Experiment E94-010 Run Plan

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Version 01.1

Abstract

We describe in this document the run plan for experiment E94-010 entitled Measurement of the Neutron (^{3}He) Spin Structure Function at Low Q^2; a Connection between the Björken and Drell-Hearn-Gerasimov Sum Rules. While the first 25 days of the full running schedule definite (energies and schedule frozen), we consider the remaining part tentative. Nevertheless this runplan is our best estimate of the running conditions and will be updated before the next Jefferson laboratory scheduling committee meeting.

1 Introduction

The goal of this experiment is to gather asymmetry data ($A_{\|}$ and $A_{\perp}$) using the CEBAF polarized electron beam and a polarized ^{3}He target over the widest range of ν and Q^2 possible (see Table 1 and Fig. 1 for the kinematics range covered). Using these data we will extract the asymmetry $A_1^{^3He}$ over the quasielastic as well as the resonance and deep inelastic excitation regions. The Q^2 evolution of the Gerasimov-Drell-Hearn (GDH) sum will be investigated first on ^{3}He. Subsequently the neutron asymmetry A_1^n will be extracted in the same domain of momentum transfers and excitation energies. In order to evaluate the GDH sum on the neutron we need first to subtract the quasielastic neutron contribution then an integral of the excitation spectrum is performed starting from the pion production threshold. Furthermore, by combining the neutron extracted asymmetry data (A_1^n) with those of the proton data from Hall B experiment E91-023, the Q^2 evolution of the Björken sum rule will be investigated from Q^2 = 2 GeV^2 down to Q^2 = 0.05 GeV^2.

2 Commissioning

During the start of experiment E94-010 a number of newly built devices crucial to the experiment will need time for commissioning. We are assigning the first three days of the experiment for a checkout period of these devices important to the success of the experiment . The following items will be part of the commisioning plan and will be performed at an incident energy of 1.719 GeV:

- Moller polarimeter
- Hadron arm new shower counter detector
- Raster with its new scheme
- Current calibration
- Reference cell pressure curve
- Elastic run
- Helicity correlated asymmetry
- Collimator in/out test

An optimized sequence of events if presented below and should be followed during the commissioning as much as possible.

1. **Beam tuning into Hall A**: When ready the beam position need to be checked using the BeO target as well as the Beam Position Monitors.

2. **Raster**: The raster new scheme need to be checked. It is important to check the raster size for 2mm, 3mm, 4mm and 5mm. We estimate a two hours period for this task.

3. **Moller commissioning**: The first eight hours should be dedicated for commissioning the Moller polarimeter and perform a polarization measurement of the beam.

4. **Hadron Arm Shower Counter**: During the commissioning of the Möller polarimeter after making sure that the current is small ($I < 1 \mu A$), the reference cell should be filled with Nitrogen at **1 atmosphere** and used to provide for scattered events to test the new hadron HRS shower counter as well the remaining detectors. As much progress as possible need to be made in checking out the detectors, the trigger and Data Aquisition on both HRS spectrometers. Both spectrometers should be used with the collimators in at their entrance and their momentum setting is **P = 1.600 GeV** to cover the quasielastic region of Nitrogen. (8hrs)

5. **Beam Current Monitor**: The beam current monitor calibration should be performed at the maximum current the machine can achieve for high a accuracy calibration. (0.5 hrs)

6. **Nitrogen Pressure Curve**: Two pressure curves are needed, one for Nitrogen and one for ^{3}He. We shall start first with Nitrogen. Both spectrometers should be set to **P = 1.67 GeV** momentum for elastic scattering. The measurement of the rate versus pressure in the cell should be performed at four different pressures (Pressure = 2, 4, 6, 8 atmospheres) at a current of 5μ A and for three different currents (3, 5, 8μ A) at a pressure of 6 atmospheres. At least 3 % statistical uncertainty is required for the integral of counts in the elastic peak. (2 hrs)

7. **Empty Cell Measurement**: The reference cell should be then emptied from Nitrogen and a measurement of the rate with the spectrometers collimators in and out. This should allow the study of the acceptance and background from the cell windows. It is important that the raster is on and its size check to be 4 mm. The momentum setting of both spetrometers is **P = 1.600 GeV** to insure a quasielastic kinematic, therefore an uniform illumination of the acceptance of the spetrometers.(1 hour)

8. **^{3}He Pressure Curve**: The reference cell should be filled with ^{3}He for a pressure curve study. Both spectrometers should be set to **P = 1.67 GeV** momentum for elastic scattering. The measurement of the rate versus pressure in the cell should be performed at six different pressures (Pressure = 6, 8, 10, 12 atmospheres) at a current of 5μ A and for three different currents (3, 5, 8μ A) at a pressure of 10 atmospheres. At least 1 % statistical uncertainty is required for the integral of counts in the elastic peak. (3hrs)

9. **Elastic Run**: The first data taking on the polarized ^{3}He target should be the elastic run. The spectrometer setting should be still in the elastic condition (**P = 1.67 GeV**).

At least 1 % statistical uncertainty is required for the integral of counts in the elastic peak.(1hour)

Other items which are a integral part of the comissioning will be left to be performed when the energy is set at 4.230 GeV, they are:

- Spectrometer acceptance runs
- A better current calibration

Here the spectrometer acceptance is left to be performed when the energy of the beam is large enough to allow for data taking in the deep inelastic region. It is important during the acceptance run to set the momentum of the spectrometers in a region where the physics does not vary strongly accross the acceptance and where the model evaluation of the energy dependence of the cross section is reliable. That is specifically the deep inelastic region.

1. **Spectrometer acceptance runs**: For three momentum settings **P = 1.93 GeV, 1.88 GeV, 1.80 GeV** a statistics of 10000 counts per 20 MeV bin (or $\frac{\delta p}{p_0} = 1\%$ momentum bin) will be needed for the runs at each momentum on both spectrometers.
2. **A Better current calibration** : If during this period the accelerator can deliver currents of the order of 20 μA, then a current calibration should be performed again.

We have identified a minimum set of four incident beam energies E_i = 1.719 GeV , 4.230 GeV, 3.020 GeV, and 1.044 GeV, at two scattering angle of 15.5 and 23.0 degrees for a self consistent experiment. For a complete experiment we would need more energies as listed in the tables by priority. As the experiment progresses we will reassess the run plan to optimize the data taking in order to reach our original physics goal of this experiment.

Below is a summary of the the kinematics and projected times we well need to perform the measurements. These times will be adjusted as soon as we test our rate estimates experimentally. It is important to notice that because of the end window of the target we might need to use the collimators all the time in order to block completely their contribution to the cross section. This will force us increase the data taking time by 20%.

3 Run Conditions

In this section we provide a summary as well as the details of the run conditions during this experiment.

The summary of time accounting for the experiment will be updated as soon as the true rates are determined during the commissioning period. We shall have then a better evaluation of the time accounting for completing the experiment.

