Determining the Beam Energy – a Report

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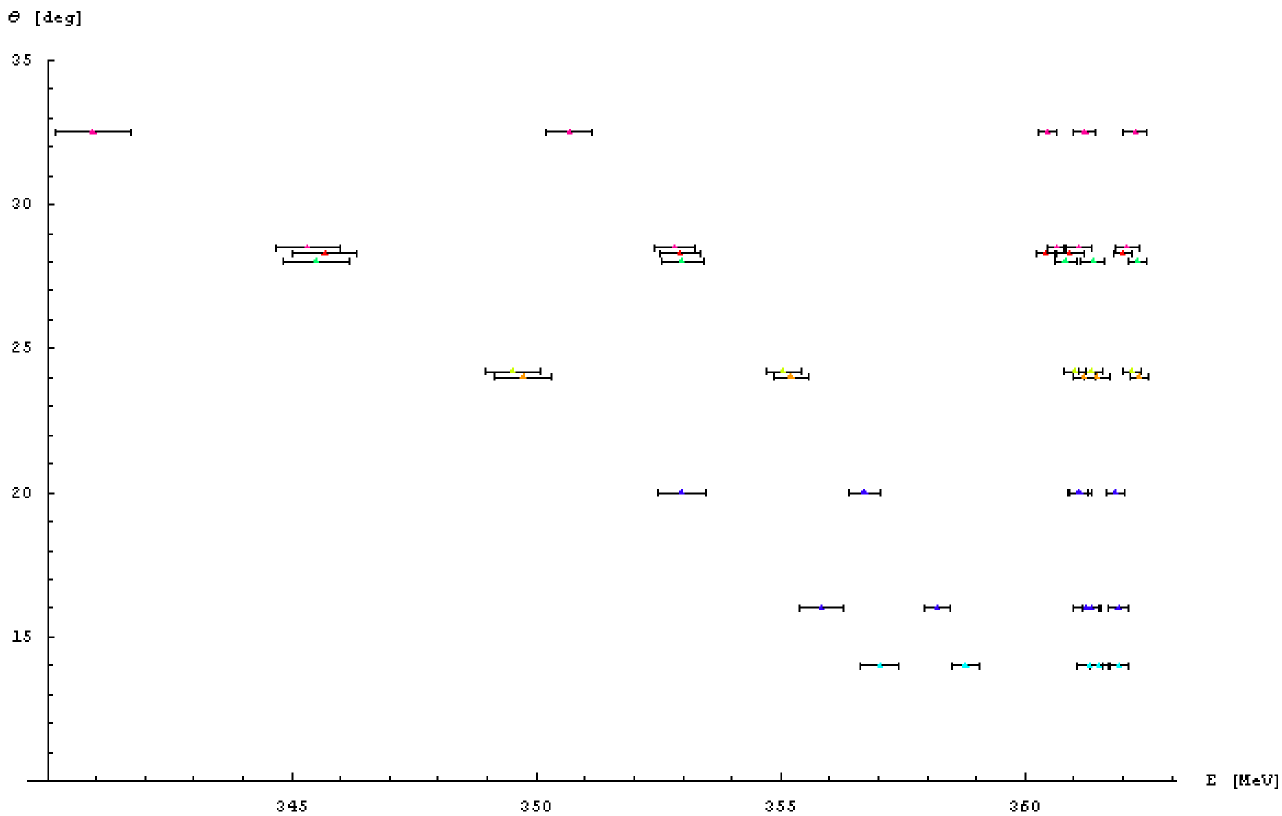

Illustration 1: The analyzed data from kinematic points: 1 (θ = 16 deg), 2(θ = 24 deg), 3(θ = 32.5 deg), 9(θ = 14 deg), 10(θ = 20 deg), 11(θ = 28.3 deg). Points with different colors correspond to different kinematic points.

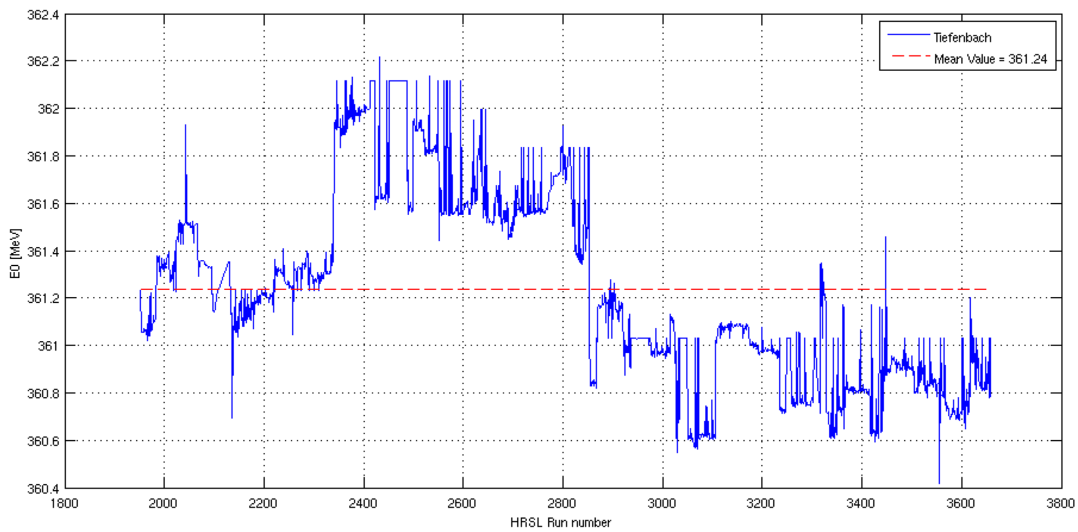

Illustration 2: Graph shows the Tiefenbach energies (extracted from HALOG) for every run in August 2006. The dashed red line shows the mean value of the Tiefenbach energy.

