6th International Workshop on the Unitarity Triangle

CKM2010

6th – 10th September 2010, University of Warwick, UK

CP (and CPT) violation studies at the Super Flavour Factories

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on behalf of the SuperB collaboration

Outline

- ✓ The SuperB project
- ✓ Analisys strategy
- ✓ Time Dependent measurements
- ✓ Current analysis status and perspectives in SuperB for
  - α
  - β
  - γ
  - CPV in mixing and CPTV in B_d system
  - CPV and CPTV in τ decays
  - (for CPV in D system @ SuperB see Brian Meadows's talk)
- ✓ Conclusions

The SuperB project: case(s) of physics

✓ much more than a SuperB_d factory:

B_d physics

75 ab^{-1} @ Υ(4S): 80million $B\bar{B}$ pairs

Observable	B Factories (2 ab^{-1})	Super$B$ (75 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%
$\mathcal{B}(B \to D\tau\nu)$	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 (†)
$S(K_S^0\pi^0\gamma)$	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%
$\mathcal{B}(B \to K\nu\bar{\nu})$	visible	20%
$\mathcal{B}(B \to \pi\nu\bar{\nu})$	–	possible

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	[illegible]
$\cos(2\beta)$ (Dh^0)	[illegible]	0.04
$S(J/\psi\,\pi^0)$	0.10	[illegible]
$S(D^+D^-)$	0.20	[illegible]
$S(\phi K^0)$	0.13	0.02 (*)
$S(\eta' K^0)$	[illegible]	[illegible]
$S(K_S^0K_S^0K_S^0)$	0.15	0.02 (*)
$S(K_S^0\pi^0)$	0.15	0.02 (*)
$S(\omega K_S^0)$	0.17	[illegible]
$S(f_0K_S^0)$	0.12	0.02 (*)
γ $(B \to DK,\ D \to CP$ eigenstates)	$\sim 15°$	2.5°
γ $(B \to DK,\ D \to$ suppressed states)	$\sim 12°$	2.0°
γ $(B \to DK,\ D \to$ multibody states)	$\sim 9°$	1.5°
γ $(B \to DK$, combined)	$\sim 6°$	1–2°
α $(B \to \pi\pi)$	$\sim 16°$	3°
α $(B \to \rho\rho)$	$\sim 7°$	1–2° (*)
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°

charm physics

75 ab^{-1} @ Υ(4S): 100 million $c\bar{c}$ pairs

+ possilbe run @ Ψ(3770)

Channel	Integrated luminosity (fb^{-1})	Integrated luminosity (fb^{-1})
$D^0 \to K^-e^+\nu_e$	1.3	33
$D^0 \to K^{*-}e^+\nu_e$	17	425
$D^0 \to \pi^-e^+\nu_e$	[illegible]	[illegible]
$D^0 \to \rho^-e^+\nu_e$	45	1125
$D^+ \to K_S^0e^+\nu_e$	[illegible]	[illegible]
$D^+ \to K^{*0}e^+\nu_e$	9	[illegible]
$D^+ \to \pi^0e^+\nu_e$	75	1900
$D^+ \to \rho^0e^+\nu_e$	110	2750
$D_s^+ \to \phi e^+\nu_e$	85	2200
$D_s^+ \to K_S^0e^+\nu_e$	1300	33000
$D_s^+ \to K^{*0}e^+\nu_e$	1300	[illegible]

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}
$D^0 \to K_S^0\pi^+\pi^-$	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}
	x_D	$2\text{–}3 \times 10^{-3}$	5×10^{-4}

τ physics

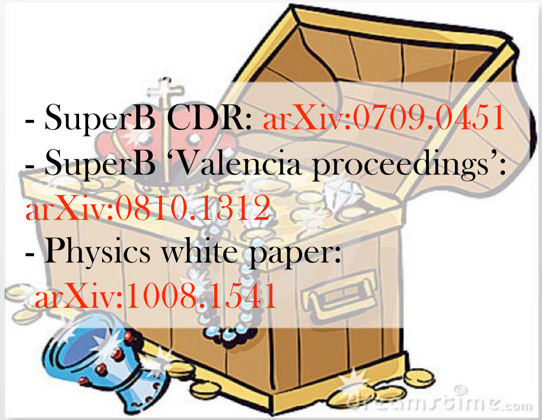
75 ab^{-1} @ Υ(4S): 70million ττ pairs

Process	Sensitivity
$\mathcal{B}(\tau \to \mu\gamma)$	2×10^{-9}
$\mathcal{B}(\tau \to e\gamma)$	[illegible]
[illegible]	[illegible]
$\mathcal{B}(\tau \to eee)$	2×10^{-10}
$\mathcal{B}(\tau \to \mu\eta)$	4×10^{-10}
$\mathcal{B}(\tau \to e\eta)$	[illegible]
$\mathcal{B}(\tau \to \ell K_S^0)$	2×10^{-10}

B_s physics

possible run @ Υ(5S)

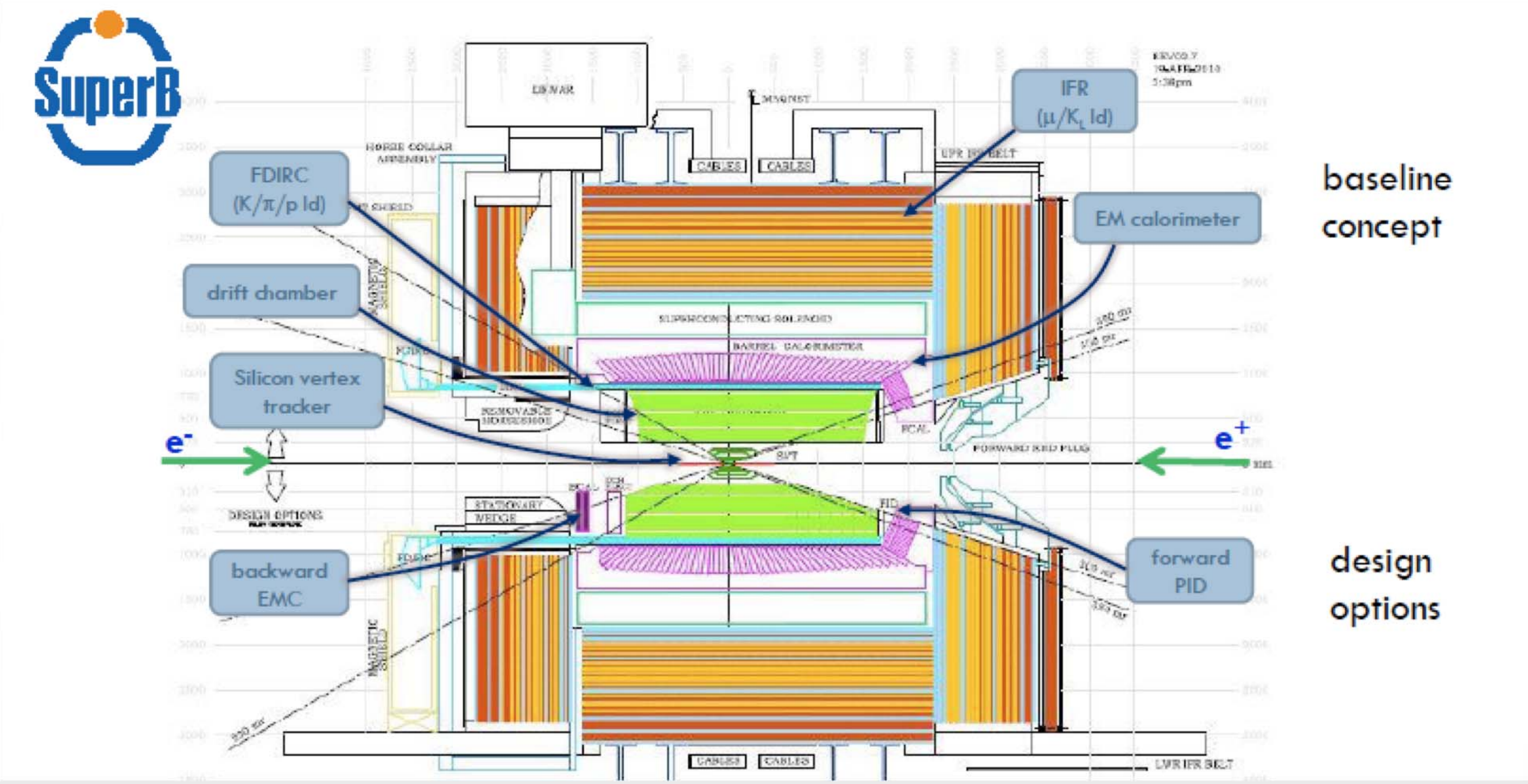
Observable	Error with 1 ab^{-1}	Error with 30 ab^{-1}
$\Delta\Gamma$	0.16 ps^{-1}	0.03 ps^{-1}
Γ	[illegible]	0.01 ps^{-1}
β_s from angular analysis	[illegible]	[illegible]
A_{SL}^s	0.006	0.004
A_{CH}	[illegible]	[illegible]
$\mathcal{B}(B_s \to \mu^+\mu^-)$	-	$< 8 \times 10^{-9}$
$\|V_{td}/V_{ts}\|$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



