Status of the SuperB project

Matteo Rama
Laboratori Nazionali di Frascati

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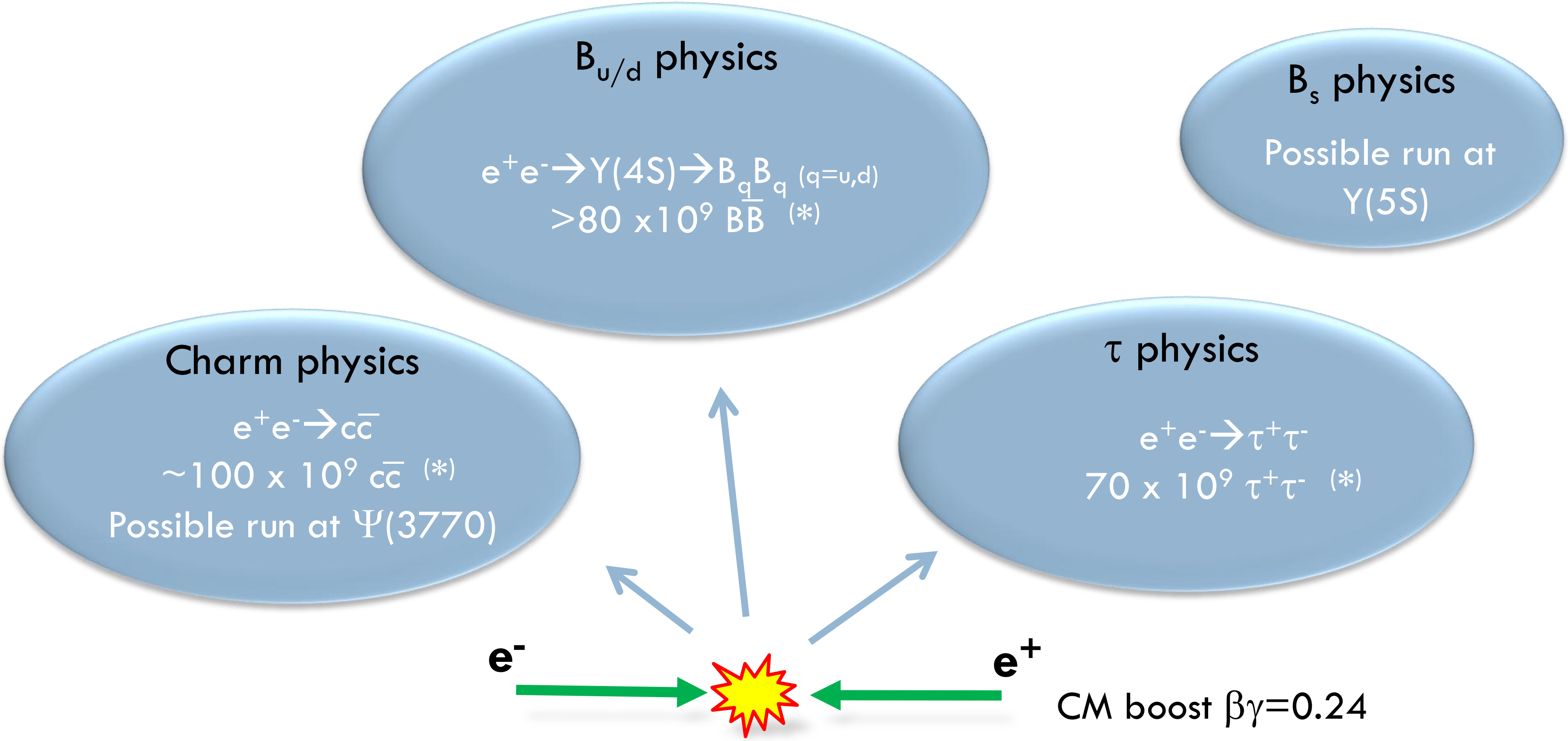
what is SuperB

- The SuperB project is a next-generation e^+e^- flavor factory based on novel accelerator concepts, aiming at reaching a baseline luminosity of $10^{36}cm^{-2}s^{-1}$
  - Luminosity 50-80 times larger than current B-factories peak records
  - mainly operating at the Y(4S) resonance, it can run at energies between Ψ(3770) and Y(5S)
  - longitudinal polarization of electron beam (~80%)
  - the candidate site is in Rome area, Italy. Site decided after approval
- B, charm, tau factory in clean environment
  - allows measurements difficult or not possible at hadronic colliders (final states with neutrals/neutrinos)
- Main physics goal: search for effects beyond the SM and constrain the flavor sector of New Physics

the data sample



$B_{u/d}$ physics

$e^+e^- \rightarrow \Upsilon(4S) \rightarrow B_q\bar{B}_q$ (q=u,d)
$>80 \times 10^9$ $B\bar{B}$ (*)

B_s physics

Possible run at $\Upsilon(5S)$

Charm physics

$e^+e^- \rightarrow c\bar{c}$
$\sim 100 \times 10^9$ $c\bar{c}$ (*)
Possible run at $\Psi(3770)$

τ physics

$e^+e^- \rightarrow \tau^+\tau^-$
70×10^9 $\tau^+\tau^-$ (*)

CM boost $\beta\gamma=0.24$

$$L = 1\times10^{36}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$$

$^{(*)}$ $75\,ab^{-1}$ in 5 years of baseline L

the role of SuperB in the LHC era

- New Physics (NP) is expected beyond the Standard Model
  - at what scale Λ? 0.5,1, 10…10^{16} TeV?

- Two scenarios:
  - LHC finds New Physics (Λ is known)
    - SuperB can study the flavour structure of NP, measure the flavour couplings, search for even heavier states
  - The NP scale is above the LHC reach
    - explore the NP scale beyond the LHC reach (up to $\Lambda \sim 10$TeV or more), look for indirect NP signals, understand where they may come from

$$\frac{|\delta_{bq}|}{\Lambda_{eff}}$$

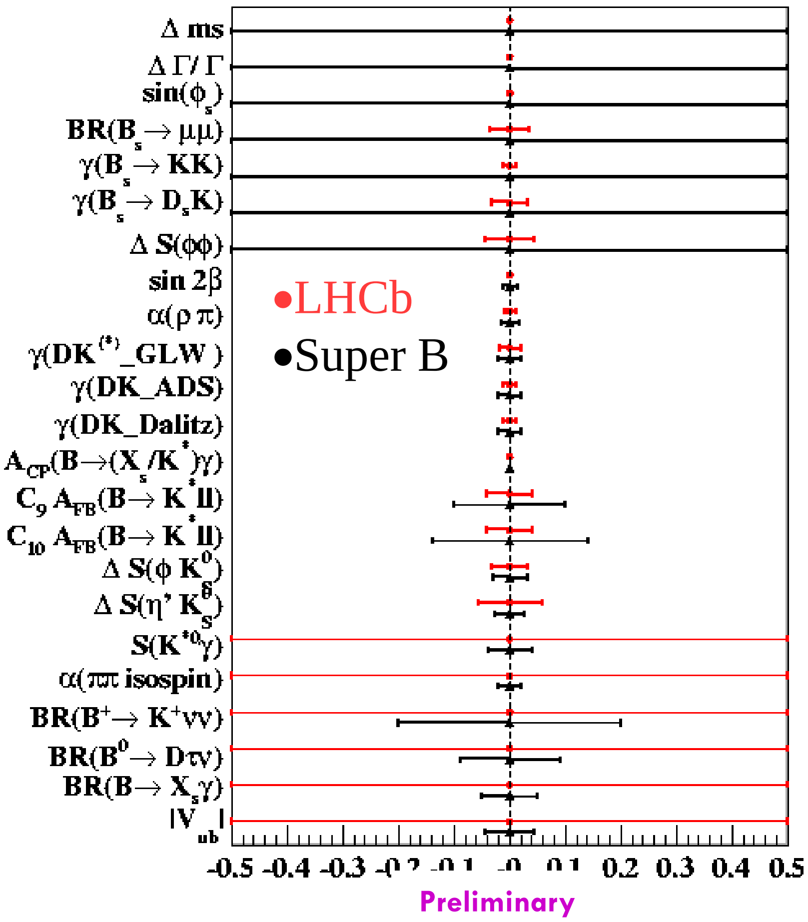
- *Complementary* to LHC
  - Many rare decay final states are only accessible at an e^+e^- machine
  - Sensitive to off-diagonal terms in the squark mixing matrix.
  - Test *CP*, *CPT*, and Lepton Flavour Violation (LFV) in τ decay, τ anomalous magnetic moment.
  - Search for *CP* (and *CPT*) violation in *D* decays

Super Flavour factory and Super LHCb

Sensitivity Comparison

LHCb 100 fb^{-1} vs Super-B factory 50 ab^{-1}

comparison from F.Muheim

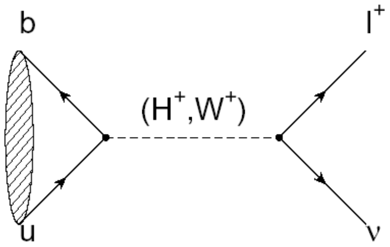


B$_s$ time dependent analysis only accessible to LHCb

Common

No neutrals, ν,
only accessible to SuperB

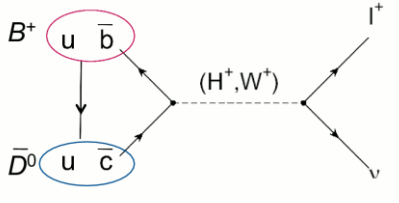
constraints on charged Higgs from B→τν



SUSY Higgs contribution in 2HDM

$$r_H \equiv \frac{\mathcal{B}_{SM+NP}}{\mathcal{B}_{SM}} = \left(1 - \frac{m_B^2}{m_H^2}\tan^2\beta\right)^2$$

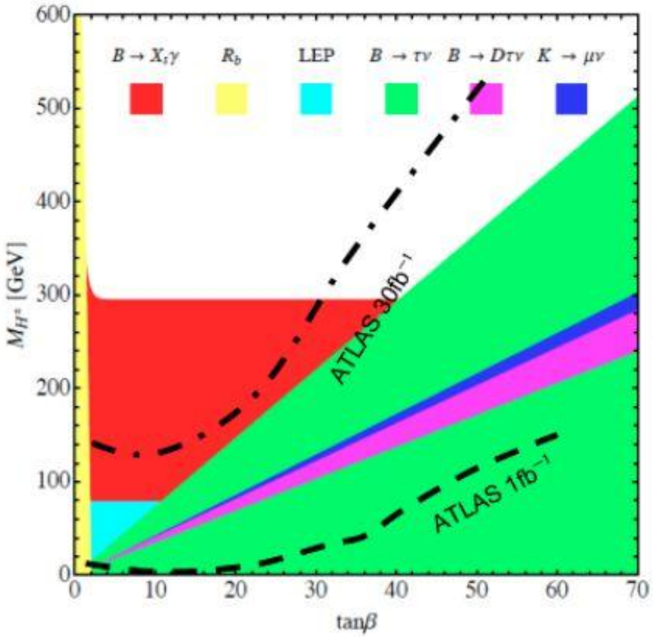
analogous constraint from B→Dτν



95% CL exclusion regions in the m(H$^+$)-tanβ

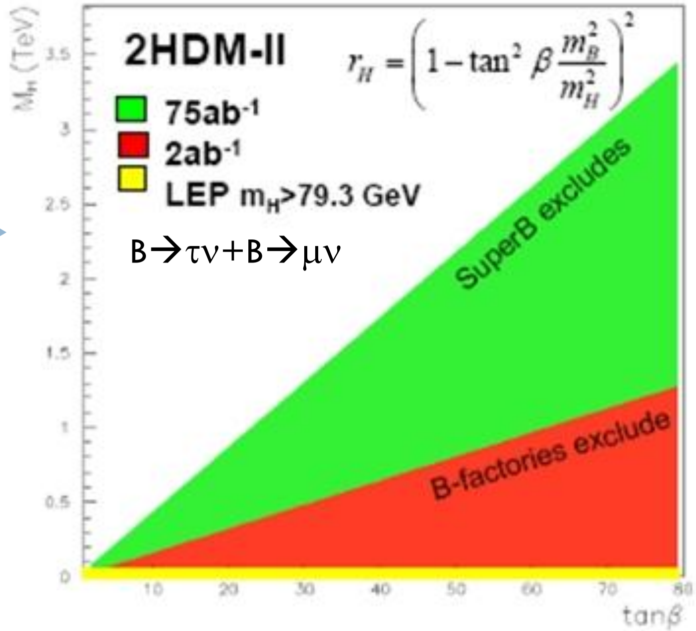
U. Haisch, arXiv:0805.2141

ATLAS coll, arXiv:0901.0512



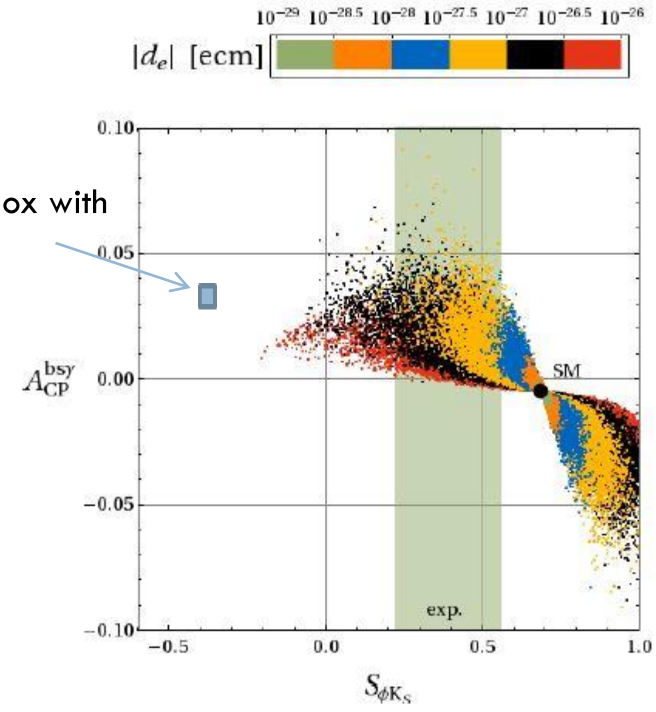
note the different scale in y

SuperB CDR, 0709.0451



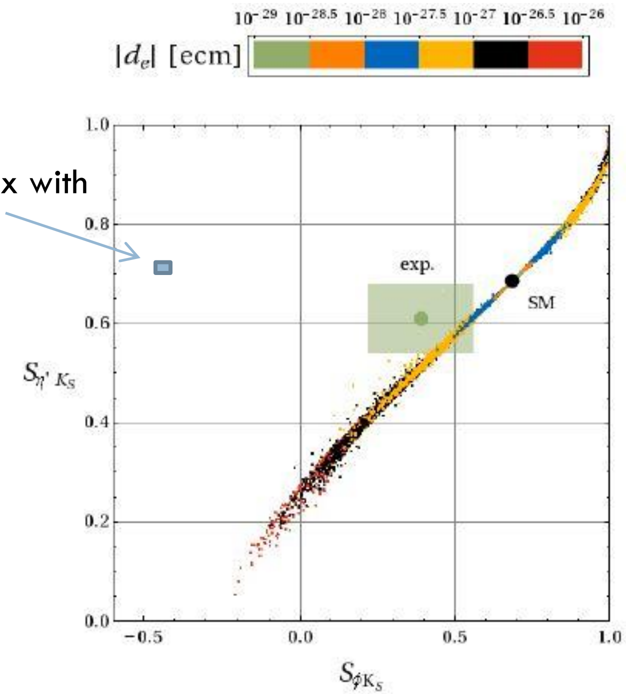
correlation of NP effects in flavor blind MSSM