First Approach:

In my first approach I have assumed that the Hall probe gives me an accurate value of the magnetic field inside the dipole magnet. From these values I have calculated the momentum (using the formulas from John LeRose's report) and used it as a central momentum of the spectrometer. Once I have had these values for each kinematic point I was able to calculate the energies of scattered electrons from measured momentum deviations δ. My second assumption was that the set spectrometer's angle equals the angle of the scattered electrons. Therefore I was left only with one variable to fit – the beam energy. I have used the formula:

$$E' + \Delta E = \frac{E_{beam}}{1 + \frac{E_{beam}}{M}(1 - \cos\theta)}$$

The results that I got are shown in figures 3 and 4. From there results we can see, that the given fit does not describe well the measured points (especially those corresponding to light targets.) There is also a big difference between calculated beam energies for different kinematic points.

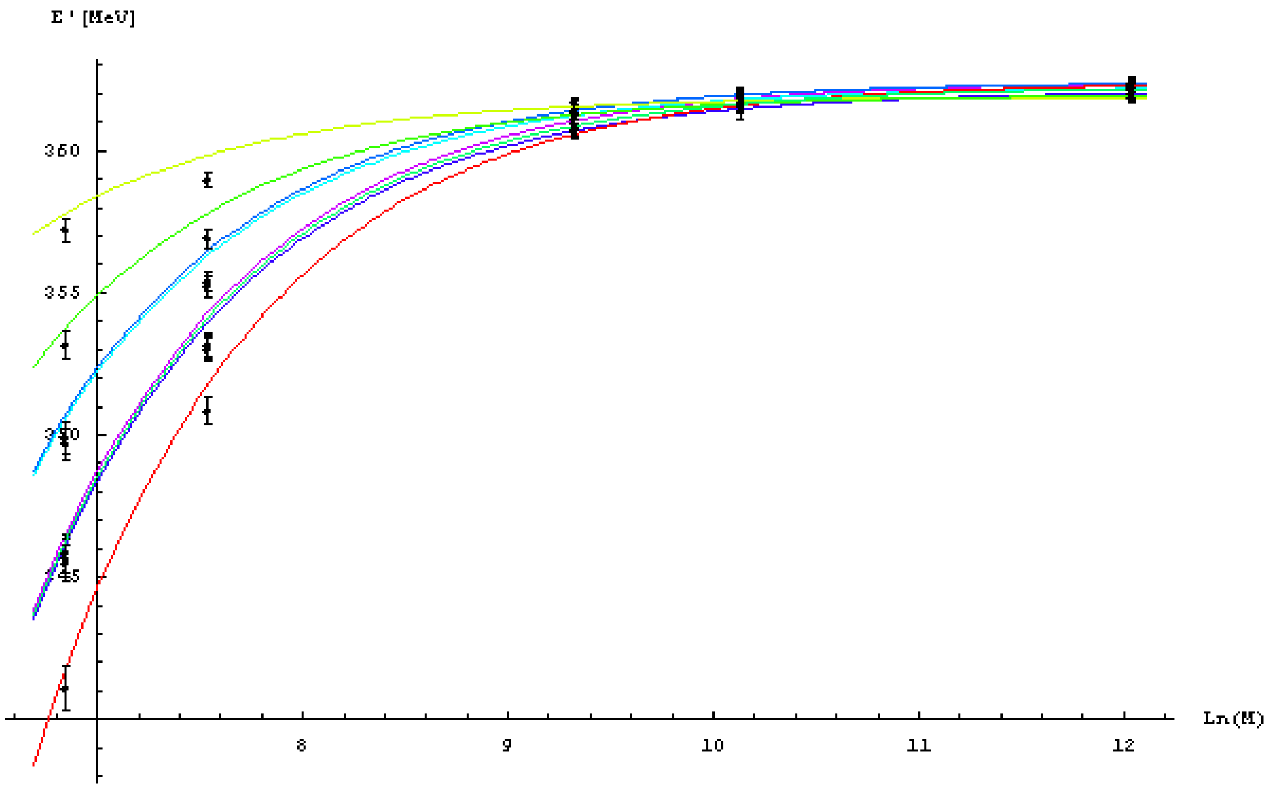

Illustration 3: This graph shows measured energies of scattered electrons from different targets at different kinematic points. The full lines show corresponding fits when using the first fitting approach.

In the next step I have decided to fit data for fixed target and for different angles. The results are shown in figures 5, 6 and 7. We can see, that the fit works pretty well for Hydrogen and Deuterium targets. The calculated beam energies from these two fits are also in a good agreement with the Tiefenbach energy. However, the energy calculated from the Tantalum data is approximately 1MeV off.

