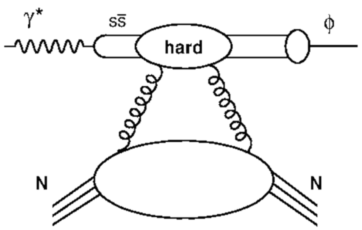
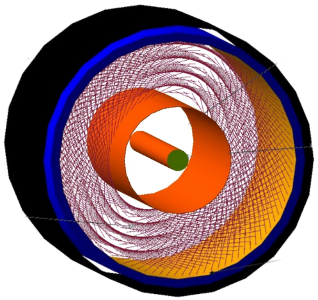
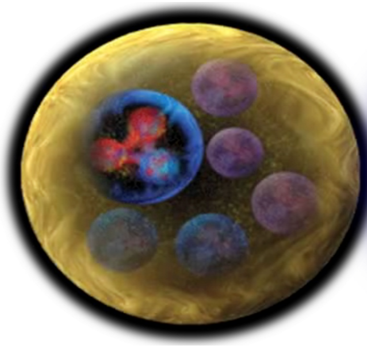
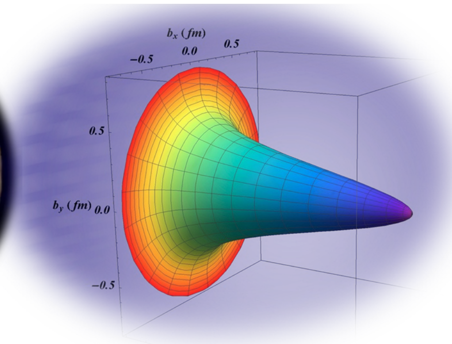
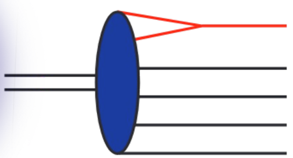
Nuclear TMDs with CLAS12











Proposition for a RG-D Run Group Proposal

R. Dupré for the authors

W. Armstrong, L. El Fassi,

ZE. Meziani, H. Szumila-Vance et al.

INSTITUT DE PHYSIQUE NUCLÉAIRE ORSAY

université PARIS-SACLAY

European Research Council
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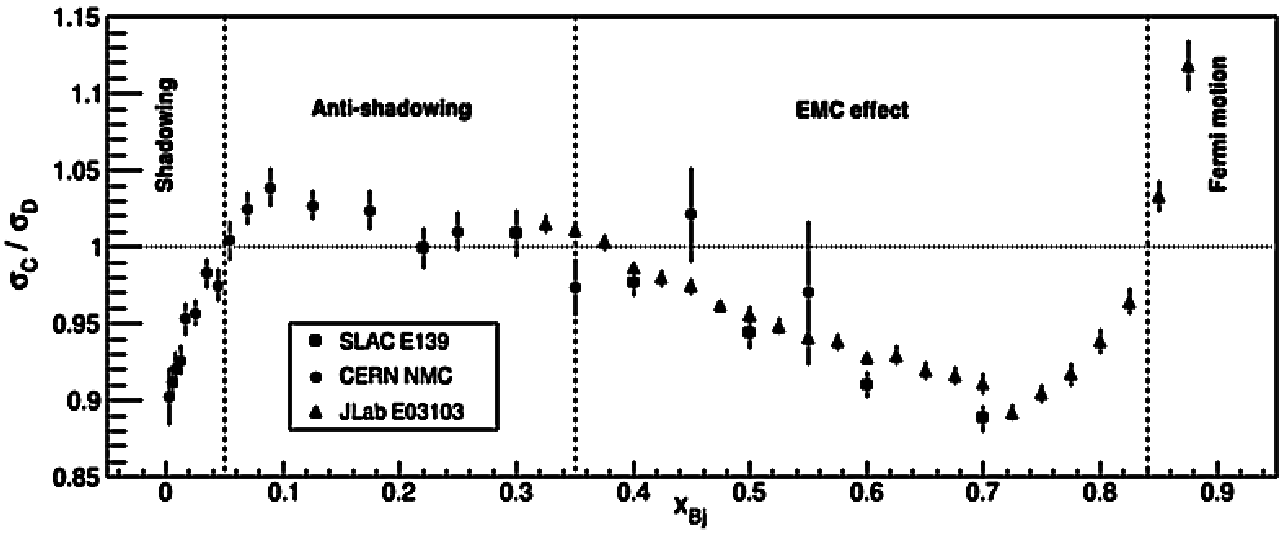
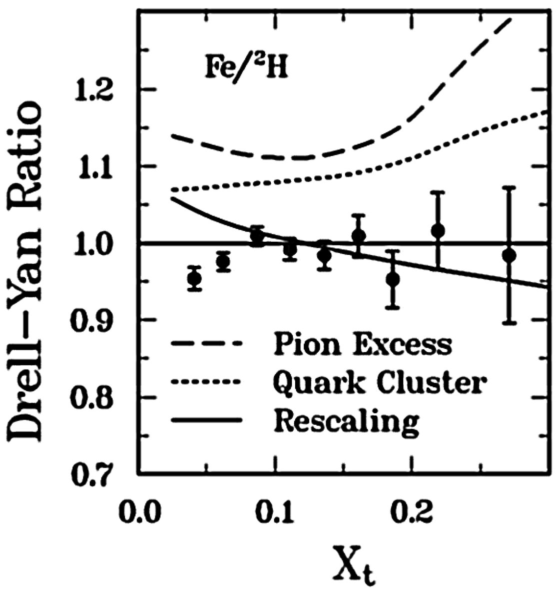
The Nuclear Effects





