EVALUATION OF n + 56Fe CROSS SECTIONS FOR THE ENERGY RANGE 1.0E-11 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 1.0E-11 to 150 MeV. The discussion here is divided into the region below and above 20 MeV.

INCIDENT NEUTRON ENERGIES < 20 MeV

Below 20 MeV the evaluation is based completely on the ENDF/B-VI.1 (Release 1) evaluation by Fu91 (see also Fu86). The following modifications were made to the ENDF/B-VI.1 evaluation:

1. The covariance files (MF=33) were removed from the file.

2. The derived MF=3 files for MT=203,205,207 were removed.

INCIDENT NEUTRON ENERGIES > 20 MeV

The evaluation above 20 MeV utilizes MF=6, MT=5 to represent all reaction data. 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 above En = 20 MeV are:

MF=3	MT=	1	Total Cross Section
	MT=	2	Elastic Scattering Cross Section
	MT=	3	Nonelastic Cross Section
	MT=	5	Sum of Binary (n,n') and (n,x) Reactions
MF=4	MT=	2	Elastic Angular Distributions
MF=6	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.

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).

The neutron optical model potential of Arthur et al. (Ar80) was used to calculate transmission coefficients and cross sections with the SCAT2 code (Be92) up to a neutron 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 below 28 MeV, and the Madland potential (Ma88) was used at higher energies. The global spherical potential of Perey (Pe63) was utilized for deuterons, 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.

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

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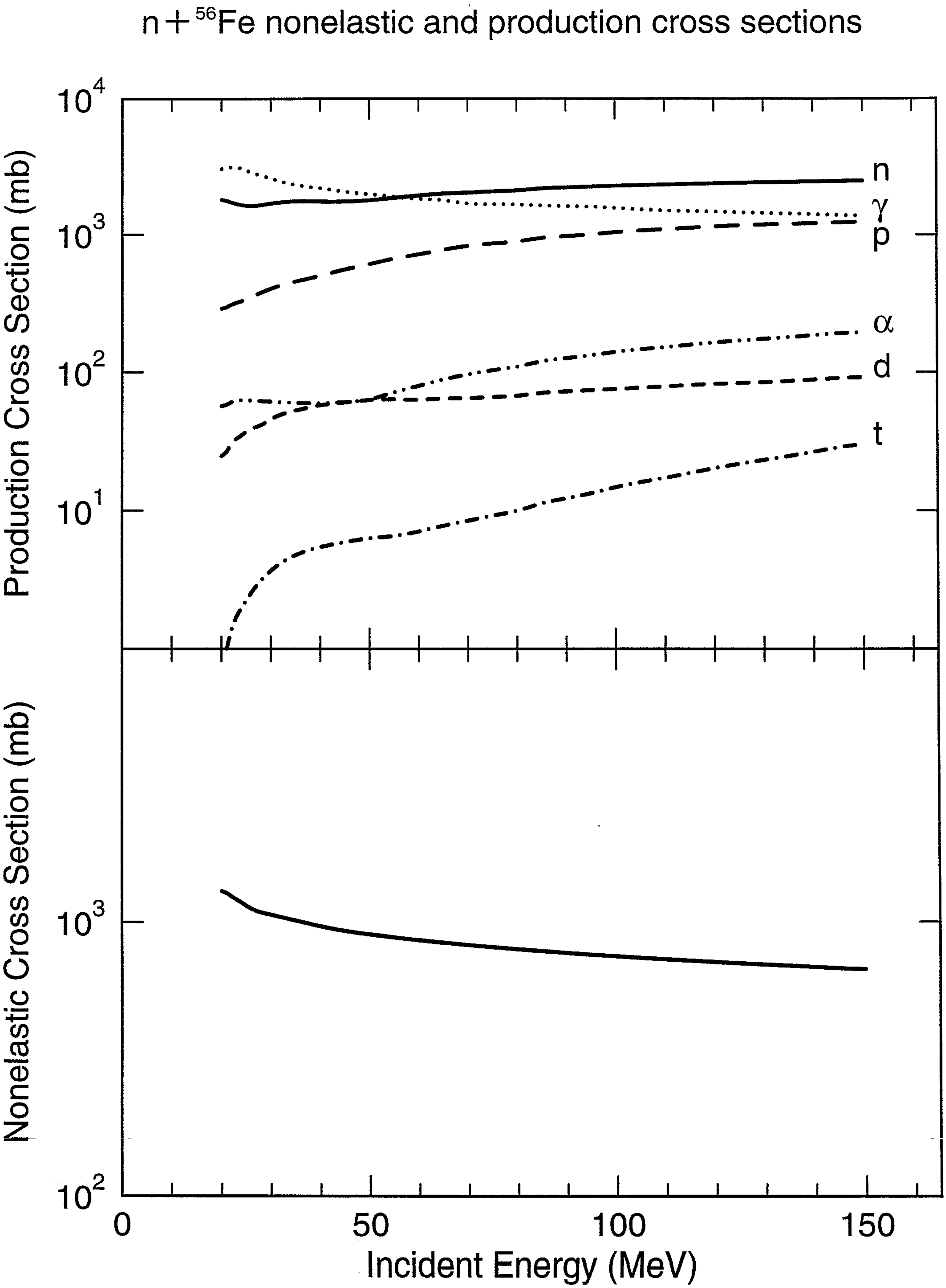
26056 = TARGET 1000Z+A (if A=0 then elemental)
1 = PROJECTILE 1000Z+A
Nonelastic, elastic, and Production cross sections for A<5 ejectiles in barns:

