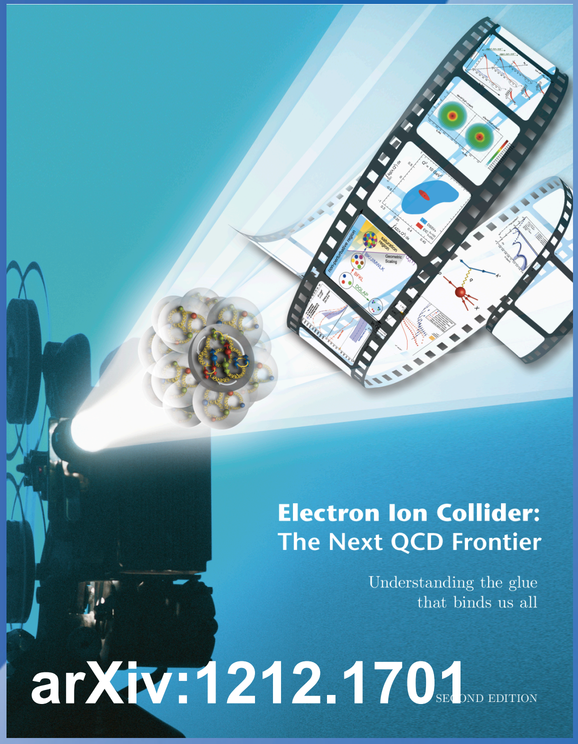
PD14-017 and PD16-007: eRHIC Design Study *and* Scientific Preparation for DOE Critical Decision Process



Thomas Ullrich

PD Mid-Project Review
BNL, July 14, 2016

BROOKHAVEN NATIONAL LABORATORY

a passion for discovery

Office of Science
U.S. DEPARTMENT OF ENERGY

PD14-017 and PD16-007

PIs: Elke-Caroline Aschenauer, Thomas S. Ullrich

PD14-017

- eRHIC Design Study
- Funding
  - FY14: $132,991
  - FY15: $527,925
  - FY16: $398,000
- YTD Expenses
  - FY14: $134,415
  - FY15: $528,360
  - FY16: $303,902

PD16-007

- eRHIC Design Study and Preparation for DOE Critical Decision Process
- Funding
  - FY16: $202,000
  - FY17: $600,000
  - FY18: $600,000
- YTD Expenses
  - FY16: $85,976

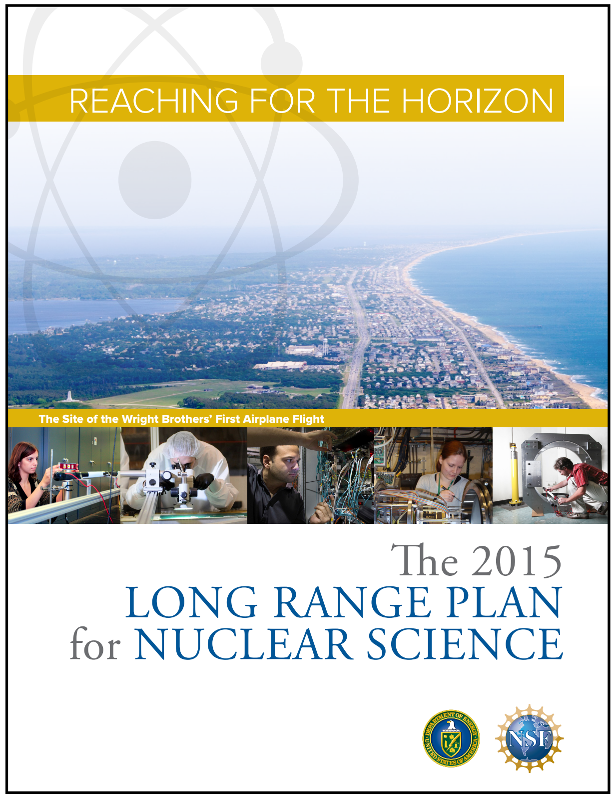
The Context

- The 2007 NSAC Long Range Plan had good words for an EIC but no recommendation
  - *"An EIC with polarized beams has been embraced by the U.S. nuclear science community as embodying the vision for reaching the next QCD frontier."*
  - Two labs compete to host the EIC, JLAB (MEIC now JLEIC) and BNL (eRHIC)