We discovered nuclear effects at the quark level

– **Shadowing, anti-shadowing and EMC effect**

The EMC effect remains a mystery to this day

– **Meson content induced by NN interaction**

– **6, 9, 12-quark clusters**

- *Both are excluded by Drell-Yan measurements*

– **Nucleon size might change → bound FF**

- *Difficult to prove due to FSI effects*

– **Q^2- or x-rescaling with widely different physical meaning**

Resolving the EMC Effect Mystery

Higher precision

- **Performed in JLab Hall-C**
- **Tough to compete with CLAS12 on this front**

New processes

- **Tagging/SRC (ALERT, BAND, Bonus)**
- **Nuclear DVCS (ALERT)**
- **Nuclear TMDs (This talk !)**

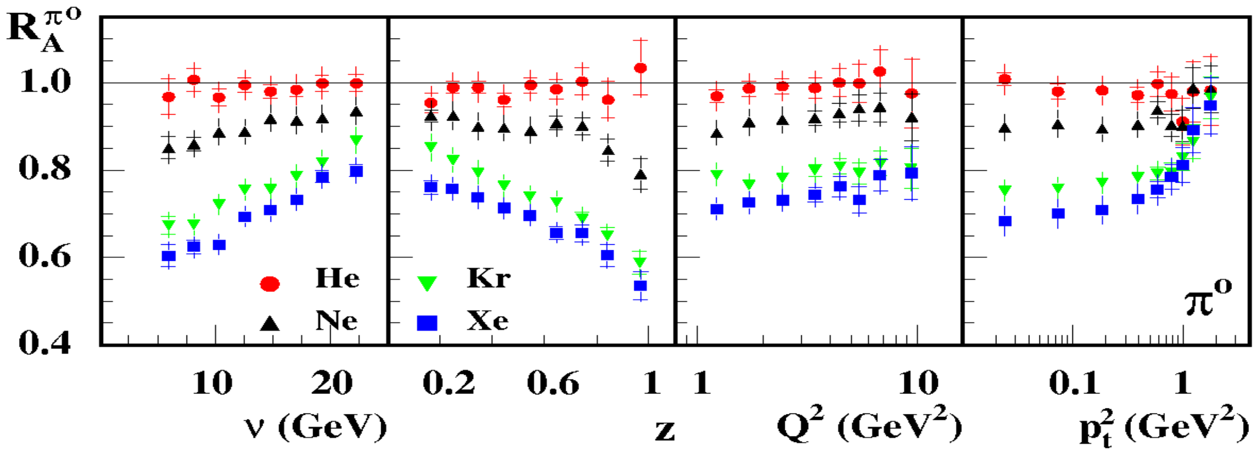
Why nuclear TMDs ?

