NEUTRON DETECTOR PERFORMANCE STUDIES

PERFORMANCE OF LARGE-VOLUME MEAN-TIMED NEUTRON COUNTERS

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This discussion updates the information in the 1979 IUCF annual report[1)] on the performance of our large-volume, mean-timed neutron counters. During the past year, we constructed, tested, and succesfully commissioned three new 20 in. x 40 in. x 4 in. and one new 40 in. x 40 in. x 4 in. mean-timed NE-102 plastic-scintillator counters. These new counters were designed with the aid of a computer program which simulates the light-collection process and the generation of a timing signal in a mean-timed neutron counter. The program was used to determine the optimum light-pipe geometry for these new counters.

The intrinsic time resolution of these detectors was measured with a cosmic-ray coincidence technique described in last year's report.[1)] Briefly, with one detector placed directly above another, we measured coincidences with cosmic rays passing through the four-inch dimension of each detector. The observed time dispersion for two 20 in. x 40 in. x 4 in. detectors was 425 ± 10 ps (fwhm). We deduce an intrinsic time resolution of 300 ± 7 ps for one of these 20 in. x 40 in. x 4 in. detectors, assuming that each contributes to the observed 425 ps in quadrature. From measurements with a 20 in. x 40 in. x 4 in. detector covering half (center to one edge) of the 40 in. x 40 in. 4 in. detector, we deduced an intrinsic time resolution of 410 ± 13 for the 40 in. x 40 in. x 4 in. counter.

In addition to the cosmis-ray studies of the intrinsic time revolution of these counters, we observed good time and energy resolution in experiments at the IUCF. Figure 1 shows a comparison of time-of-flight spectra at 45° from the $^{18}O(p,n)^{18}F$ reaction with 135 MeV protons measured with a 20 in. x 40 in. x 4 in. counter and with the 40 in. x 40 in. x 4 in. counter. (Both counters comprised a 40 in. x 60 in. neutron detector array, the largest used thus far at the IUCF). The sharp peak in each spectrum is the 5^+ state of ^{18}F at 1.12 MeV excitation. The observed

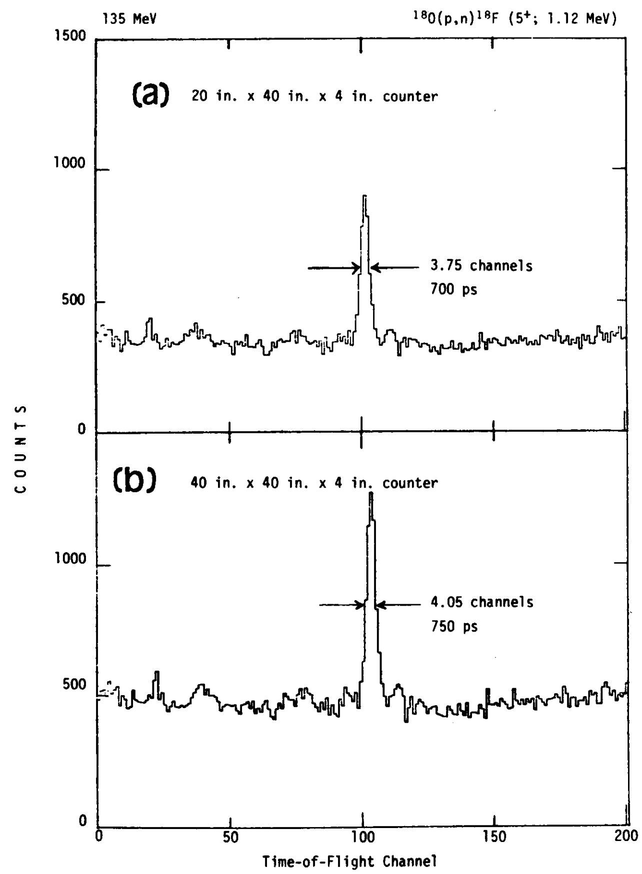

Figure 1. Neutron time-of-flight spectra at a laboratory angle of 45° from the $^{18}O(p,n)^{18}F$ reaction at 135 MeV. The sharp peak in each spectrum is the ^{18}F state at 1.12 MeV excitation with $J^{\pi} = 5^+$. Spectrum (a) was measured with a 20 in. x 40 in. 4 in. counter; spectrum (b) was measured with a 40 in. x 40 in. x 4 in. counter. The peak widths were obtained with a Gaussian peak-fitting routine.

time resolutions are 700 ps and 750 ps for the 20 in. x 40 in. x 4 in. and 40 in. x 40 in. x 4 in. counters respectively, the difference being consistent with their different intrinsic time resolutions at 300 ps and 410 ps. The observed time-of-flight resolutions of 700 ps and 750 ps correspond to 450 and 480 keV, respectively, for 130 MeV neutrons traversing the 70 m flight-path. The 40 mg/cm^2 target thickness contributed 200 keV to these energy resolutions. The nominal spread in the proton beam energy is 0.1% or 135 keV for 135 MeV protons. For the 90 m flight-paths used in our November 1980 experiments at the IUCF, we observed an overall time resolution of 700 ps with 20 in. x 40 in. x 4 in. counters, which corresponds to an energy resolution of 355 keV for 130 MeV neutrons.

The design objective for our large mean-timed counters was to combine good time resolution with large volume. The large sizes of our counters were important to our experimental program this past year. During our (p,n) run of November 1980, we were able to measure cross sections as small as 6 μb/sr, about a factor of five smaller than we had achieved previously. With the commissioning of a third neutron flight-path for the beam swinger facility at the IUCF (servicing 45° to 69°), we were able to make measurements at larger momentum transfers than was possible previously even though cross sections were small. The large size of our counters was significant also for our polarized-beam $(\vec{p},n)$ analyzing-power measurements and for our (p,pn) neutron knockout reaction studies on ^{40}Ca and ^{48}Ca.

1) IUCF Scient. and Techn. Report, 1979, p. 128.

APPENDIX: DATA TABLES

PROTON ELASTIC SCATTERING

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$p + {}^{40}Ca$, E_p = 80 MeV

θ_{cm} (deg)	$d\sigma/d\Omega_{cm}$ (mb/sr)	relat. error (mb/sr)
5.29	7.858E+03	2.298E+02
7.34	3.929E+03	5.549E+01
9.40	3.426E+03	5.900E+01
11.45	2.768E+03	4.632E+01
13.51	1.850E+03	2.865E+01
15.56	1.171E+03	1.901E+01
17.61	6.519E+02	1.168E+01
19.66	3.109E+02	6.101E+00
21.71	1.253E+02	2.593E+00
23.76	4.601E+01	8.092E-01
25.81	2.711E+01	3.528E-01
27.86	3.131E+01	3.834E-01
29.91	3.973E+01	5.108E-01
31.96	4.229E+01	4.926E-01
34.01	3.856E+01	4.581E-01
36.05	3.001E+01	4.146E-01
38.09	2.118E+01	2.985E-01
40.14	1.310E+01	2.001E-01
42.18	7.908E+00	1.179E-01
44.22	4.854E+00	7.085E-02
46.26	3.645E+00	4.874E-02
48.30	3.173E+00	3.850E-02
50.33	2.962E+00	3.596E-02
52.37	2.772E+00	3.613E-02
54.40	2.361E+00	3.118E-02
56.43	1.827E+00	2.431E-02
58.46	1.317E+00	1.870E-02
60.49	9.190E-01	1.371E-02
62.52	6.445E-01	9.739E-03
64.54	4.723E-01	7.022E-03
66.57	3.985E-01	5.548E-03
68.59	3.776E-01	5.255E-03
70.61	3.590E-01	5.045E-03
72.63	3.253E-01	4.184E-03
74.65	2.922E-01	4.072E-03
76.66	2.409E-01	3.469E-03
78.67	1.788E-01	2.645E-03
80.68	1.271E-01	1.967E-03
82.69	8.457E-02	1.384E-03
84.70	5.428E-02	9.037E-04
86.71	3.461E-02	5.714E-04
88.71	2.485E-02	4.360E-04
90.71	2.123E-02	3.662E-04
92.71	2.160E-02	5.143E-04
94.71	2.227E-02	5.508E-04

