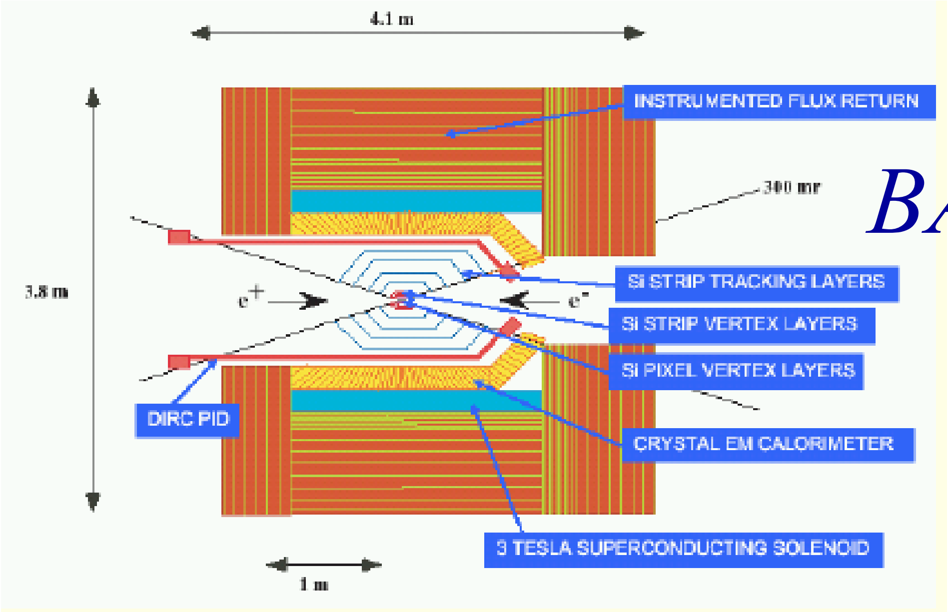


BABAR:Future prospects.
Super BABAR

Marcello A. Giorgi
Università di Pisa and INFN Pisa

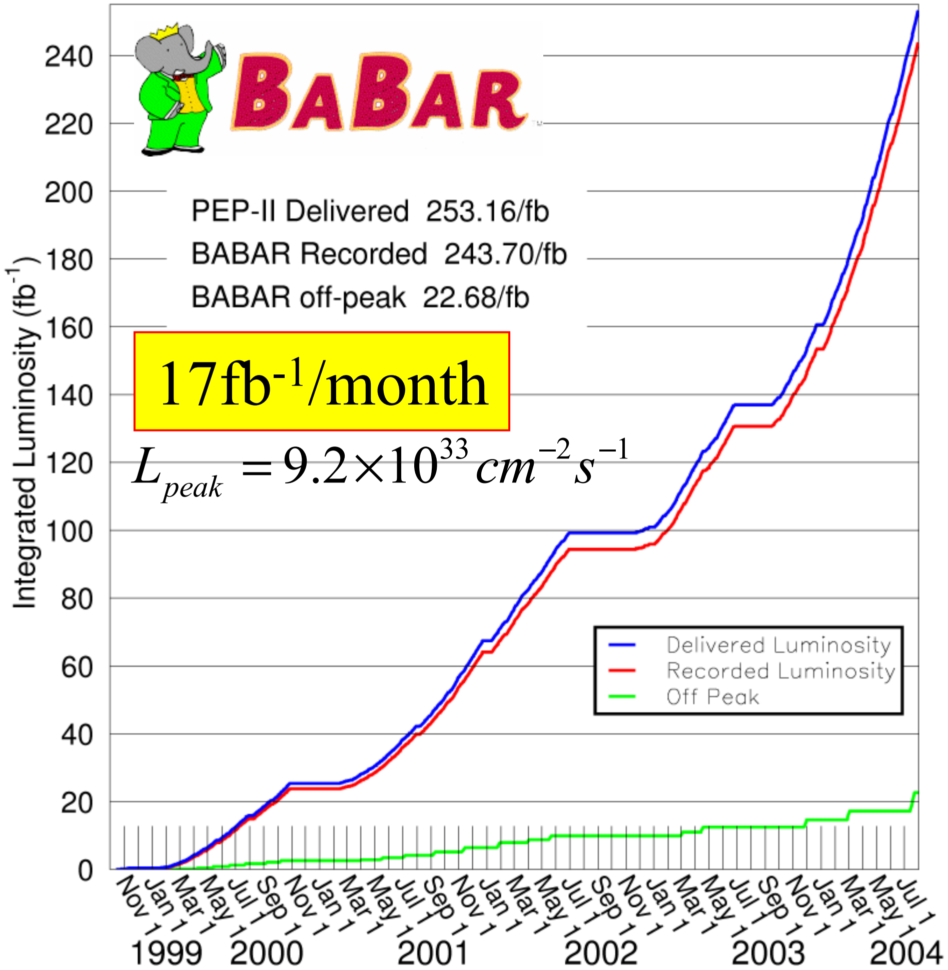
presented at
CERN December 2, 2004
CPNSH Meeting

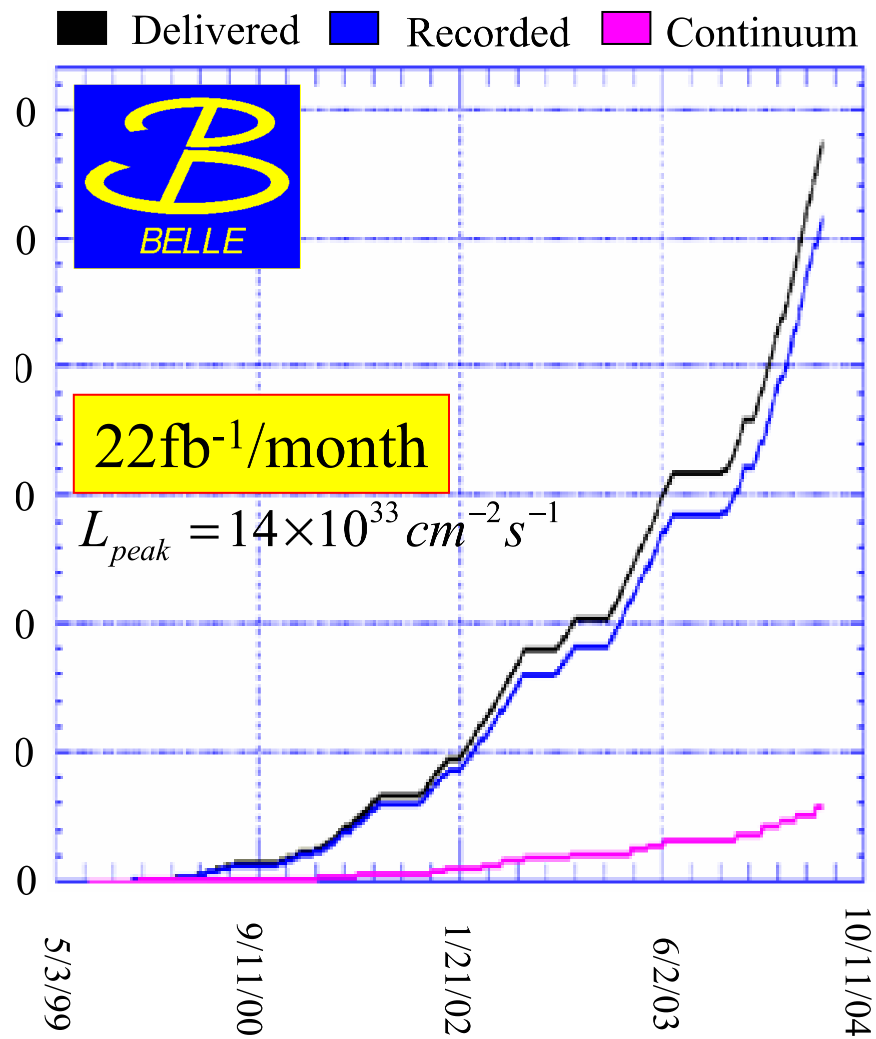
Great Success of B Factories 5 years after start

The success of the scientific program at BFactories is astonishing .The amount of physics results is huge and after the discovery of CP violation in B sector, many other results from Babar and Belle have focussed the attention of the community on the possibility of opening windows on new physics in the flavour sector.

Current luminosities and data samples

Total 244 + 286 fb^{-1} = 0.530 ab^{-1}!! As AUGUST 2004 (ICHEP04)





Since August 1st *BABAR* is not running.

BELLE has resumed the operations in September 04 and as already integrated more than 300 fb-1.

For us the restart, after the accident occurred to a technician working in the accelerator environment during normal maintenance, is expected in early ‘05.

PHYSICS MENU

- Unitarity Triangle sides measurements
  - From (semi)leptonic decays, inclusive or exclusive
  - $|V_{ub}|$, $|V_{cb}|$, $|V_{td}|$

- UT angles precision measurements
  - b→s penguin transitions very sensitive to new physics
  - CPV Asymmetries in $B \to \phi K_s$, $K_s\pi^0$ compared with $\sin 2\beta$.
  - α measurement with $B \to \pi\pi$ and $\rho\rho$; direct CPV
  - γ measurement with $B \to DK$ or similar channels.

