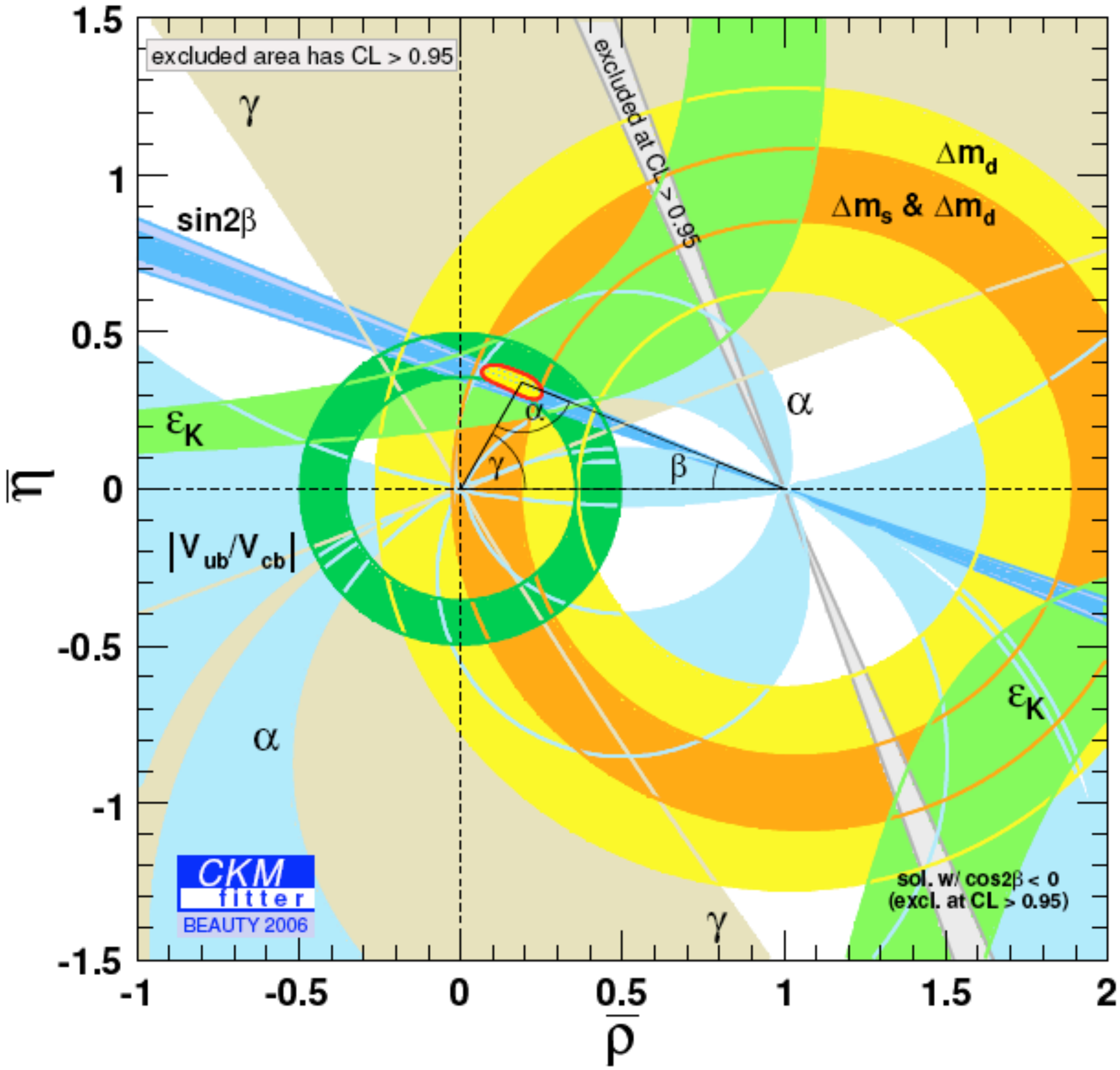
B Physics Options

Yury Kolomensky
UC Berkeley/LBNL

Present Status



Expect ~factor of 2 reduction in errors by the time current B factories end operation

