EVALUATION OF p + 54Fe CROSS SECTIONS FOR THE ENERGY RANGE 1 to 150 MeV

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This evaluation provides a complete representation of the nuclear data needed for transport, damage, heating, radioactivity, and shielding applications over the incident neutron energy range from 1 to 150 MeV. Production cross sections and emission spectra are given for neutrons, protons, deuterons, tritons, alpha particles, gamma rays, and all residual nuclides produced (A>5) in the reaction chains.

To summarize, the ENDF sections with non-zero data are:

MF=3	MT= 2	Integral of nuclear plus interference components of the elastic scattering cross section
	MT= 5	Sum of binary (n,n') and (n,x) reactions
MF=6	MT= 2	Elastic angular distributions given as ratios of the differential nuclear-plus-interference to the integrated value.
	MT= 5	Production cross sections and energy-angle distributions for emission neutrons, protons, deuterons, and alphas; and angle-integrated spectra for gamma rays and residual nuclei that are stable against particle emission

The evaluation is based on nuclear model calculations that have been benchmarked to experimental data, especially for n + Fe56 and p + Fe56 reactions (Ch96a). We use the GNASH code system (Yo92), which utilizes Hauser-Feshbach statistical, preequilibrium and direct-reaction theories. Spherical optical model calculations are used to obtain particle transmission coefficients for the Hauser-Feshbach calculations, as well as for the elastic neutron angular distributions.

Cross sections and spectra for producing individual residual nuclei are included for reactions that exceed a cross section of approximately 1 nb at any energy. The energy-angle-correlations for all outgoing particles are based on Kalbach systematics (Ka88).

A model was developed to calculate the energy distributions of all recoil nuclei in the GNASH calculations (Ch96b). The recoil energy distributions are represented in the laboratory system in MT=5, MF=6, and are given as isotropic in the lab system. Note that all other data in MT=5,MF=6 are given in the center-of-mass system. This method of representation requires a modification of the original ENDF-6 format, i.e., we use LCT=3 with LAW 1 to indicate that data for the heavy recoils are in the lab system but all other reactions are in the cm system.

Preequilibrium corrections were performed in the course of the GNASH calculations using the exciton model of Kalbach (Ka77, Ka85), validated by comparison with calculations using Feshbach, Kerman, Koonin (FKK) theory [Ch93]. Discrete level data from nuclear data sheets were matched to continuum level densities using the formulation of Ignatyuk (Ig75) and pairing and shell parameters from the Cook (Co67) analysis. Neutron and charged-

particle transmission coefficients were obtained from the optical potentials, as discussed below. Gamma-ray transmission coefficients were calculated using the Kopecky-Uhl model (Ko90).

Direct reaction cross sections to discrete states were calculated with the ECIS95 code [Re95] using deformation parameters compiled in Nuclear Data Sheets.

The optical model potential of Arthur et al. (Ar80) was used to calculate transmission coefficients with the SCAT2 code (Be92) for neutrons up to an energy of 26 MeV. Between 26 and 52 MeV, the imaginary volume component of Arthur's potential was modified to better account for nonelastic cross section measurements, and above 52 MeV the Semmering potential of Madland (Ma88) was used. For protons, the Beccetti-Greenlees potential (Be69) was utilized for both transmission coefficients and scattering and reaction cross sections below 28 MeV, and the Madland potential (Ma88) was used at higher energies. The global spherical potential of Perey (Pe63) was utilized for deuteron transmission coefficients, and the potential of Beccetti-Greenlees (Be) was adopted for tritons. Finally, the alpha potential of Lemos (Le72), as adapted by Arthur et al. (Ar80), was used for alpha particles.

MT=2 elastic scattering data in MF=3 and MF=6 are based on optical model calculations with the SCAT2 code (Be92). We have made use of the "nuclear-plus-interference" option in MF=6, which corresponds to LAW=5, LTP=12, and the appropriate integrated cross section is stored in MF=3. Note that because of the interference effect, the tabulations in both MF=6 and MF=3 can be negative at some energies and angles.

