New results on sin2β with charmonium and penguin modes

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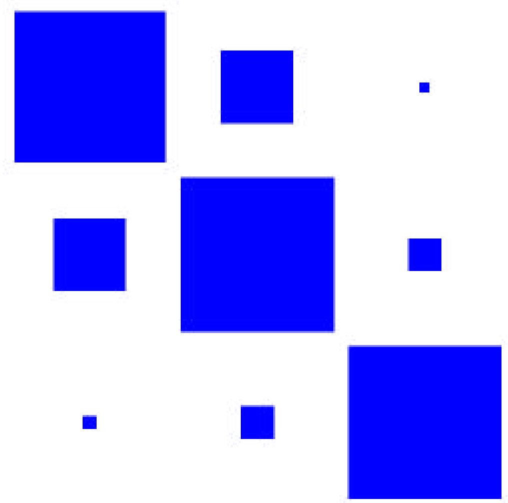
Representing the BABAR Collaboration

CP Violation in Standard Model from non-zero phase in CKM matrix

- Coupling for $Q \rightarrow W^+ q$ is $\sim V^*_{Qq}$

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



Three generations:

4 fundamental parameters

1 phase

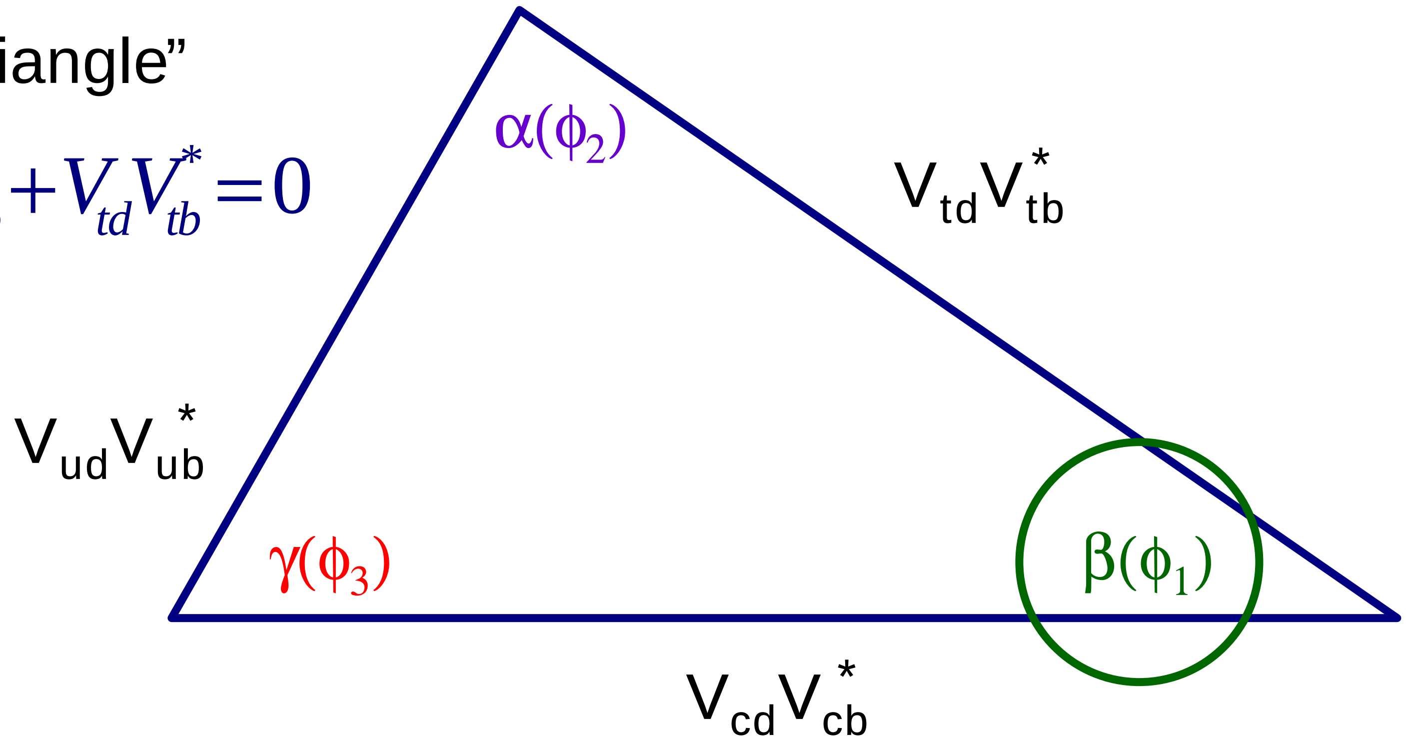
Test unitarity of matrix with B decays. Does

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

Overconstrain angles and sides of Unitarity Triangle to test the Standard Model

"Unitarity Triangle"

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

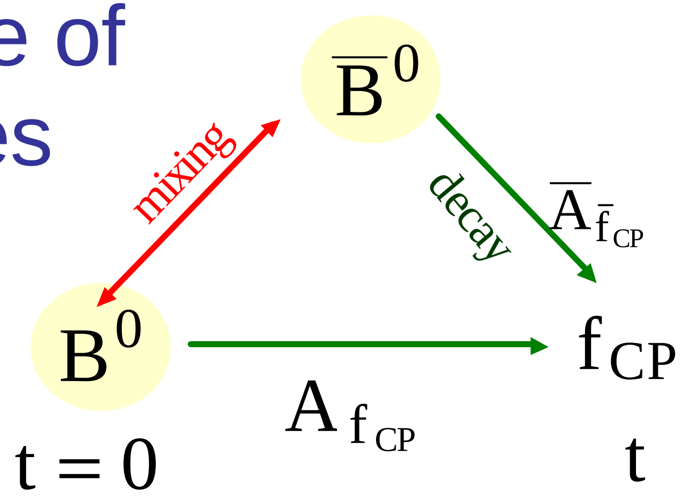


Measure β with "golden" modes $B \rightarrow J/\psi K^0$

CPV in B→J/ψK^0: Interference of decay and mixing amplitudes

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

Amplitude ratio



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

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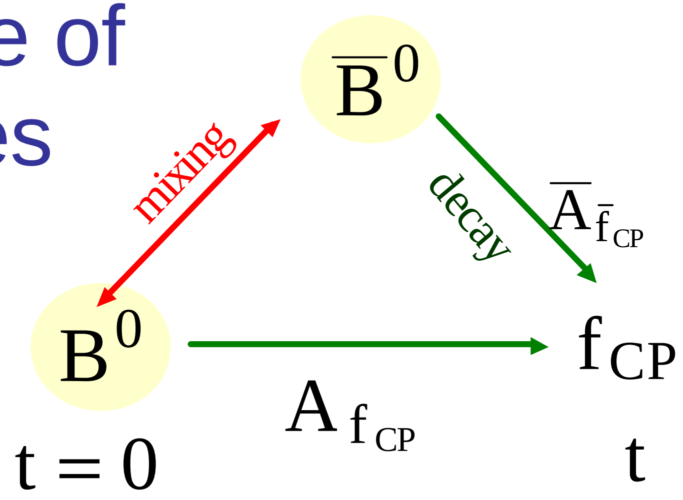
← Amplitude ratio



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

$$A_{f_{CP}}(t) = \frac{\Gamma(\bar{B}^0_{phys}(t) \to f_{CP}) - \Gamma(B^0_{phys}(t) \to f_{CP})}{\Gamma(\bar{B}^0_{phys}(t) \to f_{CP}) + \Gamma(B^0_{phys}(t) \to f_{CP})}$$
$$= C_{f_{CP}} \cdot \cos(\Delta m_{B_d} t) + S_{f_{CP}} \cdot \sin(\Delta m_{B_d} t)$$

($\Delta\Gamma$=0)

$$C_{f_{CP}} = \frac{1 - |\lambda_{f_{CP}}|^2}{1 + |\lambda_{f_{CP}}|^2}$$

$$S_{f_{CP}} = \frac{2\,\mathrm{Im}\lambda_{f_{CP}}}{1 + |\lambda_{f_{CP}}|^2}$$

C=0 and *S*=+/- sin2β for *B*→*J/y* K_S and *B*→*J/y* K_L

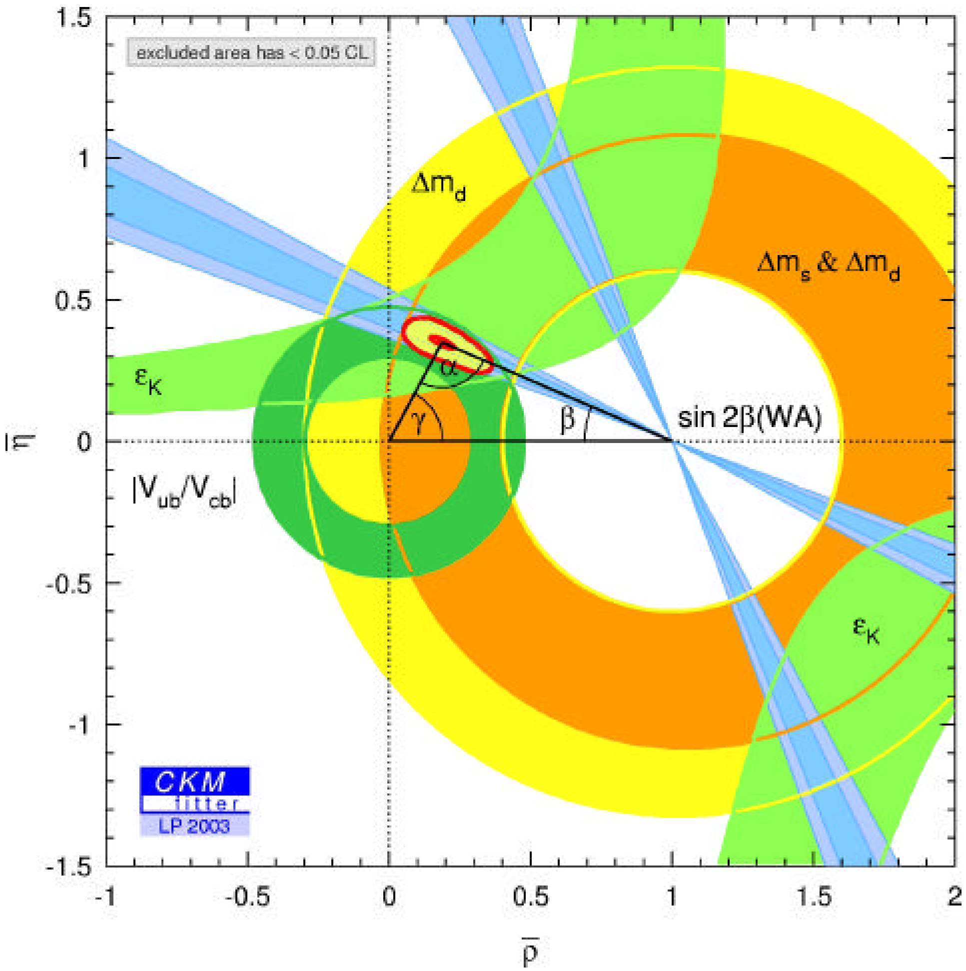
Notation translation

Belle	BABAR
ϕ_1	β
A	$-C$

2002: BABAR and Belle experiments conclusively observe that sin2β is not 0

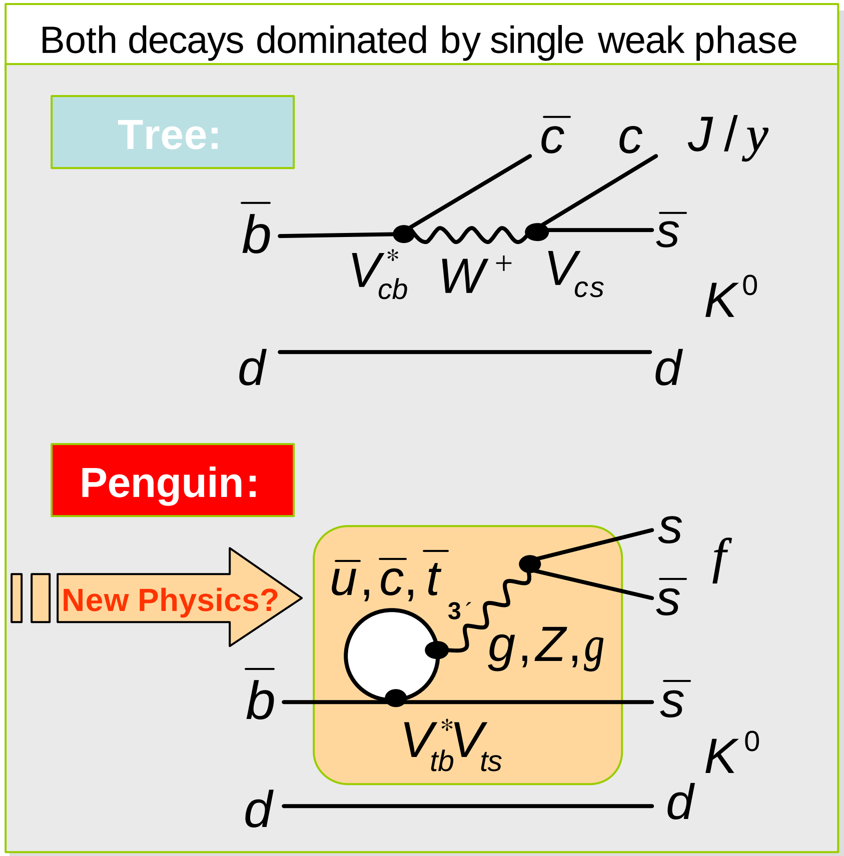
- World average:

  0.731+/-0.056
- “Perfect” agreement between constraints of apex of the Unitarity Triangle.



Penguin modes also measure sin2β

- b→s$\bar{s}$s decays also measure sin2β in the SM
  - Small Standard Model amplitude → Sensitive to new physics at high mass scales



$b \to c\bar{c}s$

$$l_{J/y K^0_{S,L}} = h_{J/y K^0_{S,L}} \left(\frac{q}{p}\right)_B \cdot \left(\frac{V_{cb}V^*_{cs}}{V^*_{cb}V_{cs}}\right) \cdot \left(\frac{q}{p}\right)_K = h_{J/y K^0_{S,L}} e^{-2ib}$$

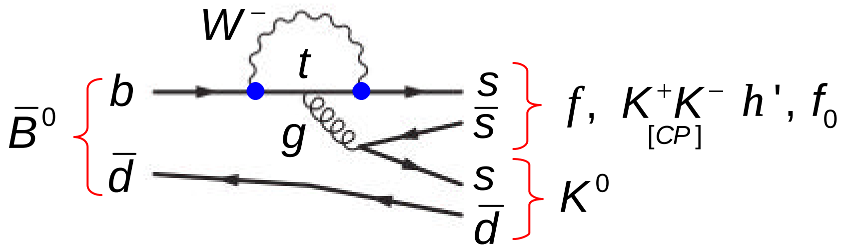
$b \to s\bar{s}s$

$$l_{fK^0_{S,L}} = h_{fK^0_{S,L}} \left(\frac{q}{p}\right)_B \cdot \left(\frac{V_{tb}V^*_{ts}}{V^*_{tb}V_{ts}}\right) \cdot \left(\frac{q}{p}\right)_K \sim h_{fK^0_{S,L}} e^{-2ib}$$

sin2b [charmonium] $\stackrel{?}{=}$ sin2b [s-penguin]

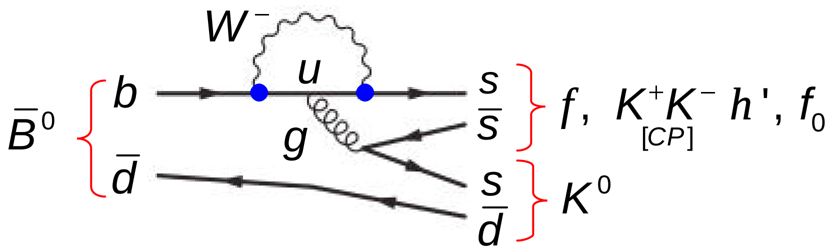
SM expectation: sin2β in some penguin modes agrees at 5% with charmonium

Dominant



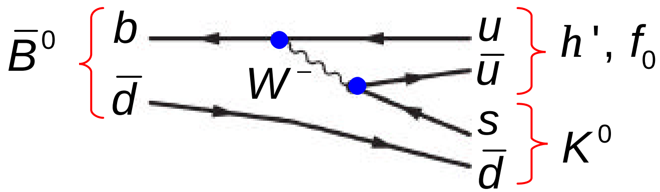
$\propto V_{tb}V_{ts}^{*} \sim l^{2}$

Suppressed



$\propto V_{ub}V_{us}^{*} \sim l^{4}R_u e^{-ig}$

Color-suppressed tree



$\propto V_{ub}V_{us}^{*} \sim l^{4}R_u e^{-ig}$

Modes with suppressed C-S tree diagram have smallest uncertainty: fK_S

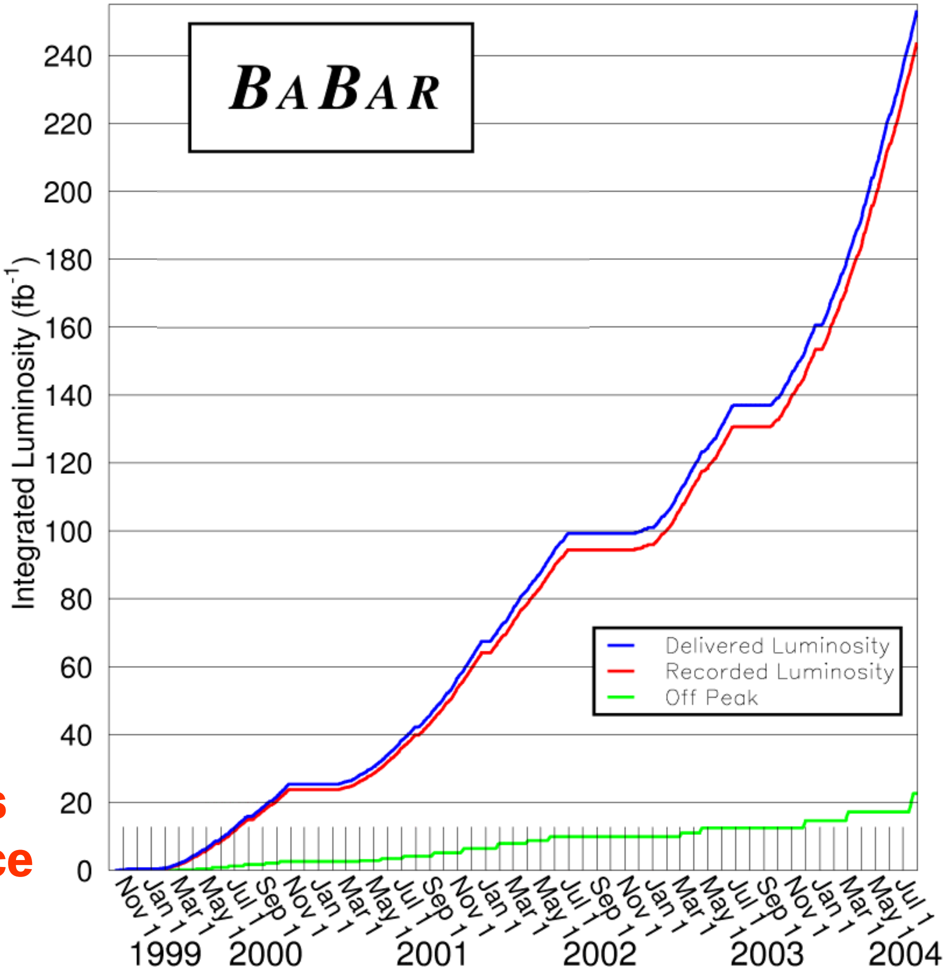
Penguin results from BABAR

Mode	η_{CP}	Branching fraction ($/10^{-6}$)	Naïve SM difference from $\sin 2\beta$ with *[cc]K*
$B \to f K^0$	–1	9	5%
$B \to K^+ K^- K_S$	~+1	27	10%
$B \to h' K_S$	–1	65	10%
$B \to f_0 K_S$	+1	6	10%
$B \to p^0 K_S$	–1	5	20%

Peak Pep-II luminosity >3x design

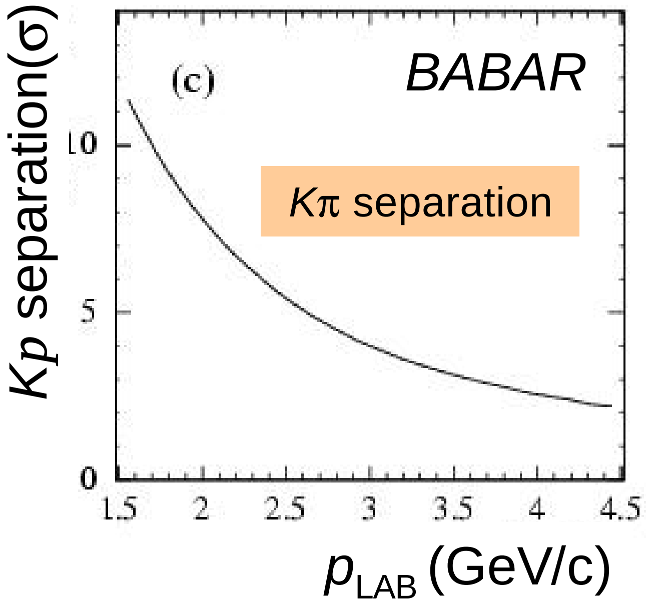
PEP-II Records	
Peak luminosity	0.923×10^{34} $cm^{-2}\ s^{-1}$
Best shift	246.3 pb^{-1}
Best day	710.5 pb^{-1}
Best 7 days	4.464 fb^{-1}
Best month	16.72 fb^{-1}
BABAR logged	246.4 fb^{-1}

