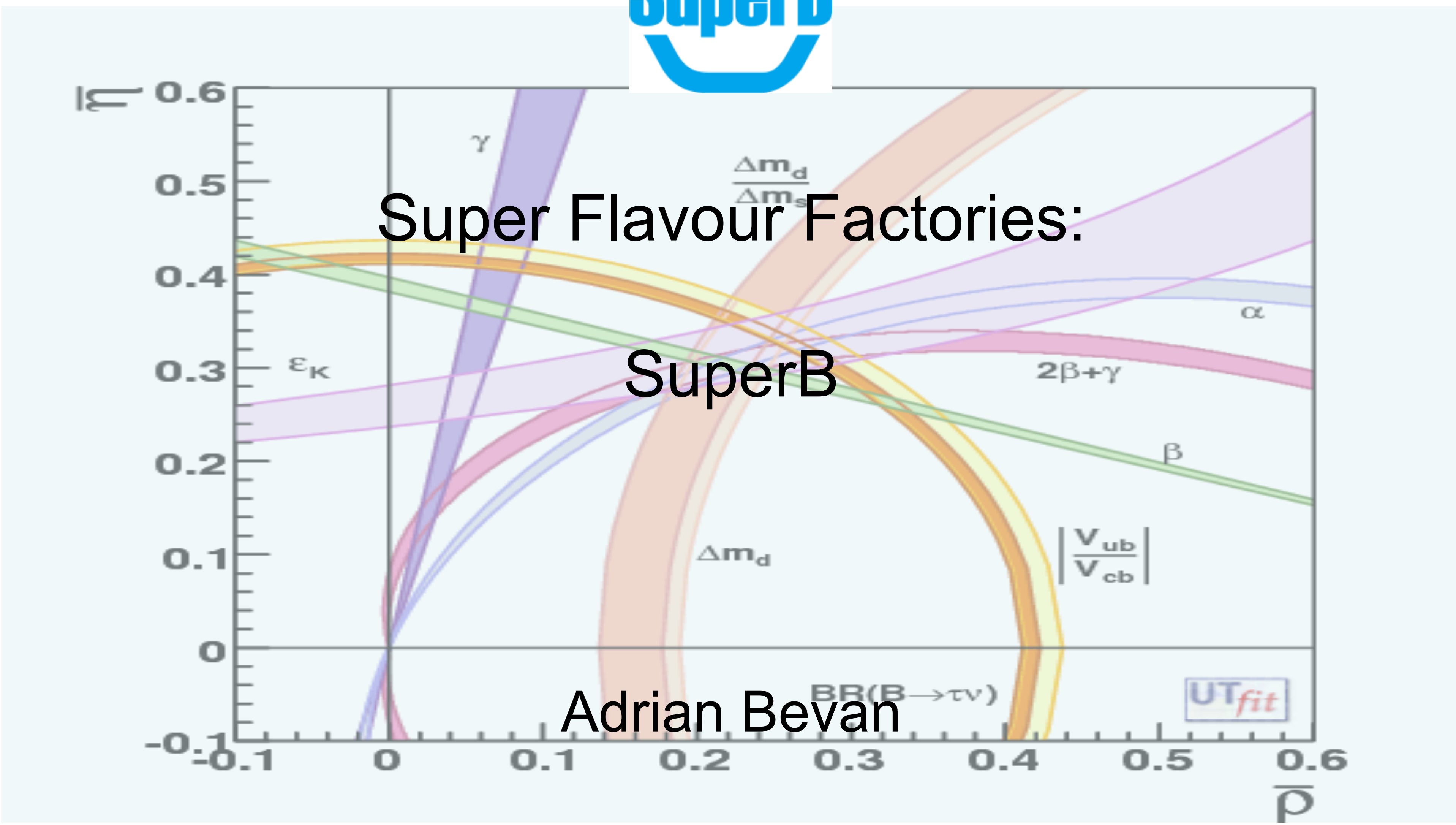
Super Flavour Factories:

SuperB

Adrian Bevan



Birmingham 11th November 2009

Conceptual Design Report: arXiv:0709.0451 (hep-ex)
http://web.infn.it/superb/index.php/home

Queen Mary
University of London

Overview

- What is SuperB?
- Physics Case in the LHC era
- Accelerator Aspects
- Detector Design
- Current Status
- Summary

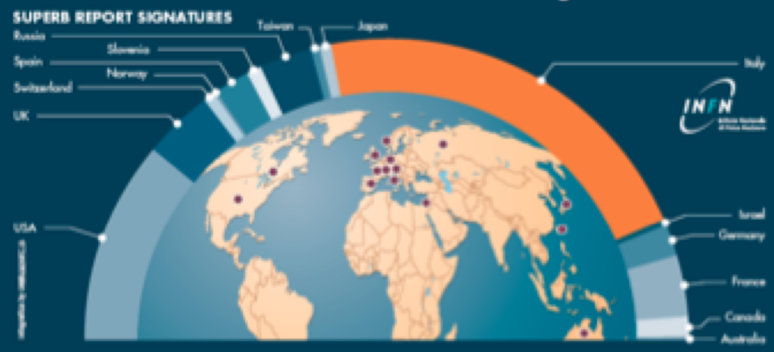
What is SuperB?

SuperB (In a Nutshell)

Site: Tor Vergata Campus (Rome II)

- Asymmetric energy e^+e^- collider
- Low emittance operation (like LC)
- Polarised beams
- Luminosity 10^{36} $cm^{-2}s^{-1}$
    - $75ab^{-1}$ data at the $\Upsilon(4S)$
    - Collect data at other $\sqrt{s}$
    - Start data taking as early as 2015
- Crab Waist technique developed to achieve these goals

- International Community



Geographical distribution of CDR signatories.

Precision B, D and τ decay studies and spectroscopy

- New Physics in loops
    - 10 TeV reach at $75ab^{-1}$
    - Rare decays
    - ΔS CP violation measurements
- Lepton Flavour & CP Violation in τ decay
- Light Higgs searches
- Dark Matter searches

http://web.infn.it/superb/index.php/home

SuperB

- Aims to constrain flavour couplings of new physics at high energy:
  - Refine understanding of nature if new physics exists at high energy.
    - We need to test the anzatz that new physics might flavour blind:
      - Case 1: trivial solution → Reject more complicated models.
      - Case 2: non-trivial solution → Reject flavour blind models.

Quarks and neutrinos have non-trivial couplings. e,g, the CKM matrix in the Standard Model of particle physics. How far fetched is a trivial flavour blind new physics sector?

$$J^{\mu} = \begin{pmatrix} \overline{u} & \overline{c} & \overline{t} \end{pmatrix} \frac{\gamma^{\mu}(1-\gamma^{5})}{2} \begin{pmatrix} c_{12}c_{13} & s_{12}c_{13} & s_{13}e^{-i\delta} \\ -s_{12}c_{23} - c_{12}s_{23}s_{13}e^{i\delta} & c_{12}c_{23} - s_{12}s_{23}s_{13}e^{i\delta} & s_{23}c_{13} \\ s_{12}s_{23} - c_{12}c_{23}s_{13}e^{i\delta} & -c_{12}s23 - s_{12}c_{23}s_{13}e^{i\delta} & c_{23}c_{13} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

SuperB

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      - Case 2: non-trivial solution → Reject flavour blind models.

e.g. MSSM: 124 (160 with v_R) couplings, most are flavour related.

Δ's are related to NP mass scale.

LHCb, SuperB

LHC, ILC - HE frontier

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

and similarly for $M^2_{\tilde u}$

SuperB

- Aims to constrain flavour couplings of new physics at high energy:
  - Refine understanding of nature if new physics exists at high energy.
    - We need to test the anzatz that new physics might flavour blind:
      - Case 1: trivial solution → Reject more complicated models.
      - Case 2: non-trivial solution → Reject flavour blind models.
  - If the LHC doesn't find new physics: SuperB indirectly places constraints beyond the reach of the LHC and SLHC.

SuperB

- The measurements to be made at SuperB fall into two categories:
  - New physics sensitive goals of the experiment
    - Some of these physics processes will be discussed in a moment: B, D, τ, Υ, ...
    - This is why we want to build SuperB!

  - Standard Model calibrations (*I won't talk about this*)
    - This is how we validate our understanding of the detector: repeating measurements done by BaBar/Belle and LHCb.
    - The equivalent of doing W, Z and PDF physics at ATLAS/CMS.

Case studies:

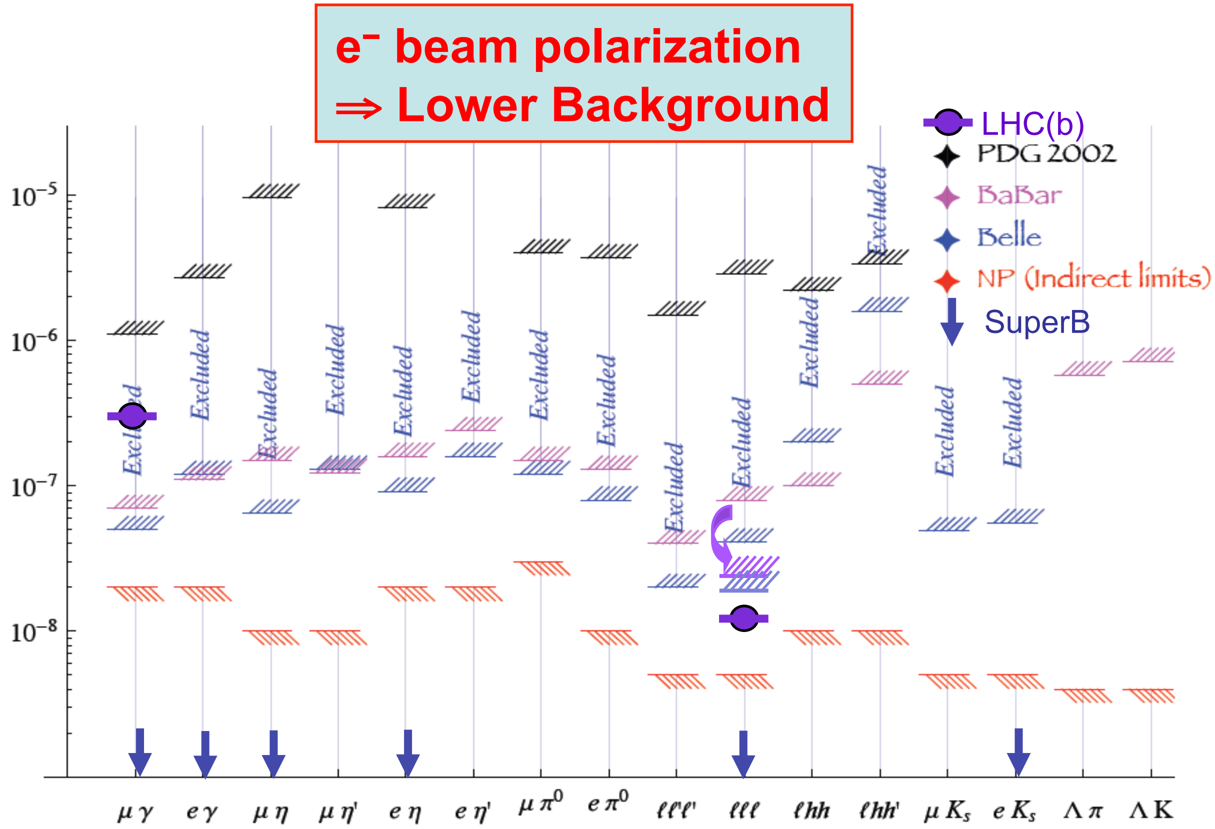
1. **Lepton Flavour Violation**: τ decay as an example of many LFV measurements possible at SuperB.
2. **Charged Higgs:** what do we know; what will LHC tell us; what does SuperB add?
3. **Neutral Higgs A0**: what can the flavour sector add to high p_T searches?
4. **ΔS measurements**: high mass particle interferometry.

Physics Case in the LHC era

Why is SuperB experiment relevant when we have the energy frontier experiments and LHCb?

What is the minimum data set to make sure that we are doing something sensible?

Lepton Flavour Violation (τ decay)



SuperB Sensitivity ($75 ab^{-1}$)

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}

- LHC is ***not*** competitive (Re: both GPDs and LHCb).
- SuperB sensitivity ~10 – 50× better than NP allowed branching fractions.

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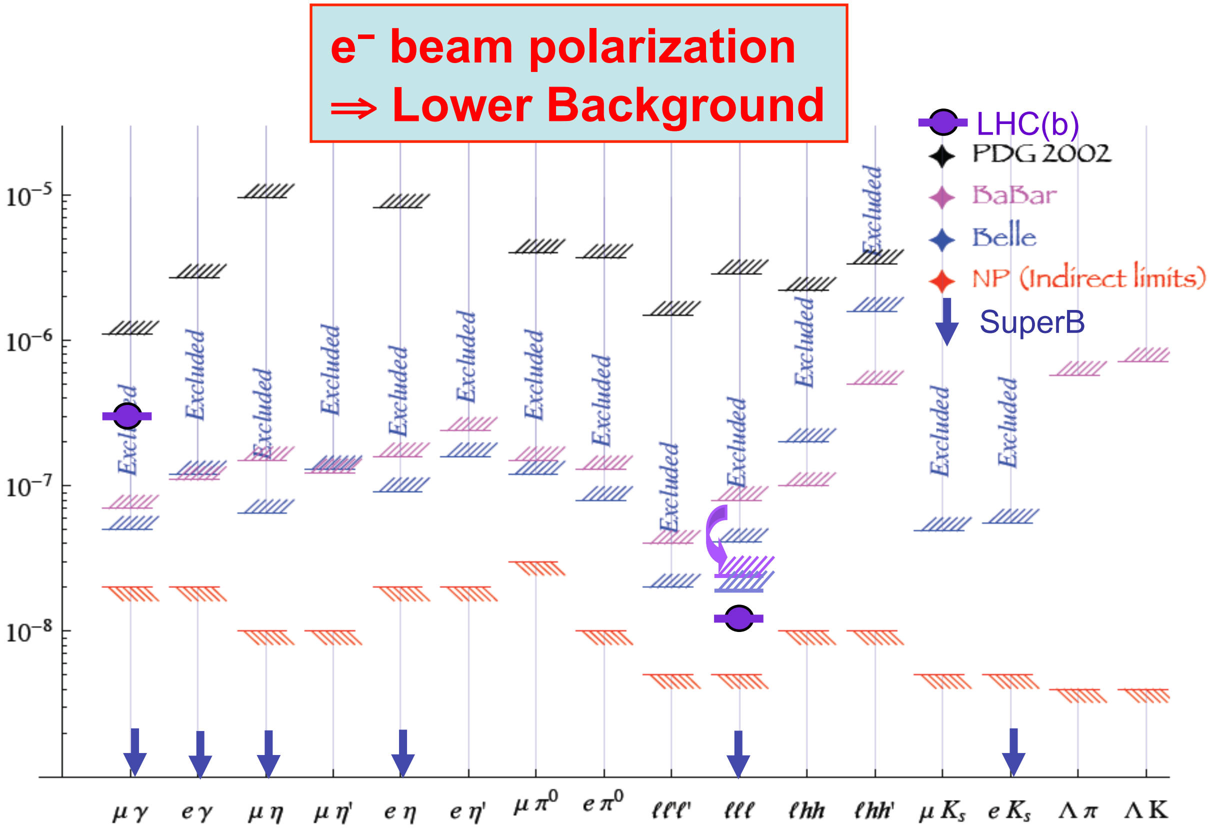

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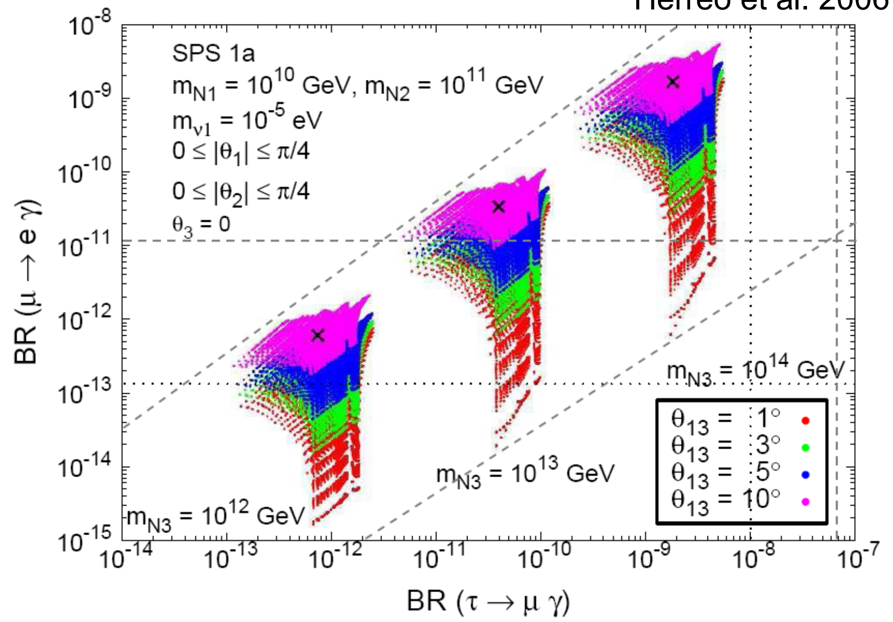
- $\tau \to \mu\gamma$ upper limit can be correlated to θ_{13} (neutrino mixing/CPV, T2K etc.) and also to $\mu \to e\gamma$.
- Complementary to flavour mixing in quarks.
- Golden modes:
  - $\tau \to \mu\gamma$ and 3μ.
- e^- beam polarization:
  - Lower background
  - Better sensitivity than competition!
- e^+ polarization may be used later in programme.
- CPV in $\tau \to K_S \pi \nu$ at the level of $\sim 10^{-5}$.
- Bonus:
  - Can also measure τ g-2 (polarization is crucial).
  - σ(g-2) $\sim 2.4 \times 10^{-6}$ (statistically dominated error).

SUSY seasaw = CMSSM + $3\nu_R$ + $\tilde{\nu}$

Herreo et al. 2006



Process	Expected 90%CL upper limited	4σ Discovery Reach
$\mathcal{B}(\tau \to \mu\gamma)$	2×10^{-9}	5×10^{-9}
$\mathcal{B}(\tau \to \mu\mu\mu)$	2×10^{-10}	8.8×10^{-10}

Use $\mu\,\gamma$/3l to distinguish SUSY vs. LHT.

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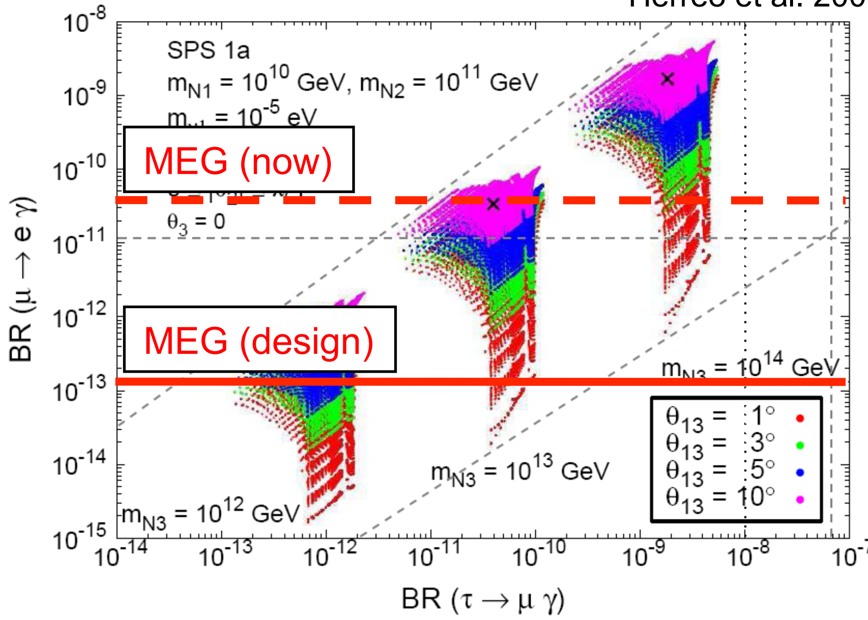

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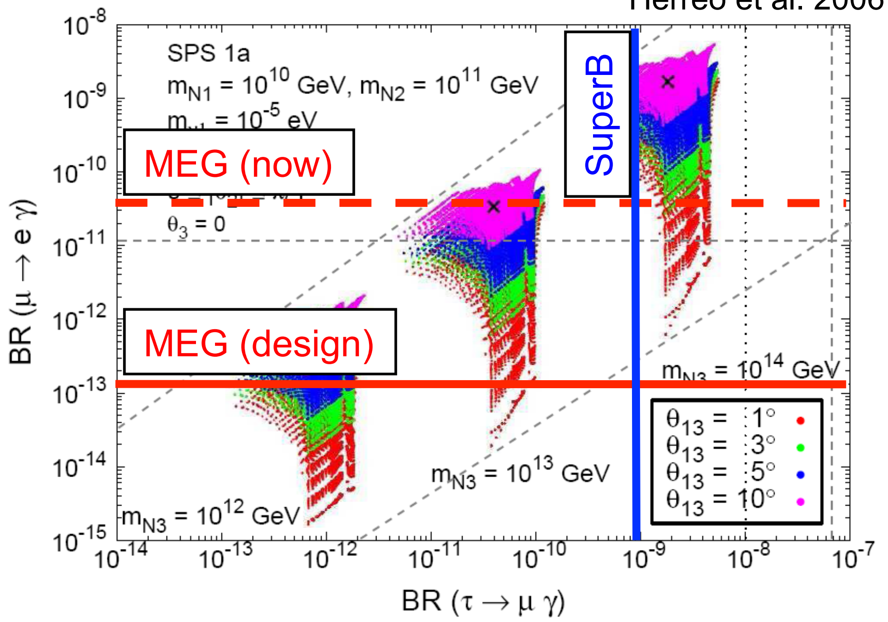

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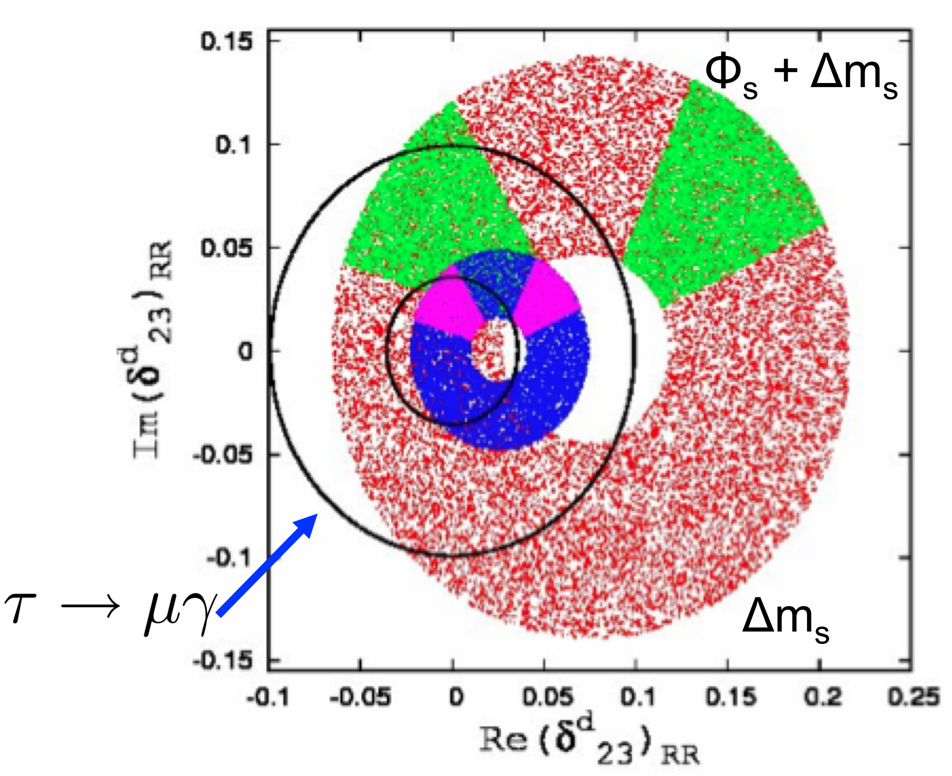
Lepton Flavour Violation (τ decay)

