Heavy Flavour Physics at e^+e^- Machines

David Hitlin
Royal Society of Edinburgh
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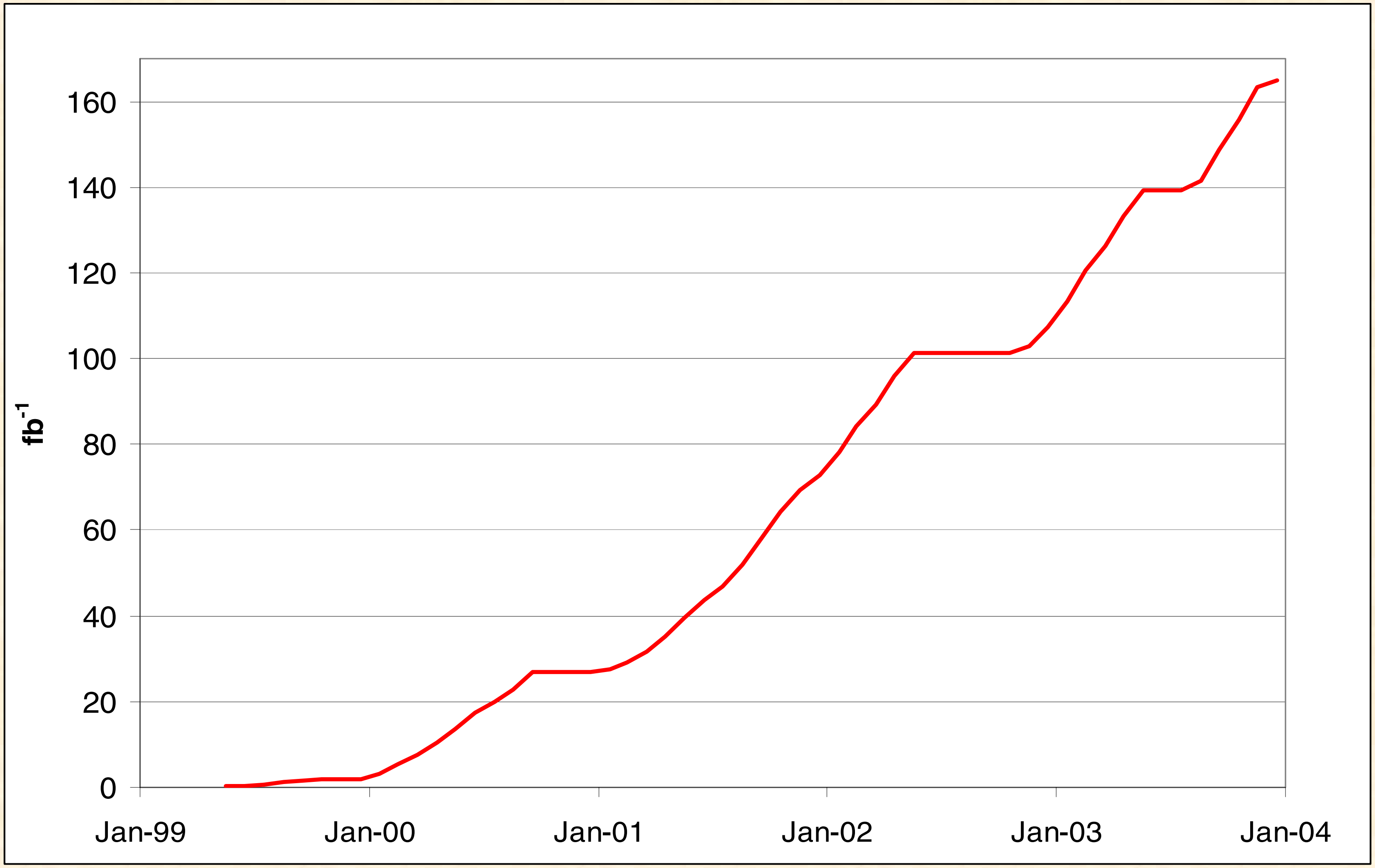
BABAR

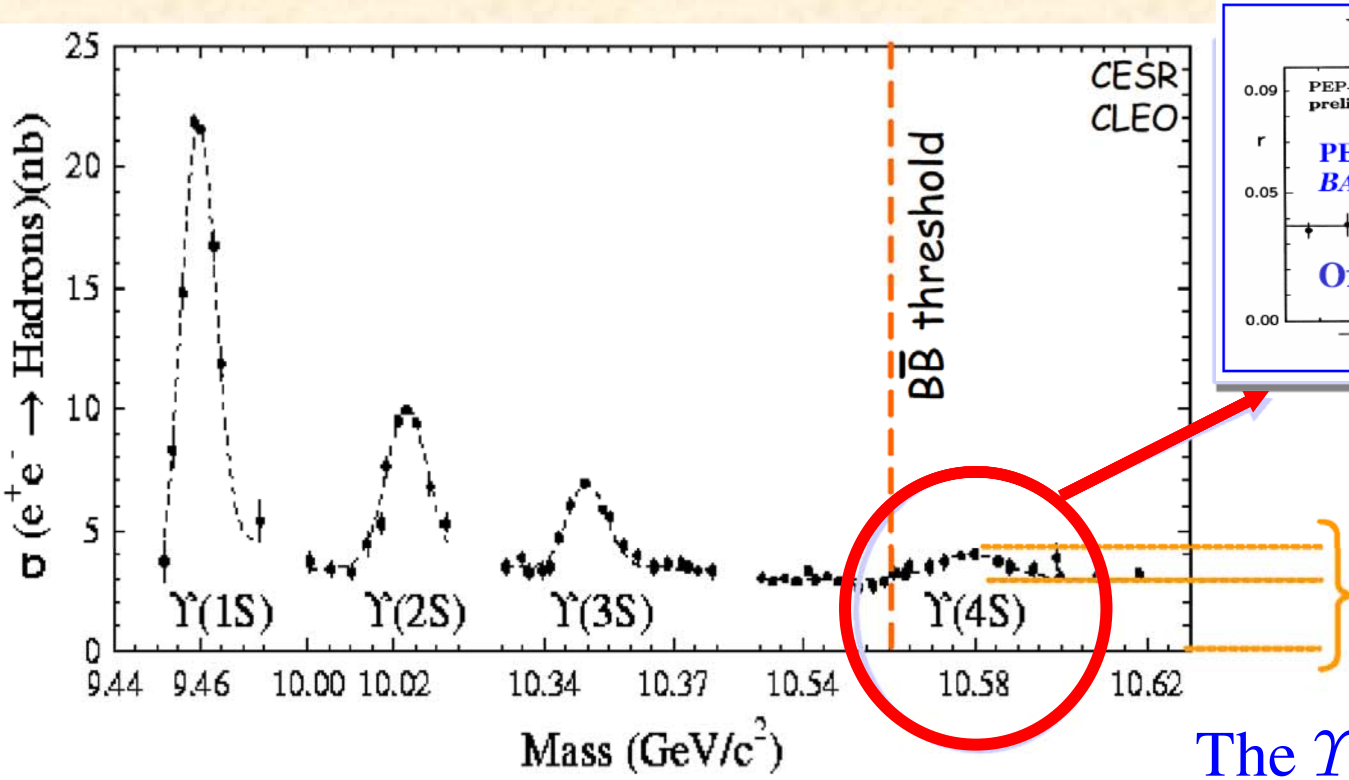
Heavy flavour physics at e^+e^- machines

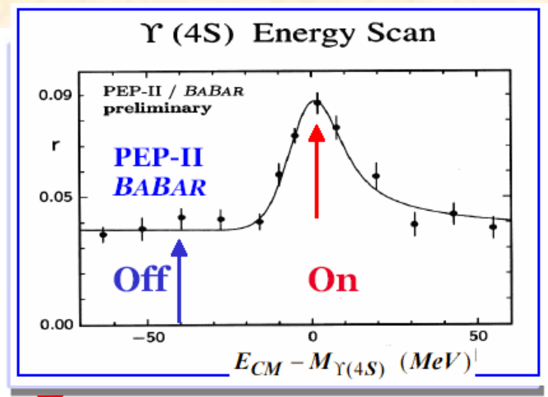
- e^+e^- colliders have provided the majority of our information on heavy quark and heavy lepton physics
  - A new generation of experiments (*BABAR*/PEP-II, Belle/KEK-B) has been quite successful, providing the first evidence of *CP* violation in the *B* meson system and precise new results on many rare decays
    - PEP-II luminosity is currently >7×10^{33} cm^{-2}s^{-1} and will reach 10^{34} by the end of the current run
    - KEK-B luminosity is currently 1×10^{34}
    - *BABAR*/PEP-II (~160 fb^{-1}) and Belle/KEK-B (~185 fb^{-1}) will each have data samples of 800-1000 fb^{-1} by late in this decade
- Near the end of the decade, a new set of experiments at the Tevatron and LHC (ATLAS, CMS, LHC*b*, *B*TeV) will provide very large samples of heavy quark decays, including the B_s, which are not produced at the $\Upsilon(4S)$ in e^+e^-
- Proposals are being prepared for substantial upgrades of PEP-II and KEK-B to luminosities of 10^{35} to 10^{36} cm^{-2}s^{-1}
  - How do these new initiatives stack up against the new hadronic experiments?

PEP-II delivered luminosity (though end of 2003)



The Υ resonances in e^+e^- annihilation: non-relativistic $b\bar{b}$ atomic systems





$$\frac{\sigma_{b\bar{b}}}{\sigma_{had}} = 0.28$$

The $\Upsilon(4S)$ decays to $B^0\bar{B}^0, B^+B^-$ in a coherent L=1 state

$$M_{\Upsilon(4S)} = 10.5841 \pm 0.0007 \text{ GeV}$$

$$\Gamma_{\Upsilon(4S)} = 11.1 \pm 3.4 \text{ MeV}$$

A practical application of EPR

What is the future of experimental flavor physics?

	e^+e^- experiments	Hadron experiments
The current lineup:	*BaBar*, Belle	CDF, DØ
The situation in ~2010	Super*BABAR* and/or SuperBelle	ATLAS, CMS, LHC*b* *B*TeV

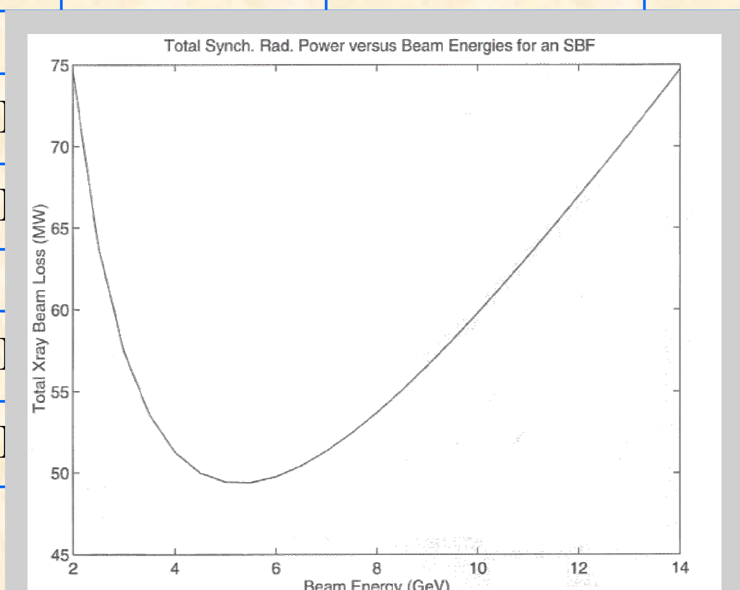
- Total *BaBar* and Belle data samples will amount to ~800-1000 fb^{-1} each
- CDF (DØ), in areas which overlap e^+e^-, are being calibrated with TeV-II data

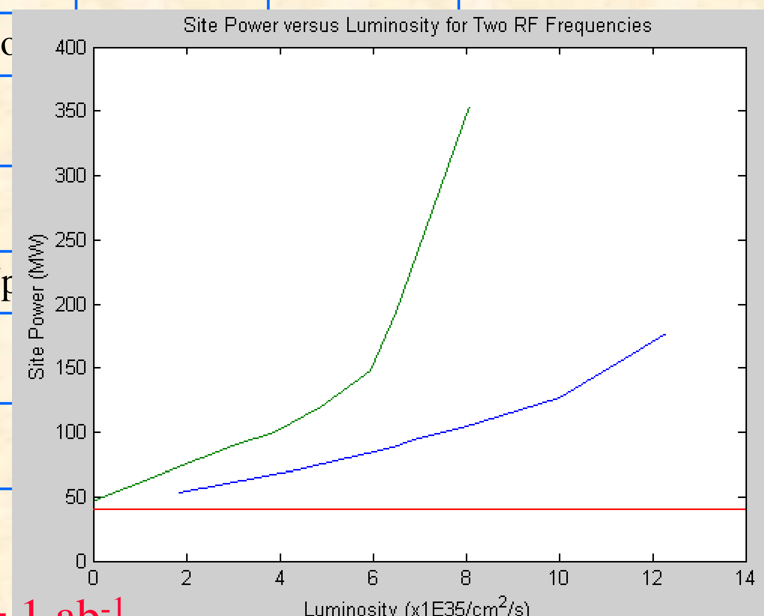
  Würthwien(SSI02): for untagged $B \rightarrow h^+h^-$: 2 fb^{-1}(CDF) ⇔ 500 fb^{-1}(*BaBar*, Belle)
  CDF/DØ can, of course, study B_s decay, but is unlikely, in general, to markedly improve on e^+e^- results in other areas
- LHC experiments will bring statistics to the next level
- In this context, is a new, very high luminosity e^+e^- effort warranted?

PEP-II and KEK-B upgrade scenarios

$$L = 2.17x10^{34}\frac{n\xi_y E I_b}{\beta_y^*}$$

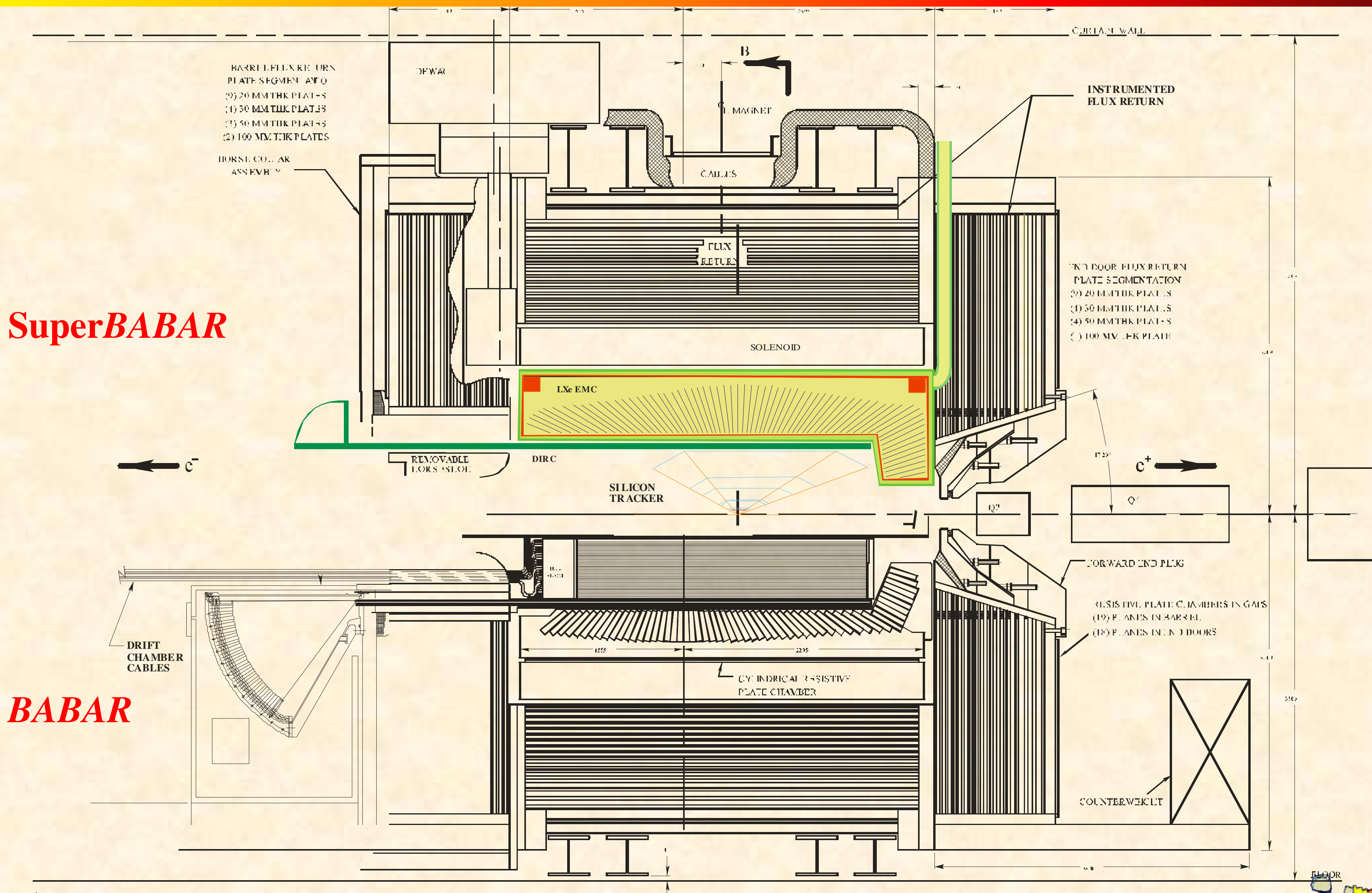
	L ($nb^{-1}s^{-1}$)	$I_{LER/HER}$ (A)	β_y* (mm)	ξ_y	Power (MW)	
			Present Performance			
PEP-II	7	1.8/1.2	12	0.05	50	Head-on
KEKB	11	2.6/1.1	6	0.05	50	±11 mrad
			witho			
PEP-I			6			rossing
KEKI			6			;
			or Up			
PEP-I			.5			, try
KEKI			3			ore rf





10^{36} for 1 Snowmass Year (10^7 s) = 1000 fb^{-1} = 1 ab^{-1}

An upgrade path from *BaBar* to Super*BaBar*



Comparison of e^+e^- B Factories and hadronic experiments

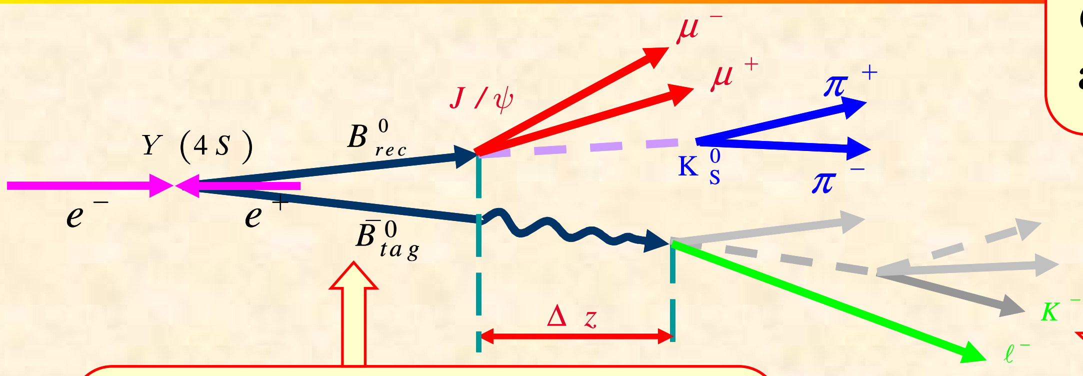
	$\Upsilon(4s)$	$p\bar{p}$
min p_T	$\sim$ 50MeV	$\sim$ 400MeV
photons	excellent	limited to poor $\Rightarrow$
PID	excellent	limited to poor $\Rightarrow$
$K_L, \bar{n}$	limited	limited to poor
	monochromatic B	unknown p_B
	hard to sep. $B \leftrightarrow \bar{B}$	hard to sep. B from fragmentation
Xsection	modest	huge
heavy vs light	limited vertex sep.	excellent vertex sep.
	only B_d, B_s	all b-hadrons

LHC*b*/ *B*TeV

Wűrthwein

Overview of the $\Upsilon(4S)$ analysis

Reconstruct exclusive B decays to CP eigenstates and flavor eigenstates and tag the flavor of the other B decay



Select B_{CP} candidates
$(B^0 \to J/\psi K^0_S, \pi^+\pi^-, etc.)$
and $B_{\rm flav}$ candidates
$(B^0 \to D^{*-}\pi^+, etc.)$

Select B_{tag} events using, primarily, leptons and K's from B hadronic decays & determine B flavor

