Elastic Cross Section Analysis for E94010 (V1)

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Abstract

The analysis of the experimental ^{3}He(e,e)X data taken on the elastic kinematic by the experiment E94010 are presented. The analysis is done for two values of the incoming electrons energy. The experimental cross sections are compared to a Monte Carlo simulation. Results agree together within 5% (preliminary).

Contents

1 Introduction.

The experiment E94010 has taken elastic data at 0.86 GeV and 1.7 GeV. The purpose is to check our understanding of the detection apparatus and, in case of discrepancy between the experimental and the simulated data, to normalise the inelastic cross sections. Data were taken at the Jefferson Lab Hall A using a polarised ^{3}He gaseous target and both HRS spectrometers in electron detection mode. The electron HRS detection angle is θ_e=15.503^o. The "Hadron" HRS detection angle is θ_h=15.528^o. Elastic asymmetry analysis is already done and can be found in [DEUR1]

The experimental cross section σ_{exp} can be written as:

$$\sigma_{exp} = \frac{N_{raw}*Det*RC*Acc}{LT*\Delta\Omega*Q/q*N_{tg}}$$

where:

- N_{raw} is the number of elastic events after the geometrical and detector cuts
- Det is the detector inefficiencies correction
- RC are the radiative corrections
- Acc are some acceptance corrections (see section 6)
- LT is the data acquisition lifetime correction
- $\Delta\Omega$ is the HRS acceptance after the geometrical cuts
- Q/q is the electron beam charge integrated over the running time divided by the electron charge (i.e. the incoming electron flux)
- N_{tg} is the target density

Thus the different points checked by comparing the experimental and the simulated results are:

- Spectrometer acceptance simulations
- Spectrometer databases
- Target density
- Beam current
- Beam energy
- Total thickness of matter in the electron path (radiative corrections)
- ^{3}He contamination by the N_2 and the target windows
- deadtime correction

The philosophy of the analysis was to simulate entirely the experiment. So the radiative and the acceptance effects are simulated event by event using a Monte Carlo.

2 Energy Determination

2.1 Method

An energy determination at the 10^{-3} level is a critical input of the simulation (see section 9 for the uncertainty level due to the error on the energy). The two energy measurement devices eP and ARC were commissioned during the experiment. No reliable measurement is available for the energies where the elastic data were take. We use the elastic peak position and the HRS momentum calibration to compute the energy. The elastic peak is plotted in w-M_{He} (w=$\sqrt{M_{He}^2 + 2M\nu - Q^2}$). We match the elastic peak simulation with the data. Then the incoming electrons energy input of the simulation gives the beam energy. This method relies mostly on the absolute measurement of the scattered electron momenta by the HRS. They are measured relatively to the HRS central momentum setting The central momentum is proportional to the HRS dipole field. The proportionality constant used are [LIY]:

- $\gamma_e = 270.3 \pm 0.15$ (MeV/c/kG)
- $\gamma_h = 270.0 \pm 0.15$ (MeV/c/kG)

The energies found for the two data sets are:

- 0.8620 GeV
- 1.7177 GeV

Only one spectrometer is needed for the energy determination. One has to notice that the energy measurement using the two HRS are not consistent. The γ_h is modified by $1.16.10^{-3}$ in order to force the "Hadron" HRS to give the same results than the electron HRS. The uncertainties on all the quantities used to compute the cross section will be given in section 9.

Note We are sensitive to the quantity of matter in the electron path. We use the optical measurement done on the target wall thickness at CalTech ([JEN]) for the target Sysiphos. For Be Happy that was destroyed during the experiment no optical measurement is available and we use the estimate of ref [KOM1] with the appropriate uncertainty.

2.2 Background

The energy determination is biased if the N_2 background under the ^{3}He elastic peak has a slope. This background is subtracted using data taken on Nitrogen (1.719 GeV) or using a simulation if no data are available (0.862 GeV). This correction is negligible for both energies.

3 Luminosities

The target used for the 0.862 GeV data taking is Sysiphos. After temperature correction the target density is 1.0485 10^{22} cm^2 for a 40 cm target length (from D1 and D2 average). The pressure at uniform temperature is 8.23±0.18

Amagat ([KOM1] and [KOM2]). The temperature distribution in the target is approximated as a triangular distribution.