$m_{\tilde{q}} = 300\, GeV$ BLUE

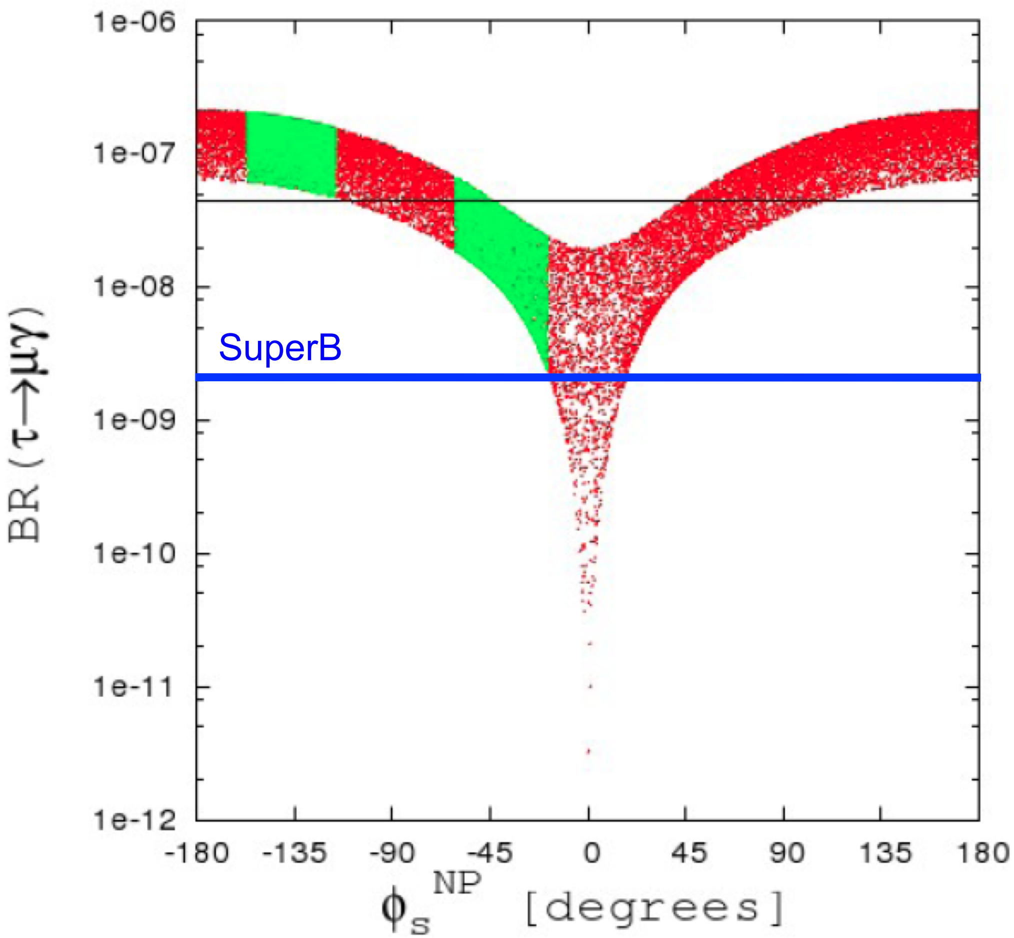
$m_{\tilde{q}} = 500\, GeV$ RED



- SU(5) SUSY GUT Model (arXiv :0710.5443, Parry and Zhang).
- Model has non-trivial SUSY squark couplings.
- Current BS mixing measurement favours B(τ➔μγ)>3X10^{-9}.
- Need SuperB to probe to this sensitivity.

N.B. Different New Physics Models have different features, and different hierarchies!

Lepton Flavour Violation (τ decay)



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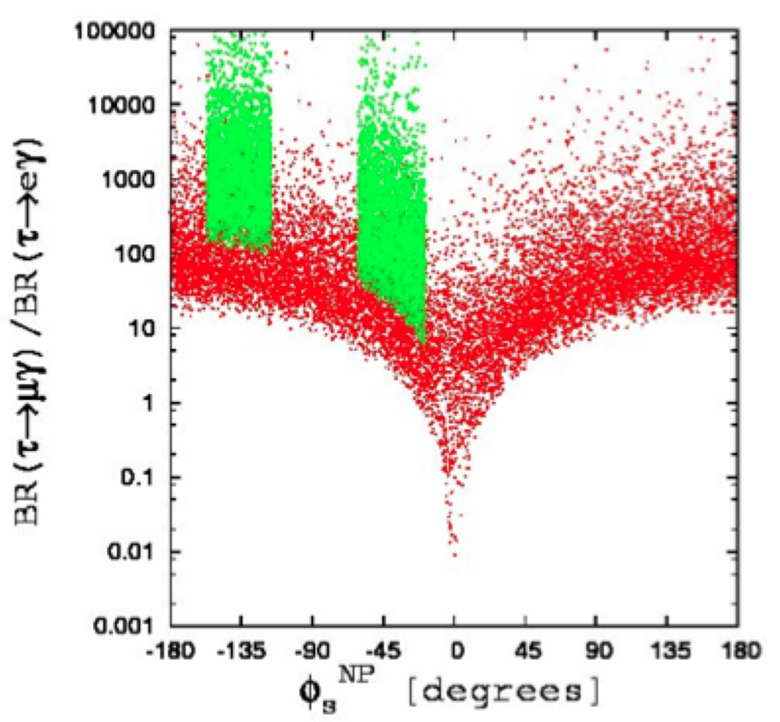

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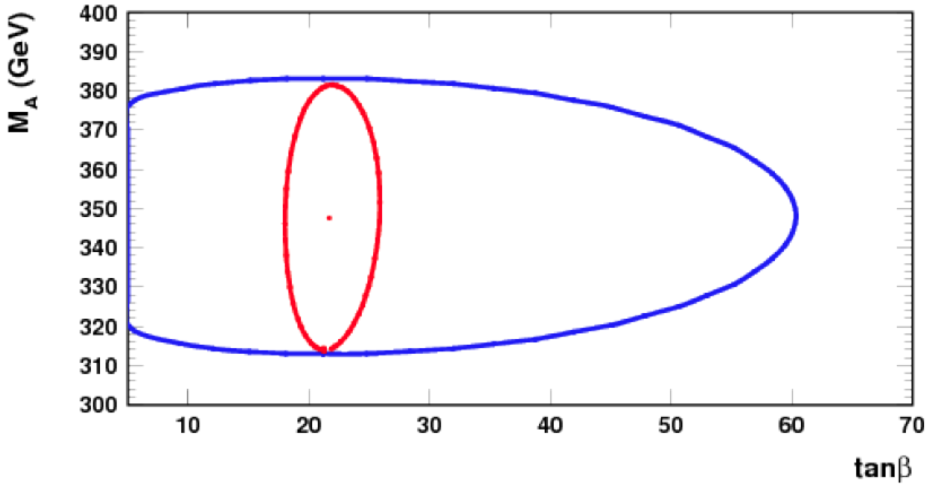
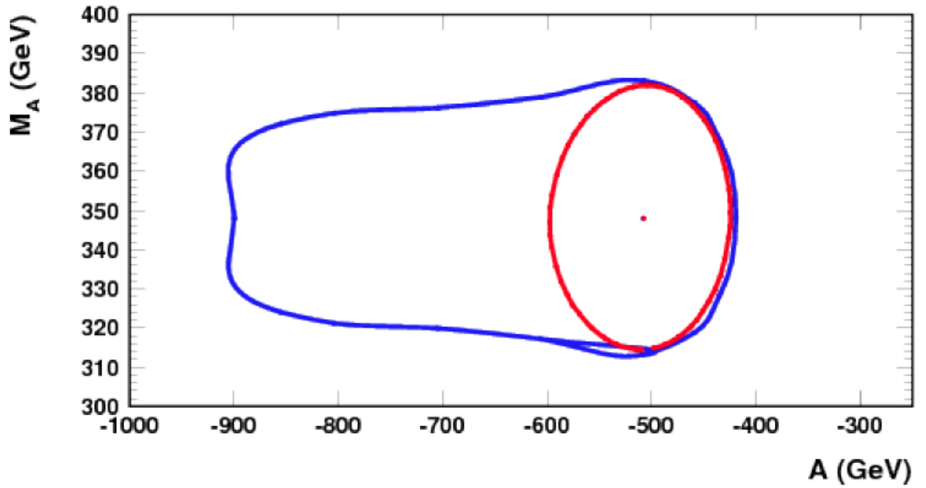
CMSSM: LHC/SuperB complementarity





Blue = LHC:

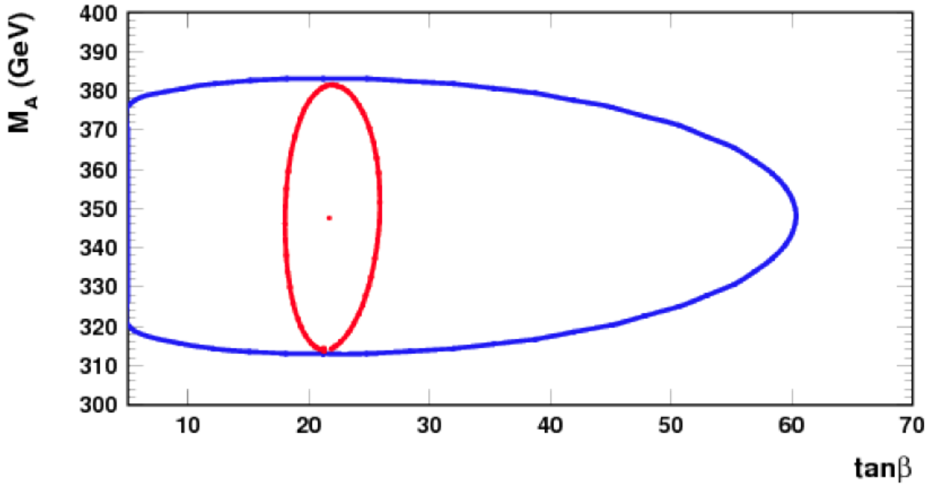
- Will be able to measure m(A) [CP odd Higgs mass]
- Poor sensitivity to tanβ [ratio of Higgs vevs]
- Poor sensitivity to A [coupling]

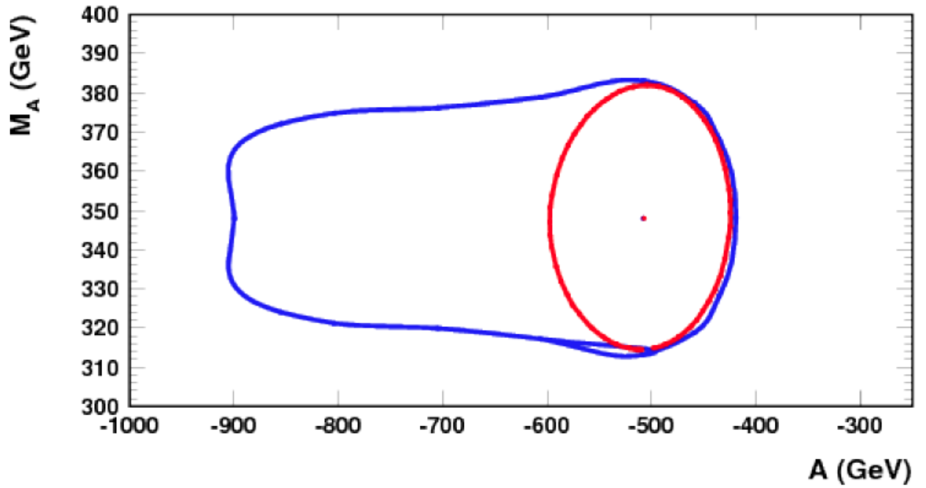
Red=LHC+EW/Low-energy constraints (includes SuperB):

Observable	Constraint	theo. error
$R_{\mathrm{BR}_{b\to s\gamma}}$	1.127 ± 0.1	0.1
$R_{\Delta M_s}$	0.8 ± 0.2	0.1
$\mathrm{BR}_{b\to\mu\mu}$	$(3.5 \pm 0.35) \times 10^{-8}$	2×10^{-9}
$R_{\mathrm{BR}_{b\to\tau\nu}}$	0.8 ± 0.2	0.1
Δa_μ	$(27.6 \pm 8.4) \times 10^{-10}$	2.0×10^{-10}
M_W^{SUSY}	80.392 ± 0.020 GeV	0.020 GeV
$\sin^2\theta_W^{\mathrm{SUSY}}$	0.23153 ± 0.00016	0.00016
$M_h^{\mathrm{light}}(\mathrm{SUSY})$	> 114.4 GeV	3.0 GeV

Current analysis of data prefers tanβ~10.

CMSSM: LHC/SuperB complementarity





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- Will be able to measure m(A) [CP odd Higgs mass]
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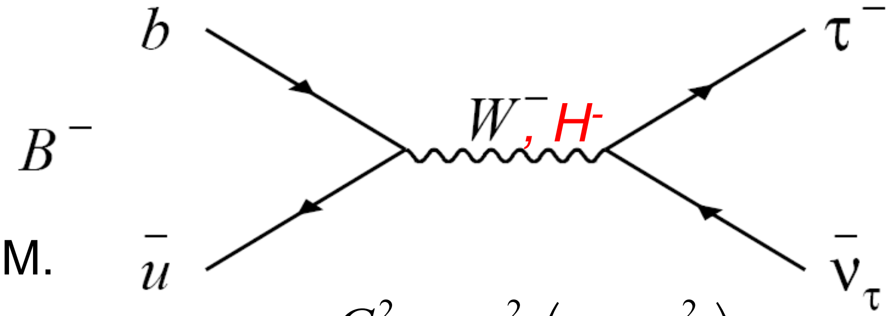
Red=LHC+EW/Low-energy constraints (includes SuperB):

- Can build on the m(A) measurement to measure tanβ.

Again LHC and SuperB are complementary experiments. Each can contribute significantly to the knowledge of new physics.

Charged Higgs: $B^{\pm} \rightarrow \tau^{\pm}\nu$

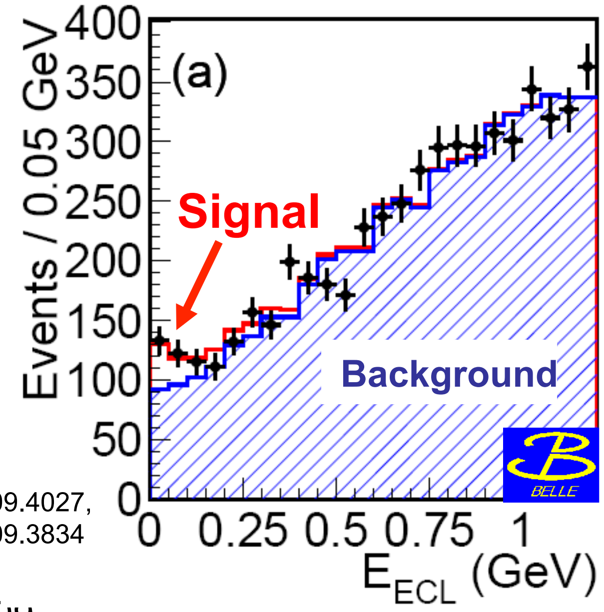
- Within the SM, sensitive to f_B and $|V_{ub}|$: $\mathcal{B}_{SM}$~1.6×10^{-4}.
- $\mathcal{B}$ affected by new physics.
  - MFV models like 2HDM / MSSM.
  - Unparticles.



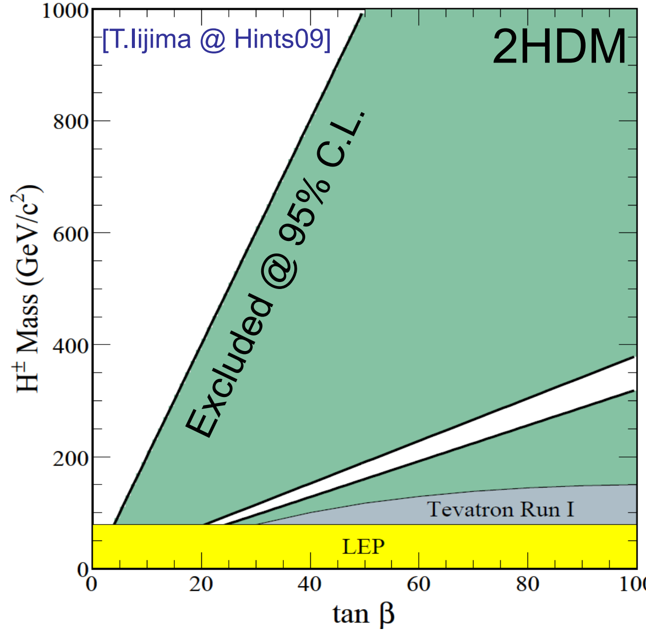
$$\mathcal{B}_{SM}(B^+ \rightarrow l^+\nu_l) = \frac{G_F^2 m_B m_l^2}{8\pi}\left(1-\frac{m_l^2}{m_B^2}\right) f_B^2 \, |V_{ub}|^2 \, \tau_B$$

- Fully reconstruct the event (modulo ν).

$$\mathcal{B}_{\rm WA} = \left(1.73 \pm 0.35\right)\times10^{-4}$$



arXiv:0809.4027,
arXiv:0809.3834

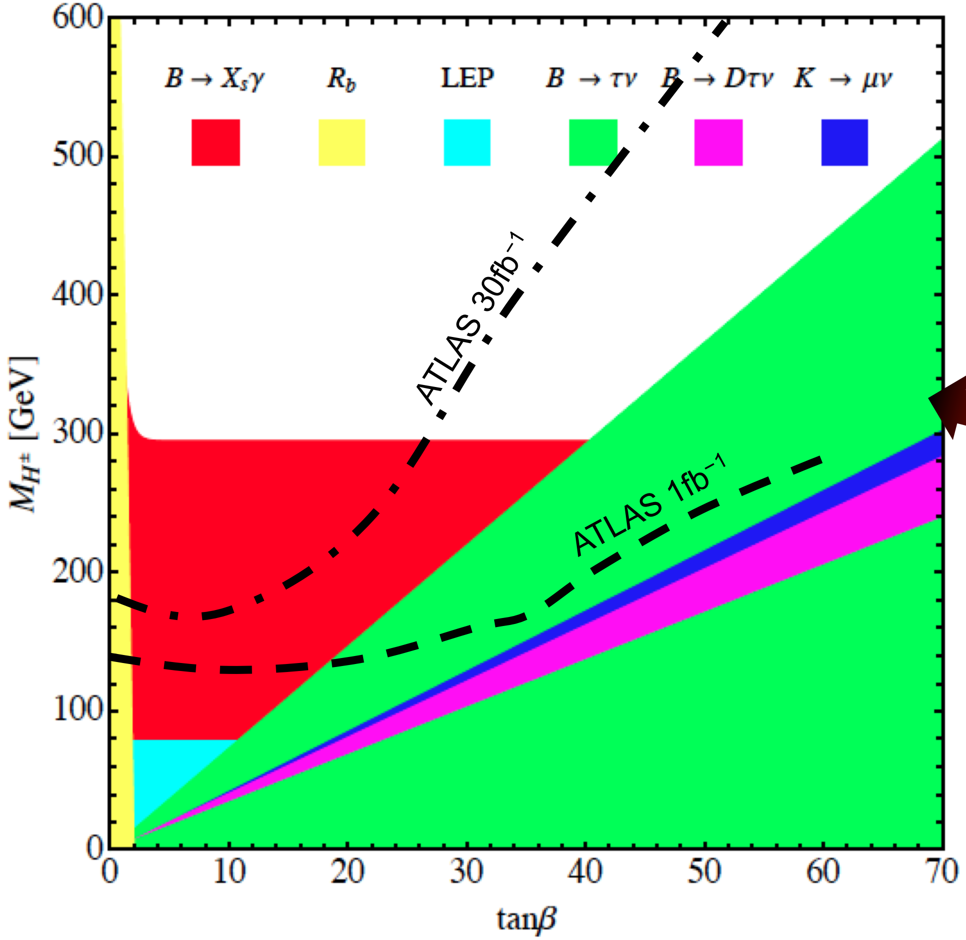


2HDM: W.-S Hou PRD **48** 2342 (1993)
MSSM: G. Isidori arXiv:0710.5377
Unparticles: R. Zwicky PRD**77** 036004 (2008)

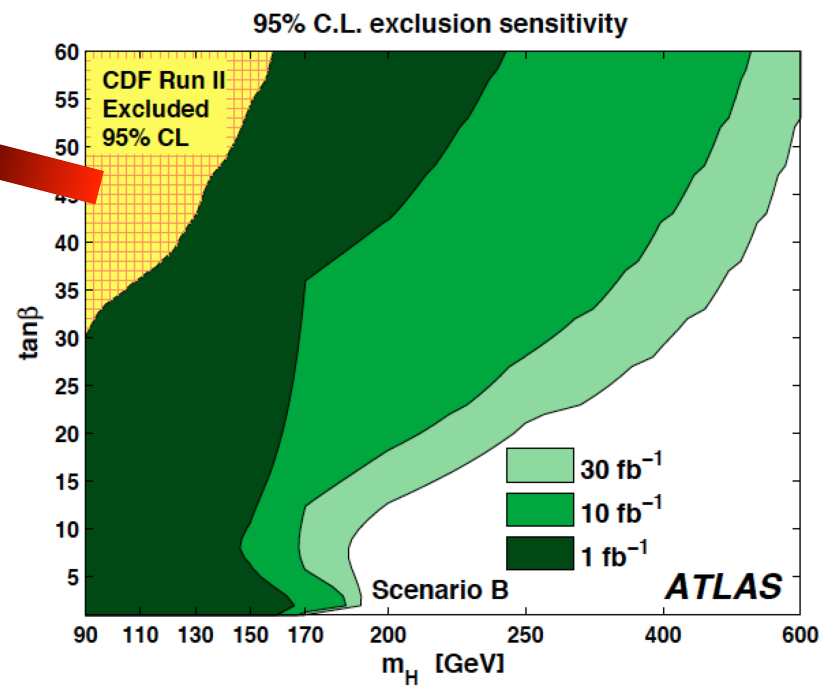
Charged Higgs

- B-factory searches competitive with LHC era: e.g. 2HDM

Existing Constraints from BaBar and Belle.
Combined Higgs search constraint from ATLAS: arXiv:0901.1502



Converted constraints expected from ATLAS onto the plot by hand.

