The Nucleus as a Quantum Liquid

Jan Ryckebusch
Miami, February 15, 2007
What are short-range correlations (SRC) and how to quantify them?
Link with classical liquids, central and tensor correlations

How to extract information about SRC from $A(e,e'pp)$ and $A(e,e'pn)$ measurements?
Factorized and unfactorized models, relative and c.m. motion of dinucleons, ratio of $(e,e'pp)/(e,e'pn)$ strength

How to extract information about SRC from semi-exclusive $A(e,e'p)$?
Factorized and unfactorized models, ratio of $(e,e'pp)/(e,e'pn)/(e,e'p)$ strength
What are Correlations and how to quantify them?

✔ Time-honored method to quantify correlations in classical and quantum liquids: CORRELATION FUNCTIONS

✔ Correlation functions in classical liquids: Given that an object is at a position \( \vec{r}_1 \) what is the likelihood to find another object at position \( \vec{r}_2 \)?

✔ Usually, the correlation function depends on the relative coordinates between the two objects \( \vec{r} = | \vec{r}_1 - \vec{r}_2 | \)

✔ In nuclear systems: the correlation functions exhibit the full complexity of the nucleon-nucleon force (spin, isospin and tensor dependence)

✔ Short-range correlations (SRC): usually associated with so-called “central” correlations \( G( | \vec{r}_1 - \vec{r}_2 | ) \) (finite extension of the nucleons, strong repulsion at short internucleon distances, granularity of the nucleus)
Classical liquids
Correlation function for a typical liquid

Correlation function from MD simulation for Ar

Molecular-dynamics simulation of hard spheres interacting by means of a Lennard-Jones interaction. Or, solve

$$m \frac{d^2 \vec{r}_i}{dt^2} = \sum_{j \neq i=1}^{N} \vec{F}_{LJ} (\vec{r}_{ij}) ,$$

for $N$ of the order 1000.

When moving with a molecule through the liquid: decreased (increased) density at short (medium) intermolecular distances
Measuring correlation functions in classical liquids?

In classical liquids the correlation functions can be readily measured and exhibit the general structure predicted by theory!

X-rays at ESRF (Grenoble)

The Nucleus as a Quantum Liquid
Short-Range Structure of Nuclei

- **Long-range structure of nuclei** is reasonably well understood
  - Nuclear shell model
  - Collective model
  - Hadronic degrees of freedom, quasiparticles

- **Short-range structure of nuclei** is NOT so well understood
  - Hard repulsive part of the nucleon-nucleon force !!
  - Window on the quark-gluon degrees of freedom !!
  - Incompatible with IPM (Jastrow Correlations) !!
  - Room for “exotics” like 6q bags ??
  - Hadronic \((N, N^*, \pi, \rho, \ldots) \iff\) Partonic \((q, g)\) picture ??
Predictions for central nuclear correlation functions

- Calculations suggest hard radius 0.3-0.6 fm
- Universality in correlation functions ($A$-independent)

General features of central correlation function are not very different from classical liquid: When moving with a nucleon through the nucleus: decreased (increased) density at short (medium) internucleon distances
Size of density fluctuations in SR encounters?

- Dipole EM FF

\[
\left(1 + \frac{Q^2}{\Lambda^2}\right)^{-2}
\]

- Fourier transform related to charge density

\[
\rho_p(r) = \frac{\Lambda^3}{8\pi} \exp(-\Lambda r)
\]

\[
\sqrt{\langle r^2 \rangle_p} \approx 0.86 \text{ fm}
\]

- Hard radius of 0.3-0.6 fm:

\[
\frac{\rho_p(r)}{\rho_{NM}} \approx 1.5 - 4
\]

- But: \( g(r_{12}) \) suggests density increases of 10 – 20%
The nucleus: spin-dependent correlation functions

Variational calculations of the ground-state of $^{16}\text{O}$ by S. Pieper et al., PR C46 (1992) 1741 with the Argonne $v_{14}$ NN potential

nucl-th/0611037: New calculations with the AV18/UIX
Universality in the correlation functions


- $f_1: \hat{1}$,
- $f_2: \hat{1} (\vec{\tau}_1 \cdot \vec{\tau}_2)$,
- $f_3: (\vec{\sigma}_1 \cdot \vec{\sigma}_2)$,
- $f_4: (\vec{\sigma}_1 \cdot \vec{\sigma}_2) (\vec{\tau}_1 \cdot \vec{\tau}_2)$,
- $f_5: \hat{S}_{12}$,
- $f_6: \hat{S}_{12} (\vec{\tau}_1 \cdot \vec{\tau}_2)$,

- Most important ones: $f_1$ (central), $f_4$ (spin-isospin) and $f_6$ (tensor-isospin)

- Diamonds are nuclear-matter results: $^{12}\text{C}$ show anomalous behaviour
How to probe short-range correlations in nuclei ??

