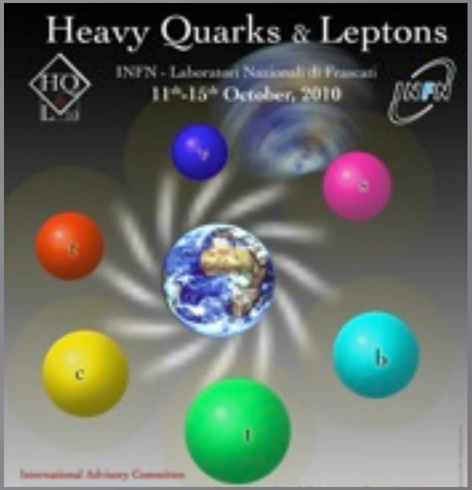


THE SUPERB PROJECT

HQL 2010

G. Finocchiaro
INFN - Laboratori Nazionali di Frascati

Outline of the Talk

- Physics Case
- Accelerator
- Detector design
- Project Status

The SuperB Physics Programme in One Slide

- New Physics (NP) is expected beyond the Standard Model
  - at what scale Λ? 0.5,1, 10…10^{16} TeV?
  - quantum stabilization of the Electroweak Scale suggests Λ ~ 1 TeV
    - **Quest for New Physics - *same motivation as the LHC!***
- Two scenarios:
  A. LHC finds New Physics (Λ is known)
    - *SuperB* can study the flavour structure of NP, measure the flavour couplings, search for still heavier states
  B. The NP scale is above the LHC reach
    - *SuperB* can look for indirect NP signals, understand where they may come from, exclude regions in parameter space, up to Λ~10TeV, or more
- *Complementary* to LHC
  - Many rare decay final states are only accessible to *SuperB*
  - Sensitive to off-diagonal terms in the squark mixing matrix.
  - Test *CP*, *CPT*, and Lepton Flavour Violation (LFV) in τ decay, τ anomalous magnetic moment.
  - Search for *CP* (and *CPT*) violation in *D* decays.
- Need to control theoretical uncertainties at a level matching the expected experimental precision (both in the SM and BSM)
  - Teraflops, Petaflops (?)

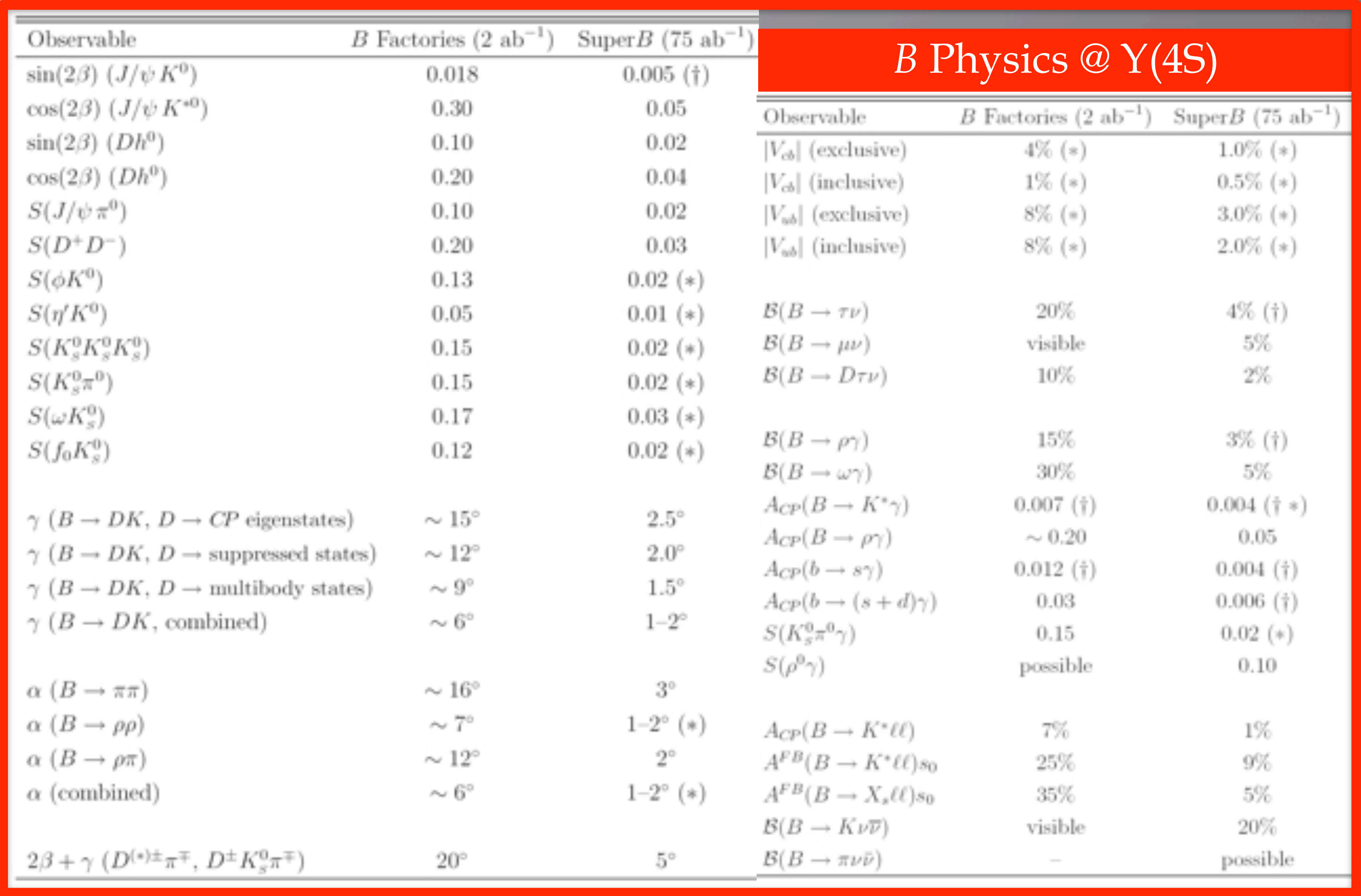
The *SuperB* Data Sample

- Sensitivity goals of the project achievable with a dataset ~ *two orders of magnitude larger* than current *B* factories
  - > 80×10^{9} *B* pairs, similar numbers of *D* mesons and τ leptons
- 75 ab^{-1} collected at the $\Upsilon(4S)$ in 5 years at design luminosity ***if***
  - $L = 10^{36} cm^{-2} s^{-1}$, ~ 50x today's best
  - efficiency as high as in present *B* factories (new *Snowmass year* $\sim 1.4 \times 10^{7}$s)
- ability to run at
  - lower energies ($\tau\tau$, $\psi(3770) \rightarrow DD$)
    - e.g. 7×10^{8} charm pairs at threshold for $500 fb^{1}$
  - higher energies ($\Upsilon(5S) \rightarrow B_s B_s$)
  - with at least one *polarized beam (≥80%)*
- machine backgrounds comparable to existing *B* factories
- increased detector hermeticity
- reasonable electricity costs

B @Υ(4S), *B*$_s$ @Υ(5S), τ, charm Physics

The SuperB Physics Programme in 1 slide (TABLES)

B @Y(4S), B_s @Y(5S), τ, charm Physics



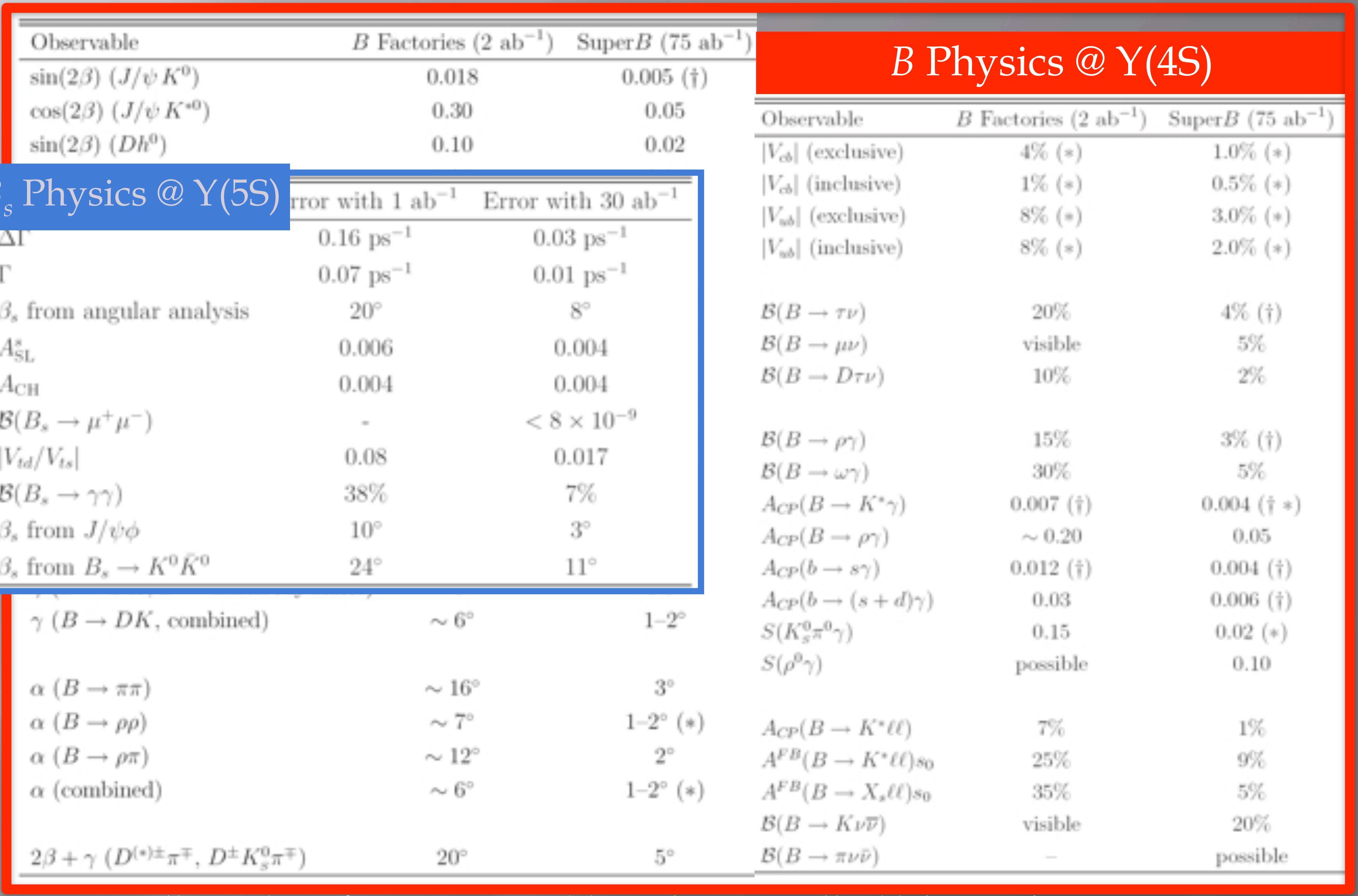
Observable	B Factories ($2\ \mathrm{ab}^{-1}$)	Super$B$ ($75\ \mathrm{ab}^{-1}$)
$\sin(2\beta)$ ($J/\psi\, K^0$)	0.018	0.005 (†)
$\cos(2\beta)$ ($J/\psi\, K^{*0}$)	0.30	0.05
$\sin(2\beta)$ (Dh^0)	0.10	0.02
$\cos(2\beta)$ (Dh^0)	0.20	0.04
$S(J/\psi\, \pi^0)$	0.10	0.02
$S(D^+D^-)$	0.20	0.03
$S(\phi K^0)$	0.13	0.02 (∗)
$S(\eta' K^0)$	0.05	0.01 (∗)
$S(K^0_s K^0_s K^0_s)$	0.15	0.02 (∗)
$S(K^0_s \pi^0)$	0.15	0.02 (∗)
$S(\omega K^0_s)$	0.17	0.03 (∗)
$S(f_0 K^0_s)$	0.12	0.02 (∗)
γ ($B \to DK$, $D \to CP$ eigenstates)	$\sim 15^\circ$	2.5°
γ ($B \to DK$, $D \to$ suppressed states)	$\sim 12^\circ$	2.0°
γ ($B \to DK$, $D \to$ multibody states)	$\sim 9^\circ$	1.5°
γ ($B \to DK$, combined)	$\sim 6^\circ$	1–2°
α ($B \to \pi\pi$)	$\sim 16^\circ$	3°
α ($B \to \rho\rho$)	$\sim 7^\circ$	1–2° (∗)
α ($B \to \rho\pi$)	$\sim 12^\circ$	2°
α (combined)	$\sim 6^\circ$	1–2° (∗)
$2\beta + \gamma$ ($D^{(*)\pm}\pi^\mp$, $D^\pm K^0_s \pi^\mp$)	20°	5°

