PEP-II/BaBar Status and Plans

By Jonathan Dorfan, Director

HEPAP Meeting, Washington DC

January 29, 2002

Recent PEP-II Luminosity Increase

- **From June through December 2001, the PEP-II luminosity increased from 3.3 to 4.5 x10^{33} and the integrated luminosity from 175 to 309 pb^{-1}/day**
- **Reasons for increase:**
  - **Number of bunches: 692 ✍ 796**
  - **LER vert. dispersion: 250 mm rms ✍ 50 mm rms**
  - **HER current: 800 mA ✍ 1005 mA**
  - **LER current: 1550 ✍ 1758 mA**
  - **HER ? $_x$*: 60 cm ✍ 50 cm**

PEP-II Records

Last update:
Dec 23, 2001

Peak Luminosity

4.513? 10^{33} cm??sec?? December 15, 2001

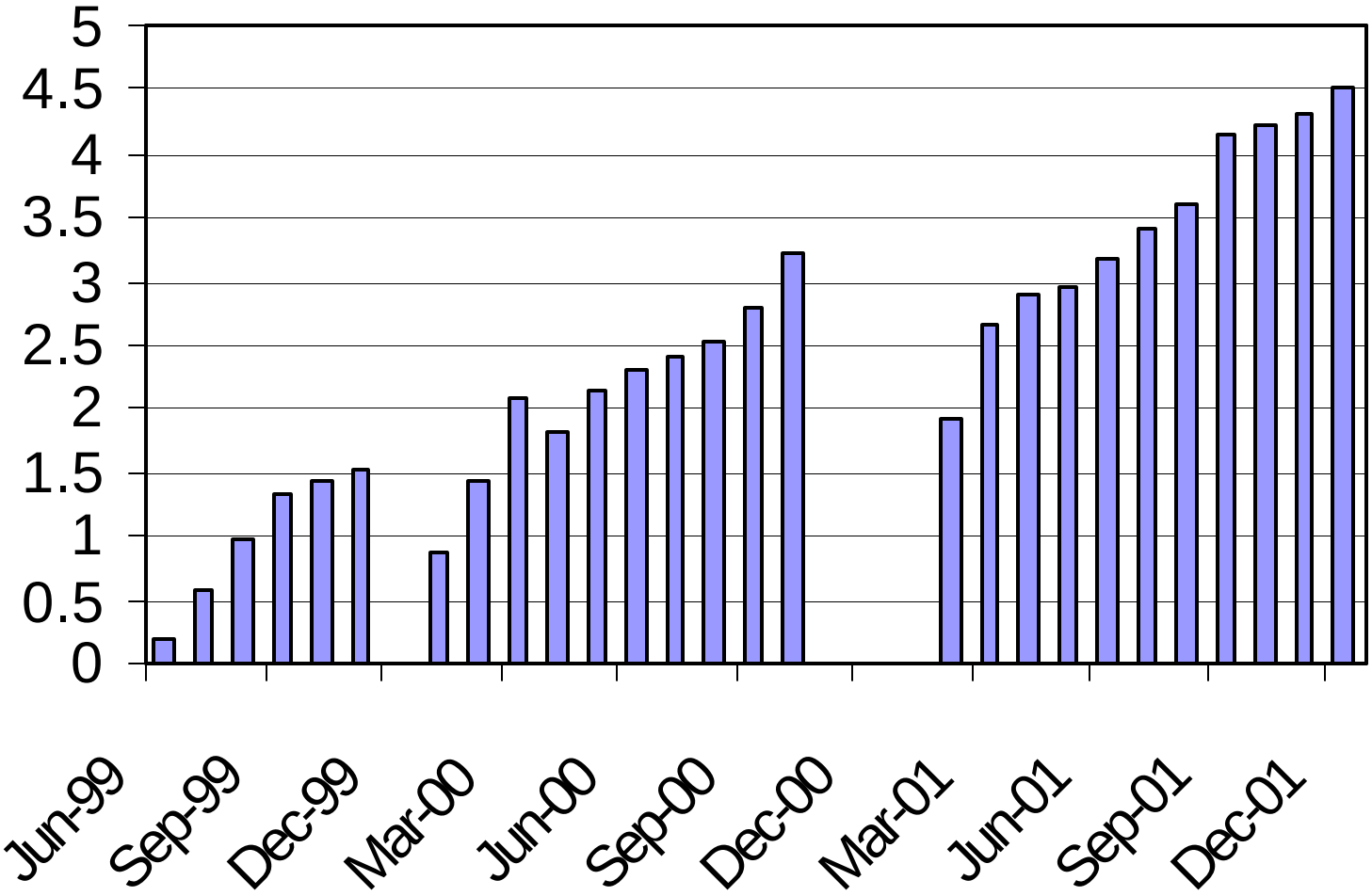
762 bunches 1675 mA LER 975 mA HER

Integration records of delivered luminosity

Best shift (8hrs)	106.2 pb??	Dec 22, 2001
Best 3 shifts in a row	308.8 pb??	Dec 22-23, 2001
Best 7 days	1.865 *f*b??	Oct 23-29, 2001
Best month	6.35 *f*b??	October 2001
Total delivered	70.7 *f*b??	In First Two Years

Design was 30*f*b^{-1}/year. Current daily average corresponds to > 60 *f*b^{-1}/year

Maximum PEP-II Luminosity (x1E33)



I HER	I LER	Luminosity	Spec Lum	E HER	E LER	E CM
985.05	1661.98	4244	2.06	8992	3120	10594
mA	mA	10^30	N*10**30 / mA**2	MeV	MeV	MeV

