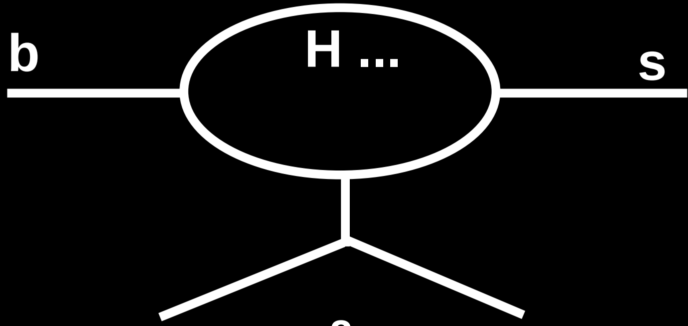
Physics at a Super Flavor Factory

B_u B_d B_s D τ...

Probing the terascale



&

over-constraining CKM

Adrian Bevan

17th January 2007

Queen Mary
University of London

Outline

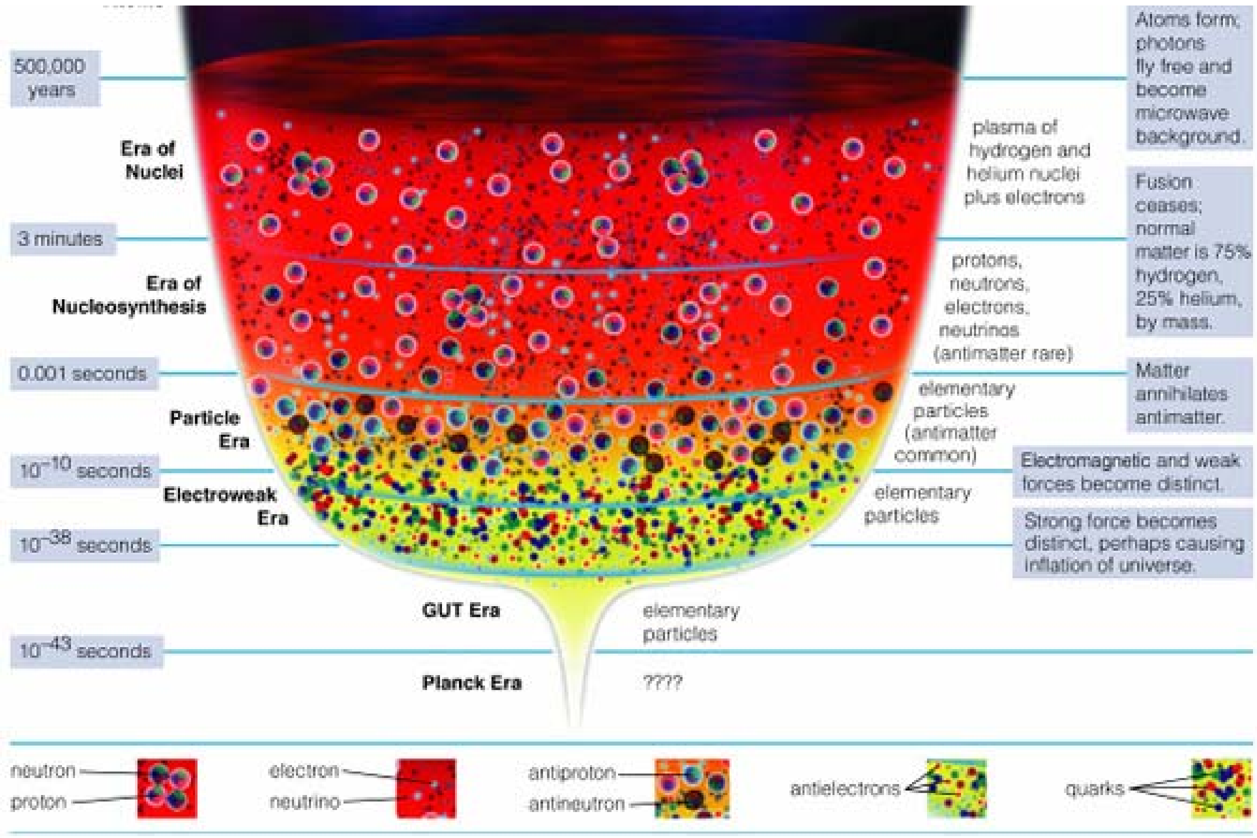
- Motivation
- Recent Activity
- The Luminosity Frontier
  - Studies of $B_{u,d}$ decays
  - Running at the $\Upsilon(5S)$: B_s decays
  - Potential for charm
  - Lepton Flavor Violation in τ decay
  - Testing Lepton Universality & studying dark matter.
- Detector concepts
- Accelerator design and R&D
- Complimentarity
- Next Steps
- Summary

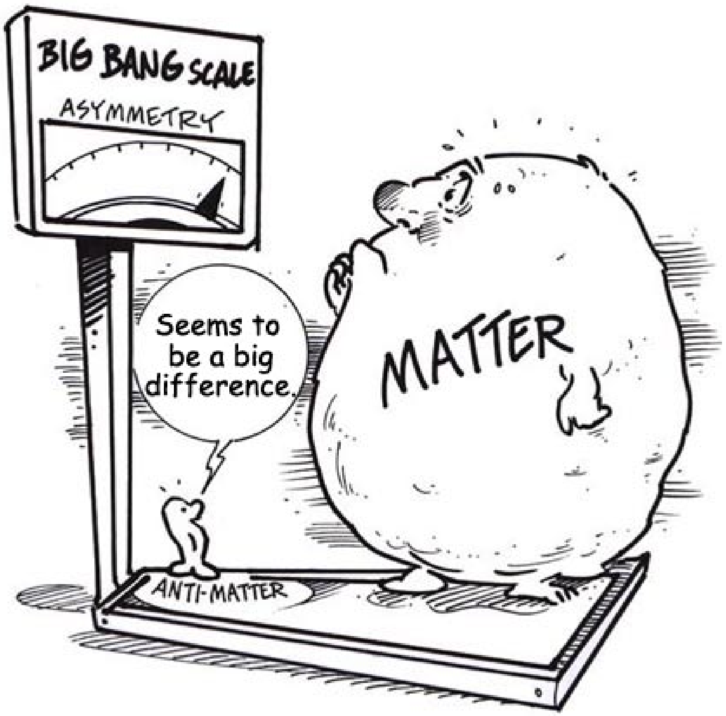
This talk covers a fraction of the total physics accessible to a Super Flavor Factory…

… and a quick tour of current accelerator designs/parameters

Motivation 1/3

- What fundamental questions are we looking to answer with a Super Flavor Factory (SFF)?

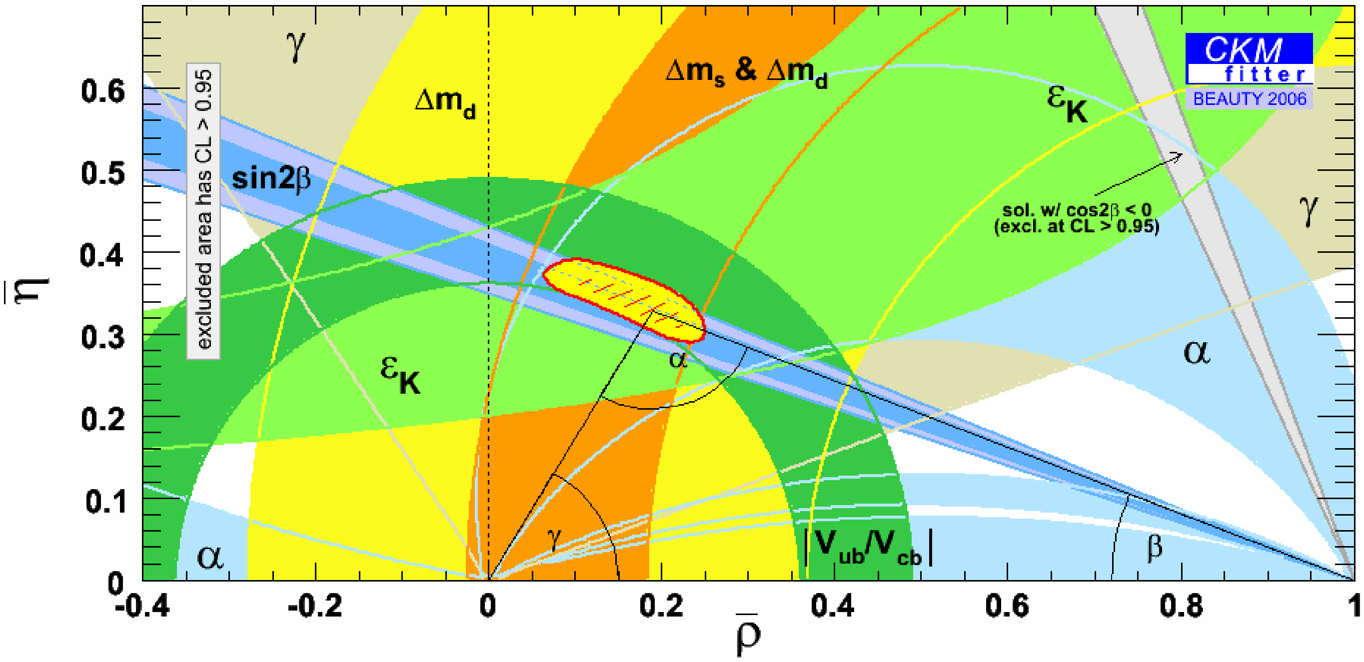




- Why is our universe matter dominated?

Motivation 2/3

- CPV: So far the CKM mechanism has passed all tests from the B-factories and the Tevatron.
    - Deviations from the CKM picture are not $\mathcal{O}(1)$



- What about higher order effects in b→s, B_s mixing c→u, or new sources of flavor physics?

Motivation 3/3

- Testing Higher order effects:
  - ΔS measurements in $b \to s$ penguins are being tested to 10% at the B-factories (see later).

Motivation 3/3

- Testing Higher order effects:
  - ΔS measurements in $b \rightarrow s$ penguins are being tested to 10% at the B-factories (see later).
  - B_s mixing measurements from the Tevatron (and later LHCb) will elucidate the issue of $\phi_{NP(S)}$.

Motivation 3/3

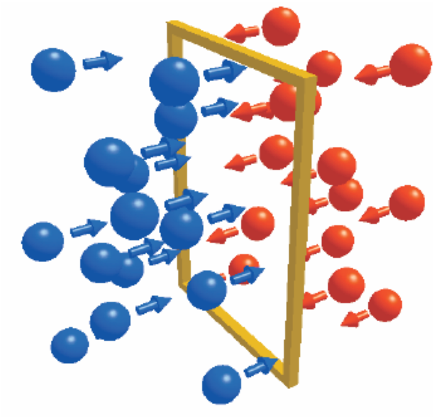
- Testing Higher order effects:
  - ΔS measurements in b→s penguins are being tested to 10% at the B-factories (see later).
  - B_s mixing measurements from the Tevatron (and later LHCb) will elucidate the issue of $\phi_{NP(S)}$.
  - Charm decays remain interesting (although theory uncertainties might make it hard to interpret large charm mixing contributions)

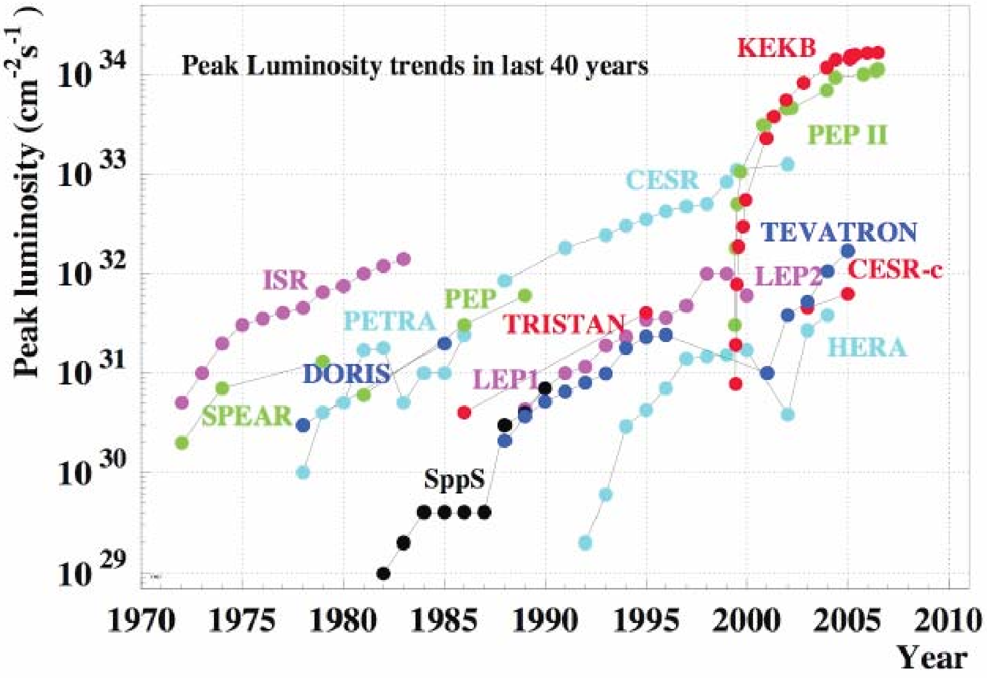
Motivation 3/3

- Testing Higher order effects:
  - ΔS measurements in $b \rightarrow s$ penguins are being tested to 10% at the B-factories (see later).
  - B_s mixing measurements from the Tevatron (and later LHCb) will elucidate the issue of $\phi_{NP(S)}$.
  - Charm decays remain interesting (although theory uncertainties might make it hard to interpret large charm mixing contributions)
  - NP in CP / Flavor problem?
    - Balance m_H fine tuning against CP/mixing observables
      - $m_H \sim 1\text{TeV} (= \Lambda_{NP})$ vs. $\Lambda_{NP} \geq 10^{3\text{-}4}$ TeV (kaon mixing etc.)
    - MFV tries to solve this conflict
      - Corrections are $\mathcal{O}(m_W/m_{NP})^2 \sim 1\%$
      - Uses a limited set of operators, and restrict **real** coupling size
- So aim for ~1% tests…

The Luminosity Frontier

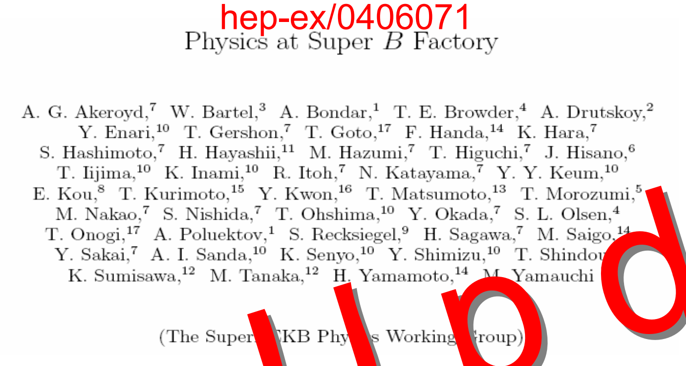
- The current generation of experiments have pushed back our understanding of Flavor Physics: CKM works well
  - All measurements of the CKM mechanism are compatible with the SM.
- Deviations, if any must be smaller than current constraints: want to perform % level tests of the CKM picture (i.e. test MFV).
  - We know that there is a gap in our knowledge from Cosmology, so there must be some NP at a level beyond the reach of our current data.
- Need more precision (more luminosity) to push back our understanding of the CKM mechanism, and its equivalent BSM.





Aim for 10^{36} cm^{-2} s^{-1} in order to integrate at least 50ab-1 (*and perhaps up to 100ab*$^{-1}$).

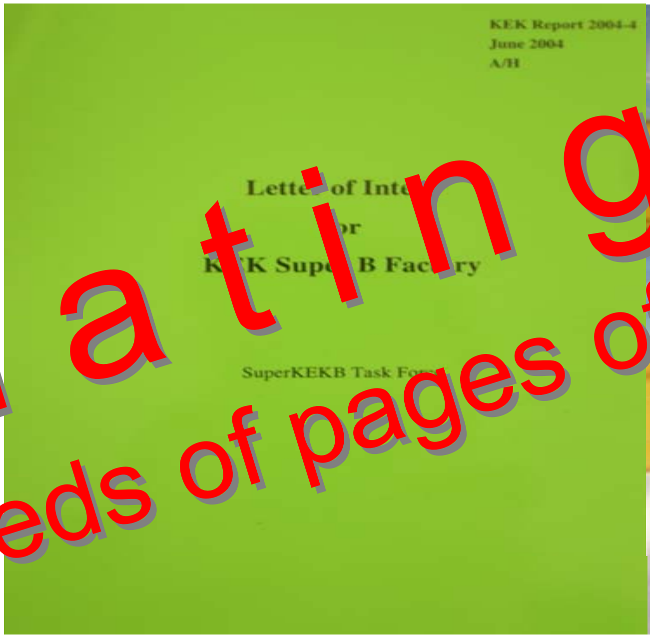
A lot of recent activity in the field


hep-ex/0406071

Physics at Super B Factory

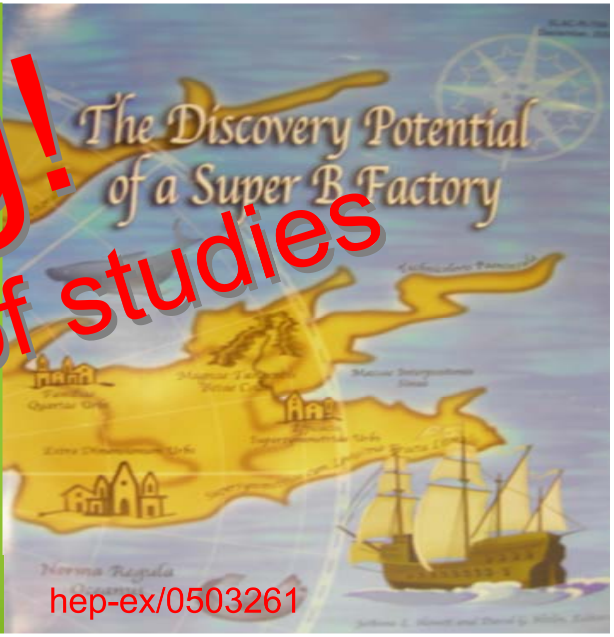
A. G. Akeroyd,[7] W. Bartel,[3] A. Bondar,[1] T. E. Browder,[4] A. Drutskoy,[2]
Y. Enari,[10] T. Gershon,[7] T. Goto,[17] F. Handa,[14] K. Hara,[7]
S. Hashimoto,[7] H. Hayashii,[11] M. Hazumi,[7] T. Higuchi,[7] J. Hisano,[6]
T. Iijima,[10] K. Inami,[10] R. Itoh,[7] N. Katayama,[7] Y. Y. Keum,[10]
E. Kou,[8] T. Kurimoto,[15] Y. Kwon,[16] T. Matsumoto,[13] T. Morozumi,[5]
M. Nakao,[7] S. Nishida,[7] T. Ohshima,[10] Y. Okada,[7] S. L. Olsen,[4]
T. Onogi,[17] A. Poluektov,[1] S. Recksiegel,[9] H. Sagawa,[7] M. Saigo,[14]
Y. Sakai,[7] A. I. Sanda,[10] K. Senyo,[10] Y. Shimizu,[10] T. Shindou
K. Sumisawa,[12] M. Tanaka,[12] H. Yamamoto,[14] M. Yamauchi

(The Super KB Phy s Working roup)


KEK Report 2004-4
June 2004
A/H

Lette of Inte
or
K K Supe B Fac ry

SuperKEKB Task Fo


The Discovery Potential of a Super B Factory

hep-ex/0503261

U p d a t i n g!

hundreds of pages of studies

- Many recent workshops at SLAC, KEK, Frascati, ITEP and elsewhere.
- Strong collaboration on MDI.
- many reports at recent conferences: FPCP, EPAC, ICHEP...

