

# JINTRAC – JET modelling suite – 2008

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## I Introduction to the code suite JINTRAC

This report summarises the new developments for the JET in-house integrated plasma transport modelling tools planned, procured and executed throughout the years 2007–2008. Plasma modelling tools such as JETTO and EDGE2D were taken and their communication and interaction schemes were revised and improved. New modelling tools such as multi-dimensional Monte-Carlo codes like ASCOT

for fast ion transport in the core plasma and EIRENE for cold and hot neutrals following in the core and edge were already available at JET and are now integrated into a new modelling suite now called JINTRAC (an acronym for: Jet INtegrated TRANsport Code).

In the past JETTO and EDGE2D were the central parts of the integrated modelling suite already available at JET, where JETTO is a 1.5D fluid plasma code solely for the core plasma evolution and EDGE2D models the 2D domain of the plasma edge for divertor machines. The combination of JETTO and EDGE2D was (and still is) called COCONUT and this integration of core and edge/SOL modelling is needed whenever fixed boundary conditions (ie at the separatrix) are unbearable anymore. COCONUT has been used for example to model fast transients like ELM-dynamics. But the need of more relevant physics models for the simulations, eg. modules for more sophisticated transport models, heating systems, MHD-activity and stability, neutrals atomic and molecular physics and more has lead eventually to a very complex and not easy-to-use integrated modelling suite. But ideally, and thus as a general principle for plasma modelling, each physics module or feature should be made switchable. With other words the user of the code should be entitled to decide him/herself what modules and what physics should be used in the simulation. Ultimately, this philosophy has lead to a modelling construction kit which is now available.

To emphasize this new view of integrated modelling at JET it was decided to create a new name for the in-house modelling suite now available, namely JINTRAC.

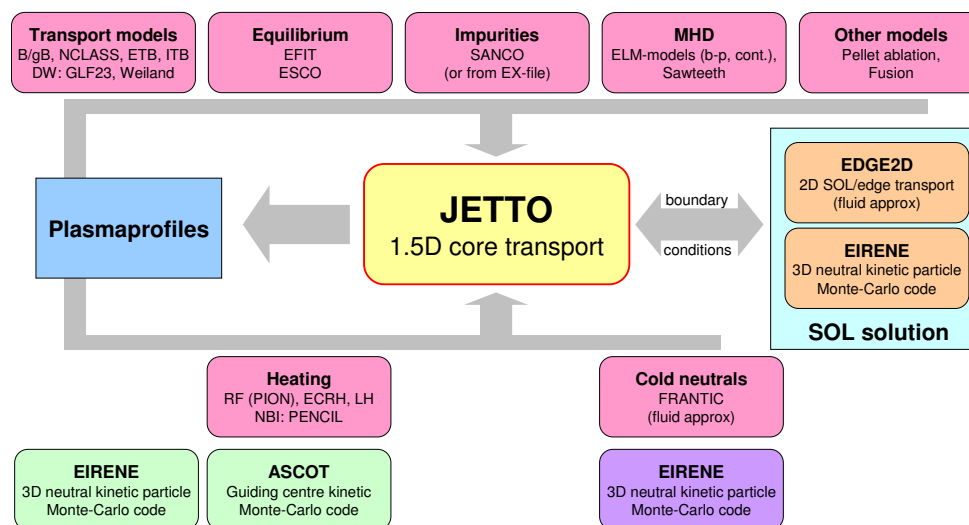


Figure 1: Schematic of JINTRAC modelling suite

Figure 1 displays a scheme of the JINTRAC modelling suite now in place. Central part of JINTRAC is JETTO the 1.5D core plasma fluid code which solves for the plasma profiles in the core including the edge up to the separatrix. JETTO can be used as a stand-alone transport model but then it needs a set of boundary conditions at the separatrix. The latter assumptions can be relaxed by using the 2D SOL layer code EDGE2D which solves 2D fluid equations for the SOL. EDGE2D is directly connected with EIRENE which is solving the volumetric particle, momentum and heat source from neutral interactions. EIRENE is a general 3D Monte-Carlo code which follows neutral particles by bookmarking their tracks and events. The latter are defined by interactions with the plasma (eg ionisation, recombination, charge exchange etc) or interactions with the outer-world ie the vessel (main-chamber and target plates).

JETTO needs additional input parameters which can be a function of the underlying plasma-profiles. Specifically, the transport models may depend on the plasma. Several models can be applied here, from simple models (fixed in time and space), experimental scaling laws, heuristic transport models (eg. Bohm/Gyro-Bohm transport) to stiff theory-based drift-wave models (eg GLF23).

The simulation domain is defined by a grid which is usually derived from the output of an equilibrium solver. For the time being there are the following options: ESCO (a self-consistent equilibrium solver included in JETTO) and EFIT. The latter is channeled through the FLUSH library which is flexible enough that also other equilibria (not only JET) can be taken into account. EDGE2D also needs information about the equilibrium to incorporate geometric effects (EDGE2D is a 2D code, thus it can handle flux-expansion effects, the X-point including a divertor geometry). An EDGE2D grid is processed by a pre-processing tool GRID2D. For the time being, in EDGE2D the grid has to be fixed for the whole simulation.

Impurities can be treated in EDGE2D (up to 2 impurity species here) and JETTO. SANCO is the model used within JETTO to calculate the impurity transport.

Special MHD models can be applied in JETTO too, eg local ELM-models based on simple adhoc assumptions on the ELM activity (duration, amplitude and structure) or more complex non-local models as well. There is a sawtooth model included. Further models for pellet ablation or the calculation of the fusion product are available in JETTO as well.

There are several heating models applied for JETTO to simulate the heat deposition profiles in a time-dependent manner: PION for RF heating, a ray-tracing ECRH model and a LH model. PENCIL can be used as a quick tool to calculate deposition profiles from NB injection.

Cold neutrals cool down the edge since they act as a heat sink when the neutrals from outside cross the separatrix and interact with the hot plasma. They also represent a fuelling mechanism for the core plasma. There is a simple fluid-approximation for these neutrals available, called FRANTIC.

Within the project 2008 two new code modules had been introduced too: Firstly, ASCOT a multi-dimensional Monte-Carlo code to provide a new model for neutral

beam deposition profiles (heat, source, torque, current etc). It consists of a stochastic approach to evaluate the slowing down of hot ions which stem from interactions of fast NB neutral emitted from an external injector. A so-called birthprofile for fast ions is needed (ie a kinetic fast-ion source distribution) which is calculated here by EIRENE (EIRENE is general enough not only to be used for cold but also for hot neutrals). The details of the new module for beam deposition (ie the ASCOT-EIRENE link) is explained in detail below.

