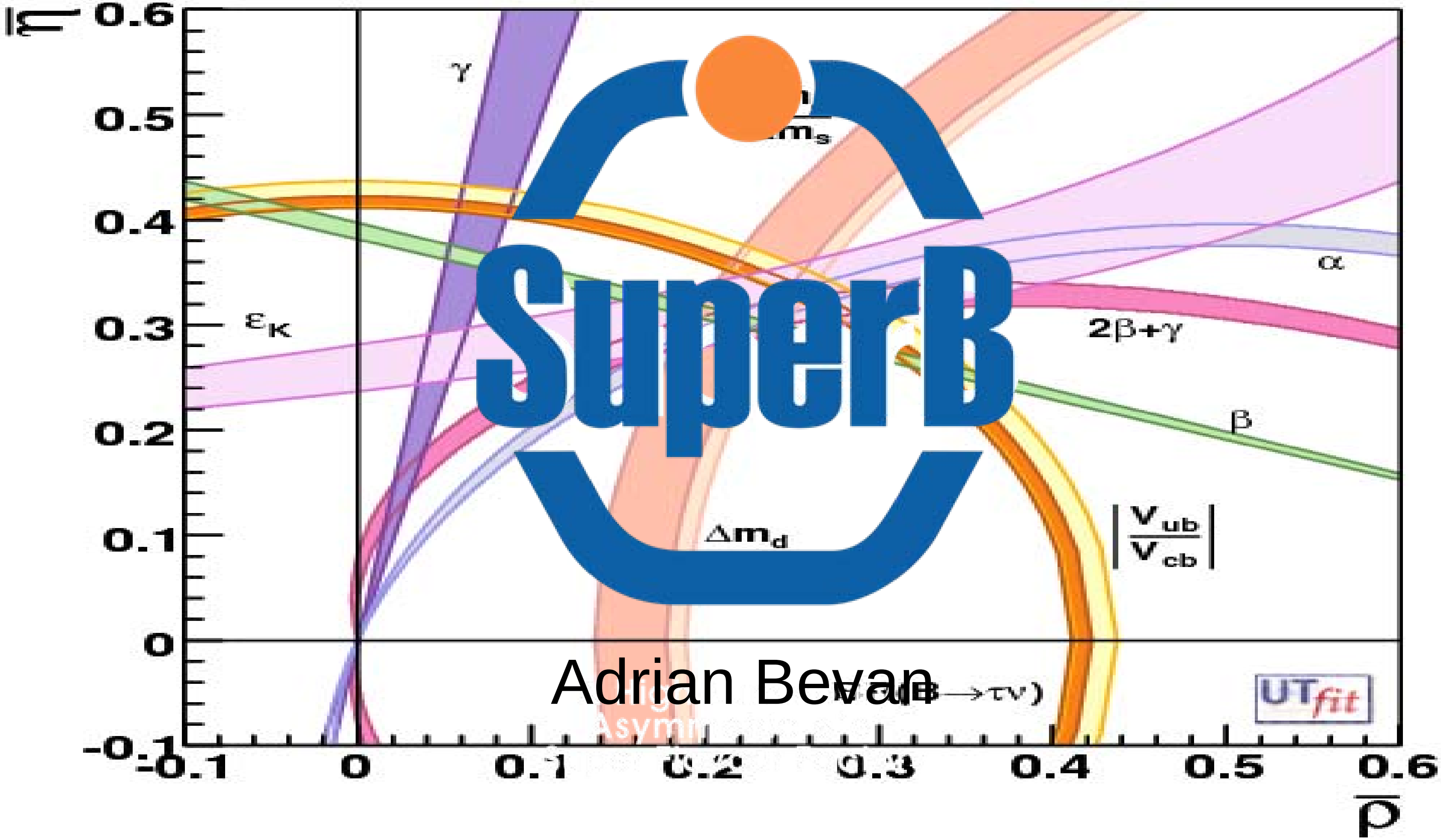
Super Flavour Factories:



Adrian Bevan

DESY, Hamburg 4th May 2010

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

Queen Mary
University of London

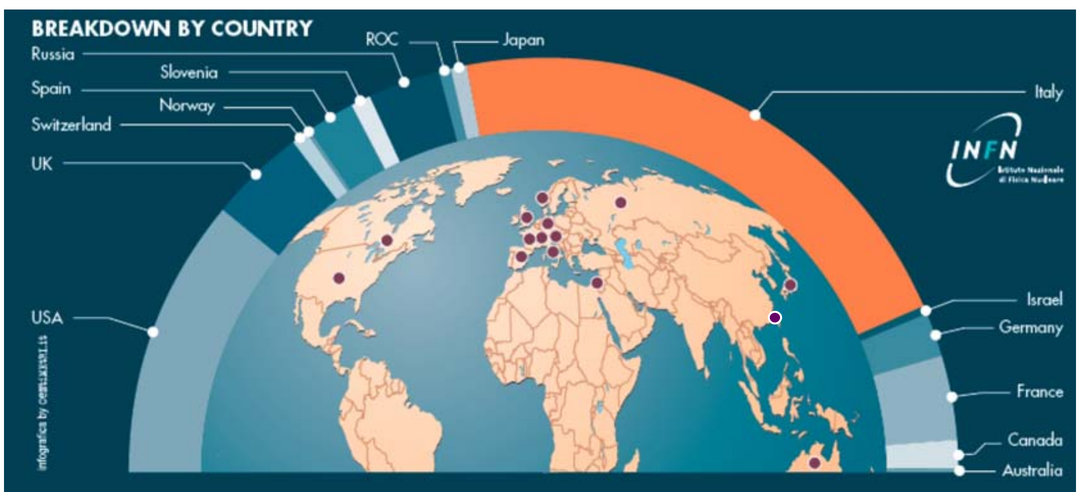
Overview

- What is SuperB?
- Physics Case in the LHC era
- Accelerator Aspects
- Detector Design
- Current Status
- A few words about Belle-II
- Summary

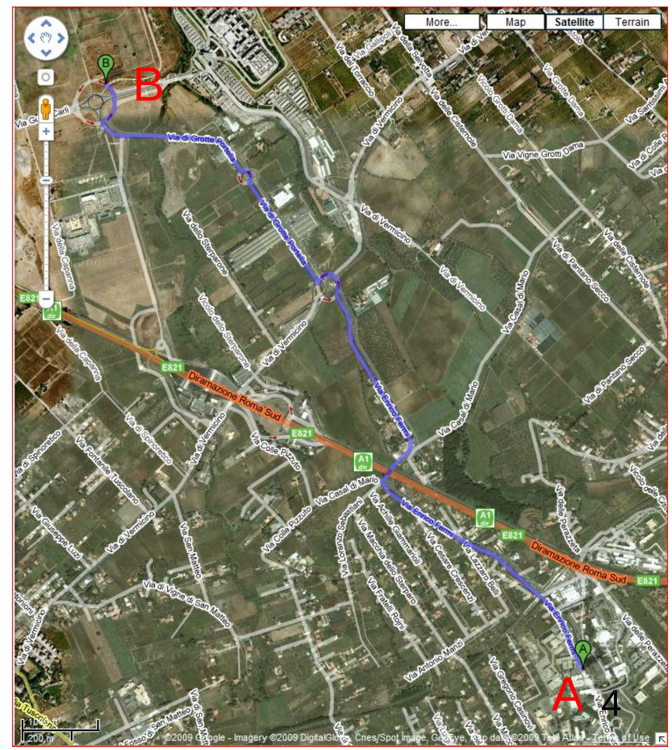
What is SuperB?

SuperB in a Nutshell

- High Luminosity e^+e^- collider.
- Aim to reach $L \geq 10^{36}$ $cm^{-2}s^{-1}$.
- Low emittance operation.
- Utilize 'crab waist' technique (now tested and proven to work).
- Stable accelerator design:
  - Approved by Machine Advisory Committee.
- Commission as early as 2015.
- Strong international interest in this physics: >300 Conceptual Design Report signatories from:



- Physics Goal:
  - **Elucidate new physics in the LHC era as thoroughly as possible.**
- Two possible sites in the suburbs of Rome:
  - INFN LNF (Frascati)/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 ansatz 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?

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

SuperB

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

Δ's are related to New Physics 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:
  - If the LHC doesn't find new physics: SuperB indirectly places constraints beyond the reach of the LHC and SLHC.
  - ... and if the LHC does find new physics, there is even more work to do at SuperB.
  - Some of the examples of this will follow shortly...

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 much*)
    - 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

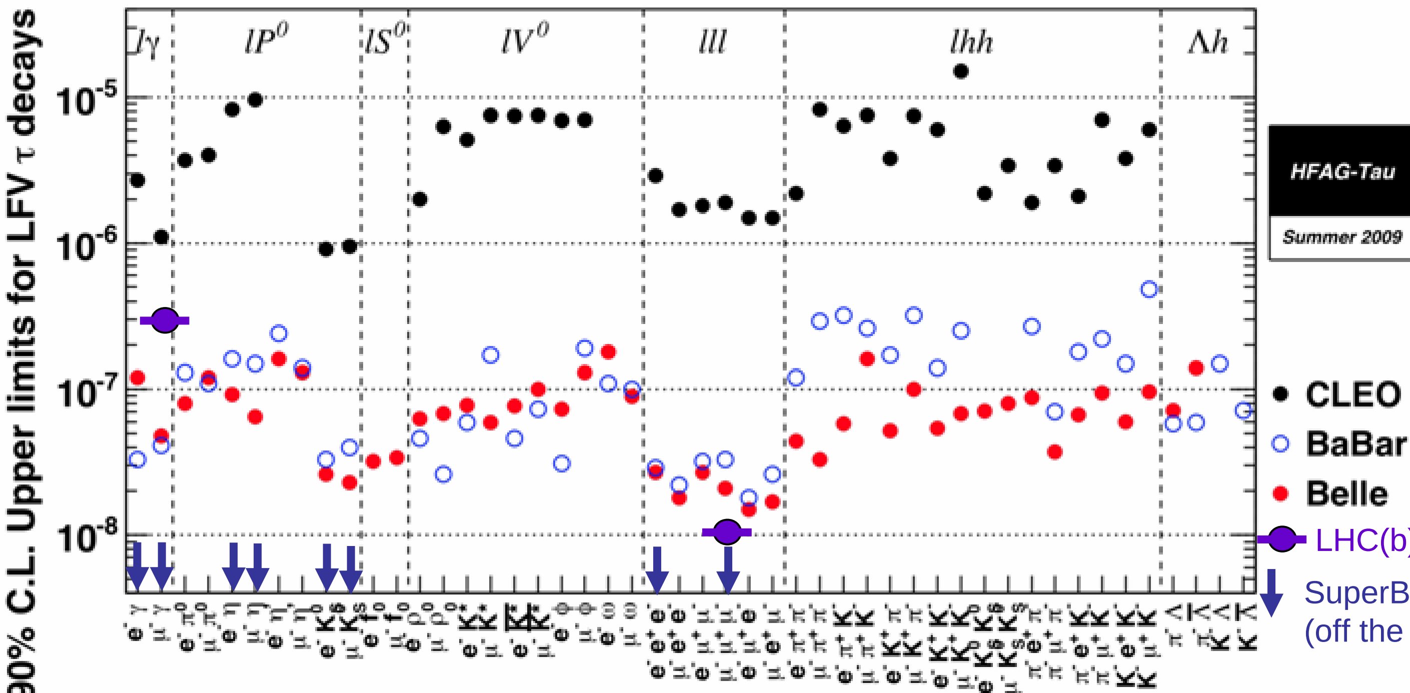
Why is a Super Flavour Factory like SuperB relevant when we have the energy frontier experiments and LHCb?

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

Charged Lepton Flavour Violation

Lepton Flavour Violation (τ decay)

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



(other modes not yet studied)

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: ATLAS, CMS, and LHCb).
- 80% polarised e⁻ beam helps reduce SM background.
- SuperB sensitivity ~10 – 50× better than New Physics allowed branching fractions.

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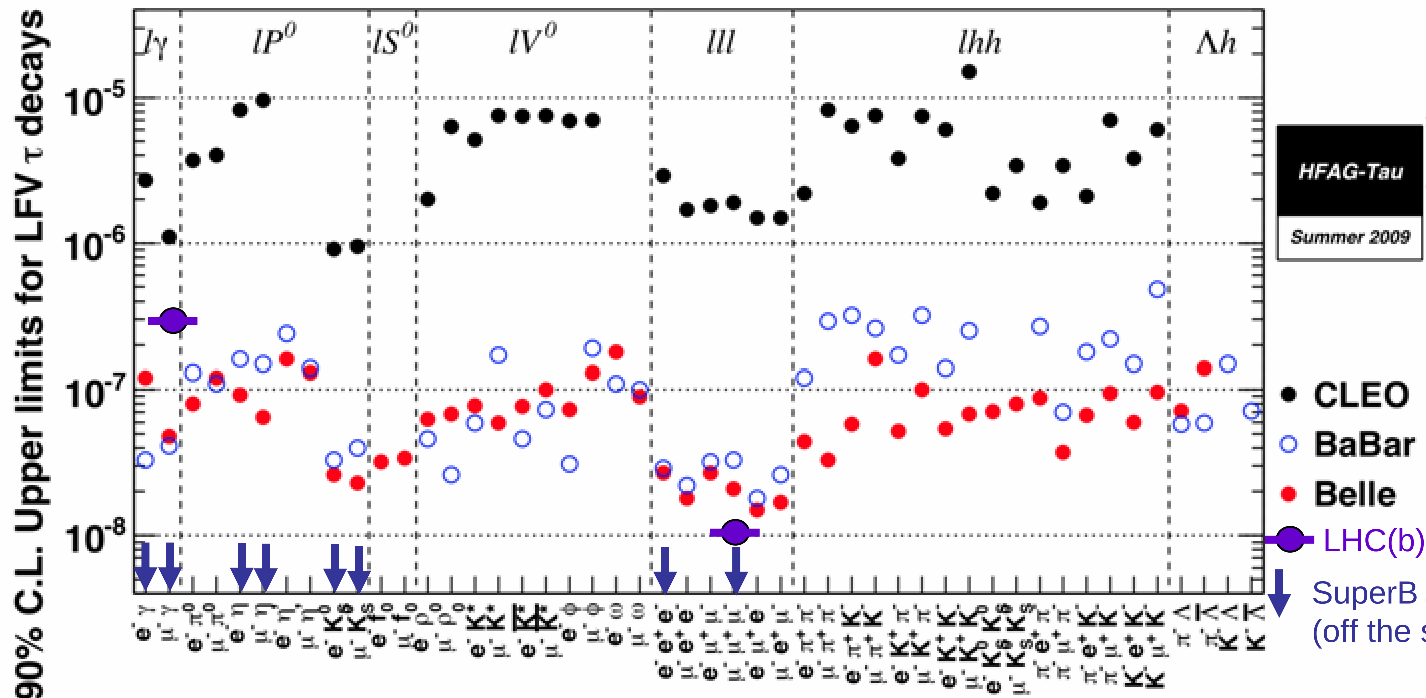

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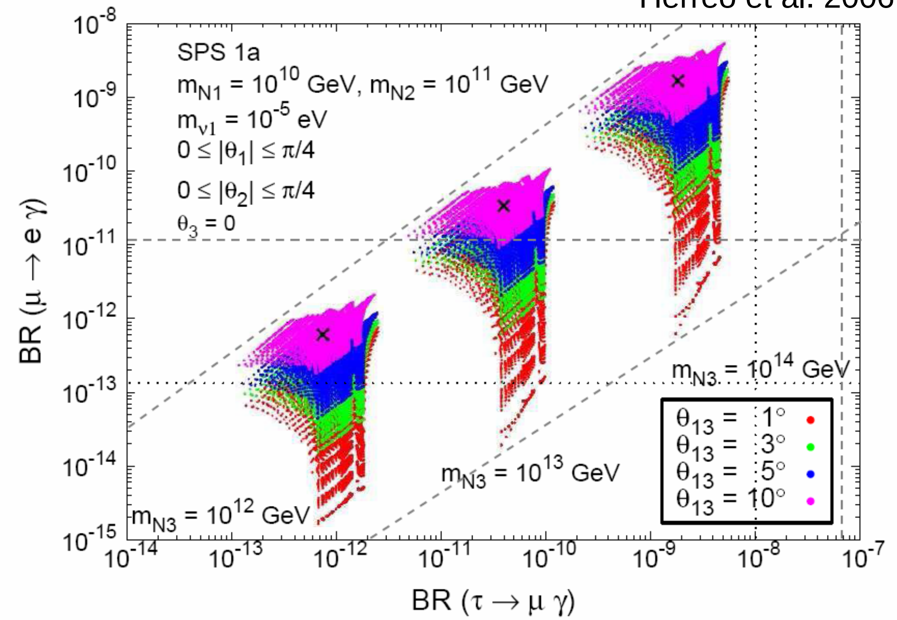
- $\tau \to \mu\gamma$ upper limit can be correlated to θ_{13} (neutrino mixing/CPV, T2K etc.) and also to $\mu \to e\gamma$.
- Complementary to flavour mixing in quarks.
- Golden modes:
  - $\tau \to \mu\gamma$ and 3μ.
- e^- beam polarization:
  - Lower background
  - Better sensitivity than competition!
- e^+ polarization may be used later in programme.
- CPV in $\tau \to K_S \pi \nu$ at the level of $\sim 10^{-5}$.
- Added 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



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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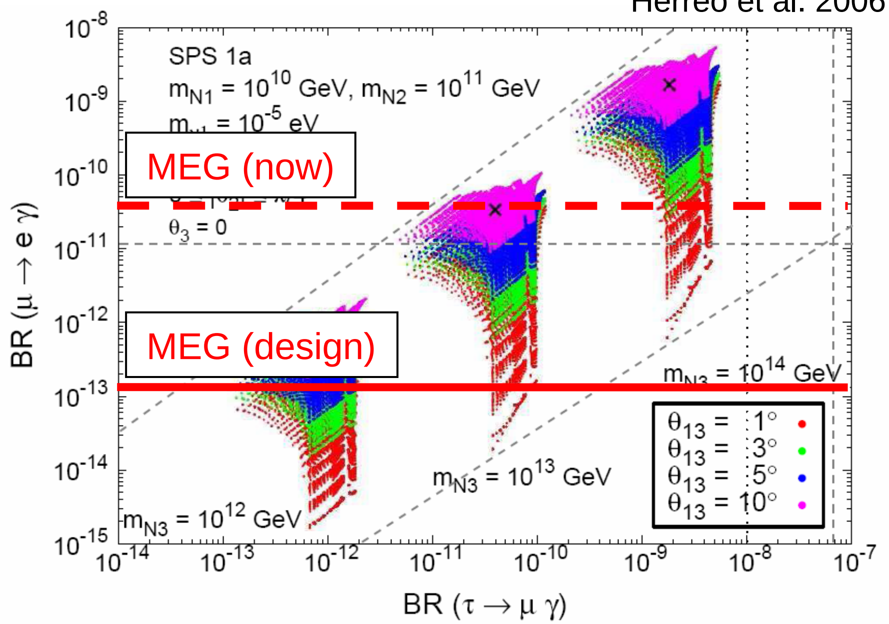