~245 million $B\bar{B}$ pairs
+23 fb^{-1} off resonance

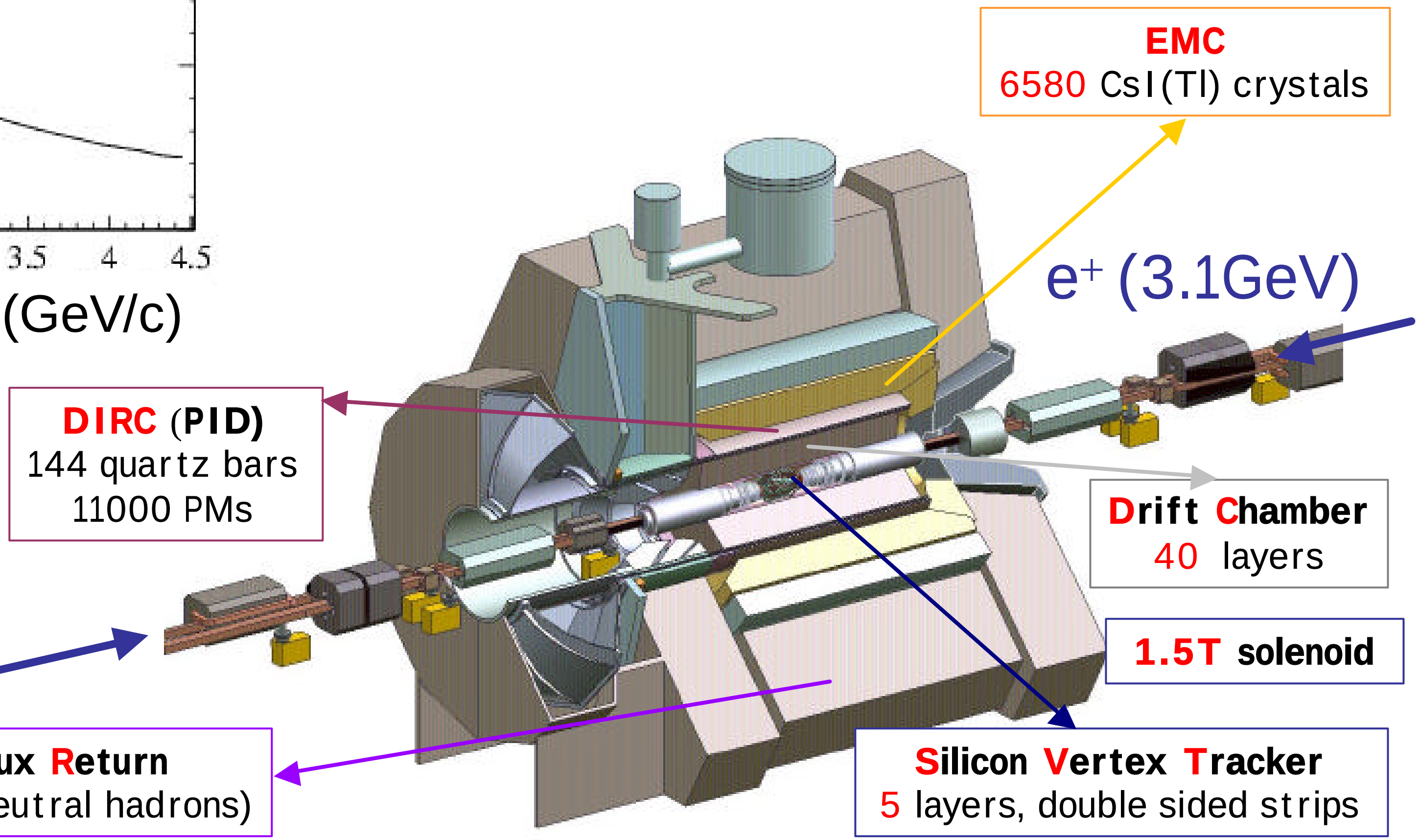


(as of July 31, 2004)

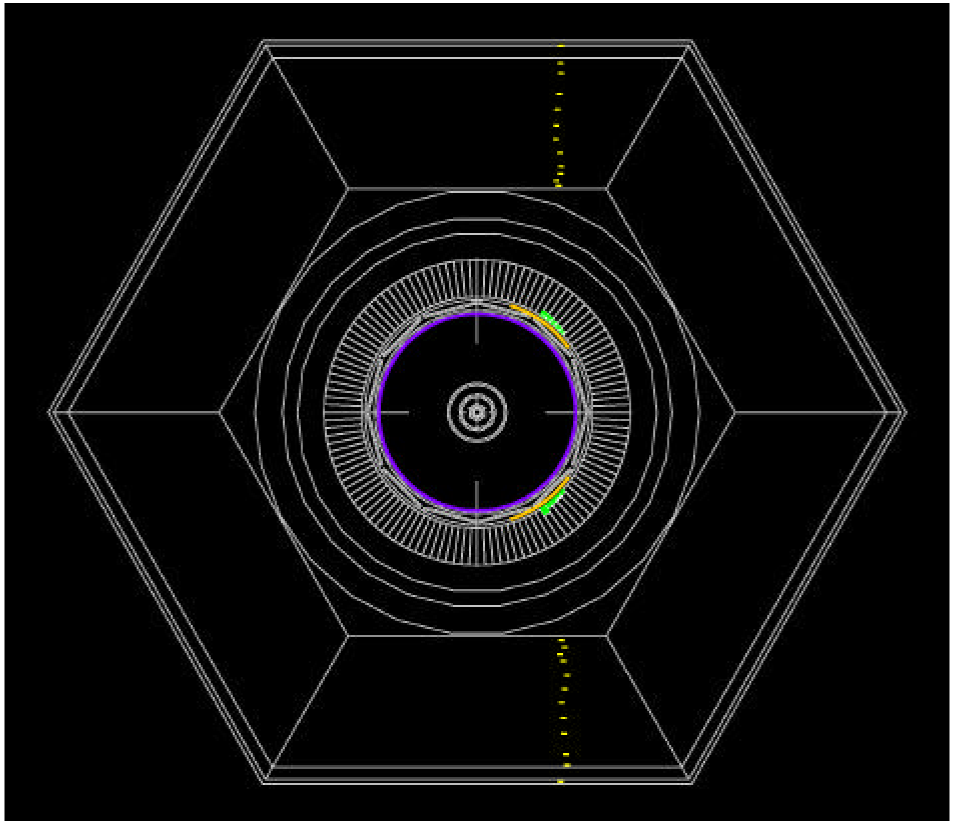
BABAR Detector

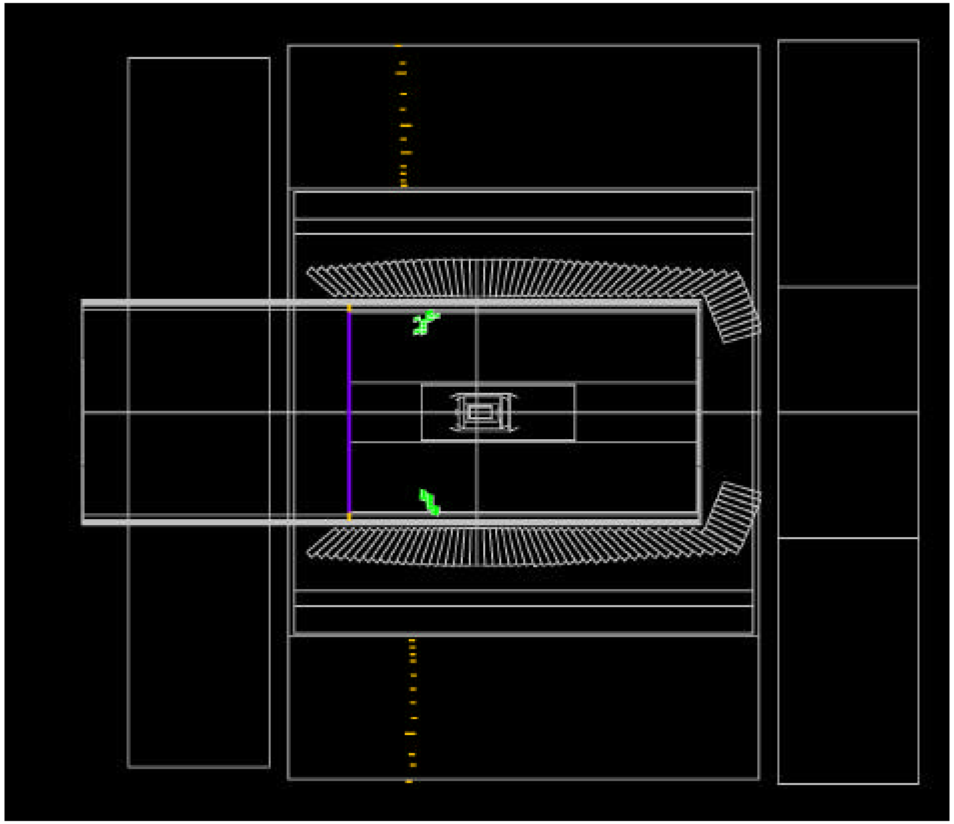


Excellent high momentum particle ID performance crucial for these analyses.



"Run 5" starts October 15 with 1/3 of IFR barrel RPCs replaced with LSTs





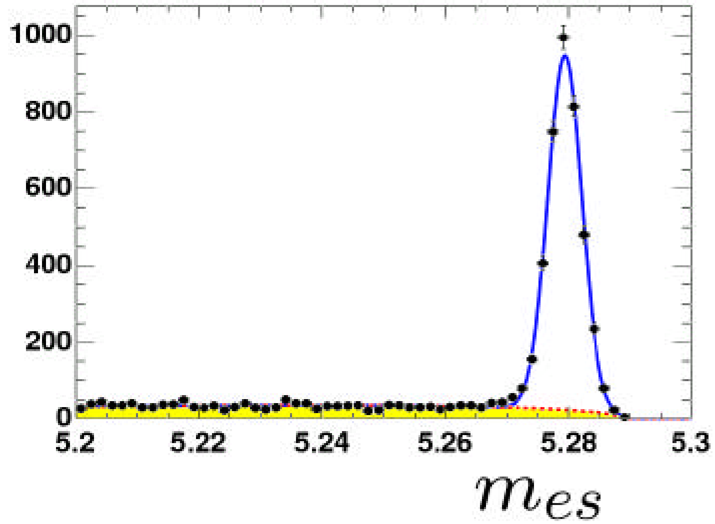
- Goal for 8 month run is 130 fb^{-1} with peak luminosity of $1.5x10^{34}$ achieved by June 2005

Typical B reconstruction variables

Variables for signal/BG discrimination

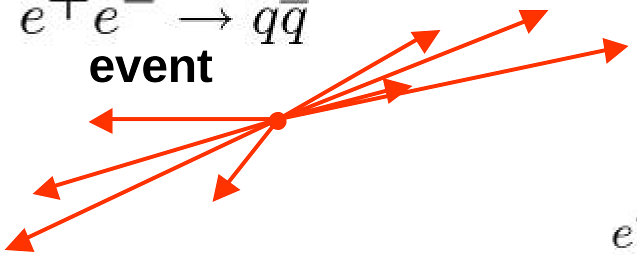
$$m_{es} = \sqrt{E^{*2}_{\text{beam}} - p^{*2}_{B}}$$

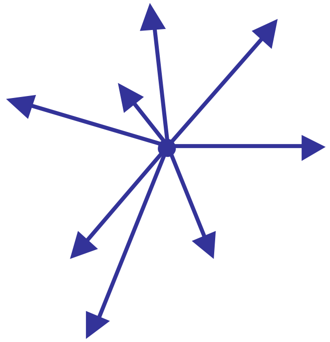
$$\Delta E = E^{*}_{B} - E^{*}_{\text{beam}}$$



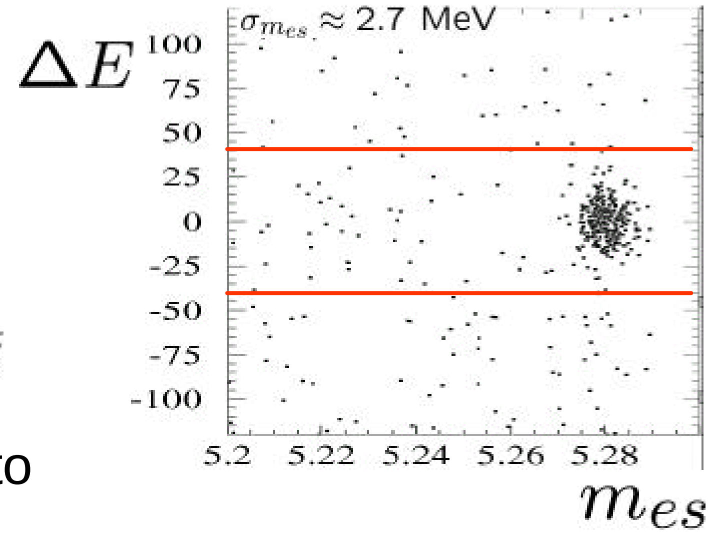
Reject $e^{+}e^{-} \to q\bar{q}$ background with event shape information.

$e^{+}e^{-} \to q\bar{q}$
event





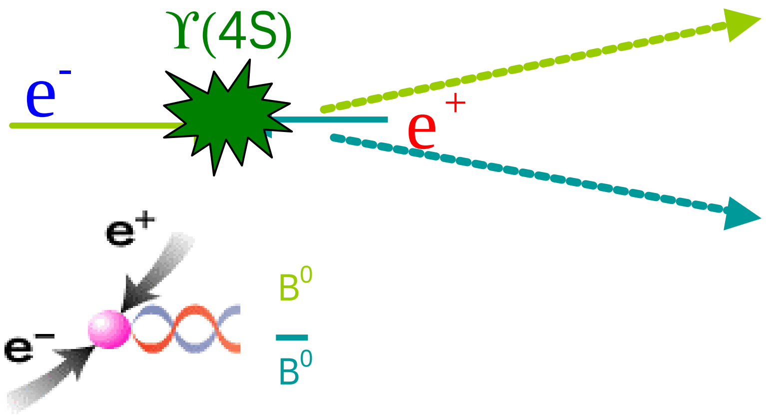
$e^{+}e^{-} \to \Upsilon(4S) \to B\overline{B}$
event



Event shape discriminators usually combined into neural network (NN) or Fisher discriminant

Experimental procedure to measure time-dependant CP Violation parameters

Boost: bg = 0.56



Coherent L=1 state

Experimental procedure to measure time-dependant CP Violation parameters

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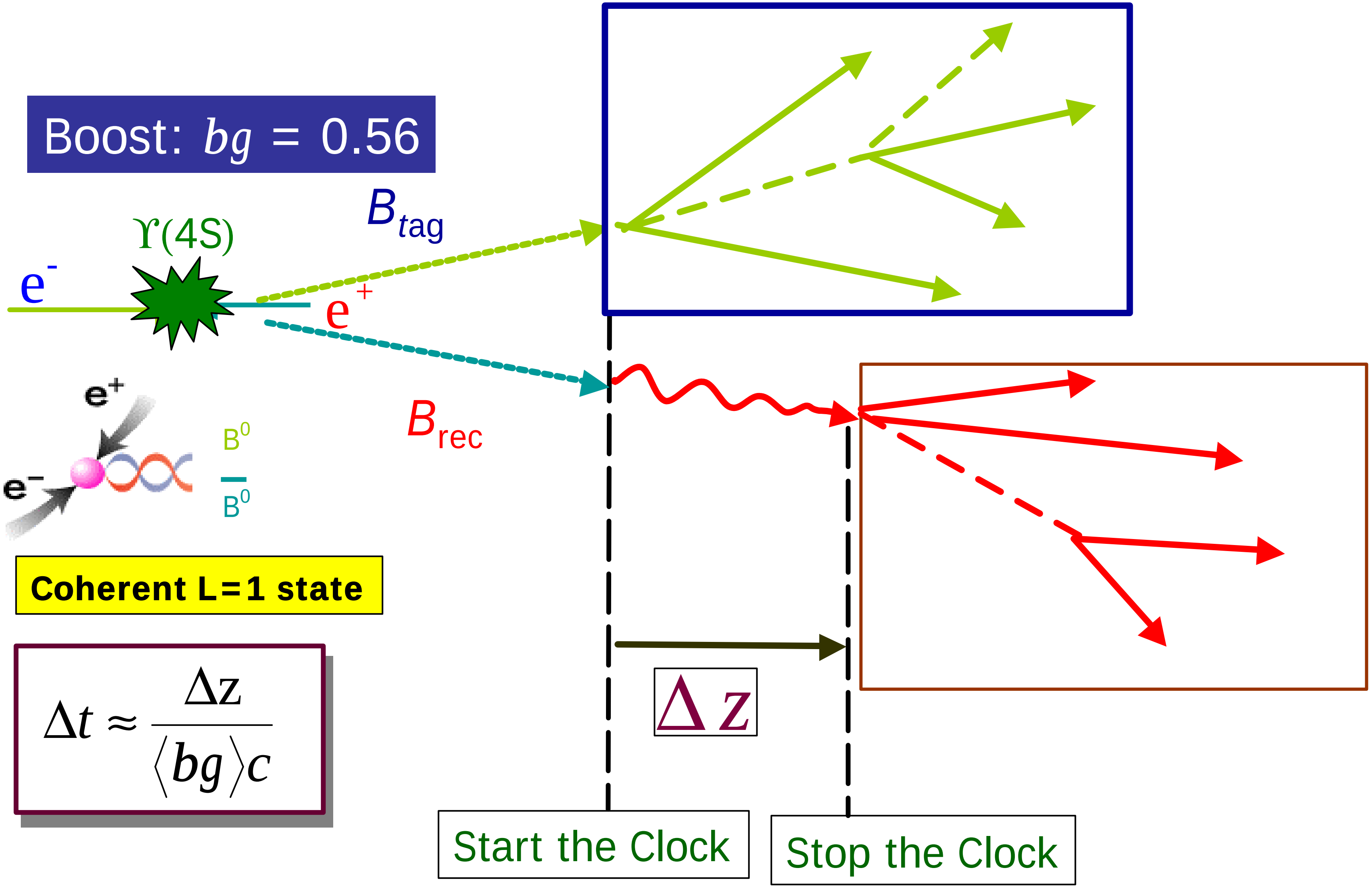
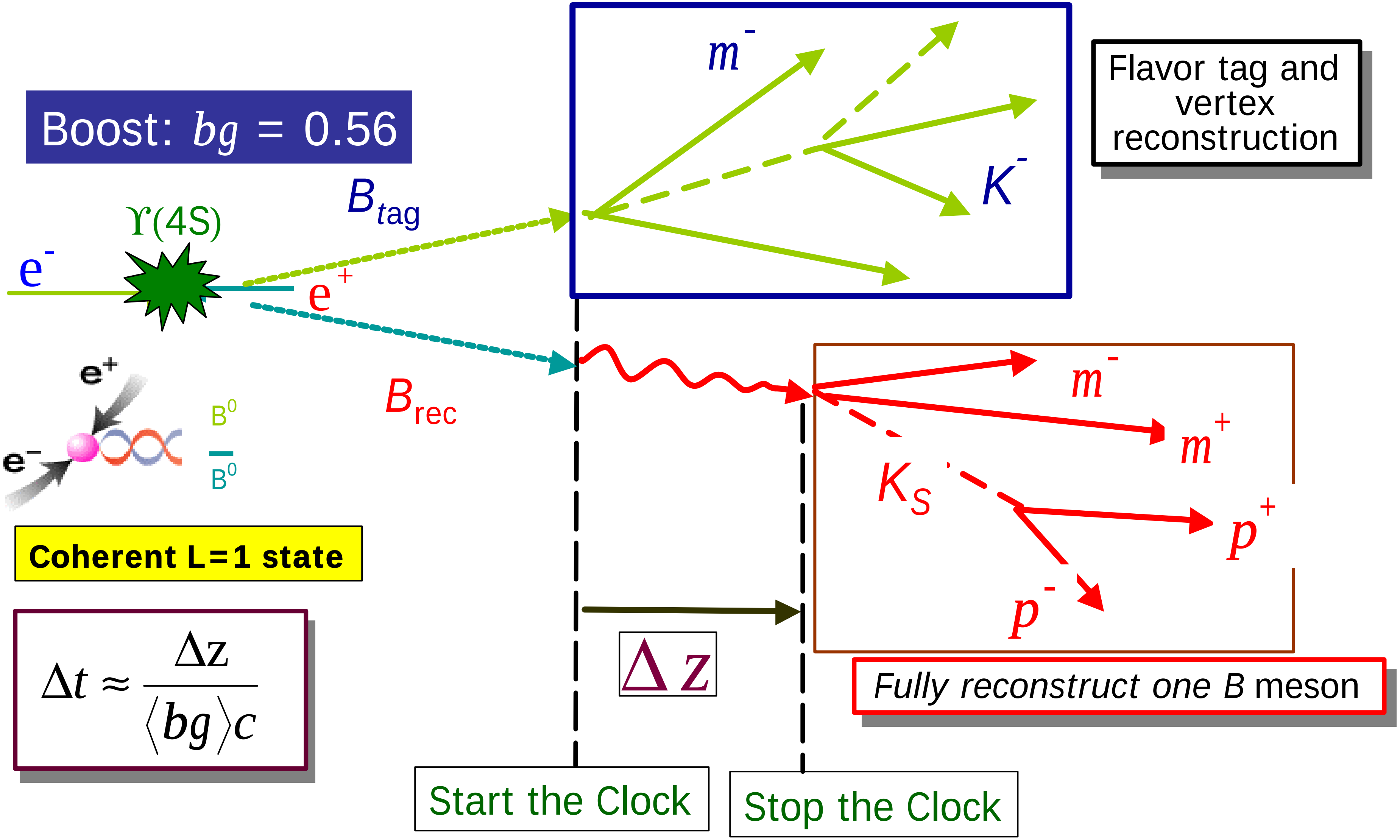


