Computing and plotting fast ion distributions in ASCOT

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*this file: ASCOT\_distributions\_01.docx*

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| switch to enable (1=ON) | spatial coordinates | | | | velocties | | | other | |
|  |  |  |  |  |  |  |  |  |  |
| ENABLE\_DIST\_5D | R | phi | z | - | ppa | ppe | - | t | q |
| ENABLE\_DIST\_6D | R | phi | z | - | pR | pphi | pz | t | q |
|  |  |  |  |  |  |  |  |  |  |
| ENABLE\_DIST\_RHO5D | rho | pol | phi | z | ppa | ppe | - | t | q |
| ENABLE\_DIST\_RHO6D | rho | pol | phi | z | pR | pphi | pz | t | q |

*Table 1. The four distributions available in ASCOT*.

ASCOT can compute four different types of distribution functions as shown in Table 1. The actual distribution data is stored as a multi-dimensional histogram, and we use postprocessors such as compare\_distributions.py to convert the histogram data into distribution functions with physically-meaningful units such as particles per m3.

I think that ASCOT can compute any combination of these distributions simultaneously, i.e. you don’t have to pick and choose among them. TDB: discuss the the computational cost (memory and CPU time) associated with computing distributions.

Note #1: if you set e.g. ENABLE\_DIST\_5D=1, then in the ASCOT input file you also need to define a *grid* for each of its coordinates, e.g. values for Rmin, Rmax, and NR would define the spatial grid in major radius (number of grid points = NR). I think the grid is constructed to be equally-spaced between the user-defined minimum and maximum values.

Note #2: the calculation of the distribution function has *nothing to do* with saving orbit positions. You could choose not to save any orbit positions at all, but if say ENABLE\_DIST\_5D =1, then ASCOT will compute the distribution function anyway.

Note #3: we probably are interested in distributions that include the minor-radial coordinate ‘rho’. For purposes of evaluating the effect of MHD on the alpha distribution function, I think that we probably want the DIST\_RHO5D distribution function, which includes the 3 spatial coordinates and momenta parallel and perpendicular to the magnetic field.

Note #4: probably for our simulations, we are not interested in the poloidal angle (pol) or the toroidal angle (phi). So when we compute say the alpha density as a function of minor radius rho, we will typically sum over all pol and all phi and all t and all q.

Spatial coordinates

R major radius

rho flux surface

pol poloidal angle

phi toroidal angle

z z-coordinate

Velocity coordinates

ppa momentum component parallel to magnetic field

ppe momentum component perpendicular to magnetic field

pphi momentum component in phi direction

pR momentum component in major radius direction

pz momentum z-component

Other

t time

q charge

Python postprocessors in the ‘mypython’ directory:

plot\_distributions.py (timestamp 8/15/2022)

compare\_distributions.py (timestamp 6/21/23)

I started writing plot\_distributions.py, but quickly realized that the main purpose of the postprocessors is to compare two ASCOT runs. So the Python script compare\_distributions.py has more functionality and is more recent. If you have only one ASCOT simulation whose distribution function you would like to plot, I would use compare\_distributions.py and just enter the single simulation twice. I think that compare\_distributions.py will malfunction if you give it just a single ASCOT run.

A sample run of compare\_distributions.py

Basically, you need the names of two or more ASCOT runIDs and the equilibria files that were used by them. You can issue an Enter (<cr>) in response to most prompts. The code takes only a minute or so to run.

myenv) sscott@perlmutter:login28:/global/cfs/cdirs/m3195/ascot/ascot5/runs> python

Enter 1 if you want 6D plots: ( default=0) 0

available colormaps: viridis, cividis, plamsa, YlOrRd, spring, summer, hot, Blues, gnuplot2, rainbow

Enter colormap: ( default=rainbow) rainbow

name of file with profile information: ( default=v1e\_profiles\_3.txt)

Suffix for pdf filename( default=) \_this\_is\_a\_test

minimum density frac for 2D delta plots: ( default=0.01) <cr>

minimum rho for velocity distribution plot: ( default=0.0) <cr>

maximum rho for velocity distribution plot: ( default=0.2) <cr>

slimming factor for vpar: ( default=4) <cr>

slimming factor for vperp: ( default=3) <cr>

Name of equilibrium file: ( default=geqdsk\_freegsu\_run0\_mod\_00.geq) <cr>

ascot output filename (<cr> to finish: ( default=) ascot\_66562578.h5

Name of equilibrium file: ( default=geqdsk\_freegsu\_run0\_mod\_00.geq) <cr>

ascot output filename (<cr> to finish: ( default=) ascot\_66512304.h5

Name of equilibrium file: ( default=geqdsk\_freegsu\_run0\_mod\_00.geq) <cr>

ascot output filename (<cr> to finish: ( default=) <cr>

* this generated output file: compare\_distributions\_66562578\_this\_is\_a\_test.pdf