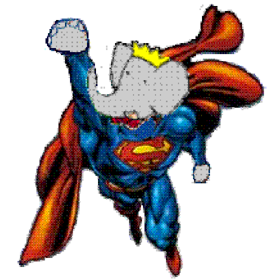


Flavour studies at present and future B Factories

Christos Touramanis

THE UNIVERSITY of LIVERPOOL

Euro-GDR Meeting, Flavours and Neutrinos Programme

IPPP, Durham, 19 April 2002

B Factories: motivation and achievements

Physics motivation:

- CP, Flavour, QCD
- Constrain/test S.M.
- First glance of new physics

In last 12 months:

- Discovery of CP violation in B system
- $\sin(2\beta)$ now precision measurement
- First measurements of $\sin(2\alpha)$
- Most precise B_d lifetime and mixing measurements
- Measurements of Vub and Vcb
- Many new decay modes and Direct CP violation searches
- Searches for D mixing

New era in B physics:

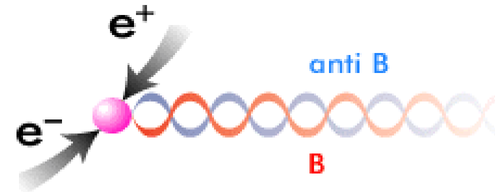
- BABAR + BELLE : 150M B pairs recorded
  - CLEO II/II.V : 10M
  - ARGUS('83-'87) : 100K
  - BABAR + BELLE best 24h : 800K

Planning the future:

- Now: $\sim 5\times10^{33}\text{cm}^{-2}\text{s}^{-1}$
- 2006: 10^{34} - $10^{35}\text{cm}^{-2}\text{s}^{-1}$ probable
- 2011: $10^{36}\text{cm}^{-2}\text{s}^{-1}$ possible

$e^+e^- \rightarrow \Upsilon(4S) \rightarrow B^0\overline{B^0}$

B Factories



- Coherent B pairs, Boost, Luminosity:

  time dependent measurements, rare decays
- (B/total hadronic) ~25% : can do $\pi^0\pi^0$, $X_S\gamma$, $l\nu(\gamma)$, $\pi(\rho)l\nu$ …
- Unique: pure "B beam" ("other side B")
  - Allows neutrino "reconstruction"

BABAR @ PEP-II (SLAC)

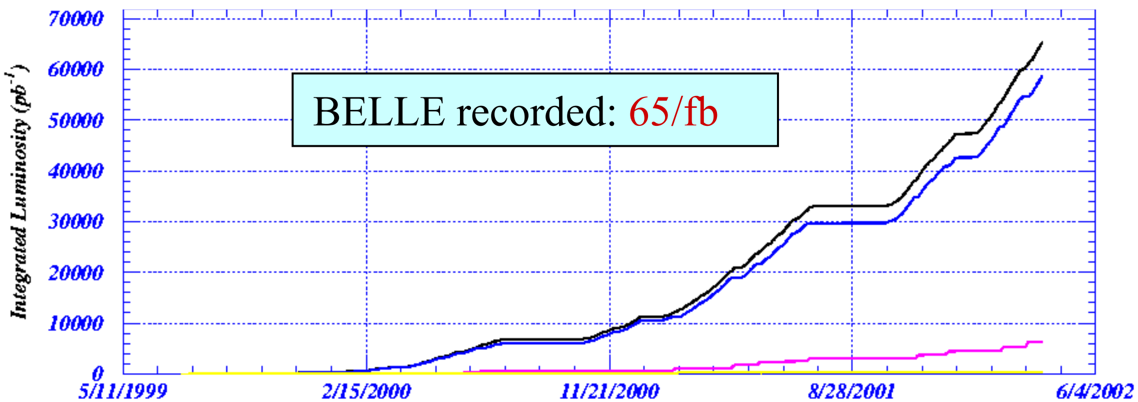
BELLE @ KEKB (KEK)

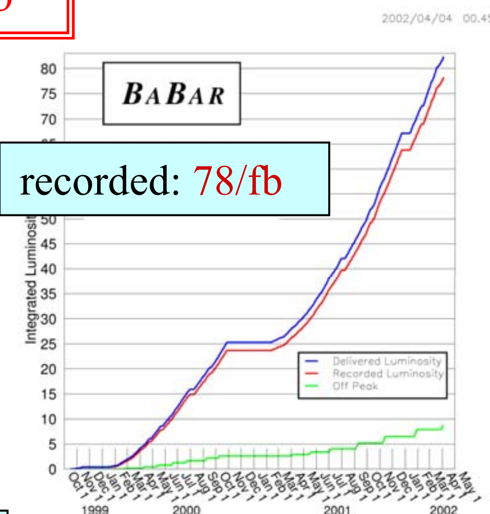
- First data: summer 1999
- CP violation in B system: summer 2001
- Recorded data:
  - 78/fb (BABAR)
  - 65/fb (BELLE)
- By 2006: ~1/ab (total)

B factories performance

	BABAR Achieved	BABAR Design	BELLE Achieved	BELLE Design
Instantaneous Luminosity	$4.6\times10^{33}cm^{-2}s^{-1}$	3.0×10^{33}	$7.2\times10^{33}cm^{-2}s^{-1}$	10.0×10^{33}
Recorded/24h	303/pb	135	364/pb	
Recorded/month	6.7/fb		7.2/fb	

Expected BABAR+BELLE 2006: ~1/ab





4 April 2002

The Future (I)

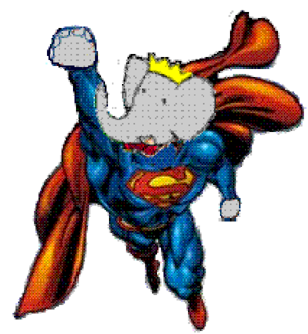
- BABAR+BELLE:
  - ~200/fb by summer 2002
  - ~500/fb by 2004
  - ~1/ab by 2006 (CKM consistency test: 5~10% level)

<u>BEYOND 2006</u>

- BELLE
  - KEKB and detector upgrade in 2006-7
  - L=10^{35} : 1/ab/year
  - 3/ab by 2011
  - Main changes in silicon, tracking, (PID)
  - Expression of Interest available
- BABAR
  - Various options considered
  - 5×10^{34} - 10^{35}
  - Main changes in silicon, (tracking)
  - Long Term Planning Task Force : recommendations in September 02

The Future (II): beyond 2010

- SUPER-BABAR
  - New accelerator (25Ax10A currents) $L=10^{36}$ 10/ab/year
  - And new (smaller) detector
  - Working group open to the international community
  - Could be operational in 2011



Few numbers to note

Integrated B Factories' samples:

~200/fb by summer 2002

~500/fb by 2004

~1/ab by 2006 (sure bets up to here)

~2/ab by 2009 (no upgrades)

~5/ab by 2010 (my bet)

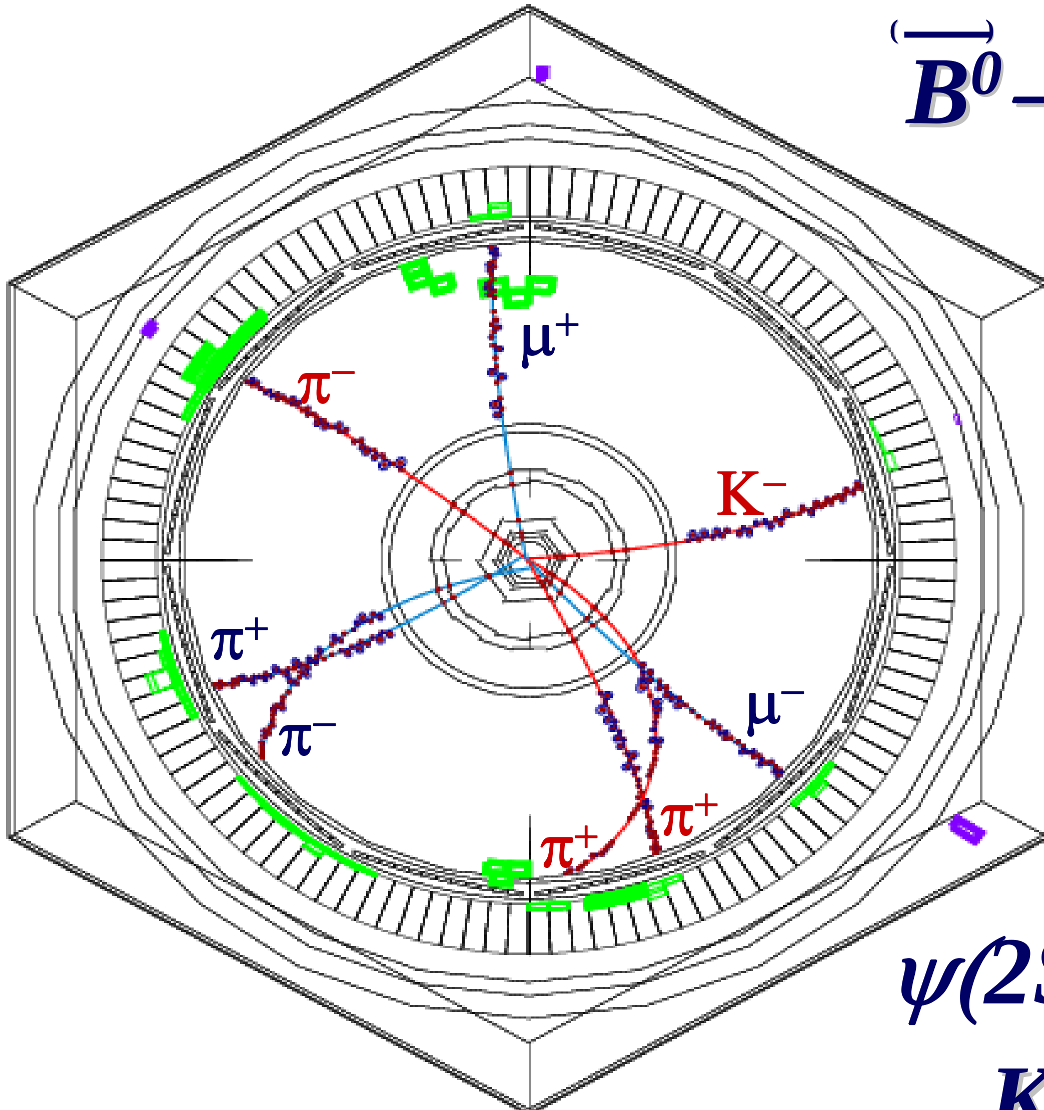
~50/ab by 2015 (maybe)

- Technically feasible
- Compelling physics case necessary
- Long lead time – must plan ahead (i.e. start now)

