Expression of Interest (EOI)
Questionnaire

Please indicate the name of the contact person for this submission:
Prof. Barbara Jacak (UCB and LBNL)
Co-PI's: Prof. Miguel Arratia (UCR), Prof. Huan Huang (UCLA), Prof. Daniel Cebra (UCD), Dr. Cesar da Silva (LANL), Dr. Ron Soltz (LLNL), and Dr. Ernst Sichtermann (LBNL)

Please indicate all institutions collectively involved in this submission of interest:

The UC Consortium consists of four University of California campuses and 3 UC-managed national laboratories:
UC Berkeley
UC Davis
UCLA
UC Riverside
LANL
LLNL
LBNL

UC Consortium members will work together on EIC physics and detector development, and build components of the silicon vertex/tracking detector and calorimeters in the western U.S.

Please indicate the items of interest for potential equipment cooperation:

Detector systems to which this consortium will contribute include silicon pixel tracking and vertex detectors, as well as electromagnetic and hadronic calorimeters for the hadron-going side.

UC and Lab-supported students, postdocs, and staff are simulating the performance of tracking and calorimeter detectors to help specify the conceptual design of an EIC experiment(s). This work is part of detector conceptual design, and is needed to specify cell sizes, detector placement, support structure location, etc. To inform and validate the design decisions, we will conduct key studies to quantify the sensitivity to key physics observables, as described below. The physics studies will be done (and indeed are already underway) by experimentalists together with theorists, for inclusion in detector Conceptual Design Reports.

Heavy quarkonium measurements impose particular detector requirements. Tracking detectors must cover a wide angular range, including near the beams. Excellent momentum resolution to separate the three Upsilon (bound bottom-antibottom meson) states is needed. A state-of-the-art silicon pixel detector is required to measure displaced decays of particles with heavy quarks. We will optimize detector designs using a number of heavy quark production models. In addition, the eSTARlight Monte Carlo generator will be used to simulate vector meson photoproduction and electroproduction, as well as to study the acceptance of candidate detector designs.

Jet measurements are of key interest to all groups in the consortium. In e+A collisions, jet production and substructure offer a tool to probe the structure of, and energy transport in, cold dense hadronic matter. In polarized e+p collisions jets offer a new tool to perform quantum imaging of the proton via measurements of TMDs. Jet reconstruction will place rigorous requirements on both tracking and calorimetry, including fine granularity and low local occupancy in the tracker, and excellent energy resolution for the calorimeters. We will evaluate physics performance of various calorimeter configurations for an optimal calorimeter system design within the constraints of cost and available space at the EIC.

The measurement of event shape observables in elementary collisions enables fundamental QCD studies, such as precise determination of the strong coupling constant α_s. Members of the Consortium are interested in carrying out Event Shape measurements at the EIC, using both e+p and e+A collisions. The precision needed for such measurements imposes specific instrumentation requirements for broad detector acceptance and high tracking efficiency, in addition to calorimeter performance.

Consortium institutions have built some of the most advanced silicon detectors, and applied them to heavy quark measurements in the STAR, PHENIX, sPHENIX and ALICE experiments at RHIC and the LHC. LBNL and UCB assessed viability and optimized initial sensor specifications for the EIC and are pursuing sensor development with US and international colleagues, jointly with the ALICE Collaboration. LANL is working on optimizing hadron endcap tracking for EIC forward heavy quark measurements. UCB and UCD will participate in next generation silicon sensor development and help characterize prototypes.

We are also working to develop a jet calorimeter system in the hadron endcap region at the EIC. The Tungsten powder and scintillating fiber (W/ScFi) technology pioneered by the UCLA group is of particular interest for the EMCal. This technology has already been utilized for a barrel EMCal in the sPHENIX experiment at RHIC. We (UCLA and UCR) envision also contributing to a Steel and Scintillator plate (Fe/Sc) sampling hadron calorimeter. A small HCal is under construction for the STAR forward upgrade project, whose performance is expected to yield valuable input for EIC calorimetry.

Simulations will be performed using existing High Performance Computing Facilities available at LLNL, LBNL, and LANL, through a combination of allocation processes available to both laboratory and university researches. All facilities provide support containers (singularity or docker) which eliminate any concerns when porting to generic CPUs. Additional support will be provided for porting selected codes to hybrid and GPU architectures in cases where significant speed-up is likely. One example is Machine Learning applications, which can be expected to have a wide range of applications from detector calibrations to physics analysis.

Please indicate what the level of potential contributions are for each item of interest:

The California Consortium received a pilot Multicampus Research Program Initiative award from the University of California Office of the President in 2019. These awards are designed to encourage multi-campus collaborations that can bring new opportunities to the University and the State of California. We consider the EIC to be a prime example of such an opportunity, and the University agreed. The Pilot award has allowed formation of the Consortium and engagement with the EIC Yellow Report efforts. This award ends in December 2020. We have applied for a full MRPI grant, and will learn in early 2021 whether we will be awarded any funding. Should we be successful, this grant will support personnel at the four campuses to work on the EIC, focused on detector development and construction. We hope to contribute personnel at the approximate aggregate level of 2 postdocs and 4 graduate students per year over four years, totalling 8 postdoc FTE and approximately 12 graduate student FTE.

