# Ion Optics Simulation for RHIC Optically Pumped Polarized H$^-$ Ion Source

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At TRIUMF, the KEK optical pumped polarized ion source (OPPIS) [1] is being upgraded for use for the RHIC project and named BOPPIS (Brookheaven optical pumped polarized ion source). The BOPPIS produces a high intensity H$^-$ ion beam which is a DC current beam with a pulsed polarization. According to the RHIC spin physics, the 70% polarized proton-proton collisions at energies up to $\sqrt{s}$ = 500 GeV with luminosity of 2 $\times$ $10^{32}$/(cm$^2$ s) are required. Estimating raughly all of beam losses of LEBT, RFQ, LINAC, AGS, and RHIC, the required performance for the BOPPIS must become 0.5$\sim$1.5 mA H$^-$ ion current with 80% polarization during the 100$\sim$300$\mu$s, within a normalized emittance of 2$\pi$ mm mrad.

Production of the polarized H$^-$ ion beam is attained by the following method[2]: H$^+$ ions produced in an ECR cavity enter a rubidium cell (Rb cell) and capture polarized electrons from an optically pumped rubidium vapor in a superconducting magnetic field (2.5T). As a result, it becomes hydrogen atoms having a polarized electron. Then, the hydrogen atom passes through a Sona region where the polarization transfer from electron to nucleus. The nuclear spin polarized hydrogen atom captures an unpolarized electron from a sodium vapor in a sodium jet ionizer cell and becomes nuclear spin polarized H$^-$ ion.

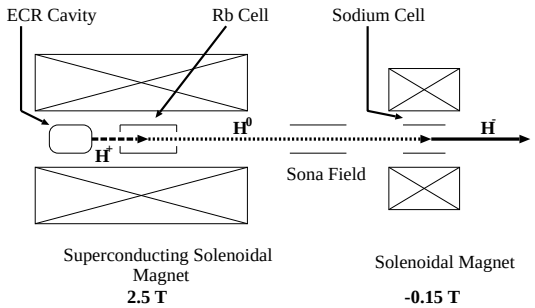


Figure 1: The simple drawing of BOPPIS.

A simulation for ion optics was performed assuming the following initial condition [3]. The 1000 H$^0$ trial atoms are generated 10 cm upstream from a sodium jet ionizer cell (20.0cm$\times\phi$2.0cm) so that an incident H$^0$ beam may have an emittance ($\pm$10mm: circle)$\times$($\pm$1mrad); almost like as a parallel beam. H$^0$ atoms are introduced to the sodium jet ionizer cell. In addition, we have to consider an effect of the sodium vapor density distribution so that the sodium "jet" ionizer cell may be pronounced. As a boundary condition for the sodium vapor density distribution, we assume that the total sodium vapor thickness becomes $10^{15}$ atoms/cm$^2$. For this purpose, we assume a Gaussian distribution as a sodium vapor density

distribution and use the sigma value ($\sigma$=5.0 cm).

We assume $H^0 \rightarrow H^-$ and $H^- \rightarrow H^0$ as charge exchange processes between H atom and Na atoms, whose cross section values are about $0.03 \times 10^{14}$ cm$^2$ and $0.30 \times 10^{14}$ cm$^2$, respectively [4]. In the present beam energy (3.5 keV), other charge exchange processes are much smaller than the cross section of above processes and are negligible processes for this simulation.

The simulation program is based on the Runge Kutta and the Monte Carlo method. The former takes a part of the particle tracking. The space mesh on the Runge Kutta method was calculated by the magnetic field calculation program [OPERA2D] The latter accepts a part of the charge exchange. Further details about the decision of the charge exchange by means of the Monte Carlo method has already been published [5].

The beam trajectory along the solenoidal axis is shown in Fig. 2. Z=0 is the center of the sodium jet ionizer cell. In Fig 2-(a), thick and thin solid lines are the magnetic field distribution and the sodium vapor density distribution, respectively. Fig 2-(b) and -(c) are $H^0$ and $H^-$ trajectory of the transverse X projection, respectively, where the 100 trial particles are traced. The point of the charge exchange are plotted in fig 2-(d). As a result, the beam radius and the normalized beam emittance at the point 30cm downstream from the sodium jet ionizer cell are 13mm and $2.4\pi$, respectively. We will be able to determine the variation of the strength and the location of an accelaratting tube and an electrostatic magnet for introducing the beam to the later high energy section of the beam line.

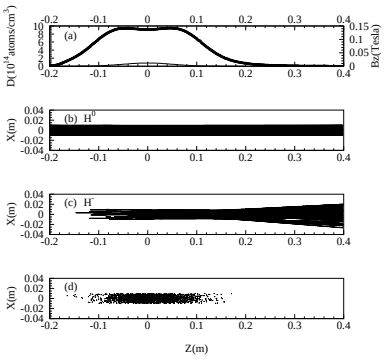


Figure 2: The beam trajectory, the magnetic field distribution, and the sodium vapor density distribution.

## References


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