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Development of detection systems for low-energy heavy ions at DRAGON

Sabine Engel [a,*], S. Bishop [b], A. Chen [b], C. Dale [b], J.M. D'Auria [b], U. Giesen [d], U. Greife [e], R. Henderson [c], D. Hunter [c], D. Hutcheon [c], R. Openshaw [c], J. Rogers [c], C. Rolfs [a], A. Shotter [f]

[a] *Ruhr-Universität, Bochum, Germany*
[b] *Simon Fraser University, Burnaby, BC, Canada*
[c] *TRIUMF, Vancouver, BC, Canada*
[d] *University of Notre Dame, South Bend, IN, USA*
[e] *Colorado School of Mines, Golden, CO, USA*
[f] *University of Edinburgh, Edinburgh, Scotland, UK*

Abstract

The new DRAGON facility at TRIUMF is designed to measure alpha and proton capture reactions with radioactive ion beams in inverse kinematics. For nucleo-synthesis in astrophysical scenarios, the relevant energies lie in the 0.15–1 MeV/u range, where very low cross sections are expected. Therefore the separation of the recoil products from the beam particles will be a difficult task. This paper focuses on the end detectors, which will be used to distinguish recoils from beam particles at the end of the DRAGON separator. © 2002 Elsevier Science B.V. All rights reserved.

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1. Astrophysical background

Explosive nucleosynthesis, such as in novae, supernovae and X-ray bursts, plays an important role in the synthesis of elements heavier than oxygen. In these relatively hot environments, alpha and proton capture reactions of radioactive species will become significant. In particular, reactions that determine the breakout to higher-order burning processes need further study. One example of such a reaction is ^{21}Na(p, γ) producing ^{22}Mg which is a precursor of ^{22}Na, visible via X-ray astronomy. Better knowledge about their

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* Corresponding author.
E-mail address: engel@triumf.ca (S. Engel).

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cross sections could lead to more accurate models concerning stellar evolution and the production of the elements [1].

2. Introduction

At the new Detector of Recoils And Gammas Of Nuclear reactions (DRAGON) at the ISAC radioactive beams facility at TRIUMF, we plan to measure rates of key reactions in explosive nucleosynthesis down to energies of 0.15 MeV/u. Using inverse kinematics and a radioactive beam, we will study a range of reactions, starting with $^{21}\mathrm{Na}(\mathrm{p},\gamma)^{22}\mathrm{Mg}$. With expected product-to-beam ratios as low as 10^{-15}, separation and detection of the recoils will be challenging [2].

3. The end detector

Although the recoil mass separator (DRAGON) will reject the incoming radioactive ion beam from the windowless gas target with an estimated suppression factor of 10^{12}, some of these ions will reach the end detectors after charge changing or scattering collisions. Because of the inverse kinematics, they will have almost the same momentum as the recoils. Therefore we need a detector which is not only able to detect heavy recoils ($A = 13$–24) of very low energies, but also to distinguish between the recoil products and ion-beam particles [3]. This separation will be aided by a BGO gamma array, surrounding the gas target. Besides the energy detection of the emitted reaction photons, the array provides also background suppression through coincidence measurements with the pulsed beam.

3.1. Time of flight

A “local” time-of-flight measurement over a distance of approximately 50 cm will be located at the end of the DRAGON separator. Two options are being considered. The first approach utilizes a microchannel plate detector (MCP) and a parallel grid avalanche counter (PGAC) coupled internally with an ionization chamber (IC) for start and stop and energy signals. The second approach uses two MCP counters to determine the time, with a silicon solid state detector for total energy detection.

3.2. Microchannel plates

To generate a fast timing signal, we detect secondary electrons produced by the recoil or beam particles traversing a thin carbon foil. Microchannel plates have proven to be an optimal device for fast electron amplification. While literature shows a wide range of different geometries to accelerate the electrons to the plates, the main feature is an equal path length for all electrons to achieve a proper timing signal. In addition, we would like to obtain information on the position of the incident particle in order to achieve further beam suppression. Resolutions of 200 ps and 2 mm, respectively, are required.

Therefore we decided to start tests with an electric mirror setup [4]. The ions cross a foil perpendicular to the beam. Secondary electrons are accelerated towards a parallel grid. When they reach the mirror, they are reflected at an angle of 90° and accelerated towards the MCPs, preserving their spatial information. To avoid using a second foil or the PGAC for the stop signal, we might be able to collect secondary electrons produced on the entrance window of the IC or on the surface of the Si detector. However this has to be tested.

3.3. Parallel Grid Avalanche Counter (PGAC)

The PGAC is a three wire-plane sandwich located immediately in front of, and in the same gas volume as the IC. Incoming particles leave a trail of ionization in the gas. The resulting primary electrons avalanche to the central anode plane, providing a gain of the order of 10^3. A fast timing signal is taken from the anode plane, while delay line readouts on the two orthogonal cathode planes provide two-dimensional position information.

3.4. Ionization chamber

We hope to separate the groups of interest further through E–ΔE discrimination. But the detection of heavy ions at energies below the Bragg peak pushes the performance of an ionization chamber to its limits. The aim is to achieve an intrinsic energy resolution of about 1% and to optimize the discrimination between beam and reaction products. Therefore, the IC has a flexible design with 25 isolated anode strips over a length of 25 cm, that can be combined as desired depending on the specific reaction. First tests with stable beams have been done at the Enge Splitpole Spectrometer at Yale University.

4. Summary

We are continuing to test the end detector system, in order to determine the best configuration. According to the present schedule, we hope to install this detector system late in 2000 to initiate commissioning of DRAGON with an alpha source.

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