As UC funds do not originate from the Department of Energy, such resources would not be subject to the supplementation ban that applies to personnel supported on base funding from the DOE. Consequently, the UCOP supported personnel could contribute directly to detector construction tasks. We note, however, that we will not have any UCOP supported engineers or technicians.

Regardless of UC support of our MRPI proposal, we will contribute personnel to detector R&D, design, and construction efforts from our regular grant funds. The total amount can be estimated by subtracted the UCOP funded personnel from the summed total in the tables below.

Assumptions as coming from the EIC Project or the labs for your items of interest:

We note that augmentation of construction costs from other DOE sources is not possible. However, in the past, the Office of Nuclear Physics has allowed scientific effort to be redirected to a broad range of tasks that can be undertaken by physicists. It should be noted that there is great educational value for graduate and undergraduate students, as well as postdocs, to participate in detector R&D and construction activities. Consequently, we plan to offer young scientists at the UC campuses the opportunity to take advantage of such activities by partnering with our national lab colleagues and taking part in work taking place there.

The FTE levels in the table below do not assume support that our UC proposal will be funded. The staffing levels assume that the grants at the campuses remain at levels comparable to those currently available. Should the MRPI proposal be funded, the aggregate staffing will increase by up to 2 postdoc FTEs, 4 graduate student FTEs and one Research Fellow.

Please indicate the labor contribution for the EIC experimental equipment activities:

The time commitment of members of the California Consortium groups in the EIC efforts described in this EoI is anticipated as shown in the table below. We summarize here the current status as well as future plans. The table shows planned commitments in three phases: initial R&D phase (Phase 1), final design phase immediately following CD-2 (Phase 2), and final construction and commissioning phase (Phase 3).

Institution Name	Professor	Research Professor	Staff Scientist	Postdoc	Graduate Student	Undergrad. student	Engineer	Designer	Technician	Total Sum
UCB Phase 1	0.15				0.8	0.2				1.15

Phase 2	0.15			0.5	0.8	0.4				1.85
Phase 3	0.25			0.5	1.5	0.4				2.65
UCLA Ph 1	0.1		0.3		0.4					0.8
Phase 2	0.1	0.2	0.4		0.6					1.3
Phase 3	0.2	0.2	1.0		1.5	1.5				4.4
UCD Phase 1	0.2			0.2	0.5	1.0				1.9
Phase 2	0.3			0.5	0.5	1.0				2.3
Phase 3	0.4			0.7	3.0	1.0				5.1
UCR Phase 1	0.4			0.2	0.6					1.2
Phase 2	0.4			0.5	1.1					2.0
Phase 3	0.5			1.0	2.5					4.0
LANL Ph 1			2	2	1		0.25			5.25
Ph 2			3	2	1		>=0.2			6.2
Ph 3			3	3	1		>=0.2			7.2
LLNL Ph 1			0.1	0.2						0.3
Ph 2			0.2	0.5						0.7
Ph 3			0.4	1						1.4
LBNL										
Phase 1			3.3	1.7	0.5	0.4				5.8
Phase 2			5.0	1.3	0.5	0.4				7.2
Phase 3			5.3	1.5	0.5	0.4				7.7
Cal Poly (Phase 1-3)	0.2					0.4				0.6

NOTE: FTE in the above table represents the annual fractional full time equivalent (FTE).

Our effort table is laid out in terms of three phases of contributions to the EIC Project goals. The first phase consists of R&D work to specify, simulate, and design the silicon pixel vertex and tracking detector system. Phase 1 is anticipated to last for approximately two years. It is followed by Phase 2 in which design is finalized, after EIC Project CD-2. This phase is anticipated to last 2-4 years, depending on the funding profile for detectors. In Phase 3, construction is in full swing, followed by initial commissioning of the EIC detectors.

Please indicate if there are timing constraints to your submission:

2021-2024 could include support from UC toward detector design and prototype studies, as well as physics reconstruction software.

After 2024, the UCOP support would finish. However, we anticipate involvement in construction of detector components in the western US.

Please indicate any other information you feel will be helpful:

Partnering UC faculty, grad and undergrad students, and postdocs with the UC-managed national laboratories will greatly increase our impact by bringing together younger and more senior scientists to take advantage of the unique infrastructure at LBNL, LLNL, and LANL. A western US initiative in the science of dense gluon matter will both increase the visibility of the science in this region of the country, and multiply the scientific and technical impact of the individual groups.

Please see the EOI's from LANL and LBNL for a list of technical infrastructure available for EIC detector R&D and construction. LLNL anticipates offering computational infrastructure, as noted above.