Hunt for two nucleons that are moving back-back with high relative momentum (CLOSE ENCOUNTERS OF NUCLEONS) ... triple-coincidence experiments of the $A(e,e'pp)$ and $A(e,e'pn)$ type.
The experimental reality ...

It is extremely challenging to find experimental evidence for the existence of SRC in nuclei!

$^{12}C(e, e'pp)$: Albert Zondervan (1992)
\[ A(e, e'pN) \iff \text{NN correlations} \]

The \( A(e,e'\text{NN}) \) cross section

\[
\frac{d^8\sigma}{dE_1d\Omega_1d\Omega_2d\epsilon'd\Omega'_e}(\bar{e}, e'N_1N_2) = \frac{1}{4(2\pi)^8} p_1p_2 E_1 E_2 f_{\text{rec}}^{-1} \sigma_M
\]

\[
\times \left[ v_T W_T + v_L W_L + v_{LT} W_{LT} + v_{TT} W_{TT} \right]
\]

\[
+ h \left[ v'_{LT} W'_{LT} + v'_{TT} W'_{TT} \right]
\]

- \( W' \)'s depend on \((q, \omega, p_1, p_2, \theta_1, \theta_2 \text{ and } \phi_1 - \phi_2)\) in an non-trivial manner

- \( W_{LT}, W_{TT} \) and \( W'_{LT} \) : extra (trivial) dependence on \( \Phi \equiv \frac{\phi_1 + \phi_2}{2} \) as \( \sin(2 \Phi) \) and \( \cos(2 \Phi) \)
Challenges for the theorists ...(I)

- Competing processes from pion-exchange and the intermediate creation of an excited nucleon $\Delta$

(a) [Diagram]
(b) [Diagram]
(c) [Diagram]
(d) [Diagram]
(e) [Diagram]
(f) [Diagram]
Challenges for the theorists ...(II)

How to extract physical information on SRC from the data and what are the proper variables?

**FACTORIZATION HELPS ...**

\[
\frac{d^8\sigma}{d\epsilon\, d\Omega\, d\Omega_1\, d\Omega_2\, dT_{p_2}}(e, e' N_1 N_2) = E_1 p_1 E_2 p_2 f_{rec}^{-1} \\
\times \sigma_{eN_1N_2}(k_+, k_-, q) F_{h_1, h_2}(P)
\]

<table>
<thead>
<tr>
<th>Relative momentum of the pair</th>
<th>[\vec{p}<em>{rel} = \vec{k}</em>\pm = \frac{\vec{p}_1 - \vec{p}_2}{2} \pm \frac{\vec{q}}{2}]</th>
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<tr>
<td>C.M. momentum of the pair</td>
<td>[\vec{P} = \vec{p}_1 + \vec{p}_2 - \vec{q}]</td>
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- \(F_{h_1, h_2}(P)\) : Probability to find a dinucleon with c.o.m. momentum \(P\)
- \(\sigma_{eN_1N_2}(k_+, k_-, q)\) : Probability to have an electromagnetic interaction with a dinucleon with relative momentum \(k_\pm\)
For $A(e, e'pp)$ an analytical expression for $\sigma_{eN_1N_2}(k_+, k_-, q) \leftrightarrow \sigma_{ep}^{(CCx)}$ in $A(e, e'p)$ was derived (including $\Delta$ currents, central and tensor correlations)