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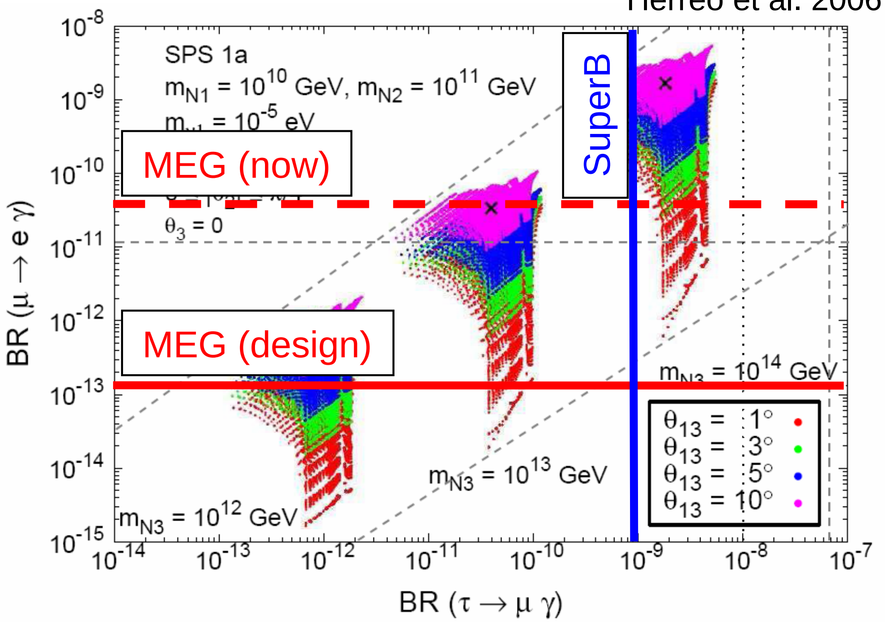

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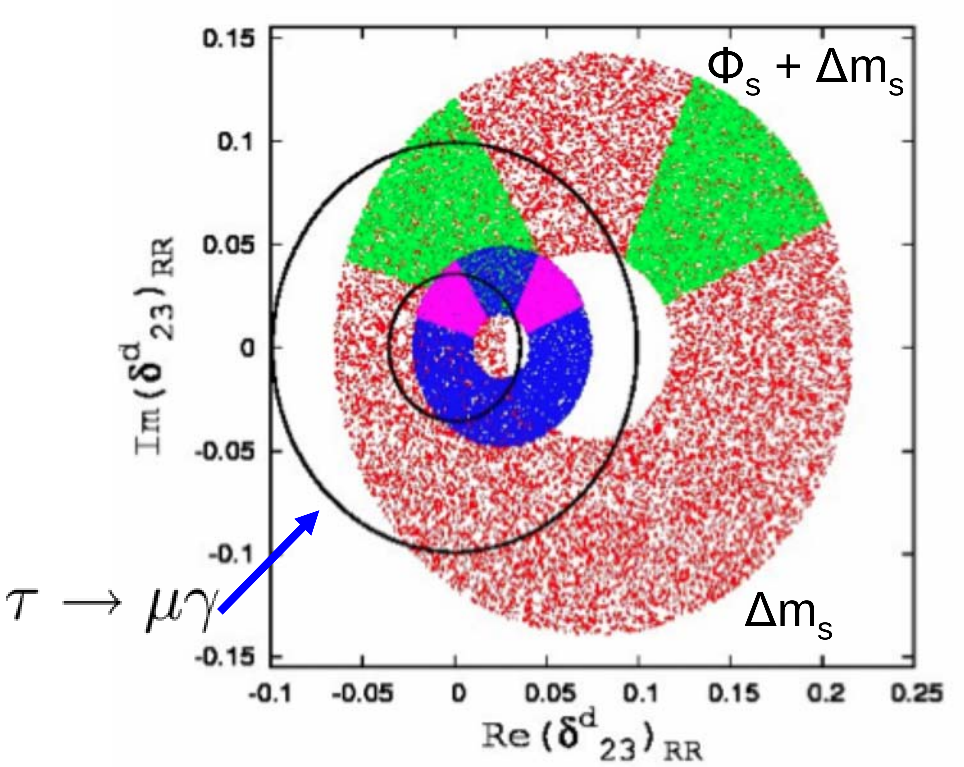
Use $\mu\gamma$/3l to distinguish SUSY vs. LHT.

Lepton Flavour Violation (τ decay)

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

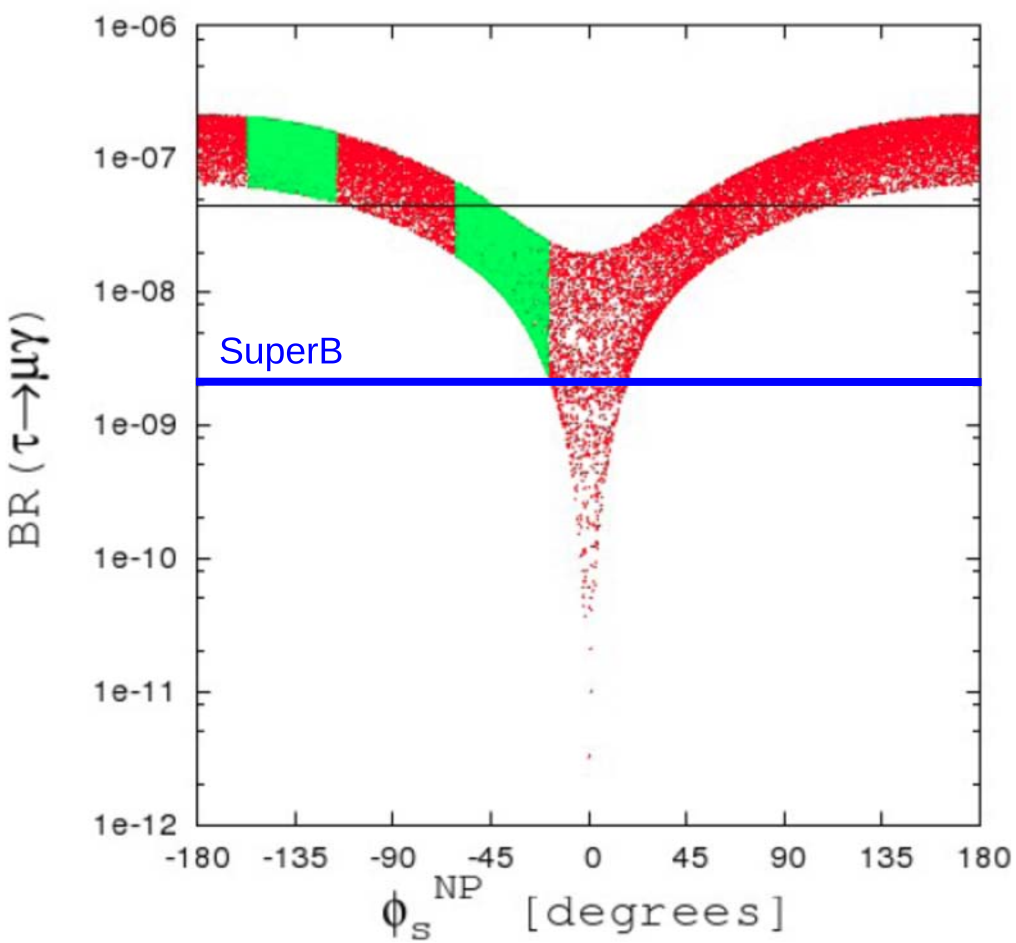
$m_{\tilde{q}} = 500\, GeV$ RED



- SU(5) SUSY GUT Model (arXiv:0710.5443, Parry and Zhang).
- Model has non-trivial SUSY squark couplings.
- Current B_S mixing measurement favours $B(\tau \rightarrow \mu\gamma) > 3 \times 10^{-9}$.
- 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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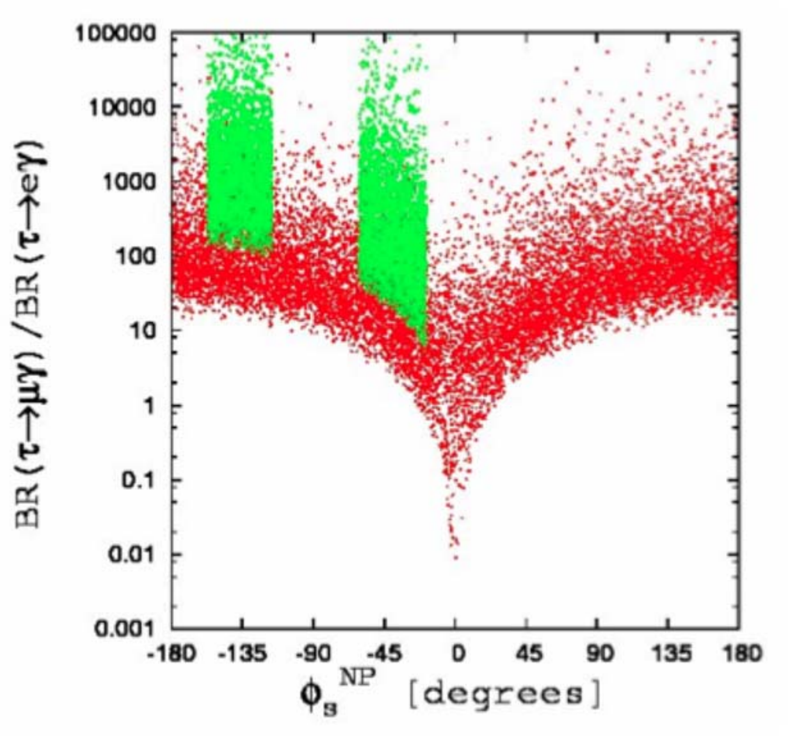

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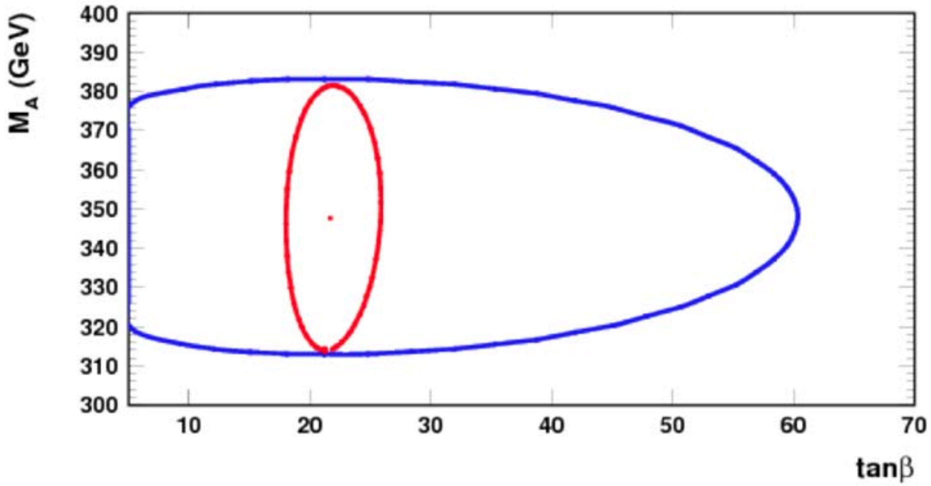
Some Higgs Phenomenology

N.B. The SM Higgs (within CMSSM) can also be constrained using b to sγ, g-2 and Ω_{CDM}. SuperB has input to sγ and the g-2 constraints. e.g. See: Weiglein et al. arXiv:0707.3447

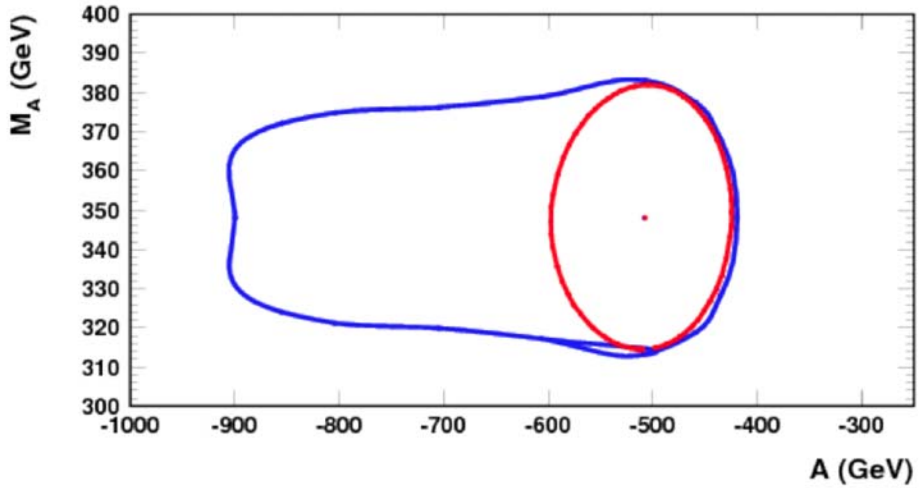
Here I show two non-SM scenarios.

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]



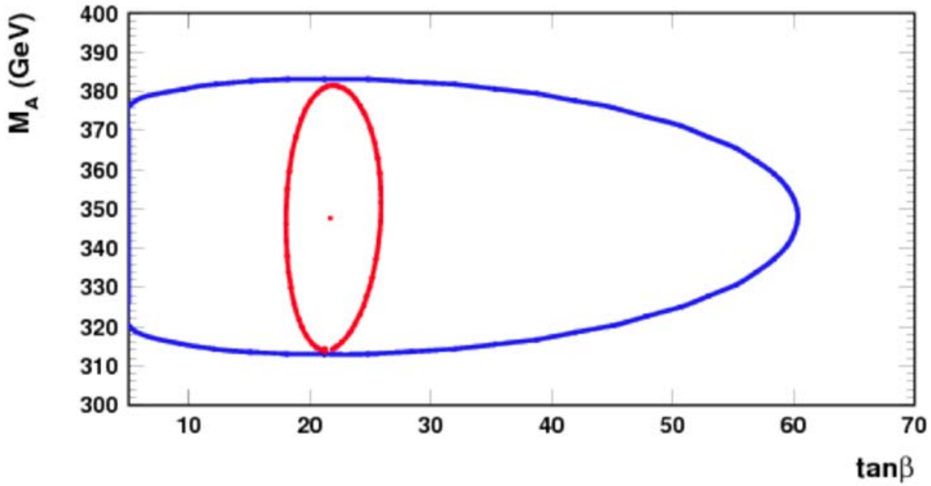
Red=LHC+EW/Low-energy constraints (includes SuperB):

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

Current analysis of data prefers tanβ~10.

EPJC **57** 183-307 (2008).

CMSSM: LHC/SuperB complementarity



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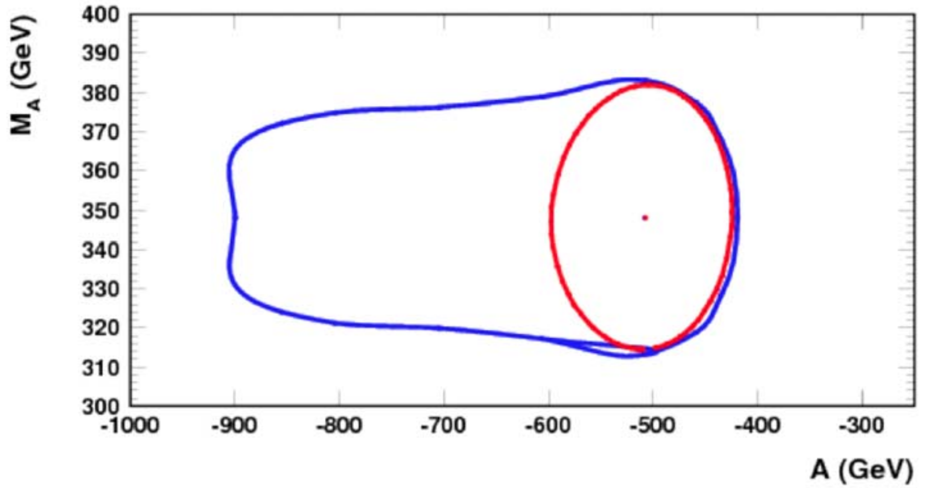


Red=LHC+EW/Low-energy constraints (includes SuperB):

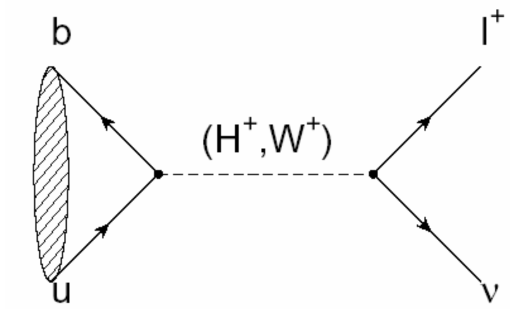
- Can build on the m(A) measurement to measure tanβ.

Current analysis of data prefers tanβ~10. EPJC **57** 183-307 (2008)

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

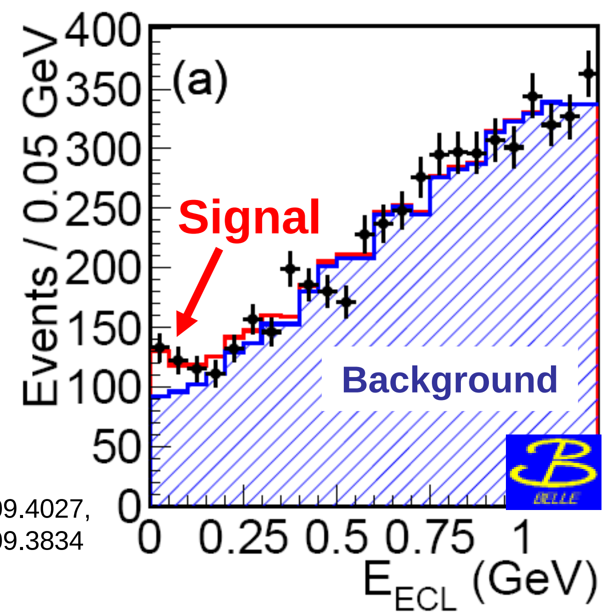
Charged Higgs: $B^{\pm} \to \tau^{\pm}\nu$

- Within the SM, sensitive to f_B and $|V_{ub}|$: B_{SM}~1.6×10^{-4}.
- B affected by new physics.
  - MFV models like 2HDM / MSSM.
  - Unparticles.
- Fully reconstruct the event (modulo ν).