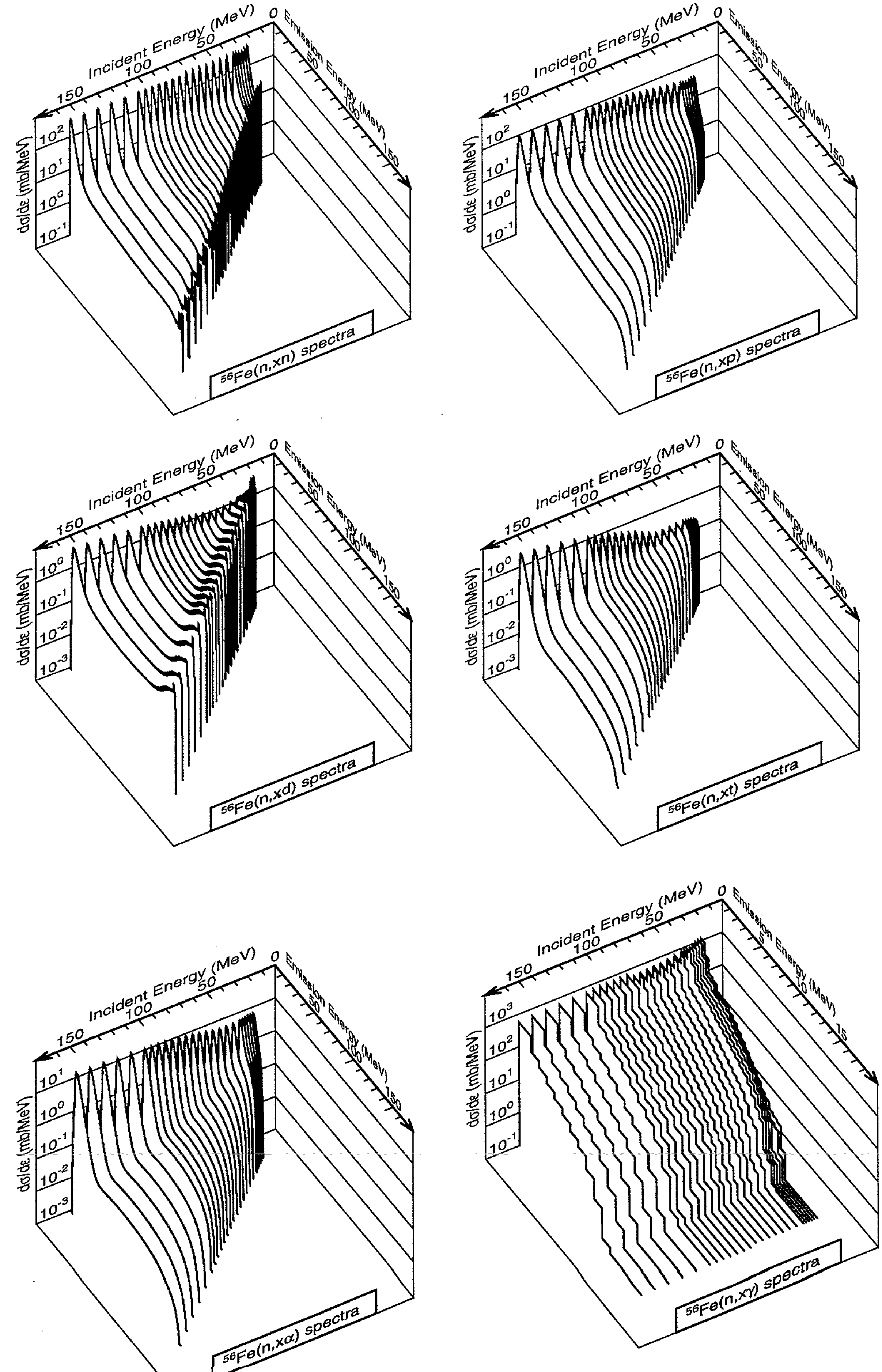
Energy	nonelas	elastic	neutron	proton	deuteron	triton	helium3	alpha	gamma
2.000E+01	1.296E+00	9.424E-01	1.808E+00	2.876E-01	2.485E-02	8.216E-04	0.000E+00	5.695E-02	3.055E+00
2.200E+01	1.240E+00	9.979E-01	1.726E+00	3.084E-01	3.037E-02	1.365E-03	0.000E+00	6.090E-02	3.141E+00
2.400E+01	1.177E+00	1.053E+00	1.653E+00	3.264E-01	3.499E-02	1.952E-03	0.000E+00	6.299E-02	3.079E+00
2.600E+01	1.117E+00	1.135E+00	1.625E+00	3.501E-01	3.902E-02	2.538E-03	0.000E+00	6.255E-02	2.880E+00
2.800E+01	1.084E+00	1.206E+00	1.653E+00	3.762E-01	4.154E-02	3.134E-03	0.000E+00	6.194E-02	2.732E+00
3.000E+01	1.063E+00	1.267E+00	1.696E+00	4.023E-01	4.577E-02	3.693E-03	0.000E+00	6.126E-02	2.599E+00
3.500E+01	1.012E+00	1.422E+00	1.765E+00	4.536E-01	5.285E-02	4.785E-03	0.000E+00	6.009E-02	2.326E+00
4.000E+01	9.637E-01	1.536E+00	1.757E+00	5.017E-01	5.781E-02	5.479E-03	0.000E+00	5.977E-02	2.193E+00
4.500E+01	9.265E-01	1.593E+00	1.758E+00	5.569E-01	6.064E-02	5.952E-03	0.000E+00	6.091E-02	2.063E+00
5.000E+01	9.004E-01	1.600E+00	1.795E+00	6.090E-01	6.308E-02	6.329E-03	0.000E+00	6.380E-02	1.980E+00
5.500E+01	8.778E-01	1.587E+00	1.869E+00	6.696E-01	6.379E-02	6.575E-03	0.000E+00	7.151E-02	1.902E+00
6.000E+01	8.578E-01	1.547E+00	1.939E+00	7.204E-01	6.336E-02	7.086E-03	0.000E+00	7.969E-02	1.837E+00