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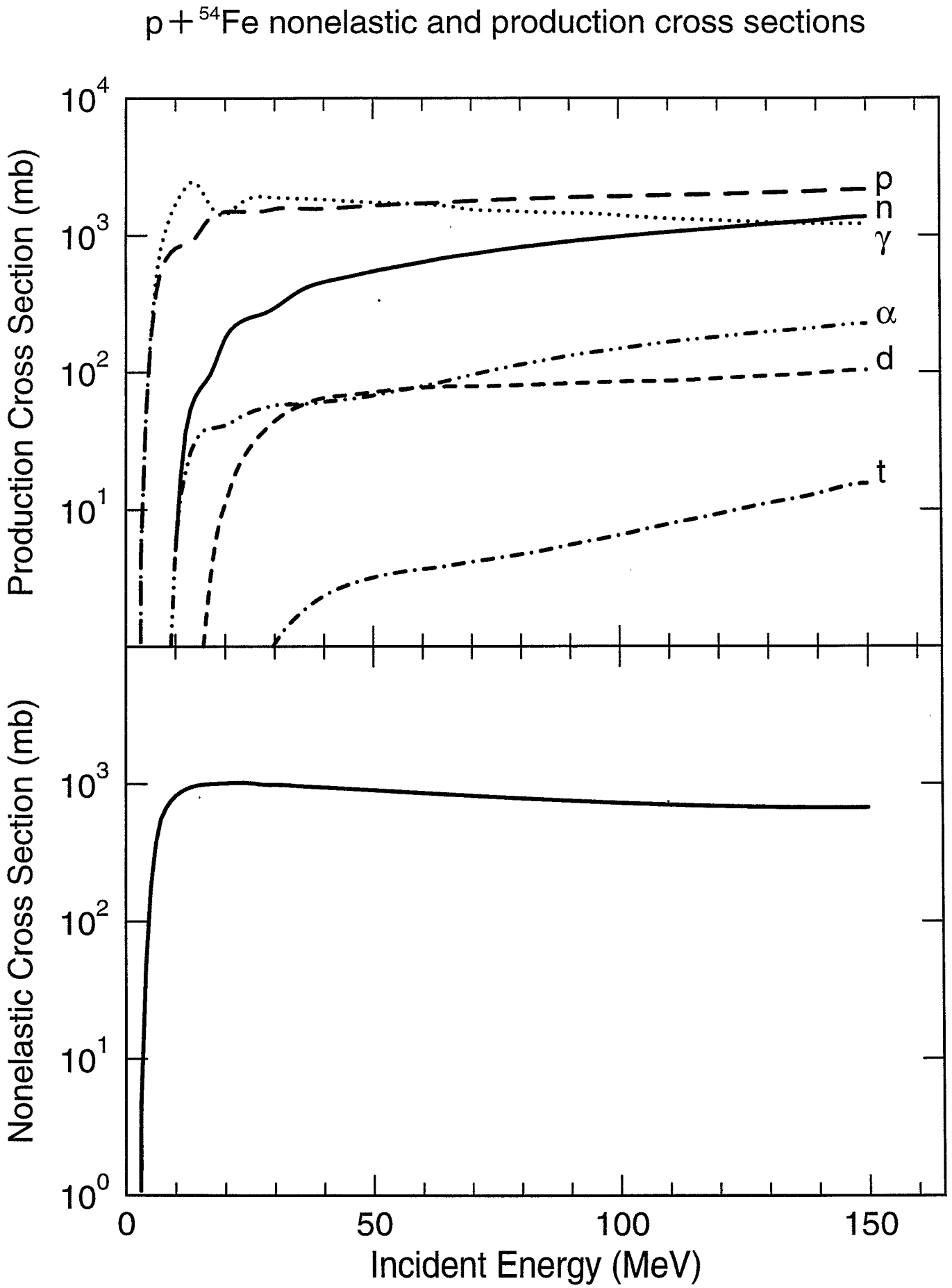
26054 = TARGET 1000Z+A (if A=0 then elemental)
1001 = PROJECTILE 1000Z+A
Nonelastic, elastic, and Production cross sections for A<5 ejectiles in barns:

Energy	nonelas	elastic	neutron	proton	deuteron	triton	helium3	alpha	gamma
2.000E+00	1.000E-20	0.000E+00	0.000E+00	1.000E-20	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.000E-20
3.000E+00	4.538E-03	0.000E+00	0.000E+00	4.538E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	4.667E-03
4.000E+00	4.766E-02	0.000E+00	0.000E+00	4.766E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	4.880E-02
5.000E+00	1.773E-01	0.000E+00	0.000E+00	1.773E-01	0.000E+00	0.000E+00	0.000E+00	2.298E-10	1.930E-01
6.000E+00	3.724E-01	0.000E+00	0.000E+00	3.724E-01	0.000E+00	0.000E+00	0.000E+00	1.591E-08	4.670E-01
7.000E+00	5.575E-01	0.000E+00	0.000E+00	5.575E-01	0.000E+00	0.000E+00	0.000E+00	4.349E-06	8.016E-01
8.000E+00	6.666E-01	0.000E+00	0.000E+00	6.665E-01	0.000E+00	0.000E+00	0.000E+00	1.138E-04	1.096E+00
9.000E+00	7.531E-01	0.000E+00	0.000E+00	7.522E-01	0.000E+00	0.000E+00	0.000E+00	9.183E-04	1.416E+00
1.000E+01	8.212E-01	0.000E+00	5.087E-03	8.106E-01	0.000E+00	0.000E+00	0.000E+00	5.573E-03	1.705E+00
1.100E+01	8.736E-01	0.000E+00	1.706E-02	8.440E-01	0.000E+00	0.000E+00	0.000E+00	1.260E-02	1.976E+00
1.200E+01	9.160E-01	0.000E+00	3.662E-02	8.621E-01	8.528E-11	0.000E+00	0.000E+00	1.879E-02	2.240E+00
1.300E+01	9.478E-01	0.000E+00	5.388E-02	8.862E-01	2.799E-06	0.000E+00	0.000E+00	2.612E-02	2.429E+00
1.400E+01	9.703E-01	0.000E+00	6.683E-02	9.594E-01	4.932E-05	0.000E+00	0.000E+00	3.181E-02	2.427E+00
1.500E+01	9.846E-01	0.000E+00	7.648E-02	1.085E+00	4.283E-04	0.000E+00	0.000E+00	3.592E-02	2.211E+00
1.600E+01	9.946E-01	0.000E+00	8.473E-02	1.230E+00	1.402E-03	0.000E+00	0.000E+00	3.825E-02	1.901E+00
1.700E+01	9.996E-01	0.000E+00	9.633E-02	1.343E+00	3.133E-03	2.624E-08	0.000E+00	3.911E-02	1.642E+00
1.800E+01	1.004E+00	0.000E+00	1.162E-01	1.416E+00	5.711E-03	1.846E-07	0.000E+00	3.948E-02	1.481E+00
1.900E+01	1.008E+00	0.000E+00	1.459E-01	1.455E+00	8.537E-03	4.179E-06	0.000E+00	4.013E-02	1.413E+00
2.000E+01	1.012E+00	0.000E+00	1.775E-01	1.482E+00	1.101E-02	2.106E-05	0.000E+00	4.085E-02	1.399E+00
2.200E+01	1.018E+00	0.000E+00	2.202E-01	1.492E+00	1.802E-02	9.150E-05	0.000E+00	4.478E-02	1.589E+00
2.400E+01	1.017E+00	0.000E+00	2.437E-01	1.485E+00	2.491E-02	2.468E-04	0.000E+00	4.875E-02	1.804E+00
2.600E+01	1.004E+00	0.000E+00	2.578E-01	1.484E+00	3.142E-02	4.850E-04	0.000E+00	5.239E-02	1.911E+00
2.800E+01	9.856E-01	0.000E+00	2.712E-01	1.502E+00	3.754E-02	7.582E-04	0.000E+00	5.484E-02	1.913E+00
3.000E+01	9.855E-01	0.000E+00	2.965E-01	1.559E+00	4.392E-02	1.048E-03	0.000E+00	5.725E-02	1.888E+00
3.500E+01	9.638E-01	0.000E+00	3.940E-01	1.569E+00	5.654E-02	1.723E-03	0.000E+00	5.833E-02	1.858E+00
4.000E+01	9.418E-01	0.000E+00	4.590E-01	1.563E+00	6.497E-02	2.350E-03	0.000E+00	6.077E-02	1.825E+00
4.500E+01	9.200E-01	0.000E+00	5.025E-01	1.603E+00	6.816E-02	2.830E-03	0.000E+00	6.346E-02	1.770E+00
5.000E+01	8.983E-01	0.000E+00	5.508E-01	1.646E+00	7.164E-02	3.196E-03	0.000E+00	6.769E-02	1.738E+00
5.500E+01	8.772E-01	0.000E+00	5.956E-01	1.684E+00	7.476E-02	3.482E-03	0.000E+00	7.333E-02	1.715E+00
6.000E+01	8.569E-01	0.000E+00	6.410E-01	1.710E+00	7.725E-02	3.688E-03	0.000E+00	7.893E-02	1.688E+00
6.500E+01	8.372E-01	0.000E+00	6.925E-01	1.742E+00	7.868E-02	3.891E-03	0.000E+00	8.628E-02	1.636E+00
7.000E+01	8.184E-01	0.000E+00	7.344E-01	1.780E+00	7.881E-02	4.163E-03	0.000E+00	9.559E-02	1.536E+00
7.500E+01	8.004E-01	0.000E+00	7.807E-01	1.813E+00	7.920E-02	4.410E-03	0.000E+00	1.046E-01	1.508E+00
8.000E+01	7.834E-01	0.000E+00	8.235E-01	1.840E+00	8.019E-02	4.709E-03	0.000E+00	1.134E-01	1.488E+00
8.500E+01	7.672E-01	0.000E+00	8.631E-01	1.866E+00	8.120E-02	5.054E-03	0.000E+00	1.218E-01	1.461E+00
9.000E+01	7.523E-01	0.000E+00	9.051E-01	1.889E+00	8.247E-02	5.523E-03	0.000E+00	1.317E-01	1.447E+00
9.500E+01	7.384E-01	0.000E+00	9.416E-01	1.907E+00	8.373E-02	5.990E-03	0.000E+00	1.399E-01	1.433E+00
1.000E+02	7.258E-01	0.000E+00	9.790E-01	1.922E+00	8.503E-02	6.510E-03	0.000E+00	1.477E-01	1.394E+00
1.100E+02	7.043E-01	0.000E+00	1.055E+00	1.960E+00	8.613E-02	7.833E-03	0.000E+00	1.657E-01	1.320E+00
1.200E+02	6.879E-01	0.000E+00	1.127E+00	1.993E+00	8.979E-02	9.287E-03	0.000E+00	1.806E-01	1.283E+00
1.300E+02	6.774E-01	0.000E+00	1.208E+00	2.040E+00	9.383E-02	1.112E-02	0.000E+00	1.969E-01	1.239E+00
1.400E+02	6.722E-01	0.000E+00	1.282E+00	2.094E+00	9.830E-02	1.309E-02	0.000E+00	2.116E-01	1.220E+00
1.500E+02	6.721E-01	0.000E+00	1.365E+00	2.158E+00	1.036E-01	1.546E-02	0.000E+00	2.267E-01	1.216E+00

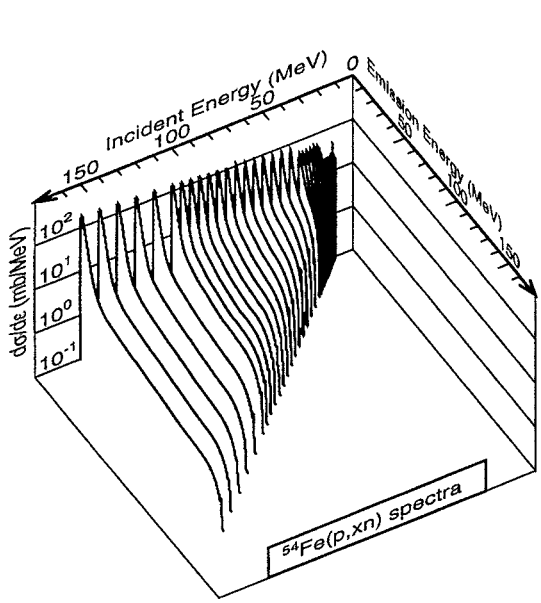
26054 = TARGET 1000Z+A (if A=0 then elemental)
1001 = PROJECTILE 1000Z+A
Aver. lab emission energies for A<5 ejectiles in MeV:

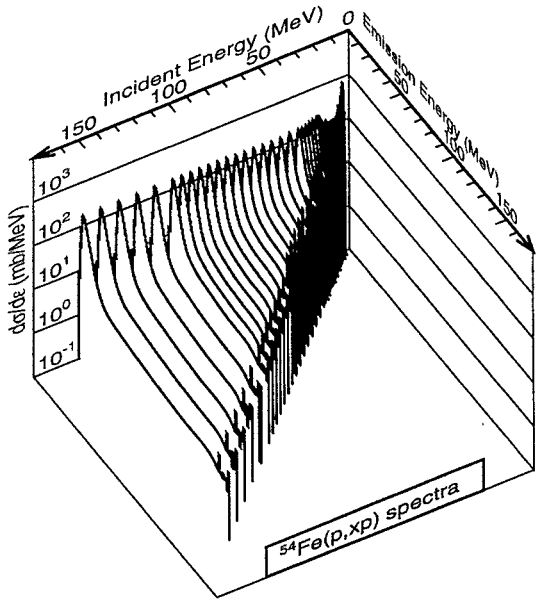
Energy	neutron	proton	deuteron	triton	helium3	alpha	gamma
2.000E+00	0.000E+00	4.915E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.428E+00
3.000E+00	0.000E+00	1.474E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.565E+00
4.000E+00	0.000E+00	2.433E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.504E+00
5.000E+00	0.000E+00	3.295E+00	0.000E+00	0.000E+00	0.000E+00	1.651E+00	1.517E+00
6.000E+00	0.000E+00	3.931E+00	0.000E+00	0.000E+00	0.000E+00	2.481E+00	1.597E+00
7.000E+00	0.000E+00	4.522E+00	0.000E+00	0.000E+00	0.000E+00	3.413E+00	1.671E+00
8.000E+00	0.000E+00	4.998E+00	0.000E+00	0.000E+00	0.000E+00	4.334E+00	1.771E+00
9.000E+00	0.000E+00	5.282E+00	0.000E+00	0.000E+00	0.000E+00	5.231E+00	1.919E+00
1.000E+01	7.162E-01	5.535E+00	0.000E+00	0.000E+00	0.000E+00	6.132E+00	2.053E+00
1.100E+01	7.901E-01	5.790E+00	0.000E+00	0.000E+00	0.000E+00	6.876E+00	2.170E+00
1.200E+01	1.166E+00	5.974E+00	7.306E-01	0.000E+00	0.000E+00	7.331E+00	2.246E+00
1.300E+01	1.550E+00	6.101E+00	1.450E+00	0.000E+00	0.000E+00	7.607E+00	2.330E+00
1.400E+01	1.920E+00	5.973E+00	2.358E+00	0.000E+00	0.000E+00	7.831E+00	2.366E+00
1.500E+01	2.246E+00	5.663E+00	3.201E+00	0.000E+00	0.000E+00	8.092E+00	2.339E+00
1.600E+01	2.534E+00	5.461E+00	3.870E+00	0.000E+00	0.000E+00	8.337E+00	2.259E+00
1.700E+01	2.719E+00	5.472E+00	4.482E+00	1.037E+00	0.000E+00	8.553E+00	2.148E+00
1.800E+01	2.686E+00	5.625E+00	5.087E+00	1.809E+00	0.000E+00	8.733E+00	2.019E+00
1.900E+01	2.688E+00	5.820E+00	5.644E+00	2.744E+00	0.000E+00	8.870E+00	1.888E+00
2.000E+01	2.864E+00	6.093E+00	6.170E+00	3.342E+00	0.000E+00	8.929E+00	1.727E+00
2.200E+01	3.190E+00	6.539E+00	7.441E+00	4.479E+00	0.000E+00	9.160E+00	1.730E+00
2.400E+01	3.726E+00	7.069E+00	8.712E+00	5.269E+00	0.000E+00	9.458E+00	1.889E+00
2.600E+01	4.207E+00	7.466E+00	9.942E+00	6.349E+00	0.000E+00	9.738E+00	2.035E+00
2.800E+01	4.739E+00	7.784E+00	1.113E+01	7.398E+00	0.000E+00	1.005E+01	2.085E+00

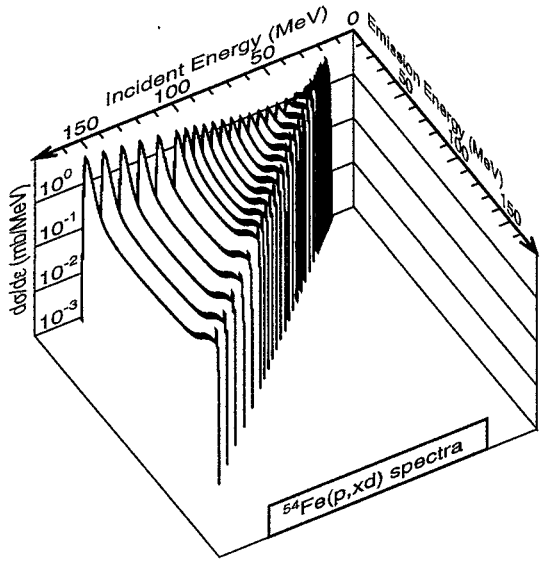
3.000E+01	5.162E+00	8.055E+00	1.230E+01	8.385E+00	0.000E+00	1.037E+01	2.034E+00
3.500E+01	5.831E+00	9.211E+00	1.531E+01	1.053E+01	0.000E+00	1.125E+01	1.861E+00
4.000E+01	6.830E+00	1.040E+01	1.850E+01	1.263E+01	0.000E+00	1.192E+01	1.880E+00
4.500E+01	7.886E+00	1.135E+01	2.136E+01	1.464E+01	0.000E+00	1.249E+01	1.899E+00
5.000E+01	8.684E+00	1.215E+01	2.430E+01	1.653E+01	0.000E+00	1.283E+01	1.892E+00
5.500E+01	9.389E+00	1.289E+01	2.727E+01	1.829E+01	0.000E+00	1.305E+01	1.912E+00
6.000E+01	1.002E+01	1.360E+01	3.012E+01	1.985E+01	0.000E+00	1.323E+01	1.874E+00
6.500E+01	1.049E+01	1.421E+01	3.278E+01	2.116E+01	0.000E+00	1.330E+01	1.871E+00
7.000E+01	1.094E+01	1.463E+01	3.491E+01	2.191E+01	0.000E+00	1.327E+01	1.872E+00
7.500E+01	1.138E+01	1.509E+01	3.701E+01	2.229E+01	0.000E+00	1.325E+01	1.856E+00
8.000E+01	1.181E+01	1.555E+01	3.920E+01	2.248E+01	0.000E+00	1.325E+01	1.845E+00
8.500E+01	1.224E+01	1.599E+01	4.128E+01	2.241E+01	0.000E+00	1.326E+01	1.824E+00
9.000E+01	1.256E+01	1.641E+01	4.300E+01	2.188E+01	0.000E+00	1.323E+01	1.828E+00
9.500E+01	1.296E+01	1.688E+01	4.484E+01	2.142E+01	0.000E+00	1.326E+01	1.843E+00
1.000E+02	1.331E+01	1.735E+01	4.658E+01	2.084E+01	0.000E+00	1.329E+01	1.825E+00
1.100E+02	1.397E+01	1.826E+01	4.838E+01	1.936E+01	0.000E+00	1.333E+01	1.887E+00
1.200E+02	1.459E+01	1.922E+01	5.126E+01	1.807E+01	0.000E+00	1.342E+01	1.910E+00
1.300E+02	1.514E+01	2.008E+01	5.323E+01	1.678E+01	0.000E+00	1.350E+01	1.910E+00
1.400E+02	1.581E+01	2.099E+01	5.524E+01	1.579E+01	0.000E+00	1.361E+01	1.901E+00
1.500E+02	1.642E+01	2.190E+01	5.669E+01	1.491E+01	0.000E+00	1.373E+01	1.924E+00