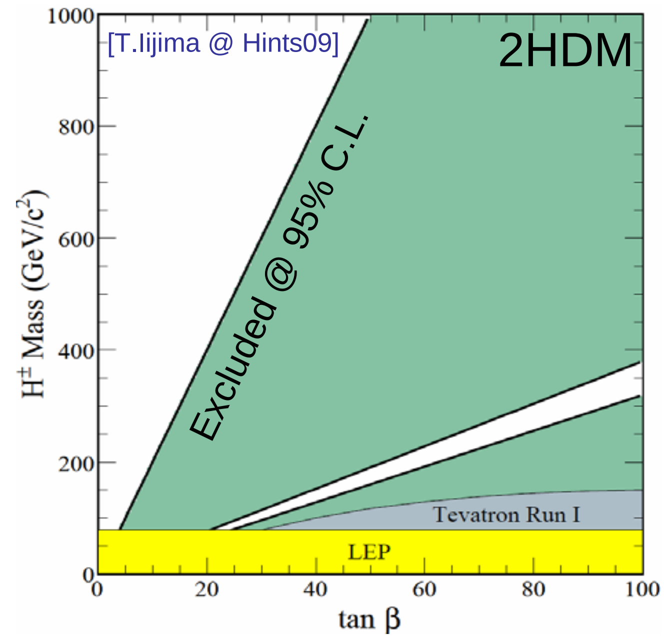


$$B_{SM}\left(B^{+}\to l^{+}\nu_{l}\right)=\frac{G_F^2 m_B m_l^2}{8\pi}\left(1-\frac{m_l^2}{m_B^2}\right) f_B^2 \,|V_{ub}|^2\, \tau_B$$

$$B_{\mathrm{WA}}=\left(1.73\pm0.35\right)\times10^{-4}$$



arXiv:0809.4027,
arXiv:0809.3834

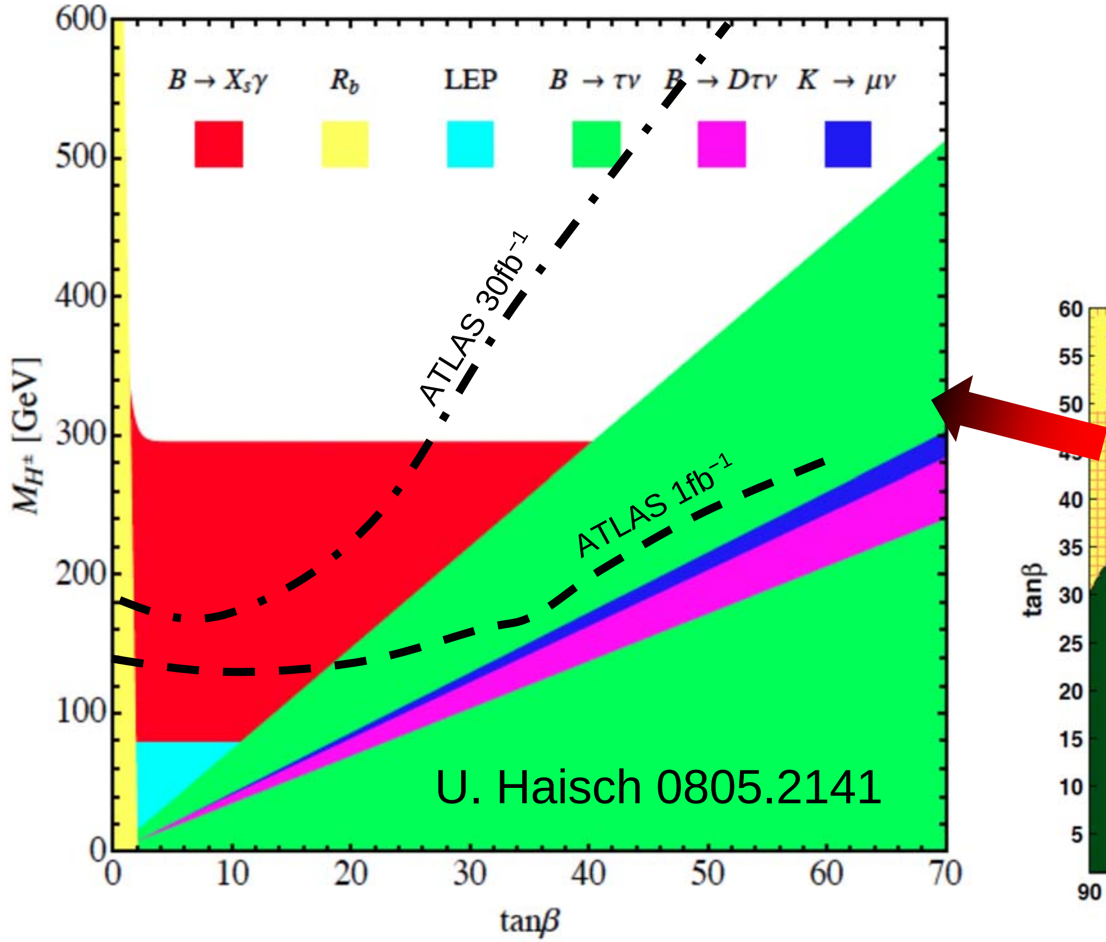


2HDM: W.-S Hou PRD **48** 2342 (1993)
MSSM: G. Isidori arXiv:0710.5377
Unparticles: R. Zwicky PRD**77** 036004 (2008)

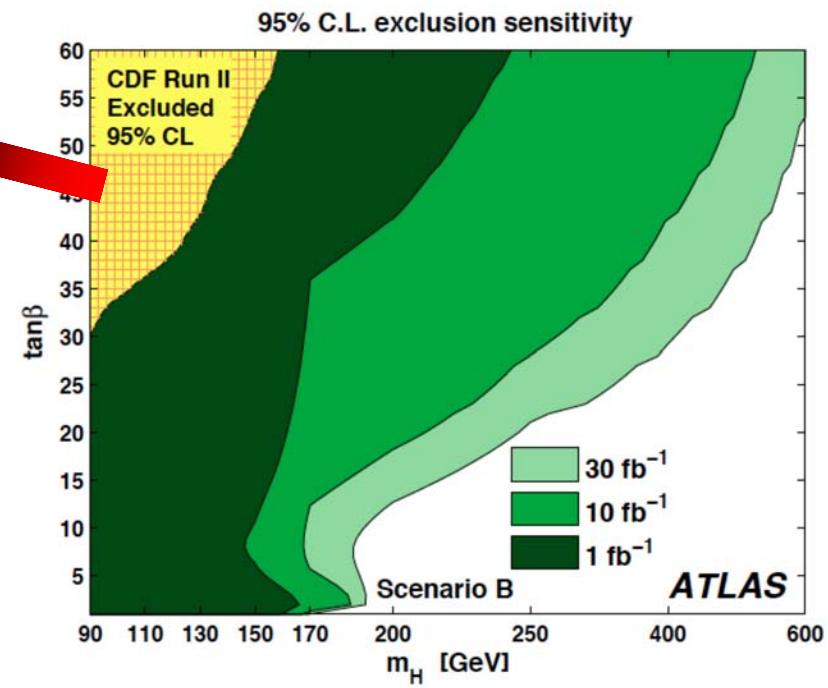
Charged Higgs

- 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 @14TeV



Converted constraints expected from ATLAS onto the plot by hand.



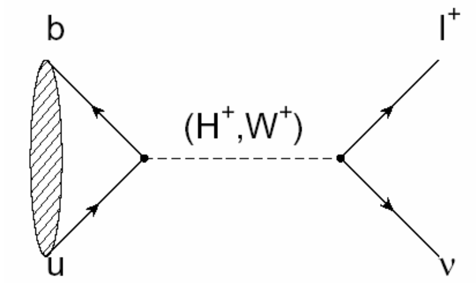
LHC expected to have 5fb-1 @14TeV ~ 2015.

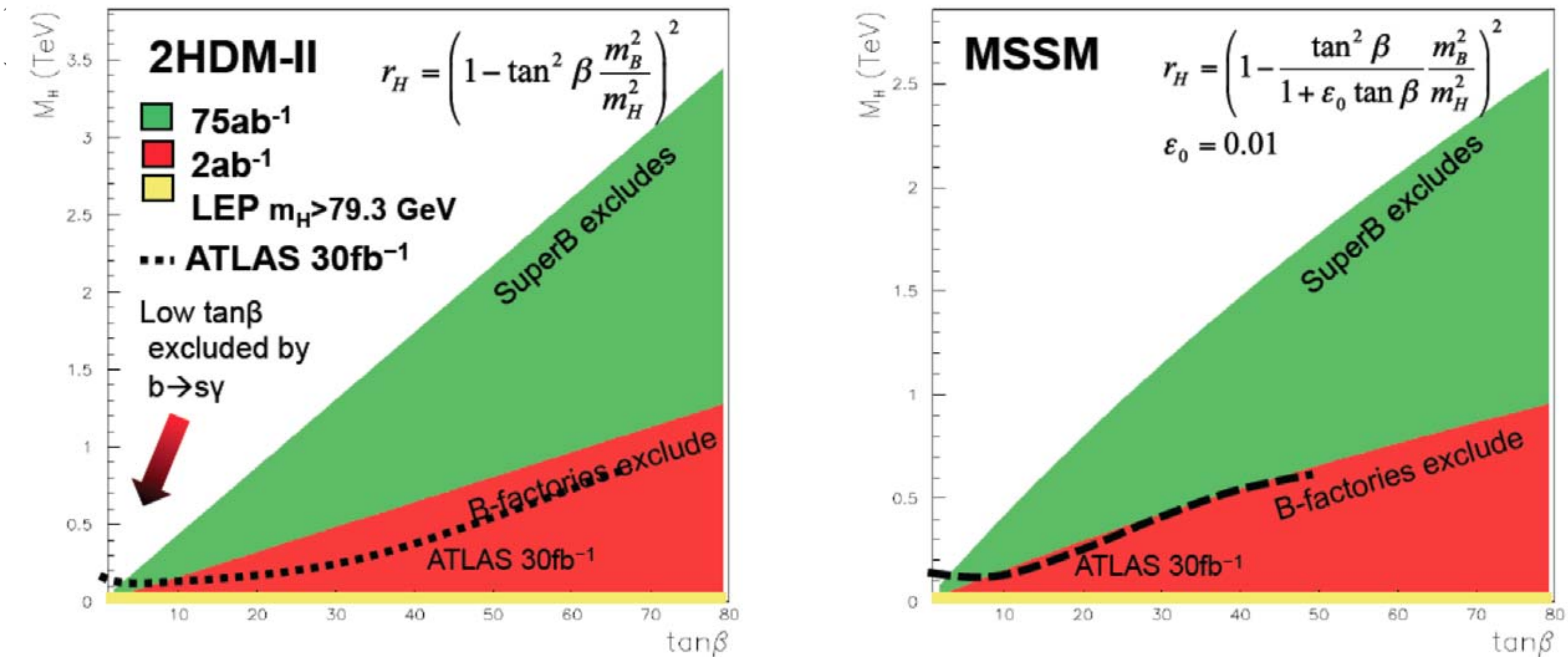
Charged Higgs

- Higgs mediated Minimal Flavour Violation

$$r_H = \frac{B_{SM+NP}}{B_{SM}}$$

(Assuming SM branching fraction is measured)





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

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

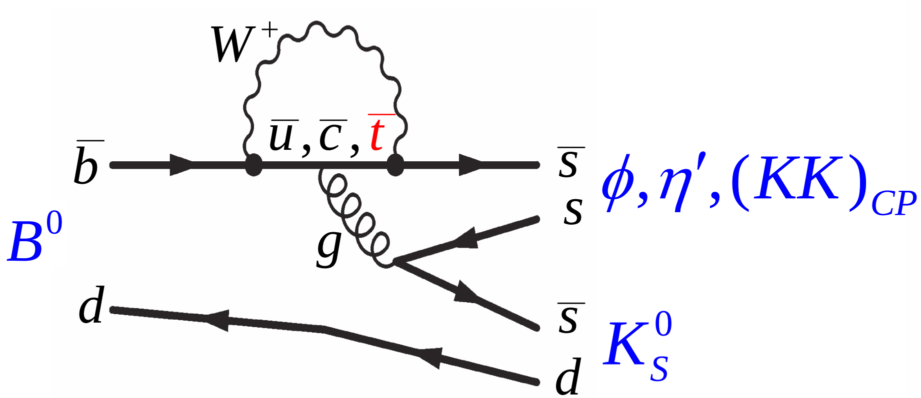
Time-dependent CP Violation as a New Physics probe

ΔS measurements

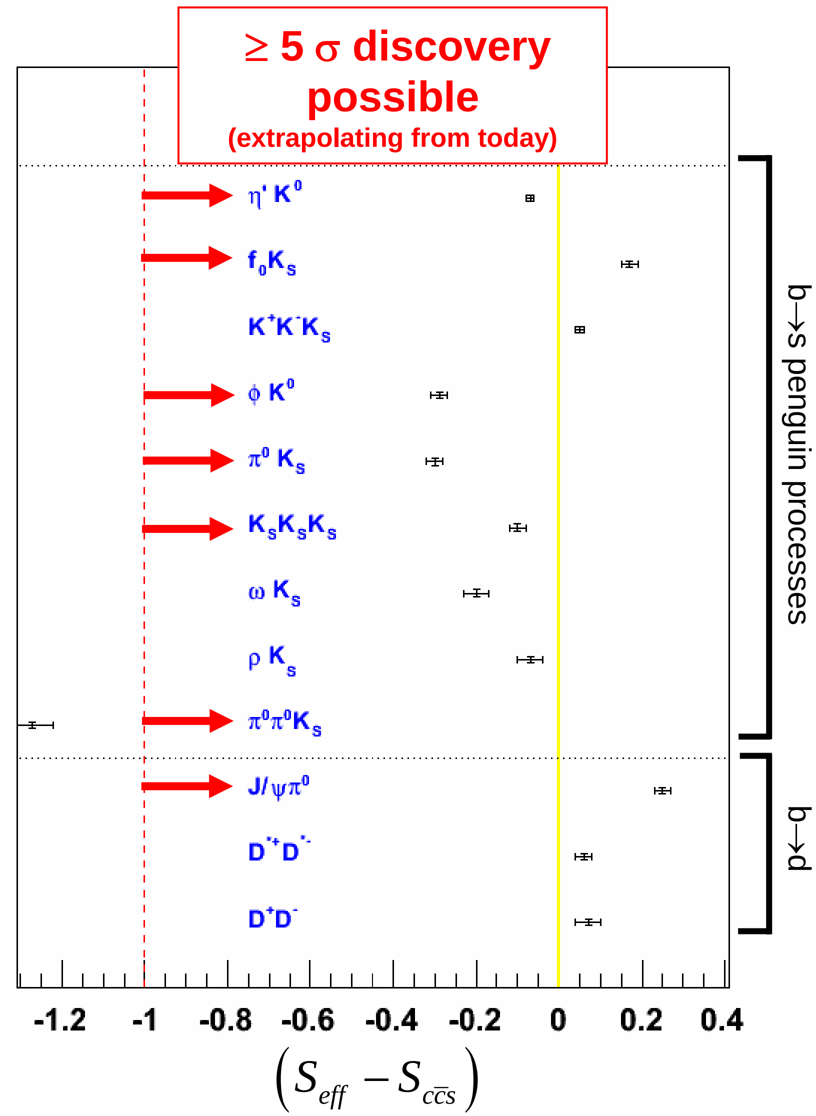
- β=(21.1±0.9)° from Charmonium decays.
- Look in many different b→s and b→d decays for sin2β deviations from the SM:

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

- The golden channel is:

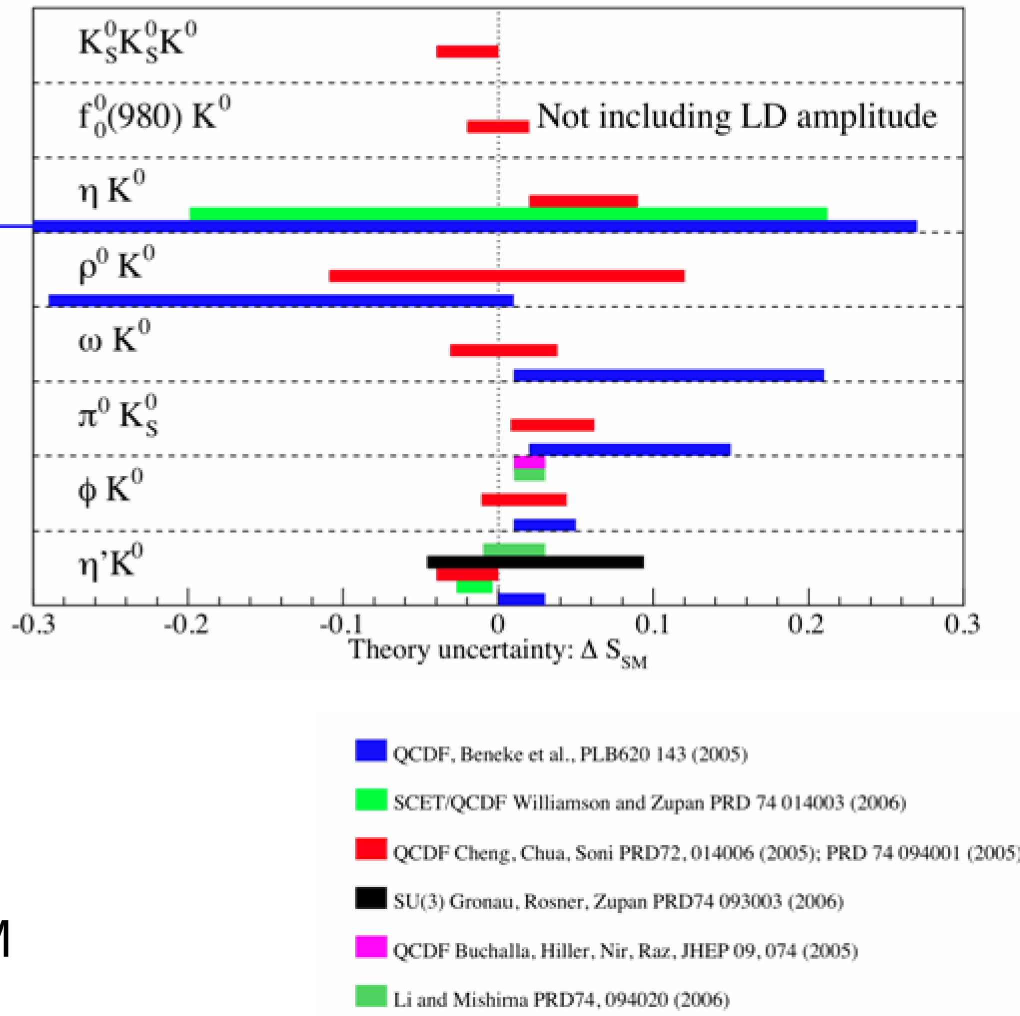


- Deviations would be from high mass particles in loops: H, χ, ...



