Status of the Super*B* Project

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BNM2008, Atami, Japan
24th January 2008

Contents of this talk

- Brief reminder: what is Super*B*?
- The Physics Case
  - Or: “Why 10/ab is Not Enough!”
- The Accelerator
  - Details in talk of Marica Biagini
- The Detector
- Recent progress and near future plans

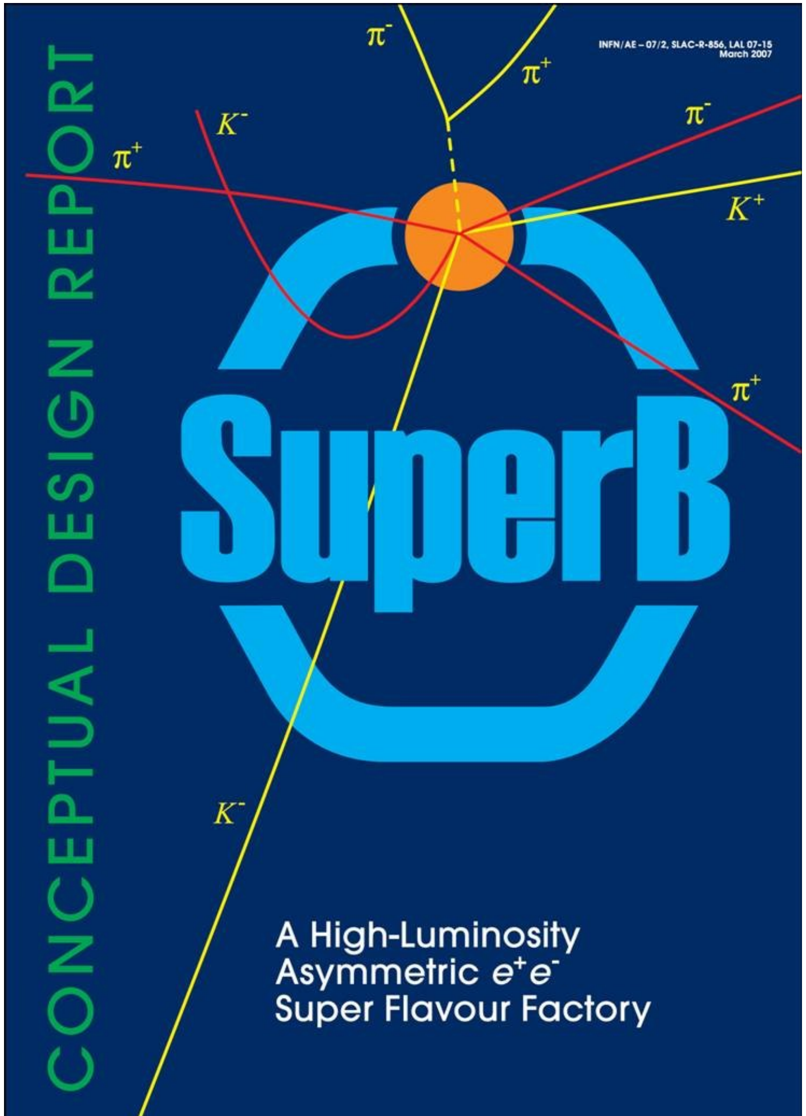
What is SuperB ?

- 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

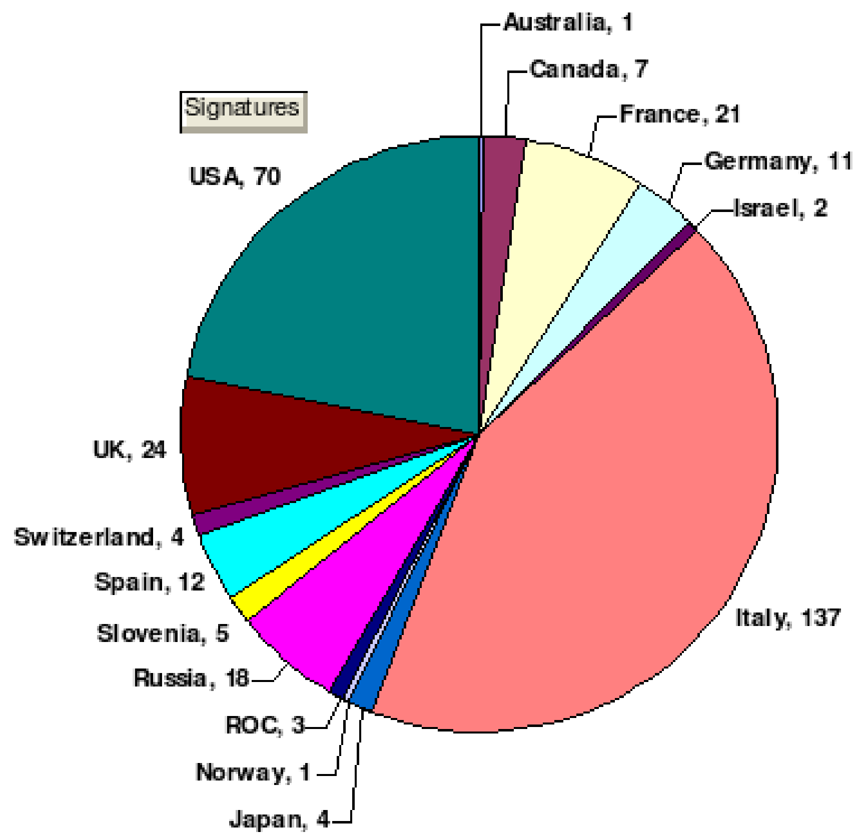
Conceptual Design Report



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

Available online:

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



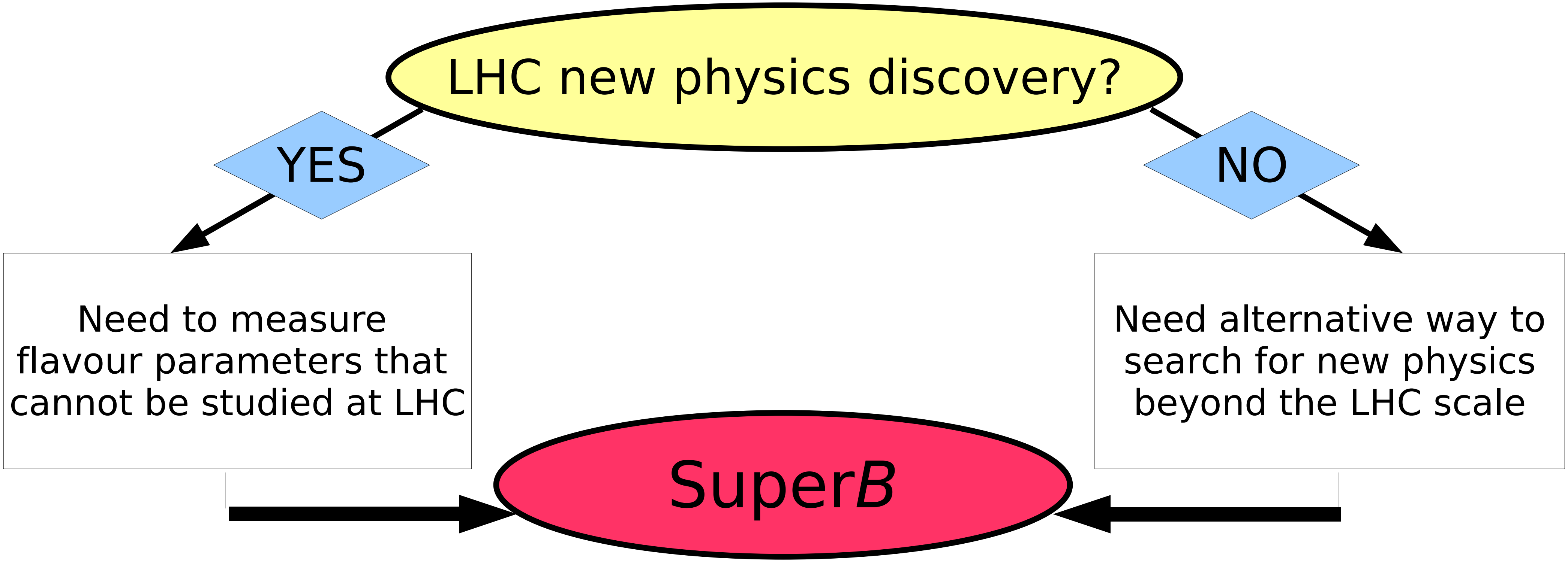
Signatures breakdown by country

New Physics Discovery 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)
     - NP follows SM pattern of flavour and CP violation
     - SFF detects NP effects for particle masses up to >600 GeV
   - What if NP flavour couplings are not suppressed?
     - SFF 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

Interplay With Energy Frontier



- Super*B* measurements obtain NP flavour structure

  "no lose"!

