Future Flavour Physics at an e^+e^- Collider

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Cosener's Forum on Heavy Flavour Physics
21^{st} – 22^{nd} June 2007

What I Will NOT Talk About

- General motivation for flavour physics in the LHC era
  - see all preceeding talks in this meeting
- Physics programme of $e^+e^- \rightarrow \varphi \rightarrow KK$
  - DANAE proposal at LNF (see G.Isidori's talk)
- Physics programme of dedicated $e^+e^- \rightarrow \psi(3770) \rightarrow DD$ (and similar energies)
  - BEPCII at IHEP and BINP proposal (see A.Schwartz's talk)
- Flavour physics at the ILC
  - see U.Martyn at final Flavour in the LHC Era workshop

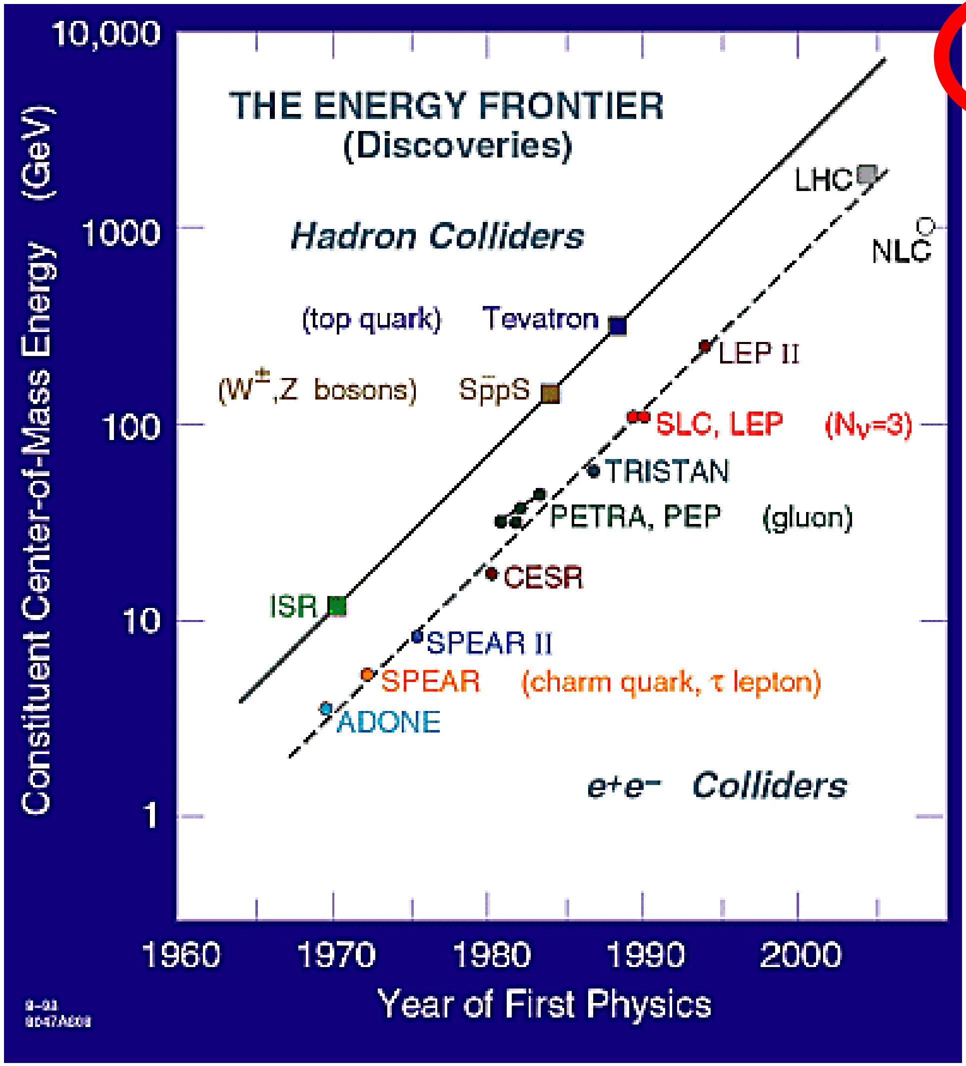
http://indico.cern.ch/getFile.py/access?contribId=3&sessionId=3&resId=1&materialId=slides&confId=12011

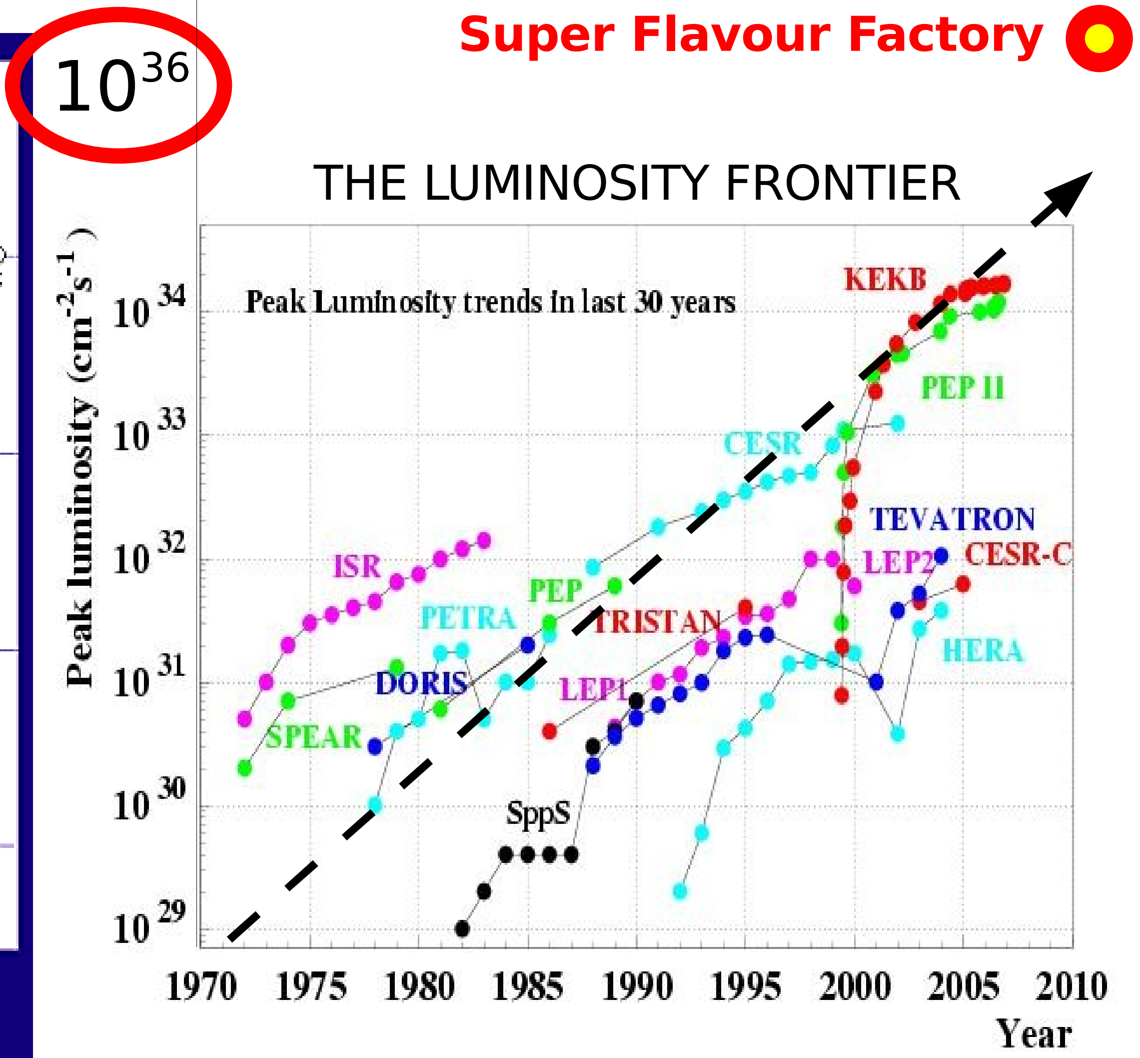
What I Will Talk About

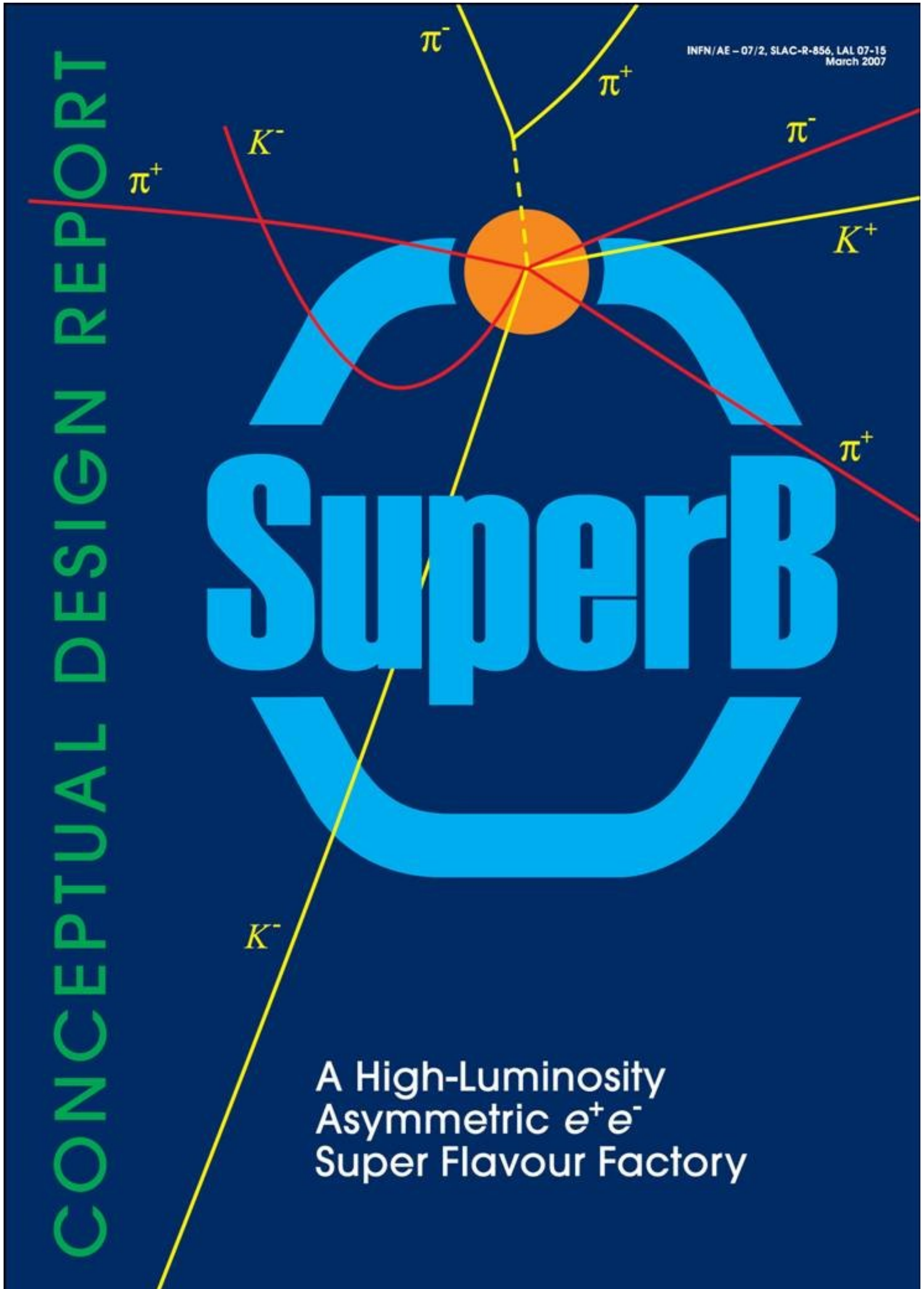
- Why a Super Flavour Factory is the single most important machine to explore flavour in the LHC era
  - "Super Flavour Factory" = asymmetric $e^+e^- \rightarrow \Upsilon(4S)$ collider

- How it can be realised
  - SuperKEKB approach
  - SuperB approach

Exploration of Two Frontiers







Largely based on SuperB conceptual design report

INFN/AE-07/02, SLAC-R-856, LAL 07-15

Available online:

http://www.pi.infn.it/SuperB

See also

- SuperKEKB Letter of Intent, KEK Report 04-4
- SuperKEKB Physics Working Group, [arXiv:hep-ex/0406071], update in preparation
- J.L.Hewett, D.Hitlin (ed.), SLAC-R-709, [arXiv:hep-ph/0503261]
- Flavour in LHC Era workshops, yellow book in preparation

Flavour Observables Sensitive to New Physics

$\Delta m_K \quad \epsilon_K \quad \epsilon'/\epsilon_K \quad B(K_L \to \pi^0 \nu \bar{\nu}) \quad B(K^+ \to \pi^+ \nu \bar{\nu}) \quad B(K^+ \to l^+ \nu)$

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

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

$\Delta m_s \quad A_{SL}(B_s) \quad S(B_s \to J/\psi \phi) \quad S(B_s \to \phi\phi)$

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

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

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

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

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

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

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

... add your favourite here ...

