laboratoire commun CEA/DRF CNRS/IN2P3

PROPOSAL FOR AN EXPERIMENT

PAC Date :	EXP # (Do not fill in):
November 2018	E

Title: Commissioning of the MUGAST+AGATA+VAMOS setup using the 16O(d,p)17O reaction.

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Collaboration : Participant names, institutions, and indicate students (S), and post-doctoral fellows (PDF):

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for the MUGAST collaboration , the AGATA collaboration and the VAMOS collaboration

Abstract:

We propose to use the $^{16}O(d,p)^{17}O$ reaction to commission the experimental setup combining MUGAST, AGATA and VAMOS for the first time prior to the corresponding experimental campaign in 2019.

EXPERIMENTAL DEVICES REQUIRED

SPECTROMETERS

VAMOS (G1 Hall)	X
LISE	
LISE 2000 (D4 Hall)	
LISE D4 (D4 Hall)	
LISE D6 (D6 Hall)	
Wien Filter? [Yes/No]	
SPEG (G3 Hall)	

REACTION CHAMBERS

ECLAN	
NAUTILUS (G42 Hall)	

DETECTION SYSTEMS

AGATA	X	CATS	X
CAVIAR		Château Cristal	
DEMON		DIAMANT	
EXOGAM (a)		INDRA	
ACTAR TPC		MUST2 (b)	
Neutron Wall		TIARA	
Other (specify)	MUGAST		

(a) Indicate the number of HPGe clovers
(b) Indicate the number of telescopes

BEAM LINES

G1	G21	G22	G3	G42	IBE
X					
D1	D2	D4	D5	D6	LIRAT

NFS SET-UP

Irradiation Station	
Sample Transfer System	

EXPERIMENTAL SET UP

Reaction Targets: List any secondary reaction targets (materials and thicknesses) that will be installed in the experimental setup: (deuterated polypropylene) CD2 target (different thicknesses from 0.5 to 3 mg.cm-2)

Data Acquisition: Will you use the standard GANIL data-acquisition system? [Yes/No]: YES
If No, please specify what system will be used: AGATA+GANIL

Safety: List any hazardous materials or substances that will be used. Include, for example, radioactive targets and sources, high voltage, liquid nitrogen, and explosive gases even if they are standard for operating existing spectrometers or germanium detectors:

Additional Equipment: List any specialized equipment that needs to be installed or new equipment that has not yet been purchased or built. Provide the date in which this equipment is expected to be ready and indicate what help you may need from GANIL staff:

Were other experiments performed at GANIL in the past that used the same (or similar) experimental setup? [Yes/No]: No
If Yes, please provide the experiment number(s):
Specify any differences or improvements you would like to make to these previous setups:

Are there other experiments at GANIL (approved or proposed) that require the same experimental setup? [Yes/No]: YES
If Yes, please provide the experiment number(s):
E768 and all experiment proposed with MUGAST at the 2018 PAC.

GANIL FACILITY

BEAM REQUEST

	Ion(s)	Energy (MeV/u)	Intensity on target (pps)	Purity (%)	Beam extension (ns)	Number of UT's (1 UT = 8 hours)
			Indicate the minimum values required.			
Stable beam(s)	1. 16O 2.	6 MeV/nucleon	10^5 for 3 UTs 10^7 for 1 UT	100%		8
Exotic Beams						
SPIRAL beam(s)	1. 2.					
LISE beam(s)*	1. 2.					
	Material*	Thickness (µm)*	Power (W)*			
LISE production* target(s)	1. 2.			** For questions please contact the LISE scientific coordinator*		

SPIRAL2 FACILITY

LINAC BEAM						
	Ion(s)	**Energy (MeV/u)**	**Intensity on target (pps)**		**Pulsed beam**	**Number of UT's (1 UT = 8 hours)**
Beam						

NFS NEUTRON BEAM						
	Experimental area	**Spectrum**	**Energy(MeV)**	**Flux ($n/cm^2/s$)**	**Pulsed beam**	**Number of UT's (1 UT = 8 hours)**
Neutron beam	☐ Converter room ☐ TOF hall	☐ Continuous ☐ Quasi-mono-energetic				

IN-BEAM TESTS
In **exceptional cases** a dedicated in-beam test can be scheduled before your experiment or the number of requested UT's could be divided into two or more separate periods. Will your experiment require this? [Yes/No]: If Yes, please specify the circumstances and explain how the UT's should be divided and the time required between test and experiment: **Important:** The number of UT's must be included in the TOTAL BEAM-TIME REQUEST.