- LHC + Super*B* begin to reconstruct NP Lagrangian

- Super*B* discovery reach beyond LHC scale

  possible NP observation!

- Results inform future energy frontier programme

Super*B* Design Necessities

- Cover large range of flavour observables
  - Flexible running energy
  - Possibility for beam polarization
- Precise measurements
  - Focus on theoretically clean observables
  - Minimize statistical and systematic errors
    - Very high luminosity
    - Improved detector performance
    - Low backgrounds

B, D, τ

Super*B* Measurements

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

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

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

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

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

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

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

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

Super*B* "treasure chest"
of new physics observables

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 $B \to X\gamma$, 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

table by M.Ciuchini

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

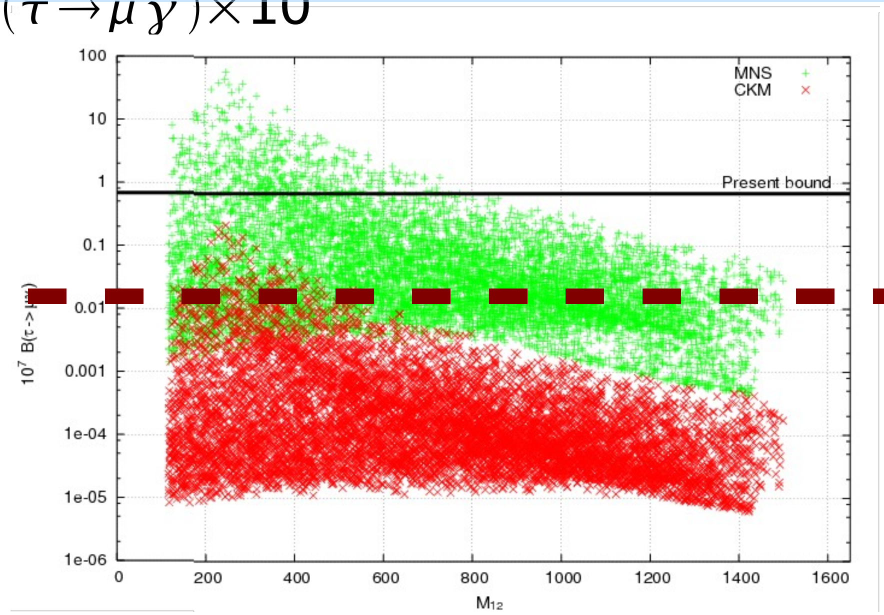
Lepton Flavour Violation

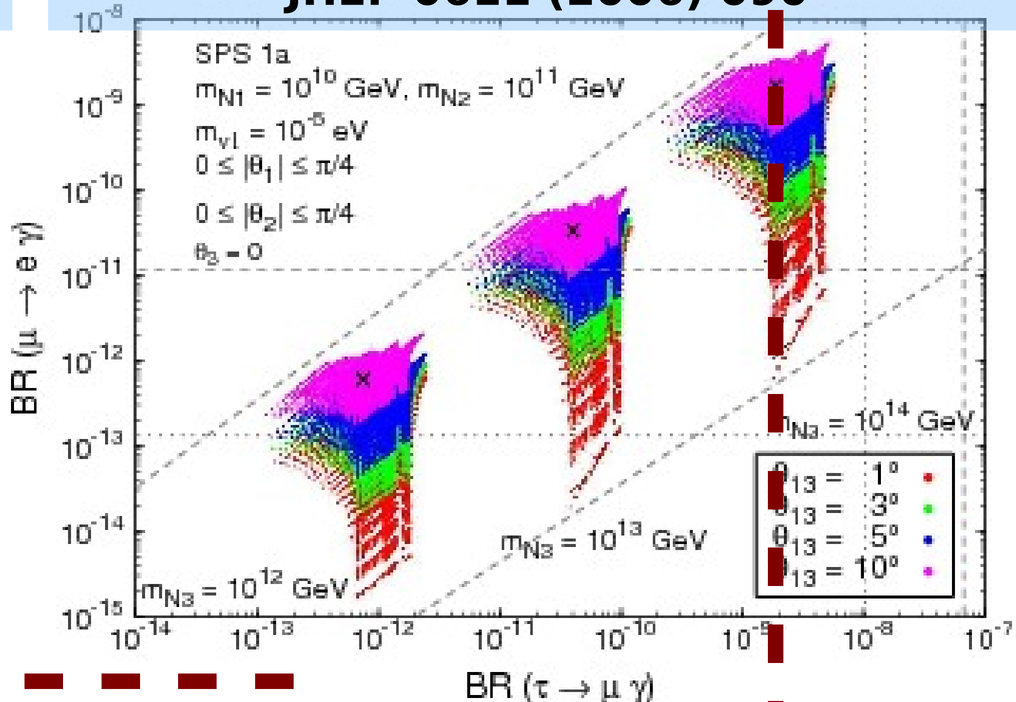
- Observable LFV signals predicted in a wide range of models, including those inspired by Majorana neutrinos

Calibbi, Faccia, Masiero & Vempati, PRD 74 (2006) 11600

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

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



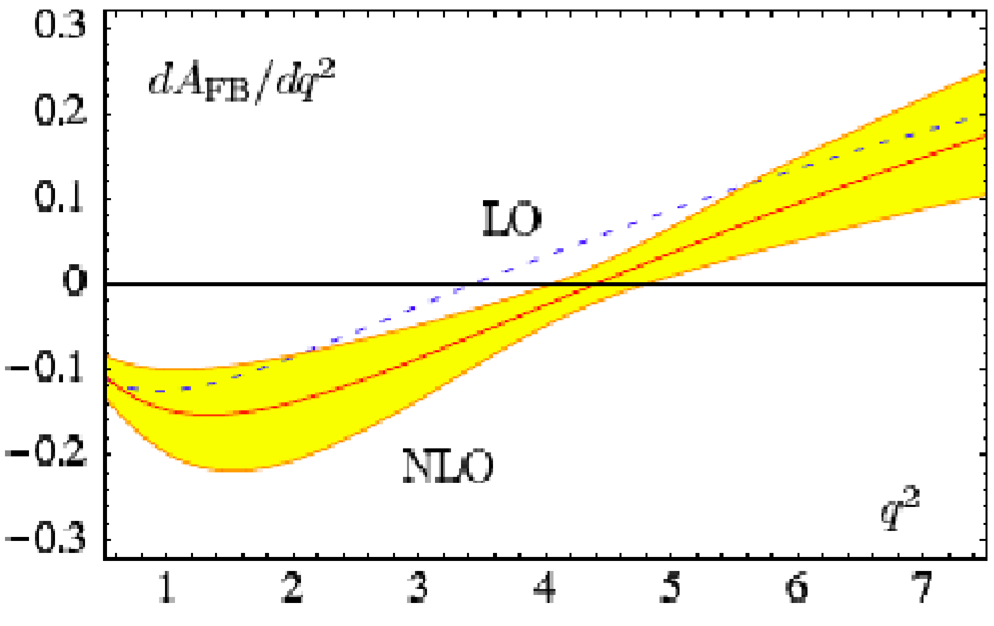


Super*B* sensitivity

Super*B* *much* more sensitive to LFV than LHC (including τ→μμμ)

