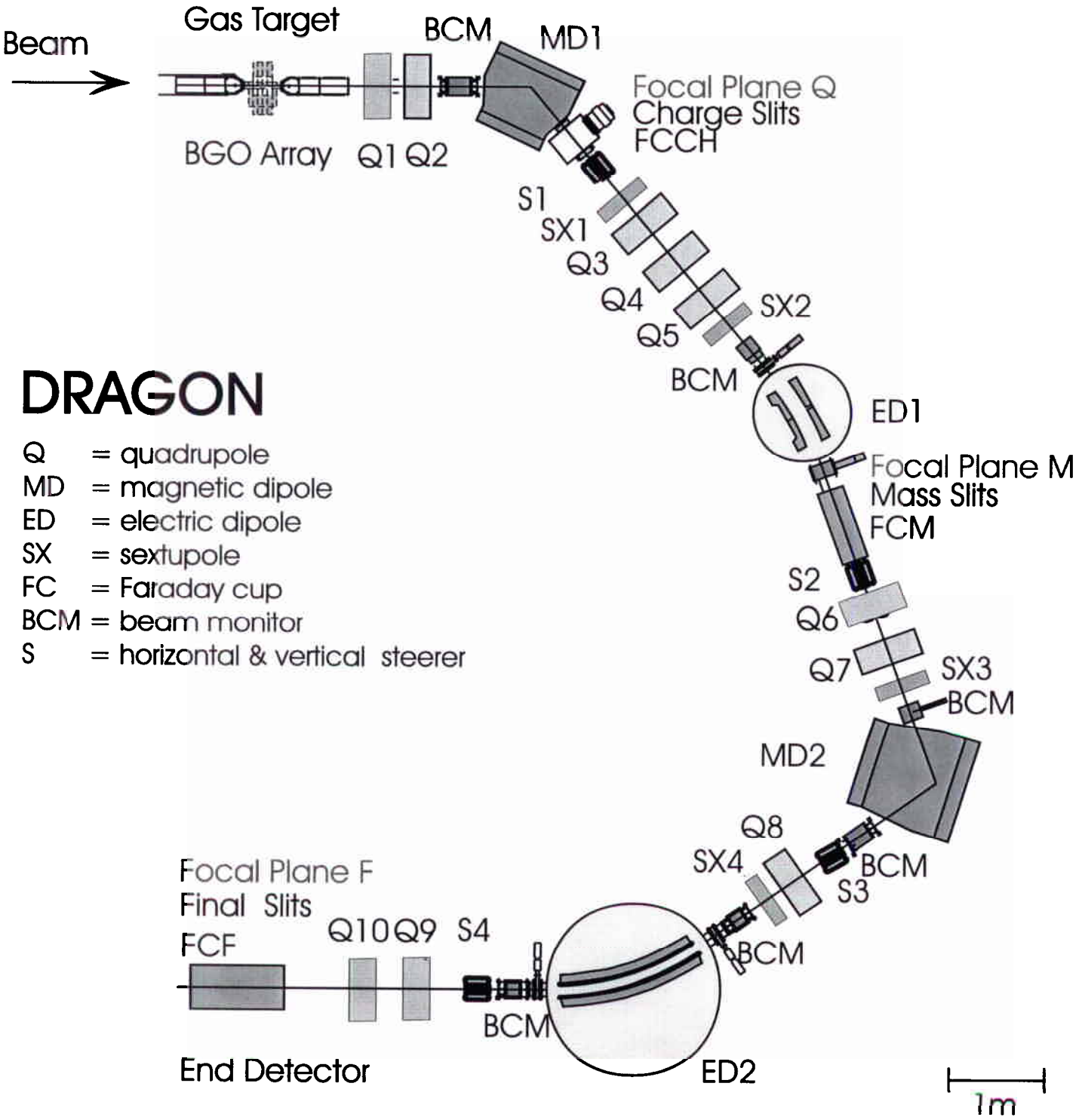


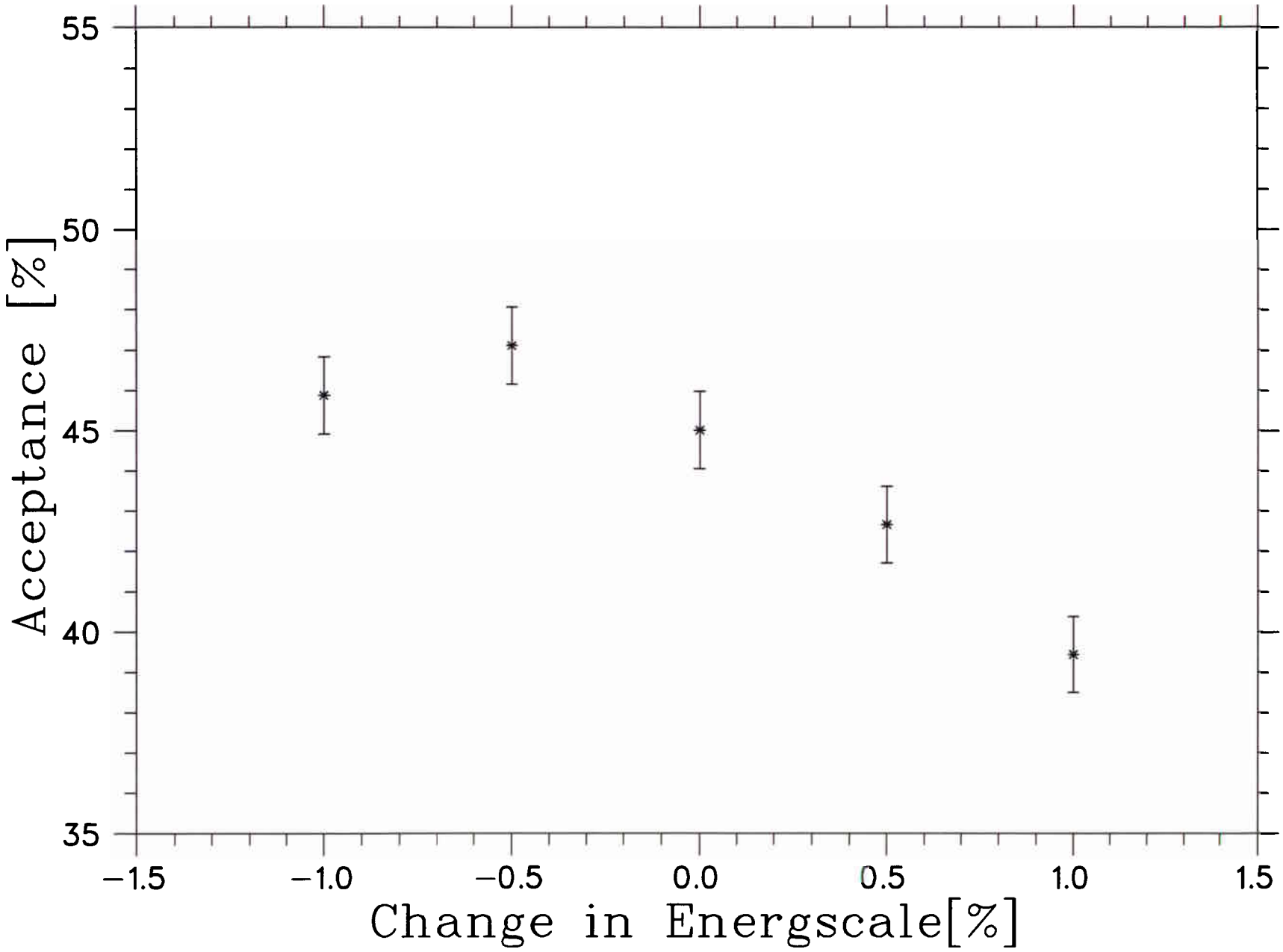
DRAGON

Q = quadrupole
MD = magnetic dipole
ED = electric dipole
SX = sextupole
FC = Faraday cup
BCM = beam monitor
S = horizontal & vertical steerer

```
TUNE 1.8885 19. 4.
MTUN 0.0  0.  0. 0.0
C BEAM 4.69951
 ****  1315552591 558647885 ****
 Beam particles entering gas cell  4626
 Reactions occurring  2684  58.019886%  +-   0.725616932%
 Recoils exiting target 2384  88.8226547% +-   0.608191013
 Recoils reaching end detector  1208  45.0074501% +-   0.960291028%
 Beam particles exiting target  2024  87.3920517% =-   0.689745426%
 Beam particles reaching FCM2  1430  61.7443886%+-   1.00989699%
1          **** NUMBER OF EVENTS PROCESSED =      5000
           **** RANDOM NUMBER GENERATOR AFTER LAST COMPLETE EVENT   1265617746  2056614856
           **** TIME TO PROCESS ONE EVENT IS =    3.1340 SECONDS



TUNE 1.8885 19. 4.
MTUN 0.3  0.  0. 0.0
C BEAM 4.69951
 ****  160971922 479210056 ****
 Beam particles entering gas cell  2038
 Reactions occurring  1259  61.7762527%  +-   1.07640409%
 Recoils exiting target 997  79.1898346% +-   1.14408851
 Recoils reaching end detector  490  38.9197769% +-   1.37411344%
 Beam particles exiting target  854  22.8281212% =-   0.686231673%
 Beam particles reaching FCM2  597  15.9582996%+-   0.598751843%
1          **** NUMBER OF EVENTS PROCESSED =      5000
           **** RANDOM NUMBER GENERATOR AFTER LAST COMPLETE EVENT   1828263940  2122359427
           **** TIME TO PROCESS ONE EVENT IS =    1.4740 SECONDS



TUNE 1.8885 19. 4.
MTUN 0.0  0.0  0.004 0.0
C BEAM 4.69951
 ****  2147247004 1349079153 ****
 Beam particles entering gas cell  4667
 Reactions occurring  2661  57.0173569%  +-   0.724654853%
 Recoils exiting target 2254  84.7050018% +-   0.697761238
 Recoils reaching end detector  1011  37.9932365% +-   0.940914631%