6.500E+01	8.399E-01	1.488E+00	2.000E+00	7.758E-01	6.472E-02	7.807E-03	0.000E+00	8.883E-02	1.792E+00
7.000E+01	8.236E-01	1.428E+00	2.034E+00	8.274E-01	6.500E-02	8.481E-03	0.000E+00	9.631E-02	1.694E+00
7.500E+01	8.087E-01	1.352E+00	2.075E+00	8.612E-01	6.627E-02	9.204E-03	0.000E+00	1.033E-01	1.676E+00
8.000E+01	7.949E-01	1.279E+00	2.113E+00	8.926E-01	6.755E-02	1.000E-02	0.000E+00	1.098E-01	1.666E+00
8.500E+01	7.823E-01	1.218E+00	2.185E+00	9.469E-01	7.078E-02	1.132E-02	0.000E+00	1.198E-01	1.639E+00
9.000E+01	7.705E-01	1.159E+00	2.221E+00	9.773E-01	7.244E-02	1.234E-02	0.000E+00	1.264E-01	1.619E+00
9.500E+01	7.596E-01	1.090E+00	2.252E+00	1.006E+00	7.400E-02	1.342E-02	0.000E+00	1.326E-01	1.602E+00
1.000E+02	7.494E-01	1.037E+00	2.287E+00	1.044E+00	7.544E-02	1.483E-02	0.000E+00	1.402E-01	1.570E+00
1.100E+02	7.307E-01	9.113E-01	2.336E+00	1.096E+00	7.875E-02	1.734E-02	0.000E+00	1.519E-01	1.505E+00
1.200E+02	7.141E-01	8.009E-01	2.383E+00	1.149E+00	8.216E-02	2.036E-02	0.000E+00	1.640E-01	1.474E+00
1.300E+02	6.992E-01	7.028E-01	2.425E+00	1.187E+00	8.458E-02	2.335E-02	0.000E+00	1.745E-01	1.440E+00
1.400E+02	6.857E-01	6.243E-01	2.467E+00	1.215E+00	8.834E-02	2.668E-02	0.000E+00	1.852E-01	1.415E+00
1.500E+02	6.734E-01	5.896E-01	2.496E+00	1.239E+00	9.159E-02	2.989E-02	0.000E+00	1.939E-01	1.379E+00