- Rare decays
  - Exclusive and inclusive $b \to s\gamma$ BFs, direct asymmetries, photon helicities
  - Exclusive and inclusive $b \to sl^+l^-$ BFs, A_{FB}, CP asymmetries
  - B decays to states with large missing energy, such as $B_{(d,s)} \to \tau^+\tau^-$, $B \to K^{(*)}\nu\nu$, $b \to s\nu\nu$, $B \to D^{(*)}\tau\nu_\tau$, $B \to X_C\tau\nu_\tau$
  - LFV in $\tau \to \mu\gamma$ and similar channels

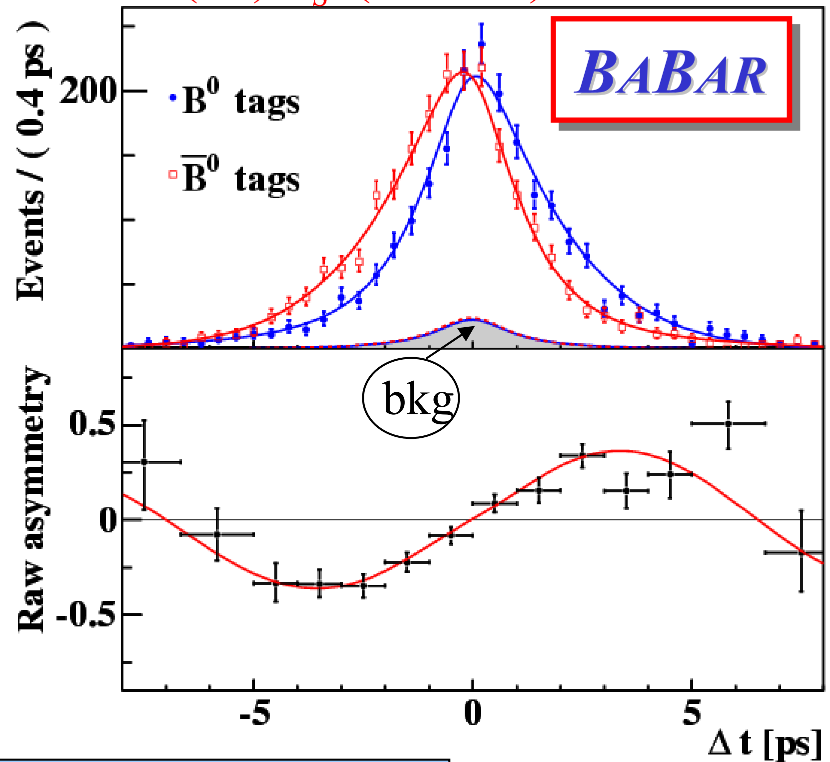
Beauty of beauty factories

Impressive physics program achieved at B-Factories

- B mesons are a powerful laboratory
  - Sizable mixing and CP violation
  - HQET works and has predictive power
  - Many transitions probe different quantities
- e^+e^- machines are fantastic probes
  - Very clean environment: ½-track trigger
  - Coherent initial state allows true interference measurements and high tagging efficiency with low dilution The tagging quality factor $Q_T = \sum_i \varepsilon_i (1-2w)^2$ is 30.5% in BABAR it is 2% for CDF.
- Luminosity counts
  - Large samples allow precision measurements
  - Rare and very rare decays are becoming more and more crucial.

$\sin 2\beta$ results from charmonium modes

$(c\bar{c})K_S^0$ (CP odd) modes



Update for ICHEP04

BABAR PUB-04/038

$$\sin 2\beta = +0.722 \pm 0.040 \pm 0.023$$
$$|\lambda| = |\bar{A}/A| = 0.950 \pm 0.031 \pm 0.013$$

Limit on direct CPV

$205\, fb^{-1}$ on peak or $227M\ B\bar{B}$ pairs

7730 CP events (tagged signal)

Belle CONF-0436

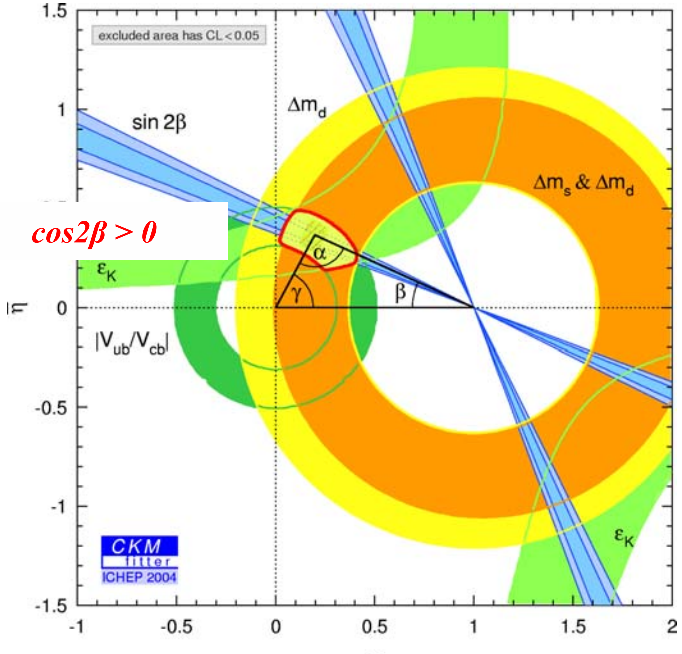
Belle 2003

$(c\bar{c})K_S^0 +$
$(c\bar{c})K_L^0$

$$\sin 2\beta = +0.728 \pm 0.056 \pm 0.023$$
$$|\lambda| = |\bar{A}/A| = 1.007 \pm 0.041 \pm 0.033$$

$140\, fb^{-1}$ on peak or $152M\ B\bar{B}$ pairs

4347 CP events (tagged signal)



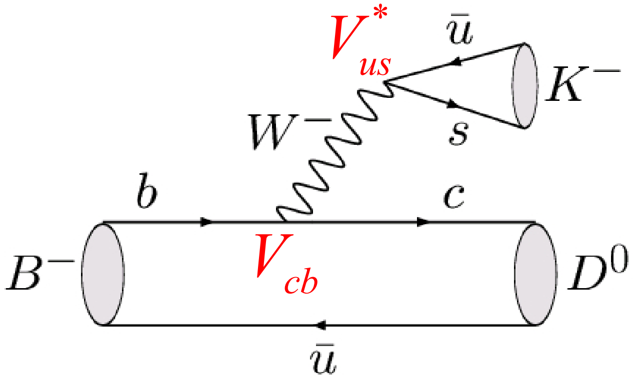
$$[\sin 2\beta]_{WA} = +0.726 \pm 0.037_{(stat+sys)}$$

Methods for extraction of γ

γ **is phase between** $b \to u$ $(\propto V_{ub})$ **and** $b \to c$ $(\propto V_{cb})$ **amplitudes**

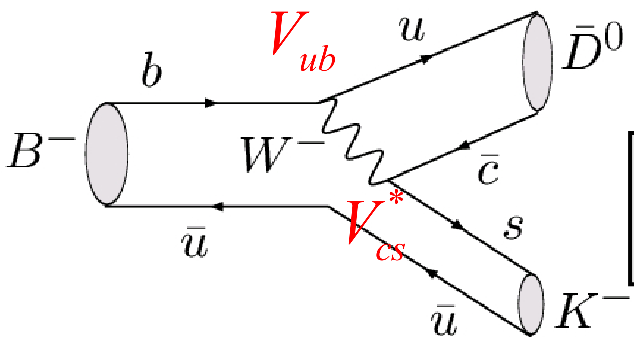
Basic Idea

Use interference between $B^- \to D^0 K^-$ and $B^- \to \bar{D}^0 K^-$ decays where the $D^0(\bar{D}^0)$ decay to a common final state f



$A \propto V_{cb} V_{us}^*$ $\propto \lambda^3$

$A \propto V_{ub} V_{cs}^*$ $\propto \lambda^3 \sqrt{\rho^2 + \eta^2}\, e^{i\gamma}$



Color suppressed

GLW *Gronau-London-Wyler, 1991*
Use $B^- \to D^0_{CP\pm} K^-$ decays

ADS *Atwood-Dunietz-Soni, 2001*
Use $B^- \to D^{(*)0}\left[K^+\pi^-\right]K^-$ decays

D⁰ Dalitz plot Use $B^- \to D^{(*)0}\left[K_S^0\pi^+\pi^-\right]K^-$ decays

Size of CP asymmetry depends on

$$r_B^{(*)} \equiv \frac{|A(B^- \to \bar{D}^{(*)0} K^-)|}{|A(B^- \to D^{(*)0} K^-)|} \sim 0.1 - 0.3$$