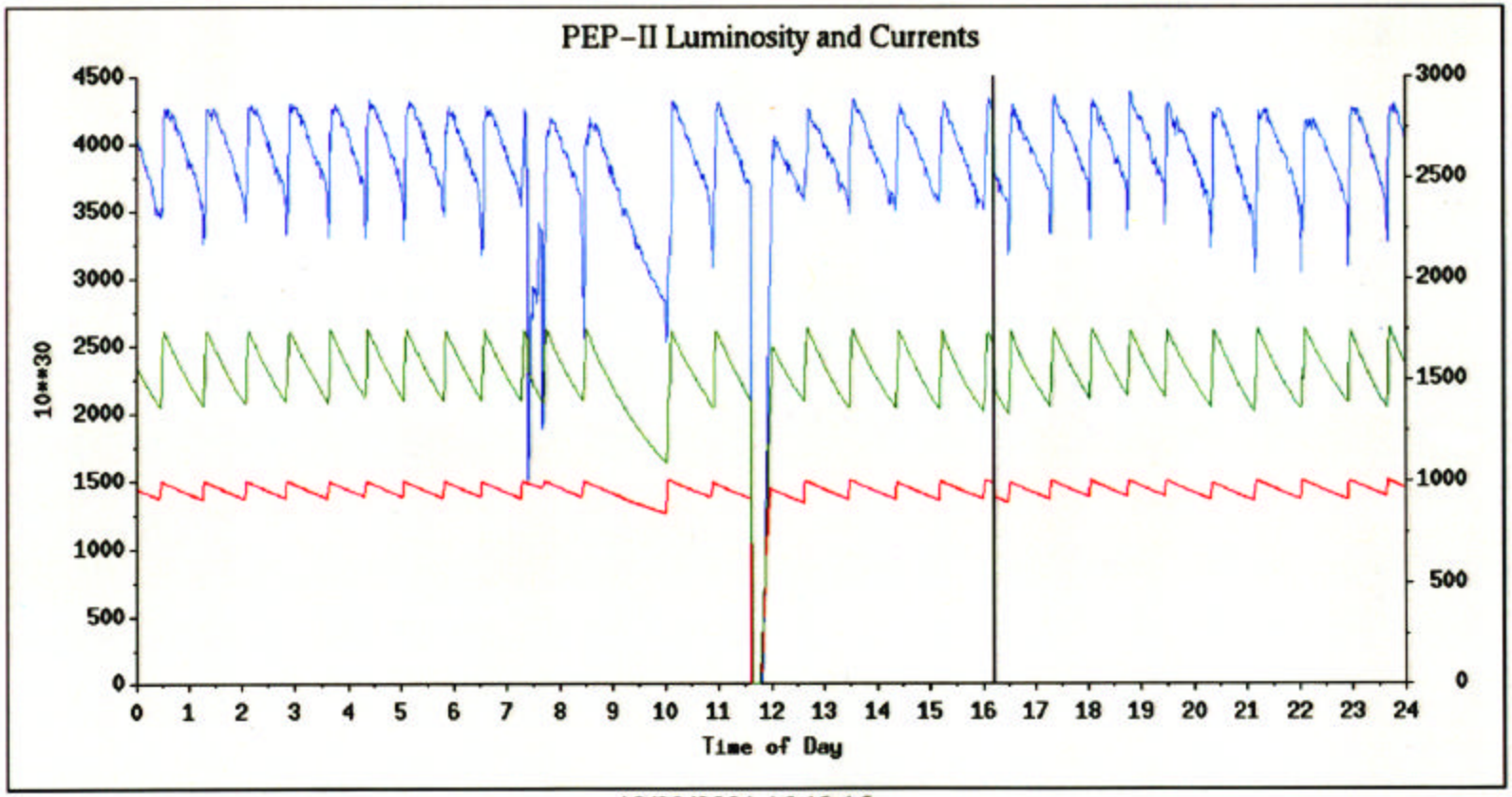
N Buckets/HER Pattern

796 by4_trains_of_23_off_by_2_her

N Buckets/LER Pattern

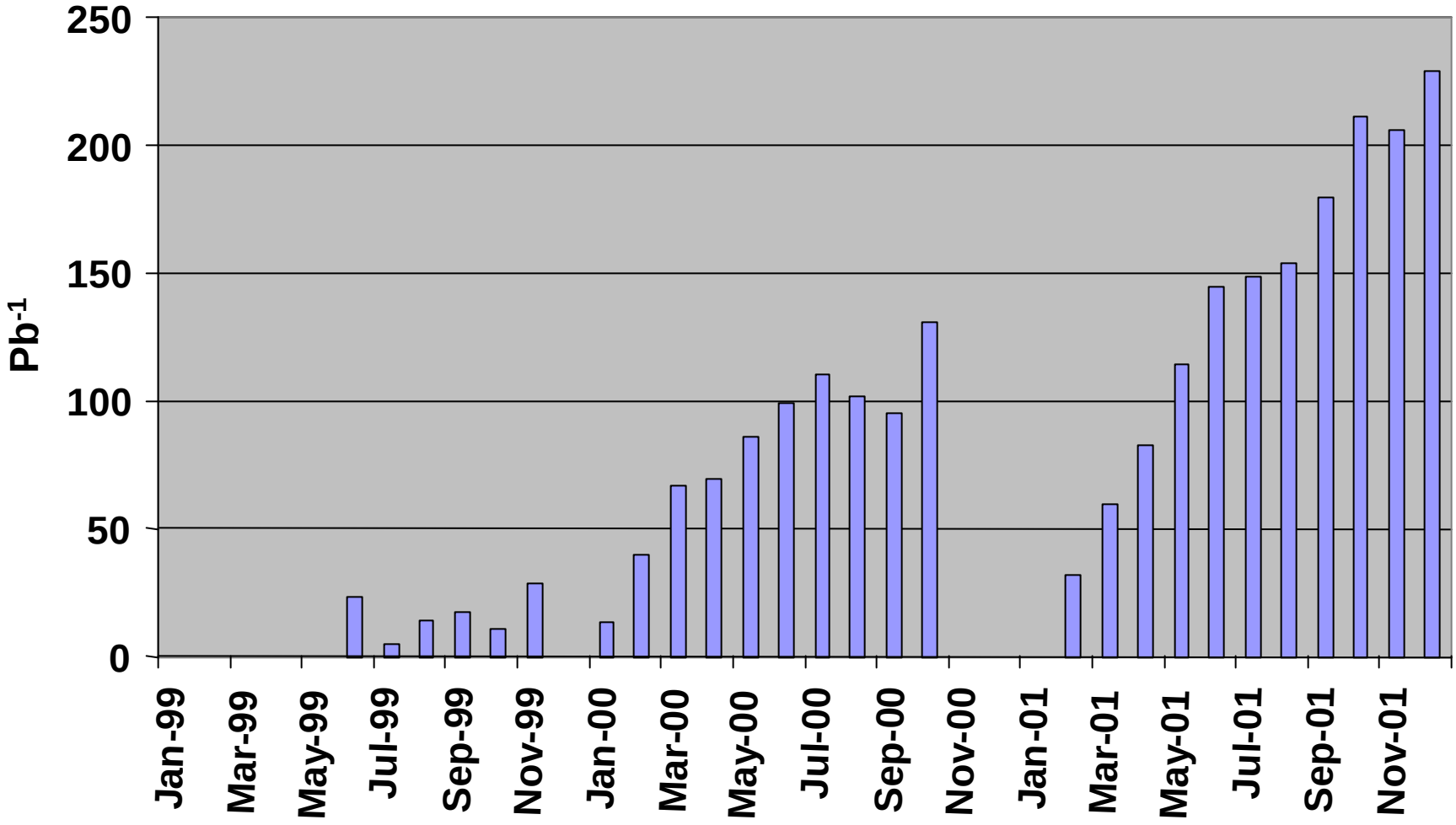
796 by4_trains_of_23_off_by_2

Last Owl/Day/Swing/24 Hr:	105.0	97.6	106.2	308.8	Shift:	2.00	/pb
Peak Luminosities:	4339	4353	4395			4353	



12/23/2001 16:13:16

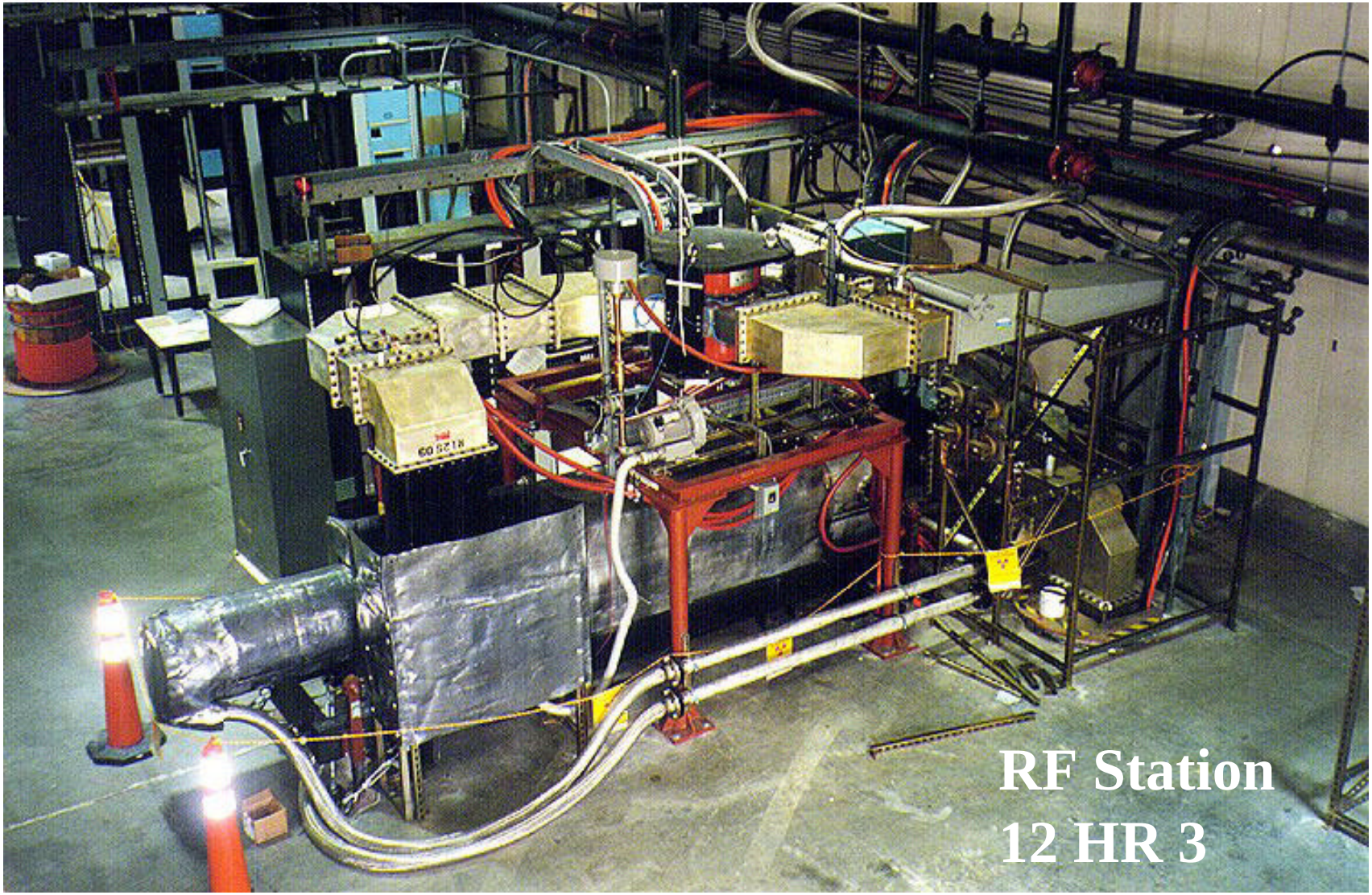
PEP-II Daily Average for each Month



PEP-II Near Term Plans

- Present run will end July 1, 2002
- Luminosity goal by June 2001 is 5 x 10^{33}
- Total integrated luminosity of 100 fb^{-1} in June 2002
- Followed by a four month down
  - Two HER RF stations, New Q2 chamber
  - New kicker feedthrus, HER upstream collimator

