# Quasi-Free Scattering of Relativistic Neutron-Deficient Carbon Isotopes*

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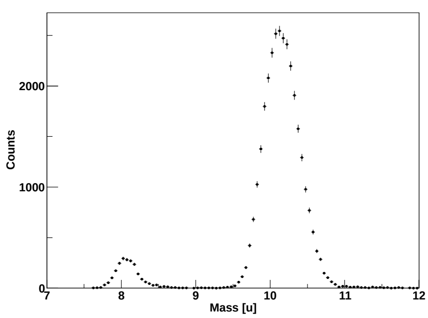
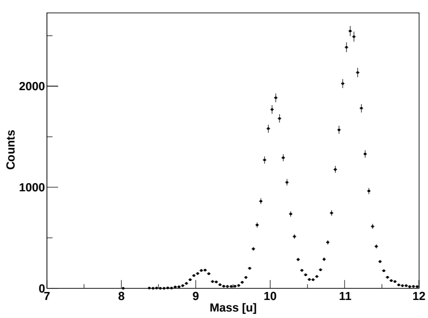
Single-nucleon knockout reactions and quasi-free scattering are valuable tools to determine single-particle properties of nuclei. The R$^3$B-collaboration conducted an experiment studying such reactions for light nuclei in a wide $A/Q$ range in August 2010 [1]. Among others, the neutron-deficient carbon isotopes $^{10}$C and $^{11}$C were measured. The study was aimed at a quantitative understanding of absolute spectroscopic factors that appear to be quenched for deeply bound nucleons [2].

A $^{40}$Ar primary beam was incident on a production target, and the selected reaction residues were then transported through the fragment separator FRS to the R$^3$B-LAND setup in Cave C. The incoming beam was identified using the time-of-flight between two scintillators, one at focus S8 of the FRS and one at the entrance of Cave C, and the energy loss in a PIN diode. The incoming angle of the beam was determined from the position on two silicon strip detectors in front of the target.




(a) Boron, $Z = 5$




(b) Carbon, $Z = 6$

Figure 1: Tracked masses of fragments coincident with a proton in the NaI array. The charge of the fragments was determined using the energy loss in the silicon strip detectors behind the target and in the time-of-flight wall.

The target area was surrounded by a NaI array used for $\gamma$ and proton detection and a box consisting of four silicon strip detectors. After passing through the ALADIN magnet, the outgoing fragments were identified and tracked using the position and energy information given by two additional silicon strip detectors, two fibre detectors, and a time-of-flight wall.

Figure 1 shows the result of this tracking. Plotted is the mass spectrum of the fragments in coincidence with a detected proton in the NaI array. By selecting $A = 10$ and requiring two proton hits in the NaI array, a preliminary cross section of 14(2) mb could be determined for the $^{11}$C(p,2p)$^{10}$B reaction at 340 MeV/nucl. incident energy.

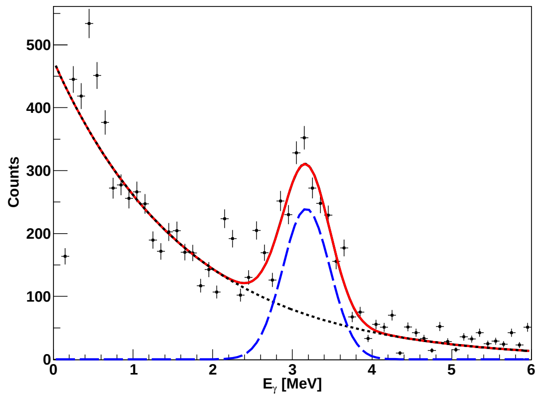



Figure 2: Gamma Spectrum measured in coincidence with the $^{11}$C(p,2p)$^{10}$B reaction. The fitted curve is a combination of a Gaussian and an exponential background.

In Figure 2 the $\gamma$-spectrum as measured in coincidence with the $^{11}$C(p,pn)$^{10}$C reaction is shown. To obtain this spectrum, the spectrum measured by the NaI array with a carbon target was subtracted from the spectrum measured with a $CH_2$ target. The spectrum is fitted by a combination of a Gaussian and an exponential background. The single bound excited state of $^{10}$C can be identified very well. In the case of $^{10}$B several excited states contribute to the spectrum which makes the disentanglement of the $\gamma$-ray spectrum more difficult. This analysis is still in progress.

## References

[1] 'Direct Reactions of light exotic beams measured in complete kinematics at R3B', GSI Scientific Report 2010, p.166,

[2] A. Gade et al., Phys. Rev. C 77 (2008)

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