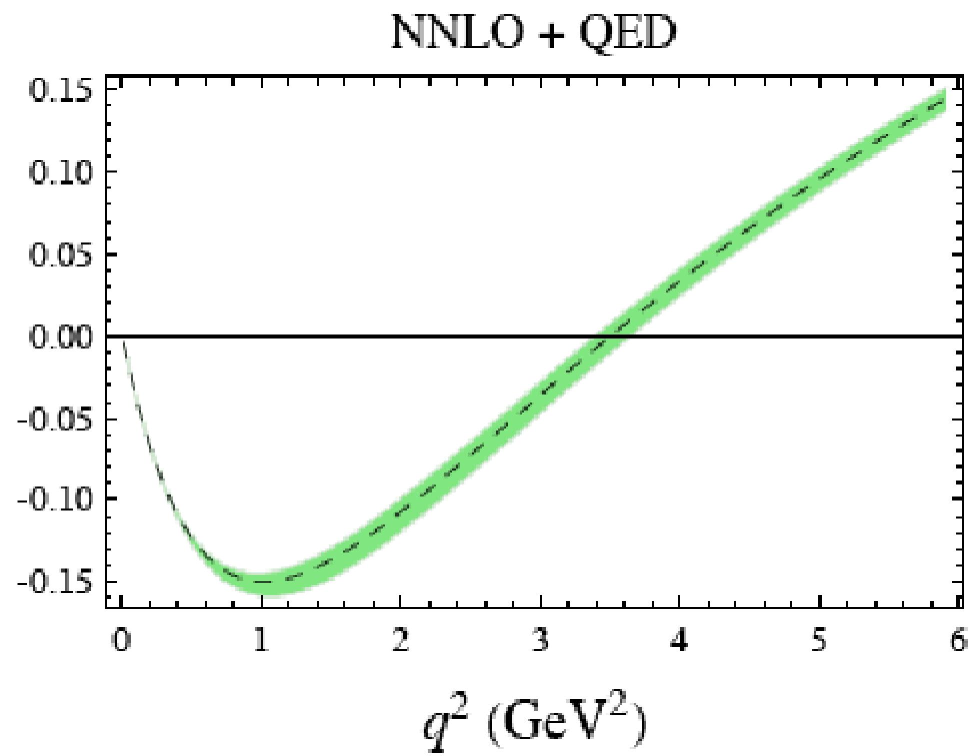
Forward-Backward Asymmetry

Exclusive: B→K*ll



Beneke, Feldmann, Seidel
EPJ C41 (2005) 173

Inclusive: b→sll

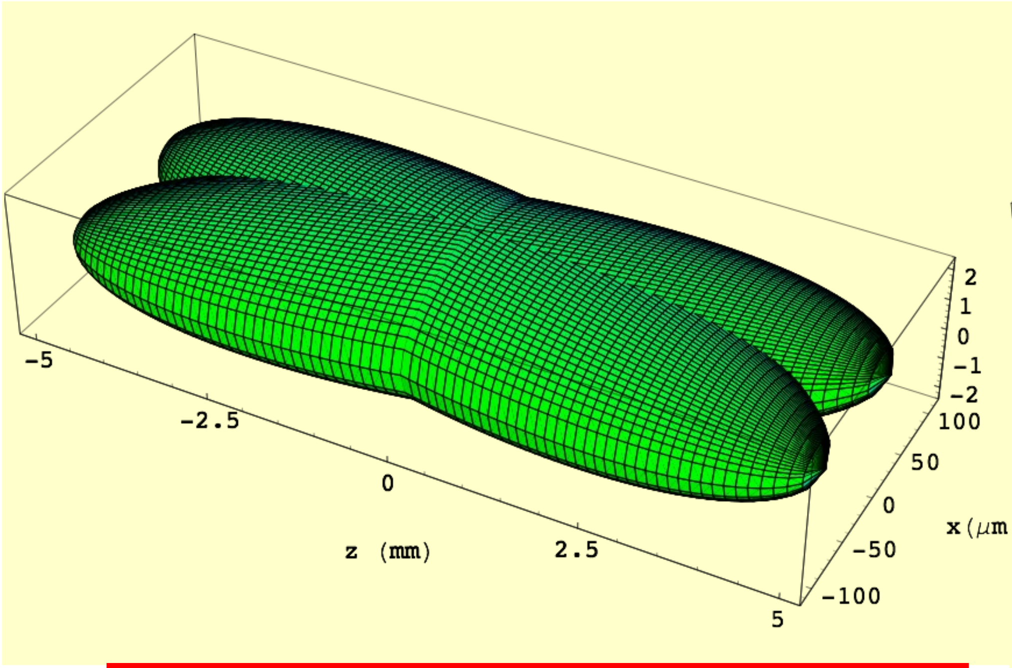


Huber, Hurth, Lunghi
arXiv:0712.3009 [hep-ph]

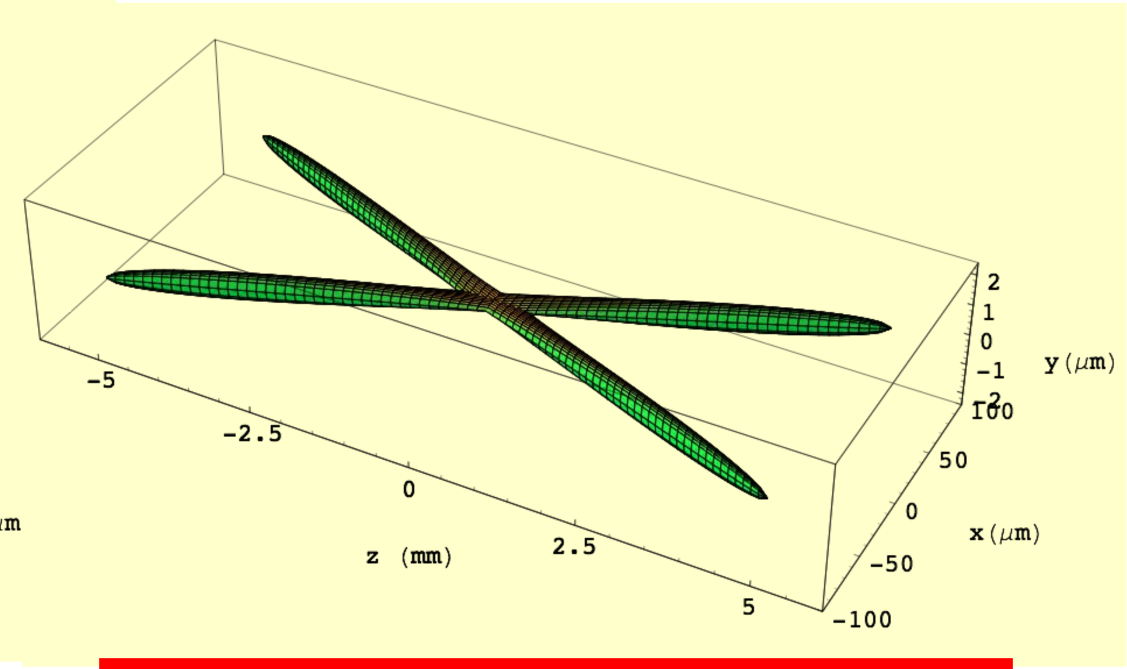
Inclusive is much cleaner ⇔ need Super*B* statistics

The Accelerator

- (Details in talk of M.Biagini tomorrow)
- Machine is based on ILC damping ring lattice
  - High luminosity through small emittance



IP beam distributions for KEKB

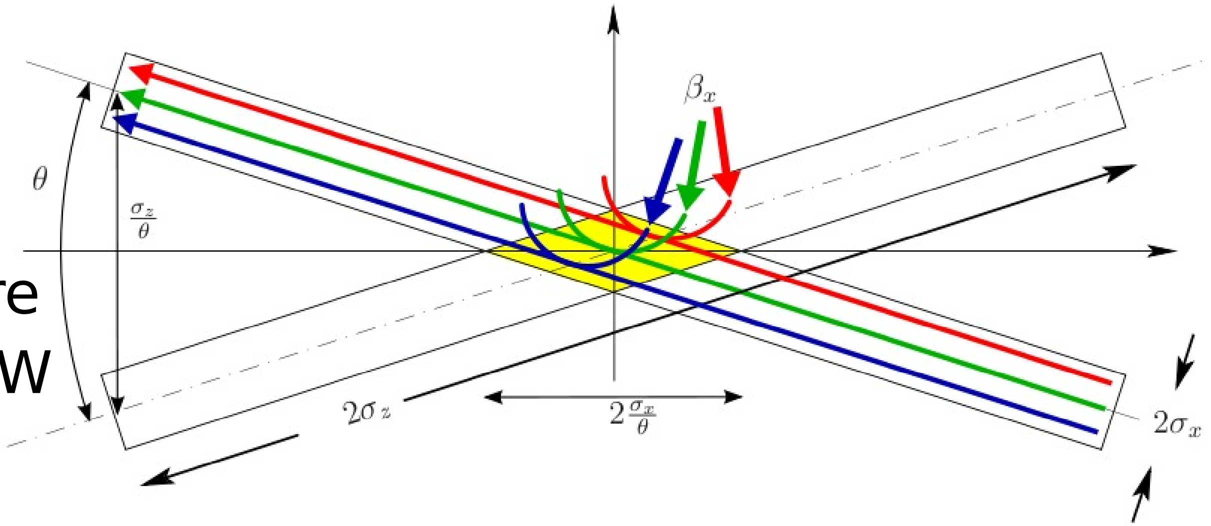


IP beam distributions for Super*B*

New Collision Scheme

- Maximize overlap of beams even with finite crossing angle using “crab waist”
- Achieved through sextupole magnets
- Minimal beam distruption

