HIGH CURRENT STORAGE RINGS FOR NEUTRAL BEAM INJECTORS

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The gas neutralizer converter used to produce a neutral hydrogen (or deuterium) beam from a H- (or D-) beam has intrinsic limitation on conversion efficiency and requires a residual ion dump for H-, and produced H+. By recirculating H- into gas neutralizer N times (with N up to 4) conversion efficiency can be increased and the ion dump size is greatly reduced. In other words, the gas neutralizer becomes one element of a large acceptance H- storage ring, which is here studied both with linear theory and with numerical simulation. Among several practical solutions, the rectangular lattice with M=2 and M=4 bending dipole seems the more convenient for an initial studies; symmetry number (number of equal section per turn) is S=2 for both lattices. It is important to control secondary ion accumulation inside storage rings, which has beneficial effect (reduction of space charge) and unwanted effects (beam stripping in dipoles); clearing electrodes may be useful. Among advanced concepts, note first that controlling secondary plasma may also produce a plasma neutralizer, with higher efficiency. Second, adding a H+ storage ring, with a long straight section in common, is a convenient method to exploit the H+ and H- mutual neutralization, so that in principle conversion efficiency may approach unity. Application to fusion and other use of dual beam technology are also reviewed.

The gas neutralizer user in ITER design has a limited D^0/D^- conversion ratio (0.45) for accidental loss and for the large pressure required, which gives plenty of D^0 to D^+ unwanted conversion (and request huge cryogenic pumps). This suggested investigation of a new concept:

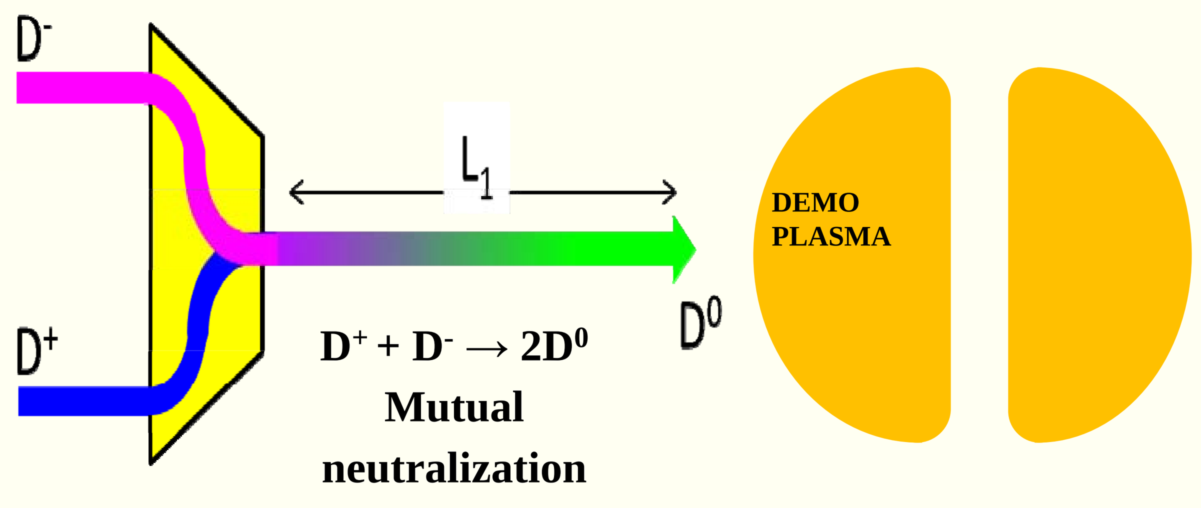

Figure 1: concept of a comoving beam neutralizer; with the negative ion source (40 A , 1 MeV) to be used for ITER and a simpler positive source (40 A , 1 MeV) a neutral beam power over 70 MW can be delivered to tokamak. Unfortunately, for feasible beam density, neutralization length L_1 is 0.3 km

