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Letter of Intent to the
ISOLDE and Neutron Time-of-Flight Experiments Committee
for experiments with HIE-ISOLDE

GASPARD at HIE-ISOLDE

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Abstract

The new array GASPARD presently being designed for nucleon transfer reactions at SPIRAL2 will bring higher *pixellation*, lower *energy thresholds*, better *particle identification* and more versatility with *novel targets*, compared to previous generations of array for transfer studies. GASPARD is essentially a silicon telescope array that will fit within alternative gamma-ray arrays (AGATA, PARIS and EXOGAM) and is optimized for coincident gamma-ray detection. It is being developed for exploitation of SPIRAL2 but is envisaged from the start as being transportable between facilities, on a campaign basis. The collaboration is open. HIE-ISOLDE offers high quality beams for species that complement those from SPIRAL2 and there are excellent opportunities for a complementary physics programme. GASPARD will be used with the VAMOS spectrometer at SPIRAL2, and at HIE-ISOLDE it would best be sited in front of a spectrometer or some suitable beam/recoil filter device. Some example physics applications are described, using neutron rich beams of carbon, sulphur and calcium, assuming that intensities of at least 10^4 pps can be developed with isotopic purity of at least 10%, for these isotopes.

1. Introduction

Nucleon transfer reactions such as (d,p), (d,t) and (p,d) are an established part of the Rex-ISOLDE research programme already, but are likely to become even more important with the increase in the bombarding energy to 5.5 and eventually 10 MeV/A. At these energies, the theoretical means of analysis via DWBA, ANC and ADWA are well developed and the angular distributions are characteristic of the transferred angular momentum. The aims are to measure spectroscopic factors and to compare with the best model predictions for energy levels and reaction strengths. This relates to the evolution of magic numbers, quenching of spectroscopic factors and energies for single particle levels near, and into the continuum. In addition, many reactions involving nucleon or alpha-particle transfer with radioactive beams have inherent interest for nuclear astrophysics.

2. Physics case

GASPARD [1] is being designed around benchmark experiments with reactions such as (d,p), (p,d), (p,t) and (^{3}He,d) in inverse kinematics, using fission-fragment beams in the Sn and Ni regions. For campaigns at HIE-ISOLDE, we have identified complementary experiments. GASPARD is an open collaboration, with many opportunities for collaboration in the development and exploitation in a wider programme. Nuclear structure in the neutron-rich carbon region can be investigated via (d,p) and compared with shell model and AMD microscopic models, in a region where cluster structure is also very important and break the N=8 shell. Carbon isotopes are also a good testing ground for (d,t) and (p,d) spectroscopic factors to be compared to knockout results [2]. Neutron-rich sulphur beams should allow access to the deformed region caused by the N=28 breakdown [3]. The N=32/34 region of neutron-rich calcium [4] can be probed for neutron single-particle information via (d,p), and then the proton-neutron interactions can be measured by follow-up studies of isotones using K and Sc beams. (We note also the separate LoI [5] highlighting the n-rich Ca region). These elements are all well suited to ISOLDE but require development for n-rich beams.

3. Experimental setup

GASPARD is being developed for SPIRAL2, to take over eventually from the existing MUST2/TIARA setup (Figure 1) which has recently been exploited at SPIRAL, coupling TIARA [6] and MUST2 [7] with EXOGAM [8] and the magnetic spectrometer VAMOS [9].