The target used for the 1.719 GeV data taking is Be Happy. After temperature correction the target density is 1.1865 10^{22} cm^2 for 40 cm. The pressure at uniform temperature is 9.33$\pm$0.15 Amagat.

The beam current is calibrated according to [SAHA] (Dx10) and is accurate to the percent level.

4 Chosen cuts

A priori the same cuts should be used in the simulation and in the data analysis.

Ref [DEUR2] compares different acceptance models with the E94010 data taken in the Deep Inelastic Scattering domain. Here the cross section variation with the virtual photon energy is almost flat. The geometrical and momentum cuts (θ_{target}, φ_{target}, $\delta p/p$) are chosen in a range where X. Jiang acceptance function reproduces well the data ([DEUR2]). Hence the error on the spectrometer acceptance simulation is minimised.

Since there is no pion production at the elastic peak, the Cerenkov, preshower and shower cuts are loose. Consequently no cut inefficiency corrections need to be done.

A cut on w selects the elastic peak.

y_{target} cuts are chosen in order to keep the longest target possible but in avoiding any window contamination. The experimental data constrain these cuts since the windows are not simulated in the Monte Carlo. The y_{target} cuts are at -4 cm and at +3 cm. This corresponds to a target length along the beam line of 26.19 cm for the electron HRS and 26.15 cm for the "Hadron" HRS. The difference is due to the slightly different detection angles of the two HRS. At this point a comparison between the experimental and the simulated data shows that the y_{target} and φ_{target} simulations do not fit well the data. See fig. 1 for the electron arm and Fig. 2 for hadron arm.

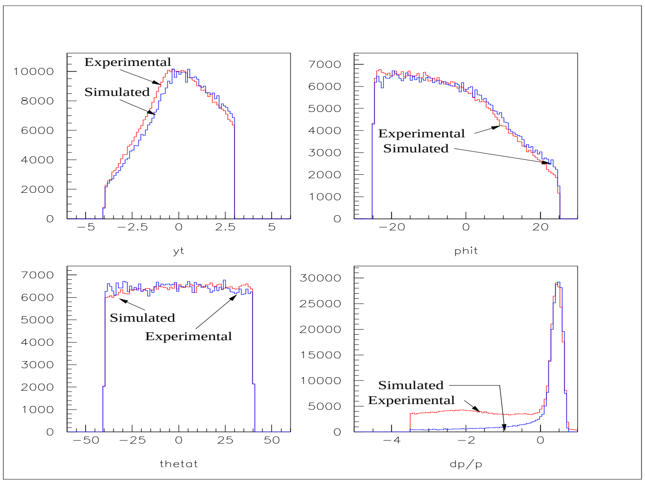

Fig. 1. Comparison between experimental (doted line) and simulated (plain line) data for the electron HRS at 0.86 GeV. The top left spectrum is y_{target} (cm), the top right is φ_{target} (mRd), the bottom left is θ_{target} (mRd) and the

bottom right is the relative momentum $\delta p/p$ (in %). The peak in the bottom right plot is the elastic peak. The difference in the tail comes from the fact that the ^{3}He quasi-elastic is not simulated here.

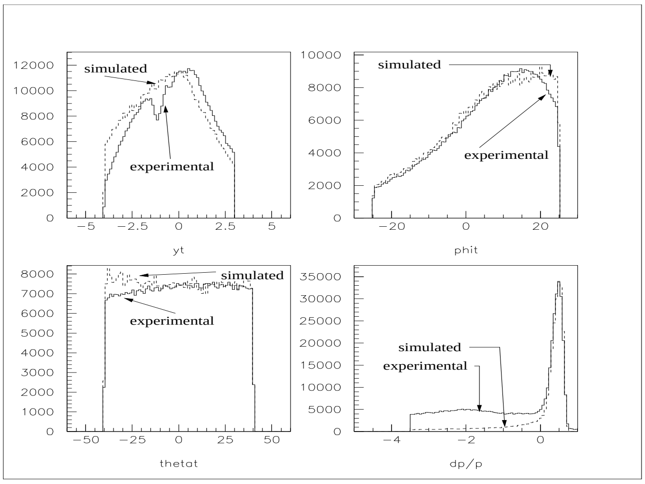

Fig. 2. Same than fig. 1 for "Hadron" HRS. The hole in the experimental y_{target} spectrum comes from wires hanging in the "Hadron" HRS acceptance.