flavor blind MSSM: CKM matrix is the only source of flavor violation



error box with 75ab^{-1}

$$|d_e| = (6.9 \pm 7.4) 10^{-28} \text{ e cm}$$



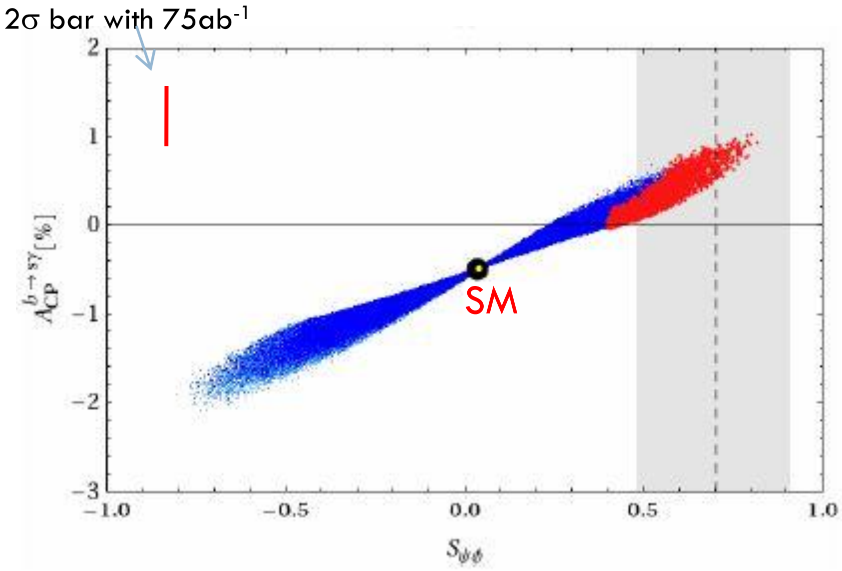
error box with 75ab^{-1}

Altmannshofer, Buras, Paradisi
Phys. LettB669, 239 (2008), 0808.0707

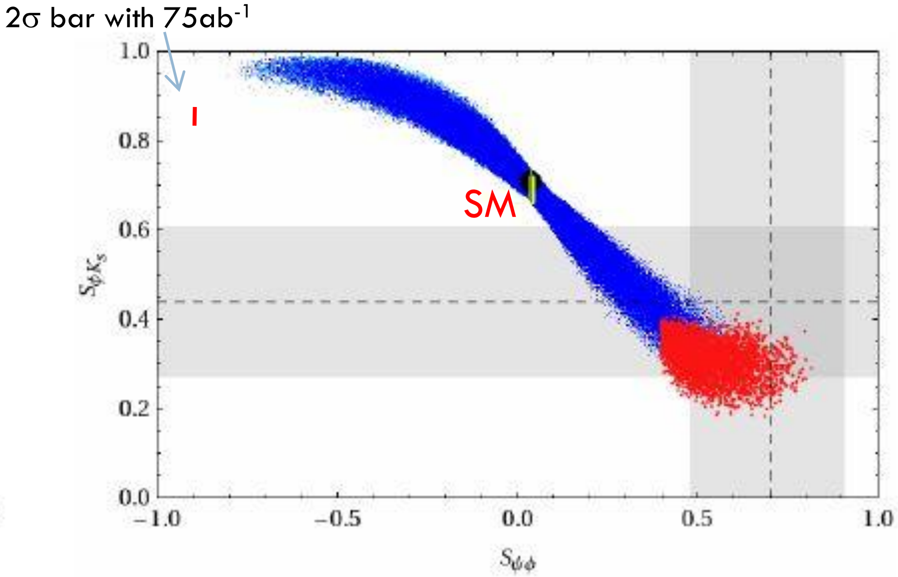
a correlated analysis of the above asymmetries at SuperB is a powerful tool to probe the FBMSSM scenario

Pattern of flavour violation in SM extended to 4 quark and lepton generations

SM extended to 4th generation of quarks and leptons (an addition of 3 angles+2 CP phases)



2σ bar with 75ab^{-1}



2σ bar with 75ab^{-1}

A.J. Buras et al, arXiv:1002.2126

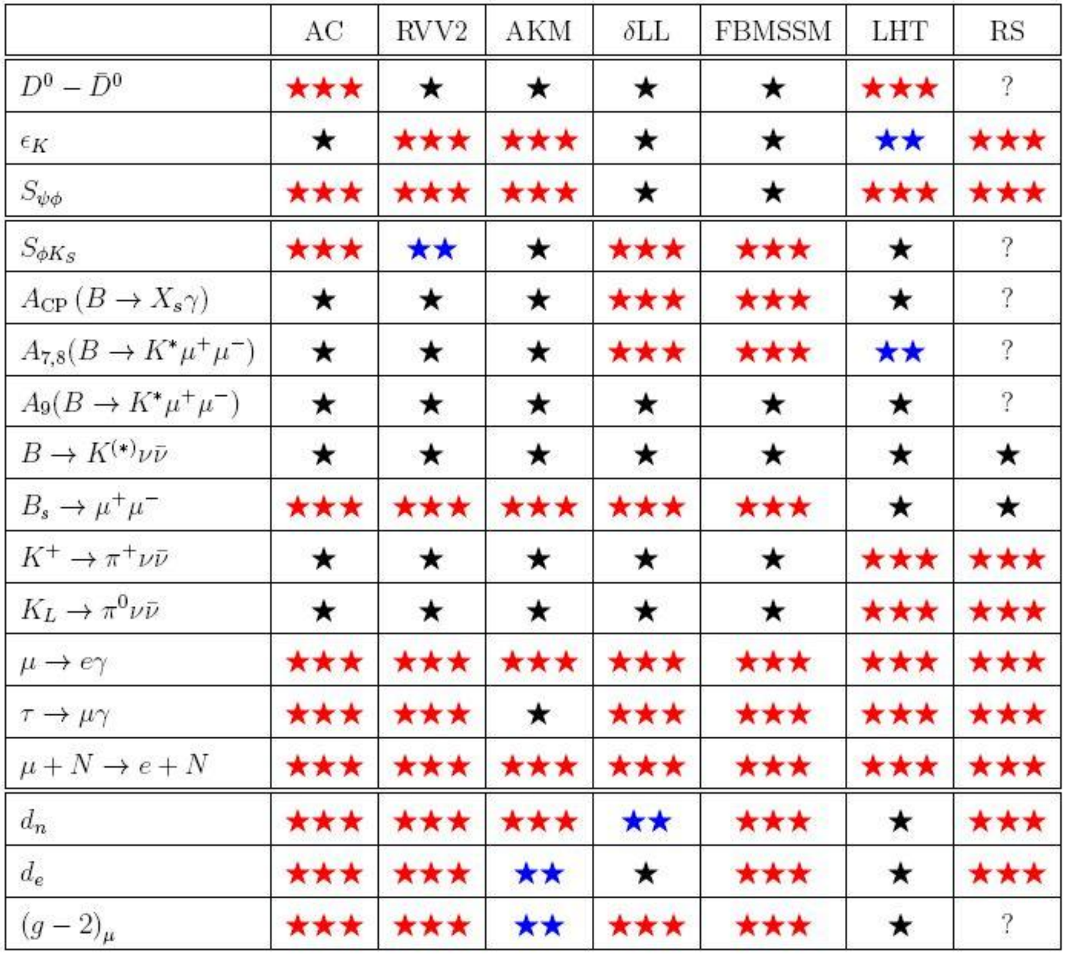
A. Soni et al, arXiv:1002.0595

Similar pattern of $A_{CP}(b\rightarrow s\gamma)$ vs $S_{\phi K_s}$ as in the FBMSSN scenario

$A_{CP}(b\rightarrow s\gamma)$ remains small also in SM4, but the sign flip for large $S_{\psi\phi}$ could help to distinguish SM4 from SM

Flavor physics to probe (non-)SUSY models

The pattern of flavor violation in SM extensions differs from model to model



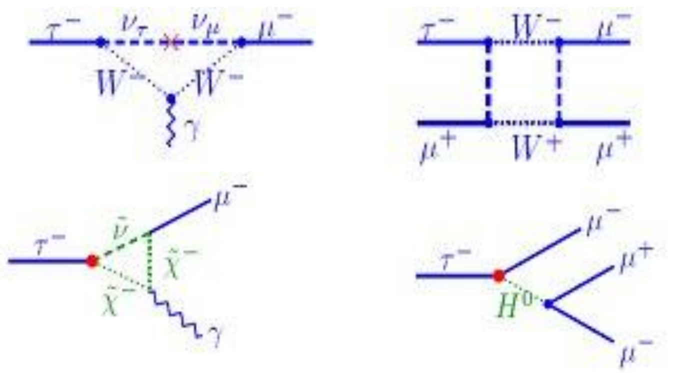
	AC	RVV2	AKM	δLL	FBMSSM	LHT	RS
→ $D^0 - \bar{D}^0$	★★★	★	★	★	★	★★★	?
ϵ_K	★	★★★	★★★	★	★	★★	★★★
$S_{\psi\phi}$	★★★	★★★	★★★	★	★	★★★	★★★
→ $S_{\phi K_S}$	★★★	★★	★	★★★	★★★	★	?
→ $A_{\rm CP}\,(B \to X_s\gamma)$	★	★	★	★★★	★★★	★	?
→ $A_{7,8}(B \to K^*\mu^+\mu^-)$	★	★	★	★★★	★★★	★★	?
→ $A_9(B \to K^*\mu^+\mu^-)$	★	★	★	★	★	★	?
→ $B \to K^{(*)}\nu\bar{\nu}$	★	★	★	★	★	★	★
$B_s \to \mu^+\mu^-$	★★★	★★★	★★★	★★★	★★★	★	★
$K^+ \to \pi^+\nu\bar{\nu}$	★	★	★	★	★	★★★	★★★
$K_L \to \pi^0\nu\bar{\nu}$	★	★	★	★	★	★★★	★★★
$\mu \to e\gamma$	★★★	★★★	★★★	★★★	★★★	★★★	★★★
→ $\tau \to \mu\gamma$	★★★	★★★	★	★★★	★★★	★★★	★★★
$\mu + N \to e + N$	★★★	★★★	★★★	★★★	★★★	★★★	★★★
d_n	★★★	★★★	★★★	★★	★★★	★	★★★
d_e	★★★	★★★	★★	★	★★★	★	★★★
$(g-2)_\mu$	★★★	★★★	★★	★★★	★★★	★	?

Altmannshofer, Buras, Gori, Paradisi, Straub
Nucl. Phys. B830, 17 (2010), 0909.1333

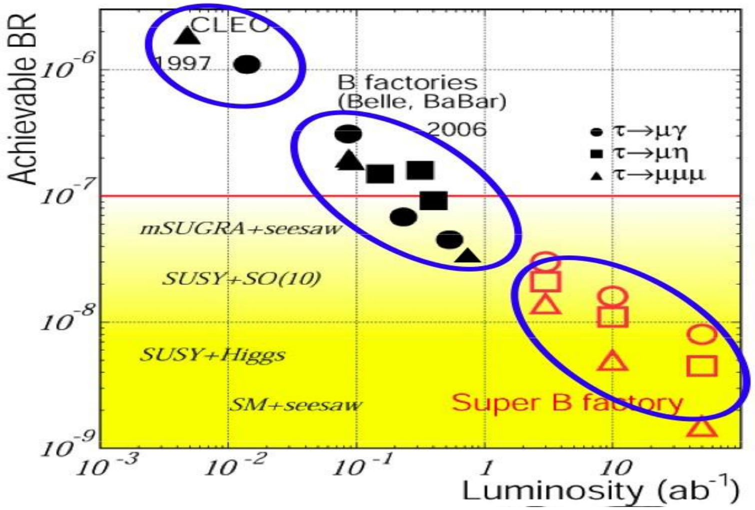
★★★ large effects
★★ visible but small effects
★ negligible effects
→ precision measurement at SuperB

Lepton flavor violation in τ decays

$\tau \rightarrow \mu\gamma$ $\tau \rightarrow \ell\ell\ell$



Process	Expected 90% CL upper limit	3σ evidence reach	PDG
$\mathcal{B}(\tau \rightarrow \mu\gamma)$	2.1×10^{-9}	4.8×10^{-9}	$<4.5 \times 10^{-8}$
$\mathcal{B}(\tau \rightarrow e\gamma)$	2.7×10^{-9}	6.0×10^{-9}	$<1.1 \times 10^{-7}$
$\mathcal{B}(\tau \rightarrow \ell\ell\ell)$	$2.3\text{–}8.3 \times 10^{-10}$	$1.2\text{–}4.0 \times 10^{-9}$	$<2.0\text{-}3.6 \times 10^{-8}$



upper bound on LFV decay BF in
LHT model with NP scale f=500GeV
hep-ph/0206021

decay	$f = 500$ GeV
$\tau \rightarrow e\gamma$	$1 \cdot 10^{-8}$
$\tau \rightarrow \mu\gamma$	$2 \cdot 10^{-8}$
$\tau^- \rightarrow e^- e^+ e^-$	$2 \cdot 10^{-8}$
$\tau^- \rightarrow \mu^- \mu^+ \mu^-$	$3 \cdot 10^{-8}$

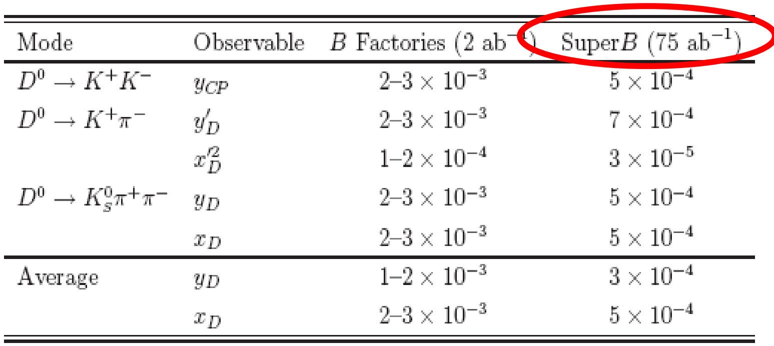
further improvement with polarized e$^-$ beam (60-80%) under study:

