Jefferson Lab
Thomas Jefferson National Accelerator Facility
Exploring the Nature of Matter

Laboratory Directed Research and Development Letter of Intent
Title: _Geometry_tagging_for_heavy_ions_at_JLEIC_

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Proposal Term:	**From:** 10/2016 **Through:** 9/2018 **If continuation, indicate year (2nd/3rd):**

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Abstract

Electron-ion collisions naturally form a major part of the physics program at the Electron-Ion Collider (EIC). In particular, they are essential for realizing key goals of the program for studying QCD, such as investigating parton/hadron propagation in cold nuclear matter, as well as coherence phenomena and QCD at large gluon densities in nuclei. These measurements can be made even more incisive using forward going particles in the ion direction to tag the geometry of the collisions on an event-by-event basis. The large-acceptance detector at the JLab EIC (JLEIC), with full acceptance for forward-going neutrons, protons and nuclear fragments, is ideally suited to such measurements. In fact, the highly integrated interaction region constitutes a unique strength of the JLEIC design approach. In order to fully exploit this technical advantage, this needs to be tied quantitatively to its physics impact, and physics tradeoffs need to be explored between detector capability and the accelerator in terms of the IR design. Therefore, a detailed simulation of these physics processes is currently the highest priority item for finalizing the JLEIC IR design, and optimizing the detector capabilities in preparation for CD0.

To address this issue, we are proposing this LDRD project as a joint effort between the physics and accelerator divisions, with a strong involvement from experts in high-energy nuclear reactions. Specifically, we propose, over the next two years, to apply existing modeling tools (DPMJetHybrid and Sartre) to investigate and develop the geometry tagging capabilities of the JLEIC large-acceptance detector for two of the highest priority items in the EIC White Paper. We will use DPMJetHybrid to address the issue of color propagation in cold nuclear matter, while with Sartre we will address gluon saturation using exclusive diffractive processes. In the second year, we also propose to apply DPMJetHybrid to the e+A program at JLab 12 GeV, where hadron propagation in cold matter constitutes a substantial part of the physics program.

1.0 Summary of Proposal

1.1 Description of Project

Electron-nucleus collisions form an essential part of the program for the Electron-Ion Collider (EIC). The EIC White Paper [1] describes this concisely: “Heavy ion beams are needed to provide precocious access to the regime of saturated gluon densities and offer a precise dial in the study of propagation-length for color charges in nuclear matter”. Unfortunately, a minimum bias scan of beam species (A) is not really all that precise a dial as it only gives a limited experimental handle on the amount of nuclear matter traversed by the collision products, and it also involves substantial accelerator and detector setup time to prepare for new running conditions for each new species. The detection of the nuclear final state can significantly improve the precision and reach of the nuclear path length “dial”, through the technique of geometry tagging.

Geometry tagging is an experimental analysis technique for selecting event samples where we can, on a statistical basis, control the geometry of the collision in order to make more incisive physics measurements. This technique has been heavily exploited in heavy ion (AA) collisions at RHIC and the LHC, and played an essential role in the discovery and detailed characterization of the quark gluon plasma (see e.g. [2]), but it has seen only very limited use to date in deep-inelastic scattering. Several physics measurements at the EIC would benefit significantly from the use of this technique, including studies of gluon anti-shadowing, studies of parton propagation, attenuation and hadronization in the nucleus, and ultimately the search for parton saturation. Using geometry tagging, we can create an event sample in eAu collisions with a saturation scale or an average path length equivalent to a minimum bias nucleus of size A=600-800. The JLEIC large-acceptance detector, with full acceptance for forward-going neutrons, protons and nuclear fragments and a high data-taking rate should be ideally suited to such geometry tagging.