- In 2009 the EIC Task Force at BNL was formed, headed by E. Aschenauer and TU
  - Initially, with the help of LDRDs and support from STAR and the physics department the task force was instrumental in building the physics case. The EIC White Paper is the most comprehensive description of the EIC physics program to-date. The studies featured in the ep and *e*A part of the White Paper were almost all carried out by the EIC Task Force.

The Context

- Strengthened by PD14-017 the task force, together with the eRHIC design group at CAD compiled the “eRHIC Design Study” laying out an EIC facility at BNL
  - Physics, Machine, Detector
  - eRHIC features higher energies than the JLAB design, and is overall cheaper
  - Cost estimate ~$750M + $200M for machine and detector
  - New and improved studies conducted for the Design Study are used to update the White Paper in preparation for the next LRP
- The 2015 NSAC Long Range Plan
  - “*We recommend a high-energy high-luminosity polarized EIC as the highest priority for new facility construction following the completion of FRIB.*”



The Context

- DOE initiated a National Academy of Science (NAS) review before taking further action
  - Committee being assembled
  - ~18 month review
  - Expect resolution Fall/Winter 2017
- According to DOE (Tim Hallman) a successful review would be promptly followed by CD-0, likely in 2018
- After CD-0, DOE will likely have to make a site selection
- JLAB is currently aggressively recruiting new personnel to work exclusively on the EIC

Original Project Goals - PD14-017

Goals of this project

- Provide scientific (post-doc, student, visitor funding) and technical support (software development and management) to complete essential documentation and community activity required for a successful eRHIC campaign in preparation for the upcoming DOE/NSF Long Range Plan activity for Nuclear Physics in 2014-2015, and the expected subsequent completion of a full Conceptual Design Report for eRHIC as a basis for a DOE Critical Decision (CD-0) to initiate a construction project.

Description of project

- We are entering a critical 2-3 year period for the realization of an Electron Ion Collider, eRHIC, at BNL as the next major facility for Nuclear Physics in the U.S. The DOE/NSF Long Range Plan process for Nuclear Physics is expected to take place with a nation-wide series of workshops beginning late in 2014, and to conclude in 2015. It is critically important that an Electron Ion Collider receive the highest recommendation for new construction in this plan and, if this is the case, BNL must have a well developed document outlining its proposed research program and machine design as input for DOE decisions to site such a facility and proceed with a construction project.

Original Project Goals - PD16-007

Goals of this project

- Provide scientific support (post-docs, students, short and long-term visitor funding) and technical support (software development and management) to help bringing the eRHIC project on track to be the only viable realization of an EIC in the US. This includes further expanding and strengthening of the physics case, detector design and integration into the machine concept, as well as physics guidance for the cost and performance optimization of the machine design for a successful campaign to host an Electron-Ion Collider at BNL and prepare the foundation for a DOE Critical Decision (CD-0) to initiate a construction project.

Description of project

- The ultimate return on investment would be if BNL is selected as the site for the EIC. The Physics Department EIC Science Task Force will play a major role in the preparation of CD-0 and for the EIC site selection. This includes intellectual leadership to continue to develop the physics potential of an EIC, broaden its portfolio further and, in parallel, work on improvements on an EIC detector design and integration into the eRHIC machine concept. Members of the task force will aid in optimizing the eRHIC machine aiming at lowering the cost without jeopardizing the physics reach.

