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Project Homepages:
http://www.hep.ucl.ac.uk/~sboogert/ http://www.homepages.ucl.ac.uk/~zcfbt17/physproj/
www.hep.ucl.ac.uk/lc/

Project outline: Investigation of e^+e^- luminosity spectrum

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Draft 2, 04/10/02.
STILL TO BE DONE:
--ADDING LIT. REFERENCES

1 Abstract

The plan for this 4C00 project consists in investigating the luminosity spectrum of e^+e^- collisions for the planned TESLA linear collider.

The general question is: how can the different sources of momentum spread & bhabha acollinearity in the beam be modelled so that the luminosity spectrum can be unfolded to an accuracy sufficient for good resolution of $W^\pm$ and $t\bar{t}$ mass.

The interacting beams are highly relativistic and the effects strongly non-linear, so any modelling must take into account these parameters. The core modelling codebase which will be used is D. Schulte's "Guinea pig" beam walkthrough simulation software.

Additional layers will be created to control exact beam specifications, and investigation will focus on different possible shapes of beams and interaction effects.

2 Physics Background

The aim of this project is to contribute to the production of a complete simulation of the TELSA beam, and its effect on the observation of the masses of the top quark and $W^\pm$ bosons.

In order to accurately determine the masses of $W^\pm$ and $t\bar{t}$, which are expected products of the e^+e^- collision, the luminosity spectrum needs to be resolved to 10^{-4} and 10^{-3} respectively.

First order analytical studies suggest that $\partial L / \partial \sqrt{s}$ (the luminosity spectrum) can be obtained within the required accuracy for the $t\bar{t}$ threshold, so that ∂m_t ~ 0.05 MeV, but for a 161GeV W mass, an accuracy to ~6MeV is required. As we stand, an accuracy of $1.5\text{x}10^{-3}$ is attainable, but $1\text{x}10^{-4}$ is needed!

What is proposed is to model the different effects that introduce momentum spread in the beam, so that the effective luminosity spectrum can be "unfolded" (modelled) from what can be inferred about the original beams. This is done by taking measurements directly on the beams with minimal disruption before they interact, and while they are interacting, as well as after the interaction, for the particles that have not produced collision events.

The simulation obtained will be part of the complete simulation ("truth"), which spans the whole physical process until detection. This gives model events to the reconstruction software, which can then be calibrated so it can be used on the experimental data.

In practice, two calorimeters are used one after the other, the ECAL (electron-cal.) and HCAL (hadron-cal.), which are assumed to work at 100% efficiency with high-energy electrons. They are positioned after a TPC (Time Projection Chamber) which should have the required precision to measure the acollinearity (~25 microns over 3 metres.)

However, the current knowledge in the area of beam interaction leaves many questions unanswered[1]:

a. Before the interaction:
   - a.i Can the mean energy be obtained as well as the shape of the beamspread (e.g. is it gaussian etc)?
   - a.ii Can the bunchlets be examined individually or only in trains?
   - a.iii What are the specific differences of TESLA with other linear colliders, e.g. Zero crossing angle, larger time spacing between bunches
b. For interacted beams, what information do the interacted spectra have?
c. How does the energy vary from train to train? (is the spread Gaussian?)
d. How can a luminosity-weighted energy mean be obtained, for one run?

1 Adapted from E. Torrence & S. Hertzbacher, cited in {Miller & Boogert talk.}

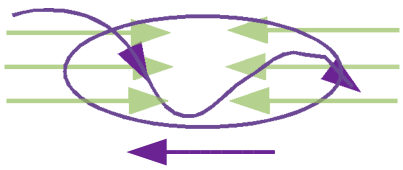
3 Specific Objects of Investigation

To be more specific, the object of this project is to do investigate the following three phenomena:

3.a Does correlated dispersion eliminate compensate for acollinearity?

At and around encounter, the beams start being disturbed by each other's E & B fields, which leads to non-linear oscillations at the time of encounter.

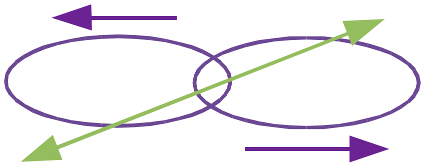
It is possible that this correlated dispersion aligns the beams in some way, if the oscillation happens in the right phase. (Observed by Telnov .)



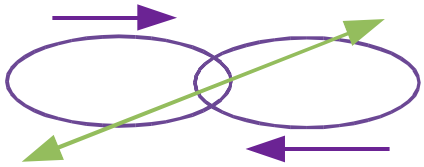
3.b Is there a correlation with position of event within the bunch?

