Super*B*
A High-Luminosity Asymmetric e^+e^- Super Flavour Factory

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Seminar at RAL
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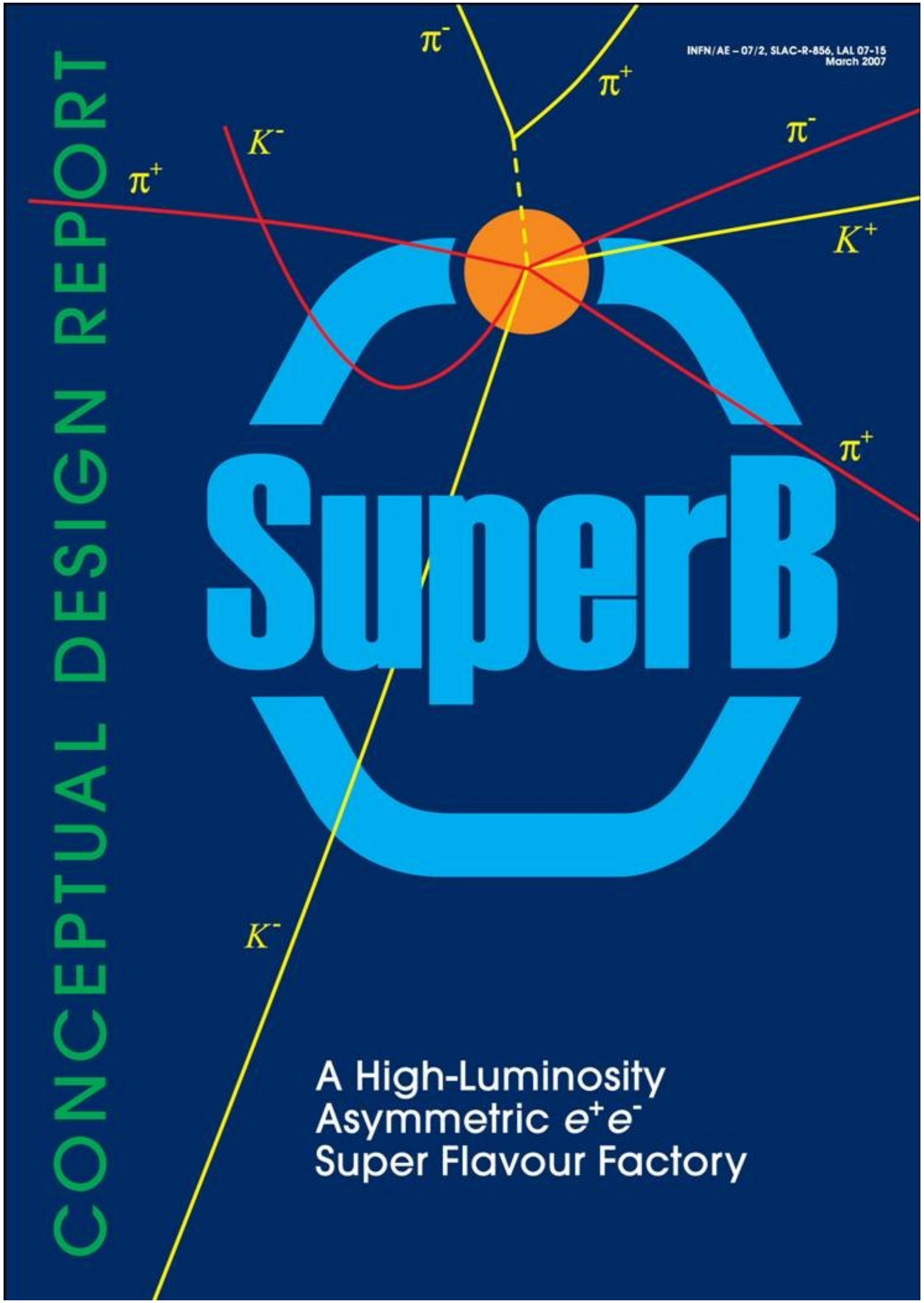
What is SuperB ?

- Super*B* is
  - A Super Flavour Factory with $L_{peak} > 10^{36}/cm^2/s$
  - An asymmetric energy e^+e^- collider
    - Nominal 7 GeV e^- on 4 GeV e^+ at Y(4S)
    - Flexible running energy & beam polarization options
  - Based on a new approach to collider design

    Avoid limitations due to high beam currents

    (high backgrounds, costly power bill, etc.)
  - The machine to measure new physics flavour couplings in the LHC era



SuperB conceptual design report

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

(completed April 2007)

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, WG2 report arXiv:0801.1833 [hep-ph]
- “On the Physics Case of a Super Flavour Factory”, arXiv:0710:3799 [hep-ph]
- “New Physics at a Super Flavor Factory”, arXiv:0802.3201 [hep-ph]

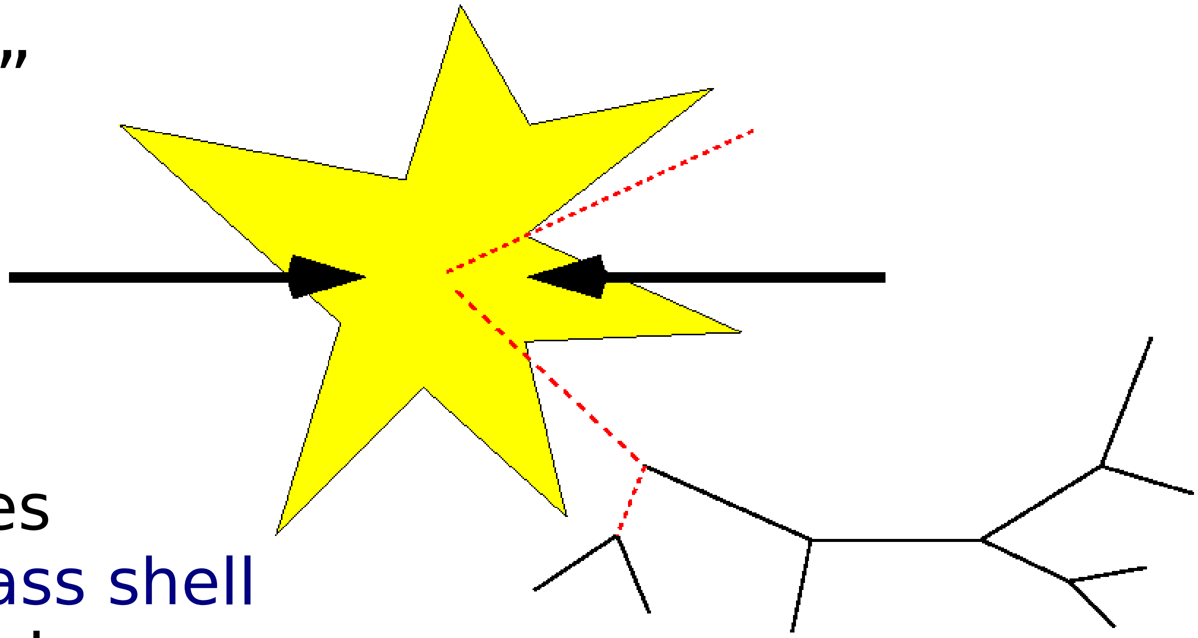
Contents

- Why?
  - Motivation for a Super Flavour Factory in the LHC era
- How?
  - Design of Super*B*
- Where? When?

Motivation

- Major challenge for particle physics in the next decade is to go beyond the Standard Model
- Two paths to new physics

  1) "relativistic"

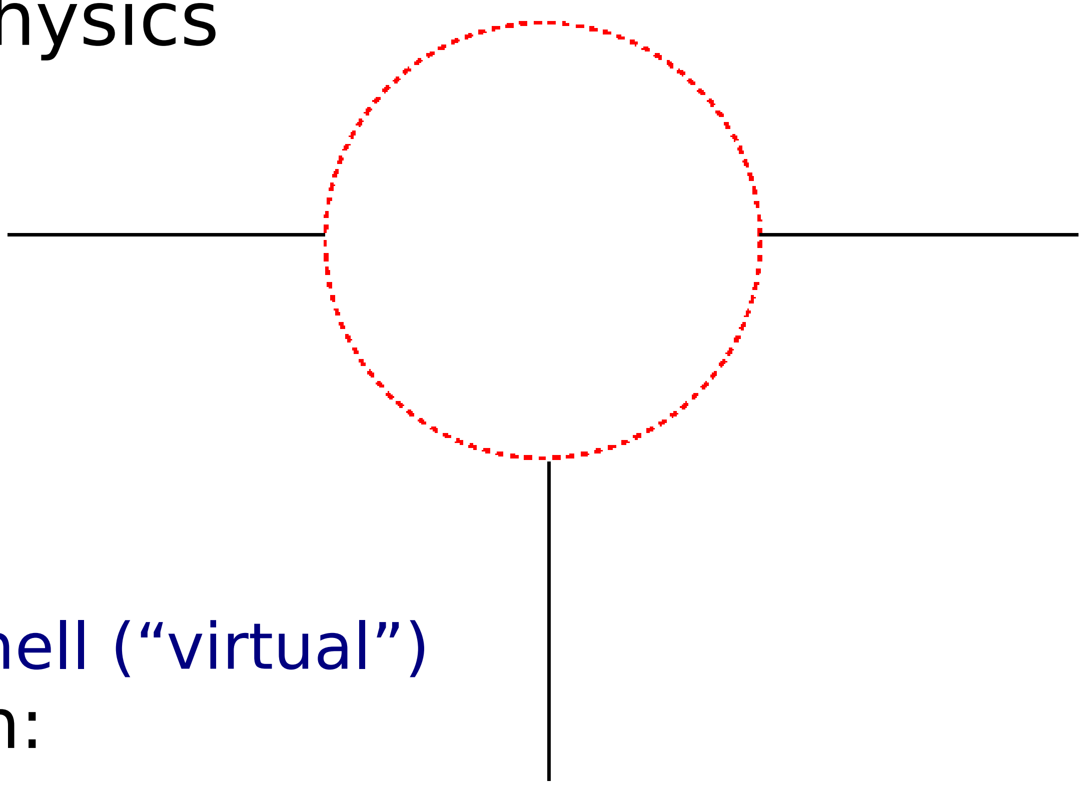


New heavy particles
produced on mass shell
Sensitivity depends on:
available centre-of-mass energy
knowledge of Standard Model backgrounds

Motivation

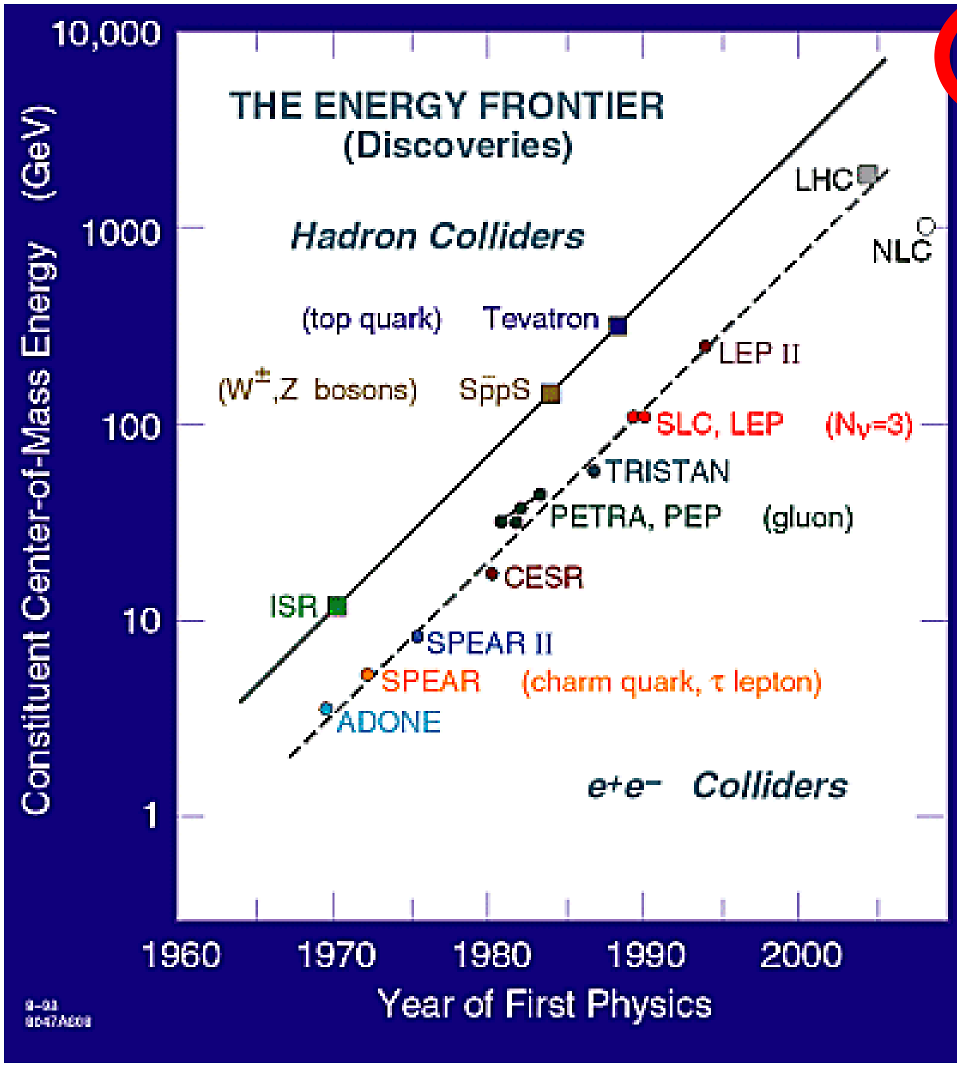
- Major challenge for particle physics in the next decade is to go beyond the Standard Model
- Two paths to new physics

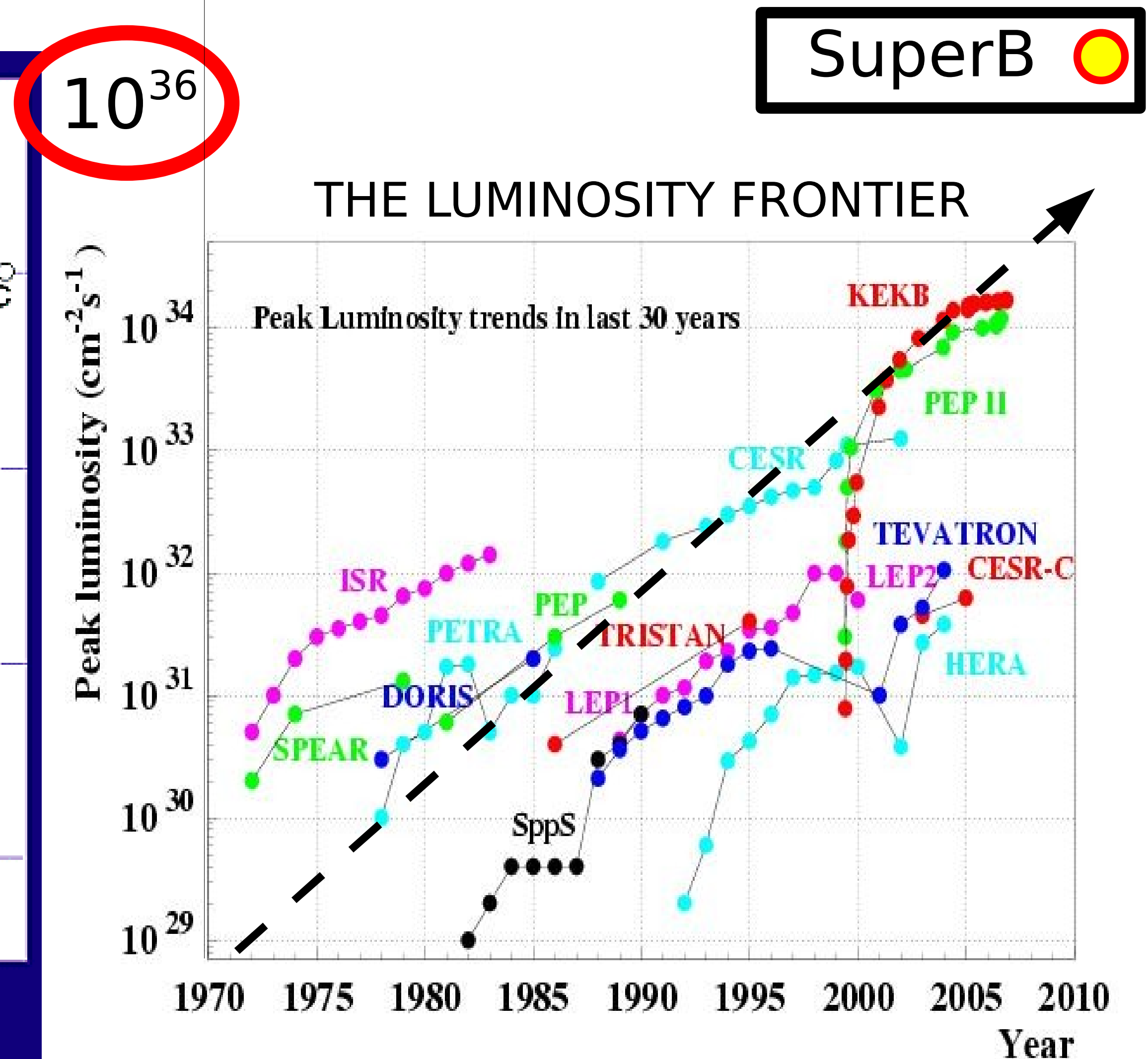
  2) “quantum”



New heavy particles
produced off mass shell (“virtual”)
Sensitivity depends on:
luminosity
knowledge of Standard Model backgrounds

