TRIUMF — EEC

NEW RESEARCH PROPOSAL

Exp. No.

Date: October 30, 2006

Title of experiment:

Reinvestigation of the 189 keV resonance in the $^{25}Mg(p,\gamma)^{26}Al$ reaction

Name of group:
DRAGON

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Current members of group: (name, institution, status, % of research time devoted to experiment)

Name	Institution	Status	Time
C. Vockenhuber	Simon Fraser University/TRIUMF	Research Associate	40%
A. Wallner	University of Vienna	Research Scientist	20%
A. Arazi	Laboratory TANDAR	Research Associate	20%
L. Buchmann	TRIUMF	Research Scientist	10%
J. Clark	Yale University	Postdoc. Associate	10%
J. M. D'Auria	Simon Fraser University	Professor emer.	10%
C. Deibel	Yale University	Graduate Student	10%
B. Davids	TRIUMF	Research Scientist	5%
U. Greife	Colorado School of Mines	Associate Professor	10%
T. Faestermann	Technische Universität München	Research Scientist	10%
J.O. Fernández-Niello	Laboratory TANDAR	Research Scientist	10%
A. Hussein	Uni. of North. British Columbia	Professor emer.	10%
D. A. Hutcheon	TRIUMF	Research Scientist	20%
J. Jose	UPC/IEEC Barcelona	Associate Professor	5%
K. Knie	University of Vienna	Research Scientist	10%
G. Korschinek	Technische Universität München	Research Scientist	10%
W. Kutschera	University of Vienna	Professor	5%
A. Parikh	Yale University	Graduate Student	10%
P. Parker	Yale University	Professor	5%
J. Pearson	McMaster University/TRIUMF	Research Associate	10%
C. Ruiz	University of York/TRIUMF	Research Associate	10%
G. Ruprecht	TRIUMF	Research Associate	10%
M. Trinczek	TRIUMF	Research Associate	10%
C. Wrede	Yale University	Graduate Student	10%

Date for start of preparations:
End of 2006

Beam time requested: (# of 12-hr shifts)
30

Date ready:
Spring 2007

Completion date:
End of 2007

Experimental area:
Base (1A, 2C, 2C4, 1B) or **ISAC** (2A):

ISAC

SUMMARY

DO NOT exceed one page

Understanding the nucleosynthesis of ^{26g}Al ($t_{1/2} = 7.2 \times 10^6$ yr) is one of the hot topics in astrophysics and studies in this context are subject to several experiments at ISAC. The recently completed measurement of the 184 keV resonance strength in the ^{26g}Al$(p,\gamma)^{27}$Si reaction at the recoil mass spectrometer DRAGON (experiment E989) reduces the uncertainty of the destruction rate of ^{26g}Al via this reaction at nova temperatures. The main uncertainty in calculating the ^{26g}Al contributions from novae comes now from the short-lived Al isotope in Mg-Al cycle, namely ^{25}Al$(p,\gamma)^{26}$Si (E922).

However, a recent measurement of the ^{26g}Al production via the ^{25}Mg$(p,\gamma)^{26g}$Al reaction at nova temperatures showed a large discrepancy to previous measurements; a factor of 5 lower resonance strength was found at 189 keV. This adds additional uncertainties to the understanding of ^{26g}Al nucleosynthesis in novae.

We propose here to reinvestigate the 189 keV resonance at the DRAGON in a very similar way as we did it for E989. In addition to the scientific motivation, there is also a technical motivation: the expected yield is about two orders of magnitude lower than the lowest yield measured so far at DRAGON ($\sim 10^{-13}$ for E989). Such extremely low yields are expected also for other important and already approved experiments at DRAGON, e.g. E813 ^{15}O$(\alpha,\gamma)^{19}$Ne. Experience gained in this experiment would certainly help other challenging experiments as well as in a possible extension of these measurements to the 92 keV-resonance of the ^{25}Mg$(p,\gamma)^{26}$Al reaction, for which no experimental data is yet available.

BEAM AND SUPPORT REQUIREMENTS

PROTON BEAM/TARGET:
(energy, intensity, pulse characteristics, ion source)

Energy (in MeV)**:** N/A

Intensity (in μA)**:** N/A

Pulse Width (in ns)**:** N/A

Rep Rate (choose one of: normal; 1/5; other)**:** N/A

PRODUCTION TARGET:
1AT1: 1 cm C; 1 cm Be or **1AT2:** 10 cm Be**:** N/A

ISAC:
Ion Source (SURFACE; FEBIAD; LASER; ECR; OLIS)**:** OLIS ECR

SECONDARY CHANNEL/ISAC BEAM LINE:

1. For Base, choose one from: M9A; M9B; M11; M13; M15; M20; 1B; 2C; PIF; NIF**:** N/A

2. For ISAC, choose one from: GPS1; GPS2; GPS3; TRINAT;
TITAN; β-NMR; β-NQR; POLARIMETER; YIELD, 8π**:** N/A

3. For ISAC-I, choose one from: DRAGON; TUDA; HEBT**:** DRAGON

4. For ISAC-II, choose one from: SEBT0; SEBT1; SEBT2; SEBT3**:** N/A

SECONDARY BEAM:
(particle type/isotope, energy, energy width, solid angle, spot size, intensity, beam purity, target, special characteristics)

Please list all isotopes:

^{25}Mg, 0.20 - 0.44 MeV/u, lowest possible energy spread, 100 pnA or more
^{27}Al, 0.20 - 0.44 MeV/u, 1 pnA or more

EXPERIMENTAL FACILITY(IES) TO BE USED:

DRAGON

TRIUMF RESOURCES REQUESTED

(Summarize the expected TRIUMF resources needed for the experiment. Identify major capital items and other costs that will be requested from TRIUMF. Note: Technical Review Forms must be provided before allocation of beam time.)