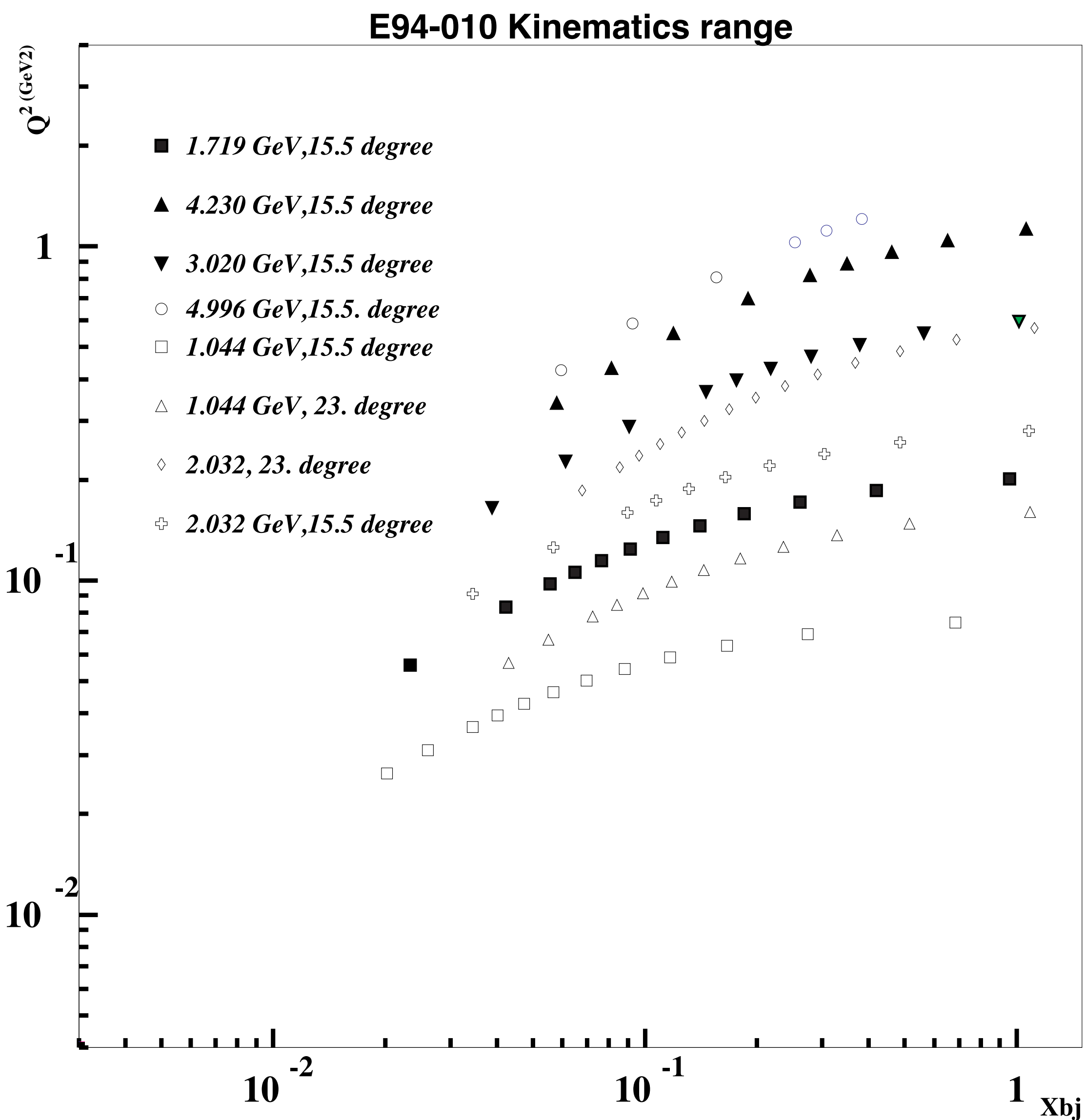

Figure 1: Kinematics range in four-momentum square Q^2 and excitation energy ν for the run plan of experiment E94-010

Run Summary

Beam Polarization $P_e = 0.7$

Target Polarization $P_T = 0.4$

Incident Energy (GeV)	**1.719**	**4.230**	**3.020**	**4.996**	**1.044**	**1.044**	**2.032**	**2.032**
Scattering Angle (deg)	**15.5**	**15.5**	**15.5**	**15.5**	**15.5**	**23**	**23**	**15.5**
Beam Current (μ A)	5	10	10	10	10	10	10	10
Run. time e^- run (hrs)	184	365	139	544	102	111	159	51
Mom. Settings	13	11	12	11	15	14	15	12
Mom. Chan. (hrs)	6.5	5.5	6	5.5	7.5	7	7.5	6
Switch Targ. Pol. (hrs)	3.25	2.75	3.0	2.75	3.75	3.5	3.75	3
Moller Meas. (hrs)	1	2	1	2	1	1	1	1
Angle Chang. (hrs)	0	0	0	0	0	0.5	0	0.5
Targ. Pol. (hrs)	1	2	1	1	1	1	1	3

Commissioning (hrs): 72

Total time for minimal experiment = hours

Total time for a complete experiment = hours

Table 1: Experiment E94-010 running time accounts

Running e-^{3}He Inelastic Priority 1 Rank 1
Incident Beam Energy E_i = 1.719 GeV
Scattering Angle $\Theta = 15.5°$
Beam Current = 5 μA
Target Length = 40 cm ^{3}He

Ep GeV	Q^2 GeV^2	Rate Hz	ΔA_1^n	$T_\parallel$ hrs	$T_\perp$ hrs	T_{tot} hrs	$N_\parallel$	$N_\perp$	Collimator Status
1.607	0.201	2000.0	0.005	6.3	2.7	9.0	45333692.	19466308.	In
1.484	0.185	546.7	0.010	9.6	8.4	18.0	18902934.	16523429.	In
1.369	0.171	901.1	0.010	5.4	4.6	10.0	17615166.	14825060.	In
1.264	0.158	981.1	0.010	4.7	3.3	8.0	16502348.	11752087.	In
1.167	0.146	514.6	0.010	8.1	4.9	13.0	15062908.	9022593.	In
1.077	0.135	417.0	0.010	8.6	4.4	13.0	12912162.	6603140.	In
0.994	0.124	321.9	0.010	9.7	4.3	14.0	11237327.	4986880.	In
0.918	0.115	331.8	0.010	7.9	3.1	11.0	9446809.	3691186.	In
0.847	0.106	294.0	0.010	8.2	2.8	11.0	8635358.	3006946.	In
0.782	0.098	264.3	0.010	8.4	2.6	11.0	7968300.	2497782.	In
0.666	0.083	168.4	0.010	10.3	2.7	13.0	6253950.	1626011.	In
0.447	0.056	81.6	0.010	15.3	2.7	18.0	4487904.	799872.	In

Momentum changes: 6.0 hours
Moller measurement: 1 hour
Total parallel time: 102.0
Total perpendicular time: 46.4
Total running time = 155.4 hours