$p + {}^{40}Ca$, E_p = 135 MeV

θ_{cm} (deg)	$d\sigma/d\Omega_{cm}$ (mb/sr)	relat. error (mb/sr)
8.65	1.911E+03	3.351E+01
10.71	1.236E+03	2.182E+01
12.76	6.594E+02	1.223E+01
14.82	2.821E+02	6.103E+00
16.88	9.245E+01	2.244E+00
18.93	2.449E+01	5.828E-01
20.98	1.669E+01	2.959E-01
23.04	2.273E+01	4.074E-01
25.06	2.395E+01	3.438E-01
27.11	2.036E+01	3.090E-01
29.16	1.384E+01	2.158E-01
31.21	8.120E+00	1.417E-01
32.93	4.835E+00	8.566E-02
34.98	2.952E+00	4.441E-02
37.03	2.021E+00	2.945E-02
39.07	1.653E+00	2.228E-02
41.12	1.262E+00	1.771E-02
43.16	9.222E-01	1.214E-02
45.20	6.176E-01	9.335E-03
47.24	4.019E-01	6.053E-03
49.28	3.040E-01	4.674E-03
51.32	2.419E-01	3.679E-03
53.36	1.996E-01	2.861E-03
55.39	1.572E-01	2.322E-03
57.42	1.127E-01	1.968E-03
59.46	7.124E-02	1.171E-03
61.48	4.056E-02	7.227E-04
63.51	2.131E-02	4.371E-04
65.54	1.263E-02	3.124E-04
67.56	9.650E-03	2.293E-04
69.58	1.013E-02	2.415E-04
71.60	9.625E-03	2.320E-04
73.62	8.657E-03	2.128E-04
75.64	6.260E-03	2.326E-04
77.65	4.730E-03	1.888E-04
79.67	2.640E-03	1.188E-04
81.68	1.311E-03	7.084E-05
83.69	5.930E-04	3.631E-05
85.69	2.973E-04	3.136E-05
87.70	2.715E-04	2.496E-05
89.70	2.483E-04	3.751E-05
91.70	4.546E-04	3.063E-05
93.70	5.421E-04	4.028E-05

$p + {}^{40}Ca$, E_p = 160 MeV

θ_{cm} (deg)	$d\sigma/d\Omega_{cm}$ (mb/sr)	relat. error (mb/sr)
7.91	1.885E+03	3.970E+01
9.45	1.420E+03	2.840E+01
10.99	8.790E+02	1.758E+01
12.54	4.837E+02	9.674E+00
14.08	2.267E+02	5.092E+00
15.62	8.532E+01	2.206E+00
17.16	3.151E+01	8.074E-01
18.71	1.685E+01	3.370E-01
20.25	1.865E+01	3.370E-01
21.79	2.178E+01	4.356E-01
23.33	2.244E+01	4.488E-01
24.87	1.945E+01	3.890E-01
26.92	1.294E+01	2.588E-01
28.97	7.539E+00	1.508E-01
31.03	4.039E+00	8.078E-02
33.08	2.357E+00	4.714E-02
35.13	1.610E+00	3.080E-02
37.17	1.165E+00	2.220E-02
39.22	7.890E-01	1.572E-02
41.27	5.410E-01	1.070E-02
43.31	3.796E-01	7.592E-03
45.35	2.904E-01	5.868E-03
47.39	2.274E-01	4.548E-03
49.43	1.692E-01	3.384E-03
51.47	1.161E-01	2.322E-03
53.51	6.098E-02	1.382E-03
55.54	3.503E-02	7.900E-04
57.58	1.828E-02	3.965E-04
59.61	1.199E-02	2.445E-04
61.64	1.078E-02	2.569E-04
63.67	9.987E-03	2.390E-04
65.69	8.798E-03	2.159E-04
67.72	7.150E-03	1.753E-04
69.74	4.403E-03	1.363E-04
71.76	2.323E-03	8.305E-05
73.78	9.836E-04	5.488E-05
75.80	3.750E-04	2.937E-05
77.81	1.900E-04	2.597E-05
79.82	2.744E-04	2.848E-05
81.83	3.671E-04	3.003E-05
83.84	3.955E-04	4.058E-05
85.85	3.649E-04	3.646E-05
87.85	3.262E-04	3.749E-05*

$p + {}^{90}Zr$, E_p = 80 MeV

θ_{cm} (deg)	$d\sigma/d\Omega_{cm}$ (mb/sr)	relat. error (mb/sr)
6.28	2.033E+04	4.635E+02
7.80	1.371E+04	2.415E+02
9.32	1.058E+04	1.841E+02
10.84	7.236E+03	1.299E+02
12.35	4.423E+03	8.970E+01
13.87	2.532E+03	5.530E+01
15.39	1.107E+03	2.875E+01
16.40	5.933E+02	1.734E+01
17.41	2.581E+02	8.996E+00
18.43	7.959E+01	3.551E+00
19.44	4.336E+01	7.784E-01
20.45	6.135E+01	1.549E+00
21.46	1.077E+02	2.409E+00
22.98	1.796E+02	3.187E+00
24.49	2.256E+02	3.507E+00
25.50	2.255E+02	3.518E+00
26.01	2.221E+02	3.557E+00
27.53	1.910E+02	3.159E+00
29.04	1.394E+02	2.491E+00
30.56	8.677E+01	1.713E+00
32.07	5.069E+01	1.093E+00
33.59	2.396E+01	5.751E-01
35.10	1.463E+01	2.585E-01
36.62	1.266E+01	2.487E-01
38.13	1.591E+01	2.413E-01
39.65	1.978E+01	2.894E-01
41.16	2.078E+01	2.420E-01
42.68	1.893E+01	2.933E-01
44.19	1.616E+01	2.440E-01
45.70	1.195E+01	1.952E-01
47.21	8.569E+00	1.335E-01
48.73	5.590E+00	9.924E-02
50.24	3.659E+00	6.283E-02
51.75	2.830E+00	4.484E-02
53.26	2.717E+00	4.254E-02
54.77	2.877E+00	4.262E-02
56.28	2.928E+00	4.294E-02
57.79	2.806E+00	4.135E-02
59.30	2.527E+00	3.767E-02
60.81	2.126E+00	3.215E-02
62.32	1.613E+00	2.539E-02
63.83	1.118E+00	1.906E-02
65.34	7.775E-01	1.368E-02
66.85	5.967E-01	1.006E-02
68.35	4.884E-01	8.184E-03
69.86	4.935E-01	8.755E-03
71.73	5.127E-01	9.023E-03
72.87	5.332E-01	1.028E-02

$p + {}^{90}Zr$, E_p = 80 MeV

θ_{cm} (deg)	$d\sigma/d\Omega_{cm}$ (mb/sr)	relat. error (mb/sr)
74.38	4.904E-01	1.077E-02
75.88	4.646E-01	9.366E-03
77.39	3.927E-01	7.923E-03
78.89	3.042E-01	7.377E-03
80.39	2.222E-01	5.253E-03
81.90	1.546E-01	3.743E-03
83.40	1.046E-01	2.566E-03
84.90	7.320E-02	1.787E-03
86.40	6.161E-02	1.576E-03
87.90	5.776E-02	1.495E-03
89.41	6.257E-02	1.625E-03
90.91	6.905E-02	1.782E-03

