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Electron Momentum Corrections for CLAS at 4.4 GeV

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Abstract

The procedure to derive electron momentum corrections for the CLAS detector at TJNAF is presented. The method uses the elastic scattering process $e + p \rightarrow e' + p'$ as reference. Simple polynomials are used for the correction functions and it is assumed that the multiple geometric dependencies can be factorized. The effect achieved is a width of 20 MeV/c^2 for the elastic peak in W ($ep \rightarrow eX$ invariant mass).

0.1 Introduction

We are aware of our lack of knowledge regarding the details of magnetic field mapping in the CLAS detector, which will influence the exactness of our measurements of the momentum vector. What one can do, using as a reference some well known process, is to introduce a function that will correct the momentum as a function of its orientation (one choice).

For this, it is handy to use a simple and well known interaction: elastic scattering of e^- on H. This analysis presented in this material is done on E1 H_2 data at 4.4 GeV, at a torus current of 2250 A. From the whole invariant mass spectrum, we select the W range from 0.80 to 1.05 GeV, which corresponds to the elastic peak (see Fig.1). We discard data with $\theta < 16^o$. This selection leaves us with approximately 5% of the total number of events in the rootDST file. We make the assumption that the corrections derived in the elastic region will hold for the whole spectrum.

Methodology

In general there is no consensus on the expression the correction function should have. It clearly will depend on the absolute value p of the momentum of the electron as well as on its angles θ and ϕ, and we expect variations from sector to sector. The generic expression is then:

$$\mathbf{p}_{corr} = f(p, \theta, \phi, s) \tag{1}$$

where p_{corr} will be the 'real' value, and s indicates the sector.

Since the main uncertainties are due to the distribution of the torus field and angles mainly defined by DC geometry, we assume that the angles are measured correctly and the value of the momentum needs to be corrected. This is to say that eq.(1) may be written as:

$$p_{corr} = p \cdot \chi(\theta, \phi, s) \tag{2}$$

The geometry of the detector implies a certain correlation between the range of ϕ angle and the θ of a detected particle. At large θ values, the ϕ range is large and most of the particles are far from the edges of the fiducial region, while at small θ, where the ϕ range is quite small, the influence of the vicinity of the coils is more significant (see figures 2 and 3). But the amount of this effect will be almost completely eliminated by the fiducial cuts.

In a good approximation, then, we can assume that the correction function χ from eq.(2) can be factorized as:

$$\chi(\theta, \phi, s) = f_2(\theta, s) \cdot f_1(\phi, s) \tag{3}$$

where f_1 and f_2 are different functions for each sector s.

In this case, the procedure is simple: we correct the ϕ dependence, insert it into the code, and with it derive the θ correction functions. The overall correction function χ will be the product of the two.

The correction functions are simply the ratio between the calculated modulus of the electron momentum p_{calc} and the measured one p_{exp}, for each sector.

$$f_i(\alpha_i, s) = \frac{p_{calc}(\alpha_i, s)}{p_{exp}} \qquad \alpha_1 = \phi, \quad \alpha_2 = \theta \tag{4}$$

For the elastic scattering of electron we can approximate successfully:

$$p_{calc} = \frac{E_{beam}}{1 + E_{beam}(1 - \cos\theta)/m_p} \tag{5}$$

where $E_{beam} = 4.4$ GeV is the beam energy (we assume that this is accurately measured), and m_p is the mass of the proton. The formula (5) contains no ϕ terms, and therefore we calculate f_1 based on the assumption of isotropy in ϕ.

We plot then the ratio f_1 from (4) versus ϕ for each sector (please see the example in Fig.4). Obtained two-dimensional histograms, like the one in Fig.4.a, are sliced along ϕ, each slice fitted with a Gaussian and the mean values plotted again versus ϕ. The graph in Fig.4.b shows the fit to the centroids of the Gaussians with a polynomial function. Then polynomial function is used as a correction function $f_1(\phi, s)$. In figure 6 one can see how the position and width of the elastic peak in W is changed (compare with Fig.1).

After the ϕ correction is done, the same procedure is repeated for parameterizing $f_2(\theta)$.