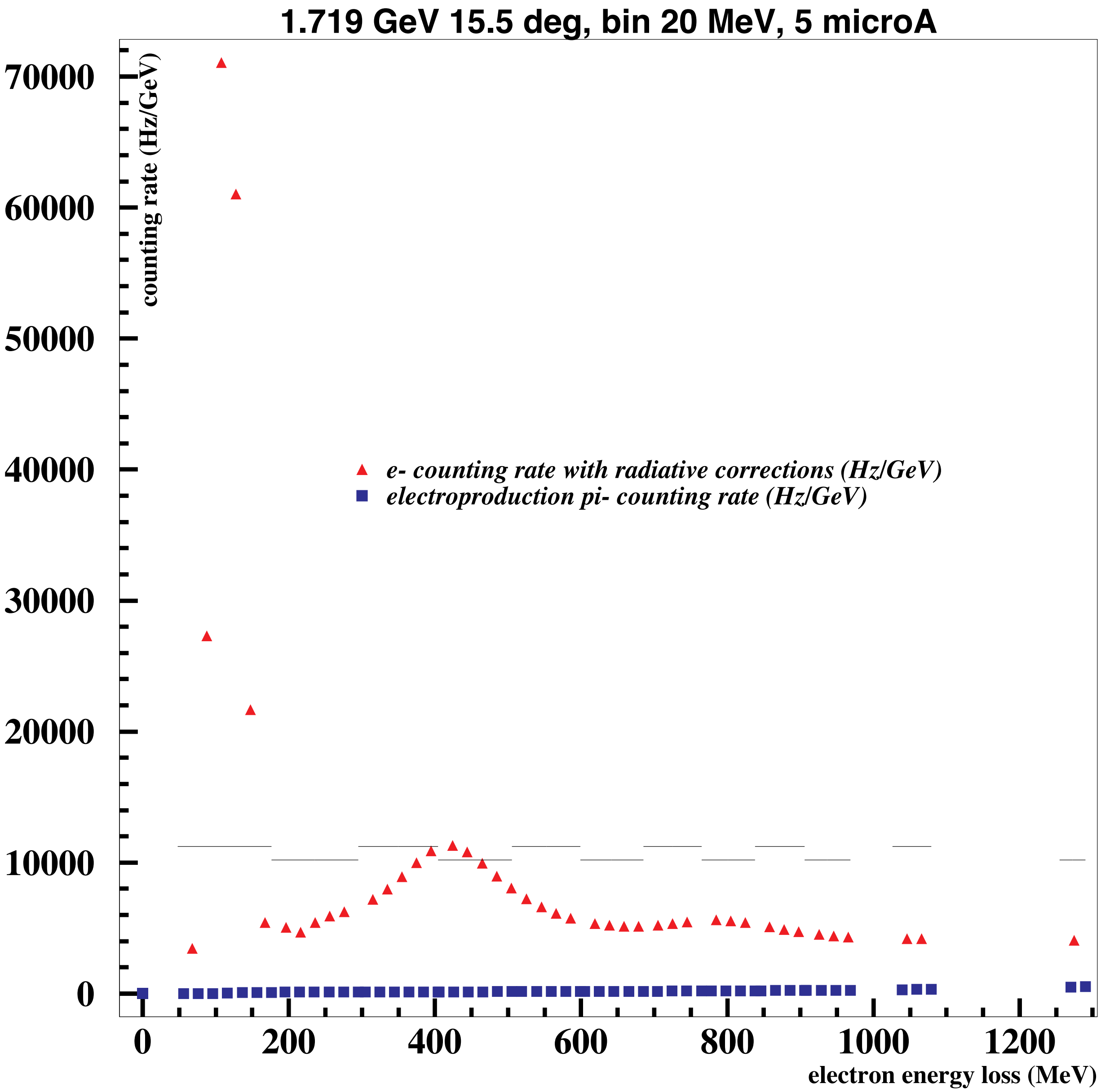

Figure 2: Electron scattering and pion production rates across the excitation energy range to be measured. The inelastic radiative corrections are included in the electron rate evaluation. The horizontal lines indicate the coverage of the momentum acceptance at each momentum setting. We have assumed $\delta p \ / \ p_0 = \pm 4\%$

Running e-^{3}He Inelastic Priority 1 Rank 2
Incident Beam Energy E_i = 4.230 GeV
Scattering Angle $\Theta = 15.5°$
Beam Current = 10 μA
Target Length = 40 cm ^{3}He

Ep GeV	Q^2 GeV^2	Rate Hz	ΔA_1^n	$T_\parallel$ hrs	$T_\perp$ hrs	T_{tot} hrs	$N_\parallel$	$N_\perp$	Collimator and HRS elec or had
3.663	1.127	122.8	0.005	40.1	34.9	75	66265584	57525224	out e-
3.381	1.040	137.9	0.010	16.2	13.8	30	18010892	15247238	out e-
3.121	0.960	168.1	0.010	26.8	19.2	46.0	16210534	11631714	in e-
2.881	0.886	205.4	0.011	15.6	9.4	25.0	11531220	6956478	in had
2.659	0.818	199.7	0.011	14.5	7.5	22.0	10441856	5373315	in had
2.266	0.697	164.4	0.011	13.6	5.4	19.0	8074498	3171239	in had
1.782	0.548	123.6	0.010	14.0	4.0	18.0	6229954	1779326	in had
1.402	0.431	88.6	0.011	14.7	3.3	18.0	4698340	1040838	in had
1.102	0.339	75.4	0.010	16.1	2.9	19.0	4373470	781709	in had

Momentum change: 4.5 hours
Moller measurement: 1 hour
Total parallel time: 163.7
Total perpendicular time: 111.0
Total time: 261.5 hours

