LABORATÓRIO ABERTO DE FÍSICA NUCLEAR
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Proposal	N°
Title: **Study of two neutron transfer via the $^{19}F(\,^{6}He,\, \alpha + \gamma\,)\,^{21}F$ reaction**	
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Spokeperson: Juan Zamora (IFUSP)	e-mail: cardona@if.usp.br
Telephone: (11) 993048970	Skype:
Number of days for experiment:	**17**
Period planned for the experiment (are the setup ready for beam time?): 2019. New setup will need to be tested	

Technical information

Ion source			Accelerator			Experimental Area	
Beam	Cathode	$I_{mínima}$	V_{min}	V_{max}	Bunched beam?	Beam line	Target
7Li		500 nA	6.0	8.0	No	45B	9Be

Other relevant/needed information:

Study of two neutron transfer via the $^{19}\mathrm{F}(^{6}\mathrm{He}, \alpha + \gamma)^{21}\mathrm{F}$ reaction

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I. PHYSICS JUSTIFICATION

Pairing correlation in nuclei play a fundamental role in describing properties as the nuclear masses, binding energy and other quantities that depend on the low energy microscopic structure of the nucleus [1]. Pairing is also essential to understand the exotic structures that exhibit the nuclei far from stability, for instance a two neutron halo configuration. Although the importance of pairing for describing nuclear phenomena is well accepted, the reaction probes used to measure pairing are still poorly understood. Two nucleon transfer reaction is an usual probe to study pairing effects. However, the description of the reaction mechanism associated with the transfer of a pair of particles in heavy-ion reactions has always been a rather complex problem. Usually, (t,p) or (p,t) reactions are used to investigate two-neutron correlation [2, 3]. An advantage of using these probes is the possibility to study not only the ground state of the recoiling nucleus but also its excited states which are accessible through energy and angular momentum matching. For example in Ref. [4], low-lying states of ^{21}F were investigated via $(t,p+\gamma)$ reactions. Coincidence measurements of proton and gamma rays were used to identify several excited states populated through the two-neutron transfer reaction, as shown in Fig. 1. As the structure of the tritium nucleus is well established, reaction calculations can be relatively simple, but still the cross sections in these experiments require large normalization factors (between 2 and 3) to describe the experimental data [5]. Other possible probe that can be used to study two-neutron transfer is $(^6\text{He},\alpha)$. The struc-

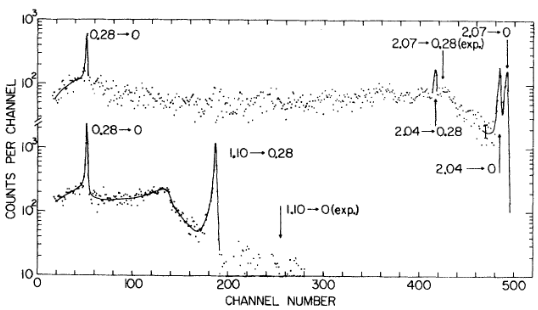

TABLE III. Energies and assignments of γ rays from $F^{19}(t,p\gamma)F^{21}$.

E_γ (keV)	Assignment (MeV)
279.92 ± 0.06	0.28 → 0
821.0 ± 2.0	1.10 → 0.28
1450.0 ± 2.0	1.73 → 0.28
1729.6 ± 1.0	1.73 → 0
1754.9 ± 0.7	1.75 → 0
1759.0 ± 1.5	2.04 → 0.28
2041.1 ± 2.0	2.04 → 0
2070.9 ± 2.0	2.07 → 0

FIG. 1. Experimental results from Ref. [4] of two neutron transfer using a $(t,p+\gamma)$ probe. Left: gamma-ray spectrum that shows the different states populated on ^{21}F. Right: List of gamma-ray peaks observed and its assignment to the states of ^{21}F

ture of ^{6}He makes it a very attractive candidate for two neutron transfer reactions because of its Borromean nature and its very low two-neutron separation energy ($S_{2n} = 0.97$ MeV). It has been observed in several experiments a large dominance of the two-neutron over one-neutron transfer cross section [6]. In a recent work in Sao Paulo, the reaction mechanism of two-neutron transfer with $^6\text{He} + {}^{120}\text{Sn}$ was investigated and analyzed using 4-body Continuum Discretized Coupled Channels (CDCC) calculations [7]. Also, studies with light targets have been used to understand the reaction mechanism of two neutron transfer with ^{6}He, for instance in Ref. [8]. Such experiment used a ^{12}C target and gamma-ray detectors to observe the excited states populated on ^{14}C. The angular distributions were gated on the gamma-ray peak corresponding to the known states of ^{14}C, as the 2_2^+ state at 8.32 MeV (see Fig.2). This method permits to clearly identify the two-

