BaBar Physics Program

Jeffrey D. Richman

BaBar Physics Coordinator

UC Santa Barbara and SLAC

DOE High Energy Physics Program Review, June 3, 2004

Outline

- **Major physics goals**
- **Physics productivity, organization, planning**
- **Physics progress: a sampling**
  - **CP violation in *B* decays: a brief primer**
  - **The new sin2b program: the charmonium benchmark vs. the penguins**
  - **Quest for alpha: a new approach**
  - **Rare decays: a growth industry**
  - ***B* "beams" & their applications—CKM elements and the dynamics of B decay**
  - **Surprising spectroscopy: the new charm-strange mesons**
- **Prospects for summer 2004 and beyond**
- **Conclusions**

BABAR Physics Goals

1. Perform comprehensive set of measurements of CP-violating asymmetries in *B* meson decays. Test the SM and search for CP-violating amplitudes from processes beyond the SM.
2. Systematically map out the new territory of rare *B* decay processes, including all that have sensitivity to new physics. (Also probe new physics in τ and charm decays.)
3. Measure the rates for all processes that can be used to extract the magnitudes of CKM elements and other well-defined theoretical parameters.
4. Perform detailed studies to elucidate the decay dynamics and spectroscopy of particles containing *b* or *c* quarks.
5. Perform studies of other accessible physics processes allowed by the broad acceptance of the *BABAR* trigger: τ-lepton physics, physics utilizing ISR processes (including R-related measurements at low energy), searches for new states such as pentaquarks, etc.

Publications: *BABAR* vs. Belle (published or submitted)

	BABAR	Belle
<2003	34	54
2003	47	28
2004 (June 1)	16	10
Total	97	92

- ***BABAR*** **papers are labeled according to the date the paper goes into 2-week Collaboration Wide Review (CWR).**
- **At time of Jan IFC meeting: 75 (*BABAR*) vs. 77 (Belle).**
- **Analyses now in CWR or FN/FR:** (1) $B \rightarrow f_0 K_S$, (2) $B \rightarrow K^*$g, (3) $B \rightarrow D^* l$n: *Vcb*, (4) $B \rightarrow$ tn , (5) $B \rightarrow a_0 X$ (charmless)
- **Other papers nearing completion:** (1) $B \rightarrow K_2^*(1430)$g, (2) $B \rightarrow D^{(*)} D_{sJ}$, (3) $B \rightarrow J/y\ K$p: cos(2b), (4) $B \rightarrow D^* D^*$ and related modes
- ***GOAL: submit 100th paper by the July collaboration meeting!***

Some recent physics highlights - June 2004

- $B \to r^+ r^-$: 1st observation of mode; demonstrated that polarization is almost 100% longitudinal → CP=+1, not a mix. (PRL accepted.)
- $B \to r^+ r^-$: 1st time-dependent CP asymmetry: presented at La Thuile and Moriond. Since G-Q bound is 13 degrees, this measurement provides a much better constraint on a than $B \to p^+ p^-$. Belle has not yet produced a branching fraction measurement. Submitted to PRL.
- $B \to K_S\, p^0$: 1st time-dependent CP analysis; b measurement using beam constraint to get *B* vertex. Submitted to PRL.
- $B \to K^{*0}\, (\to K_S\, p^0)\, g$: 1st time-dependent CP analysis of an electroweak penguin mode. Submitted to PRL.
- $B \to f_0(980) K_S$: 1st time-dependent CP analysis (b) and observation of new mode. PRL draft in Final Notice.
- $B \to J/y\ Kp$: 1st ambiguity-free measurement of cos2b and strong phases using *s*-wave *Kp* interference with *p*-wave (*K**). Preliminary result presented at Moriond EW. PRD in progress.

Some recent research highlights - June 2004

- $|V_{cb}|$ from inclusive B decays, hadron spectrum moments, lepton spectrum moments: 2 PRDs accepted and 1 PRL submitted. Uncertainty on $|V_{cb}|$ is significantly reduced.
- $B \rightarrow f K_S$, $B \rightarrow f K_L$: final Run 1-3 result, submitted to PRL
- $B \rightarrow K^+ K^- K_S$ with $m(K^+K^-)$ above the *f* mass (sin2*b* measurement consistent with $B \rightarrow J/y\ K_S$). *BABAR* and Belle agree above the *f* mass! PRL submitted.
- $B \rightarrow$ *h w (4.3s), hh, hh', h'h', h f, h'w, h'f , ff* : PRL submitted.
- $B \rightarrow D(Kp)\ K$ (Atwood Dunietz Soni method) –limit: submitted to PRL
- Observation of *X(3872)* in $B \rightarrow X(3872)K$; presented at Moriond QCD, PRL in Final Notice.
- Observation of *DsJ(2317)* and *DsJ(2460)* in *B* decay. Presented at Moriond QCD. Several new modes observed. PRD in preparation.
- Angular analysis of $B \rightarrow f K^*$ preliminary result presented at Moriond. Mystery of the very low longitudinal polarization (52%) compared to other $B \rightarrow VV$ modes. Will be updated with Run 4 before publication.

Current analysis status- June 2004

Research highlights, continued

- $B \rightarrow h'(K^*, r, p^0) + (w, f)\, p^0$: PRD submitted
- $B \rightarrow X_s\, l^+ l^-$: PRL submitted
- $B \rightarrow X_s\, g$ *direct CP:* PRL submitted
- $B \rightarrow K^* g$ *branching fractions and direct CP search*: PRL in Final Notice.
- $B \rightarrow a_0\, (K, K^0, p)$: now in CWR
- $B \rightarrow K^0 p^+ p^-$: preliminary result
- New results for APS! $B \rightarrow ppK$; $B \rightarrow wr$, $K^* w$; $B \rightarrow fg$; 1st results from pentaquark searches.

Other recent physics papers

- $B^+ \to h\ p^+$, $h\ K^+$, $B^0 \to wK^0$ **1st observations: accepted**
- **Color suppressed B decays: $B \to D^{*0}\ h$, $D^{*0}\ w$, $D^0\ h'$ 1st observations: accepted**
- $B \to J/y\ h\ K$ **1st observation: submitted**
- DG **and CPT limits from $B \to J/y\ K^0$: PRL and PRD submitted**
- **sin(2b+g): inclusive & exclusive $B \to D^* p$: 2 papers submitted**
- $B \to p\ \bar{p}$ **search accepted**
- t$\to$**3 leptons (limits): accepted (Belle paper followed)**
- **D_s(2458): accepted**
- **Mass and width of Y(4S): submitted**

BABAR Physics Planning
Fall 2003/Winter 2004

CKM Angles, Recoil Workshops

τ, V_{xb} Workshops

Spectroscopy workshop: charm, charmonium, pentaquarks → May

Stage 1

AWGs, Conveners, PAC

• BAD 736

Review

Physics Advisory Group

• BAD 780

Stage 2→BAIS

AWGs, Conveners (many new), PAC

• Enter active & summer 2004 analyses in BAIS

PAC/Convener Regular Meetings

Fall Physics Harvest

AWGs, Conveners, PAC, Pub Board

Winter Conference Prep

AWGs, Conveners, PAC, Pub Board, Speakers Bureau; see links on BABAR home page & Physics page.

Sep — Oct — Nov — Dec — Jan — Feb — Mar

Physics Organization: Working Groups

Physics AWG	Conveners (new since Sep 03)
sin2b/Mixing & Lifetime	David Lange, Owen Long
B decays to charm final states (Breco)	Vivek Sharma, Wouter Verkerke
Charmonium	Enrico Robutti, Denis Bernard
Inclusive Hadronic B Decay (IHBD)	Abi Soffer, Sergey Ganzhur
Charmless 2 Body	Gianluca Cavoto, Carlo Dallapiccola
Charmless Quasi 2 Body	Jim Smith, Adrian Bevan
Charmless 3 Body	Andreas Hoecker, Yibin Pan
Radiative Penguin	Jeff Berryhill, Jim Libby
Exclusive Semileptonic	Franco Simonetto, Robert Kowalewski
Inclusive Semileptonic	Riccardo Faccini, Vera Luth
Leptonic	Steven Robertson, Gregory Dubois-Felsmann
Charm	David Williams, Antimo Palano
Tau/QED	Mike Roney, Eric Torrence
Inclusive Hadronic Particle Spectra	Blair Ratcliff, David Muller

Tools Group	Conveners (new since Sep 03)
Generators	Abi Soffer
Particle ID	Thorsten Brandt, David Aston
Neutrals	Vincent Tisserand, David Payne
Tracking efficiency task force	Thomas Allmendinger
Tracking [in computing]	Wouter Hulsbergen
Tagging	David Lange, Gabriella Sciolla
Pentaquark Task Force	Pat Burchat, Valerie Halyo
Physics Software Manager	Chris Roat→Chih-hsiang Chen
Data Quality Group Coordinator	Chris Hearty→Walter Toki
Data Quality Group Deputy	Walter Toki→David Hutchcroft
Publications Board (12 members)	Chair: G.H. Monchenault→Robert Cahn

Powerful physics organization

- AWG Leadership has broad geographical base
- Conveners: many leadership opportunties for postdocs
- 21 new Physics/Tools Group conveners since Sept 03
- Formal links between Tools groups and Physics Groups

Comments on Physics Productivity

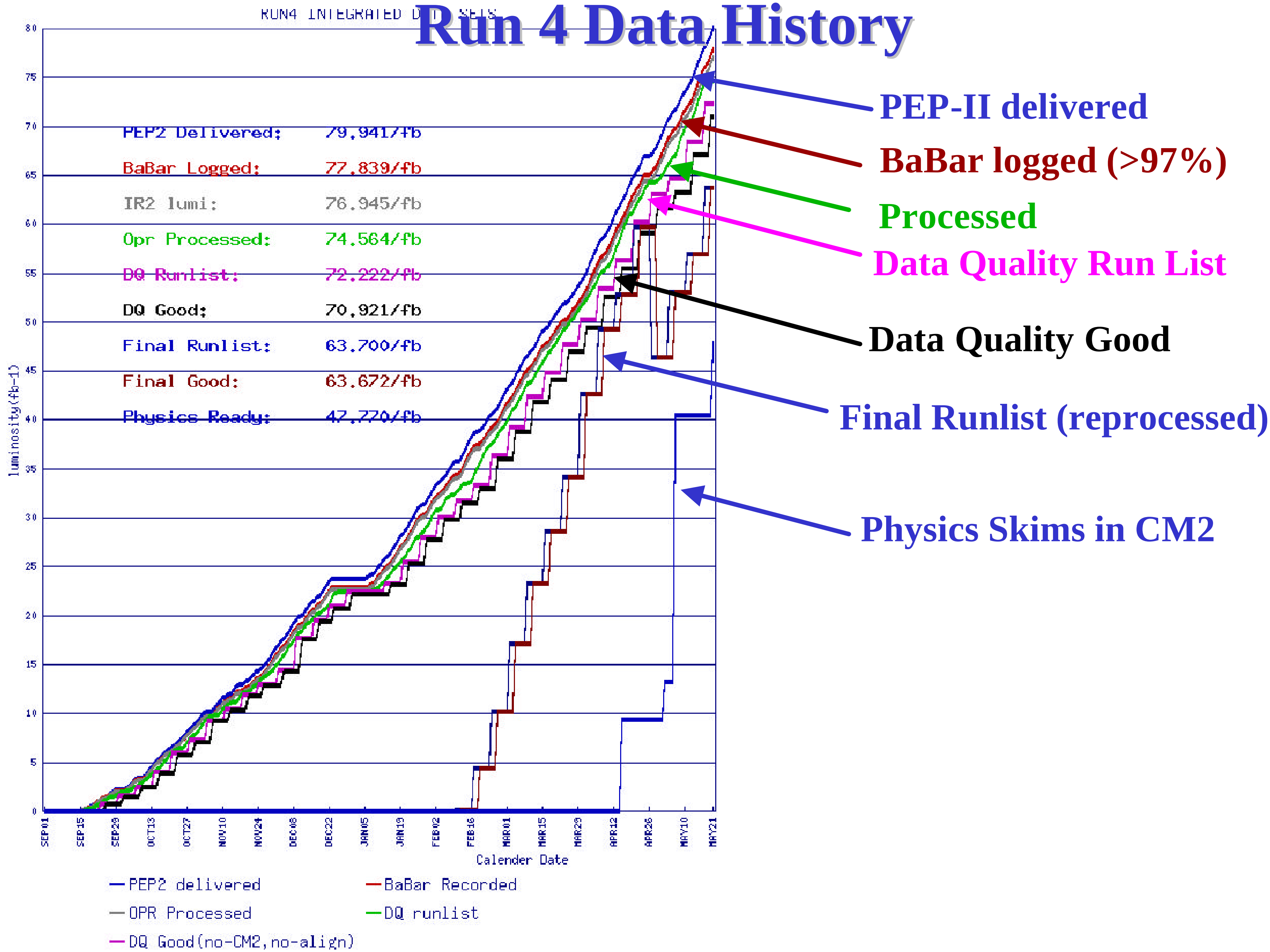
- **We are working to increase physics productivity even more:**
  - **Maintain very strong emphasis on physics planning.**
  - **We are working towards making the review process more efficient, while maintaining the quality of our results.**
  - **Steady stream of theorists interacting with physics analysis groups. Series of physics workshops to generate ideas and facilitate planning.**
  - **New “interdisciplinary” meetings across analysis working groups.**

PAC Champagne Challenges

Data Quality Group

- <u>In fall 2003, we greatly strengthened our effort to monitor and control data quality.</u>
  - Have always had online data quality monitoring & a small number of people looking at data quality offline.
  - Offline effort is now much larger (about 20 people) and has leadership from senior physicsists. Coordinated effort of Detector, Computing, and Physics organizations. This is essential, given how rapidly we take data.
- The DQG monitors several different data streams:
  - Run 4 data & Run 4 reprocessing with final constants
  - Run 1—3 conversion to CM2
  - Trickle injection monitoring
  - Overall rates from physics skims
- Data quality protocol based on rapid data processing in Padova & SLAC
  - Tues morning: run list up to Mon is defined
  - by Weds night: subsystem experts define individual bad run lists
  - Thurs weekly meeting: define official good run list

Run 4 Data History



Physics Analysis Database: new starting Jan 2004

BAIS - BaBar Analysis Information System

Help | Analysis Index | Analysis Detailed Index | AWG Index | IRG Index | Admin & Maintenance

Create new analysis entry | Create new AWG | Review Committees | Analyst List | Reviewer List

HN userid: "richman"

Analysis index for all AWGs

BAIS contains 235 analyses.

Already has 235 analyses entered!

Analysis Selection & Sort Form

Sort by: AWG Code | Publication Status | Analysis Name | Conference Status

Sort order: Ascending | Descending

Select AWG: Any

Select target publication period: Any

Select target publication: Any

Select target conference: Any

Sorting and searching

Access to supporting documentation and publication, review committees, data samples used, code releases used, status history.

Sorted by AWG code, in ascending order. This result contains 235

	AWG Code	Analysis Name	Publication Status	Target Pub Period	Target Journal	Conference Status	Target Conference	Review Comm.
1	breco-02/01	Study of the decay B- to D*0 K*-	PUB	3/03	PRL	APPROVED/INTERNAL	FPCP 2003	
2	breco-02/02	BF of the decay B- to D0 K*- (KS pi)	ACCEPT	4/03	PRD-RAPID	APPROVED/INTERNAL	LP'03	comm83 [HN06]
3	breco-02/03	BF and ACP of B- to D0(CP+)K-/pi-	ACCEPT	4/03	PRL			comm26 [HN06]
4	breco-02/04	BF of Color-Suppressed Decays of the B0 to D(*)0 (pi0,eta,omega,rho0,eta_prime)	ACCEPT	4/03	PRD			
5	breco-02/05	Measurement of sin(2b+g) in fully reconstructed B->D(*)pi decays	ACCEPT	3/03	PRL	APPROVED/INTERNAL	EPS HEP2003	comm71 [HN71]

https://www.slac.stanford.edu/babar-internal/BAIS/info/analyses.html?bat_id=226

Physics Analysis Database: Info for one Analysis Working Group

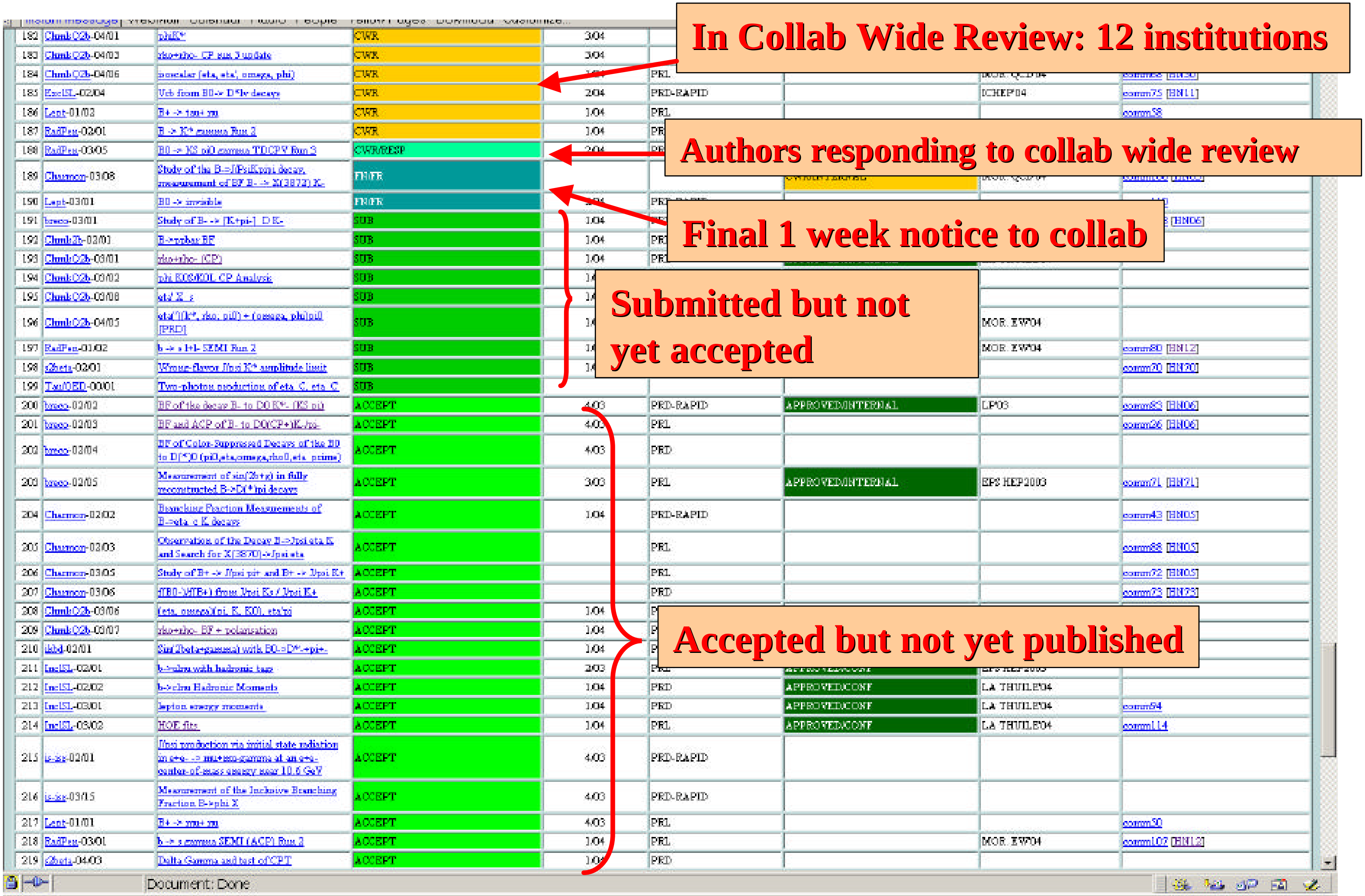
Analysis name: link to details

Status code

	AWG Code	Analysis Name	Publication Status	Target Pub Period		nce Status	Target Conference	Review Comm.
1	ChmlsQ2b-01/01	eta'K, omegapi/K BR (run1)	PUB	4/01	PRL		LP'01	
2	ChmlsQ2b-01/02	phiK(*) BR (run 1)	PUB	4/01	PRL		LP'01	
3	ChmlsQ2b-02/01	eta'K, omegapi, phiK(*) Acp (run 1)	PUB	4/02	PRD-RAPID		MOR. EW'02	
4	ChmlsQ2b-03/01	rho+rho- (CP)	SUB	1/04	PRL	APPROVED/INTERNAL	LA THUILE'04	
5	ChmlsQ2b-03/02	phi K0S/K0L CP Analysis	SUB	1/04	PRL	APPROVED/CONF		
6	ChmlsQ2b-03/03	eta'K run1+2	PUB		PRL			
7	ChmlsQ2b-03/04	phiK BF, Acp run 1+2	PUB	4/03	PRD-RAPID			
8	ChmlsQ2b-03/05	VV PRL '03	PUB	3/03	PRL			
9	ChmlsQ2b-03/06	(eta, omega)(pi, K, K0), eta'pi	ACCEPT	1/04	PRL			
10	ChmlsQ2b-03/07	rho+rho- BF + polarisation	ACCEPT	1/04	PRD-RAPID		LP'03	
11	ChmlsQ2b-03/08	eta' X_s	SUB	1/04	PRL			
12	ChmlsQ2b-03/09	omega(K*, rho)	CWR	2/04				comm128
13	ChmlsQ2b-04/01	phiK*	CWR	3/04		APPROVED/CONF	ICHEP'04	comm119
14	ChmlsQ2b-04/02	rho0rho0 search '04	AWG/RC	3/04			ICHEP'04	comm121
15	ChmlsQ2b-04/03	rho+rho- CP run 3 update	CWR	3/04			MOR. EW'04	comm95
16	ChmlsQ2b-04/04	phiphiK	AWG	3/04			ICHEP'04	
17	ChmlsQ2b-04/05	eta(')(k*, rho, pi0) + (omega, phi)pi0 [PRD]	SUB	1/04	PRD		MOR. EW'04	
18	ChmlsQ2b-04/06	isoscalar (eta, eta', omega, phi)	CWR	1/04	PRL		MOR. QCD'04	comm68 [HN30]
19	ChmlsQ2b-04/07	a0^(+/0) (pi/K/K0)	AWG/RC	1/04		APPROVED/CONF	MOR. EW'04	comm115
20	ChmlsQ2b-04/08	K*0rho+ etc	RC-REQ	2/04			ICHEP'04	
21	ChmlsQ2b-04/09	rho+rho- (CP) run1-4	AWG	3/04	PRD		ICHEP'04	
22	ChmlsQ2b-04/10	a1pi, K	AWG/RC	4/04			ICHEP'04	comm137
23	ChmlsQ2b-04/11	eta' K0s run 4 update	AWG/RC				ICHEP'04	comm139
24	ChmlsQ2b-04/12	BR and Acp of etapi, K,omega and		4/04			ICHEP'04	

Document: Done

Physics Analysis Database: Analyses in Final Stages



182	ChmkQ2b-04/01	phiK*	CWR	3/04				
183	ChmkQ2b-04/03	rho+rho- CP run 3 update	CWR	3/04				
184	ChmbQ2b-04/06	pscalar (eta, eta', omega, phi)	CWR		PRL			
185	ExclSL-02/04	Vcb from B0-> D*lv decays	CWR	2/04	PRD-RAPID		ICHEP'04	comm75 [HN11]
186	Lept-01/02	B+ -> tau+ nu	CWR	1/04	PRL			comm58
187	RadPen-02/01	B -> K* gamma Run 2	CWR	1/04	PR			
188	RadPen-03/05	B0 -> KS pi0 gamma TDCPV Run 3	CWR/RESP					
189	Charmon-03/08	Study of the B->J/PsiKpipi decay, measurement of BF B- -> X(3872) K-	FN/FR					
190	Lept-03/01	B0 -> invisible	FN/FR					
191	breco-03/01	Study of B- -> [K+pi-]_D K-	SUB	1/04				[HN06]
192	ChmkZb-02/01	B->rhobar BF	SUB	1/04	PR			
193	ChmkQ2b-03/01	rho+rho- (CP)	SUB	1/04	PR			
194	ChmkQ2b-03/02	phi K0S/K0L CP Analysis	SUB					
195	ChmkQ2b-03/08	eta' X_s	SUB					
196	ChmkQ2b-04/05	eta'(K*, rho, pi0) + (omega, phi)pi0 [PRD]	SUB				MOR. EW'04	
197	RadPen-01/02	b -> s l+l- SEMI Run 2	SUB				MOR. EW'04	comm80 [HN12]
198	s2beta-02/01	Wrong-flavor J/psi K* amplitude limit	SUB					comm70 [HN70]
199	Tau/QED-00/01	Two-photon production of eta_C, eta_C'	SUB					
200	breco-02/02	BF of the decay B- to D0 K*- (KS pi)	ACCEPT	4/03	PRD-RAPID	APPROVED/INTERNAL	LP03	comm83 [HN06]
201	breco-02/03	BF and ACP of B- to D0(CP+)K-/pi-	ACCEPT	4/03	PRL			comm26 [HN06]
202	breco-02/04	BF of Color-Suppressed Decays of the B0 to D(*)0 (pi0,eta,omega,rho0,eta_prime)	ACCEPT	4/03	PRD			
203	breco-02/05	Measurement of sin(2b+g) in fully reconstructed B->D(*)pi decays	ACCEPT	3/03	PRL	APPROVED/INTERNAL	EPS HEP2003	comm71 [HN71]
204	Charmon-02/02	Branching Fraction Measurements of B->eta_c K decays	ACCEPT	1/04	PRD-RAPID			comm43 [HN05]
205	Charmon-02/03	Observation of the Decay B->Jpsi eta K and Search for X(3870)->Jpsi eta	ACCEPT		PRL			comm88 [HN05]
206	Charmon-03/05	Study of B+ -> J/psi pi+ and B+ -> Jpsi K+	ACCEPT		PRL			comm72 [HN05]
207	Charmon-03/06	r(B0-)/f(B+) from Jpsi Ks / Jpsi K+	ACCEPT		PRD			comm73 [HN73]
208	ChmkQ2b-03/06	(eta, omega)(pi, K, K0), eta'pi	ACCEPT	1/04	P			
209	ChmkQ2b-03/07	rho+rho- BF + polarization	ACCEPT	1/04	P			
210	ikbd-02/01	Sin(2beta+gamma) with B0->D*-+pi+-	ACCEPT	1/04	P			
211	InclSL-02/01	b->ulnu with hadronic tags	ACCEPT	2/03	PRL			
212	InclSL-02/02	b->clnu Hadronic Moments	ACCEPT	1/04	PRD	APPROVED/CONF	LA THUILE'04	
213	InclSL-03/01	lepton energy moments	ACCEPT	1/04	PRD	APPROVED/CONF	LA THUILE'04	comm94
214	InclSL-03/02	HQE fits	ACCEPT	1/04	PRL	APPROVED/CONF	LA THUILE'04	comm114
215	is-ks-02/01	J/psi production via initial state radiation in e+e- -> mu+mu-gamma at an e+e- center-of-mass energy near 10.6 GeV	ACCEPT	4/03	PRD-RAPID			
216	is-ks-03/15	Measurement of the Inclusive Branching Fraction B->phi X	ACCEPT	4/03	PRD-RAPID			
217	Lept-01/01	B+ -> mu+ nu	ACCEPT	4/03	PRL			comm50
218	RadPen-03/01	b -> s gamma SEMI (ACP) Run 2	ACCEPT	1/04	PRL		MOR. EW'04	comm107 [HN12]
219	s2beta-04/03	Delta Gamma and test of CPT	ACCEPT	1/04	PRD			

Physics Analysis Database: Info on an analysis

Data samples and code release

"richman"

BF and ACP of B- to D0(CP+)K-/pi- — Analysis Details

Quick links to other analyses in this AWG: breco-02/01, breco-02/02, breco-02/04, breco-02/05, breco-02/06, breco-02/07, breco-02/08, breco-02/09, breco-02/10, breco-03/01, breco-03/03, breco-03/04, breco-03/06, breco-03/08, breco-03/09, breco-03/10, breco-03/11, breco-03/12, breco-03/13, breco-03/14, breco-03/15, breco-03/16, breco-03/17, breco-04/03, breco-04/04, breco-04/05, breco-04/06, breco-04/07

Authors & review committee

AWG Code	Analysis Name	Description	Data Information	Schedule/Timeline	Updated (By)	Created (By)
Status: ACCEPT; Status: N/A	BF and ACP of B- to D0(CP+)K-/pi-	We present the measurement of the Cabibbo suppressed decays B- ->D0K-, with D^0 reconstructed in the decay channels K^-\pi^+, K^-\pi^+\pi^+\pi^- and K^-\pi^+\pi^0, in a sample of 61.0 million \FourS\ decays into BBbar pairs collected with the BaBar detector at the PEP-II asymmetric-energy e+e- storage ring. We also report observation of the Bch->D0cp K decays, where D0cp is reconstructed into the CP-even \pi^-\pi^+ and K^-K^+ channels, in a sample of 88.8 million BBbar pairs. We measure the ratio of Cabibbo suppressed to Cabibbo favored branching fractions BR(Bch->D0K)/BR(Bch->D0pi)=(8.31+-0.35+-0.20)10^{-2}. We also measure the ratio [BR(B^- ->D0cpK^-)+BR(B^+ ->D0cpK^+)]/[BR(B^- ->D0cp pi^-)+BR(B^+ ->D0cp pi^+)]= (8.8+-1.6+-0.5)10^{-2} and the CP asymmetry [BR(B^- ->D0cpK^-)-BR(B^+ ->D0cpK^+)]/[BR(B^- ->D0cpK^-)+BR(B^+ ->D0cpK^+)]= 0.07+-0.17+-0.06.	**Sources:** Objy; **Samples:** Run1 Run2; **Additional comments:**		09 February 2004 13:30 (verkerke)	30 January 2004 14:33 (verkerke)

Analysts	Batignani, Giovanni; Marchiori, Giovanni; Rama, Matteo
Review Committee	comm26 [HN06] Members: Fry, John R., Lee
Institutional Reading Group	None
Target Publication Period	4th Quarter 2003
Target Journal	Physical Review Letters (PRL)
Target Conference	

Links to supporting documentation, drafts, and publication

BADs:

BAD #	Doc Type(s)	BAD Title
BAD 0404	Supporting Document	Analysis of B->D0(CP)K decays
BAD 0571	Journal Draft	Measurement of B- ->D0(CP)K- decays with the BaBar detector

PubDb Doc:

BaBar #	Preprint #	SLAC PUB #	PubDb Title
PUB-03/032	hep-ex/0311032	–	Measurement of B- -> D0_(CP)K- decays with the BaBar detector

Other D…
Internal …
Related …

Document: Done

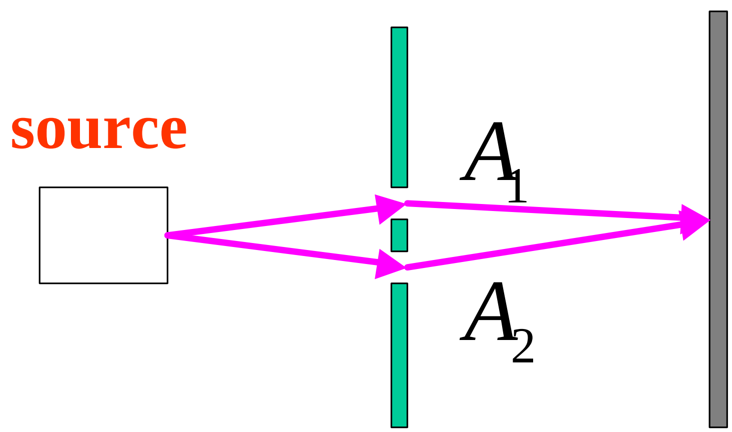
Most of our physics analyses are performed by a small group of authors. Huge number of opportunities for graduate students and postdocs!