The second update installed within the 2008 project was another use of EIRENE to replace FRANTIC, ie to use EIRENE also to calculate the cold neutrals distribution in the core plasma within JETTO. Here, not a 1D fluid-approach but a 2D kinetic description of the neutrals is applied. Details for this new option is also explained below in this report.

## **Ib JINTRAC modelling kit**

JINTRAC, schematically represented in figure 1, comprises of a closed loop for the time-dependent evolution of the plasma core profiles including an evaluation of boundary conditions (ie interaction with the outer world) and relevant physics models. But normally, the user does not want to have all features of JINTRAC enabled at the same time since some modules of JINTRAC can be very slow. For example the evolution of the boundary conditions (separatrix) can provide JINTRAC with a bad performance since the SOL will transport the plasma on a much faster time-scale as for the core and thus the time-step in SOL evolution of the plasma can be very low. On top, the application of a Monte-Carlo method for the cold divertor neutrals can worsen the performance of JINTRAC, specifically when the user does actually know that a time-evolution of the boundary conditions is of no importance or when the core density is not evolved anyway and the separatrix density could be fixed. Basically, then the evolution of the SOL plasma is of no big interest and should therefore be excluded.

Essentially, the user should be enabled to decide whether he or she wants a specific module or feature switched on or not. This is indeed possible within JINTRAC.

Figure 2 shows in general all the options the user can have. Here, only the codes with most impact on the performance (acting as separate codes) are listed, ie JETTO, EDGE2D, EIRENE and ASCOT. In principle, it can be seen as a modelling construction kit where one can decide to use JETTO as stand-alone or in connection with EDGE2D-EIRENE. Whether EIRENE should be used for the cold neutrals in edge region or not. Or whether ASCOT is needed to simulate the beam deposition profiles or not.

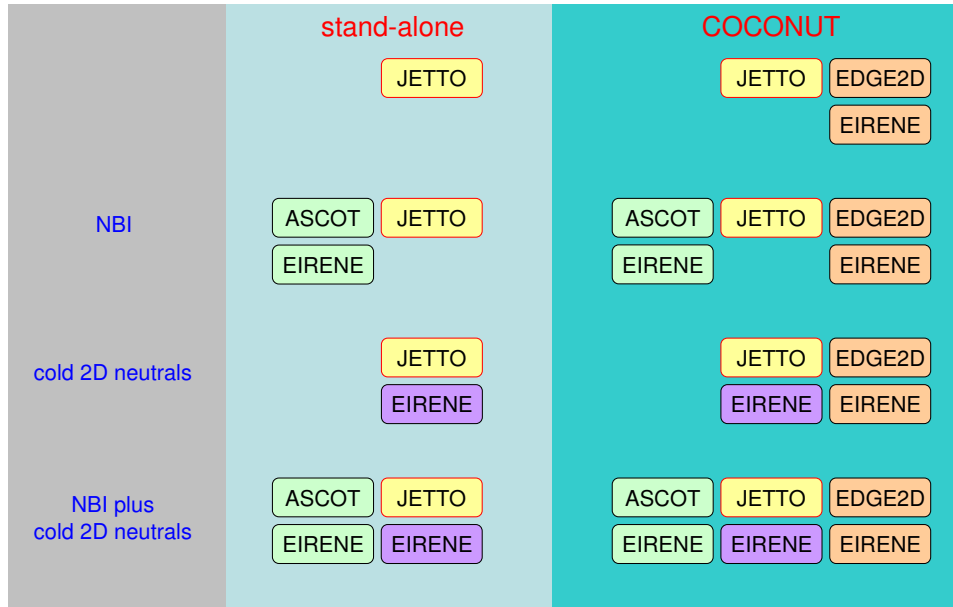


Figure 2: JINTRAC modelling construction kit

### Ic JINTRAC communication layer

Since JINTRAC consists of code parts (JETTO, EDGE2D, EIRENE, ASCOT) which are smoothly and transparently integrated into each other, the user generally does not realise when and how the codes communicate with each other. ASCOT as a performance demanding kinetic code for the fast-ions is MPI parallelised. JET has a cluster of separate CPU nodes which communicate through the network. So, ASCOT parallel feature can be used (and in fact the user can define the number of processors for ASCOT being allocated). On the other hand, JETTO, EDGE2D and EIRENE are running on a single node only (though EIRENE has the capability to be run in MPI parallel mode but we do not make any use out of it yet). The communication between JETTO, EIRENE and ASCOT is given by communication through the NFS (network file system), eg JETTO is told when ASCOT has finished its calculation of the deposition profiles whereas JETTO is idling at the same time. Generally, this way of communication between the codes works fair enough. Sometimes we experience a delay when the NFS is not updated on time. Thus from time to time it happens that some additional overhead is created simply by an uneffective communication which stems from the fact that files on the NFS are not fully synchronised (though we speak only about a few seconds, but they can accumulate). It is foreseen, to overcome this issue in the future by a direct communication between the codes running on different nodes via TCP/IP sockets.

