Estimation of the angular transmission of projectile residues in RUN89

1 Summary

This note shows the calculation of the transmission *T*, which describes the relative yield of products of a given mass, which pass through the FRS for the reaction ^{56}Fe on protons at different beam energies. The calculation includes three steps, which consist of the calculation of the momentum width of the projectile residue in the rest frame, determining the corresponding opening angle of the velocity cone of the projectile residues in the laboratory frame and calculating the transmission *T* as a function of the angle determined in the previous step.

2 The momentum distribution width

Goldhaber model

The first case follows the result of the Goldhaber approach for the estimation of the width of the momentum distribution of the projectile residues [1]. It is asumed, that the distribution is isotropic in rest frame of reference (see formula (1)) . For the constant σ_0 the value of 103 MeV/c was used, which is consistent with the previously estimated results for reactions with similar energies, in which medium-mass nuclei are involved [1,3]. In this case, no other correction corresponding to the momentum transfer during the emission of particles or particle groups during the different reaction steps has been made, due to the fact, that in the statistical Goldhaber approach the processes which occur in the reaction are not described explicitly.

Morrissey systematics

The entire mass loss on which the transfered momentum depends is the result of two separate steps, namely the abrasion of nucleons and the following deexcitation of the prefragment by emission of nucleons or nucleon groups (ablation step). The Goldhaber formula describes only the momentum transfer caused by the abrasion, therefore a description of the transfered momentum, based on the entire mass loss requires a separate treatment of both steps, which is effectively included in the Morrissey systematics. The next two cases consist the empirical result of the momentum spread of projectile residues in which the width of the momentum distribution depends linearly on the square root of the projectile mass loss [3]. The constant of proportionality estimated by Morrissey [3] amounts to 150 MeV/c per unit of $\sqrt{A}$. In the present case this value is divided in addition by a factor of $\sqrt{3}$, because the calculations of the deflection angle refers to one cartesian component of the momentum in the rest frame of reference. Due to possible uncertainties of the estimated constant, the doubled value of 300 $/\sqrt{3}$ MeV/c is used to describe the kinematics in the third case. The third case should not be considered to be realistic, it just gives an extreme upper estimate for the width of the momentum spread, here it is used as a measure of the confidence range of our predictions.

3 The transmission estimation

The yield of the reaction products transmitted through the FRS without losses is calculated only by taking into account the opening angle of the velocity cone in the laboratory frame of reference, where the cone has a point source of origin. The broadening of the angular distribution due to angular straggling phenomena in the target or other layers of matter passed by the products are not included. Following the determination of the angular transmission proposed recently by Benlliure et al [3] an effective acceptance angle of 15mrad for the FRS spectrometer has been used. While a Gaussian shape of the distribution of the products with respect to the deflection angle in the laboratory frame of reference is assumed, the yield *T* is calculated by the use of equation (7), as quoted in [3].

References

[1] A. S. Goldhaber, Phys. Lett. B 53 (1974) 306-8

[2] D.J. Morrissey, Phys. Rev. C 39 (1989) 460

[3] J. Benlliure, J. Pereira-Conca, K.-H. Schmidt, Nucl. Instr. and Meth A(2001), accepted; preprint GSI ,http://www-wnt.gsi.de/kschmidt/bep00.htm