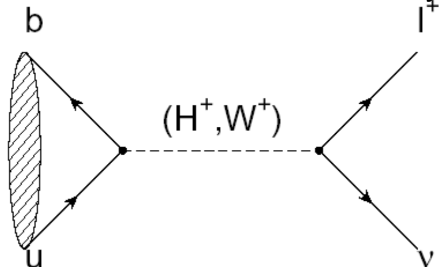


U. Haisch 0805.2141

Charged Higgs

Charm equivalent: $D_s^+ \rightarrow \mu^+\nu, \tau^+\nu$

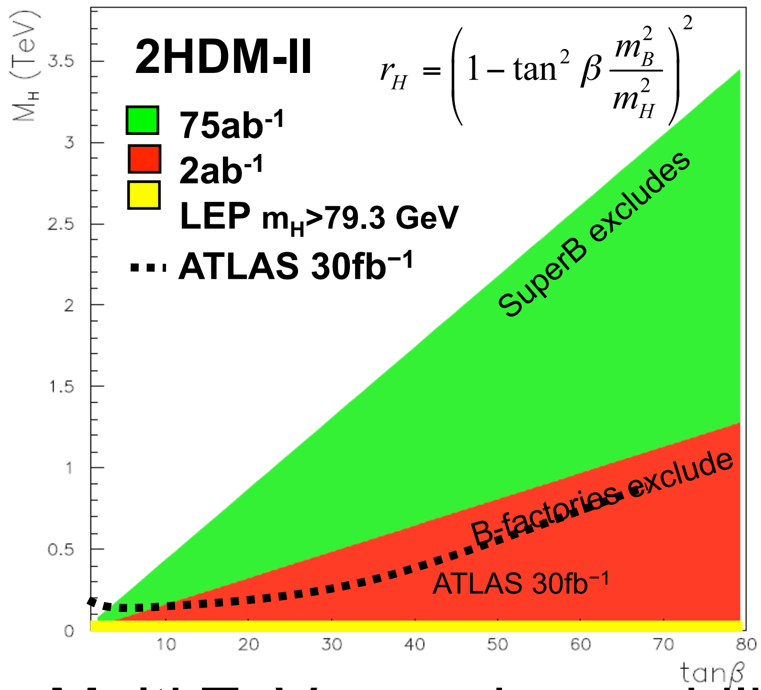
B-factories have $1.5ab^{-1}$ of data.
ATLAS sensitivity sketched from combined sensitivity plots in arXiv:0901.0512.

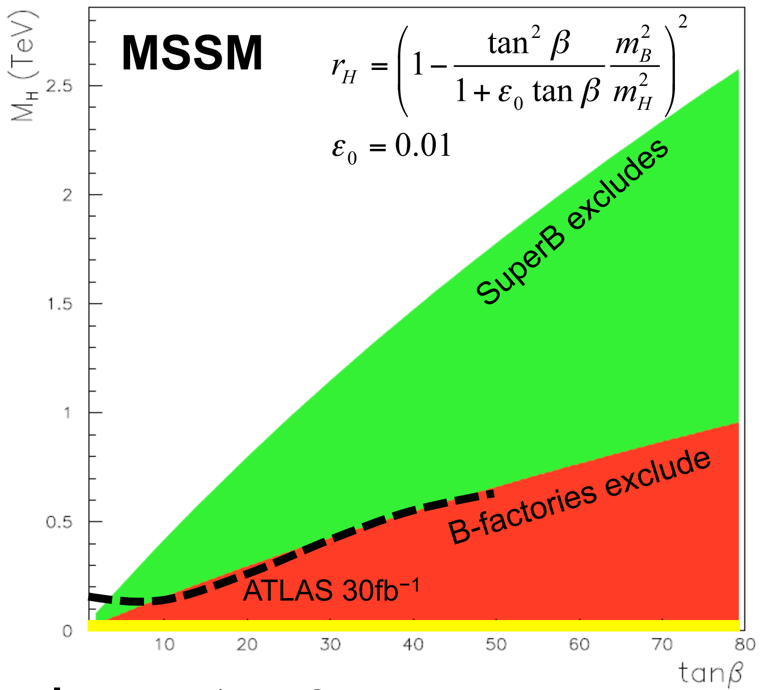


- Higgs mediated MFV:

$$r_H = \frac{\mathcal{B}_{SM+NP}}{\mathcal{B}_{SM}}$$

(Assuming SM branching fraction is measured)





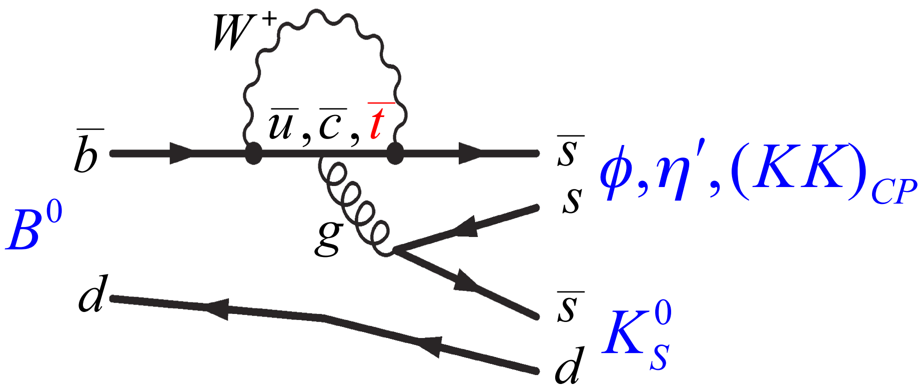
- Multi TeV search capability for large tanβ.
- Includes SM uncertainty ~20% from V_{ub} and f_B.

ΔS measurements

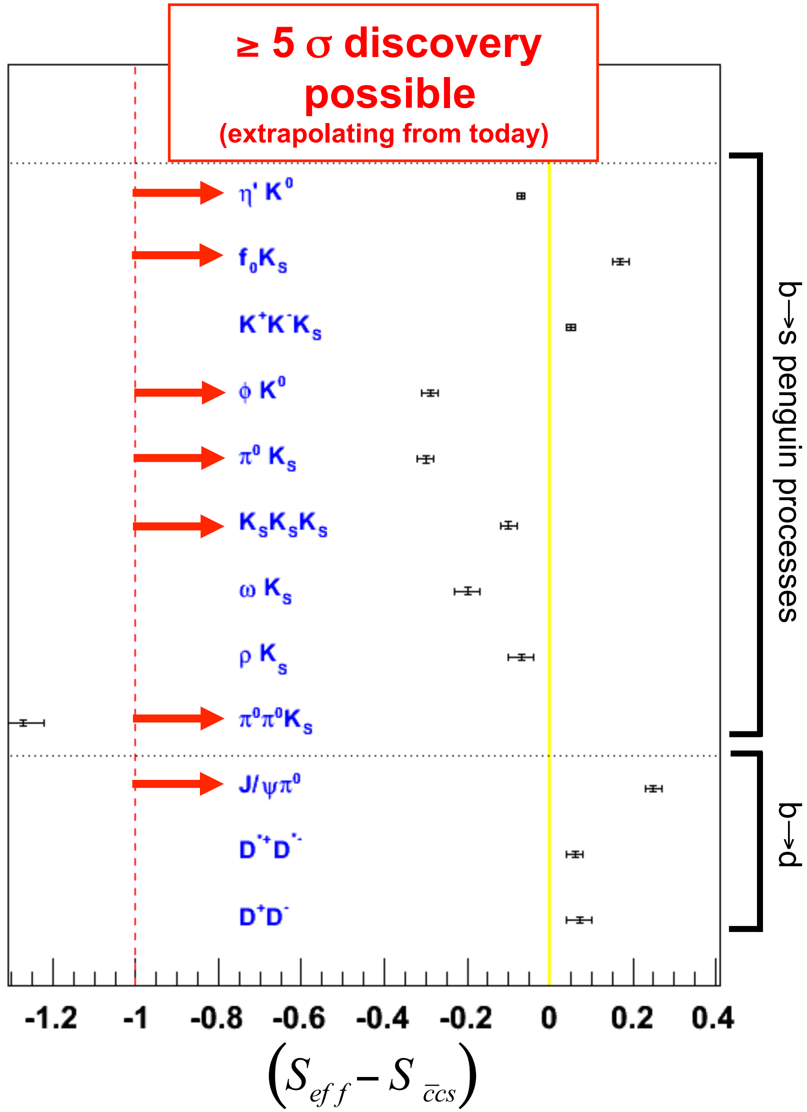
- $\beta=(21.1\pm0.9)^\circ$ from Charmonium decays.
- Look in many different b→s and b→d decays for sin2β deviations from the SM:

$$\Delta S_{\rm NP} = S_{eff} - S_{c\bar{c}s} - \Delta S_{\rm SM}$$

- The golden channel is:

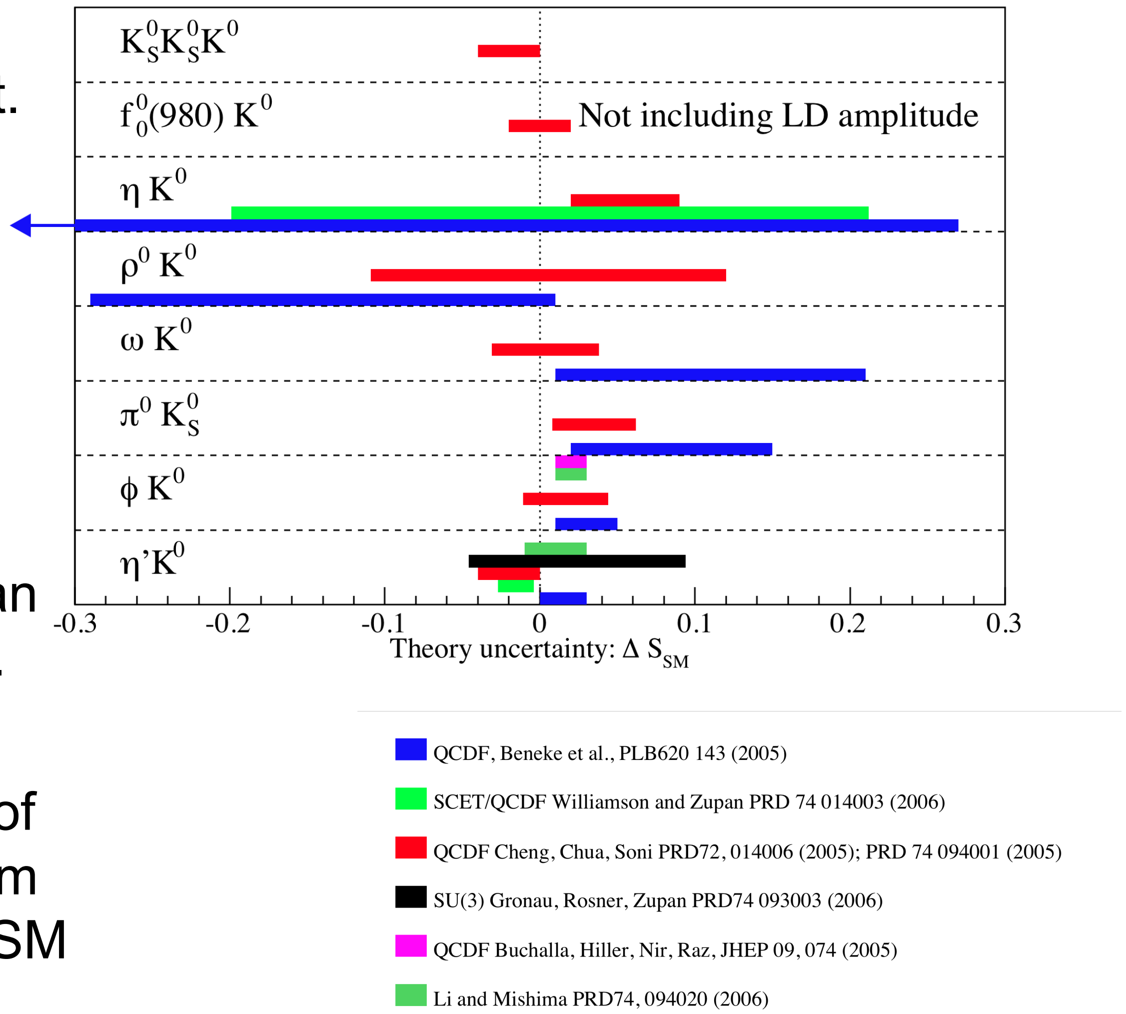


- Deviations would be from high mass particles in loops: H, χ, ...



ΔS measurements

- The SM uncertainty is strongly mode dependent.
- Golden modes have to be well measured and theoretically clean.
- Prefer to also have robust constraints from more than one theoretical approach.
- Precision measurements of the reference Charmonium decay also have a small SM uncertainty.



ΔS measurements

- We were reminded that we should be careful with what we compare:
  - NP could affect $c\bar{c}s$ sin2β.

1) Predict sin2β from indirect constraints.

$$[\sin(2\beta)]^{\rm prediction}_{{\rm no}\ V_{ub}} = 0.87 \pm 0.09 \,.$$

2) Compare to $\bar{c}cs$ measurement.

$$[\sin 2\beta]_{c\bar{c}s} = 0.672 \pm 0.023$$

3) Compare to clean penguin measurements.

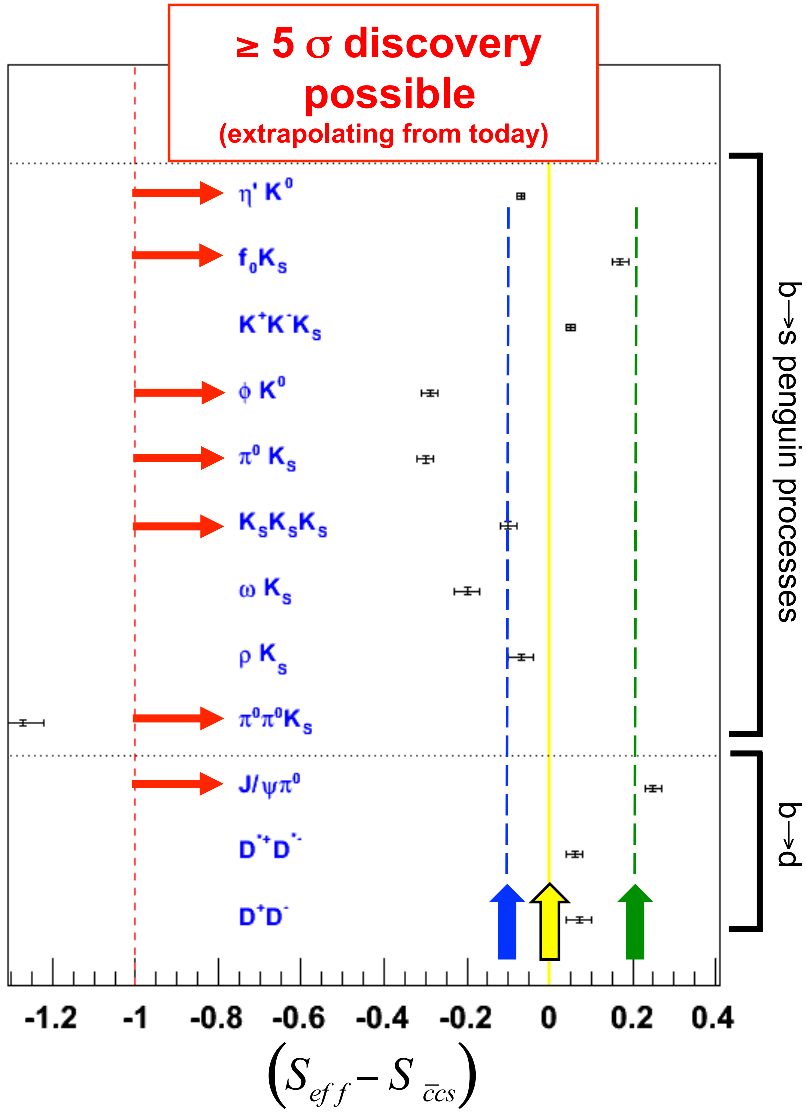
$$[\sin 2\beta]^{clean}_{b\to s-penguin} = 0.58 \pm 0.06$$

(or the average of the two)

Are these 2.1-2.7σ hints for new physics?

Lunghi and Soni, Phys.Lett.B**666** 162-165 (2008).
Buras and Guadagnoli Phys Rev D **78** 033005 (2008).

- **Can theory error be reduced for other modes?**



Standard Model measurements.

B Physics at Υ(4S)

Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab^{-1})
$\sin(2\beta)$ $(J/\psi K^0)$	0.018	0.005 (†)
$\cos(2\beta)$ $(J/\psi K^{*0})$	0.30	0.05
$\sin(2\beta)$ (Dh^0)	0.10	0.02
$\cos(2\beta)$ (Dh^0)	0.20	0.04
$S(J/\psi \pi^0)$	0.10	0.02
$S(D^+D^-)$	0.20	0.03
$S(\phi K^0)$	0.13	0.02 (∗)
$S(\eta' K^0)$	0.05	0.01 (∗)
$S(K_S^0 K_S^0 K_S^0)$	0.15	0.02 (∗)
$S(K_S^0 \pi^0)$	0.15	0.02 (∗)
$S(\omega K_S^0)$	0.17	0.03 (∗)
$S(f_0 K_S^0)$	0.12	0.02 (∗)
γ $(B \to DK, D \to CP$ eigenstates)	$\sim 15^\circ$	2.5°
γ $(B \to DK, D \to$ suppressed states)	$\sim 12^\circ$	2.0°
γ $(B \to DK, D \to$ multibody states)	$\sim 9^\circ$	1.5°
γ $(B \to DK$, combined)	$\sim 6^\circ$	1–2°
α $(B \to \pi\pi)$	$\sim 16^\circ$	3°
α $(B \to \rho\rho)$	$\sim 7^\circ$	1–2° (∗)
α $(B \to \rho\pi)$	$\sim 12^\circ$	2°
α (combined)	$\sim 6^\circ$	1–2° (∗)
$2\beta + \gamma$ $(D^{(*)\pm}\pi^\mp, D^\pm K_S^0 \pi^\mp)$	20°	5°
$\lvert V_{cb}\rvert$ (exclusive)	4% (∗)	1.0% (∗)
$\lvert V_{cb}\rvert$ (inclusive)	1% (∗)	0.5% (∗)
$\lvert V_{ub}\rvert$ (exclusive)	8% (∗)	3.0% (∗)
$\lvert V_{ub}\rvert$ (inclusive)	8% (∗)	2.0% (∗)
$\mathcal{B}(B \to \tau\nu)$	20%	4% (†)
$\mathcal{B}(B \to \mu\nu)$	visible	5%
$\mathcal{B}(B \to D\tau\nu)$	10%	2%
$\mathcal{B}(B \to \rho\gamma)$	15%	3% (†)
$\mathcal{B}(B \to \omega\gamma)$	30%	5%
$A_{CP}(B \to K^*\gamma)$	0.007 (†)	0.004 († ∗)
$A_{CP}(B \to \rho\gamma)$	~ 0.20	0.05
$A_{CP}(b \to s\gamma)$	0.012 (†)	0.004 (†)
$A_{CP}(b \to (s+d)\gamma)$	0.03	0.006 (†)
$S(K_S^0 \pi^0 \gamma)$	0.15	0.02 (∗)
$S(\rho^0 \gamma)$	possible	0.10
$A_{CP}(B \to K^*\ell\ell)$	7%	1%
$A^{FB}(B \to K^*\ell\ell)s_0$	25%	9%
$A^{FB}(B \to X_s\ell\ell)s_0$	35%	5%
$\mathcal{B}(B \to K\nu\overline{\nu})$	visible	20%
$\mathcal{B}(B \to \pi\nu\bar{\nu})$	–	possible

Rare Charm Decays: 1 month at ψ(3770)

Channel	Sensitivity
$D^0 \to e^+e^-$, $D^0 \to \mu^+\mu^-$	1×10^{-8}
$D^0 \to \pi^0 e^+e^-$, $D^0 \to \pi^0\mu^+\mu^-$	2×10^{-8}
$D^0 \to \eta e^+e^-$, $D^0 \to \eta\mu^+\mu^-$	3×10^{-8}
$D^0 \to K_S^0 e^+e^-$, $D^0 \to K_S^0\mu^+\mu^-$	3×10^{-8}
$D^+ \to \pi^+ e^+e^-$, $D^+ \to \pi^+\mu^+\mu^-$	1×10^{-8}
$D^0 \to e^\pm\mu^\mp$	1×10^{-8}
$D^+ \to \pi^+ e^\pm\mu^\mp$	1×10^{-8}
$D^0 \to \pi^0 e^\pm\mu^\mp$	2×10^{-8}
$D^0 \to \eta e^\pm\mu^\mp$	3×10^{-8}
$D^0 \to K_S^0 e^\pm\mu^\mp$	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}

Charm Mixing

Mode	Observable	$\Upsilon(4S)$ (75 ab^{-1})	$\psi(3770)$ (300 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		$(1-2) \times 10^{-3}$
	$\cos\delta$		$(0.01-0.02)$

See CDR and Valencia report for details of the SM measurements and other possible NP searches.

τ: LFV / CPV / …

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}

B Physics at Υ(5S)

Observable	Error with 1 ab^{-1}	Error with 30 ab^{-1}
$\Delta\Gamma$	0.16 ps^{-1}	0.03 ps^{-1}
Γ	0.07 ps^{-1}	0.01 ps^{-1}
β_s from angular analysis	20°	8°
A_{SL}^s	0.006	0.004
A_{CH}	0.004	0.004
$\mathcal{B}(B_s \to \mu^+\mu^-)$	-	$< 8 \times 10^{-9}$
$\lvert V_{td}/V_{ts}\rvert$	0.08	0.017
$\mathcal{B}(B_s \to \gamma\gamma)$	38%	7%
β_s from $J/\psi\phi$	10°	3°
β_s from $B_s \to K^0\bar{K}^0$	24°	11°

Golden Matrix

- No one smoking gun… rather a ‘***golden matrix***’.

	H^+ high $\tan\beta$	MFV	Non-MFV	NP Z-penguins	Right-handed currents	LTH	SUSY
$\mathcal{B}(B \to X_s\gamma)$		L	M		M		
$A_{CP}(B \to X_s\gamma)$			L		M		
$\mathcal{B}(B \to \tau\nu)$	L-CKM						
$\mathcal{B}(B \to X_s\ell\ell)$			M	M	M		
$\mathcal{B}(B \to K\nu\overline{\nu})$			M	L			
$S_{K_S\pi^0\gamma}$					L		
The angle β (ΔS)			L-CKM		L		
$\tau \to \mu\gamma$							L
$\tau \to \mu\mu\mu$						L	

… + other generic models

L = Large effect.
M = Measureable effect.
CKM= Precision CKM (from SuperB) required.

… + charm + spectroscopy (DM /Light Higgs etc).

- Need to measure all observables in order to select/eliminate new physics scenarios!

