SuperB: A Detector For A Very High Luminosity Electron Positron Collider @ Y(4S)

Eugenio Paoloni (I.N.F.N & Università di Pisa) for The SuperB collaboration
## MACHINE AT A GLANCE

\[ \mathcal{L} \approx f_{\text{coll}} \frac{N^+ N^-}{4\pi \sigma_y \sqrt{\sigma_x^2 + \sigma_z^2 \tan^2 \theta}} \geq 10^{36} \text{Hz/cm}^2 \]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>LER</th>
<th>HER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle type</td>
<td>(e^+)</td>
<td>(e^-)</td>
</tr>
<tr>
<td>Energy (GeV)</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Luminosity (cm(^{-2})s(^{-1}))</td>
<td>1.0 (\times 10^{36})</td>
<td></td>
</tr>
<tr>
<td>Circumference (m)</td>
<td>2250</td>
<td></td>
</tr>
<tr>
<td>Number of bunches</td>
<td>1733</td>
<td></td>
</tr>
<tr>
<td>Particles/bunch (\times 10^{10})</td>
<td>6.16</td>
<td>3.52</td>
</tr>
<tr>
<td>Beam current (A)</td>
<td>2.28</td>
<td>1.30</td>
</tr>
<tr>
<td>(\beta_y) (mm)</td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td>(\beta_x) (mm)</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>(\epsilon_y) (pm-rad)</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>(\epsilon_x) (nm-rad)</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>(\sigma_y^*) (nm)</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>(\sigma_x^*) ((\mu)m)</td>
<td>5.657</td>
<td></td>
</tr>
<tr>
<td>Bunch length (mm)</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>RF Power (MW)</td>
<td>17</td>
<td></td>
</tr>
</tbody>
</table>
Detector Design ~ BaBar

• Driving forces

  • Machine: lower boost (smaller longitudinal separation of secondary vertices)

  ✴ Vertex detector with higher resolution

  • Physics goals: higher luminosity (hence bkg. rates)

  ✴ Faster & more robust detectors

  • Common sense: costs

  ✴ Reuse as much as possible & reasonable

• BaBar/Belle will fit the requirements

  • Improve performances where needed & feasible
**Backgrounds Issues**

- Luminosity scaling backgrounds are the main issue
- Huge QED cross sections at the IP
  - Low currents / high luminosity
    - Beam-gas backgrounds are not a problem
    - Synchrotron radiation light from the Final Focus can be shielded

<table>
<thead>
<tr>
<th></th>
<th>Cross section</th>
<th>Evt/bunch xing</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiative Bhabha</td>
<td>~340 mbarn (Eγ/Ebeam &gt; 1%)</td>
<td>~680</td>
<td>0.3THz</td>
</tr>
<tr>
<td>e^+_e^- pair production</td>
<td>~7.3 mbarn</td>
<td>~15</td>
<td>7GHz</td>
</tr>
<tr>
<td>Elastic Bhabha</td>
<td>O(10^{-5}) mbarn (Det. acceptance)</td>
<td>~20/Million</td>
<td>10KHz</td>
</tr>
<tr>
<td>Υ (4S)</td>
<td>O(10^{-6}) mbarn</td>
<td>~2/million</td>
<td>1 KHz</td>
</tr>
</tbody>
</table>
SuperB emittances cannot be achieved with the present B-factories energy asymmetries

Lower energy to boost the B mesons
- Babar: 9 GeV + 3.1 GeV \( \beta\gamma = 0.56 \)
- Belle: 8 GeV + 3.5 GeV \( \beta\gamma = 0.45 \)
- SuperB: 7 GeV + 4 GeV \( \beta\gamma = 0.28 \)

Time dependent analyses are possible only if the vertexing resolution is able to distinguish the two B decay vertices:
- small radius beam pipe
- very little material in b.p. and first layer

