Status of the SuperB project

Matteo Rama
Laboratori Nazionali di Frascati
The SuperB project is a next-generation e^+e^- flavor factory based on novel accelerator concepts, aiming at reaching a baseline luminosity of $10^{36}\text{cm}^{-2}\text{s}^{-1}$

- Luminosity 50-80 times larger than current B-factories peak records
- mainly operating at the $Y(4S)$ resonance, it can run at energies between $\Psi(3770)$ and $Y(5S)$
- longitudinal polarization of electron beam ($\sim 80\%$)
- 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**

\[ e^+ e^- \rightarrow Y(4S) \rightarrow B_q \bar{B}_q \]  
\[ (q=u,d) \]  
\[ >80 \times 10^9 \text{ BB} \]  
\[ (*) \]

**B_s physics**

Possible run at \( Y(5S) \)

**Charm physics**

\[ e^+ e^- \rightarrow c\bar{c} \]

\[ \sim 100 \times 10^9 \text{ c}\bar{c} \]  
\[ (*) \]

Possible run at \( \Psi(3770) \)

**\( \tau \) physics**

\[ e^+ e^- \rightarrow \tau^+ \tau^- \]

\[ 70 \times 10^9 \text{ } \tau^+ \tau^- \]  
\[ (*) \]

\[ L = 1 \times 10^{36} \text{ cm}^{-2} \text{s}^{-1} \]

\[ (*) \]  
\[ 75 \text{ ab}^{-1} \text{ in 5 years of baseline } L \]

CM boost \( \beta \gamma = 0.24 \)
the role of SuperB in the LHC era

* New Physics (NP) is expected beyond the Standard Model
  – at what scale $\Lambda$? 0.5, 1, 10...$10^{16}$ TeV?

* Two scenarios:
  – LHC finds New Physics ($\Lambda$ 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

* 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 $\tau$ decay, $\tau$ 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$^{-1}$

- $\Delta m_s$
- $\Delta \Gamma / \Gamma$
- $\sin(\phi_s)$
- $\text{BR}(B_s \to \mu\mu)$
- $\gamma(B_s \to K\bar{K})$
- $\gamma(B_s \to D_s\bar{K})$
- $\Delta S(\phi)$
- $\sin 2\beta$
- $\alpha(\rho, \pi)$
- $\gamma(DK^{(*)}_{GLW})$
- $\gamma(DK_{ADS})$
- $\gamma(DK_{Dalitz})$
- $A_{CP}(B \to (X_s/K^*)\gamma)$
- $C_0 A_{FB}(B \to K^*\ell\bar{\nu})$
- $C_{10} A_{FB}(B \to K^*\ell\nu)$
- $\Delta S(\phi K^0)$
- $\Delta S(\eta' K^0 S)$
- $S(K^*\gamma)$
- $\alpha(\eta \to \text{isospin})$
- $\text{BR}(B^+ \to K^+\nu\bar{\nu})$
- $\text{BR}(B^0 \to D\nu\bar{\nu})$
- $\text{BR}(B \to X_s\gamma)$

- LHCb
- Super B

$B_s$ time dependent analysis only accessible to LHCb

Common

No neutrals, $\nu$, only accessible to SuperB

Comparison from F. Muheim
constraints on charged Higgs from $B \rightarrow \tau \nu$

SUSY Higgs contribution in 2HDM

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

95% CL exclusion regions in the $m(H^+)\cdot \tan\beta$

U. Haisch, arXiv:0805.2141
ATLAS coll, arXiv:0901.0512

analogous constraint from $B \rightarrow D \tau \nu$

note the different scale in $\gamma$

SuperB CDR, 0709.0451

B $\rightarrow \tau \nu$ + B $\rightarrow \mu \nu$
correlation of NP effects in flavor blind MSSM

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

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

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)

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

A. Soni et al, arXiv:1002.0595
Flavor physics to probe (non-)SUSY models

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

- ★★★ large effects
- ★★★ visible but small effects
- ★ negligible effects
- ➡ precision measurement at SuperB