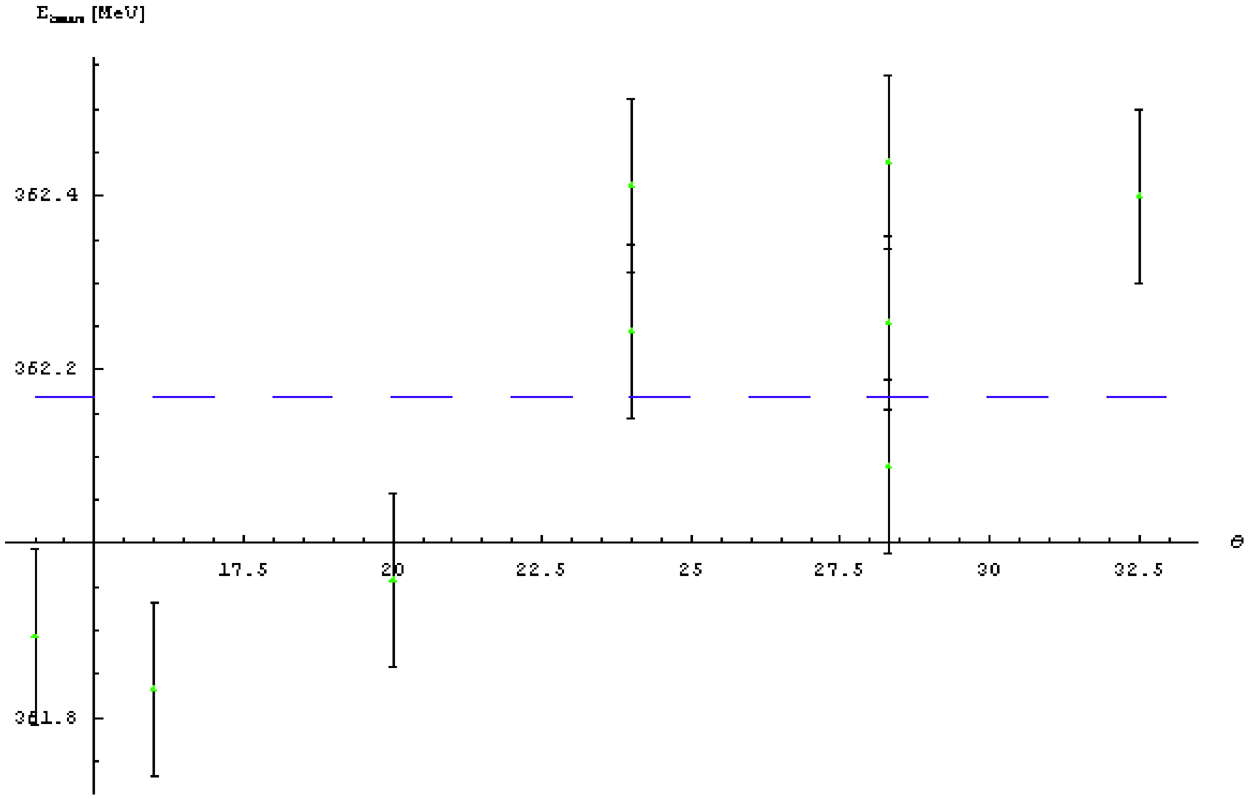

*Illustration 4: Green points show the calculated beam energies using the first approach. The blue line represents the mean beam energy **<Ebeam> = 362.2 MeV***

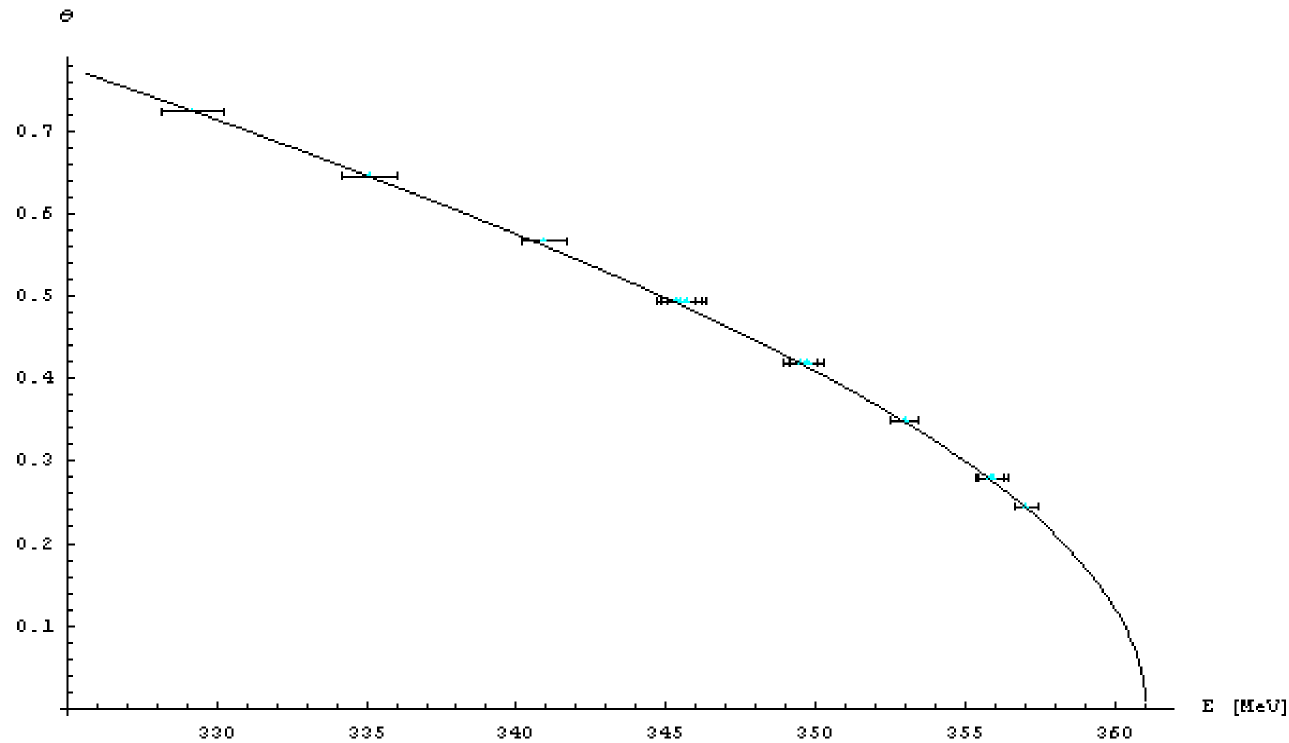

*Illustration 5: Cyan triangles show the energies of scattered electrons at different scattering angles when using a **hydrogen** target. The full line represents the analytic fit for **Ebeam = 361.4 MeV***

