High Yield Production of ^{6}He for Beta-Beam experiments

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Abstract
One critical requirements for upcoming Beta-Beam experiments is a high performance ion source. We present a simple production method proposed by T.Hirsh, M. Hass et. al.. The idea is to use a low energy deuteron beam ($\approx$ 40 MeV, 2 mA) in a two stage irradiation setup, which produces the desired ions (most importantly ^{6}He, but also ^{8}Li). We present the production concept, preliminary simulations, indicating production rates in the magnitude of 10^{13} ^{6}He ions per second.

1 Introduction

The idea of the Beta-Beam concept is the production of a focused, high energy neutrino beam by the β-decay of radioactive ions inside the straight section of an otherwise circular particle accelerator. In order to achieve sufficient events a high neutrino flux and thus a high production rate of the radioactive ions (usually ^{6}He for anti-neutrinos) is required.
One way of achieving the production rates is the ISOL method [7], but a more "lightweight' approach might be desirable.
Such an approach has been proposed in [1]. The idea is to use a low energy deuteron beam form a LINAC ($\approx$ 40 MeV, 2 mA) in a two target setup. The deuterons first hit a primary, light element target producing fast neutrons which, subsequently produce radioactive ions in a secondary target from where they can be extracted.
Such a LINAC (5.2 MeV, 2 mA until 2011-13, 40 MeV after) is available at the Soreq Nuclear Research Center in Israel, where the concept will be studied [5].

2 Production Concept

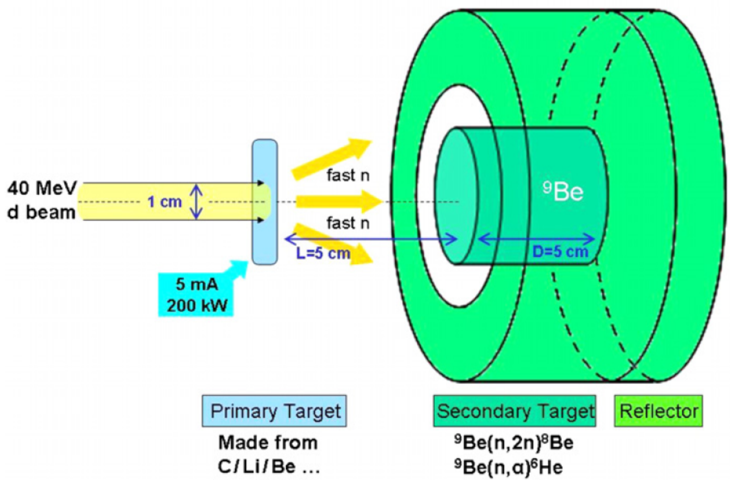

Fig. 1: ^{6}He production concept [1]

The production concept is shown in Fig. 1.
Deuterons from the LINAC impinging on the light, primary target produce fast neutrons via (d,xn) reactions, which subsequently produce the desired ^{6}He in the ^{9}Be-cylinder via the ^{9}Be(n,α)^{6}He reaction.
This setup has the additional advantage of being modular. Issues of cooling,extraction,heating etc. can be addressed separately if necessary.
By exchanging the ^{9}Be-cylinder with a ^{11}B-cylinder, ^{8}Li can be produced via the ^{11}B(n,α)^{8}Li reaction.
For practical reasons a more porous secondary target like BeO is more ideal since this increases diffusion and thus allows for better extractability.

3 Materials for the primary target

With the nuclear reaction program Talys [4] the yield of fast (> 4 MeV) neutrons from the primary target for different materials was simulated [6] for the (5.2 MeV,2 mA)-testing phase (also of general interest for higher energies). In addition to the absolute neutron yield the neutron yield in forward direction is also given since only these neutrons reach the secondary target. The results are shown in Table 1.

Table 1: Fast neutron yield of a 5.2 MeV deuteron beam; (N/s): fast neutrons per second (40°: regarding d-beam); Nat. Ab.: natural abundance; MP: melting point

Isotope	(N/s)	(N/s) below 40°	Nat. Ab.	Q-Val. (MeV),	MP. (°C)
^{7}Li	$8.37 \cdot 10^{12}$	$1.27 \cdot 10^{12}$	92.41	15.03	181
^{9}Be	$2.75 \cdot 10^{12}$	$4.89 \cdot 10^{11}$	100	4.36	1287
^{11}B	$2.08 \cdot 10^{12}$	$3.44 \cdot 10^{11}$	80.1	13.73	2075
^{13}C	$1.45 \cdot 10^{12}$	$2.78 \cdot 10^{11}$	1.07	5.32	4489
^{7}LiF	$4.00 \cdot 10^{12}$	$6.29 \cdot 10^{11}$	-	-	848
^{11}BN	$1.24 \cdot 10^{12}$	$2.12 \cdot 10^{11}$	-	-	2967

This suggests ^{7}Li as a liquid-jet/gas target with the other materials, with higher melting points, as possible solid targets.

4 ^{6}He Yield for a 40 MeV beam

Using the Monte Carlo simulation program MCNP^{TM}4b the production rates of ^{6}He in a BeO target and the production rates of ^{8}Li in a BN target were calculated as shown in Fig. 2, the results can be found in Table 2.

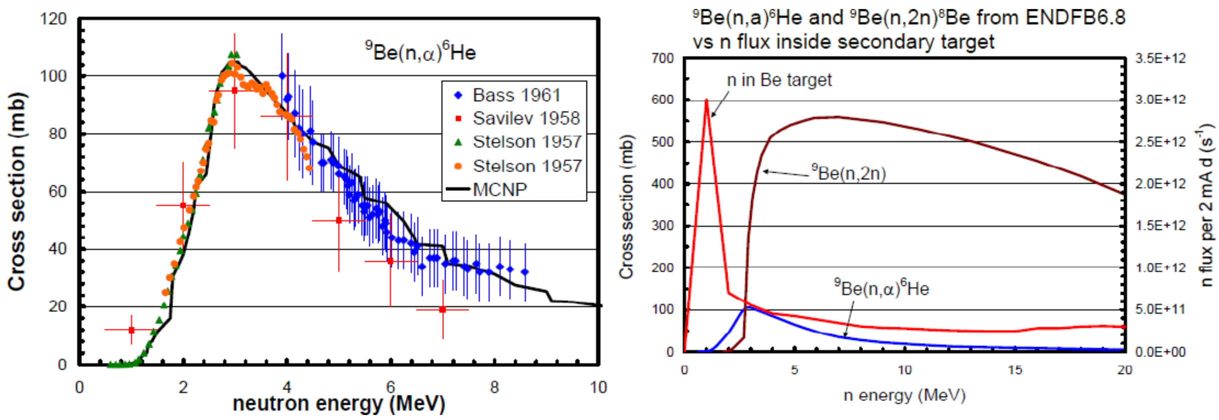

Fig. 2: MCNP calculation [2, 3]

Table 2: Simulated Ion Production [2, 3]

Setup	Ion	Rate
SARAF (40 MeV, 2 mA)	^{6}He	$8 \cdot 10^{12}$ ^{6}He/s
SARAF (40 MeV, 2 mA)	^{8}Li	$2 \cdot 10^{12}$ ^{6}He/s

The results are very promising, especially ^{6}He with a production rate in the order of magnitude of 10^{13} ^{6}He/sec. The next critical issues will be production and extraction measurements in the 5.2 MeV phase.

5 Conclusion

The simulated production rates verify this production concept as a possible "lightweight' alternative ion source for Beta-Beam Experiments. The next steps will be extraction measurements and the development of an efficient extraction technique.

References

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