Effects have been observed in simulation by Moening, whereby the position of the event within the bunch will have an effect on the resultant momentum: if the momentum spread within a bunch is some sort of peak curve around some higher middle, and the particles collide early or late in the bunch, they will have less energy, thus reducing the acollinearity.

Can this reduction in acollinearity be estimated from the beamstrahlung rate of the bunches (their mean momentum spread)?



Collision late in bunch

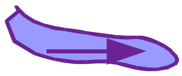


Collision early in bunch.

3.c Offsets and beam bending:

Linac Beams, are engineered to be "flat" on one of the axes perpendicular to the axis of travel, to facilitate analysis of the collision by removing one dimension. However, they can suffer from offsets and bending for different technical and physical reasons (e.g. Self EM disturbance.)

Do offsets and beam bending introduce correlation in any way? What can be investigated about this statistically?

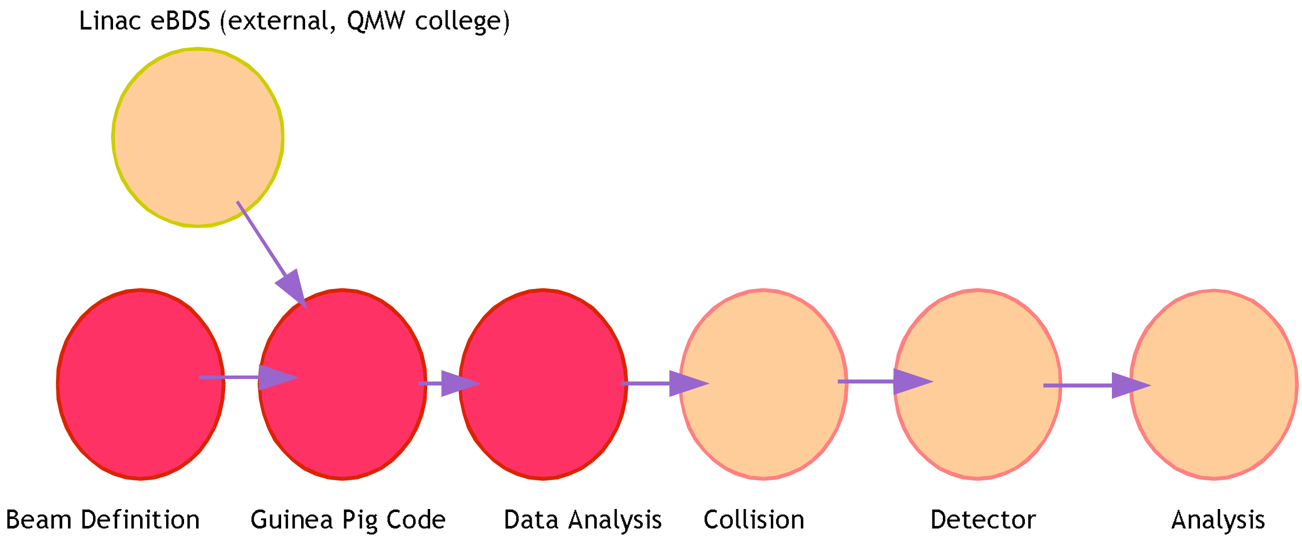


Banana shaped bunch

(nb: this part will be investigated only if time allows, as 3.a and 3.b have a higher priority, and their investigation is somewhat open-ended.)

4 Programming code structure: the practical aspect.

As all the investigations mentioned below are statistical, suitable code will have to be developed and used to allow for systematic study. The code can be broken down into the following components:



So the software tasks that I would undertake, as part of the existing team:

1. Develop a program that would generate beam definition files for different shape/size beams, in ASCII, in a format readable by the guinea pig (some external beam simulation programs such as linac EBDs may be used for cross-checking.)
2. Learn to use the root package, interface it in some way with the simulation and use it to analyse it.
3. Produce simulations of the phenomena detailed in part 3, and analyse their physical significance.

Notes on the guinea pig program:
--Developed by D. Schulte, as part of thesis in 1999, and has been cross-checked extensively: is believed to produce trustworthy output.
--Uses ASCII input and output files.
--Is a walk-through simulation program, which includes the dynamics/physics of beam interactions.

Notes on programming environment:
--Programming will be done in c^{++}, rather than fortran.
--Will be using linux, software should compile on gcc 2.9x and gcc 3.x, to maintain forward compatibility. This should not be a problem, however, as gcc3 should easily handle code which, although computationally intensive, mainly uses standard c^{++} syntax. In fact the code will probably be quite easy to port in case of platform change, as it is unlikely that a fancy API is needed.