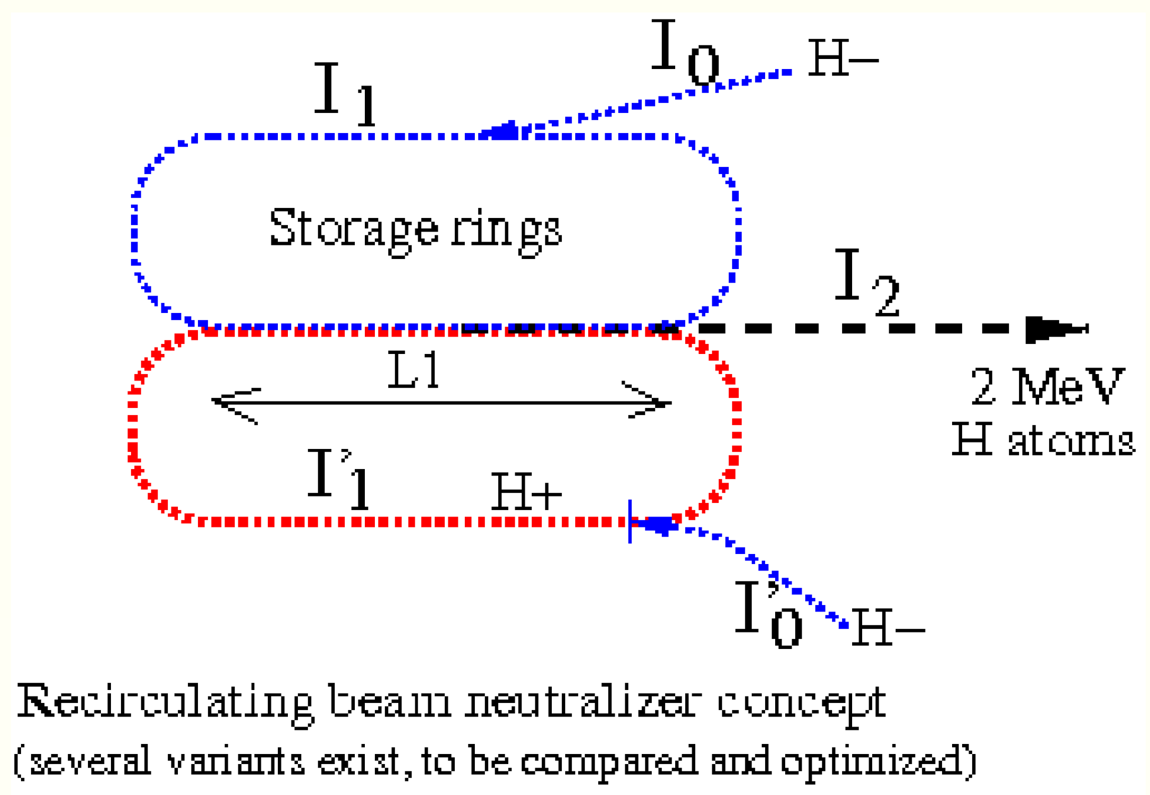

Figure 2: concept of a comoving beam neutralizer requiring two storage rings. By recirculating the beam at least 20 times, L_1 can be reduced below 20 m. Anyway smaller primary current are used (I0 about 3 A, to better control beam, and beam energy is increased, to allow better injection into DEMO. Note that D+ may be stored starting from a negative ion beam with a target, or with from a D+ source, using the phase space manipulations described later, or in the other poster

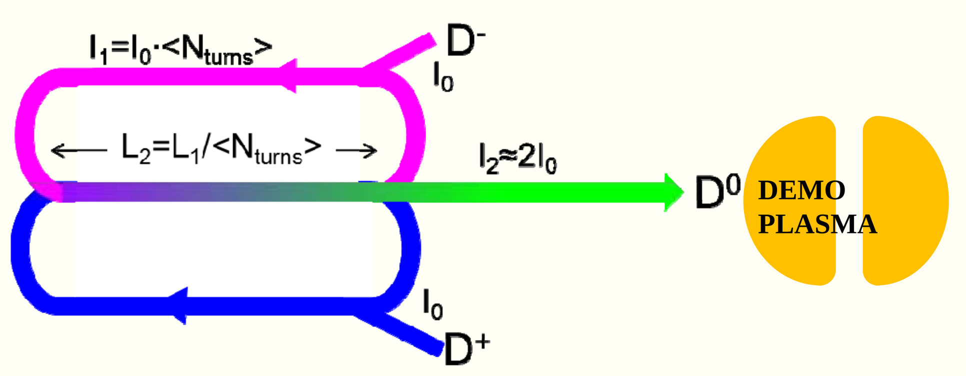

Figure 3: some remarks on length in 2 storage rings concept.

