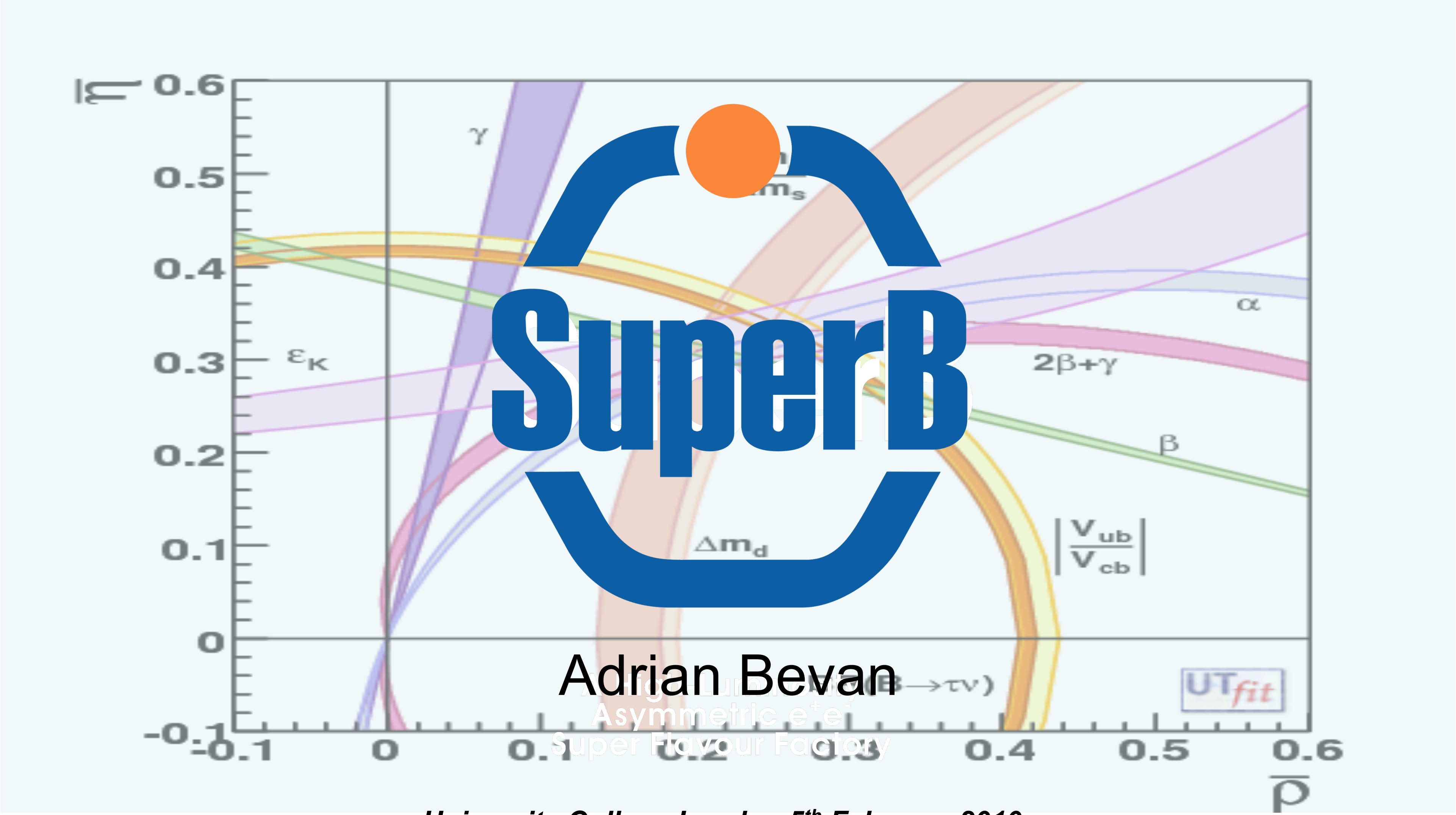
Super Flavour Factories:



Adrian Bevan

University College London 5th February 2010

Conceptual Design Report: arXiv:0709.0451
Valencia Workshop Report: arXiv:0810.1312
http://web.infn.it/superb/

Queen Mary
University of London

Overview

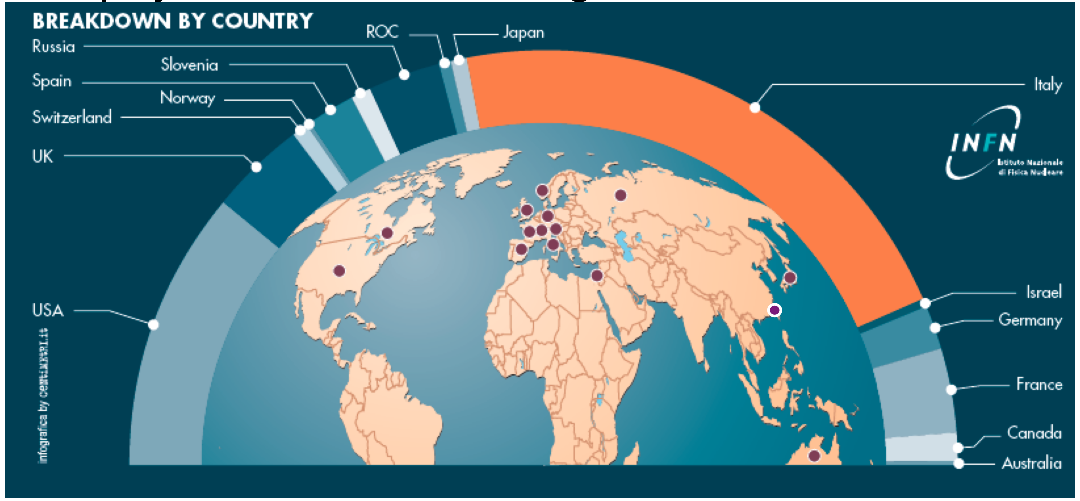
- What is SuperB?
- Physics Case in the LHC era
- Accelerator Aspects
- Detector Design
- Current Status
- Summary

What is SuperB?

SuperB in a Nutshell

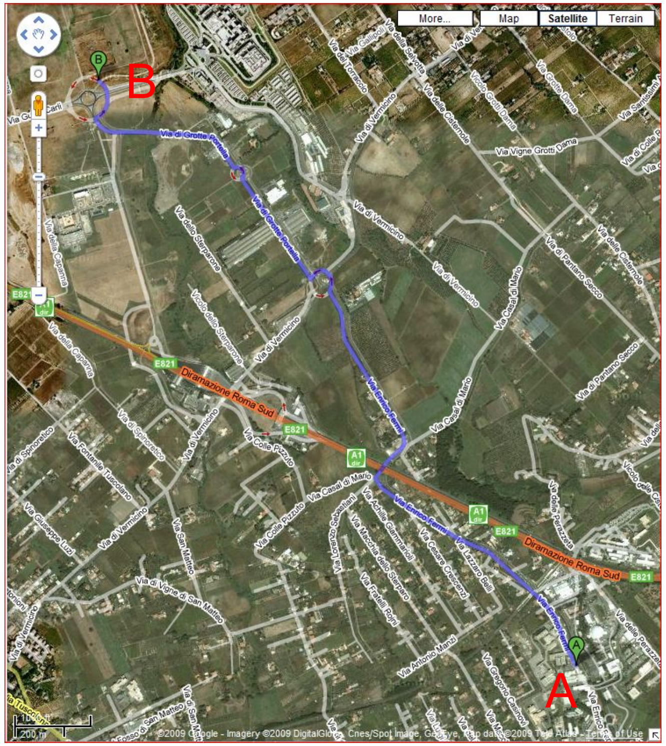
- High Luminosity e+e− collider.
- Aim to reach $\mathcal{L}$~10^{36} $cm^{-2}s^{-1}$.
- Low emittance operation.
- Utilize 'crab waist' technique (now tested and proven to work).
- Stable accelerator design:
  - Approved by MAC.
- Data taking as early as 2015.

- Strong international interest in this physics: >300 CDR Signatories from:



- Physics Goals:
  - Elucidate new physics in the LHC era as thoroughly as possible.

- Two possible sites in the suburbs of Rome:
  - INFN LNF/ESRA [A]
  - Tor Vergata Campus (Rome II) [B]



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 be 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?

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

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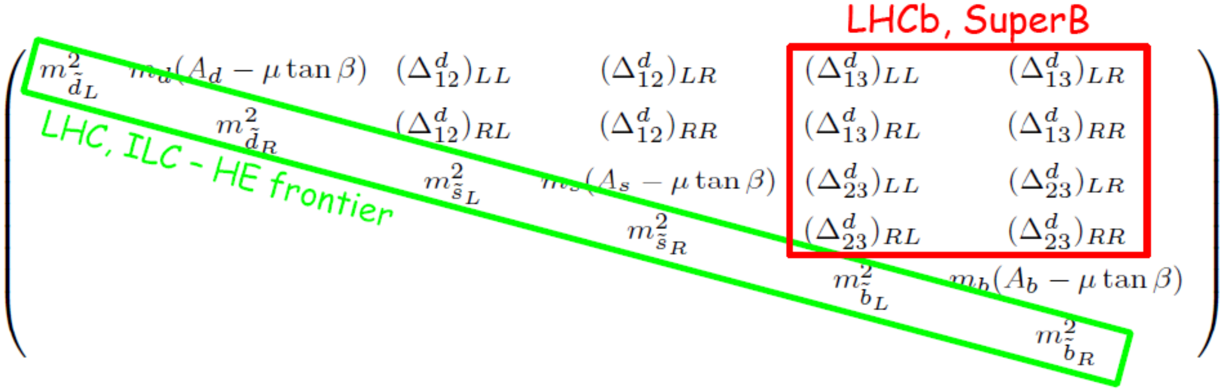
e.g. MSSM: 124 (160 with ν_R) couplings, most are flavour related.

Δ's are related to NP mass scale.



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

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

SuperB

- Aims to constrain flavour couplings of new physics at high energy:
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    - 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. **Neutral Higgs A0**: what can the flavour sector add to high p_T searches?
3. **Charged Higgs:** what do we know; what will LHC tell us; what does SuperB add?
4. **ΔS measurements**: high mass particle interferometry.

Physics Case in the LHC era

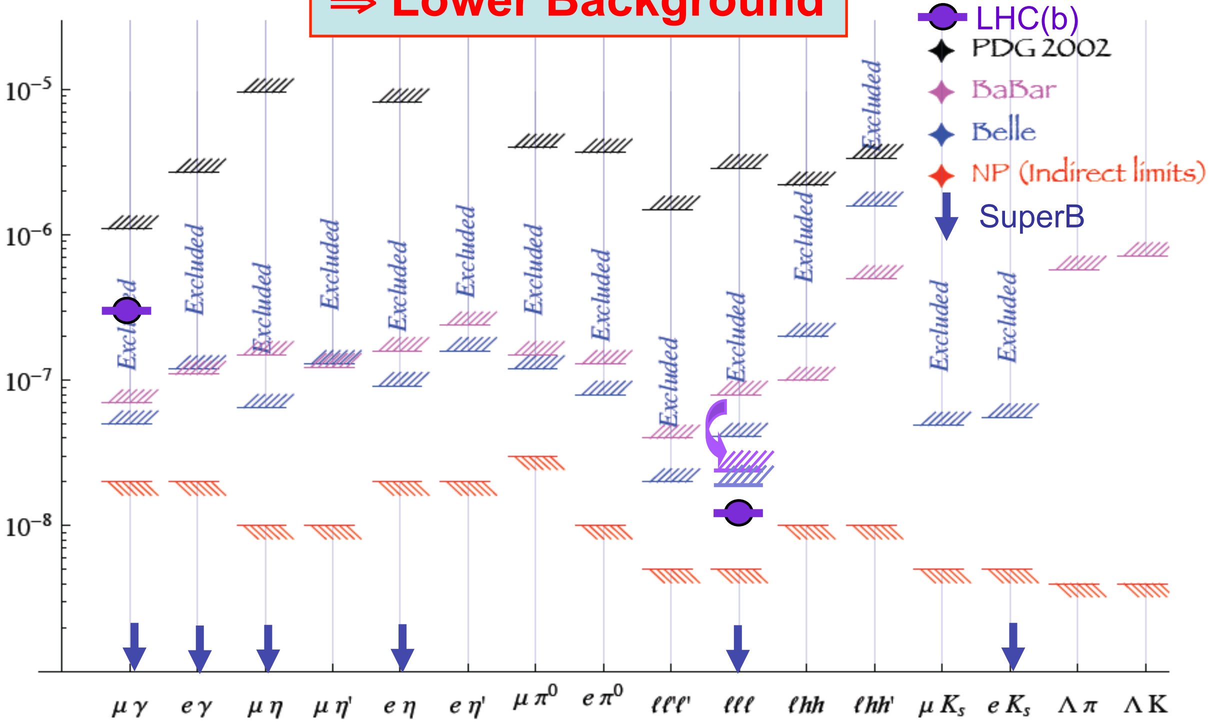
Why is SuperB experiment relevant when we have the energy frontier experiments and LHCb?

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

February 2010

Lepton Flavour Violation (τ decay)

e⁻ beam polarization
⇒ Lower Background



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

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}

(other modes not yet studied)

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

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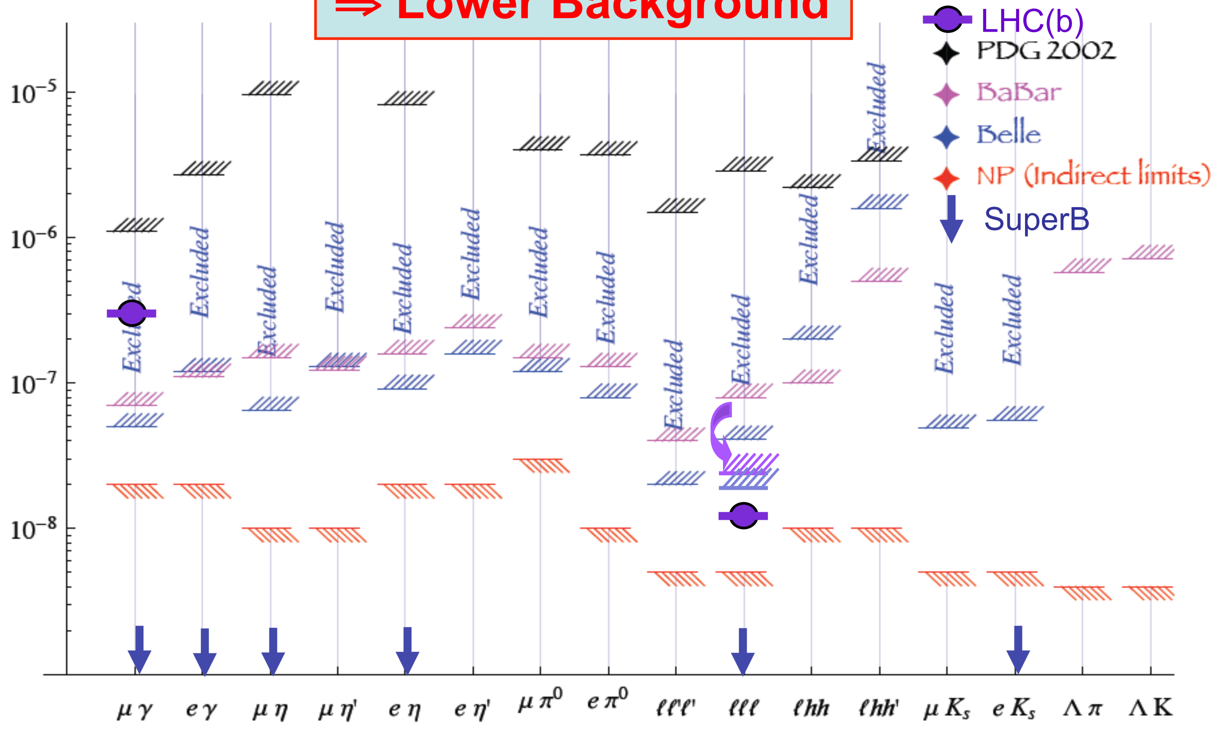

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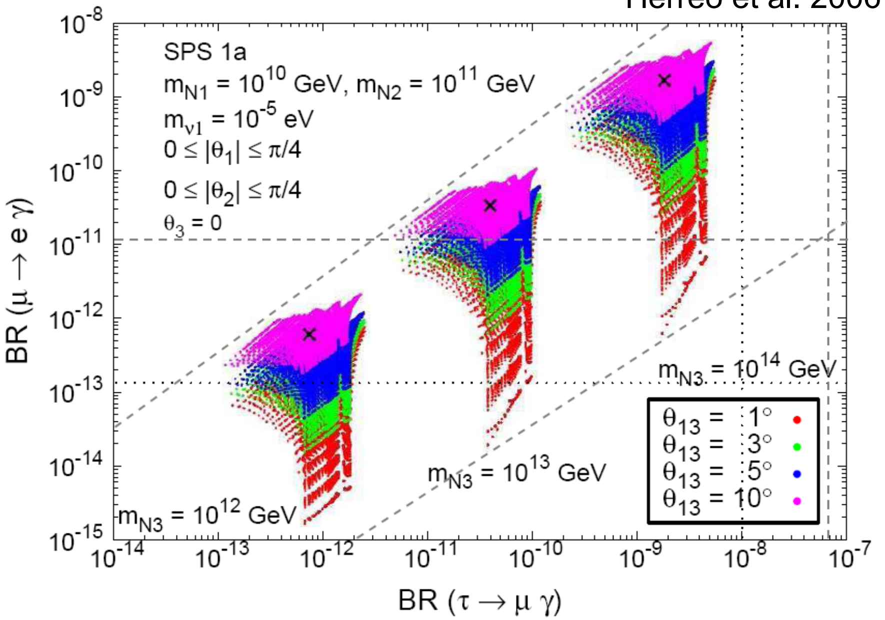
- Complementary to flavour mixing in quarks.
- Golden modes:
  - $\tau \to \mu\gamma$ and 3μ.
- e^- beam polarization:
  - Lower background
  - Better sensitivity than competition!
- e^+ polarization may be used later in programme.
- CPV in $\tau \to K_S \pi \nu$ at the level of $\sim 10^{-5}$.
- Bonus: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

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

Herreo et al. 2006



Use μ γ/3l to distinguish SUSY vs. LHT.

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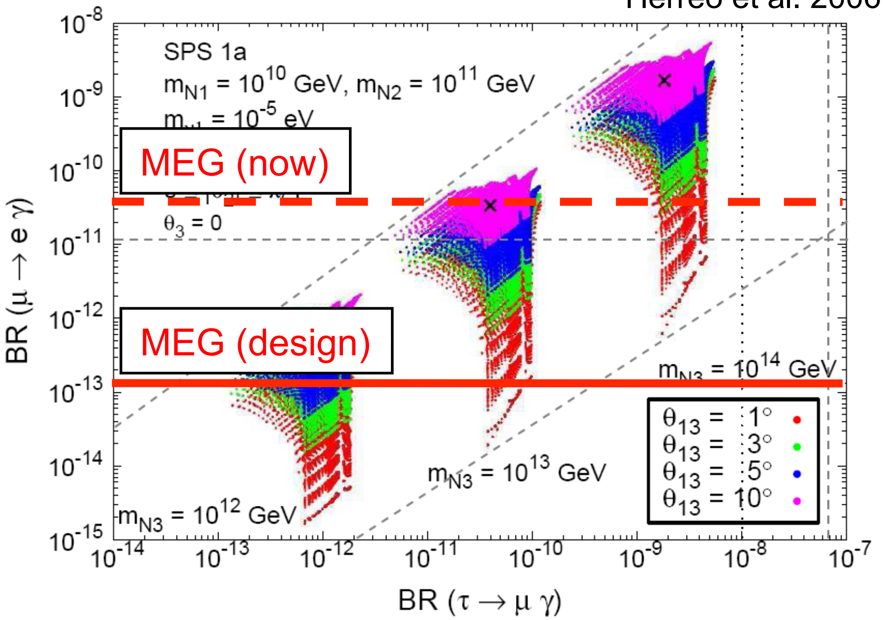

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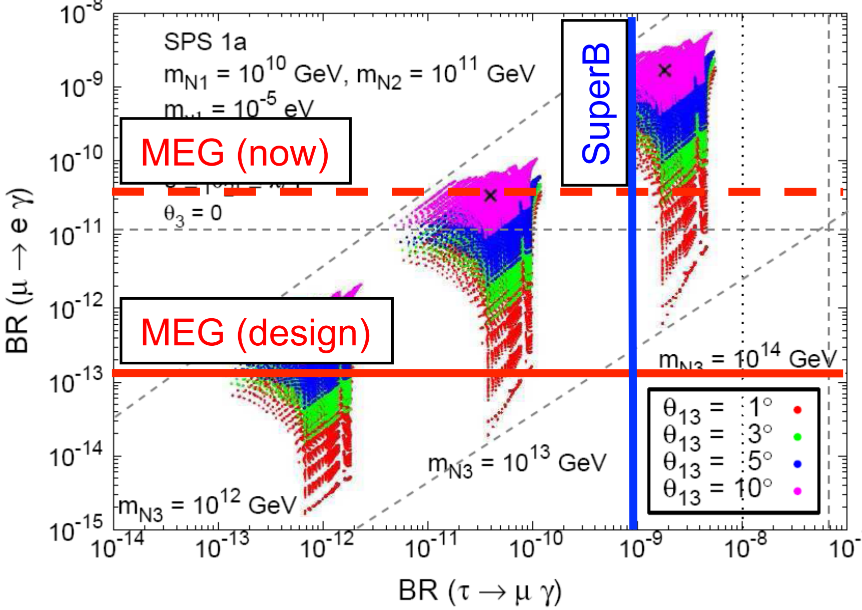
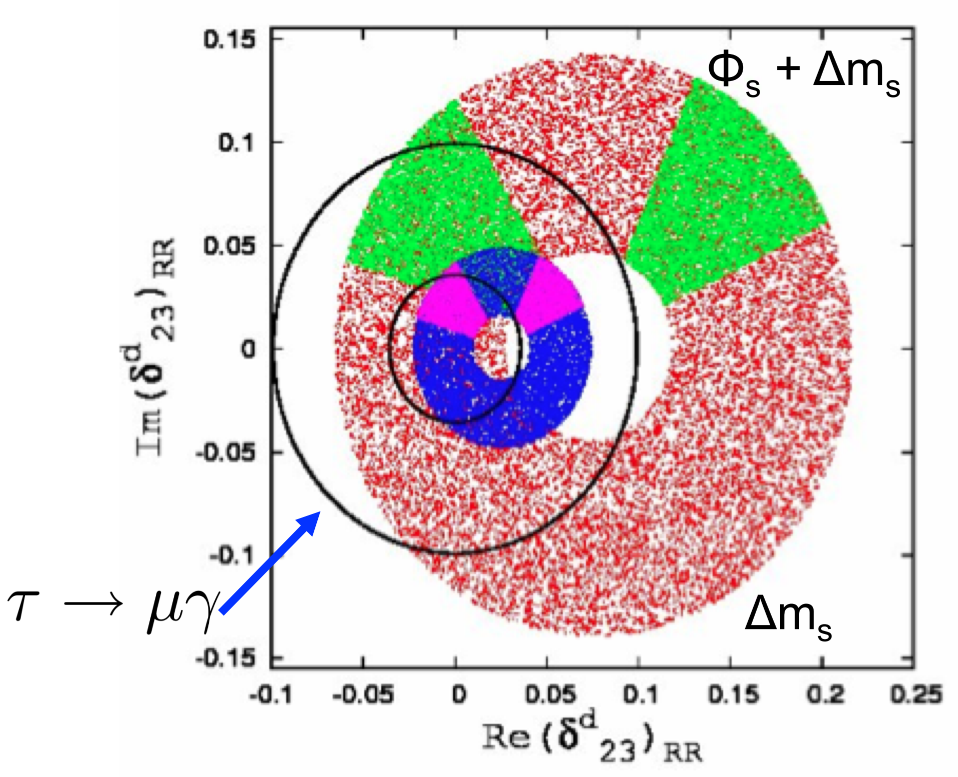


Use $\mu\,\gamma$/3l to distinguish SUSY vs. LHT.