A Tale of Two Frontiers





LHC-Super*B* Interplay

1) LHC discovers new physics

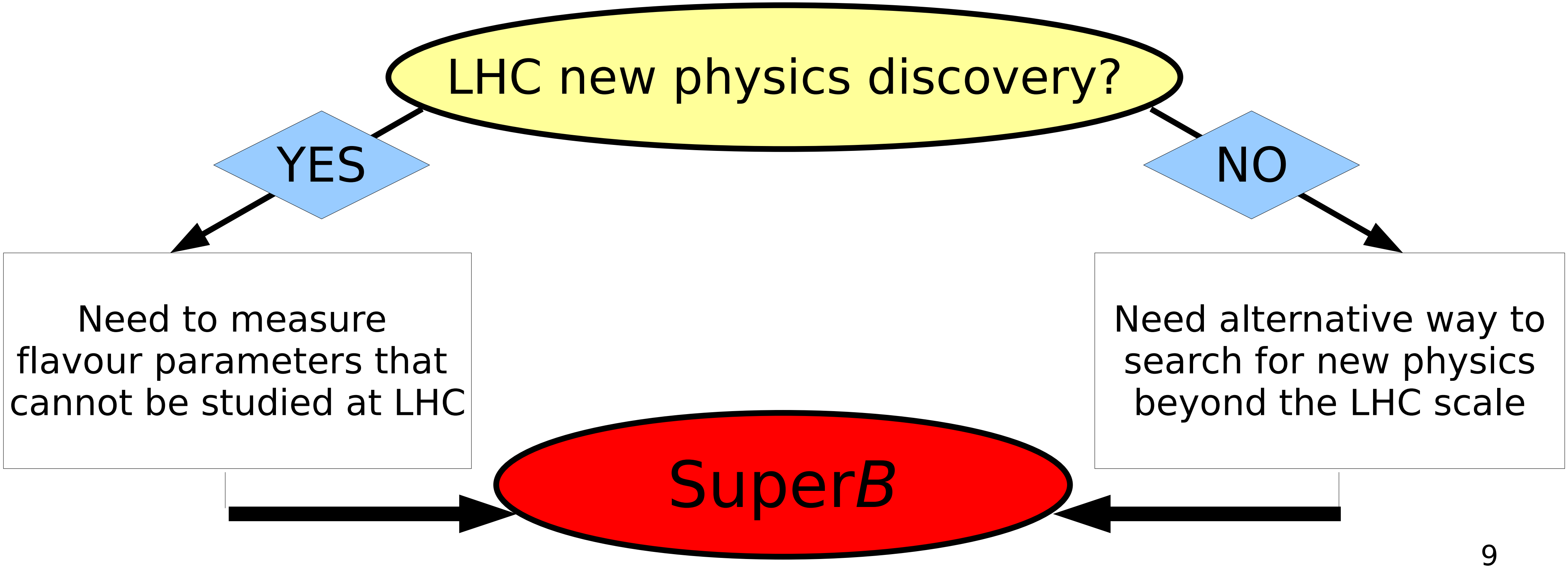
- Can it be flavour blind? (ie. no signals in flavour)
  - No, it must couple to SM, which violates flavour
  - Any TeV scale NP model includes new flavoured particles
- What is the minimal flavour violation? (ie. worst case)
  - NP follows SM pattern of flavour and CP violation
  - Super*B* detects NP effects for particle masses up to >600 GeV
- What if NP flavour couplings are not suppressed?
  - Super*B* measures NP flavour couplings and distinguishes models

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

LHC-Super*B* Interplay

- Flavour observables are *complementary* to those at the energy frontier
  - measure different new physics parameters
  - powerful to distinguish models



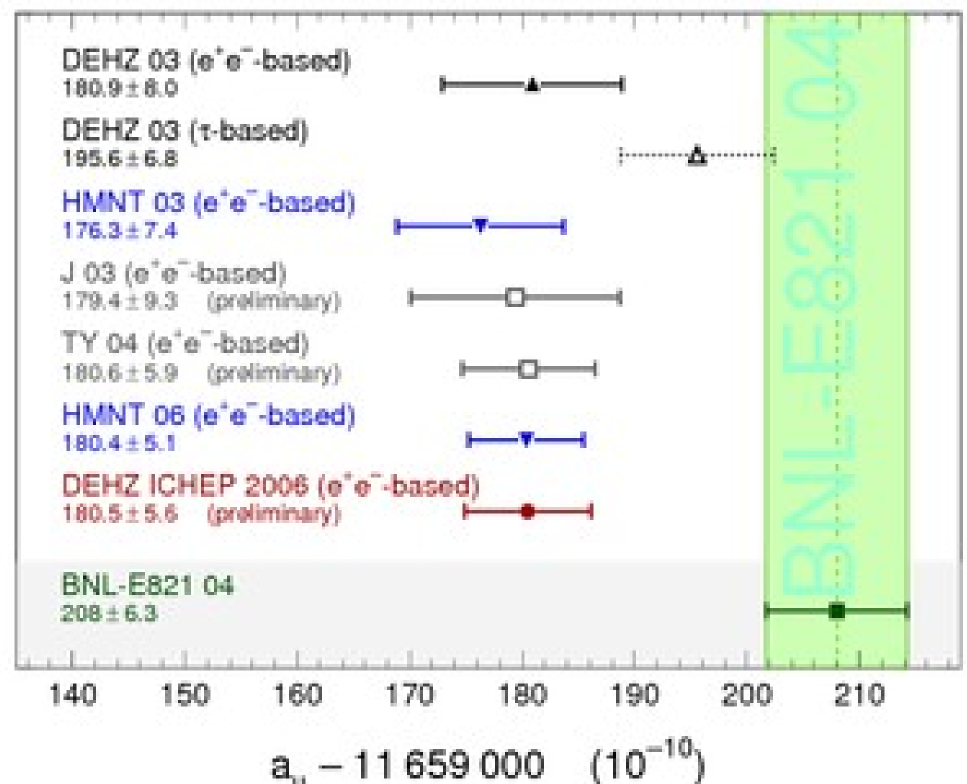
Hints of New Physics in Flavour

- Several exciting recent measurements
  - Discrepancy in $(g\text{-}2)_\mu$

See, eg, arXiv:0801.4905 [hep-ph]

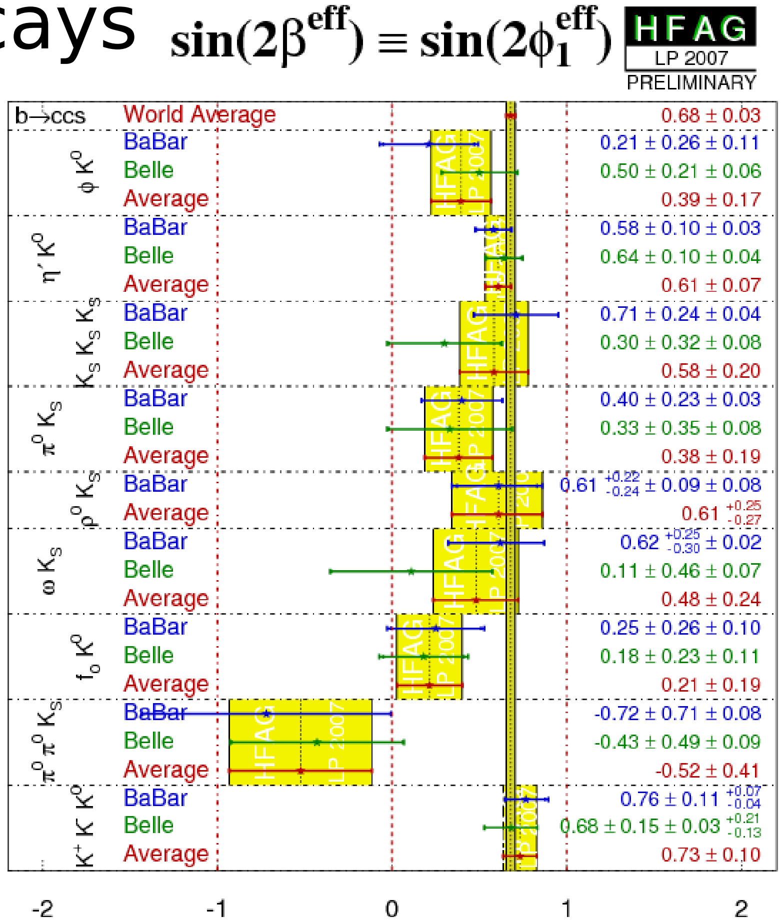
theory

experiment
PRD 73 (2006) 072003



Hints of New Physics in Flavour

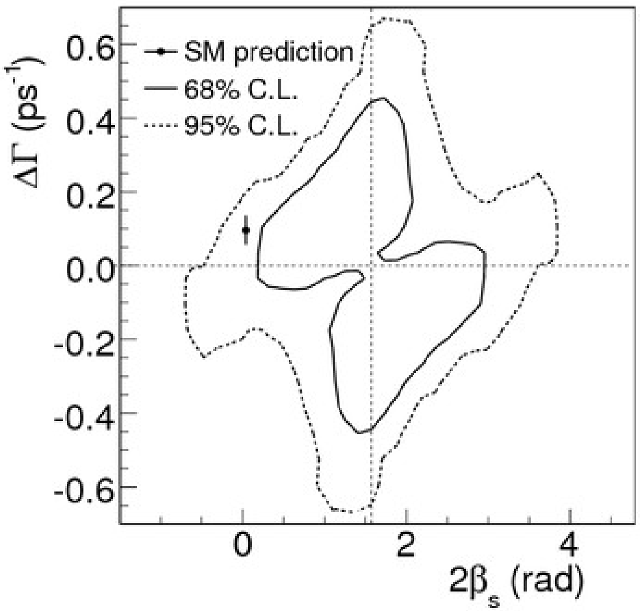
- Several exciting recent measurements
  - Time-dependent CP violation in hadronic b→s penguin dominated decays



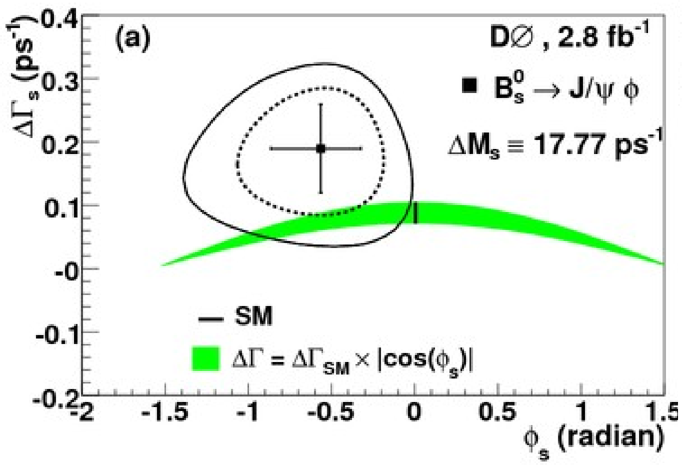
Hints of New Physics in Flavour

- Several exciting recent measurements
  - Anomalous CP violating phase in $B_s \to J/\psi\ \varphi$

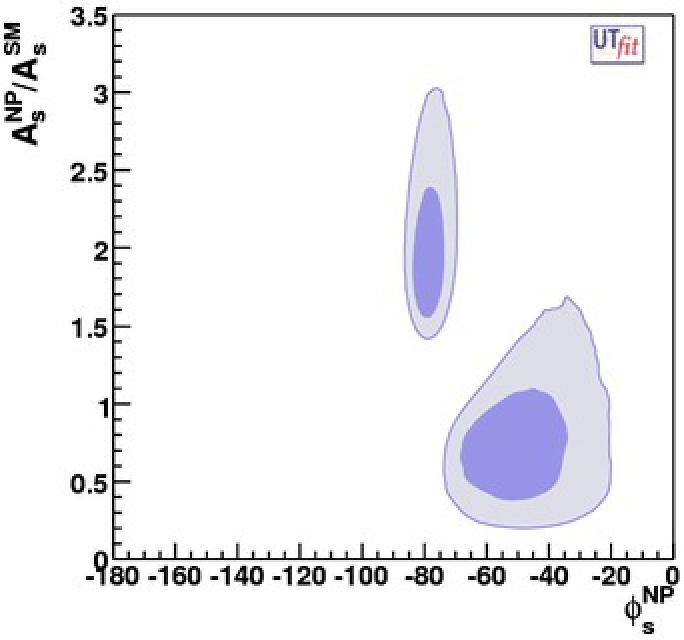
CDF arXiv:0712.2397



D0 arXiv:0802.2255



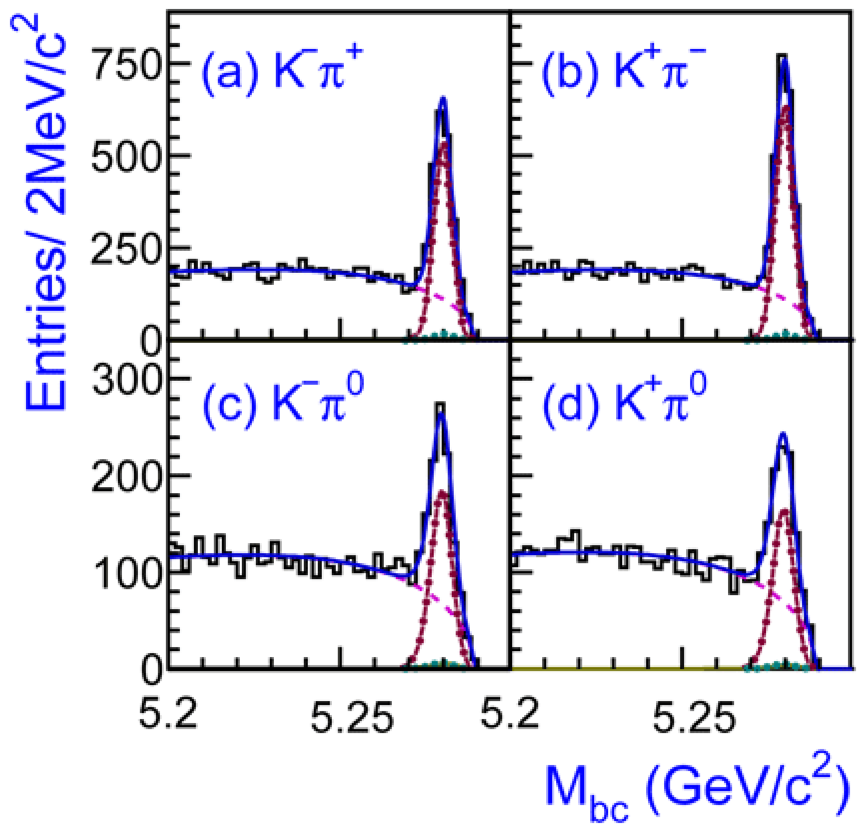
UTfit
arXiv:0803.0659 [hep-ph]



Hints of New Physics in Flavour

- Several exciting recent measurements
  - Opposite sign CP asymmetries in $B^{+/0} \rightarrow K^{+}\pi^{0/-}$

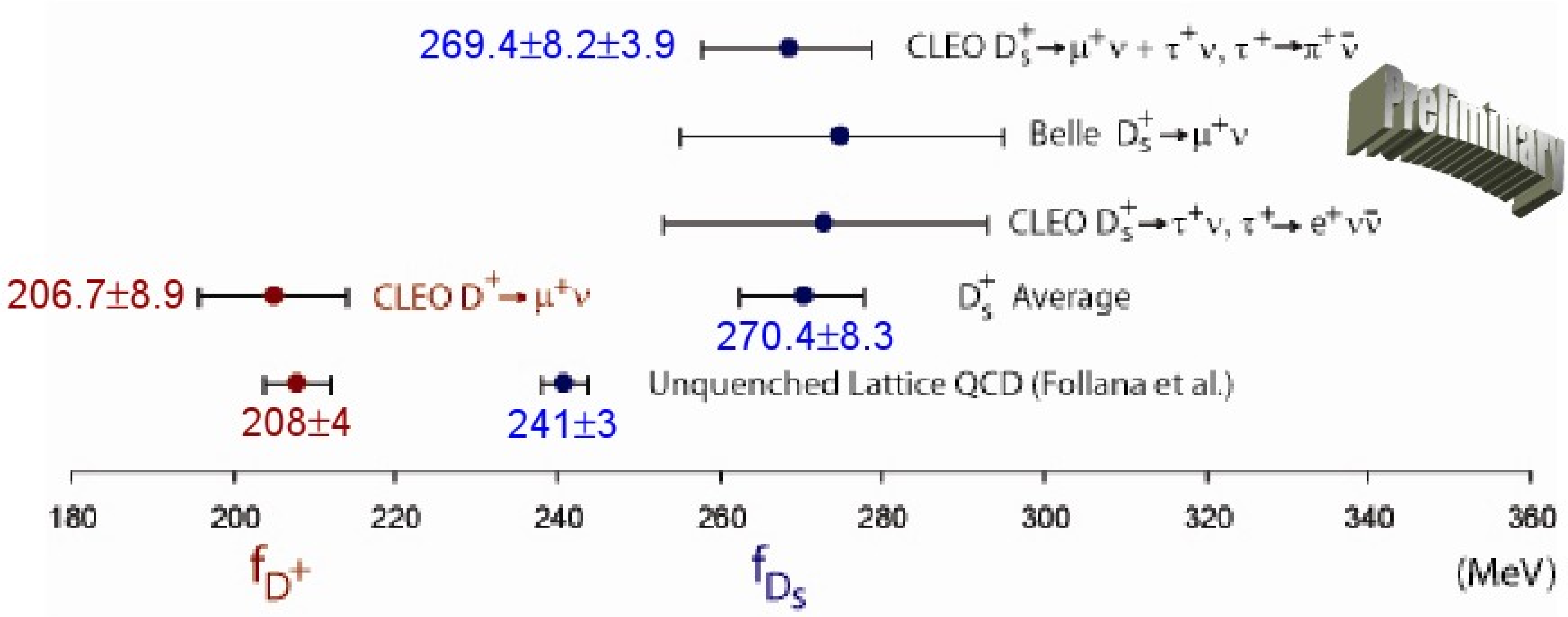
Belle: Nature 452 (2008) 332



Hints of New Physics in Flavour

- Several exciting recent measurements
  - Rates of D_s leptonic decays

arXiv:0803.0512 [hep-ph]
CLEOc results updated at FPCP 2008



Hints of New Physics in Flavour

- Several exciting recent measurements
  - ... and many more
    - "tension" in UTfit, rate for $b \to s\gamma$, etc.
- Rather than discuss details of each measurement, draw general conclusions from the overall picture
  - Flavour is highly sensitive to NP
  - MFV hypothesis may be disproved
  - Need to focus on theoretically clean channels