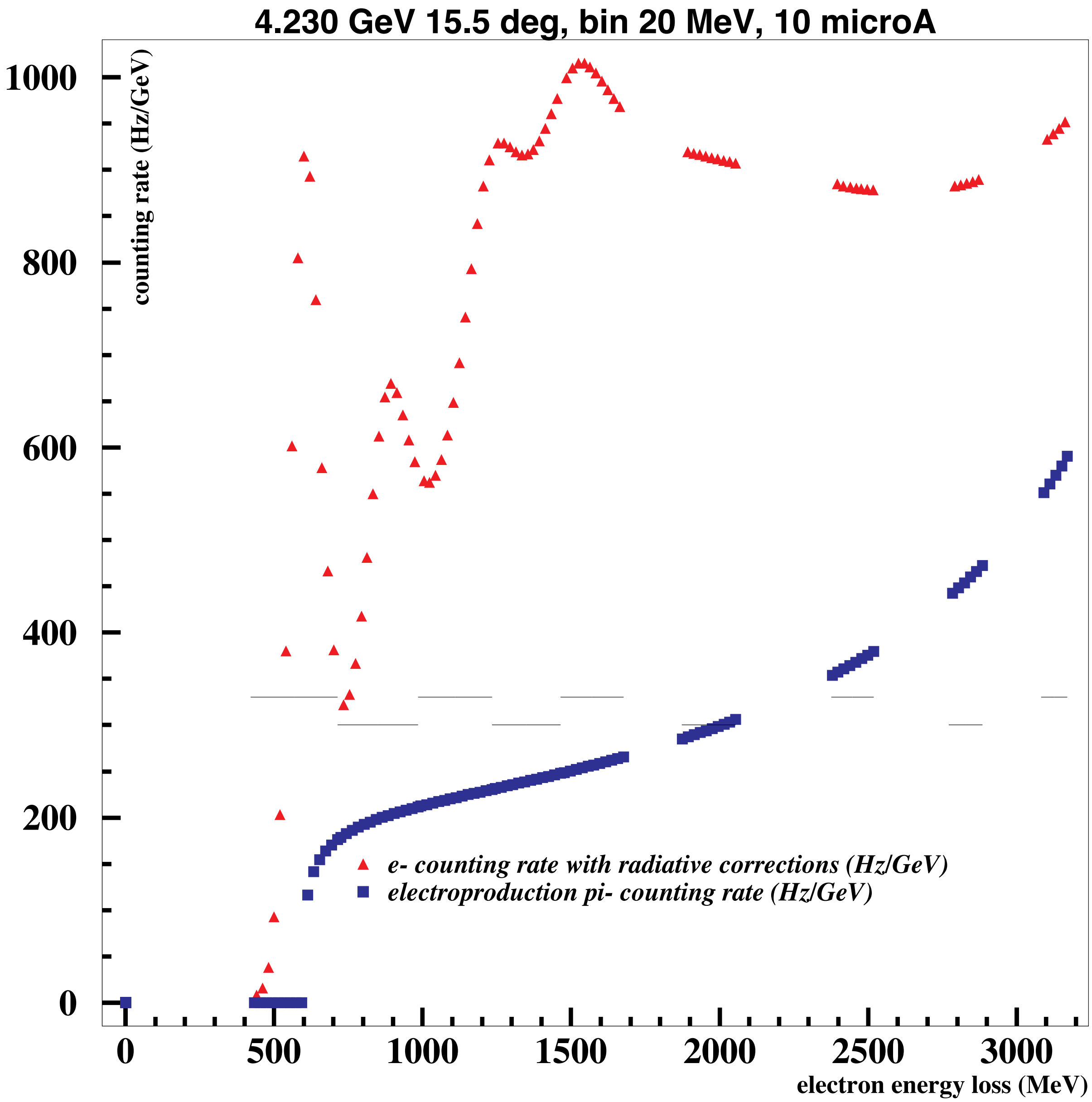

Figure 3: Electron scattering and pion production rates across the excitation energy range to be measured. The inelastic radiative corrections are included in the electron rate evaluation. The horizontal lines indicate the coverage of the momentum acceptance at each momentum setting. We have assumed $\delta p \ / \ p_0 = \pm 4\%$

Running e-^{3}He Inelastic Priority 1 Rank 3
Incident Beam Energy E_i = 3.020 GeV
Scattering Angle $\Theta = 15.5°$
Beam Current = 10 μA
Target Length = 40 cm ^{3}He

Ep GeV	Q^2 GeV^2	Rate Hz	ΔA_1^n	$T_\parallel$ hrs	$T_\perp$ hrs	T_{tot} hrs	$N_\parallel$	$N_\perp$	Collimator HRS elec/had
2.707	0.595	762.1	0.005	25.8	19.2	45.0	70878096	52582276	in/in
2.499	0.549	410.8	0.010	12.2	10.8	23.0	18031394	15981506	in/in
2.307	0.507	482.5	0.010	9.6	7.4	17.0	16645252	12886365	in/in
2.130	0.468	423.6	0.010	9.7	6.3	16.0	14792703	9609507	in/in
1.966	0.432	397.8	0.010	9.0	5.0	14.0	12933463	7115776	in/in
1.814	0.399	371.8	0.010	8.1	3.9	12.0	10896822	5163259	in/in
1.675	0.368	304.7	0.010	8.5	3.5	12.0	9305707	3857266	in/in
1.317	0.289	206.3	0.010	9.2	2.8	12.0	6869424	2044706	in/in
1.036	0.228	158.3	0.010	8.9	2.1	11.0	5100751	1168947	in/in
0.752	0.165	127.2	0.010	9.4	1.6	11.0	4298446	740206	in/in

Momentum change: 5 hours
Moller measurement: 1 hour
Total parallel time: 110.5 hours
Total perpendicular time: 62.5 hours
Total time: 179.0 hours

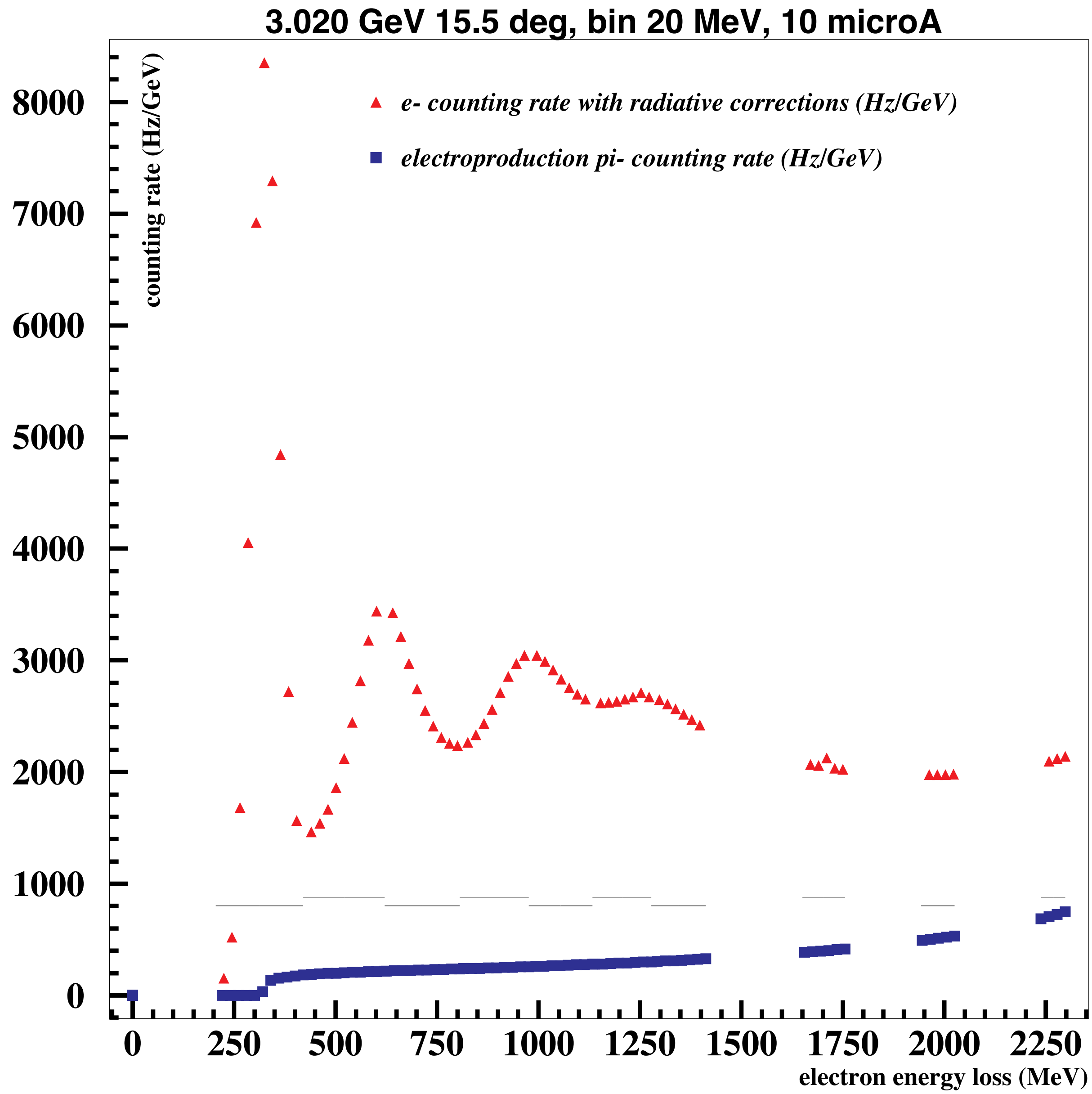

Figure 4: Electron scattering and pion production rates across the excitation energy range to be measured. The inelastic radiative corrections are included in the electron rate evaluation. The horizontal lines indicate the coverage of the momentum acceptance at each momentum setting. We have assumed $\delta p \ / \ p_0 = \pm 4\%$