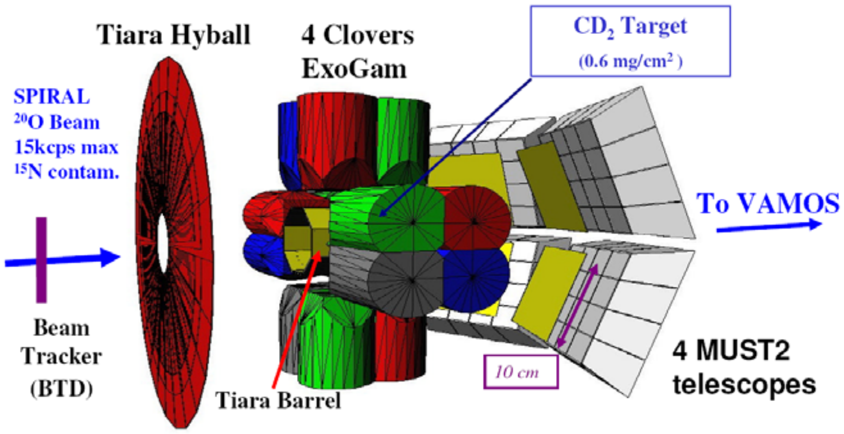

Figure 1: Current setup at SPIRAL for combining MUST2 and TIARA with EXOGAM

GASPARD is planned to be ready for experiments by 2014/2015; the very first experiments at SPIRAL2 could continue to use MUST2/TIARA. The new array will improve performance in the key areas of: particle identification, low energy thresholds, the angular resolution and an improved angular range for the gamma-rays. A silicon array involving multiple Si layers, with high pixellation for the first layer, combined with new multichannel high density electronics has been chosen for GASPARD. This will be designed for use with various separate gamma-ray arrays and with the option of including cryogenic and gas targets. A schematic of the setup is shown in Figure 2. Because time-of-flight is required for particle identification at low energies, a thin transmission detector for the beam is planned and will require space in front of the reaction chamber.

GASPARD is being designed in cooperation with the PARIS consortium [10] who are developing a large LaBr3(Ce) array within a SPIRAL2 development project. As for GASPARD, PARIS is intended from the outset as being available at different facilities on a campaign basis [10]. PARIS offers the highest gamma-ray efficiency for use with GASPARD.

GASPARD will have its own structure that will support it inside existing gamma-ray arrays, with the vacuum vessel diameter being less than 40 cm. The outer side of the vacuum vessel will have the first stage FEE boards that carry the minimum amount of electronics needed very close to the detectors. Further cables will take signals to electronics located outside of the gamma-array. GASPARD is intended to include optional use of cryogenic targets. This array would need to be sited in front of a spectrometer device, if one is built at HIE-ISOLDE. This could feasibly be anything from an EMMA-style device [11] to a large-acceptance spectrometer such as VAMOS [9] to a simpler quadrupole or solenoid filter [12] that could separate beam particles and transfer products from fusion-evaporation products physically and/or by time-of-flight.

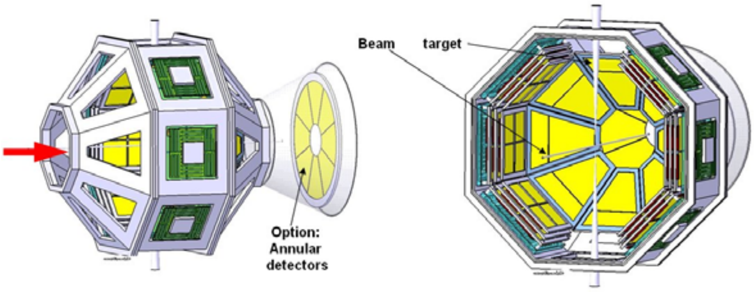

Figure2: Barrel plus trapezoid “Gasp-Hyde” design proposed for GASPARD, including three-stage Si telescopes, FEE close to the detectors, good access at 90 degrees and customizable forward angles.

4. Beam requirements

This is a general purpose device and is intended for a wide range of isotopes. The beam is transmitted through the device and beyond the array, to a shielded beam dump. The angular divergence of the beam should be less than or equal to one degree and a beam spot of diameter 1mm would be ideal, and up to 1.5mm tolerable in some cases (weakest beams). Absolute isotopic purity is of course preferable, but in the case of gamma-ray coincidence experiments (i.e. the main class of experiment anticipated with GASPARD) we estimate being able to cope via gamma-ray selection with beams in which as little as a few percent of the beam is the isotope of interest, if necessary. This is based upon experience with beams up to 10^7 pps using SHARC/TIGRESS at ISAC2 with no spectrometer. At SPIRAL we have successfully used 20% pure ^{20}O beams (80% ^{15}N) thanks to stripping in the target removing ^{15}N products from the VAMOS focal plane. Beam bunches would require resolution of sub-nanosecond, if it were used for the time-of-flight identification of low energy particles, but it is anticipated that the timing reference will be supplied by a thin beam detector at the entrance. The beam optimization and focusing requires a removable monitor detector, ideally position-sensitive, at the exit of the vessel plus a permanent beam monitor (at a location that depends on the zero-degree device). We request the further development of neutron-rich beams of C, S, K, Ca and Sc towards intensities of 10^4 pps for ^{16}C, ^{40}S and ^{50}Ca (and nearby K and Sc isotopes).

5. Safety aspects – no specific requirements; beam is transmitted to a shielded beam dump.

6. References

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