SLD note 264

Calibration of the WISRD Energy Spectrometer with a Z Peak Scan.

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Abstract

We have calibrated the energy spectrometer used at the SLC against the Z mass as determined at LEP. Our result is an offset to the reported WISRD energy of -46±25 MeV. The resulting corrected luminosity weighted mean center-of-mass energy for the 1997-98 SLD run, including WISRD instrumental systematic errors, is $E_{cm} = 91.237 \pm 0.029$ GeV.

1 Introduction

Since their original application with the Mark II experiment, the SLC extraction line energy spectrometers have owed their absolute calibration to magnetic measurements done on the bench in 1988[1] and to *in situ* surveys which have been done about once per SLC run. The quoted precision for the WISRD, based in part on the original magnetic calibrations, suggested an uncertainty on E_{cm} of about 20 MeV [2]. Originally, the Mark II experiment employed phosphor screen monitors (PSMs) as detectors; only towards the end of the experiment were the WISRDs used and they were not included in the published lineshape measurements. The original Mark II Z mass determination compares well with the present precise value from LEP (presently 91.1867±0.0021 GeV[3]), but the error is too large ($\delta M_Z = -50 \pm 120$ MeV) to be useful, and it is also true that in the intervening 10 years the calibration may have changed. As the present uncertainty for the Z mass is an order of magnitude smaller than our spectrometer precision, a lineshape calibration is an excellent choice. However, up until the 1998 run, the SLD had never scanned the Z lineshape due to low luminosities that would have rendered this a time consuming exersize, but for the recent high luminosity running it was determined that a scan with suitable precision (20 MeV) could be performed in less than one week[4]

The figure of merit for energy precision derives from the associated uncertainty in correcting for gamma/Z interference and initial state radiation in deducing A^0_{LR} from the observed asymmetry at the luminosity-weighted E_{cm} : *An 80 MeV uncertainty corresponds to a 1% error on* A^0_{LR} . A reasonable target is that the systematic errors due to energy measurement are kept below the dominant polarimetry error, or $\lesssim 0.5\%$, which would require $\delta E_{cm} \lesssim 40$ MeV. In this note, the Z peak scan of May 1998 and the data analysis are described , and the results presented. Where appropriate, reference to additional detail will be provided

2 Z Peak Scan

The optimal scan that minimizes total running time includes two off-peak points placed at about +1 GeV and -1 GeV (where the resonance curve is steepest) - more accurately these points are at +0.88 GeV and -0.93 GeV, as shown in the figure below [4].

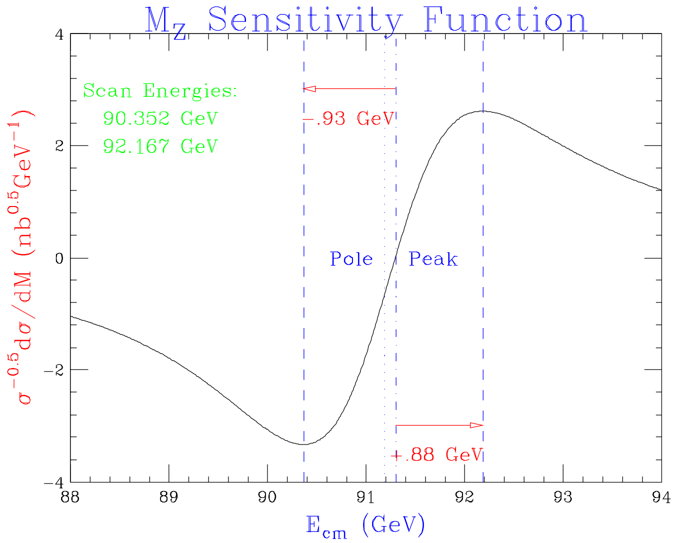

Figure 1 : Optimal energies for a three point Z-peak scan.

The fitting procedure allows one free parameter, the Z mass, while fixing the width to the very precisely known value from LEP (the overall normalization is not constrained). With a total luminosity of 150 nb^{-1} per scan point, or about 9K Zs peak-running equivalent, a statistical error of 20 MeV can be achieved. Systematic effects needn't enter significantly, unless they are different for the two off-energy points compared to each other, or to data taken on peak : these includes Z backgrounds, detection efficiency, and trigger deadtimes, as well as any energy spectrometer calibration effects.

