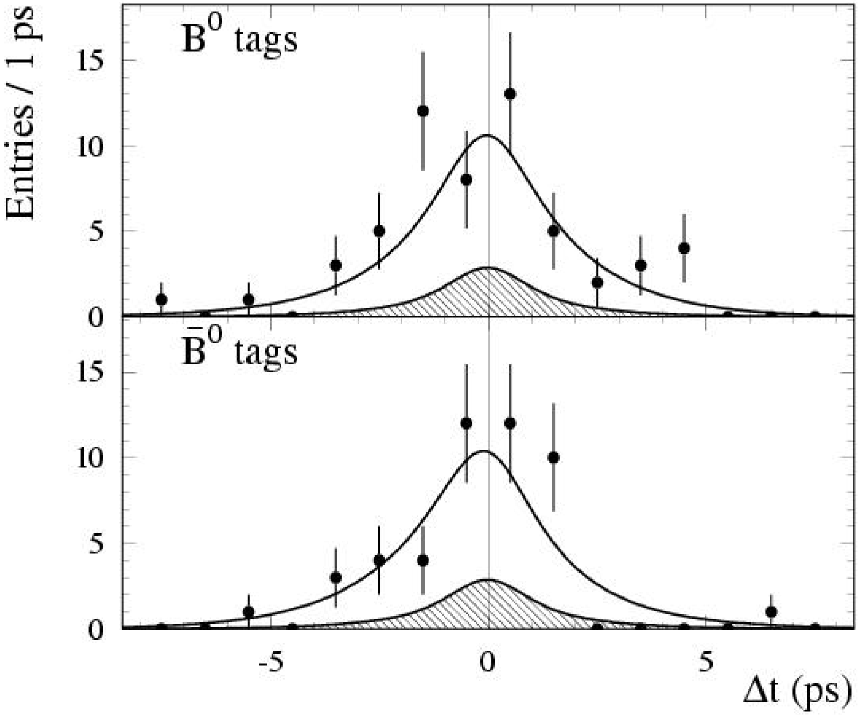


$$\frac{d\Gamma}{\Gamma d\cos J_{tr}} = \frac{3}{4}(1-R_\perp)\sin^2 J_{tr} + \frac{3}{2}R_\perp\cos^2 J_{tr}$$



- Almost pure CP even state. Take advantage of this in CP fit.

CP asymmetry fit



- Improved fitting strategy:
  - Parameterize in terms of CP even (λ_+) and odd ($\lambda_\perp$) components, include angular information from partial-wave analysis
  - Fix CP odd component to $\lambda_\perp=1$, $\mathrm{Im}(\lambda_\perp) = -0.741$
- We measure:

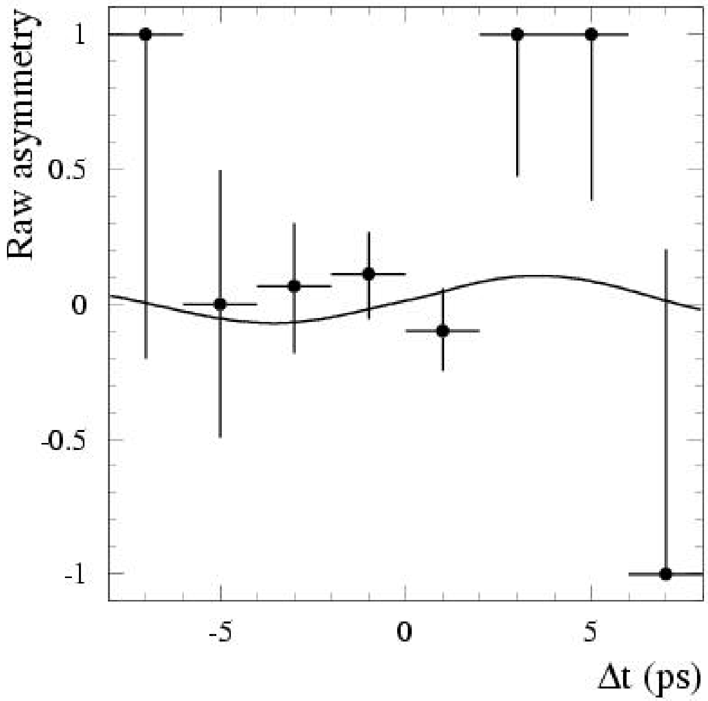
Preliminary

$$|\lambda_+| = 0.98 \pm 0.25\ (\text{stat}) \pm 0.09\ (\text{syst})$$

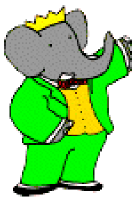
$$\mathrm{Im}(\lambda_+) = 0.31 \pm 0.43\ (\text{stat}) \pm 0.10\ (\text{syst})$$

hep-ex/0207072

If penguins negligible: $\mathbf{Im}(l_+) = -\sin 2b$



Im(λ_+) measurement ~2.7σ from BaBar sin2*b* in charmonium, assuming no penguins.



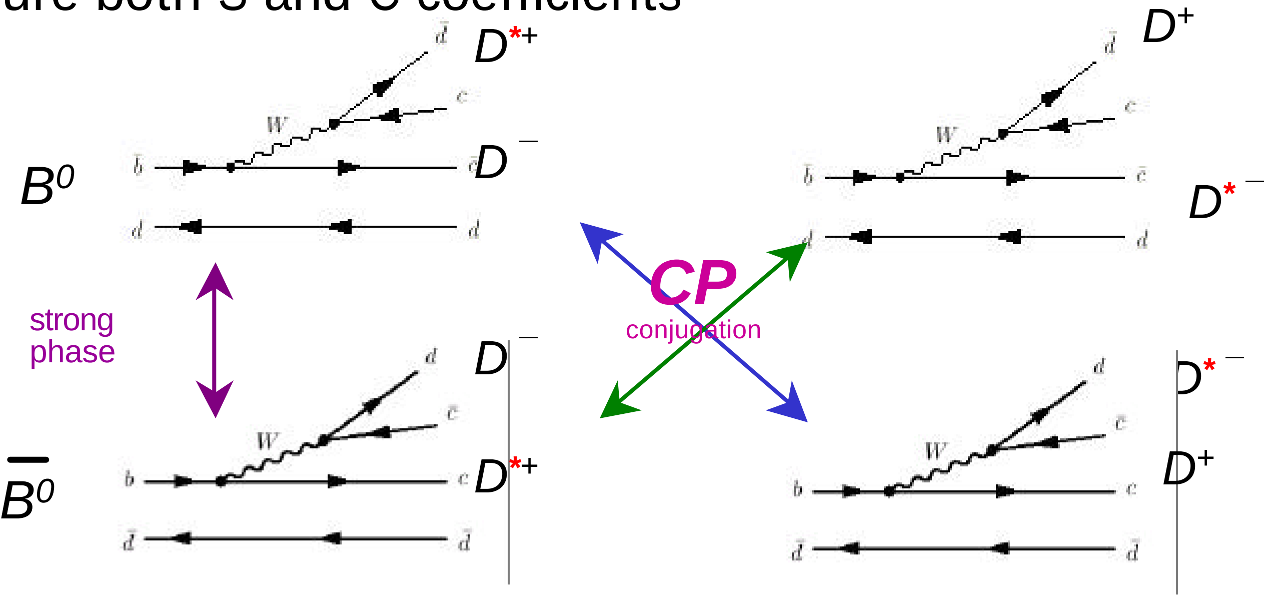
(b → c$\bar{c}$d) mode $B^0 \to D^{*+}D^-$

