DRAGON Beam Normalization Study

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Abstract

Following the work of Hutcheon (2002), a study to determine the relationship of the beam current incident on the DRAGON gas target to the beta monitor counts and the elastic monitor counts was undertaken. Data for fourteen runs utilizing a ^{21}Na beam were collected, and three different ratios were calculated for each run: elastic monitor counts to FC4 reading (R1), elastic monitor counts to beta monitor counts (R2), and beta monitor counts to FC4 reading (R3). Results indicate that R2 is the most constant ratio, with both R1 and R3 displaying larger standard deviations.

1 Introduction

Understanding the results of the experiments performed by DRAGON requires a good knowledge of the beam current incident on the gas target. Currently, it is only possible to measure this current by the insertion of a Faraday cup, a process which interupts the beam and thus, data collection.

The DRAGON beta monitor is located in the mass slit box upstream of the slits. It detects beta particles from the decay of unstable beam after it has been stopped by the mass separator. The elastic monitor is located in the gas target, with solid state Si detectors positioned at 30° and 57° to monitor scattering events. The scaler rate from both monitors is available during the entire course of a data acquisition run, unlike a Faraday cup. If a relation could be found between the beta and/or the elastic monitor rate and some value directly related to the beam current (such as a Faraday cup reading), it is hoped that one or both of these monitors could be used as a continuous monitor of the beam current throughout a run.

Preliminary analysis indicates that a constant relationship between the elastic monitor and the FC4 reading shows large error. A similar conclusion was made for the beta monitor. The ratio between the elastic monitor counts and the beta monitor counts showed the lowest scatter, giving us confidence that both monitors measure the same beam property. It remains only to find a way to relate these values to the beam current.

2 Data Analysis

Data for fourteen runs involving a ^{21}Na beam taken between 2002 December 1 and 2002 December 8 were assembled from various sources. Three different ratios were calculated for each run: elastic monitor counts to FC4 reading (R1), elastic monitor counts to beta monitor counts (R2), and beta monitor counts to FC4 reading (R3). With corrections for Rutherford scattering, the fraction of beam particles in the selected charge state, the livetime of the device, and the pressure, these ratios are given by

$$R1 = \frac{Elastics \times E_{in}^2}{FC4 \times LT \times t \times P}, \tag{1}$$

$$R2 = \frac{Elastics \times E_{in}^2 \times F}{P \times LT \times \beta Scaler}, \tag{2}$$

$$R3 = \frac{\beta Scaler}{FC4 \times t \times F}. \tag{3}$$

The run number, pressure, incoming energy, and Faraday cup readings were obtained from the log book. The ratio of the FCCH reading to the FC4 reading was used to determine the charge state fraction F.

$$F = \frac{FCCH/q_{sel}}{FC4/5} \tag{4}$$

The livetime LT was determined by the ratio of heavy ions acquired to heavy ions presented, as documented in the .odb file. This information was used in the analysis of all ratios of interest.

Depending on the ratio being studied, the elastic monitor rate and beta monitor rate was calculated by one of two separate methods. Since the beam is not stable throughout a run, one could not compare the FC4 reading taken at the beginning of the run to the beta/elastic monitor counts taken over the entirety of the run. Instead, R1 and R3 were calculated by considering only a period at the beginning of the run where the elastic monitor counts were considered to be stable. The counts were obtained by integrating over the specified period of time in the NOVA program.

Since R2 does not depend on the Faraday cup readings, statistics for this ratio were improved by comparing the beta monitor counts to those of the elastic monitor over the entire length of the run. The beta monitor counts were obtained from the .odb file, while the elastic monitor counts were determined by integrating under the elastics spectrum.

In each method, it was necessary to remove background counts in the elastic spectrum resulting from β^+ particles produced from the decay of ^{21}Na ions stopped at the gas target. This was done by extrapolating the background to the energies associated with elastic scattering events, and subtracting the counts under the extrapolated curve (Figure **??**).

3 Results

After collecting all relevant data, the ratios R1, R2, and R3 were calculated for each run. The results are given in Tables **??**, **??**, and **??** respectively.