Table 1: Formulas and constants

Width of the momentum distribution in the rest frame in MeV/c, Eq.(1): Goldhaber theory[1] Eq.(2): Morrissey systematics [2]	$$\sigma^2 = \sigma_0^2 \frac{K(A-K)}{A-1} \quad (1)$$ *K*: Fragment mass *A*: Projectile mass $$\sigma = \frac{150}{\sqrt{3}}.\sqrt{\Delta A} \quad (2)$$ ΔA: Mass loss
Momentum to velocity Transformation	$$\Delta\beta_{cm} = \frac{\frac{pc}{A \cdot 931.5}}{\sqrt{1+\left(\frac{pc}{A \cdot 931.5}\right)^2}} \quad (3)$$
Time transform from rest to lab. frame of reference.	$$\frac{dt}{dt'} = \frac{1+\frac{u'v}{c^2}}{\sqrt{1-\frac{v^2}{c^2}}} \quad (4)$$
Transformation laws of the velocity components from the rest to lab. frame of reference.	$$u_{\parallel} = \frac{u'_{\parallel} + v}{1+\frac{u'_{\parallel} v}{c^2}} \quad , \quad u_{\perp} = \frac{u'_{\perp}\sqrt{1-\frac{v^2}{c^2}}}{1+\frac{u'_{\parallel} v}{c^2}} \quad (5)$$
Deflection angle in the lab. frame of reference in [rad].	$$\theta = \frac{u'}{v}\sqrt{1-\frac{v^2}{c^2}} \mapsto \frac{\Delta\beta_{cm}}{\beta}\sqrt{1-\beta^2} \text{ if } u' << v \quad (6)$$
Transmission estimate of the FRS according to Benlljure et all [3].	$$T = 1 - \exp\left(-\frac{\alpha_{eff}^2}{2\sigma_\theta^2}\right) \quad (7)$$

The denoted constants in the following table are listed below:

σ_G, σ_M :	Calculated widths of the momentum distribution in one direction in the rest frame of reference according to the Goldhaber formula (G) and Morrissey systematics (M);
θ_G, θ_M :	Maximum deflection angle in the laboratory frame of reference induced by a transfered momentum with the values σ_G and σ_M in the rest frame of refence;
θ_{DM} :	Maximum deflection angle in the laboratory frame of reference induced by a transfered momentum with the value $2.\sigma_M$;
T_G, T_M, T_{DM} :	Transmission coefficients for cone shaped velocity distributions of the projectile residues in the laboratory frame of refence, with the corresponding opening angles $\theta_G, \theta_M, \theta_{DM}$.

Table 2: Results

300 A.MeV								
A	σ_G [MeV/c]	σ_M [MeV/c]	θ_G [mrad]	θ_M [mrad]	θ_{DM} [mrad]	T_G	T_M	T_{DM}
10	274.7	587.4	34.09	72.77	144.69	0.079	0.021	0.005
11	285.0	580.9	32.15	65.46	130.29	0.088	0.026	0.007