- *D*D* not CP eigenstate → added complication
  - B→ρπ is similar (α)
- Strong phase contribution (and still have penguins)
- Different (but related) decay time distributions

$$A(B\to D^{*+}D^-) = C_{+,-}\cos(\Delta m\Delta t) \pm S_{+,-}\sin(\Delta m\Delta t)$$

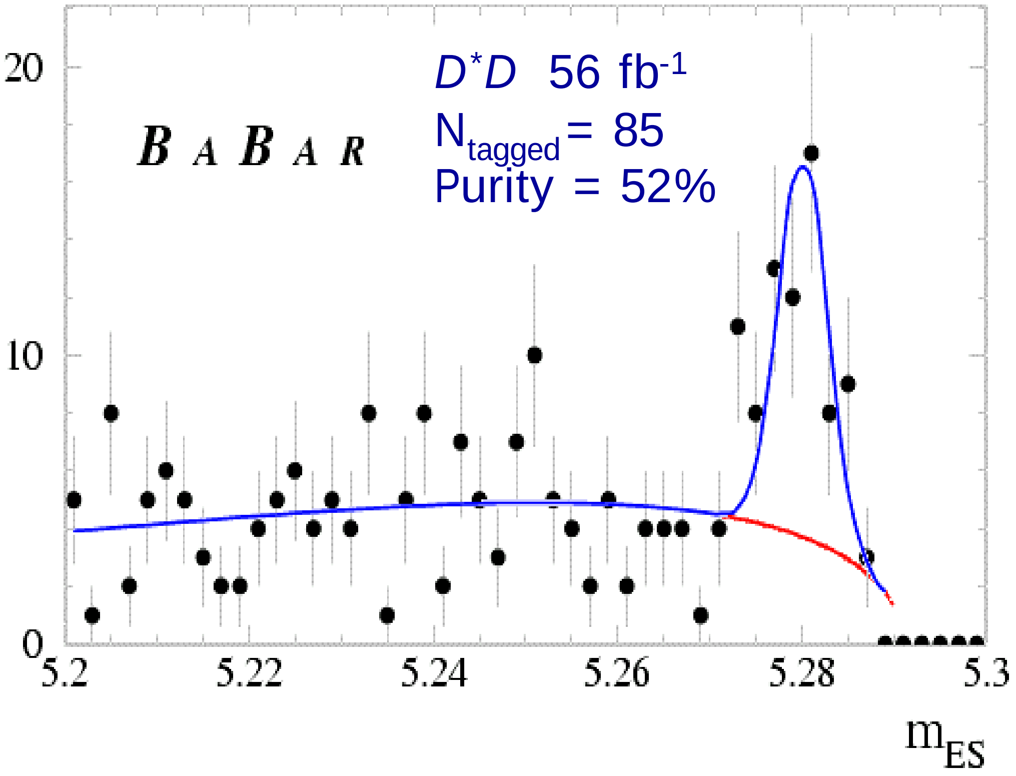
$$A(B\to D^{*-}D^+) = C_{-,+}\cos(\Delta m\Delta t) \pm S_{-,+}\sin(\Delta m\Delta t)$$

- Measure both S and C coefficients



(b → $c\bar{c}d$) mode $B^0 \rightarrow D^{*+}D^-$

56 fb^{-1}

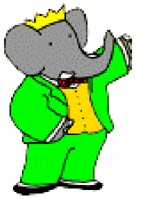


S_{+-} = -0.43 ± 1.41 ± 0.20
C_{+-} = 0.53 ± 0.74 ± 0.13

S_{-+} = 0.38 ± 0.88 ± 0.05
C_{-+} = 0.30 ± 0.50 ± 0.08

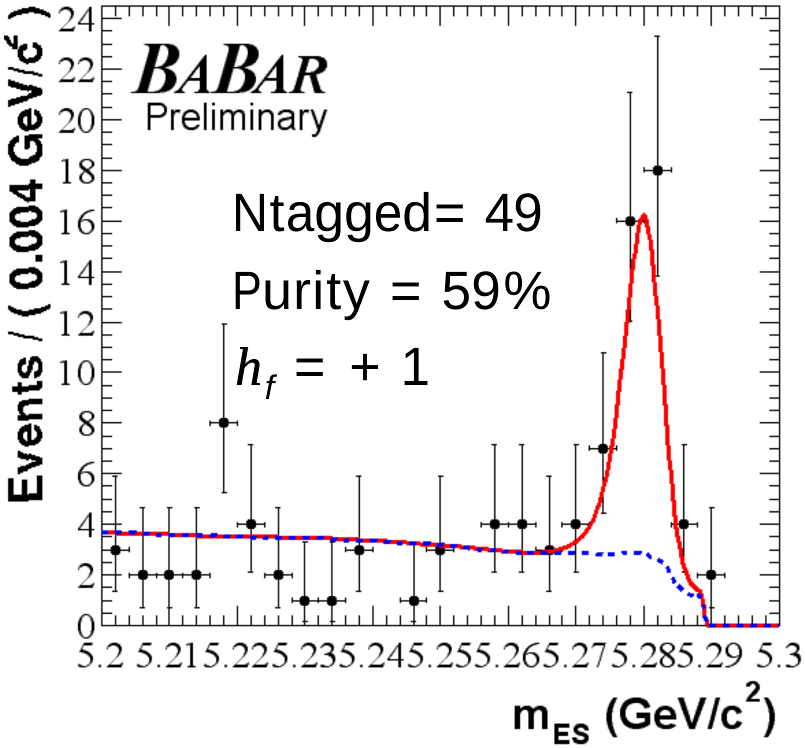
Preliminary

Update to full data set in progress



(b→c$\bar{c}$d) mode $B^0 \rightarrow J/y\ p^0$

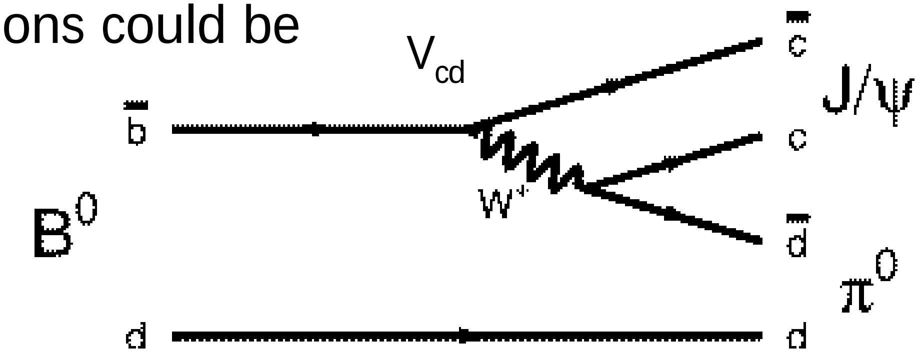
- Cabibbo and color-suppressed mode
  - Tree and penguin contributions could be comparable.