A positive φ_{target} angle corresponds to a negative y_{target} vertex position so the two discrepancies are related. Cuts on positive φ_{target} was tighten from +25 to +10 mRd. Fig. 3 and Fig. 4 present the same spectra with the new φ_{target} cut. The y_{target} shape matches better the data as expected but the experimental and simulated spectra are shifted by about 3mm for both HRS.

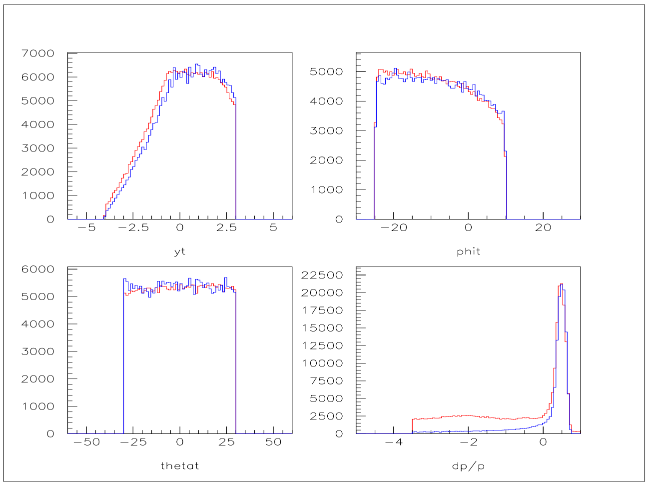

Fig. 3. Same as Fig. 1 but with tighter φ_{target} cut. The y_{target} spectrum shape is better. The experimental and simulation spectra are shifted by about 3mm.

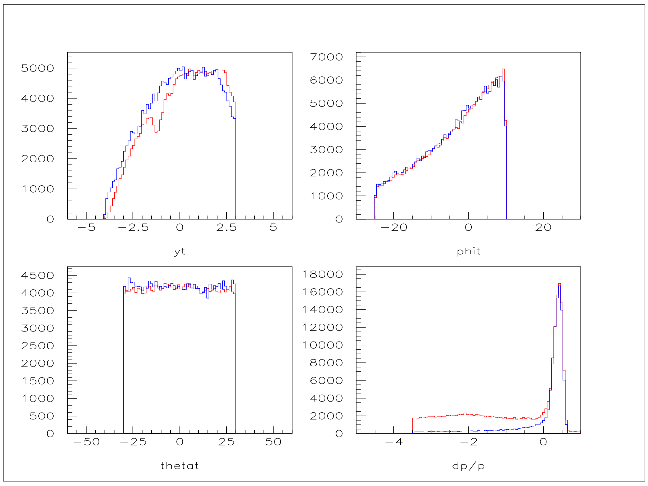

Fig 4. Same as Fig. 2 but with tighter φ_{target} cut. The experimental and simulation spectra are shifted by about 3mm as for electron HRS.

The reason of the y_{target} shift is not found yet. The z_{target} cuts on the simulation are sifted by $3/\sin(\theta_{e,h})$ mm to take care of the difference. This shift can change the simulated cross section up to 5%. The following table summarises the cuts chosen for the simulation and the experimental analysis.

cut	Simulation	Experiment
y_{target} h-arm	-4.3,+2.7 cm	-4,+3 cm
y_{target} e-arm	-3.7,+3.3 cm	-4,+3 cm
φ_{target}	-20,+15 mRd	-20,+15 mRd
θ_{target}	-30,+40 mRd	-30,+40 mRd
$\delta p/p$	-3.5,+2.7 %	-3.5,+2.7 %
w-m_{He}	-1,+5 MeV	-1,+5 MeV

Note: The y_{target} h-arm cut means a -16.066<z_{lab}<10.088 cm cut and the y_{target} e-arm cut means a -13.843<z_{lab}<12.346 cm

5 Detector efficiencies

The shower and preshower efficiencies are taken at 100 % [KOM2] as well as the Cerenkov efficiencies [SLIFER]. This is the consequence of the absence of pions at these kinematics.

The scintillator inefficiency correction is done for each allowed combination of paddles and run by run. It can reach 20 % for the 0.86 GeV data but are of the order of 5 % for the 1.72 GeV data.

The VDC inefficiency is estimated following the method set in the note on the VDC analysis [DEUR3]. The inefficiency is of the order on 1.5 %.