More details can be found at:

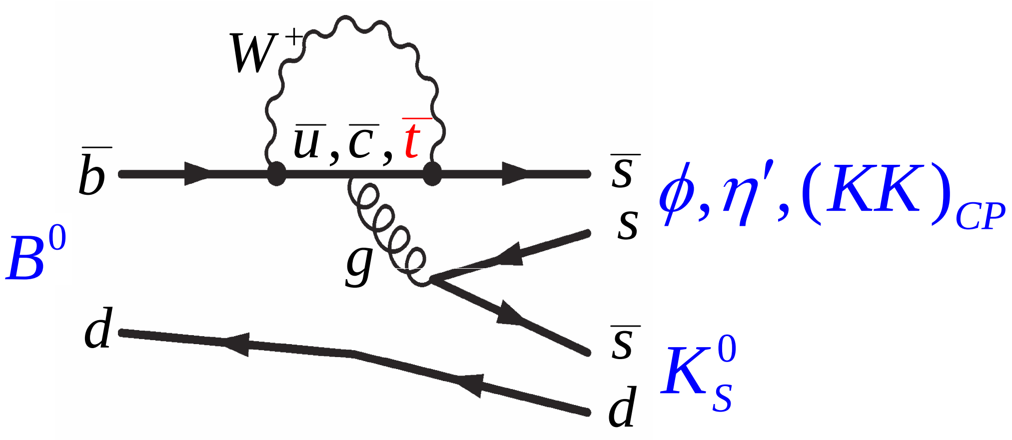
http://belle.kek.jp/superb/
http://www.pi.infn.it/SuperB/

INFN CDR and **KEK LOI** due to be submitted next month.

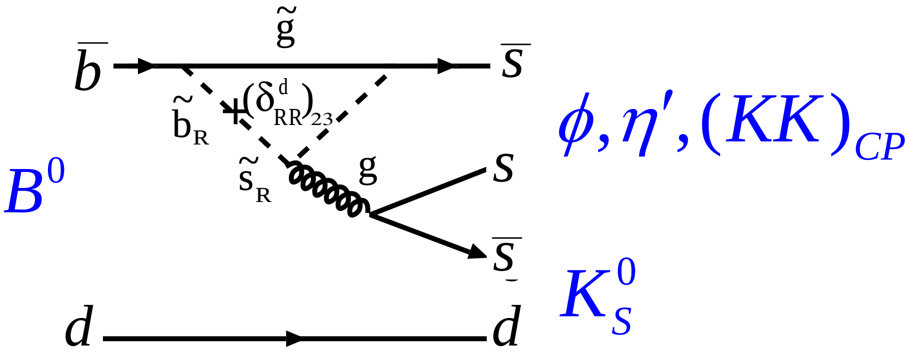
+ LHCb upgrade studies underway

Probing new physics at the $\Upsilon(4S)$

- Time dependent CP asymmetry measurements can constrain possible NP contributions.



SM: measure β



New phases from SUSY?

- $\Delta S = S - \sin 2\beta \neq 0$ signals NP.
- SM Deviations from $\sin 2\beta$ from $J/\psi K_s$ are mode dependent.
  - Need to improve knowledge of theoretical uncertainty in $\sin 2\beta$. Best / Worst scenario is currently at a level of 10^{-4} / 0.015.

Standard Model corrections to ΔS

- Can use $B\to\eta\eta$, $\eta'\eta'$, $\eta'\eta$, $\eta'\pi^0$, $\eta\pi^0$ to bound $\Delta S=\sin2\beta-\sin2\beta_{\rm eff}$ in the golden s-penguin modes $B\to\eta' K^0$ and ϕK^0. [uses flavor SU(3) sym.]
- All final states have neutrals to reconstruct.

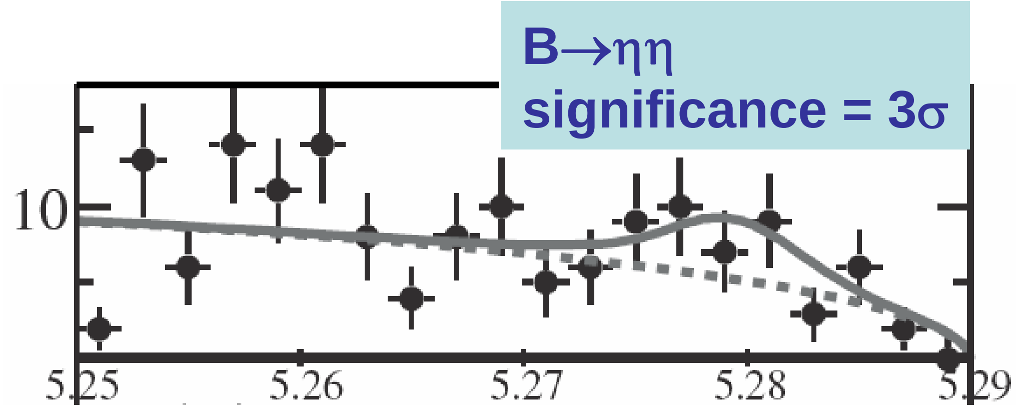
$$B(\eta\eta)=(1.1^{+0.5}_{-0.4}\pm0.1)\times10^{-6}$$

$$B(\eta'\eta')<2.4\times10^{-6}$$

$$B(\eta'\eta)<1.7\times10^{-6}$$

$$B(\eta\pi^0)<1.3\times10^{-6}$$

$$B(\eta'\pi^0)<2.1\times10^{-6}$$



$B\to\eta\eta$
significance = 3σ

PRD **73** 071102 (2006)
PRD **74** 051106 (2006)

- SM bound is sub 0.1, and a little larger than experimental precision.

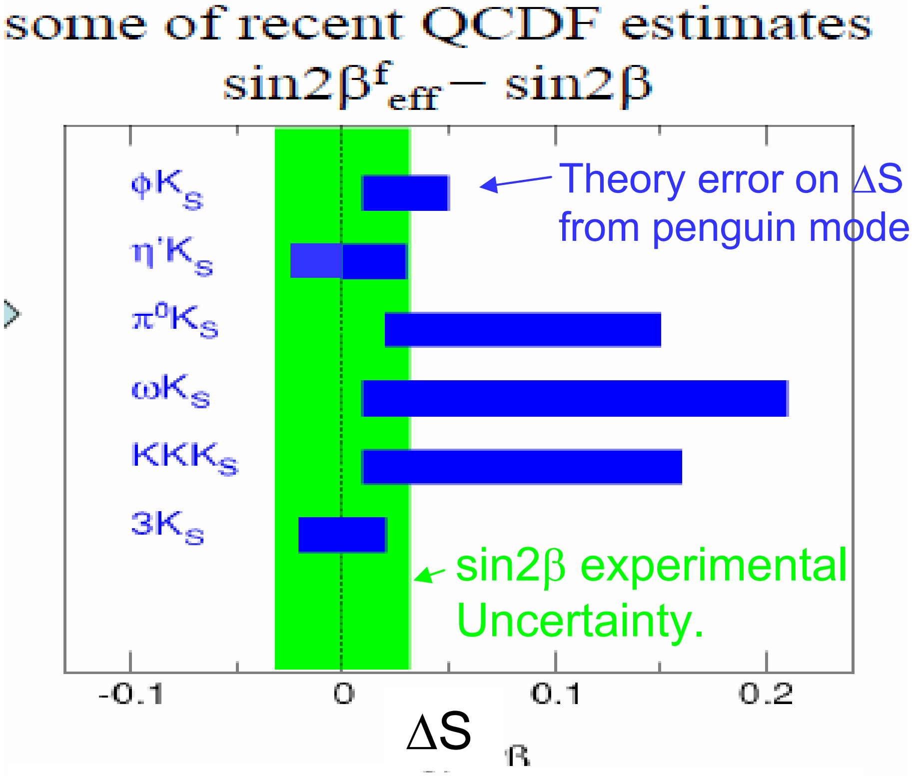
$$-0.046<\Delta S(\eta' K^0)<0.094$$

$$|\Delta S(\phi K^0)|<0.38$$

e.g. see Gronau et al., hep-ph/0608085

Standard Model corrections to ΔS

- A variety of theoretical calculations have been made to estimate the theory error on ΔS mode by mode.
- Current best levels of constraint are ~0.01.
- This theory error becomes a limiting factor with approx 50ab^{-1} of data.



Theory error on ΔS from penguin mode

sin2β experimental Uncertainty.

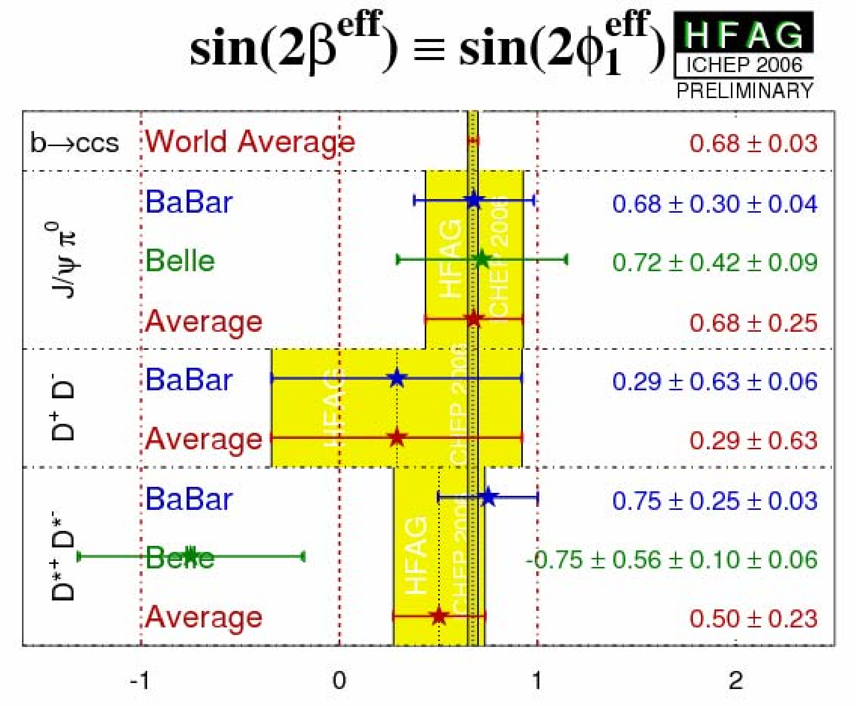
QCDF: (Beneke, PLB620 (2005), 143-150, Cheng et al., PRD72 (2005) 094003 etc.
SCET: (Williamson & Zupan, hep-ph/0601214)
Can estimate ΔS and mostly see a positive shift.

SU(3): Grossman *et al*, PRD68 (2003) 015004; Gronau *et al*, PRD71 (2005) 074019; …).

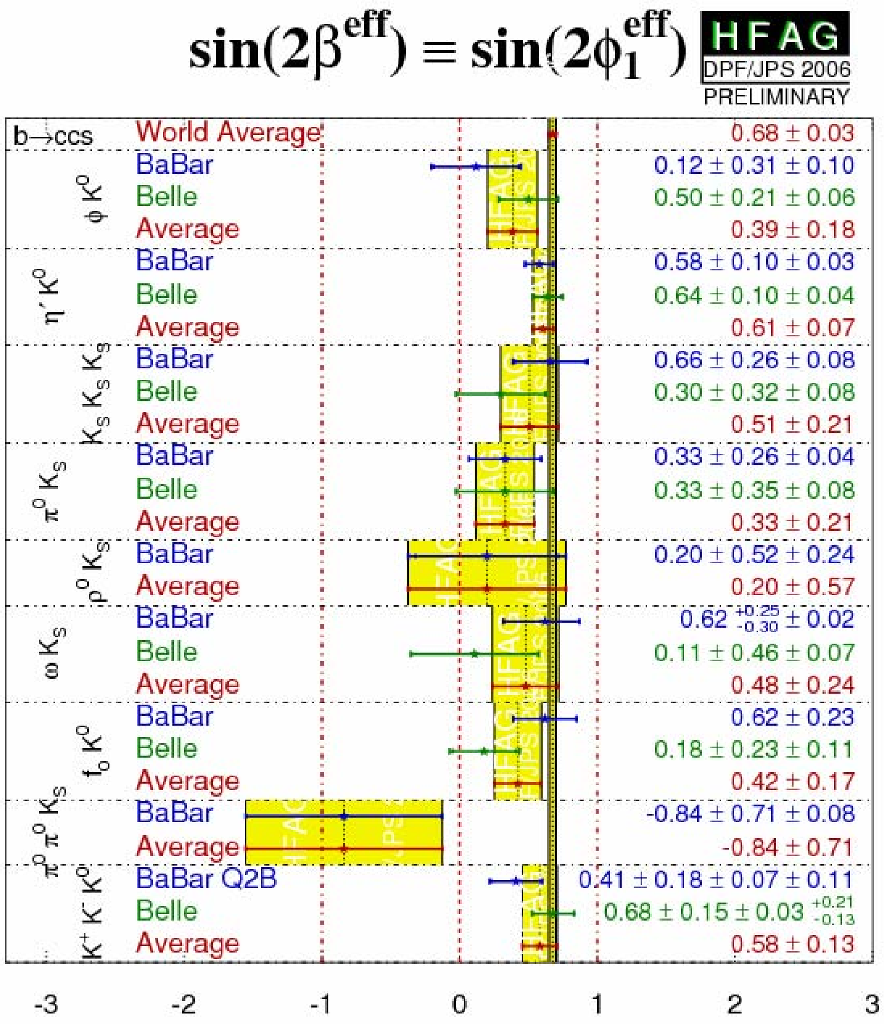
- $\eta' K^0$ is the most promising channel
  - most precise S currently measured & CPV has been observed
  - $B \to K^+K^-K_s$ (ϕK_s) is next on the list.

Current constraints on ΔS

$b \to c\bar{c}d$ decays



$b \to s$ penguin decays

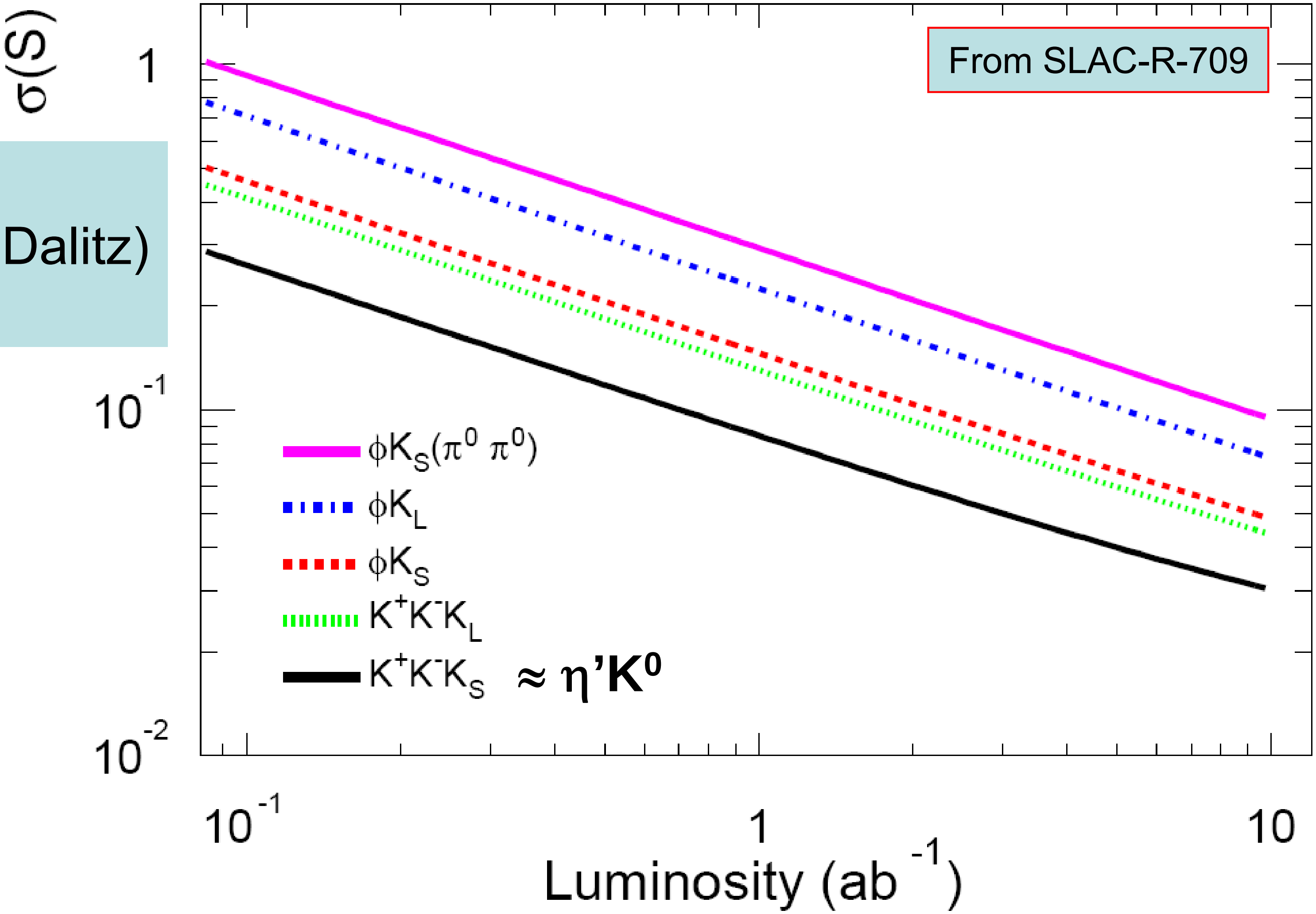


- ΔS is consistent with zero for $c\bar{c}s$ and $c\bar{c}d$ decays.
- However the average for $c\bar{c}s$ decays is 2.6σ away from sin2β.
- Need a SFF to elucidate this intriguing pattern.