12	294.3	574.5	30.44	59.35	118.23	0.098	0.031	0.008
13	302.9	567.9	28.91	54.17	107.98	0.108	0.038	0.010
14	310.6	561.2	27.54	49.72	99.17	0.119	0.044	0.011
15	317.7	554.5	26.28	45.86	91.50	0.129	0.052	0.013
16	324.1	547.7	25.14	42.47	84.76	0.141	0.060	0.016
17	329.8	540.8	24.08	39.47	78.80	0.152	0.070	0.018
18	335.0	533.9	23.10	36.80	73.49	0.164	0.080	0.021
19	339.6	526.8	22.19	34.40	68.71	0.177	0.091	0.024
20	343.7	519.6	21.33	32.24	64.40	0.190	0.103	0.027
21	347.3	512.3	20.53	30.28	60.49	0.203	0.115	0.030
22	350.3	505.0	19.77	28.49	56.92	0.217	0.129	0.034
23	352.9	497.5	19.05	26.84	53.65	0.232	0.145	0.038
24	355.0	489.9	18.36	25.33	50.63	0.247	0.161	0.043
25	356.6	482.2	17.71	23.94	47.85	0.263	0.178	0.048
26	357.8	474.3	17.08	22.64	45.26	0.280	0.197	0.053
27	358.4	466.4	16.48	21.44	42.86	0.297	0.217	0.059
28	358.7	458.3	15.90	20.31	40.61	0.315	0.239	0.066
29	358.4	450.0	15.34	19.26	38.50	0.334	0.262	0.073
30	357.8	441.6	14.80	18.27	36.53	0.354	0.286	0.081
31	356.6	433.0	14.28	17.34	34.66	0.375	0.312	0.089
32	355.0	424.3	13.77	16.46	32.90	0.396	0.340	0.099
33	352.9	415.3	13.27	15.62	31.24	0.419	0.369	0.109
34	350.3	406.2	12.79	14.83	29.65	0.443	0.400	0.120
35	347.3	396.9	12.32	14.08	28.14	0.468	0.433	0.132
36	343.7	387.3	11.85	13.35	26.70	0.494	0.468	0.146
37	339.6	377.5	11.39	12.66	25.32	0.521	0.504	0.161
38	335.0	367.4	10.94	12.00	24.00	0.550	0.542	0.177
39	329.8	357.1	10.50	11.37	22.73	0.580	0.581	0.196
40	324.1	346.4	10.06	10.75	21.50	0.612	0.622	0.216
41	317.7	335.4	9.62	10.16	20.31	0.645	0.664	0.239
42	310.6	324.0	9.18	9.58	19.15	0.679	0.707	0.264
43	302.9	312.2	8.74	9.01	18.03	0.714	0.750	0.293
44	294.3	300.0	8.30	8.46	16.93	0.750	0.792	0.325
45	285.0	287.2	7.86	7.92	15.85	0.787	0.833	0.361
46	274.7	273.9	7.41	7.39	14.78	0.825	0.873	0.402
47	263.5	259.8	6.96	6.86	13.72	0.861	0.908	0.450
48	251.0	244.9	6.49	6.33	12.67	0.897	0.939	0.504
49	237.2	229.1	6.01	5.80	11.61	0.929	0.965	0.566
50	221.9	212.1	5.51	5.27	10.53	0.957	0.983	0.637
51	204.6	193.6	4.98	4.71	9.43	0.979	0.994	0.718
52	184.7	173.2	4.41	4.13	8.27	0.993	0.999	0.807
53	161.5	150.0	3.78	3.51	7.03	0.999	1.000	0.898
54	133.1	122.5	3.06	2.82	5.63	1.000	1.000	0.971
55	95.0	86.6	2.14	1.95	3.91	1.000	1.000	0.999

