Rates on HPS SVT L1 from inclusive quasi-elastic electron scattering

S. Stepanyan (JLAB) and T. Maruyama (SLAC)

(Dated: November 2, 2013)

Computer code *inclusive*[1] is used to estimate single electron rate on HPS SVT Layer-1 from scattering of 200 nA, 2.2 GeV electron beam on 0.00125 r.l. tungsten (W). Code uses parameterization of nucleon form factors that is based on available world data, takes into account nuclear, and radiative effects. It was written in 1990, since than some of parameterizations have been improved but no new fits to the data have been done to improve overall parametrization.

I. Cross sections and Rates on HPS SVT

Here we will discuss HPS 2.2 GeV setting. Cross sections of inclusive electron scattering off nucleons of tungsten nucleus have been calculated for scattering angles from $\theta_{min} = 0.015$ rad to $\theta_{max} = 0.06$ rad in steps of $\Delta\theta = 0.005$ rad. In Fig. 1 inclusive electron scattering cross sections, A(e,e′), at 2.2 GeV are presented as a function of scattered electron energy (E′). Cross sections are calculated in 2 MeV steps of scattered electron energy. Fermi momentum tail was set to 150 MeV. "Virtual nucleon" approximation was used to account nucleon form factor modifications in nuclear medium. For purposes of radiative effects, 0.0004 cm thickness of tungsten target was used. As can be seen from the plots, at this kinematics process is dominated by quasi-elastic (QE) scattering of electrons off bound nucleons. Nuclear elastic (Coulomb) scattering is not included in the calculations.

In order to calculate electron rate on Layer-1 SVT, simple geometrical acceptance was used (magnetic field was ignored, no momentum dependence of acceptance). For each angular bin acceptance was defined as:

$$\Delta\Omega_i = \sin\theta_i \Delta\theta\Delta\phi \tag{1}$$

where θ_i is taken at the center of the bin and $\Delta\theta = 0.005$ rad. The $\Delta\phi = 2 \times \phi_c$ was calculated taking into account the distance of L1 from the target $d = 10$ cm and from the