Running e-^{3}He Inelastic Priority 1 Rank 4
Incident Beam Energy $E_i = 4.996$ GeV
Scattering Angle $\Theta = 15.5°$
Beam Current = 10 μA
Target Length = 40 cm ^{3}He

Ep GeV	Q^2 GeV^2	Rate Hz	ΔA_1^n	$T_{\parallel}$ hrs	$T_{\perp}$ hrs	T_{tot} hrs	$N_{\parallel}$	$N_{\perp}$	Collimator Status and HRS elec or had
3.321	1.207	140.9	0.006	51.0	29.0	80.0	34475664	19781704	out e-
3.066	1.114	135.4	0.012	13.0	6.0	19.0	8170456	4019918	out e-
2.830	1.028	125.6	0.010	22.4	9.6	32.0	10130392	4343036	in had
2.226	0.809	91.8	0.010	20.7	6.3	27.0	6834600	2087134	in had
1.616	0.587	71.1	0.010	18.9	4.1	23.0	4841670	1047908	in had
1.173	0.426	53.3	0.010	20.6	3.4	24.0	3952871	649182	in had

Momentum change: 4.5 hours
Moller measurement: 1 hour
Total parallel time: 163.7 hours
Total perpendicular time: 111.0 hours
Total time: 280.2 hours

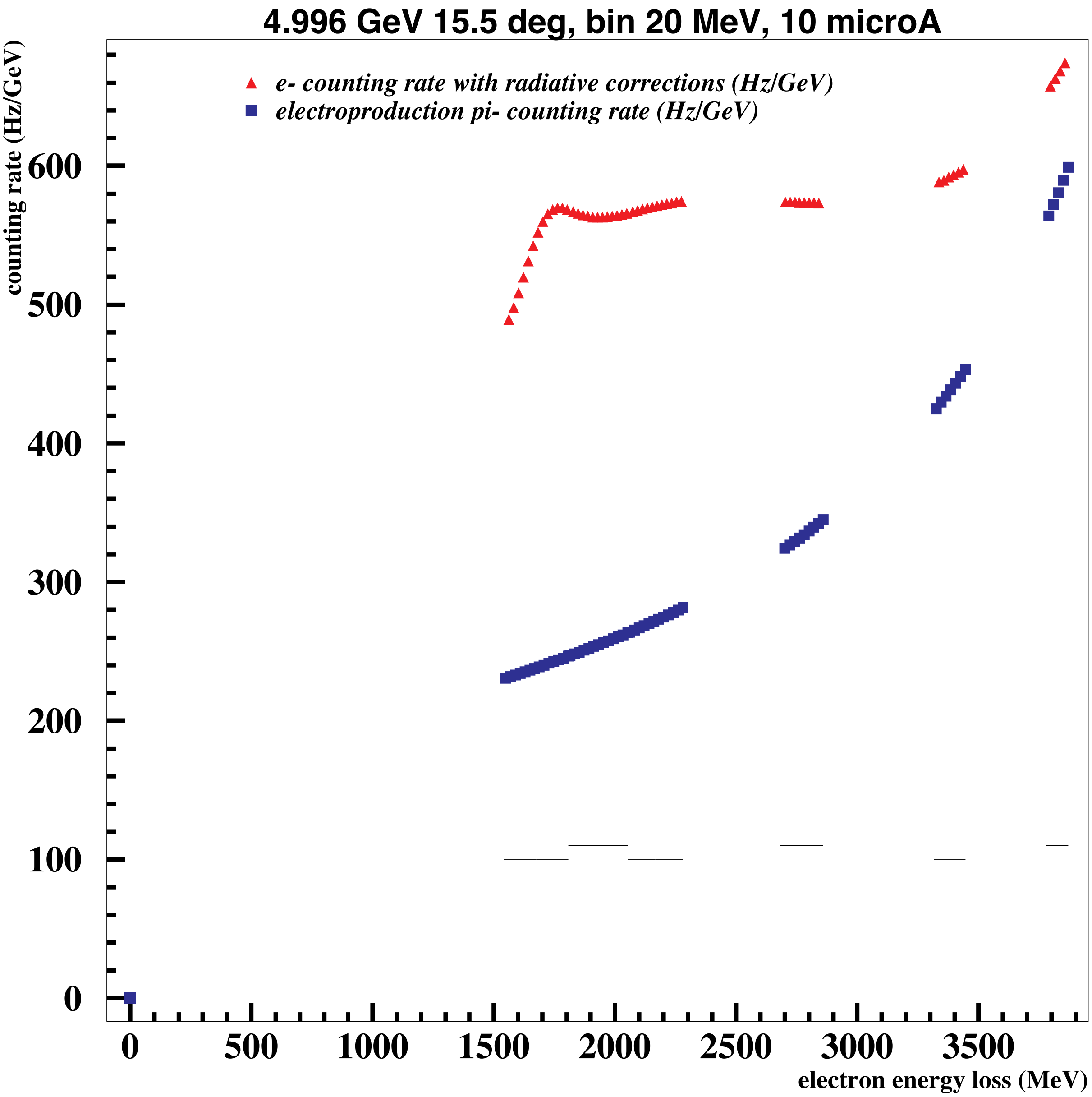

Figure 5: Electron scattering and pion production rates across the excitation energy range to be measured. The inelastic radiative corrections are included in the electron rate evaluation. The horizontal lines indicate the coverage of the momentum acceptance at each momentum setting. We have assumed $\delta p \ / \ p_0 = \pm 4\%$

Running e-^{3}He Inelastic Priority 1 Rank 5
Incident Beam Energy E_i = 1.044 GeV
Scattering Angle $\Theta = 15.5°$
Beam Current = 10 μA
Target Length = 40 cm ^{3}He

Ep GeV	Q^2 GeV^2	Rate Hz	ΔA_1^n	$T_\parallel$ hrs	$T_\perp$ hrs	T_{tot} hrs	$N_\parallel$	$N_\perp$	Collimator Status elec/had
0.986	0.075	2000.0	0.005	5.2	1.8	7.0	37463580	12936422	in/in
0.910	0.069	2000.0	0.010	2.7	2.3	5.0	19416296	16583703	in/in
0.840	0.064	2000.0	0.010	2.7	2.3	5.0	19401640	16598359	in/in
0.775	0.059	2000.0	0.010	2.3	1.7	4.0	16669703	12130297	in/in
0.716	0.054	1990.0	0.011	1.9	1.1	3.0	13337818	8154610	in/in
0.660	0.050	1909.7	0.010	2.0	1.0	3.0	13561814	7062613	in/in
0.610	0.046	1474.3	0.010	2.1	0.9	3.0	10972460	4949733	in/in
0.563	0.043	1174.2	0.011	2.1	0.9	3.0	9080191	3600803	in/in
0.520	0.039	1013.3	0.010	2.2	0.8	3.0	8088940	2854772	in/in
0.480	0.036	473.6	0.010	4.6	1.4	6.0	7764508	2464232	in/in
0.409	0.031	454.5	0.010	4.0	1.0	5.0	6478802	1702350	in/in
0.348	0.026	483.4	0.010	3.3	0.7	4.0	5691663	1268719	in/in

Momentum changes: 6 hours
Moller measurement: 1 hour
Total parallel time: 35.0
Total perpendicular time: 16.0
Total time: 58 hours