Lepton Flavour Violation (τ decay)

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

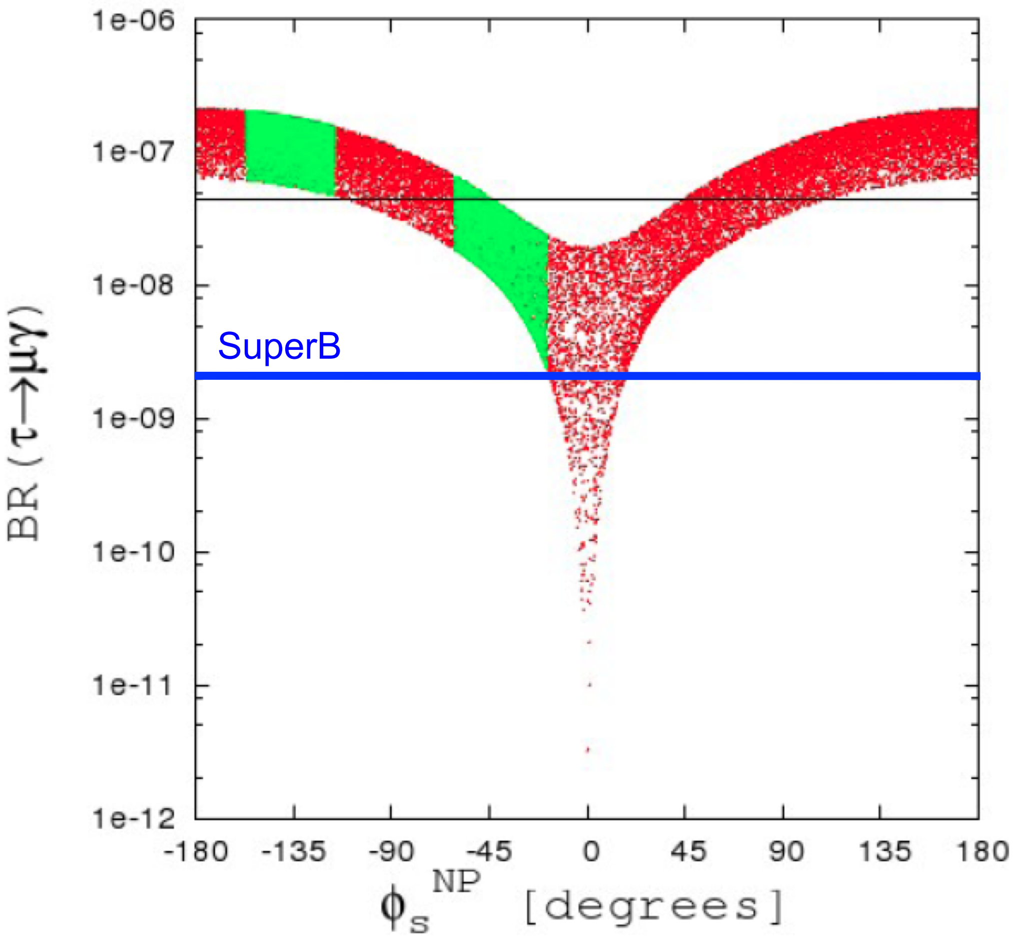
$m_{\tilde{q}} = 500\,GeV$ RED



- 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)>3×10^{-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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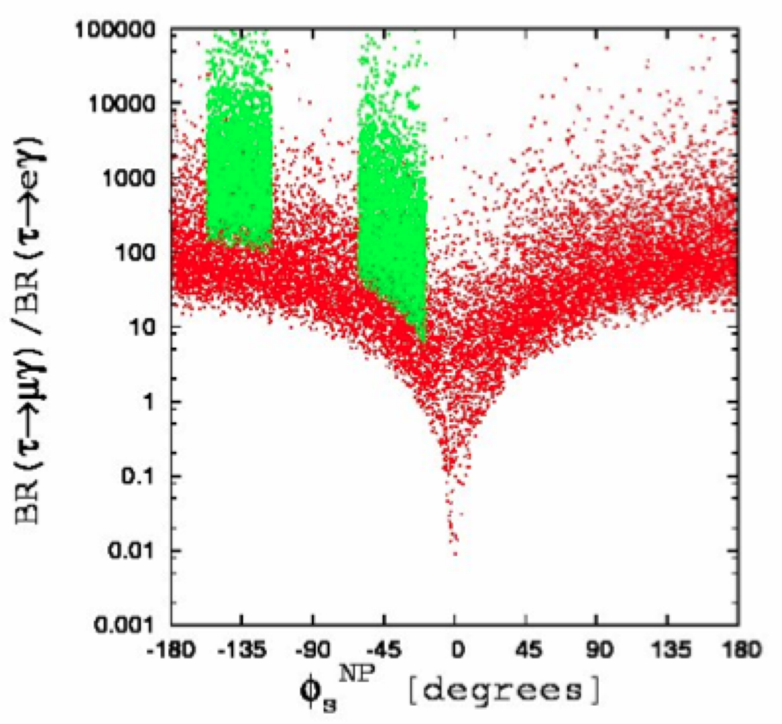

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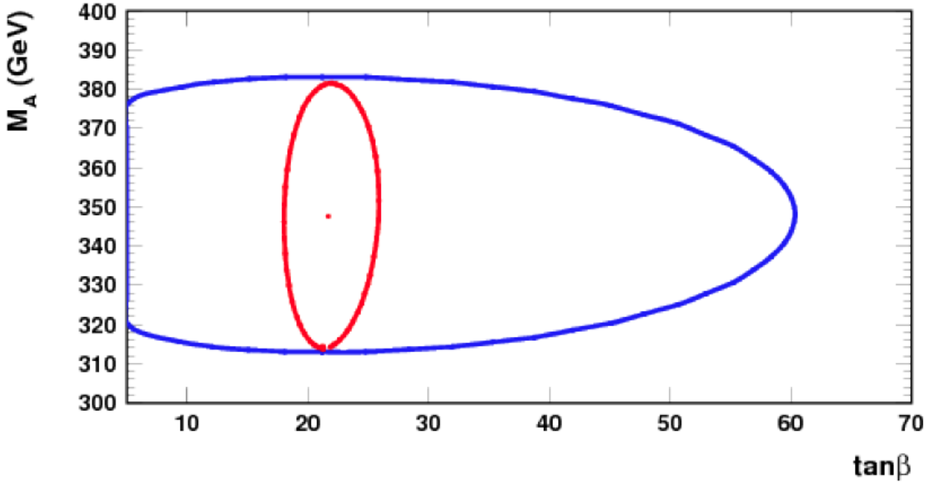
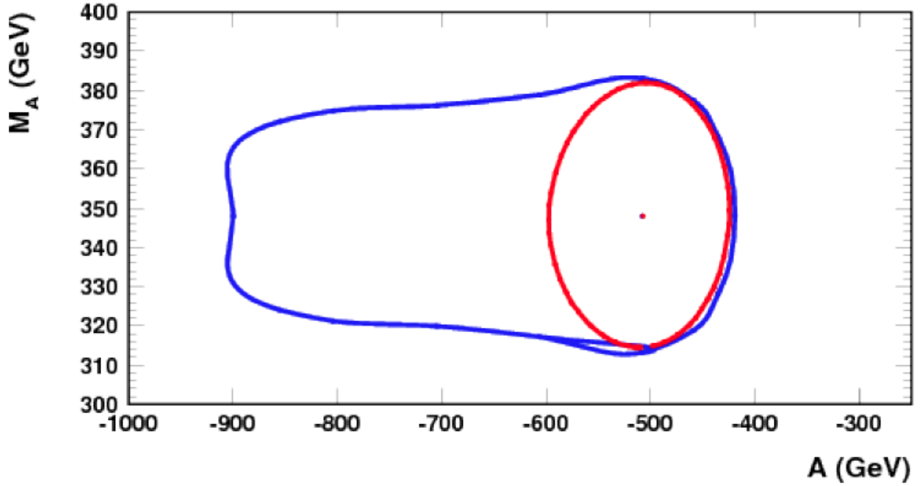
CMSSM: LHC/SuperB complementarity



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]

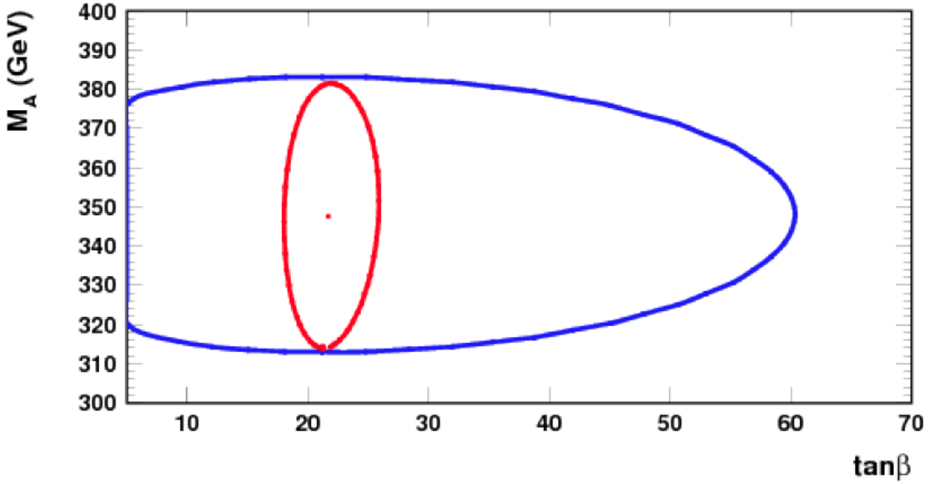


Red=LHC+EW/Low-energy constraints (includes SuperB):

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}	$80.392 \pm 0.020\,\mathrm{GeV}$	$0.020\,\mathrm{GeV}$
$\sin^2\theta_W^{\mathrm{SUSY}}$	0.23153 ± 0.00016	0.00016
$M_h^{\mathrm{light}}(\mathrm{SUSY})$	$> 114.4\,\mathrm{GeV}$	$3.0\,\mathrm{GeV}$

Current analysis of data prefers tanβ~10.

CMSSM: LHC/SuperB complementarity



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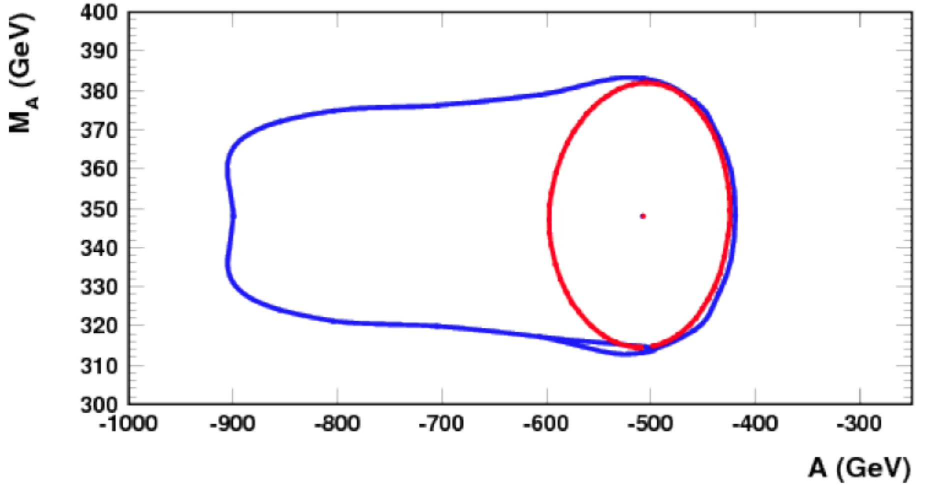


Red=LHC+EW/Low-energy constraints (includes SuperB):

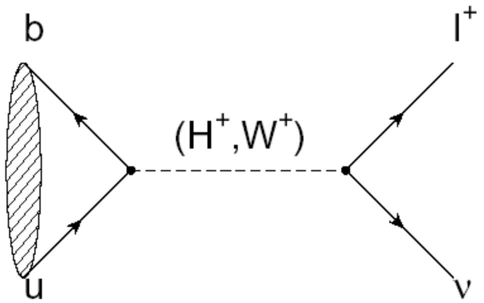
- Can build on the m(A) measurement to measure tanβ.

Current analysis of data prefers tanβ~10.

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

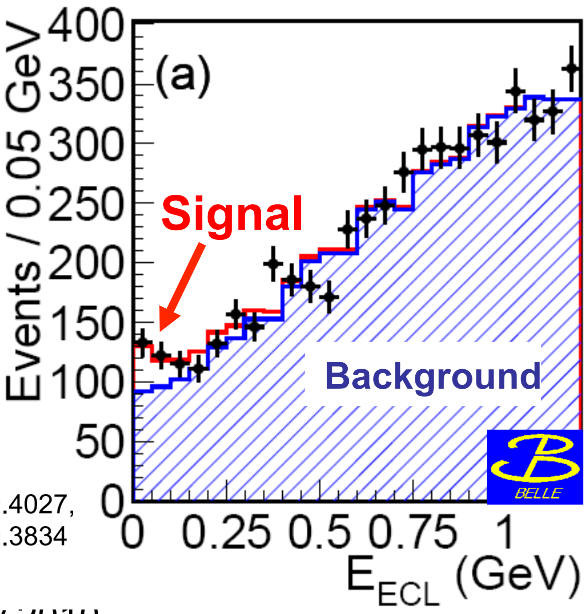
Charged Higgs: $B^{\pm} \to \tau^{\pm}\nu$

- 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.
- Fully reconstruct the event (modulo ν).

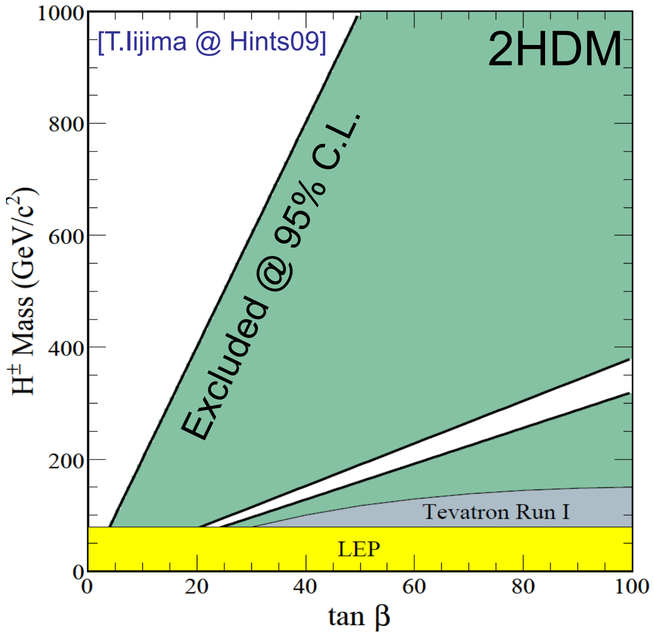


$$\mathcal{B}_{\mathcal{SM}}(B^+ \to l^+\nu_l) = \frac{G_F^2 m_B m_l^2}{8\pi}\left(1-\frac{m_l^2}{m_B^2}\right) f_B^2 \, |V_{ub}|^2 \, \tau_B$$

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



arXiv:0809.4027,
arXiv:0809.3834

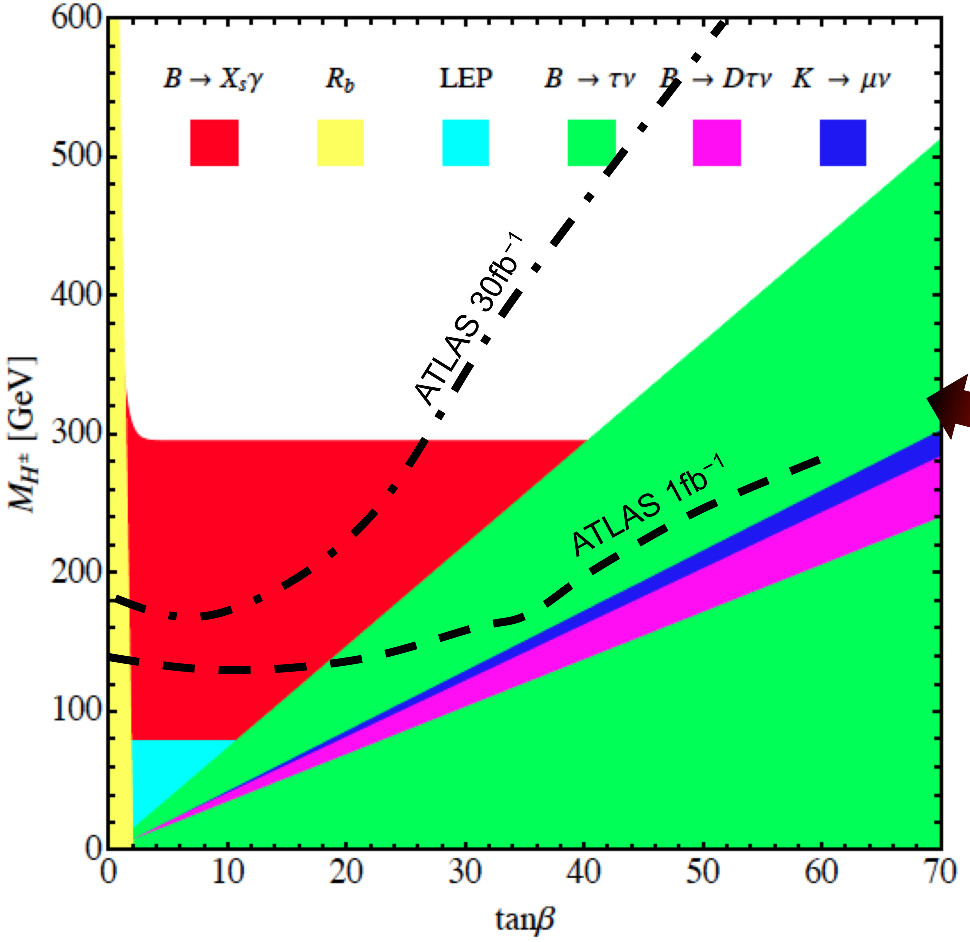


2HDM: W.-S Hou PRD **48** 2342 (1993)
MSSM: G. Isidori arXiv:0710.5377
Unparticles: R. Zwicky PRD**77** 036004 (2008)

Charged Higgs

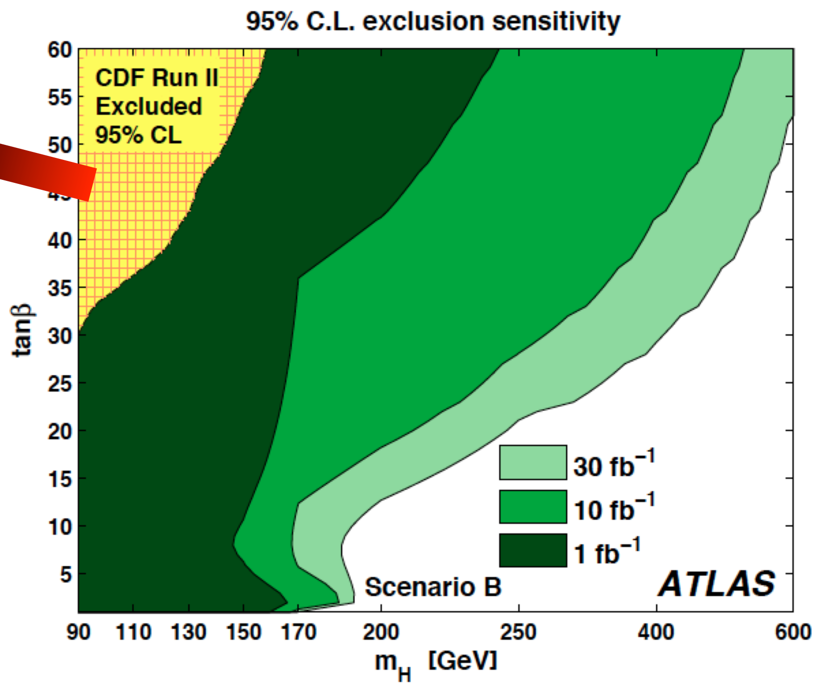
- B-factory searches competitive with LHC era: e.g. 2HDM

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



U. Haisch 0805.2141

Converted constraints expected from
ATLAS onto the plot by hand.



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

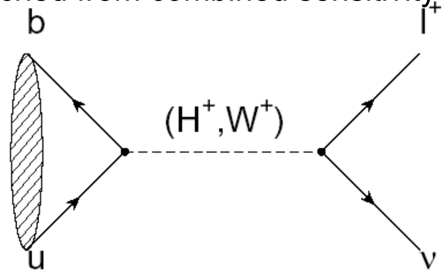
Charged Higgs

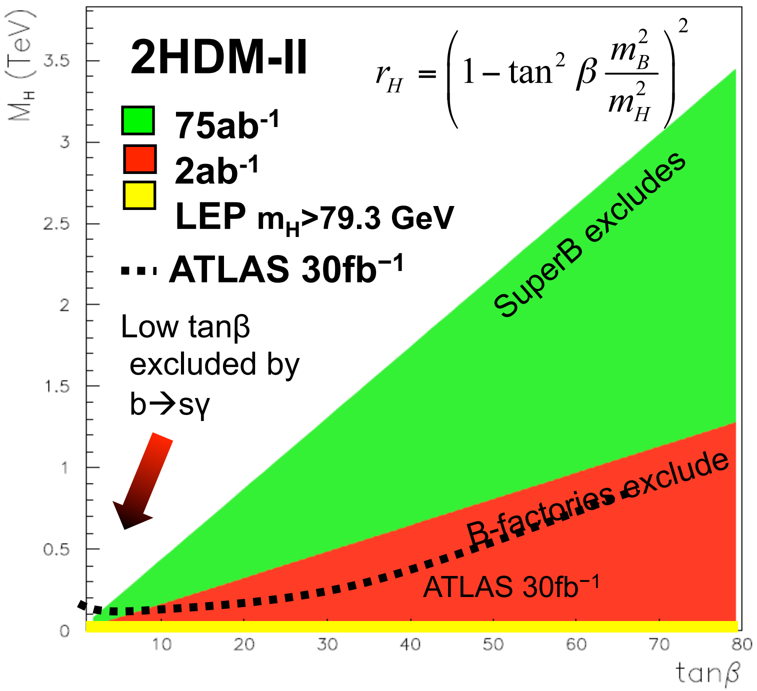
B-factories have 1.5ab^{-1} of data.
ATLAS sensitivity sketched from combined sensitivity plots in arXiv:0901.0512.

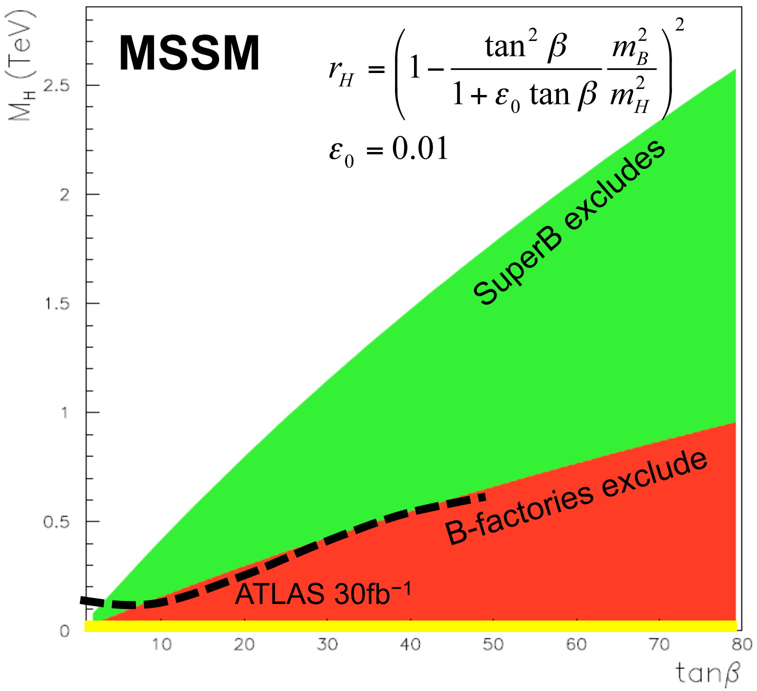
- Higgs mediated MFV:

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

(Assuming SM branching fraction is measured)







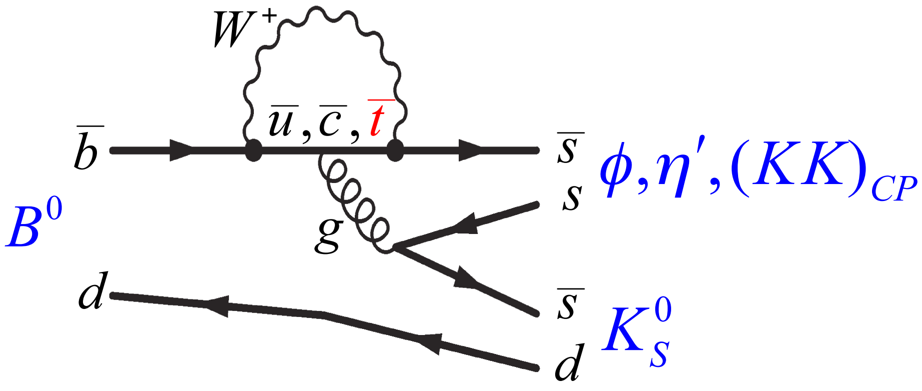
- Multi TeV search capability for large tanβ.
- Includes SM uncertainty ~20% from V_{ub} and f_B.