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

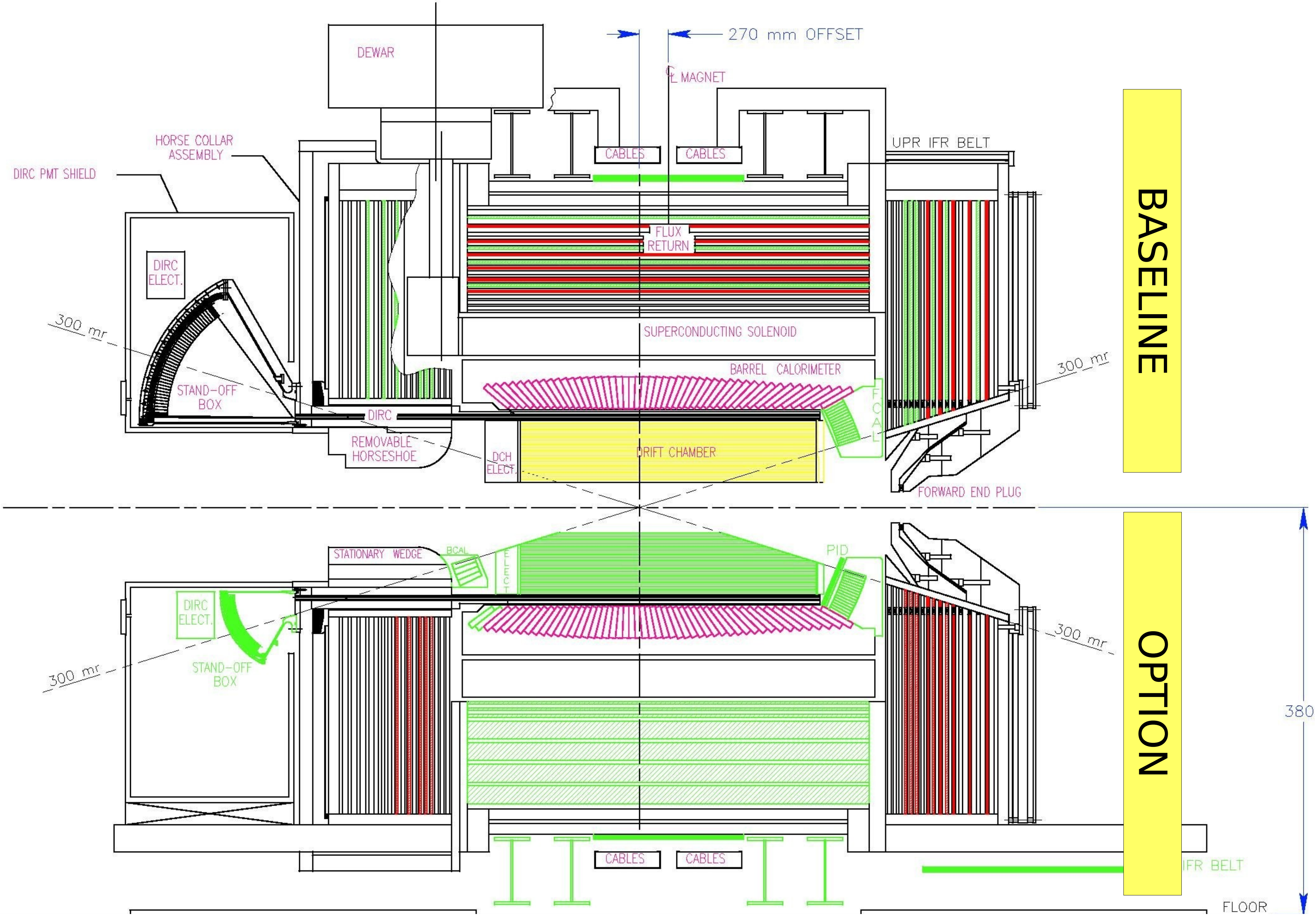


Maximize beam overlap with finite crossing angle

Detector

- Currents and backgrounds similar to today's *B* factories
  - Existing detectors can largely be reused
  - CDR describes detector based on BaBar
- Upgrades motivated mainly by physics
  - Smaller beam asymmetry
    - high resolution vertex detector
    - improvements to detector hermeticity
  - Some other necessary upgrades
    - new drift chamber; forward endcap; muon detection

Conceptual SuperB Detector



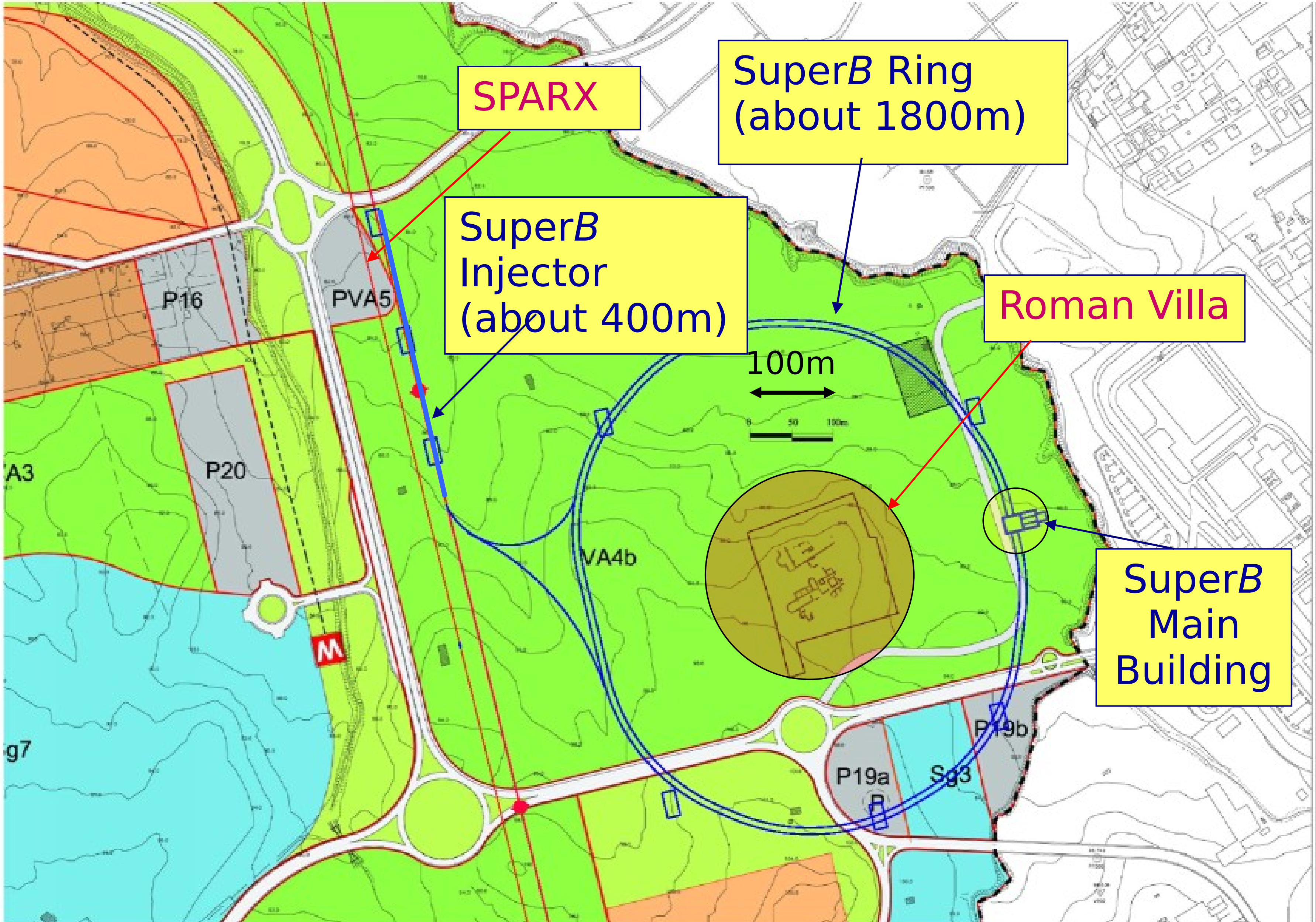
Detector R&D

- Detector R&D ongoing for many 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
    - CsI(Tl) too slow for endcaps → L(Y)SO? pure CsI?
    - backward endcap under consideration
  - electronics, trigger, DAQ & offline computing
    - need to deal with high physics trigger rate

