B Physics Observables for New Physics Discoveries

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Contents of this talk

- What has already been done
  - the physics case in the CDR
  - progress since April 2007
- What remains to be done
  - improvements to the physics case
  - refined Super*B* sensitivity estimates
  - answers to IRC questions
- Goals for this meeting
  - ... and beyond

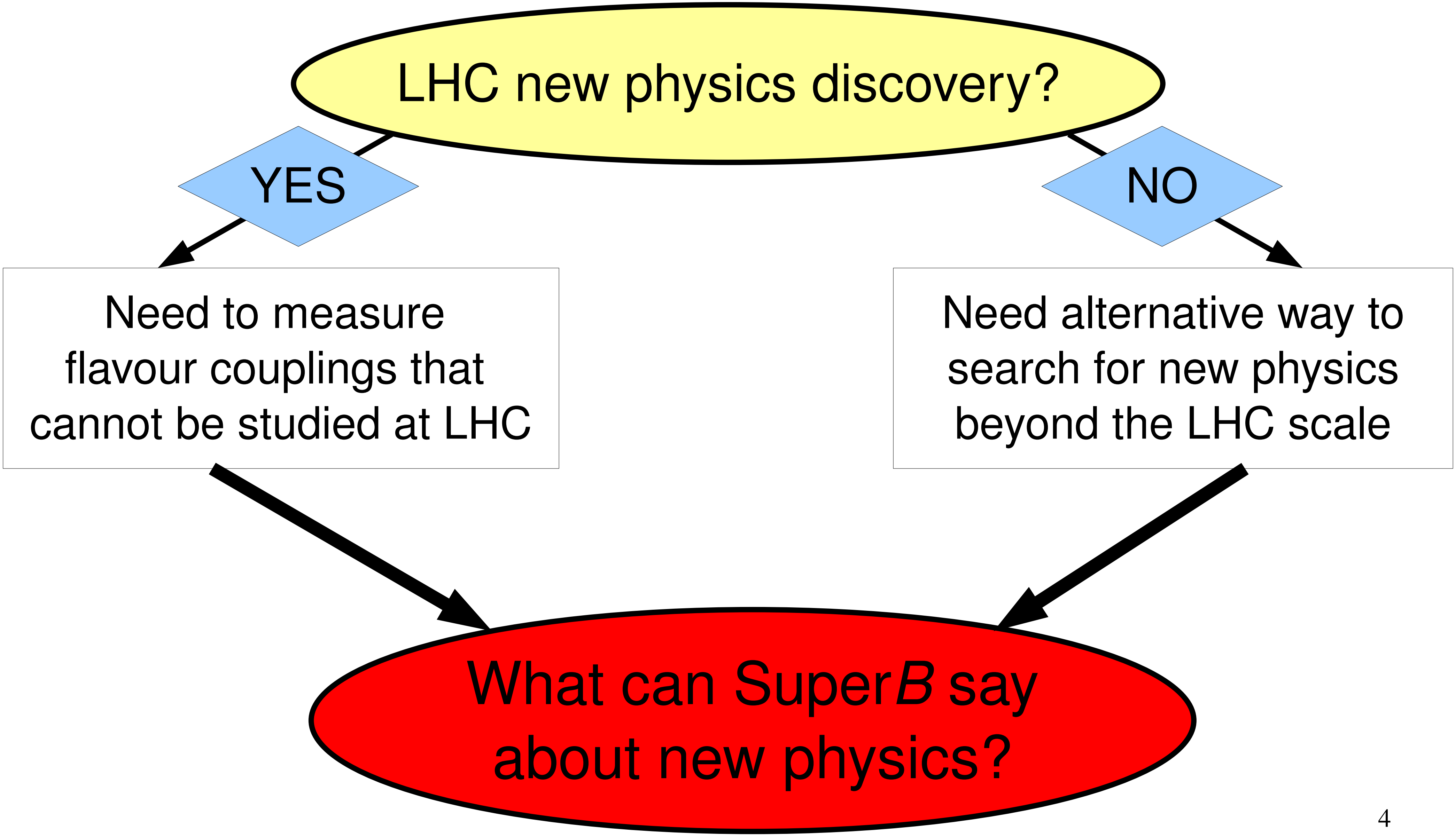
Need more and better publicity material!

