LEBT WITH HYBRID MAGNETS IN A PROTON LINAC FOR COMPACT NEUTRON SOURCE

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Abstract

A compact neutron source using Li(p,n) or Be(p,n) reaction is proposed. The proton linac consists of ECR ion source, LEBT(Low Energy Beam Transport), RFQ linac and post accelerator. We assume that energy of the proton beam is 3MeV and its peak current is 40 mA operated at the repetition rate is 25Hz with the pulse width of 1ms. The beam from the ion source should be matched to the RFQ, where solenoid coils can handle the large current beam in this LEBT section.

To reduce energy consumption in LEBT we're trying to design the Hybrid Electromagnet that consists of solenoid coils and permanent magnets. We use PANDIRA, TRACE-2D, and PBGUNS computer codes in order to simulate the magnetic field and the beam transport through LEBT. In this paper the design of this magnet and the result of its beam matching based on simulation will be reported.

INTRODUCTION

Neutron beams are effective probes for material science and fundamental physics. However, there are only a few neutron facilities available for such experiments. We aim to develop a compact accelerator-driven neutron source we can fabricate easier than the conventional large powerful facilities.

The purpose of the LEBT is to transport the 40mA-25keV proton beam extracted from the ECR ion source to the RFQ. Figure 1 shows the integration of the proton injector with the RFQ. We compose the LEBT system of two solenoid focus magnets in order to control the beam size and convergence angle to match the required Twiss parameters of the RFQ. We assume beam neutralization of 97% occurs in the LEBT and the system is required to deliver 40 mA of proton at 25 keV into the RFQ accelerator with a normalized rms emittance of less than 0.20 π mm mrad and with Twiss parameters of α=3.23, β=0.079 mm/mrad.

SOLENOID COIL

Because our target current is large in contrast to the beam energy, the beam has large divergence angle at the exit of ion source. We determine the aperture of solenoid at 80 mm width large enough not to lose beam at the walls. Energy consumption in solenoid coil increases proportional to the volume of coil, then a solenoid coil with a large bore is inefficient from this viewpoint.

Figure 2 shows our design of hybrid solenoid LEBT.

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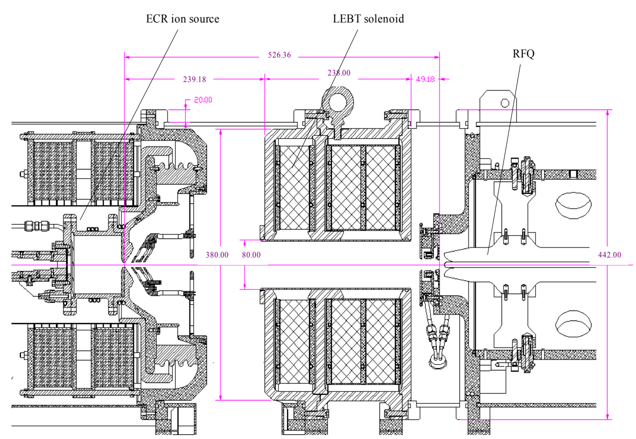

Figure 1: Schematic of ECR ion source, LEBT, and entrance of RFQ.

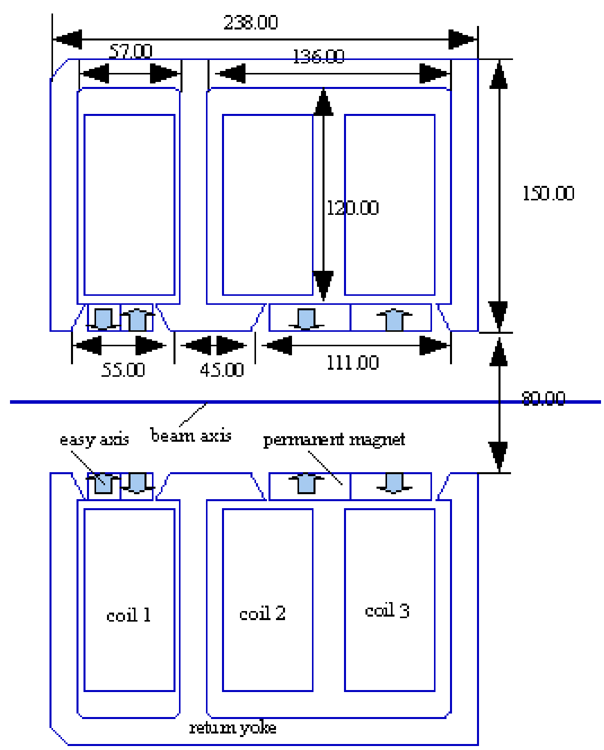

Figure 2: Cross section of the hybrid solenoid coil.