PEP-II *B* Factory



Other PEP-II parameters tried but not ready for production collisions

- ? $_y$*: 12.5 ✍ 11.5 mm (problem: e+ lifetime)
- Horizontal tunes 0.58 ✍ 0.52 (LER beta beats large)
- Trickle charge -- constant e+ injection (BaBar bkgds)
- Bunch spacing of 2 RF buckets (5% parasitic beam-beam tune shift loss)
- Add third LER RF station (short bunches heat IR Beampipe bellows)
- HER emittance 50 nm ✍ 38 nm (steers LER)
- HER/LER ? $_x$* 50 cm ✍ 35 cm (larger vertical tune shifts)

PEP-II and KEKB Schedules

Accelerator:	PEP-II	KEKB
Winter shut down	Dec 23	Dec 27
Winter turn on	Jan 11	Jan 15
Summer shut down	July 1	July 1
Fall turn on	Nov 1	Sept 1

The *BABAR* Collaboration

9 Countries
74 Institutions
527 Physicists

50% Outside US

USA [37/261]

California Institute of Technology
UC, Irvine
UC, Los Angeles
UC, San Diego
UC, Santa Barbara
UC, Santa Cruz
U of Cincinnati
U of Colorado
Colorado State
Florida A&M
Harvard
U of Iowa
Iowa State U
LBNL
LLNL
U of Louisville
U of Maryland
U of Massachusetts, Amherst
MIT
U of Mississippi
Mount Holyoke College
Northern Kentucky U
U of Notre Dame
ORNL/Y-12
U of Oregon
U of Pennsylvania
Prairie View A&M
Princeton
SLAC
SUNY Albany
U of South Carolina
Stanford U
U of Tennessee
U of Texas at Austin
U of Texas at Dallas
Vanderbilt
U of Wisconsin
Yale

Canada [4/15]

U of British Columbia
McGill U
U de Montréal
U of Victoria

China [1/5]

Inst. of High Energy Physics, Beijing

France [5/52]

LAPP, Annecy
LAL Orsay
LPNHE des Universités Paris 6/7
Ecole Polytechnique
CEA, DAPNIA, CE-Saclay

Germany [3/24]

U Rostock
Ruhr U Bochum
Technische U Dresden

Italy [12/94]

INFN and U Bari
INFN and U Ferrara
Lab. Nazionali di Frascati dell' INFN
INFN and U Genova
INFN and U Milano
INFN and U Napoli
INFN and U Padova
INFN and U Pavia
INFN, SNS and U Pisa
INFN, Roma and U "La Sapienza"
INFN and U Torino
INFN and U Trieste

Norway [1/3]

U of Bergen

Russia [1/8]

Budker Institute, Novosibirsk

United Kingdom [10/65]

U of Birmingham
U of Bristol
Brunel University
U of Edinburgh
U of Liverpool
Imperial College
Queen Mary & Westfield College
Royal Holloway, University of London
U of Manchester
Rutherford Appleton Laboratory

Building for the Future!

POST DOC/GRAD STUDENT SUMMARY		
(BaBar Physicist Members, not including Associates)		*02/10/01*
Country	**Grad Students**	**Post-docs**
CANADA	4	4
CHINA	0	0
FRANCE	10	* 2
GERMANY	14	3
ITALY	21	* 12
NORWAY	1	0
RUSSIA	0	* 0
UK	25	19
USA	56	59
Totals	131	99

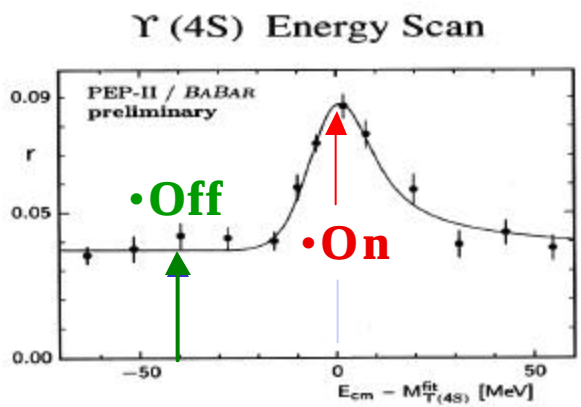
*** Underestimated --** people obtain permanent positions very early

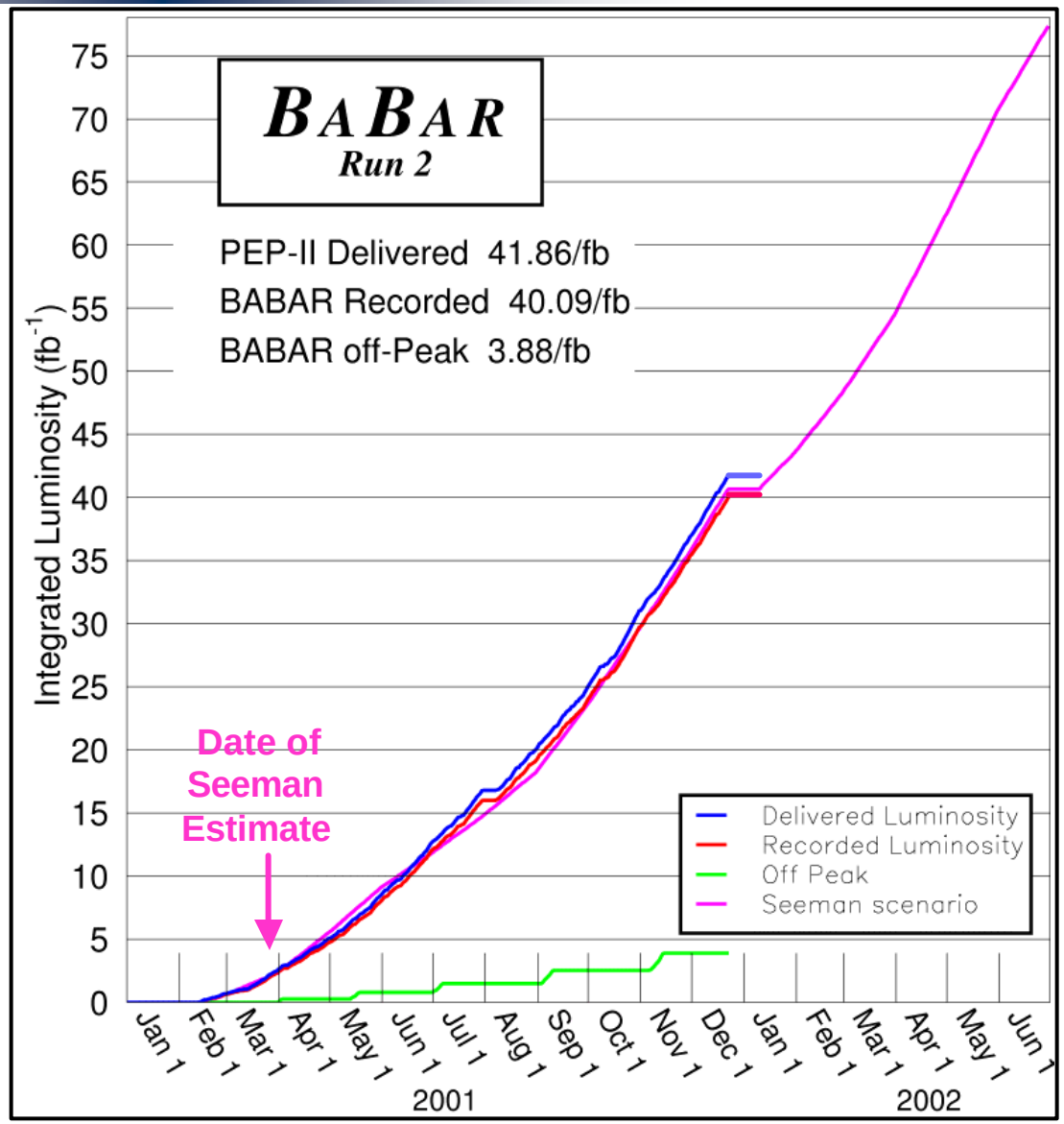
2000 – 2002 Operations

- 24 fb^{-1} in 2000
- 40 fb^{-1} in 2001
- 36 fb^{-1} by June 30 '02
- 4-month shutdown