ΔS measurements

- β=(21.1±0.9)° from Charmonium decays.
- Look in many different b→s and b→d decays for sin2β deviations from the SM:

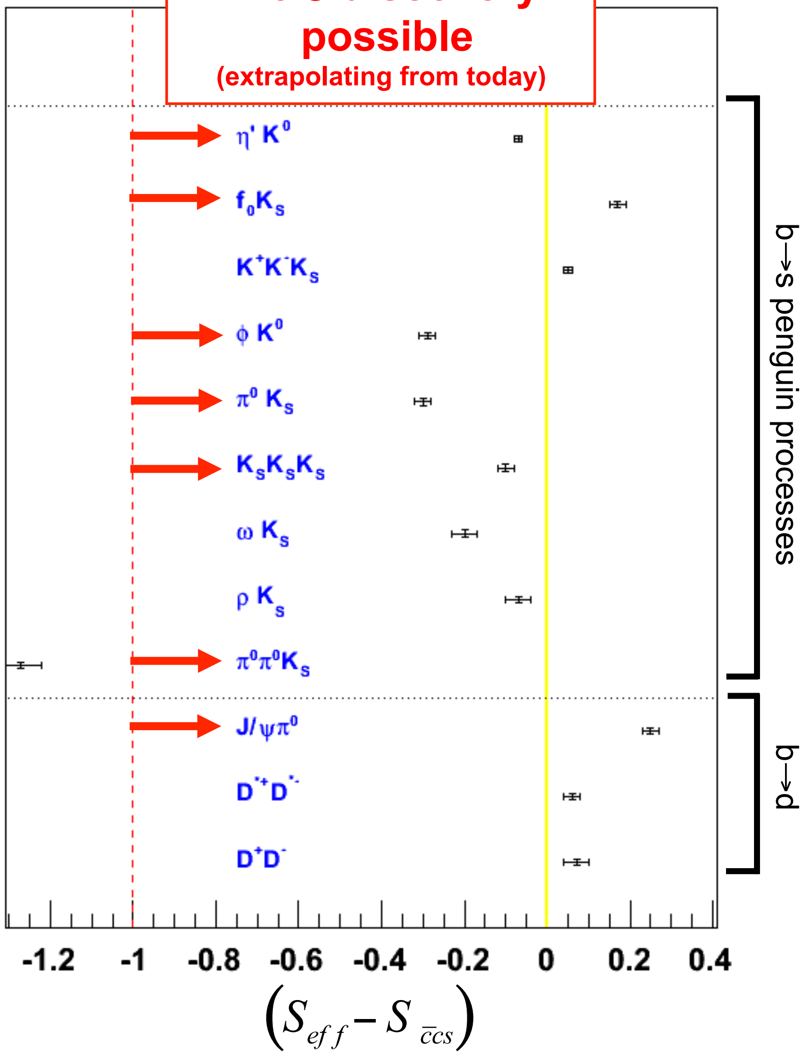
$$\Delta S_{\mathrm{NP}} = S_{eff} - S_{c\bar{c}s} - \Delta S_{\mathrm{SM}}$$

- The golden channel is:



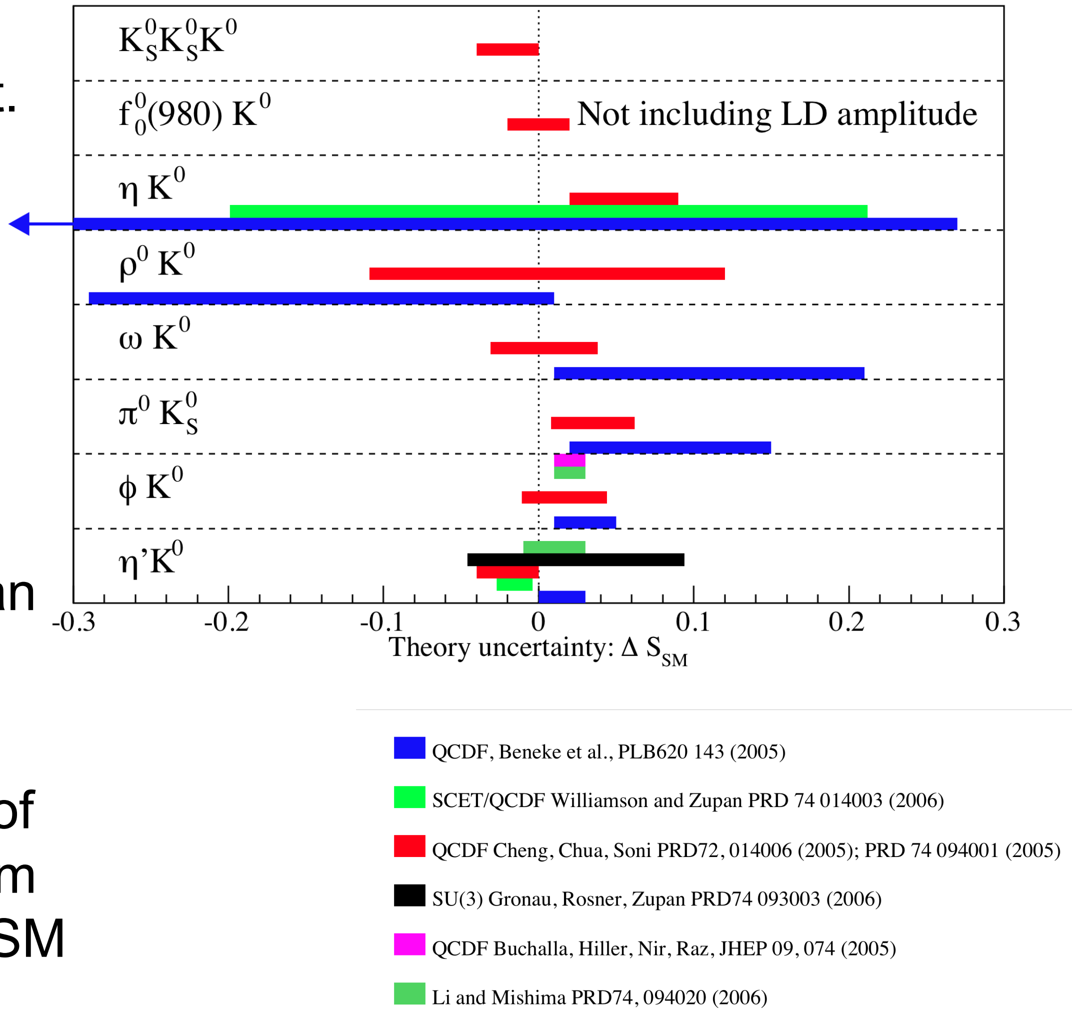
- Deviations would be from high mass particles in loops: H, χ, ...

≥ 5 σ discovery possible
(extrapolating from today)



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.

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

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.

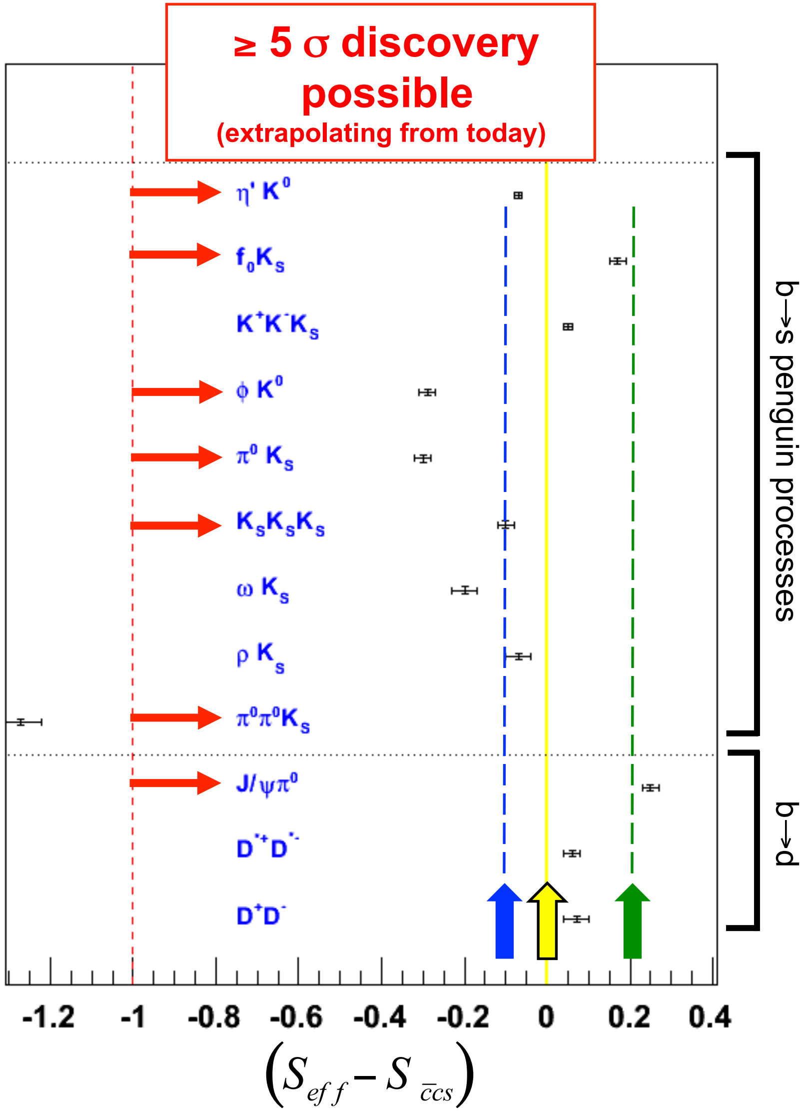
$$[\sin 2\beta]^{clean}_{b\to s-penguin} = 0.58 \pm 0.06$$ 🟦

(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).

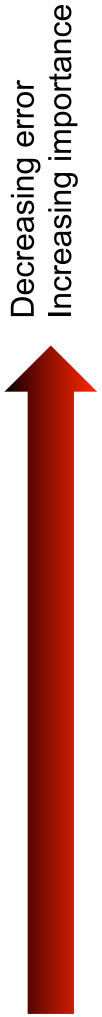
- **Can theory error be reduced for other modes?**



≥ 5 σ discovery possible
(extrapolating from today)

ΔS measurements

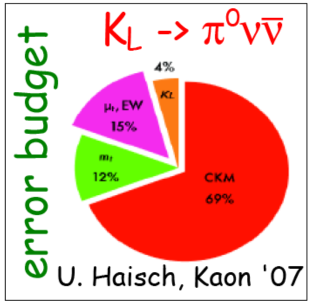
Mode	Current Precision			Predicted Precision ($75\,\text{ab}^{-1}$)			Discovery Potential	
	Stat.	Syst.	Th.	Stat.	Syst.	Th.	3σ	5σ
$J/\psi K^0_S$	0.022	0.010	< 0.01	0.002	0.005	< 0.001	0.02	0.03
$\eta' K^0_S$	0.08	0.02	0.014	0.006	0.005	0.014	0.05	0.08
$\phi K^0_S \pi^0$	0.28	0.01	–	0.020	0.010	–	0.07	0.11
$f_0 K^0_S$	0.18	0.04	0.02	0.012	0.003	0.02	0.07	0.12
$K^0_S K^0_S K^0_S$	0.19	0.03	0.013	0.015	0.020	0.013	0.08	0.14
ϕK^0_S	0.26	0.03	0.02	0.020	0.010	0.005	0.09	0.14
$\pi^0 K^0_S$	0.20	0.03	0.025	0.015	0.015	0.025	0.10	0.16
ωK^0_S	0.28	0.02	0.035	0.020	0.005	0.035	0.12	0.21
$K^+ K^- K^0_S$	0.08	0.03	0.05	0.006	0.005	0.05	0.15	0.26
$\pi^0 \pi^0 K^0_S$	0.71	0.08	–	0.038	0.045	–	0.18	0.30
ρK^0_S	0.28	0.07	0.14	0.020	0.017	0.14	0.41	0.61
$J/\psi \pi^0$	0.21	0.04	–	0.016	0.005	–	0.05	0.08
$D^{*+} D^{*-}$	0.16	0.03	–	0.012	0.017	–	0.06	0.11
$D^+ D^-$	0.36	0.05	–	0.027	0.008	–	0.09	0.14



Precision CKM

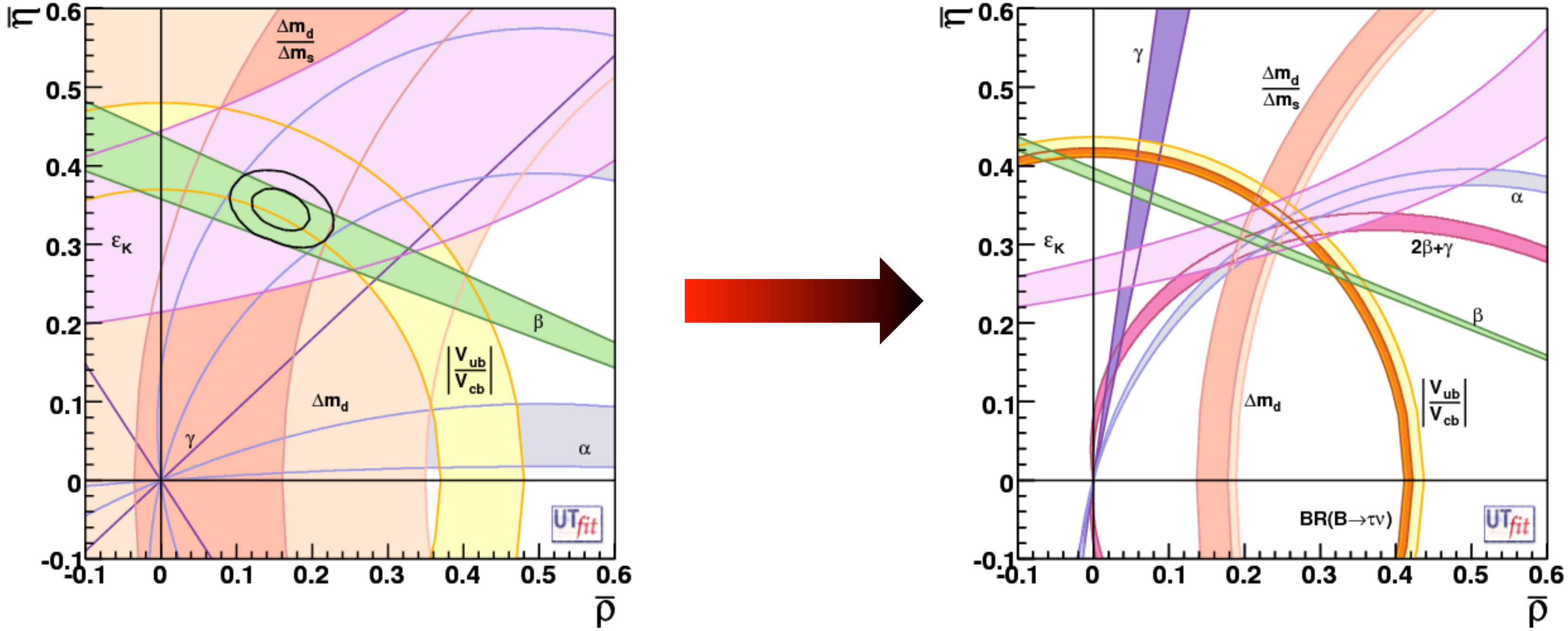
- CKM is a 36 year old anzatz.
- Works at the 10% level.
- No underlying physical insight.
- Small new physics contributions not ruled out (% level).

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



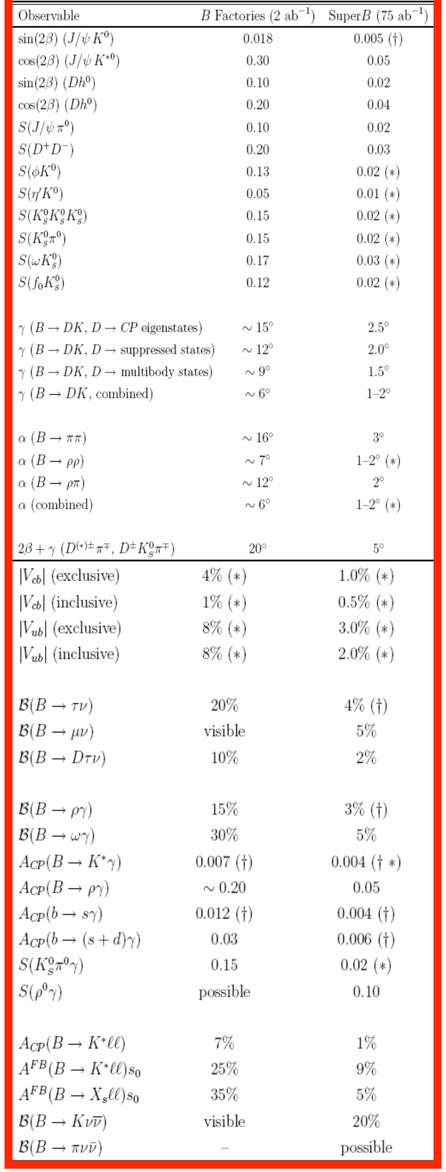
U. Haisch, Kaon '07

K+ decay has a similar error budget.



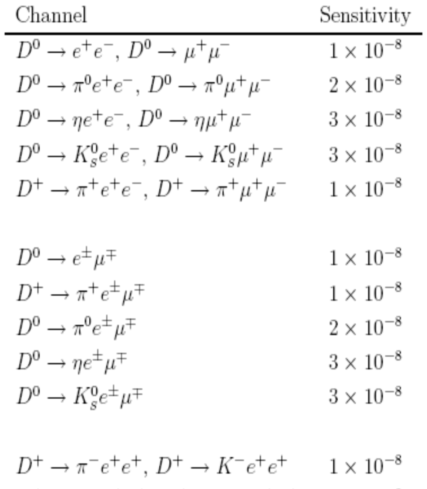
Standard Model measurements.

B Physics at Υ(4S)



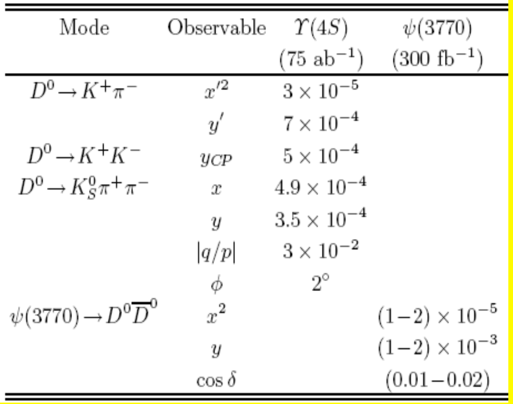
Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab^{-1})
$\sin(2\beta)$ $(J/\psi\,K^0)$	0.018	0.005 (†)
$\cos(2\beta)$ $(J/\psi\,K^{*0})$	0.30	0.05
$\sin(2\beta)$ (Dh^0)	0.10	0.02
$\cos(2\beta)$ (Dh^0)	0.20	0.04
$S(J/\psi\,\pi^0)$	0.10	0.02
$S(D^+D^-)$	0.20	0.03
$S(\phi K^0)$	0.13	0.02 (∗)
$S(\eta' K^0)$	0.05	0.01 (∗)
$S(K^0_s K^0_s K^0_s)$	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% (∗)
$\mathcal{B}(B \to \tau\nu)$	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 (†)
$S(K^0_S \pi^0 \gamma)$	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%
$\mathcal{B}(B \to K\nu\overline{\nu})$	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}
$D^0 \to K^0_S e^+e^-$, $D^0 \to K^0_S \mu^+\mu^-$	3×10^{-8}
$D^+ \to \pi^+ e^+e^-$, $D^+ \to \pi^+\mu^+\mu^-$	1×10^{-8}
$D^0 \to e^\pm\mu^\mp$	1×10^{-8}
$D^+ \to \pi^+ e^\pm\mu^\mp$	1×10^{-8}
$D^0 \to \pi^0 e^\pm\mu^\mp$	2×10^{-8}
$D^0 \to \eta e^\pm\mu^\mp$	3×10^{-8}
$D^0 \to K^0_S e^\pm\mu^\mp$	3×10^{-8}
$D^+ \to \pi^- e^+e^+$, $D^+ \to K^- e^+e^+$	1×10^{-8}
$D^+ \to \pi^-\mu^+\mu^+$, $D^+ \to K^-\mu^+\mu^+$	1×10^{-8}
$D^+ \to \pi^- e^\pm\mu^\mp$, $D^+ \to K^- e^\pm\mu^\mp$	1×10^{-8}

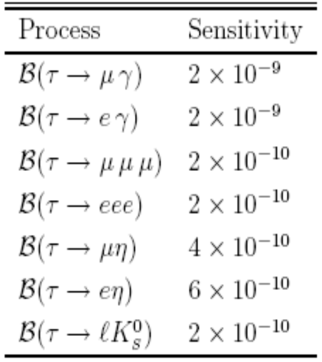
Charm Mixing



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}	
$D^0 \to K^0_S \pi^+\pi^-$	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		$(1-2) \times 10^{-3}$
	$\cos\delta$		$(0.01-0.02)$

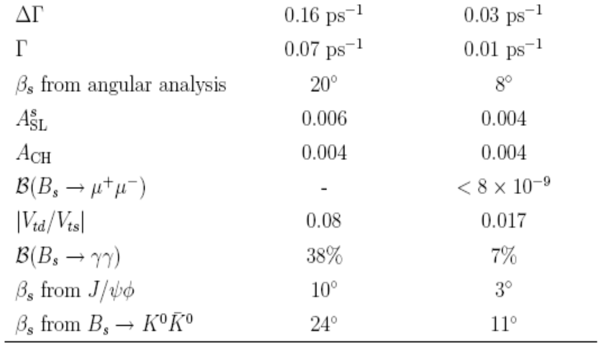
See CDR and Valencia report for details of the SM measurements and other possible NP searches.

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}
$\mathcal{B}(\tau \to \ell K^0_S)$	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°
$A^s_{\rm SL}$	0.006	0.004
$A_{\rm CH}$	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!

