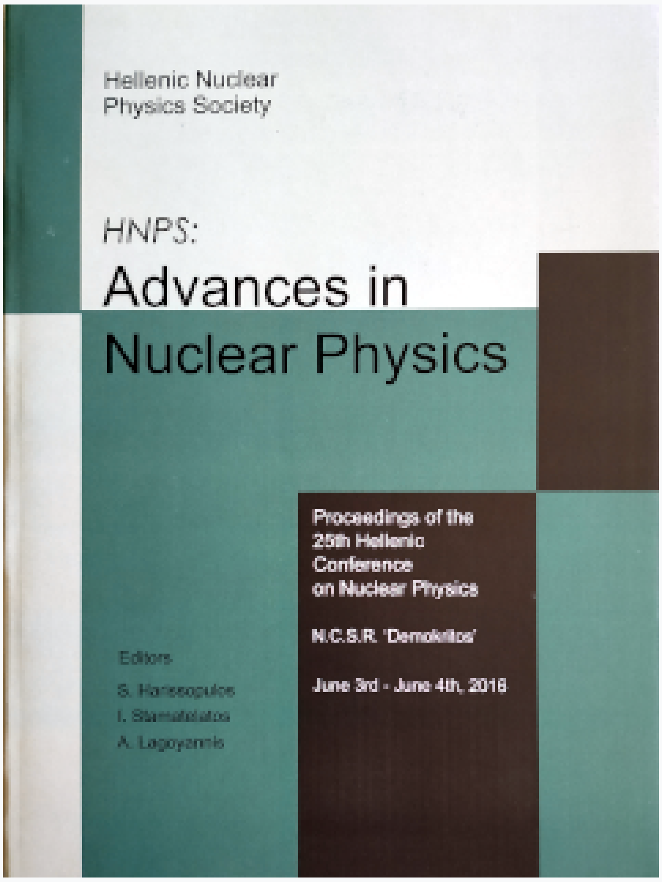
HNPS Advances in Nuclear Physics

Vol 24 (2016)

HNPS2016



Exploring the feasibility of magnetic moment measurements in the exotic 20C nucleus using LISE++ calculations

D. Papaioannou, S. K. Peroulis, T. J. Mertzimekis

doi: [10.12681/hnps.1878](https://doi.org/10.12681/hnps.1878)

Exploring the feasibility of magnetic moment measurements in the exotic ^{20}C nucleus using LISE++ calculations

D. Papaioannou[1], S. K. Peroulis[1], T. J. Mertzimekis[1,*]

[1] *Department of Physics, Zografou Campus, 15784, University of Athens, Greece*

Abstract Nuclear magnetic moment measurements in neutron-rich isotopes require special techniques that have to be applied in the latest generation of RIB factories. Fragmentation reactions used in these labs can produce exotic species as secondary beams. Specialized fragment separators are used to optimize the production of secondary beams. In this work, a simulation code, LISE++, is used to explore the feasibility of a magnetic moment measurement in the exotic ^{20}C nucleus, produced as a secondary beam in NSCL A1900 and RIKEN RIPS fragment separators, by optimizing the settings of operations in both.

Keywords ^{20}C, LISE++, fragmentation, magnetic moment

INTRODUCTION

Nuclear magnetic moment measurements in isotopes at extreme N/Z ratios are impeded by mainly two factors: the struggling low rates of exotic nuclei produced in fragmentation factories and the scarcity of efficient techniques targeting nuclear magnetic moments at very high ion velocities. For light exotic isotopes produced in fragmentation facilities, such as NSCL (USA) and RIKEN (Japan), recent experiments have proven successful in populating excited states and measuring important observables (e.g. lifetimes in Ref. [1]). In an attempt to explore the feasibility of a magnetic moment measurement in ^{20}C using the High-Velocity Transient Field (HVTF) technique [2] at in-flight separator facilities, extensive calculations were carried out using the LISE++ software suite [3]. From beam optics tuning to transmission calculations, realistic conditions for an experiment producing secondary ^{20}C beams were optimized for both NSCL and RIKEN laboratories. The results exhibit low production rates, but marginally sufficient to carry out a nuclear magnetic moment measurement in the 2_1^+ state of ^{20}C with reasonable precision.

