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Electron Tracking Study and Catcher Design

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In the SNS injection straight section, stripped electrons will have the same velocity as H^- and, hence, a kinetic energy centered at 545 keV. In order to protect the foil and mechanical system, the second chicane dipole magnet provided monotonically decreased magnetic field along the vertical direction. The third chicane dipole magnet then provides the compensation on the uniformity of integrated field. The total integrated field produced by the second and third chicane dipoles must cancel the total integral field of the first and the forth chicane dipoles seen by the circulating protons [1]. In this note, we present part of our study results on the stripped electrons and the final design of the catcher.

(I) Tracking Study in a Simple (theoretical) Model

The electron tracking study was performed in Opera3d [2] post-processor field environment, without considering the interactions between electrons and others (circulating protons, catcher surfaces, etc.). In the gradient field, the electron trajectory basically has a radius around 1.2 cm, which is determined by $\rho_c = \frac{\gamma m_0 \upsilon_\perp}{eB}$ where γ is 2; and B is the magnetic field varies from 2.5 kG (near the foil) down to 2.4 kG (near the bottom vacuum chamber wall), which is more or less perpendicular to the momentum of the electron. The local field gradient determines the pitch of the helical motion, which is on the order of 2.4 cm (average). From the foil center (where electrons are born), to the upper surface of the catcher, electrons usually fulfill more than 5.5 turns (but less than 6 turns) around their curved central trajectories.

Figure 1 shows the typical electron ray trace projected in horizontal and vertical planes. The system origin is located at the center of the second chicane dipole magnet; x is in outward radial direction of the accumulation ring; y is the vertical direction; z is along the beam tangential direction. The electron initially starts at (4.0, 2.0, 30.7 cm) with kinetic energy of 545 keV and horizontal momentum direction (parallel to z-axis). It follows a counter-clockwise helical path (if we view from the top) and finally hits the catcher at (6.9, -10.0, 32.0 cm) with a 19.1 degree landing angle respect to Y=0 plane.

More than 200 sample rays were tracked, which cover the phase space of stripped electrons: dx = dy = ±0.4 cm and x' = y' =± 6 m-rad were studies. Deviations of foil longitudinal position (dz = ±1.0 cm) were also tested to search the reasonable mechanical tolerances for installation of the foil drive and the catcher.

Studies have shown that if the foil z-position can be controlled within ± 2 mm, then we can collect electrons sufficiently by using a semi-circular catcher with a radius of 3 cm. (The stripped electrons actually hit the collector within a much smaller area, less than 1 cm. The catcher is mounted on the bottom of the vacuum chamber. The center of the semi-circle (the middle point of the diameter) should be located at x=5.0 cm, z=32.0 cm, with position error less than ±1 mm.

(II) Tracking Study in a Realistic Model

The electron catcher (Fig. 2) has complicated geometrical shape. It consists 5 pieces machined carbon wedges. Each wedge has an angle of 25 degree. Since the studies in part (I) have shown that the landing angle is in the range of 17.6 to 20.5 degree, which are much smaller than the wedge angle, therefore ideally, if the landing electron misses one wedge mouth, then it will be captured by the next adjacent one, instead of being reflected by the wedge's top surface. In the real world, however, this is not always true; electrons make gyration motions and may go down to hit the top surface no matter the wedge angle of 25 or 35 degree.

