BDS report

BDS Area leaders
Deepa Angal-Kalinin, Hitoshi Yamamoto, Andrei Seryi
VLCW06, Vancouver, July 19-22, 2006
Contents

- Important design updates since Bangalore
- Cost of baseline and other configurations
- Plans
Design updates since Bangalore

- Prototyping SC magnets for 14mr FD
- Evaluation of losses in extraction lines
- Detailed design of crab cavities
- Design of anti-solenoid & tail-folding octupoles
- Wakes in vacuum chamber
- Studies of SUSY reach
- SR backscattering in 2mrad extraction
- Evaluation of downstream diagnostics
- Work on 0mrad case
- 2mrad extraction magnet brainstorm
- More updates & more details in BDS R&D talk
FD14: SD0/OC0 prototype

QD0 short model successfully tested earlier
FD14 design

Focus on 14mr design to push technology
Size and interface of shared cryostat being optimized with detector
Feedback area being designed

14 mr Shared Cryostat
(IP End)

Sized optimized for detector opening

Interface region being optimized with forward detector region

Feedback kicker area

1 m

QF1

SD0

BNL

Global Design Effort
Losses in extraction line

20mrad: losses < 100W/m at 500GeV CM and 1TeV CM

20mrad

Losses < 100W/m at 500GeV CM and 1TeV CM

2mrad: losses are at 100W/m level for 500GeV CM and exceed this level at 1TeV

2mrad

Losses are mostly due to SR. Beam loss is very small

Radiation conditions and shielding to be studied

J. Carter, I. Agapov, G.A. Blair, L. Deacon (JAI/RHUL), A.I. Drozhdin, N.V. Mokhov (Fermilab), Y.M. Nosochkov, A.A. Seryi (SLAC)
Crab cavity

Right: earlier prototype of 3.9GHz deflecting (crab) cavity designed and build by Fermilab.

Left: Cavity modeled in Omega3P, to optimize design of the LOM, HOM and input couplers.


Collaboration of FNAL, SLAC and UK labs is working on the design.

Submitted coordinated UK & US plans to design and build ILC compatible crab cavity & develop phase stabilization.
Tail folding octupoles & antisolenoids

Antisolenoids (needed for both IRs to compensate solenoid coupling locally) with High Temperature Superconductor coils

Superferric TFOs (for beam halo handling) with modified serpentine pattern can achieve 3T equivalent at r=10mm
Emittance growth for SS vacuum chamber is unacceptably large.

Partial change to Cu or Al chamber and optimization of aperture reduces the growth to ~5% for 1σ initial offset.

Misalignments of vacuum chamber can cause emittance growth – require further R&D.
Benchmarks for evaluation of ILC detectors