Predictions for the future

- Extrapolations from BaBar analysis indicate % level precision at ~50ab^{-1}.

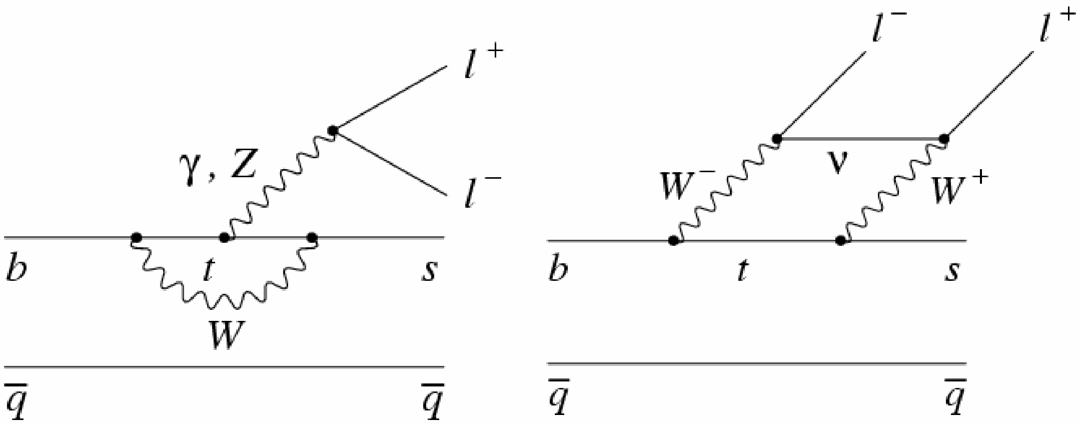
Best: B→η’K^0
2nd best:B→K$^+$K$^-$K^0 (Dalitz)
3rd best:B→ϕK^0



From SLAC-R-709

≈ η’K^0

B→K$^{(*)}$ll



- FCNC, sensitive to NP in loops.
- A_{CP}=0 in SM can get NP enhancement
- $$R_K = \frac{\Gamma(B \to K\mu\mu)}{\Gamma(B \to Kee)} = 1.0000 \pm 0.0001 \text{ (SM)}$$

  $$R_{K^*} = \frac{\Gamma(B \to K^*\mu\mu)}{\Gamma(B \to K^*ee)} \approx 0.75 \text{ to } 1.0 \text{ depending on } q^2 \text{ region (SM)}$$
- $R_{K^{(*)}}$ can be enhanced for Higgs doublet models with large tanβ.
- The forward backward asymmetry has a SM distribution as a function of q^2:

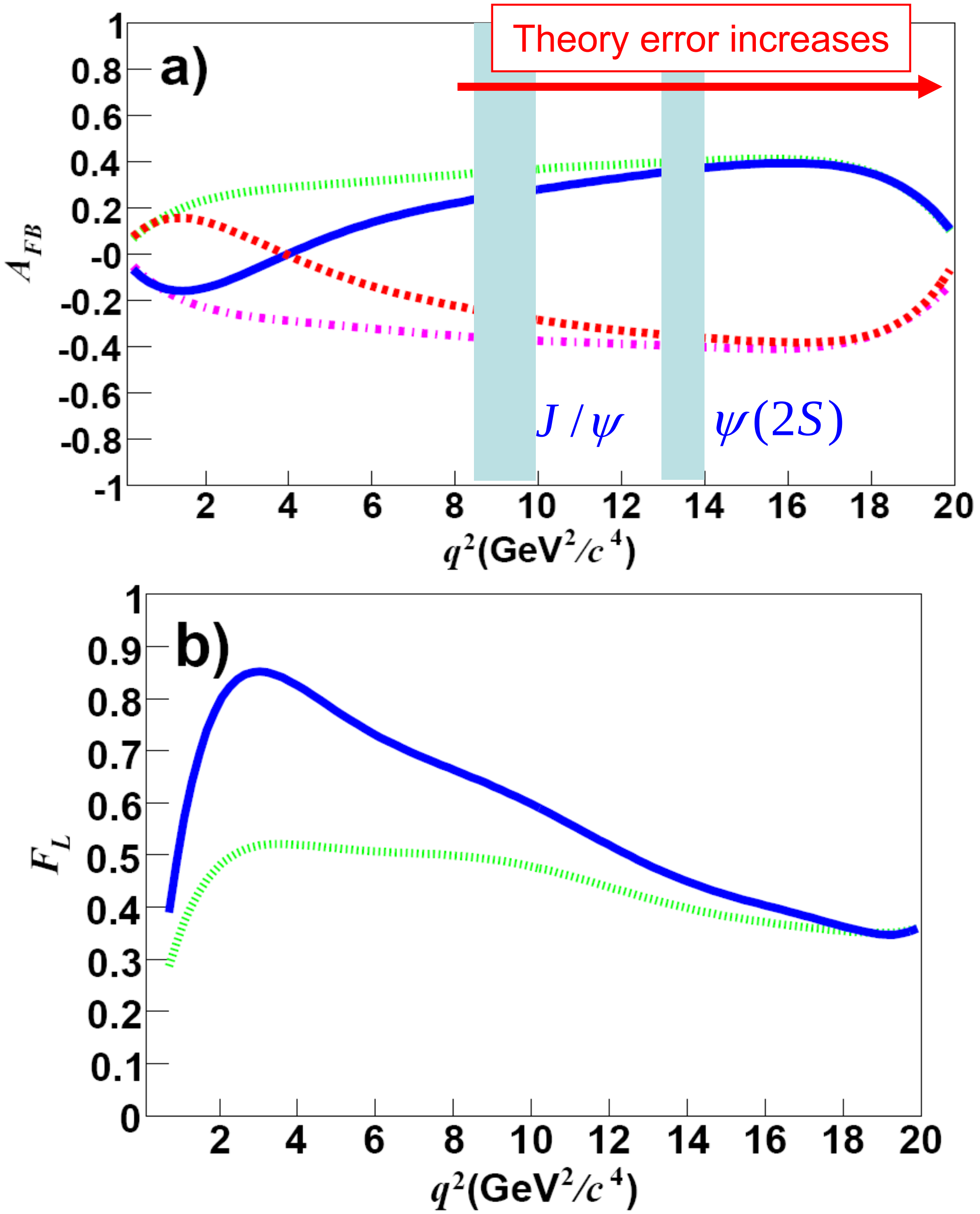
$$A_{FB}(s) \equiv \frac{\int_{-1}^{1} \mathrm{d}\cos\theta \, \frac{\mathrm{d}^2\Gamma(B \to K^{(*)}\ell^+\ell^-)}{\mathrm{d}\cos\theta \, \mathrm{d}s} \mathrm{Sign}(\cos\theta)}{\mathrm{d}\Gamma(B \to K^{(*)}\ell^+\ell^-)/\mathrm{d}s},$$

F. Kruger, et al. PRD**61** 114028 (2000), Erraturm D**63** 019901 (2001); F. Kruger, E. Lunghi PRD **63** 014013 (2001); G. Hiller & F. Kruger PRD**63** 014013 (2001); Q. Yan et al PRD62 094023 (2000). etc.

B→K$^{(*)}$ll

Figures from hep-ex/0604007

- Shape of $A_{FB}(q^2)$ can be used to test SM
  - measure effective parameters related to Wilson coefficients C_i.
- K*ll has $F_L(q^2)$
  - Deviations from SM expectations can signal right handed currents (e.g. lepto-quarks)

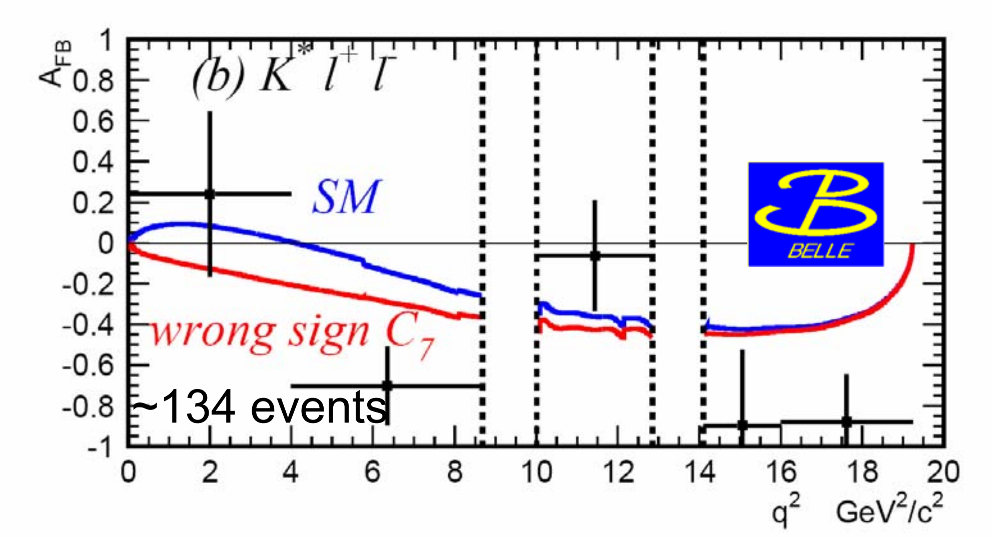

Theory error increases

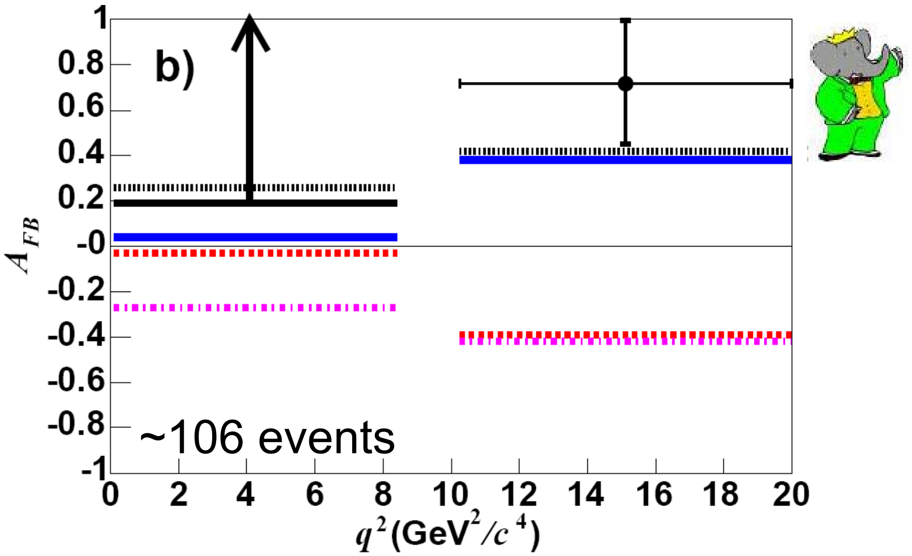
A. Ali et al. PRD**66** 034002 (2002); PRD**61** 074024 (200); F. Kruger & J. Matias PRD71 094009 (2005); S. Davidson et al, Z.Phys C**61** 613 (1994)

$B \to K^{(*)}ll$

hep-ex/0410006
hep-ex/0604007

- First A_{FB} measurements from the B-factories are compatible with SM.

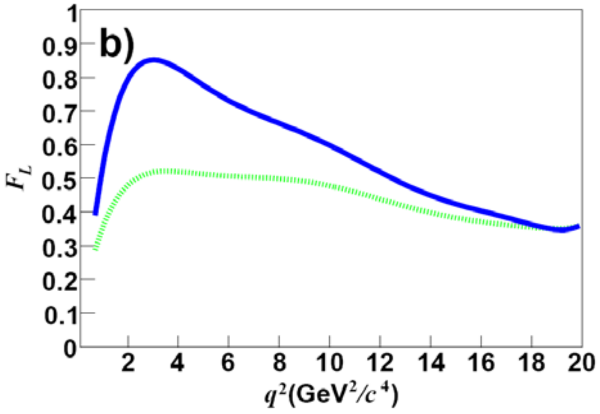


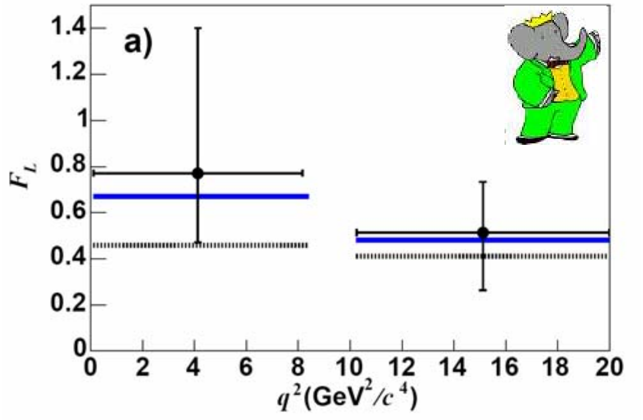


- With a SFF, expect to measure effective parameters related to C_9 and C_{10} to 9% with 50ab^{-1} [can test for complex C_i].

hep-ph/0701046

- Should measure A_{CP} to ~1% with 50ab^{-1}.
- Also measured F_L and need more data to test SM.

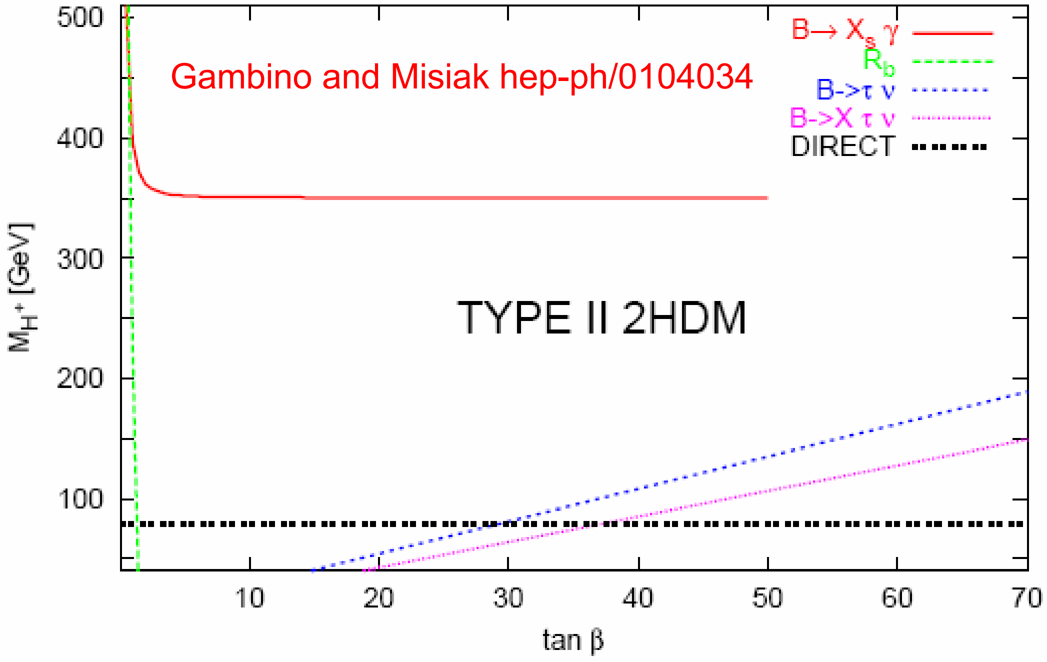




$B \to K^* \gamma$

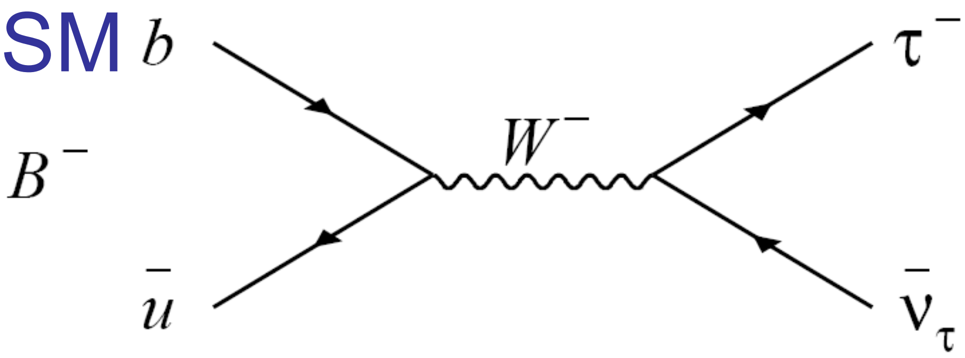
- Physics similar to K*ll (but with an on-shell photon)
- Can be a more stringent constraint than direct searches at colliders: NP signatures
  - rate enhancement.
  - $A_{CP} \neq 0$.
  - Expect precision of 0.3% (0.5%) on $K^*\gamma$ ($X_s\gamma$) at $50ab^{-1}$.