B Physics @ Y(4S)

Observable	B Factories ($2\ \mathrm{ab}^{-1}$)	Super$B$ ($75\ \mathrm{ab}^{-1}$)
$\lvert V_{cb}\rvert$ (exclusive)	4% (∗)	1.0% (∗)
$\lvert V_{cb}\rvert$ (inclusive)	1% (∗)	0.5% (∗)
$\lvert V_{ub}\rvert$ (exclusive)	8% (∗)	3.0% (∗)
$\lvert V_{ub}\rvert$ (inclusive)	8% (∗)	2.0% (∗)
$\mathcal{B}(B \to \tau\nu)$	20%	4% (†)
$\mathcal{B}(B \to \mu\nu)$	visible	5%
$\mathcal{B}(B \to D\tau\nu)$	10%	2%
$\mathcal{B}(B \to \rho\gamma)$	15%	3% (†)
$\mathcal{B}(B \to \omega\gamma)$	30%	5%
$A_{CP}(B \to K^*\gamma)$	0.007 (†)	0.004 († ∗)
$A_{CP}(B \to \rho\gamma)$	~ 0.20	0.05
$A_{CP}(b \to s\gamma)$	0.012 (†)	0.004 (†)
$A_{CP}(b \to (s+d)\gamma)$	0.03	0.006 (†)
$S(K^0_s \pi^0 \gamma)$	0.15	0.02 (∗)
$S(\rho^0\gamma)$	possible	0.10
$A_{CP}(B \to K^*\ell\ell)$	7%	1%
$A^{FB}(B \to K^*\ell\ell)s_0$	25%	9%
$A^{FB}(B \to X_s\ell\ell)s_0$	35%	5%
$\mathcal{B}(B \to K\nu\overline{\nu})$	visible	20%
$\mathcal{B}(B \to \pi\nu\bar{\nu})$	–	possible

Very small number of systematics (†) or theoretically (*) limited measurements

B @Y(4S), B_s @Y(5S), τ, charm Physics



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γ ($B \to DK$, combined)	$\sim 6°$	1–2°
α ($B \to \pi\pi$)	$\sim 16°$	3°
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α ($B \to \rho\pi$)	$\sim 12°$	2°
α (combined)	$\sim 6°$	1–2° (∗)
$2\beta+\gamma$ ($D^{(*)\pm}\pi^\mp$, $D^\pm K_S^0\pi^\mp$)	20°	5°

B_s Physics @ Y(5S)

	rror with 1 ab^{-1}	Error with 30 ab^{-1}
$\Delta\Gamma$	$0.16\ \mathrm{ps}^{-1}$	$0.03\ \mathrm{ps}^{-1}$
Γ	$0.07\ \mathrm{ps}^{-1}$	$0.01\ \mathrm{ps}^{-1}$
β_s from angular analysis	20°	8°
A_{SL}^s	0.006	0.004
A_{CH}	0.004	0.004
$\mathcal{B}(B_s \to \mu^+\mu^-)$	-	$< 8 \times 10^{-9}$
$\|V_{td}/V_{ts}\|$	0.08	0.017
$\mathcal{B}(B_s \to \gamma\gamma)$	38%	7%
β_s from $J/\psi\phi$	10°	3°
β_s from $B_s \to K^0\bar{K}^0$	24°	11°

B Physics @ Y(4S)

Observable	B Factories ($2\ \mathrm{ab}^{-1}$)	Super$B$ ($75\ \mathrm{ab}^{-1}$)
$\|V_{cb}\|$ (exclusive)	4% (∗)	1.0% (∗)
$\|V_{cb}\|$ (inclusive)	1% (∗)	0.5% (∗)
$\|V_{ub}\|$ (exclusive)	8% (∗)	3.0% (∗)
$\|V_{ub}\|$ (inclusive)	8% (∗)	2.0% (∗)
$\mathcal{B}(B \to \tau\nu)$	20%	4% (†)
$\mathcal{B}(B \to \mu\nu)$	visible	5%
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$\mathcal{B}(B \to \rho\gamma)$	15%	3% (†)
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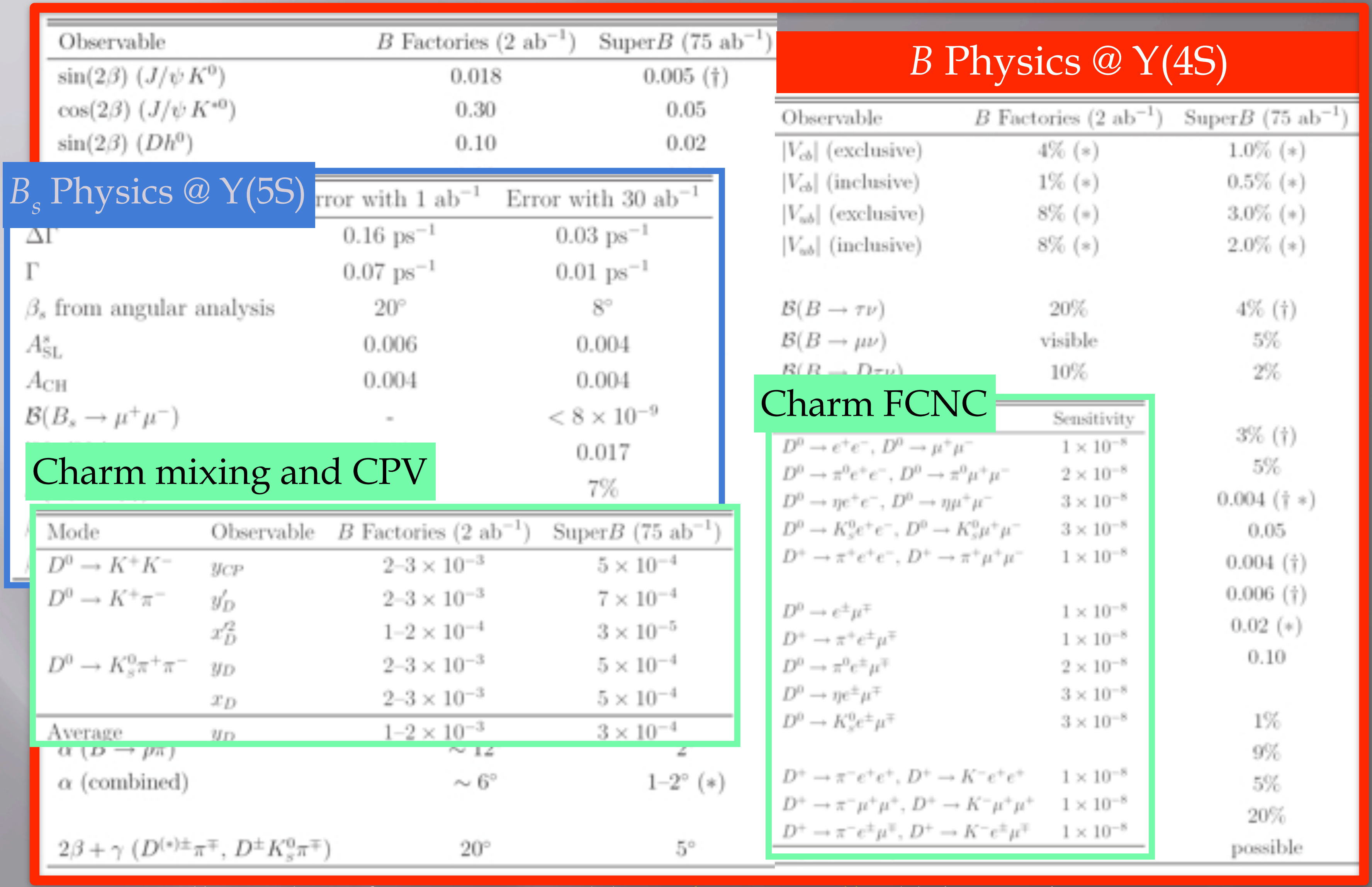
$A_{CP}(B \to K^*\gamma)$	0.007 (†)	0.004 († ∗)
$A_{CP}(B \to \rho\gamma)$	~ 0.20	0.05
$A_{CP}(b \to s\gamma)$	0.012 (†)	0.004 (†)
$A_{CP}(b \to (s+d)\gamma)$	0.03	0.006 (†)
$S(K_S^0\pi^0\gamma)$	0.15	0.02 (∗)
$S(\rho^0\gamma)$	possible	0.10
$A_{CP}(B \to K^*\ell\ell)$	7%	1%
$A^{FB}(B \to K^*\ell\ell)s_0$	25%	9%
$A^{FB}(B \to X_s\ell\ell)s_0$	35%	5%
$\mathcal{B}(B \to K\nu\overline{\nu})$	visible	20%
$\mathcal{B}(B \to \pi\nu\bar{\nu})$	–	possible

Very small number of systematics (†) or theoretically (*) limited measurements

B @Υ(4S), B_s @Υ(5S), τ, charm Physics



B Physics @ Υ(4S)

Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab^{-1})
$\sin(2\beta)$ $(J/\psi\, K^0)$	0.018	0.005 (†)
$\cos(2\beta)$ $(J/\psi\, K^{*0})$	0.30	0.05
$\sin(2\beta)$ (Dh^0)	0.10	0.02
α (combined)	$\sim 6^\circ$	1–2° (*)
$2\beta+\gamma$ $(D^{(*)\pm}\pi^\mp, D^\pm K^0_S\pi^\mp)$	20°	5°

Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab^{-1})
$\lvert V_{cb}\rvert$ (exclusive)	4% (*)	1.0% (*)
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$\mathcal{B}(B \to \tau\nu)$	20%	4% (†)
$\mathcal{B}(B \to \mu\nu)$	visible	5%
$\mathcal{B}(B \to D\tau\nu)$	10%	2%
		3% (†)
		5%
		0.004 († *)
		0.05
		0.004 (†)
		0.006 (†)
		0.02 (*)
		0.10
		1%
		9%
		5%
		20%
		possible

B_s Physics @ Υ(5S)

	rror with 1 ab^{-1}	Error with 30 ab^{-1}
$\Delta\Gamma$	0.16 ps^{-1}	0.03 ps^{-1}
Γ	0.07 ps^{-1}	0.01 ps^{-1}
β_s from angular analysis	20°	8°
A^s_{SL}	0.006	0.004
A_{CH}	0.004	0.004
$\mathcal{B}(B_s \to \mu^+\mu^-)$	-	$< 8 \times 10^{-9}$
		0.017
		7%