- SuperB CDR: arXiv:0709.0451
- SuperB 'Valencia proceedings': arXiv:0810.1312
- Physics white paper: arXiv:1008.1541

The SuperB detector

✓ start from BaBar experience (and re-usable parts) to obtain equal or better performances in an higher background environment and with different beam conditions (boost)



Detector white paper:
arXiv:1007.4241

Assumptions and strategy

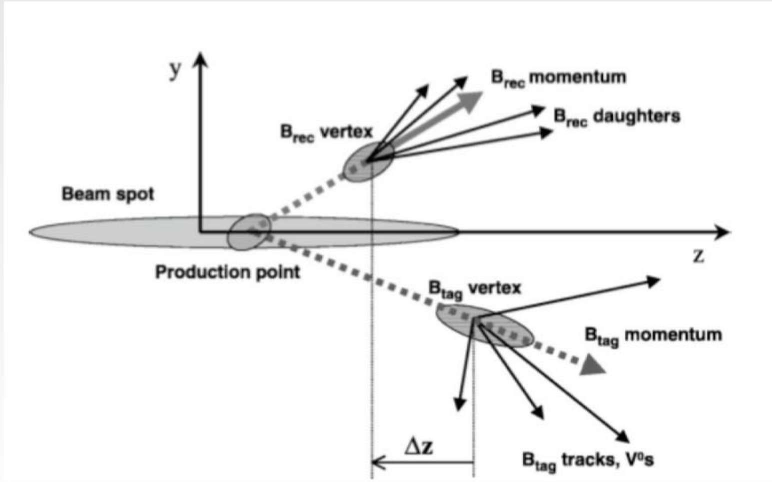
- ✓ SuperB initial peak luminosity: $10^{36} cm^{-2} s^{-1}$ @ Y(4S) resonance
  - Can integrate 15 ab^{-1} in a Snowmass Year of 10^7 s
  - integrate 75ab^{-1} in 5 years of operation

- ✓ extrapolate BaBar most recent measurements to 5 year of SuperB data takingmaking consideration on how to improve systematic errors
  - some statistical in origin, i.e.: fixed fit parameters, background composition and CP content knowledge, signal and background pdf parameterization → use of data and MC control samples
  - some require analysis technique improvement, i.e. : fit biases due to hidden correlation not accounted for in BaBar due to limited statistics, high background contamination

- ✓ most of the improvements due to upgraded detector still under study, e.g.
  - effect of new PID devices
  - improvements in Δt resolution and tagging technique (see next slides)

→ not included in most of the SuperB projections that will be shown

Time dependent analysis (I)



$\Delta t \approx \Delta z/(\beta\gamma)$

BaBar: $\beta\gamma$=0.56

SuperB: $\beta\gamma$=0.28

✓ $f_+(f_-)$: Δt distribution function for B^0 ($\overline{B}^0$) tagged events (not accounting for experimental effects)

$$\boxed{f_{\pm}(\Delta t) = \frac{e^{-|\Delta t|/\tau_{B^0}}}{4\tau_{B^0}}[1 \pm S sin(\Delta m \Delta t) \mp C cos(\Delta m \Delta t)]}$$

✓ S and C related to CPV in the interference between mixing and decay (CKM angles, i.e. f = J/Ψ Ks, S =sin2β) and direct CPV + indirect CPV, risp.

Time dependent analysis (II)

Changes in the two main ingredients of TD analysis:

✓ Δt resolution: SuperB boost < BaBar boost → smaller Δz, worst Δt resolution

to cure this:

- add SVT L_0, reducing SVT inner raius (3.32 cm → 1.60 cm)
- reduced beamspot size
- lower material budget for the beampipe

→ preliminary studies: Δt determined with similar precision wrt BaBar

✓ Flavor tagging algorithm (to determine Btag flav and decay vertex):

- BaBar: Neural Network approach to isolate high momentum leptons, K and π
- figure of merit

$$\boxed{Q = \epsilon_{tag}(1-2\omega)^2 \simeq 30\%}$$

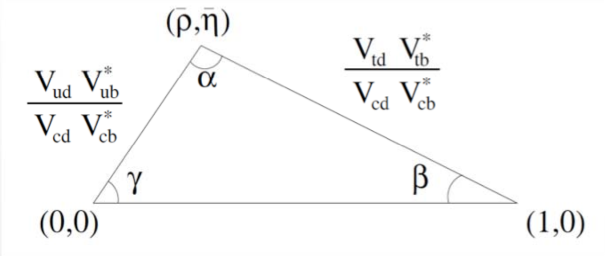
$$\epsilon_{tag} = \text{tagging efficiency}$$
$$\omega = \text{mistag probability}$$

- resolution on S and C related to Q : $\boxed{\sigma_{S,C} \propto 1/\sqrt{Q}}$

→ SuperB: expect to increase Q thanks to larger tracking coverage, improved PID, improved vertexing (under study)

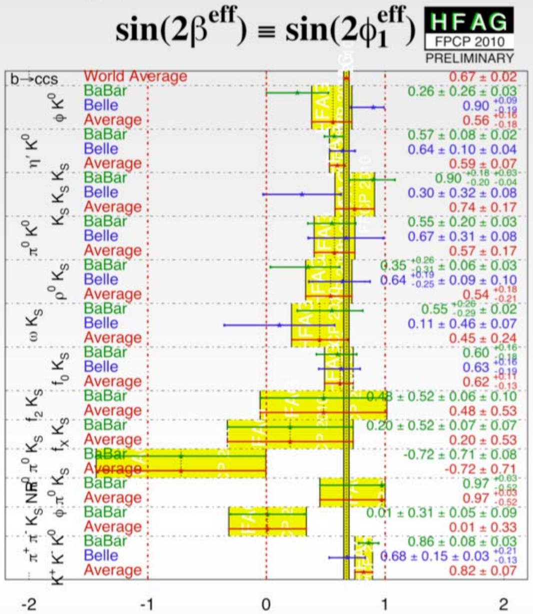
Measurements of β

$$\beta \equiv arg[-V_{cd}V_{cb}^*/V_{td}V_{tb}^*]$$



Experimental status

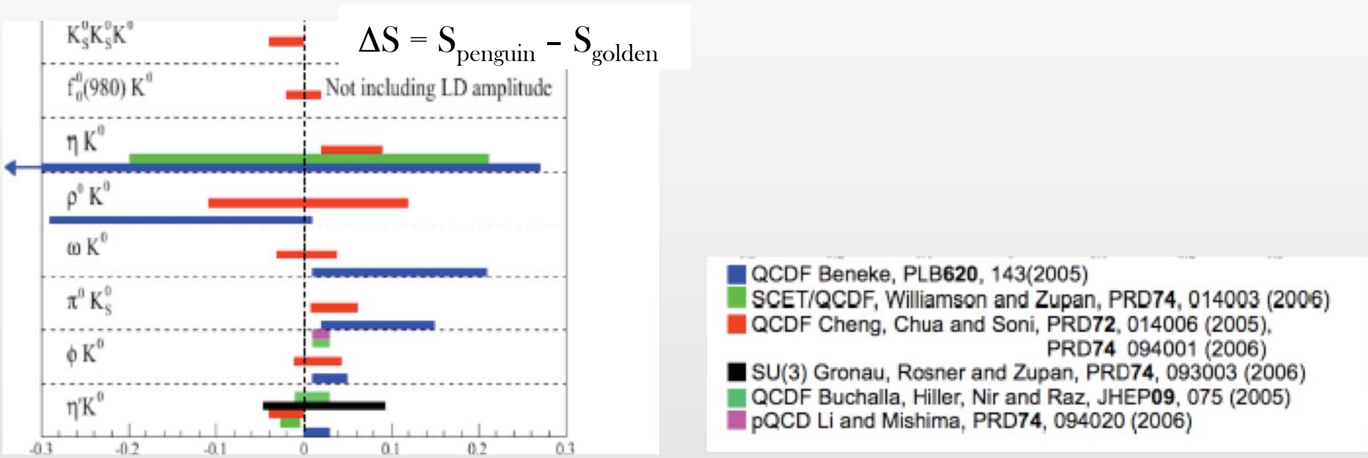
- ✓ β: CKM angle measured with the highest precision, using golden $b \to c\bar{c}s$ modes



- ✓ golden modes: interfering tree level and penguin diagrams with ~ same weak phase → measure β

- ✓ penguin dominated modes: interference between diagrams with different weak phases
→ expect small discrepancies wrt to β from golden modes
→ if not: hint of NP in the loop