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

Recent Progress and Future Plans

- CDR is being evaluated by an International Review Committee (IRC)
- Continuing work on
  - Physics case
  - Detector R&D
  - Accelerator design
    - Beam tests ongoing at LNF – promising so far
- Expect IRC report April 2008
  - If positive, will request endorsement from CERN strategy group
  - After this milestone, will request funding

International Review Committee

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

- The committee members are:

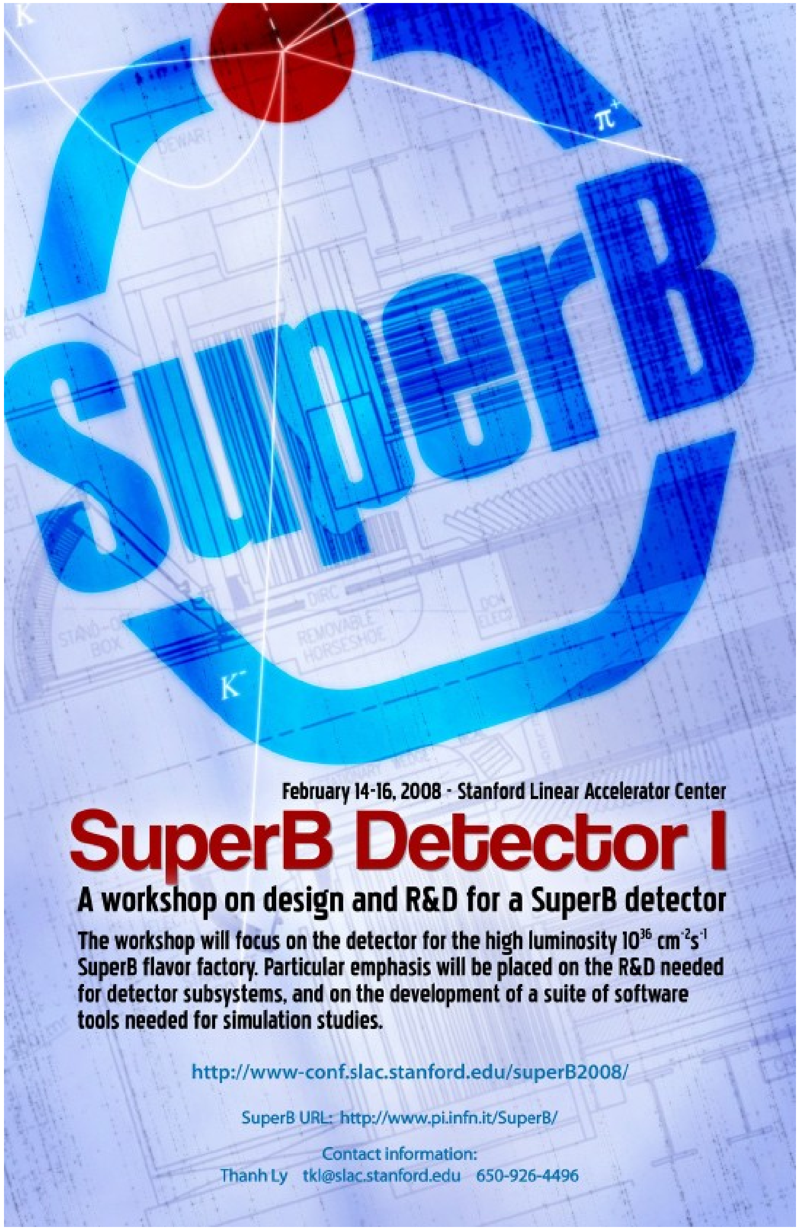
J. Dainton (chair) [UK]	J. LeFrancois [France]	
H. Aihara [Japan]	R. Heuer [Germany]	Y.-K. Kim [US]
A. Masiero [Italy]	A. Seiden [US]	D. Shulte [CERN]

- Meeting with the committee held November 2007

- Requests for further information being responded to

- Expect final report April 2008

Ongoing Activity



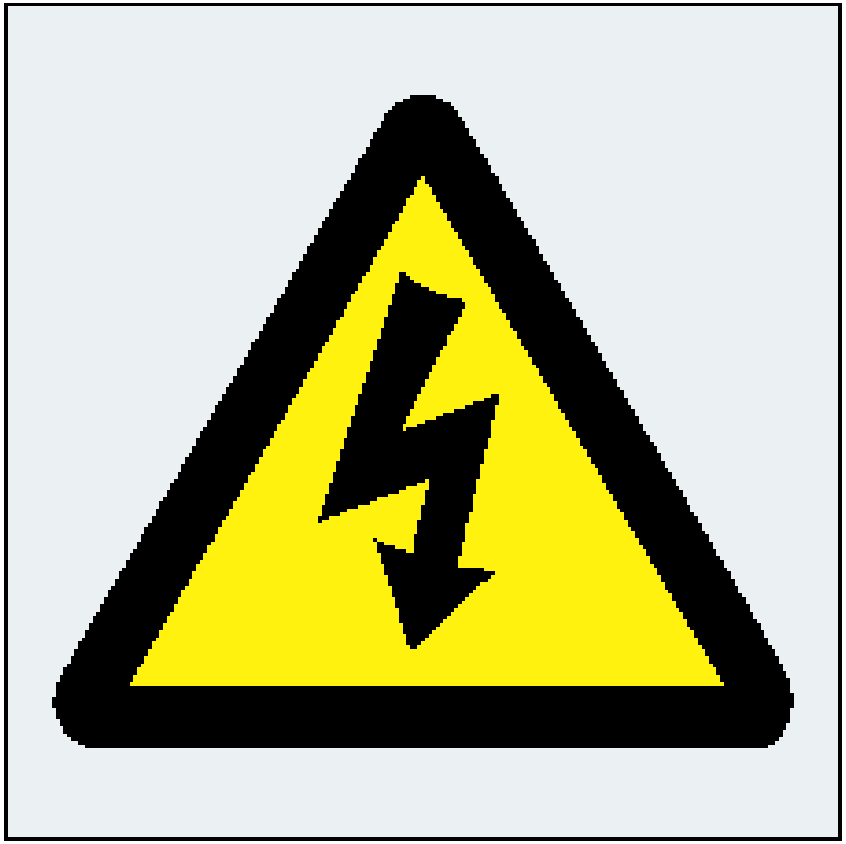
Super*B* cost and governance

- 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

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

Back Up



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

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

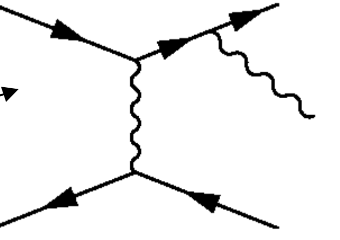
Costs are in 2007 € inflation adjusted

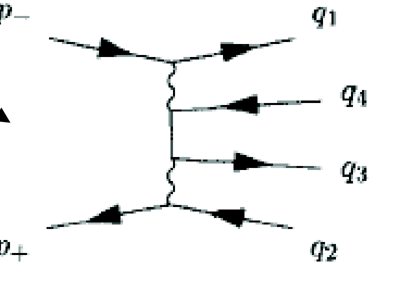
Possible savings from reusing other hardware not yet considered in detail