- **The missing piece of the nucleus description**
  - *We observed surprising behavior for the GPDs*
- **Involves the fragmentation functions**
  - *These are affected by the medium*
  - *In particular with the transverse momentum broadening*
  - *The TMD framework can help treat consistently the data*
- **It will modernize the way we study nuclear SIDIS**

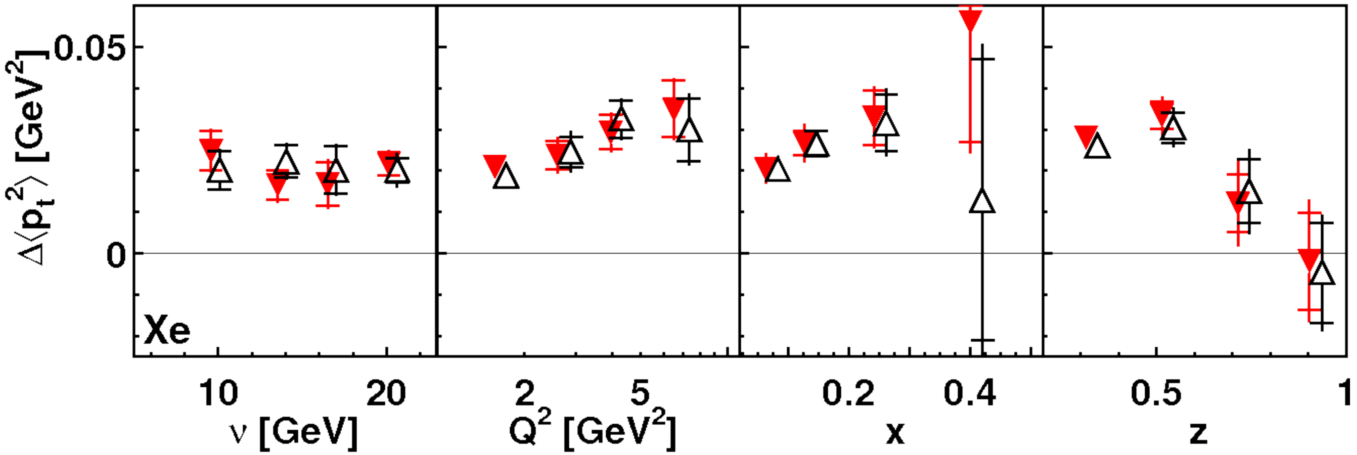
The HERMES data

Multiplicity ratio

- Hadron absorption



Transverse momentum broadening



Extracting Signal of the TMDs

TMD extraction is simple, in principle

- **Each function has a different modulation**
- **It is a bit more complicated**
  - *Resolving the convolution with fragmentation functions*

Experimental needs

- **High acceptance**
  - *CLAS12 !*
- **Polarized beam**
  - *Easy in JLab*
- **Polarized targets**
  - *Probably not anytime soon for nuclear targets*

$$\frac{d\sigma}{dx_B\, dy\, d\phi_S\, dz\, d\phi_h\, dP_{h\perp}^2} = \frac{\alpha^2}{x_B y Q^2} \frac{y^2}{2(1-\varepsilon)}$$
$$\times \Big\{ F_{UU,T} + \varepsilon F_{UU,L} + \sqrt{2\varepsilon(1+\varepsilon)} \cos\phi_h F_{UU}^{\cos\phi_h}$$
$$+ \varepsilon \cos(2\phi_h) F_{UU}^{\cos 2\phi_h} + \lambda_e \sqrt{2\varepsilon(1-\varepsilon)} \sin\phi_h F_{LU}^{\sin\phi_h}$$
$$+ S_\parallel \Big[\sqrt{2\varepsilon(1+\varepsilon)} \sin\phi_h F_{UL}^{\sin\phi_h} + \varepsilon \sin(2\phi_h) F_{UL}^{\sin 2\phi_h} \Big]$$
$$+ S_\parallel \lambda_e \Big[\sqrt{1-\varepsilon^2} F_{LL} + \sqrt{2\varepsilon(1-\varepsilon)} \cos\phi_h F_{LL}^{\cos\phi_h} \Big]$$
$$+ |S_\perp| \Big[\sin(\phi_h - \phi_S) \Big(F_{UT,T}^{\sin(\phi_h-\phi_S)} + \varepsilon F_{UT,L}^{\sin(\phi_h-\phi_S)} \Big)$$
$$+ \varepsilon \sin(\phi_h + \phi_S) F_{UT}^{\sin(\phi_h+\phi_S)} + \varepsilon \sin(3\phi_h - \phi_S) F_{UT}^{\sin(3\phi_h-\phi_S)}$$
$$+ \sqrt{2\varepsilon(1+\varepsilon)} \sin\phi_S F_{UT}^{\sin\phi_S} + \sqrt{2\varepsilon(1+\varepsilon)} \sin(2\phi_h - \phi_S) F_{UT}^{\sin(2\phi_h-\phi_S)} \Big]$$
$$+ |S_\perp| \lambda_e \Big[\sqrt{1-\varepsilon^2} \cos(\phi_h - \phi_S) F_{LT}^{\cos(\phi_h-\phi_S)} + \sqrt{2\varepsilon(1-\varepsilon)} \cos\phi_S F_{LT}^{\cos\phi_S}$$
$$+ \sqrt{2\varepsilon(1-\varepsilon)} \cos(2\phi_h - \phi_S) F_{LT}^{\cos(2\phi_h-\phi_S)} \Big] \Big\}.$$