- ✓ need theoretically clean penguin modes (even if exp errors dominate in most of the cases)

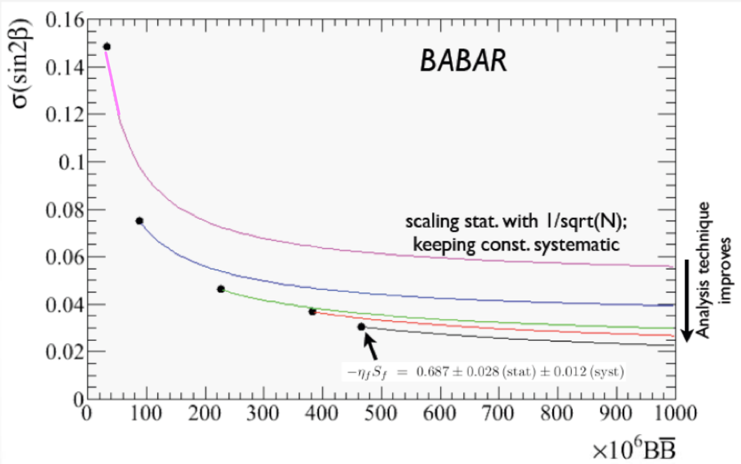


β from golden modes

✓ BaBar measurement (averaging on many charmonium modes) : $sin(2\beta) = 0.687 \pm 0.028 \pm 0.012$

Phys.Rev.D79:072009,2009
465 million $B\bar{B}$ pairs

✓ sin2β uncertainty history and major systematic uncertainties



Main Syst sources	Error
S	
Tagging	0.006
Δt resolution	0.007
Bkg characteristics (fraction, CP content,..)	0.008
$\sigma_{S,tot} = 0.012$	
C	
Tag Side interference (DCSD)	0.014
$\sigma_{C,tot} = 0.016$	

✓ possible analysis technique improvement:

– with highest stat, use only cleaner modes to reduce bkg syst, i.e. lepton tag only: cleanest tag category, eliminate tag side interference, account for > 25% of Q (~ 30%)

✓ @ SuperB: with 75 ab^{-1}, possible reduction of syst error down to 0.005 (considering $B \rightarrow J/\Psi K_s$ only)

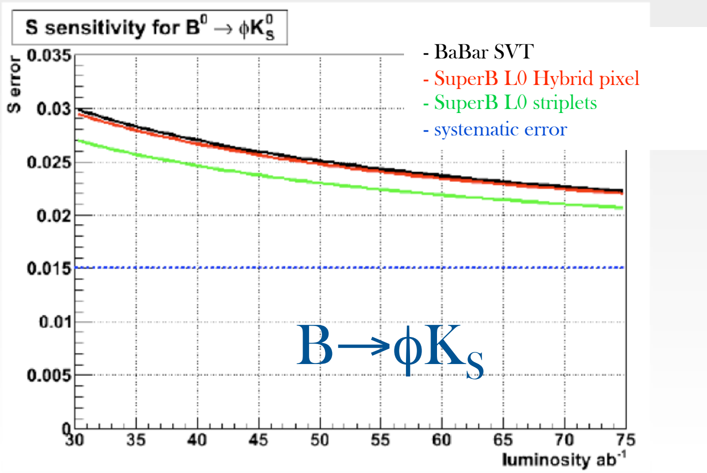
β from penguins: $B^0 \to \phi(K^+K^-)K_s$ and $B^0 \to \eta' K_s$

(BaBar measurement uses K_S + K_L samples)

$\phi(K^+K^-)K_s$:arXiv:0808.0700,2008
$\eta' K_s$ Phys.Rev.D79:052003,2009
465 million $B\overline{B}$ pairs

$\sin(2\beta)_{\phi KS} = 0.26 \pm 0.26 \pm 0.03$

- ✓ $|\sin 2\beta_{\eta' K0} - \sin 2\beta_{golden}| \sim O(0.01)$ *ref-sb1
- ✓ $\sigma(S)_{BaBar,\ syst} \sim 0.02$
- ✓ SuperB projection @ 75ab^{-1}:
- – reduction on S syst error by a factor 2
- – stat and syst errors comparable: $\sigma(S) \sim 0.02$



$\sin(2\beta)_{\eta' K0} = 0.57 \pm 0.08 \pm 0.02$

- ✓ $|\sin 2\beta_{\eta' K0} - \sin 2\beta_{golden}| \sim 0.03 \div 0.09$ *ref-sb2
- ✓ Preliminary studies on $\eta'(\eta(\gamma\gamma)\pi^+\pi^-)\ K_S(\pi^+\pi^-)$: $\sigma(S)_{syst}$ reduction down to 0.005 with higher statistics data and MC control samples
- ✓ possible syst reduction by removing most contaminated modes as $K_S \to \pi^0\pi^0$, used in BaBar

β @ SuperB: summary

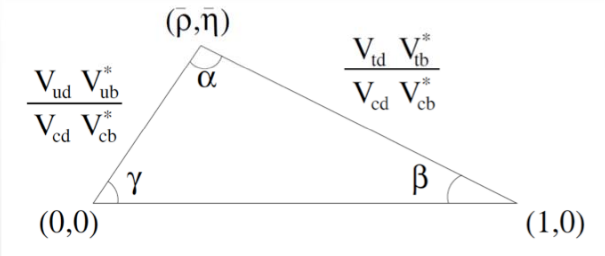
- ✓ Overview on β measurements with current precision and SuperB projection @ $75ab^{-1}$
  - scale stat and reducible syst uncertainties by luminosity
  - detector performance improvements not accounted for

Mode	Current Precision			Predicted Precision ($75\,\mathrm{ab}^{-1}$)		
	Stat.	Syst.	Th.	Stat.	Syst.	Th.
$J/\psi K^0_S$	0.022	0.010	< 0.01	0.002	0.005	< 0.001
$\eta' K^0_S$	0.08	0.02	0.014	0.006	0.005	0.014
$\phi K^0_S \pi^0$	0.28	0.01	–	0.020	0.010	–
$f_0 K^0_S$	0.18	0.04	0.02	0.012	0.003	0.02
$K^0_S K^0_S K^0_S$	0.19	0.03	0.013	0.015	0.020	0.013
ϕK^0_S	0.26	0.03	0.02	0.020	0.010	0.005
$\pi^0 K^0_S$	0.20	0.03	0.025	0.015	0.015	0.025
ωK^0_S	0.28	0.02	0.035	0.020	0.005	0.035
$K^+ K^- K^0_S$	0.08	0.03	0.05	0.006	0.005	0.05
$\pi^0 \pi^0 K^0_S$	0.71	0.08	–	0.038	0.045	–
ρK^0_S	0.28	0.07	0.14	0.020	0.017	0.14
$J/\psi \pi^0$	0.21	0.04	–	0.016	0.005	–
$D^{*+} D^{*-}$	0.16	0.03	–	0.012	0.017	–
$D^+ D^-$	0.36	0.05	–	0.027	0.008	–

arXiv:1008.1541 (2010)

Measurement of α

$$\alpha \equiv arg[-V_{td}V_{tb}^*/V_{ud}V_{ub}^*]$$

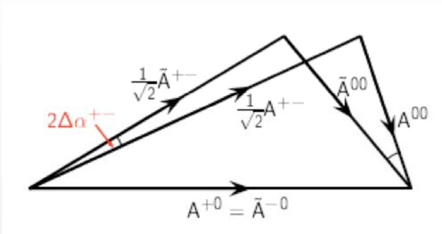


Experimental methods

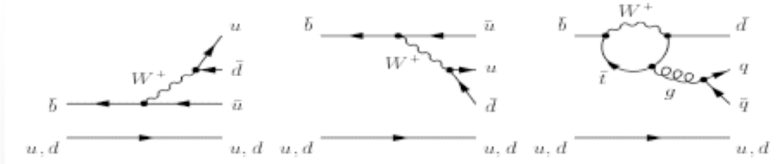
- examine b→uūd decays
  - $\sin 2\alpha_{eff} = \sin 2(\alpha - \Delta\alpha)$ entering time dependent rate: $S = \sqrt{1-C^2}\, sin2\alpha_{eff}$
  - $\Delta\alpha$ due to penguin pollution

- time dependent analysis allows to measure $\sin 2\alpha_{eff}$, SU(X) symmetries allows to disentangle α and $\Delta\alpha$, i.e.:
  - SU(2) analysis*ref_sa1: $B \to \pi\pi$, $\rho\rho$
  - SU(3) analysis*ref_sa2: $B \to \rho\rho$, $a_1\pi$