Plan/Approach

- We hired (and are in the process of hiring) extremely talented people with experience in Deep Inelastic Scattering (DIS) and in the physics topics that drive the EIC
- We established collaborations with the best theorist in and outside the US on the respective topic for guidance and hands-on calculations
- We had and plan to have experts in various aspects if an EIC listing BNL for short or longer periods to work with us (cost efficient).
- We hired experts to design a detector and integrate it in the eRHIC machine design
- We participate actively in the Detector EIC R&D program
- We defined physics driven design criteria for the eRHIC machine and the detector design and work in close collaboration with the EIC design team in CAD
- We actively promote eRHIC/EIC by giving colloquia and seminars at major universities in and outside the US, give talks at big conferences, publish articles in popular magazines, and work closely with BNL's public relation department to reach a wide audience
- We have regular meetings to discuss and monitor the progress on the goals
- We organize and participate in EIC specific conferences and workshops
- We continue to improve the physics case for an EIC in collaboration with theory

Accomplishments

With support of initially LDRDs and later PD, we carried out ~80% all of the studies on which the EICs physics case rest. Key achievements are:

- EIC White Paper (v2 in early 2015)
  - Definite expression of the scientific case
- eRHIC Design Report (Winter 2014)
  - Together with CAD overall design for an EIC at BNL
- The group was instrumental in the preparations for the LRP
  - Highest recommendation for new construction of EIC in 2015 Long Range Plan
- We have and still do develop event generators for physics simulation specific for an EIC
- We have been supporting the EIC Detector R&D with detailed simulations and proposed major EIC R&D activities which have been reviewed by the R&D committee very positively w/o exception
- We have integrated the entire auxiliary detectors into the current IR ring-ring and linac-ring design

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All goals of PD14-017 were achieved …

PD16-007 as the successor aims at taking the necessary next steps towards the realization of an EIC

- Th
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People Supported by PD Funds

- **Past**
  - Dr. Matt Lamont: assoc. physicist, eA physics case, structure functions
  - Dr. Tobias Toll: postdoc, eA physics, diffractive events
  - Dr. Liang Zhang: Grad. student, till August 2014 graduated in Nov. 2014 at Central China Normal University in Wuhan China
- **Current**
  - Dr. J.H. Lee: Physicists, forward detector physics and Roman Pot designs, hadron correlations
  - Dr. A. Kiselev: Physics Assoc II, detector design and simulations
  - Dr. B. Page: Postdoc since January 2015, jet tomography in ep and eA
  - Dr. S. Fazio: Physics Assoc II, 3+1d imaging of the proton, DVCS, structure functions
  - Dr. Matthew Sievert, Postdoc (theory), TMDs, quark helicity
  - Xiaoxuan Chu: Grad. student since January 2015, jets
- **Ongoing search for postdoc (short list exists)**