<table>
<thead>
<tr>
<th></th>
<th>AC</th>
<th>RVV2</th>
<th>AKM</th>
<th>δLL</th>
<th>FBMSSM</th>
<th>LHT</th>
<th>RS</th>
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<td>$A_{CP}(B \to X_s\gamma)$</td>
<td>★</td>
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<td>$A_{\tau K}(B \to K^*\mu^+\mu^-)$</td>
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<td>$B \to K^{(*)}\nu\bar{\nu}$</td>
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<tr>
<td>$d_e$</td>
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<tr>
<td>$(g-2)_\mu$</td>
<td>★★★</td>
<td>★★★</td>
<td>★★</td>
<td>★★★</td>
<td>★★★</td>
<td>★</td>
<td>?</td>
</tr>
</tbody>
</table>
Lepton flavor violation in $\tau$ decays

**Upper bound on LFV decay BF in LHT model with NP scale $f=500\,\text{GeV}$**

**hep-ph/0206021**

<table>
<thead>
<tr>
<th>decay</th>
<th>$f = 500,\text{GeV}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\tau \rightarrow e\gamma$</td>
<td>$1 \cdot 10^{-8}$</td>
</tr>
<tr>
<td>$\tau \rightarrow \mu\gamma$</td>
<td>$2 \cdot 10^{-8}$</td>
</tr>
<tr>
<td>$\tau^- \rightarrow e^- e^+ e^-$</td>
<td>$2 \cdot 10^{-8}$</td>
</tr>
<tr>
<td>$\tau^- \rightarrow \mu^- \mu^+ \mu^-$</td>
<td>$3 \cdot 10^{-8}$</td>
</tr>
</tbody>
</table>

Further improvement with polarized $e^-$ beam (60-80%) under study:
- background suppression
- helicity structure of LFV coupling

**PDG**
- $<4.5 \times 10^{-8}$
- $<1.1 \times 10^{-7}$
- $<2.0-3.6 \times 10^{-8}$
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 !!

*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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SM Fit today</th>
<th>SM Fit at SuperB</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\overline{\theta}$</td>
<td>$0.163 \pm 0.028$</td>
<td>$\pm 0.0028$</td>
</tr>
<tr>
<td>$\overline{\eta}$</td>
<td>$0.344 \pm 0.016$</td>
<td>$\pm 0.0024$</td>
</tr>
<tr>
<td>$\alpha$ (°)</td>
<td>$92.7 \pm 4.2$</td>
<td>$\pm 0.45$</td>
</tr>
<tr>
<td>$\beta$ (°)</td>
<td>$22.2 \pm 0.9$</td>
<td>$\pm 0.17$</td>
</tr>
<tr>
<td>$\gamma$ (°)</td>
<td>$64.6 \pm 4.2$</td>
<td>$\pm 0.38$</td>
</tr>
</tbody>
</table>

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.

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

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

Error budget

U. Haisch, Kaon '07
The SuperB physics program is much wider. For extensive reviews see:

- the SuperB CDR: arXiv:0709.0451
- the Physics white paper: will be released soon

**Charm mixing and CP**

<table>
<thead>
<tr>
<th>Observable</th>
<th>B Factories (2 ab$^{-1}$)</th>
<th>SuperB (75 ab$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sin(2\beta)$ $(J/\psi K^0)$</td>
<td>0.30</td>
<td>0.005</td>
</tr>
<tr>
<td>$\cos(2\beta)$ $(J/\psi K^0)$</td>
<td>0.10</td>
<td>0.02</td>
</tr>
<tr>
<td>$\sin(\phi)$ $(D_s^0)$</td>
<td>0.12</td>
<td>0.24</td>
</tr>
<tr>
<td>$\cos(\phi)$ $(D_s^0)$</td>
<td>0.15</td>
<td>0.02</td>
</tr>
</tbody>
</table>