TOTAL BEAM-TIME REQUEST	
Number of UT's required for beam tuning (including production of radioactive beams in LISE, contact your scientific coordinator):	**1**
Number of UT's required for planned settings/modifications of the experimental set-up:	**2**
Number of UT's requested for performing the experiment (data taking) and in-beam calibrations DURING the experiment:	**4**
Number of UT's required for performing in-beam tests BEFORE the experiment (if needed, see IN-BEAM TESTS above):	
Total number of UT's (sum of the 4 values above):	**7**

SCHEDULING
On what date will your experiment be ready to run? : april 2019
Time required (UT's) **before** the scheduled beam time for setting up the apparatus: Time required (UT's) **after** the scheduled beam time for calibration and take down:
Do you require **auxiliary (parasitic beam)** to be delivered before the experiment for debugging purposes? [Yes/No]: If Yes, provide a range of possible isotopes, masses, and energies (MeV/u) that would be most suitable:

SCIENTIFIC PRODUCTION

Status of previous experiments performed by the spokesperson(s) in the last 3 years at GANIL (or related experiments elsewhere) :

Publications, presentations, and theses completed in the last 3 years from past experiments at GANIL (or related experiments elsewhere):

ADDITIONAL INFORMATION

Please provide any additional information that may be relevant for the experiment:

Commissioning time for the MUGAST AGATA VAMOS campaign

Commissioning of the MUGAST+AGATA+VAMOS setup using the $^{16}O(d,p)^{17}O$ transfer reaction.

In the perspective of the 2019 MUGAST-AGATA-VAMOS campaign, a commissioning beam time prior to the run is crucial in order to validate the coupling of the different detectors, happening for the first time. Such a beam time, reasonably separated in time with the first experiment scheduled (at least one week) would allow to fix unexpected issues, if any, and ensure a more efficient experimental run afterwards.

The strategy we propose for such a commissioning include three steps:

- 2 UTs of beam time to tune electronics parameters of the different elements (MUGAST, AGATA, VAMOS, CATS), which can't be tuned using calibration sources or pulsers alone.
- 3 UTs of beam time to measure the $^{16}O(d,p)^{17}O$ to the first excited ½+ state necessary to obtain proton-gamma coincidences and benchmark the full acquisition+analysis chain in standard conditions.
- 1 UT of beam at high intensity (typically 10^7 pps) specifically to check the performance of the setup in more extreme conditions in terms of trigger rate, required for some experiments (in particular C. Diget et al already accepted at the PAC of 2017 with the highest priority).

Measurement of the $^{16}O(d,p)^{17}O$ transfer reaction

The $^{16}O(d,p)^{17}O$ reaction is considered because it has been studied in direct kinematics at various energies (See [1-3] for example) but also in inverse kinematics using the MUST2 setup at GANIL [4] and thus provide a good reference for a benchmark. It is quite favorable in terms of statistics because of the large spectroscopic factor (close to unity) between the ^{16}O ground state and the first excited ½+ state of ^{17}O at 871 keV. Since this transfer involves a L=0 (1s1/2) neutron, the momentum matching favors transfer at rather low beam energy (few MeV/nucleon). To keep outgoing proton energies high enough to remain easily measurable, a beam energy of 6 MeV/nucleon is sufficient. The simulated kinematics of the outgoing proton is shown in Fig.1 together with the excitation energy resolution obtained (about 500 keV FWHM).

With 3 UTs of ^{16}O beam at an intensity of 10^5 pps, and a 1 mg.cm^{-2} CD_2 target, we would detect about 1100 proton-gamma coincidences for the 871-keV state of interest (details are given in table). This will allow building a gated angular distribution with moderate statistical error. Having such a gated- angular distribution is important to check the full data chain, from acquisition to treatment, and allow to check that the ratio between ungated and gamma-gated protons is compatible with measured efficiencies using sources (no obvious loss of coincidences).

	16O(d,p)17O*(1/2+)
Energy	6 MeV/nucleon
Number of Uts	3
Yield (pps)	100000
CD2 target (mg/cm²)	1
s.p. cross section (mb)	52
Spec. Factor	0,90
Nreactions	30427
Ndetected(p)	11085
Ndetected(p+g)	1109

Table 1: Count rate estimations

Additional remarks:

- *The choice of 6 MeV/u for the ^{16}O beam is just to optimize between the matching and the cross section to the state of interest and the energy of the outgoing protons. Lower beam energy is not possible because the emitted protons would have too low energies. Higher beam energy is however possible if more simple for beam tuning, up to about 10 MeV/nucleon.*
- *An alternative commissioning beam could be ^{22}Ne at 6 MeV/nucleon if it would be more advantageous for any scheduling or production reasons. The $^{22}Ne(d,p)^{23}Ne$ is quite similar to the case proposed with ^{16}O but only less advantageous in terms of statistics (factor of 2-3 less).*

