# ILC Beam Diagnostics using BeamCal and GamCal

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Two detectors in the very forward region of ILC apparatus, BeamCal and GamCal, are going to be used for beam monitoring purposes. Their potential in this field is being studied and several optimization possibilities are considered. A few preliminary results are presented in this report [1].

## 1 Introduction

Due to the high bunch charge density ILC is expected to have the largest amount of beamstrahlung background ever. This situation will result in a noticeable energy loss of about 1.5% of bunch energy but instead of dumping it into beam pipe it was proposed to utilize it for beam diagnostics. This duty is planned to be performed by two detectors in very forward region, GamCal and BeamCal.

The GamCal is projected to consist of two parts - the IBS Calorimeter for spectral measurement of beamstrahlung gammas energy, and the IBS Camera to obtain the profile of those gammas having their energies in a narrow range [2]. For the current preliminary studies only total energy of gammas was used as an input from GamCal.

Electromagnetic calorimeter BeamCal aims to capture electron-positron pairs produced by beamstrahlung gammas. It is positioned around outgoing beam pipe 3.5 meters from IP and contains thirty disks of tungsten separated by segmented layers of sensor made of diamond or other suitable radiation hard material. Each of two parts of BeamCal has about 45000 sensor sells and only part of them will be used for beam monitoring.

## 2 Beam diagnostics using beamstrahlung analysis

This analysis procedure was proposed by Achim Stahl in [3]. Majorly consists in reconstruction of beam parameters from distribution of beamstrahlung pairs energy that was deposited in BeamCal. Considered there are several observables can be calculated from the shape of this energy distribution, they can be approximately bonded with beam parameters by first order Tailor series:

$$O_{meas} = M \times [P_{act} - P_{nom}] + O_{nom} \quad (1)$$

Here $O_{meas}$ is a vector of observables measured for actual beam parameters $P_{act}$, $O_{nom}$ – one that would be measured in case of nominal parameters $P_{nom}$ and $M$ is a non-square matrix of first order Tailor series. To obtain an expression for beam parameters that has to be reconstructed one must apply Moore-Penrose inverse to the matrix M.

$$P_{rec} = M_{inv} \times [O_{meas} - O_{nom}] + P_{nom} \quad (2)$$

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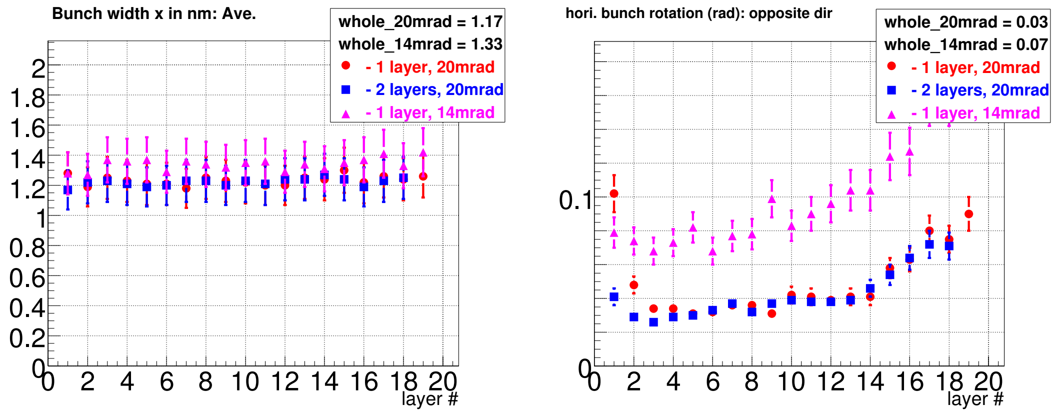


Figure 1: Beam parameters resolution depending on number of layer used as signal one.

Using simulated data with varied beam parameters it is possible to get this Moore-Penrose inverse which will serve for real-time reconstruction. A list of observables used for reconstruction may vary depending on detector geometry and magnetic field type.