Continued infrastructure support from TRIUMF for DRAGON at ISAC, including assigned personnel.

Support for installation of new ECR at OLIS

EXTERNAL FUNDING SOURCES

(Summarize expected non-TRIUMF sources of funding for the experiment.)

1. NSERC:

NSERC DRAGON Equipment Grant for new MCP plus electronics.

NSERC DRAGON Project Grant (D. Hutcheon) to be applied for.

2. OTHER (Please describe)**:**

SAFETY

(Summarize possible hazards associated with the experimental apparatus, precautions to be taken, and other matters that should be brought to the notice of the Safety Officer. Details must be provided separately in a safety report to be prepared by the spokesperson under the guidance of the Safety Report Guide available from the Science Division Office.)

Standard DRAGON procedures for stable beam experiments and operation of hydrogen gas target will be observed.

1 Scientific Justification

The detection of extraterrestrial ^{26}Al by space-based telescopes has made this radionuclide ($t_{1/2} = 7.2 \times 10^5$ yr) one of the most important observable in astrophysics and it has still high priority in current missions like ESA's INTEGRAL (see e.g. [1] for a recent review on γ-ray astronomy). The total mass of ^{26}Al in our galaxy is estimated to be 2.8 ± 0.8 M$_\odot$ based on the detection of the 1.809 MeV γ-ray line [2]. The gross amount is believed to be produced in massive stars either exploding as core collapse supernovae or in the Wolf-Rayet phase, but contributions from novae might be important as well.

Although many experiments for a better understanding of ^{26}Al nucleosynthesis have been performed, model calculations are still uncertain since some key reactions in the network calculations are poorly constrained [3]. The recently completed measurement of the 184 keV resonance strength in the ^{26g}Al$(p,\gamma)^{27}$Si reaction at the recoil mass spectrometer DRAGON (experiment E989, [4]) reduced the uncertainty of the destruction rate via this reaction at at temperature regimes typical for novae scenarios. The main uncertainty comes now from short-lives isotopes in the Mg-Al cycle (Fig. 1), in particular the ^{25}Al$(p,\gamma)^{26}$Si . This reaction represents a path through the 6.3 s isomeric state in ^{26}Al, bypassing the long-lived ground-state of ^{26g}Al. ^{26m}Al decays by β^+ emission directly to the ground state of ^{26}Mg (Fig. 2). Thus, in this path no 1.809 MeV γ ray is emitted. As discussed by Ward and Fowler [5] thermal equilibrium between ^{26g}Al and ^{26m}Al is not reached at temperatures $T_9 < 0.4$, thus both states have to be treated as separate nuclear species. It should be noted, that both reactions mentioned above involving short-lived isotopes in the Mg-Al cycle are subject to already approved experiments at ISAC, E922 and 2$^{\text{nd}}$ part of E989, respectively.

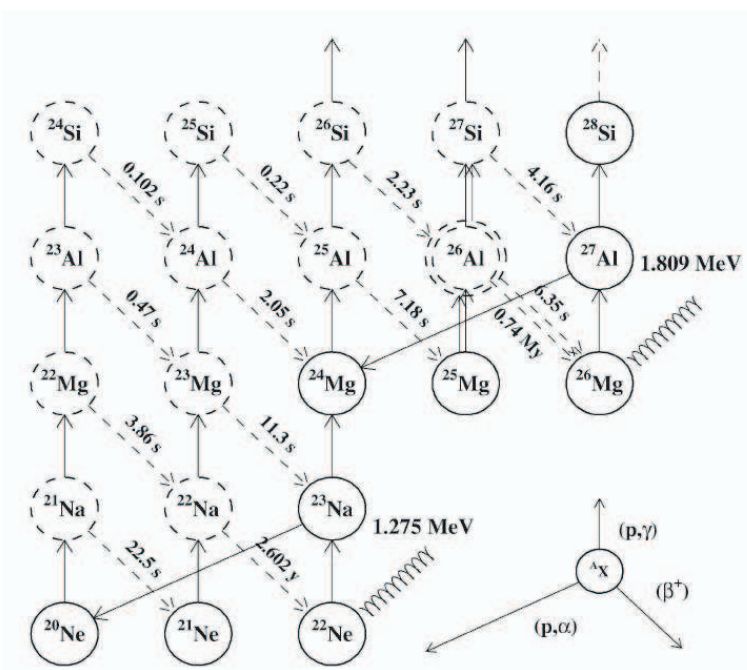

Fig. 1 Nuclear reactions in the Ne-Na and Mg-Al cycle. Figure taken from [3].

