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User's Guide for
MCFRM, a Monte Carlo Particle Code for FRM Studies

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MCFRM User's Guide

The Monte Carlo particle code MCFRM, described in this work is also written in the FORTRAN language and is available on either the MFE-7600 or the CRAY-1 computers. The discussion presented here will, however, deal only with the steps required to execute the code on the CRAY, since the majority of its use should be on that machine. The file containing the source can be obtained through FILEM by using the command:

```
FILEM .RDS 1345 .DRIEM MCFRMD / t v.
```

Presently, the program requires precompilation because of the dual machine option; therefore, before sending the FORTRAN source to the CRAY, the following must be done:

```
TOCFT MCFRMD MCFRM / t v.
```

This converts the program to a format that is acceptable by the CRAY, and the result is in a file named MCFRM, which is now ready to be sent to the CRAY. The file is transferred using the command:

```
NETOUT C MCFRM / t v.
```

Once logging onto the CRAY the user is ready to compile and load the MCFRM code by issuing the command:

```
RCFT I=MCFRM,L=0,LIB=(F',T') / t v.
```

This writes the executable file, XMCFRM, which can subsequently be run by typing:

```
XMCFRM D=data,H=output / t v.
```

Here the data, and output files can have any names, and a value for the time allocation t can be estimated by using the fact that the code runs at $\sim 50\mu s$ per particle per timestep; thus following 1000 particles through 1000 timesteps requires ~ 50 seconds of execution time. The code can, however, be restarted by typing:

```
+XMCFRM? / t v,
```

where ? is a letter corresponding to the channel being used, should the initial time allocation run out.

Upon completion, two output files will have been generated. The first (whose name was specified on the execute line) contains printed output, and the second is a graphics file beginning with the letter F. This file contains plots of the instantaneous particle distribution vs r , and the distribution vs P_0 , during slow down. It also contains a brief summary of the printed output along with a plot of one particle's trajectory. This graphics file can either be given to the operating system (which produces output in the form of microfiche) or plotted at a remote site by using the NETPLOT utility. The first option is selected by typing:

```
GIVE ALWITH. F 999999 END / t v,
```

while the second option is implemented by typing:

```
NETOUT <site> ALWITH. F F. L. D. BOX & ID / t v.
```

In the latter case, <site> is the code identifying the remote destination, and the D. option can be omitted if the user wishes to keep a copy of the graphics file on disk.

To illustrate the use of the MCFRM code, a typical data file and a condensed version of the corresponding output file are given in Tables B2 and B4. As Table B2 indicates, the input to the code is specified in NAMELIST format, and therefore a complete listing of the input variables is provided in Table B1. In addition, to aid in interpreting the printed output of Table B4, a summary of the output symbols is also provided in Table B3. Finally, for those individuals who are interested in the details of the code, a brief flow chart is provided in Fig. B1. This should help in locating general sections of coding; however specific questions should be referred to the author.

TABLE B1

Input Variables to the MCFRM Code

Block	Variable Name	Default Value	Remarks
TPART	RO	20*0.0	Selected by subroutine DISTRIB (if IFLAT is false) to represent the birth distribution of fps in the FRM.
TPART	UO	20*0.0	Note: The code assures that PARTO histories are followed in its initialization of particles.
TPART	CTHO	-1.0	Used to initialize particles in velocity space, if only one history is desired: CTH = 1.0 + CTHO
TPART	PHIO	0.0	PHI = PI + PHIO. Otherwise, the values of CTH and PHI are selected isotropically.
TPART	ET	Default values	Energy, mass, and charge of the test particles, corresponding to the following
	AMT	chosen	six cases by default:
		from	IFP = 1 --> 820-keV, D-D, ³ He.
	ZT	the	= 2 --> 1010-keV, D-D, T.
		value	= 3 --> 3020-keV, D-D, p.
		of	= 4 --> 3520-keV, D-T, α.
		IFP	= 5 --> 3670-keV, D- ³ He, α.
			= 6 --> 14680-keV, D-He, p.

Block	Variable Name	Default Value	Remarks
			However, an alternate type of test particle can be specified by entering new values for ET(1), AMT(1), and ZT(1).
TPART	PTHETA	10.0	Used for making orbit studies where only one particle history is calculated. For these studies, IONE and IFLAT must be true; furthermore, NLCP must be false to see unconfined particles. (PTHETA is entered in units of $m_{\omega} R_{HV}^2$.)
TPART	PARTO	1000	The number of particle histories that the code tries to assure are followed.
TPART	NPTH	20	The number of P_{θ} groups used in constructing the distribution plots vs P_{θ} during slow down.
TPART	NUMR	Chosen by DISTRIB	The number of radial starting positions, R_0 , in physical space.
TPART	NUMU	Chosen by DISTRIB	The number of starting angle cosines, U_0 , in physical space.
TPART	NUMTHET	Chosen isotrop'ly	The number of starting angle cosines, CTH , in velocity space.
TPART	NUMPHI	Chosen isotrop'ly	The number of starting azimuthal angles, PHI , in velocity space.

