

# Summary: Exploring QCD with light nuclei at EIC

CFNS Workshop, Stony Brook University, Jan 21-24, 2020 [\[Webpage\]](#)

Organizers: Abhay Deshpande (Stony Brook U. & BNL), Raphael Dupre (CNRS Saclay), Maria Patsyuk (JINR Dubna), Misak Sargsian (Florida International U.), Mark Strikman (Penn State U.), Christian Weiss (JLab)



- Basic information
- Context and objectives
- Outcomes and follow-up
- CFNS venue and support

## Participants

~50 participants total, ~30-35 present each day, 5-10 remote

International: Chile, France, Israel, Italy, Japan, Russia

Communities: Short-range nuclear physics JLab, GSI, NICA; DIS & Spin physics JLab, RHIC; Theory; EIC developers detector/IR

Diversity: 7 talks by students/postdocs (20%), >10 junior participants, ~10 Female/URM

## Format

3.5 days, 0900-1800 EST, in-person, remote participation in talks/discussions

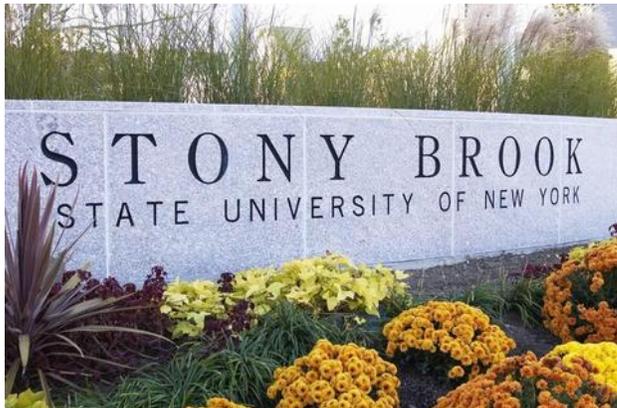
Agenda organized in ~8 topics, focused presentations + group discussions

## Special circumstances

First EIC-related meeting after DOE CD0 announcement, great excitement

EIC User Group remote meeting on Thu 23 Jan integrated into workshop agenda

Last CFNS in-person event before pandemic restrictions



## Emerging “light ion physics” program with EIC

Physics: Neutron structure, nuclear interactions hadronic/partonic, coherent processes, imaging

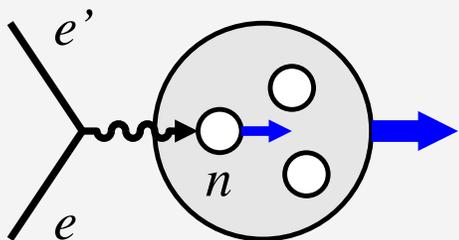
Capabilities: Energy, luminosity, polarized beams, forward detection

Communities: DIS & Spin JLab12, COMPASS, RHIC  
Short-range nuclear physics JLab6/12, GSI, JINR NICA, J-PARC  
Diffraction & small-x LHC, RHIC

Previous meetings: “Polarized light ion physics with EIC”, 5-9 Feb 2018, Ghent U., Belgium [\[Webpage\]](#)  
“Short-range nuclear correlations at EIC,” CFNS/BNL, 5-7 Sep 2018 [\[Webpage\]](#)

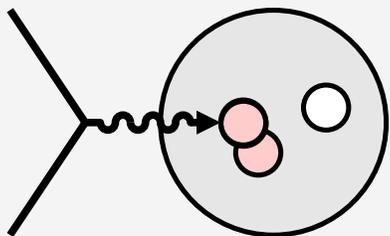
## Workshop objectives

- Discuss status and perspectives in short-range nuclear physics with JLab12 and other facilities
- Explore potential of measurements with light ions at EIC, esp. using polarization and forward detection
- Connect short-range nuclear physics community with EIC developments
- Initiate collaboration in theory, simulations, program development



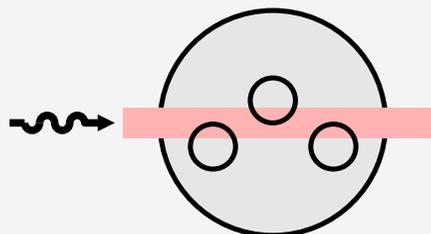
## Neutron spin structure

- Flavor separation PDFs, GPDs, TMDs
- Singlet-nonsinglet QCD evolution,  $\Delta G$
- Energy-momentum tensor form factors
- Bjorken sum rule



## Nucleon interactions

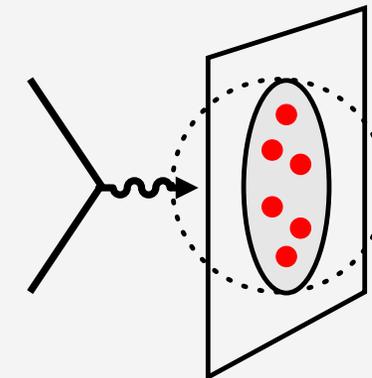
- Hadronic: Short-range NN correlations, nuclear core
- Partonic: EMC effect quarks/gluons
- QCD origin of nuclear force



## Coherent phenomena

- Nuclear shadowing
- Approach to saturation
- Diffraction, quantum fluctuations

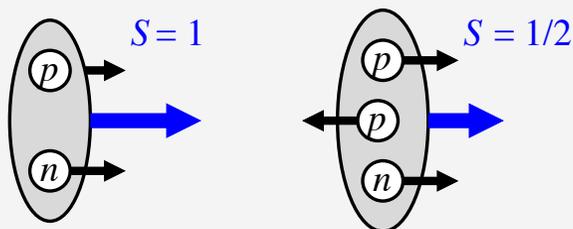
[Nuclear rest frame view]