CP Violation Primer

- **CP violation can be observed by comparing decay rates of particles and antiparticles**

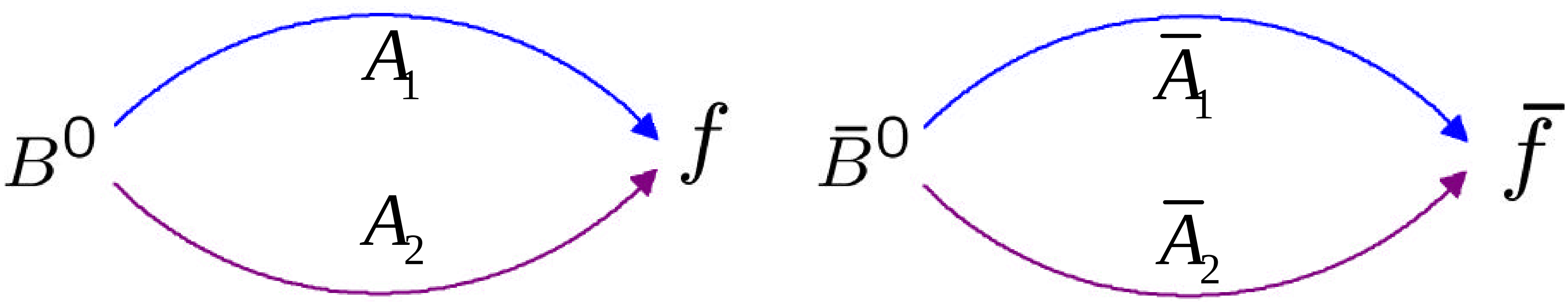
$$\Gamma(a \to f) \neq \Gamma(\bar{a} \to \bar{f}) \quad \Rightarrow CP \text{ violation}$$

- **The difference in decay rates arises from a different interference term for the matter vs. antimatter process. Analogy to double-slit experiment:**

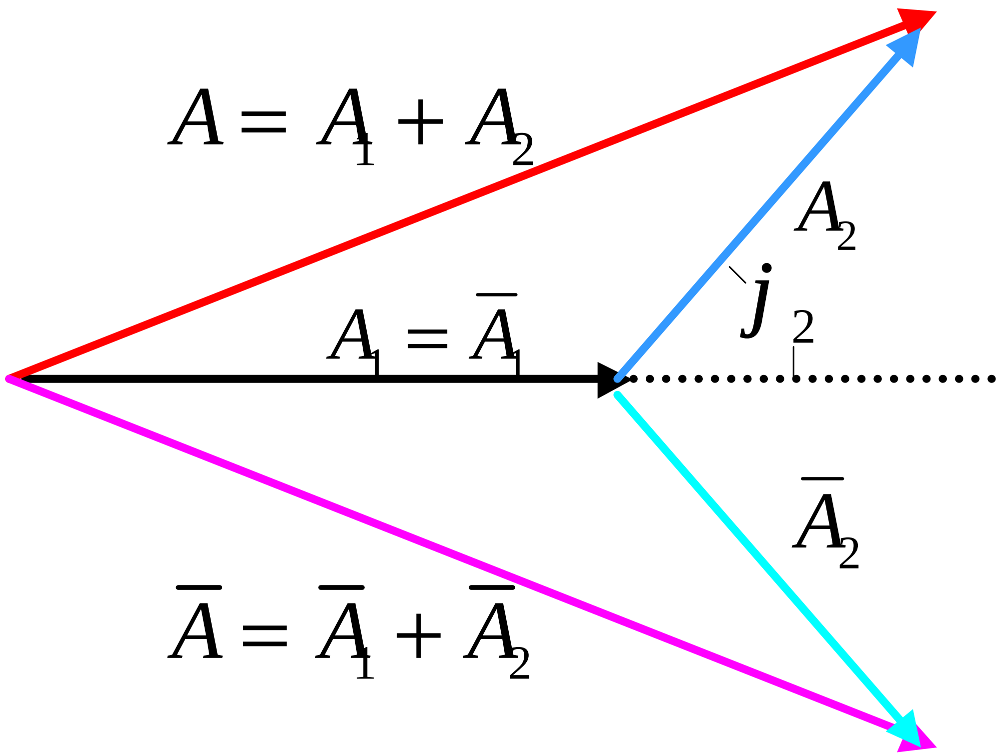


Classical double-slit experiment:
Relative phase variation due to different path lengths: interference pattern in space

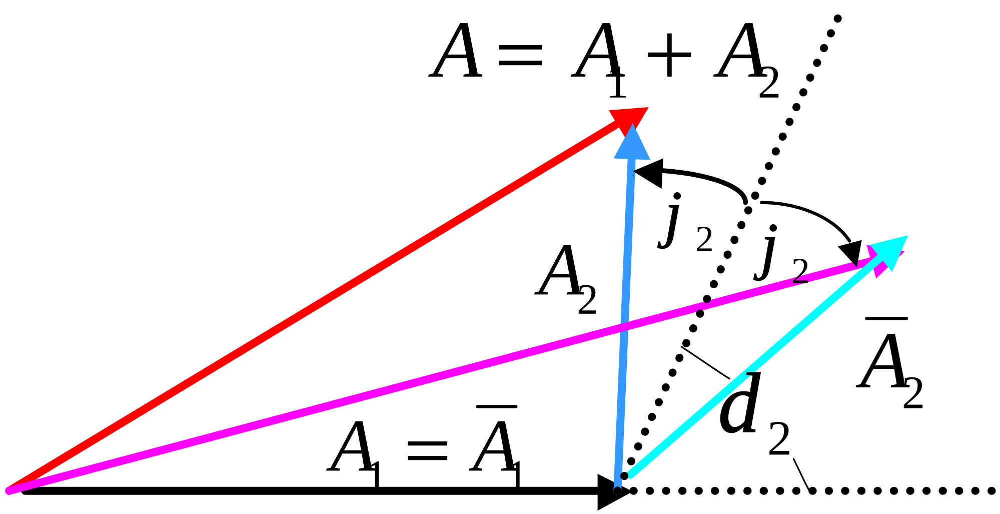
B system: extraordinary laboratory for quantum interference experiments: many final states, multiple "paths."



Conditions for CP violation



- **Two amplitudes, *A_1* and *A_2*, with a relative CP-violating phase (f_2) only.**
- **No CP violation: the magnitudes of *A* and *$\bar{A}$* are the same!**



- **Two amplitudes, *A_1* and *A_2*, with <u>both</u> a relative CP-violating phase and CP-conserving phase (d_2).**
- **Now have CP violation!**

A dictionary of CP violating effects in decay processes

- CP violation in the interference between two decay amplitudes ("Direct CP violation")
  - Decay amps must have different CP violating and CP conserving phases.
  - CP conserving phase from strong, final-state interaction, so difficult to interpret results in terms of CKM parameters
  - Can measure in both $B^0/\overline{B}^0$ and B^+/B^- decays (time-indep); tagging not needed
- CP violation in mixing
  - Interference is between bundle of amplitudes with on-shell (real) intermediate states and bundle of amplitudes for off-shell (virtual) intermediate states.
  - CP conserving phase from mixing
  - B mixing is completely dominated by processes with virtual intermediate states, so there is very little CP violation in mixing (q/p).
- CP violating in the interference between mixing and decay amplitudes
  - Tagging required
  - CP conserving phase from mixing
  - If only one direct decay amplitude, has clean CKM interpretation

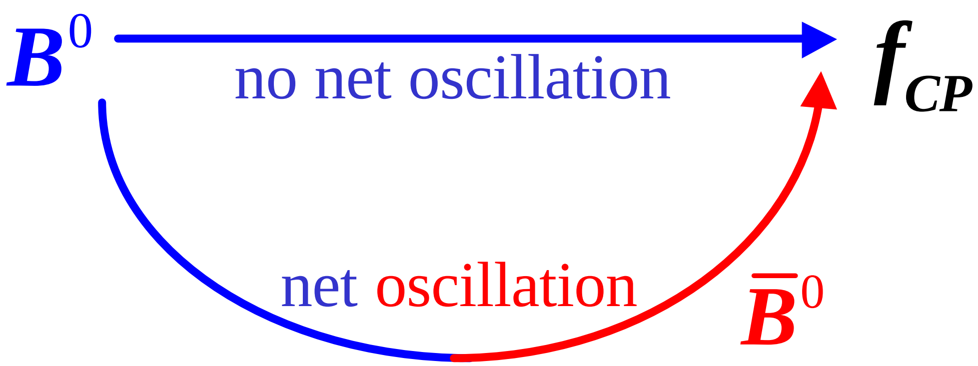
Looking for the perfect way to study CP violation

Type of CP violation	Sources of amplitudes	Source of CP conserving phase	Remarks
Direct	2 or more direct decay amplitudes	strong, final-state interactions; value is usually not known	Can study both neutral and charged particle decays.
CPv in particle-antiparticle oscillations (mixing) (K^0-$\overline{K^0}$, B^0-$\overline{B^0}$)	DG: group of amps with real intermediate states DM: group of amps with virtual intermediate states	mixing phase: between real and virtual amplitudes	Dependence on theory. Very small in B system due to tiny DG.
CP from interference between mixing & decays	direct decay after no net mixing and decay after mixing	phase in mixing: exactly known!	Interference pattern in time due to time-dependence of mixing amplitude.

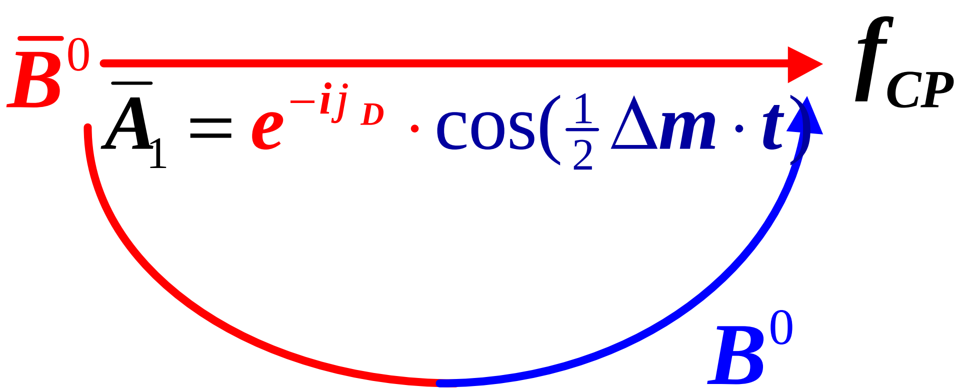
In the SM, the CKM matrix is the only source of CP violating phases.

Time-dependent CP asymmetries from the interference between mixing and decay

$$A_1 = e^{ij_D}\cos(\tfrac{1}{2}\Delta m \cdot t)$$



$$A_2 = ie^{-2ij_M}\sin(\tfrac{1}{2}\Delta m \cdot t)e^{-ij_D}$$



$$\bar{A}_1 = e^{-ij_D}\cdot\cos(\tfrac{1}{2}\Delta m \cdot t)$$

$$\bar{A}_2 = ie^{+2ij_M}e^{+ij_D}\cdot\sin(\tfrac{1}{2}\Delta m \cdot t)$$

$$\Gamma(B^0_{phys}(t) \to f_{CP})$$

$$\neq$$

$$\Gamma(\bar{B}^0_{phys}(t) \to f_{CP})$$

Requires tagging and measurement of time dependence.

Calculating the CP Asymmetry

$$A_{f_{CP}}(t) = \frac{\left|\langle f_{CP}|H|\overline{B}^0(t)\rangle\right|^2 - \left|\langle f_{CP}|H|B^0(t)\rangle\right|^2}{\left|\langle f_{CP}|H|\overline{B}^0(t)\rangle\right|^2 + \left|\langle f_{CP}|H|B^0(t)\rangle\right|^2} = \frac{\Gamma\left(\overline{B}^0(t)\to f_{CP}\right) - \Gamma\left(B^0(t)\to f_{CP}\right)}{\Gamma\left(\overline{B}^0(t)\to f_{CP}\right) + \Gamma\left(B^0(t)\to f_{CP}\right)}$$

$$A_{f_{CP}}(t) = S\cdot\sin(\Delta m\cdot t) - C\cdot\cos(\Delta m\cdot t)$$

$$S = \frac{2\cdot \mathrm{Im}(l)}{1+|l|^2} \qquad C = \frac{1-|l|^2}{1+|l|^2}$$

If single direct-decay amp, hadronic matrix element divides out, leaving pure phase.

Pure phase factor in B decays since mixing is dominated by M_{12} (virtual intermediate states).

$$l = \sqrt{\frac{M_{12}^* - \frac{i}{2}\Gamma_{12}^*}{M_{12} - \frac{i}{2}\Gamma_{12}}}\cdot\frac{\langle f_{CP}|H|\overline{B}^0\rangle}{\langle f_{CP}|H|B^0\rangle}$$

$$|l| = 1 \Rightarrow S = \mathrm{Im}(l) \text{ and } C = 0$$

The magic of having just one direct decay amplitude

Even through we are using hadronic final states, the complexities of QCD interactions are completely avoided!

$$|l| = 1 \qquad A_{f_{CP}}(t) = \mathrm{Im}(l) \cdot \sin(\Delta m \cdot t)$$

For the modes *B→J/y K$_S$ (J/y K$_L$)*

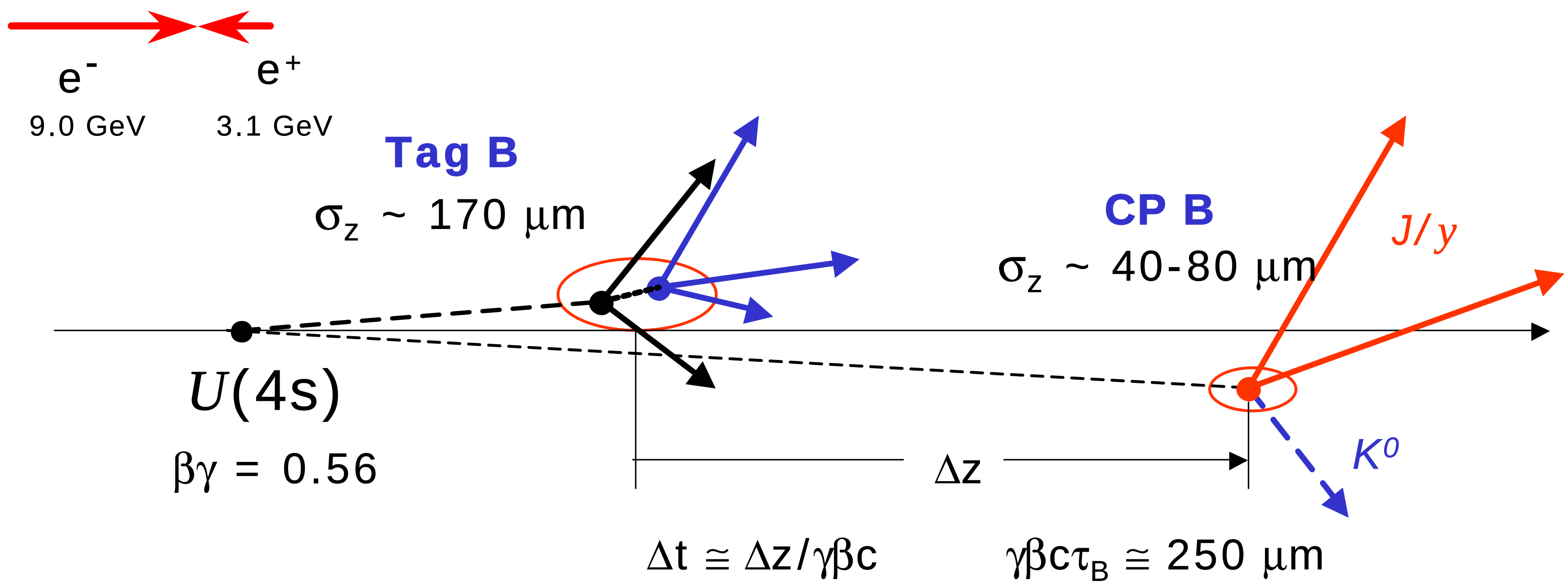
$$A_{J/y\,K^0_{S,L}}(t) = -h_{J/y\,K^0_{S,L}} \cdot \sin(2b) \cdot \sin(\Delta m \cdot t)$$

If CP violation is due to *interference between mixing and one direct decay amp*:

- **Pure sin(*Dm t*) time dependence**
- **No dependence of asymmetry on hadronic physics**

The Lorentz Boost

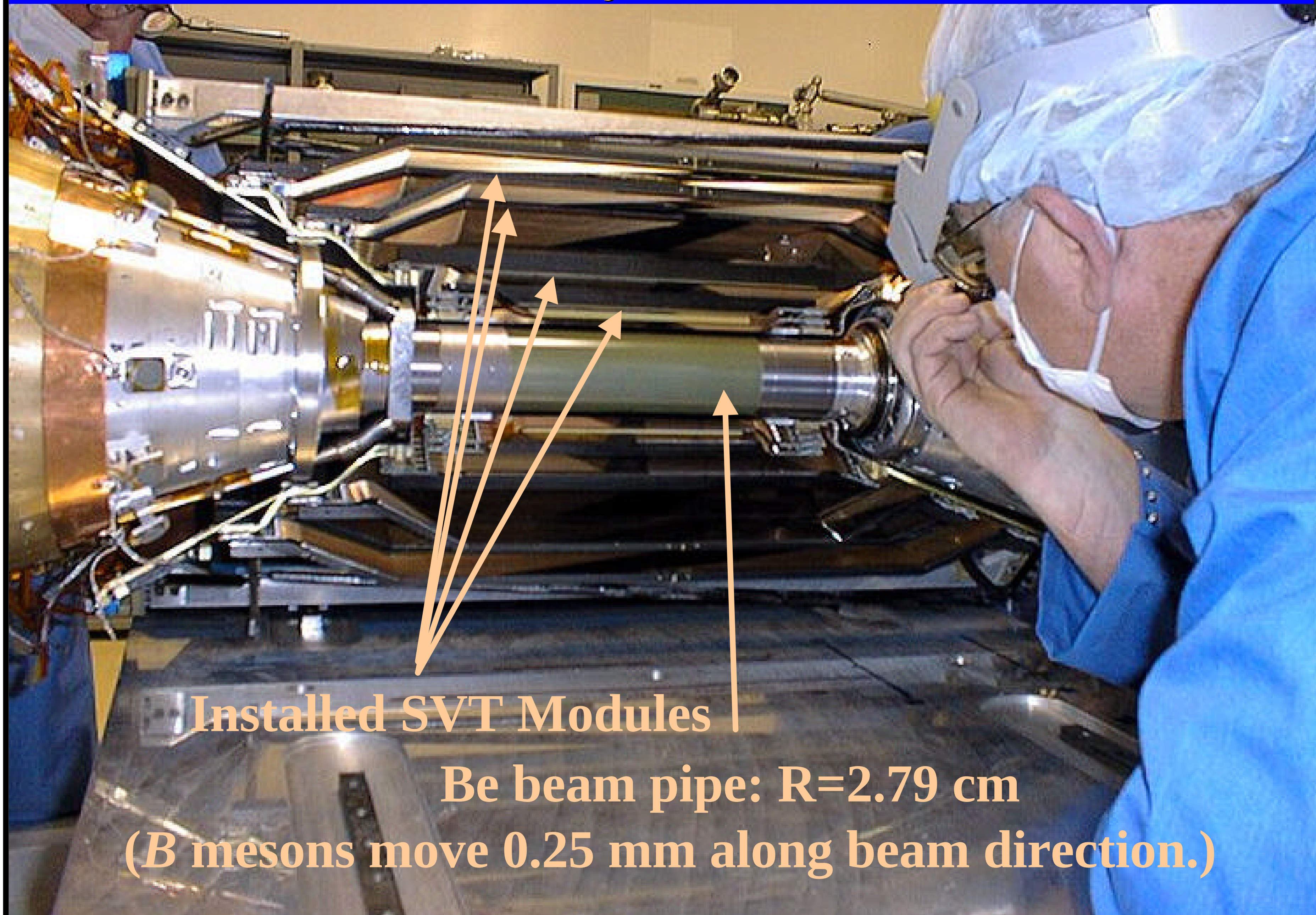
- **The asymmetric beam energies of PEP-II allow us to measure quantities that depend on decay time.**



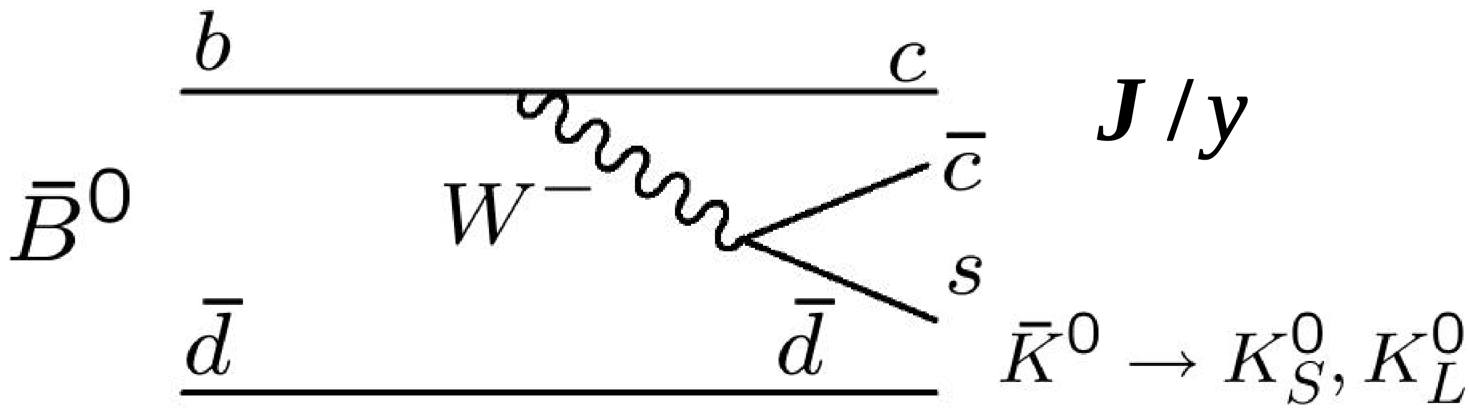
$$1\ \text{ps} \Leftrightarrow 170\ \mu\text{m}$$

$$1.6\ \text{ps} = t_B \Leftrightarrow 250\ \mu\text{m}$$

Innermost Detector Subsystem: Silicon Vertex Tracker

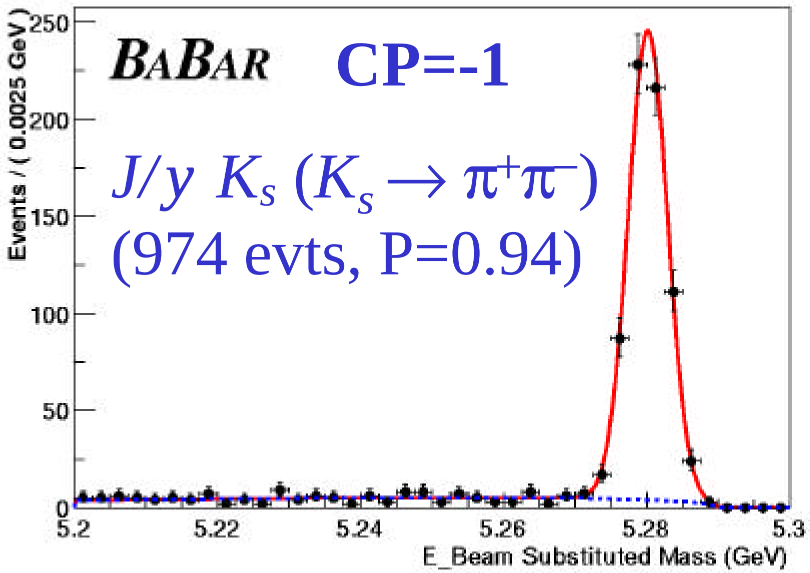


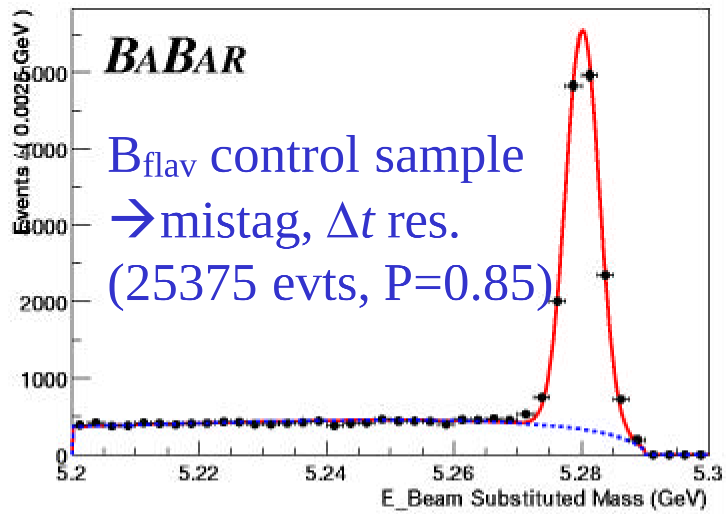
The sin2*b* program: the charmonium benchmark vs. the penguins

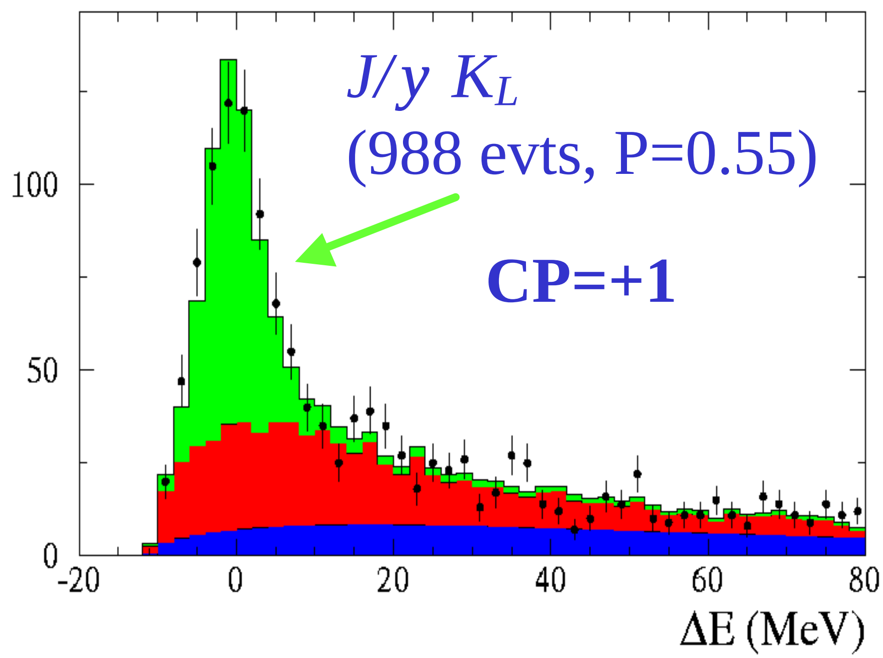


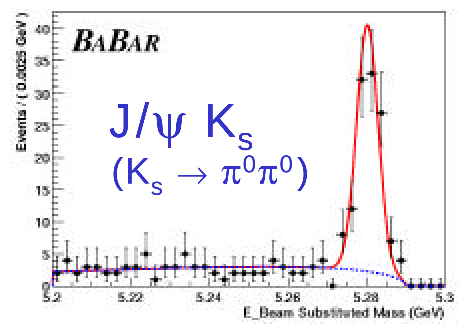
- sin2b from $b \rightarrow c\bar{c}s$ modes was last published by *BABAR* with Runs 1-2 (88 M BB events). Published in PRL, 89, 20182 (2002).
- We will add Runs 3-4 for ICHEP'04 and then publish. sin2b is becoming a precision measurement.
- We have also improved our tagging software, so there should be some modest additional improvement beyond the added statistics.
- Theory error < 1%.