Mode	Sensitivity Current	10 ab^{-1}	75 ab^{-1}
$\mathcal{B}(B \to X_s\gamma)$	7%	5%	3%
$A_{CP}(B \to X_s\gamma)$	0.037	0.01	0.004–0.005
$\mathcal{B}(B^+ \to \tau^+\nu)$	30%	10%	3–4%
$\mathcal{B}(B^+ \to \mu^+\nu)$	X	20%	5–6%
$\mathcal{B}(B \to X_s l^+l^-)$	23%	15%	4–6%
$A_{FB}(B \to X_s l^+l^-)_{s_0}$	X	30%	4–6%
$\mathcal{B}(B \to K\nu\overline{\nu})$	X	X	16–20%
$S(K^0_S\pi^0\gamma)$	0.24	0.08	0.02–0.03

- **The golden modes**
  - **will be measured by SuperB.**
  - **`smoking guns’ for their models.**
- **Measurements not yet made are denoted by X.**
- **With 75ab^{-1} we can**
  - **Reach above a TeV with $B \to \tau\nu$**
  - **See $B \to K\nu\overline{\nu}$**

Accelerator Aspects

How can we obtain a data sample of $75ab^{-1}$?

Target Integrated Luminosity

- Why at least 75ab^{-1} of data?
  - Many of these new physics searches become systematically or theoretically limited.
    - e.g. time dependent asymmetry measurements with $b \rightarrow s$ penguin decays).
  - This data sample represents almost two orders of magnitude larger sample than current experiments.
    - The current B-factories have over 1ab^{-1} (combined) on disk/tape.
    - Will record a total of ~1.5ab^{-1}.
  - Ensures that if new physics is found (e.g. in LFV) that one can start to perform rudimentary measurements of such phenomena.
    - 10ab^{-1} of data is sufficient to start to constrain models of LFV in τ decays.
    - Need more than this to ensure discovery.
  - Will be able to start measuring parameters in V_{SCKM} (if SUSY exists), or constrain Multi TeV energy level NP in your favourite scenario.
    - Strong constraints on NP that complement the LHC direct searches!
  - Will be able to test for light Higgs/dark matter particles and lepton universality by running at the Y(3S) resonance [hundreds of fb^{-1} from a few months running].

How to get increased $\mathcal{L}$

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

Lorentz factor, classical $e^{\pm}$ radius and ratio of beam sizes

Beam current: I
beam-beam parameter: ξ
vertical β function at IP

Reduction factor from crossing angle and the hourglass effect

- Option 1: Brute Force.
  - Increase beam current.
  - Decrease β^*_y.
  - Increase beam-beam effect ξ (reduce bunch length).

(Hard – but possible – to do all of this efficiently)

How to get increased $\mathcal{L}$

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

Lorentz factor, classical $e^{\pm}$ radius and ratio of beam sizes

Beam current: I
beam-beam parameter: ξ
vertical β function at IP

Reduction factor from crossing angle and the hourglass effect

P. Raimondi's Crab Waist concept.

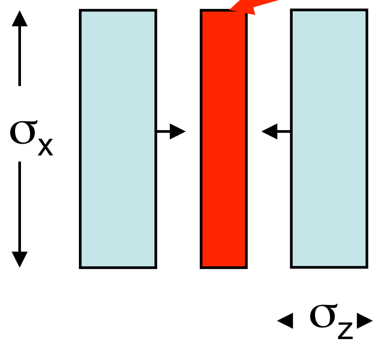
- Option 2: Large Crossing Angle.
  - Have a 15mrad crossing angle of beams.
  - Focus beams at IP (small β*).
  - Retain longer bunch lengths.
  - Rotate colliding bunches so no geometric loss at IP.
    - Align the focussed parts of bunches that cross each other at the IP. Call this "Crab Crossing/Waist".

Large crossing angle, small x-size

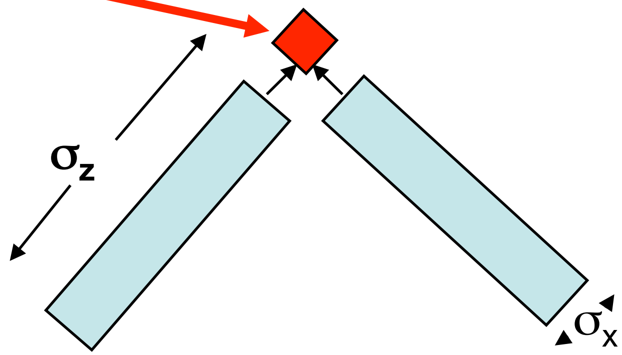
1) Head-on, Short bunches

Overlap region

2) Large crossing angle, long bunches



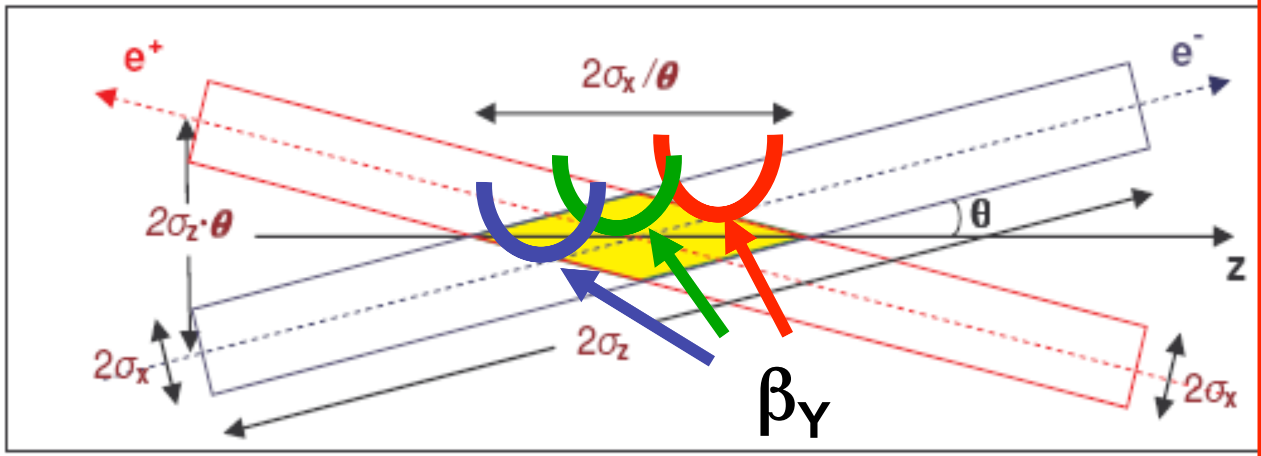
(1) and (2) have same Luminosity, but (2) has longer bunches and smaller σ_x



With large crossing angle the x and z planes are swapped

Large Piwinski angle:

$$\Phi = tg(\theta)\sigma_z/\sigma_x$$



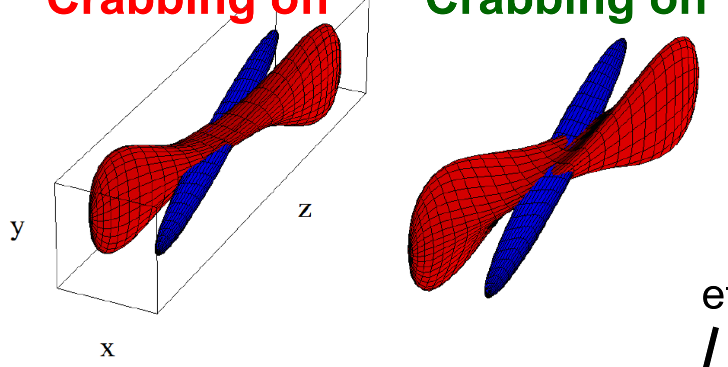
y waist can be moved along z with a sextupole on both sides of IP at proper phase

⇓

"Crab Waist"

Crab waist tests at DAΦNE

Crabbing off **Crabbing on**



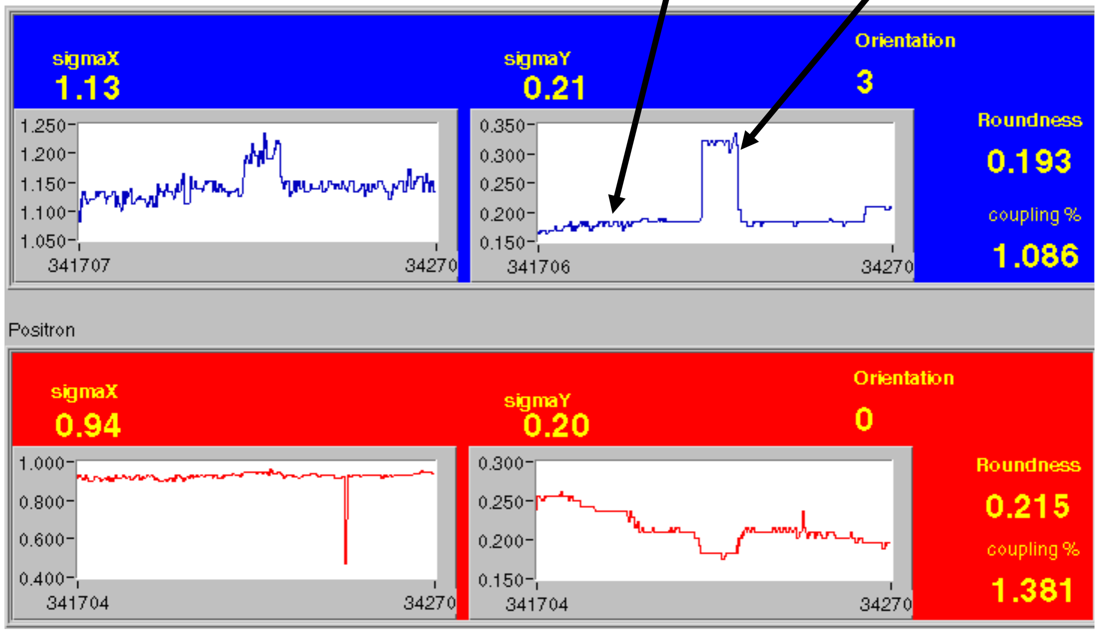
Crab sextupoles give luminosity improvement of roughly factor 2.

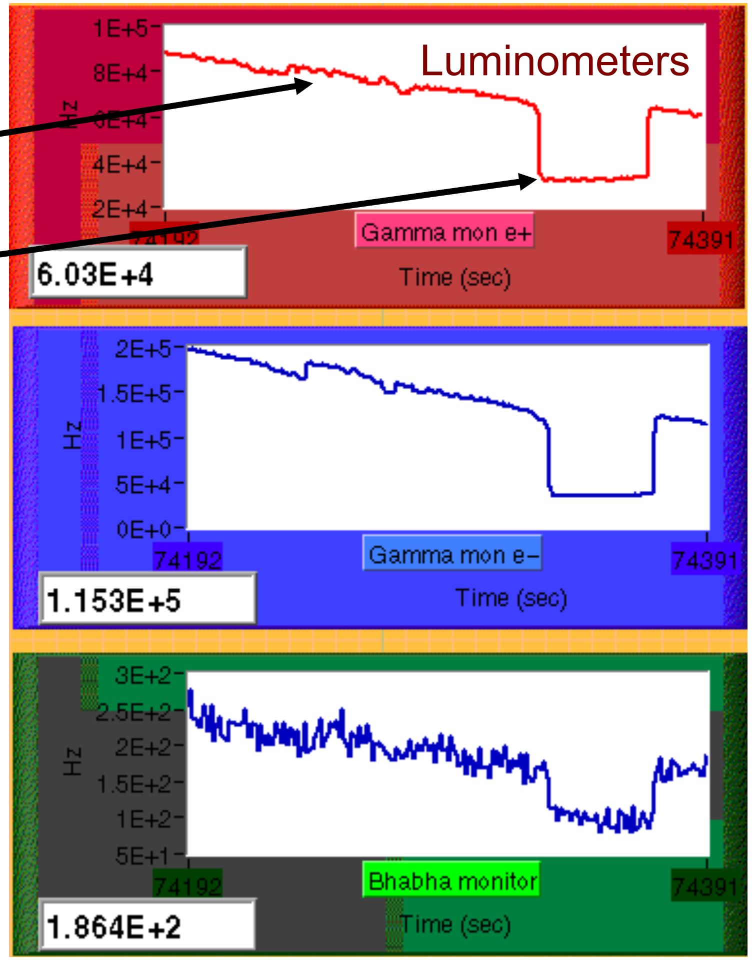
(Factor of 4 achieved in latest run!)

Transverse beam sizes at Synchrotron Light Monitors

e^- sextupoles on

e^- sextupoles off





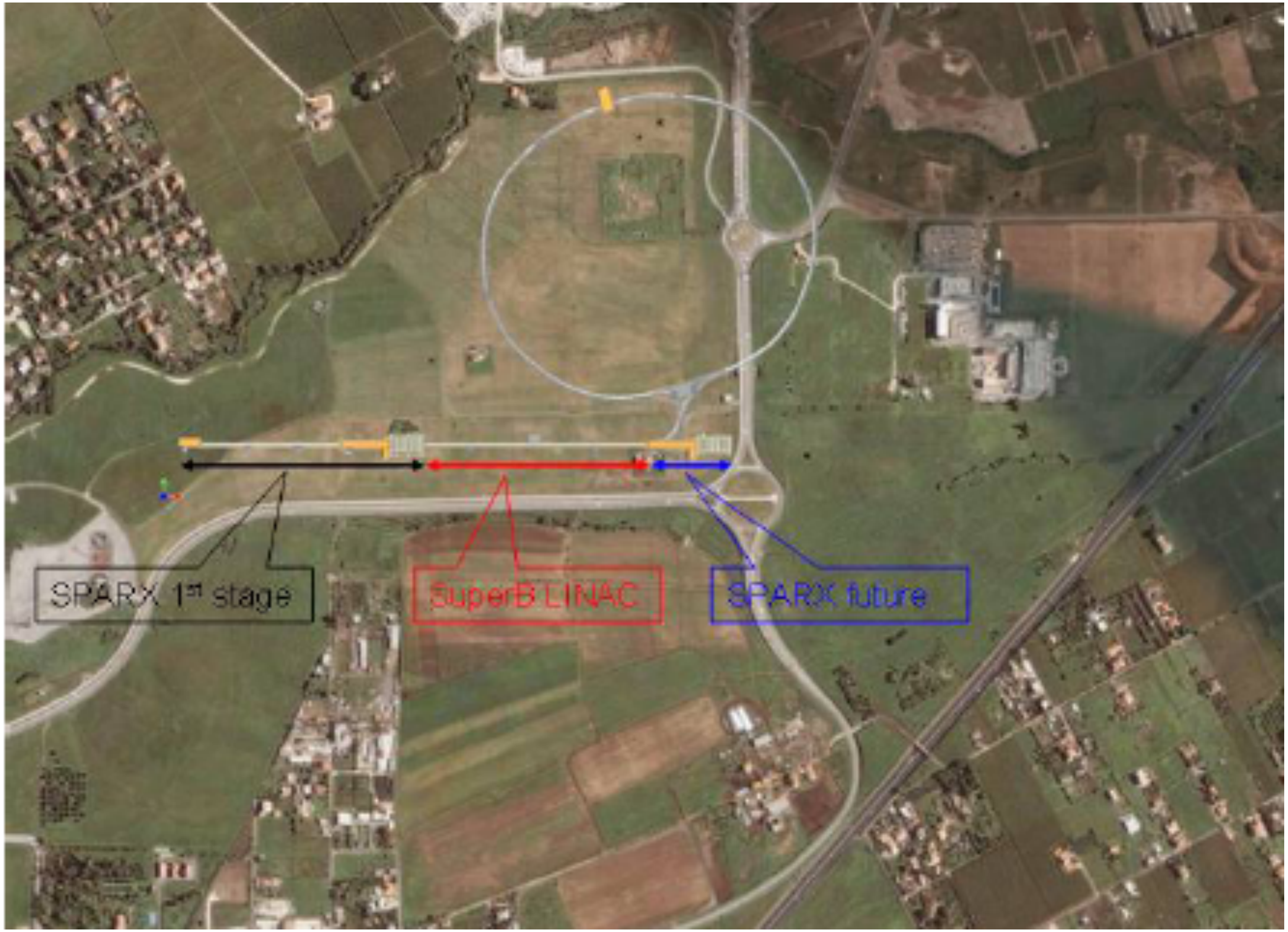
P. Raimondi (INFN-LNF)

PARAMETERS

J.Seeman @MiniMac

LER/HER	Unit	June 2008	Jan. 2009	March 2009	LNF site
E+/E-	GeV	4/7	4/7	4/7	4/7
L	$cm^{-2}\ s^{-1}$	$1x10^{36}$	$1x10^{36}$	$1x10^{36}$	$1x10^{36}$
I^+/I^-	Amp	1.85 /1.85	2.00/2.00	2.80/2.80	2.70/2.70
N_{part}	$x10^{10}$	5.55 /5.55	6/6	4.37/4.37	4.53/4.53
N_{bun}		1250	1250	2400	1740
I_{bunch}	mA	1.48	1.6	1.17	1.6
$\theta/2$	mrad	25	30	30	30
β_x^*	mm	35/20	35/20	35/20	35/20
β_y^*	mm	0.22 /0.39	0.21 /0.37	0.21 /0.37	0.21 /0.37
ε_x	nm	2.8/1.6	2.8/1.6	2.8/1.6	2.8/1.6
ε_y	pm	7/4	7/4	7/4	7/4
σ_x	µm	9.9/5.7	9.9/5.7	9.9/5.7	9.9/5.7
σ_y	nm	39/39	38/38	38/38	38/38
σ_z	mm	5/5	5/5	5/5	5/5
ξ_x	X tune shift	0.007/0.002	0.005/0.0017	0.004/0.0013	0.004/0.0013
ξ_y	Y tune shift	0.14 /0.14	0.125/0.126	0.091/0.092	0.094/0.095
RF stations	LER/HER	5/6	5/6	5/8	6/9
RF wall plug power	MW	16.2	18	25.5	30.
Circumference	m	1800	1800	1800	1400

SITES : Tor Vergata…….



LNF option

From J. Dorfan report of MINI MAC April 24,2009

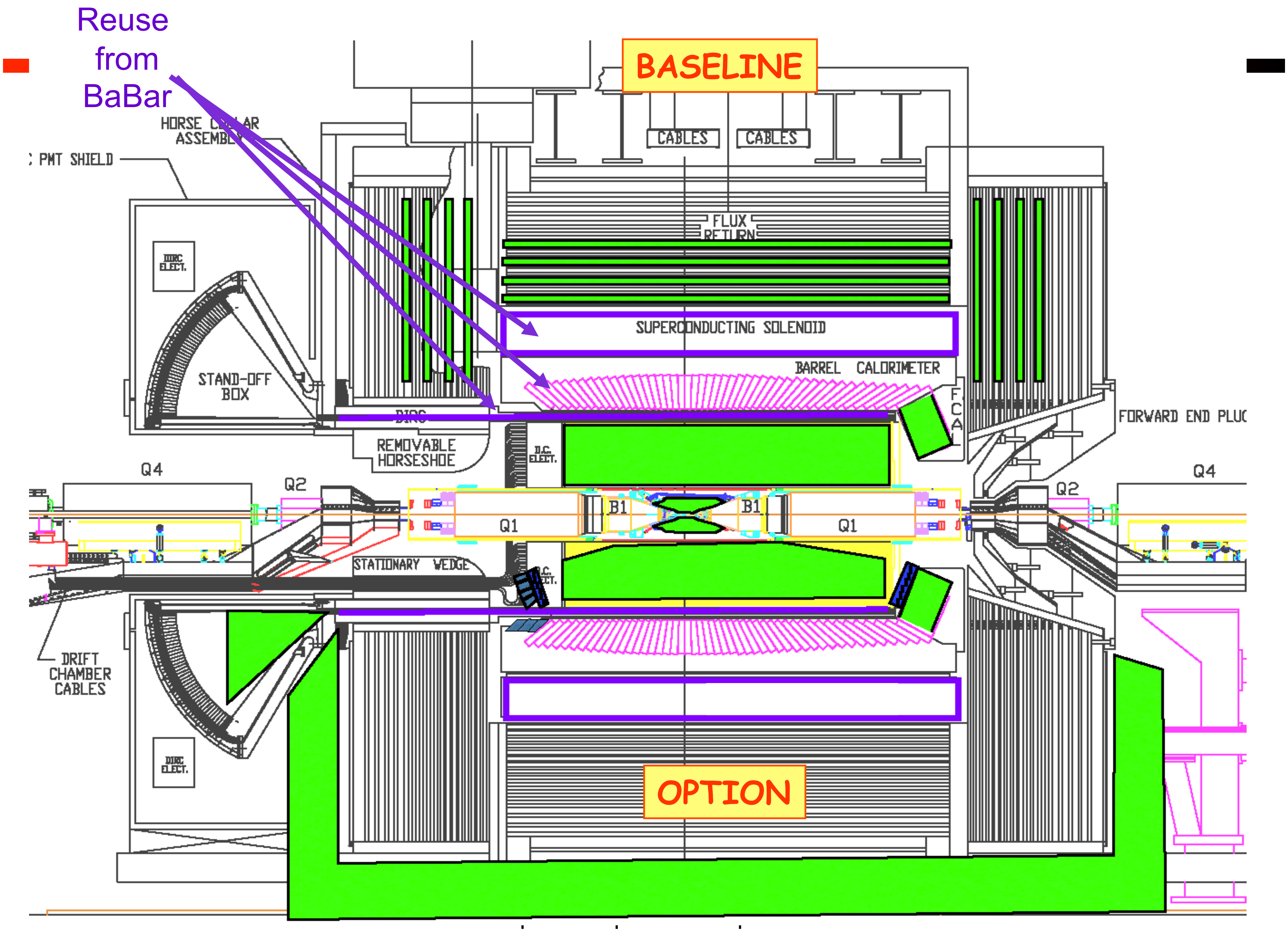
…. "Mini-MAC now feels secure in enthusiastically encouraging the SuperB design team to proceed to the TDR phase, with confidence that the design parameters are achievable"

Machine is possible!