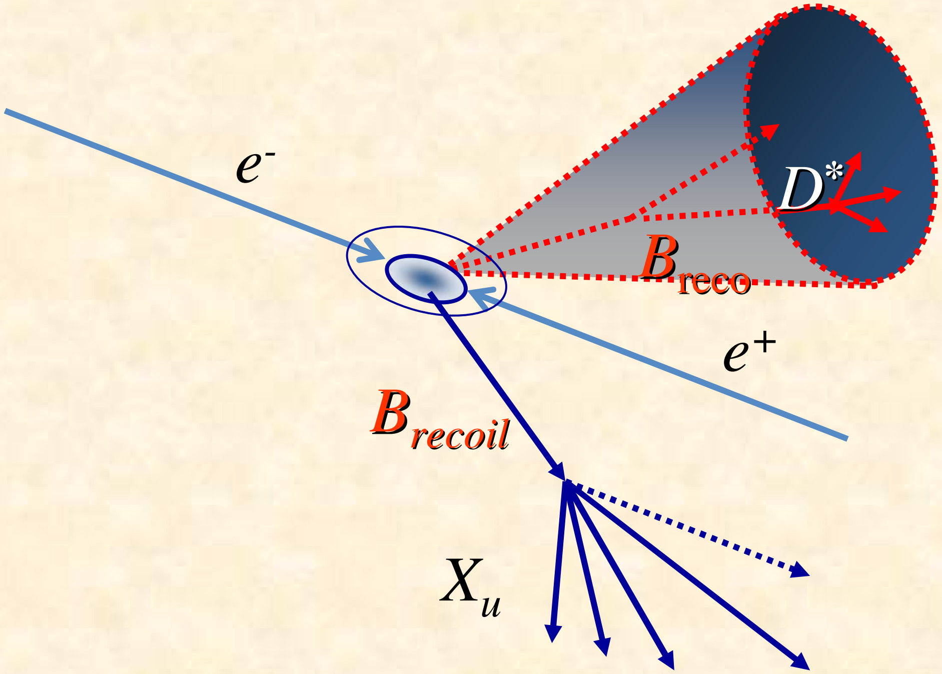
Measure the mistag fractions $w_{\rm i}$ and determine the dilutions $\mathcal{D}_{\rm i} = 1 - 2\,w_{\rm i}$

Measure Δz between B_{CP} and B_{tag} to determine the signed time difference Δt between the decays

Determine the resolution function for Δz

$$\mathcal{R}(\Delta t;\hat{a}) = \sum_{i=1}^{i=3} \frac{f_i}{\sigma_i\sqrt{2\pi}} \exp\left(-(\Delta t - \delta_i)^2\right)/2\sigma_i^2$$

Recoil physics at the $\Upsilon(4S)$



- Fully reconstruct one of the two B's in hadronic modes (for some topics, in semileptonic modes as well)
- …and do it with "high" efficiency
- The rest of the event is the other B, whose four-momentum is known

You have a single B beam, with reduced systematics in V_{cb}, V_{ub} studies, and

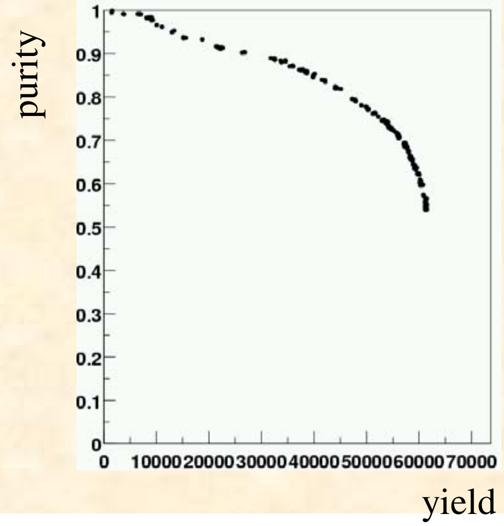
reduced backgrounds for rare decays, especially those involving neutrinos or photons

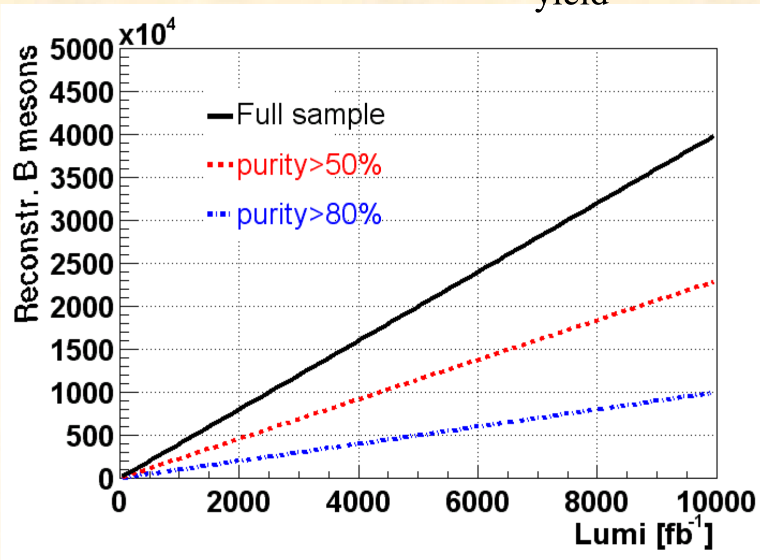
- Semileptonic decays
  - $B \to D^{(*)}\ell\nu$, $B \to (\pi,\rho)\ell\nu$, $B \to X_{c,u}\ell\nu$ …… ()
  - $B \to D^{(*)}\tau\nu$ (sensitive to New Physics)
  - $B \to D^{(*)}\tau\nu$
- Purely leptonic decays $B \to \tau\nu$, ….
- $B \to K\nu\bar{\nu}$
- $B \to$ invisible
- $B \to X_s\gamma$

The recoil method

Pros

- Subtract combinatorial background
- B_{reco} (recoil) kinematics known with small uncertainties
- B_{reco} (recoil) flavor determined
- B_{reco} (recoil) charge (B^0- B^+ separation)
- Direct m_X reconstruction
- Lepton charge – B_{reco} (recoil) flavor correlation
- Kinematic constraints to improve m_X resolution



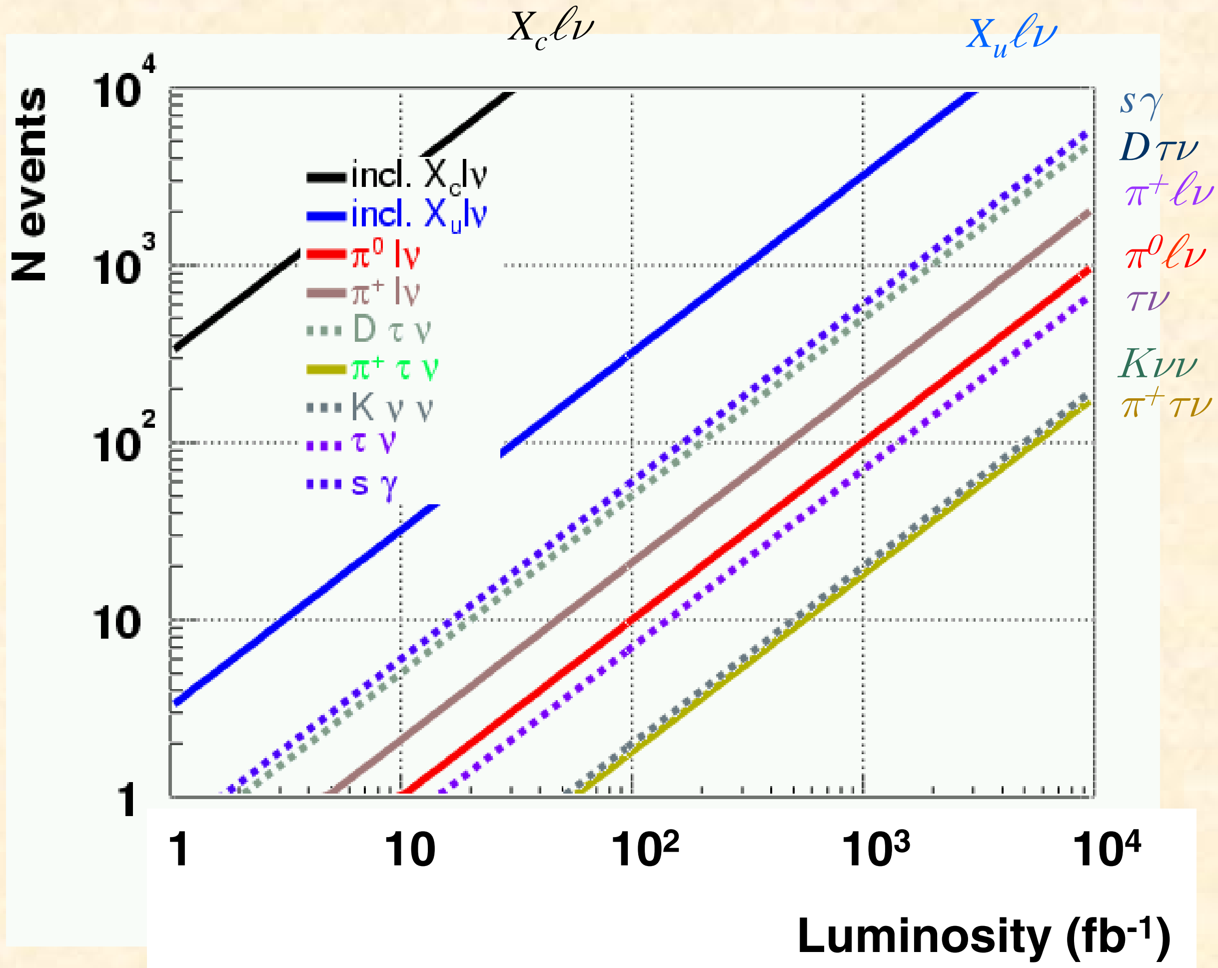


Cons

- Low efficiency- can be tuned for purity

The final efficiency is low
(~0.4% (per $B\bar{B}$ pair),
but samples are large: $4\text{x}10^6\ B/\text{ab}^{-1}$ [3 B^0:5 B^+]

Recoil sensitivity summary



Probes of new physics using the b UT

Measure sides and angles of the Unitarity Triangle to best possible precision

Improve measurements of $|V_{ub}|$ and $|V_{cb}|$ essentially independent of new physics
Super *B* Factory using the recoil technique

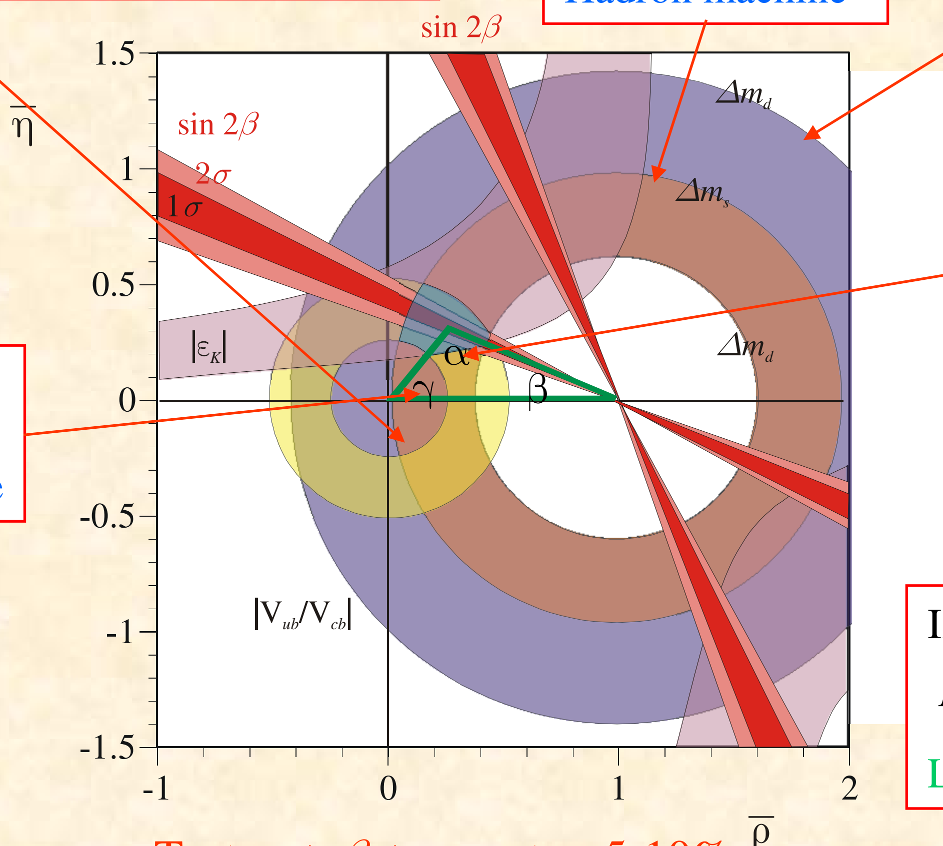
Measure Δm_s
Hadron machine

Improve measurement of Δm_d
Super *B* Factory

Measure $\sin 2\alpha_{\mathrm{eff}}$
Super *B* Factory
Hadron machine

Measure $\sin 2\alpha$
Super *B* Factory using $\pi^0\pi^0$

Measure γ
Super *B* Factory
Hadron machine



Measure $\sin 2\beta$
Super *B* Factory
Hadron machine

Improve calculations of $|V_{ub}|$, $|V_{cb}|$, $\hat{B}_K$, $\xi = \sqrt{\hat{B}_{B_s}} f_{B_s} / \sqrt{\hat{B}_{B_d}} f_{B_d}$
Lattice

Test $\alpha + \beta + \gamma = \pi$ to ~5-10%

The Unitarity Triangle – is there room for New Physics?

- The usual Unitarity Triangle (b triangle) is only one of six such relations
  - It has been the most extensively studied because it is the most sensitive to Standard Model CP violation
  - It is particularly sensitive to new physics that violates CKM unitarity
- Experimental data used in the b UT study is sensitive to $b \to d$ and $s \to d$ transitions, but not particularly to $b \to s$
- These processes are used precisely because they are the cleanest in the Standard Model, so it is difficult for New Physics to compete with them
- Thus increases in experimental precision of the b UT, which are certainly warranted, especially in view of expected improvements in the precision of lattice QCD calculations, are not the most likely to be the most direct approach to study new flavor physics

Probes of New Physics in B Meson Decays at *BABAR* (and Super*BABAR*)

- Physics beyond the Standard Model can produce measurable effects in rare B meson decays, in particular in decays involving gluonic or radiative $b \to s$ penguins
- There are different categories of probes
  - CP-violating asymmetries and the unitarity triangle construction
    - Consistency of the most precise measurements with (three generation) unitarity (sides + angles): V_{ub}, V_{cb}, $\Delta m_{d,s}$, ε, α, β, γ
    - Consistency of different CPV measurements that in the SM measure the same weak phase: *e.g.* "$\sin 2\beta$" in different modes, e.g. A_{CP} in $B^0 \to J/\psi K_S^0$ vs ϕK_S^0
  - Rare decay branching ratios and kinematic distributions
    - Inclusive (and semi-inclusive): $B \to K^*\gamma,\ \rho\gamma,\ K^{(*)}\ell\ell,\ \ell\ell,\ K\nu\bar{\nu}$........
    - Exclusive: $B \to s\gamma, s\ell\ell,$ ....
- In SUSY, measuring these loop effects is required for a full understanding of off diagonal terms in the squark coupling matrix
  - It is crucial that Standard Model theory uncertainties be brought under control
- At the current level of statistics (~10^8 B meson decays) there are tantalizing experimental results
- This talk will
  - summarize the current experimental situation in selected areas
  - discuss prospects for improvements in probing new physics with very high statistics samples which could be obtained at a Super B Factory

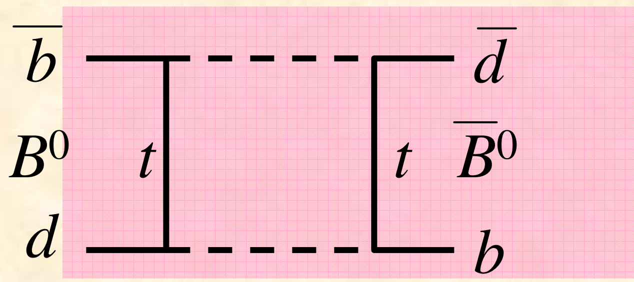
New physics should be around the corner

- Due to the unstable Higgs mass in the SM, we expect to see New Physics at the TeV scale
- The impact on low-energy observables depends on the amount of flavor/CPV, the presence of large parameters, the new particle spectrum and measurement precision
- In non-minimal flavor violation (MFV) scenarios:
  - Large (O(1)) signals are possible in time-dependent CP asymmetries: $A_{FB}(B \to (X_s, K^*)\ell^+\ell^-)$, $A_{CP}(b \to s\gamma)$, ...
  - Effects in "SM-zero" observables: can be large, producing baryon polarization in $\Lambda_b \to \Lambda\gamma$, differences in $\sin 2\beta(c\bar{c}_A K)$ and $\sin 2b(c\bar{c}_V K)$
- In MFV scenarios
  - Large effects in helicity-flip operators $f'_{L(R)}\Gamma f_{R(L)}$ at large $\tan\beta$, *e.g.*, $\mathcal{B}(B_{d,s} \to \mu^+\mu^-)$, $C_{7\gamma}$ flips sign (A_{FB})
- Searches for these effects are complementary to direct collider searches at the Tevatron, LHC or NLC, where searches are flavor-diagonal

CP violation in $B^0 \to J/\psi K_s$

mixing

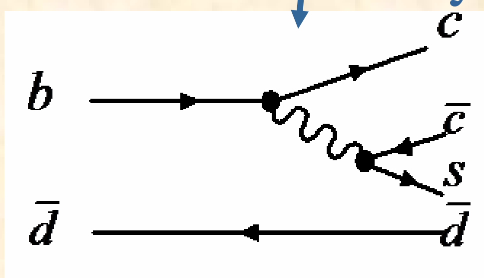
$$\lambda_{J/\psi K_s} = \frac{V_{tb}^{*} V_{td}}{V_{tb} V_{td}^{*}} \frac{V_{cd}^{*} V_{cb}}{V_{cd} V_{cb}^{*}}$$



decay

Tree(T)

$\bar{B}^0$



Penguin(P)
(has same weak phase)

Tree only

$$\lambda_{J/\psi K_s} = e^{2i\beta}$$

$$C_{J/\psi K_s} = \cos 2\beta = 0$$

$$S_{J/\psi K_s} = \sin 2\beta$$

Time-Dependent *CP* Asymmetries

Time-dependence of $B^0\overline{B}^0$ mixing in decays to **flavor eigenstates** (*CP*-conserving)

$$\boxed{A_{mixing}(\Delta t) = \frac{N(unmixed) - N(mixed)}{N(unmixed) + N(mixed)} \approx (1-2w)\cos(\Delta m_{B_d}\Delta t)}$$

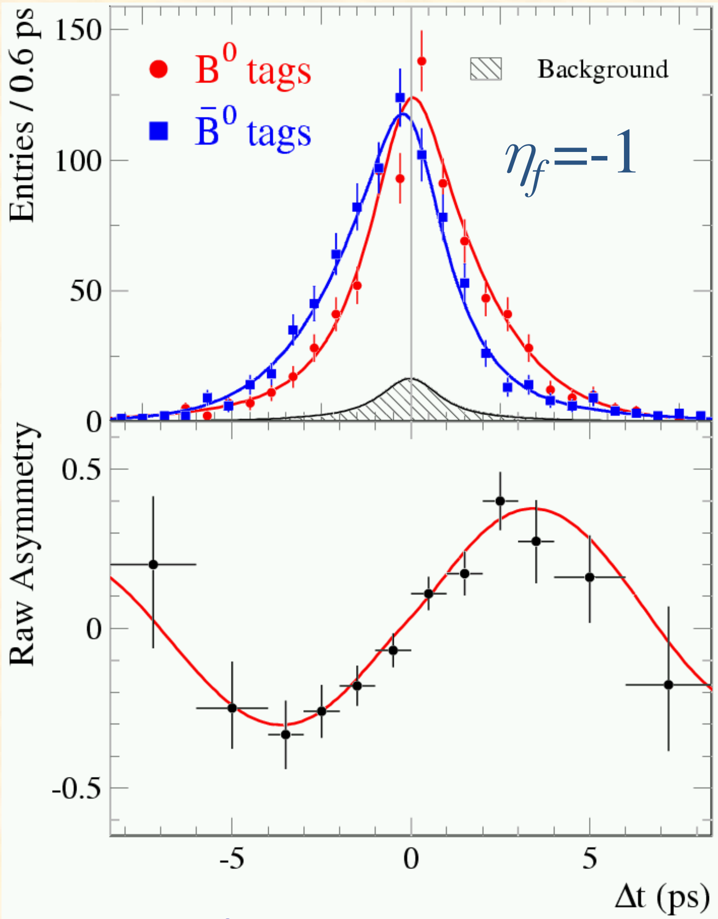
Time-dependence of *CP*-violating asymmetry in in decays to *CP* eigenstates

dilution due to wrong tags

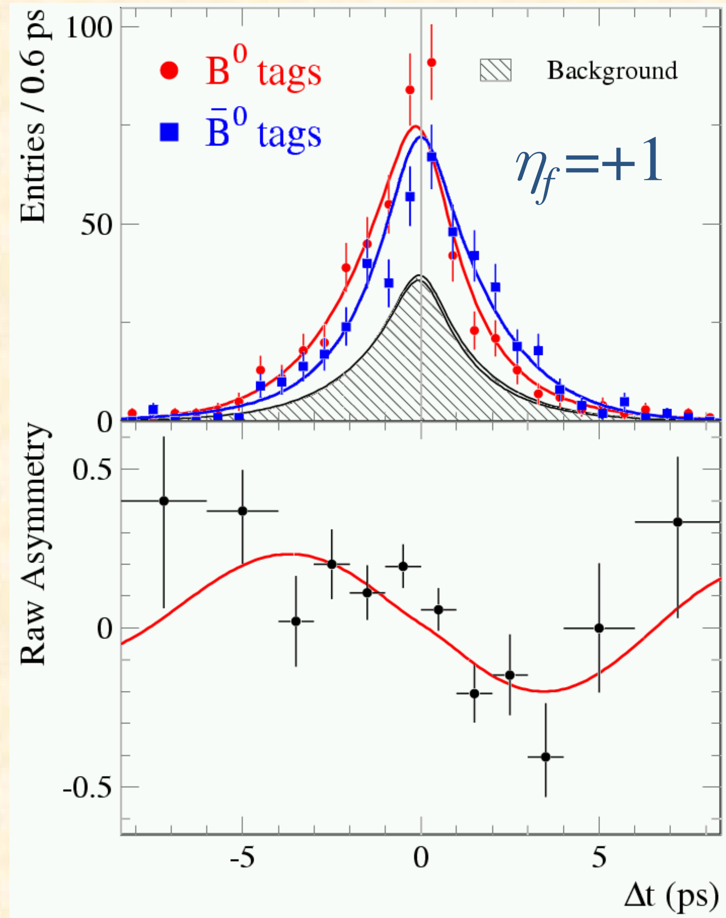
$$A_{CP}(\Delta t) = \frac{N(B_{tag}=B^0) - N(B_{tag}=\overline{B}^0)}{N(B_{tag}=B^0) + N(B_{tag}=\overline{B}^0)} \approx (1-2w)[\overbrace{S}^{\sin 2\beta}\sin(\Delta m_{B_d}\Delta t) + C\cos(\Delta m_{B_d}\Delta t)]$$