The main production of the astrophysical relevant ground state ^{26g}Al in the Mg-Al

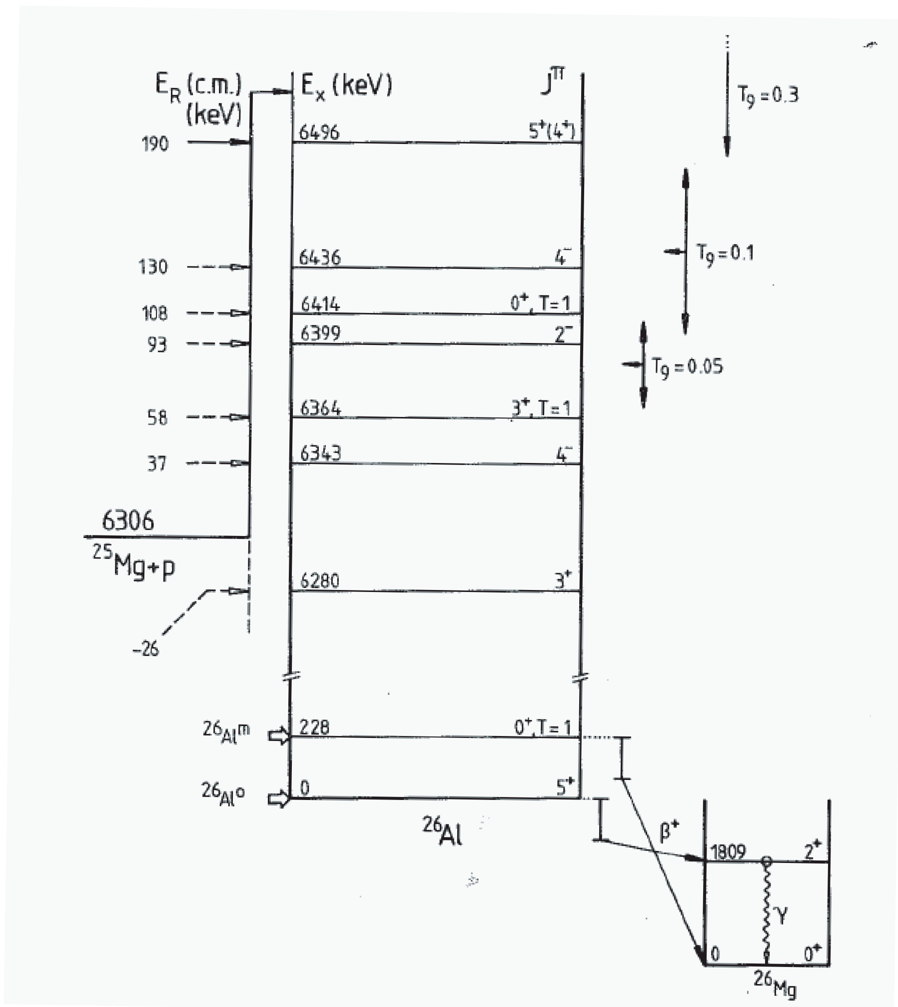

Fig. 2 Level scheme of ^{26}Al near the proton threshold. Also indicated is the isomeric state at 228 keV with a half-life of 6.3 s and which decays to the ground state of ^{26}Mg and bypassing the 1.809 MeV γ-ray line. Temperatures to the right are the relevant Gamov windows at given temperatures ($T_9 = 10^9$ K). Figure taken from [6]. Note, resonance energies are slightly off due to older Q-values.

follows the reaction sequence:

$$^{24}\mathrm{Mg}(p,\gamma)^{25}\mathrm{Al}(\beta^{+}\nu)^{25}\mathrm{Mg}(p,\gamma)^{26g}\mathrm{Al} \quad (1)$$

The last reaction, ^{25}Mg$(p,\gamma)^{26g}$Al, has been studied experimentally by several groups via observation of the prompt γ rays associated with the deexcitation of ^{26}Al. for stellar temperatures of $T_9 > 0.2$ (T_9 denotes here GK) [6–11]. Several resonances dominate the astrophysical reaction rate in this temperature region, i.e. $E_{\rm cm}$ = 189, 304, 374, and 418 keV (Fig. 5a). Previous measurements have been evaluated by NACRE (Nuclear Astrophysics Compilation of REaction rates) and recommended resonance strengths where given [12]. For the production of astrophysical relevant ground state ^{26g}Al the branching between ground state ^{26g}Al and the isomeric state ^{26m}Al has to be known. The branching ratio of the ^{26}Al levels to the ground state is described as f_0. This information comes from a detailed analysis of γ-ray spectra. Fig. 3 shows one example of a γ-ray spectrum as measured by Elix et al. [7]. It should be noted that the low yield of weak resonances can lead to substantial uncertainties and/or confusion with background peaks (see e.g. [10]). For the 189 keV resonance for instance f_0 was determined to be 0.74 [6] or 0.66 [7]. A table of commonly used branching ratios is given in [6].