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:
  - New Physics could affect $c\bar{c}s$ $\sin 2\beta$.

1) Predict sin2β from indirect constraints.

$$[\sin(2\beta)]^{prediction}_{noV_{ub}} = 0.87 \pm 0.09.$$

2) Compare to ccs measurement.

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

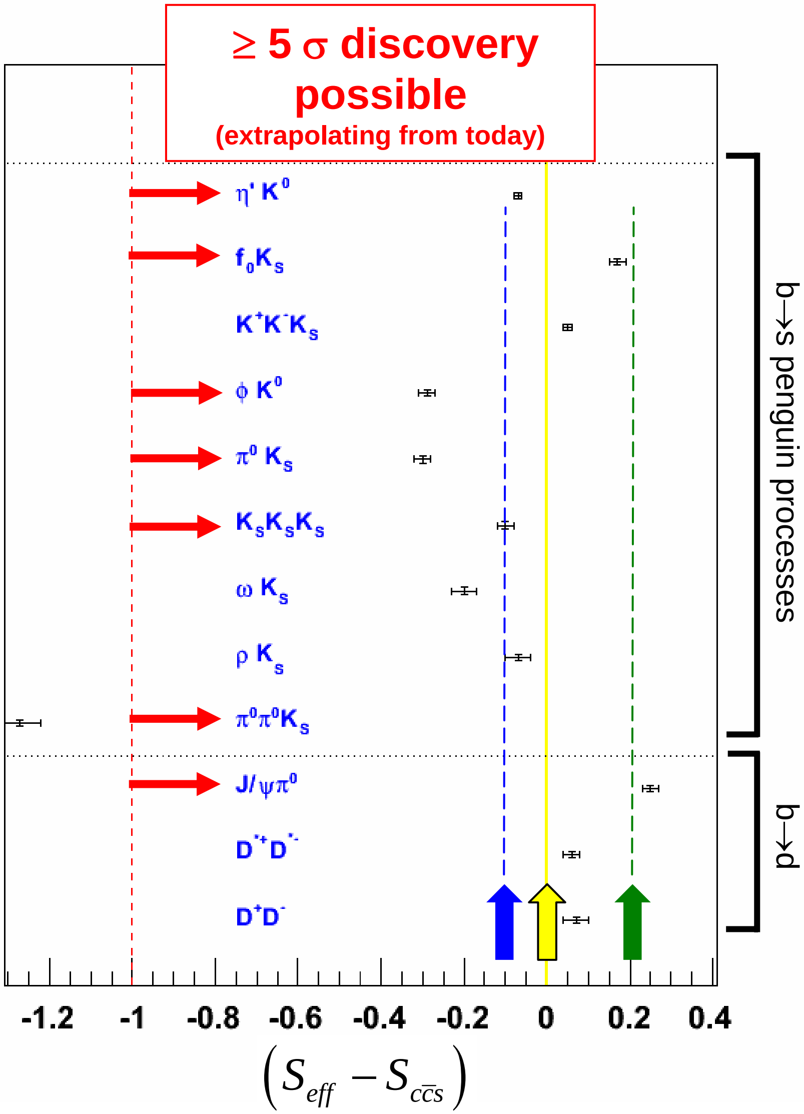
3) Compare to clean penguin measurements.

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

(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?**

ΔS measurements

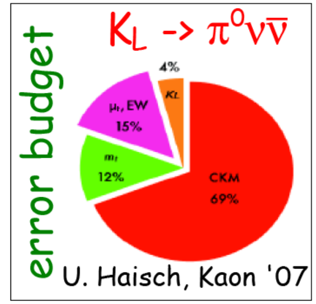
Mode	Current Precision			Predicted Precision ($75\,ab^{-1}$)			Discovery Potential	
	Stat.	Syst.	Th.	Stat.	Syst.	Th.	3σ	5σ
$J/\psi K^0_S$	0.022	0.010	< 0.01	0.002	0.005	< 0.001	0.02	0.03
$\eta' K^0_S$	0.08	0.02	0.014	0.006	0.005	0.014	0.05	0.08
$\phi K^0_S \pi^0$	0.28	0.01	–	0.020	0.010	–	0.07	0.11
$f_0 K^0_S$	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

Decreasing error
Increasing importance

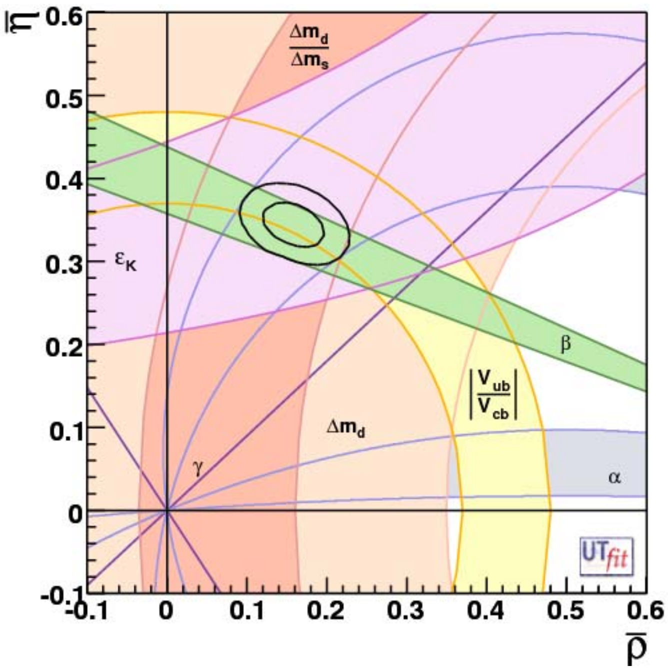
Precision CKM

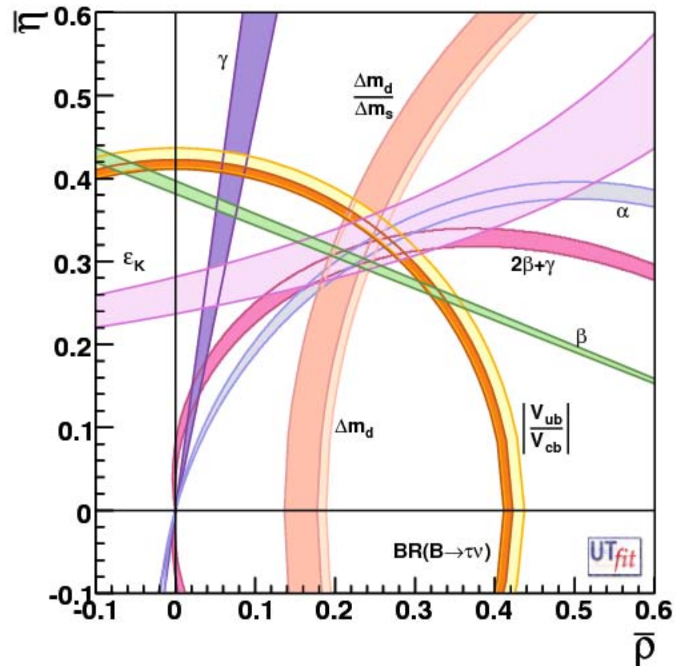
- CKM is a 36 year old ansatz.
- Works at the 10% level.
- No underlying physical insight.
- Small new physics contributions not ruled out (% level).

Precision CKM from SuperB will open up more new physics search opportunities: e.g. $K \rightarrow \pi\nu\nu$:



K^+ decay has a similar error budget.





B physics @ Y(4S)

Variety of measurements for any observable

Observable	B Factories (2 ab^{-1})	SuperB (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
α ($B \to \pi\pi$)	$\sim 16°$	3°
α ($B \to \rho\rho$)	$\sim 7°$	1–2° (*)
α ($B \to \rho\pi$)	$\sim 12°$	2°
α (combined)	$\sim 6°$	1–2° (*)
γ ($B \to DK$, $D \to CP$ eigenstates)	$\sim 15°$	2.5°
γ ($B \to DK$, $D \to$ suppressed states)	$\sim 12°$	2.0°
γ ($B \to DK$, $D \to$ multibody states)	$\sim 9°$	1.5°
γ ($B \to DK$, combined)	$\sim 6°$	1–2°
$2\beta+\gamma$ ($D^{(*)\pm}\pi^\mp$, $D^\pm K^0_S\pi^\mp$)	20°	5°
$S(\phi K^0)$	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 (*)
$\|V_{cb}\|$ (exclusive)	4% (*)	1.0% (*)
$\|V_{cb}\|$ (inclusive)	1% (*)	0.5% (*)
$\|V_{ub}\|$ (exclusive)	8% (*)	3.0% (*)
$\|V_{ub}\|$ (inclusive)	8% (*)	2.0% (*)

Observable	B Factories (2 ab^{-1})	SuperB (75 ab
$\mathcal{B}(B \to \tau\nu)$	20%	4% (†)
$\mathcal{B}(B \to \mu\nu)$	visible	5%
$\mathcal{B}(B \to D\tau\nu)$	10%	2%
$\mathcal{B}(B \to \rho\gamma)$	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%
$\mathcal{B}(B \to K\nu\bar{\nu})$	visible	20%
$\mathcal{B}(B \to \pi\nu\bar{\nu})$	–	possible

Possible also at LHCb

Similar precision at LHCb

Example of « SuperB specifics »

- inclusive in addition to exclusive analyses
- channels with π^0, γ's, ν, many Ks…

τ physics (polarized beams)

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}

Charm at Υ(4S) and threshold

Mode	Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab^{-1})
$D^0 \to K^+K^-$	y_{CP}	$2\text{–}3 \times 10^{-3}$	5×10^{-4}
$D^0 \to K^+\pi^-$	y'_D	$2\text{–}3 \times 10^{-3}$	7×10^{-4}
	x'^2_D	$1\text{–}2 \times 10^{-4}$	3×10^{-5}
$D^0 \to K_S^0\pi^+\pi^-$	y_D	$2\text{–}3 \times 10^{-3}$	5×10^{-4}
	x_D	$2\text{–}3 \times 10^{-3}$	5×10^{-4}
Average	y_D	$1\text{–}2 \times 10^{-3}$	3×10^{-4}
	x_D	$2\text{–}3 \times 10^{-3}$	5×10^{-4}
$D^0 \to K^+\pi^-$	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°

To be evaluated at LHCb

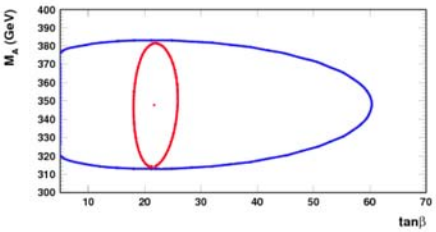
Channel	Sensitivity
$D^0 \to e^+e^-$, $D^0 \to \mu^+\mu^-$	1×10^{-8}
$D^0 \to \pi^0e^+e^-$, $D^0 \to \pi^0\mu^+\mu^-$	2×10^{-8}
$D^0 \to \eta e^+e^-$, $D^0 \to \eta\mu^+\mu^-$	3×10^{-8}
$D^0 \to K_S^0e^+e^-$, $D^0 \to K_S^0\mu^+\mu^-$	3×10^{-8}
$D^+ \to \pi^+e^+e^-$, $D^+ \to \pi^+\mu^+\mu^-$	1×10^{-8}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

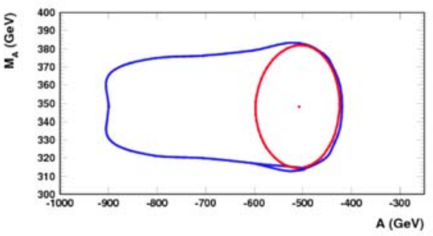
B_s at Υ(5S)

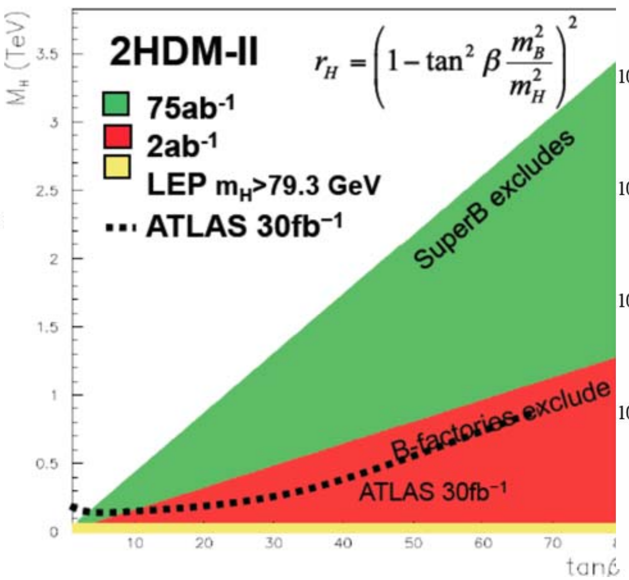
Observable	Error with 1 ab^{-1}	Error with 30 ab^{-1}
$\Delta\Gamma$	0.16 ps^{-1}	0.03 ps^{-1}
Γ	0.07 ps^{-1}	0.01 ps^{-1}
β_s from angular analysis	20°	8°
A_{SL}^s	0.006	0.004
A_{CH}	0.004	0.004
$\mathcal{B}(B_s \to \mu^+\mu^-)$	-	$< 8 \times 10^{-9}$
$\lvert V_{td}/V_{ts}\rvert$	0.08	0.017
$\mathcal{B}(B_s \to \gamma\gamma)$	38%	7%
β_s from $J/\psi\phi$	16°	6°
β_s from $B_s \to K^0\bar{K}^0$	24°	11°

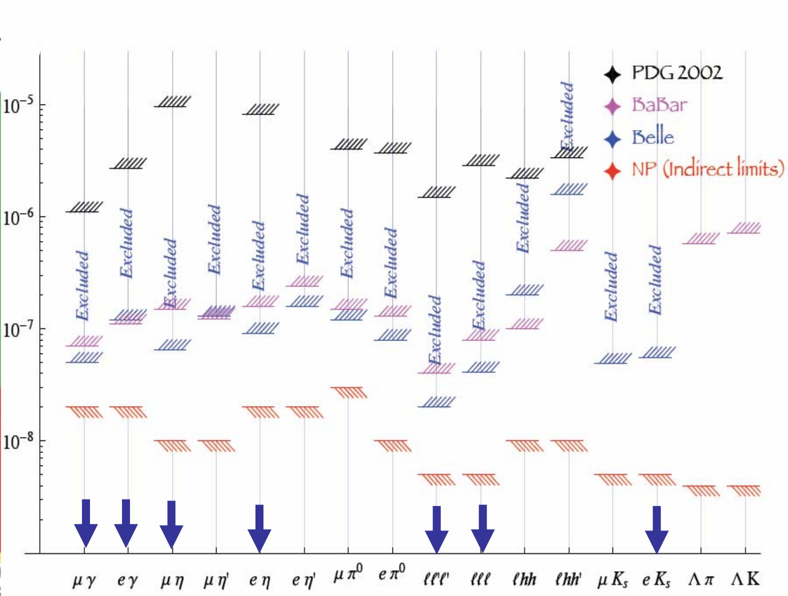
Bs : Definitively better at LHCb

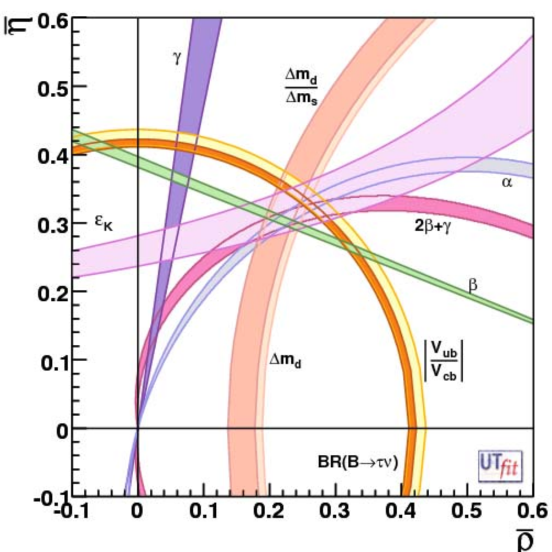
The Physics Case in 1 Page

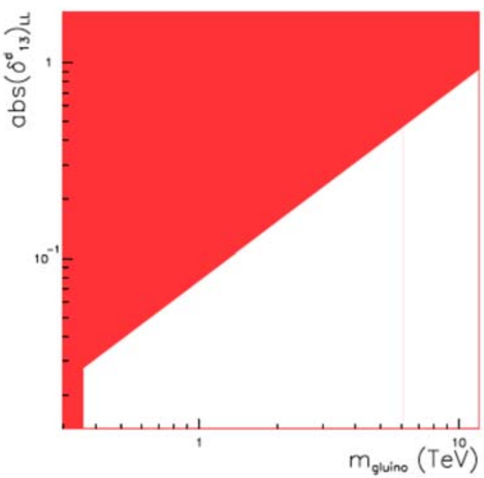


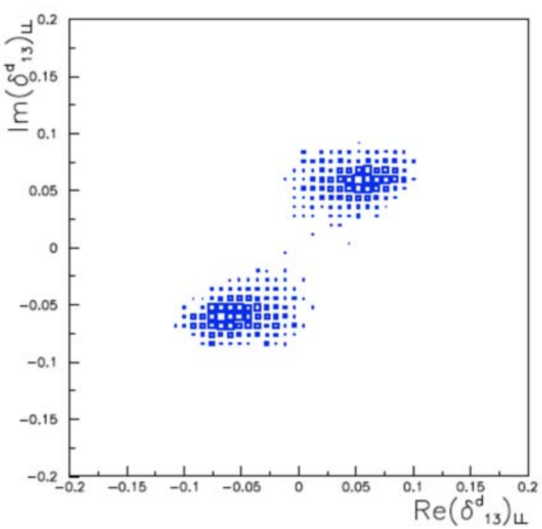












The Golden Matrix

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

	H^+ high $\tan\beta$	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	

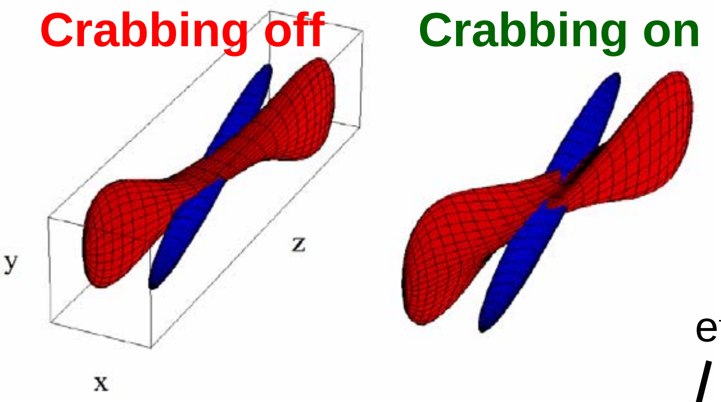
... + charm + spectroscopy (DM /Light Higgs etc).

