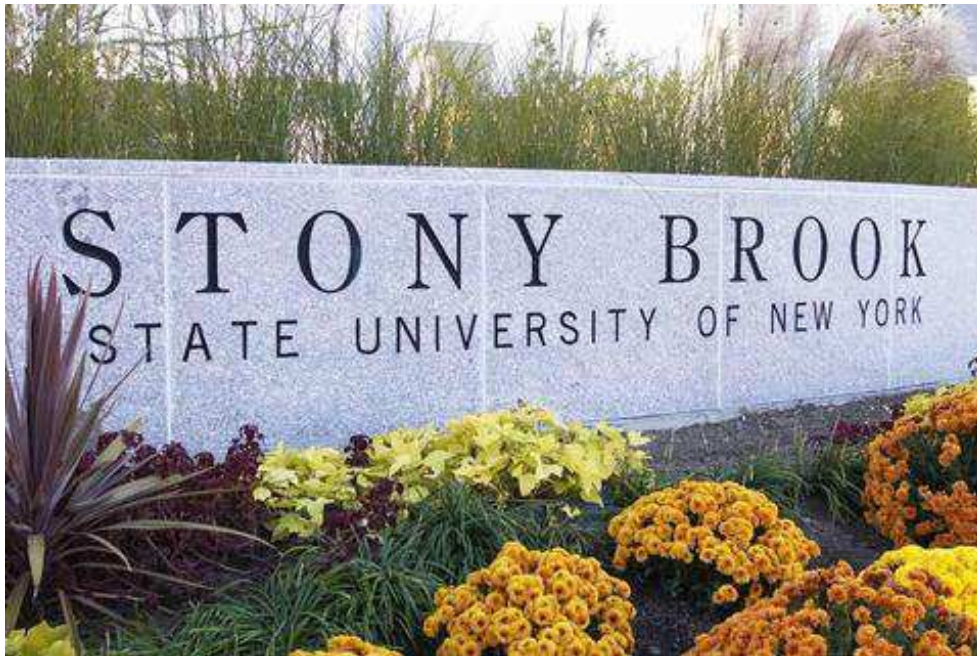


Next-generation GPD studies with exclusive meson production at EIC

Topical Workshop, Center for Frontiers in Nuclear Science,
Stony Brook University, 4-6 June 2018

Marie Boër, Salvatore Fazio, Lech Szymanowski, Christian Weiss (Organizers)