Good News and Bad News

- Bad news
  - no single “golden mode”
  - (of course, some channels preferred in certain models)
- Good news
  - 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

Will be Studied at SuperB

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

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

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

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

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

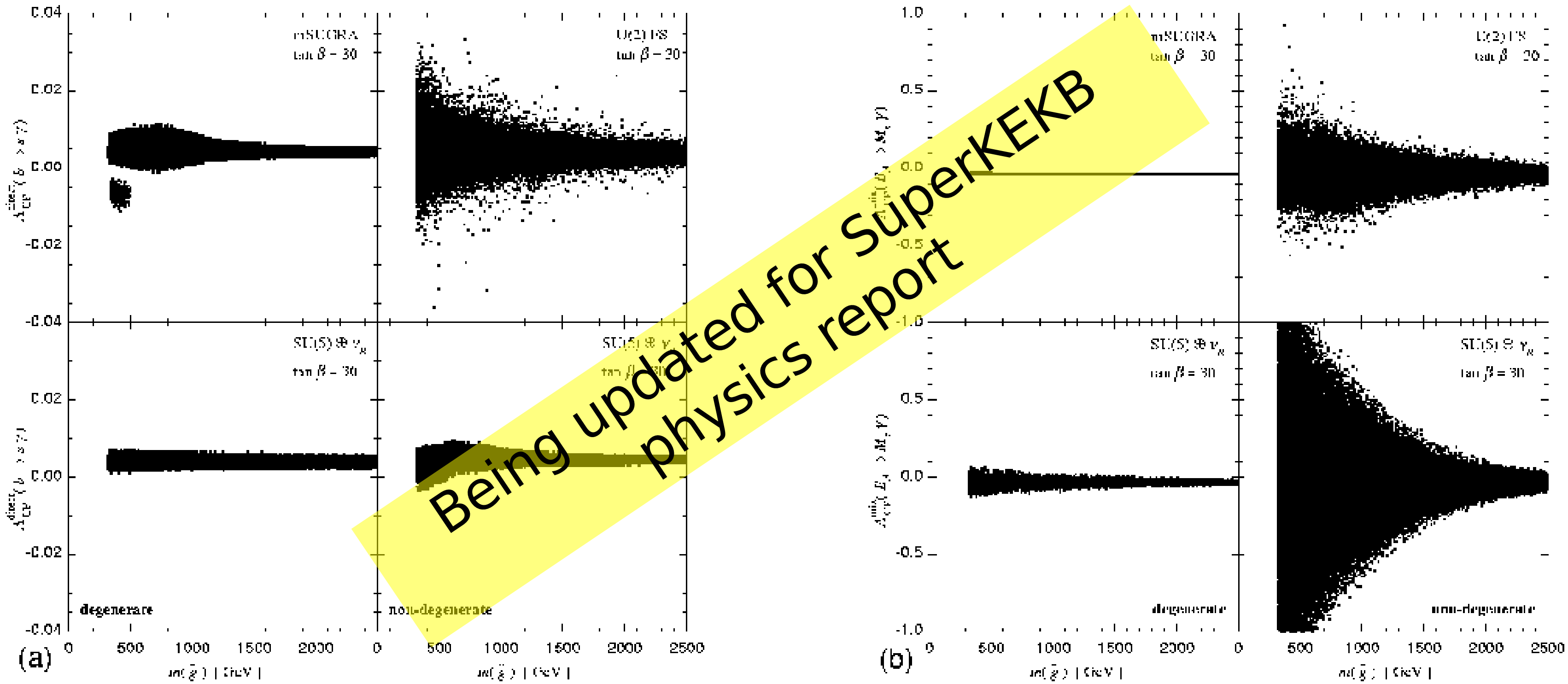
$B(\mu \to e\gamma)$ $B(\mu \to e^+ e^- e^+)$ $(g-2)_\mu$ μ EDM

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

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

Correlations Distinguish Models

T.Goto, Y.Okada, Y.Shimizu, T.Shindou, M.Tanaka, PRD 70, 035012 (2004)



$$A_{CP}(b \to s\gamma)$$

SFF can reach ~0.4% precision

$$S(B^0 \to K_S \pi^0 \gamma)$$

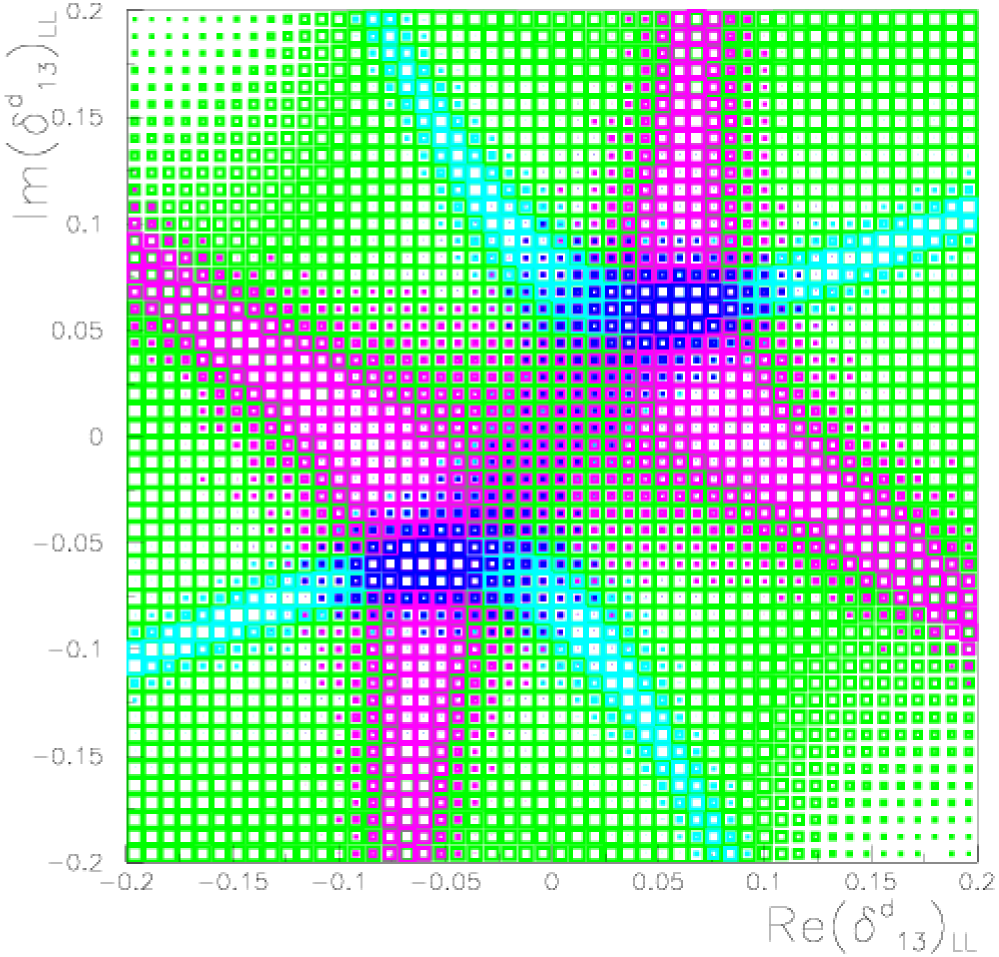
SFF can reach 2% precision

Plots show parameter scans in four different SUSY breaking schemes:

– mSUGRA
– U(2) flavour symmetry
– SU(5) + ν_R degenerate
– SU(5) + ν_R non-degenerate

MSSM + Generic Squark Mass Matrices

Today's central values with SuperB precision



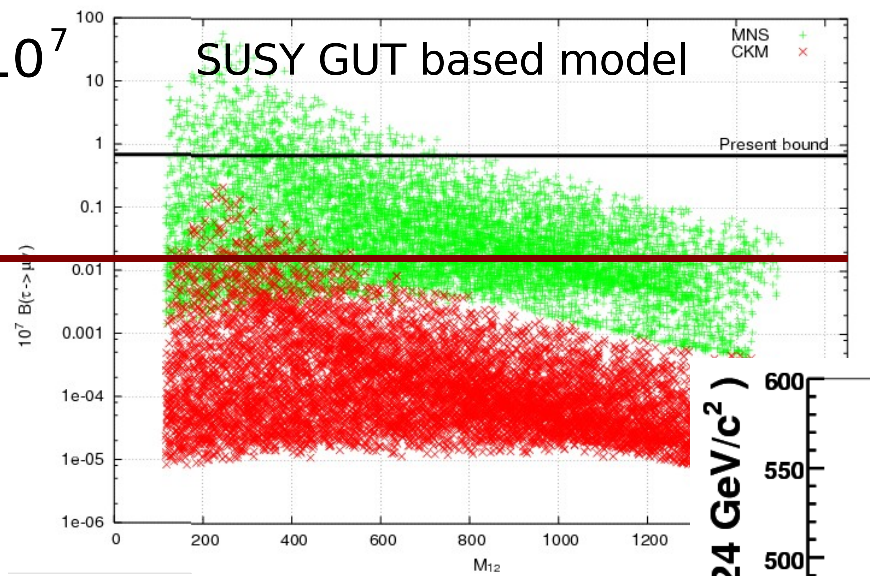
Δm_d	**magenta**
A_{SL}	**green**
β	**cyan**
All	**blue**

Real vs. imaginary parts of mass-insertion parameter $(\delta_{13})_{LL}$

Lepton Flavour Violation

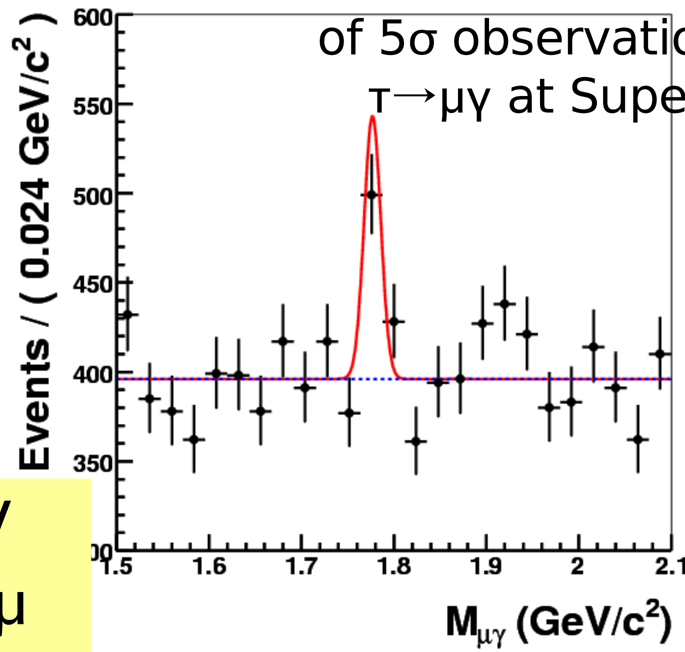
- Observable LFV signals predicted in a wide range of models, including those inspired by Majorana neutrinos

$B(\tau \to \mu\gamma) \times 10^7$



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}
$\mathcal{B}(\tau \to \ell K_S^0)$	2×10^{-10}

Monte Carlo simulation of 5σ observation of $\tau \to \mu\gamma$ at SuperB



SuperB is *much* more sensitive to LFV than LHC experiments, even for $\tau \to \mu\mu\mu$

Some Scenarios

1) LHC discovers new physics

- Can it be flavour blind? (ie. no signals in flavour)
  - No, it must couple to SM, which violates flavour
  - Any TeV scale NP model includes new flavoured particles
- What is the minimal flavour violation? (ie. worst case) (see T.Feldmann talk)
  - NP follows SM pattern of flavour and CP violation
  - SFF detects NP effects for particle masses up to >600 GeV

    (analysis relies on CKM fits and improvements in lattice calculations)
- What if NP flavour couplings are not suppressed?
  - SFF observes rich phenomenology: unique potential to measure NP flavour couplings and distinguish models

