Gluonic Probe for the Short Range Correlations in Nucleus

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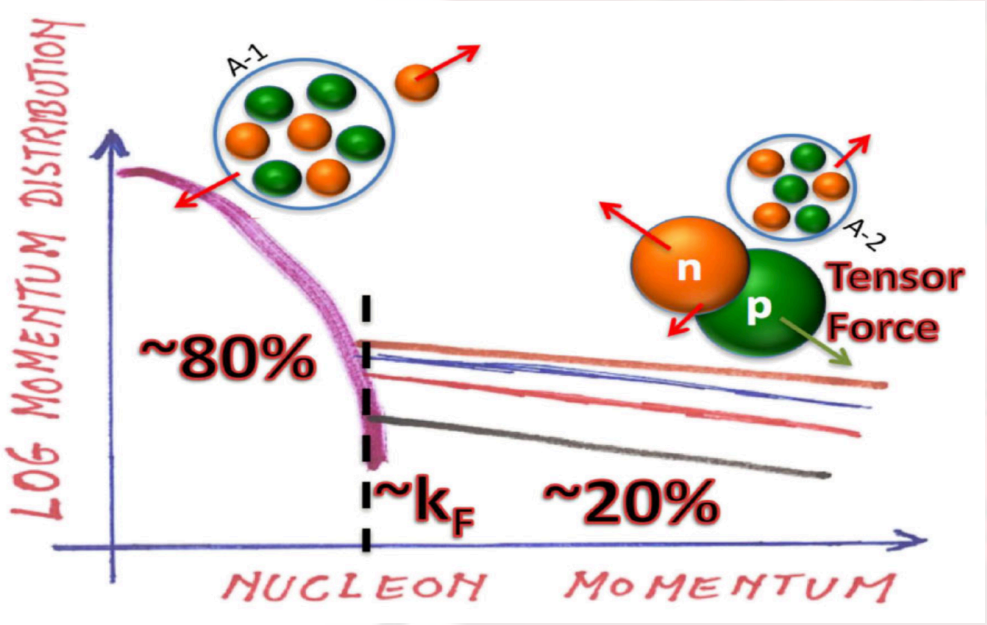
References: Xu, Yuan, Phys.Lett.B 801, 135187, 1908.10413

Hatta, Strikman, Xu, Yuan, Phys.Lett.B 803, 135321, 1911.11706

Short-range correlation in nuclear structure



Hen et al, RMP 2017

- Nucleon-nucleon close in coordinate space
- Momentum space
  - Low total momentum
  - High relative momentum

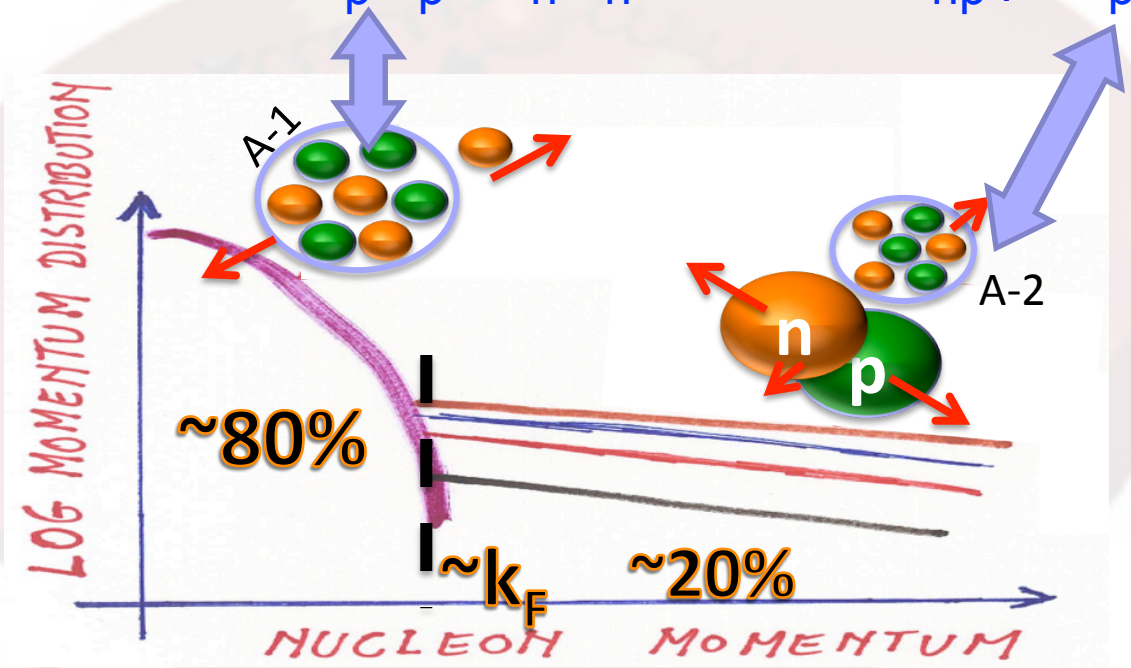
Different Ways to Probe SRC

- Momentum distribution of nucleons
  - Limited to low momentum region
- Knock out experiments
- Hard hadronic processes: structure function modifications
  - EMC effects
  - Fast moving partons
    - (Structure function at x_B>1)

JLab's major Activities: Quark

Bound = 'quasi Free' + Modified SRCs

$$\sigma_A = n_p\sigma_p + n_n\sigma_n + n_{np}(\Delta\sigma_p + \Delta\sigma_n)$$



Universality is the key to establish the physics associated with SRC!!