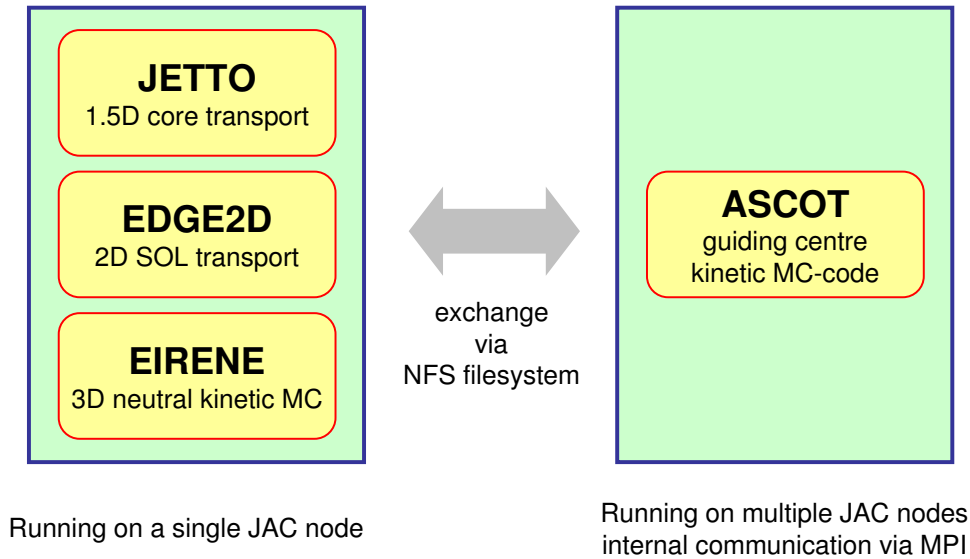


Figure 3: JINTRAC communication

## II Implementation of new code

### IIa generalised use of EIRENE in JINTRAC

When EIRENE was linked into EDGE2D in 2005/6 it was not foreseen to link it with anything else at that time. Therefore, EIRENE was part solely of the EDGE2D source code repository. But generally, EIRENE is solving the Boltzmann integral (Fredholm equation of the second kind) through a general Monte-Carlo method, ie simply by following pseudo particles along their track and bookmarking of events. Thus, EIRENE can simulate not only cold neutrals for tokamak divertors, its generality allows to model any particle species which transport is prescribed by the Boltzmann equation (in fact EIRENE can also model radiation transport by following photons).

Thus, EIRENE was thought to be used to produce the cold neutral distribution for the core plasma in JETTO as well as the fast-ion birthpoint distribution functions and therefore EIRENE was taken out of EDGE2D source repository and its interface to EDGE2D (namely EIRINT2D) was generalised. In fact, EIRINT2D is still in place within in EDGE2D (with ensured backwards compatibility) and a new interface solely for interfacing with JETTO was created, namely JETEIR described below.

EIRENE communicates now only through EIRINT2D and JETEIR with other codes. The sourcecode of EIRENE was extracted and can now be maintained seperately from EDGE2D or JETTO which makes it much easier to update EIRENE.

The communication of EIRENE with EDGE2D through EIRINT2D is explained elsewhere. The following sections describe JETEIR which handles communication

of EIRENE with JETTO and ASCOT for its purposes mentioned above.

### IIb triangular grid generation

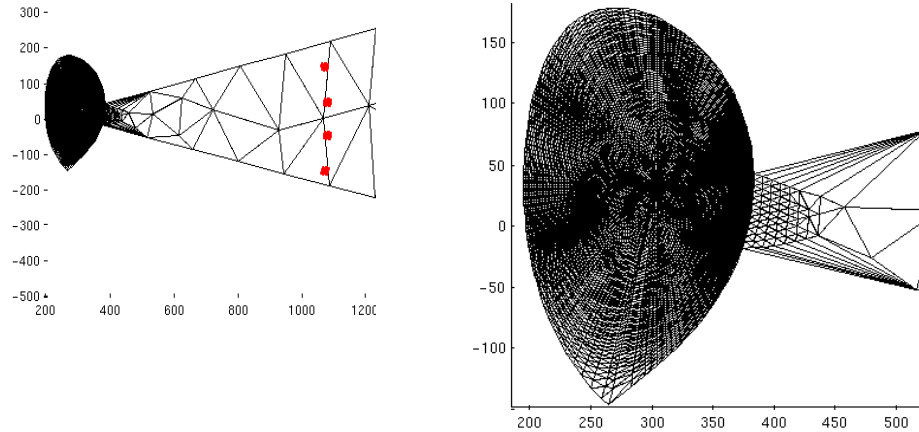


Figure 4: Combined JETTO triangularised core grid with idealised NBI simulations domain for EIRENE. The red structures in the left picture resemble the emitter surface of neutral beam particles.

EIRENE is able to follow Monte-Carlo particles on various geometry definitions. For the purpose envisaged here a triangularised (FEM-like) flat discretisation of the simulation grid in the poloidal cross section is applied. The toroidal direction is assumed to be periodic and is discretised in a number of equally sized toroidal slices.

To discretise the core part of the plasma (ie the region up to last close flux surface) the current equilibrium of the nested flux surfaces is extracted from the JETTO simulation by using the FLUSH library. JETTO, when it calls JETEIR, has already initialised FLUSH so that the equilibrium for the current time-step is available.

JETEIR extracts a set of flux surfaces in form of a set of closed polygons. The space between two surfaces is filled up by discretising it into triangles assuming that FLUSH provides surface polygons with the same number of vertices per polygon and that each polygon vertex has a direct neighbor on the next polygon. With that, it is easy to create a set of triangles filling up the space between the polygons. The innermost set of triangles is created by a point lying on the magnetic axis.

This core grid can already be used for the cold neutral simulation JETTO – EIRENE (see below). But for the link with ASCOT, the grid needs to be extended. The fast neutral emitting surfaces (see next subsection) need to be placed within the triangular simulation domain. Instead of actually including a detailed neutral beam duct, an area sufficiently large to encompass the NBI emission surfaces is used, discretised and attached to the core grid mentioned above.

The triangular discretisation of this artificial NBI duct geometry is done via a triangulation procedure named TRIA which has been regularly used in the past to

prepare triangular simulation domains for EIRENE. TRIA has been modified and generalised and is now included into JETEIR.

When attaching triangular grids it needs to be assured that each triangle in the simulation domain knows its neighbour and/or its boundary surface. JETEIR does this automatically and an example of the final triangular simulation domain is shown in figure 4.

### **IIc plasma redistribution in the core domain**

The 1D plasma profile coming from JETTO needs to be redistributed on the generated 2D triangular grid. JETEIR assumes that the plasma quantities like density and temperature are frozen to the flux surfaces and therefore are redistributed on the new 2D grid accordingly. There is no interpolation of plasma quantities involved here.

In fact, ASCOT can decide by itself, whether it is using the 2D distribution of the plasma or using the 1D representation, both are delivered by JETEIR. By the assumption of a frozen plasma to the flux surfaces there is no difference between the two. But maybe later one might redistribute the 1D plasma as a function of poloidal angle (for example to introduce some ballooning effect or else) and then ASCOT is indeed able to process a 2D plasma profile. EIRENE uses always a 2D representation (periodically continued in toroidal direction) for the plasma.

The artificial NBI duct mentioned above is assumed to be empty, ie there is no plasma data and thus no interactions of fast neutral beam particles. The artificial beam duct geometry is just needed for technical reasons.