Assumptions

- Super*B* will accumulate 75/ab on the Υ(4S)
  - beam energies 7 GeV e^- on 4 GeV e^+
  - 5 years operation @ $L_{peak} \sim 10^{36}/cm^2/s$
  - data taking starts ~2014 ⇒ 75/ab by ~2020
- LHC operation will be successful
  - LHCb will accumulate 10/fb before Super*B* starts
  - ATLAS & CMS will have plenty of data

(no assumption whether or not NP is discovered at LHC)

Two Scenarios



What has already been done?

- Physics case in the CDR builds mainly on extrapolations of existing experiments
  - SuperBaBar:
    - SLAC-R-709 [arXiv:hep-ph/0503261]
  - SuperKEKB:
    - Letter of Intent, KEK Report 04-4 & arXiv:hep-ex/0406071
  - Other extrapolations from (mainly) BaBar results
- Identified need for strong focus on theoretically clean observables

Will be Studied at Super*B*

Δm_K ϵ_K ϵ'/ϵ_K $B(K_L \to \pi^0 \nu \bar{\nu})$ $B(K^+ \to \pi^+ \nu \bar{\nu})$ $B(K^+ \to l^+ \nu)$

Δm_d $A_{SL}(B_d)$ $S(B_d \to J/\psi K_S)$ $S(B_d \to \phi K_S)$

$\alpha(B \to \pi\pi, \rho\pi, \rho\rho)$ $\gamma(B \to DK)$ CKM fits

Δm_s $A_{SL}(B_s)$ $S(B_s \to J/\psi \phi)$ $S(B_s \to \phi\phi)$

$B(b \to s\gamma)$ $A_{CP}(b \to s\gamma)$ $S(B^0 \to K_S \pi^0 \gamma)$ $S(B_s \to \phi\gamma)$

$B(b \to d\gamma)$ $A_{CP}(b \to d\gamma)$ $A_{CP}(b \to (d+s)\gamma)$ $S(B^0 \to \rho^0 \gamma)$

$B(b \to s l^+ l^-)$ $B(b \to d l^+ l^-)$ $A_{FB}(b \to s l^+ l^-)$ $B(b \to s \nu \bar{\nu})$

$B(B_s \to l^+ l^-)$ $B(B_d \to l^+ l^-)$ $B(B^+ \to l^+ \nu)$

$B(\mu \to e\gamma)$ $B(\mu \to e^+ e^- e^+)$ $(g-2)_\mu$ μ EDM

$B(\tau \to \mu\gamma)$ $B(\tau \to e\gamma)$ $B(\tau^+ \to l^+ l^- l^+)$ τ CPV τ EDM

$B(D^+_{(s)} \to l^+ \nu)$ x_D y_D charm CPV

Super*B* Physics Strength

- very many observables sensitive to new physics
- maximize sensitivity by combining information
- correlations between results distinguish models

Super Flavour Factory
“treasure chest”
of new physics observables

SuperB is a **general purpose detector** for flavour physics

(beware tendency to focus on “golden channels”)