Permanent magnets inserted in the gaps of yoke strengthen the magnetic field. Convergence performance of the solenoid lens is approximately evaluated from the integral of the squared axial component of magnetic field on the axis. We use the computer code PANDIRA to predict magnetic field distribution. We use the value of remanent field of permanent magnets at 1.29T.

Figure 3 shows axial component of magnetic field along with solenoid axis, and the variation of current parameters is shown in Table 1. We can expect that it is effective for reducing energy consumption to insert permanent magnet in the coils from this simulation.

Table 1: Current Parameters.

	Current of Solenoid #1 (kA turn)	Current of solenoid #2 (kA turn)
Set1	12.0	28.0
Set2	15.0	35.0
Set3	20.0	40.0
Ser4	22.5	47.5

Table 2: Integral of Squared Axial Field Strength Along Axis.

	Conventional solenoid	Hybrid solenoid
Set1	1.05 E-02	1.59E-02
Set2	1.63 E-02	2.25E-02
Set3	2.29 E-02	3.00E-02
Set4	3.11 E-02	3.85E-02

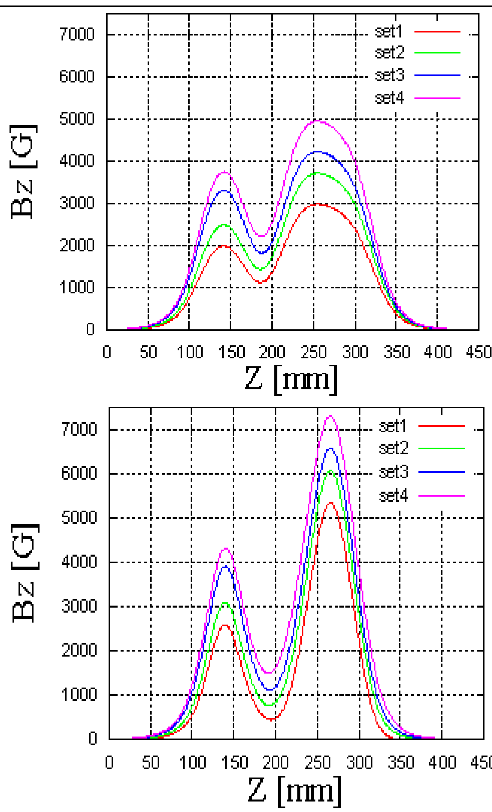

Figure 3: Magnetic field distribution. Conventional solenoid (above) and hybrid model (below).

BEAM MATCHING

The LEBT is simulated with the computer code PBGUNS. The beam neutralization is assumed to be 3%, and 15% of total current delivered by H_2^+. We also use the computer code TRACE-2D to estimate starting values roughly. Figure 4 shows tuning diagram of twiss parameter calculation with PBGUNS using 2-D magnetic field distribution calculated by PANDIRA. We fix current of solenoid #1 at some values and change magnetic field strength of solenoid #2 at 200-gausses intervals.

From Fig.4, the pair of parameters which satisfy twiss parameter required to transport the beam into RFQ should exist, although permanent magnets change magnetic field distribution. However, in this hybrid model, the strength of magnetic fields increases so rapidly at larger radius that the effect of the aberration increases the beam emittance as the beam radius increases. The emittance growth between hybrid solenoid is twice of that between the conventional solenoid in this simulation. Figure 5 shows the x-x' emittance plot at RFQ matching point, and current parameters is shown in Table 3. From this calculation, the hybrid solenoid loses about 20% of beam current compared with conventional design.

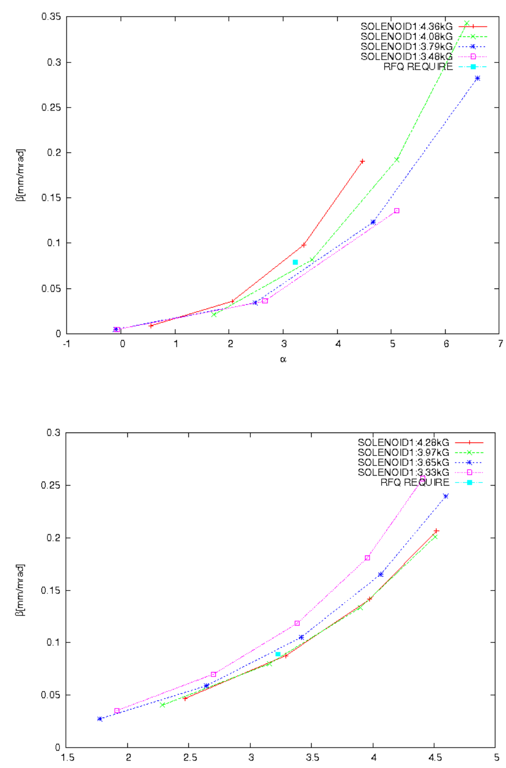

Figure 4: The PBGUNS-simulated tuning curves with variation of axial magnetic field strength. Conventional solenoid magnet (above) and hybrid solenoid magnet (below).