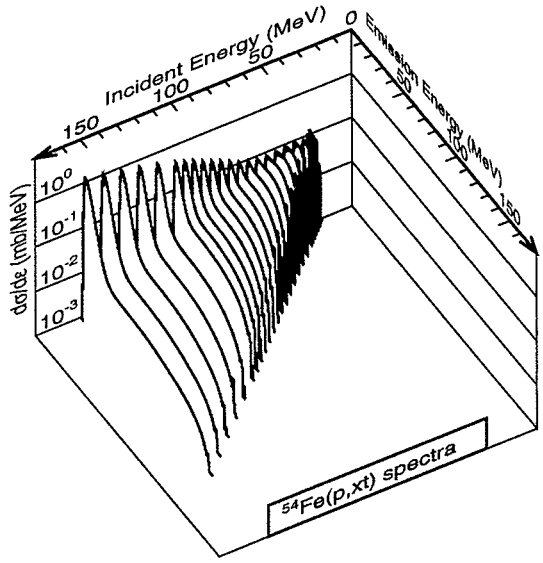

p + 54Fe nonelastic and production cross sections
Production Cross Section (mb)
Nonelastic Cross Section (mb)
Incident Energy (MeV)
p
n
γ
α
d
t
10^4
10^3
10^2
10^1
10^0
0
50
100
150

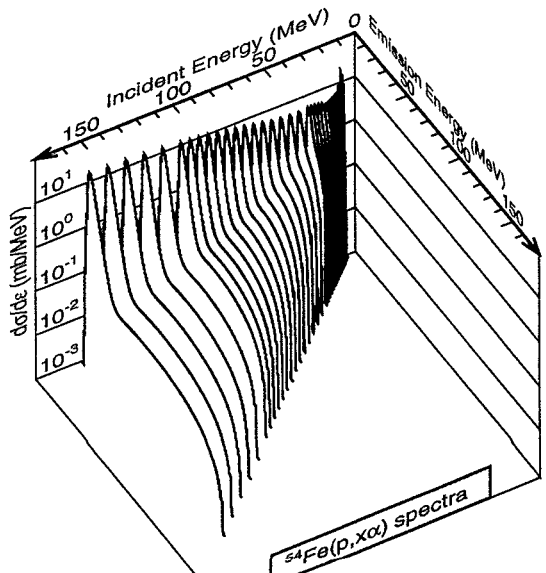
p + ^{54}Fe angle-integrated emission spectra