One of the most striking results of this study is the drop in the value of R1 at 774.7 keV/u. Run 7240 has the most abnormally low value of R1, possibly due to a statistical fluctuation in the elastic counts (though this too

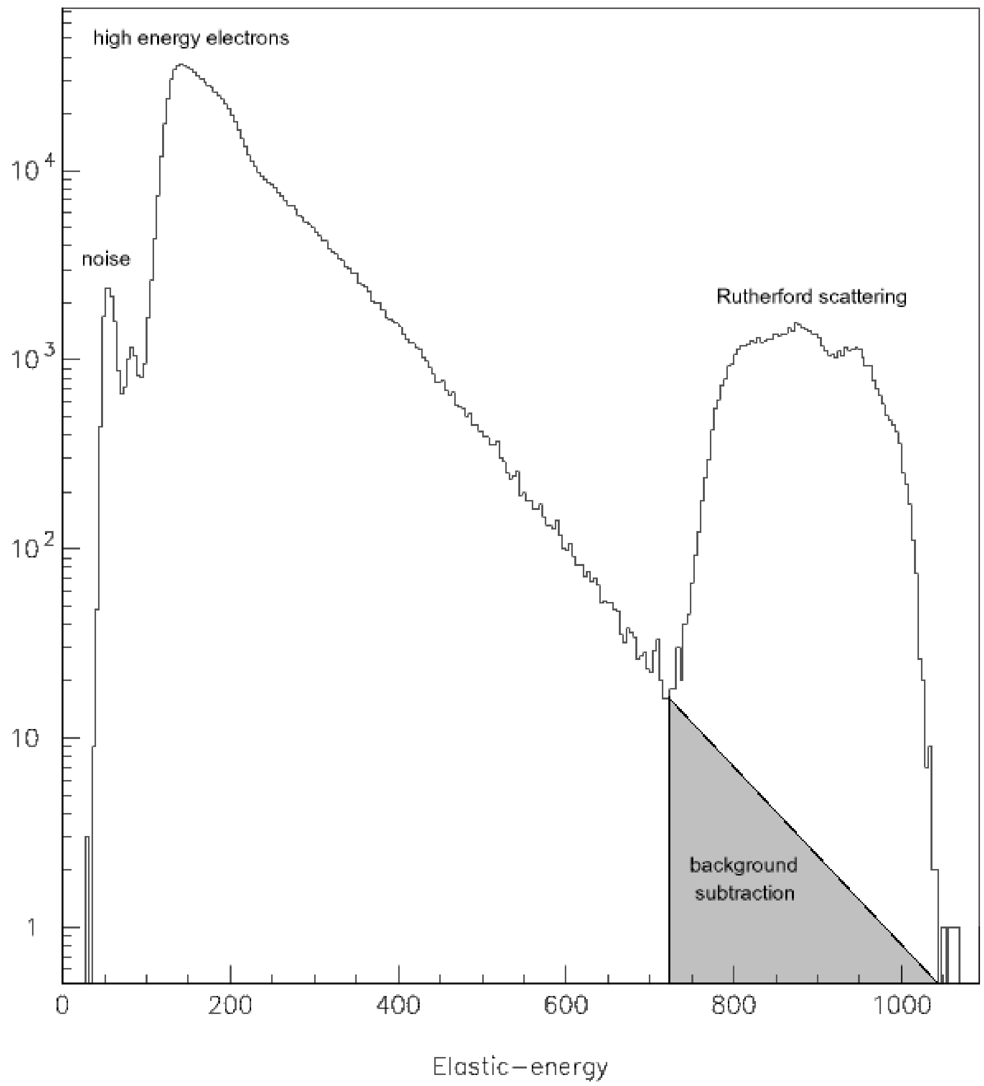

Figure 1: Elastic monitor spectrum for run #7191 plotted on a log scale.

Run	E_{in}	Pressure	FC4 (epA)	Livetime	Time (s)	Elastics	R1
7191	582.7	4.57	480	0.96	326	1421	702.2
7192	582.7	8.12	425	0.96	518	3726	740.6
7193	582.7	6.22	450	0.94	1160	6285	697.7
7194	582.7	6.21	430	0.92	748	4085	753.7
7202	471.9	5.82	387	0.90	696	4511	713.3
7210	784.2	7.42	350	0.95	2266	6696	740.1
7212	784.2	7.35	305	0.95	692	1758	734.6
7238	774.7	7.96	25	0.99	1150	203	540.4
7239	774.7	7.80	16	0.99	744	91	593.1
7240	774.7	7.80	17	1.00	394	21	242.2
7241	774.7	7.80	14	0.99	876	76	481.8
7242	774.7	7.86	13	0.99	1240	117	559.9
7243	774.7	7.73	15	0.99	1766	195	576.9
7244	774.7	7.77	13	0.99	2902	193	400.8

