Response of the Magnetic Spectrometer PRISMA in the Mass Region $A \approx 50-130$

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The PRISMA magnetic spectrometer has a large acceptance solid angle ($\approx 80$ msr) and is well suited to study multi-nucleon transfer reactions with medium-heavy projectile nuclei. With such large acceptance, it becomes unfeasible to use complex magnetic elements to correct for the ion optical aberrations. Thus, for PRISMA the adopted solution was to simplify the magnetic element configuration and to apply the trajectory reconstruction procedure.

In this report we present a study of the response of the PRISMA magnetic spectrometer based on a Monte Carlo simulation of the ion trajectories. A special algorithm has been developed on the basis of a ray-tracing method, where the kinematics of the reaction and the geometry of the spectrometer and characteristics of the magnetic elements and detectors are taken into account. The response has been calculated for three nuclear systems in different regions of projectile mass, $A = 50, 90$ and $136$, aiming at obtaining a universal response for the spectrometer.

The response of PRISMA has been obtained starting from a distribution of incoming ions with uniform kinetic energy and uniform ($\theta, \phi$) angular distribution, accordingly to the experimental values relevant for the three studied heavy ion reactions: $^{48}$Ca on $^{64}$Ni at 280 MeV, $^{90}$Zr on $^{208}$Pb at 560 MeV and $^{136}$Xe on $^{238}$U at 926 MeV.

The trajectories through the spectrometer are calculated, event by event, and the ions position at the focal plane and the path length are calculated on the basis of a detailed knowledge of the magnetic fields and of the geometry of the instruments. The procedure employs a ray-tracing code, which uses numerical integrators to determine the trajectories of individual rays through the electromagnetic fields, the latter being calculated by means of the Finite Element Method [1-2]. Thus, the reliability of the simulation is very sensitive to a precise calculation of the magnetic fields and corresponding fringing fields.

The response function has been calculated following a number of steps: i) generation of a uniform distribution of events; ii) tuning of the magnetic fields; iii) transport of the uniform distribution in the spectrometer; iv) definition of the response function $R$ [3].

The response function of PRISMA $R = R(\theta_{lab}, E_K)$ corrects for the transmission of the spectrometer and it has been defined as the ratio between the output distribution of events $N_o(\theta_{lab}, E_K)$ detected on the focal plane and the uniform input distribution $N_i(\theta_{lab}, E_K)$. The reciprocal function $f = f(\theta_{lab}, E_K)$ gives directly the multiplication factors needed to correct the experimental differential cross sections.
Figure 1 shows on the left side the correction matrix \( f(\theta_{lab}, E_k) \) for the \(^{48}\text{Ca}\) case. The left vertical axis is expressed in MeV units, while the momentum is plotted on the right vertical axis in GeV/c units. Projections on the \( \theta_{lab} \) axis of the two-dimensional matrix \( f(\theta_{lab}, E_k) \), for different energy intervals, are shown in figure 1 right panel for \(^{48}\text{Ca} + ^{64}\text{Ni}\), figure 2 left panel for \(^{90}\text{Zr} + ^{208}\text{Pb}\), figure 2 right panel for \(^{136}\text{Xe} + ^{238}\text{U}\).

In all the three cases, as figures depict, the correction strongly depends on the kinetic energy of the incoming ion, being the correction the largest at the borders of the angular acceptance.

Fig. 3. Projections on the kinetic energy (left panels) and scattering angle (right panels) axis for the pure one-nucleon stripping and pick-up channels of \(^{48}\text{Ca} + ^{64}\text{Ni}\) at 270 MeV. Open circles are the events after the transport in PRISMA, full dots are the same corrected by the matrix \( f(\theta_{lab}, E_k) \), solid lines are the input calculated distributions.

To test the validity of the correction factor \( f(\theta_{lab}, E_k) \) we applied the same method, using as input the \( (\theta_{lab}, E_k) \) distributions calculated with the semi-classical model GRAZING [4]. These distributions have been transported through the spectrometer for the same three systems. The results of the input, transported and corrected distributions are plotted in figure 3 (\(^{48}\text{Ca} + ^{64}\text{Ni}\)), figure 4 (\(^{90}\text{Zr} + ^{208}\text{Pb}\)) and figure 5 (\(^{136}\text{Xe} + ^{238}\text{U}\)). Projections have been done on the \( \theta_{lab} \) and \( E_k \) axis. In each panel the open circles correspond to the distributions observed at the focal plane, the full dots are the events after the correction function \( f(\theta_{lab}, E_k) \) has been applied and the solid lines are the input distributions calculated by GRAZING.

The agreement between the initial GRAZING \( f(\theta_{lab}, E_k) \) distributions and the corrected distributions of events for all the studied systems gives support to the validity of the calculated response functions over the studied mass interval.