Flavour Observables Sensitive to New Physics

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

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

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

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

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

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

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

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

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

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

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

... 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
  - multitude of new physics sensitive observables
  - maximize sensitivity by combining information
  - correlations between results distinguish models

SuperB
“treasure chest”
of new physics sensitive
flavour 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*

Focus on theoretically clean channels

DECREASING 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->Xγ, D and τ decays zero of FB asymmetry B->$X_s l^+ l^-$	NP insensitive or null tests of the SM or SM already known with the required accuracy
improved lattice QCD	meson mixing , B->D(*)lν,B->$\pi(\rho)$lν, B->K*γ, B->$\rho\gamma$, B->lν, B_s->$\mu\mu$	target error: ~1-2% Feasible
improved OPE+HQE	B->$X_{u,c}$lν, B->Xγ	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

table by M.Ciuchini

Super Flavour Factory

- Data taken at $\Upsilon(4S)$ allows studies of B, tau, charm, charmonia, ISR, $\gamma\gamma$ physics (and more)

- Super*B* is designed with flexible running energy
  - charm-tau threshold region
  - other Upsilon resonances – including $\Upsilon(5S)$

⇒ can study B_s sector, including $\Delta\Gamma_s$ and φ_s (but not Δm_s)

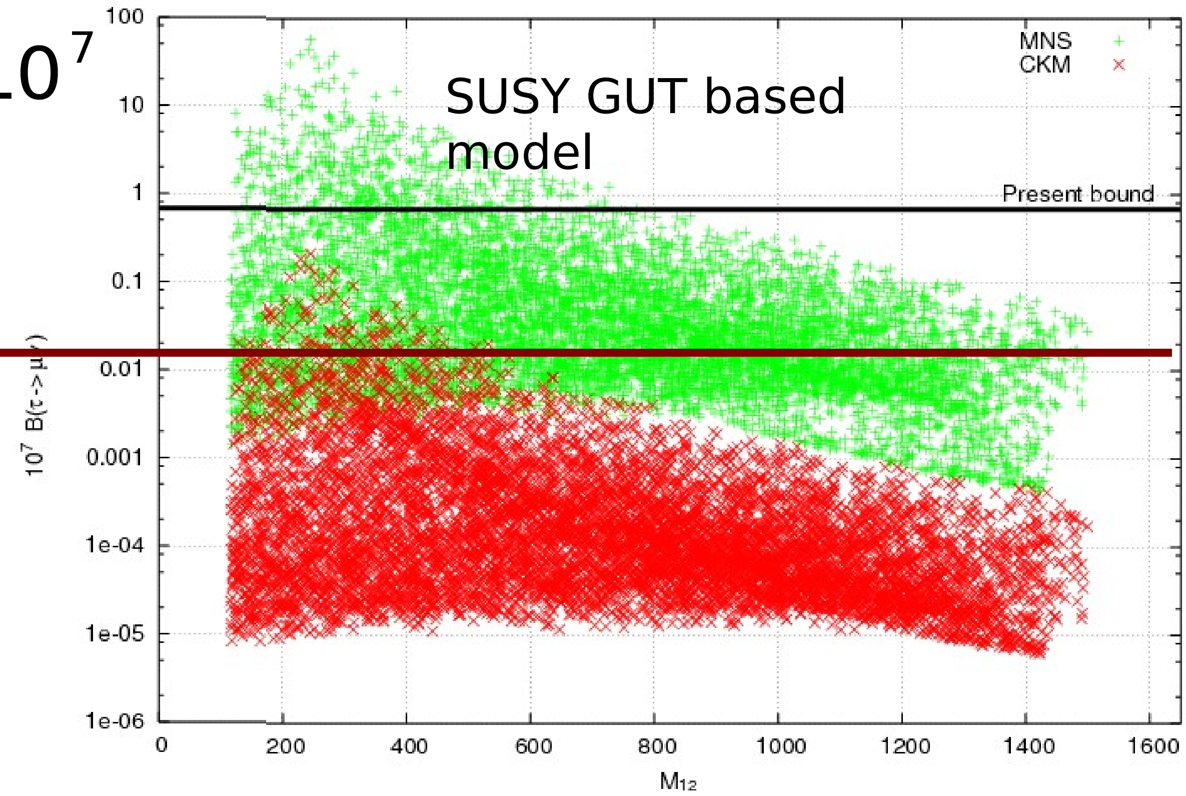
- Considering beam polarization option
  - study chiral structure of various processes
  - significant improvement in sensitivity for τ EDM

see arXiv:0707.1658 and arXiv:0707.2496

Lepton Flavour Violation

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

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



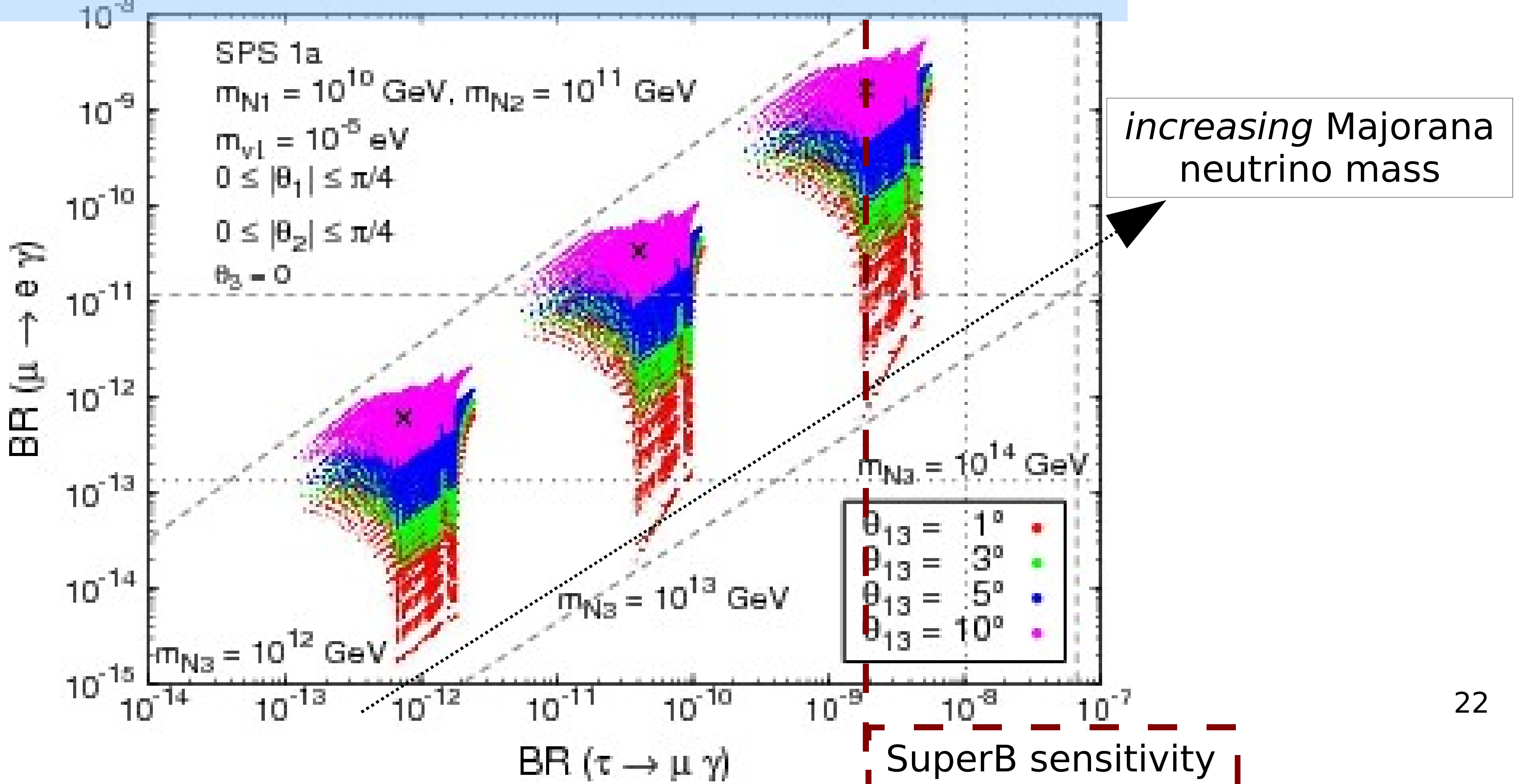
Process	Sensitivity
$\mathcal{B}(\tau \to \mu \gamma)$	2×10^{-9}
$\mathcal{B}(\tau \to e \gamma)$	2×10^{-9}
$\mathcal{B}(\tau \to \mu \mu \mu)$	2×10^{-10}
$\mathcal{B}(\tau \to eee)$	2×10^{-10}
$\mathcal{B}(\tau \to \mu\eta)$	4×10^{-10}
$\mathcal{B}(\tau \to e\eta)$	6×10^{-10}
$\mathcal{B}(\tau \to \ell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

Much better sensitivity than LHC, even for $\tau \to \mu\mu\mu$

Lepton Flavour & Neutrino Physics

- In many scenarios, LFV rates are linked to (both low and high energy) neutrino parameters

Antusch, Arganda, Herrero & Teixeira, JHEP 0611 (2006) 090



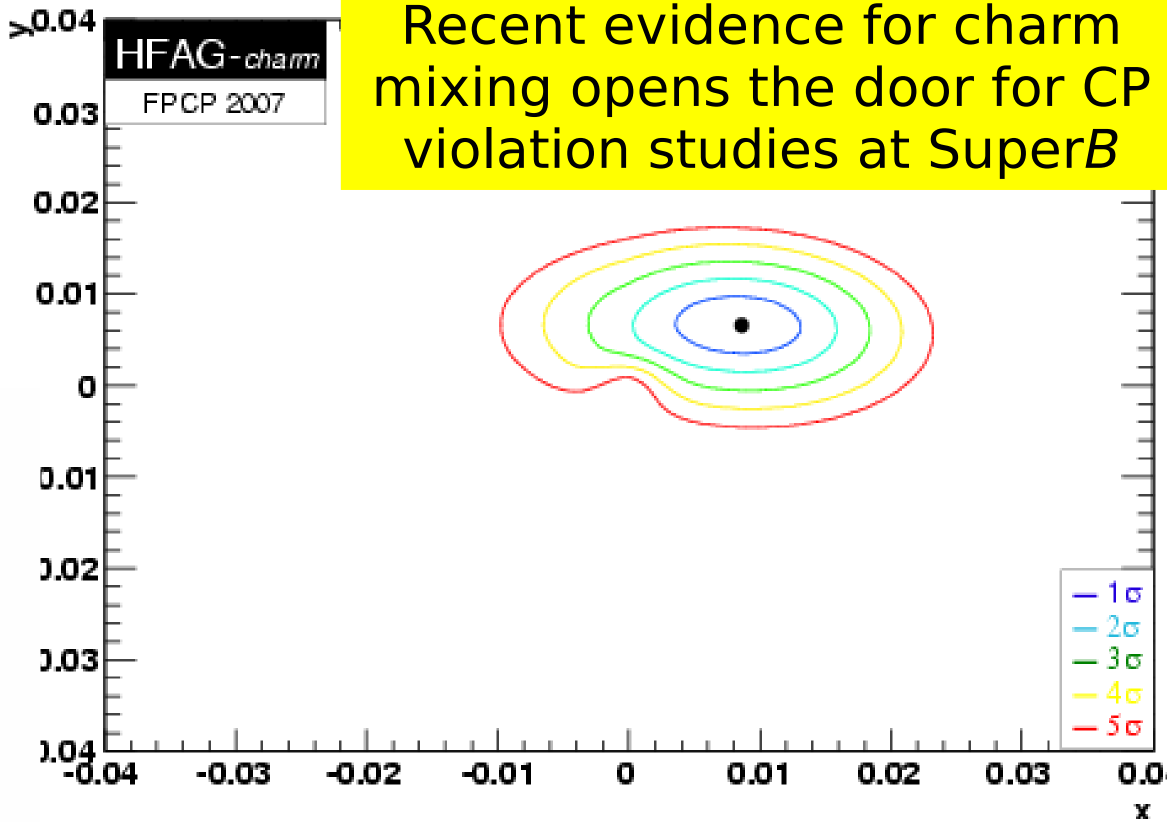
Charm at Super*B*

- Super*B* can study the full range of charm phenomena – including CP violation

CP violation in charm highly sensitive new physics probe

sensitivity: $\varphi_D \sim 1°$

Mode	Observable	$\Upsilon(4S)$ ($75\ \mathrm{ab}^{-1}$)	$\psi(3770)$ ($300\ \mathrm{fb}^{-1}$)
$D^0 \to K^+\pi^-$	x'^2	3×10^{-5}	
	y'	7×10^{-4}	
$D^0 \to K^+K^-$	y_{CP}	5×10^{-4}	
$D^0 \to K_S^0\pi^+\pi^-$	x	4.9×10^{-4}	
	y	3.5×10^{-4}	
	$\lvert q/p \rvert$	3×10^{-2}	
	ϕ	$2°$	
$\psi(3770) \to D^0\overline{D}^0$	x^2		$(1-2) \times 10^{-5}$
	y		$(1-2) \times 10^{-3}$
	$\cos\delta$		$(0.01-0.02)$



Recent evidence for charm mixing opens the door for CP violation studies at Super*B*

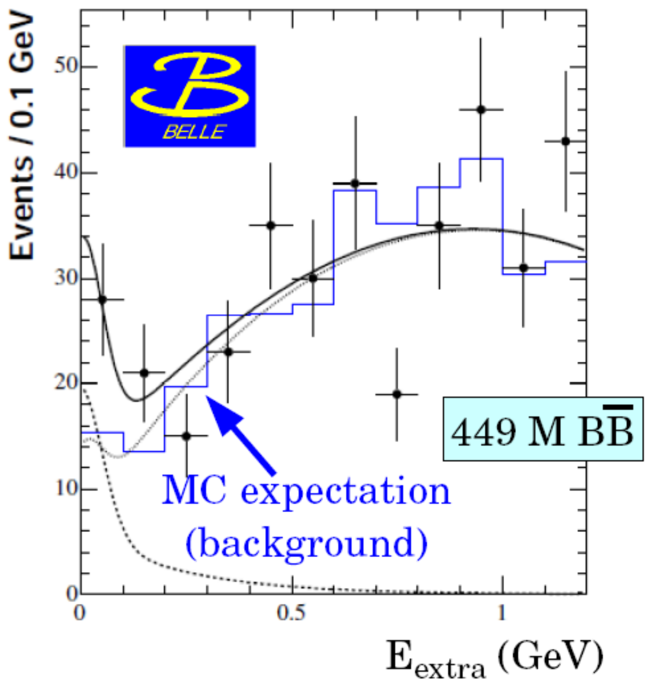
Leptonic B Decays

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

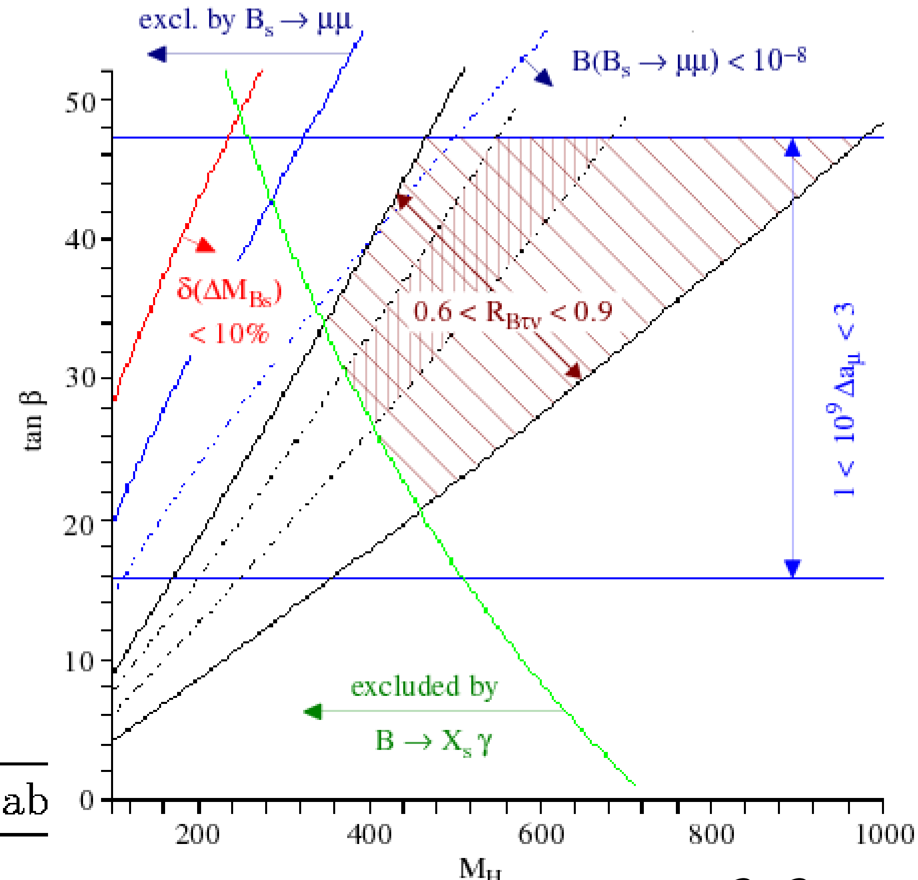
W.-S.Hou, PRD 48, 2342 (1993)