We use the high statistics B_{flav} data sample to determine the **mis-tagging probabilities** w and the parameters of the **time-resolution function**

Asymmetry for tagged decays to *CP* eigenstates



$\sin 2\beta = 0.755 \longleftarrow 0.074$



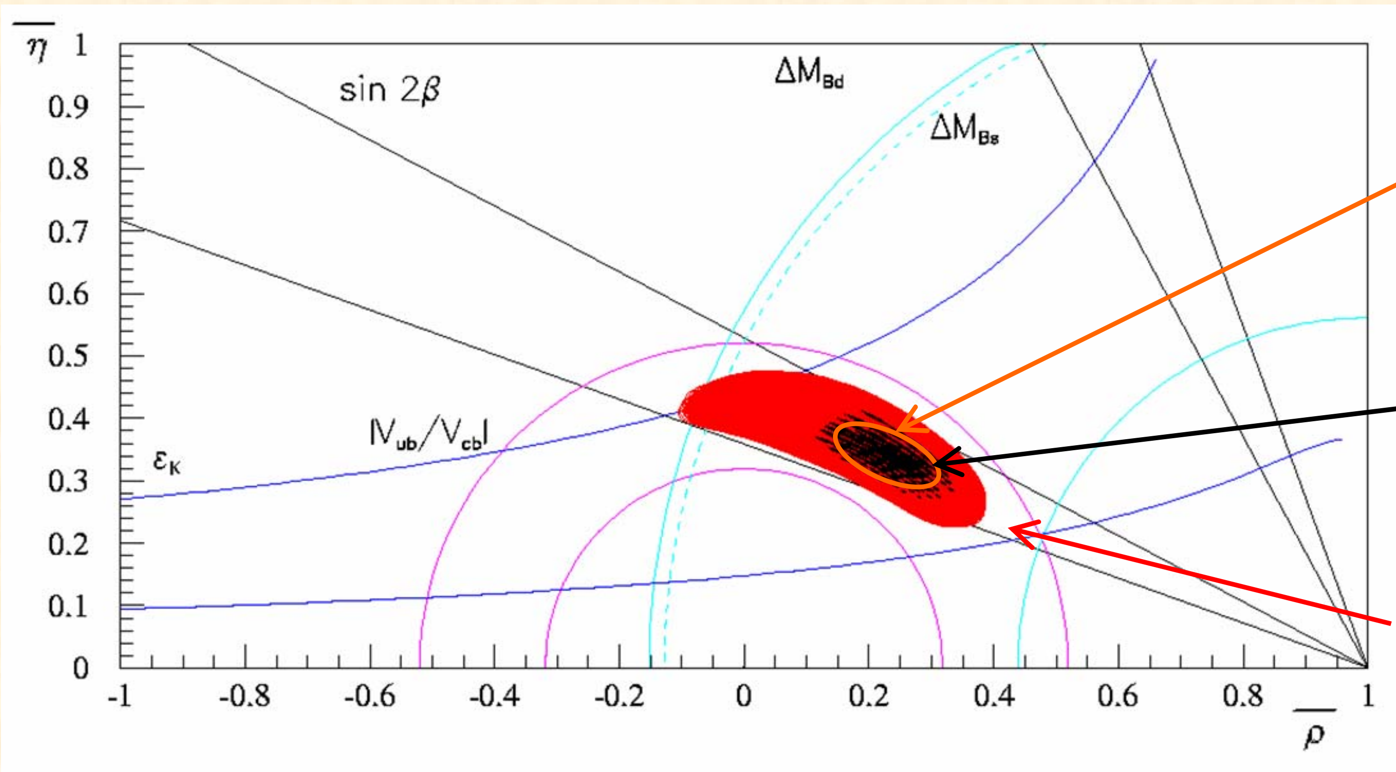
$\sin 2\beta = 0.723 \longleftarrow 0.158$

BABAR

$\sin 2\beta = 0.741 \longleftarrow 0.067\ (\text{stat}) \longleftarrow 0.033\ (\text{sys})$

Present Status of the Unitarity Triangle in a Standard Model fit

- Standard Model fit to $A, \bar{\rho}, \bar{\eta}$



Contour of individual fit

central values from individual fits to models

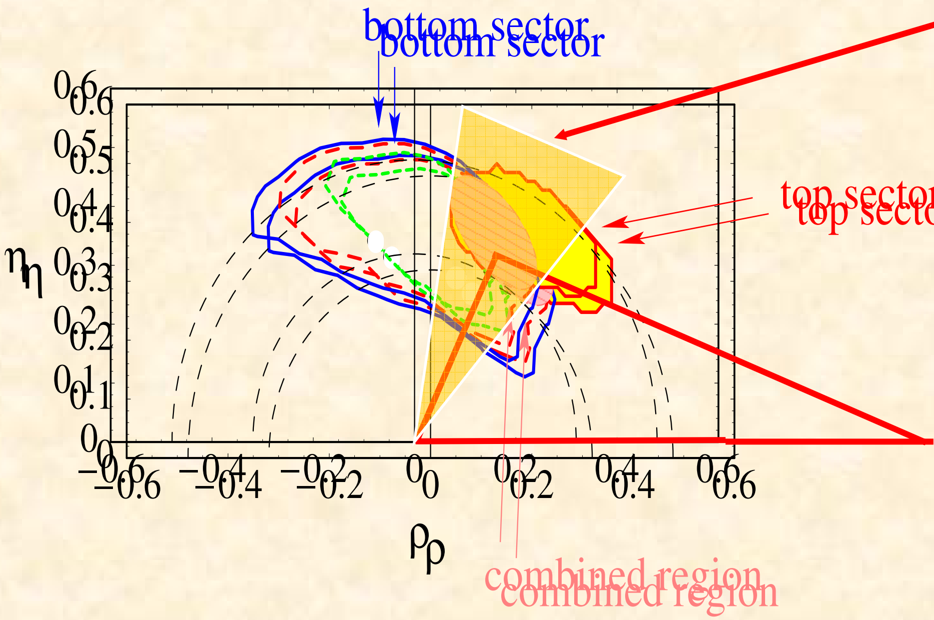
Overlay of 95% CL contours, each represents a "model"

- Range of ρ-η values resulting from fits to different models

$\boxed{0.116 \le \bar{\rho} \le 0.335 \; {}^{+0.027}_{-0.11}}$ $\boxed{0.272 \le \bar{\eta} \le 0.411 \; {}^{+0.036}_{-0.026}}$

Dubois-Felsmann, Eigen, Hitlin, Porter

BBNS Fit to $B \to \pi K$ and $B \to \pi\pi$



Constraint from $A_{CP}(B \to \rho\pi)$
[Beneke, Neubert]

CKM parameters:

$\beta = (24 \pm 2)^o$
$\gamma = (67 \pm 15)^o$
$\rho = 0.15 \pm 0.08$
$\eta = 0.36 \pm 0.09$

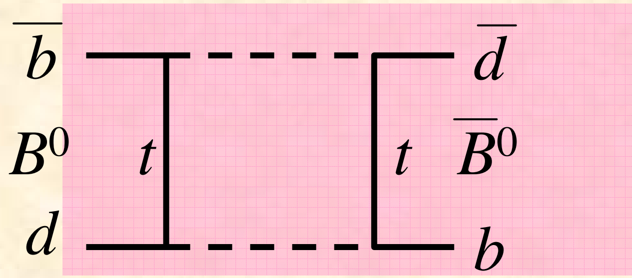
[Beneke, Buchalla, Neubert, Sachrajda]

- Establishes CP violation in the b sector ($\mathrm{Im} V_{ub} = 0$)
- Leaves room for New Physics in $b \to s$ FCNC processes!

CP violation in $B^0 \rightarrow \pi^+\pi^-$

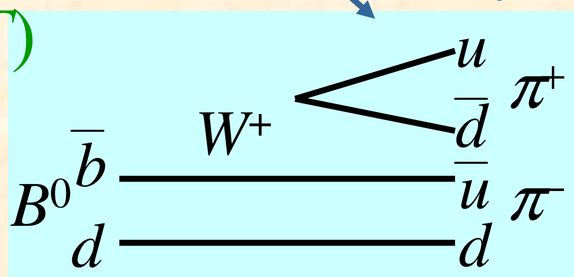
mixing

$$\lambda_{\pi\pi} = \frac{V_{tb}^{*} V_{td}}{V_{tb} V_{td}^{*}} \frac{V_{ud}^{*} V_{ub}}{V_{ud} V_{ub}^{*}}$$

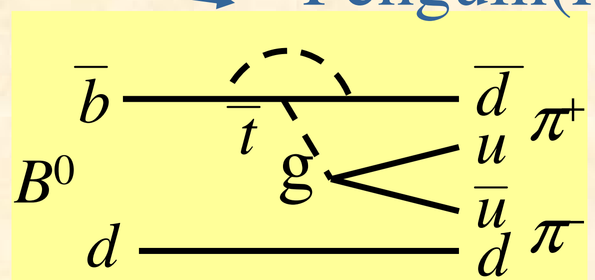


decay

Tree(T)



Penguin(P)



Tree only

$$\lambda_{\pi\pi} = e^{2i\alpha}$$

$$C_{\pi\pi} = 0$$

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

Tree + Penguin

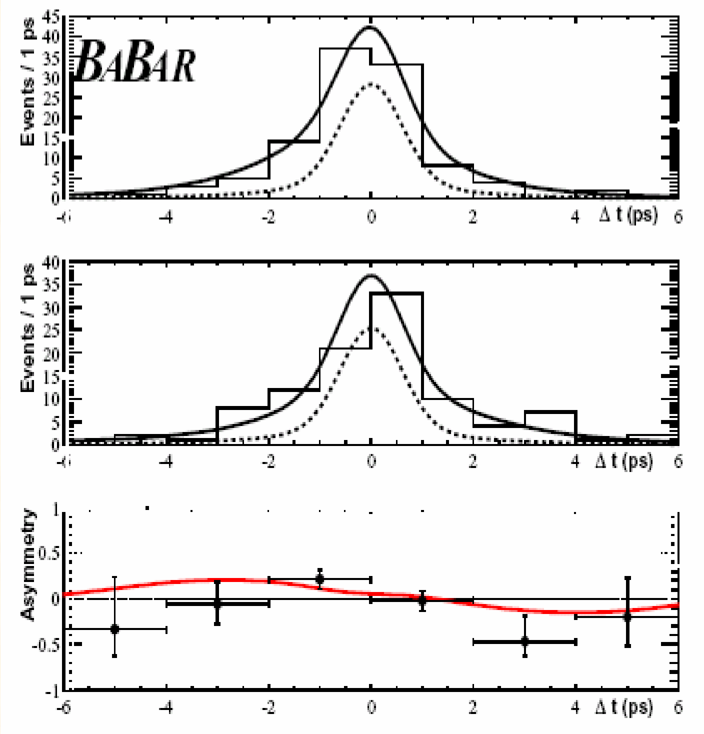
$$\lambda_{\pi\pi} = e^{2i\alpha} \frac{1+|P/T|e^{i\delta}e^{i\gamma}}{1+|P/T|e^{i\delta}e^{-i\gamma}},$$

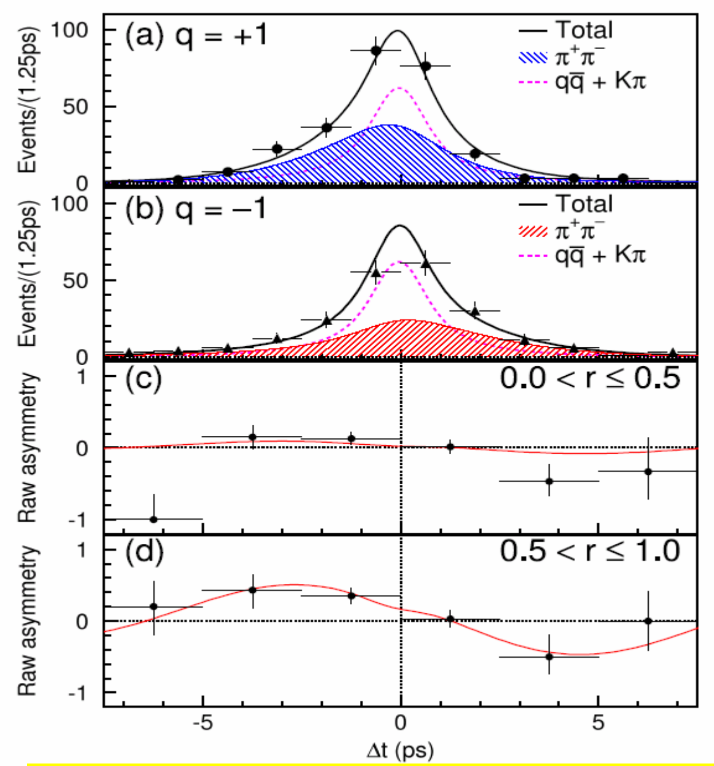
$$C_{\pi\pi} \propto -\sin(\delta) \rightarrow \textit{direct CP violation}, \quad (A_{\pi\pi} = -C_{\pi\pi})$$

$$S_{\pi\pi} = \sqrt{1-C_{\pi\pi}^2}\, \sin(2\alpha_{eff}) \rightarrow \textit{related to } \alpha \textit{ by isospin analysis}$$

CP asymmetry in $B^0 \to \pi^+\pi^-$: a discrepancy

BABAR
113 fb-1





Belle
140 fb^{-1}

$$S_{\pi\pi} = -0.40 \pm 0.22 \pm 0.03$$

$$C_{\pi\pi} = -0.19 \pm 0.19 \pm 0.05$$

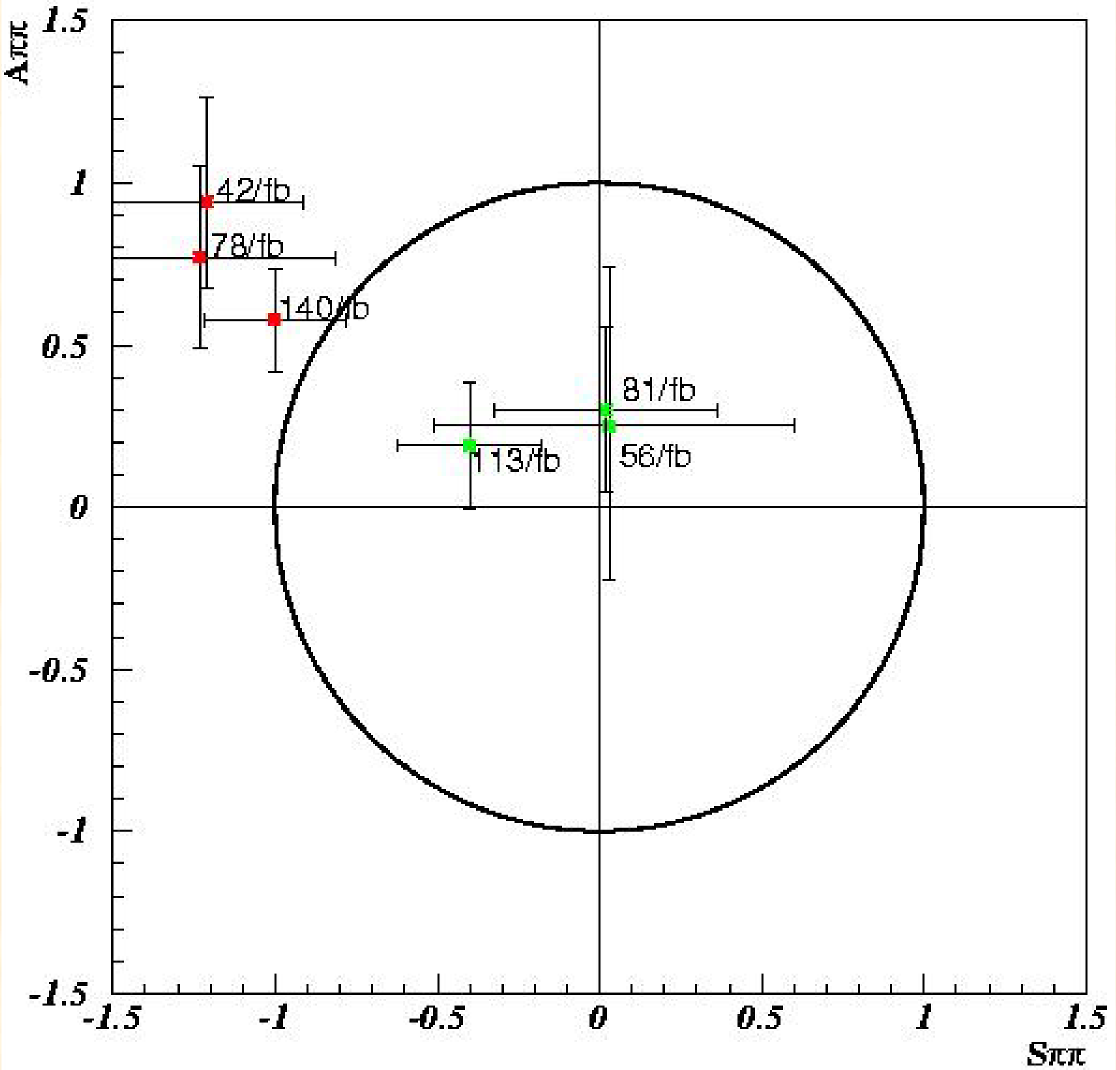
$$S_{\pi\pi} = -1.00 \pm 0.21 \pm 0.07$$

$$A_{\pi\pi} = +0.58 \pm 0.15 \pm 0.07$$

Small asymmetry seen by *BABAR*, but Belle sees a large (unphysical) asymmetry

$$\text{Physical region}: S_{\pi\pi}^2 + C_{\pi\pi}^2 \le 1!$$

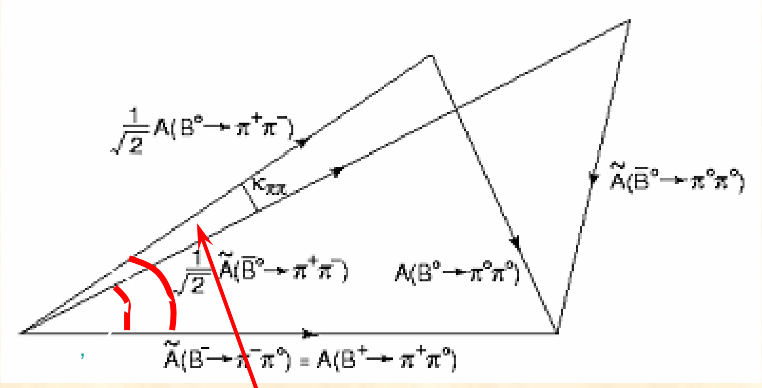
BaBar/Belle difference is still at ~2σ level



- Results seem to be converging
- Measurement is of $\sin 2\alpha_{\text{eff}}$, not $\sin 2\alpha$
- To extract a, need a measure of the penguin contribution
  - The cleanest theoretical construction is due to Gronau and London

Isolating the penguin contribution to $\sin 2\alpha$ using $B^0 \to \pi^0\pi^0$

With 10 ab^{-1}, the Gronau-London construction can place a stringent limit on penguin amplitudes

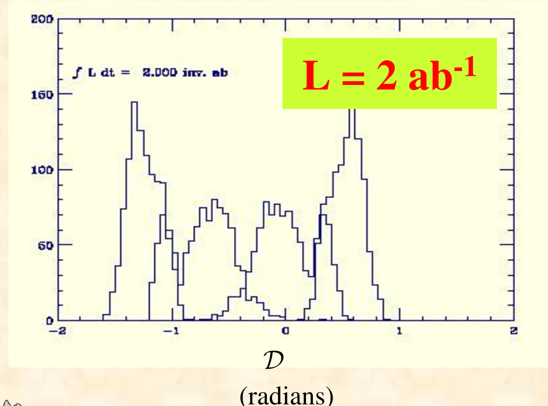


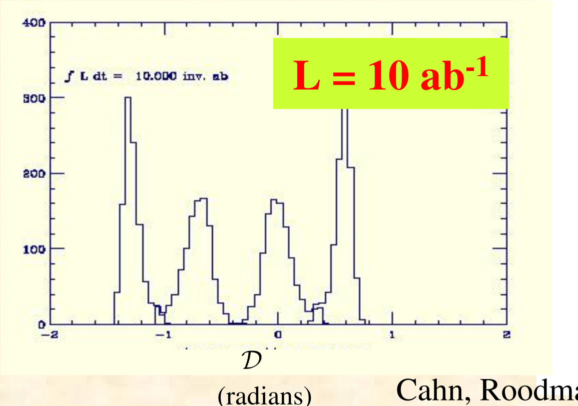
measure ϕ (ϕ') for $B(\bar{B})$ from

$$\cos\phi = \frac{\mathcal{B}(\pi^+\pi^0)+\frac{1}{2}\mathcal{B}(\pi^+\pi^-)-\mathcal{B}(\pi^0\pi^0)}{\sqrt{2\mathcal{B}(\pi^+\pi^-)\mathcal{B}(\pi^+\pi^0)}}$$

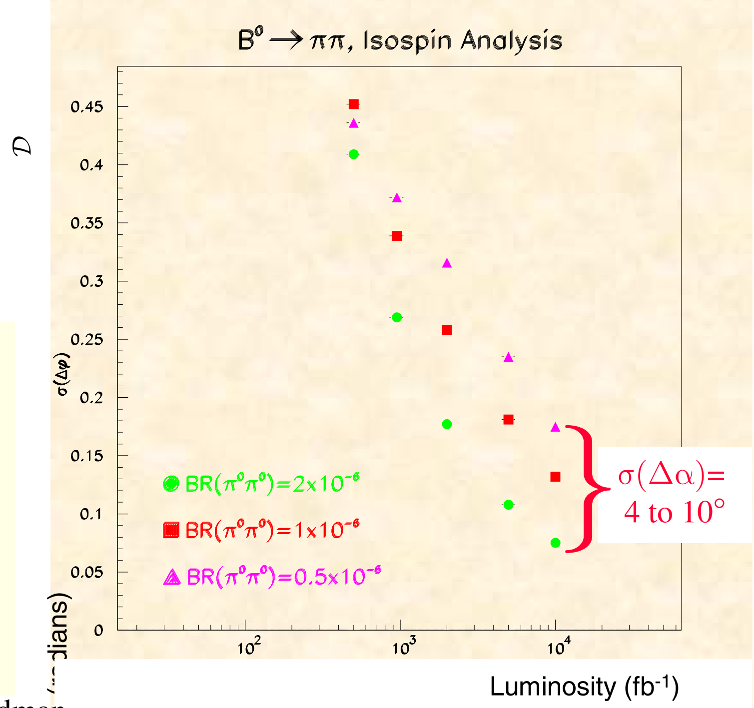
$\sin 2\alpha_{\text{eff}} = 0.02\pm0.34\pm0.05$
with $2\alpha_{\text{eff}} = 2\alpha + 2\delta$

… but there is a 4-fold ambiguity!