- background suppression
- helicity structure of LFV coupling

CPV in charm decays

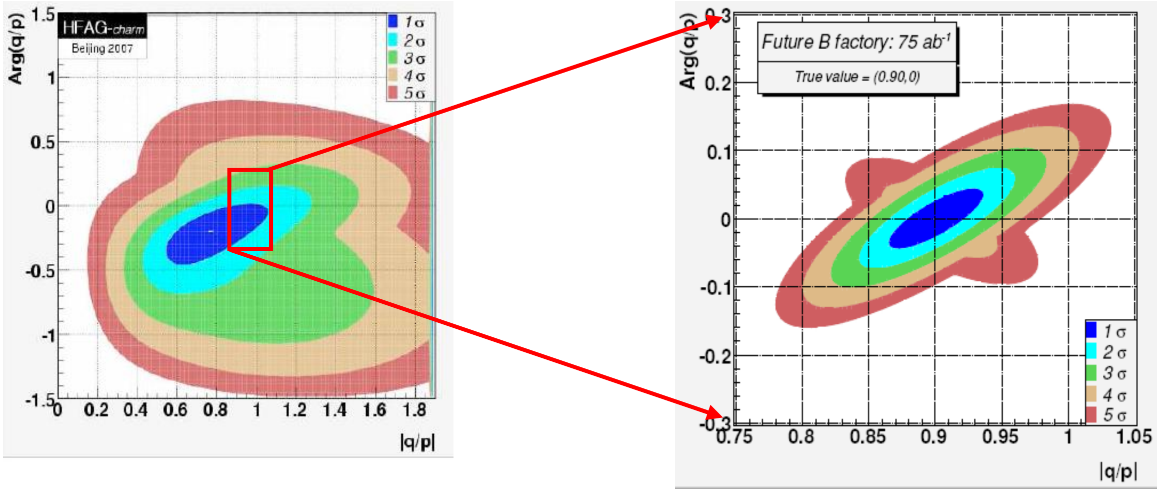
- ☐ D mixing observed by BaBar, CDF and Belle
- ☐ Size of charm sample at SuperB reduces errors by an order of magnitude
- ☐ Plus, possibility of running @ Ψ(3S):

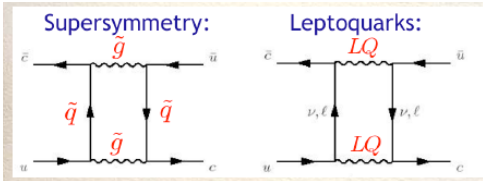
in 4 months ~0.3ab^{-1} → 1000x CLEO-c, 10x BESIII ‼

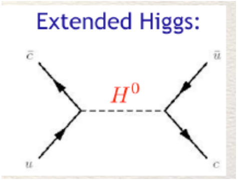


Mode	Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab^{-1})
$D^0 \to K^+K^-$	y_{CP}	2–3×10^{-3}	5×10^{-4}
$D^0 \to K^+\pi^-$	y'_D	2–3×10^{-3}	7×10^{-4}
	x'^2_D	1–2×10^{-4}	3×10^{-5}
$D^0 \to K^0_S\pi^+\pi^-$	y_D	2–3×10^{-3}	5×10^{-4}
	x_D	2–3×10^{-3}	5×10^{-4}
Average	y_D	1–2×10^{-3}	3×10^{-4}
	x_D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

* Measurement of D oscillations opens new window to search of CPV in charm. Observation of CPV would provide unequivocal NP signals

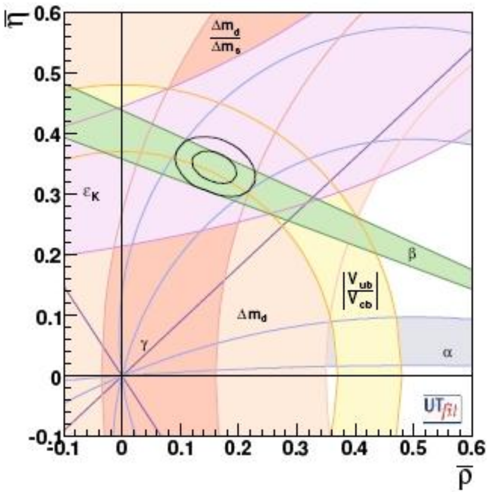




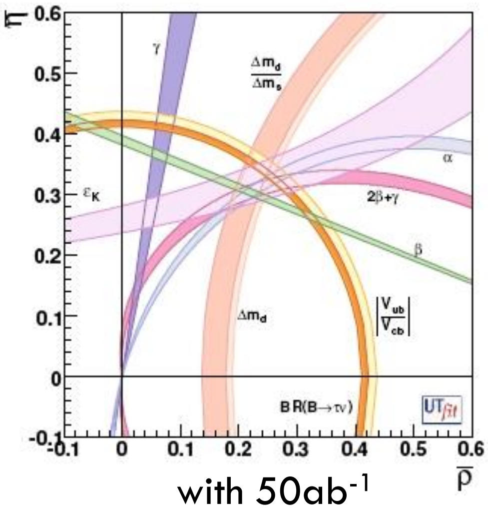


Precise measurement of the CKM matrix

Precise measurement of CKM matrix elements is the prelude of the SuperB physics program

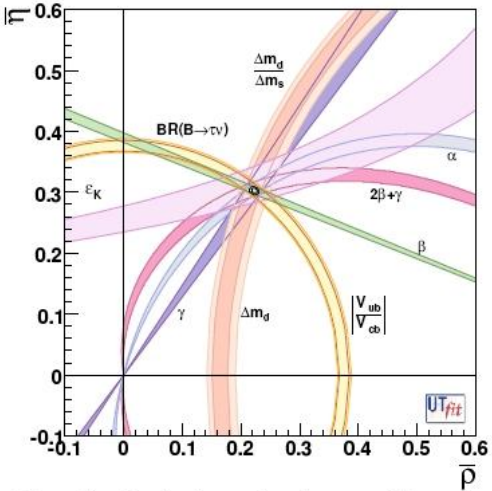


ρ–η plane today



with $50ab^{-1}$

(+ lattice improvements)

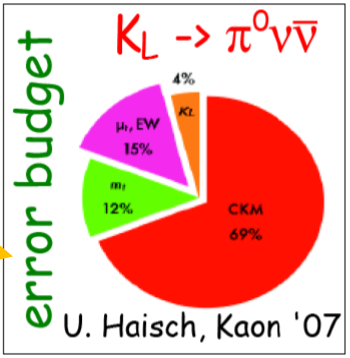


$50ab^{-1}$, if SM holds

Parameter	SM Fit today	SM Fit at Super*B*
$\bar{\rho}$	0.163 ± 0.028	± 0.0028
$\bar{\eta}$	0.344 ± 0.016	± 0.0024
α (°)	92.7 ± 4.2	± 0.45
β (°)	22.2 ± 0.9	± 0.17
γ (°)	64.6 ± 4.2	± 0.38

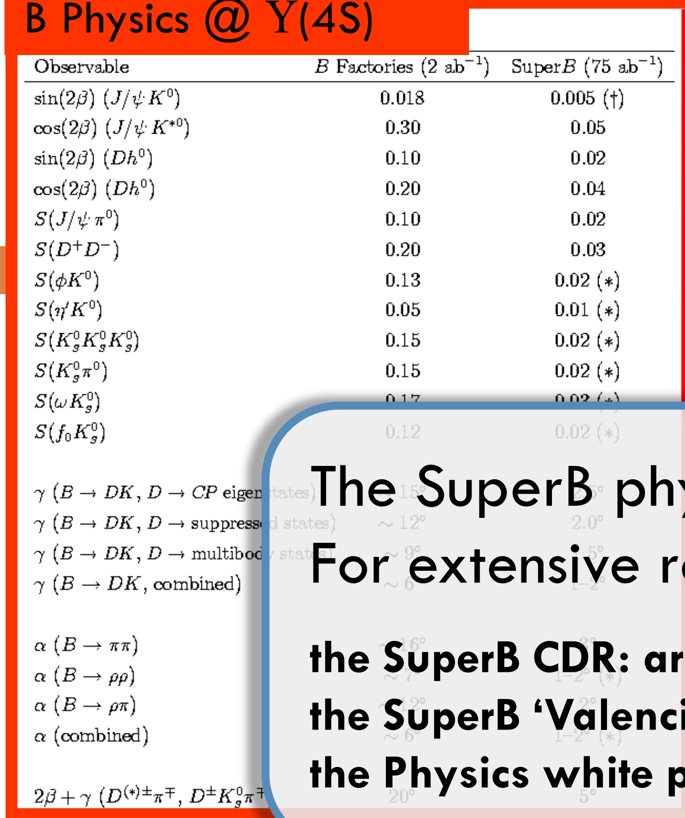
in some cases a reduction of theoretical error (e.g. Vub) is required (should be possible)

Precise CKM knowledge crucial for NP searches. Here just an example

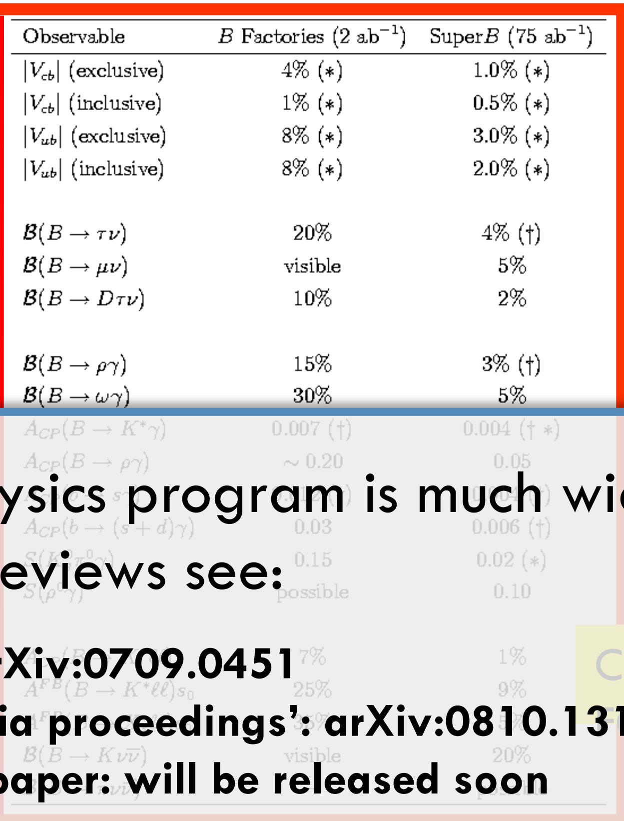

$K_L \to \pi^0 \nu \bar{\nu}$

U. Haisch, Kaon '07

B Physics @ Υ(4S)

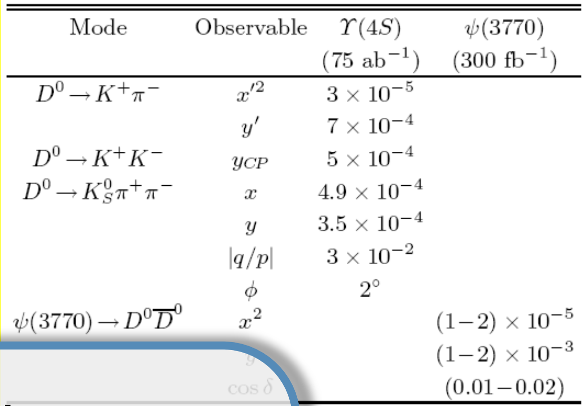


Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab^{-1})
$\sin(2\beta)$ $(J/\psi K^0)$	0.018	0.005 (†)
$\cos(2\beta)$ $(J/\psi K^{*0})$	0.30	0.05
$\sin(2\beta)$ (Dh^0)	0.10	0.02
$\cos(2\beta)$ (Dh^0)	0.20	0.04
$S(J/\psi\,\pi^0)$	0.10	0.02
$S(D^+D^-)$	0.20	0.03
$S(\phi K^0)$	0.13	0.02 (∗)
$S(\eta' K^0)$	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°



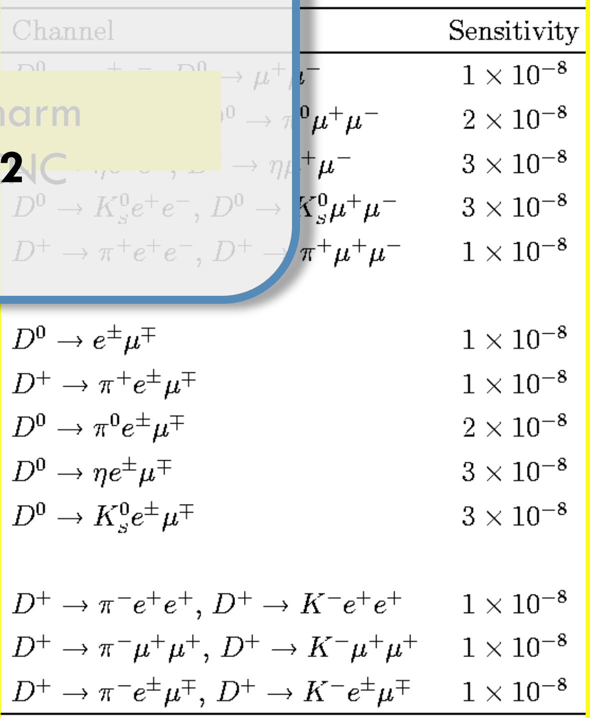
Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab^{-1})
$\lvert V_{cb}\rvert$ (exclusive)	4% (∗)	1.0% (∗)
$\lvert V_{cb}\rvert$ (inclusive)	1% (∗)	0.5% (∗)
$\lvert V_{ub}\rvert$ (exclusive)	8% (∗)	3.0% (∗)
$\lvert V_{ub}\rvert$ (inclusive)	8% (∗)	2.0% (∗)
$\mathcal{B}(B \to \tau\nu)$	20%	4% (†)
$\mathcal{B}(B \to \mu\nu)$	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%
$\mathcal{B}(B \to \pi\nu\overline{\nu})$	–	possible

Charm mixing and CP



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		$(1-2) \times 10^{-3}$
	$\cos\delta$		$(0.01-0.02)$

Charm FCNC



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

The SuperB physics program is much wider

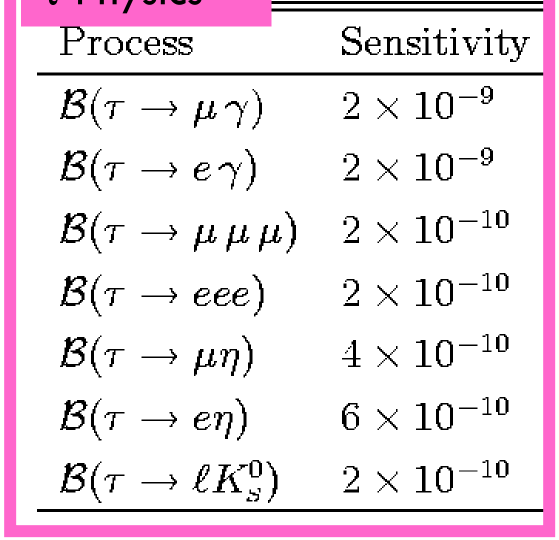
For extensive reviews see:

the SuperB CDR: arXiv:0709.0451

the SuperB 'Valencia proceedings': arXiv:0810.1312

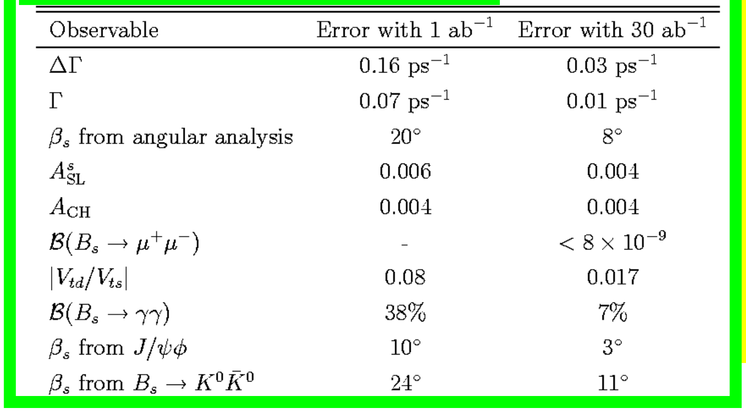
the Physics white paper: will be released soon