- Welcome
- Context and objectives
- Plan of meeting



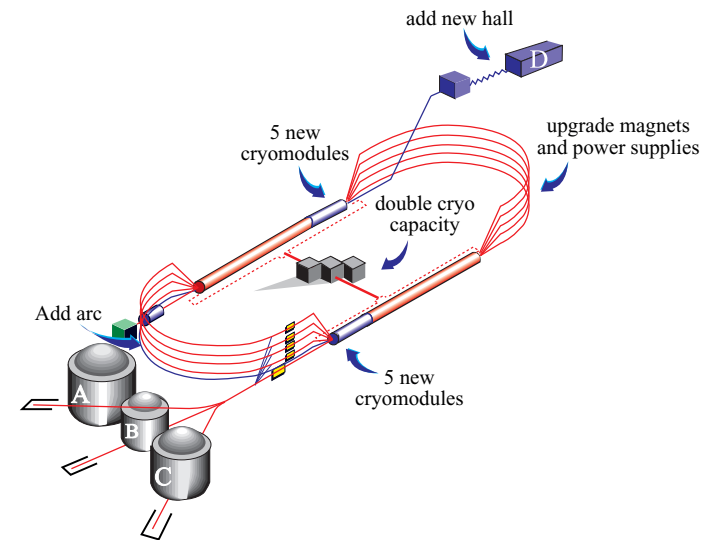
Nuclear physics with EM probes

- JLab 12 GeV operations started

Hall A & D first physics results, Hall C physics running, CLAS12 engineering run

Four-hall operation demonstrated

Expect physics results 5-10 years



- CERN COMPASS muon beam

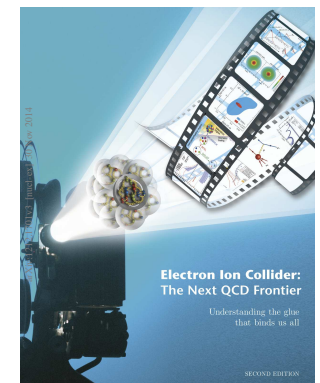
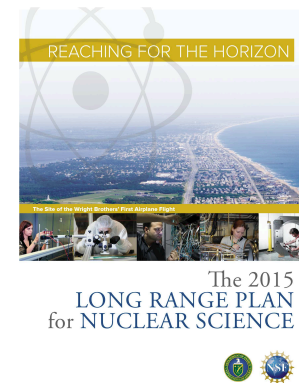
- Electron-Ion Collider as future facility

Recommended in 2015 NSAC Long-Range Plan

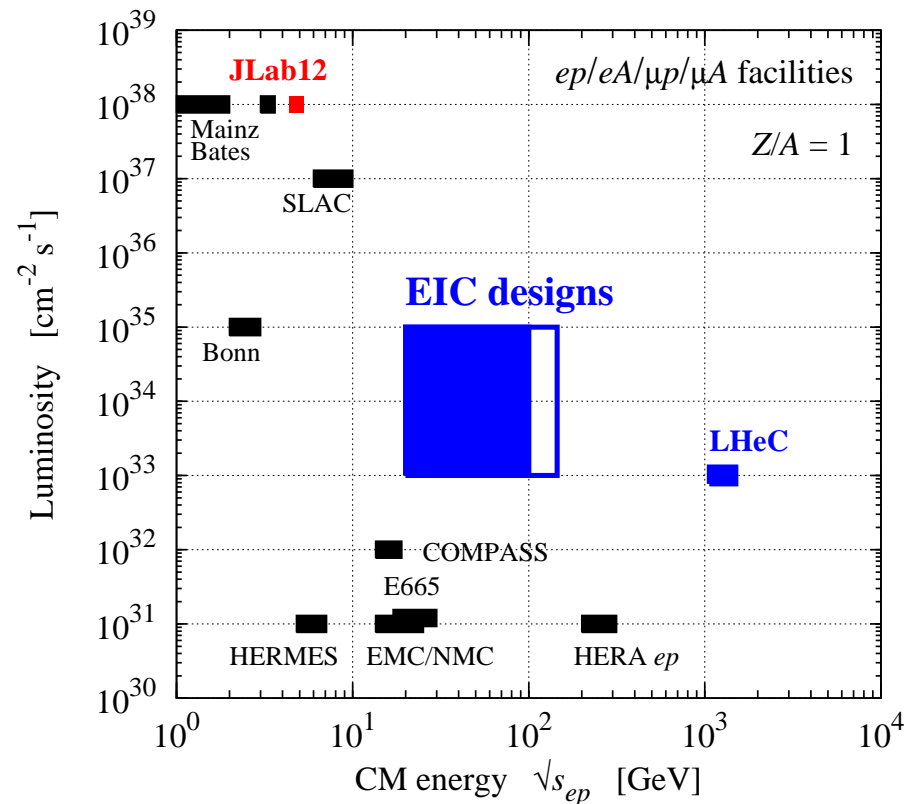
Designs by BNL and JLab

Vigorous accelerator and detector R&D

Driving physics research in exp & thy



- Ultraperipheral pA/AA at LHC, RHIC



- CM energy $\sqrt{s_{ep}} \sim 20\text{--}100$ GeV

Deep-inelastic scattering at
 $x \sim 10^{-1}\text{--}10^{-3}$, $Q^2 \lesssim 10^2 \text{ GeV}^2$