We propose a dedicated R&D Project to apply existing modeling codes and detector descriptions to study this physics. In order to study color propagation in the nucleus, we will use DPMJetHybrid to investigate the geometry tagging capabilities of the JLEIC large-acceptance detector in semi-inclusive deep inelastic scattering (SIDIS) at modest Bjorken x ($x>0.02$) where the complications of nuclear shadowing can be avoided. DPMJetHybrid [3] combines the nuclear modeling of DPMJet, including a Glauber model with formation-time suppressed intranuclear cascading and a nuclear evaporation model, with Pythia, and a parton quenching afterburner [4-5] based on the Salgado-Wiedemann quenching weight formalism [6] for final state interactions. This will allow us to estimate the capabilities of the JLEIC detector to study the in-medium propagation of color charges and the space-time evolution of the hadronization process [7]. We will then use Sar*t*re [8] combined with DPMJetHybrid to estimate the geometry tagging capabilities of the JLEIC large-acceptance detector for inclusive incoherent diffraction, as "central" diffractive events have been shown to be sensitive to rare parton configurations with a large saturation scale Q_s [9]. In order to study gluon saturation more directly, we will use Sar*t*re [8] to compare coherent diffraction of J/ψ & ϕ which is a sensitive measure of gluon saturation [8,10]. In the case of coherent diffraction, we are not tagging the geometry per se, but rather the fact that the nucleus remains intact for coherent events. We also plan to test our ability to tag "truly coherent" events where the nucleus not only remains intact, but also unexcited.

The project meets three of the criteria for eligibility for JLab LDRD support: 1) Advanced study of new hypotheses, new concepts and innovative approaches to scientific or technical problems; 2) Conception and preliminary technical analysis of experimental facilities or devices. 3) Computer modeling, conceptual design and feasibility studies.

The project addresses a key DOE Office of Science mission: "fundamental understanding of matter and energy", by advancing our understanding of QCD and of the strong interaction as discussed in the 2015 Long Range Plan for Nuclear Science [11]. Specifically, this proposal is relevant to Section 2 "Quantum Chromodynamics: The Fundamental Description at the Heart of Visible Matter" particularly Section 2.3 "Understanding the Glue that Binds Us All: The Next QCD Frontier in Nuclear Physics".

1.2 Expected Results

Specific expected results include:

- The implementation of the model codes at JLab, interfacing them to detector simulations and making any needed improvements.
- A detailed study of the resolution of the nuclear geometry parameters *d* (distance traveled in the nucleus after first collision) and *b* (impact parameter), in SIDIS and incoherent exclusive diffractive events using the JLEIC Large Acceptance Detector.
- A detailed study of the efficiency and purity of the tag for coherent exclusive vector diffraction.
- Measuring the physics impact of various forward detector capabilities:
    - Very large neutral Zero Degree Calorimeter acceptance
    - Complete coverage for protons (and other Z=+1 particles)
    - Coverage for nuclear fragments
    - Coverage/id of forward photons
    - Coverage for forward negatively-charged particles
- Simulated physics results showing the ability of JLEIC to use geometry tagging to address key goals of the EIC Program:
    - Study the sensitivity of JLEIC to gluon saturation by tagging exclusive coherent diffractive events and showing that the gluon distribution seen by ϕ particles is suppressed at small impact parameters, using the J/ψ as a control.
    - A detailed study of light and heavy flavor propagation in the target nucleus to better confront and constrain theoretical models of in-medium parton propagation and hadronization.
- Development of a simulation and a plan for how to explore geometry tagging using already approved JLab 12 experiment (E12-06-117). This will improve the scientific reach of the experiment and help validate the simulation tools developed.

2.0 Proposal Narrative

2.1 Purpose/Goals

Electron-ion collisions are essential for realizing key goals of the EIC program for studying QCD. Specifically, heavy ion beams are needed in order to access the regime of saturated gluon densities at EIC energies, and to study the propagation of color charges in nuclear matter.

The purpose of this proposal is to make these measurements even more incisive using forward going particles in the ion direction to tag the geometry of the collisions on an event-by-event basis. For a given energy and nuclear beam species, this will allow even better access to saturated gluon densities and it can significantly improve the precision and reach of the nuclear path length "dial" for the study of color-charge propagation. The JLEIC Large-acceptance detector, ideally suited to such measurements, constitutes a unique strength of the JLEIC design approach. In order to fully exploit this advantage, the JLEIC technical advantages need to be tied quantitatively to physics impact and physics tradeoffs need to be explored between detector capability and the accelerator in terms of the IR design.