τ Physics



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$_s$ Physics @ 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_{SL}	0.006	0.004
A_{CH}	0.004	0.004
$\mathcal{B}(B_s \to \mu^+\mu^-)$	-	$< 8 \times 10^{-9}$
$\lvert V_{td}/V_{ts}\rvert$	0.08	0.017
$\mathcal{B}(B_s \to \gamma\gamma)$	38%	7%
β_s from $J/\psi\phi$	10°	3°
β_s from $B_s \to K^0\bar{K}^0$	24°	11°

Spectroscopy

The accelerator concept

$$\mathcal{L} = f_{coll} \times \frac{N^+ N^-}{4\pi\sigma_x\sigma_y} \times R_l$$

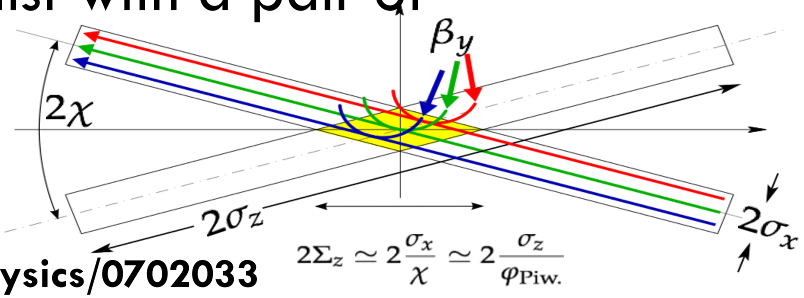
N^-,N^+: number of electrons/positrons in the bunch
f_{coll} : the collision frequency
σ_x (σ_y) : horizontal (vertical) beam size at the IP
R_l : luminosity reduction factor from crossing angle and 'hourglass effect'

Two approaches to increase the luminosity:

- increase the currents
  - large backgrounds, large wall plug power
- decrease the beams section (SuperB)

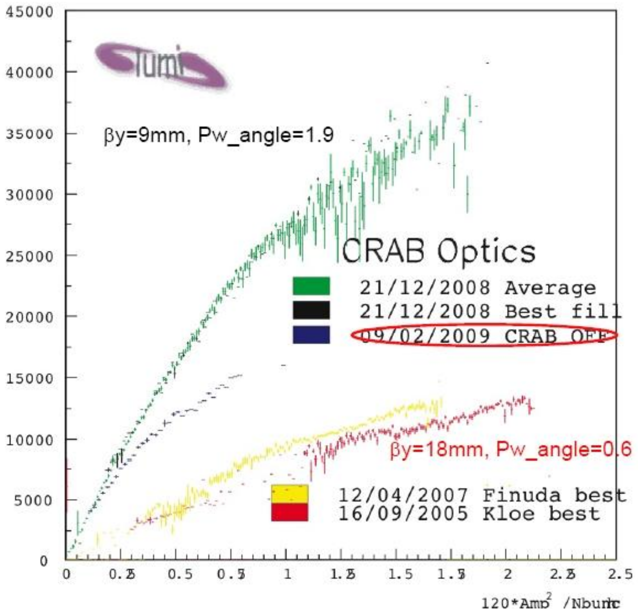
The 'Italian scheme':

- small beams
- Large Piwinsky angle and crab waist with a pair of sextupoles/ring
- Currents comparable to present B-factories



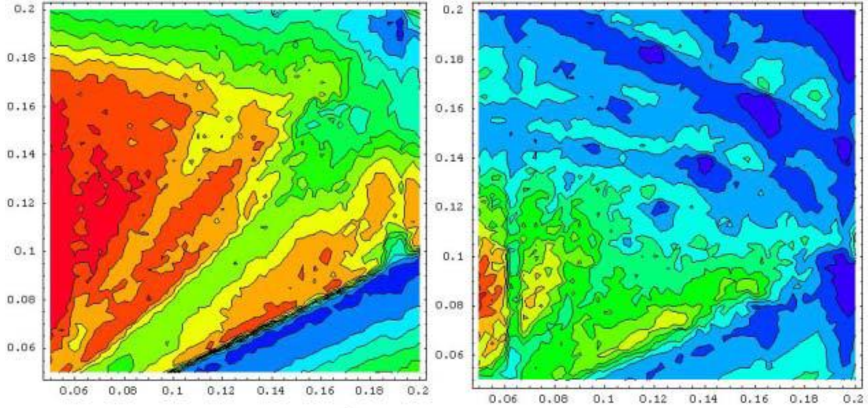
physics/0702033

crab waist test at Dafne



luminosity scan in the tunes plane performed for DAFNE in the Siddharta configuration

Red: max. luminosity **Blue**: minimum



Crab ON → 0.6/θ

$L_{max} = 2.97\times10^{33}\ cm^{-2}s^{-1}$

$L_{min} = 2.52\times10^{32}\ cm^{-2}s^{-1}$

Crab OFF

$L_{max} = 1.74\times10^{33}\ cm^{-2}s^{-1}$

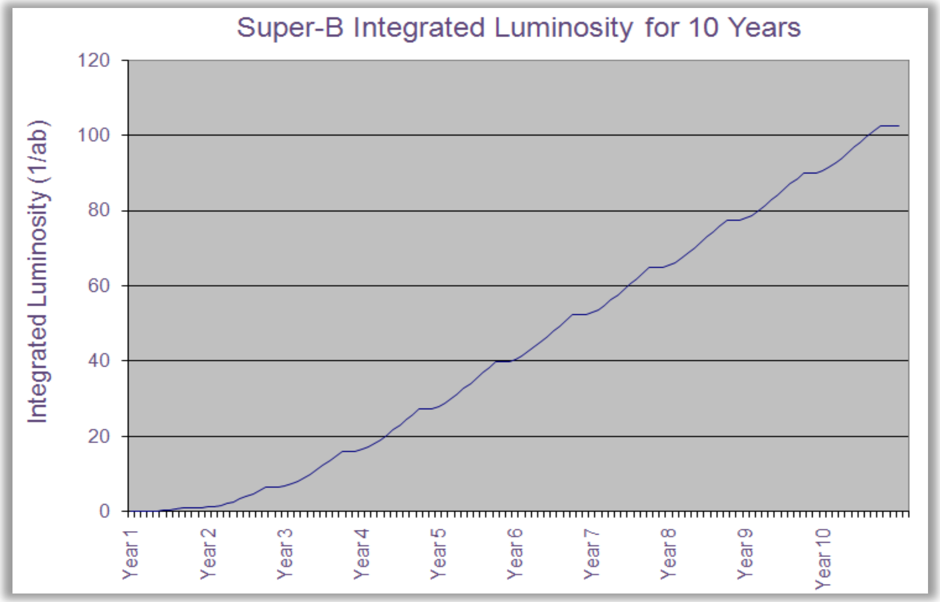
$L_{min} = 2.78\times10^{31}\ cm^{-2}s^{-1}$

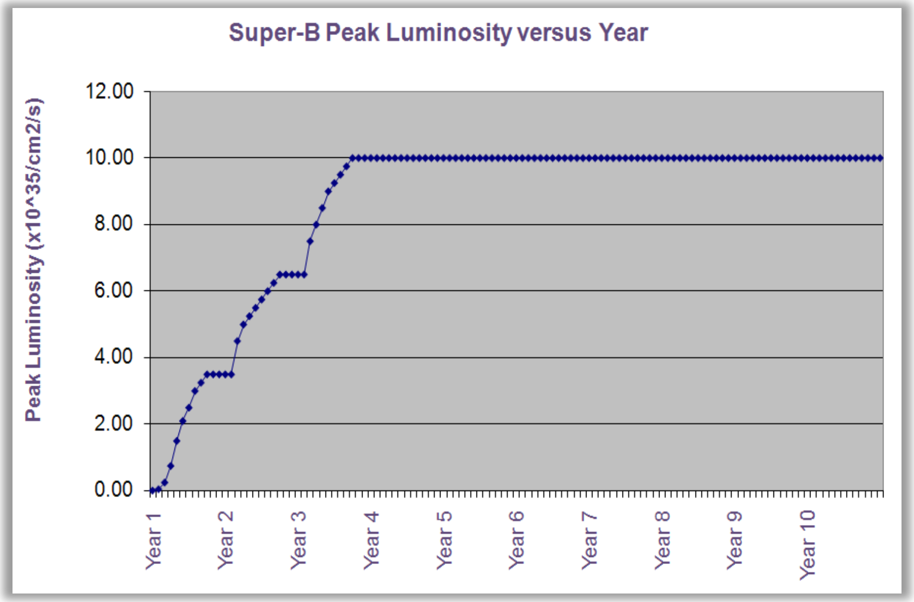
- When the crab waist is turned off:
  - beam size increases
  - luminosity drops down

with the crab waist:

- many X-Y betatron resonances disappear or become weaker
- good working area is significantly enlarged (→ larger integrated luminosity)

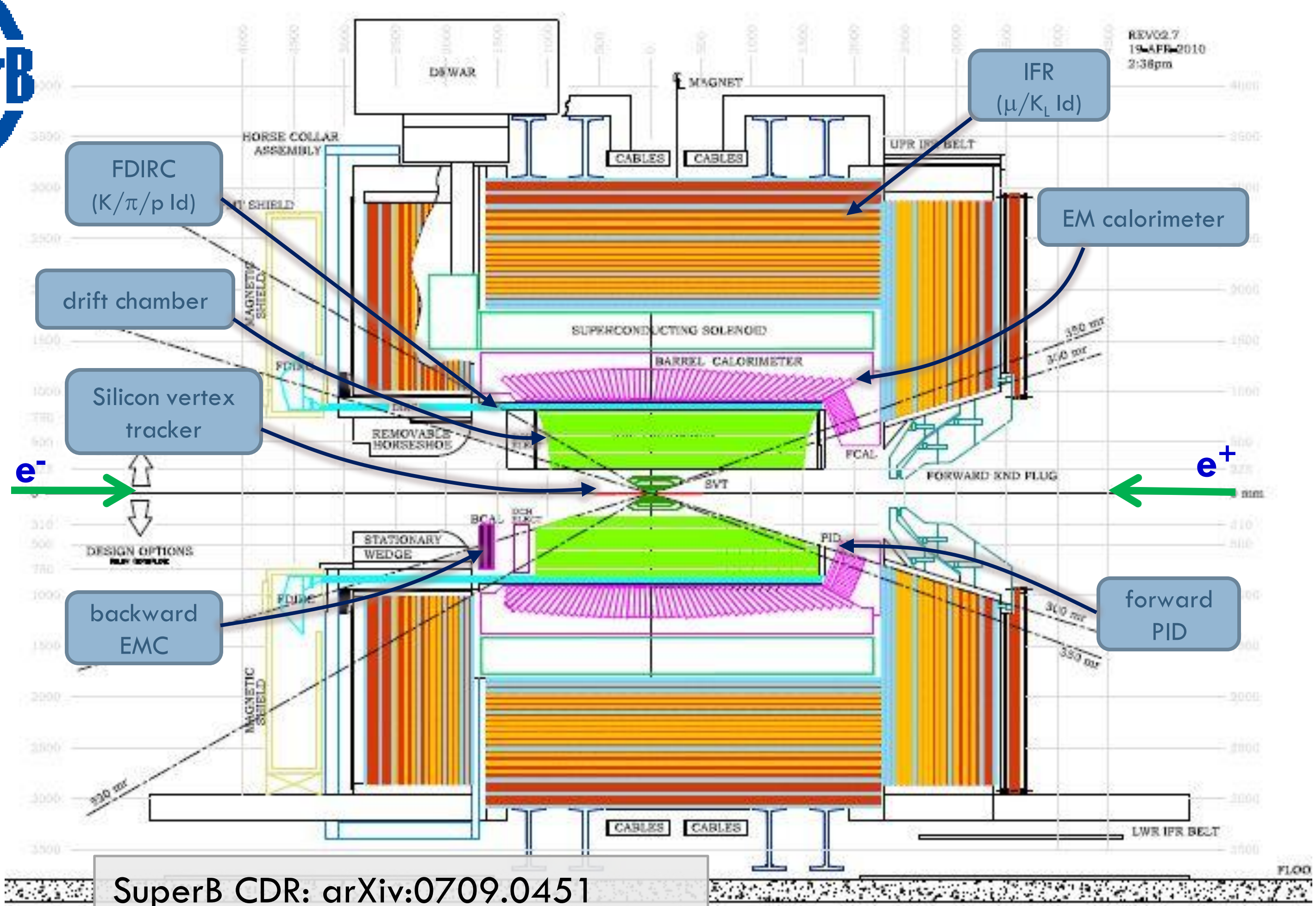
SuperB luminosity expectation





J. Seeman

detector layout: baseline and options



IFR (μ/K_L Id)

FDIRC ($K/\pi/p$ Id)

drift chamber

EM calorimeter

Silicon vertex tracker

backward EMC

forward PID

baseline concept

design options

SuperB CDR: arXiv:0709.0451
detector white paper in preparation

the baseline detector

(compared to the BaBar detector)

Goal: equal or improve the BaBar performance in environment with much higher bkg rates

IFR

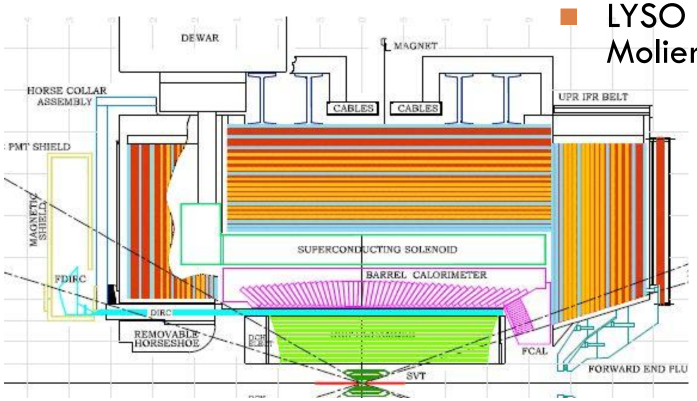
- amount and distribution of iron re-optimized
- Use extruded plastic scintillator coupled to geiger mode APDs through WLS fibers

FDIRC

- based on BaBar DIRC design
  - reuse BaBar quartz bar
  - photon camera 25x smaller (10x bkg suppression)
  - PMTs 10x faster (another10x bkg suppression)

EMC

- barrel
  - reuse BaBar CsI(Tl) crystals
- forward
  - LYSO crystals (fast, rad hard, small Moliere radius, good light yield)



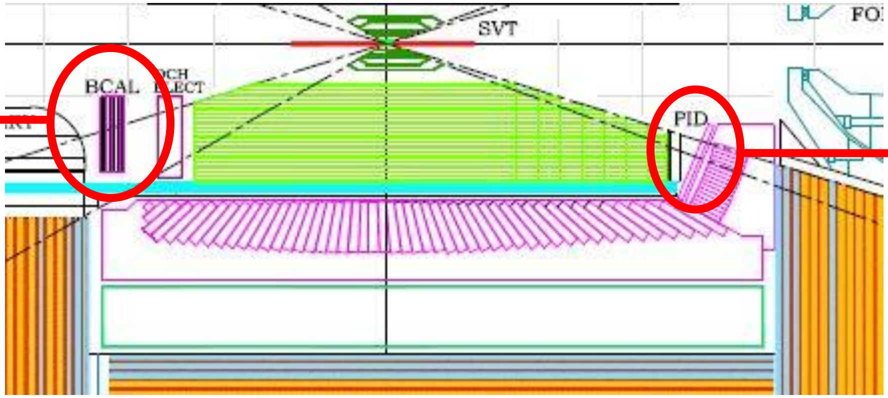
SVT

- layer-0
  - as close to the IP as possible
  - striplets is the baseline technology for TDR
- 5 external layers
  - double-sided microstrip sensors a la BaBar

DCH

- design based on BaBar drift ch. concept
  - faster and lighter electronics
  - lighter structure
  - optimization of gas mixture and wires layout

detector options under evaluation

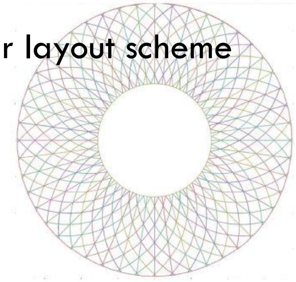


backward
EM calorimeter

forward
PID device

backward EMC

- Meant to increase EMC hermiticity at modest cost. <u>Used as veto</u>
- 24 layers of lead(3mm) + scintillator(3mm) read by WLS fibers coupled to SiPM
- Benefits on Physics under evaluation



fiber layout scheme

forward PID

- pros and cons under evaluation
  - ☺ improved hadron Id in the forward region compared to dE/dx only
  - ☹ material in front of fwd EMC, cost
- Several options:
  - Time of Flight (2 options)
  - FARICH (better PID separation but 3x material and R&D less advanced)
  - use of EMC LYSO crystal fast component
- Bernefits on Physics under evaluation

the approval process

- The TDR phase has started. The detector and machine TDR are currently expected to be released in 2011
    - MoU signed between INFN and France, Russia (BINP) and US (SLAC). Letter of commitment from Canada (IPP)
- The Italian Minister of Research has presented the project to the Italian Government. The project is inserted as flagship project in the Italian National Research Plan 2010-2012. Government decision expected soon
- Joint agreement of mutual financial support of a fusion research reactor (IGNITOR) in Russia and the SuperB project in Italy signed by Prime Ministers Berlusconi and Putin.