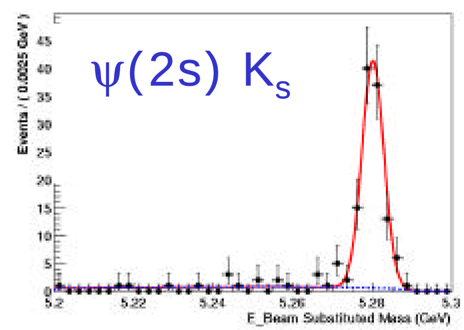
sin2b signal and control Samples (88M BB)

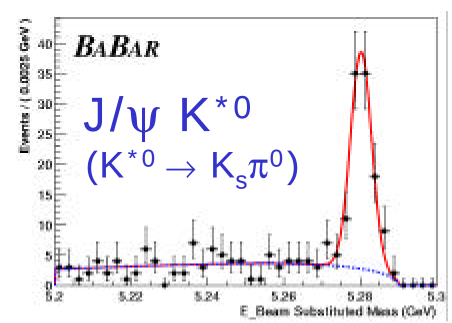


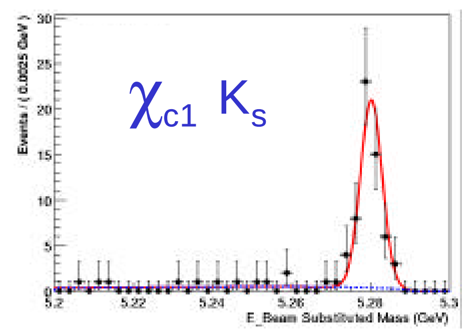






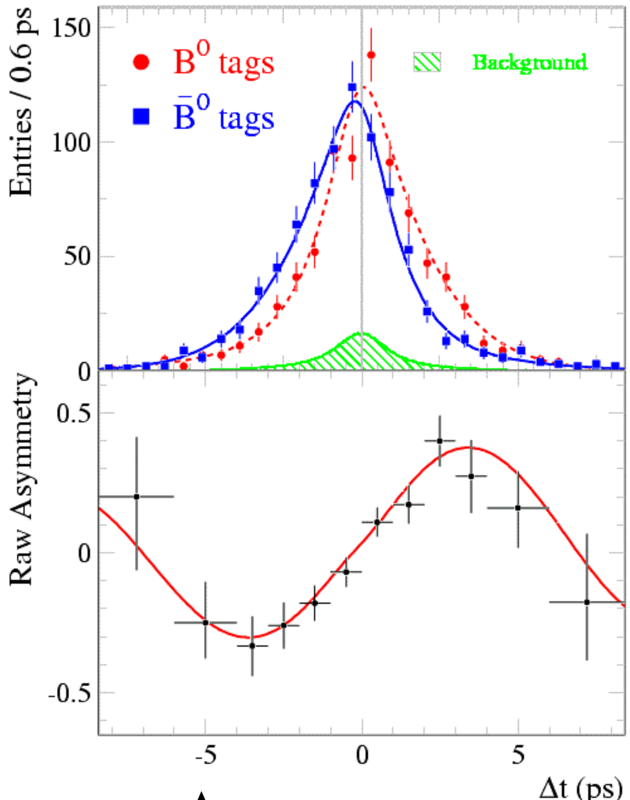






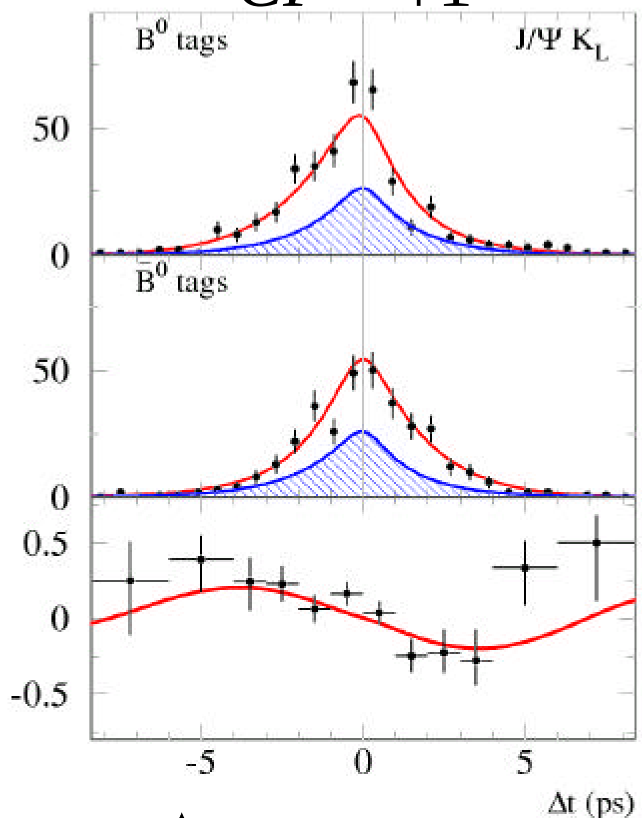
sin2b from $B \rightarrow$ charmonium K^0 (88M $B\bar{B}$)

$CP = -1$



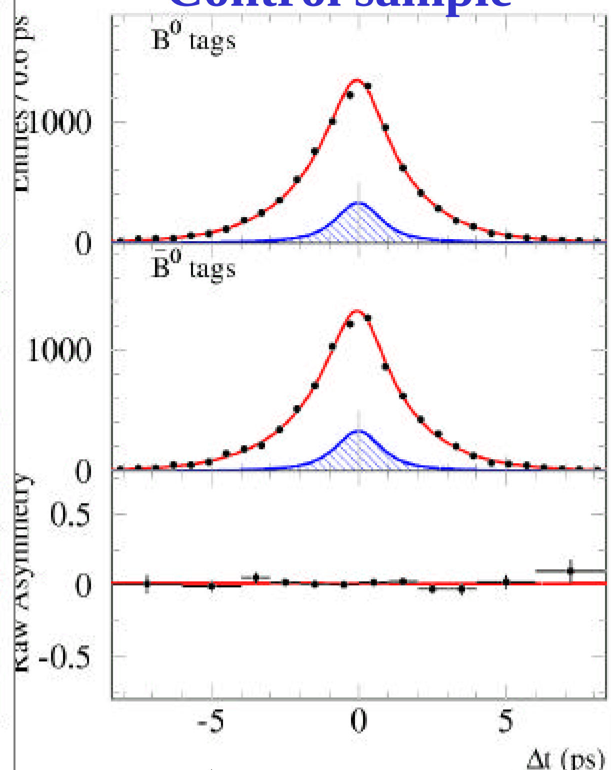
$$\Delta t = t_{CP} - t_{tag}$$

$CP = +1$



$$\Delta t = t_{CP} - t_{tag}$$

Control sample



$$\Delta t = t_{CP} - t_{tag}$$

$A_{CP} = -0.004 \pm 0.027$

$$\sin(2b) = 0.741 \underbrace{\pm 0.067 \text{ (stat)} \pm 0.034 \text{ (syst)}}_{\text{both uncertainties are data driven}} \quad [C=0]$$

both uncertainties are data driven

$$|l| = 0.948 \pm 0.051 \pm 0.030$$

(consistent with unity → no direct CPv)

Testing the assumptions in the extraction of sin2b extraction from charmonium modes

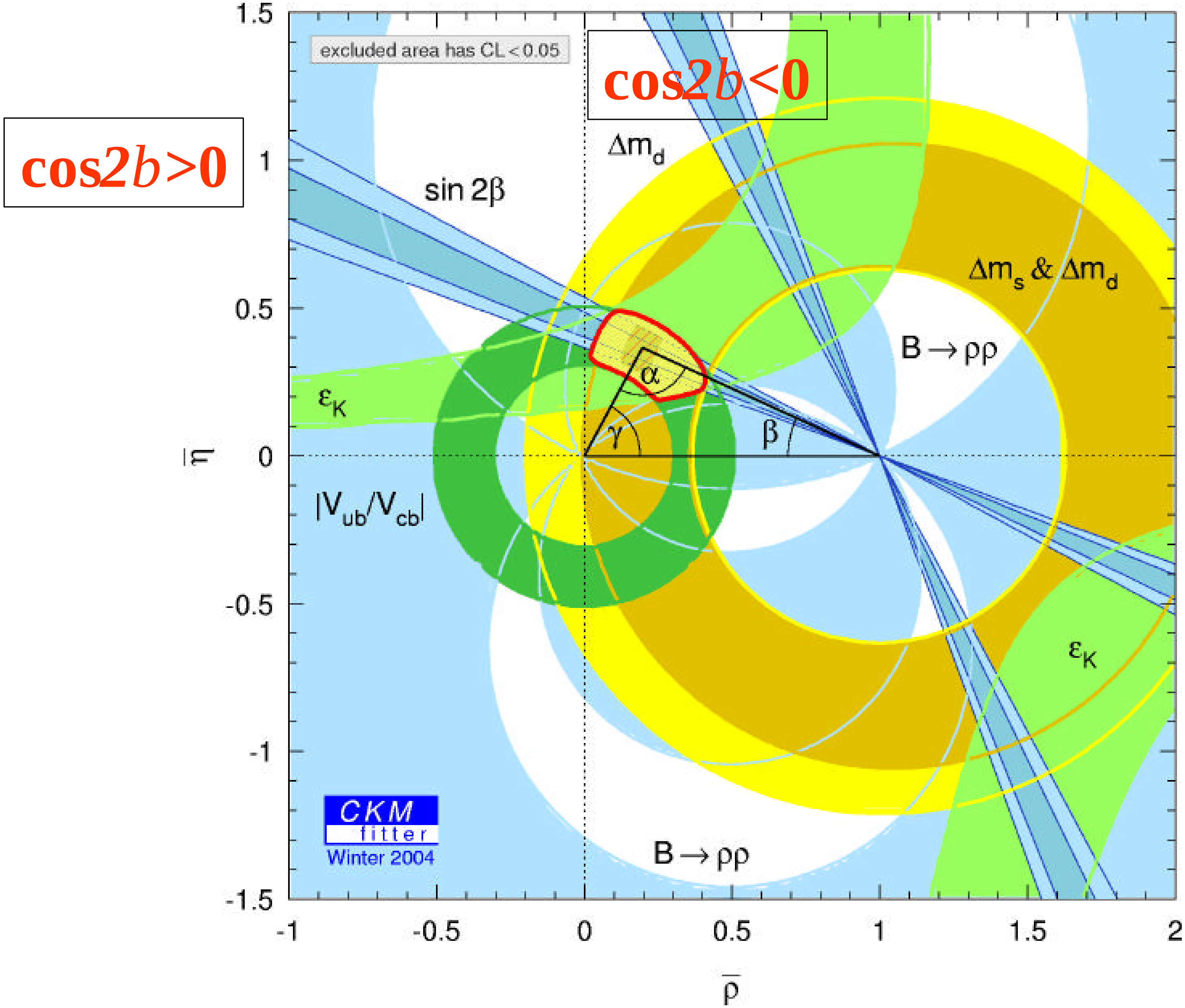
- **The extraction of sin(2b) assumes**
  - DG/G**=0 (no lifetime difference between neutral *B* mass eigenstates)**
  - **|*q/p*|=1 (checked with dilepton CP asymmetry measurement.)**
  - **CPT is conserved**

$$|q/p| = 0.998 \pm 0.006 \pm 0.007$$

- **We have performed a detailed study to check these assumptions:**
  - **2 papers accepted: PRL and PRD**

Quantity	**Measured value**	**Theory**
(DG/G) **sgn(Re** l **)**	$-0.008 \pm 0.037 \pm 0.018$	-0.2% to -0.3%
|*q/p*|	$1.029 \pm 0.013 \pm 0.011$	$\|q/p\| - 1 = (2.5 - 6.5) \times 10^{-4}$
(Re z)(Re(l**)/|**l**|)**	$0.014 \pm 0.035 \pm 0.034$	0 if CPT conserved
Im z	$0.038 \pm 0.029 \pm 0.025$	0 if CPT conserved

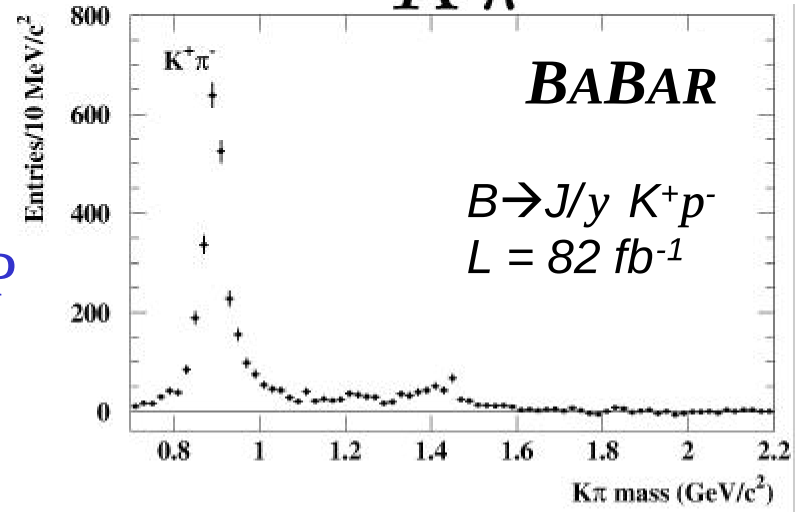
r - h plane with all constraints (sin2b not combined with others)

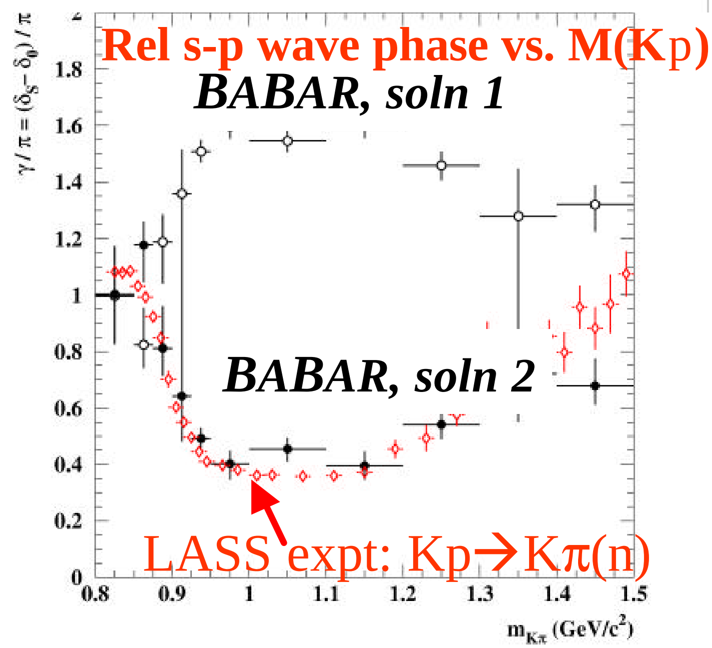


Determination of the sign of cos(2*b*) with *B*→*J*/*y* (*Kp*)

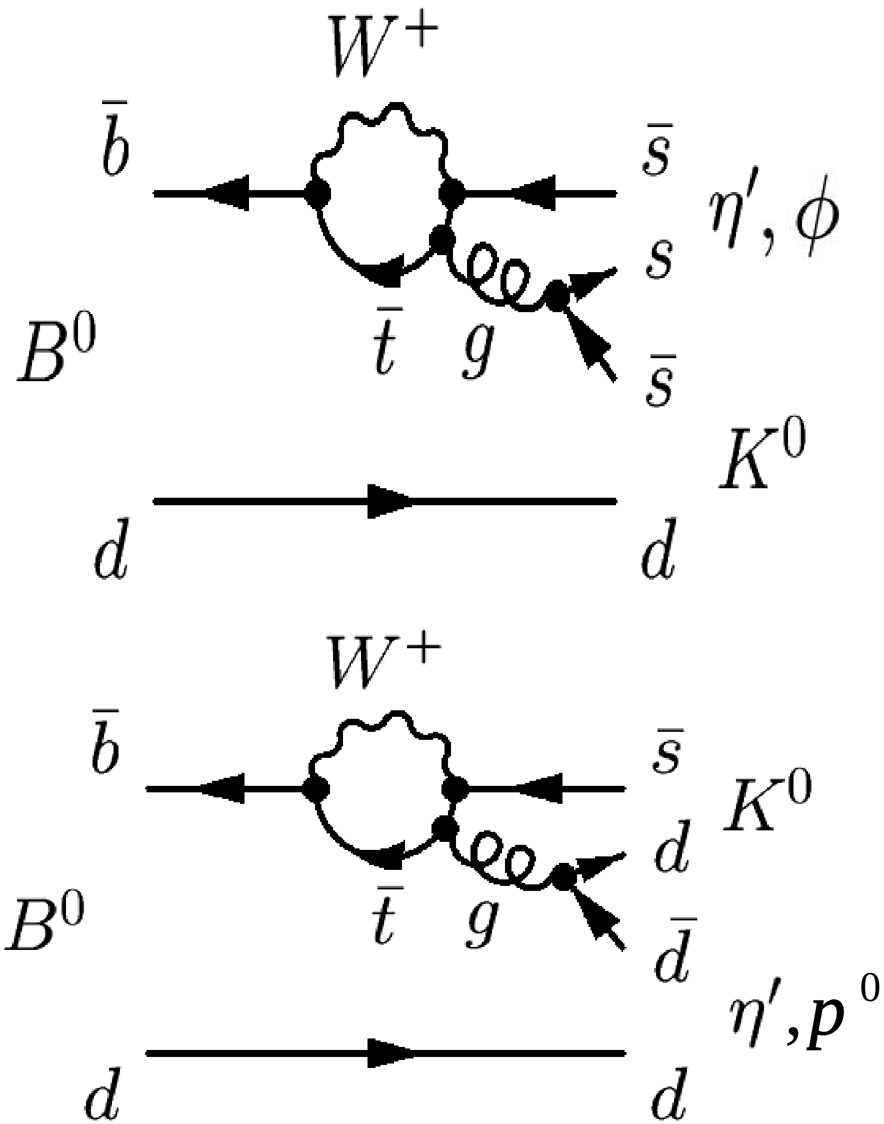
- From B→J/ψK_s, we are used to seeing the sin(2β)sin(Δm_d t) term.
- In B→J/ψ K^{*0} (K^{*0}→K_s π^0), terms with cos(2β)sin(Δm_dt) appear due to interference between CP-even and CP odd amplitudes.
- Problem: there is a sign ambiguity associated with the strong phases!
- Solution
    1. Measure magnitudes of strong phases from angular analysis
    2. Signs of phases determined from Kπ s-wave/p-wave interference
    3. *t*-dependent CP analysis→excludes cos2β=-0.68 @89% C.L.

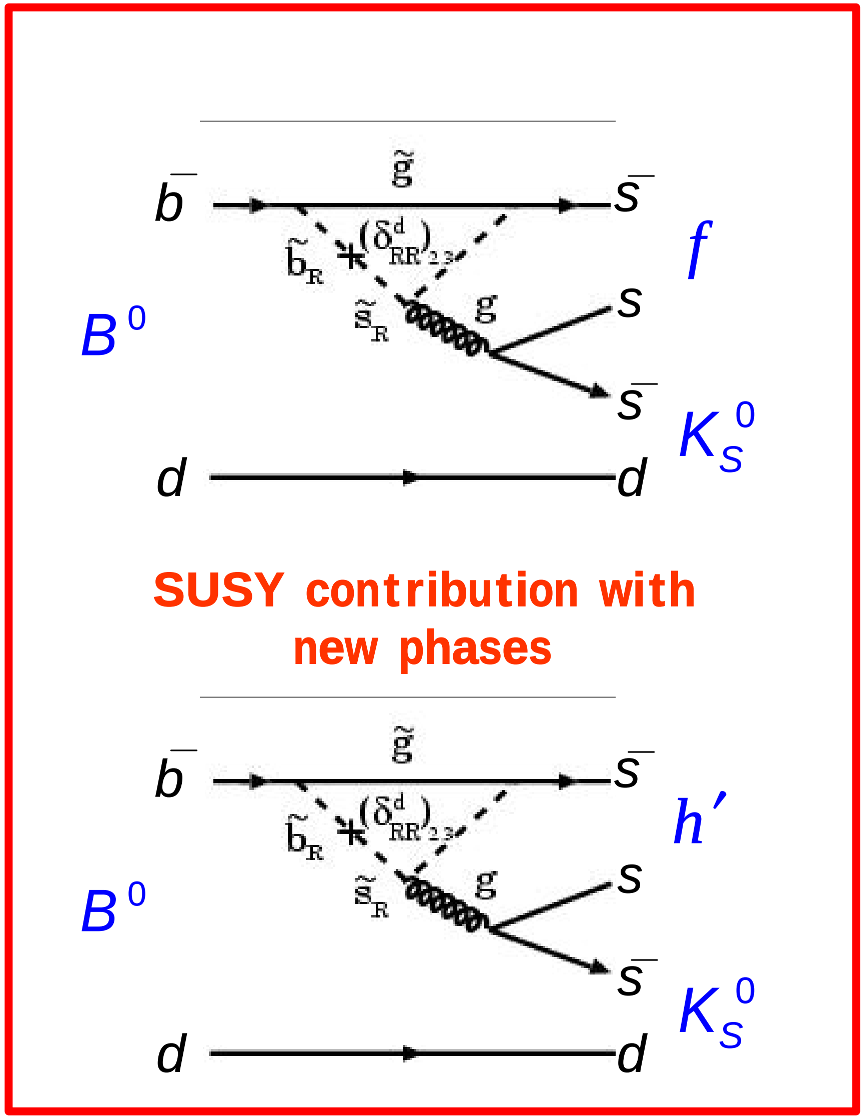
$m_{K\pi}$



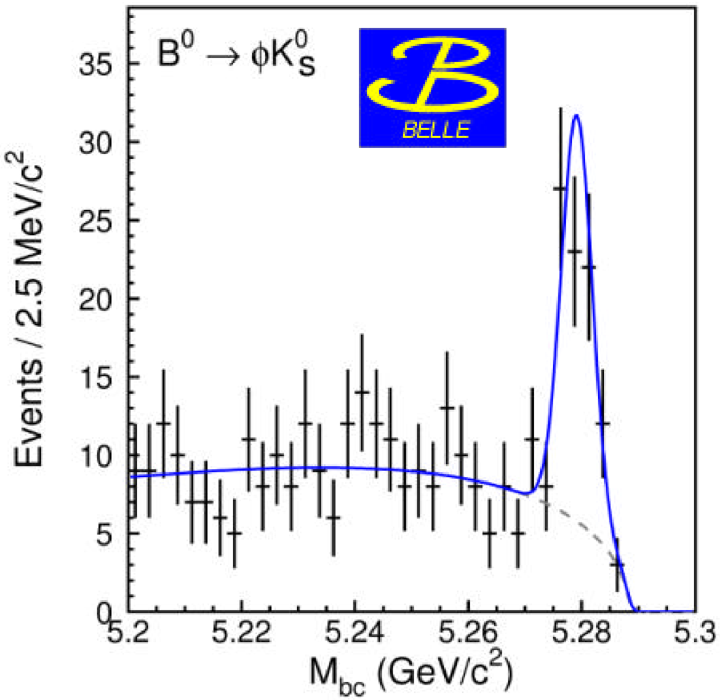


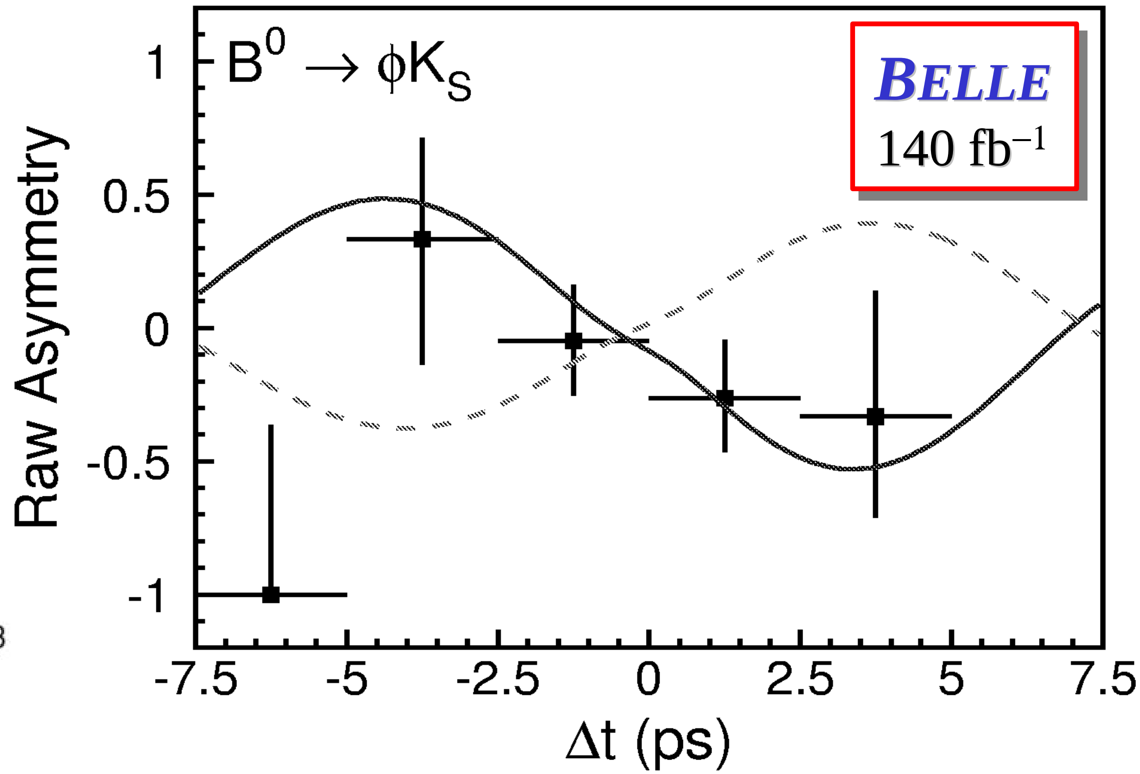
The next step for sin2*b*: search for phases from new particles & couplings in loop processes