2.2 Approach/Methods

Due to the different strength of the primary fundamental interaction, geometry tagging in eA collisions is different than in AA or pA collisions and presents several unique challenges and opportunities. The relatively weaker interaction of the virtual photon with the nucleus reduces the multiplicity of the primary particle production in the eA collision compared to pA. As an advantage, this means that the effects of evaporation from the excited nucleus and intranuclear cascading are much easier to detect. In fact, the main experimental handles we have are neutrons produced by evaporation from the excited nuclear remnant after the collision [12-14], and "knock-out" protons and other charged particles produced during the primary interaction or during the "intranuclear cascade" as remnants of the primary collision re-interact with the rest of the nucleus [15-16]. These experimental handles are correlated with the nuclear path length seen by the reaction products [14]. Previous models of geometry tagging in eA have focused on either evaporation neutrons [13-14] or charged particles [16], but not both together.

On the technical front, the JLEIC Large Acceptance Detector, capable of detecting nuclear fragments of all rigidities over a wide range in transverse momentum, p_T, will represent a significant advance in capability over previous (fixed target) studies which comprised low-efficiency soft neutron measurements [12] and high-efficiency, but very low statistics, measurements of highly ionizing (low energy) charged particles using emulsions or streamer chambers [15-16]. The combination of large acceptance and high luminosity will allow us to measure the number of neutrons, protons and even charged nuclear fragments on an event-by-event basis with large statistics, which will allow fine binning in new degrees of freedom. This capability will provide an unprecedented handle on nuclear effects and geometry tagging.

Figure 1, reproduced from [14], shows the definition of "*d*", the path length traveled in the medium following the first collision. In many A-dependence studies, such as in semi-inclusive hadron production, eA→e'hX, we have to average over all possible values of *d,* potentially washing out our desired physics effect. Figure 2 shows the distribution of *d* (labeled as distance) for minimum bias e+A DIS collisions on a variety of nuclei. The average value of *d* increases with A, $<d> = 2.75 + 0.82A^{1/3}$, but, for each nucleus A, the distribution in *d* is quite wide and there is substantial overlap between the *d* distributions for different choices of A. Figure 3 shows the result of a centrality selection based on evaporation neutrons (the larger the number of detected evaporation neutrons, the longer the in-medium interaction). There are two features that are advantageous: first of all the two samples are more distinct and second, the <*d*> (9.7 fm) for the central eAu sample is quite a bit larger than for the minimum bias. To get a <*d*> value that large with a minimum bias eA would require an unphysical value of A,

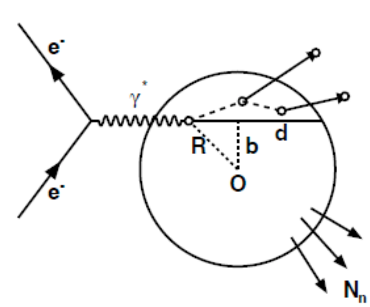

Figure 1. Geometric parameters *b*, representing the impact parameter, and *d*, the distance traveled in the nuclear medium after the first collision. Reproduced from Ref.[14].

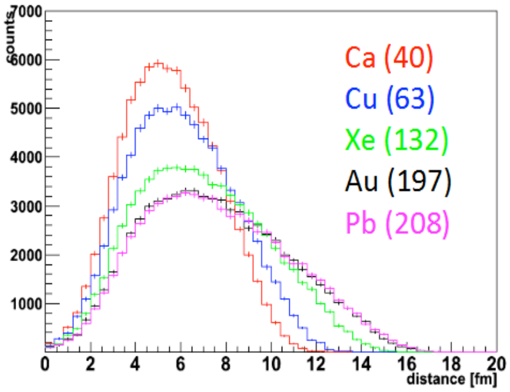

Figure 2. Distance (d) distribution for minimum bias DIS collisions for e+A on five nuclei at 10x100 GeV/A.