Charm mixing and CPV

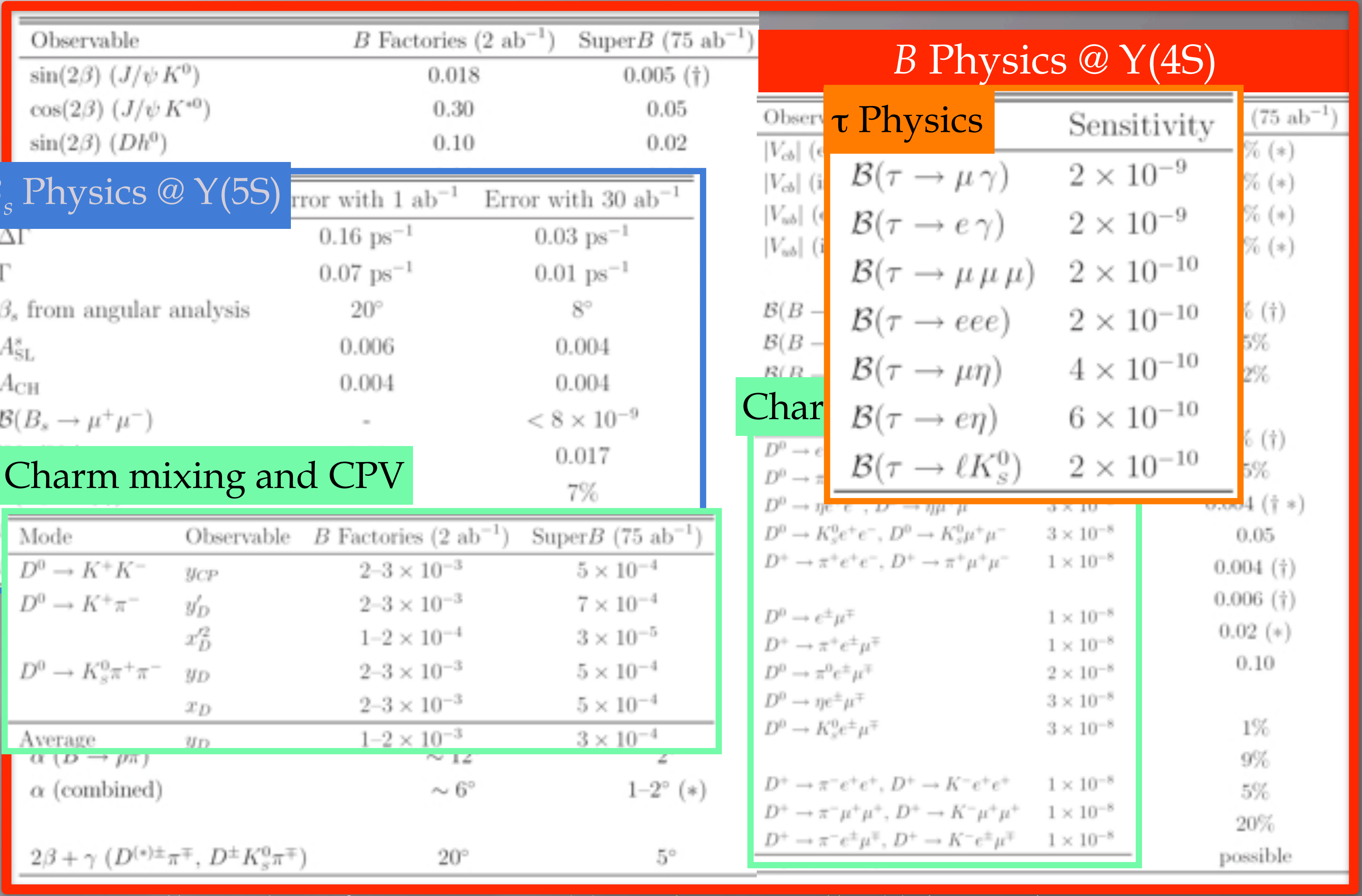
Mode	Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab^{-1})
$D^0 \to K^+K^-$	y_{CP}	$2\text{–}3 \times 10^{-3}$	5×10^{-4}
$D^0 \to K^+\pi^-$	y'_D	$2\text{–}3 \times 10^{-3}$	7×10^{-4}
	x'^2_D	$1\text{–}2 \times 10^{-4}$	3×10^{-5}
$D^0 \to K^0_S\pi^+\pi^-$	y_D	$2\text{–}3 \times 10^{-3}$	5×10^{-4}
	x_D	$2\text{–}3 \times 10^{-3}$	5×10^{-4}
Average	y_D	$1\text{–}2 \times 10^{-3}$	3×10^{-4}

Charm FCNC

	Sensitivity
$D^0 \to e^+e^-$, $D^0 \to \mu^+\mu^-$	1×10^{-8}
$D^0 \to \pi^0 e^+e^-$, $D^0 \to \pi^0\mu^+\mu^-$	2×10^{-8}
$D^0 \to \eta e^+e^-$, $D^0 \to \eta\mu^+\mu^-$	3×10^{-8}
$D^0 \to K^0_S e^+e^-$, $D^0 \to K^0_S\mu^+\mu^-$	3×10^{-8}
$D^+ \to \pi^+ e^+e^-$, $D^+ \to \pi^+\mu^+\mu^-$	1×10^{-8}
$D^0 \to e^\pm\mu^\mp$	1×10^{-8}
$D^+ \to \pi^+ e^\pm\mu^\mp$	1×10^{-8}
$D^0 \to \pi^0 e^\pm\mu^\mp$	2×10^{-8}
$D^0 \to \eta e^\pm\mu^\mp$	3×10^{-8}
$D^0 \to K^0_S e^\pm\mu^\mp$	3×10^{-8}
$D^+ \to \pi^- e^+e^+$, $D^+ \to K^- e^+e^+$	1×10^{-8}
$D^+ \to \pi^-\mu^+\mu^+$, $D^+ \to K^-\mu^+\mu^+$	1×10^{-8}
$D^+ \to \pi^- e^\pm\mu^\mp$, $D^+ \to K^- e^\pm\mu^\mp$	1×10^{-8}

Very small number of systematics (†) or theoretically (*) limited measurements

B @Υ(4S), B_s @Υ(5S), τ, charm Physics



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$\cos(2\beta)$ $(J/\psi K^{*0})$	0.30	0.05
$\sin(2\beta)$ (Dh^0)	0.10	0.02
α (combined)	$\sim 6^\circ$	1–2° (∗)
$2\beta+\gamma$ $(D^{(*)\pm}\pi^\mp, D^\pm K^0_S\pi^\mp)$	20°	5°

B_s Physics @ Υ(5S)

	Error with 1 ab^{-1}	Error with 30 ab^{-1}
$\Delta\Gamma$	0.16 ps^{-1}	0.03 ps^{-1}
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β_s from angular analysis	20°	8°
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Charm mixing and CPV

Mode	Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab^{-1})
$D^0 \to K^+K^-$	y_{CP}	2–3×10^{-3}	5×10^{-4}
$D^0 \to K^+\pi^-$	y'_D	2–3×10^{-3}	7×10^{-4}
	x'^2_D	1–2×10^{-4}	3×10^{-5}
$D^0 \to K^0_S\pi^+\pi^-$	y_D	2–3×10^{-3}	5×10^{-4}
	x_D	2–3×10^{-3}	5×10^{-4}
Average	y_D	1–2×10^{-3}	3×10^{-4}

τ Physics

	Sensitivity
$\mathcal{B}(\tau \to \mu\,\gamma)$	2×10^{-9}
$\mathcal{B}(\tau \to e\,\gamma)$	2×10^{-9}
$\mathcal{B}(\tau \to \mu\,\mu\,\mu)$	2×10^{-10}
$\mathcal{B}(\tau \to eee)$	2×10^{-10}
$\mathcal{B}(\tau \to \mu\eta)$	4×10^{-10}
$\mathcal{B}(\tau \to e\eta)$	6×10^{-10}
$\mathcal{B}(\tau \to \ell K^0_S)$	2×10^{-10}

Char

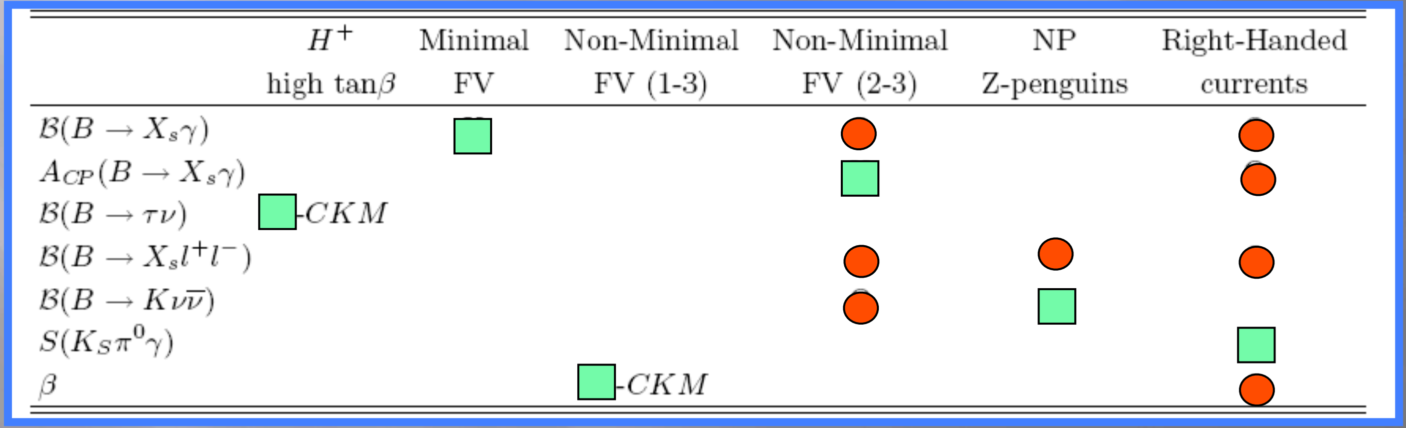
$D^0 \to K^0_S e^+e^-$, $D^0 \to K^0_S\mu^+\mu^-$	3×10^{-8}
$D^+ \to \pi^+e^+e^-$, $D^+ \to \pi^+\mu^+\mu^-$	1×10^{-8}
$D^0 \to e^\pm\mu^\mp$	1×10^{-8}
$D^+ \to \pi^+e^\pm\mu^\mp$	1×10^{-8}
$D^0 \to \pi^0e^\pm\mu^\mp$	2×10^{-8}
$D^0 \to \eta e^\pm\mu^\mp$	3×10^{-8}
$D^0 \to K^0_S e^\pm\mu^\mp$	3×10^{-8}
$D^+ \to \pi^-e^+e^+$, $D^+ \to K^-e^+e^+$	1×10^{-8}
$D^+ \to \pi^-\mu^+\mu^+$, $D^+ \to K^-\mu^+\mu^+$	1×10^{-8}
$D^+ \to \pi^-e^\pm\mu^\mp$, $D^+ \to K^-e^\pm\mu^\mp$	1×10^{-8}

Very small number of systematics (†) or theoretically (*) limited measurements

The NP "Golden Matrix"

- As shown by the *B* factories, a *huge* number of measurements can be performed in the clean environment of $e^+e^- \rightarrow \Upsilon(4S) \rightarrow BB$
- Most are statistics-limited, and worth to be studied with $75ab^{-1}$
  - in most cases, large control samples can further reduce syst./theor. errors
- We do not know what NP is out there
  - having many observables is a feature!
- *Correlations among variables particularly useful to elucidate nature of NP*

`Illustrative example of golden channels in different scenarios`



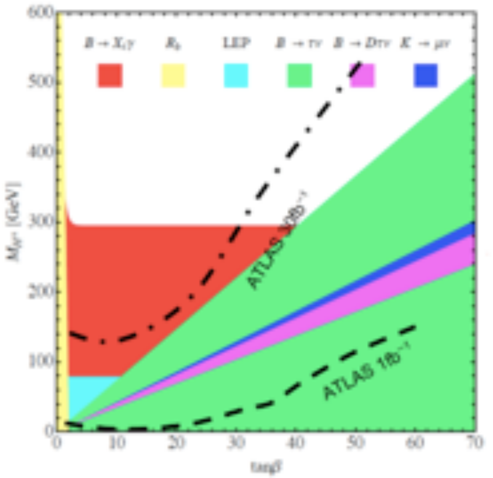
	H^+ high $\tan\beta$	Minimal FV	Non-Minimal FV (1-3)	Non-Minimal FV (2-3)	NP Z-penguins	Right-Handed currents
$\mathcal{B}(B \to X_s\gamma)$		🟩		🔴		🔴
$A_{CP}(B \to X_s\gamma)$				🟩		🔴
$\mathcal{B}(B \to \tau\nu)$	🟩-CKM					
$\mathcal{B}(B \to X_s l^+l^-)$				🔴	🔴	🔴
$\mathcal{B}(B \to K\nu\overline{\nu})$				🔴	🟩	
$S(K_S\pi^0\gamma)$						🟩
β			🟩-CKM			🔴

🟩 Golden mode for a given scenario
🔴 Non-golden, but still sensitive to deviations from the SM
-CKM requires high precision on CKM parameters (obtainable with *SuperB*)