Constraints on r_b and γ

ADS

favored: $B^- \to D^0 K^-$ suppressed: $D^0 \to K^+\pi^-$

suppressed: $B^- \to \overline{D}^0 K^-$ favored: $\overline{D}^0 \to K^+\pi^-$

$\Rightarrow [K^+\pi^-]_D K^-$

$$R_{ADS} = \frac{BF([K^+\pi^-]K^-) + BF([K^-\pi^+]K^+)}{BF([K^-\pi^+]K^-) + BF([K^+\pi^-]K^+)} \sim r_B^2$$

Belle: $r_b < 0.28\ (90\%\ CL)$

BABAR: $r_B < 0.23\ (90\%\ CL)$

DALITZ Analysis

BABAR:

$r_B < 0.17(90\%CL)$

$\delta_B = (130 \pm 45 \pm 8 \pm 10_{(model)})^0$

$\gamma_B = (88 \pm 41 \pm 19 \pm 10_{(model)})^0$

Belle 140 fb^{-1}:

$\gamma = 77^\circ {}^{+17}_{-19} \pm 13 \pm 11_{(model)}$

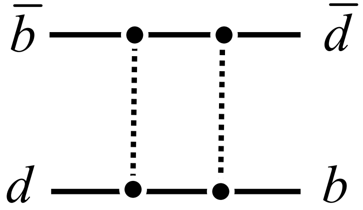
$26 < \gamma < 126^\circ$ [95% CL]

$\sin 2\alpha$ from $B \to \pi\pi, \rho\pi, \rho\rho$

Interference of suppressed
$b \to u$ "tree" decay with mixing

but: "penguin"
is sizeable!

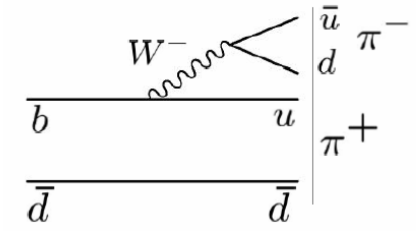
B^0 mixing



$$q/p \propto V_{tb}^* V_{td} / V_{tb} V_{td}^*$$

$\oplus$

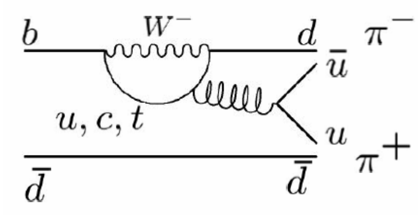
B^0 decay: tree



$$A \propto V_{ub}^* V_{ud} \quad \propto \lambda^3$$

$\oplus$

B^0 decay: penguin



$$A \propto V_{td}^* V_{tb} \quad \propto \lambda^3$$

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

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

Coefficients of time-dependent CP Asymmetry

With no penguins

$$S_{\pi\pi} = \sin 2\alpha$$
$$C_{\pi\pi} = 0$$

With large penguins
and |P/T| ~ 0.3

$$S_{\pi\pi} = \sqrt{1 - C_{\pi\pi}^2}\, \sin 2\alpha_{eff}$$
$$C_{\pi\pi} \propto \sin \delta$$

Results from $B \to \pi\pi$ and $\rho\rho$ decays

BABAR: Updated for ICHEP04

$B^0 \to \pi^+\pi^-$ (227M pairs)

$S_{\pi\pi} = -0.30 \pm 0.17 \pm 0.03$

$C_{\pi\pi} = -0.09 \pm 0.15 \pm 0.04$

Belle: PRL 93 (2004) 021601

BELLE

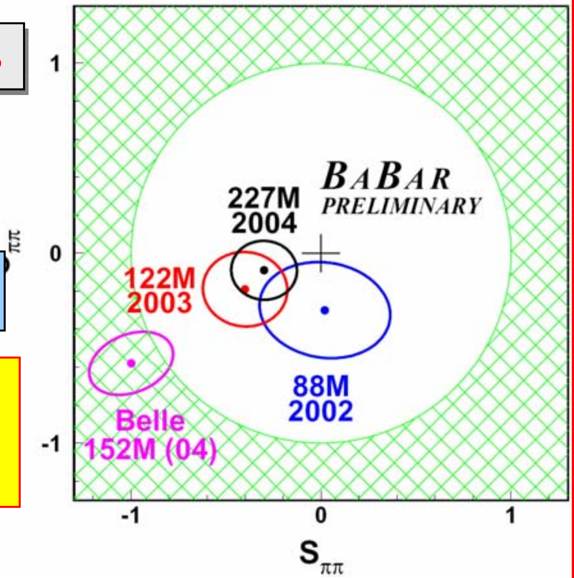
$S_{\pi\pi} = -1.00 \pm 0.21 \pm 0.07$

$C_{\pi\pi} = -0.58 \pm 0.15 \pm 0.07$

152M pairs

Comparison

Caution averaging!



($\pi\pi$)

$A_{\pi^\pm\pi^0} = -0.01 \pm 0.10 \pm 0.02$

$BF_{\pi^\pm\pi^0} = (5.8 \pm 0.6 \pm 0.4) \times 10^{-6}$

BABAR

$BF_{\pi^0\pi^0} = (1.17 \pm 0.32 \pm 0.10) \times 10^{-6}$

$C_{\pi^0\pi^0} = -0.12 \pm 0.56 \pm 0.06$ First measurements

$\alpha - \alpha_{eff} \leq 35^\circ$ at 90% CL

($\rho\rho$) Isospin Corrections for α

$B^0 \to \rho^+\rho^-$ (122M $B\bar{B}$ pairs)

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

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

Signal: 314 ± 34 events

$f_{long} = 1.00 \pm 0.02$

$B^0 \to \rho^+\rho^0$ 224M pairs

BABAR

$BF(B^+ \to \rho^+\rho^0) = (22.5^{+5.7}_{-5.4} \pm 5.8) \times 10^{-6}$

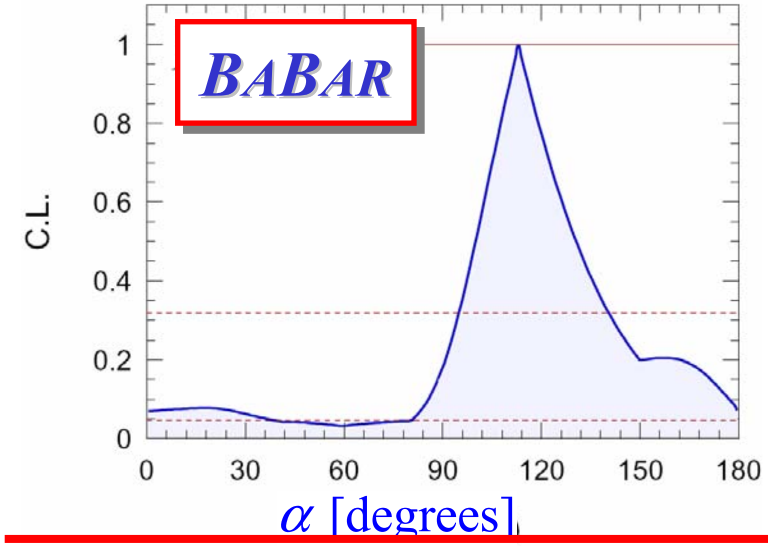
$B^0 \to \rho^0\rho^0$ 224M pairs

$BF(B^0 \to \rho^0\rho^0) < 1.1 \times 10^{-6}$ (90% CL)

:From Grossman-Quinn bound on $2\delta\alpha_{peng}$

$\alpha = \left[96 \pm 10_{(stat)} \pm 4_{(sys)} \pm 11_{(peng)}\right]^\circ$

More on α from ρπ



Results from Dalitz analysis of $B^0 \to (\rho\pi)^0$

BELLE

$\alpha = (102 \pm 11 \pm 15)^{o}$

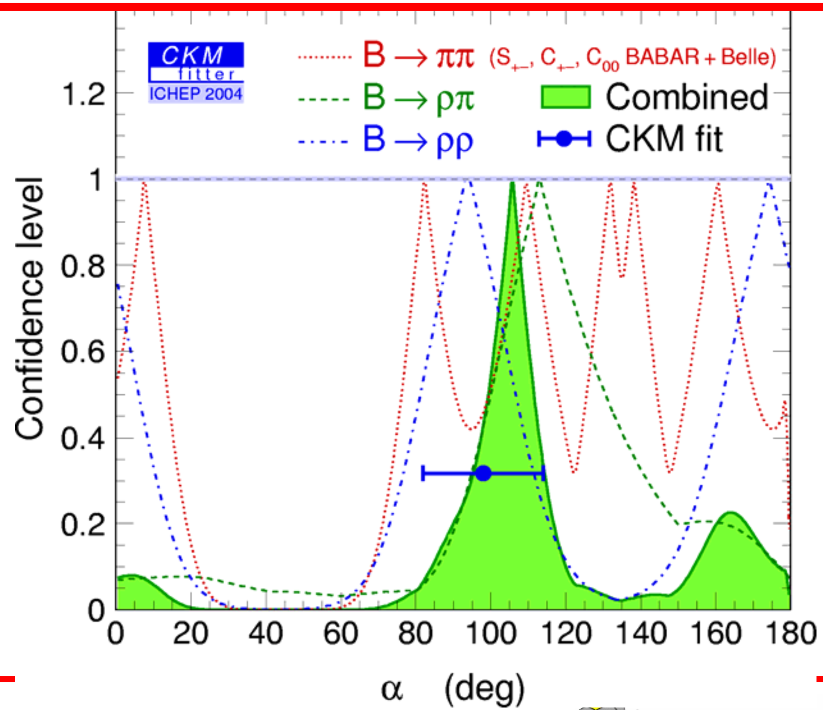
[Based on factorization & SU(3); Gronau & Zupan]