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



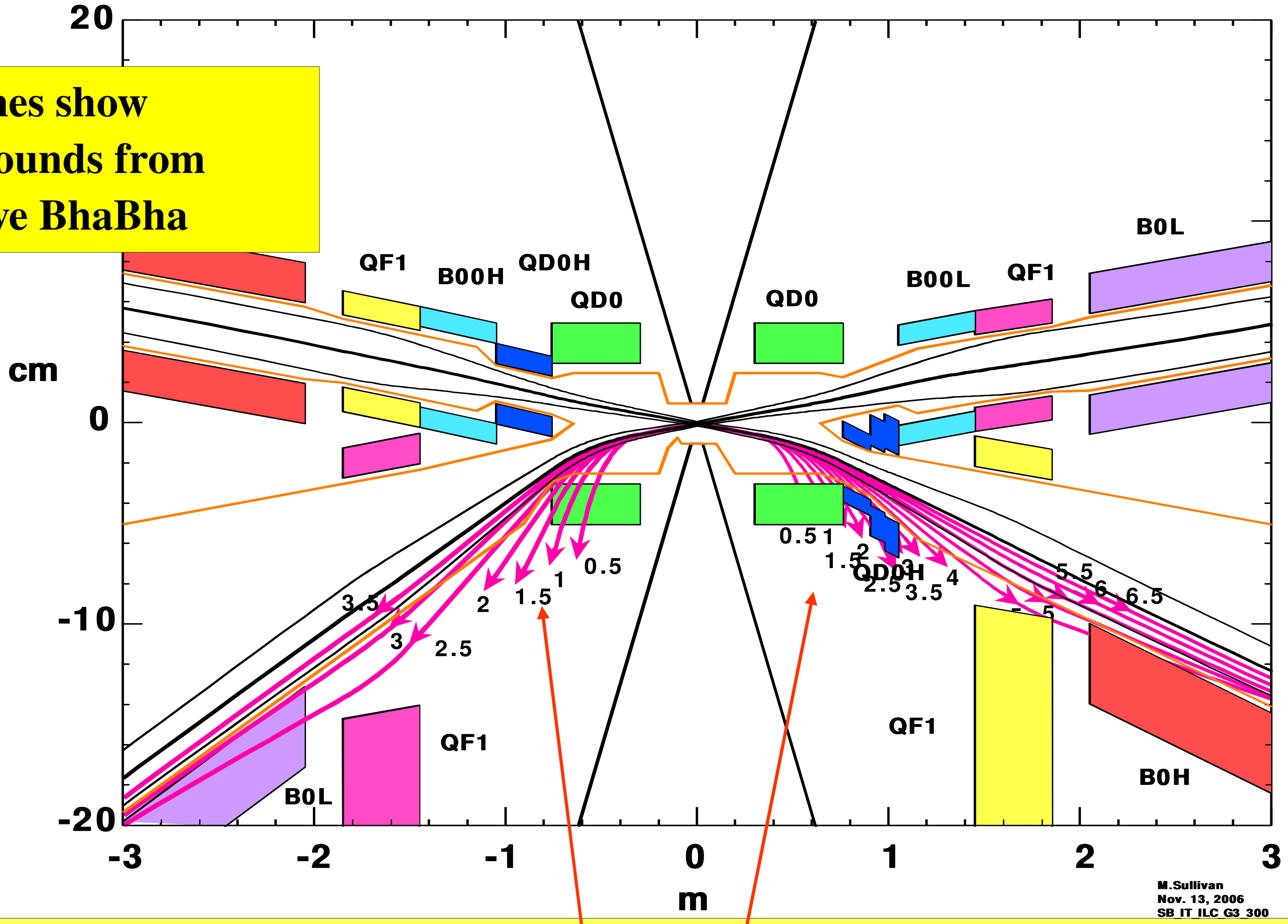


Backgrounds and Detectors

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

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

Interaction Region Design



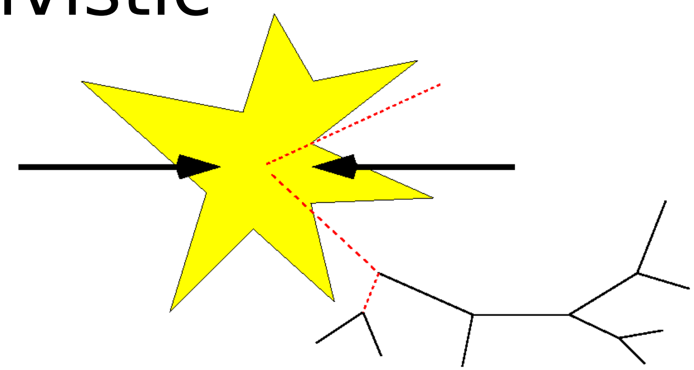
Pink lines show backgrounds from radiative BhaBha

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

Motivation

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

“relativistic”



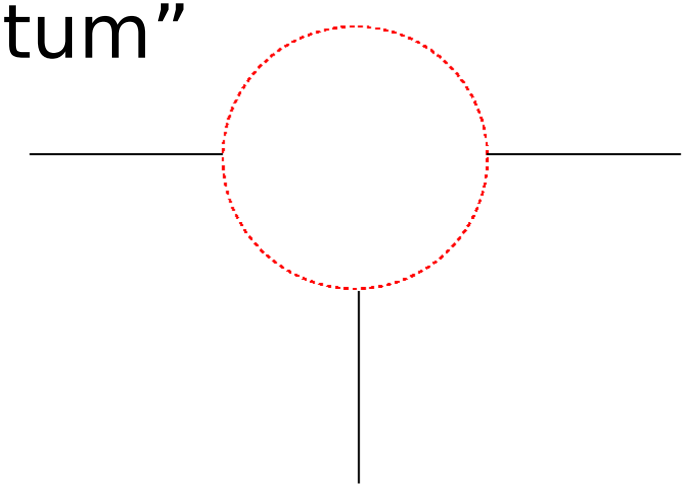
New heavy particles produced on mass shell

Sensitivity depends on:

available centre-of-mass energy

knowledge of Standard Model backgrounds

“quantum”



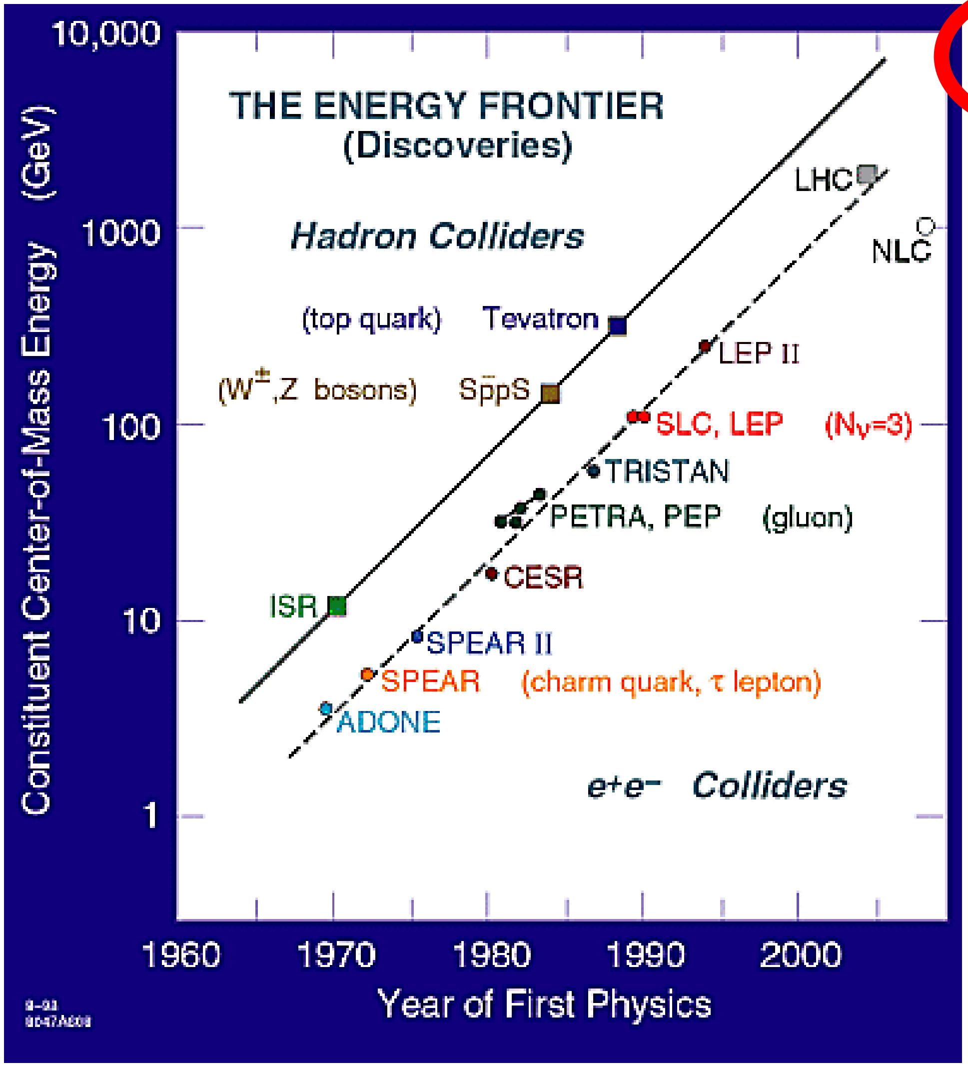
New heavy particles produced off mass shell (“virtual”)