\[
\begin{align*}
    w_L &= 4e^2(2\pi)^6 (g(k_+) + g(k_-))^2 (G_E(q_\mu q^\mu))^2 + 40e^2(2\pi)^6 (f_\sigma(k_+) + f_\sigma(k_-))^2 (G_E(q_\mu q^\mu))^2 \\
    &\quad + 24e^2(2\pi)^6 (g(k_+) + g(k_-)) (f_\sigma(k_+) + f_\sigma(k_-)) (G_E(q_\mu q^\mu))^2 \\
    &\quad + \frac{16}{3} \sqrt{\frac{\pi}{5}} (2\pi)^6 (g(k_+) + g(k_-)) \left( f^0_t(-\vec{k}_+) + f^0_t(-\vec{k}_-) \right) (G_E(q_\mu q^\mu))^2 \\
    w_T &= \frac{\mu_p^2 e^2 q^2}{M_p^2} (2\pi)^6 (g(k_+) - g(k_-))^2 (G_E(q_\mu q^\mu))^2 \\
    &\quad + \frac{e^2}{2M_p^2} (2\pi)^6 [(k_1,x g(k_-) + k_2,x g(k_+))^2 + (k_1,y g(k_-) + k_2,y g(k_+))^2] (G_E(q_\mu q^\mu))^2 \\
    &\quad + \frac{256}{81} \left( \frac{f_\gamma N \Delta f_\pi N \Delta f_\pi NN}{m_\pi^3} \right)^2 G^2_\Delta (G_E(q_\mu q^\mu))^2 \left( \vec{q} \times \left( \frac{\vec{k}_1 - \vec{k}_2}{2} \right) \right)^2 \\
    &\quad \times \left[ k_+^2 \left( \frac{1}{k_+^2 + m_\pi^2} \right)^2 + k_-^2 \left( \frac{1}{k_-^2 + m_\pi^2} \right)^2 - 2\vec{k}_+ \cdot \vec{k}_- \frac{1}{k_+^2 + m_\pi^2} \frac{1}{k_-^2 + m_\pi^2} \right]
\end{align*}
\]
A(e, e'NN) : UNFACTORIZED APPROACHES

The $W$'s are determined by

$$m^f_i(\lambda = \pm 1, 0) = \langle \tilde{\Psi}_f(E_f) \mid J_{\pm 1,0}(\vec{q}) \mid \tilde{\Psi}_i(E_i) \rangle$$

**Final State**

$$|\Psi_f\rangle = |\Psi_f^{A-2}(E_x, J_R M_R); \vec{p}_1 m_{s_1} \vec{p}_2 m_{s_2} \rangle$$

**Correlated Wave Functions**

$$|\tilde{\Psi}\rangle \equiv \hat{G} |\Phi\rangle \quad (\Phi : \text{Slater determinant})$$

$$\hat{G} = S \left[ \prod_{i<j=1}^{A} \left( 1 - g_c(r_{ij}) + f_{t\tau}(r_{ij}) \tilde{S}_{ij} \vec{\tau}_i \cdot \vec{\tau}_j + f_{\sigma\tau}(r_{ij}) \tilde{\sigma}_i \tilde{\sigma}_j \vec{\tau}_i \cdot \vec{\tau}_j \right) \right]$$

$g_c, f_{t\tau}$ and $f_{\sigma\tau}$ : central, tensor and spin-isospin correlation function
\[
J_{\pm 1,0}(\vec{q}) = J_{\pm 1,0}^{[1]}(\vec{q}) + J_{\pm 1,0}^{[2]}(\vec{q})
\]

- \(J_{\pm 1,0}^{[1]}\): one-body current from the impulse approximation
- \(J_{\pm 1}^{[2]}\): two-body pion-exchange (MEC) and \(\Delta\) current
UNCORRELATED PART

\[ \langle \Phi_f(E_f) | J^{[2]}_{\mu}(q) | \Phi_i(E_i) \rangle \]

Two-body currents !!
\textit{(pion exchange and intermediate } \Delta \textit{ creation)}

CORRELATED PART

\[ \langle \Phi_f | \sum_{i<j=1}^A \left[ \left( J^{[1]}_{\mu}(i; q) + J^{[1]}_{\mu}(j; q) + J^{[2]}_{\mu}(i, j; q) \right) \right. \]
\[ \times \left. \left( -g_c(r_{ij}) + f_{t\tau}(r_{ij}) \mathbf{S}_{ij} \cdot \bar{\mathbf{r}}_i \bar{\mathbf{r}}_j + f_{\sigma\tau}(r_{ij}) \bar{\mathbf{S}}_i \bar{\mathbf{S}}_j \cdot \bar{\mathbf{r}}_i \bar{\mathbf{r}}_j \right) \right] + h.c. \right] | \Phi_i \rangle \]