Continuation of table 2

500 A.MeV								
A	σ_G [MeV/c]	σ_M [MeV/c]	θ_G [mrad]	θ_M [mrad]	θ_{DM} [mrad]	T_G	T_M	T_{DM}
10	274.7	587.4	25.26	53.93	107.23	0.139	0.038	0.010
11	285.0	580.9	23.83	48.51	96.56	0.155	0.047	0.012
12	294.3	574.5	22.56	43.98	87.62	0.171	0.056	0.015
13	302.9	567.9	21.43	40.14	80.03	0.188	0.067	0.017
14	310.6	561.2	20.41	36.85	73.49	0.205	0.080	0.021
15	317.7	554.5	19.48	33.98	67.81	0.223	0.093	0.024
16	324.1	547.7	18.63	31.47	62.82	0.241	0.107	0.028
17	329.8	540.8	17.85	29.25	58.40	0.260	0.123	0.032
18	335.0	533.9	17.12	27.27	54.46	0.279	0.140	0.037
19	339.6	526.8	16.44	25.50	50.92	0.298	0.159	0.042
20	343.7	519.6	15.81	23.89	47.73	0.318	0.179	0.048
21	347.3	512.3	15.21	22.44	44.83	0.339	0.200	0.054
22	350.3	505.0	14.65	21.11	42.18	0.360	0.223	0.061
23	352.9	497.5	14.11	19.89	39.76	0.381	0.247	0.069
24	355.0	489.9	13.61	18.77	37.52	0.404	0.273	0.077
25	356.6	482.2	13.12	17.74	35.46	0.426	0.301	0.086
26	357.8	474.3	12.66	16.78	33.54	0.450	0.329	0.095
27	358.4	466.4	12.21	15.89	31.76	0.474	0.360	0.106
28	358.7	458.3	11.78	15.05	30.10	0.498	0.391	0.117
29	358.4	450.0	11.37	14.27	28.54	0.523	0.424	0.129
30	357.8	441.6	10.97	13.54	27.07	0.549	0.459	0.142
31	356.6	433.0	10.58	12.85	25.69	0.575	0.494	0.157
32	355.0	424.3	10.21	12.20	24.39	0.601	0.531	0.172
33	352.9	415.3	9.84	11.58	23.15	0.628	0.568	0.189
34	350.3	406.2	9.48	10.99	21.98	0.655	0.606	0.208
35	347.3	396.9	9.13	10.43	20.86	0.683	0.644	0.228
36	343.7	387.3	8.78	9.90	19.79	0.711	0.683	0.250
37	339.6	377.5	8.44	9.39	18.77	0.739	0.721	0.273
38	335.0	367.4	8.11	8.89	17.79	0.767	0.759	0.299
39	329.8	357.1	7.78	8.42	16.84	0.794	0.795	0.327
40	324.1	346.4	7.45	7.97	15.93	0.821	0.830	0.358
41	317.7	335.4	7.13	7.53	15.05	0.848	0.863	0.391
42	310.6	324.0	6.80	7.10	14.19	0.873	0.893	0.428
43	302.9	312.2	6.48	6.68	13.36	0.898	0.920	0.468
44	294.3	300.0	6.15	6.27	12.54	0.920	0.943	0.511
45	285.0	287.2	5.83	5.87	11.74	0.940	0.962	0.558
46	274.7	273.9	5.49	5.48	10.95	0.958	0.976	0.608
47	263.5	259.8	5.16	5.09	10.17	0.973	0.987	0.663
48	251.0	244.9	4.81	4.69	9.39	0.984	0.994	0.721
49	237.2	229.1	4.45	4.30	8.60	0.992	0.998	0.781
50	221.9	212.1	4.08	3.90	7.81	0.997	0.999	0.842
51	204.6	193.6	3.69	3.49	6.99	0.999	1.000	0.900
52	184.7	173.2	3.27	3.06	6.13	1.000	1.000	0.950
53	161.5	150.0	2.80	2.60	5.21	1.000	1.000	0.984
54	133.1	122.5	2.27	2.09	4.17	1.000	1.000	0.998
55	95.0	86.6	1.59	1.45	2.90	1.000	1.000	1.000