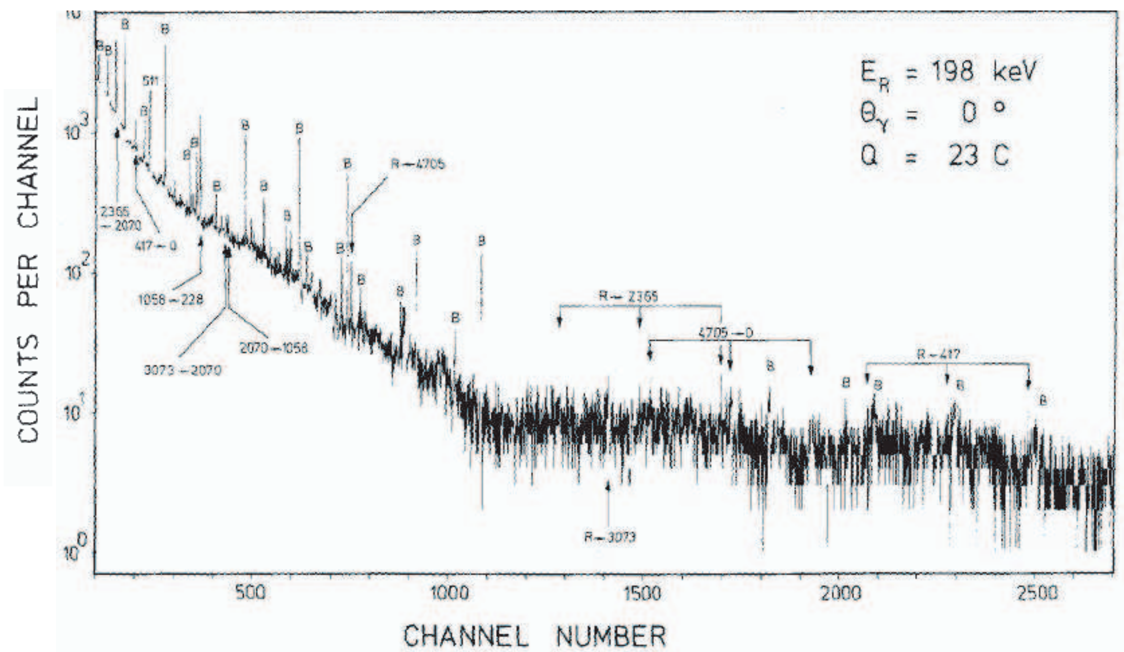

Fig. 3 γ-ray spectrum of the 189 keV resonance as measured by Elix et al. [7]. Primary and most secondary transitions are indicated. Background peaks are labeled with the letter B.

A very recent measurement reinvestigated the above mentioned four resonances and measured the ^{26g}Al directly, independent of the branching ratio f_0 [13]. These measurements were performed in two steps: An irradiation of ^{25}MgO targets with protons of the right energy at an implanter facility, and a subsequent quantification of produced ^{26}Al by accelerator mass spectrometry. Since the ^{26}Al measurement was done days after the irradiation, all ^{26m}Al had already decayed and only the long-lived ground state ^{26g}Al was quantified. A good agreement was found for the upper three resonances, with a slightly lower value for the 418 keV resonance compared to NACRE. In contrast, the measurement of the 189 keV resonance resulted in a significant lower (factor of 5) resonance strength compared to the NACRE recommendation (Fig. 4). This resonance is particulary important for nova temperatures. The influence of this lower resonance strength is emphasized in Fig. 5b showing the comparison of the new reaction rate with the recommended one by NACRE.

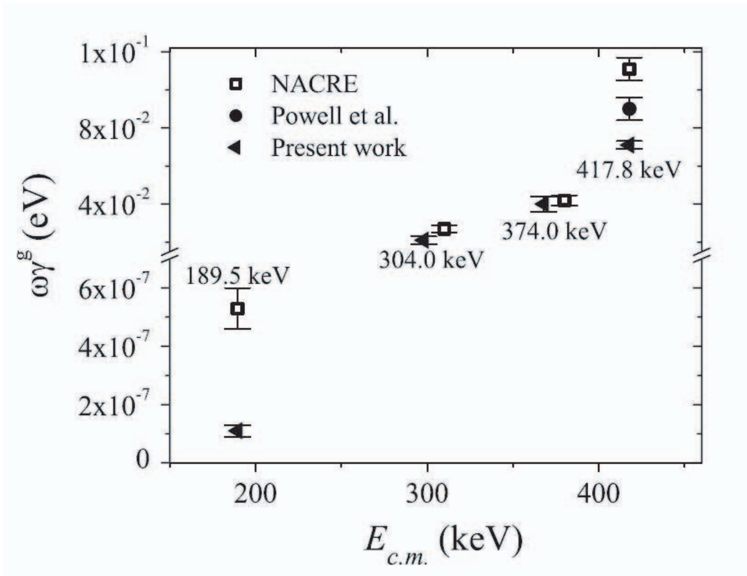

Fig. 4 Comparison of resonance strengths. Present work is from Arazi et al. [13], Powell et al. is from [11] . Figure taken from [13].

For temperatures $T_9 < 0.2$ no direct measurements of resonance strengths have been performed so far. Experiments are very difficult since the expected yield is about three orders of magnitude lower than the already low yield of the 189 keV resonance. However, especially the resonance at 92 keV is likely to play a role in ^{26}Al nucleosynthesis in massive stars during their Wolf-Rayet phase. The resonance strength of this resonance recommended by NACRE is based on a careful analysis of experimental data of the $^{25}\mathrm{Mg}(^{3}\mathrm{He}, d)^{26}\mathrm{Al}$ reaction [14]. However, as emphasized in that paper the uncertainty in the reaction rate estimation can be as large as a factor of 2 or even larger. Thus, they call for a direct measurement of this resonance. The present conditions at DRAGON with current limitations of the ISAC accelerators make a measurement not feasible at the moment (see next section), but future upgrades together with experience gained at higher resonances could make a direct measurement possible.