Summary

- SuperB is a next generation e^+e^- flavor factory which employs a novel design to achieve unprecedented high luminosity, $L=10^{36}cm^{-2}s^{-1}$ as baseline

- The physics program of SuperB complements that of the high-energy frontier experiments at hadron colliders

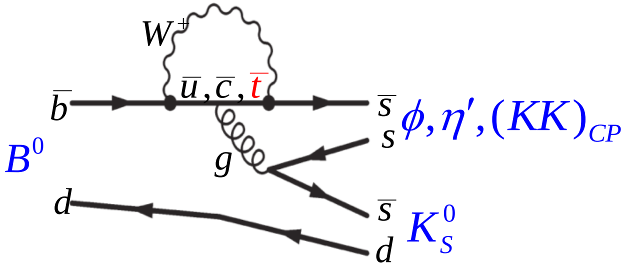
- The project has entered the TDR phase, which is expected to end in 2011

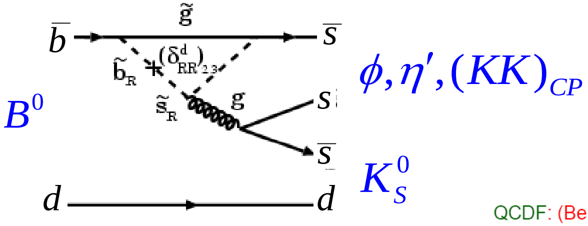
- A decision on the project approval by the Italian Government is expected to be taken soon

BACKUP

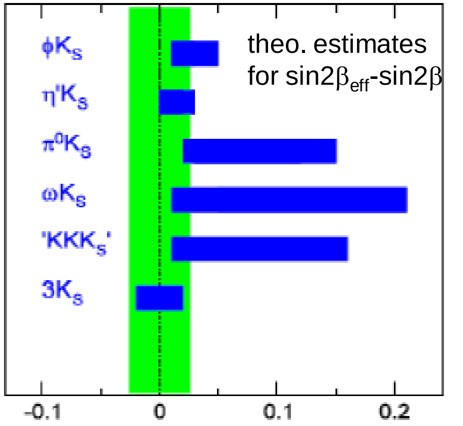
New Physics in $|\Delta F|=1$ transitions

- FCNC processes mediated by loops in SM can receive significant contributions from NP



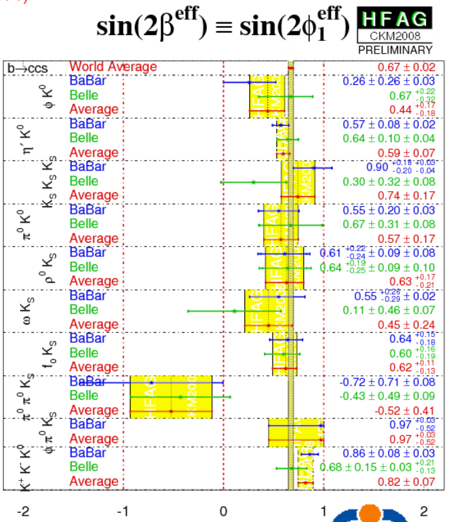


- SM corrections to the dominant loop diagram must be evaluated carefully
  - O(0.01) correction for B→η'Ks and 3Ks
  - SM corrections tend to prefer $\sin 2\beta_{eff}-\sin 2\beta>0$
  - exp. results overall statistically compatible with SM
- Need to look at as many modes as possible
- With SuperB @75ab^{-1} exp. errors at the level of 0.01-0.03, smaller than theory uncertainties



QCDF: (Beneke, PLB620 (2005), 143-150, Cheng et al., PRD72 (2005) 094003 etc.
SCET: (Williamson & Zupan, hep-ph/0601214)

SU(3): Grossman *et al*, PRD68 (2003) 015004; Gronau *et al*, PRD71 (2005) 074019; …).



INFN Istituto Nazionale di Fisica Nucleare

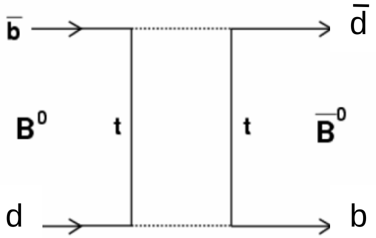
SuperB

New Physics in |ΔF|=2 transitions

- ΔF=2 transitions mediated by box diagrams
- NP can contribute to these processes
    - parameterize NP as:

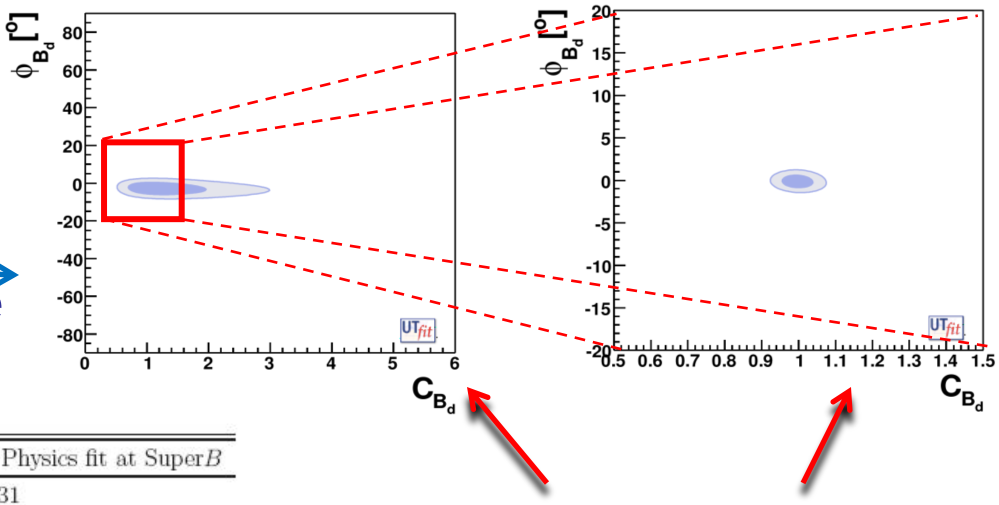
$$C_q e^{i\phi_q} = \frac{\langle B_q^0 | H_{SM+NP} | \overline{B}_q^0 \rangle}{\langle B_q^0 | H_{SM} | \overline{B}_q^0 \rangle}$$

B mixing



- In SM C_q=1 and ϕ_q=0
- present measurements already constrain NP in B_d mixing
- SuperB will dramatically improve the constraint

hep-ph/0509219



Parameter	New Physics fit today	New Physics fit at Super$B$
C_{B_d}	1.24 ± 0.43	± 0.031
ϕ_{B_d} (°)	-3 ± 2	± 0.4

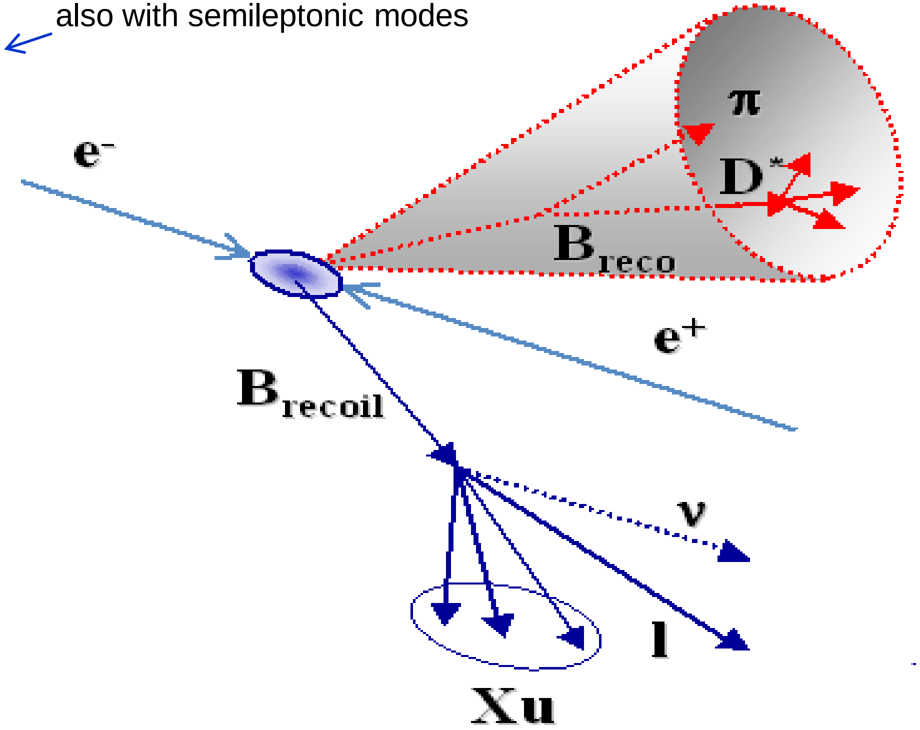
note the different scales

B-recoil technique

Powerful technique possible only at e^+e^- B-factories

- Fully reconstruct one of the two B in hadronic modes
  - Relatively high efficiency: a few 0.1%
  - > 10^7 recoil B's in $10ab^{-1}$
- Search signal B decay in the remaining of the event
  - High purity sample
  - Can look at channels with a lot of missing energy
  - For example BR(B→nothing) measured, $B\to K\nu\bar{\nu}$, $B\to\tau\nu$, ...

also with semileptonic modes



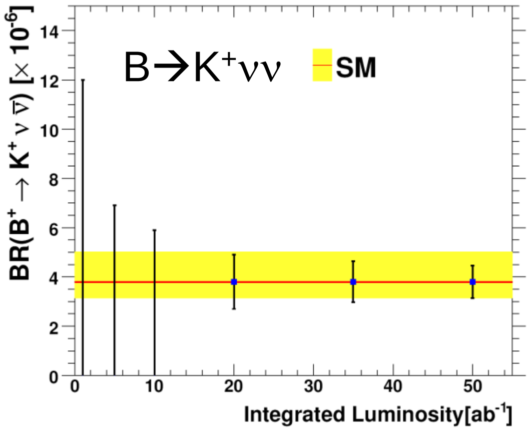
unique feature of e^+e^- machine

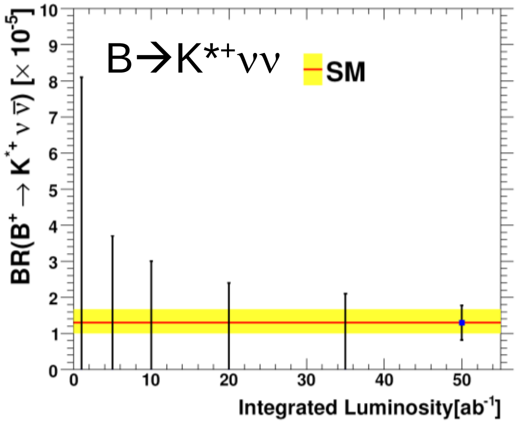
Recoil kinematics well known
Recoil flavour and charge are determined

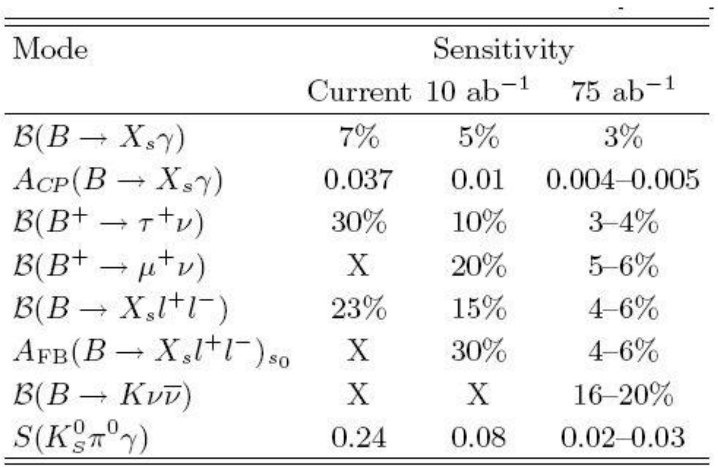
NP search in $B \rightarrow s$ invisible

- $B \rightarrow K^{(*)}\nu\bar{\nu}$ can probe NP in Z^0 penguins
- Best exp. bound: $BF(B \rightarrow K\nu\bar{\nu}) < 14 \times 10^{-6}$
- SM prediction: 4×10^{-6} → 20% error with $75ab^{-1}$
- B-recoil analysis crucial for this analysis
  - measurement only possible at e^+e^- (Super)B-factories
  - important to improve detector hermiticity: bkg-dominated, 30% bkg reduction corresponds to 1/0.7~1.40 more luminosity

closely related to $K \rightarrow \pi\nu\bar{\nu}$







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%
$A_{\mathrm{FB}}(B \to X_s l^+ l^-)_{s_0}$	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