Fully reconstructed Y(4S) event

$\overline{B^0} \to D^{*+} \pi^-$

$\overset{(-)}{B^0} \to \psi(2S) K^0_s$



$D^{*+} \to D^0 \pi^+$

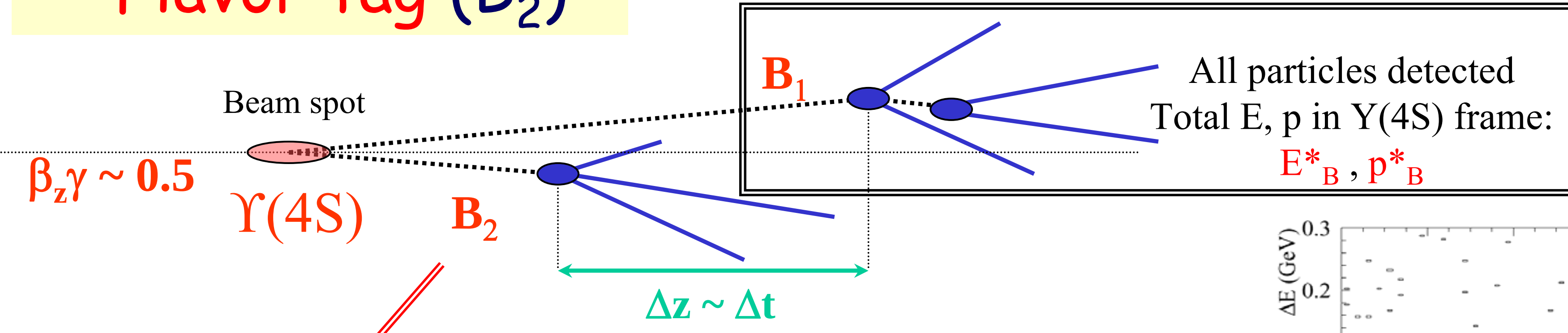
$D^0 \to K^- \pi^+$

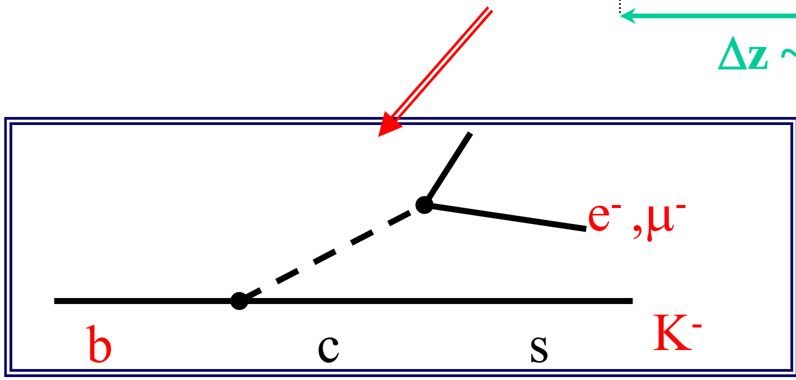
$\psi(2S) \to \mu^+ \mu^-$

$K^0_s \to \pi^+ \pi^-$

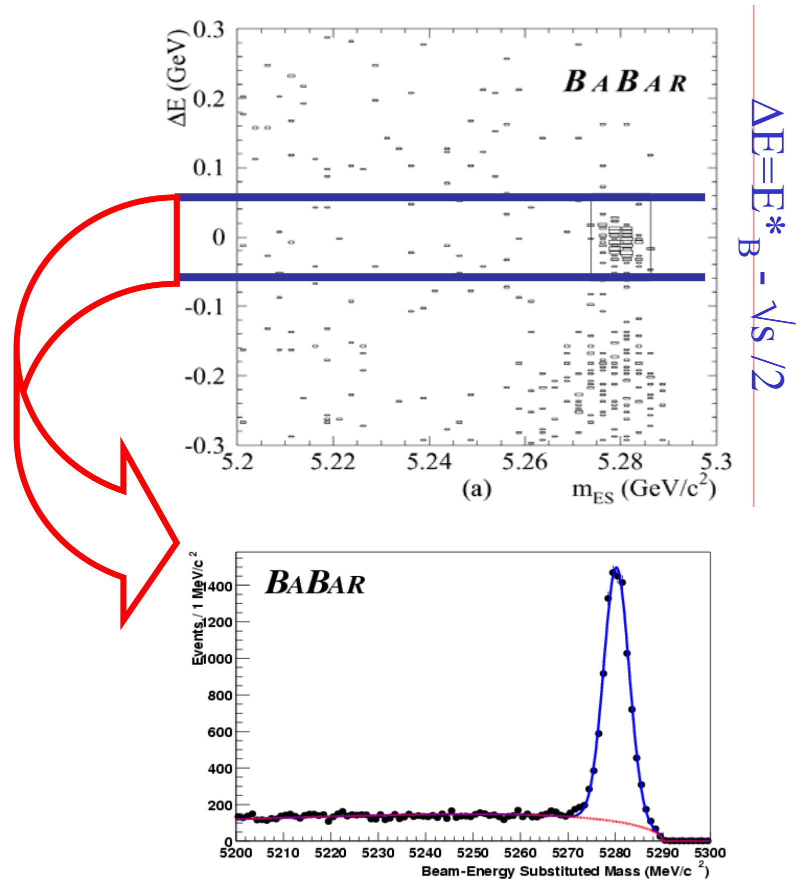
B pair reconstruction

- B_{CP} or B_{FLAV} (B_1)
- Δz $(B_1 - B_2)$
- Flavor tag (B_2)





B flavor tagging:
Lepton, Kaons, kinematics



$m_{ES} = \sqrt{(s/4 - p^{*2}_B)}$

<u>Tagging performance (from Data)</u>

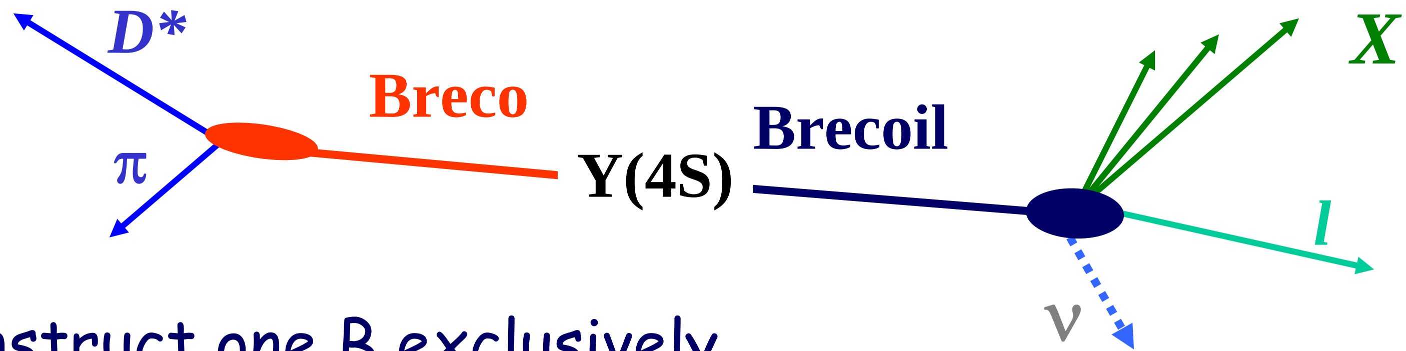
ε : fraction of tagged events

w : wrong tag fraction

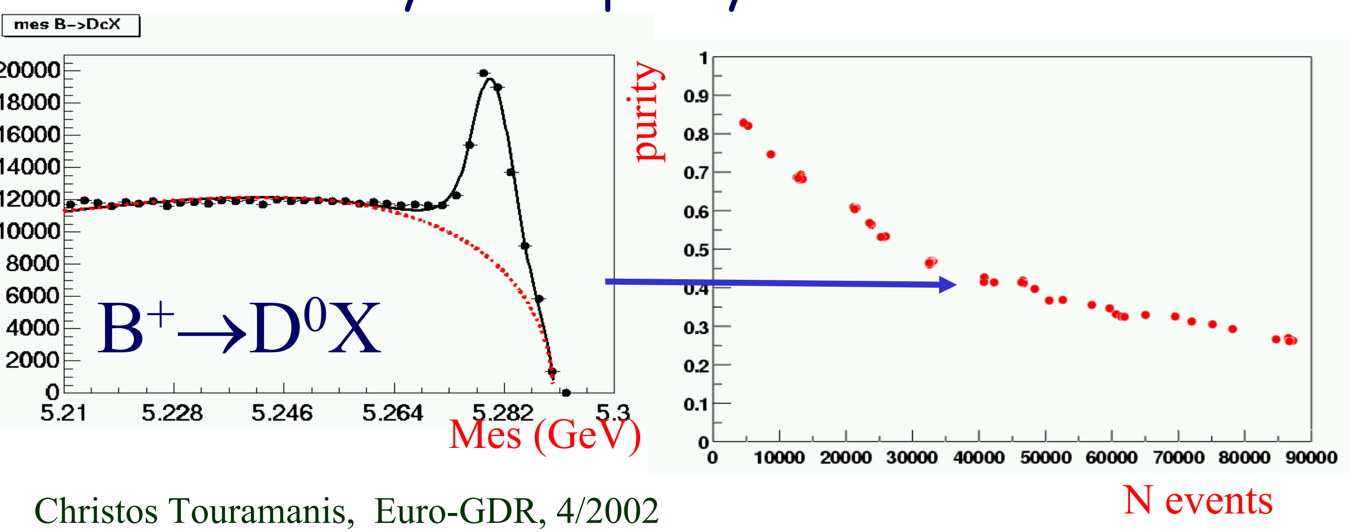
Figure Of Merit: $Q = \varepsilon(1-2w)^2$

25.1%(BABAR) – 27.0% (BELLE)

Other side B sample (single B beam)



- Reconstruct one B exclusively
- Recoil: single B beams (charged, neutral)
  - Clean sample
  - Neutrino "reconstruction"
  - Charge/flavour correlation
  - Tunable yield vs purity

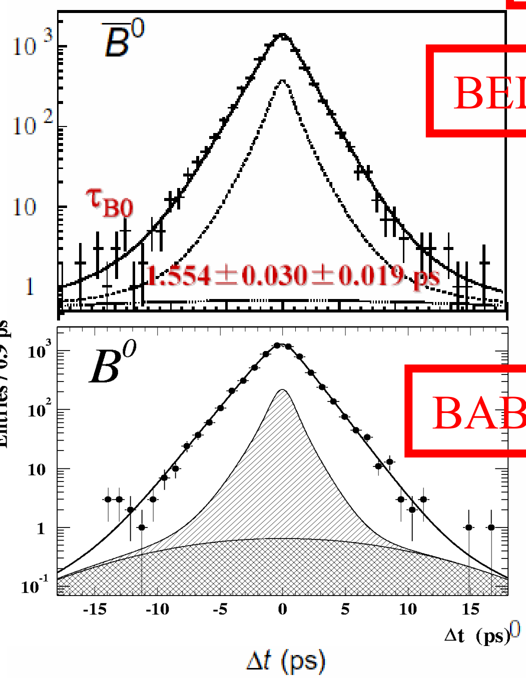


Purity 50%:
10^6 B^0/ab^{-1}
10^6 B^+/ab^{-1}

Purity 30%:
2×10^6 B^0/ab^{-1}
4×10^6 B^+/ab^{-1}

B lifetimes

Exclusive B reconstruction



BELLE 29/fb

$\tau_{B0} = 1.554 \pm 0.030_{stat} \pm 0.019_{syst}$ ps

$\tau_{B+} = 1.673 \pm 0.026_{stat} \pm 0.015_{syst}$ ps

$\tau_{B+}/\tau_{B0} = 1.091 \pm 0.023_{stat} \pm 0.014_{syst}$ (2.7 %)