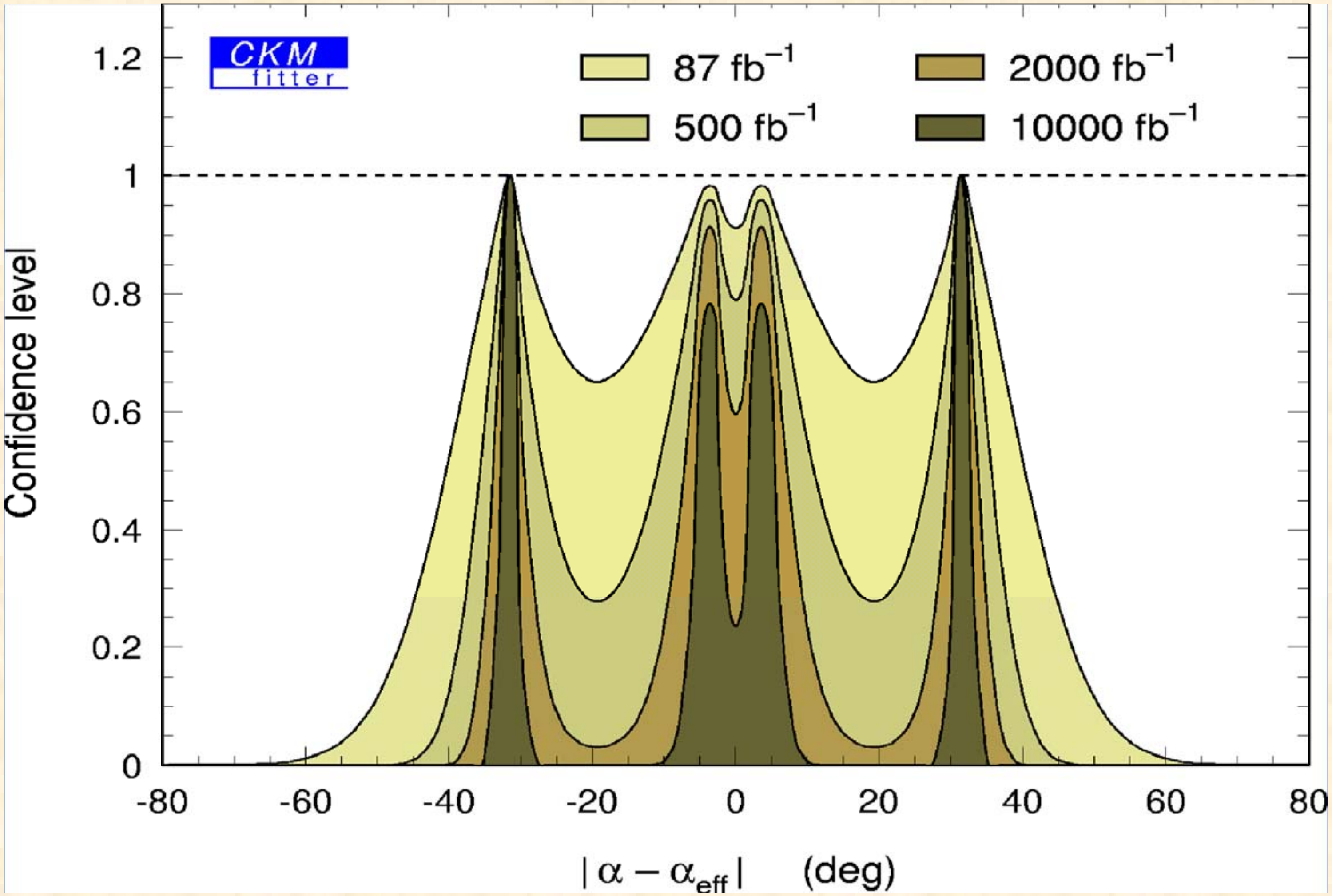




Cahn, Roodman



Another estimate of the Gronau-London construction

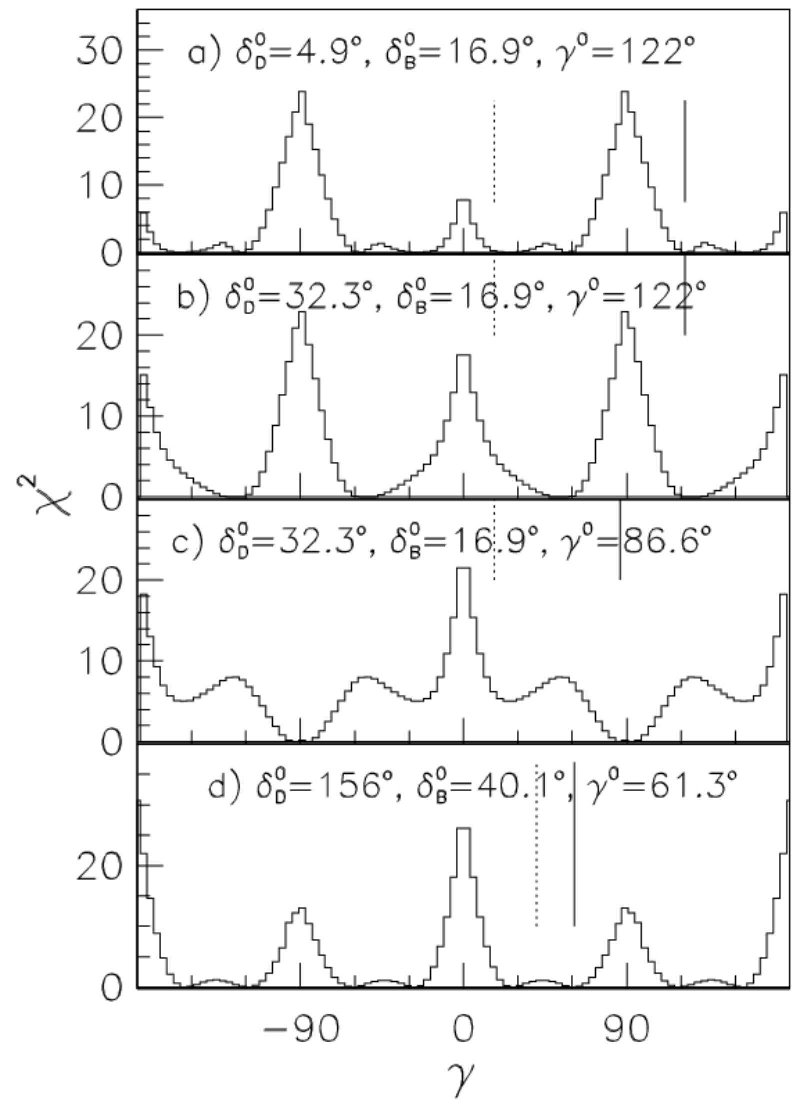


Uses current central values

Measuring γ with $B \to DK$

- Gronau-Wyler, Atwood, Dunietz and Soni method:
  Comparison of BR's for $B \to DK$ modes can allow extraction of γ
- There is an 8-fold ambiguity
- With sufficient luminosity, it is possible to resolve the ambiguity:
  with 10 ab^{-1}, it appears that a precision of $\Delta\gamma \cong 1^{o}$-2.5^{o} can be achieved

  Study was done with 600 fb^{-1}, scaled to 10 ab^{-1}



- There are many other methods for extracting γ using tagged and untagged branching ratios
- These can be done at e^+e^- and at hadron machines

Soffer

γ extraction may involve hadronic engineeering

- There are many (albeit related) clean ways to measure γ
  - Frequent improvements & new ideas
  - "Clean" measurements may not be absolutely clean
    - D^0 mixing may affect $B \rightarrow DK$.
    - Current limits on D mixing yield an effect at the few-degree level (Silva, Soffer., PRD61, 112001)
    - The effect will decrease as D mixing limits tighten, or will be incorporated into the analysis once D mixing is measured
  - Some techniques require tagging, some do not

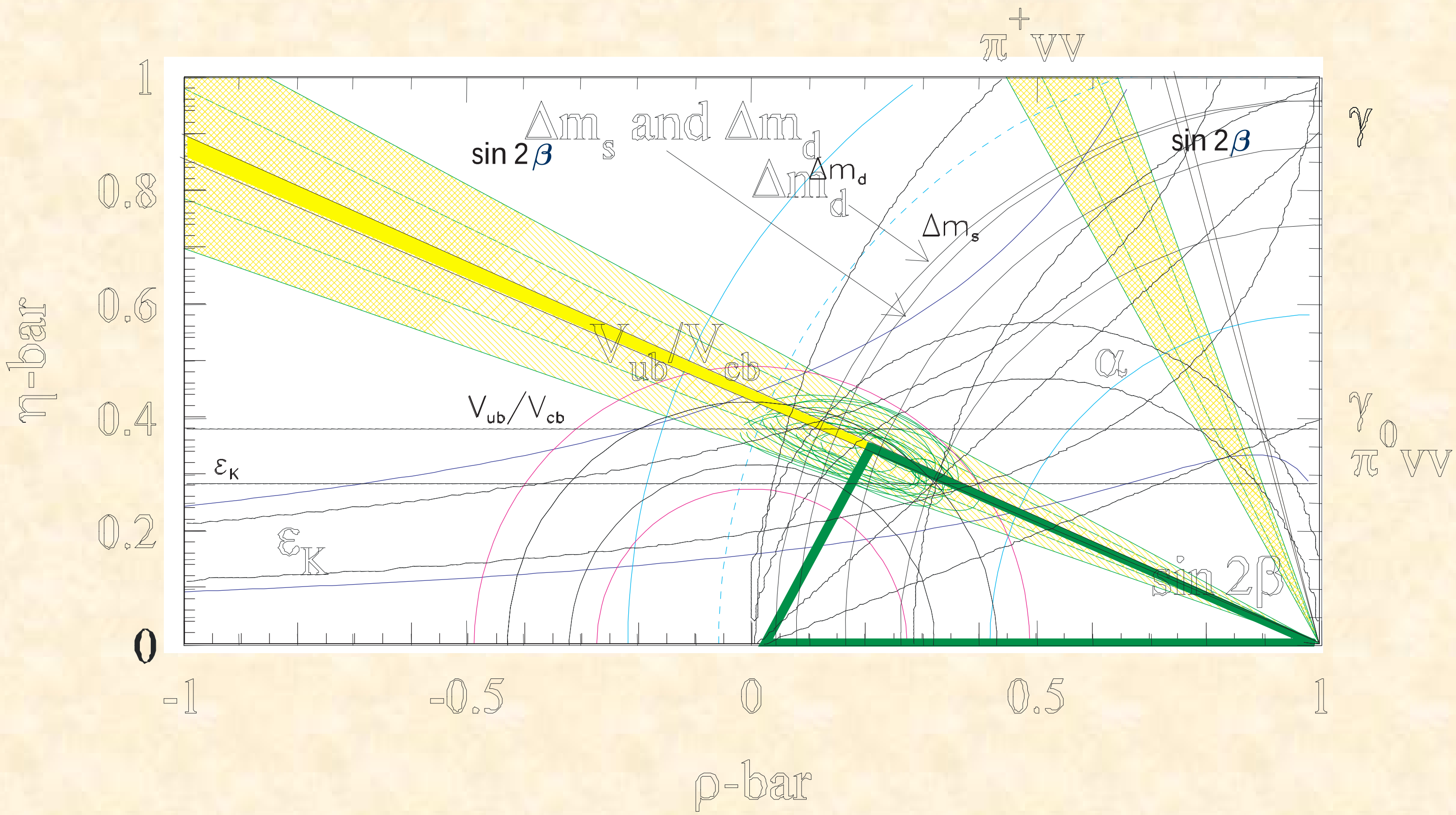
- Given foreseeable improvements in the precision of mixing, theory and lattice calculations, the target for γ precision should be ~1°
  - This may decrease by the time the machine is built, depending on developments in theory and experiment
- With 10 ab^{-1} we will
  - Measure γ to ~ 2° or less (statistical)
  - Resolve essentially all ambiguities
  - Understanding systematic errors at this level will be crucial, for both e^+e^- and hadron experiments

Lattice uncertainties (%) – C. Bernard

quantity	now	1-2 yrs. MILC0	3-5 yrs. MILC1	5-8 yrs. MILC2
f_B	15	10, $\boxed{9}$, 7, 6	9, 8, 5, $\boxed{4}$	8, 8, 4, $\boxed{3}$
$f_B\sqrt{B_B}$	15-20	12, $\boxed{11}$, 8, 7	10, 10, $\boxed{6}$, 5	9, 9, 5, $\boxed{4}$
f_{B_s}/f_B	6	5, $\boxed{3}$	3, $\boxed{2}$	3, $\boxed{1}$
ξ	7	6, $\boxed{4}$	4, $\boxed{3}$	3, $\boxed{1.5}$
$B \to \pi\ell\nu$	15	$\boxed{11}$, 10, 8, 7	9, 9, 6, $\boxed{5}$	8, 8, 4, $\boxed{3}$
$B \to D\ell\nu$	6	$\boxed{4}$, 3, 3, 2	3, 3, 2, $\boxed{1.6}$	3, 3, 2, $\boxed{1.2}$

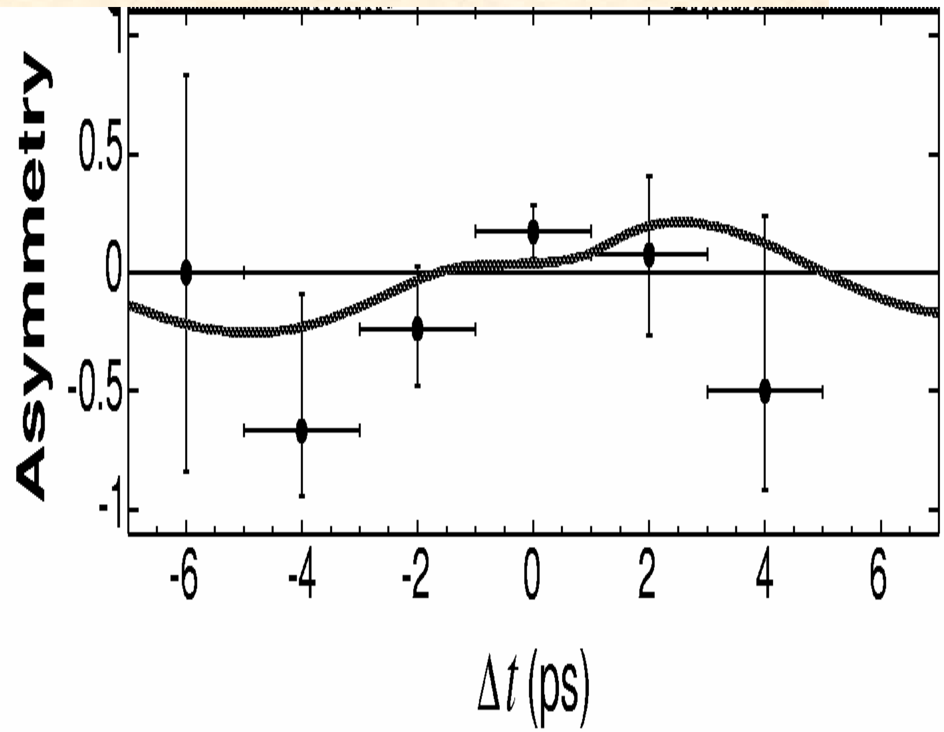
Key: red= NO SχPT; 1-loop pert. th.
purple= SχPT; 1-loop pert. th.
navy= NO SχPT; 2-loop pert. th. (or pert. th. not needed)
blue= SχPT; 2-loop pert. th. (or pert. th. not needed)

A projection to 2010 by the CKM Fitter group

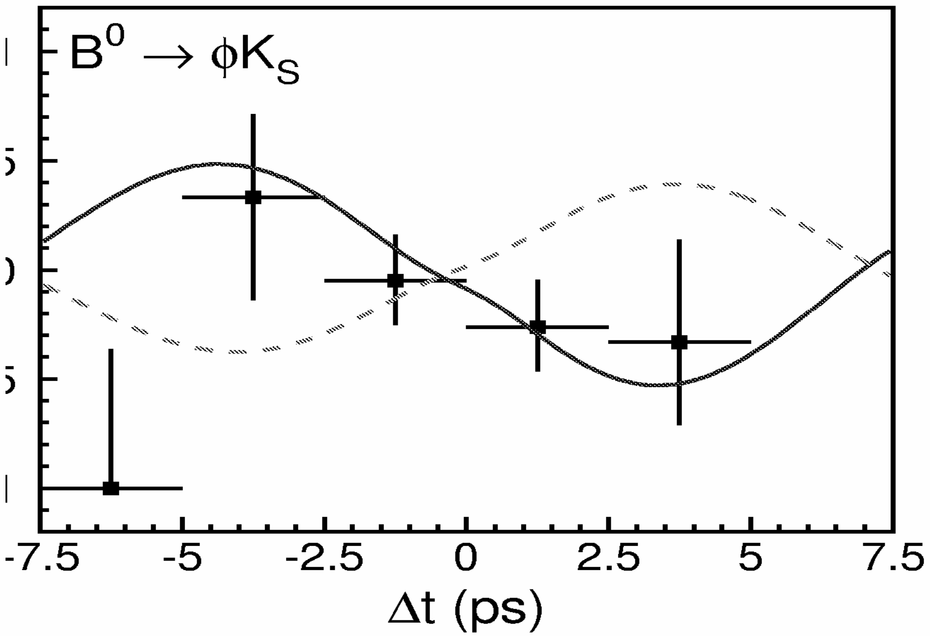


Another disagreement

BABAR



Belle



$\sin 2\beta(\varphi K_S) = +0.45 \pm 0.43 \pm 0.07$

$\sin 2\beta(\varphi K_S) = -0.96 \pm 0.50$

ϕK_s

Strong agreement on phase in $B \to \psi K_S$:

$$\sin 2\beta_{\psi K} = \begin{cases} 0.741 \pm 0.075 & (BABAR) \\ 0.733 \pm 0.064 & (\text{Belle}) \end{cases} \implies 0.736 \pm 0.049 \quad (\text{average})$$

"Old" published data showed discrepancy between $\beta_{\psi K}$ and $\beta_{\phi K}$, but not convincing:

$$\sin 2\beta_{\phi K} = \begin{cases} -0.18 \pm 0.51 & (BABAR) \\ -0.73 \pm 0.68 & (\text{Belle}) \end{cases}$$

LP03 results are more complicated:

$$\sin 2\beta_{\phi K} = \begin{cases} 0.45 \pm 0.44 & (BABAR) \\ -0.96 \pm 0.51 & (\text{Belle}) \end{cases}$$

Belle data shows a 3.3σ discrepancy, but Babar within 1σ. Data disagree at 2.7σ.

