nuCARIBU: An upgrade for the CARIBU facility at the Argonne Tandem Linac Accelerator System

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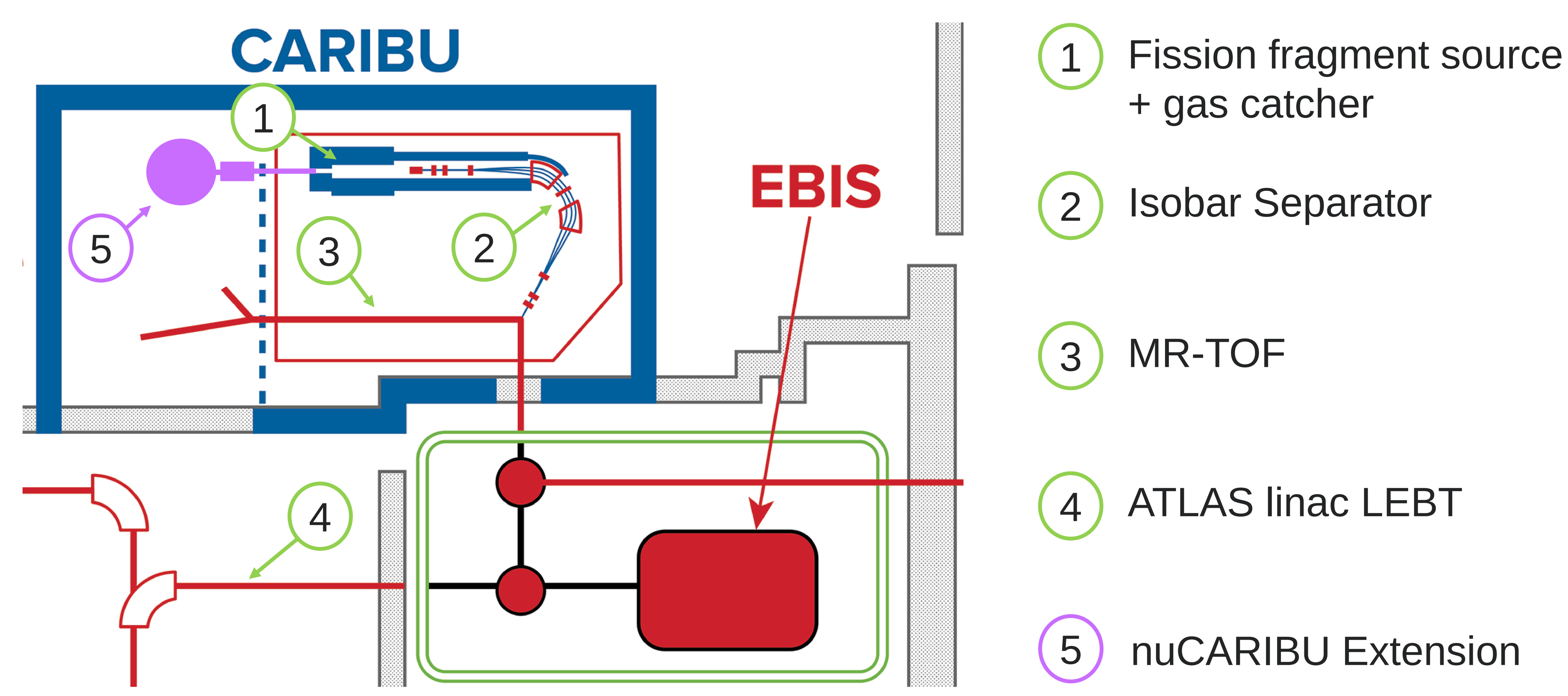
ABSTRACT

The Californium Rare Isotope Breeder Upgrade (CARIBU) facility is changing the mechanism for creating neutron-rich fission products. Spontaneous fission from a ^{252}Cf source has provided beams to support the low energy and accelerated-beams ATLAS programs. ^{252}Cf has a 2.65-year half-life, requiring the source to be replaced every three years to maintain high beam intensities. Fabricating an appropriately thin ^{252}Cf source to efficiently release the fission products has been challenging. The solution to these problems is nuCARIBU, a new system that provides neutron-induced fission on actinide foils. The Best Cyclotron B6P System (6-MeV proton beam at 0.5mA) is chosen, utilizing a multi-cusp negative ion source extracting into a cyclotron, which uses carbon foils to strip the H^- ions to protons. These protons are delivered to a ^{7}Li target to produce neutrons. The fast neutrons are moderated to thermal energies to induce fission in an actinide foil, providing neutron-rich fission products.