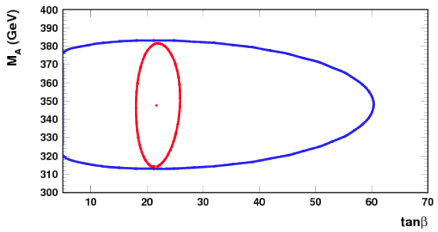
Mode	Sensitivity Current	10 ab^{-1}	75 ab^{-1}
$\mathcal{B}(B \to X_s\gamma)$	7%	5%	3%
$A_{CP}(B \to X_s\gamma)$	0.037	0.01	0.004–0.005
$\mathcal{B}(B^+ \to \tau^+\nu)$	30%	10%	3–4%
$\mathcal{B}(B^+ \to \mu^+\nu)$	X	20%	5–6%
$\mathcal{B}(B \to X_s l^+ l^-)$	23%	15%	4–6%
$A_{\rm FB}(B \to X_s l^+ l^-)_{s_0}$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

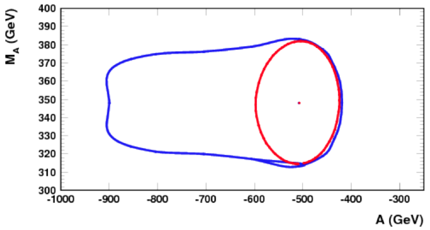
- **The golden modes**
  - **will be measured by SuperB.**
  - **`smoking guns’ for their models.**

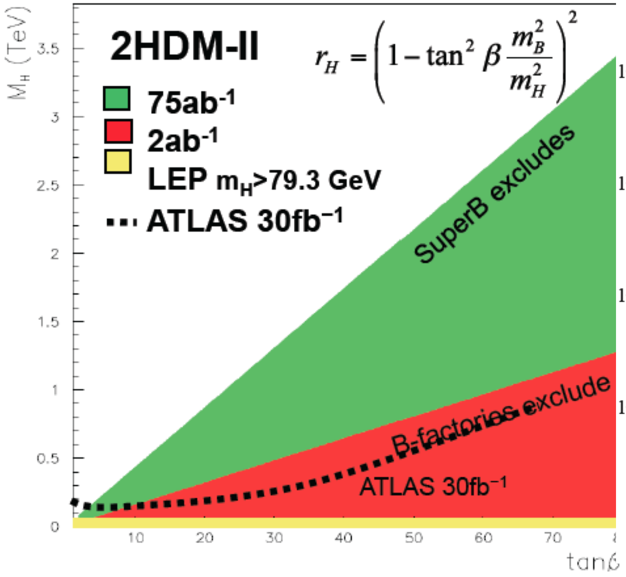
- **Measurements not yet made are denoted by X.**

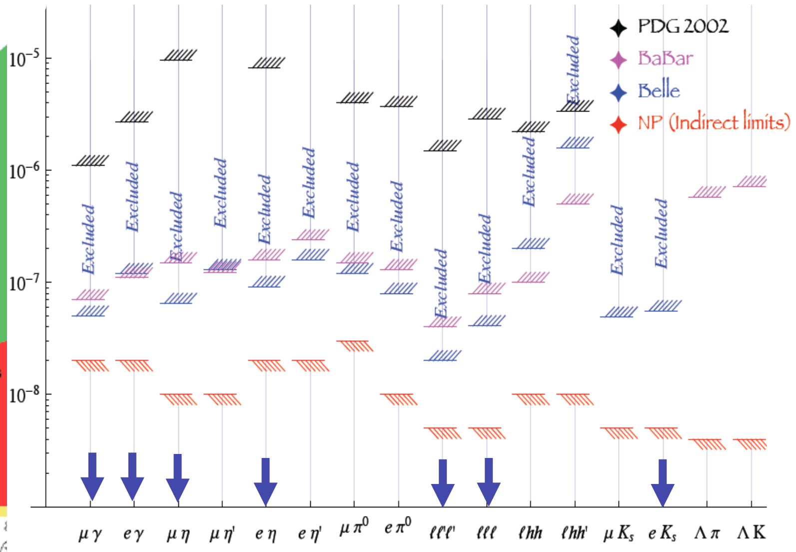
- **With 75ab^{-1} we can**
  - **Reach above a TeV with B→ τν**
  - **See B→Kν$\overline{\nu}$**

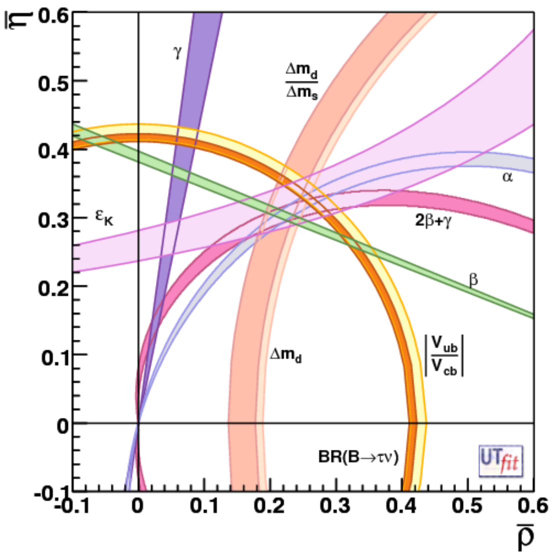
The Physics Case in 1 Page

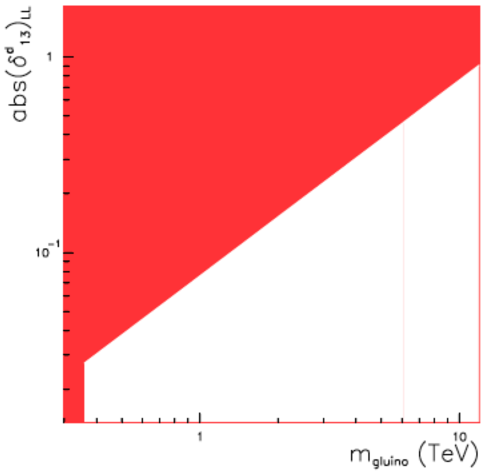


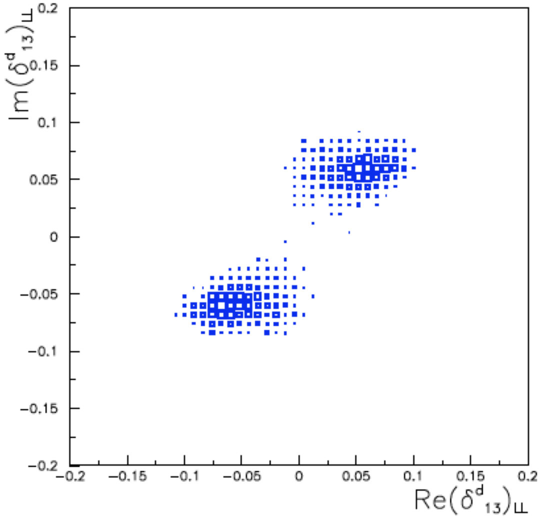






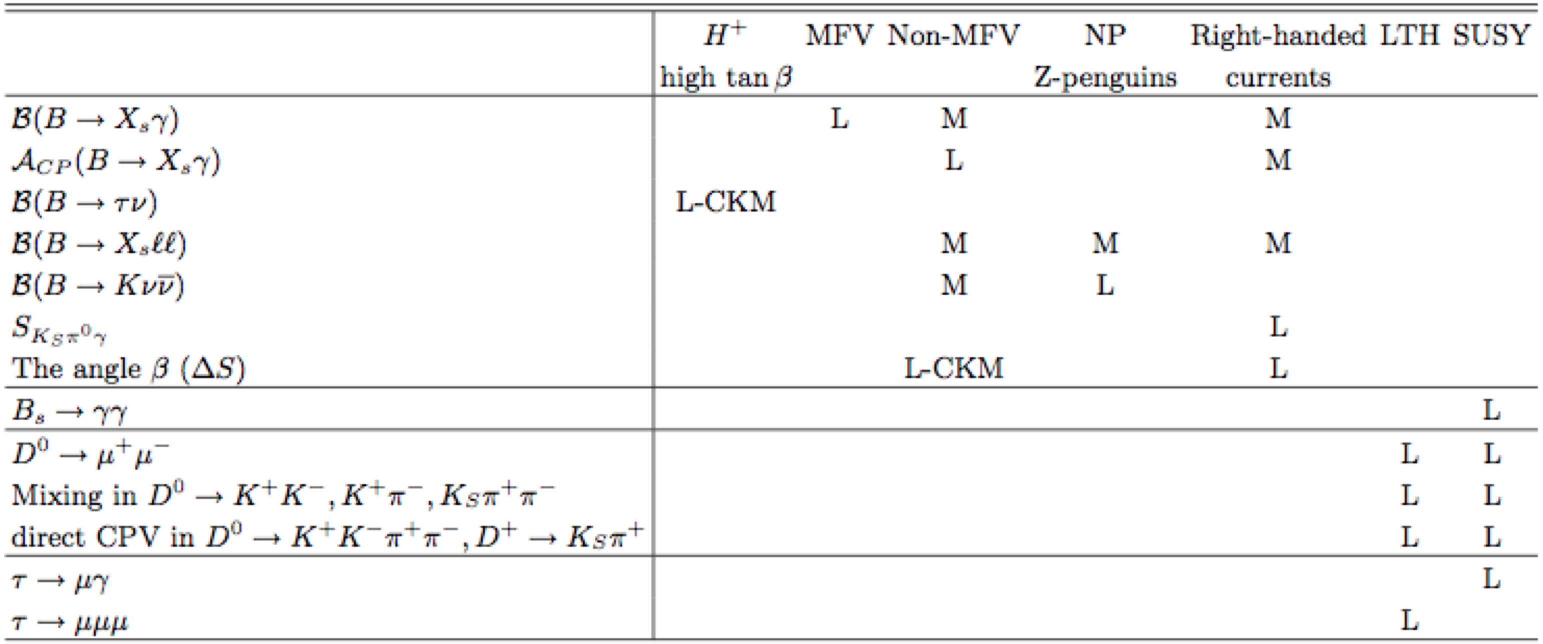






The Golden Matrix

- Each mode is a golden signature of new physics.
  - A priori we need to measure them all!



	H^+ high tan β	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		
$B_s \to \gamma\gamma$							L
$D^0 \to \mu^+\mu^-$						L	L
Mixing in $D^0 \to K^+K^-, K^+\pi^-, K_S\pi^+\pi^-$						L	L
direct CPV in $D^0 \to K^+K^-\pi^+\pi^-, D^+ \to K_S\pi^+$						L	L
$\tau \to \mu\gamma$							L
$\tau \to \mu\mu\mu$						L	

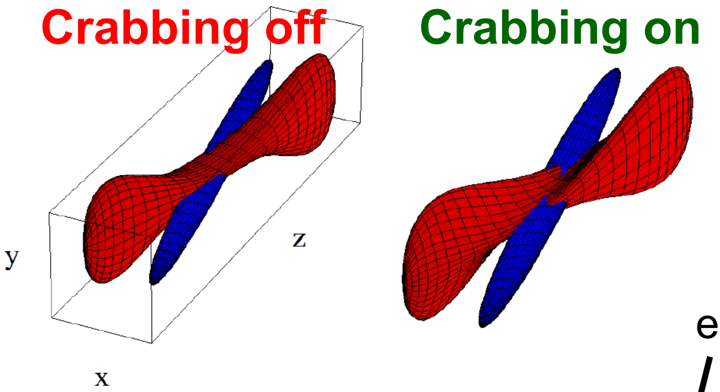
Accelerator Aspects

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

February 2010

Crab waist tests at DAΦNE

Crabbing off **Crabbing on**



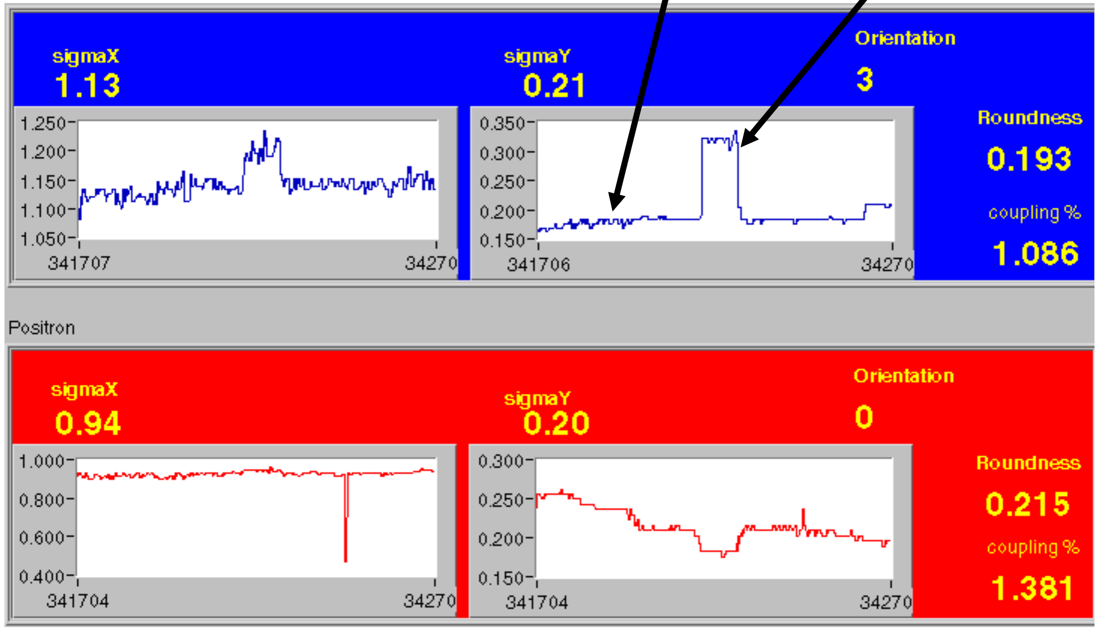
Crab sextupoles give luminosity improvement of roughly factor 2.

(Factor of 4 achieved in latest run!)

e^- sextupoles on

e^- sextupoles off

Transverse beam sizes at Synchrotron Light Monitors


sigmaX 1.13

sigmaY 0.21

Orientation 3

Roundness 0.193

coupling % 1.086

Positron

sigmaX 0.94

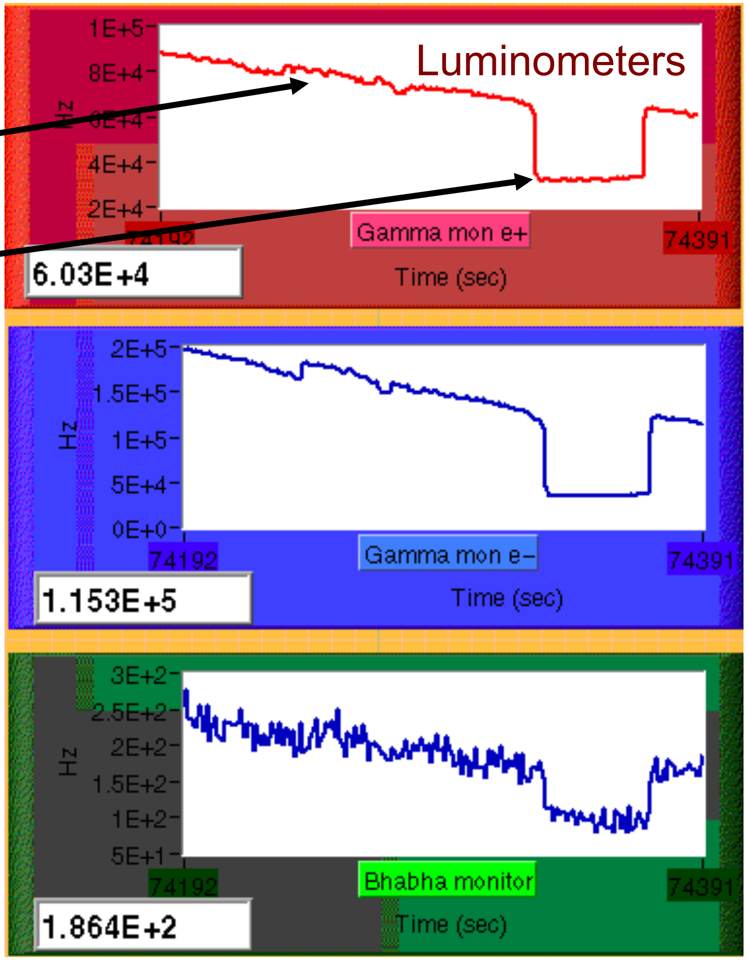
sigmaY 0.20

Orientation 0

Roundness 0.215

coupling % 1.381

Luminometers


Gamma mon e+ 6.03E+4

Gamma mon e− 1.153E+5

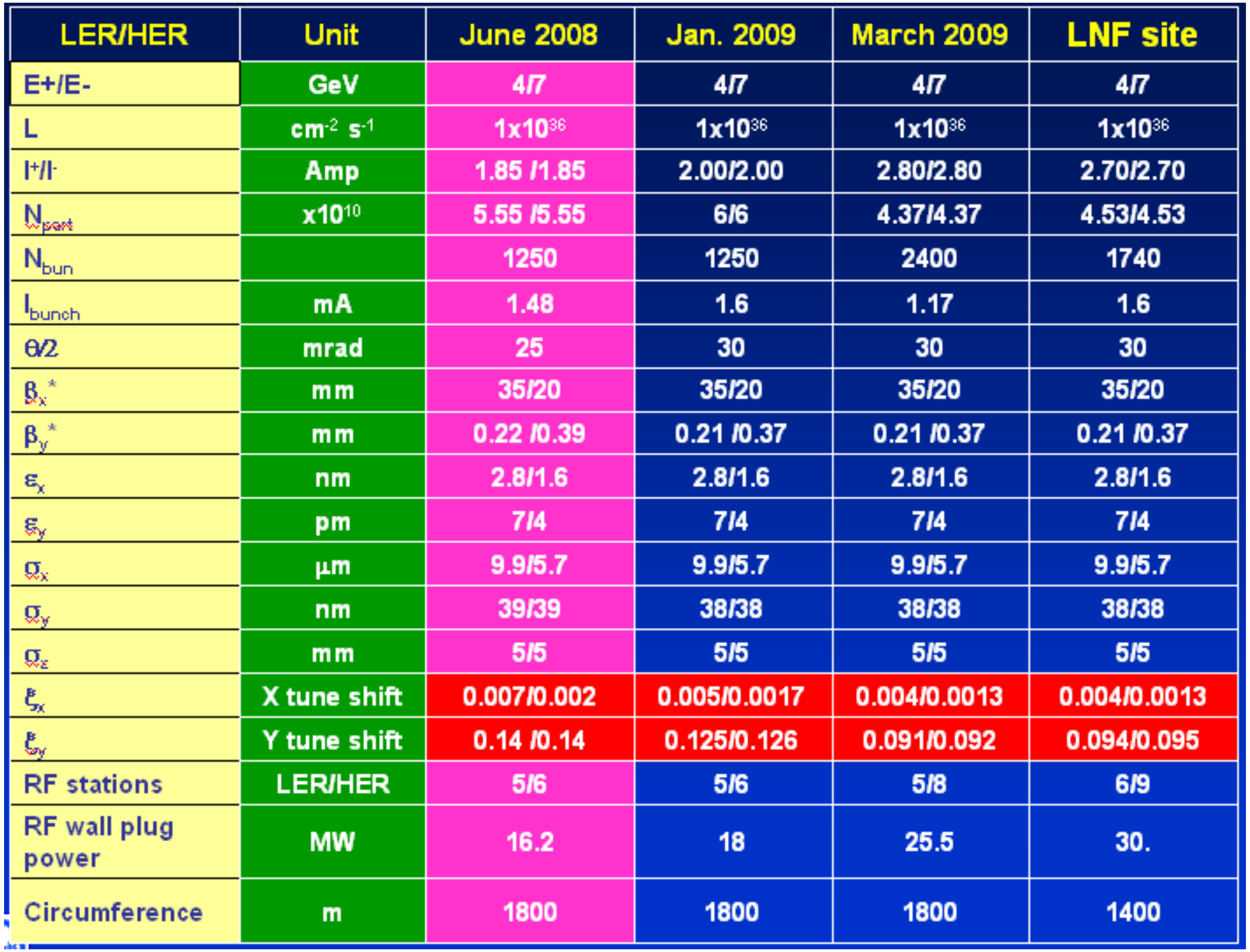
Bhabha monitor 1.864E+2

P. Raimondi (INFN-LNF)

PARAMETERS

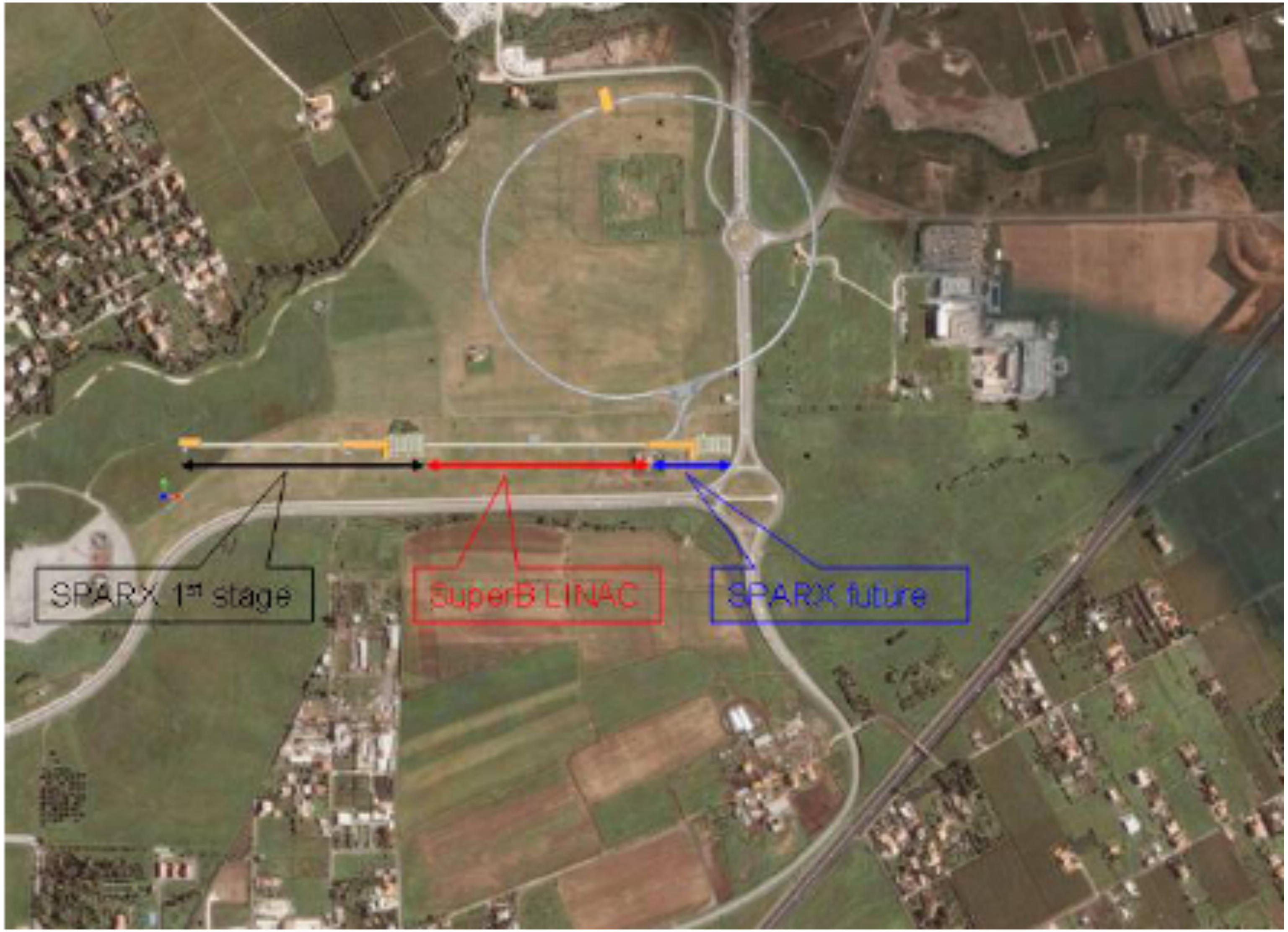
J.Seeman @MiniMac

Spring/Summer 09 parameter set.