Block	Variable Name	Default Value	Remarks
BACK	RHV	20.0	Hill's vortex radius (cm).
BACK	BVAC	60.0	Vacuum magnetic field strength (kG).
BACK	TI1	100.0	Closed field ion temperature (keV).
BACK	TE1	90.0	Closed field electron temperature (keV).
BACK	T2	0.05	Open field temperature (keV).
BACK	DEN10	5.0E15	Peak closed field ion density (cm^{-3}).
BACK	DEN20	2.0E13	Open field ion density (cm^{-3}).
BACK	FFI	1.0	Used to "turn off" the ion drag, while still including the electron drag.
BACK	DRGEN	1.0E04	variable drag enhancement factor.
BACK	AMI	2.6	Average ion mass (AMU).
BACK	AME	5.5e-4	Electron mass (AMU).
BACK	ZION	1.5	Average ion charge.
BACK	FCUTOFF	3.0	The multiple of the hot ion temperature corresponding to the cutoff energy.
BACK	CAPRIST	1.0	Used to allow for a vacuum layer between the open and closed field regions. Vacuum exists if CAPRIST>1.
BACK	ZK	1.0	Plasma elongation factor, K.
BACK	FRV	0.001	Maximum allowable change in the particle velocity during a timestep. FRV is used to determine DRGEN during the run.

Block	Variable Name	Default Value	Remarks
ONE	RMIN	0.0	Minimum radial boundary on orbit plots.
ONE	RMAX	1.6	Maximum radial boundary on orbit plots.
ONE	ZMIN	-1.6	Minimum axial boundary on orbit plots.
ONE	ZMAX	1.6	Maximum axial boundary on orbit plots.
ONE	ESCALE	0.0	The number of hot ion temperatures equal to the maximum energy on the energy distribution plots. The maximum energy on the plots will be chosen by the code if ESCALE=0.0.
ONE	NEPLT	20	The number of energy groups used.
ONE	NPDEL	1000	The number of timesteps between intermediate printouts.
ONE	NITPLT	9000	The maximum number of timesteps per orbit plot.
ONE	NDT	32	The number of timesteps per cyclotron period.
ONE	NITMAX	10	The maximum number of timesteps.
ONE	NRU	12	The number of radial bins used in constructing plasma heating profiles.
ONE	NZU	30	The number of axial bins used in construction plasma heating profiles.
ONE	NPLT	1	The particle history that is plotted.

Block	Variable Name	Default Value	Remarks
LGIC	NDRG	FALSE	Used to specify "no drag".
LGIC	NPAS	FALSE	Used to specify "no pitch-angle scattering or velocity diffusion."
LGIC	IFLAT	FALSE	Used to specify that a "test case" is being run where the background density is uniform.
LGIC	IONE	FALSE	Used to specify only one history, NPLT chooses which one.
LGIC	NLCP	TRUE	Used to include histories of particles that are not confined.
LGIC	IQUIT	FALSE	Used to run multiple cases.

TABLE B3

Definition of Symbols Found in the Output File

Symbol	Meaning
NIT	Integer number of timesteps in units of $2\pi/\text{NDT}/\omega_0$ where $2\pi/\omega_0$ is the cyclotron period of the test particle in the vacuum field, and NDT is the number of timesteps that correspond to a cyclotron period.
NSTOP	The number of particle histories that have been terminated by NIT.
ETAV	The average energy of the remaining test particles in (keV).
FDRG	The average fractional change in the particles' velocity, due to drag, during the last timestep.
FPAS	The average fractional change in the particles' velocity, due to pitch-angle scattering and velocity diffusion during the last timestep.
DRGEN	The drag enhancement factor.
DVXSQ	The deviation in the particles position relative to the x-plane (in units of RHV^2).
DVRSQ	The deviation in the particles position relative to the cylindrical axis (in units of RHV^2).

Symbol	Meaning
BVAC	The vacuum magnetic field strength (kG).
RHV	The radius of the spherical vortex region (cm).
VTOT	The initial velocity of the test particles, in units of $(RHV \times NDT \times \omega_o / 2\pi)$.
OMEG	The cyclotron frequency of the test particles in the vacuum field, ω_o , (sec^{-1}).
DELTA	The length of a timestep (sec).
NDT	The number of timesteps per cyclotron period.
TI-1	The ion temperature in the closed field region (keV).
TE-1	The electron temperature in the closed field region (keV).
DEN1	The average ion density in the closed field region (cm^{-3}).
T-2	The temperature in the open field region (keV).
DEN2	The ion density in the open field region (cm^{-3}).
RTST	The minimum radius where the cold plasma properties are used in the calculation (same as CAPRTST).
FION	The fraction of the retained fp energy that is given to the ions.
FELE	The fraction of the retained fp energy that is given to the electrons.
FAC	The fraction of the charged fps that are absolutely confined.
FHCF	Fraction of the charged fp energy that is deposited in the closed field region.

Symbol	Meaning
FHOF	Fraction of the charged fp energy that is deposited in the open field region.
FHLC	Fraction of the charged fp energy that is carried out of the system by unconfined fps.
PDCF	Fraction of the charged fps that are deposited in the closed field region.
PDOF	Fraction of the charged fps that are deposited in the open field region.
PDWA	Fraction of the charged fps that hit the wall.
ETAV	The average superthermal fp energy (keV).
TAUSD	The average slowing down time for the confined fps (sec).
TAUP	The average confinement time for the fps (sec).
CLNE1	The Coulomb logarithm for ion-electron interactions in the closed field region.
CLNI1	The Coulomb logarithm for ion-ion interactions in the closed field region.
NLC	The number of the test particles that were in the loss cone (i.e., unconfined at birth).
CLNE2	The Coulomb logarithm for ion-electron interactions in the open field region.
CLNI2	The Coulomb logarithm for ion-ion interactions in the open field region.
NSTOP	The total number of histories that were calculated.