 Beam particles exiting target  2083  89.0551529% =-   0.645534217%
 Beam particles reaching FCM2  1479  63.232151%+-   0.996983528%
1          **** NUMBER OF EVENTS PROCESSED =      5000
           **** RANDOM NUMBER GENERATOR AFTER LAST COMPLETE EVENT   1129383942  1743917305
           **** TIME TO PROCESS ONE EVENT IS =    2.9875 SECONDS



TUNE 1.8885 19. 4.
MTUN 0.0  0.0  0.0 0.004
C BEAM 4.69951
 ****  573644894 809654650 ****
 Beam particles entering gas cell  4617
 Reactions occurring  2726  59.0426674%  +-   0.723717153%
 Recoils exiting target 2264  83.0520935% +-   0.718572199
 Recoils reaching end detector  1117  40.9757881% +-   0.941923916%
 Beam particles exiting target  1981  87.1152191% =-   0.702571213%
 Beam particles reaching FCM2  1423  62.5769577%+-   1.01480246%
1          **** NUMBER OF EVENTS PROCESSED =      5000
           **** RANDOM NUMBER GENERATOR AFTER LAST COMPLETE EVENT   1389159547  1098051206
           **** TIME TO PROCESS ONE EVENT IS =    3.0518 SECONDS
```

```
mt1/944.ibm00.log: +++++++++++++++++RECOIL++++++++++++++++++++++
mt1/944.ibm00.log- Recoil Mean Energy from reaction  12.9869127 MeV
mt1/944.ibm00.log- Gas half thickness  6.421947 cm
mt1/944.ibm00.log- dE/dx in target     0.0118161328 MeV/cm
mt1/944.ibm00.log- ++++++++++++++++++++++++++++++++++++++++++++++++
mt1/944.ibm00.log- Recoil Mean Energy leaving target  12.9869127 MeV
mt1/944.ibm00.log- Recoil Momentum leaving target  622.219543 MeV/c
mt1/944.ibm00.log- ++++++++++++++++++++++++++++++++++++++++++++++++
--
mt2/945.ibm00.log: +++++++++++++++++RECOIL++++++++++++++++++++++
mt2/945.ibm00.log- Recoil Mean Energy from reaction  12.9869127 MeV
mt2/945.ibm00.log- Gas half thickness  6.421947 cm
mt2/945.ibm00.log- dE/dx in target     0.0118161328 MeV/cm
mt2/945.ibm00.log- ++++++++++++++++++++++++++++++++++++++++++++++++
mt2/945.ibm00.log- Recoil Mean Energy leaving target  12.3375673 MeV