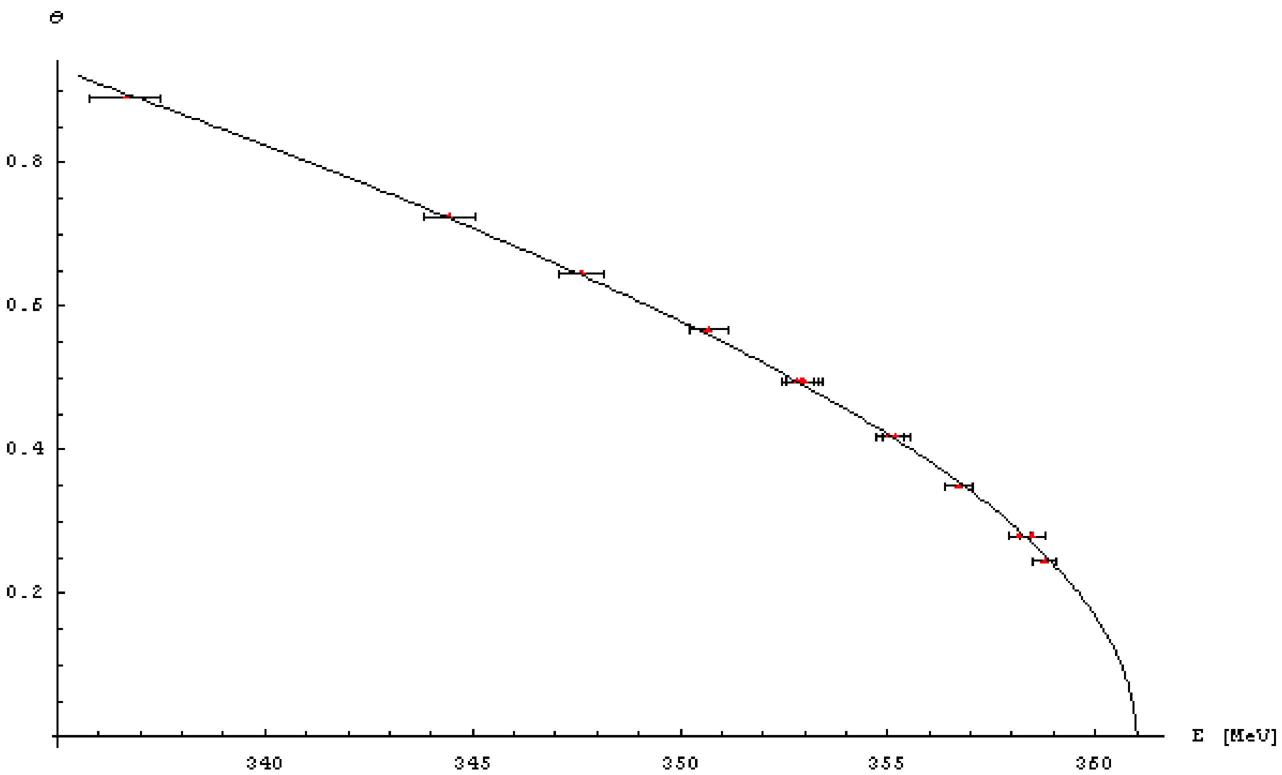

Illustration 6: Red triangles show the energies of scattered electrons at different scattering angles when using a ***deuterium*** *target. The full line represents the analytic fit for* ***Ebeam = 361.2 MeV***

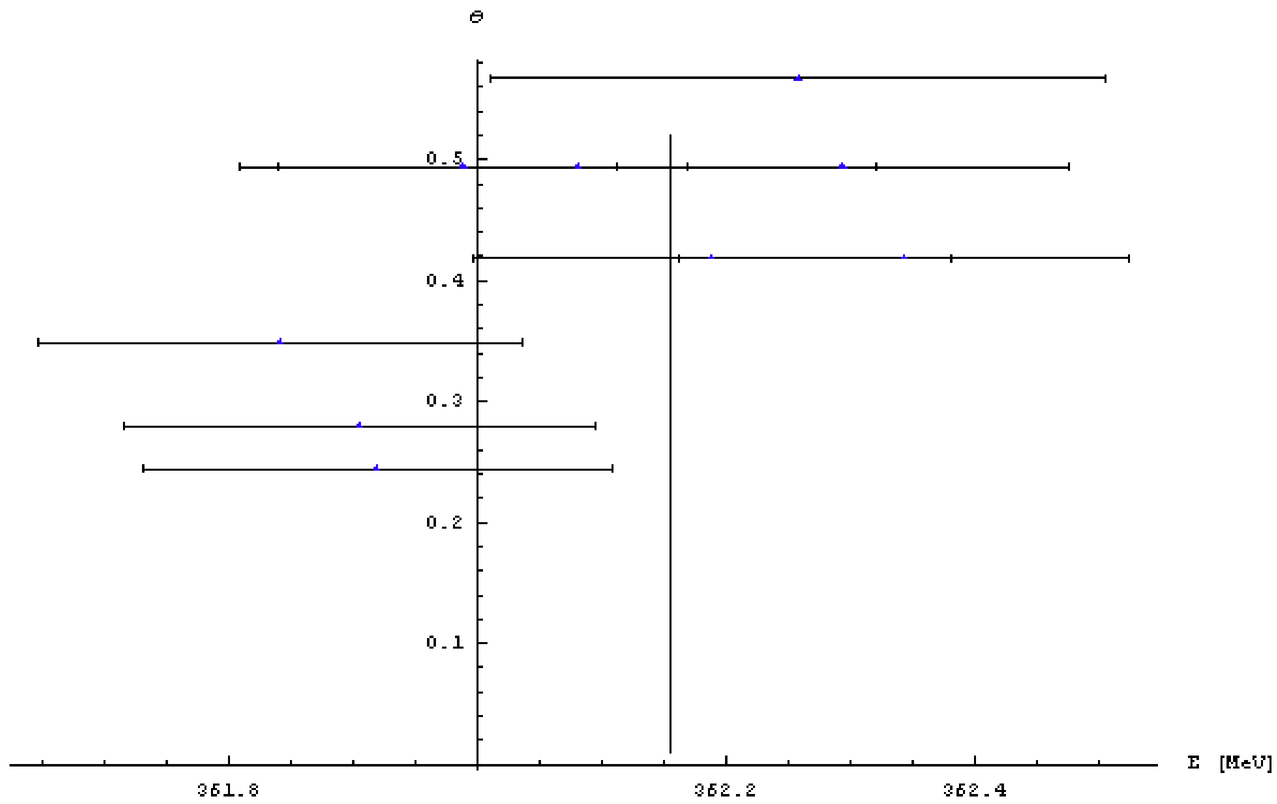

Illustration 7: Blue triangles show the energies of scattered electrons at different scattering angles when using a ***tantalum*** *target. The vertical full line represents the analytic fit for* ***Ebeam = 362.2 MeV***

Second Approach:

In my next approach I have used only the assumption about the spectrometer's angle and used the central momentum of the spectrometer (Ec) as an additional parameter in my fit function (along with the beam energy):

$$\delta = -1 - \frac{\Delta E}{E_c} + \frac{\delta_0}{1 + \frac{\delta_0 E_c}{M}(1-\cos\theta)}$$

where

$$E_{beam} = \delta_0 E_c$$

Using this formula I was able to fit my data quite well. See figure 8. I have fitted directly the momentum deviation δ. However, when I have calculated back the beam energy from Ec and δ0, the result became very strange (See figure 9). If we assume that the E_Ta is approximately E_beam then we quickly realize that the calculated beam energies are spread over a range of approx. 80 MeV. This is not useful at all.

