Machine constraints on the vertex beampipe radius

following discussion started at Cornell in July 2003

ALCPG 2004

Andrei Seryi
SLAC
Will discuss the following:

1. **Vertex radius (or, equivalently, FD radius)** rigidly defines the collimation gaps, for a given BDS design

2. **IR apertures are not independent. Optimal IR apertures are slightly diverging:**
   \[
   R_{FD} < R_{VX} < R_{exit\ hole}
   \]

3. **Small collimation gaps, due to wakes, amplify beam jitter and increase beam emittance, which is not negligible at low energy**

4. **To reduce effect of collimation wakes, need to either degrade luminosity at low energy, or increase IR apertures**
Collimation system removes the beam halo. Losses of halo occur in dedicated places.
No losses after last FF collimator.

SR emitted by halo is lost only on dedicated masks, and do not touch vertex detector.

K=1 corresponds to nominal collimation depth when SR from the halo do not touch the vertex detector

Assumed halo is 0.1% of the beam
1. Vertex radius (or FD radius) rigidly defines the collimation gaps, for a given BDS design

Collimation gaps are defined by requirement to protect Vertex Detector from synchrotron radiation emitted by beam halo

For a given optics design, gaps are proportional to the Vertex Radius (and are independent on beam energy)

Smallest spoiler gaps in NLC BDS are $\pm 0.2\text{mm}$
(or $\pm 0.6\text{mm}$ with tail folding octupoles)
2. Optimal IR apertures are slightly diverging

The max radius of SR photon distribution is increasing by ~ 2mm/3.5m in the IR region

Would be natural to have
\[ R_{FD} < R_{VX} < R_{LUMI} \]

do not forget that vertex is tilted by 10mrad w.r.to beam => add another ~0.3mm to \( R_{VX} \)

Distribution of synchrotron radiation photons from the beam halo at the IP and at the downstream location 3.5m downstream.
3. Collimation gaps and wakes

Small gaps is an issue (TRC R3) because collimator wakes cause the IP beam jitter to increase.

For NLC $A_\beta \sim 1.3$ (or 0.7 with Octupoles) that means that $\gamma$-jitter increase by 64% (or 22% with Octupoles) at 500 GeV CM.

The 22% or even 64% are OK at 500 GeV CM, however, the effect scales as $1/\text{Energy}$.

At 90 GeV CM, will have $A_\beta \sim 7$ (or $A_\beta \sim 3.9$ with octupoles). Unacceptable.

Since $A_\beta$ almost does not depend on optics, have only two choices:

- Option 1: Degrade $\beta^*$ and Luminosity expectations at low $E$

- Option 2: Increase the vertex detector radius (and, consequently, FD and exit hole, which require careful consideration, e.g. of the FD design feasibility)
4. Possible reduction of NLC luminosity at low E due to collimation wakes

Assume that tolerable $A_\beta$ is 0.7 (or 1.4), which gives 22% (or 72%) $\gamma$-jitter increase

Luminosity reduction at $Z$ is 2.5 times (or 1.7 times)

Luminosity reduction at light Higgs is ...

For $R_v \times 2$, the reduction is 1.4 times (or none)

This assumes the tail folding
Octupoles are ON (more optimistic case)

Assumed that for typical spoilers, $A_\beta$ scales
as $A_\beta \sim \beta \; N / (\sigma_\gamma^{1/2} \; \gamma \; \text{gap}^{3/2})$ or, equivalently, as $A_\beta \propto \frac{N \; L^2}{z^{1/2} \; R_v^{3/2}}$
5. Collimation wakes in Cold LC
relevant considerations

• Evaluation of the effect in Cold LC is complicated and was not yet done. Relevant issues are the following

• IP intratrain feedback may fix train-to-train IP jitter, even if it is somewhat amplified
  – but amplification of bunch-to-bunch position jitter within the train cannot be fixed and is dangerous

• Cold LC assumed to have larger beam jitter allowed to come out of the linac into BDS, \( \sim 1\sigma \)
  – possibly, this jitter could be corrected by the second intratrain feedback, but no serious consideration of this case was done
  – With larger incoming jitter, in addition to jitter amplification, there is beam emittance growth
    \( \Delta \varepsilon /\varepsilon = n^2 (0.4 \, \text{A})^2 \) where \( n \) is relative jitter (i.e. \( n \sim 1 \) for Cold LC). Requesting emittance growth
    \( < 5\% \) limits \( A \) to about 0.5

• High disruption Cold LC collision are sensitive to “banana” beam distortions. Possibly, requirements to
  \( \Delta \varepsilon /\varepsilon \) should be tighter
5. Collimation wakes in Cold LC

very preliminary

Assume that tolerable $A_B$ is 0.5, from emittance considerations

Assume larger $L^*=4m$ (as considered in some talks) and $R_{vx}=1.5cm$

The luminosity reduction in this Cold LC is shown by dashed line

Limitation is very similar to Warm LC

Limiting curves scale as

$$L \propto A_B^{3/2} \left( \frac{A_B^{3/2} R_{vx}^{3/2}}{N L^*} \right)^{1/2}$$
Conclusion

• There are potential limitations at $Z$ or low Higgs energy due to collimation wake fields, both in Warm and Cold LC

• These limitations depend on vertex detector radius, and should be taken into account when detector parameters will be chosen