Cross-references to other Expressions of Interest:

As described in this submission, the UC EIC Consortium includes 4 UC campuses and 3 UC-managed national laboratories. Please see the EOIs from LANL and LBNL for more detail about the scope of work and infrastructure at those laboratories. It is our plan to work together to realize our suite of exciting physics goals at the EIC. We have recently been joined by Professor Jenn Klay from California Polytechnic State University. More detail about Cal Poly is given below.

Cal Poly Background and Team Experience:

Cal Poly, San Luis Obispo is a predominantly undergraduate 4-year university within the California State University system with a comprehensive polytechnic focus on training students for technical careers. Our "Learn by doing" motto is exemplified in our curriculum, which is grounded in laboratory courses, project-based learning, and undergraduate research experiences.

The physics department has over thirty full-time faculty in a wide array of experimental, computational, and theoretical physics fields. We admit approximately 60 first-time freshmen students into the major each year and all are required to complete a senior project as part of their degree requirements.

In 2017, Cal Poly chemistry alumnus, William Frost, and his wife, Linda donated $110M to the College of Science and Mathematics to support a new interdisciplinary research center, sponsor scholarships to attract top students, provide cutting-edge equipment, and increase the hiring of instructors, giving faculty members more time to mentor student researchers. This gift supports student research projects during the summer and throughout the academic year, enabling the college to maintain a vibrant summer research program for faculty and students, while helping faculty members develop research programs that can be competitive for external funding from agencies such as the NSF.

The relativistic heavy ion group headed by P.I. Jennifer Klay has been funded for over 13 years through the National Science Foundation Research at Undergraduate Institutions (RUI) program to participate in the ALICE experiment at the CERN LHC. Most recently, the P.I. received a three-year award (#2012154, $255k, 8/2020-7/2023) to work with undergraduate students to contribute to the ALICE LHC Run 3 physics program by supporting the commissioning, operations, data collection, and analysis of the ALICE Fast Interaction Trigger detector (FIT). This follows the P.I.'s successful completion of a National Science Foundation Major Research Initiative Consortium award (#1624988, $191k, 8/2016-7/2019) with Chicago State University and RUI (#1713894, $210k, 9/2017-8/2020) to contribute to the design, construction, and installation of the T0+ component of the ALICE FIT detector. For this project, the P.I. and students carried out bench-tests and analysis of MCP-PMT photo-sensors for the T0+ and contributed software and analysis of detector simulations to validate the design parameters.

Cal Poly EIC involvement:

The EIC will provide unique opportunities to investigate QCD with a variety of experimental probes of nuclear matter. The P.I. and students are motivated to explore the structure of hadrons and nuclei to better understand the propagation of quarks and gluons through strongly coupled color-charged media, building on our physics interests in heavy-flavor jet quenching in the QGP formed at RHIC and the LHC.

For the EIC, the P.I. would seek funding to support typically two undergraduate students per year to contribute to the design, construction, commissioning, and operation of a detector with collaborators from the California regional EIC consortium. Her expertise in detector simulation, testing, and analysis would assist in the development of a consortium-led detector proposal beginning immediately with small targeted projects (2020-2023), then ramping up our involvement after the end of the P.I.'s current award. She could be in a position to submit a proposal for funding to the NSF RUI program as early as 2022 for a projected start in 2023 that would transition our group from ALICE to EIC. The table includes the projected annual FTE effort from Cal Poly beginning in 2023.

It is anticipated that the collaborative effort of Cal Poly on the EIC would include (at an annual basis) 0.2 full-time equivalent FTEs of a professor, 0.4 FTEs of undergraduate students. There is the possibility of a new hire for an experimental physics assistant professor that could be targeted to involvement in EIC as early as 2023, or the appointment of an in-house postdoctoral research position funded through the Cal Poly Frost Fund endowment, on a similar timescale. We anticipate the duration of this collaborative effort to cooperate on the EIC to start at the design phase and to continue for a period of five years.

Facilities and other infrastructure at Cal Poly:

The William and Linda Frost Center for Research and Innovation, a new undergraduate research complex at the heart of the Cal Poly campus, is scheduled to open in 2021. The complex is a 15,000 square foot research space shared among three colleges that will be outfitted with state-of-the-art equipment to support undergraduate research and upper division courses. The P.I. has been allocated approximately 400 sq.ft. of space in a 1200 sq.ft. room that will house the Cal Poly Particle Detector Development Laboratory, a joint initiative of several physics faculty working in high energy particle, nuclear, and astrophysics. The room will be outfitted with lab benches, optical table, soldering station, storage, and standard utility, network, and laboratory infrastructure.

The P.I. manages an array of instruments and state-of-the-art equipment, including a low-background lead-shielded gamma ray coincidence spectrometer, desktop digitizer, picosecond low-power, pulsed blue laser, high voltage power supply, and fast digital oscilloscopes for detector development projects. The department employs technicians who are qualified to provide machine shop support and technical troubleshooting.

In addition to laboratory infrastructure, the P.I. and students have access to shared computing resources within the college that can be used for detector simulation and analysis projects