Modelling NBI in ITM environment with ASCOT

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Motivation

Neutral beam injection (NBI) is an important source of heating, particles, and toroidal momentum in current tokamaks. It is also foreseen to be one of the main heating schemes in ITER. However, the significance of NBI is not limited to heating. It will also be the dominant non-inductive current drive source in ITER and, thus, particularly important for steady-state scenarios. Therefore, accurate modelling of NBI is vital.

ASCOT [1]

- Guiding centre orbit following Monte Carlo -code
- Numerically integrates particle's equations of motion in Cartesian coordinates using 5th order error-monitoring Runge-Kutta method
- Monte Carlo collision operators [2] affecting particle pitch and energy accurately model neoclassical transport and slowing down
- Acceleration of collision time scales and nearly ideal parallelization $\Longrightarrow$ large amount of test particles and long simulations
- Collects a myriad of data: n_{fast}, collisional power transfer to ions, electrons & impurities; v, $v_{\parallel}$, and $v_{\perp}$ distributions; parallel, radial, and orbit loss current, ...

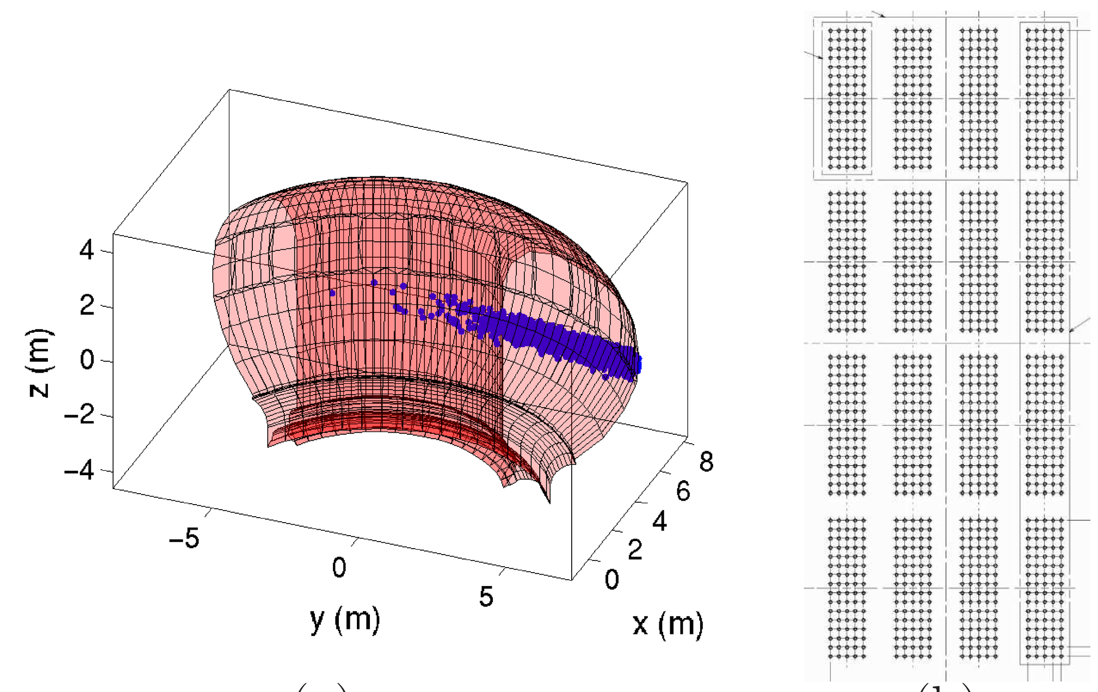
Beamlet-based NBI-model

BBNBI will eventually become a stand-alone Kepler actor. Its development is, however, closely related to that of ASCOT, because BBNBI needs the same input CPOs as ASCOT (and then some).

Model description:

1. Choose a neutral particle from random beamlet (e.g. ITER injectors have 1280 beamlets)
2. Assign the neutral a velocity in the direction of the beamlet offset by a (bi-)gaussian dispersion
3. Choose a random threshold (between 0 and 1) and advance the particle until the probability of the particle surviving further is below the threshold
4. Ionization $\Longrightarrow$ create a test particle for ASCOT

For ionization cross-sections σ, calculated at each time step using the local T and n, analytical fits to macroscopic ionization cross-sections given by Suzuki *et al.* [3] are used.