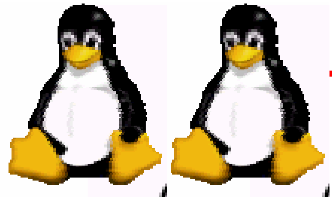
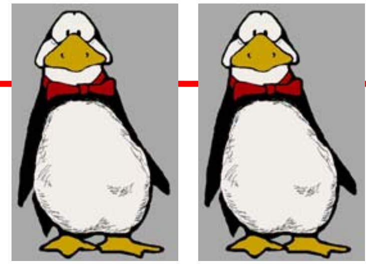
$\alpha = (113^{+27}_{-17} \pm 6)^{o}$

Full analysis

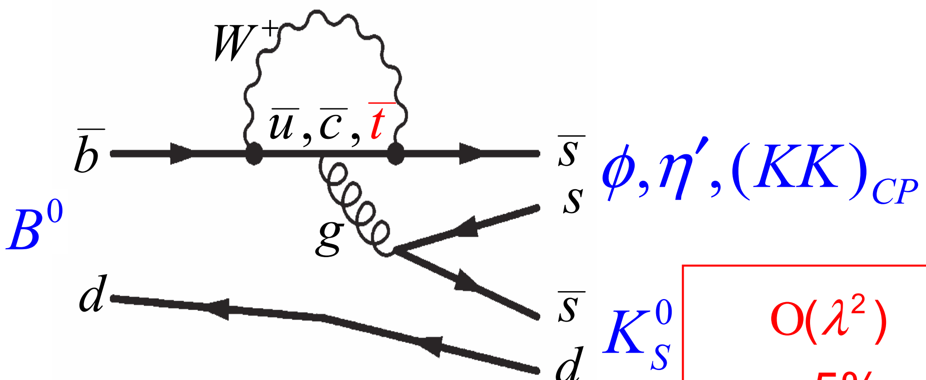
From combined $\pi\pi, \rho\pi, \rho\rho$ results:

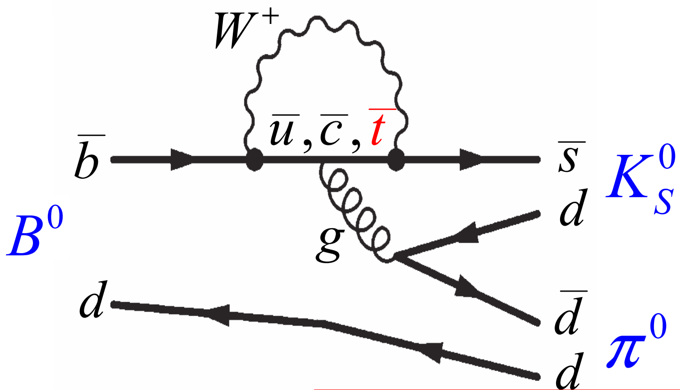
$$\alpha = \left[106^{+8}_{-11}\right]^{o}$$



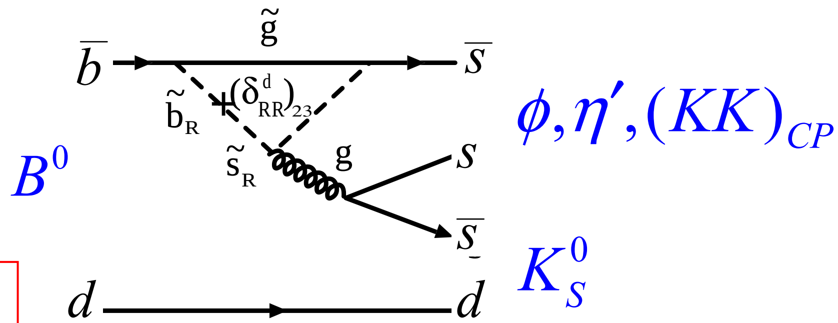
sin2β and..  and.... 

In SM interference between B mixing, K mixing and Penguin $b \to s\bar{s}s$ or $b \to s\bar{d}d$ gives the same $e^{-2i\beta}$ as in tree process $b \to c\bar{c}s$. However loops can also be sensitive to New Physics!

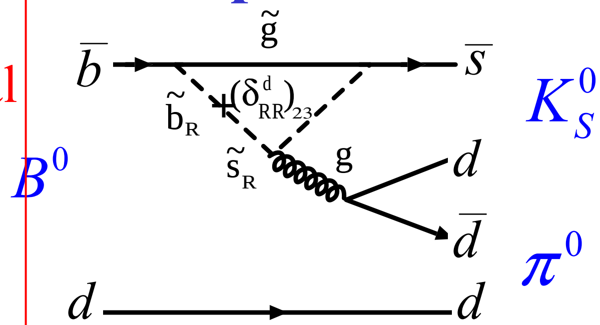




$O(\lambda^2)$
~ 5%
Purely dimensional estimate
$O(\lambda^2/\bar{\lambda})$
~ 20%



New phases from SUSY?



Note that within QCD these uncertainties turn out to be smaller !

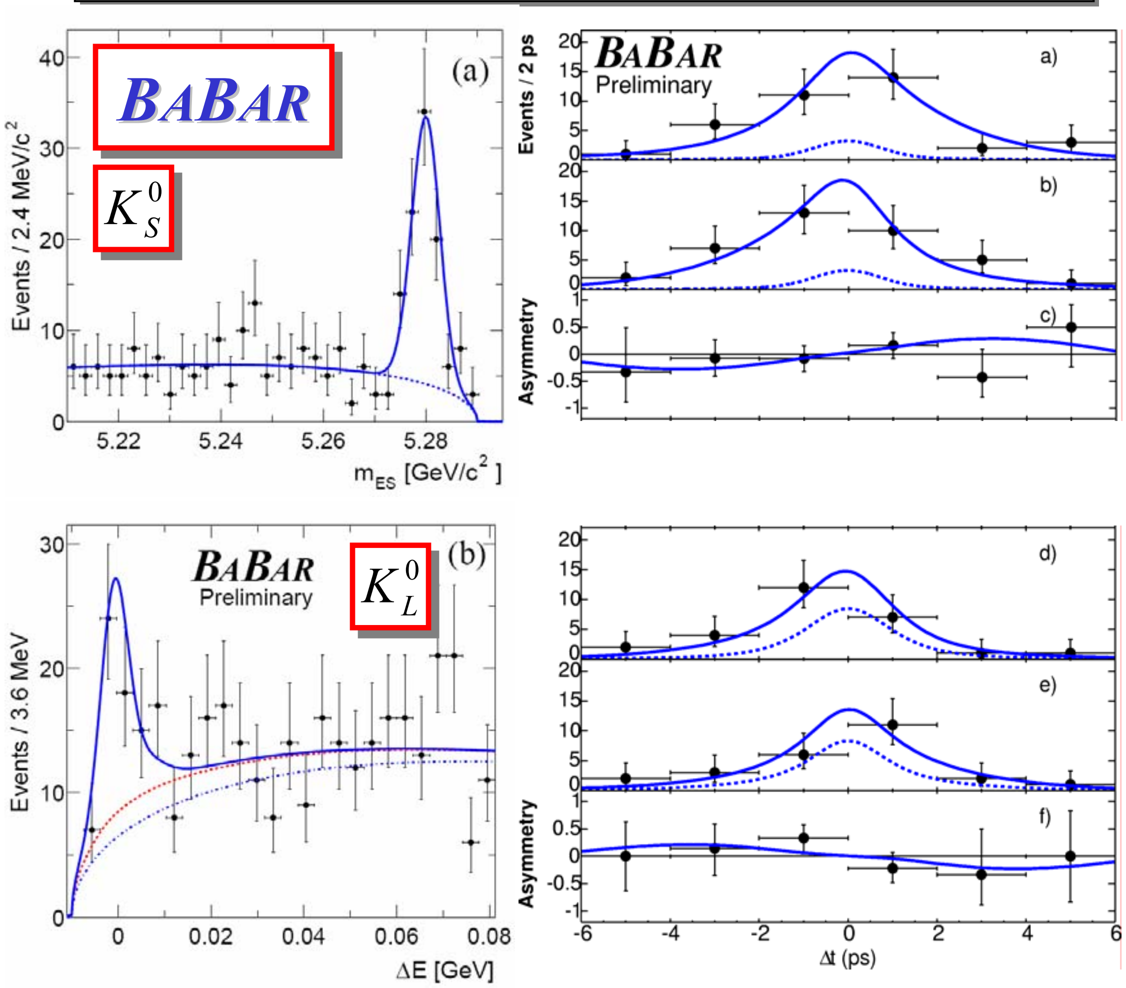
A.Hoecker ICHEP04

BABAR results for $B^0 \to \phi K^0$

2004 = 227*M BB* pairs (2003 = 120M pairs)