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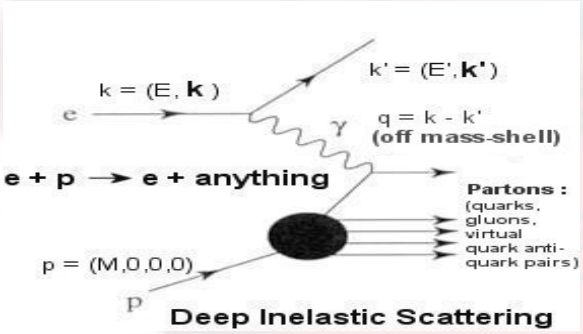
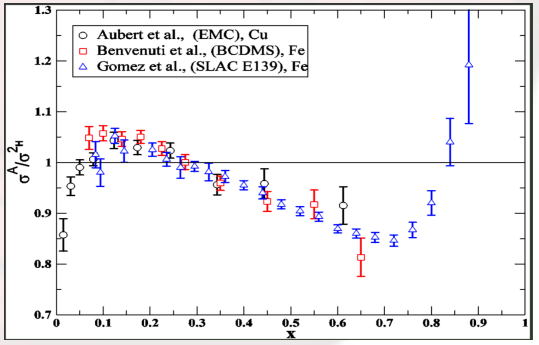
Universality of SRC Contributions

- Different processes
  - Same SRC pair contribute to different hard processes
  - Universal partonic structure
- Different nuclei
  - Only depend on the probability of the SRC pair, nuclear dependence same for different processes
  - Link different nuclei by the SRC factors

EMC: nuclear modification of structure functions

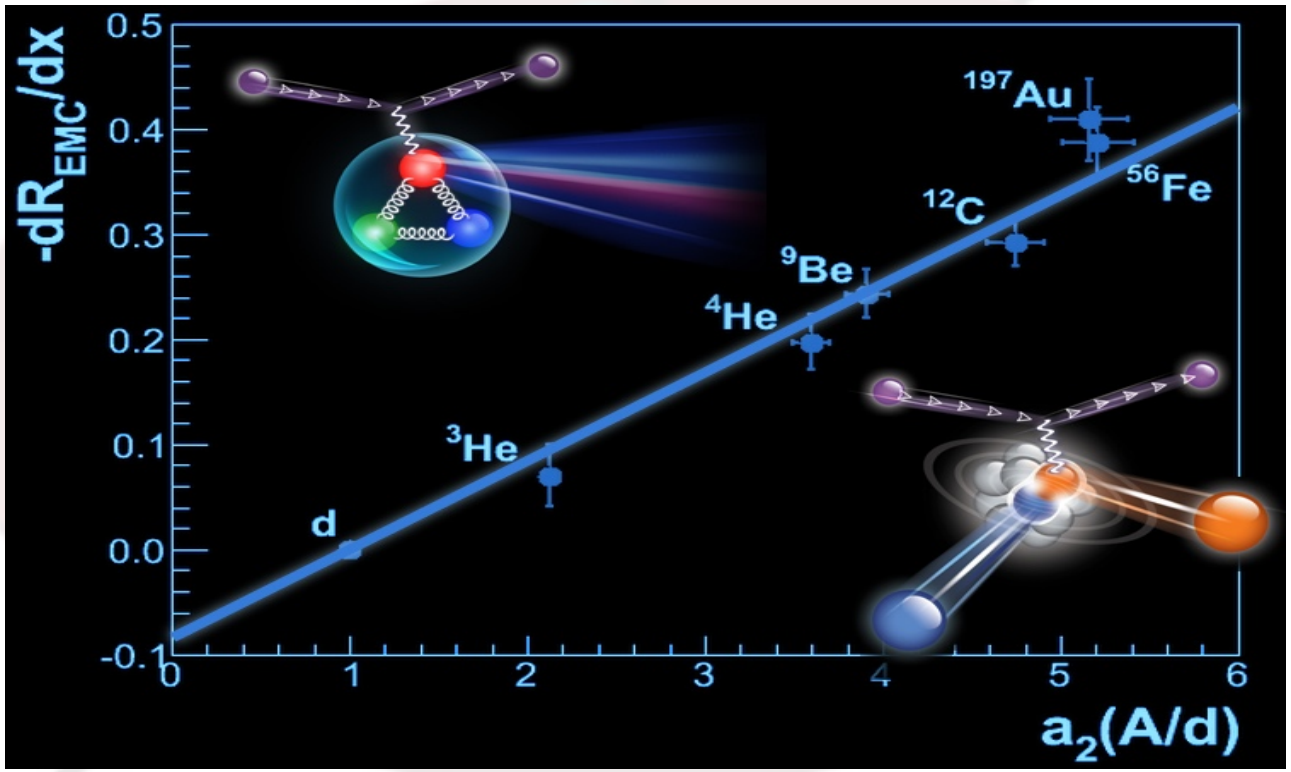
- DIS structure function measures the parton distribution in nucleon/nucleus