But other $b \to \bar{s}ss$ transitions also give low $S_{\phi K}$, including $B \to K^+K^-K_S$ and $B \to \eta' K_S$. For all $b \to \bar{s}ss$ processes,

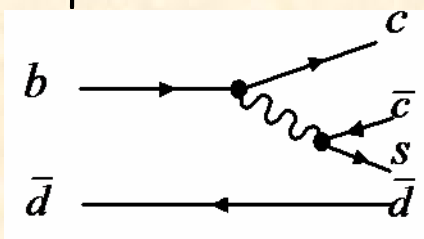
$$S_{\phi K} = 0.24 \pm 0.15 \quad \Leftarrow \ 3.1\sigma \text{ below } b \to c\bar{s}s \text{ modes}$$

Probes of new physics

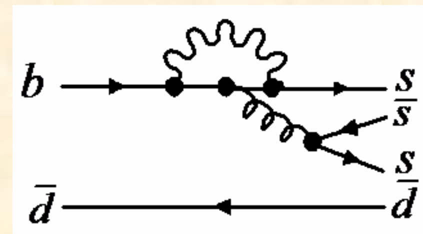
1) Measure the CP asymmetry in modes other than $B^0 \to J/\psi K_S^0$ that measure $\sin 2\beta$ in the Standard Model

- Precision of benchmark $\sin 2\beta$ in $B^0 \to J/\psi K_S^0$ can improve to the ~1% level
- Expect the same value for "$\sin 2\beta$" in $b \to c\bar{c}s$, $b \to c\bar{c}d$, $b \to s\bar{s}s$, but different SUSY models can produce different asymmetries
- A great deal of luminosity is required to make these measurements to meaningful precision

$B^0 \to J/\psi K_S^0$

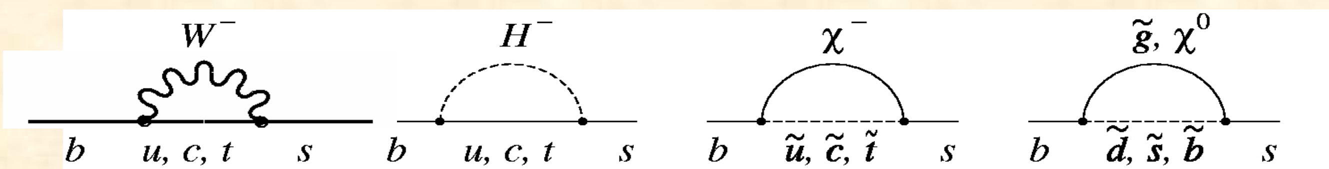


$B^0 \to \phi K_S^0$



$$\lambda_{tree} = \frac{q}{p}\frac{\bar{A}}{A} = \eta \frac{V_{tb}^* V_{td}}{V_{tb} V_{td}^*} \frac{V_{cb} V_{cs}^*}{V_{cb}^* V_{cs}} = (-1) e^{-2i\beta}$$

$$\lambda_{penguin} = \frac{q}{p}\frac{\bar{A}}{A} = \eta \frac{V_{tb}^* V_{td}}{V_{tb} V_{td}^*} \frac{V_{tb} V_{ts}^*}{V_{tb}^* V_{ts}} = (-1) e^{-2i\beta}$$



$$\lambda = e^{i(2\beta + \phi^{\mathrm{SUSY}})} \frac{|\bar{A}|}{|A|} \quad \Rightarrow S_{\phi K} = \sin(2\beta + \phi^{\mathrm{SUSY}})$$

A selection of papers on $A_{CP}(B \rightarrow \phi K_s)$

- T. Moroi, Phys. Lett. B **493**, 366 (2000) [arXiv:hep-ph/0007328].
- E. Lunghi and D. Wyler, Phys. Lett. B **521**, 320 (2001) [arXiv:hep-ph/0109149].
- D. Chang, A. Masiero and H. Murayama, arXiv:hep-ph/0205111.
- M. B. Causse, arXiv:hep-ph/0207070.

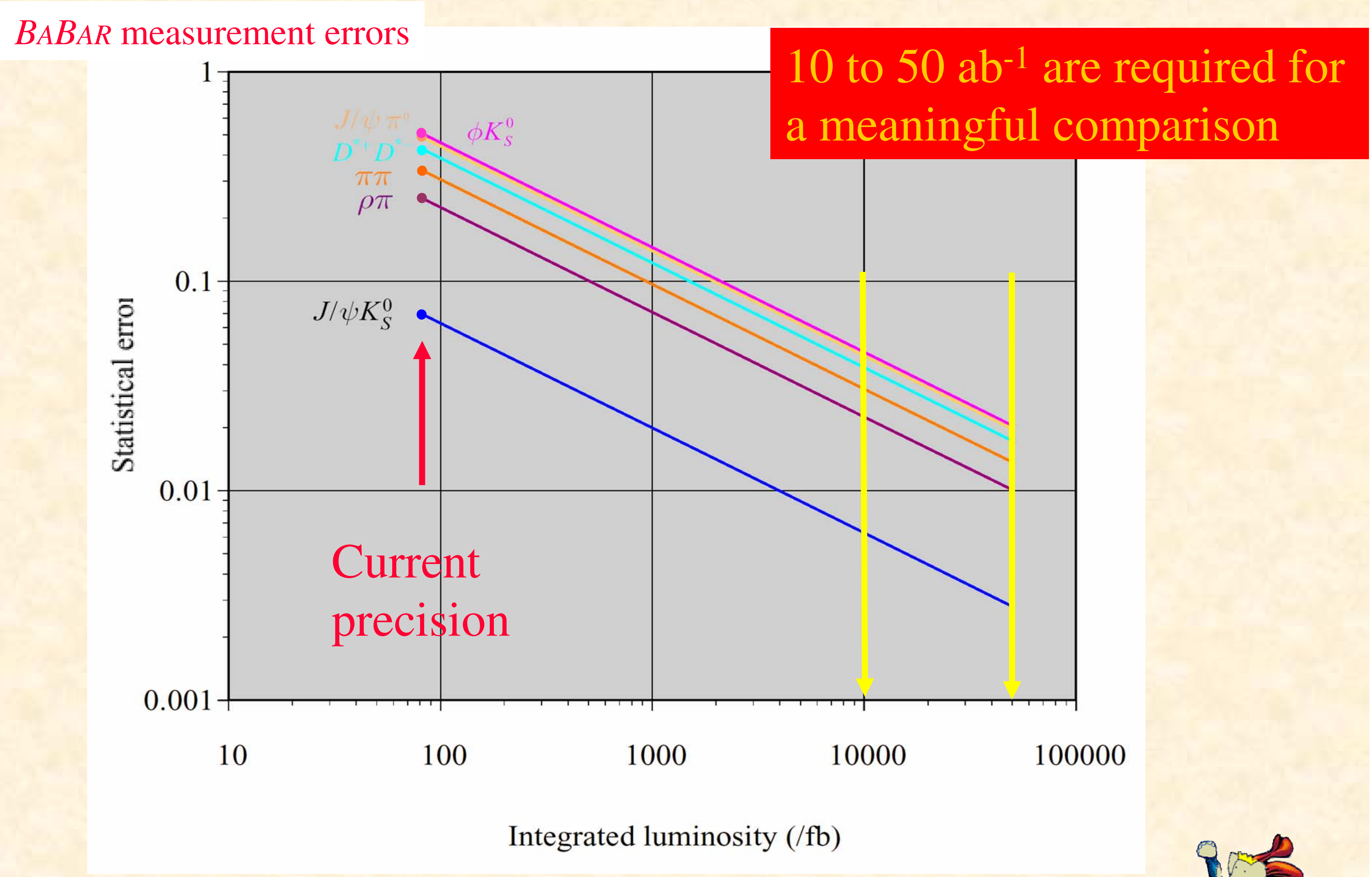
$\Longleftarrow$ Babar/Belle $S_{\phi K}$ results $\Longrightarrow$

- G. Hiller, arXiv:hep-ph/0207356.
- A. Datta, Phys. Rev. D **66**, 071702 (2002) [arXiv:hep-ph/0208016].
- M. Ciuchini and L. Silvestrini, arXiv:hep-ph/0208087.
- M. Raidal, Phys. Rev. Lett. **89**, 231803 (2002) [arXiv:hep-ph/0208091].
- B. Dutta, C. S. Kim and S. Oh, arXiv:hep-ph/0208226.
- G. L. Kane, P. Ko, H. b. Wang, C. Kolda, J. H. Park and L. T. Wang, arXiv:hep-ph/0212092 and Phys. Rev. Lett. **90**, 141803 (2003) [arXiv:hep-ph/0304239].
- R. Harnik, D. T. Larson, H. Murayama and A. Pierce, arXiv:hep-ph/0212180.
- M. Ciuchini, E. Franco, A. Masiero and L. Silvestrini, Phys. Rev. D **67**, 075016 (2003) [arXiv:hep-ph/0212397].
- S. Baek, Phys. Rev. D **67**, 096004 (2003) [arXiv:hep-ph/0301269].
- J. Hisano and Y. Shimizu, Phys. Lett. B **565**, 183 (2003) [arXiv:hep-ph/0303071].
- K. Agashe and C. D. Carone, Phys. Rev. D **68**, 035017 (2003) [arXiv:hep-ph/0304229].
- D. Chakraverty, E. Gabrielli, K. Huitu and S. Khalil, arXiv:hep-ph/0306076.
- T. Goto, Y. Okada, Y. Shimizu, T. Shindou and M. Tanaka, arXiv:hep-ph/0306093.

What level of precision is required ?

- Statistical/systematic error on $\sin 2\beta$ from $B^0 \to J/\psi K_S^0$ will improve to somewhat beyond the 1% level. This is more than adequate
- SUSY effects on $\sin 2\beta$ in other modes can be quite large, tens of percent of the CKM value
- With what precision must one measure $\sin 2\beta$ in other, more difficult decay modes in order to establish an effect?
- An example:
  - Assume $\sin 2\beta\,(J/\psi K_S^0) = 0.75$ (its current value), but the error is reduced to 1%, σ = 0.0075,
  - $\sin 2\beta\,(\varphi K_S^0) = 0.60$, *i.e.*, the SUSY contribution to $B^0 \to \varphi K_S^0$ is 20%
  - For a 5 sigma effect: $\Delta \sin 2\beta$ = 0.15/5 = 0.03, a 5% measurement
  - This requires a data sample of the size provided by a 10^{36} asymmetric B Factory

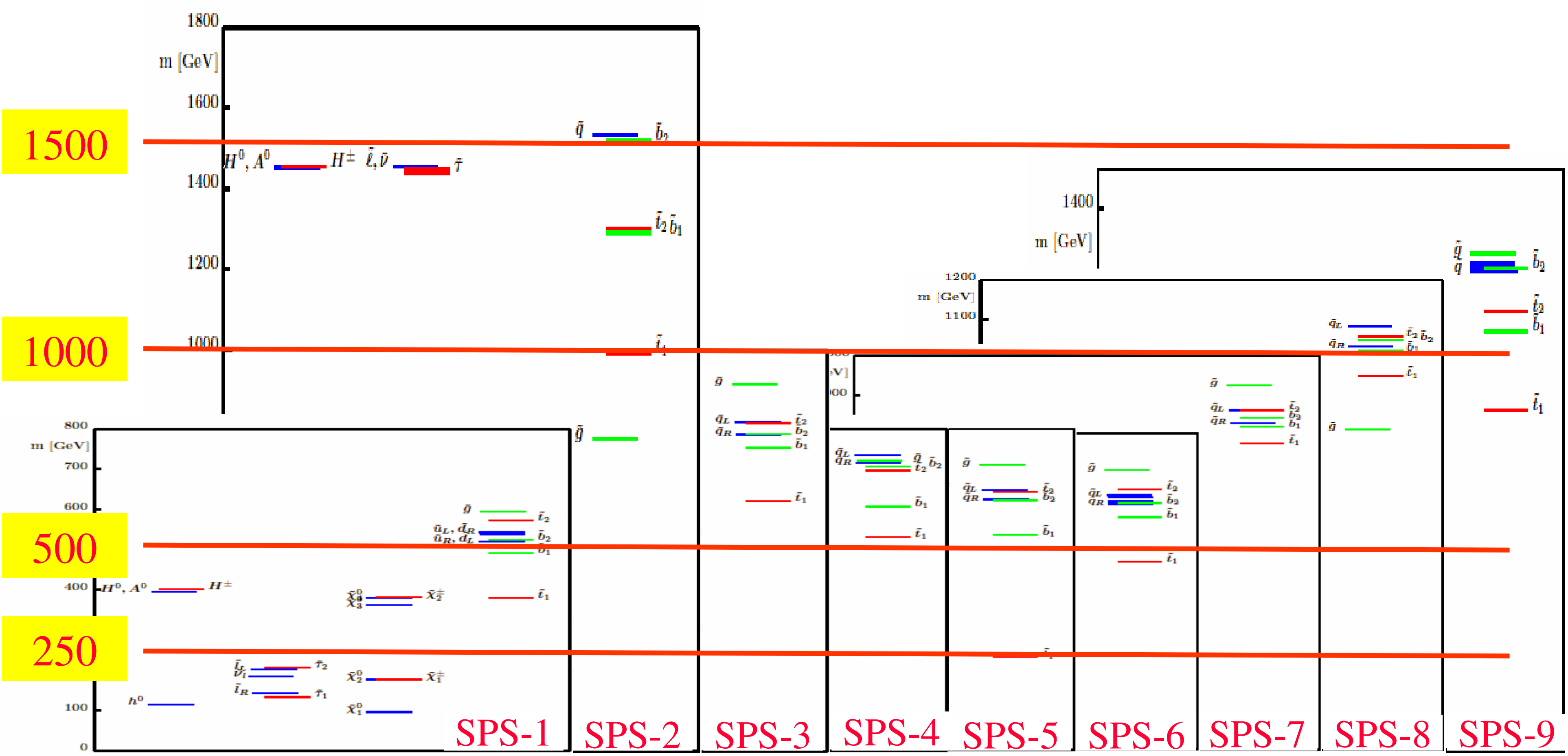
Extrapolated statistical errors on *CP* asymmetries



New CP Violating effects must be there

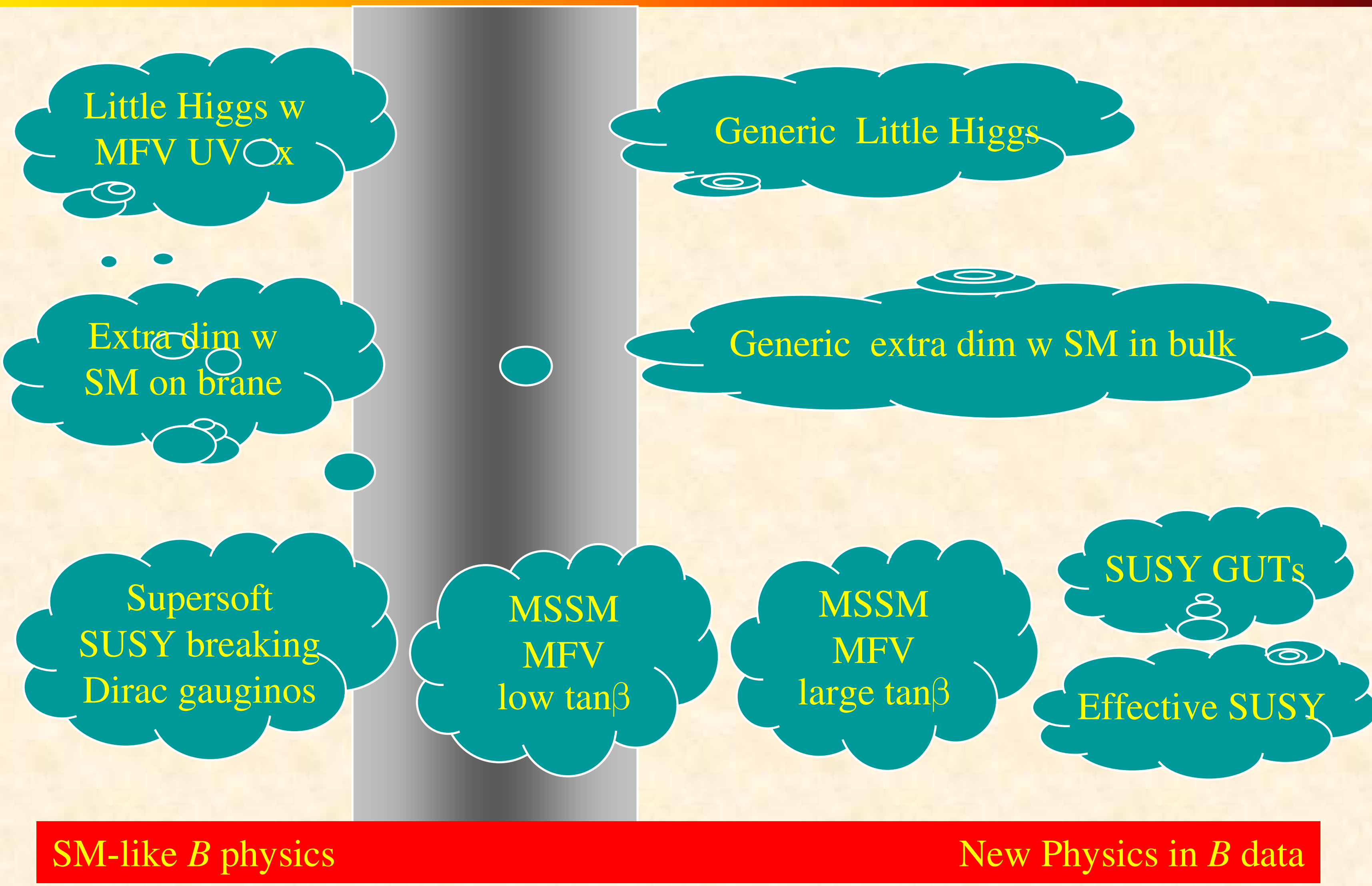
- CP effects in the flavor sector that are not accounted for by the CKM phase must exist
  - If they do not exist, SUSY and other models constructed with the same motivation will be ruled out
- The sensitivity required to see these effects can be reached
  - It is possible, though not likely, that SUSY could be discovered through loop effects before there is explicit production of new particles at LHC
- Assume that evidence for SUSY is found at the LHC or NLC
  - What will we actually know?
    - The masses of some of the SUSY partners: gluino, squark, ……..
    - Something about coupling constants
    - Perhaps the identity of the LSP
    - Even if the first evidence for SUSY comes from LHC, it will be important to study CPV in flavor physics at the scale of 10^{10} to 10^{11} B decays

SUSY mass spectra for the 9 Snowmass points & slopes



Ghodbane and Martyn

Many SM extensions yield measurable effects in B physics



after G. Hiller

Constraints on SUSY from existing measurements

- In order to obey the constraints from K decay:
  - Indirect CPV in $K \to \pi\pi$ and $K \to \pi \ell \nu_\ell$ decays: $|\varepsilon|$ = (2.28 $\pm$ 0.02) x 10^{-3}
  - Direct CPV in $K \to \pi\pi$ decays: Re$|\varepsilon'/\varepsilon|$=(1.66 $\pm$ 0.16) x 10^{-3}
  - it is necessary to invoke one or more of the following:
    - Heavy squarks: $\tilde{m} \gg 100\ \mathrm{GeV}$
    - Universality: $\Delta m^2_{\tilde{s}\tilde{d}} \ll \tilde{m}^2$
    - Alignment: $\left|K^d_{12}\right| \ll 1$
    - Approximate CP: CPV phases are small
  - All viable models of SUSY-breaking use one or more of these mechanisms
  - Two other measurements:
    - A_{CP} in $B^0 \to J/\psi K^0_S$ decay: Im $\lambda_{\psi K} = 0.734 \pm 0.054$
    - Limits on EDM's (through T violation and CPT)

    impose serious additional constraints
  - For example, A_{CP} effectively kills Approximate CP models
  - EDM limits imply that the source of CPV beyond the Standard Model in models with minimal flavor violation is Yukawa couplings, which can be flavor dependent

Effects of SUSY breaking on CPV in flavor physics

- Specific models produce specific CPV patterns
- There are a variety of models of SUSY breaking on the market
- Many of these models generate specific, calculable CP-violating effects in hadronic and rare B decays
- Other extensions (extra dimensions, Little Higgs,….) have the same sorts of effects, although they often have distinguishable patterns
- In order to exploit CP violation as a tool to search for physics beyond the Standard Model we must do two things:
  - Achieve the highest meaningful precision on CPV (α, β, γ) measurements of the B unitarity triangle
    - This requires several x 10 ab^{-1}
  - Measure kinematic distributions and CP-violating (and sometimes CP-conserving) asymmetries in very rare decays with branching fractions of $<10^{-5}$, both inclusive and exclusive
  - These are decay modes such as $B^0 \to K\ell^+\ell^-$ where we have at present only a handful of events

Many *CP* asymmetries can be changed by SUSY

TABLE II. CP phases for B decays. $\phi^D_{\rm SM}$ denotes the decay phase in the SM; for each channel, when two amplitudes with different weak phases are present, one is given in the first row, the other in the last one, and the ratio of the two in the $r_{\rm SM}$ column. $\phi^D_{\rm SUSY}$ denotes the phase of the SUSY amplitude, and the ratio of the SUSY to SM contributions is given in the r_{250} and r_{500} columns for the corresponding SUSY masses.