2003 result

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



Update for ICHEP04

$B^0 \to \phi K_S^0$ — 114 ± 12 events

$$S_{\phi K_S^0} = +0.29 \pm 0.31$$

$B^0 \to \phi K_L^0$ — 98 ± 18 events

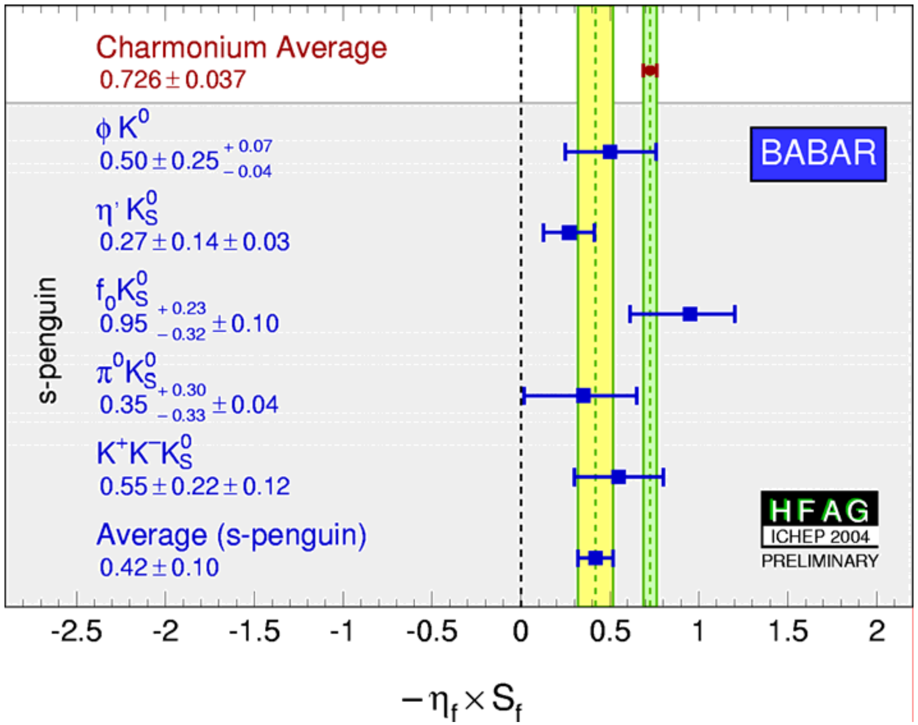
$$S_{\phi K_L^0} = -1.05 \pm 0.51$$

$$-\eta_{CP} \cdot S_{\phi K^0} = +0.50 \pm 0.25 {}^{+0.07}_{-0.04}$$
$$C_{\phi K^0} = +0.00 \pm 0.23 \pm 0.05$$

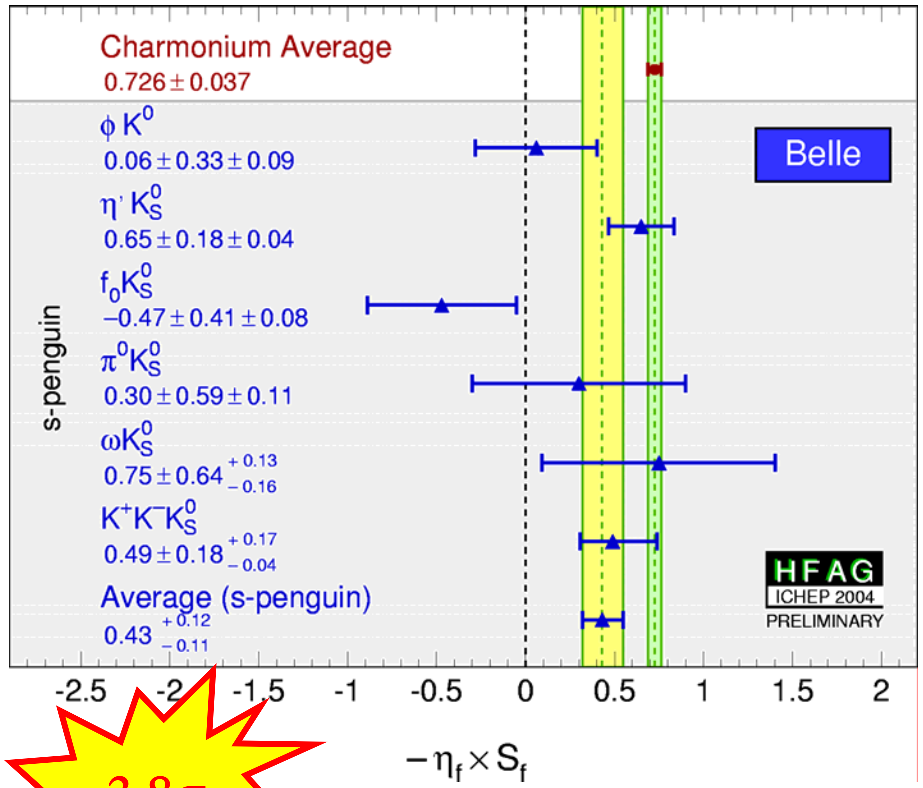
BABAR-CONF 04/033

Results on sin2β from s-penguin modes

All new!



All new!



≈3.8σ

2.7σ from s-penguin to sin2β ($c\bar{c}$)

2.4σ from s-penguin to sin2β ($c\bar{c}$)

Comment on averaging

On purely dimensional considerations the corrections to the $b \rightarrow s$ penguins are ranging between 5% and 20% , on the other hand the sign of the corrections is far from been the same for different channels.

As I mentioned at ICHEP averaging the results on penguins is something adventurous and not simply legitimate.

The averaged value can be diluted and non reflecting the real amount of the difference from $\sin 2\beta$ value of charmonium.

However the distance of the (*BABAR-BELLE*) average value of penguins of 3.9 σ from the w.a. $\sin 2\beta = 0.726$ is already something and intriguing.

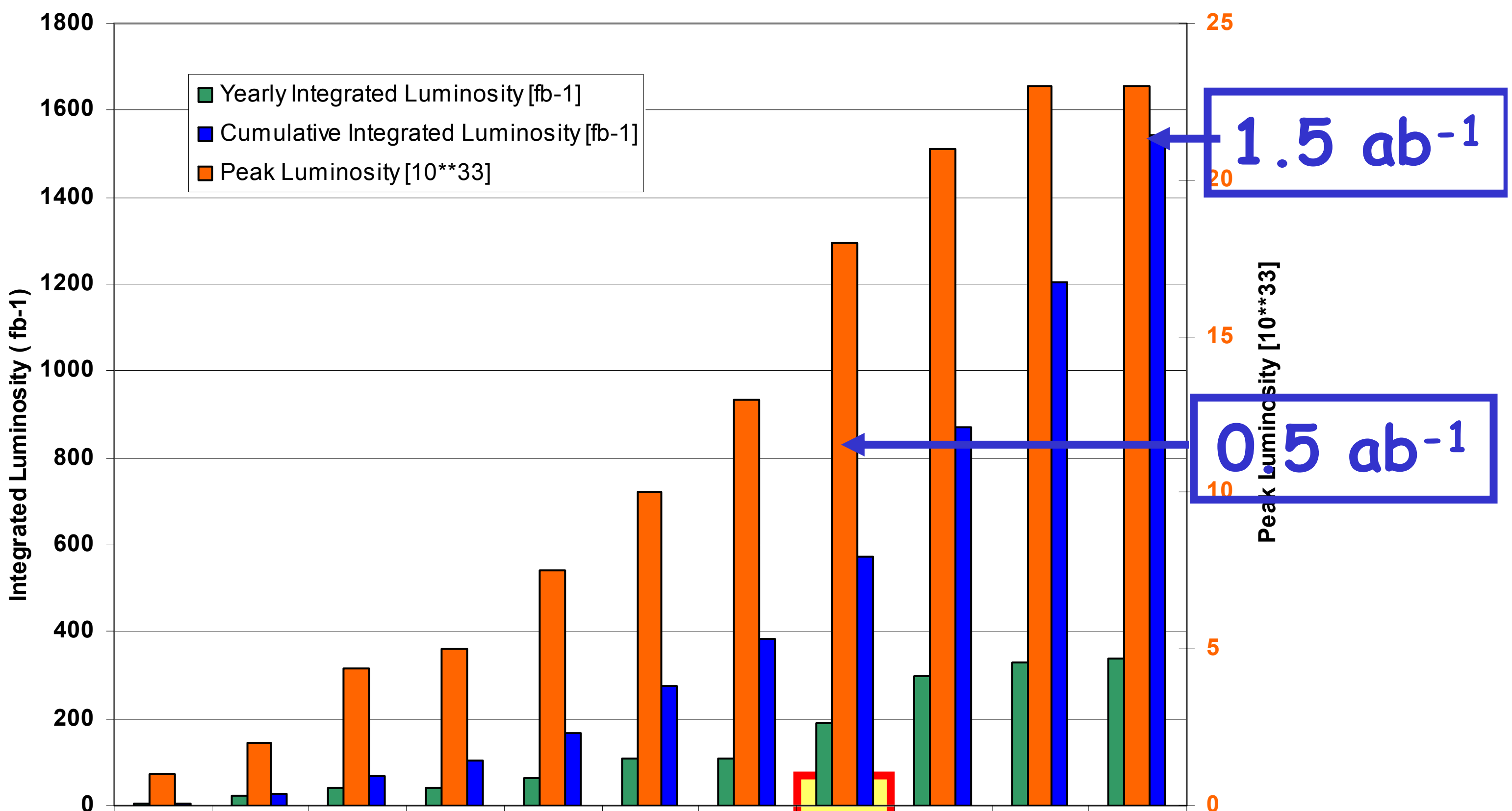
CP asymmetries in $b \rightarrow s$ penguins will show perhaps the first indications of new physics.