The algebraic functions that we found the most suitable (see figures 4 and 5) are:

$$f_1(\phi, s) = P_2(\phi, s) \tag{6}$$

$$f_2(\theta, s) = a_s + P_2(\theta, s) \cdot e^{-\theta} \tag{7}$$

where P_2 is a second degree polynomial and a_s is a fit parameter. One notices that we tried to limit ourselves to the simplest functions. The correction in ϕ is a parabola, and we found that it fits very well the points in Fig.4.b within the region of interest. If at the extremities it goes wrong, it does not affect the final result because these regions will be cut out anyway when the fiducial cuts are applied.

The correction in θ is a little more complicated (eq.7). At larger θ angles $f_2(\theta)$ reaches a plateau. Therefore, we insert the offset a_s and the inverse exponential function $e^{-\theta}$, with which we force the polynomial into a flat horizontal curve in this region (that will be approximately above 25^o, as seen in figure 5.b). Since we are not interested in what happens below $\theta = 16^o$, the continuation of the functions in this region is not guaranteed to hold.

As one may have noticed, not all the details of these plots have been fitted. What we intended to correct is the general trend and this is successfully accomplished with both θ and ϕ.

The number of the resulting parameters is $6 \times (4 + 3) = 42$. The parameters of correction functions go into the file `EMCP_4GeV.par` that is read by **SetMomCorrParameters()** included in the **TE2AnaTool** package.

In Fig.7 you can see the final aspect of the elastic peak in W (the peak, ideally, should be centered at 0.9382 GeV/c^2, corresponding to the mass of proton m_p). Assuming that the resolution scales with the magnetic field, one expects from other such calibrations (e.g. E1 experiment) that a resolution between 19.6 and 24.0 MeV/c^2 is feasible. We get here an overall $\sigma = 20.3$ MeV/c^2.

A look at the energy spectra of the electrons in Fig.8 shows good agreement with the conclusions drawn in [2]. As we see in this figure, the shape of the distribution is not changed much by the momentum corrections, except the high energy/small θ region. This is due to the extremities of the fit curves as discussed above. Once we discard data below $\theta = 16^o$, the unphysical points vanish and the curve agrees with the one dictated by the fiducial cuts (see [ref.2]).

Summary

We made the important assumption that the correction function can be factorized in a ϕ- and a θ-dependent part. We chose to correct the modulus rather than the orientation of the electron momentum vector. First the ϕ dependence is corrected, then included into the code, then used to derive the θ-dependent correction. The corrected momentum vector preserves the angles from the EVNT bank but has the modulus modified by formula (2).

Somewhere at the beginning of his (her) analysis code, the user must initialize the fiducial cut function by calling **SetMomCorrParameters()**, which reads the values from the file mentioned above.

During the execution, the corrected value of the electron 4-momentum is obtained by calling the function **EMomentumCorrection(V4e)** which returns the corrected value of the **V4e** 4-vector. Also implemented is the function **GetCorrectedElectron4Vector()**, which returns directly the corrected value of the electron **V4e** 4-vector.

For details about the procedure as well as for the codes used to derive these results, the reader is advised to consult the extensive documentation available on web in [1].

Acknowledgements

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References

[1] Electron Momentum Corrections for CLAS at 4.4 GeV, D.Protopopescu, July 2000, documentation in html format, **http://einstein.unh.edu/protopop/MomentumCorrections/emc4E2.html**

[2] Fiducial Cuts for CLAS at 4.4 GeV, D.Protopopescu, July 2000, documentation in html format, **http://einstein.unh.edu/protopop/FiducialCuts/fc4E2.html**

[3] C++ code bank, by D.Protopopescu, available on web at **http://einstein.unh.edu/protopop/cpp_codes.dir/cpp4E2.html**

Acronyms used in text

1. CLAS stands for CEBAF Large Acceptance Spectrometer
2. TJNAF is the acronym of Thomas Jefferson National Accelerator Facility
3. GSIM is the CLAS version of the GEANT Simulation Package
4. TOF stands for time-of-flight detector