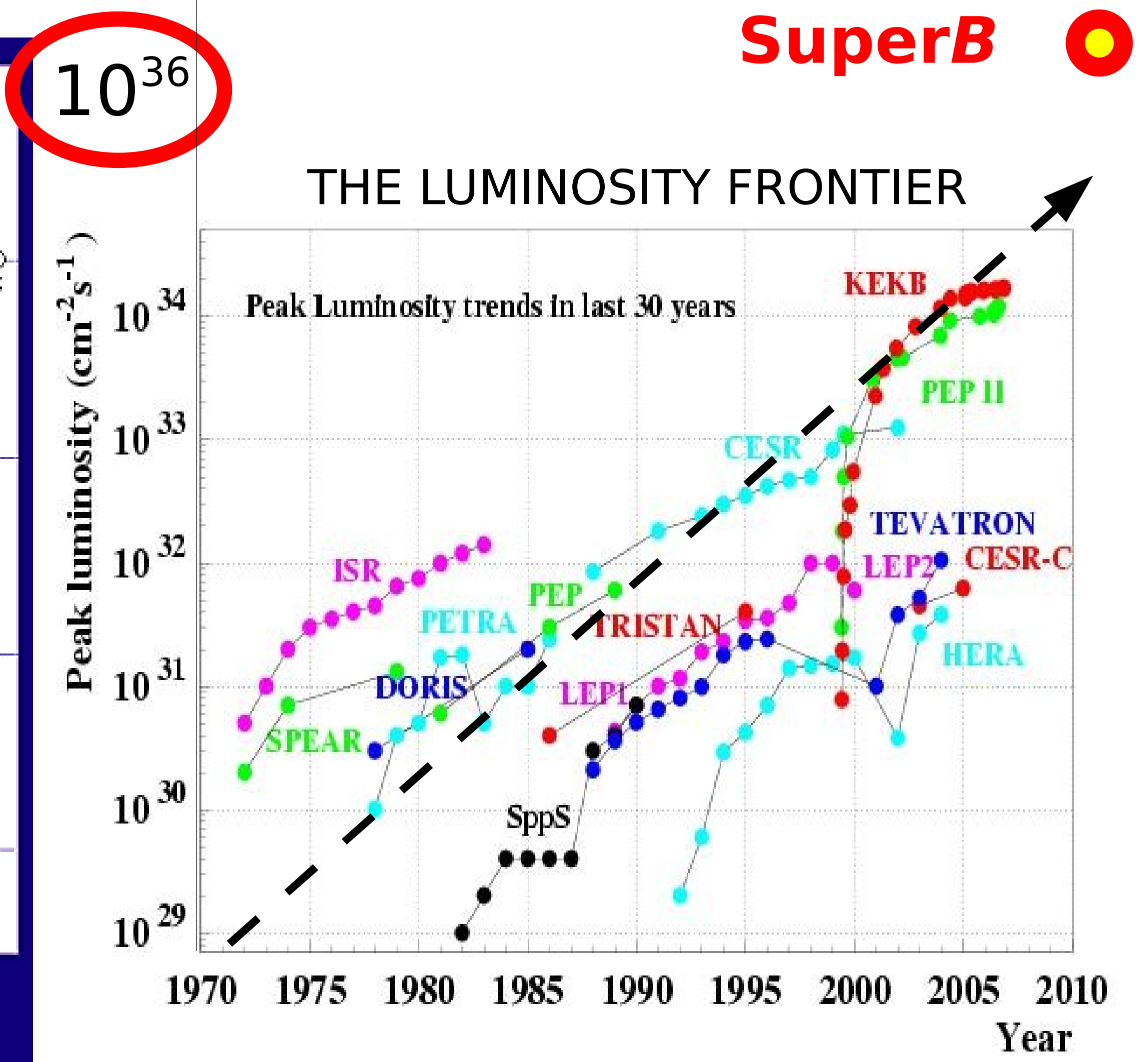
Sensitivity depends on:

luminosity

knowledge of Standard Model backgrounds

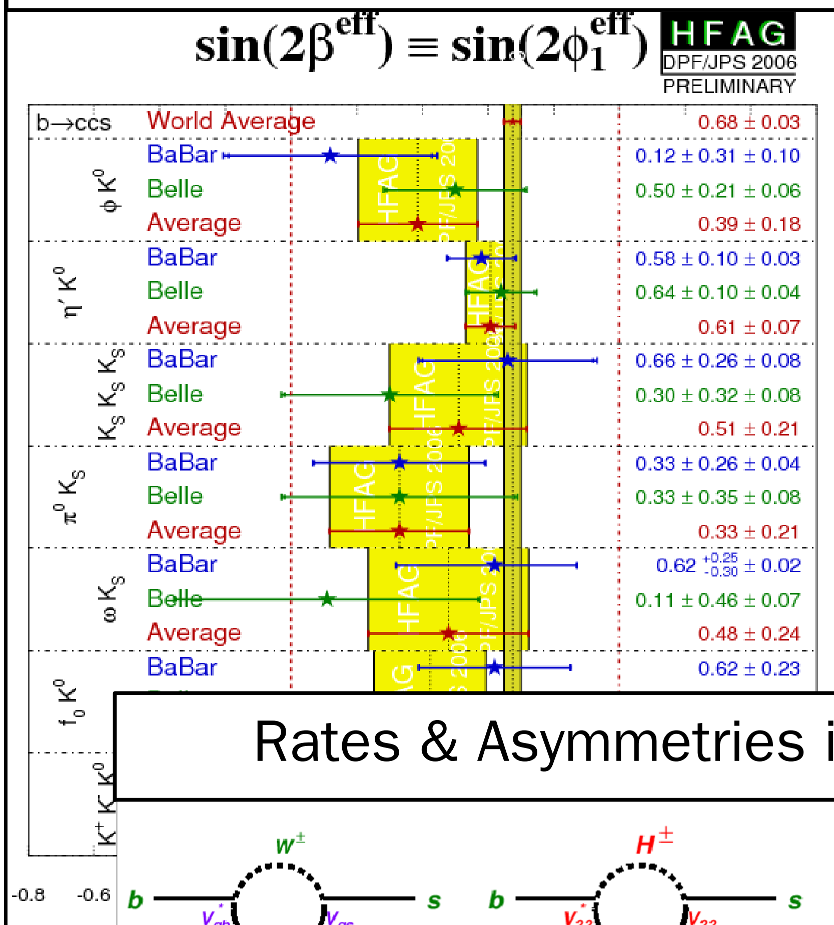
Exploration of Two Frontiers



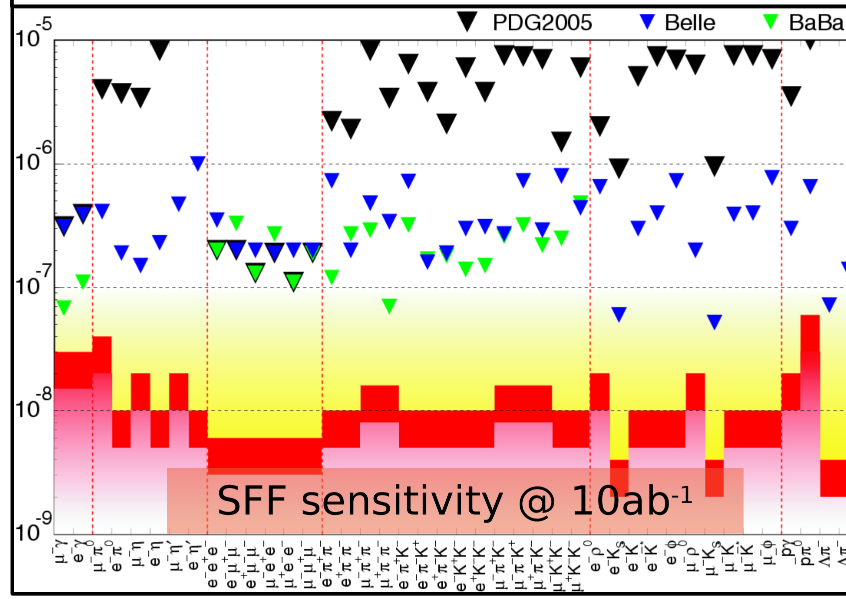


Some Key Measurements

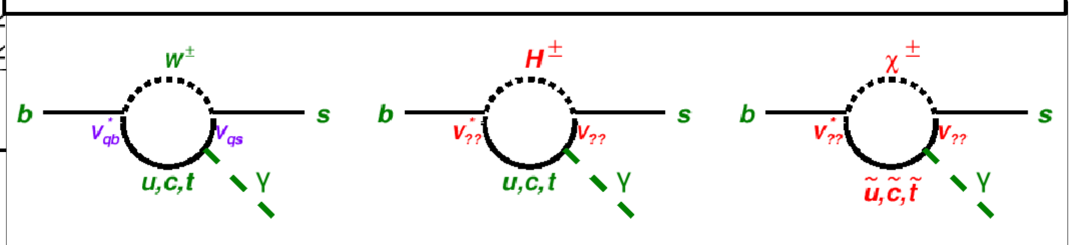
CP Violation in Hadronic b→s



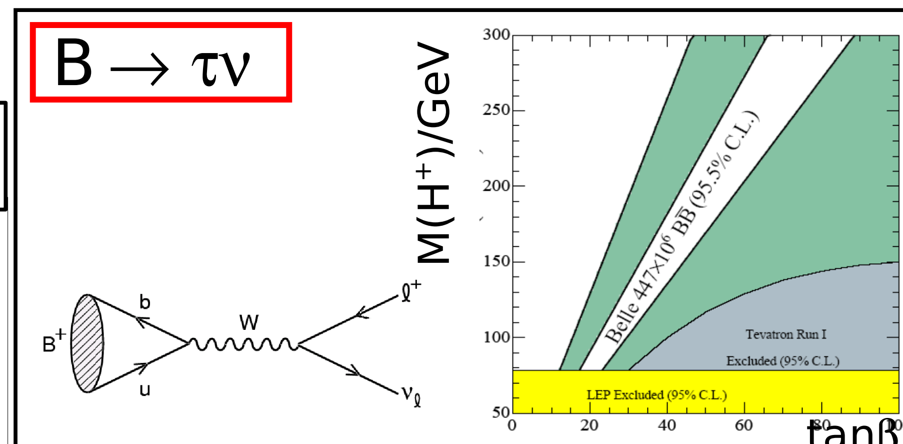
Lepton Flavour Violation in τ Decay



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)

MSSM

$M^2_{\tilde d} =$

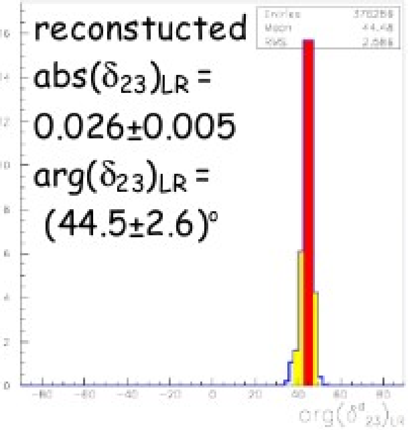
SuperB

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

LHC, ILC - HE frontier

Mass Insertions

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

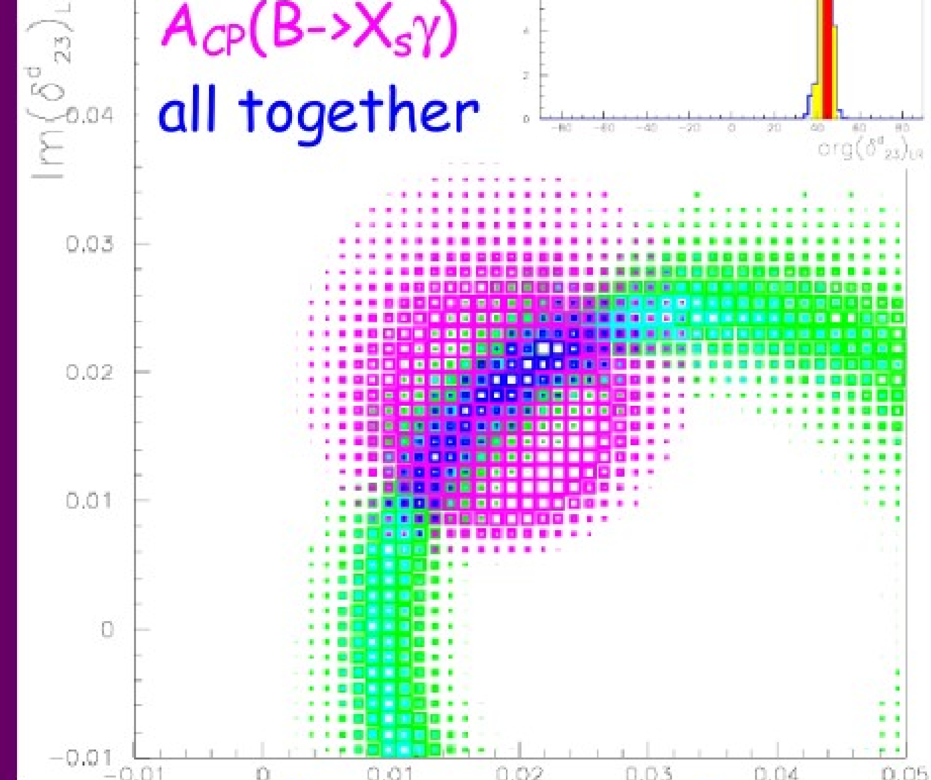


BR(B->$X_s\gamma$)

BR(B->$X_s$ll)

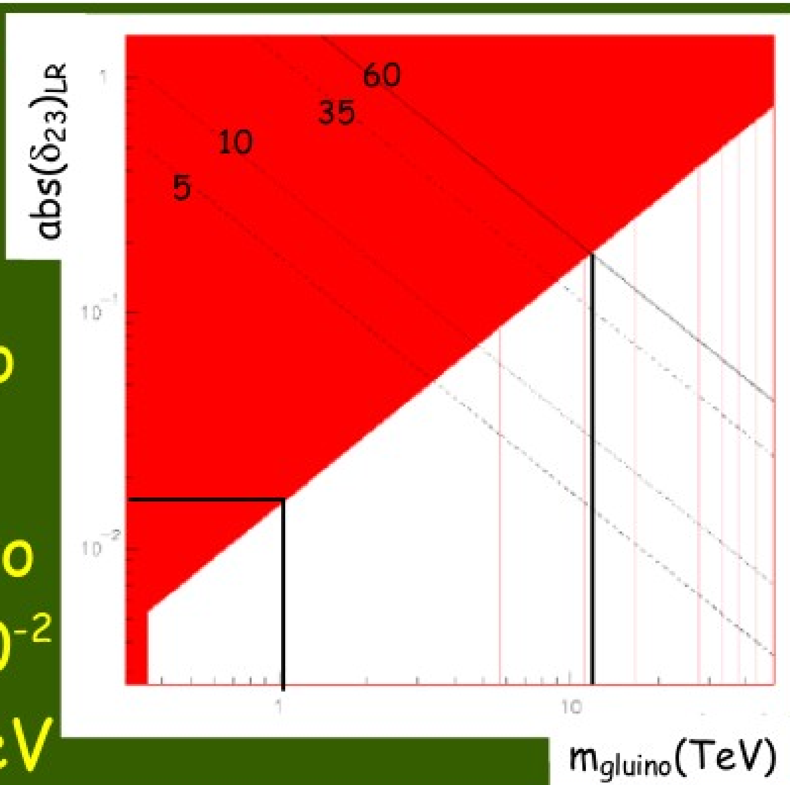
A_{CP}(B->$X_s\gamma$)

all together



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

3σ from 0 sensitivity plot



i) sensit. to $\Lambda<20$ TeV

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

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

M.Ciuchini at SuperB Review, LNF, 12 November

New Physics Sensitivity in MFV

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

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

Today
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→sγ)

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 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