



S. Fegan/N. Santiesteban University of York/University of New Hampshire June 8th, 2023



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Uncovering Hadron Structure With Generalised Parton Distributions, A.V. Belitsky and A.V. Radyushkin

	UNIVERSITY	Introduction	The EIC	DVMP Studies	Summary and Outlook
	of Vork	Accessing GPDs			
	June				



- GPDs are experimentally accessed via DVCS (left) and DVMP (right)
- DVMP, Deeply Virtual Meson Production, is an analogous process to DVCS, where a meson is produced in the final state instead of a photon.

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arXiv:1511.04535

- Heavy vector mesons, such as J/Ψ and Υ , can probe gluon GPDs
- This can provide information about saturation by measuring the change in the spatial gluon distribution from low to high x_B
- However, this lies beyond current JLab kinematics



- The Electron Ion Collider, has been designated by the US Department of Energy as the next machine to address fundamental questions in QCD and hadron structure
- EIC will operate at the intensity frontier, reaching well into gluon dominated kinematics
- A range of experimental probes will explore QCD at a single facility



US DOE Office of Science



- Precision of the electromagnetic interaction will be combined with the determinative properties of polarised nucleon beams
- Heavy ion beams for in-depth studies of nuclear matter
- Addressing burning questions in nuclear physics
 - What is the internal arrangement of quarks and gluons in nucleons and nuclei?
 - What role do quarks and gluons play in overall nucleon properties, such as spin?
 - How does the nuclear environment affect quarks and gluons in nuclei?
- To do this, we need
 - High energy
 - High luminosity
 - The ability to exploit polarisation in beams and targets
- We need the EIC!



In late 2019, the DoE announced "Critical Decision-0" for the EIC, formally commencing the project

CD-0 also outlined the basic design requirements

- Highly polarised electron and proton beams (70%)
- Ion beams ranging from deuterons to heavy nuclei such as gold and lead
- Centre of mass energies of 20-100 GeV in e + p collisions (upgradable to 140 GeV)
- Luminosities of $10^{33} 10^{34} \text{cm}^{-2} \text{s}^{-1}$
- Possibility of more than one interaction region

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	fyork	EIC Reach			





In early 2020, Brookhaven was announced as the host lab for the EIC

- Existing RHIC beamline will be upgraded, with an electron accelerator installed in the same tunnel
- The first detector, ePIC, will be located at one of the interaction regions (IP6)





Essentially a merger of two "Detector One" concepts

- ECCE EIC Comprehensive Chromodynamics Experiment
- ATHENA A Totally Hermetic Electron-Nucleus Apparatus



- Intended lower risk design, with a BaBar-derived magnet
- Barrel plus two endcaps for large acceptance
- Leveraging established and state-of-the-art detector technologies for maximum effect



ePIC consists of three major components:

- Central Detector
- Far Forward Systems
- Far Backward Systems



 Forward detector in the hadron/nuclear beam direction, backward detectors in the electron beam direction





 Forward detector in the hadron/nuclear beam direction, backward detectors in the electron beam direction



Both the ATHENA and ECCE groups have published numerous aspects of their studies, providing useful benchmarks for our continuing work in ePIC



- Exclusive vector meson channel J/Ψ , studied in ECCE
- \blacksquare Recall our motivation to study gluon GPDs using heavy vector mesons, such as J/Ψ
- Simulation focussed on J/Ψ, but potential to expand to lower (φ) and higher mass vector mesons (ψ(2s), Υ)
- Goal of evaluating ECCE performance against VM event generators and show feasibility of measurement



IAger - Argonne generic I/A-event generator (S. Joosten)

- The LAGER generator was used to produce event samples for the ECCE studies presented.
- Modular accept-reject generator, capable of simulating both fixed target and collider kinematics
- \blacksquare Significant recent developmental effort in support of DVMP studies, with a focus on J/Ψ and Υ

DEEPsim (M. Boer, VT)

- Derived as an extension of an existing generator used for fixed target experiments at JLab
- Focus on ϕ and J/Ψ , opportunity for complementary studies



lAger generated J/Ψ event samples on eP collisions, 10 fb⁻¹ at 18×275 GeV











J/Psi decay products (Top: electron, Bottom: positron)







Scattered proton detection in Roman Pots. B0 outside acceptance of kinematics studied

S. Fegan	Hadron 2023, Genova	June 8th, 2023	16/22





- Scattered electron distribution
- Some J/Ψ decay electrons will be seen at negative η
- MC truth was used for this study
- Keenly aware of the need to be able to separate these experimentally



- J/Ψ Differential cross section
- Physics interest will come from the evolution over -t
- Q² dependence will be useful for multi-dimensional binning



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	of York	Next Steps for J_{j}	/Ψ		
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- Studies shown from the ECCE detector model
- The ePIC design uses this as a starting point, but generated events have been processed through the latest geometry
- Investigations motivated by lessons learned so far (e.g. can we adequately separate scattered electron from J/Ψ decay electron in the real world?)





- Generate and repeat studies for other Vector Mesons of interest
- A limited event sample was produced for Υ , but not yet passed through ePIC geometry
- Complimentary study with J/Ψ events from DEEPsim
- Other VM, e.g. $\Psi(2S)$



The EIC is one of the next big machines in nuclear physics



- First beam expected in the early 2030s
- Will reach well into gluon dominated kinematics with unprecidented precision
- Leveraging polarisation, electromagnetic probes and heavy ion beams to enhance deteminative properties of this machine
- DVMP with VM is feasible in an EIC detector design



- This work is part of the Exclusive, Diffractive and Tagging working group, one of many physics working groups in the ePIC collaboration
- The ECCE simulation studies are from an earlier iteration of this group, with a publication in process (arXiv:2208.14575)
- Thanks to all my collaborators, particularly in the relevant software groups for providing the tools to realise this work, and processing events through the detector concepts
- Special thanks to Nathaly Santiesteban (UNH), whose analysis was at the heart of the J/Ψ studies in ECCE
- Several other ePIC talks this week at Hadron 2023, showcasing the plans and physics capabilities of this upcoming facility