Superconducting Solenoid Spectrometer as Fragment Analyzer

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Introduction:

Experimental study of the nuclei far from stability is much more difficult than the stable nuclei. Life time of the exotic nuclei are very small (≈ ms). So these nuclei cannot be used as targets, rather they have to be used as beams, called radioactive ion beams. Another difficulty is that production cross section of these nuclei are very small. These nuclei are also produced with large background of stable nuclei and they have to be separated out before delivering to the experimental area.

There are two complementary techniques for the production of radioactive nuclei: Isotope separation online or ISOL method and in-flight fragmentation IFS technique. In ISOL technique high energy ions accelerated by a driver accelerator hits a thick target and deposits all its energy in the target. Out of the various reaction products the desired ion is selected and ionized. These ions then again accelerated to desired energy in a post accelerator and delivered to the experimental area. In IFS technique a heavy mass projectile is accelerated to high energy and it hits a thin target thereby producing highly forward peaked radioactive nuclei. The desired exotic nuclei is separated by using electric or magnetic separators and delivered to the experimental area.

Another technique which belongs to the fragmentation technique is nucleonic transfer. In this method one or two nucleon transfer occurs and highly forward peaked exotic nuclei close to the stable line are produced. Recent years, there have been quite a few light ion RIB facilities developed using nucleonic transfer method and super conducting solenoid magnets as fragment analyser[1-3]. In our country, we do not have yet a proposal to develop mega RIB facility, but there are efforts to develop light ion RIB facilities around existing accelerators in the country using nucleonic transfer method and super conducting solenoid magnets as fragment analyser. In Nuclear Physics Division, B.A.R.C., we have also a proposal to develop light ion RIB facility at B.A.R.C.-T.I.F.R. Pelletron facility, Mumbai. In the present work, we report our simulation results on ray trace of various radioactive nuclei through a solenoid.

Analyzer Geometry:

One should have a proper production target and primary beam combination so that the desired beam is produced with maximum intensity. To separate the exotic beam a solenoid magnet is used. This has some specific advantages desirable for the focusing of exotic nuclei. For example angular acceptance of solenoid is comparatively large i.e. it can intercept particles which immerge from the production target out to relatively large angles and still focus most of them at secondary beam spot.

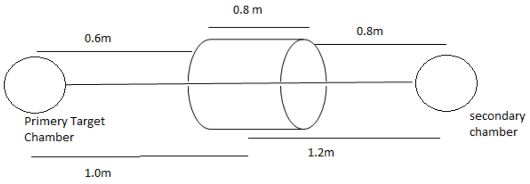

FIG.1: Schematic diagram showing the geometry of the fragment analyser.

Fig.1 shows a schematic diagram of the set up used for ray tracing in the present work. The geometry of the solenoid provides large collection efficiency of 2π coverage around the beam axis. Due to azimuthal symmetry of all ion trajectories, baffles, beam blocks for a solenoid are simple apertures or circular disk. Therefore large background particles can easily be eliminated. But it should be mentioned here that the geometry of the solenoid, image and object distance depends on the type of exotic nuclei and their energy range. Depending on the magnetic rigidity of the charged particles the length of the solenoid should be chosen such that the beam does not cross solenoid axis unnecessarily.

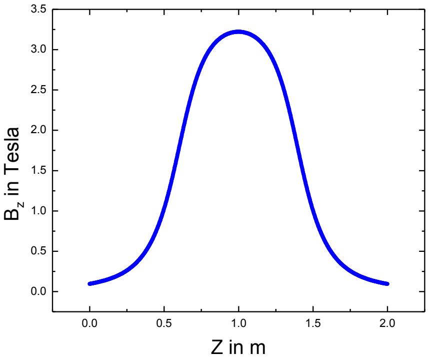

Fig.2: Magnetic field B_Z component as seen by ^{8}Li nucleus whose emittance angle is 6˚ and azimuthal angle is 45˚. Maximum magnetic field is 3.2 tesla.

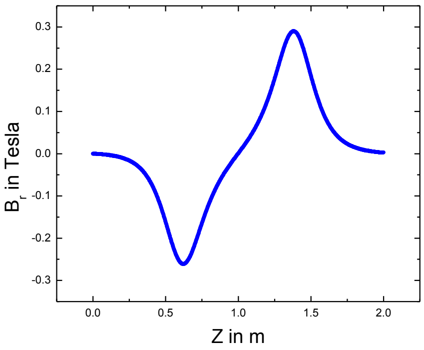

Fig.3: Same as Fig.2 but for B_r magnetic field component.

In a uniform magnetic field a charged particle travels in helical path with a radius determined by its magnetic rigidity and the applied magnetic field. But if a particle (a beam of particles) enters one end of a solenoid from a field free region then the particle (the whole beam of particles) gets focused on the axis of the solenoid as it comes out of the solenoid. The main reason for this focusing is the presence of radial component of magnetic field at the two ends of the solenoid[4,5].

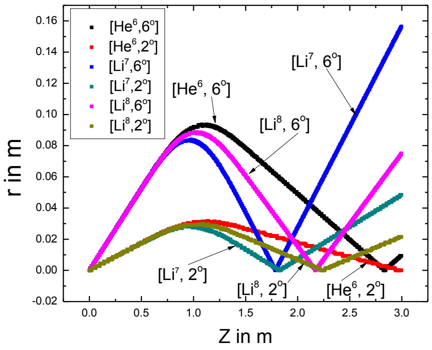

Fig.4: Ray diagram of ^{8}Li, ^{7}Li and ^{6}He through the solenoid.

Simulation Results:

We have carried simulations to optimize focusing parameters for focusing Li^7 ,^{8}Li and ^{6}He beams having energy 5 MeV/nucleon at the secondary target placed at 1.2m downstream the centre of the solenoid with length 0.8m, inner radius 0.20m and outer radius 0.25m. The angular width of the beam is 2°-6°. The primary target is placed at 1.0m upstream the solenoid centre so that the divergence of the secondary beam is minimum. The optimum magnetic field is found to be 3.2T. The Figs. 2 and (3) show the magnetic field components seen by ^{8}Li nucleus as it passes through the solenoid. The ray trace for Li^7 ,^{8}Li and ^{6}He beams across the solenoid is shown in Fig.4. It is seen that desired beam can be selected and focused in secondary chamber by using appropriate beam blocks.

References:

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