**Spectroscopy**

<table>
<thead>
<tr>
<th>Observable</th>
<th>Error with 1 ab$^{-1}$</th>
<th>Error with 30 ab$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta \tau$</td>
<td>0.16 ps$^{-1}$</td>
<td>0.03 ps$^{-1}$</td>
</tr>
<tr>
<td>$\Gamma$</td>
<td>0.07 ps$^{-1}$</td>
<td>0.01 ps$^{-1}$</td>
</tr>
<tr>
<td>$\beta_\tau$ from angular analysis</td>
<td>20°</td>
<td>8°</td>
</tr>
<tr>
<td>$A_{UL}$</td>
<td>0.006</td>
<td>0.004</td>
</tr>
<tr>
<td>$A_{CH}$</td>
<td>0.004</td>
<td>0.004</td>
</tr>
<tr>
<td>$\mathcal{B}(B_s \to \mu^+\mu^-)$</td>
<td>-</td>
<td>&lt; 8 x 10$^{-9}$</td>
</tr>
<tr>
<td>$</td>
<td>V_{ub}/V_{us}</td>
<td>$</td>
</tr>
<tr>
<td>$\mathcal{B}(B_s \to \gamma \gamma)$</td>
<td>38%</td>
<td>7%</td>
</tr>
<tr>
<td>$\beta_\mu$ from $J/\psi\phi$</td>
<td>10°</td>
<td>3°</td>
</tr>
<tr>
<td>$\beta_\phi$ from $B_s \to K^0 K^0$</td>
<td>24°</td>
<td>11°</td>
</tr>
</tbody>
</table>
The accelerator concept

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

- \( N^+, N^- \): number of electrons/positrons in the bunch
- \( f_{\text{coll}} \): the collision frequency
- \( \sigma_x, \sigma_y \): 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
crab waist test at Dafne

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

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

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

**with the crab waist:**
- many X-Y betatron resonances disappear or become weaker
- good working area is significantly enlarged (large integrated luminosity)
SuperB luminosity expectation

Super-B Integrated Luminosity for 10 Years

Super-B Peak Luminosity versus Year

J. Seeman
detector layout: baseline and 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 (another 10x 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 EMC
- 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
- Benefits on Physics under evaluation

forward PID
- pros and cons under evaluation
  - ☺ improved hadron ld 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
- Benefits 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, $L=10^{36} \text{cm}^{-2}\text{s}^{-1}$ 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 $B \rightarrow \eta'K_s$ and $3K_s$
  - SM corrections tend to prefer $\sin^2 \beta_{\text{eff}} - \sin^2 \beta > 0$
  - 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
New Physics in $|\Delta F|=2$ transitions

* $\Delta F=2$ transitions mediated by box diagrams
* NP can contribute to these processes
  * parameterize NP as:

\[
C_q e^{i\phi_q} = \frac{\langle B_q^0 \mid H_{SM+NP} \mid \bar{B}^0_q \rangle}{\langle B_q^0 \mid H_{SM} \mid \bar{B}^0_q \rangle}
\]

* In SM $C_q=1$ and $\phi_q=0$
* present measurements already constrain NP in $B_d$ mixing
* SuperB will dramatically improve the constraint

<table>
<thead>
<tr>
<th>Parameter</th>
<th>New Physics fit today</th>
<th>New Physics fit at SuperB</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_{B_d}$</td>
<td>$1.24 \pm 0.43$</td>
<td>$\pm 0.031$</td>
</tr>
<tr>
<td>$\phi_{B_d}$ $^{(\circ)}$</td>
<td>$-3 \pm 2$</td>
<td>$\pm 0.4$</td>
</tr>
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</table>
**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 $10\text{ab}^{-1}$

* 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 $\text{BR}(B\rightarrow\text{nothing})$ measured, $B\rightarrow K\nu\bar{\nu}$, $B\rightarrow \tau \nu$, ...

Recoil kinematics well known
Recoil flavour and charge are determined

unique feature of $e^+e^-$ machine
NP search in $B \to s$ invisible

* $B \to K^{(*)}\nu\bar{\nu}$ can probe NP in $Z^0$ penguins
  
* Best exp. bound: $\text{BF}(B \to K\nu\bar{\nu}) < 14 \times 10^{-6}$
  
* SM prediction: $4 \times 10^{-6} \to 20\%$ error with 75$ab^{-1}$
  
* 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 $1/0.7\sim1.40$ more luminosity

\[ B \to K^{+}\nu\bar{\nu} \quad \text{SM} \]