INCREASING THEORETICAL UNCERTAINTY

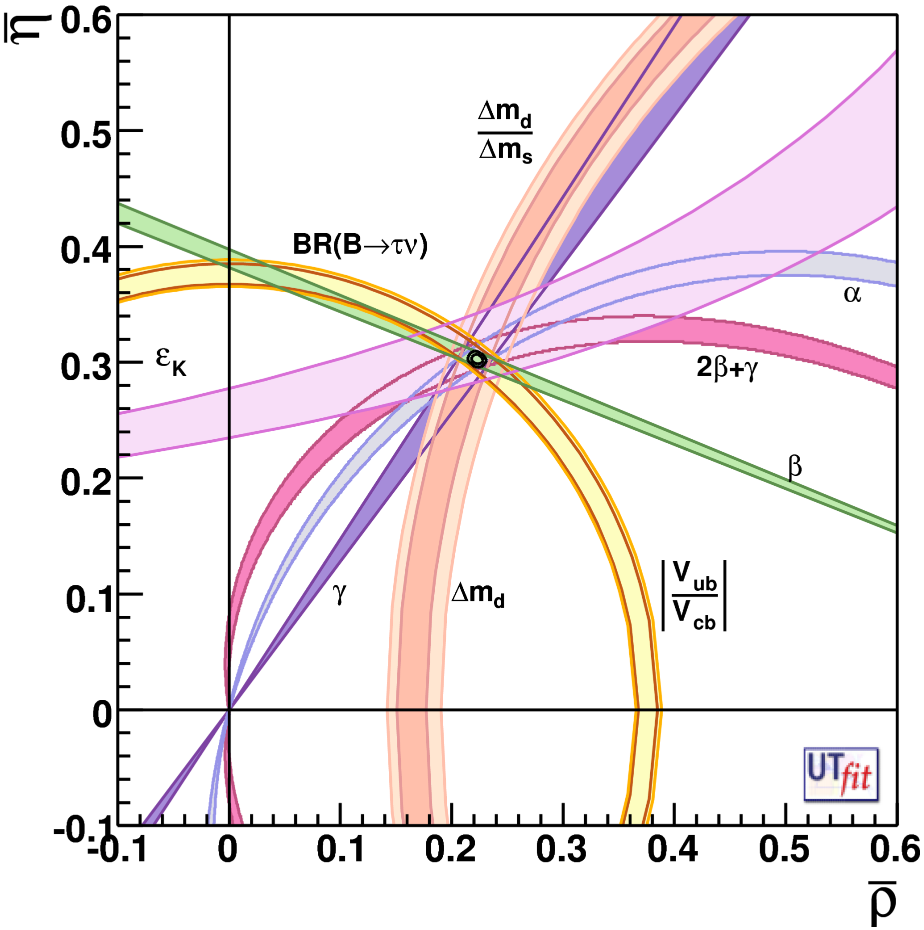
no theory improvements needed	$\beta(J/\psi\, K)$, $\gamma(DK)$, $\alpha(\pi\pi)$*, lepton FV and UV, $S(\rho^0\gamma)$ CPV in $B\to X\gamma$, D and τ decays zero of FB asymmetry $B\to X_s l^+ l^-$	NP insensitive or null tests of the SM or SM already known with the required accuracy
improved lattice QCD	meson mixing , $B\to D(*)l\nu$, $B\to\pi(\rho)l\nu$, $B\to K^*\gamma$, $B\to\rho\gamma$, $B\to l\nu$, $B_s\to\mu\mu$	target error: ~1-2% Feasible (see below)
improved OPE+HQE	$B\to X_{u,c}l\nu$, $B\to X\gamma$	target error: ~1-2% Possibly feasible with SuperB data getting rid of the shape function. Detailed studies required
improved QCDF or SCET or flavour symmetries	S's from TD A_{CP} in b -> s transitions	target error: ~2-3% large and hard to improve uncertainties on small corrections. In addition, FS+data can bound the theoretical error