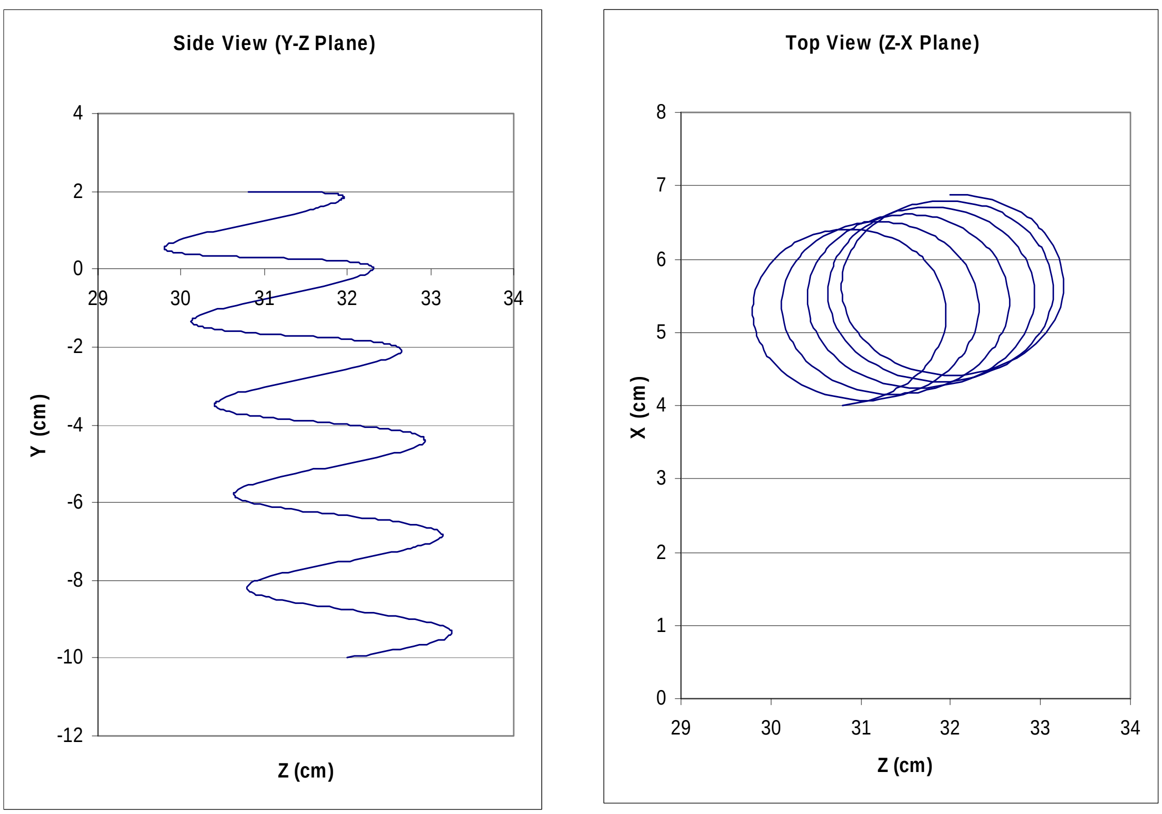

Fig. 1 Typical Electron Trajectory

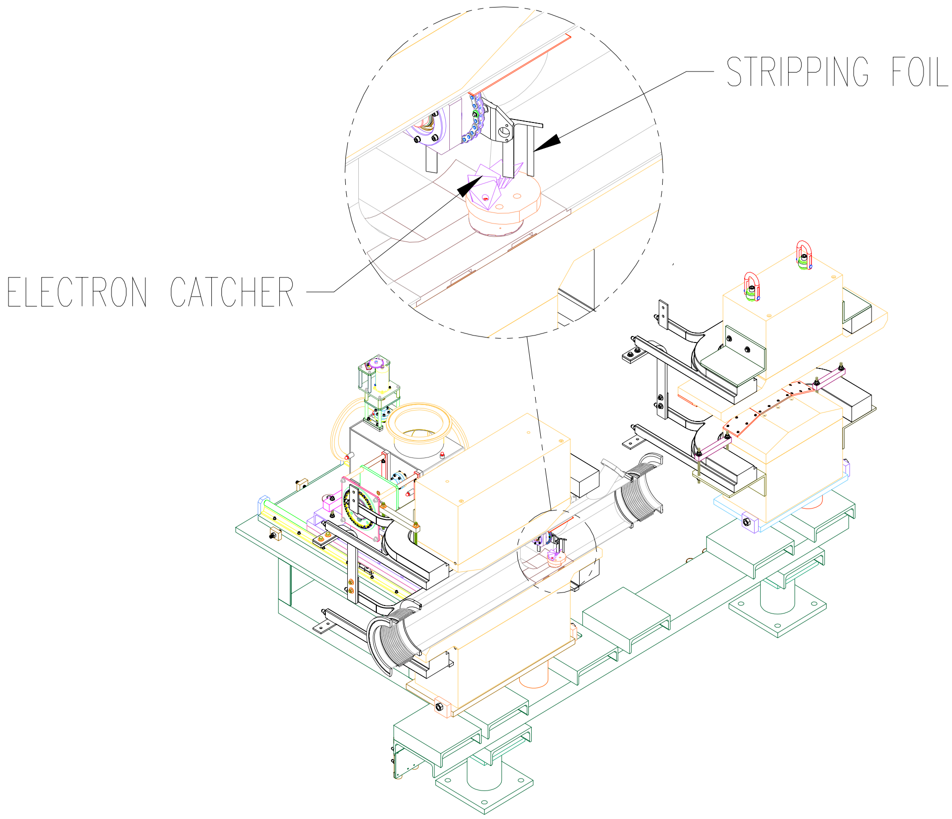

Fig. 2 Stripping Foil and Electron Catcher

To further study the interactions between the electrons and the catcher surface, a full model was established, which includes the realistic catcher geometry and the field. Simulation shows that the position of the stripped electrons at the catcher is sensitive to the vertical and longitudinal position of the catcher. In order to confine the secondary electrons and reduce the chance of reflection of the back-stripped electrons, the catcher should be located at a suitable location. Figure 3 shows one example of