G.Isidori, P.Paradisi, PLB 639, 499 (2006)

$B(B^+ \to \tau^+ \nu)$



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

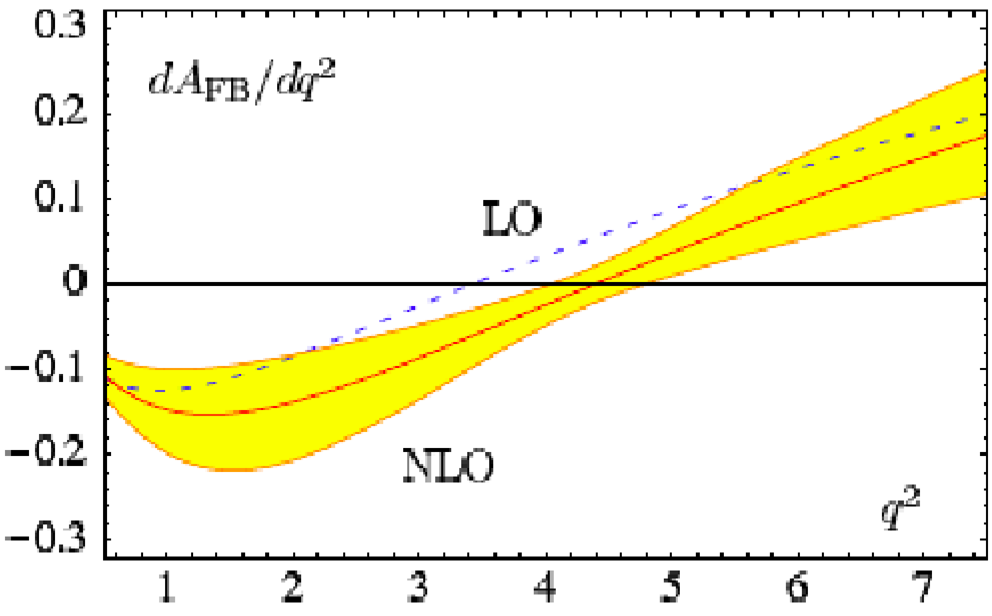


Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab
$\mathcal{B}(B \to \tau\nu)$	20%	4% (†)
$\mathcal{B}(B \to \mu\nu)$	visible	5%
$\mathcal{B}(B \to D\tau\nu)$	10%	2%

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

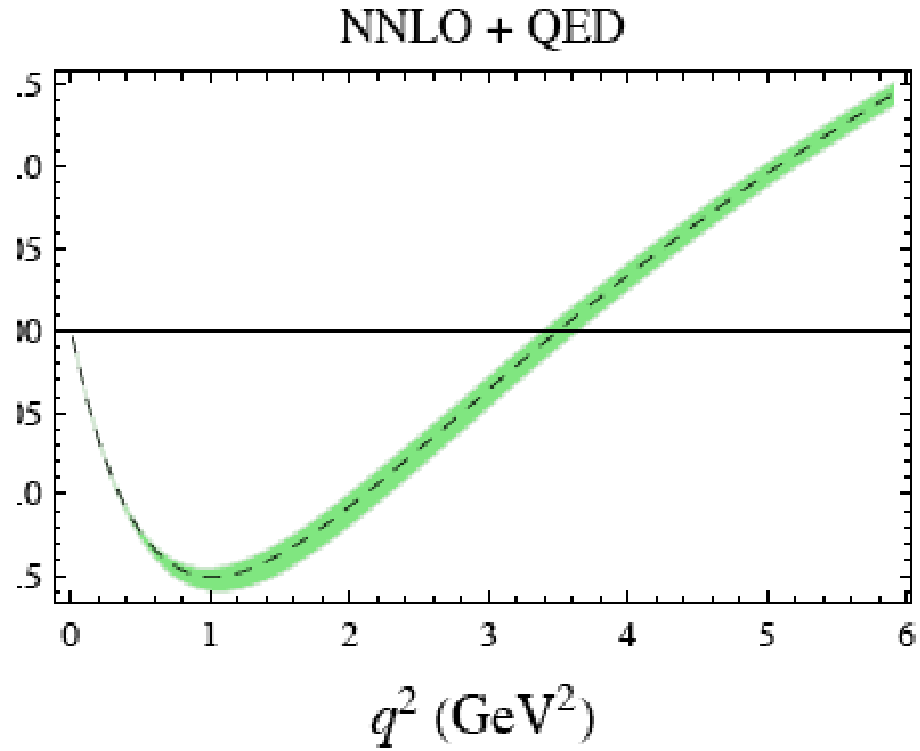
Forward-Backward Asymmetry

Exclusive: B→K*ll



Beneke, Feldmann, Seidel
EPJ C41 (2005) 173

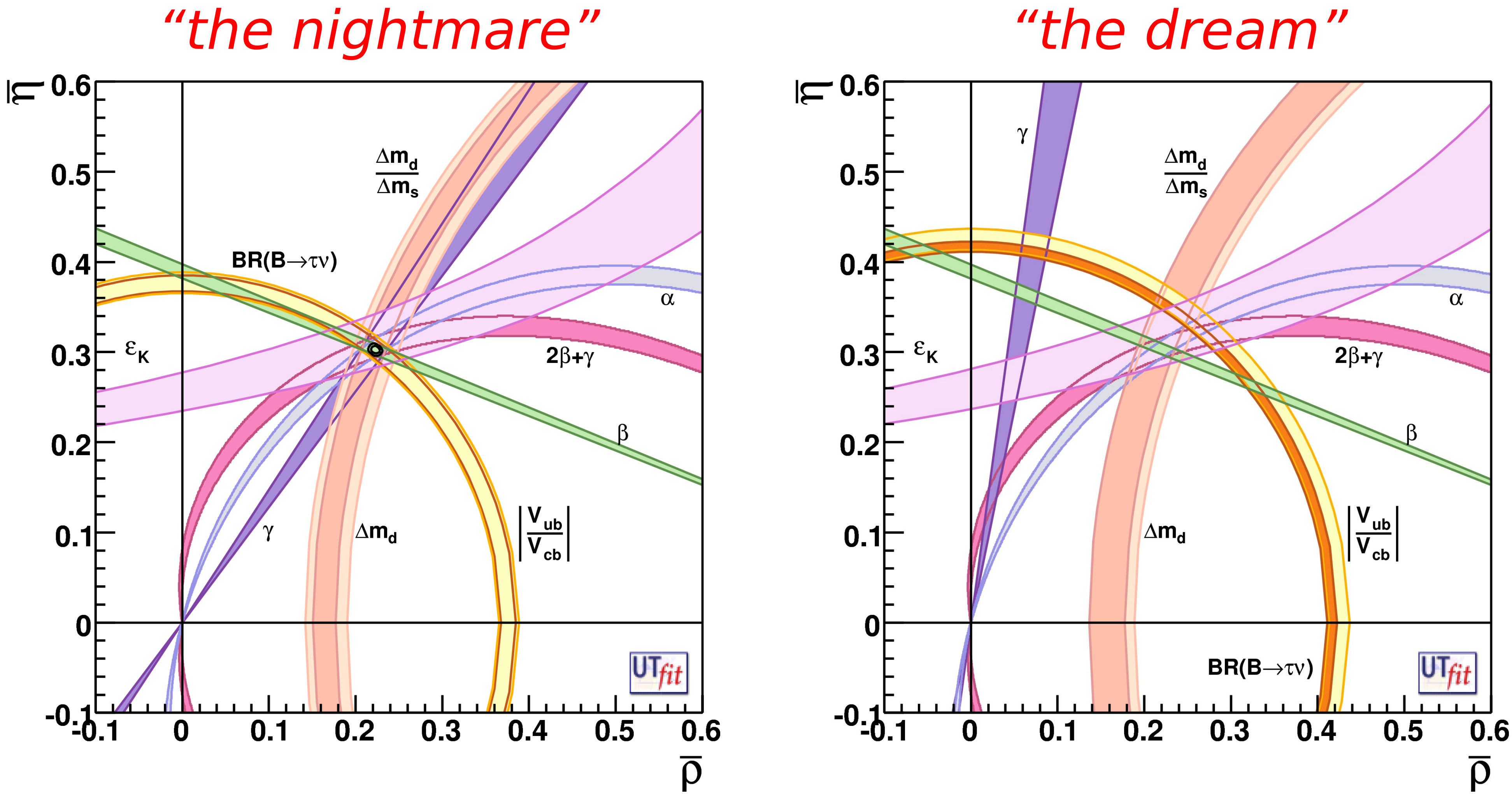
Inclusive: b→sll



Huber, Hurth, Lunghi
arXiv:0712.3009 [hep-ph]

Inclusive is much cleaner ⇔ need Super*B* statistics

Super*B* UT fit scenarios



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

MSSM

$$M^2_{\tilde d} = \begin{pmatrix} m^2_{\tilde d_L} & m_d(A_d - \mu\tan\beta) & (\Delta^d_{12})_{LL} & (\Delta^d_{12})_{LR} & (\Delta^d_{13})_{LL} & (\Delta^d_{13})_{LR} \\ & m^2_{\tilde d_R} & (\Delta^d_{12})_{RL} & (\Delta^d_{12})_{RR} & (\Delta^d_{13})_{RL} & (\Delta^d_{13})_{RR} \\ & & m^2_{\tilde s_L} & m_s(A_s - \mu\tan\beta) & (\Delta^d_{23})_{LL} & (\Delta^d_{23})_{LR} \\ & & & m^2_{\tilde s_R} & (\Delta^d_{23})_{RL} & (\Delta^d_{23})_{RR} \\ & & & & m^2_{\tilde b_L} & m_b(A_b - \mu\tan\beta) \\ & & & & & m^2_{\tilde b_R} \end{pmatrix}$$

SuperB

LHC, ILC - HE frontier

Mass Insertions

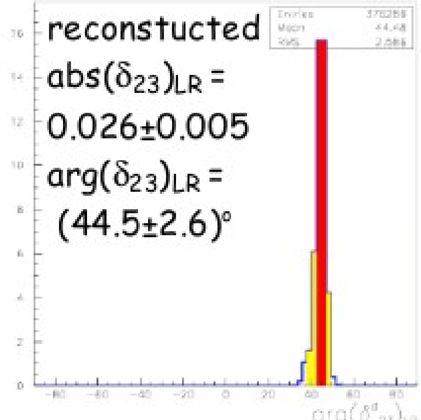
$(\delta^d_{ij})_{AB} = (\Delta^d_{ij})_{AB}/m_{\tilde q}^2$

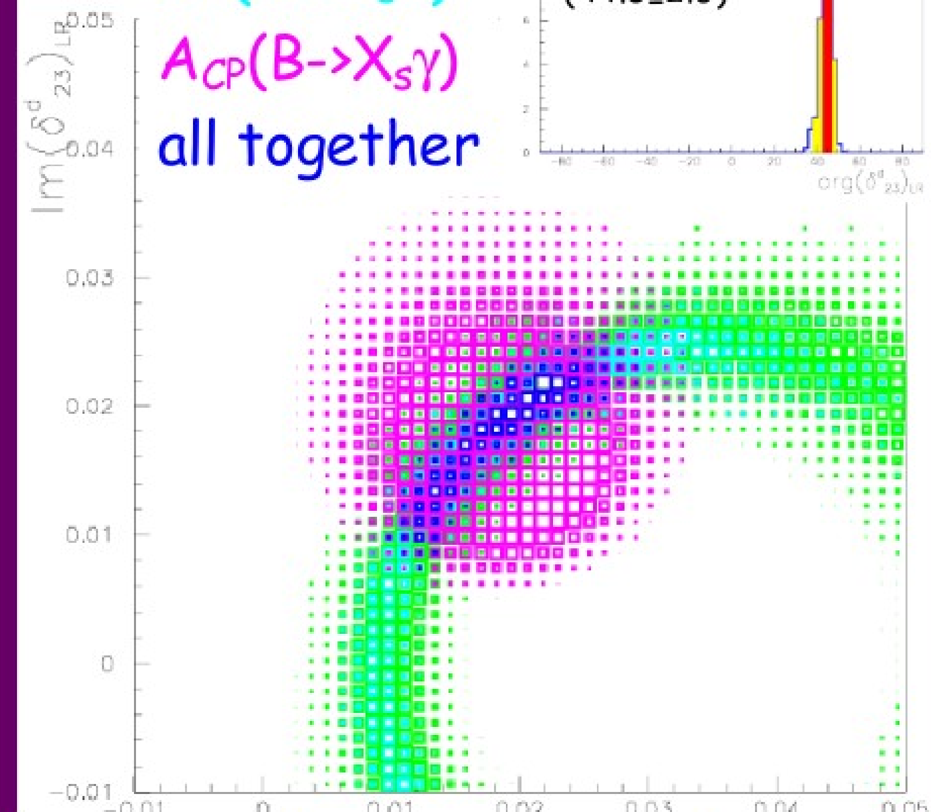
BR(B->$X_s\gamma$)

BR(B->$X_s$ll)

A_{CP}(B->$X_s\gamma$)

all together





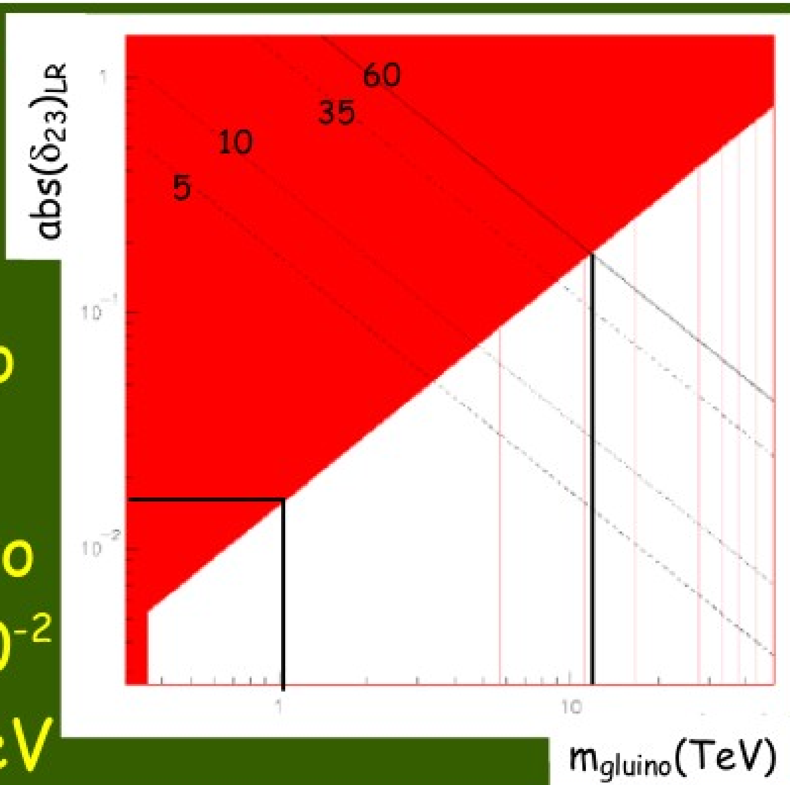
Im$(\delta^d_{23})_{LR}$ vs Re$(\delta^d_{23})_{LR}$

Reconstruction of $(\delta^d_{23})_{LR}=0.028\ e^{i\pi/4}$ for $\Lambda = m_{\tilde g} = m_{\tilde q} = 1$ TeV

3σ from 0 sensitivity plot

i) sensit. to Λ<20 TeV

ii) sensit. to $|(\delta^d_{23})_{LR}|>10^{-2}$ for Λ<1 TeV



By M.Ciuchini

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}
$D^0\to\pi^0e^+e^-,\ D^0\to\pi^0\mu^+\mu^-$	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}
$D^0\to\pi^0e^\pm\mu^\mp$	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}

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

SuperB: How?