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

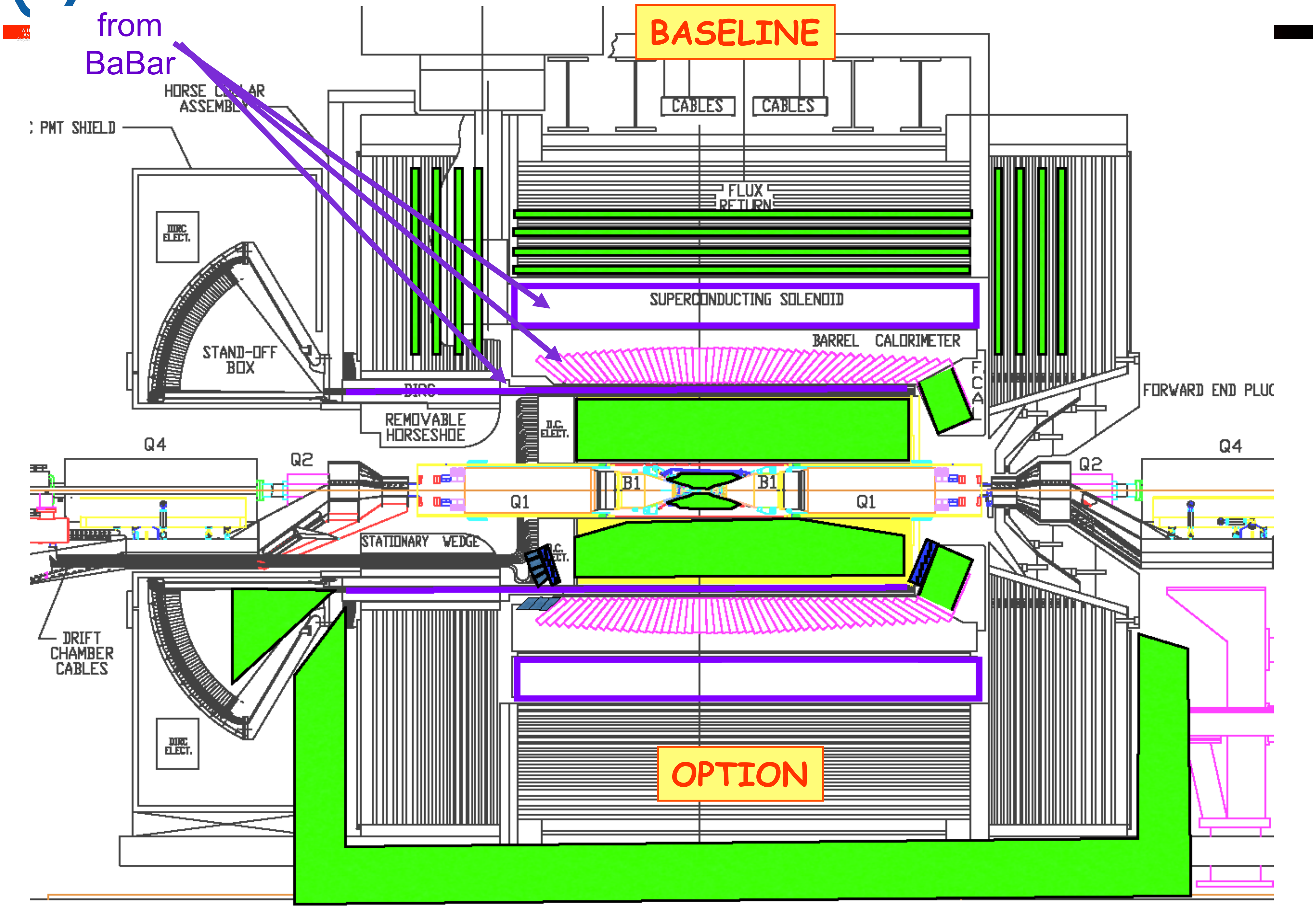
SITES : Tor Vergata……..



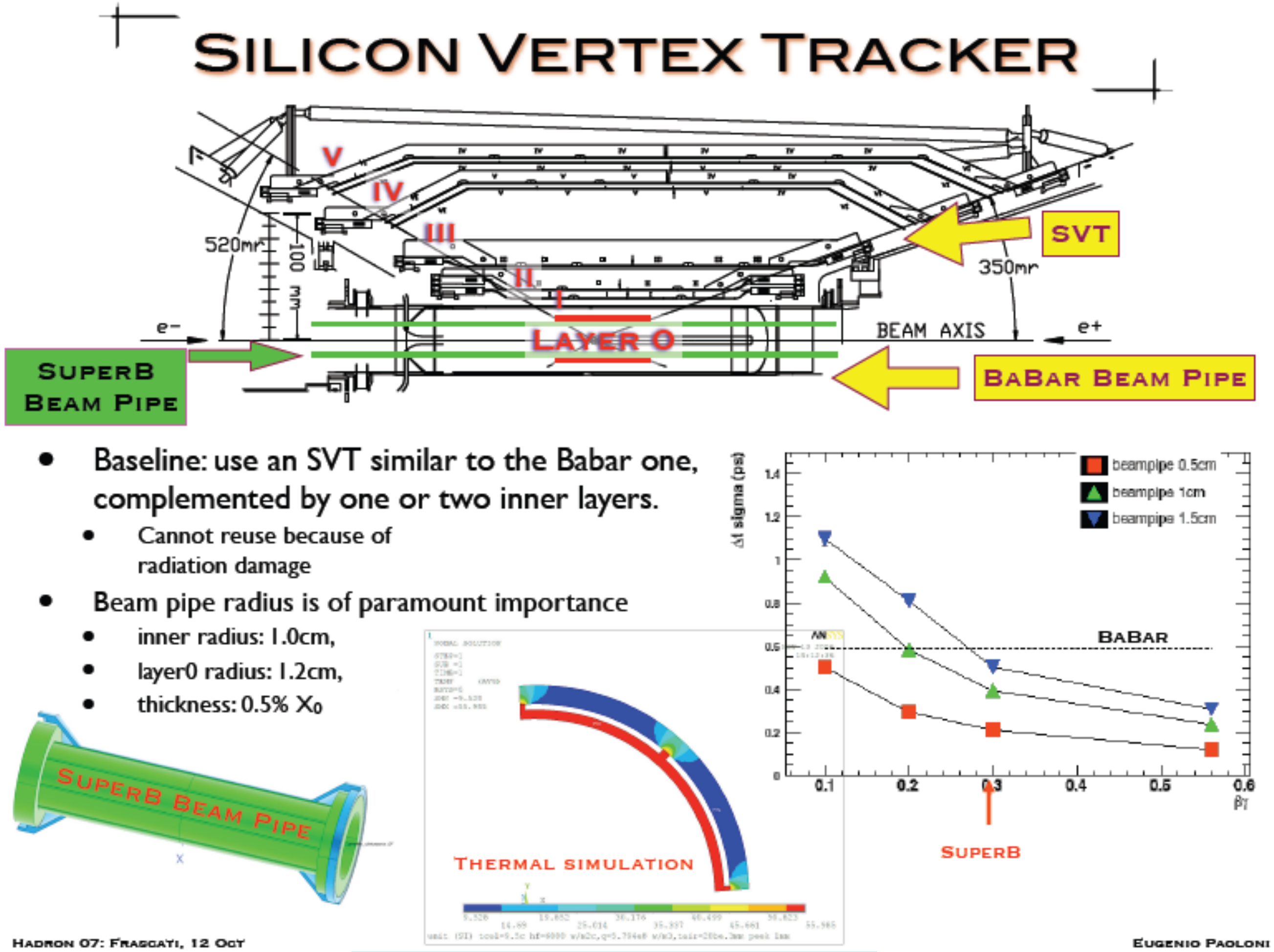
LNF option

Detector Design

Reuse from BaBar



Tracking



SILICON VERTEX TRACKER

- Baseline: use an SVT similar to the Babar one, complemented by one or two inner layers.
  - Cannot reuse because of radiation damage
- Beam pipe radius is of paramount importance
  - inner radius: 1.0cm,
  - layer0 radius: 1.2cm,
  - thickness: 0.5% X_0

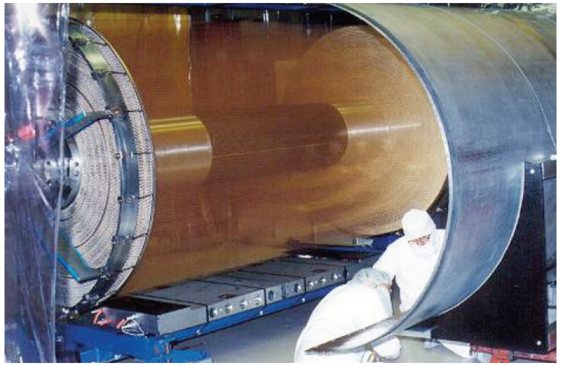
Hadron 07: Frascati, 12 Oct

Eugenio Paoloni

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

BaBar DCH Design

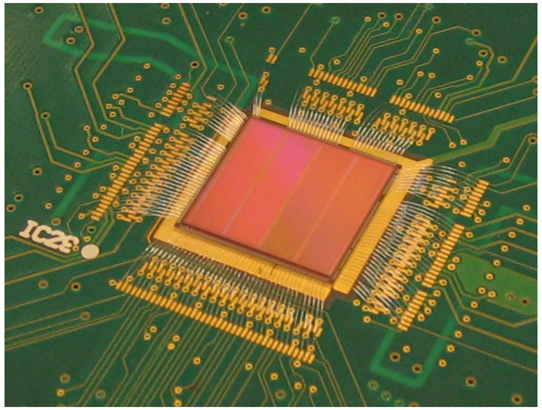
- Adequate performance.
- Needs to be replaced as the existing detector is aging.

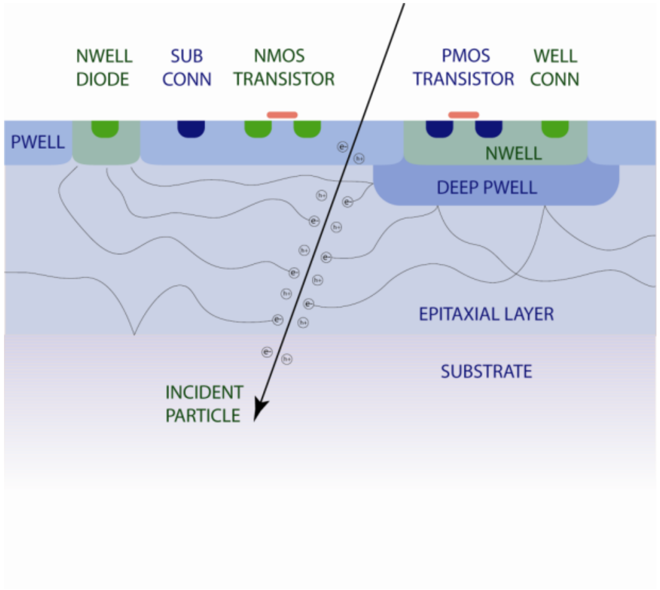


February 2010

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.





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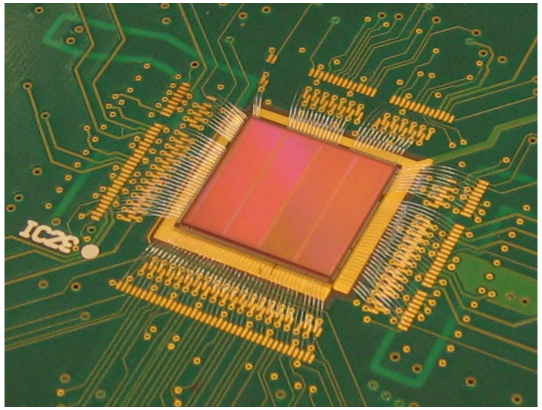
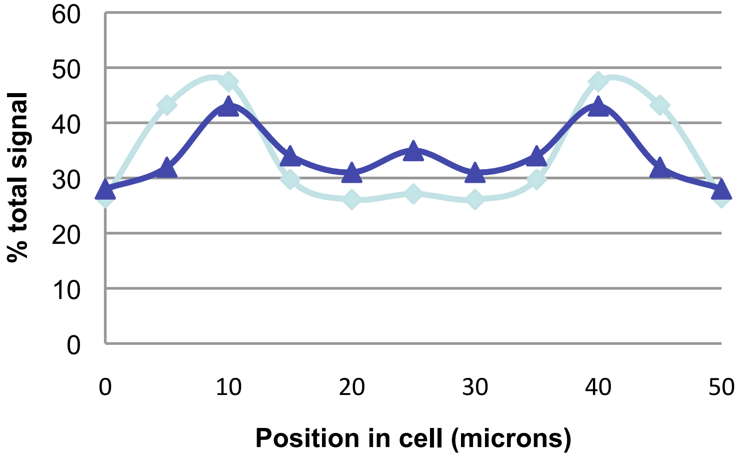
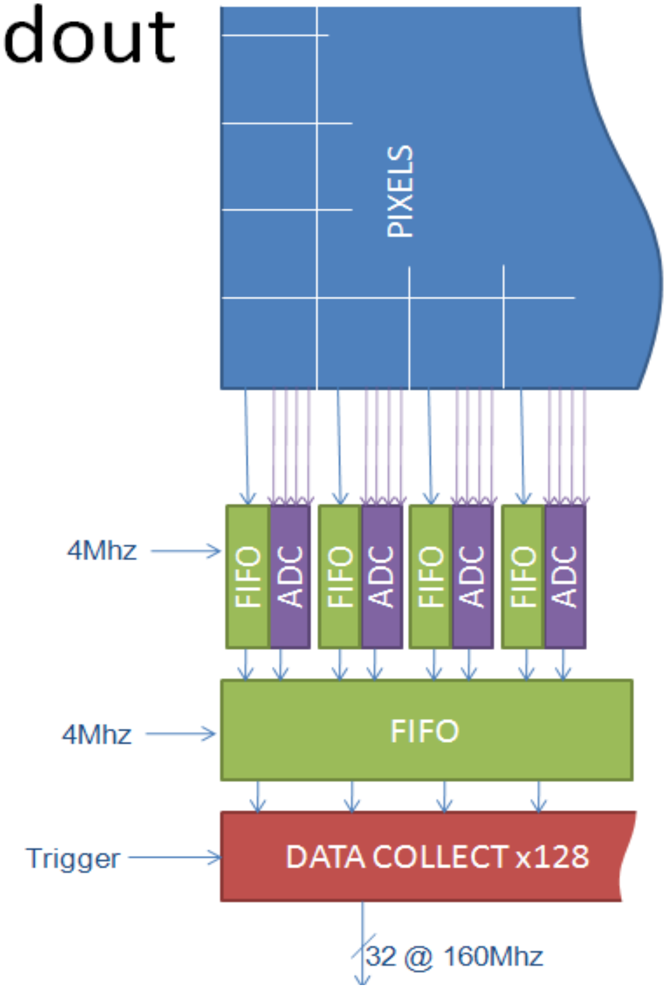




All Pixel SVT Concept

- 400Mpix CMOS Detector with stave approach:

Readout



PIXELS

4Mhz

FIFO ADC FIFO ADC FIFO ADC FIFO ADC

4Mhz

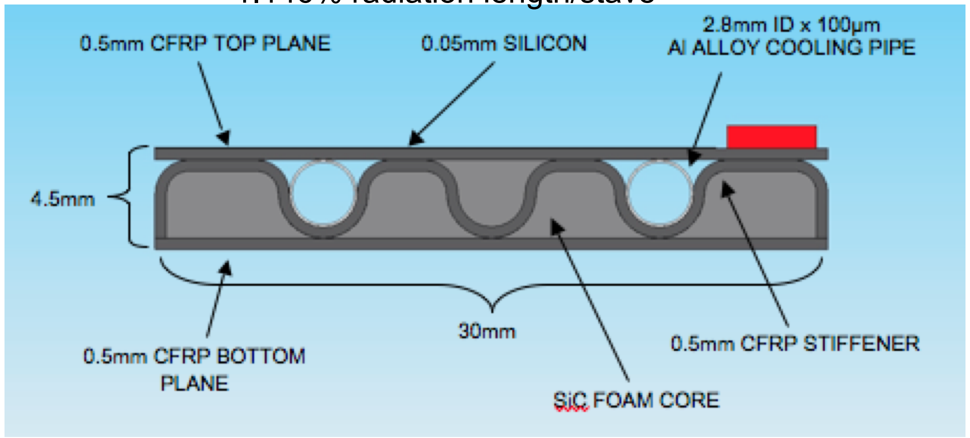
FIFO

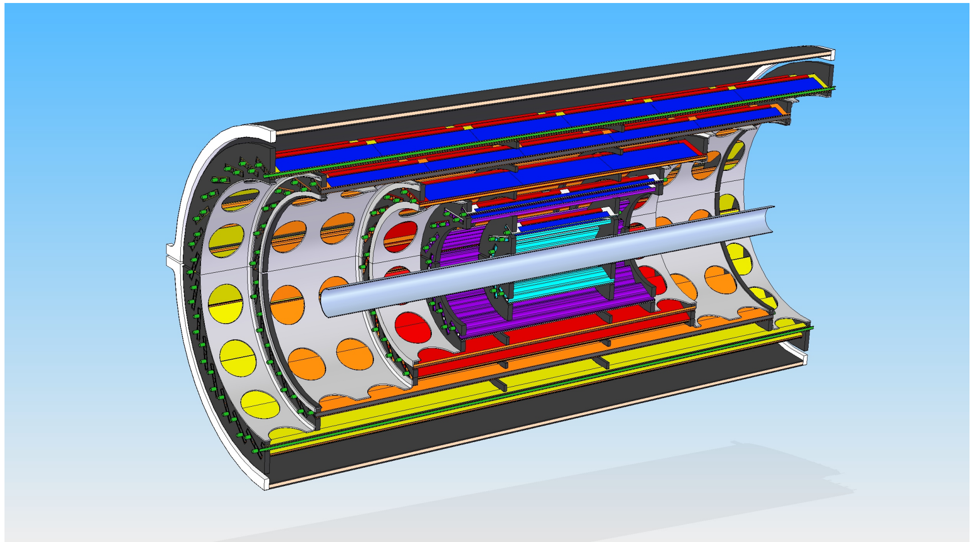
Trigger

DATA COLLECT x128

32 @ 160Mhz

1.146% radiation length/stave

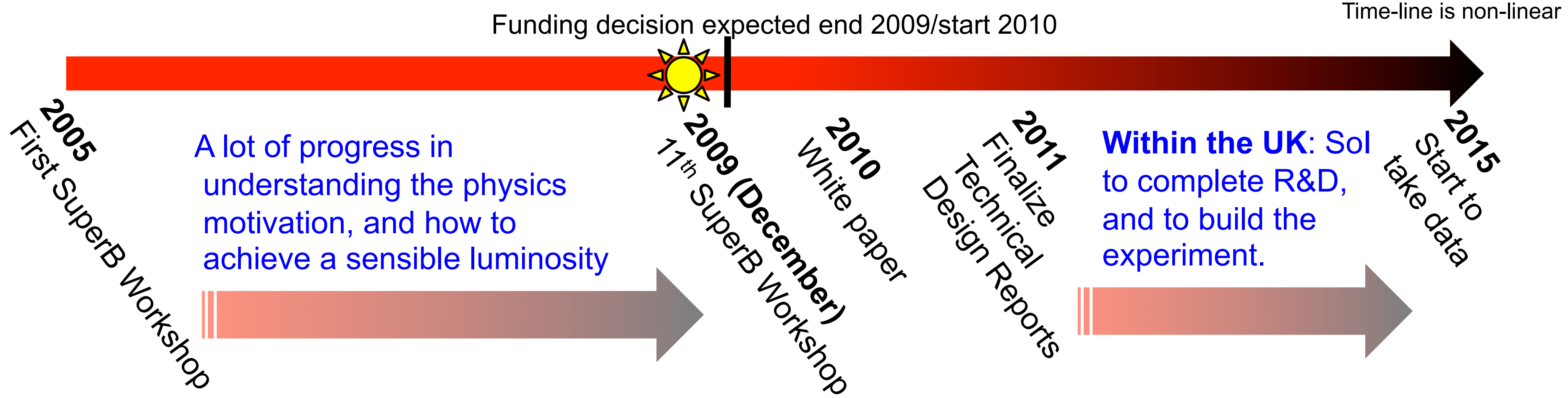




Current status

February 2010

Timeline of the project



Funding decision expected end 2009/start 2010

Time-line is non-linear

2005
First SuperB Workshop

A lot of progress in understanding the physics motivation, and how to achieve a sensible luminosity

2009 (December)
11th SuperB Workshop

2010
White paper

2011
Finalize Technical Design Reports

Within the UK: SoI to complete R&D, and to build the experiment.

2015
Start to take data

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.

What about Belle-II?

- Similar concept:
  - Adiabatic upgrades from KEKB through to a ~0.8×10^{36} machine.
    - Funding situation similar 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
$E_{HER/LER}$	7 / 4 GeV	7 / 4 GeV
$I_{HER/LER}$	< 3.5 A (both)	2.6 / 3.6 A
ε_x	2.8 / 1.6 nm	3.2 / 1.7 nm
ε_y	7 / 4 pm	12.8 / 8.2 pm
$\mathcal{L}$	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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Polarisation increases potential of τ physics studies and $\sin^2\theta_W$.

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.

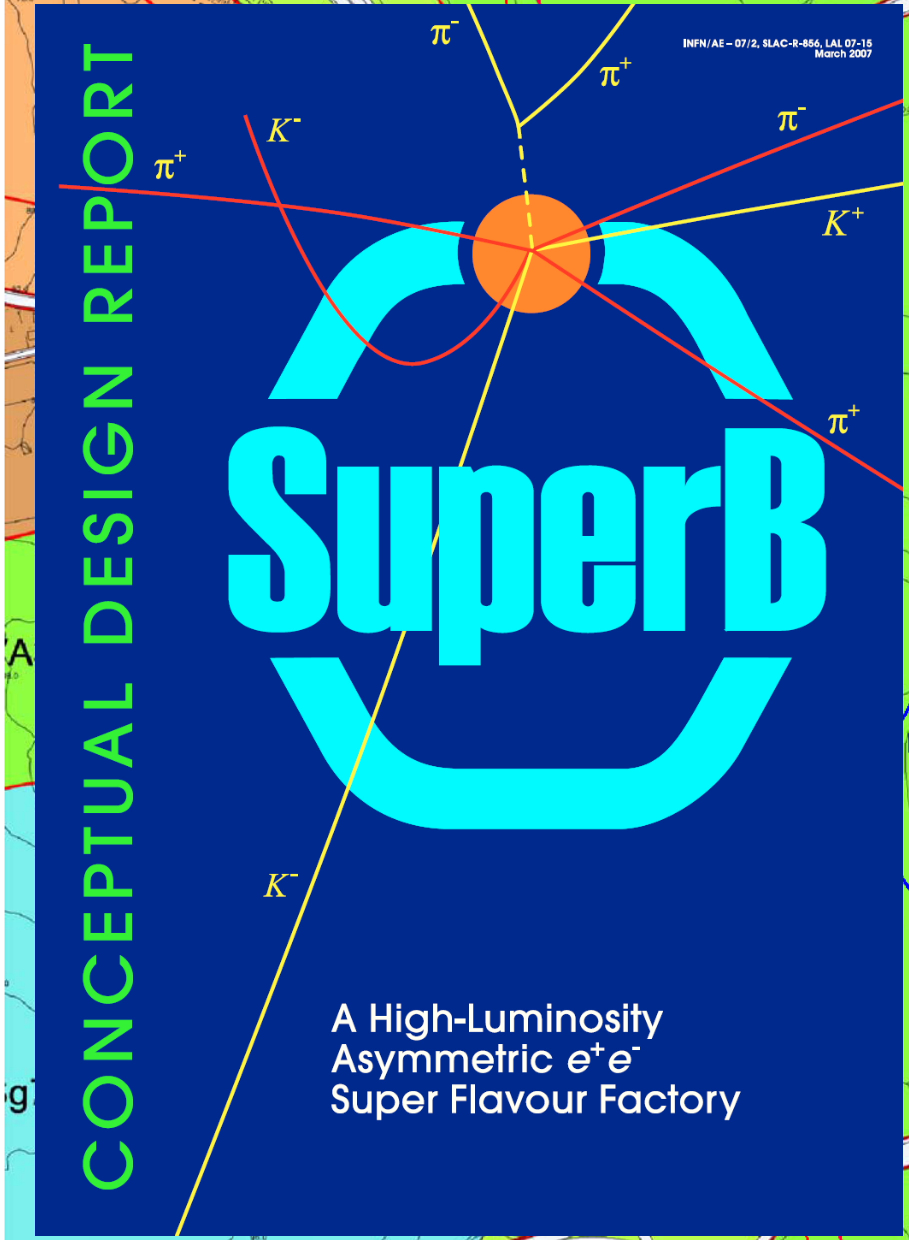
  - don't know if the NP flavour sector is trivial or complicated:
    - Prior experience suggests it will be complicated.

  - 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.