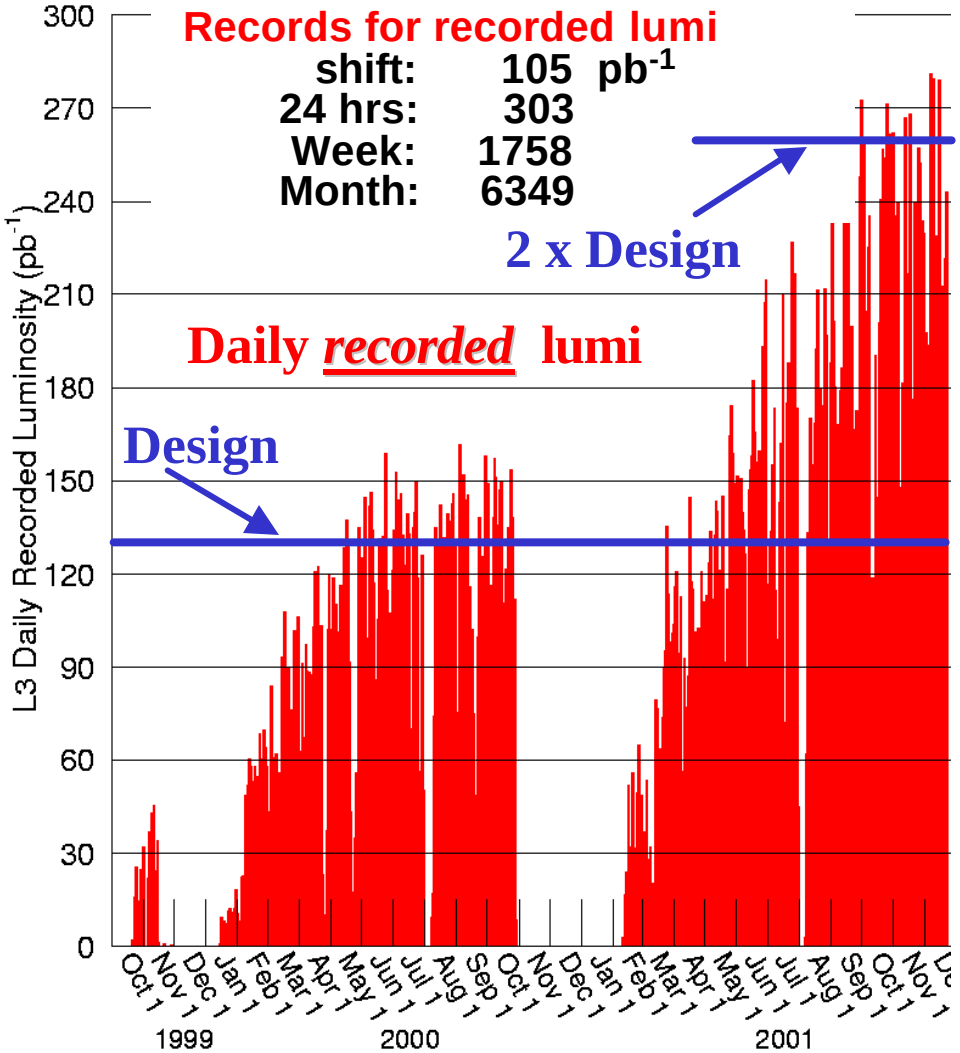
100 fb^{-1} by June 30

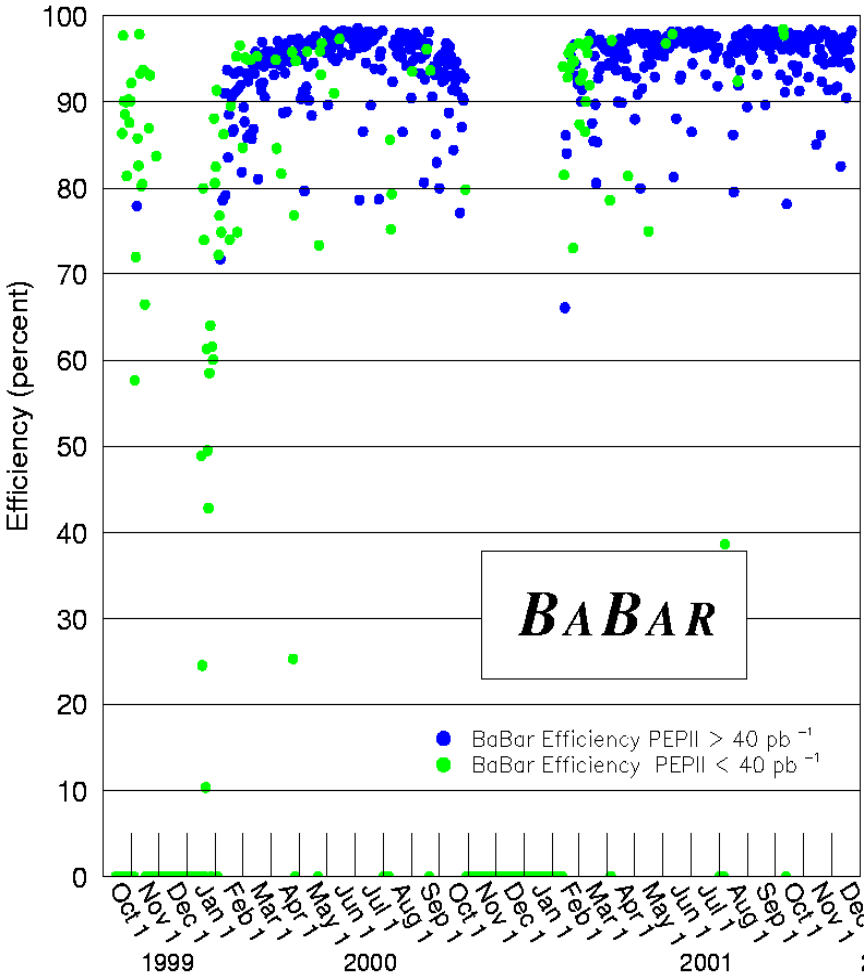
(~12% off peak)





PEPII/BaBar Performance





Physics Reach of BaBar

- **B Physics: <u>A B factory</u>**
  - **The Primary testing ground for the *CP* mechanism of the SM**
  - **<u>The CKM Matrix</u>**
    - Is it complex?
    - Precision measurement of its parameters, by measurements of *CP* violation in B decays, BB(bar) mixing, B lifetime, Br for hadronic, semi-leptonic, and leptonic B decays.
  - **Rare B decays and search for physics beyond the SM.**
- **Charm Physics: <u>A charm factory</u>**
  - **Search for D0-D0(bar) mixing, and *CP* violation in D decays.**
  - **Charmed hadron Lifetimes**
  - **Strong interaction effects in charmed hadron decays**
  - **Engineering information: Absolute branching ratios**
- **Tau Physics: <u>A Tau factory</u>**
- **Physics with the ISR events:**
  - **Measuring R vs sqrt(s)**
  - **Measuring absolute branching ratios of charm decays**

BABAR Physics Results

- Journal publication
- Submitted for Publication
- Preliminary Conference Presentation

CP Violation Studies

- *CP* violation in B Decays to charmonium states (sin2?)
- Direct CPV in 2-body charmless Decays (? +*K*-, ? +?⁰, ? +
- CP violation in the decay B ? ??? ? ?sin2? ? eff)
- Direct CP violation in B Decays to charmonium states
- Direct CP violation in quasi 2-body charmless Decays
- CP violation in mixing with Dileptons
- CP violation in B Decays to Double-Charm states (sin2?)

Charmonium Studies

- *J*/? production in continuum
- *J*/? *K** angular analysis
- Exclusive branching fractions
- *J*/? *K* versus *J*/? ?
- ? *(2s)* *e+e-*/ ? *)2s)* ? ? ? ?
- Inclusive branching fractions

Charmless *B* Decays

- Branching Ratios for 2-body charmless decays:
  ? +? -, ? +*K*-, *K*+*K*-, ? ?⁰, ? *Ks*, ? ⁰*Ks*, *KsKs*, (??
- B->? (with *K*, *Ks* or *K** ??
- B (? ?, ?) (? ??? ?
- Inclusive B->? ? X_s
- ? a⁰ (? ??? ?
- B 3-body(? ? ? ??? ? ??? ? ? ?
- B (? ???) (K*, ? ??? ??? ')
- B (? ?? ')(K*)
- 4-prong modes (B a1? ?

B Lifetimes and Mixing

- B^0 and B^+ Lifetimes with fully Reconstructed hadronic B decays
- B^0 Mixing with Dilepton Events
- B^0 mixing with fully reconstructed hadronic B decays
- B^0 mixing, lifetimes with Semileptonic decays
- B lifetimes with Dilepton Events
- B Lifetimes with partially reconstructed B's
- B^0 mixing with partially reconstructed B's

BABAR Physics Results

- Journal publication
- Submitted for Publication
- Preliminary Conference Presentation

Radiative Penguins

- B ? ? ?
- B ? K* ?
- B ? K(*)ll
- b ? s ? - semi inclusive
- limits on B- ? ?? ??
- B->s ??– fully inclusive

B Decays to Open Charm

- B D(*)D(*)
- B D(*) D(*)K modes
- Ratio of Br. For B D K /B D?
- B D_s(*) D(*) & Inclusive Ds
- B DD(*)
- Ratio of B D* K /B D*? ??Partially Reco)
- Color suppressed modes: D^0? ^{0}?? ??

Semileptonic B Decays
Vub & Vcb measurements

- Ratio of B^0 & B^+ SL Branching Fractions
- Semi-leptonic B Branching Fractions
- Branching Fracs for B (? ?? ????*l*? ?? $|V_{ub}|$)
- $|V_{ub}|$ from Lepton Spectrum
- Exclusive *D(*)l*? ? (*$|V_{cb}|$)

Charm Physics

- Lifetime-Differences: D^0 K-? ? ?vs D^0
- K+K-
- Wrong sign fraction in D^0 Decays
- Limits on D^0 mixing
- Dalitz analyses (Ds and D0 Decays)
- Branching fraction For ? $_c$ pk?
- D-mixing with SL
- Branching fract for charm Decays with ISR events

Leptonic *B* Decays

- *B* ? ? ? ??*ee*,
- *B* ? ?? ???? ???

