The Clover detector array for the PRISMA spectrometer

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I. INTRODUCTION

The nuclear structure studies on nuclei far from the stability valley has been one of the main goals of experimental and theoretical nuclear physics in the last years. The final aim of this studies is to develop models for the nuclear interaction potential, describing the new nuclear structure phenomena like the nuclear halos (connected with loosely bound nucleons), the evolution of the shell closures and the new regions of nuclear deformation with structural and dynamical symmetries.
The coupling of an array of Clover detectors [1] with the PRISMA [2,3] spectrometer will allow to study the nuclear structure of moderately neutron rich nuclei, populated at relatively high angular momentum, by means of binary reactions such as multinucleon transfer and deep inelastic. The project will benefit largely from the stable beams, at medium and high intensity, which will be available from the PIAVE+ALPI complex, following its commissioning in the second half of 2002.
The physic topics covered by this setup will complement studies performed with current radioactive beam (RIB) facilities, at least until the second generation of RIB facilities like SPES, SPIRAL II, SIRIUS or RIA, is working fully. The use of these reactions, where possible, has the advantage that the outgoing reaction products have relatively low velocity, in contrast to the products of fragmentation reactions. Consequently, their use is compatible with the characteristics of the present generation of $\gamma-$arrays, which consist of non segmented detectors without tracking capabilities.
This production method also works for proton rich nuclei, but in this case other mechanisms, such as compound nucleus reactions, are more efficient in general.
The project is strongly supported by the international EUROBALL collaboration.

II. THE PRISMA AND CLOVER ARRAY SET-UP

PRISMA is a large acceptance magnetic spectrometer for heavy ions [2,3], which is in the last phase of construction at LNL. It has has been designed for the A=100-200, E = 5-10 MeV$\times$A heavy-ion beams of the XTU Tandem-ALPI-PIAVE accelerator complex. The most interesting features are its large solid angle of 80 msr; momentum acceptance $\pm$10%; mass resolution 1/300 via TOF; energy resolution up to 1/1000 and rotation around the target in a large angular range ($-20^o \leq \theta \leq 130^o$).
The above performance will be achieved by software reconstruction of the ion tracks using the position, time and energy signals from the entrance (start) Micro-Channel-Plate and focal-plane detectors. A more detailed description of Prisma can be found in Ref. [4].
The use of the PRISMA spectrometer coupled to an anti-Compton $\gamma-$ array marks a step forward with respect to the previous spectroscopy studies with deep inelastic or multinucleon transfer reactions. The high resolving power of PRISMA will give, for most of the reaction products, the full identification of mass and Z and therefore lower the sensitivity limit in the measurements. This will make available information from reaction products of very low cross section and thus allow measurements on nuclei further away from stability.
In the definition of this project we have tried to optimize the sensitivity of the $\gamma-$ray detector array considering the boundary conditions imposed by PRISMA and by the nature of the binary reactions of deep inelastic scattering or multinucleon transfer. Considering the detectors available in the Euroball collaboration, an optimal array to be coupled to the PRISMA spectrometer could be based on the composite EUROBALL CLOVER detectors [1]. They are composed of four Ge-HP crystals, each with a diameter of 50 mm, mounted in a single cryostat.

The energy signals from the four crystals are acquired independently and, since one $\gamma-$ray can interact with more than one crystal, add-back algorithms are used off-line to determine the $\gamma-$ray energy.