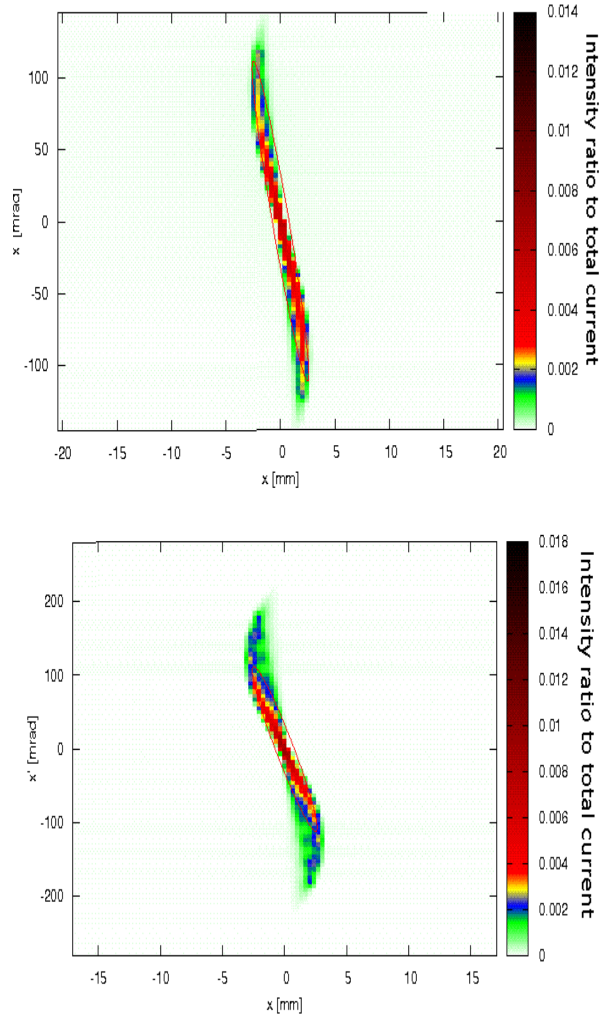

Figure 5: Emittance plot in x-x' plane and the ellipse of RFQ acceptance. Conventional solenoid (above) and hybrid model (below).

Table 3: Parameters of Coil in Fig.5.

	Conventional solenoid	Hybrid solenoid
Current of coil 1 (kA.turn)	25.0	20.5
Current of coil 2 (kA.turn)	17.0	16.5
Current of coil 3 (kA.turn)	17.0	16.5
$\int B_z^2 dz [T^2 m]$	2.15E-02	2.60E-02

SUMMARY

To introduce permanent magnet to solenoid lens easily improves the performance of convergence. Our hybrid solenoid model is expected to suppress energy consumption about 20% in this simulation. However, the low energy beam is very sensitive to the shape of magnetic field distribution, then, in order to use this solenoid we may need to place a focussing element upstream or downstream to suppress emittance growth.

REFERENCES

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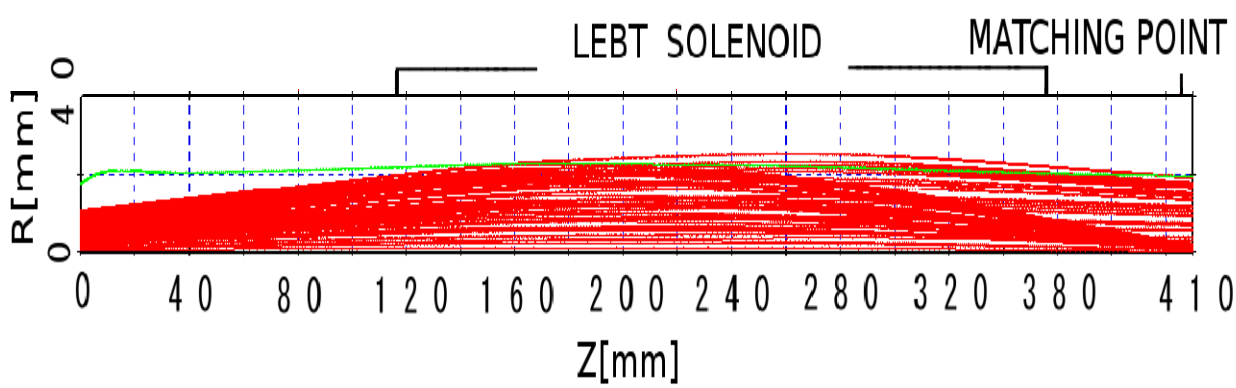

Figure 6: Trajectries in LEBT simulated by PBGUNS