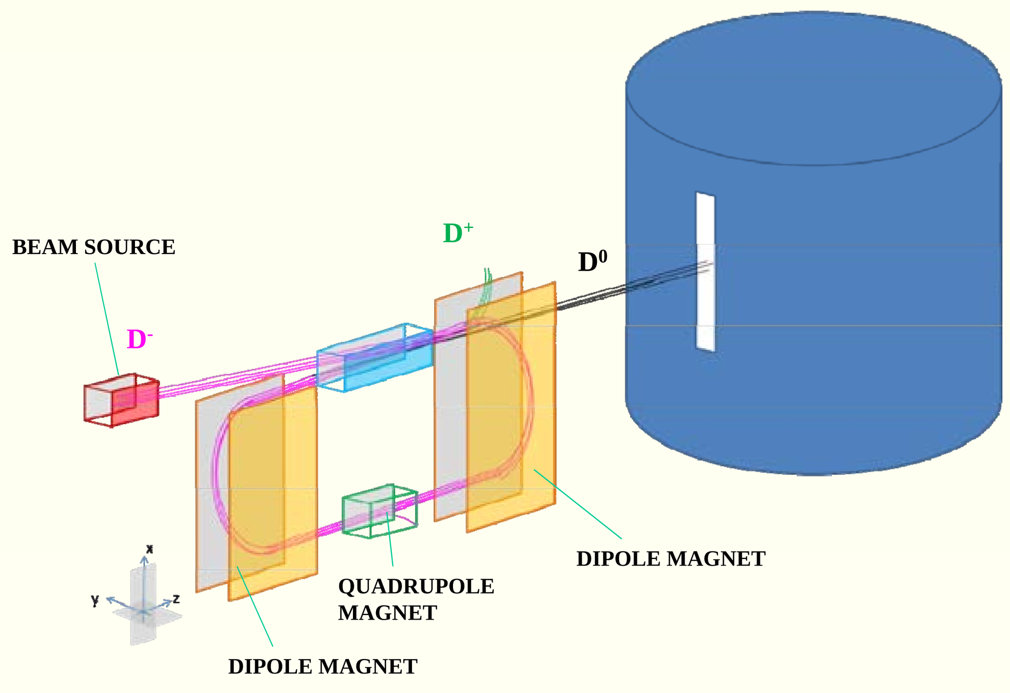

Figure 4: the baseline concept of one storage ring for D-, where a neutralizer cell is inserted. Say that D- pass n=4 times inside cell: for 70 % total efficiency, a 25 % neutralization per passage is enough, so gas pressure can be held lower, and conversion of D0 to D+ is greatly reduced. Note the vertical construction, since tokamak have typically rectangular input ports.

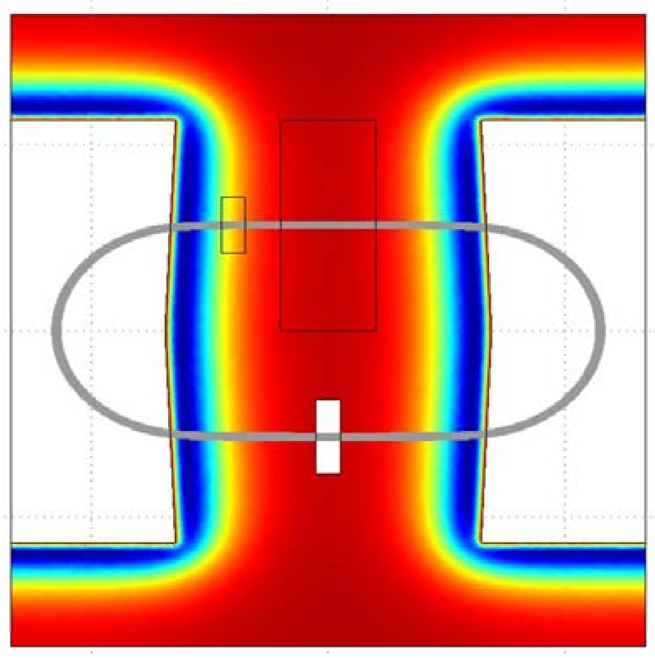

Figure 5: color map of By fringe fields; inside dipoles gap (white area, By=0.06 T is constant); the baseline concept has special magnet pole shape, with a reentrant border. Since only M=2 bending dipoles are used, reference orbit is easily closed. A quadrupole is needed for linear orbit stability, which is optimized by numerical methods.

