Light-front Hamiltonian dynamics description of few-nucleon systems

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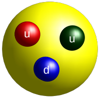
Based on:

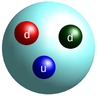
- R. Alessandro, A. Del Dotto, E. Pace, G. Perna, G. Salmè and S. Scopetta, *Light-Front Transverse Momentum Distributions for $\mathcal{J} = 1/2$ Hadronic Systems in Valence Approximation* **Phys.Rev.C 104 (2021) 6, 065204**
- A. Del Dotto, E. Pace, G. Salmè, and S. Scopetta, *Light-Front spin-dependent Spectral Function and Nucleon Momentum Distributions for a Three-Body System*, **Phys. Rev. C 95, 014001 (2017)**
- E. Pace, M. Rinaldi, G. Salmè, and S. Scopetta, *EMC effect, few-nucleon systems and Poincaré covariance*, **Phys. Scr. 95, 064008 (2020)**
- E. Pace, M. Rinaldi, G. Salmè, and S. Scopetta, *The European Muon Collaboration effect in Light-Front Hamiltonian Dynamics* **arXiv:2206.05485**
- MARATHON Coll. *Measurement of the Nucleon Fn2/Fp2 Structure Function Ratio by the Jefferson Lab MARATHON Tritium/Helium-3 Deep Inelastic Scattering Experiment*, **Phys. Rev. Lett. 128, 132003**

Outline

Motivations

- **Phenomenological**: a reliable flavor decomposition needs sound information on the neutron parton structure (PDFs, GPDs, TMDs, etc.).





Accurate and long-lasting experimental efforts in developing effective neutron targets to carefully investigate its electromagnetic responses. $^3\tilde{\mathrm{H}}\mathrm{e}$ is special:

$\Rightarrow$ **the polarized $^3\mathrm{He}$ target, 90% neutron target**

(e.g. H. Gao et al, PR12-09-014; J.P. Chen et al, PR12-11-007, @JLAB12)

- Due to high experimental energies (at JLAB and the planned EIC), the accurate theoretical description of a (polarized ^{3}He) has to be *relativistic*

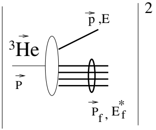
- **Theoretical**: to develop a Poincaré covariant description of three-body interacting systems! Bonus: i) Transverse-Momentum Distributions (**TMDs**), for addressing in a an unconventional way the dynamics of nuclear bound systems, and ii) a novel description of the nuclear part of the EMC effect.

On the theory side, we need

- to describe the dynamics, retaining as many general properties as possible;
- to validate sound procedures to *extract* the Nucleon (neutron) structure from experimental data (e.g. the nucleon effective polarizations)

In our approach, the key quantity is the *Spectral Function* (SF) (⇒ nucleon Green's function in the medium)

$$P_{\sigma'\sigma}(k, E) = -\frac{1}{\pi}\Im m\left\{\langle\Psi_{gr}|a^{\dagger}_{\mathbf{k},\sigma'}\ \frac{1}{E - H + i\epsilon}\ a_{\mathbf{k},\sigma}|\Psi_{gr}\rangle\right\}$$



with

$$H = \sum_{\alpha,\beta}\langle\alpha|H_1|\beta\rangle\ a^{\dagger}(\alpha)\ a(\beta) + \frac{1}{2}\sum_{\alpha,\beta,\gamma,\eta}\langle\alpha\gamma|H_2|\beta\eta\rangle\ a^{\dagger}(\alpha)\ a^{\dagger}(\gamma)a(\beta)\ a(\eta) + \ldots\ \ldots$$

Diagonal terms: probability distribution to find a constituent with σ, k and an energy E of the spectator system, that in turn yields the constituent missing energy.

Quite familiar in nuclear Physics. In hadron physics one introduces the LC correlator:

$$\Phi^{\tau}(x, y) = \langle\Psi_{gr}|\bar{\psi}^{\tau}(x)\mathcal{W}(\hat{n}\cdot A)\psi^{\tau}(y)|\Psi_{gr}\rangle$$

Our point: in valence approximation, $P_{\sigma'\sigma}(k, E)$ (given in a Poincaré covariant framework) and $\Phi^{\tau}(x, y)$ can be related.