Inclusive Hadron Spectra

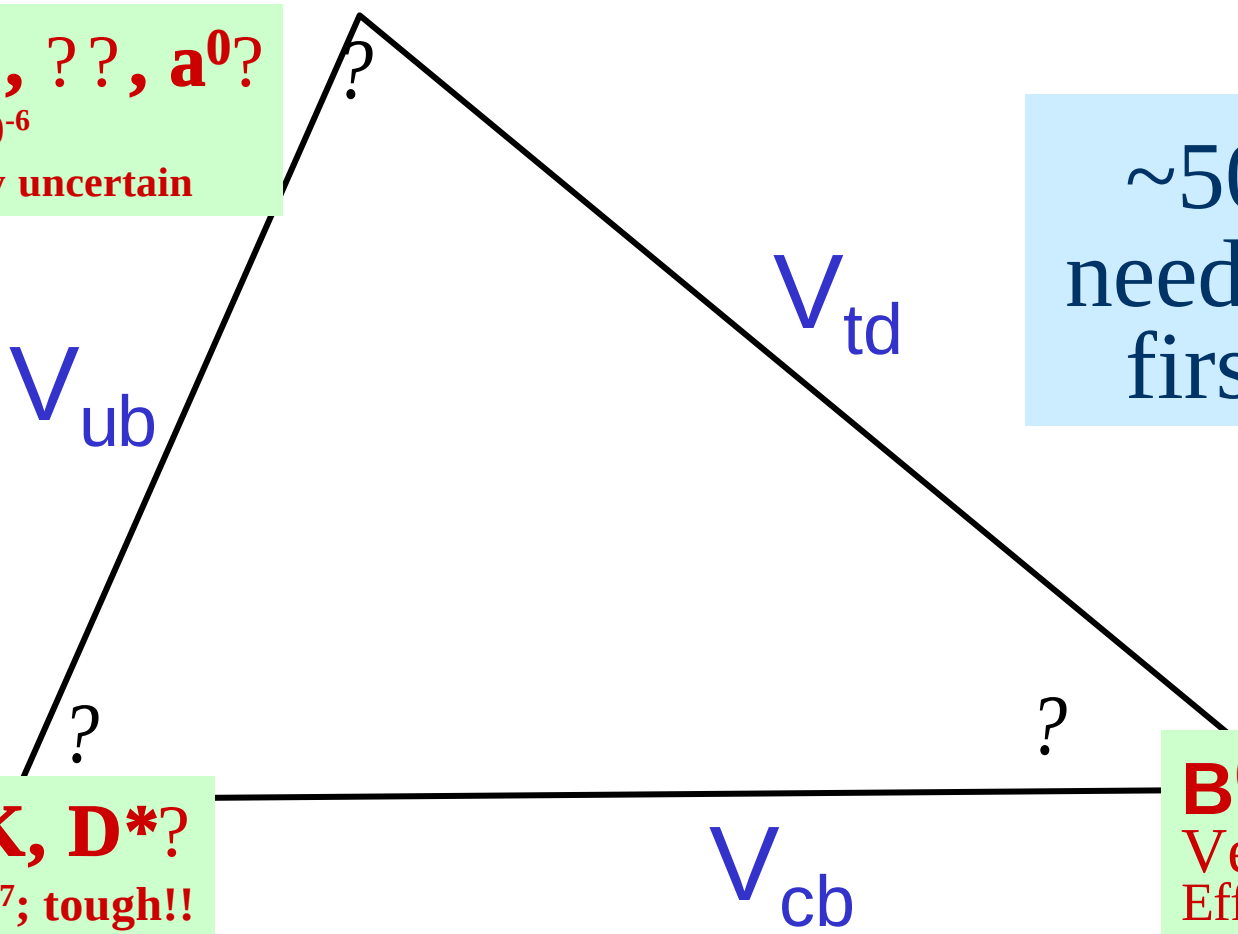
Tau/QED

- ? ? ? ?
- CP violation in ?? decays
- ?? ? $_c$

$\not{CP}$ with BABAR

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

B^0? ??, ??, a^0?
B.R. ~ few 10^{-6}
Theoretically uncertain



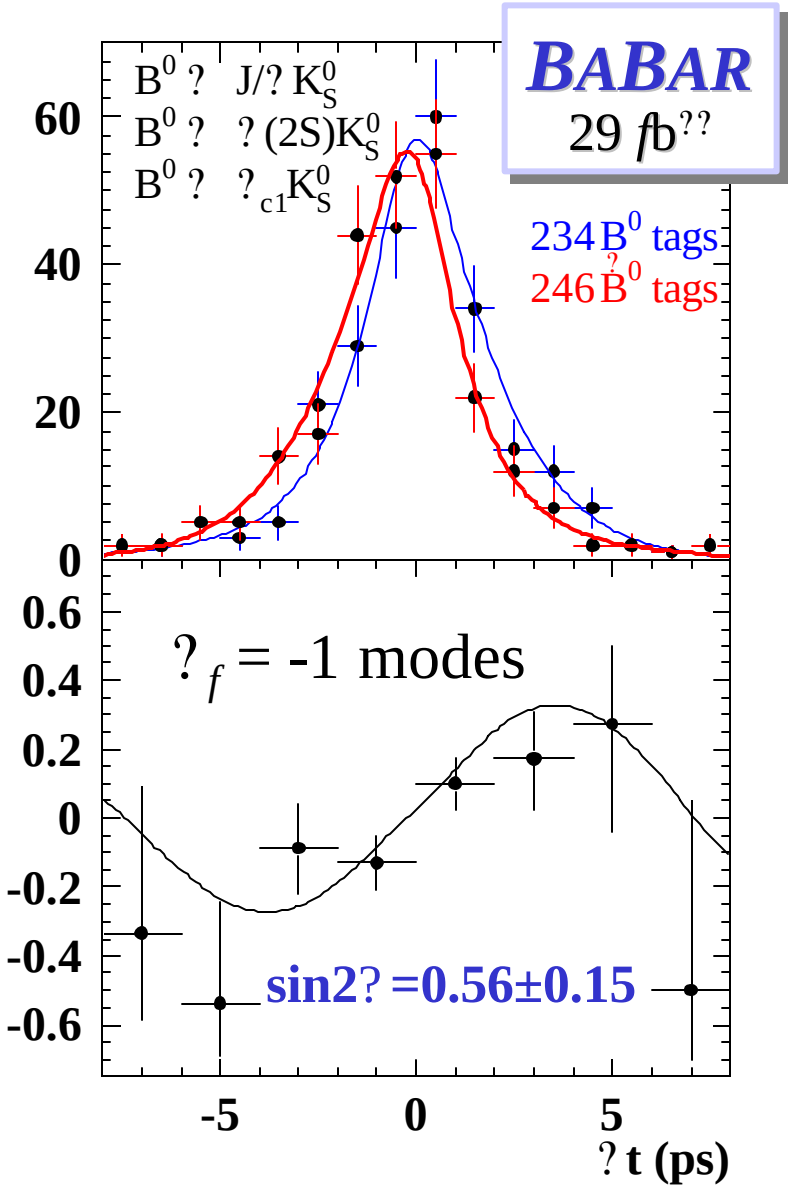
~500 fb^{-1} needed for a first pass

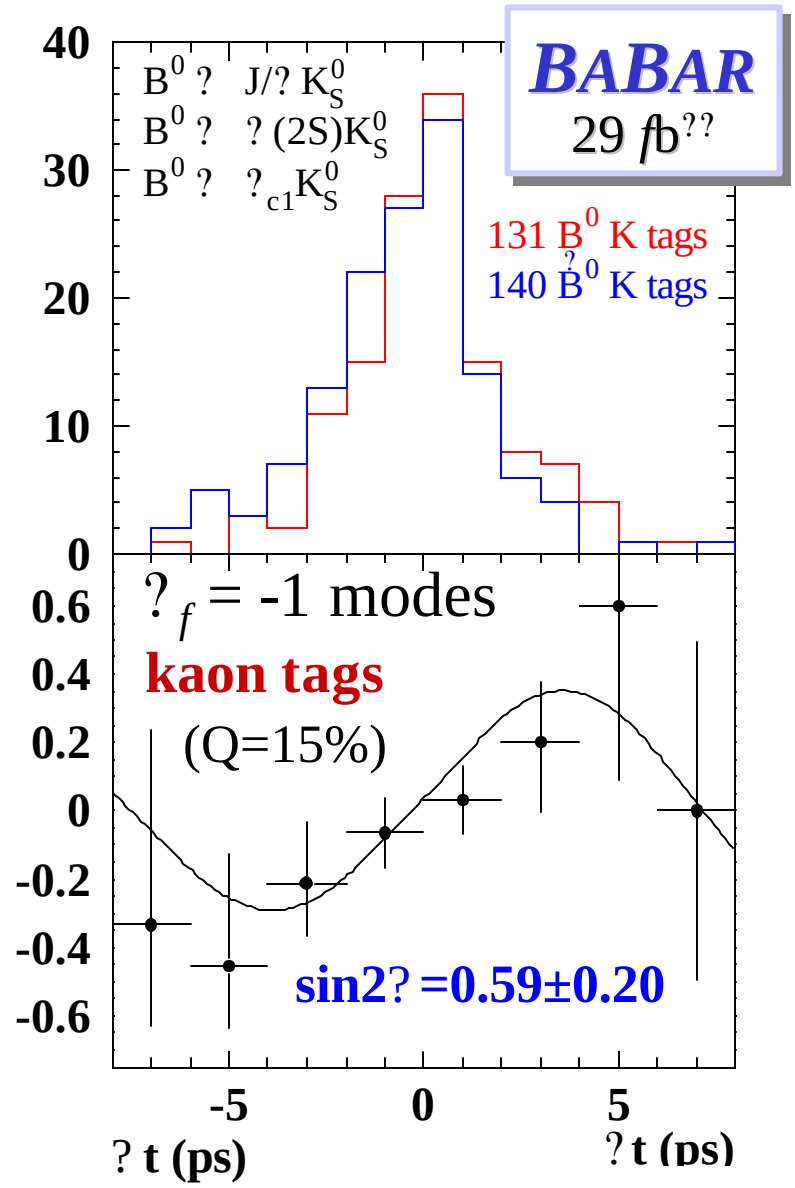
B^0? DK, D*?
Eff B.R ~10^{-7}; tough!!

B^0? J/? K^0_S
Very clean,
Eff B.R. ~ 10^{-4}

Raw Asymmetries

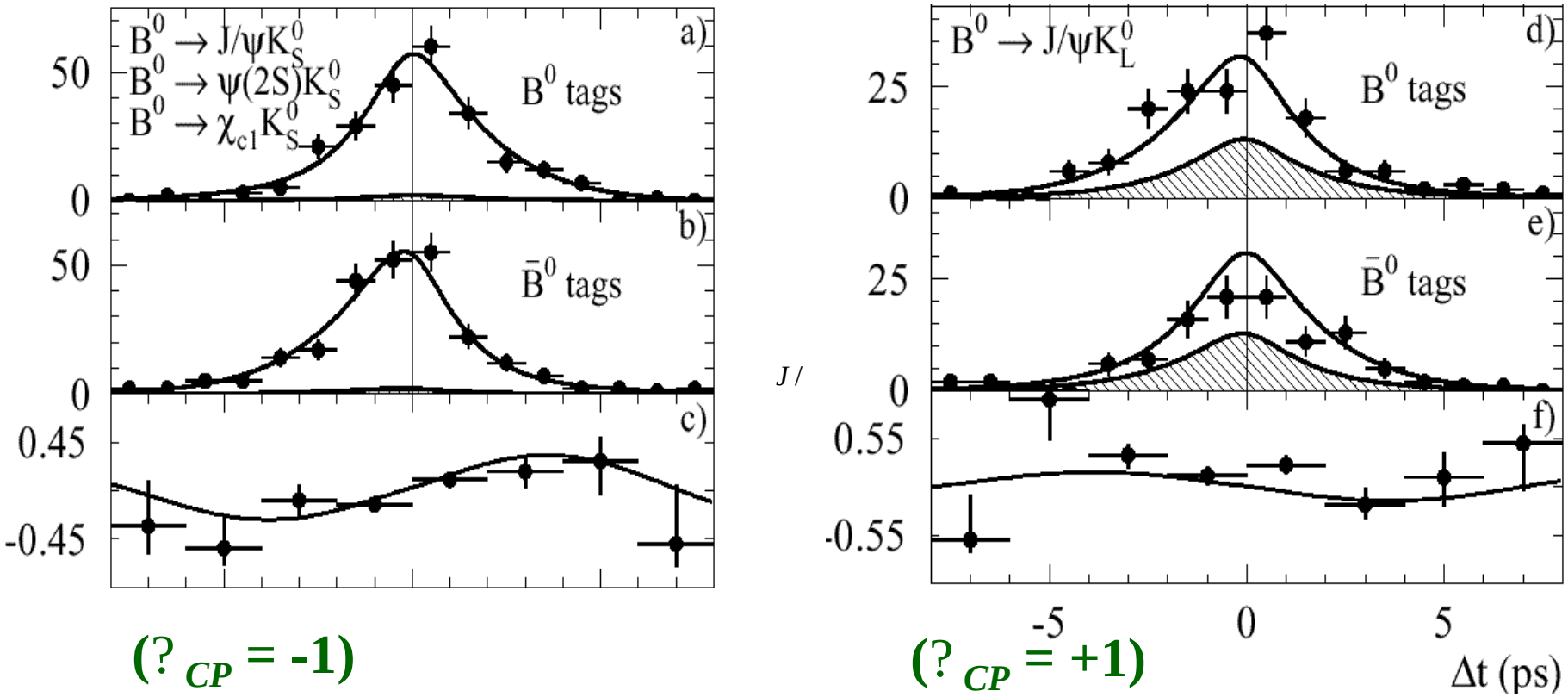
$$A_{CP}(?t) ? ?1 ? 2w? \sin 2ß \sin(?m_d ?t)$$





The sin(2?) Result

(obtained from likelihood fit)



(? $_{CP}$ = -1)

(? $_{CP}$ = +1)

sin(2?) = 0.59 ± 0.14$_{stat}$ ± 0.05$_{syst}$