List of Figures

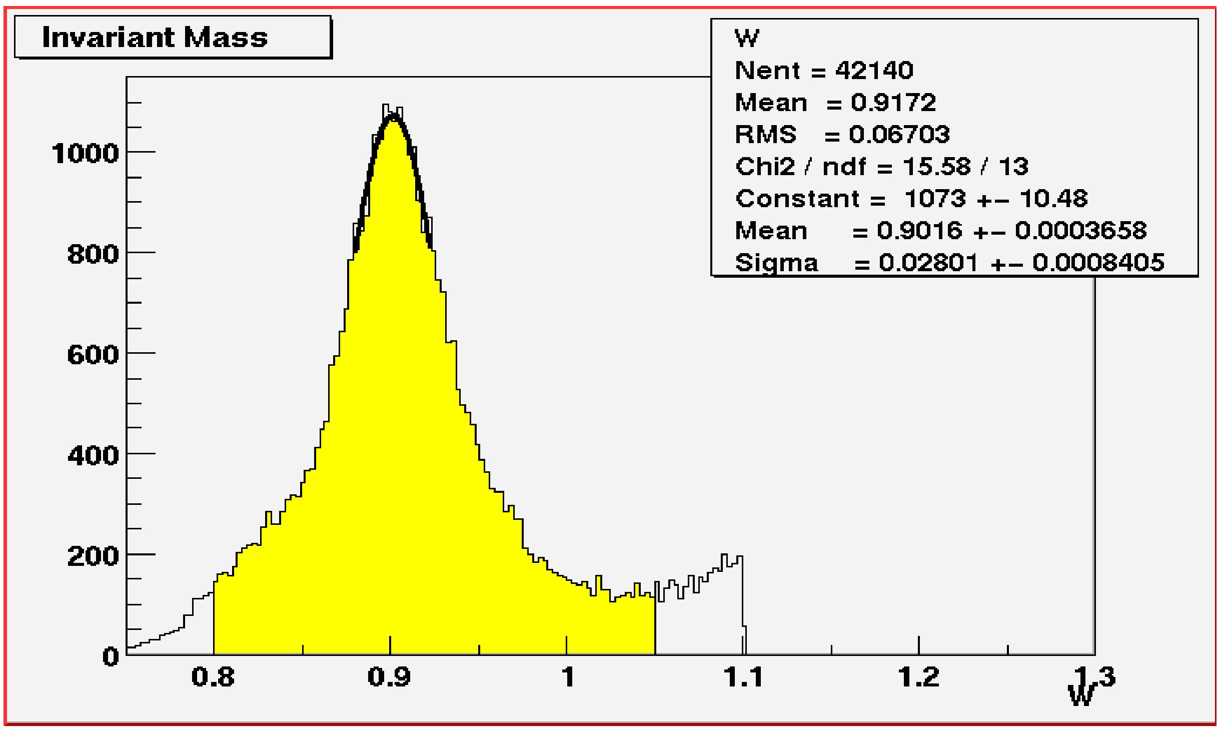

Figure 1: The elastic peak in W before applying any corrections. All sectors together.