<table>
<thead>
<tr>
<th>Process and Final states</th>
<th>Energy (TeV)</th>
<th>Observables</th>
<th>Target Accuracy</th>
<th>Detector Challenge</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>$e^+e^-	o Z^0 h^0 \to t\bar{t}+X$</td>
<td>0.35</td>
<td>$\sigma_{gg}$, $\Gamma_{h^0}$</td>
<td>$\delta\sigma_{gg}=2.5%$, $\delta\Gamma_{h^0}=1%$</td>
<td>T</td>
<td>(1)</td>
</tr>
<tr>
<td>$e^+e^-	o Z^0 h^0, h^0 \to b\bar{b}/(e/\gamma\tau)$</td>
<td>0.35</td>
<td>$\sigma_{gg}$, $\Gamma_{h^0}$</td>
<td>$\delta\sigma_{gg}=40$ MeV, $\delta(\sigma_{gg} \times BR)=1%/7%/5%$</td>
<td>V</td>
<td>(2)</td>
</tr>
<tr>
<td>$e^+e^-	o Z^0 h^0, h^0 \to WW^{*}$</td>
<td>0.35</td>
<td>$\sigma_{gg}$, $\sigma_{gg}WW^{*}$</td>
<td>$\delta\sigma_{gg}=BR_{WW^{*}}=5%$</td>
<td>C</td>
<td>(3)</td>
</tr>
<tr>
<td>$e^+e^-	o Z^0 h^0, h^0 \to \gamma\gamma$</td>
<td>1.0</td>
<td></td>
<td>$\delta\sigma_{gg}=BR_{\gamma\gamma}=5%$</td>
<td>C</td>
<td>(4)</td>
</tr>
<tr>
<td>$e^+e^-	o Z^0 h^0, h^0 \to \mu^+\mu^-$</td>
<td>1.0</td>
<td>$M_{h^0}$</td>
<td>$5\sigma$ Evidence for $M_{h^0}=120$ GeV</td>
<td>T</td>
<td>(5)</td>
</tr>
<tr>
<td>$e^+e^-\to h^0, h^0 \to invisible$</td>
<td>0.35</td>
<td>$\sigma_{gg}$</td>
<td>$5\sigma$ Evidence for BR invisibility=2.5%</td>
<td>C</td>
<td>(6)</td>
</tr>
<tr>
<td>$e^+e^-\to t\bar{t}+0$</td>
<td>1.0</td>
<td>$\sigma_{t\bar{t}}$</td>
<td>$\delta\sigma_{t\bar{t}}=5%$</td>
<td>C</td>
<td>(7)</td>
</tr>
<tr>
<td>$e^+e^-\to Z^0 h^0, h^0 \to \phi\phi$</td>
<td>0.5/1.0</td>
<td>$M_{h^0}$, $M_{h^0}$</td>
<td>$\delta\sigma_{gg}=1%$</td>
<td>C</td>
<td>(8)</td>
</tr>
<tr>
<td>$e^+e^-\to W^+W^-$</td>
<td>0.5</td>
<td>$\Delta\sigma_{W}, \Delta \lambda = 2 \times 10^{-4}$</td>
<td>$\Delta\sigma_{W}, \Delta \lambda = 3$ TeV</td>
<td>V</td>
<td>(9)</td>
</tr>
<tr>
<td>$e^+e^-\to W^+W^-/Z^0Z^0$</td>
<td>1.0</td>
<td>$\sigma_{W}$</td>
<td>$\Delta\sigma_{W}, \Delta \lambda = 3$ TeV</td>
<td>C</td>
<td>(10)</td>
</tr>
<tr>
<td>$e^+e^-\to Z^0 h^0, h^0 \to \gamma\gamma$</td>
<td>0.5</td>
<td>$E_{\gamma}, E_{\gamma\gamma}$</td>
<td>$\delta M_{\gamma\gamma}=50$ MeV</td>
<td>T</td>
<td>(12)</td>
</tr>
<tr>
<td>$e^+e^-\to Z^0 h^0, h^0 \to \mu^+\mu^-$</td>
<td>0.5</td>