Belle Results for $B \to \phi K_S$



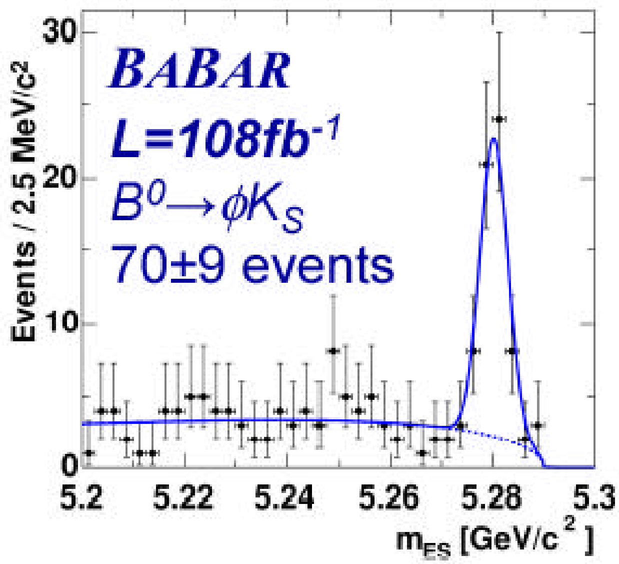


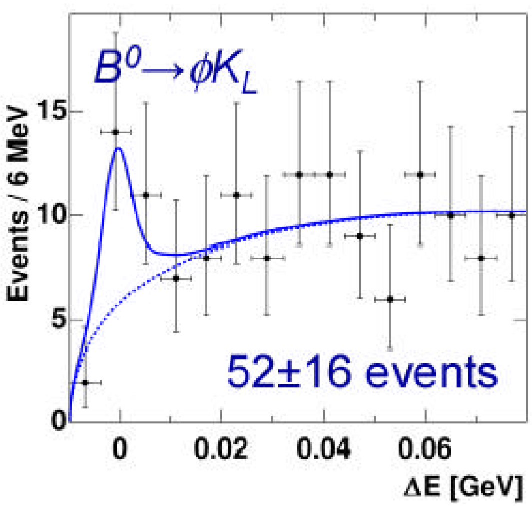
$$N\left(\phi K_S^0\left(\to \pi^+\pi^-\right)\right) = 68 \pm 11$$

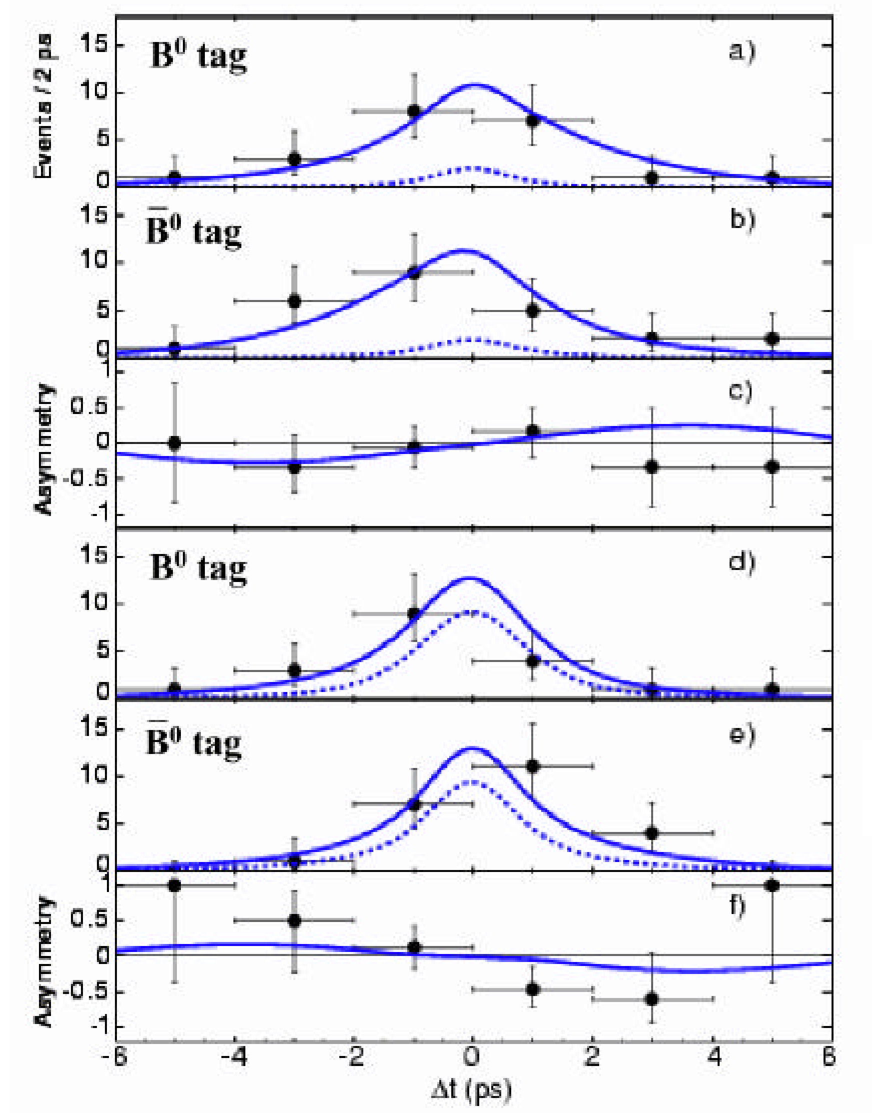
$$S_{\phi K_S^0} = -0.96 \pm 0.50_{(stat)} {}^{+0.09}_{-0.11}{}_{(syst)}$$

$$C_{\phi K_S^0} = +0.15 \pm 0.29_{(stat)} \pm 0.07_{(syst)}$$

BABAR results for $B \to \phi K_S$, ϕK_L (Runs 1-3)







$B \to \phi K_S$

$B \to \phi K_L$

$$S_{\phi K} = 0.47 \pm 0.34\ (\text{stat})\ ^{+0.08}_{-0.06}\ (\text{sys}) \quad C_{\phi K} = 0.01 \pm 0.33\ (\text{stat})\ \pm 0.10\ (\text{sys})$$

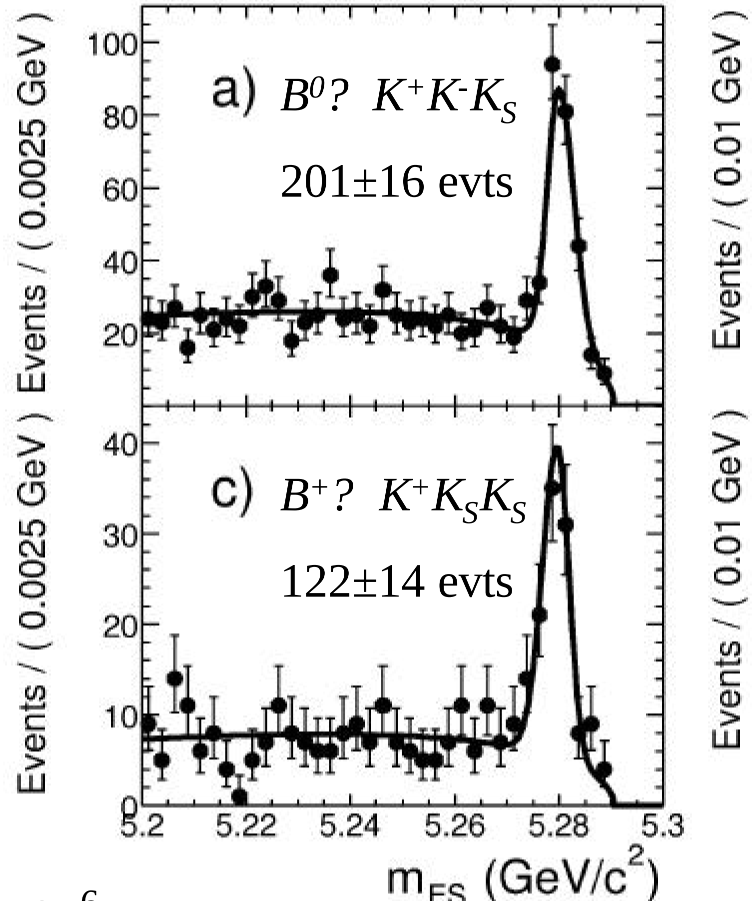
$B \rightarrow K^+K^- K_S$ and $B^+ \rightarrow K^+ K_S K_S$ branching fractions and CP asymmetry

- **There is a substantial rate for $B \rightarrow K^+K^- K_S$ for $M(K^+K^-)$ outside the f mass region.**
- **The CP eigenvalue of the final state is not a priori known, but it can be measured from**

$$f_{even} = \frac{2\Gamma(B^+ \to K^+K_S^0K_S^0)}{\Gamma(B^0 \to K^+K^-K_S^0)}$$

- **For the non-f region,**

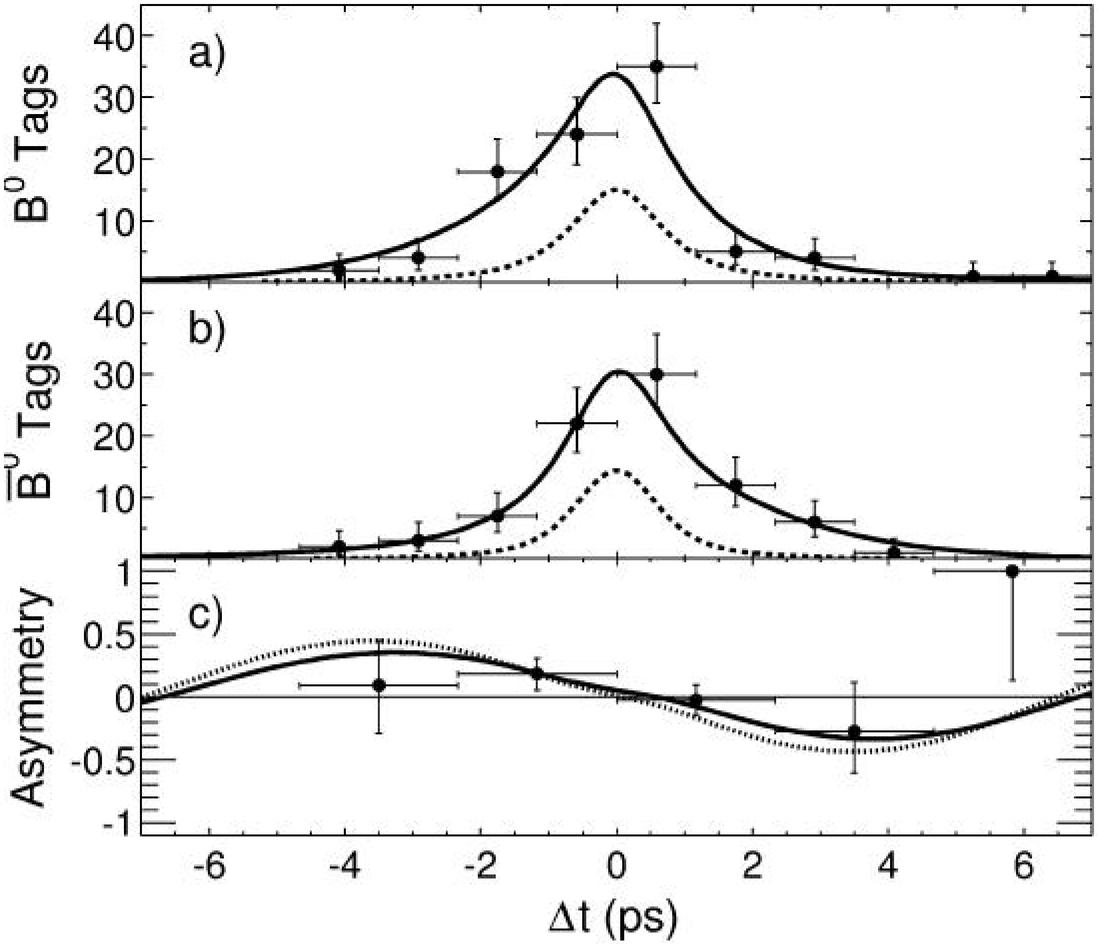
$$f_{even} = 0.98 \pm 0.15 \pm 0.04$$



$$B(B^+ \to K^+K_S^0K_S^0) = (10.7 \pm 1.2 \pm 1.0) \times 10^{-6}$$

$$B(B^0 \to K^+K^-K_S^0) = (23.8 \pm 2.0 \pm 1.6) \times 10^{-6}$$

$B \rightarrow K^+K^- K_S$ time-dependent CP asymmetry



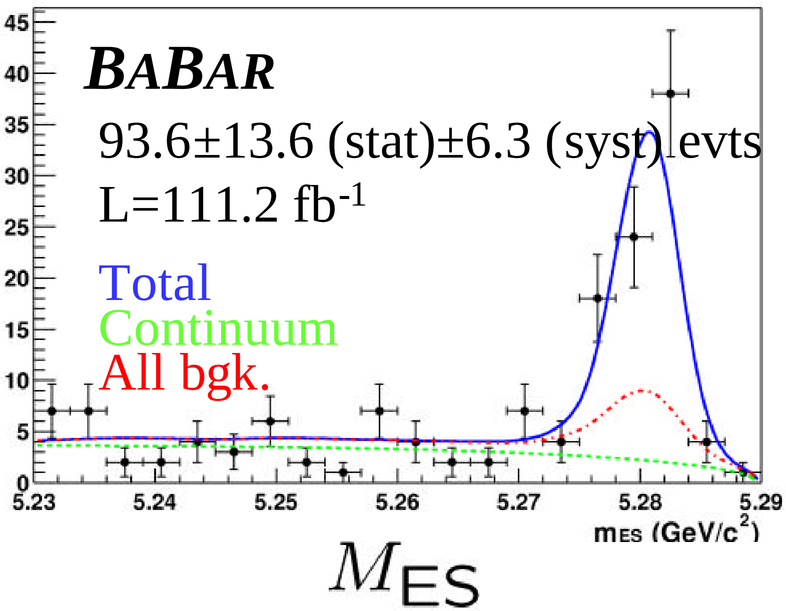
$$S(K^+K^-K_S^0) = -0.56 \pm 0.25(\text{stat}) \pm 0.04(\text{syst})^{+0}_{-0.17} \quad (f_{even})$$

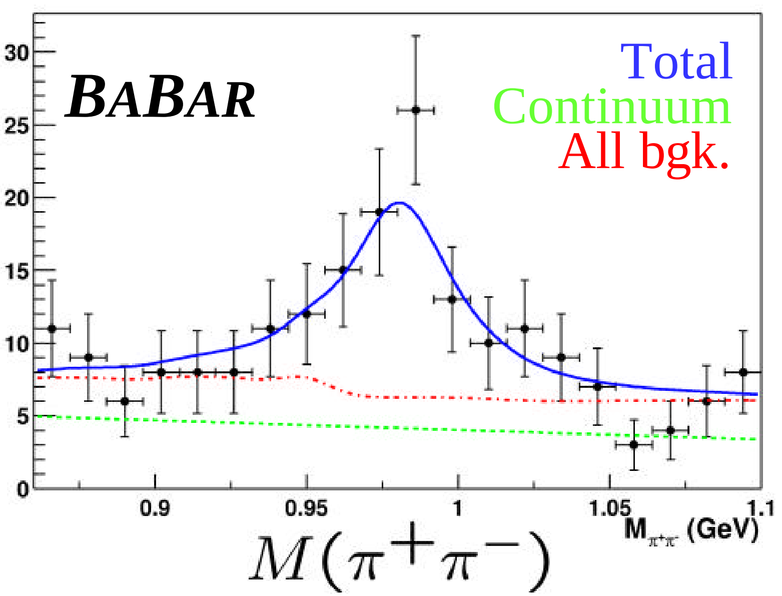
$$C(K^+K^-K_S^0) = -0.10 \pm 0.19(\text{stat}) \pm 0.09(\text{syst})$$

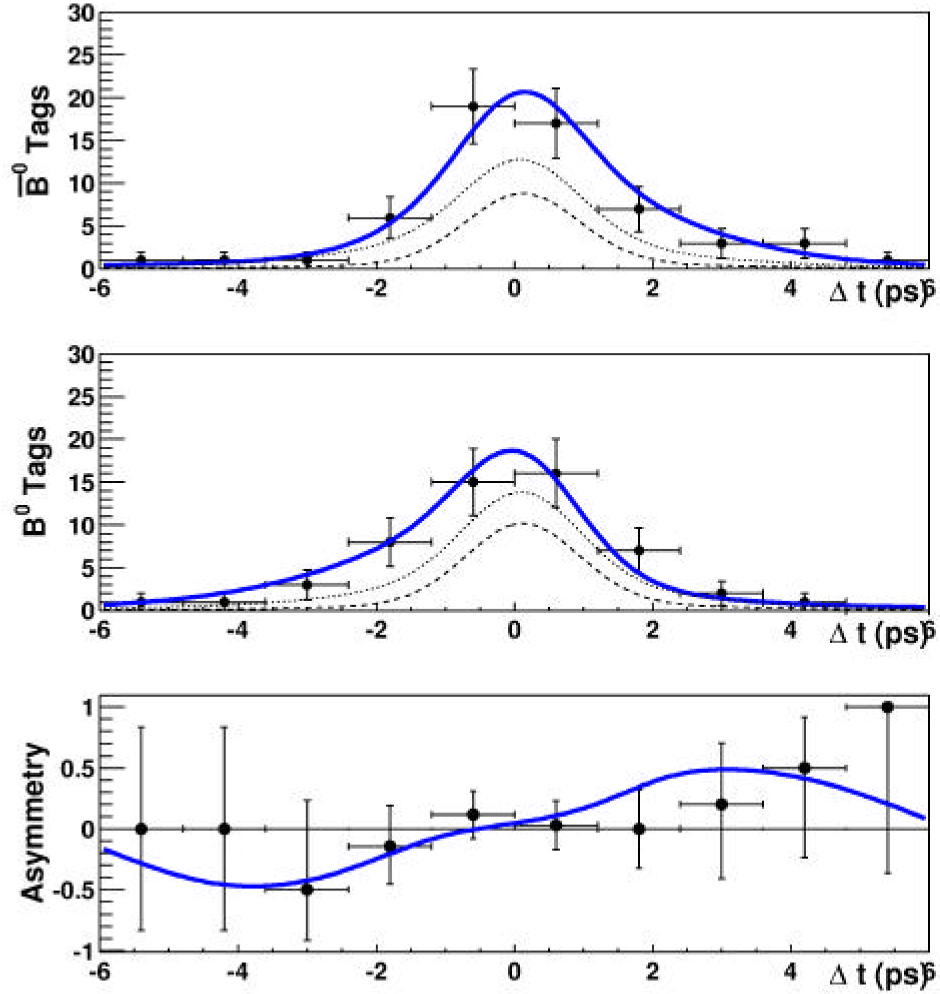
$$(S \simeq -\sin 2b \quad \text{in SM})$$

B→ f_0 (980) K_S observation and CP asymmetry

Presented at Moriond EW. PRL now submitted. **CP(f_0 K_S)=+1** **CP(J/y K_S)=-1**







$$S_{f_0K_S^0} = -1.62^{+0.56}_{-0.51} \pm 0.09 \pm 0.04$$

$$C_{f_0K_S^0} = 0.27 \pm 0.36 \pm 0.10 \pm 0.07$$

B→ f_0 (980) K_S observation and CP asymmetry

- **Branching fraction**

$$\mathcal{B}(B^0 \rightarrow f_0(980)K^0)\times\mathcal{B}(B^0 \rightarrow \pi^+\pi^-) = (6.0\pm0.9\pm0.6\pm1.2)\times10^{-6}$$

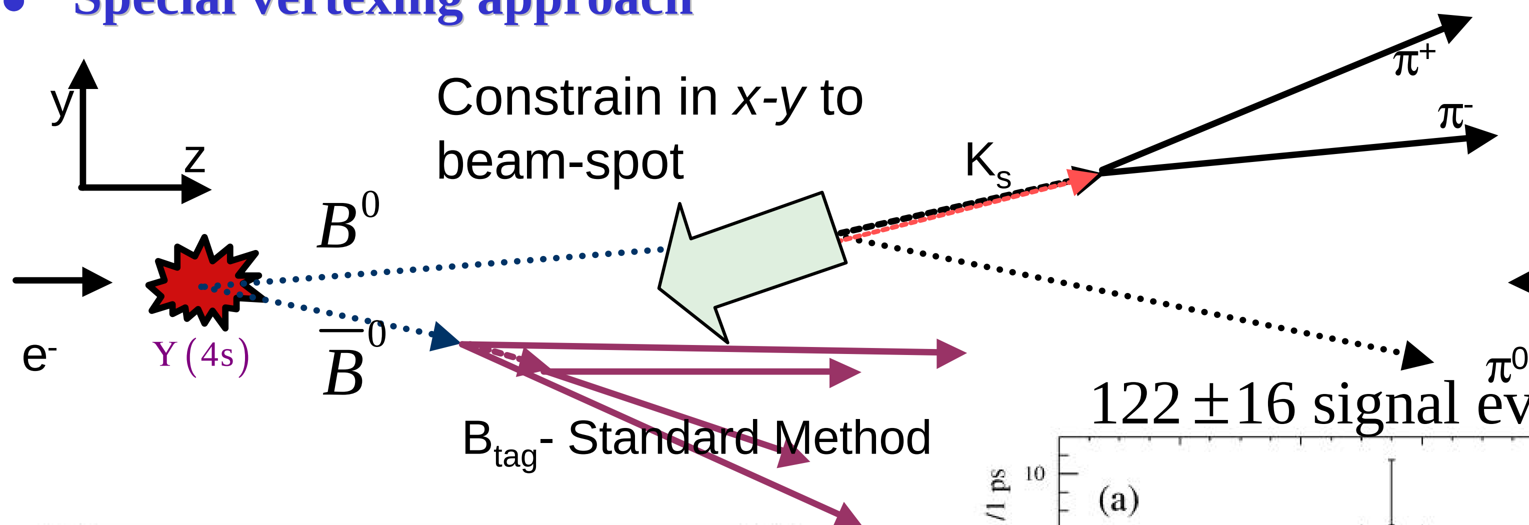
- ***f_0*(980) resonance parameters**

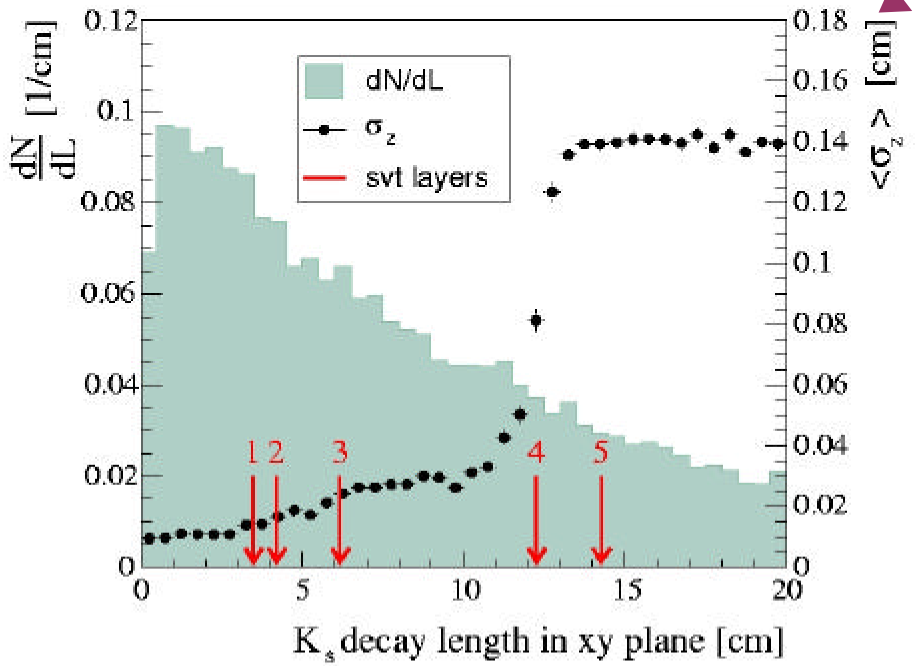
$$m_{f_0} = 980.6 \pm 4.1 \pm 0.5 \pm 4.0)\ \mathrm{MeV}/c^2,$$
$$\Gamma_{f_0} = (43^{+12}_{-9} \pm 3 \pm 9)\ \mathrm{MeV}/c^2$$

- **Systematic errors**
  - **Dominant sys. errors on branching fraction: fit procedure (0.26), B background (0.30), Q2B approx (1.21) in units of 10^{-6}.**
  - **Dominant sys. errors on S: fit procedure (0.06) and B background (0.05); Q2B approx is (0.04) so this does not dominate.**
- **Comments on S and C**
  - **S is 1.2 s from physical limit and is 1.7 s from SM; no CP violation is excluded at 2.7 s**
  - **C is 0.8 s from SM**

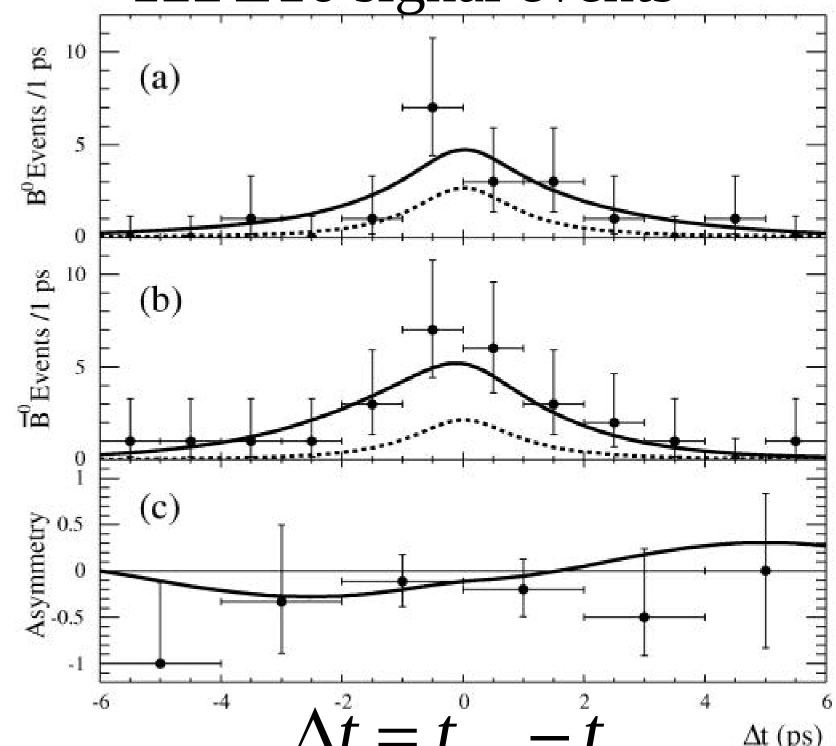
BABAR measurement of sin2b from $B \rightarrow K_S p^0$

