



### LERHI / NUC-RIA Activity Report

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ENSAR	

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Braga, Jornadas LIP 2020

February 15th, 2020

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**LERHI / NUC-RIA Activity Report** 

## Outline







Production of relativistic exotic beams never studied before

## R<sup>3</sup>B (a) FAIR

### **R**eactions with **R**elativistic **R**adioactive **B**eams



## **Towards Phase-0**

### First experiments in 2020



### **CAVE** is closed! Ready for first real **EXPERIMENT**!!!!

# **CALIFA Benchmark** (a) Lisbon



to produce γ > 10 MeV to challenge CALIFA barrel segments

Q-value: 11.59 MeV

# Nuclear reaction line @ tandem accelerator LATR-CTN



More Information under http://www.ctn.tecnico.ulisboa.pt

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# **CALIFA Benchmark** (a) Lisbon





# **Calorimetric response**



## **INVERSE-ALPHA**

 Sensitivity studies of *p*-process nucleosynthesis point out the strong dependence of the α-nuclear potential in the production of heavy *p*-nuclei



W. J. Rapp et al., Astrophys. J 653, 474 (2006)

## **INVERSE-ALPHA**

### Novel Helium Targets developed at Seville



**Development of He solid targets for nuclear reaction experiments** 

	GODINHO et al. (MS)	Vanderbist et al. (Ionic Implant.)	Raabe et al. (Ionic Implant.)	Ujic et al. (Ionic Implant.)
Metal (10 <sup>15</sup> at/cm <sup>2</sup> )	9250 (Si)	1200 (Al)	4200 (AI)	1200 (Al)
He (10 <sup>15</sup> at/cm <sup>2</sup> )	4060	275	270	130
O (10 <sup>15</sup> at/cm <sup>2</sup> )	700	60	100	??





RBS spectrum of Si:He target using 2,0 MeV protons and 165° scattering angle



SEM corss section of the Si:He target

### Adopted from F. J. Ferrer, Univ. Seville



## **INVERSE-ALPHA**

### **Proposal** lead by **LIP**, approved with **highest priority**!



# **PIGE Studies:** stable Cl isotopes



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# PIGE Studies: ${}^{35}Cl(p,p'\gamma_{1-0}){}^{35}Cl$



## **PIGE Studies: Resonance Pix**



### Activities



### **INVERSE-ALPHA**



#### **INVERSE-ALPHA**:

A new approach to measure the elastic scattering of  $\alpha$  particles in inverse kinematics at energies around the Coulomb Barrier for the astrophysical p-process







### **R3B** Fibers



### Tracker Systems Based on Scintillating Fibers

#### INTRODUCTION

Nuclear reactions are a powerful tool to study and understand the fundamental properties of nuclei. This is achieved with nuclear and particle detectors. The aim of this work, under the scope of the R3B experiment (Reactions with Relativistic Radioactive Beams), is to investigate

the response, performance and properties of scintillating fibers used as tracker detection systems for heavy ions at relativistic energies.

#### FAIR /R<sup>3</sup>B

The Facility for Antiproton and Ion Research (FAIR) laboratory is a scientific research facility located in Darmstadt, Germany, visible in fig. 1 It combines a linear accelerator and a synchrotron to accelerate nuclei to up to 0.9c that pass through the Super Fragment Separator (FRS) allowing the execution of experiments with new and extremely rare isotopes [1].



RB

SCINTILLATING FIBRE DETECTOR Charged particles deposit their energy in the fiber optic creating a scintillation. These photons travel through the fiber optic to a photodetector to be amplified and converted to an electric signal

that can be analyzed.

- Dopant material with a refractive index 1.59;
- refractive index.

The usage of aluminum coatings applied on the top end of fibers is known to increase the light collection by 75% [4] and when applied along the fiber length to reduce the cross-talk between

Cladding Thickness: T= 2% of S Numerical Aperture: NA+0.55 Trapping Efficiency: 4.2% Cladding Thickness: T= 2% of D Numerical Aperture: NA=0.55 Trapping Efficiency: 3.1% Fig. 3- Schematic view of fibres circular and square [3] OBJECTIVES This work aims to study several features related to the construction of scintillating fiber trackers. This will be accomplished by developing simulations with GEANT4 that will be validated in the LOMaC's laboratory (fig. 4) as well using the

- currently R<sup>3</sup>B simulation: Optical characteristics of scintillating optical fibers;
- Dimensions and geometry effects resulting from cross-section variation and shape (circular vs square); Effect of coating (aluminum) on the response characteristics of the fiber tracker





REFERENCES Research at GSI – An Introduction. URL: https: research\_an\_overview.htm (visited on 11/24/2019). research\_an\_overview.ntm (visited on as/ewy.existy). [2] Besearch at GSI – A next generation experimental setup for studies of Reactions wi Relativistic Radioactive Beams. URL: https://www.gsi.de/work/forschung/nustarenn Marketarena/Sectore/Se Kuraray - Plastic scintillating fibers (PSF). URL: isited on 12/19/2019). (4) JG Saraka et al. "The aluminization of 600 k WLS fibers for the TileCal/ATLAS/LHC". In: IEEE Transactions on Nuclear Science 51.3 (2004), pp. 1235–1241.

[5] RC Ruchti. "The use of scintillating fibers for charged-particle tracking". In: Annual Review of Nuclear and Particle Science 46.1 (1996), pp. 281–319.



