CAVEL Reference Manual

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1. Introduction

The program CAVEL simulates the motion of ELectrons inside an RF CAVity. The cavity is assumed to be either an azimuthally symmetric cylinder or a rectangular box. The cavity may be immersed in a 2D or 3D external magnetic field. For the cylinder the cavity boundary coordinates and RF fields come from SuperFish.

The coordinate system used in the program has the z axis along the axis of the cavity. The cylindrical cavity is assumed to be centered at z=0. The rectangular cavity is assumed to extend from z=0 to z=cavity length. The external field can translated with respect to the cavity location using the ZOFF parameter. For the cylindrical cavity particles are normally launched in the y-z plane, in which case the radial direction is y. Secondary emission of electrons may also be simulated.

2. Input parameters

The program looks for the input file CAVEL.INP . This file contains the input parameters in Fortran namelist format. Default values for the parameters are listed below in parentheses.

ASCRF (I) Specifies left-right symmetry of the SuperFish cavity (0)
- 0: symmetric cavity
- 1: not symmetric

BNDNAME (A) Name of SuperFish file containing the cavity boundary coordinates

BX2D (R) Constant B_X field added to the 2D field grid [T] (0)

BY2D (R) Constant B_Y field added to the 2D field grid [T] (0)

BZ2D (R) Constant B_Z field added to the 2D field grid [T] (0)

CSCALE (R) Current normalization factor for external magnetic field (1.0)

EPSSTEP (R) Requires stepping accuracy (1d-5)

LAUNCH (I) Specifies electron launch conditions (1)
- 1: launch at maximum electric field location
- 2: use specified launch parameters
- 3: use list of boundary point numbers

Option 3 requires that RFDIM=2. For option 3 the user must supply a file named CAVEL.LST . The first line should contain the number of points (up to 20) that follow. The next line(s) is a list of boundary points separated by spaces. You can determine the boundary point numbers from the file CAVEL.LOG . The particle is launched along the local normal to the surface at the given boundary point.

MAGDIM (I) Specifies dimensions of external magnetic field (2)
- 0: no external field
- 2: azimuthally symmetric field
- 3: 3D field

MAGNAME (A) Name of external magnetic field map

MAXSTEPS (I) Maximum number of allowed steps for each track (2000)

NFIX (I) Maximum number of fixed steps near cavity boundary (10)

NPHI (I) Number of RF phase angles (1)

NTEMP (I) Number of random “temperature” related launches (1)

OFFLAUN (R) Displacement from the surface at start of tracking when LAUNCH=1 or 3. [m] (1d-6)

OTHERSIDE (L) If true => force the trajectory to start on the high field point on the opposite side. (false)
This command only works when LAUNCH=1 and ASCRF=0.

PHILO (R) Starting RF phase angle [deg]

PHISTP (R) Step in RF phase angle [deg]

PSURF (R) Initial momentum perpendicular to the surface when LAUNCH=1 [MeV/c]

PXLAUNCH (R) Initial p_X when LAUNCH=2 [MeV/c]

PYLAUNCH (R) Initial p_Y when LAUNCH=2 [MeV/c]

PZLAUNCH (R) Initial p_Z when LAUNCH=2 [MeV/c]

RFDIM (I) Specifies type of cavity (2)
2: SuperFish cylindrical cavity
3: rectangular cavity

RFNAME (A) Name of file containing RF fields
If RFDIM=2 this is a SuperFish T7 file. If RFDIM=3 this file contains the Cartesian field components for a rectangular cavity. See section 3 for a detailed description of the file contents.

RFNRM (R) Normalization factor for cavity RF field (1.0)

RNSEED (I) Random number seed (-1)

ROBTH (R) Polar rotation angle of external magnetic field from the *z* axis. [deg] (0.)

ROBPHI (R) Azimuthal rotation angle of external magnetic field from the *y* axis. [deg] (0.)
If the external file has a constant field along *z* (axial solenoid), then ROBTH=90, ROBPHI=0 gives a constant field along *y*, and ROBTH=90, ROBPHI=90 gives a constant field along *x*.

RSKIP (I) Number of RTUPLE steps to skip in output file (1)

RTUPLE (L) If true => write out electron parameters while stepping thru cavity (false)

SECEM (I) Controls secondary emission simulation (0)
- 0: no secondary emission
- 1: computes secondary emission yield (SEY) only
- 2: tracks secondary electrons

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See Section 5 for more details. The following four
parameters control the SEY model.
```

SEDELM (R) Parameter for calculating SEY. See Sec.5. (2.0)

SEEMAX (R) Parameter for calculating SEY. See Sec.5. (160 eV)

SEEPS0 (R) Parameter for calculating SEY. See Sec.5. (150 eV)

SEFANG (R) Parameter for calculating SEY. See Sec.5. (0.45)

SEMXDAU (I) Maximum number of daughter particles in secondary emission interaction (3) {1-8}

SEMXGEN (I) Maximum number of generations of secondary emission interactions (3) {1-8}

SIGP (R) Width of Gaussian momentum distribution at surface [MeV/c] (0.)

STEP (R) Initial time step [s] (1d-10)

STEPMAX (R) Maximum allowed time step [s] (1d-9)

STEPMIN (R) Minimum allowed time step [s] (1d-12)

XLAUNCH (R) Initial x position when LAUNCH=2 [m]

YLAUNCH (R) Initial y position when LAUNCH=2 [m]

ZLAUNCH (R) Initial axial position when LAUNCH=2 [m]

ZOFF (R) Axial offset of the center of the RF cavity in the coordinate system of the external magnetic field. [m] (0)