The real-time reconstruction process follows several steps. First, same observables are calculated from energy deposition in calorimeter for several consequent bunch collisions. For each of them a vector of beam parameters is calculated by (2). These vectors are averaged to get a vector of current beam parameters which can be sent to beam adjustment systems.

The whole process should take no longer than few bunch-crossings to be effective as beam monitoring. This is why the speed optimization is essential. Naturally it can be done reducing the amount of readout channels, but should not lead to significant resolution drop.

## 3 Read-out scheme optimization

This research is carried to study the potential of various read-out schemes from the point of view of the beam diagnostics system performance. It largely employs the simulation code written by Achim Stahl and standalone Geant4 simulation of BeamCal calorimeter. The main course consists in comparison of reliability and resolution of different read-out patterns and picking those which fit performance and precision requirements. Another important option is the construction feasibility: there are several design features to deal with on a hardware level.

Beamstrahlung gammas and $e^+e^-$ pairs are simulated using Guinea-Pig generator [4]. These pairs are given as an input to Geant4 simulation of BeamCal and resulting energy distribution is used to calculate sets of observables. According to the technique described above, part of these sets is used to build Moore-Penrose inverse matrix, another part serves for beam parameters reconstruction.

The sets of observables and beam parameters involved in these studies are largely the same as those described in Achim Stahl's note mentioned above. There are several differences in list of observables, they include additional asymmetries and phi momenta.

Table 1 generally represents significance of GamCal data for the reconstruction. The beam parameters resolution is compared for two crossing angles with and without observable

| | | BeamCal | | BeamCal+GamCal($E_\gamma$) | |
|---|---|---|---|---|---|
| bp, unit | nom. | 20mrad | 14mrad | 20mrad | 14mrad |
| $\sigma_x$, nm | 655. | 654.1 ± 2.47 | 654.9 ± 2.60 | 653.6 ± 1.17 | 653.9 ± 1.33 |
| $\Delta\sigma_x$, nm | 0.0 | -0.06 ± 6.77 | 3.51 ± 5.59 | -1.71 ± 2.40 | -0.96 ± 2.12 |
| $\sigma_z$, $\mu$m | 300 | 308.0 ± 4.72 | 306.2 ± 3.72 | 299.8 ± 1.69 | 301.1 ± 1.65 |
| $\Delta\sigma_z$, $\mu$m | 0.0 | 2.43 ± 7.94 | -0.37 ± 3.98 | -0.15 ± 2.21 | -0.67 ± 1.90 |
| $\varepsilon_x$, $10^{-6}$ | 10.0 | — ± — | 9.94 ± 2.16 | — ± — | 9.94 ± 2.16 |
| $\Delta\varepsilon_x$,$10^{-6}$ | 0.0 | — ± — | 0.61 ± 1.21 | — ± — | 0.61 ± 1.21 |
| $\Delta x$, nm | 0.0 | 4.55 ± 8.14 | -3.86 ± 11.07 | 4.57 ± 8.13 | -3.84 ± 11.08 |
| $\Delta y$, nm | 0.0 | -2.22 ± 1.19 | -1.26 ± 0.84 | 0.15 ± 1.26 | -0.39 ± 0.84 |
| $w_x$, $\mu$m | 0.0 | — ± — | 286. ± 593. | — ± — | 286. ± 593. |
| $w_y$, $\mu$m | 0.0 | -8. ± 14. | 9. ± 27. | -8. ± 14. | 9. ± 27. |
| $\alpha_h$, rad | 0.0 | -0.036 ± 0.045 | 0.017 ± 0.092 | -0.036 ± 0.045 | 0.005 ± 0.092 |
| $\Delta\alpha_h$, rad | 0.0 | 0.052 ± 0.033 | -0.011 ± 0.064 | 0.053 ± 0.033 | -0.008 ± 0.070 |
| $N$, $10^{10}$ | 2.0 | 1.999 ± 0.005 | 2.005 ± 0.004 | 1.999 ± 0.002 | 2.000 ± 0.003 |
| $\Delta N$,$10^{10}$ | 0.0 | -0.006 ± 0.023 | 0.005 ± 0.012 | -0.005 ± 0.016 | 0.002 ± 0.010 |

Table 1: Beamstrahlung gamma energy influence on reconstruction precision.

representing total beamstrahlung gamma energy. Some positive influence of this observable can be noticed for bunch sizes and other parameters.