α from $B \to \pi\pi$ analysis



$$A = \alpha_T \cdot T + \quad \alpha_C \cdot C + \quad \alpha_P \cdot P$$

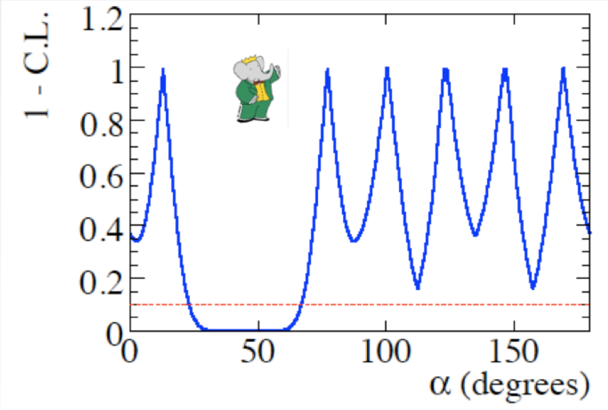


	isospin factors α_T	α_C	α_P	exp. quantities
$B^0 \to \pi^0\pi^0$ (A_{00})	0	1	-1	BF_{00}, C_{00}, (S_{00})
$B^0 \to \pi^+\pi^-$ (A_{+-})	$\sqrt{2}$	0	$\sqrt{2}$	BF_{+-}, C_{+-}, S_{+-}
$B^+ \to \pi^+\pi^0$ (A_{+0})	1	1	0	BF_{+0}

- Dominant uncertainties on C and S common to $\sin 2\beta$ analysis
- Should consider also syst on the Branching Fraction (BF) and longitudinal polarization fraction (f_L), used in the SU(2) and SU(3) method

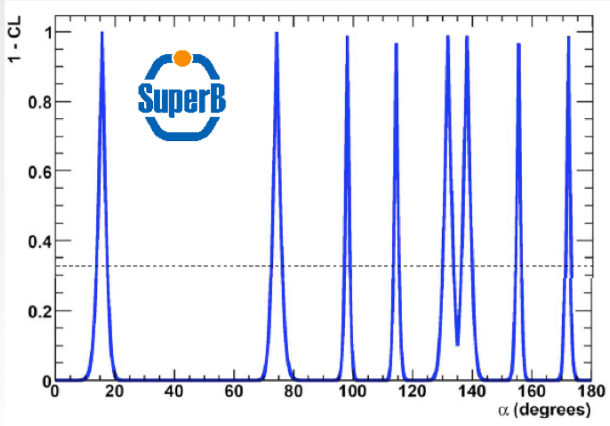
$B \rightarrow \pi\pi$ - SU(2)

✓ BaBar analysis [arXiv:0807.4226]
467 million BB pairs



$\alpha \in [71°,109°]$ @ 68% CL
choosing SM preferred solution*ref_sa3

SuperB with $75ab^{-1}$



6 physics observables:
- $\mathcal{B}(B^0 \rightarrow \pi^+\pi^-)$, $\mathcal{B}(B^0 \rightarrow \pi^0\pi^0)$, $\mathcal{B}(B^+ \rightarrow \pi^+\pi^0)$
- $C(\pi^+\pi^-)$, $S(\pi^+\pi^-)$, $C(\pi^0\pi^0)$

$S(\pi^0\pi^0)$ not measured (hard to make vertex)

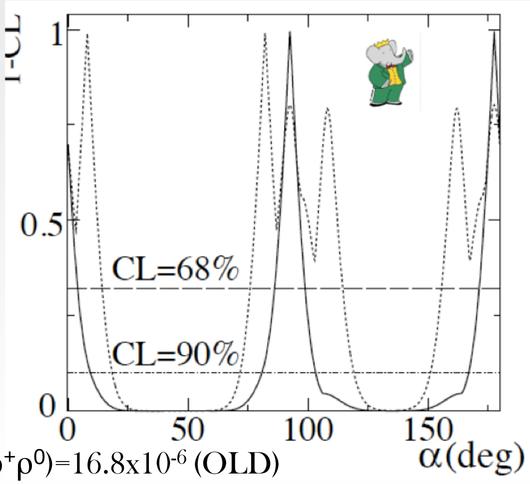
- solution clearly separated
- $\sigma(\alpha) = 0.9° \div 1.9°$
- S_{00} measurements feasible @ 50 ab^{-1} using photon conversion*ref_sa4 → further resolve ambiguities

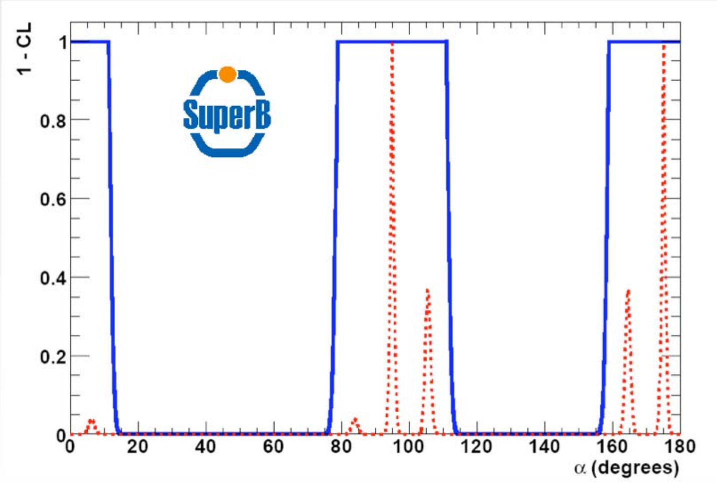
Systematic uncertainties:
- CP parameters: common to sin2β analysis
- BF: important contribution from discrepancy between data and MC affecting selection efficiencies estimation (overall signal selection, π^0 selection,...) → room for improvement

$B \to \rho\rho$ - SU(2)

✓ BaBar analysis PRD 78 (2008), 071104
465 million BB pairs

SuperB with 75ab^{-1}





····· $\mathcal{B}(B^+ \to \rho^+\rho^0)=16.8\times10^{-6}$ (OLD)
---- $\mathcal{B}(B^+ \to \rho^+\rho^0)=23.7\times10^{-6}$ (NEW)

$\alpha = (92.4^{+6.0}_{-6.5})^\circ$ @ 68% CL

physics observables:
- $(BF + f_L) \times 3$ and $(C_L,S_L)\times2$

3 σ evidence for $B^0 \to \rho^0\rho^0$, will benefit of SuperB higher stat.
- NEW $\mathcal{B}(B^+ \to \rho^+\rho^0)$: ambiguities degenerate

- blue histo: ignoring C_{00} and S_{00} → ambiguities not solved
- red curve: OLD $\mathcal{B}(B^+ \to \rho^+\rho^0)$ measurement
- $\sigma(\alpha) \sim 0.75^\circ$

Systematic uncertainties:
- CP parameters: common to sin2β analysis
- BF and F_L: important contribution from fit biases and bkg characterization → improvements in the analysis technique needed

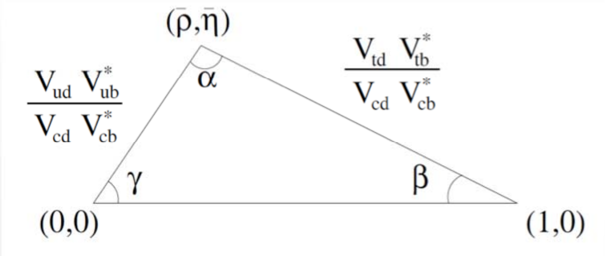
Other analysis and general comments on α @ SuperB

- ✓ $B^0 \rightarrow (\rho\pi)^0$:
  - BaBar measurement (Phys.Rev,D76:012004,2007) : $\alpha = (87^{+45}_{-13})^\circ$
  - NOW not competitive, in terms of precision, with other measurements; hard to make an estimate of the SuperB reach due to the complex analysis technique
  - 12 physical quantities involved in the isospin analysis → useful to resolve ambiguities
- ✓ $B \rightarrow a_1\pi + B \rightarrow K_{1A}\pi$, $+ B \rightarrow a_1K$: SU(3) analysis
  - BaBar measurement (Phys.Rev,D81:052009,2010) : $\alpha = (79 \pm 7 \pm 11)^\circ$
  - statistic uncertainties of TD analysis comparable to $\rho\rho$ analysis
  - @ SuperB time can benefit from higher statistics, improved analysis technique and theoretical inputs

- ✓ In summary:
  - $\approx 1^\circ$level precision reachable with $75ab^{-1}$ using SU(2) $\pi\pi$ and $\rho\rho$ analysis
  - combination of measurements, in particular $B^0 \rightarrow (\rho\pi)$, will resolve ambiguities
  - at high lumi, measurements will be dominated by systematics → need to work on analysis techniques (i.e. improve tagging algorithm and/or use lepton tag only, more accurate treatment of correlation)