mt2/945.ibm00.log- Recoil Momentum leaving target  606.458008 MeV/c
mt2/945.ibm00.log- ++++++++++++++++++++++++++++++++++++++++++++++++
--
mt3/946.ibm00.log: +++++++++++++++++RECOIL++++++++++++++++++++++
mt3/946.ibm00.log- Recoil Mean Energy from reaction  12.9869127 MeV
mt3/946.ibm00.log- Gas half thickness  6.421947 cm
mt3/946.ibm00.log- dE/dx in target     0.0118161328 MeV/cm
mt3/946.ibm00.log- ++++++++++++++++++++++++++++++++++++++++++++++++
mt3/946.ibm00.log- Recoil Mean Energy leaving target  12.921978 MeV
mt3/946.ibm00.log- Recoil Momentum leaving target  620.661377 MeV/c
mt3/946.ibm00.log- ++++++++++++++++++++++++++++++++++++++++++++++++
--
mt4/947.ibm00.log: +++++++++++++++++RECOIL++++++++++++++++++++++
mt4/947.ibm00.log- Recoil Mean Energy from reaction  12.9869127 MeV
mt4/947.ibm00.log- Gas half thickness  6.421947 cm
mt4/947.ibm00.log- dE/dx in target     0.0118161328 MeV/cm
mt4/947.ibm00.log- ++++++++++++++++++++++++++++++++++++++++++++++++
mt4/947.ibm00.log- Recoil Mean Energy leaving target  12.8570433 MeV
mt4/947.ibm00.log- Recoil Momentum leaving target  619.099243 MeV/c
mt4/947.ibm00.log- ++++++++++++++++++++++++++++++++++++++++++++++++
--
mt5/948.ibm00.log: +++++++++++++++++RECOIL++++++++++++++++++++++
mt5/948.ibm00.log- Recoil Mean Energy from reaction  12.9869127 MeV
mt5/948.ibm00.log- Gas half thickness  6.421947 cm
mt5/948.ibm00.log- dE/dx in target     0.0118161328 MeV/cm
mt5/948.ibm00.log- ++++++++++++++++++++++++++++++++++++++++++++++++
mt5/948.ibm00.log- Recoil Mean Energy leaving target  13.0518475 MeV
mt5/948.ibm00.log- Recoil Momentum leaving target  623.773804 MeV/c
mt5/948.ibm00.log- ++++++++++++++++++++++++++++++++++++++++++++++++
--
mt6/949.ibm00.log: +++++++++++++++++RECOIL++++++++++++++++++++++
mt6/949.ibm00.log- Recoil Mean Energy from reaction  12.9869127 MeV
mt6/949.ibm00.log- Gas half thickness  6.421947 cm