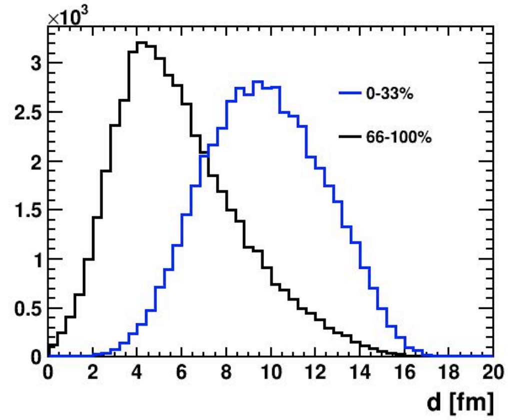

Figure 3. Distribution in d for a peripheral (black, leftmost) and central (blue, rightmost) selection of data in 10x100GeV/A e+Au using evaporation neutrons detected in a 4mr ZDC. Adapted from Ref.[13].

approximately 600, which is triple the size of the Au nucleus.

The resolution shown in Figure 3 for 100 GeV/A nuclei would also apply at JLEIC energies (40 GeV/A), given our expected neutron acceptance of q<10mr. It should be noted that we expect to achieve an improved resolution in *d* by using more information than just the forward neutrons, as we expect high efficiency for the detection of forward fragments over a very wide kinematic range. In particular:

- Neutrons can be detected in a high resolution (~30%/√E, 0.3 mr for energy and angular resolution) ZDC in a cone of half-opening angle 10 mr (q<10mr).
- Protons, deuterons, and other light charged fragments will be detected with high resolution and PID in a cone of half-angle 8mr (conservative 6T baseline)
- Wide angle charged fragments (up to a 75 mr half-angle cone, offset 25 mr from the ion beam direction) will be analyzed in the 2 Tm forward dipole with a momentum resolution Dp/p~(0.2%)p/GeV. This includes negative fragments, e.g. pions.

Using DPMJetHybrid and the JLAB Large-Angle Detector simulation, we will be able to study the propagation of strongly interacting matter in the nucleus. The EIC White Paper[1] again describes this well: "The suppression [of fast moving hadrons produced in relativistic heavy ion collisions] is believed to be due to the energy loss of colored partons traversing the QGP. It has been puzzling that the production is nearly as much suppressed for heavy as for light mesons, even though a heavy quark is much less likely to lose its energy via medium-induced radiation of gluons. Some of the remaining mysteries surrounding heavy vs. light quark interactions in hot matter can be illuminated by EIC studies of related phenomena in a better known cold nuclear matter. The variety of ion beams available for electron-nucleus collisions at the EIC would provide a femtometer filter to test and to help determine the correct mechanism by which quarks and gluons lose energy and hadronize in nuclear matter." Geometry tagging should allow us to significantly extend the reach of this "femtometer filter" in <*d*> as well as potentially providing narrower distributions in *d* for each sample (see Figures 2 and 3). In the second year of the proposal we will extend the geometry tagging studies to lighter nuclei such as Ca, and heavier nuclei such as U. In the case of light nuclei, we can determine if we have any resolution for <*d*> bins in such collisions. In order to study eU collisions, we will need to upgrade the code to handle deformed nuclei, which will allow us to potentially extend our <*d*> reach even further as some collisions will occur when the nucleus is oriented with the long-axis along the direction of the γ*.

In addition, during year 2, we will investigate the use of DPMJetHybrid at fixed target JLab energies. While not as easy to detect as in the collider mode, slow recoil nucleons can be informative even in fixed target experiments [12]. In particular, the experiment E12-06-117 approved for CLAS12 plans to study parton propagation with a wide scan of nuclear species (up to Au or Pb) and should be able to use the developed tools with minimal adaptation. The event generator described above will need only minor adaptation of its parameters to describe lower energy DIS and can therefore be used to prepare for the JLab 12 measurement. This study will allow us to explore the possibility to perform geometry tagging in this experiment, enhancing significantly its scientific reach and at the same time allowing us to directly check against data, when they will be available, some of the main assumptions made for the development of the event generator. The tools developed in this proposal will facilitate the analysis and enhance the physics output of many proposed JLab12 experiments, making these timely and relevant for the design of the EIC project.