26056 = TARGET 1000Z+A (if A=0 then elemental)
1 = PROJECTILE 1000Z+A
Kerma coefficients in units of f.Gy.m^2:

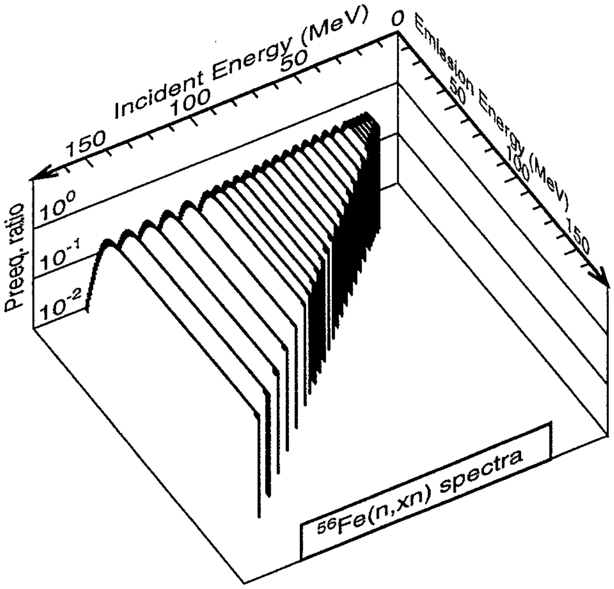
Energy	proton	deuteron	triton	helium3	alpha	non-rec	elas-rec	TOTAL
2.000E+01	3.018E-01	3.548E-02	7.378E-04	0.000E+00	8.950E-02	9.794E-02	1.898E-02	5.445E-01
2.200E+01	3.482E-01	4.966E-02	1.426E-03	0.000E+00	9.912E-02	1.021E-01	3.030E-02	6.308E-01
2.400E+01	3.873E-01	6.405E-02	2.328E-03	0.000E+00	1.059E-01	1.039E-01	3.300E-02	6.965E-01
2.600E+01	4.262E-01	7.890E-02	3.388E-03	0.000E+00	1.085E-01	1.047E-01	3.609E-02	7.578E-01
2.800E+01	4.753E-01	9.069E-02	4.616E-03	0.000E+00	1.106E-01	1.067E-01	3.688E-02	8.247E-01
3.000E+01	5.360E-01	1.087E-01	5.938E-03	0.000E+00	1.121E-01	1.094E-01	3.647E-02	9.085E-01
3.500E+01	6.945E-01	1.513E-01	9.256E-03	0.000E+00	1.155E-01	1.164E-01	3.418E-02	1.121E+00
4.000E+01	8.529E-01	1.965E-01	1.237E-02	0.000E+00	1.193E-01	1.214E-01	3.138E-02	1.334E+00
4.500E+01	1.022E+00	2.371E-01	1.525E-02	0.000E+00	1.247E-01	1.262E-01	2.843E-02	1.554E+00
5.000E+01	1.200E+00	2.776E-01	1.791E-02	0.000E+00	1.329E-01	1.317E-01	2.556E-02	1.785E+00
5.500E+01	1.387E+00	3.073E-01	1.948E-02	0.000E+00	1.482E-01	1.384E-01	2.087E-02	2.021E+00
6.000E+01	1.564E+00	3.252E-01	2.169E-02	0.000E+00	1.651E-01	1.442E-01	1.909E-02	2.239E+00
6.500E+01	1.735E+00	3.544E-01	2.399E-02	0.000E+00	1.839E-01	1.500E-01	1.747E-02	2.465E+00
7.000E+01	1.908E+00	3.737E-01	2.618E-02	0.000E+00	2.000E-01	1.557E-01	1.614E-02	2.679E+00
7.500E+01	2.070E+00	4.026E-01	2.832E-02	0.000E+00	2.153E-01	1.597E-01	1.482E-02	2.891E+00
8.000E+01	2.233E+00	4.311E-01	3.045E-02	0.000E+00	2.300E-01	1.632E-01	1.368E-02	3.101E+00
8.500E+01	2.456E+00	4.696E-01	3.357E-02	0.000E+00	2.521E-01	1.690E-01	1.279E-02	3.394E+00
9.000E+01	2.628E+00	5.005E-01	3.591E-02	0.000E+00	2.674E-01	1.722E-01	1.199E-02	3.617E+00
9.500E+01	2.795E+00	5.298E-01	3.822E-02	0.000E+00	2.821E-01	1.749E-01	1.115E-02	3.831E+00
1.000E+02	2.961E+00	5.497E-01	4.083E-02	0.000E+00	2.994E-01	1.782E-01	1.050E-02	4.040E+00
1.100E+02	3.295E+00	6.069E-01	4.557E-02	0.000E+00	3.277E-01	1.831E-01	9.108E-03	4.467E+00
1.200E+02	3.623E+00	6.549E-01	5.079E-02	0.000E+00	3.572E-01	1.876E-01	7.937E-03	4.882E+00
1.300E+02	3.953E+00	6.868E-01	5.593E-02	0.000E+00	3.833E-01	1.960E-01	6.925E-03	5.282E+00
1.400E+02	4.269E+00	7.364E-01	6.143E-02	0.000E+00	4.097E-01	2.072E-01	6.124E-03	5.690E+00
1.500E+02	4.585E+00	7.822E-01	6.674E-02	0.000E+00	4.322E-01	2.168E-01	5.759E-03	6.089E+00