INFN/AE – 07/2, SLAC-R-856, LAL 07-15
March 2007

CONCEPTUAL DESIGN REPORT

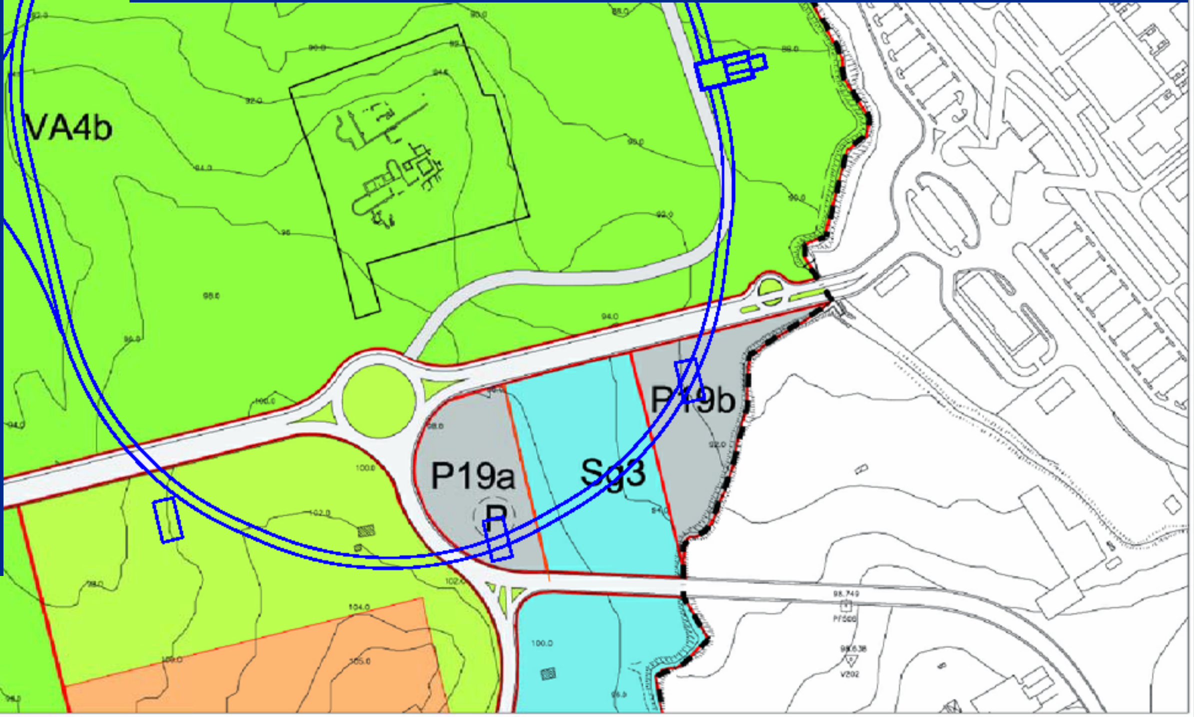
SuperB

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

All we need to do is build it!

New effort is welcome!

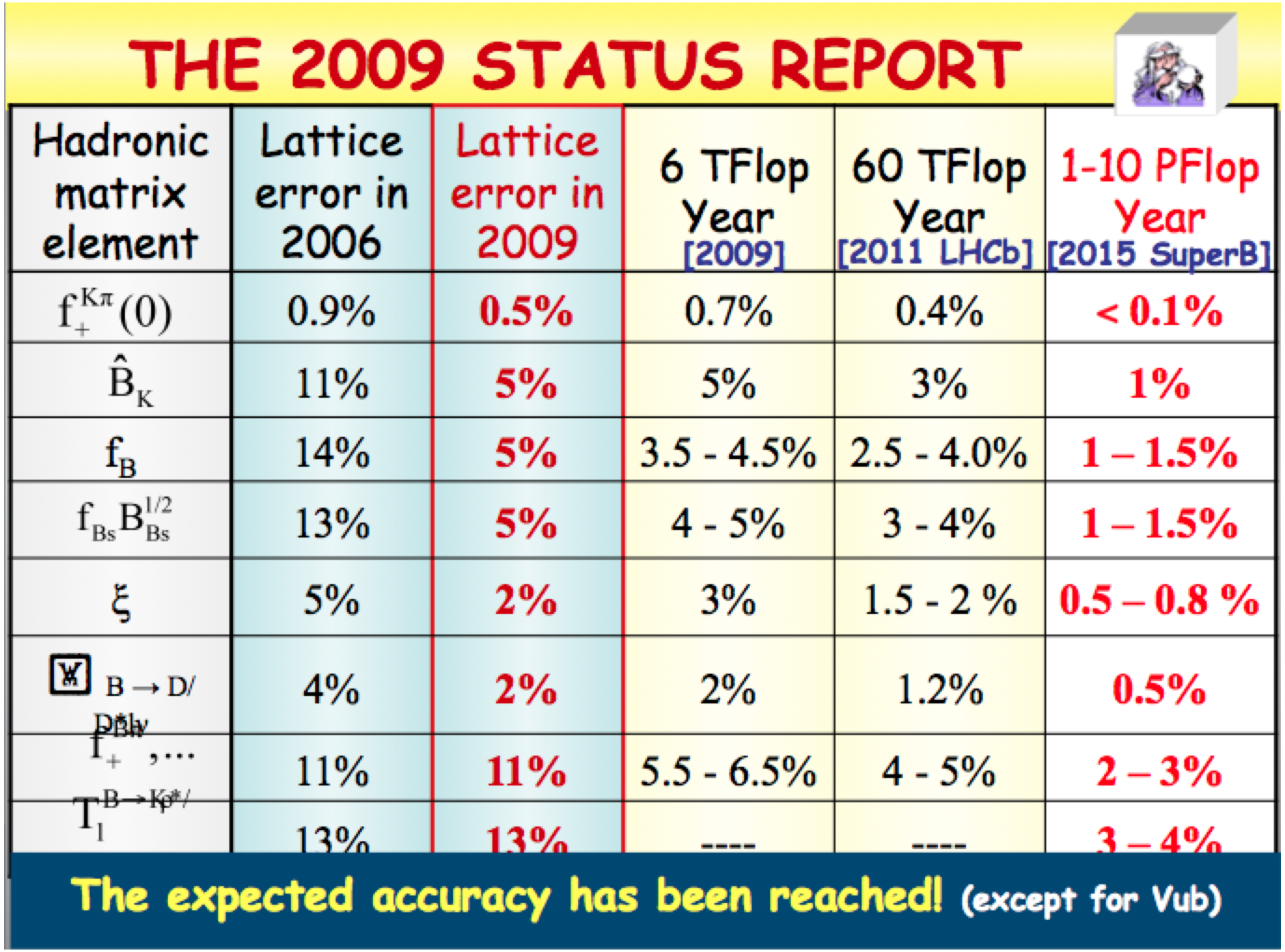
http://web.infn.it/superb



Extra Material

What about Lattice?

Vittorio Lubicz
Dec 2009

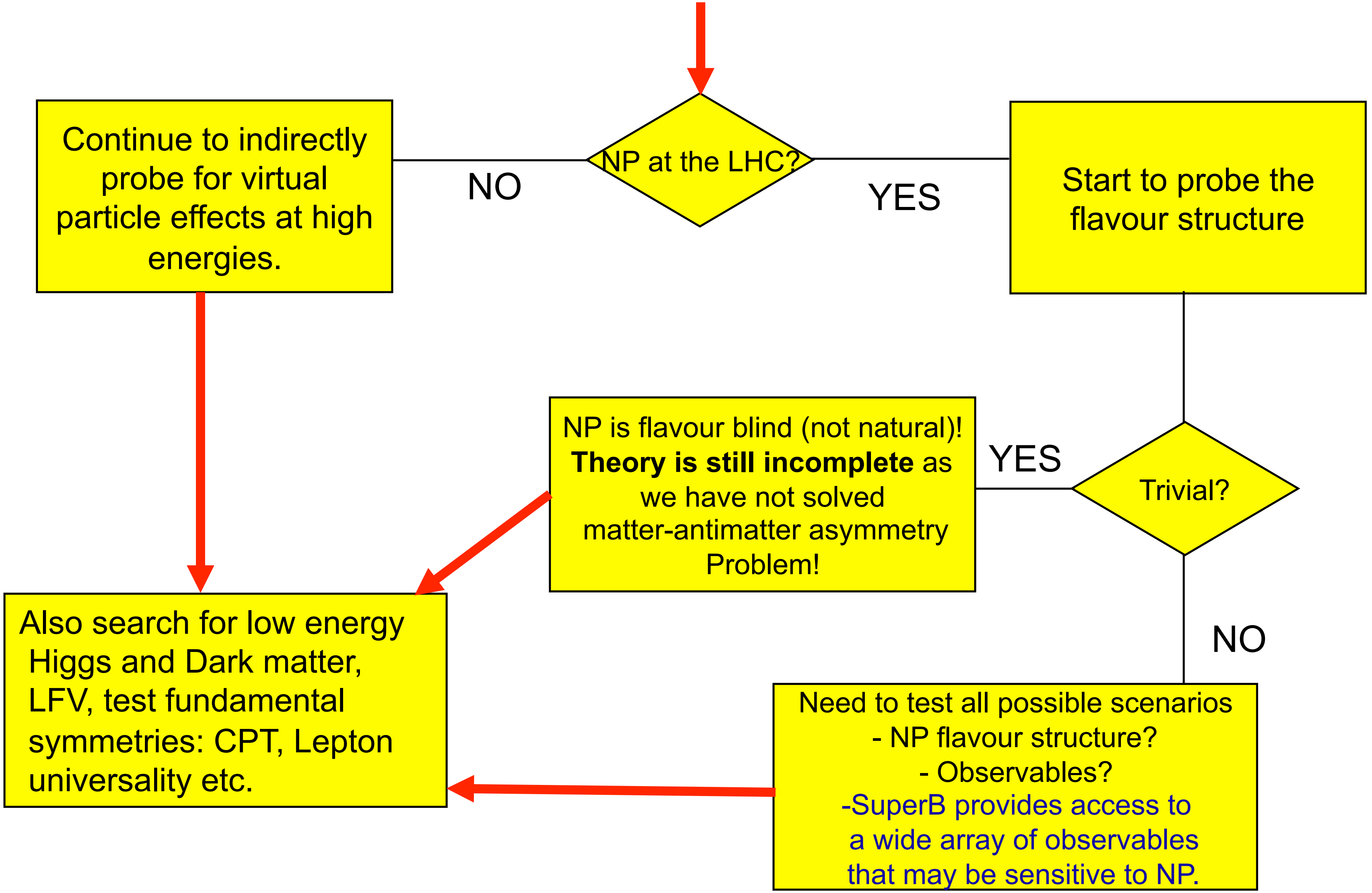


THE 2009 STATUS REPORT

Hadronic matrix element	Lattice error in 2006	Lattice error in 2009	6 TFlop Year [2009]	60 TFlop Year [2011 LHCb]	1-10 PFlop Year [2015 SuperB]
$f_+^{K\pi}(0)$	0.9%	0.5%	0.7%	0.4%	< 0.1%
$\hat{B}_K$	11%	5%	5%	3%	1%
f_B	14%	5%	3.5 - 4.5%	2.5 - 4.0%	1 – 1.5%
$f_{Bs}B_{Bs}^{1/2}$	13%	5%	4 - 5%	3 - 4%	1 – 1.5%
ξ	5%	2%	3%	1.5 - 2 %	0.5 – 0.8 %
$_{B\to D/D^*l\nu}$	4%	2%	2%	1.2%	0.5%
$f_+^{B\pi}, \ldots$	11%	11%	5.5 - 6.5%	4 - 5%	2 – 3%
$T_1^{B\to K\rho^*/}$	13%	13%	----	----	3 – 4%

The expected accuracy has been reached! (except for Vub)

Particle Physics Landscape circa 2015



NP at the LHC?

NO

Continue to indirectly probe for virtual particle effects at high energies.

YES

Start to probe the flavour structure

Trivial?

YES

NP is flavour blind (not natural)! **Theory is still incomplete** as we have not solved matter-antimatter asymmetry Problem!

NO

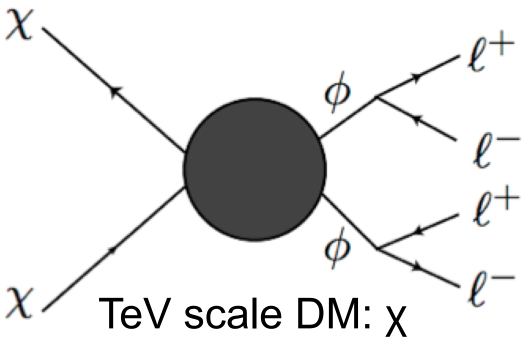
Need to test all possible scenarios
- NP flavour structure?
- Observables?
-SuperB provides access to a wide array of observables that may be sensitive to NP.

Also search for low energy Higgs and Dark matter, LFV, test fundamental symmetries: CPT, Lepton universality etc.

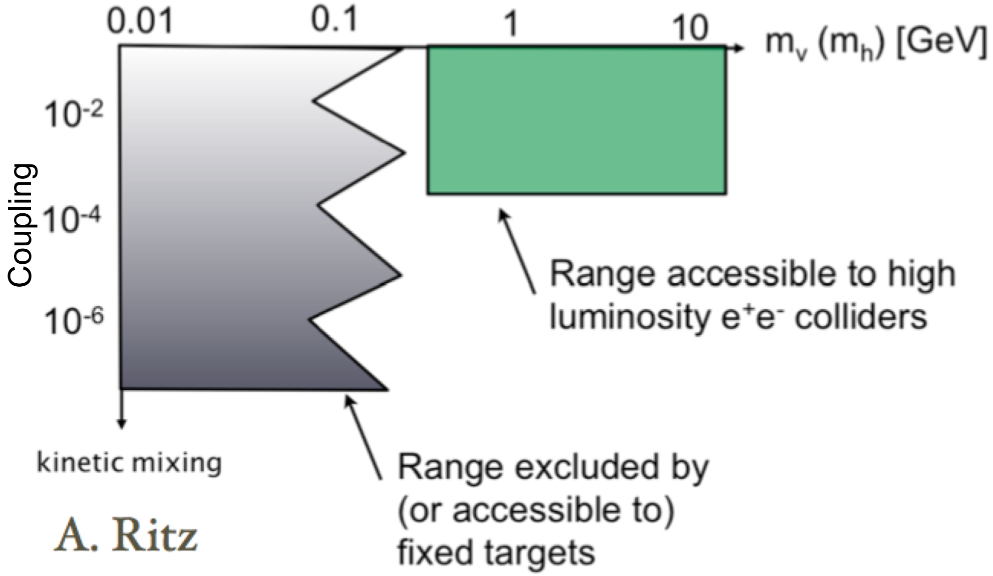
Dark Forces

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



Range accessible to high luminosity e^+e^- colliders

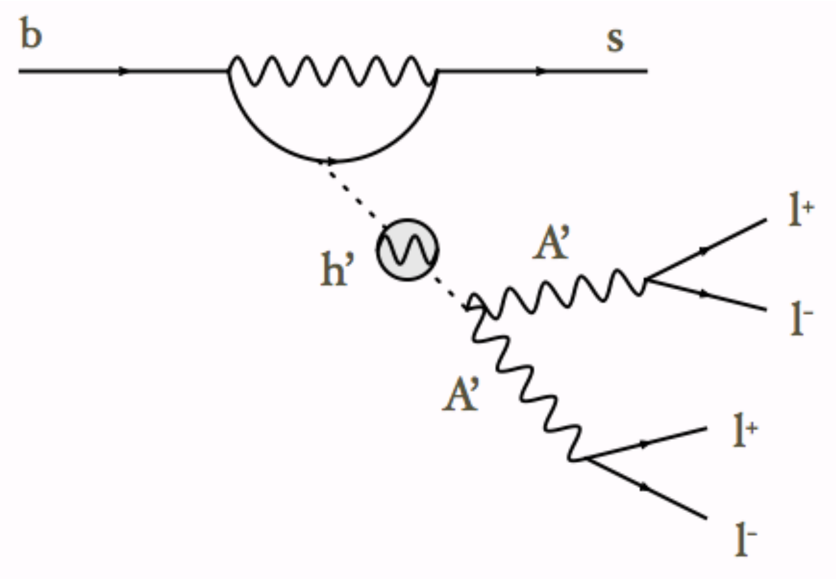
Range excluded by (or accessible to) fixed targets

Dark Forces

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

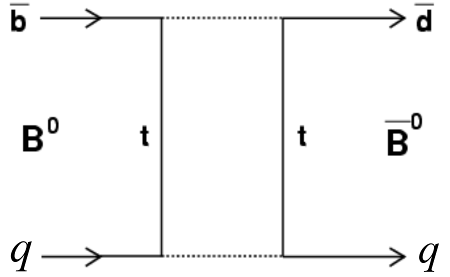
In addition to the vector 'portal' with the kinetic coupling, there should be a Higgs coupling term:

- 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.

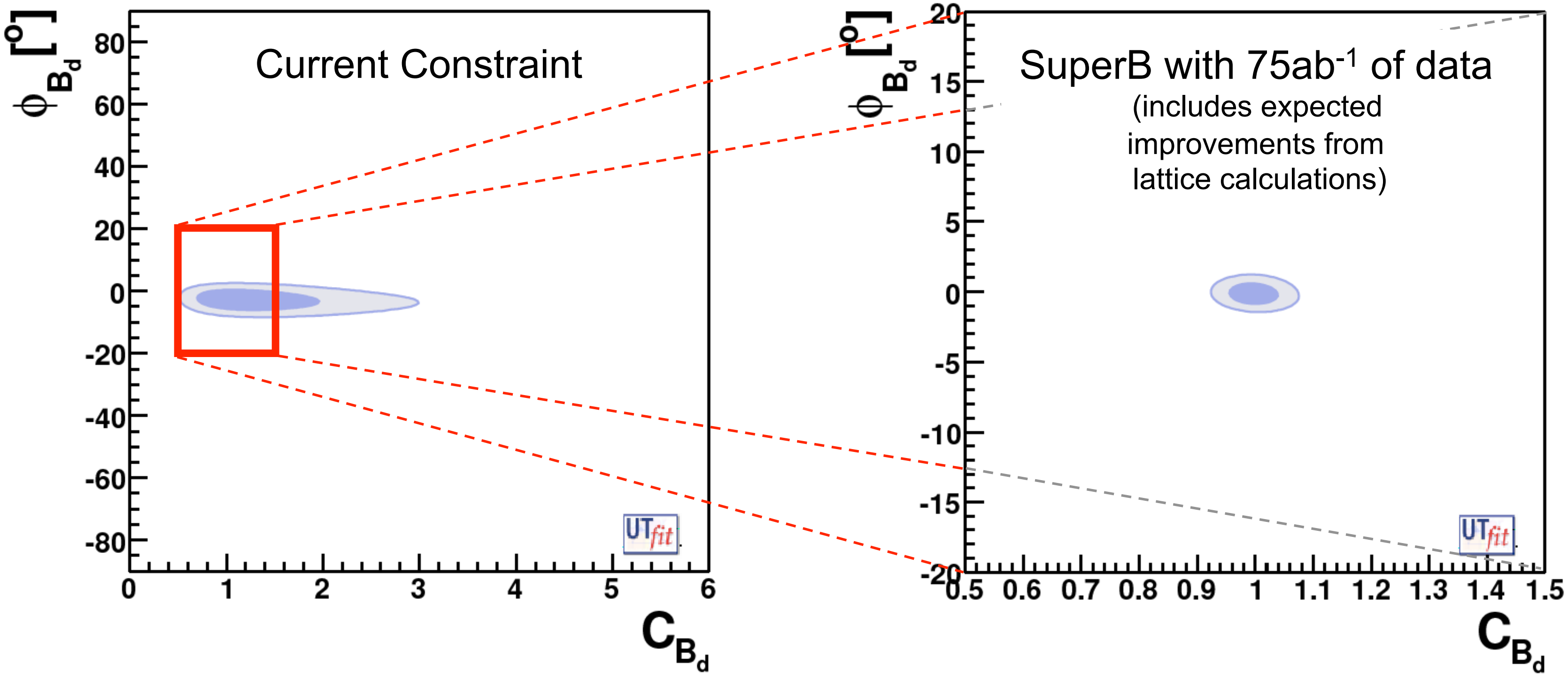
$$C_q e^{i\phi_q} = \frac{\langle B^0_q \,|\, H_{SM+NP} \,|\, \overline{B}^0_q \rangle}{\langle B^0_q \,|\, H_{SM} \,|\, \overline{B}^0_q \rangle}$$

- C_q=1, and ϕ_q=0 for the Standard Model (SM).

hep-ph/0509219

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.

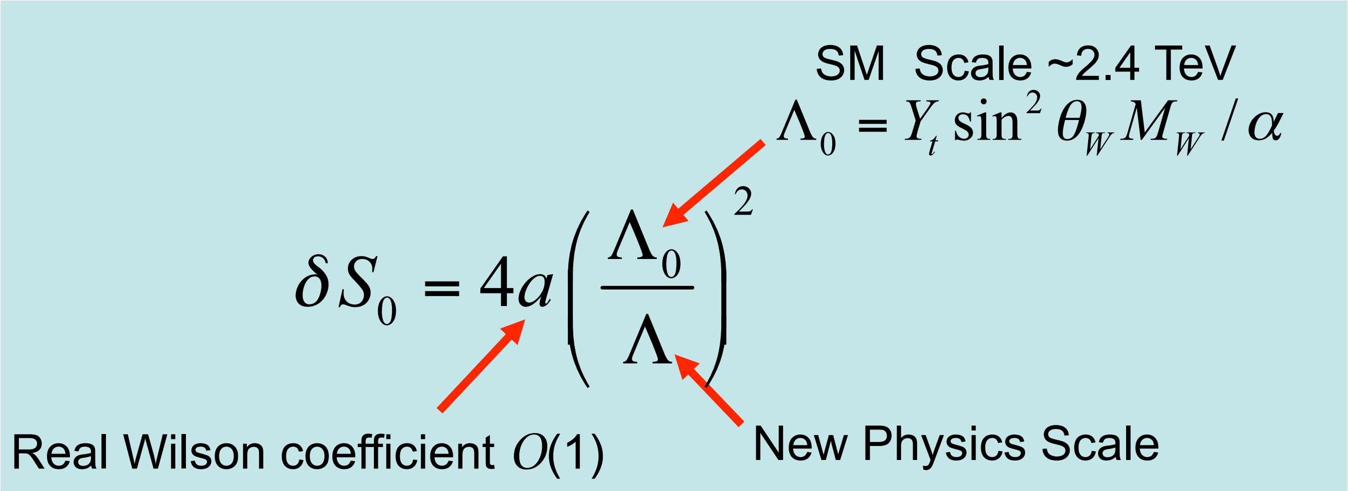


Note that the two plots have very different scales!

hep-ph/0509219

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 $\Lambda \sim 700$GeV.

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:

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

  - Using B$_S$ mixing, A$_{SL}$, lifetime and tagged J/ψφ results (Δ Γ 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

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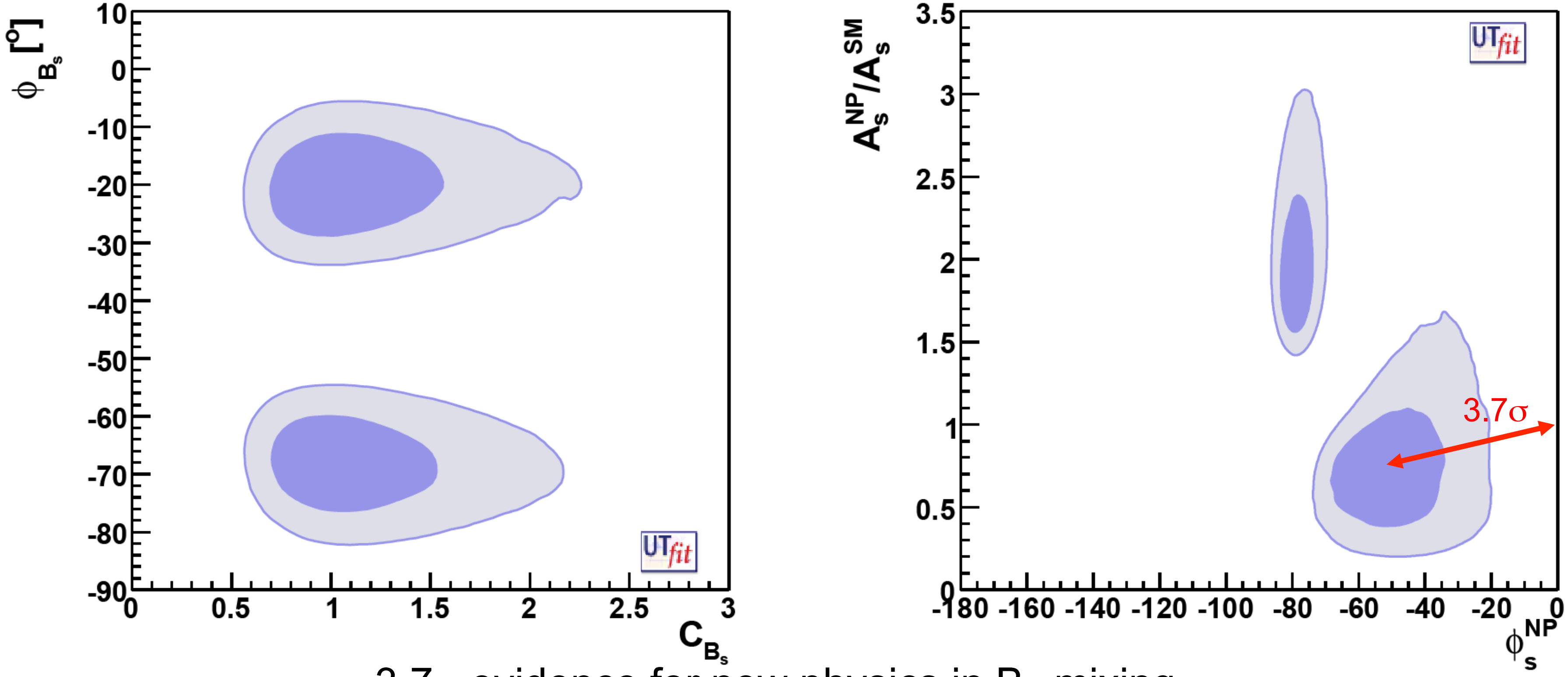

3.7σ evidence for new physics in B_S mixing.