Nuclear TMD

Very little theory on the topic

- Using the model from Liang et al. (PRD 77 125010)

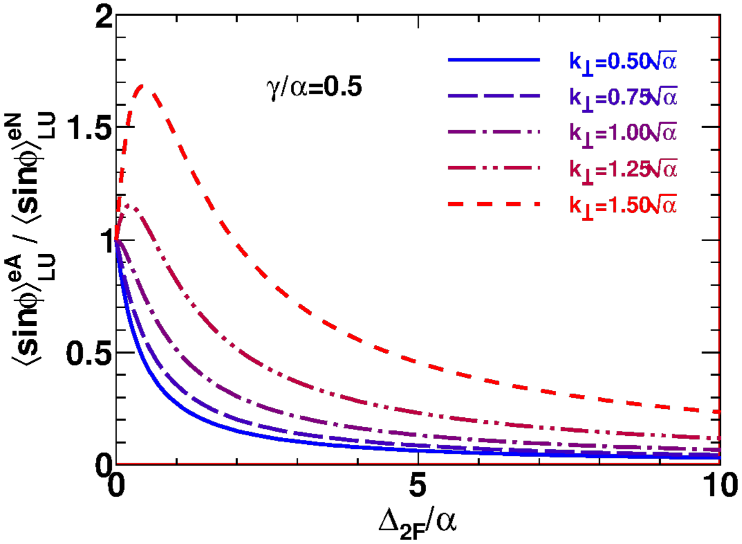
$$f_q^A(x,k_\perp) \approx \frac{A}{\pi\Delta_{2F}}\int d^2\ell_\perp e^{-(\vec{k}_\perp-\vec{\ell}_\perp)^2/\Delta_{2F}} f_q^N(x,\ell_\perp)$$

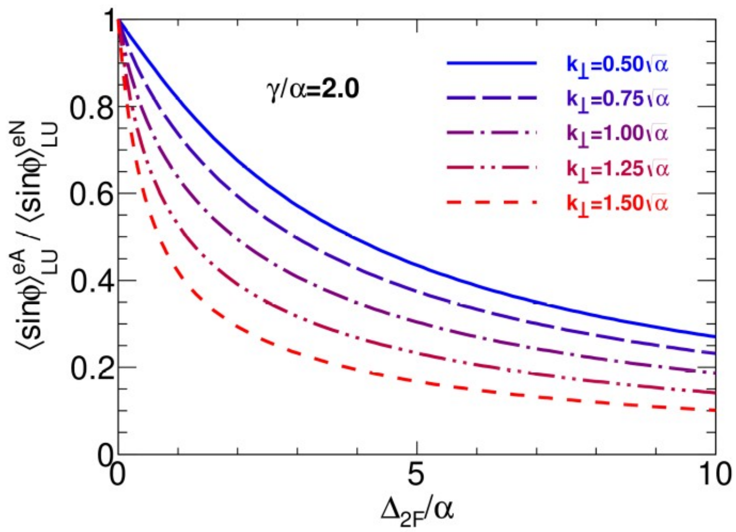
$$\Delta_{2F} = \int d\xi_N^- \hat{q}_F(\xi_N)$$

$$\hat{q}_F(\xi_N) = \frac{2\pi^2\alpha_s}{N_c}\rho_N^A(\xi_N)[xf_g^N(x)]_{x\to 0}$$