BABAR 21/fb

$\tau_{B0} = 1.546 \pm 0.032_{stat} \pm 0.022_{syst}$ ps

$\tau_{B+} = 1.673 \pm 0.032_{stat} \pm 0.023_{syst}$ ps

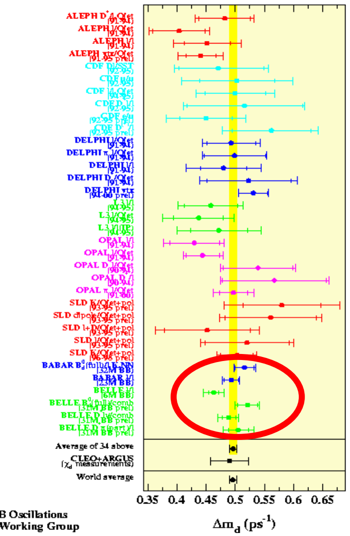
$\tau_{B+}/\tau_{B0} = 1.082 \pm 0.026_{stat} \pm 0.012_{syst}$ (2.9 %)

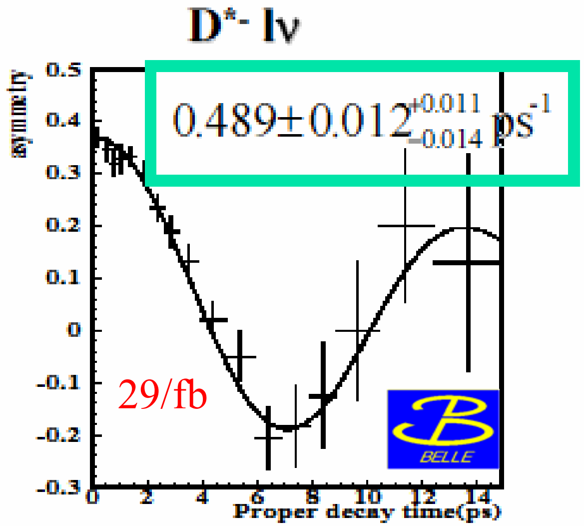
BABAR Dileptons 21/fb

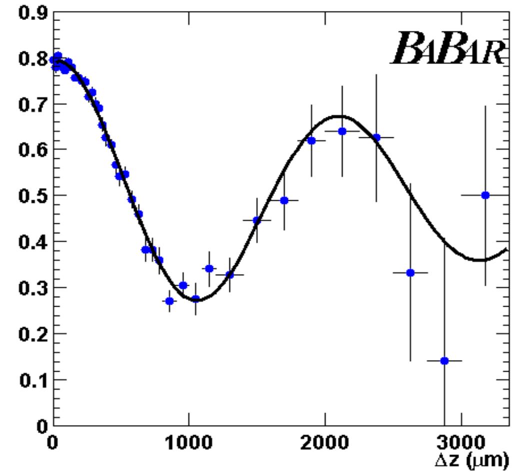
- τ_{B0} =1.557±0.028(stat)±0.027(syst)±0.004(Δm)ps.
- τ_{Bch}=1.655±0.026(stat)±0.027(syst)±0.002(Δm)ps.
- r_τ =1.064±0.031(stat)±0.026(syst)±0.002(Δm). (4.1 %)

compare to PDG 2000 (pre-BFact): τ_{B+}/τ_{B0} = **1.062 ± 0.029** (2.9 %)

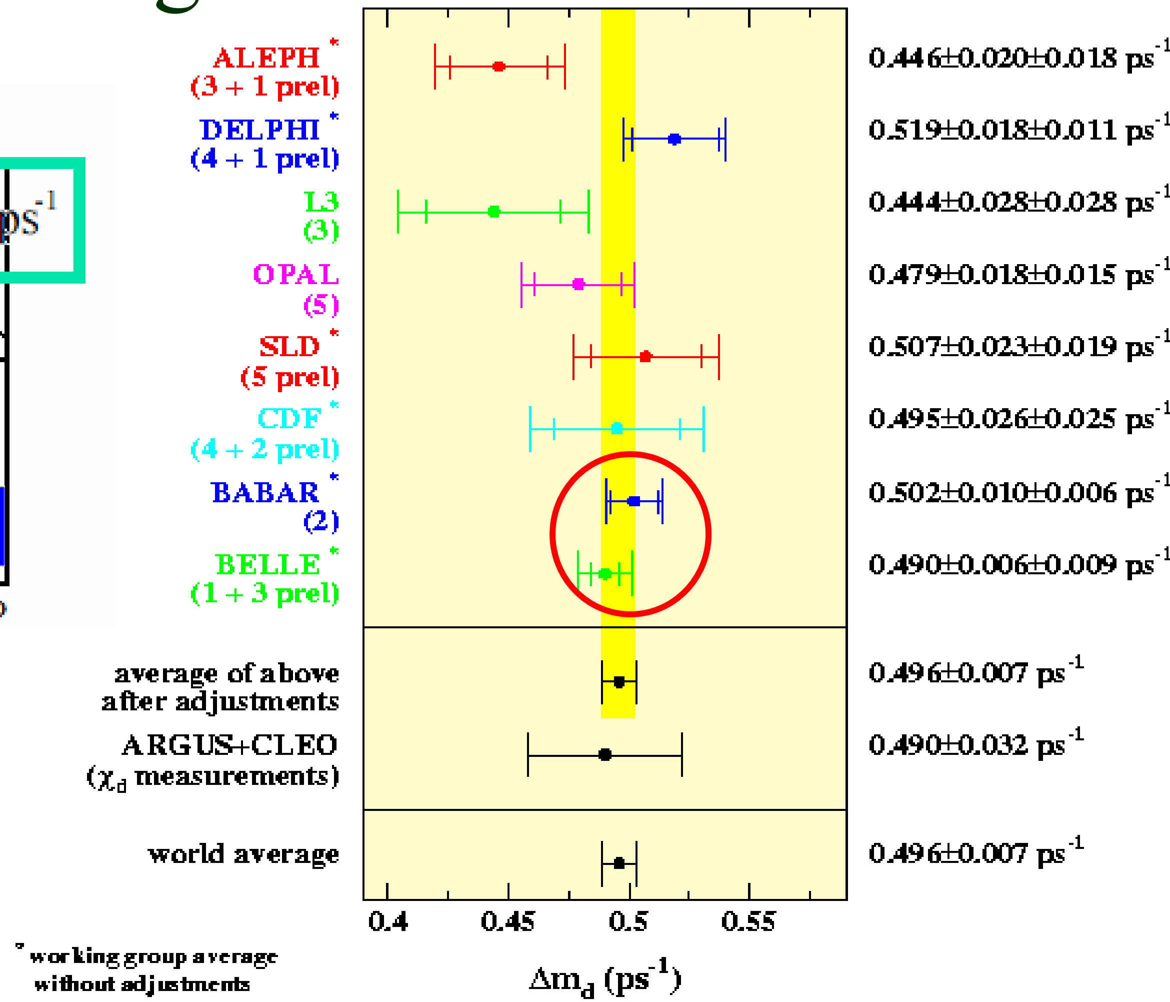
B_d mixing







21/fb dilepton sample



CP violation in mixing BABAR dileptons, 21/fb:

$$Re(\varepsilon)/(1+|\varepsilon|^2) = (0.12 \pm 0.29 \pm 0.36)\%$$

Time-dependent CP asymmetries

$$A_{cp,f}(\Delta t) \equiv \frac{\Gamma(\overline{B^0}(\Delta t) \to f) - \Gamma(B^0(\Delta t) \to f)}{\Gamma(\overline{B^0}(\Delta t) \to f) + \Gamma(B^0(\Delta t) \to f)}$$

Mixing-decay interference: time-dependent CP asymmetry

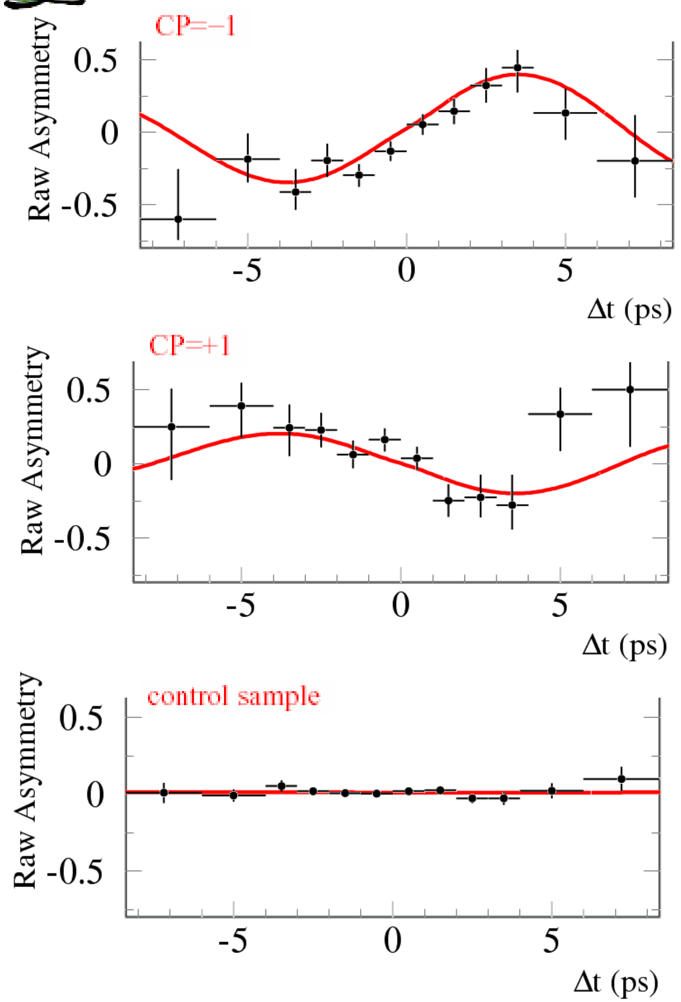
$$A_{cp,f}(t) = S_f \sin \Delta m \Delta t - C_f \cos \Delta m \Delta t$$

$$C_f \equiv \frac{1 - |\lambda_f|^2}{1 + |\lambda_f|^2} \qquad S_f \equiv \frac{2\,\mathrm{Im}\lambda_f}{1 + |\lambda_f|^2}$$

General technique: fit for the sine and cosine coefficients in the time-dependent asymmetry.