The aim of this proposed experiment is to reinvestigate the resonance at 189 keV with DRAGON which allows a direct measurement of the resonance strength and possibly the branching ratio f_0. Discrepancies in the 418 keV resonance (see Fig. 4) can be investigated in parallel.

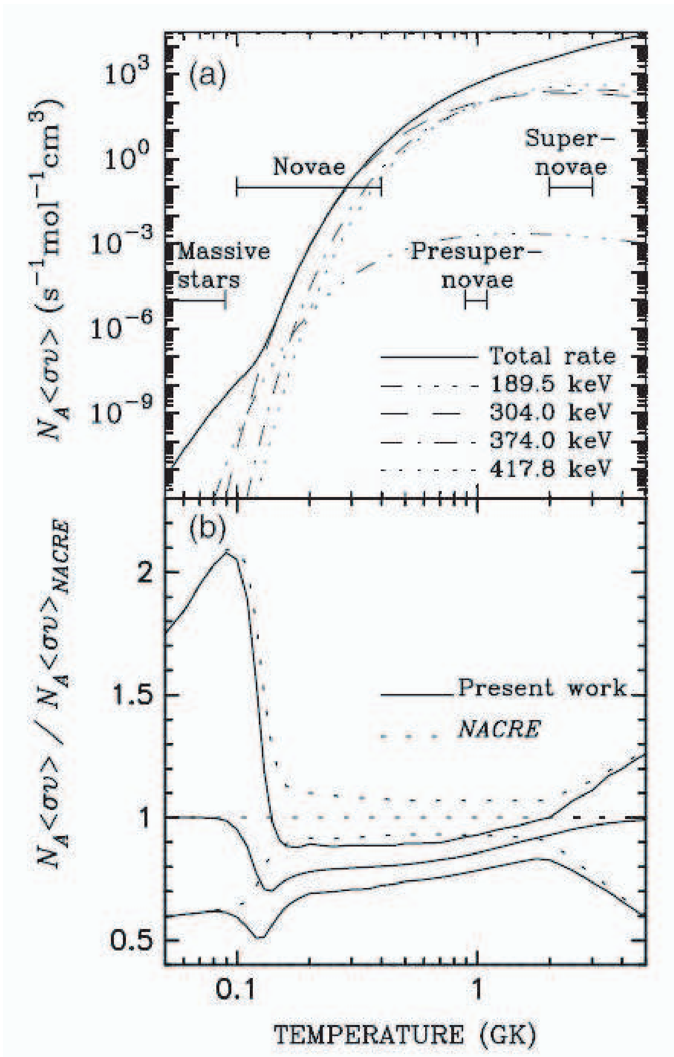

Fig. 5 Dependence of the ^{25}Mg$(p,\gamma)^{26g}$Al reaction rate with the stellar temperature. (a) Individual contributions of the four mentioned resonances are shown together with the total rate. (b) Ratio of the total rate from the recent work by Arazi et al. [13] (solid lines with 68% confidence interval) to that recommended by NACRE [12] (dashed lines). Figure taken from [13].

2 Description of the Experiment

The $^{25}Mg(p, \gamma)^{26}Al$ reaction will be measured in inverse kinematics using the DRAGON recoil separator. A layout of the spectrometer is shown in Figure 6, details of the setup are presented in [15]. Stable ^{25}Mg beam will be provided by the new ECR at OLIS and subsequent acceleration using ISAC-I [16].

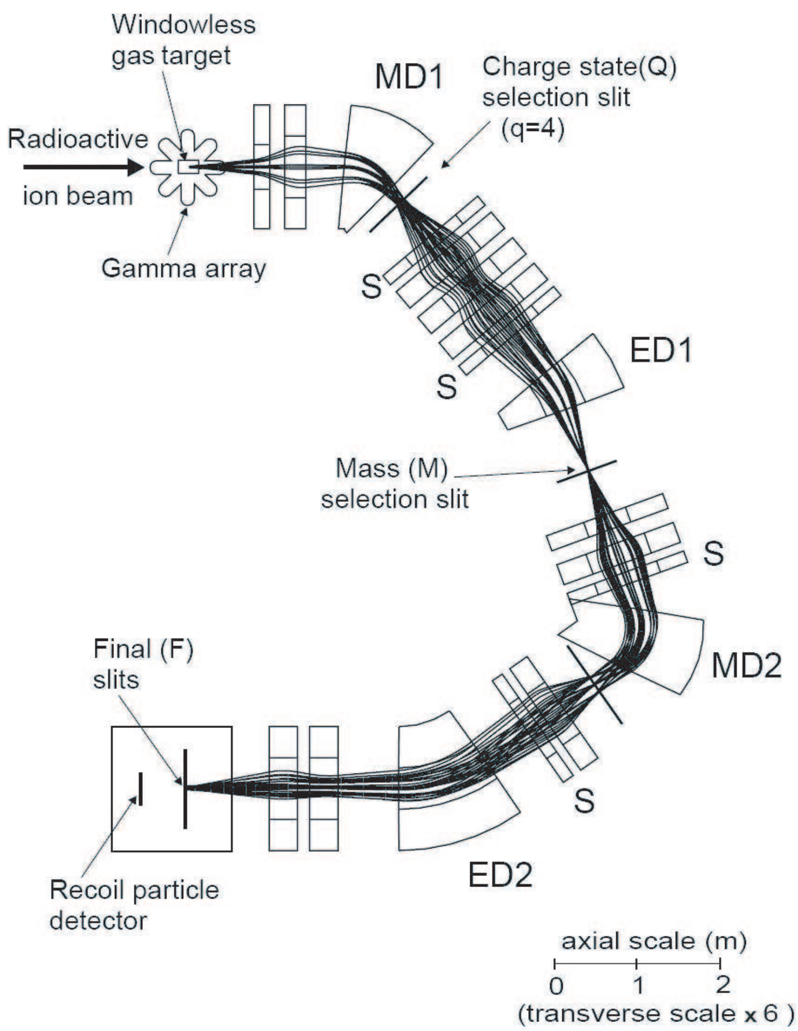

Fig. 6 Layout of the DRAGON setup. Figure taken from [15].