Geometry tagging at JLEIC is also valuable for understanding the transition from a diluted to a saturated gluon state because the higher density for small impact parameter b (see again Figure 1) increases the saturation scale Q_s^2 [17]. Figure 4, adapted from the EIC White Paper [1], can help us quantify the value of geometry tagging. The curves represent the saturation scale Q^2_s for a given value of Bjorken x for four cases: minimum bias ep, minimum bias eCa, minimum bias eAu and central eAu. The ep and eAu minbias curves at fixed x differ by a factor of $A^{1/3}$ (~6 for Au), which is often called the nuclear "oomph" factor. At fixed Q^2, the ep and eAu curves differ in x by a factor of about 300. Since the minimum achievable x value at fixed Q^2 is given by $x_{min} \cong Q^2/s_{eN}$, where s_{eN} is the square of the e-nucleon cms collision energy, an eAu collision has a saturation reach similar to an ep collision with a factor 300 larger beam energy ($s \cong 4E_e E_N$). This immediately illustrates the power of using eA collisions to search for saturation effects. We can perform a similar exercise, comparing central and minimum bias eAu collision, which allows us to quantify the additional geometric "oomph" factor of about 1.6, potentially achievable using geometry tagging. This is equivalent to either using an effective A of ~800 or an additional shift in E_{beam} of 3.3, for a bin where the geometry tagging is used to enhance the Q_s^2 of the sample. Thus, the impact of the combination of geometry tagging and high luminosity on the reach in Q_s^2 is almost exactly equivalent to an increase of the accelerator energy for eAu from 12 on 40 GeV/A to 20 on 80 GeV/A. A future energy upgrade would further add to this effective Q_s^2 reach.

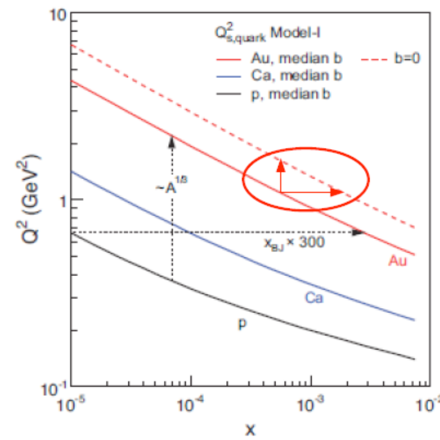

Figure 4. Theoretical expectations for saturation scale for p, minbias Ca and Au and central Au. Adapted from Fig 3.9 of Ref.[1].

In order to have a first look at this physics, we will use a combination of the DPMJetHybrid and Sar*t*re codes to investigate the geometry tagging capabilities of the JLEIC Large Angle detector for central (small "b") incoherent exclusive diffractive events. In general, measuring b is more difficult than measuring d (see e.g. [14]), so the complete coverage for neutrals and charged particles may be a significant advantage for JLEIC. E665 showed that even a single slow charged particle in the nucleus rest frame ("grey track") is an excellent tag for the existence of an Intra-Nuclear Cascade (INC) [16], which in turn should be correlated with large d and small b. It is possible that forward negative charged hadrons, again unique to JLEIC, will also be a sensitive measure of INC since forward π^-'s are otherwise rare.

