THE **TRACE ION MODULE** FOR THE MONTE CARLO CODE EIRENE

A new tool for investigation of *Impurity Transport* in Fusion Edge Plasmas

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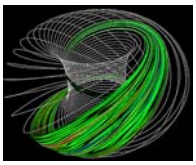
Modelling of **Plasmas** in Fusion Devices:

two regions: **core plasma** and **scrape off layer**

Modelling the Scrape Off Layer:



I ***magnetic field:*** Grad Shafranov equations (**EFIT**)

II ***fluid description of the main plasma:*** Braginskii equations (**B2**(2d) and **EMC3**(3d))

III ***impurities:*** ***kinetic model for neutral impurities (EIRENE)***

until now: ***fluid description of impurity ions***

new: ***kinetic model for charged impurities; Fokker Planck equation***

…and a lot more: atomic physics, chemistry, radiation physics, plasma wall transition, …

The Monte Carlo Code EIRENE …

- solves multispecies **neutral gas transport** equations
- can access external databases for atomic and molecular data and surface data
- can be coupled to plasma fluid codes like B2, EMC3, …

Greek goddess of peace
EIRENE

more info:
www.eirene.de

The idea: extend EIRENE to allow for transport of **charged particles**:

TRACE ION MODULE

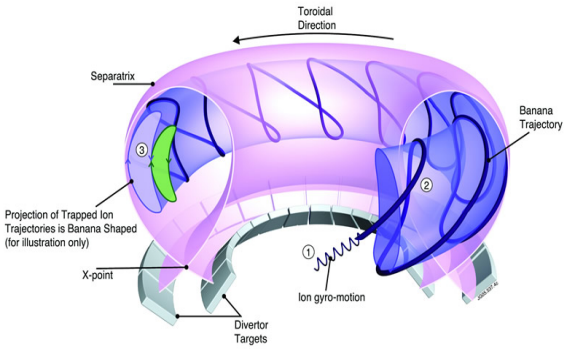
TRACE ION MODULE:

…solves the gyro-averaged Fokker Planck equation

$$f = f(\vec{x}, v_{\parallel}, v_{\perp})$$

$$v_{\parallel} = \vec{v}\cdot\vec{b}, \quad v_{\perp} = |\vec{v}\times\vec{b}|$$

$$\begin{aligned}\frac{\partial f}{\partial t} = &-\frac{\partial}{\partial \vec{x}}\left(\dot{\vec{x}} f\right) - \frac{\partial}{\partial v_{\parallel}}\left(\dot{v}_{\parallel} f\right) - \frac{\partial}{\partial v_{\perp}}\left(\dot{v}_{\perp} f\right) \\ &- \frac{\partial}{\partial v_{\parallel}}\left(K_{\parallel} f\right) - \frac{\partial}{\partial v_{\perp}}\left(K_{\perp} f\right) \\ &+ \frac{1}{2}\frac{\partial^2}{\partial v_{\parallel}^2}\left(D_{\parallel\parallel} f\right) + \frac{1}{2}\frac{\partial^2}{\partial v_{\parallel}\partial v_{\perp}}\left(D_{\parallel\perp} f\right) \\ &+ \frac{1}{2}\frac{\partial^2}{\partial v_{\perp}\partial v_{\parallel}}\left(D_{\perp\parallel} f\right) + \frac{1}{2}\frac{\partial^2}{\partial v_{\perp}^2}\left(D_{\perp\perp} f\right)\end{aligned}$$

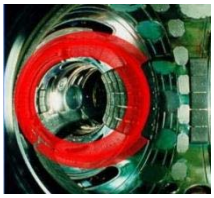


method of solution:
tracing the motion and collisions of millions of Monte Carlo particles

Components of the TRACE ION MODULE

1. trajectory integrator:

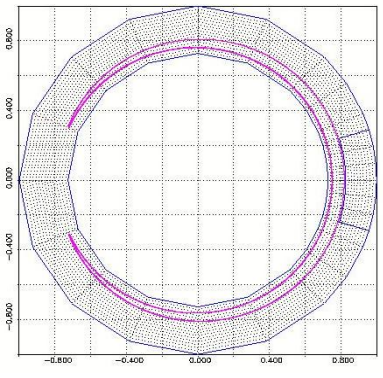
$$\dot{\vec{x}} = v_{\parallel}\vec{b} + \frac{\vec{E}\times\vec{B}}{B} + \frac{1}{2}\frac{v_{\parallel}^2}{\Omega}\frac{\vec{b}\times\nabla\vec{B}}{B} + \frac{v_{\perp}^2}{\Omega}\vec{b}\times\left(\vec{b}\cdot\nabla\vec{b}\right)$$

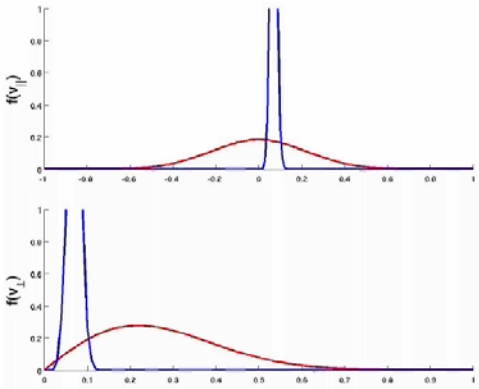


2. numerical representation of the Fokker Planck collision operator

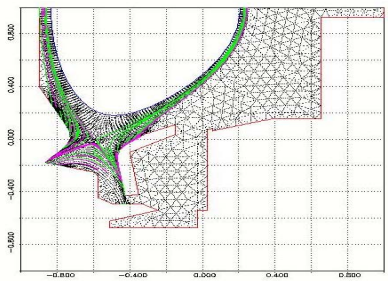
$$C_{\alpha\beta}^{FPK}\left(f_\alpha, f_\beta\right) = -\sum_i \frac{\partial}{\partial v_{\alpha i}}\left(K_i^{\alpha\beta} f_\alpha\right) + \frac{1}{2}\sum_{i,j}\frac{\partial^2}{\partial v_{\alpha i}\partial v_{\alpha j}}\left(D_{ij}^{\alpha\beta} f_\alpha\right)$$

EIRENE velocity spectrum for one of the grid cells:

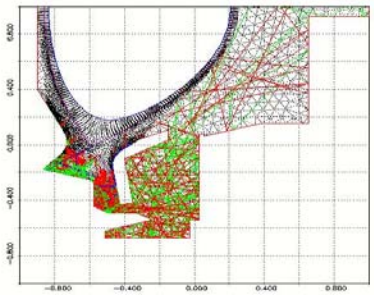




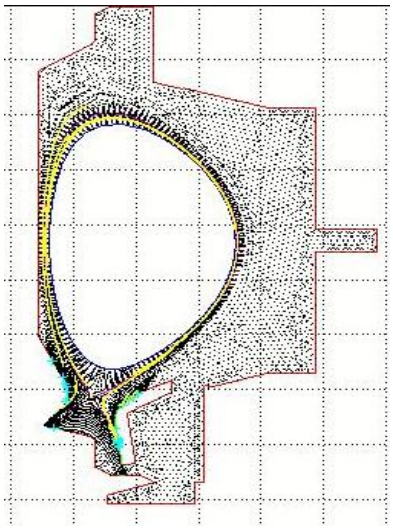
EIRENE trajectories, Alcator CMOD Tokamak, MIT



traces of charged particles



traces of the neutrals



Status of the extended EIRENE Code

The TRACE ION MODULE is fully working within EIRENE. Benchmarking, verification and validation will be finished till the end of the year.

Future Plans

- **Incorporation of the Trace Ion Module into the master version of the EIRENE code at IPP in FZ-Jülich.**
- **Physics applications focused: hydrocarbon physics near the divertor, tritium retention problems**
- **Ph.D thesis**