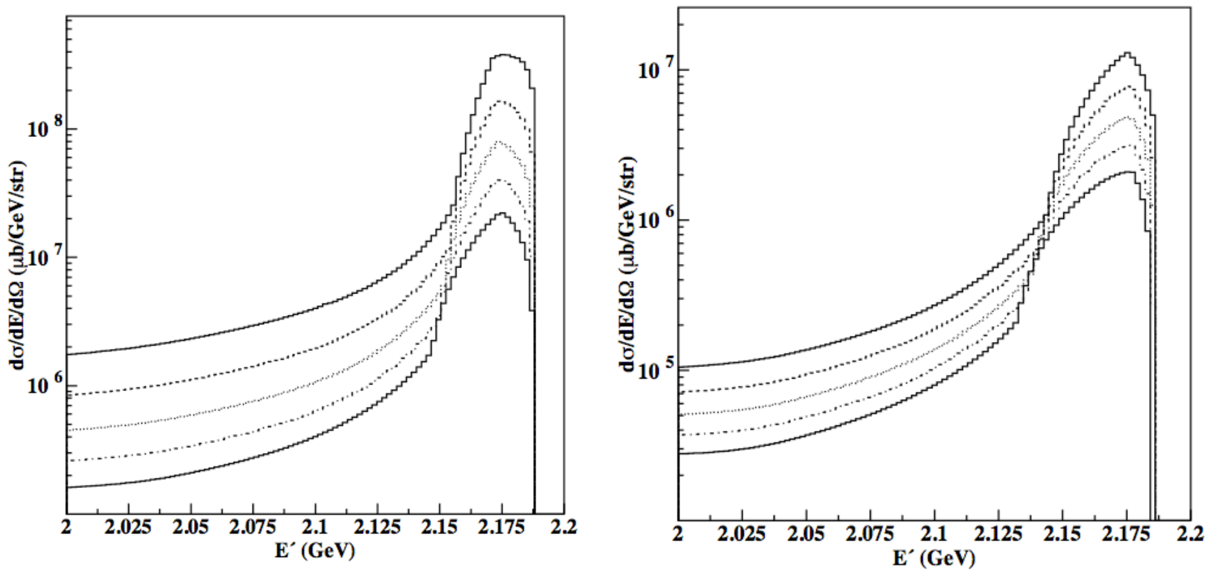

FIG. 1: Cross section of inclusive electron scattering on 0.00125 r.l. tungsten target at 2.2 GeV. On the left: scattering angles 0.015 rad, 0.02 rad, 0.025 rad, 0.03 rad and 0.035 rad. On the right: angles 0.04 rad, 0.045 rad, 0.05 rad, 0.055 rad and 0.06 rad.

beam plane, $r = 0.15$ cm (see Fig.2):

$$\phi_c = acos(r/R) \quad (2)$$

$$R = d \times \tan\theta_i \quad (3)$$

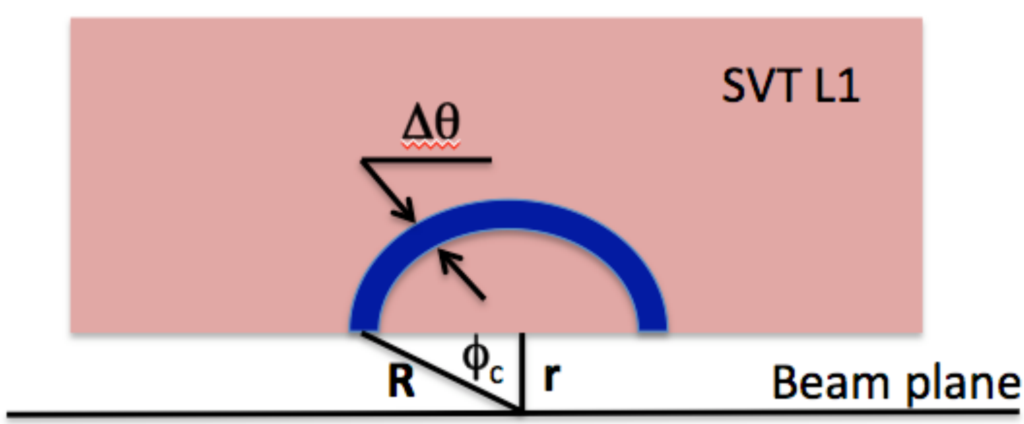

FIG. 2: Projection .

In Table I, acceptances for 10 bins of θ are presented.

TABLE I: Acceptance values for 10 bins of scattering angle.

θ (rad)	$sin\theta\Delta\theta$	ϕ_c (rad)	$\Delta\Omega$
0.015	0.75E-04	0.0122	0.184E-05
0.02	1E-04	0.723	0.145E-03
0.025	0.125E-03	0.927	0.232E-03
0.03	0.15E-03	1.05	0.314E-03
0.035	0.175E-03	1.128	0.395E-03
0.04	0.2E-03	1.187	0.474E-03
0.045	0.225E-03	1.23	0.554E-03
0.05	0.25E-03	1.266	0.633E-03
0.055	0.275E-03	1.295	0.71E-03
0.06	0.3E-03	1.318	0.79E-03

The luminosity, L, was calculated using 0.00125 r.l. tungsten target and 200 nA beam current:

$$L = 0.00125 \times 6.67 \times 6.022 \times 10^{23} \times \frac{200 \times 10^{-9}}{1.6 \times 10^{-19}} = 6360\ \mu b^{-1} s^{-1} \tag{4}$$

Differential rates of inclusive electrons in acceptance region of SVT L1 are shown in Fig.3. Rates integrated over all angles, from 0.015 rad to 0.06 rad are shown in Fig.4. At the peak, the rate is $\sim$ 2.5 MHz.The total singles rate on SVT L1, integrated over scattered electron energy, $E' > 2$ GeV is 33 MHz.