[Alessandro, Del Dotto, Pace, Perna, Scopetta and GS, Phys.Rev.C 104 (2021) 6, 065204]

Constructing a rigorous Poincaré covariant approach

- The Standard Model of Few-Nucleon Systems, with nucleon and meson degrees of freedom within a non relativistic (NR) framework, has achieved high sophistication **[e.g. the NR $^3\mathrm{He}$ and $^3\mathrm{H}$ Spectral Functions in Kievsky, Pace, Salmè, Viviani PRC 56, 64 (1997)].**
- Once we are intrested to nucleons with large 4-momenta, at least, we should carefully treat the boosts of the nuclear states, $|\Psi_i\rangle$ and $|\Psi_f\rangle$!
- Clearly, the implementation of the full covariance wrt the Poincaré Group, $\mathcal{G}_P$, is highly desirable, for the self-consistency of the approach pursued.

Our definitely preferred **framework for embedding** the successful **NR** phenomenology:

★ Light-front Relativistic Hamiltonian Dynamics (RHD ⇒ fixed dof)

+

★ ★ Bakamjian-Thomas (BT) construction of the Poincaré generators for an interacting theory. They introduced the interaction through the the mass operator

The **Light-Front framework** has several advantages:

- 7 Kinematical generators: i) three LF boosts (In Instant Form they are dynamical!), ii) $\tilde{P} = (P^+ = P^0 + P^3, \mathbf{P}_\perp)$, iii) Rotation around the z-axis.
- The LF boosts have a subgroup structure: i) a simple treatment of the boost of the final state; ii) trivial separation of intrinsic and global motion, as in the NR case.
- $P^+ \geq 0 \longrightarrow$ meaningful Fock expansion, once massless constituents are absent
- No square root in the dynamical operator P^-, propagating the state in the LF-time.
- The infinite-momentum frame (IMF) description of DIS is easily included.

Drawback: the transverse LF-rotations are dynamical

But within the Bakamjian-Thomas (BT) construction of the generators in an interacting theory, one can construct an intrinsic angular momentum fully kinematical!

★ The Mass Operator, developed within a *non relativistic framework*, is fully acceptable for a BT construction of the Poincaré generators, i.e. fulfills the BT constraints★

Keister, Polyzou, Adv. Nucl. Phys. 20, 225 (1991)

To complete the matter: the spin

- Coupling spins and orbital angular momenta is naturally accomplished in the Instant Form (IF) of RHD (kinematical hyperplane t=0) through Clebsch-Gordan coefficients, since in IF the three rotation generators are kinematical.
- To embed the CG machinery in the LFHD one needs **unitary operators**, the so-called **Melosh** rotations that relate the LF spin wave function and the canonical one ($\equiv$ Instant Form RHD). For a particle of spin (1/2) with LF momentum $\tilde{\mathbf{k}} \equiv \{k^+, \vec{k}_\perp\}$

$$|\mathbf{k}; \frac{1}{2}, \sigma\rangle_{IF} = \sum_{\sigma'} D^{1/2}_{\sigma',\sigma}(R_M(\tilde{\mathbf{k}}))\ |\tilde{\mathbf{k}}; \frac{1}{2}, \sigma'\rangle_{LF}$$

where

$D^{1/2}_{\sigma',\sigma}(R_M(\tilde{\mathbf{k}}))$ is the standard Wigner function for the $\mathcal{J} = 1/2$ case ,
$R_M(\tilde{\mathbf{k}})$ is the Melosh rotation relating the intrinsic LF and canonical frames, reached through different boosts from a given frame where the particle is moving.

$$D^{1/2}[R_M(\tilde{\mathbf{k}})]_{\sigma'\sigma} = \chi^\dagger_{\sigma'}\ \frac{m + k^+ - \imath\boldsymbol{\sigma}\cdot(\hat{z}\times\mathbf{k}_\perp)}{\sqrt{(m+k^+)^2 + |\mathbf{k}_\perp|^2}}\ \chi_\sigma = \ _{LF}\langle\tilde{\mathbf{k}}; s\sigma'|\mathbf{k}; s\sigma\rangle_c$$

χ_σ is a two-dimensional spinor.