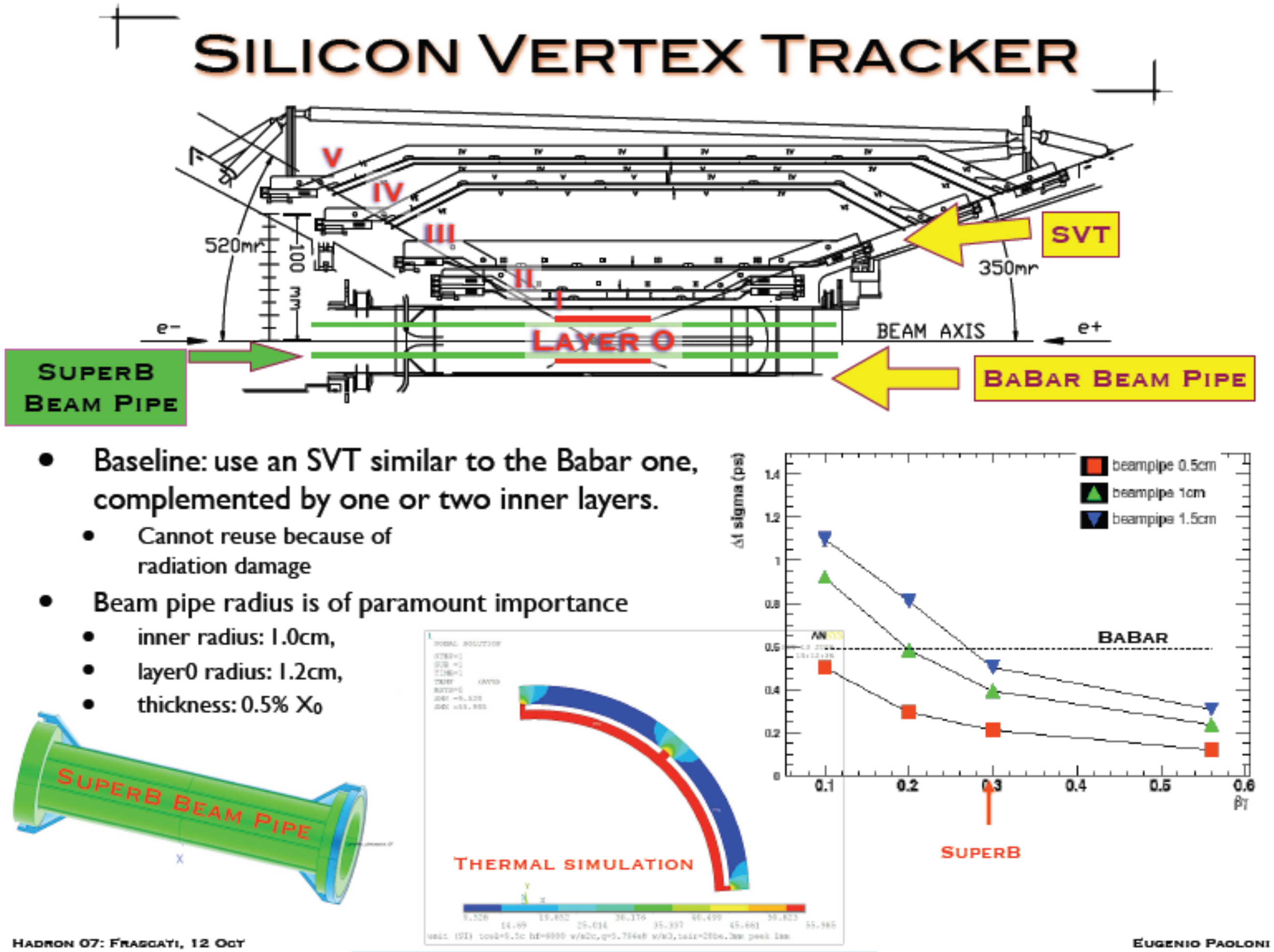
The 2 rings can be built largely with the components of PEPII:

Magnets and RF stations.

Detector Design


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

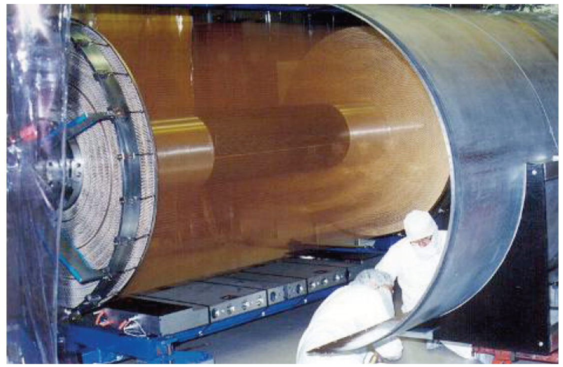
Tracking



Slide taken from a talk by E. Paoloni @ Hadron 07

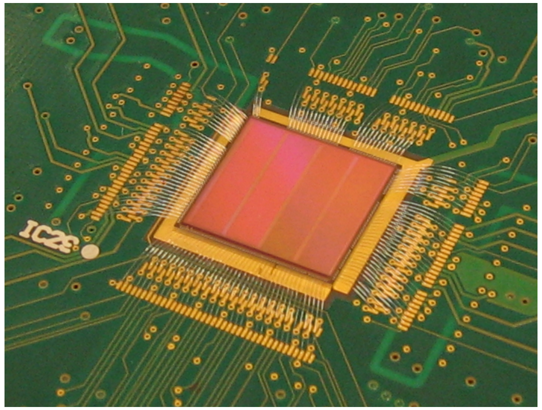
BaBar DCH Design

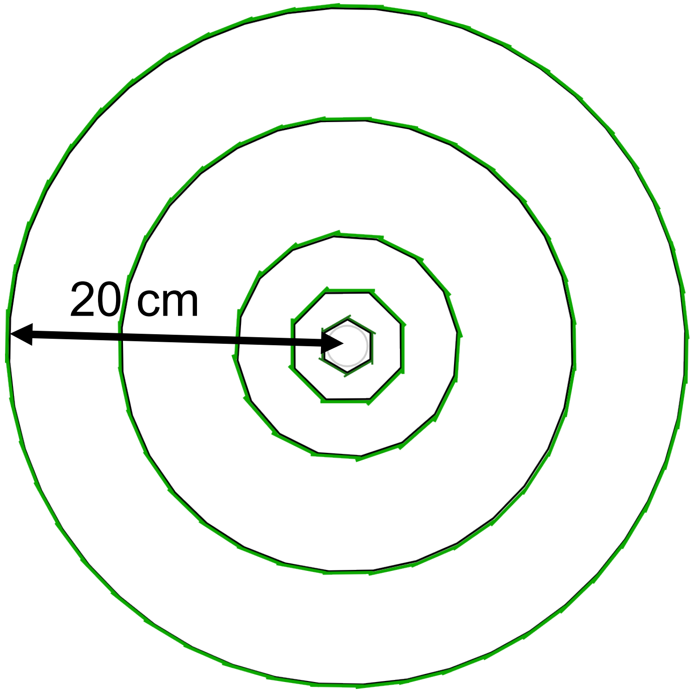
- Adequate performance.
- Needs to be replaced as the existing detector is aging.



All Pixel SVT Concept

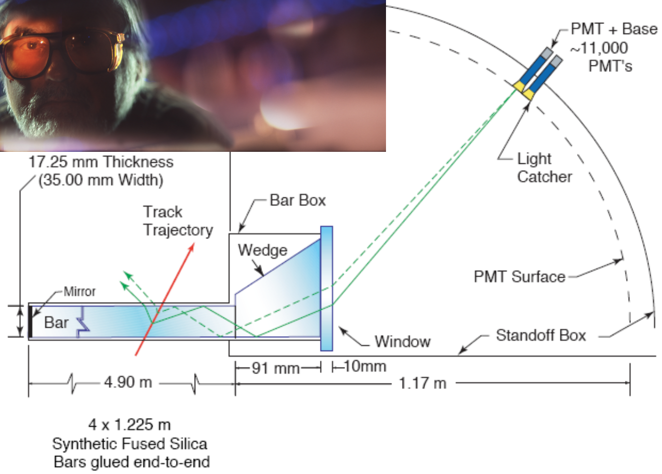
- Use INMAPS chips for a 5 layer all pixel vertex detector.
  - Adapt well understood leading STFC funded design to use with SuperB.
  - Common infrastructure for sub -system.
  - Physics studies required to understand performance (in progress) as part of detector optimisation.
  - UK has world leading expertise in this area.
  - Building on expertise and developments from SPiDeR and CALICE, LCFI ...
  - Concept well received by SuperB.

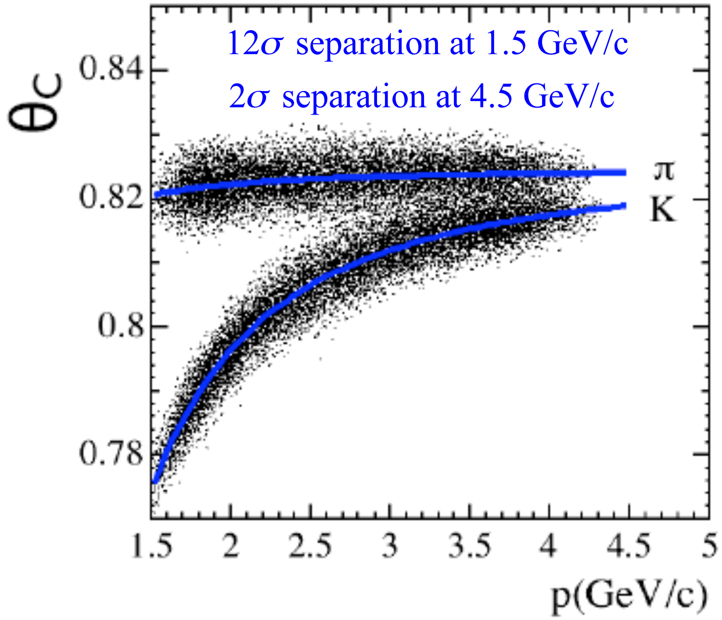




Particle ID

- Detector of Internally Reflected Cherenkov light (DIRC) works extremely well.
- Aim to reuse this principle with state of the art readout.



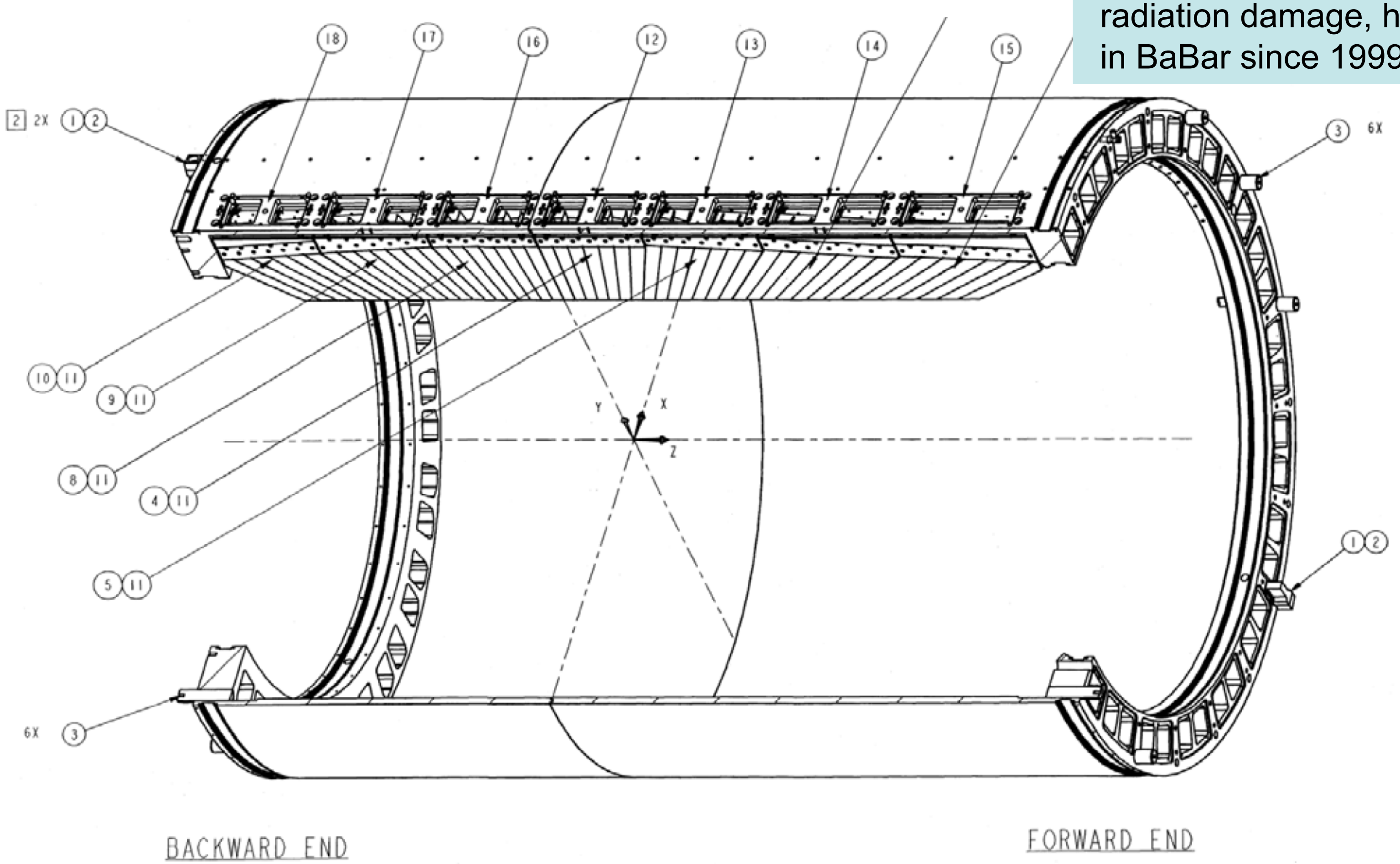


Can benefit from reducing the volume of water between the end of the quartz bars and the photodetectors (PMTs) at SuperB.

Calorimeter Barrel

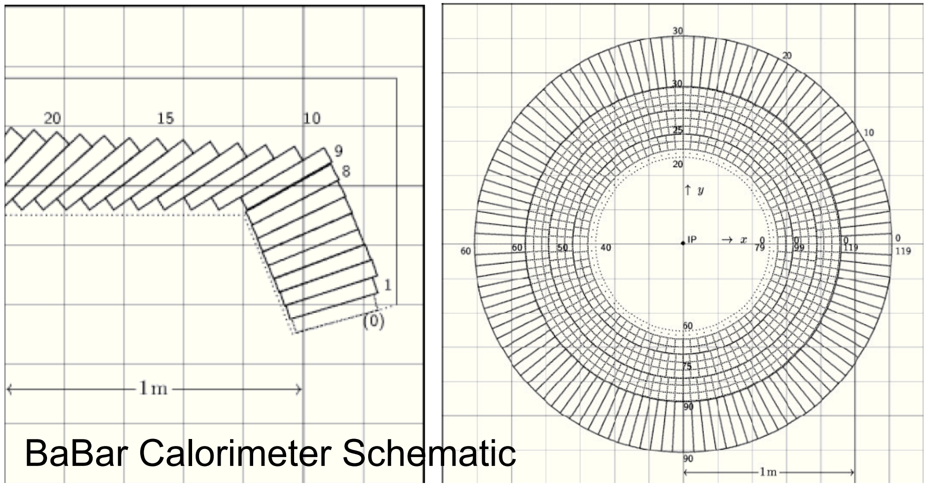
- Calorimeter Barrel is more than sufficient for our needs.

•Fast enough signal output for the expected rates at SuperB
•Not suffering from any signs of radiation damage, having been used in BaBar since 1999.



Calorimeter End-Cap

- BaBar End-Cap doesn't have a fine enough granularity for rates at SuperB.
  - Need a finer segmentation.
  - Similar total X_0.
  - Faster readout electronics.
  - Several candidate materials for End-Cap replacement.
    - LYSO is baseline
      - expensive at the moment (~ $40/cc).
      - Aim for $15/cc.
  - Need to integrate into the existing Barrel, and optimise segmentation.
  - R&D underway toward a LYSO Calorimeter test-beam in ~2009.

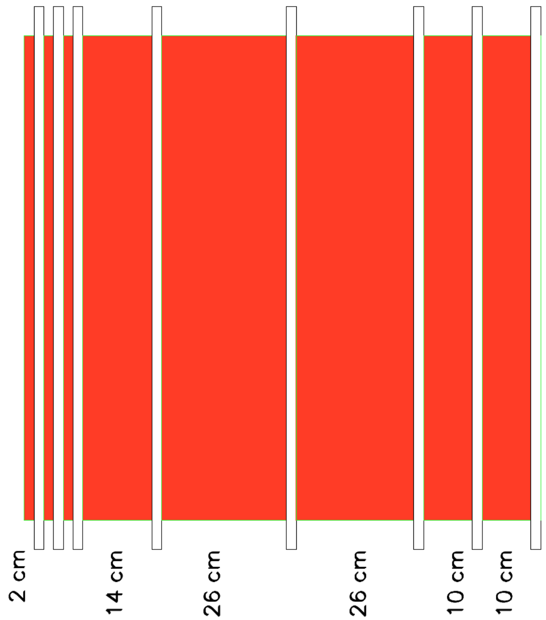


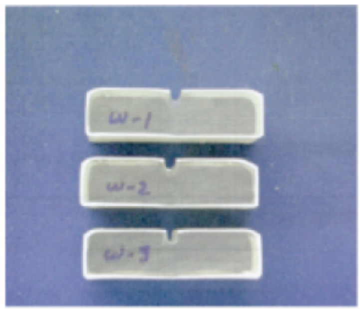
BaBar Calorimeter Schematic

2.5 x 2.5 x 20 cm (18 X_0) Bar

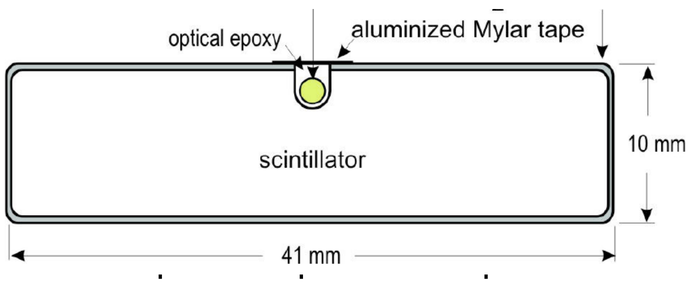
Instrumented Flux Return

- BaBar has 5 radiation lengths of material for μ identification in the flux return.
  - This is not optimal.
  - SuperB will have more iron.
- The segmentation of active regions of the flux return will remain the same as BaBar (3.7cm pitch).
- 7-8 layers of MINOS style scintillator bars.

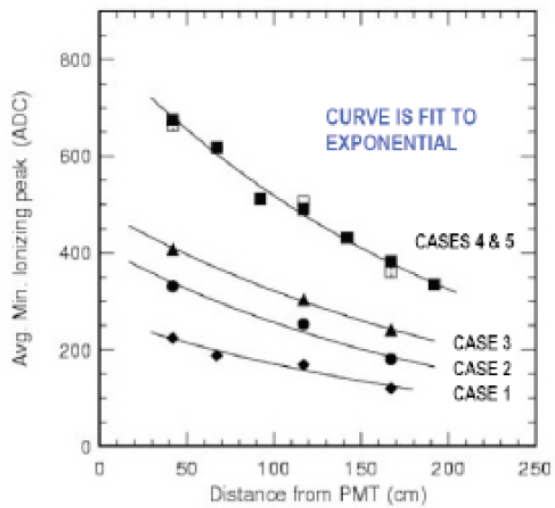




MINOS PRODUCTION BARS SHOWING 4 x 1 cm² CROSS SECTION WITH CO-EXTRUDED TiO_2 AND GROOVE FOR WLS FIBER

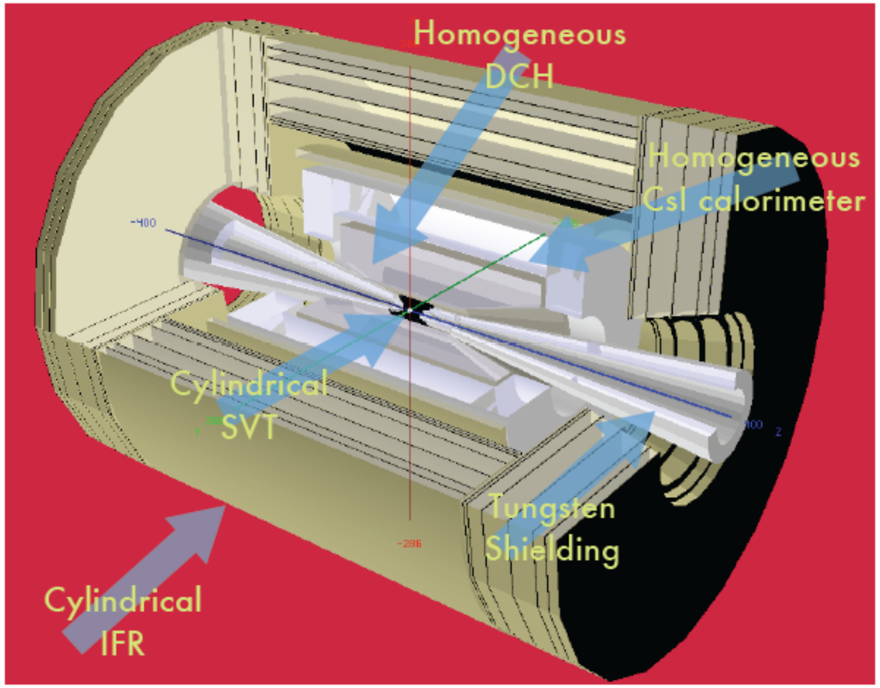


ATTENUATION LENGTH MEASUREMENTS FOR 5 CASES



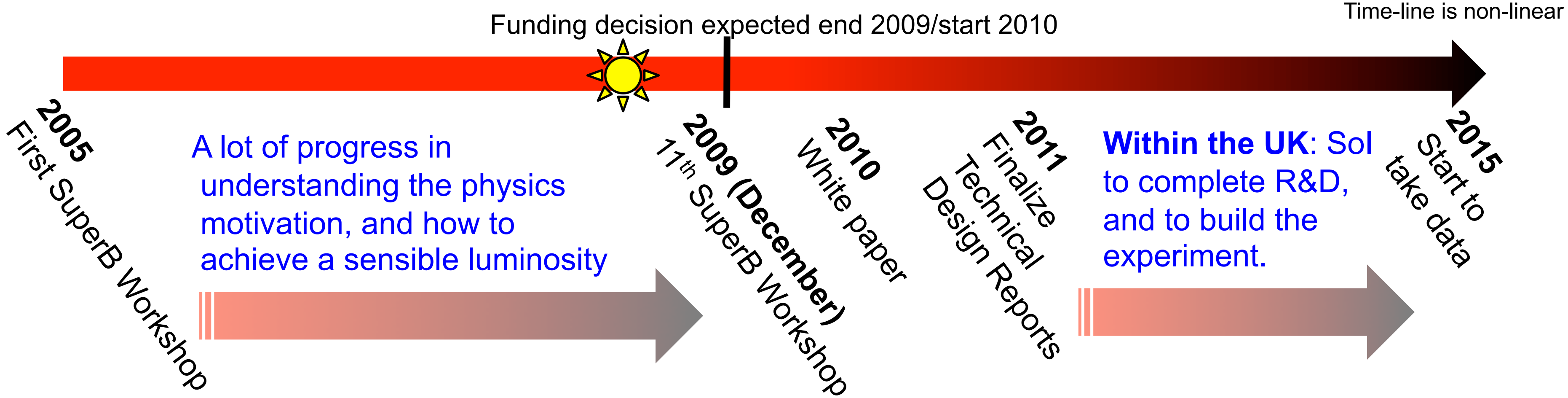
Detector Simulation

- Simulation:
  - FastSim (validated on using geometry for BaBar)
    - Reproduces BaBar resolutions etc.
    - Change to SuperB geometry and boost for development of benchmark studies.
    - Then move to GEANT 4 for more detailed work.
  - GEANT 4 model of SuperB shown.
  - Using BaBar framework.
  - Draw on a decade of analysis experience from BaBar and Belle to optimize an already good design.



Current status

Timeline of the project



Prior to 2005, there was no clear way to achieve an interesting data sample on an interesting timescale ($\mathcal{L} < 10^{36}$ $cm^{-2}s^{-1}$).

Then there was a revelation: The crabbed waist and inspiration from the ILC.

Working toward a coherent description of what we want to build and why:

White paper end of 2009
Technical Design Reports end of 2010.

Expect a funding decision from host country by the end of this year.

5 years of nominal data taking will give $75ab^{-1}$ of data.

Global situation

- Global community is working on the SuperB TDR effort: Accelerator, Detector, Physics.

Global community working toward the realization of a Super Flavour Factory.

Two Concepts: SuperB (this seminar) and Belle-II.

- R&D funding from:
  - Italy
  - France
  - Canada
- Other R&D efforts at various levels from:
  - Israel, Poland, Norway, Russia, Spain, UK, Ukraine, US.
- Other countries are watching the development of the process.
- Please contact me if you want more information or want to join the effort: a.j.bevan@qmul.ac.uk.