$p + {}^{90}Zr$, E_p = 135 MeV

θ_{cm} (deg)	$d\sigma/d\Omega_{cm}$ (mb/sr)	relat. error (mb/sr)
6.13	1.056E+04	1.994E+02
7.14	8.183E+03	1.646E+02
8.15	6.298E+03	1.428E+02
9.17	4.449E+03	1.140E+02
10.18	2.914E+03	8.681E+01
11.19	1.636E+03	8.878E+01
12.20	8.215E+02	3.491E+01
13.22	3.170E+02	1.814E+01
13.72	1.754E+02	1.201E+01
14.23	9.474E+01	7.225E+00
14.74	4.830E+01	3.623E+00
15.24	3.411E+01	1.174E+00
15.75	3.219E+01	1.921E+00
16.25	4.769E+01	1.931E+00
17.27	9.214E+01	2.700E+00
18.28	1.325E+02	2.630E+00
19.29	1.579E+02	2.612E+00
20.30	1.577E+02	2.328E+00
21.31	1.294E+02	2.501E+00
22.33	1.034E+02	2.245E+00
23.34	7.363E+01	1.860E+00
24.35	4.478E+01	1.331E+00
24.45	4.354E+01	1.584E+00
25.36	2.596E+01	8.441E-01
25.46	2.676E+01	1.052E+00
26.37	1.502E+01	4.723E-01
26.47	1.436E+01	5.179E-01
27.38	9.700E+00	2.179E-01
27.48	8.899E+00	2.345E-01
28.40	8.694E+00	1.787E-01
28.50	8.699E+00	2.169E-01

$p + {}^{90}Zr$, E_p = 135 MeV

θ_{cm} (deg)	$d\sigma/d\Omega_{cm}$ (mb/sr)	relat. error (mb/sr)
29.41	9.337E+00	2.283E-01
29.51	9.564E+00	2.522E-01
30.42	1.076E+01	2.665E-01
30.52	1.075E+01	2.590E-01
31.43	1.128E+01	1.833E-01
31.53	1.124E+01	3.097E-01
32.54	1.105E+01	2.804E-01
33.55	1.003E+01	2.633E-01
34.56	8.147E+00	2.025E-01
35.57	6.214E+00	1.991E-01
36.58	4.633E+00	1.579E-01
37.59	3.298E+00	1.151E-01
38.50	2.528E+00	7.228E-02
38.60	2.496E+00	8.418E-02
39.61	2.014E+00	5.787E-02
40.52	1.683E+00	4.251E-02
40.62	1.709E+00	4.737E-02
41.63	1.558E+00	4.689E-02
42.64	1.430E+00	4.042E-02
43.65	1.325E+00	4.130E-02
44.66	1.251E+00	3.644E-02
45.67	9.270E-01	2.693E-02
47.18	7.048E-01	2.237E-02
48.70	4.712E-01	1.336E-02
50.21	3.349E-01	1.139E-02
51.72	2.629E-01	1.030E-02
53.23	2.435E-01	1.197E-02
54.74	2.251E-01	1.110E-02
56.26	1.939E-01	7.570E-03
57.77	1.462E-01	6.693E-03
59.28	1.010E-01	4.359E-03
60.79	6.506E-02	2.420E-03
62.30	3.780E-02	1.523E-03
63.80	2.562E-02	1.039E-03
65.31	2.328E-02	1.011E-03
66.82	2.364E-02	1.030E-03
68.33	2.469E-02	1.056E-03
69.84	2.301E-02	1.064E-03
71.34	1.835E-02	8.997E-04
72.85	1.207E-02	6.834E-04
74.35	7.732E-03	5.127E-04
75.86	4.449E-03	3.049E-04
77.36	2.300E-03	1.882E-04
78.87	1.753E-03	1.539E-04
80.37	2.060E-03	1.627E-04
81.87	2.423E-03	1.816E-04
83.38	2.803E-03	2.532E-04
84.88	2.890E-03	2.582E-04
86.38	1.948E-03	2.089E-04
87.88	1.328E-03	1.643E-04
89.38	1.048E-03	1.467E-04
85.88	2.060E-03	8.300E-05

$p + {}^{90}Zr$, E_p = 135 MeV

θ_{cm} (deg)	$d\sigma/d\Omega_{cm}$ (mb/sr)	relat. error (mb/sr)
88.39	1.390E-03	6.500E-05
90.91	5.280E-04	3.600E-05
93.43	1.780E-04	1.210E-05
95.95	1.800E-04	1.080E-05
98.47	2.950E-04	1.670E-05
100.97	3.150E-04	1.490E-05
103.49	2.110E-04	1.290E-05
106.00	1.160E-04	9.800E-06
108.51	3.600E-05	4.650E-06
111.03	0.510E-05	2.170E-06
113.54	2.160E-05	2.520E-06
116.04	3.160E-05	3.370E-06
118.55	3.320E-05	2.950E-06
121.06	2.210E-05	2.170E-06
123.57	1.160E-05	1.690E-06
126.08	6.860E-06	1.380E-06

$p + {}^{90}Zr$, E_p = 160 MeV

θ_{cm} (deg)	$d\sigma/d\Omega_{cm}$ (mb/sr)	relat. error (mb/sr)
4.74	1.435E+04	2.911E+02
6.26	9.630E+03	1.417E+02
7.78	6.124E+03	9.981E+01
9.30	2.997E+03	6.477E+01
10.82	1.147E+03	3.297E+01
12.34	2.855E+02	1.202E+01
13.86	4.656E+01	1.210E+00
15.38	7.114E+01	1.584E+00
16.90	1.309E+02	2.020E+00
18.41	1.404E+02	1.921E+00
19.93	1.117E+02	1.994E+00
21.45	6.921E+01	1.824E+00
22.97	3.217E+01	1.023E+00
24.49	1.379E+01	3.162E-01
26.00	9.747E+00	1.290E-01
27.52	9.324E+00	1.349E-01
29.04	1.019E+01	1.326E-01
30.56	9.117E+00	1.331E-01
32.07	6.801E+00	1.200E-01
33.59	4.423E+00	8.036E-02
35.11	2.731E+00	4.580E-02
36.62	1.871E+00	2.527E-02
38.14	1.428E+00	1.797E-02
39.65	1.199E+00	1.561E-02
41.17	9.369E-01	1.347E-02
42.68	6.740E-01	1.084E-02
44.20	4.641E-01	7.858E-03
45.71	3.556E-01	5.586E-03
47.23	2.887E-01	4.333E-03
48.74	2.381E-01	3.538E-03
50.25	1.976E-01	3.297E-03
51.76	1.461E-01	2.758E-03
53.28	9.612E-02	2.251E-03
54.79	5.710E-02	1.553E-03
56.30	3.514E-02	8.832E-04
57.81	2.645E-02	7.519E-04
59.32	2.513E-02	7.101E-04
60.83	2.440E-02	7.347E-04
62.34	2.140E-02	7.334E-04
63.85	1.726E-02	5.199E-04
65.36	1.204E-02	4.203E-04
66.87	6.718E-03	2.467E-04
68.37	3.171E-03	1.642E-04
69.88	1.745E-03	9.675E-05
71.39	1.574E-03	8.739E-05
72.89	2.082E-03	1.155E-04
74.40	2.513E-03	1.255E-04
75.90	2.658E-03	1.378E-04
77.41	2.109E-03	1.148E-04
78.91	1.589E-03	8.498E-05
80.42	8.098E-04	5.510E-05
81.92	3.829E-04	3.250E-05