\[ B \to K^{*+}\nu\bar{\nu} \quad \text{SM} \]
<table>
<thead>
<tr>
<th>Mode</th>
<th>Sensitivity</th>
<th>Current</th>
<th>10 ab$^{-1}$</th>
<th>75 ab$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B(B \to X_s \gamma)$</td>
<td>7%</td>
<td>5%</td>
<td>3%</td>
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<tr>
<td>$A_{CP}(B \to X_s \gamma)$</td>
<td>0.037</td>
<td>0.01</td>
<td>0.004–0.005</td>
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<tr>
<td>$B(B^+ \to \tau^+\nu)$</td>
<td>30%</td>
<td>10%</td>
<td>3–4%</td>
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<tr>
<td>$B(B^+ \to \mu^+\nu)$</td>
<td>X</td>
<td>20%</td>
<td>5–6%</td>
<td></td>
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<td>$B(B \to X_s l^+ l^-)$</td>
<td>23%</td>
<td>15%</td>
<td>4–6%</td>
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<tr>
<td>$A_{FB}(B \to X_s l^+ l^-)_{s_0}$</td>
<td>X</td>
<td>30%</td>
<td>4–6%</td>
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<tr>
<td>$B(B \to K\nu\overline{\nu})$</td>
<td>X</td>
<td>X</td>
<td>16–20%</td>
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<td>$S(K_s^0 \pi^0\gamma)$</td>
<td>0.24</td>
<td>0.08</td>
<td>0.02–0.03</td>
<td></td>
</tr>
</tbody>
</table>

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 $B$. 

<table>
<thead>
<tr>
<th>$H^+$ high tan$\beta$</th>
<th>Minimal FV</th>
<th>Non-Minimal FV (1-3)</th>
<th>Non-Minimal FV (2-3)</th>
<th>NP Z-penguins</th>
<th>Right-Handed currents</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B(B \to X_s \gamma)$</td>
<td>X</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>$A_{CP}(B \to X_s \gamma)$</td>
<td>X</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>$B(B \to \tau\nu)$</td>
<td>X-CKM</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>$B(B \to X_s l^+ l^-)$</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>X</td>
<td>X-CKM</td>
</tr>
<tr>
<td>$B(B \to K\nu\overline{\nu})$</td>
<td>O</td>
<td>X</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>$S(K_s^0 \pi^0\gamma)$</td>
<td>X-CKM</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>$\beta$</td>
<td>X-CKM</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>
flexibility for the parameters choice

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
Tests of crab waist at Dafne

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

It works!

successful test at DAFNE

two luminosity monitors
possible sites

SuperB at LNF with Polarization

Tor Vergata campus site
Machine Parameters for $10^{36}$ cm$^{-2}$ s$^{-1}$ (Raimondi)

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 $\rightarrow$ dominant effect on lifetime
  - $e^+e^-e^+e^-$ production $\rightarrow$ $\sim 3\%$ contribution to lifetime, important source for SVT layer-0

- Single beam
  - synchrotron radiation $\rightarrow$ strictly connected to IR design
  - Touschek $\rightarrow$ negligible in BaBar, important in SuperB
  - beam-gas
  - intra-beam scattering

<table>
<thead>
<tr>
<th>Source</th>
<th>Cross section</th>
<th>Evt/bunch$_{\text{xing}}$</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam Strahlung</td>
<td>$\sim 340$ mbarn (E$<em>Y$/E$</em>{\text{beam}} &gt; 1%$)</td>
<td>$\sim 680$</td>
<td>0.3THz</td>
</tr>
<tr>
<td>rad. Bhabha</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\sim 40$ mbarn (E$<em>Y$/E$</em>{\text{beam}} &gt; 50%$)</td>
<td>$\sim 80$</td>
<td>35GHz</td>
</tr>
<tr>
<td>pair production</td>
<td>$\sim 7.3$ mbarn</td>
<td>$\sim 15$</td>
<td>7GHz</td>
</tr>
<tr>
<td>Elastic Bhabha</td>
<td>O(10$^{-4}$) mbarn (Det. acceptance)</td>
<td>$\sim 200$/Million</td>
<td>100KHz</td>
</tr>
<tr>
<td>$\Upsilon(4S)$</td>
<td>O(10$^{-6}$) mbarn</td>
<td>$\sim 2$/Million</td>
<td>1 KHz</td>
</tr>
</tbody>
</table>
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: $<\Delta L>=250\mu m$; SuperB: $<\Delta L>=106\mu m$
- 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
  - keep material of beampipe+layer-0 to a minimum to minimize mult. scattering