- Physics case for Super Flavour Factory is compelling
- Luminosity should be above 10^{36}/cm^2/s
  - Enables integration of over 10/ab/year
  - Backgrounds and running efficiency should be comparable to current B factories
  - Power consumption should be affordable
- Attempts to upgrade PEP-II and KEKB with high current hit limitations due to beam instabilities, backgrounds and power

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

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

Classical electron radius

Beam size ratio

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

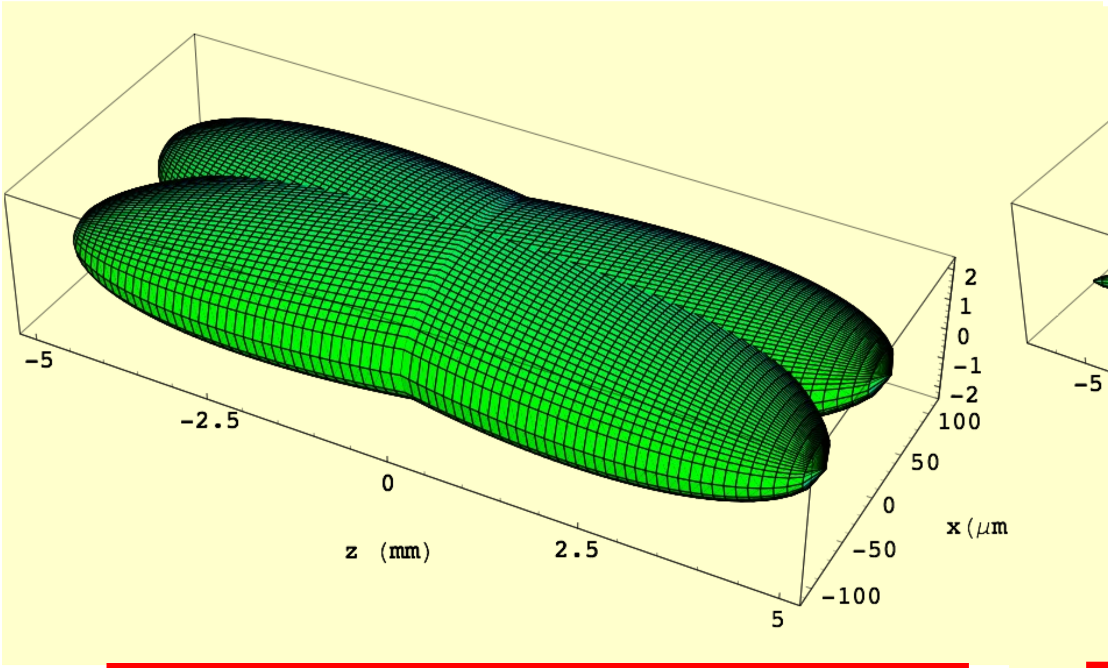
Luminosity:
0.16×10^{35} cm^{-2}s^{-1} (KEKB)
8×10^{35} cm^{-2}s^{-1} (SuperKEKB)

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

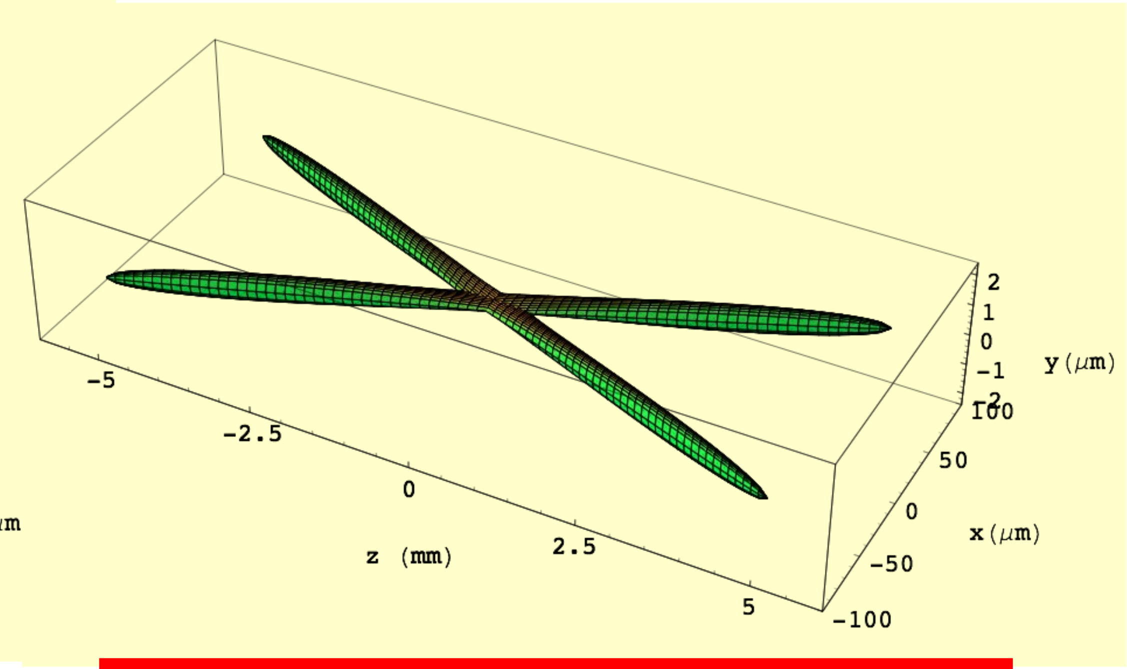
squeezed bunches
(possible instabilities)

Alternative approach

- Machine is based on ILC damping ring lattice
  - High luminosity through small emittance
  - Collide with large Piwinski angle & crab waist



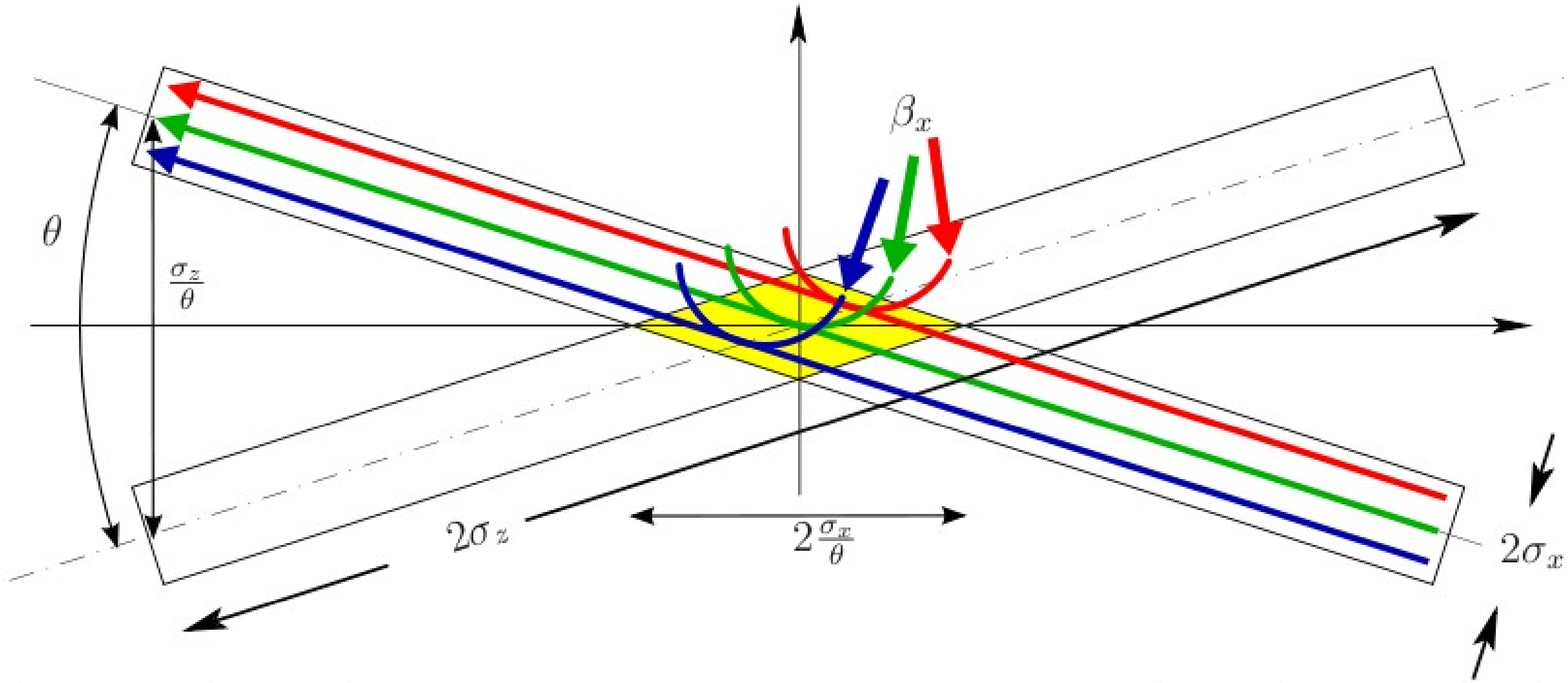
IP beam distributions for KEKB



IP beam distributions for Super*B*

Collision Scheme

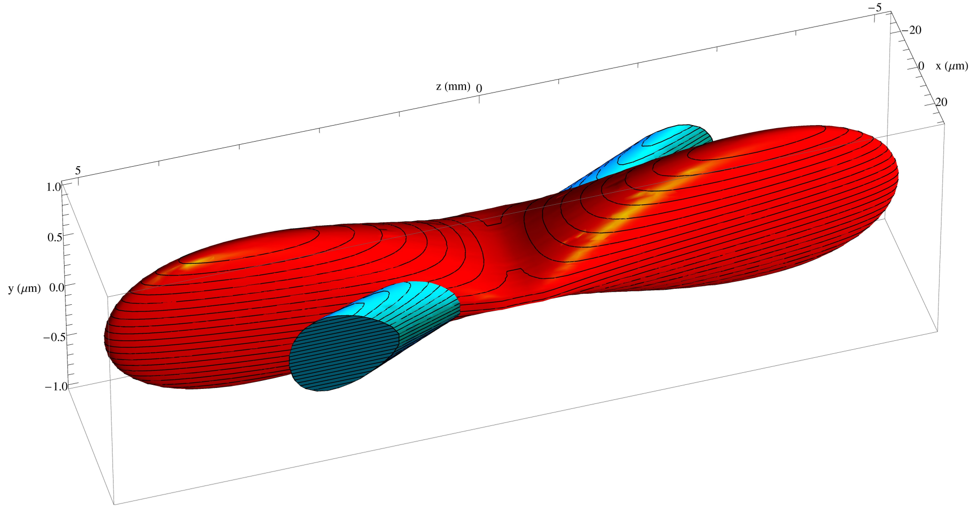
Large Piwinski angle ($\varphi = \theta\ \sigma_z/\sigma_x$) & "crab waist"



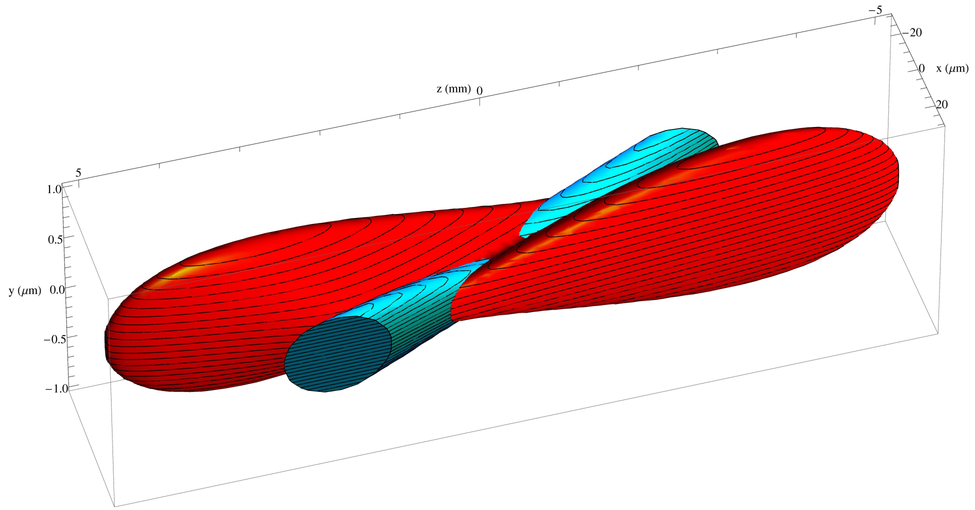
- ⇒ High luminosity, Low currents, Small backgrounds
- ⇒ Stable dynamic aperture
- ⇒ Wall plug power ~ 20 MW

Collision scheme

Without crab



With crab



Now tested at LNF DaφNe accelerator
Expected luminosity enhancement seen
Very promising indeed!

Super*B* Parameters

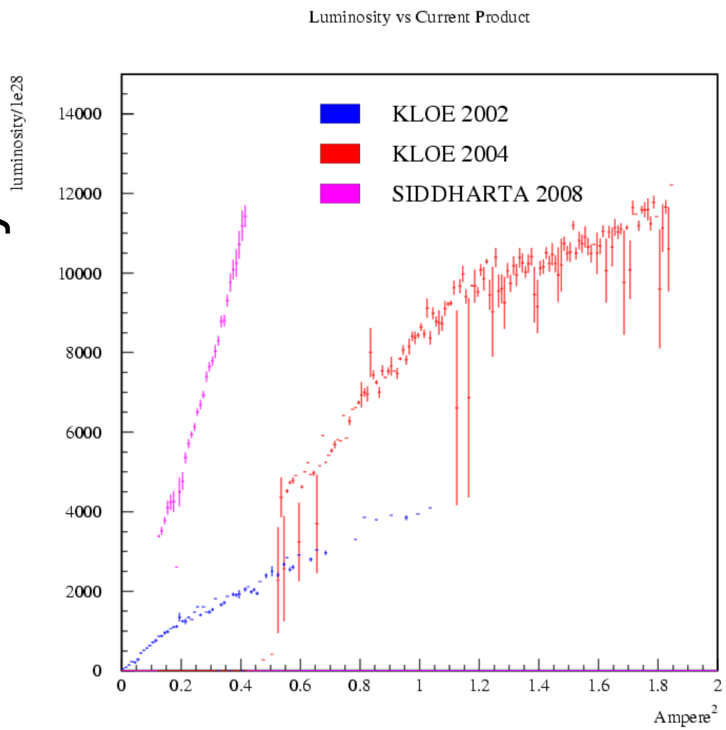
Circumference (m)	**1800.**
Energy (GeV) (LER/HER)	**4/7**
Current (A)/beam	**2.**
No. bunches	**1342**
No. part/bunches	**5.5×10^{10}**
θ (rad)	**2x24**
ε_x (nm-rad) (LER/HER)	**2.8/1.6**
ε_y (pm-rad) (LER/HER)	**7/4**
β_y^* (mm) (LER/HER)	**0.22/0.39**
β_x^* (mm) (LER/HER)	**35/20**
σ_y^* (μ m) (LER/HER)	**0.039**
σ_x^* (μ m) (LER/HER)	**10/6**
σ_z (mm)	**5**
Power (MW)	**17**
L ($cm^{-2}s^{-1}$)	**$1.\times10^{36}$**

Future upgrades can reach even higher luminosities!

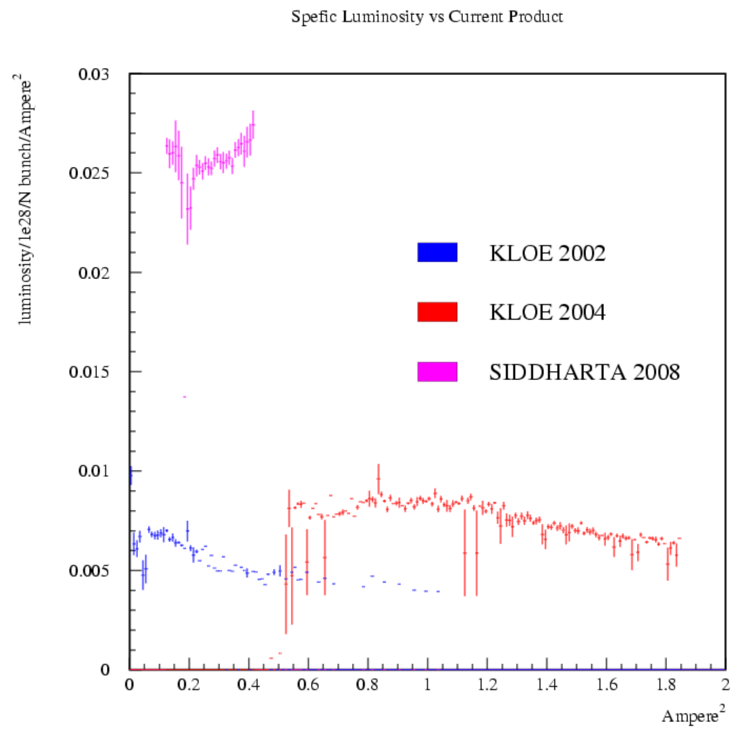
Crab Waist Beam Tests

- Tests ongoing at DaΦNe accelerator (LNF)
- Also planned as part of DaΦNe upgrade
  - Will reach peak luminosity of $10^{33}/cm^2/s$
- Results promising so far ...