<td>$E_{\mu}, E_{\mu\mu}$</td>
<td>$\delta M_{\mu\mu}=200$ MeV</td>
<td>T</td>
<td>(13)</td>
</tr>
<tr>
<td>$e^+e^-\to Z^0 h^0, h^0 \to \tau^+\tau^-$</td>
<td>0.5</td>
<td>$E_{\tau}, E_{\tau\tau}$</td>
<td>$\delta M_{\tau\tau}=2$ GeV</td>
<td>C</td>
<td>(14)</td>
</tr>
<tr>
<td>$e^+e^-\to Z^0 h^0, h^0 \to \gamma\gamma$</td>
<td>0.5</td>
<td>$M_{h^0}$ in $jj\ell\ell$, $M_{h^0}$ in $jj\ell\ell$</td>
<td>$\delta M_{h^0}=1$ GeV, $\delta M_{h^0}=500$ MeV</td>
<td>F</td>
<td>(15)</td>
</tr>
<tr>
<td>$e^+e^-\to Z^0 h^0, h^0 \to ZZ^{<em>}$, $W^{</em>}W^{*}$</td>
<td>0.5</td>
<td>$Z^{<em>}Z^{</em>}, W^{<em>}W^{</em>}$</td>
<td>$\delta M_{Z^{<em>}Z^{</em>}}, \delta M_{W^{<em>}W^{</em>}}=500$ MeV</td>
<td>C</td>
<td>(16)</td>
</tr>
<tr>
<td>$e^+e^-\to H^0 A^0$, $H^0 A^0 \to b\bar{b}b\bar{b}$</td>
<td>1.0</td>
<td>Mass constrained $M_{h^0}$</td>
<td>$\delta M_{h^0}=1$ GeV</td>
<td>C</td>
<td>(17)</td>
</tr>
<tr>
<td>$e^+e^-\to Z^0 h^0, h^0 \to b\bar{b}b\bar{b}$</td>
<td>1.0</td>
<td>Mass constrained $M_{h^0}$</td>
<td>$\delta M_{h^0}=1$ GeV</td>
<td>C</td>
<td>(18)</td>
</tr>
<tr>
<td>$e^+e^-\to Z^0 h^0, h^0 \to \gamma\gamma$</td>
<td>0.5</td>
<td>Heavy stable particle</td>
<td>$\delta M_{h^0}$</td>
<td>T</td>
<td>(19)</td>
</tr>
<tr>
<td>$e^+e^-\to Z^0 h^0, h^0 \to \gamma\gamma$</td>
<td>0.5</td>
<td>Non-pointing $\gamma$</td>
<td>$\delta\sigma_{\gamma}=10%$</td>
<td>C</td>
<td>(20)</td>
</tr>
<tr>
<td>$e^+e^-\to Z^0 h^0, h^0 \to E_{\gamma}$</td>
<td>0.5</td>
<td>Soft $\pi^0$ above $\gamma\gamma$ bkgd</td>
<td>$5\sigma$ Evidence for $\Delta m_{\gamma}=0.2$-2 GeV</td>
<td>F</td>
<td>(21)</td>
</tr>
<tr>
<td>$e^+e^-\to Z^0 h^0, h^0 \to h^0 h^0$</td>
<td>0.5</td>
<td>$\sigma_{gg}$, $\sigma_{gg}h^0h^0$</td>
<td>$5\sigma$ Sensitivity for $(y-2\pi)/2 \leq 10^{-3}$</td>
<td>V</td>
<td>(22)</td>
</tr>
<tr>
<td>$e^+e^-\to Z^0 h^0, h^0 \to h^0 h^0$</td>
<td>0.5</td>
<td>$\sigma_{gg}$, $\sigma_{gg}h^0h^0$</td>
<td>$5\sigma$ Sensitivity to $M_{h^0}=7$ TeV</td>
<td>C</td>
<td>(23)</td>
</tr>
<tr>
<td>$e^+e^-\to Z^0 h^0, h^0 \to h^0 h^0$</td>
<td>0.5</td>
<td>$\sigma_{gg}$, $\sigma_{gg}h^0h^0$</td>
<td>$5\sigma$ Sensitivity to $M_{h^0}=7$ TeV</td>
<td>C</td>
<td>(24)</td>
</tr>
</tbody>
</table>