$p + {}^{90}Zr$ E_p = 180 MeV

θ_{cm} (deg)	$d\sigma/d\Omega_{cm}$ (mb/sr)	relat. error (mb/sr)
6.43	7.353E+03	1.510E+02
7.44	5.229E+03	1.320E+02
8.46	3.290E+03	1.020E+02
9.47	1.811E+03	6.800E+01
10.48	7.930E+02	4.000E+01
11.50	2.920E+02	1.880E+01
12.51	7.350E+01	5.500E+00
13.52	2.090E+01	4.000E+00
14.53	5.460E+01	2.900E+00
15.55	9.700E+01	2.000E+00
17.57	1.260E+02	1.800E+00
19.60	8.060E+01	1.900E+00
21.62	3.200E+01	1.000E+00
23.65	1.050E+01	3.200E-01
25.67	7.710E+00	1.200E-01
27.70	7.600E+00	1.200E-01
29.72	6.020E+00	1.400E-01
31.74	3.760E+00	1.100E-01
33.77	1.980E+00	6.400E-02
35.79	1.160E+00	3.400E-02
37.81	7.560E-01	2.000E-02
39.83	4.950E-01	1.300E-02
41.85	3.570E-01	6.900E-03
43.87	2.680E-01	4.700E-03
45.89	2.020E-01	4.200E-03
47.91	1.270E-01	3.700E-03
49.93	6.990E-02	2.400E-03
51.94	3.500E-02	1.200E-03
53.96	2.400E-02	5.100E-04
55.97	2.150E-02	4.600E-04
57.99	1.900E-02	4.500E-04
60.00	1.280E-02	4.000E-04
62.02	6.100E-03	2.800E-04
64.03	2.000E-03	1.300E-04
66.04	1.100E-03	6.000E-05
68.05	1.450E-03	9.000E-05
70.06	1.700E-03	1.000E-04
72.07	1.500E-03	8.000E-05
74.08	1.000E-03	5.000E-05
76.09	5.500E-04	3.200E-05
78.09	2.200E-04	2.100E-05
80.10	1.000E-04	1.900E-05
82.10	1.500E-04	2.800E-05
84.11	2.400E-04	4.300E-05
86.11	1.800E-04	2.900E-05

$p + {}^{208}Pb$, E_p = 80 MeV

θ_{cm} (deg)	$d\sigma/d\Omega_{cm}$ (mb/sr)	relat. error (mb/sr)
6.20	1.230E+05	3.936E+03
7.71	5.865E+04	1.527E+03
9.22	3.202E+04	6.637E+02
10.73	1.537E+04	4.643E+02
12.23	5.789E+03	1.651E+02
13.74	1.705E+03	5.785E+01
15.25	6.402E+02	1.427E+01
16.76	6.957E+02	1.379E+01
18.26	9.740E+02	1.528E+01
19.77	1.032E+03	1.562E+01
21.28	8.462E+02	1.343E+01
22.79	5.237E+02	1.059E+01
24.29	2.460E+02	6.525E+00
25.80	8.069E+01	2.916E+00
27.31	2.696E+01	4.627E-01
28.81	4.312E+01	1.057E+00
30.32	8.493E+01	1.388E+00
31.83	1.033E+02	1.560E+00
33.33	9.594E+01	1.478E+00
34.84	6.780E+01	1.137E+00
36.35	3.775E+01	7.965E-01
37.85	1.615E+01	4.113E-01
39.36	7.489E+00	1.232E-01
40.87	8.907E+00	1.643E-01
42.37	1.359E+01	2.306E-01
43.88	1.755E+01	2.709E-01
45.38	1.708E+01	2.576E-01
46.89	1.357E+01	2.277E-01
48.38	8.826E+00	1.676E-01
49.90	4.884E+00	1.046E-01
51.40	2.726E+00	4.836E-02
52.91	2.353E+00	3.484E-02
54.41	2.887E+00	5.049E-02
55.92	3.660E+00	5.382E-02
57.42	3.800E+00	5.421E-02
58.93	3.418E+00	5.164E-02
60.43	2.607E+00	4.318E-02
61.93	1.641E+00	3.072E-02
63.44	9.950E-01	1.942E-02
64.94	6.800E-01	1.218E-02
66.45	6.991E-01	1.258E-02
67.95	8.711E-01	1.536E-02
69.45	9.944E-01	1.740E-02
70.95	9.838E-01	1.731E-02
72.46	8.532E-01	1.544E-02
73.96	6.479E-01	1.246E-02
75.46	4.436E-01	8.562E-03
76.96	2.966E-01	5.824E-03
78.46	2.223E-01	4.003E-03
79.97	2.132E-01	4.454E-03
81.47	2.409E-01	4.697E-03
82.97	2.830E-01	4.807E-03
84.47	2.983E-01	4.458E-03
85.97	2.767E-01	5.136E-03
87.47	2.304E-01	4.600E-03
88.97	1.638E-01	3.303E-03
90.47	1.096E-01	2.411E-03
91.97	7.076E-02	1.773E-03
93.47	5.515E-02	1.630E-03

$p + {}^{208}Pb$, E_p = 121 MeV

θ_{cm} (deg)	$d\sigma/d\Omega_{cm}$ (mb/sr)	relat. error (mb/sr)
5.08	9.317E+04	2.573E+03
5.58	6.643E+04	1.482E+03
6.08	5.019E+04	1.018E+03
6.59	3.944E+04	8.025E+02
7.09	3.202E+04	9.519E+02
7.59	2.573E+04	8.726E+02
8.09	1.997E+04	5.909E+02
8.60	1.511E+04	4.679E+02
9.10	1.115E+04	4.430E+02
9.60	7.828E+03	2.541E+02
10.10	5.275E+03	3.068E+02
11.11	2.092E+03	8.825E+01
12.12	6.979E+02	2.243E+01
13.12	4.189E+02	8.411E+00
14.13	5.764E+02	1.427E+01
15.13	7.808E+02	1.304E+01
16.14	8.455E+02	1.246E+01
17.14	7.604E+02	1.294E+01
18.15	6.061E+02	1.233E+01
19.15	3.582E+02	9.468E+00
20.16	1.764E+02	5.837E+00
21.16	6.753E+01	2.757E+00
22.17	2.584E+01	6.129E-01
23.17	2.892E+01	8.607E-01
24.18	4.951E+01	1.180E+00
25.18	7.269E+01	1.225E+00
26.19	7.297E+01	9.520E-01
27.19	7.224E+01	1.272E+00
28.20	5.494E+01	1.171E+00
29.20	3.568E+01	9.012E-01
30.21	1.938E+01	5.621E-01
31.21	9.513E+00	2.790E-01
32.22	6.251E+00	1.379E-01
33.22	6.363E+00	1.576E-01
34.23	8.960E+00	2.012E-01
35.23	1.080E+01	2.147E-01
36.23	1.155E+01	1.950E-01
37.24	1.037E+01	1.742E-01
38.24	8.151E+00	1.576E-01
39.25	5.757E+00	1.276E-01
40.25	3.623E+00	8.712E-02
41.26	2.141E+00	4.839E-02
48.28	1.500E+00	3.904E-02
49.29	9.974E-01	3.238E-02
50.29	6.830E-01	2.065E-02
51.29	4.460E-01	1.547E-02
52.30	3.635E-01	1.304E-02
53.30	3.643E-01	1.315E-02
54.30	4.122E-01	1.451E-02
55.31	4.600E-01	1.364E-02
56.31	4.535E-01	1.350E-02
57.31	4.103E-01	1.288E-02
58.32	3.372E-01	1.184E-02
59.32	2.395E-01	1.016E-02
60.32	1.597E-01	8.188E-03
61.32	8.840E-02	5.248E-03
62.33	6.651E-02	3.873E-03
63.33	5.837E-02	3.338E-03
64.33	7.306E-02	4.203E-03
65.33	7.837E-02	4.337E-03
66.34	8.724E-02	4.580E-03
67.34	9.037E-02	4.898E-03
68.34	8.747E-02	4.760E-03
69.34	7.000E-02	3.879E-03
70.85	4.531E-02	2.860E-03
72.35	2.274E-02	1.729E-03
73.85	1.453E-02	1.197E-03
75.35	1.488E-02	1.435E-03
76.85	1.677E-02	1.439E-03
78.36	1.728E-02	1.633E-03
79.86	1.557E-02	1.526E-03
81.36	1.422E-02	1.437E-03
82.86	7.128E-03	1.138E-03