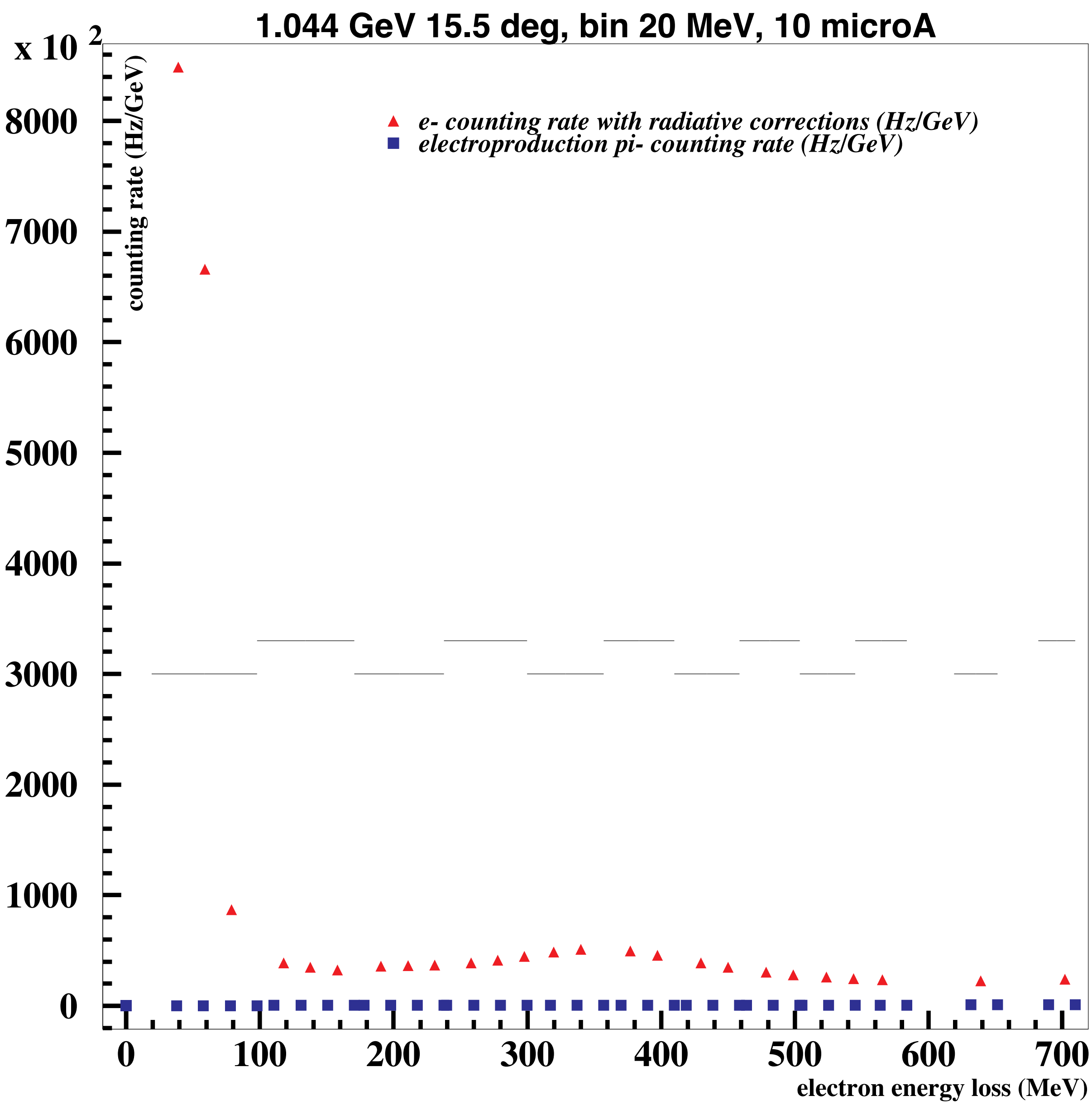

Figure 6: Electron scattering and pion production rates across the excitation energy range to be measured. The inelastic radiative corrections are included in the electron rate evaluation. The horizontal lines indicate the coverage of the momentum acceptance at each momentum setting. We have assumed $\delta p \ / \ p_0 = \pm 4\%$

Running e-^{3}He Inelastic Priority 2 Rank 1
Incident Beam Energy $E_i = 1.044$ GeV
Scattering Angle $\Theta = 23.0°$
Beam Current = 10 μA
Target Length = 40 cm ^{3}He

Ep GeV	Q^2 GeV^2	Rate Hz	ΔA_1^n	$T_\parallel$ hrs	$T_\perp$ hrs	T_{tot} hrs	$N_\parallel$	$N_\perp$	Collimator and HRS elec/had
0.965	0.160	2000.0	0.005	2.1	0.5	2.6	14857785	3600000	in/in
0.891	0.148	346.0	0.010	6.8	3.8	10.6	8488801	4744063	in/in
0.822	0.137	307.7	0.010	8.7	6.3	15.0	9610652	6963432	in/in
0.759	0.126	394.8	0.010	6.7	5.0	11.7	9538285	7043313	in/in
0.701	0.116	348.1	0.010	7.3	5.0	12.3	9153242	6306422	in/in
0.647	0.107	382.4	0.010	6.3	3.9	10.2	8633752	5394558	in/in
0.597	0.099	311.5	0.010	7.2	4.0	11.2	8062358	4540228	in/in
0.551	0.091	245.3	0.010	8.5	4.3	12.8	7490660	3807531	in/in
0.509	0.084	209.0	0.010	9.2	4.3	13.5	6952160	3204701	in/in
0.470	0.078	97.2	0.010	18.5	7.8	26.2	6461152	2715474	in/in
0.400	0.066	94.0	0.010	16.6	5.9	22.5	5631030	1996772	in/in
0.341	0.057	102.4	0.010	13.5	4.1	17.6	4985944	1517852	in/in

Momentum change: 6.0 hours
Angle change: 1 hour
Moller measurement: 1 hour
Total parallel time: 111.4 hours
Total perpendicular time: 54.9 hours
Total time: 174.3 hours