Table 1: Elastic monitor counts normalized to Faraday cup reading

Run	E_{in}	Pressure	Charge Fraction	Livetime	Elastics	β Scaler	R2
7191	582.7	4.57	0.34	0.96	61904	89.6M	18.3
7192	582.7	8.12	0.46	0.96	103794	91.8M	22.6
7193	582.7	6.22	0.40	0.94	39818	43.6M	21.0
7194	582.7	6.21	0.45	0.92	58324	68.5M	22.7
7202	471.9	5.82	0.41	0.90	71292	55.2M	22.8
7210	784.2	7.42	0.50	0.95	37058	65.5M	24.8
7212	784.2	7.35	0.47	0.95	16651	29.2M	23.7
7238	774.7	7.96	0.50	0.99	3391	4.92M	26.4
7239	774.7	7.80	0.51	0.99	981	1.42M	27.3
7240	774.7	7.80	0.37	1.00	194	3.57M	15.4
7241	774.7	7.80	0.45	0.99	3608	5.31M	23.6
7242	774.7	7.86	0.53	0.99	2946	4.39M	27.4
7243	774.7	7.73	0.42	0.99	1834	2.77M	21.6
7244	774.7	7.77	0.46	0.99	1201	1.74M	24.8

Table 2: Elastic monitor counts normalized to beta monitor

Run	E_{in}	FC4 (epA)	Charge Fraction	Time (s)	β Scaler	R3
7191*	582.7	480	0.34	326	2.06M	38.5
7192	582.7	425	0.46	518	3.09M	30.7
7193	582.7	450	0.40	1160	7.07M	34.1
7194	582.7	430	0.45	748	4.52M	31.3
7202	471.9	387	0.41	696	3.43M	30.8
7210	784.2	350	0.50	2266	12.0M	30.2
7212*	784.2	305	0.47	692	2.75M	27.7
7238*	774.7	25	0.50	1150	0.27M	18.5
7239*	774.7	16	0.51	744	0.12M	19.4
7240	774.7	17	0.37	394	0.08M	30.6
7241*	774.7	14	0.45	876	0.14M	25.3
7242*	774.7	13	0.53	1240	0.17M	19.8
7243*	774.7	15	0.42	1766	0.32M	29.1
7244*	774.7	13	0.46	2902	0.39M	22.7

* Data had unstable beta monitor readings.

Table 3: Beta monitor counts normalized to Faraday cup reading

is unclear). Even if we exclude this run, however, all other runs at the energy show a significant decrease in R1 compared to those at 784.keV/u. There is no evidence of a strong resonance at this energy, so it is unclear what could be causing this anomaly. The beam intensity is fairly low at this energy, though, so the FC4 readings may be approaching the level of noise, making the error quite large.

R3 also had a large uncertainty associated with it. This may be partially a result of unstable beta readings which occurred in eight out of the fourteen runs (our time window was defined by the time in which the elastic monitor counts, not the beta monitor counts, were constant). Of the runs with stable beta readings, one included the anomalous run 7240. Left with only five reliable results, there does not seem to be enough data to make any conclusions about the reliability of R3.

The most constant ratio proved to be R2. Its largest source of deviation appeared to be caused by a scatter in the charge state fraction F. If we assumed a constant F, however, the scatter decreased, and if we omitted the outlier run 7240, R2 showed only a 3.7% variation at 582.7 keV/u, and a 1.9% variation at 774.7 keV/u. A constant value for R2 indicates that while the beam may fluctuate, the counters are stable, and measure the same value to a few percent. As energy increases, however, there appears to be a slight increase in R2, making it uncertain whether this value will be useful as a "universal constant."

4 Recommendations

As a result of the failure of the ratios R1 and R3 to produce a constant relationship, an alternate means of relating the elastic monitor counts to the beam current was considered.

If a Faraday cup was placed between the MD1 and ED1, it would be possible to take beam current readings while simultaneously recording elastic monitor counts. This would provide a direct and continuous relationship between beam current and elastic monitor counts. Since not all of the beam continues past the first charge slit, it would be necessary to take Faraday cup readings for each charge state, then sum the readings and compare them to the elastic monitor count for the same time period.

$$\frac{\sum Q_i}{Elastics} = constant \tag{5}$$

If carried out for every new beam energy, this procedure would provide the correct calibration constant even when the elastic cross section deviates from pure Rutherford scattering.