p + ^{208}Pb, E_p = 160 MeV

θ_{cm} (deg)	$d\sigma/d\Omega_{cm}$ (mb/sr)	relat. error (mb/sr)
6.13	3.145E+04	1.301E+03
7.14	1.705E+04	5.356E+02
8.15	8.113E+03	2.842E+02
9.15	2.920E+03	1.235E+02
10.16	9.613E+02	4.479E+01
11.16	3.372E+02	1.070E+01
12.17	4.445E+02	1.404E+01
13.17	6.712E+02	1.035E+01
14.18	7.052E+02	1.077E+01
15.18	6.037E+02	1.074E+01
16.19	4.553E+02	1.251E+01
17.20	2.354E+02	7.345E+00
18.20	7.477E+01	3.144E+00
19.21	2.854E+01	9.761E-01
20.21	2.192E+01	5.875E-01
21.22	4.078E+01	1.025E+00
22.22	5.886E+01	9.813E-01
23.23	5.775E+01	9.449E-01
24.23	4.652E+01	8.891E-01
25.24	2.954E+01	6.909E-01
26.24	1.546E+01	4.196E-01
27.25	7.582E+00	2.080E-01
28.25	4.678E+00	8.126E-02
29.26	5.335E+00	9.378E-02
30.26	6.853E+00	1.494E-01
31.27	7.595E+00	1.632E-01
32.27	6.782E+00	1.397E-01
33.28	5.409E+00	1.112E-01
34.28	3.718E+00	7.970E-02
35.29	2.312E+00	5.108E-02
36.29	1.533E+00	2.914E-02
37.30	1.250E+00	1.995E-02
38.30	1.204E+00	1.817E-02
39.30	1.202E+00	1.805E-02
40.31	1.101E+00	1.712E-02
41.31	9.031E-01	1.587E-02
42.32	7.012E-01	1.283E-02
43.32	5.051E-01	9.610E-03
44.33	3.638E-01	6.981E-03
45.33	3.024E-01	5.297E-03
46.33	2.783E-01	4.754E-03
47.34	2.614E-01	4.709E-03
48.34	2.358E-01	4.336E-03
49.35	1.921E-01	3.979E-03
50.35	1.354E-01	3.115E-03
51.35	9.587E-02	2.340E-03
52.36	6.283E-02	1.938E-03
53.36	5.034E-02	1.599E-03

p + ^{208}Pb, E_p = 160 MeV

θ_{cm} (deg)	$d\sigma/d\Omega_{cm}$ (mb/sr)	relat. error (mb/sr)
54.36	4.976E-02	1.544E-03
55.37	5.033E-02	1.602E-03
56.37	5.021E-02	1.586E-03
57.37	4.732E-02	1.516E-03
58.38	3.760E-02	1.493E-03
59.38	2.892E-02	1.259E-03
60.38	1.835E-02	9.216E-04
61.38	1.098E-02	9.072E-04
62.39	7.421E-03	5.631E-04
63.39	6.986E-03	4.810E-04
64.39	8.880E-03	5.840E-04
65.39	1.016E-02	6.352E-04
66.40	1.068E-02	6.163E-04
67.40	8.585E-03	5.444E-04
68.40	7.194E-03	4.900E-04
69.40	4.806E-03	4.238E-04
70.41	3.041E-03	3.049E-04
71.41	1.407E-03	2.278E-04
72.41	1.240E-03	2.107E-04
73.41	9.336E-04	1.519E-04
75.41	1.730E-03	1.775E-04
77.42	1.777E-03	2.246E-04

p + ^{208}Pb, E_p = 182 MeV

θ_{cm} (deg)	$d\sigma/d\Omega_{cm}$ (mb/sr)	relat. error (mb/sr)
6.26	2.228E+04	4.600E+02
7.27	1.141E+04	2.320E+02
8.28	4.530E+03	9.400E+01
9.28	1.317E+03	2.700E+01
10.79	3.100E+02	7.000E+00
12.30	6.410E+02	1.340E+01
13.81	6.440E+02	1.360E+01
15.29	3.440E+02	7.700E+00
16.83	8.680E+01	1.940E+00
18.33	1.825E+01	3.700E-01
19.84	4.105E+01	9.200E-01
21.35	5.895E+01	1.320E+00
22.86	4.330E+01	1.010E+00
24.36	1.815E+01	4.100E-01
25.87	5.930E+00	1.300E-01
27.38	5.430E+00	1.180E-01
28.89	6.990E+00	1.530E-01
30.40	6.360E+00	1.400E-01
31.91	3.690E+00	8.100E-02
33.41	1.840E+00	4.100E-02
34.92	1.255E+00	3.000E-02

p + ^{208}Pb, E_p = 182 MeV

θ_{cm} (deg)	$d\sigma/d\Omega_{cm}$ (mb/sr)	relat. error (mb/sr)
36.42	1.080E+00	2.400E-02
37.93	9.340E-01	2.450E-02
39.44	6.860E-01	1.750E-02
40.95	4.650E-01	1.200E-02
42.45	3.560E-01	9.200E-03
43.96	2.540E-01	6.600E-03
45.46	1.720E-01	4.800E-03
46.97	9.630E-02	3.250E-03
48.48	6.770E-02	2.000E-03
49.98	6.340E-02	1.850E-03
51.49	5.980E-02	1.800E-03
52.99	4.750E-02	1.430E-03
54.50	2.920E-02	1.030E-03
56.00	1.310E-02	5.500E-04
57.51	8.000E-03	3.700E-04
59.01	9.350E-03	4.800E-04
60.52	1.020E-02	4.800E-04
62.02	9.200E-03	4.500E-04
63.53	4.850E-03	2.600E-04
65.03	2.150E-03	1.350E-04
66.53	8.900E-04	8.500E-05
68.04	1.050E-03	9.800E-05
69.54	1.700E-03	1.100E-04
71.04	1.750E-03	1.200E-04
72.54	1.200E-03	1.000E-04
74.05	6.100E-04	7.300E-05
75.55	1.700E-04	3.100E-05
77.05	1.150E-04	3.000E-05
78.55	2.550E-04	4.400E-05
80.06	3.550E-04	5.100E-05

LITHIUM-6 ELASTIC SCATTERING

submitted by P. Schwandt
Indiana University Cyclotron Facility, Bloomington, Indiana 47405

$^{6}Li + ^{28}Si$, 99 MeV

θ_{cm} (deg)	$d\sigma/d\Omega_{cm}$ (mb/sr)	relat. error (mb/sr)
7.31	5.593E+03	4.646E+02
7.91	3.377E+03	3.550E+02
9.13	2.162E+03	1.688E+02
10.96	1.330E+03	1.105E+02
11.56	9.500E+02	1.009E+02
12.78	9.436E+02	1.923E+01
14.60	7.701E+01	6.003E+00
16.12	1.366E+02	4.872E+00
16.42	1.376E+02	1.046E+01
18.24	6.058E+01	4.724E+00
18.54	4.715E+01	2.349E+00
18.84	3.372E+01	3.306E+00
19.14	2.279E+01	1.218E+00
19.75	7.804E+00	9.570E-02
20.05	4.453E+00	3.654E-01
21.86	1.097E+01	9.657E-01
22.17	1.253E+01	4.524E-01
22.47	1.555E+01	9.570E-01
22.77	1.522E+01	7.656E-01
23.37	1.470E+01	5.220E-01
23.67	1.548E+01	1.296E+00
24.58	1.009E+01	5.046E-01
25.48	5.194E+00	4.159E-01
25.78	3.384E+00	1.218E-01
26.08	1.864E+00	1.253E-01
26.38	1.314E+00	7.482E-02
27.29	5.272E-02	1.044E-02
28.19	8.787E-01	8.700E-02
28.49	1.208E+00	1.496E-01
29.39	1.966E+00	1.044E-01
29.69	2.149E+00	1.409E-01
29.99	2.297E+00	1.131E-01
31.48	1.546E+00	1.192E-01
31.78	1.305E+00	6.612E-02
32.08	1.155E+00	1.340E-01
33.28	3.993E-01	3.088E-02
33.58	2.775E-01	3.132E-02
35.07	1.097E-01	2.001E-02
36.85	3.339E-01	2.688E-02
37.15	3.245E-01	1.740E-02
38.63	2.883E-01	2.184E-02
40.41	1.138E-01	8.874E-03
42.18	2.941E-02	3.349E-03
43.95	4.187E-02	4.054E-03
45.71	4.853E-02	4.376E-03
47.47	3.066E-02	3.149E-03
49.22	1.438E-02	1.740E-03
52.71	9.509E-03	1.305E-03