- LHCb expects sub % level precision with $10fb^{-1}$ for A_{CP}
- This trend continues for LHC vs SFF.



$B^+ \to \tau^+ \nu$

- Supressed by V_{ub} in the SM



SM prediction
$(1.59 \pm 0.40) \times 10^{-4}$

$$\mathcal{B}(B^+ \to l^+ \upsilon_l) = \frac{G_F^2 m_B m_l^2}{8\pi}\left(1-\frac{m_l^2}{m_B^2}\right) f_B^2 \, |V_{ub}|^2 \, \tau_B$$

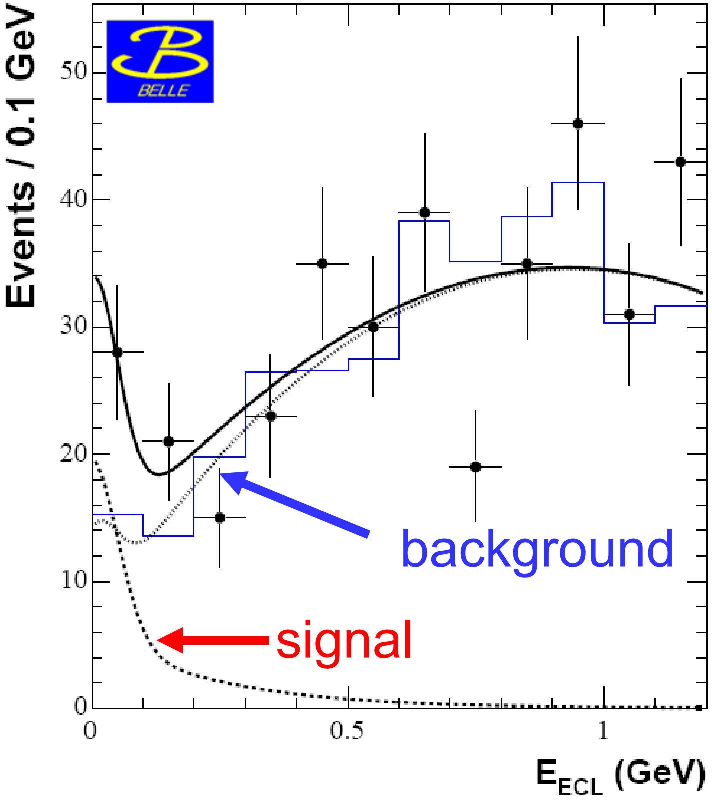
  - Within the SM, this measurement can be used to constrain f_B.
- Can replace W^+ with H^+
  - $\mathcal{B}$ can be suppressed or enhanced by a factor of r_H

$$r_H = \left(1 - \frac{m_B^2}{m_H^2}\tan^2\beta\right)^2$$

2HDM: W.S. Hou, PRD **48**, 2342 (1993).

$B^+\to\tau^+\nu$

- Reconstruct signal decay.
- and other B in the event:
  - Belle: fully reconstructed B mesons in 180 channels,
  - BaBar: Tag with $B\to D^{(*)}l\upsilon$.
- Look at the remaining energy in the calorimeter: signal peaks at $E_{ECL/extra}=0$.



BELLE

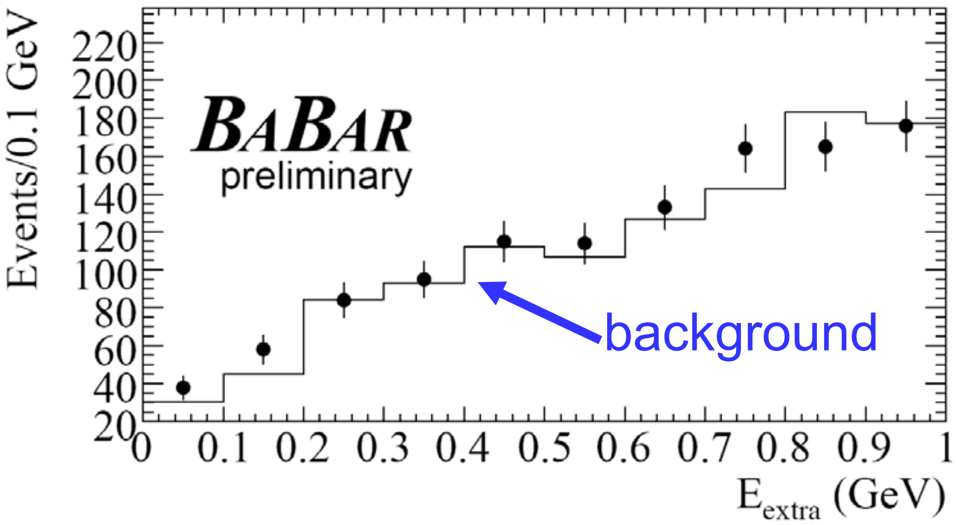
$$\mathcal{B}=(1.79^{+0.56+0.39}_{-0.49-0.46})\times10^{-4}$$

(revised). 3.5 σ significance

BABAR

$$\mathcal{B}=(0.88^{+0.68}_{-0.67}\pm0.11)\times10^{-4}$$

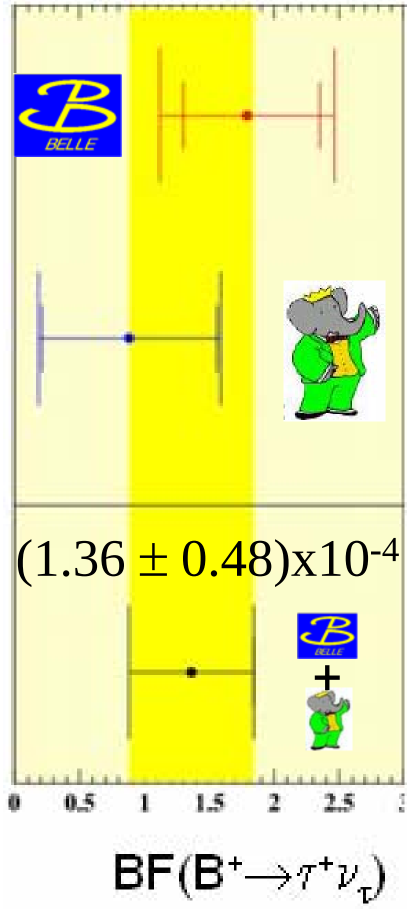
BF<1.80@90%CL

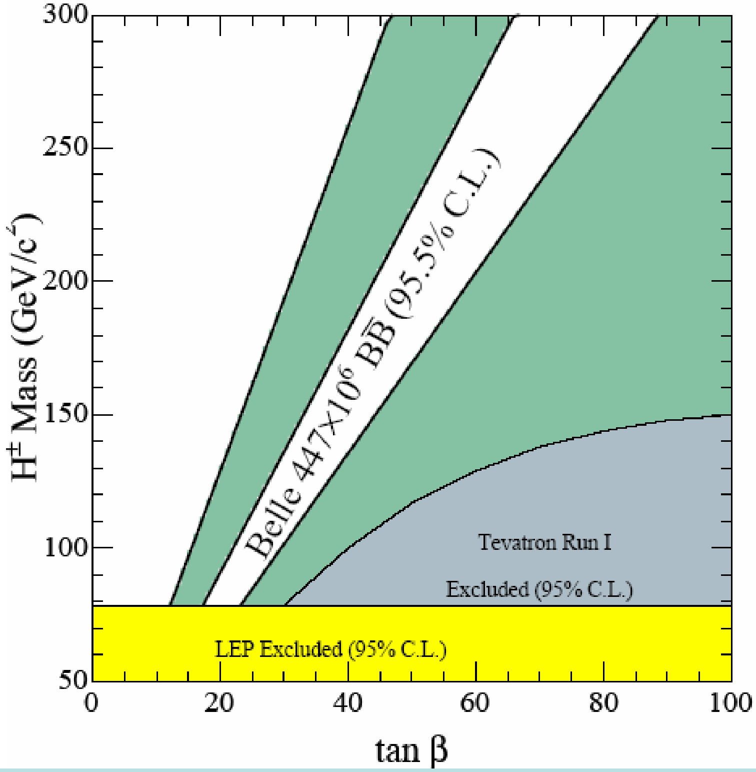


Constraints from $B^+ \to \tau^+ \nu$

e.g. the 2HDM of W.S. Hou, PRD **48**, 2342 (1993).

- SM prediction can be enhanced/reduced by a factor r_H: $r_H = \left(1 - \frac{m_B^2}{m_H^2}\tan^2\beta\right)^2$



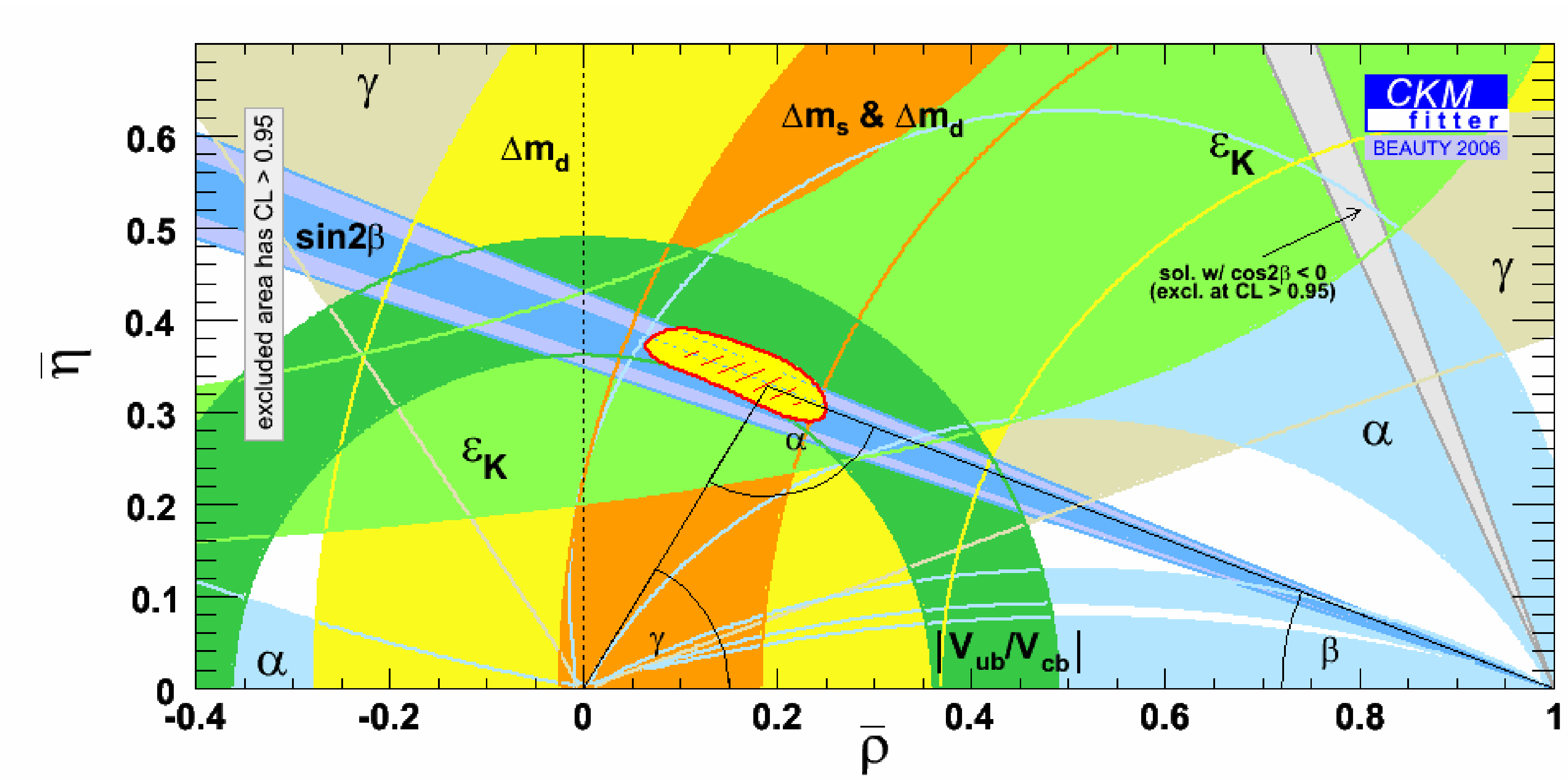


Expect to measure rate to 4% with 50ab^{-1}.

Charm equivalent: $D_s^+ \to \mu^+\nu$, $\tau^+\nu$

Elucidating the CKM mechanism

- With 0.8 ab^{-1} of data (combining both experiments)



Stat of the art in CKM Metrology today

$$\alpha \sim 10^\circ$$

$$\beta \sim 0.7^\circ$$

$$\gamma \sim 10^\circ$$

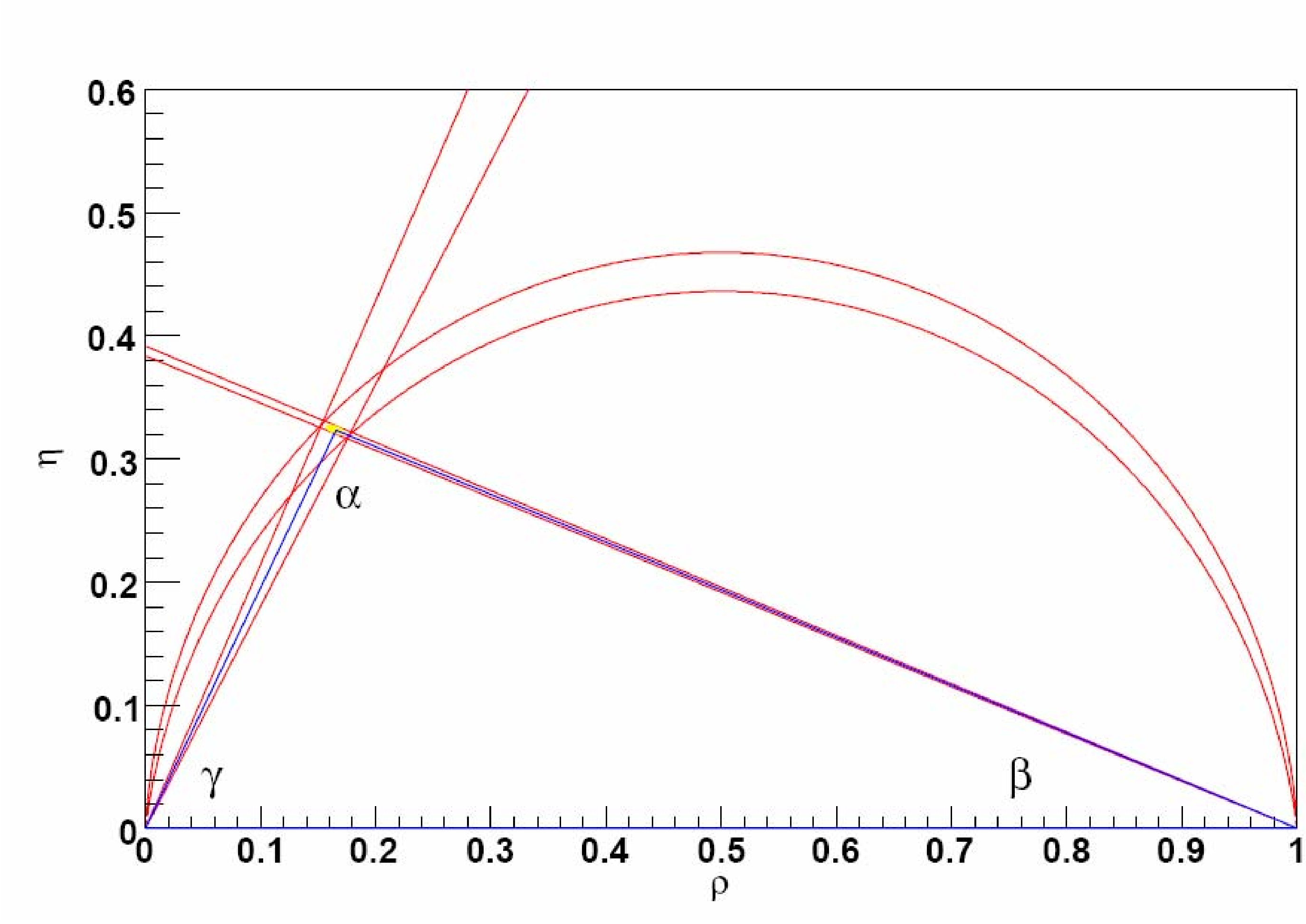
$$\bar{\rho} = 0.195^{+0.022}_{-0.055} \quad (10\text{-}28\%)$$

$$\bar{\eta} = 0.326^{+0.027}_{-0.015} \quad (5\text{-}8\%)$$

All constraints

Elucidating the CKM mechanism

- With 50 ab^{-1} of data we can expect



α Use ππ, ρπ, ρρ

β Use $c\bar{c}s$, assume theory error can be better constrained.