Some Scenarios

2) LHC does not discover new physics

- Problem for naturalness?
  - Not really – just an order of magnitude argument
- How to probe higher mass scales?
  - NP models with unsuppressed flavour couplings can reach scales of 10s, 100s or even 1000s of TeV

Super Flavour Factory is best chance to observe NP beyond LHC reach

Estimated Sensitivities

Observable	Super Flavour Factory sensitivity
$\sin(2\beta)$ $(J/\psi\, K^0)$	0.005–0.012
γ $(B \to D^{(*)}K^{(*)})$	1–2°
α $(B \to \pi\pi, \rho\rho, \rho\pi)$	1–2°
$\lvert V_{ub}\rvert$ (exclusive)	3–5%
$\lvert V_{ub}\rvert$ (inclusive)	2–6%
$\bar{\rho}$	1.7–3.4%
$\bar{\eta}$	0.7–1.7%
$S(\phi K^0)$	0.02–0.03
$S(\eta' K^0)$	0.01–0.02
$S(K_S^0 K_S^0 K_S^0)$	0.02–0.04
$\mathcal{B}(B \to \tau\nu)$	3–4%
$\mathcal{B}(B \to \mu\nu)$	5–6%
$\mathcal{B}(B \to D\tau\nu)$	2–2.5%
$\mathcal{B}(B \to \rho\gamma)/\mathcal{B}(B \to K^*\gamma)$	3–4%
$A_{CP}(b \to s\gamma)$	0.004–0.005
$A_{CP}(b \to (s+d)\gamma)$	0.01
$S(K_S^0\pi^0\gamma)$	0.02–0.03
$S(\rho^0\gamma)$	0.08–0.12
$A^{\rm FB}(B \to X_s\ell^+\ell^-)\, s_0$	4–6%
$\mathcal{B}(B \to K\nu\bar{\nu})$	16–20%
$\mathcal{B}(\tau \to \mu\gamma)$	$2\text{–}8 \times 10^{-9}$
$\mathcal{B}(\tau \to \mu\mu\mu)$	$0.2\text{–}1 \times 10^{-9}$
$\mathcal{B}(\tau \to \mu\eta)$	$0.4\text{–}4 \times 10^{-9}$

Range of estimated sensitivities from SuperB CDR and SuperKEKB LoI

Super Flavour Factory

- Data taken at Υ(4S) allows studies of tau, charm, charmonia, ISR, γγ physics (and more)
- SuperB is designed with flexible running energy
  - charm-tau threshold region
  - other Upsilon resonances – including Υ(5S)

$\Rightarrow$ can study B_s sector, including φ_s (but not Δm_s)

- Considering beam polarization option
  - provides luminosity enhancement
  - significant improvement in sensitivity for τ EDM

How Can it be Achieved?

Luminosity must be ~10^{36}/cm^2/s or higher

- Enables integration of over 10/ab/year
- Two orders of magnitude higher than now

⇒ Push current B factories to the limit (SuperKEKB)

Stored current:
1.36/1.75 A (KEKB)
→ 4.1/9.4 A (SuperKEKB)

Beam–beam parameter:
0.059 (KEKB)
→ >0.24 (SuperKEKB)

high currents
(power consumption ~85 MW)

crab cavities
(being tested now at KEKB)

Lorentz factor

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

Classical electron radius

Beam size ratio

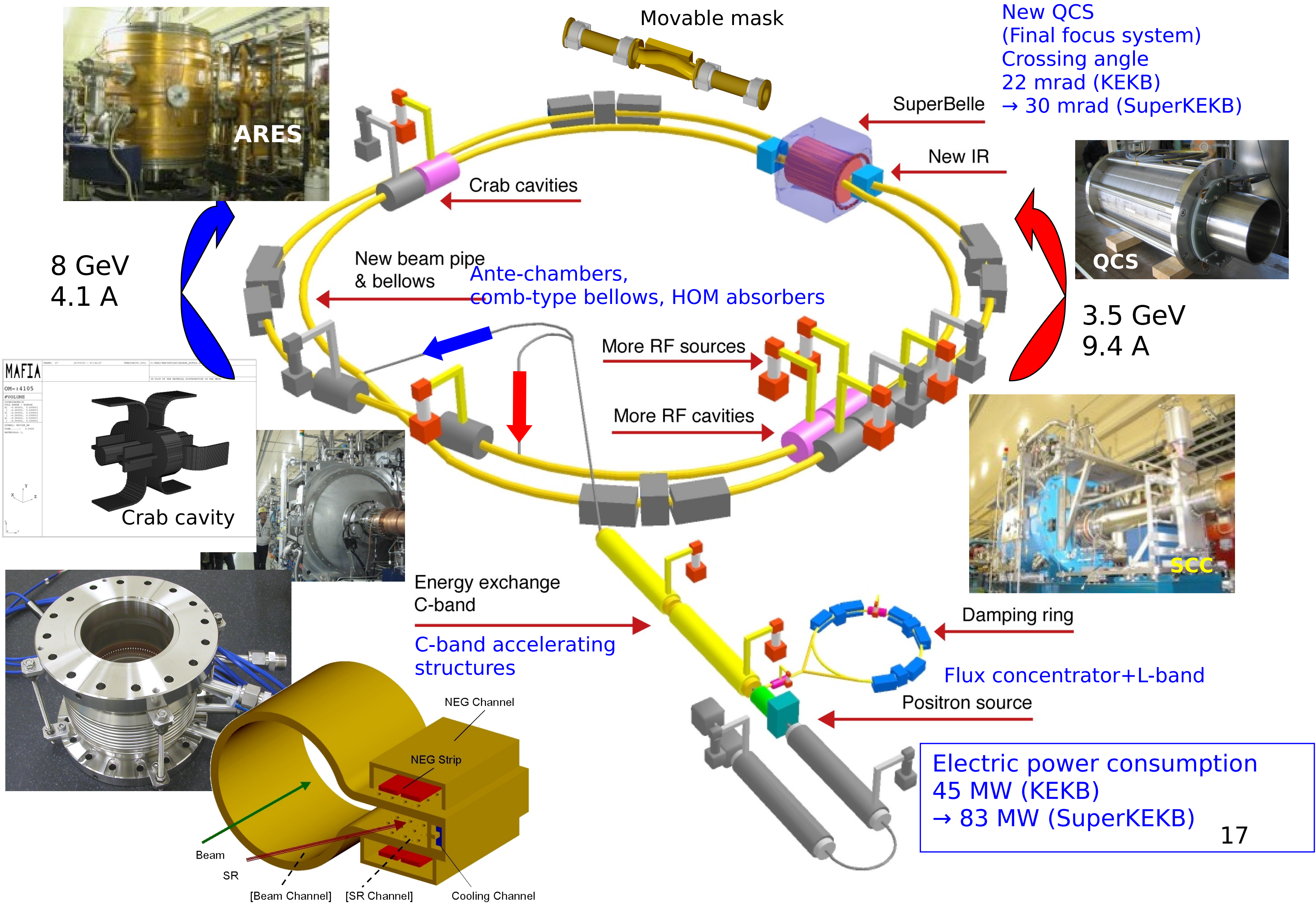
Geometrical reduction factors due to crossing angle and hour–glass effect

Luminosity:
0.16×10^{35} cm^{-2}s^{-1} (KEKB)
8×10^{35} cm^{-2}s^{-1} (SuperKEKB)

Vertical β at the IP:
6.5/5.9 mm (KEKB)
→ 3.0/3.0 mm (SuperKEKB)

squeezed bunches
(possible instabilities)

Upgraded Components for SuperKEKB



Something Completely Different

Attempts to upgrade PEP-II and KEKB with high current hit limitations due to beam instabilities, backgrounds and power

⇒ Approach with small emittance bunches (SuperB)

- initially inspired by ILC damping rings
- large Piwinski angle ($\varphi = \theta\ \sigma_z/\sigma_x$)
- "crab waist"

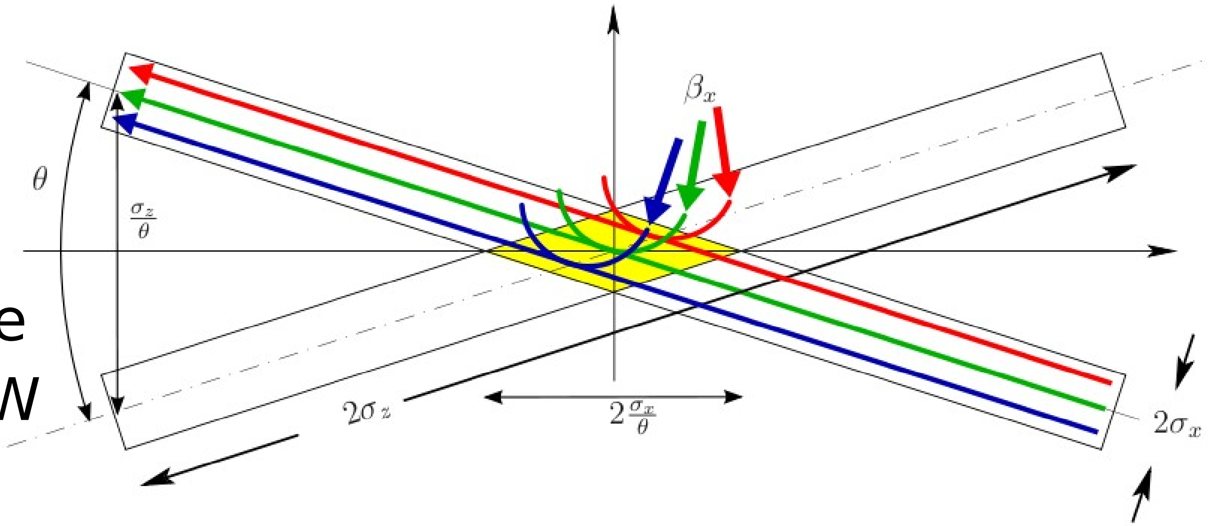
⇒ High luminosity

⇒ Low currents

⇒ Small backgrounds

⇒ Stable dynamic aperture

⇒ Wall plug power ~30 MW



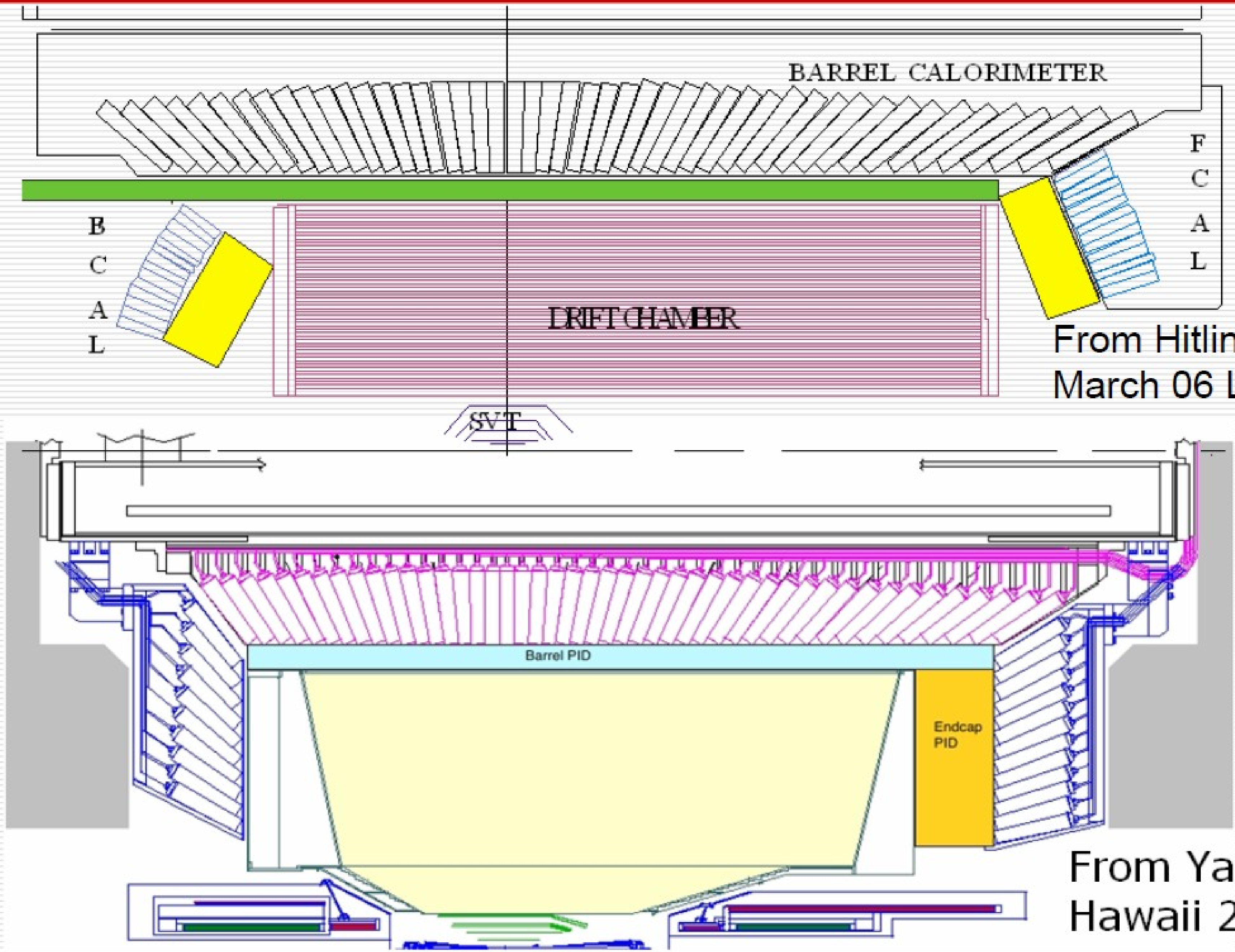
Maximize beam overlap with finite crossing angle