Landscape in ~2015

- BaBar and Belle with ~1 ab^{-1} (10^9 B^0/B^+ decays) each
  - Final results in ~2010
    - High precision on b in charmonium modes, moderate precision on a and g
    - Moderate precision in CP observables in penguin modes
    - Other rare decays
- LHCb with ~10 fb^{-1} of data
  - Similar to BTeV in reach
    - cleanest charmonium and penguin modes, unique B_s channels
- SuperB proposal
  - $L \sim 10^{36}$ $cm^{-2}s^{-1}$ → 75 ab^{-1} in 5 years
  - Could start operations in 2015 ?
    - Many accessible B_d channels with high precision
    - Limited Bs reach, t and charm physics with high statistics

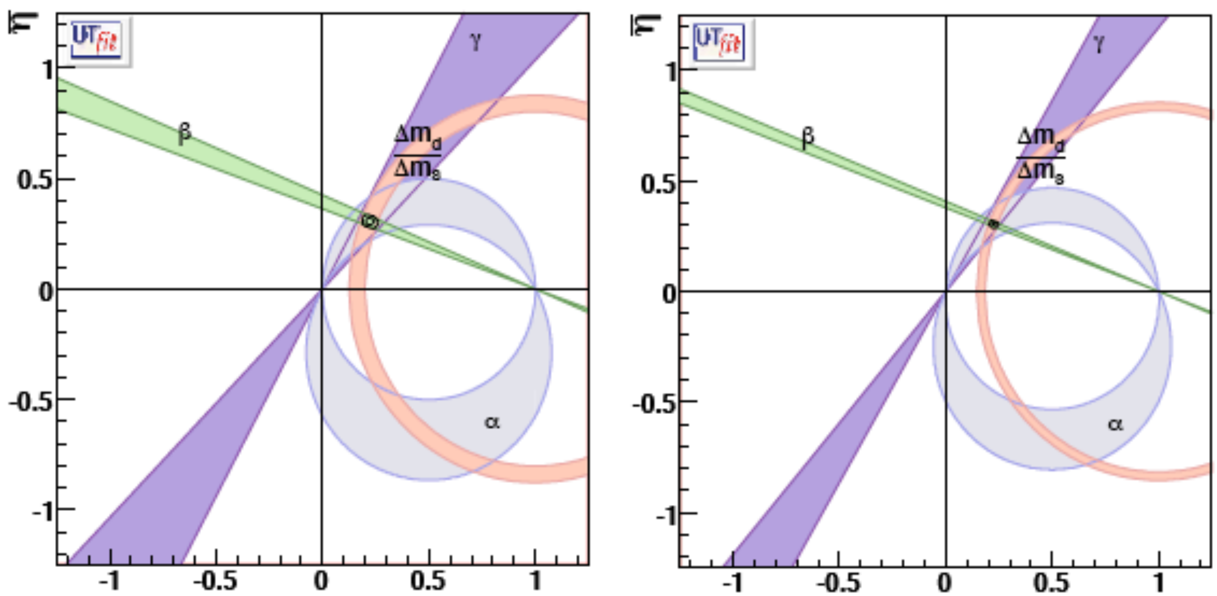
LHCb reach

- CP measurements
  - B_d decays
    - ☞ sin2β in $B^0 \rightarrow J/\Psi K_S$ to ~0.01-0.02
    - ☞ Not as competitive in penguin modes
    - ☞ α in charmless decays ($B^0 \rightarrow \rho\rho$, $\rho\pi$) to ~10^o
    - ☞ γ in $B \rightarrow D_{(s)}K$ to 3-5^o
  - B_s
    - ☞ ϕ_s in "golden" modes to 0.01-0.02
    - ☞ New physics phases in strange penguins to 0.04-0.06
- Rare decays
  - Monopoly on Bs
    - ☞ E.g. can have a 5σ observation for $B_s \rightarrow \mu^+\mu^-$
    - ☞ High statistics samples of $B_d \rightarrow K^{(*)}l^+l^-$