N.B. If $|\mathbf{k}_\perp| << k^+, m \longrightarrow D_{\sigma'\sigma} \simeq I_{\sigma'\sigma}$

The spin-dependent Light-Front spectral function

A. Del Dotto, E. Pace, G. Salmè, S. Scopetta, Physical Review C 95, 014001 (2017)

$$\mathcal{P}^{\tau}_{\sigma'\sigma}(\tilde{\boldsymbol{\kappa}}, \epsilon, S) = \rho(\epsilon) \sum_{JJ_z\alpha} \sum_{Tt} {}_{LF}\langle tT; \alpha, \epsilon; JJ_z; \tau\sigma', \tilde{\boldsymbol{\kappa}} | \Psi_{\mathcal{M}}; ST_z \rangle$$
$$\times \langle ST_z; \Psi_{\mathcal{M}} | \tilde{\boldsymbol{\kappa}}, \sigma\tau; JJ_z; \epsilon, \alpha; Tt \rangle_{LF}$$

- $Tr[\boldsymbol{\mathcal{P}}^{\tau}] \equiv$probab. distribution to find a fermionic constituent with a given isospin τ, $\tilde{\boldsymbol{\kappa}}$ and missing energy (fixed by ϵ), inside a bound system, $|\Psi_{\mathcal{M}}; ST_z\rangle$ with polarization vector $\boldsymbol{S}$.
- $|\tilde{\boldsymbol{\kappa}}, \sigma\tau; JJ_z; \epsilon, \alpha; T\tau\rangle_{LF} \equiv$ tensor product of a plane wave for particle 1 with LF momentum $\tilde{\boldsymbol{\kappa}}$ in the intrinsic reference frame of the $[1 + (23)]$ cluster $\times$ fully interacting state of the (23) pair of energy eigenvalue ϵ. It has eigenvalue

$$\mathcal{M}_0(1, 23) = \sqrt{m^2 + |\boldsymbol{\kappa}|^2} + E_S , \quad E_S = \sqrt{M_S^2 + |\boldsymbol{\kappa}|^2} , \qquad M_S = 2\sqrt{m^2 + m\epsilon}$$

and fulfills the macroscopic locality .

$$\tilde{\boldsymbol{\kappa}} = (\kappa^+ = \xi\ \mathcal{M}_0(1, 23), \mathbf{k}_\perp = \boldsymbol{\kappa}_\perp)$$

The LF overlaps for ^{3}He SF in terms of the IF ones are

$$\overbrace{\langle T\tau;\alpha,\epsilon;JJ_z;\tau_1\sigma,\tilde{\boldsymbol{\kappa}}}^{<\tilde{\boldsymbol{\kappa}}|\times 2N\ inter.\ state}|\overbrace{j,j_z;\epsilon_3;\frac{1}{2}T_z\rangle_{LF}}^{3N\ bound\ state} \swarrow = \sum_{\tau_2\tau_3}\int d\mathbf{k}_{23}\sum_{\sigma'_1} D^{\frac{1}{2}}[\mathcal{R}_M(\tilde{\mathbf{k}})]_{\sigma\sigma'_1}$$

$$\sqrt{(2\pi)^3\ 2E(\mathbf{k})}\sqrt{\frac{\kappa^+E_{23}}{k^+E_S}}\sum_{\sigma''_2,\sigma''_3}\sum_{\sigma'_2,\sigma'_3}\mathcal{D}_{\sigma''_2,\sigma'_2}(\tilde{\mathbf{k}}_{23},\tilde{\mathbf{k}}_2)\ \mathcal{D}_{\sigma''_3,\sigma'_3}(-\tilde{\mathbf{k}}_{23},\tilde{\mathbf{k}}_3)$$