Prob. of this result if *CP* is conserved : < 3x10^{-5}

Prob. of this result if *CP* is conserved (? $_{CP}$ = -1) : < 2x10^{-4}

Submitted to PRL July 5, 2001

Future of *sin2?* Measurements

- **Increased Statistics in (c $\bar{c}$) s (Golden) modes: B ? (J/? ,? ?2s),? $_C$) K^0_S**

- **Other *CP* modes can provide independent measurements:**
  - different **quark processes**
  - various **penguin contributions**
  - **angular analyses** for VV modes

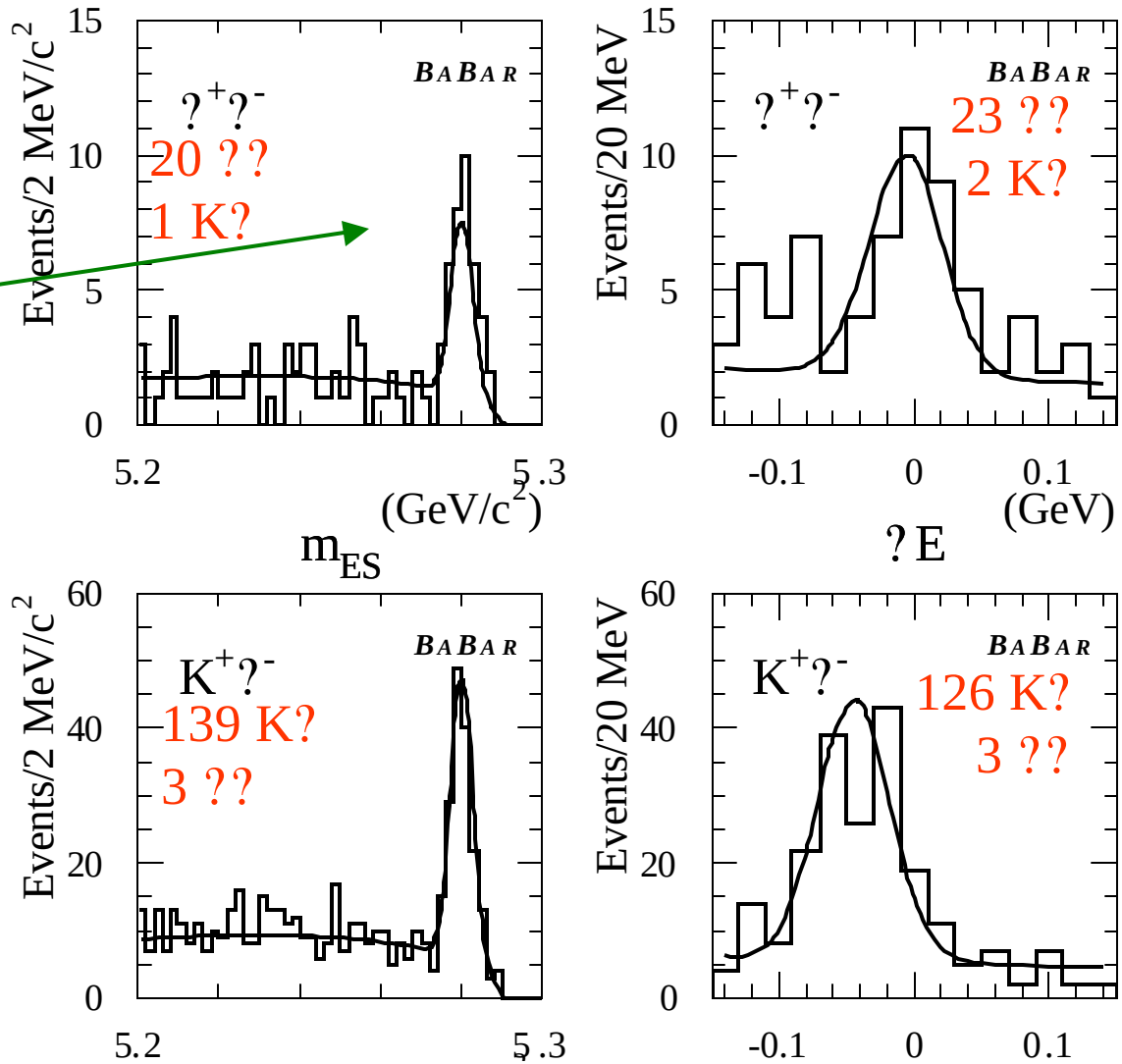
Error in *sin2?*

Luminosity (fb^{-1})	30	100	500
(c $\bar{c}$) s (B ? J/? K_S , etc)	**0.14**	**0.07**	**0.03**
c $\bar{c}$ d (B ? D^{*+} D^{*-})	**--**	**0.3**	**0.13**
s $\bar{s}$ s (B ? ? K_S)	**--**	**0.4**	**0.17**