```
This parameter equals the external field coordinate
corresponding to the center of the RF cavity.
```

3. Input files

3.1 Cavity boundary file

This file is identified using the BNDNAME parameter. For RFDIM=2 the boundary information is contained in the SuperFish file OUTAUT.TXT . The maximum number of boundary points is 2000 for left-right symmetric cavities and 4000 for non-symmetric cavities.

3.2 Cavity RF fields

This file is identified using the RFNAME parameter.

For RFDIM=2 the RF field information is obtained by running the SuperFish postprocessor and requesting a Parmela output file with the extension T7. The cavity field map can have a maximum of 2000 radial and 2000 axial field points.

For RFDIM=3 the user must supply a file with the following format.

```
        Title                          (A80)
        cavity width  [m]
        cavity height  [m]
        cavity length  [m]
        cavity resonant frequency  [MHz]
        # of x grid points, nx         {<101}
        # of y grid points, ny         {<101}
        # of z grid points, nz         {<101}
For k=1,nz
  For j=1,ny
    For i=1,nx
        x(i)  y(j)  z(k)  Ex(i,j,k)  Ey(i,j,k)  Ez(i,j,k)  Bx(i,j,k)  By(i,j,k)  Bz(i,j,k)
```

E is in [MV/m], B is in [T].

3.3 External magnetic fields

For azimuthally symmetric fields the input has the same format as used by ICOOL SOL model 6. The required format of the field map is

```
        Title                          (A80)
        # of z grid points, nz         (I)          {1-5000}
        # of r grid points, nr         (I)          {1-100}
For j=1,nz
  For i=1,nr
        i   j   z(j)   r(i)   Bz(i,j)   Br(i,j )
```

A compatible field grid can be conveniently prepared in SLD version 1.21 or later by giving the AUXILIARY COMPUTATIONS command and then selecting FIELD GRID. After the grid has been calculated give the EXTRACT DATA command and then select

B grid. This will save the data to an external file.

For 3D fields the input has the same format as used by ICOOL STUS model 3.

```
        title                 (a80)
        mxg                   (I)    number of x grid points  {<101}
        myg                   (I)    number of y grid points  {<101}
        mzg                   (I)    number of z grid points  {<501}
        href                  (R)    curvature  [m^-1]
        (xgr(i),i=1,mxg)      (R)    x grid points  [m]
        (ygr(i),i=1,myg)      (R)    y grid points  [m]
        (zgr(i),i=1,mzg)      (R)    z grid points  [m]
For k=1,mzg
  For j=1,myg
    For i=1,mxg
        i   j   k   Bx(i,j,k)   By(i,j,k)   Bz(i,j,k)          [T]
```

4. Output files

4.1 Log file

A log file, which may contain error information, is written to CAVEL.LOG . In addition the file contains

Input parameters
Cavity boundary points (if RFDIM=2)
Trajectory summary data

4.2 Output file

Electron trajectory information for the starting and ending points are written to CAVEL.DAT . If RTUPLE is true, additional information along the trajectory inside the cavity is also written to CAVEL.DAT . The following information is recorded on this file:

Particle number
Step number
Flag
Initial phase [deg]
Position x, y, z [m]
Momentum p_x, p_y, p_z [MeV/c]
Time [s]
Kinetic energy [MeV]
Surface angle [deg]
Secondary emission yield
Initial position x_0, y_0, z_0 [m]
Initial momentum p_{x0}, p_{y0}, p_{z0} [MeV/c]
Initial time [s]
Total magnetic field B_x, B_y, B_z [T]
Electric field E_x, E_y, E_z [V/m]
Step [s]
Distance to boundary [m]
Closest cavity boundary point

5. Secondary emission model

The SEY(0) for normal incidence is calculated using the model given in R. Cimino et al., Phys. Rev. Lett. 93:014801, 2004, where

SEEMAX = E_{max}*
SEDELM = δ_{max}*
SEEPS0 = ε_o .

The SEY(θ) for non-normal incidence is calculated using the model from R. Kirby et al., SLAC-PUB-8380, 2000, p.18, where

$$SEY(\theta) = SEY(0) \exp[\alpha(1-\cos(\theta)]$$

and

SEFANG = α .

When SECEM=2 the value of SEY is used generate a number of secondary tracks determined from a Poisson distribution. The generated polar angle comes from a cosine distribution and the azimuthal angle comes from a uniform distribution [cf. M. Furman & M. Pivi, PRSTAB 5:124404, 2002, p. 4]. The energy distribution comes from a Gaussian due to "true secondaries" centered at 5 eV, a Gaussian due to elastic scattering centered at the energy of the parent particle, and a constant background at all energies. The relative height of the two Gaussians is adjusted depending on the parent energy roughly in accord with Fig. 1 in Cimino et al. Conservation of energy is enforced in the secondary production.

The program allows a maximum of 8 secondary particles to be created at the end of each track. The program will follow the secondary cascade for a maximum of 8 generations. The maximum number of produced secondaries for a given initial primary particle is 99.

6. Program execution flags

0	good tracking
1	Runge-Kutta stepper wants to use a step size less than HMIN (warning)
2	tracking driver wants to use a step size less than HMIN (warning)
3	this step went outside the cavity surface (informative)
-10	exceeded maximum number of allowed steps
-11	couldn't find nearest RF grid point inside cavity