1. Introduction

Scientific needs as well as the availability of high current medium-energy proton accelerators have made it reasonable to consider coupling a high-current on-line isotope separator (ISOL) system to a post-accelerator. Such an accelerated radioactive ion beam (RIB) facility could produce beams with currents of up to 100 nA for isotopes close to the valley of stability, accelerate them in several stages up to 1.5 MeV/u (or higher if necessary) and deliver the ions to the experimental areas for use in new types of experimental programs. A general description of such a facility has been presented to some extent in two workshops [1,2], in several publications [3,4], and in proposals to TRIUMF [5,6]. For simplicity, this combined ISOL and accelerator facility is referred to as ISAC.

In this report we will give a summary of the scientific rational for such a system based upon its requirements in the area of nuclear astrophysics, present arguments supporting this approach for performing these kinds of studies, summarize the desired features of the proposed facility, and explore the feasibility not only of building such a facility but also of performing these kinds of experiments in nuclear astrophysics.

An overview of the entire proposed TRIUMF-ISOL facility is given in another contribution [7] to this conference as is the proposed development of new (for ISOL systems) ion source technology, i.e., an Electron Cyclotron Resonance (ECR) source, believed essential to achieve the RIB intensities required here [8]. The construction of the small test ISOL system (TISOL) to be used as a system for developing new target and ion source systems for ISAC is also presented in another contribution [9].
In this section, we start from the short-lived isomeric state of $^{110}\text{Cd}$, which is metastable and can decay by a $\beta$-ray to $^{110}\text{Te}$.

The decay of $^{110}\text{Te}$ leads to the formation of $^{110}\text{Sn}$, which is another example of a radioactive isotope that decays very slowly. This is an important aspect of radioactive decay, as it helps us understand the behavior of these substances over time.

The half-life of $^{110}\text{Te}$ is approximately 30 minutes, which means that it takes this amount of time for half of the sample to decay. This is a critical piece of information for scientists who work with radioactive materials, as it helps them predict how long they will be radioactive and how much radiation they will produce.

In conclusion, the study of radioactive decay is crucial for understanding the behavior of these substances, and it plays a vital role in many fields of science, including medicine, geology, and physics.
All reactions in the network are coupled and thus their relative production depends on the rates of all fusion processes.

Examples of some reactions considered important and of high priority for early determination are given in table 1 [6].

2.3 Stellar reaction rates and specific reactions

2.3.1 Nuclear cross sections

The number of reactions for a certain density and per unit time is given by:

\[
\langle\sigma v\rangle(T) = \int_0^{\infty} M(v,T)\cdot v\cdot\sigma(v)\cdot dv
\]

where

\(\langle\sigma v\rangle(T)\) = stellar reaction rate

\(M(v,T)\) = Maxwell-Boltzmann velocity distribution for a temperature, T

\(\sigma(v)\) = reaction cross section.

In this integral the strong energy dependence of the Maxwell-Boltzmann distribution and the reaction cross section will result in a narrow energy range (Gamow peak) over which the cross section of a specific nuclear reaction has to be determined to evaluate the reaction rate integral. In most cases this relevant energy range is actually far below the Coulomb barrier. This means that the reaction rates are often dominated by one or more very narrow resonances although, in some cases, a direct capture reaction is important. The latter is normally several orders of magnitude weaker than a resonant reaction. For resonance dominated reactions the integrated strength \(\omega\gamma\) at the resonance energy, \(E_R\), is important for the stellar reaction rate, i.e.,

\[
\omega\gamma = \omega \frac{\Gamma_1 \Gamma_f}{\Gamma}
\]

with

\[
\omega = \frac{2J_R + 1}{(2J_p + 1)(2J_T + 1)} = \text{statistical factor}
\]

and

\(J_R\) = spin of the resonance state

\(J_p\) = spin of the projectile

\(J_T\) = target spin

\(\Gamma_1\) = energy width of incident channel

\(\Gamma_f\) = energy width of final exit channel

\(\Gamma = \Gamma_1 + \Gamma_f + \Gamma_a + ...\) = total width of resonant state

and

\[
\langle\sigma v\rangle \sim \omega \exp(E_R/kT).
\]

For several narrow resonances the total rate is given by the incoherent sum of single resonance rates. These rates are in general difficult to predict accurately due to uncertainties in the nuclear configurations as well as a strong dependence on the (sometimes uncertain) energy of a state.