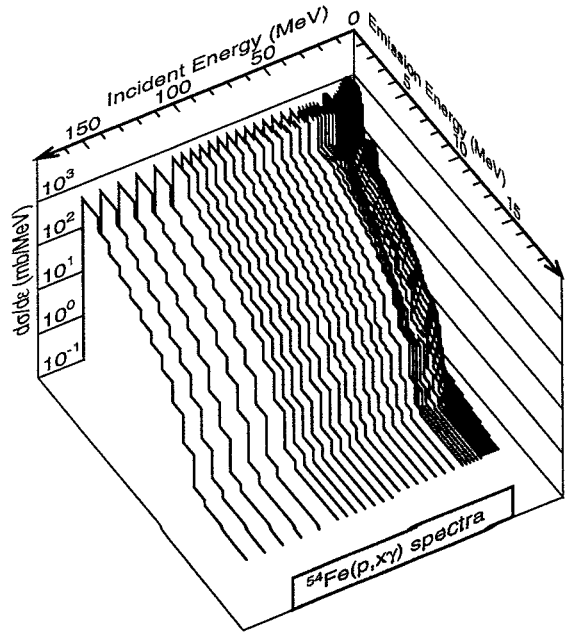




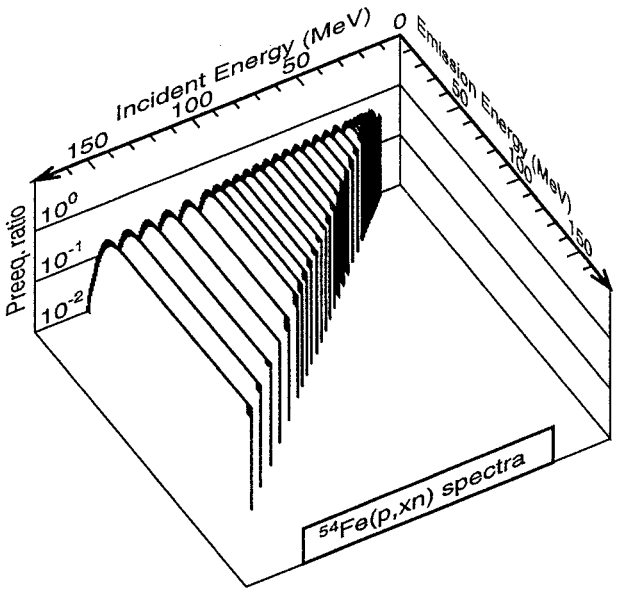


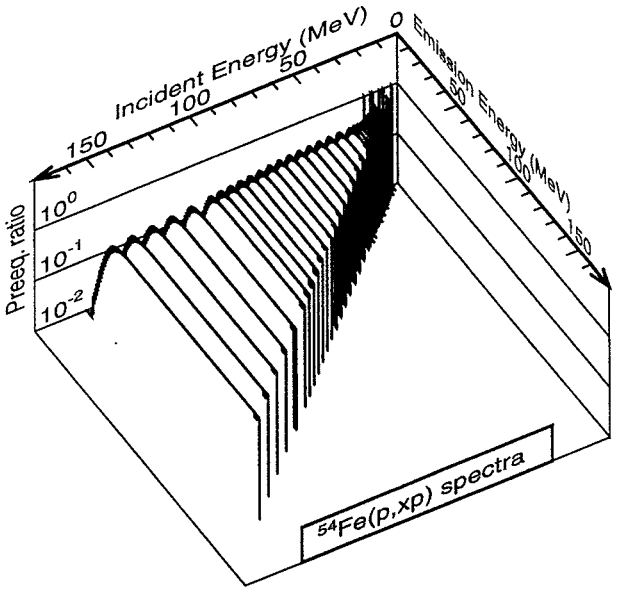


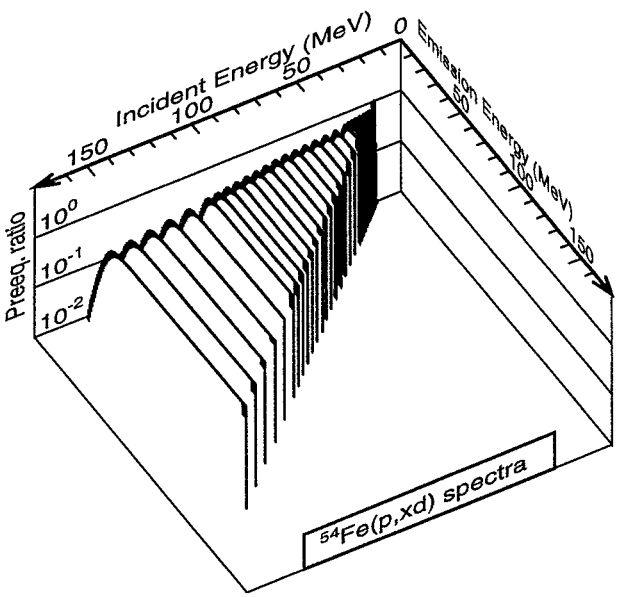


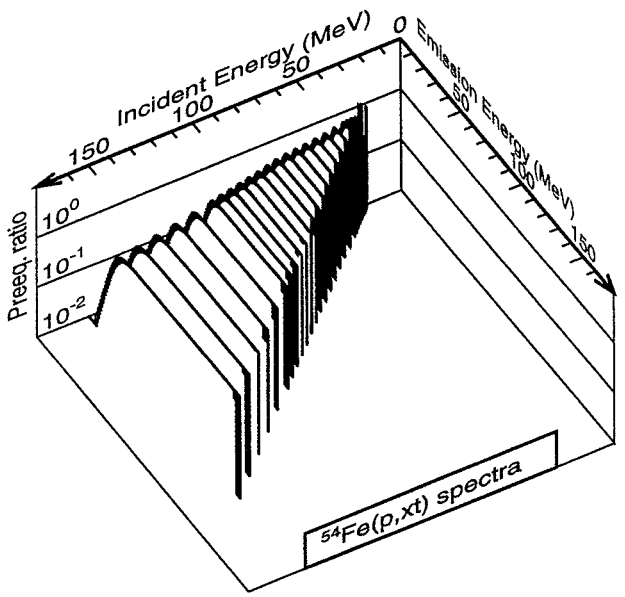


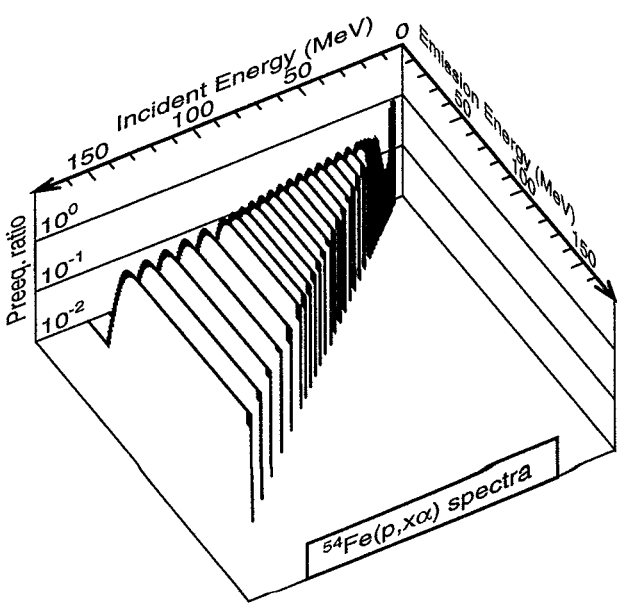
p + ^{54}Fe Kalbach preequilibrium ratios