$$\searrow\ {}_{IF}\langle T,\tau;\alpha,\epsilon;JJ_z|\mathbf{k}_{23},\sigma''_2,\sigma''_3;\tau_2,\tau_3\rangle\ \langle\sigma'_3,\sigma'_2,\sigma'_1;\tau_3,\tau_2,\tau_1;\mathbf{k}_{23},\mathbf{k}|j,j_z;\epsilon_3;\frac{1}{2}T_z\rangle_{IF} \swarrow$$

where the effect of boosts manifests itself in both the Jacobians and the combination

$$\mathcal{D}_{\sigma''_i,\sigma'_i}(\pm\tilde{\mathbf{k}}_{23},\tilde{\mathbf{k}}_i) = \sum_{\sigma_i} D^{\frac{1}{2}}[\mathcal{R}^\dagger_M(\pm\tilde{\mathbf{k}}_{23})]_{\sigma''_i\sigma_i}\ D^{\frac{1}{2}}[\mathcal{R}_M(\tilde{\mathbf{k}}_i)]_{\sigma_i\sigma'_i}$$

★ Using the Bakamjian-Thomas construction, one is allowed to approximate the momentum space wave functions for the 2- and 3-body systems in IF with the NR ones, →

$$\langle\quad\dots\quad|j,j_z;\epsilon_3;\frac{1}{2}T_z\rangle_{IF} = \langle\quad\dots\quad|j,j_z;\epsilon_3;\frac{1}{2}T_z\rangle_{NR}$$

While preserving the Poincaré covariance, one fully exploits the successful NR phenomenology.

A. Del Dotto et al , PRC 95, 014001 (2017).

LC Correlator and LF spin-dependent SF

In Relativistic Quantum-Field theory the non perturbative dynamics, involved in DIS processes, is described by the fermion correlator, that in terms of the LF coordinates reads **[e.g., Barone, Drago, Ratcliffe, Phys. Rep. 359, 1 (2002)]**

$$\Phi^{\tau}_{\alpha,\beta}(p,P,S) = \frac{1}{2}\int d\xi^- d\xi^+ d\boldsymbol{\xi}_T \; e^{ip\cdot\xi} \left\langle P,S,A|\bar{\psi}^{\tau}_{\beta}(0)\psi^{\tau}_{\alpha}(\xi)|A,S,P\right\rangle$$

where $|A,S,P\rangle$ is the A-particle bound state and $\psi^{\tau}_{\alpha}(\xi)$ the particle field (e.g. a nucleon of isospin τ in a nucleus, or in valence approximation a quark in a nucleon).

The particle contribution to the correlator in valence approximation, i.e. without antifermion contributions, is related to the LF spectral function by

$$\begin{aligned}\Phi^{\tau}(p,P,S) &= \frac{(\not{p}_{on} + m)}{2m}\,\Phi^{\tau}(p,P,S)\,\frac{(\not{p}_{on} + m)}{2m} = \ldots \\ &= \frac{2\pi\,(P^+)^2}{(p^+)^2\;4m}\,\frac{E_S}{\mathcal{M}_0[1,(23)]}\sum_{\sigma\sigma'} u_{\alpha}(\tilde{\mathbf{p}},\sigma')\,\mathcal{P}^{\tau}_{\mathcal{M},\sigma'\sigma}(\tilde{\boldsymbol{\kappa}},\epsilon,S)\,\bar{u}_{\beta}(\tilde{\mathbf{p}},\sigma)\end{aligned}$$

In deriving this expression it naturally appears the momentum $\tilde{\boldsymbol{\kappa}}$ in the intrinsic reference frame of the cluster [1,(23)], where particle 1 is free and the (23) pair is fully interacting.