The procedure called for rescaling of the B32 spectrometer bend magnets in the SLC extraction lines (along with the magnets in the arcs and final focus of course), a procedure that maintains the steering of the bremsstrahlung stripes in the acceptance of the WISRDs (optimized before changing the beam energies). The WISRD energies are corrected for any changes in spectrometer B-field by real-time flip coil data. The nominal scan is detailed below,

Scan Point	**Energy (E_{cm})**	$\int \mathcal{L} dt$ **(Z count)**
off-peak high	92.167 GeV	3,300
off-peak low	90.352 GeV	3,000

Table 1.

where the peak cross section (and nominal running point) is at 91.284 GeV. When the scan was actually performed on 5-4-98, the high energy point was done first. As expected, machine related backgrounds were higher than normal when off energy, but the situation was exacerbated when an attempt was made to increase the luminosity (normal conditions were later restored) for the low energy scan point. This mistake wasn't made during the high energy point data taking, and it may be true that the resulting disparate running conditions contributed to the complications in the WISRD data analysis discussed in the following sections. The peak scan experiment lasted about 5 days, and ran at the energies indicated (according to the WISRD values available online), with collected luminosities of approximately 3,700 and 3,300 Z events for the high and low energy points respectively.

2.1 Instrumental Effects : the WISRD

During the course of the 1997-98 run, it was noticed that occassionally the WISRD seemed to be behaving improperly - in particular, the energy reading appeared to be unstable in a way not likely to be SLC related. These episodes seemed to be correlated with unusual "tails" in the WISRD synchrotron radiation stripe displays, and the resulting energy readings appeared to be bimodal. Unfortunately, while this behavior was rare during the bulk of the run, it was significant during the peak scan. In fact, in analysing the peak scan spectrometer data, we were (unintentionally) afforded an opportunity to study and better understand a number of systematic effects in the WISRD system.

The dominant effects fall into two categories

- An effect in the south (electron) WISRD that correlates unphysically high energy width measurements with incorrect energy measurements.
- An effect in the north (positron) WISRD that correlates anamolously high collected ionization (that is position dependent at the WISRD wire array) with incorrect energy measurement.

The south WISRD phenomenon were initially observed during data taking from the online WISRD displays, but was studied in greater detail using both the SLD 120Hz data stream and triggered event data offline. Our understanding of the origin of this effect is not complete, but can be summarized as follows. In the case of the south WISRD, it appears that truncation point used in the energy determination algorithm fluctuates between a position close to the peak position, and one farther away. This is due to the juxtapostion of a tail in the synchrotron signal and electronic noise in the WISRD. It appears that the effect can pull the energy result either high or low, is time dependent, and is sensitive to the location of the synchrotron stripe on the WISRD screen. This observation is consistent with evidence for intermittent “hot” channels that can increase the deduced width and pull and calculated average energy. The effect is recognized by a clearly bimodal energy width distribution in the offline data - reflecting the two widths calculated for the wide and narrow positions of the algorithm truncation points. Sample electron energy width distibutions are shown in the figures 2 and 3 for the high and low energy scan points respectively - the bimodal shape is much clearer for the low energy data, but in both cases the effect is visible.

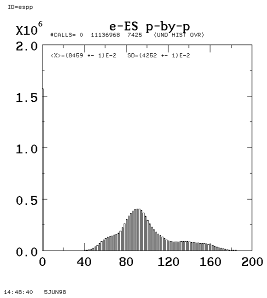

Figure 2 : High scan point.

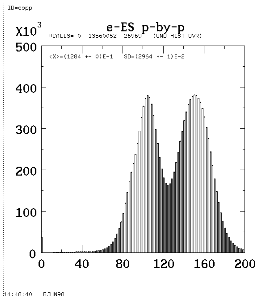

Figure 3 : Low scan point.

The correlation between width data and the mean energy data (which shouldn’t be there) is clear from figure 4 : shown in this scatterplot are data from the high, low, and on-energy scan data where the energy is plotted vertically in MeV (offset) units, and the width is plotted horizontally in absolute MeV. The on-peak data is only contaiminated slightly by the effect in the overall average (less obvious from a scatterplot of this type, but the vast bulk of the data is uneffected by the problem). From this figure it is also clear how a simple cut on energy width can be used to exclude the spurious (high) measurements, to remove the resulting bias in the mean energy estimate.

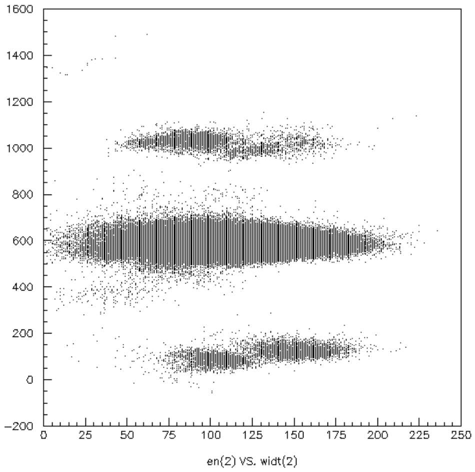

Figure 4 : Electron energy spread versus electron energy for the low, peak and high energy scan points.