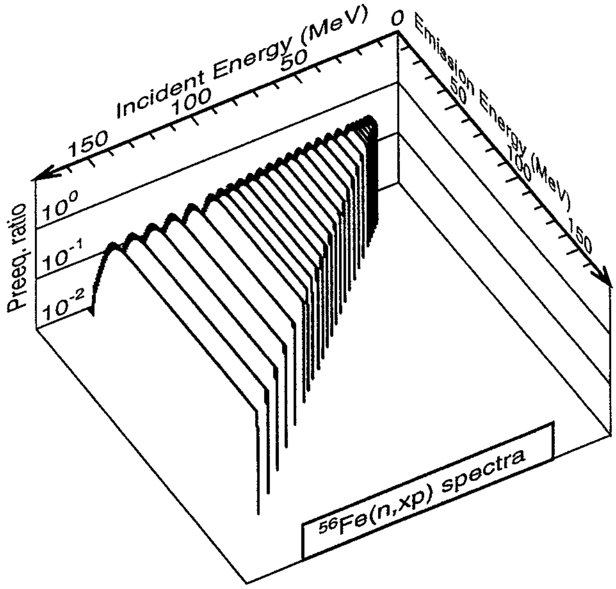

n + 56Fe nonelastic and production cross sections
Production Cross Section (mb)
Nonelastic Cross Section (mb)
Incident Energy (MeV)
10^4
10^3
10^2
10^1
n
γ
p
α
d
t
0
50
100
150

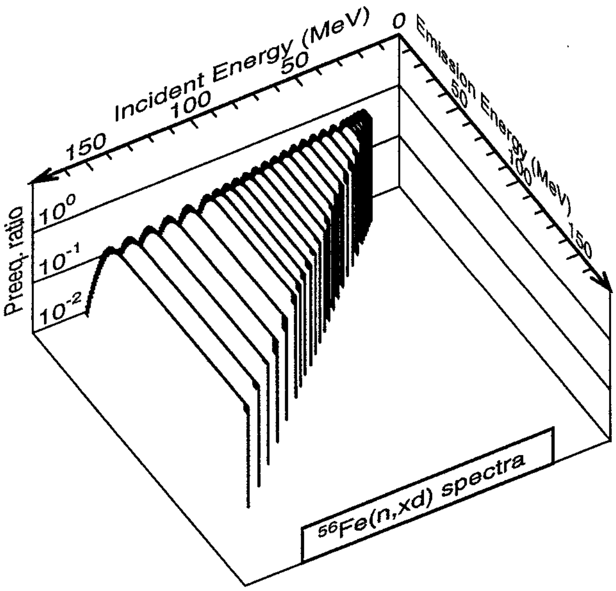
n + ^{56}Fe angle-integrated emission spectra