LHCb reach

LHCb + LQCD only

2 fb^{-1} (2010) | **10 fb^{-1} (2014)**



$\sigma(\bar{\rho})/\bar{\rho}$ = 7.1%
$\sigma(\bar{\eta})/\bar{\eta}$ = 3.9%

$\sigma(\bar{\rho})/\bar{\rho}$ = 3.6%
$\sigma(\bar{\eta})/\bar{\eta}$ = 1.8%

- LHCb (2 fb^{-1}, 10 fb^{-1}):
  - LHCb:
  - $\sigma(\sin(2\beta))$ = 0.02, 0.01
  - $\sigma(\gamma) = 4.2^o, 2.4^o$
  - $\sigma(\alpha) = 10^o, 4.5^o$
- Lattice QCD (2010, 2014):
  - 40, 1000 Tflop year
  - $\sigma(\xi)/\xi$ = 2.5%, 1.5%
- Central values:
  - SM assumed (just for illustration)

From V. Vagnoni, CKM workshop, Dec 2006

BTeV

Table 2.6: Comparison of CP Reach of Hadron Collider Experiments and SuperBABAR. The last column is a prediction of which kind of facility will make the dominant contribution to each physics measurement. (From the E2 summary [7].)

	BTeV† 10^7s	LHCb 10^7s	BABAR Belle (2005)	e^+e^- 10^{35} 10^7s	e^+e^- 10^{36} 10^7s	e^+e^- at 10^{36} vs hadron collider
$\sin 2\beta$	0.017	0.02	0.037	0.026	0.008	Equal
$\sin 2\alpha$	0.05	0.05	0.14	0.1	0.032	Equal
$\gamma\ [B_s(D_sK)]$	$\sim 11.5^o$					Had
$\gamma\ [B(DK)]$	$\sim 13.2^o$		$\sim 20^o$		12^o	Equal
$\sin 2\chi$	0.024	0.04	-	-	-	Had
$\mathcal{B}(B \to \pi^o\pi^o)$	-	-	$\sim 20\%$	14 %	6%	e^+e^-
V_{ub}	-	-	$\sim 2.3\%$	$\sim 1\%$ (sys)	$\sim 1\%$ (sys)	e^+e^-

† We have changed the BTeV numbers to correspond to the one-arm version.

SuperB Factory

- Concept:
  - Low-emittance storage rings based on ILC damping ring design
    - Reuse PEP-II components
    - 4 GeV (e^+) x 7 GeV (e^-)
- Much cleaner leptonic environment
  - Fully reconstructed final states possible
  - Lower multiplicity: access to rare hadronic modes
  - Also τ and charm physics and other e^+e^- final states
- Quite competitive to LHCb with O(75 fb^{-1})
  - Proposal to INFN
    - CDR available