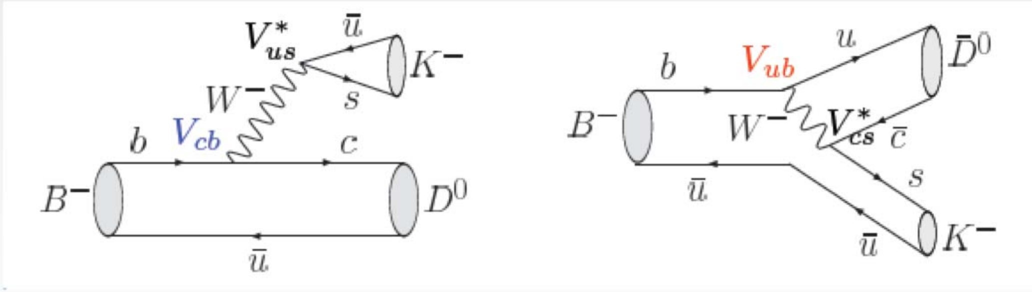
Measurements of γ

$$\gamma \equiv arg[-V_{ud}V_{ub}^{*}/V_{cd}V_{cb}^{*}]$$



Experimental methods

- γ-dependent observables in $B \to D^{(*)0}K^{(*)}$ processes :
  - interference between b→c color favoured vertex and b→u color suppressed transition



  - use D final states accessible to D^0 and $\bar{D}^0$
  - consider processes with tree level diagrams @ leading order → negligible NP effects (if any)
  - exp. challenging due to small BF & sensitivity to $\gamma \sim 1/r_B$ with

$r_B = |A(b \to u)| / |A(b \to c)| \sim 0.1 - 0.2$

- different methods for different D final states:
  - Dalitz plot or GGSZ method*ref_g1 : Cabibbo favoured 3-body final states
  - GLW*ref_g2 : Cabibbo suppressed CP eigenstates
  - ADS*ref_g3 : doubly Cabibbo suppressed modes

for details on BaBar Analysis see Giovanni Marchiori's talk

GGSZ method

- ✓ $D^0 \to K_s h^+ h^-$ with h = K,π :
$$A(B^- \to [K_S h^+ h^-]_{D^0} K^-) \propto A_{D+} + r_B e^{-i\delta_B - i\gamma} A_{D-}$$
$$A(B^+ \to [K_S h^+ h^-]_{D^0} K^+) \propto A_{D-} + r_B e^{+i\delta_B + i\gamma} A_{D+}$$
- ✓ measure γ from Dalitz plot distribution of D^0 daughters:
  - equations for B→DK (similarly for B→D*K and B→DK*)

$$\Gamma_\pm(m_-^2, m_+^2) \propto |A_{D\pm}|^2 + r_B^2 |A_{D\mp}|^2 + 2\lambda\{x_\pm Re[A_{D\pm} A_{D\mp}^*] + y_\pm Im[A_{D\pm} A_{D\mp}^*]\}$$

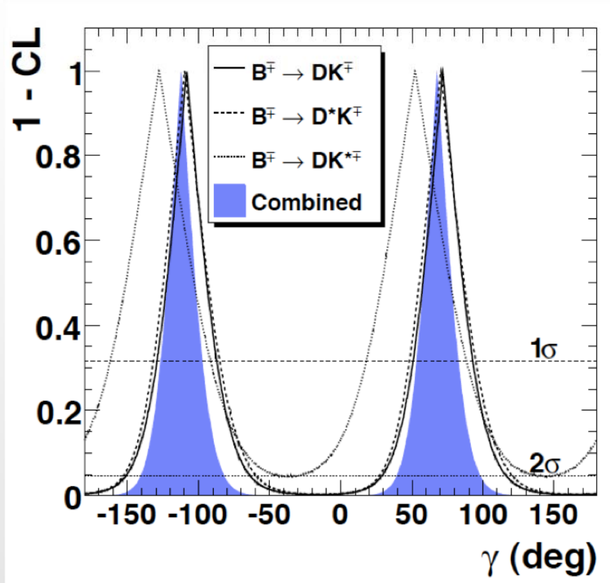
$$\boxed{\begin{array}{l} m_\pm = m(K_S h^\pm) \\ A_{D\pm}: \; D^0/\bar{D}^0 \;\; \text{decay amplitudes} \\ \lambda = +1 \quad \text{for } B \to D^0K, D^{*0}(D^0\pi^0)K, D^0K^* \\ \quad = -1 \quad \text{for } D^{*0}(D^0\gamma)K \end{array}}$$

$$x_\pm = r_B cos(\delta_B \pm \gamma);$$
$$y_\pm = r_B sin(\delta_B \pm \gamma);$$
$$\delta_B: \; A(b \to u) - A(b \to c) \;\; \text{strong phase difference;}$$
$$r_B^2 = (|A(b \to u)|/|A(b \to c)|)^2 = x^2 + y^2$$

- ✓ measure (x,y) (12 params) to extract $3x(r_B, \delta)+ \gamma$

hep-ex:10051096
468 million BB pairs

$\gamma = (68 \pm 14_{stat} \pm 4_{syst} \pm 3_{model})°$ (mod 180°)



- ✓ Main contribution to syst error reducible with higher statistics
- ✓ 3° error related to Dalitz model

→ estimated precision on (x,y) pairs due to syst = 0.003, due to model = 0.006

GLW and ADS methods

GLW

- ✓ reconstruct $D_{CP} \to K^+K^-$ / $\pi^+\pi^-$/ $K_S\pi^0/K_S\phi/K_S\omega$ and $D_{flav} \to K\pi$ and measure

$$A_{CP\pm} \equiv \frac{\Gamma(B^- \to D_{CP\pm}K^-) - \Gamma(B^+ \to D_{CP\pm}K^+)}{\Gamma(B^- \to D_{CP\pm}K^-) + \Gamma(B^+ \to D_{CP\pm}K^+)} = \frac{\pm 2r_B sin\delta_B sin\gamma}{1 + r_B^2 \pm 2r_B cos\delta_B cos\gamma}$$

$$R_{CP\pm} \equiv 2\frac{\Gamma(B^- \to D_{CP\pm}K^-) + \Gamma(B^+ \to D_{CP\pm}K^+)}{\Gamma(B^- \to D^0K^-) + \Gamma(B^+ \to \bar{D}^0K^+)} = 1 + r_B^2 \pm 2r_B cos\delta_B cos\gamma$$

- ✓ results:

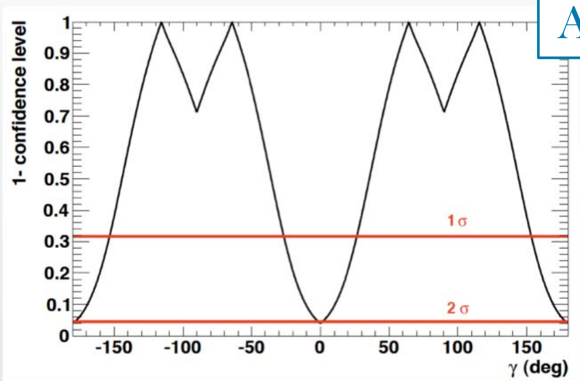
arXiv:1006.4241,2008
467 million BB pairs

	γ mod 180 [°]
68% CL	[11.3, 22.7]
	[80.9, 99.1]
	[157.3, 168.7]
95% CL	[7.0, 173.0]

- ✓ Systematics
  - estimated irreducible systematics on $R_{CP\pm}$ and $A_{CP\pm}$ = 0.02 and 0.01

ADS

- ✓ Reconstruct $D \to K^\pm\pi^\mp$ and measure charge-averaged decay rate (R_{ADS}) and CP asymmetry A_{ADS} to constrain γ
- ✓ less stringent than other two methods measurements
- ✓ estimated irreducible systematics on R_{ADS} and A_{ADS} = 0.02×10^{-2} and 0.01 respectively



Method combination

Expected precision on γ measurements combining GGSZ+GLW+ADS @ 75ab^{-1}:

- ✓ GGSZ only : $\sigma(\gamma) = 2.8°$
- ✓ GGSZ+GLW : $\sigma(\gamma) = 2.5°$
- ✓ GGSZ+GLW+ADS : $\sigma(\gamma) = 1.7°$

GGSZ method provides most precise constraint, main syst due to Dalitz Model → room for improvements?