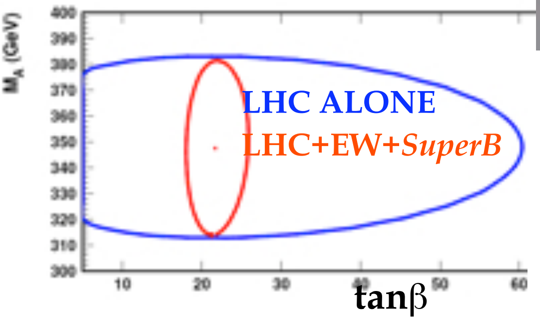
The physics White Paper has a section on the task of trying to reconstruct features of the NP Lagrangian using *SuperB*

B Physics Highlights, in 1 page

Sensitivity to $m_{H}/\tan\beta$



Sensitivity to tanβ



Sensitivity to SUSY parameters in 3-1 and 3-2 transitions

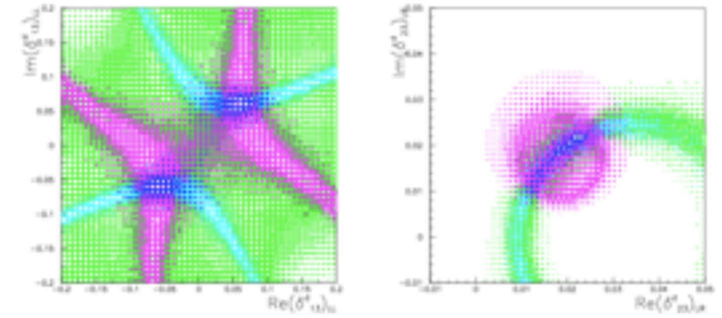
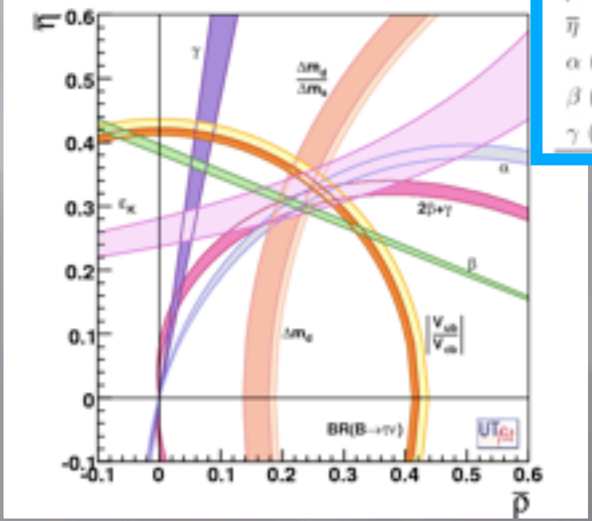
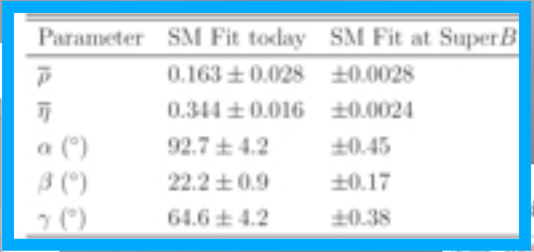


FIG. 31: Left: Density plot of the selected region in the $Re(\delta^d_{13})_{LL} - Im(\delta^d_{13})_{LL}$ for $m_{\tilde{q}} = m_{\tilde{g}} = 1$ TeV and $(\delta^d_{13})_{LL} = 0.085e^{i\pi/4}$ using *SuperB* measurements (namely, 1-3 generation transitions). Different colors correspond to different constraints: A^{d}_{SL} (green), β (cyan), Δm_d (magenta), all together (blue). Right: Density plot of the selected region in the $Re(\delta^d_{23})_{LR} - Im(\delta^d_{23})_{LR}$ for $m_{\tilde{q}} = m_{\tilde{g}} = 1$ TeV and $(\delta^d_{23})_{LR} = 0.028e^{i\pi/4}$ using *SuperB* measurements (namely, 2-3 generation transitions). Different colors correspond to different constraints: $\mathcal{B}(B \to X_s\gamma)$ (green), $\mathcal{B}(B \to X_s l^+ l^-)$ (cyan), $A_{CP}(B \to X_s\gamma)$ (magenta), all together (blue).

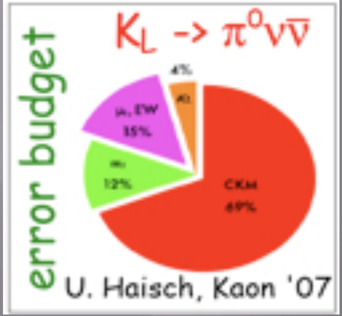
CKM (& NP)

“tensions”

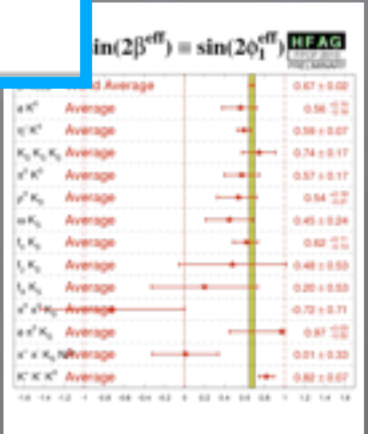




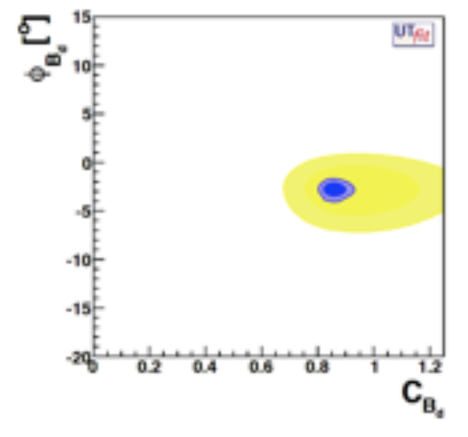
Parameter	SM Fit today	SM Fit at *SuperB*
$\bar{\rho}$	0.163 ± 0.028	± 0.0028
$\bar{\eta}$	0.344 ± 0.016	± 0.0024
α (°)	92.7 ± 4.2	± 0.45
β (°)	22.2 ± 0.9	± 0.17
γ (°)	64.6 ± 4.2	± 0.38



ΔF=1



NP in ΔF=2



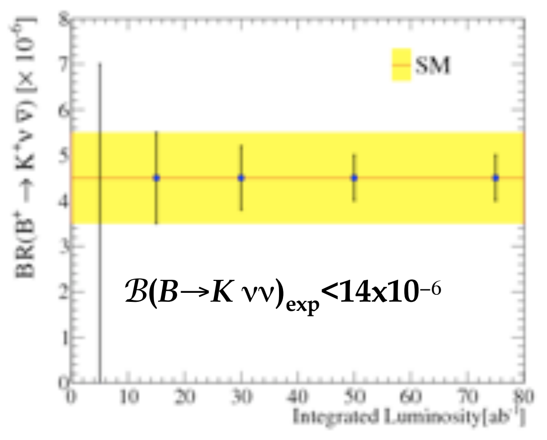
A Few Specific Examples

$B \to K^{(*)}\nu\bar{\nu}$

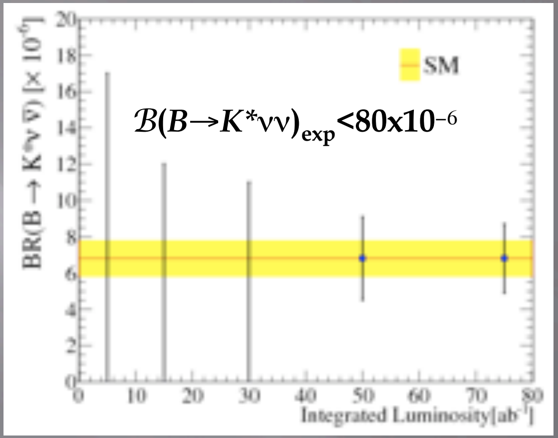
$$\mathcal{H}_{\rm eff} = -\frac{4\,G_F}{\sqrt{2}} V_{tb}V_{ts}^{*}\left(C_L^{\nu}\mathcal{O}_L^{\nu} + C_R^{\nu}\mathcal{O}_R^{\nu}\right) + \text{h.c.}$$

Not in SM

- BSM: Right handed currents and complex Wilson coefficients

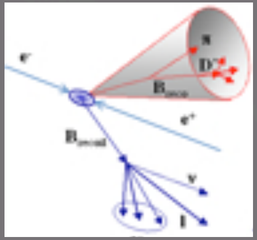


$\mathcal{B}(B \to K\,\nu\nu)_{\rm exp} < 14\times10^{-6}$



$\mathcal{B}(B \to K^{*}\nu\nu)_{\rm exp} < 80\times10^{-6}$

e.g. Z^0 penguins
G. Isidori, arXiv:
hep-ph/0009024

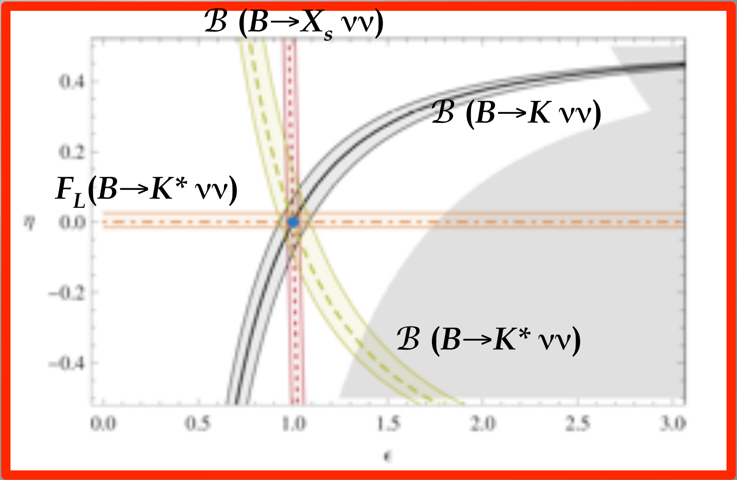


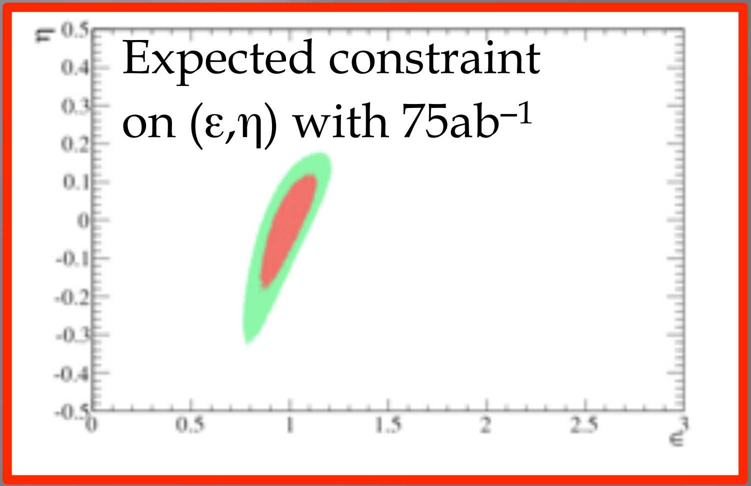
- Detailed analysis based on recoil technique (CLEO, *B* Factories)
  - one *B* meson fully reconstructed (ε ~ 3‰ had, ~1% s.l.)
    - high purity sample with known kinematics, flavor and charge
  - improved *SuperB* hermeticity (see later) crucial in bkg-dominated channels
    - 20-30% increase in S/√B ratio (i.e., 50% more luminosity…)
- Only feasible in e^+e^- environment

$b \to s\nu\bar{\nu}$: Correlations

- $F_L(q^2)$ additional observable in K^* decays
  - $\mathcal{B}$ ($B \to X_s\ \nu\nu$) cleanest theoretically, very challenging experimentally
- Strong correlation among complex Wilson coefficients allows only the ε, η combinations (1,0 in the SM)

