Probing Nuclear properties of Imbalanced Fermi Systems with Quasi-free Proton Knock-out Reactions

Sam Stevens, Jan Ryckebusch, Wim Cosyn, Andreas Waets

Research Goals

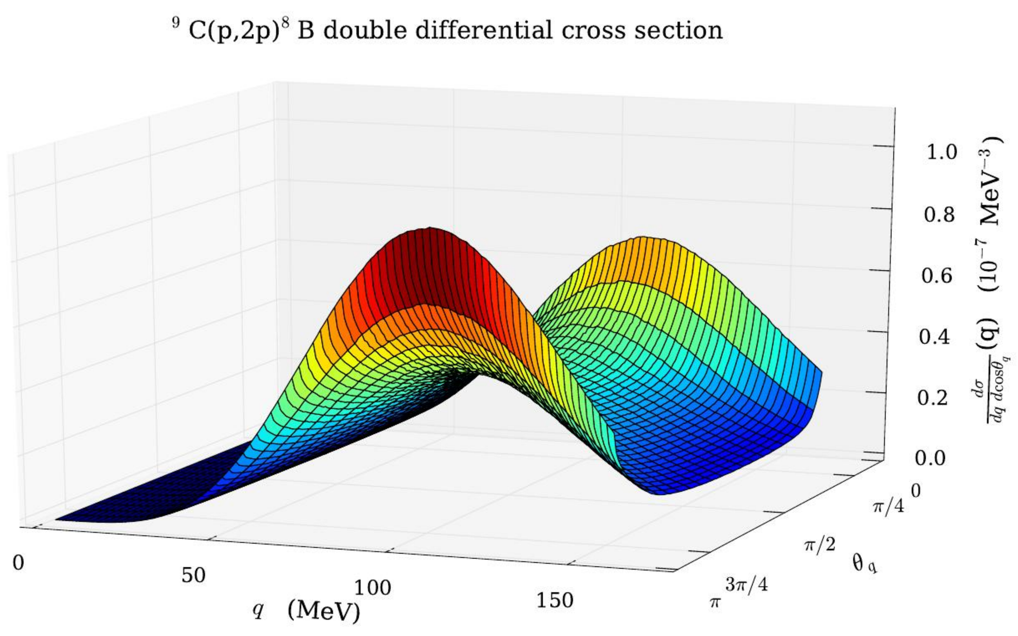
In order to gain a better understanding of asymmetric Fermi liquids, we investigate the mean-field properties of asymmetric nuclei. A great tool to probe these properties is offered by quasi-free knockout reactions in inverse kinematics.

We are developing a reaction model for quasi-free ^{A}X(p,pN)$^{A-1}$Y reactions with unstable nuclei. We wish to connect experimental data from (p, pN) measurements in inverse kinematics at radioactive-beam facilities [1], to the mean-field properties (spectroscopic factors and single-particle wave functions).