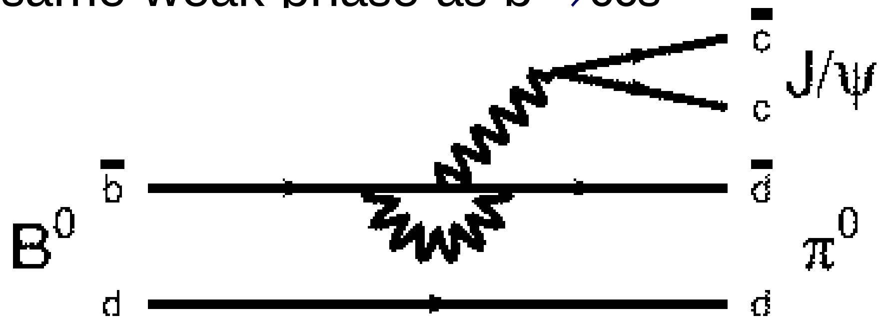
Ntagged= 49

Purity = 59%

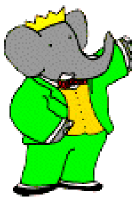
h_f = + 1



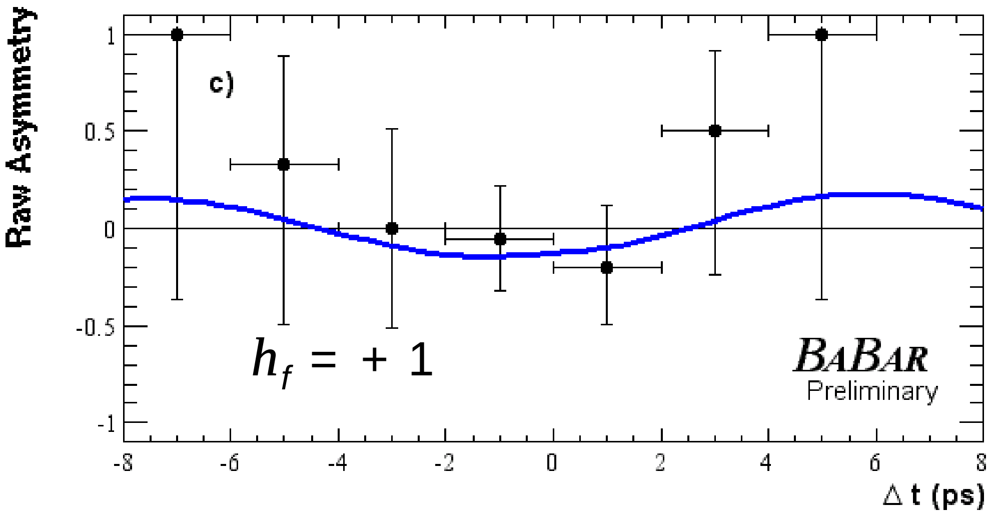
Tree: ~$V_{cb}V_{cd}^*$ ~ O(λ^3)
same weak phase as b→ccs