The TMDs, that allow one to suitably decompose the fermion correlator, are obtained by means of traces of the LC correlator $\times$ combinations of Dirac structures and four-momenta at disposal, in turn, in valence approximation, using traces that involve the LF SF

Alessandro,Del Dotto, Pace, Perna, Salmè, Scopetta, Phys.Rev.C 104 (2021) 6, 065204

$$\mathrm{Tr}(\gamma^+\Phi^\tau) = D \; Tr\left[\hat{\boldsymbol{\mathcal{P}}}^\tau_{\mathcal{M}}(\tilde{\boldsymbol{\kappa}}, \epsilon, S)\right] \qquad D = \frac{(P^+)^2}{p^+}\;\frac{\pi}{m}\;\frac{E_S}{\mathcal{M}_0[1,(23)]}$$

$$\mathrm{Tr}(\gamma^+\gamma_5\;\Phi^\tau) = D \; Tr\left[\sigma_z\;\hat{\boldsymbol{\mathcal{P}}}^\tau_{\mathcal{M}}(\tilde{\boldsymbol{\kappa}}, \epsilon, S)\right]$$

$$\mathrm{Tr}(\not{p}_\perp\;\gamma^+\;\gamma_5\;\Phi^\tau) = D \; Tr\left[\boldsymbol{p}_\perp\cdot\boldsymbol{\sigma}\;\hat{\boldsymbol{\mathcal{P}}}^\tau_{\mathcal{M}}(\tilde{\boldsymbol{\kappa}}, \epsilon, S)\right]$$

$$\dots \quad \dots \qquad (1)$$

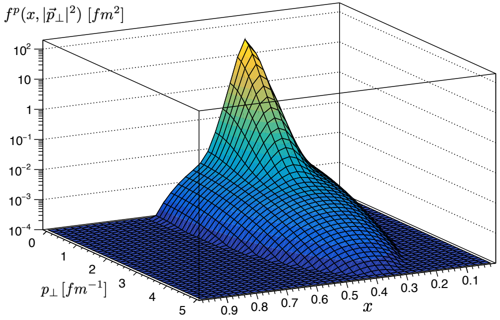
We have calculated the six leading-twist T-even TMDs:

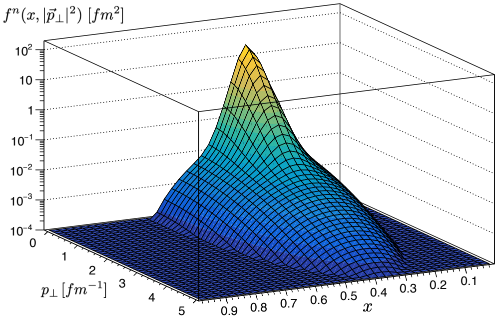
$$f(x,\mathbf{p}_\perp^2) = b_0\;,\;\Delta f(x,|\mathbf{p}_\perp|^2) = b_{1,\mathcal{M}} + b_{5,\mathcal{M}}\;,\;\; g_{1T}(x,|\mathbf{p}_\perp|^2) = \frac{M}{|\mathbf{p}_\perp|}\;b_{4,\mathcal{M}}\;,$$

$$\Delta'_T f(x,|\mathbf{p}_\perp|^2) = b_{1,\mathcal{M}} + \frac{1}{2}b_{2,\mathcal{M}}\;,\; h^\perp_{1L}(x,|\mathbf{p}_\perp|^2) = \frac{M}{|\mathbf{p}_\perp|}\;b_{3,\mathcal{M}}\;,\; h^\perp_{1T}(x,|\mathbf{p}_\perp|^2) = \frac{M^2}{|\mathbf{p}_\perp|^2}b_{2,\mathcal{M}}$$

where $b_{i,\mathcal{M}}$ are integral over ϵ of the SF, with given τ (dropped for simplicity).

$\Longrightarrow$ An excerpt of our calculation of the $^3\mathrm{He}$ TMDs **(Alessandro et al Phys.Rev.C 104 (2021) 6, 065204)** , carried out by using Pisa wf obtained from Av18 (2N) + UIX (3N) interactions





$f^\tau(x, |\mathbf{p}_\perp|^2)$, unpolarized TMD in an unpolarized ^{3}He.

Upper panel: Proton.

