§14. Upgrades of the Raytracing Code "LHDGauss" to Incorporate TS Mesh Database

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The raytracing code "LHDGauss" which has been developed for analyzing the ray propagation and absorption in three dimensional configuration plasma, and has been utilized for analyzing the ray behavior and the power deposition profile of the electron cyclotron resonance heating (ECRH) in LHD, where the ECRH power is injected as strongly focused Gaussian beam. This code is updated to incorporate the "TSmesh" database which is generated soon after the LHD shot utilizing YAG-Thomson scattering data.

The original LHDGauss code had utilized pre-calculated VMEC output files for selected magnetic configurations. This VMEC output is expanded and mapped on the cylindrical mesh points. These mesh points are constructed of radially 65 points, vertically 65 points in every 0.05 m centered at $R_0 = 3.9$ m on the mid-plane for 17 poloidal cross-section from 0 to 18 degree (every 18/16 degree, half toroidal period). The vacuum magnetic field components on each mesh point are also pre-calculated for sets of helical and poloidal field coil currents. The density and temperature profiles are given as polynomial coefficients as a function of the normalized minor radius ρ. These pre-calculation of the magnetic fields and ρ on the mesh points enabled relatively fast calculation of the ray trajectory by interpolating the the plasma parameters on each ray step. The magnetic configuration file and magnetic field, injection beam parameters (injection point, waist size waist position) and injected power had been selected and set into the input file of "LHDGauss". These process is shown in Fig. 1.

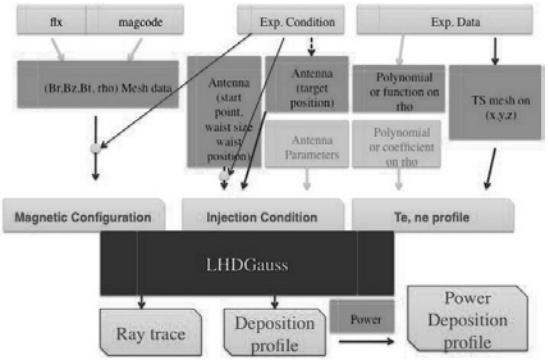

Fig. 1: Original flow chart of "LHDGauss"

In order to incorporate "TSmesh" database and to automate the ray-tracing calculation process, several upgrades of "LHDGauss" have been made. In Fig. 2 is shown upgraded flow chart.

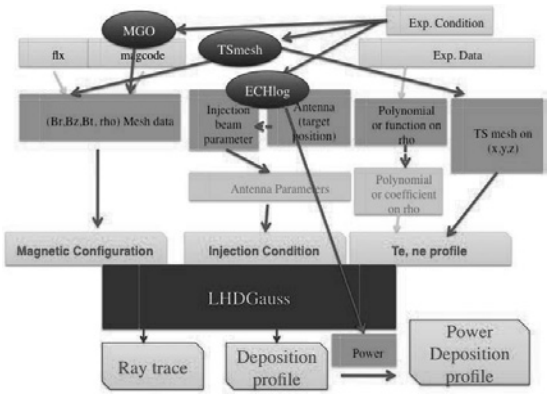

Fig. 2: Flow chart of upgraded "LHDGauss"

The registered "TSmesh" database consists of the same mesh size as that used in the previous LHDGauss but only within the last closed flux surface (LCFS) for 10 poloidal cross-section from 0 to 18 degree (every 2 degree, half toroidal period) in every meaningful YAG-Thomson time slice of every LHD shot. Due to the absence of the flux surface label ($r_{\rm eff}$) outside of LCFS, and also the need for the interpolated data on the mesh points on the poloidal cross section at 0 to 18 degree every 18/16 degree, $r_{\rm eff}$ is extrapolated and interpolated by determining the bi-quadratic coefficients in Cartesian coordinates so as to fit nearest 512 original mesh points inside LCFS. This fitting is executed using singular value decomposition (SVD) and these derived coefficients are saved at each mesh point for smooth interpolation between mesh points during the ray calculation. Although the magnetic field components are also available in the "TSmesh" database, vacuum magnetic field components on each mesh point are recalled from pre-calculated mesh data for sets of helical and poloidal field coil currents of the given shot number. This is because the magnetic field components near the magnetic axis and outside of LCFS are not available in the "TSmesh" database and the utilization of the magnetic fields in the database is left for the future upgrade. The polynomial density and temperature profile coefficients are retrieved from registered database "TSwpe" for relevant shot and time slice as a default. Injection condition (antenna position, angle, polarization, power) is also automatically retrieved from ECH log database.

Another upgrade independent to the database is that the fraction of the O- and X-mode is calculated automatically calculated using the peripheral data and solving full wave along straight line corresponding the center of the ray using injected polarization from the antenna. The peripheral data is given by fitting the TSmap data outside of effective minor radius a_{99} within which 99% of the kinetic energy included as a function of expanded $r_{\rm eff}$. Experimental validation of this method of polarization determination is underway.