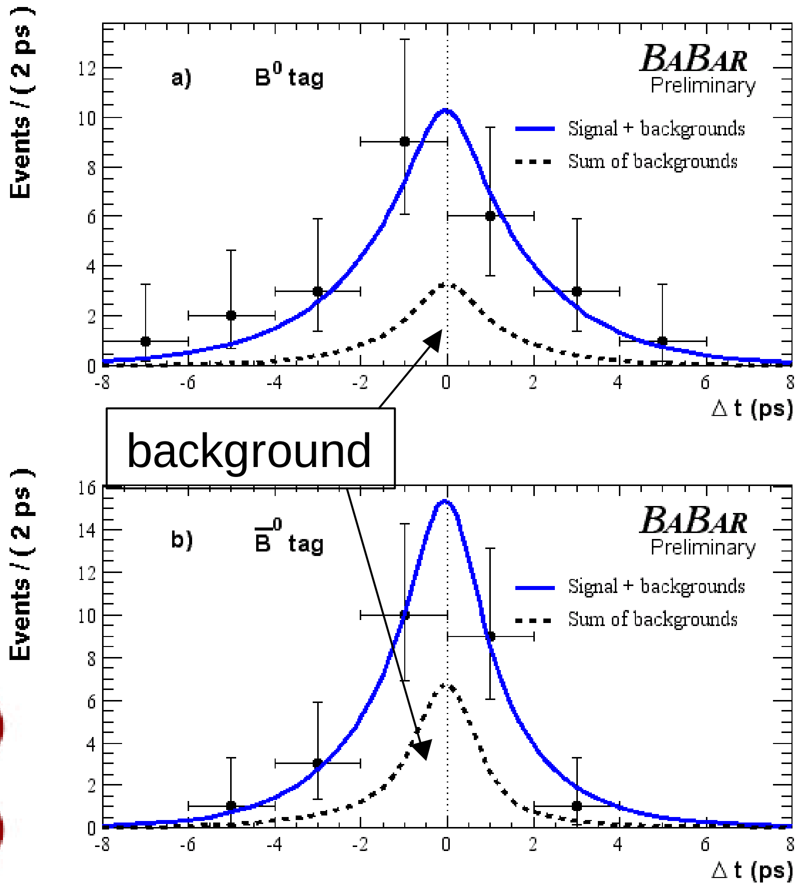


Penguin:~$V_{cb}V_{cd}^*$ + $V_{ub}V_{ud}^*$ ~ O(λ^3)
adds additional weak phase



CP asymmetry fit for $B^0 \to J/y\ p^0$





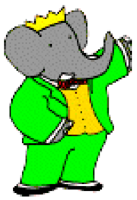
background

Preliminary

$$C_{J/\psi\,\pi^0} = 0.38 \pm 0.41\ (\text{stat}) \pm 0.09\ (\text{syst})$$

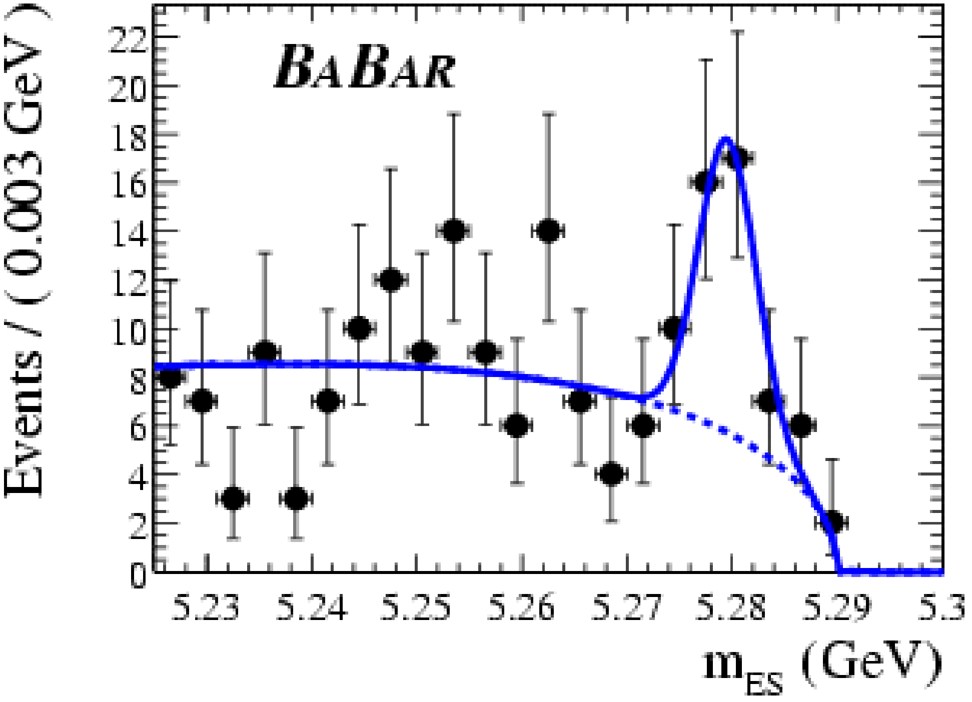
$$S_{J/\psi\,\pi^0} = 0.05 \pm 0.49\ (\text{stat}) \pm 0.16\ (\text{syst})$$

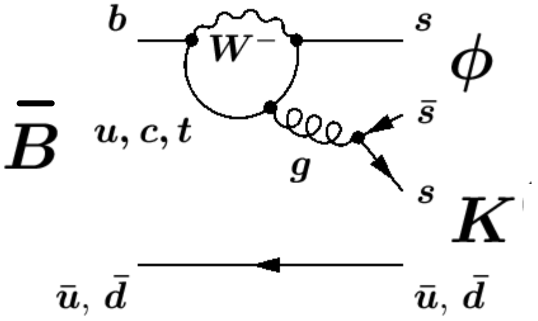
In absence of penguins $C_{yp}=0$, $S_{yp} = -\sin 2b$



sin2*b* from penguin mode $B^0 \rightarrow f\ K_S$

- Charmless decay dominated by (b → $s\bar{s}s$) gluonic penguins
- Weak phase same as b → $c\bar{c}s$. Sensitive to new physics in loops



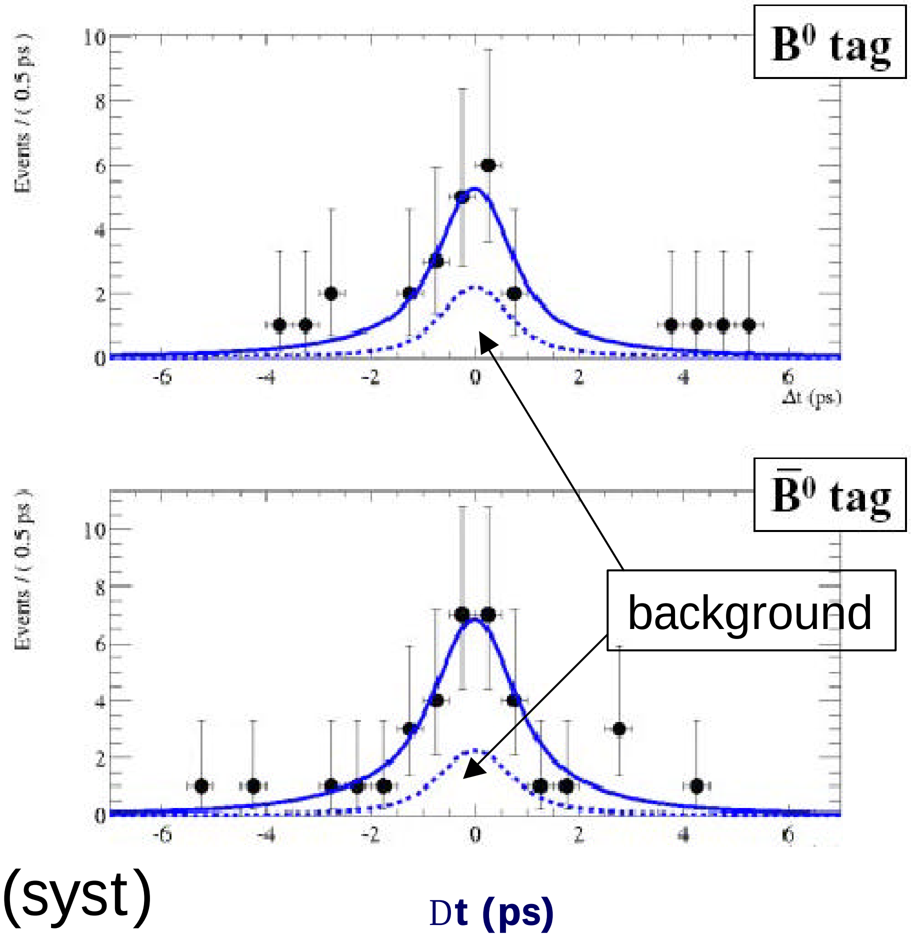


N_{tagged} = 66
Purity = 50%

- Small branching fraction O(10^{-5})
- Significant background from qq continuum
- Using only *f* ® K^+K^-