In general because of the low cross-sections involved experimental determination of these cross-sections or total resonance strengths take considerable periods of time using high intensity/low energy proton (or α) facilities and targets able to withstand the high currents. When using radioactive heavy ion beams the actual laboratory reaction will be inverted. To effect a \((p,\gamma)\) reaction a hydrogen gas target would be used while for an \((a,\gamma)\) or \((a,p)\) reaction helium gas will be the target.

Highly efficient detectors will be required as discussed below, though the cross sections in explosive stellar burning are somewhat higher than in hydrostatic burning due to the higher temperatures of these events.
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extract a value of $\Gamma = 38.1$ keV from the width of the $^{14}\text{N}(^3\text{He},t)^{14}\text{O}$ triton-particle group feeding this state [29]. Particle recoil-coincidence techniques will eventually lead to a ratio of $\Gamma_d/\Gamma$ [32] and, since $\Gamma_p \gg \Gamma_d$ for few eV, the strength $\omega = \omega_0 \frac{\Gamma_p}{\Gamma}$ is thus determined via $\Gamma_d$. Such measurements are rather difficult and time-consuming and thus have not yet been successful for radioactive isotopes. For example, the determination of the $^3\text{He}[\omega(a,\gamma)^{6}\text{He}(a,\gamma)^{12}\text{C}]$ reaction rate via such indirect measurements took about 12 years. These examples demonstrate that such indirect determination of $\langle a\rangle$ via individual level structure studies is not a viable solution for the wide field of reactions, in particular for cases where the compound nucleus has a more complex structure and single states cannot be resolved by present techniques. In addition, one can never be sure of having not missed or confused states by indirect measurements as recent results on $^{26}\text{Al}$ demonstrate [33,34]. Furthermore, direct capture components or interfering state contributions are impossible to access by indirect spectroscopic means.

3.2 Radioactive beams and radioactive targets

Direct determinations of $\langle a\rangle$ require either the availability of a radioactive target (RT) or RIB. An important question is then the relative merit of these two alternatives. Suppose, for example, that one has a separated beam of radioactive nuclei and wants to study the reaction $A+x \rightarrow B+y$, where $x$ is a stable nucleus (here mainly protons and $\alpha$-particles). Should one (fig. 4) collect nuclei $A$ to form a radioactive target and bombard this target with the projectiles $x$, or should one accelerate the nuclei $A$ and let them impinge on a target of $x$-type nuclei? If the radioactive nuclei with half-life $T_{1/2} = 12\text{n}_2$ are produced with a rate $N_A$ and form a target of area $F$ (fig. 4a), the total number of reactions $A(x,y)B$ over the bombarding time $T$ is

$$N(\text{RT}) = \frac{\sigma N_A N_x(b)T}{F} \left[ 1 - \exp(-T/T_d) \right]$$

(4)

where $\sigma$ is the reaction cross-section and $N_x(b)$ the beam current. If the radioactive nuclei are accelerated (with a loss factor $f$) and impinge on a target of $N_x(t)$ target atoms per cm$^2$ (fig. 4c), the total number of reactions over the time $T$ is:

$$N(\text{RIB}) = \frac{\sigma N_A N_x(t) f T}{F}$$

(5)

For the case of $T_{1/2} \gg T$, both approaches provide the same number of reactions, $N(\text{RT}) = N(\text{RIB})$, for the (mean life) condition

$$\tau = Ff \frac{N_x(t)}{N_x(b)}$$

(6a)

and this condition is independent of $\sigma$, $N_A$ and $T$. For an order of magnitude estimate, the values $F=1 \text{ cm}^2$, $f=10\%$, $N_x(t) = 10^{19}$ atoms/cm$^2$ and $N_x(b) = 100 \mu\text{A} = 6\times10^{14}$ projectiles/sec, one finds $\tau = 28$ min.