Adopted strategy :
“extract” correlation functions
from comparing model calculations with data
Models for exclusive \( A(\gamma^*, NN) \) \((A \geq 5)\)
(Pavia, Gent, Granada)

- spectator approximation
- cross sections can be calculated for each individual state in the A-2 system
- distorted wave description for the ejectiles

Gent:
- consistent shell-model description for the initial and final state:
  (orthogonality and anti-symmetry conditions are obeyed and \( A(e,e'pp) \) calculations are GAUGE INVARIANT)
- center-of-mass and relative motion of the pair is treated in its full complexity (no formal separation)

Pavia, Granada: optical potentials and Harmonic-Oscillator basis for bswf
What about the c.o.m. motion of dinucleons (I)?

$^{12}\text{C}(e, e'pp) \@ \text{MAMI (Mainz)}$ (Physics Letters B 421 (1998) 71.)

Up to $P = 0.5 \text{ GeV}$ c.o.m. motion in $^{12}\text{C}$ is mean-field like!
What about the c.o.m. motion of dinucleons (II)?

Results from the MEA-AmPS accelerator ...

C.o.m. motion is mean-field like, no evidence that correlations affect this aspect of nuclear dynamics!
What about the c.o.m. motion of dinucleons (III)?

\[ ^{12}\text{C}(\gamma, pn) \] @ MAMI

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G. Orlandini, Effect of correlations upon the c.m. motion of nucleon pairs in \(^{16}\text{O}\)

\[ 16 \text{O}(e, e'pp) @ NIKHEF \]

\[ 16 \text{O}(e,e'pp)^{14}_C ; \omega=210 \text{ MeV} ; q=300 \text{ MeV/c} \]

- \( \Delta \)-current accounts for most of the measured \((e, e'pp)\) strength!
- The missing momentum \( P \) (\( = \text{c.o.m. momentum of the pair} \)) is a scaling variable!
- Indications for SRC at low \( P \) for the “ground-state” transition: two protons are subject to SRC if they are in \( {}^1S_0 \) relative state (Pauli principle!)

G. Onderwater \textit{et al.}, PRL \textbf{81} (1998) 2213
Accelerator probes the Private Lives of Nucleons: Census data can tell us much about how the average person lives, but they are inevitably miss the interplay between the individuals that ultimately makes our society tick. Nuclear physicists face similar difficulties in their attempts to fathom the crowds of nucleons that populate the atomic nucleus. The interaction of so many nucleons is immensely complicated, so physicists have had to contend themselves with models that average out nucleon behavior. Now, however, a team at NIKHEF has been able to coax pairs of protons out of the nucleus just at the moment when their interactions are at their most intense, revealing the intimate relationships how the nucleus works. ‘‘What we are trying to learn is how the fact that two nucleons are bound in the nucleus influences their mutual interaction, ‘‘ says NIKHEF’s Gerco Onderwater.
The quantum numbers of the initial and final state make sure that the proton pair is in a $^1S_0$ relative state.

Contribution from $\Delta$-current is short-dashed curve.

Two independent calculations (Pavia en Gent) confirm large contributions from SRC (long-dashed)!

R. Starink et al., PLB 474 (2000) 33
$^3\text{He}(e, e'pp)n \ @ \ NIKHEF$

$\iff$ Fadeev Calculations (Bochum group)

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1-Body (SRC) - - - 1-Body + $\pi\rho$
Follow-up experiments: $^{16}\text{O}(e, e'pp)^{14}\text{C} @ \text{MAINZ}$

Three-spectrometer setup and super-parallel kinematics:

Unprecedented resolution in a three-arm experiment! Can be exploited to pin down the quantum numbers of the pair!
Minimize the FSI (Fast-Backward nucleons)

Selected number of structure functions
High resolution $^{16}\text{O}(e, e'pp)^{14}\text{C}$

Ground-state transition: $0^+ \rightarrow 0^+$

Diproton: $^1S_0(\Lambda = 0)$ (lower $P$) and $^3P_1(\Lambda = 1)$ (higher $P$)

Central correlations bring about an $(e, e'pp)$ cross section of the order 0.5 picobarn!!
High resolution $^{16}\text{O}(e, e'pp)^{14}\text{C}$