METHODOLOGY

The present study has been carried out using the LISE++ software suite, a tool developed to simulate the full array of optical elements in RIB factories. LISE++ can calculate the transmission and yields of fragments (fusion residues) produced and collected in a fragment separator, such as NSCL's A1900 and RIKEN's RIPS. It also allows for fully simulating the radioactive beams production, from the parameters of the reaction mechanism to the detection of products selected by the separator, while it offers a full set of physical calculators. In the present work, version 9.10.263 was used.

The first step was choosing the optimum primary beam from the list provided by each lab. ^{48}Ca (140 MeV/A, 80 pnA) and ^{22}Ne (180 MeV/A, 360 pnA) resulted to be the most

---

* email: tmertzi@phys.uoa.gr

suitable primary beams for A1900 and RIPS fragment separator, respectively. Using the default settings for each fragment separator, the particle ID at focal plane (Figs. 1, 5) is full of contaminants, while a very small ^{20}C yield was observed. Adjusting the optical and magnetic elements in the beam lines (achromatic wedges, Bρ, slits etc.) resulted in optimizing the spectrometers for the exotic secondary fragment beam of ^{20}C. Transmission and purity was calculated for each case. A detailed list of the parameters used to optimize the final beam of ^{20}C in both spectrometers are presented in Table 1.

Table 1. Detailed list of setting for A1900 and RIPS fragment separators used to optimize LISE++

A1900			**RIPS**		
Projectile	Energy (MeV/u)	Intensity (pnA)	**Projectile**	Energy (MeV/u)	Intensity (pnA)
^{48}Ca	140	80	^{22}Ne	110	360
Target	Thickness ($mgcm^{-2}$)	Angle (deg)	**Target**	Thickness ($mgcm^{-2}$)	Angle (deg)
^{9}Be	613.081	0	^{9}Be	816.088	16.38
Dipole	M. Rigidiy (Tm)		**Dipole**	M. Rigidiy (Tm)	
D1	5.4890		D1	4.4412	
D2	5.4890		D2	4.2678	
D3	5.1315		-	-	
D4	5.1315		-	-	
Degrader	Thickness ($mgcm^{-2}$)	Angle (mrad)	**Degrader**	Thickness ($mgcm^{-2}$)	Angle (mrad)
Wedge	1586.9168	-3.1296	Wedge	486.36	2.428
Device	E. Field (kV/m)	M. Field (G)	**Device**	E. Field (kV/m)	M. Field (G)
Wien	3000	225.77	-	-	-
Dipole	M. Rigidiy (Tm)	Angle (deg)	**Dipole**	M. Rigidiy (Tm)	Angle (deg)
CD	5.1305	5	-	-	-
Slits	Aperture (mm)		**Slits**	Aperture (mm)	
I1	100		F1 Horizontal	72	
I2	150		F1 Vertical	50	
Wien Horizontal	-15 and +16		F2	-7.5 and +8	
Wien Vertical	8		-	-	
CD Horizontal	-7.5 and +20		-	-	
CD Vertical	8		-	-	
FP Horizontal	25		-	-	
FP Vertical	25		-	-	

RESULTS AND DISCUSSION

NSCL A1900

The A1900 fragment separator at NSCL was the first ever lab where the High Velocity Transient Field (HVTF) technique for magnetic moment measurements in exotic species was applied [2]. For this reason, A1900 was the first choice to explore the feasibility of such a measurement in ^{20}C. Figures 1-4 illustrate beam particles and contaminants distribution at various points along the spectrometer.