In the other extreme case, $T_{1/2} \ll T$, equality of $N(\text{RT})$ and $N(\text{RIB})$ leads to the relation

$$T = \frac{\tau^2}{\tau - F N_x(t)/N_x(b)}$$

(7)

which requires for $T > 0$ the condition

$$\tau = F f \frac{N_x(t)}{N_x(b)}$$

(6b)

which is the same condition as above. Note again that this relationship is independent of $\sigma$ and $N_A$. Taking both together, the decision, of which approach to take becomes almost independent of the measuring time. It follows then that for half-lives shorter than about 0.5-1 h, radioactive ion beams are needed (fig. 3-2c), while for half-lives longer than
accelerated focal ratio beam with $N_{a} = 100$ UPSs, $N_{o} = 0.10$ and $N_{p} = 100$, $P_{o} = 10^6$.

In the perfect production reactions with $P_{o} = 1$ and $N_{o} = 0.10$ UPSs, $N_{p} = 100$, $P_{o} = 10^6$.

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have to be decelerated to energies around 1 MeV/u causing another reduction in beam intensity. Such techniques are presently being developed at several heavy-ion laboratories. A related approach uses relativistic heavy-ion beams \( (E > 1 \text{ GeV/u}) \) to produce radioactive beams by electromagnetic dissociation of the projectile \([10]\).

As indicated a viable alternative is to combine an ISOL device (as the front end) with a booster post-accelerator stage leading to the production of intense RIB \([3-5,39]\). In this method a thick target \( (\sim 6 \times 10^{23} \text{ atoms/cm}^2) \) is bombarded with an intense proton beam \( (>10 \mu \text{A} = 6 \times 10^{13} \text{ protons/s}^{-1}) \) of about 200-600 MeV. The radioactive nuclides are produced by spallation or proton-induced fission \( (\sigma = 20 \text{ mb}) \) at a rate of about \( 10^{12} \text{ ions/s}^{-1} \). Nuclides are continuously extracted from the target, ionized and mass separated on-line to provide a RIB with characteristics appropriate for studies of astrophysically interesting nuclear reactions. Accelerator systems such as a linear accelerator are able to provide the necessary beam energies \( (E = 1 \text{ MeV/u}) \) and acceptable energy spreads. These systems have a beam transmission efficiency of greater than 50\%, so a luminosity of greater than \( L = 5 \times 10^{23} \text{ cm}^2 \text{ s}^{-1} \), sufficient for most applications would be achievable.

Thus the ISOL accelerator (ISAC) approach shows the highest luminosity (about 3 orders of magnitude higher than the best of the others) achievable for radioactive ions.

Similar luminosities could be achieved with the use of a low-energy (50 MeV) proton cyclotron with a high current of, for example, 500 \( \mu \text{A} \). The beam would then intercept a thinner target than used with medium energy protons. Combined with the higher cross sections near stability this would lead to a similar yield of radioactive ions. Subsequently the radioactive products would have to be released and ionized as with an ISOL as discussed above, followed by an accelerator. Thus it would be the same kind of facility as described here, but with only a limited range of experimental possibilities. For example, nuclei far from stability would not be produced in this approach.

3.4 Specifications of the TRIUMF-ISOL radioactive beams facility

The discussion above indicates that the ISAC facility is a most promising approach to measure small cross sections of interest to nuclear astrophysics from the point of view of expected yields and experimental conditions. Based upon the requirements for the successful completion of such experiments, a set of specifications has been determined for the ISAC facility and these are listed in Table 4 \([40]\). It is now of importance to consider the feasibility of such a facility from the point of view of producing the required intensities of the isotope of interest as well as a realistic method of accelerating these separated isotopic ion beams.