### **IIId link JETTO – ASCOT – EIRENE**

#### **IIId.1 neutral beam geometry**

Generally, EIRENE can model arbitrary particle source for the neutral beam emission. In principle, a very detailed representation of the neutral beam Pini can be simulated. But for the time being, just a parametrised beam geometry has been implemented which is an exact replica of the beam structure within PENCIL. As seen from figure 5, each pini is represented as a set of parameters, ie angles, distance and elevation (the actual dataset for these quantities have been taken from the PENCIL code and is installed into JETEIR).

The only thing which is different as compared to PENCIL is the fact that the Pini particle source is defined as a quadrangular emitter surface in EIRENE, from which the beam particles are sampled uniformly from the surface. In PENCIL, rather a circular surface is assumed and the beam particles are assumed to be gaussian distributed in space to model some sort of beam divergence. Surely, these details can be added into the EIRENE model as well but it has been decided to do this at a later time.

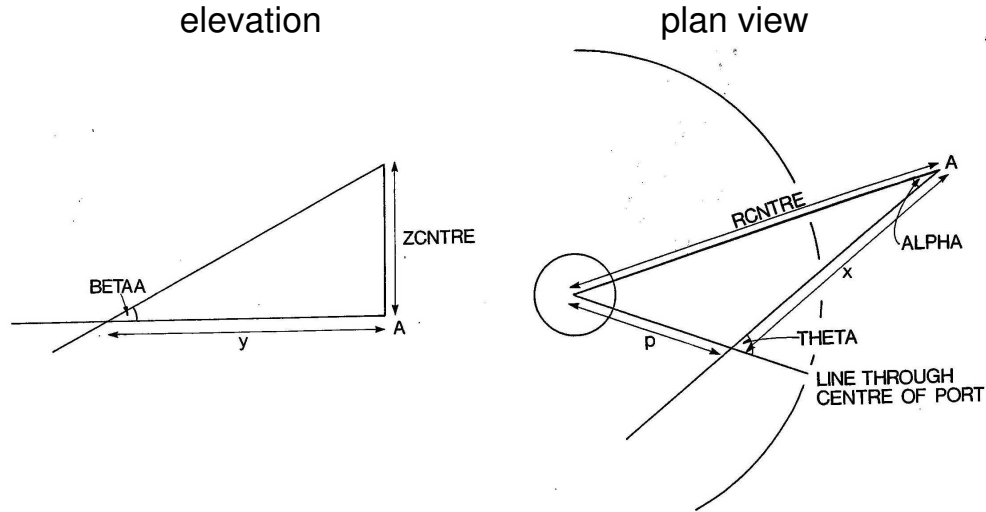


Figure 5: Beam geometry parametrisation in PENCIL

### IId.2 atomic database

In principle, a fast neutral particle entering the core plasma experiences two basic atomic processes: ionisation and charge exchange with the bulk plasma and impurities. But there is experimental evidence that one underestimates the total absorption rate of fast neutrals when excited states of the neutral are disregarded. In fact, the beam stopping rate is increased when the excited states are taken into account (ie ionisation and charge exchange not only with atoms in the groundstate). There is ADAS data available which provides the total beamstopping rate  $\langle \sigma v_{rel} \rangle$  including excited states as function of  $T_e$ ,  $n_e$  and  $E_{rel}$  and is used already within PENCIL. EIRENE is able to digest easily double-parametric fits of reaction rates also in form of ADAS dataset (adf11 files), eg as function of  $T_e$  and  $n_e$ , but then the dependency of the relative energy  $E_{rel}$  is not included. Even worse, depending on the configuration of the beam energy within JETTO,  $E_{rel}$  can vary in time. To overcome this JETEIR creates whenever it is called new temporary ADAS adf11 files by itself by fixing  $E_{rel}$  at the given time-step. These files representing a  $n_e/T_e$  dependence only (ie.  $E_{rel}$  dependency removed) are created temporarily in the current run-directory (a new beam directory is created with new adf11 files inside) and the new files are fed into EIRENE so that in fact all three parameters in the evaluation of the beam stopping reaction rate are incorporated.

### IId.3 generation of fast-ion birthpoint distributions

After setting up the grid and redistribution of the core plasma on it, and with the definition of the neutral beam particle source, the set up of the atomic database and automatic creation of the EIRENE input-file, JETEIR will call EIRENE internally

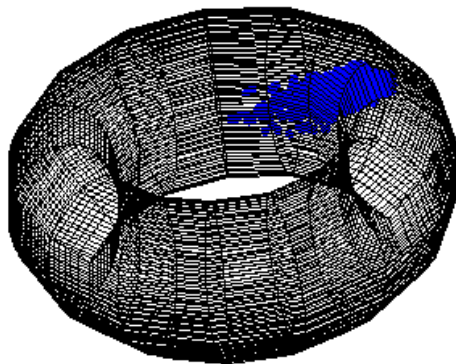


Figure 6: Spatial distribution (birthprofile) for hot ions, generated by EIRENE as input for ASCOT

with given number of Monte-Carlo particle histories. All three energy components per Pini are simulated. Whenever a particle is experiencing an event (ie it is stopped by ionisation or charge exchange) this event is registered (ie binned on a tally) and written out into special birthprofile file passed later to ASCOT. Also, the shinethrough of beam particles is registered since this is considered as a power loss to the inner wall of the vessel. In fact, only the net power absorbed within the plasma is passed to ASCOT.

Figure 6 shows an example of the spatial distribution of the birthprofile created by EIRENE in 3D. The following quantities for each birthpoint are actually transferred to ASCOT:

- location of absorbed neutral particle in  $R, Z, \Phi$  coordinates
- pitchangle  $v_0/v$
- energy  $E$
- weight (always unity at the moment for all energy harmonics, ie the beam energy fraction distribution is already represented within the beam particle source sampling)
- velocity components  $v_x, v_y, v_z$

#### IIId.4 triggering ASCOT

After the creation of all input files for ASCOT:

- core plasma distribution in 1D or 2D
- cold neutral distribution in 1D or 2D
- fast-ion birthpoint distribution in 3D

ASCOT is triggered by creating a file containing information about the absorbed power in the core and the magnetic field configuration. The latter is needed since ASCOT creates its own grid by evaluating FLUSH. When ASCOT is running, JETEIR is idling, ie waiting for ASCOT to provide a signal (again a trigger file) telling JETTO that the new profile for beam deposition is ready and available. After that ASCOT switches to idling mode and JETTO advances its time-evolution of the core plasma.

ASCOT also provides a recommendation to JETTO after which  $\Delta t$  the beam deposition simulation should be advanced in time, ie at what time ASCOT should be called next.