Incl.	Excl.	$\phi^D_{\rm SM}$	$r_{\rm SM}$	$\phi^D_{\rm SUSY}$	r_{250}	r_{500}
$b \to c\bar{c}s$	$B \to J/\psi K_S$	0	–	ϕ_{23}	$0.03 - 0.1$	$0.008 - 0.04$
$b \to s\bar{s}s$	$B \to \phi K_S$	0	–	ϕ_{23}	$0.4 - 0.7$	$0.09 - 0.2$
$b \to u\bar{u}s$		Tree γ				
	$B \to \pi^0 K_S$		$0.009 - 0.08$	ϕ_{23}	$0.4 - 0.7$	$0.09 - 0.2$
$b \to d\bar{d}s$		Penguin 0				
$b \to c\bar{u}d$		0				
	$B \to D^0_{CP}\pi^0$		0.02	–	–	–
$b \to u\bar{c}d$		γ				
	$B \to D^+D^-$	Tree 0	$0.03 - 0.3$		$0.007 - 0.02$	$0.002 - 0.006$
$b \to c\bar{c}d$				ϕ_{13}		
	$B \to J/\psi\pi^0$	Penguin β	$0.04 - 0.3$		$0.007 - 0.03$	$0.002 - 0.008$
	$B \to \phi\pi^0$	Penguin β	–		$0.06 - 0.1$	$0.01 - 0.03$
$b \to s\bar{s}d$				ϕ_{13}		
	$B \to K^0\overline{K}^0$	u-Penguin γ	$0 - 0.07$		$0.08 - 0.2$	$0.02 - 0.06$
$b \to u\bar{u}d$	$B \to \pi^+\pi^-$	Tree γ	$0.09 - 0.9$	ϕ_{13}	$0.02 - 0.8$	$0.005 - 0.2$
$b \to d\bar{d}d$	$B \to \pi^0\pi^0$	Penguin β	$0.6 - 6$	ϕ_{13}	$0.06 - 0.4$	$0.02 - 0.1$
	$B \to K^+K^-$	Tree γ	$0.2 - 0.4$		$0.04 - 0.1$	$0.01 - 0.03$
$b\bar{d} \to q\bar{q}$				ϕ_{13}		
	$B \to D^0\overline{D}^0$	Penguin β	only β		$0.01 - 0.03$	$0.003 - 0.006$

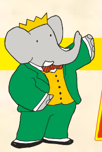
Ciuchini, Franco, Martinelli, Masiero, & Silvestrini

Pattern of deviations from SM predictions

- Minimal (MFV) or non-minimal flavor violation (non-MFV):
  - MFV – flavor/CP violation as in Standard Model (CKM), in Yukawa couplings
    - 2HDM, MSSM w/ flavor blind SUSY breaking
  - non-MFV
    - 2HDM with tree level FCNC, 4th generation, VLdQ (tree level FCNC to the Z), generic MSSM w/o R-parity

	Unitarity triangle			Rare decays		
	B_d unitarity	ε	Δm_s	ΔA_{CP} $B \to \phi K_s$	$B \to M_s \gamma$ indirect CP	$b \to s\gamma$ direct CP
mSUGRA	closed	small	small	small	small	small
SU(5) SUSY GUT + ν_R (degenerate)	closed	large	small	small	small	small
SU(5) SUSY GUT + ν_R (non-degenerate)	closed	small	large	large	large	small
U(2) Flavor symmetry	large	large	large	large	large	sizable

Okada – SLAC 10^{36} Workshop



Squark mass matrix (d sector) and current constraints

CP-conserving processes

$(\delta^d_{12})_{LL} < 4\times 10^{-2}$

$\sqrt{\mathrm{Im}\,(\delta^d_{12})^2_{LL}} < 3\times 10^{-3}$	$\sqrt{\mathrm{Im}\,(\delta^d_{12})^2_{LR}} < 3\times 10^{-4}$	from ϵ_K
$\left\lvert\mathrm{Im}\,(\delta^d_{12})_{LL}\right\rvert < 0.5$	$\left\lvert\mathrm{Im}\,(\delta^d_{12})_{LR}\right\rvert < 2\times 10^{-5}$	ϵ'_K
	$\left\lvert\mathrm{Im}\,(\delta^d_{12})_{LR}\right\rvert < 10^{-6}$	d_n

$$
\begin{pmatrix}
m^2_{\tilde d_L} & m_d(A_d-\mu\tan\beta) & (\Delta^d_{12})_{LL} & (\Delta^d_{12})_{LR} & (\Delta^d_{13})_{LL} & (\Delta^d_{13})_{LR} \\
 & m^2_{\tilde d_R} & (\Delta^d_{12})_{RL} & (\Delta^d_{12})_{RR} & (\Delta^d_{13})_{RL} & (\Delta^d_{13})_{RR} \\
 & & m^2_{\tilde s_L} & m_s(A_s-\mu\tan\beta) & (\Delta^d_{23})_{LL} & (\Delta^d_{23})_{LR} \\
 & & & m^2_{\tilde s_R} & (\Delta^d_{23})_{RL} & (\Delta^d_{23})_{RR} \\
 & & & & m^2_{\tilde b_L} & m_b(A_b-\mu\tan\beta) \\
 & & & & & m^2_{\tilde b_R}
\end{pmatrix}
$$

LHC

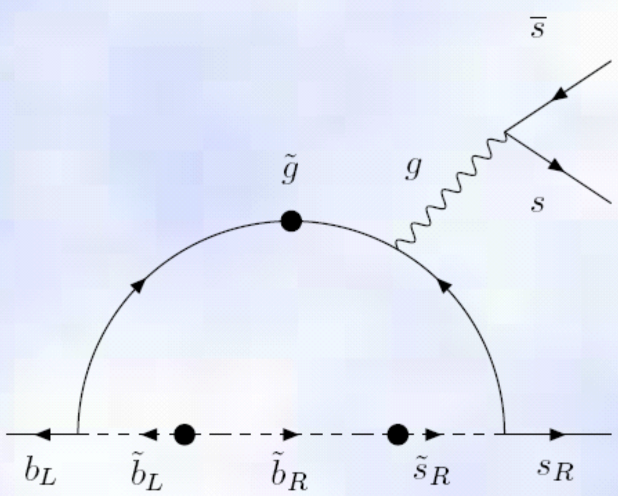
$(\delta^d_{23})_{LL}$ unbounded $\quad (\delta^d_{23})_{LR} < 2\times 10^{-6} \quad \Delta b\to s\gamma$

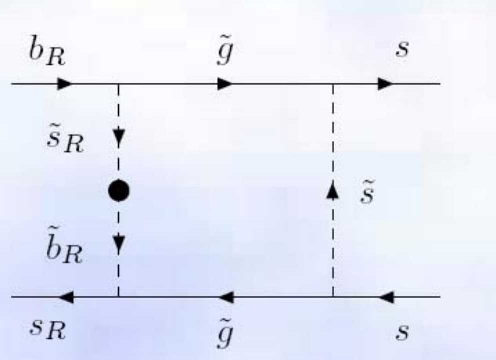
$$(\delta^d_{ij})_{AB} = \frac{(\Delta^d_{ij})_{AB}}{\tilde m^2}$$

Kolda, Masiero

Gluino contribution to $B \to \phi K_S$

Large $\tilde{s}_R$-$\tilde{b}_R$ mixing





The contribution from the penguin diagram is dominant.

$$H = -C_8^R \frac{g_s}{8\pi^2} m_b \overline{s_R} \sigma^{\mu\nu} T^A b_L G^A_{\mu\nu}$$

Mass insertion approximation

$$C_8^R = \frac{\pi\alpha_s}{m_{\tilde{q}}^2} \frac{m_{\tilde{g}}}{m_b} (\delta^{(d)}_{RR})_{23} (\delta^{(d)}_{LR})_{33} (\frac{1}{3} M_1(x) + 3M_2(x))$$

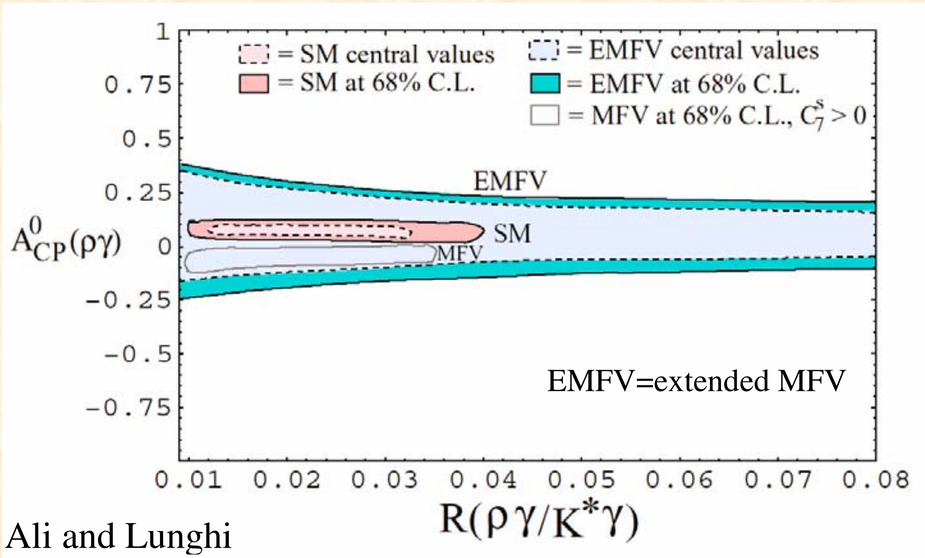
where

$$\begin{aligned}
(\delta^{(d)}_{LL})_{23} &= \left(m^2_{\tilde{d}_L}\right)_{23} / m^2_{\tilde{q}}, \quad (\delta^{(d)}_{RR})_{32} = \left(m^2_{\tilde{d}_R}\right)_{32} / m^2_{\tilde{q}}, \\
(\delta^{(d)}_{LL})_{33} &= m_b \,(A_b - \mu \tan\beta) / m^2_{\tilde{q}},
\end{aligned}$$

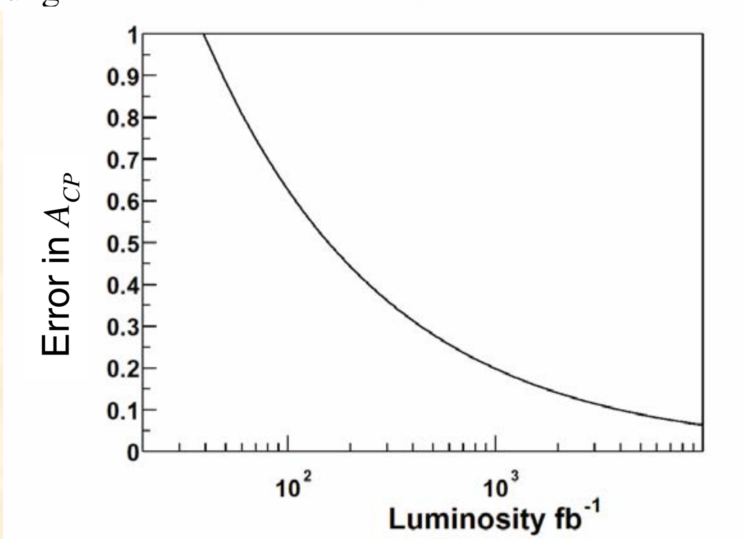
Double mass insertion $LR + RR$ is dominant

Measuring *CPV* in radiative decays requires large samples

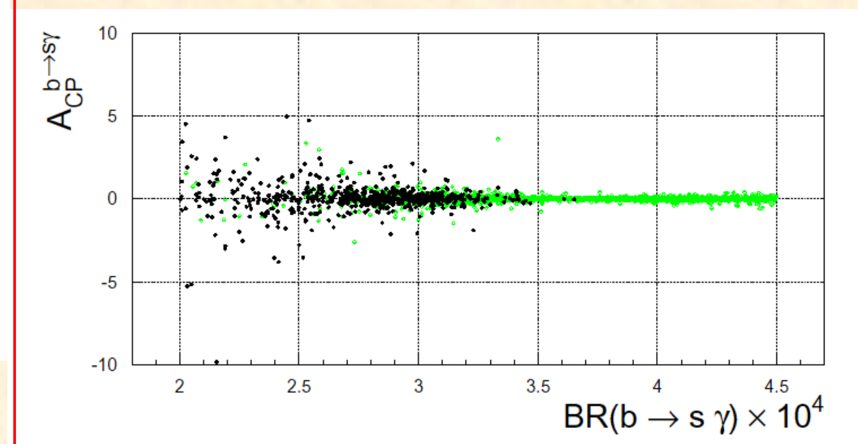
Exclusive



Ali and Lunghi

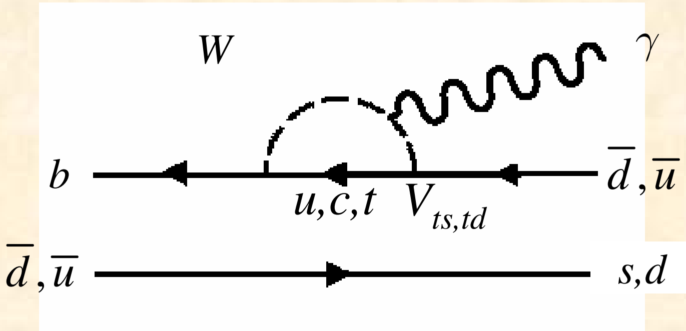


Standard Model: $A_{CP}(B \to X_s \gamma) \sim 0.6\%$ but can be larger in a variety of SUSY models

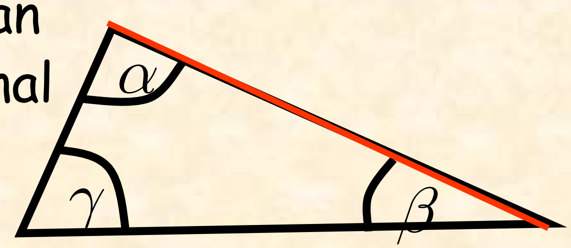


Bartl, Gajdosik, Lunghi, Masiero, Porod, Stremnitzer and Vives, hep-ph/0103324

Limit on V_{td}/V_{ts}



$B \to K^*$, $B \not\cong \rho,\gamma$ can provide an additional Unitarity Triangle constraint



$$\mathcal{R} = \frac{\mathcal{B}(B \to \rho\gamma)}{\mathcal{B}(B \to K^*\gamma)} = \left|\frac{V_{td}}{V_{ts}}\right|^2 \left(\frac{1 - m_\rho^2 / M_B^2}{1 - m_{K^*}^2 / M_B^2}\right) \zeta^2 \left[1 + \Delta R\right]$$

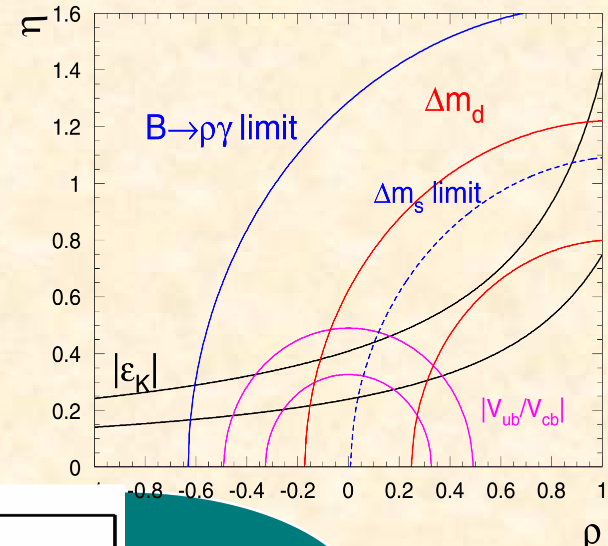
SU(3) factor: $\zeta = 0.76 \pm 0.10$

Annihilation $\left(B^+\right)$: $\Delta R = 0.0 \pm 0.2$

Ali and Parkhomenko hep/ph/0105302

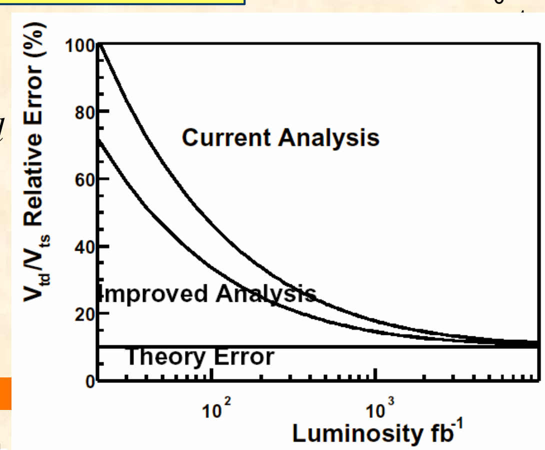
$$\left|\frac{V_{td}}{V_{ts}}\right| < 0.36$$

@ 90% CL



12% error in V_{td}/V_{ts} extraction, compared with 7% using $\Delta m_s/\Delta m_d$

Improvement of V_{ts}/V_{td} determination is limited by theory error, however ………



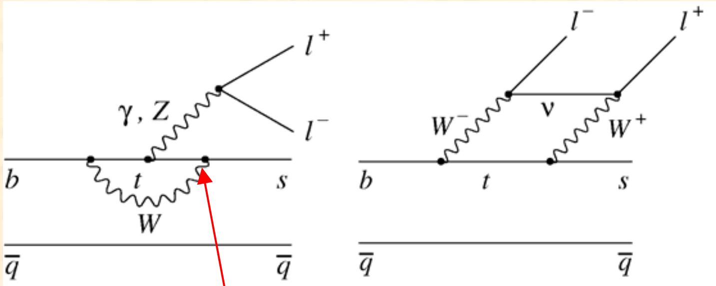
$b \to s\gamma + d\gamma$ - inclusive A_{CP}

- Can only be done in e^+e^-
- Events identified by high energy photon and lepton tag of other B-decay
  - Use lepton charge to tag flavor
- No discrimination between $B \to X_s\gamma$ and $B \to X_d\gamma$
- There is a significant mistag rate due to mixing and cascade decays
- $w = 0.13 \Rightarrow 35\%$ increase in raw statistical error
- Systematic uncertainties from detector charge asymmetries and background asymmetries – measured from data samples and limited by statistics
- Systematic B-background and theoretical modeling are insignificant compared to $\mathcal{B}(B \to X_s\gamma)$ measurement
- It is possible to reach an interesting level of precision

Luminosity [ab^{-1}]	Statistical error [δA_{CP}]	Systematic error [δA_{CP}]
0.1	0.1	0.01
1	0.03	0.003
10	0.01	0.001 (?)