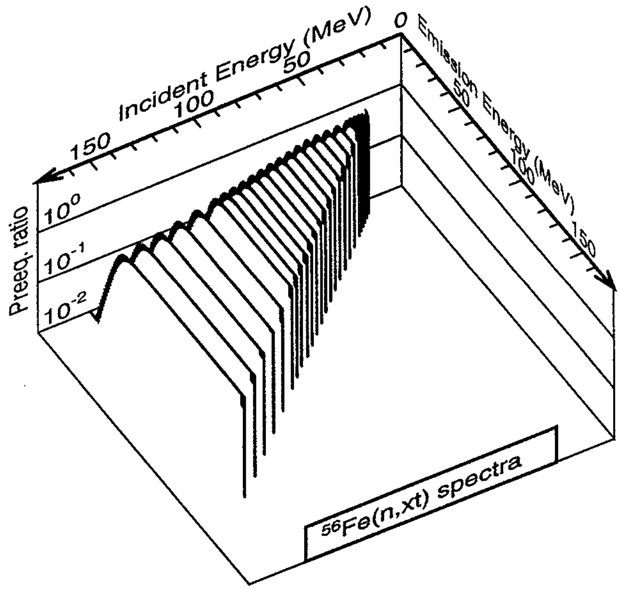


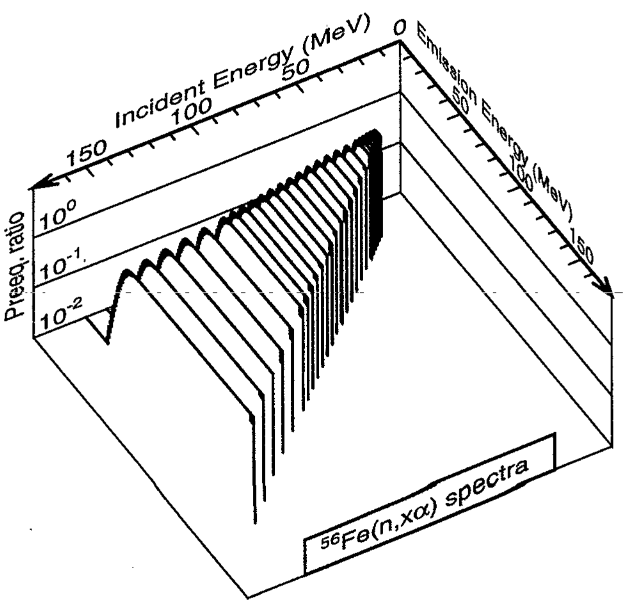
n + ^{56}Fe Kalbach preequilibrium ratios