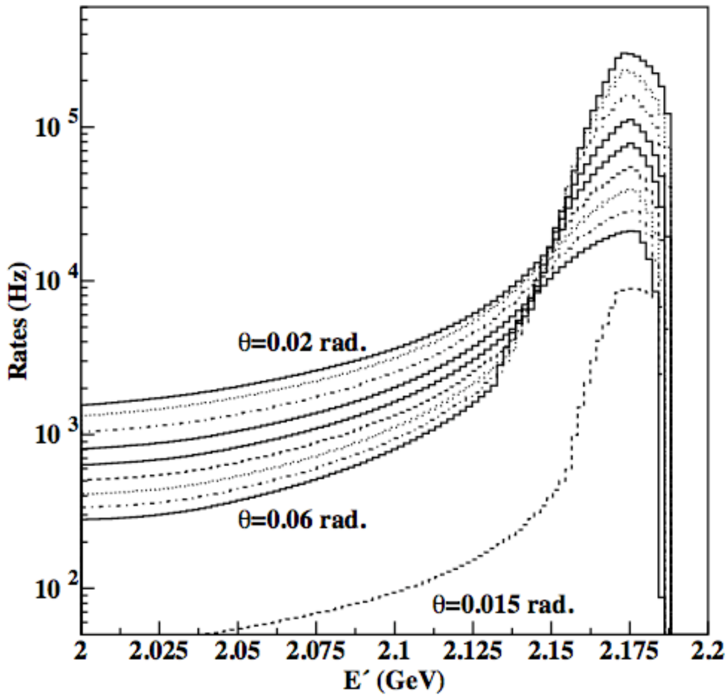

FIG. 3: Singles rate as a function of scattered electron energy for 10 scattering angles from 0.015 rad to 0.06 rad.

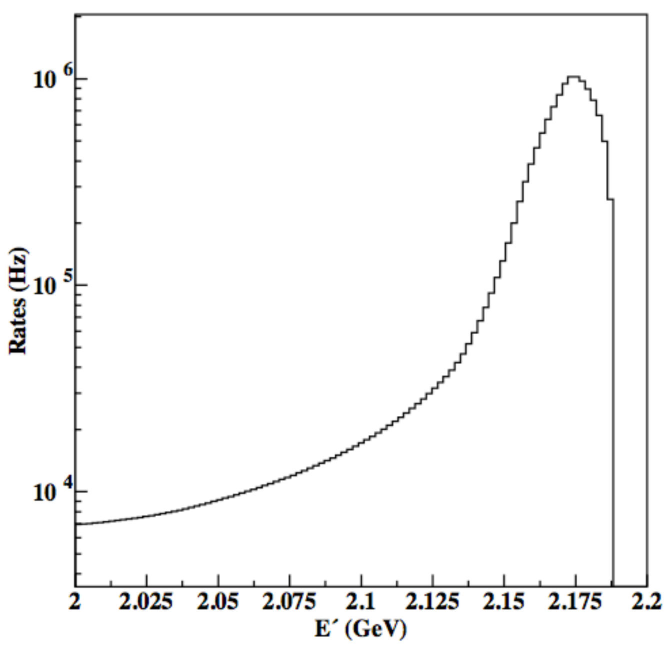

FIG. 4: Singles rate as a function of scattered electron energy integrated over scattering angular range from 0.015 rad to 0.06 rad.

II. Comparison with nuclear elastic (Coulomb) rates

The total cross section of Coulomb scattering was extracted from EGS5 simulation by integrating events within 5 MeV off of beam energy of 2.2 GeV. In Table II angular dependence of cross section is presented. On the top plot of Fig.5 comparison Coulomb and QE cross sections is shown. QE cross section integrated within 50 MeV of QE peak region. The ratio of these two cross sections is shown on the bottom plot of the figure. In the HPS angular range Coulomb scattering cross section larger than QE cross section by two orders of magnitude.

TABLE II: Coulomb cross section.