Reaction which cares most about crossing angle is
\[ ee \to \tilde{\tau}_1^+ \tilde{\tau}_1^-, \tilde{\chi}_1^+ \tilde{\chi}_1^- \] (Point 3)

Detection is challenged by copious
\[ ee \to \tau^+\tau^- e^+e^- \]
which require low angle tagging.

Tagging is challenged by background from pairs and presence of exit hole.
Study of SUSY reach

• SUSY reach is challenged for the large crossing angle when $\Delta m$ (slepton-neutralino) is small

• Studies presented at Bangalore (V.Drugakov) show that for 20mrad+DID (effectively ~40mrad for outgoing pairs), due to larger pairs background, one cannot detect SUSY dark matter if $\Delta m=5$GeV

• The cases of 20 or 14mrad with anti-DID have same pairs background as 2mrad. Presence of exit hole affects detection efficiency slightly. The SUSY discovery reach may be very similar in these configurations

• Several groups are studying the SUSY reach, results may be available after Vancouver
Backscattering of SR

FD produce SR and part will hit BYCHICMB surface
Total Power = 2.5 kW
\(<E_\gamma> = 11\text{MeV (for 250GeV/beam)}\)

Takashi Maruyama

<table>
<thead>
<tr>
<th>Energy (GeV)</th>
<th>Rate (10^{-8})</th>
<th>#(\gamma) at IP/BX</th>
<th>#(\gamma) in SiTracker from pairs</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>1.1</td>
<td>2200</td>
<td>700</td>
</tr>
<tr>
<td>500</td>
<td>2.9</td>
<td>11700</td>
<td>1900</td>
</tr>
</tbody>
</table>

Flux is 3-6 times larger than from pairs. More studies & optimization needed.

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BDS: 12
Downstream diagnostics evaluation (1)

Study achievable precision of polarization and energy measurements, background & signal/noise, requirements for laser, etc.
## Downstream diagnostics evaluation (2)

<table>
<thead>
<tr>
<th>Comparisons for 250GeV/beam</th>
<th>20mr</th>
<th>2mr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam overlap with 100mm laser spot at Compton IP</td>
<td>48%</td>
<td>15%</td>
</tr>
<tr>
<td>Polarization projection at Compton IP</td>
<td>99.85%</td>
<td>99.85%</td>
</tr>
<tr>
<td>Beam loss from IP to Compton IP</td>
<td>&lt;1E-7</td>
<td>&gt;2.6E-4</td>
</tr>
<tr>
<td>Beam SR energy loss from IP to middle of energy chicane</td>
<td>119MeV</td>
<td>854MeV</td>
</tr>
<tr>
<td>Variation of SR energy loss due to 200nm X offset at IP</td>
<td>&lt; 5MeV (&lt; 20 ppm)</td>
<td>25.7MeV (~100 ppm)</td>
</tr>
<tr>
<td>The need for SR collimator at the Cherenkov detector</td>
<td>yes</td>
<td>No</td>
</tr>
</tbody>
</table>

The need for SR collimator at the Cherenkov detector is **yes** for 20mr and **No** for 2mr, which is comparable with the goal for E precision measurements.
Recent work on 0mr

Put together a full optics with downstream diagnostics (FF is optimized for this case)

Design only for 500GeV CM, and bunch separation 307ns or more

A lot more design work is needed before it could be fully evaluated

Design for 1TeV to be studied

UK-France-SLAC task force


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0 mrad disrupted $\sqrt{\beta} \varepsilon$ at 250 GeV

$\max \sim 0.3 \text{ cm}$

0 mrad $\sqrt{\beta} \varepsilon$ at $\Delta p/p = -30\%$

$\max \sim 170 \text{ cm}$

Over-focusing by FD increases the size of disrupted beam starting from $\Delta E > 10\%$
Brainstorm to design magnets in 2mrad extraction

Some magnet sizes on this drawing are tentative
Brainstorm for 2mrad magnets

Recent suggestions

Power @ 1TeV CM is 1MW/magnet. Temperature rise is very high. Use of HTS? Pulsed? Further feasibility study and design optimization are needed.

Power @ 1TeV CM is 635-952 KW/magnet. Pulsed may be feasible?

Vladimir Kashikhin, Brett Parker, John Tompkins, Cherrill Spencer, Masayuki Kumada, Koji Takano, Yoshihisa Iwashita, Eduard Bondarchuk, Ryuhei Sugahara

QEX3 should have 6-60GS field!