Decay	Mode	$\lvert\lambda\rvert$	$\mathrm{Im}\lambda$	Comments
$b \to c\bar{c}s$	$J/\Psi\, K_s$	1	$\sin 2\beta$	Single weak phase. *Theoretically clean*
$b \to c\bar{c}d$	$D^* D^{(*)}$	?	$\sin 2\beta$ if $\lvert\lambda\rvert=1$	Tree and penguin
$b \to u\bar{u}d$	$\pi^+\pi^-$	?	$\sin 2\alpha$ if $\lvert\lambda\rvert=1$	Tree and penguin

sin(2β) : time dependent asymmetries



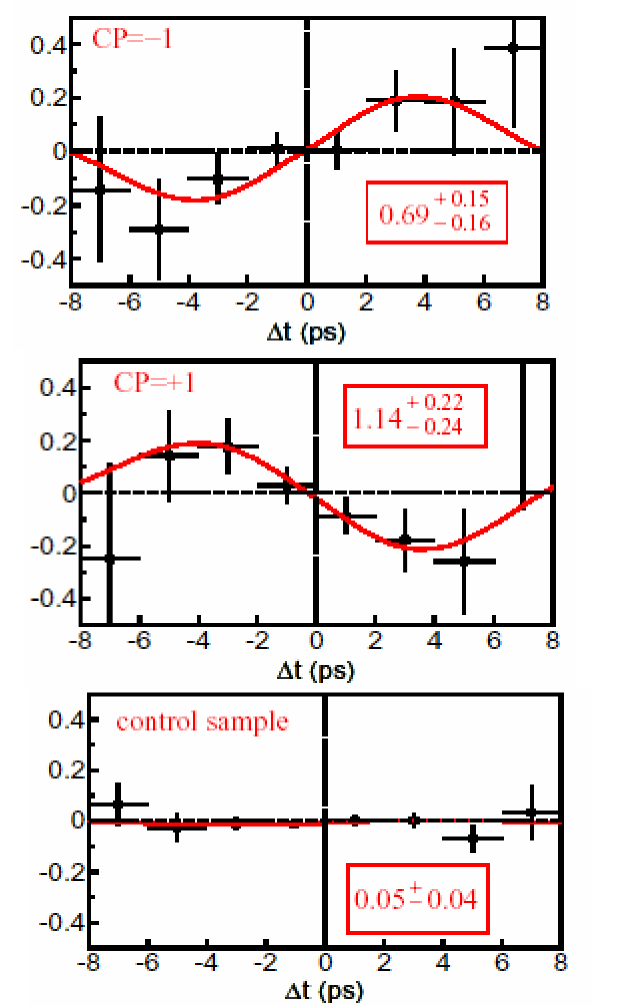
$J/\psi K_S(\to \pi^+\pi^-)$
$J/\psi K_S(\to \pi^0\pi^0)$
$\psi(2S)(\to l^+l^-)K_S$
$\psi(2S)(\to J/\psi\pi^+\pi^-)K_S$
$\chi_{c1}(\to J/\psi\gamma)K_S$
* $\eta_c(\to K_S K^+\pi^-)K_S$
$\eta_c(\to K^+K^-\pi^0)K_S$

(*BABAR has shown independent result from these modes)

$J/\psi K_L$

Flavor eigenstates

$B^0 \to D^{*-}\pi^+ , D^{*-}\rho^+ , D^{*-}a_1^{\ +}$
$B^0 \to D^-\pi^+ , D^-\rho^+ , D^-a_1^{\ +}$
$B^0 \to J/\Psi K^{*0} (K^+\pi^-)$

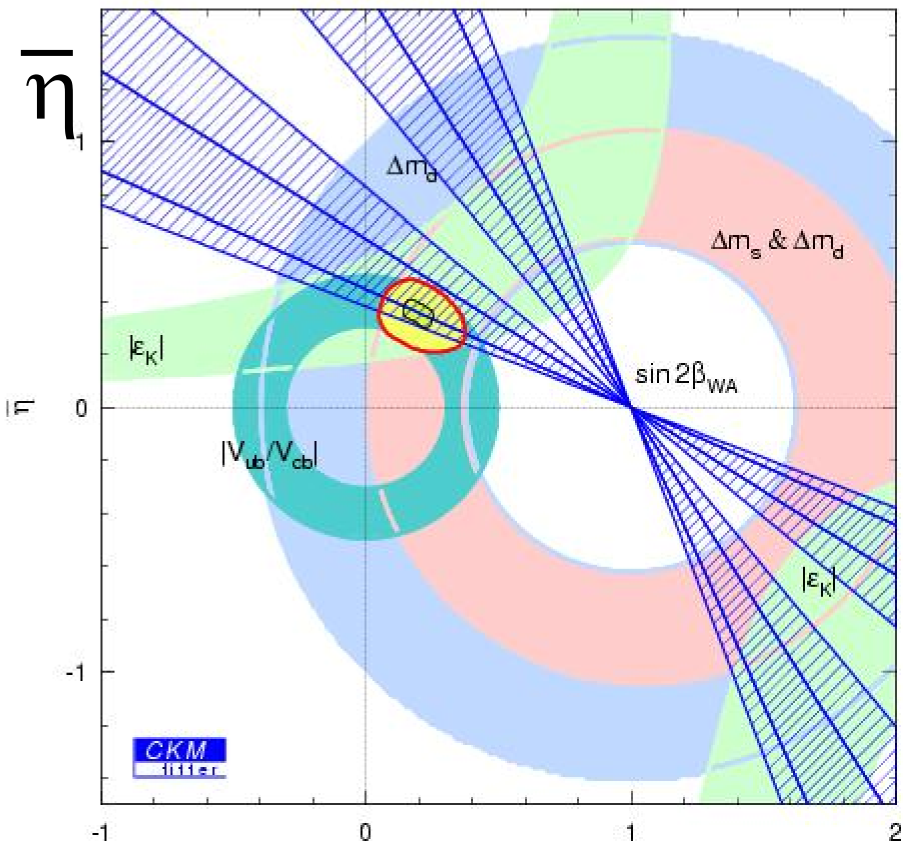


March 2002 sin(2β) results

	BABAR (56/fb)	BELLE (42/fb)
Prelim. result	0.75 ± 0.09 ± 0.04	0.82 ± 0.12 ± 0.05
sin(2β) stability and checks		
CP=-1	0.76 ± 0.10	0.69 ± 0.15
CP=+1	0.73 ± 0.19	1.14 ± 0.23
B0	0.83 ± 0.12	0.60 ± 0.19
B0bar	0.66 ± 0.13	1.00 ± 0.15
Control (B_{FLAV})	0.00 ± 0.03	0.05 ± 0.04

CKM interpretation of sin(2β)

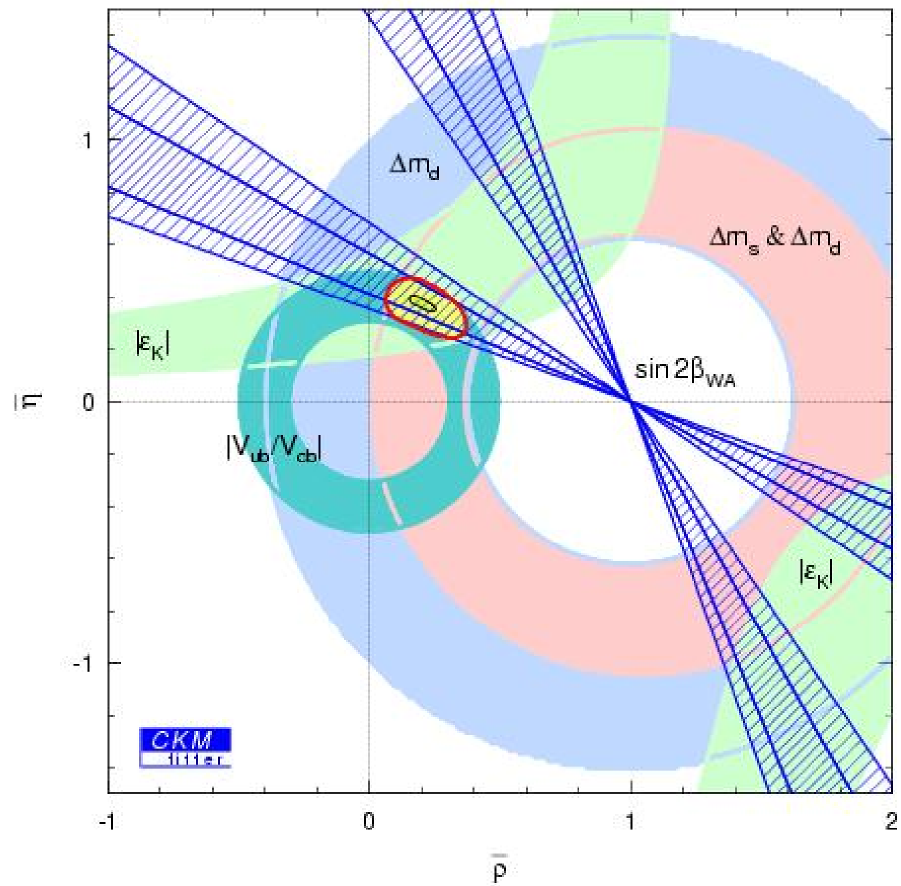
Red area ignores sin2(β).



$\bar{\rho}$

$\bar{\rho} = \rho(1-\lambda^2/2)$
$\bar{\eta} = \eta(1-\lambda^2/2)$

Global fit including World Average of sin2(β) measurments.



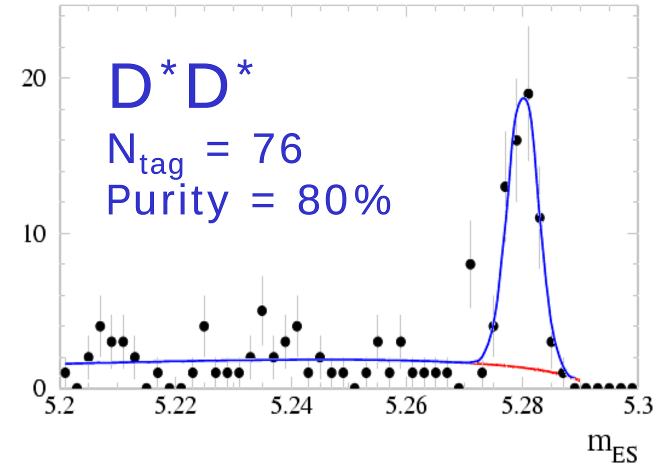
Method as in Höcker et al, Eur.Phys.J.C21:225-259,2001

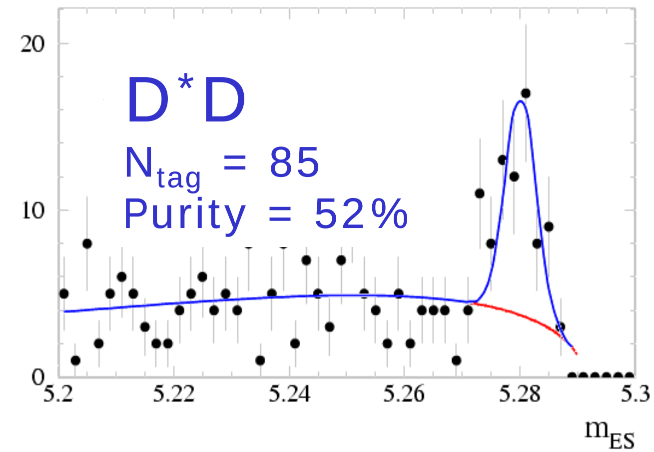
CP asymmetry in $b \to c\bar{c}d$ decays: $D^{*\pm}\bar{D}^{*+}$ and $D^{*\pm}\bar{D}^{+}$

- Tree decay: same weak phase as for $b \to c\bar{c}s$
- Watch out for penguins!
- D^*D^* is vector-vector decay (L=0,1,2) so mix of CP=+1 and –1.
- Fit for S_f and C_f (no penguin assumptions).

$$A_{cp,f}(t) = S_f \; \sin \Delta m \Delta t - C_f \; \cos \Delta m \Delta t$$

- Separate S_f and C_f for $D^{*+}D^-$ and $D^{*-}D^+$.