4. Production of intense RIB for low Z isotopes

4.1 Overview

The goal is to achieve RIB intensities of the order of or better than \( 10^{10} \text{ ions/s}^{-1} \), although some useful studies could be performed with lower intensities. In general such intensities are obtainable from the point of view of production using intermediate energy protons and thick targets, at least for species close to stability. Both calculations and studies elsewhere \([41]\) support this in principle, with yields up to \( 10^{11} \text{ ion/s}^{-1} \) per \( \mu \text{A} \) of incident proton, presently available for selected species. With the possibility of using proton beam intensities over 100 \( \mu \text{A} \) at today’s meson facilities such as TRIUMF, LAMPF, and SIN, the RIB intensities required should be within reach with technology available.
4.2.3. Section II

In this section, a discussion on the efficiency of the production process is presented. The current production process is compared to a theoretical ideal production process. Theoretical production process is considered to be the most efficient, and actual production process is considered to be the least efficient. The differences in efficiency between the two processes are discussed, with particular emphasis on the factors contributing to the observed differences.

4.2.4. Section III

This section presents the results of the experimental study conducted to evaluate the efficiency of the production process. The experimental study involved the use of a novel modeling technique to simulate the production process under various conditions. The results of the study are presented in graphical form, and the implications of these results are discussed in detail.

4.3. Section IV

In this section, the impact of environmental factors on the production process is analyzed. The effects of temperature, humidity, and other environmental variables on the efficiency of the production process are investigated. The results of the analysis are presented, and suggestions for improving the process are made.

4.4. Section V

This section concludes the report by summarizing the findings of the study. The importance of efficiency in production processes is emphasized, and the need for continued research in this area is highlighted.

Appendix

Additional data and supporting information are provided in the appendix, including detailed tables and graphs that were not included in the main body of the report.
silicon) which is known to release sodium efficiently [47] or perhaps molten aluminum, if developed, the required production rates should be achievable.

4.4 Areas for improvement/developments

A general description of possible systems including targets which might increase the production rates for isotopes from helium to calcium can be found in [45]. The question of handling of high power and high radiation levels will require attention. An increase in the diameter of the target and the beam is an obvious first attempt to keep power densities similar to present levels. Such massive targets would introduce longer holding times but this should not be a problem given that the half-lives of the isotopes of interest are of the order of seconds. A new concept of remote handling of the target/ion source systems is presented in the TRIUMF-ISOL facility proposal [5] and is discussed in a separate contribution to this conference [7].

5. Acceleration of RIB

Since no ion source is available which delivers high charge state ions with about the same efficiency as singly charged ions, it has been decided [40] to aim for an accelerator with the specifications of table 4 capable of handling the low charge to mass ratio (q/A = 1/60) and the low incident energy of 1 keV/u. Studies on electrostatic Tandem accelerators were excluded at an early stage since negative ions are not readily available for a great variety of isotopes at ISOL facilities. No provisions have been taken to include an experimental storage ring using internal targets in the accelerator solution, since it can be shown that under all circumstances such a storage ring is inferior in luminosity to the use of external target in the energy range considered here [48].

Thus the investigations concentrated on a cyclotron and a linear accelerator solution, the latter consisting of a Radio Frequency Quadrupole LINAC (RFQ) and a Drift Tube Linac (DTL), either of the room temperature or superconducting variety.

5.1 Cyclotrons

The cyclotron solution [49] would consist of two cyclotrons, either of them normal or superconducting. Stripping would be applied between the machines to increase the charge to mass ratio. The injection into the first cyclotron appears most feasible with lowest losses using a spiral (Belmont-Pasot) system. Prior to injection the beam would be bunched leading to about 25% losses. The beam would have to be operated close to the beta frequency, but the beam separation remains sufficient for a septum extraction. Different methods for adjusting the magnetic field and the frequency for specific ions and energies are feasible, but an adjustment of both at the same time seems to be the most convenient. The extracted energy range of the first cyclotron is expected to be between 0.017 and 0.17 MeV/u, depending on the configuration but with a fixed T/A. The diameter of the first normal-conducting cyclotron would be about 2.5 m (1.5 T field).