The read-out optimization studies consisted of several parts and so far were performed only for single parameter reconstruction. First part considered the possibility to reduce amount of layers from which the information is collected. This was done by changes in script calculating observables by setting it to include only selected layers at various positions along calorimeter axis. The plots on Figure 1 show that there is slight dependence in resolution on geometry and number of signal layers and their position, but not for all beam parameters. For most of them the reconstruction precision does not vary dramatically for the first twenty layers and also doesn't differ greatly from precision that whole calorimeter allows to obtain.

The second part of studies included calorimeter re-segmenting with a purpose of reducing amount of parallel processed data. There were two styles of re-segmentation proposed – unifying 16 and 32 original segments into super-segments. Re-segmentation scheme for 32 channel unification is shown on Figure 2. The results for 6th layer used as signal one obtained for 14mrad crossing angle geometry are summarized in Table 2. It can be seen that for most parameters the resolution is not getting much worse.

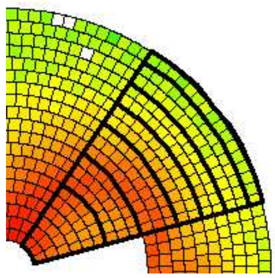

Figure 2: 32 channel re-segmentation scheme.

## 4 Summary

The results presented here are obtained for single parameter reconstruction and therefore are very preliminary. However one can see promising reconstruction stability and persistence of resolution as the amount of input information is reduced. Inclusion of beamstrahlung gamma energy into observables list was noticed to

| bp | unit | nom. | RO scheme detailed | 16 channel | 32 channel |
|---|---|---|---|---|---|
| $\sigma_x$ | nm | 655.0 | 653.72 ± 1.29 | 653.97 ± 1.30 | 654.04 ± 1.27 |
| $\Delta\sigma_x$ | nm | 0. | -1.72 ± 2.01 | -1.65 ± 2.01 | -1.65 ± 2.02 |
| $\sigma_z$ | $\mu$m | 300. | 300.90 ± 1.69 | 300.48 ± 1.56 | 300.39 ± 1.47 |
| $\Delta\sigma_z$ | $\mu$m | 0. | -0.59 ± 1.82 | -0.41 ± 1.77 | -0.33 ± 1.82 |
| $\varepsilon_x$ | $10^{-6}$m rad | 10 | 10.18 ± 2.62 | 10.18 ± 2.62 | 10.18 ± 2.62 |
| $\Delta x$ | nm | 0 | -5.35 ± 11.52 | -7.26 ± 9.80 | -7.78 ± 9.76 |
| $\alpha_v$ | rad | 0 | -0.056 ± 0.019 | -0.076 ± 0.025 | -0.077 ± 0.025 |

Table 2: Resolution of beam parameters reconstructed from re-segmented 6th layer of BeamCal.

have positive influence on reconstruction precision.

For the next step one has to broaden the studies to simultaneous reconstruction of several or, if possible, all beam parameters in order to approach to real life situation. The effectiveness of this beam monitoring system can be tested using more realistic bunches provided by ILC simulation software.

## References


[1] Slides:
`http://ilcagenda.linearcollider.org/contributionDisplay.py?contribId=171&sessionId=78&confId=1296`

[2] W. Morse, *GamCal, a Device for Beam Diagnostics*, these proceedings.

[3] A. Stahl, *Diagnostics of Colliding Bunches from Pair Production and Beam Strahlung at the IP*, LC-DET-2005-003, 2005

[4] D. Schulte, TESLA-97-08 (1996)