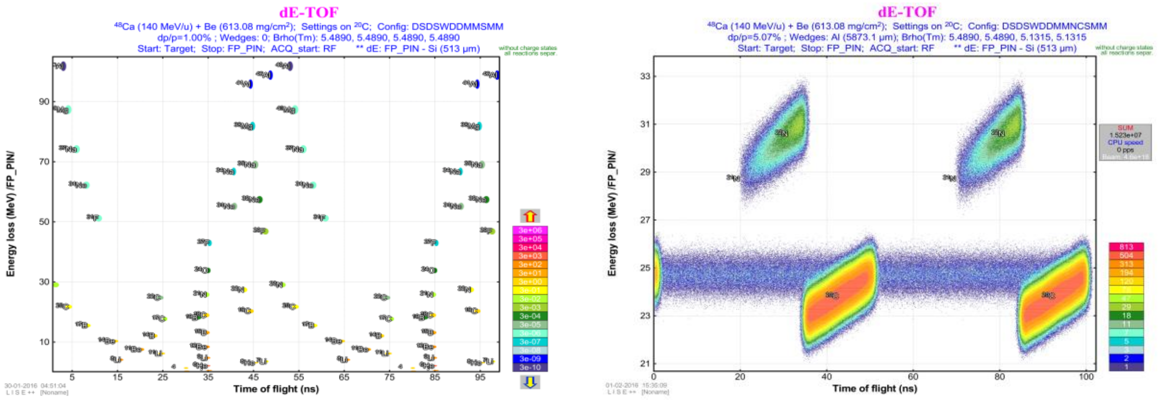


Fig. 1-2. dE-TOF with default settings after the target and with final settings at the focal plane.

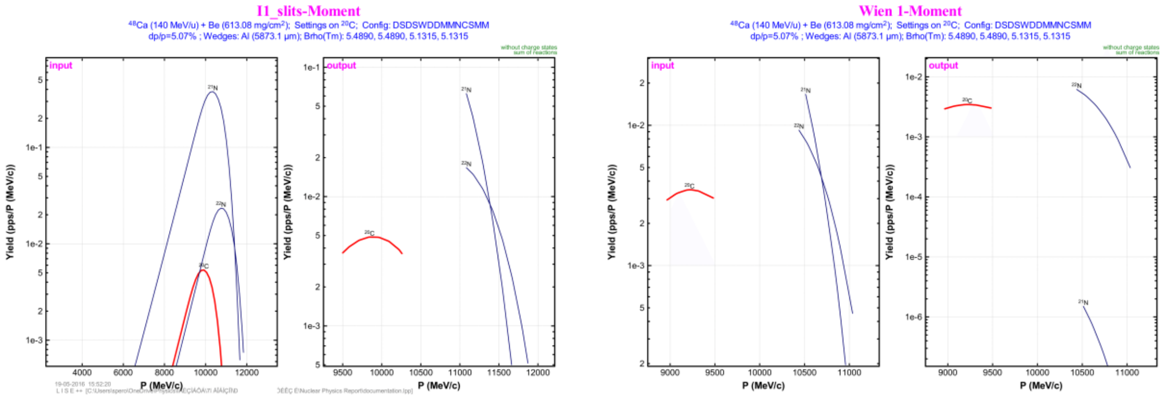


Fig. 3-4. (Left) Momentum distributions before and after I1 slits. (Right) Momentum distributions before and after Wien Filter.

RIKEN RIPS

With respect to A1900, LISE++ calculations for RIPS show a reduced amount of contaminants. Figures 5-8 illustrate beam particles and contaminants distribution at various points along the spectrometer.