The DRAGON window-less gas target will be filled with hydrogen gas with several Torr, which contains about 5×10^{18} H atoms / cm^2. This leads to an energy loss of about 17 keV/u, large enough to cover the narrow resonances. The BGO array surrounding the gas target will detect prompt γ rays from the reaction and will be used in coincidence with the detected recoil ^{26}Al at the DRAGON end detector. The efficiency of the BGO array depends on the γ energy as well as on the γ-ray multiplicity. The single γ-ray efficiency is between 40% to 60% for γ-ray energies of 1 to 10 MeV.

The maximal opening angle of this reaction depends on the energy of the emitted

γ-ray energy. The Q-value of the (p,γ) reaction lies at 6306 keV, plus the energy of level, defines the maximal possible γ-ray energy, which leads to maximal opening half-angles ($\Phi_{1/2}$) of around 10 mrad for resonances at $300-400$ keV and 13.6 mrad at 189 keV. The 92 keV resonance would lead to 19.2 mrad, which is very close to the nominal acceptance of DRAGON of ± 20 mrad. However, since the drop-off is not fully understood at the moment and is subject to ongoing acceptance studies with an α source, a measurement at this resonance should be postponed until the full acceptance is understood and corrected (if necessary). It should be noted, that if the states deexcite by a γ cascade the actual cone angle is usually smaller.

Under the conditions that the resonance width is smaller than the covered energy range, the measurement of the resonance strength $\omega\gamma$ is based on the thick target yield, Y, which is the number of recoils per incoming projectile:

$$Y = \frac{\lambda^2}{2}\frac{m_p + m_t}{m_t}\left(\frac{dE}{n\ dx}\right)^{-1}\omega\gamma \tag{2}$$

with λ the de Broglie wavelength of the reduced mass of the compound system, m_p and m_t the mass of projectile and target, $dE/(n\ dx)$ the stopping power of the projectile in the target in the laboratory system and $\omega\gamma$ defined as:

$$\omega\gamma = \frac{2J_R + 1}{(2J_t + 1)(2J_p + 1)}\frac{\Gamma_p\Gamma_\gamma}{\Gamma} \tag{3}$$

with J_R, J_t and J_p the spins of the resonance, target and ground state of projectile, respectively, and Γ_p, Γ_γ the partial proton and gamma widths of the resonance, and $\Gamma = \Gamma_p + \Gamma_\gamma$.

The reaction yield in this experiment, Y, will be extremely small and will range from $\sim 10^{-10}$ for resonances at $300-400$ keV to as low as $\sim 10^{-15}$ for the resonance at 189 keV. This is a special challenge for DRAGON. The smallest resonance strength measured previously was the 184 keV resonance in the ^{26g}Al$(p,\gamma)^{27}$Si reaction (Experiment 989 by Chris Ruiz et. al. [4] with a corresponding yield of $\sim 2.5\times10^{-13}$). Since the energy and the mass is very similar in this experiment, the suppression of the recoil spectrometer should be very similar (about 10^9). Further suppression should come from the coincidence with the γ BGO array with a narrow time cut (e.g. 200 ns). Since no radioactive beam is involved, in contrast to the ^{26g}Al(p,γ) reaction, the count rate at the BGO detectors should be dominated by room background, which is about 50 γ-rays per second. Together with the high beam intensity, a suppression of about 5 orders of magnitude should be possible.

Additional separation might be required from the particle end detector. Whereas the double-sided silicon strip detector (DSSSD) provides only modest energy resolution of slow heavy ions (dE/E about 9% FWHM), which is not enough for a clear separation between recoils and leaky beam, an optimized ionization chamber equipped with an ultra-thin silicon nitride (SiN) entrance window should give the required resolution. Alternatively or in combination, the use of local time-of-flight (TOF) information of the detected particles could be advantageous since the ions are slow due to the low energy and thus better separated in TOF. This approach would require the installation of a second timing detector based on secondary electron emission from a thin foil and a fast micro-channel plate

(MCP) (in addition to the already existing MCP detector). The flight path would be about 0.5 m with a time resolution of at least 500 ps; the expected difference in TOF between recoils (^{26}Al) and leaky beam (^{25}Mg) is more than 3 ns. The combination of good timing resolution with a appropriate energy measurement should clearly separate recoils (^{26}Al) from leaky beam (^{25}Mg) in 2D plots (Fig. 7).