Time-dependent Asymmetries in (rare) B^0 ? ? $^+$? $^-$ decays

L= 30.4 fb^{-1}

Events after likelihood ratio cuts



Total Yields:

? ? ? ?	65	? 12 / 11
K ? ? ?	217	? 18
K ? K ?	4.3	? 6.3 / 4.3

Preliminary Results for $\sin 2\alpha_{eff}$

$$f_{?}(?t) ? \frac{e^{(??t/?)}}{4?}[1 ? S_f \sin(?m_d ?t) ? C_f \cos(?m_d ?t)]$$

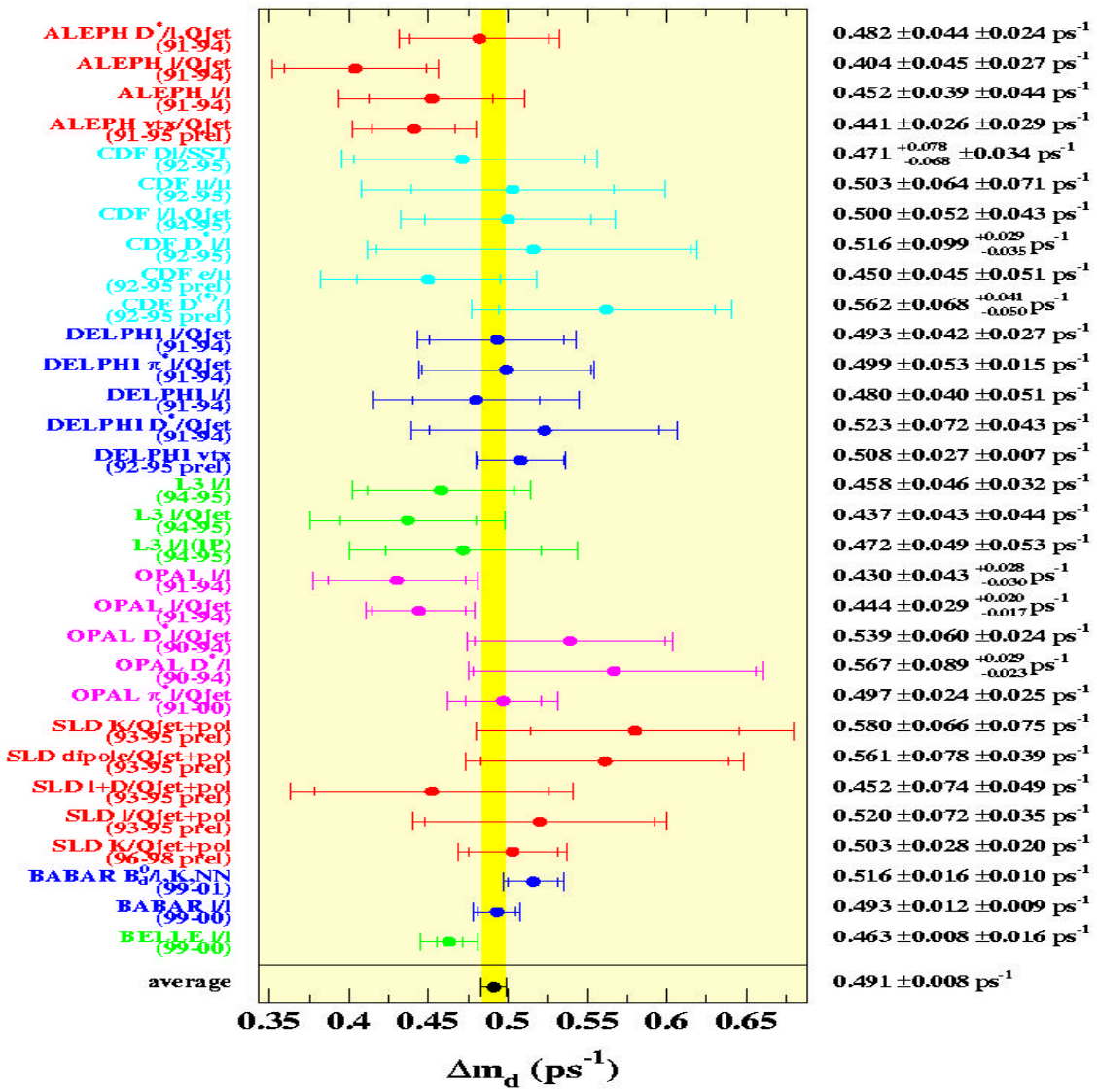
$(\sin 2 ?_{eff})$

$$S(?^{?}?^{?}) ? 0.03^{?0.53}_{?0.56}(stat) ? 0.11(syst)$$

$$C(?^{?}?^{?}) ? ?0.25^{?0.45}_{?0.47}(stat) ? 0.14(syst)$$

$$A_{CP}(K^{?}?^{?}) ? ?0.07 ? 0.08(stat) ? 0.02(syst)$$

? m_d Measurement in Comparison



BABAR *CP* Measurements

Mode	BaBar
Sin2? ; J/? Ks: J/? Kl : |?????*for J/? K^0*)	0.59+/-0.14+/-0.05 0.45+/-0.18 0.70+/-0.34 0.93+/-0.09+/-0.03
CP /T in mixing AT(Asymmetry in like-sign dileptons) |q/p|	(0.005+/-0.012+/-0.014) 0.998+/-0.006+/-0.007
Sin2? -eff; S: C:	0.03+/-0.53+/-0.11 -0.25+/-0.45+/–0.14
Direct CP; K-???	-0.07+/-0.08+/-0.02
?????	0.00+/-0.18+/-0.04
? s??	-0.21+/-0.18+/-0.03
? 'K+:	-0.11+/-0.11+/-0.02
? ??	-0.01+/-029(0.31)+/-0.03
?? ??	-0.05+/-0.020+/-0.03
?? ???	-0.43+/-0.36(0.30)+/-0.06
?? ???	0.00+/-0.27+/-0.03
???	-0.044+/-0.076+/-0.012
???	-0.04+/-0.18+/-0.02
J/????	0.002+/-0.030+/-0.004
J/????	0.04+/-0.22+/-0.004

BABAR Measurements of Lifetime and Mixing measurement

Mode	BaBar
B0 lifetime: Fully reco'ed: Dileptons: B->D*l?: (Partial reco)	1.546+/-0.032+/-0.022 ps 1.557+/-0.028+/-0.027+/-+(0004) ps 1.529+/-0.012+/- 0.029 ps
B+ liftime; Full Reco: Dileptons:	1.673+/-0.032+/-0.023 ps 1.655+/-0.027+/0.027 +/-(0.002) ps
? m_d; Fully Reco'ed: Dileptons:	0.516+/-0.016+/-010 ps-1 0.493+/-0.012+/-0.009 ps-1

Charmless Hadronic B Decays

Mode	BaBar ($Br/10^{-6}$)
B0->????	4.1+/-1.0+/-0.7
B0->K+?-	16.7+/-1.6+/-1.3
B->K+K-	<2.5
B->????	<9.6 (3.4 ??
B->K+??	10.8+/-2.1(1.9)+/-1.0
B->??? +	18.2+/-3.3(3.0)+/-2.0
B->K0(bar)K+	<2.4
B->????	8.2+/-3.1(2.7)+/-1.2
K0K0(bar)	<7.3
B0->? K+	7.7+/-1.6(1.4)+/-0.8
B0->? K0	8.1+/-3.1(2.5)+/-0.8
B0-> ? K*+	9.7+/-4.2(3.4)+/-1.7
B0->? K*0	8.7+/-2.5(2.1)+/-1.1
B0->? pi+	<1.4
B->? ' K+	70+/-8+/-5
B-> ?' eta' k0	42+/-13(11)+/-4
B-> ?' eta' pi+	<12
B-> ? K*0	19.8+/-6.5(5.6)+/-1.7
B-> ? K*+	<33.9
B-> ?' X	6.8+/-0.7(1.0)+/0.0(0.5)x10^2
? ? ?	<4
? ? ?	<13
? ??	6.6+/-2.1(1.8)+/-0.7
???	<3