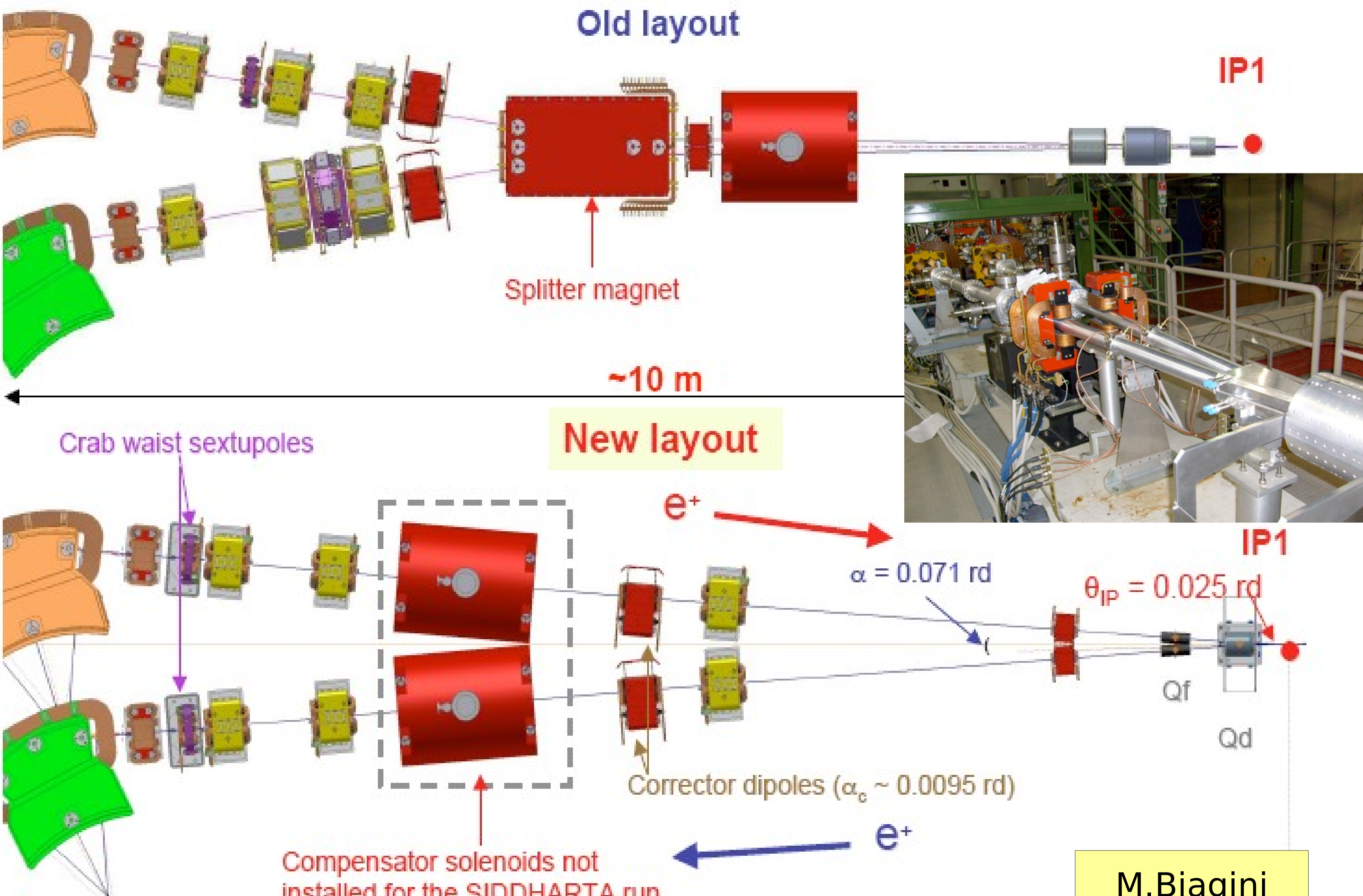
luminosity



specific luminosity



Half IR1 Magnetic Layout



M.Biagini

Good News

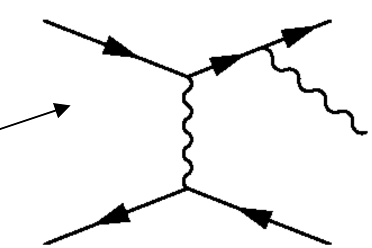
- Although collider scheme is completely new, it can be constructed largely by recycling existing hardware (eg. PEP-II magnets)
- Some new hardware required (eg. sextupole magnets for crab waist)
- Backgrounds comparable to current B factories, so Super*B* detector can be based on BaBar (or Belle)

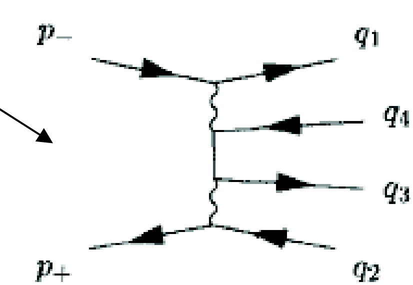
Significant cost savings!

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 ($E\gamma$/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
Υ(4S)	O(10^{-6}) mbarn	~2/million	1 KHz





Backgrounds and Detectors

- Backgrounds depend on various factors
  - luminosity
    - radiative BhaBha scattering
    - e^+e^- pair production
  - currents
    - synchrotron radiation
    - beam-gas interaction
  - beam size
    - Touschek scattering
    - beam-beam interactions

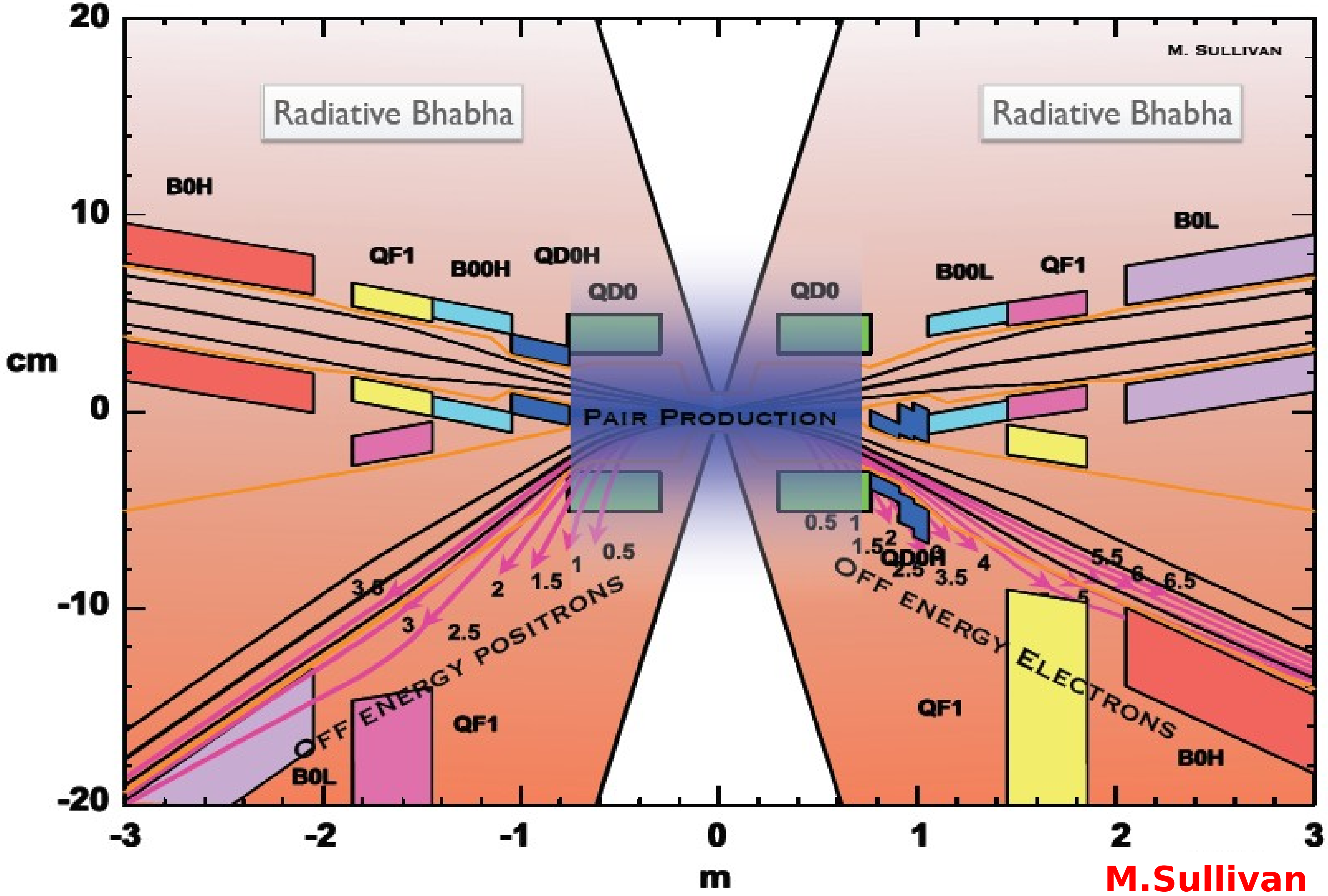
luminosity lifetime ~ 5 minutes

main problem for SuperKEKB: beam backgrounds ~ 20 x today

possible problem for Super*B*: motivates smaller beam asymmetry (7 GeV on 4 GeV)

- Interaction point design & shielding requires care
- Detector can be based on existing BaBar / Belle

Interaction Region Design

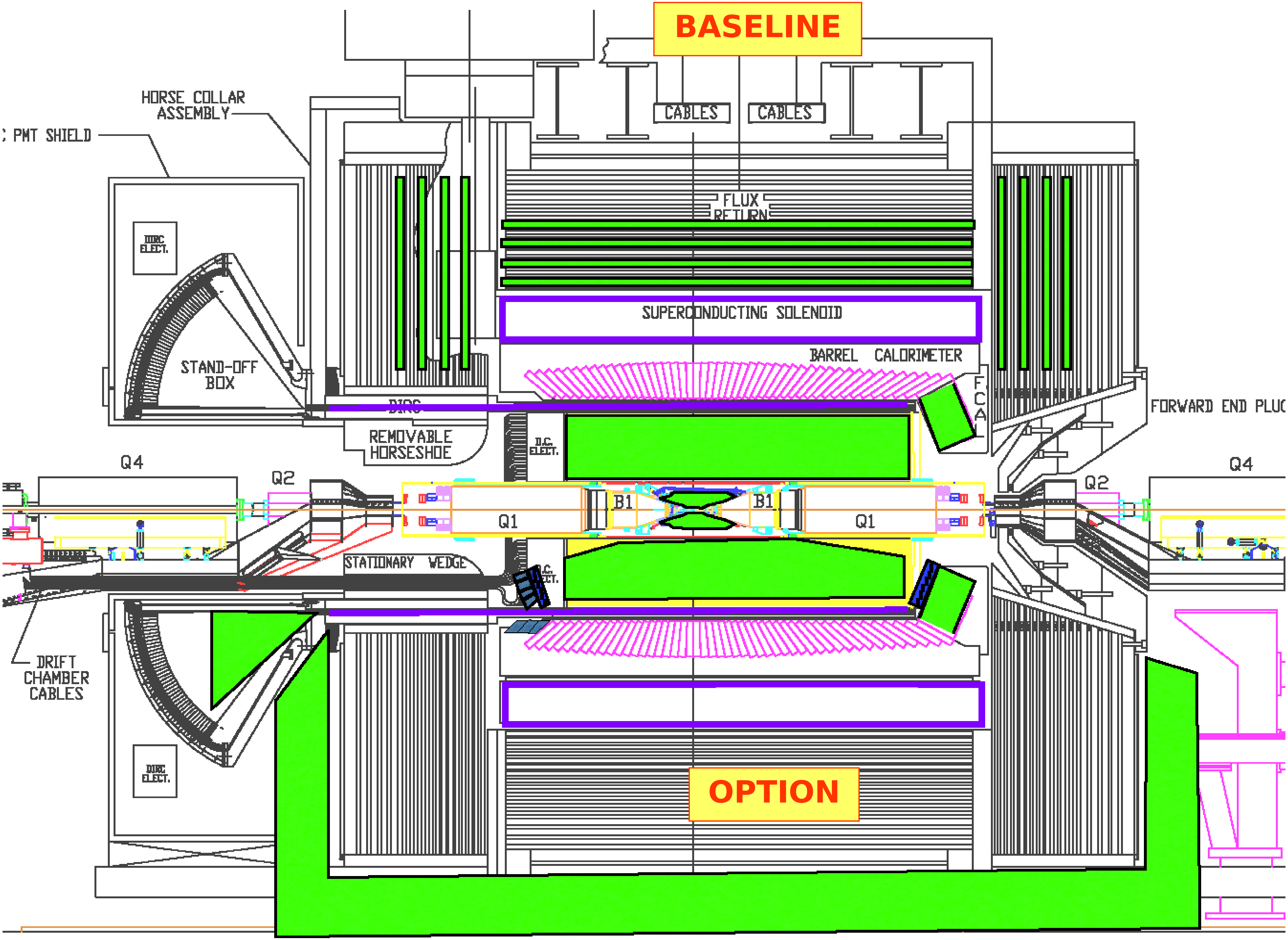


M.Sullivan

Detector R&D

- Detector R&D required for most 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 under consideration
  - calorimeter
    - LYSO based forward endcap
    - backward endcap (veto counter?) under consideration
  - electronics, trigger, DAQ & offline computing
    - need to deal with high physics trigger rate

improvements in hermeticity important for many measurements


BASELINE
CABLES
CABLES
HORSE COLLAR ASSEMBLY
PMT SHIELD
FLUX RETURN
DIRC ELECT.
SUPERCONDUCTING SOLENOID
BARREL CALORIMETER
STAND-OFF BOX
DIRC
FCA
FORWARD END PLUG
REMOVABLE HORSESHOE
D.C. ELECT.
Q4
Q2
B1
B1
Q2
Q4
Q1
Q1
STATIONARY WEDGE
D.C. ELECT.
DRIFT CHAMBER CABLES
DIRC ELECT.
OPTION

Super*B*: Where and When?

- Physics case for Super Flavour Factory is compelling
- Machine and detector can be realised at reasonable cost
- How can this project fit into global and regional roadmaps?
  - Well established priorities: LHC, ILC, neutrinos
  - Scope for additional regional project
    - unique physics potential
    - right timescale (2010s)

European Strategy for Particle Physics
(CERN Council Strategy Group)

Super*B* cost and governance

- Super*B* will proceed as a “regional initiative”, in line with the CERN Council Strategy group recommendation
- Total cost under 500 M€
  - Approx. 350 M€ needed as new money
- Governance similar to XFEL & FAIR
  - International committee formed by the interested funding agencies

CDR includes a 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

Engineering, Design, Inspection, Acceptance

Materials & Services

Value of reusable items from PEP-II and *BABAR*

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

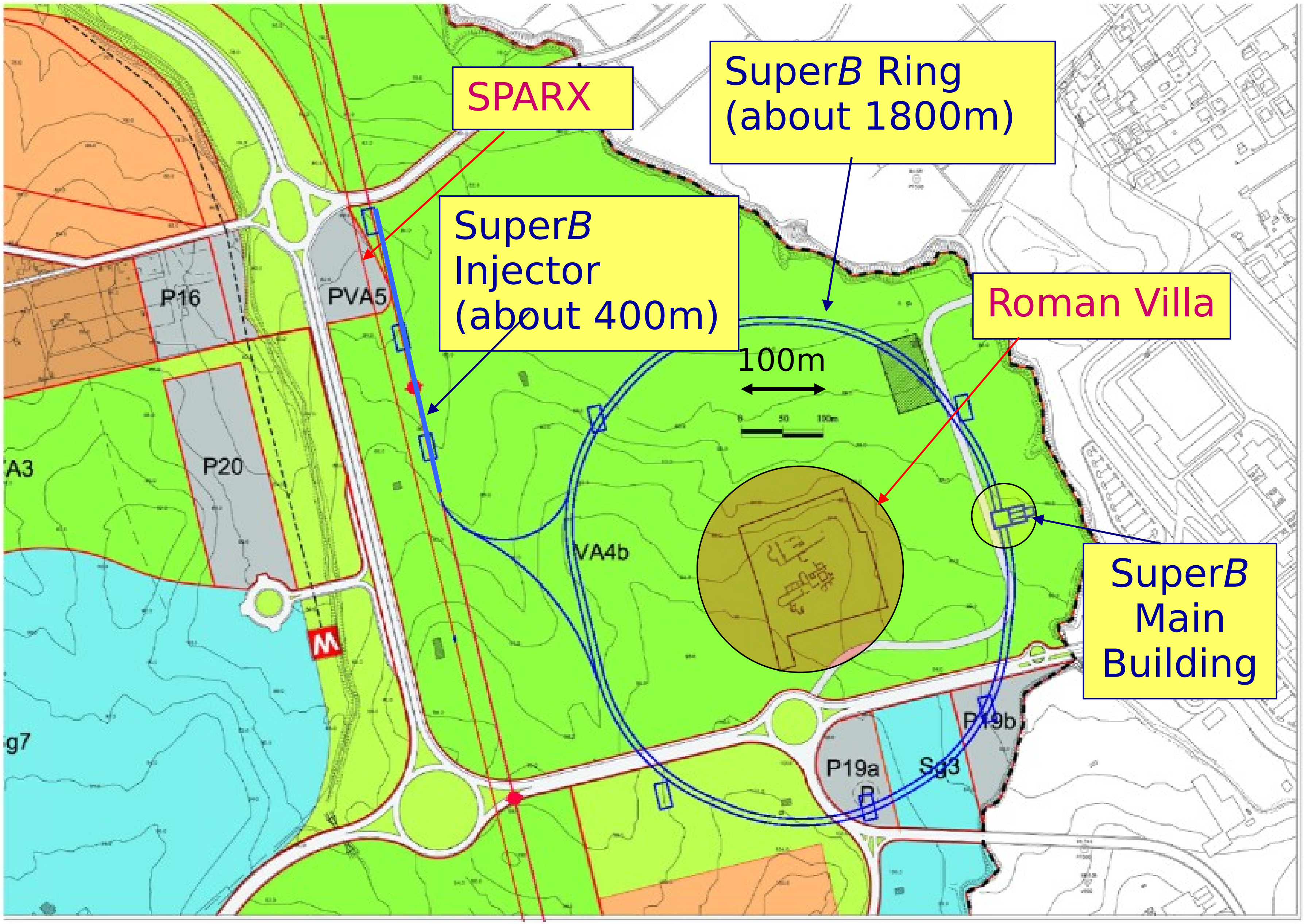
Costs are in 2007 € inflation adjusted

Possible savings from reusing other hardware not yet considered in detail

Potential SuperB site on the University of Rome Tor Vergata campus

Potential SuperB site on the University of Rome Tor Vergata campus

Footprint



by F.Forti

International Review Committee

- R. Petronzio, President of INFN, formed an International Review Committee to evaluate the Super*B* CDR

- The committee members are:

J. Dainton (chair) [UK] J. LeFrancois [France]
H. Aihara [Japan] R. Heuer [Germany] Y.-K. Kim [US]
A. Masiero [Italy] A. Seiden [US] D. Shulte [CERN]

- Project has been presented to ECFA
  - subcommittee set up (chair: T.Nakada)

- 1st report (May 2008) highly encouraging

Report of the IRC

First Report
of the International Review Committee[1] (IRC)
for the Super*B* Project

Hiroaki Aihara, John Dainton, Young Kee Kim, Jacques Lefrançois, Antonio Masiero, Steve Myers, Tatsuya Nakada[2], Daniel Schulte, Abe Seiden

Roma, May 21st 2008

Introduction and Context

The quest for a deeper understanding of the physics of the Universe, and therefore for the physics which underpins the Standard Model (SM), is at the heart of contemporary particle physics. The role of quark and lepton flavour in this new physics will be a cornerstone in our understanding.