Backgrounds and Detectors

- Backgrounds depend on various factors
  - luminosity
    - radiative BhaBha scattering
    - e^+e^- pair production
  - currents
    - synchrotron radiation
    - beam-gas interaction ← main problem for SuperKEKB: beam backgrounds ~ 20 x today
  - beam size
    - Touschek scattering ← possible problem for SuperB: motivates smaller beam asymmetry (7 GeV on 4 GeV)
    - beam-beam interactions

- For either SuperKEKB or SuperB:
  - interaction point design & shielding requires care
  - detector can be based on existing BaBar / Belle

Comparison – *BABAR* and Belle for *SuperB*



From Hitlin's talk at March 06 LNF

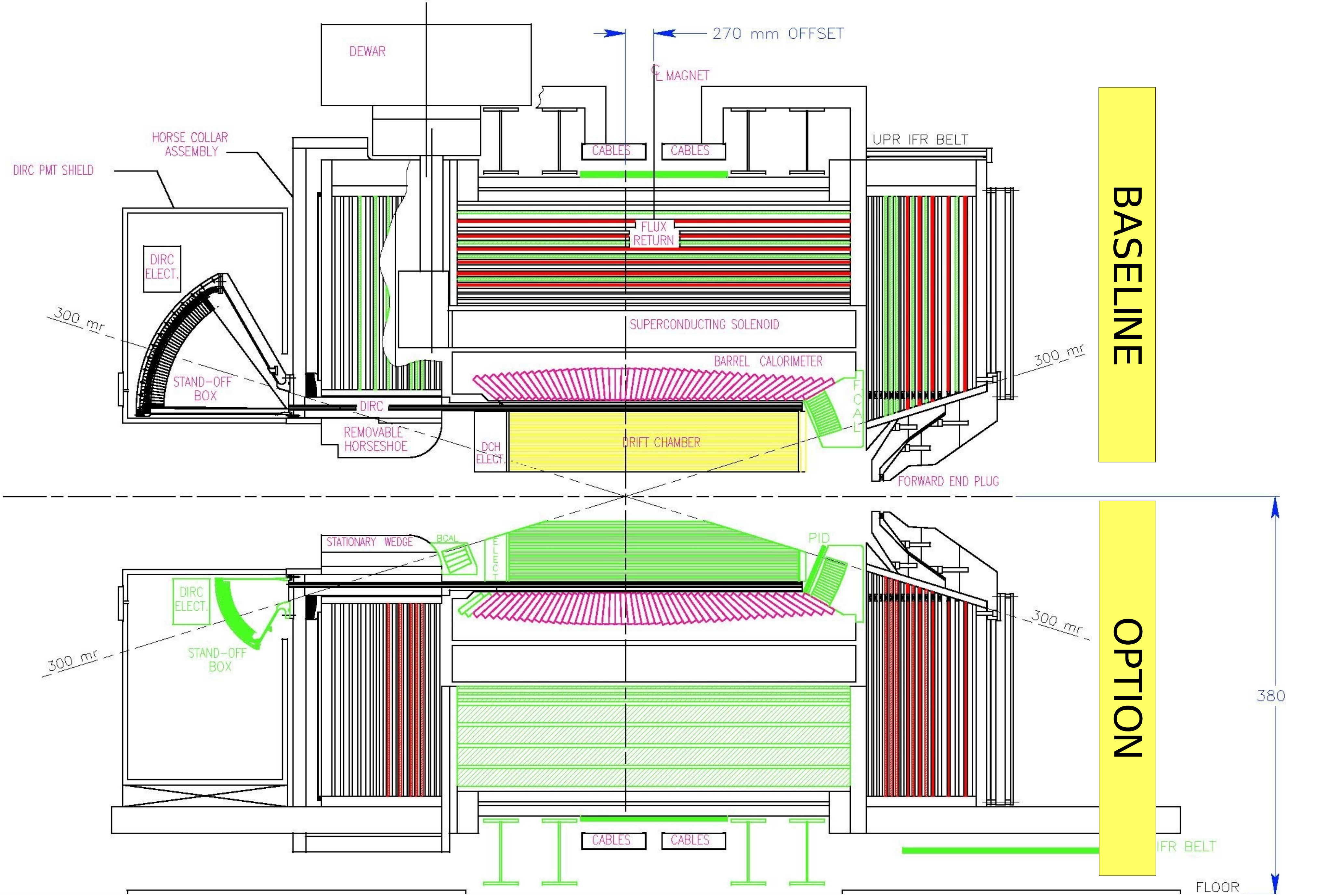
From Yamauchi's Hawaii 2005 talk

Detector R&D

- Both designs require detector R&D for the same subsystems
  - vertex detector
    - first layer close (~1cm) to beam spot
    - use pixels or striplets to cope with occupancy
  - particle identification
    - improved readout for barrel (DIRC)
    - forward PID device (focussing RICH?)
  - calorimeter
    - CsI(Tl) too slow for endcaps → pure CsI? LSO?
  - electronics, trigger, DAQ & offline computing
    - need to deal with high physics trigger rate

improvements in hermeticity important for many measurements

SuperB Detector



Site

SuperKEKB

- would be sited at KEK

SuperB

- site not yet fixed
- SuperB design at, eg., SLAC, FNAL or KEK "possible"

(political &/or technical difficulties notwithstanding)

- however, there is, of course, a baseline …

Potential SuperB site on the University of Rome Tor Vergata campus

Synergy with approved and funded FEL project (SPARX)

NB. Baseline 2250m circumference (similar to PEP-II)

Costs & Funding Model

SuperKEKB

- Total cost ~415 M$

  + unspecified “replacement value”

- Funded by KEK + international (in kind?) contributions

SuperB

- Total cost ~340 M€

  + ~170 M€ “replacement value”

- Funding model under development:
  - Italian government ad hoc contribution
  - Regione Lazio contribution
  - INFN regular budget
  - EU contribution
  - In-kind contributions (PEP-II + BaBar elements)
  - Partner countries contributions

What's Next?

SuperKEKB

- JAHEP has approved pursuit of flavour physics (*K*, *B* & *ν*) before ILC
- Recommendation from KEK director general expected this summer
- No serious funding available until end of JPARC construction
- Approx. 2 years construction time necessary

SuperB

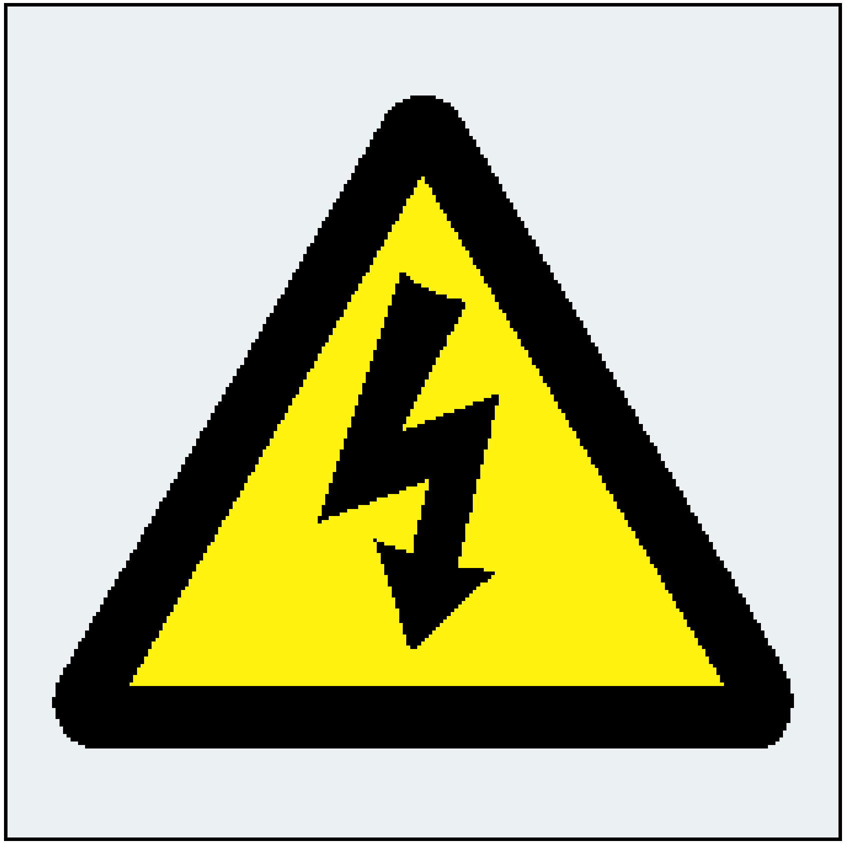
- CERN Council Strategy Group approved flavour physics as regional initiative
- CDR being read by an international review committee
- Expect report by end of year
- Crab waist beam tests planned at LNF in autumn
- Approx. 5 years construction time necessary

Assumption that only one Super Flavour Factory will be built.
“contraction and convergence” ?

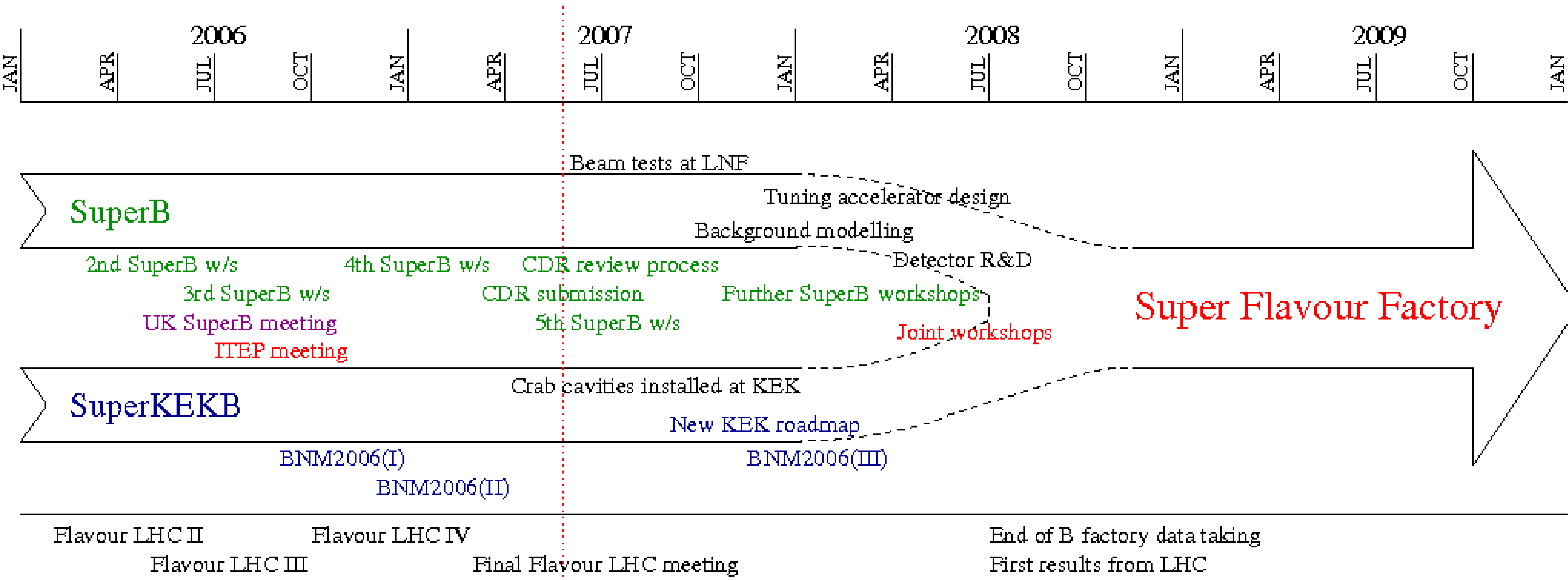
Summary

- The case for flavour physics in the LHC era is compelling
- A Super Flavour Factory is the ideal tool to explore the new phenomenology
- Two approaches to achieve the necessary luminosity, based on radically different concepts
  - exciting progress in accelerator technology
  - both have strong regional support
- Clear road ahead to explore the flavour treasure chest by mid-2010s
  - stay tuned for further developments