D^*D^*

$S = -0.05 \pm 0.45 \pm 0.05$

$C = 0.12 \pm 0.30 \pm 0.05$

D^*D

$S_{+-} = -0.43 \pm 1.41 \pm 0.20$

$C_{+-} = 0.53 \pm 0.74 \pm 0.13$

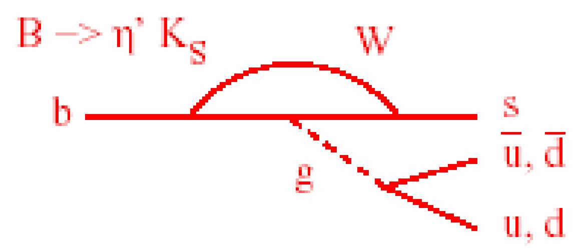
$S_{-+} = 0.38 \pm 0.88 \pm 0.05$

$C_{-+} = 0.30 \pm 0.50 \pm 0.08$

Next step: angular analysis for D^*D^*

New Physics searches through sin(2β)

- Penguin only(dominated) modes
- measure sin(2β') : $\beta' = \beta + \phi_{NewPhys}$

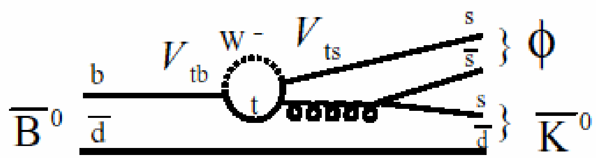


"tree pollution" ($b \to u\bar{u}s$) expected to be small

Belle preliminary (42/fb, 73 events):

sin(2β') = 0.29 ± 0.54 ± 0.07

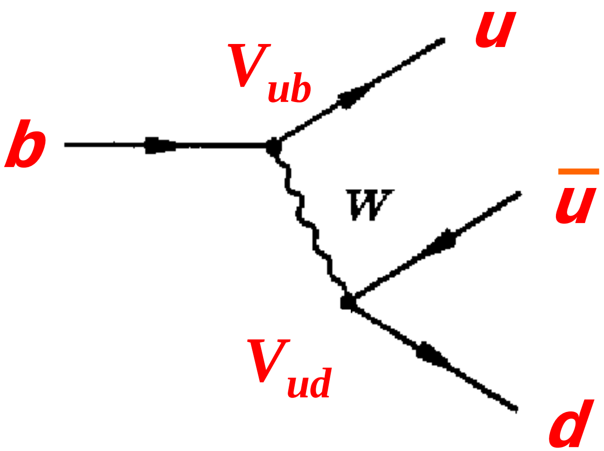
$B^0 \to \phi K_S$



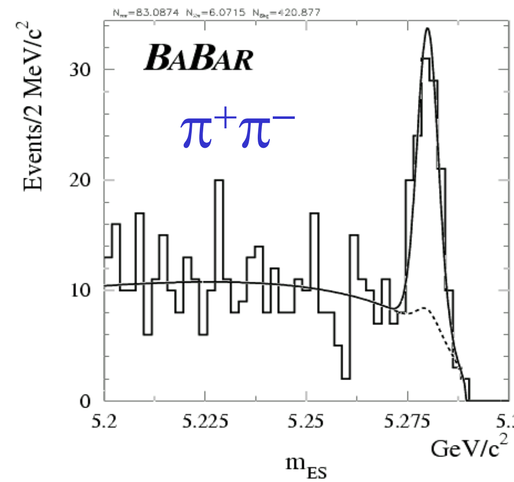
BABAR expects to have sin(2β') to ~0.5 by summer 2002

$b \to s$ transition forbidden at tree level ⇒ pure penguin decay

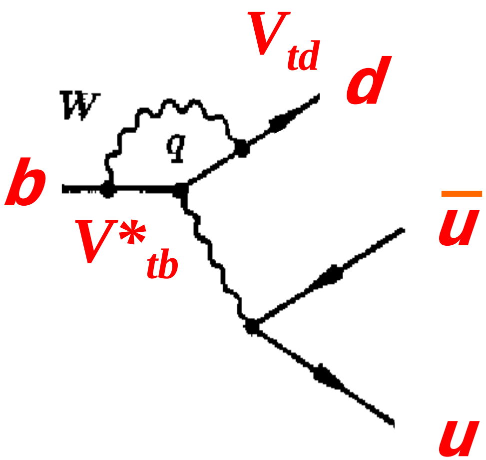
sin(2α)



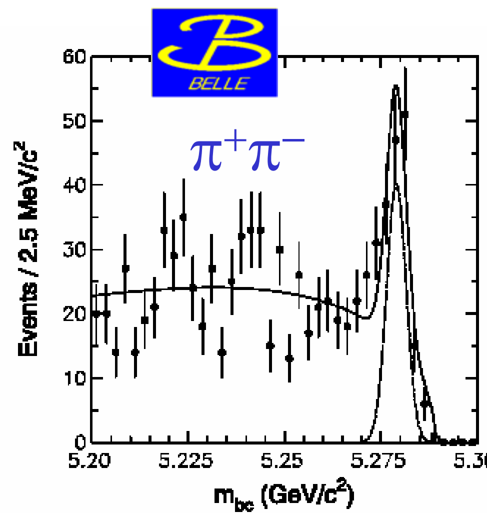
u
V_ub
b
W
ū
V_ud
d



BABAR
π+π−
Events/2 MeV/c2
30
20
10
0
5.2
5.225
5.25
5.275
5.3
GeV/c2
mES



V_td
d
W
q
b
V*_tb
ū
u



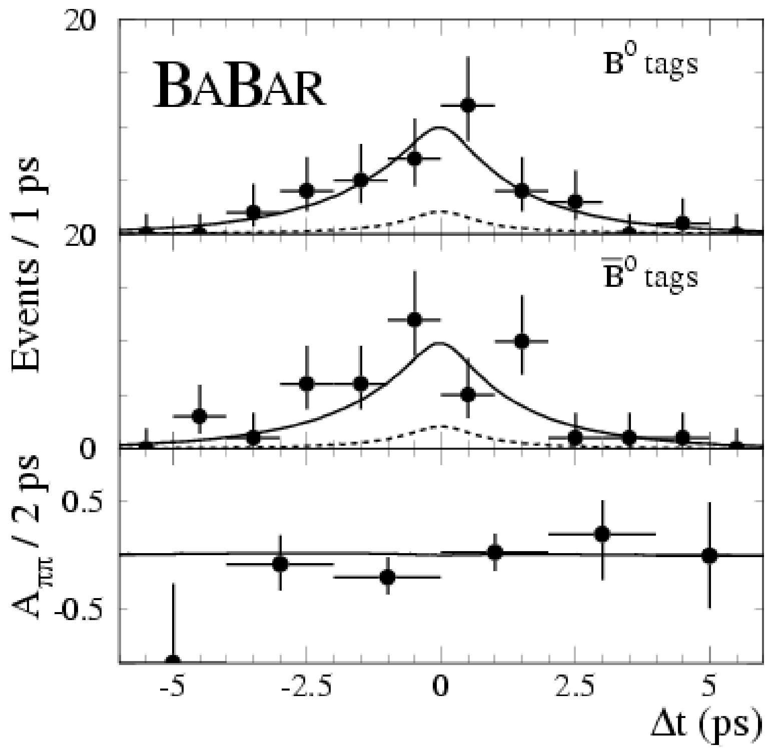
BELLE
π+π−
Events / 2.5 MeV/c2
60
50
40
30
20
10
0
5.20
5.225
5.25
5.275
5.30
mbc (GeV/c2)

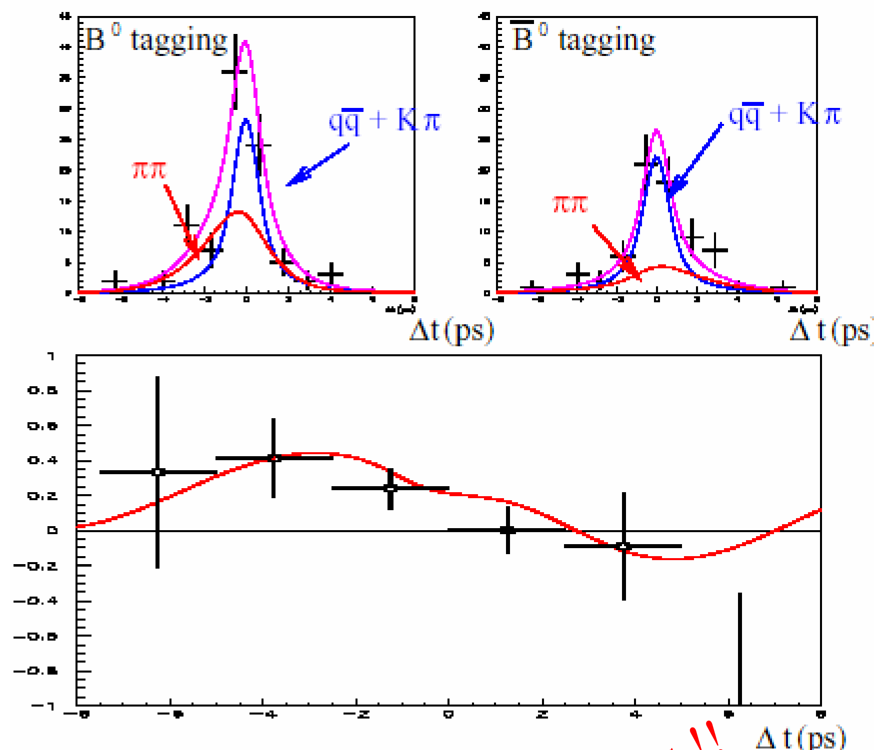
And the CP results are….

$S_{\pi\pi} = -0.01 \pm 0.37 \pm 0.07$ [−0.66,+0.62]
90% CL
$C_{\pi\pi} = -0.02 \pm 0.29 \pm 0.07$ [-0.54,+0.48]

$S_{\pi\pi} = -1.21^{+0.38}_{-0.27}$ (stat.) $^{+0.16}_{-0.13}$ (syst.)