γ Use B→DK, $D^0 \to \pi^+\pi^- K_s$

CKM Metrology with unprecedented precision

$\alpha \sim 1-2^\circ$

$\beta \sim 0.2^\circ$

$\gamma \sim 2^\circ$

$\bar{\rho} = 0.165 \pm 0.009 \quad (5\%)$

$\bar{\eta} = 0.324 \pm 0.004 \quad (1.3\%)$

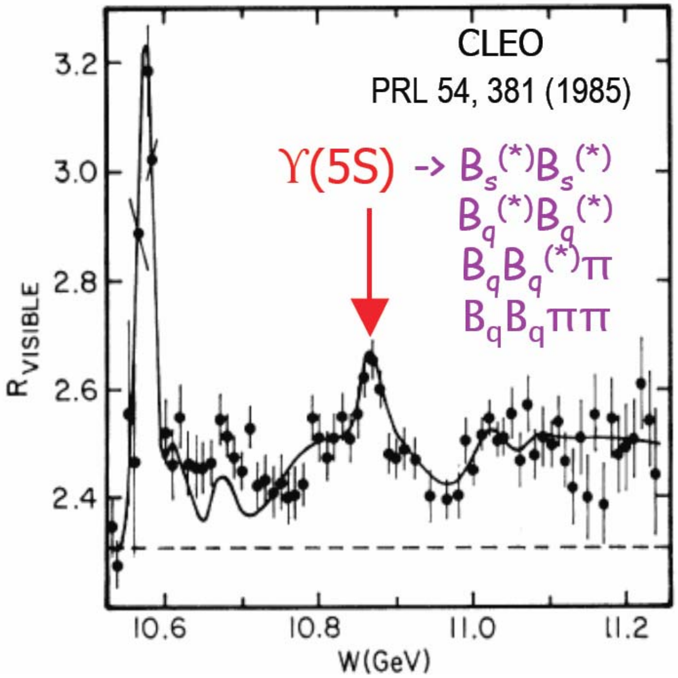
Just angles

	Observable	CKM2008-10 (2ab^{-1})	SuperB (50ab^{-1})	Comments
	$\sin(2\beta)$ ($b \to ccs$)	<1 °	<1°	no improvement
NP	$\sin(2\beta)$ (Peng.) ϕK $(f_0,\eta'\pi^0)K^0$ 3K	 ~4° ~(6,3,5)° ~3°	 <2° ~(2,1,2)° ~1°	Globally could be a factor 5 improvement Theory limited
	α ($\pi\pi,\rho\rho,\rho\pi$)	5° -8°	~1°	Theory limited
	γ (DK)	(5-10)°	(1-2)°	(Tree decays)GLW+ADS+Dalitz **also precisely measured at LHCb**
	V_{cb}-incl V_{cb}-excl	1%-1.5% 4%	0.5? 1%?	More theo. parameters from data Depends on **Lattice**
	$B \to D^*\tau\nu$	10-15%	2-3%	SM -senstitive to NP ($H^\pm$)
	V_{ub}-incl V_{ub}-excl	10% 10%	2%? 2%?	More theo. parameters from data Depends on **Lattice**
	$Br(B \to l\nu)$ $Br(B \to \mu\upsilon)$	20% visible	4% 8%	>5 imprpropement **Lattice** is crucial
NP radiative	$Br(B \to (\rho,\omega),\gamma)$	0.1×10^{-6}	0.03×10^{-6}	$\lvert V_{td}/V_{ts}\rvert$ from $\rho\gamma/K^*\gamma$ dep. **Lattice**
	$Br(B \to \mu\mu)$ $Br(B \to e\mu)$	90%CL @ 1×10^{-8} 90%CL @ 2×10^{-8}	not measurable	Intersting for MFV – at 2ab^{-1} off by two order of magnitude..
	$A_{FB}(X_s l^+l^-)$ -s0 $A_{FB}(K^* l^+l^-)$ –s0 $A_{CP}(K^* l^+l^-)$ at high masses	25% 25% 6% 12%	5% 9% [1-1.5]% 2.5%	**for exclusive modes (and mainly for muons)** **also precisely measured at LHCb**
	$A_{FB}(X_s\gamma)$ $A_{FB}(K^*\gamma)$	[1-2]% 0.65%	[0.5-1]% ~0.3%	Interesting if σ<0.5 (SM) Interesting if σ<0.5 (SM) **Exclusive modes precisely measured @ LHCb**

17th January 2007

From A. Stocchi, CKM WS Dec 2006, Nagoya

Running at Υ(5S)



- $e^+e^- \rightarrow \Upsilon(5S)$ creates mostly $B^*_sB^*_s$.
- Belle have recorded 23.6fb^{-1} at the 5S.
- e.g. $B_s \rightarrow \gamma\gamma$, $\phi\gamma$ are unique probes beyond the SM that are available at a SFF.
- Testing the ratio

$$\frac{BR(B_s \rightarrow K^*\gamma)}{BR(B_s \rightarrow \phi\gamma)} = \frac{V_{td}}{V_{ts}} \frac{1}{\xi^2}$$

SU(3) breaking term from Lattice QCD & sum rules

can constrain new physics in loops.

- Semileptonic decays $B_s^\pm \rightarrow l^\pm X$ can be used to constrain possible new physics.
- Measure $\Delta\Gamma/\Gamma$ using $B_s \rightarrow D_s^{(*)} D_s^{(*)}$ decays. $\Delta\Gamma/\Gamma$ ~O(10%) in the SM.
- + reach of TDCPV measurements under study.

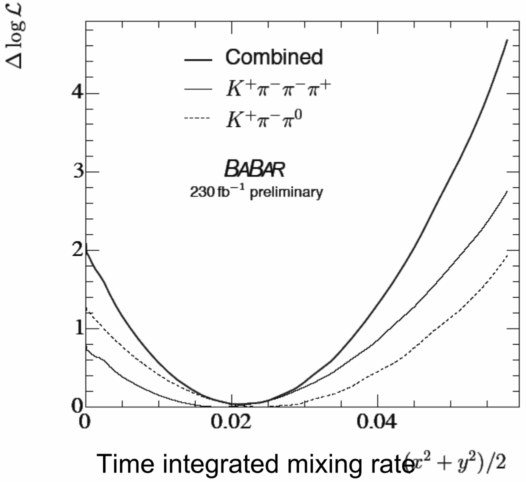
(see proceedings of BNM2006: Pierini, Drutskoy), hep-ex/0608015 & CKM workshop talks from same

Charm physics

e.g. see Bigi, hep-ph/0608225
& Charm talks at Beauty 2006

- Charm sector is unique: only up type quark to give access to the full range of NP effects.
- Provides tools to validate QCD and theoretical tools B-physics studies.
- Search for D⁰-D̄⁰ mixing.
  - Box diagram contribution is small.
  - long distance effects can dominate.

$$x \equiv 2\frac{m_B - m_A}{\Gamma_B + \Gamma_A}, \qquad y \equiv \frac{\Gamma_B - \Gamma_A}{\Gamma_B + \Gamma_A}$$

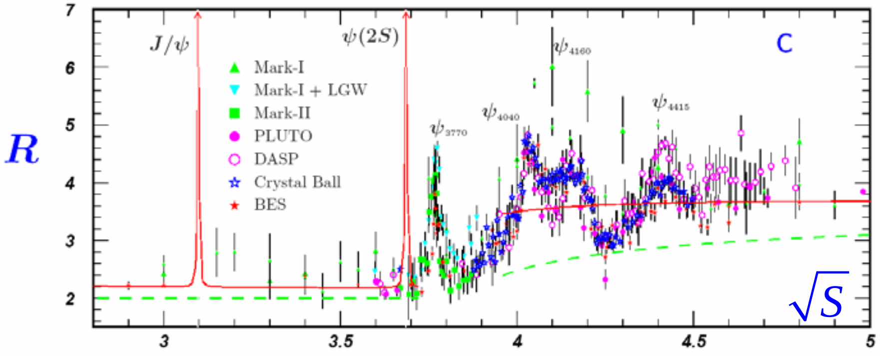


Results consistent with no mixing at 2.1% C.L.

- Search for CPV in D decay.
  - Rich structure in D→PP, PV, VV decays (c.f. B decays).
    - ΔC=1 and ΔC=2 transitions.
    - VV decays sensitive to T-odd triple products and provide windows on the dynamics of the processes involved.
    - Time dependent Dalitz plots needed to fully exploit this area (c.f. $B \to \pi^+\pi^-\pi^0$).
- Charm baryons.
  - Λ_c branching fractions.
- precision R scan.

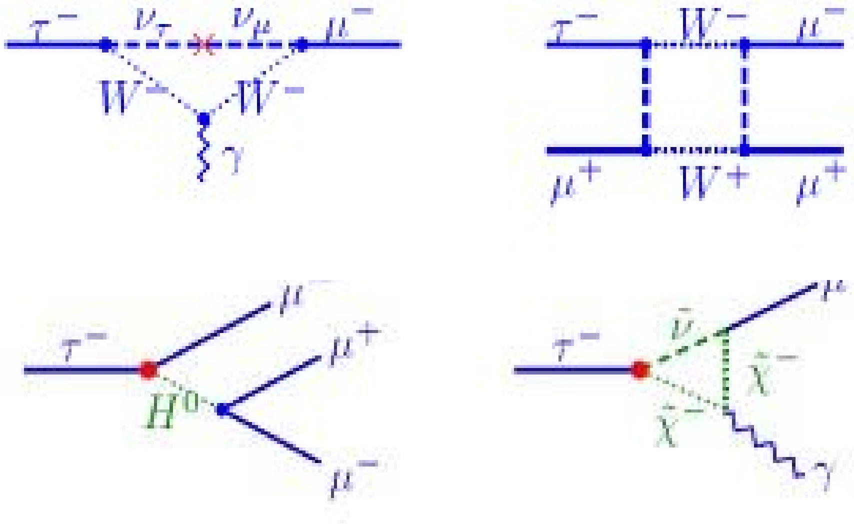
$$R = \frac{\sigma(e^+e^- \to hadrons)}{\sigma(e^+e^- \to \mu^+\mu^-)}$$

- ...



LFV in $\tau \to l\gamma$

- The B-factories are τ factories.
- $\sigma(\tau^+\tau^-)$=0.89 nb at Υ(4S)
- $N_\tau = 1.5 \times 10^9$



90% confidence levels:

$$\mathcal{B}(\tau \to e\gamma) < 12 \times 10^{-8}$$

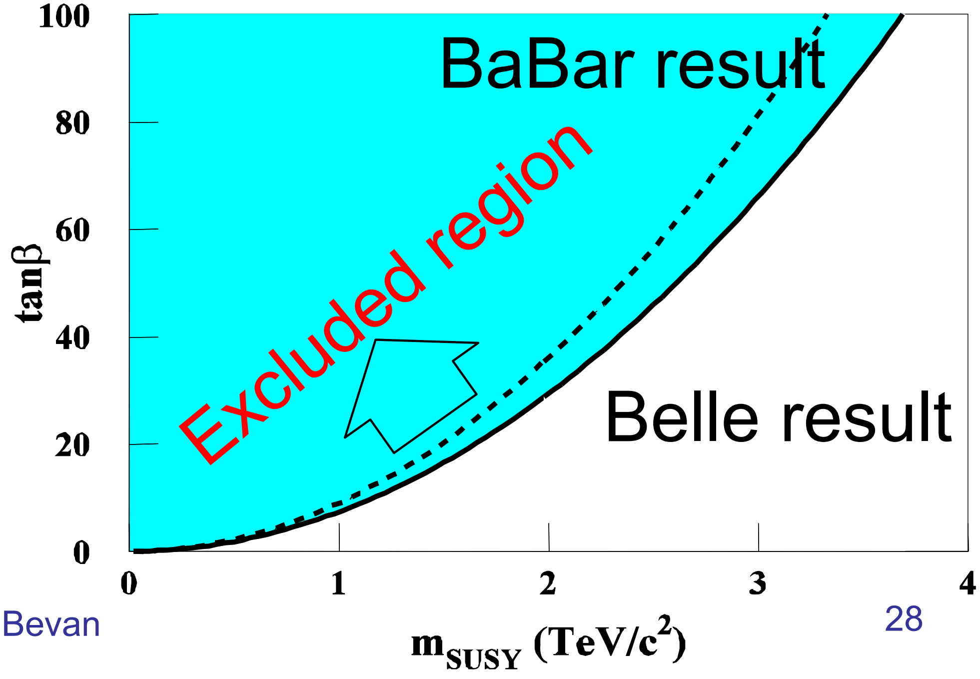
$$\mathcal{B}(\tau \to \mu\gamma) < 4.1 \times 10^{-8}$$

$$\mathcal{B}(\tau \to e\gamma) < 11 \times 10^{-8}$$

$$\mathcal{B}(\tau \to \mu\gamma) < 6.7 \times 10^{-8}$$

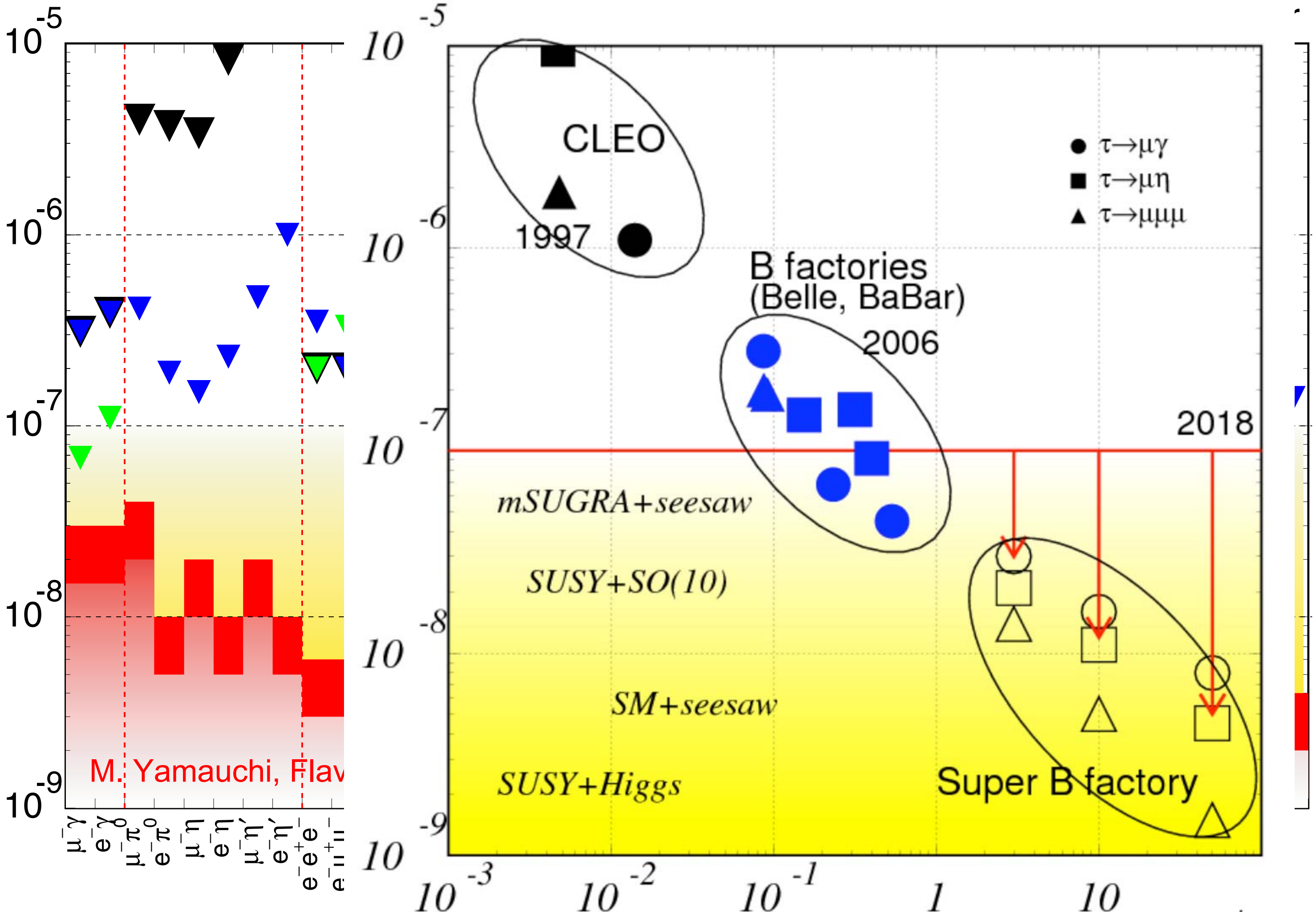
Belle: hep-ex/0609049
BaBar: hep-ex/0508012,
PRL **95** 41802 (2005)

$$Br(\tau \to \mu\gamma) = 3.0 \times 10^{-6} \times \left(\frac{\tan\beta}{60}\right)^2 \times \left(\frac{M_{SUSY}}{1\text{TeV}}\right)^{-4}$$



LFV in τ lepton decay

- Search for LFV with 50 fold increase in statistics at a SFF.
- SUSY breaking at low energies should result in large FCNC [e.g. τ→μγ, μ→eγ].



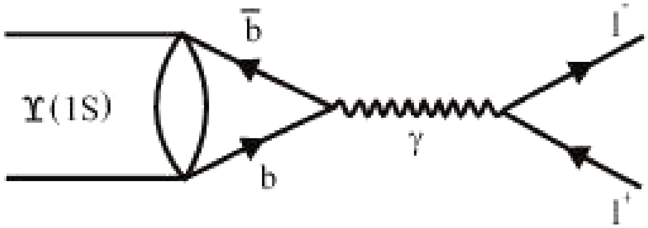
Current Best Limit

New Physics ?