Back Up



Timeline



SuperKEKB

- Construction 2009-10
- Data taking starts 2011

SuperB

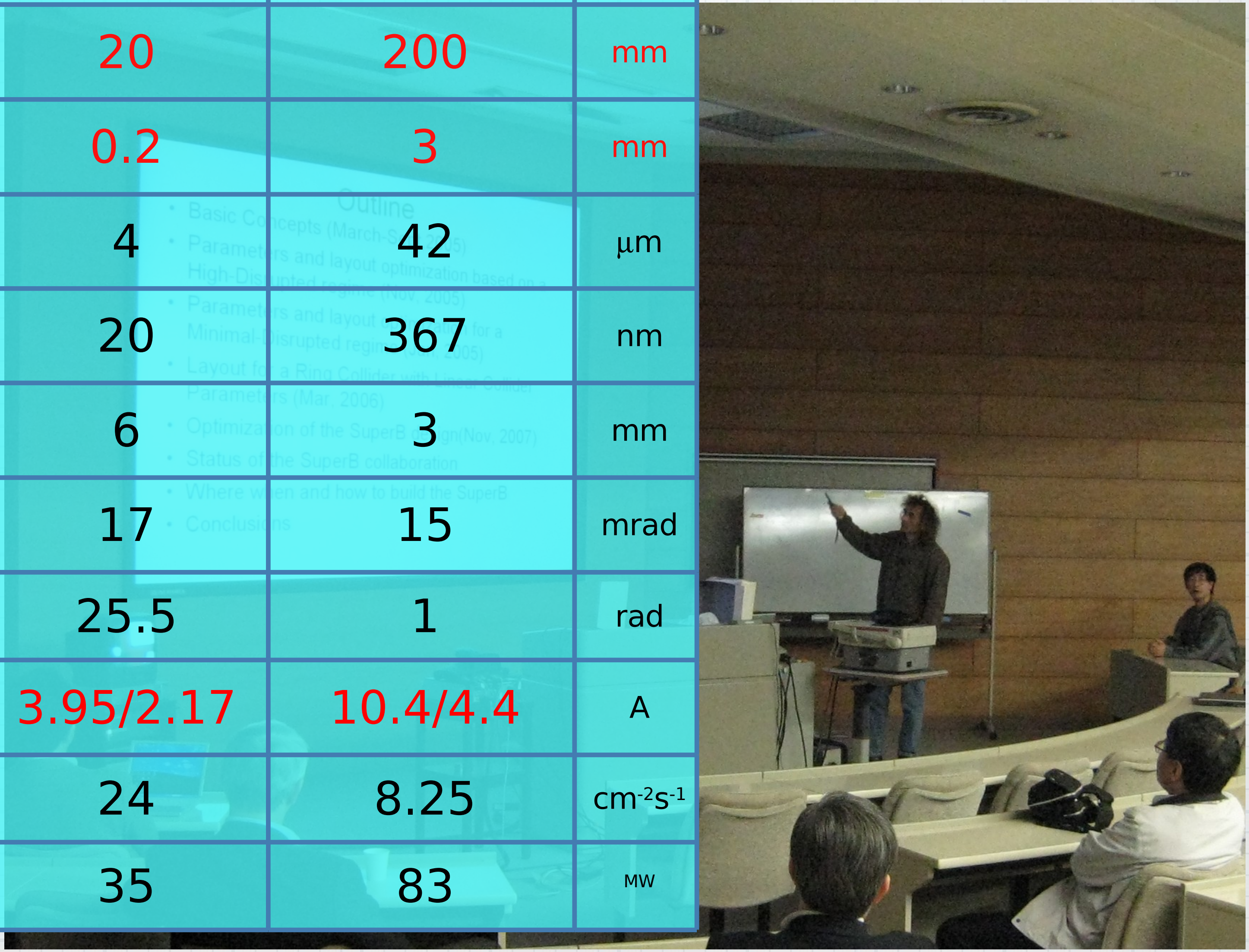
- Construction 2008-2012 (?)
- Data taking starts 2013

Either scenario gives large data samples by mid-2010s

Comparison between SuperB and SuperKEKB

		SuperB (Upgrade)	SuperKEKB (Low Emittance)	
Emittance	ε_x	0.8	9	nm
Horizontal beta	β_x^*	20	200	mm
Vertical beta	β_y^*	0.2	3	mm
Horizontal beam size	σ_x^*	4	42	μm
Vertical beam size	σ_y^*	20	367	nm
Bunch length	σ_z	6	3	mm
Half crossing angle	ϕ_x	17	15	mrad
Piwinski angle	φ	25.5	1	rad
Current(LER/HER)	I_b	3.95/2.17	10.4/4.4	A
Luminosity ($\times 10^{35}$)	L	24	8.25	$cm^{-2}s^{-1}$
AC Plug Power	P	35	83	MW

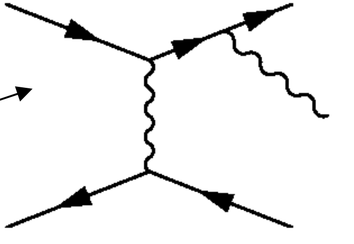
One order magnitude smaller than SuperKEKB

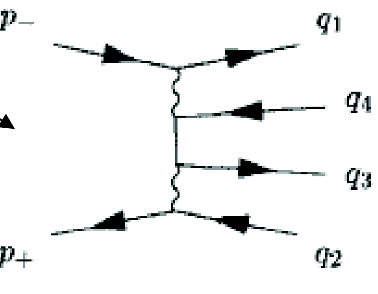


Backgrounds

- Dominated by QED cross section
  - Low currents / high luminosity
    - Beam-gas are not a problem
    - SR fan can be shielded

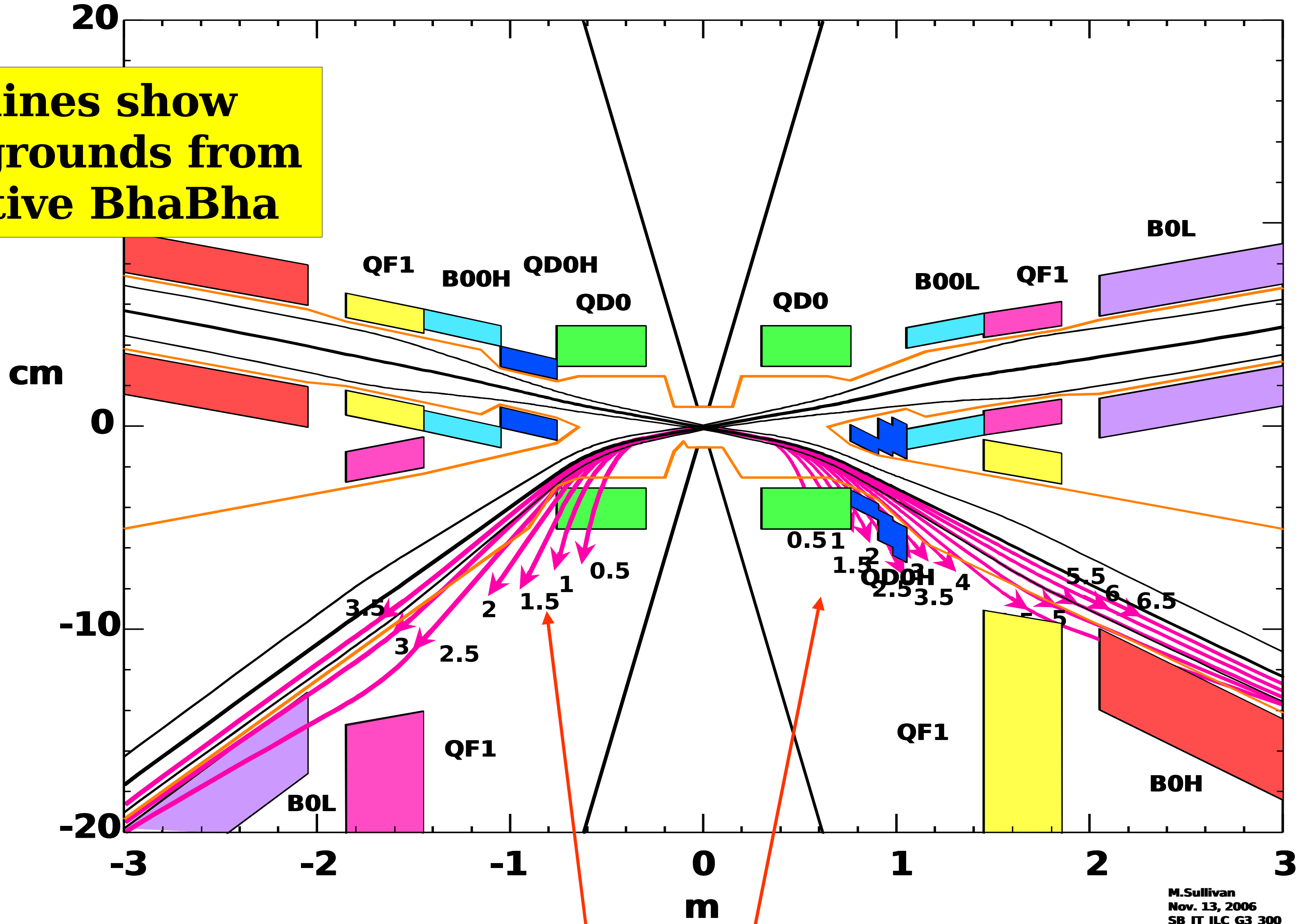
	Cross section	Evt/bunch xing	Rate
Radiative Bhabha	~340 mbarn (Eγ/Ebeam > 1%)	~680	0.3THz
e^+e^- pair production	~7.3 mbarn	~15	7GHz
Elastic Bhabha	$O(10^{-5})$ mbarn (Det. acceptance)	~20/Million	10KHz
$\Upsilon(4S)$	$O(10^{-6})$ mbarn	~2/million	1 KHz





Interaction Region Design

Pink lines show backgrounds from radiative BhaBha



Need serious amount of shielding to prevent the produced shower from reaching the detector.