DCPV asym.
$C_{\pi\pi} = +0.94^{+0.25}_{-0.31}$ (stat.) ± 0.09(syst.)





No evidence for charge asymmetry in Kπ (direct CP):
BABAR: -0.05 ± 0.06 ± 0.01
BELLE: -0.06 ± 0.08 ± 0.01

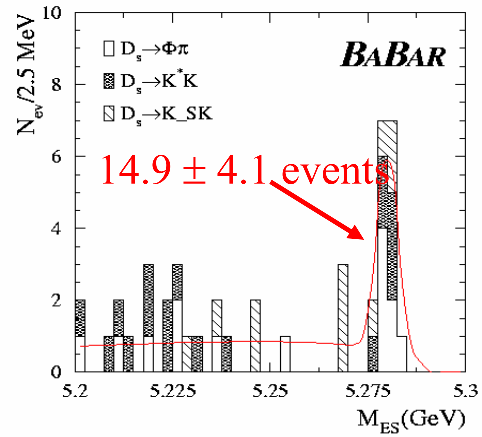
Watch out for the next updates !!

2-Body Charmless	Branching Fraction or 90% limit (10^{-6})	
	BABAR (23M B pairs, **56M)	BELLE (32M B pairs)
$K^+\pi^-$	17.8 ± 1.1 ± 0.8 **	21.8 ± 1.8 ± 1.5
$K^+\pi^0$	10.8 ± 2.1 ± 1.0	12.5 ± 2.4 ± 1.2
$K^0\pi^-$	18.2 ± 3.3 ± 2.0	18.8 ± 3.0 ± 1.5
$K^0\pi^0$	8.2 ± 3.1 ± 1.2	7.7 ± 3.2 ± 1.6
$\pi^+\pi^-$	5.4 ± 0.7 ± 0.4 **	5.1 ± 1.1 ± 0.4
$\pi^+\pi^0$	< 9.6	7.0 ± 2.2 ± 0.8
$\pi^0\pi^0$	< 3.4 **	< 5.6
K^+K^-	< 1.1 **	< 0.5
K^+K^0	< 2.4	< 3.8
K^0K^0	< 7.3	< 13.0

Both BABAR and BELLE:

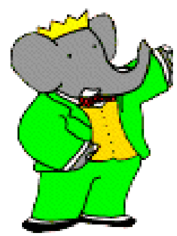
- Many 2- and 3-body charmless decay mode observations
- Direct CPV (charge asymmetry) searches in ~20 modes: none found so far

Selected hadronic B decay results



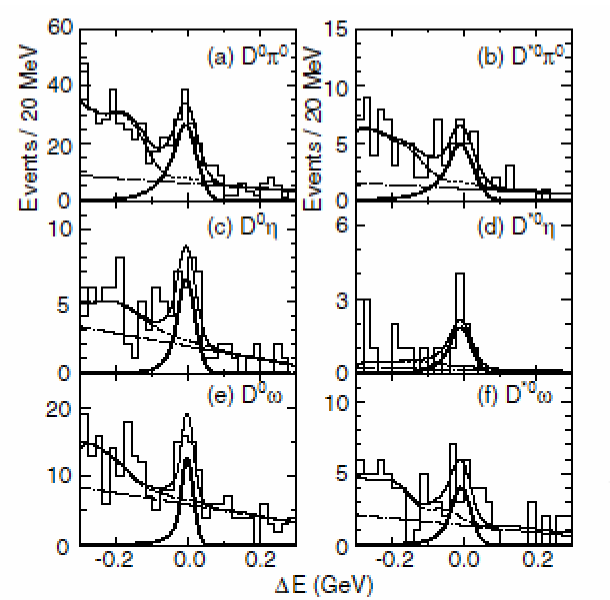
$$\mathrm{BF}(B^0 \to D_s^+ \pi^-) = (3.1 \pm 1.0 \pm 1.0) \times 10^{-5}$$

1st measurement

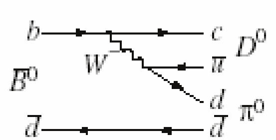


$$\mathrm{BF}(\bar{B}^0 \to D^0) = (50.3 \pm 3.0 \pm 3.7)\,\%$$
$$\mathrm{BF}(\bar{B}^0 \to \bar{D}^0) = (7.6 \pm 1.7 \pm 1.1)\,\%$$
$$\mathrm{BF}(\bar{B}^0 \to D^+) = (32.8 \pm 2.5 \pm 3.5)\,\%$$
$$\mathrm{BF}(\bar{B}^0 \to D^-) = (2.7 \pm 1.2 \pm 0.6)\,\%$$

1st measurements of flavor tagged D production in B^0 decays



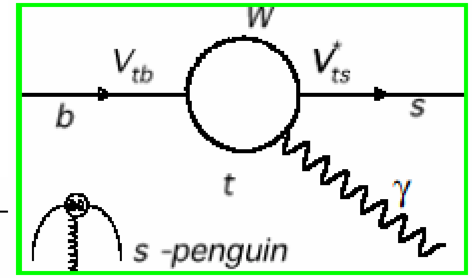
BELLE



mode	B.F. / 90% U.L. (10^{-4})
$D^0\pi^0$	3.1 ± 0.4 ± 0.5
$D^{*0}\pi^0$	2.7 ± 0.8 ± 0.5
$D^0\eta$	1.4 ± 0.5 ± 0.3
$D^0\omega$	1.8 ± 0.5 ± 0.4
$D^{*0}\eta$	< 4.6
$D^{*0}\omega$	< 7.9

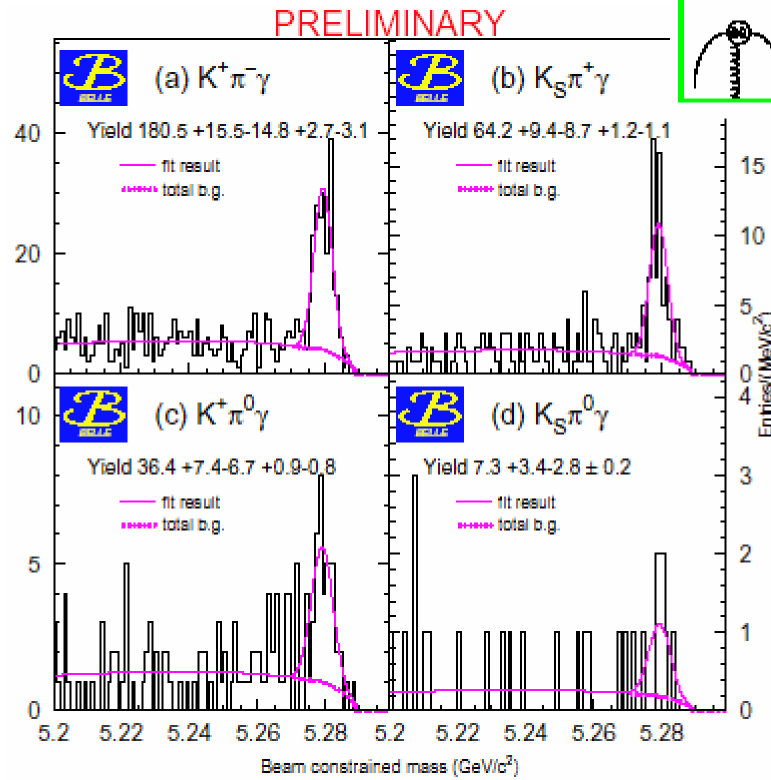
First observation of $B^0 \to D^{(*)0}h^0$

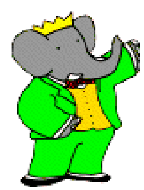
More penguins: b→sγ



	mode	BF($\times 10^{-5}$)
Exclusive	$K^{*0}\gamma$	$4.08 \pm 0.34 \pm 0.26$
	$K^{*+}\gamma$	$4.92 \pm 0.57 \pm 0.38$
	$K_2^*(1430)^0\gamma$	$1.50 \pm 0.56 \pm 0.12$
	$K^*\pi^-\gamma$	$2.04 \pm 0.65 \pm 0.22$
	$K^+\rho^0\gamma$	$1.03 \pm 0.50 \pm 0.24$
	total	11.65 ± 2.03
Inclusive	$X_S\gamma$	33.6 ± 8.5

$-8.5 < A_{CP}(K^*\gamma) < 14.9\%$ 90%CL





$$\mathcal{B}(B^0 \to K^{*0}\gamma) = (4.23 \pm 0.40 \pm 0.22) \times 10^{-5}$$

$$\mathcal{B}(B^+ \to K^{*+}\gamma) = (3.83 \pm 0.62 \pm 0.22) \times 10^{-5}$$

$-0.170 < A_{CP} < 0.082$ at 90% CL

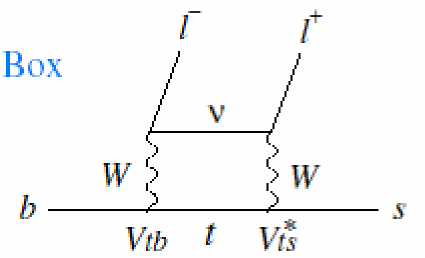
Also b→dγ

$$\mathcal{B}(B^0 \to \rho^0\gamma) < 1.5 \times 10^{-6} \text{ at } 90\% \text{ CL}$$

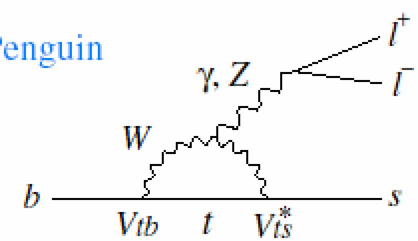
$$\mathcal{B}(B^+ \to \rho^+\gamma) < 2.8 \times 10^{-6} \text{ at } 90\% \text{ CL}$$

More penguins: b→sll

Box



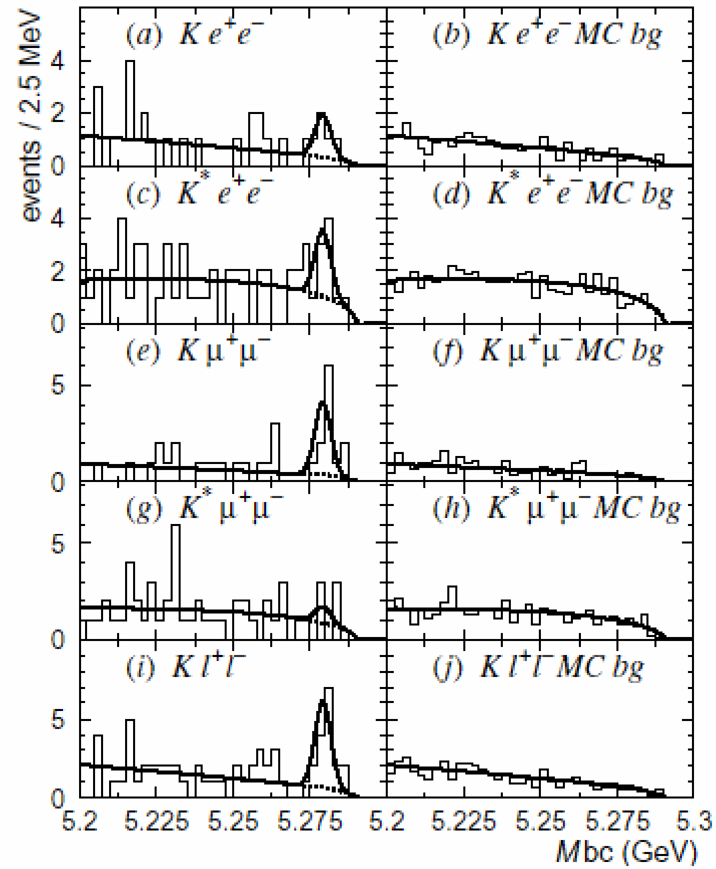
Penguin

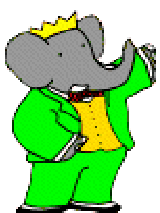


Observation of Kl^+l^- !!