$^{6}Li + ^{40}Ca$, 99 MeV

θ_{cm} (deg)	$d\sigma/d\Omega_{cm}$ (mb/sr)	relat. error (mb/sr)
6.80	2.184E+04	1.425E+03
7.95	9.499E+03	5.415E+03
9.10	5.628E+03	3.211E+02
10.25	3.197E+03	1.919E+02
11.41	1.092E+03	6.764E+01
12.56	4.190E+02	2.641E+01
13.48	3.838E+02	1.805E+01
13.71	3.876E+02	1.995E+01
14.63	3.638E+02	1.805E+01
14.85	3.442E+02	1.824E+01
15.30	2.869E+02	1.425E+01
15.77	2.261E+02	1.140E+01
16.00	1.827E+02	1.083E+01
16.45	1.263E+02	6.365E+00
16.92	7.353E+01	3.610E+00
18.07	2.413E+01	1.235E+00
18.74	2.831E+01	1.425E+00
19.22	3.334E+01	1.710E+00
19.89	4.170E+01	2.090E+00
20.36	3.990E+01	1.805E+00
21.51	2.641E+01	1.235E+00
22.18	1.520E+01	7.790E-01
22.65	8.825E+00	4.275E-01
23.32	3.154E+00	1.710E-01
23.80	1.852E+00	9.500E-02
24.94	3.866E+00	1.995E-01
26.08	6.336E+00	3.230E-01
27.22	4.968E+00	2.470E-01
28.36	2.175E+00	1.140E-01
29.50	2.717E-01	2.280E-02
30.64	3.068E-01	2.280E-02
32.91	1.021E+00	5.320E-02
34.04	7.227E-01	4.085E-02
35.17	2.403E-01	1.900E-02
36.30	2.033E-02	6.175E-02
37.43	6.555E-02	7.885E-03
38.56	1.501E-01	9.975E-03
39.69	1.615E-01	9.975E-03
40.81	1.092E-01	5.700E-03
41.94	4.645E-02	3.705E-03
43.06	1.178E-02	2.375E-03

$^{6}Li + ^{58}Ni$, 99 MeV

θ_{cm} (deg)	$d\sigma/d\Omega_{cm}$ (mb/sr)	relat. error (mb/sr)
6.20	1.006E+05	6.364E+03
7.30	3.758E+04	3.354E+03
8.40	2.038E+04	1.806E+03
9.50	9.804E+03	6.880E+02
10.60	4.128E+03	2.408E+02
11.70	1.892E+03	1.032E+02
12.80	1.428E+03	6.880E+01
13.90	9.976E+02	5.160E+01
15.00	5.005E+02	2.494E+01
16.10	1.987E+02	1.032E+01
17.20	1.281E+02	6.880E+00
18.30	1.324E+02	6.880E+00
19.40	8.858E+01	4.300E+00
20.50	3.664E+01	1.978E+00
22.70	1.359E+01	7.740E-01
23.80	1.651E+01	8.600E-01
24.90	1.066E+01	5.160E-01
26.00	4.102E+00	2.236E-01
27.10	1.049E+00	6.880E-02
28.20	1.763E+00	1.032E-01
29.30	2.460E+00	1.376E-01
30.40	1.651E+00	9.460E-02
31.50	6.923E-01	4.214E-02
32.60	9.804E-02	1.118E-02
33.70	1.565E-01	1.376E-02
34.80	4.068E-01	2.580E-02
35.90	4.248E-01	2.752E-02
37.00	2.064E-01	1.462E-02
38.00	4.678E-02	5.762E-03
39.10	9.202E-03	4.300E-03
40.20	6.183E-02	5.504E-03
41.30	9.460E-02	6.880E-03
42.40	6.923E-02	5.418E-03
43.40	2.795E-02	2.924E-03
45.60	8.600E-03	2.924E-03
46.70	1.565E-02	1.806E-03
50.00	5.194E-03	7.826E-04

$^{6}Li + ^{90}Zr$, 99 MeV

θ_{cm} (deg)	$d\sigma/d\Omega_{cm}$ (mb/sr)	relat. error (mb/sr)
5.34	4.986E+05	2.520E+04
6.41	2.304E+05	1.260E+04
7.47	1.098E+05	5.670E+03
8.54	5.940E+04	2.970E+03
9.61	3.042E+04	1.530E+03
10.68	1.503E+04	7.560E+02
11.48	1.012E+04	5.121E+02
11.74	7.956E+03	3.960E+02
12.54	5.769E+03	2.880E+02
12.81	4.878E+03	2.520E+02
13.08	4.131E+03	2.070E+02
13.88	2.718E+03	1.350E+02
14.68	1.728E+03	9.090E+01
14.94	1.386E+03	7.110E+01
15.74	9.540E+02	4.950E+01
16.01	8.892E+02	4.950E+01
16.27	7.551E+02	3.870E+01
17.07	5.940E+02	3.240E+01
17.87	3.888E+02	2.160E+01
18.14	3.915E+02	2.070E+01
18.94	2.052E+02	1.170E+01
19.20	2.043E+02	1.170E+01
19.47	1.512E+02	8.010E+00
20.27	1.260E+02	5.040E+00
21.33	8.829E+01	4.860E+00
22.40	5.679E+01	3.150E+00
23.46	3.456E+01	1.350E+00
23.99	2.304E+01	1.620E+00
24.52	1.818E+01	7.200E-01
25.58	1.485E+01	5.940E-01
26.65	1.251E+01	5.130E-01
27.18	1.170E+01	9.000E-01
27.71	7.740E+00	3.060E-01
28.77	3.672E+00	1.890E-01
29.83	2.637E+00	1.440E-01
30.89	2.457E+00	1.260E-01
31.95	1.782E+00	1.080E-01
33.01	9.180E-01	8.910E-02
34.06	4.563E-01	3.780E-02
35.12	4.032E-01	2.790E-02
36.18	3.816E-01	4.140E-02
37.24	3.033E-01	3.240E-02
38.29	1.386E-01	1.350E-02
39.35	5.490E-02	4.860E-03
40.40	5.427E-02	6.390E-03
41.45	7.740E-02	8.460E-03
42.50	6.849E-02	5.220E-03
43.56	2.835E-02	3.960E-03