CDR cost estimate

Costs are presented "ILC-style", with replacement value for reusable PEP-II/*BABAR* components

	EDIA [my]	Labor [my]	M&S [k€]	Replacement value [k€]
Accelerator	452	291	191,166	126,330
Site	119	138	105,700	0
Detector	283	156	40,747	46,471

EDIA: Engineering, Design, Inspection, Acceptance

M&S: Materials & Services

Replacement value: Value of reusable items from PEP-II and *BABAR*

Disassembly, crating, refurbishment and shipping costs are included in columns to the left

Costs are in 2007 € inflation adjusted

Possible savings from reusing other hardware not yet considered in detail

CDR schedule

- Impossible to read here, check the CDR
- Includes site construction, PEP-II & BaBar disassembly, shipping, reassembly, etc.
- Five years from T0 to commissioning

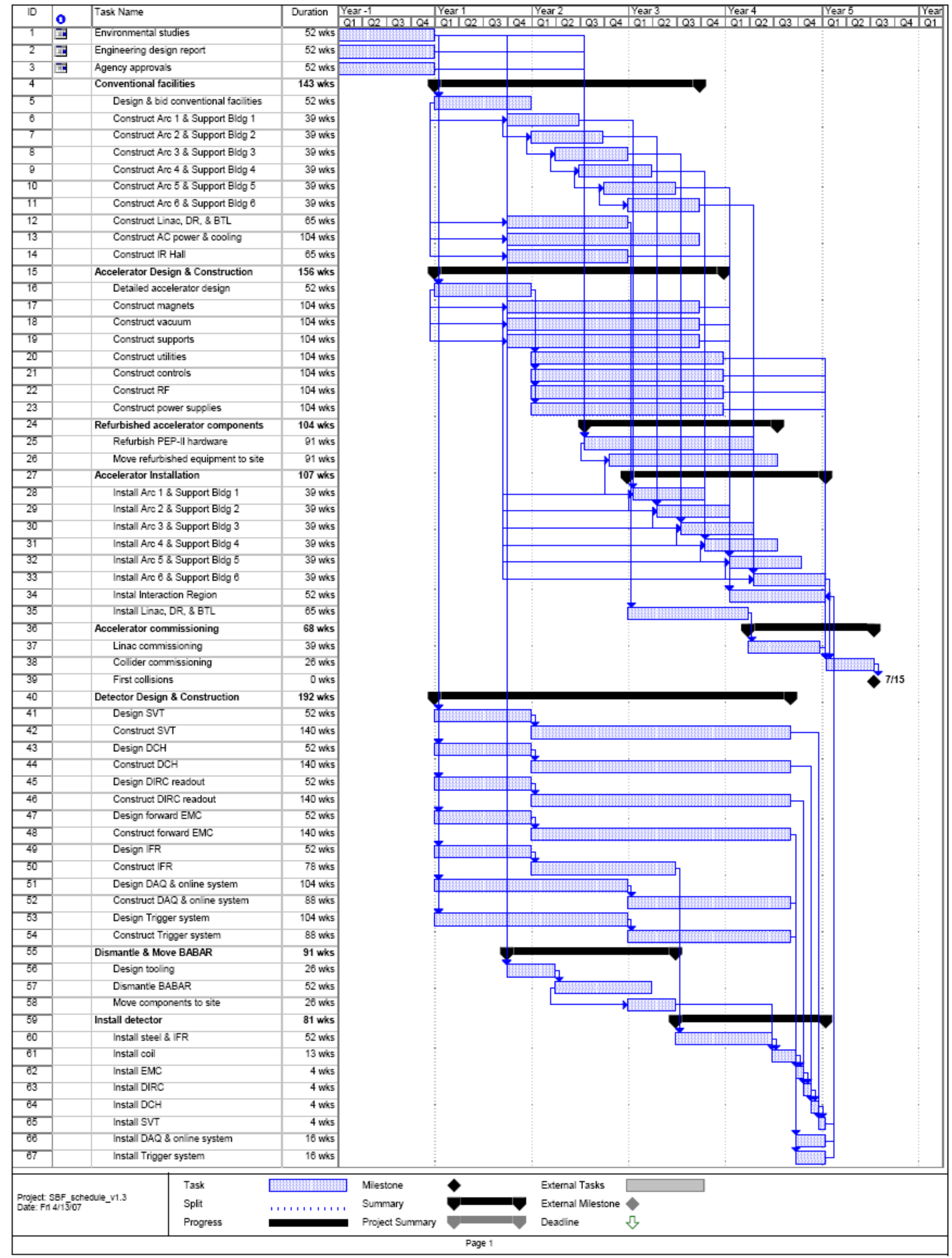


Figure 5-1. *Overall schedule for the construction of the SuperB project.*

Compare to ILC "value estimate"

Costs are presented "ILC-style", with replacement value for reusable PEP-II/*BABAR* components

	EDIA [my]	Labor [my]	M&S [k€]	Replacement value [k€]
Accelerator	452	291	191,166	126,330
Site	119	138	105,700	0
Detector	283	156	40,747	46,471

Totals 337,613 k€ 172,801 k€

SHARED VALUE = 4.87 Billion ILC VALUE UNITS

SITE-DEPENDENT VALUE = 1.78 Billion ILC VALUE UNITS

TOTAL VALUE = 6.65 Billion ILC VALUE UNITS

(shared + site-dependent)

= 5,519,500 k€

LABOUR = 22 million person-hours = 13,000 person-years (assuming 1700 person-hours per person-year)

1 ILC VALUE UNIT = 1 US Dollar (2007) = 0.83 Euros = 117 Yen

NB. ILC costs do not include detector, land acquisition, inflation

MORE THAN AN ORDER OF MAGNITUDE DIFFERENCE!

International Review Committee

- R. Petronzio, President of INFN, has formed an International Review Committee to evaluate SuperB CDR

- The committee members are:

  J. Dainton (chair) [UK]

  H. Aihara [Japan] R. Heuer [Germany] Y.-K. Kim [US]

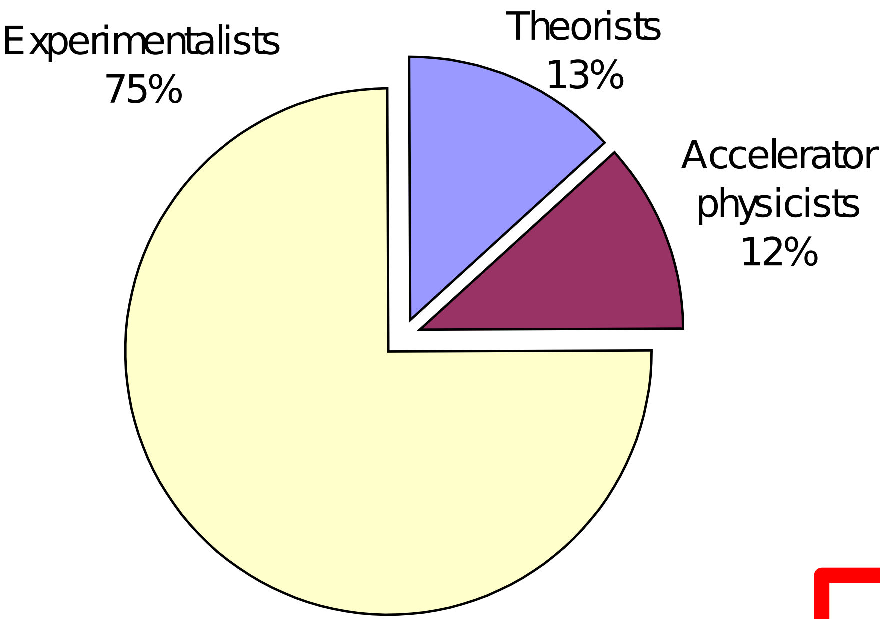
  A. Masiero [Italy] J. Siegrist [US] D. Shulte [CERN]

- First meeting of the committee expected July 2007

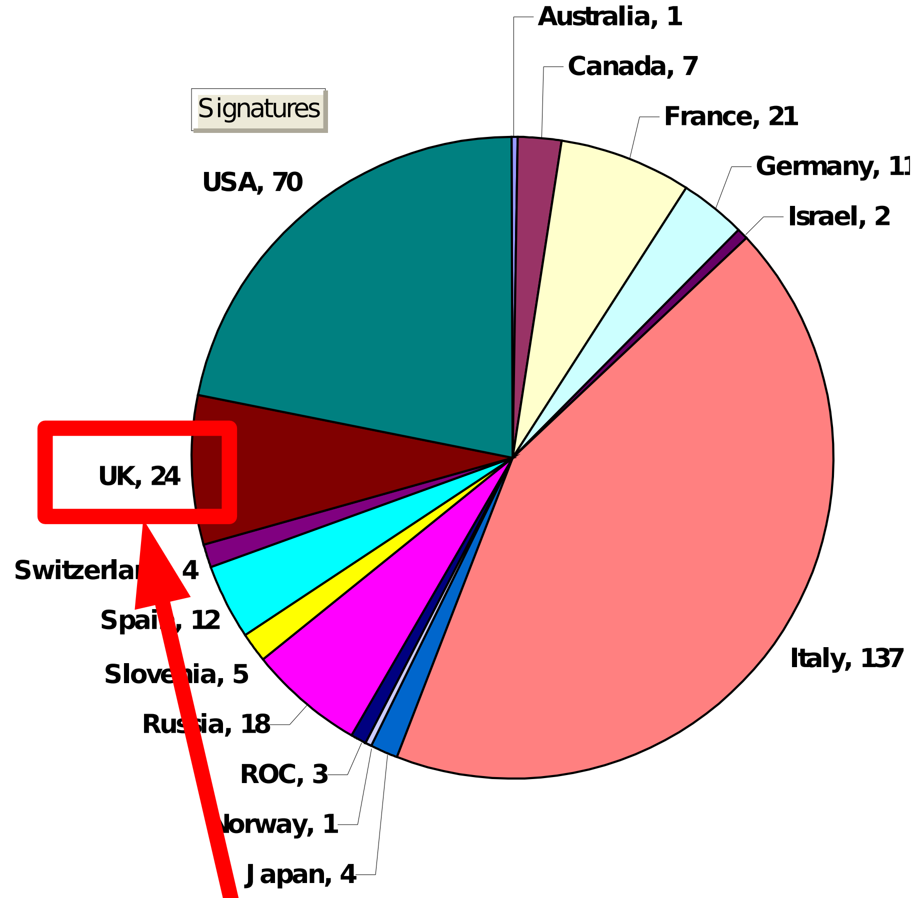
- Expect several IRC meetings, some with interactions with primary authors, and a report by end of the year

- Possible further report in Spring 2008 following DaΦNe beam test results

- 320 Signatures
- About 85 institutions
- 174 Babar members
- 65 non Babar experimentalists.



Signatures breakdown by type



Signatures breakdown by country

UK 3rd biggest block of signatures

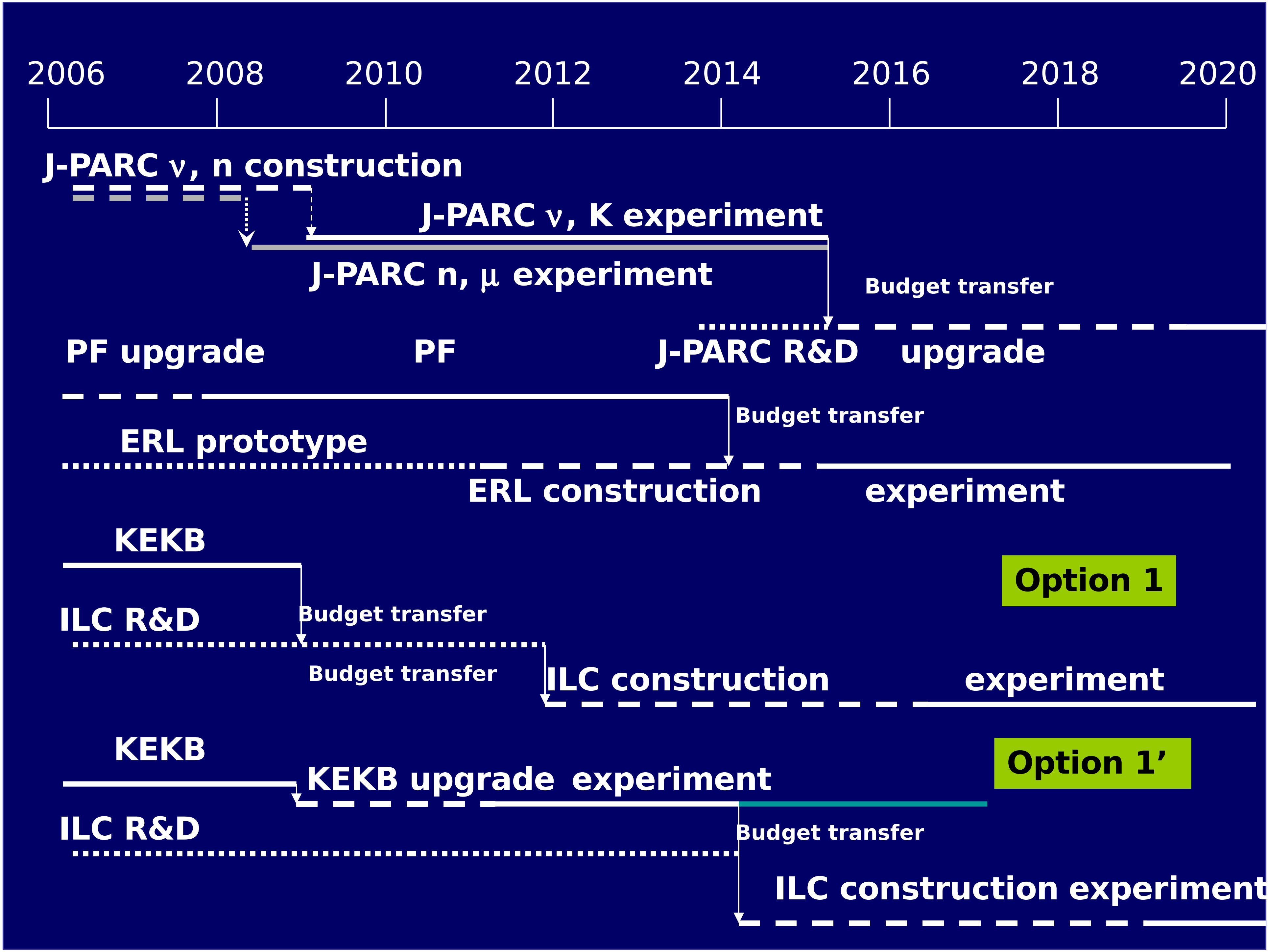
UK signatories

- University of Birmingham (1)
- Brunel University (1)
- ASTeC, Daresbury Laboratory (1)
- IPPP, Durham University (3)
- University of Edinburgh (2)
- Imperial College London (1)
- University of Liverpool (2)
- University of Liverpool and Cockcroft Institute (1)
- Royal Holloway University of London (1)
- Queen Mary University of London (3)
- University of Manchester (2)
- Rutherford Appleton Laboratory (1)
- University of Warwick (5)