Continuation of table 2

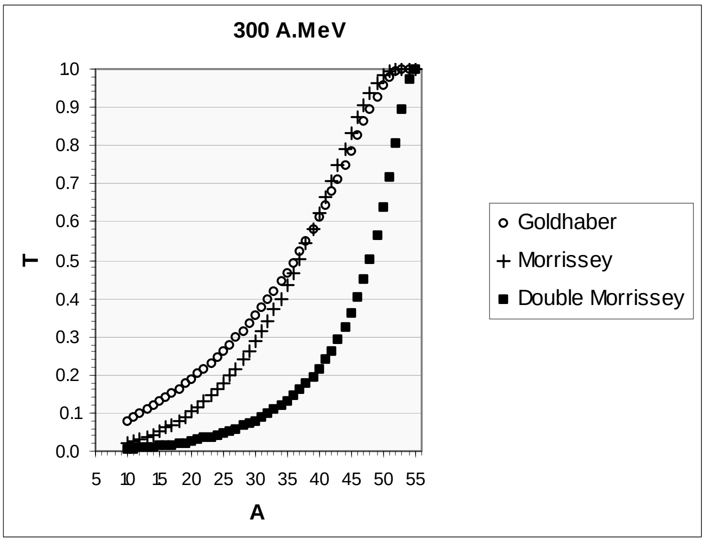
750 A.MeV								
A	σ_G [MeV/c]	σ_M [MeV/c]	θ_G [mrad]	θ_M [mrad]	θ_{DM} [mrad]	T_G	T_M	T_{DM}
10	274.7	587.4	19.62	41.87	83.26	0.220	0.062	0.016
11	285.0	580.9	18.50	37.67	74.97	0.244	0.076	0.020
12	294.3	574.5	17.52	34.15	68.03	0.268	0.092	0.024
13	302.9	567.9	16.64	31.17	62.14	0.292	0.109	0.029
14	310.6	561.2	15.84	28.61	57.06	0.317	0.128	0.034
15	317.7	554.5	15.12	26.39	52.65	0.342	0.149	0.040
16	324.1	547.7	14.46	24.44	48.78	0.367	0.172	0.046
17	329.8	540.8	13.86	22.71	45.35	0.393	0.196	0.053
18	335.0	533.9	13.29	21.18	42.29	0.418	0.222	0.061
19	339.6	526.8	12.77	19.80	39.54	0.444	0.250	0.069
20	343.7	519.6	12.27	18.55	37.06	0.470	0.279	0.079
21	347.3	512.3	11.81	17.42	34.81	0.496	0.310	0.089
22	350.3	505.0	11.37	16.39	32.75	0.523	0.342	0.100
23	352.9	497.5	10.96	15.45	30.87	0.549	0.376	0.111
24	355.0	489.9	10.56	14.58	29.13	0.576	0.411	0.124
25	356.6	482.2	10.19	13.77	27.53	0.602	0.447	0.138
26	357.8	474.3	9.83	13.03	26.04	0.629	0.485	0.153
27	358.4	466.4	9.48	12.34	24.66	0.655	0.523	0.169
28	358.7	458.3	9.15	11.69	23.37	0.681	0.561	0.186
29	358.4	450.0	8.83	11.08	22.16	0.707	0.600	0.205
30	357.8	441.6	8.52	10.51	21.02	0.733	0.639	0.225
31	356.6	433.0	8.22	9.98	19.95	0.758	0.677	0.246
32	355.0	424.3	7.92	9.47	18.93	0.782	0.715	0.269
33	352.9	415.3	7.64	8.99	17.97	0.806	0.751	0.294
34	350.3	406.2	7.36	8.53	17.06	0.829	0.787	0.321
35	347.3	396.9	7.09	8.10	16.19	0.851	0.820	0.349
36	343.7	387.3	6.82	7.68	15.37	0.872	0.851	0.379
37	339.6	377.5	6.56	7.29	14.57	0.892	0.880	0.411
38	335.0	367.4	6.30	6.91	13.81	0.910	0.905	0.446
39	329.8	357.1	6.04	6.54	13.08	0.927	0.928	0.482
40	324.1	346.4	5.79	6.19	12.37	0.943	0.947	0.521
41	317.7	335.4	5.53	5.84	11.69	0.956	0.963	0.561
42	310.6	324.0	5.28	5.51	11.02	0.968	0.975	0.604
43	302.9	312.2	5.03	5.19	10.37	0.977	0.985	0.648
44	294.3	300.0	4.78	4.87	9.74	0.985	0.991	0.695
45	285.0	287.2	4.52	4.56	9.12	0.991	0.996	0.742
46	274.7	273.9	4.27	4.25	8.50	0.995	0.998	0.789
47	263.5	259.8	4.00	3.95	7.90	0.997	0.999	0.835
48	251.0	244.9	3.74	3.65	7.29	0.999	1.000	0.880
49	237.2	229.1	3.46	3.34	6.68	1.000	1.000	0.920
50	221.9	212.1	3.17	3.03	6.06	1.000	1.000	0.953
51	204.6	193.6	2.87	2.71	5.42	1.000	1.000	0.978
52	184.7	173.2	2.54	2.38	4.76	1.000	1.000	0.993
53	161.5	150.0	2.18	2.02	4.04	1.000	1.000	0.999
54	133.1	122.5	1.76	1.62	3.24	1.000	1.000	1.000
55	95.0	86.6	1.23	1.12	2.25	1.000	1.000	1.000