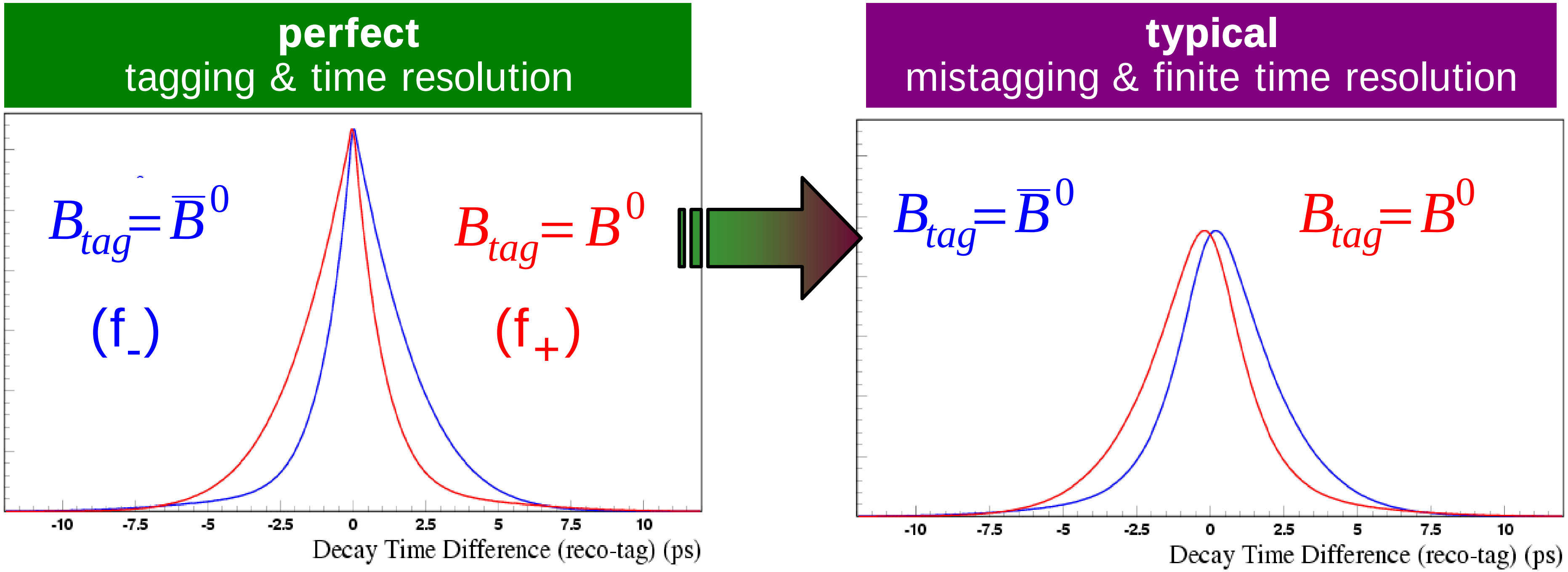
Coherent L=1 state

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

Experimental procedure to measure time-dependant CP Violation parameters

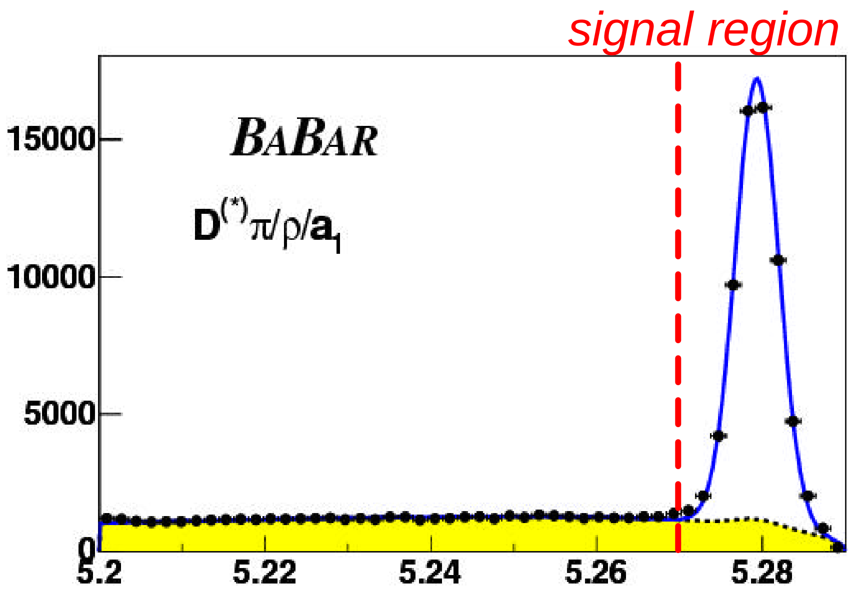


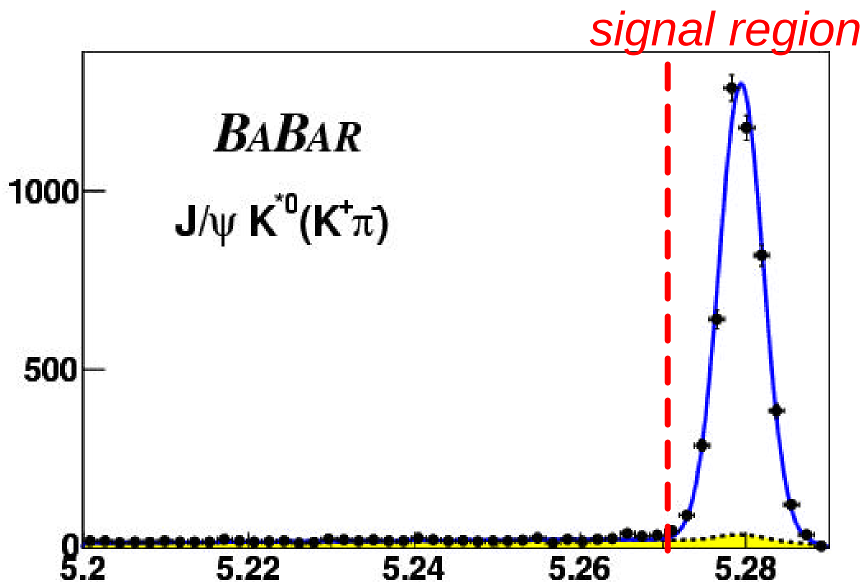
Tagging and Δt resolution parameters are determined from data



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

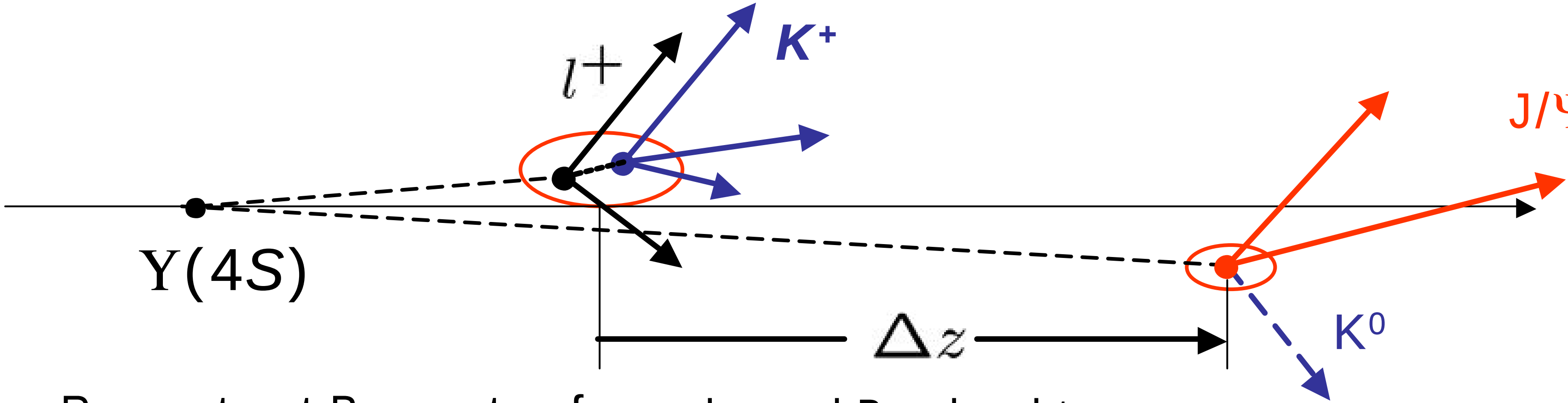
Determine *w* and *R* parameters from more plentiful B^0-$\bar{B}^0$ decays to flavor eigenstates.





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

Boosted center-of-mass plus silicon vertex detector required for Δt determination



- 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)
- High efficiency: 95%
- Average Δz resolution ~ 180 μm (dominated by B_{Tag})

  $<|\Delta z|>$ ~ 260 μm

  B mesons produced just above threshold: <|Dz|> ~ 30 mm if no boost…

B decay properties used to determine if tagging B decayed as a B^0 or $\bar{B}^0$

Measure of tagging performance Q:

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

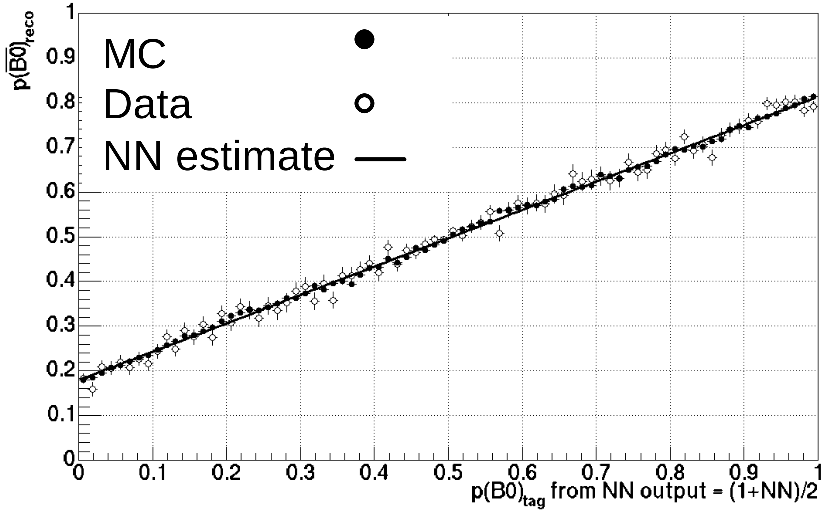
$$\sigma(\sin 2\beta) \propto \frac{1}{\sqrt{Q}}$$

	ε(%)	w(%)	Q(%)
Lepton	8.6+/-0.1	3.2+/-0.4	7.5+/-0.2
KaonI	10.9+/-0.1	4.6+/-0.5	9.0+/-0.2
KaonII	17.1+/-0.1	15.6+/-0.5	8.1+/-0.2
K-π	13.7+/-0.1	23.7+/-0.6	3.8+/-0.2
π	14.5+/-0.1	33.9+/-0.6	1.7+/-0.1
Other	10.0+/-0.1	41.1+/-0.8	0.3+/-0.1
Total	74.9+/-0.2		30.5+/-0.4

5% (relative) improvement in tagging algorithm.

Tagging algorithm improvements

- New tagger based on same idea/framework as previous one.
- "Physics" changes
  - Improved use of correlations between Kaons in event
  - $\Lambda \rightarrow \pi p$ as source of tagging
  - Secondary electrons



- New way to categorize events
  - Category #1: Primary leptons
  - Categories #2-#6: Split remaining events based on estimated mistag rate (from NN).
- Not all analyses use new tagger yet.

sin2β with Charmonium modes

Event sample for "Golden" channels

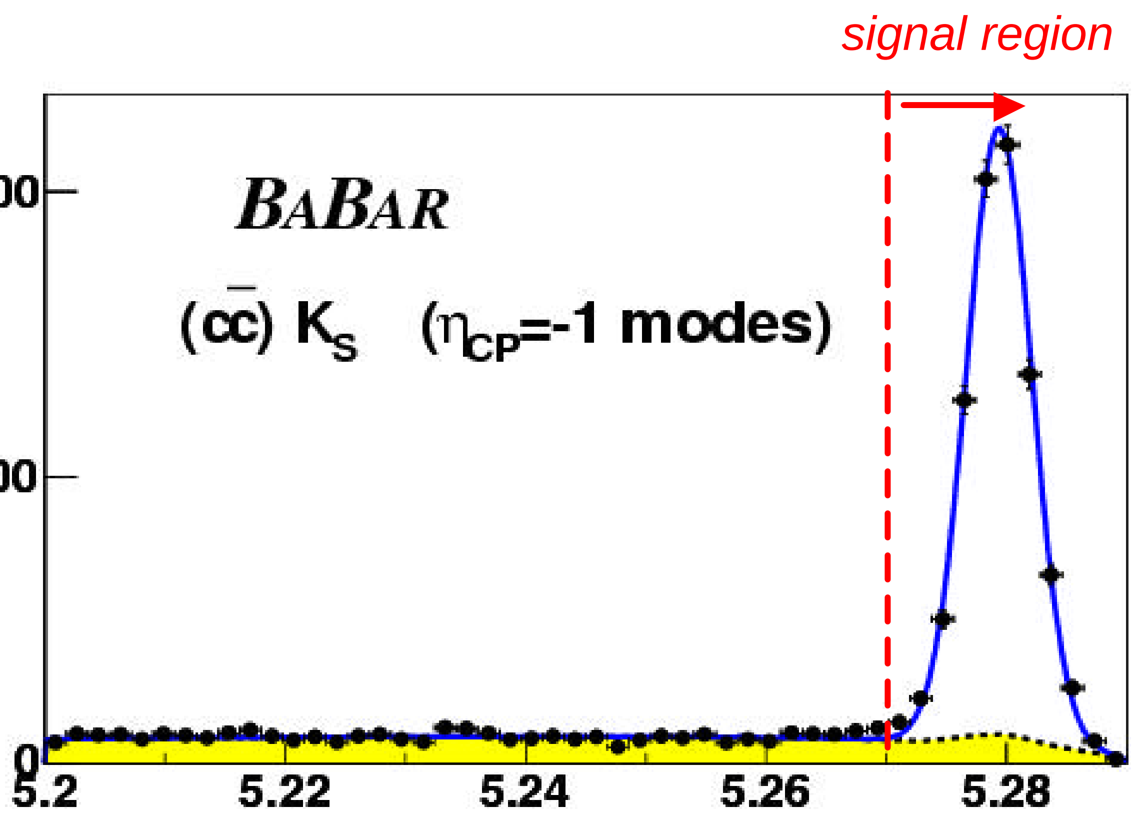
$B^0 \to J/\psi K_S\ (\pi^+\pi^-)$

$B^0 \to J/\psi K_S\ (\pi^0\pi^0)$

$B^0 \to \psi(2S) K_S$

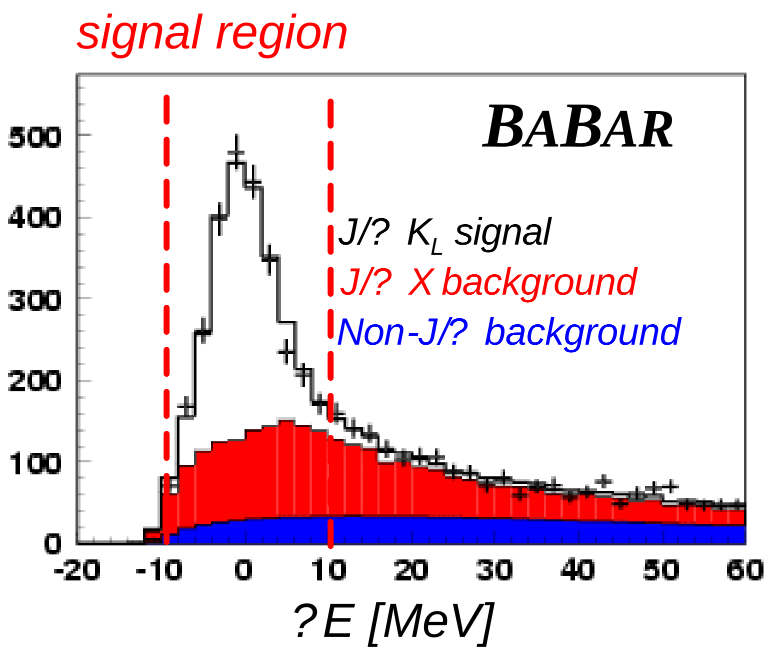
$B^0 \to \chi_{c1} K_S$

$B^0 \to \eta_c K_S$



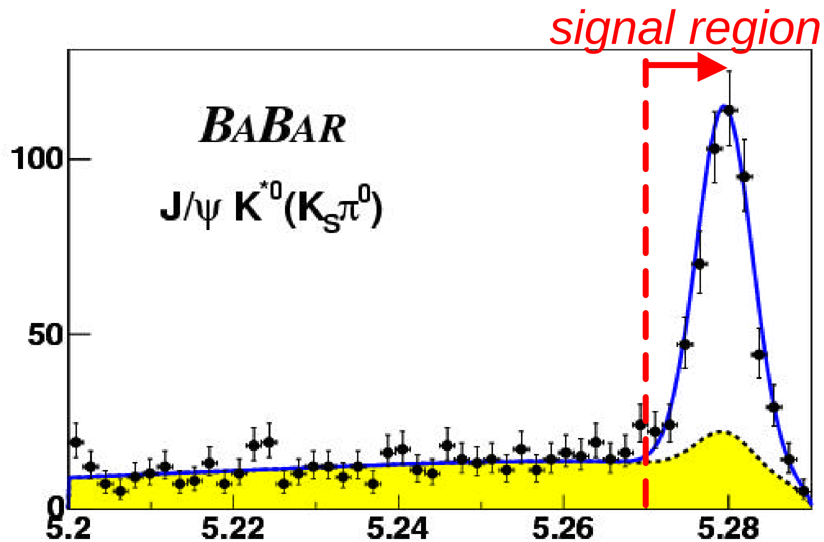
3900 $\eta_{CP} = -1$ tagged signal events

$B \rightarrow J/\psi K_L$ and $B \rightarrow J/\psi K^{*0}(K_S\pi^0)$

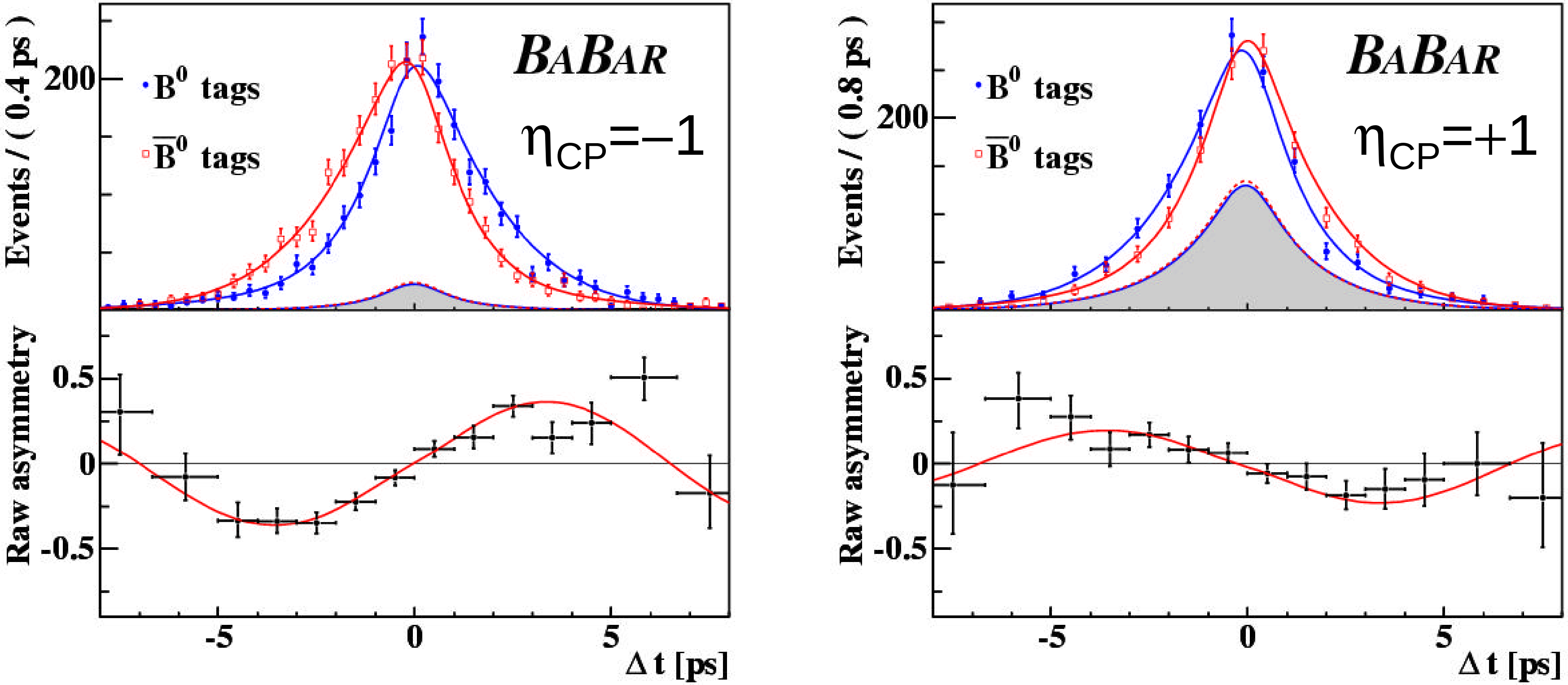


- 1600 $J/\psi K_L$ tagged signal events

- 400 $J/\psi K^{*0}$ tagged signal events



New sin2β Results: 227 $B\bar{B}$ events



sin2ß = 0.722 ± 0.040 (stat) ± 0.023 (sys)