Theoretical uncertainties

Measurement (in SM)	Theoretical limit	Present error
$B \to \psi K_S \ (\beta)$	$\sim 0.2^\circ$	1.6°
$B \to \phi K_S,\ \eta^{(\prime)} K_S, \ldots (\beta)$	$\sim 2^\circ$	$\sim 10^\circ$
$B \to \pi\pi,\ \rho\rho,\ \rho\pi \ (\alpha)$	$\sim 1^\circ$	$\sim 15^\circ$
$B \to DK \ (\gamma)$	$\ll 1^\circ$	$\sim 25^\circ$
$B_s \to \psi\phi \ (\beta_s)$	$\sim 0.2^\circ$	—
$B_s \to D_s K \ (\gamma - 2\beta_s)$	$\ll 1^\circ$	—
$\lvert V_{cb}\rvert$	$\sim 1\%$	$\sim 3\%$
$\lvert V_{ub}\rvert$	$\sim 5\%$	$\sim 15\%$
$B \to X \ell^+ \ell^-$	$\sim 5\%$	$\sim 25\%$
$B \to K^{(*)} \nu\bar{\nu}$	$\sim 5\%$	—

Ligeti, ICHEP 2004

PEP II Luminosity Projections

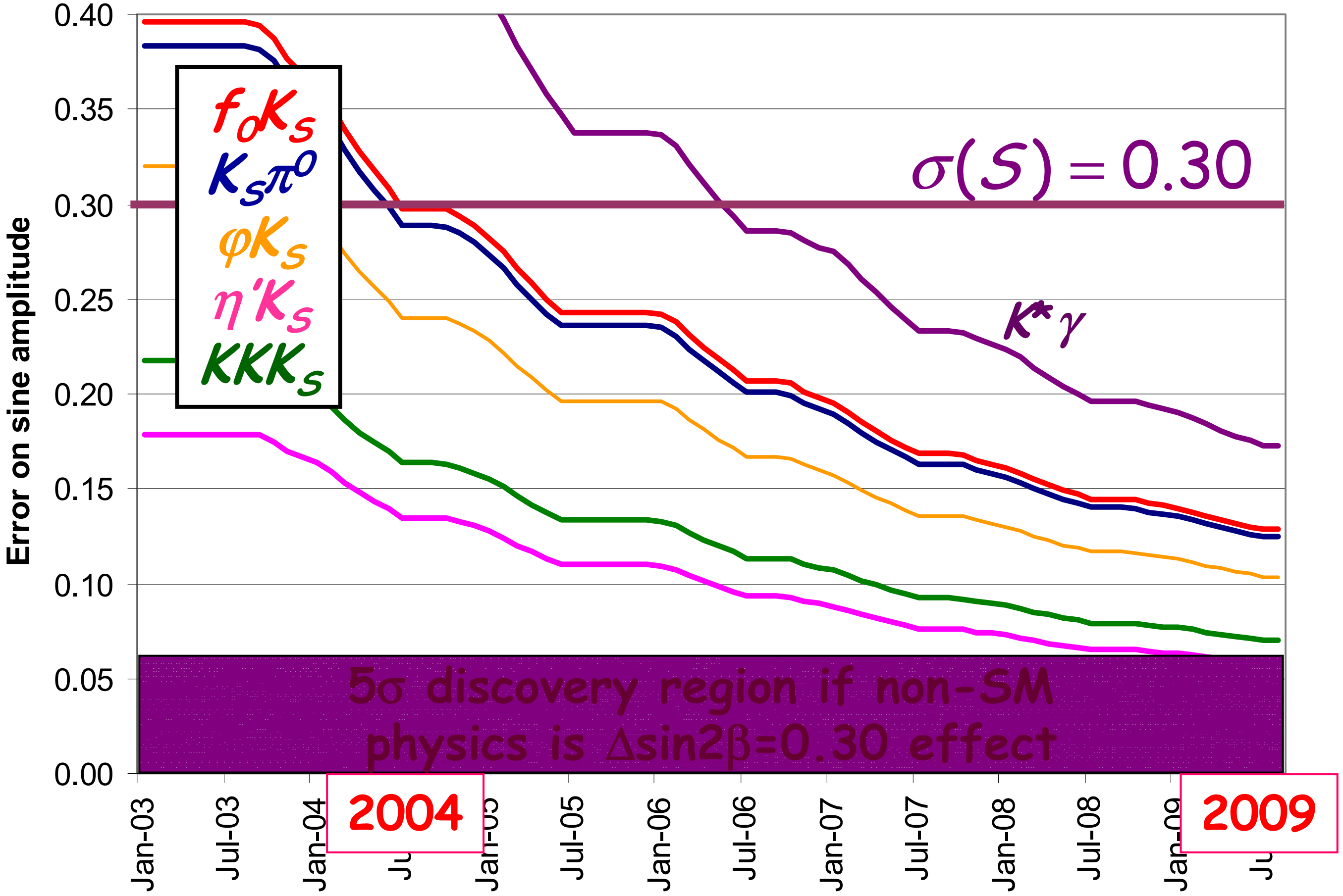


	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Yearly Integrated Luminosity [fb-1]	3	23	41	39	62.6	107.3	109.6	187.8	298.6	331.3	339.5
Cumulative Integrated Luminosity [fb-1]	3	26	67	106	168.6	275.9	385.5	573.3	871.9	1203.2	1542.7
Peak Luminosity [10**33]	1	2	4.4	[illegible]	[illegible]	[illegible]	[illegible]	18	21	23	23

Calendar Year

2006 ← 1.8×10^{34}

Projections for Penguin Modes



Luminosity expectations:

2004=240 fb^{-1}
2009=1.5 ab^{-1}

Similar projections for Belle as well

Projections are statistical errors only;
but systematic errors at few percent level

SUPER BFACTORY ?

BABAR has shown that in the continuous injection operation mode and thanks to the data taking efficiency >98% is able to integrate in one year 10^7x L_{peak} . 7.0 10^{35} cm^{-2} s^{-1} corresponds to 10000 fb^{-1}/year.

After 7 months study in BABAR the preferred option is a machine of *7.0 1035 cm-2 s-1* to integrate *10000 fb-1/year and upgradable to investigate NP at a mass scale* ~ 1 TeV

Possible Super B parameters

Luminosity	2-3x10^{34}	1.5x10^{35}	2.5x10^{35}	7x10^{35}	Units
e^+	3.1	3.1	3.5	8.0	GeV
e^-	9.0	9.0	8.0	3.5	GeV
I^+	4.5	8.7	11.0	6.8	A
I^-	2.0	3.0	4.8	15.5	A
β(y*)	7	3.6	3.0	1.5	mm
β(x*)	30	30	25	15	cm
Bunch length	7.5	4	3.4	1.7	mm
# bunches	1700	1700	3450	6900	
Crossing angle	0	0	±11	±15	mrad
Tune shifts (x/y)	8/8	11/11	11/11	11/11	x100
rf frequency	476	476	476	952	MHz
Site power	40	75	85	100	MW

PEPII before 09

Unitarity Triangle – Sides& Angles

Unitarity Triangle - Sides		e^+e^- Precision		
Measurement	**Goal**	**3/ab**	**10/ab**	**50/ab**
V_{ub} (inclusive)	syst =5-6%	2%	1.3%	
V_{ub} (exclusive) (π,ρ)	syst=3%	5.5%	3.2%	
f_b B($B\to\mu\nu$)	SM: B~5x10^{-7}			
F_b B($B\to\tau\nu$)	SM: B~5x10^{-5}	3.3 σ	6 σ	13σ f_b to ~10%
V_{td}/V_{ts} ($\rho\gamma/K^*\gamma$)	Theory 12%	~3%	~1%	