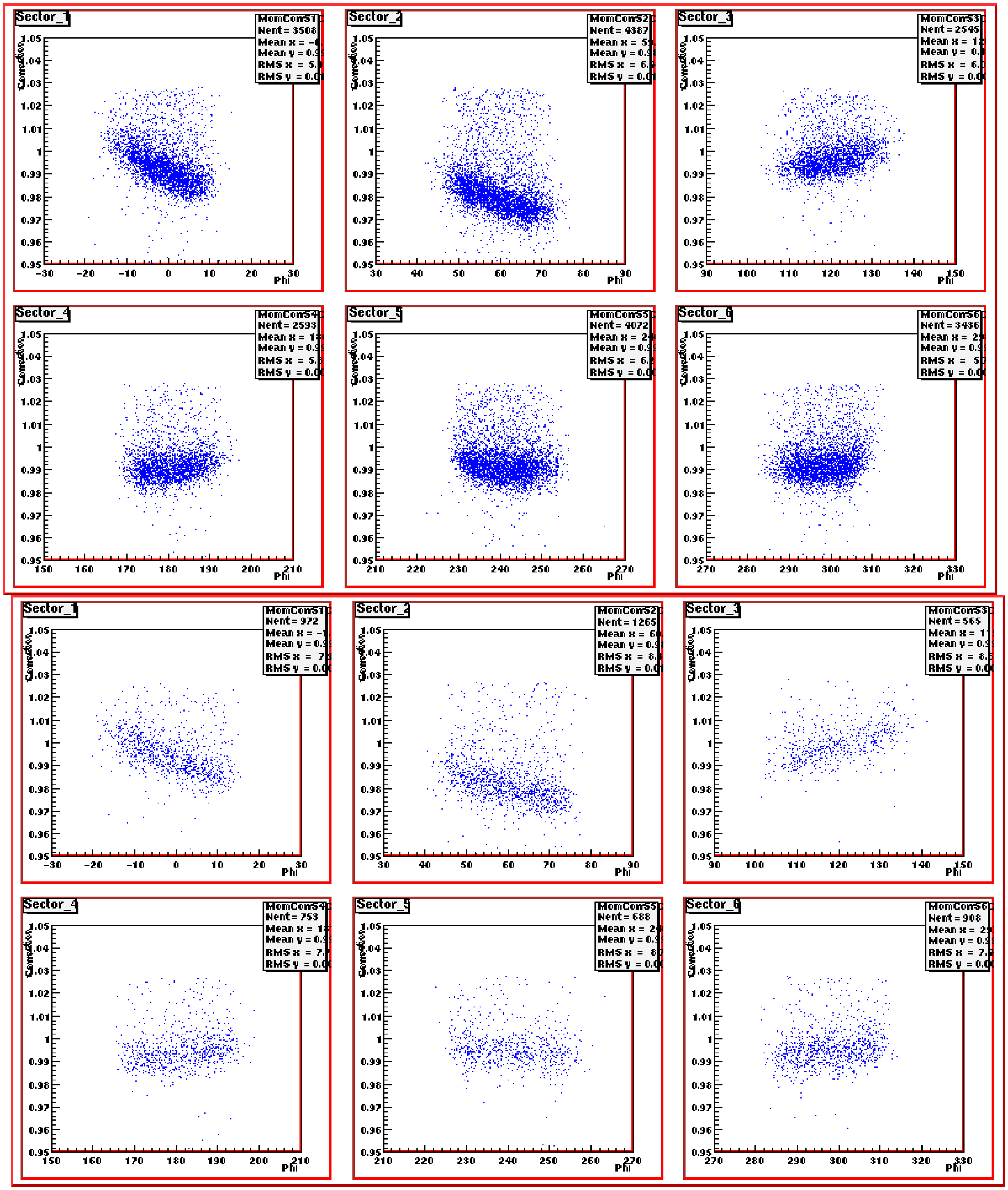

Figure 2: Plots of the correction f_1 versus the angle ϕ for different θ intervals: $16^o < \theta < 20^o$ (upper), $20^o < \theta \leq 25^o$ (lower).