$$\eta_f = +1$$

CP asymmetry fit for $B^0 \rightarrow f\ K_S$



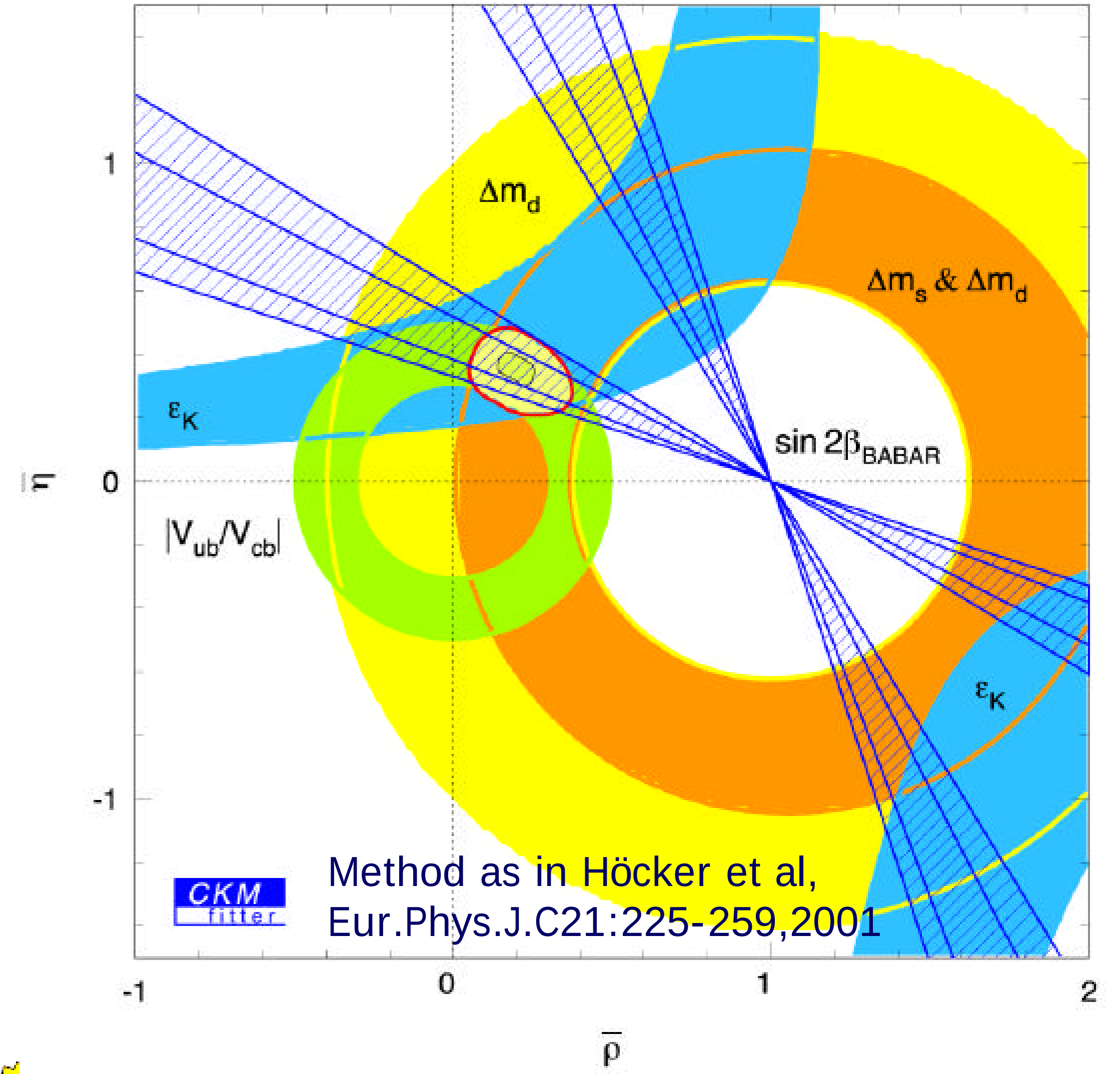
- Low statistics. So:
  - Fix $|l_{fK}| = 1$
  - Fit for S_{fK}

Preliminary

- $S_{fK} = -0.19\ ^{+0.52}_{-0.50}$ (stat) ± 0.09 (syst)

If no new physics, $S_{fK} = \sin 2b$

Standard Model comparison



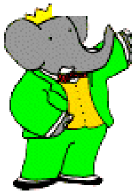
Method as in Höcker et al,
Eur.Phys.J.C21:225-259,2001

One solution for *b* is in excellent agreement with measurements of unitarity triangle apex

$$\overline{r} = r\,(1-\lambda^2/2)$$

$$\overline{h} = h\,(1-\lambda^2/2)$$

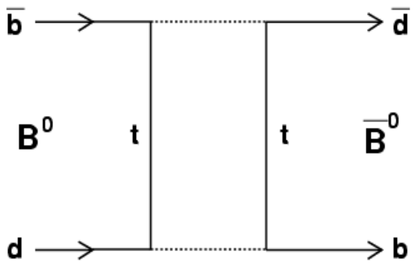
1 CKM angle down...

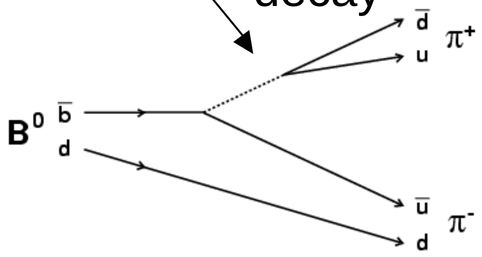


$B \rightarrow pp$ to measure sin2α$_{eff}$

No Penguins (Tree only):

$$l_{pp} = \underbrace{\frac{V_{tb}^{*}V_{td}}{V_{tb}V_{td}^{*}}}_{\text{mixing}}\ \underbrace{\frac{V_{ud}^{*}V_{ub}}{V_{ud}V_{ub}^{*}}}_{\text{decay}}$$



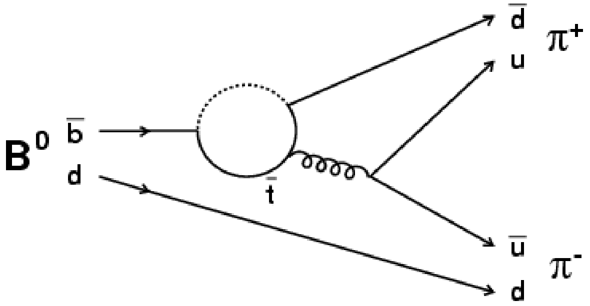


$$l_{pp} = e^{2ia}$$

$$C_{pp} = 0$$

$$S_{pp} = \sin(2a)$$

With Penguins (P):

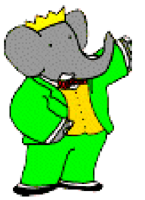


$$l_{pp} = e^{2ia}\,\frac{1+|P/T|e^{id}e^{ig}}{1+|P/T|e^{id}e^{-ig}}$$

$$C_{pp} \propto \sin(d)$$

$$S_{pp} = \sqrt{1-C_{pp}^{2}}\,\sin(2a_{\text{eff}})$$

Need branching fractions for $\pi^+\pi^-$, $\pi^\pm\pi^0$, and $\pi^0\pi^0$ to get α from α$_{eff}$ → isospin analysis