- ✓ hard to reduce Dalitz Plot model error down to 3°
- ✓ can combine measurements from different multi-body final states ($D \to K_S K\pi$, $K_S\pi^0\pi\pi$, $KK\pi\pi$)
  - GGSZ (multi-Dalitz analysis) + GLW + ADS : $\sigma(\gamma) = 1°$
- ✓ perform a model independent analysis [*ref_g1] using a high statistic $\Psi(3770) \to DD$ correlated data sample to study the Dalitz plot
  - estimated 1 week of running to reduce $\sigma(x)$ and $\sigma(y)$ down to 0.003 (stat error)
  - GGSZ (model independent) + GLW+ADS : $\sigma(\gamma) = 0.72°$

indirect CPV and CPTV in neutral B_d decays

theory and experimental status

- ✓ investigate T, CP, and CPT violation in B^0 mesons: key relations and simmetry conservation:

$$|B_L\rangle = p\sqrt{1-z}|B^0\rangle + q\sqrt{1-z}|\bar{B^0}\rangle$$
$$|B_H\rangle = p\sqrt{1+z}|B^0\rangle - q\sqrt{1-z}|\bar{B^0}\rangle$$

$B_{H,L}$ mass eigenstates, B^0 strong eigenstates

symmetry	conserved if ..
CPT	z $= 0$
T	$\|q/p\| = 1$
CP	z $= 0$ && $\|q/p\| = 1$

$$A_{T/CP} = \frac{P(\bar{B^0}\to B^0) - P(B^0\to\bar{B^0})}{P(\bar{B^0}\to B^0) + P(B^0\to\bar{B^0})} = \frac{1-|q/p|^4}{1-|q/p|^4}$$

$$A_{CPT/CP}(|\Delta t|)) = \frac{P(B^0\to B^0) - P(\bar{B^0}\to\bar{B^0})}{P(B^0\to B^0) - P(\bar{B^0}\to\bar{B^0})} \simeq 2\frac{Imz\ sin(\Delta m\Delta t) - Rez\ sinh(\frac{\Delta\Gamma\Delta t}{2})}{cosh(\frac{\Delta\Gamma\Delta t}{2}) + cos(\Delta m\Delta t)}$$

- ✓ most precise BaBar measurement

(Phys.Rev.Lett.96:251802,2006, 232 million BB pairs):

$$\left|\frac{q}{p}\right| - 1 = (-0.8 \pm 2.7 \pm 1.9) \times 10^{-3}$$
$$Imz = (-13.9 \pm 7.3 \pm 3.2) \times 10^{-3}$$
$$\Delta\Gamma \times Rez = (-7.1 \pm 3.9 \pm 2.0) \times 10^{-3}$$

consistent with SM expectations

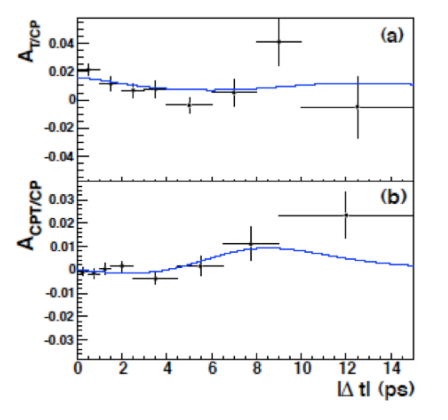


FIG. 1: (a) $A_{T/CP}$ asymmetry between (ℓ^+,ℓ^+) and (ℓ^-,ℓ^-). A larger charge asymmetry for cascade muons, dominant at small $|\Delta t|$, explains the non-flatness of the curve. (b) $A_{CPT/CP}$ asymmetry between (ℓ^+,ℓ^-) dileptons with $\Delta t > 0$ and $\Delta t < 0$.

Systematics and SuperB projections

✓ systematic uncertainties:

estimated on MC and data control samples

depends on precision of other measurements

need improvements in the detector knowledge

Systematic Effects	$\sigma(\lvert q/p\rvert)$ $(\times 10^{-3})$	$\sigma(\mathrm{Im}\, z)$ $(\times 10^{-3})$	$\sigma(\Delta\Gamma \times \mathrm{Re}\, z)$ $(\times 10^{-3}\,\mathrm{ps}^{-1})$
Ch. asym. of non-$B\bar{B}$ bkg	0.6	0.0	0.0
Ch. asym. in tracking	1.0	0.0	0.0
Ch. asym. of electrons	1.4	0.0	0.0
PDF modeling	0.3	2.5	1.2
Fraction of bkg components	0.2	0.4	0.1
Δm, τ_{B^0}, $\tau_{B^\pm}$ and $\Delta\Gamma$	0.2	1.9	1.1
SVT alignment	0.5	0.6	1.2
Total	1.9	3.2	2.0

✓ achievable precision @ Superb with 75 ab^{-1}:

- $\sigma(\mathrm{Im}\, z) = 0.6 \times 10^{-3}$
- $\sigma(\Delta\Gamma \times \mathrm{Re}\, z) = 0.3 \times 10^{-3}$

✓ data @ $\Psi(3770)$ threshold allow to do similar CPT tests in D decays

→ potential of SuperB for this scenario under study

CPV in τ decays

CPV in $\tau \rightarrow hK_S\nu_\tau$

- ✓ SM CPV in τ decays expected to be negligible (i.e. in $\tau \rightarrow K\pi^0\nu_\tau$ A_{CP}~ $O(10^{-12})$)
- ✓ $\tau \rightarrow \pi K_S \nu_\tau$: small CP asymmetry due to K^0 mixing (3.3×10^{-3}), computed with 2% precision[*ref_tau1], calibration measurements for CP searches in τ decays

- ✓ BaBar analysis (ICHEP10 preliminary result, 900 million τ decays):
  - measure:

$$A_Q = \frac{\Gamma(\tau^+ \rightarrow h^+ K_S n\pi^0 \bar{\nu_\tau}) - \Gamma(\tau^- \rightarrow h^- K_S n\pi^0 \nu_\tau)}{\Gamma(\tau^+ \rightarrow h^+ K_S n\pi^0 \bar{\nu_\tau}) + \Gamma(\tau^- \rightarrow h^- K_S n\pi^0 \nu_\tau)} = (-0.10 \pm 0.21 \pm 0.22)$$

SM expectation: $(0.17 \pm 0.01)\%$

h = K, π

  - systematics from detector charge asymmetry (from data control samples) and selection biases (from MC sample)
  - also in this case, the higher SuperB samples will reduce the syst (estimation ongoing)

CPT tests

✓ evidence for CPT violation if $r_m = \frac{m_{\tau^-} - m_{\tau^+}}{m_{\tau^-} + m_{\tau^+}} \neq 0$ and/or $r_\tau = \frac{\tau_{\tau^-} - \tau_{\tau^+}}{\tau_{\tau^-} + \tau_{\tau^+}} \neq 0$

Phys.Rev.D80:092005,2009
460 million ττ pairs

✓ BaBar analysis:

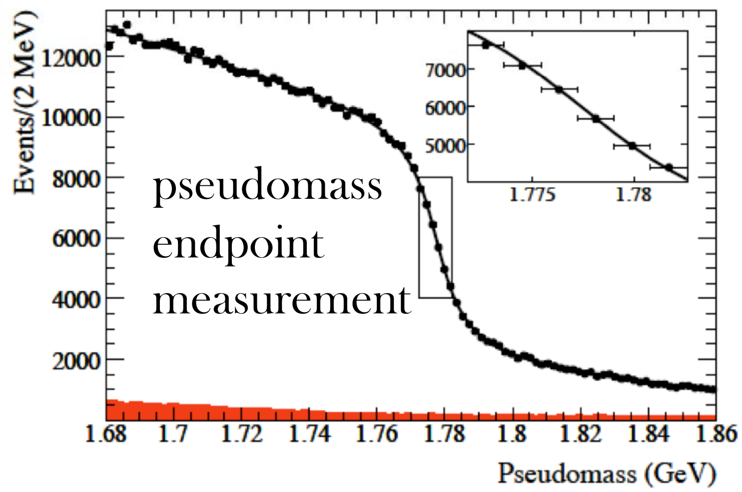
$r_m = (-3.4 \pm 1.3 \pm 0.3) \times 10^{-4}$

$\rightarrow r_m < 5.5 \times 10_{-4}$ @ 90% CL

✓ major syst uncertainties due to uncertainty on the momentum measurement due to knowledge of magnetic field and support tube material budget

✓ @ SuperB: measurement systematically limited; challenging to reduce syst but higher statistic control samples should help

✓ work in progress



✓ BaBar preliminary result with $80 fb^{-1}$ in $\tau \rightarrow$3-prong vs $\tau \rightarrow$1-prong sample:

$r_\tau = (0.12 \pm 0.32 \pm X_{syst})$

Nucl.Phys.Proc.Suppl.
144,105,2005
71 million ττ pairs

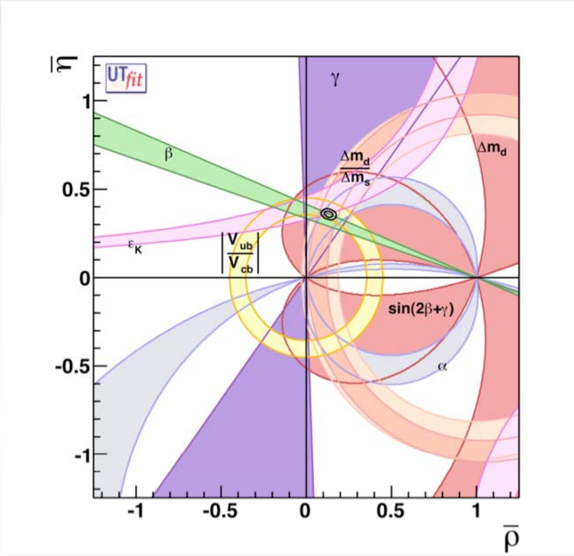
✓ aim to 10^{-4} precision

✓ under study

Unitary triangle evolution

✓ fit to the Unitary triangle TODAY

(not updated to ICHEP10 results)