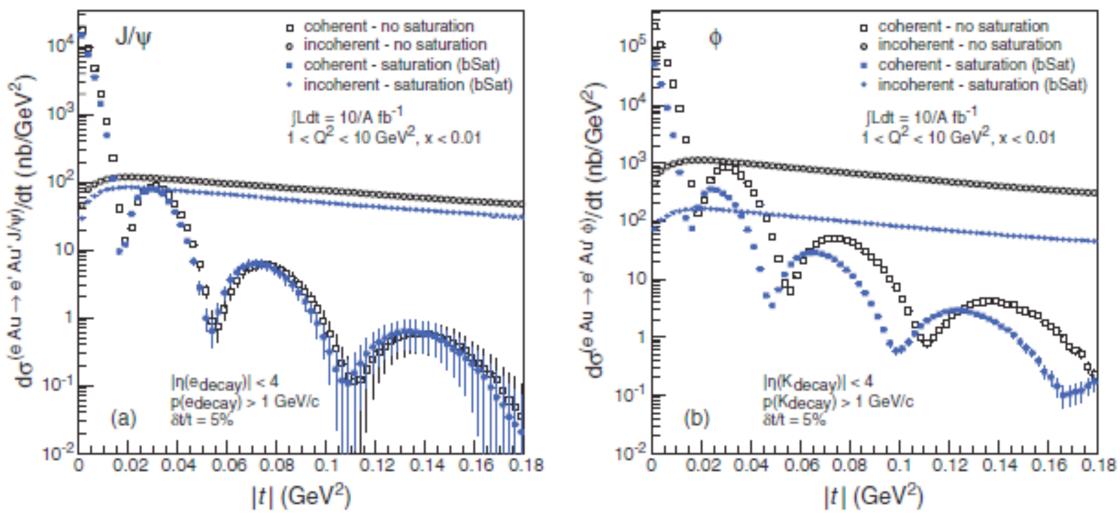

Figure 5. Differential distributions with respect to t for coherent and incoherent (a) exclusive J/ψ and (b) ϕ production from Ref. [8].

Finally, another powerful probe of gluon saturation is coherent exclusive diffraction: comparing J/y and f production in cases where the nucleus remains intact, leading to a quantum mechanical diffraction pattern. By measuring this to large values of the target four-momentum transfer, $|t|$, we can obtain a Fourier transform of the gluon distribution in the nucleus. In order to measure this diffraction pattern accurately, we must ensure that the nucleus really remains intact and unexcited. Again, this is a potential strength of JLEIC. Figure 5, taken from Ref. [8], shows the t distribution for 20x100 GeV eAu collisions for two different models, one with and one without saturation. Note that at the highest values of t plotted, the coherent diffraction pattern is up to a factor of 1000 smaller than incoherent diffraction, posing an experimental challenge. In this project, we will investigate the efficiency and purity of our ability to tag coherent events by vetoing on incoherent diffraction where nuclear breakup products are detected. For heavy elements, such as Pb, we will look for neutrons, protons or light nuclear fragments. We will also study our ability to veto events where the nucleus was excited to bound states below neutron threshold. For ^{208}Pb, specifically, we will use the fact that all gamma-decays either pass through the $3^{-}\rightarrow$g.s. 2.614 MeV transition, or through a higher energy g-decay[18]. For a 40 GeV/A Pb beam, the relativistic boost is ~40. Thus ≥50% of these photons will be detectable either in the ZDC, or a pre-Ecal, or in the high resolution $PbWO_4$ forward calorimeter in front of the first ion FFQ. In fact, most of these decay sequences have multiple photons above 1 MeV in the Pb rest frame, which will further enhance the veto-tagging efficiency.

In year two, we will extend our study of coherent diffraction to include a lighter nucleus, Ca. Comparing the diffraction pattern for J/y and f for both a light and a heavy nucleus should provide a stronger constraint on the physics. In this case, we may be able to detect *all* of the products of a nuclear breakup, including a large nuclear remnant, such as ^{39}Ca (after a neutron emission) or ^{39}K (after a proton emission).

In summary, this proposed project, "Geometry Tagging for Heavy Ions at JLEIC", when completed, will highlight the fact that key strengths of the JLEIC design allow us to fully realize two of the key goals of the EIC program for studying QCD with eA collisions: studying parton/hadron propagation in "cold" nuclear matter as well as the approach to saturation in QCD at large gluon densities. Simulation and analysis tools will be in place to take advantage of the unique JLEIC capabilities and to refine the design of its large-acceptance detector.

2.3 Specific Location of Work

The development and adaptation of the event generators will be subcontracted to Mark Baker (MDBPADS). Having played a significant role in developing AA geometry (centrality) tagging in PHOBOS, and being a co-author of E665, Mark is an expert in the field whose input is essential for the success of the project. Mark will carry out most of the work remotely, but be in close contact with the JLab staff.