What about Belle-II?

- Similar concept:
  - Adiabatic upgrades from KEKB through to a ~0.8×10^{36} machine.
    - Funding situation was equivalent to SuperB.
    - Timeline is start data taking in 2013 (low luminosity).
    - Incremental upgrades to reach the ultimate lumi.
    - Target data sample: $50ab^{-1}$.
  - Some differences between SuperB and Belle-II by ~2020:

Experiment:	SuperB	Belle-II
I_{LER}	4 GeV	tbd
I_{HER}	7 GeV	tbd
ε_x	2.8 / 1.6 nm	tbd
ε_y	7 / 4 pm	tbd
$\mathcal{L}$	$75ab^{-1}$	$50ab^{-1}$
e^- Polarisation	80%	none
run at ψ(3770)	yes	no

N.B. Some parameters for the experiments may change. The Belle-II accelerator concept is in the process of being re-worked from a high current to a low emmitance (Italian) one, so the total cost of both projects will be the about the same.

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e^- Polarisation	80%	none
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Polarisation increases potential of τ physics studies.

ψ(3770) increases charm/CPV /Mixing study potential.

N.B. Some parameters for the experiments may change. The Belle-II accelerator concept is in the process of being re-worked from a high current to a low emmitance (Italian) one, so the total cost of both projects will be the about the same.

Summary

Hindsight always gives us 20:20 vision.

Until we have understood new physics, we are left trying to piece together the jigsaw puzzle of a high energy world where the possibilities are limited only by (a theorists) imagination.

Summary

- Want to elucidate new physics in as many ways as possible. Currently we
  - don't know the fine detail of NP.
  - don't know the relevant NP energy scale (yet).
    - The LHC may, or may not elucidate this issue.
  - don't know if the NP flavour sector is trivial or complicated:
    - Prior experience suggests it will be complicated.
  - But we do know that there are many models: 2HDM (type-n), MSSM, NMSSM, ...
    - Many *assume* flavour couplings are zero.

Summary

- The LHC won't be able to solve the SUSY flavour problem.
  - LHCb may help in a few specific channels: e.g. K*ll, B_S decays.
  - The GPDs may help with some ultra-rare B decays.
  - Some NP sensitive observables are accessible through studies at dedicated flavour experiments.
  - A large number of observables are only measureable competitively at a Super Flavour Factory.
    - Need this to unravel the nature of new physics.

Summary

- A subset of interesting light meson flavour-physics circa 2015: Predictions from Koppenberg: '09.

Summary

Mode	Improved by 2014	Limited by theory	Interesting In 2014?	Where
$B_d \to \mu\mu$	Yes	**No**	**Yes**	pp
$B \to \tau\nu$	Hardly	**No**	**Yes**	$\Upsilon(4S)$
$b \to s\gamma$ polarisation	Yes	**No**	**Yes**	Both
$B \to \ell\ell K^*$	Yes	**No**	**Yes**	pp
$B \to \nu\nu K$	Hardly	**No**	**Yes**	$\Upsilon(4S)$
CP ($b \to s\gamma$+$b \to d\gamma$)	No	**No**	**Yes**	$\Upsilon(4S)$
Exclusive $b \to d$	Yes	**No**	**Yes**	Both
BF($b \to s\gamma$)	Hardly	Yes(?)	Unlikely	$\Upsilon(4S)$
$B_s \to \mu\mu$	Yes	Yes	No	
D decays	Yes	Maybe	Unclear	Both
$K \to \pi\nu\nu$	Yes	**No**	**Yes**	Dedic.

Imperial College London P. Koppenburg

Rare Decays— 13/07/09 — PPAP community review – p. 33/34

Caveats I:

Focuses on what can be done now.

SuperB would open the doors to many new interesting modes.

Most interesting measurements are possible at SuperB.

Read in conjunction with the next slide.

Summary

- A subset of interesting light meson flavour-physics circa 2015: Predictions from Koppenberg: '09.

Summary

Mode	Improved by 2014	Limited by theory	Interesting In 2014?	Where
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Rare Decays— 13/07/09 — PPAP community review – p. 33/34

Caveats II:

Inclusive measurements are theoretically clean: so they are more interesting to make.

You need a clean environment (e^+e^-) to do inclusive measurements: i.e. SuperB

Quantum correlations at the ψ(3770) open up an equivalent set of measurements at charm threshold.

Summary

- The rest of the golden matrix includes:
  - more τ Lepton Flavour Violation studies.

	H^+ high $\tan\beta$	MFV	Non-MFV	NP Z-penguins	Right-handed currents	LTH	SUSY
$\mathcal{B}(B \to X_s\gamma)$		L	M		M		
$\mathcal{A}_{CP}(B \to X_s\gamma)$			L		M		
$\mathcal{B}(B \to \tau\nu)$	L-CKM						
$\mathcal{B}(B \to X_s\ell\ell)$			M	M	M		
$\mathcal{B}(B \to K\nu\overline{\nu})$			M	L			
$S_{K_S\pi^0\gamma}$					L		
The angle β (ΔS)			L-CKM		L		
$\tau \to \mu\gamma$							L
$\tau \to \mu\mu\mu$						L	

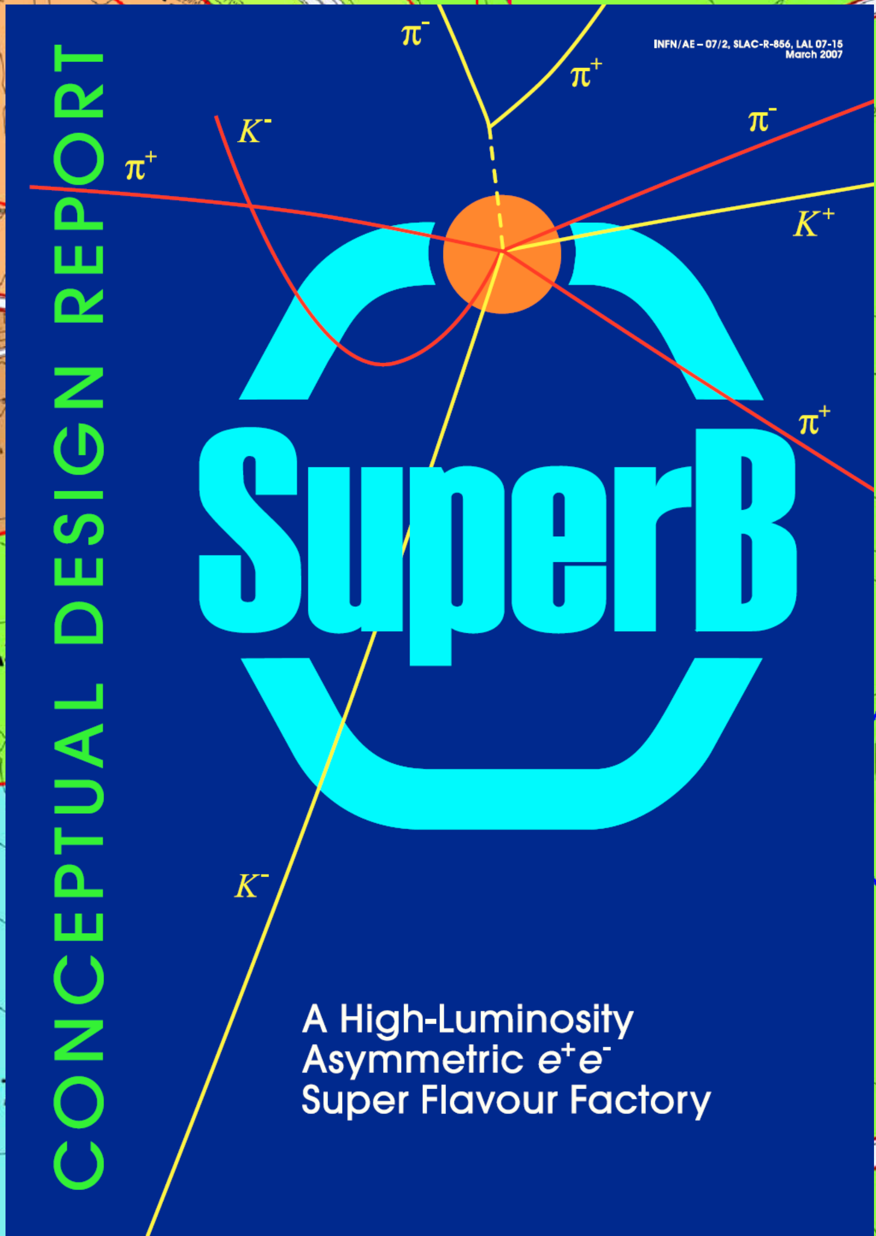
  - ϒ decay studies:
    - Light Higgs
    - Dark Matter
    - Lepton number conservation

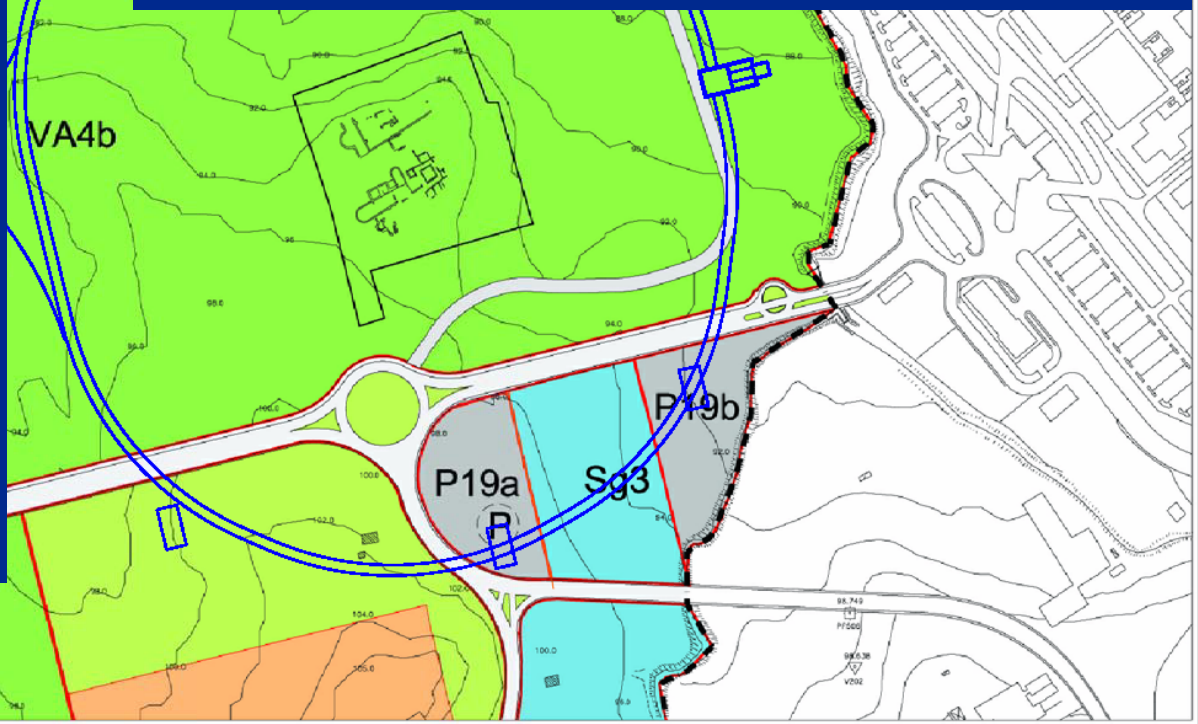
Not discussed here.

  - Probe Dark Sector: 'Dark Forces'
    - Learn about simple, and complex models of Dark Matter through meson decays.
    - http://www-conf.slac.stanford.edu/darkforces2009/

Summary

- Many questions will remain after the anticipated discoveries from the LHC.
  - What is the nature of flavour couplings beyond the Standard Model?
    - What can this tell us about any (un-)observed new particles?
  - Are there additional contributions that help resolve the Matter-antimatter asymmetry fine tuning problem?
  - Charged Lepton Flavour Violation: is it SM $\sim 10^{-54}$, or significantly enhanced?
  - Is there a charged Higgs?
  - What is the structure of Dark Matter?
- SuperB can shed some light in all these areas.





All we need to do is build it!

New effort is welcome!

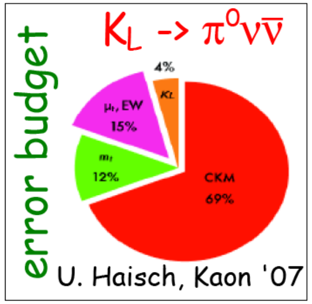
http://web.infn.it/superb/index.php/home

Extra Material

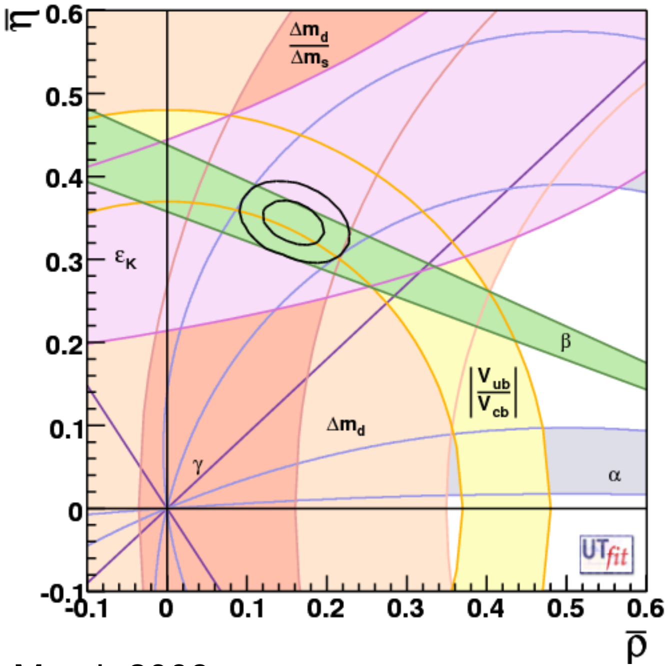
Precision CKM

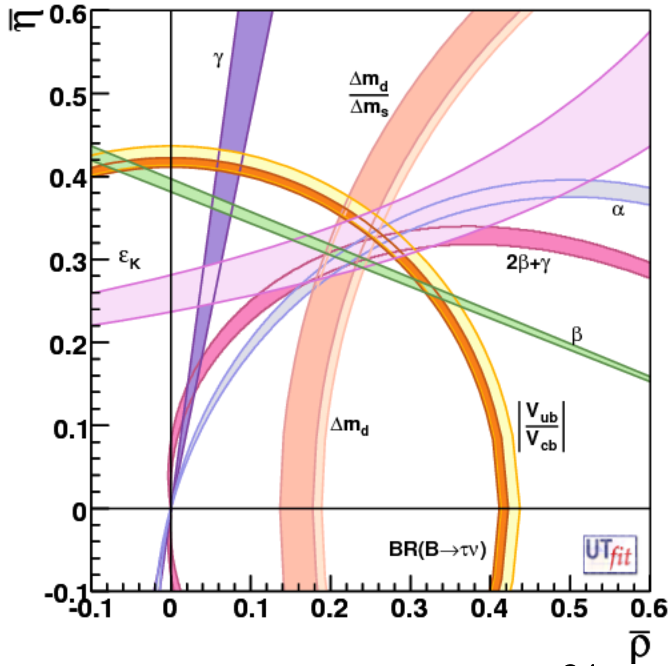
- CKM is a 36 year old anzatz.
- Works at the 10% level.
- No underlying physical insight.
- Small new physics contributions not ruled out (% level).

Precision CKM from SuperB will open up more new physics search opportunities: e.g. K➔πνν:

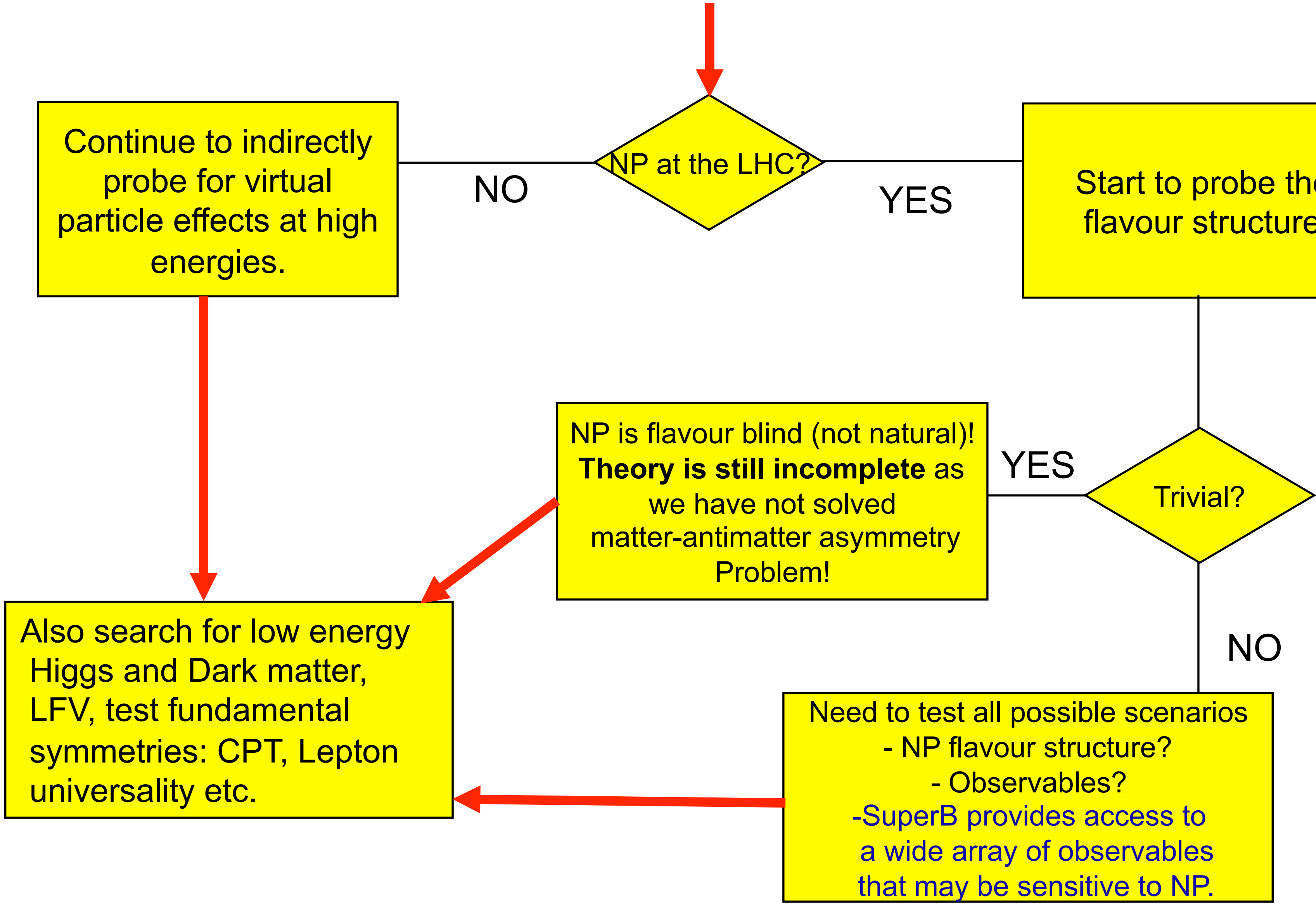


K+ decay has a similar error budget.





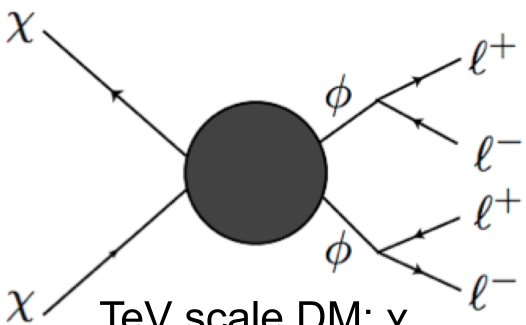
Particle Physics Landscape circa 2015



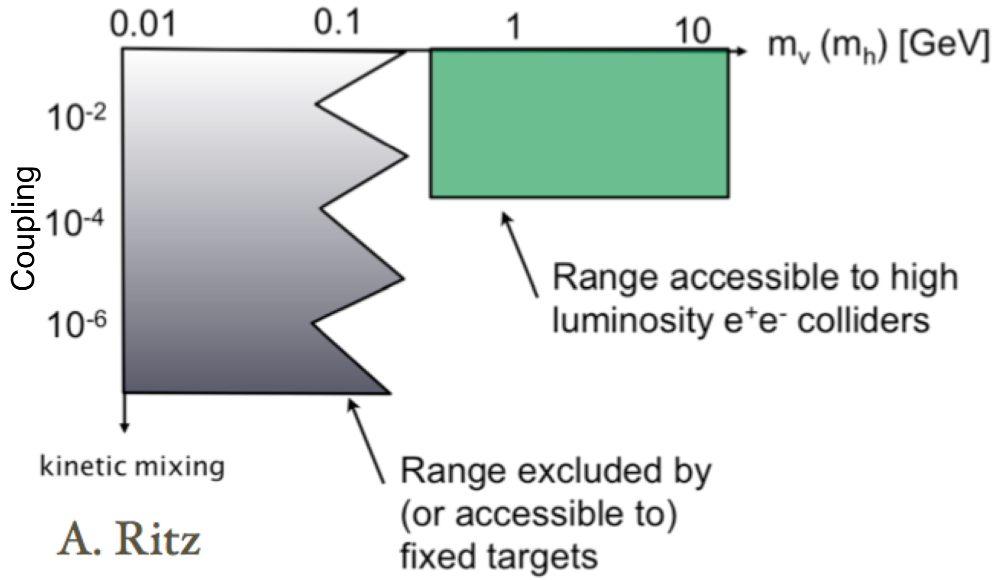
Dark Forces

See the recent workshop http://www-conf.slac.stanford.edu/darkforces2009/
Summarised by Mat Graham at the October 2009 SLAC SuperB meeting

Arkani-Hamed, Finkbeinder, Slatyer, Weinder hep-ph/0810.0713
Pospelov, Ritz hep-ph/0810.1502



TeV scale DM: χ
GeV scale boson: Φ
m(Φ)<2GeV
Couples to SM γ

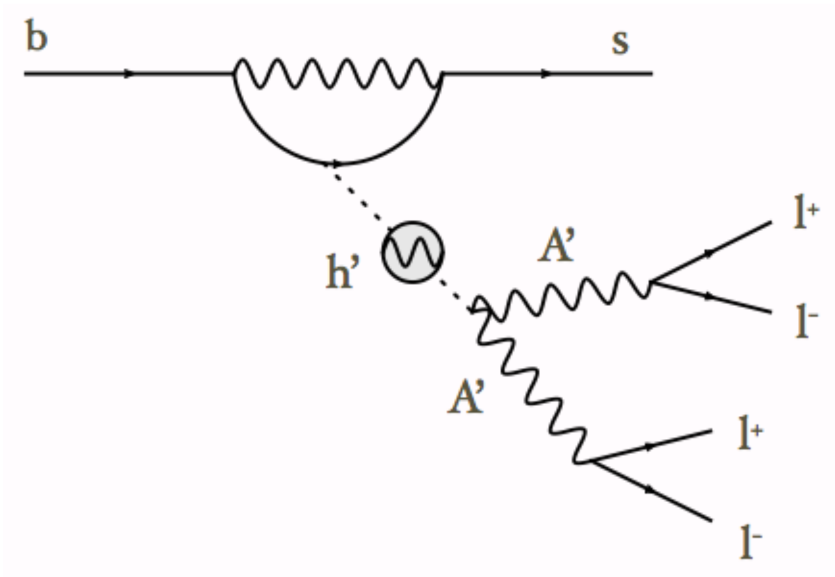


Dark Forces

See the recent workshop http://www-conf.slac.stanford.edu/darkforces2009/
Summarised by Mat Graham at the October 2009 SLAC SuperB meeting

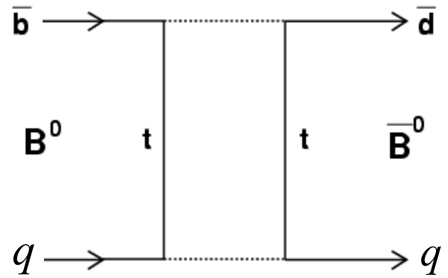
In addition to the vector 'portal' with the kinetic coupling, there should be a Higgs coupling term:

•B→K*4l is an interesting channel to search for this.