mt6/949.ibm00.log- dE/dx in target     0.0118161328 MeV/cm
mt6/949.ibm00.log- ++++++++++++++++++++++++++++++++++++++++++++++++
mt6/949.ibm00.log- Recoil Mean Energy leaving target  13.1167822 MeV
mt6/949.ibm00.log- Recoil Momentum leaving target  625.32428 MeV/c
mt6/949.ibm00.log- ++++++++++++++++++++++++++++++++++++++++++++++++
mt1/944.ibm00.log- ***** DATA CARD CONTENT     TUNE 1.8885 19. 4.

mt1/944.ibm00.log: ***** DATA CARD CONTENT     MTUN 0.0  0.0  0.0  0.0  0.0

mt1/944.ibm00.log- ***** DATA CARD CONTENT     C BEAM 4.69951

--
mt2/945.ibm00.log- ***** DATA CARD CONTENT     TUNE 1.8885 19. 4.

mt2/945.ibm00.log: ***** DATA CARD CONTENT     MTUN 0.0  0.0  0.0  0.0  -0.05

mt2/945.ibm00.log- ***** DATA CARD CONTENT     C BEAM 4.69951

--
mt3/946.ibm00.log- ***** DATA CARD CONTENT     TUNE 1.8885 19. 4.

mt3/946.ibm00.log: ***** DATA CARD CONTENT     MTUN 0.0  0.0  0.0  0.0  -0.005

mt3/946.ibm00.log- ***** DATA CARD CONTENT     C BEAM 4.69951
```

```
mt4/947.ibm00.log- Beam particles entering gas cell  4651
mt4/947.ibm00.log- Reactions occurring  2727  58.6325531%  +-   0.722146988%
mt4/947.ibm00.log- ** Recoil efficiencies are with respect to the number of Reactions **
mt4/947.ibm00.log- Recoils exiting target 2439  89.438942% +-   0.588537931%
mt4/947.ibm00.log- Recoils reaching Q3 (Sext 1)  2325  85.2585297% +-   0.678885937%
mt4/947.ibm00.log- Recoils reaching Q8 (Quad 6)  2300  84.3417664% +-   0.695905268%
mt4/947.ibm00.log- Recoils reaching end detector  1251  45.874588% +-   0.954210341%
mt4/947.ibm00.log- Beam particles exiting target  2006  88.2534103% +-   0.675339162%
mt4/947.ibm00.log- Beam particles reaching FCM2  1433  63.0444336% +-   1.01242673%
--
mt5/948.ibm00.log: Time elapsed after initialization =     0.15518E+05
mt5/948.ibm00.log- Total number of events generated 5000
mt5/948.ibm00.log- Number of events that went to output 0