  - When finished, the physics white paper will have a more complete matrix than the one shown here.

Accelerator Aspects

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

Crab waist tests at DAΦNE



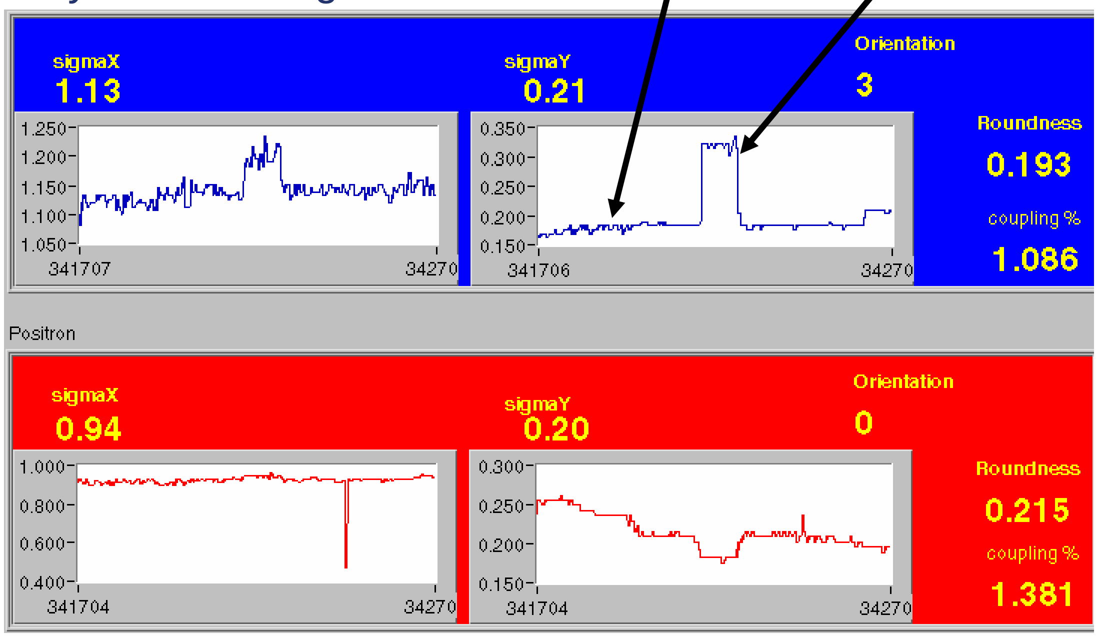
Crab sextupoles give luminosity improvement of roughly factor 2.

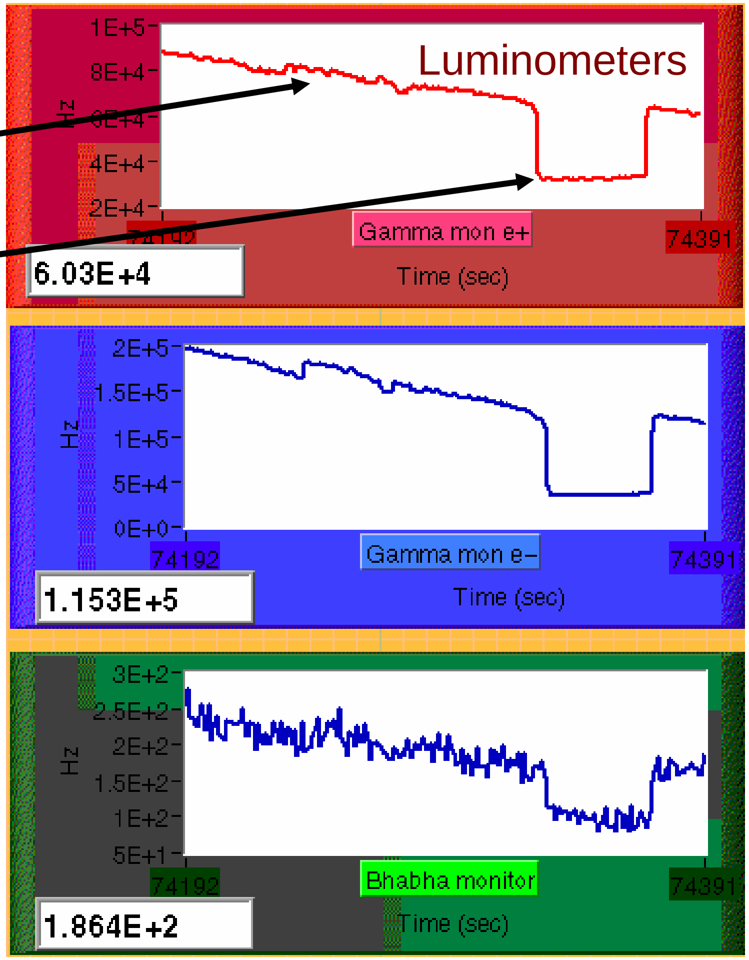
(Factor of 4 achieved in latest run!)

e⁻ sextupoles on

e⁻ sextupoles off

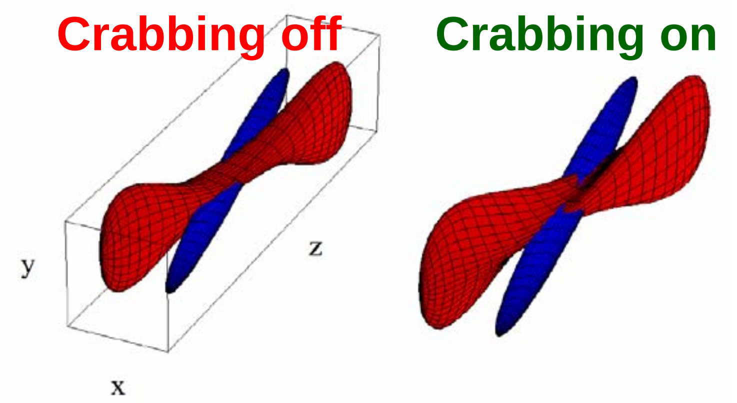
Transverse beam sizes at Synchrotron Light Monitors





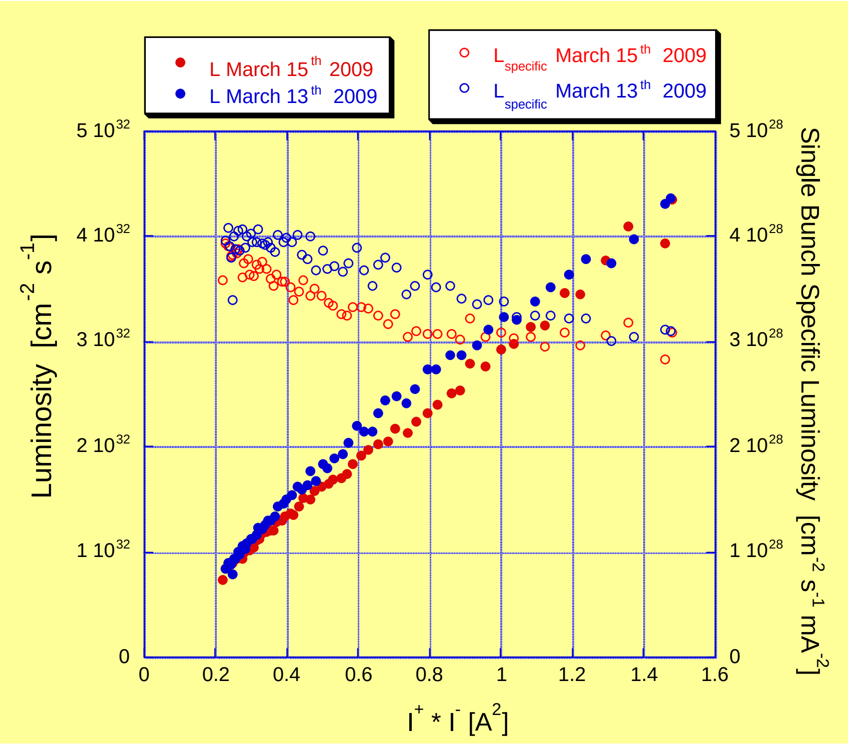
P. Raimondi (INFN-LNF)

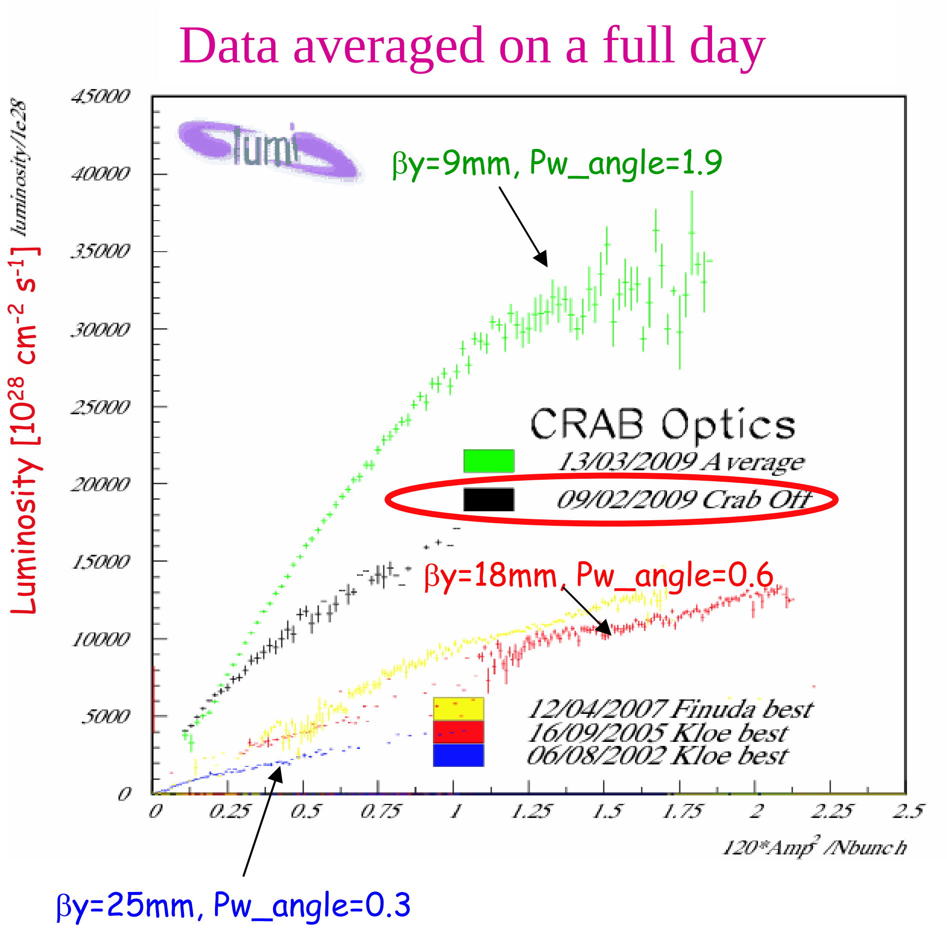
Crab waist tests at DAΦNE



Crab sextupoles give luminosity improvement of roughly factor 2.

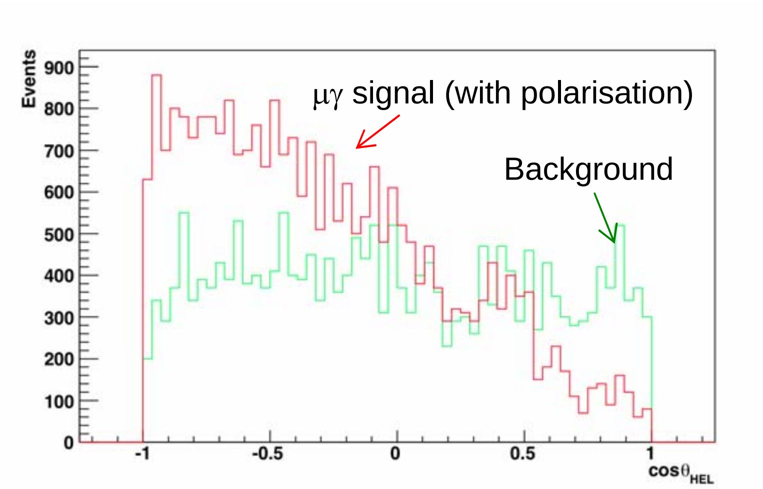
(Factor of 4 achieved in latest run!)



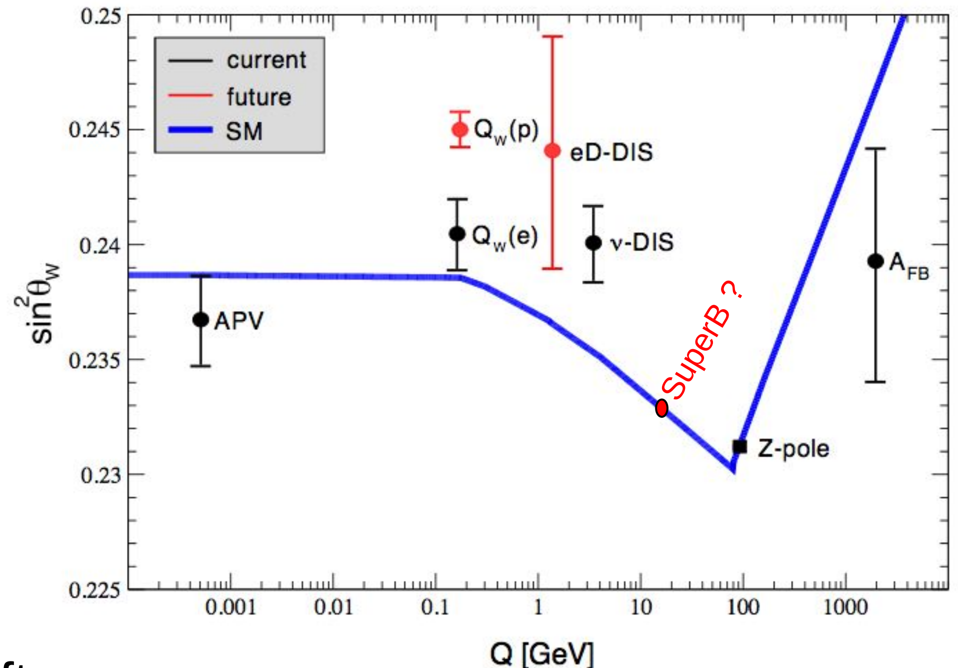


Polarisation

- A unique feature of SuperB is a polarised e^- beam.
  - 80% polarisation from the outset.
  - Crucial to deliver on physics: Lower background for LFV measurements, τ EDM and g−2, and precision $\sin^2\theta_W$.



Polarisation gives an additional discriminating variable to τ LFV searches that can be used to suppress background..



With Polarised e^- beam, SuperB can measure $\sin^2\theta_W$ as accurately as LEP.

  - Use solenoids before and after IP to longitudinally polarise the electron beam.

SuperB→Results of two year work. Parameters as at 18/3/2010

		Base Line		Low Emittance		High Current		Tau/Charm (prelim.)	
Parameter	Units	HER (e+)	LER (e-)	HER (e+)	LER (e-)	HER (e+)	LER (e-)	HER (e+)	LER (e-)
LUMINOSITY	$cm^{-2}\ s^{-1}$	1.00E+36		1.00E+36		1.00E+36		1.00E+35	
Energy	GeV	6.7	4.18	6.7	4.18	6.7	4.18	2.58	1.61
Circumference	m	1258.4		1258.4		1258.4		1258.4	
X-Angle (full)	mrad	66		66		66		66	
Piwinski angle	rad	22.88	18.60	32.36	26.30	14.43	11.74	8.80	7.15
β_x @ IP	cm	2.6	3.2	2.6	3.2	5.06	6.22	6.76	8.32
β_y @ IP	cm	0.0253	0.0205	0.0179	0.0145	0.0292	0.0237	0.0658	0.0533
Coupling (full current)	%	0.25	0.25	0.25	0.25	0.5	0.5	0.25	0.25
ε_x (without IBS)	nm	1.97	1.82	1.00	0.91	1.97	1.82	1.97	1.82
ε_x (with IBS)	nm	2.00	2.46	1.00	1.23	2.00	2.46	5.20	6.4
ε_y	pm	5	6.15	2.5	3.075	10	12.3	13	16
σ_x @ IP	μm	7.211	8.872	5.099	6.274	10.060	12.370	18.749	23.076
σ_y @ IP	μm	0.036	0.036	0.021	0.021	0.054	0.054	0.092	0.092
Σ_x	μm	11.433		8.085		15.944		29.732	
Σ_y	μm	0.050		0.030		0.076		0.131	
σ_L (0 current)	mm	4.69	4.29	4.73	4.34	4.03	3.65	4.75	4.36
σ_L (full current)	mm	5	5	5	5	4.4	4.4	5	5
Beam current	mA	1892	2447	1460	1888	3094	4000	1365	1766
Buckets distance	#	2		2		1		1	
Ion gap	%	2		2		2		2	
RF frequency	Hz	4.76E+08		4.76E+08		4.76E+08		4.76E+08	
Harmonic number		1998		1998		1998		1998	
Number of bunches		978		978		1956		1956	
N. Particle/bunch		5.08E+10	6.56E+10	3.92E+10	5.06E+10	4.15E+10	5.36E+10	1.83E+10	2.37E+10
Tune shift x		0.0021	0.0033	0.0017	0.0025	0.0044	0.0067	0.0052	0.0080
Tune shift y		0.0970	0.0971	0.0891	0.0892	0.0684	0.0687	0.0909	0.0910
Long. damping time	msec	13.4	20.3	13.4	20.3	13.4	20.3	26.8	40.6
Energy Loss/turn	MeV	2.11	0.865	2.11	0.865	2.11	0.865	0.4	0.166
σ_E (full current)	dE/E	6.43E-04	7.34E-04	6.43E-04	7.34E-04	6.43E-04	7.34E-04	6.94E-04	7.34E-04
CM σ_E	dE/E	5.00E-04		5.00E-04		5.00E-04		5.26E-04	
Total lifetime	min	4.23	4.48	3.05	3.00	7.08	7.73	11.41	6.79
Total RF Power	MW	17.08		12.72		30.48		3.11	

Different solutions to reach 10^{36}

Baseline + other 2 options:
- **Lower y-emittance**
- **Higher currents (twice bunches)**