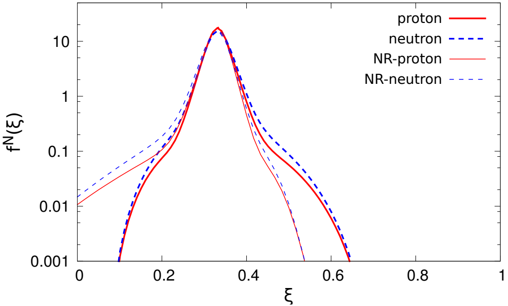
Lower panel: Neutron.

Notice the peak @ $x = 1/3$.

The integral over $\mathbf{p}_\perp$ yields the longitudinal light-cone momentum $f_1^\tau(x)$

^{3}He unpolarized light-cone momentum distributions – Pace, Rinaldi, Scopetta and GS

arXiv:2206.05485



$$\int_0^1 d\xi\ f_1^\tau(\xi;A) = 1$$

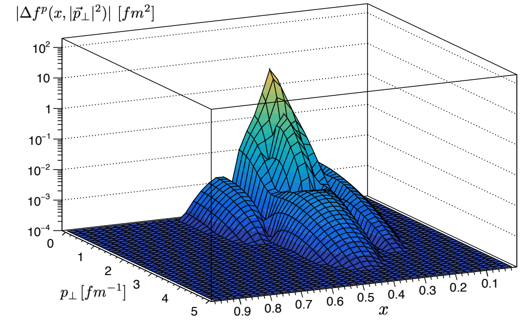
$$\int_0^1 d\xi\ \xi\ f_1^\tau(\xi;A) = 1$$

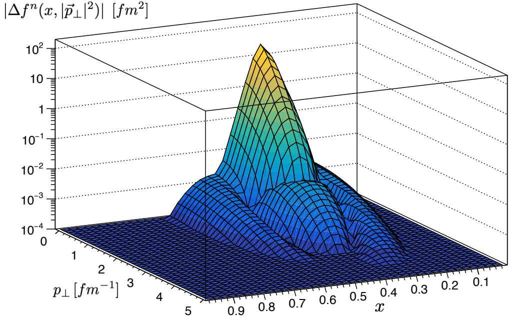
One can formally obtain and numerically check that normalization and momentum sum-rule (MSR) are fulfilled in the LFHD! ★ crucial for the EMC effect ★

For a nucleus, one gets

$$N_A = \int d\xi\ [Z f_1^p(\xi;A) + (A-Z) f_1^n(\xi;A)] = 1\,, \int d\xi\ \xi\,[Z f_1^p(\xi;A) + (A-Z) f_1^n(\xi;A)] = 1$$

Well-known that in IF, normalization and MSR cannot be fulfilled at the same time **(see Frankfurt & Strikman; Miller; ...80's)**



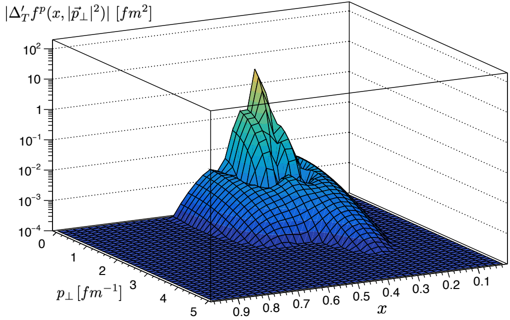


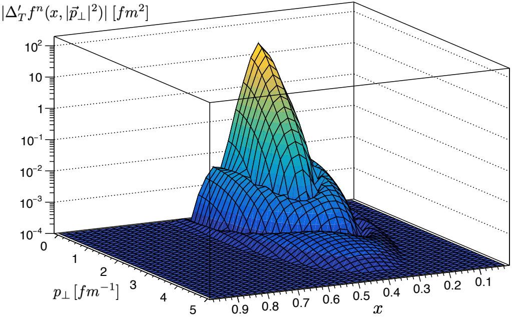
Absolute value of the nucleon longitudinal-polarization distribution, $\Delta f^\tau(x, |\mathbf{p}_\perp|^2)$, in a longitudinally polarized ^{3}He.

Upper panel: Proton.
Lower panel: Neutron.