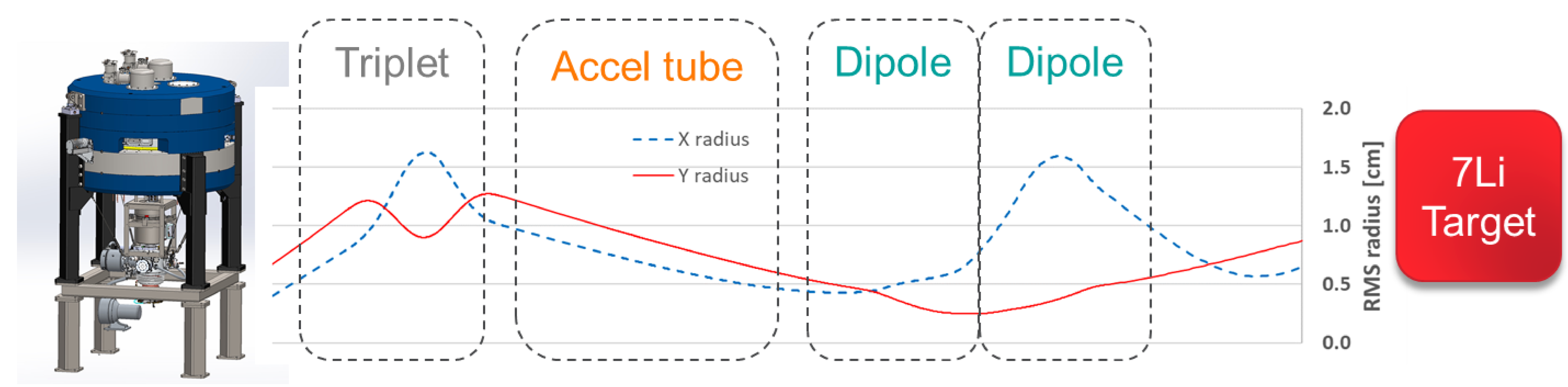
INTRODUCTION AND MOTIVATION

The Californium Rare Isotope Breeder Upgrade (CARIBU) was commissioned in 2011 at the Argonne Tandem Linac Accelerator System (ATLAS). CARIBU utilizes a ^{252}Cf source to provide a spectrum of neutron-rich fission fragments for use in both the low energy and reaccelerated physics programs [1,2]. The ^{252}Cf source must be replaced once it has decayed to a point where it is no longer capable of delivering acceptable beam intensities. It has been challenging to fabricate a new ^{252}Cf source, and new approaches were considered to replace the passive ^{252}Cf source. A cyclotron-based neutron generator system that delivers thermal neutrons onto an actinide foil to produce fission fragments was chosen.