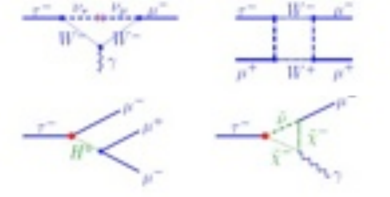
$$\epsilon = \frac{\sqrt{|C_L^\nu|^2 + |C_R^\nu|^2}}{|(C_L^\nu)^{\mathrm{SM}}|} \qquad \eta = \frac{-\mathrm{Re}\,(C_L^\nu C_R^{\nu *})}{|C_L^\nu|^2 + |C_R^\nu|^2}$$



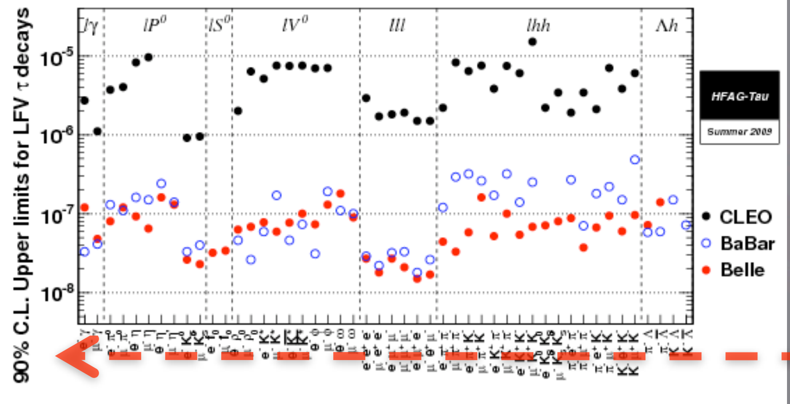


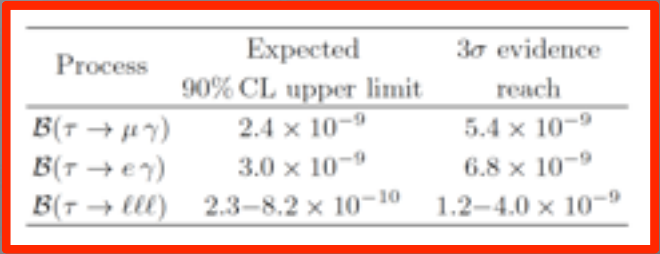
Expected constraint on (ε,η) with $75\,\mathrm{ab}^{-1}$

SFF as a τ factory: LFV in τ decays



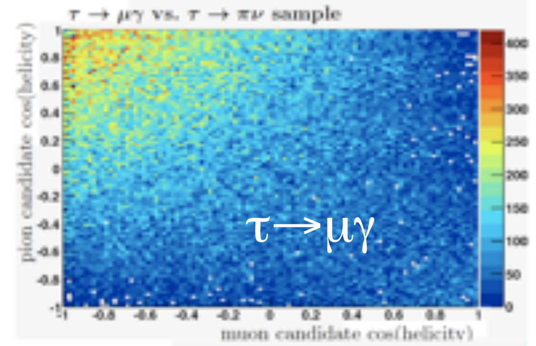
- LVF negligibly small in the SM, larger in several SM extensions
- Many limits already pushed down by the *B* factories

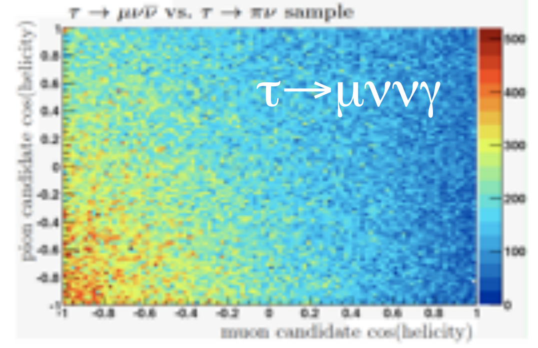




Process	Expected 90% CL upper limit	3σ evidence reach
$\mathcal{B}(\tau \to \mu\gamma)$	2.4×10^{-9}	5.4×10^{-9}
$\mathcal{B}(\tau \to e\gamma)$	3.0×10^{-9}	6.8×10^{-9}
$\mathcal{B}(\tau \to \ell\ell\ell)$	2.3–8.2×10^{-10}	1.2–4.0×10^{-9}

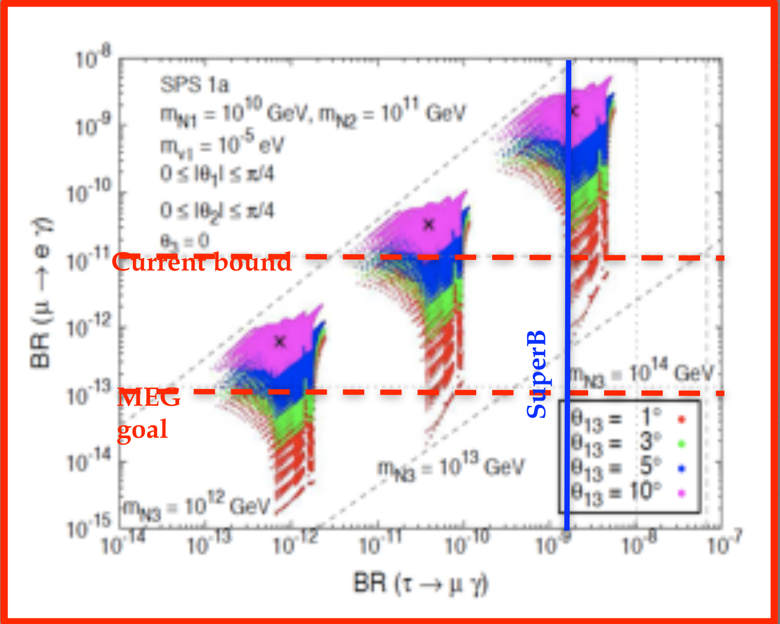
- Extrapolation of bounds to *SuperB* luminosity (1/√*L*) based on *BABAR* experience
  - with improvements in *reconstruction* and *angular coverage* but not *analysis re-optimization* (1/*L*)
- 80% polarized *e*⁻ beam further suppresses irreducible backgrounds
  - example: cos(helicity) of *signal* τ vs. *tag* τ



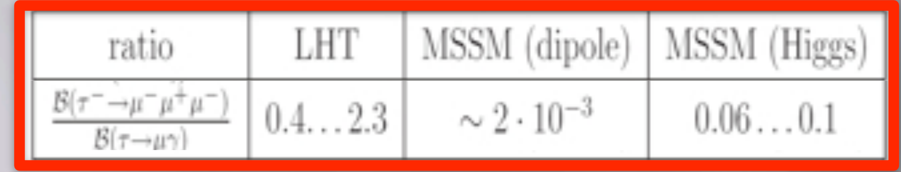


- Limits for *SuperB* golden modes (τ→*ℓ*γ and τ→*ℓℓℓ*) off the HFAG plot scale!

More in τ's: LFV(*SuperB* vs. MEG), *CPV*, EDM, a_τ



- LVF in $\tau \to \mu\gamma$ correlated with $\mu \to e\gamma$ and θ_{13} neutrino mixing angle, for different values of BSM parameters
- Ratio of BR's also sensitive to the NP model

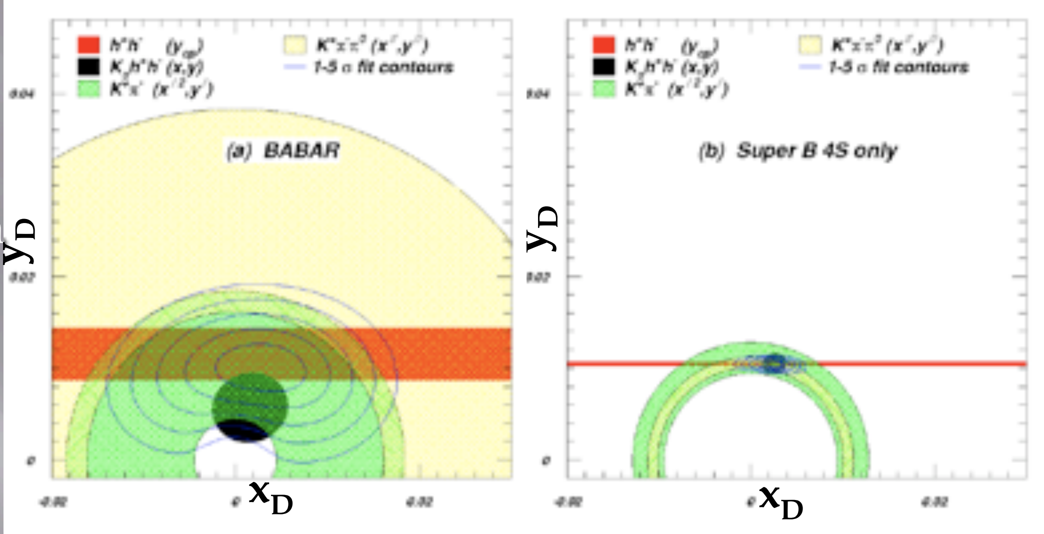


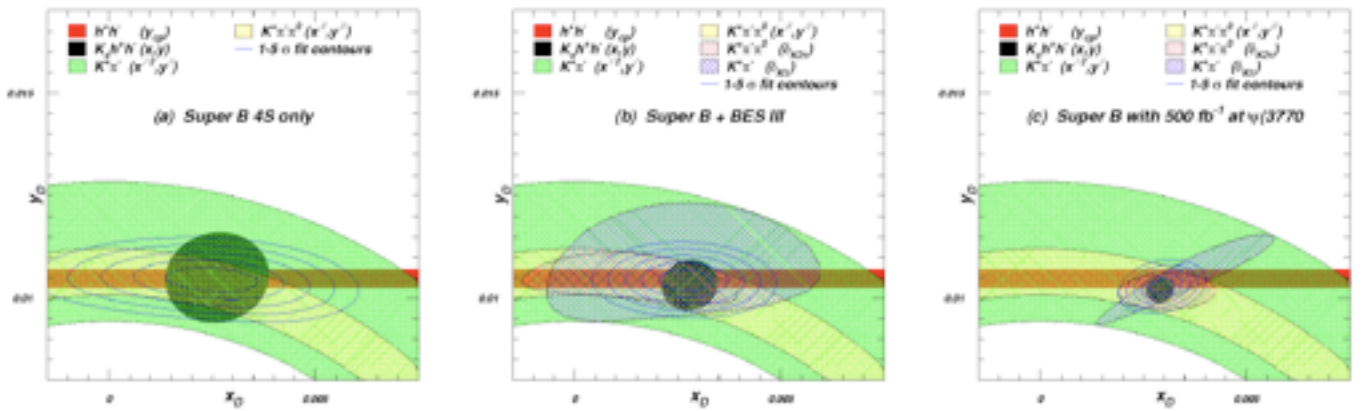
ratio	LHT	MSSM (dipole)	MSSM (Higgs)
$\frac{\mathcal{B}(\tau^- \to \mu^- \mu^+ \mu^-)}{\mathcal{B}(\tau \to \mu\gamma)}$	$0.4 \ldots 2.3$	$\sim 2 \cdot 10^{-3}$	$0.06 \ldots 0.1$

- *CPV* vanishing in SM (e.g. $\sim 10^{-12}$ in $\tau^\pm \to K^\pm \pi^0 \nu$)
  - CPV_{SM} $\sim 10^{-5}$ in $\tau^+ \to K_S \pi^+ \nu$
  - 1.8×10^{-3} bound from CLEO with $13 fb^{-1}$
  - 2.3×10^{-5} from SuperB @ $75 ab^{-1}$
- EDM – potentially large effect in general MSSM on angular distribution+τ polarization. Belle limit with $30 fb^{-1}$ [$d_\tau < (0.9,1.7) \times 10^{-17}$] extrapolates to [$d_\tau < (17,34) \times 10^{-20}$] @ $75 ab^{-1}$, 10×10^{-20} (3×10^{-5} asymmetry) with polarized beam (single τ needed).
- g-2 – Helpful to understand origin of discrepancy $\Delta a_\mu = a_\mu^{exp} - a_\mu^{SM} = (3 \pm 1) \times 10^{-9}$. If due to NP, expect $\Delta a_\tau = \Delta a_\mu x (m_\tau / m_\mu)^2 \sim 10^{-6}$, within *SuperB* sensitivity with $75 ab^{-1}$ and polarized beam