The second stage cyclotron could be a normal room temperature sector focussed facility or a superconducting machine. Axial injection would be possible, and the frequency and magnetic field, B, should be variable. The necessary dynamic energy range of about a factor of 10 is considered to be large but not impossible to achieve.

5.2 Linear accelerators

5.2.1 The RFQ

All linear accelerator solutions considered [50,51] consist of a RFQ
6.1. The LHC

6. Experimental targets and detection system for a Higgs facility

The use of superconducting magnets is critical to the success of a hadron collider. Calculations have not been performed and focusing problems might make a facility virtually impossible. However, the development of high-energy particle accelerators is a major R&D challenge.

A superconducting LHC is used to control the power of the Higgs field generated in high-energy particle accelerators. Calculations have not been performed and focusing problems might make a facility virtually impossible. However, the development of high-energy particle accelerators is a major R&D challenge.

The combination of these factors would yield a value of 0.048 (0.134) for the LHC energy. A beam power of 0.048 (0.134) for the LHC energy.

6.2.2. The LHC energy

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developed. They are (1) a quasi-static, geometrically extended gas target [55], and (2) a supersonic, quasi-potential jet gas target [56,57]. The latter is of particular importance if the heavy reaction products (recoil nuclei) are to be detected (see below). At present, these supersonic jet systems can provide H₂ and He densities of up to about 10^{17} atoms·cm⁻². However, for the above studies, higher gas densities are required. Higher densities can possibly be achieved by improvements in the pumping units but, more importantly by cooling the jet gas flow to a low temperature.

6.2 Detection systems

Radiative capture reactions A(x,γ)B are important processes for the formation of most of the elements. They are usually studied in the laboratory by detecting the emitted γ-rays. In the radioactive target approach studies via standard γ-ray spectroscopy are extremely hampered by the radioactive decay of the target itself. For example, 1 μg targets of ²²Na (T₁/₂ = 2.602 γ), ¹⁸F (T₁/₂ = 110 min), or ¹³N (T₁/₂ = 10 min) produce a 511- and 1274- keV γ-ray flux of 4.8×10⁸, 7.3×10¹², and 1.1×10¹⁰ s⁻¹, respectively. To reduce the ¹³N γ-ray flux to a level of, say, 10⁶ s⁻¹ requires a 15 cm thick lead shielding around the target. This shielding also reduces the flux of the typical 3-8 MeV captive γ-rays by a factor of 10¹⁰. In the RIB approach the beam is stopped in a beam dump far away from the gas target zone and the problem of a "hot" target appears to be absent. In practice, however, interception of the RIB with the apertures of the gas target system as well as divergence of the beam passing through the gas target may lead to non-negligible levels of background radiation at the target area. An ideal detector for γ-ray spectroscopic studies would thus have the following properties:

i) low sensitivity for γ-rays accompanying B decay;
ii) high and nearly uniform efficiency for fusion reaction products (γ-rays and/or heavy recoils);
iii) sufficient energy resolution;
iv) 4π geometry;
v) low sensitivity to internal as well as external background.

6.2.1 Threshold detectors

Since the fusion γ-rays are normally of a higher energy (3-8 MeV) than those from radioactive decay, it is possible to use threshold effects (e.g. photodisintegration of nuclei, pair production) for the construction of a suitable detector for radioactive beams. Such a detector based on the photodisintegration of the deuteron (in heavy water) is presented in one of the contributions to this conference [58].

6.2.2 Recoil detectors

Since the recoiling nuclei B of a capture reaction A(x,γ)B travel essentially in the same direction as the beam, their direct detection with detectors having up to a 100% efficiency could greatly improve the experimental sensitivity. This approach clearly requires a quasi-point source gas jet target. There are however some obvious problems if a detector is placed in the beam direction. One observes not only the capture products, but also the incident beam (including beam contaminants) the elastic scattering products, and other background events (from multiple scattering processes). These problems have been overcome using detection techniques such as Wien filters plus electrostatic and magnetic deflect ion devices. These and other techniques (i.e. coincidences between capture γ-rays and recoil nuclei B, time-of-flight to identify the recoil nuclei B, etc) are presently being exploited at several
In other fields of physics and nuclear physics are applied and are an
important class of detectors. The further applications of this
approach to radioactive detectors, however, are only now being
explored. In particular, the development of new techniques for the
measurement of activities and the use of new detectors, such as gas
and liquid scintillators, can be used to advantage.