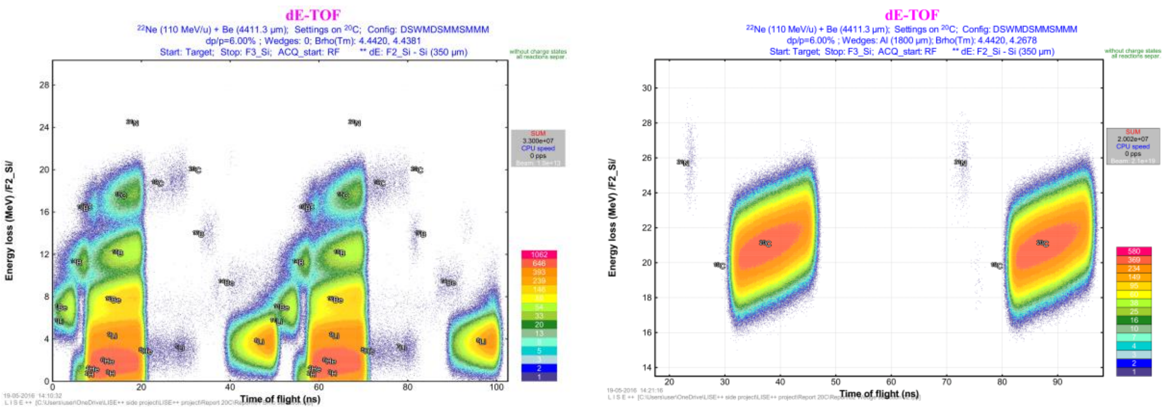


Fig. 5-6. dE-TOF with default settings after the target and with final settings at the focal plane.

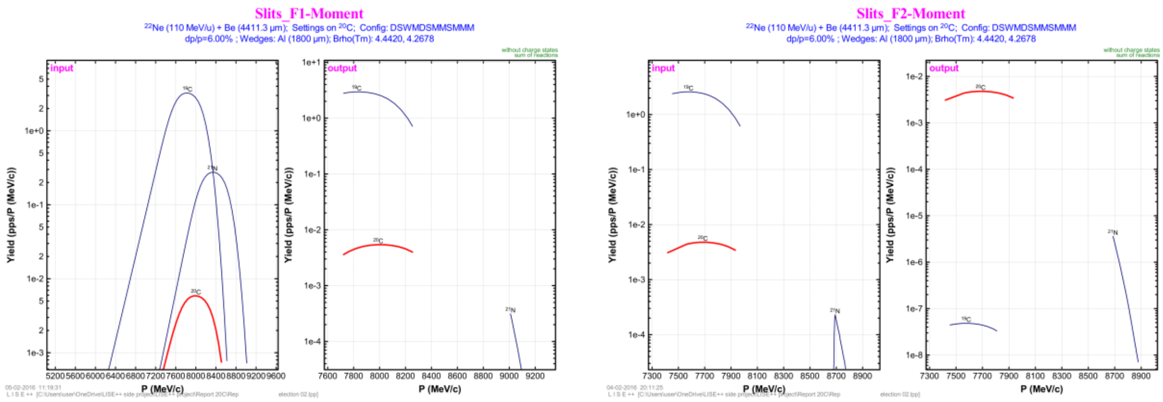


Fig. 7-8. (Left) Momentum distributions before and after F1 slits (left) and F2 slits (right).

Further decreasing the aperture of the slits would result in 100% purity, but in expense of transmission and yield. The remaining isotopes (mainly ^{21}N) that reach the focal plane are now only a tiny fraction of the secondary beam.

The optimal settings for both fragment separators in NSCL and RIKEN result in the values listed in Table 2 for secondary beam yield, purity and transmission. Achieving those values required opening up the slits so as to allow for full momentum spread dp/p.

Table 2. Detailed list of setting for A1900 and RIPS fragment separators used to optimize LISE++

Layout	Yield (pps)	Sum (pps)	Purity (%)	Transm. (%)	d*p* /*p* (%)
A1900	1.63	1.8	90.56	10.547	5.07 (full)
RIPS	2.17	2.2	98.64	25.919	6.00 (full)

Both fragment separators were found to be able to achieve similar yields for ^{20}C. The results 1.6 pps and 2.2 pps for A1900 and RIPS, respectively, are rather on the low production side. However, based on the requirements of the HVTF technique for a satisfactory measurement [4], both separators could potentially be used for such an experiment given the proper allocated time (a week or more of beam time).

CONCLUSIONS

The production of the neutron-rich isotope ^{20}C, very close to the neutron dripline, was investigated by means of LISE++ calculations. Despite the rather low production rate, the purity of the beams is promising for a future magnetic moment measurement at either NSCL A1900 or RIKEN RIPS fragmentation facilities.

References

[1] M. Petri et al., Phys. Rev. Lett. 107, 102501 (2011)
[2] A.D. Davies et al., Phys. Rev. Lett. 96, 112503 (2006)
[3] O.B. Tarasov and D. Bazin, Nucl. Instrum. Meth. Phys. Res. B 266, 4657 (2008)
[4] T.J. Mertzimekis, private comm. (2016)