Charm Physics @ Y(4S) & ψ(3770)

- Measurement of *D* oscillations opens new window to search of *CPV* in charm. Observation of *CPV* would provide unequivocal NP signals
- Dramatic improvement of precision in *D*-*D* mixing with 75ab^{-1} @ Y(4S)
  - strong phase difference δ_f unmeasured
- @ *DD* threshold, *SuperB* can exploit:
  - *D*-recoil technique; quantum coherence
- with 0.5ab^{-1} @ ψ(3770) can measure
  - FCNC modes to 10^{-8}
  - strong phase differences δ_f to ±1°
  - DP model uncertainty in γ angle measurement also greatly reduced





THE ACCELERATOR

The SuperB Accelerator

HOW TO INCREASE THE LUMINOSITY OF B FACTORIES BY X 100?

$$L \propto \frac{I_{\pm}\xi_{\pm y}}{\beta_y^*} R_l$$

Traditional approach to increase L:

1. Increase $I_{\pm}$ (1A/2A ➔ up to 4.1A/9.4A)
2. Decrease β_y^*
3. Increase ξ (reduce bunch length)
4. Crab crossing to increase R_l and optimize beam dynamics

- **High wall-plug power**
- **HOM in beam pipe**
  - **overheating, instabilities, power cost**
- **Smaller dynamic aperture**
- **Shorter LER Touschek lifetime**

Hard to surpass 5x10^{35} cm^{2}s^{-1}

New idea by P. Raimondi (2006)

[P.Raimondi, 2° SuperB Workshop, March 2006]
[Raimondi, Shatilov, Zobov, physics/0702033]

- Ultra-low emittance, very small beams at IP
  - ✓ very small β_y^*, σ_y from 3μm down to 40nm
- Same currents as in PEP-II
- Retain longer bunch lengths
- Large Piwinski angle, "Crab Waist" transformation to optimize beam dynamics
  - ✓ reduce parasitic crossings, x/y betatron resonances
- A synergy between *B*-factory and ILC-type concepts

Lumi: 10^{36} cm^{2}s^{-1} (baseline).

Crab Waist

Move beam waist to the axis of other beam with a pair of sextupoles

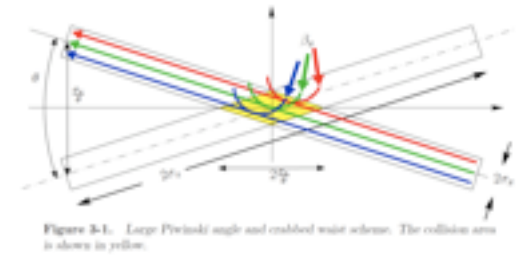
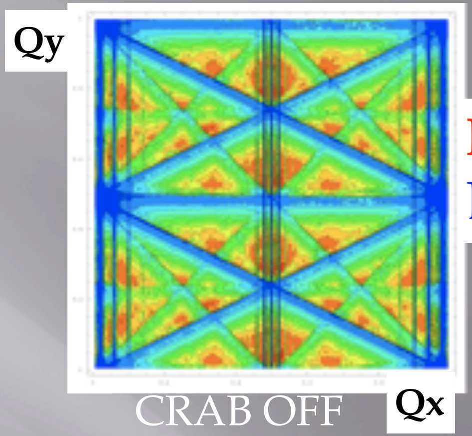
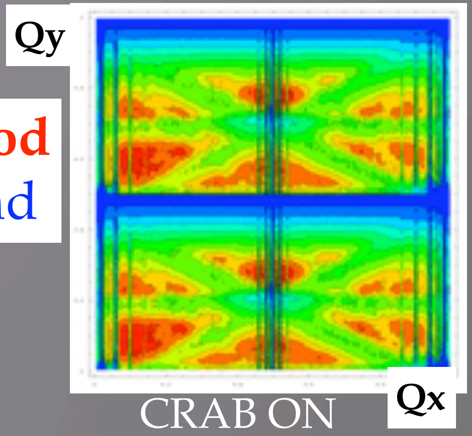


Figure 3-1. Large Piwinski angle and crabbed waist scheme. The collision area is shown in yellow.

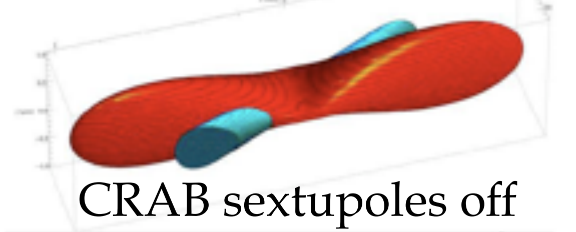


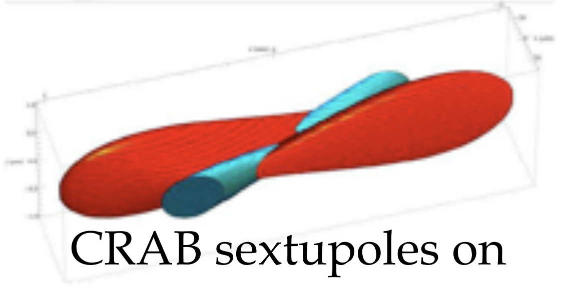
CRAB OFF

RED is good
BLUE is bad

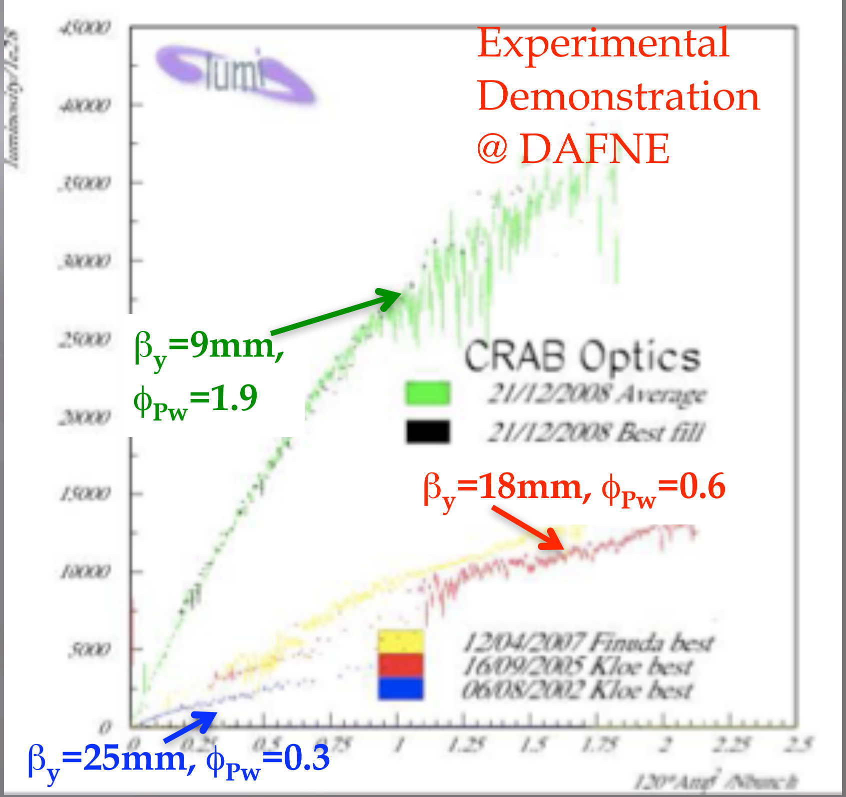


CRAB ON


CRAB sextupoles off


CRAB sextupoles on

All particles from both beams collide in the minimum β^*_y region, with a net luminosity gain



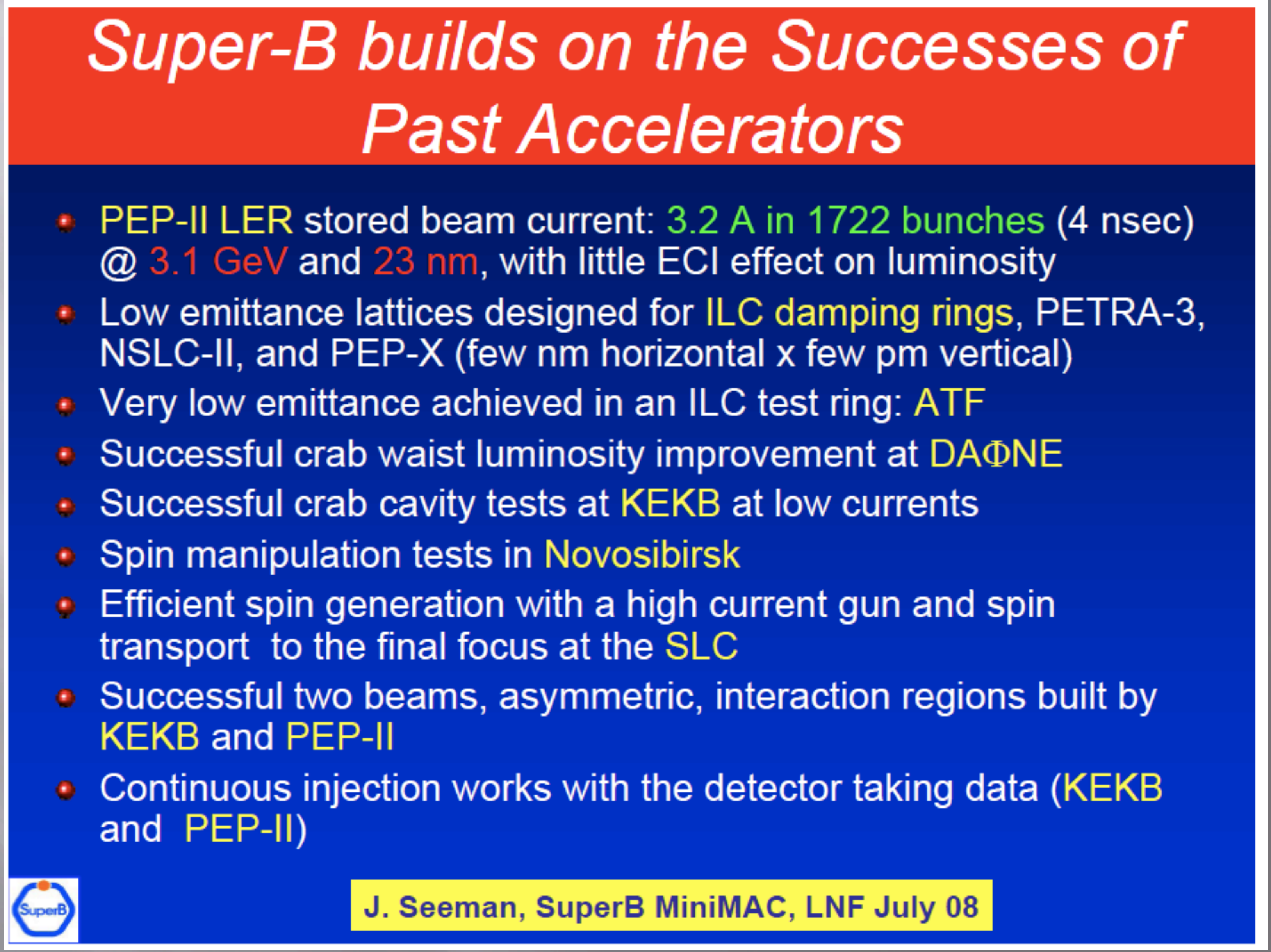
Experimental Demonstration @ DAFNE

β_y=9mm, ϕ_{Pw}=1.9

β_y=18mm, ϕ_{Pw}=0.6

β_y=25mm, ϕ_{Pw}=0.3

Ambitious, but on solid grounds



Super-B builds on the Successes of Past Accelerators

- PEP-II LER stored beam current: 3.2 A in 1722 bunches (4 nsec) @ 3.1 GeV and 23 nm, with little ECI effect on luminosity
- Low emittance lattices designed for ILC damping rings, PETRA-3, NSLC-II, and PEP-X (few nm horizontal x few pm vertical)
- Very low emittance achieved in an ILC test ring: ATF
- Successful crab waist luminosity improvement at DAΦNE
- Successful crab cavity tests at KEKB at low currents
- Spin manipulation tests in Novosibirsk
- Efficient spin generation with a high current gun and spin transport to the final focus at the SLC
- Successful two beams, asymmetric, interaction regions built by KEKB and PEP-II
- Continuous injection works with the detector taking data (KEKB and PEP-II)