+ Solution for running at the Tau/charm threshold: L = 10^{35}

SuperB→Results of two year work. Parameters as at 18/3/2010

Parameter	Units	Base Line HER (e+)	Base Line LER (e-)	Low Emittance HER (e+)	Low Emittance LER (e-)	High Current HER (e+)	High Current LER (e-)	Tau/Charm (prelim.) HER (e+)	Tau/Charm (prelim.) LER (e-)
LUMINOSITY	$cm^{-2} s^{-1}$	1.00E+36		1.00E+36		1.00E+36		1.00E+35	
Energy	GeV	6.7	4.18	6.7	4.18	6.7	4.18	2.58	1.61
Circumference	m	1258.4		1258.4		1258.4		1258.4	
X-Angle (full)	mrad	66		66		66		66	
Piwinski angle	rad	22.88	18.60	32.36	26.30	14.43	11.74	8.80	7.15
β_x @ IP	cm	2.6	3.2	2.6	3.2	5.06	6.22	6.76	8.32
β_y @ IP	cm	0.0253	0.0205	0.0179	0.0145	0.0292	0.0237	0.0658	0.0533
Coupling (full current)	%	0.25	0.25	0.25	0.25	0.5	0.5	0.25	0.25
ε_x (without IBS)	nm	1.97	1.82	1.00	0.91	1.97	1.82	1.97	1.82
ε_x (with IBS)	nm	2.00	2.46	1.00	1.23	2.00	2.46	5.20	6.4
ε_y	pm	5	6.15	2.5	3.075	10	12.3	13	16
σ_x @ IP	μm	7.211	8.872	5.099	6.274	10.060	12.370	18.749	23.076
σ_y @ IP	μm	0.036	0.036	0.021	0.021	0.054	0.054	0.092	0.092
Σ_x	μm	11.433		8.085		15.944		29.732	
Σ_y	μm	0.050		0.030		0.076		0.131	
σ_L (0 current)	mm	4.69	4.29	4.73	4.34	4.03	3.65	4.75	4.36
σ_L (full current)	mm	5	5	5	5	4.4	4.4	5	5
Beam current	mA	1892	2447	1460	1888	3094	4000	1365	1766
Buckets distance	#	2		2		1		1	
Ion gap	%	2		2		2		2	
RF frequency	Hz	4.76E+08		4.76E+08		4.76E+08		4.76E+08	
Harmonic number									
Number of bunches									
N. Particle/bunch									
Tune shift x									
Tune shift y									
Long. damping time									
Energy Loss/turn									
σ_E (full current)									
CM σ_E									
Total lifetime	min	4.23	4.48	3.05	3.00	7.08	7.73	11.41	6.79
Total RF Power	MW	17.08		12.72		30.48		3.11	

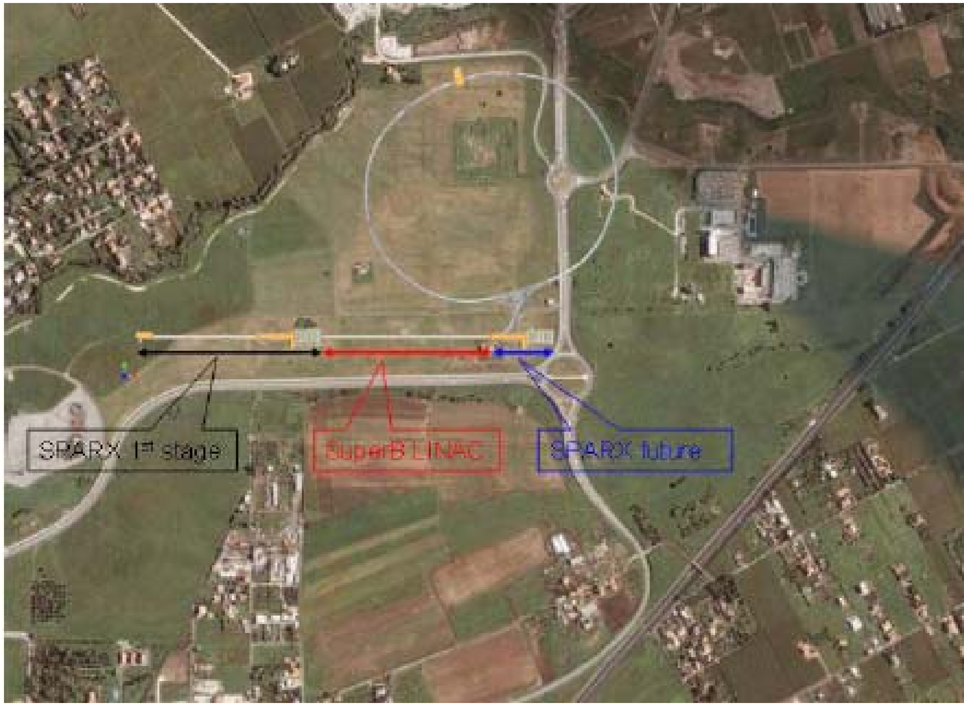
The SuperKEKB machine design now looks very similar to this design.

Different solutions to reach 10^{36}

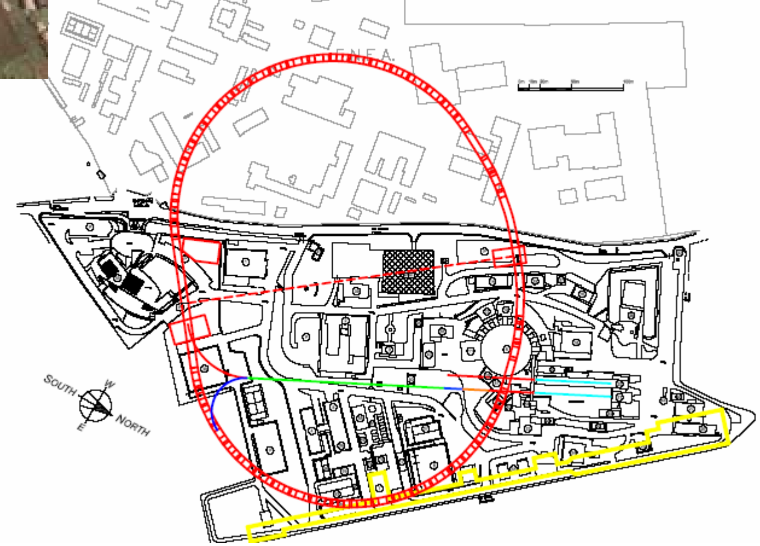
Baseline + other 2 options:
- **Lower y-emittance**
- **Higher currents (twice bunches)**

+ Solution for running at the Tau/charm
hold: L = 10^{35}

SITES



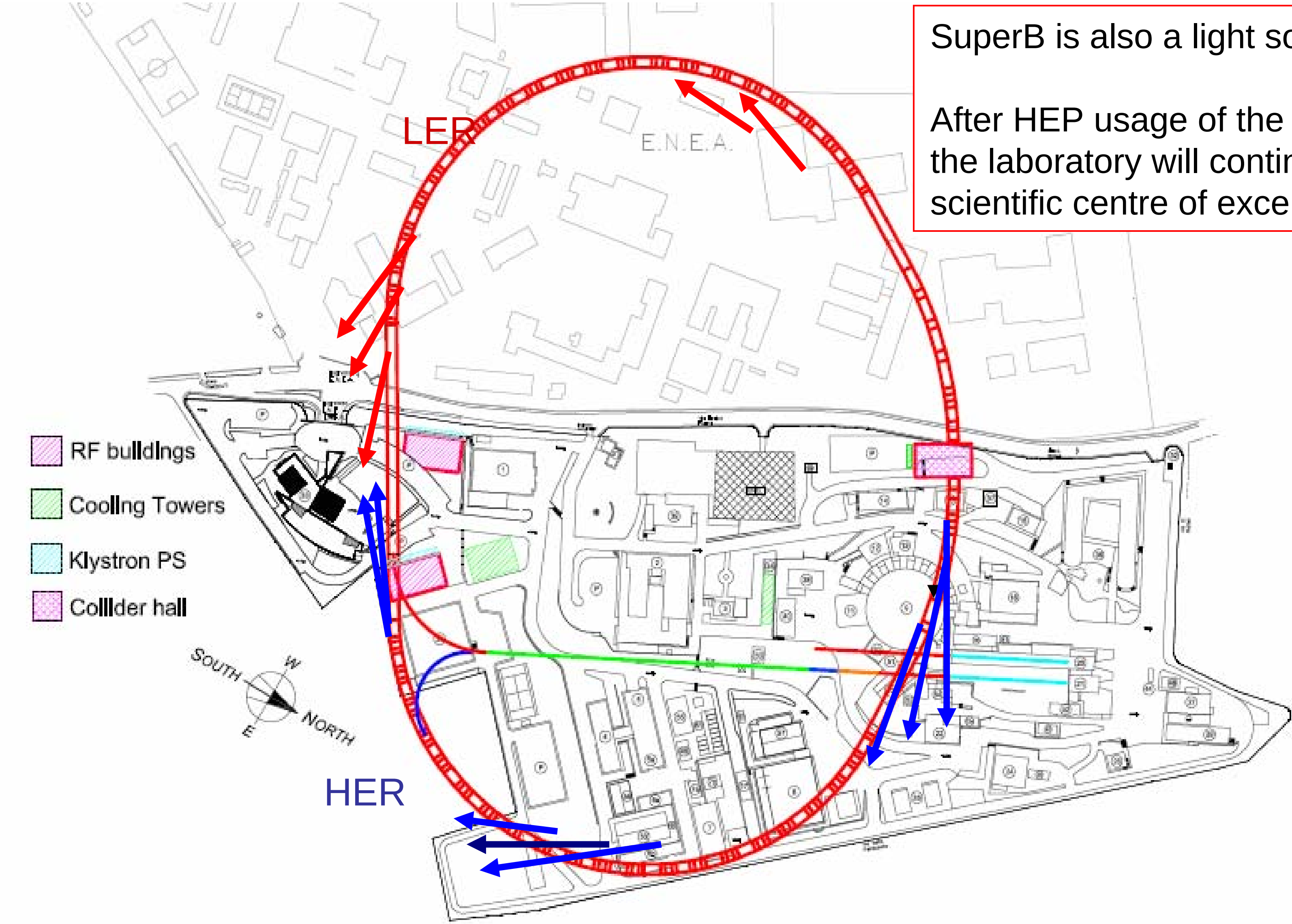
- Identified two suitable sites for the SuperB project.
- Conceptual design works in both places.
- Both sites are geologically stable.
- Will make site decision soon after project approval.



Frascati Site: Potential HER Synch Radiation Beam Lines

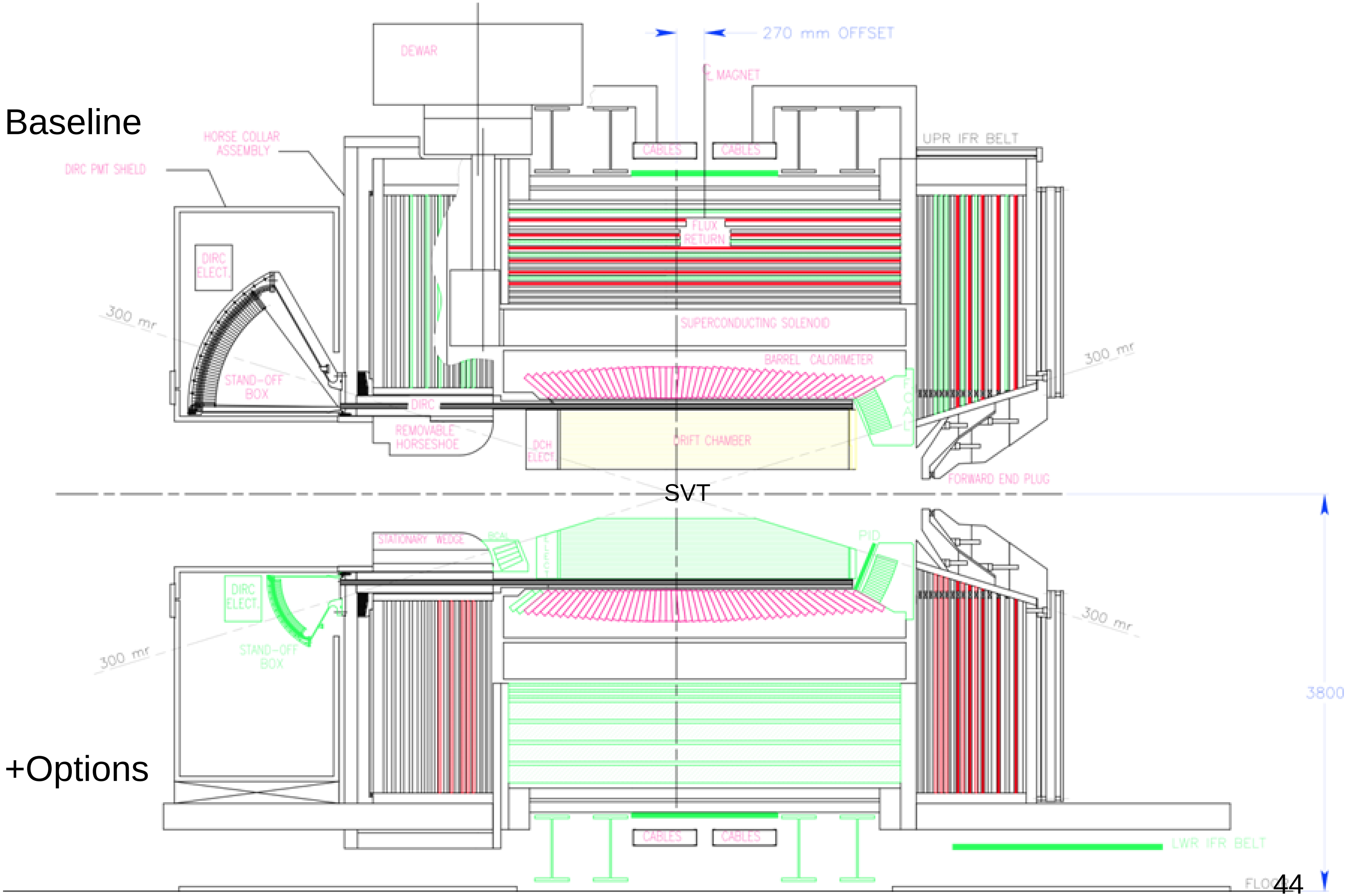
SuperB is also a light source.

After HEP usage of the machine the laboratory will continue to be a scientific centre of excellence.



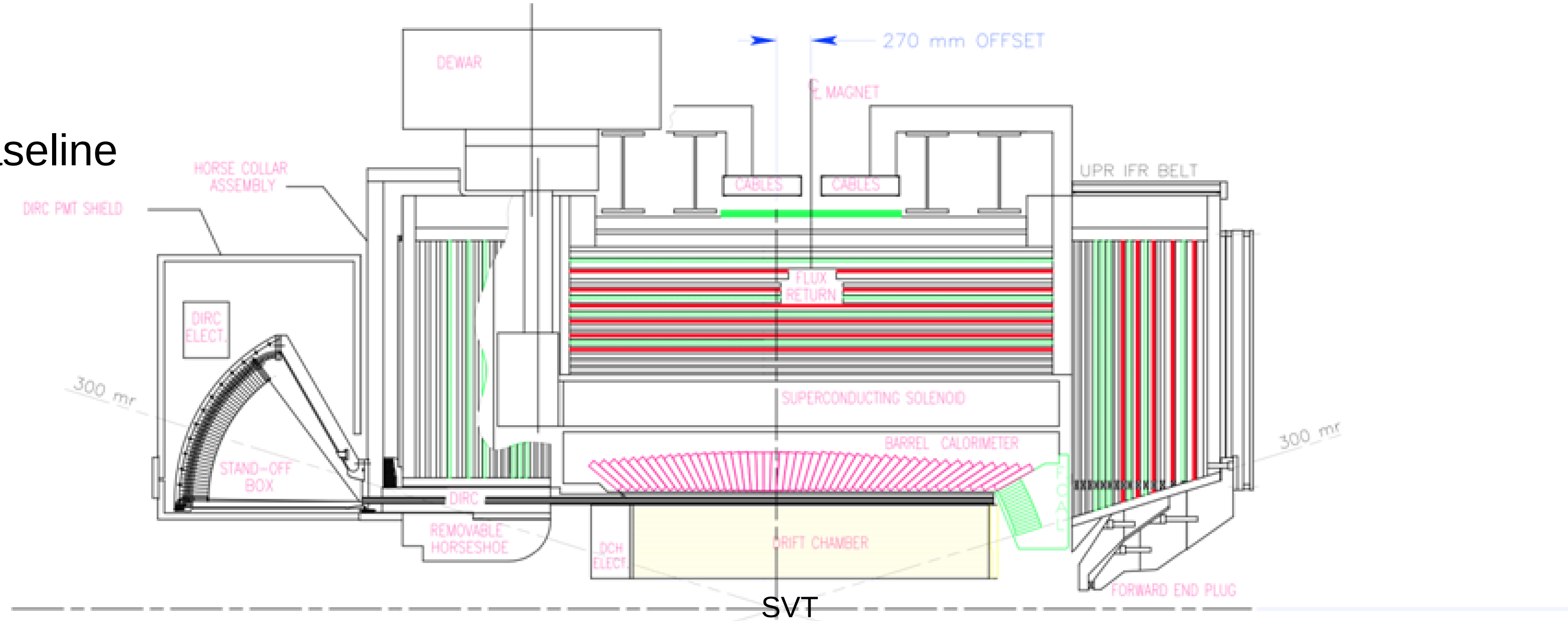
Detector Design

Baseline



+Options

Baseline



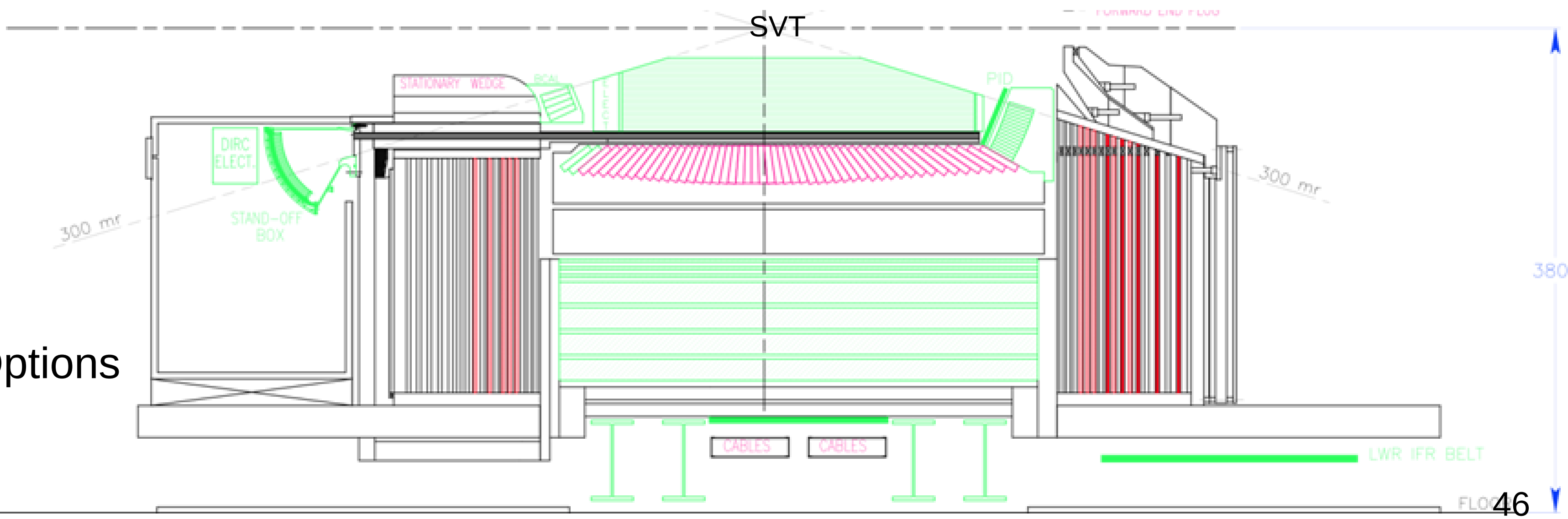
Some parts of BaBar will be re-used:

- DIRC Quartz Bars
- Calorimeter Barrel (crystals + mechanical support)
- Superconducting Solenoid
- Absorber material from IFR

This will lead to significant cost saving in building the detector.