- **Special vertexing approach**



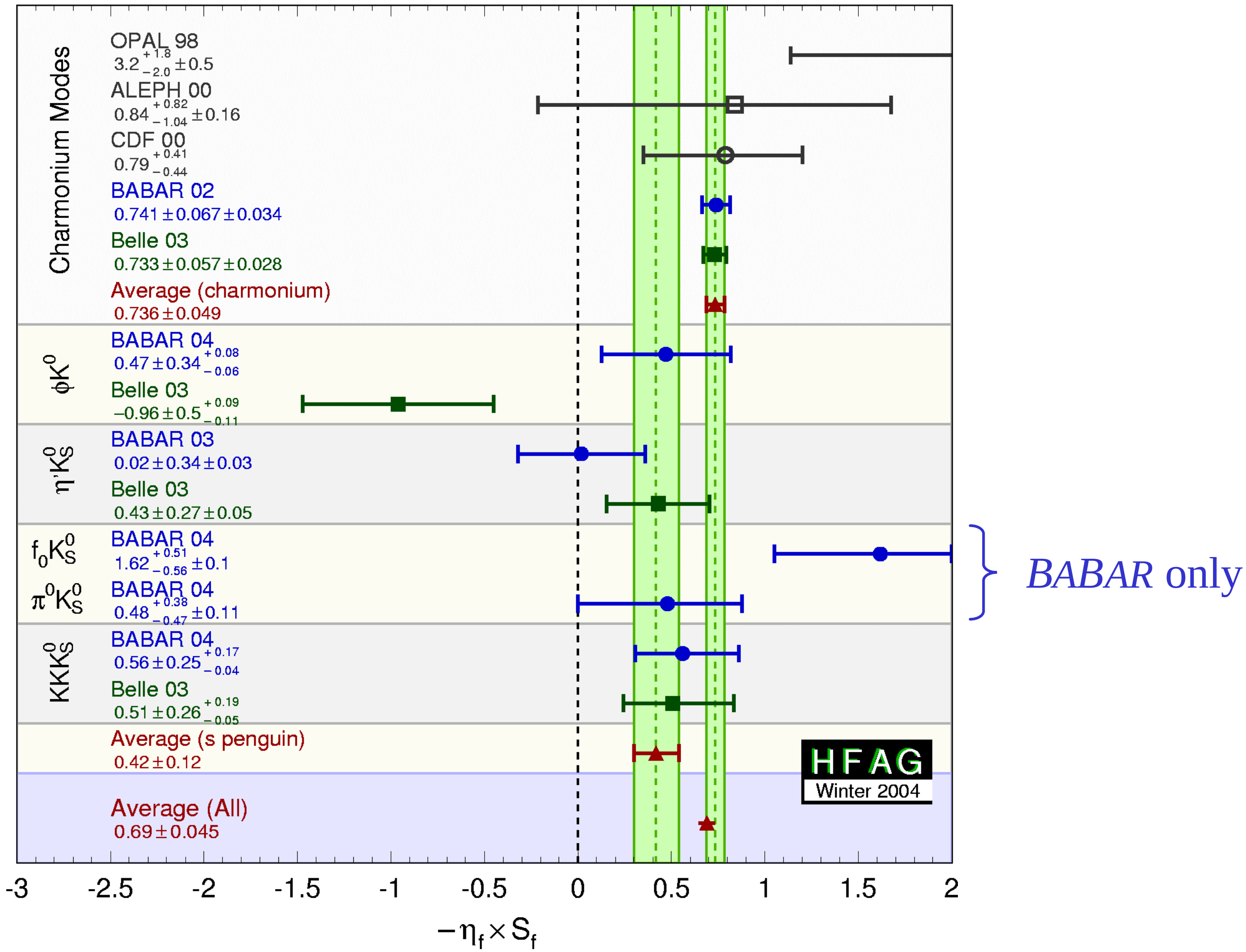


122±16 signal events

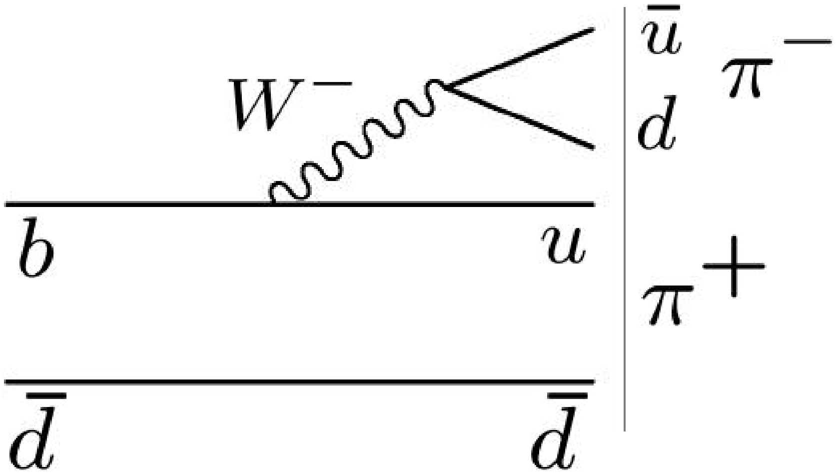


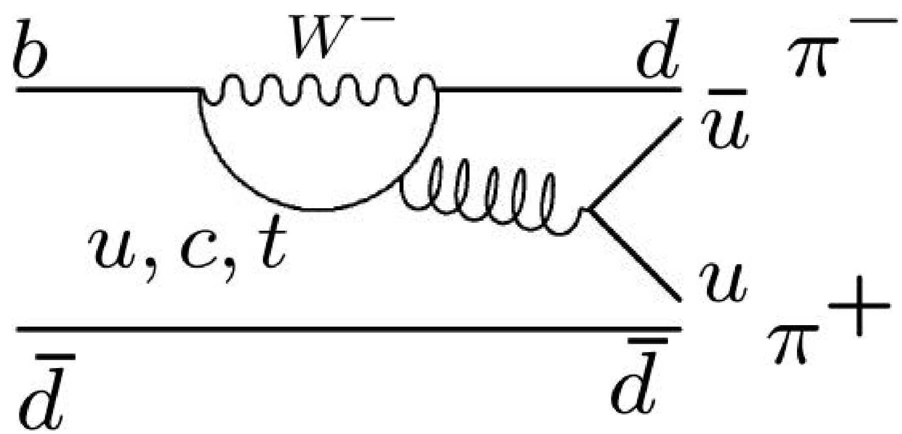
$$\Delta t = t_{CP} - t_{tag}$$

The sin2*b* program: the charmonium benchmark vs. the penguins



The Quest for Alpha





- **The angle** a **enters into the CP asymmetries for *b*→*u* modes:**

$$B \to p^+p^-, B \to r^\pm p^\mp, B \to r^+r^-$$

- ***Assuming* the b→u tree diagram dominates**

$$\lambda_{\pi^+\pi^-} = e^{-i2\beta}\frac{\overline{A}_{\pi^+\pi^-}}{A_{\pi^+\pi^-}} = e^{-i2\beta}e^{-i2\gamma} = e^{i2\alpha}$$

- **But penguin amplitude is sizeable**

$$\lambda_{\pi^+\pi^-} = e^{i2\alpha}\frac{T + P\, e^{+i\gamma}\, e^{i\delta}}{T + P\, e^{-i\gamma}\, e^{i\delta}}$$

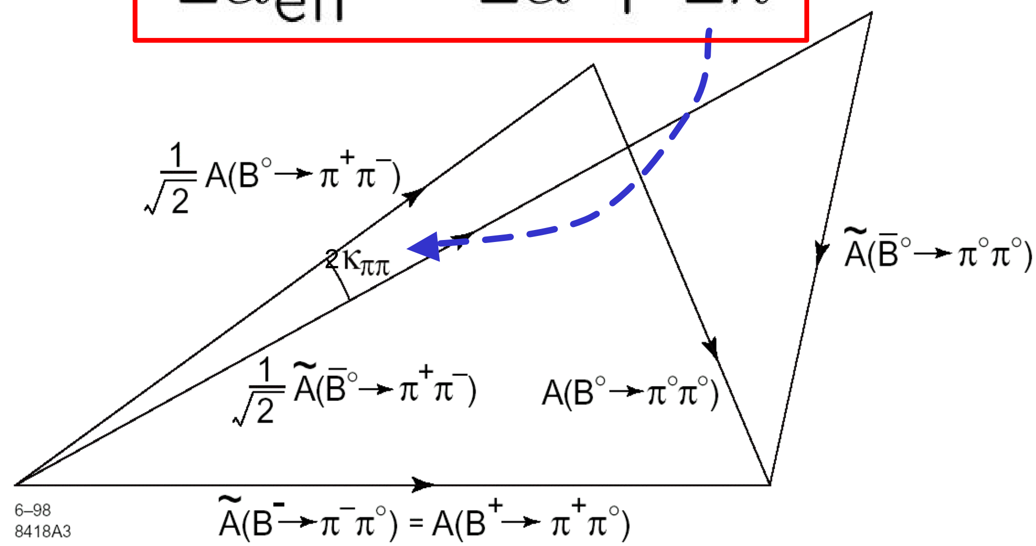
Coping with penguins: isospin analysis

- **Gronau-London isospin analysis: J=0 two-pion state has no *I*=1, so *B*→*pp* can be described in terms of two *I*-spin amplitudes.**

$$A^{+0} = A^{00} + \frac{1}{\sqrt{2}} A^{+-}$$

$$\overline{A}^{+0} = \overline{A}^{00} + \frac{1}{\sqrt{2}} \overline{A}^{+-}$$

$$2\alpha_{\rm eff} = 2\alpha + 2\kappa$$



- **A^{+0} has no gluonic penguin →base is common to B^+ and B^-**
- **Grossman-Quinn bound:**

$$\sin^2(\alpha - \alpha_{\rm eff}) \leq \frac{\mathcal{B}(B^0 \to \pi^0\pi^0) + \mathcal{B}(\overline{B}^0 \to \pi^0\pi^0)}{\mathcal{B}(B^+ \to \pi^+\pi^0) + \mathcal{B}(B^- \to \pi^-\pi^0)}$$

  - Useful if $\pi^0\pi^0$ is small.
  - Does not require $\pi^0\pi^0$ events to be tagged since uses sum.

BABAR results related to a

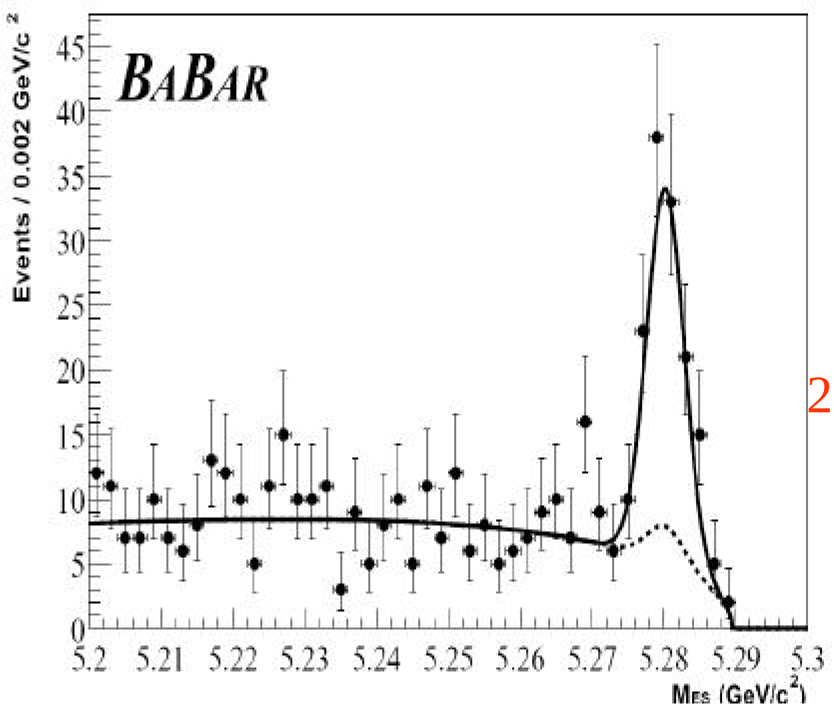
- Intensive effort in *BABAR* to explore all modes that can constrain a. All of the following will be updated for ICHEP'04.

Mode	Comments
$B \rightarrow p^+p^-$ time-dependent CP asymmetry	BABAR $S = -0.40 \pm 0.22 \pm 0.03$, $C = -0.19 \pm 0.19 \pm 0.0.05$ Belle observes $S = -1.00 \pm 0.21 \pm 0.07$, $C = -0.58 \pm 0.15 \pm 0.0.07$
$B \rightarrow p^0p^0$ branching fraction	1st observation >4s; published in PRL $\lvert \alpha - \alpha_{\text{eff}} \rvert_{\pi\pi} \leq 47^0 \ (90\%)$
$B \rightarrow r^+p^-, r^-p^+$ time-dependent CP asymmetry	*BABAR* has only measurement
$B \rightarrow r^+r^-$ branching fraction and polarization	1st observation; BABAR has only measurement; almost 100% long. pol. $\lvert \alpha - \alpha_{\text{eff}} \rvert_{\rho\rho} \leq 19^0 \ (90\%)$
$B \rightarrow r^+ r^-$ time-dependent CP asymmetry $B \rightarrow r^0 r^0$: limit only so far	BABAR has only measurement; currently is best a constraint

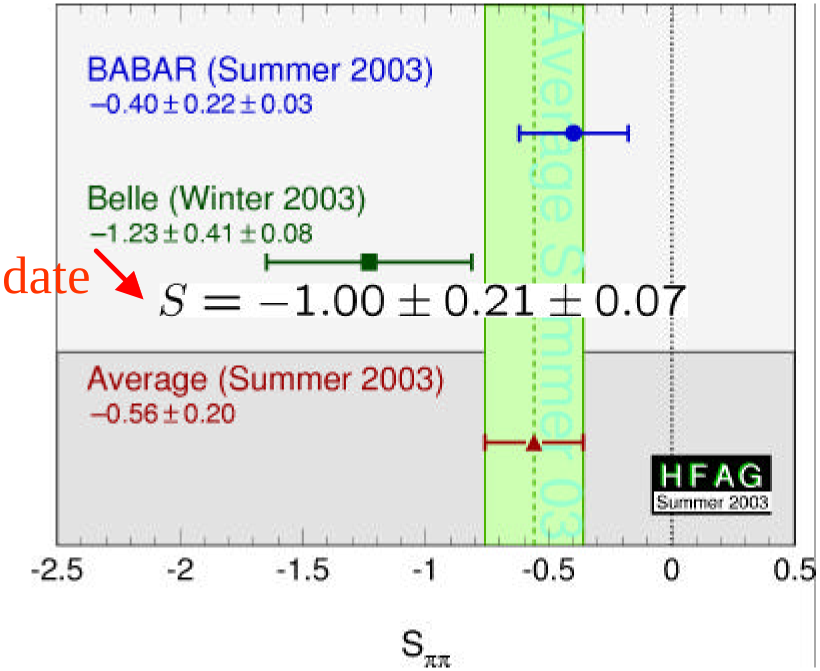
BABAR and Belle on $B \to \pi^+\pi^-$

- Belle observes a rather large negative value of $s_{\pi\pi}$.
- Another analysis to watch closely!

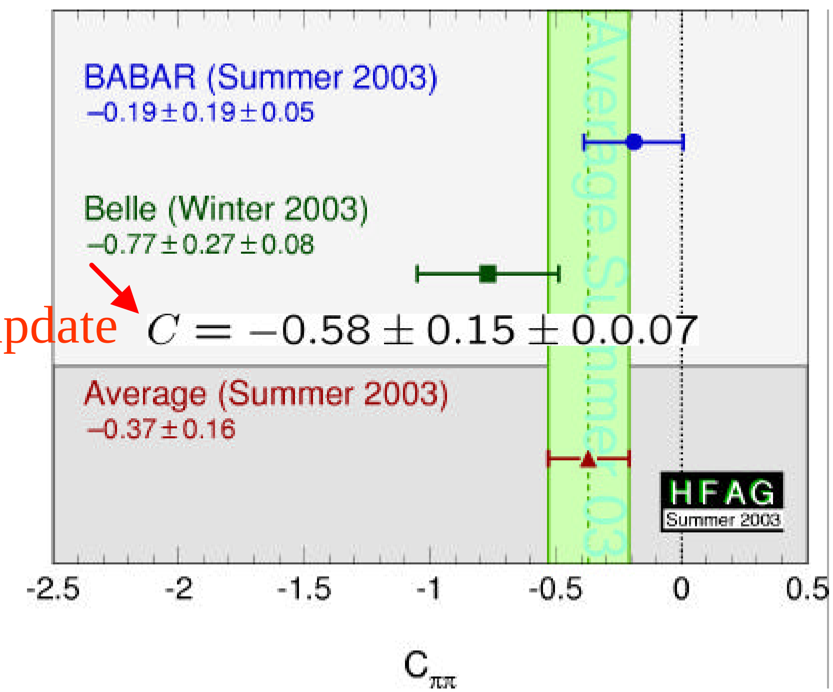
$266 \pm 24\ \pi^+\pi^-$ candidates



2004 update



2004 update

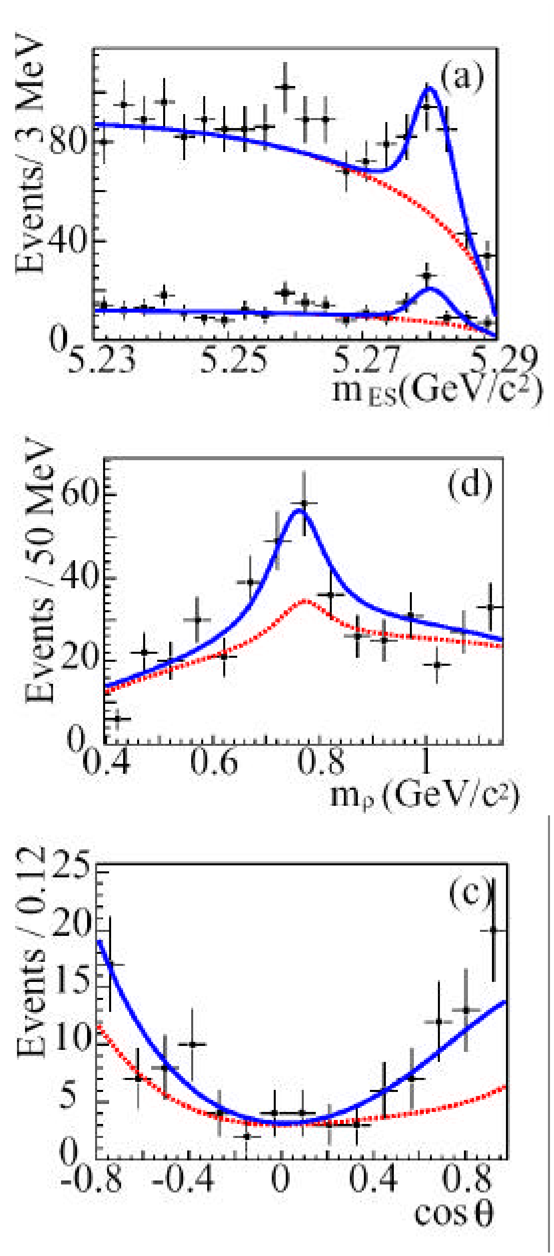


Observation of *B*→ $r^+ r^-$ and polarization measurement

- **From the *BABAR* Physics Book, 1998**
  - **At first glance, the decays *B*→ r r appear to be completely analogous to *B*→pp. However, there is an important difference. Because the r is a vector meson, the r r pair can be in a state of angular momentum L=0, 1, or 2. States of even and odd angular momentum correspond to states of even and odd CP, respectively…**
- **After discovering *B*→ $r^+ r^-$, we measured the polarization**

$$\Gamma_L/\Gamma = 0.98^{+0.02}_{-0.08} \pm 0.03$$

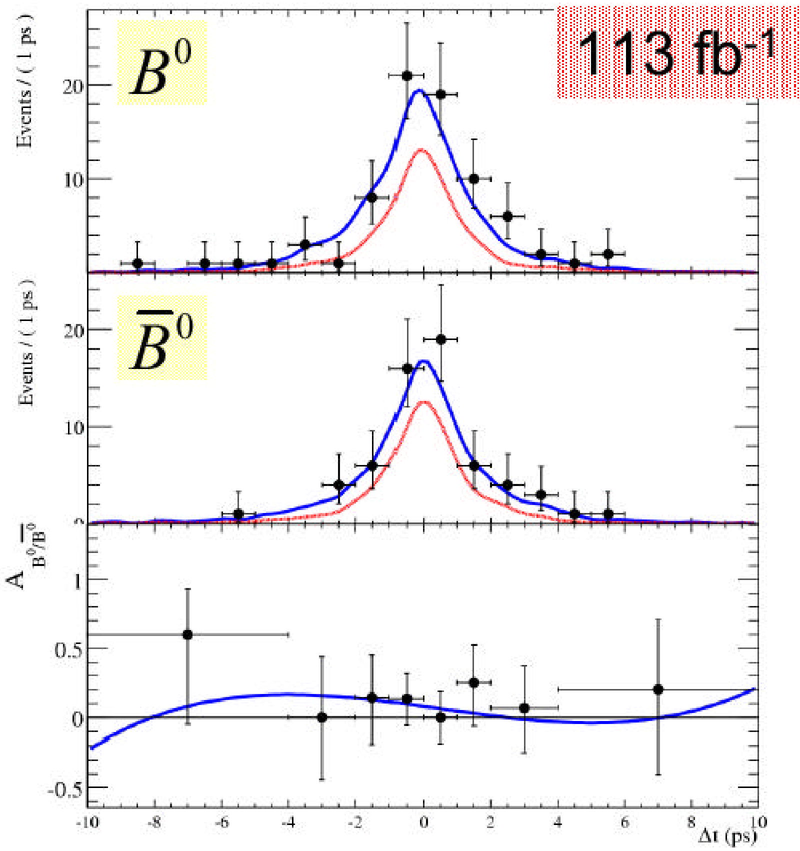
→Nearly pure CP even eigenstate!



Measurement of CP asymmetry in $B\rightarrow r^{+}\, r^{-}$

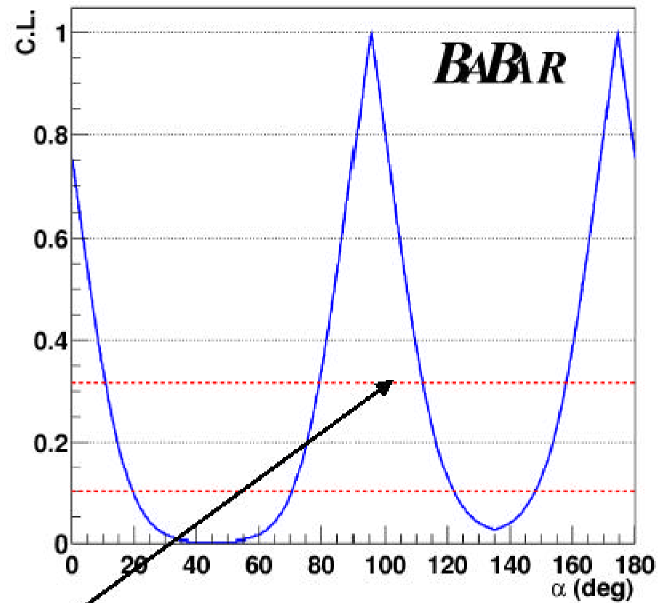
$$S_{long} = -0.19 \pm 0.33_{stat} \pm 0.11_{syst}$$

$$C_{long} = -0.23 \pm 0.24_{stat} \pm 0.14_{syst}$$



§ Main systematics: CPV in B bkg

§ Detailed study of B background: 209 B decay modes simulated



$$\alpha = (96 \pm 10_{stat} \pm 4_{syst} \pm 13_{peng})^{\circ}$$

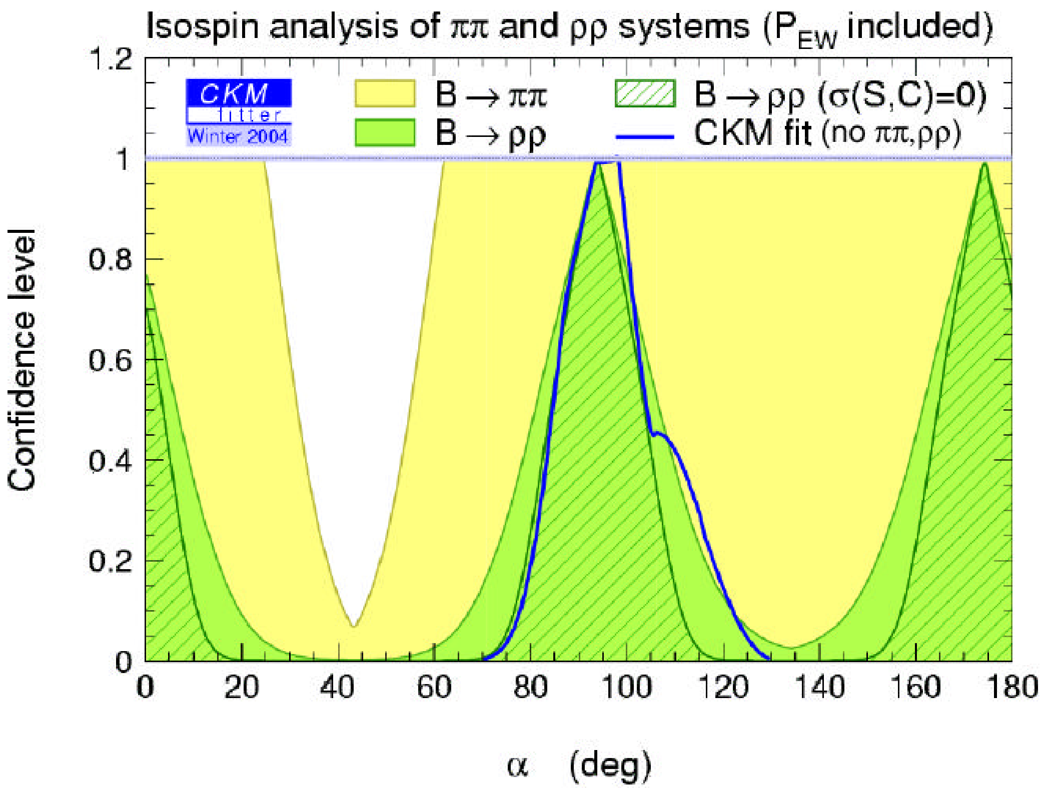
§ Isospin analysis: interference, NR contributions, I=1 amplitudes neglected

