Nuclear Instruments and Methods in Physics Research A 846 (2017) 23–28

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

# The calibration of elastic scattering angular distribution at low energies on HIRFL-RIBLL

G.X. Zhang[a], G.L. Zhang[a,*], C.J. Lin[b,*], W.W. Qu[a,d], L. Yang[b], N.R. Ma[b], L. Zheng[a], H.M. Jia[b], L.J. Sun[b], X.X. Liu[a], X.T. Chu[a], J.C. Yang[a], J.S. Wang[c], S.W. Xu[c], P. Ma[c], J.B. Ma[c], S.L. Jin[c], Z. Bai[c], M.R. Huang[c], H.L. Zang[e], B. Yang[e], Y. Liu[e]

[a] School of Physics and Nuclear Energy Engineering, Beihang University, Beijing 100191, China
[b] China Institute of Atomic Energy, Beijing 102413, China
[c] Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou 730000, China
[d] School of Radiation Medicine and Protection, Medical College of Soochow University, Soochow 215123, China
[e] School of Physics and State Key Laboratory of Nuclear Physics and Technology, Peking University, Beijing 100871, China

ARTICLE INFO

*Keywords:*
Particle identification
Simulation
Angular distribution

ABSTRACT

The precise calibration of angular distribution of heavy-ion elastic scattering induced by Radioactive Ion Beams (RIBs) at energies around Coulomb barrier on the Radioactive Ion Beam Line in Lanzhou (RIBLL) at the Heavy-Ion Research Facility in Lanzhou (HIRFL) is presented. The beam profile and the scattering angles on the target are deduced by a measurement with two Multi Wire Proportional Chambers (MWPC), and four sets of detector telescopes (including Double-sided Silicon Strip Detectors (DSSD) placed systematically along the beam line, incorporating with Monte Carlo simulation. The MWPCs were used to determine the beam trajectory before the target, and the energies and the positions of scattered particles on the detectors were measured by the DSSDs. Minor corrections on the beam spot and the detector position are performed by assuming the pure Rutherford scattering at angles which are smaller than the related grazing angle. This method is applied for the elastic scattering of $^{17}$F on $^{89}$Y target at $E_{lab}$=59 MeV and 50 MeV.

## 1. Introduction

The nuclear reactions of unstable nuclei are the research topics of current interest. The reactions may provide a new path for studying the exotic structure and the new reaction mechanisms which are different from those of stable nuclei at energies around Coulomb barrier [1–4]. Elastic scattering has been considered as an important tool to explore the inner structure of nuclei and the reaction mechanisms. Elastic scattering measurements involving weakly bound nuclei at low energies have been performed to investigate their exotic features. Recently as low-energy Radioactive Ion Beam (RIB) facilities have been available in a few laboratories [5–8] with these exotic nuclei produced with good beam features, the measurements of elastic scattering angular distributions induced by these RIBs were achieved.

The precise measurement of elastic scattering angular distribution is a crucial task. In a typical setup, a series of collimators is required along the beam line to collimate the beam spot and several sets of large area detectors are employed to measure the beam trajectory before the secondary target since the beam spot of RIB is much larger than that of stable beam. Because of its high energy and spatial resolution, Double-sided Silicon Strip Detector (DSSD) is often used for the detection of scattered particles. Some silicon strip detectors, such as EXPADES detector array [9] and Compact Disk (CD) double-sided silicon strip detector array [10], are used for elastic scattering experiments. If the beam spot size and emittance are small enough, the scattering angle of each particle can be directly obtained from the geometry relationship between the fired silicon strip and the beam spot. However, if the beam spot size and emittance on the target are not negligible compared with the distance between the target and the detectors, the angles of particles need to be tracked event by event and cannot be directly obtained from the position of the silicon strip alone.