θ bin	σ_{tot}
0.015-0.020	4.8×10^5
0.020-0.025	2.4×10^5
0.025-0.030	1.3×10^5
0.030-0.035	7.9×10^4
0.035-0.040	4.9×10^4
0.040-0.045	3.5×10^4
0.045-0.050	2.4×10^4
0.050-0.055	1.8×10^4
0.055-0.060	1.6×10^4

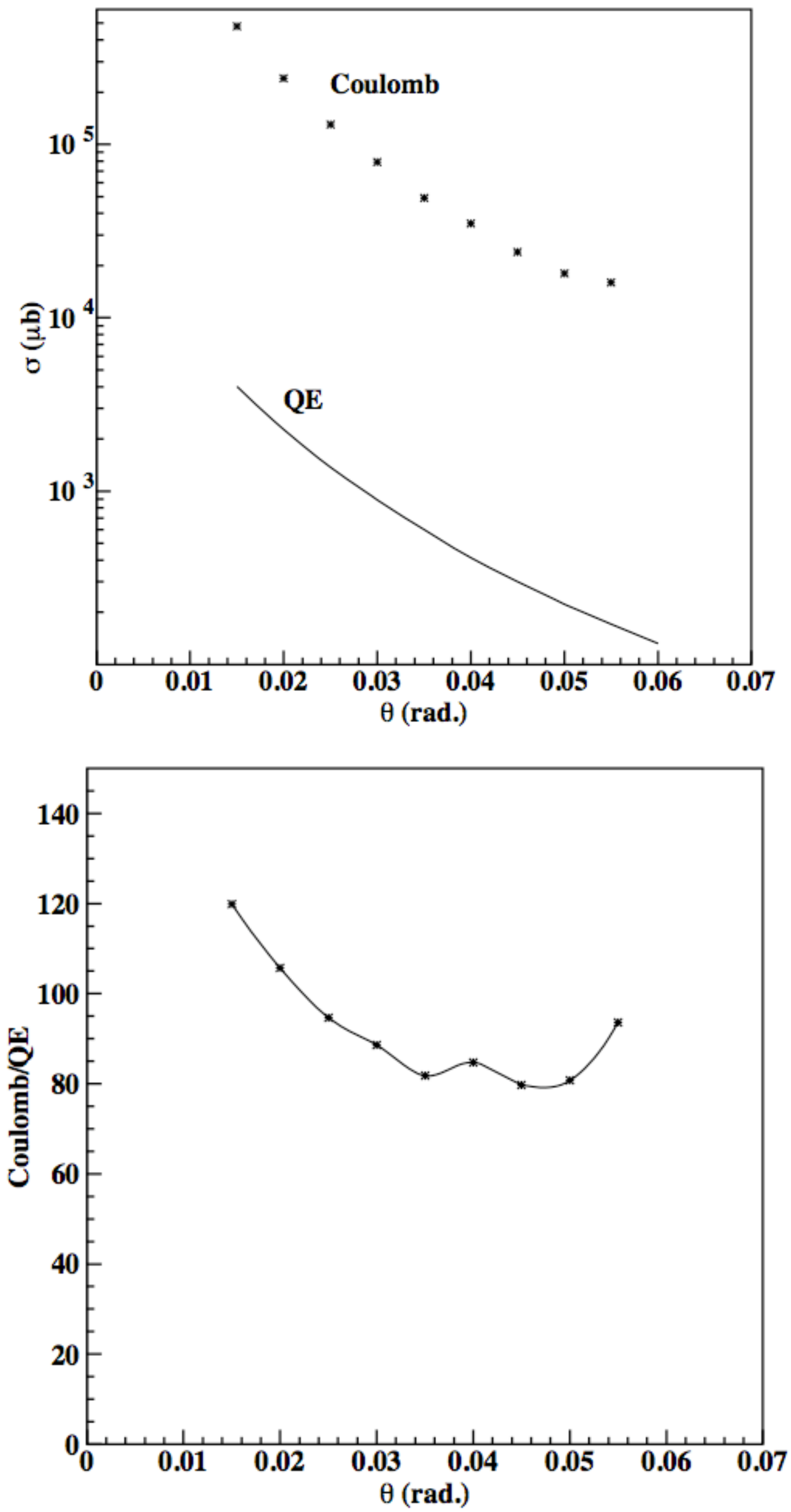

FIG. 5: Total cross section of Coulomb and QE scattering, left, and the ration of Coulomb cross section to QE, right.