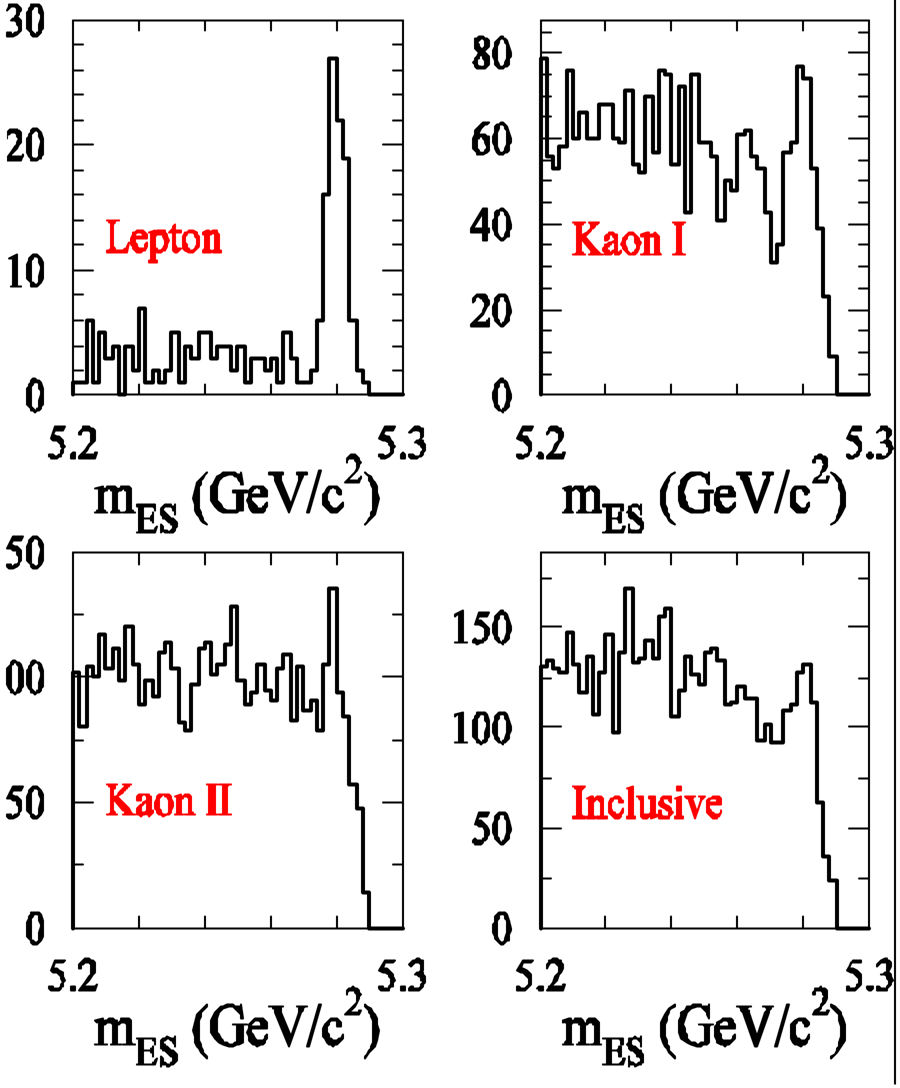
Time dependant analysis for Charmless B Decays

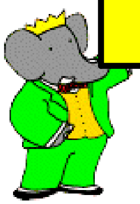
- Analysis methods similar to yK with additional challenges
- For example:
  - The tagging efficiency is very different for signal and bkg
  - Strong bkg suppression in categories with the lowest mistag prob (Lepton/Kaon)

Tagging Efficiencies (%)

Category	Signal	$\pi\pi$ background
Lepton	9.1	0.5
Kaon I	16.6	8.9
Kaon II	19.8	15.5
Inclusive	20.1	21.5
Untagged	34.4	53.6

81/fb B→ h^+h^- sample split by tagging category





Validation of Tagging, Vertexing, and ML Fit

- Kπ decays are self-tagging
  - T = tag charge
  - Q = kaon charge

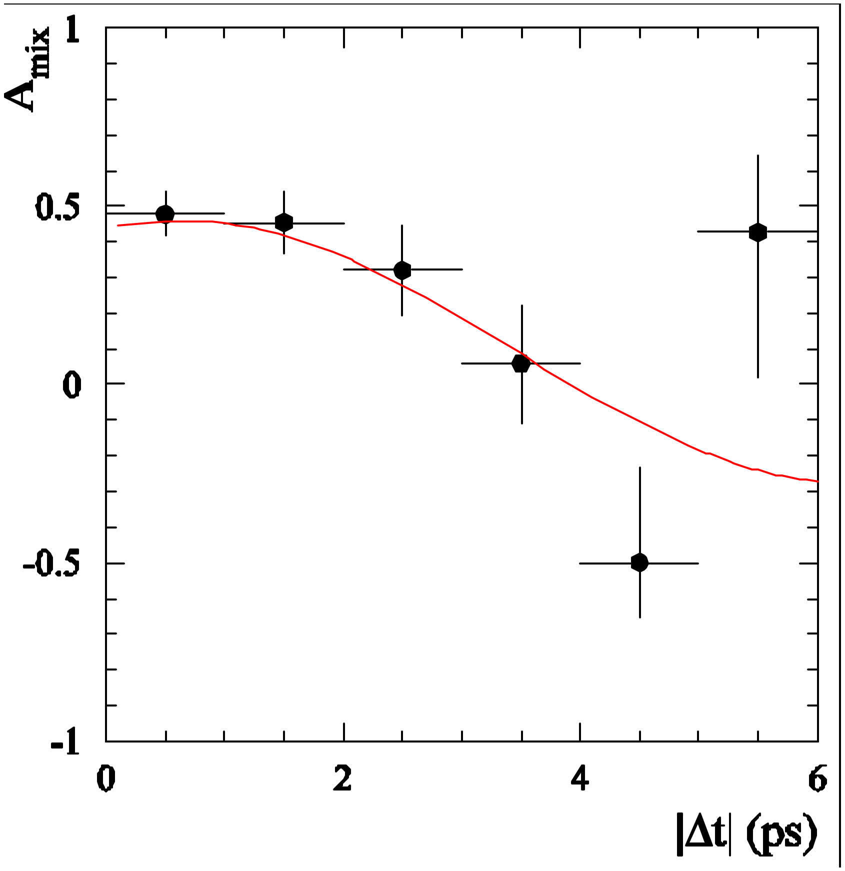
$$f_{T,Q}^{Kp}(\Delta t) \approx \frac{e^{-|\Delta t|/t}}{4t}\left[1 - TQ(1-2w)\cos(\Delta m_d \Delta t)\right]$$