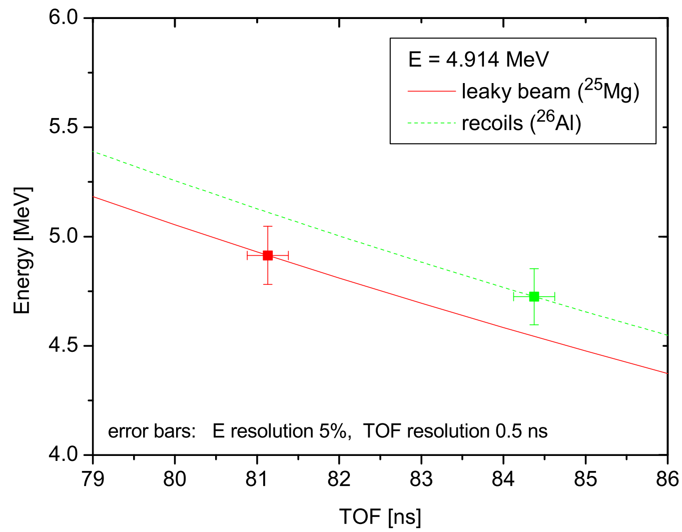

Fig. 7 Expected separation of recoils (^{26}Al) from leaky beam (^{25}Mg) assuming no beam energy spread. Detector resolution (5% in energy and 0.5 ns in TOF) are shown as error bars.

The γ-ray spectrum can be used to deduce information about the branching ratio f_0. Coincidences between γ-rays and recoils should give a spectrum clean of background peaks (unlike the spectrum shown in Fig. 3). Additionally, because of the granularity of BGO detector array an analysis of γ-γ coincidences can be done. However, the limited energy resolution of the BGO detectors and the complex decay with several possible branches make a distinction between decays to the ground state or to the isomeric states quite difficult. Comparison with GEANT simulation can be done, but at the expected low statistics it will be hard to resolve different branches.

Alternatively we can get the branching ratio f_0 by detecting the isomeric ^{26m}Al component of the ^{26}Al recoils by its 6.3 s decay. In this case the recoils will be stopped in a metal plate (or the DSSSD). Any ^{26m}Al decays by β^+ directly to the ground state of ^{26}Mg, thus no primary γ ray is involved. However, the positron emission can be detected directly by a scintillator or Si(Li) detector or by the two 511 keV annihilation photons measured with NaI detectors. Due to the limited statistics a high detection efficiency is essential. To improve the detection efficiency, a rotating stop plate can be used. Recoils and leaky beam are stopped off-axis in a metal plate until a trigger from local TOF and/or BGO coincidence indicating a ^{26}Al recoil was implanted. The implanted region is then rotated between a pair of NaI detectors in close geometry which allows a high efficiency measurement of the β^+ decay of ^{26m}Al. Since the expected rate of ^{26}Al recoils is quite low (about 1 per hour), the time window for the measurement can be made sufficiently large (10 half-lifes $\sim$ 60 s) without introducing much dead time. For the high rates at the higher lying resonances, the dead time can be significant. Multiple detection position at the plate can increase the usable life time. Calculations of various possible detector designs will be presented at the EEC meeting. A schematic setup is shown in Fig. 8.

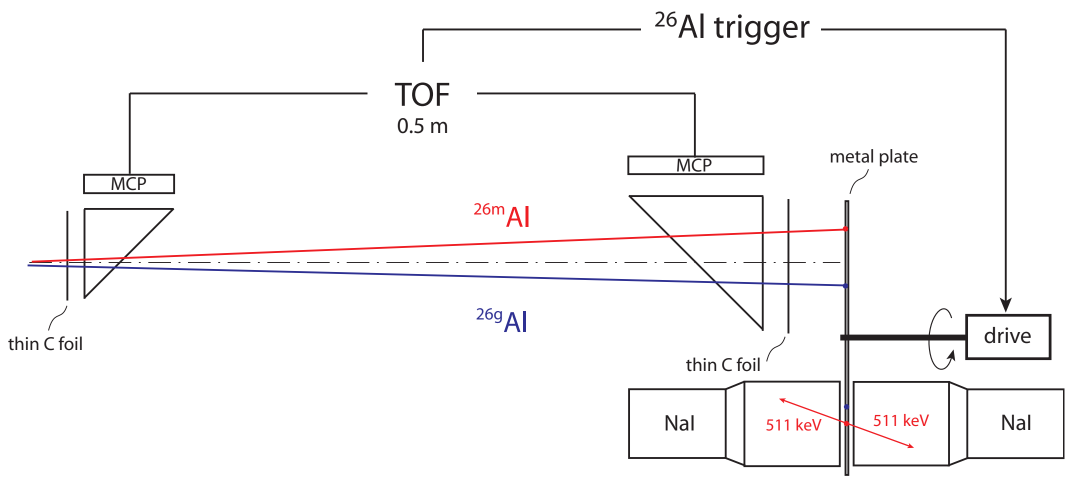

Fig. 8 Schematic detection setup consisting of a local TOF measurement based on two MCP detectors and a final stop plate. The local TOF (with a possible combination with γ coincidence) provides the trigger for a ^{26}Al event. The implanted area is then rotated between two NaI detectors for ^{26m}Al (red) identification by β^+ detection of the two 511 keV annihilation photons. No decay will be observed for the long-lived ^{26g}Al (blue).