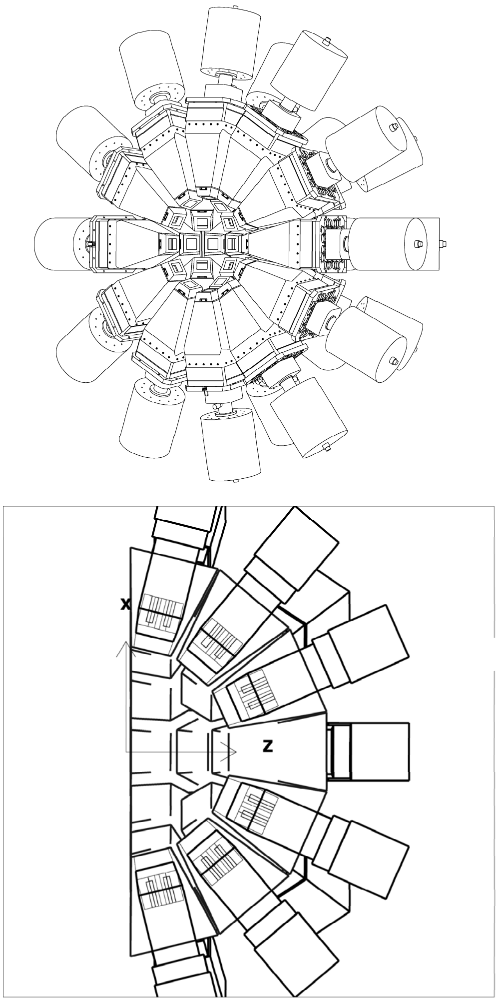

FIG. 1. View (upper panel) and cut (lower panel) of the proposed configuration for the CLOVER detector array .

To make use of the escape-suppression technique, the detectors are surrounded by a BGO anti-Compton shield, allowing a consistent improvement of the peak-to-total ratio.
As a possible design for the array to be coupled to PRISMA we propose to build a hemisphere of CLOVER detectors. They will be placed at backward angles between $\theta = 104^o$ and 180^o with respect to the entrance direction of the spectrometer. To estimate the performance of this array based on CLOVER detectors, Monte-Carlo simulations have been performed. The CERN detector design and simulation tool GEANT3 [5] library has been used. The simulation of the interaction of $\gamma-$ray with the detectors has been carried out including all relevant physics processes and with the geometry shown in figure 1. It has been carried out under the kinematic conditions expected when measuring with PRISMA. From these calculations we have obtained the following performance figures:

- Total peak efficiency $\approx$3% for E_γ=1.3 MeV.
- Peak/Total ratio $\approx$50%.
- Energy resolution $\approx$10 keV for v/c=10% and E_γ=1.3 MeV.

In figure 2 a schematic drawing of the CLOVER array at the PRISMA target position is shown. The detector system, installed on a mobile platform, will rotate together with the spectrometer, in such a way that reaction products detected in the spectrometer focal plane, in coincidence with the $\gamma-$rays, will have a forward trajectory with respect to the array. The PRISMA start detector (micro channel plate) allows one to determine the trajectory of the products with an angular resolution $\Delta\theta < 0.5^o$. Because the high accuracy in the direction of the nuclei emitting the $\gamma-$rays the final Doppler broadening will be due to the angular aperture of the Ge crystals alone.
The present status of the project can be described as the starting point for the design of the different elements and infrastructure for the setup.

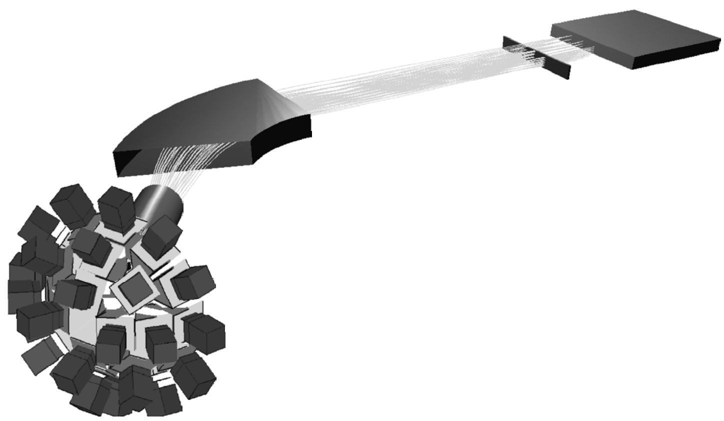

FIG. 2. Scheme of the coupling between the CLOVER array and the PRISMA spectrometer.

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