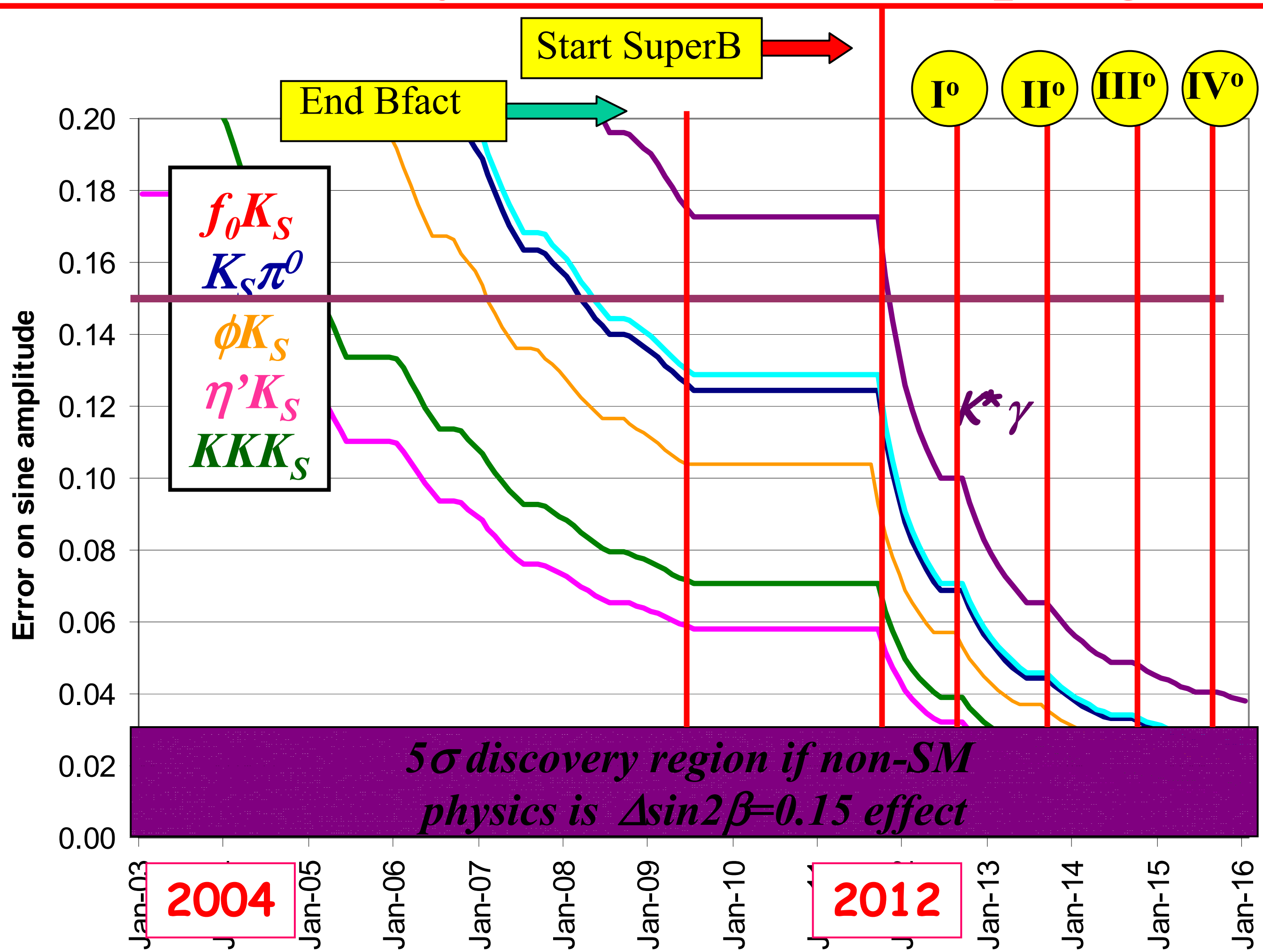
Unitarity Triangle - Angles	e^+e^- Precision			1 Year Precision	
Measurement	**3/ab**	**10/ab**	**50/ab**	**LHC*b***	***B*TeV**
$\alpha\,(\pi\pi)$ ($S_{\pi\pi}$, $B\to\pi\pi$ BR's+ isospin)	6.7°	3.9°	2.1°	-	-
$\alpha\,(\rho\pi)$ (Isospin, Dalitz) (syst ≥3°)	3, 2.3°	1.6, 1.3°	1, 0.6°	2.5° -5°	4°
$\alpha\,(\rho\rho)$ (penguin, isospin, stat+syst)	2.9°	1.5°	0.72°		
$\beta\,(J/\psi K_S)$ (all modes)	0.3°	0.17°	0.09°	0.57°	0.49°
$\gamma(B\to D^{(*)}K)$ (ADS)		2-3°		~10°	<13°
$\gamma(all)$		1.2-2°		7°	8°

Theory: α~1° β~ 0.2° γ<<1°

CP Violation in b→s penguins

Rare Decays – New Physics – *CPV (?)*		**e^+e^- Precision**			**1 Year Precision**	
Measurement	**Goal**	**3/ab**	**10/ab**	**50/ab**	**LHC*b***	***B*TeV**
$S(B^0 \to \phi K_S)$	SM: <0.25 (0.05)	*0.08*	*0.05*	*0.02 (?)*	*0.08?*	*0.04?*
$S(B^0 \to \phi K_S + \phi K_L)$	SM:<0.25 (0.05)					
$S(B \to \eta' K_s)$	SM:<0.3 (0.1)	*0.06*	*0.03*	*0.01*		
$S(B \to K_s \pi^0)$	SM:<0.2 (0.15)	*0.08*	*0.05*	*0.04 (?)*		
$S(B \to K_S \pi^0 \gamma)$	SM:<0.1	*0.11*	*0.06*	*0.04 (?)*		
$A_{CP}(b \to s\gamma)$	SM: <0.6%	2.4%	1%	0.5% (?)		
$A_{CP}(B \to K^* \gamma)$	SM: <0.5%	0.59%	0.32%	0.14%	-	-
CPV in mixing ($\lvert q/p \rvert$)		<0.6%			X	X

Projections for b→s penguins

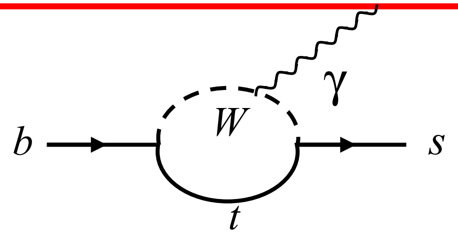


Luminosity expectations:

Super *B* Factory
5-7x10^{35} cm^{-2}s^{-1}

Projections are statistical errors only;
but systematic errors at few percent level

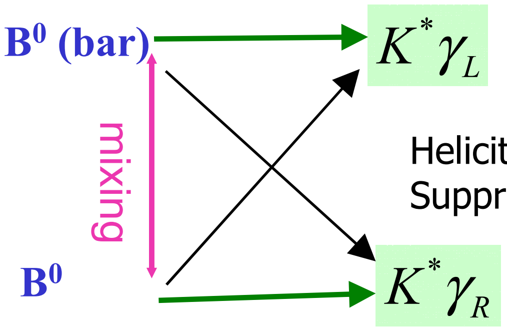
$B \rightarrow K_s \pi^0 \gamma$



The dominant SM amplitude gives: $b \rightarrow s\gamma_L$, $b(bar) \rightarrow s\gamma_R$

NP can modify helicity structure: e.g. LR symmetry, higgs in loops

Use TDCP to probe the helicity structure: (**but limited to $K^{*0} \rightarrow K_s \pi^0 \sim 11\%$**)



Helicity Flip
Suppressed by m_s/m_b

→ Expect:

$$S_{K^*\gamma} = 2\frac{m_s}{m_b}\sin 2\beta \approx 0$$

~0.042

David Atwood, Michael Gronau, Amarjit Soni (1997)

PRL **79** ,185(1997)

	$0.1\ ab^{-1}$	$2\ ab^{-1}$	$5\ ab^{-1}$	$10\ ab^{-1}$	$50\ ab^{-1}$		
$S(K_s \pi^0 \gamma)$	0.6	0.14	0.09 (0.12)	0.06	0.04(?)		