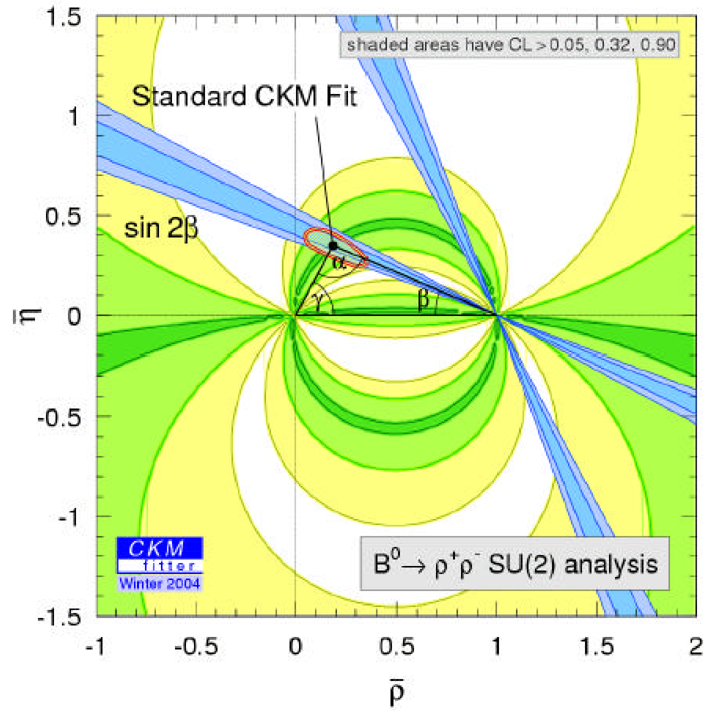
PRELIMINARY

From L. Roos Moriond talk

Plots from CKM fitter group: I-spin analysis of $B \rightarrow r^{+} r^{-}$

- **Presented by Lydia Roos at Moriond EW**





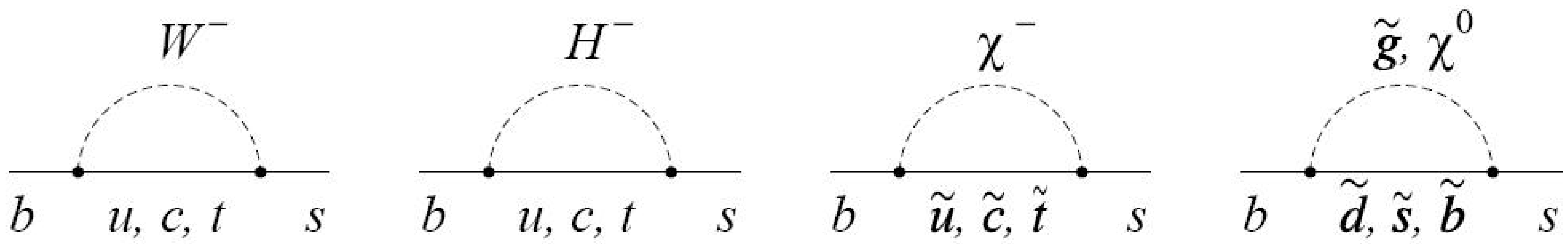
81fb^{-1} submitted	113 fb^{-1} preliminary
$S_{long} = -0.42 \pm 0.42_{stat} \pm 0.14_{syst}$	$S_{long} = -0.19 \pm 0.33_{stat} \pm 0.11_{syst}$
$C_{long} = -0.17 \pm 0.27_{stat} \pm 0.14_{syst}$	$C_{long} = -0.23 \pm 0.24_{stat} \pm 0.14_{syst}$

§ Constraint on α in perfect agreement with the Standard Fit;

$$\alpha = (96 \pm 10_{stat} \pm 4_{syst} \pm 13_{peng})^{\circ}$$

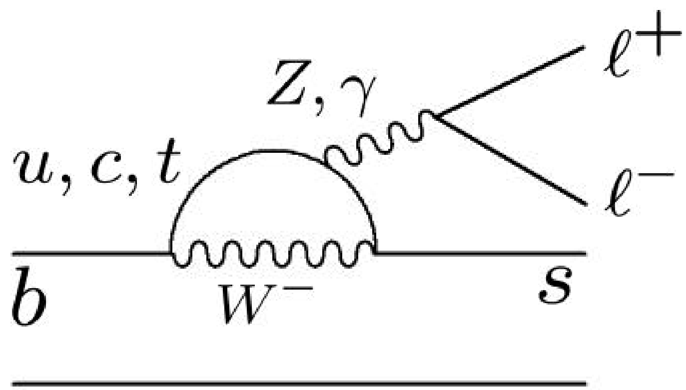
Rare Decays: A Major Growth Industry

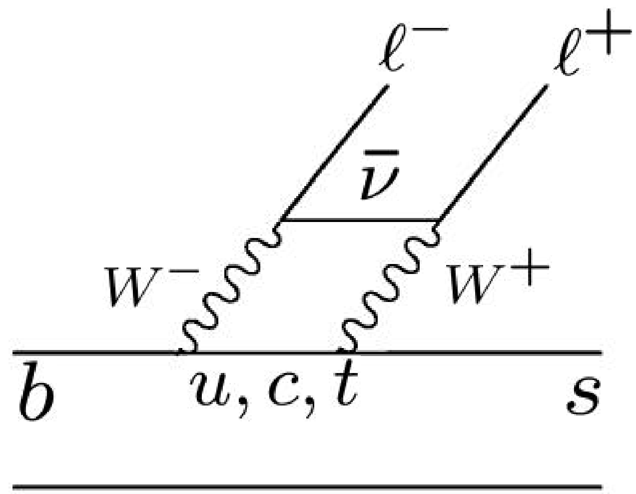
- BABAR has five separate analysis groups focussed on rare B (or charm) decays. (t group also looks at rare decays.)
  - rare hadronic decays (3 groups), electroweak penguins, leptonic decays (discussed many hadronic rare decays earlier)
- We have pushed our sensitivity to the 10^{-6} level for many processes and even lower for some processes.
- Main goal is to search for effects of new physics in processes with Flavor Changing Neutral Currents (FCNC). Due to the presence of loops, such processes can be sensitive to new physics.
- Large industry of theoretical predictions for SM and SUSY models.
- Branching fractions, CP asymmetries, kinematic distributions, I-spin relations can all be affected by new physics.



Electroweak Penguins and Related Processes

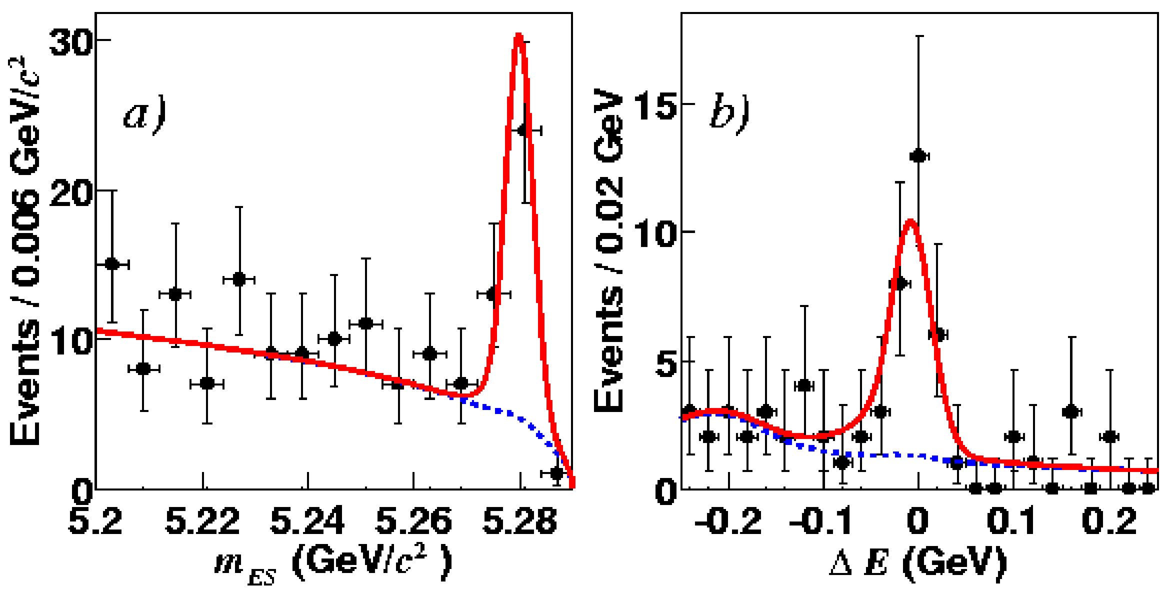
- **Rarest B decay so far observed: B→K l^+l^-**



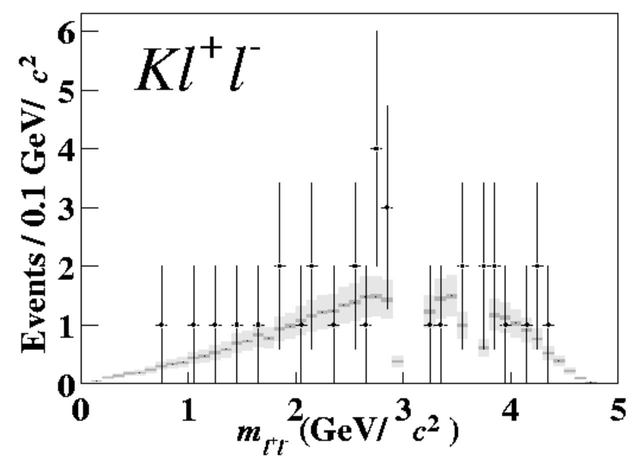


~ 8s significance

$$\mathcal{B}(B \to K\ell^+\ell^-) = (6.5^{+1.4}_{-1.3} \pm 0.4) \times 10^{-7}$$

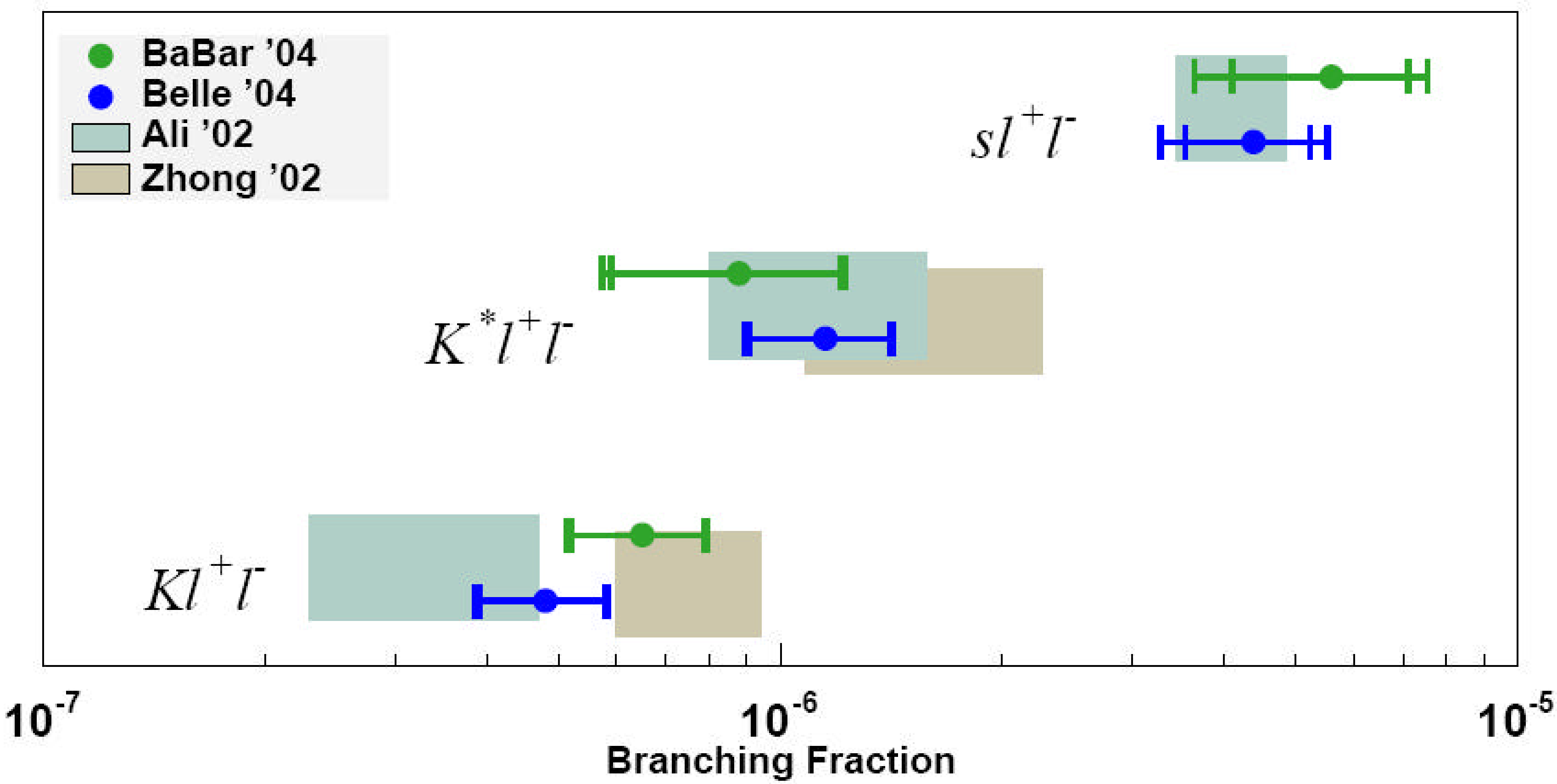


Dilepton mass distribution



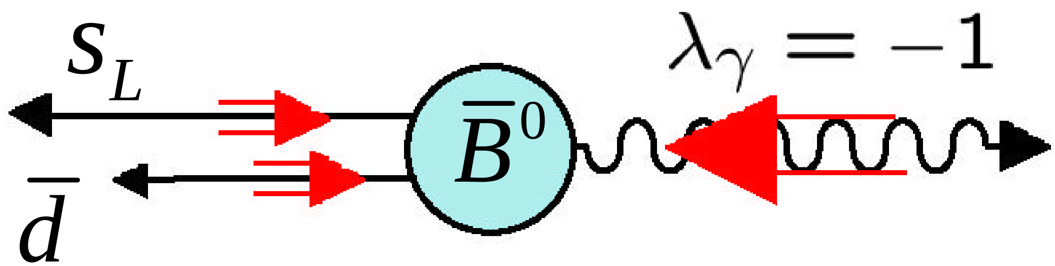
Electroweak Penguins and Related Processes

- So far, observations are in line with theoretical predictions.
- Some of the best observables are kinematic distributions which we are just beginning to have enough events to study.



Time-dependent CP asymmetry measurement for B→K^{*0} g; K^{*0}→ *K*sp^0

- **1st t-dependent CP measurement for any radiative penguin process! Submitted to PRL.**
- **Uses same beam-constrained vertexing technique that we used for B→*K*sp^0.**
- **The photon helicity is a final state quantum number that is highly correlated with B flavor. This tends to destroy the interference between mixing and decay, assuming SM couplings:**

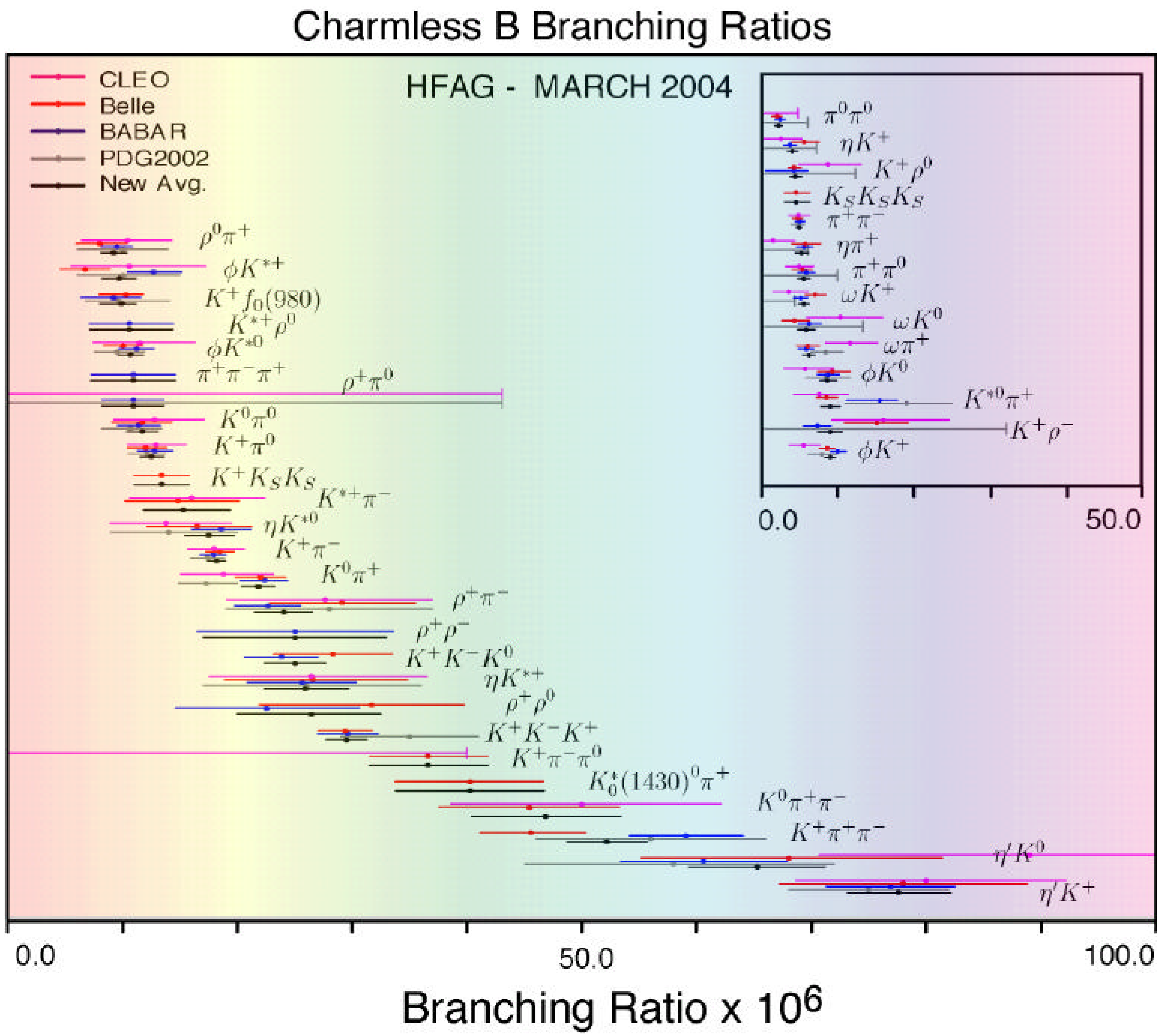


- **In the SM**

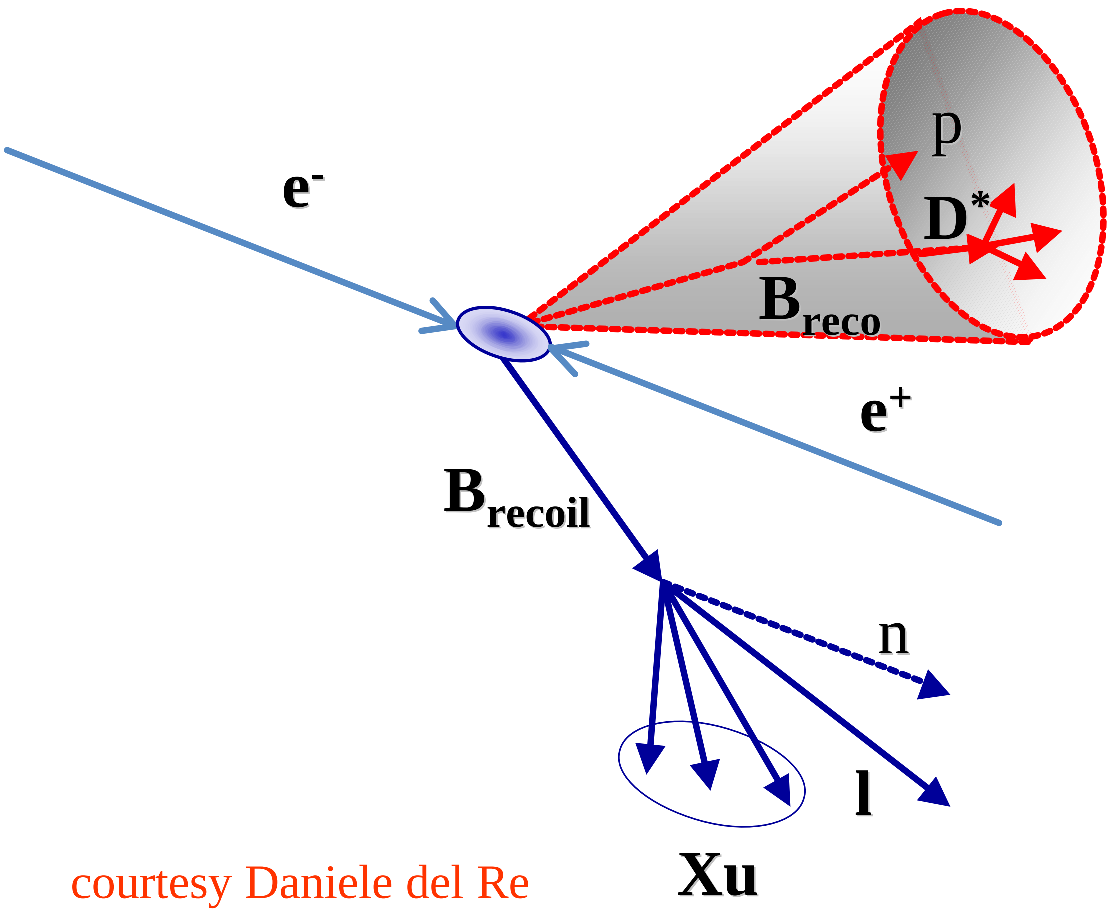
$$S = 2(m_s/m_b)\sin(2\beta) \approx 4\%$$

- **In some left-right symmetric extensions, S can be up to 50%. [Atwood, Gronau, and Soni, PRL, 79, 185 (1997)]**
- **With Run 1-3 data (124 M BB events):**

$$S_{K^*\gamma} = 0.25 \pm 0.63 \pm 0.14$$
$$C_{K^*\gamma} = -0.57 \pm 0.32 \pm 0.09$$


Charmless B Branching Ratios
HFAG - MARCH 2004
CLEO
Belle
BABAR
PDG2002
New Avg.
$\rho^0\pi^+$
ϕK^{*+}
$K^+f_0(980)$
$K^{*+}\rho^0$
ϕK^{*0}
$\pi^+\pi^-\pi^+$
$\rho^+\pi^0$
$K^0\pi^0$
$K^+\pi^0$
$K^+K_SK_S$
$K^{*+}\pi^-$
ηK^{*0}
$K^+\pi^-$
$K^0\pi^+$
$\rho^+\pi^-$
$\rho^+\rho^-$
$K^+K^-K^0$
ηK^{*+}
$\rho^+\rho^0$
$K^+K^-K^+$
$K^+\pi^-\pi^0$
$K_0^*(1430)^0\pi^+$
$K^0\pi^+\pi^-$
$K^+\pi^+\pi^-$
$\eta' K^0$
$\eta' K^+$
$\pi^0\pi^0$
ηK^+
$K^+\rho^0$
$K_SK_SK_S$
$\pi^+\pi^-$
$\eta\pi^+$
$\pi^+\pi^0$
ωK^+
ωK^0
$\omega\pi^+$
ϕK^0
$K^{*0}\pi^+$
$K^+\rho^-$
ϕK^+
0.0
50.0
0.0
50.0
100.0
Branching Ratio x 10^6

Physics with the Recoil Method



Fully reconstruct one B meson in the event.

The remaining particles in the event must be associated with the other B meson.

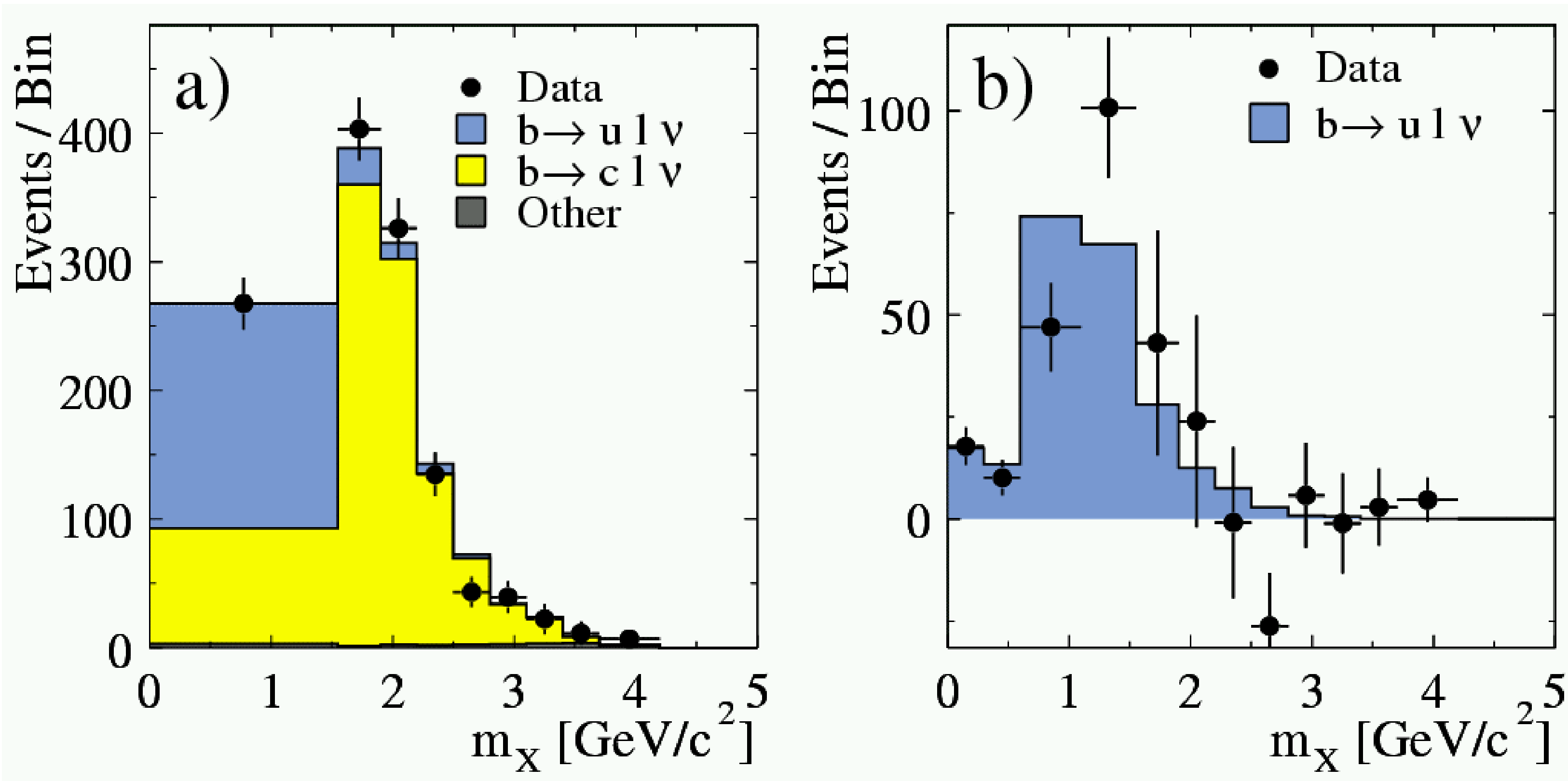
You have a single B beam!!

courtesy Daniele del Re

- **Reconstruct *B,D* mesons in ~1000 modes:** $B \to D^{(*)}p, D^{(*)}pp^0, D^{(*)}3p, ...$
- **Efficiency ~0.4% or ~4000 *B* mesons/fb^{-1} (charged and neutral)**
- **Will soon have ~800 K events tagged with a fully reconstructed *B* meson**

Measurement of $|V_{ub}|$ with inclusive semileptonic decays (but not restricted to lepton-endpoint region!)

