The ANL high resolution injector

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Abstract:

The ANL (Argonne National Laboratory) high-resolution injector has been installed to obtain higher mass resolution and higher preacceleration, and to utilize effectively the full mass range of ATLAS (Argonne Tandem Linac Accelerator System). Preliminary results of the first beam test are reported briefly. The design and performance, in particular a high-mass-resolution magnet with aberration compensation, are discussed.

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As a part of the ATLAS (Argonne Tandem Linac Accelerator System) project, a new high resolution injector was developed for installation for the ANL FN-Tandem. Before September, 1985, most components of the new injector were installed in the tandem vault. The first beam test took place on September 27th, 1985, with successful transmission of the beam through the tandem. What follows is a discussion about some features of the injector, its objectives, in particular a high-mass-resolution magnet with aberration compensation, and a brief report on the beam test.

Table I shows 5 objectives of the injector. The first one is high-mass resolution of $M/\Delta M=300$. A double-focusing 90° inflection magnet with aberration compensation was specified with a field strength sufficient to bend tantalum ions at 50 KeV and a mass resolution to exceed $M/\Delta M=300$. The mass resolution of a conventional 14" radius magnet without compensation is limited to $M/\Delta M=125$ by aberrations resulting from the large pole gap (1.8") and small pole width (6.3").¹ Beam transport from the ion source to the tandem entrance waist was designed for an acceptance of 4π mm.mrad.MeV^{1/2} at 30 KV preacceleration voltage and 130- 300 KV acceleration voltage. This acceptance is very close to the geometrical acceptance of the magnet, when half width and half angle in the x and y direction are 1 mm and 23 mrad, respectively. As mentioned in the 3rd objective of Table I, mass analysis before acceleration to injection energy allows us to use a smaller magnet and to remove undesired ion species at lower energies for lower radiation levels.

The second objective (Table I) was that the injector should accommodate existing ion sources (SNICS² and an inverted sputter source³) and be flexible enough in layout and capabilities to allow for future improvements. Thus, for example, source power supplies can be floated at preacceleration potential, and a sublevel in the source rack can be further floated at cathode

potential. Also, an oil-insulated isolation transformer provides a vibration-free 25 KVA of AC power at platform potential.

Existing east and west injectors provide adequate injection conditions for ions up to about mass 60 at 130 KV. As shown in the fourth objective of Table I, higher injection voltage is desirable to utilize effectively the full mass range of ATLAS. Because the higher injection energy is thought to extend the performance of the Argonne gridded harmonic buncher to the heavier masses ($A \sim 130$), the fifth objective is also needed to maintain good pretandem bunching and good longitudinal emittance.

Figure 1 shows the overall layout of the ANL high resolution injector. The injector structure is supported and insulated by 10 levels of standard commercial porcelain-post insulators. The NEC power supply with SF₆ insulation is about 5' high and about 4' in diameter. The platform and the power supply are tied together electrically with a copper wire covered with a thick polyethylene tube to minimize corona, and all of their corners and edges are rounded to give them larger radii. The platform consists of a flat table and a 10' by 13' by 6.5' high-voltage cube. As shown in Fig. 2, this cube is made of 6" and 5" aluminum alloy tubes with larger corner radii.

Next, we would like to report on field mapping and the ray tracing calculation for the high-resolution magnet with aberration compensation. Original design aims of the magnet, by Professor H. A. Engle of MIT, and by General Ionex Corporation, are a mass resolution better than 300, and low aberrations with larger acceptance than 23π mm.mrad to the injector.

As shown in Fig. 4, each pole tip of the magnet has four pole boundaries of two 45° dipole. The two boundaries facing each other in a v-shaped central valley are designed to simulate a higher multipole field of two circular-pole boundaries. Both entrance and exit pole boundaries of the magnet have a

concave circular boundary which is inclined to the beam axis at 28.7 degrees. These four boundaries work as a sextupole quartet, and compensate sextupole and higher multipole deformations of the magnet. A three dimensional bar histogram of the field map shown in Fig. 5 illustrates every feature of the field reflecting the pole tip as just mentioned above. By utilizing a fitting program⁴ for a two-dimensional field map of the median plane, we extracted the parameter set of the magnetic field, which is compatible with ray tracing calculations. Then, by using a ray tracing program "RAYTRACE",⁵ we tried to calculate image sizes and a mass resolution. Figure 6 shows one example of the calculated results of the image sizes vs. object half angles.

A theoretical design parameter set (THP as an abbreviation) describing the optical properties of the high-resolution magnet were obtained.⁶ This set shows some discrepancies in comparison with the sets (EXP as an abbreviation) which were extracted from our field mapping. The calculation using his set shows a good mass resolution and low aberrations, but the extracted one does not. Though there are several differences between these two sets, some major ones are listed in Table II.

There are no significant differences between the THP and the EXP for the calculated curves falling off the fringing field. Therefore, we can see that the differences come from other origins than the curves. An EXP value of inverse radius of the entrance and exit pole boundaries (RAP(E) as an abbreviation) deviates from the THP value with 23% or more, and an EXP value of inverse radius of the central v-shaped valley pole boundaries (RAP(C) as an abbreviation) with only 1.7% or less. Because we should estimate the errors of a few % for the extraction of the parameter, the largest and most meaningful deviation from the THP values happened to be in the RAP(E).