Some theoretically clean channels

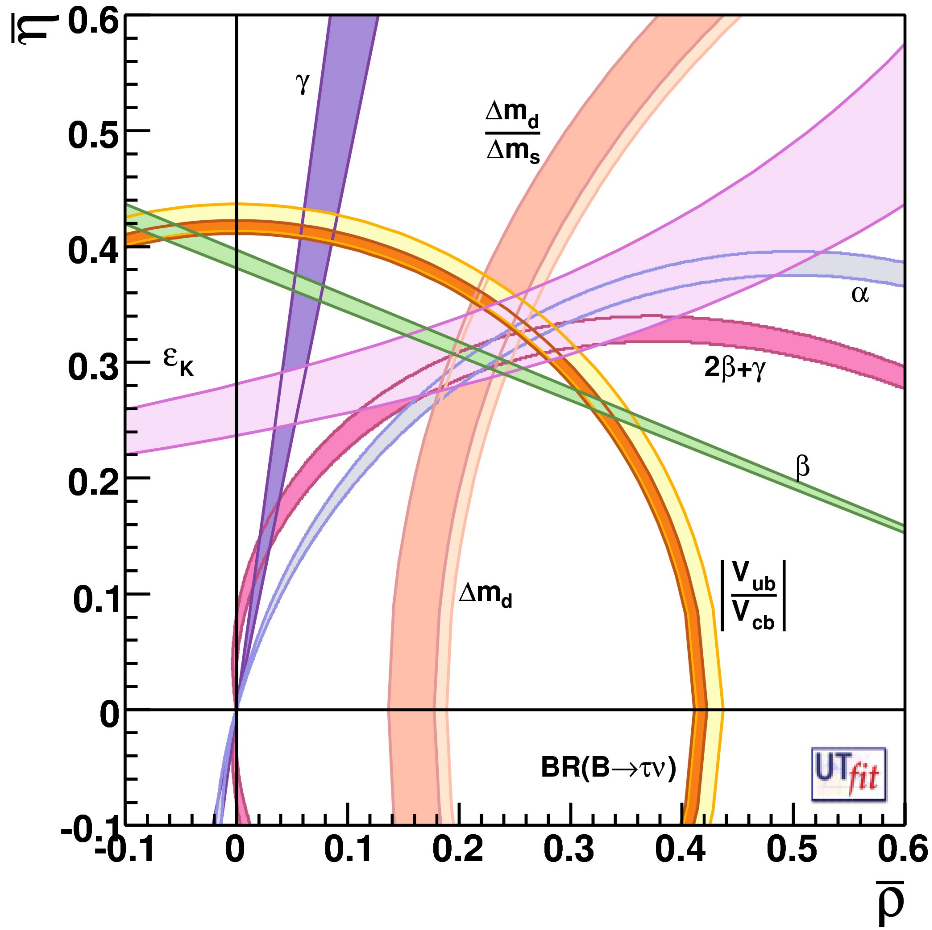
- Unitarity Triangle angles (α, β, γ)
  - Not discussed in this meeting
  - Work required:
    - How to reach 1˚ precision on α (theory + experiment)
    - Limiting systematics on β
- Unitarity Triangle sides (V_{ub}, V_{cb})
  - Talks of Viaud, Gambino
  - Work required
    - How to reach 1-2% precision on V_{ub}, V_{cb}

SuperB UT fit scenarios

"the nightmare"



"the dream"



- Possible NP discovery from precise CKM metrology
- Precise knowledge of SM parameters essential in any scenario

More theoretically clean channels

- $B \to X_s \gamma$
  - Talks of Walsh, Hurth
- $B \to X_s l^+ l^-$
  - Talks of Renga, Hurth
- $B \to X_s \nu\nu$
  - Talk of Renga

Inclusive channels:

- need detailed study of sensitivity for realistic Super*B* accelerator & detector
- effect of hermeticity on recoil analyses
- Important to work with tools group

Some exclusive channels

- $B \to l\nu(\gamma)$
  - Talks of Kou, Bevan/Cavoto
- $B \to K^{(*)}\tau^+\tau^-$
  - Talk of Robertson