Table 2. Response of various detectors to 14 MeV neutrons

<table>
<thead>
<tr>
<th>Detector</th>
<th>1 MeV</th>
<th>10 MeV</th>
<th>100 MeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ge detector</td>
<td>0.0001</td>
<td>0.01</td>
<td>0.1</td>
</tr>
<tr>
<td>Si detector</td>
<td>0.001</td>
<td>0.1</td>
<td>1</td>
</tr>
<tr>
<td>Plastic scintillator</td>
<td>0.1</td>
<td>1</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 3. Some reactions of astrophysical interest [6]

<table>
<thead>
<tr>
<th>Reaction</th>
<th>T/L of antiparticle</th>
</tr>
</thead>
<tbody>
<tr>
<td>p(p, d)n</td>
<td>1.2 MeV</td>
</tr>
<tr>
<td>n(n, p)H</td>
<td>1.4 MeV</td>
</tr>
<tr>
<td>d(d, n)He</td>
<td>2.2 MeV</td>
</tr>
</tbody>
</table>

Table 4. Results of astrophysical measurements [9]

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>1.2 MeV</td>
</tr>
<tr>
<td>Pressure</td>
<td>1.4 MeV</td>
</tr>
<tr>
<td>Density</td>
<td>1.2 MeV</td>
</tr>
</tbody>
</table>

Table 3. Thick target yields into 4π for \(^{19}\text{Ne}(p,\gamma)^{20}\text{Na}\)

<table>
<thead>
<tr>
<th>Resonance energy (MeV)</th>
<th>State energy (MeV)</th>
<th>(E_R) (MeV)</th>
<th>(E/u(^{19}\text{Ne})) (MeV/(u))</th>
<th>(\omega_\text{a)}) (eV)</th>
<th>Yield (h(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.694(^{b)})</td>
<td>2.890</td>
<td>13.88</td>
<td>0.731</td>
<td>0.004</td>
<td>11</td>
</tr>
<tr>
<td>0.770</td>
<td>2.966</td>
<td>15.40</td>
<td>0.811</td>
<td>0.005</td>
<td>13</td>
</tr>
<tr>
<td>0.771</td>
<td>2.967</td>
<td>15.42</td>
<td>0.812</td>
<td>0.006</td>
<td>15</td>
</tr>
<tr>
<td>0.979</td>
<td>3.175</td>
<td>19.58</td>
<td>1.031</td>
<td>0.002</td>
<td>5</td>
</tr>
<tr>
<td>1.292</td>
<td>3.488</td>
<td>25.84</td>
<td>1.360</td>
<td>0.003</td>
<td>6</td>
</tr>
<tr>
<td>1.330</td>
<td>3.526</td>
<td>26.60</td>
<td>1.400</td>
<td>0.001</td>
<td>4</td>
</tr>
<tr>
<td>1.391</td>
<td>3.587</td>
<td>27.82</td>
<td>1.464</td>
<td>0.007</td>
<td>13</td>
</tr>
<tr>
<td>1.485</td>
<td>3.681</td>
<td>29.70</td>
<td>1.563</td>
<td>0.006</td>
<td>11</td>
</tr>
<tr>
<td>1.565</td>
<td>3.761</td>
<td>31.30</td>
<td>1.647</td>
<td>0.006</td>
<td>11</td>
</tr>
</tbody>
</table>

\(a)\) Ref. [19]  
\(b)\) See ref. [16]

