File 4 - Angular Distributions

File 4 is used to describe the angular distribution of emitted particles. It is used for reactions with incident neutrons only; see File 6 for for other projectiles. Angular distributions should be given for elastically scattered neutrons and for the neutrons resulting from discrete level excitation due to inelastic scattering. File 4 can also be given for particles resulting from (n,n'continuum), (n,2n), and other continuum reactions, but in these cases only the integral over all final energies is provided. There is normally coupling between the secondary energy and angle in these cases, and File 6 is preferred. File 4 may also contain angular distributions of emitted charged particles for a reaction where only a single outgoing charged particle is possible (MT=600 through 849).

In some cases, it may be possible to compute the angular distributions in the resolved range from resonance parameters. In such cases, the computed distributions may be preferable to the distributions from File 4, which will be a smoothed average when the resonances are close together.

Angular distributions for a specific reaction type (MT number) are given for a series of incident energies, in order of increasing energy. The energy range covered should be the same as that for the same reaction type in File 3. Angular distributions for several different reaction types (MT's) may be given in File 4 for each material in ascending order of MT number.

The angular distributions can be expressed as normalized probability distributions or as Legendre expansions of the probability distributions:

$$f(\mu,E) = \frac{2\pi}{\sigma_s(E)}\sigma(\mu,E) = \sum_{l=0}^{\mathrm{NL}} \frac{2l+1}{2} a_l(E) P_l(\mu)$$

$$\int_{-1}^{1} f(\mu,E)\, d\mu = 1$$

where $f(\mu,E)d\mu$ is the probability that a particles of incident energy E will be scattered into the interval $d\mu$ about an angle whose cosine is μ. The units of $f(\mu,E)$ are (unit cosine)$^{-1}$. In addition,

μ
: cosine of the scattered angle in either the laboratory or the center-of-mass system,

E
: energy of the incident particle in the laboratory system,

$\sigma_s(E)$
: the scattering cross section from File 3 for this MT,

l
: order of the Legendre polynomial,

$\sigma(\mu,E)$
: differential scattering cross section in units of barns per steradian, and

a_l

the *l*th Legendre polynomial coefficient, and it is understood that a_0=1.0 (only *l* values of 1, 2, ..., NL are given).

The angular distributions may be given in either the center-of-mass (CM) or laboratory (LAB) system.

There are some obsolete formats in File 4 for representing the transformation matrix from the CM to the laboratory frame. They may be found in older ENDF/B files, but they are not used anymore. They are not described in these online notes.

Formats

File 4 is divided into sections, each containing data for a particular reaction type (MT number), and ordered by increasing MT number. Each section always starts with a HEAD record and ends with a SEND record. The following quantities are defined:

ZA,AWR
standard material charge and mass parameters

LTT
flag to specify the representation used:

- LTT=0, all angular distributions are isotropic,
- LTT=1, the data are given as Legendre expansion coefficents, a_l, or
- LTT=2, the data are given as tabulated normalized probability distributions, $f(\mu,E)$.

LI
flag to specify whether all the angular distributions are isotropic:

- LI=0, not all isotropic, or
- LI=1, all isotropic.

LCT
flag to specify the frame of reference used:

- LCT=1, the data are given in the LAB system, or
- LCT=2, the data are given in the CM system.

LVT
an obsolete flag, now always zero.

NE
number of incident energy points at which angular distributions are given (up to 1200).

NL
higher order Legendre polynomial coefficient that is given at each energy (up to 64).

NK
obsolete parameter. Now always zero.

NM
maximum order Legendre polynomial that will be required to describe the angular distributions of elastic scattering in either the center-of-mass or the laboratory system. NM should be an even number.

NP

number of angular points (cosines) used to give the tabulated probability distributions for each energy.

The structure of a section depends on the values of LTT.

Legendre Polynomial Coefficients

```
[MAT, 4, MT/ ZA, AWR, LVT, LTT, 0, 0] HEAD   LVT=0, LTT=1
[MAT, 4, MT/ 0., AWR, LI, LCT, 0, 0] CONT   LI=0
[MAT, 4, MT/ 0., 0., 0, 0, NR, NE/ Eint] TAB2
[MAT, 4, MT/ 0., 0., 0, 0, NL, 0/ a_l(E_1)] LIST
[MAT, 4, MT/ 0., 0., 0, 0, NL, 0/ a_2(E_2)] LIST
 ...
[MAT, 4, 0/ 0.0, 0.0, 0, 0, 0, 0] SEND
```

Tabulated Probability Distributions

```
[MAT, 4, MT/ ZA, AWR, LVT, LTT, 0, 0] HEAD   LVT=0, LTT=2
[MAT, 4, MT/ 0., AWR, LI, LCT, 0, 0] CONT   LI=0
[MAT, 4, MT/ 0., 0., 0, 0, NR, NE/ Eint] TAB2
[MAT, 4, MT/ 0., 0., 0, 0, NR, NP/ muint/ f(mu,E_1)] TAB1
[MAT, 4, MT/ 0., 0., 0, 0, NR, NP/ muint/ f(mu,E_1)] TAB1
 ...
[MAT, 4, 0/ 0.0, 0.0, 0, 0, 0, 0] SEND
```

All Angular Distributions are Isotropic

```
[MAT, 4, MT/ ZA, AWR, LVT, LTT, 0, 0] HEAD   LVT=0, LTT=0
[MAT, 4, MT/ 0., AWR, LI, LCT, 0, 0] CONT   LI=1
[MAT, 4, 0/ 0.0, 0.0, 0, 0, 0, 0] SEND
```

Procedures

The angular distributions for two-body reactions should be given in the CM system (LCT=2). It is recommended that other reactions (such as continuum inelastic, fission, etc.) should be given in the LAB system.

For Legendre polynomial expansions, a linear-linear interpolation scheme (INT=2) should be used for the incident energy.

For tabulated distributions, the cosine interval should span the entire range -1 to +1. The interpolation scheme for incident energy *E* should be linear-linear (INT=2) and the interpolation scheme for the cosine should be log-linear (INT=4).

See ENDF102, Chapter 4