Some modes not discussed in CDR

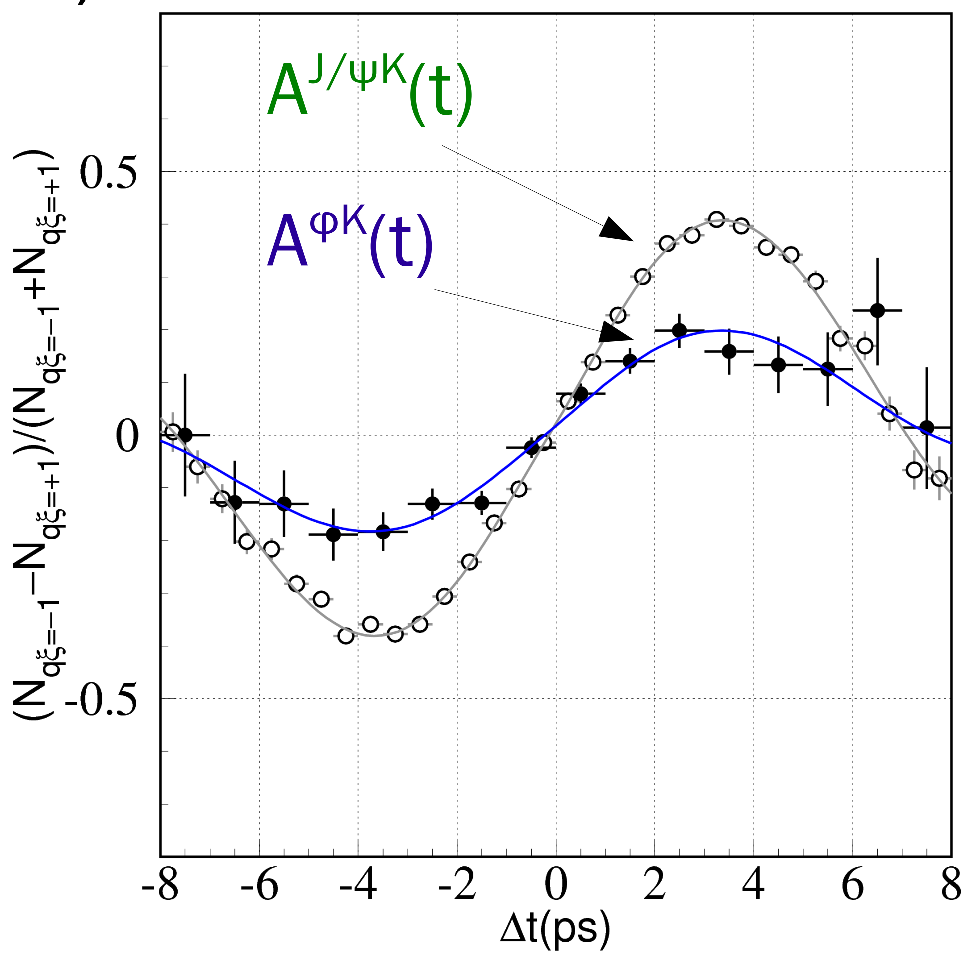
- Assess interest and feasibility of measurements at Super*B*

Some topics <u>not</u> covered

- Make Super*B* version of this plot (from SuperKEKB physics case)

- Focus more on *really* theoretically clean channels

- However, this is a good example of the kind of discovery plot that we need to make



Some topics not covered

- Various exclusive channels, eg. $K^{(*)}l^+l^-$
- This specific example is sensitive to new physics **BUT**
  - Not as clean as the inclusive channel
  - Will be well measured by LHCb
- There are other similar examples

Progress since the CDR

- Important new experimental results
  - A couple of examples:
    - $B \to X_d \gamma$ (BaBar arXiv:0708.1652)
    - $B \to D^{(*)} \tau \nu$ (Belle arXiv:0706.4429 & BaBar arXiv:0709.1698)
  - These have impact on Super*B* sensitivity estimates
- Final "Flavour in the LHC Era" workshop
  - Commencement of follow-up workshops ("Interplay of Collider and Flavour Physics")
  - A lot of ongoing work in this important area – highly relevant to Super*B* physics case