Parameter	SM Fit today	SM Fit at Super$B$
$\overline{\rho}$	0.163 ± 0.028	± 0.0028
$\overline{\eta}$	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

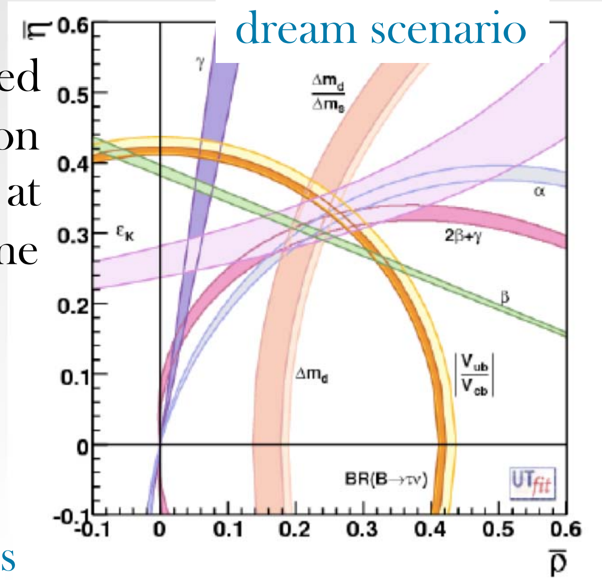
@ SuperB CDR time

(arXiv:0709.0451, 2007)

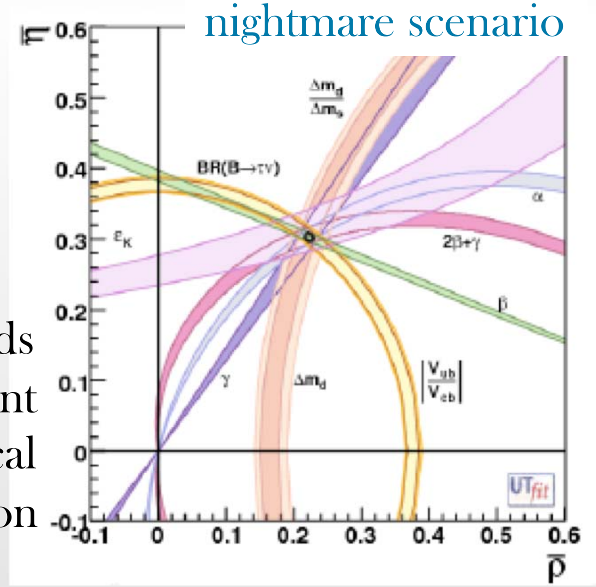
SuperB projections @ 50 ab^{-1}

with expected lattice calculation available at Superb-50ab^{-1} time

dream scenario



nightmare scenario



if SM holds with current theoretical calculation

Conclusions

- ✓ Super Flavor Factory will allow to make precise tests on CP and CPT violation in B_d, τ, D and B_s system

- ✓ expected sensitivities @ Superb after 5 years ($75ab^{-1}$)
  - $\sigma(\alpha) \approx$ some degree (statistically dominated)
  - $\sigma(\sin 2\beta) \approx 0.005$ for golden modes (syst dominated), some of the penguin mode measurements are theoretically limited
  - $\sigma(\gamma) \approx 1^{\circ}$ reducing syst on GGSZ measurement
  - test CPV in mixing and CPTV parameters in B^0 decays down to 10^{-3}
  - potential of SuperB for CPV and CPTV tests in τ decays under study

- ✓ 5 years of SuperB running will allow precise CKM metrology: wide array of measurements of constraint on the CKM mechanism can display inconsistency signaling NP effects (the dream) or confirming our understanding on quark mixing (the nightmare)

Theoretical references

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- ref-sb2 : M. Grounau et al., Phys.Rev.D74:093003,2009; M. Beneke, Phys.Lett.B620:143,2005; S. Williamson et al., Phys.Rev.D74:014003,2006; Cheng et al., Phys.Rev.D72:014006,2005
- ref-sa1: M. Gronau and D. London, Phys.Rev.Lett.**65:**3381,1990;H.J. Lipkin et al. Phys.Rev.D44:1454-1460,1991; H.R. Quinn and A.E. Snyder, Phys.Rev.D48:2139-2144,1993
- ref-sa2: M. Beneke, M. Gronau, J Rohres, and M. Spranger, Phys.Lett.B638:68,2006; M-Gronau and J. Zupan Phys.Rev.D**71:074017,2005;**
- res_sa3: M Gronau, J.L. Rosner, Phys.Lett.B651:166,2007
- ref-sa4: S.Ishino et. al., hep-ex/0703039,2007

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- ref_g2: M. Gronau and D. London, Phys.Lett.B253:483,1991; M. Gronau and D. Wyler, Phys.Lett.B265,172,1991
- ref_g3: D. Atwood, I. Dunietz, and A. Soni, Phys.Rev.D63:036005,2001

- ref-tau1: I. I. Bigi and A. I. Sanda, Phys.Lett.B625:47,2005

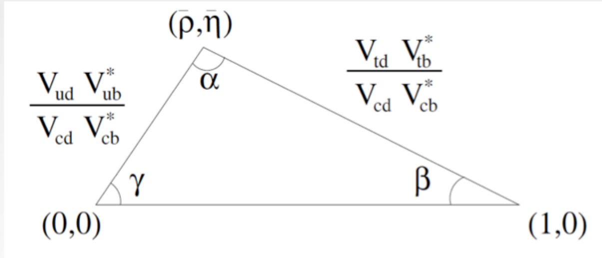
Back-up slides

CKM angle metrology: where are we

- ✓ Unitarity of the CKM matrix: 6 relations from off-diagonal components
  - one of them related to B_d system properties

$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$$



- ✓ UT angles related to CP violation
  - measure them to test SM prediction for

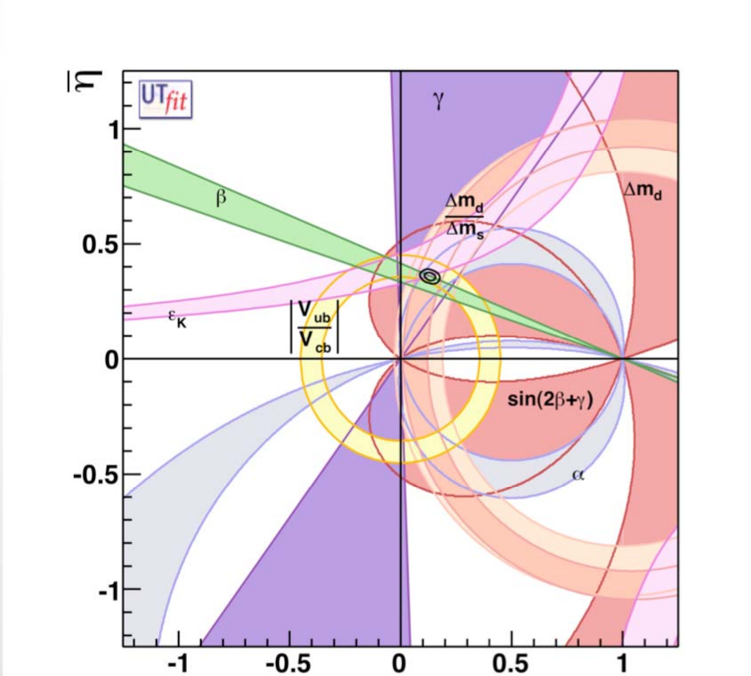
CP violation eqv unitarity of the CKM matrix

$$\begin{aligned} \alpha &\equiv arg[-V_{td}V_{tb}^*/V_{ud}V_{ub}^*] \\ \beta &\equiv arg[-V_{cd}V_{cb}^*/V_{td}V_{tb}^*] \\ \gamma &\equiv arg[-V_{ud}V_{ub}^*/V_{cd}V_{cb}^*] \end{aligned}$$

- ✓ Pre-ICHEP10 Utfit estimation

(from B-factories measurements) :

$$\boxed{\begin{aligned} \alpha &= 87.8 \pm 3.0 \\ \beta &= 22.42 \pm 0.74 \\ \gamma &= 69.8 \pm 3.0 \end{aligned}}$$