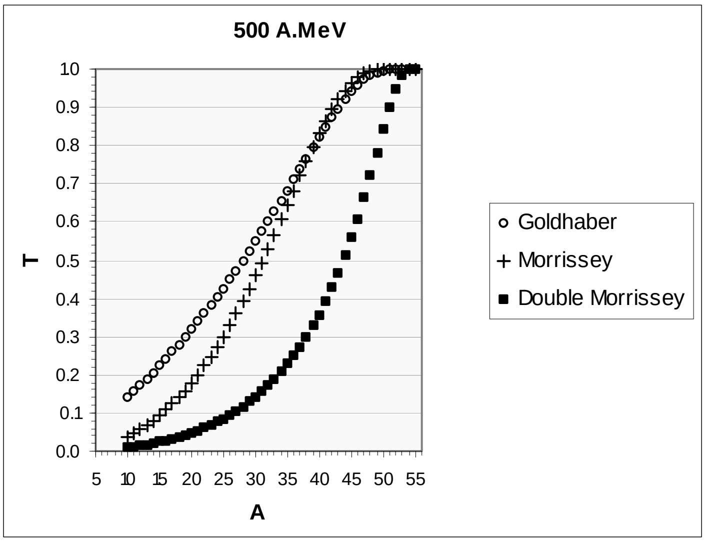
Continuation of table 2

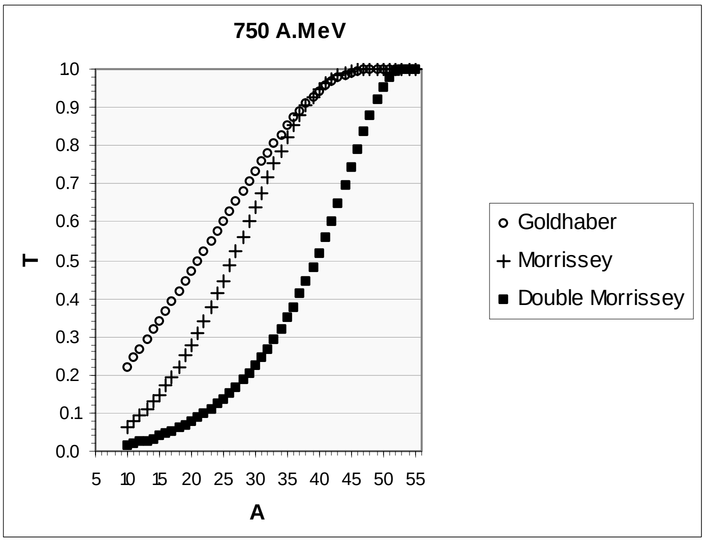
1000 A.MeV								
A	σ_G [MeV/c]	σ_M [MeV/c]	θ_G [mrad]	θ_M [mrad]	θ_{DM} [mrad]	T_G	T_M	T_{DM}
10	274.7	587.4	16.23	34.64	68.88	0.305	0.089	0.023
11	285.0	580.9	15.31	31.16	62.03	0.335	0.109	0.029
12	294.3	574.5	14.49	28.25	56.29	0.366	0.131	0.035
13	302.9	567.9	13.76	25.79	51.41	0.397	0.156	0.042
14	310.6	561.2	13.11	23.67	47.21	0.427	0.182	0.049
15	317.7	554.5	12.51	21.83	43.56	0.457	0.210	0.058
16	324.1	547.7	11.97	20.22	40.35	0.487	0.241	0.067
17	329.8	540.8	11.46	18.79	37.52	0.517	0.273	0.077
18	335.0	533.9	11.00	17.52	34.99	0.547	0.307	0.088
19	339.6	526.8	10.56	16.38	32.71	0.576	0.343	0.100
20	343.7	519.6	10.16	15.35	30.66	0.605	0.380	0.113
21	347.3	512.3	9.77	14.41	28.80	0.633	0.418	0.127
22	350.3	505.0	9.41	13.56	27.10	0.661	0.458	0.142
23	352.9	497.5	9.07	12.78	25.54	0.688	0.498	0.158
24	355.0	489.9	8.74	12.06	24.10	0.714	0.539	0.176
25	356.6	482.2	8.43	11.40	22.78	0.740	0.579	0.195
26	357.8	474.3	8.13	10.78	21.55	0.765	0.620	0.215
27	358.4	466.4	7.85	10.21	20.40	0.789	0.660	0.237
28	358.7	458.3	7.57	9.67	19.33	0.812	0.700	0.260
29	358.4	450.0	7.30	9.17	18.33	0.834	0.738	0.285