6 y_target Correction for "Hadron" Arm

The event loss due to wires hanging in the "Hadron" HRS acceptance during the 0.86 GeV data taking (see fig. 2 and fig. 4) has to be corrected. We fit the experimental spectrum y_{target} with the simulation and estimated the number of missing events by measuring the hole area. The correction found is 1.9 %.

7 Contamination

About 1% of N_2 is mixed with the ^{3}He in the target. It is needed as a quencher to increase the target polarisation efficiency. The N_2 excitation differs from the ^{3}He one so the ^{3}He/N_2 yield ration depends on the kinematics. Data or simulation of N_2 excitation spectrum are necessary to correct from this contamination.

7.1 1.72 GeV data

N_2 data are available for 1.72 GeV. The N_2 elastic cross section in the case of data taken with a N_2 target is normalised to the N_2 elastic cross section in the case of data taken with the regular ^{3}He target. Then the contamination estimate is done according to the w cut chosen for the analysis. In Addition there is some ^{3}He quasi-elastic contamination: It is not possible to separate clearly the two reactions because of the closeness of the ^{3}He quasi-elastic threshold and the elastic peak radiative tail. The w cut is chosen as tight as possible to minimise this contamination. Two models were tried to simulate the ^{3}He quasi-elastic threshold region without satisfying results. The contamination estimate is done by simulating the radiated ^{3}He elastic peak, using the simulation to fit the experimental data subtracted from N_2 and assuming the remaining part comes from the non simulated ^{3}He quasi-elastic peak. This method relies on a good radiative processes simulation. The reliability of the radiative process simulation was checked in several ways. An error in the estimate can still come from the uncertainty on the quantity of matter crossed by the electrons.

The total contamination correction for the 1.72 GeV data is 7.5 %.

7.2 0.86 GeV Data

No N_2 data are available for this energy. ^{3}He and N_2 quasi-elastic peaks simulations show that this contamination is negligible (of the order of 0.1%). The contamination comes from the N_2 elastic radiative tail: The N_2 elastic peak sits at smaller energy loss and consequently the radiative tail extends under the ^{3}He elastic peak. The radiated N_2 elastic peak is simulated (the Nitrogen form factors are not taken into account) and normalised to the N_2 elastic peak in the experimental data taken with the ^{3}He target. The contamination is of 0.7%.

8 Simulation

The simulation of the experiment is done using the Monte Carlo mce94010 [DEUR4].

8.1 Acceptance

The acceptance simulation is provided by X. Jiang (jiang@jlab.org). The analysis was also conducted using J. Lerose acceptance function (lerose@jlab.org). In the chosen cuts both functions agree well together with the data. The spectrometer acceptance simulations are studied in [DEUR2] and compared with the experimental data. At larger cuts it shows that the acceptance from X. Jiang is better suited for an extended 40 cm target. In fig 5 and 6 the cross section dependence with the cuts is studied: The geometrical cuts are extended, the ratio of the elastic simulated cross section to the experimental cross section is calculated for each new cut and plotted. This is done with both J. Lerose and X. Jiang functions.

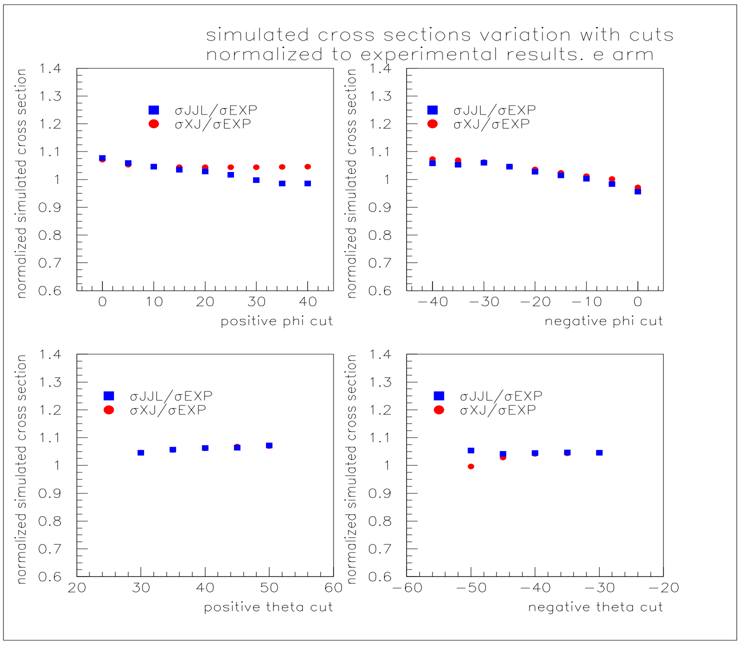

Fig 5. Ratio of the electron HRS elastic simulated cross section to the experimental cross section calculated for different geometrical cuts. The squares are the cross sections simulated with J. Lerose acceptance function divided by the experimental cross section. The circle used X. Jiang acceptance simulation.