- Uses the transport coefficient of the nuclear matter
  - *This nuclear property is poorly known, we have here the chance to measure it properly*
  - *It is directly linked to the saturation scale and should vary with A*
- Asymmetries are generated at the partonic level
  - *Links cleanly to the definition of the transport coefficient*

Using TMDs for Hadronization





Model give wide predictions

- **α and γ are the width of the TMDs**

Usual hadronization measurements use outdated methods

- **We should use the TMD framework to study semi-inclusive DIS on nuclei**
- **The sin and cos moments give direct parton level sensitivity to the transport coefficient**

Two independent transport coefficient measurements

- **To be compared with the absorption and the transverse momentum broadening**

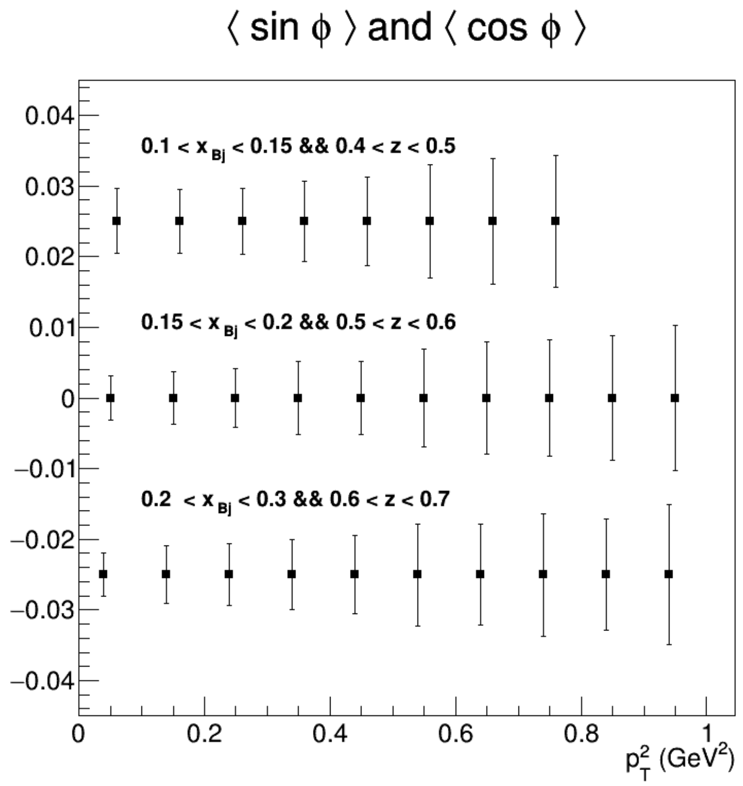
Projections

We ran full simulations

- HERMES generator gmc_trans
- Pass it to GEMC & Full CLAS12 reconstruction

Results for the sin and cos moment

- Identical because only statistical
- Smaller reach in Pt than for the RG-A proton target
- Logical since the beam time is much smaller



This is enough for a first measurement

- Ratios to the proton measurement are key
  - *The amount of systematic uncertainty that can be canceledwill be key*
- We will use the different targets to test if a A dependence can be detected

Summary

We have studied nuclear hadronization and the EMC effect for a long time

- Both topics remain very active to this day
- Using TMD framework is a modernization of the hadronization studies as it is accounting for all components of the SIDIS cross section

The TMD framework will help progress in our understanding

- Asymmetries are generated at the partonic and level allowing a clean interpretation of the data
- Different asymmetries allow to cross check the results from the same data set with different observables
- Different nuclei allow to assess the expected variation of the transport coefficient

The Proposal

- Run group proposal that will run within the RG-D
- We only request the addition of polarization
- We know these data are prone to data mining, it is important to highlight this potential for the jeopardy process