### II.d.5 data transferred back into JETTO from ASCOT

The following signals are fed back into JETTO in form of a 1D profile as function of normalised radius:

- power density to electron
- power density to ions
- power density to impurities
- beam particle density
- beam energy density
- current density
- torque density, divided up into collisional,  $j \times b$ , thermal and finite-larmor-radius part
- fusion rate
- particle source due to ionisation, charge exchange and interaction with thermal ions

JETEIR redistributes the data on the internal JETTO grid since ASCOT and JETTO spatial discretisation might be different.

### II.d.6 benchmark with PENCIL and TRANSP

Figure 7 shows one example of two fast-ion birthpoint distribution profiles: one from EIRENE and the other created by sampling birthpoint locations from PENCIL. Both look rather similar apart from the fact that the affected volume differs (the shape of the neutral beam emitter source is different and there is no divergence

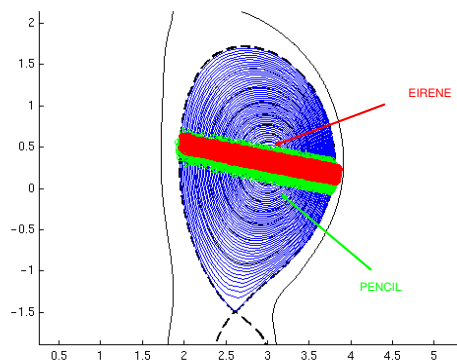


Figure 7: Comparison of PENCIL and EIRENE fast-ion birthpoint distribution for a single JET NBI pini.

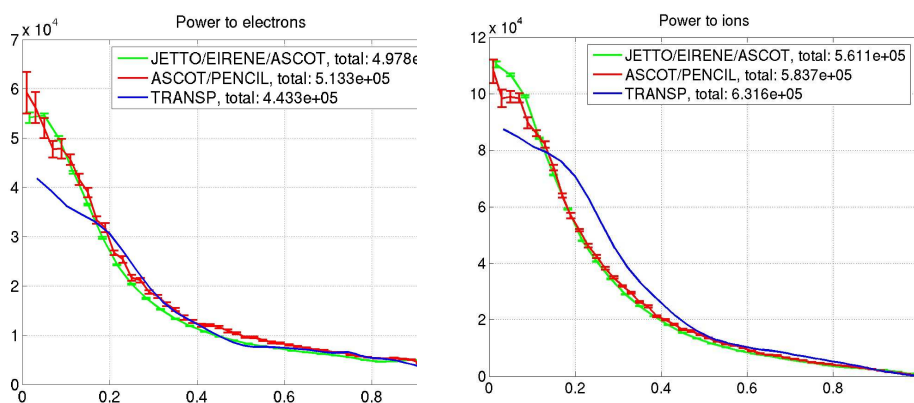


Figure 8: Benchmark of single neutral beam Pini, comparing JETTO – EIRENE – ASCOT, PENCIL – ASCOT and TRANSP. Left: power to electrons, Right: power to ions

assumed in EIRENE). But there is an overall agreement on the birthprofile.

A rigorous benchmark test has been pursued, too, comparing EIRENE – ASCOT with ASCOT – PENCIL (ie by sampling birthprofiles from PENCIL and putting them into an ASCOT stand-alone run) and TRANSP. Only a single Pini has been simulated here. Figures 8 to 10 display the comparison of profiles including error bars for ASCOT – EIRENE and ASCOT – PENCIL. There is a reasonable good agreement between the three codes.

## IIe link JETTO – EIRENE

Similar to FRANTIC, EIRENE can provide now the neutrals distribution in the core region to JETTO. Whereas FRANTIC is assuming a fluid approximation, EIRENE calculates the distribution kinetically through the Monte-Carlo method.

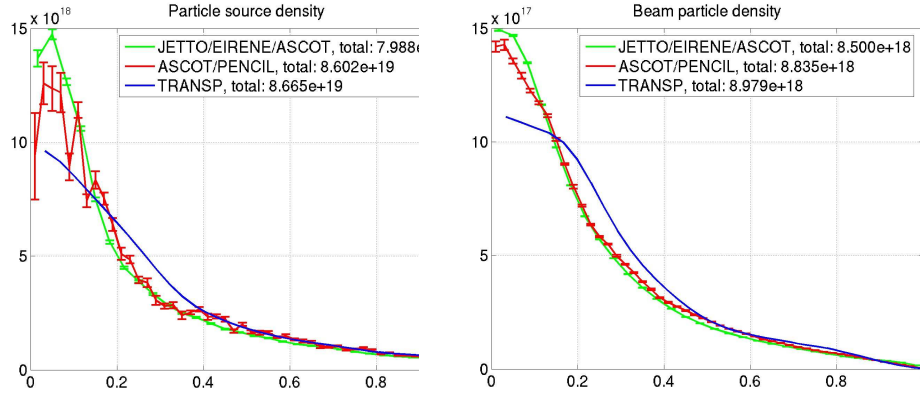


Figure 9: Benchmark of single neutral beam Pini, comparing JETTO – EIRENE – ASCOT, PENCIL – ASCOT and TRANSP. Left: particle source density, Right: beam particle density

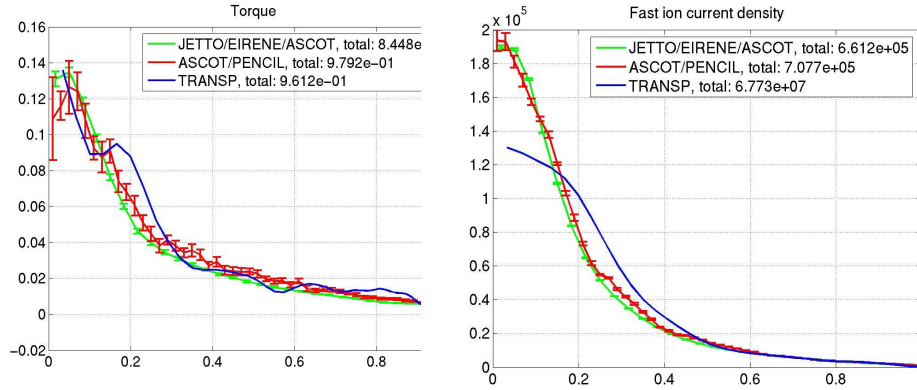


Figure 10: Benchmark of single neutral beam Pini, comparing JETTO – EIRENE – ASCOT, PENCIL – ASCOT and TRANSP. Left: total beam torque, Right: total beam current

### IIe.1 neutral source profile

As a function of a recycling matrix (see also description below in next section) the ion flux crossing the separatrix is taken and fed back into the edge in form of neutrals. On top of that, an additional gas flux can be applied. The total neutral source flux is  $\Gamma_0 = \Gamma_{recyc} + \Gamma_{gas flux}$ . The energy  $E_0$  of the neutrals crossing the separatrix is specified by the user of the code.