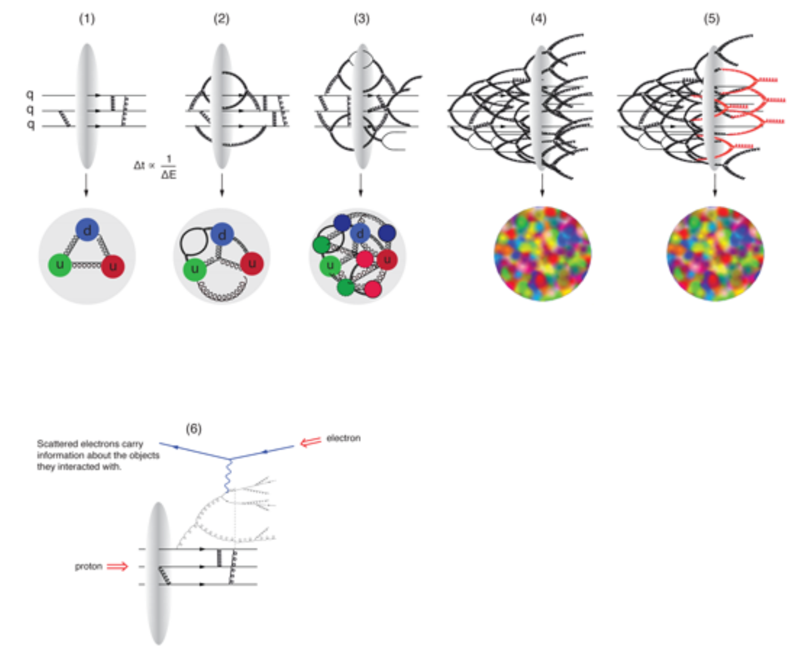
Publications

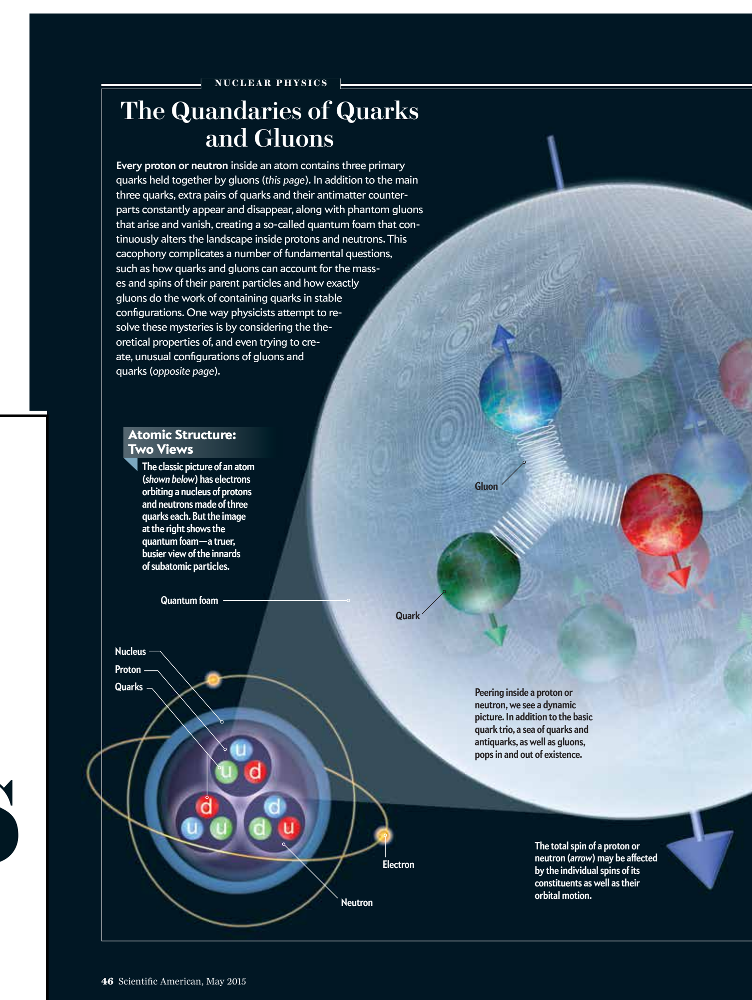
- eRHIC Design study: An Electron-Ion Collider at BNL, E.C. Aschenauer et al. arXiv;1409:1633
- EIC White Paper: Electron Ion Collider: The Next QCD Frontier – Understanding the glue that binds us all – 2nd Edition, A. Accardi et al., arXiv:1212:1701 (v2 2015)
- Determination of electron-nucleus collision geometry with forward neutrons, L. Zheng, E. C. Aschenauer, J. H. Lee, Eur. Phys. J. A (2014) 50: 189
- Probing gluon saturation through dihadron correlations at an Electron-Ion Collider, L. Zheng, E. C. Aschenauer, J. H. Lee, Bo-wen Xiao, arXiv:1403.2413 PRD 89 (2014) 074037
- Studying photon structure at an EIC, Xiaoxuan Chu, Elke-Caroline Aschenauer, Jeong-Hun Lee, arXiv:1607.01705 (2016)
- Unveiling the Proton Spin Decomposition at a Future Electron-Ion Collider, Elke C. Aschenauer (Brookhaven), R. Sassot (Buenos Aires U.), M. Stratmann (Tubingen U.), Phys. Rev. D92 (2015) no.9, 094030
- The dipole model Monte Carlo generator Sartre 1, Tobias Toll, Thomas Ullrich., Comput.Phys.Commun. 185 (2014) 1835-1853
- Probing short-range nucleon-nucleon interactions with an Electron-Ion Collider, Gerald A. Miller, Matthew D. Sievert, and Raju Venugopalan, Phys. Rev. C93 (2016) 045202
- Helicity Evolution at Small-x, Yuri V. Kovchegov (Ohio State U.), Daniel Pitonyak (RIKEN BNL), Matthew D. Sievert (Brookhaven), JHEP 1601 (2016) 072
- Calculating TMDs of a Large Nucleus: Quasi-Classical Approximation and Quantum Evolution, Yuri V. Kovchegov (Ohio State U.), Matthew D. Sievert (Brookhaven). Nucl. Phys. B903 (2016) 164-203
- Predictions for Sivers single spin asymmetries in one- and two-hadron electroproduction at CLAS12 and EIC, H. Matevosyan, A. Kotzinian, E.C. Aschenauer, H. Avakian, and A. W. Thomas, Phys. Rev. D 92, 054028 (2015)

