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Expected Data Rates of the Beam Calorimeter

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Abstract

A short overview is given about the expected data rates of the BeamCal. BeamCal is an electromagnetic calorimeter of an ILC detector positioned just around the beam pipe. It will measure the energy deposition of beamstrahlung pairs for each bunch crossing. The special focus of this document is on finding upper limits for the data rate of the interface to the machine control system.

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1 Rate of Produced Data

The BeamCal system comprises of two calorimeters, one in the very forward and one in the very backward direction of an ILC detector. These calorimeters are built as diamond/tungsten or silicon/tungsten sandwich calorimeters. The depth of each detector will correspond to 30 radiation lengths X_0. The longitudinal subdivision will be into layers of $1\,X_0$. The granularity of the thirty layers has to be high to detect single high energy electrons or photons with high efficiency on top of the huge background of low energy electron positron pairs originating from beamstrahlung. This leads to ≈ 3000 channels/layer. The needed digitization has a moderate requirement of 10 bit resolution. Due to the high occupancy a full readout of all channels is necessary.
Given these numbers the total amount of produced data per bunch crossing is about 2.0 Mbit/bx. The number of bunch crossings per second should be considered to estimate a peak and an average data rate. The first one gives the necessary bandwidth during a bunch train, the second one corresponds to the total amount of produced data when integrating over time. This estimation is done for the worst case scenario, the LowQ beam parameter set [1]. In this scenario the standard bunch spacing[1] of 307.7 ns is reduced by a factor of two and the number of bunches is doubled. The peak bunch crossing frequency is thus ≈ 6.5 MHz leading to a peak data rate of 13 Tbit/s and the average bunch crossing frequency is 28.4 kHz leading to ≈ 57 Gbit/s.

2 Readout Schemes under Study

2.1 Physics Analysis

An off-detector buffer stage has to be able to store the data of one or multiple bunch trains. Reformatting and zero-suppression will take place there and the triggered data will be read out from these buffers. The full BeamCal information is available up to this point. This is independent of the machine.

2.2 Fast Luminosity Measurement

A small number of signals will be derived from the BeamCal and fed into the feedback system of the collider in real time. This could be e.g.: the total deposited energy in the BeamCal or the total deposited energy in the first layer (proportional to the number of pairs). These signals should be delivered on a bunch by bunch basis with a latency of some bunch crossings.
$\rightarrow$ One or two 100 Mbit digital signals (peak data rate) or analog signals directly fed to the FONT[2] system.

[1] Time between subsequent bunch crossings.
[2] Feedback On Nano-second Timescales

2.3 Fast Beam Parameter Reconstruction

Similar to the fast luminosity feedback. A dedicated hardware farm of DPSs[3] or FPGAs[4] analyzes a part of the BeamCal information in real time. A fast algorithm is used to determine parameters of the colliding beams. A set of relevant beam parameter signals (≈ 30) is then available with adequate resolution (10 bit), each with a peak data rate of ≈ 100 Mbit.
$\rightarrow$ About thirty 100 Mbit beam parameter signals (peak data rate).

2.4 Slow Beam Parameter Reconstruction

The determination of the beam parameters can also be done using fitting methods taking into account correlations and higher order dependencies. A set of signals proportional to relevant observables (≈ 30) will be fed to the control system on a bunch by bunch basis for further analysis. Other systems like PhotoCal deliver additional ≈ 20 signal lines of 100 Mbit each (again peak data rate).
$\rightarrow$ About fifty 100 Mbit observable signals (peak data rate)

2.5 Bunch Train Data Storage

An exhaustive and more time intensive analysis of the complete BeamCal information might be helpful to maximize the machine performance. In addition to 2.1 the accessibility of the full set of buffered data for the analysis of e.g. an individual complete bunch train should be foreseen.
$\rightarrow$ Assuming 6000 bunches per train a total data of 12 Gbit/bunch train.

3 Conclusion

A very large amount of data will be produced in the BeamCal. For an efficient electron reconstruction the granularity of the detector has to be high, which leads to a very high number of channels. Together with a large BeamCal (necessary for large crossing angles and DID[5] magnetic field configuration) and a small bunch spacing scenario, this might end with more than 10 Tbit/s peak data rate. As far as it concerns the machine and its control system, three readout schemes are of interest as described in Section 2.2, 2.3 and 2.4. An upper limit on the necessary data rate at the interface to the machine control system is estimated to be: no more than 100 channels of 100 Mbit. 100 Mbit is the peak data rate and the average data rate is a factor of more than 200 less.

[3] Digital Signal Processor
[4] Field Programmable Gate Array
[5] Detector Integrated Dipole

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References

[1] T. Raubenheimer, "Suggested ILC Beam Parameter Range", available at http://www-project.slac.stanford.edu/ilc/acceldev/beamparameters.html.