- Float τ and Δm_d in same sample used to extract CP asymmetries:

$$t = (1.56 \pm 0.07)\,\mathrm{ps}$$

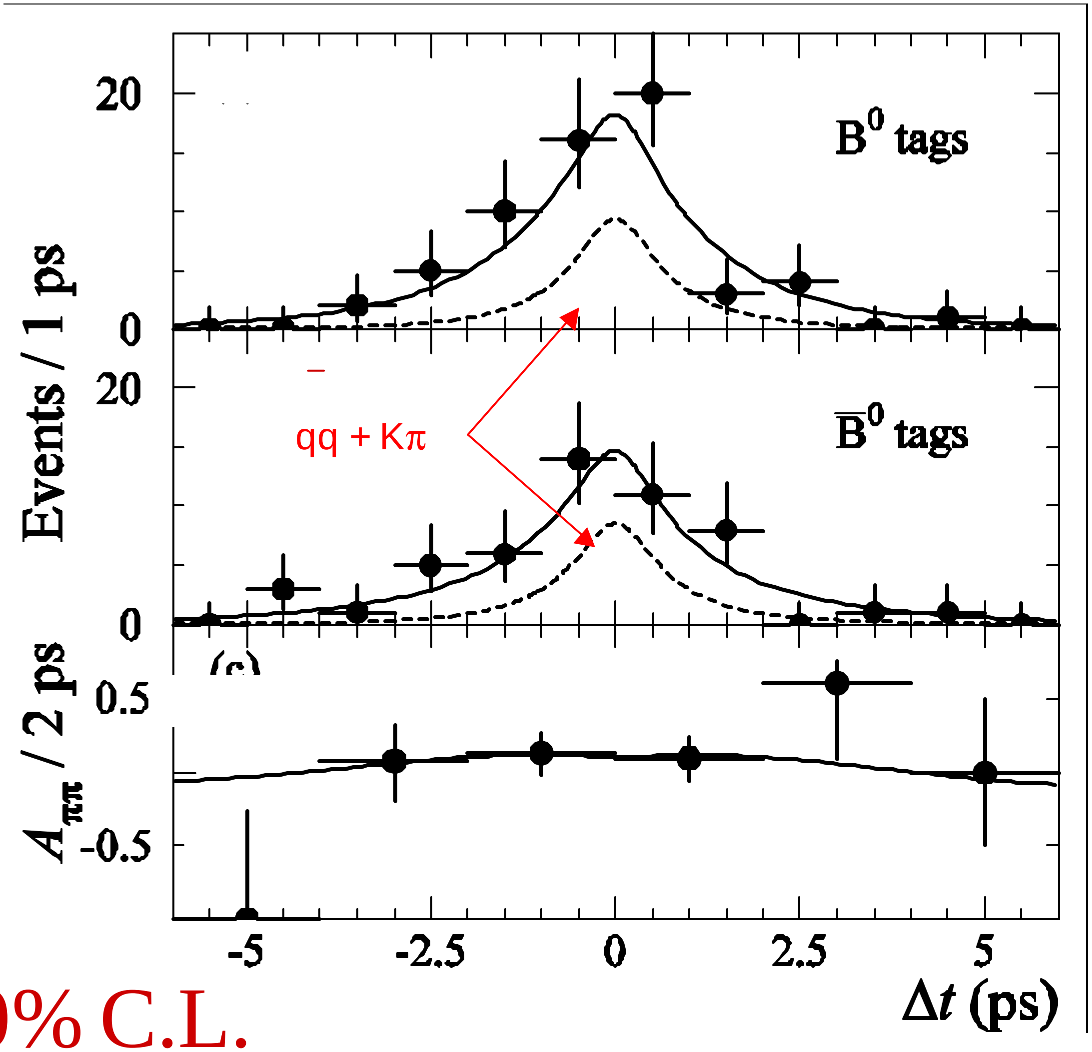
$$\Delta m_d = (0.52 \pm 0.05)\,\mathrm{ps}^{-1}$$

Fit projection in sample of Kp-selected events



$B \rightarrow pp$ CP Asymmetry Results

Fit projection in sample of pp-selected events



Preliminary

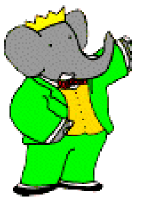
$$S_{pp} = 0.02 \pm 0.34 \pm 0.05$$
$$C_{pp} = -0.30 \pm 0.25 \pm 0.04$$

Submitted to Phys Rev (hep-ex/0207055)

Using Grossman/Quinn bound (isospin only), combine with $B \rightarrow \pi^+\pi^0$ and BABAR upper limit on $B \rightarrow p^0 p^0$:

$$|a_{\text{eff}} - a| < 51^\circ \ @ 90\% \ \text{C.L.}$$

See P. Bloom talk for $B\text{->}p^0p^0$

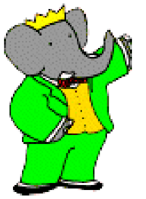


CP-Violating Asymmetries in $B^0 \rightarrow r^+p^-, r^+K^-$

R. Aleksan et al., Nucl. Phys. B361, 141 (1991)

A. Snyder and H. Quinn, Phys Rev D48 2139 (1993)

- Opportunity and challenges
  - In principle, can measure α directly, even with penguins
  - Much more difficult than $\pi^+\pi^-$
    - Three-body topology with neutral pion (combinatorics, lower efficiency)
    - Significant fraction of misreconstructed signal events and backgrounds from other B decays
    - Need much larger sample than currently available to extract α cleanly
- We perform a “quasi-two-body” analysis:
  - Select the ρ-dominated region of the $\pi^+\pi^-\pi^0/K^+\pi^-\pi^0$ Dalitz plane
  - Use multivariate techniques to suppress qq backgrounds
  - Simultaneous fit for $\rho^+\pi^-$ and ρ^+K^-



