TRIUMF - EEC SUBMISSION EEC meeting: 200712S *Progress Report*		**Exp. No.** S810 **Date Submitted:** 2007-11-12 12:58:19

Title of Experiment:

First direct study of the $^{23}Mg(p,\gamma)^{24}Al$ reaction with a recoil mass separator

Name of group:

DRAGON

Spokesperson(s) for Group

C. Vockenhuber, U. Greife

Current Members of Group:
(name, institution, status, % of research time devoted to experiment)

C. Vockenhuber	TRIUMF	Research Associate	40%
U. Greife	Colorado School of Mines	Associate Professor	25%
L. Erikson	Colorado School of Mines	Student (Graduate)	50%
C. Ruiz	TRIUMF	Research Scientist	40%
D.A. Hutcheon	TRIUMF	Senior Research	30%
U. Hager	TRIUMF	Research Associate	30%
K. Chipps	Colorado School of Mines	Student (Graduate)	25%
A. Shotter	TRIUMF	Professor	20%
M. Aliotta	University of Edinburgh	Lecturer	20%
P. Parker	Yale University	Professor	20%
A. Hussein	University of Northern British Columbia	Professor Emeritus	15%
A. Parikh	UPC Barcelona	Research Associate	15%
A.A. Chen	McMaster University	Associate Professor	15%

C. Deibel	Yale University	Student (PhD)	15%
C. Wrede	Yale University	Student (PhD)	15%
D. Kahl	McMaster University	Student (Graduate)	15%
J. Chen	McMaster University	Student (Graduate)	15%
J. Clark	Yale University	Research Associate	15%
K. Setoodehnia	McMaster University	Student (Graduate)	15%
A. Olin	TRIUMF	Research Scientist	10%
A. Wallner	University of Vienna	Research Scientist	10%
A.J. Murphy	University of Edinburgh	Lecturer	10%
A.M. Laird	University of York	Lecturer	10%
G. Ruprecht	TRIUMF	Research Associate	10%
J. Jose	UPC/IEEC Barcelona	Associate Professor	10%
J.M. D#Auria	SFU and ORNL	Professor Emeritus	10%
L. Buchmann	TRIUMF	Research Scientist	10%
L. Snyder	Colorado School of Mines	Student (Graduate)	10%
N. Galinski	Simon Fraser University	Student (Graduate)	10%
B. Davids	TRIUMF	Research Scientist	5%
M. Pavan	TRIUMF	Research Associate	5%

Beam Shifts Used:

Beam Shifts Remaining:

New Beam Requests:

Basic Information:

Date Submitted: 2007-11-12 12:58:19

Date Experiment Ready: 2008-01-01

Summary: The reaction ^{23}Mg(p,γ)^{24}Al plays a key role in the breakout from the NeNa to the MgAl cycle. Within this cycle the long-lived ^{26}Al nucleus is produced, which has been observed by orbital γ-ray observatories, e.g. COMPTEL and INTEGRAL. Thus, nuclear physics data on ^{23}Mg(p,γ)^{24}Al will be extremely useful in the modeling of possible stellar site(s) for ^{26}Al production. In the astrophysically interesting energy range the reaction rate is dominated by the nuclear resonance at E_{cm} = 458 keV. Only at higher temperatures the E_{cm} = 651 keV resonance can play a role. So far, the energies of this resonances have been determined by measuring the excitation energies of the relevant states in ^{24} Al via transfer reactions. Resonance parameters like the widths and strengths have been concluded from analog states in ^{24}Na. Due to the uncertainty going along with this method, the ^{23}Mg(p,γ)^{24}Al reaction rate is still not well known at all temperatures. We propose to measure the resonance strengths of the two astrophysically interesting resonances using the DRAGON facility. With ^{23}Mg intensities of 10^8 s^{-1} an accuracy of about 20% can be achieved. Contamination of ^{23}Na and the corresponding reation product ^{24}Mg can be separated in the ion chamber.