![Graph showing $\Delta t$ sigma vs Layer 0 $X_0$ for different radii and comparing SuperB and BaBar data]

B$\rightarrow\pi\pi$ channel, 10 $\mu$m hit resolution
layer 0 strategy

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

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

background occupancy summary*

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Small-angle Bhabha</td>
<td>~2%</td>
</tr>
<tr>
<td>Pair production</td>
<td>0.5-1.0%</td>
</tr>
<tr>
<td>Large-angle radiative Bhabha</td>
<td>0.4%</td>
</tr>
</tbody>
</table>

* 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 \( P(\pi, K) > 0.7\text{GeV}/c \) (use \( dE/dx \) for \( p < 0.7\text{GeV}/c \))
- Baseline is to reuse BaBar DIRC design
  - Excellent performance to 4\( \text{GeV}/c \)
  - 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

\[ \rightarrow 10 \text{ times bkg rate reduction} \]

PMTs 10 times faster than Babar

\[ \rightarrow 10 \text{ times bkg rate reduction} \]

**Total:** 100 times bkg rate reduction
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)
  - $5\sigma$ significance (stat-only):
    - BaBar: $\sim 55ab^{-1}$
    - SuperB-base line: $\sim 48ab^{-1}$
    - $+TOF$: $\sim 44ab^{-1}$
  - Gain on significance:
    - boost $\sim 7\text{-}8\%$
    - fwd PID $\sim 5\%$

  - Results without machine backgrounds
The electromagnetic calorimeter

BaBar Barrel
5760 CsI(Tl) Crystals

Essential detector to measure energy and direction of $\gamma$ and $e$, discriminate between $e$ and $\pi$, 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 free 10cm for a fwd PID system
    - expensive (~40$/cc) [price of 2009]

- **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

![Diagram of EMC endcaps]

- $B \to \tau\nu$: $S/\sqrt{S+B}$ increases by $\sim 8\%$
  
  - with bwd EMC (machine bkg **NOT** included)

  - need to repeat the analysis with machine bkg
The IFR

- Provides discrimination between $\mu$ and $\pi^\pm$. Help detection and direction measurement of $K_L$ (together with EMC)
- Add absorber w.r.t. BaBar to improve $\pi/\mu$ separation. Amount and distribution is being optimized
  - baseline: 92cm of iron (5.5 $\lambda$), 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
Layout optimization

three configurations

\[
\begin{array}{|c|c|c|c|c|c|}
\hline
| & 12 & 12 & 12 & 12 & 10 | \\
\hline
C_{14} & Fe & 620 \text{ mm} \\
\hline
| & 16 & 16 & 16 & 16 & 14 | \\
\hline
C_{13} & Fe & 820 \text{ mm} \\
\hline
| & 24 & 24 | & 14 | & 10 | \\
\hline
C_{12} & Fe & 920 \text{ mm} \\
\hline
\end{array}
\]

beam test of prototype planned at Fermilab

muon efficiency when pion misId=2%

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
SuperB Organization Chart for TDR Phase

Project Office
Director (M. Giorgi)
Deputy Director (D. Hitlin)
Deputy Director (D. Leith)
Deputy Director (G. Wormser)

Project Board

Oversight Board
International Board of Representatives
Machine Advisory Committee

Accelerator Consortium (J. Seeman)

Detector Collaboration (F. Forti, B. Ratcliff)

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

Detector R&D, Engineering and Construction
SVT
- Offline Computing
DCH
- Online Computing
PID
- Electronics
EMC
- Trigger
IFR
- DAQ
Magnet
- Rad. Monitor
MDI
- Lum. Monitor

Detector Technical Board

Computing (M. Morandin)

Site Computing System, offline Infrastructure, Facilities, Services

Computing Model

COMP-Adv Committee

Local Infrastructure (S. Tomassini)(?)

Tunnel, power, water, utilities, ........