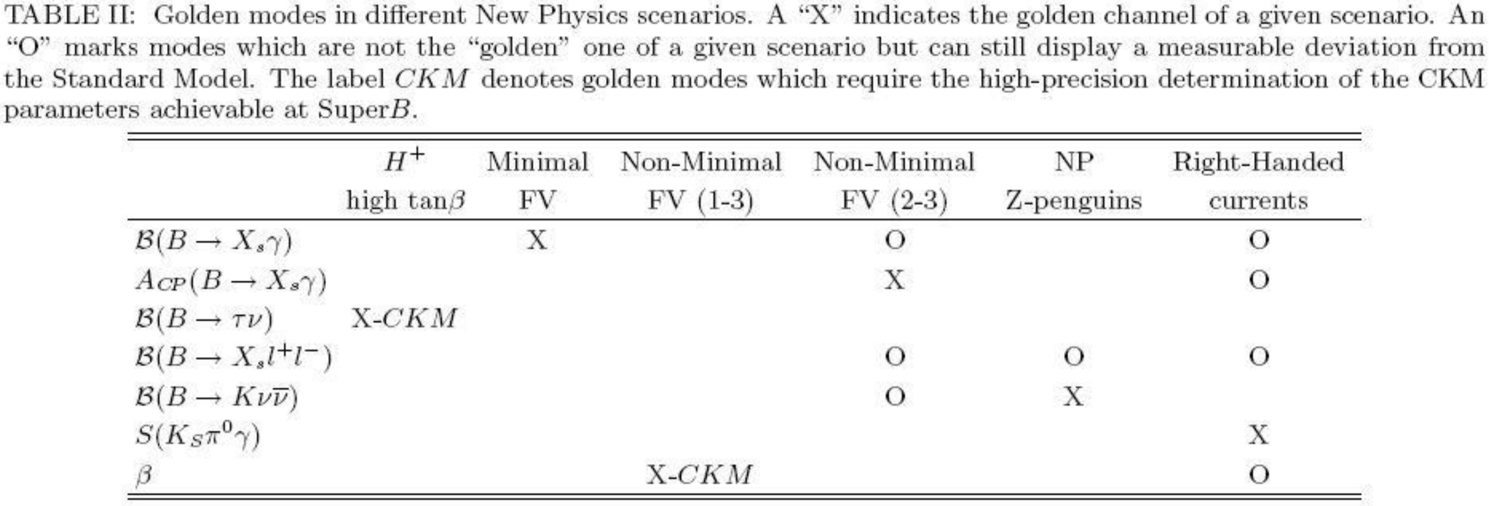
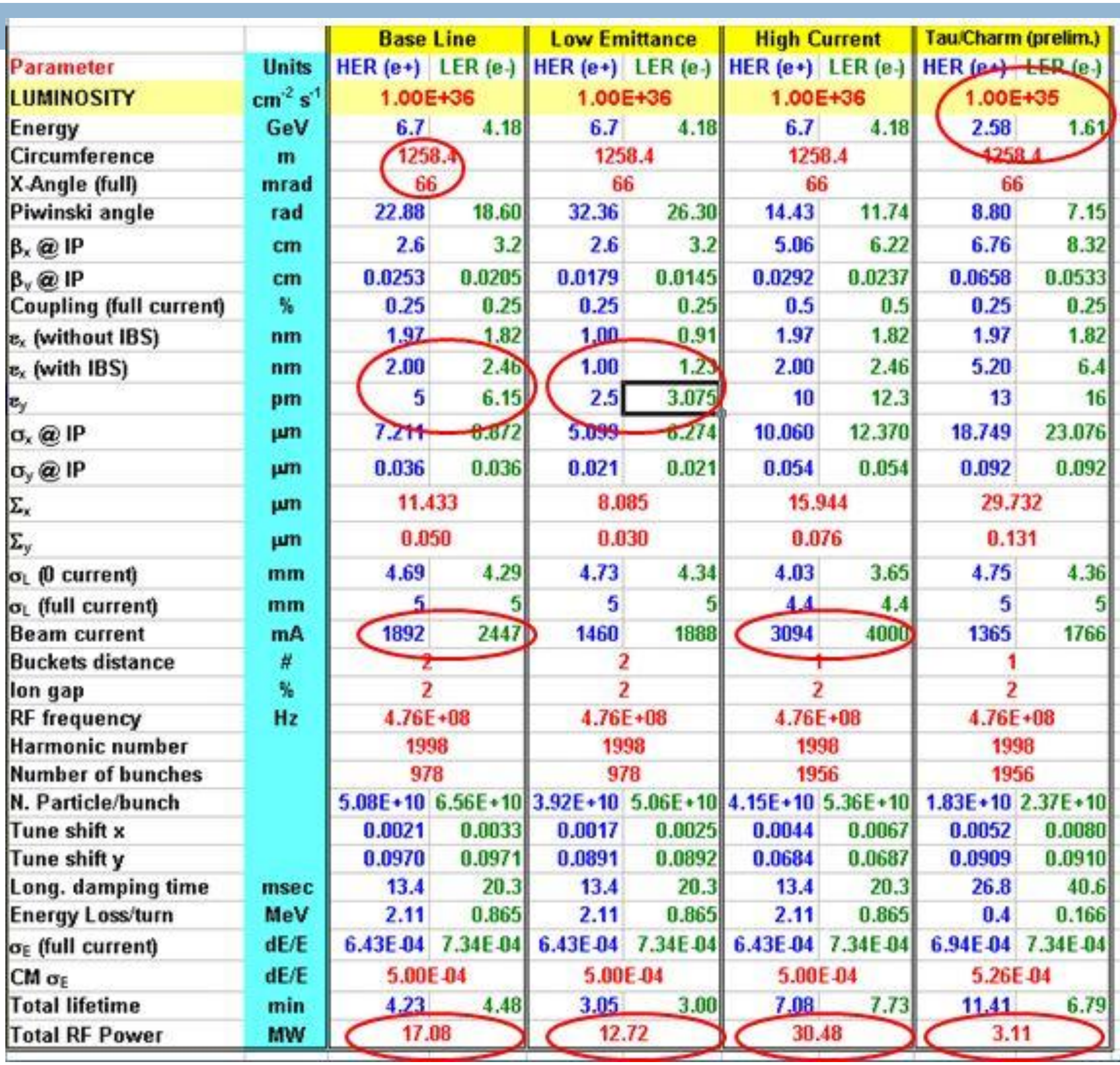


TABLE II: Golden modes in different New Physics scenarios. A "X" indicates the golden channel of a given scenario. An "O" marks modes which are not the "golden" one of a given scenario but can still display a measurable deviation from the Standard Model. The label *CKM* denotes golden modes which require the high-precision determination of the CKM parameters achievable at Super*B*.

	H^+ high $\tan\beta$	Minimal FV	Non-Minimal FV (1-3)	Non-Minimal FV (2-3)	NP Z-penguins	Right-Handed currents
$\mathcal{B}(B \to X_s\gamma)$		X		O		O
$A_{CP}(B \to X_s\gamma)$				X		O
$\mathcal{B}(B \to \tau\nu)$	X-*CKM*					
$\mathcal{B}(B \to X_s l^+ l^-)$				O	O	O
$\mathcal{B}(B \to K\nu\overline{\nu})$				O	X	
$S(K_S\pi^0\gamma)$						X
β			X-*CKM*			O

flexibility for the parameters choice

P. Raimondi @ Annecy10



		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	

Tau/charm threshold running at 10^{35}

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

Baseline:
- Higher emittance due to IBS
- Asymmetric beam currents

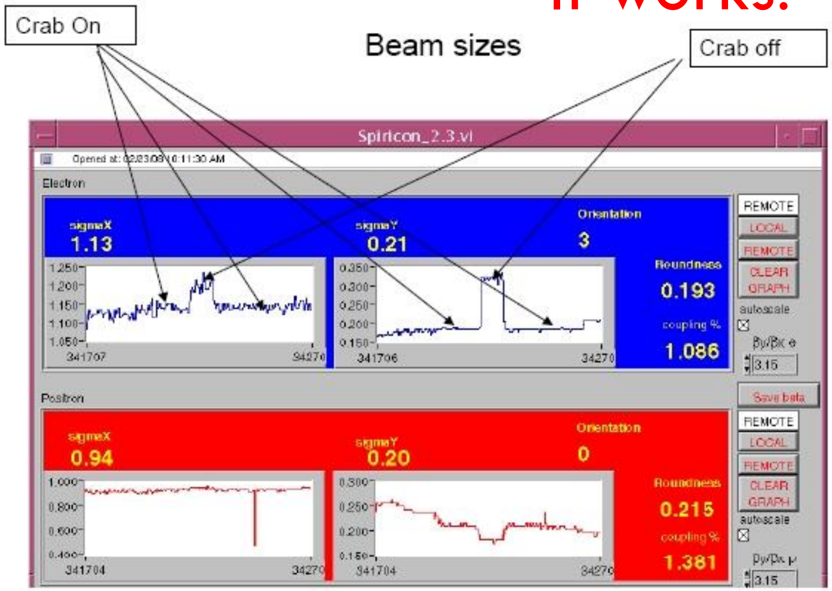
RF power includes SR and HOM

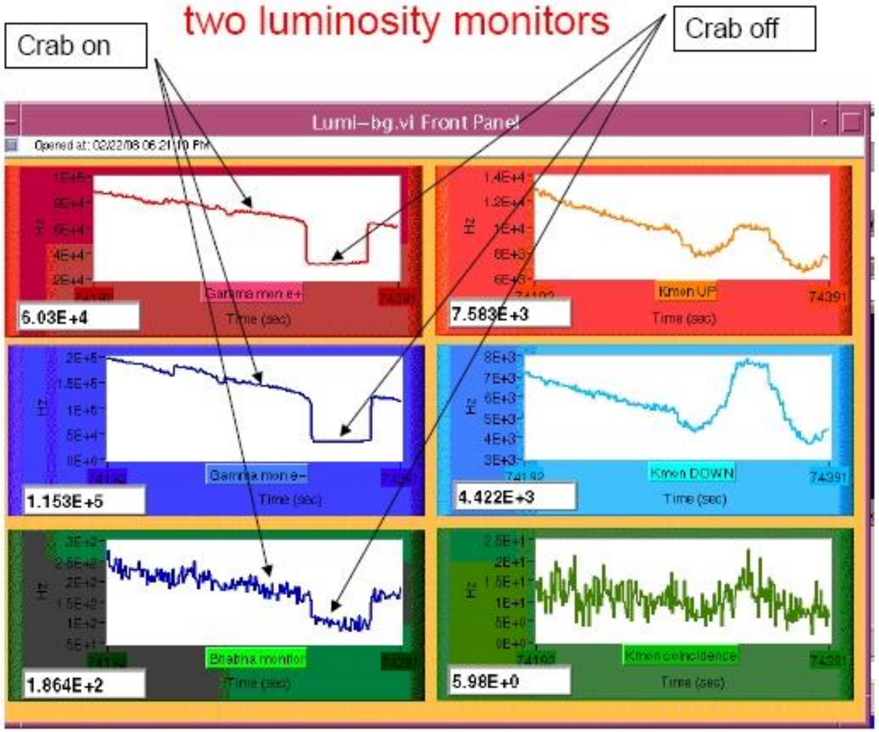
PPA Particle Physics & Astrophysics

Tests of crab waist at Dafne

It works!

successful test at DAFNE

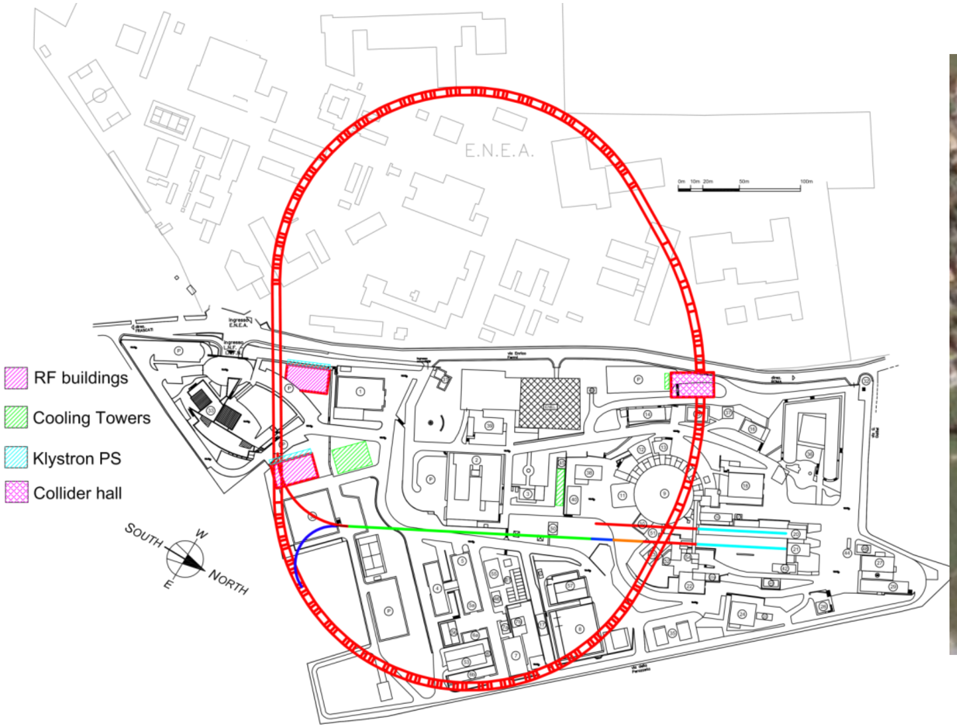




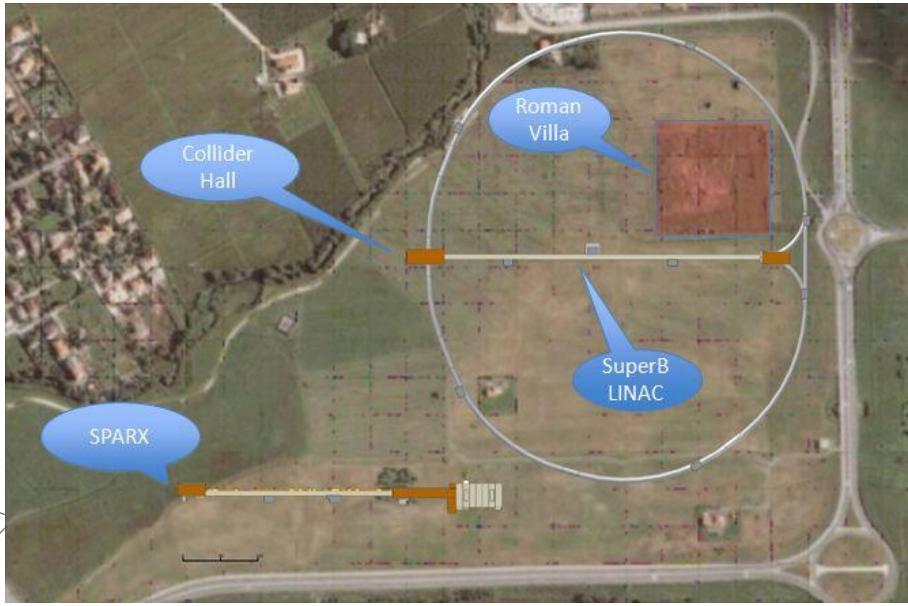
- ☐ When the crab waist is turned off:
  - beam size increases
  - luminosity drops down

possible sites

SuperB at LNF with Polarization



Tor Vergata campus site



Machine Parameters for 10^{36} cm^{-2} s^{-1} (Raimondi)

J. Seeman
June 2010

The IP and ring parameters have been optimized based on several constraints to maintaining wall plug power, beam currents, bunch lengths, and RF requirements comparable to present B Factories.

- Planning for the reuse as much as possible of the PEP-II hardware.
- Simplifying the IR design as much as possible. In particular, reduce the synchrotron radiation in the IR, reduce the HOM power and increase the beam stay-clear.
- Relaxing as much as possible the requirements on the beam demagnification at the IP. Improved chromatic correction in arc cells.