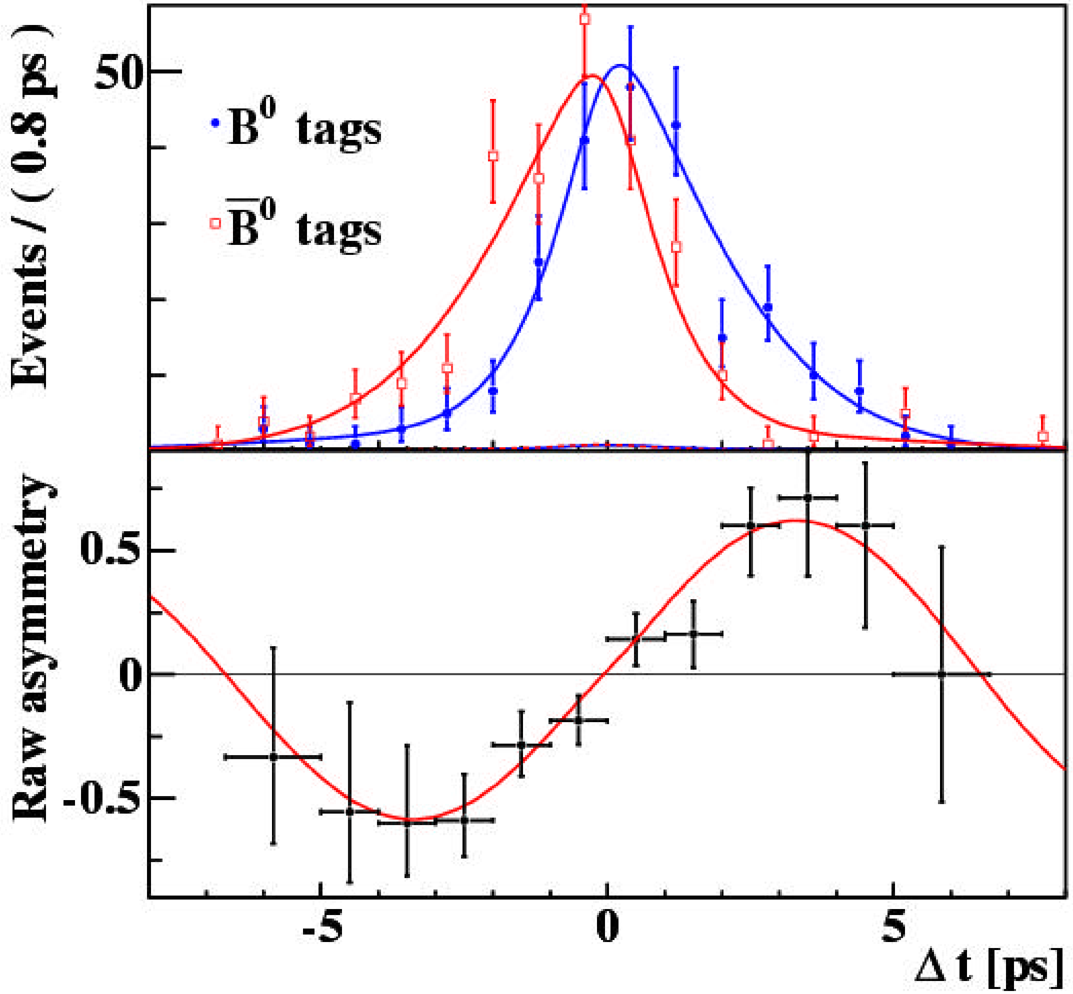
Best of the best: Lepton tagged η_{CP}=–1 events

Lower background

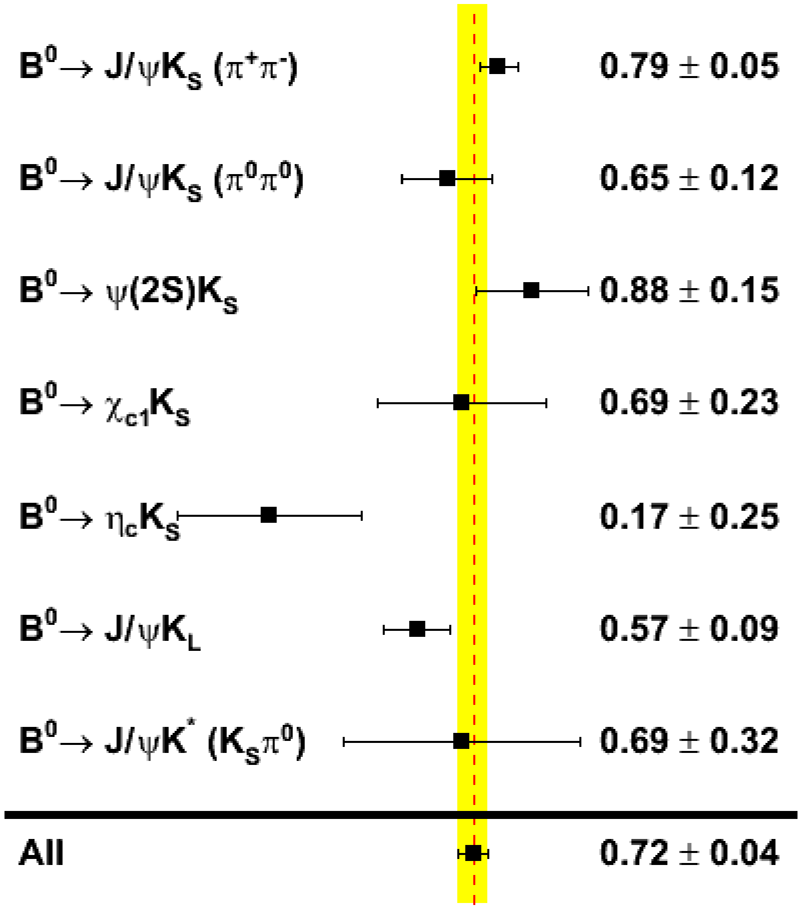
Close to perfect tagging

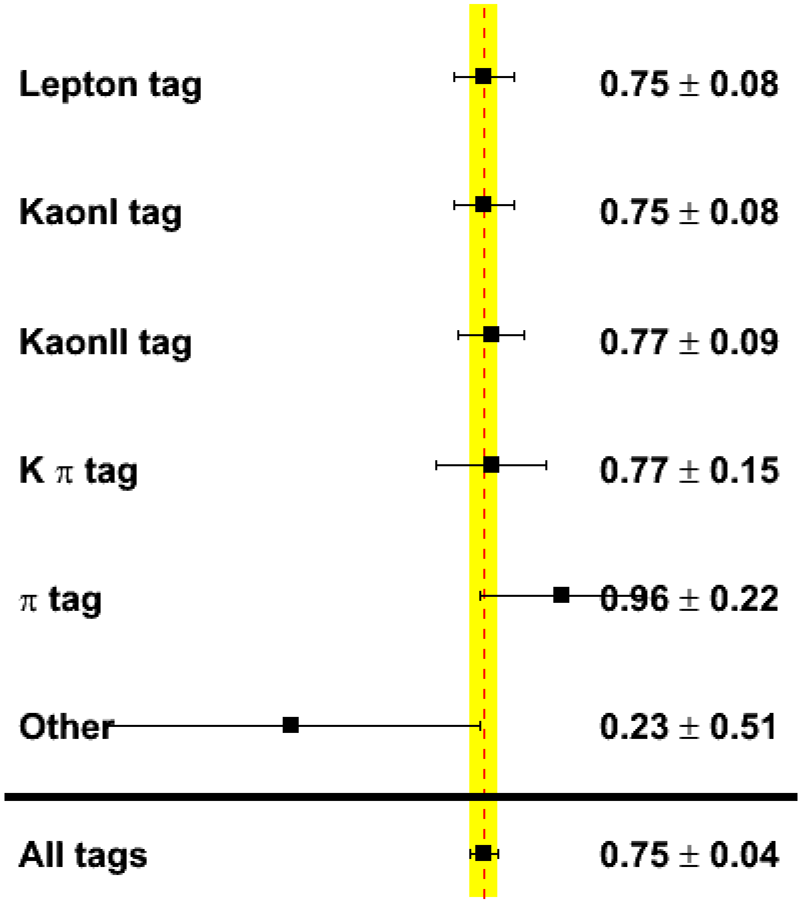
Better Δt determination

sin2β=0.75+/–0.08



Consistent results when data is split by decay mode and tagging category





$?^2$=11.7/6 d.o.f.
Prob ($?^2$)=7%

$?^2$=1.9/5 d.o.f.
Prob ($?^2$)=86%

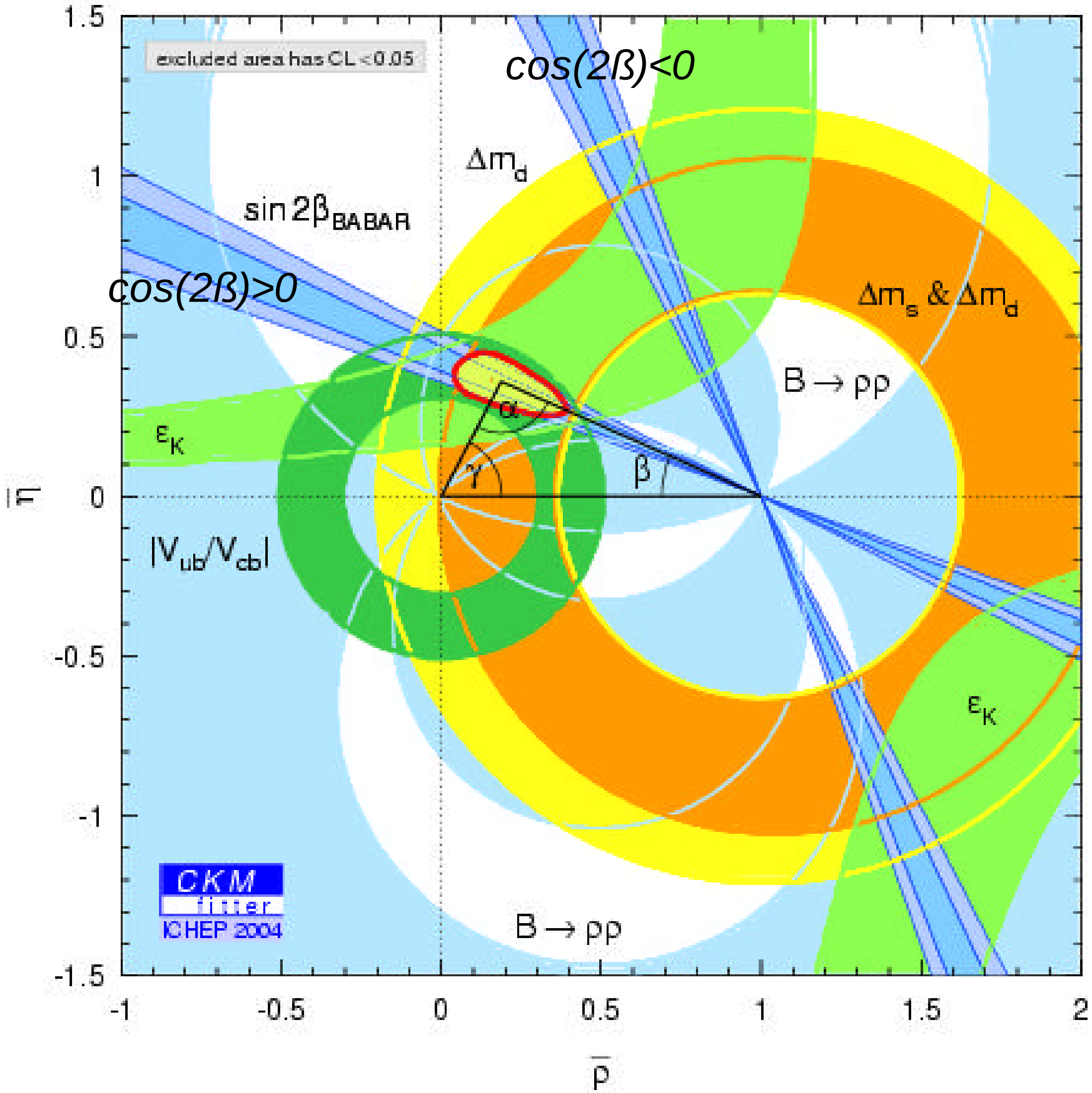
Decreasing systematic error: sin2β measurement still statistics limited.

	σ(sin2*b*)
Description of background events	0.012
CP content of peaking background	
Background shape uncertainties	
Mistag differences between B_{CP} and B_{flav} samples	0.007
Composition and content of $J/y\ K_L$ background	0.011
Δt resolution and detector effects	0.011
Silicon detector alignment uncertainty	
Δt resolution model	
Beam spot position	0.007
Fixed ?m, t, ?G/G, |?|	0.005
Tag-side interference/ DCSD decays	0.003
MC statistics/bias	0.003
TOTAL	**0.023**

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

CKM picture with new sin2β measurement

- 1 of 4 solutions for β overlays allowed region by other constraints.



B→J/ψK* channel sensitive to cos2β if angular variables are included in analysis

- CP even (L=0,2) and odd (L=1) amplitudes averaged over in nominal sin2β analysis.
- Terms proportional to cos2β also in full amplitude
  - Sign of cos2β mathematically ambiguous
    - Two-fold ambiguity in determination of strong phases

$$\pm e^{-G|?t|} f_4(\vec{?}) |A_\perp||A_\parallel| \cos(d_\perp - d_\parallel)\cos(2ß)\sin(?m?t)$$

$$\pm e^{-G|?t|} f_6(\vec{?}) |A_\perp||A_0| \cos(d_\perp - d_0)\cos(2ß)\sin(?m?t)$$

angular amplitudes

decay angles:

$$\vec{?} = (\cos(?_{K^*}), \cos(?_{tr}), f_{tr})$$

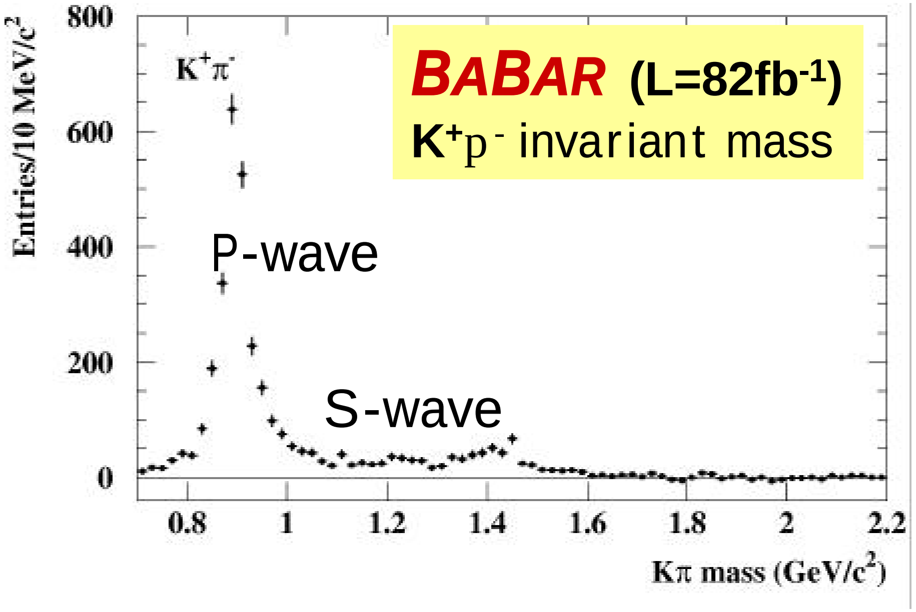
$$A_\perp = |A_\perp| e^{id_\perp} \text{ (CP odd)}$$

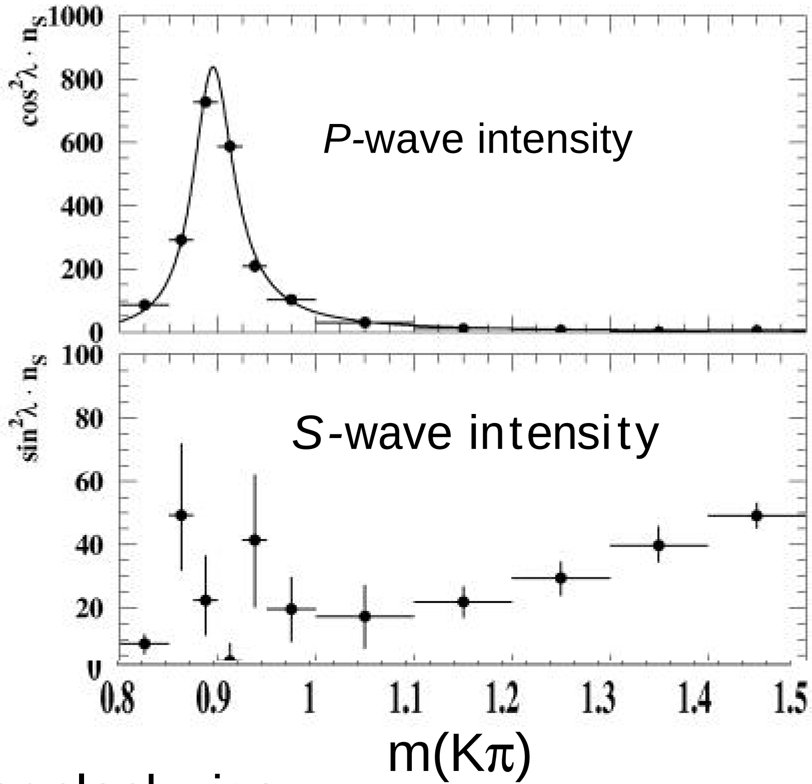
$$A_0 = |A_0| e^{id_0} \text{ (CP even)}$$

$$A_\parallel = |A_\parallel| e^{id_\parallel} \text{ (CP even)}$$

angular amplitudes in transversity basis

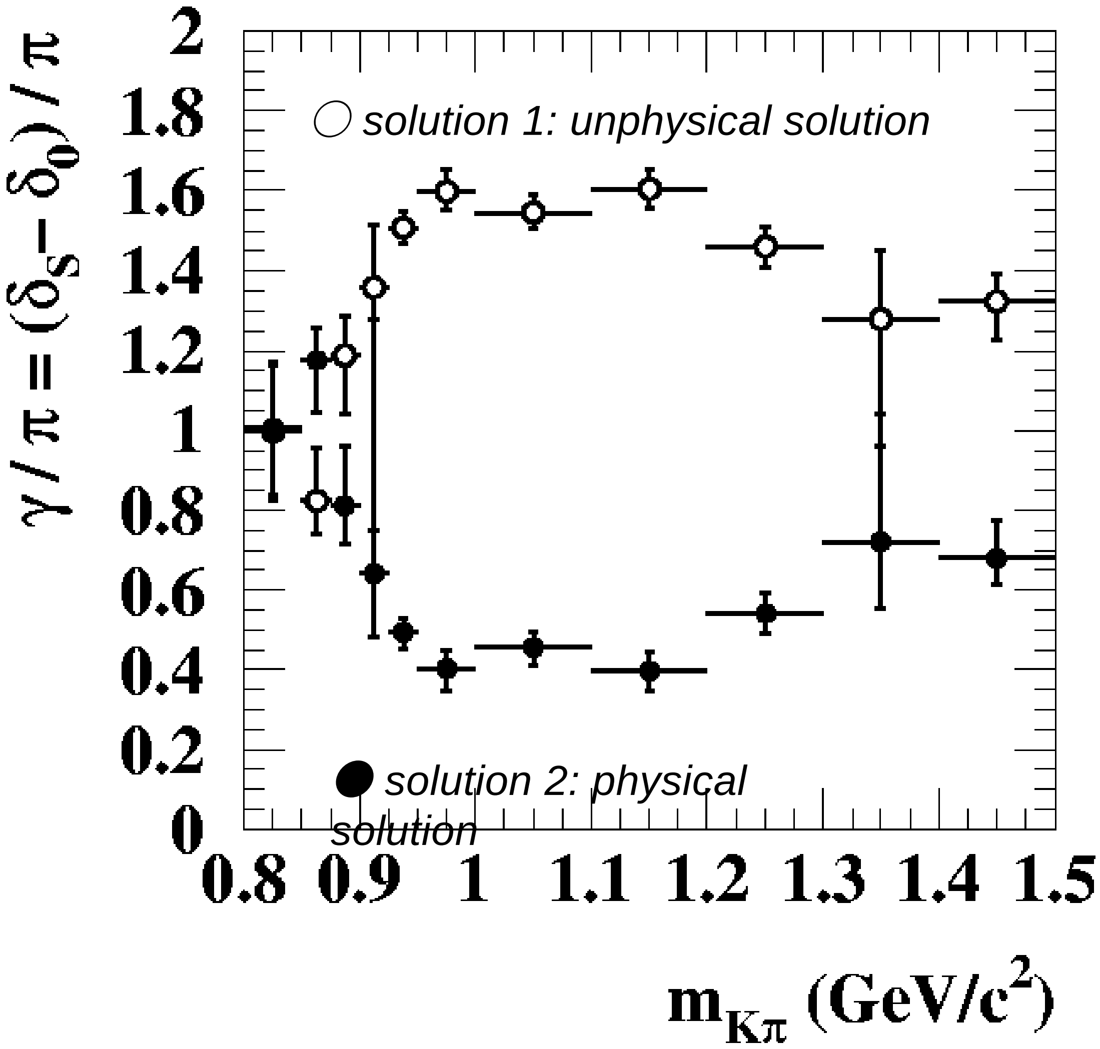
Ambiguity solved via S-wave – P-wave interference





- Wigner causality:
  - Resonance phase rotates counter-clockwise
  - P-wave moves "fast", S-wave moves "slow"
- Look at interference term in amplitude analysis
  - δ_S-δ_P vs. m(Kπ) : Which solution is physical?