mode	signal	BF($\times 10^{-6}$)	signif.
Ke^+e^-	$4.1^{+2.7+0.6}_{-2.1-0.8}$	< 1.3	2.5
$K^*e^+e^-$	$6.3^{+3.7+1.0}_{-3.0-1.1}$	< 5.6	2.5
$K\mu^+\mu^-$	$9.5^{+3.8+0.8}_{-3.1-1.0}$	$0.99^{+0.40+0.13}_{-0.32-0.14}$	4.7
$K^*\mu^+\mu^-$	$2.1^{+2.9+0.9}_{-2.1-1.0}$	< 3.1	–
Kl^+l^-	$13.6^{+2.9+0.9}_{-2.1-1.0}$	$0.75^{+0.25}_{-0.21}\pm 0.09$	5.3

Phys. Rev. Lett. 88. 021801 (2002)





	90% limit (10^{-6})
Kll	< 0.5
K*ll	< 2.9

BUT: 56/fb update coming (next month)

Semileptonic, leptonic decays

$\overline{B}^0 \to D^{*+} e^- \overline{\nu}_e$ $F(1)|V_{cb}| = (3.54 \pm 0.19 \pm 0.18) \times 10^{-2}$

$|V_{cb}| = (3.88 \pm 0.21 \pm 0.20 \pm 0.19) \times 10^{-2}$

$\overline{B}^0 \to D^+ \ell^- \overline{\nu}$ $F_D(1)|V_{cb}| = (4.11 \pm 0.44 \pm 0.52) \times 10^{-2}$

$|V_{cb}| = (4.19 \pm 0.45 \pm 0.53 \pm 0.30) \times 10^{-2}$

$B \to X \ell \nu$ $|V_{cb}| = (4.08 \pm 0.10 \pm 0.25) \times 10^{-2}$ Preliminary

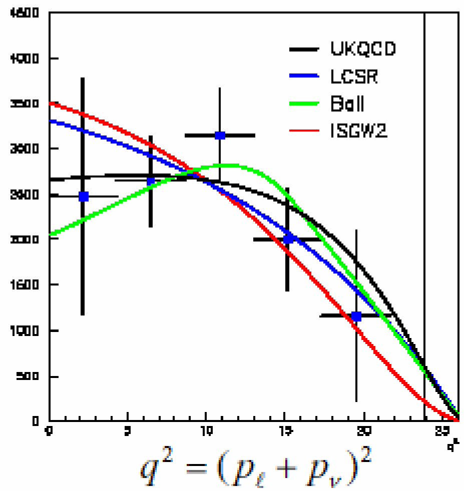
$|V_{ub}|$ was measured with $B \to \pi \ell \nu$ decay mode.

$|V_{ub}| = (4.09 \pm 0.17 \pm 0.33 \pm 0.76) \times 10^{-3}$ (LCSR) Preliminary

$|V_{ub}| = (3.71 \pm 0.15 \pm 0.29 \pm 0.67) \times 10^{-3}$ (UKQCD)

$\overline{B}^0 \to \pi^+ \ell^- \overline{\nu}$

UKQCD and LCSR were used for obtaining B.R. The other models are just reference.



Semileptonic branching fractions:

$$\frac{BF(B^+ \to Xe\nu)}{BF(B^0 \to Xe\nu)} = \frac{(10.3 \pm 0.6 \pm 0.5)\%}{(10.4 \pm 0.8 \pm 0.5)\%} = 0.99 \pm 0.10 \pm 0.04$$

→ improves with statistics

From $B \to Xe\nu$ decays: $|V_{cb}| = (40.8 \pm 0.4 \pm 0.8 \pm 2.0) \cdot 10^{-3}$ (stat) (sys) (theory)

→ method limited by theory

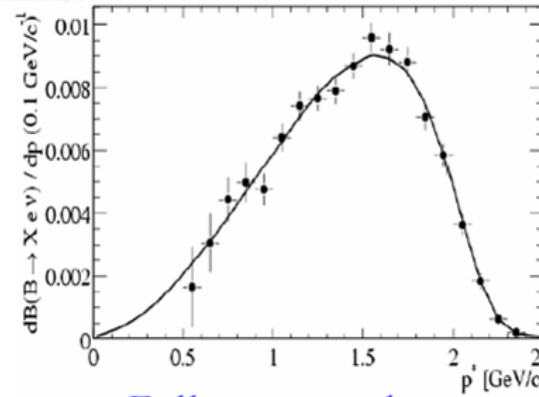
From $B \to \rho e \nu$ decays: $|V_{ub}| = (3.57 \pm 0.36 {}^{+0.33}_{-0.38} \pm 0.60) \cdot 10^{-3}$

→ method limited by theory

90% c.l. limit on $BF(B^0 \to e^+ e^-)$: $< 3.3 \cdot 10^{-7}$

→ most stringent limit to date

All results are preliminary

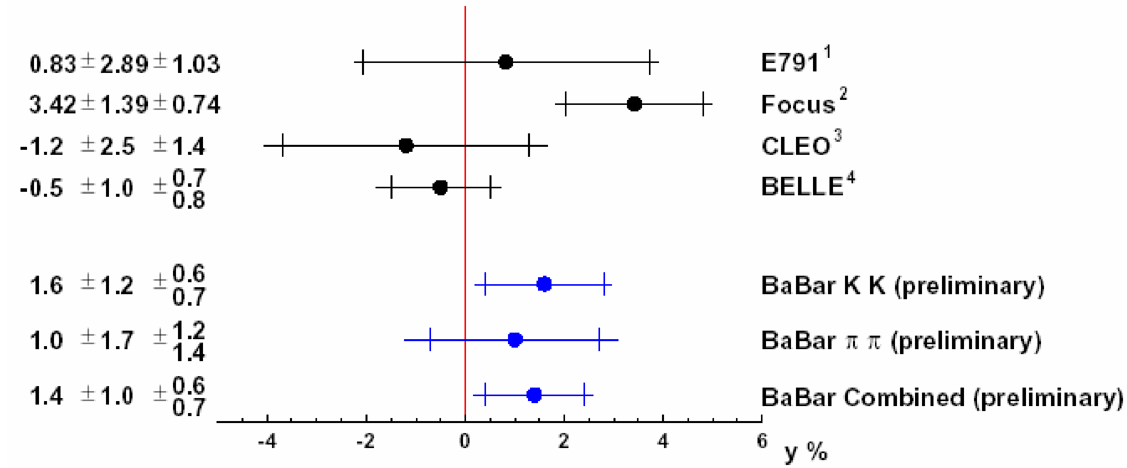


Fully corrected $B \to Xe^- \nu$ spectrum

Much more for which there is no time …

- B→ρπ: B.F., Dalitz plot analysis, sin(2α)
- D mixing/CPV searches
- τ physics

… and more



$$y = \left[1.4 \pm 1.0(\text{stat})^{+0.6}_{-0.7}(\text{syst})\right]\%$$

Prospects

- What follows ranges from clear extrapolations to educated guesswork
- Many analyses being tested on MC as we speak
- Machine Backgrounds could make some rare modes a bit more difficult
- We learn as we go.. Analyses will improve
- See :
  - BELLE EoI (BELLE web page)
  - SuperBABAR at Snowmass 2001 (SLAC-PUB-8970)
- Or speak to your local BABAR / BELLE member (quite a lot of us around it seems…)

Expected precision in sin(2β)

	0.5/ab	5/ab	50/ab
Golden stat	0.029	0.009	0.006 Lepton tag
Golden syst	0.016	0.015	0.006 Lepton tag
ϕK_S	0.25	0.08	0.03
$J/\psi\pi^0$	0.21	0.05	0.02
D(*)D(*)	0.25	0.05	0.03

Expected precision in sin(2α)

	0.5/ab	5/ab	50/ab
$\pi^+\pi^-$	S 0.14 C 0.12	S 0.05 C 0.05	S ~0.01 C ~0.01
$\rho\pi$	0.09 - 0.03	0.05 - 0.01	
$\alpha-\alpha_{eff}$ ($\pi^0\pi^0$)	~14^0	<~10^0	

The angle γ

- B^+ to D^0K^+
- Discrete ambiguities
- 5^0~10^0 precision/ambiguity with 500/fb
- 2^0/ambiguity with 10/ab, and more modes to distinguish between them
- (LHCb: ~19^0)
- B to $D^{(*)}[\rho/\pi]$: $\sin(2\beta+\gamma)$ ~0.3 with 500/fb
  - ~0.05 with 10/ab

FCNC

$b \rightarrow s\gamma$

- $B \rightarrow K^*\gamma$: ~10events/fb^{-1}
- A_{CP}: 1~2% at 10/ab^{-1}

Kll

- Efficiency: ~5%
- 500 $X_s ll$ at 500/fb
- ~120 $K^*\mu\mu$ at 500/fb (1.5×10^{-6})