J. Seeman, SuperB MiniMAC, LNF July 08

SuperB Accelerator Update

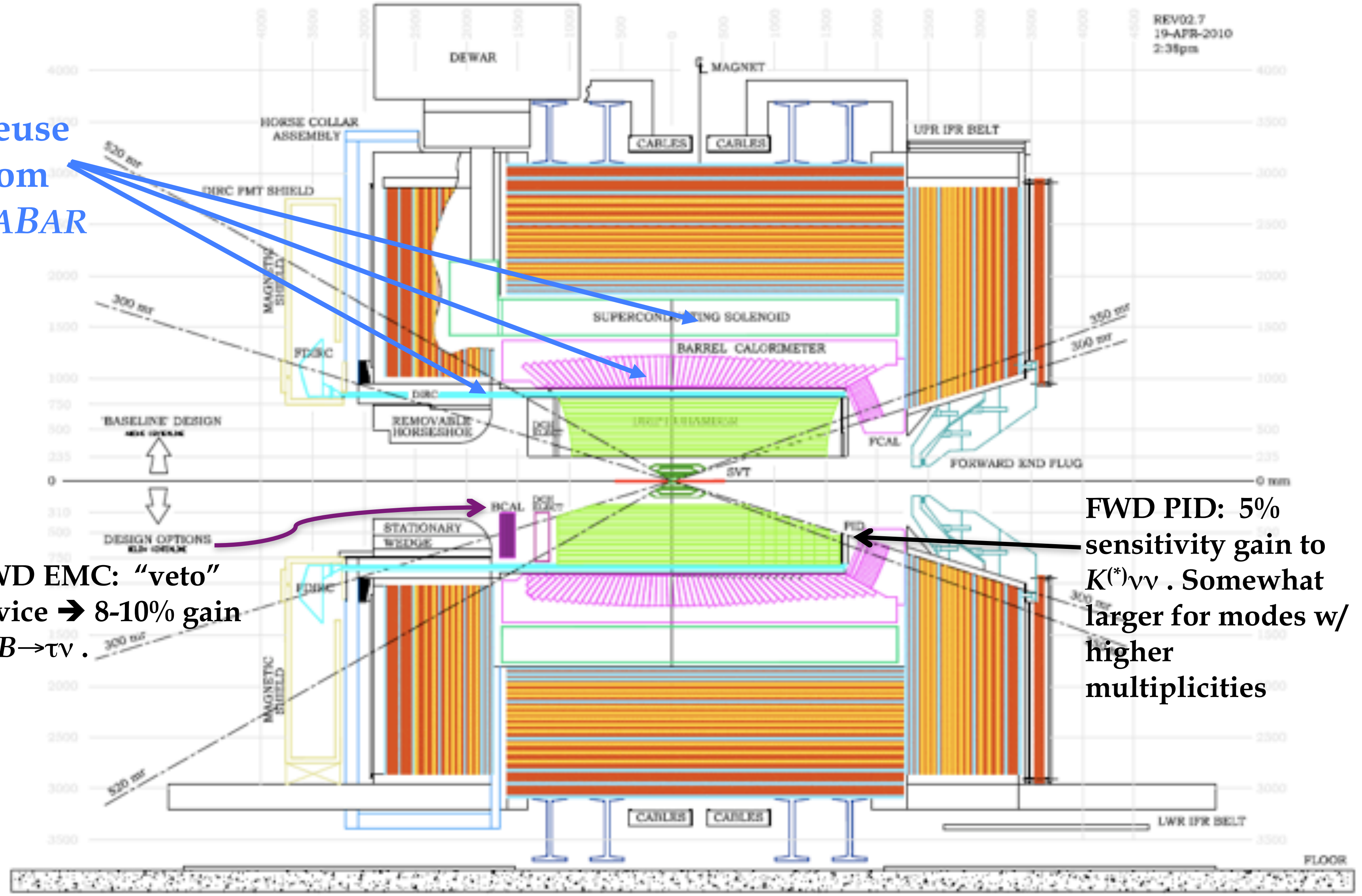
- Flexibility: Luminosity of 10^{36} it is not a "singularity" in the parameter space. It can be achieved with different settings of parameters, varying independently their values from nominal as:
  - Increase vertical emittance in HER and LER by x 4
  - Increase β_y* by 40% in both rings
  - Increase vertical emittance and β_y* by 40% in both rings
  - Increase x and y emittance by 40%
  - Decrease Vertical tune shift from 0.117 to 0.09
- Maximum currents: 3.5 A in both rings (based on RF best design), however the nominal operating is ≈ 2.1 A
- Design based on recycling PEP-II hardware (substantial money saving)
- Optimal choice for accelerator design, including polarization, is:
  - 4.18/6.71 - $\beta\gamma$=0.24

DETECTOR (HIGHLIGHTS)

The Detector: General Considerations

- *SuperB* requirements very similar to those of the present *B* factories
  - Large solid angle coverage, good lepton ID, particle ID over large momentum range (π/*K* separation to over 4 GeV), measurement of the relative decay times of the *B* mesons, good low momentum resolution, good low energy photon energy measurement
- Main differences:
  - lower machine boost (βγ=0.24 vs βγ=0.56 in *BABAR*)
    - Need to improve vertex detector resolution
  - Much higher luminosity (and L-scaling background rates)
    - Faster & more robust detectors
    - Keep an open, 100% efficient trigger
- Can re-use as much as possible & reasonable of the old detector
  - only possible because of low beam currents!

The SuperB Detector (with options)

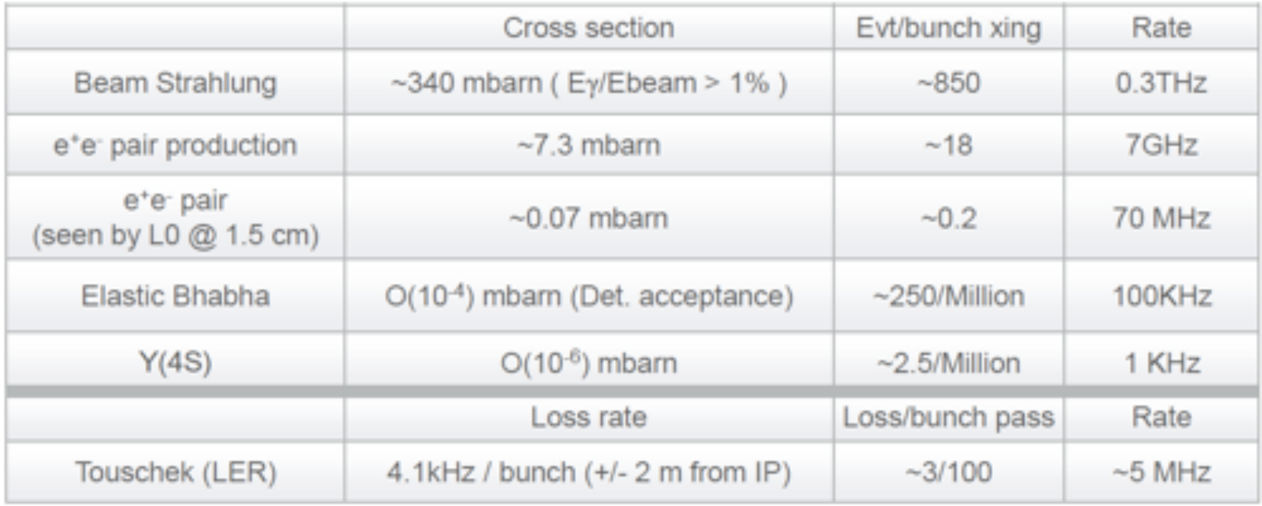


Reuse from *BABAR*

BWD EMC: "veto" device ➔ 8-10% gain in $B\to\tau\nu$.

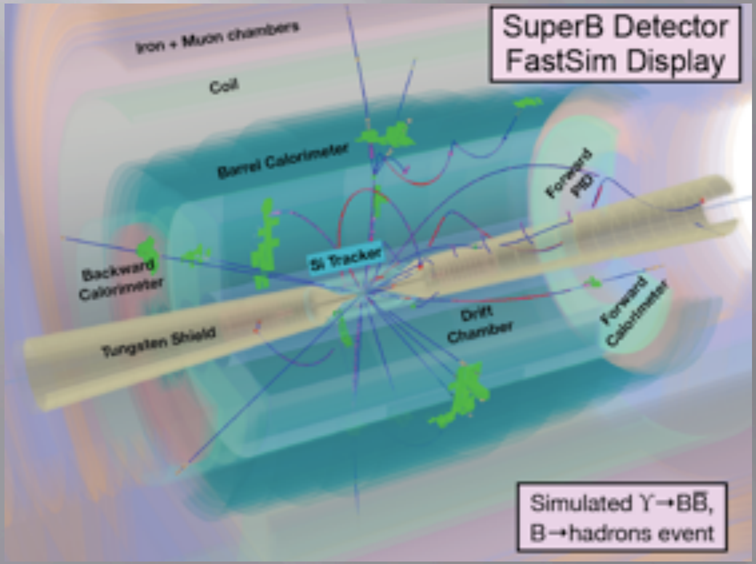
FWD PID: 5% sensitivity gain to $K^{(*)}\nu\nu$. Somewhat larger for modes w/ higher multiplicities

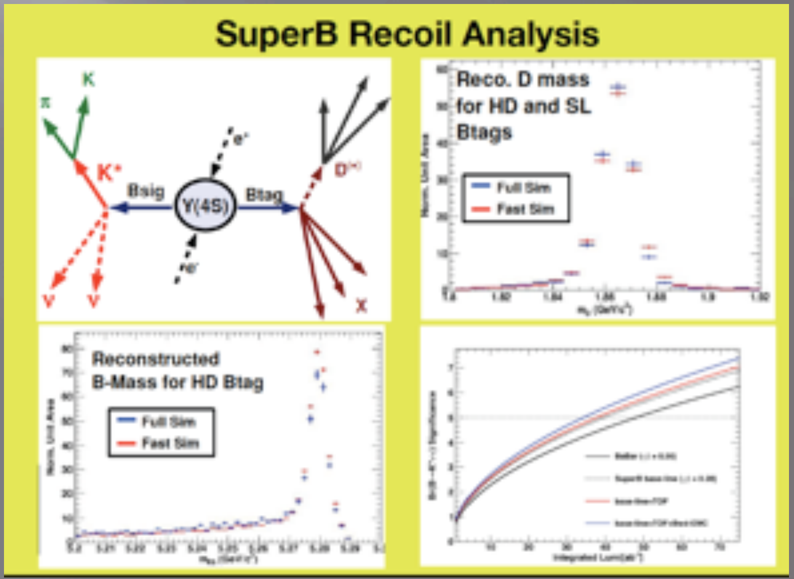
Simulation for Detector Optimization



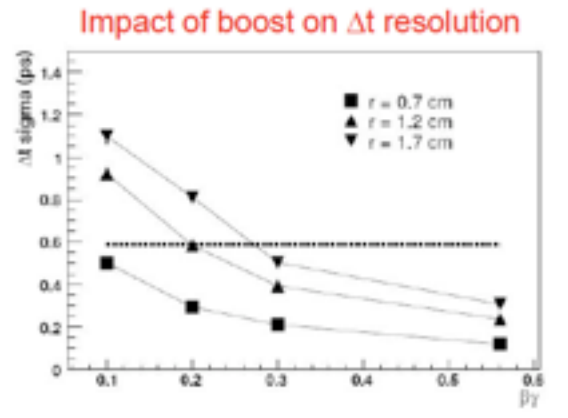
	Cross section	Evt/bunch xing	Rate
Beam Strahlung	~340 mbarn (Eγ/Ebeam > 1%)	~850	0.3THz
e^+e^- pair production	~7.3 mbarn	~18	7GHz
e^+e^- pair (seen by L0 @ 1.5 cm)	~0.07 mbarn	~0.2	70 MHz
Elastic Bhabha	O(10^{-4}) mbarn (Det. acceptance)	~250/Million	100KHz
Υ(4S)	O(10^{-6}) mbarn	~2.5/Million	1 KHz
	Loss rate	Loss/bunch pass	Rate
Touschek (LER)	4.1kHz / bunch (+/- 2 m from IP)	~3/100	~5 MHz