Mode	BaBar ($Br/10^{-6}$)
<u>B->h+h -h0</u>	
B??????	28.9+/-5.4+/-4.3
B->????	<10.6
B->pi+pi-pi0(NR)	<7.3
B->K+????	
B->f0??	
? ???????	
? ????? ?	
B->?????????	
Limits on Br. For regions of Dalitz plot	<(3 to 11)
<u>B->h+h -h+</u>	
B->K+????	
? ????? ???	
? ?????????	
? ????? ?? ?	
B->K*0 ?+	15.5+/-3.4+/-1.5
B->f0(980)K+	
B->?????? (a0??	<11.5

EW Radiative Penguins

Mode	BaBar (Br/10^{-6})
B->Xs ?(incl.)	
B0->K*0(890) ?	42.3+/-4.0+/-2.2
B+->K*+(890) ?	38.3+/-6.2+/-2.2
B+->K*2(1430) ?	
B+->K+? 0 ? B+->K*? + ?	
B->? ? /K* ? B->? ?? /K* ?	
<u>B->Kl+l--</u> B->Ke+e-- B->? ? ? ? ? <u>B->K*l+l—</u> B->K*e+e- B->K? ? ? ? ? B->Xs e+e- B->Xs ? ? ? ?	<0.5 <0.8(K+); <3.9(K0) <0.8(K+); <3.7(K0) <2.9 <5.8(K*0); <10.5(K*+) <2.0(K*0);<17.2(K*+)
B->??	<1.7

Inclusive Measurements

(*cc*) state	? +?− / *e*+*e*−	BR(*B* ? (*cc*) *X*) (%)	PDG 2000
J/?	0.995 ± 0.036	1.044 ± 0.013 ± 0.028	1.15 ± 0.06
J/? ?diret	0.999 ± 0.045	0.789 ± 0.010 ± 0.034	0.80 ± 0.08
? (2*S*)	1.03 ± 0.16	0.275 ± 0.020 ± 0.029	0.35 ± 0.05
?$_{c1}$	1.09 ± 0.21	0.378 ± 0.034 ± 0.026	0.37 ± 0.07
?$_{c1}$ direct	1.11 ± 0.23	0.353 ± 0.034 ± 0.024	0.37 ± 0.07
?$_{c2}$	0.78 ± 0.68	0.137 ± 0.058 ± 0.012	–
?$_{c2}$ limit		< 0.21 90% C.L.	< 0.38

J/? ?production in continuum e+e- annihilation

$$?_{ee? \ J/? \ X} = (2.52 \ ? \ 0.21_{stat} \ ? \ 0.21_{syst}) \text{ pb}$$

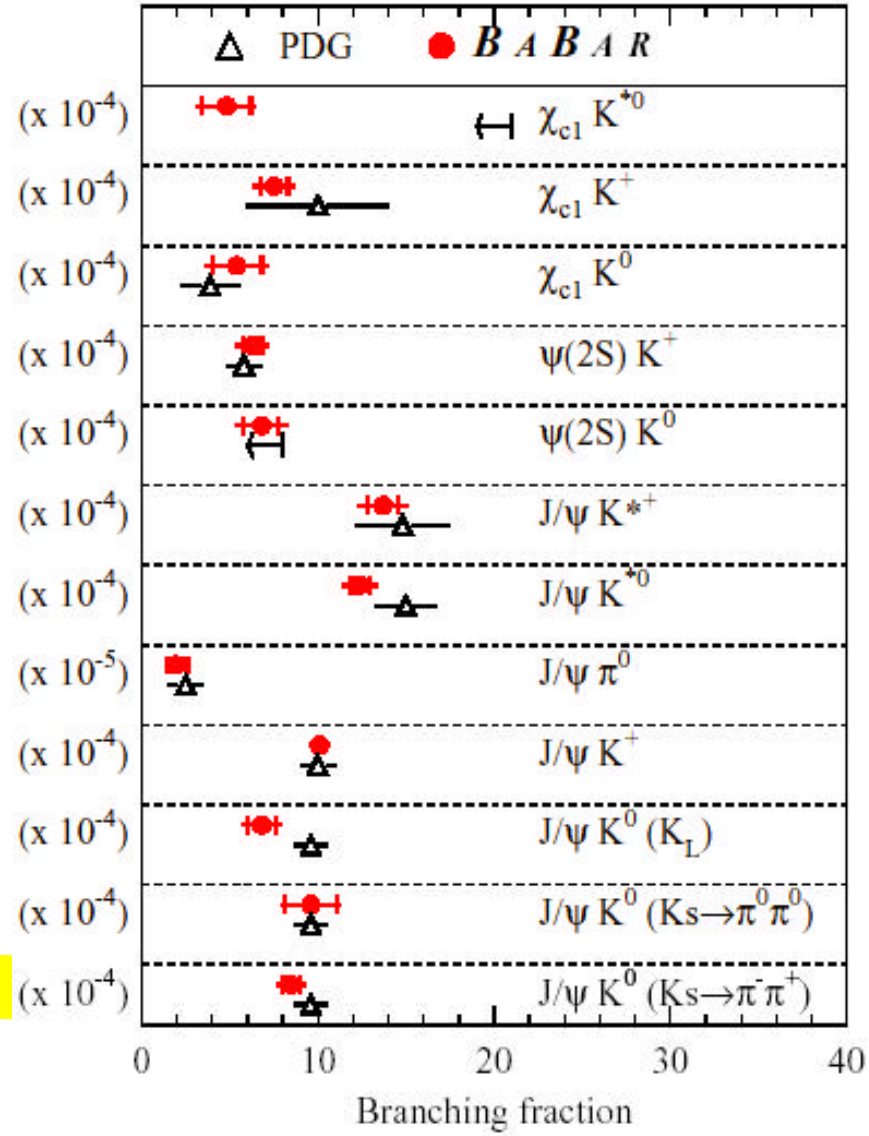
Exclusive *B* Decays to Charmonium States

Branching Fractions Summary

Mode		BR (?10⁻⁴)
B^0 ? $J/?$ K^0	K^0_S ? ?⁺?⁻	8.5 ± 0.5 ± 0.6
	K^0_S ? ?⁰??	9.6 ± 1.5 ± 0.7
	K^0_L	6.8 ± 0.8 ± 0.8
	All	8.3 ± 0.4 ± 0.5
B^+ ? $J/?$ K^+		10.1 ± 0.3 ± 0.5
B^0 ? $J/?$ K^{*0}		12.4 ± 0.5 ± 0.9
B^+ ? $J/?$ K^{*+}		13.7 ± 0.9 ± 1.1
B^0 ? $J/?$?⁰		0.20 ± 0.06 ± 0.02
B^0 ? $J/?$?⁺?⁻		0.46 ± 0.11 ± 0.08
B^0 ? ? (2S) K^0		6.8 ± 1.0 ± 1.1
B^+ ? ? (2S) K^+		6.3 ± 0.5 ± 0.8
B^0 ? $?_{c1}$ K^0		5.4 ± 1.4 ± 1.1
B^+ ? $?_{c1}$ K^+		7.5 ± 0.8 ± 0.8
B^0 ? $?_{c1}$ K^{*0}		4.8 ± 1.4 ± 0.9

BR(B^+ ? $J/?$?⁺) / BR(B^+ ? $J/?$ K^+) = (3.91 ? 0.78 ? 0.19)?%

BR(B^+ ? $J/?$?⁺) / BR(B^+ ? $J/?$ K^+) = (5.1 ? 1.4)?% ?PDG)



B ✍ Charm X

Mode	BaBar
B0->D*+D*-	0.88+/-0.16+/-0.12x 10^{-3} (Rt=0.22+/-0.18+/-0.03)
B->D0D*-K+ B->D*-D*0K+ B->D*D*-K+	2.8+/-0.7+/-0.5x10^{-3} 6.8+/-1.7+/-1.7x10^{-3} 3.4+/-1.6+/-0.9x10^{-3}
B->D-D*+ (c.c.) (partial reco.)	Seen
B->D*+K-/D*+? - B->D*0K-/D*?? - B->D+K-/D+? - B->D0K+/D?? + B->Dcp K+	6.6+/-1.3+/-0.6% 8.3+/-0.6+/-0.3%
B0->D0? ? B0->D*? ? ?	
B0->D0 ? B->D*0? B0->D0 ? B->D*0 ?	
B0->Ds+ pi- B0->Ds+K- B->Ds+ X B->Ds*+X B->Ds(*)+D(*) B->Ds*+D(*) B->D0 (D0(bar)) X B->D+ (D-) X	 10.93+/-0.19+/-0.58+/-2.73% 7.9+/-0.8+/-0.7+/-2.0% 5.07+/-0.14+/-0.30+/-1.27% 4.1+/-0.2+/-0.4+/-1.0%