mt5/948.ibm00.log- Random Number at the beginning of last event
mt5/948.ibm00.log- ****  1982710494 1751926546 ****
mt5/948.ibm00.log- Beam particles entering gas cell  4634
mt5/948.ibm00.log- Reactions occurring  2731  58.9339676%  +-   0.722680211%
mt5/948.ibm00.log- ** Recoil efficiencies are with respect to the number of Reactions **
mt5/948.ibm00.log- Recoils exiting target 2454  89.857193% +-   0.577689707%
mt5/948.ibm00.log- Recoils reaching Q3 (Sext 1)  2255  82.570488% +-   0.725929081%
mt5/948.ibm00.log- Recoils reaching Q8 (Quad 6)  2200  80.556572% +-   0.757314146%
mt5/948.ibm00.log- Recoils reaching end detector  1165  42.6583672% +-   0.946403444%
mt5/948.ibm00.log- Beam particles exiting target  1985  87.4834747% +-   0.694684625%
mt5/948.ibm00.log- Beam particles reaching FCM2  1385  61.0401039% +-   1.02376258%
--
mt6/949.ibm00.log: Time elapsed after initialization =     0.14849E+05
mt6/949.ibm00.log- Total number of events generated 5000
mt6/949.ibm00.log- Number of events that went to output 0
mt6/949.ibm00.log- Random Number at the beginning of last event
mt6/949.ibm00.log- ****  1309197443 316384824 ****
mt6/949.ibm00.log- Beam particles entering gas cell  4621
mt6/949.ibm00.log- Reactions occurring  2703  58.4938316%  +-   0.724842012%
mt6/949.ibm00.log- ** Recoil efficiencies are with respect to the number of Reactions **
mt6/949.ibm00.log- Recoils exiting target 2417  89.4191666% +-   0.591632843%
mt6/949.ibm00.log- Recoils reaching Q3 (Sext 1)  2034  75.2497253% +-   0.830079019%
mt6/949.ibm00.log- Recoils reaching Q8 (Quad 6)  1974  73.0299683% +-   0.853627264%
mt6/949.ibm00.log- Recoils reaching end detector  1066  39.4376602% +-   0.940013051%
mt6/949.ibm00.log- Beam particles exiting target  1996  86.8959503% +-   0.704080045%
mt6/949.ibm00.log- Beam particles reaching FCM2  1403  61.07967% +-   1.01731658%
```