SFF sensitivity @ $10ab^{-1}$

Test Lepton Universality

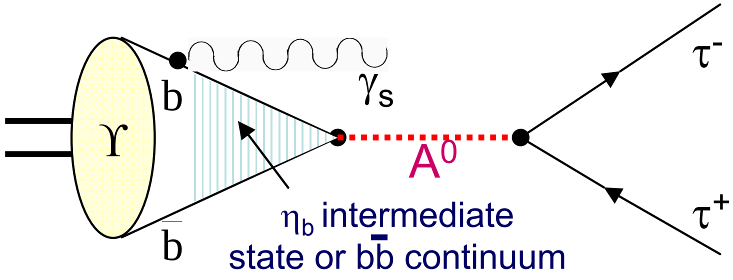
- Use Y(3S) decays to test lepton universality



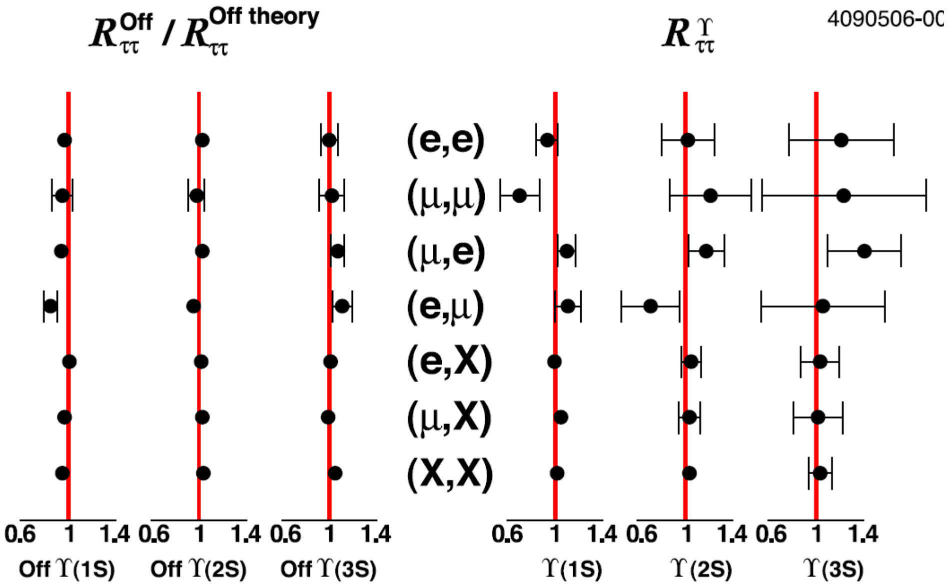
$$R_{\tau/\ell} = \frac{\Gamma_{\Upsilon(nS)\to\gamma_s\tau\tau}}{\Gamma^{(em)}_{\ell\ell}} = \frac{B_{\tau\tau}-B_{\ell\ell}}{B_{\ell\ell}} = \frac{B_{\tau\tau}}{B_{\ell\ell}} - 1$$

= 0 if lepton universality holds

- Light H and H doublets can break universality.



- Current experimental data is from CLEO: CLEO: hep-ex/0607019

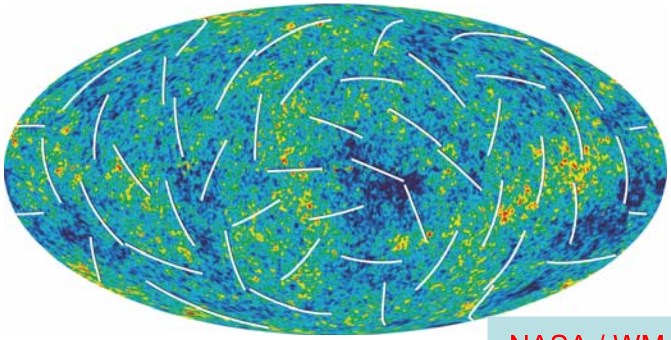


- The data are consistent at a level of 2.6σ with LU.
- Precision of this test is O(10%).
- SFF could easily perform a precision test of LU.
- Need to understand when this becomes systematically limited.

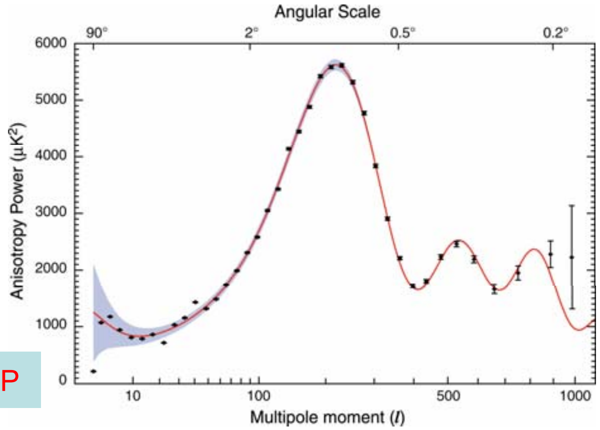
M. A. Sanchis-Lozano, hep-ph/0610046, hep-ph/0510374, Int. J. Mod. Phys. A19 (2004) 2183

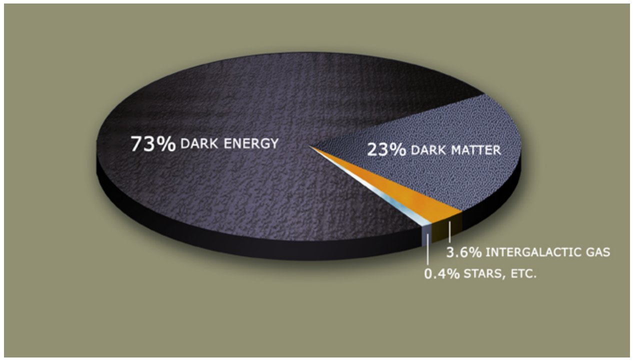
Study Dark Matter

- Dark matter consitutes ~1/4 of of the energy in the universe:



NASA / WMAP





- Most models have a SM-dark matter interaction that can be probed by experiment:

$$\begin{array}{rl} \Upsilon \to invisible & J/\Psi \to invisible \\ \eta \to invisible & \Upsilon \to \gamma + invisible \\ B^+ \to K^+ + invisible & \Upsilon \to \gamma A_1, A_1 \to \tau^+\tau^- \\ K^+ \to \pi^+ + invisible & J/\Psi \to \gamma A_1 \end{array}$$

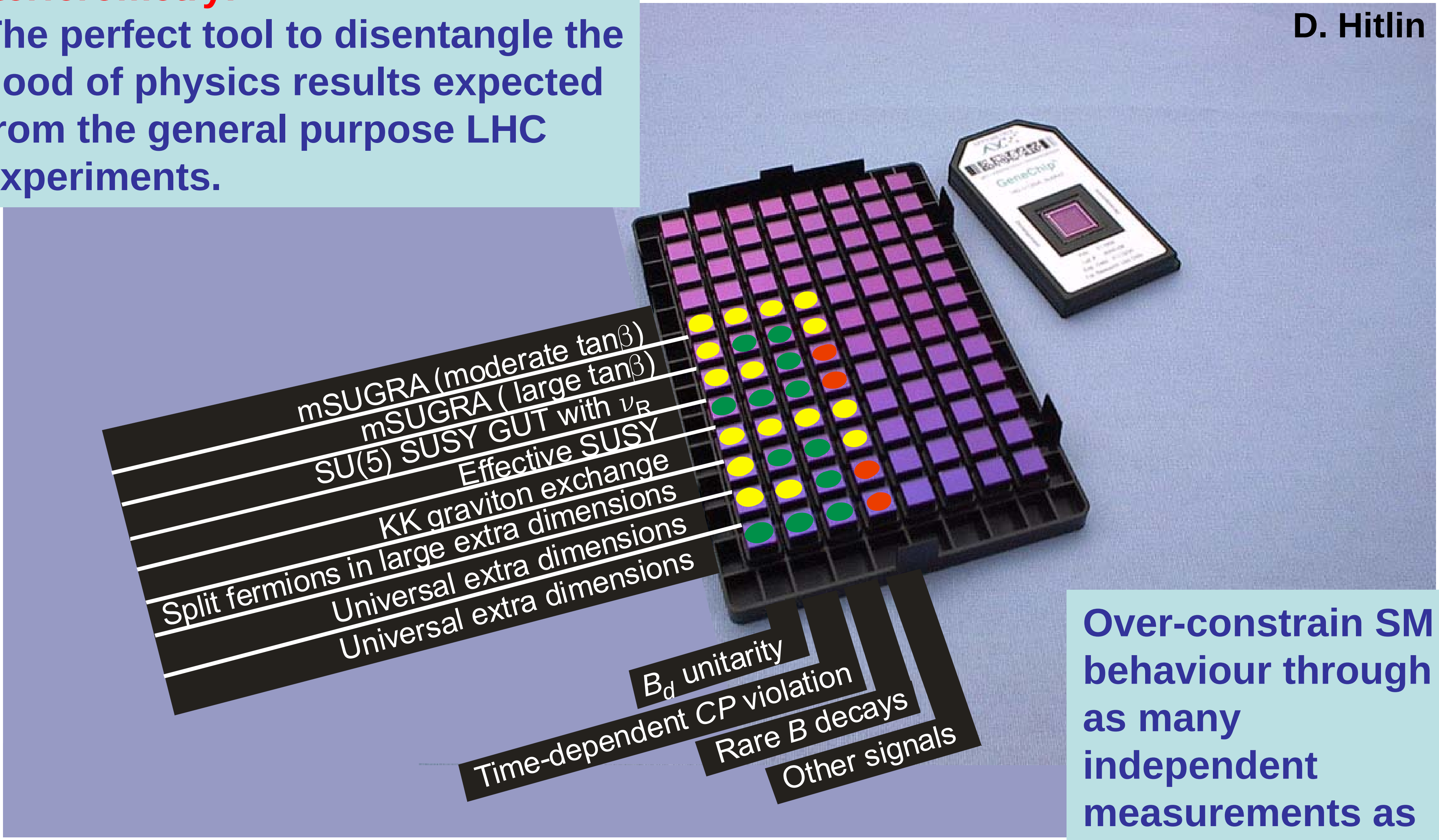
hep-ph/0506151, hep-ph/0509024, hep-ph/0401195, hep-ph/0601090, hep-ph/0509024, hep-ex/0403036 ...

- Use radiative return to the Υ(3S) to gain stats.

Demystifying new physics scenarios

Interferometry:

The perfect tool to disentangle the flood of physics results expected from the general purpose LHC experiments.

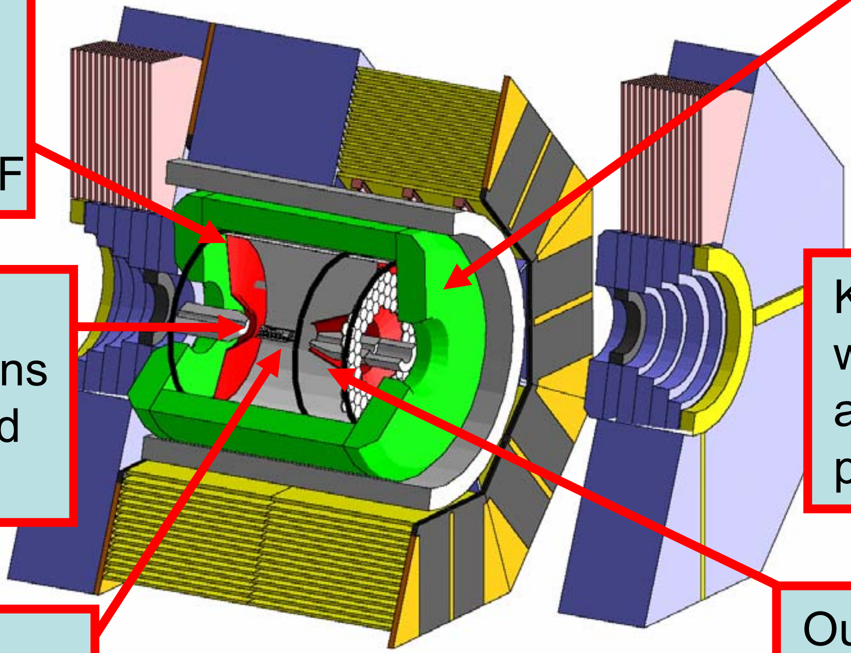


D. Hitlin

Over-constrain SM behaviour through as many independent measurements as possible in order to elucidate NP.

Detector Concepts I

- Detector technology research ongoing.
- Need to improve upon Belle and BaBar to operate at the higher occupancy environment of a 10^{36} machine.
- Several viable technologies to choose from.
- Possibility to get more efficient PID detector than at Babar.



PID:
Super DIRC
AEROGEL Rich
Combine RICH with TOF

Beam pipe:
Smaller beam pipe, means tracking closer to IP, and better S/N.

Si:
Inner pixel detector surrounding a small radius beam pipe needs R&D.

Fast calorimetry:
LSO
Pure CsI end-cap
(reuse CsI(Tl) barrel)

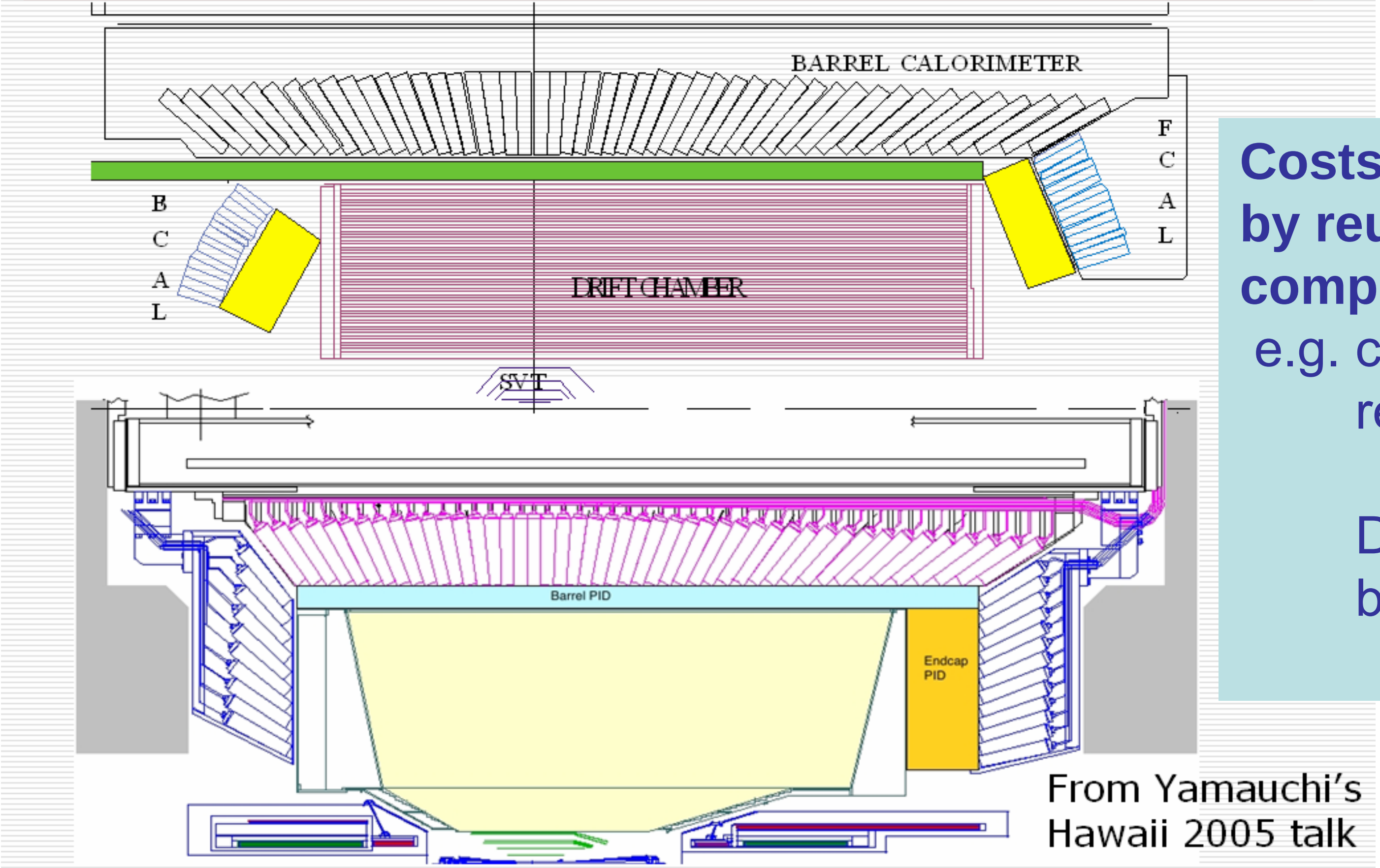
K_L/μ detection:
with scintillator
and new generation
photon sensors

Outer tracker:
Thin silicon wafers
Small cell tracking detector

Detector Concepts II

- Some R&D required e.g. doing pixel R&D now, but most technologies are already proven.

Comparison – *BABAR* and Belle for *SuperB*



From Yamauchi's Hawaii 2005 talk

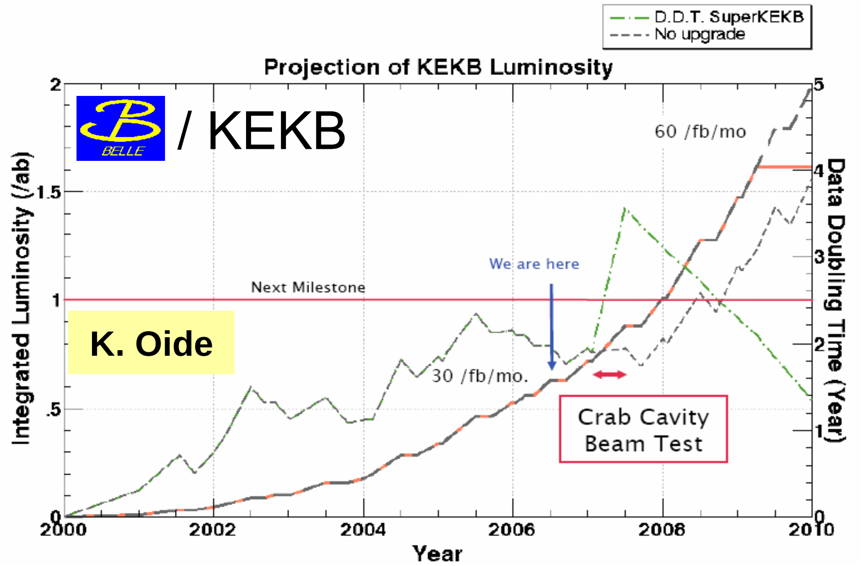
Costs can be kept down by reusing some existing components:

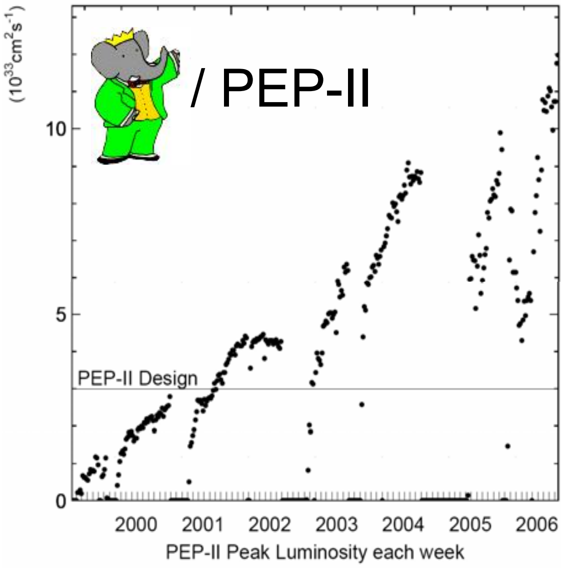
e.g. calorimeter barrel will be reused.