III. Validation of *inclusive* code

Using data available at [3], electron scattering cross section from *inclusive* have been compared with experimental measurements from [4] and [5] at energies 0.96 GeV to 1.65 GeV, using targets ^{12}C, ^{56}Fe, and ^{184}W. Unfortunately measurements at small angles, close to HPS kinematics are not available. The smallest angle available was 11.95^o.

In Fig.6, comparison of measured and calculated cross sections on ^{12}C at 1.5 GeV and 1.65 GeV are presented. Data at 1.65 GeV and $\theta = 13.54^o$ (right graph) have been published in PRL article, [4], while data at 1.5 GeV and $\theta = 11.95^o$ have been available only in data base. In both cases calculation agrees with measurements within 20%.

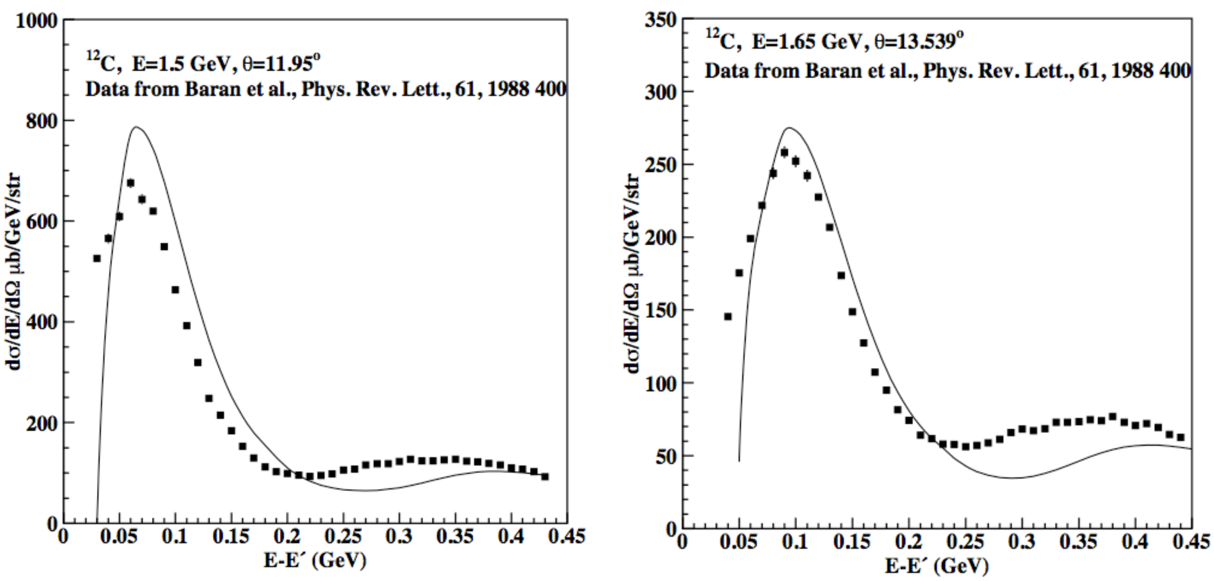

FIG. 6: Cross section of inclusive electron scattering, ^{12}C(e,e′). On the left: beam energy 1.5 GeV and electron scattering angle 11.95^o. On the right beam energy 1.65 GeV, scattering angle 13.54^o (published in PRL) Points are experimental measurements, [4], solid line is calculation using *inclusive* code.

Comparison also has been made with heavier targets. In [4], cross section of the reaction ^{56}Fe(e,e′) is measured at 1.65 GeV and scattering angle of 13.54 degree. In Fig.7 comparison of measured and calculated cross sections is shown. As in case of carbon nucleus, calculation with *inclusive* describes scattering on iron quite well.