$$F_2^A = Z F_2^p + N F_2^n \Rightarrow \frac{\sigma_A / A}{\sigma_D / 2} \approx 1$$

Universality: Quark Sector



Parton distributions in nucleus: SRC contributions

- Because of isospin symmetry:

$$g_A(x,Q^2) = A g_p(x,Q^2) + 2n^A_{src}\delta\tilde{g}(x,Q^2)$$

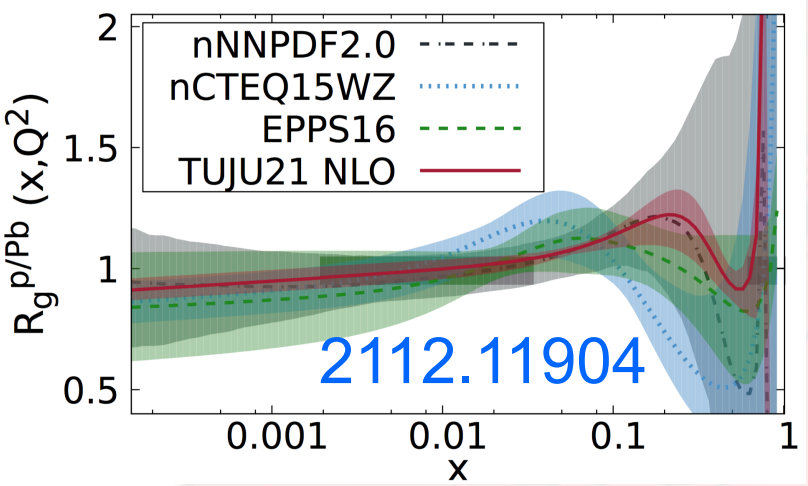
  - Compare to the quark sector

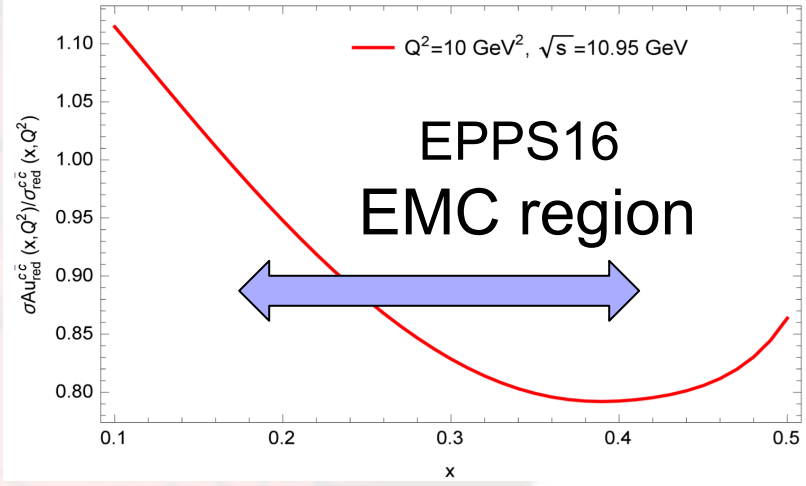
$$F_2^{\mathrm{A}} = (Z - n_{\mathrm{SRC}}^{\mathrm{A}})F_2^p + (N - n_{\mathrm{SRC}}^{\mathrm{A}})F_2^n + n_{\mathrm{SRC}}^{\mathrm{A}}(F_2^{p*} + F_2^{n*})$$

$$= ZF_2^p + NF_2^n + n_{\mathrm{SRC}}^{\mathrm{A}}(\Delta F_2^p + \Delta F_2^n)$$