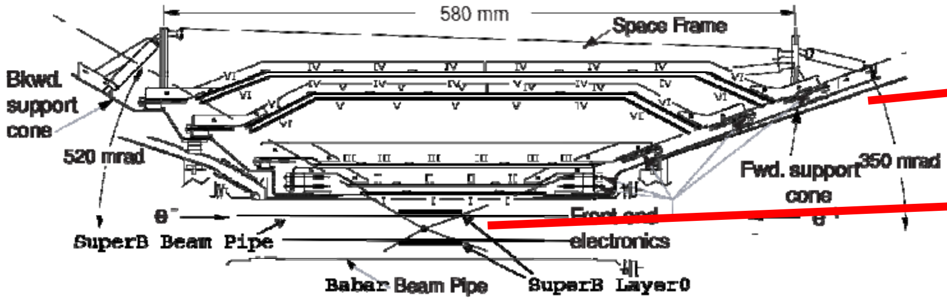
Options include:

- Several possible pixel technologies for the SVT (incl. an all pixel option).
- Forward PID.
- Backward calorimetry (primarily as a veto).
- \+ a number of other variants on baseline technology choices.



+Options

SVT



L1 – L5: Strips or Pixels

L0: Striplets or Pixels

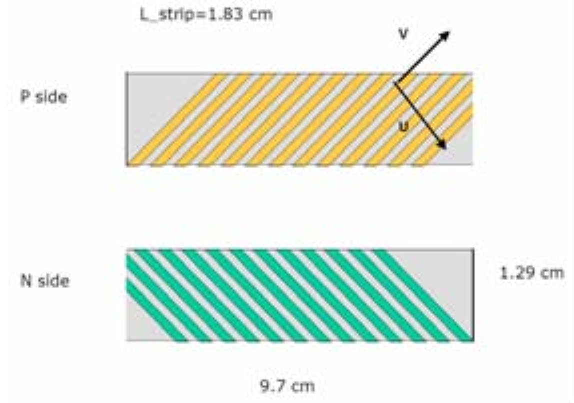
L0: Problem dominated by occupancy/flux:

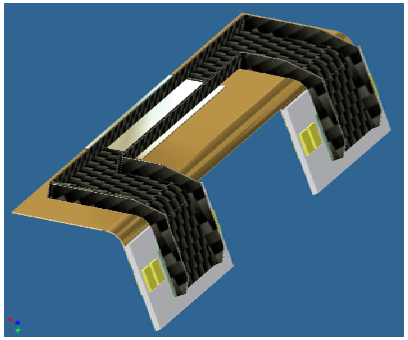
r = 1.6cm (striplets), with a length of 10cm

Designed for rate of 100MHz/cm^2.

Alternative solutions: INMAPS / DNW MAPS / Hybrid Pixels.

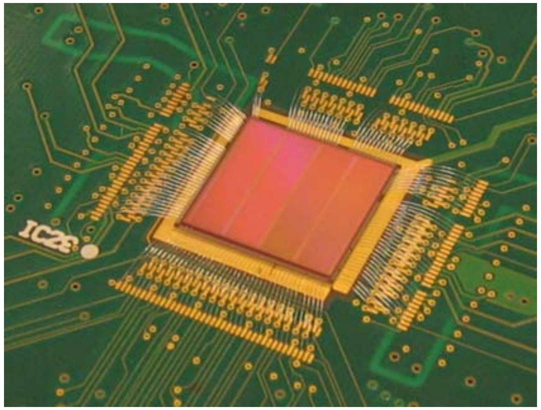
INMAPS are an option for outer layers.

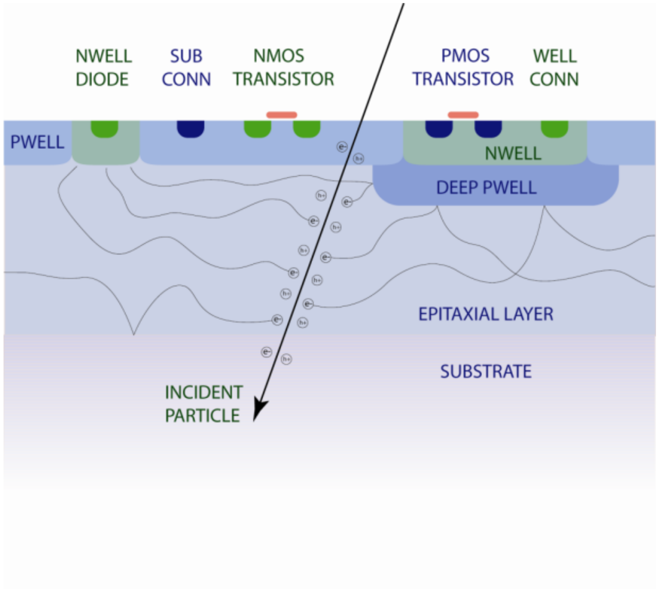




All Pixel SVT Concept

- 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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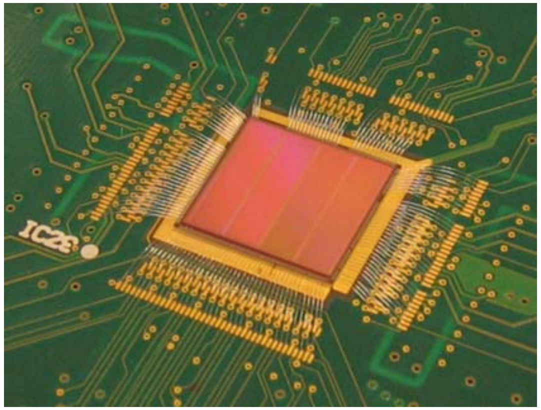
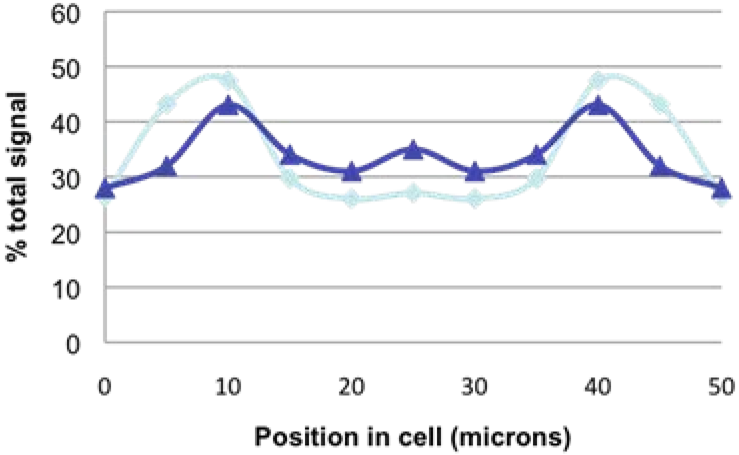
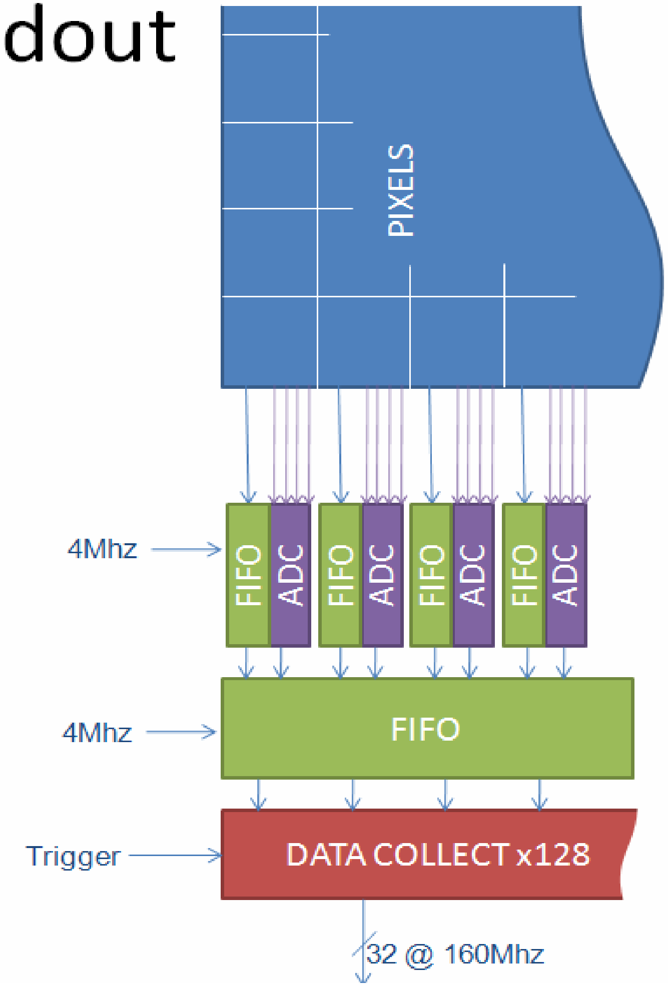


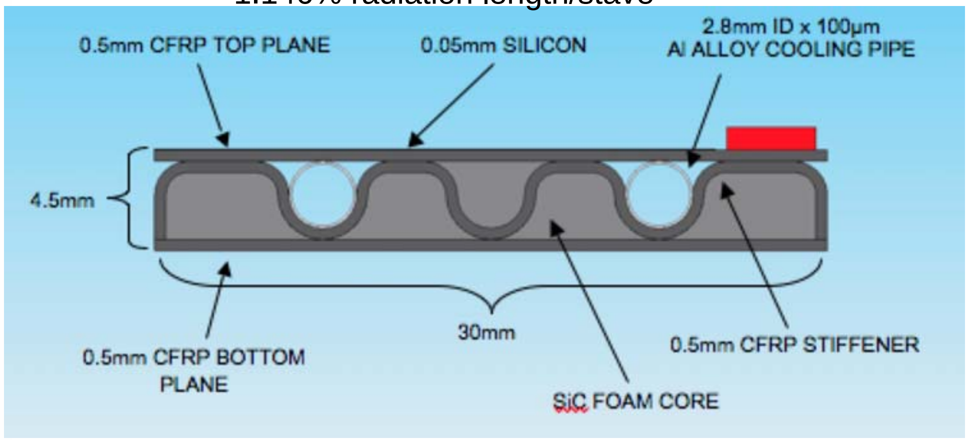


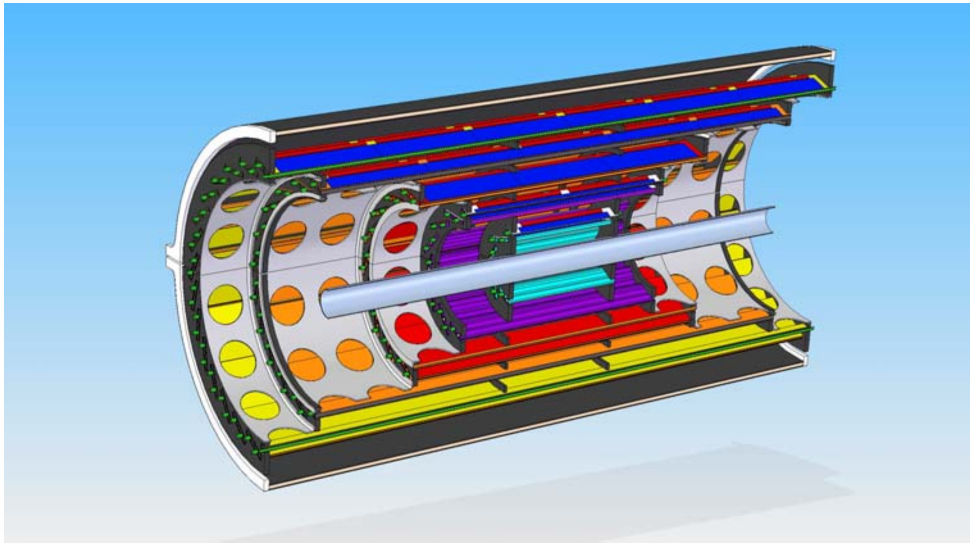
- 400Mpix CMOS Detector with stave approach:

1.146% radiation length/stave

Readout

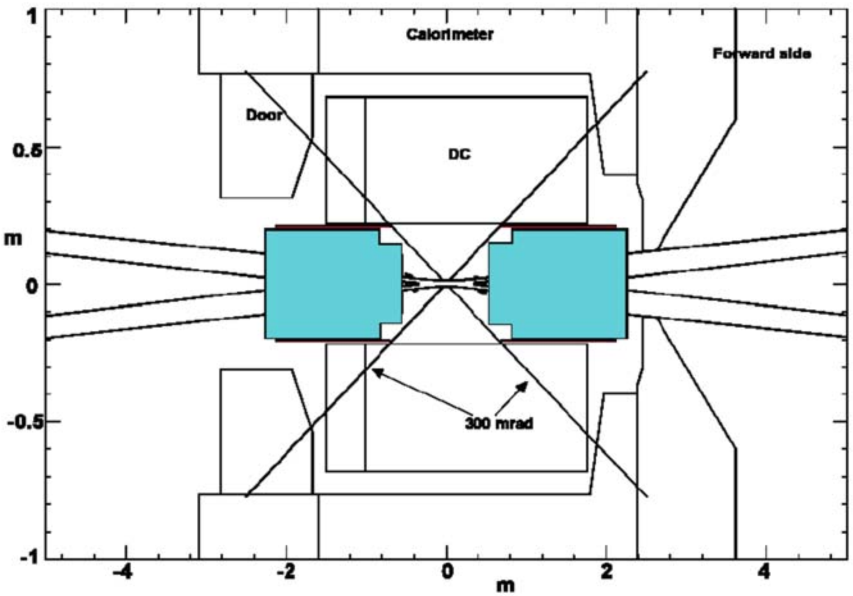


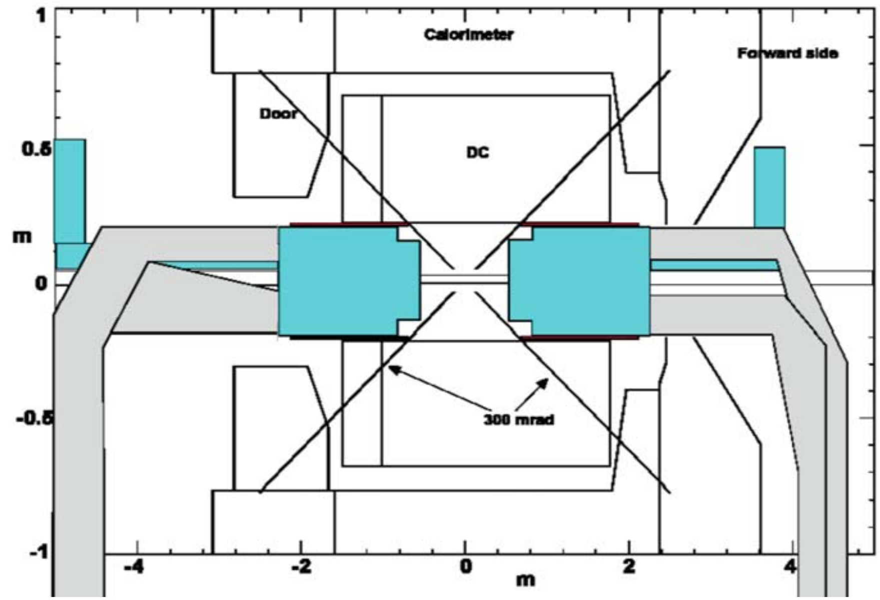




Interaction Region Layout

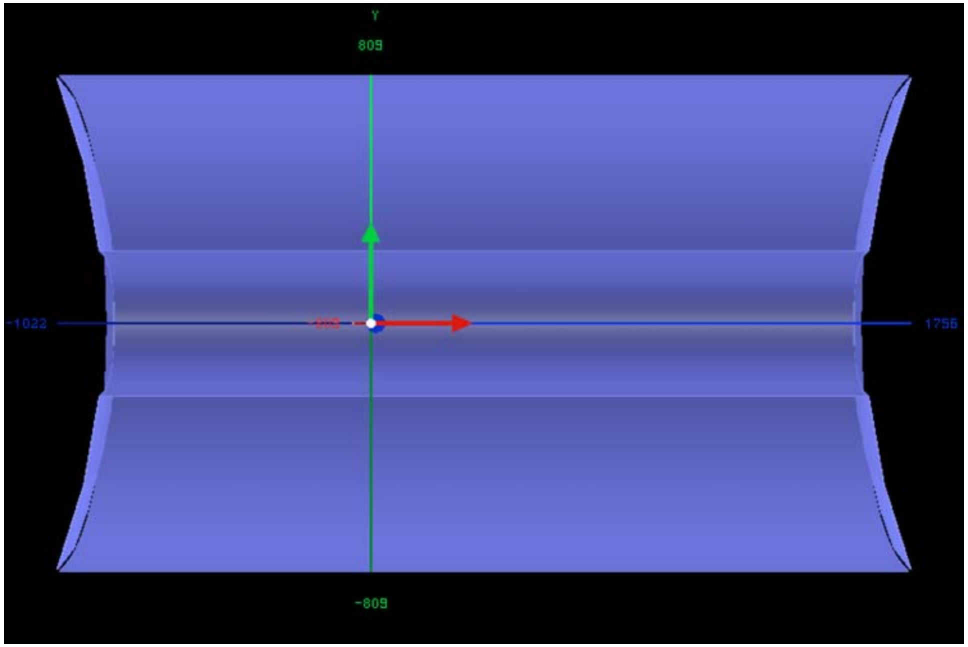
- Aim:
  - Access SVT/permanent magnets in the IR within a few days.
  - Central cryostat/magnet SVT supported off of the same object.
  - Modifications/repairs on the innermost detector/accelerator components will be relatively quick to perform.