It was decided to place a cut at energy spread <124 MeV (based on the low energy point data) to all electron data. The effect of this procedure is to move the measured mean electron energy for each point ; in the case of the peak and high energy data the effect is very small, but it is significant for the low-energy scan point as tabulated below (note that the energies are offsets from 45 GeV) :

scan point E_{cm}	**mean (offset MeV)**	**below cut**	**above cut**	**correction**
high energy	1023	**1026**	1011	+3.0±0.8
low energy	110.9	**90.0**	126.3	-20.9±1.0
on peak	585.1	**580.2**	600.1	-4.9±0.2

Table 2.

The effect of the correction is about 21 MeV for the low energy data, and less than 5 MeV for the peak and high energy data. The errors on the corrections given above are purely statistical. Our systematic error (and hence overall error due to the small statistical errors) for each of these corrections will be taken to be one half the size of the correction, or 1.5 MeV, 11 MeV and 2.5 MeV respectively.

We now consider the second WISRD systematic effect, this time on the positron energy measurements. The north WISRD phenomena appears to be due to a collimation problem with one of the two WISRD wire arrays (the incoming synchrotron stripe array). When inspected in situ, the upper lead collimator for the incoming radiation stripe (there are two collimators per stripe) was discovered out of position and rotated in front of this wire array. The onset of the problem is very clearly correlated with a particular position on this array

- starting at this location the total collected charge jumps by a large amount and a correlation between reconstructed beam energy and charge develops.

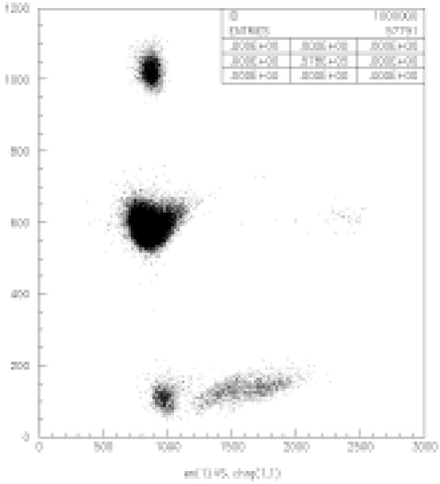

Figure 5 : Positron energy vs. stripe charge.

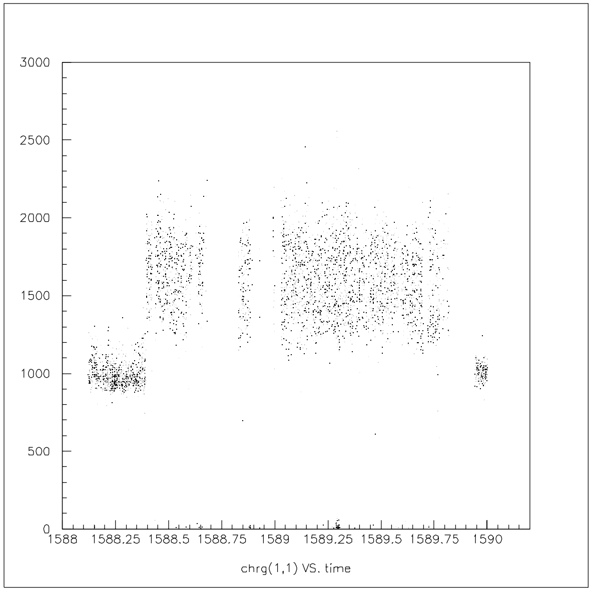

Figure 6 : Stripe charge vs. time.

Figure 5 shows the data (energy plotted vertically, collected charge horizontally) for the low, peak and high energy points from bottom to top. The population of anamolously high charge data is clearly visible for the low energy data, and completely absent for the high energy data ; also evident, is the resulting energy/charge correlation in that population. It is interesting to examine a plot of the collected stripe charge as a function of stripe postion, as shown in Figure 7. The onset of increasing charge at 315 mils (arbitrary WISRD coordinate system) exhibits a slope that is nicely consistent with the observed collimator “roll” of about 5 degrees. The face of the collimator is a square of about 1 1/8 inch on a side, and when rotated about an axis perpendicular to the face the non-horizontal collimator edge, relative to the fixed lower collimator, produces an acceptance gap that is not uniform. The sudden onset of increasing charge corresponds to passing the corner of the collimator.