The experiment in the present work was performed on Radioactive Ion Beam Line in Lanzhou (RIBLL) which was designed as a double-achromatic anti-symmetry separator. RIBLL was constructed on the basis of the Heavy-Ion Research Facility of Lanzhou (HIRFL) [11,12] and has been in operation since 1998. It is a Projectile Fragmentation (PF) type RIB separator with a large momentum acceptance and solid angle. Fig. 1 shows its schematic view. There are three focal points (T0,

* Corresponding authors.
*E-mail addresses:* zgl@buaa.edu.cn (G.L. Zhang), cjlin@ciae.ac.cn (C.J. Lin).

http://dx.doi.org/10.1016/j.nima.2016.11.058
Received 31 May 2016; Received in revised form 27 November 2016; Accepted 27 November 2016
Available online 02 December 2016
0168-9002/ © 2016 Elsevier B.V. All rights reserved.

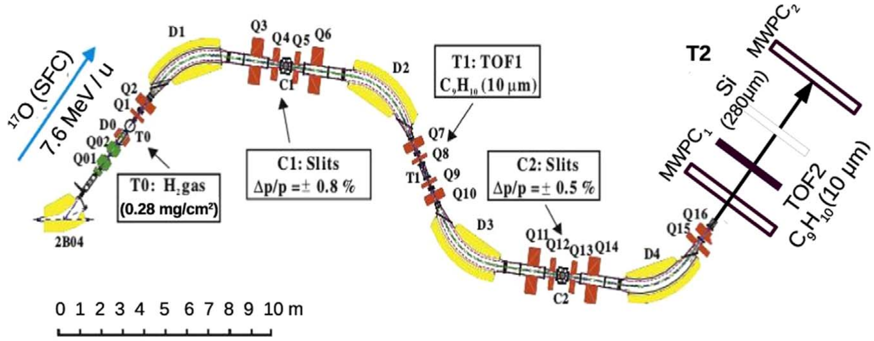


**Fig. 1.** The schematic view of low energy radioactive ion beam line on RIBLL and the experimental setup.

T1 and T2) under the achromatic mode, and two focal planes (C1, C2) where the horizontal momentum dispersion ($\Delta x/(\Delta p/p)$) is about 20 mm/%. The detailed information about it can be found in Refs. [13,14]. Since RIBLL has a large beam emittance with a designed value of 50 mm mrad in both horizontal $X$ - and vertical $Y$ -directions and an actual value of approximately 30 mm mrad and 40 mm mrad in $X$ - and $Y$ -directions respectively for the secondary beam on the secondary target position [15], the calculation of angular distribution of heavy-ion elastic scattering needs to be tracked event by event. Recently a new low energy radioactive beam line for nuclear astrophysics studies at Lanzhou on the basis of RIBLL was developed [16]. In order to perform the nuclear reaction of low energy RIBs on this beam line and study the nuclear reaction mechanisms at energies around Coulomb barrier, the experiment of $^{17}$F+$^{89}$Y elastic scattering at energies around Coulomb barrier was carried out. A secondary beam $^{17}F^{9+}$ was separated and transported by RIBLL to the secondary target chamber. However, since PF type separator has a broad beam distribution in coordinate space, it is difficult to obtain the accurate cross sections of elastic scattering by a high statistics measurement when small collimator is used to produce a well-defined beam. In this paper the methods how to calibrate the elastic scattering angles and how to deduce the angular distributions of elastic scattering at energies around Coulomb barrier in this experiment are introduced.