Disfavours MFV hypothesis!

e.g. see arXiv:0803.0659

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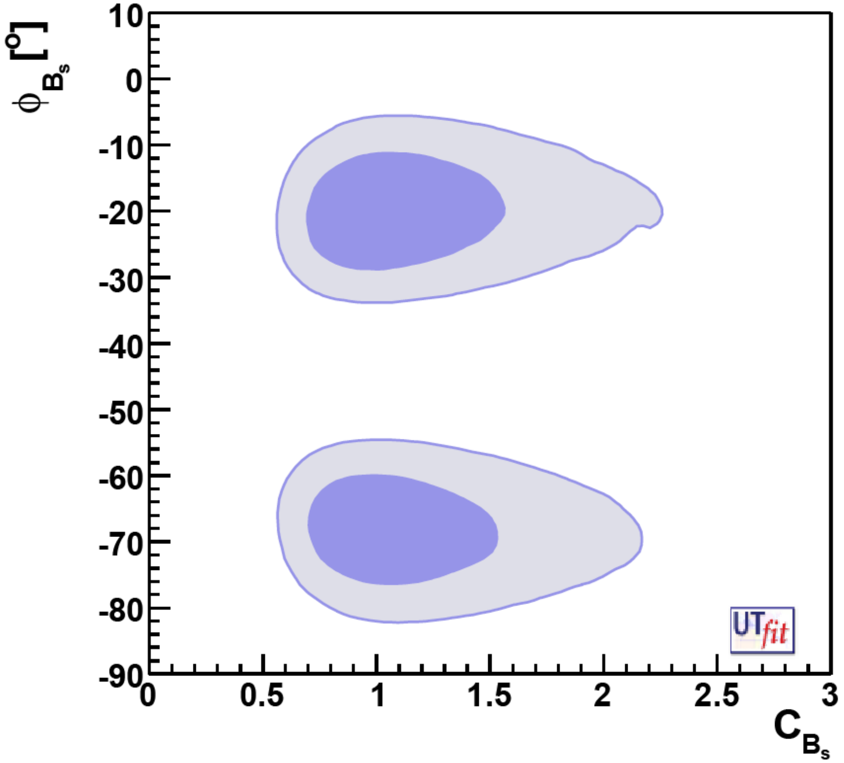


Observable	68% Prob.	95% Prob.
$\phi_{B_s}[^\circ]$	-19.9 ± 5.6	[-30.45,-9.29]
	-68.2 ± 4.9	[-78.45,-58.2]
C_{B_s}	1.07 ± 0.29	[0.62,1.93]
$\phi_s^{\mathrm{NP}}[^\circ]$	-51 ± 11	[-69,-27]
	-79 ± 3	[-84,-71]
$A_s^{\mathrm{NP}}/A_s^{\mathrm{SM}}$	0.73 ± 0.35	[0.24,1.38]
	1.87 ± 0.06	[1.50,2.47]
Im $A_s^{\mathrm{NP}}/A_s^{\mathrm{SM}}$	-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!

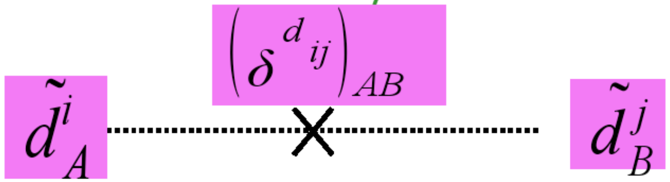
e.g. see arXiv:0803.0659

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}.

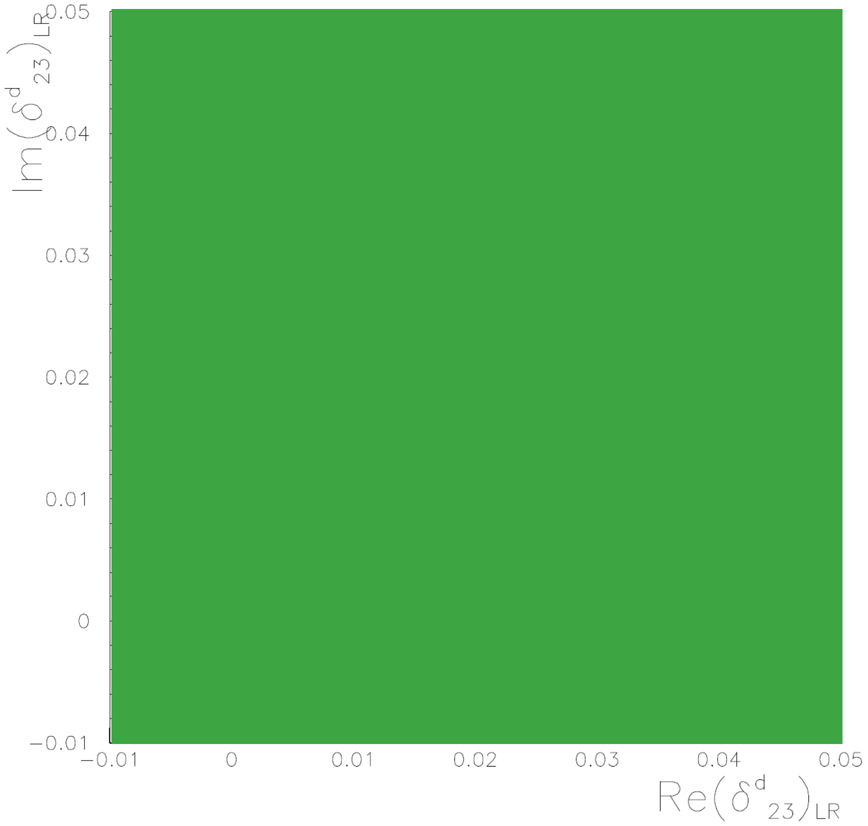
- SuperB probes the Luminosity Frontier.
  - Measures the off-diagonal elements V_{SCKM}.

SUSY CKM

L. Silvestrini (SuperB IV)

- Couplings are $(\delta^q_{ij})_{AB}$ where *A*,*B*=*L*,*R*, and *i*,*j* are squark generations.
- e.g. Constrain parameters in V_{SCKM} using:

- $\mathcal{B}(B\rightarrow X_s\,\gamma)$ [green]
- $\mathcal{B}(B\rightarrow X_s\,l^+l^-)$ [cyan]
- $A_{CP}(B\rightarrow X_s\,\gamma)$ [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!

SUSY CKM

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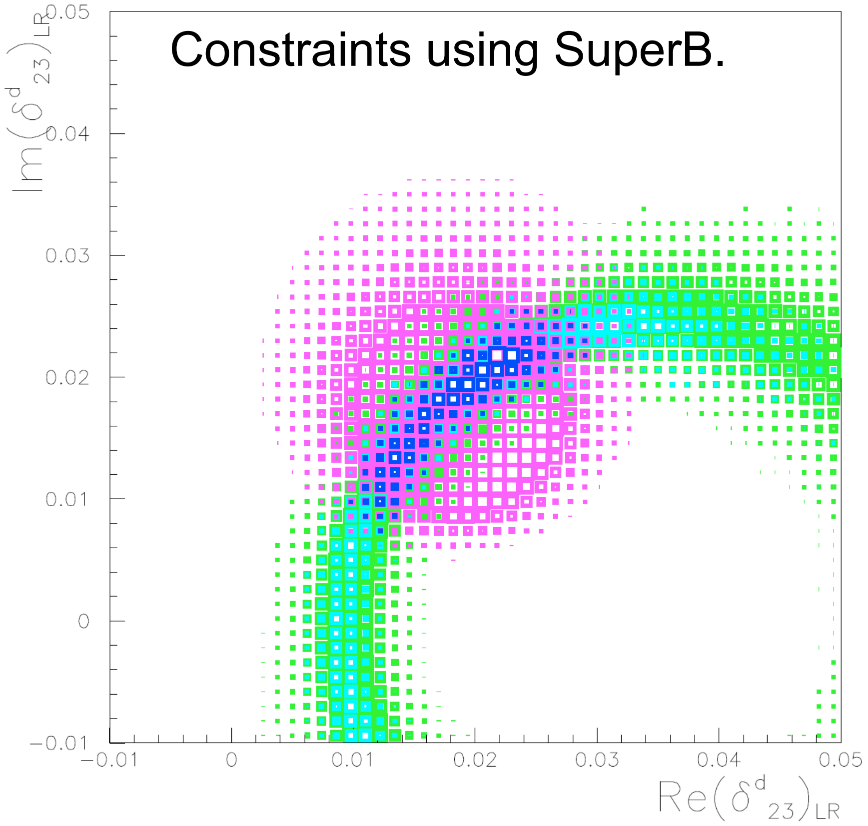
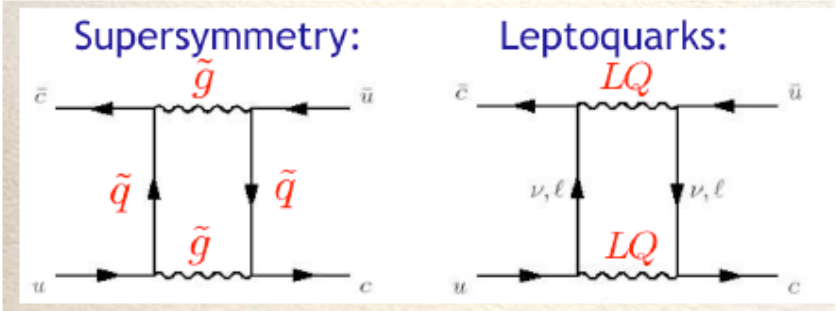
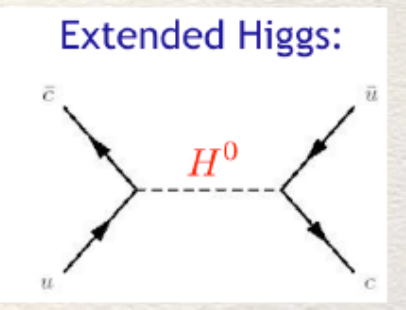


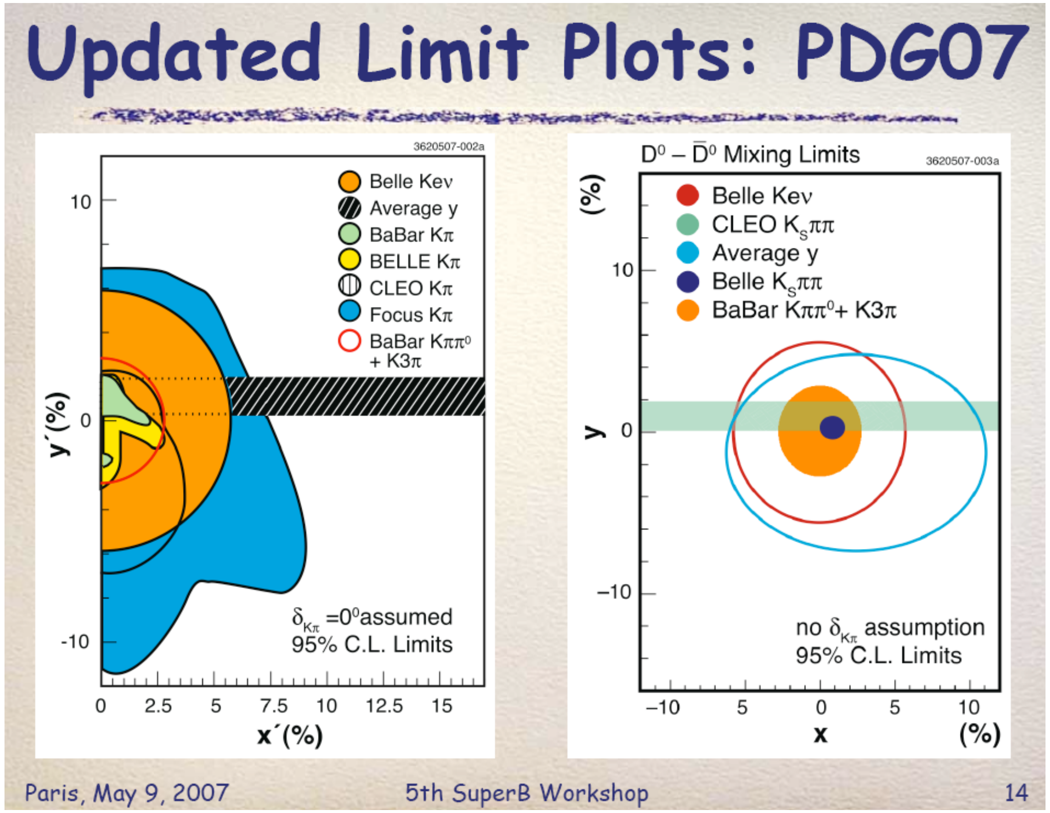
With current data, the whole range shown is allowed!

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





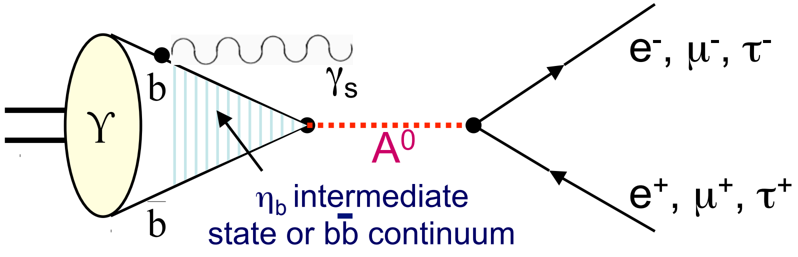


Updated Limit Plots: PDG07

Paris, May 9, 2007 5th SuperB Workshop 14

Searching for a Light Higgs

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



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

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

- 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 ($H^\pm$)

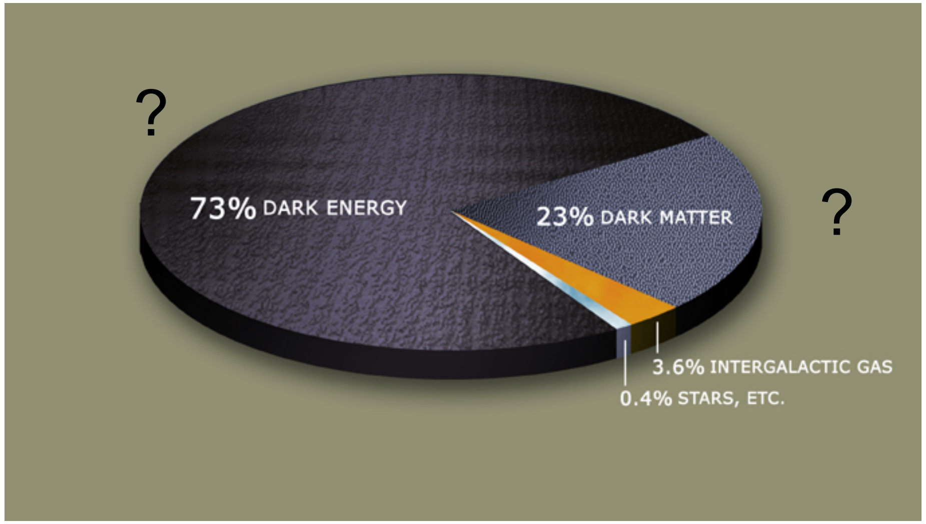
Possible NMMSM Scenario

A_1 ~ 10 GeV
H_1 ~ 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:

$\Upsilon \to invisible$

$\eta \to invisible$

$B^+ \to K^+ + invisible$

$K^+ \to \pi^+ + invisible$

$J/\Psi \to invisible$

$\Upsilon \to \gamma + invisible$

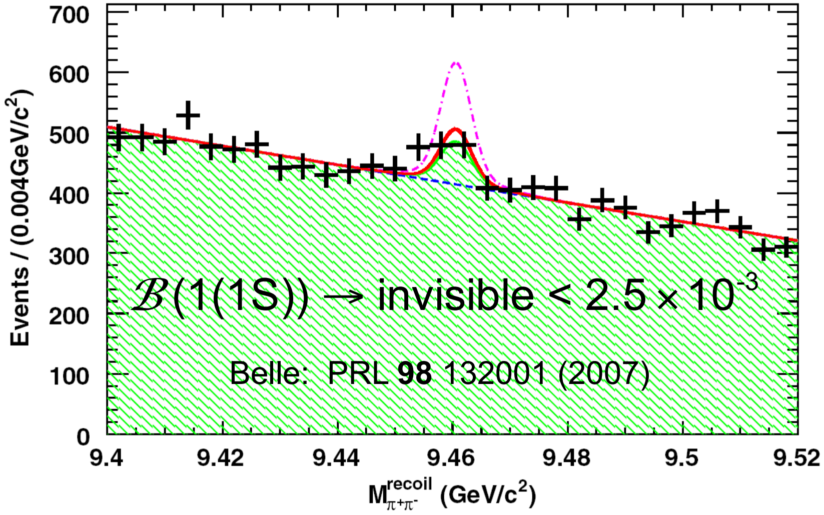
$\Upsilon \to \gamma A_1, A_1 \to \tau^+\tau^-$

$J/\Psi \to \gamma A_1$

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:

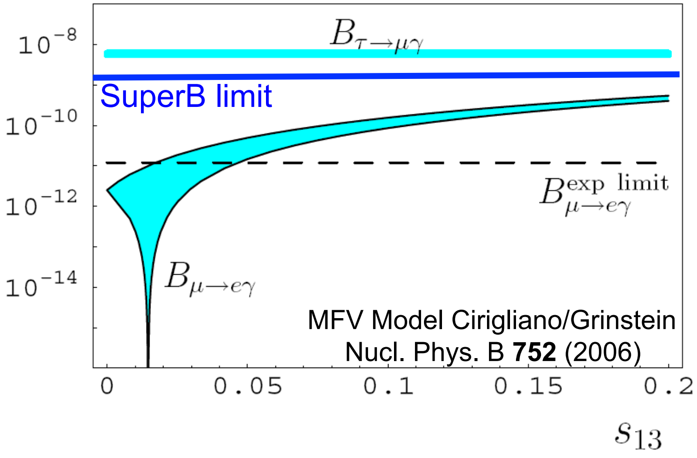
  $\mathcal{B}(\Upsilon(1S) \to \chi\chi)$ up to 6×10^{-3}
- SuperB should be able to provide a precision constraint on this channel.



τ Decays

τ→μγ / 3leptons

- Comparison of μ→eγ and τ→μγ rates can distinguish between NP scenarios.

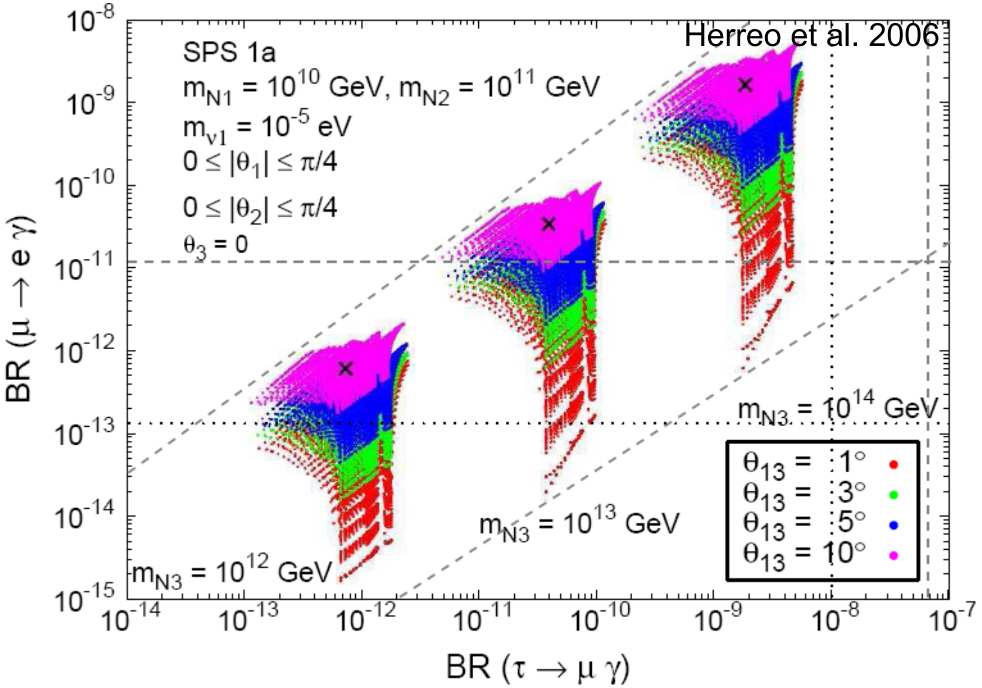


MFV Model Cirigliano/Grinstein Nucl. Phys. B **752** (2006)

- Can depend on the value of θ_{13}.

- Best search capability for LFV in τ→3leptons of any experiment.

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



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

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.

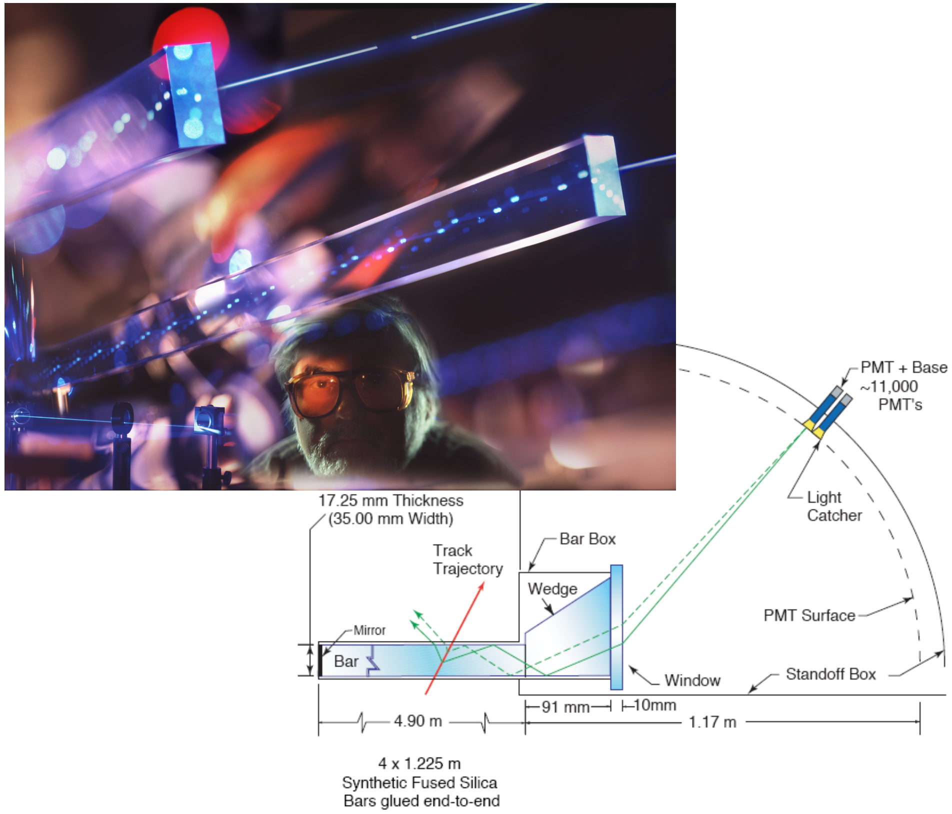
e.g. PRD **51** 3172 (1995); arXive :0707.2496 [hep-ph]

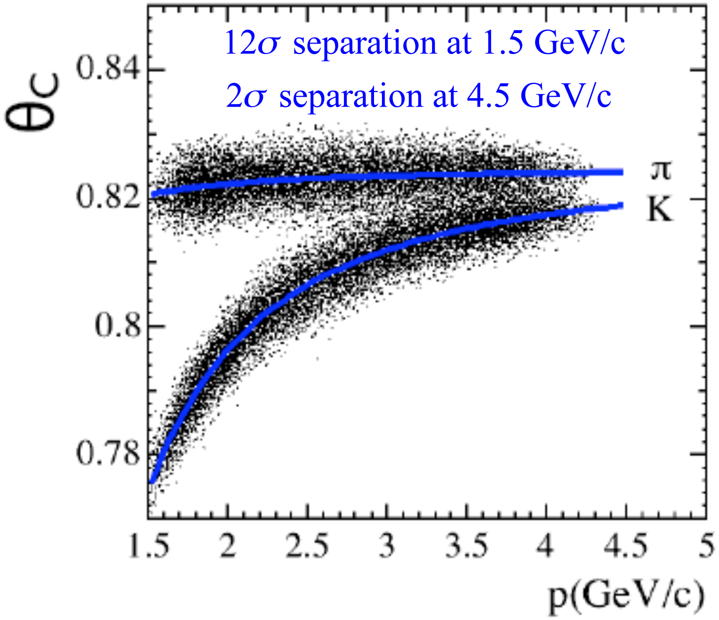
Detector Design

February 2010

Particle ID

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



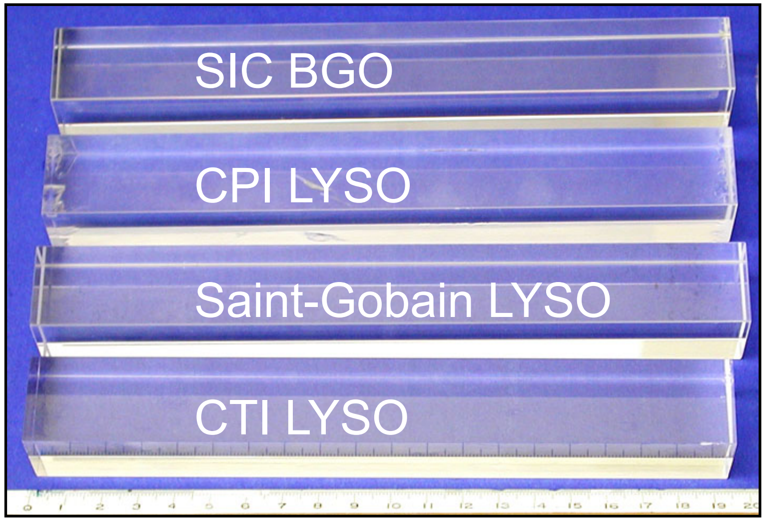


Can benefit from reducing the volume of water between the end of the quartz bars and the photodetectors (PMTs) at SuperB.