Differently from FRANTIC a poloidal redistribution of this neutral source flux can be taken into account since EIRENE is following the neutrals in 3D

$$f(\theta) = \exp\left(-\alpha(\theta - \theta_0)^2\right) \quad (1)$$

whereas  $\alpha$  defines a gaussian width and  $\theta_0$  the centre of the poloidal redistribution (with the reference  $\theta = 0$  at the X-point).

JETEIR creates an input for EIRENE with the separatrix polygon (defined by the

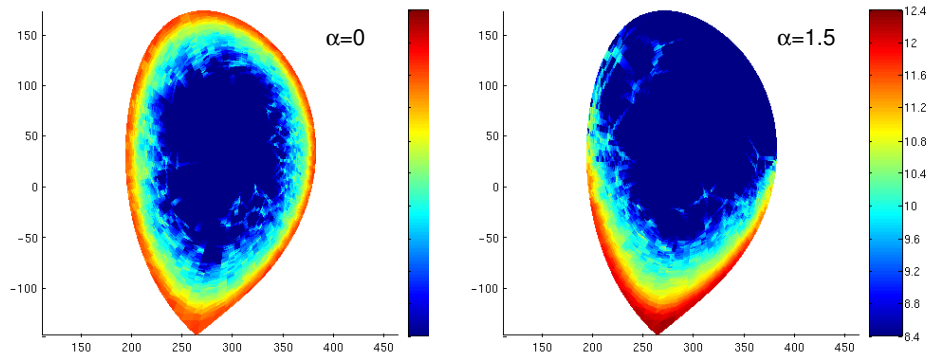


Figure 11: Cold neutrals distribution for varying poloidal parameter  $\alpha$

grid, originating from FLUSH reconstruction of the last closed flux surface) being the neutral flux source surface where the total flux  $\Gamma_0$  is redistributed on the segments of the polygon using the gaussian.

Neutral particles are sampled on these source segments in EIRENE and they are followed until they are absorbed (ie ionised) or scattered (charge exchange process) or lost (crossing the separatrix). The propagation and events are registered (binned onto tallies) and statistically averaged over a sufficiently large number of particle histories.

## IIe.2 atomic database

The atomic physics model for cold neutrals in the core is rather simple. The following reaction rates have been used within EIRENE (standard reaction rates):

- ionisation AMJUEL 2.1.5
- charge exchange HYDHEL 3.1.8
- recombination AMJUEL 2.1.8 (neglected)

For details see the atomic and molecular physics database reference on [www.eirene.de](http://www.eirene.de).

## IIe.3 data transferred back into JETTO from EIRENE

EIRENE provides spatial distributions of the neutral density, temperature and particle and heat source and sink terms which are given back to JETTO:

- neutral density  $n_0(\rho)$
- neutral temperature  $T_0(\rho)$
- particle source  $S_0(\rho)$  due ionisation  
(a particle sink due recombination is neglected)

- electron and ion energy source/sink due ionisation  $Q_{e,i}^{ion}(\rho)$   
(energy sinks due recombination are neglected)
- ion energy source/sink due charge exchange  $Q_i^{CX}(\rho)$

Figure 11 displays an example of the spatial neutral density distribution homogeneous and inhomogeneous poloidal redistribution of the neutral source flux. The 2D distribution of neutrals can be passed to ASCOT.

#### IIe.4 benchmark with FRANTIC

At the time when JETTO – EIRENE was tested and benchmarked with JETTO – FRANTIC it turned out that FRANTIC heavily underestimates the neutral density and hence the charge exchange losses for the heat (a factor of  $\approx 10^4$ ). The reason for this discrepancy is found within the FRANTIC atomic physics database. EIRENE, using the correct set of atomic physics database actually provides JETTO now with the correct distributions (although a fix has been introduced to repair the underestimated neutral density in case of FRANTIC after the benchmark exercise. FRANTIC can still be used with and without that fix for backward compatibility).

#### IIf future extensions to JINTRAC

The following extensions can and probably should be introduced into JINTRAC with respect to the JETEIR interface:

- Inclusion of the SOL in ASCOT.  
ASCOT is able to follow fast-ions also in the SOL including the real geometry. But at the moment in ASCOT it is assumed that there is no plasma in that region. In principle the SOL plasma data can be derived from EDGE2D, specifically in the case of COCONUT.
- Direct communication of JETTO, EIRENE and ASCOT through the network.  
The codes communicate through the file system by creating files containing plasma data, neutral beam data, birth profiles, neutral distribution etc. Even the triggering of a code (ie when all the input files are configured) is done through files. It turned out that on a NFS system this can lead to unexpected delays and should be avoided. A direct communication of the codes via the network, ie passing data files and triggering through TCP/IP sockets, seems to be feasible and would remove the overhead and improve somewhat the overall performance.
- Speed up EIRENE.  
EIRENE is generally able to be run in parallel MPI mode. In combination

with EDGE2D, EIRENE is the slowest part in the integrated simulation loop. This would probably mean to extract also EIRENE from the rest of the codes similar to ASCOT (cf fig. 3) to make it able to run with MPI, externally from JETTO and EDGE2D.

- Detailed beam particle source.  
A general and more detailed description of the beam particle source (spatial structure, divergence) can be introduced into the model.

### III Use of JINTRAC through the JAMS graphical user interface

The JAMS graphical user interface already available at JET is the main tool to run modelling codes at JET. With JAMS the user can prepare data before it is actually used as input going into the transport codes like JETTO or EDGE2D. Post-processing utilities are available like MHD-stability codes and JAMS provides the user also with a run monitor and access to an easy-to-use catalogue system for the finished runs of all transport codes. With JAMS, an introduced user can run, maintain and evaluate transport simulations without neglecting a reasonable amount of complexity. Of course, JINTRAC as a methodology driven plasma transport code can be used through JAMS, too.