Fit to the mX distribution | **Subtracted spectrum**



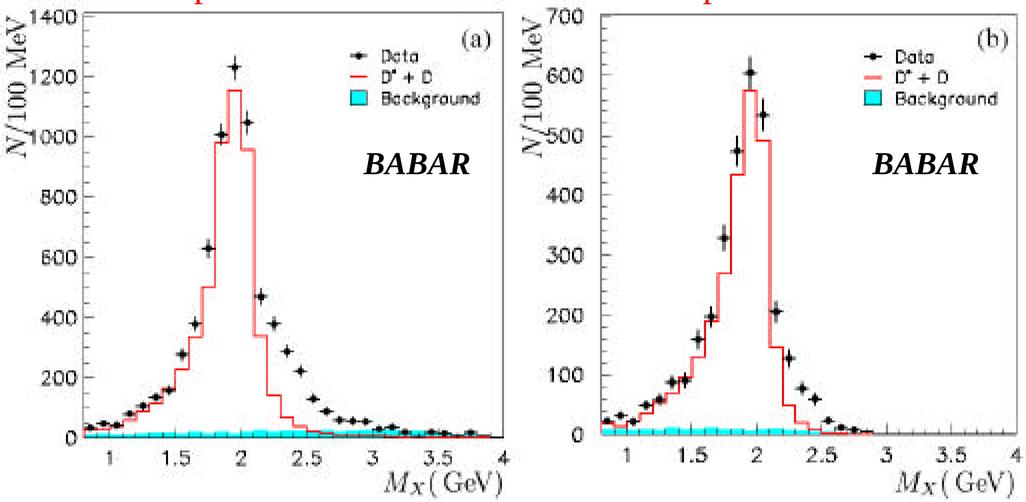
$$B(B \to X_u ln) = (2.24 \pm 0.27 \pm 0.26 \pm 0.39) \times 10^{-3}$$

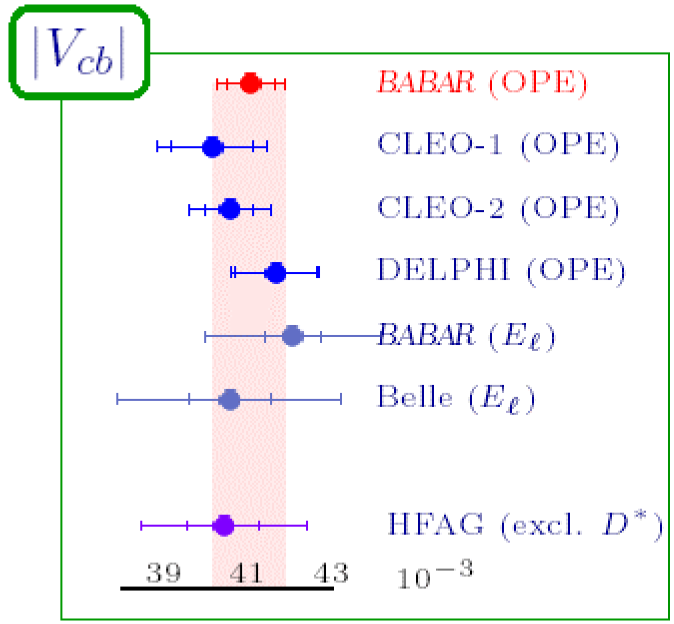
$$|V_{ub}| = (4.62 \pm 0.28(stat) \pm 0.27(sys) \pm 0.48(thy)) \times 10^{-3}$$

Measurement of $|V_{cb}|$ from Inclusive Semileptonic Decay

- **Three papers: 1 PRL and 2 PRDs accepted**
- **Study Lepton energy spectrum and mass spectrum of hadronic recoil system (below).**

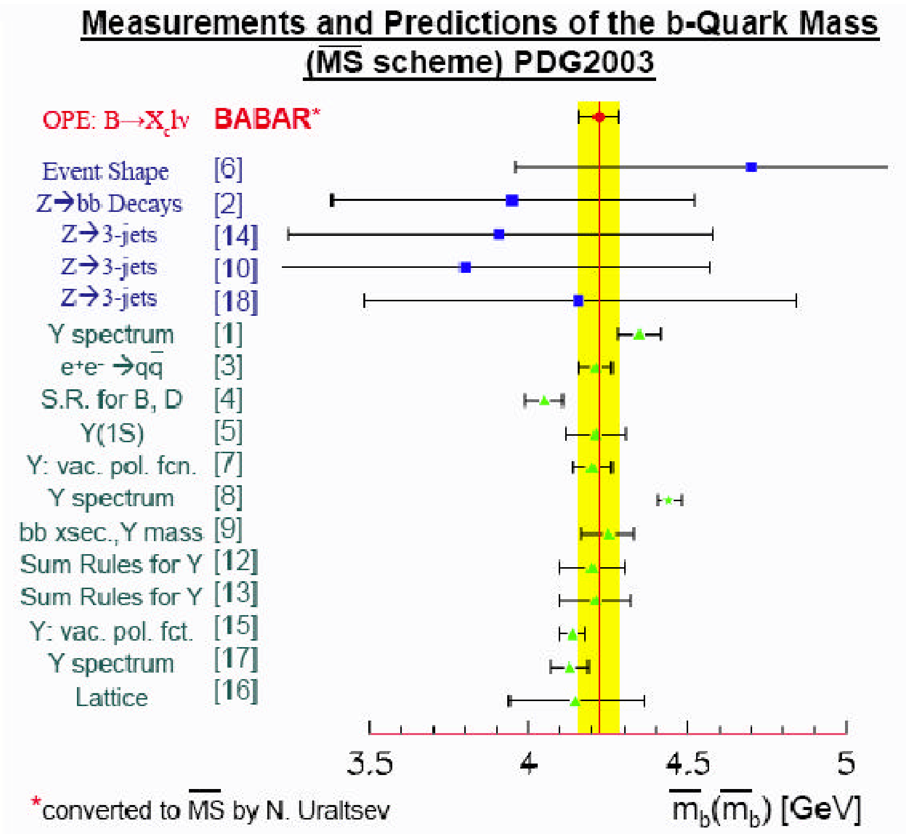
p* > 0.9 GeV   p* > 1.6 GeV

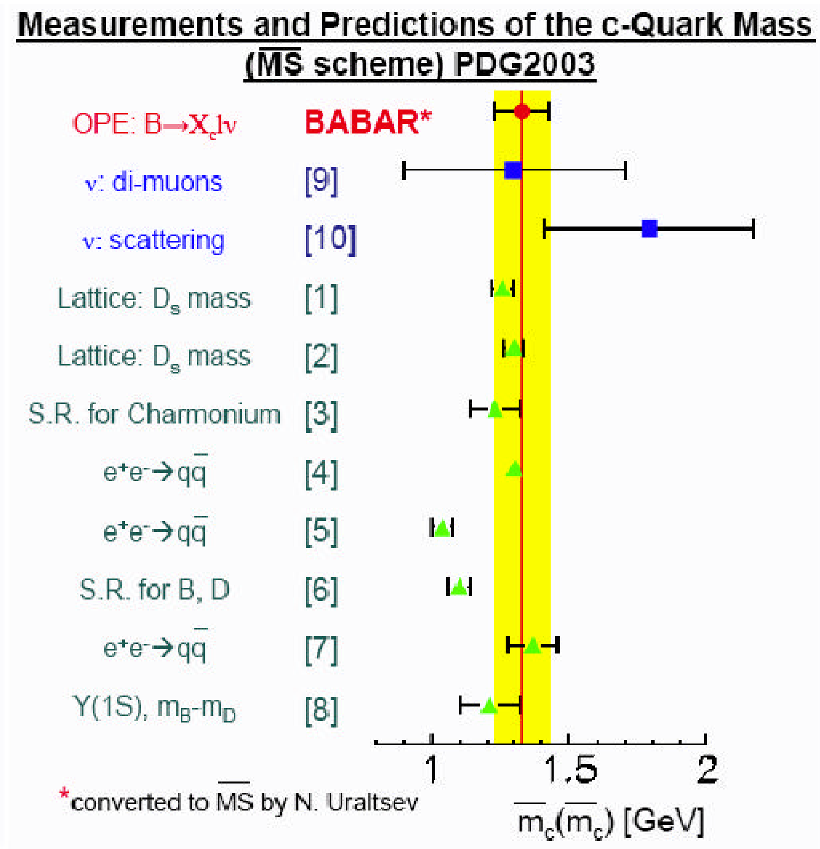




$$
\begin{aligned}
|V_{cb}| &= (41.4 \pm 0.4_{\text{exp}} \pm 0.4_{\text{HQE}} \pm 0.6_{\text{th}}) \times 10^{-3} \\
Br(B \to X_c e n) &= (10.61 \pm 0.16_{\text{exp}} \pm 0.06_{\text{HQE}})\% \\
m_b(1\,GeV) &= (4.61 \pm 0.05_{\text{exp}} \pm 0.04_{\text{HQE}} \pm 0.02_{\text{th}})\,GeV \\
m_b(1\,GeV) - m_c(1\,GeV) &= (3.44 \pm 0.03_{\text{exp}} \pm 0.02_{\text{HQE}} \pm 0.01_{\text{th}})\,GeV \\
m_p^2 &= (0.45 \pm 0.04_{\text{exp}} \pm 0.04_{\text{HQE}} \pm 0.01_{\text{th}})\,GeV^2
\end{aligned}
$$

Measurement of m_b and m_c from Inclusive Semileptonic Decay



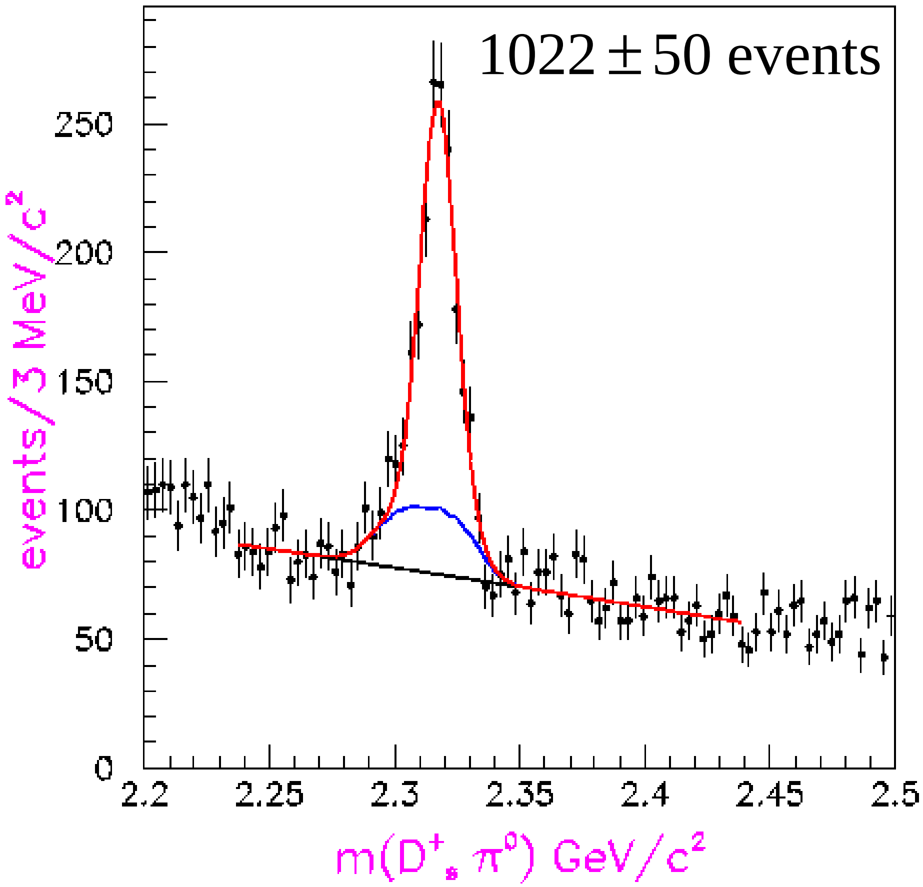


$\overline{m}_b(\overline{m}_b) = 4.22 \pm 0.06$ GeV ***BABAR*** $\overline{m}_c(\overline{m}_c) = 1.33 \pm 0.10$ GeV

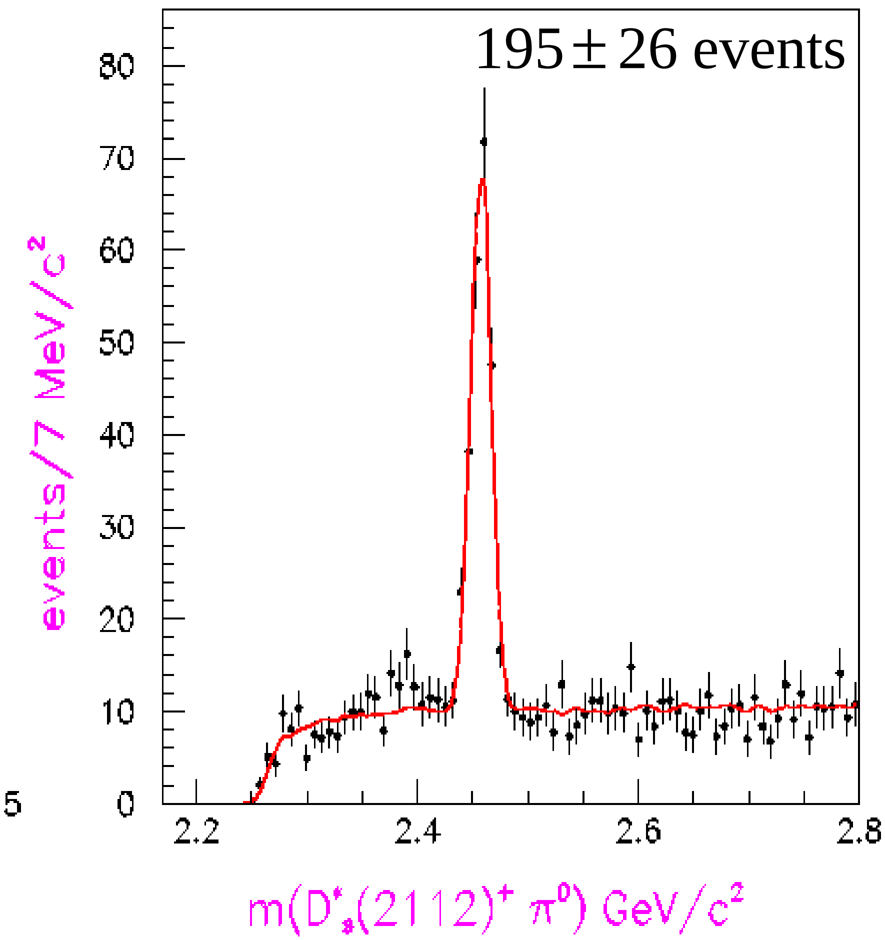
Conversion from kinetic mass scheme to $\overline{MS}$ scheme with hep-ph/9708372, hep-ph/0302262
See also report from CKM WS hep-ph/0304132

Signals for new states

$D_{sJ}(2317) \rightarrow D_s \pi^0$



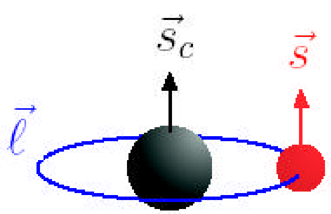
$D_{sJ}(2458) \rightarrow D_s^*(2112)\pi^0$



- Masses below DK threshold ➔ natural decay channel is forbidden.
- Decay widths are within experimental resolution, about 10 MeV.
- Pionic decays are I-spin violating, explaining the narrow observed widths.

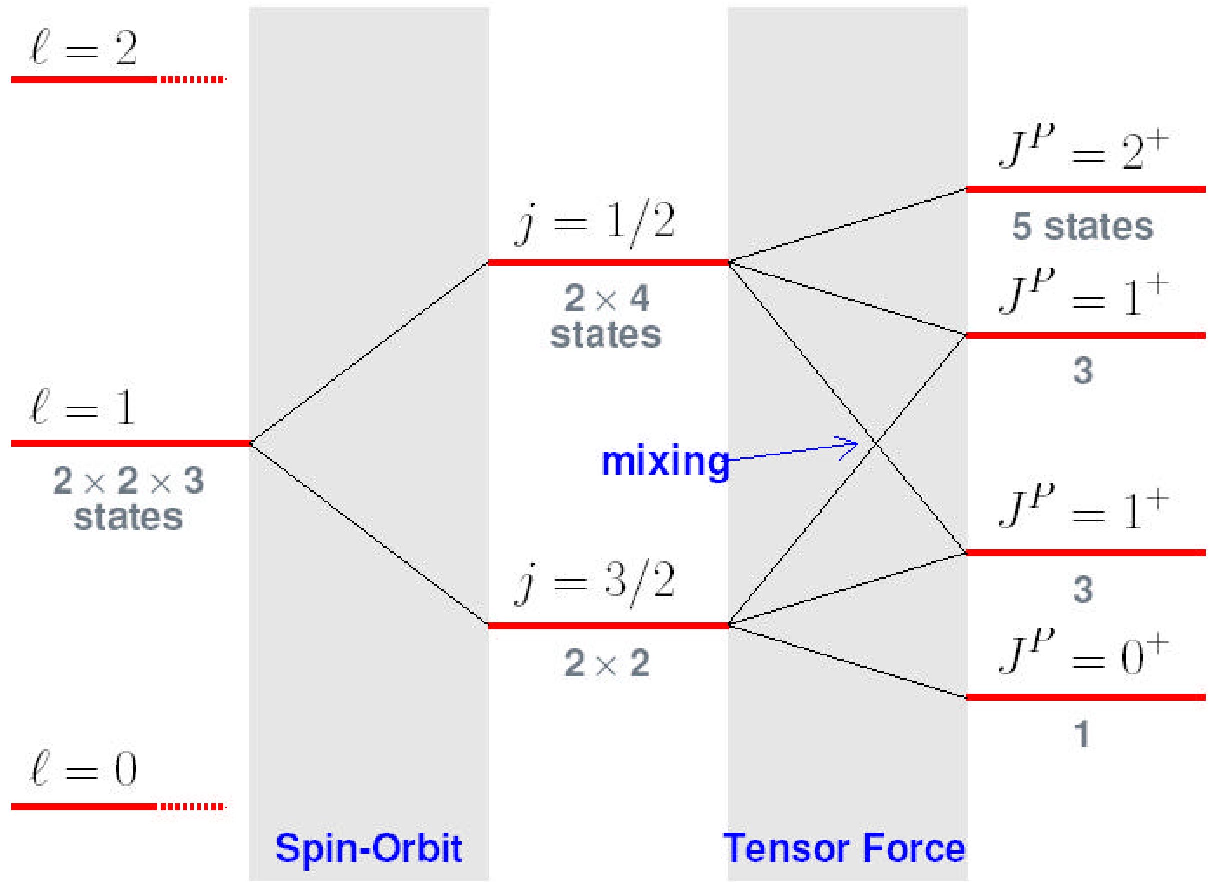
Interpretation: $c\bar{s}$ states with *l*=1

- In limit of infinitely heavy charm-quark mass, its spin decouples from the dynamics, so that the combined angular momentum j of the light-quark orbital and spin angular momentum is a good quantum number.
- For p-wave states, get j=1/2 and j=3/2. These levels are split by the spin-orbit interaction. Hyperfine interactions mean that j is not truly a good quantum number.



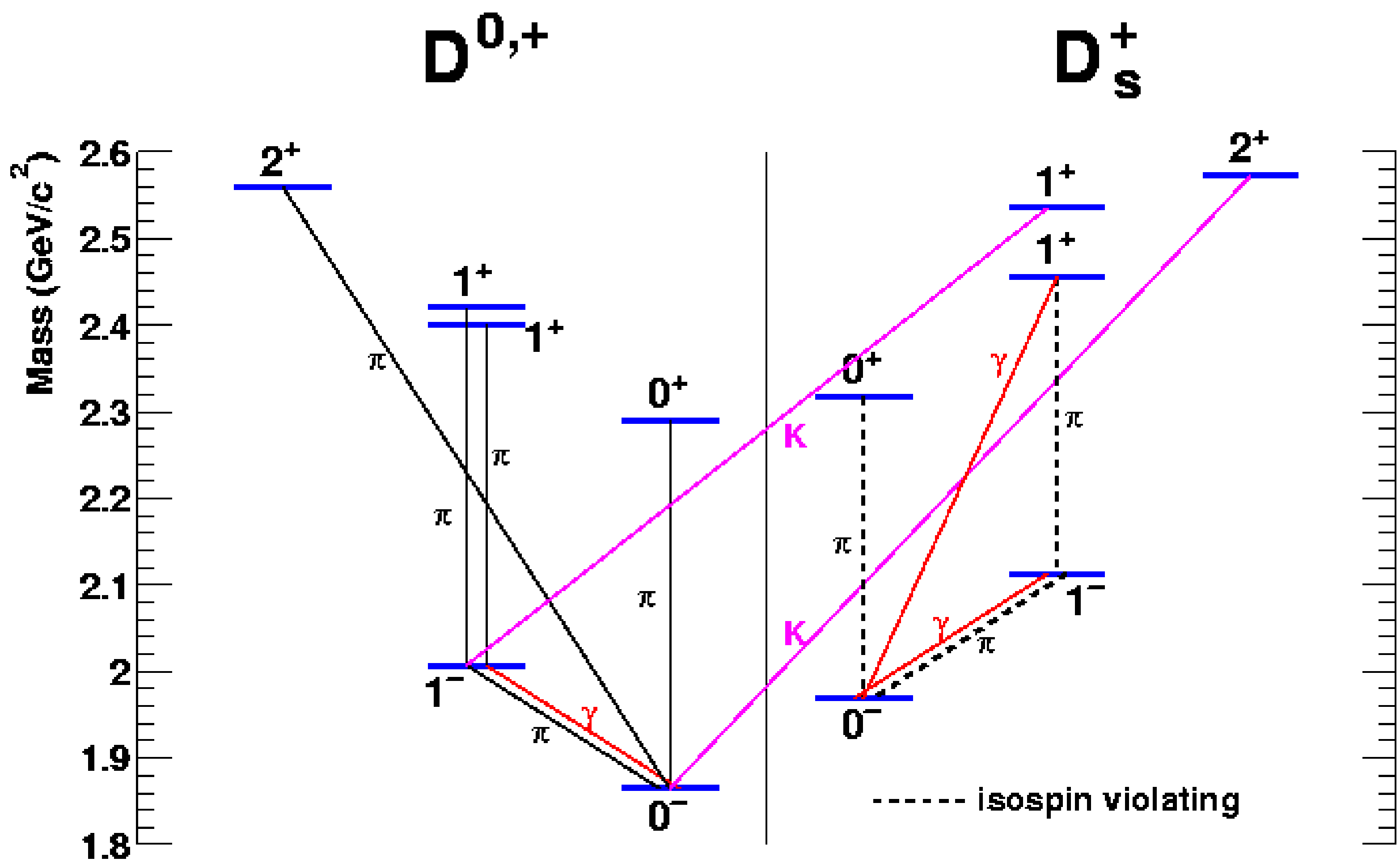
$$\vec{j} = \vec{\ell} + \vec{s}$$

$$\vec{J} = \vec{j} + \vec{s}_c$$



Decay pattern for excited charm mesons

- The properties of the new states are consistent with J^P=0+ and J^P=1+.
- Pionic decays are I-spin violating, explaining the narrow observed widths.



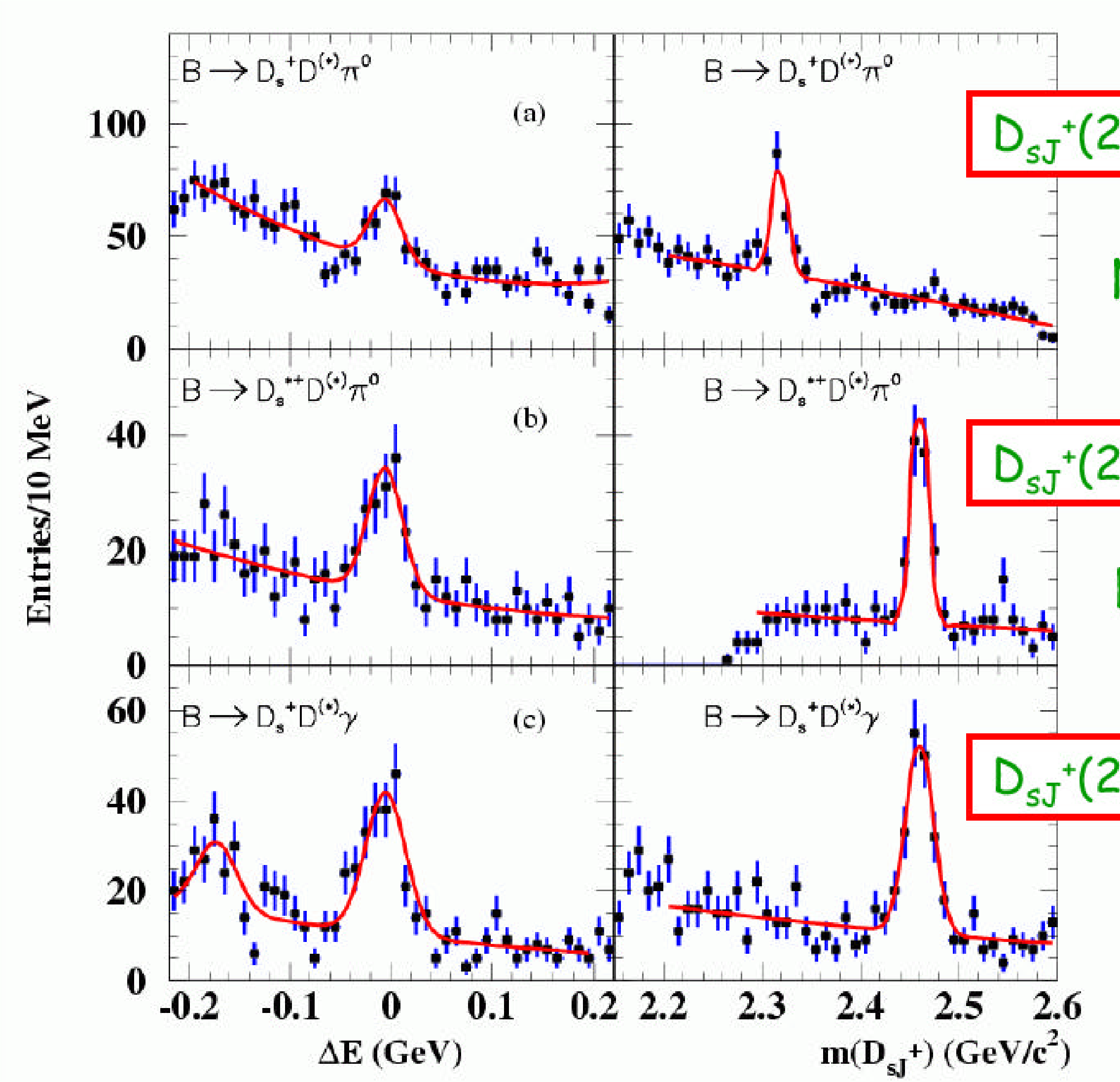
Observation of $B \rightarrow D_{sJ}\, D^{(*)}$ Modes

Presented by G. Calderini at Moriond QCD

	Decay Mode	Branching Fraction $\times 10^3$	
		this analysis	Belle [1]
I	$B^0 \to D_{sJ}^*(2317)^+ \overline{D}^-$ $[D_{sJ}^*(2317)^+ \to D_s^+ \pi^0]$	$2.09 \pm 0.40 \pm 0.34^{+0.70}_{-0.42}$	$0.86 \pm 0.26^{+0.33}_{-0.26}$
II	$B^0 \to D_{sJ}^*(2317)^+ \overline{D}^{*-}$ $[D_{sJ}^*(2317)^+ \to D_s^+ \pi^0]$	$1.12 \pm 0.38 \pm 0.20^{+0.37}_{-0.22}$	—
III	$B^+ \to D_{sJ}^*(2317)^+ \overline{D}^0$ $[D_{sJ}^*(2317)^+ \to D_s^+ \pi^0]$	$1.28 \pm 0.37 \pm 0.22^{+0.42}_{-0.26}$	$0.81 \pm 0.24^{+0.30}_{-0.27}$
IV	$B^+ \to D_{sJ}^*(2317)^+ \overline{D}^{*0}$ $[D_{sJ}^*(2317)^+ \to D_s^+ \pi^0]$	$1.91 \pm 0.84 \pm 0.50^{+0.63}_{-0.38}$	—
V	$B^0 \to D_{sJ}^*(2460)^+ \overline{D}^-$ $[D_{sJ}^*(2460)^+ \to D_s^{*+} \pi^0]$	$1.71 \pm 0.72 \pm 0.27^{+0.57}_{-0.35}$	$2.27 \pm 0.68^{+0.73}_{-0.68}$
VI	$B^0 \to D_{sJ}^*(2460)^+ \overline{D}^{*-}$ $[D_{sJ}^*(2460)^+ \to D_s^{*+} \pi^0]$	$5.89 \pm 1.24 \pm 1.16^{+1.96}_{-1.17}$	—
VII	$B^+ \to D_{sJ}^*(2460)^+ \overline{D}^0$ $[D_{sJ}^*(2460)^+ \to D_s^{*+} \pi^0]$	$2.07 \pm 0.71 \pm 0.45^{+0.69}_{-0.41}$	$1.19 \pm 0.36^{+0.61}_{-0.49}$
VIII	$B^+ \to D_{sJ}^*(2460)^+ \overline{D}^{*0}$ $[D_{sJ}^*(2460)^+ \to D_s^{*+} \pi^0]$	$7.30 \pm 1.68 \pm 1.68^{+2.40}_{-1.43}$	—
IX	$B^0 \to D_{sJ}^*(2460)^+ \overline{D}^-$ $[D_{sJ}^*(2460)^+ \to D_s^+ \gamma]$	$0.92 \pm 0.24 \pm 0.11^{+0.30}_{-0.19}$	$0.82 \pm 0.25^{+0.22}_{-0.19}$
X	$B^0 \to D_{sJ}^*(2460)^+ \overline{D}^{*-}$ $[D_{sJ}^*(2460)^+ \to D_s^+ \gamma]$	$2.60 \pm 0.39 \pm 0.34^{+0.86}_{-0.52}$	—
XI	$B^+ \to D_{sJ}^*(2460)^+ \overline{D}^0$ $[D_{sJ}^*(2460)^+ \to D_s^+ \gamma]$	$0.80 \pm 0.21 \pm 0.12^{+0.26}_{-0.16}$	$0.56 \pm 0.17^{+0.16}_{-0.15}$
XII	$B^+ \to D_{sJ}^*(2460)^+ \overline{D}^{*0}$ $[D_{sJ}^*(2460)^+ \to D_s^+ \gamma]$	$2.26 \pm 0.47 \pm 0.43^{+0.74}_{-0.44}$	—