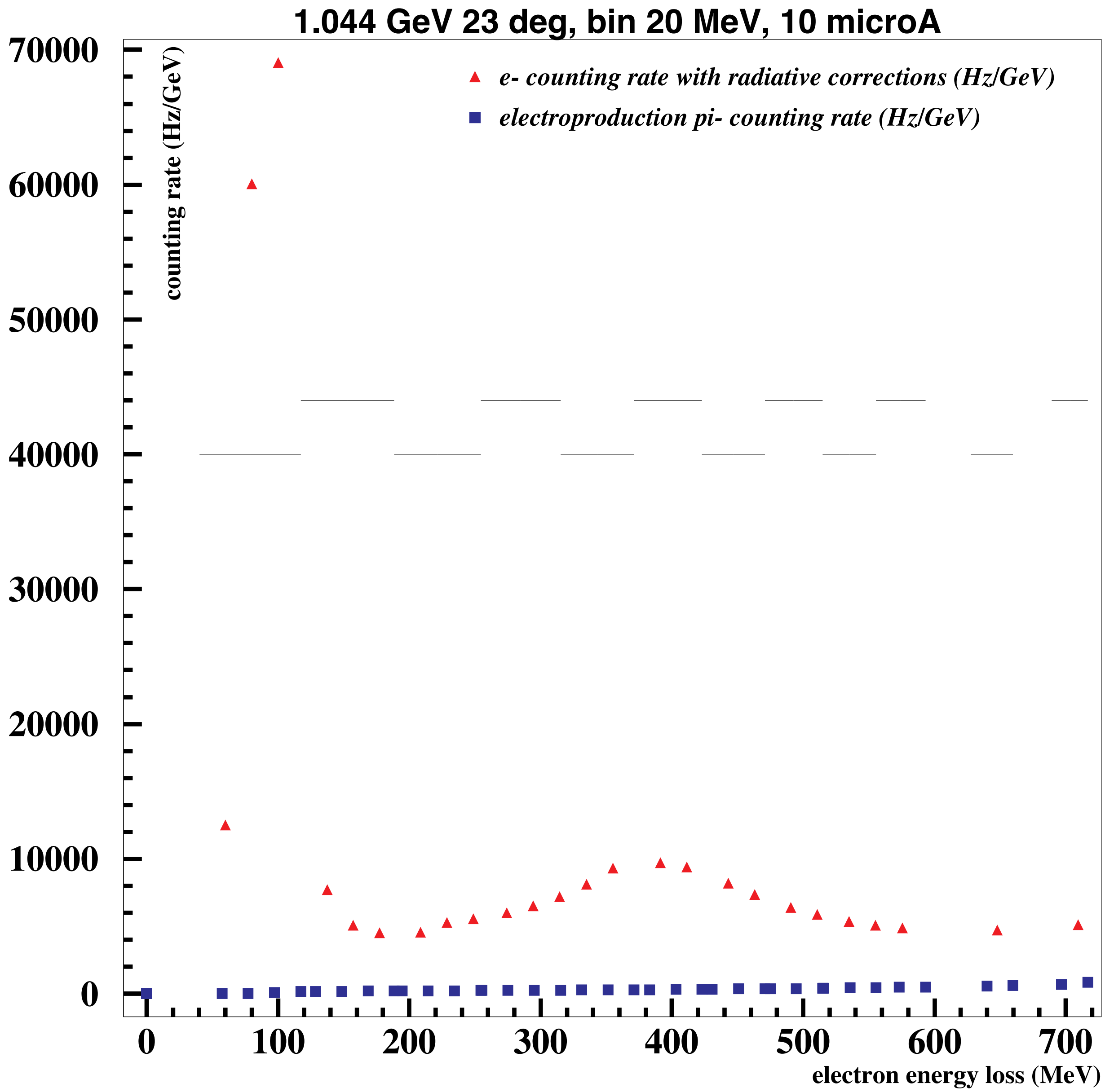

Figure 7: Electron scattering and pion production rates across the excitation energy range to be measured. The inelastic radiative corrections are included in the electron rate evaluation. The horizontal lines indicate the coverage of the momentum acceptance at each momentum setting. We have assumed $\delta p \ / \ p_0 = \pm 4\%$

Running e-^{3}He Inelastic Priority 2 Rank 2
Incident Beam Energy E_i = 2.032 GeV
Scattering Angle $\Theta = 23.0^\circ$
Beam Current = 10 μA
Target Length = 40 cm ^{3}He

Ep GeV	Q^2 GeV^2	Rate Hz	ΔA_1^n	$T_\parallel$ hrs	$T_\perp$ hrs	T_{tot} hrs	$N_\parallel$	$N_\perp$	Collimator Status HRS ele/had
1.761	0.569	226.3	0.005	27.5	14.0	41.5	29749244	15054942	out/out
1.625	0.525	78.7	0.010	25.0	17.7	42.7	9455514	6691928	out/out
1.500	0.485	135.2	0.011	17.2	12.8	30.0	8376623	6223220	in/in
1.385	0.447	114.4	0.011	18.8	13.2	32.0	7753369	5430038	in/in
1.278	0.413	95.5	0.011	20.8	13.2	34.0	7143870	4550474	in/in
1.180	0.381	84.0	0.011	21.6	12.4	34.0	6531377	3750400	in/in
1.089	0.352	95.9	0.011	19.1	9.9	29.0	6596162	3416928	in/in
1.005	0.325	87.0	0.011	19.7	9.3	29.0	6184034	2902616	in/in
0.928	0.300	63.1	0.011	23.1	9.9	33.0	5255122	2246265	in/in
0.857	0.277	65.1	0.011	21.6	8.4	30.0	5054645	1977982	in/in
0.791	0.255	64.8	0.011	19.9	7.1	27.0	4631246	1667262	in/in
0.730	0.236	41.4	0.012	26.3	8.7	35.0	3909624	1300619	in/in
0.674	0.218	40.4	0.011	26.0	8.0	34.0	3782656	1167474	in/in
0.574	0.185	40.0	0.011	25.2	6.8	32.0	3637197	975913	in/in

Momentum changes: 7.0 hours
Moller measurement: 1 hour
Total parallel time: 311.6 hours
Total perpendicular time: 151.5 hours
Total time: 471.0 hours