Clear solution to strong phase ambiguity



"solution 1"

$$d_{\parallel} - d_0 = 2.729 \pm 0.0101 \pm 0.052$$
$$d_{\perp} - d_0 = 0.184 \pm 0.070 \pm 0.046$$

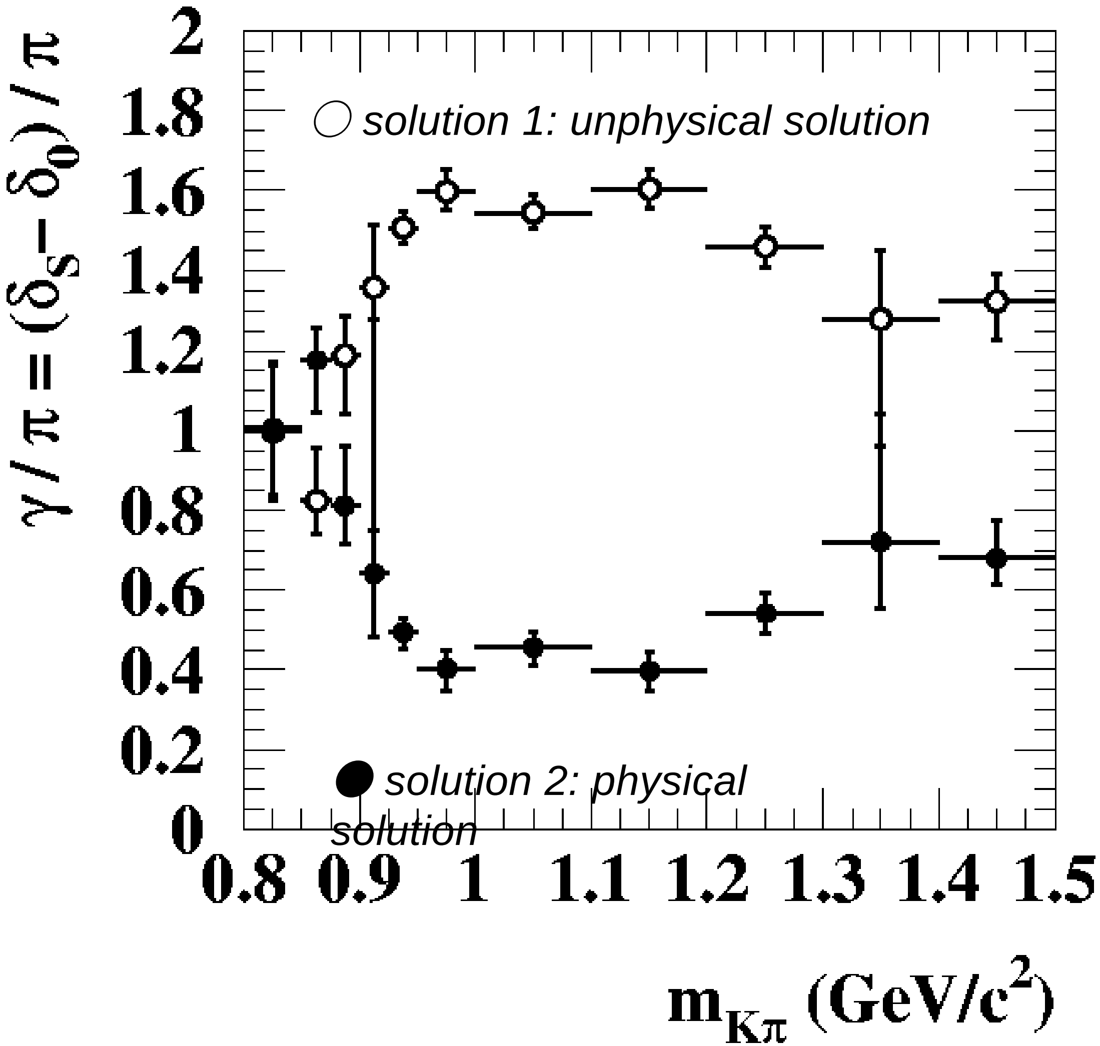
Preliminary

"solution 2"

$$d_{\parallel} - d_0 = -2.729 \pm 0.0101 \pm 0.052$$
$$d_{\perp} - d_0 = 2.958 \pm 0.070 \pm 0.046$$

$$|A_0|^2 = 0.566 \pm 0.012 \pm 0.005$$
$$|A_{\parallel}|^2 = 0.204 \pm 0.015 \pm 0.005$$
$$|A_{\perp}|^2 = 0.230 \pm 0.015 \pm 0.004$$

Clear solution to strong phase ambiguity



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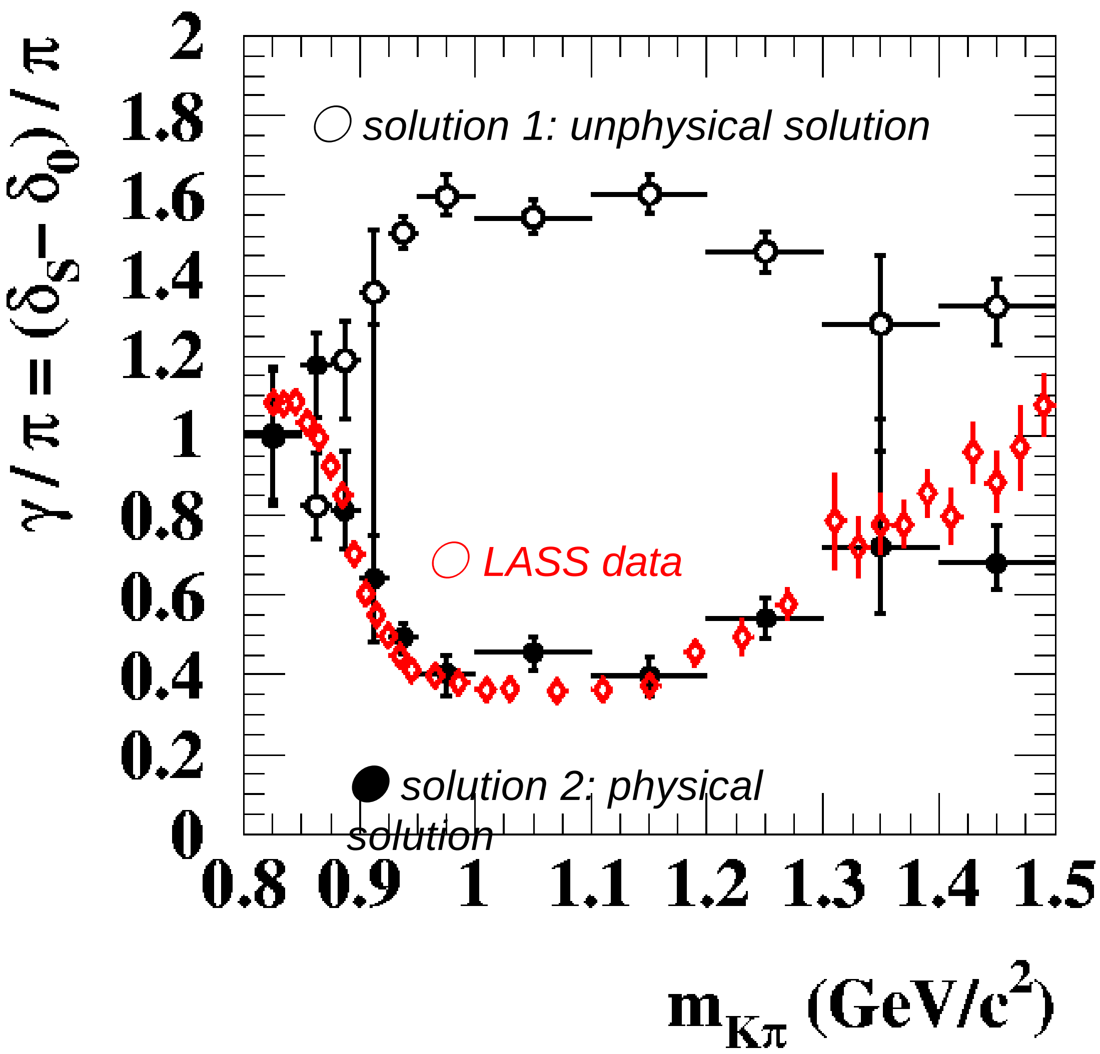
Comparison with LASS Kπ scattering data



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"solution 2"

$$d_{\parallel} - d_0 = -2.729 \pm 0.0101 \pm 0.052$$
$$d_{\perp} - d_0 = 2.958 \pm 0.070 \pm 0.046$$

$$|A_0|^2 = 0.566 \pm 0.012 \pm 0.005$$
$$|A_{\parallel}|^2 = 0.204 \pm 0.015 \pm 0.005$$
$$|A_{\perp}|^2 = 0.230 \pm 0.015 \pm 0.004$$

Measure cos2β with angular and time dependent analysis

- Current results on 88 million BB events.
  - 104 tagged signal events.

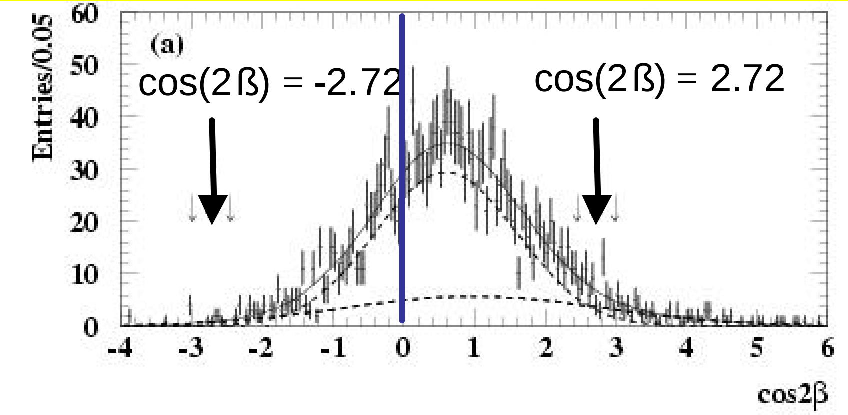
Preliminary

$$\cos(2\beta) = 2.72^{+0.50}_{-0.79}(stat.) \pm 0.27(syst.)$$

(with sin(2ß) fixed to 0.731)

$$\cos(2\beta) = -\sqrt{1-\sin^2(2\beta)}$$
$$= -0.68$$
$$\text{excluded at } 86.6\% \text{ CL}$$

Distribution of cos(2ß) results from data-sized Monte Carlo samples, generated with cos(2ß)=0.68



Standard Model sign of cos(2β) favored by our data.

Conclusion for sin2β with Charmonium

- Updated measurement of sin2β with B→J/ψK^0 decays using full BABAR data sample

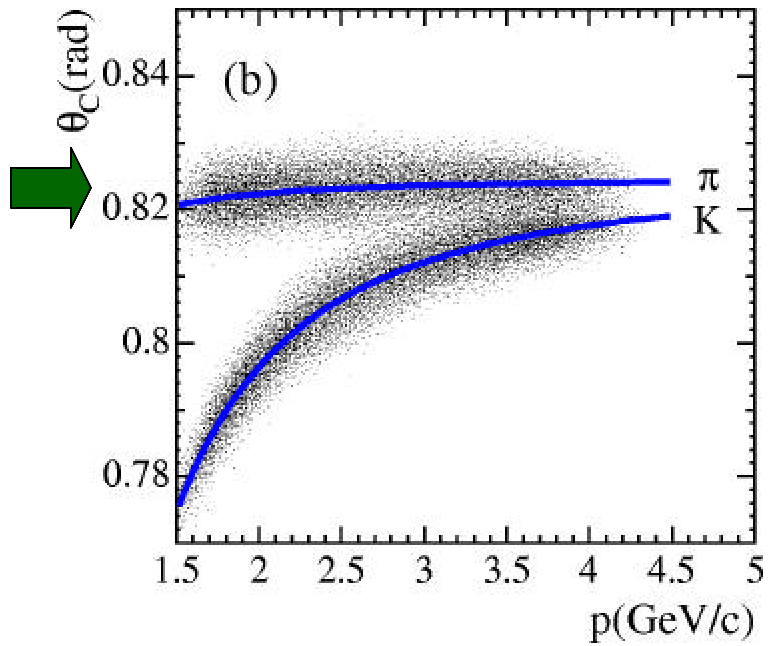
$$\sin 2b = 0.722 \pm 0.040\ (\mathrm{stat}) \pm 0.023\ (\mathrm{syst})$$

- Novel method to break strong phase ambiguity in measurement of cos2β in B→J/ψK* decays

$$\cos(2ß) = 2.72^{+0.50}_{-0.79}(stat.) \pm 0.27(syst.)$$

- cos2β=-0.68 excluded at 86.6% level. More data to be included in this analysis.

BABAR charmless analysis requirements



- DIRC for separation of high momentum π and K.
- Continuum rejection
  - Neural network or Fisher to optimally combine event shape discriminants.
- Design high efficiency selection. Maximum likelihood fit to untangle signal from background in optimal way.
  - Variables: m_{ES}, ΔE, (NN or Fisher), resonance mass, decay angle, tagging, and Δt
  - Contributions: Signal, continuum, B background(s)

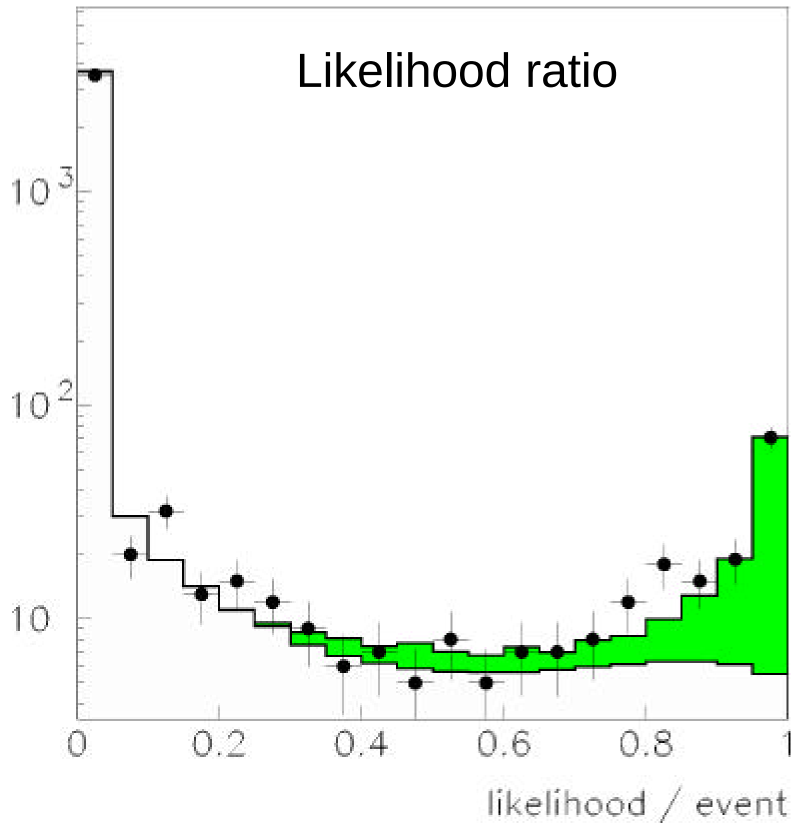
$B \rightarrow f K_S$ and $B \rightarrow f K_L$

- $f \rightarrow K^+K^-$: dE/dx + DIRC information
- $B \rightarrow f K_L$ mode like $B \rightarrow J/y K_L$
  - Add continuum suppression variables
- New for updated analysis
  - New tagger
  - Event yields determined along with CP parameters
  - Improved B background treatment

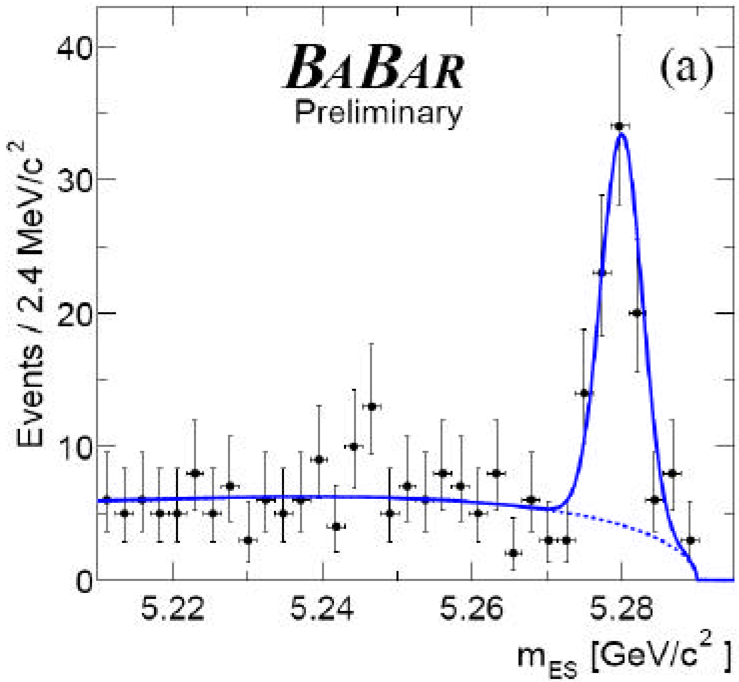
Event yield results for 227x10^6 $B\bar{B}$

$$B^0 \to f K_S^0 \to K^+K^-p^+p^-$$

114 ± 12 signal events



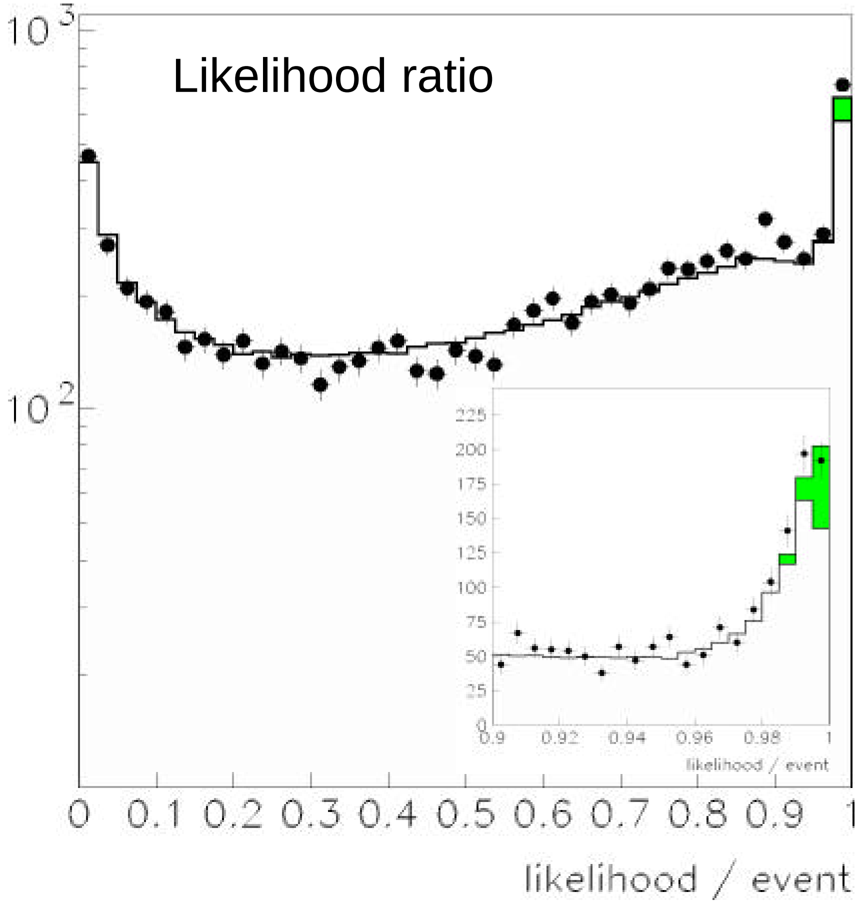
Projection onto m_{ES} after likelihood ratio (w/o m_{ES})



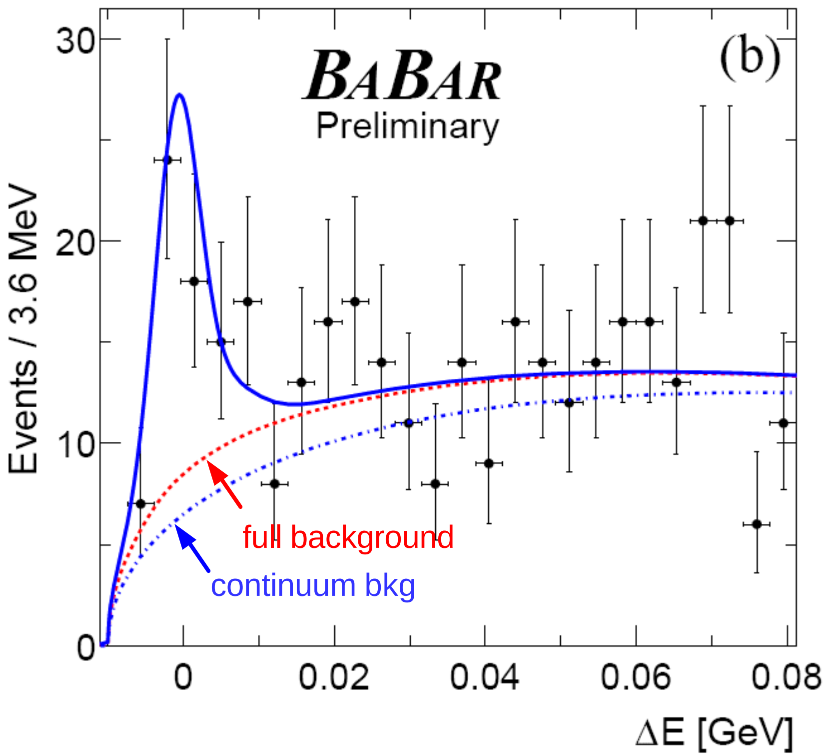
Event yield results for 227x10^6 $B\bar{B}$