- Luminosity $\sim 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$
 - Low-rate processes
 - Multi-variable final states
 - Polarization observables
- Polarized protons and light ions
 - eRHIC: pol ^3He
 - JLEIC: pol d and ^3He with figure-8
- Forward detection of p, n, A
 - Exclusive and diffractive processes
 - Nuclear breakup and spectator tagging

EIC physics areas

I) 3D nucleon structure and spin

Sea quark and gluon polarization, nucleon spin decomposition
Spatial distributions and orbital motion of quarks/gluons
Quark-gluon correlations

II) QCD in nuclei

Nuclear quark/gluon densities, NN interactions in QCD
Color transparency and opacity
Nonlinear effects and gluon saturation at small x

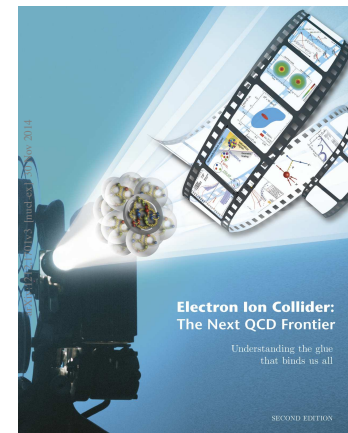
III) Emergence of hadrons from color charge

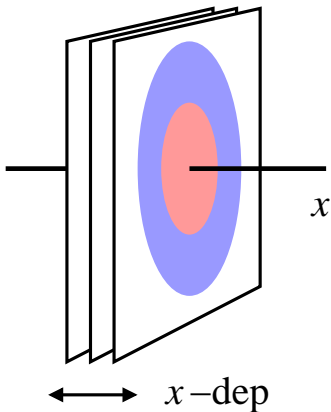
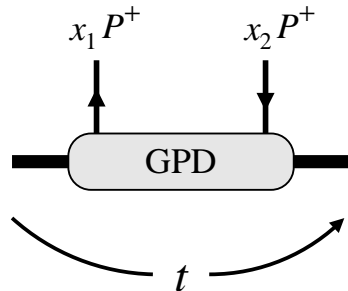
Quark/gluon fragmentation and hadronization
Interaction of color charge with matter

IV) Electroweak physics

Evolving program! Open to new ideas – concepts, measurements, connections

Topical workshops. INT Program Oct-Nov 2018.





$$\langle N' | \hat{O}_{\text{QCD}} | N \rangle$$

- Unify concepts of parton density and form factor

Objectively defined, measurements \leftrightarrow calculations

- Establish “3D structure” of nucleon in QCD

x -dependence, gluons \leftrightarrow sea \leftrightarrow valence quarks

Connection with dynamics

- Access “new operators” in QCD

Angular momentum of quarks and gluons

\rightarrow Burkardt, Rajan

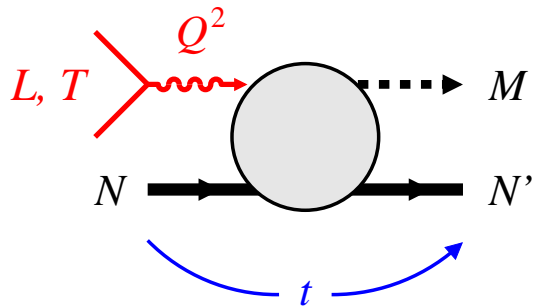
Energy-momentum tensor

\rightarrow Schweitzer, Zahed

Chiral-odd structures and transversity

\rightarrow Liuti

Exclusive meson production



- Exclusive electroproduction
 - Q^2 size of probe, resolution scale
 - t size of target configurations

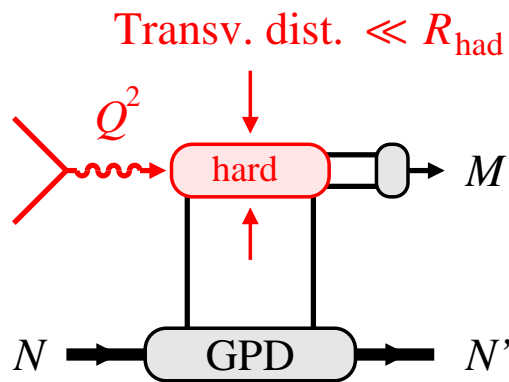
- Exclusive production at $Q^2 \gg (\text{hadronic size})^{-2}$