$^{6}Li + ^{208}Pb$, 99 MeV

θ_{cm} (deg)	$d\sigma/d\Omega_{cm}$ (mb/sr)	relat. error (mb/sr)
4.32	4.051E.06	1.920E+05
5.87	1.258E+06	6.720E+04
7.41	4.762E+05	1.632E+04
8.95	2.237E+05	6.624E+03
10.50	1.171E+05	3.936E+03
12.04	7.987E+04	2.400E+03
13.58	5.069E+04	1.795E+03
15.13	3.302E+04	1.190E+03
15.74	2.515E+04	8.832E+02
16.67	1.728E+04	8.736E+02
17.28	1.421E+04	7.104E+02
18.21	9.888E+03	4.992E+02
18.62	8.074E+03	4.032E+02
18.83	7.344E+03	2.592E+02
19.75	5.069E+03	2.592E+02
20.17	4.310E+03	2.208E+02
20.37	4.013E+03	2.016E+02
21.30	2.746E+03	9.792E+01
21.71	2.496E+03	1.248E+02
21.91	2.131E+03	7.469E+01
23.25	1.210E+03	6.163E+01
23.45	1.181E+03	6.144E+01
24.38	7.882E+02	2.784E+01
24.79	7.430E+02	3.840E+01
26.33	3.600E+02	1.824E+01
27.46	2.371E+02	7.008E+00
27.87	2.381E+02	1.248E+01
29.41	1.190E+02	6.336E+00
30.54	7.551E+01	1.920E+00
30.95	7.181E+01	4.224E+00
32.48	3.610E+01	2.112E+00
33.61	2.410E+01	6.336E-01
34.02	2.189E+01	9.024E-01
35.56	1.258E+01	5.568E-01
36.68	8.026E+00	2.112E-01
37.09	7.162E+00	4.224E-01
38.63	4.560E+00	2.688E-01
39.75	2.698E+00	7.488E-02
40.16	2.544E+00	1.536E-01
41.70	1.315E+00	9.600E-02
42.82	9.475E-01	3.264E-02
43.23	9.398E-01	6.720E-02
44.76	5.280E-01	4.512E-02
45.89	3.302E-01	1.536E-02
46.29	3.139E-01	2.496E-02
47.82	2.150E-01	2.400E-02
48.95	1.267E-01	7.584E-03
49.35	1.085E-01	1.152E-02
50.88	7.104E-02	1.152E-02
52.00	4.646E-02	2.784E-03
52.41	4.205E-02	3.936E-03
55.06	1.546E-02	1.920E-03
55.46	1.546E-02	1.920E-03

$^{6}Li + ^{28}Si$, 154 MeV

θ_{cm} (deg)	$d\sigma/d\Omega_{cm}$ (mb/sr)	relat. error (mb/sr)
5.90	3.073E+03	3.500E+02
6.51	1.847E+03	6.700E+01
7.12	1.783E+03	5.800E+01
7.73	1.819E+03	6.100E+01
8.33	1.519E+03	7.800E+01
8.94	1.033E+03	7.900E+01
9.55	5.515E+02	6.000E+01
10.15	1.254E+02	3.300E+01
10.77	5.410E+01	1.050E+01
11.38	4.135E+01	3.200E+00
12.00	8.275E+01	6.900E+00
12.60	1.232E+02	6.300E+00
13.20	1.280E+02	5.500E+00
13.81	1.096E+02	5.600E+00
14.42	6.880E+01	5.600E+00
15.03	3.240E+01	3.800E+00
15.63	1.530E+01	2.000E+00
16.25	4.910E+00	5.500E-01
16.85	6.680E+00	5.700E-01
17.46	1.175E+01	9.400E-01
18.06	1.590E+01	8.700E-01
18.67	1.475E+01	9.100E-01
19.27	1.375E+01	7.600E-01
19.88	8.350E+00	6.000E-01
21.69	2.050E+00	1.800E-01
24.11	2.420E+00	1.400E-01
25.32	1.910E+00	1.390E-01
27.12	6.460E-01	1.900E-02
28.93	4.620E-01	1.400E-02
28.93	4.310E-01	1.300E-02
31.33	3.960E-01	1.200E-02
31.33	4.220E-01	1.300E-02
33.72	2.310E-01	7.000E-03
34.91	1.570E-01	5.000E-03
36.10	1.450E-01	4.000E-03
38.48	1.350E-01	4.000E-03
42.04	8.300E-02	2.000E-03
45.57	4.900E-02	1.500E-03
49.08	2.370E-02	7.000E-04
52.57	1.260E-02	4.000E-04
56.03	4.300E-03	4.500E-04
66.27	4.000E-04	8.000E-05

PROTON-INDUCED PION PRODUCTION

submitted by F. Soga[(a)]

$^{12}C(p,\pi^+)^{13}C(g.s.)$

T_{lab}[(b)] (MeV)	θ^{π}_{cm} (deg)	q_{cm} (MeV/c)	$d\sigma/d\Omega_{cm}$ (nb/sr)	error (nb/sr)
156.4	22.3	472	106	5.7
	51.0	486	57.9	3.7
	77.9	507	28.4	1.9
	117.9	537	4.7	0.9
	154.2	556	3.4	0.9
159.1	28.2	473	120	3.4
	33.8	475	109	3.6
	66.5	500	47.2	1.2
	97.5	528	13.1	0.6
	126.5	551	3.8	0.3
	153.8	566	3.2	0.5
200.0	27.0	479	425	25
	48.3	512	200	11
	64.0	543	75	7
	79.4	576	25	4
	93.5	606	7.6	1.6
	109.4	637	5.4	1.0
	123.9	662	4.5	0.4
	142.9	688	4.3	0.6
	156.9	701	4.5	0.7

(a) present address: Institute for Nuclear Study, University of Tokyo, Tokyo, Japan.
(b) incident proton energy

$^{12}C(p,\pi^+)^{13}C(3.09\ MeV)$

156.4	23.1	482	48.2	4.6
	52.8	494	32.4	3.5
	80.2	509	19.3	2.1
	120.2	532	15.2	2.4
	155.4	546	23.2	4.8
159.1	34.5	483	80.5	3.2
	67.7	504	32.8	1.1
	98.9	527	16.5	0.23
	145.7	555	40.0	3.6
200.0	27.0	483	410	12
	47.8	515	198	9.5
	64.1	544	59.7	3.4
	79.5	576	5.4	0.9
	93.6	605	23.3	1.6
	109.5	635	87	12
	124.0	659	127	9.0
	143.0	684	215	18
	156.9	696	194	23

$^{12}C(p,\pi^+)^{13}C$ (3.85 MeV)

T_{lab} (MeV)	θ^{π}_{cm} (deg)	q_{cm} (MeV/c)	$d\sigma/d\Omega_{cm}$ (nb/sr)	error (nb/sr)
170.6	27.6	478	336	11
	44.0	491	318	13
	60.1	507	197	6.9
	77.9	528	92.7	5.1
	95.7	550	38.3	3.1
	101.2	556	32.2	3.3
	111.0	567	24.7	3.8
	125.3	581	54.6	8.4
	143.9	596	74.7	10.7
	155.8	602	117	12.7
174.4	27.5	478	299	7.6
	43.8	492	276	8.1
	59.8	510	174	5.5
	77.5	533	78.8	3.7
	95.8	558	20.7	3.5
	110.6	576	23.4	5.2
	125.0	592	66.7	9.3
	143.7	608	148	12.8
	157.0	616	178	14.4
200.0	27.0	484	467	18
	48.3	515	309	20
	64.1	545	136	7.0
	79.5	576	31.2	4.6
	93.6	605	14.1	3.3
	109.5	635	116	15.4
	124.0	659	186	41
	143.0	683	260	73
	156.9	695	349	84

$^{12}C(p,\pi^+)^{13}C$ (6.86 MeV)

166.0	21.6	483	53.0	4.2
	28.4	486	43.0	3.2
	37.3	490	29.0	3.2
	45.1	495	26.8	2.7
	56.1	503	15.8	1.6
	66.9	512	11.0	1.2
	82.6	526	8.09	1.01
	92.9	535	8.51	1.17
	102.9	544	11.3	1.4
	112.6	552	19.0	2.2
	126.8	563	20.5	2.8
	140.5	571	25.6	3.4
	149.5	575	34.5	3.9

$^{12}C(p,\pi^+)^{13}C$ (3.68 MeV)