- Backgrounds studied with detailed GEANT4 simulations
- Detailed Fast Simulation (>1Hz fully analyzed) used to:
  - Optimize detector design under realistic conditions
  - Compute physics sensitivity to extremely rare processes

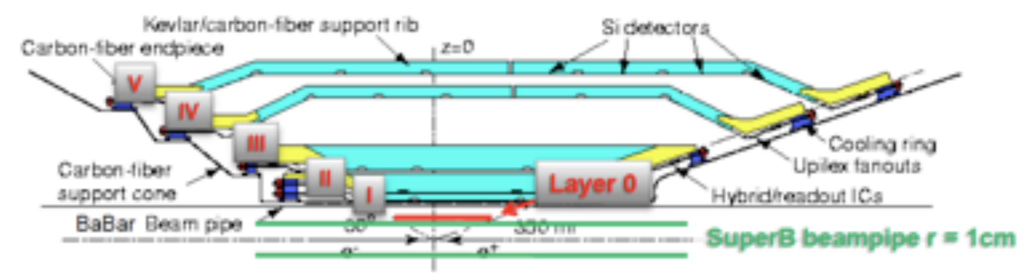




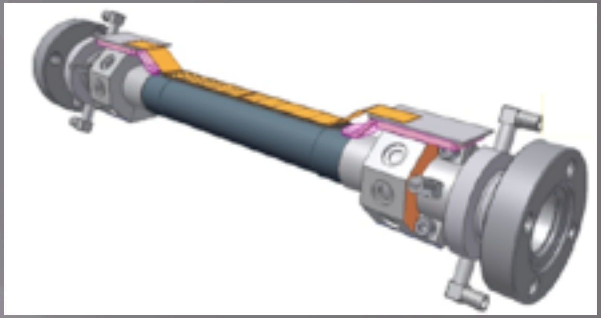
Vertex Detector



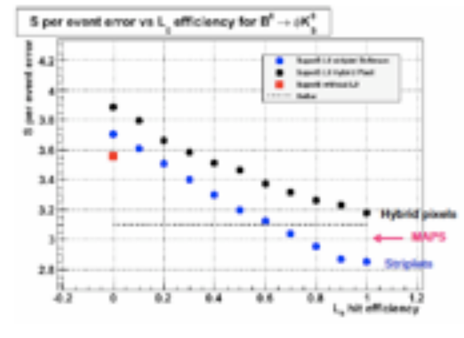
- Reduced boost in *SuperB* impacts vertex separation
- For R>3cm use design similar to BaBar SVT
  - double-sided silicon sensors
  - 300mm thick,10-25μm spatial resolution



- Add layer-0
  - beam pipe radius 1.0cm
  - layer0 radius 1.5cm
  - spatial resolution 10μm
  - thickness (beam pipe + L0) ≤1.0% X0
  - Background, material, needed R&D are important ingredients
  - striplets Layer0 baseline TDR solution



Possible Layer0 design integrated w/ beam pipe



PROJECT STATUS

Project Status

- International endeavor with collaborators from Canada, France, Italy, Poland, Russia, Spain, UK, USA
- Since early 2007 the project, both its physics motivation and the machine design, has been extensively reviewed by several International committees:
    - International Review Committee (J. Dainton Chair)
    - ECFA appointed committee (T. Nakada Chair)
    - Machine Advisory Committee (Mini-MAC, J. Dorfan Chair)
    - No show stoppers found → April 2009: green light from technical reviews to proceed
- The SuperB project is part of Europe's HEP strategic plan
    - CERN Council's Strategy Group appointed dedicated reviewers
    - Spring 2009, INFN Board of Directors approved the SuperB TDR as a "Special Project"
    - INFN funded Detector R&D for 800 k€ for 2009 and same for 2010

Project Status (cont.)

- A substantial financial request from Science Ministry has resulted in the SuperB project being identified as the leading research activity in the National Research Plan, and being nominated for funds from the Infrastructure Inter-ministerial Panel (CIPE).
- There is a new plan to build photon beam lines and exploit a broader science program for the SuperB facility, in partnership with the Italian Institute of Technology, (IIT). IIT has strongly supported SuperB and proposes participation in providing the construction funds.
- No official approval yet . The Minister of Finance, the Science Minister, the president of INFN and the DG of IIT are all optimistic that the Italian government will soon approve construction. The Science Minister asked for patience, and a little more time.

Summary and Outlook

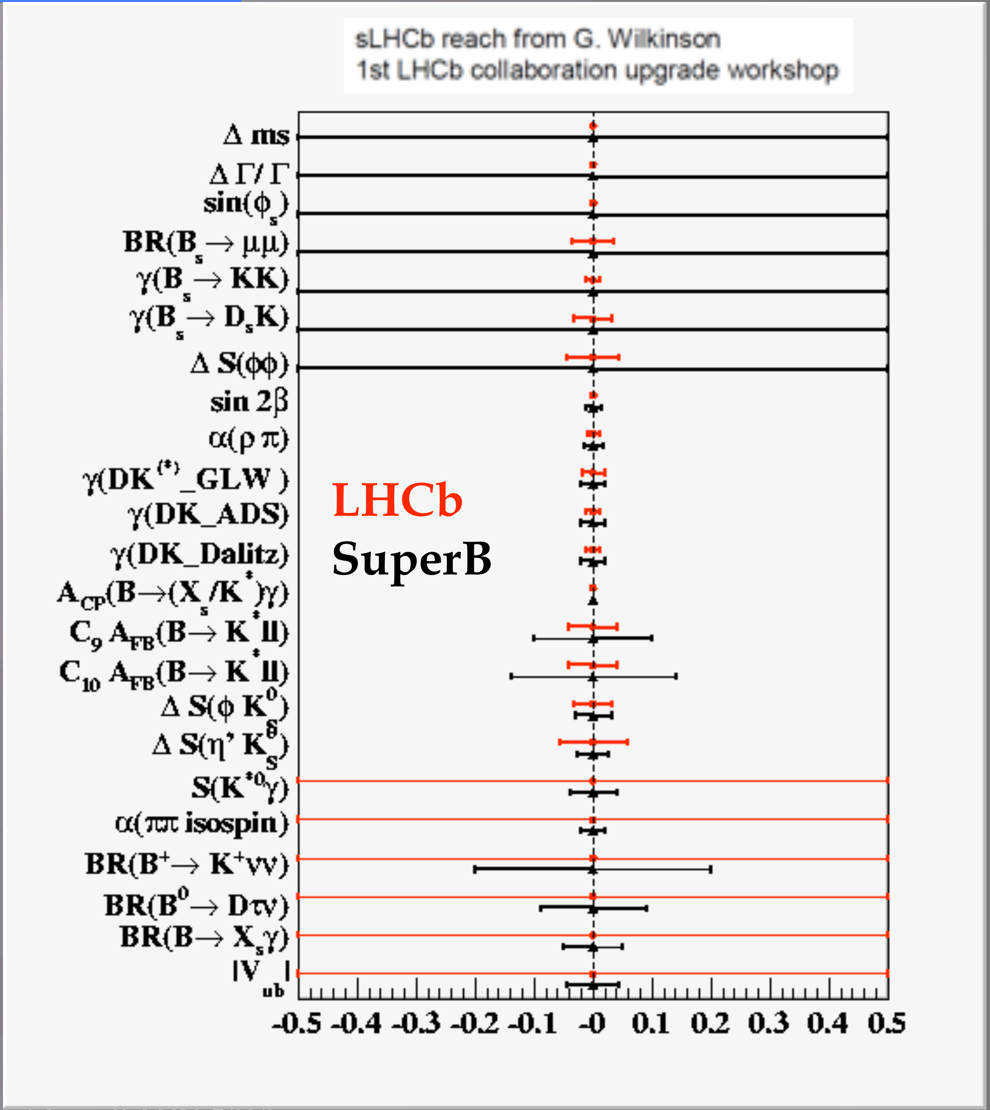
- A well-motivated community is working hard to complete the design of the accelerator and detector for this exciting experiment
- Physics potential as good as the Belle-II/SuperKEKB, with somewhat higher baseline luminosity, possibility to run at ψ(3770), and with polarized beam
- References:
  - Conceptual Design Report, arXiv:0709.0451 (2007)
  - SuperB Progress Reports (2010) – in many case with TDR-like details
    - arXiv:1007:4241 (Detector)
    - arXiv:1008.1541 (Physics)
    - arXiv:1009.6178 (Accelerator)
- Technical Design Report intended by the end of 2011

BACKUP SLIDES

SuperB vs. LHCb

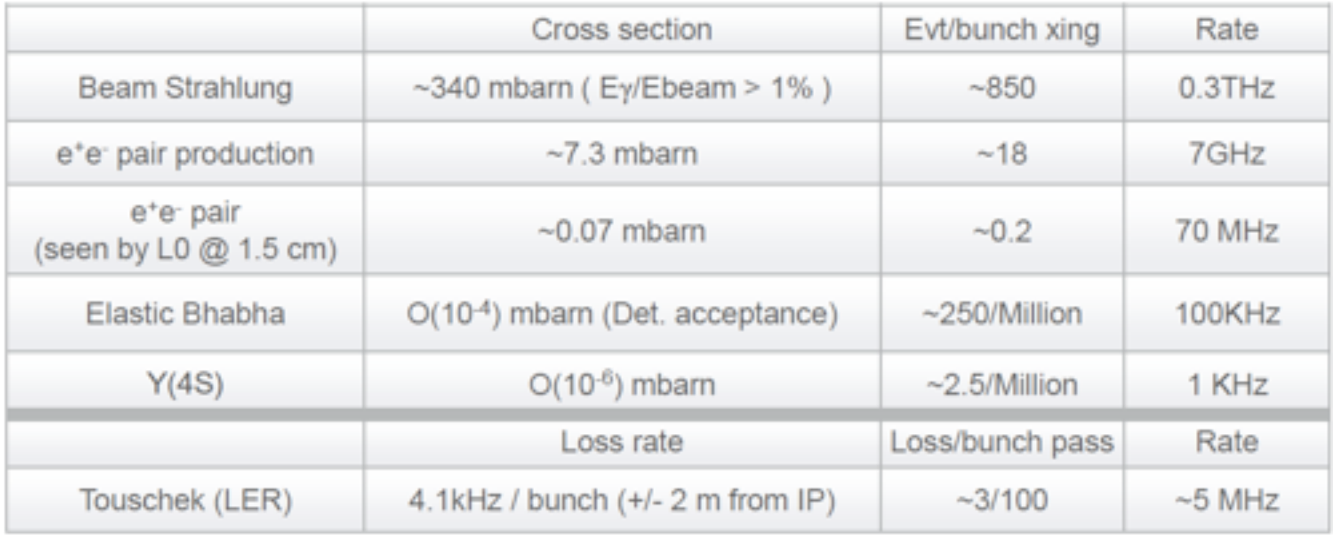
SuperB 50 ab^{-1} vs LHCb 100 fb^{-1}

- SuperB
  - has no handle on B_s time-dependent measurements
  - is much better in modes with neutrals
  - has no competition in channels with missing energy
- Programs largely complementary



sLHCb reach from G. Wilkinson
1st LHCb collaboration upgrade workshop

Machine-Detector Interface - Background Studies



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Touschek (LER)	4.1kHz / bunch (+/- 2 m from IP)	~3/100	~5 MHz

- *Colliding beams*
  - *Beam lifetime dominated by radiative Bhabha's*
  - *$e^+e^-e^+e^-$ production important source for SVT layer-0*
  - *impact on beam pipe,vertex detector design and B physics*
- *Single beam*
  - *synchrotron radiation strictly connected to IR design*
  - *Touschek negligible in BaBar, potentially important in SuperB*
  - *beam-gas, intra-beam scattering*
  - Collimators, dynamic aperture and energy acceptance optimization solve the problem of Touschek Background in LER