I have also tried to fit data for each target separately, as I did in the first approach, but I wasn't able to find a reasonable fit for any of the targets. I believe that this proves, that this approach is not a good choice.

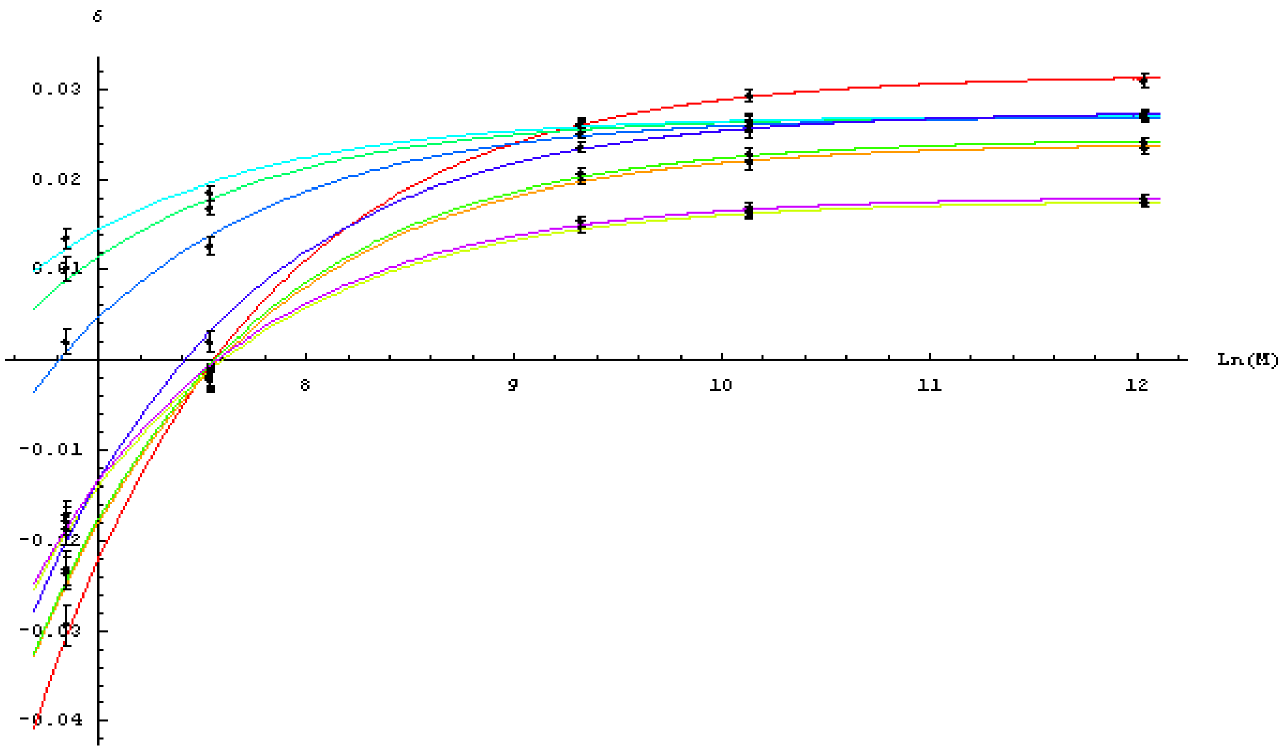

Illustration 8: This graph shows measured deviations δ for different targets at different kinematic points. The colored lines represent the corresponding analytical fits. Cyan, green, and both blue lines (that join at ln(m)=12) correspond to the data, that were measured with the R-HRS. Red, yellow, orange, violet and light green line correspond to the data, that were measured with the L-HRS spectrometer.