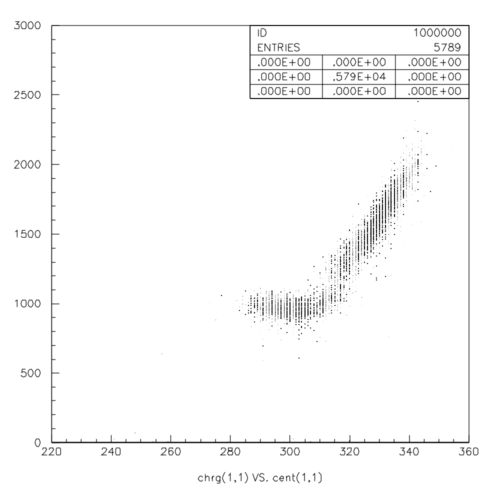

Figure 7 : Stripe charge vs. position.

In the peak running, the problem can be seen, but fractionally is relatively insignificant (although that fraction is not evident from a scatterplot due to point overlays). In figure 6 a time history of the problem shows a sharp onset coincident with the the start of the low energy scan point data taking (in arbitrary SLD units, day 1588 at about 9:30 AM), and precisely correlated with a particular position on the screen (about 315 mils from the reference edge). Correcting for this effect is relatively straightforward due to the clean separation between the normal and anamolous populations, but only so long as there isn’t a correlation in time with the positron beam energy. It was verified that there did not appear to be any such correlation during the low energy scan point by checking other energy measurements available at the SLC (for instance, the beam switchyard BPMs and the final focus BPMs). A cut was placed at <1100 ADC units for the collected charge at the incoming stripe north WISRD array. The table below shows the results, once again in MeV offsets from 45 GeV.

scan point E_{cm}	**mean (offset MeV)**	**below cut**	**above cut**	**correction**
high energy	1025	**1025**	N/A	none
low energy	125.3	**111.9**	134.7	-13.4±0.8
on peak	590.3	**590.0**	636.2	-0.3±0.2

Table 3.

The errors shown for the corrections are purely statistical. Once again, systematic errors will be taken to be one half the correction itself, or 0, 7 MeV and 0, respectively.

These WISRD intrumental effects, as well as a description of the work done to check magnetic and survey data and a number of geometrical corrections (for small angle approximations and for WISRD wire array angular offsets) are to be described in detail in an upcoming note[5].

2.2 Extraction Line Energy loss Corrections

Due to the several bends in the final focus and extraction lines seen by the spent beams on their way to the energy spectrometer and then the beam dumps, some beam energy is lost due to synchrotron radiation prior to measurement. The nominal energy loss had been estimated at SLC startup at about 45 MeV per beam, and this amount was added to the energy spectrometer results offline. More recently, motivated by our need for a more precise number, Mark Woodley recalculated this quantity, and his results are given in detail in an appendix. The new calculation includes energy losses up to the midpoint of the B32 analysing bend used by the energy spectrometer (the older calculation seems to include the entire magnet). The result is 41.9 MeV per beam. However, for the 1998 data, a new setup in the final focus was implemented that included reduced dipole bending in lieu of an off-center trajectory in several quadrapole magnets. The reduced mean radius of curvature for this configuration lead to a smaller energy loss of 36.9 MeV per beam, and it is this correction that is relevant for the Z-peak scan data. The difference between the calculations for the north and south final foci and extraction lines is small (about 1 MeV) - it is reasonable to take the errors on these numbers as similarly small (and, in the overall picture, negligible)

2.3 Beam-beam Disruption Corrections

The effect of one beam on the other during the collision, negligibly small in earlier SLC running, became significant in the last run. In the 1994-95 run, a simple procedure was used to estimate the energy losses due to disruption. The observed beam energies were compared with the beams in collision, and not in collision, and the simple assumption was made that half of the collision energy loss occurred prior to the collision. The result was an estimated 10±10 MeV correction to be added to the center-of-mass energy as measured by the energy spectrometers[7]. In more recent higher luminosity running, these beamstrahlung losses became much larger. Prompted by this fact, simulations of beam disruption for 1998 SLC beam conditions using the GINEAPIG package have been performed [6]. These simulations confirm, to the modest precision we need, (∽10%) the simple picture where pre-post collision losses are 50/50, and also give quantitatively consistent results for the size of the effect compared to the results of two-beam/one-beam comparisons.