A b.p. with r \( \sim \)1cm is highly desirable
Silicon Vertex Tracker

- Baseline: use an SVT similar to the Babar one, complemented by one or two inner layers.
  - Cannot reuse because of radiation damage
- Beam pipe radius is of paramount importance
  - Inner radius: 1.0 cm,
  - Layer 0 radius: 1.2 cm,
  - Thickness: 0.5% $X_0$
SVT Layer Zero

Severe background from pairs production ($e^+e^- \rightarrow e^+e^- e^+e^-$)

- **Striplets (baseline)**
  - Basically already available technology but more sensitive to background. OK up to $\sim \text{MHz/cm}^2$
  - Some margin to improve background sensitivity

- **Monolithic Active Pixel (option)**
  - Big safety margin in terms of performance and occupancy
  - Cooling and mechanical issues need to be addressed
  - But R&D is still ongoing.
Drift Chamber

• Basic technology adequate.
• Cannot reuse BaBar DCH because of aging
• Baseline:
  • Same gas, same cell shape
  • Carbon fiber endplates instead of Al to reduce thickness
• Options/Issues to be studied:
  • Miniaturization and relocation of readout electronics
    • Critical for backward calorimetric coverage
  • Conical endplate
  • Further optimization of cell size/gas
• DIRC is essential for Kaon-Pion discrimination above 0.7 GeV
• Barrel DIRC baseline
  • Quartz bars are OK and can be reused
    • Almost irreplaceable
    • PMTs are aging and need to be replaced
  • Keep mechanical support
• Barrel Options
  • Faster PMTs
  • Focusing readout
  • Different radiator
**Option: EndCaps PID**

- Extending PID coverage to the forward and backward considered
- Possibly useful, physics case needs to be established quantitatively
- Serious interference with other systems
  - Material in front of the EMC
  - Needs space
    - cause displacement of front face of EMC
    - require miniaturization and displacement of DCH electronics
  - TOF seems the only viable option

**Technologies**

- Aerogel-based focusing RICH
  - Working device
  - Requires significant space (>25 cm)
- Time of flight
  - Need about 10ps resolution to be competitive with focusing RICH
  - 15-20ps OK, 10ps seems to be achievable, although not easy
Calorimeter

- Barrel CsI(Tl) crystals
  - Still OK and can be reused (the most expensive detector in BaBar)
  - Baseline is to transport barrel as one device
    - Various other transportation options

- Forward Endcap EMC
  - BaBar crystal are damaged by radiation and need to be replaced
  - Occupancy at low angle makes CsI(Tl) too slow
    - Pure CsI, LSO

- Backward EMC option
  - Because of material in front will have a degraded performance
    - Maybe just a VETO device for rare leptonic B decays as $B \rightarrow \tau \nu$.
  - Physics impact needs to be quantitatively assessed
  - DIRC bars are necessarily in the middle
  - DCH electronics relocation is critical for the performance
Both pure CsI and LSO could be used in the forward EMC

- LSO more expensive, but more light, more compact, and more radiation hard
  - Now LSO is available industrially
  - Cost difference still significant, but not overwhelming.

- Use LSO as baseline
  - Gives better performance
  - Leaves PID option open

- CsI option still open
  - in case of cost/availability issues

\[\text{SIPAT LSO}\]

<table>
<thead>
<tr>
<th>Crystal</th>
<th>CsI (Tl)</th>
<th>CsI</th>
<th>LSO</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\tau) decay (ns)</td>
<td>680, 16</td>
<td>3340</td>
<td>47</td>
</tr>
<tr>
<td>(\chi_0) (cm)</td>
<td>1.86</td>
<td>1.86</td>
<td>1.14</td>
</tr>
<tr>
<td>(R_{\text{moliere}}) (cm)</td>
<td>3.8</td>
<td>3.8</td>
<td>2.3</td>
</tr>
<tr>
<td>(\lambda_{\text{nuclear}}) (cm)</td>
<td>37</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>(\text{LY (}\gamma/\text{MeV}))</td>
<td>56000, 2500</td>
<td>64:36%</td>
<td>27000</td>
</tr>
<tr>
<td>(\lambda_{\text{peak}}) (nm)</td>
<td>550</td>
<td>315</td>
<td>420</td>
</tr>
<tr>
<td>(\text{Rad Hard (Mrad)})</td>
<td>.01</td>
<td>.01 - .1</td>
<td>100</td>
</tr>
<tr>
<td>(\rho) (g/cm³)</td>
<td>4.51</td>
<td>4.51</td>
<td>7.40</td>
</tr>
<tr>
<td>(n_0)</td>
<td>1.79</td>
<td>1.95</td>
<td>1.82</td>
</tr>
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</table>