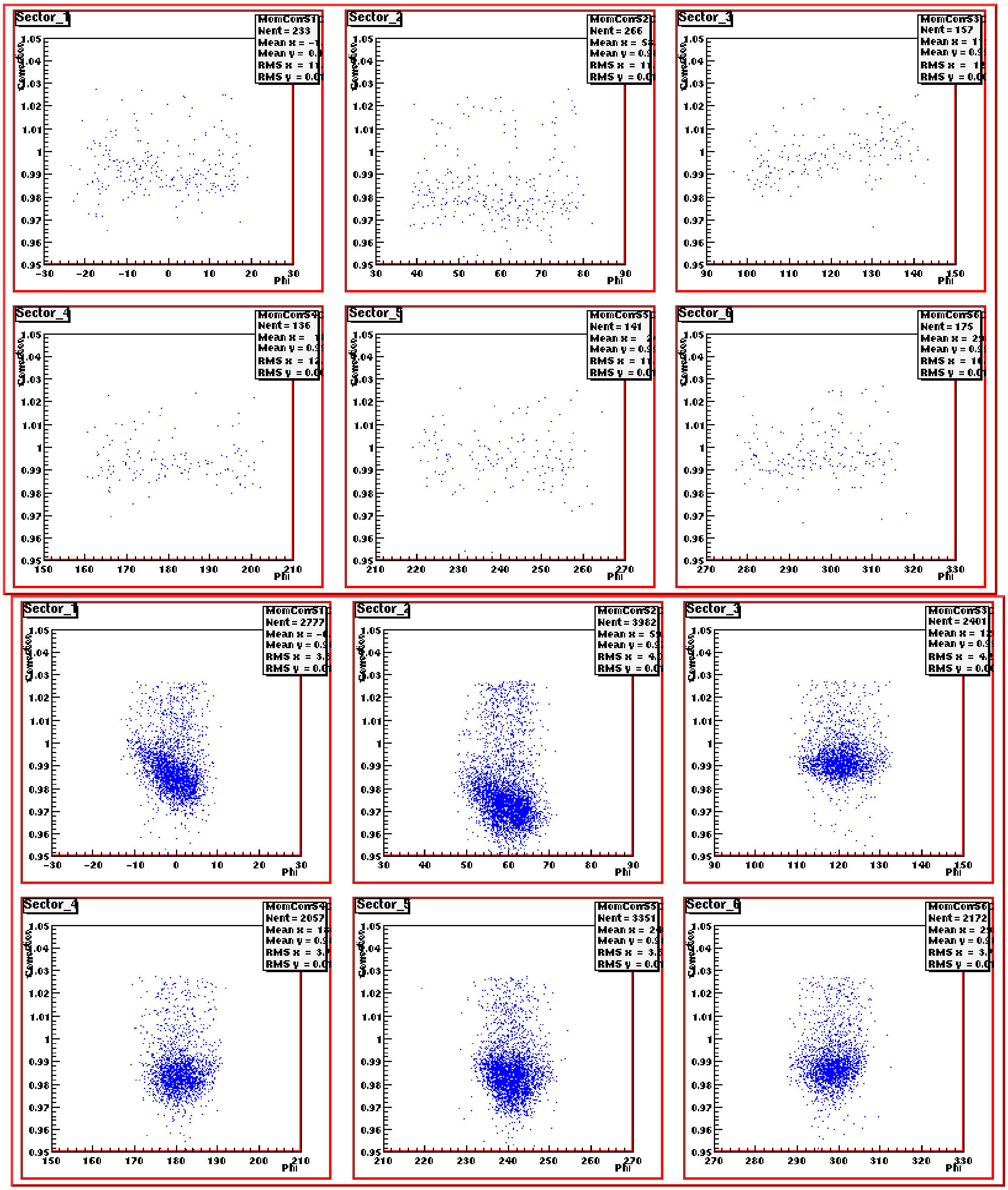

Figure 3: Plots of the correction f_1 versus the angle ϕ for two other θ intervals: $\theta > 25^o$ (upper) and $\theta \leq 16^o$ (lower).

