Charge Exchange (CEX) Model

This technical note describes the method implemented in CEXInteractor class for simulation charge exchange.
The parameters accessible to the user at GUI level are described in the general HowTo page ../HowTo/Controlling NUM from UI.html#VolumeInteractions.

MCC model

The model is of MCC type (Monte Carlo Collisions), sometimes also called TPMC (Test Particle Monte Carlo).
It is an easy way of simulating gas phase collisions between two populations, when you mostly consider the effects on the first one, the second one being less affected.
The idea is to consider the second population as a "background density" to compute the collision probability of the particles of the first population, which is described following a Monte Carlo method, hence sampled through super-particles representative of physical particles.

Provided the density n_2 of the background density is known, the probability of collision for a particle of the first population during the duration dt is:

$$dp = \langle n_2 \, v_r \, \sigma(v_r) \, dt \rangle \quad (1)$$

where σ is the CEX cross section and v_r the relative velocity, and the average is taken over the distribution function of the kackground density.
If the thermal velocity of the background density is small compared to the relative velocity, the relative velocity can be considered constant, which simply leads to

$$dp = n_2 \, v_r \, \sigma(v_r) \, dt \quad (2)$$

CEXInteractor model

This assumption is considered as valid in the CEX model implemented in SPIS, since the background density is usually a neutral density of temperature less than 0.1 eV while the incoming fast ion energy is in the tens-hundreds of eV range.
The CEXInteractor class implements this model in the following way.

Background density

At API level, the neutral background density (2^{nd} population) is simply passed to the class constructor as volume distribution. Its value is then computed at the location of each particle (1^{st} population) to be used in (2). The velocity of this neutral background density is considered as zero (relative velocity is thus equal to the fast ion velocity).

When using SPIS from the user interface the background density may be used as another existing source by defining *inPop2VolInteract* parameter as *sourceX*, etc. (cf. ../HowTo/Controlling NUM from UI.html#VolumeInteractions) but an extra possibility has been offered for modelling electric thrusters plumes:
if first population (fast ions) is defined from an artificial source (*inPop1VolInteract = source1, source2…*), defining *inPop2VolInteract* parameter as *fractionOfFirstPopSource*, leads to the following definition for the second population (neutrals):
It is generated from the same surfaces as the first population is (typically a thrusters exit) with:

- a flux equal to the flux defined for the first population reduced by the factor *parameter1VolInteract* (typically in EP a few percents, hence the default *parameter1VolInteract* = 0.05 = 5%)
- a Lambertian distribution (*flux* ~ cos(*theta*))
- a temperature given by *parameter2VolInteract* [eV].

It leads to a static second population (type *LocalMaxwellVolDistrib*), of which density is computed from the far field density generated by a Maxwellian source:

$$n_2 = \mathrm{sum}_{\text{emitting surfaces}}(\,flux\ area\ \cos(theta) / (r^2\ v_{th}\ (8\mathrm{pi})^{1/2})\,)$$

with $v_{th} = (kT/m)^{1/2}$.

Cross section

As documented in Controlling NUM from UI.html, it can either be a constant or a function of energy.

Over all process

Summing over all fast ions in each volume cell, the total production rate for slow ions is computed from these values, through equation (2).
This production rate computed at each time step and stored as *LocalMaxwellVolDistrib* (outPop1).
Note that:

- the neutral density is static (never updated, simply computed from source flux)
- the CEX interaction only results in the creation of slow CEX ions, but has no effect on primary populations (fast ions or neutrals), consistently with the MCC scheme (at least for neutrals)

The dynamics of the generated CEX ions must then be simulated in an extra PIC volume distribution. When SPIS-NUM library is controlled from user interface this PICVolDistrib is automatically generated, with a volume source of particles being the *LocalMaxwellVolDistrib* (outPop1) giving the CEX production rate (and, temperature = the one of the neutrals, average velocity = 0).