SUMMARY OF ENERGY CALIBRATION MINI-WORKSHOP

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Abstract

A summary of the conclusions of the Energy Calibration Mini-Workshop is presented, with particular focus on the un-answered questions and the Research and Development needed for final designs.

1 INTRODUCTION

The Mini-Workshop on Energy Calibration at Linear Colliders has many thematic overlaps with the other sessions at Nanobeam 2002, even though the topic may have seemed initially unrelated. The issues of nanometer-scale stabilization, precision alignment, and beam diagnostics are clearly common ground between accelerator development and physics-related beam instrumentation. Here, we present an overview of the current thinking regarding energy measurements at a future electron-positron linear collider, as well as some necessary research and development that will allow us to refine the designs of the systems that will be built to perform these measurements.

At present, most of the interest in Energy Calibration hardware is focussed on the two technologies which have already been used for energy measurements at high-energy e^+e^- accelerators: The WISRD system, used at the SLC, and the in-line spectrometer, built for LEP2. As a "Strawman" design for energy calibration needs, one each of these devices is forseen at an LC. A non-invasive in-line spectrometer would be installed upstream of the Interaction Point (IP), and a WISRD-like spectrometer would be installed in the extraction line to observe the out-going beam close to the IP.

Of course, there is still interest in evolving new ways to perform the energy measurement "easily" (*i.e.*, with small systematic errors and less technical complexity). One potential scheme, involving a measurement of the rotation of the polarization axis before and after a large bend, was discussed at this workshop[1]. A combination laser-wire diagnostic instrument and Compton-backscatter energy measurement was also discussed.

2 BENCHMARKS

Three measurements characterize the accuracy required from the Energy Calibration system. During "normal" running of an LC, mass measurements from direct reconstruction or even mass measurements using production threshold scans (the top quark will be studied both ways, for example) require an accuracy of $\sigma E/E = 1 - 2 \times 10^{-4}$. Two "special case" scenarios, remeasuring the Z^0 Lineshape and a W mass measurement using a threshold scan, place much more stringent demands on the beam energy measurement. To better the LEP results, $\sigma E/E = 1 \times 10^{-6}$ would be required to re-scan the Z^0 Lineshape. The W threshold scan is less demanding from a calibration perspective, needing only $\sigma E/E = 3 \times 10^{-5}$. It is likely, however, that if these physics programs are pursued, substantial modifications to the operating mode of the LC will need to be made. At this time, it will be possible to modify the energy measurement system to produce the required accuracy.

3 EXISTING SPECTROMETERS

Both the SLAC WISRD and the LEP Spectrometer achieved approximately $\sigma E/E = 2 \times 10^{-4}$. The main limitations of the WISRD design are detector alignment and the detector technology used to measure the positions of the synchrotron fans that provided the energy determination. R& D for an LC implementation is focussed on improving the resolution and robustness of the detector technology, possibly through the use of silicon strips or quartz fibers. One advantage the WISRD scheme holds is that it may be able to measure the differential luminosity as a function of energy, $d\mathcal{L}/dE$, if it is installed downstream of the IP. This location implies that the space for instrumentation in the extraction lines is provided.

The largest systematic errors in the LEP spectrometer energy measurement come from instability of the BPM electronics used to make the angle measurement. Careful design and testing of BPMs in "real" accelerator environments should lead to engineering solutions to these problems. The overall scale of the problem, however, is approximately a factor of ten more restrictive than the LEP case. For an upstream spectrometer in an LC, the maximal bend angle is limited by emittance growth due to synchrotron radiation, requiring BPM accuracy and stability on the 10-100 nm scale. This will require the use of RF BPMs. In order to make an absolute energy determination, a "straight-line" reference is required, corresponding to the beam trajectory for zero magnetic field on the spectrometer bend magnet. The deviation of the beam's position from this straight line gives the bend angle directly. It also may mean that the BPMs would have to be moved and re-centered on the beam in order to make the measurements. Or, of course, a wide-aperture BPM with 10 nm resolution over a huge horizontal range might be easier[2]. A "switching" spectrometer design which measures a positive and negative bend and/or the difference between them may allow the cancellation of some systematic errors.

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4 R& D PROGRAMME

This section outlines some of the research and development needed to arrive at final designs for energy measurement instrumentation.

4.1 Design Studies

Baseline designs in terms of overall dimensions, tolerances, and alignments need to be derived.

4.2 Accelerator Layouts

All of the potential designs need locations in the overall accelerator lattice. Each of the collider designs should include as detailed a representation of beam instrumentation as is possible given our current knowledge of what these systems will look like.

4.3 Evaluation of Operational Issues

As yet, we have no idea how these measurement systems will be used. This needs to be discussed in the overall context of running the LC. Will we need bunch-by-bunch measurements of the beam energy continuously? If so, is a relative energy measurement good enough? Will absolute calibrations be made daily? Hourly? How long will a measurement take?

4.4 Technical Demonstrations

Most demanding in this regard is the in-line spectrometer, which places stringent demands on RF-BPM precision and stability. Tests need to be made on the resolution, stability, and the stability of the null point to insure that the BPM performance is commensurate with the resolution goals. Tests are currently planned at the ATF in Japan to examine some of these issues. Also unproven in the in-line spectrometer design are the nano-scale movers necessary to re-center the BPMs on the beam after they have been moved for the "straight-line" reference measurement. Movers of this resolution exist, but they have not yet been tested in a system such as this. Another element is the "straight line" alignment system to insure that no transverse motion has occured during the energy measurement. The WISRD design will require signficant effort in designing the mechanical and detector structures to minimize systematic effects while simultaneously rendering the detectors impervious to the huge photon and background fluxes expected at the downstream location.

4.5 Beam Tests

It is critical for the prototype systems to take part in a beam test which creates as closely as possible LC beam conditions. It is likely that, in order to minimize systematic errors, the original designs may have to be revised. Precision measurement is not an easy science; the more testing that occurs before the systems are actually installed in the LC, the more likely they are to reach their design accuracy.

5 CONCLUSIONS

The energy measurement systems for the LC are ready to begin their design phases. Before final decisions can be made on several of the issues, however, substantial R& D needs to be done. Communication between the beam instrumentation proponents and the accelerator design team will be crucial for the success of these instruments.

6 REFERENCES

[1] V. Telnov, *"Beam Energy Measurement at Linear Colliders Using Spin Precession"*, these proceedings.

[2] A. Ljapine, *"Tesla Energy Measurement T&D"*, these proceedings.