Table 4. Specifications for an accelerated radioactive beams facility

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i) Beam intensity</td>
<td>acceptable range, (10^5-10^{12}) ions (\cdot) s(^{-1})</td>
</tr>
<tr>
<td>(ii) Energy range</td>
<td>0.2-1.5 MeV/(u)</td>
</tr>
<tr>
<td>(iii) Energy resolution</td>
<td>(&lt;0.1%) desirable, (&lt;1%) acceptable</td>
</tr>
<tr>
<td>(iv) Energy increments</td>
<td>continuous variability desirable, increments (\geq 0.25) MeV/(u) acceptable</td>
</tr>
<tr>
<td>(v) Mass limit</td>
<td>all nuclides up to (A = 60) ((q = \pm 1))</td>
</tr>
<tr>
<td>(vi) Time structure</td>
<td>either continuous or pulsed (assuming minimum losses). A microstructure of pulse duration (&lt; 1) ns may be desirable for some applications</td>
</tr>
<tr>
<td>(vii) Priority items for the future</td>
<td>higher energy (up to 5 MeV/(u)), higher mass limit</td>
</tr>
</tbody>
</table>

Table 5. Present status for isotopes of interest to astrophysics

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Obs. Prod. Rate (ions (\cdot) s(^{-1}) (\cdot) mA)</th>
<th>Target, (g) (cm(^{-2}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>(^{14}\text{N})</td>
<td>4.1 (\times) 10(^{5})</td>
<td>CNO 2.6</td>
</tr>
<tr>
<td>(^{17}\text{N})</td>
<td>(\geq 1)</td>
<td>MgO 3</td>
</tr>
<tr>
<td>(^{17}\text{O})</td>
<td>(\geq 1)</td>
<td>MgO 3</td>
</tr>
<tr>
<td>(^{14}\text{Ne})</td>
<td>(\geq 1)</td>
<td>Ta 122</td>
</tr>
<tr>
<td>(^{18}\text{Ne})</td>
<td>(\geq 1)</td>
<td>Ta 122</td>
</tr>
<tr>
<td>(^{20}\text{Na})</td>
<td>(\geq 1)</td>
<td>Sc 2.32</td>
</tr>
<tr>
<td>(^{20}\text{Ne})</td>
<td>(\geq 1)</td>
<td>Sc 2.32</td>
</tr>
<tr>
<td>(^{22}\text{Ne})</td>
<td>(\geq 1)</td>
<td>Sc 2.32</td>
</tr>
<tr>
<td>(^{23}\text{Ne})</td>
<td>(\geq 1)</td>
<td>Sc 2.32</td>
</tr>
<tr>
<td>(^{31}\text{P})</td>
<td>(\geq 1)</td>
<td>Sc 2.32</td>
</tr>
</tbody>
</table>

\(a)\) As taken from [41]  
\(b)\) Calculated using empirical formulation of ref. [61]  
\(c)\) As taken from [45]
References


[48] L. Buchmann, submitted for publication to NIM.
ret. [3] A charge space separator is included behind the stripper.

5. The time-reactivation beam (TIME) facility as calculated in the primary reactivation beam.

Improvement of the reaction cross section and the intensity of the preferred method. It should be noted that this conclusion is in
It is is longer than a reactivation target experiment may be the
about 1, then the reactivation beam experiment is more advantageous.
life of the reactivation nuclei. If the half-life is shorter than
studying such a reaction is found to be only a function of the half-
in the entrance channel. A detection on the most advantageous way of
particulate interaction, nuclear reactivation involving a reactivation nucleus
a) Experimental determination of reactivation techniques for the study of charged

14H(p,γ)14N1p reaction,

2) Determined levels structure of 14N1p and 14H2p of importance for the
3) Prepared level structure of 14N1p and 14H2p of importance for the
4) Prepared for the hydrogen binding in target materials
5) No reaction networks of the reaction and the reaction 2p,
6) Reaction times (14p,δ) and (14p,nn) are well at few decades.

In terms, including other half-lives, various limitations of different
2 types, the first one cycle, large impact with reactivation technique

Figure captions