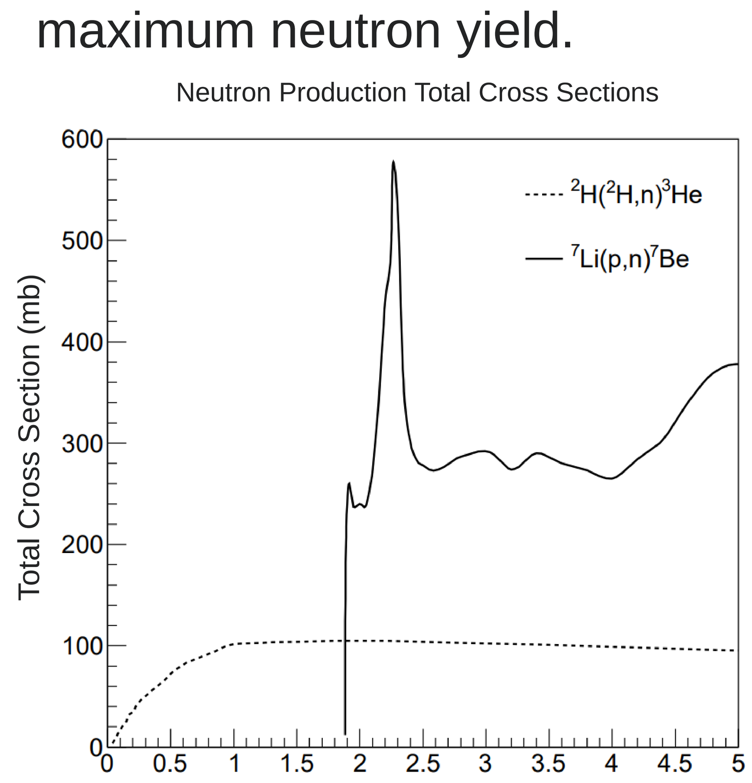
nuCARIBU SUBSYSTEMS

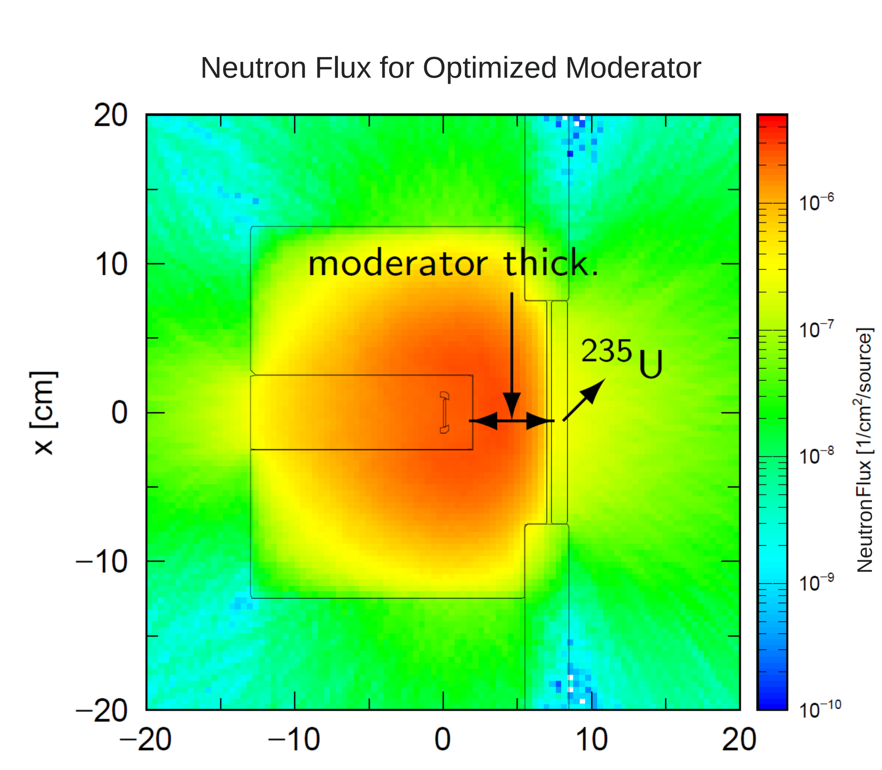
The nuCARIBU neutron generator system consists of multiple subsystems. The proton source is a system that uses a multi-cusp H^- source injected into a 6-MeV cyclotron with carbon stripping foils in the extraction beam line to strip the H^- ions to protons. The protons are transported to a ^{7}Li target to produce neutrons via the p-^{7}Li reaction. Once fast neutrons are generated, they are moderated to thermal energies and react with an actinide foil to produce fission fragments that enter the gas catcher to be ionized and extracted into a low energy beam line. The desired beam is then m/q filtered and delivered to EBIS [3] for charge breeding before reacceleration into ATLAS or delivered to a low energy target area.



Neutron Production

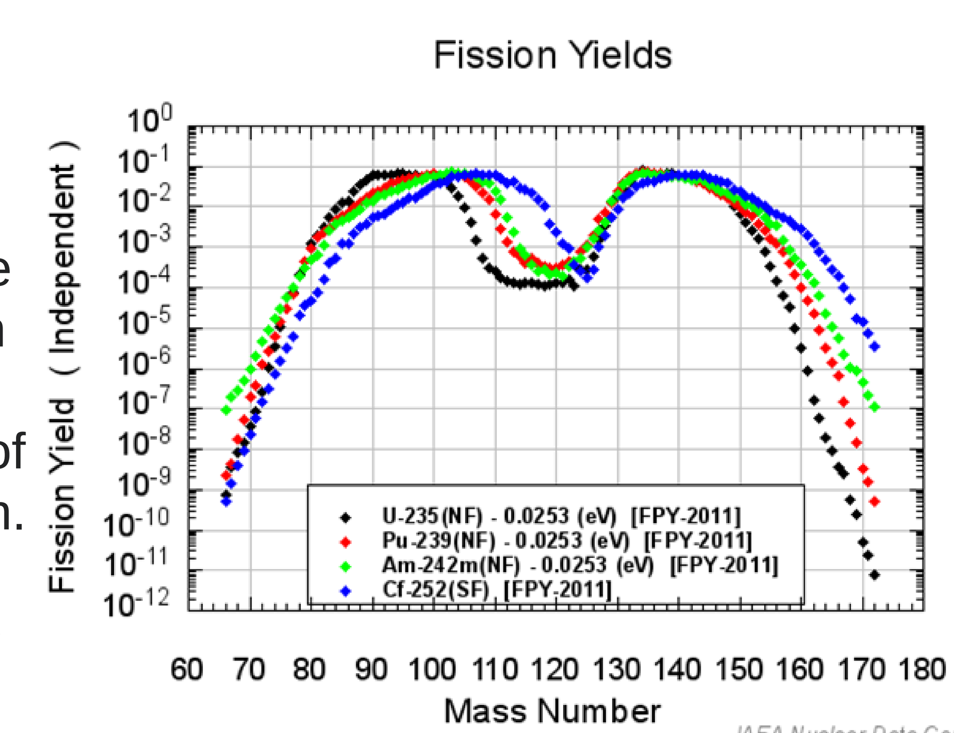
The Best B6P Cyclotron System is chosen as the 6-MeV proton source for nuCARIBU. The D-D and p-^{7}Li reactions were considered, and because the p-^{7}Li reaction possesses much higher cross sections, it was chosen as the neutron production mechanism. The beam optical devices from the cyclotron to the ^{7}Li target are designed to deliver up to a 3cm beam diameter onto the ^{7}Li target. Simulations were carried out to optimize the beam transport for transmission and beam spot size, and moderator design was optimized for maximum neutron yield.