Plain Text Summary: The reaction 23Mg(p,gamma)24Al plays a key role in the breakout from the NeNa to the MgAl cycle. Within this cycle the long-lived 26Al nucleus is produced, which has been observed by orbital gamma-ray observatories, e.g. COMPTEL and INTEGRAL. Thus, nuclear physics data on 23Mg(p,gamma)24Al will be extremly useful in the modelling of possible stellar site(s) for 26Al production. In the astrophysically interesting energy range the reaction rate is dominated by resonances at Ecm = 458 keV and Ecm = 651 keV. We propose to measure the resonance strengths of these resonances using the DRAGON facility.

Primary Beam Line: isac2a

ISAC Facilities

ISAC Facility:

ISAC-I Facility: DRAGON

ISAC-II Facility:

Secondary Beam

Isotope(s): Mg-23, Na-23, Mg-24, Al-27, Na-21

Energy: 400 - 700

Energy Units: keVA

Energy spread - maximum : 1-2 keV, FWHM

Time spread - maximum : 1-2 ns, FWHM

Angular Divergence : 2 mr, FWHM

Spot Size: 2 mm, FWHM

Intensity Requested: 1e8 Mg-23 pps

Minimum Intensity: 5e7 pps

Maximum Intensity: 1e12 pps

Charge Constraints: 5+ or most probable

Beam Purity: Na-23 as low as possible, but an intensity of 500x Mg-23 is tolerable %

Special Characteristics:

Experiment Support

Beam Diagnostics Required: Faraday cup, slits, wire scanner, DRAGON CCD camera, ion chamber

Signals for Beam Tuning: Faraday cup, mass slit current, beta monitor, ion chamber

DAQ Support (Summary of Requirements): standard DAQ support for DRAGON experiments

TRIUMF Support (Resources Needed): Mg-23 beam production with TRILIS or FEBIAD ion source. Possible suppression of Na-23.

NSERC: DRAGON NSERC grant

Other Funding:

Safety Issues: Standard DRAGON saftey procedures for operation the H_2 gas target and the ion chamber. No long-lived activities are expected at A=23; slit boxes where most of the beam is dumped is surrounded by 5 cm Pb shielding; a fence/gate exclusion system prevents access closer than 1 m to the beam line at DRAGON

TRIUMF EEC Re-Submission

E810: First direct study of the ^{23}Mg(p,g)^{24}Al reaction with a recoil mass separator (DRAGON)

P.I.'s: Uwe Greife / Christof Vockenhuber

This experiment was first proposed by the DRAGON collaboration in June 1997 as part of the motivational push to build the DRAGON recoil separator experiment. The proton capture on ^{23}Mg is one of the reactions bridging the reaction flow from the astrophysical NeNa to the MgAl cycle. Within the latter, the important astronomical observable ^{26}Al is produced. The 1997 EEC noted that "a convincing case (was) made that the results are of considerable astrophysical interest." To our knowledge no additional experimental information exists that would change the scientific case compared to what was presented in our original proposal. However, additional theoretical efforts [H. Herndl et al., Phys. Rev. C 58 (1998) 1798] to predict the reaction rate should be noted.
However, the EEC also noted that: "^{23}Mg beams have not so far been produced at TISOL and will require development of an alternative source which may not be available for several years at ISAC. Na contamination in the beam will be a critical factor which will push for excellent performance of the mass separator and the DRAGON facility." Recent beam developments with both the FEBIAD and the TRILIS sources prompted us to evaluate the performance of the DRAGON experiment with a mixed ^{23}Na/^{23}Mg beam. We had proposed to measure the ^{23}Mg(p,γ)^{24}Al reaction at the resonance energies of 458 and 651 keV. In order to establish the possible level of background from a mixed beam, we investigated in the summer of 2007 the ^{23}Na(p,γ)^{24}Mg reaction at these energies with DRAGON. As expected, strong (factor 5 larger resonance strength than predicted for ^{23}Mg(p,γ)^{24}Al) yield was found around 651 keV (Fig.1), while no ^{24}Mg recoils were recorded at the lower energy resulting in an upper limit for the ^{24}Mg yield of ~5×10^{-14} which is a factor ~1000 lower than the expected yield of ^{24}Al.
Using the best results from the ISAC ion sources (in this case TRILIS), we can expect 1×10^{8} 1/s ^{23}Mg at DRAGON immersed in a factor about 500 stronger ^{23}Na ion beam. A ^{23}Na contamination as low as possible is desirable as it will reduce systematic uncertainties and the required beam time, however, we emphasize that we can perform this experiment with the current achieved intensity and purity. The ratio of the two beams will be determined by comparing our elastic scattering and beta decay monitors as in previous experiments. We are relying in this case on Z-identification at the DRAGON focal plane with an ionization chamber (IC). A five times segmented anode allows us to follow the energy deposits through the chamber and construct very stringent conditions for ion identification. Our tests indicate that the measurements on the lower, astrophysically more important, resonance will be straightforward yielding ~100 events/day (with 1×10^{8} 1/s ^{23}Mg intensity). The higher energy resonance will (with the factor 500 stronger ^{23}Na) require good isobar separation at the ion chamber. However, based on the tests with ^{23}Na beam (Fig. 1) we are confident to be able to separate ^{24}Al from ^{24}Mg recoils. Therefore, we intent to perform additional IC calibration measurements using ^{23}Na,