DIRC quartz bars can be re-used

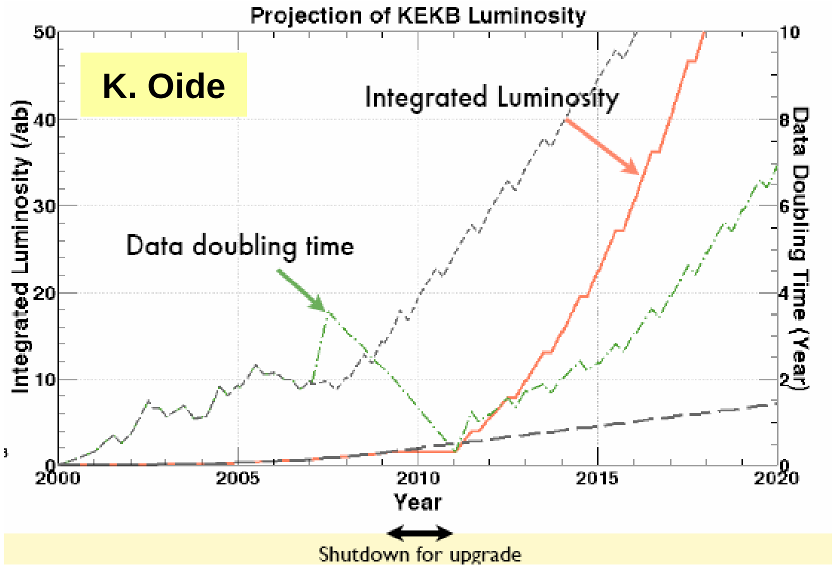
B-factory Performance

- Both B-factories continue to increase their peak luminosity delivered and have reliable integrated luminosity predictions.


K. Oide



- Belle and BaBar now have a combined total integrated luminosity in excess of 1ab^{-1}.
- A next generation machine aims to integrate at least 50ab^{-1} on a timescale interesting for physics.

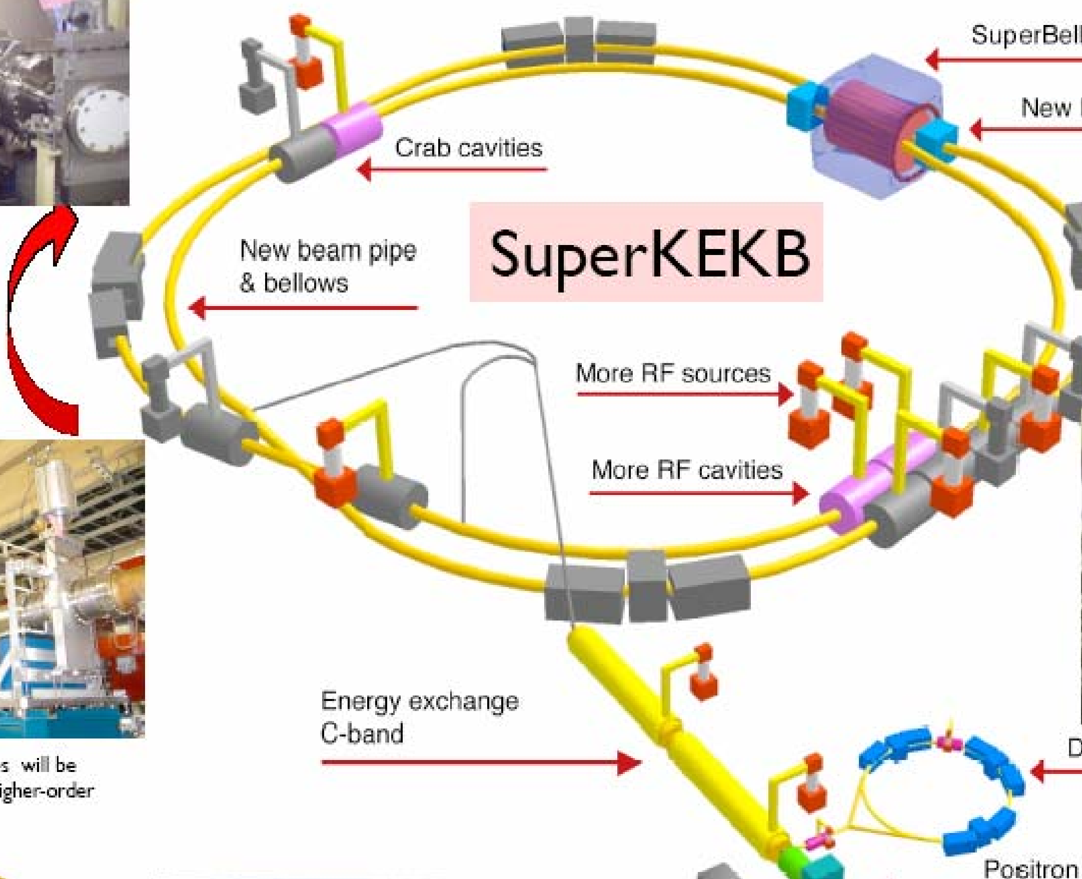

K. Oide

Super KEK-B: Overview

K. Oide

Crab cavities will be installed and tested with beam in 2006.

e+ 4.1 A

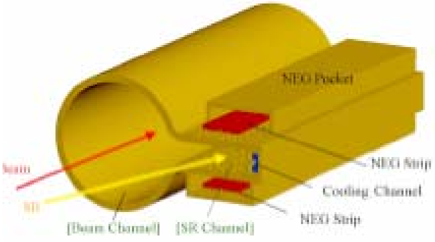


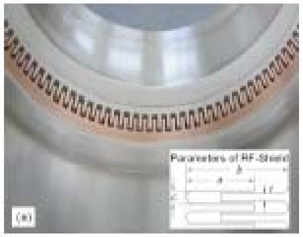
$\beta^*_y = \sigma_z = 3$ mm

e- 9.4 A

The state-of-art ARES copper cavities will be upgraded with higher energy storage ratio to support higher current.

The superconducting cavities will be upgraded to absorb more higher-order mode power up to 50 kW.





The beam pipes and all vacuum components will be replaced with higher-current-proof design.

$$L = \frac{\gamma_{\pm}}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\boxed{\frac{I_{\pm}\xi_{\pm y}}{\beta_y^*}}\left(\frac{R_L}{R_y}\right)$$

will reach 8 × 10^{35} cm^{-2}s^{-1}.

Super KEKB: Luminosity predictions

- The luminosity is given by:

$$L = \underbrace{\frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)}\underbrace{\left(\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\right)}\underbrace{\left(\frac{R_L}{R_y}\right)}$$

Lorentz factor, classical e± radius and ratio of beam sizes

Beam current: I
beam-beam parameter: ξ
vertical β function at IP

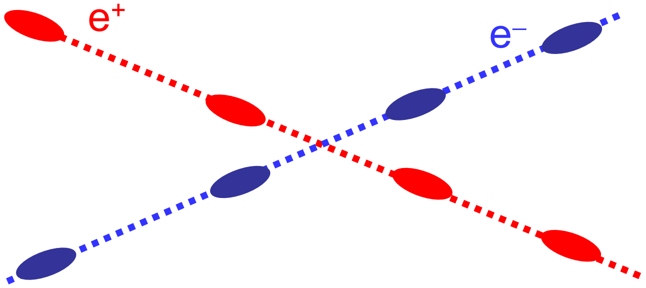
Reduction factor from crossing angle and the hourglass effect

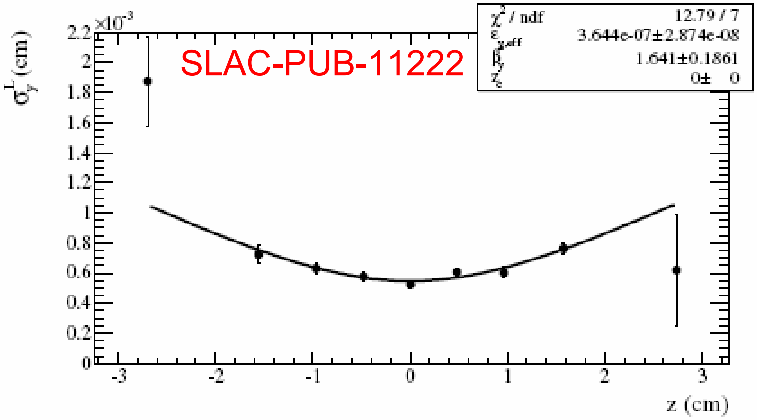
The beam beam parameter ξ is the result of a transverse kick of an incoming e⁺ bunch against an outgoing e⁻ bunch.

$$\varepsilon = \sigma\sigma'$$

$$\beta = \sigma / \sigma'$$

Where σ is the beam spread and σ' is the angular divergence



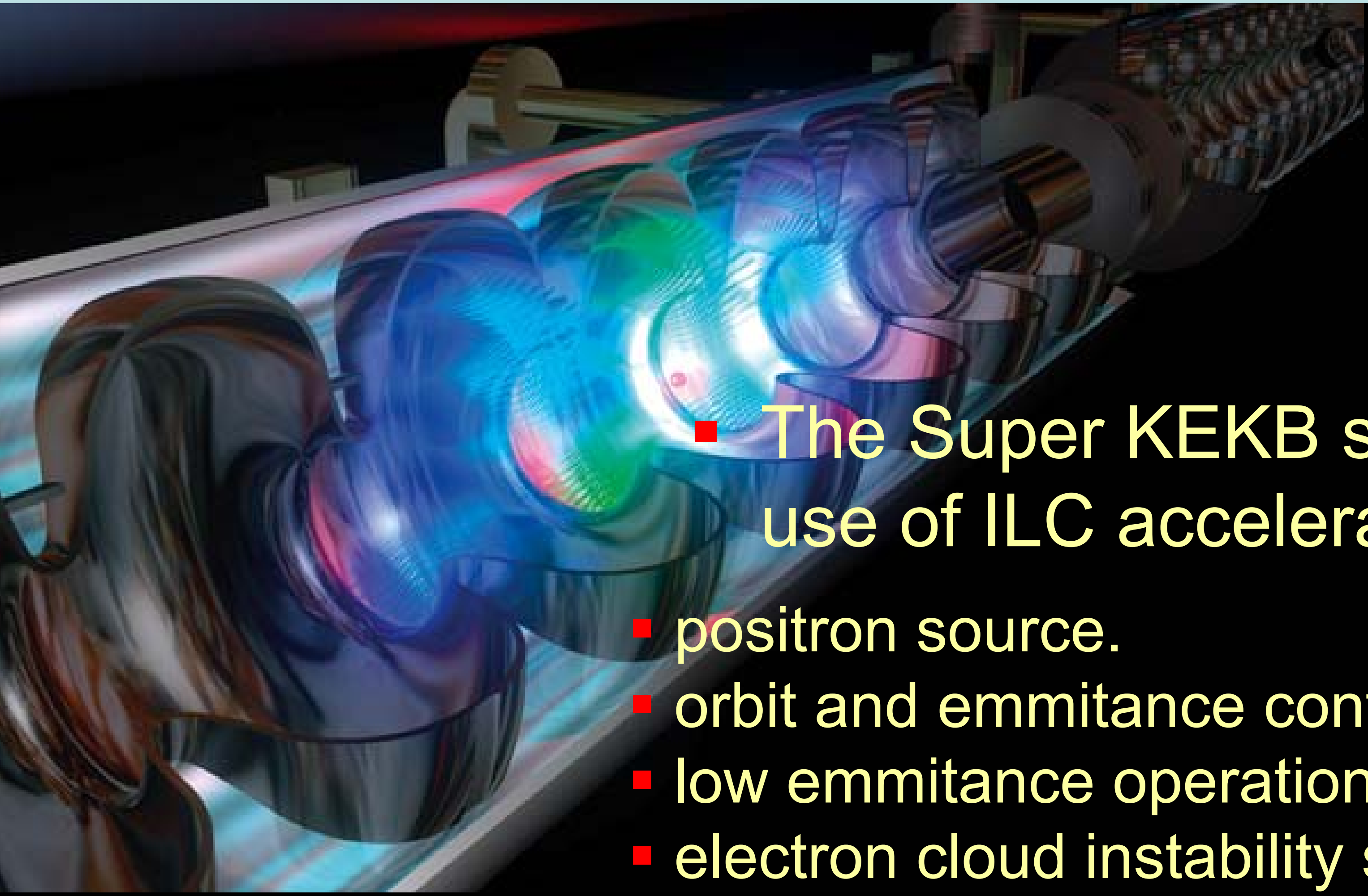

SLAC-PUB-11222

SLAC-PUB-8699

The hourglass effect leads to ~6% luminosity reduction for PEP-II

- The solution to gain a factor of 100 in luminosity at Super KEKB comes from $\frac{I_\pm \xi_{\pm y}}{\beta_y^*}$.

Synergy with ILC R&D



- The Super KEKB scheme makes use of ILC accelerator R&D

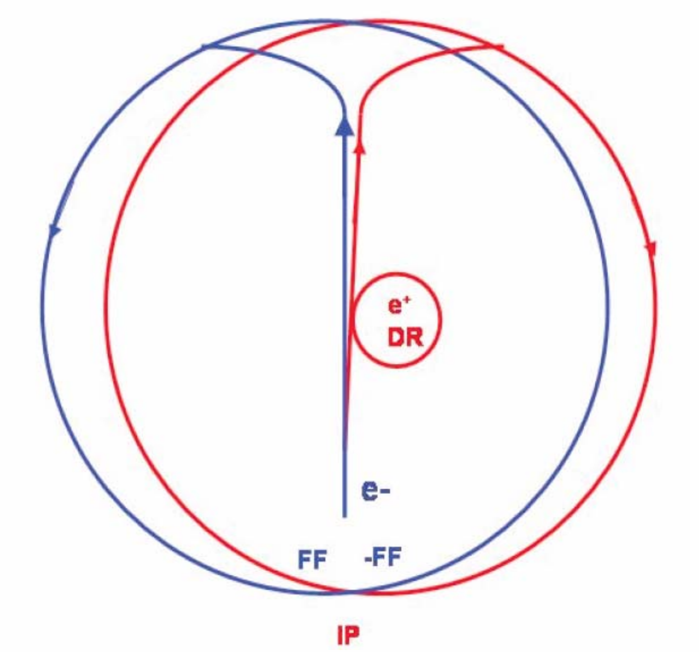
- positron source.
- orbit and emmitance control in linac.
- low emmitance operation of LER.
- electron cloud instability studies.
- effect of wiggler.
- development of ring RF system with ILC specs and klystrons for the ring.
- next generation bunch-by-bunch feedback.
- detector component R&D.

Image courtesy of interactions.org
An ILC image of the field within superconducting RF cavities.

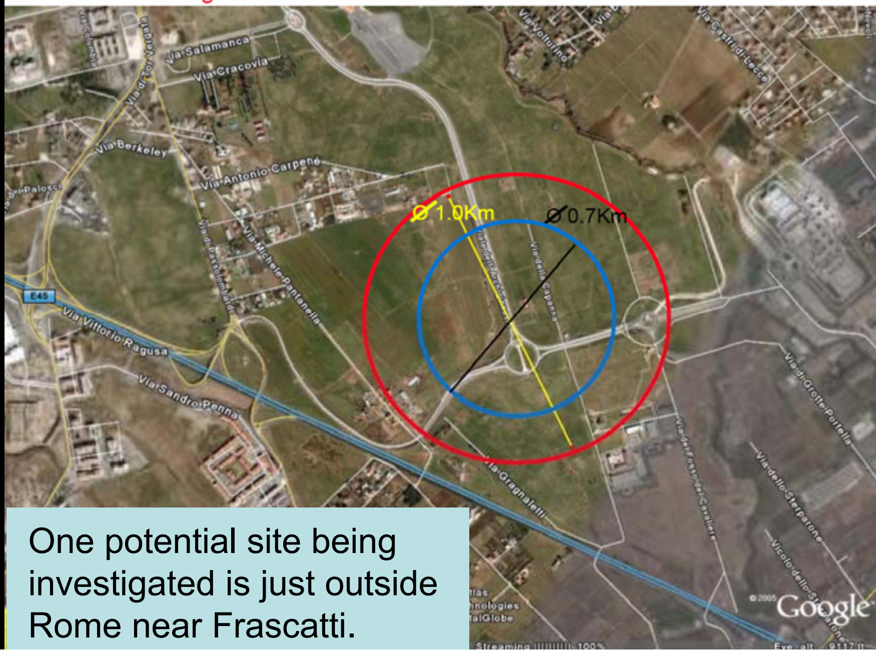
List taken from a talk by K. Oide

“ILC inspired design” collider

- Rapidly evolved through several configurations from PEP-II through to the current design.
- Low emmitance operation to push up luminosity.
- ILC like final focus.
- Don’t need strong damping.
- ILC technology for the storage rings.
- Site independent design.