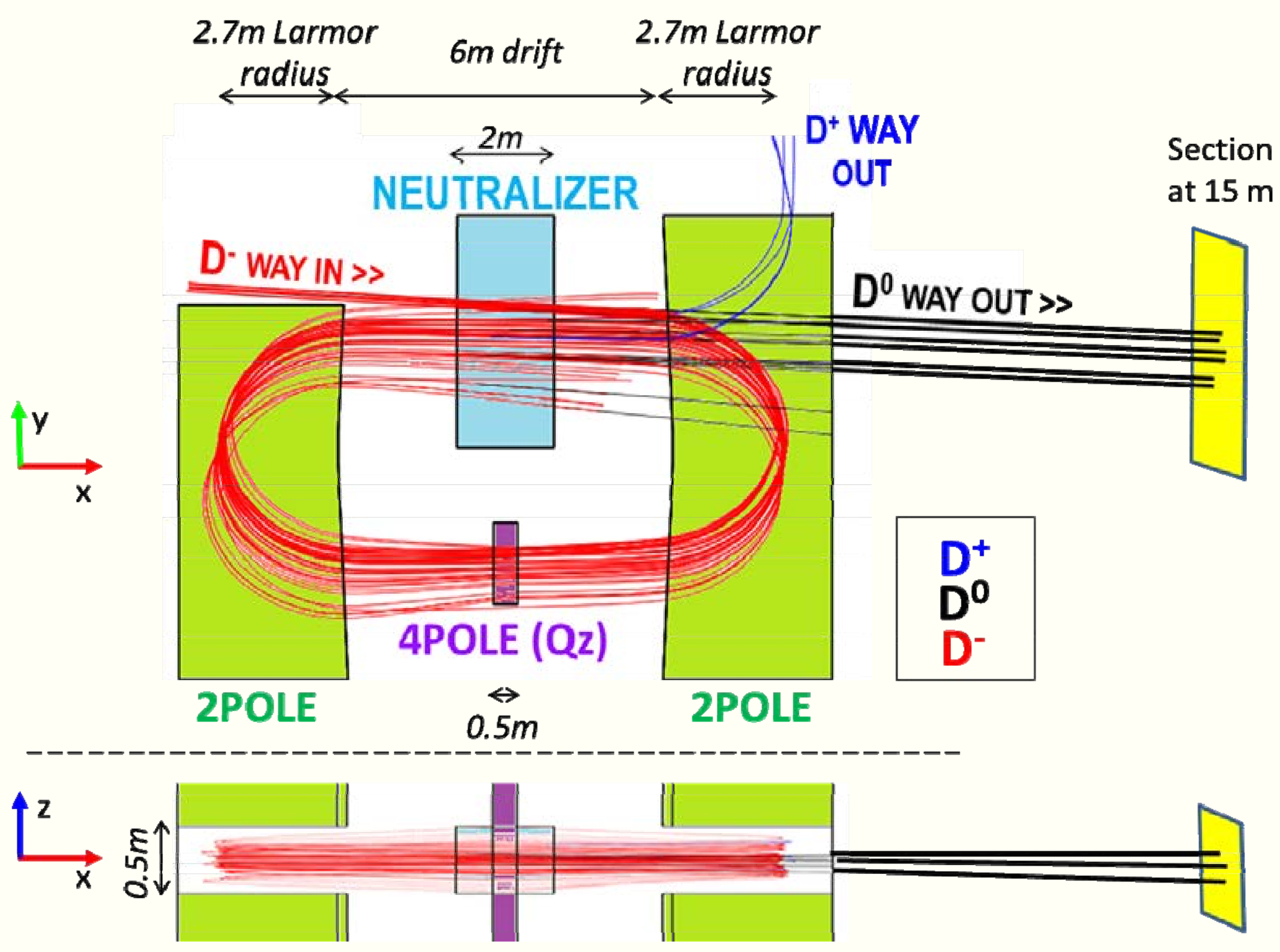

Figure 6: many particle calculation for baseline concept, with neutralizing collision modelled with Monte Carlo approach; note that angular spread of D0 output is still acceptable, notwithstanding the large angle used for special injection arrangement.

Beam energy: 1 MeV
Beam Size: 0.2x0.05 m
Divergence= 5mrad
Injection angle: angle 5 deg.
Dipole angles= -2 deg.
Neutral Yield: 75 %
(≈ no losses in 3 turns)