#### IIIa JETTO – ASCOT – EIRENE neutral beam deposition

Figure 12 shows the NBI panel within the heating panel of JETTO within JAMS. Similarly to PENCIL, the different Pinis of the NBI system are available through a definition of so called beam boxes. The user configures within the Octant 4 and 8 beam box specification (cf. fig. 13) by defining the neutral beam particle energy and mass, its energy fractions, the actual number and location of Pinis. The Pini configuration is the same as in PENCIL.

The user also needs to select the number of processors for running ASCOT in parallel mode. On top, the number of Monte-Carlo particle histories is selected. This number specifies the number of fast-ions tracked within ASCOT. With increasing that number, the statistics improve by means of reducing noise scaling with  $1/\sqrt{N}$ . The number of birthpoint locations calculated by EIRENE is internally taken to be  $N/10$  (ASCOT applies an oversampling technique, ie less points in the fast-ion birthprofile distribution is needed as compared to the allocated number  $N$  in ASCOT).

The user can also decide whether ripple effects and charge exchange losses should

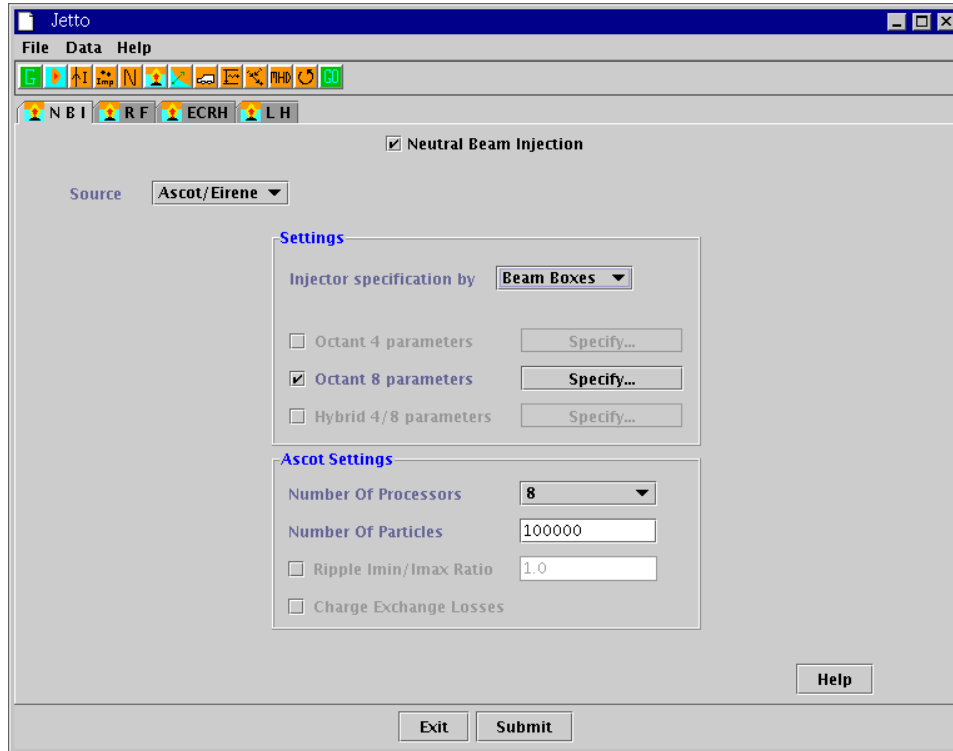


Figure 12: JAMS ASCOT panel in JETTO

be included when ASCOT is following the fast-ions.

### IIIb JETTO – EIRENE cold neutrals

EIRENE can be used to replace FRANTIC to provide the neutral particle distribution (ie. plasma particle and heat sources and sink) for the core/edge region in JETTO. As seen from figure 14 the general input for EIRENE is similar to FRANTIC: the user can apply a gas-puff (a neutral flux located at the separatrix pointing inwards) and a recycling matrix. The definition of the neutral source can be specified in another panel (cf. fig 15). Apart from the call-frequency of the neutrals package and neutral particle energy the user can add some more details into EIRENE. Firstly, the number of Monte-Carlo particle histories can be selected for EIRENE. The statistical noise of the Monte-Carlo procedure scales with  $1/\sqrt{N}$ .

EIRENE evaluates the neutral distribution in 2D. Whereas for JETTO this 2D neutrals distribution is convoluted together to have a 1D poloidally averaged profile, the actual 2D distribution can be used as an input into ASCOT, since the latter is able to account for charge-exchange losses also in 2D.

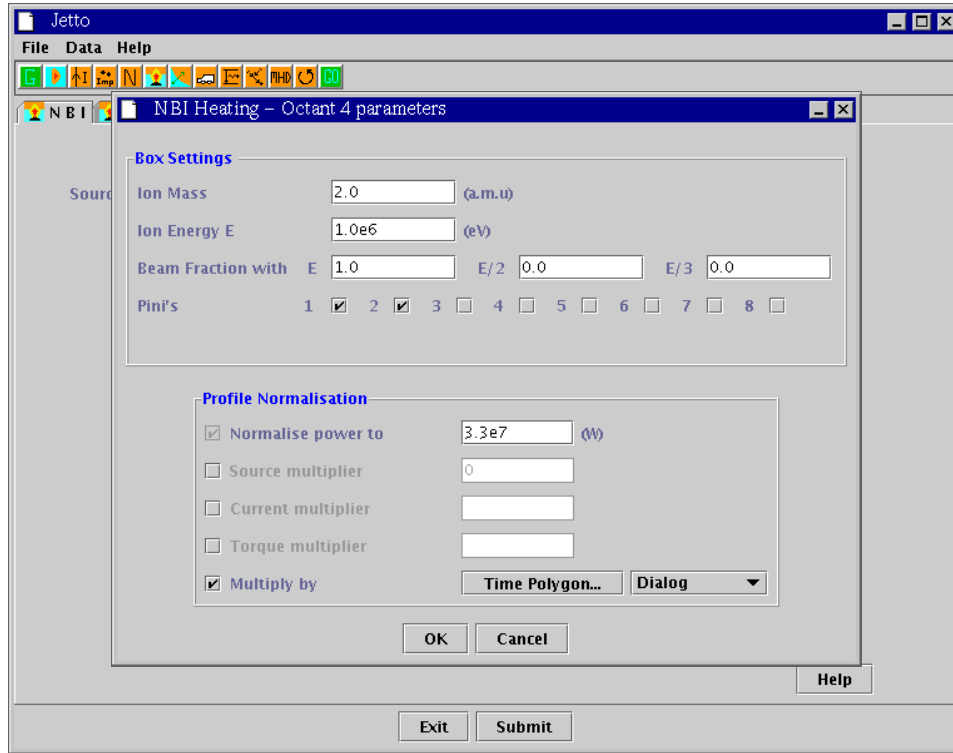


Figure 13: Beam box specification within JAMS ASCOT panel in JETTO

In principle, for JETTO the neutral flux specified at the separatrix is poloidally homogeneous distributed. But the user can define a poloidal redistribution of the flux and therefore redistribute the 2D neutral particle distribution which affect results in ASCOT. As a model paramter, the user can define parameters  $\alpha$  as exponential paramter for the poloidal redistribution defined by  $f(\theta) = \exp(-\alpha(\theta - \theta_0)^2)$  where  $\theta_0$  is an angular shift with the X-point location as the reference.