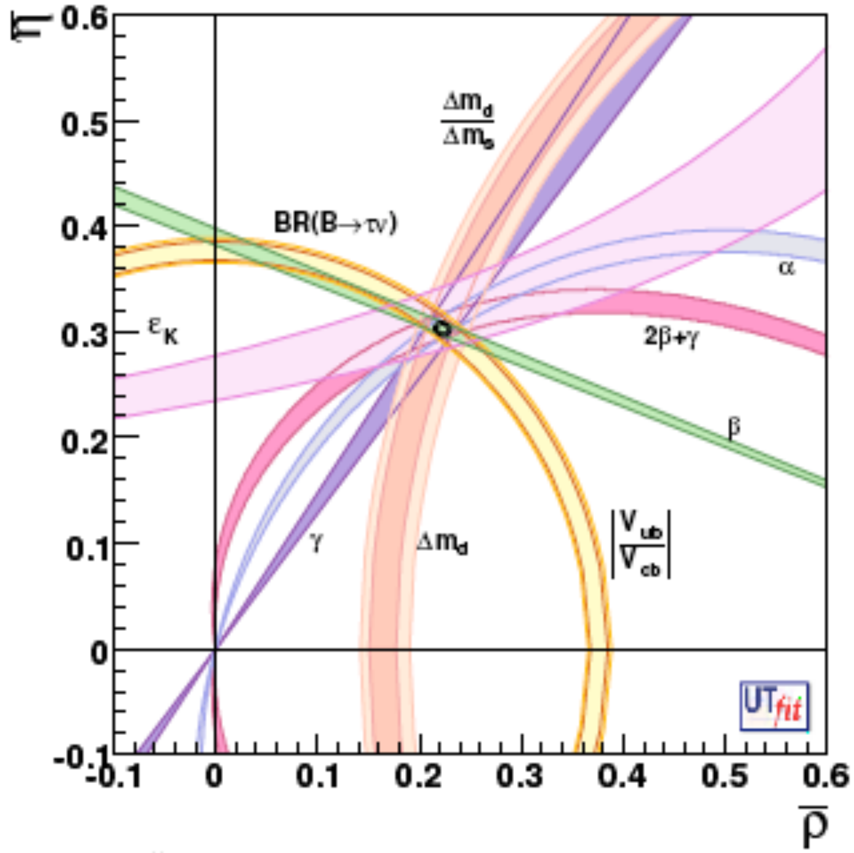
SuperB Reach

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
$\cos(2\beta)$ (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 (∗)
$S(K_S^0 K_S^0 K_S^0)$	0.15	0.02 (∗)
$S(K_S^0 \pi^0)$	0.15	0.02 (∗)
$S(\omega K_S^0)$	0.17	0.03 (∗)
$S(f_0 K_S^0)$	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° (∗)
$2\beta + \gamma$ $(D^{(*)\pm}\pi^\mp, D^\pm K_S^0 \pi^\mp)$	20°	5°

Observable	B Factories (2 ab^{-1})	Super$B$ (75 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 (†)
$S(K_S^0 \pi^0 \gamma)$	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

SuperB Reach

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 ($^\circ$)	92.7 ± 4.2	± 0.45
β ($^\circ$)	22.2 ± 0.9	± 0.17
γ ($^\circ$)	64.6 ± 4.2	± 0.38



Running at Υ(5S) possible, though hard to compete with LHCb in Bs sector.

Also large τ and D meson samples (~x6 increase over B-factories)

Options for Fermilab ?

- Assume for a moment no politics
- Three options
  - B at the Tevatron → some version of BTeV
    - Pros: BTeV was a better detector
    - Cons: few potential advantages vs LHCb, timing
    - Interference with neutrino program ?
  - SuperB at FNAL
    - Pros: ILC R&D, potential for ep collider ?
    - Synergy with proton driver ? Reuse existing infrastructure ?
    - Cons: dilute FNAL's strength in ILC ?
  - Dedicated (fixed target) facility ?
    - Some version of (ill-fated) HERA-B ?
    - Still need Tevatron, p or anti-p
    - Only makes sense to design a dedicated experiment with unique sensitivities → rare decays, CP in B_s, PID

Questions

- Is Tevatron available with neutrino program ?
- How much of the infrastructure can be reused in a SuperB scenario ?
  - Rings ?
    - ☞ A little large, and design calls for wiggler-dominated optics
  - E.g. 7-8 GeV electron linac:
    - ☞ Common with proton driver ?

Wilder Ideas Related to FNAL

- Not necessarily accelerator-based or flavor physics:
- Atomic parity violation with relativistic ions
  - D.Budker and M.Zolotorev, PRL**78**, 4717 (1997)
    - ☞ Idea is to accelerate a hydrogenic ion (1 electron on the orbit) with Z~10 to E~100-200 GeV/nucleon, and excite forbidden 1S→2S transitions with a convensional laser
    - ☞ Can potentially probe $\sin^2\theta_W$ down to 0.001 or below, complementary to NuTeV and Cs APV
    - ☞ Main injector may work well for this, Tevatron even better
- Laser-driven axion searches
  - New motivation with Zavattini et al "observation" ?
  - There used to be E-877 at Fermilab
    - ☞ But most of the equipment and manpower are gone now
    - ☞ Is it worth resurecting with modest resources and Tevatron magnets ?