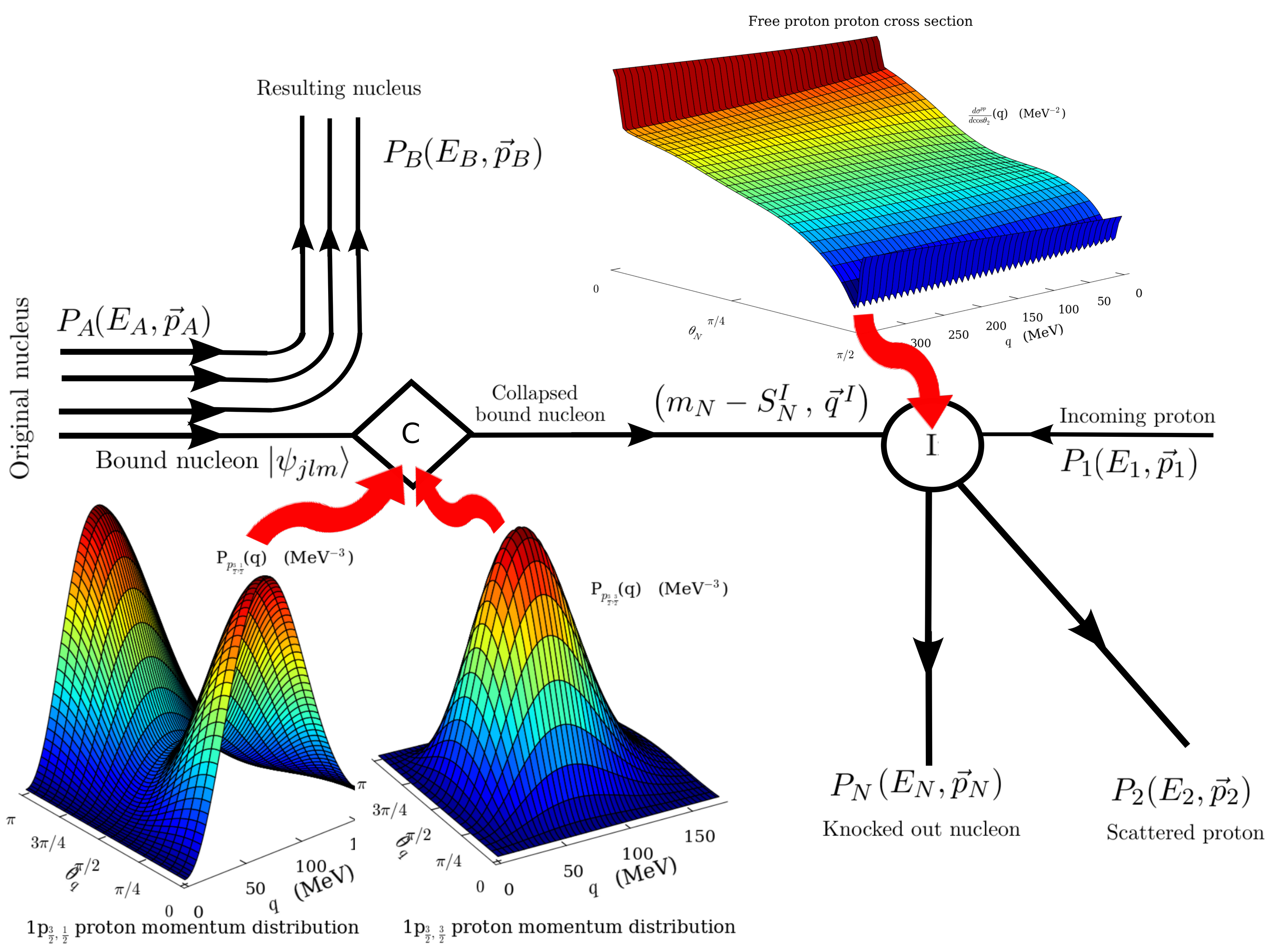
Model Overview

By adopting the spectator (SA) and impulse approximation (IA), cross sections for the ^{A}X(p,pN)$^{A-1}$Y reactions can be factorised, following the approach developed in Refs. [2] and [3].

The intranuclear attenuation of the impinging proton and the ejected nucleons (initial and final state interactions, IFSI) is accounted for by the Relativistic Multiple Scattering Glauber Approximation (RMSGA), which is a natural approximation at short nucleon wave lengths and does not require information about the nucleon-nucleus interaction. Charge exchange effects will be included in a semi-classical way.



The $^{A}X(p,pN)^{A-1}Y$ cross section



Adopting the SA, the remaining nucleus is not affected by the interaction between the proton and the struck nucleon and its only influence is phase space restriction. The struck bound nucleon "collapses" in a plane wave momentum eigenfunction (momentum measurement), with the single particle momentum distribution as the collapsing probability:

$$P(\vec{q}) = \sum_{m_s,m} \left| F^{m_s}_{Ejlm}(\vec{q}) \right|^2 = \sum_{m_s,m} \left| \frac{1}{(2\pi)^{3/2}} \int d\vec{r}\, e^{-i\vec{q}\cdot\vec{r}} \psi^{m_s}_{jlm}(\vec{r}) \right|^2$$

with the wave function $\psi_{Ejlm}(\vec{r})$ calculated in a mean field harmonic oscillator (MFHO) potential. The collapsed nucleon interacts "freely" with the impinging proton in one "hard" pN interaction process, introducing the free elastic nucleon-nucleon cross section $\frac{d^2\sigma}{d\Omega_2}$, modelled by inserting available elastic pp or pn cross section data. The intranuclear attenuation of the impinging proton and the ejected nucleons is accounted for by distorting the plane waves using the Relativistic Multiple Scattering Glauber Approximation:

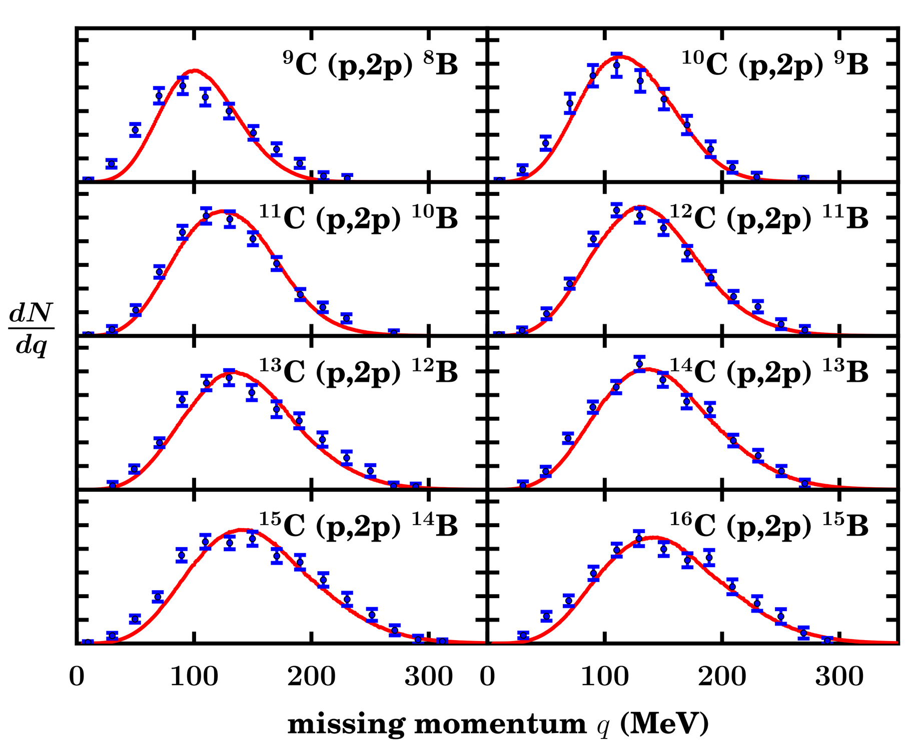
$$F^{DWIA}_{Ejlm,m_s}(\vec{q}) = \frac{1}{(2\pi)^{3/2}} \int d\vec{r}\; \widehat{S}^{RMSGA}_{IFSI}(\vec{r})\; e^{-i\vec{q}\cdot\vec{r}} \psi^{m_s}_{jlm}(\vec{r})$$

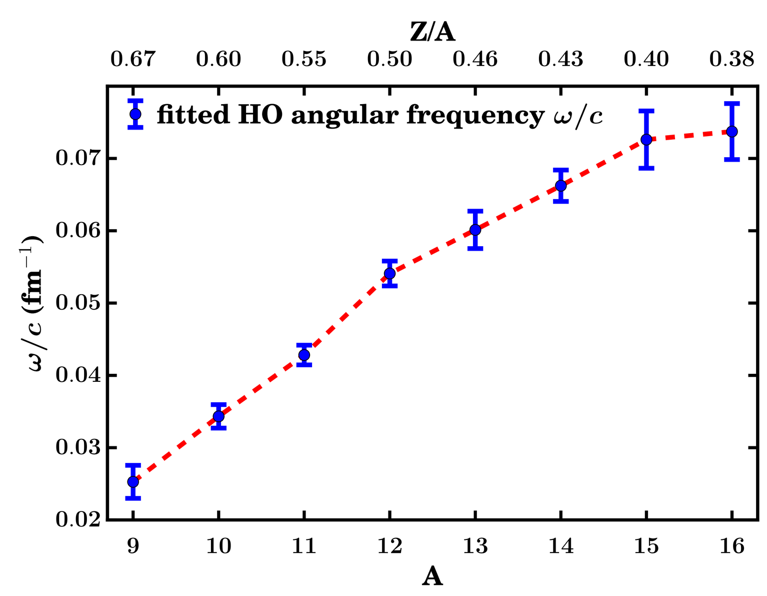
where the Glauber operator $\widehat{S}^{RMSGA}_{IFSI}(\vec{r})$ depends only on parameters that can be determined from elementary nucleon-nucleon scattering data.

$$\frac{d^5\sigma}{d^3\tilde{q}^I\, d\Omega^0_N}\left(d^3\tilde{q}^I, \Omega^0_N\right) = \frac{S(lj)}{2j+1} \frac{\sqrt{\lambda\left(s_f, m_p^2, m_q^2\right)}}{\sqrt{\lambda\left(s_i, m_p^2, M_A^2\right)}} \frac{m_A}{E^I_q} \sum_{m_s,m} \left| F^{DWIA}_{Ejlm,m_s}(\tilde{q}^I) \right|^2 \left(\frac{d^2\sigma^{free}_{(\tilde{p}^0_1;\tilde{q}^0 \to \tilde{p}^0_2;\tilde{p}^0_N)}}{d\Omega^0_N} \right)$$

Results for ^{A}C(p,2p)^{A-1}B [4]