QEX5 should have 6-60GS field!

beamstrahlung

Clear aperture is 305 x 80 mm for a 2.5 mm wall thickness

1/4 of Full Model

$B_0 = 0.439 \, T$

$|B|$ is about 1 gauss inside cutout region

Make simple racetrack coils that go around poles and insert right/left cutouts with beam pipes during final assembly.

Power @ 1TeV CM is 635-952 KW/magnet. Pulsed may be feasible?
2 mrad extraction magnet status

- There were a lot of recent work and ideas
- Some of recent suggested designs did not take all constraints into account
- It appears that there is a chance that a working design would be found, if not DC then pulsed magnets
- There is a lot of work and R&D to be done to come to a reasonable design
- Implications for operation and MPS to be studied, mitigations to be found
- For the cost, assigned same as QEX6 for these magnets
BDS cost status

- So far haven’t received:
  - cost of kickers & septa
  - cost of anti-solenoids
  - some CF&S costs not available, e.g. beam dump enclosures
  - use estimated placeholder for these costs
- Some items may be missing, like part of support for FD, cost of concrete neutron wall, etc.
- Overall > 90% complete
- The design and cost is for 1TeV CM
Overall cost: BDS 20/2 baseline

- Cost drivers
  - CF&S
  - Magnet system
  - Vacuum system
  - Installation
  - Dumps & Colls.

- They are analyzed below
Cost of different configuration

- The WBS includes counts, lengths, or cost fractions from different subsystems of BDS:

<table>
<thead>
<tr>
<th>WBS Description</th>
<th>comm</th>
<th>spec</th>
<th>large</th>
<th>small</th>
<th>total</th>
<th>IR20</th>
<th>IR2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.6 BDS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.6.1.1 D166L1000</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>1.6.1.2 D166L2000</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>1.6.1.3 D20L12000</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
</tbody>
</table>

- WBS has ~240 input lines * 39 columns not including the sub-WBSs
- This allows calculating the total cost and also the common cost, additional cost for 20mrad IR and additional cost for 2mrad IR
Overall cost split: BDS 20/2

• Additional costs for IR20 and IR2 are different
• They are explained below
Instrumentation cost splits rather evenly. Difference of the length of extraction line is responsible for cost difference of add_IR20 and add_IR2. Large common fraction is due to shared lasers.
Control cost dominated by the cost of crab cavity which costs somewhat more for IR_20. This explains the difference and the smaller common cost.
Vacuum system: BDS 20/2 alt

Long large aperture extraction line and additional vacuum chamber for beamstrahlung photons cause the cost difference.

Have two versions of estimation, with different materials:

This version uses Al in main beamlines, and Cu where larger losses may be expected. The SS chamber used in $\gamma$ extraction line.

Other version is SS+Cu coated in regions contributing most to the wakes (slightly more expensive).
Dumps & collimators: BDS 20/2

Larger number of collimators in 2mrad extraction line and additional photon dump cause the difference.
Magnet system: BDS 20/2

Larger number of huge extraction line magnets, and its power supplies (PS) cause the cost difference.
Power for magnets

BDS power for magnets (1TeV CM)

Power, MW

- Common: 1.3 MW
- Add for IR 20: 8.0 MW
- Add for IR 2: 62.2 MW
The common fraction is quite large. The difference come from beam dump halls and mostly from cooling water.
Full length service tunnel in BDS solves issues of access, egress, T stability, places for PS, access to laser rooms, etc. This solution saves ~percent of BDS cost (could be site dependent).
CF&S conceptual layout

Example of CF&S layouts for the regions of the IR halls
Compared configurations

- Compare the relative cost of
  - 20/2 baseline = normalized to 1.000
  - single IR case, 20mrad
  - single IR case, 2mrad
    » The single IR cases have all the common elements, in particular they have tapered tunnel in BSY, which allow to construct second IR in the future

- 14/14 two IR case with common collider hall
  » the common collider hall with same total volume (2*72*32*42m)
Cost adjustments for 14/14