Transverse distances in interaction \ll hadronic size

Collinear factorization: GPDs \times hard process \times DA
 Collins, Frankfurt, Strikman 96

$Q^2 \rightarrow \infty$: Pointlike $q\bar{q}$ pair, pQCD interactions,
 L response dominant

$Q^2 \sim \text{few GeV}^2$: Finite size distribution,
 non-perturbative interactions, $L + T$ responses



Exclusive meson production: Questions

- Where does approach to small-size regime take place?

How to observe & quantify it?

Model-independent criteria?

- What interactions mediate the production process?

How to account for finite-size effects?

pQCD interactions with finite-size corrections

Frankfurt, Strikman, Koepf 96+; Musatov, Radyushkin 97; Goloskokov, Kroll 08+

→ Kroll

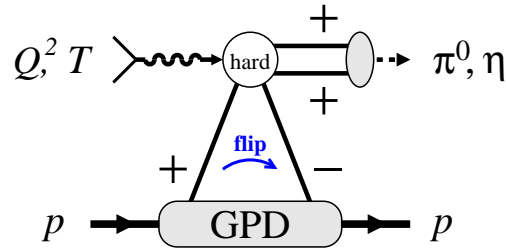
Non-perturbative interactions, chiral symmetry breaking?

- What structures in nucleon and meson are probed?

GPDs: Quarks vs. gluons, chiral even-odd, spin-flavor

Meson DAs: chiral even-odd, higher twist

Questions are interrelated. Need to consider all available evidence.
Need to assess channel by channel. Need experimental data and theory.



- Helicity-flip mechanism (Twist-3)

Goldstein Liuti et al. 08+, Goloskokov, Kroll 11+

→ Kroll, Liuti

Large helicity-flip pion DA from χ SB

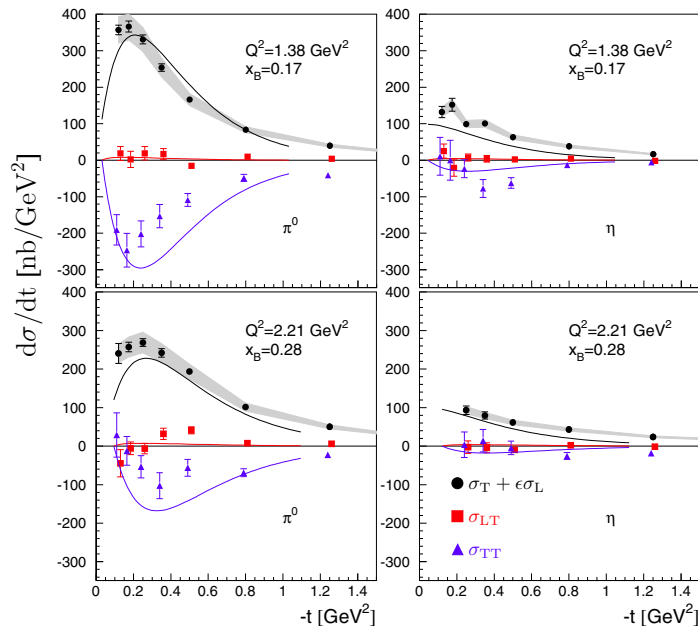
Helicity-flip GPD \leftrightarrow transversity

- JLab experiments $x > 0.1$

→ Roche

6 GeV: Cross sections, L/T responses

12 GeV: Test mechanism



- Topics

Structure of helicity-flip GPDs?

→ Tezgin

Pseudoscalars at $x < 0.1$?