24 individuals (~9 non faculty), 13 institutes

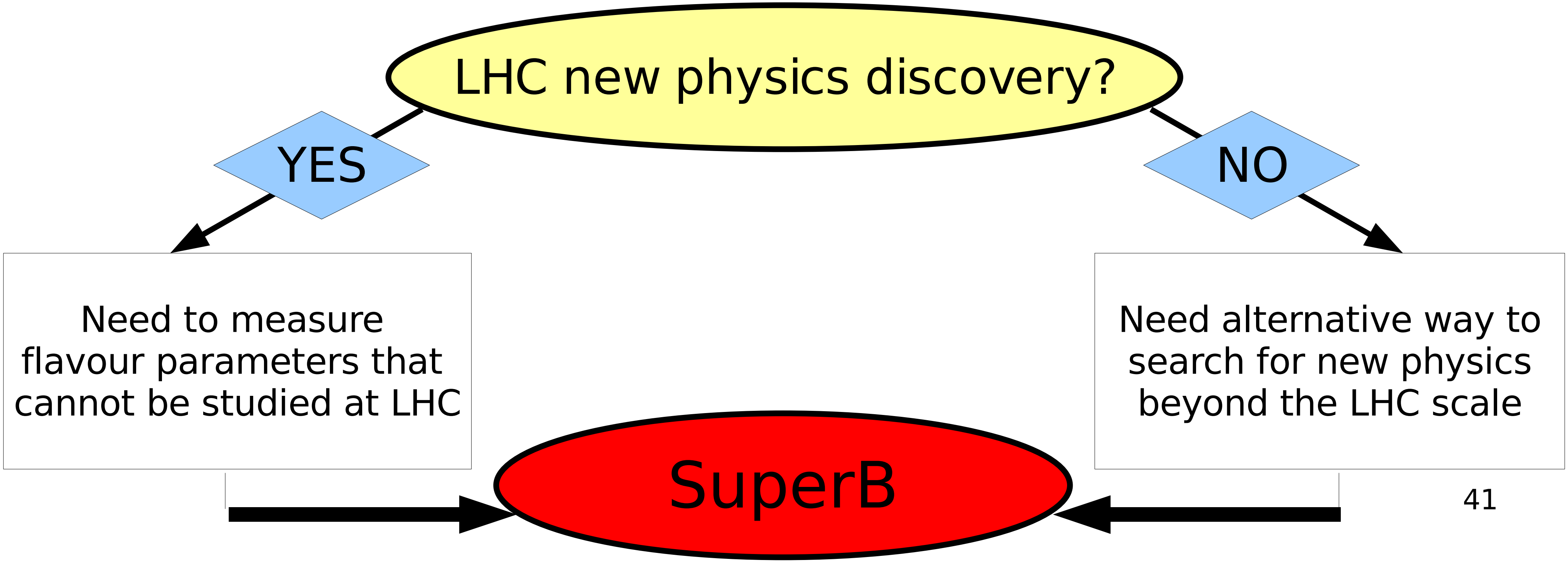
News from Japan

- Crab cavities installed and being tested
  - some improvement in specific luminosity seen at low currents
  - now testing with higher currents
- Low emittance scheme under consideration at KEK
  - no stable dynamic aperture found as yet
  - concerns over geological stability
  - intermediate schemes also being considered
- Support for SuperKEKB from
  - Japanese High Energy Physics community (JAHEP)
  - Belle Program Advisory Committee (PAC)
  - statement from KEK director general expected this summer
- No funds available until end of J-PARC construction


2006
2008
2010
2012
2014
2016
2018
2020
J-PARC ν, n construction
J-PARC ν, K experiment
J-PARC n, μ experiment
Budget transfer
PF upgrade
PF
J-PARC R&D
upgrade
Budget transfer
ERL prototype
ERL construction
experiment
KEKB
Option 1
ILC R&D
Budget transfer
Budget transfer
ILC construction
experiment
KEKB
Option 1’
KEKB upgrade
experiment
ILC R&D
Budget transfer
ILC construction experiment

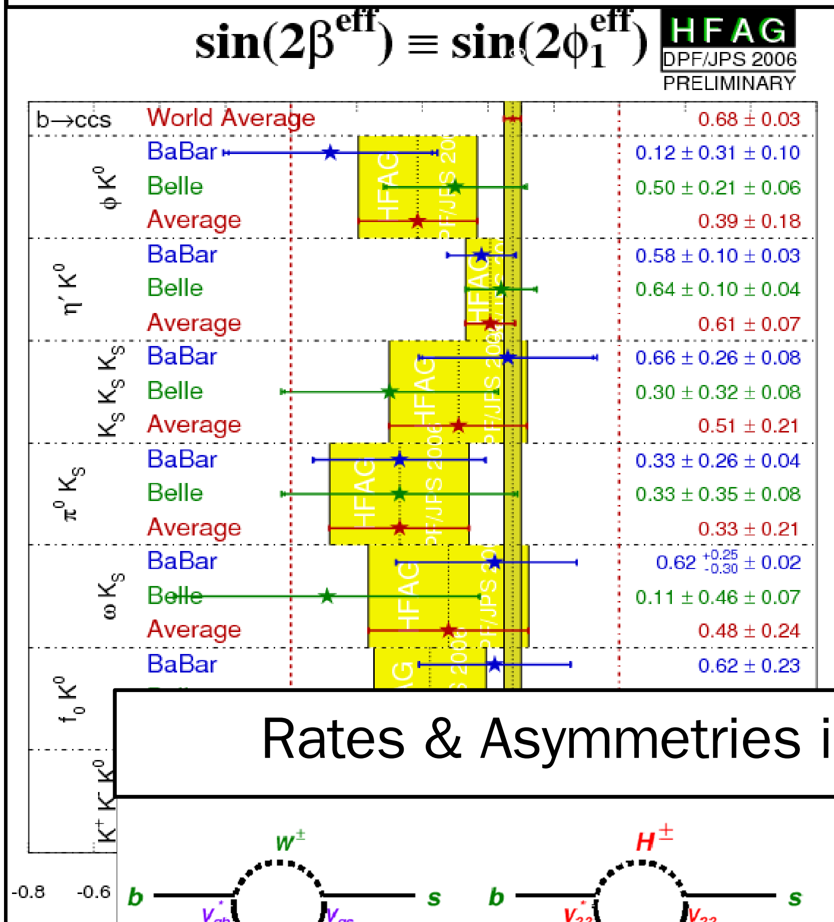
What about LHC?

- Important to note that flavour observables are complementary to those at the energy frontier
  - measure different new physics parameters
  - powerful to distinguish models
- Why not wait for LHC?

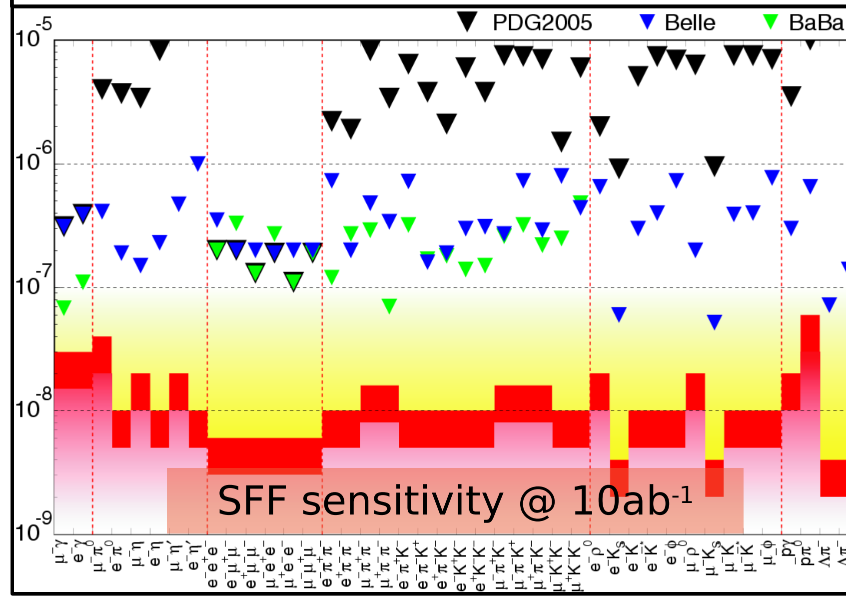


Some Key Measurements

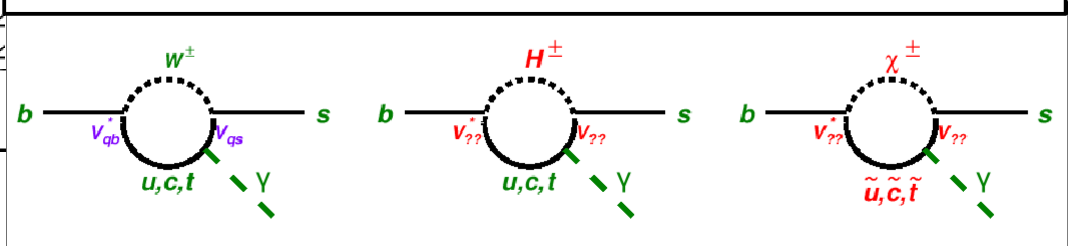
CP Violation in Hadronic b→s



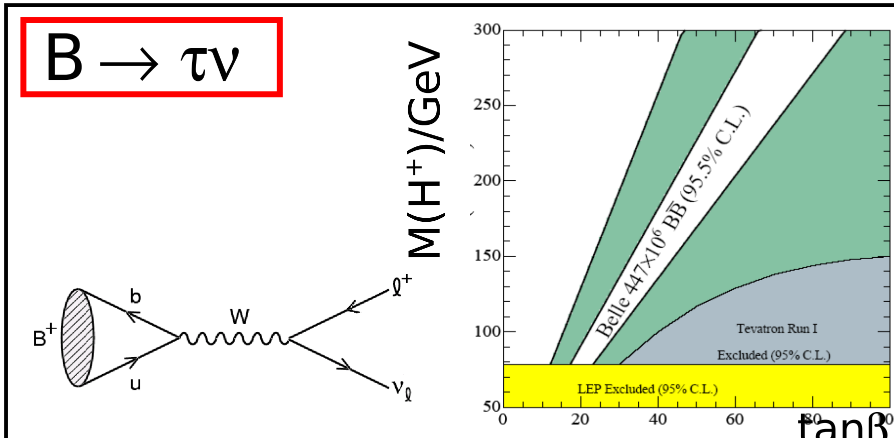
Lepton Flavour Violation in τ Decay



Rates & Asymmetries in b→sγ



B → τν



Couplings and Scales

$$L = L_{SM} + \sum_{k=1} \left(\sum_i c_i^k Q_i^{(k+4)} \right) / \Lambda^k$$

- New physics effects are governed by:
  - new physics scale Λ
  - effective flavour-violating couplings c_i
    - couplings may have a particular pattern (symmetries)
    - coupling strengths can vary (different interactions)

- If Λ known from LHC, measure c_i
- If Λ not known, measure c_i / Λ

MFV Confronts the Data

- Current experimental situation
  - some new physics flavour couplings are small
- Minimal flavour violation
  - all new physics flavour couplings are zero

MFV is a long way from being verified!