30	357.8	441.6	7.05	8.70	17.39	0.854	0.774	0.311
31	356.6	433.0	6.80	8.25	16.50	0.874	0.808	0.338
32	355.0	424.3	6.56	7.83	15.66	0.892	0.840	0.368
33	352.9	415.3	6.32	7.44	14.87	0.909	0.869	0.399
34	350.3	406.2	6.09	7.06	14.12	0.924	0.895	0.431
35	347.3	396.9	5.86	6.70	13.40	0.938	0.918	0.466
36	343.7	387.3	5.64	6.36	12.71	0.951	0.938	0.501
37	339.6	377.5	5.42	6.03	12.06	0.961	0.955	0.539
38	335.0	367.4	5.21	5.71	11.43	0.971	0.968	0.578
39	329.8	357.1	5.00	5.41	10.82	0.978	0.979	0.617
40	324.1	346.4	4.79	5.12	10.23	0.985	0.986	0.658
41	317.7	335.4	4.58	4.83	9.67	0.990	0.992	0.700
42	310.6	324.0	4.37	4.56	9.12	0.993	0.996	0.742
43	302.9	312.2	4.16	4.29	8.58	0.996	0.998	0.783
44	294.3	300.0	3.95	4.03	8.06	0.998	0.999	0.823
45	285.0	287.2	3.74	3.77	7.54	0.999	1.000	0.861
46	274.7	273.9	3.53	3.52	7.04	1.000	1.000	0.897
47	263.5	259.8	3.31	3.27	6.53	1.000	1.000	0.928
48	251.0	244.9	3.09	3.02	6.03	1.000	1.000	0.955
49	237.2	229.1	2.86	2.76	5.53	1.000	1.000	0.975
50	221.9	212.1	2.62	2.51	5.01	1.000	1.000	0.989
51	204.6	193.6	2.37	2.24	4.49	1.000	1.000	0.996
52	184.7	173.2	2.10	1.97	3.94	1.000	1.000	0.999
53	161.5	150.0	1.80	1.67	3.35	1.000	1.000	1.000
54	133.1	122.5	1.46	1.34	2.68	1.000	1.000	1.000
55	95.0	86.6	1.02	0.93	1.86	1.000	1.000	1.000