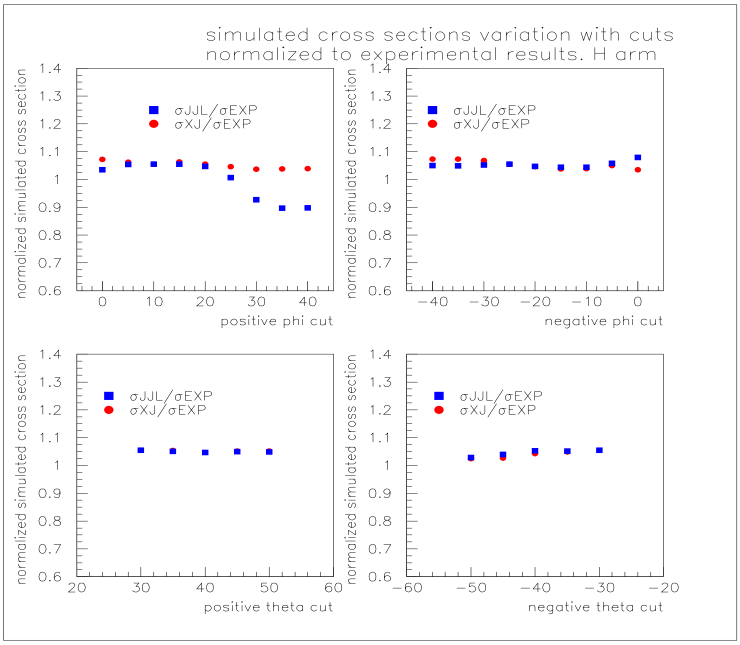

Fig 6. Same than fig. 5 but for "Hadron" HRS.

8.2 Radiative Corrections.

The internal and external bremsstrahlung photon emissions are simulated event by event. Thus the radiative processes are folded into the simulated data that are compared to the uncorrected experimental data. The method and the emission probabilities used are detailed in [DEUR4]. A consistency check was done by simulating the radiated elastic tail and by doing the correction using the Mo and Tsai formulae [MT] for different $\delta P/P$ cuts. The corrections for the different cuts are consistent. This method was also applied to the experimental data but the closeness of the ^{3}He quasi-elastic peak forbids to extend the $\delta P/P$ cuts. The results are consistent with the estimate event by event. The correction factor in this case is $1+\delta = 1.55$ (for 0.86 GeV data).

The correction was also compared with another simulation [XIONG] using J.A Templon functions for the bremsstrahlung emissions [TEMP]. Results are in very good agreement.

Hence the only significant errors expected could come from the radiative correction inputs.

The nominal inputs are listed in the table below. They are computed using the direct measurement of the matter thickness [KOM1], [ESP]. The unit is electron radiation lengths

Target	Incoming	Outgoing to h HRS	Outgoing to e HRS
Be Happy	0.00593	0.0338	0.0342
Sysiphos	0.00593	0.03790	0.03732

The straggling is also simulated event by event using a Landau Distribution. The densities of matter crossed by the electrons are:

Target	Incoming	Outgoing to h HRS	Outgoing to e HRS
Be Happy	0.1743	0.941	0.952
Sysiphos	0.1743	1.0495	1.04137