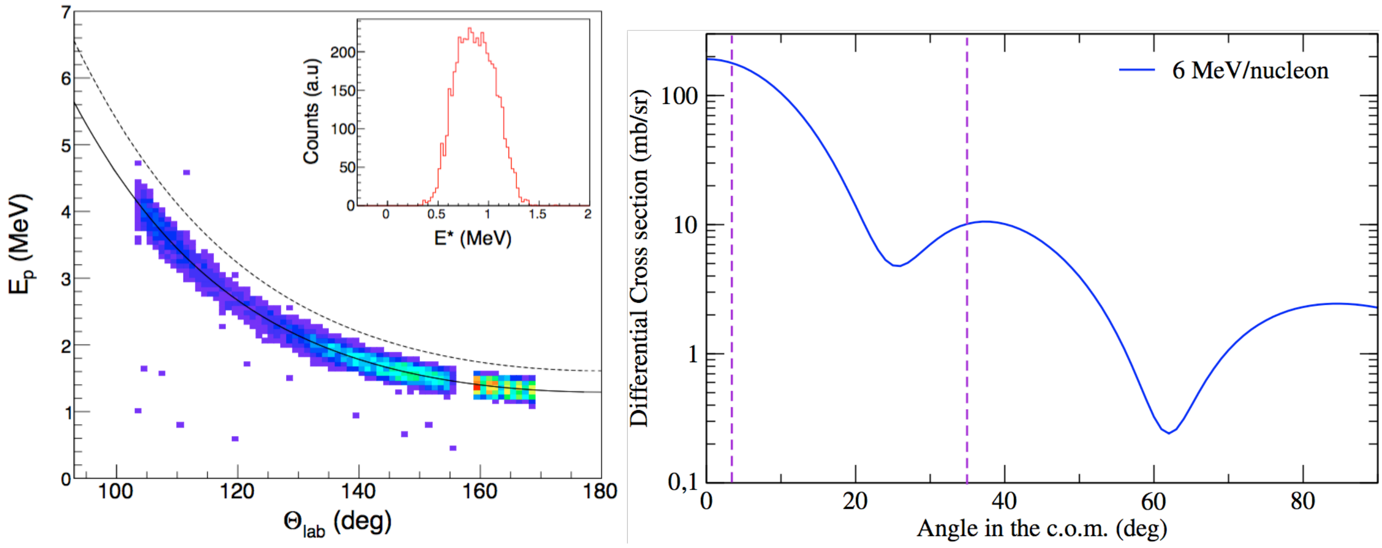

Figure 1: (Left) Simulations for the $^{16}O(d,p)^{17}O^*(1/2+)$ reaction: Kinematics of the protons detected in MUGAST at backward angles, the dashed line indicate the ground state kinematic line (Insert) Reconstructed excitation energy spectrum for the 871 keV state, trapezoid detectors only (FWHM about 500 keV). (Right) DWBA calculation of the $^{16}O(d,p)^{17}O^*(1/2+)$ cross section with dashed line indicating the range covered by MUGAST detectors at backward laboratory angle (forward in the center of mass).

High beam intensity test

After measuring ^{16}O(d,p) in "standard conditions" and validating the electronics+ acquisition + analysis chain, we plan to increase progressively the beam intensity to reach about 10^7 pps. In C. Diget *et al* experiment, accepted with highest priority at the GANIL PAC of 2017, an ^{15}O beam at up to 1.8 10^7 pps is asked for.

For this test, we will use a CD_2 target with a thickness equivalent to 1 mg/cm^2 of LiF. We will remove the CATS detectors and put a beam stopper in VAMOS. In the first place, the MUST2 detectors (forward) will be switched on and possibly switched off if the counting rate (and trigger rate) becomes too high. We do not expect high counting rate in the backward direction (trapezoidal detectors). However this is non-standard trigger conditions and there might be dead time or acquisition issues that can only be identified during a commissioning beam time.

Summary

We request a total 7 UTs (including one UT for beam production and tuning) to perform the commissioning of the MUGAST setup and its coupling with AGATA and VAMOS. For that we propose the use of a ^{16}O stable beam at 10^5 and 10^7 pps, accelerated at about 6 MeV/nucleon.

The main objective is to perform a coincident detection of the proton emitted from the $^{16}O(d,p)^{17}O^*(1/2+)$ in MUGAST, the de-exciting gamma-ray of 871 keV in AGATA and the recoiling ^{17}O in VAMOS at different beam intensities i.e. trigger rates.

References

[1] S. E. Darden et al., NPA 208, 77 (1973).

[2] M. D. Cooper et al., NPA 218, 249 (1974).

[3] D. R. Tilley et al., NPA 564, 1 (1993).

[4] T. Alkalanee, PhD thesis GANIL (2011)