98 ± 18 signal events

$B^0 \to f K_L^0$



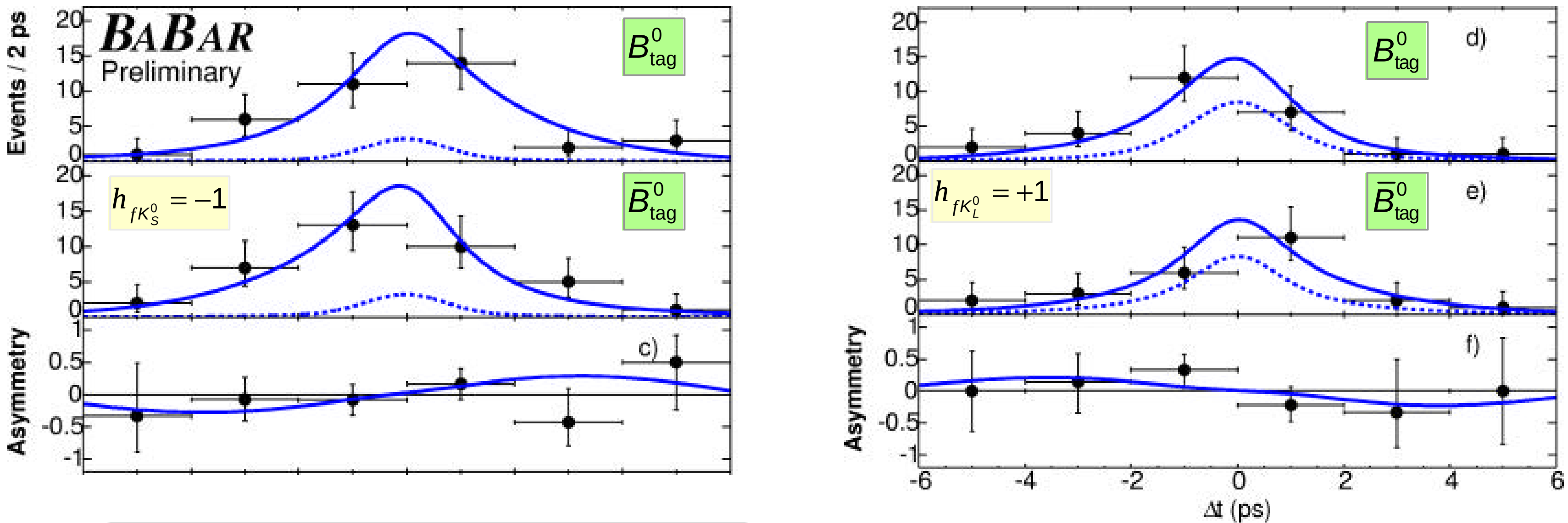
Projection onto ΔE after likelihood ratio (w/o ΔE)



New CP asymmetry results confirm previous measurement

B^0 ® f K_S $S_{fK^0_S} = +0.29 \pm 0.31$

B^0 ® f K_L $S_{fK^0_L} = -1.05 \pm 0.51$



$$S_{fK^0} = +0.50 \pm 0.25 \; {}^{+\,0.07}_{-\,0.04}$$

$$C_{fK^0} = +0.00 \pm 0.23 \pm 0.05$$

Systematic errors dominated by

- opposite-*CP* background
- PDF modeling
- Tag-side *CP* violation

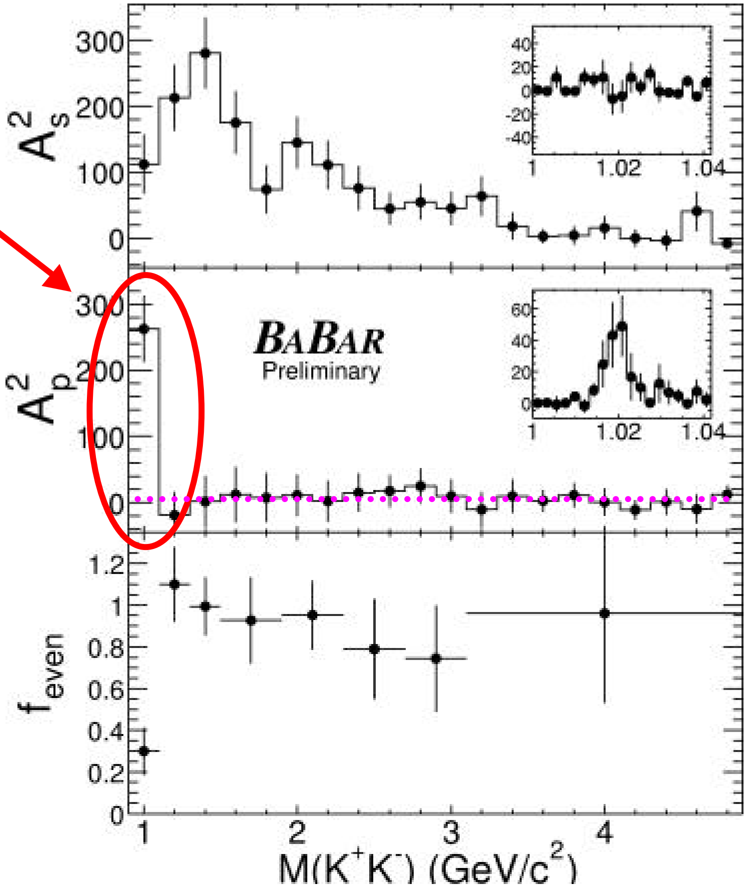
Previous result: 114x10^6 $B\bar{B}$

$S_{\phi K^0_S} = 0.47 \pm 0.34^{+0.08}_{-0.06}$ $C_{\phi K^0_S} = 0.01 \pm 0.33 \pm 0.10$

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

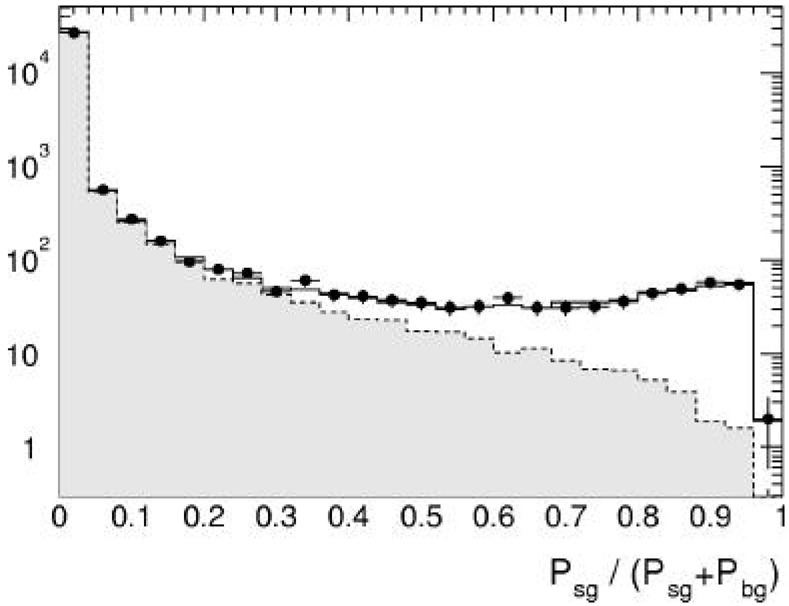
- $B \rightarrow fK_S$ only 15% of $B \rightarrow K^+K^-K_S$ events
  - We analyze the rest excluding the $B \rightarrow fK_S$ contribution.
  - Determine the CP content via angular moments analysis of K^+K^- helicity angle distribution.
  - Dominantly CP-even

$$f_{CP\text{-even}} = \frac{A_s^2}{A_s^2 + A_p^2} = 0.89 \pm 0.08 \pm 0.06$$

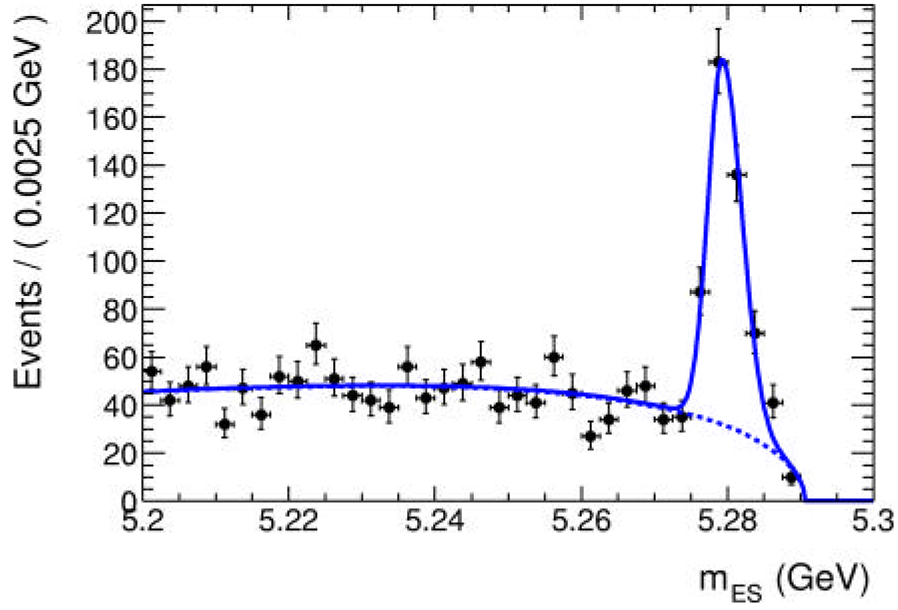


$B \to K^+K^-K_S$ event sample

Likelihood ratio



Likelihood projection onto m_{ES} (after LR cut)



452 ± 28 signal events

(excluding f K_S events)

$B \rightarrow K^+K^-K_S$ (227x10^6 $B\bar{B}$ pairs)

$$S_{K^+K^-K^0_S} = -0.42 \pm 0.17 \pm 0.04$$
$$C_{K^+K^-K^0_S} = +0.10 \pm 0.14 \pm 0.06$$

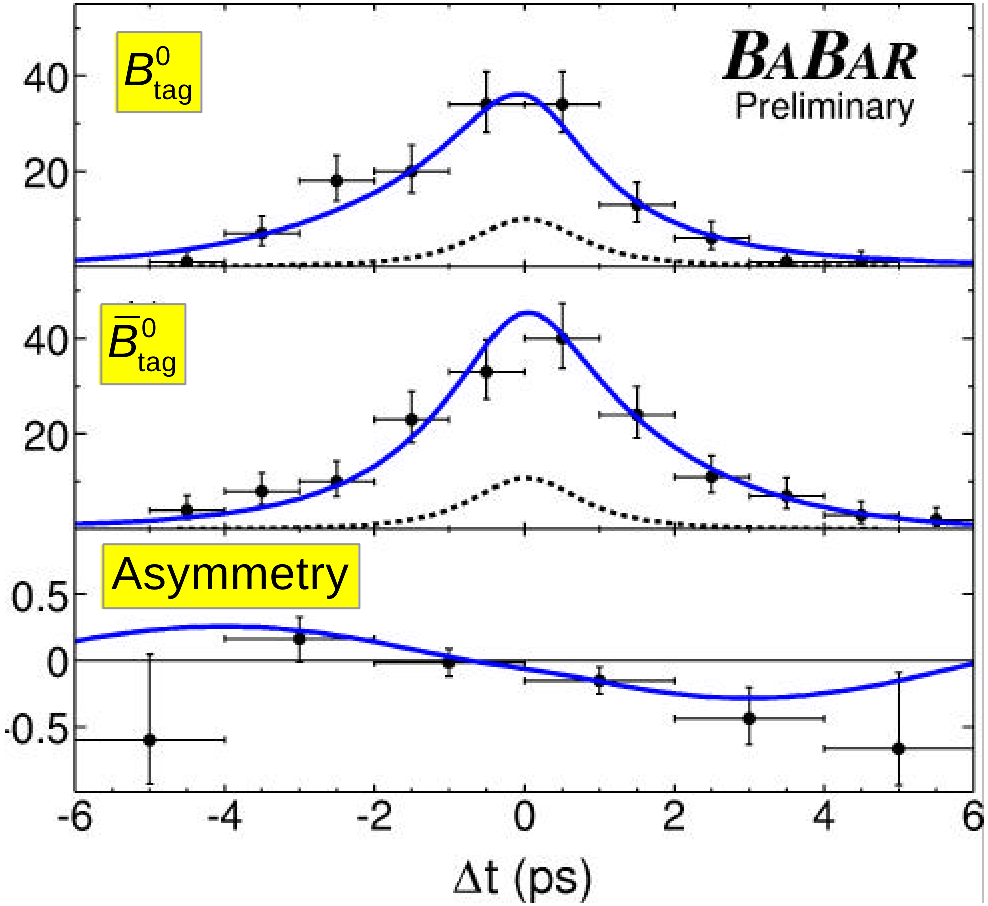
Systematic errors dominated by

- Fit bias
- Tag-side *CP* Violation

Previous result: 122x10^6 $B\bar{B}$

$S = -0.56 \pm 0.25 \pm 0.04$

$C = -0.10 \pm 0.19 \pm 0.10$



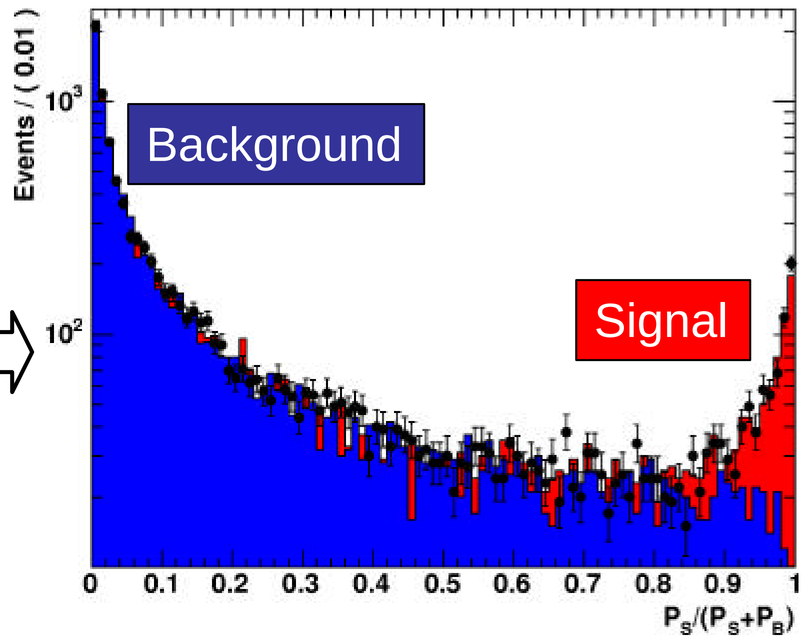
$$\sin 2b \left[\sim -S_{K^+K^-K^0_S} / (2f_{CP\text{-even}} - 1)\right] = +0.55 \pm 0.22 \pm 0.04 \pm \underset{CP\text{ content}}{0.11}$$

$B \rightarrow h'K_S$

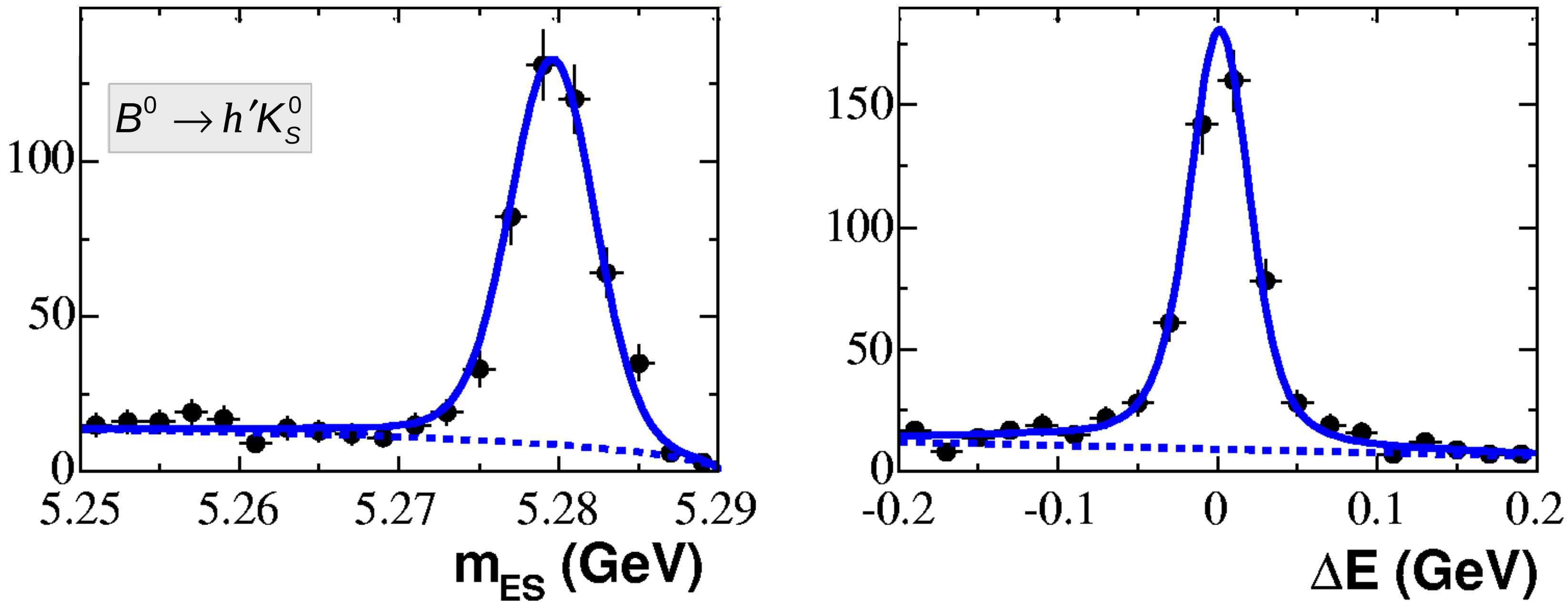
- Definitely not a “rare” decay mode

$$\mathrm{BR}(B^0 \rightarrow h'_{\mathrm{rec}} K_S^0) \sim 14.9 \times 10^{-6}$$

- Reconstruct in multiple final states:
  - $h' \rightarrow hp^+p^-,\ r^0 g$
  - $h \rightarrow gg\ ,\ p^+p^-p^0$
  - $K_S \rightarrow p^+p^-\ , p^0p^0$
- Likelihood projection ⇨



Projections of $B \rightarrow h'K_S$ (227×10^6 $B\bar{B}$)

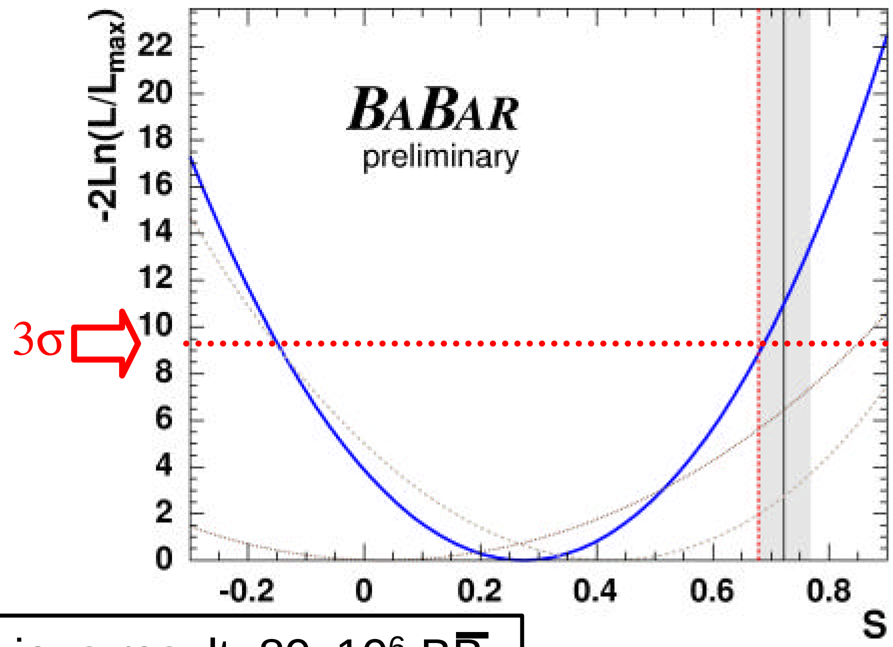


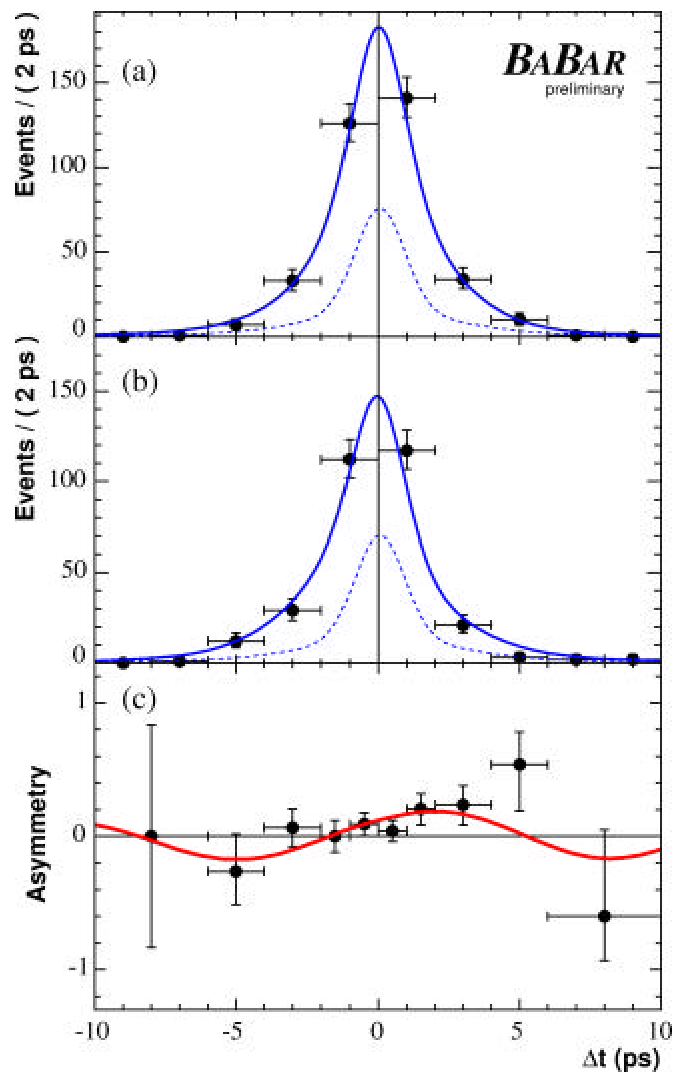
- Likelihood projections onto m_{ES} and ΔE.
  - Most modes have very low background.
- Yield from fit: 819 ± 38 signal events