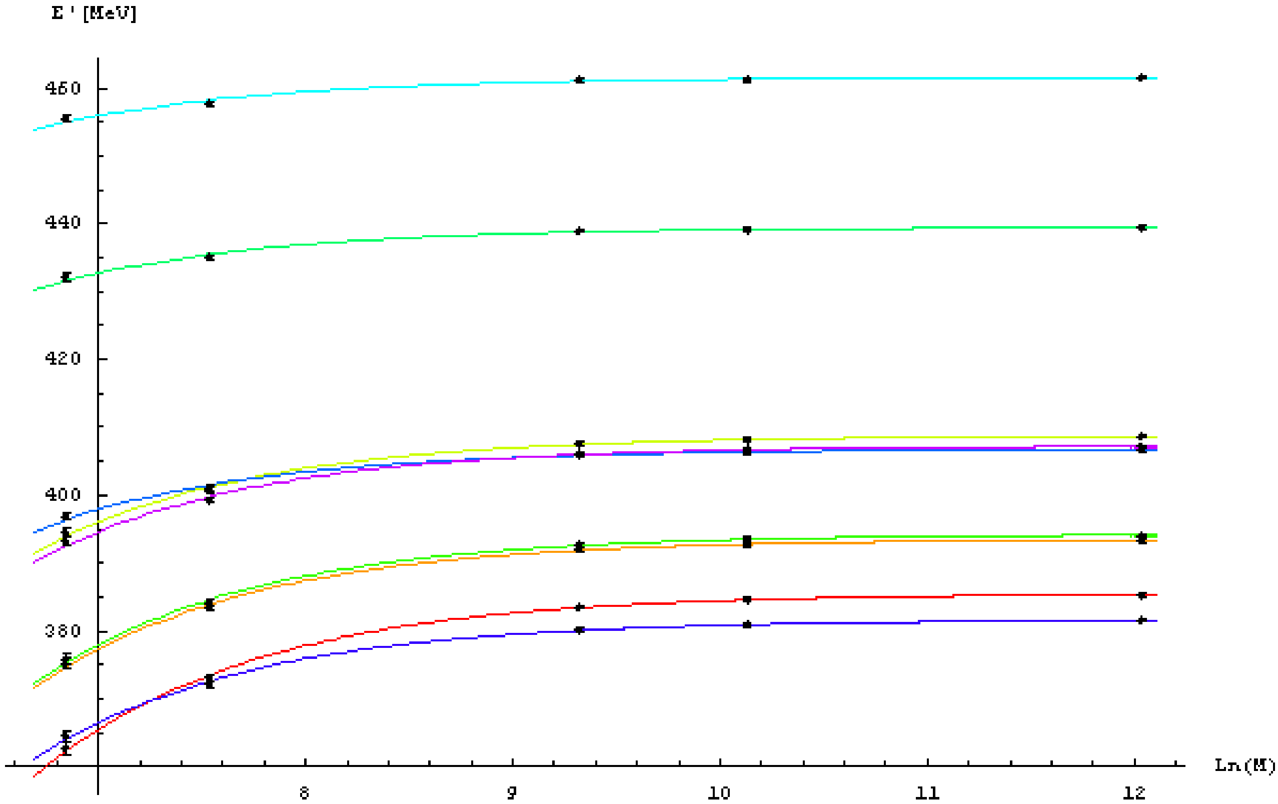

Illustration 9: This graph shows calculated energies of scattered electrons from different targets at different kinematic points using the measured data and the fitted energies Ec and δ0.

Third Approach:

In my last approach I have assumed that the central momentum of the spectrometer can be determined good enough with the Hall probe and used Beam energy and spectrometer angle as parameters in my fit. I have used the formula:

$$E'+\Delta E=\frac{E_{beam}}{1+\frac{E_{beam}}{M}(1-\cos(\theta_0+\Delta\theta))}$$

where θ0 is the set spectrometer's angle.

In this approach I got consistent (reasonable) results with both fitting techniques (fitting at fixed angle and fitting at fixed target). See figures 10, 12, 13, 14. However, there is a problem with the angle difference Δθ. From graph 11 we can see, that this difference is more than 1 deg. This of course can not be right.

I actually believe that this problem is closely related to the problem I had in the second approach. In both cases I have added an additional parameter to the second term of the denominator of the fitting function. This gives us a better agreement of the fitting function with the data, but spoils one of the fitting parameters – the spectrometer's angle in this approach and the beam energy in the second approach.

Therefore I believe, that there is a hidden connection between the energy of scattered electrons , the beam energy and the scattering angle (E' = E' (θ, E_beam)) that I haven't considered yet. I hope I will find this connection soon and solve my problems.

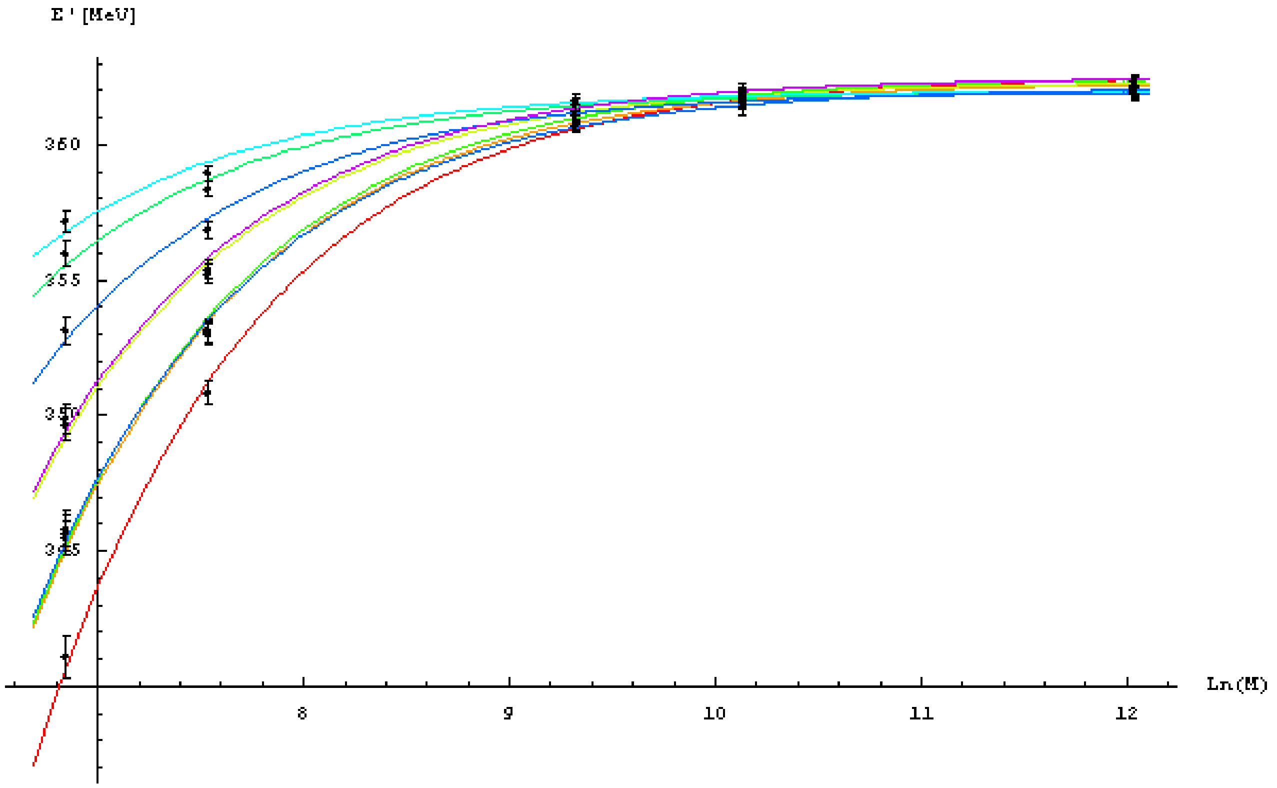

Illustration 10: This graph shows measured energies of scattered electrons from different targets at different kinematic points. The full lines show corresponding fits when using the third fitting approach.