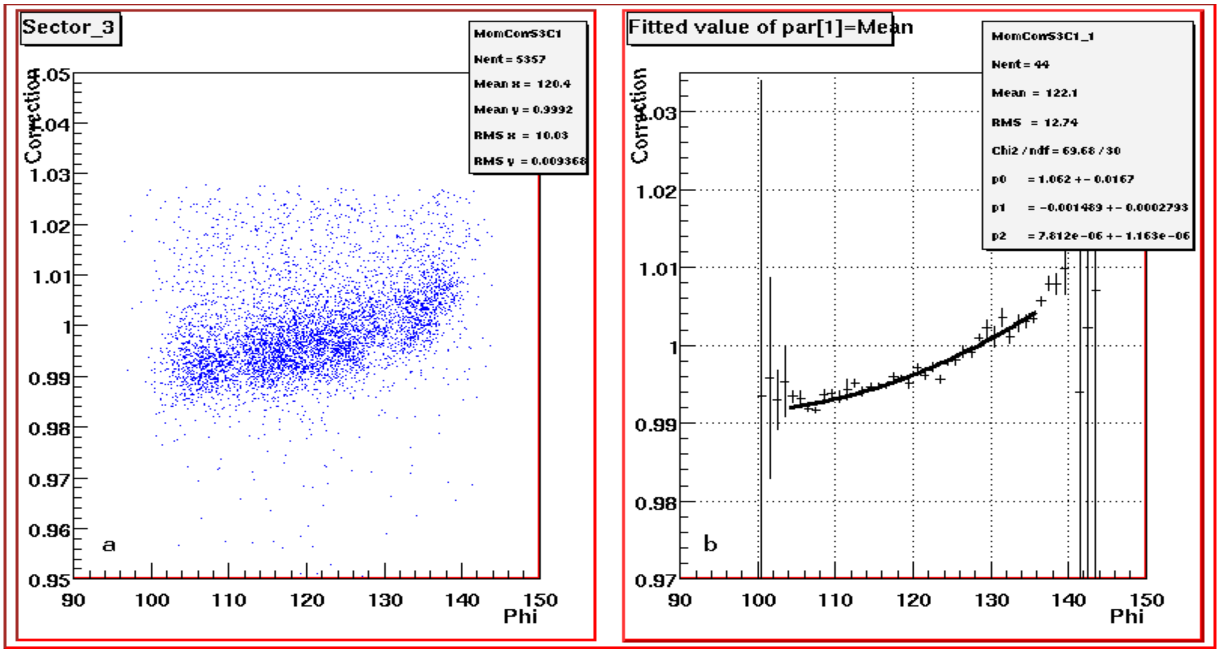

Figure 4: Plots of the correction f_1 versus the angle ϕ for $\theta > 16^o$: a 2D Histogram (left) is sliced and fitted (right). Only sector 3 is shown. For the other five plots, please see [1]

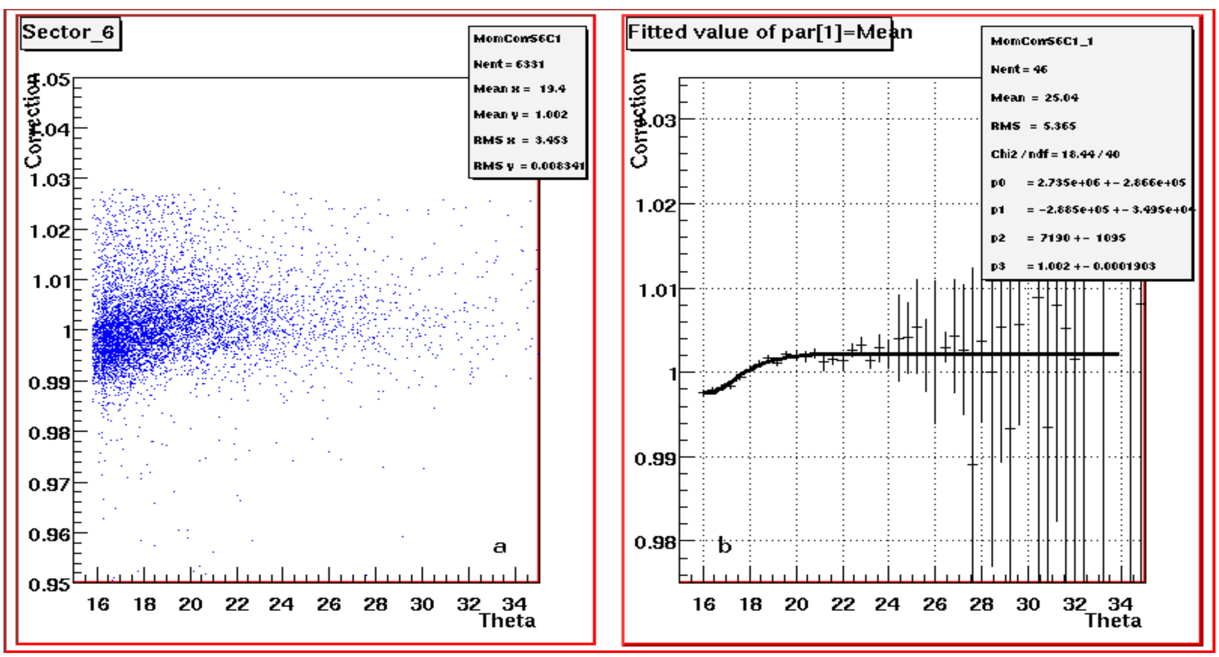

Figure 5: Plot of the correction f_2 versus the angle θ (left) and the fit with the function from eq.(7) (right). Only sector 6 is shown. For the others, please consult [1].