Tor Vergata site between 3.0 Km and 2.2 Km



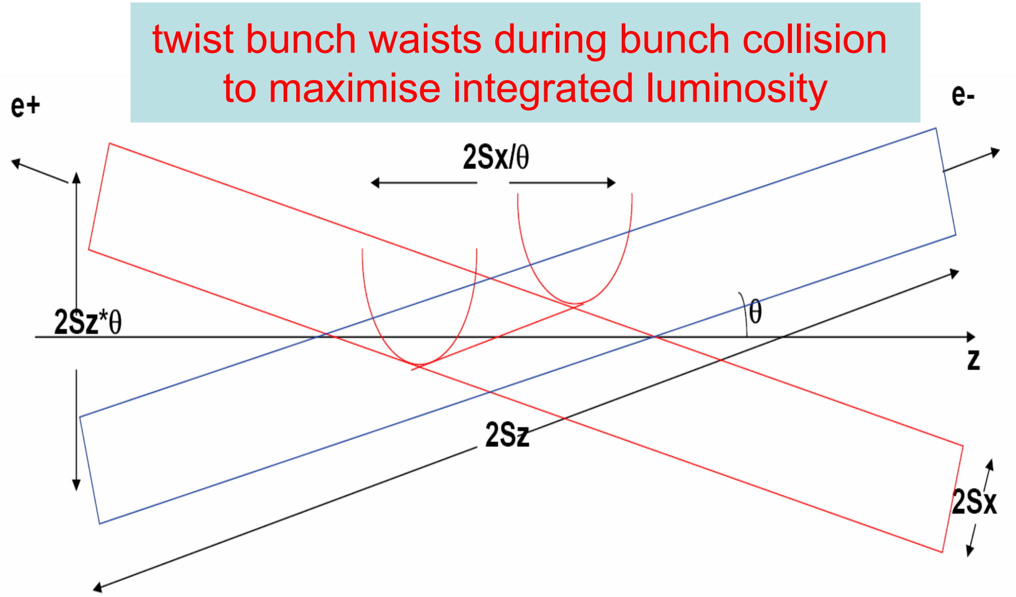
One potential site being investigated is just outside Rome near Frascatti.

Image courtesy of interactions.org
An ILC image of the field within superconducting RF cavities.

Luminosity goal of the accelerator

- Target is to reach 1×10^{36} cm^2s^{-1}.
- Novel ideas are being used to improve the design performance
- Can obtain few $\times10^{36}$ cm^2s^{-1}.
- e.g. Crabbed waist to maximise overlap of the colliding bunches.

Parameter	Super KEKB	Linear Inspired
ε_x (nm)	9.0	0.8
ε_y (nm)	0.045	0.002
β_x (mm)	200.0	20.0
β_y (mm)	3.0	0.2
σ_z (mm)	3.0	7.0
I (e^-) A	9.4	2.5
I (e^+) A	4.1	1.4
lumi (10^36 $cm^{-2}s^{-1}$)	0.8	1.0
2θ (mrad)	15	30.0


twist bunch waists during bunch collision to maximise integrated luminosity

- Both designs are expected to deliver a luminosity of $\sim10^{36}$ $cm^{-2}s^{-1}$.
- This will deliver
  - 1.25×10^{10} $B\overline{B}$ per year,
  - 1.0×10^{10} $\tau^+\tau^-$ per year.
- Total data sample $\times50$ improvement over current generation of e^+e^- experiments.

Complimentarity with existing experiments

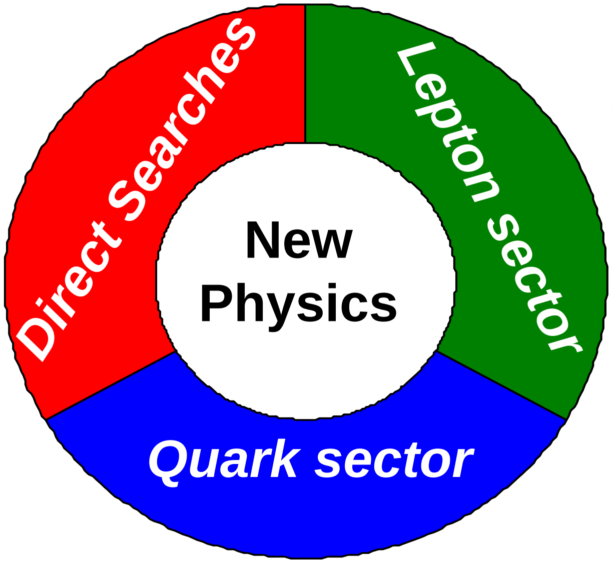
- A crucial part of a unified effort to understand new physics!

LHC, ILC

Higgs boson mass and couplings. New particle searches

ν experiments, g_μ-2, $\mu \rightarrow e\gamma$, etc.

ν mass hierarchy and mixing, CPV, and LFV



τ LFV,
τ CPV,
lepton universality

Flavor mixing,
CPV phases,
CPT

Only the SFF delivers all of this!

Many measurments are complamantary to LHCb

Super Flavor Factory,
LHC-b, Rare K experiments, BESIII…

Next steps

- ILC inspired design:
  - Finalise CDR for INFN. Will be completed by the end of the year and submitted Feb 07.
- Super KEK B design:
  - Finalise update of LOI on the same timescale.
- Most recent workshops:
  - 13th-15th November, Monte Porzio Catone, Italy.
  - 18th-19th December, Nara, Japan.
- Converge on a single proposal for the SFF.

Villa Mondragone
Monte Porzio Catone - Italy
13 - 15 November 2006

UK Involvement

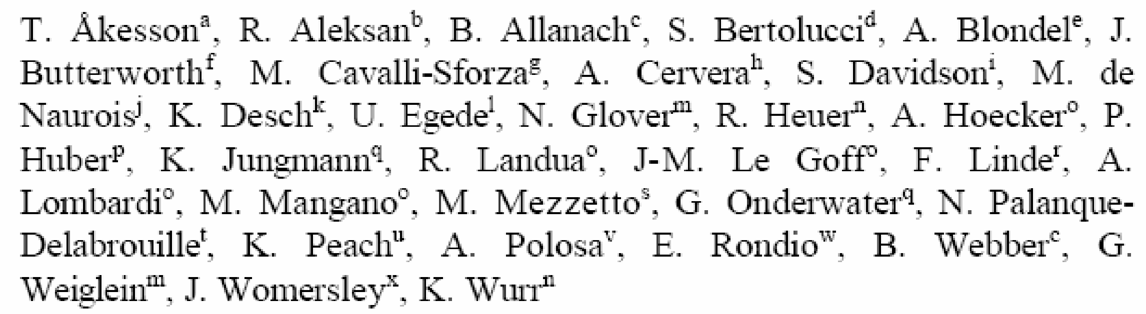
- Longstanding interest in UK’s BaBar community.
  - Developments over the last few years have taken interest above critical mass.
- Recently submitted a proposal to PPARC for PRD funding toward travel, physics studies, 1 FTE of accelerator and detector R&D for a SFF.
- 8 UK institutes involved
  - ***Brunel, Cockcroft Institute, Edinburgh, Liverpool, Manchester, RAL, QMUL and Warwick.***
- Contacts:
  - A.B. (Physics WP)
  - T. Gershon (overall)
  - S. Playfer (Detector WP)
  - A. Wolski (Accelerator WP)

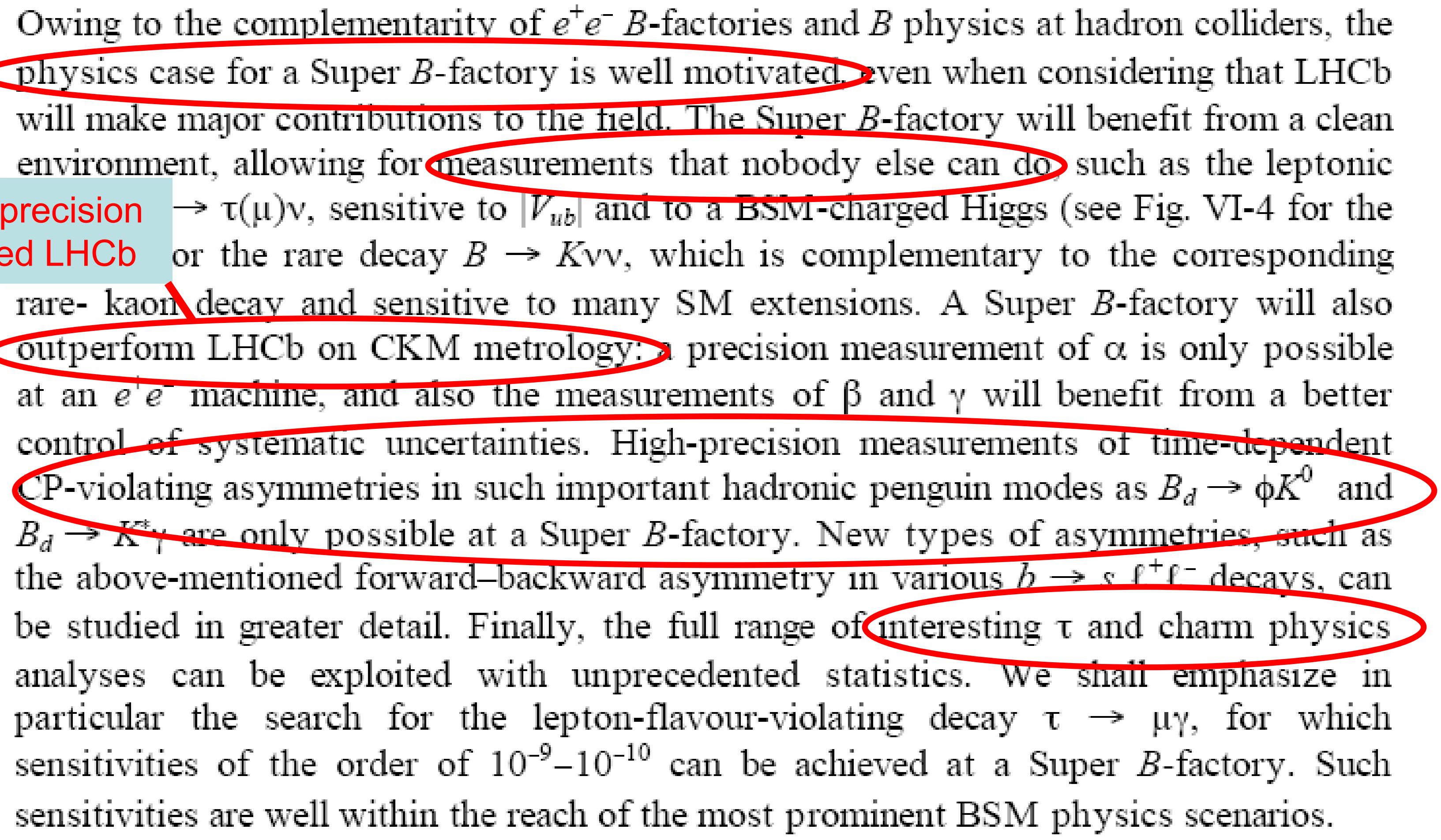
Case for a Super Flavor Factory

- Precision understanding of SM processes.
- Can over-constrain NP models with many independent measurements (ΔS + rare decays).
  - This is not a NP direct discovery machine → LHC does that.
  - % level tests for NP at 50ab^{-1} (test MFV etc.)
- LFV/CPV searches in τ decays to interesting levels to exclude (or confirm one of) several models.
- Ancillary measurements
  - Search for mixing, CPV and NP in D decays.
  - Test lepton universality at the Υ(3S).
  - Improve constraints on CPT in correlated $P^0\overline{P}^0$ systems.
    - Larger data sets may be used to remove systematic limitations.
  - Update measurements of R for g-2, sinθ_W, search for DM and much *much* more!

Towards the European Strategy for Particle Physics: The Briefing Book

hep-ph/0609216


T. Åkesson[a], R. Aleksan[b], B. Allanach[c], S. Bertolucci[d], A. Blondel[e], J. Butterworth[f], M. Cavalli-Sforza[g], A. Cervera[h], S. Davidson[i], M. de Naurois[j], K. Desch[k], U. Egede[l], N. Glover[m], R. Heuer[n], A. Hoecker[o], P. Huber[p], K. Jungmann[q], R. Landua[o], J-M. Le Goff[o], F. Linde[r], A. Lombardi[o], M. Mangano[o], M. Mezzetto[s], G. Onderwater[q], N. Palanque-Delabrouille[t], K. Peach[u], A. Polosa[v], E. Rondio[w], B. Webber[c], G. Weiglein[m], J. Womersley[x], K. Wurr[n]

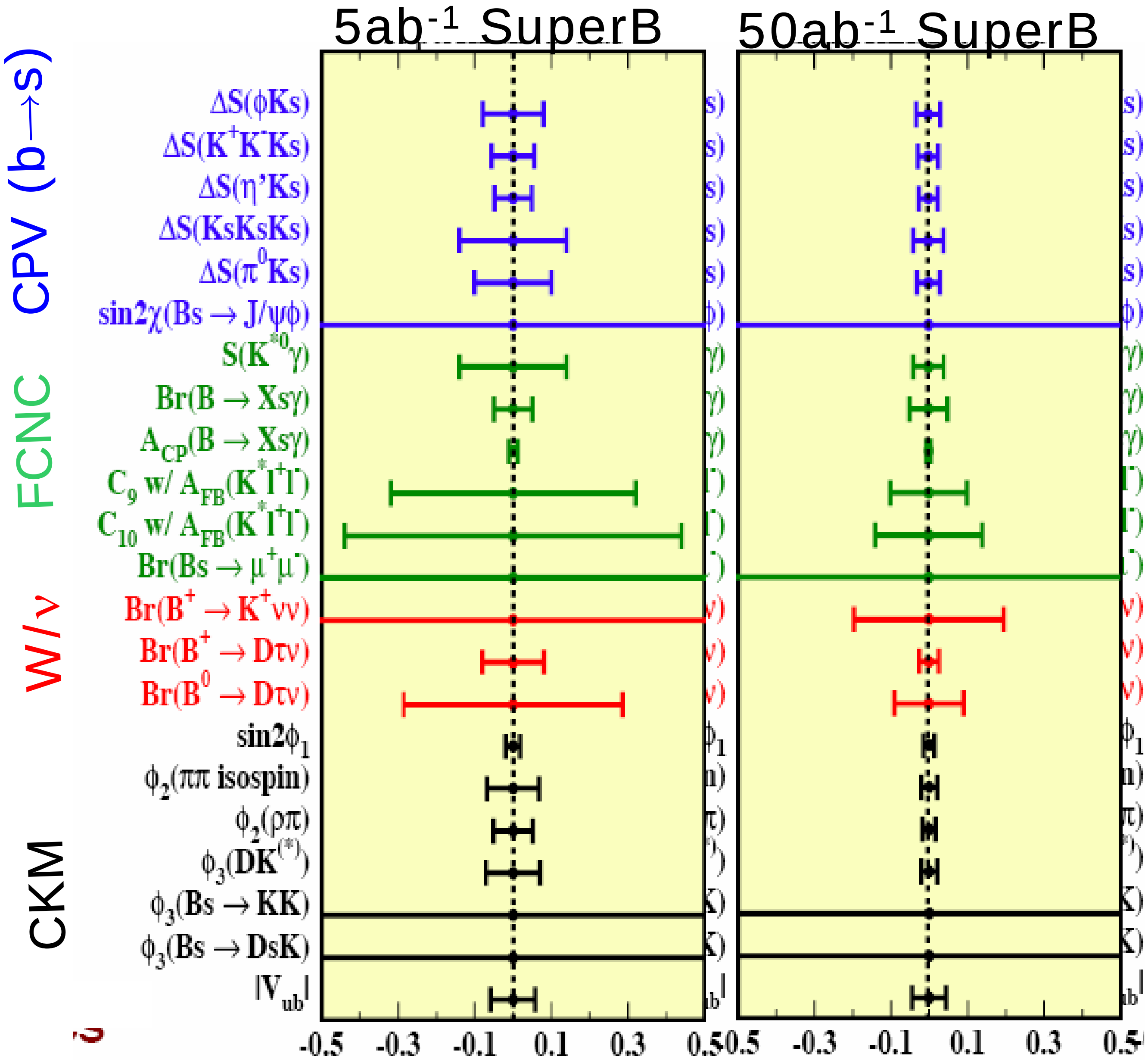

Owing to the complementarity of e^+e^- B-factories and B physics at hadron colliders, the physics case for a Super B-factory is well motivated, even when considering that LHCb will make major contributions to the field. The Super B-factory will benefit from a clean environment, allowing for measurements that nobody else can do, such as the leptonic $\rightarrow \tau(\mu)\nu$, sensitive to $|V_{ub}|$ and to a BSM-charged Higgs (see Fig. VI-4 for the or the rare decay $B \rightarrow K\nu\nu$, which is complementary to the corresponding rare- kaon decay and sensitive to many SM extensions. A Super B-factory will also outperform LHCb on CKM metrology: a precision measurement of α is only possible at an e^+e^- machine, and also the measurements of β and γ will benefit from a better control of systematic uncertainties. High-precision measurements of time-dependent CP-violating asymmetries in such important hadronic penguin modes as $B_d \rightarrow \phi K^0$ and $B_d \rightarrow K^*\gamma$ are only possible at a Super B-factory. New types of asymmetries, such as the above-mentioned forward–backward asymmetry in various $b \rightarrow s\,\ell^+\ell^-$ decays, can be studied in greater detail. Finally, the full range of interesting τ and charm physics analyses can be exploited with unprecedented statistics. We shall emphasize in particular the search for the lepton-flavour-violating decay $\tau \rightarrow \mu\gamma$, for which sensitivities of the order of 10^{-9}–10^{-10} can be achieved at a Super B-factory. Such sensitivities are well within the reach of the most prominent BSM physics scenarios.

Comparable precision to an upgraded LHCb

Additional material

Projected Sensitivities

Projections from
F. Forti, CERN WS
October 2006



The SFF gives the best NP reach in a wide range of measurements! Complementary to the LHC program, and provides a number of ancillary measurements to pin down theory.