One more comparison has been made with measurements using tungsten target. In [5],

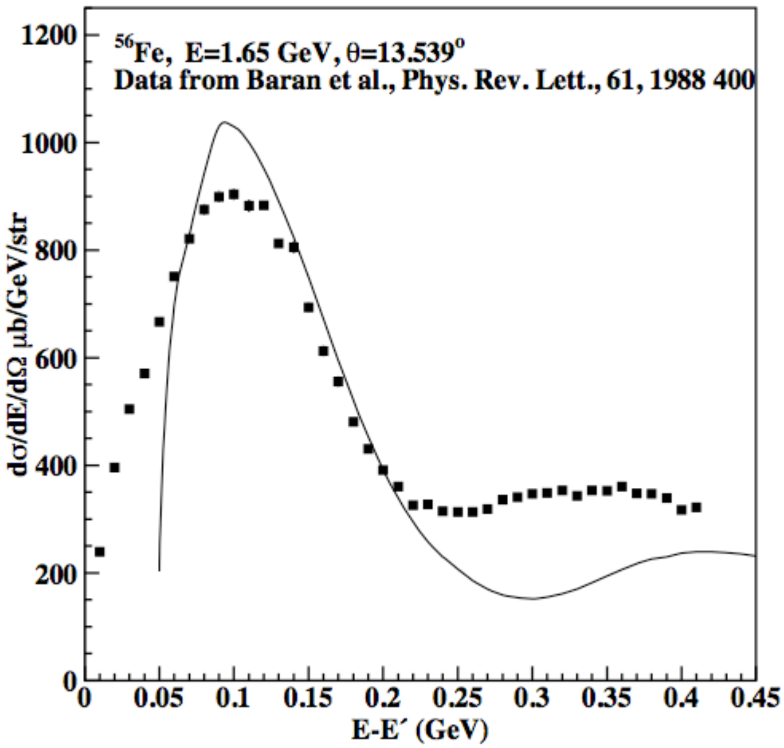

FIG. 7: Cross section of inclusive electron scattering, ^{56}Fe(e,e$'$), at beam energy 1.65 GeV and electron scattering angle 13.54^o. Points experimental measurements from [4], solid line is calculation using *inclusive* code.

the reaction ^{184}W(e,e$'$) was measured at several energies around 1 GeV but at large angles. In Fig.8 comparison of measured and calculated cross sections is presented for E= 0.961 GeV and scattering angle of 37.5 degrees. Again, in quasielastic scattering region calculation is within 15% of the experimental data.

One question that still must be addressed is validity of calculations at very small transferred momenta (HPS kinematics). For this we compare calculated cross sections at 1 degree with calculation at 37.5 degrees but scaled by $\sin^4(1/2^o)/\sin^4(35/2^o)$ (Mott cross section scales as $\sin^4\theta/2$). As one can see from Fig.9 the scale of the cross section at 1 degree corresponds to the "Mott corrected" scale of the cross section at 37.5 degrees, which, in turn, was describing experimental cross sections reasonably well.