Table 1 lists the estimated conditions for the planned measurement of the resonances at interest, assuming 100 pnA on target (= 6.25×10^{11} ^{25}Mg per second), 40% charge state fraction and 60% detection efficiency (mainly the BGO efficiency). The first part of the experiment will be measurements at three resonances in the energy range between 300 and 400 keV: 418, 374 and 304 keV. With the high reaction rates associated with these energies more than 10^4 ^{26}Al will be detected in one hour of data taking. This high yield allows us also to study beam suppression in a short amount of time. Also, the setup for β^+ detection can be tested and calibrated from known branching ratios f_0 [6]. As an intermediate step the resonance at 292 keV could be measured as well.

The second and main part will be the measurement at 189 keV. With a beam of 100 pnA on the target the ^{26}Al rate will be about one per hour. Thus, about hundred events could be collected within a week of beam time making the statistical uncertainty comparable to the systematic uncertainties (which include BGO efficiency, beam normalization, charge state fraction). It should be noted, that the time estimates depend very much on the available beam intensity. The ECR at OLIS should be able to provide currents in the micro Ampere region in charge state 6+ (Keerthi Jayamanna, private communication). There are, however, limitations to about 500 pnA due to space charge effects in the first section of the RFQ accelerator (Bob Laxdal, private communication). In addition, the maximal current depends also on the leaky beam rate at DRAGON. Given the maximal (practical) rate at the end detector of about 100 cts/s and assuming a charge state fraction of 0.4, the beam suppression in the spectrometer should be at least 2.5×10^9 for a beam of 100 pnA. Accordingly at 1 μA the required beam suppression is 2.5×10^{10}. During commissioning of DRAGON the suppression of several beams has been studied

[17] and shows that the above mentioned suppression factors are achievable. The 92 keV resonance would require a beam intensity of at least a few μA to perform a measurement in a reasonable time frame (3 weeks). This is currently beyond the capabilities of the RFQ accelerator.

At the 189 keV resonance we expect low counting statistics. Thus background correction will be a significant part of the final uncertainty. An additional off-resonance run of sufficient length will be taken for background correction.

The stopping power of ^{25}Mg in hydrogen, which is required to calculate a resonance strength, will be measured at each energy by centering the beam after the first magnetic dipole at different hydrogen pressures. For estimates in this proposal the value from SRIM2003 [18] is used.

To measure the charge state distribution (CSD) of ^{26}Al, a beam of stable ^{27}Al at the same velocity as the recoils will be used. The CSD will be determined for different gas target pressures by measuring the current in the Faraday cup downstream of the first bending magnet. Beams of a few pnA will be enough for that purpose.

Table 1 Resonance strength for the astrophysical relevant ground state ^{26}Al and expected yields from NACRE compilation [12] and Ref. [13].

E_{cm} [keV]	E_{lab} [keV]	$\Phi_{1/2}$ [mrad]	f_0 [1]	$\omega\gamma_{NACRE}$ [2] [μeV]	$\omega\gamma_{Arazi}$ [μeV]	Y_{NACRE}	Y_{Arazi}	$rate_{NACRE}$ [3] [1/h]	$rate_{Arazi}$ [3]
92.2	2378	19.2	0.85	$(1.0 \pm 0.1) \times 10^{-4}$	$< 2 \times 10^{-2}$	2.52×10^{-18}	$< 5.0 \times 10^{-16}$	1.4×10^{-3}	$< 3 \times 10^{-1}$
189.5	4887	13.6	0.74	$(5.3 \pm 0.7) \times 10^{-1}$	$(1.1 \pm 0.2) \times 10^{-1}$	3.41×10^{-15}	0.71×10^{-15}	1.8×10^{0}	0.4×10^{0}
291.9	7528	11.2	0.78	$(3.7 \pm 0.4) \times 10^{1}$	n.m.	1.20×10^{-13}		6.5×10^{1}	
304.0	7839	10.9	0.87	$(2.7 \pm 0.2) \times 10^{4}$	$(2.1 \pm 0.2) \times 10^{4}$	0.84×10^{-10}	0.65×10^{-10}	4.5×10^{4}	3.5×10^{4}
374.0	9646	9.9	0.67	$(4.2 \pm 0.3) \times 10^{4}$	$(4.0 \pm 0.4) \times 10^{4}$	0.99×10^{-10}	0.95×10^{-10}	5.4×10^{4}	5.1×10^{4}
417.8	10776	9.5	0.96	$(11.1 \pm 0.6) \times 10^{4}$	$(7.1 \pm 0.2) \times 10^{4}$	2.30×10^{-10}	1.47×10^{-10}	1.2×10^{5}	8.0×10^{4}

[1] branching ratio to the ground state, taken from [6].
[2] resonance strength from NACRE [12] multiplied by f_0.
[3] rate calculated for a ^{25}Mg intensity of 100 pnA, a charge state fraction of 0.4 and a detection efficiency of 0.6.

3 Experimental Equipment

OLIS, ISAC, DRAGON

4 Readiness

DRAGON will be ready to accept beam for first tests and measurements in spring 2007.

5 Beam Time required

Measurement	Shifts required
resonances at 300 − 400 keV (including studies of beam suppression, testing of the ^{26m}Al detection setup)	6
resonance at 198 keV	14
off resonance	6
Al charge state distribution	4

6 Data Analysis

Standard DRAGON procedures for data acquisition and data analysis.

References

1. R. Diehl, N. Prantzos, and P. von Ballmoos. Astrophysical constraints from gamma-ray spectroscopy. *Nucl. Phys. A*, 777:70–97, 2006.

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