Transition: $0^+ \rightarrow 2^+$
Diproton: $^1S_0(\Lambda = 2), ^3P_{1,2}(\Lambda = 1), ^1D_2(\Lambda = 0)$
High resolution $^{16}\text{O}(e,e'pp)^{14}\text{C}$

Transition: $0^+ \rightarrow 1^+$
Diproton: $^3P_{0,1,2}(\Lambda = 1)$
$^{16}\text{O}(e,e'pn)^{14}\text{N}$ and tensor correlations

$^{16}\text{O}(e,e'pn)^{14}\text{N}(1^+(T=0); E_x=3.95\text{ MeV})$

$^{16}\text{O}(e,e'pn)^{14}\text{N}(1^+;\text{g.s.})$

$\sigma \frac{d^4\Omega}{d\Omega_{el}d\Omega_{e'}d\Omega_p} (\text{pb}/\text{sr}^3\text{MeV}^2)$

$\theta_{e'}=18^\circ$

$e=855\text{ MeV} e'=640\text{ MeV}$

$W_L + W_T$

$W_{LT}$

$W'_{LT}$

$P_{t}$

$P'_{t}$

$P_n$

$P'_n$

$P_{p}$

$P'_{p}$

$P_{e}$

$P'_{e}$

missing momentum (MeV)

$^3S_1(\Lambda = 0, 2), ^3P_{0,1,2}(\Lambda = 1)$

$^1P_1(\Lambda = 1), ^3D_1(\Lambda = 0)$

$^3S_1(\Lambda = 0, 2), ^3P_{0,1,2}(\Lambda = 1)$

$^1P_1(\Lambda = 1), ^3D_1(\Lambda = 0)$

correlations affect $^3S_1$ proton-neutron pairs! Cross section is considerably larger than corresponding $A(e,e'pp)$ one!
A(e, e'pN) : what has and can maybe be learnt?

✔ A(e, e'pp) and A(γ, pp) : C.M. Motion of Nucleon Pairs is compatible with IPM up to $P \approx 0.5$ GeV/c

✔ A(e, e'pp) : Only the Relative Motion of $^1S_0$ diprotons is subject to large corrections from short-range correlations (hard back-to-back collisions with $p_{rel} >>$ and $P \approx 0$ ; “ridge” in the correlated spectral function $P(\vec{k}, E)$)

Further evidence for “hard” short-range correlations in nuclei !

✔ Stronger signals from TENSOR than from CENTRAL correlations ($A(e, e'pn)$ program with one of the HADRON detectors ...).

✔ At lower $Q^2$ : meson and isobar degrees of freedom are VERY competitive with SRC signals !
Separation of the individual states in the residual nucleus out of reach.

Unfactorized approaches are very costly with regard to computing time! A factorized approach is more suitable: the cross sections can be computed in a grid which covers the experimental acceptance.

In the factorized approach: the effect of FSI can be computed in a Glauber approach (work in progress).

Major problem: the background of meson-exchange and Δ-isobar currents (if there) is difficult (if not impossible) to compute: one reaches the scale of the hadronic form factors

$$\frac{1}{1 + \frac{Q^2}{\Lambda^2}} \quad (0.8 \leq \Lambda \leq 1.2 \text{ GeV}) ,$$

which are used in the two-body currents.
Semi-Exclusive $A(e, e'p) \iff$ NN correlations (I)

NIKHEF; $^{16}\text{O}(e, e'p)$; $\omega = 215 \text{ MeV}; q = 400 \text{ MeV}$

JLAB; $^{16}\text{O}(e, e'p)$; $\omega = 439 \text{ MeV}; q = 1000 \text{ MeV}$
Semi-Exclusive $A(e, e'p) \iff$ NN correlations (II)

**FACTORIZED APPROACH**

$$\frac{d^4\sigma}{dT_p d\Omega_p d\epsilon' d\Omega_{e'}}(e, e'p) = \frac{p_p E_p}{(2\pi)^3} \sigma_{ep} P_D(p_m, E_m),$$