55
50
45
40
35
Acceptance [%]
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
Change in Energscale[%]

```
++++++++++++++++RECOIL++++++++++++++++++++++
Recoil Mean Energy from reaction  12.9869127 MeV
Gas half thickness  6.421947 cm
dE/dx in target     0.0118161328 MeV/cm
++++++++++++++++++++++++++++++++++++++++++++++
Recoil Mean Energy leaving target  12.9869127 MeV
Recoil Momentum leaving target  622.219543 MeV/c
++++++++++++++++++++++++++++++++++++++++++++++
***** DATA CARD CONTENT     TUNE 1.8885 19. 4.

***** DATA CARD CONTENT     MTUN 0.0  0.0  0.0  0.0  0.0

***** DATA CARD CONTENT     C BEAM 4.69951

Time elapsed after initialization =     0.15714E+05
Total number of events generated 5000
Number of events that went to output 0
Random Number at the beginning of last event
****  1315552591 558647885 ****
Beam particles entering gas cell  4626
Reactions occurring  2684  58.019886%  +-   0.725616932%
** Recoil efficiencies are with respect to the number of Reactions **
Recoils exiting target 2384  88.8226547% +-   0.608191013%
Recoils reaching Q3 (Sext 1)  2304  85.8420258% +-   0.672913492%
Recoils reaching Q8 (Quad 6)  2262  84.2771988% +-   0.702633321%
Recoils reaching end detector  1208  45.0074501% +-   0.960291028%
Beam particles exiting target  2024  87.3920517% +-   0.689745426%
Beam particles reaching FCM2  1430  61.7443886% +-   1.00989699%


++++++++++++++++RECOIL++++++++++++++++++++++
Recoil Mean Energy from reaction  12.9869127 MeV
Gas half thickness  6.421947 cm
dE/dx in target     0.0118161328 MeV/cm
++++++++++++++++++++++++++++++++++++++++++++++
Recoil Mean Energy leaving target  12.9869127 MeV
Recoil Momentum leaving target  622.219543 MeV/c
++++++++++++++++++++++++++++++++++++++++++++++
***** DATA CARD CONTENT     TUNE 1.8885 19. 4.

***** DATA CARD CONTENT     MTUN 0.0  0.0  0.0  0.0  0.0

***** DATA CARD CONTENT     C BEAM 4.69951

Time elapsed after initialization =     0.12539E+05
Total number of events generated 5000
Number of events that went to output 0
Random Number at the beginning of last event
****  1204938361 1020822511 ****
Beam particles entering gas cell  3453
Reactions occurring  2106  60.9904442%  +-   0.830076456%
** Recoil efficiencies are with respect to the number of Reactions **
Recoils exiting target 1896  90.0284882%  +-   0.652891874%
Recoils reaching Q3 (Sext 1)  1843  87.5118713%  +-   0.720365644%
Recoils reaching Q8 (Quad 6)  1815  86.1823349%  +-   0.75196439%
Recoils reaching end detector  1028  48.8129158%  +-   1.08922696%
Beam particles exiting target  1422  49.1361427%  +-   0.929299951%
Beam particles reaching FCM2  1004  34.6924667%  +-   0.884809852%
```