9 Uncertainty Estimate

9.1 Uncertainty on data

- Beam current uncertainty is 1%
- Statistical uncertainty is negligible
- Trigger inefficiency can reach 20% at worst for some paddle combinations for 0.86 GeV. The uncertainty on this number is about 0.5 % for a typical 5 million events run. Therefore the uncertainty on the cross section is below 1%. In the case of 1.72 GeV runs the uncertainty due to the correction is neglected.
- The uncertainty on φ_{target} is about 3.10^{-3} mRd. This is due to the wire chambers accuracy level. This propagates to the uncertainty on the target length cut. For a HRS angle of 15.5^o it is 8 mm. This bring a 3.2 % uncertainty on the cross section.
- Target temperature uncertainty is respectively 2% ([JEN]).
- Target density uncertainty is 3.4 % (Sysiphos) and 3.2 % (Be Happy) ([KOM2]).
- N_2 contamination uncertainty was taken to be 1% for 0.86 GeV data and 2% for 1.73 GeV data.
- The uncertainty on the 1% y_{target} correction due to the wires hanging in the acceptance is neglected.
- The uncertainty on the deadtime is neglected.

These number added in quadrature yield a 5.27 % error for the 0.86 GeV data and 5.43 % for the 1.72 GeV data.

9.2 Uncertainties on simulation

- The statistical error is negligible.
- The error on the energy is taken as ± 2 MeV. This yield a 2.2 % error on the simulated cross sections for the 0.862 GeV simulation and a 2.6 % error for the 1.72 GeV simulation.
- We used the ^{3}He form factor fits of [AMR] to compute the cross section. The error on it is arbitrarily assumed to be 5%.
- In the particular case of X. Jiang acceptance, the uncertainty due to the acceptance is dominated by the numbers of event in the central bin of the acceptance. We use it to normalize the acceptance. With the chosen bining of the acceptance the statistical error is 5%.

- We have .6 % uncertainty due to the radiative correction inputs (i.e. uncertainty of 2 % in the length of matter crossed by the outgoing electron).
- The spectrometer angle accuracy is taken as ± 1 mRd. This yield a 5% error on the 0.62 GeV simulation and a 10% error on the 1.72 GeV simulation.

This yield a 7.83 % uncertainty on the 0.862 GeV simulation and a 9.26 % uncertainty for the 1.72 GeV simulation. This latter is larger mainly because we are near a refractive point of the Coulomb form factor.

10 Results

The figures 7 and 8 present the results. They were computed using the two acceptance functions. These results cannot be compare to the world data because radiative correction and finite acceptance effect are still folded in. This could be done by normalizing the simulation result to the cross section at the central acceptance bin.

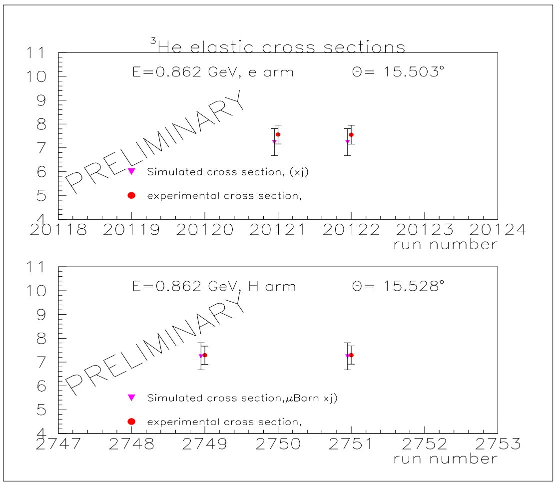

Fig 7. Elastic cross section at 0.86 GeV. The top plot is for the electron HRS while the bottom is for the "Hadron" HRS.

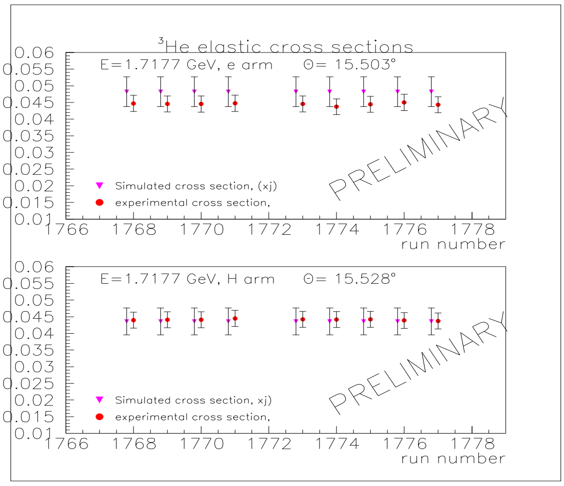

Fig 8. Elastic cross section at 1.72 GeV. The top plot is for the electron HRS while the bottom is for the "Hadron" HRS.

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