Presentations (2015 & 2016)

- Elke Aschenauer
  - Seminar at University of Frankfurt
  - Seminar at University of Tuebingen
  - Electron Ion Collider Users Meeting
  - Seminar MIT Nuclear Physics Group
  - DIS-2016
  - Precision Radiative Corrections for Next Generation Experiments
  - QCD Evolution
  - ECFA-Plenary Meeting
- Xiaoxuan Chu
  - Electron Ion Collider Users Meeting
  - DIS-2016
  - RHIC/AGS Users' Meeting 2016
- Alexander Kiselev
  - DIS 2016
  - EIC User Group Meeting
  - Spring 2016 fsPHENIX Workshop
  - EIC User Group Meeting
  - SPIN 2016
- J.H. Jee
  - InitialStages2016
  - RHIC/AGS Users' Meeting 2016
- Brian Page
  - Electron Ion Collider Users Meeting, Argonne
  - Electron Ion Collider Users Meeting, Argonne, Berkeley
  - Rencontres de Moriond
- Thomas Ullrich
  - EIC User Group Meeting, Argonne
  - Colloquium at Heidelberg University
  - Colloquium at Old Dominion University
  - Colloquium at University of Houston
  - EIC User Group Meeting, Berkeley
  - NSAC EIC Cost Review, Chicago
  - DIS 2015
  - Hard Probes 2015
- Petti Richard
  - Hard Probes 2015
  - SPIN 2016
  - EIC Users Meeting Summer 2016
  - Electron Ion Collider User Group Meeting
  - BNL Young Researcher Symposium 2015

Public Relation & NAS Review Preparation





- Sci. Am. Article on Glue and EIC
- Close collaboration with BNLs PR group and graphic designers to create brochures
- Prepare for NAS review in collaboration with BNLs graphic designers

Remaining Goals

Overarching Goal:

- Actively support and prepare the NAS Review and subsequent CD-0
- Further strengthen the physics case and the portfolio
  - Examples of ongoing efforts:
    - eA: Hadron correlation specific to saturation physics (ridge)
    - eA: Revisiting structure function (F_2, F_L, $F_{2,cc}$) measurements
    - ep: Study feasibility of measuring gluon Sivers function ep/eA: Jet physics
    - eA: Geometry tagging, multi-nucleonic recoil of intrinsic k_T
    - ep: Working on feasibility study to measure Wigner functions
- Built a stronger user base for eRHIC
- Further improve detector designs and integration to harvest the rich physics
- Conduct detailed studies on background at an eRHIC

Return on Investment

- The ultimate return on investment would be if BNL is selected as side for the electron ion collider
  - eRHIC is one of the strategic pillars at the lab
  - only project currently at BNL being able to replace RHIC
  - allow to maintain the size of NP or even grow it
- BNL currently has and should make any effort to keep the intellectual leader ship for an EIC
- The development of many new innovative technologies for the eRHIC machine and the detector