The work on detector simulations and development will be undertaken at JLab by the postdoc, who will be supervised by P. Nadel-Turonski (PI). The standard JLEIC GEMC Geant4 framework will be used. V. Morozov will carry out the corresponding design and optimizations for the JLEIC interaction region.

Optimizations of the detector layout will be carried out by C. Hyde and summer student(s) at ODU, in close collaboration with JLab staff.

2.4 Anticipated Outcomes/Results

The project will result in working modeling codes, released to the JLab community, which will allow the study of geometry tagging with realistic detectors in deep inelastic scattering at both JLEIC and JLAB12 energies, as well as exclusive diffractive collisions at JLEIC energies. We expect to perform several studies, detailed below, which should result in multiple presentations at scientific conferences, as well as refereed publications.

Expected results for year 1 focus on implementing new model codes at JLab, interfacing them to the detector simulation, and analyzing color propagation physics using geometry tagging for eAu collisions at JLEIC energy. In addition, we will take a first look at diffraction physics using Sar*t*re and expand it's capabilities by ensuring that the cross-section tables are complete for Au, Pb and Ca.

- By April 2017 (mid-year of proposal year 1)
  - Implementation of the DPMJetHybrid [3] and Sar*t*re [8] codes at JLab, and interfacing them to JLEIC Large-Angle Detector simulations (GEMC).
  - Confirmation that the DPMJetHybrid code is tuned to describe key existing data [12,15,16,19], as well as possible for the non-shadowing region, fine-tuning it if needed.
  - Investigating the interpolation properties of existing Sar*t*re cross-section tables for Au, Pb and Ca. If needed for accurate interpolation at JLEIC energies, we will improve the interpolation mechanism and/or add finer grid tables in certain kinematic regions for Au.
- By October 2017 (end of proposal year 1)
  - A detailed study of the resolution of the nuclear geometry parameters *d* (distance traveled in the nucleus after first collision) and *b* (impact parameter), for SIDIS eAu collisions using the JLEIC Large Acceptance Detector, using DPMJetHybrid.
  - Using the geometry tagging, a detailed study of the ability to constrain key physics model parameters: τ_0 , the average formation time of the produced particles in their own rest frame before they are allowed to participate in intranuclear cascades and *q*-hat, the parameter controlling the strength of particle absorption in nuclear matter.
  - Using the geometry tagging, a detailed study of light and heavy flavor propagation in the target nucleus to better confront and constrain theoretical models of in-medium parton propagation and hadronization.
  - A first look, using Sar*t*re, at our ability to tag coherent diffraction events by rejecting incoherent diffraction based on nuclear evaporation.
  - If needed for accurate interpolation at JLEIC energies, we will add finer grid tables in certain kinematic regions for Pb and Ca.
  - Tuning DPMJetHybrid to JLab12 energies.

Expected results for year 2 of the proposal will include increasing the capabilities of the modeling programs. This will allow us to study the physics of interest more fully as well as to clarify the physics impact of key detector and IR features.

- By April 2018 (mid-year proposal year 2)

  - Implement a 3D version of Glauber in DPMJetHybrid, allowing deformed nuclei such as U to be studied.
  - Using parameterizations of the data on elastic [20-21] and inelastic [22] electron scattering on ^{208}Pb, together with a simple, but qualitatively accurate model [23], we will estimate the relative probability of coherent diffraction to bound excited states vs. coherent diffraction to the ground state in e Pb scattering. This will be implemented in Sar*t*re as an option.
  - Interfacing DPMJetHybrid to CLAS12 detector simulations.
  - Implement a combination of DPMJetHybrid and Sar*t*re to allow investigation of combined intranuclear cascade (ballistic protons) and nuclear evaporation for incoherent exclusive diffraction (J/ψ and ϕ).
- By October 2018 (end of proposal year 2)
  - Investigate the possibility of geometry tagging for CLAS12 in the context of experiment E12-06-117.
  - Using a combination of Sartre and DPMJetHybrid, we will
    - refine our estimate of our ability to tag coherent diffraction events by rejecting incoherent diffraction.
    - perform a first estimate of the resolution of the nuclear geometry parameters d and b for exclusive incoherent J/ψ and ϕ diffraction for eA using the JLEIC Large Acceptance Detector.
  - A more comprehensive look at geometry tagging and color propagation physics for SIDIS at JLEIC, including a light nucleus (such as Ca) and the heavy deformed nucleus U, investigating the maximum range of "*d*" that can be reached.
  - Investigate whether forward negatively charged hadrons (mostly π-) improve geometry tagging resolution because of their strong correlation with INC.
  - Using the upgraded Sar*t*re, we will investigate the value of forward photon tagging in further purifying the sample for coherent J/ψ and ϕ diffraction in ePb collisions.
  - We can study tagging of the nuclear remnant in the case of coherent diffractive eCa collisions and see if it further increases the purity.