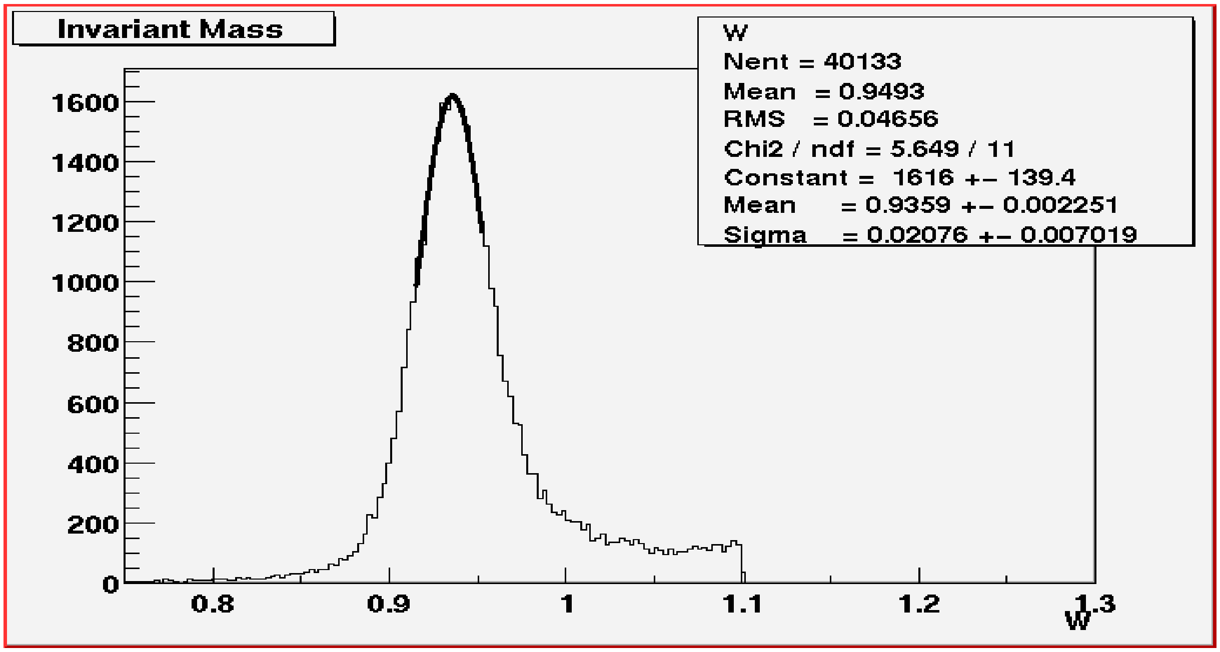

Figure 6: The elastic peak in W after ϕ-corrections were applied. All sectors. The width decreases to 21 MeV and the mean value shifts to 0.936 MeV/c^2.