Soni: m_s is the "current" mass: (m_s ~150 +/- 50 MeV), m_b ~5 GeV

→ Theory error ~0.01 to 0.02 (??) (~30% of SM value of S)

$b \rightarrow sl^+l^-$ precision measuements

New Physics – Kl^+l^-, sl^+l^-		e^+e^- **Precision**			**1 Year Precision**	
Measurement	**Goal**	**3/ab**	**10/ab**	**50/ab**	**LHC*b***	***B*TeV**
$B(B \longrightarrow K\mu^+\mu^-)$ /$B(B \longrightarrow Ke^+e^-)$	SM: 1	~8%	~4%	~2%	X	X
$A_{CP}(B \longrightarrow K^* l^+l^-)$ (all) (high mass)	SM: < 0.05%	~6% ~12%	~3% ~6%	~1.5% ~3%	~1.5% ~3% (?)	~2% ~4% (?)
$A^{FB}(B \longrightarrow K^*l^+l^-) : s_0$ $A^{FB}(B \longrightarrow K^*l^+l^-) : A_{CP}$	SM: ±5%	~20%	~9%	9%	~12%	
$A^{FB}(B \rightarrow sl^+l^-) : \hat{s}_0$		27%	15%	6.7%		
$A_{FB}\ (B \rightarrow sl^+l^-) : C_9\ , C_{10}$		36-55%	20-30%	9-13%		

NP observables in s/d l+l- decay

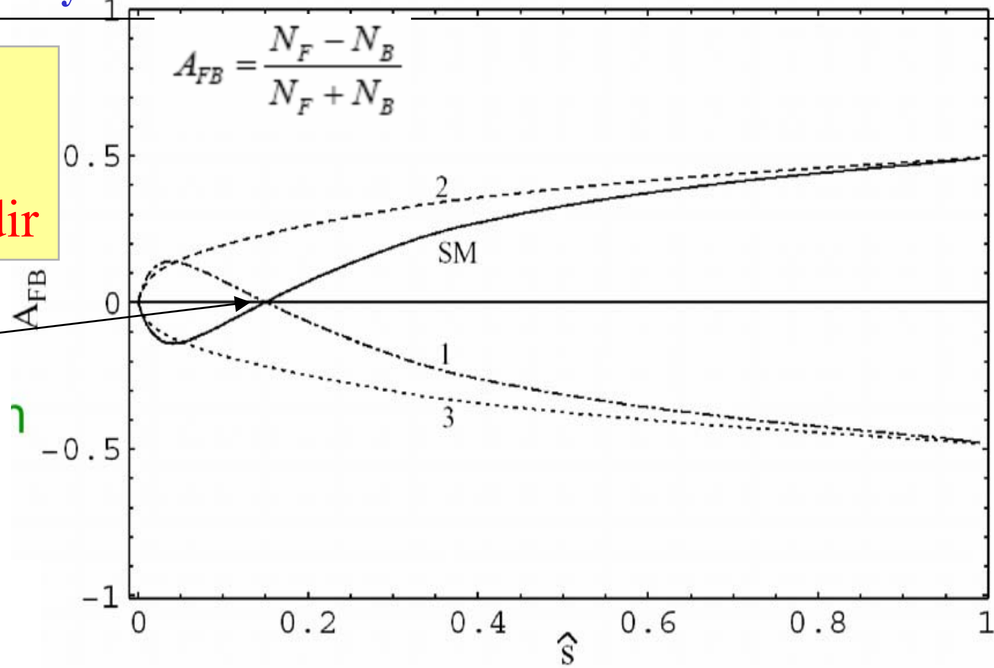
$A_{cp}(B \rightarrow s\, l^+ l^-)$	SM: <0.5% (0.05% for $K^*\, l^+ l$)
$A_{cp}(B \rightarrow d\, l^+ l^-)$	SM: -~(4.4+/-4)%
$B(B \rightarrow s\mu^+\mu^-)/B(B \rightarrow se^+e^-)$	SM: ~1
$A^{FB}(K^* l^+ l^-)$:s_0(zero crossing)	SM predicts with ~5% accuracy
$A^{FB}(K^* l^+ l^-)$:CP asymmetry	Very small in SM

In dilepton rest frame
N_F = when l^+ along b dir
N_B = when l^+ opposite b dir

SM:
S_0 NNLO error = 5%

S_0 = 0.162+/-0.008 ~ C7/C9

$$\hat{s} = (m_{l^+l^-}/m_b)^2$$



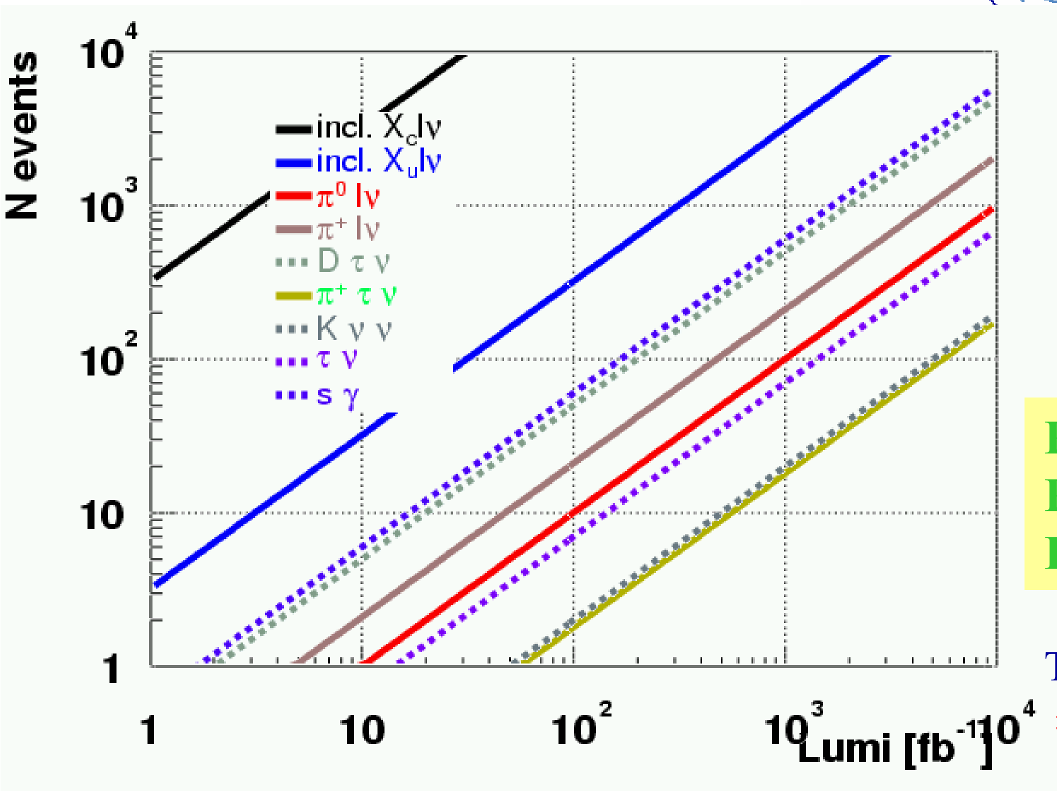
$$\hat{s} = (m_{l^+l^-}/m_b)^2$$

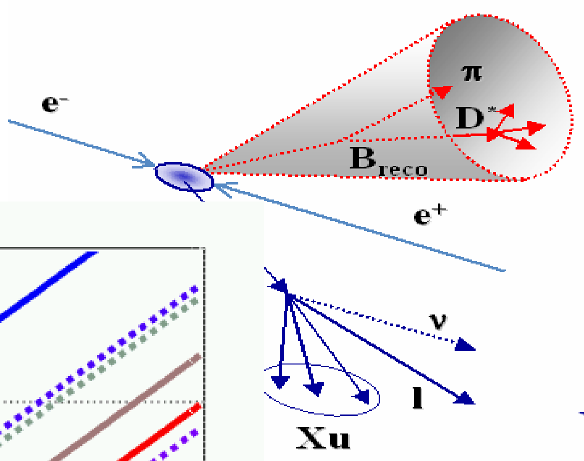
In SM: A^{CP}_{FB}~ 0
Determination of sign of AFB very important.

SUPER B Rare Decays

MEASUREMENT	Goal	3/ab	10/ab	50/ab
$B(B\to D^*\tau\nu)$	SM: B: 8×10^{-3}	10.2%	5.6%	2.5%
$B(B\to s\nu\nu)K,K^*$	SM:Theory ~5% 1 excl: 4×10^{-6}			~3σ
$B(B\to invisible)$		$<2\times10^{-6}$	$<1\times10^{-6}$	$<4\times10^{-7}$
$B(B_d\to\mu\mu)$		-	-	?
$B(B_d\to\tau\tau)$		-	-	?
$B(\tau\to\mu\gamma)$			$<10^{-8}$	

Recoil Method as pure B beam





- Fully reconstruct one of the two Bs in hadronic modes…
- …and do it with "high" efficiency

- The remaining of the event is the other B

You have a single B beam!!

Daniele del Re UCSD

Recoil cinematics well known
Recoil flavor and charge is determined
Event closure needed with neutrinos

The final efficiency is ~0.4% (per bb_{bar} pair)

$\Rightarrow$ ~4000 B/fb^{-1} (at 30% purity)

$\Rightarrow$ 1500 B^0/fb^{-1}

$\Rightarrow$ 2500 B^+/fb^{-1}

> 10^7 recoil Bs in $10ab^{-1}$

Conclusions

- Babar has a promising future for the next 5 years

The experiment has become a "laboratory" with high capability of inventing new analyses

- A Super B-Factory at 10ab^{-1}/year or more has discovery potential:
  - *NP effects in loops are becoming accessible*
  - In LHC era
    - masses of NP from LHC experiments
    - *flavour experiments can give phases and also couplings.*
    - *further informations UT precision measurements*
- Complementary and competitive with LHCB/BTeV
  - *No B_s, but on remaining same or higher precision*
  - *Sample very clean (see. Recoil technique allowing pure B beam)*
  - *Access to channels with neutrals and neutrinos : γ, ν, π^0*
  - *no bias from selective triggers*