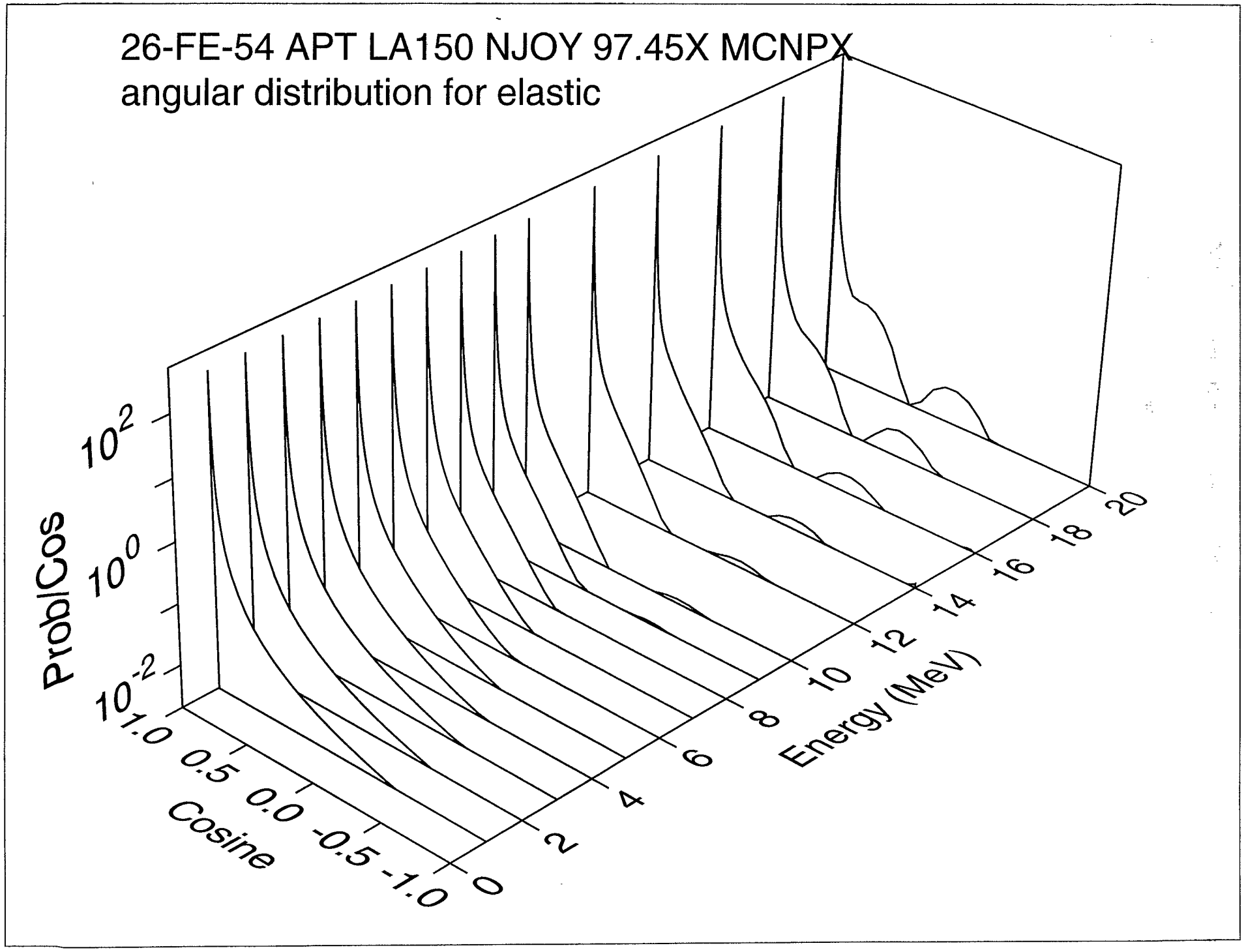


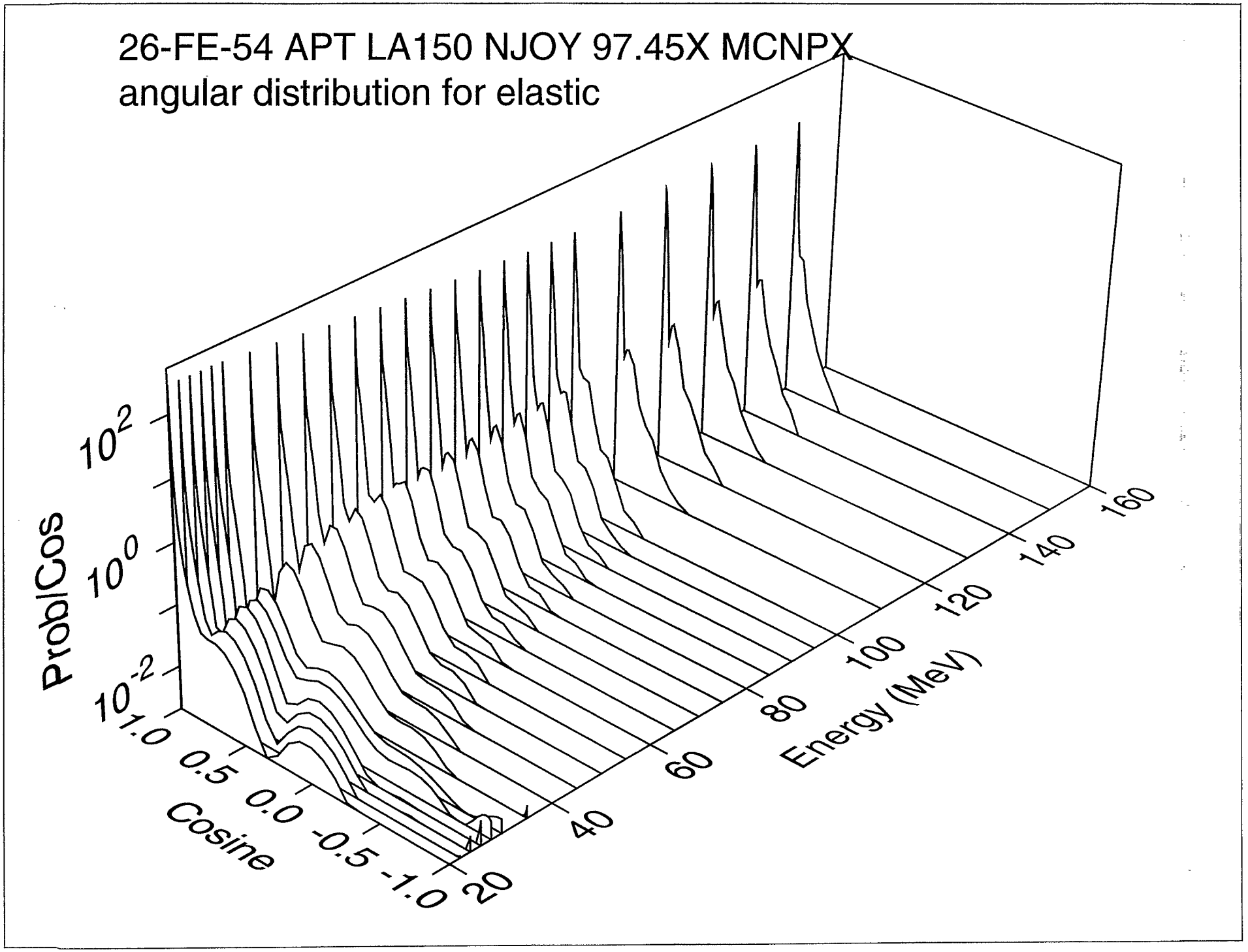


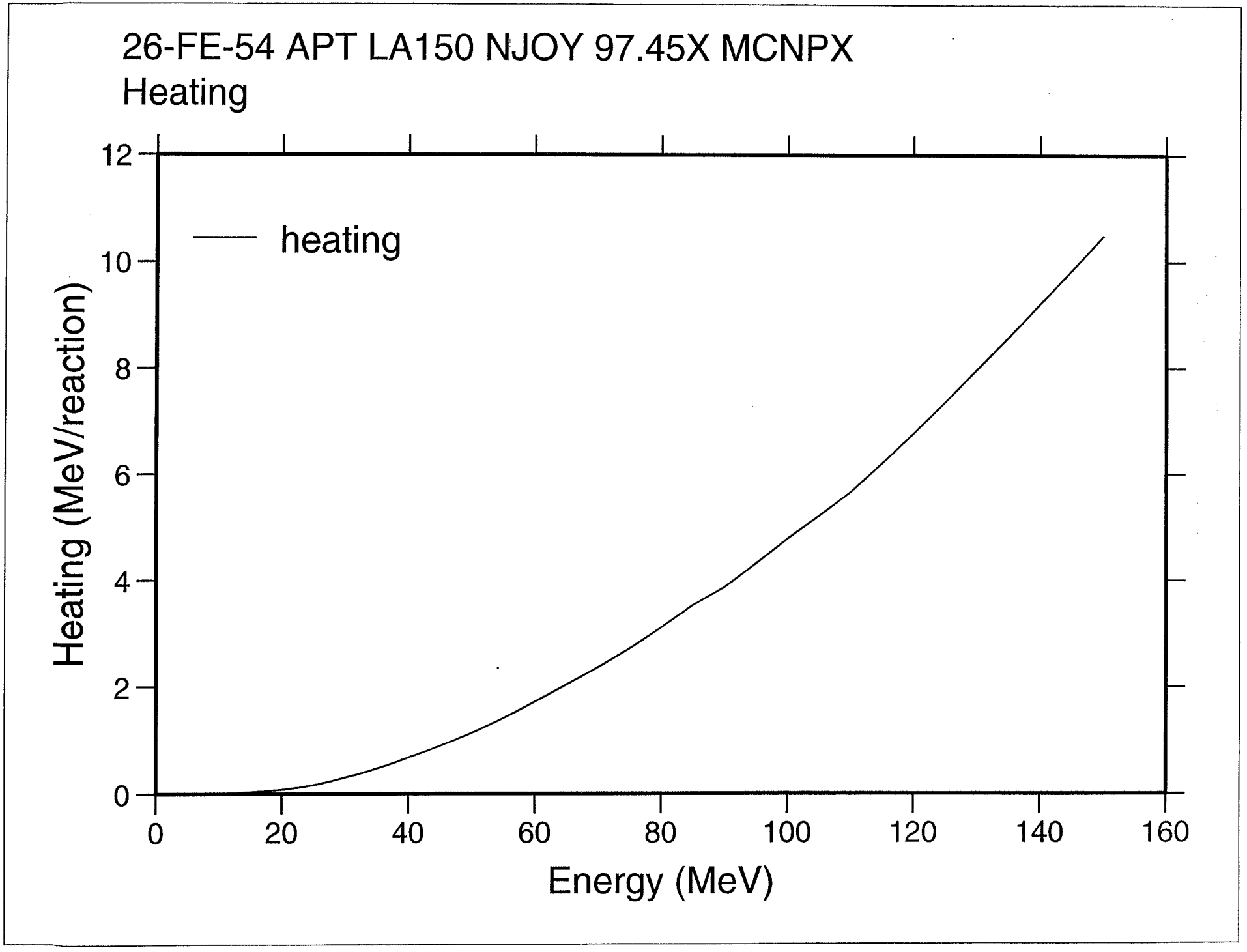







26-FE-54 APT LA150 NJOY 97.45X MCNPX
angular distribution for elastic
Prob/Cos
10^2
10^0
10^{-2}
Cosine
1.0
0.5
0.0
-0.5
-1.0
Energy (MeV)
0
2
4
6
8
10
12
14
16
18
20


26-FE-54 APT LA150 NJOY 97.45X MCNPX
angular distribution for elastic
Prob/Cos
10^2
10^0
10^{-2}
Cosine
1.0
0.5
0.0
-0.5
-1.0
Energy (MeV)
20
40
60
80
100
120
140
160


26-FE-54 APT LA150 NJOY 97.45X MCNPX
Heating
heating
Heating (MeV/reaction)
Energy (MeV)
0
2
4
6
8
10
12
0
20
40
60
80
100
120
140
160