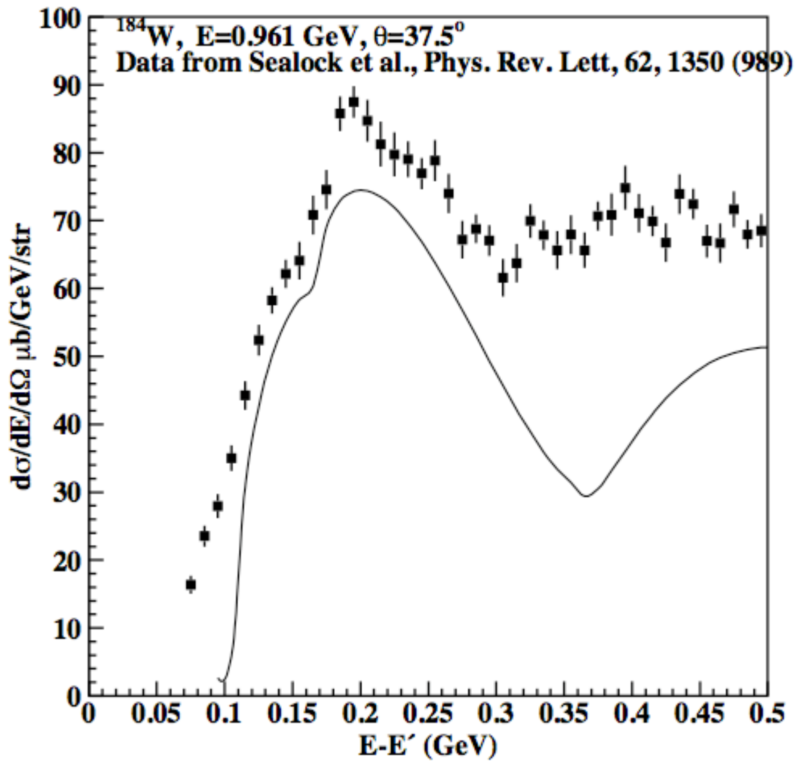

FIG. 8: Cross section of inclusive electron scattering, ^{184}W(e,e′), at beam energy 0.961 GeV and electron scattering angle 37.5^o. Points are experimental measurements from [5], solid line is calculation using *inclusive* code.

IV. Conclusion

From studies presented above one can draw the following conclusions:

1. existing code *inclusive* for calculation of the cross section of the processes A(e,e′) describes experimental data reasonably well in wide range of kinematics

2. scaling of calculated cross sections to HPS kinematical range works as expected and the code can be trusted in the kinematical range of HPS

3. from preliminary studies it is expected to have ~ 33 MHz rate on SVT Layer 1 from mostly quasi-eleastic scattered electrons

4. electron Coulomb scattering cross section is higher than QE scattering cross section by $80 - 120$ times.

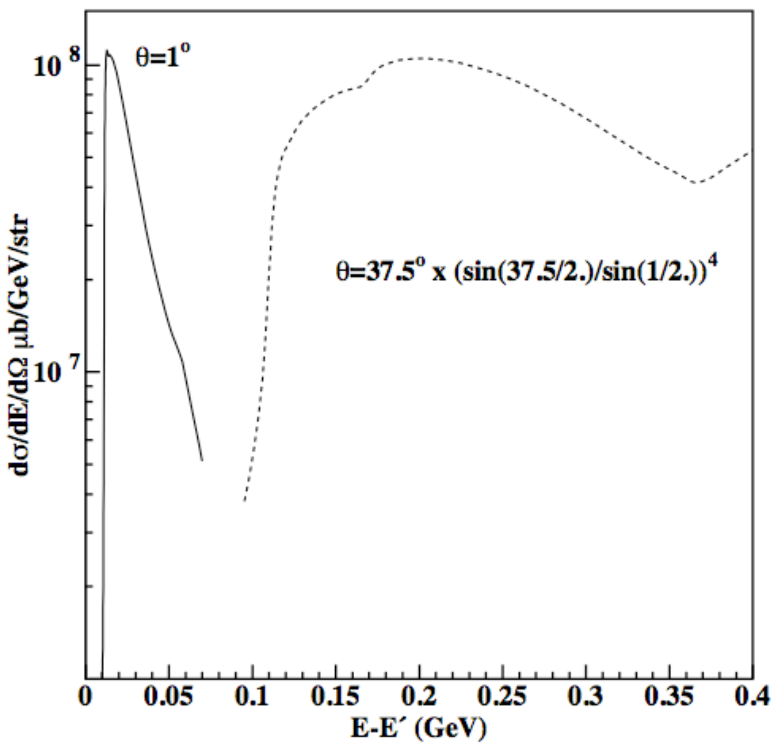

FIG. 9: Cross section of inclusive electron scattering, ^{184}W(e,e$'$), at beam energy 0.961 GeV. The solid line corresponds to electron scattering angle of 1 degree. The dashed line corresponds to the cross section for scattering at 37.5^o but scaled by $\sin^4(1/2^o)/\sin^4(35/2^o)$. .

[1] M. Sargsian, http://www.jlab.org/Hall-B/notes/clas_notes90/note90-007.pdf

[2] J. Jaros et al., JLAB PAC37 proposal "Heavy Photon Search" (2010).

[3] O. Benhar, D. Day and I. Sick, nucl-ex/0603032, Website - http://faculty.virginia.edu/qes-archive/index.html

[4] D.T. Baran et. al, Phys. Rev. Lett., 61, 1988 400-403. SLAC (NPAS) experiment NE1.

[5] R. Sealock et al. Phys. Rev. Lett., 62, 1350-1353,1989. SLAC (NPAS) experiment NE5