### $^{118}$ Sn(p,g) $^{119}$ Sb

Determination of  ${}^{118}$ Sn $(p,\gamma)$  ${}^{119}$ Sb cross-section at astrophysical energies from X-ray emission yields



#### Manuel Xarepe, Daniel Galaviz, Jorge Sampaio

ich combined with Eq. (2), can be used t culate the cross section

Image taken from [6]

It is impossible to use this method if the clei only decay by electron capture with

neasure the decay of the X-rays that mitted in cascade after the electron of

N. Özkan et al., Nucl. Phys. A 710(3-4):469-485

2] J.P. Desclaux, Comput. Phys. Comm

5] G.G. Kiss et al., Physics Letters B 695(5):419

Gy Gyürky The European Physical Journal A 55(3):41 2019

9(1):31-45 (1975)

423 (2011)

Both the irradiation and acquisitie pend on how long is the half-life;

Introduction		119S	o decay si	cheme	
stellar synthesis of elements heavier than Fe is explained by slow (s) and rapid (r) neutronly ures in explosive events (e.g. supernovae and kilonovae). About 35 proton-rich naturally pring isotopes between Se and Hg can not be produced via $\beta^{-}$ decay, which means they can	Elec	Electron canture and $\gamma$ -emission decay			
be produced solely by neutron capture processes. The reaction network for the production of sclei combines $(\gamma, n)$ and $(p, \gamma)$ reactions on preexisting s- and r-process seed nuclei.					23.86eV
iew of the huge number of reactions involved, stellar networks will always have to rely on s-sections obtained with theoretical models. It is of utmost importance to validate these models				-12-	n <sub>69</sub>
a grid of experimental cross-sections spread over the entire reaction network. Such data are	K-lii	ne X-ray e	nissions		
ial since the calculated cross-sections exhibit uncertainties of several hundred percent even for	X-13	uy Energy [keV]	Relative X-ray i	ntensity per	decay [%]
le isotopes.	ka;	25.044	2	$0.0 \pm 0.5$	
		05.071		301.05	

n this work, the Activation Method is used to measure for the first time o in p-process chain – the radiative proton capture reaction  $^{118}Sn(p,\gamma)^{119}Sb$ . The  $\gamma$ -emission associated to the electron capture to the excited state of  $^{119}Sb$  will be used to validate the method.

Bending

rget irradiation will be made at CTN/IST with a 3 MV Tandem Accelerator. The target wi made by evaporating hyperpure metallic <sup>118</sup>Sn onto a thick aluminium foil. A key paramete e standard method used for cross-section assurements is the Activation Method [1 e vaporation is the surface density of the target. This will be measurements is the Activation Method [1, 5, 4]. By irradiating the target, in most cases, radioactive nuclei are created, and even though they are trapped in the target, their decay radi-ation has enough kinetic energy to escape. By measuring these particles it is possible to calcu-late the number of produced muclet,  $N_D$ , at the end of the irradiation, see Eq. (1) therford backscattering technique. ie relevant energy range between 3 and 4 MeV will be measured corresponding to stellar temp

ares of 2.5 GK. Due to the long half-life of  $^{119}$ Sb ( $t_{1/2} = 38.2$  hours), the irradiation time will ne acceed two half-lifes. Special care will be taken to keep a well known constant flux,  $\phi_{b}$ . e of the Tandem accelerator at CTN/IST

 $N_{decay} = N_D \cdot e^{-\lambda t_w} \cdot (1 - e^{-\lambda t_s}),$  (1)

The X-ray en The X-ray emission spectra will be acquired using a the XR-100SDD (Silicon Drift Detector) from mptek, which has a 125 eV FWHM Resolution at 5.9 keV. The energy calibration and energy ndence of the ion in the region of interest will be determined using known X-ray emis

#### Simulations of the emission spectra

fonte Carlo simulations of the experimental setup will be done to determine contributions of th tup geometry to the overall uncertainty and also to obtain the efficiency of the detector. The mulations will be done in Geant4, which is the state of the art for simulation of particle interactic with matter

ince the energy of the  $\gamma$  emission is very close to the K $\alpha$  emission of <sup>119</sup>Sb, we will carry ou Since the energy of the  $\gamma$  emission is very close to the K\alpha emission of <sup>145</sup>Nb, we will carry out simulation of the measured X-ray spectrum in order to accurately decovariate the two lines. This simulation will use as an input the spectrum of X-ray emission lines calculated using the state-of-bact relativistic atomic structure code. For this all dipolar andiative transitions between one-blue K-abell configurations and all final configurations is the relevant energy range (20-30 keV) will be accluated with the MCDFGME code [2, 3]. was proposed by G.G.Kiss and his team [5]

Data analysis
A Root-based algorithm is being developed to fit the experimental spectra and determine the pereas. From the peak area $A$ , the number of decays, $N_{decay}$ can be calculated using, Eq. 1
$N_{decay} = \frac{A - A_{bckgnd}}{n \cdot \epsilon}$ ,

here  $\epsilon$  is the detector efficiency and  $\epsilon$  the relative intensity of the decay. Fitting Eq. (1) to the d<sub>dccay</sub> values as a function time, we obtain the fit parameter N<sub>D</sub>. From this we get the cross-section , using Eq. (2). P. Indelicato, Phys. Rev. A 51:1132–1145 (1995) Michael A Famiano, Nuclear Physics A 802(1-4):26–44 (2008)

> CSMPETE 2020 FCT Pundação para a Ciência e a Tecnologia

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Plastic scintillating fibers characteristics (fig. 3): Emission of blue light [3]:

Scintillating core made of polystyrene;

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Multiple thin cladding layers made of polymer with a smaller
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fibers [5].



# Past joint efforts and future perspectives (Phase-0 @ FAIR)

### **X** Importance of Alpha potentials



# NUC-RIA @ LERHI

### Low Energy Reactions with Hadrons and Ions



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