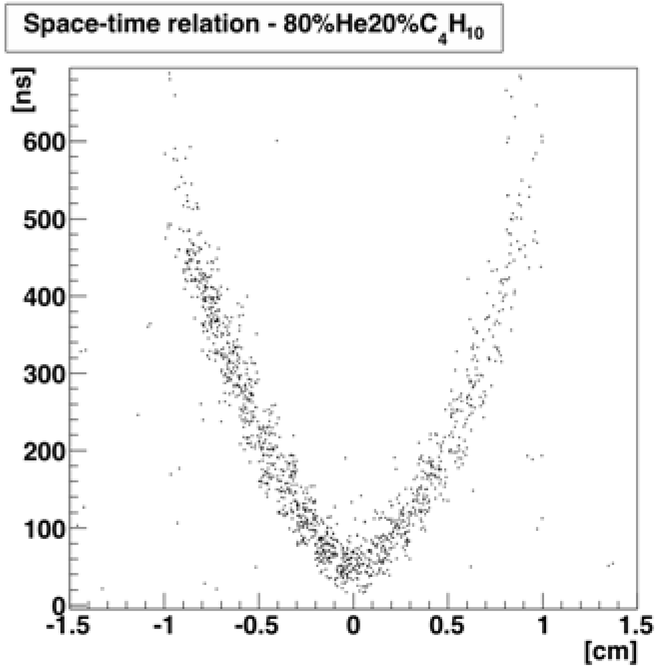


DCH

- Optimizing this subsystem from scratch: Disk/stepped endplates / cell size and geometry / gas mixture etc.



- Baseline shown (disk endplates).
- 10,000 cells.
- 3.5% av. occupancy (5% inner layers).
- Carbon Fibre endplates.

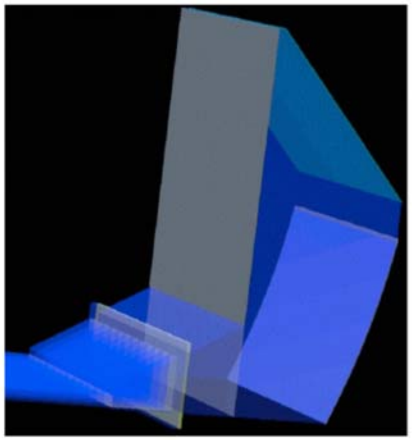


Studying response time vs. spatial resolution for various gas mixtures.

PID

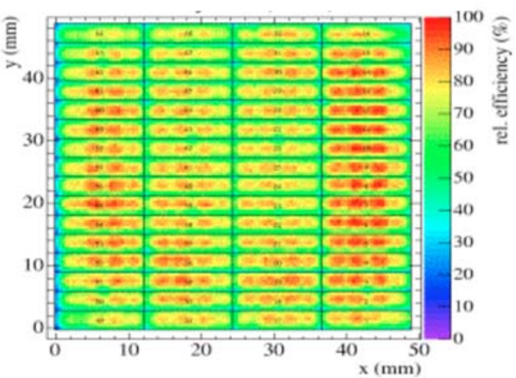
- Build on the DIRC concept: reuse the bars of fused silica that form the barrel of the DIRC.
- Instead of a water SOB, use a fused silica focussing block: FBLOCK.

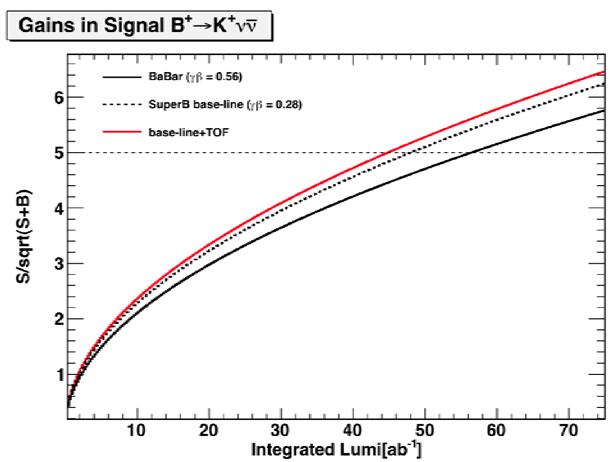
(b)



Many advantages over water based SOB design:
- Less sensitive to backgrounds: esp. neutrons.
- Can use timing to measure chromatic dispersion and improve performance.
- Modular.
- Less MaPMTs required for readout.
- No risk of water leaks into detector.
- Lower maintenance operation.

Example single photon response for a H-9500 MaPMT.

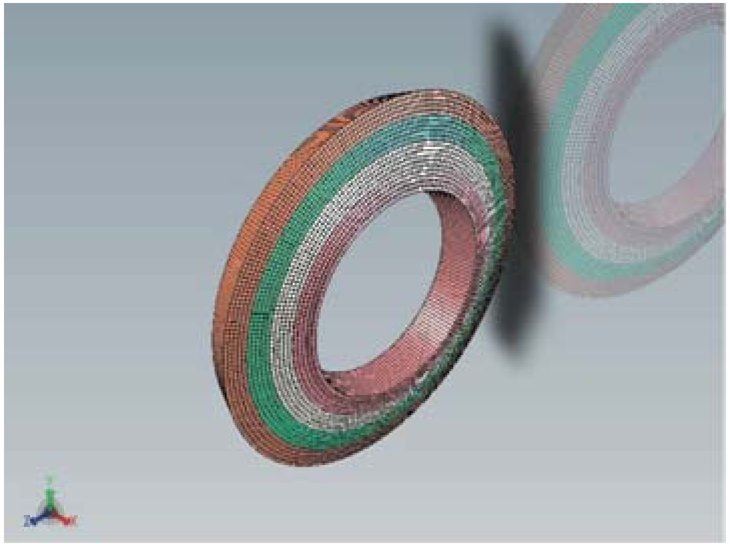




- Aerogel forward PID option could give additional performance benefits.
- Need to optimize vs. calorimeter performance.

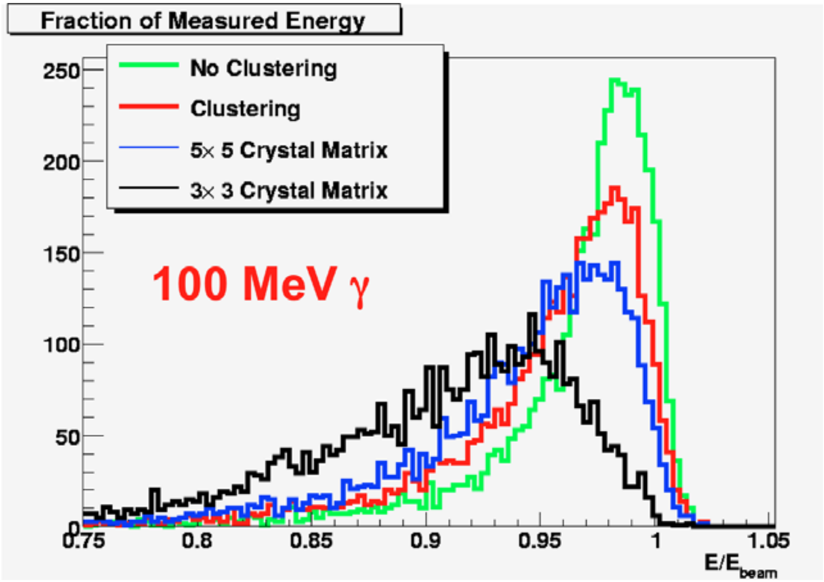
EMC

- BaBar's EMC barrel (with modern readout) is good enough for SuperB.
- Forward Calorimeter: LYSO based end cap.
- Backward Calorimeter: scintillator option under study.



- 4 Layers of 5 crystals.
- 4500 Crystals in total.
- 2.5cm^2 back face (tapers to front)
- PID diodes and APDs under study for signal readout.

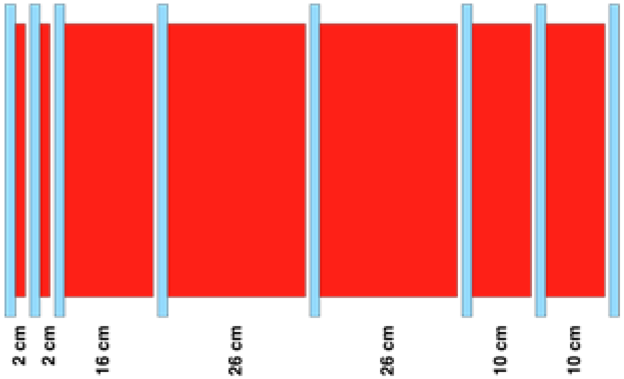
- Optimizing understanding/performance of the calorimeter using simulation and a series of test beams.



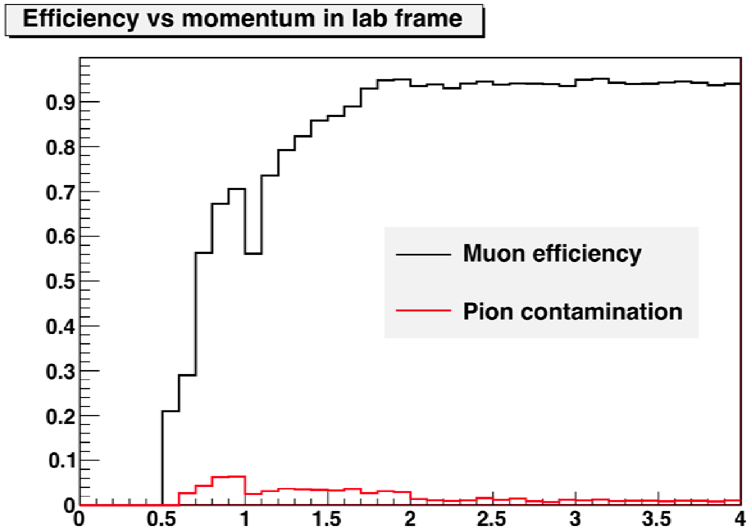
- Clustering uses γ > 1 MeV.

IFR

- Baseline: Scintillating WLS fibre based system.
  - RPC/LST technology used on BaBar not suitable for rates at SuperB.
- Detector is a sandwich of scintillator and iron (similar to BaBar).
- BaBar's 5 X/X0 non optimal for μ ID; so SuperB will have more material.



- Initial studies indicative of good performance achievable at SuperB.



Improvements in IFR detection capability will impact widely upon the physics programme:

- Decays with K_L
- LFV studies with μ final states
- LU tests.

Status of SuperB

- 2007: Conceptual Design Report
- 2009: Physics Workshop Proceedings
- 2010 (soon): White papers on Det/Acc/Phys.

- Current state of all aspects of the project.
  – Accelerator concept has been in good shape for a long time now.
  – Detector concept is well understood.
  – Physics interplay and sensitivity studies using SuperB Monte Carlo are continually being updated.
  – Expect funding decision soon (this year).

- Meanwhile:
  – Formalising R&D on TDR with MOUs.
  – Expect TDR by the end of the year.

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- Me...
  - Fo...alising R&D on TDR with MOUs.
  - Expect TDR by the end of the year.

Still plenty of room for new collaborators to contribute.

A few words concerning SuperB & Belle-II

- Similar concept: Belle-II has:
  - Target data sample: $50ab^{-1}$. ($L \sim 0.8 \times 10^{36}$)
  - No polarisation: Limits physics case in some areas.
  - No plan (yet) to run at τ/charm threshold.
  - Now converging on the "Italian Scheme" for the accelerator.
    - Community agrees that this is the way to build the machine!

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	13 / 8.4 pm
L	$75ab^{-1}$	$50ab^{-1}$
e^- Polarisation	80%	none
run at $\psi(3770)$	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.

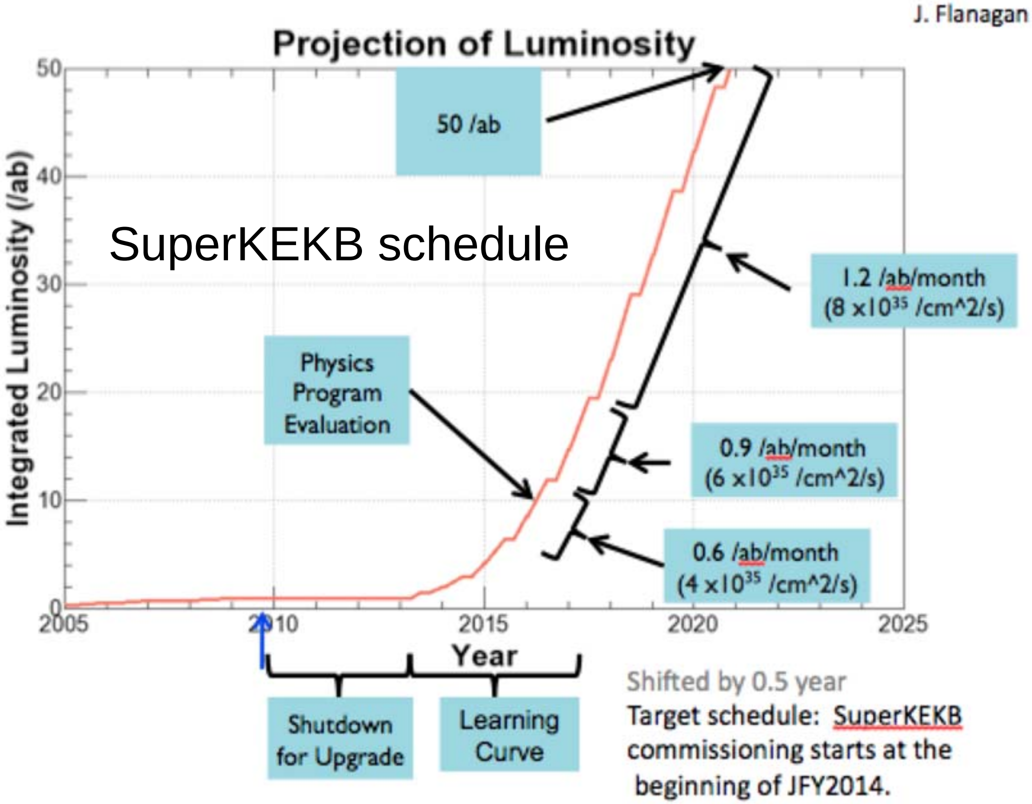
A few words concerning SuperB & Belle-II

SuperB

The TDR phase of the project has been approved (6MEuros/year)
Aim for project approval (during this phase) by 2010

SuperKEKB

KEK authorized to use a part of its operating money to start building a damping ring. Equivalent usage of « KEKB upgrade » or « SuperKEKB project »
Aim for approval in 2010.



- + 6 months delay not included in this plot.
- Belle-II and SuperB will integrate nominal data sample on the same timescale.
- This will coincide with major LHC upgrades.
- SuperB/Belle-II have a perfect timescale to optimize synergy with SLHC programme.

A few words concerning SuperB & Belle-II

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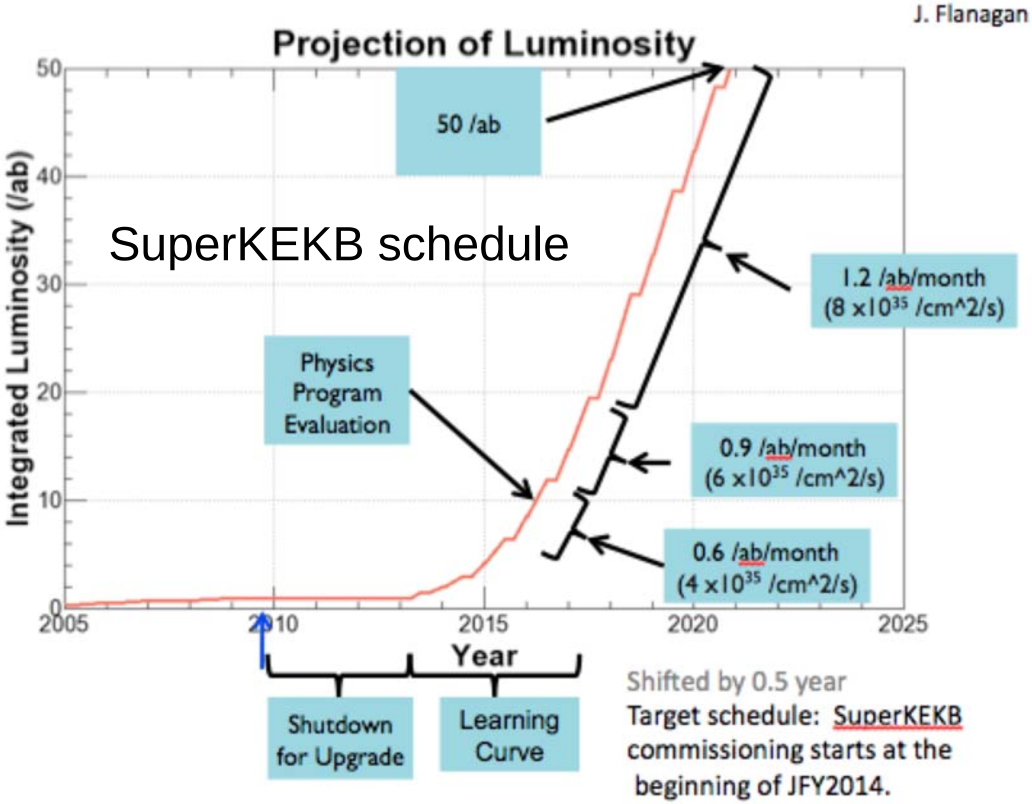

- SuperB will integrate 15ab^{-1} per year during nominal running.
- SuperB should have 75ab^{-1} by 2020.
- The B Factories were the most successful experiments in history. ~1 paper/wk in a peer reviewed over 4 years.
- It would be good if we could repeat this with a new generation of experiments.

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 New Physics.
  - Don't know the relevant New Physics energy scale (yet).
    - The LHC may, or may not elucidate this issue.
  - Don't know if the New Physics 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.
  - ATLAS/CMS may help with some ultra-rare B decays.
  - Some New Physics 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.

Extra Material

What about Lattice?

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_+,…	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