## 2. Experimental setup

The primary beam $^{17}O^{8+}$ with a beam intensity of 1 pμA was accelerated up to 7.6 MeV/u and passed through a 21 μm aluminum foil, then bombarded a $H_2$ gas target which was installed at T0 of RIBLL. The gas was confined into a cylindrical cell with windows of 30-mm $\phi$ and a length of 80 mm. The forward and backward windows were covered by Havar foils with 2.5 μm in thickness. The gas cell was cooled around 5°C by a water-cooling system and the gas pressure was kept around 600 Torr. The secondary beam $^{17}$F was generated by $^{1}$H ($^{17}$O,$^{17}$F) n reaction, then separated, purified and transported by RLBLL to the secondary target chamber at T2 as shown in Fig. 1. At T1 and T2 two plastic scintillators ($C_9H_{10}$) with 10 μm in thickness were installed in the beam line to give the Time Of Flight (TOF) information. The purity and the beam intensity of the produced $^{17}$F are around 60% and 3× $10^4$ pps, respectively. Two Multi Wire Proportional Chambers (MWPC) were installed at the location of 1666 mm and 1285 mm in front of the secondary target $^{89}$Y. Therefore, the beam position on the secondary target can be determined by analyzing the two-dimensional hit positions measured by two MWPCs. Two collimators with $\phi$30 were installed behind the two MWPCs and in front of the secondary target to limit the beam spot. The secondary target $^{89}$Y with 0.981 mg/cm$^2$ in thickness was tilted at 65° with respect to the beam line. Around the $^{89}$Y target four sets of $\Delta$ E-E detector telescopes were symmetrically mounted along the beam direction and covered an angular range of 15–115° (Fig. 2). They are composed of DSSD with 65 μm in thickness and 50× 50 mm$^2$ in area, and Square Silicon

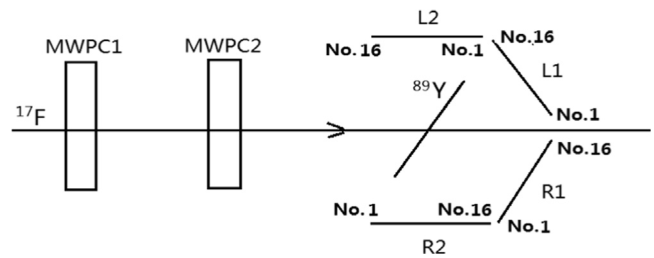


**Fig. 2.** The schematic top view of detector setup of this experiment.

Detectors (SSD) with 300 μm in thickness and 50× 50 mm$^2$ in area. SSD was mounted behind DSSD, which was with 3 mm strip width and 0.1 mm strip span.

## 3. Data analysis

### 3.1. Particle identification

Two processes were performed in the experiment. The first process was to identify the secondary beam, and the second was to measure the reactions of the secondary beam on the secondary target. Firstly, a silicon detector with a thickness of 300 μm was inserted into the beam line between MWPC2 and the plastic scintillation detector at T2 as an E detector to stop the beam. The plot of E-TOF for beam particle identification is shown in Fig. 3. Since the flight distance is fixed, with the calibration values of TOF and the total kinetic energy $E$, each beam particle can be identified (marked in Fig. 3). With the magnetic rigidity B$\rho$ set for the last dipole magnet D4, the energy of each component can be calculated. Then the calibrated energies are compared to the calculation in order to check the validity of the identification. We confirmed that the present calibration is in agreement with the experimental data, showing that the identification of beam particles is reliable. In the experiment, $^{17}$F beams with 59 MeV and 50 MeV

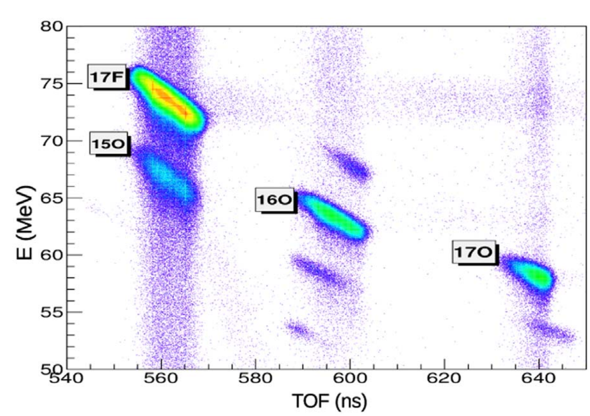


**Fig. 3.** The plot of E-TOF for beam particle identification.

Download English Version:

https://daneshyari.com/en/article/5493163

Download Persian Version:

https://daneshyari.com/article/5493163

Daneshyari.com