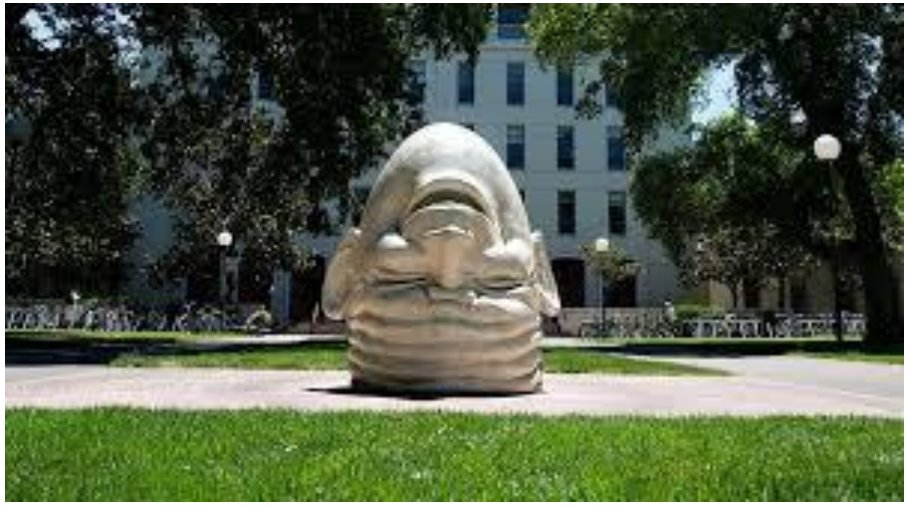
UC Davis Progress and Plans

Daniel Cebra and Manuel Calderon
UC Davis

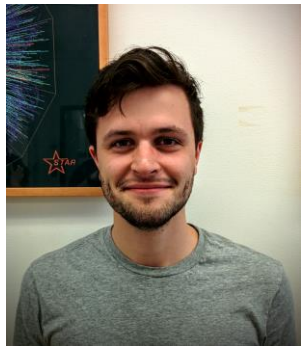


Progress

The UC Davis team for EIC:

- Daniel Cebra
- Manuel Calderon
- Sam Heppelmann
- (Ramona Vogt)





The Davis effort has focused on Heavy Quarkonia.

Our main progress has been the work that has been be reported on by our senior graduate student – Sam Heppelmann. He has been using STARlight as an event generator for vector meson and heavy flavor quarkonia and testing the efficiency of reconstruction using detector models.

Progress

From the MRI Budget justification:

The graduate student at UC Davis will collaborate with personnel from UC Berkeley, LBNL and LANL to perform EIC experiment integrated tracker simulations and collaborate with personnel from LBNL. S/he will also work with laboratory personnel to develop an EIC software package to run on high performance computing platforms.

Sam is a senior graduate student (now in his sixth year). As an undergraduate, he had worked with Elke Aschenauer on the STAR forward upgrade. At Davis, he had done service work developing a GEANT model of the Event Plane Detector (EPD) and for the target and target frame added into STAR for the fixed target program. He has relocated to Berkeley and has been applying this previous expertise to the challenge of reconstructing vector mesons and heavy Quarkonia in proposed EIC detector models. At LBNL, he has been sharing his time between analysis of the STAR data and on EIC software development.

Progress

Statement of Work from 2019 MRI proposal:

UC Davis will commit one graduate student for two quarters each year to work at LBNL or LLNL on simulations and design for forward tracking for a future EIC detector. This student will spend six months resident (or commuting) to work with lab personnel to develop an EIC software package to run on high performance computing platforms. In the second year, the student will spend six months resident (or commuting) at LBNL to work with the package developed in the previous year to simulate the performance of proposed forward tracker designs to allow for optimization of that design. Faculty from UCD with work with lab staff, and faculty from other collaborating campuses to evaluate the performance of various tracker designs. The end product of the two year project will help to prepare a fully evaluated design for the forward tracker for an EIC detector.

