# CHAPTER 6: MCNP SOURCE PARAMETERS

## 6.1 General

There are four possible source types:

1. Fixed (or general source) source (SDEF card).
2. MCNP generated surface source (SSW to write and SSR to read).
3. Criticality Source (KCODE Card); needs also an initial source (KSRC, SDEF card or SRCTP file from a previous calculation written by the SSW card).
4. User supplied source (if SDEF, SSR and KCODE are all missing).

Cards SI (source information), SP (source probability), SB (source bias) and DS (dependent source) cards can be used with any of the above sources. A source comments (SC) card can also be used to print source distribution headers.

The MODE card implies the type of source particle.

A particle source has an intensity, energy, direction, shape and temporal characteristics, and needs to be positioned somewhere within the phase space of the problem. We are concerned here with fixed sources, or primary sources; not secondary sources such as those generated by fission, neutron capture, or electron recoil.

The source strength is represented in MCNP by the starting weight, WGT, which is usually assigned to unity to represent a normalized source. All source particles, regardless of their attributes (position, energy, direction and age) are assigned the same weight of WGT. The frequency of occurrence of a particle of a particular attribute is determined by the source's probability density function (pdf).

The starting age, TME, is needed if a time-dependent problem is to be solved. Time dependence is provided by keeping track of the chronological age (distance of travel/velocity) of each particle.

If the source is not monoenergetic, it has to be sampled from a given, or designated energy spectrum, $f(x)$. If the spectrum source is biased according to an importance function, $g(x)$, the source energies are selected from the distribution $f(E)g(E)$, and the source weight is adjusted to give less weight to those particles that are chosen more frequently that they should and vice versa. A similar approach applies to the biasing of other source attributes.

The number of source particles is defined by a data card, NPS.

A difficult problem frequently encountered by Monte Carlo users is to determine how long a computer run is needed to get acceptable statistics. After the completion of a run, the user may decide to obtain better statistics (lower standard deviation). MCNP provides at the end of each run a binary start-restart data file (default name RUNTPE, see NDMP in PRDMP card).

Note that if this file exists from a previous job, the code will assign a new file name. To continue a previous job, simply add the C option in the job control (execution) card. The job will pick up where it left and continue till the problem is terminated again. Remember however to increase the number of histories required in the NPS card. If you are using execution-time cut off, CTME will be the new more minutes to run. In a continue-run, the input file is optional, and if used must contain the word CONTINUE as the first entry in the title card. Note however that only a certain number of cards are allowed in the continue-run input file, consult manual.

Often after running a problem, one wishes that more output information would have been printed. A continue-run with a negative entry of NPS comes handy here, as it instructs the code to print an output file at the time of the last history and stop. It is useful for example to obtain additional print out that was not obtained initially; use then the PRINT card with the required additional print options.

## 6.2 General Source

SDEF is the source definition card that defines the basic parameters of a basic source: SDEF source variable (var) = specification. The specification could be an explicit value, a distribution number (Dn) and requires SP and/or SB cards, or the name of another variable (Fvar Dn) and an DS card. The equal sign is optional. The following variables are required to define a source of particle:

**Particle Type:** PAR= source particle type, 1 for neutrons, 2 for photons, 3 for electrons.

**Weight:** WGT= starting weight (default 1).

**Age**: TME= starting time (default 0), units shakes (1 shake $=10^{-8}$ s).

**Location:** POS= (*x y z* )= initial position (default 0 0 0), units cm.

**CELL:** starting cell number, determined automatically for a point source.

## 6.3 Spatial Distribution (Shape)

In general, use SUR for a surface source and CELL for a volume source.

### 6.3.1 Volume Sources

SUR is zero (default value). It can be used in combination with the CEL variable to sample uniformly throughout the interior of a cell; a source that completely contains a cell must be specified, if sampled point is found outside the cell, it is rejected.

**Cartesian:** These are specified with X, Y, and Z.

**Point:** X, Y and Z are all constants.

**Line:** one variable, the others are constant, e.g. X=D1 Y=5 Z=5, with SI1 20 30 and SP1 0 1 samples a line source extending from *x*=20 to x=30, with *y*=5 and z=5.

**Rectangular Plane:** Fix one variable and vary the other two.

**Rectangular Polyhedron:** vary the three variables.

**Spherical:** These are specified by POS (center of sphere) and RAD (radius), do not specify X Y Z and AXS.

**Point:** RAD=0, or not specified at all.

**Set of Point Sources:** do not specify RAD and specify a distribution for position with an L on the SIn card.

**Between Two Spherical Surfaces:** Specify two radii for RAD on an SIn card.

**Biased:** SP card can be used to define the power law $p(x)=c|x|^a$ with *f*=-21. The default value of a is equal to 2, providing a uniform distribution over the sphere volume. Changing the value of *a* can bias distribution of source.

**Cylindrical:** These are specified with POS (point on axis), AXS (direction cosines of axis), RAD (radius of cylinder), and EXT (distance form POS). The distance of the ends of a cylinder from POS are entered on the SI card for EXT and power law, with *a*=1 gives uniform volume sampling.

**Disk:** set EXT=0, which provides a source with circular symmetry on a plane.

## 6.3.2 Surface Sources

SUR is nonzero. Sampled values of X Y and Z determine position (make sure that the point is on surface). IF X Y Z are not specified, the position is sampled from SUR.

**Plane**: SUR defines a name of a plane, POS must be a point on plane. The position of sampled uniformly on the circle of radius RAD centered around POS. Uniform sampling in area is obtained when RAD has a power distribution with *a*=1, default in this case.