## Nuclear quark-gluon imaging

- Nuclear GPDs
- Spatial distributions of quarks/gluons
- Spin effects, deformation

- Many connections; same measurement can serve multiple purposes
- Complement information from ep, eA(heavy)

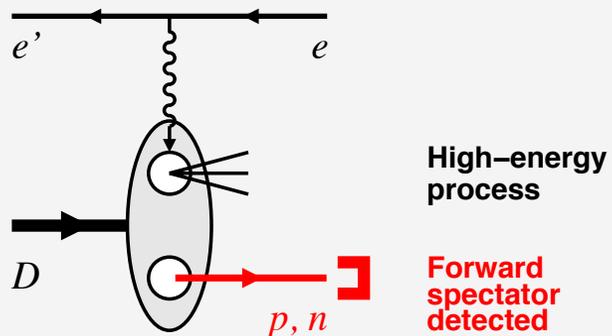


## Polarized nuclear targets/beams

- Fixed-target: D, 3He
- EIC beams: D(?), 3He, A>3?
- Used for neutron spin structure, GPDs, spin-dependent EMC, tensor-polarized observables...

## Nuclear structure from theory

- Nonrelativistic: EFT interactions with controlled accuracy and 3N forces, few-body bound states
- Light-front: Approximate methods
- Challenges: Non-nucleonic DoF, e.g. intrinsic  $\Delta$ 's; final-state interactions in breakup



## Nuclear breakup detection

- Fixed-target: Breakup detector near target: JLab BONuS, ALERT, TDIS
- EIC: Forward detectors integrated in beam optics and IR design
- Used for identifying active nucleon, controlling nuclear configuration in high-energy process

- Unique “set of tools”
- Methods specific to light nuclei: distinct field of research!
- Synergies with low-energy nuclear structure physics

## Target fragmentation in DIS

QCD factorization and fracture functions, dynamics and spin dependence, nuclear breakup and FSI  
*Ceccopieri, Strikman, Keppel, Weiss*

## Neutron spin structure measurements

Polarized  $^3\text{He}$  DIS/SIDIS, non-nucleonic DoF in nuclear spin structure, polarized deuteron and spectator tagging, neutron GPDs  
*Maxwell, Guzey, Cosyn, Scopetta, Biselli*

## Coherent processes with light nuclei

Heavy quarkonium production and DVCS on light nuclei, nuclear GPDs  
*Joosten, Scopetta*

## Small-x dynamics in light nuclei

Nuclear shadowing, diffraction, quantum fluctuations  
*Guzey, Schenke*

*Topics covered in presentations and group discussions*

## Short-range correlations in light nuclei

Limit of nucleon degrees of freedom, nuclear core, contact formalism, universality, exclusive and inclusive measurements, 3N correlations  
*Sargsian, Boeglin, Piassetzky, Cruz Torres, Pybus, Denniston, Nguyen, Day*

## Nuclear interactions and partonic structure

EMC effect, SRC-EMC connection, QCD structure of SRCs, nuclear pions  
*Miller, Arrington, Segarra*

## Tensor-polarized deuteron

Partonic structure, polarized target development, EIC studies  
*Kumano, Slifer, Long*

## Forward ion detection with EIC

Acceptance and resolution, IR and forward detector design  
*Nadel-Turonski, Hyde, Jentsch*

## Next steps in light-ion physics with EIC

Simulation tools, planning, collaboration  
*Schmookler*

## Observations and conclusions

- Dedicated community, great interest, good interactions
- EIC enables new probes of short-range nuclear structure and interactions: gluons, coherent/diffractive processes
- EIC can not only explore nuclear partonic structure (EMC effect, shadowing) but also resolve open questions in hadronic picture of nuclei (SRCs, nuclear core)
- Forward proton/neutron/ion detection critical for many physics applications (tagging, coherent processes), design/optimization should continue with high priority
- Natural path to EIC for short-range nuclear physics community around JLab/GSI/NICA
- Low-energy nuclear structure in high-energy processes: Theory input needed, synergies with low-energy NP
- Many ideas for light-ion physics studies for EIC Yellow Report and beyond

## Some specific outcomes reported by participants

- Publication on pD scattering with linearly polarized deuteron and gluon transversity inspired by exchanges at workshop: S. Kumano and Qin-Tao Song, Phys. Rev. D 101 (2020) 094013
- Publication on short-range correlation and EMC effect studies with D and  $^3\text{He}$  emerged from discussions at workshop: E.P. Segarra et al., 2006.10249
- Collaboration to develop event generator for nuclear DVCS generator advanced by workshop (R. Dupre, S. Scopetta et al.); initiative for new physics studies in coherent processes with light nuclei (V. Guzey, S. Scopetta, M. Strikman, et al.)
- Influence on Workshop “Physics program for the first stage of the NICA SPD experiment,” Dubna, Russia, Oct 5-6, 2020 (Yu. Uzikov et al.) [\[Webpage\]](#); summary of results from CFNS workshop presented by M. Strikman
- Influence on CFNS Workshop “Target fragmentation physics with EIC,” 28-30 2020 (J.-H. Lee, M. Ruspa, A. Stasto, M. Strikman, C. Weiss) [\[Webpage\]](#)

- Excellent communication with CFNS staff  
Socorro Delquaglio, Marlene Vera-Viteri, Rachel Nieves, Ciprian Gal, Jinlong Zhang, Barak Schmookler & Colleagues
- University-based venue very well suited
  - Participants enjoy informal, relaxed atmosphere
  - Short distances (coffee, food) enable interactions, flexibility
  - Contacts with SBU students, postdocs, and faculty
- Good experiences with transportation and accommodation