➔ As indicated from Sam's talk, UCD has completed the proposed task

Plans

Integrated Tracker Simulations

Calderon and Cebra's primary expertise focuses on the software and data analysis of the Time Projection Chamber. Calderon was part of the team that developed the original tracking packages for STAR. Cebra authored early versions of the vertexing code. Therefore EIC tracking code and simulations seemed to be the area where we could best contribute.

Heppelmann has experience running heavy-ion event simulators through the STAR GEANT model which is essential for studying the tracking performance.

Plans

Physics Goals: Heavy quarkonia production in DIS and in photon-nucleus collisions

Building on the expertise of Calderon, who has studied upsilon production at RHIC and at the LHC in p+p, p+A, and A+A collisions, and the theoretical work of our colleague, Ramona Vogt, we would like to continue this research into the EIC era.

Photonuclear collisions involving the exclusive production of light vector mesons (ρ, ω, Φ) and of heavy quarkonia (J/ψ and Υ particles) provide an excellent tool to probe gluon distributions at low *x*. Tagging the outgoing electron and is necessary to fully constrain the kinematics. Tracking is essential for the measurement of the leptons from the decays of the vector mesons and heavy quarkonia – this stimulates our interest in tracking simulations and performance.

Longer Term Plans

One goal of the Consortium is to stimulate faculty hiring:
A EIC-focused hire in Nuclear Physics was voted as the third priority for hiring in department in 2020. Last year, the department was authorized for to search for one position (Condensed Matter Theory). This search is complete and an offer had been made. For AY 2021/22, the department is requesting to fill the second priority (Experimental Particle Physics). The chair has announced that she will form a planning committee to develop a new hiring plan during the next academic year.

A new planning committee will review proposals from all groups in the department, and competition to be the top priority will be fierce. To strengthen our case, we are pursuing an opportunity of a joint hire with LBNL.

The UC Davis group is positioned to assist in a construction effort:
Cebra served at interim director of the Cyclotron Lab on campus, and during that period he re-organized and consolidated the machine shop facilities of the Cyclotron Lab, and the Departments of Physics, Chemistry, and Earth and Physical Sciences.
The UC Davis HEP group built the CMS inner silicon vertex detector ➔ there is expertise.

Joint Hires between UCD and LBNL

In the fall of 2020, an agreement was reached between the Chancellor of UC Davis and the Director of LBNL. This agreement called for a total of eight joint positions, two of which would be in physical sciences.

For the physics sciences, three break-out groups were formed to evaluate opportunities related to:

- The Electron Ion Collider (EIC)
- Dark Matter Searches (LZ)
- Neutrino experiments (DUNE)

To the best of my knowledge, these three directions have not been ranked.

However, there was an informal competition in the form of two LDRD opportunities made available to promote UCD/LBNL collaborations in the physics sciences ➔ EIC and LZ proposals were selected.

The 2021 LDRP, and the next steps

- **This LDRD funds a summer 2021 project between an LBNL posdoc and a UCD graduate student (Zach Sweger).**

- **It focuses on backward production of vector mesons, including heavy quarkonia, which has been identified as the next step (see Sam's conclusions).**

- **It focuses on topics which are of physics interests to Cebra (stopping), Calderon (heavy flavor quarkonia), and LBNL (backward production).**

Experimental Study of Backward and Near-threshold Production of Vector Mesons at the Electron-Ion Collider

Daniel Cebra (UC Davis), Xin Dong (NSD) Spencer Klein (NSD), Grazyna Odyniec (NSD)