Continuation of table 2

1500 A.MeV								
A	σ_G [MeV/c]	σ_M [MeV/c]	θ_G [mrad]	θ_M [mrad]	θ_{DM} [mrad]	T_G	T_M	T_{DM}
10	274.7	587.4	12.23	26.10	51.89	0.473	0.152	0.041
11	285.0	580.9	11.53	23.48	46.73	0.513	0.185	0.050
12	294.3	574.5	10.92	21.29	42.40	0.552	0.220	0.061
13	302.9	567.9	10.37	19.43	38.73	0.589	0.258	0.072
14	310.6	561.2	9.88	17.83	35.57	0.625	0.298	0.085
15	317.7	554.5	9.43	16.45	32.82	0.659	0.340	0.099
16	324.1	547.7	9.02	15.23	30.40	0.692	0.384	0.115
17	329.8	540.8	8.64	14.16	28.26	0.723	0.430	0.131
18	335.0	533.9	8.29	13.20	26.36	0.752	0.476	0.150
19	339.6	526.8	7.96	12.34	24.65	0.779	0.522	0.169
20	343.7	519.6	7.65	11.56	23.10	0.805	0.569	0.190
21	347.3	512.3	7.36	10.86	21.70	0.829	0.615	0.213
22	350.3	505.0	7.09	10.22	20.41	0.851	0.660	0.237
23	352.9	497.5	6.83	9.63	19.24	0.871	0.703	0.262
24	355.0	489.9	6.58	9.09	18.16	0.890	0.744	0.289
25	356.6	482.2	6.35	8.59	17.16	0.907	0.783	0.318
26	357.8	474.3	6.13	8.12	16.23	0.922	0.818	0.347
27	358.4	466.4	5.91	7.69	15.37	0.935	0.851	0.379
28	358.7	458.3	5.70	7.29	14.56	0.947	0.880	0.412
29	358.4	450.0	5.50	6.91	13.81	0.958	0.905	0.446
30	357.8	441.6	5.31	6.55	13.10	0.966	0.927	0.481
31	356.6	433.0	5.12	6.22	12.43	0.974	0.945	0.517
32	355.0	424.3	4.94	5.90	11.80	0.980	0.960	0.554
33	352.9	415.3	4.76	5.60	11.20	0.985	0.972	0.592
34	350.3	406.2	4.59	5.32	10.64	0.989	0.981	0.630
35	347.3	396.9	4.42	5.05	10.09	0.993	0.988	0.669
36	343.7	387.3	4.25	4.79	9.58	0.995	0.993	0.707
37	339.6	377.5	4.09	4.54	9.08	0.997	0.996	0.744
38	335.0	367.4	3.93	4.30	8.61	0.998	0.998	0.781
39	329.8	357.1	3.77	4.08	8.15	0.999	0.999	0.816
40	324.1	346.4	3.61	3.86	7.71	0.999	0.999	0.849
41	317.7	335.4	3.45	3.64	7.28	1.000	1.000	0.880
42	310.6	324.0	3.29	3.43	6.87	1.000	1.000	0.908
43	302.9	312.2	3.14	3.23	6.47	1.000	1.000	0.932
44	294.3	300.0	2.98	3.04	6.07	1.000	1.000	0.953
45	285.0	287.2	2.82	2.84	5.68	1.000	1.000	0.969
46	274.7	273.9	2.66	2.65	5.30	1.000	1.000	0.982
47	263.5	259.8	2.50	2.46	4.92	1.000	1.000	0.990
48	251.0	244.9	2.33	2.27	4.54	1.000	1.000	0.996
49	237.2	229.1	2.16	2.08	4.16	1.000	1.000	0.998
50	221.9	212.1	1.98	1.89	3.78	1.000	1.000	1.000
51	204.6	193.6	1.79	1.69	3.38	1.000	1.000	1.000
52	184.7	173.2	1.58	1.48	2.97	1.000	1.000	1.000
53	161.5	150.0	1.36	1.26	2.52	1.000	1.000	1.000
54	133.1	122.5	1.10	1.01	2.02	1.000	1.000	1.000
55	95.0	86.6	0.77	0.70	1.40	1.000	1.000	1.000







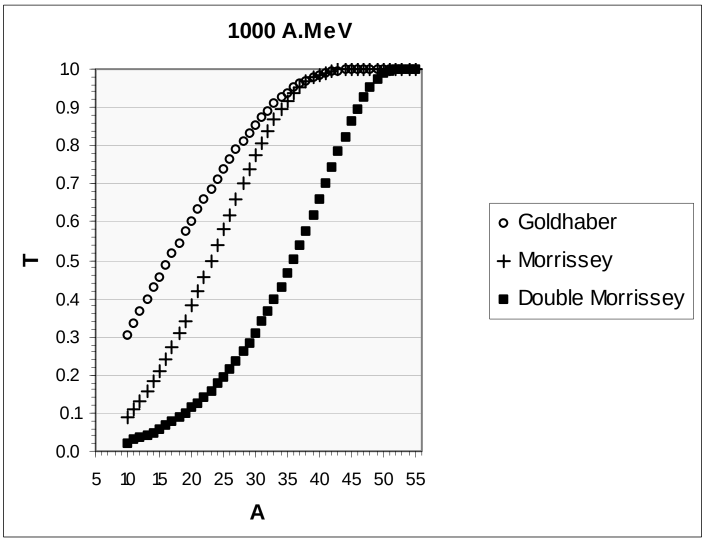


Figure 1: Calculated transmission as a function of the mass of the projectile residue for different beam energies, described by the Goldhaber model and Morrissey systematics.

open circles: Goldhaber model

crosses: Morrissey systematics

squares: Transmission calculated using the doubled value of the momentum evaluated by the Morrissey systematics (see text for explanation).