the electron position with different catcher position. The catcher on the right is only 6 mm lower than the left one. Note that the area of the stripped electron on the catcher surface is very small: on the order of 5 mm vertically and 2mm longitudinally. Fig 4 shows that percentage of the electrons, which hit the front surface of the catcher with different location of the catcher center. These color contours concluded that the best location of the catcher center is X_c=76mm, Y_c= -106mm and Z_c=290mm.

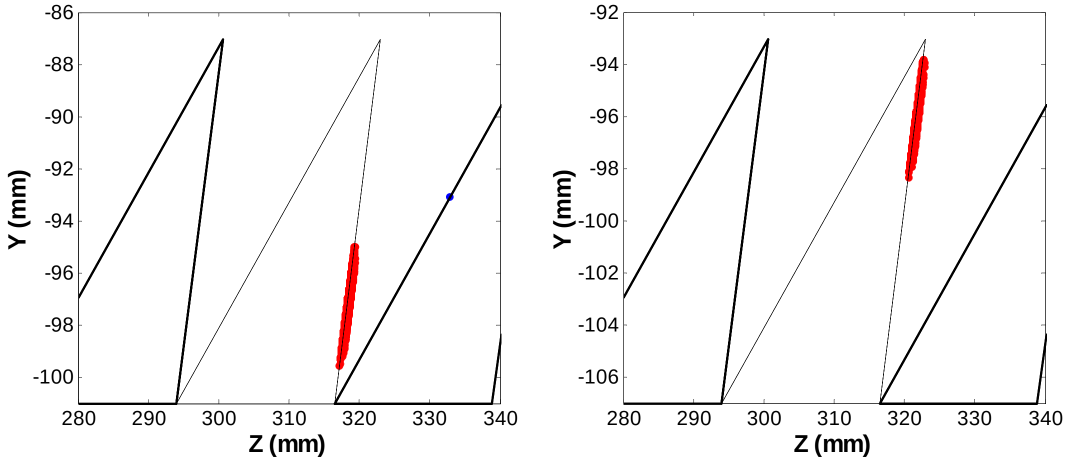

Fig 3 Distribution of stripped electrons on the catcher surface. The catcher is moved down vertically by 6mm at the right plot.