SRC Factor: n^A_{src}

EMC Effects in Charm F_2 at EIC

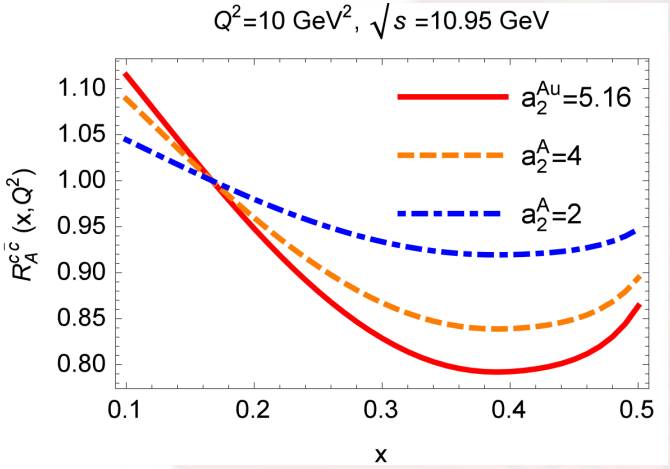




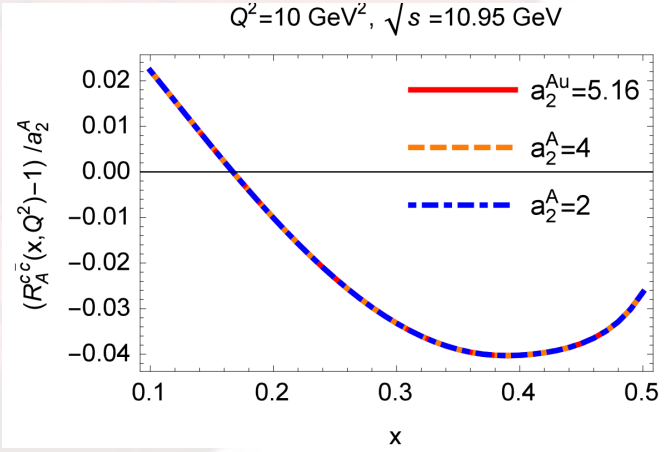
There is no constraint for the gluon: EPPS16, 1612.05741; nNNPDF, 2006.14629; nCTEQ, 2007.09100; TUJU21, 2112.11904

Gluon momentum=$x(1+4m_c^2/Q^2)$
See also, Kelsey et al,2107.05632; Aschenauer et al, 1708.05654; Chudakov, 1610.08536

Universality of the nuclear modifications



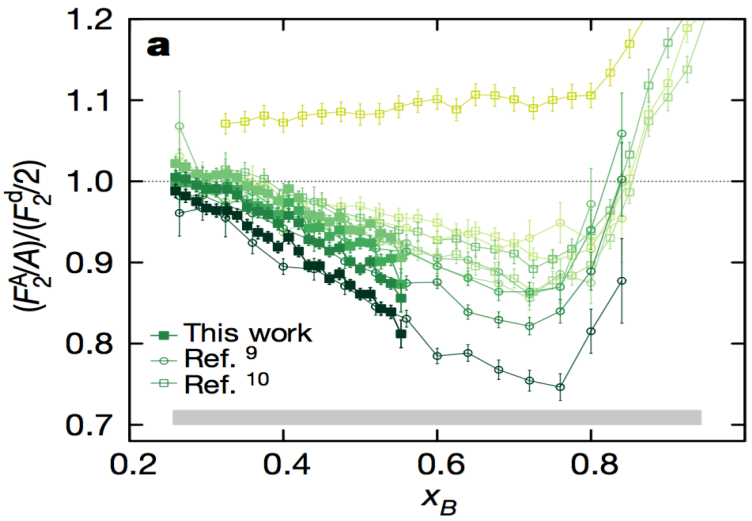
Au: EPPS16; others follow the universal behavior

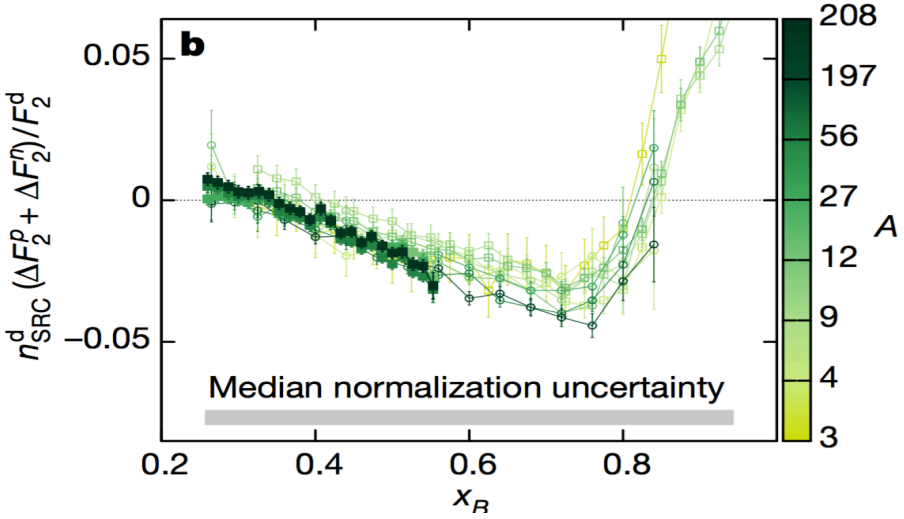


Divide by the SRC Factor

$$a_2^A = (n_{src}^A/A)/(n_{src}^d/2)$$

Quark sector: Isospin dependence





CLAS Coll., Nature 2019
See also, Hen et al,1908.02223

$$\frac{n^{\mathrm{d}}_{\mathrm{SRC}}(\Delta F_2^p + \Delta F_2^n)}{F_2^{\mathrm{d}}} = \frac{\frac{F_2^{\mathrm{A}}}{F_2^{\mathrm{d}}} - (Z-N)\frac{F_2^p}{F_2^{\mathrm{d}}} - N}{(A/2)a_2 - N}$$

Universality of SRC: two facts

- EMC effects for different nuclei can be described by the same universal SRC contributions
  - Quark/gluon shall differ
- The same SRC factor for both quark and gluon sectors
  - Any other place to study the gluon sector?