Bakward calorimeter

- Keep as an option
  - Backward endcap
  - Barrel extension

- Could be less performant
  - Lead – scintillator?

- Benchmark physics gain
**IFR: Steel Thickness**

- **BaBar configuration has too little iron for \( \mu \) ID**
  - > 6.5 \( \lambda_i \) required; 4-5 available in barrel

- **Fine segmentation overdid \( K_L \) efficiency optimization**
  - Focus on \( \mu \) ID: fewer layers and more iron

- **Baseline:**
  - Fill gaps in Babar IFR with more iron
  - Leave 7-8 detection layers
  - Need to verify structural issues
  - Scintillator bars à la MINOS because rates in the 100Hz/cm\(^2\) range

- **Cost effectiveness of steel reuse needs to be fully assessed**
Hadron 07: Frascati, 12 Oct

Extruded Scintillators

- R&D going on
- Studies on Wavelength Shifter (WLS) optical fiber
- Matching of WLS fiber with the scintillator bars
- First measurements from a cosmic test stand
- Light yield, efficiency, spatial/temporal resolution
**Data Acquisition**

- **L1 Trigger rate of 100-150KHz**
  - Unless a hardware Bhabha rejector is developed
  - Up from 5KHz current Babar rate

- **Event size**
  - More readout channels
  - “Interesting Physics” rate
    - @ SuperB 5 KHz (S/N = 20-30)
    - @ BaBar 50Hz (S/N = 100)
  - Bigger mean event size

- **Some electronics could be reusable**
  - Especially front-end cards, maybe power supplies

- **The bulk of the electronics is obsolete and unmaintainable**
  - Should be remade with state-of-the-art technology

- **Clearly a major cost driver**
  - Costed using recent experiments experience (LHC)

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<table>
<thead>
<tr>
<th>Parameter</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
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<tbody>
<tr>
<td>Luminosity (ab⁻¹)</td>
<td>2</td>
<td>6</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Storage (PB)</td>
<td></td>
<td></td>
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<tr>
<td>Tape</td>
<td>3.1</td>
<td>10.2</td>
<td>22.0</td>
<td>26.2</td>
<td>27.8</td>
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<td>Disk</td>
<td>0.83</td>
<td>3.35</td>
<td>7.55</td>
<td>10.2</td>
<td>10.2</td>
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<tr>
<td>CPU (Mflop/2000)</td>
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<td></td>
<td></td>
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<tr>
<td>Data reconstruction</td>
<td>3.0</td>
<td>8.8</td>
<td>14.7</td>
<td>8.8</td>
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<tr>
<td>Skimming</td>
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<td>9.1</td>
<td>16.1</td>
<td>12.1</td>
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<td>Monte Carlo</td>
<td>9.5</td>
<td>28.0</td>
<td>46.6</td>
<td>28.0</td>
<td>0.0</td>
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<tr>
<td>Physics analysis</td>
<td>5.1</td>
<td>15.0</td>
<td>30.0</td>
<td>30.0</td>
<td>30.0</td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
<td>61</td>
<td>107</td>
<td>79</td>
<td>30</td>
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</table>
Lot more informations written into our Conceptual Design Report

(physics + machine + detector)

INFN/AE-07/02, SLAC-R-856, LAL 07-15

Available at:

www.pi.infn.it/SuperB

arxiv.org/abs/0709.0451

476 pages

Printed and available

Copies can be requested from Lucia.Lilli@pi.infn.it

Join you too the SuperB team!
Figure 5.1. Overall schedule for the construction of the SuperB project.