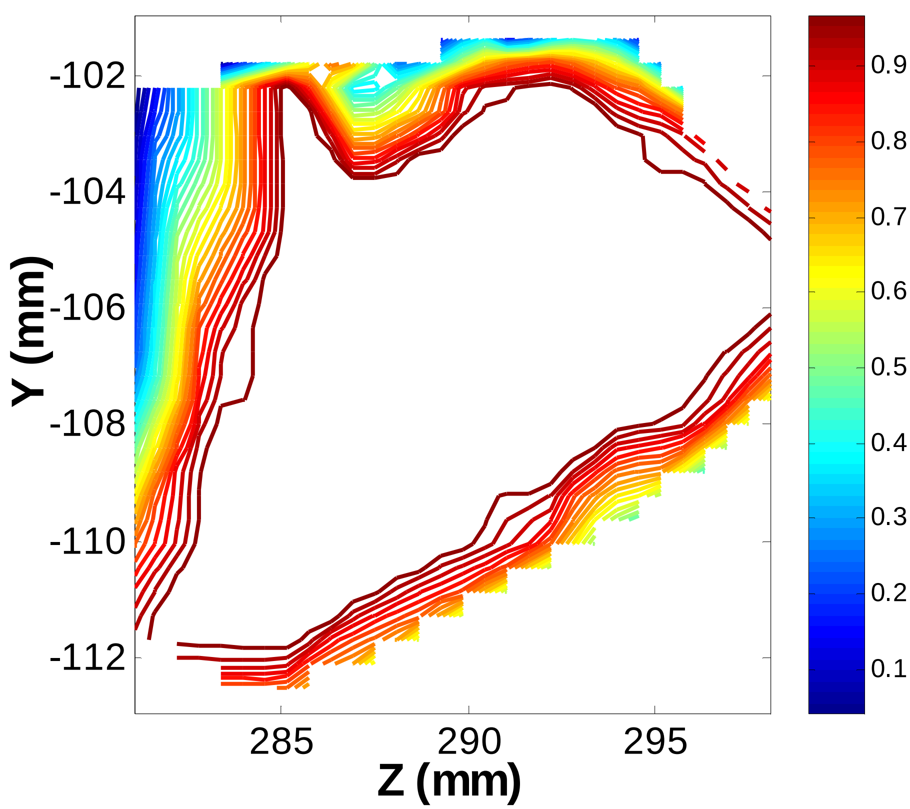

Fig 4 Catch efficiency vs catcher location

Carbon material is used for the catcher due to its low backscattered and secondary electron yield. If the catcher is located a good position so that all stripped electrons hit the front surface of the catcher, the number of electron re-enter the beam-chamber is less than 1% , Fig 5 shows the transverse distribution of the electron cloud.

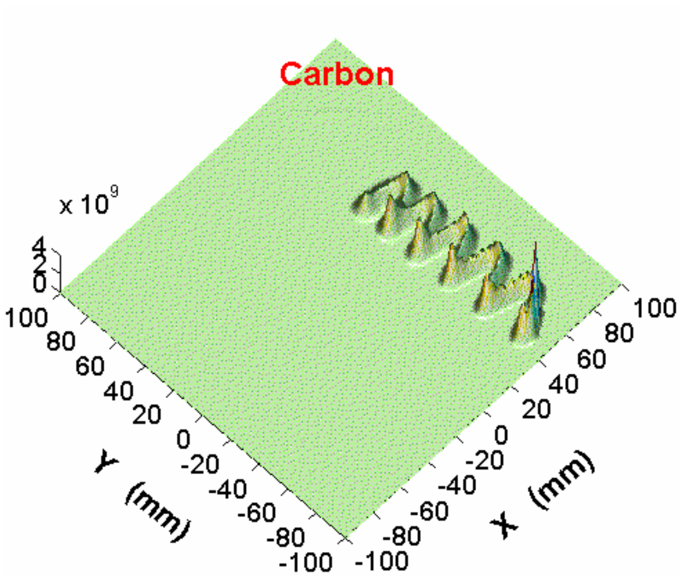

Fig. 5 Electron cloud distribution

Reference:

[1] **Injection into the SNS Accumulator Ring: Minimizing Uncontrolled Losses and Dumping Stripped Electrons**, D.T. Abell, Y.Y. Lee, W. Meng, EPAC 2000;

[2] Vector Fields Limited, Oxford, England.