For this analysis, SLD 120Hz data is used, instead of triggered SLD data, as this is our only source of e^- or e^+ single beam WISRD information. The one-beam condition is determined from the state of the relevant beam-dumper signal, although the bias introduced by using the beam current toroids instead was verified to be very small. The complication in this analysis relates to the WISRD instrumental effects discussed in section 2.1. These effects are present, and are in principle different for the single beam data, than the tabulated corrections given above for collision data. In the case of the south (e^-) WISRD, the WISRD energy spreads are available in the 120 Hz data and cuts (albeit different cuts) can be applied as was described. However, for the north (e^+) WISRD, the 120Hz data does not include the WISRD stripe charge or position information necessary to duplicate the two-beam analysis. Therefore, the positron disruption estimate cannot be fully corrected. However, if the two-beam data is any guide, only the low energy scan point data needs correcting and the effect is less than 15 MeV. Our quoted errors will have to reflect the uncertainties associated with this problem.

The table below gives the two-beam vs. one-beam energy differences for both the corrected and uncorrected electron data, and for the positron data. We note here that the corrections applied to the single-beam elecron data were somewhat more complex than those for the two-beam data, and include a combined cut on energy width and energy as a population of unphysically low energy measurements was seen here (about 100 MeV low). Define the one beam - two beam energy difference $\Delta^{\pm}$ for positrons and electrons, given below in MeV (statistical errors are negligible) :

scan point E_{cm}	Δ^-_{uncorr}	Δ^-_{corr}	Δ^+_{uncorr}
high energy	27.7	18.4	27.8
low energy	46.1	39.6	27.1
on peak	44.7	38.3	26.6

Table 4.

The one standout here are the electron corrections for the high energy point. The GINEAPIG simulations are perhaps more consistent with the higher losses seen for the low energy and peak running, although the uncertainties are large (for example, luminosity and bunch length information is poor for the Z-peak scan running). Some comments :

- The consistency of the positron energy loss results may be telling us that the WISRD instrumental corrections do cancel in the one-beam - two-beam difference. They fact that the two points where no correction is expected (high energy point and on peak data) agree well may indicate that conditions were relatively stable.

- The discrepant behavior of the high energy electron energy loss result may be real, or may indicate some kind of instrumental effect that hasn't been correctly accounted for. It is possible, for example, that the WISRD algoritm truncation effect is somehow larger here (see below). The differences seen in this table will help set our systematic error.

The systematic error due to the high energy correction can be minimized by splitting the difference between the more typical 38.3 MeV (on peak) and the low corrected result (18.4 MeV), for a correction of 28.4 MeV with a 10 MeV error to cover this unknown effect. For all points, a measure of the error is given by difference between the corrected and uncorrected results (about 6 MeV for the low energy and on peak numbers, and 9 MeV for the high energy point). The total correction to E_{cm} is then given by $(\Delta^{-}_{corr} + \Delta^{+}_{uncorr})/2$, where the modified high energy electron result given above is used. Taking the errors for the positron losses to be 5 MeV, it seems reasonable to take the error for the low energy and on peak results at 10 MeV, and 15 MeV for the high energy point in the total correction, as given below :

scan point E_{cm}	$\Delta^{E_{cm}}_{corr}$
high energy	28.1±15
low energy	33.4±10
on peak	32.5±10

Table 5.

2.4 Corrected scan E_{cm} results

The final results for the scan point energies take the WISRD corrected ('below cut') results, add the extraction line loss corrections, and add the appropriate beam-beam collision loss corrections, while all the time adding the quoted systematic errors in quadrature. The table below gives the results - recall that the original quoted energy spectrometer precision is about 20 MeV in E_{cm}, and is not included here :

scan point	$E_{cm}(corrected)$ GeV
high energy	92.153±0.015
low energy	90.309±0.016
on peak	91.277±0.010

Table 6.

3 Relative cross section determination

For each of the three scan points, the relative Z cross section is required, where normalization is provided by Bhabha event rates as measured in the luminosity monitors (LUM). Even in the presence of elevated backgounds (for which the was really no evidence), the Z selection taken from the A_{LR} analysis is fairly robust, and contamination should be easily held well below 1%. The Bhabha identification in the LUM is to excellent approximation background free. One subtlety is that in principle trigger/DAQ related deadtimes or inefficiencies need to be accounted for, but only to the extent that these effects differ between the three scan points. To simplify the analysis of trigger effects, and to minimize them, the purely calorimetric Z selection (known as KAL) is used, rather than the tracking assisted method (TAKAL) that is presently the default in the A_{LR} procedure ; nominally these selections have $\backsim 0.3\%$ and $\backsim 0.1\%$ impurities respectively[8].