**Cylindrical:** This must be specified with as a volume source, specify two equal radii for RAD on an SIn card.

**Spherical:** SUR is the name of a spherical surface. If AXS is not specified, position is sampled uniformly on surface. If AXS is specified, EXT is used for the cosine of the angle between the direction AXS and the vector from the center of the sphere to the position point (EXT can have a distribution). An exponentially biased distribution (*f*=-31 in SB) can be used to start more particles in one side of the sphere.

**Spheriodal:** SUR is the name of ellipse revolved around one of its axis. A spheroid must have its axis parallel to one of the coordinate axis.

## 6.4 Energy Spectrum

ERG= starting energy (default 14 MeV). Use an SP card to define a distribution : Maxwell fission spectrum (*f*=-2), Watt fission spectrum (*f*=-3), Gaussian fusion spectrum (*f*=-4), evaporation spectrum (*f*=- 5), Muir velocity Gaussian fusion spectrum (*f*=-6) and spare (user supplied) energy spectrum (*f*=-7).

Alternatively, DS can be used to define a discrete distribution.

## 6.5 Directional distribution

The default is isotropic distribution. VEC defines a reference vector (which can be itself a distribution); the default for a surface source is the normal to the source in a direction defined by NRM.

DIR defines the cosine of the polar angle; cosine distribution for a surface source is the default. The azimuthal angle is sampled uniformly.

DIR=1 gives a monodirectional source (beam) in the direction of VEC. DIR can be biased to a preferred direction, see BIASING.
Note: discrete values of DIR will prevent direct (uncolided) contributions to point detectors; unless the source is a plane surface, sampled uniformly in area (ARA) within a circle (using RAD sampled from SP -21 1), VEC is perpendicular to the surface and DIR=1. Also, DS can be used to define a discrete distribution.

## 6.6 Temporal distribution

TME = time (in units of shakes, default=0). SP with *f*=-1 defines a Gaussian distribution with time.

Alternatively, DS can be used to define a discrete distribution.

## 6.7 Biasing

It allows the production of more source particles, with suitably reduced weights, in the more important regimes of each variables. Source biasing is the only variance reduction allowed with F8 tallies having energy bins.

### 6.7.1 Arbitrary Frequency

SB card defines a new biased frequency for various source parameters, code adjusts weights accordingly.

## 6.7.2 Directional Biasing

**Continuous Exponential Function:** $p(\mu)=C\exp(K\mu)$, $\mu$ is cosine angle relative to biasing direction, $C$ is a normalization constant $=K/[\exp(K)-\exp(-K)]$, $K$ is a constant that defines the ratio of weight of tracks starting in the biased direction to tracks starting in the opposite direction being equal to $\exp(2K)$, use SB card , with DIR , $f$=-31, $a$=$K$. Example: SDEF DIR D1; SB1 -31 1.

**Fixed-size Cones:** It limits source direction within a cone, but not preferable due to discontinuities at cone boundaries, cone cosines are defined by the SI card, true (original) distribution with the SP card and biasing probabilities with the SB card. For example an isotropic source, SDEF DIR D2, defined by the $\mu$ intervals =-1, $\nu$, 1, e.g. SI2 -1 0 1, with a uniform pdf , i.e. SP2 0 $(1+\nu)/2$ $(1-\nu)/2$ 1, biased by the SB2 0 p1 p2, $\mu$ will be sampled uniformly within the cone $-1< \mu <\nu$ with probability p1, and within the cone $\nu < \mu < 1$ with probability p2, with p1+p2=1. Of course $\nu$, p1, p2 are actual numbers, e.g. $\mu$=0, p1=0.3, p2=0.7. Note that the sampling of the azimuthal angle is not biased.

**Cylinder Extent (Axial):** SDEF EXT allows the automatic spatial biasing of source particles in a cylindrical-source-covering- volume along the axis of the cylinder.

**Cylinder or Sphere (Radial):** SDEF RAD allows the automatic radial biasing of source particles in a either a cylindrical or spherical source-covering- volume along the axis of the cylinder.

Above two are used to aid in the escape of source particles from optically thick source regions. The power law, $p(x)=c|x|^a$, *f*=-21 with "*a*" defined in SB card can be used for RAD and EXT, while the exponential distribution, *f*=-31 in SB, is allowed only with EXT.

### 6.7.3 **Cookie-Cutter**

Cell CCC can be used with either a cell or a surface. When CCC is present in the SDEF card, the sampled position is accepted only if it is within cell CCC. The efficiency, EFF, applies to both CCC and CEL rejection, and the job is terminated if MAX(number of successes, 10) < EEF ≤ number of trials.

### 6.7.4 Standard Source Functions

Functions such as the Watt and the evaporation spectrum can also be biased by a negative entry in the SP card, see manual.

### 6.7.4 **Photon Production**

Photon production can be biased to a certain energy range, to high energies, using the PIKMT card.

**6.8 Others** See manual for:

1. Repeated source structure (use CEL with a path from level 0 to level n).
2. Surface source write (SSW card).
3. Surface source read (SSR card).
4. Criticality source (KCODE and KSRC cards).
5. User supplied source (Subroutines SOURCE and SRCDX).

## 6.8 Work Problems

Write the SDEF card, and associated cards, explaining each instruction, for
1. An inward directed source on spherical surface.
2. A monodirectional source emitted from a surface in the direction of the direction positive to the surface.
3. A two-cell source neutron problem with uranium present in one cell and thorium present in the other.
4. A point source in which the low-energy particles are emitted with a cosine distribution, while the higher-energy particles have an isotropic distribution (use the Q option). Hint: the solution for some of these problems is in the MCNP manual.