MEMO September 29, 2003

To: John D'Auria cc: L.Buchmann, B.Davids, D.Hutcheon, & A.Olin

From: Joel Rogers

Re: GIOS Tune for First 1/2 Dragon

In preparation for upcoming 12C(a,g)16O running, GIOS has been used to optimize a 100%-transmission tune, up to the DSSSD detector at the mass-slit location. It is proposed to use the DSSSD singles rate to verify the tune, by measuring magnet settings above and below the optimum settings, where the rate first drops below 100% as the magnets are varied. If the rate stays constant within the +- 2% predicted by GIOS, then the GIOS tune is verified and the same tune can be scaled to acquire data off-resonance. If the range of constant-rate is less than +- 2%, an usable tune can still be determined by adjusting the magnets one-at-a-time to the center of each measured range. Such an empirical tune is valid for the energy at which the tuning is done, and (scaled) for any higher energy. However, due to the nonlinear relationship between cone-angle and beam-energy, a tune optimized at one energy does not scale downward to the lowest energy.

A narrow resonance is better for tuning than a wide resonance because the final tune can be verified by performing a rate vs beam-energy scan. A narrow resonance produces a steep fall-off at the edges of the target (c.f. Fig. 1) as opposed to the gradual fall-off with a broad resonance (c.f. Fig. 2), which would be difficult to distinguish from poor tuning. For this reason, the lower-2+ resonance-energy, Ebeam = 0.89MeV/u, was simulated to develop the GIOS tune. The table below shows the GIOS-predicted beam envelope at the critical "squeeze-points". Three target positions were simulated, corresponding to recoil-emission at the upstream-edge, center(c.f. GIOS input script, over), and downstream-edge of the target gas-cell. The GIOS predicted 1st+2nd-order envelopes(mm) are:

Element	Max-envelope	Upstream-	Center-	Downstream-envelope
Q1-exit	50 x 50	48 x 21	46 x 20	44 x 20
C-slits	50 x 50	20 x 32	19 x 35	19 x 37
Q5	76 x 76	52 x 61	50 x 68	48 x 74
ED1	50 x 76	43 x 36	42 x 40	41 x 45
MS(=DSSSD)	25 x 25	25 x 22	25 x 21	22 x 24

GIOS also predicted where in the separator the envelope first exceeded a maximum as the magnets were varied. For (positive,negative) variation of quads, loss-points are: Q1(ED1-X/MS-X,Q5-Y), Q2(Q5-Y,MS-X), Q3(MS-Y,MS-X), Q4(MS-X/Y, MS-Y), and Q5(MS-Y,MS-X/Y), where MS stands for mass-slit, i.e. DSSSD position. In order to extend the full-transmission tune to lower energies, as required for the 12C(a,g) proposal, new separator hardware will be required. Installing a larger-area DSSSD detector would enlarge the limits on all quads except Q1. Therefore a larger-bore Q1 might also be needed before "going down for Lothar"*.

* (Historical note: In the early days of nuclear astrophysics Caltech grad-students coined a phrase to describe the difficulty of the quest imposed upon them by their adviser, William Fowler. They referred to their quest to extend measurements to lower and lower energies as "going down for Willie":)

joel

(over)

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s and Methods in Physics Research A 498 (2003) 190–210

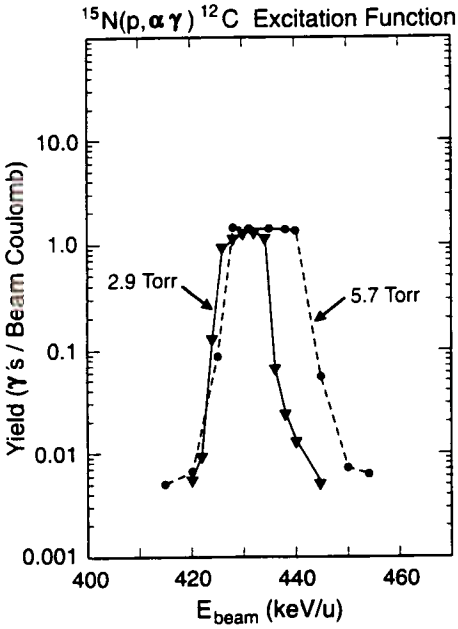

Fig. 1. Excitation function for the $^{15}N(^1H,\alpha\gamma)^{12}C$ reaction around the narrow resonance at a beam energy of 420 keV/u.