New Physics in ΔF=2 Transitions

- ΔF=2 transitions in $B^0_{d,s}\overline{B}^0_{d,s}$ systems are box diagrams (mixing or FCNC).



$$q = d, s$$

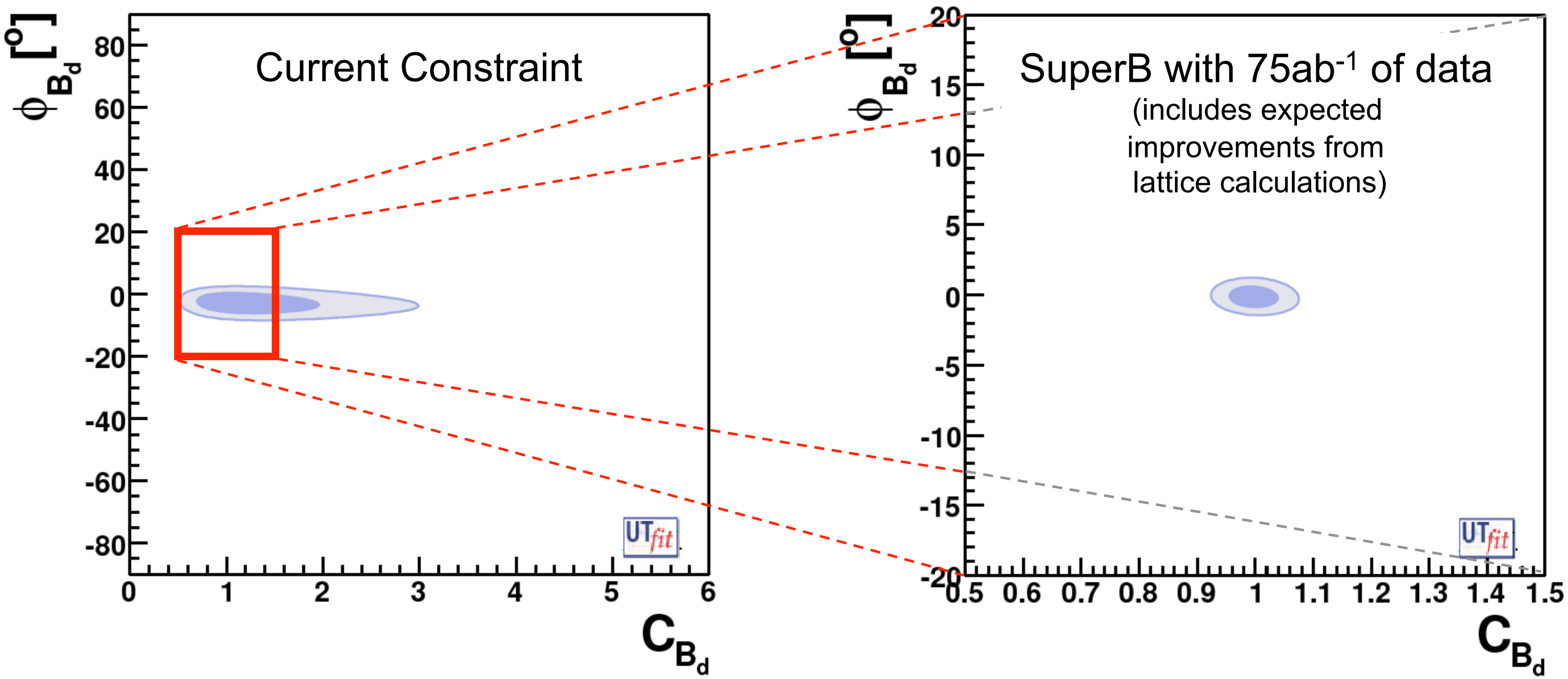
- New physics (NP) can contribute with an amplitude ratio C_q and phase ϕ_q.

$$C_q e^{i\phi_q} = \frac{\left\langle B^0_q \mid H_{SM+NP} \mid \overline{B}^0_q \right\rangle}{\left\langle B^0_q \mid H_{SM} \mid \overline{B}^0_q \right\rangle}$$

- $C_q=1$, and $\phi_q=0$ for the Standard Model (SM).

New Physics in ΔF=2 Transitions

- Existing measurements already constrain NP in B_d mixing (See later for B_S).
- SuperB will significantly improve this constraint.



Note that the two plots have very different scales!

Minimal Flavour Violation

- Suppose that there are no new physics flavour couplings (MFV).
  - CP violation comes from the known SM Yukawa couplings.
  - The top quark contribution dominates the SM.
  - NP contribution in ΔB=2 transitions is:

SM Scale ~2.4 TeV

$$\Lambda_0 = Y_t \sin^2\theta_W M_W / \alpha$$

$$\delta S_0 = 4a\left(\frac{\Lambda_0}{\Lambda}\right)^2$$

Real Wilson coefficient $O(1)$

New Physics Scale

  - MFV Includes many NP scenarios i.e. 1HDM/2HDM, MSSM, ADD, RS.
- What is the energy scale that we are sensitive to?

e.g. see hep-ph/0509116 (NMFV), hep-ph/0509219(MFV) and references therein.

Minimal Flavour Violation

- Sensitive to new physics contributions with Λ up to 14 TeV (= $6\Lambda_0$).
- For loop mediated NP contributions the constraint can be weakened so that $\Lambda \sim$ 700GeV.

Worst Case!

- Don't require that the EWSB scale match Λ.

e.g. see hep-ph/0509116 (NMFV), hep-ph/0509219(MFV) and references therein.

Aside: MFV & B_S?

- Recent preprint from UT Fit claims evidence for new physics in B_S decays.
  - Test for NP via:

$$C_s e^{i\phi_s} = \frac{\langle B_s^0 \mid H_{SM+NP} \mid \overline{B}_s^0 \rangle}{\langle B_s^0 \mid H_{SM} \mid \overline{B}_s^0 \rangle}$$

  - Using B_S mixing, A_{SL}, lifetime and tagged $J/\psi\phi$ results ($\Delta\Gamma$ vs β_S) from CDF and D0.

$$\beta_S = 0.018 \pm 0.001 \text{ (SM)}$$

$$= \arg\left(\frac{-V_{ts}V_{tb}^*}{V_{cs}V_{cb}^*}\right)$$

e.g. see arXiv:0803.0659

Aside: MFV & B_S?

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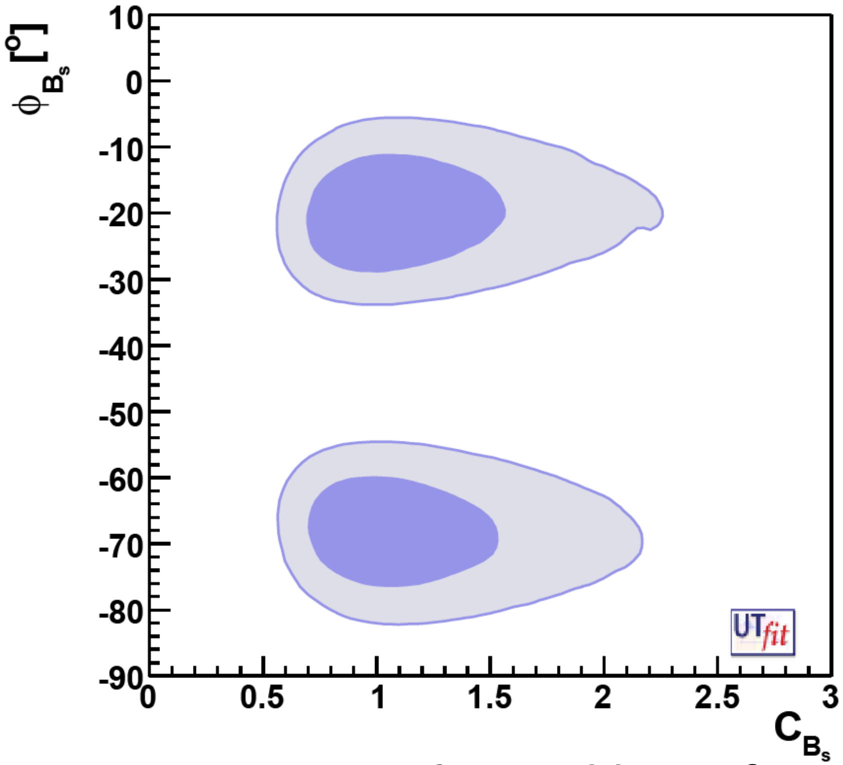
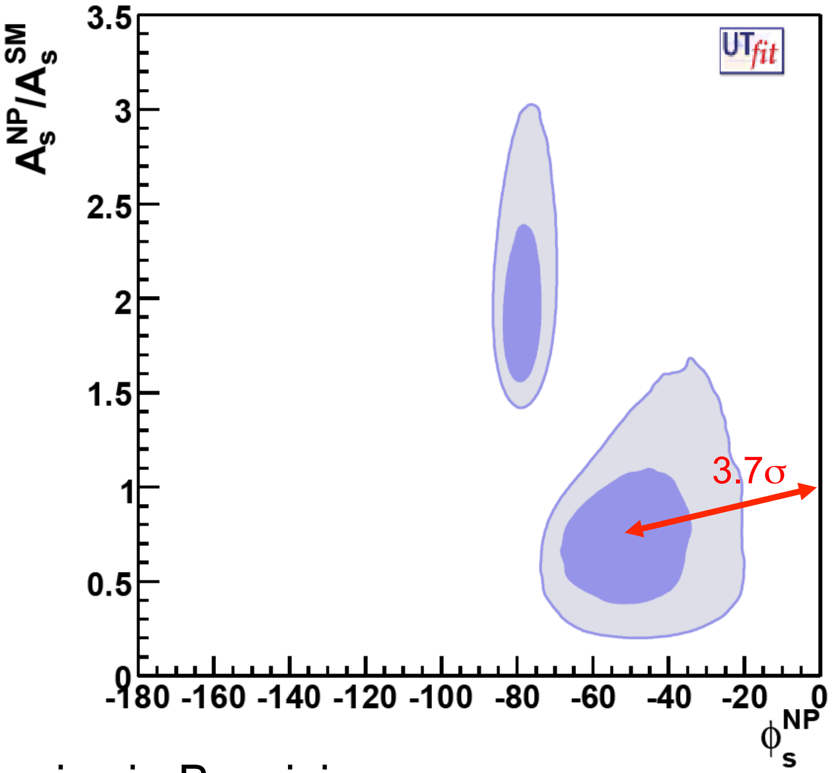




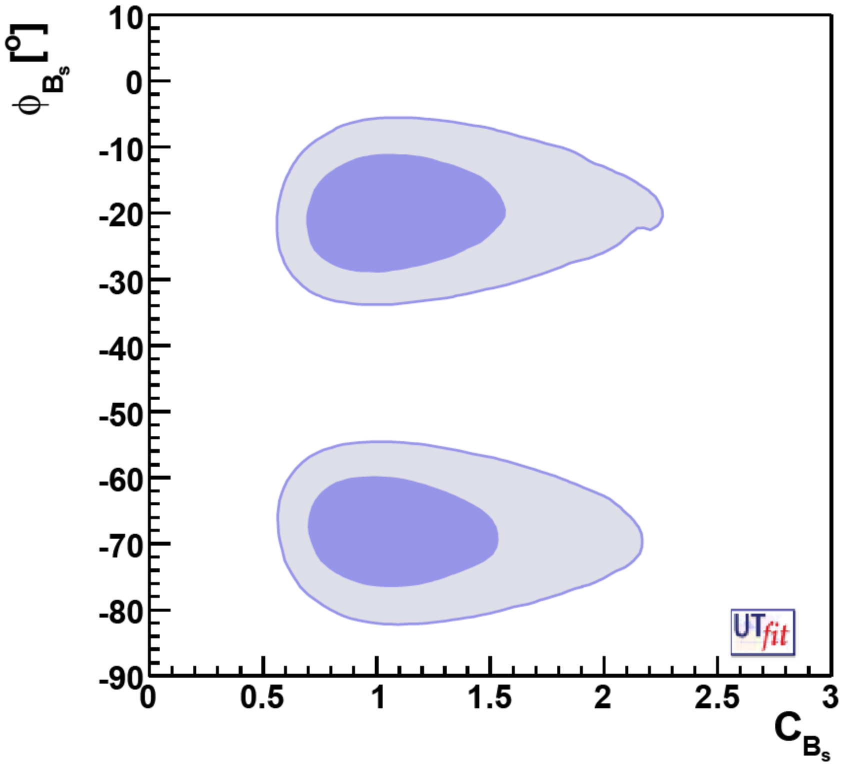
3.7σ evidence for new physics in B_S mixing.

Disfavours MFV hypothesis!

e.g. see arXiv:0803.0659

Aside: MFV & B_S?

- Recent preprint from UT Fit claims evidence for new physics in B_S decays.
  - Test for NP via:



Observable	68% Prob.	95% Prob.
$\phi_{B_s}[^\circ]$	-19.9 ± 5.6	[-30.45,-9.29]
	-68.2 ± 4.9	[-78.45,-58.2]
C_{B_s}	1.07 ± 0.29	[0.62,1.93]
$\phi_s^{\mathrm{NP}}[^\circ]$	-51 ± 11	[-69,-27]
	-79 ± 3	[-84,-71]
$A_s^{\mathrm{NP}}/A_s^{\mathrm{SM}}$	0.73 ± 0.35	[0.24,1.38]
	1.87 ± 0.06	[1.50,2.47]
Im $A_s^{\mathrm{NP}}/A_s^{\mathrm{SM}}$	-0.74 ± 0.26	[-1.54,-0.30]
Re $A_s^{\mathrm{NP}}/A_s^{\mathrm{SM}}$	-0.13 ± 0.31	[-0.61,0.78]
	-1.82 ± 0.28	[-2.68,-1.36]
$A_{\mathrm{SL}}^s \times 10^2$	-0.34 ± 0.21	[-0.75,0.03]
$A_{\mathrm{SL}}^{\mu\mu} \times 10^3$	-2.1 ± 1.0	[-4.7,-0.3]
$\Delta\Gamma_s/\Gamma_s$	0.105 ± 0.049	[0.02,0.20]
	-0.098 ± 0.044	[-0.19,-0.02]

$$\beta_S = 0.0409 \pm 0.0038$$

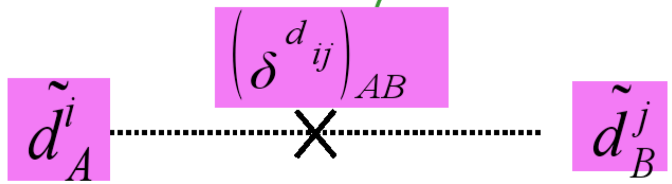
Eagerly awaiting a final result from CDF and D0: AND results from LHCb!

SUSY CKM

- The SM encodes quark mixing in the CKM matrix, ν mixing with the MSW matrix …. so

- SUSY encodes squark mixing in a Super CKM equivalent of the CKM matrix: V_{SCKM}.
  - Have couplings for LL, LR, RL, RR interactions.

Let us now consider a MSSM with generic soft SUSY-breaking terms, but dominant gluino contributions only



- LHC probes the High Energy Frontier.
  - Measures the diagonal elements of V_{SCKM}.

- SuperB probes the Luminosity Frontier.
  - Measures the off-diagonal elements V_{SCKM}.

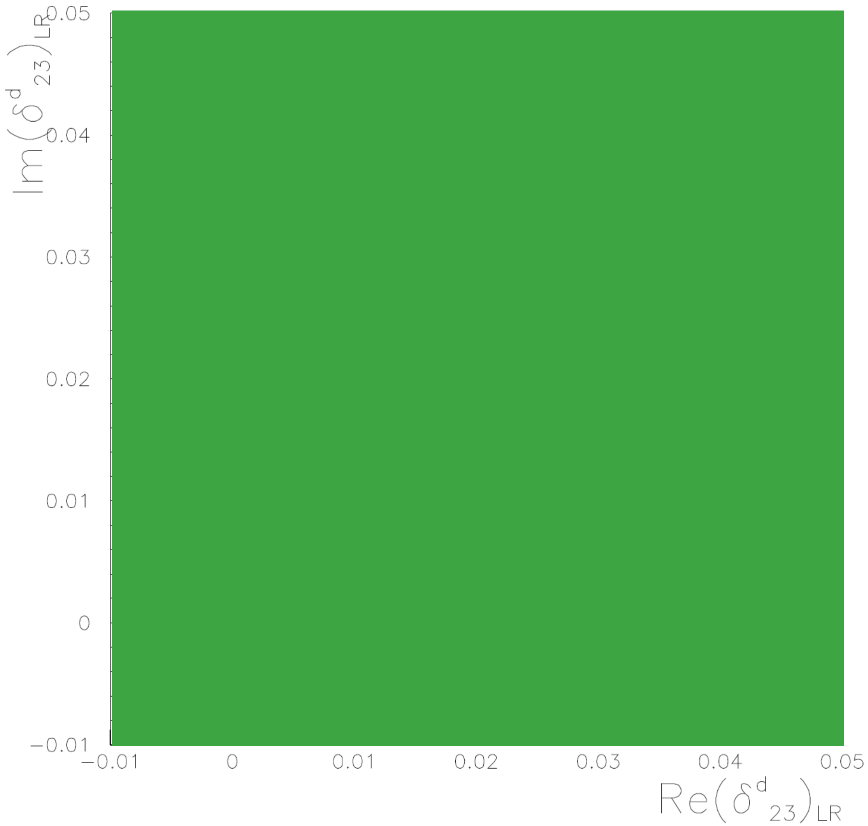
SUSY CKM

- Couplings are $(\delta^q_{ij})_{AB}$ where A,B=L,R, and i,j are squark generations.

L. Silvestrini (SuperB IV)

- e.g. Constrain parameters in V_{SCKM} using:

• $\mathcal{B}(B \to X_s \gamma)$ [green]
• $\mathcal{B}(B \to X_s l^+l^-)$ [cyan]
• $A_{CP}(B \to X_s \gamma)$ [magenta]
• Combined [blue]



SuperB probes new physics in SUSY larger than 20TeV (and up to 300TeV in some scenarios)

With current data, the whole range shown is allowed!

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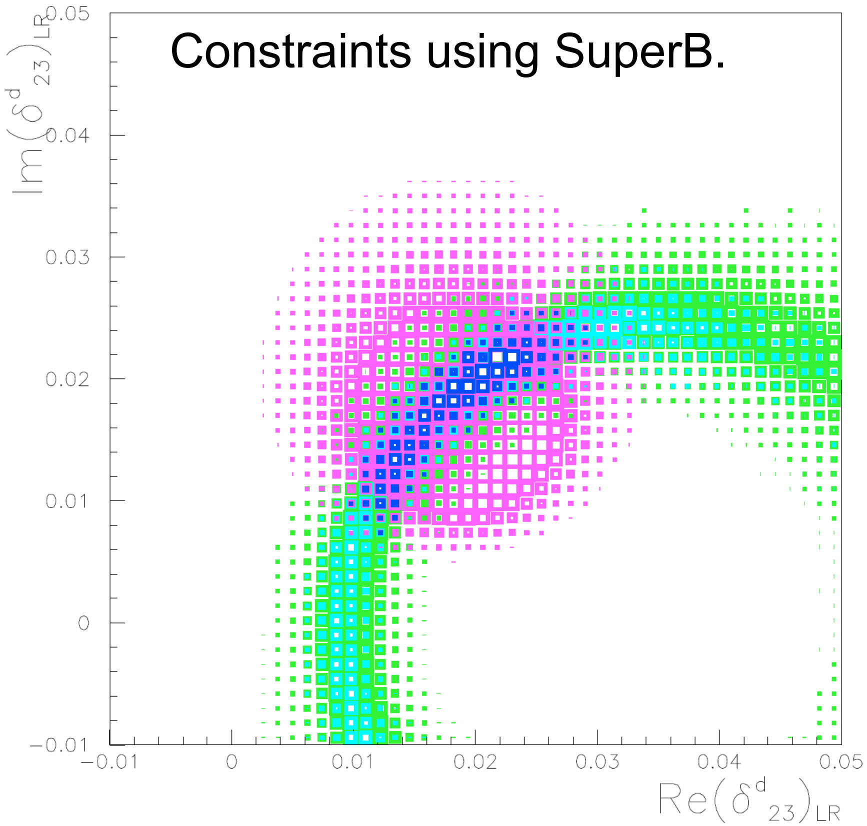
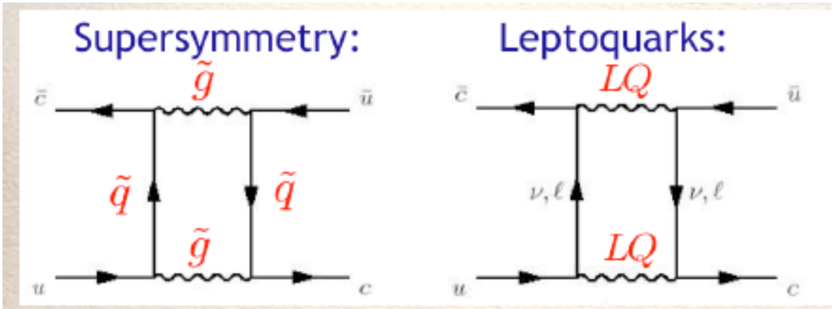


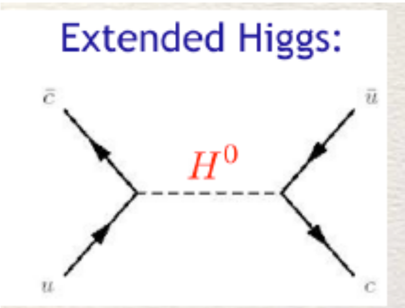
SuperB probes new physics in SUSY larger than 20TeV (and up to 300TeV in some scenarios)

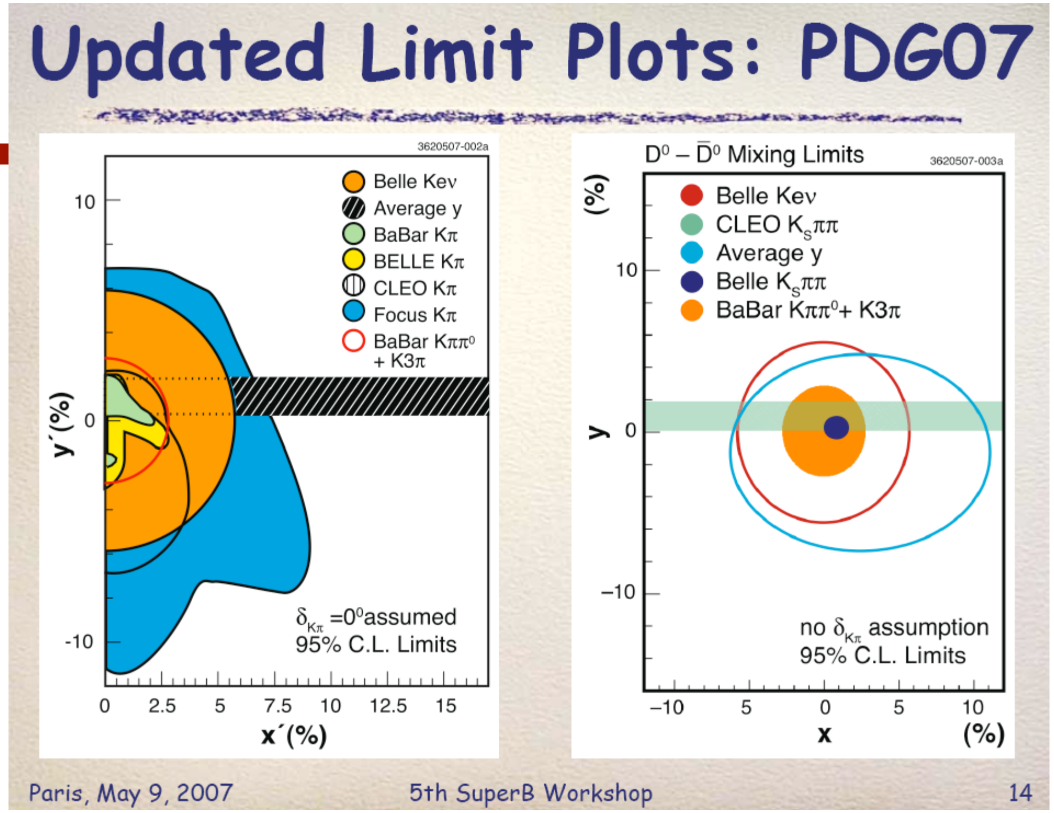
With current data, the whole range shown is allowed!