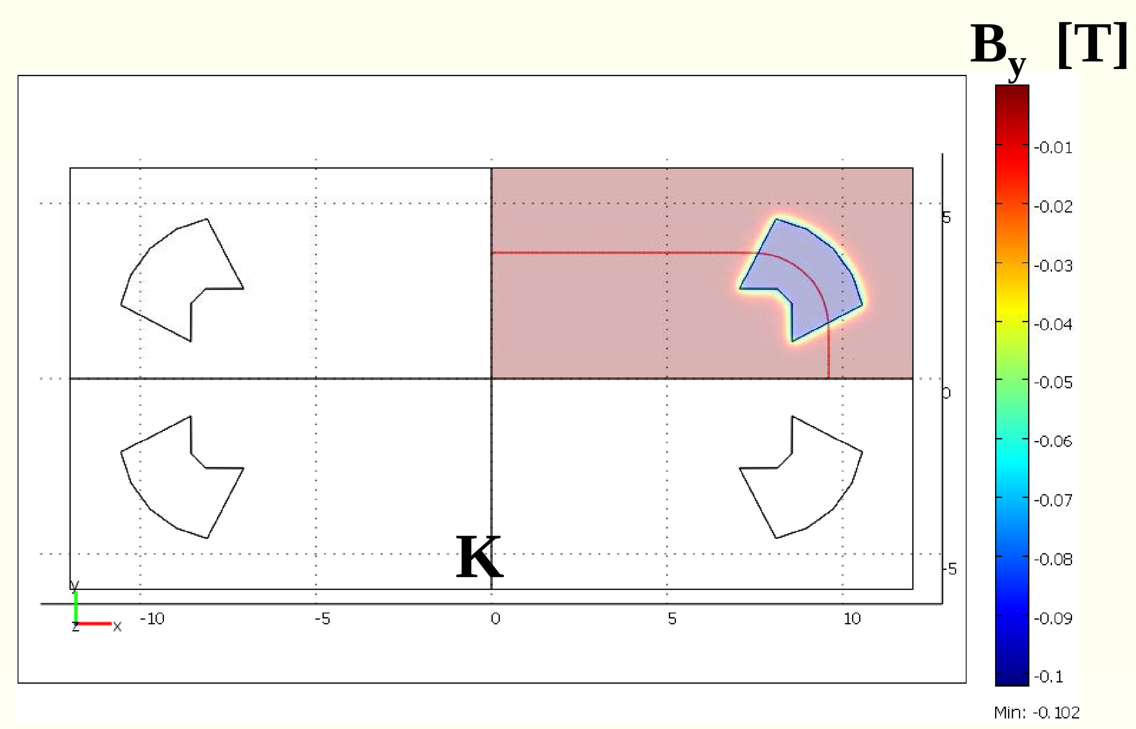

Figure 7: color map of By for M=4 dipole storage ring (see next poster for details); due to symmetries, only 1/8 of apparatus volume need to simulated; this applies also to reference orbit, provided that dipole current is adjusted to get perpendicular crossing of symmetry planes. Position of inflector K is approximately marked

With B_y about 0.1 T, a Larmor radius R about 2m results. Due to limited field, iron may economized by using a composite of iron and concrete as a yoke material (as done for LEP, for eddy current reduction) or a composite of iron and air. C-shaped yokes are preferable (over H-shaped yokes) for economy, and most important to give a wider exit (or entrance) to beams. Superconductive coil may still needed for power economy.

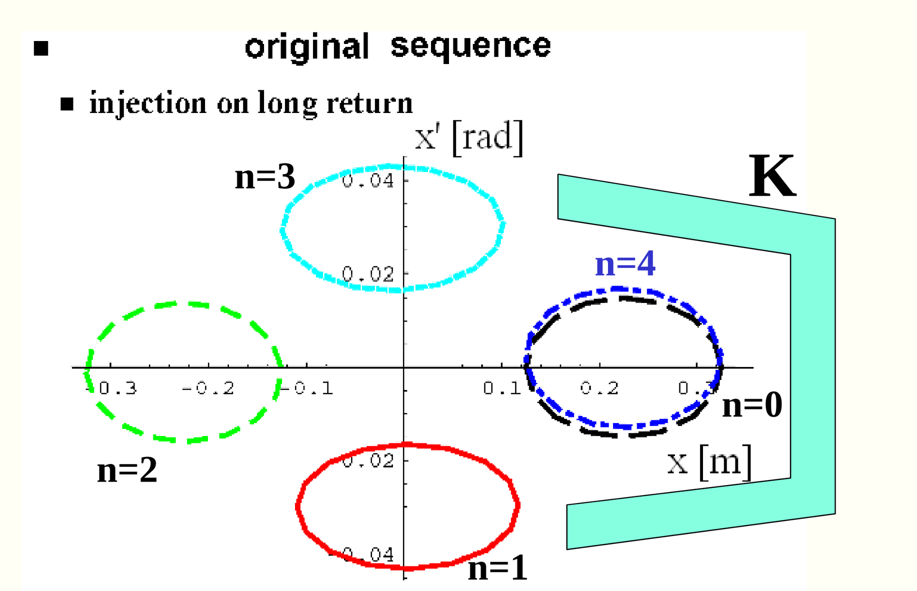

Figure 8: x,x' phase space nominal beam (colored ellipse), for the turn number n as labeled. Remaining beam is ejected at n=4, by the action of the inflector K, whose yoke position is approximately marked