T_{lab} (MeV)	θ^{π}_{cm} (deg)	q_{cm} (MeV/c)	$d\sigma/d\Omega_{cm}$ (nb/sr)	error (nb/sr)
170.6	27.6	477	87.6	5.5
	44.0	490	60.5	5.8
	60.1	507	37.8	3.1
	77.9	528	27.4	4.1
	95.7	550	20.4	2.4
	101.2	556	25.7	3.1
	111.0	567	34.5	4.2
	125.3	582	37.4	7.6
	143.9	596	44.3	9.0
	155.8	603	65.2	10.8
174.4	27.5	477	78.2	3.9
	43.8	492	54.4	3.6
	59.8	510	33.1	2.4
	77.5	533	17.6	1.7
	95.8	558	24.3	3.7
	110.6	576	44.1	7.3
	125.0	592	40.6	8.0
	143.7	609	53.3	9.6
	157.0	617	70.0	11.5
200.0	27.0	484	260	16
	48.3	515	85.4	15.8
	64.1	545	44.9	5.6
	79.5	576	19.2	4.3
	93.6	605	38.7	3.8
	109.5	635	62.0	7.7
	124.0	659	117	42
	143.0	683	273	69
	156.9	695	268	80

$^{12}C(p,\pi^+)^{13}C$ (3.68 + 3.85 MeV)

156.4	23.4	485	150	9.4
	53.8	496	84.6	7.3
	81.0	510	58.9	4.6
	121.1	531	28.2	4.7
159.1	34.6	485	232	6.0
	68.3	505	147	4.8
	99.4	527	50.5	2.5
	146.0	554	79.8	7.1

$^{12}C(p,\pi^+)^{13}C$ (6.86 MeV) cont'd.

T_{lab} (MeV)	θ^{π}_{cm} (deg)	q_{cm} (MeV/c)	$d\sigma/d\Omega_{cm}$ (nb/sr)	error (nb/sr)
174.4	27.7	483	90.0	3.3
	44.0	496	53.3	3.3
	60.1	513	20.6	1.5
	77.9	534	9.13	0.9
	95.7	556	4.67	0.58
	111.0	574	25.0	3.4
	125.4	588	38.9	4.8
	144.0	603	56.9	5.8
	157.1	610	58.3	5.9
200.4	27.1	488	423	18.6
	43.1	509	264	12.7
	59.0	537	121	6.4
	74.5	566	40.1	4.6
	84.7	587	16.0	2.6
	94.8	606	24.8	3.4
	109.6	633	50.7	5.0
	124.1	656	85.7	4.8
	138.3	675	103	5.8
	152.4	688	102	7.3

$^{12}C(p,\pi^+)^{13}C$ (9.50 MeV)

166.0	22.0	491	207	14.5
	28.9	493	208	12.9
	38.0	497	191	13.2
	46.0	501	202	10.3
	57.1	508	180	10.9
	68.0	516	182	9.6
	75.5	521	187	12.3
	83.9	527	173	9.0
	94.2	535	191	10.2
	104.2	543	179	11.1
	113.9	549	145	14.0
	128.0	558	152	10.7
	141.5	565	120	12.0
	150.3	568	108	10.8
200.4	27.1	492	615	20.8
	34.6	500	475	15.5
	43.2	512	381	17.2
	53.8	529	323	14.1
	64.3	548	333	14.0
	76.7	571	271	21.6
	89.9	596	218	15.5
	104.8	623	173	11.4
	119.4	646	113	8.7
	133.7	666	66.7	5.9
	152.4	684	30.7	4.5

SUMMARY OF IUCF MEASUREMENTS OF THE ANALYZING POWER OF THE (p,π^+) REACTION NEAR THRESHOLD

submitted by T.P. Sjoreen*

FINAL[a] STATE	T_p^{lab}[b] (MeV)	T_π^{cm} (MeV)	θ_π^{cm}	q^{cm} (MeV/c)	A(θ)[c]	$(d\sigma/d\Omega)_{cm}$[d] (nb/sr)
^{11}B g.s.	154.33	9.79	34.4	459	−0.26 ±0.05	278 ±7
			67.6	484	−0.38 ±0.03	162 ±4
			127.5	536	−0.21 ±0.07	54.3 ±2.4
^{11}B 2.125 MeV	154.33	7.62	34.9	464	−0.23 ±0.10	36.0 ±2.4
			68.5	487	−0.42 ±0.09	25.4 ±1.3
			128.4	532	−0.07 ±0.24	6.5 ±1.0
^{11}B 4.44 MeV	154.33	5.33	35.8	471	+0.04 ±0.10	53.6 ±4.2
			70.0	490	−0.29 ±0.12	34.5 ±3.1
			129.9	528	−0.64 ±0.41	22.1 ±4.1
^{13}C g.s.	152.89	9.64	33.8	475	−0.36	109
	158.93	9.64	66.5	500	−0.74 ±0.05	45.1 ±2.2
	158.95	9.74	97.5	528	−0.65 ±0.08	14.9 ±2.2
^{13}C 3.09 MeV	158.89	6.59	34.5	483	−0.40 ±0.06	80.5 ±3.2
	158.93	6.59	67.7	504	−0.80 ±0.07	32.8 ±1.1
	158.95	6.68	98.9	527	−0.19 ±0.11	16.5 ±0.3
	159.02	6.59	145.7	555	+0.07 ±0.13	40.0 ±3.6
^{13}C 3.68 + 3.85 MeV States	158.89	5.95	34.6	485	−0.34	232
	158.93	5.95	68.3	505	−0.57 ±0.04	147 ±4.8
	158.95	5.99	99.4	527	−0.35 ±0.06	50.5 ±2.5
	159.02	6.07	146.0	554	−0.34 ±0.12	79.8 ±7.1
^{17}O g.s.	156.84	9.72	32.8	482	−0.46 ±0.04	280±7
	156.84	9.72	64.9	506	−0.91 ±0.04	116±5
	156.84	9.72	95.6	534	−0.64 ±0.05	38.0 ±1.8
	156.95	10.02	124.8	559	−0.17 ±0.06	106±4
	156.95	10.02	152.8	575	−0.03 ±0.05	233±8
^{17}O 0.87 MeV	156.84	8.83	32.9	484	COULD NOT BE EXTRACTED FROM DATA	
	156.84	8.83	65.1	507	−0.07 ±0.17	14.5 ±1.7
	156.84	8.83	95.9	534	−0.21 ±0.07	34.8 ±1.7
	156.95	9.15	125.0	558	−0.17 ±0.08	66.9 ±3.8
	156.95	9.15	152.9	573	−0.21 ±0.10	76.7 ±5.2
^{41}Ca g.s.	146.69	10.09	62.0	505	−0.01 ±0.07	29.9 ±1.5
	146.07	9.69	92.3	533	−0.37 ±0.06	71.5 ±3.3
	146.98	10.39	121.9	561	−0.25 ±0.08	88.5 ±5.1
	146.61	10.19[e]	151.1	577	−0.24 ±0.08	79.2 ±4.4

*Present address: Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn. 37830

a) The B, C and Ca data were analyzed by P.H. Pile and that for O by T.P. Sjoreen.
b) Average proton energy at center of target.
c) Uncertainties are statical only.
d) See note c.
e) T_π for spin up is 9.99 MeV and that for spin down is 10.39 MeV.

$^9Be(\vec{p},\pi^-)^{10}C(g.s.)$, T_p = 200 MeV[a]

submitted by T.P. Sjoreen[b]

θ^π_{lab}	θ^π_{cm}	A(θ)	$d\sigma/d\Omega_{cm}$ (nb/sr)
25	27.6	−0.02 ±0.14	1.38 ±0.14
50	54.7	−0.27 ±0.14	1.37 ±0.17
75	80.9	0.08 ±0.15	1.23 ±0.13
100	106.0	0.48 ±0.14	2.16 ±0.23
120	125.2	0.29 ±0.13	2.92 ±0.29
150	153.0	±0.14	±0.40

(a) incident lab energy
(b) present address: Oak Ridge National Lab
P.O. Box X, Oak Ridge, TN 37830