Interplay

Some (not all!) of the papers on flavour-LHC interplay in the last ~2 years

E. Accomando *et al.*, CERN-2006-009 [arXiv:hep-ph/0608079].
B. C. Allanach and C. G. Lester, Phys. Rev. D **73** (2006) 015013 [arXiv:hep-ph/0507283].
B. C. Allanach, Phys. Lett. B **635** (2006) 123 [arXiv:hep-ph/0601089].
R. R. de Austri, R. Trotta and L. Roszkowski, JHEP **0605** (2006) 002 [arXiv:hep-ph/0602028].
M. S. Carena, A. Menon, R. Noriega-Papaqui, A. Szynkman and C. E. M. Wagner, Phys. Rev. D **74** (2006) 015009 [arXiv:hep-ph/0603106].
J. R. Ellis, S. Heinemeyer, K. A. Olive and G. Weiglein, arXiv:hep-ph/0604180.
G. Isidori and P. Paradisi, Phys. Lett. B **639** (2006) 499 [arXiv:hep-ph/0605012].
E. Lunghi, W. Porod and O. Vives, Phys. Rev. D **74** (2006) 075003 [arXiv:hep-ph/0605177].
B. C. Allanach, C. G. Lester and A. M. Weber, JHEP **0612** (2006) 065 [arXiv:hep-ph/0609295].
M. K. Parida *et al.*, Pramana **67** (2006) 849.
G. Isidori, F. Mescia, P. Paradisi and D. Temes, Phys. Rev. D **75** (2007) 115019 [arXiv:hep-ph/0703035].
M. S. Carena, A. Menon and C. E. M. Wagner, Phys. Rev. D **76** (2007) 035004 [arXiv:0704.1143 [hep-ph]].
P. J. Fox, Z. Ligeti, M. Papucci, G. Perez and M. D. Schwartz, arXiv:0704.1482 [hep-ph].
L. Roszkowski, R. Ruiz de Austri and R. Trotta, JHEP **0707** (2007) 075 [arXiv:0705.2012 [hep-ph]].
J. R. Ellis, S. Heinemeyer, K. A. Olive, A. M. Weber and G. Weiglein, arXiv:0706.0652 [hep-ph].
J. R. Ellis, S. Heinemeyer, K. A. Olive and G. Weiglein, arXiv:0706.0977 [hep-ph].
Y. Grossman, Y. Nir, J. Thaler, T. Volansky and J. Zupan, arXiv:0706.1845 [hep-ph].
O. Buchmueller *et al.*, arXiv:0707.3447 [hep-ph].
S. Dittmaier, G. Hiller, T. Plehn and M. Spannowsky, arXiv:0708.0940 [hep-ph].
J. Ellis, T. Hahn, S. Heinemeyer, K. A. Olive and G. Weiglein, arXiv:0709.0098 [hep-ph].

Talks in this meeting on interplay

- Talks in this meeting
  - Tools HEP/Flavour interplay (Ronga)
  - SUSY breaking scenario (Shindou)
  - MFV + Snowmass point (Ciuchini + Silvestrini)
- Slight emphasis on theoretical side at present, but experimentalists should pay close attention (and get involved)

Snowmass points

- From hep-ph/0202233
  - "The question of which parameter choices are useful as benchmark scenarios depends on the purpose of the actual investigation."
  - "It should be obvious that it is not possible to define a single set of benchmark scenarios that will serve all purposes. The usefulness of a particular scenario will always depend on which sector of the theory and which physics issue is investigated."
- We should not be afraid to define our own benchmark parameter points if necessary

Digression: Target Luminosity

- $L_{peak} \sim 10^{36}/cm^2/s \Leftrightarrow$ 75/ab on the Y(4S)
- Most of the theoretically clean observables will still be experimentally limited
- Do we need to aim higher?
- Contrary question: would 10/ab be enough?

SuperB physics in tables

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 (∗)
$S(K^0_S K^0_S K^0_S)$	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°
$\lvert V_{cb}\rvert$ (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% (∗)
$BR(B \to \tau\nu)$	20%	4% (†)
$BR(B \to \mu\nu)$	visible	5%
$BR(B \to D\tau\nu)$	10%	2%
$BR(B \to \rho\gamma)$	15%	3% (†)
$BR(B \to \omega\gamma)$	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%
$BR(B \to K\nu\overline{\nu})$	visible	20%
$BR(B \to \pi\nu\bar{\nu})$	–	possible

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}
	x_D	2–3×10^{-3}	5×10^{-4}

	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}

5-10x improvement

Process	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}

+ τ FC physics (CPV, ...)