The KAL selected Z counts, for the specified run ranges (corresponding to the high, low and peak energy points), along with the LUM Bhabha counts (tallied using the precise-gross method[9]) are given below.

scan point E_{cm}	**SLD run range**	**KAL Z total**	**LUM Bhabha total**
high energy	43166-43202	3,724	11,174
low energy	43203-43258	3,312	12,621
on peak	42786-43153	52,123	122,850

Table 7.

3.1 Trigger/DAQ Efficiency Corrections

There are small known effects in the SLD trigger/DAQ system, generally referred to as "deadtimes" (although this terminology is not entirely accurate). These effects need to be accounted for in our fit, but only to the extent that they vary for the three scan points. In order to minimize these effects, and also to allow for their straightforward evaluation, we decided to employ calorimetrically selected Z events (known as KAL Zs), rather than the present standard selection (for the A_{LR} analysis) that uses tracking information (TAKAL Zs). This is because the SLD LAC trigger and readout cause no deadtime - however, this fact can lead to the misconception that the KAL energy trigger is deadtimeless. In fact, while the LUM trigger can go at the full 120 Hz collision repetition rate, the KAL trigger incurs deadtime due to the fact that the entire SLD is readout, including the slow wire systems (CDC and CRID) for which about 9 beam crossings are required for completion.

The SLD 120Hz data was used to determine the size of the effect for each of the three scan points. The "slot state vector" for the ENERGY trigger is checked and the BUSY and VETO (trigger vetos contribute a small fraction of the deadtime) bits are examined. If the particular beam crossing is "good", as defined by over threshold electron and positron currents and finite beamsstrahlung signal (verifying the beams are in collision), the OR of the BUSY and VETO bits is used to define the DEAD state, which is then tallied. The fraction of these beamcrossings that show the DEAD condition as defined as the trigger/DAQ inefficiency, or "deadtime". The distributions in deadtimes, calculated for blocks of 1000 good beamcrossings, are histogrammed (Figures 8,9 and 10 for the high, low and peak scan points respectively) and the means of these distributions are extracted and tabulated below :

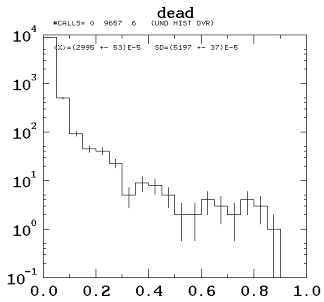

Figure 8 : High scan point.

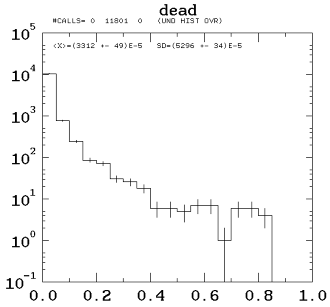

Figure 9 : Low scan point.

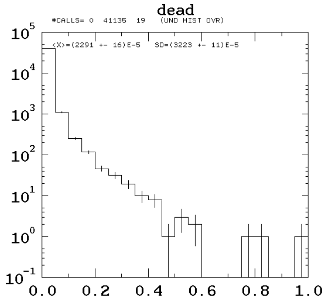

Figure 10 : Peak scan point.

scan point E_{cm}	**trigger/DAQ ineff.**
high energy	0.033
low energy	0.030
on peak	0.023

Table 8.

These inefficiencies (ϵ) are corrected for at each scan point simply by multiplying the Z/Bhabha ratios by $\frac{1}{1-\epsilon}$. The errors on these corrections are negligible compared to the statistical errors on the Z event totals and are ignored.

4 1997-98 luminosity weighted E_{cm} Results

The luminosity weighted results for the recent 1997-98 run are determined in the usual way (from selected Z events), but the calculation also includes the same corrections for the North and South WISRD instrumental effects that were uncovered in the Z-peak scan analysis. These corrections have a small effect on the bulk of the data (about 1 MeV in 1997, and about 4 MeV in 1998). The appropriate extraction line energy loss corrections detailed above are applied, and the beam-beam disruption energy loss corrections are determined as for the scan data by using two-beam to one-beam comparisons. The beam-beam disruption loss corrections are time dependent, and a luminosity weighted mean is determined for the 1997 and 1998 time periods from the weighted averages of 8 "blocks" of time for each time period (see the 120 Hz asymmetry analysis [7]). The results are given below (note that the 1998 period here excludes the runs used for the Z-peak scan) :

run period	**SLD run range**	**beam-beam disrupt.corr.**	**lum.weight.** E_{cm}(GeV)
1997	37418-40725	22.3±10 MeV	91.277±0.010
1998	41098-43934	30.4±10 MeV	91.286±0.010

Table 9.