Calorimeter 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.

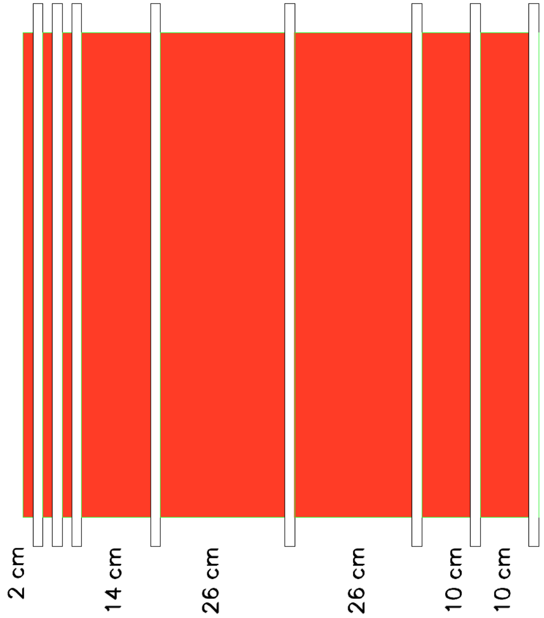
BaBar Calorimeter Schematic

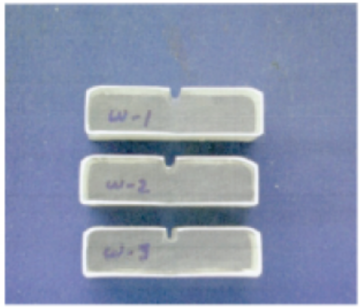


2.5 x 2.5 x 20 cm (18 X_0) Bar

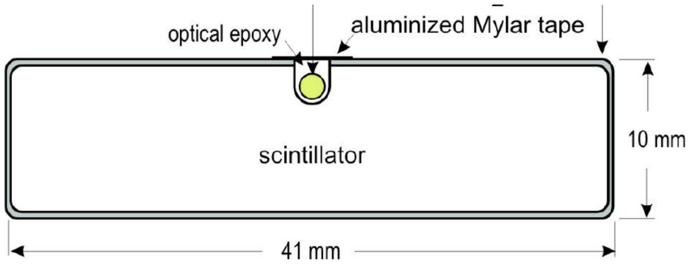
Instrumented Flux Return

- 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.

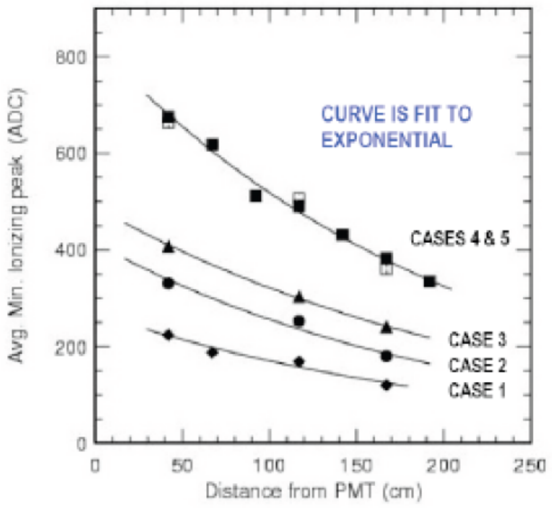




MINOS PRODUCTION BARS SHOWING 4 x 1 cm² CROSS SECTION WITH CO-EXTRUDED TiO₂ AND GROOVE FOR WLS FIBER

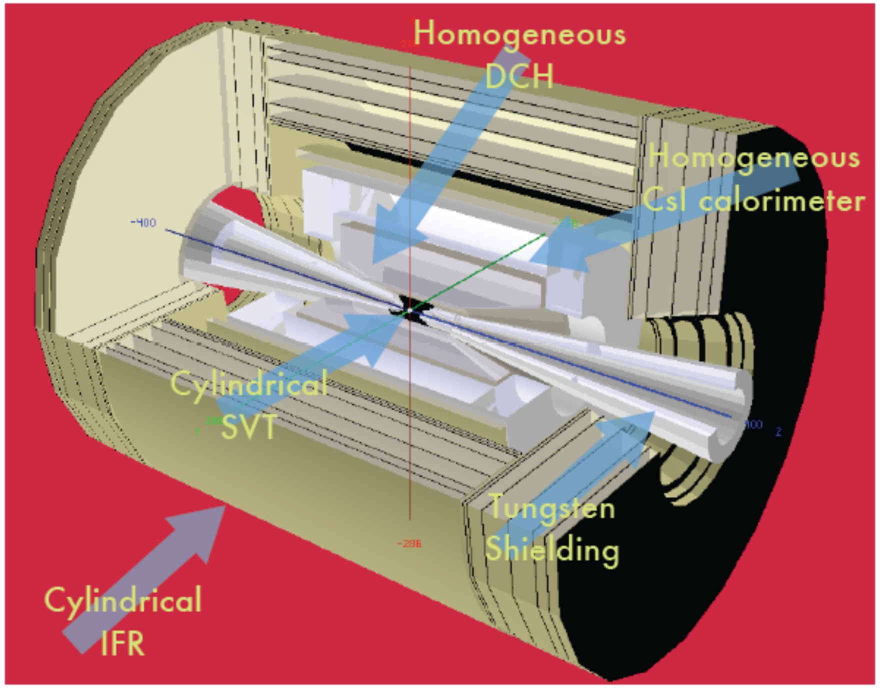


ATTENUATION LENGTH MEASUREMENTS FOR 5 CASES



Detector Simulation

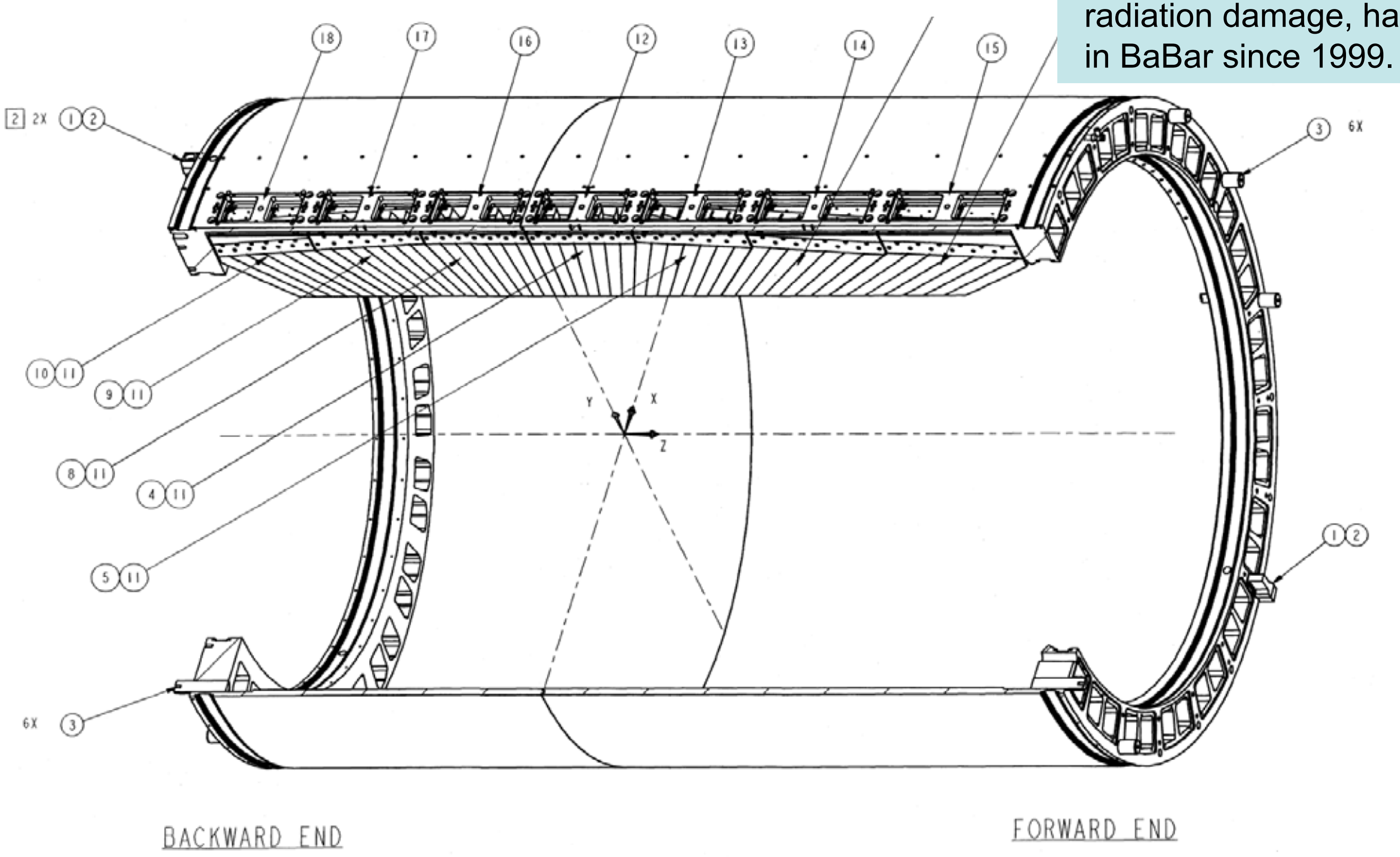
- Simulation:
  - FastSim (validated on using geometry for BaBar)
    - Reproduces BaBar resolutions etc.
    - Change to SuperB geometry and boost for development of benchmark studies.
    - Then move to GEANT 4 for more detailed work.
  - GEANT 4 model of SuperB shown.
  - Using BaBar framework.
 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



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.



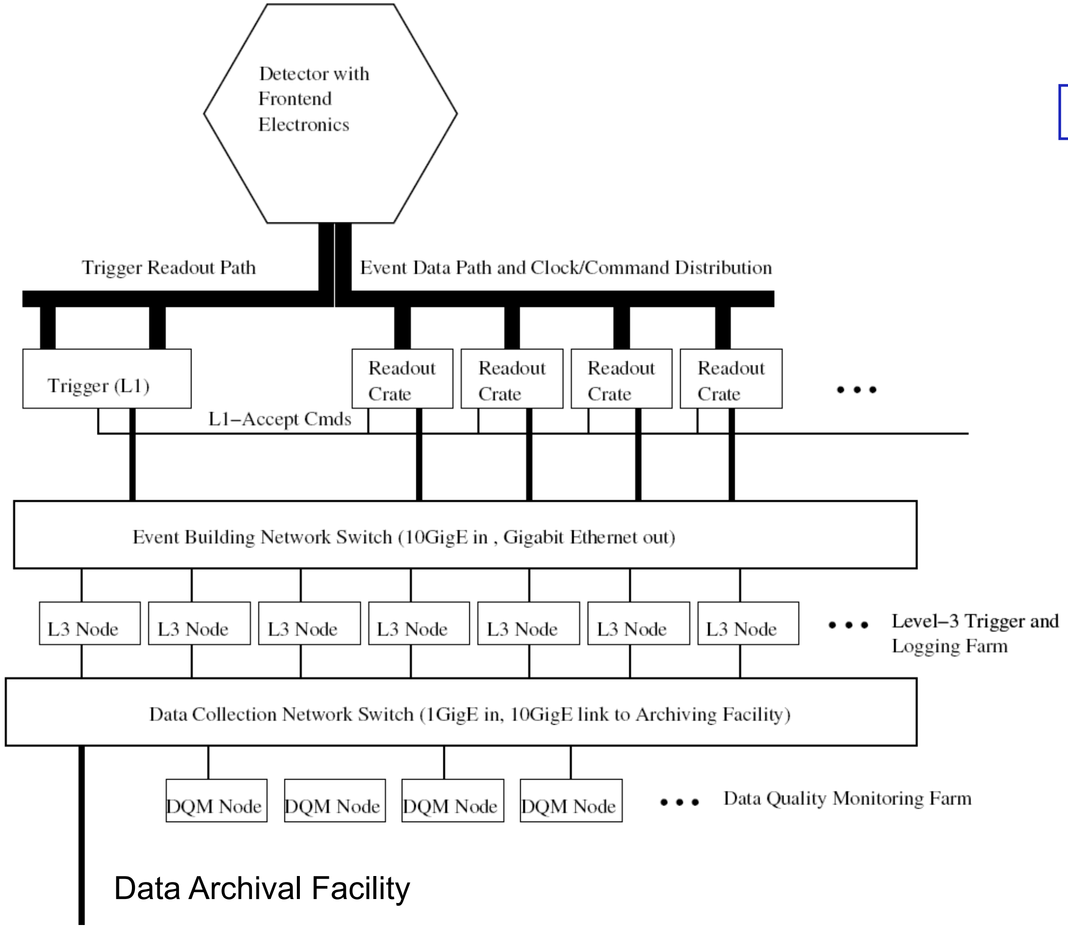
Requirements

- 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

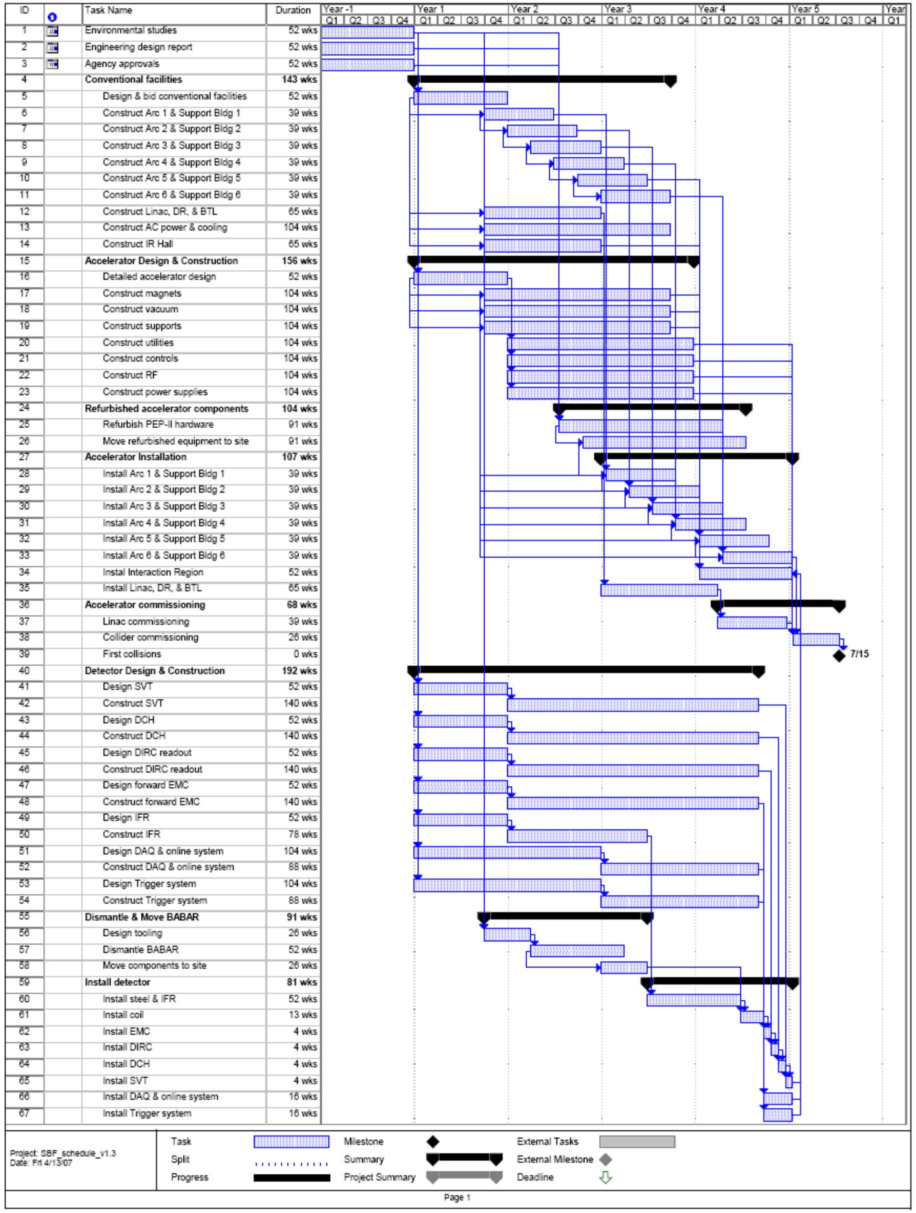
Parameter	Year 1	Year 2	Year 3	Year 4	Year 5
Luminosity (ab^{-1})	2	6	12	12	12
Storage (PB)					
Tape	3.1	10.2	22.0	26.2	27.8
Disk	0.83	3.35	7.55	10.2	10.2
CPU (MSpecInt2000)					
Data reconstruction	3.0	8.8	14.7	8.8	0.0
Skimming	2.7	9.4	16.1	12.1	0.0
Monte Carlo	9.5	28.0	46.6	28.0	0.0
Physics analysis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



ID	Task Name	Duration
1	Environmental studies	52 wks
2	Engineering design report	52 wks
3	Agency approvals	52 wks
4	**Conventional facilities**	**143 wks**
5	Design & bid conventional facilities	52 wks
6	Construct Arc 1 & Support Bldg 1	39 wks
7	Construct Arc 2 & Support Bldg 2	39 wks
8	Construct Arc 3 & Support Bldg 3	39 wks
9	Construct Arc 4 & Support Bldg 4	39 wks
10	Construct Arc 5 & Support Bldg 5	39 wks
11	Construct Arc 6 & Support Bldg 6	39 wks
12	Construct Linac, DR, & BTL	65 wks
13	Construct AC power & cooling	104 wks
14	Construct IR Hall	65 wks
15	**Accelerator Design & Construction**	**156 wks**
16	Detailed accelerator design	52 wks
17	Construct magnets	104 wks
18	Construct vacuum	104 wks
19	Construct supports	104 wks
20	Construct utilities	104 wks
21	Construct controls	104 wks
22	Construct RF	104 wks
23	Construct power supplies	104 wks
24	**Refurbished accelerator components**	**104 wks**
25	Refurbish PEP-II hardware	91 wks
26	Move refurbished equipment to site	91 wks
27	**Accelerator Installation**	**107 wks**
28	Install Arc 1 & Support Bldg 1	39 wks
29	Install Arc 2 & Support Bldg 2	39 wks
30	Install Arc 3 & Support Bldg 3	39 wks
31	Install Arc 4 & Support Bldg 4	39 wks
32	Install Arc 5 & Support Bldg 5	39 wks
33	Install Arc 6 & Support Bldg 6	39 wks
34	Instal Interaction Region	52 wks
35	Install Linac, DR, & BTL	65 wks
36	**Accelerator commissioning**	**68 wks**
37	Linac commissioning	39 wks
38	Collider commissioning	26 wks
39	First collisions	0 wks
40	**Detector Design & Construction**	**192 wks**
41	Design SVT	52 wks
42	Construct SVT	140 wks
43	Design DCH	52 wks
44	Construct DCH	140 wks
45	Design DIRC readout	52 wks
46	Construct DIRC readout	140 wks
47	Design forward EMC	52 wks
48	Construct forward EMC	140 wks
49	Design IFR	52 wks
50	Construct IFR	78 wks
51	Design DAQ & online system	104 wks
52	Construct DAQ & online system	88 wks
53	Design Trigger system	104 wks
54	Construct Trigger system	88 wks
55	**Dismantle & Move BABAR**	**91 wks**
56	Design tooling	26 wks
57	Dismantle BABAR	52 wks
58	Move components to site	26 wks
59	**Install detector**	**81 wks**
60	Install steel & IFR	52 wks
61	Install coil	13 wks
62	Install EMC	4 wks
63	Install DIRC	4 wks
64	Install DCH	4 wks
65	Install SVT	4 wks
66	Install DAQ & online system	16 wks
67	Install Trigger system	16 wks

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.

How to get increased $\mathcal{L}$

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

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 $\mathcal{L}$

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

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.

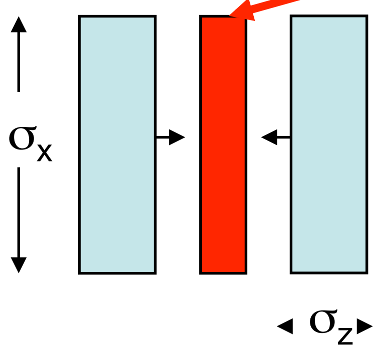
- Option 2: Large Crossing Angle.
  - Have a 15mrad crossing angle of beams.
  - Focus beams at IP (small β*).
  - Retain longer bunch lengths.
  - Rotate colliding bunches so no geometric loss at IP.
    - Align the focussed parts of bunches that cross each other at the IP. Call this "Crab Crossing/Waist".

Large crossing angle, small x-size

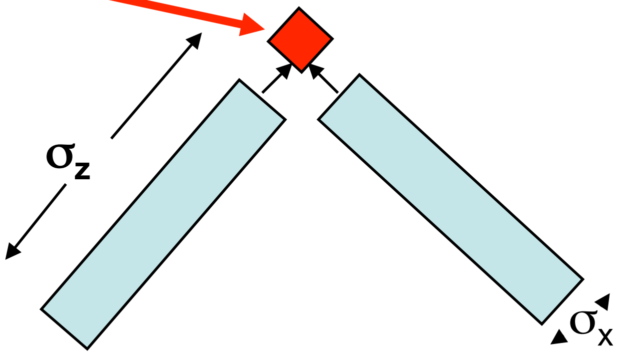
1) Head-on, Short bunches

Overlap region

2) Large crossing angle, long bunches



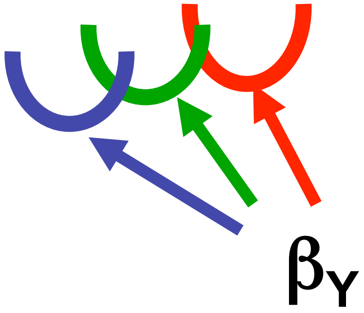
(1) and (2) have same Luminosity, but (2) has longer bunches and smaller σ_x



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”