The preser
[1] (CDR)
measurem
physics. It
manifestat
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5. Conclusion

We recommend strongly that work towards the realisation of a Super*B*, taken to be an asymmetric e^+e^- collider with luminosity at least 10^{36} cm^{-2} s^{-1}, continues.

The Super*B* project addresses this challenge by means of an electron-positron (e^+e^-) collider, with asymmetric beam energies, and with two orders of magnitude more luminosity, 10^{36} cm^{-1} s^{-1}, than hitherto. It is thus a very ambitious project which makes possible a new level, both in sensitivity and in precision, of inclusive e^+e^- annihilation measurements of flavour production. It anticipates by the latter half of the next decade the exhaustion of present, and presently foreseen, e^+e^- experimental

SuperB – Next Steps

- First stage (establish physics case) is completed
- Second stage (demonstrate machine feasibility) beginning
  - Mini-MAC formed (chair J.Dorfan)
  - Work towards TDR beginning
- Strong encouragement from INFN
- Positive statements also, eg., in P5 report
- CERN / ECFA approval will be sought

Summary

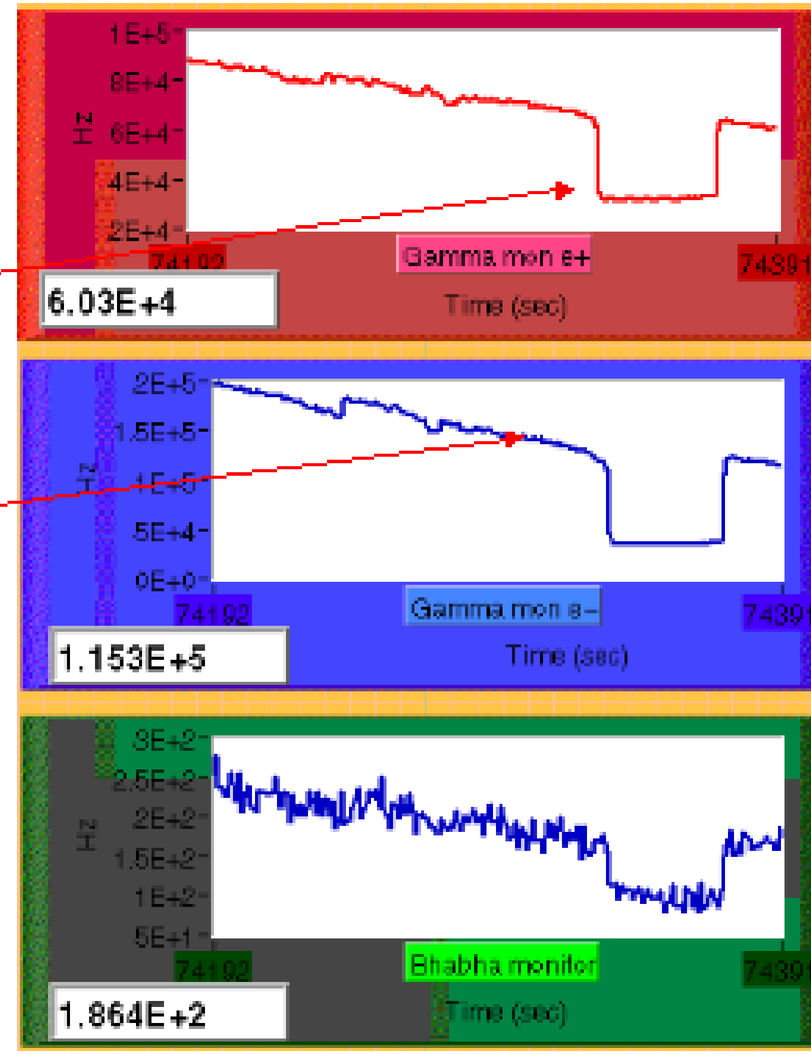
- The case for flavour physics in the LHC era is compelling
  - strong complementarity with energy frontier
  - requires peak luminosity $L_{peak} > 10^{36}/cm^2/s$
- Super*B* is the ideal tool to explore the new phenomenology
  - based on a radically new accelerator concept
- Strong European initiative to probe this window on new physics
  - explore the flavour treasure chest by mid-2010s
  - expect further developments within 6-9 months

Effect of crab sextupoles on luminosity

P.Raimondi

A huge work on machine optimization has been done and is still in progress in term of feedbacks systems tuning, background minimization and tuning of the machine luminosity

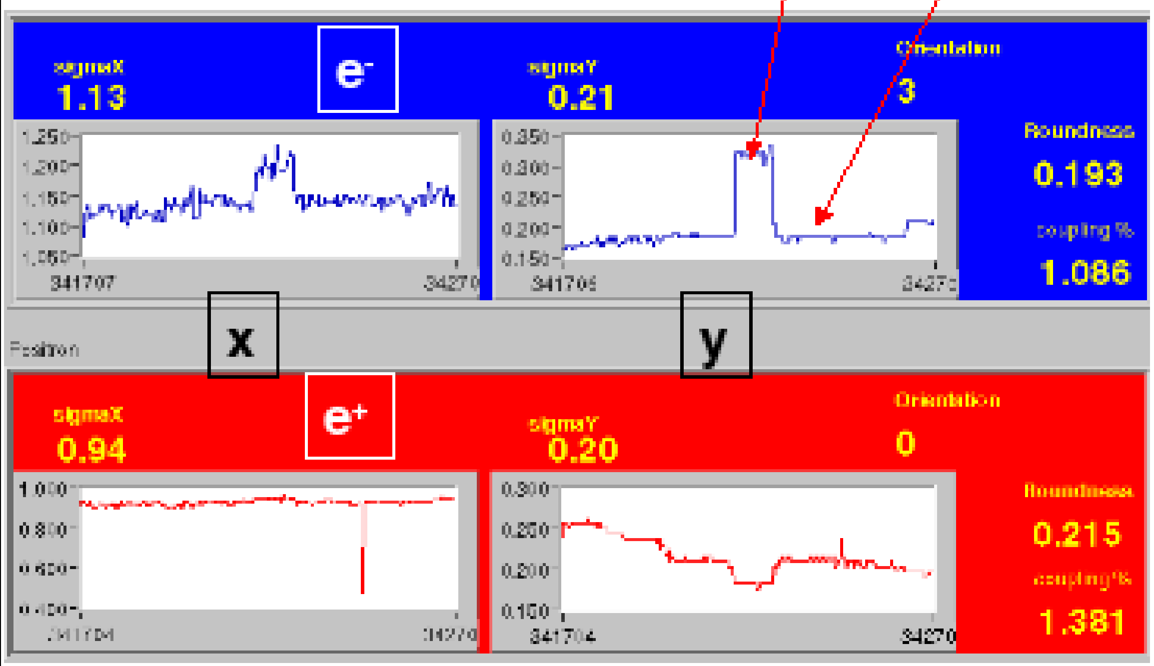
LUMINOMETERS



Crab OFF

Crab ON

Transverse beam dimensions at the Synchrotron Light Monitor



Blow-up in beam sizes and decrease in Bhabha rates observed when crab sexts for one ring OFF (other ring ON)

CDR includes a cost estimate

WBS	Item	EDIA mm	Labor mm	M\&S kEuro	Rep.Val. kEuro
1	**Accelerator**	**5429**	**3497**	**191166**	**126330**
1.1	Project management	2112	96	1800	0
1.2	Magnet and support system	666	1199	28965	25380
1.3	Vacuum system	620	520	27600	14200
1.4	RF system	272	304	22300	60000
1.5	Interaction region	370	478	10950	0
1.6	Controls, Diagnostics, Feedback	963	648	12951	8750
1.7	Injection and transport systems	426	252	86600	18000

WBS	Item	EDIA mm	Labor mm	M\&S kEuro	Rep.Val. kEuro
2.0	**Site**	**1424**	**1660**	**105700**	**0**
2.1	Site Utilities	820	1040	31700	0
2.2	Tunnel and Support Buildings	604	620	74000	0

CDR includes a cost estimate

WBS	Item	EDIA mm	Labor mm	M\&S kEuro	Rep.Val. kEuro
1	**SuperB detector**	**3391**	**1873**	**40747**	**46471**
1.0	**Interaction region**	**10**	**4**	**210**	**0**
1.1	**Tracker (SVT + L0 MAPS)**	**248**	**348**	**5615**	**0**
1.1.1	**SVT**	**142**	**317**	**4380**	**0**
1.1.2	***L0 Striplet option***	***23***	***33***	***324***	***0***
1.1.3	**L0 MAPS option**	**106**	**32**	**1235**	**0**
1.2	**DCH**	**113**	**104**	**2862**	**0**
1.3	**PID (DIRC Pixilated PMTs + TOF)**	**110**	**222**	**7953**	**6728**
1.3.1	**DIRC barrel - Pixilated PMTs**	**78**	**152**	**4527**	**6728**
1.3.1	***DIRC barrel - Focusing DIRC***	***92***	***179***	***6959***	***6728***
1.3.2	**Forward TOF**	**32**	**70**	**3426**	**0**
1.4	**EMC**	**136**	**222**	**10095**	**30120**
1.4.1	**Barrel EMC**	**20**	**5**	**171**	**30120**
1.4.2	**Forward EMC**	73	152	6828	0
1.4.3	**Backward EMC**	42	65	3096	0
1.5	**IFR (scintillator)**	**56**	**54**	**1268**	**0**
1.6	**Magnet**	**87**	**47**	**1545**	**9623**
1.7	**Electronics**	**286**	**213**	**5565**	**0**
1.8	**Online computing**	**1272**	**34**	**1624**	**0**
1.9	**Installation and integration**	**353**	**624**	**3830**	**0**
1.A	**Project Management**	**720**	**0**	**180**	**0**

NB. Items in italics (L0 striplet, focusing DIRC) are not included in the baseline

CDR includes a schedule

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

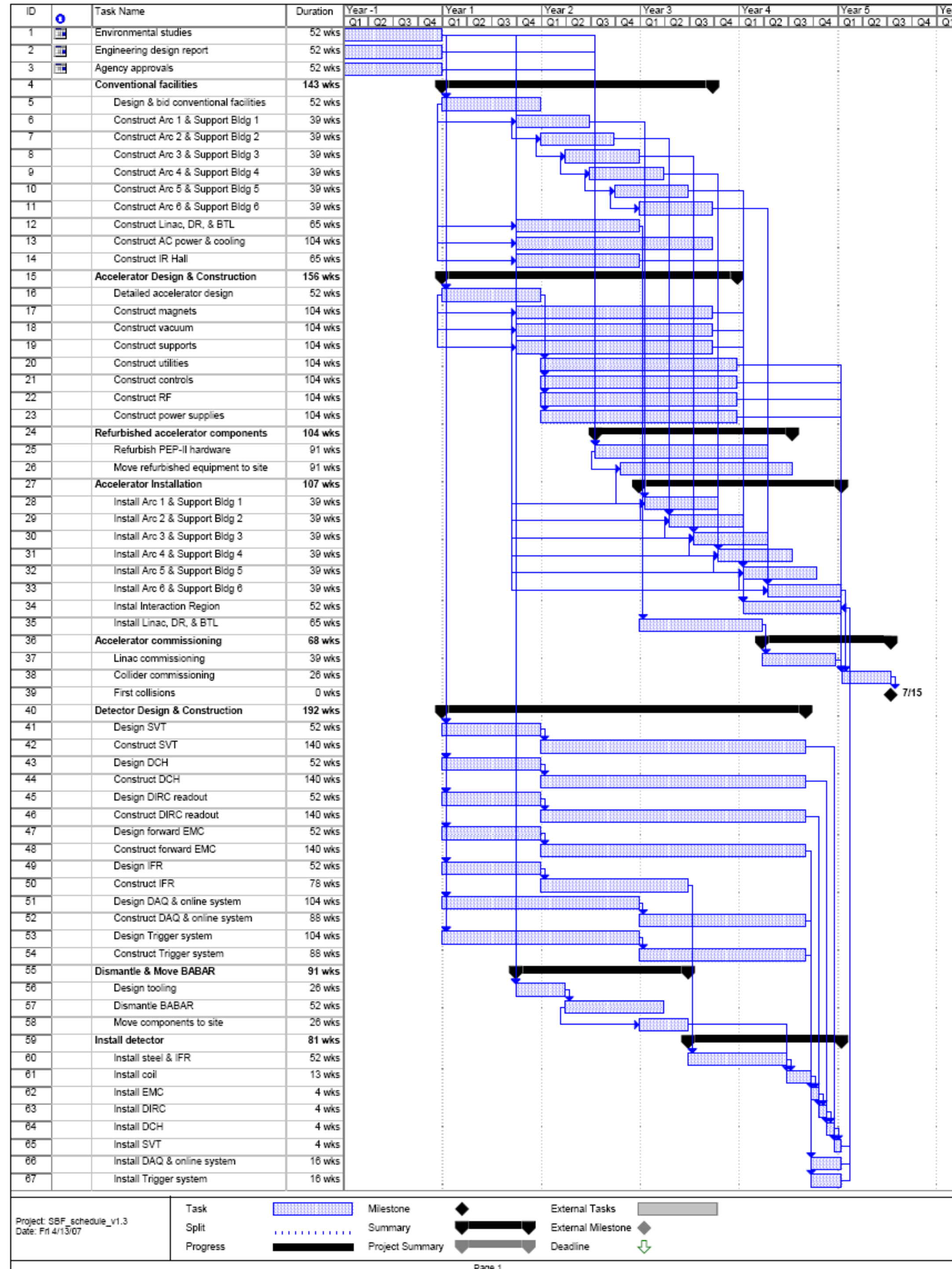
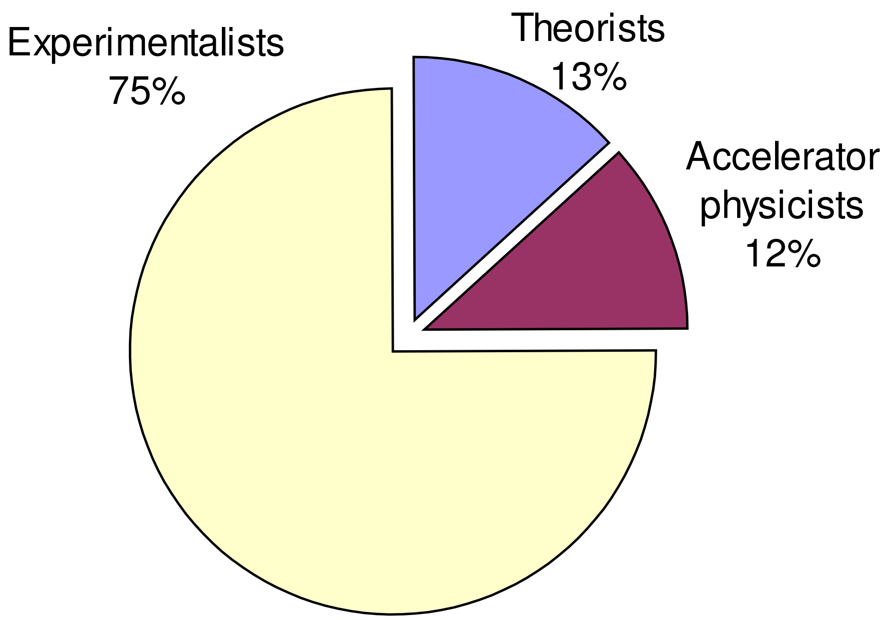


Figure 5-1. *Overall schedule for the construction of the SuperB project.*

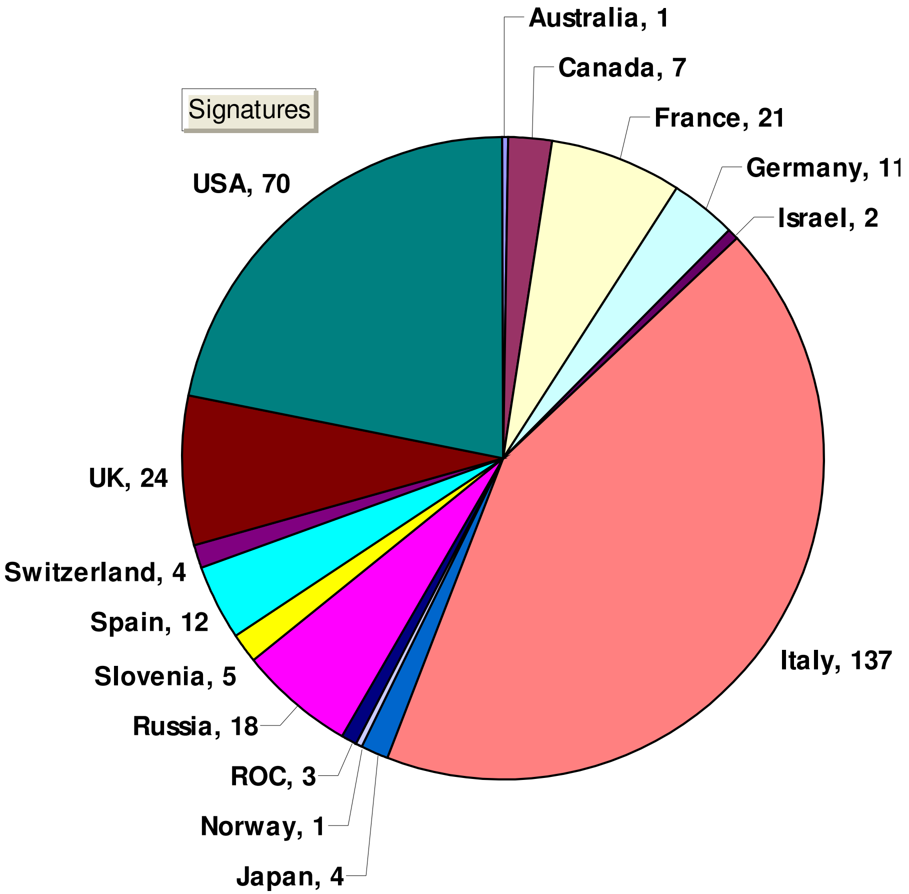
Table 3-2. *Comparison between parameters for the SuperB storage rings and the ILC damping rings.*

Unit	SuperB LER	SuperB HER	ILC DRs
Beam energy (GeV)	4	7	5
Circumference (m)	2249	2249	6695
Particles per bunch	6.16×10^{10}	3.52×10^{10}	2×10^{10}
Number of bunches	1733	1733	2767
Average current (A)	2.28	1.30	0.40
Horizontal emittance (nm)	1.6	1.6	0.8
Vertical emittance (pm)	4	4	2
Bunch length (mm)	6	6	9
Energy spread (%)	0.084	0.09	0.13
Momentum compaction	1.8×10^{-4}	3.1×10^{-4}	4.2×10^{-4}
Transverse damping time (ms)	32	32	25
RF voltage (MV)	6	18	24
RF frequency (MHz)	476	476	650

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



Signatures breakdown by type



Signatures breakdown by country

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

The Worst Case Scenario

- Can new physics be flavour blind?
  - No, it must couple to Standard Model, which violates flavour
- What is the minimal flavour violation?
  - new physics follows Standard Model pattern of flavour and CP violation

    G. D'Ambrosio, G.F. Giudice, G. Isidori, A. Strumia, NPB 645, 155 (2002)
  - even in this unfavourable scenario Super*B* is still sensitive, up to new physics particle masses of 600-1000 GeV

    (analysis relies on CKM fits and improvements in lattice calculations)
- MFV is a long way from being verified!