Super Flavour Factory

a "treasure chest" of new physics-sensitive observables

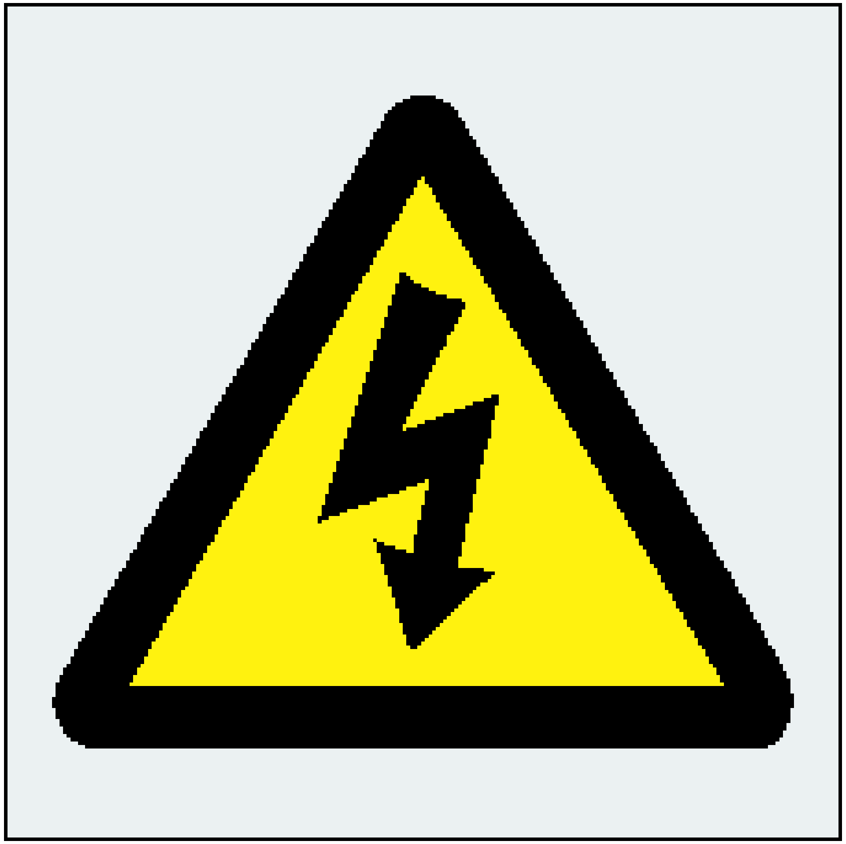
Observable	Error with 1 ab^{-1}
$\Delta\Gamma$	$0.16\ ps^{-1}$
Γ	$0.07\ ps^{-1}$
β_s from angular analysis	20°
A^s_{SL}	0.006
A_{CH}	0.004
$\mathcal{B}(B_s \to \mu^+\mu^-)$	-
$\lvert V_{td}/V_{ts}\rvert$	0.08
$\mathcal{B}(B_s \to \gamma\gamma)$	38%
β_s from $J/\psi\phi$	10°

M.Ciuchini at SuperB Review, LNF, 12 November

Goals for this meeting (and beyond)

- answers to IRC questions
- produce more and better publicity material
- new ideas always welcome
- refined Super*B* sensitivity estimates
  - need to go significantly beyond what is in the CDR
  - realistic machine and detector simulation
  - work closely with tools group

Back Up



SuperB and LHCb (upgrade)

- SuperB will start running >2015
- Results from LHCb will be in
  - Dramatically improve knowledge in B_s sector
  - Much better determination of γ
  - Precise studies of some exclusive modes
    - eg. $B_s \rightarrow \mu\mu$, $B \rightarrow K(*)\mu\mu$
- These improvements on the current knowledge are assumed in SuperB physics case
  - Strong focus on theoretically clean processes