Jpsi production at sub-threshold

- Jpsi production in photo-nuclear collisions

$$\sigma_{\gamma A\to J/\psi}(\sqrt{s_{\gamma p}}) = A\sigma_{\gamma p\to J/\psi}(\sqrt{s_{\gamma p}}) + n^A_{src}(\sigma_{\gamma(pn)\to J/\psi}(\sqrt{s_{\gamma p}}) - 2\sigma_{\gamma p\to J/\psi}(\sqrt{s_{\gamma p}}))$$

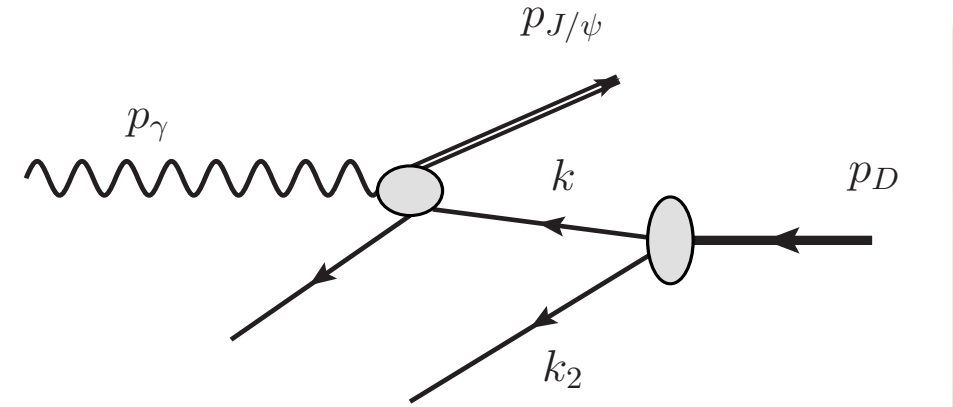
- Below the photon-proton threshold

$$\sigma_{\gamma A\to J/\psi}(\sqrt{s_{\gamma p}} < M_p + M_{J/\psi}) = n^A_{src}\sigma_{\gamma(pn)\to J/\psi}(\sqrt{s_{\gamma p}})$$

- Universality

$$\frac{\sigma_{\gamma A\to J/\psi}(\sqrt{s_{\gamma p}} < M_p + M_{J/\psi})}{\sigma_{\gamma d\to J/\psi}(\sqrt{s_{\gamma p}} < M_p + M_{J/\psi})} = \frac{n^A_{src}}{n^d_{src}} = \frac{F_2^A(x_B)}{F_2^d(x_B)}|_{1.5<x_B<2.0}$$

Example: Deuteron Case

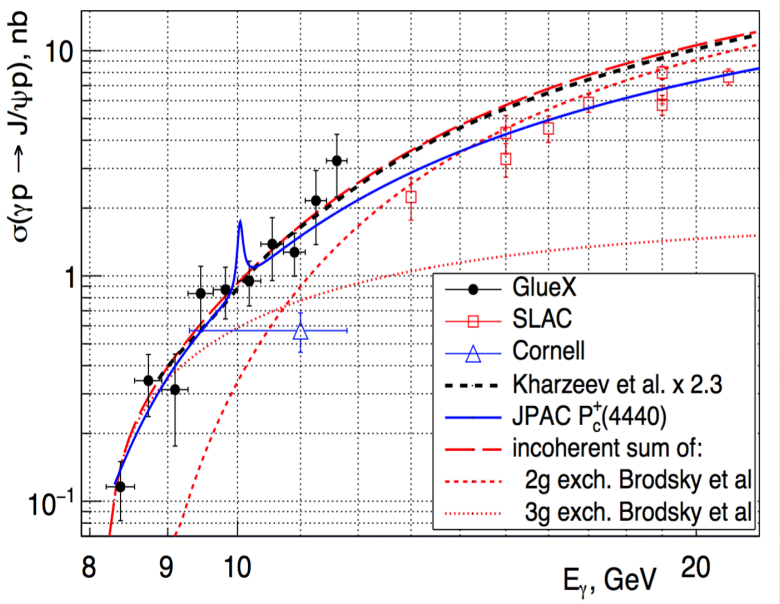


$$\sigma_{\gamma D}(W_{\gamma p}) = 2 \int d^3k \rho_n(k) \widetilde{\mathcal{F}}(k) \sigma_{\gamma p}(W_{\gamma p'})$$