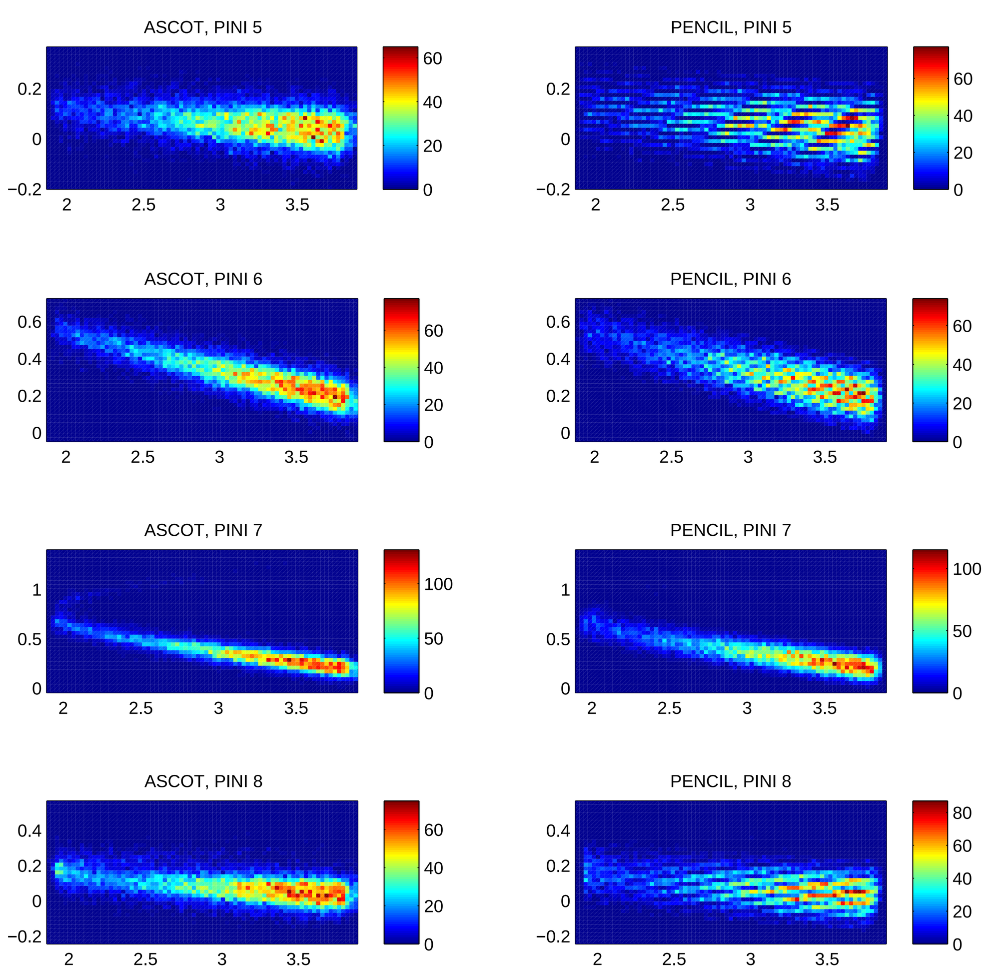


(a) (b)

(a) Test particles from ITER NBI and (b) the grounded grid showing the beamlet starting points.

Comparison against PENCIL at JET

In order to verify the model, comparisons with the NBI codes currently used at tokamaks were performed.



NBI test particle ionization locations from JET Octant 8 PINIs 5-8 with ASCOT and PENCIL projected to an (R,z) plane. The "pencils" can be seen in PENCIL figures.

Results:

- Test particle locations and pitches practically identical

  $\Longrightarrow$ Model works with the hard-coded geometry
- No "pencils" seen in the figures

  $\Longrightarrow$ beamlets with divergence produce smoother ensembles

The next step is to be able to produce similar particle ensembles without hard-coded geometry, but only CPO input.

Status with regards to ITM

- ASCOT has been ported to the ITM Gateway
- Basic CPO input implemented and tested (1D n and T, axisymmetric $\mathbf{B}$ and wall)
- Readiness for more complex input (2D n and T, 3D $\mathbf{B}$ and wall) as soon as the data exists in CPOs
- Code specific input converted to XML
- Stand-alone testbed program exists
- NBI input CPO still missing $\Longrightarrow$ no testing of NBI with CPOs done yet
- CPO output not implemented. Need to discuss what outputs are required

Conclusions and Future Work

- ASCOT is up and running on the Gateway
- BBNBI has been tested and shown to work
- Still coding/testing to do to make them work fully with CPOs
- ASCOT and BBNBI should be turned into Kepler actors
- Development of the codes is ongoing, e.g. including ADAS cross-sections to BBNBI

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References

[1] T. Kurki-Suonio *et al.* Nucl. Fusion **49** (2009) 095001
[2] A. H. Boozer and G. Kuo-Petravic, Phys. Fluids, **24** (1981) 851-859
[3] S. Suzuki *et al.*, Plasma Physics and Controlled Fusion, **40** (1998) 2097