HERMES, COMPASS

→ Van Hulse, Sandacz

Role of helicity-conserving mechanism?

GPD physics with π^+ / K^+ ?

Prospects for EIC?

→ Discussion

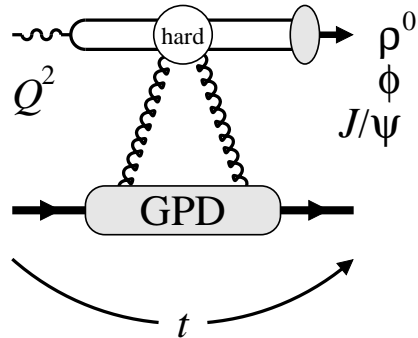
CLAS6 2017 Bedlinskiy et al.
Also: Flavor separation using π^0 / η

- Collinear description with finite-size effects

Brodsky et al. 94; Frankfurt, Strikman, Koepf 96; Goloskokov, Kroll 08+

Cross sections, kinematic dependences

Space-time picture \leftrightarrow dipole model, k_T factorization



- HERA experiments $x = (10^{-4}, 10^{-2})$

[→ Van Hulse](#)

Approach to small-size regime, t -slope of gluon GPD

- Many opportunities with EIC!

- Topics

Establish mechanism, universality of gluon GPD

$J/\psi \leftrightarrow \phi \leftrightarrow \rho^0, \gamma$

[→ Discussion](#)

Nucleon imaging of gluons and singlet quarks

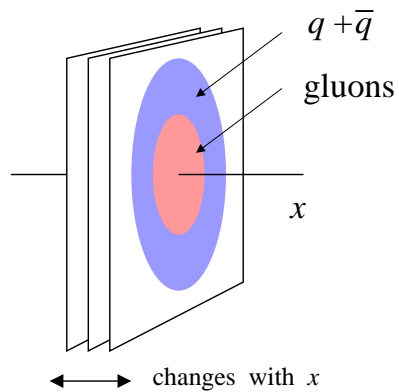
Helicity-flip structures at small x ? Spin observables?

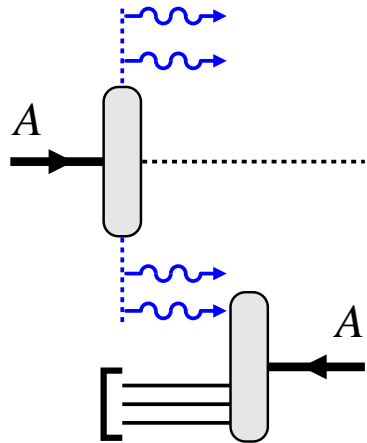
COMPASS ρ^0 spin density results

[→ Sandacz, Diehl](#)

Non-singlet vector meson channels at small x ?