Need to establish correlations between different flavour sectors (B_d,B_s,K)

New Physics Sensitivity in MFV

$$\mathcal{H}_{\rm eff}^{\Delta F=2} = \mathcal{H}_{\rm SM} + \mathcal{H}_{\rm NP} = \left(V_{tq} V_{tq'}^*\right)^2 \left(\frac{S_0(x_t)}{\Lambda_0^2} + \frac{a_{\rm NP}}{\Lambda^2}\right) (\bar{q}' q)_{(V-A)} (\bar{q}' q)_{(V-A)}$$

$$S_0(x_t) \rightarrow S_0(x_t) + \delta S_0, \quad |\delta S_0| = O\left(4 \frac{\Lambda_0^2}{\Lambda^2}\right), \quad \Lambda_0 = \frac{\pi Y_t}{\sqrt{2} G_F M_W} \sim 2.4\,\mathrm{TeV}$$

Today	SuperB
Λ(MFV) > 2.3Λ_0 @95C.L.	Λ(MFV) >~6Λ_0 @95C.L.
NP masses >200GeV	NP masses >600GeV

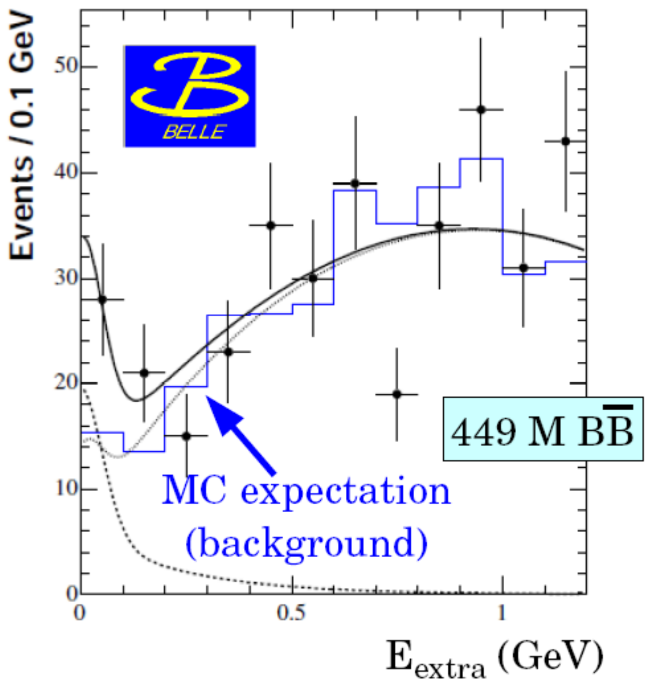
- analysis relies on CKM fits and improvements in lattice calculations
- only ΔF=2 (mixing) operators considered
- further improvements possible including also ΔF=1 (especially b→sγ)

Leptonic B Decays

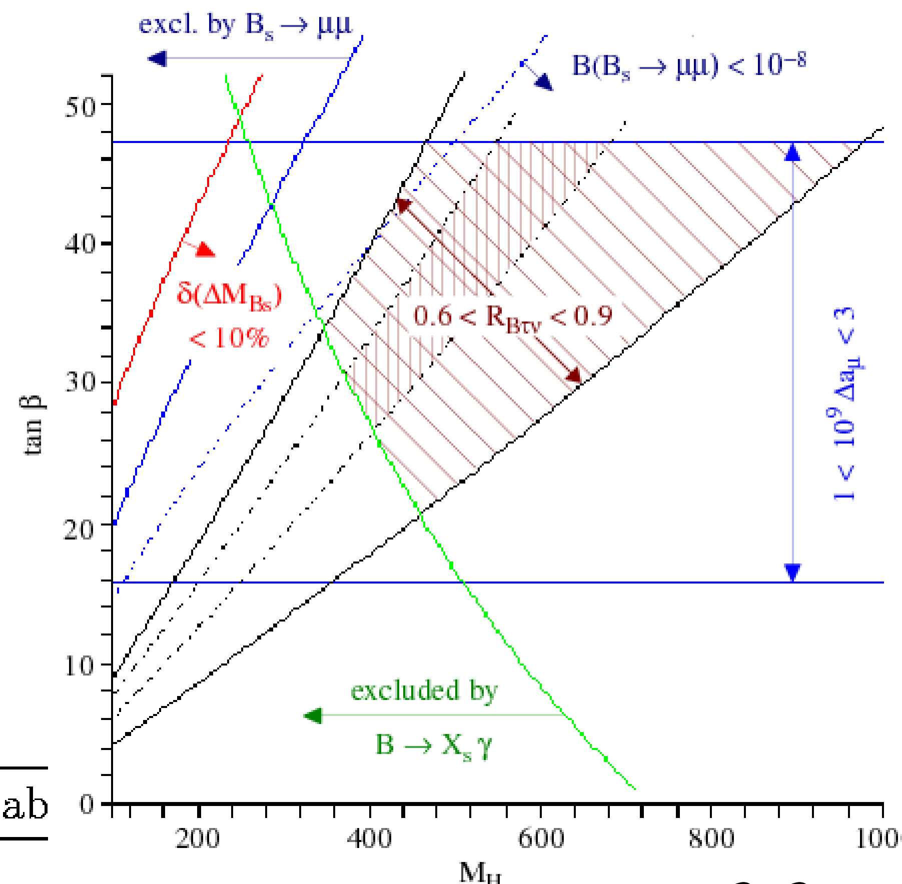
Crucial for MFV models with large tan β (and MSSM)

W.-S.Hou, PRD 48, 2342 (1993)
G.Isidori, P.Paradisi, PLB 639, 499 (2006)

$$\mathcal{B}(B^+ \to \tau^+ \nu)$$



$17.2^{+5.3}_{-4.7}$ events

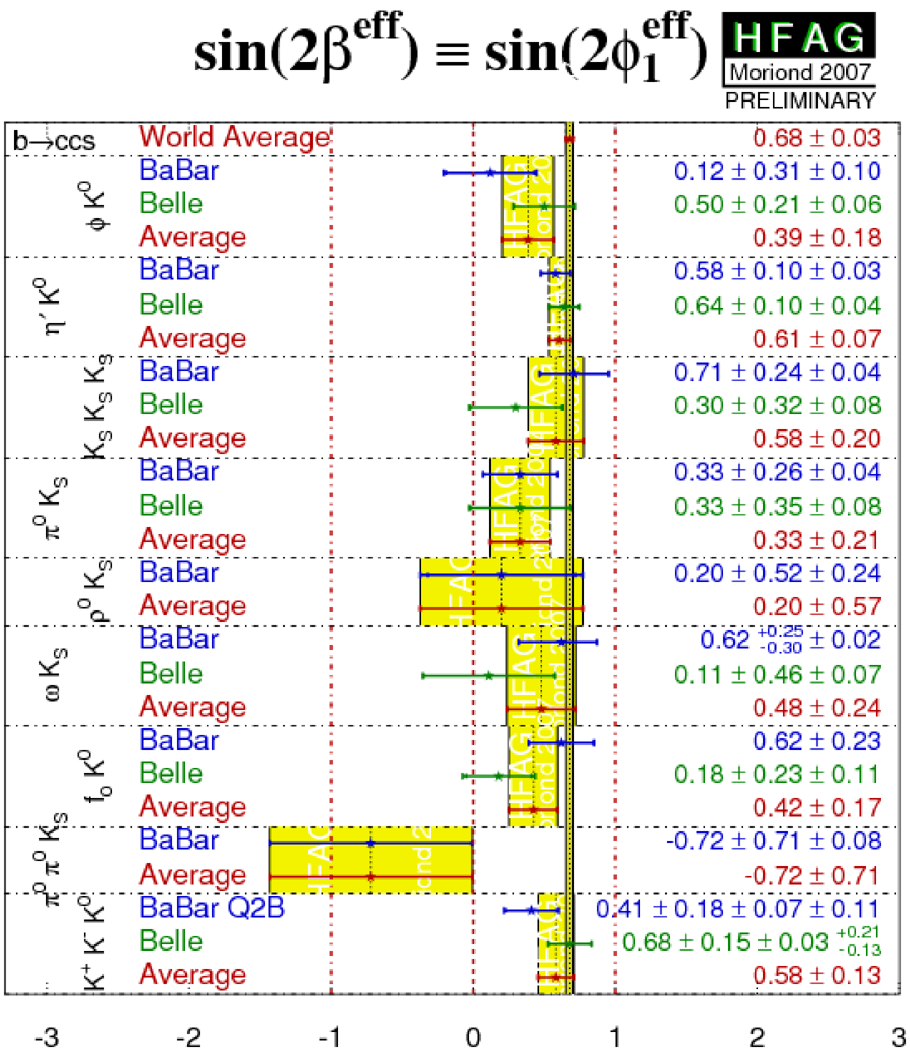


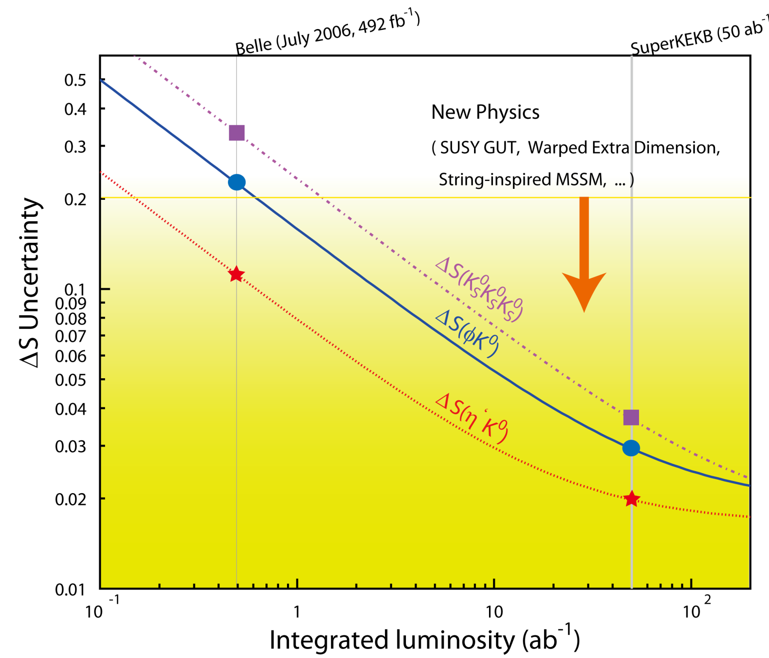
Observable	B Factories ($2\ \text{ab}^{-1}$)	Super$B$ (75 ab
$\mathcal{B}(B \to \tau\nu)$	20%	4% (†)
$\mathcal{B}(B \to \mu\nu)$	visible	5%
$\mathcal{B}(B \to D\tau\nu)$	10%	2%

$$B = B_{SM}\left(1 - \tan^2\beta \frac{M_B^2}{M_H^2}\right)^2$$

Hadronic b→s Penguins

Current B factory hot topic





Many channels can be measured with ΔS~(0.01-0.04)

Observable	B Factories (2 ab^{-1})	**SuperB**	
$S(\phi K^0)$	0.13	0.02 (*)	[0.030]
$S(\eta' K^0)$	0.05	0.01 (*)	[0.020]
$S(K^0_s K^0_s K^0_s)$	0.15	0.02 (*)	[0.037]
$S(K^0_s \pi^0)$	0.15	0.02 (*)	[0.042]
$S(\omega K^0_s)$	0.17	0.03 (*)	
$S(f_0 K^0_s)$	0.12	0.02 (*)	

(*) theoretical limited

Running at the Y(5S)

- Belle & CLEO have demonstrated potential for $e^+e^- \rightarrow Y(5S) \rightarrow B_s^{(*)}B_s^{(*)}$
- Some important channels, such as $B_s \rightarrow \gamma\gamma$, $A_{SL}(B_s)$ are unique to SuperB
- Problem: cannot resolve fast Δm_s oscillations
  - retain some sensitivity to φ_s, since $\Delta\Gamma_s \neq 0$

$$\Gamma_{\bar{B}_s\to f}(\Delta t) + \Gamma_{B_s\to f}(\Delta t) = \mathcal{N}\frac{e^{-|\Delta t|/\tau(B_s)}}{2\tau(B_s)}\left[\cosh(\frac{\Delta\Gamma_s\Delta t}{2}) - \frac{2\,\mathrm{Re}\,(\lambda_f)}{1+|\lambda_f|^2}\sinh(\frac{\Delta\Gamma_s\Delta t}{2})\right]. \quad (1.34)$$

cf. D0 untagged measurement of φ_s

Large New Physics Contributions Excluded

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

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

$B(b \to d\gamma)$ $A_{CP}(b \to d\gamma)$ $A_{CP}(b \to (d+s)\gamma)$

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

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

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

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

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

Will be Studied at SuperB

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

Will be studied at LHCb (+ upgrade)

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

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

$B(b \to d\gamma)$ $A_{CP}(b \to d\gamma)$ $A_{CP}(b \to (d+s)\gamma)$

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

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

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

dashed box = exclusive modes only