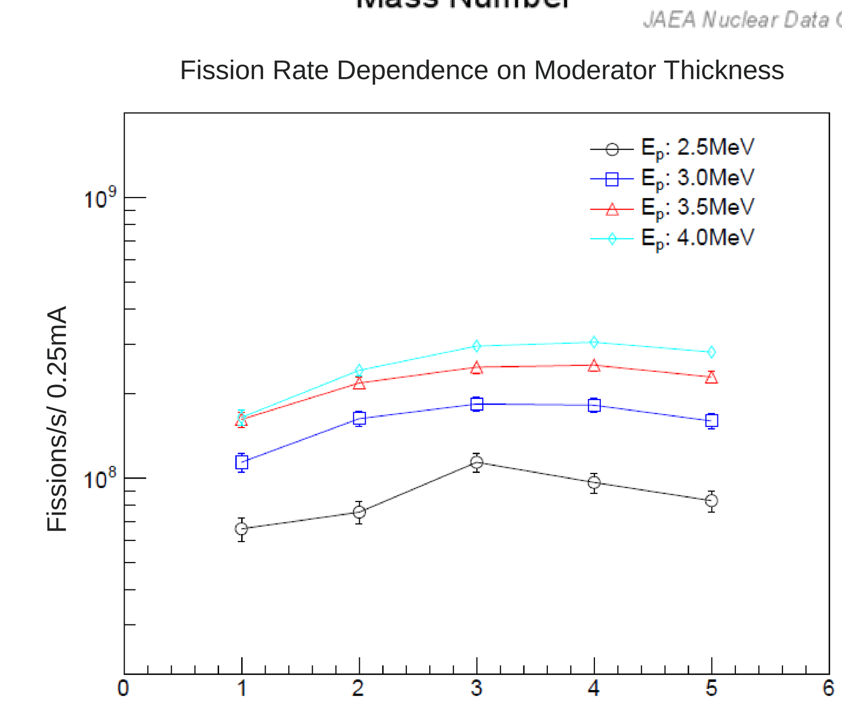


Neutron Induced Fission

After the neutrons are produced, they are moderated to thermal energies to maximize the neutron induced fission cross section in the actinide foil target. While ^{252}Cf spontaneously fissioned, the actinide foils of interest require neutron irradiation to fission. ^{252}Cf was capable of higher relative fission yields over A=140 when compared with the actinides considered for fission targets [4], but nuCARIBU's increase in fission rate can overcome that deficit for many desired beams. A table comparing the relative yields for desired beams is below.



Fission Product	Fissioning Material: ^{252}Cf	^{239}Pu	^{235}U	^{229}Th
^{82}Ge	5.4E-05	2.7E-04	1.3E-03	1.2E-02
^{90}Se	4.1E-05	1.2E-05	1.3E-04	6.2E-05
^{110}Ru	3.6E+00	5.7E-01	1.0E-02	1.4E-04
^{132}Sn	1.4E-01	4.8E-01	5.9E-01	1.1E-01
^{164}Gd	2.6E-04	1.7E-05	4.3E-08	7.9E-12



CONCLUSIONS

CARIBU currently provides 3000-4000 hours of low energy and reaccelerated beams per year, and many of the delivered beams are unique to the CARIBU facility. The demand is high and increases annually, where only about half of the requested beam hours are currently approved. More beam hours could be approved with the increased intensities, safety, reliability, and maintenance simplicity that nuCARIBU will provide.

REFERENCES

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[3] Vondrasek R C et al 2017 *Review of Scientific Instruments* **89** 052402
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ACKNOWLEDGMENT

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