N.B. longitudinal wrt the virtual-photon axis. TMDs receive contributions from both $L = 0$ and $L = 2$ orbital angular momenta

The integral over $\mathbf{p}_\perp$ yields the longitudinal light-cone momentum $g_1^\tau(x)$





Absolute value of the nucleon transverse-polarization distribution, $\Delta'_T f^\tau(x, |\mathbf{p}_\perp|^2)$, in a ^{3}He transversely polarized in the same direction of the nucleon polarization.

Upper panel: Proton.
Lower panel: Neutron.

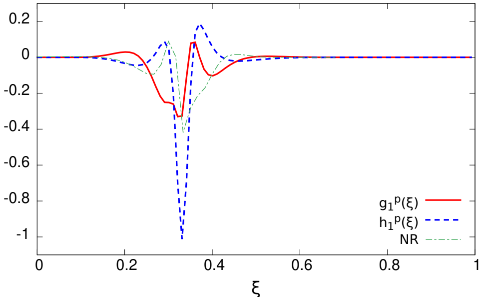
N.B. transverse wrt the virtual-photon axis. TMDs receive contributions from both $L = 0$ and $L = 2$ orbital angular momenta.

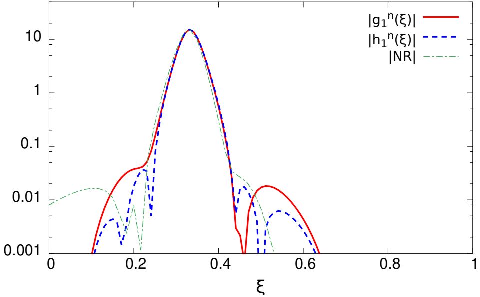
(Small) Difference wrt the previous slide due to relativistic effects

The integral over $\mathbf{p}_\perp$ yields the longitudinal light-cone momentum $h_1^\tau(x)$

The ^{3}He polarized proton and neutron LF momentum distributions

Pace, Rinaldi, Scopetta and GS, arXiv:2206.05485





$g_1^\tau(\xi)$ longitudinal-polarization distribution

$h_1^\tau(\xi)$ transverse-polarization distribution

★ They would be the same in a NR framework;

★★ Crucial for the extraction of the neutron information from DIS and SIDIS off ^{3}He.

⇒ The difference between the LF polarizations and the NR ones are up to 2% in the neutron case, larger for the proton, but it has an overall small contribution.

Interestingly, R. Jacob et al. [NPA 626, 937 (1997)] and B. Pasquini et al. [PRD 78, 034025 (2008)] suggested approximate relations between quark TMDs, viz

$$\Delta f(x, |\mathbf{p}_\perp|^2) = \Delta'_T f(x, |\mathbf{p}_\perp|^2) \; + \; \frac{|\mathbf{p}_\perp|^2}{2M^2} \; h^\perp_{1T}(x, |\mathbf{p}_\perp|^2)$$

$$g_{1T}(x, |\mathbf{p}_\perp|^2) = \; - \; h^\perp_{1L}(x, |\mathbf{p}_\perp|^2)$$

$$(g_{1T})^2 \; + \; 2 \; \Delta'_T f \quad h^\perp_{1T} = 0$$

In our approach: for the nuclear TMDs:

- the first relation is recovered retaining only the $L = 0$ contribution. Taking into account both $L = 0, \; 2$, the difference between the lhs and rhs is small for the neutron, not negligible for the proton;
- the second relation holds in modulus, since if the $L = 0$ component, tiny for those TMDs, is retained the minus sign works, while the dominant $L = 2$ contribution leads to a plus sign.
- The third relation does not hold, even if the $L = 2$ contribution is vanishing. Noteworthy, the integration on k_{23}, imposed by **Macro-locality**, spoils the relation:
  $\Rightarrow$ its effect becomes measurable ! (Importance of 2-3 interaction!)

Nuclear TMDs can be experimentally investigated in exclusive processes, where the polarization degrees of freedom of the target and the nucleons in the final state are exploited.

EMC effect: explanations?

