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Post-stripper study for the (^{20}Ne, ^{20}O) double charge exchange reaction at zero degrees with the MAGNEX spectrometer

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Abstract. A study of different post-stripper materials for the (^{20}Ne, ^{20}O) double charge exchange and (^{20}Ne, ^{20}F) single charge exchange reactions at zero degrees using the MAGNEX spectrometer at 22 and 15 AMeV is presented. All these experiments belongs to the experimental campaign planned in the NUMEN project (NUclear Matrix Elements for Neutrinoless double beta decay).

1. Introduction

Recently, some experiments have been performed by the NUMEN Collaboration [1-4] at INFN - LNS to study the ^{116}Cd(^{20}Ne, ^{20}O)^{116}Sn and ^{130}Te(^{20}Ne, ^{20}O)^{130}Xe double charge exchange reactions together with the competing processes at zero degrees using the MAGNEX spectrometer [5-7].
In this kind of experiment with ^{20}Ne^{10+} beam, it is necessary to take into account the abundance of the beam components characterized by lower charge states (^{20}Ne^{9+} and ^{20}Ne^{8+}) produced by the interaction between the ^{20}Ne^{10+} incident beam and the target material. These components have in fact a magnetic

rigidity that is similar to the ejectiles of interest $^{20}F^{9+}$ and $^{20}O^{8+}$ for single charge exchange and double charge exchange reaction, respectively. Consequently, they enter in the focal plane detector acceptance, generating a large background that requires the limitation of the beam intensity.

For this reason, a system of shields upstream of the focal plane detector entrance was placed to stop such undesired background. However, due to the proximity of the $^{20}Ne^{9+}$ to $^{20}F^{9+}$ and $^{20}Ne^{8+}$ to $^{20}O^{8+}$ in the focal plane, the shields solution allows only partially the background reduction.

The horizontal angles θ_{FOC} versus the horizontal positions X_{FOC} measured at the focal plane are shown in Figure 1. Black points correspond to experimental data for the ^{20}Ne + ^{116}Cd reaction at 15 AMeV taken with the shield solutions and with MAGNEX at magnetic rigidity Bρ = 1.3764 Tm. The various colors points represent simulations [8-10] (same ^{20}Ne incident energy and MAGNEX Bρ) of different charge states of the ejectiles emerging from the following reactions:

- $^{116}Cd(^{20}Ne,^{18}O^{8+})^{118}Sn$ two-proton transfer
- $^{116}Cd(^{20}Ne,^{20}O^{8+})^{116}Sn$ double charge exchange reaction
- $^{116}Cd(^{20}Ne,^{18}F^{8+})^{118}In$ deuteron transfer
- $^{116}Cd(^{20}Ne,^{18}F^{9+})^{118}In$ deuteron transfer
- $^{116}Cd(^{20}Ne,^{19}F^{8+})^{117}In$ one-proton transfer
- $^{116}Cd(^{20}Ne,^{19}F^{9+})^{117}In$ one-proton transfer
- $^{116}Cd(^{20}Ne,^{20}F^{8+})^{116}In$ single charge exchange
- $^{116}Cd(^{20}Ne,^{20}F^{9+})^{116}In$ single charge exchange
- $^{116}Cd(^{20}Ne,^{20}Ne^{9+})^{116}Cd$ elastic
- $^{116}Cd(^{20}Ne,^{20}Ne^{8+})^{116}Cd$ elastic
- $^{116}Cd(^{20}Ne,^{21}Ne^{9+})^{115}Cd$ one-neutron transfer
- $^{116}Cd(^{20}Ne,^{22}Ne^{8+})^{114}Cd$ two-neutron transfer
- $^{116}Cd(^{20}Ne,^{22}Ne^{9+})^{114}Cd$ two-neutron transfer.

Together with the shields solution, the use of post-stripper material placed behind the reaction target was taken into account in order to minimize the amount of residual $^{20}Ne^{9+}$ and $^{20}Ne^{8+}$ beams downstream of the ^{116}Cd target.