S coefficient is 3σ from $[cc]K$ sin2β

$$S_{h'K^0_S} = +0.27 \pm 0.14 \pm 0.03$$

$$C_{h'K^0_S} = -0.21 \pm 0.10 \pm 0.03$$





Previous result: 89x10[6] $B\overline{B}$

$S = 0.02 \pm 0.34 \pm 0.03$

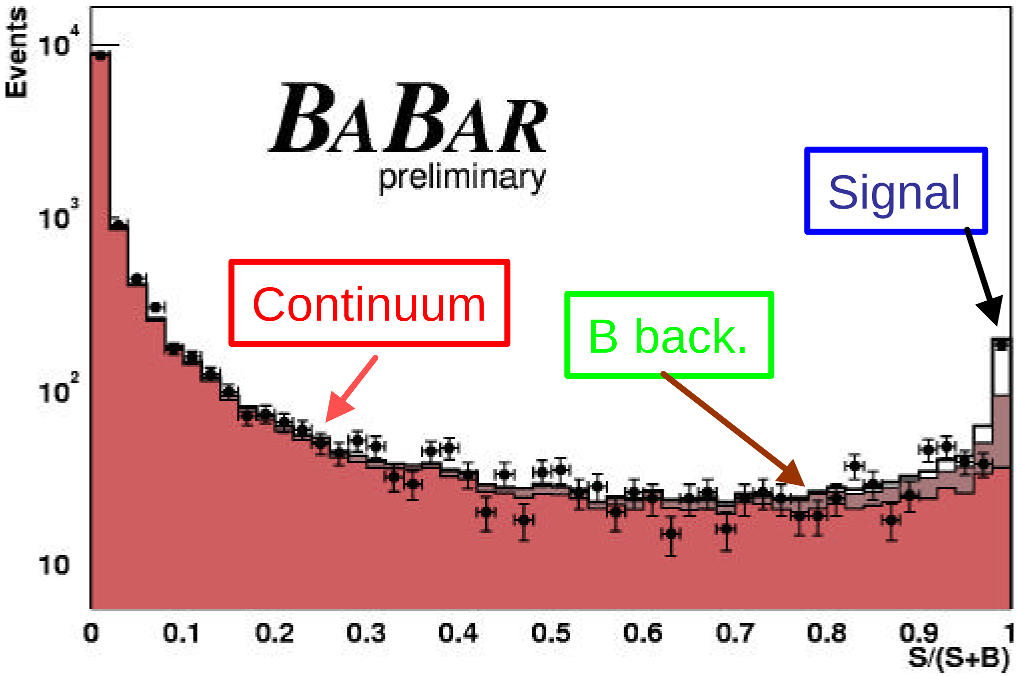
$C = 0.10 \pm 0.22 \pm 0.04$

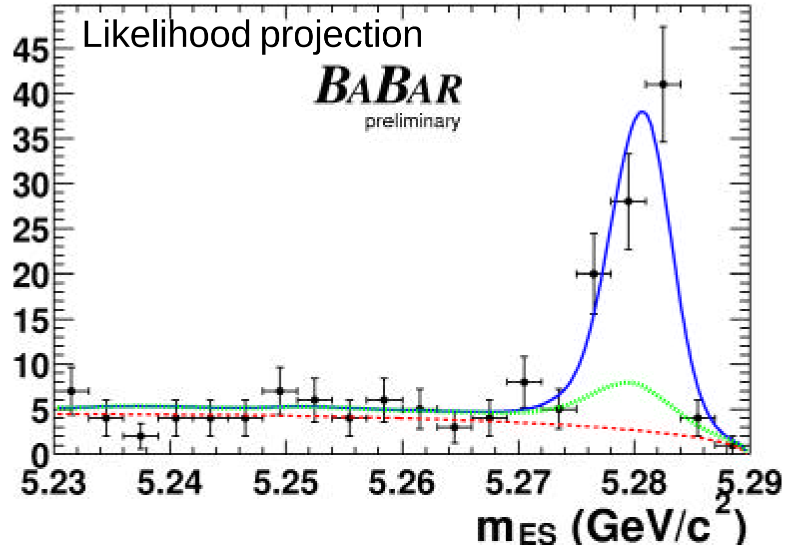
$B \rightarrow f_0(980)K_S$ ($f_0 \rightarrow p^+p^-$)

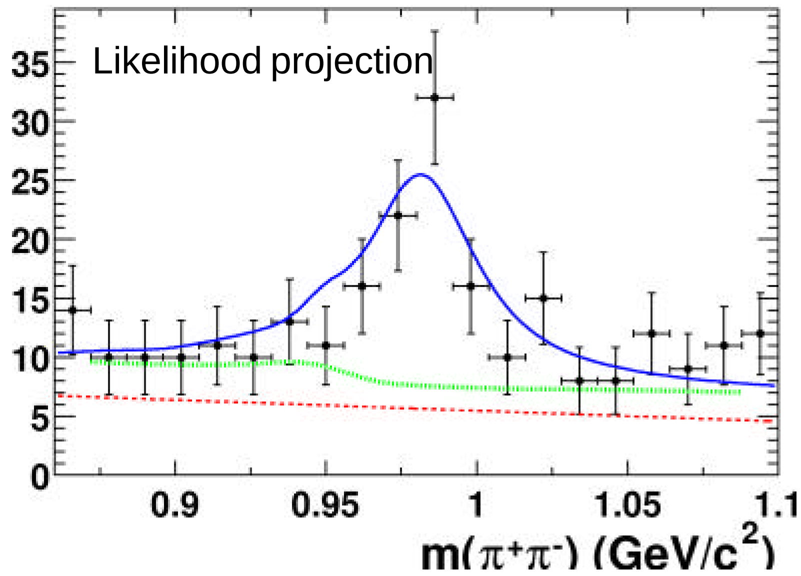
- f_0(980) is broad. Use “quasi two-body” approach:
  - Analyze $f_0 \rightarrow \pi^+\pi^-$ region of $\pi^+\pi^-K_S$ Dalitz plot
  - Account for other $B \rightarrow \pi^+\pi^-K_S$ contributions
    - Vary size and relative phase of contributing amplitudes as part of systematic error
  - Mass and width parameters of relativistic BW floating in likelihood fit
    - Not sensitive to different lineshapes
- No analysis changes for updated results

$B \rightarrow f_0 K_S$ from 206x10^6 $B\bar{B}$ pairs

152 ± 19 signal events





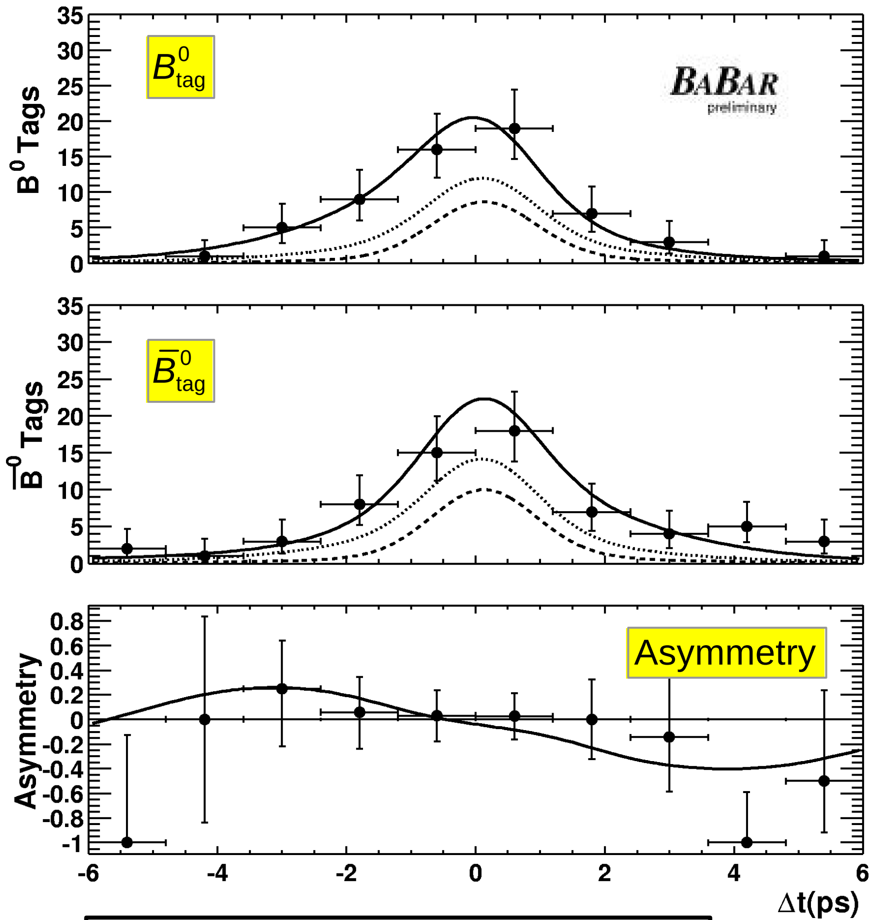


CP results from $B \to f_0(\to p^+ p^-) K_S$

$$S_{f_0 K_S^0} = -0.95\,^{+0.32}_{-0.23} \pm 0.10$$

$$C_{f_0 K_S^0} = -0.24 \pm 0.31 \pm 0.15$$

- Larger than expected improvement in errors as well as shift in S largely due to new lepton tagged event with high signal probability and "good" Δt.
- Systematic error dominated by unknown $\pi\pi K_S$ contributions in f_0 region of Dalitz plot. (Q2B approach)



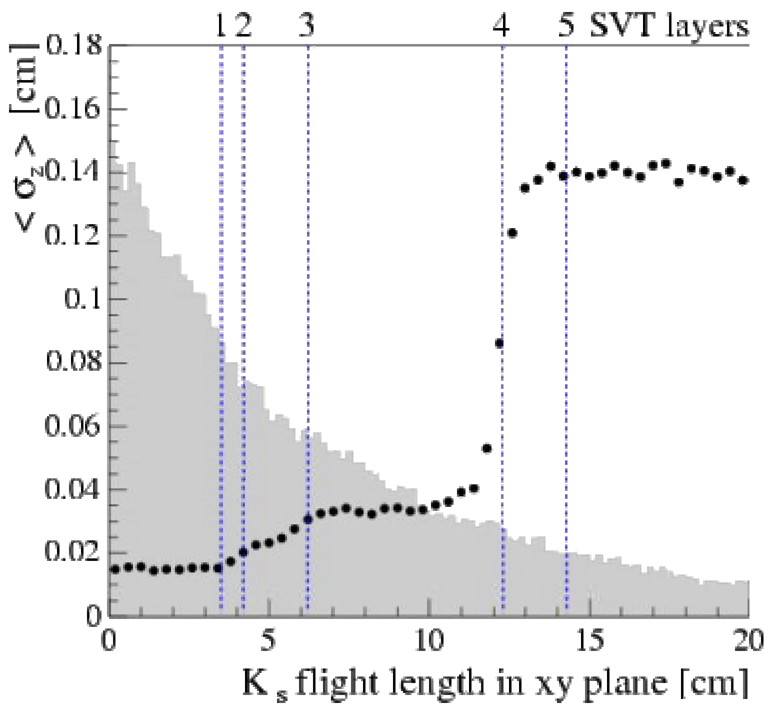
Previous result: 123×10^6 $B\bar{B}$

$$S_{f_0 K_S^0} = -1.62^{+0.56}_{-0.51} \pm 0.09 \pm 0.04$$

$$C_{f_0 K_S^0} = 0.27 \pm 0.36 \pm 0.10 \pm 0.07$$

Time-dependant analysis of $B \rightarrow \rho^0 K_S$ using novel vertexing technique

- Lifetime of K_S requires additional information to be used to determine Δt with adequate precision
  - Require at least 4 SVT hits on each $K_S \rightarrow \pi^+\pi^-$ daughter track.
    - 40% of events failing this criterion are still used to determine the direct CP coeff.
  - Include beam energy and beam spot (determined run by run) constraints and fit full $\Upsilon(4S)$ decay tree.



209×10^6 $B\bar{B}$ results for $B\rightarrow \rho^0 K_S$

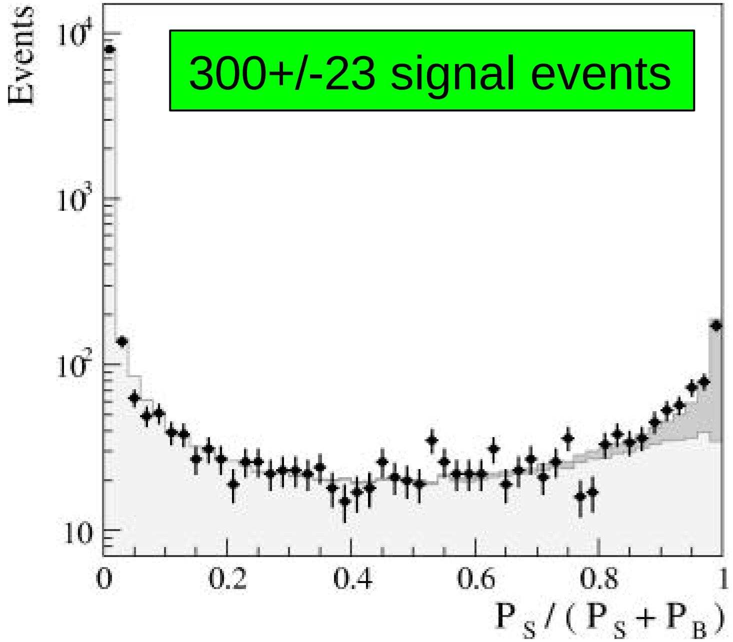
Replace ΔE and m_{ES}

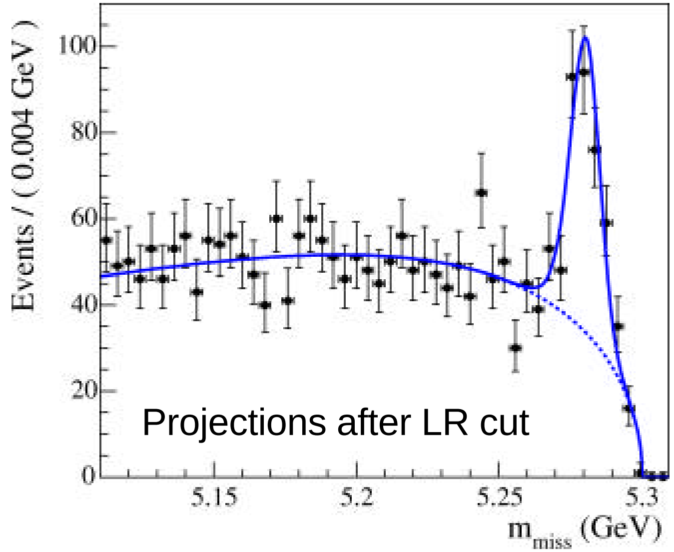
$$m_{miss} = |q_{e^+e^-} - \hat{q}_{B\rightarrow K_S^0\rho^0}| \approx 2m_{ES} - m_B^{PDG}$$

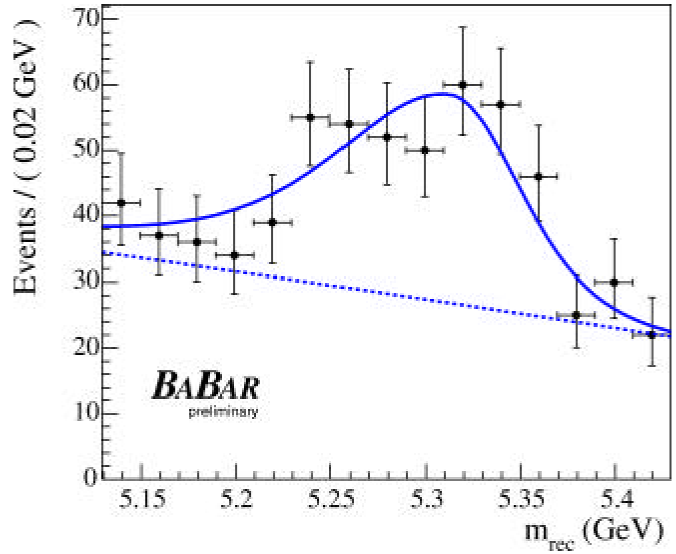
mass-constrained

$$m_{rec} = |q_{B\rightarrow K_S^0\rho^0}| \approx \Delta E + m_B^{PDG}$$

Reduced correlation, improved resolution (m_{miss})







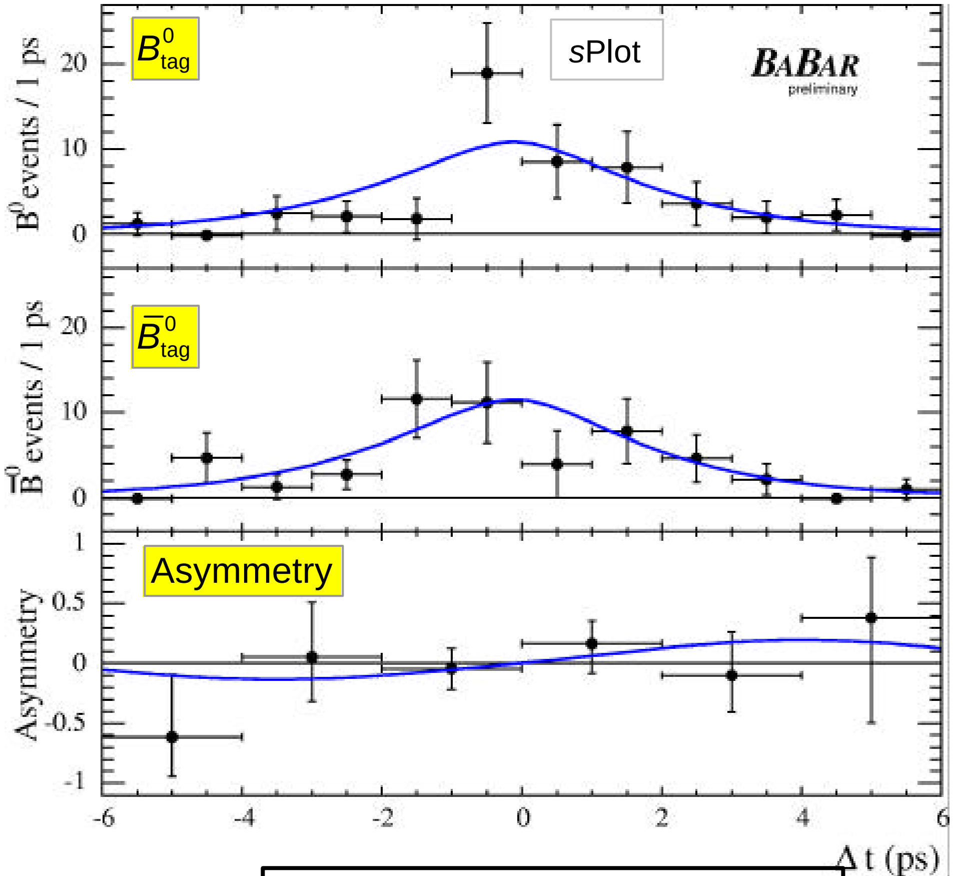
New CP results for $B \rightarrow \rho^0 K_S$

$$S_{\rho^0 K^0_S} = +0.35 \,^{+0.30}_{-0.33} \pm 0.04$$

$$C_{\rho^0 K^0_S} = +0.06 \pm 0.18 \pm 0.06$$

Systematic errors dominated by

- Background tagging asymmetry
- SVT alignment, vertexing

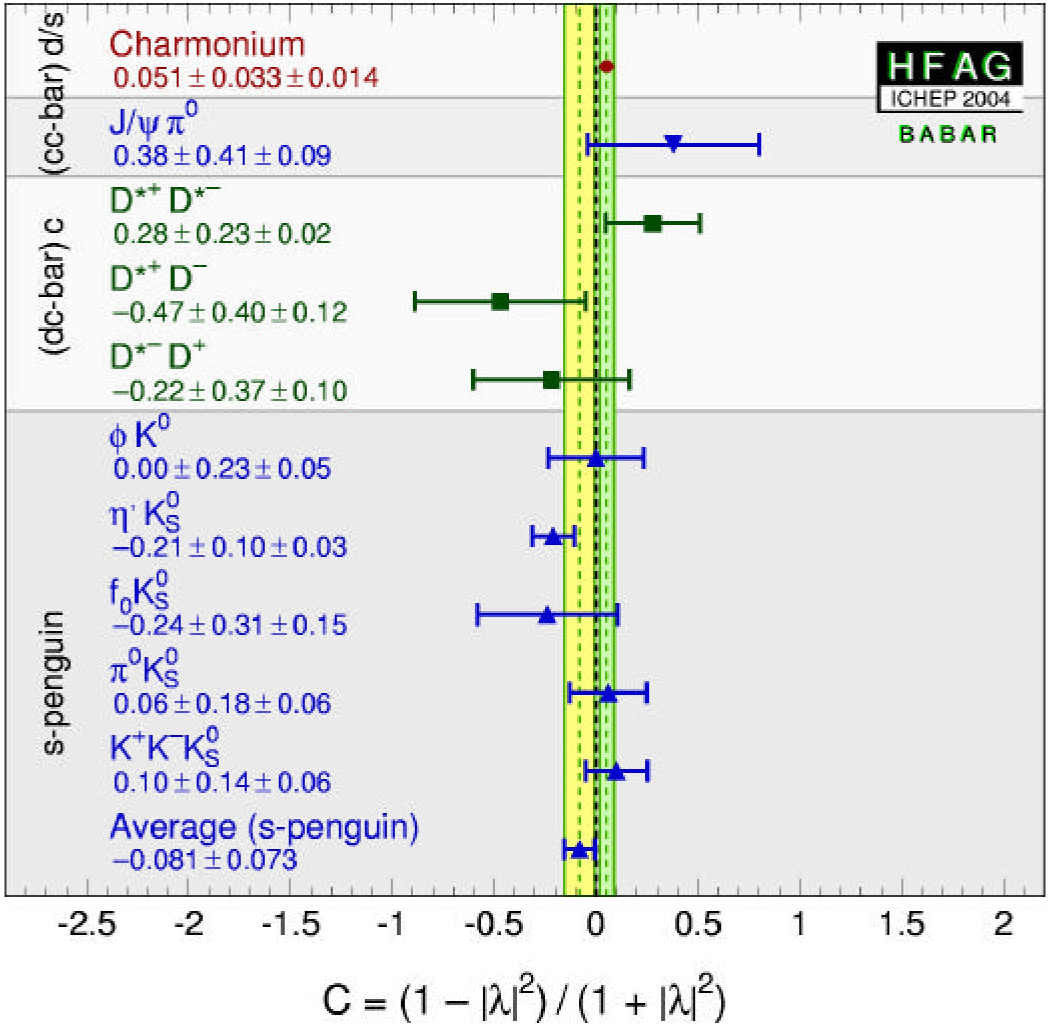


Previous result: 124×10^6 $B\bar{B}$

$$S_{f_0 K^0_S} = 0.48^{+0.38}_{-0.47} \pm 0.06$$

$$C_{f_0 K^0_S} = 0.40^{+0.27}_{-0.28} \pm 0.09$$

No indication of significant direct *CP* violation (cos(ΔmΔt) term)