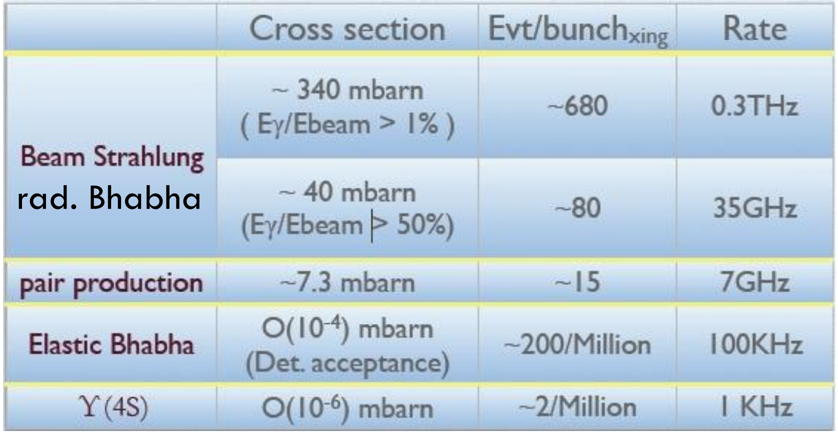
Flexibility for the parameters choice:

The horizontal emittance can be decreased by about a factor 2 in both rings by changing the partition number (by changing the RF frequency [LEP] or the orbit in the ARCS) and the natural ARC emittance by readjusting the lattice functions.

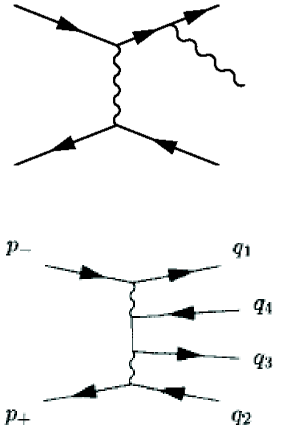
- The Final Focus system as a built-in capability of about a factor 2 in decreasing the IP beta functions.
- The RF system will be able to support higher beam currents (up to a factor x1.6) over the baseline, when all the available PEP RF units are installed.

Machine backgrounds

- Two colliding beams
  - radiative Bhabha → *dominant effect on lifetime*
  - $e^+e^- e^+e^-$ production → *~3% contribution to lifetime, important source for SVT layer-0*
- Single beam
  - synchrotron radiation → *strictly connected to IR design*
  - Touschek → *negligible in BaBar, important in SuperB*
  - beam-gas
  - intra-beam scattering

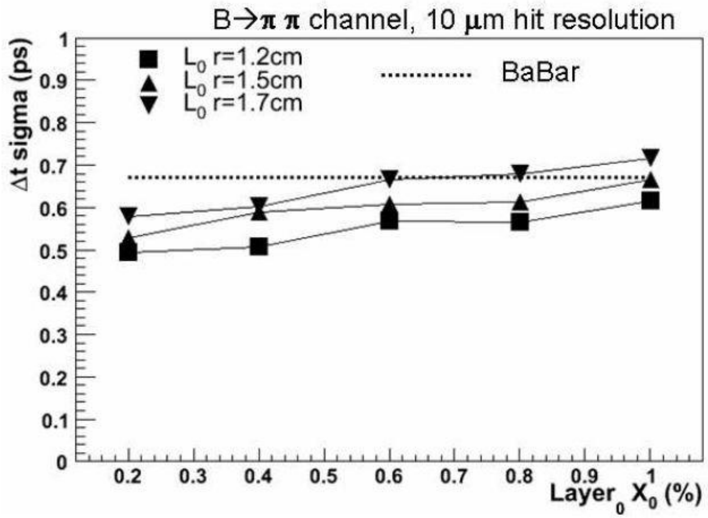


	Cross section	$\text{Evt/bunch}_{\text{xing}}$	Rate
Beam Strahlung rad. Bhabha	~ 340 mbarn (Eγ/Ebeam > 1%)	~680	0.3THz
	~ 40 mbarn (Eγ/Ebeam > 50%)	~80	35GHz
pair production	~7.3 mbarn	~15	7GHz
Elastic Bhabha	$O(10^{-4})$ mbarn (Det. acceptance)	~200/Million	100KHz
$\Upsilon(4S)$	$O(10^{-6})$ mbarn	~2/Million	1 KHz

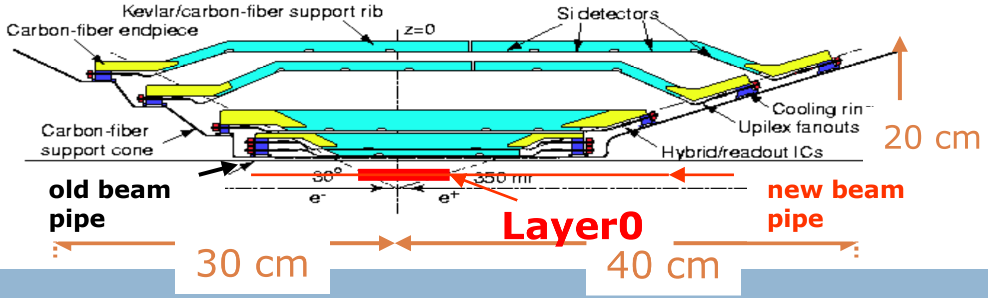


vertex detector: need of “layer 0”

- The nominal SuperB boost is $\beta\gamma$=0.24 (BaBar’s is 0.56)
- Time-dependent analyses require to separate the two B vertices:
  - BaBar: <ΔL>=250μm ; SuperB: <ΔL>=106μm
- Solution: compensate low boost with improved vertex resolution by reducing the beam pipe radius and putting layer-0 as close as possible to the IP → driven by the $e^+e^- \rightarrow e^+e^-e^+e^-$ bkg rate
  - keep material of beampipe+layer-0 to a minimum to minimize mult. scattering



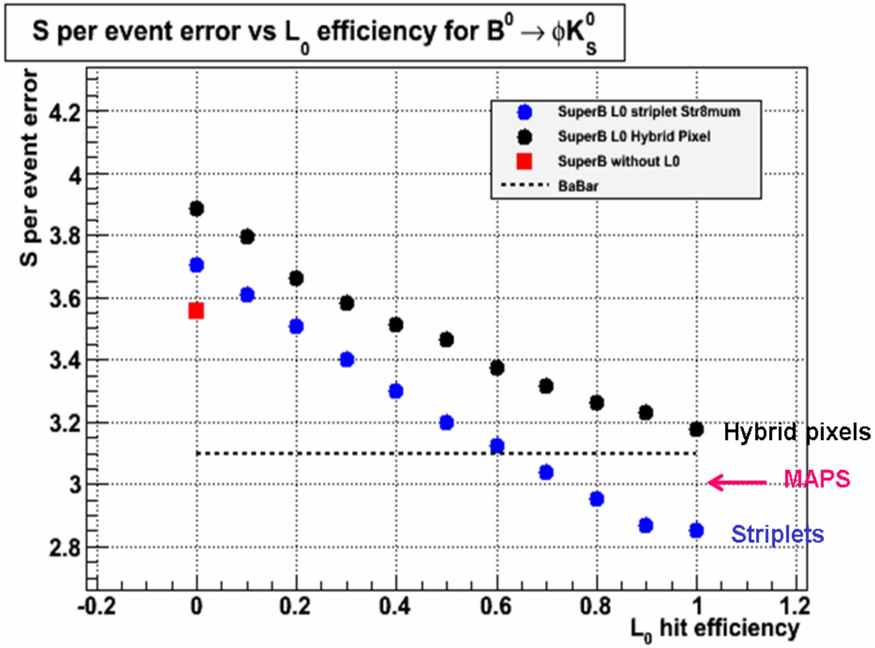
layer 0 strategy



- Striplets baseline option for TDR:
  - Better physics performance (lower material) even with some inefficiency, due to high background conditions.

  striplets at r=1.6cm if bkg rate sustainable

- Upgrade to pixel (Hybrid or CMOS MAPS), more robust against background, is foreseen for a second generation of Layer0
  - Very challenging to keep the material for a pixel system at the level of the striplets (~0.5%X0)
  - R&D continue on various pixel items: CMOS MAPS, high rate readout electronics, low material support with cooling.
  - Need IR and SVT mechanics designed for a rapid replacement of Layer0.



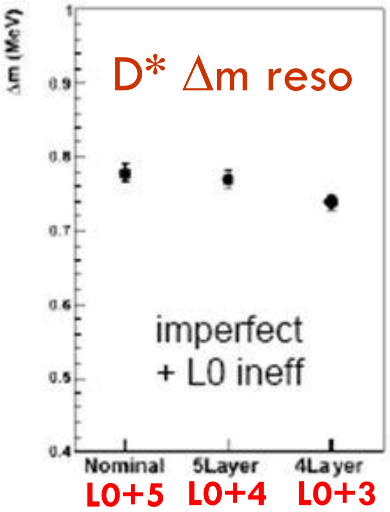
external layers of SVT

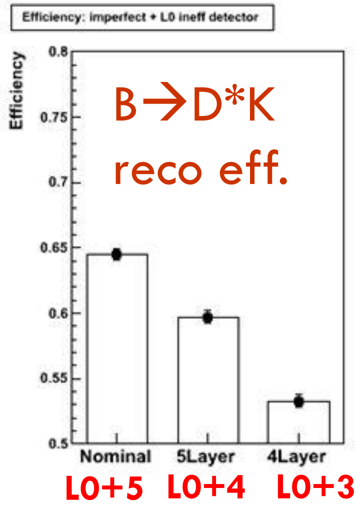
- the external layers will be made of double sided microstrip sensors

tracking studies to determine number and position of layers

- Number of layers besides layer-0
  - modest gain in tracking performance in L0+3 or L0+4 w.r.t. L0+5
  - improved reco efficiency in L0+5
  - L0+5 has redundancy

➔ L0+5 preferred to L0+3 or L0+4

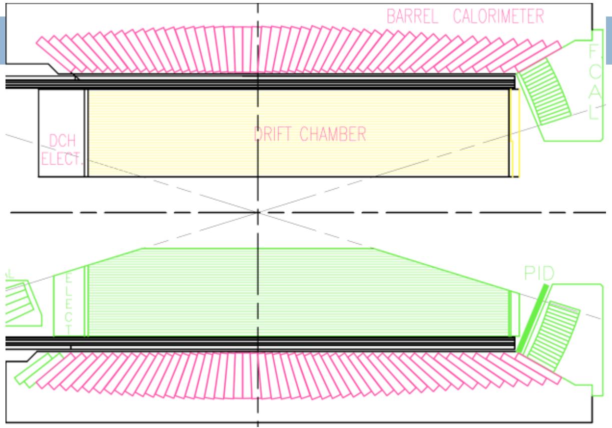




- Which external radius of SVT?
  - tracking performance worsens if SVT radius larger than in BaBar
  - …and in any case it would be limited by space needed by cryostats

➔ external radius as in BaBar in baseline configuration

The drift chamber



Build on *BABAR* drift chamber concept: no major R&D effort needed, but:

- Lighter structure, all in Carbon Fiber (CF)
  - Preliminary studies show that dome-shaped CF end-plates with X0~2% seem achievable (compare 13-26% in BaBar DCH)
- Design faster&lighter electronics (taking into account detectors options to be possibly installed behind backward end-plates)
- To control expected increase in occupancy:
  - studying faster gas mixtures
  - considering smaller cells
  - alternative solutions being explored
    - tapered shape of end-plates

drift chamber

geometric constraints

outer radius	80 cm	cons. by DIRC quartz bars
inner radius	20-25 cm	cons. by cryostats of IR magnets
bwd length	+30cm w.r.t. Babar if NO bwd EMC is built	but little impact on tracking and dE/dx overall
fwd length	~ as in BaBar	~ not affected by a fwd TOF

background occupancy summary*

Small-angle Bhabha	~2%
Pair production	0.5-1.0%
Large-angle radiative Bhabha	0.4%

* prel results to be confirmed

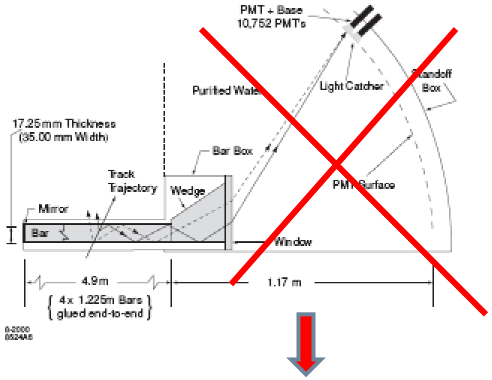
- Some indications that conical endplates are not required after all

cluster counting: interesting but very challenging R&D item

- single ionization clusters are resolved time-wise and counted, improving dE/dx and space resolutions
- not proven to be feasible
- impact on physics to be quantified

PID – the focusing DIRC

- Hadronic PID system essential for P(π,K)>0.7GeV/c (use dE/dx for p<0.7GeV/c)
- Baseline is to reuse BaBar DIRC design
  - Excellent performance to 4GeV/c
  - Robust operation
  - Elegant mechanical support
  - Photon detectors outside field region
  - Radiation hard fused silica radiators
  - But… PMTs are slow and aging. Need replacement. Large SOB region sensitive to backgrounds so volume reduction is necessary
- Photon detector replacement
  - Baseline: Use pixelated fast PMTs with a smaller SOB to improve background performance by x100 with identical PID performance



the Babar SOB is replaced with photon camera 25 times smaller

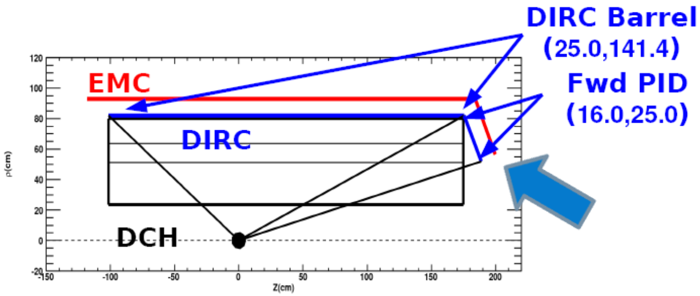
➔ <u>10 times bkg rate reduction</u>

PMTs 10 times faster than Babar

➔ <u>10 times bkg rate reduction</u>

Total: <u>100 times bkg rate reduction</u>

forward PID

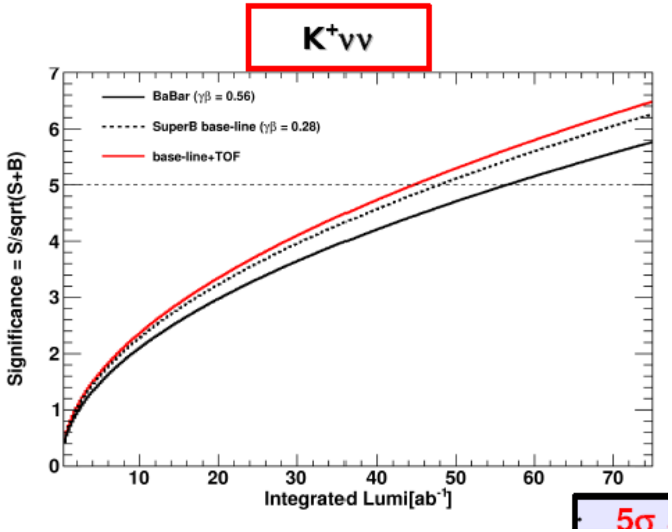


- ☐ Is it worth it?
  - ☺ improved hadron Id in the forward region compared to dE/dx only
  - ☹ material in front of fwd EMC
  - ☹ cost
- ☐ Several options:
  - Time of Flight (2 options)
  - FARICH (better PID separation but 3x material and R&D less advanced)
  - use of EMC LYSO crystal fast component
- ☐ Physics case (preliminary results)