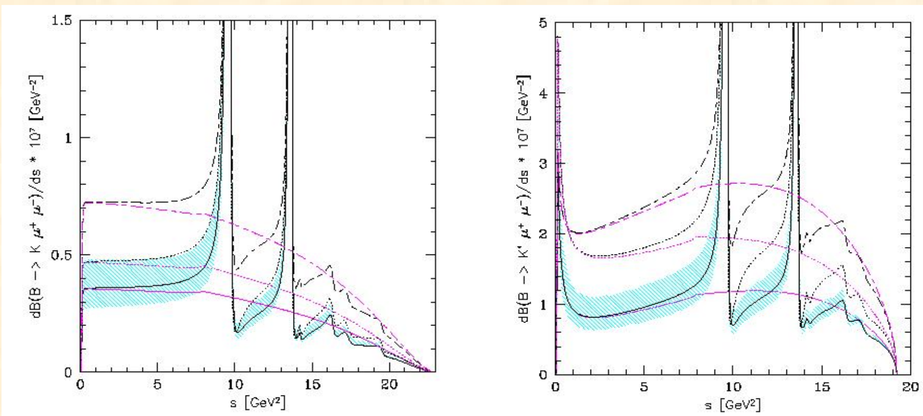
Brown, Bucci, Eisner, Jessop, Libby, Lu, Schmitz, Tinslay, Walsh

$b \to s\ell^+\ell^-$ *via* exclusive modes $B \to K^{(*)}\ell^+\ell^-$



+ new physics insertions

$B \to K\mu^+\mu^-$ $B \to K^*\mu^+\mu^-$



- Solid line+blue bands: SM range ($\pm 35\%$); Ali *et al.* form factors
- Dotted line: SUGRA model ($R_7 = -1.2$, $R_9 = 1.03$, $R_{10} = 1$; $R_i = C_i/C_i^{SM}$)
- Long-short dashed line: SUSY model ($R_7 = -0.83$, $R_9 = 0.92$, $R_{10} = 1.61$)

Typical Standard Model branching fractions:
(other models vary by up to 30%, largely due to form factor uncertainties

Exclusive decays:

$$\mathcal{B}(B \to K\ell^+\ell^-) = (0.35 \pm 0.12) \times 10^{-6}$$

$$\mathcal{B}(B \to K^* e^+e^-) = (1.58 \pm 0.49) \times 10^{-6}$$

$$\mathcal{B}(B \to K^* \mu^+\mu^-) = (1.19 \pm 0.39) \times 10^{-6}$$

Inclusive decays:

$$\mathcal{B}(b \to s e^+e^-) = (6.9 \pm 1.0) \times 10^{-6}$$

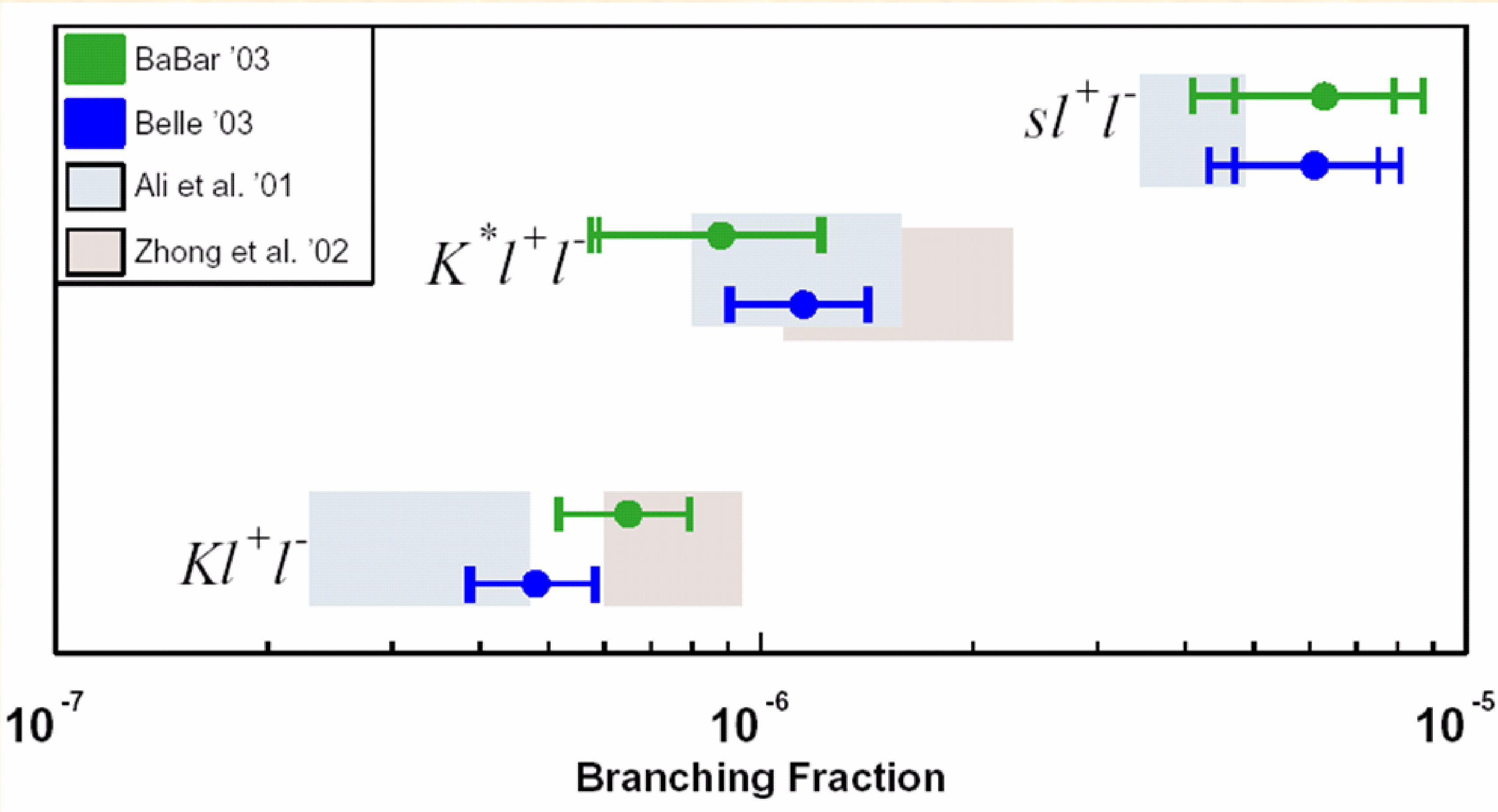
$$\mathcal{B}(b \to s \mu^+\mu^-) = (4.2 \pm 0.7) \times 10^{-6}$$

Ali, Lunghi, Greub & Hiller, hep-ph/0112300

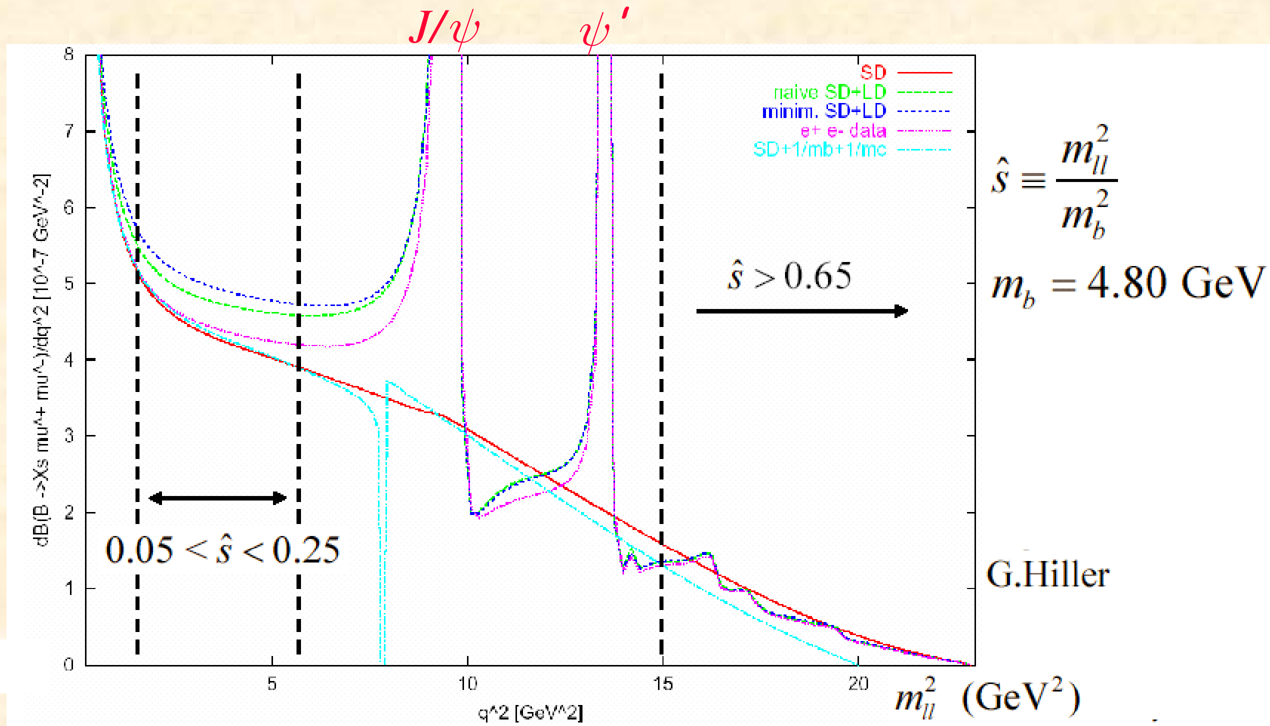
NNLO

Shape of $m_{\ell+\ell-}$ distribution is sensitive to presence of new physics

BABAR and Belle have made first measurements of branching fractions



Restricting dilepton mass reduces uncertain long distance contributions

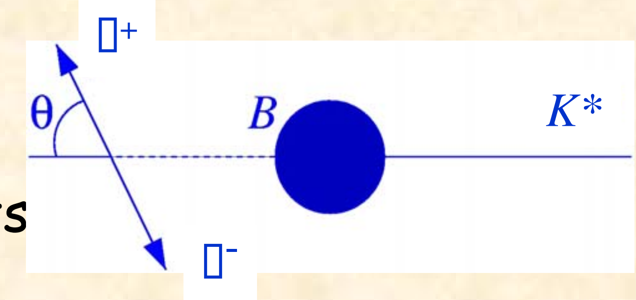


Signal yield $X_s e^+e^- + X_s\mu^+\mu^-$	500 fb^{-1}	1000 fb^{-1}	10 ab^{-1}	50 ab^{-1}
All $\hat{s}$ (excluding J/ψ veto)	σ_{stat} = 10% 7% < σ_{syst} < 14%	σ_{stat} = 7% 5% < σ_{syst} < 14%	σ_{stat} = 2.1% 1.5% < σ_{syst} < 6%?	σ_{stat} = 1.0% 0.7% < σ_{syst} < 6%?
0.05 < ŝ < 0.25	σ_{stat} = 16%	σ_{stat} = 11%	σ_{stat} = 3.4%	σ_{stat} = 1.5%
ŝ > 0.65	σ_{stat} = 22%	σ_{stat} = 15%	σ_{stat} = 5.0%	σ_{stat} = 2.3%

S. Willocq

A_{FB} in $B \rightarrow K^*\ell^+\ell^-$ is very sensitive to new physics

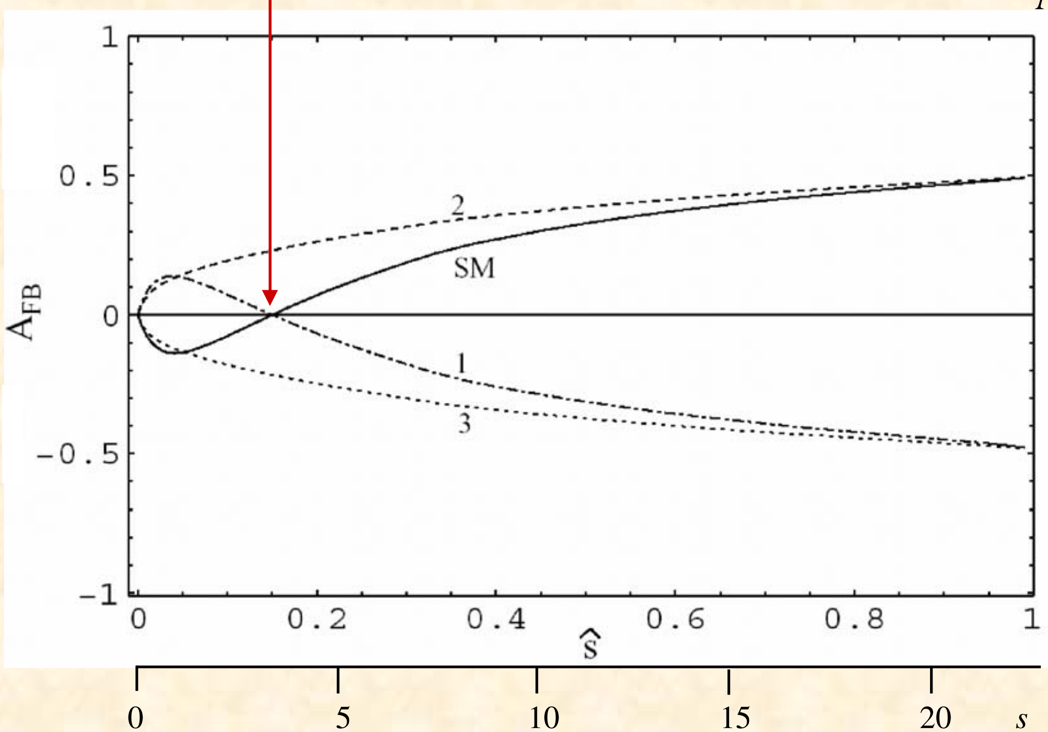
$$A_{FB} = \frac{N_F - N_B}{N_F + N_B}$$



- Prediction of a zero point $\hat{s}_0$ of A_{FB} and its position is robust in the Standard Model:

$$A_{FB} = 0 \text{ for } s = \hat{s}_0 = 0.162 \pm 0.008 \text{ (NNLL)}$$

Ghinculov, Hurth, Isidori & Yao, *Nucl.Phys.* **B**648,254 (2003)



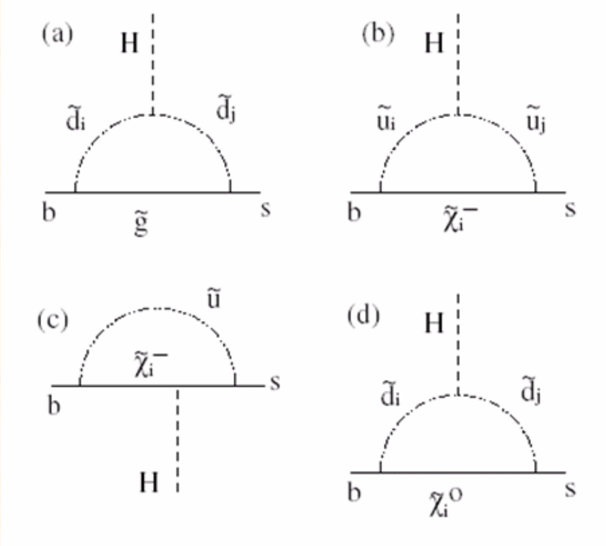
Non-MFV
    1,3
    A_{FB}~0 is also possible
MFV 2
    flip sign of C_7, no zero

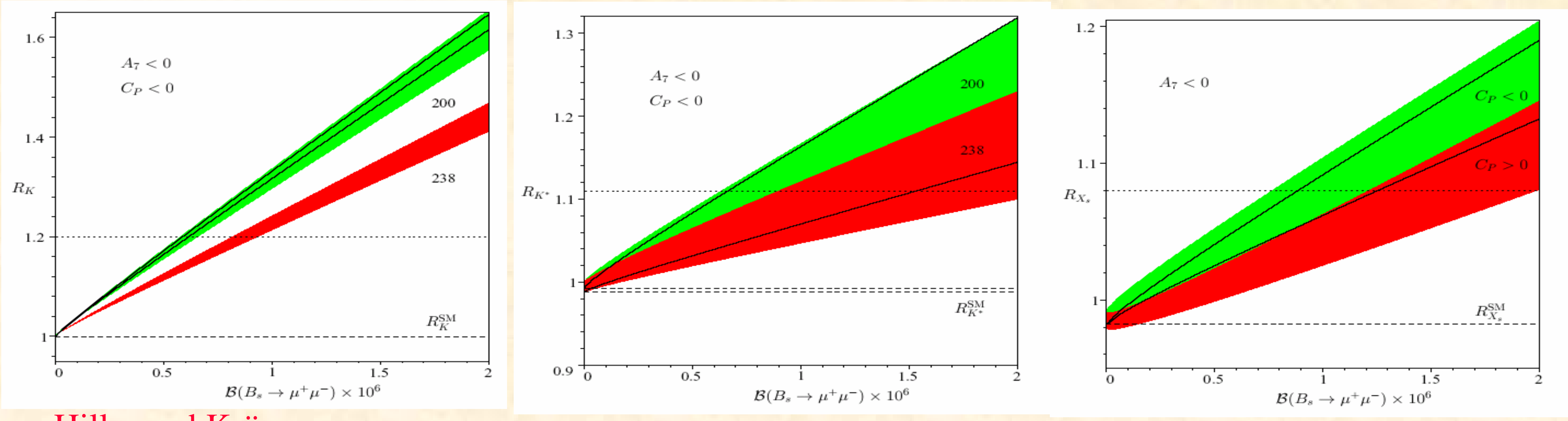
(More) model-independent analysis of NP (pseudo)scalar couplings

New Physics scalar and pseudoscalar couplings can result in a difference in

$$R_{K,K^*,x_s} = \frac{\mathcal{B}(B\to(K,K^*,x_s)e^+e^-)}{\mathcal{B}(B\to(K,K^*,x_s)\mu^+\mu^-)}$$

from unity. R_{K,K^*,x_s} is correlated with the (unobserved) rate $\mathcal{B}(B_s\to\mu^+\mu^-)$





Hiller and Krüger

Measuring A_{FB} at low $\hat{s}$ requires a large data sample

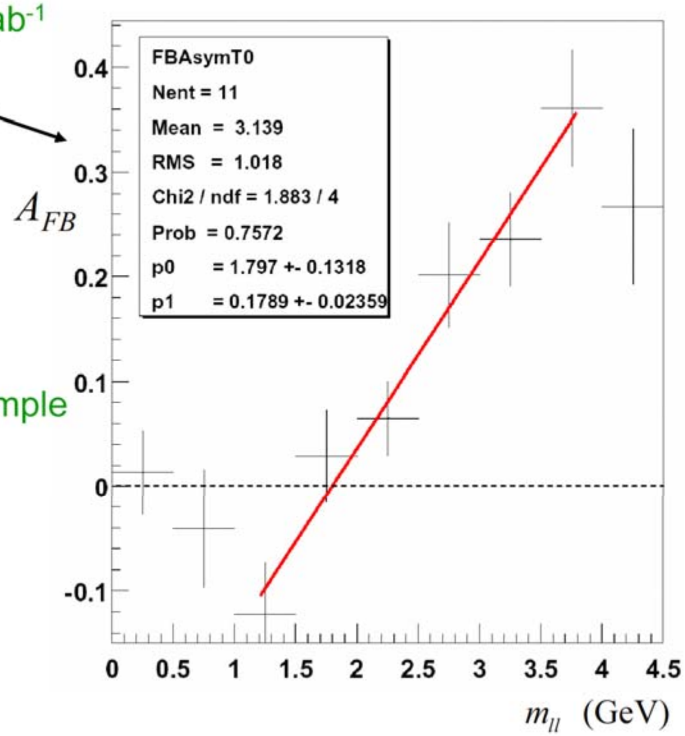
A_{FB} $X_s e^+ e^- + X_s \mu^+ \mu^-$	500 fb^{-1}	1000 fb^{-1}	10 ab^{-1}	50 ab^{-1}
$\hat{s} < \hat{s}_0$	-0.02 ± 0.17	-0.02 ± 0.12	-0.017 ± 0.039	-0.017 ± 0.017
$\hat{s} > \hat{s}_0$	0.17 ± 0.22	0.17 ± 0.16	0.173 ± 0.050	0.173 ± 0.022

Is there a zero ? If yes, where is it ?

- A_{FB} zero-point for pure signal 10 ab^{-1}

M_{ll0} = 1.80 $\pm$ 0.13(stat) GeV
$\Rightarrow \hat{s}_0$ = 0.141 $\pm$ 0.020(stat)

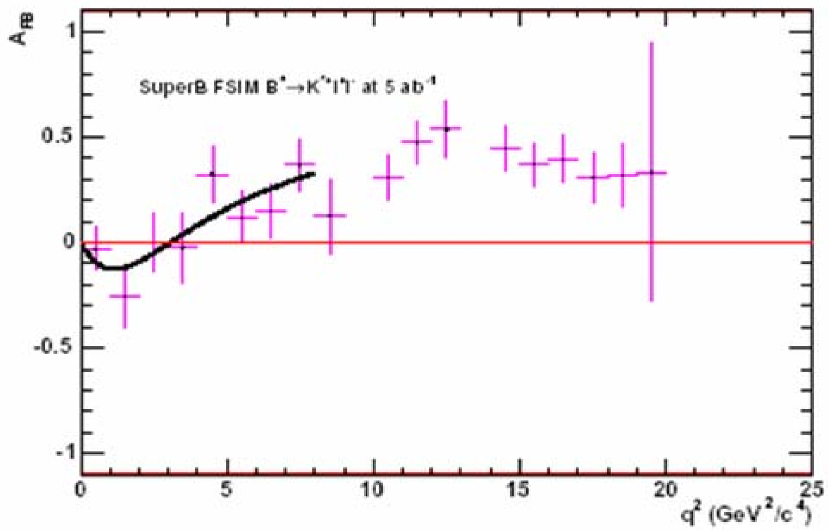
- For background-subtracted full sample
$\Rightarrow \hat{s}_0 \simeq$ 0.14 $\pm$ 0.04(stat)

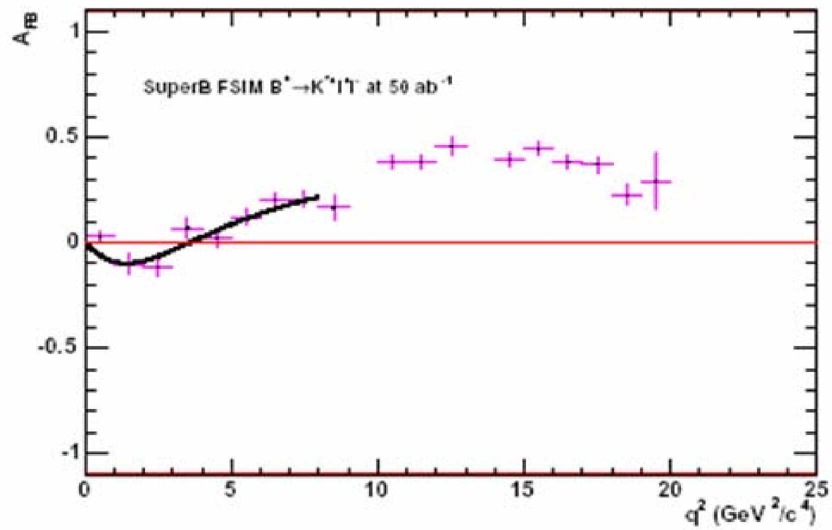


S. Willocq

Model-independent extraction of *C9, C10* from A_{FB} in K^*ll

- C7 fixed by future precise measurement of B(b sg)





$5\ ab^{-1}$

$\Rightarrow \delta C_9 \sim \delta C_{10} \sim 30\%(\text{stat}) \pm 5\%$

(from $\delta C_7 = \pm 5\%$)