^{24}Mg and ^{27}Al stable ion beams. The latter two beams are also necessary to measure the charge state distribution after the gas target. We rely with our choice of beam energies on the transfer reaction measurement of Kubono et al. that is cited in our proposal. It should be noted that an additional measurement was found in our review for this re-submission [M.B. Greenfield et al., Nucl. Phys. A524 (1991) 228] which shows different energies for the two states (plus 41 and 25 keV respectively). However, based on past good experience with data from the Kubono group, we will start with their level information. As DRAGON with its gas target can cover approximately 10-15 keV of an excitation function per energy, only a few additional data points would be necessary if no yield is found at our starting values.
Over the years, naturally, the composition of the collaboration has changed somewhat as reflected in our updated coversheet.

Our requirements of beam time are:

^{21}Na	1 shift	Calibration of beta monitor
^{24}Mg	4 shifts	IC calibration and charge state distributions
^{23}Na	4 shifts	IC calibration and background studies
^{27}Al	4 shifts	IC calibration and charge state distributions
^{23}Mg	20 shifts	On and off resonance measurements at 490 keV/u and 690 keV/u

Because of the availability of the radioactive ^{23}Mg beam and the successful tests at DRAGON, we ask for stage 2 approval for this experiment and scheduling of beam time in the upcoming ISAC schedule.

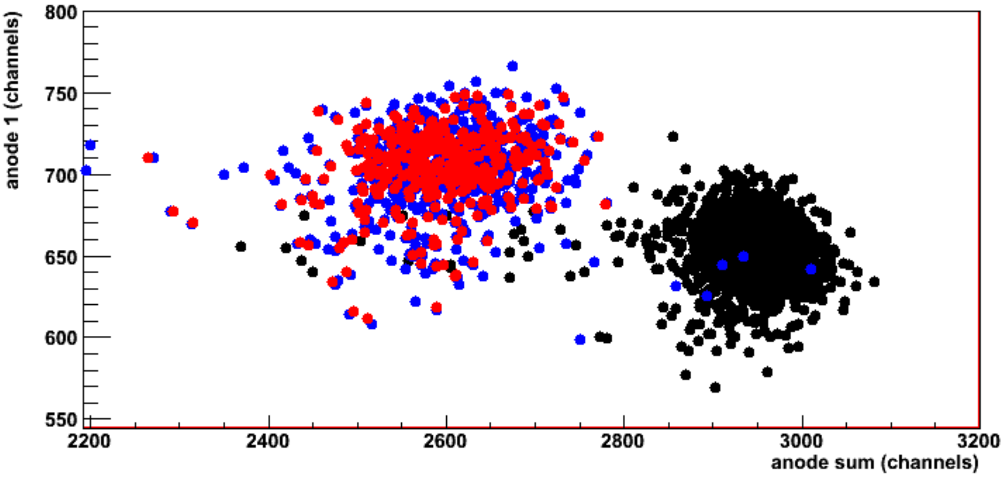

Fig. 1: Identification of recoils and beam particles of the ^{23}Na(p,γ)^{24}Mg reaction (resonance at 647 keV) at the DRAGON ion chamber. Blue and red dots show ^{24}Mg recoils in singles and coincidence, respectively. Black dots indicate the location of the beam particles, measured in a separate run with attenuated beam. Only one of the 5 anode segments versus the total energy (sum of all 5 segments) is shown here.