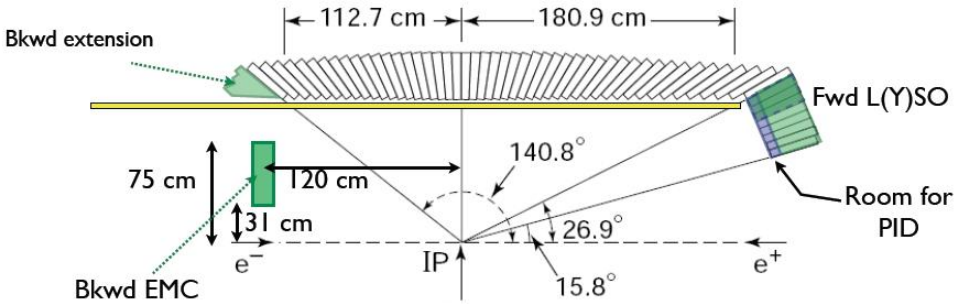
- 5σ significance (stat-only):
- BaBar: ~55ab^{-1}
- SuperB-base line: ~48ab^{-1}
- +TOF: ~44ab^{-1}

Gain on significance:
boost ~ 7-8%
fwd PID ~ 5%

results without machine backgrounds



The electromagnetic calorimeter



BaBar Barrel
5760 CsI(Tl) Crystals

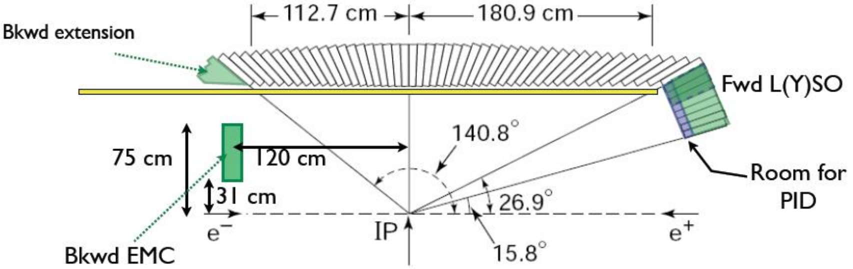
$$\frac{\sigma_E}{E} = \frac{2.30\%}{\sqrt[4]{E(GeV)}} \oplus 1.35\% \qquad \sigma_\theta = \frac{4mrad}{\sqrt{E(GeV)}}$$

Essential detector to measure energy and direction of γ and e, discriminate between e and π, and detect neutral hadrons

- Barrel
  - BaBar barrel crystals not suffering signs of radiation damage. They're sufficiently fast and radiation hard for the SuperB needs

    ➔They can be reused (Would have been) most expensive detector component
- Endcaps
  - Best possible hermiticity important for key physics measurements
  - New forward endcap
  - backward endcap is an option

EMC endcaps – forward and backward

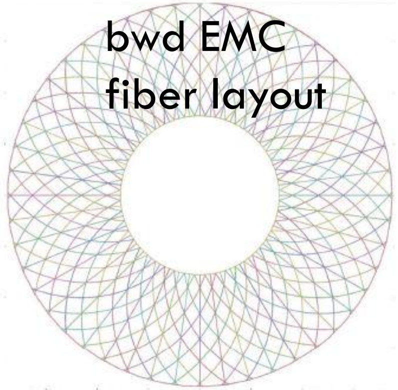


- ☐ **forward endcap**

  BaBar CsI(Tl) endcap inadequate for higher rates and radiation dose of SuperB

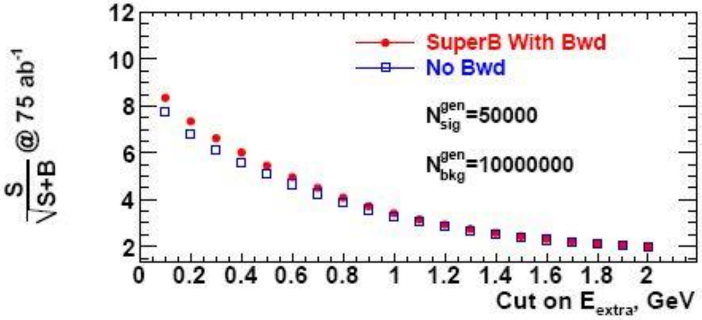
  - need finer granularity, faster crystals and readout electronics, comparable X0

  ➔ LYSO crystals:
    - radiation hard, fast, small Moliere radius, good high yield
    - more compact, could free10cm for a fwd PID system
    - expensive (~40$/cc) [price of 2009]



bwd EMC fiber layout

- ☐ **backward endcap** (still an option)
  - meant to increase EMC hermiticity at modest cost (used as veto)
  - 24 layers of lead(3mm)+scintillator(3mm) read by WLS fibers coupled to SiPM



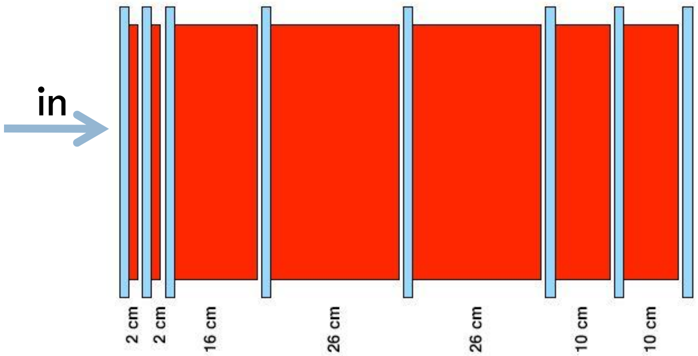
B→τν: S/sqrt(S+B) increases by ~8% with bwd EMC (machine bkg **NOT** included)

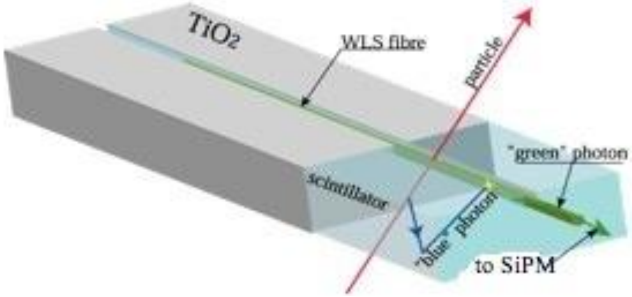
→need to repeat the analysis with machine bkg

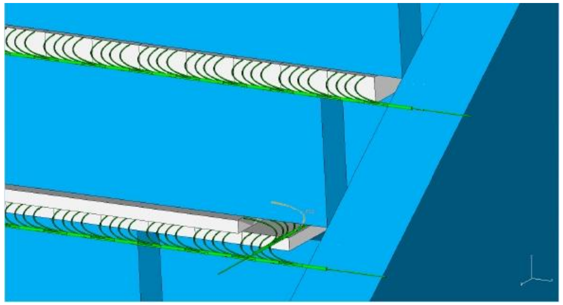
The IFR

- Provides discrimination between μ and $\pi^{\pm}$. Help detection and direction measurement of K_L (together with EMC)
- Add absorber w.r.t. BaBar to improve π/μ separation. Amount and distribution is being optimized
  - baseline: 92cm of iron (5.5 λ_I), 7 layers, reuse of BaBar IFR iron
- Use extruded plastic scintillator coupled to geiger mode APDs through WLS fibers
  - expected hit rates of O(100) Hz/cm^2
  - single layer or double coord. layout depending on the x-y resolution needs

baseline configuration layout







IFR

Layout optimization

three configurations

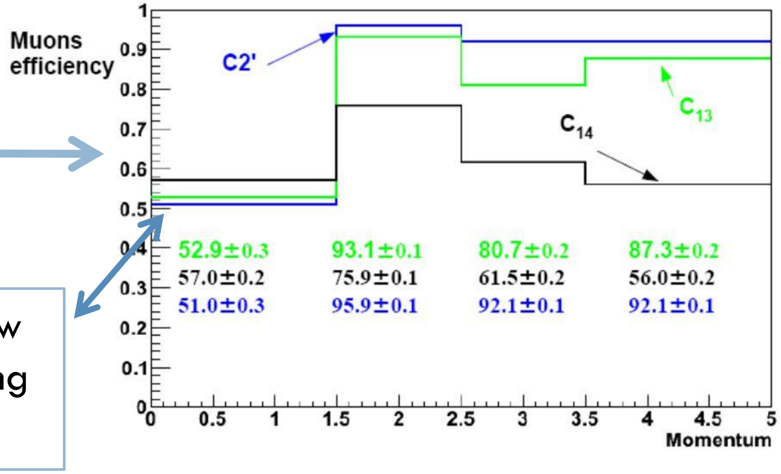
```
|=|=|========|============|============|=======|=====|
|2|2|   16   |     24     |     24     |  14   | 10  |

|=|=|========|========|========|========|=======|
|2|2|   16   |   16   |   16   |   16   |  14   |

|=|=|======|======|======|======|=====|
|2|2|  12  |  12  |  12  |  12  | 10  |
```

C_2' Fe 920mm

C_{13} Fe 820mm

C_{14} Fe 620mm

muon efficiency when pion misId=2%



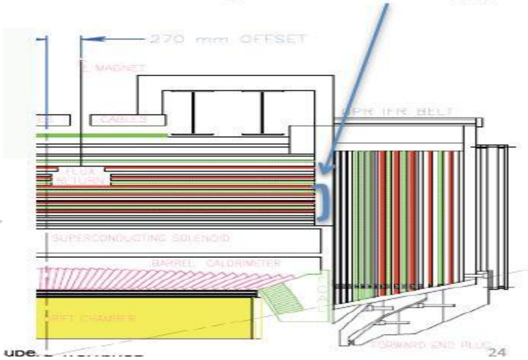
beam test of prototype planned at Fermilab

performance at low p can increase using DIRC and EMC

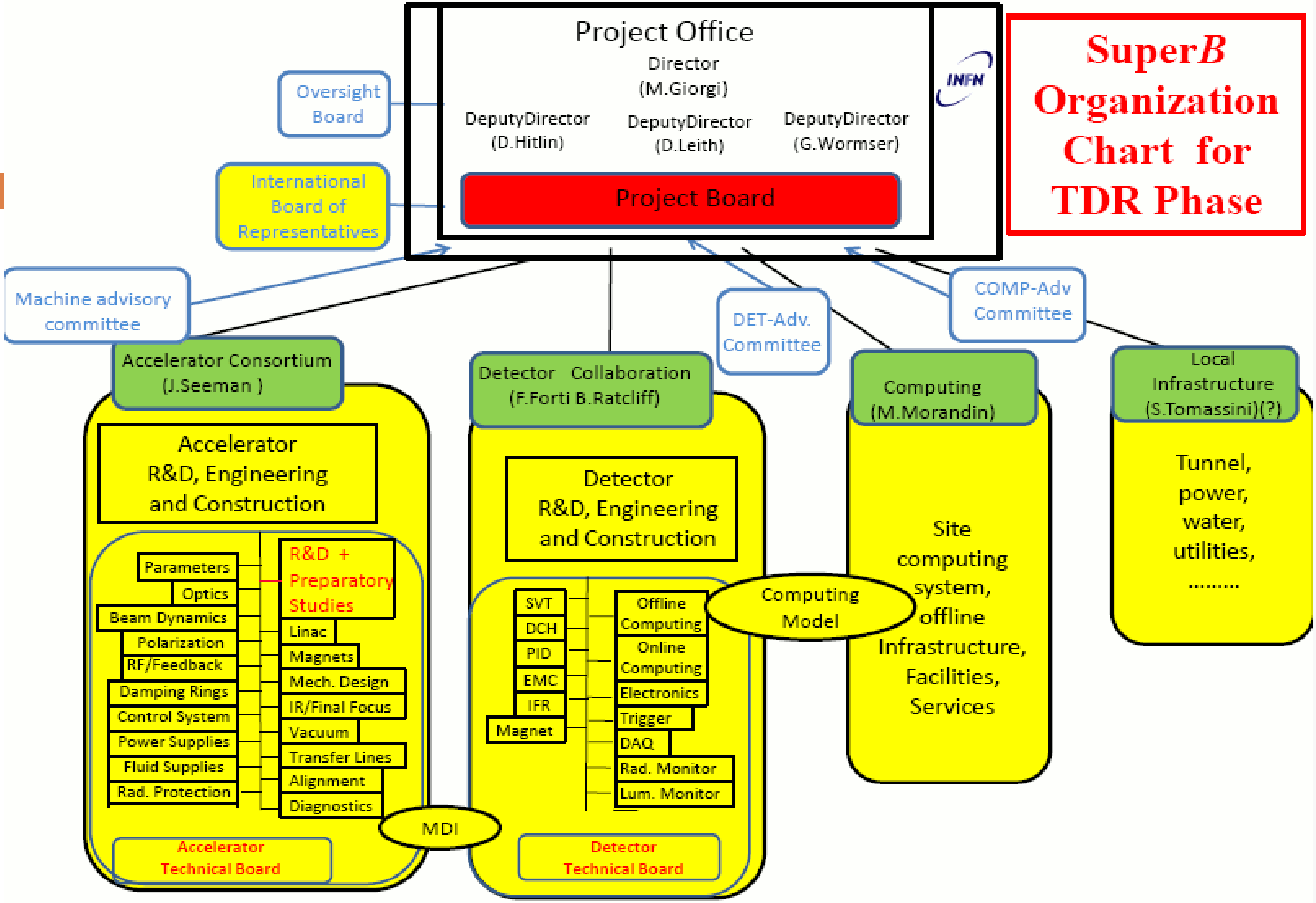
Neutron background

- SiPM are degraded by neutrons, many of them being produced by the tungsten EM shield
- neutron rate decreases with distance from beampipe
- possibly move innermost SiPM outside

Investigating the possibility to move the SiPM of the inner layers in a outer gap



Super*B* Organization Chart for TDR Phase



Project Office

Director (M.Giorgi)

DeputyDirector (D.Hitlin)

DeputyDirector (D.Leith)

DeputyDirector (G.Wormser)

Project Board

INFN

Oversight Board

International Board of Representatives

Machine advisory committee

DET-Adv. Committee

COMP-Adv Committee

Accelerator Consortium (J.Seeman)

Accelerator R&D, Engineering and Construction

- Parameters
- Optics
- Beam Dynamics
- Polarization
- RF/Feedback
- Damping Rings
- Control System
- Power Supplies
- Fluid Supplies
- Rad. Protection

- R&D + Preparatory Studies
- Linac
- Magnets
- Mech. Design
- IR/Final Focus
- Vacuum
- Transfer Lines
- Alignment
- Diagnostics

Accelerator Technical Board

MDI

Detector Collaboration (F.Forti B.Ratcliff)

Detector R&D, Engineering and Construction

- SVT
- DCH
- PID
- EMC
- IFR
- Magnet

- Offline Computing
- Online Computing
- Electronics
- Trigger
- DAQ
- Rad. Monitor
- Lum. Monitor

Detector Technical Board

Computing Model

Computing (M.Morandin)

Site computing system, offline Infrastructure, Facilities, Services

Local Infrastructure (S.Tomassini)(?)

Tunnel, power, water, utilities, ………