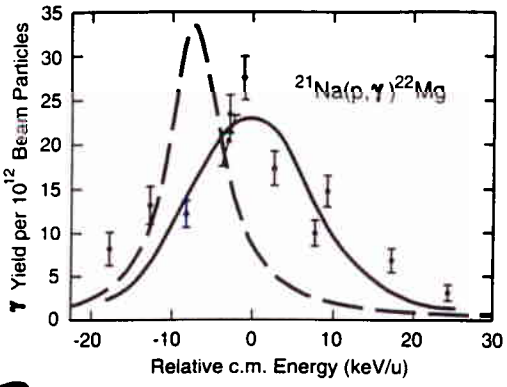

Fig. 2. Excitation function of the resonance at 863 keV/u in the $^{21}Na(p,\gamma)^{22}Mg$ reaction. The Breit–Wigner cross section (dashed curve), broadened and shifted by target thickness (solid line) is compared to the data.

```
c12/e1608037q5d40a20.gios Ecm=2.68 MeV @ target CENTER
CALCULATION  ORDER 2 2 ;
REFERENCE PARTICLE  8.037  16.0  5.0 ;
P X 0.0025 .020 ;
P Y 0.0025 .020 ;
D P 0.  0.040 ;
A =  -0.116   ; Q1
B =   0.114   ; Q2
E =   0.136   ; Q3
F =  -0.153   ; Q4
G =   0.0749  ; Q5
U =   0.0269  ; SX1
W =  -0.00157 ; SX2
C =   B * 0.0529 ; SXQ2
H =   1.06885 + 0.00 ; Subtract 1/2 tgt. to move DOWNSTREAM
DRIFT LENGTH =H  ; distance from source point to Q1 entrance
F  F  1  ;
M  Q  0.2523  =A  0.053975 ; Q1
F  F  1  ;
DRIFT LENGTH 0.17 ; to transition piece
P  N ; Q1 exit envelope (4" circle)
DRIFT LENGTH 0.086925 ;
F  F  1 ;
M  M  0.33385 =B  =C 0.0 0.07935 ; Q2
F  F  1 ;
DRIFT LENGTH .638075 ;
F  F  1  5.8  0 ;
M  S  1.000 50  .05 ; MD1
F  F  1  5.8  0 ;
DRIFT LENGTH 0.3079 ;
P  N  ; Charge Slit
DRIFT LENGTH .7109 ;
M  M  0.1941  0.0 =U 0.0 0.0795 ; SX1
DRIFT LENGTH 0.1581 ;
P  N  ; Q3 entrance envelope (6" circle)
F  F  1  ;
M  Q  0.3338 =E   0.079375 ;
```

JOEL'S NEW (OLD) GIOS'S LARGEST 1st ORDER MATRIX ELEMENTS AGREE WITH DON'S [$^{15}O(\alpha,\gamma)^{19}Ne$]

ed in the separator. We first dipole is magnetic the charge states with gas target, followed by is avoids having beam states striking smooth s, which might happen trostatic. Quadrupoles omatic focus after the slits allow transmission uct while blocking the stage with larger bend dipole followed by an liminary optics design electrostatic followed by nulations showed that E–M) could transmit two charge-changing . The final M–E–M–E such charge changes. nging collisions with considered a white ng through the charge ety of angles, as might tered off the pumping was verified that such ough the final selection from walls or residual

sing quadrupoles and oles is shown in Fig. 1 ion trajectories in the different initial angles

Table 2
GIOS first-order transfer matrix elements at the four horizontal image points: x is horizontal position (m); a is horizontal angle (rad); y is vertical position (m); b is vertical angle (rad); d is fractional energy difference; g is fractional mass difference; t is fractional difference in time-of-flight ← 25.sep03

26 sep 03

	Charge	Mass NEW	Final NEW
$(x\|x)$	−0.440	0.689 .703	0.980 1.01
$(x\|a)$	0.000	0.000 .032	0.000 .060
$(x\|g)$	0.302	−0.472 −.469	−1.828 −1.828
$(x\|d)$	0.302	0.000 .002	0.000 .002
$(a\|x)$	−1.648	1.147 1.16	0.052 .034
$(a\|a)$	−2.273	1.451 1.47	1.020 .99
$(a\|g)$	0.401	−0.321 −.321	1.303 1.304
$(a\|d)$	0.401	0.015 .015	−0.022 −.022
$(t\|x)$	0.172	0.002 .002	−0.002 −.002
$(t\|a)$	0.368	0.000 −.0006	0.000 −.0001
$(t\|g)$	0.515	0.504 .504	0.515 .515
$(t\|d)$	−0.485	−0.492 −.492	−0.477 −.477
$(y\|y)$	−3.554	0.980 .807	−1.767 −1.775
$(y\|b)$	0.018	−0.430 −.445	0.000 .013
$(b\|y)$	−1.563	2.307 2.24	1.657 1.70
$(b\|b)$	−0.273	0.008 .004	−0.566 −.576

Table 3
Properties of DRAGON magnetic dipoles

	MD1	MD2
Bending radius	1.00 m	0.813 m
Bending angle	50°	75°
Gap	100 mm	120 mm
Edge angles	5.8°	29°
Maximum field (500 A)	5.9 kG	8.2 kG