The EXP of RAP(E), as shown in Table II, is smaller than the THP of RAP(E). The RAYTRACE calculation using the EXP shows larger sextupole and higher multipole deformations than the THP. Because the inverse radii of the pole boundaries mainly determine the sextupole and higher multipole deformations, and because a well-balanced relationship between RAP(C) and RAP(E) is needed to assure the high mass resolution, we can conclude that the EXP of RAP(E) smaller than the THP causes these higher multipole deformations, and as a result deteriorates the mass resolution.

The relationship between RAP(E) and RAP(C) with a good mass resolution calculated by the RAYTRACE program indicates that there are two simple ways to obtain good mass resolution: i) change RAP(E) from 0.0281 to 0.0365; ii) change RAP(C) from 0.023 to 0.017.

A RAP(E) should have nearly the same value as an inverse radius of mechanical boundary if the pole width is large enough in comparison with the gap. Because the width divided by the gap was too small (about 3.7), and the inner edges of the pole boundaries were too thin, the EXP of RAP(E) became much smaller than the inverse radius of the mechanical boundary. Therefore, in order to enlarge RAP(E), we should remachine the mechanical boundary with a smaller curvature.

On the contrary with RAP(E), RAP(C) is very similar to the mechanical one because of the good pole-tip symmetry along the 45-degree line. By utilizing FPCC program,⁷ we can see how much we should fill in the central v-shaped valley, and provide it the larger curvature.

We decided to make the RAP(E) large by introducing iron shims on the pole boundaries. We chose to use the original design concept, because the raytrace calculation shows that the smaller RAP(C) makes the y-object size slightly larger. The position and size of the shims are determined by simple magnetic

field calculations and the two dimensional field mapping as described above. After the final correction of the magnet, we performed the field mapping and the raytrace calculation to check the corrected RAP(E) and the x and y image sizes. These results are illustrated in Figs. 6 and 7.

During the first beam test, we tried to measure actual mass resolution of the magnet and bunching property and we successfully accelerated a ^{58}Ni beam from the SNICS ion source through the system. Although the mass resolution and the bunching property were tentatively measured to be 150 with about 5 mm openings, and about 2 nsec or more, respectively, we had little time to do the beam test further.

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TABLE I. Objectives of High Resolution Injector.

What	Why	How
1. High mass resolution $M/\Delta M=300$	a. Good isotope separation up to Uranium b. Low background from adjacent isotopes for acceleration of rare isotopes	Double focusing 90° magnet with aberration-compensation
2. Preacceleration between ion source and magnet	a. Reduction of beam divergence for better transmission through magnet b. Adaptation to several varieties of ion sources	50 KV pre-acceleration
3. Mass analysis before Acceleration to injection energy	a. Smaller magnet b. Easy ion source setup c. Undesired ion species are dumped at lower energies for lower radiation levels	90° magnet is located on the high voltage platform
4. 300 KV injection energy	a. Improvement of pre- tandem bunching for very heavy ions b. Improvement of the transmission through tandem for all heavy ions	300 KV platform
5. Low energy spread of injected beam	a. Needed for good pre- tandem bunching	Isolation transformer is an integral part of the high voltage platform to reduce capacitive coupling of leads

TABLE II. Major differences between the theoretical parameter sets and the extracted parameter sets.

Parameter		Theoretical parameter (THP as an abbreviation)	Extracted parameter (EXP)
inverse radius RAP(E) (an entrance-pole surface of the 1st dipole and the exit of the 2nd) concave		0.0365	0.0281
inverse radius RAP(C) (an entrance-pole surface of the 2nd dipole and the exit of the 1st) convex		0.0240	0.0236
fringing-field falling-down curve (1st dipole's entrance and 2nd dipole's exit)	C01	0.2319	0.0415
	C02	2.1989	2.1197
	C03	-0.5878	-0.8346
	C04	0.3744	1.2998
	C05	0.0	0.0865
	C06	0.0	0.1719
fringing-field falling-down curve (2nd dipole's entrance and 1st dipole's exit)	C11	0.0	0.0
	C12	20.0	4.6636
	C13	0.0	-0.0495
	C14	0.0	-1.2953
	C15	0.0	0.0139
	C16	0.0	0.1955

Figure Captions

Figure 1 The ANL high-resolution injector layout.

Figure 2 Sideview of the injector platform.

Figure 3 Pole tip of the high resolution magnet.

Figure 4 Three-dimensional histogram of field map

Figure 5 Raytrace calculation for x and y image sizes.

Figure 6 Entrance and exit curvature before and after the correction.

Fig. 1

Fig. 2

ANL-P-17,840

POLE TIP DESIGN OF
GENERAL IONEX CORP. MODEL 901014LA
90 DEGREE DOUBLE FOCUSSING MAGNET

Fig. 3

Fig. 4

ANL-P-18,039

Fig. 5

Fig. 6