- Spectral function $P(\vec{p}, E)$ is very well studied
- Correlated part has a weak $A$ dependence!
- $P^{(COR)}(\vec{p}, E)$ strength confined to $E = \frac{A-2}{A-1}\ell_2^{p^2}N + S_2N(A \rightarrow A-2)$
- **Ridge in the Spectral Function**
- Existence of “a” ridge: confirmed in high $E_m A(e, e'p)$ measurements @ Saclay, Amsterdam, Bonn, JLAB
- L/T separations suggest asymmetric behaviour (*excess transverse strength: two-body currents*)
$^{12}$C spectral function from semi-exclusive A(e, e'p)

\[ S(E_m, P_m) = \text{[MeV}^{-4} \text{sr}^{-1}] \]

Momentum distribution for $^{12}$C
parallel
perpendicular

\[ n(P_m) = \text{[fm}^{-3} \text{sr}^{-1}] \]

E97-006 (Hall-C), D. Rohe et al. PRL93 (2004) 182501
$^{12}\text{C}(e, e'p)$: LT separation

D. Dutta et al., PRC 61 (2000) 061602
A(e, e′p) @ HIGH E_m : UNFACTORIZED MODEL


✗ Include competing multi-nucleon mechanisms (MEC/IC)

✗ Unfactorized : “correlations” and “FSI” can act differently in 
  T and L responses

“Correlated partner” will be ejected from the residual A − 1 system

\[ | \Psi_f^{A-1}(E_{A-1}); \vec{p}_p m_s \rangle = | \Psi_f^{A-2}(E_{A-2}, J_{RM}); \vec{p}_N m_s; \vec{p}_p m_s \rangle , \]

\[
\frac{d^4\sigma}{dT_p d\Omega_p d\epsilon' d\Omega_{\epsilon'}}(e, e'p) = \sum_{N=p,n} \int d\Omega_N dE_{A-2} \frac{d^6\sigma}{dT_N d\Omega_N dT_p d\Omega_p d\epsilon' d\Omega_{\epsilon'}}(e, e'pN),
\]

Single-nucleon knockout from two-nucleon knockout
$^{16}\text{O}(e, e'p) : \omega = 0.3 \text{ and } q = 0.42 \text{ GeV/c}$

“central”

“central+tensor”

“central+tensor+MEC+IC”

“missing momentum”
Ridges (I): Where to look for Correlations?

“central”

“central + tensor”

“position of the ridge $\pm 40$ MeV”

Signatures of correlations: wide $(\theta_p, E_m)$ region along the ridge!!
Ridges (II): What about the two-body currents??

Signatures of two-body currents: wide \((\theta_p, E_m)\) region along the ridge!!
Dip region
\[ \epsilon = 0.575 \text{ GeV} \]
\[ \omega = 0.21 \text{ GeV} \]
\[ q = 0.3 \text{ GeV} \quad (\theta_e = 27^\circ) \]
\[ q = 0.4 \text{ GeV} \quad (\theta_e = 43.5^\circ) \]
$^{16}\text{O}(e,e'p) @ \text{AmPS}: \omega = 0.21$ and $q = 0.30, 0.40 \text{ GeV}$
Bjorken $x \approx 2 : \epsilon = 2.5 \text{ GeV}, \; Q^2 = 1.1 \text{ GeV}^2$

<table>
<thead>
<tr>
<th>“central”</th>
<th>“central+tensor”</th>
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<tbody>
<tr>
<td><img src="image1.png" alt="Graph" /></td>
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<td><img src="image5.png" alt="Graph" /></td>
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About ratio’s of $pp$ and $pn$ strength

NIKHEF: $^{12}\text{C}(e,e'p)$
$\omega = 212\text{ MeV}; q = 270\text{ MeV}$

dashed: $(e,e'pn)$
dotted: $(e,e'pp)$

Semi-exclusive $A(e, e'p)$

- Framework permitting a systematic investigation of the effects of central/ tensor/ spin-isospin NN correlations upon $A(e, e'NN)$ and semi-exclusive $A(e, e'p)$ reactions.
- Framework is unfactorized and allows to compute the competing effects of meson-exchange and $\Delta$-isobar currents.
- Tensor NN correlations produce stronger signals than the central correlations do.
- Also the unfactorized approach produces a broad “ridge” where the signals of NN correlations reside.
- For $x \leq 1$, MEC/IC are a STRONG source of semi-exclusive $A(e, e'p)$ strength (transverse strength !!) along the “ridge” !
- For $x \approx 2$ the effect of MEC/IC upon $A(e, e'p)$ is heavily suppressed and direct access to NN correlations seems possible.