$50\ ab^{-1}$

$\Rightarrow \delta C_9 \sim \delta C_{10} \sim 10\%(\text{stat}) \pm 5\%$

Nakao, SuperBelle

Super B Factory measurement precision on Kll, K^*ll and sll

		2 ab^{-1} (%)	10 ab^{-1} (%)	50 ab^{-1} (%)
All $\hat{s}$	Kl^+l^-	5.4	2.4	1.1
Excluding	$K^*l^+l^-$	7.0	3.1	1.4
J/ψ, $\psi(2S)$	sl^+l^-	4.5	2.0	0.9
Low $\hat{s}$	Kl^+l^-	6.9	3.1	1.4
$0.05<\hat{s}<0.25$	$K^*l^+l^-$	9.9	4.4	2.0
	sl^+l^-	7.5	3.4	1.5
High $\hat{s}$	Kl^+l^-	11.5	5.1	2.3
$\hat{s}>0.65$	$K^*l^+l^-$	13.8	6.2	2.8
	sl^+l^-	11.4	5.1	2.3

Based on HFAG branching fractions and statistical errors and *BABAR* relative efficiency *vs* s

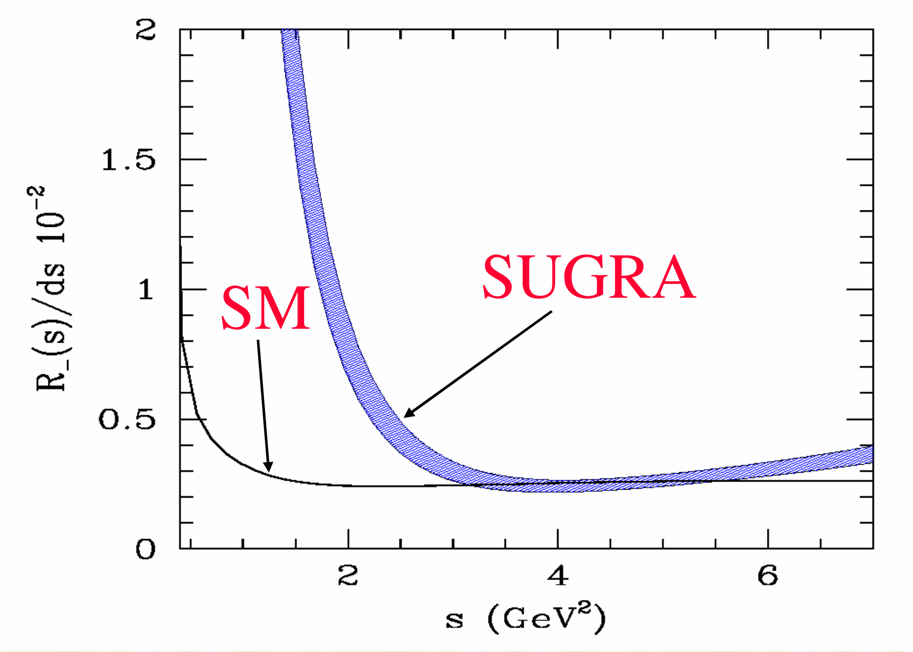
Detector systematics limited for absolute rate

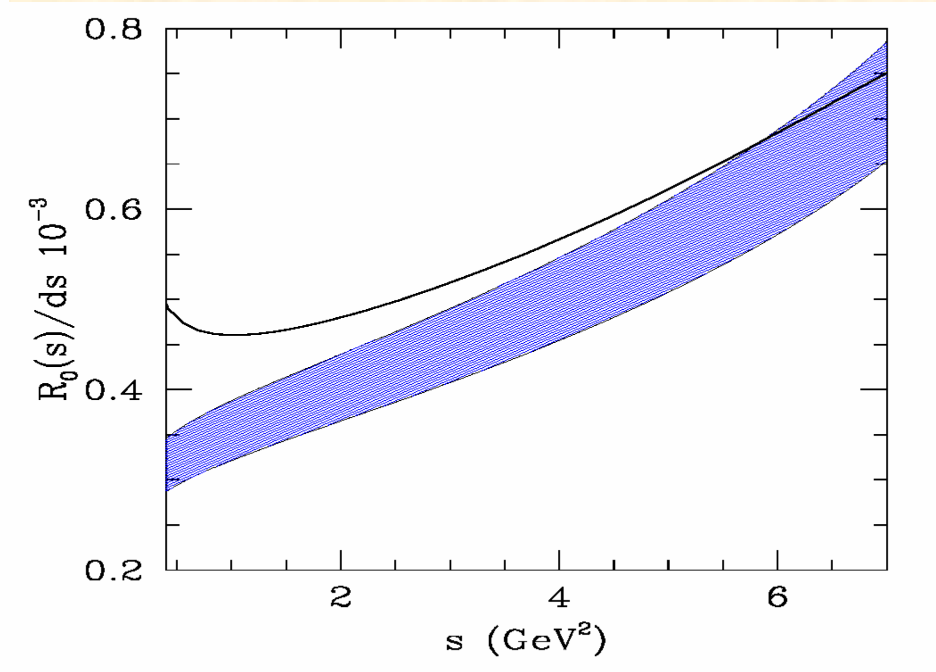
Likely to be limited by theory systematics for absolute rate

J. Berryhill

Probe of SUSY in $B^0 \to K^* \ell^+ \ell^-$ and $B^0 \to \rho \ell \nu$

$$R_i(s) = \frac{d\Gamma_{H_i}^{B \to K^* \; l^+ l^-}/ds}{d\Gamma_{H_i}^{B \to \rho \; l \bar{\nu}}/ds} \quad (i = 0, -1, +1)$$





Standard Model predictions are robust

Ali and Safir

Comparison of 1 year yields – *B*Tev and Super *B* Factory

Mode	*B*TeV		Super *B*	
	Yield	Tagged	Yield	Tagged
$B_s \to J/\psi\,\eta^{(\prime)}$	12650	1645	-	-
$B^- \to \phi K^-$	11000	11000	14000	14000
$B^0 \to \phi K_s$	2000	200	5000	1500
$B^0 \to K^* \mu^+ \mu^-$	2530	2530	~1000	~1000
$B_s \to \mu^+ \mu^-$	6	0.7	-	
$B^0 \to \mu^+ \mu^-$	1	0.1	0	-
$D^{*+} \to \pi^+ D^0,\ D^0 \to K^- \pi^+$	~10^8	~10^8	1.6x10^7	1.6x10^7

A BTeV-generated comparison (updated from 10^{34})

α

- Number of flavor tagged $B^0 \to \pi^+ \pi^-$ (B=0.45x10^{-5})

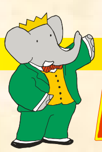
	$\mathcal{L}$ ($cm^{-2}s^{-1}$)	σ	$B^0/10^7$s	ε	εD^2	Tagged events
Super B	10^{36}	1.1 nb	1.1×10^{10}	0.45	0.26	5600
BTeV	2×10^{32}	100 μb	1.5×10^{11}	0.021	0.1	1426

- Number of $B^- \to D^0 K^-$ (Full product B=1.7x10^{-7})

γ

	$\mathcal{L}$ ($cm^{-2}s^{-1}$)	σ	$B^0/10^7$s	ε	Events
Super B	10^{36}	1.1 nb	1.1×10^{10}	0.4	500
BTeV	2×10^{32}	100μb	1.5×10^{11}	0.007	176

- B_s , B_c and Λ_b studies are, of course, not done at the $\Upsilon(4S)$ e^+e^-

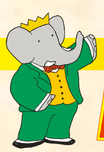


BABAR

At 10^{36}, e^+e^- is fully competitive in rare decay studies

		Hadron Collider Experiments			e^+e^- B Factories	
Decay Mode	Branching Fractions	**CDF D0** (2 fb^{-1})	**BTeV*** **LHCb** (10^7 s)	**ATLAS CMS** (1 Year)	***BABAR*** **BELLE** (0.5 ab^{-1})	**10^{36}** (10 ab^{-1})
$B \to X_s\gamma$	$(3.3 \pm 0.3) \times 10^{-4}$				11K	220K
					1.7K (B Tagged)	34K (B Tagged)
$B \to K^*\gamma$	5×10^{-5}	170	25K		6K	120K
$B \to \rho(\omega)\gamma$	2×10^{-6}				300	6K
$B \to X_s\mu^+\mu^-$	$(6.0 \pm 1.5) \times 10^{-6}$		3.6K		300	6K
$B \to X_s e^+e^-$					350	7K
$B \to K^*\mu^+\mu^-$	$(2 \pm 1) \times 10^{-6}$	60-150	2.2K/4.5K	665/4.2K	120	2.4K
$B \to K^* e^+e^-$					150	3K
$B \to X_s\nu\overline{\nu}$	$(4.1 \pm 0.9) \times 10^{-5}$				8	160
$B \to K^*\nu\overline{\nu}$	5×10^{-6}				1.5	30
$B_d^0 \to \tau^+\tau^-$	10^{-7}					
$B_s^0 \to \mu^+\mu^-$	10^{-9}	5/1.5-6	5/11	9/7		
$B_d^0 \to \mu^+\mu^-$	8×10^{-11}	0/0	1/2	0.7/20		
$B \to \tau\nu$	5×10^{-5}				17	350
$B \to \mu\nu$	1.6×10^{-7}				8	150
$B^0 \to \gamma\gamma$	10^{-8}				0.4	8

* Two arm BTeV



Super *B* Factory activity at KEK, SLAC

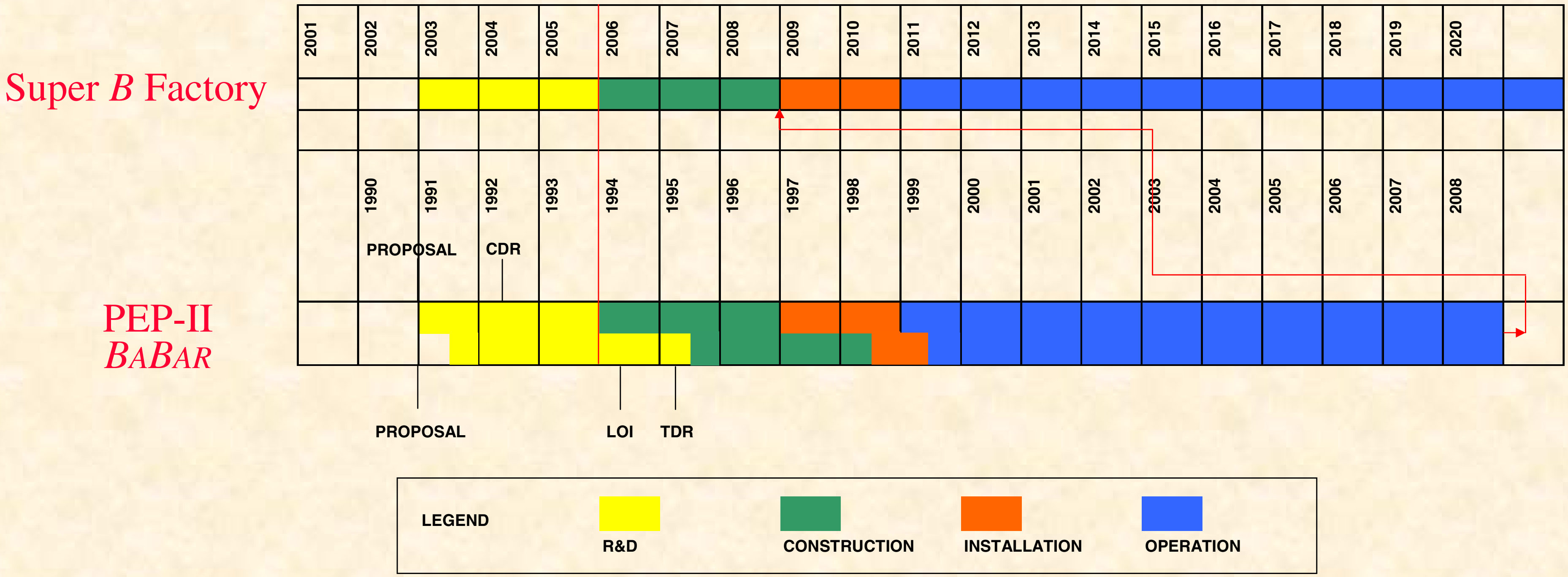
- The Directors of SLAC and KEK have encouraged cooperation between *BABAR*ians and Bellies on future activities, since they believe that "there will be at most one new high luminosity *B* Factory"
  - The core of a Super *B* Factory effort will likely be drawn from the *BABAR* and Belle Collaborations (others are certainly welcome)
    - Accelerator and detector R&D is underway in both labs and at several of the collaborating institutions

Workshops

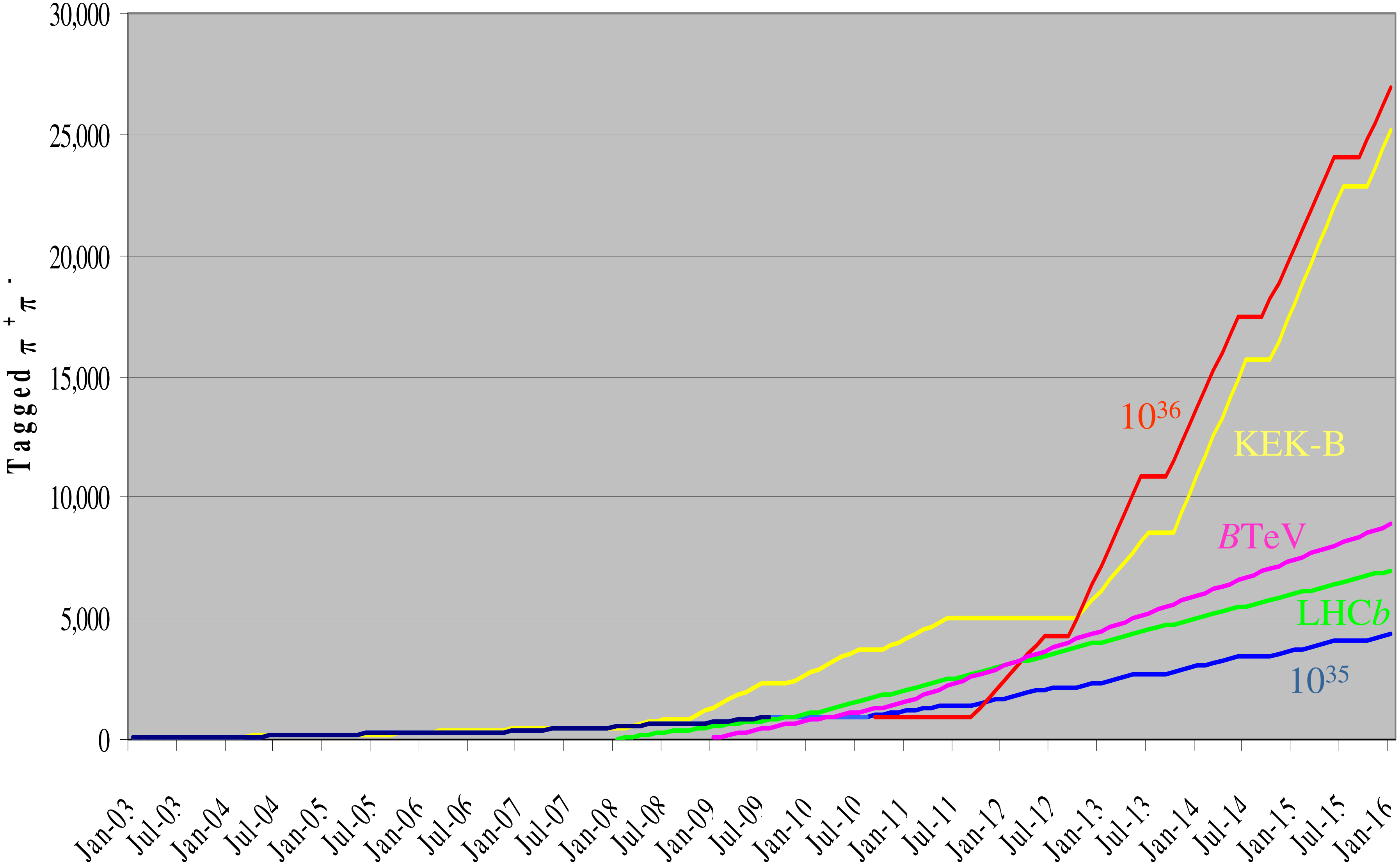
- KEK has held five workshops on physics, detector and accelerator aspects
- SLAC has held two workshops on physics potential
- There was a *BABAR*/Belle joint workshop in Hawaii in mid-January
- There was an ICFA Accelerator Workshop at SLAC in October, focusing on very high luminosity e^+e^- circular machines

- There will be a Belle/KEK-B upgrade LOI in a few months
- There will be a *BABAR*/PEP-II upgrade LOI by the end of 2004

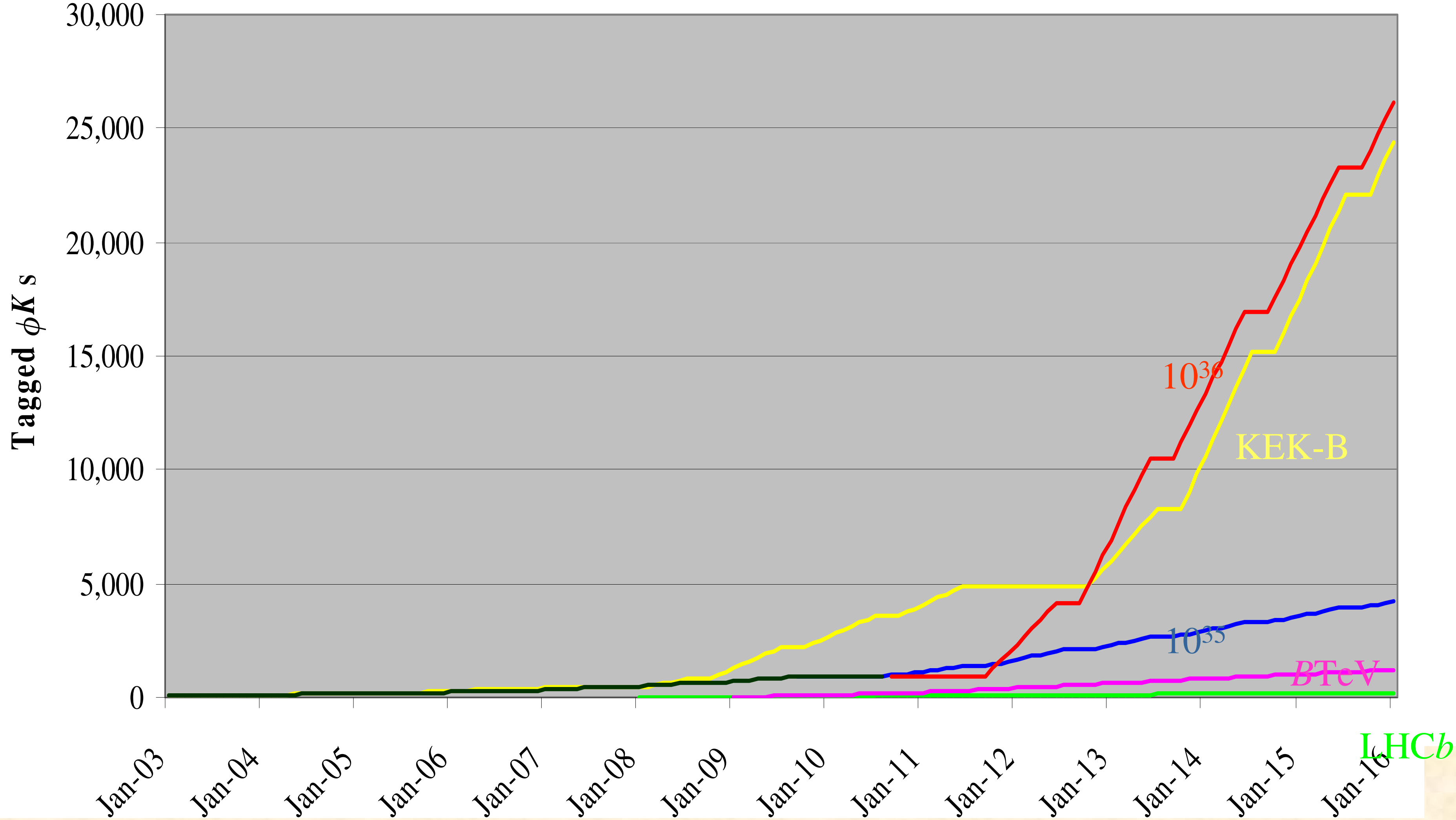
Technically limited schedule



Tagged $\pi^+\pi^-$ scenarios



Tagged ϕK_s scenarios



Conclusions

- If the scale of new physics is below 1 TeV, as motivated by our current understanding of the Higgs mechanism, there will be measurable effects in the heavy quark/heavy lepton sector
  - LHC can yield information on masses and couplings of new particles by direct production
  - Information on squark off-diagonal couplings requires detailed studies of heavy quark decays at Super B Factories or dedicated hadronic experiments
- The effects of new physics loops can be seen in rare decay branching fractions and kinematic distributions and in CP-violating asymmetries in channels with very small branching fractions
- The new generation of experiments at hadronic accelerators will doubtless extend the fruitful programs of the current B Factories
- Upgraded B Factory accelerators and detectors can, early in the next decade, provide unique high precision measurements as well as results complementary to those of hadronic experiments