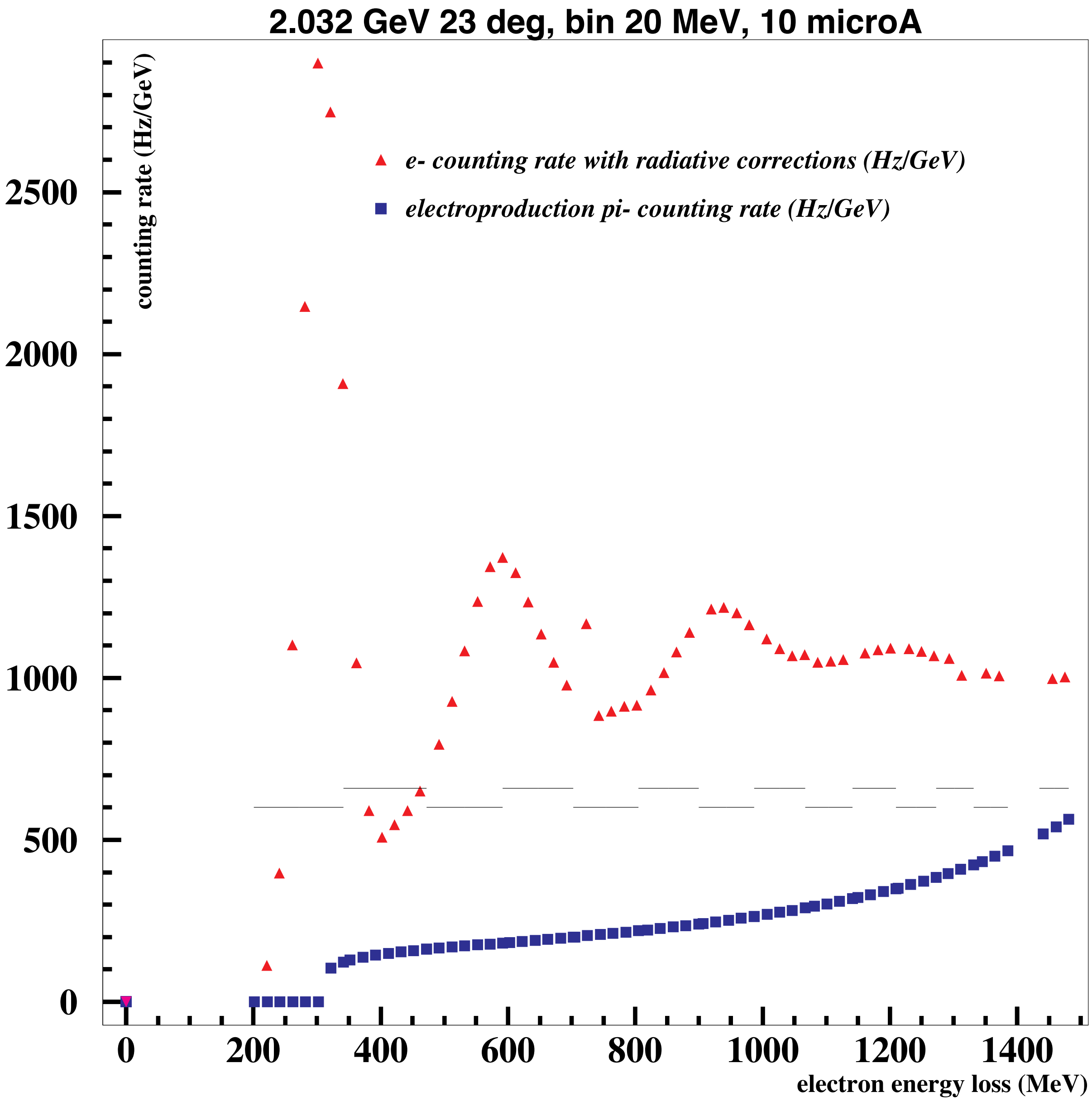

Figure 8: Electron scattering and pion production rates across the excitation energy range to be measured. The inelastic radiative corrections are included in the electron rate evaluation. The horizontal lines indicate the coverage of the momentum acceptance at each momentum setting. We have assumed $\delta p \;/\; p_0 = \pm 4\%$

Running e-^{3}He Inelastic Priority 2 Rank 3
Incident Beam Energy E_i = 2.032 GeV
Scattering Angle $\Theta = 15.5°$
Beam Current = 10 μA
Target Length = 40 cm ^{3}He

Ep GeV	Q^2 GeV^2	Rate Hz	ΔA_1^n	$T_\parallel$ hrs	$T_\perp$ hrs	T_{tot} hrs	$N_\parallel$	$N_\perp$	Collimator Status HRS elec/had
1.894	0.280	2000.0	0.005	6.2	2.8	9.0	44507488	20292512	in/in
1.748	0.258	811.7	0.010	6.4	5.6	12.0	18664958	16402574	in/in
1.614	0.239	1553.1	0.010	3.3	2.7	6.0	18261136	15284829	in/in
1.490	0.220	1075.9	0.010	4.1	2.9	7.0	15880424	11233137	in/in
1.375	0.203	761.1	0.010	5.0	3.0	8.0	13741852	8178629	in/in
1.269	0.188	789.4	0.011	4.0	2.0	6.0	11304317	5747714	in/in
1.172	0.173	632.8	0.011	4.2	1.8	6.0	9482458	4186424	in/in
1.082	0.160	536.4	0.011	4.3	1.7	6.0	8341650	3244446	in/in
0.851	0.126	355.6	0.011	4.7	1.3	6.0	5983934	1696200	in/in
0.618	0.091	209.6	0.011	5.8	1.2	7.0	4385007	895869	in/in

Momentum change: 5 hours
Angle change: 1 hour
Moller measurement: 1 hour
Total parallel time: 47.9 hours
Total perpendicular time: 25.1 hours
Total time: 80.0 hours

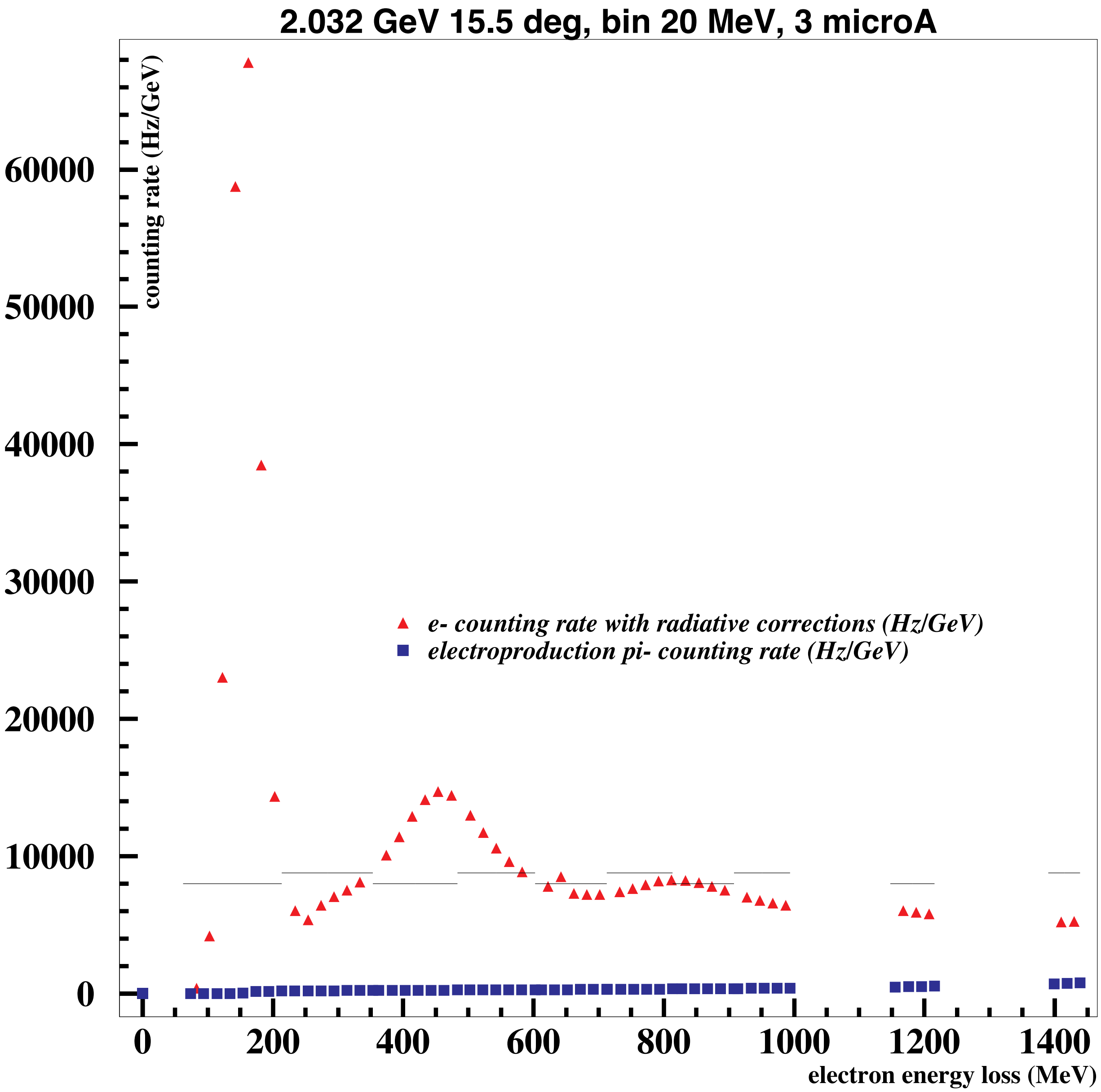

Figure 9: Electron scattering and pion production rates across the excitation energy range to be measured. The inelastic radiative corrections are included in the electron rate evaluation. The horizontal lines indicate the coverage of the momentum acceptance at each momentum setting. We have assumed $\delta p \ / \ p_0 = \pm 4\%$