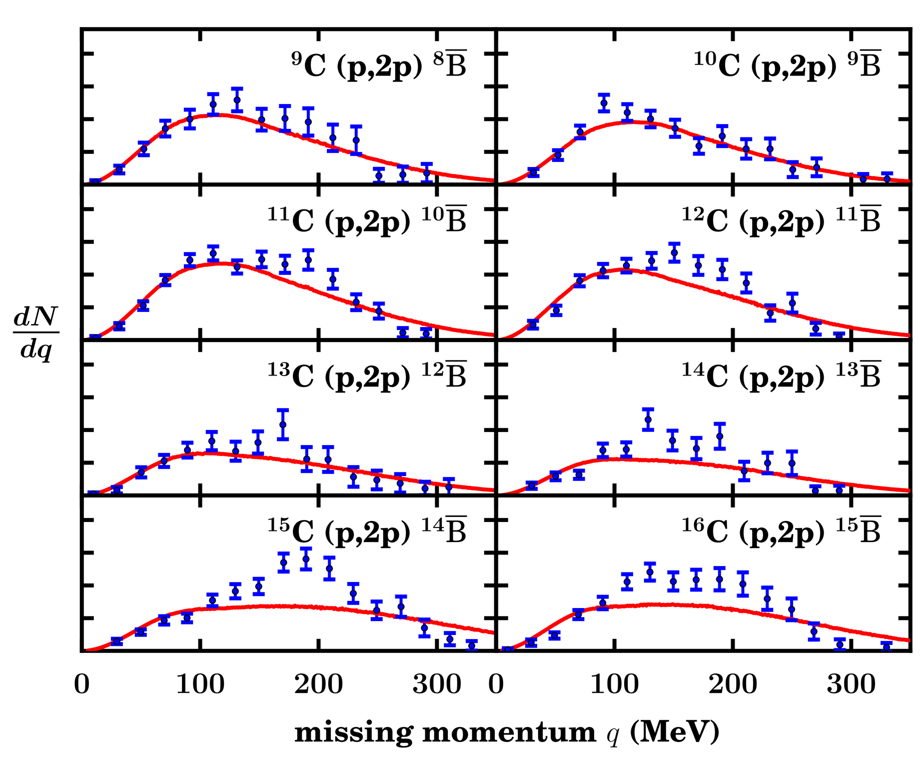
$\frac{3}{2}$ p-proton knockout

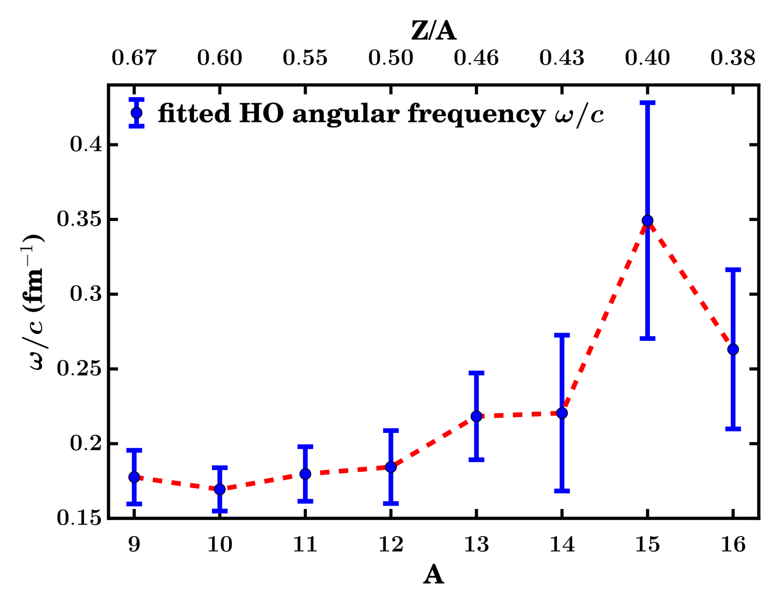




Results for ^{A}C(p,2p)$^{A-1}\overline{B}$ [4]

$\frac{1}{2}$ s-proton knockout





Outlook

Initial and final state interactions:
The implementation of the RMSGA in the model is ongoing. Results including initial and final state interaction will be available soon.

Charge exchange:
Charge exchange effects will be included in a semi-classical way, using the total neutron-proton cross section in the charge exchange range as an absorption coefficient.

Short Range Correlations:
Short range correlations (SRC) will be implemented using the model of Ref. [5]. This model corrects the mean field approximation for central, spin-isospin and tensor correlations.

Two-nucleon knockout:
Two-nucleon knockout will be implemented in a factorised way (factor out relative momentum part).

References

[1] T. Aumann, Prog. Part. Nucl. Phys. **59** (2007) 3.

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[3] B. Van Overmeire, W. Cosyn, P. Lava, and J. Ryckebusch, Phys. Rev. C **73** (2006) 064603.

[4] T. Kobayashi, K. Ozeki, K. Watanabe, Y. Matsuda, Y. Seki, T. Shinohara, T. Miki and Y. Naoi *et al.*, Nucl. Phys. A **805** (2008) 431.

[5] J. Ryckebusch, M. Vanhalst, W. Cosyn J. Phys. G **42** (2015) 055104.