- Adjustments included for 14/14mrad cost
  - removed stretches in optics
  - shorter (~11/14) tapered tunnels
  - remove one surface building
  - savings due to common hall (but volume still twice the single volume)
  - add cost of 42% more gradient bends (for 14mrad bend), their PS, BPMs, movers, etc
Cost of different BDS configurations

Relative cost (a.u.) of two and single IR configurations

- Single IR20: 0.599
- Single IR2: 0.725
- 14/14, common collider hall with twice volume: 0.844
- 20/2 baseline: 1.000

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## Savings and very rough effects

Savings may be not possible, not additive, and require more studies

<table>
<thead>
<tr>
<th>Action</th>
<th>Effect,%</th>
<th>Consequence, risk or issue</th>
</tr>
</thead>
<tbody>
<tr>
<td>use single 5m wall instead of two 9&amp;18m walls</td>
<td>-(2.5-3)</td>
<td>cannot collimate 1e-3 , limited to 2e-5</td>
</tr>
<tr>
<td>remove cost of spare FDs</td>
<td>-(0.5-1)</td>
<td>spare FDs not available if needed</td>
</tr>
<tr>
<td>decrease size of collider hall from 32<em>72</em>40m to ~32<em>54</em>35m &amp; surface detector assembly</td>
<td>-(3-4)</td>
<td>cannot simultaneously assemble detector underground and commission the BDS</td>
</tr>
<tr>
<td>do not install PS for 1TeV at the start</td>
<td>-(1-2)</td>
<td>harder 1TeV upgrade</td>
</tr>
<tr>
<td>do not install full cooling capacity for 1TeV</td>
<td>-(2-4)</td>
<td>harder 1TeV upgrade</td>
</tr>
<tr>
<td>Reduce number of bends</td>
<td>-(0.3-0.5)</td>
<td>E upgrade more difficult</td>
</tr>
<tr>
<td>Decrease vacuum chamber aperture</td>
<td>-(0.2-0.4)</td>
<td>more losses and background</td>
</tr>
<tr>
<td>Reduce number of movers</td>
<td>-(&lt;0.1)</td>
<td>more complex tuning</td>
</tr>
<tr>
<td>Shorten extraction lines, rely on sweeping</td>
<td>-(0.2-0.5)</td>
<td>MPS issues in beam dumps</td>
</tr>
<tr>
<td>Shorten the separate low E e+ tunnel</td>
<td>-(0.3-0.6)</td>
<td>cannot access part of beamlines of IR which is off</td>
</tr>
<tr>
<td>Combine two IR halls (14/14 case), on surface detector assembly, decrease hall size to ~98<em>32</em>35m</td>
<td>-(3-4)</td>
<td>for simultaneous commissioning of beamline &amp; underground detector assembly, may have to make final assembly at other IP, then move detector</td>
</tr>
<tr>
<td>Shorten the fraction of the tapered tunnel</td>
<td>-(0.5-1)</td>
<td>Difficult access around beamlines in BSY region</td>
</tr>
<tr>
<td>Full power tune-up dump =&gt; low power</td>
<td>-(1-2)</td>
<td>MPS and operation</td>
</tr>
<tr>
<td>Combine tune-up dump with main dump</td>
<td>+(1-2)</td>
<td>MPS &amp; operation, accessibility of collider hall</td>
</tr>
<tr>
<td>Remove service tunnel</td>
<td>+(0.5-1)</td>
<td>Access, egress, T stability, cabling, laser rooms,</td>
</tr>
</tbody>
</table>
Plans and Goals

• This workshop
  – discuss design, costs and cost savings with technical groups and MDI panel

• between this and the Valencia workshop
  – study and if found possible, implement agreed upon cost savings
Towards the TDR

- Coordinated activity in all three regions
- Coordinated R&D plans are being submitted for next three years in UK and for the next year in US
- For the test facilities, international collaborations for ESA and ATF2 – the ILC FF model:
Summary

• The status of BDS design and cost estimation was presented