Yields and Charge Asymmetries

$$N_{rp} = 413^{+34}_{-33}$$

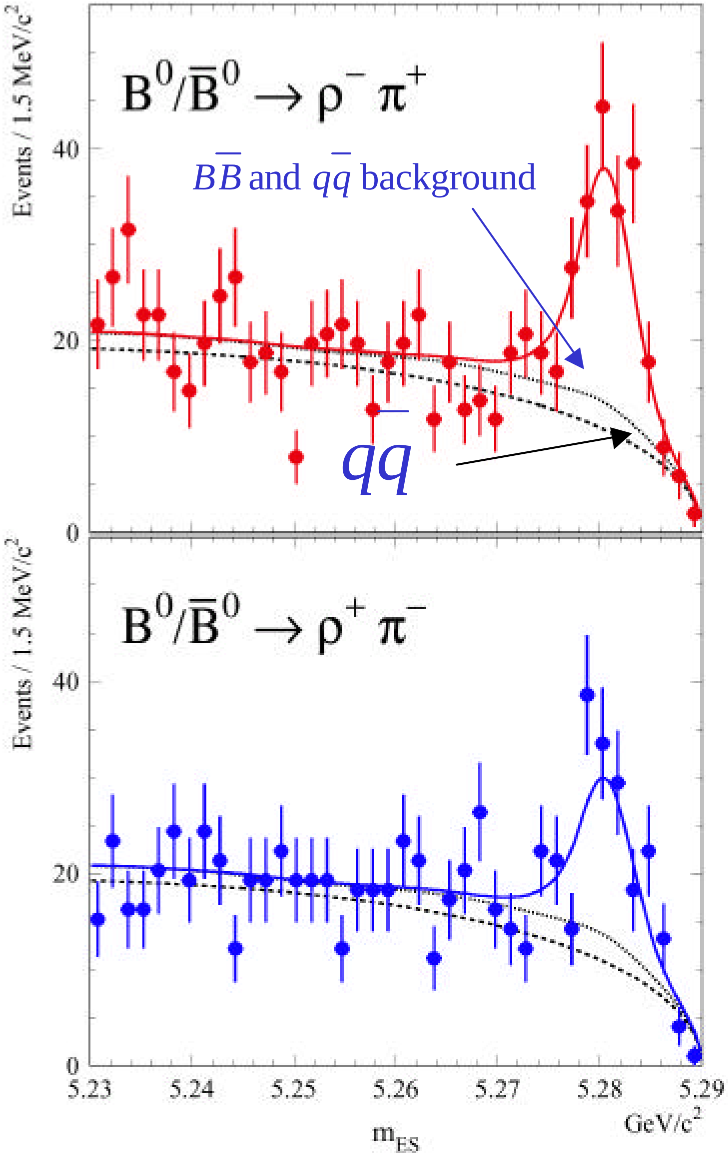
$$N_{rK} = 147^{+22}_{-21}$$

hep-ex/0207068

$$A_{CP}^{rp} = -0.22^{+0.08}_{-0.08}(\textit{stat}) \pm 0.07(\textit{syst})$$

$$A_{CP}^{rK} = 0.19^{+0.14}_{-0.14}(\textit{stat}) \pm 0.11(\textit{syst})$$

Preliminary



$B^0 \rightarrow \rho\pi$ time-dependent asymmetry

Observables similar to D*D:

$$S = \frac{S_{+,-} + S_{-,+}}{2}$$

$$\Delta S = \frac{S_{+,-} - S_{-,+}}{2}$$

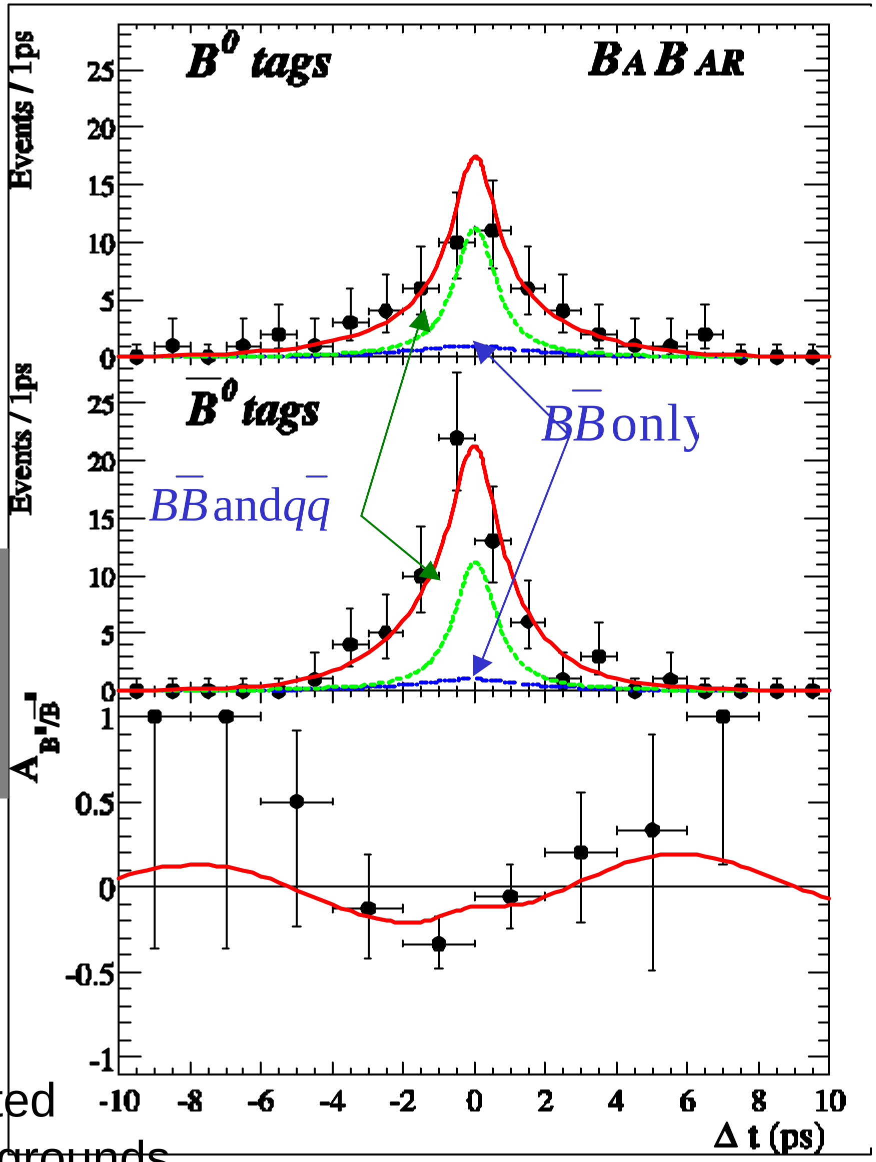
hep-ex/0207068

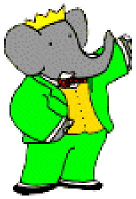
$$C_{\rho\pi} = 0.45^{+0.18}_{-0.19}(\mathbf{stat}) \pm 0.09(\mathbf{syst})$$

$$S_{\rho\pi} = 0.16^{+0.25}_{-0.25}(\mathbf{stat}) \pm 0.07(\mathbf{syst})$$

$$\Delta C_{\rho\pi} = 0.38^{+0.19}_{-0.20}(\mathbf{stat}) \pm 0.11(\mathbf{syst})$$

$$\Delta S_{\rho\pi} = 0.15^{+0.25}_{-0.25}(\mathbf{stat}) \pm 0.05(\mathbf{syst})$$





Preliminary

Systematic error dominated by uncertainty on B backgrounds

Conclusion and outlook

- Searching for CP violating effects in time independent and time dependent studies of *B* meson decays.
- Growing # of direct CP violation searches
- sin2β from *b*→*ccs* (c̄harmonium): (88M BB)

sin2*b* = 0.741 ± 0.067 (stat) ± 0.033 (syst)

- Sin2α_{eff} from *B*→*pp* :(88M BB)

$$S_{pp} = 0.02 \pm 0.34 \pm 0.05$$

$$C_{pp} = -0.30 \pm 0.25 \pm 0.04$$

- Much more than *J/y* K *and pp*:
  - *B*→*D*D**
  - *B*→ *fK*
  - *B*→*J/y p*
  - *B*→*rp*

More data required to turn these into “precision” measurements.

- Just completed long 20 month run.
- Machine and detector upgrades underway for improved luminosity performance.