Nucleon's Momentum distribution

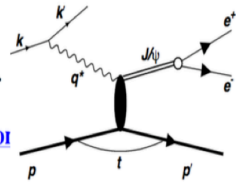
$$\int d^3k \rho_n(k) = 1$$

Photon-proton cross section as input



GlueX Coll., PRL 2019, 1905.10811

Heavy quarkonium production near threshold: a very hot topic



Near threshold heavy vector meson photoproduction at LHC and EicC,
Ya-Ping Xie, V.P. Gonçalves, e-Print: 2103.12568 [hep-ph]
QCD Analysis of Near-Threshold Photon-Proton Production of Heavy Quarkonium.
Yuxun Guo, Xiangdong Ji, Yizhuang Liu, e-Print: 2103.11506 [hep-ph]
Trace Anomaly of Proton Mass with Vector Meson Near-Thresholds Photoproductio
Wei Kou, Rong Wang, Xurong Chen e-Print: 2103.10017 [hep-ph]
Nucleon mass radii and distribution: Holographic QCD, Lattice QCD and GlueX data,
Kiminad A. Mamo, Ismail Zahed, e-Print: 2103.03186 [hep-ph]
ϕ-meson lepto-production near threshold and the strangeness D-term,
Yoshitaka Hatta, Mark Strikman e-Print: 2102.12631 [hep-ph]
Proton mass decomposition: naturalness and interpretations,
Xiangdong Ji, e-Print: 2102.07830 [hep-ph]
Extraction of the proton mass radius from the vector meson photoproductions near thresholds,
Rong Wang, Wei Kou, Ya-Ping Xie, Xurong Chen e-Print: 2102.01610 [hep-ph]
The mass radius of the proton,
Dmitri E. Kharzeev, e-Print: 2102.00110 [hep-ph]
Quantum Anomalous Energy Effects on the Nucleon Mass,
Xiangdong Ji, Yizhuang Liu e-Print: 2101.04483 [hep-ph]

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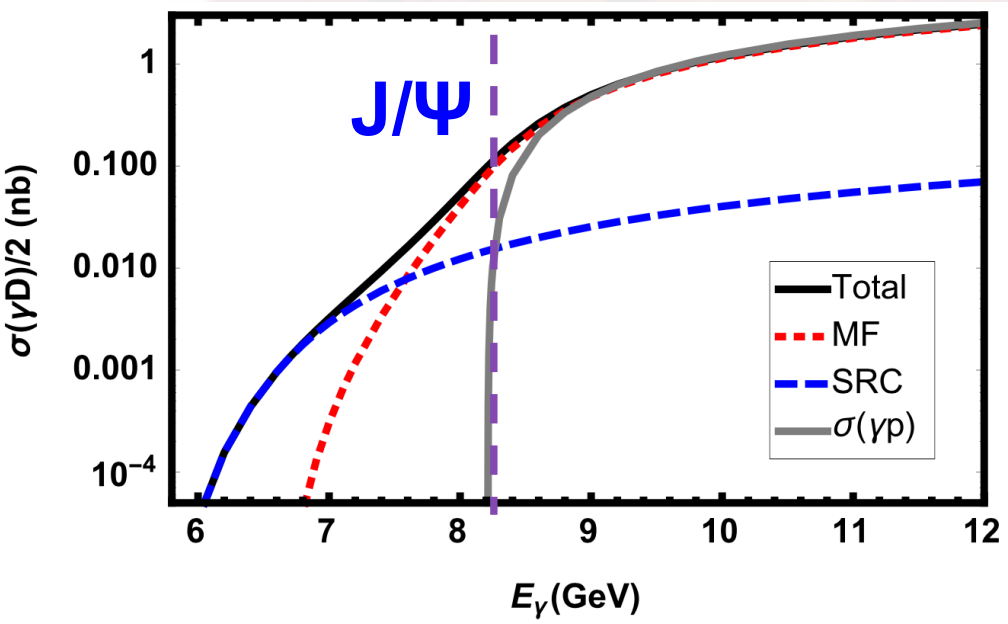
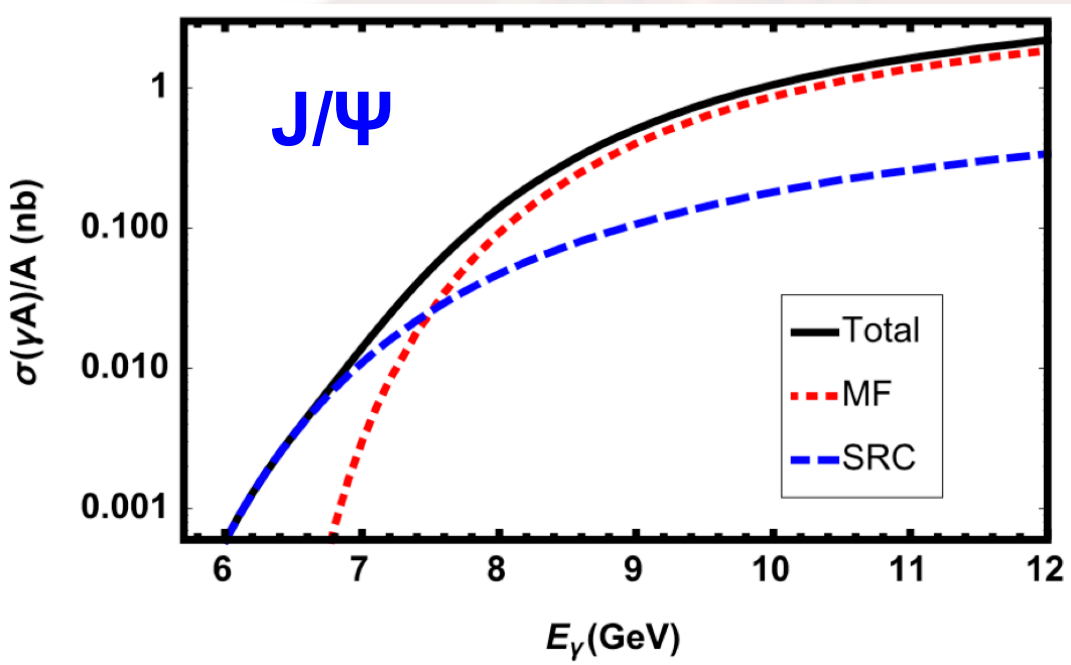
Sub-threshold Jpsi production in photon-deuteron collisions