3.0 VITA Nadel-Turonski, Pawel (Lead Scientist)

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Academic Degrees

Ph.D., Nuclear Physics, Uppsala University, Uppsala, Sweden, 2004. (UPCs at 0.25 GeV/A)
M.Sc., Chalmers University of Technology, Göteborg, Sweden, 1996.

Professional Appointments

Staff Scientist, Jefferson Lab, 2014 - present.
Nathan Isgur Fellow, Jefferson Lab, 2009 - 2014.
Postdoctoral Research Associate, The Catholic University of America, 2007 - 2009.
Postdoctoral Research Scientist, The George Washington University, 2004 - 2007.
Research Engineer (CLIC project), The Svedberg Laboratory, Uppsala, Sweden, 1996 - 1997.

Awards

Nathan Isgur Fellowship (2009).

Project Leadership

Co-spokesperson (contact) of CLAS experiments E06-103 and E12-12-001.
Co-spokesperson of SoLID run group experiment E12-12-006A
Co-PI (contact) of Generic EIC R&D projects eRD4 (DIRC) and eRD14 (PID consortium), funded at the level of $485k over four years (eRD4) and $329k in its first year (eRD14, ongoing)

Main Areas of Research

EIC science and detector development
3D imaging through exclusive processes (Timelike Compton Scattering, J/psi near threshold)
Hadron spectroscopy (strange decays of N* states) and few-body physics (light nuclear targets)

Publications

141 records at INSPIRE-HEP: http://inspirehep.net/search?p=find+a+nadel-turonski

4.0 Budget Explanation

1) **Effort of JLab Staff**: As PI, P. Nadel-Turonski (0.1 FTE) will coordinate project activities, supervise the postdoc, and take responsibility for integration with the JLEIC detector. V. Morozov (0.05 FTE) will be responsible for the integration with the JLEIC accelerator. The postdoc (0.3 FTE) will carry out the detector simulations. All the JLab staff members involved in this project are playing important roles in the development in the JLEIC detector and accelerator.
2) **Subcontract**: M. Baker (0.2 FTE) is a highly experienced physicist (PHOBOS, E665) and an expert in simulations of geometry tagging of the final state in collisions with heavy nuclei. As a subcontractor ($47k in FY17 and $48k in FY18), he will be responsible for the development of the event generators and evaluation of the physics results.
3) **Users:** An ODU student ($3k/year) will work under the supervision of C. Hyde on optimizations of the tagging detectors. C. Hyde is a long-time collaborator in the development of the JLab EIC, with particular interest in forward detection
4) **Travel for visiting scientists:** A key to the success of this project also lies in the expertise the unfunded users who are involved in JLab experiments (Brooks, Dupre, Hafidi), development of simulation tools (Toll, Zheng) and theory (Accardi) for electron scattering on heavy ions. In-person meetings for detailed discussions are thus essential. We request $25k/year to cover such travel.

In summary, we request funding for two years for the following items:

0.1 FTE Pawel Nadel-Turonski (PI)

0.05 FTE Vasiliy Morozov

0.3 FTE Postdoc (TBD)

0.2 FTE Mark Baker (subcontract, MDBPADS)

10 weeks/year ODU undergraduate student (supervised by C. Hyde)

Travel for visiting scientists

Details are provided in the separate budget file.

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