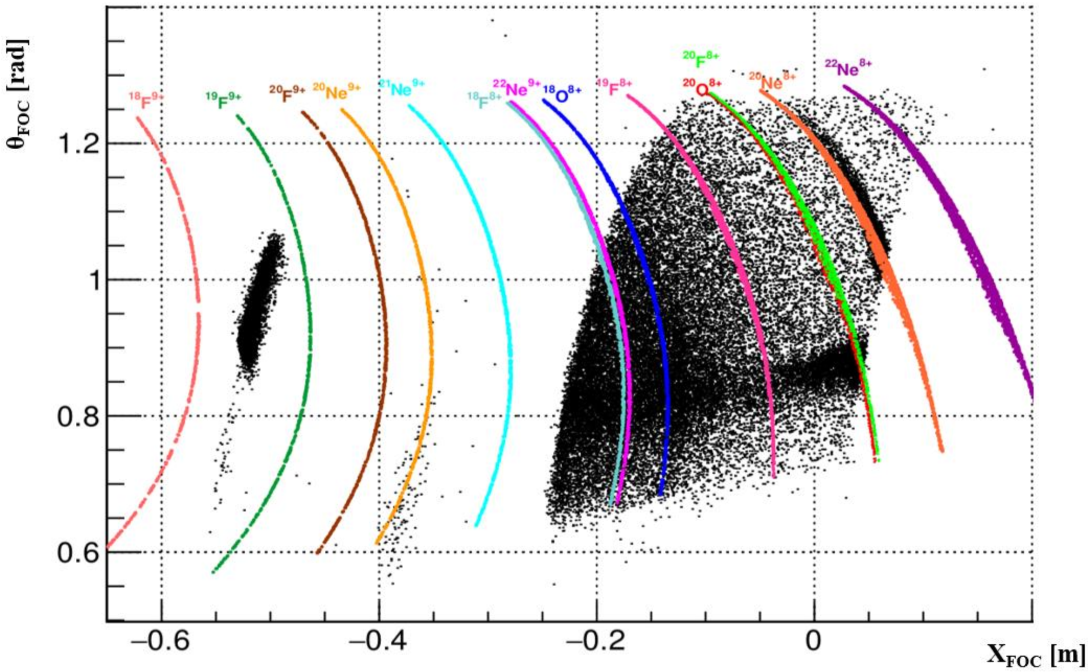

Figure 1. Comparison between data taken with the shield solution (black points) and simulations (various colors) of different ejectiles at the MAGNEX Focal Plane Detector (see text).

2. Experimental setup and results

A first test was realized concerning the study of different post-stripper materials using a beam of $^{20}Ne^{10+}$ at 22 AMeV incident energy extracted by the K800 Superconducting Cyclotron, bombarding a 77 ± 8 μg/cm² C foil positioned downstream of the 1080 ± 110 μg/cm² ^{116}Cd target.
A second test was realized with a beam of $^{20}Ne^{10+}$ at 15 AMeV incident energy extracted by the K800 Superconducting Cyclotron, bombarding a 900 ± 50 μg/cm² ^{12}C target.
The outgoing ejectiles produced in the different reactions were momentum analyzed by the MAGNEX spectrometer and detected by the Focal Plane Detector FPD [11]. The total charge collected for each run was integrated by a Faraday cup, downstream of the target.
In both these experiments, in order to estimate the amounts of $^{20}Ne^{10+}$, $^{20}Ne^{9+}$ and $^{20}Ne^{8+}$ ions produced by the interaction between the $^{20}Ne^{10+}$ incident beam and the target material, three different runs have been performed (one for each different ^{20}Ne charge state).
The three corresponding elastic peaks were momentum selected changing time by time the magnetic rigidity of the spectrometer. After a data reduction phase, consisting in the particle identification [12], the number of ^{20}Ne ions were determined counting the events belonging to the elastic peaks 10^+, 9^+ and 8^+. These quantities were normalized for the efficiency of the spectrometer and for the charge collected by the Faraday cup for the each corresponding run. In this way it was possible to determine the relative ratios $^{20}Ne^{9+}/^{20}Ne^{10+}$ and $^{20}Ne^{8+}/^{20}Ne^{10+}$ that are shown in Table 1, for the target post-stripper configurations for 15 and 22 AMeV $^{20}Ne^{10+}$ beam incident energy. In the third and fourth row of Table 1 the values of the ratios measured experimentally and published in Ref. [13] are shown.
An estimation of the errors was also done. Considering a precision of about 10% in the total charge collected, the efficiency in data collected by the spectrometer, and the systematic errors, the calculated values are affected by an uncertainty of about ± 13%.
As one can see from Table 1, the calculated values for the ^{116}Cd – C are comparable with the ones in literature, even if it is good to remind that the values in Ref. [13] were determined bombarding a C foil with a 15 and 20 AMeV $^{20}Ne^{10+}$ beam incident energy.
The 900 μg/cm² C target gives worse results respect to the literature [13]. This is likely due to the thickness which is too high and it is not suitable for the post-stripper purpose.

Table 1. Comparison between the $^{20}Ne^{9+}/^{20}Ne^{10+}$ and $^{20}Ne^{8+}/^{20}Ne^{10+}$ ratios for a $^{20}Ne^{10+}$ incident beam at 15 and 22 AMeV obtained in the tests performed at LNS and ratio values published in Ref. [13].

Target – Stripper (μg/cm²)	$^{20}Ne^{8+}/^{20}Ne^{10+}$	$^{20}Ne^{9+}/^{20}Ne^{10+}$	Energy (AMeV)
^{116}Cd (1080) – C (70)	4.09 E-06	3.84 E-03	22
C (900)	9.94 E-05	1.58 E-02	15
^{12}C Foil Ref.[5]	2.66 E-06	3.26 E-03	20
^{12}C Foil Ref.[5]	2.00 E-05	8.90 E-03	15

More recently, a systematic survey on different post-stripper materials was realized using a beam of $^{20}Ne^{10+}$ at 15 AMeV incident energy extracted by the K800 Superconducting Cyclotron, bombarding different post-stripper foils (Al, Be, C, CH_2, $C_{10}H_8O_4$, LiF, polypropylene, and others) with different thicknesses positioned downstream of some targets (Au, Cd, Te).
For each configuration three runs were performed (one for each different ^{20}Ne charge state) in order to carry out the above described procedure concerning the calculation of the charge states ratios.
The data analysis for these data are presently in progress.
Very preliminary results suggest that the best stripping ratios are obtained for light and C-like materials compatibly with information present in literature [14].

In particular it seems very promising the use of polypropylene. However this material has proven to be useless because of its fragility when bombarded by $^{20}Ne^{10+}$ beam.
This aspect has to be better understood and will be better investigated in the next future.
Furthermore, experiment with other C-like material (i.e. graphite [15]), will be performed in next test runs.

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