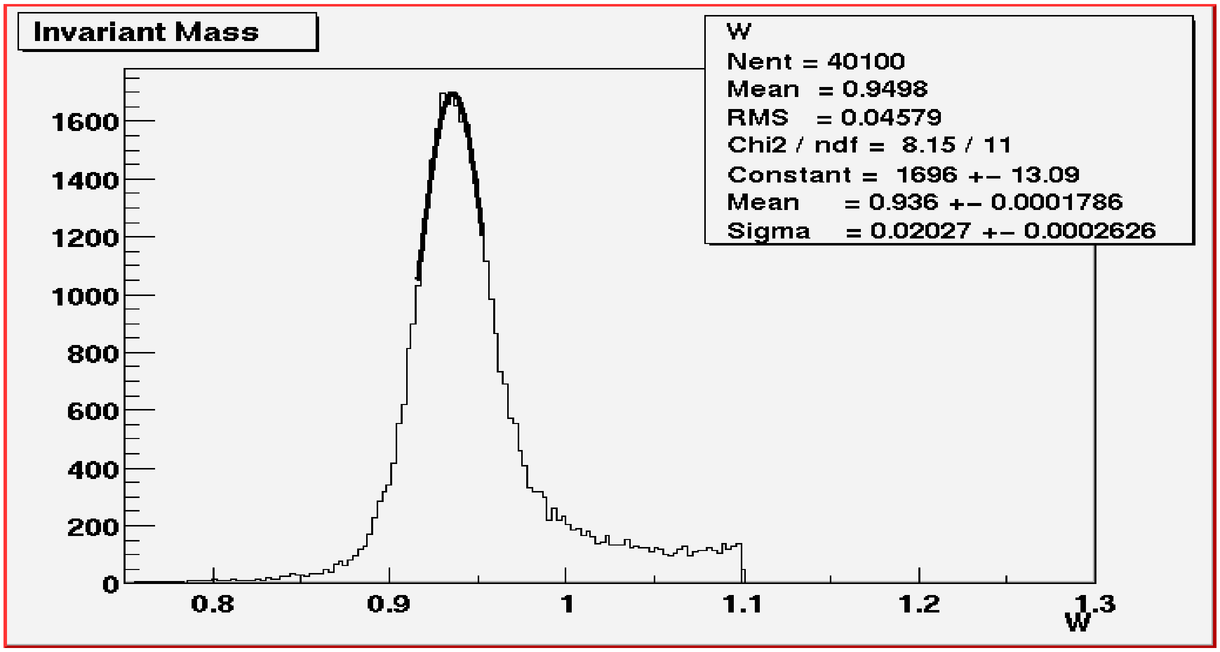

Figure 7: The final aspect of the elastic peak in W, when all corrections are done. All sectors. The peak is now even sharper.

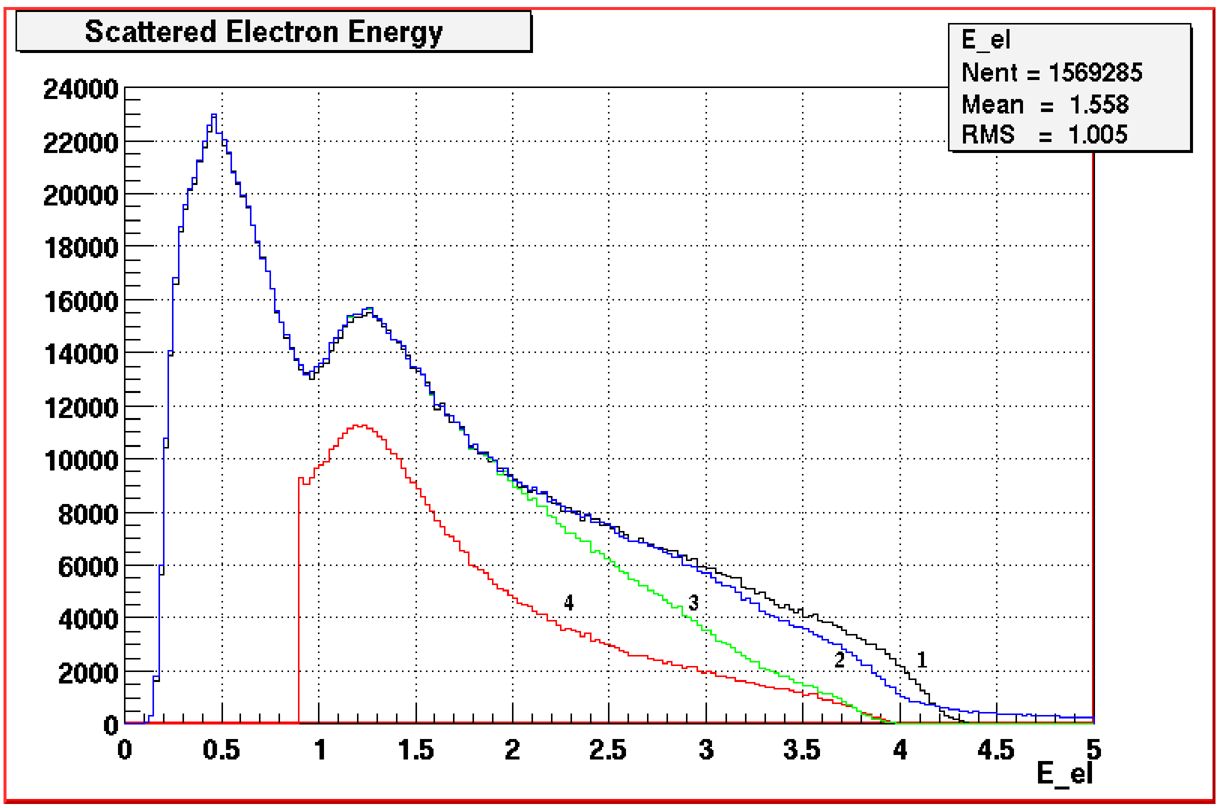

Figure 8: The aspect of the energy spectrum before (1) after the corrections (2), with the events below $\theta = 16^o$ discarded (3) and with the fiducial cuts applied (4). The unphysical tail in (2) vanishes when the erroneous events are discarded. Notice the agreement with the fiducial cuts.