around 7GeV dominated by SRC

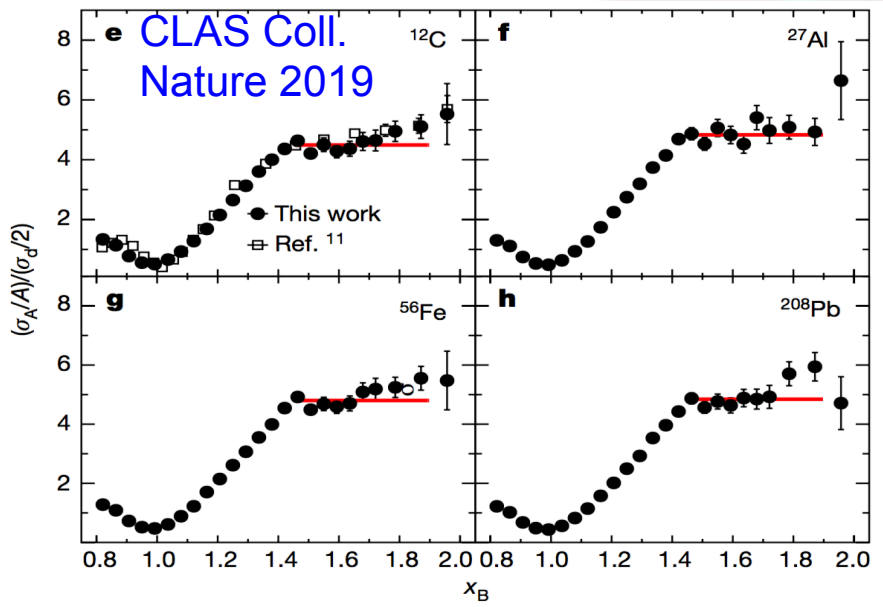
A Generic nucleus

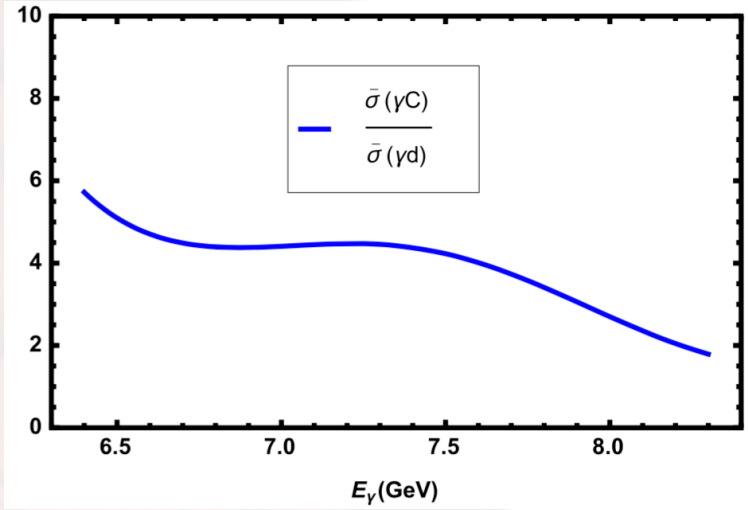


- 15% SRC
- 85% MF

SRC spectral function from Jackson Pybus

SRC Universality





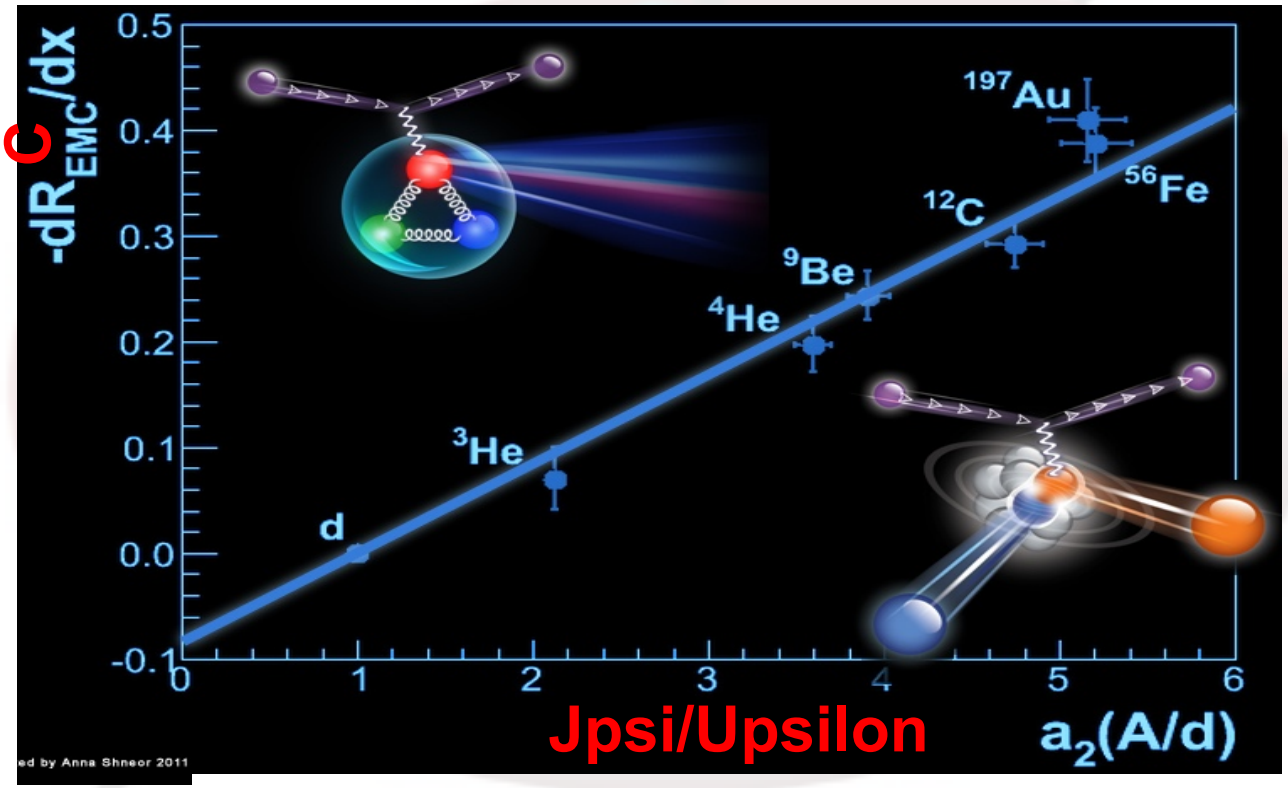
$$\frac{\tilde{\sigma}_{\gamma A\to J/\psi}}{\sigma_{\gamma d\to J/\psi}}\Big|_{E_\gamma\sim 7\mathrm{GeV}} = \frac{n^A_{src}}{n^d_{src}} = \frac{F_2^A(x_B)}{F_2^d(x_B)}\Big|_{1.5<x_B<2.0}$$

Extend to Open Flavors

- Charm and Bottom quarks and Upsilons as well

$$\frac{\tilde{\sigma}_{\gamma A\to J/\psi}}{\sigma_{\gamma d\to J/\psi}}\Big|_{W_{\gamma p}<M_{pJ/\psi}} = \frac{\tilde{\sigma}_{\gamma A\to \Upsilon}}{\sigma_{\gamma d\to \Upsilon}}\Big|_{W_{\gamma p}<M_{p\Upsilon}}$$
$$= \frac{\sigma_{\gamma A\to c\bar{c}}}{\sigma_{\gamma d\to c\bar{c}}}\Big|_{W_{\gamma p}<M_{pc\bar{c}}} = \frac{n^A_{src}}{n^d_{src}} = \frac{F_2^A(x_B)}{F_2^d(x_B)}\Big|_{1.5<x_B<2.0}$$

Universality: Gluon Sector



Summary

- Heavy flavor production in eA collisions provide the gluonic probe of the nucleon-nucleon short range correlation in nucleus
- Charmonium (Jpsi) can be easily measured at Jlab
  - Small cross section could be challenge
- Charm structure function and Upsilon can be studied at the future EICs