[1] PRL 91, 262002 (2003)

Statistics based on 112.5 fb-1 (124 x 10^6 BB)



$D_{sJ}^+(2317)$

Nsig = 87.1 +/- 17.1

$D_{sJ}^+(2460)$

Nsig = 89.0 +/- 12.0

$D_{sJ}^+(2460)$

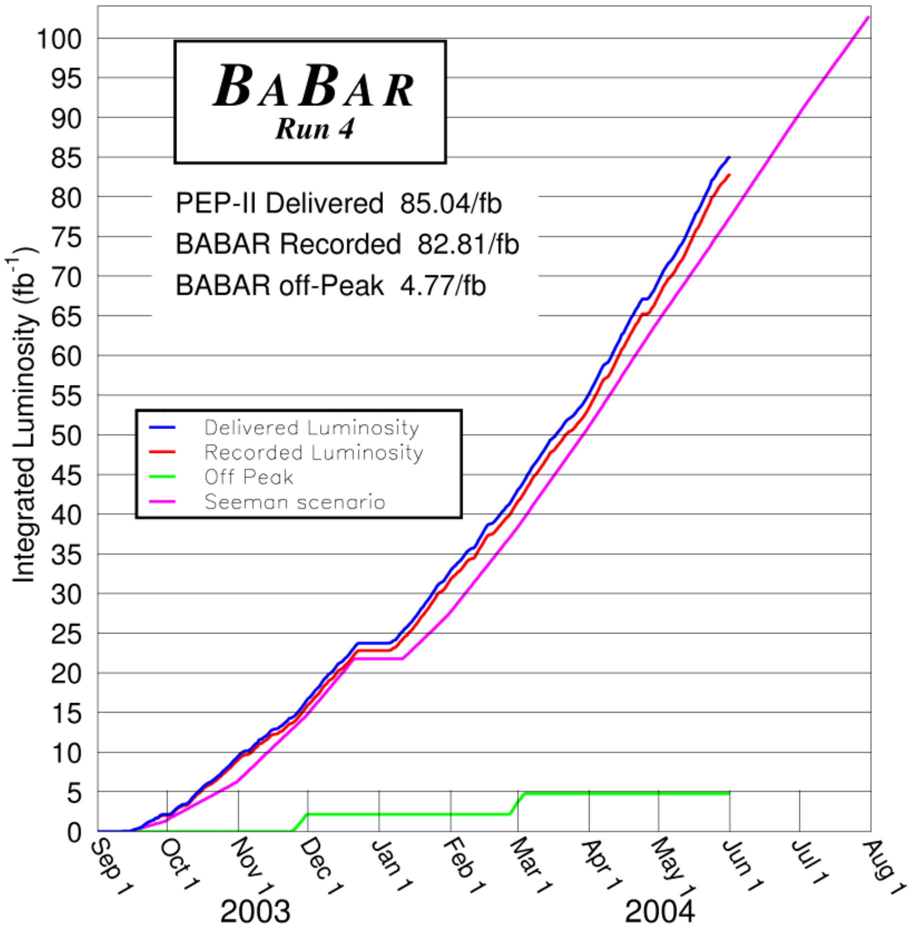
Nsig = 147.0 +/- 15.4

added over $D^{(*)}$ modes

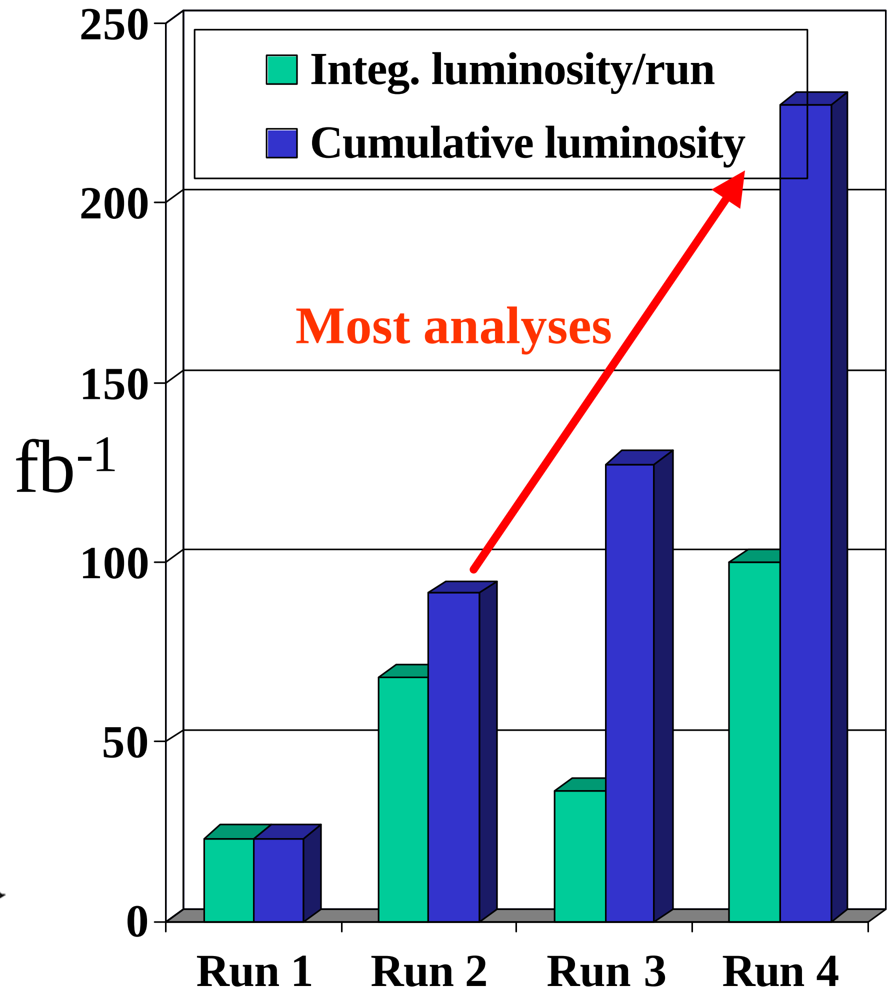
from G. Calderini Moriond talk

Plans for ICHEP'04

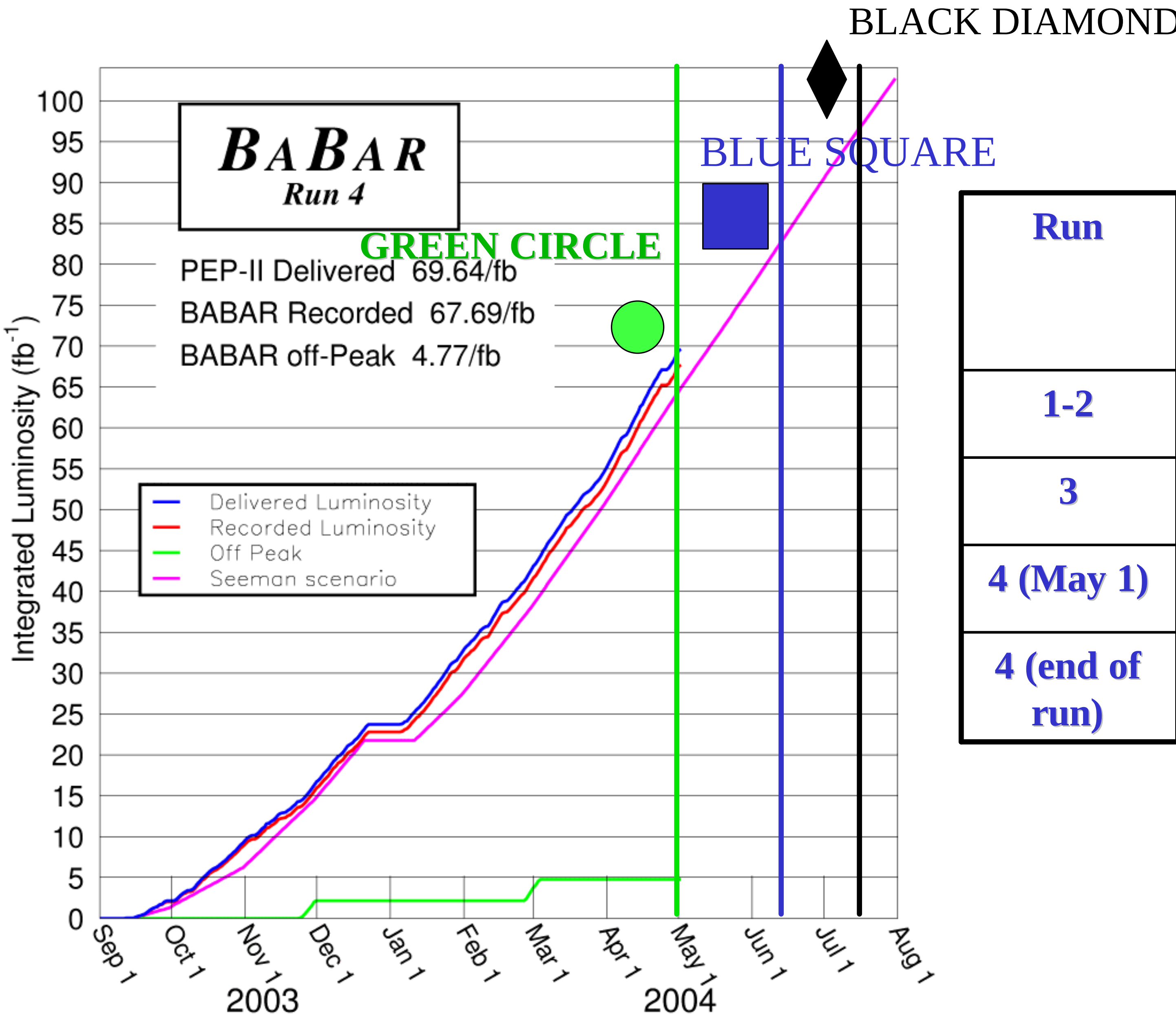
Run 4 is on track…



Run 4 goal



PEP-II/*BABAR* integrated luminosity and summer data samples



Run	Lumi (On Res) fb^{-1}
1-2	82.0
3	31.4
4 (May 1)	62.9
4 (end of run)	90

Key analyses for Run4/Summer 2004

BLACK DIAMOND (data up to mid-July)

- sin2b from charmonium
- $B \to p^+p^-$ (incl. K^+p^-, K^+K^-)
- $B \to f\ K_S$
- one more from list below?

BLUE SQUARE (data up to mid-June)

- $B \to K^+K^- K_S$
- $B \to K_S\ p^0$
- $B \to f_0\ K_S$
- $B \to h'\ K_S$
- $B \to r^0 K_S$
- $B \to r^+r^-$
- $B \to r^+p^-$ Dalitz
- $B \to p^0\ p^0$
- $B \to r^0 r^0$
- $B \to f\ K^*$ angular analysis

(The first seven Blue Square modes, $B \to K^+K^- K_S$ through $B \to r^+p^-$ Dalitz, are grouped by a brace: CP(t))

GREEN CIRCLE (data up to May 1)

- $B \to D^*D^*$ CP(t) [Full reco & incl D*]
- $B \to J/y\ Kp$ cos(2b) CP(t)
- $B \to p^+p^0$, K^+p^0
- $B \to K^+K^0$, K^0p^+ ; $B \to K^0K^0$
- $B \to h^+h^-h^0$ Dalitz
- $B \to K_S p^0 g$ CP(t)
- $B \to r\ g$
- $B \to K^*\ l^+\ l^-$
- $B \to D^*p$: CP(t), sin(2b+g) [full & partial D*]; Tag side CPV
- $B \to D^0(CP-)K^-$
- $B \to D(Kp)\ K$ (ADS)
- $B \to D^0$ (3 body) K^- Dalitz (?)
- $B \to Dr$ (?)
- $B \to D_s(*)(r, a_1)$

There are no longer just 3-4 “key” analyses!

Analyses Targeted for ICHEP '04 (I)

Instant Message WebMail Calendar Radio People Yellow Pages Download Customize...

	AWG Code	Analysis Name	Publication Status	Target Pub Period	Target Journal	Conference Status	Target Conference	Review Comm.
1	breco-02/06	Study of B0 to D(*)0K(*)0	AWG/RC	2/04		APPROVED/INTERNAL	ICHEP'04	comm91 [HN91]
2	breco-02/07	BF and ACP of B- to D*0 K-	AWG/RC	2/04		APPROVED/INTERNAL	ICHEP'04	comm26
3	breco-03/03	Study of B- to D0(CP-) K-	AWG	3/04			ICHEP'04	
4	breco-03/04	Study of D_sJ D(*)	AWG/RC	2/04			ICHEP'04	comm117
5	breco-03/08	BF and ACP of B- to D0(CP+) K*-(KS pi)	AWG	3/04			ICHEP'04	
6	breco-03/10	Study of B to D_s(*) D(*), B to D(*) D(*)	AWG/RC	2/04			ICHEP'04	comm122 [HN23]
7	breco-03/11	Study of B to D_s(*) rho/a1	AWG/RC	3/04			ICHEP'04	comm131
8	breco-03/12	Dalitz analysis of B to D0(3-body) K-	AWG	3/04			ICHEP'04	
9	breco-03/16	sin(2b+g) from B to D rho	AWG	3/04			ICHEP'04	
10	breco-04/03	sin(2b+g) from B to D* rho	AWG	3/04			ICHEP'04	
11	breco-04/05	Study of B -> [K+ pi-]_D K- and B -> (D*0 -> [K+ pi-]_D pi0(gamma)) K-	AWG	3/04			ICHEP'04	
12	breco-04/06	B0 to Ds Ds	Planned	3/04			ICHEP'04	
13	breco-04/07	B to D(*) p pbar pi	AWG	3/04			ICHEP'04	
14	Charm-02/01	Semileptonic Charm Mixing	AWG/RC	1/04	PRD-RAPID		ICHEP'04	comm125
15	Charm-02/02	Ds* Branching Fraction	RC-REQ	3/04	PRL		ICHEP'04	
16	Charm-02/03	Search for CP violation in D+->K+K-pi+	RC-REQ	2/04	PRD-RAPID		ICHEP'04	
17	Charm-03/02	DsJ radiative	AWG	2/04	PRD		ICHEP'04	comm90
18	Charm-03/04	Dalitz plot Analysis of D0->K0s K+ K-	AWG	2/04	PRD		ICHEP'04	
19	Charm-03/08	Study of Xi_c	AWG	4/04	PRD		ICHEP'04	
20	Charm-03/10	Lambda_c Cabibbo suppressed branching fractions	RC-REQ	3/04	PRD		ICHEP'04	
21	Charm-03/12	Search for D0->e/mu e/mu	AWG/RC	2/04	PRL		ICHEP'04	comm132
22	Charmon-03/01	Search for B0 -> Jpsi Gamma	AWG/RC	2/04	PRD-RAPID		ICHEP'04	comm124 [HN05]
23	Charmon-03/02	Study of B==> Jpsi + sbar Mesons, Part II	AWG	3/04	PRD		ICHEP'04	
24	Charmon-03/03	Search for B==> XK, X==> jpsi rho+/-	RC-REQ	3/04	PRL		ICHEP'04	
25	Charmon-03/04	Search for B==> XK , X==> rho pi & K*K	AWG	3/04	PRL		ICHEP'04	
26	Charmon-03/07	Double Charmonium Production around 10.58 GeV	AWG/RC				ICHEP'04	comm113
27	Charmon-03/11	Search for Factorization Suppressed c cbar s B decays	AWG	3/04	PRL		ICHEP'04	
28	Charmon-03/12	charmonia on the recoil of a K	AWG	3/04	PRL		ICHEP'04	
29	Charmon-03/14	Measurement of branching fractions for exclusive Bdecays to charmonium final states	AWG	3/04	PRL		ICHEP'04	
30	Charmon-04/03	Charmonium K* Angular Analysis	AWG	4/04	PRL		ICHEP'04	
31	Charmls2b-00/01	B-> h+h- CP asym and BF	Started	3/04	PRL		ICHEP'04	comm14
32	Charmls2b-01/01	B ->pi0pi0 BF and CP asymmetry	AWG	3/04	PRL		ICHEP'04	comm14
33	Charmls2b-03/03	B ->K0sX (X = pi+,pi0,K+,K0s) BF and direct CP asymmetry	Started	3/04	PRL		ICHEP'04	comm14

Document: Done

Analyses Targeted for ICHEP '04 (II)

33	Chmls2b-03/03	B->K0sX (X = pi+,pi0,K+,K0s) BF and direct CP asymmetry	Started	3/04	PRL		ICHEP'04	comm14
34	Chmls2b-04/01	B+->h+pi0 BF and ACP	AWG	3/04	PRL		ICHEP'04	comm14
35	Chmls2b-04/02	B->KSpi0 time dep analysis	Started	3/04	PRL	APPROVED/INTERNAL	ICHEP'04	comm100
36	Chmls3b-00/01	Analysis of B+ -> pi+pi-pi+ (Dalitz)	AWG	4/04	PRL		ICHEP'04	
37	Chmls3b-02/01	CP(t) in B0->rho+-pi-+ (Dalitz)	AWG	4/04	PRL		ICHEP'04	
38	Chmls3b-03/02	BF and CP(t) in B0->rho0KS (Q2B)	AWG/RC	2/04	PRL		ICHEP'04	comm123 [HN15]
39	Chmls3b-03/05	BFs and Acp's in B0->K+pi-pi0 (full Dalitz)	AWG	4/04	PRL		ICHEP'04	
40	Chmls3b-03/06	BF and Acp in B+->K*+(->K+pi0)pi0	AWG/RC	2/04	PRL		ICHEP'04	comm126 [HN15]
41	Chmls3b-03/07	BFs and Acp in B+ -> rho+K0s and B+ -> K*+pi0 (Q2B)	AWG	2/04	PRL		ICHEP'04	
42	Chmls3b-03/08	Analysis of B+ -> K+ pi- pi+ (Dalitz)	AWG	4/04	PRL		ICHEP'04	
43	Chmls3b-03/09	CP(t) and BF in B0 -> KSKSKS	AWG	4/04	PRL		ICHEP'04	
44	Chmls3b-03/10	Study of CP violating asymmetry in B to three kaon final states with KL	AWG	4/04	PRL		ICHEP'04	
45	Chmls3b-04/01	CP(t) in phiKS/KL	AWG	4/04	PRL		ICHEP'04	comm136
46	Chmls3b-04/02	CP(t) and BF in B0 -> K+K-KL	AWG				ICHEP'04	
47	Chmls3b-04/03	CP(t) and BF in K+K-KS (excl. phiKS) - Run 4 update	Started				ICHEP'04	
48	Chmls3b-04/04	CP(t) and BF in B0->f0(980)K0 - Run 4 update	Started				ICHEP'04	
49	Chmls3b-04/05	Analysis of B+ -> K+K-K+ (Dalitz)	AWG				ICHEP'04	
50	Chmls3b-04/06	CP(t) in PhiKS/KL	AWG				ICHEP'04	comm136 [HN15]
51	ChmlsQ2b-04/01	phiK*	CWR	3/04		APPROVED/CONF	ICHEP'04	comm119
52	ChmlsQ2b-04/02	rho0rho0 search '04	AWG/RC	3/04			ICHEP'04	comm121
53	ChmlsQ2b-04/04	phiphiK	AWG	3/04			ICHEP'04	
54	ChmlsQ2b-04/08	K*0rho+ etc	RC-REQ	2/04			ICHEP'04	
55	ChmlsQ2b-04/09	rho+rho- (CP) run1-4	AWG	3/04	PRD		ICHEP'04	
56	ChmlsQ2b-04/10	a1pi, K	AWG/RC	4/04			ICHEP'04	comm137
57	ChmlsQ2b-04/11	eta' K0s run 4 update	AWG/RC				ICHEP'04	comm139
58	ChmlsQ2b-04/12	BR and Acp of etapi, K,omega and eta'pi,K		4/04			ICHEP'04	
59	ExclSL-02/01	Form Factors in B0 -> D*+ l- nubar decay	AWG/RC	3/04	PRD		ICHEP'04	comm79 [HN11]
60	ExclSL-02/02	Exclusive semileptonic b->u using neutrino reconstruction	AWG	3/04	PRD-RAPID		ICHEP'04	
61	ExclSL-02/04	Vcb from B0-> D*lv decays	CWR	2/04	PRD-RAPID		ICHEP'04	comm75 [HN11]
62	ExclSL-03/01	B -> pi l nu on the recoil of semileptonic B reco	AWG	3/04	PRD-RAPID		ICHEP'04	
63	ExclSL-03/03	T violation in B0 -> D*- l+ nu decays	AWG	3/04	PRL		ICHEP'04	
64	ExclSL-03/04	B->pi-l+v on the recoil of partially reconstructed B0	AWG	4/04			ICHEP'04	
65	ihbd-02/02	B mixing with B->D*lnu	AWG/RC	3/04	PRL		ICHEP'04	comm111 [HN09]
66	ihbd-02/03	BR(Ds+->phipi+)	AWG/RC	3/04	PRL		ICHEP'04	comm78 [HN13]
67	ihbd-02/04	BR(Ups(4S)->B0B0bar) with B->D*lnu	AWG/RC	2/04	PRL		ICHEP'04	comm81 [HN73]

Document: Done

Analyses Targeted for ICHEP '04 (III)

BAIS - BaBar Analysis Information System - Netscape

File Edit View Go Communicator Help

Back Forward Reload Home Search Netscape Print Security Shop Stop

Bookmarks Location: https://www.slac.stanford.edu/babar-internal/BAIS/info/index.html What's Related

Instant Message WebMail Calendar Radio People Yellow Pages Download Customize...

68	ibbd-03/02	[illegible] B0->D*-l+nu		4/04	PRD		ICHEP'04	
69	ibbd-04/01	CP asymmetry with B0->D(*)*pi/rho(*)pi		3/04	PRD		ICHEP'04	cconf64 [HN09]
70	InclSL-01/01	Vub from the lepton endpoint	AWG/RC	2/04	PRL		ICHEP'04	cconf118
71	InclSL-02/03	Vub with a Q^2 El analysis	AWG/RC	2/04	PRL		ICHEP'04	cconf120
72	InclSL-03/03	Detailed b->u l nu studies with Hadronic Tags	AWG	4/04	PRD		ICHEP'04	
73	InclSL-03/04	Vub without shape function	Started	4/04	PRL		ICHEP'04	
74	ii-isr-03/01	ISR 4pi production: 4pi cross section	AWG/RC	3/04	PRD	APPROVED/CONF	ICHEP'04	cconf108
75	ii-isr-03/05	Study of e+e- -> pi+pi-pi0 process using initial state radiation with BaBar	AWG/RC	3/04	PRD		ICHEP'04	cconf105
76	ii-isr-03/09	Inclusive lambda_c	AWG	2/05			ICHEP'04	
77	ii-isr-03/12	Pentaquark in 2 Charm baryon events	AWG	2/05			ICHEP'04	
78	ii-isr-04/05	A search for Pentaquark decay to cascade Pi and cascade K	AWG/RC		PRD-RAPID		ICHEP'04	cconf130
79	ii-isr-04/06	Pentaquark->pKs search	AWG/RC	3/04	PRD-RAPID		ICHEP'04	cconf130
80	Lept-02/01	B+ -> K+ nu nubar	AWG/RC	1/04	PRL		ICHEP'04	cconf58 [HN58]
81	Lept-02/02	B0-> l+l-	RC-REQ	2/04	PRL		ICHEP'04	
82	Lept-03/03	B+ -> tau+ nu (RUN 4)	AWG	1/05	PRL		ICHEP'04	cconf58 [HN58]
83	RadPen-02/03	b -> s gamma FULL Run 2	AWG	3/04	PRD		ICHEP'04	cconf53 [HN12]
84	RadPen-03/03	B0 -> gamma gamma Run 3	RC-REQ	3/04	PRD-RAPID		ICHEP'04	
85	RadPen-03/06	B -> rho/omega gamma Run 4	AWG	4/04	PRL		ICHEP'04	
86	RadPen-03/07	b -> s gamma SEMI (BF and Spectrum) Run 2	AWG	3/04	PRD		ICHEP'04	cconf102 [HN12]
87	RadPen-04/01	b -> s l+l- Run 4	Started	4/04	PRL		ICHEP'04	
88	RadPen-04/02	B -> K(*) l+l- Run 4	Started				ICHEP'04	
89	RadPen-04/03	B -> K* gamma Run 4	Planned	4/04	PRD-RAPID		ICHEP'04	
90	RadPen-04/04	B0 -> D*0 gamma Run 2	AWG	3/04	PRL		ICHEP'04	cconf101 [HN12]
91	RadPen-04/05	B0 -> KS pi0 gamma TDCPV Run 4	Started	4/04	PRD-RAPID		ICHEP'04	
92	s2beta-02/03	delta m_d from dileptons	AWG				ICHEP'04	
93	s2beta-04/01	sin2beta from (c cbar) K0	Planned	3/04			ICHEP'04	
94	s2beta-04/02	sin2beta from D(*)D(*)	Planned	3/04			ICHEP'04	
95	s2beta-04/04	cos2beta update	Planned	4/04			ICHEP'04	
96	s2beta-04/05	|q/p| from dileptons	AWG	4/04			ICHEP'04	
97	Tau/QED-03/09	Five prong tau decays	RC-REQ	3/04	PRL		ICHEP'04	

Key to Publication Status Values

Status Code	Description
Planned	Analysis is planned but has not started
Started	Analysis is started; no AWG presentations
AWG	Analysis in progress by analysts
RC-REQ	Review Committee Requested
AWG/RC	Analysis is under review by the review committee
CWR	Analysis is in collaboration-wide review

Key to Conference Status Values

Status Code	Description
CWR/CONF	Conference paper draft approved by review committee and in CWR
CWR/INTERNAL	Internal note approved by review committee and in CWR
APPROVED/CONF	Approved conference paper
APPROVED/INTERNAL	Approved internal physics note

Document: Done

Conclusions

- *BaBar* physics productivity is very high: we are producing 40-50 papers/year. The collaboration is extremely enthusiastic about our physics program.
- The remarkable performance of PEP-II is creating a wealth of new physics opportunities, and there are about 200 active physics analyses. Most of them are performed by small groups, providing opportunities for graduate students and postdocs.
- We and our colleagues in Belle have significantly expanded the set of hadronic penguin modes used for sin2β measurements. Such modes provide a promising way to search for new physics.
- We are making significant progress in the measurement of α, a major goal in heavy-quark physics.
- We are exploring a vast territory of rare decays. This area is a major part of our physics program that is a window on new physics.

Conclusions, continued

- Due to BABAR's open trigger, which is characteristic of e^+e^- experiments, we are able to study a huge number of processes and to make discoveries in unexpected areas. The discovery of the new charm-strange states is just one example.
- We have used a variety of approaches that enable us to pursue measurements previously considered impossible. We are using these methods to improve the precision on the magnitudes of CKM elements, and we are determining key QCD parameters that characterize *B*–meson decays.
- Nearly all of our measurements are statistics limited. <u>We need the DOE's continued strong support for the *B* factory to realize the huge potential of this program.</u>