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

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

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

Today

Λ (MFV) > 2.3Λ_0 @95C.L.

NP masses >200GeV

SuperB

Λ (MFV) >~6Λ_0 @95C.L.

NP masses >600GeV

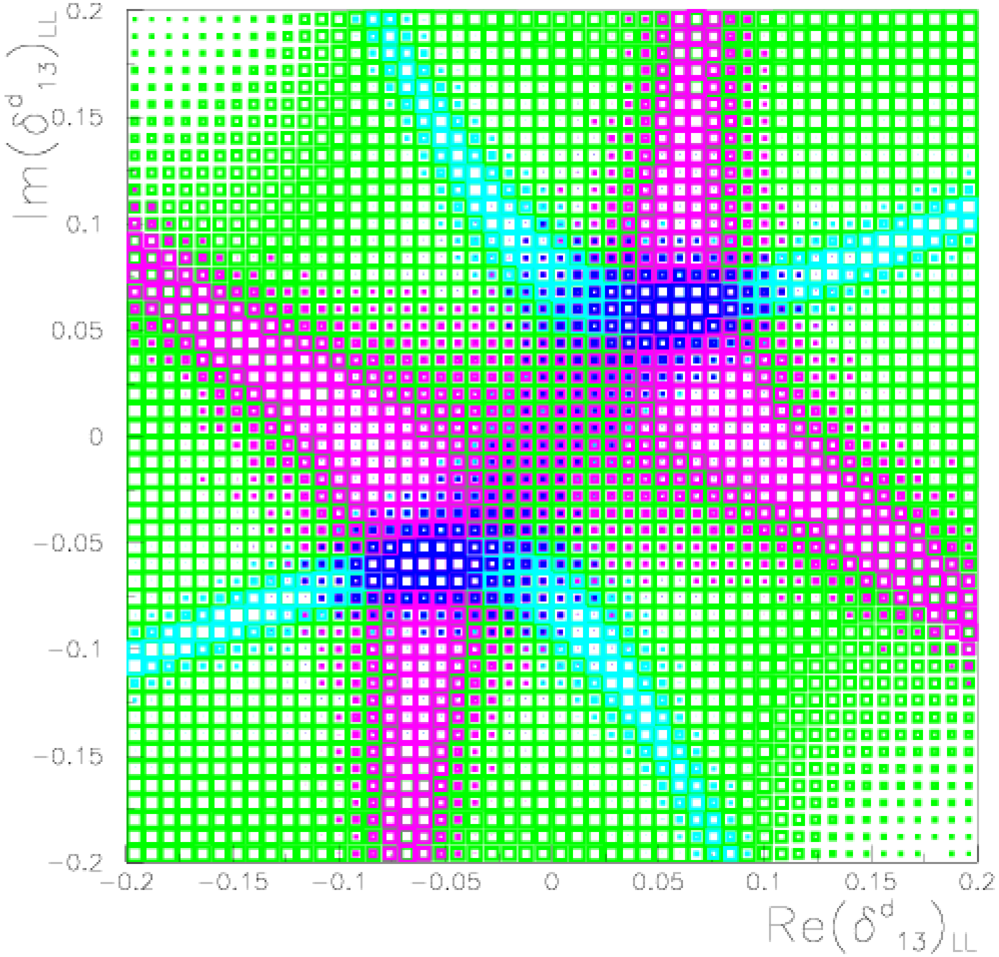
- analysis relies on CKM fits and improvements in lattice calculations
- only ΔF=2 (mixing) operators considered
- further improvements possible including also ΔF=1 (especially $b \rightarrow s\gamma$)

Better Scenarios

- Move slightly away from the worst case scenario
  - minimal flavour violation with large tan β
    - SuperB sensitive to scales of few TeV
  - next-to-minimal flavour violation
    - SuperB sensitive to scales above 10 TeV
  - generic flavour violation
    - SuperB sensitive to scales up to ~1000 TeV
- Look now at a few specific channels

MSSM + Generic Squark Mass Matrices

Today's central values with SuperB precision



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

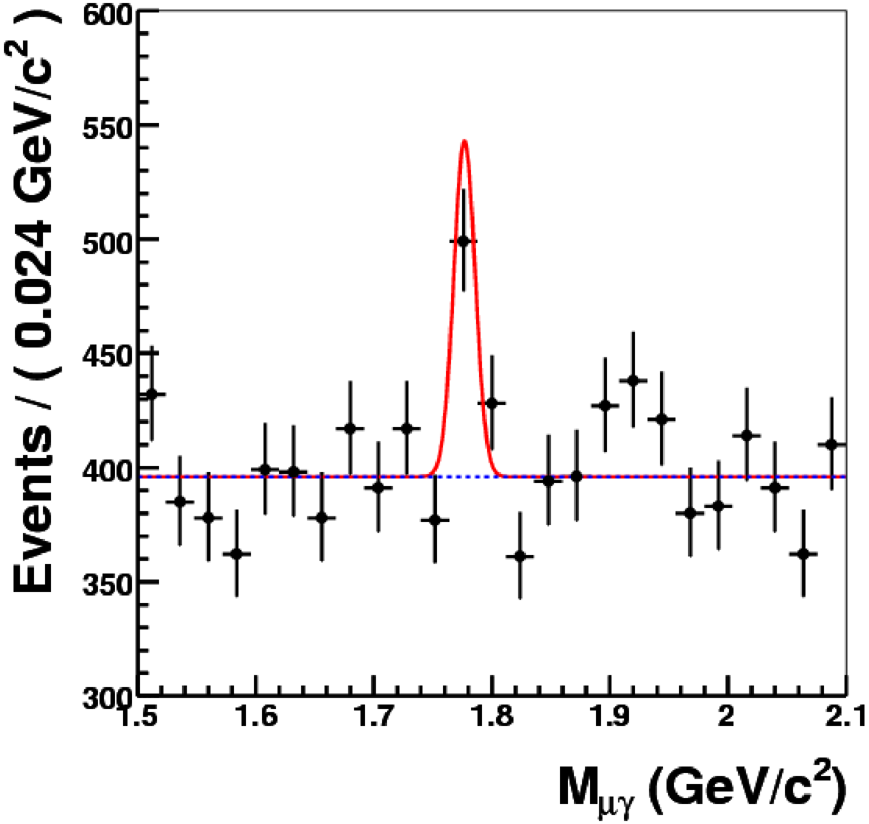
Real vs. imaginary parts of mass-insertion parameter $(\delta_{13})_{LL}$

Lepton Flavour Violation

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

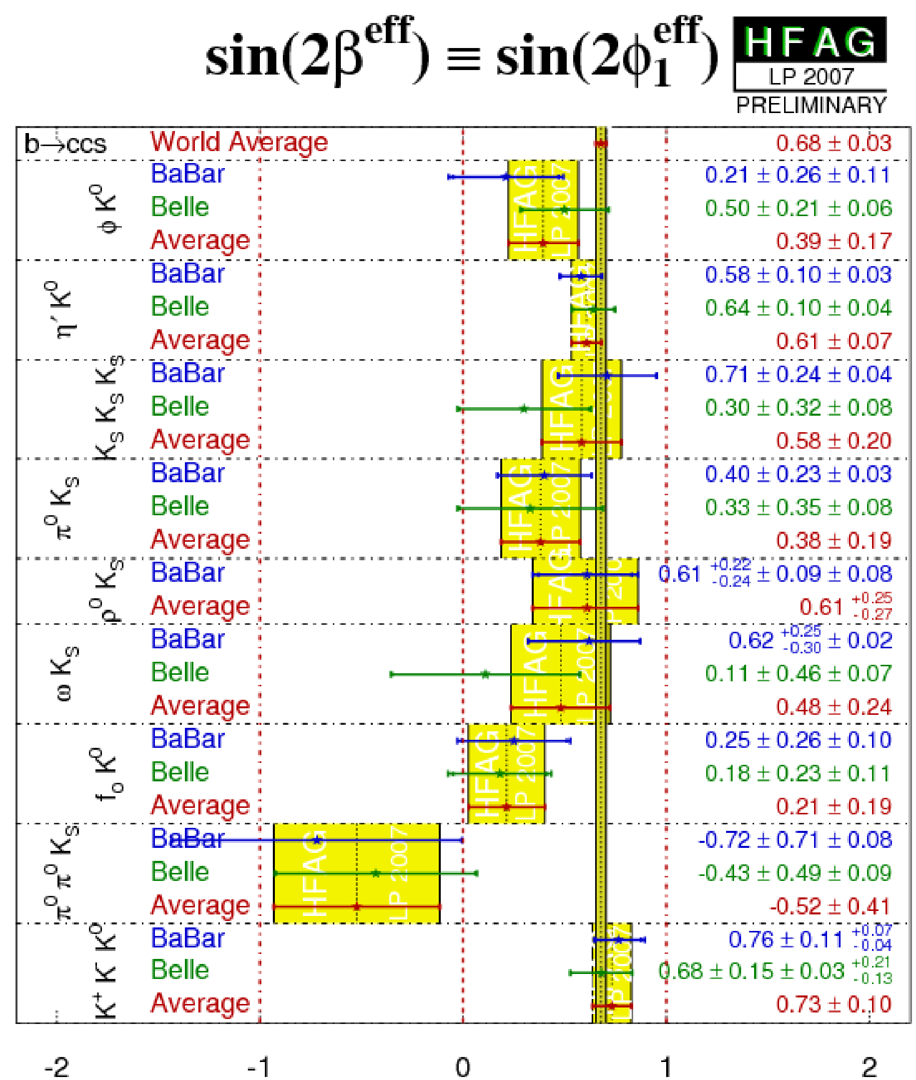
M.Roney @ Flavour in the LHC Era Workshop, CERN, March 2007

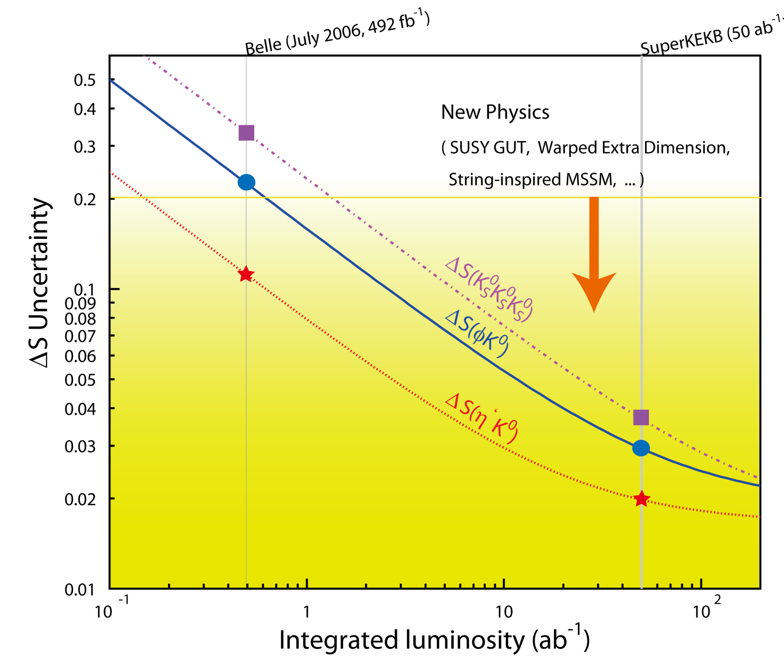
Monte Carlo simulation of 5σ observation of $\tau \to \mu\gamma$ at SuperB



Hadronic b→s Penguins

Current B factory hot topic





Many channels can be measured with Δ S~(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

N.B. This plot does not include results on f0KS from BaBar time-dependent Dalitz plot analysis of Ksπ+π– (arXiv:0708.2097)

Correlations Distinguish Models

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

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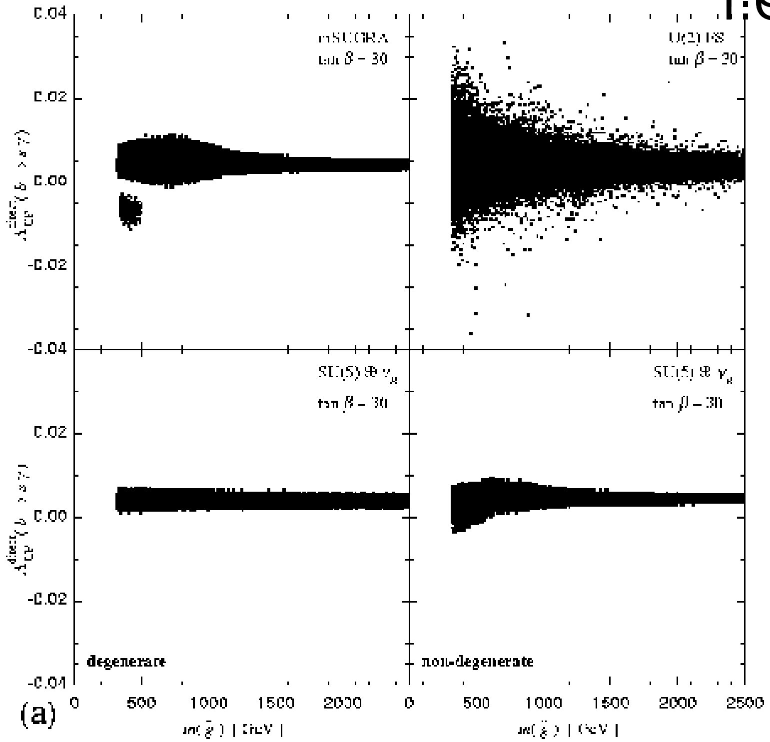

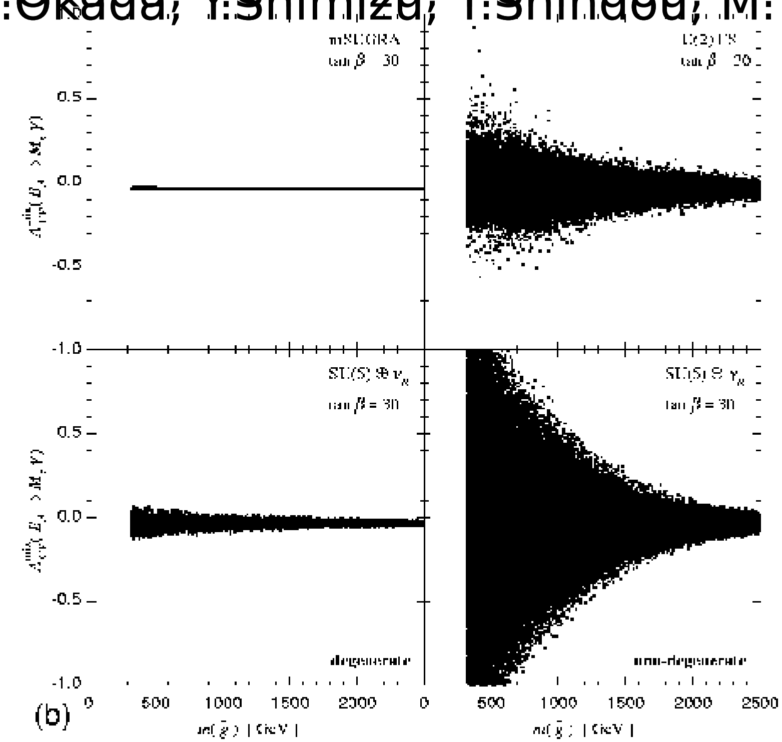

$A_{CP}(b \to s\gamma)$ $S(B^0 \to K_S \pi^0 \gamma)$

SuperB can reach ~0.4% precision

SuperB 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

Running at the Υ(5S)

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

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

cf. D0 untagged measurement of φ_s

Why 10/ab Is Not Enough!

Just a few examples ...

- Lepton flavour violation
  - Need a big push into the unexplored region
- Forward-backward asymmetry in $b \to sll$
  - Must improve beyond 10% theory error of exclusive modes
- Rare B decays ($B \to K^{(*)} \nu\nu$, $B \to \mu^+\mu^-$)
  - Prospects for observation marginal at 10/ab
- Null tests, such as CP violation in charm
  - Limited only by statistics