Unfortunately a detailed explanation is stll lacking. We need to know the reaction mechanism of hard processes off nuclei and the degrees of freedom which are involved (see G. Miller talk). Some issues:

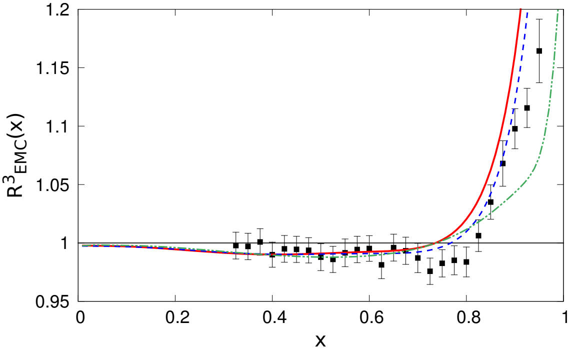
- the knowledge of nuclear PDFs is crucial for the analysis of heavy ions collisions;
- neutron parton structure, fundamental for addressing genuine QCD effects, is necessarily measured by means of nuclear targets; Hence, Nuclear Physics plays an important role!

Status of "Conventional" calculations for light nuclei:

- **IF (NR) Calculations**: qualitative agreement but no simultaneous fulfillment of both particle and momentum sum-rule.
- **LF Calculations**: in heavy systems, mean field approaches do not find an EMC effect in the valence region (**Miller and Smith, PRC C 65 (2002) 015211**);
  For light nuclei, no realistic calculations available (an approximate attempt in **Oelfke, Sauer and Coester NPA 518 (1990) 593**)

The EMC effect can be calculated through the unpolarized $f_1^\tau(\xi)$!
In the Bjorken limit, it is enough LF momentum distribution, obtained directly from the nuclear wave function, and the full spectral function $\boldsymbol{\mathcal{P}}$: a great advantage for heavier nuclei

Good news: ^{4}He calculations are almost completed



$R^3_{EMC} = R^3_2(x)/R^2_2(x)$, where

$$R^A_2(x) = \frac{A\ F^A_2(x)}{Z\ F^p_2(x)+(A-Z)\ F^n_2(x)}$$

Pace, Rinaldi, Scopetta and GS arXiv:2206.05485

- Solid line: i) ^{3}He wf, with Av18(2N)+UIX(3N), ii) *SMC* $F^p_2(x)$ (Adeva et al PLB **412**, 414 (1997)), iii) $F^n_2(x)/F^p_2(x)$ extracted from the MARATHON data, PRL **128** (2022) 132003.
- Dashed line: the same as the solid line, but excluding the NNN potential.
- Dash-dotted line: as the solid line but with the *CJ15* $F^p_2(x)$ (Accardi et al PRD **93** (2016) 114017).
- Full squares: data from J. Seely et al., PRL. 103, 202301 (2009) reanalyzed by Kulagin and Petti, PRC **82**, 054614 (2010)

Conclusions: small but solid effect; waiting for MARATHON data; essential the extension to ^{4}He (which presents a bigger effect)

Conclusions & Perspectives

- **A Poincaré covariant description of nuclei, based on the light-front Hamiltonian dynamics, has been proposed.** The Bakamjian-Thomas construction of the Poincaré generators allows one to embed the successful phenomenology for few-nucleon systems in a Poincaré covariant framework.
  N.B. Normalization and momentum sum rule are both automatically fulfilled.
- ★ Macro-locality can be implemented, as it must be and plays a role in precision experiments (see also TMDs relations).
- ★ The Spectral Function is related to the valence contribution to the correlator introduced for a QFT description of SiDIS reactions involving the nucleon, applied for the first time to ^{3}He.

  ★★ General principles fulfilled by the LF Spectral function entail relations among T-even twist-2 (and also twist-3) valence TMDs, with interesting angular momentum dependence.
- encouraging calculation of $^3\mathrm{He}$ EMC, that sheds light on the role of a reliable description of the nucleus, and a truly Poincaé-covarint formalism.
  Crucial extension to ^{4}He!
- Analyses of exclusive reactions, with polarized initial and final states, for accessing nuclear TMDs in ^{3}He are in progress