$X_s ll$

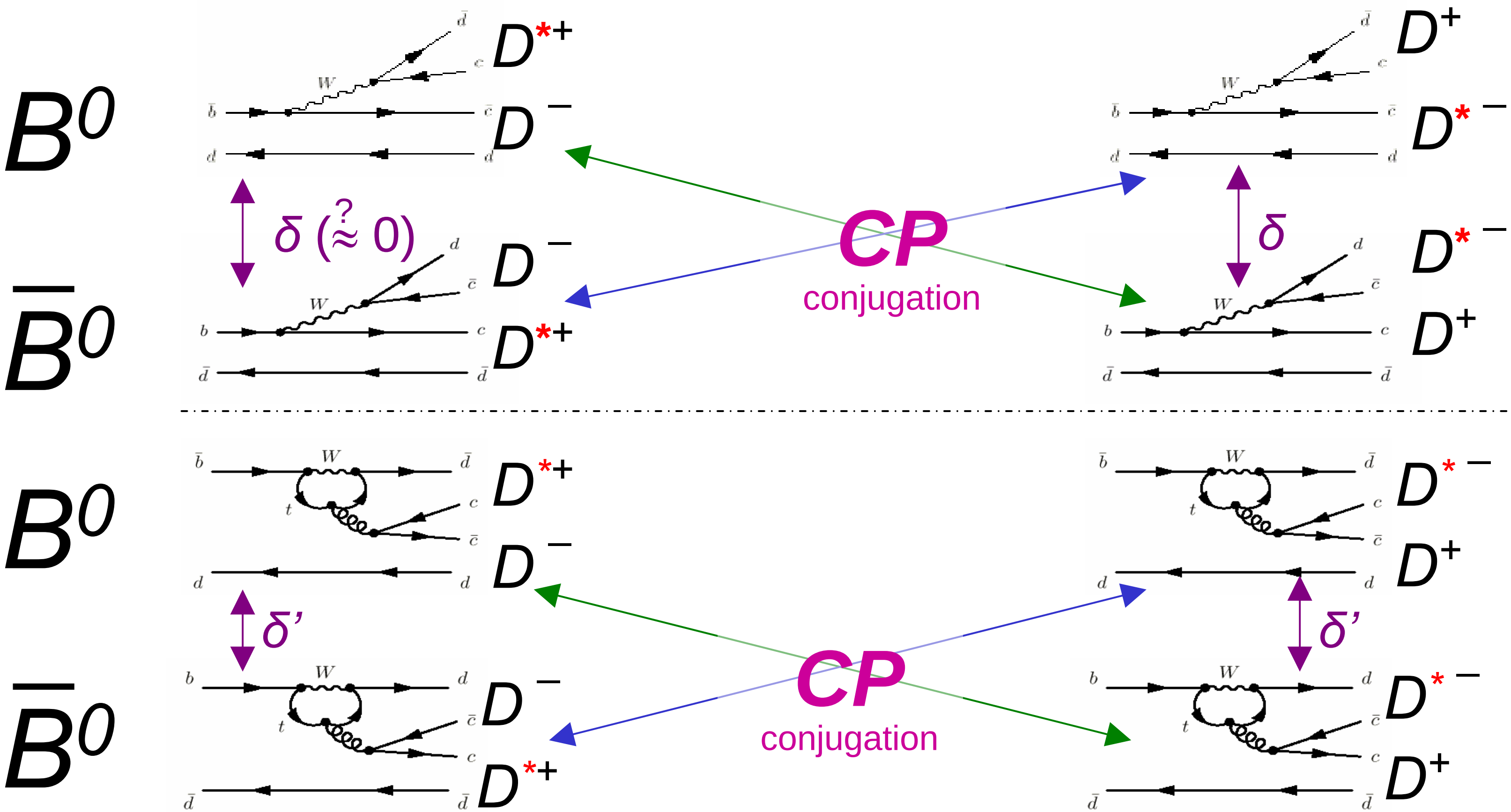
- Could get 8 events at 500/fb (4.5×10^{-5})

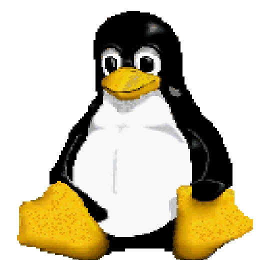
Conclusions

- B Factories in good health and full production
- CP and B physics in a new exciting era
- Important physics output in next 5 years guaranteed
- B factories (with some upgrades) will be around throughout the decade
- Significant interest (case) for a follow-up
- Competitive + unique opportunities in hadronic B experiments' era

CP asymmetry in D^*D

- D^*D final states are not *CP* eigenstates (situation akin to, for example, $\rho\pi$).
- There are **4** separate diagrams that contribute to D^*D amplitude:





CP asymmetry in D^*D

- Thus, there are not one, but two, time-dependent asymmetry parameters:

$$\lambda_{D^{*-}D^{+}} = \frac{q}{p}\frac{A(\overline{B}^{0} \to D^{*-}D^{+})}{A(B^{0} \to D^{*-}D^{+})} = e^{-2i\phi}\frac{\left|\overline{A}_{D^{*-}D^{+}}\right|}{\left|A_{D^{*-}D^{+}}\right|}$$

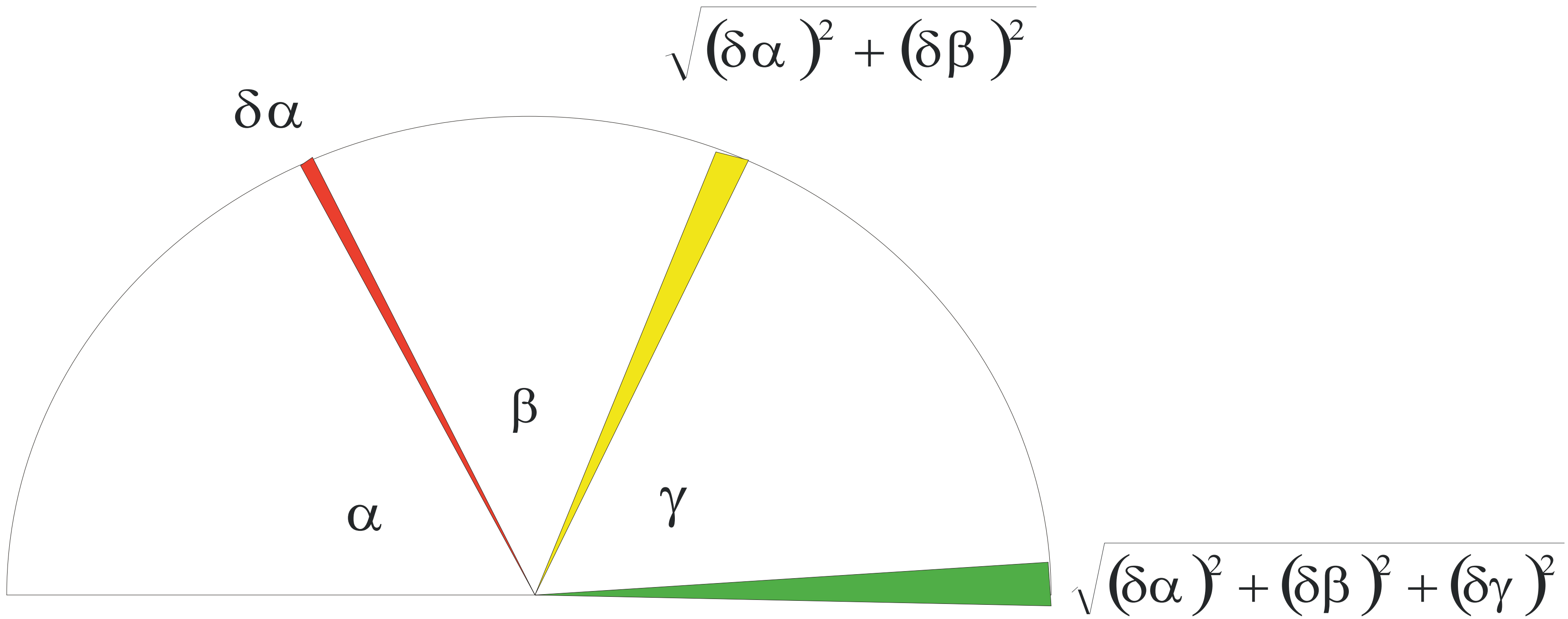
$$\lambda_{D^{*+}D^{-}} = \frac{q}{p}\frac{A(\overline{B}^{0} \to D^{*+}D^{-})}{A(B^{0} \to D^{*+}D^{-})} = e^{-2i\phi}\frac{\left|\overline{A}_{D^{*+}D^{-}}\right|}{\left|A_{D^{*+}D^{-}}\right|}$$

- In the Standard Model, if the penguin amplitude is negligible, then $\phi \equiv \beta$.
- Furthermore, if one takes the HQET limit, the ratios of the amplitude norms are exactly 1.[*]
- Thus one would then measure $\sin(2\beta)$ in $D^{*-}D^{+}$ and $D^{*+}D^{-}$ exactly as in charmonium golden modes.
- However the above are assumptions; we always prefer to fit for the general case.

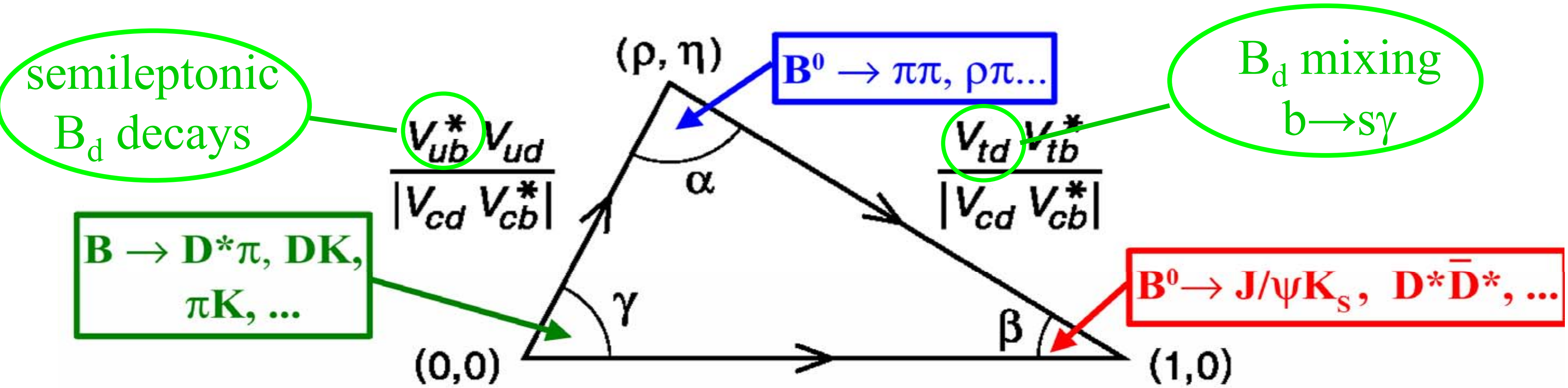
[*] Aleksan *et al.*, Phys. Lett. **B 317**, 173 (1993)

Unitarity angles determinations

CKM Angle	*BABAR* (0.5 ab^{-1})	Super*BABAR* (10 ab^{-1})	BTeV	LHCb	Atlas/CMS
$\sin 2\beta$ ($B^0 \to J/\psi K^0_S$)	0.037	0.008	0.025	0.014	0.021/0.025
$\sin 2\beta$ ($B \to \phi K_s$)	0.25	0.056			
$\sin 2\alpha$ ($B^0 \to \pi^+\pi^-$)	0.14	0.032	0.024	0.056	0.10/0.17
$\alpha_{\mathrm{Eff.}} - \alpha$ ($B^0 \to \pi^0\pi^0$)	$< 18^\circ$	$< 7^\circ$	-	-	-
$\sin(2\beta+\gamma)$ ($B^0 \to D^*\pi$)	0.15	0.03			
γ ($B \to DK$)	-	$< 2.5^\circ$	$< 10.0^\circ$	$< 19.^\circ$	
γ ($B_s \to D_s K$)	-	$< 15^\circ$	$< 7.0^\circ$	$< 13.^\circ$	



Unitarity triangle



_CP_ violating asymmetries A(Δt) in B^0 decays measure α, β, γ