Exclusive vector meson production is a key probe of quantum chromodynamics (QCD). In this process, a photon fluctuates to virtual vector meson (a quark-antiquark dipole), which then scatters from a target nucleus, emerging as a real vector meson. The scattering is typically at small momentum transfer and is believed to be mediated by the Pomeron, an object made mostly of gluons. Measurement of vector meson, particularly heavy vector meson, production at Electron Ion Collider (EIC) will offer unique insights into the gluon's role in the structure of nucleons and nuclei and its importance to baryon stopping. This project builds on the strengths of the two institutions, with UC Davis having expertise in quarkonium production and baryon stopping, while LBNL has expertise on vector meson photoproduction and proposed EIC hardware. Specifically, the project will take place over the summer of 2021 and will involve the day-to-day analysis and code development by an LBNL postdoc and a UCD graduate student working closely together, and twice weekly meetings between the postdoc, student, and senior scientists from both LBNL and UCD to provide guidance and direction. The third-year UCD graduate student, Zach Sweger, will be relocating to Berkeley for the remainder of his graduate program. The results of this project will define the direction of his jointly-mentored dissertation project. With respect to longer term collaboration, this project will provide specific and tangible results to define the scientific case for a joint faulty hire between UCD and LBNL. Both institutions envision working collaboratively on construction of key components of a future EIC detector.

Backward production (also known as u-channel exchange) of mesons adds a unique, and poorly understood twist to photoproduction. It is similar to conventional vector meson photoproduction, except that the vector meson and proton target swap momenta, so that the proton stops, ending up at mid-rapidity, while the vector meson acquires most of the proton momentum, so it is produced in the proton/ion-going direction; in EIC terminology, this is the far forward direction. The momentum transfer between the dipole and target must be very large. The baryon is shifted many units in rapidity, from the far forward region to the central region. This has an apparent similarity with baryon stopping in heavy ion collisions. These measurements could provide significant clues toward this process.

Backward production is studied in fixed-target experiments. The EIC is an excellent place to extend these studies upward in energy and to study production of a variety of different mesons, including the ϕ and the J/ψ. Heavy mesons (quarkonium) are of particular interest, since nothing is known about them. The forthcoming EIC Yellow Report notes the importance of backward production as a new particle production mechanism, and includes rough estimates of production rates for the ω meson. However, it does not consider the experimental feasibility of these studies at an EIC, where it will be challenging to detect vector mesons in the far-forward region.

We will also study the feasibility of using near-threshold production of quarkonium (J/ψ, Y) to probe the gluon contribution to the proton mass and short-range correlations (SRC) in nuclei. Recently, the GlueX experiment at Jefferson Lab made the first measurement of near-threshold J/ψ production, allowing the first attempt to decompose the proton mass contributions. With its much higher collision energies, the EIC will let us study not only J/ψ but also Y near-threshold production and in a wide range of scales (Q^2). Recent JLab experiments have demonstrated that the EMC effect in the nuclear structure function can be closely connected to the nucleon-nucleon SRC. It is crucial to demonstrate the existence and the universality of the SRC contributions to the EMC effect for gluons. This can be studied via near/sub-threshold J/ψ and Y photoproduction using different nuclei. The SRC contribution should be the dominant contribution to their production cross section in the lowest collision energy. These measurements require reconstruction of quarkonium in the forward region, similar to backward production.

We propose to study the experimental feasibility of observing backward vector meson and near-threshold heavy vector meson photoproduction at the EIC. We will adapt Monte Carlo event generators (e.g. eSTARlight, which was developed at LBNL) to simulate the final states from u-channel and near-threshold vector mesons, and use it to evaluate the kinematic distributions to determine the best approach, including beam energies, to studying backward production of different mesons. It is important to study different mesons, to probe how quark content and spin affect the production rates – key input for more detailed theories. UC Davis will contribute a graduate student and senior faculty; LBNL will contribute a postdoc and the senior participants.

Summary

- **UCD has completed the goals and proposed work of the 2019 MRPI pilot project**
- **Going forward:**
  - **We have identified the student to work on full MRPI project (Zach Sweger)**
  - **We have identified a first introductory summer project (LDRD proposal)**
  - **We are actively campaigning within the department for a future faculty hire**