QCD Reggeon \leftrightarrow Pomeron





- Ultraperipheral AA/pA collisions

Use Weizsäcker-Williams photons of nucleus

Highest available energies $W = 500\text{--}1800$ GeV

- Hard exclusive processes

Heavy meson production

Dilepton pairs

- Topics

Heavy meson production in UPCs at LHC

→ Anson

Nuclear shadowing in heavy meson production

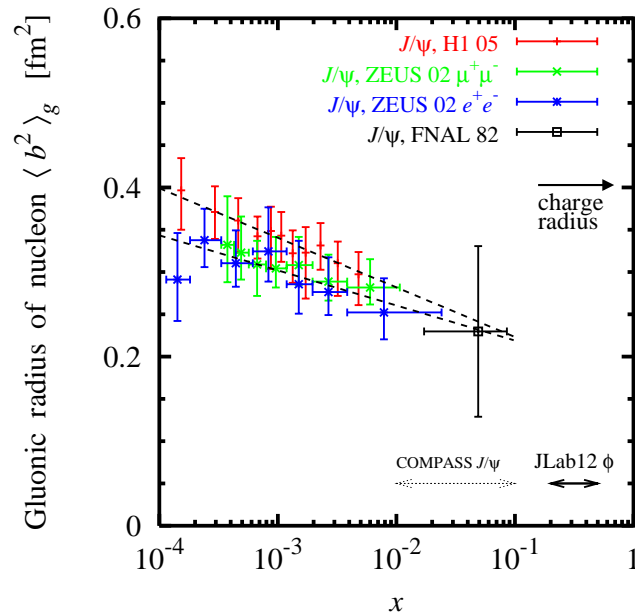
→ Guzey

Simulation tools from photoproduction for electroproduction
eSTARLIGHT

→ Klein

GPDs in dilepton photoproduction at RHIC

→ Aschenauer, Wagner

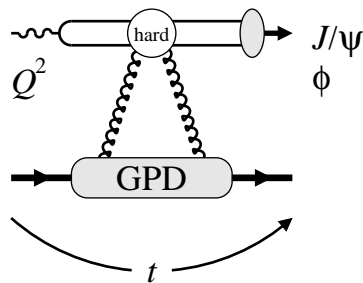


- $J/\psi, \phi$ gluon-dominated at large x

Use for gluon imaging

- Light VM production at large x ?

Mechanism? GPD-based description?



- Topics

Gluon imaging at large x

→ Joosten

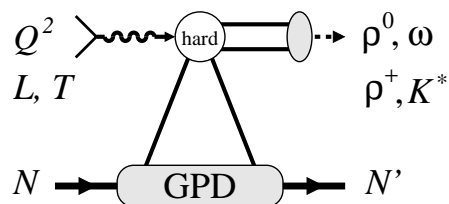
Light VM and GPDs at EIC

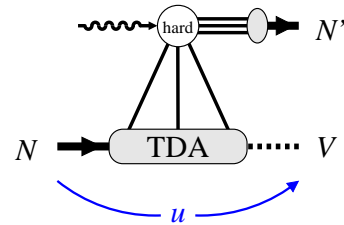
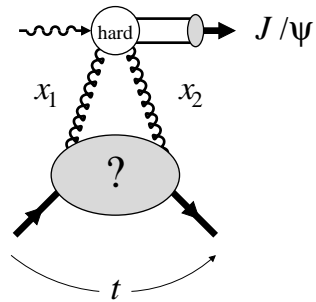
→ Discussion

Polarization observables in VM production

$\pi\pi$ production in ρ and σ channel

→ Bulumulla





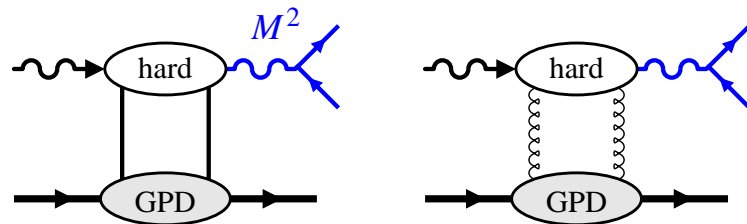
- Near-threshold J/ψ production → Paremuzyan

$|t_{\min}| \sim 2 \text{ GeV}^2$, high- t gluon GPD

- Backward meson production → Wenliang Li

$|u| \ll 1 \text{ GeV}^2$, $N \rightarrow M$ transition DA

Exclusive dilepton production



- Photoproduction of high-mass dilepton

Timelike version of DVCS
access to $\text{Re}(\text{Amp})$

→ Wagner

JLab12 experiments

→ Boer

UPCs at RHIC

→ Aschenauer

Potential at EIC

→ Discussion

Theoretical description — factorization, approach to small distance regime

Access to GPD components — spin, flavor, quarks/antiquarks/gluons

Experimental challenges — detection, analysis

→ Discussion

EIC detector and simulation tools

- Forward detection for exclusive processes: requirements, implementations

→ Furltova, Kiselev

- Simulation tools: status, development needs

→ Joo, Fazio

- Possibilities for collaboration

→ Discussion