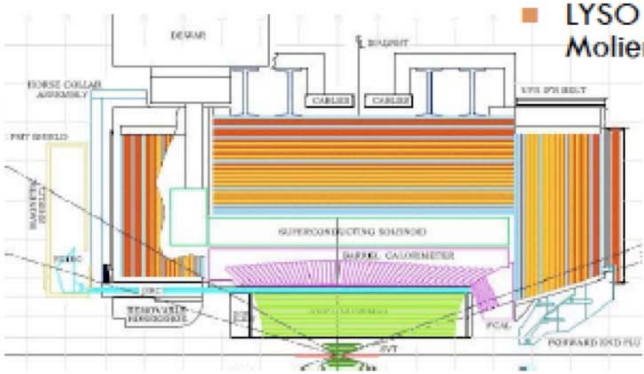
http://www.utfit.org/UTfit/

SuperB baseline detector

IFR
- amount and distribution of iron re-optimized
- Use extruded plastic scintillator coupled to geiger mode APDs through WLS fibers

FDIRC
- based on BaBar DIRC design
  - reuse BaBar quartz bar
  - photon camera 25x smaller (10x bkg suppression)
  - PMTs 10x faster (another10x bkg suppression)

EMC
- barrel
  - reuse BaBar CsI(Tl) crystals
- forward
  - LYSO crystals (fast, rad hard, small Moliere radius, good light yield)



SVT
- layer-0
  - as close to the IP as possible
  - striplets is the baseline technology for TDR
- 5 external layers
  - double-sided microstrip sensors a la BaBar

DCH
- design based on BaBar drift ch. concept
  - faster and lighter electronics
  - lighter structure
  - optimization of gas mixture and wires layout

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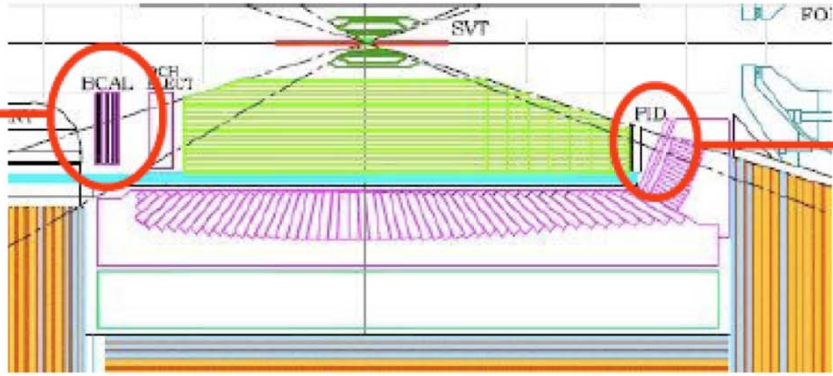
SuperB detector options

backward EM calorimeter

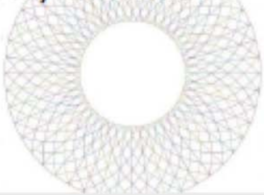


forward PID device

backward EMC

- Meant to increase EMC hermiticity at modest cost. Used as veto
- 24 layers of lead(3mm) + scintillator(3mm) read by WLS fibers coupled to SiPM
- Benefits on Physics under evaluation

fiber layout scheme



forward PID

- pros and cons under evaluation
  - ☺ improved hadron Id in the forward region compared to dE/dx only
  - ☹ material in front of fwd EMC, cost
- Several options:
  - Time of Flight (2 options)
  - FARICH (better PID separation but 3x material and R&D less advanced)
  - use of EMC LYSO crystal fast component
- Bernefits on Physics under evaluation

β, penguin modes

Syst sources	Parameter C	Parameter β_{eff}
Fixed PDF params	0.014	0.010
Fit Bias	0.009	0.012
DCSD, Beam Spot, other	0.015	0.004
Dalitz Model	0.009	0.002
Total	0.024	0.016

$B^0 \to \phi(K^+K^-)K_s$

Main Syst sources	Error
S	
Fixed PDF params	0.006
Fit Bias	0.006
Δt resolution	0.009
Bkg description	0.009
$\sigma_{S,tot} = 0.016$	
C	
Tag Side interference (DCSD)	0.015
Fixed PDF params	0.009
Δt resolution	0.009
$\sigma_{C,tot} = 0.024$	

$B^0 \to \eta' K$

γ GGSZ (I)

Source	x_-	y_-	x_+	y_+	x^*_-	y^*_-	x^*_+	y^*_+	x_{s-}	y_{s-}	x_{s+}	y_{s+}
m_{ES}, ΔE, $\mathcal{F}$ shapes	0.001	0.001	0.001	0.002	0.002	0.004	0.004	0.005	0.003	0.002	0.001	0.004
Real D^0 fractions	0.001	0.001	0.001	0.001	0.001	0.001	0.004	0.001	0.002	0.004	0.001	0.001
Charge-flavor correlation	0.002	0.002	0.001	0.001	0.002	0.002	0.002	0.001	0.001	0.002	0.001	0.001
Efficiency in the Dalitz plot	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.002	0.003	0.001	0.005
Background Dalitz plot shape	0.012	0.007	0.013	0.003	0.010	0.007	0.007	0.007	0.014	0.006	0.012	0.005
$B^- \to D^{*0}K^-$ cross feed	···	···	···	···	0.003	0.002	0.007	0.001	···	···	···	···
CP violation in $D\pi$ and $B\bar{B}$ bkg	0.001	0.001	0.001	0.001	0.005	0.001	0.001	0.004	0.006	0.002	0.003	0.001
Non-K^* $B^- \to \tilde{D}^0 K^0_S \pi^-$ decays	···	···	···	···	···	···	···	···	0.035	0.058	0.025	0.045
Total experimental	0.015	0.007	0.014	0.006	0.014	0.009	0.014	0.010	0.039	0.058	0.028	0.051

Source	x_-	y_-	x_+	y_+	x^*_-	y^*_-	x^*_+	y^*_+	x_{s-}	y_{s-}	x_{s+}	y_{s+}
Mass and width of Breit-Wigner's	0.001	0.001	0.001	0.002	0.001	0.002	0.001	0.003	0.003	0.001	0.002	0.002
$\pi\pi$ S-wave K-matrix solutions	0.003	0.012	0.003	0.001	0.003	0.007	0.002	0.009	0.001	0.001	0.013	0.003
$K\pi$ S-wave parametrization	0.001	0.001	0.002	0.004	0.001	0.003	0.001	0.003	0.005	0.001	0.004	0.002
Angular dependence	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.003	0.001	0.003	0.001
Blatt-Weisskopf radius	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.003
Add/remove resonances	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.002	0.001	0.001	0.001	0.002
Dalitz plot efficiency	0.006	0.004	0.008	0.001	0.002	0.004	0.002	0.003	0.008	0.001	0.008	0.004
Background Dalitz plot shape	0.003	0.002	0.004	0.001	0.001	0.001	0.001	0.001	0.004	0.001	0.004	0.002
Normalization and binning	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.002	0.002	0.001	0.003	0.001
Mistag rate	0.008	0.006	0.006	0.005	0.002	0.001	0.002	0.003	0.008	0.010	0.004	0.007
Dalitz plot complex amplitudes	0.002	0.002	0.003	0.004	0.001	0.001	0.002	0.006	0.003	0.003	0.004	0.002
Total Dalitz model	0.011	0.015	0.011	0.008	0.004	0.010	0.005	0.012	0.014	0.011	0.018	0.010

γ GLW and ADS

statistical in origin

depends on precision of other measurements

TABLE V: Summary of systematic uncertainties.

Source	A_{CP+}	A_{CP-}	R_{CP+}	R_{CP-}
Fixed fit parameters	0.004	0.005	0.026	0.022
Peaking background	0.014	0.005	0.017	0.013
Bias correction	0.004	0.004	0.006	0.005
Detector charge asym.	0.010	0.010	-	-
Opposite-CP background	-	0.003	-	0.006
$R_{CP\pm}$ vs. $R_{\pm}$	-	-	0.026	0.023
Signal self cross-feed	0.000	0.001	-	-
$\varepsilon(\pi)/\varepsilon(K)$	-	-	0.009	0.008
$\Delta E_{\mathrm{shift}}$ PDFs	0.007	0.011	0.029	0.024
Total	0.019	0.017	0.051	0.043

BaBar GLW

Error source	$\Delta\mathcal{R}(10^{-2})$ DK	$\Delta\mathcal{R}(10^{-2})$ $D^*_{D\pi^0}K$	$\Delta\mathcal{R}(10^{-2})$ $D^*_{D\gamma}K$
Signal NN	±0.1	±0.1	±0.3
$B\overline{B}$ background NN	±0.1	±0.3	±0.4
$q\bar{q}$ background NN	±0.1	±0.1	±0.1
$B\overline{B}$ comb. bkg shape (m_{ES})	±0.1	±0.1	±0.1
Peaking background WS	±0.2	±0.3	±0.6
Peaking background RS	±0.0	±0.1	±0.1
Floating $B\overline{B}$ comb. bkg	-	±0.1	±0.2
Combined	±0.2	±0.4	±0.8

BaBar ADS