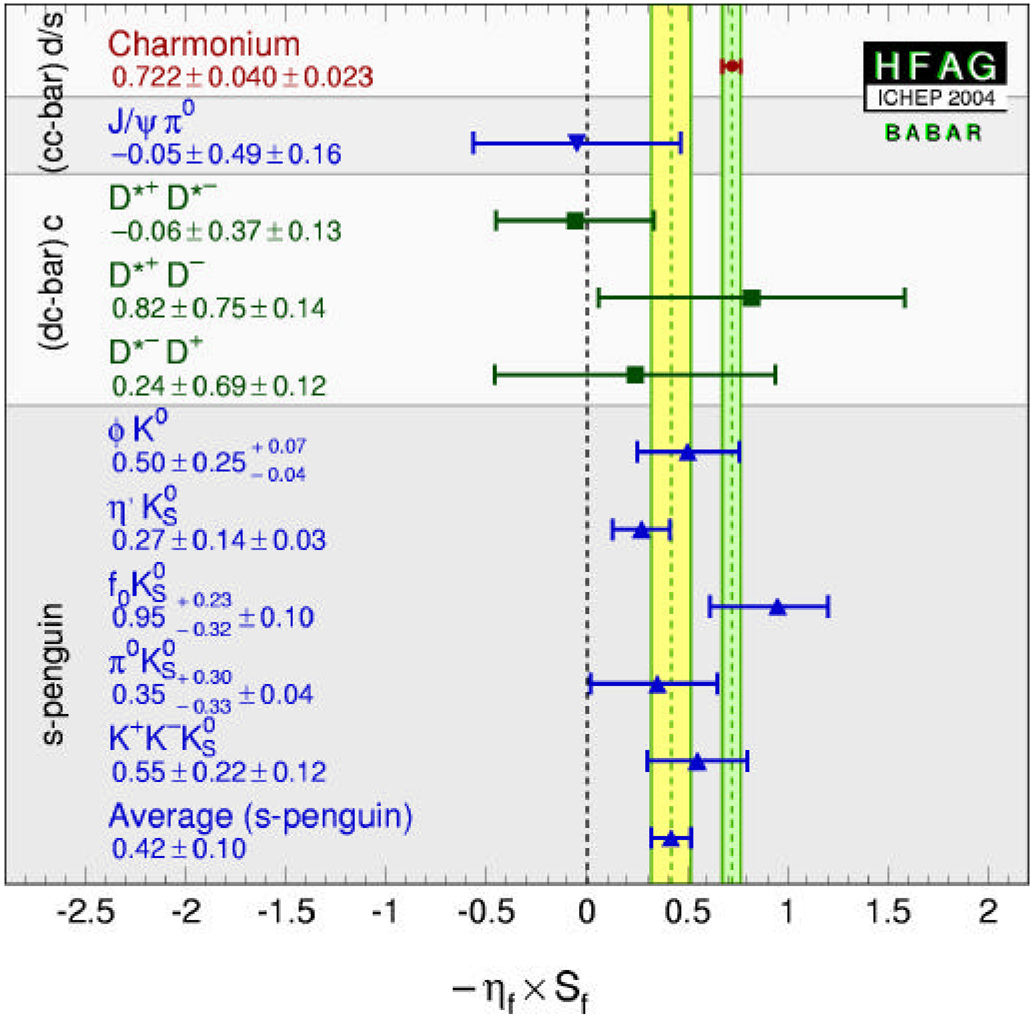


Still 81 fb^{-1} results

Charmonium average

Penguin average

Penguin and tree measurements of $\sin(\Delta m \Delta t)$ coefficient differ at 2.7σ

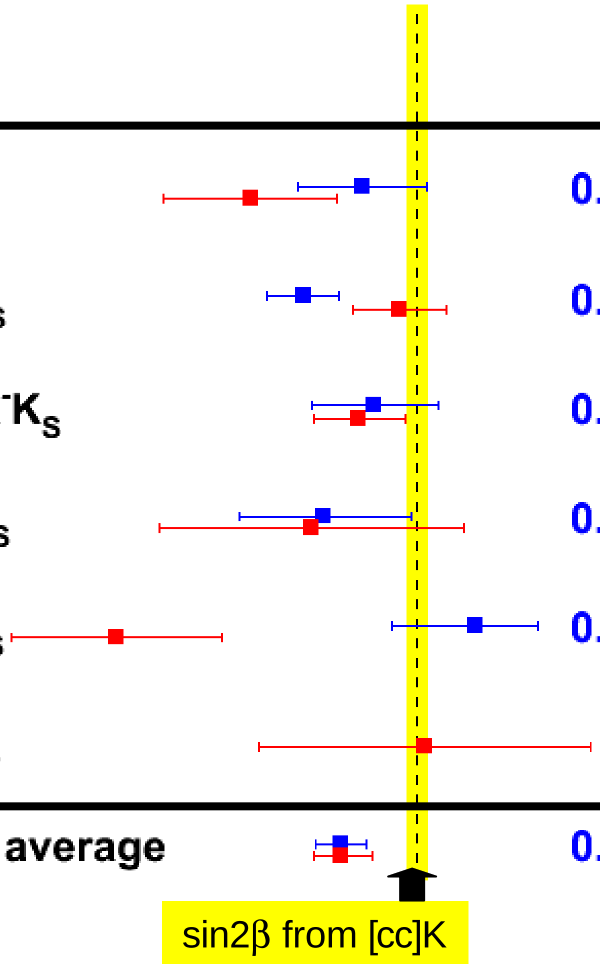


Still 81 fb^{-1} results

Charmonium average

Penguin average

Belle results also show a difference with respect to sin2β from *[cc]K⁰*



	BABAR	Belle
$B^0 \to \phi K^0$	$0.50 \pm 0.25 \pm^{0.07}_{0.04}$	$0.06 \pm 0.33 \pm 0.09$
$B^0 \to \eta' K_S$	$0.27 \pm 0.14 \pm 0.03$	$0.65 \pm 0.18 \pm 0.04$
$B^0 \to K^+ K^- K_S$	$0.55 \pm 0.22 \pm 0.12$	$0.49 \pm 0.18 \pm 0.04$
$B^0 \to \pi^0 K_S$	$0.35 \pm^{0.30}_{0.33} \pm^{0.17}_{0.04}$	$0.30 \pm 0.59 \pm 0.11$
$B^0 \to f_0 K_S$	$0.95 \pm^{0.23}_{0.32} \pm 0.10$	$-0.47 \pm 0.41 \pm 0.08$
$B^0 \to \omega K_S$		$0.75 \pm 0.64 \pm^{0.13}_{0.16}$
Penguin average	0.42 ± 0.10	$0.42 \pm^{0.12}_{0.11}$

Prob. of χ^2 between experiments is ~5%

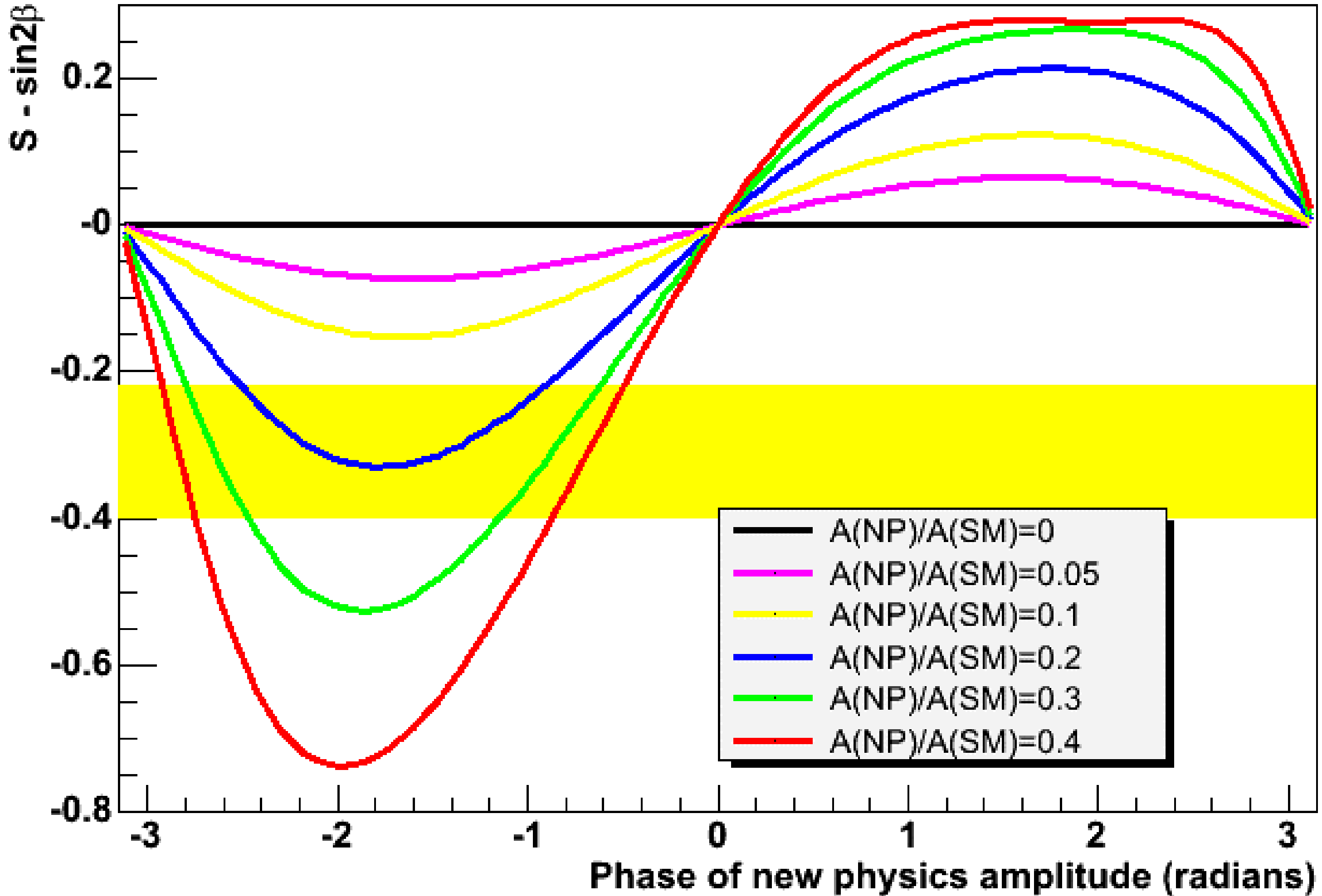
$S([cc]K^0) - S_{pen.} = \mathbf{0.31 \pm 0.09}$ ***3.6s from expectation?***

Are we seeing hints of new physics?

- Maybe you believe the "glass is ½ full" or that the "glass is ½ empty".
  - 3+σ indication of additional CPV amplitude contribution.
  - Expect new physics effects to appear differently in different modes
    - Averaging most relevant in Standard Model case
  - For BABAR, $B \rightarrow \eta' K_S$ drives average away from [cc]K_S sin2β.
  - Do we worry about BABAR vs Belle agreement?

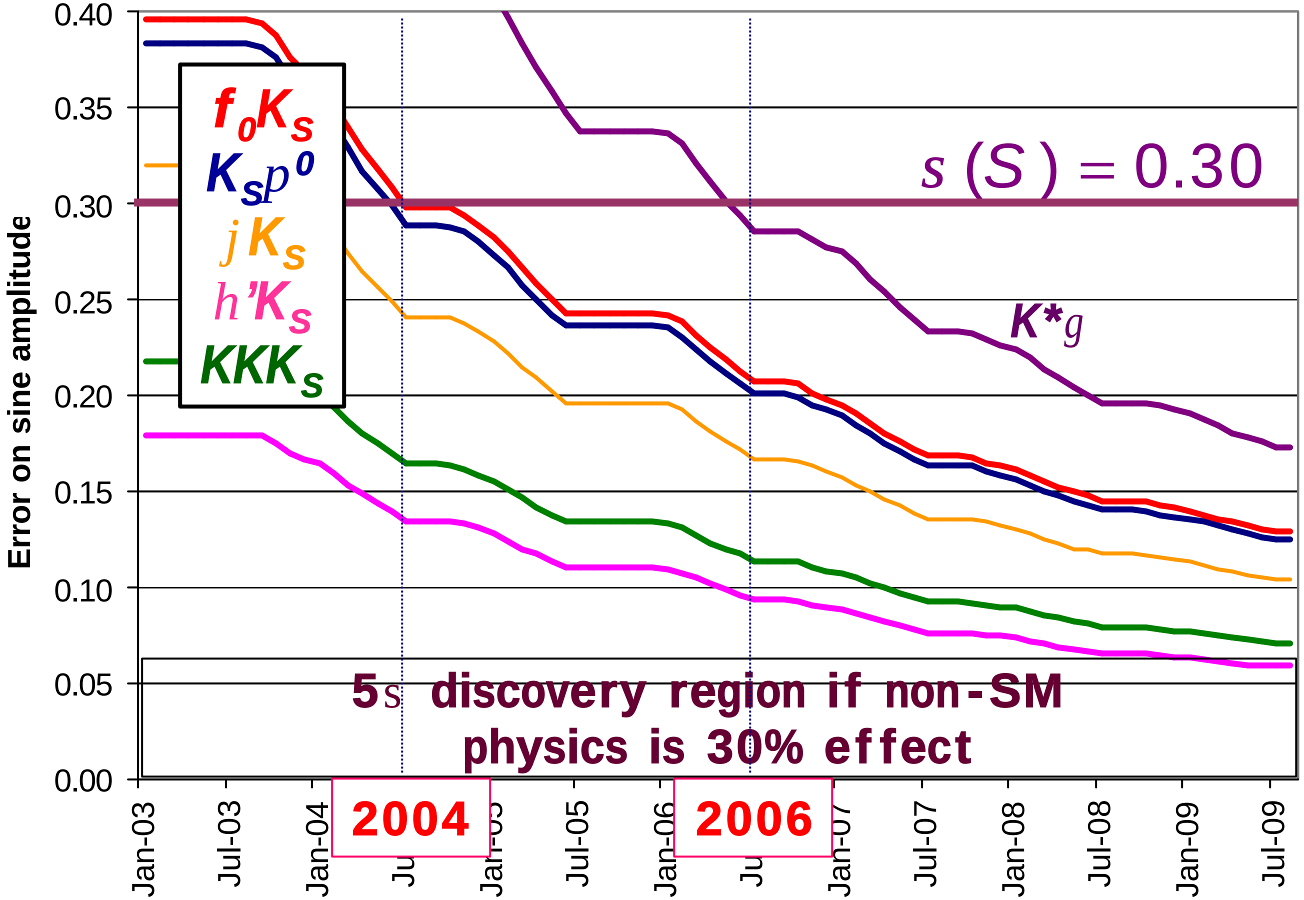
Current situation gives interesting hint.
But it is too early to draw any conclusion

Sizable "new physics" amplitudes would be required to explain current results



(assume maximal relative strong phase)

Future expectations



Luminosity expectations:

2004=240 fb^{-1}
2006=500 fb^{-1}

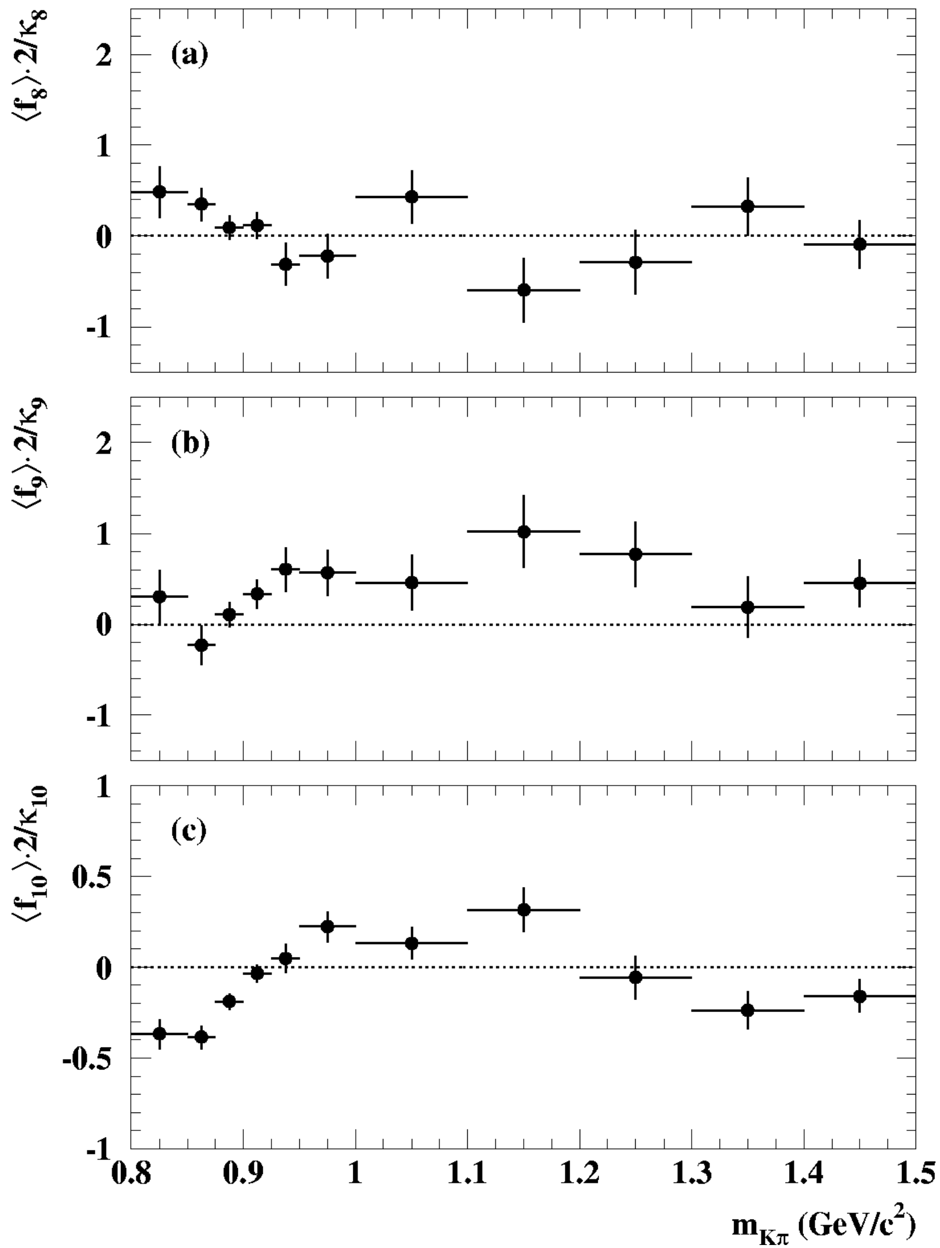
Conclusion

- BABAR has updated its *[cc]K⁰* and penguin sin2β measurements to include its latest data
  - Most up to 227 $B\bar{B}$ pairs.
- BABAR sin2β with *[cc]K⁰* now a 5% measurement.

$$\sin 2\beta = 0.722 \pm 0.040\ (\text{stat}) \pm 0.023\ (\text{syst})$$

- Hints that sin2β measured in penguin modes is not the same as in golden $B \to [cc]K^0$ modes.
  - 3σ deviation in $B \to h'K_S$.
    - $B \to h'K_S$ is also the most precise penguin measurement (+/- 0.18).
  - $B \to fK^0$ agrees with $[cc]K^0$ within 1σ.

Stay tuned for increasingly precise results as B Factory samples increase



(a)
(b)
(c)
$\langle f_8 \rangle \cdot 2/\kappa_8$
$\langle f_9 \rangle \cdot 2/\kappa_9$
$\langle f_{10} \rangle \cdot 2/\kappa_{10}$
$m_{K\pi}$ (GeV/c^2)
2
1
0
-1
0.5
-0.5
0.8
0.9
1.1
1.2
1.3
1.4
1.5

How do we display the results of our likelihood fits?

- Plot of likehood ratio: L(sig)/(L(sig)+L(background))
- Projection onto mES (or other variable) after cut on likelihood ratio.
  - Plotted variable not used to calculate likelihood ratio
  - Superimpose signal and background PDFs from primary likelihood fit.
- sPlots (ref: physics/0402083)
  - Weighted histogram of mES
    - Weights determined from other variables in fit
    - Weights chosen so histogram is unbiased estimator of m_{ES} for signal contribution. (or background)