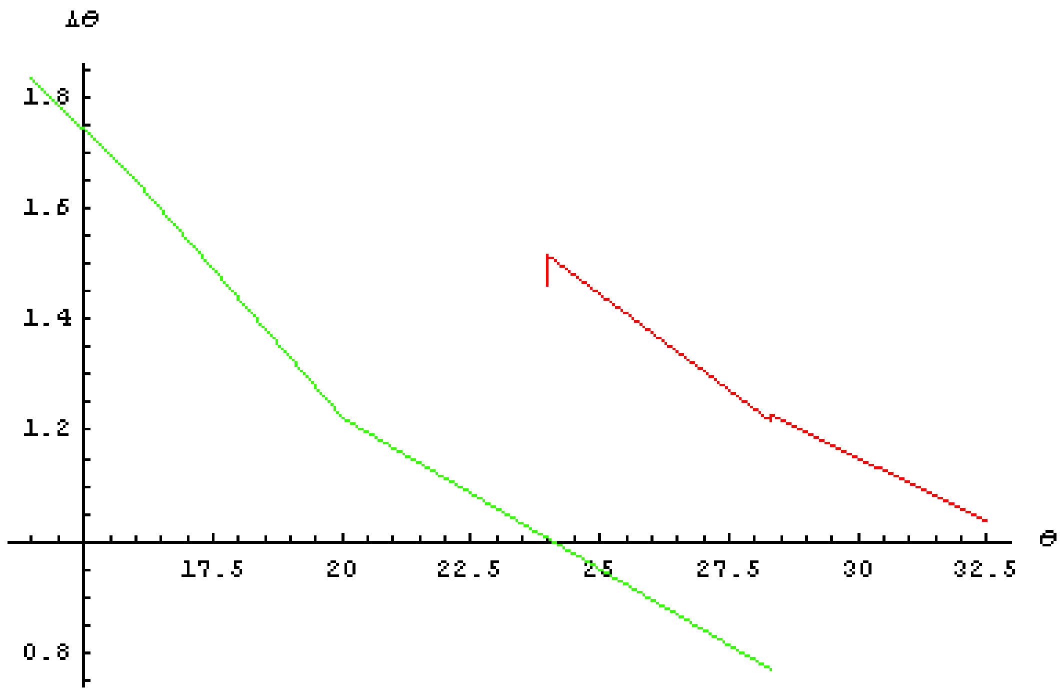

Illustration 11: This graph shows the difference (in degrees) between the fitted spectrometer angle and the set angle. The red line corresponds to the L-HRS and the green line to the R-HRS.

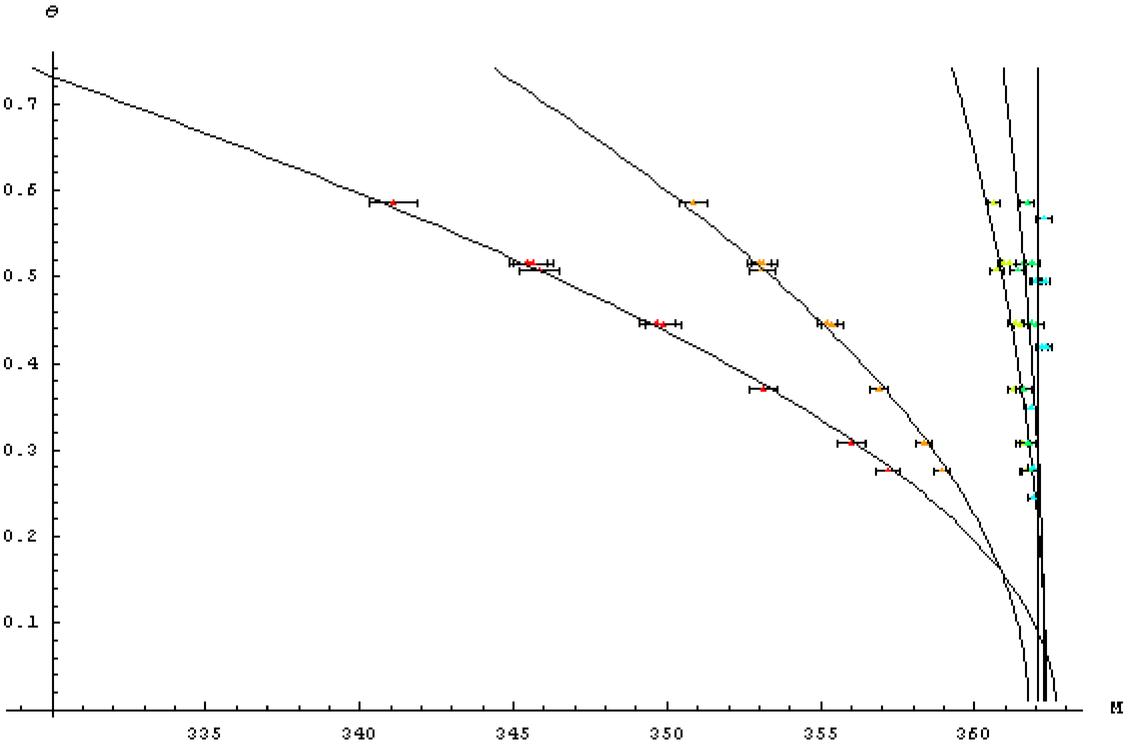

Illustration 12: This graph shows the measured data and their fits. Red points correspond to the Hydrogen target, the orange points to the Deuterium target, the yellow points to the Carbon target, the green points to the Aluminum target and the cyan points to the Tantalum target. I have fitted the data for each target separately.