The errors shown here are due to the systematic errors on the corrections, given in the previous sections, and do not include any calibration uncertainty. Statistical errors are negligible. The 1997 and 1998 results can be averaged, with the correct luminosity weight, to yield the result :

$$E_{cm}(\text{ lum.weight. 1997-98}) = 91.283 \pm 0.014 \text{ GeV}$$

To this result we now apply our calibration correction derived from the Z-peak scan.

5 Calibration Correction from the Z-peak Scan

Two fitting methods were used for the Z lineshape fit. The first method (M. Swartz) uses the Z lineshape and radiative corrections program ZFITTER [10], where the small-angle Bhabha to Z decay ratios are the input, and the ratios of these cross sections are calculated internally. The second method (Ray Frey) uses the program BHK[11] to calculate the Bahbha cross sections (with an acceptance cutoff at 37 milliradians - detailed detector response simulation is unnecessary as overall normalization is irrelevant), and a fitting function for the Z lineshape from Kuraev and Fadin[12] that sums initial-state radiation to all orders and includes virtual corrections to order α using a structure function formalism. Both fits also include an 100 MeV energy smearing to account for the ~0.15% average per pulse energy spread of each beam.

The fits to the peak scan data, compared to the LEP Z mass, yields an offset of -43±25 MeV, with a $\chi^2 = 1.2$ for the ZFITTER based fit, and -39±25 MeV, with a $\chi^2 = 1.5$ for the fit using the function of Kuraev and Fadin (there is one degree of freedom in both fits). The error here includes the statistical error of the fit (which dominates), and the systematic errors associated with the scan energies from corrected WISRD data. The fits are comfortably consistent with each other. The latter fit result is shown below. If we split the difference between the scan results, and inflate the error accordingly, we obtain the WISRD based offset of -41±25 MeV.

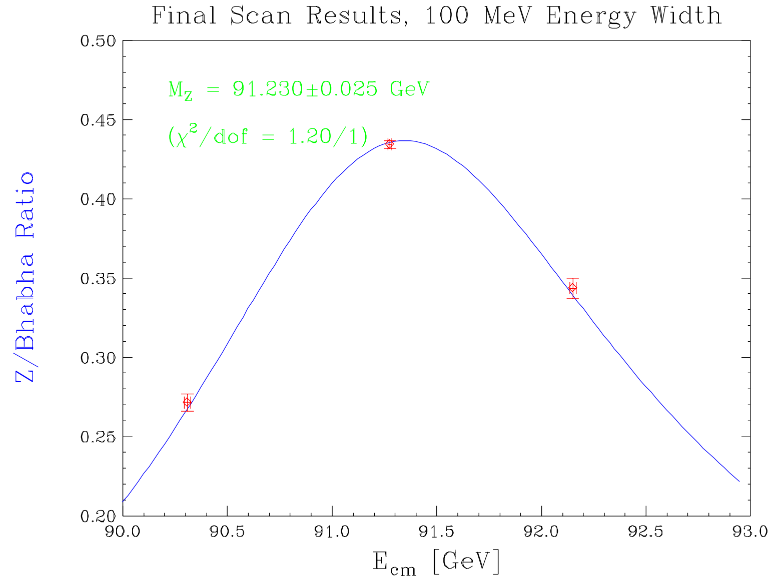

Figure 11 : WISRD based peak scan fit (ZFITTER method).

The total error on the corrected center-of-mass energy would then be the quadrature sum of the 14 MeV error on the luminosity-weighted average, and the 25 MeV error on the fit result, or about 30 MeV.

We have additional information, however, from Pantaleo Raimondi's final focus beam position monitors (BPM) analysis, as described in Mike Wood's memo [13][1], that is completely independent of the WISRD energy spectrometer data. The scan point energies deduced from the BPM analysis are given in Table 3. of the memo, and are reproduced below. No systematic errors were assigned.

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[1] The results presented in the present memo for the WISRD analysis supersede the preliminary results given in the memo of M. Woods.

scan point	$E_{cm}(BPM\ analysis)$ GeV
high energy	92.178
low energy	90.327
on peak	91.287

Table 10.