Figure 11 shows an example of the neutrals distribution with  $\alpha = 0$  and  $\alpha = 1.5$  assuming no shift  $\theta_0 = 0$ .

### IIIc COCONUT

For COCONUT simulations where JETTO and EDGE2D are linked together with the separatrix as an interfacing surface to exchange plasma and neutrals fluxes and plasma paramters, there is no difference in the definition for the ASCOT-EIRENE NBI deposition model. It is assumed that the NBI will not deposit any energy or particles within the SOL.

For the cold neutral core distribution calculated by EIRENE the only difference to a stand-alone simulation is the fact that the actual neutral source flux is not fixed

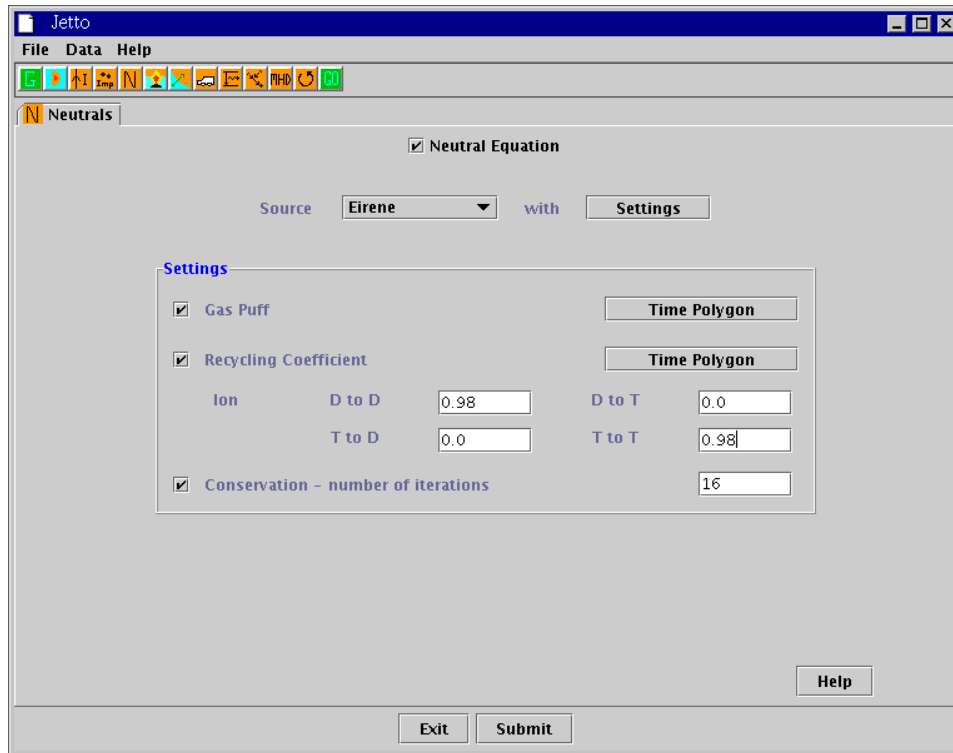


Figure 14: JAMS general cold neutrals panel

but rather given by EDGE2D. It evolves in time and reflects the transients of the neutral flux crossing the separatrix.

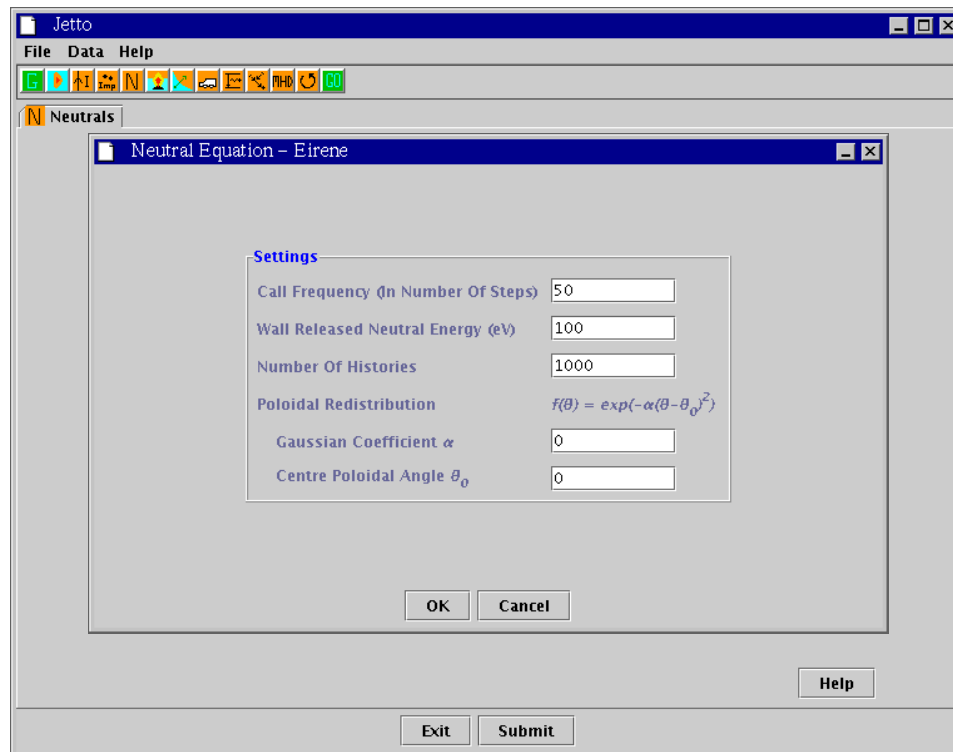


Figure 15: JAMS EIRENE cold neutrals panel