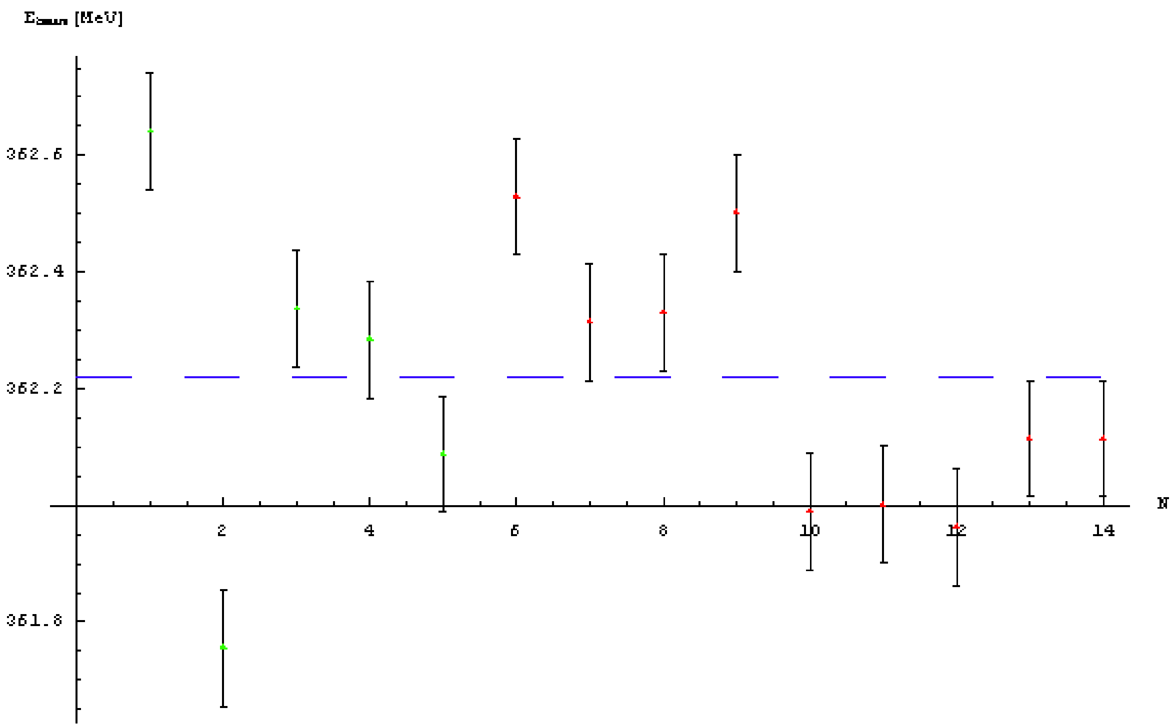

Illustration 13: The red points show the calculated beam energies for each kinematic points (fitting the data at fixed spectrometer angle for different targets.) The green points represent calculated beam energies for various targets (fitting the data for fixed target at different spectrometer angles.) The blue dashed line shows the mean beam energy ***<Eb> = 362.2 MeV.***

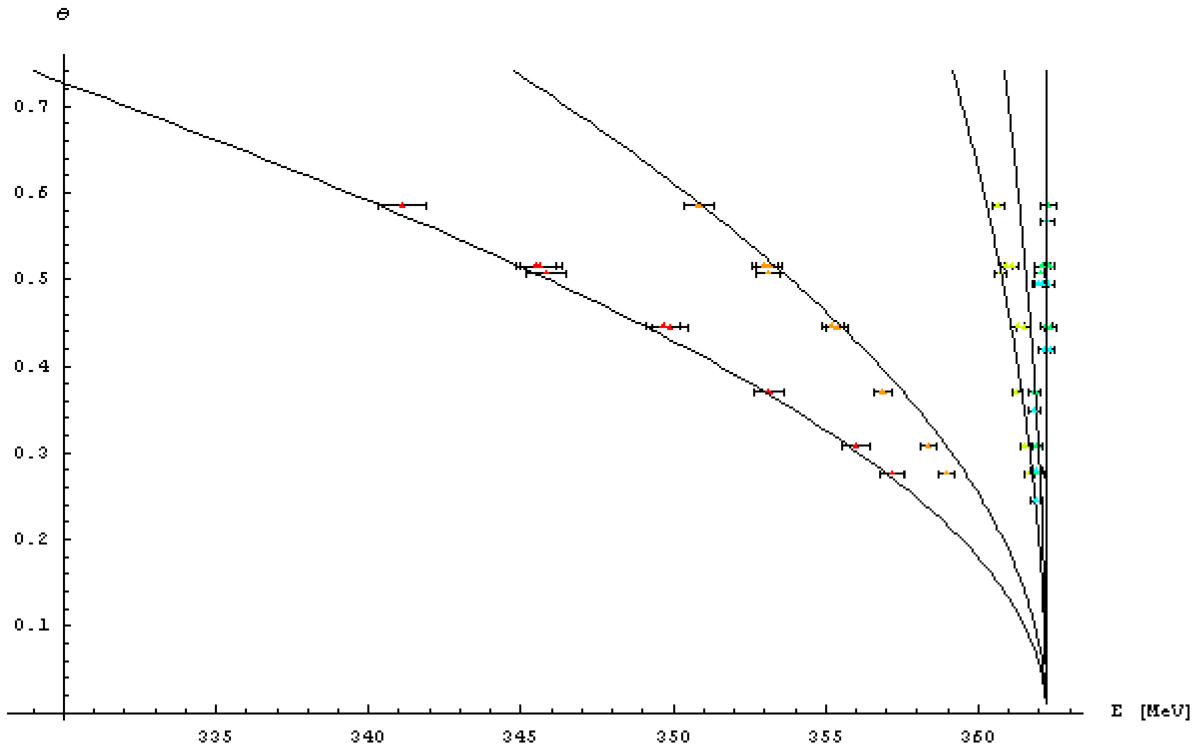

Illustration 14: The colored points show the measured data points for different targets and different spectrometer angles. The black lines show the calculated functions θ (E) using the mean beam energy <Eb> = 362.2 MeV.