These energies are systematically higher than our results which were shown in Table 6, by 18, 10 and 25 MeV respectively. However, the absolute scale in the BPM analysis is not fixed and was set by assumming that SLC operators had maintained the peak energy at its nominal value. In fact, our data indicate that the actual peak point was 10±10 MeV lower than this assumption. If we apply this offset and it's error to the results quoted in the BPM analysis memo, the discrepancies between the WISRD and BPM energies decrease to 8, 15 MeV for the high- and low-energy scan points respectively, comfortably within our quoted WISRD errors. Including this offset correction, the result of identical fitting procedures to the BPM derived energies is to deduce an offset of -52±22 MeV with a $\chi^2 = 1.6$ and -47±22 MeV with a $\chi^2 = 2.2$, where the errors here are purely statistical. Once again, we can split the difference and inflate the error to obtain -50±22 MeV for the BPM based offset. Even though only for the WISRD analysis have the systematic errors been completely evaluated, as a relative measurement, the BPM procedure is expected to be precise at the few MeV level.. A reasonable approach is to split the diffference between the WISRD based and BPM based estimates, and to assign an additional systematic error of one half their separation. The result is then,

$$\Delta_{calibration} = \text{-46} \pm 25 \text{ MeV}.$$

Applying this offset to the corrected luminosity weighted results yields

$$E_{cm}(\text{ lum.weight. 1997-98, calibrated}) = 91.237 \pm 0.014 \pm 0.025 \text{ GeV}.$$

This implies that the total error on E_{cm} is ±29 MeV, corresponding to 0.36% in A_{LR} , where the offset itself is a 0.58% effect.

6 Comments on Possible Calibration Effects

It is not the purpose of this note to provide an explanation of the reason for the observed calibration offset, nor a complete list of corrections to the WISRD data (these are discussed in another memo [5]). Some additional independent information is pertinent, however, and some hypotheses can be made.

Early on in our investigations of the WISRD performance, in fact as early as 1993, it was realized that SLD muon pair events could be used to constrain the *difference* between the electron and positron beam energies, which at that time was not particularly well monitored by SLC operators. Within large errors (about 50%), the mean 30 MeV beam energy offset seen in the WISRD data was confirmed by the muon-pair acolinearity results. Since then, we have considerably more data, with better tracking performance, and are able to track the muon pair acolinearity for relatively short (of order a week) time periods. The muon-pair data for the full SLD history (1992, 1993, 1994/95, 1996 and 1997/98 runs) was studied as an offshoot of vertexing and tracking analyses, and the acolinearity information compiled at our request[14]. In the earliest data, the difference is consistent with zero within large errors, but starting in the 1994/95 run a mean difference of about -35 MeV (the difference is defined as the positron energy minus the electron energy) was observed, and this difference appeared to be time dependent. In 1996, in fact, a larger mean difference is observed (-50±8 MeV), than in 1997/98 (-34±8 MeV), and in both datasets smaller and larger effects are observed. In light of the expectation that beam-beam energy loss effects are roughly inversely proportional to the bunch length of the incoming bunch, and therefore can differ for the two beams, it is plausible that the beam-beam energy difference arises in part from this effect. For example, it is known that during 1996, unusually short positron bunch lengths occurred for a fraction of the run which might explain the slightly larger positron/electron energy difference that is observed.

From the Z-peak scan, we obtain an estimate for the *sum* of the calibration offsets for the north and south WISRDs, which we will call δ^+ and δ^- respectively. From the muon pair acolinearity, the *difference* is obtained, which for the relevant time period (the run range defined for the peak energy data) works out to -46±9 MeV (the error includes an 8 MeV systematic uncertainty[14]. From this information we obtain :

$$(\delta^+ + \delta^-)_{peakscan} = \text{-46} \pm 25 \text{ MeV} \;;\; (\delta^+ - \delta^-)_{muonpairs} = \text{-46} \pm 9 \text{ MeV}.$$

$$\text{Hence, } \delta^+ = \text{-46} \pm 27 \text{ MeV and } \delta^- = 0 \pm 27 \text{ MeV}$$

This result suggests a calibration effect in the positron WISRD, although the errors are large and the result is also consistent with equal electron and positron offsets. To date, studies of the time histories of WISRD magnetic monitoring data, both NMR and flip-coil based, as well as detector and spectrometer survey, have failed to turn up a plausible cause for miscalibration of the desired magnitude and sign (see the upcoming memo for details[5]).

For large disruption high luminosity running, the overall offset of the WISRD deduced E_{cm} due to a bias in the WISRD algorithm, according to GINEAPIG estimates, can be -18 MeV [6], comparable to he deduced correction of -46±25 MeV within errors. Perhaps this effect is partially responsible for the miscalibration. In the absence on any instrumental explanation for an overall calibration problem, and some suspicions that the high disruption of the 1997/98 run played some role, only this most recent run (representing about 70% or our statistical power) was corrected in forming the A^0_{LR} update for the Summer 1999 conferences (EPS 99, and Lepton Photon 99).

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