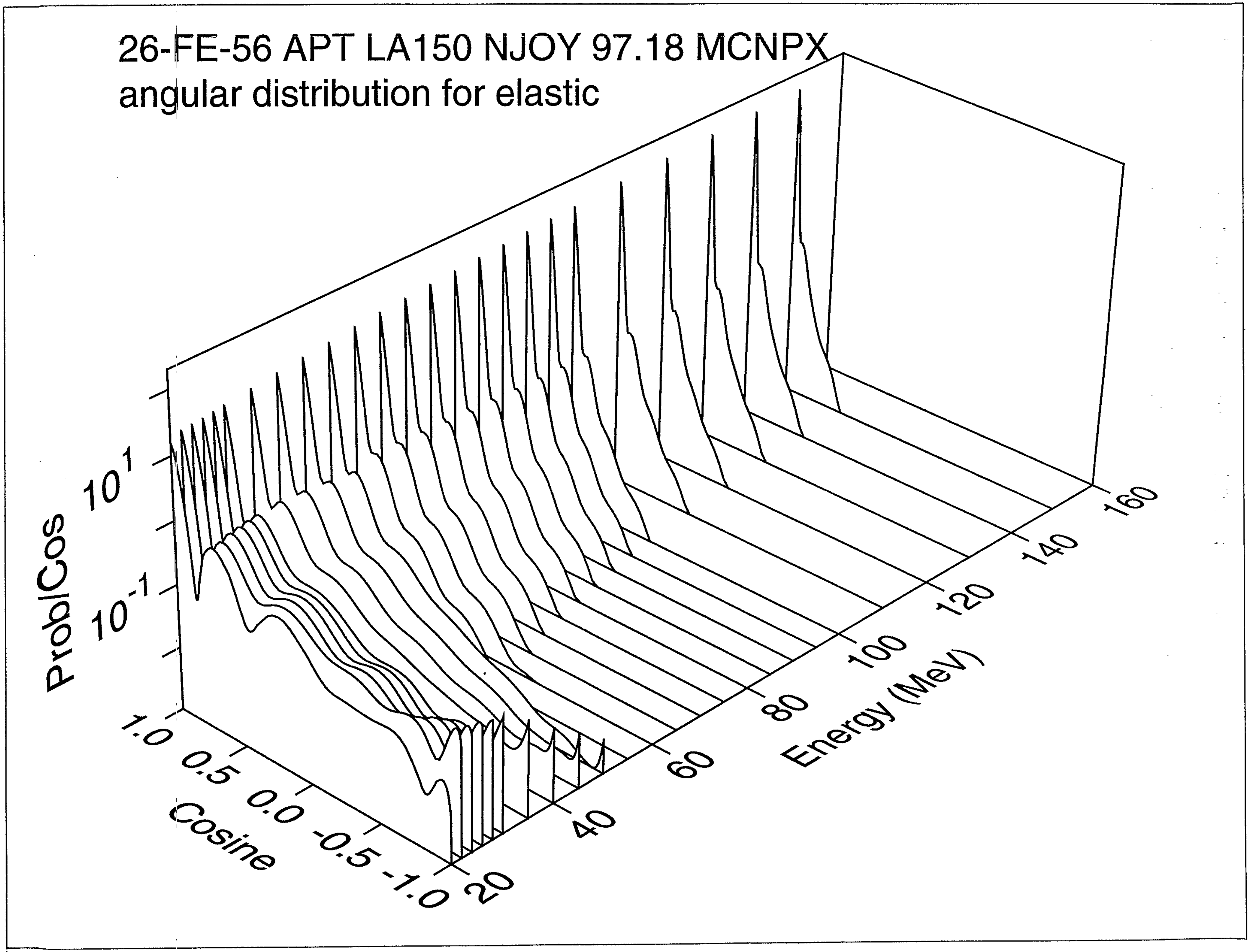


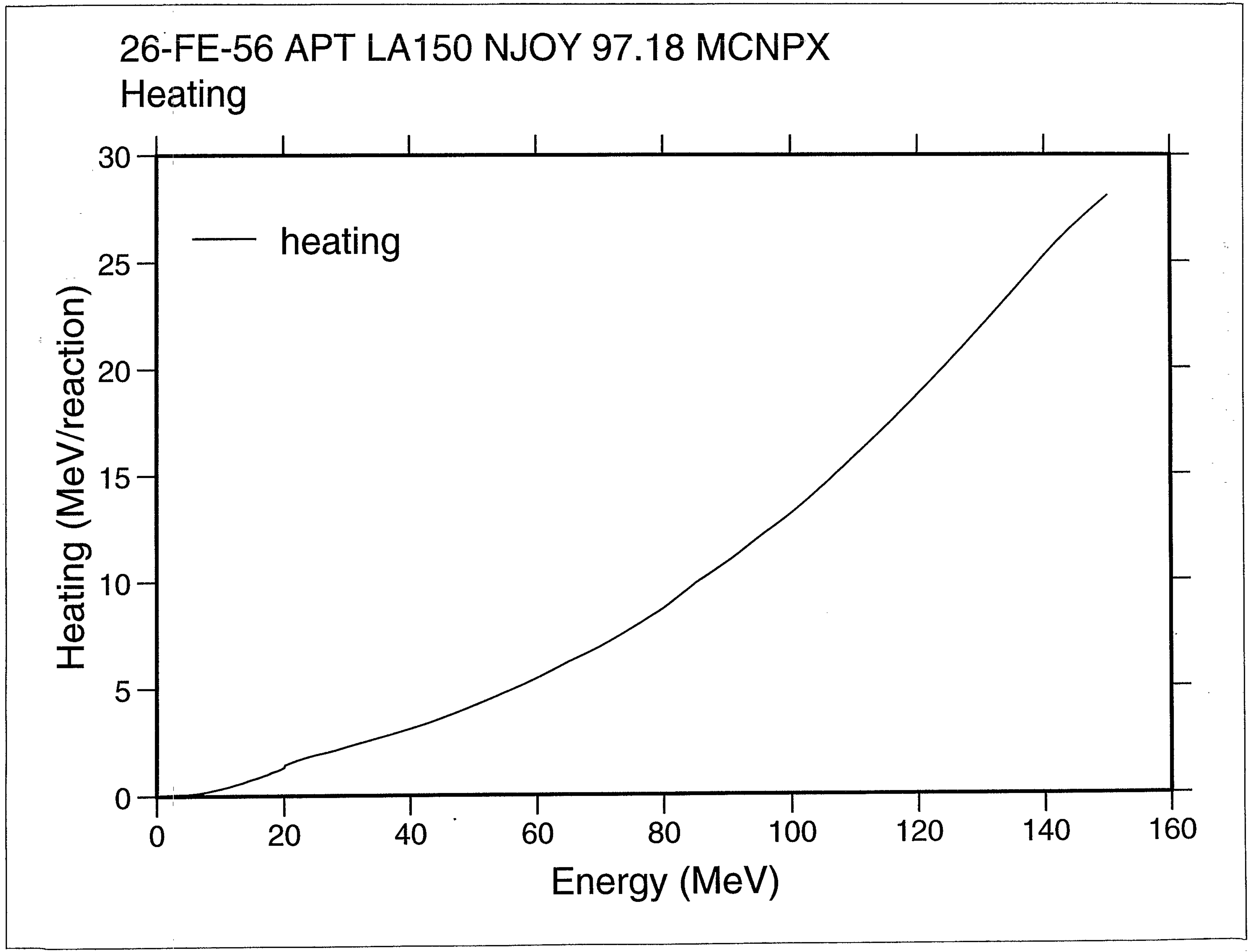


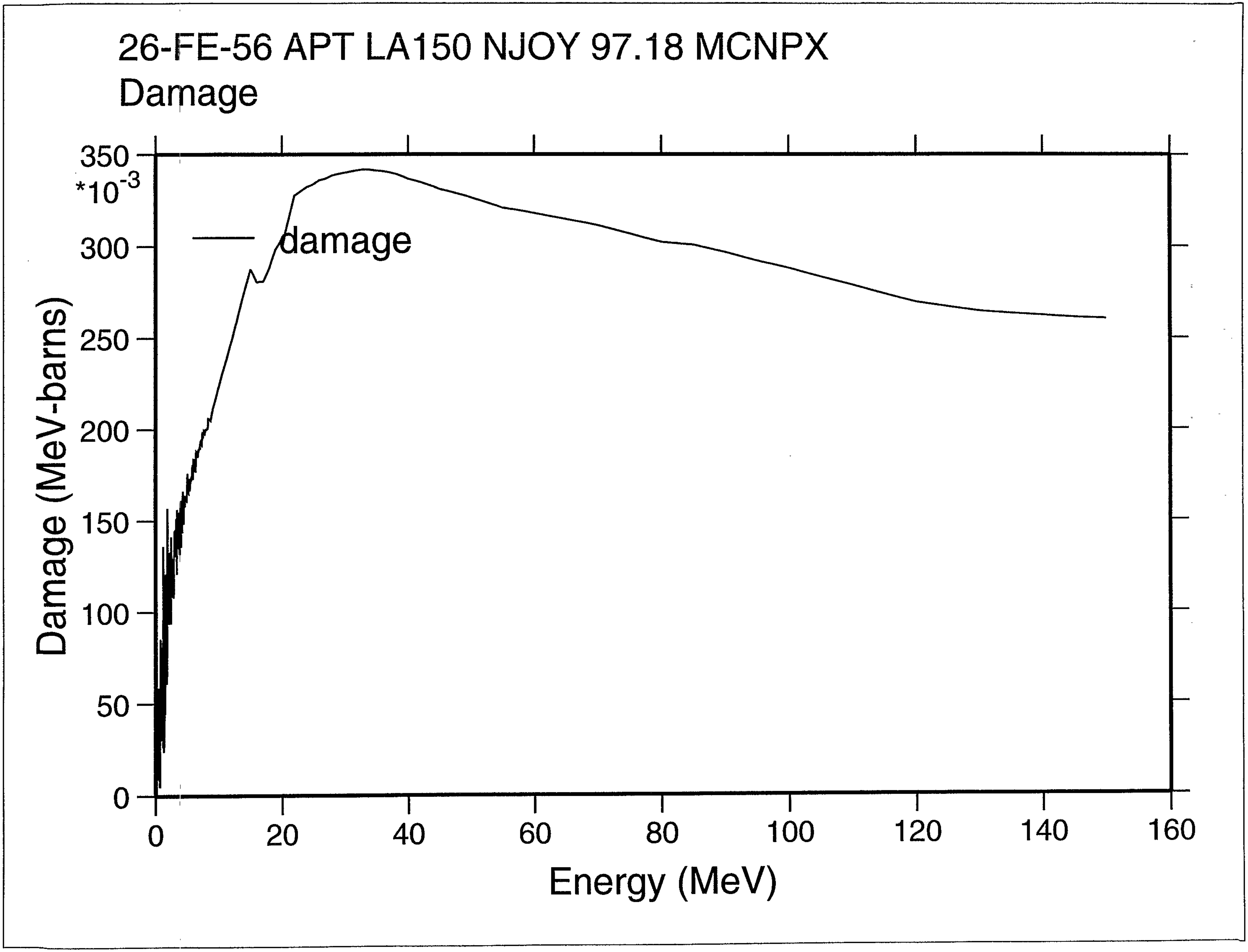







26-FE-56 APT LA150 NJOY 97.18 MCNPX
angular distribution for elastic
Prob/Cos
10^1
10^{-1}
1.0
0.5
0.0
-0.5
-1.0
Cosine
20
40
60
80
100
120
140
160
Energy (MeV)


26-FE-56 APT LA150 NJOY 97.18 MCNPX
Heating
heating
Heating (MeV/reaction)
Energy (MeV)
0
5
10
15
20
25
30
0
20
40
60
80
100
120
140
160



26-FE-56 APT LA150 NJOY 97.18 MCNPX
Damage
damage
350
*10^-3
300
250
200
150
100
50
0
Damage (MeV-barns)
0
20
40
60
80
100
120
140
160
Energy (MeV)