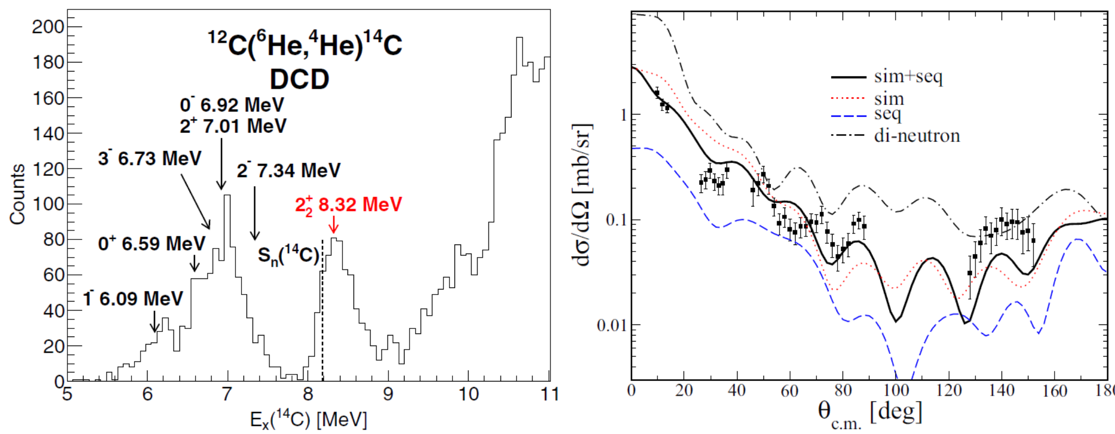

FIG. 2. Experimental results of two neutron transfer using a ^{6}He beam on a ^{12}C target [8]. Left: Excitation energy spectrum which shows several states populated in ^{14}C. Right: Angular distribution gated on the 2_2^+ state at 8.32 MeV.

neutron transfer from other reaction channels like the breakup. The experimental data 30 MeV was successfully described by assuming a realistic three-body structure for ^{6}He. However, this model failed to describe experimental data at 18 MeV. Therefore, it might be very interesting to investigate this reaction mechanism also with a light target (due to the small Coulomb barrier) and at similar energies. ^{19}F is a very good candidate to study the two-neutron transfer mechanism with ^{6}He. Comparison with results using the (t, p) probe [4] can help to understand in better detail dynamic effects of the reaction.

II. GOALS OF THE PROPOSED EXPERIMENT

In the proposed experiment there are three main goals:

- To measure the elastic scattering angular distribution of ^{6}He on ^{19}F. This data is unpublished and of great importance to complement systematic studies elastic and total cross section of ^{6}He on several targets.

- To measure the two-neutron transfer cross section in the reaction $^{19}\mathrm{F}(^6\mathrm{He}, \alpha + \gamma)^{21}\mathrm{F}$. Coincidence with gamma rays will permit to gate on the excited states populated on ^{21}F, and at the same time, to select the α particles originating in the two neutron transfer reaction.

- To test the production of a tritium beam. Such beam can also be an interesting probe to measure two neutron transfer reactions.

III. EXPERIMENT DETAILS

A ^{6}He beam will be produced and selected in the RIBRAS system with an intensity of about 10^5 pps. Using the double solenoid configuration, the secondary beam will be focused on the large scattering chamber where a target and detector system are placed. The reaction target will be a foil of polytetrafluoroethylene ($(C_2F_4)_n$) which is also known as a Teflon. Runs with a pure carbon target will be needed for normalization and subtraction of the contaminants. The detector array will consist on several silicon detectors (covering angles from 20 up to 60 degrees) for detecting charged particles and several LYSO(Ce) crystals (surrounding the target) for gamma-ray measuring. This experiment will be a great opportunity to test and use large acceptance silicon detectors which were recently purchased in the laboratory. Also, the use of an array LYSO(Ce) crystals to achieve gamma-particle measurements can bring new opportunities for studies with unstable beams delivered by RIBRAS.

The elastic scattering cross section at 20 degrees is estimated to be around 100 mb/sr and at 60 degrees decreases up to 2 mb/sr. Assuming a beam intensity of 10^5 pps and a target of 30 mg/cm^2, the expected count rate is 26 counts/h for the most backward silicon detectors. The two-neutron transfer cross section is is smaller and is assumed to have a value of about 1 mb/sr at 20 degrees, what can bring to a count rate of about 747 counts/day. But as one of the goals of this experiment is to make coincidence with gamma rays, such count rate has to be multiplied by the acceptance and efficiency of the LYSO(Ce) scintillators. This can have a reduction effect in the cont rate by roughly a factor 100.

In total we request for **17 days**: **2 days** for setting and calibrating our setup, **12 days** of beam on target and **3 days** for performing production test of a triton beam.

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