D^0 mixing

- Recent measurements from BaBar and Belle demonstrated B factory capabilities in charm physics
- Possibility to measure CP violation in the charm sector







Projected Sensitivity

Exp't / 1 σ	y_{CP} (10^{-3})	y' (10^{-3})	x'^2 (10^{-4})	cosδ
B-factories (2ab⁻¹)	2-3	2-3	1-2	-
SuperB (50 ab⁻¹)	0.5	0.7	0.3	-
LHCb (10 fb⁻¹) Only B->D*	?	0.7	0.7	-
LHCb (100 fb⁻¹) Prompt D*	?	?	?	-
CLEO-c (750 pb⁻¹)	10	-	2-3	0.1-0.2
BESIII (20 fb⁻¹)	4	-	0.5-1	0.05
SuperB - 4 GeV (0.2 ab⁻¹)	1-2	-	<0.2	<0.05

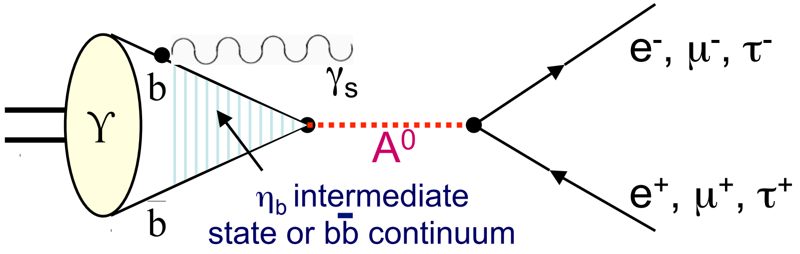
Searching for a Light Higgs or Dark Matter Candidates

LEP data do not exclude the possibility!

For more details see the talks of McElrath and Sanchis at the SuperB retreat in Valencia Jan '08:
http://ific.uv.es/superb/

Searching for a Light Higgs

- Many NP scenarios have a possible light Higgs Boson (e.g. 2HDM).
- Can use $\Upsilon(nS) \to l^+l^-$ to search for this.
  - Contribution from A^0 would break lepton universality



M. A. Sanchis-Lozano, hep-ph/0510374,
Int. J. Mod. Phys. A19 (2004) 2183

Can expect hundreds of fb^{-1} recorded at the $\Upsilon(3S)$ in SuperB

- NMMSM Model with 7 Higgs Bosons

Physical Higgs bosons: (seven)

2 neutral CP-odd Higgs bosons ($A_{1,2}$)
3 neutral CP-even Higgs bosons ($H_{1,2,3}$)
2 charged Higgs bosons ($H^{\pm}$)

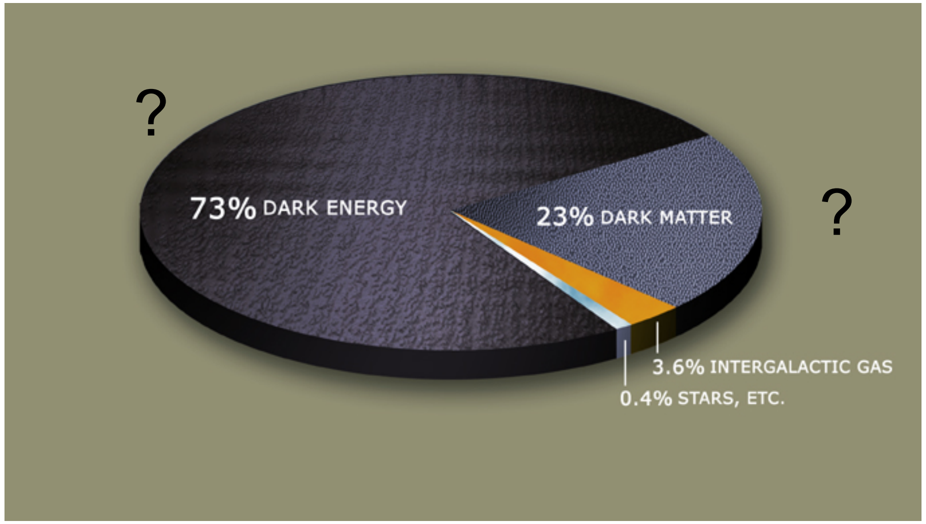
Possible NMMSM Scenario

$A_1 \sim 10$ GeV
$H_1 \sim 100$ GeV (SM-like)
Others ~300 GeV (almost degenerate)

- A_1 could be a light DM candidate.

Gunion, Hooper, McElrath [hep-ph:0509024]
McElrath [hep-ph/0506151], [arXiv:0712.0016]

Searching for Dark Matter

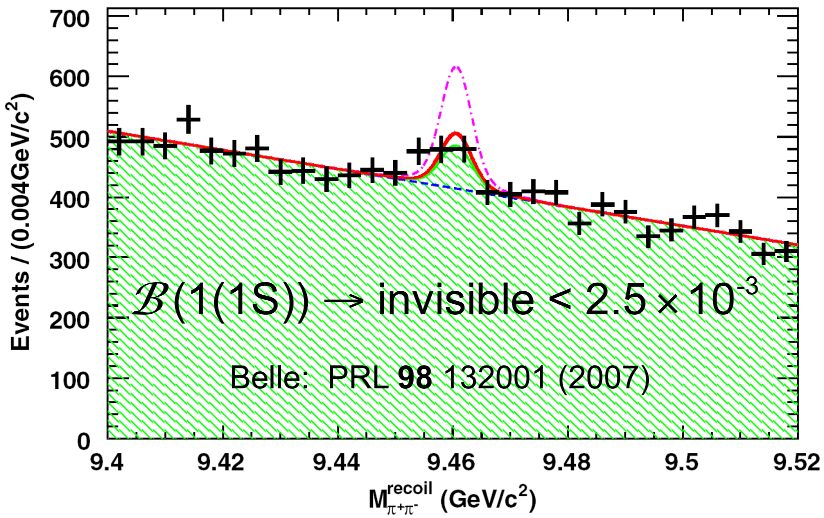


- Possible to search for the effect of DM at the B-factories for most modes:

$$\Upsilon \to invisible \qquad J/\Psi \to invisible$$
$$\eta \to invisible \qquad \Upsilon \to \gamma + invisible$$
$$B^+ \to K^+ + invisible \qquad \Upsilon \to \gamma A_1, A_1 \to \tau^+\tau^-$$
$$K^+ \to \pi^+ + invisible \qquad J/\Psi \to \gamma A_1$$

hep-ph/0506151, hep-ph/0509024, hep-ph/0401195, hep-ph/0601090, hep-ph/0509024, hep-ex/0403036 ...

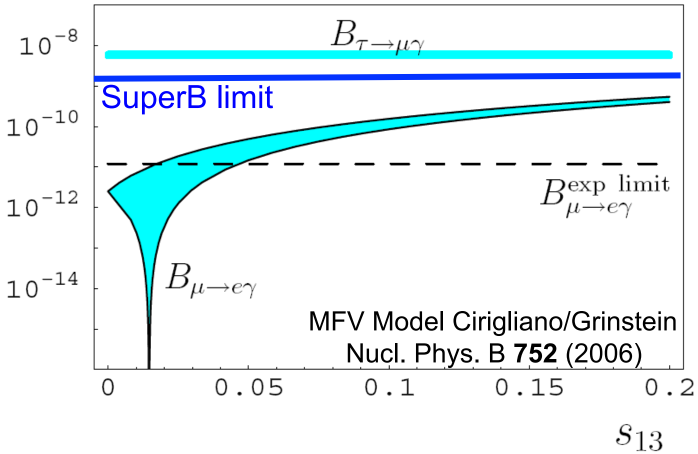
- SM Expectation:
  $\mathcal{B}(\Upsilon(1S) \to \nu\bar{\nu}) = (9.9 \pm 0.5) \times 10^{-6}$
- NP extension:
  $\mathcal{B}(\Upsilon(1S) \to \chi\chi)$ up to 6×10^{-3}
- SuperB should be able to provide a precision constraint on this channel.



τ Decays

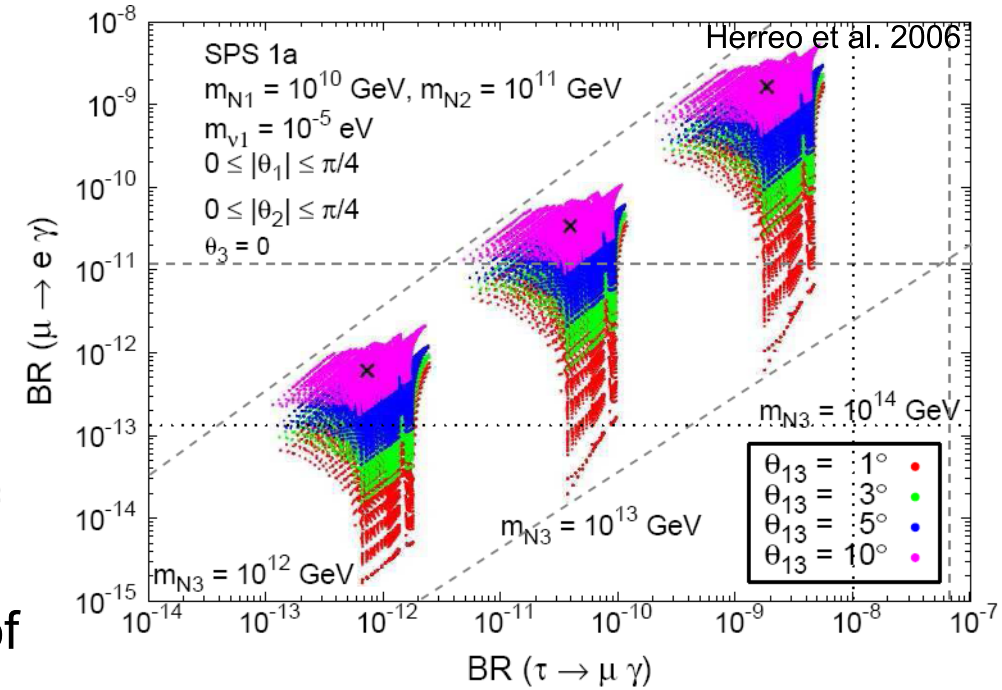
$\tau \to \mu\gamma$ / 3leptons

- Comparison of $\mu \to e\gamma$ and $\tau \to \mu\gamma$ rates can distinguish between NP scenarios.



- Can depend on the value of θ_{13}.

SUSY seasaw = CMSSM + $3\nu_R$ + $\tilde{\nu}$



- Best search capability for LFV in $\tau \to$3leptons of any experiment.

$\tau^- \to e^- e^+ e^-$	$2 \cdot 10^{-8}$
$\tau^- \to \mu^- \mu^+ \mu^-$	$3 \cdot 10^{-8}$
$\tau^- \to e^- \mu^+ \mu^-$	$2 \cdot 10^{-8}$
$\tau^- \to \mu^- e^+ e^-$	$2 \cdot 10^{-8}$
$\tau^- \to \mu^- e^+ \mu^-$	$2 \cdot 10^{-14}$
$\tau^- \to e^- \mu^+ e^-$	$2 \cdot 10^{-14}$

CP and CPT Violation

- CP Violation.
  - SM decays of the τ have only a single amplitude – so any CP violation signal is an unambiguous sign of NP.
  - Can have NP contributions from a $H^{\pm}$ in many modes, and largely experimentally un-explored.

Studies starting in this area

e.g. see Datta et al., hep-ph/0610162

- CPT Violation.
  - Expect to be able to measure $\frac{\tau_{\tau-} - \tau_{\tau+}}{\tau_{\tau-} + \tau_{\tau+}}$ at the level of 10^{-4} (statistical).
  - Current bound is $(0.12 \pm 0.32)\%$.

Nucl. Phys. Proc. Suppl. **144** 105 (2005)

- Polarisation of e^+e^- beams benefits the search for CP and CPT violation in τ decay and the τ anomalous magnetic moment.

e.g. PRD **51** 3172 (1995); arXive :0707.2496 [hep-ph]

Detector Design

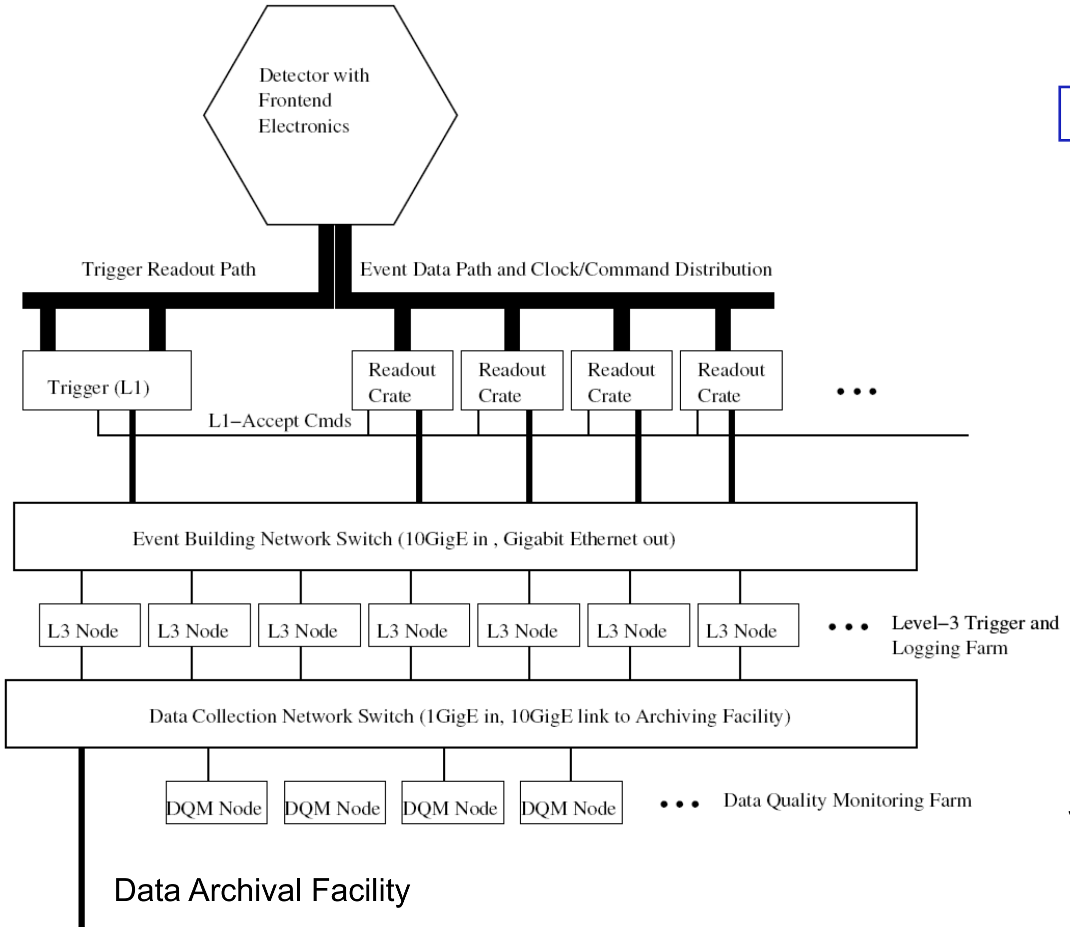
Requirements

- The B-factory detectors work extremely well.
  - Design of a SuperB detector, essentially means a refinement of the existing detectors.
- SuperB environment will have a higher rate.
  - Some existing detector parts are reusable.
    - CsI Calorimeter barrel.
    - DIRC quartz bars from BaBar. These 3m long bars are required for the particle identification system.
    - Superconducting Solenoid Magnet: creates a 2T magnetic field.
  - Some existing detector parts need to be replaced to cope with the expected rates.
    - Central tracking inside the particle ID system.
    - End Cap of the calorimeter.
    - Instrumented Flux Return (μ, K^0_L detector).
    - Readout electronics.
  - Makes sense to optimise reuse in order to limit the cost of the project.

DAQ

- Modelled on the BaBar Data Acquisition system.

As is the norm with modern experiments, will need tens -hundreds of Pb storage for SuperB.



Cumulative Storage (Pb)	3.9	17.5	47.0	83.4	121.4

Parameter	Year 1	Year 2	Year 3	Year 4	Year 5
Luminosity (ab^{-1})	2	6	12	12	12
Storage (PB)					
Tape	3.1	10.2	22.0	26.2	27.8
Disk	0.83	3.35	7.55	10.2	10.2
CPU (MSpecInt2000)					
Data reconstruction	3.0	8.8	14.7	8.8	0.0
Skimming	2.7	9.4	16.1	12.1	0.0
Monte Carlo	9.5	28.0	46.6	28.0	0.0
Physics analysis	5.1	15.0	30.0	30.0	30.0
Total	20	61	107	79	30

First Year Requirements

Subsequent year increments

Timescale

- Overall schedule dominated by:
  - Site construction.
  - PEP-II/Babar disassembly, transport, and reassembly.
- Possible to reach the commissioning phase after 5 years from T0.
- Physics from circa 2015?

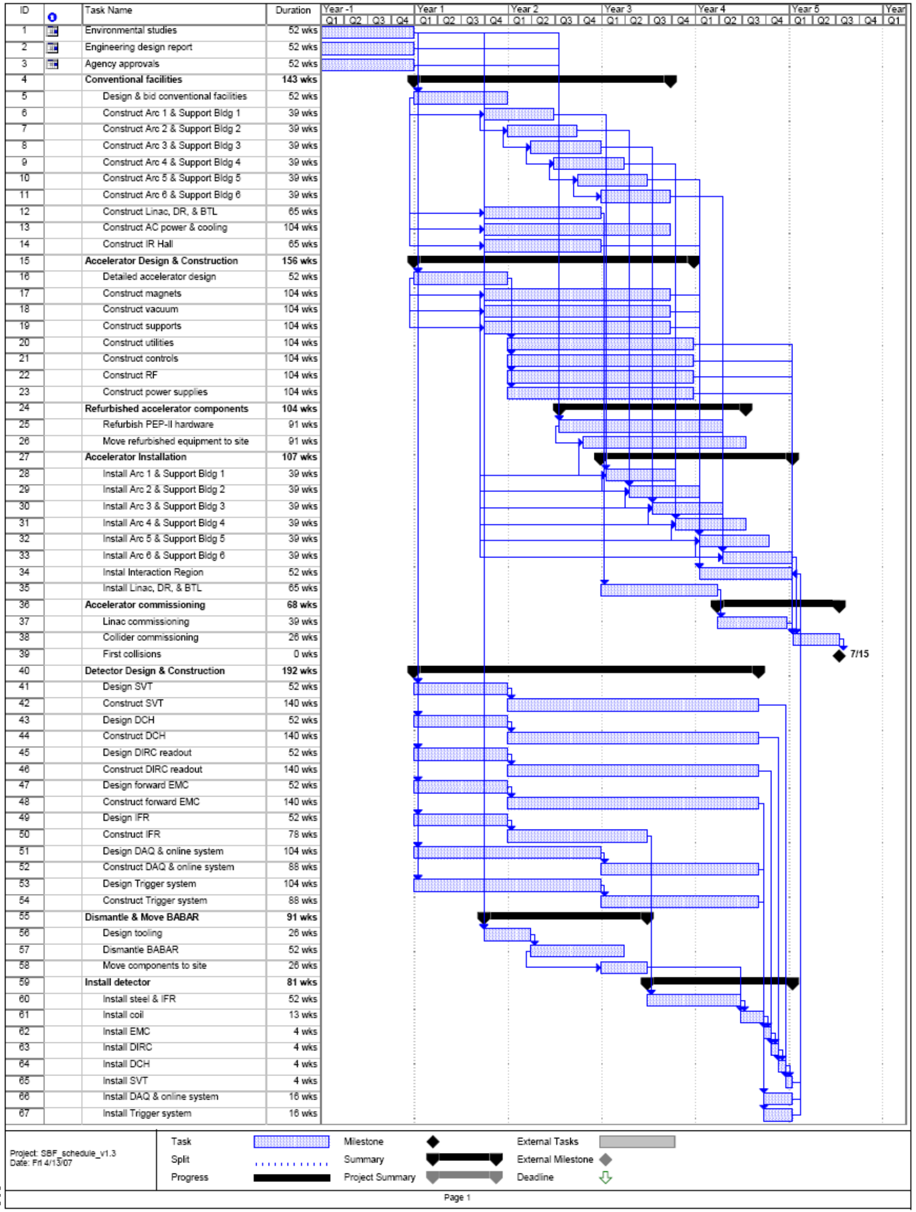


Figure 5-1. *Overall schedule for the construction of the SuperB project.*

Accelerator and site costs

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

Note: site cost estimate not as detailed as other estimates

Funds needed to build experiment

Replacement value of parts that we can re-use.

Detector cost

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**

Note: options in italics are not summed. We chose to sum the options we considered most likely/necessary.

Total = 338M Euro.
= 510M Euro (counting the cost of re-used parts).
⇒ 1/3 of the cost of the project can be saved by re-using parts of BaBar and PEP-II.