Report of the EIC Detector Advisory Committee
Inaugural meeting, May 9-10 2011

BNL, in association with Jefferson Lab and DOE Office of Nuclear Physics, has established a generic detector R&D program to address the scientific requirements for measurements at a future Electron Ion Collider (EIC). The primary goals of this program are to develop detector concepts and technologies that are suited to experiments in an EIC environment, and to help ensure that the techniques and resources for implementing these technologies are well established within the EIC user community.

On May 9-10, 2011 the EIC Detector Advisory Committee met at BNL to review six proposals received in response to the first solicitation. The Committee members are:
M. Demarteau (ANL), R. Klanner (Hamburg), I. Shipsey (Purdue, Chair), R. Van Berg (U. Pennsylvania), J. Va'vra (SLAC), H. Wieman (LBNL), G. Young (JLab)

General Remarks on the Program

This is an important and timely program.

As stated in the guidelines of the program, proposals should be aimed at optimizing detection capability to fully exploit the scientific reach of polarized electron-proton and electron-ion collisions with center-of-mass energies in the range 50-200 GeV and e-p luminosities up to a few times 10^{34} cm^{-2} s^{-1} and e-A luminosities up to approximately 10^{32} cm^{-2} s^{-1} for the heaviest ions.

At this early stage in the development of the EIC it is important to identify golden measurements and how well they need to be made to achieve the physics goals of the program.

A working model for each machine design to predict the radiation dose and charged and neutral particle fluence in the detector for the nominal luminosity is urgently needed. This model must then be the basis for detailed simulations of machine backgrounds to the golden measurements and radiation damage to the detectors. We consider this to be an appropriate responsibility for each of the Laboratories as part of the machine and detector development programs. A contact person for each machine would be highly desirable.

Simulation of the golden measurements as benchmark processes is an effective method to identify the most appropriate detector geometry, resolution, granularity, and background suppression. Specifically these simulations can be used to maximize acceptance and efficiency for each golden measurement while minimizing machine backgrounds, and backgrounds from other physics processes.

The formation of consortia of universities and national labs to fully explore classes of detection techniques: vertexing, tracking, particle identification, calorimetry, muon identification, as well as triggering, and data acquisition, for application to the EIC are to be encouraged.
The formation of consortia is important for at least two reasons. First each class of detection technique is extensive and much work needs to be done to identify the appropriate technologies,

through simulation, laboratory characterization, including the effects of irradiation, and qualification. Second, the formation of consortia is the first step towards building scientific collaborations that can mount successful EIC experiments. In these six proposals we have already seen evidence of such consortia forming around tracking and PID, but not in other areas such as calorimetry, electronics and triggering, data acquisition, etc.

Other items we feel are important are: luminosity and polarization measurements, tagging detectors and calorimeters downstream in both the hadron and electron directions, and low-mass precision vertex measurement.

Following discussions with BNL management, the Committee agrees to meet again in approximately six months, to evaluate new proposals for this program, and to review progress on the proposals that are now being funded. The Committee endorses BNL's plan to require quarterly progress reports on these activities. A template is being prepared for the progress reports.

Proposal #1 Development of a New Detector Technology for Fiber Sampling Calorimeters for EIC and STAR

H.Z. Huang, G. Igo, S. Trentalange, O. Tsai (UCLA), C. Gagliardi (Texas A&M), S. Heppleman (Penn. State).

Using tungsten powder as the absorber and fiber readout as the active element it is proposed to construct fine-grained sampling electromagnetic and hadronic calorimeter prototypes. In phase one of the proposed R&D the project goal is a "proof of principle" with the construction and beam test of a small EM prototype (16 towers) with the fibers in an accordion geometry. And the construction and tests (EM parameters only) of a small SPACAL type hadronic prototype module with a beam test at SLAC or FNAL. Funds are requested for phase one.

In phase two it is proposed to extend the size of the hadronic prototype and test it with beams of hadrons and electrons to measure energy and position resolutions, e/h rejection power etc. The proponents will also investigate alternative readout schemes including APDs and/or SiPMs (also known as G-APDs) and compare to PMT readout.

Calorimetry is a critical component of EIC detectors. Fiber sampling calorimetry has attractive features. The technique allows, in principle, construction of versatile compact and fine-grained sampling electromagnetic and hadronic calorimeters with good energy resolution, hermeticity, homogeneity, timing and position resolution. It is appropriate to explore this technique in the context of the EIC R&D program.

The fibers can be scintillating, quartz, non-scintillating optical fibers or a combination and can be selectively used to read out scintillation and/or Cherenkov light produced by showering particles. This dual-readout allows the measurement of the electromagnetic fraction in the hadronic shower on an event-by-event basis.

This technology is well-suited to take advantage of modern developments in photo-detectors (APD, SiPM) .

The technology proposed is in principle suitable for photon measurements and recoil jets at EIC and for electron and hadron energy measurements in STAR future upgrades or eSTAR configurations.

The proponents have adequate prior experience as they constructed a prototype and tested it in 2003 in beam. A second improved prototype was not tested due to the SLAC beam accident. It is a third prototype they intend to build and test with the funds requested here. The second prototype was built addressing some of the shortcomings of the first prototype such as non-uniformity. Would it be possible and desirable to test the second prototype?

The proponents are asked to discuss if the physics at the EIC requires a tower-type geometry. If so, is this feasible with the proposed technology.

The proposal would have benefitted from a simulation to identify the required calorimeter resolutions to perform the golden measurements.

Utilization of tungsten powder as an absorber opens new ways to construct fiber calorimeters but also presents challenges. In particular, there was a lack of uniformity in response in the first prototype tested in 2003. Plausible explanations and solutions were presented. For example packing uniformity, but the absence of the test of the second prototype preclude a demonstration that these limitations were overcome.

Strict mechanical tolerances and uniform internal structure were recognized to be critical but the mechanisms to achieve this and quality control during construction were not identified and explained.

What is the mechanical integrity of the towers under mechanical loading and after a substantial irradiation? In particular, what is the radiation hardness of the optical epoxy? Does loading or radiation change the calorimetric response? There is a lack of uniformity in the region where two towers meet. This should be explored by simulation. With the fibers arranged in accordion geometry this lack of uniformity would be exacerbated. How stacking is to be addressed, should be explored in the proposal. Overall mechanical support would benefit from engineering input.

It was unclear why 7 years have elapsed since the 2^{nd} prototype was constructed without follow-up. The proposed phase 1 work is ambitious. Emphasis should be placed on careful construction of the prototypes, rather than completion of a beam test within the first year. From the outset, a calibration scheme should be established.

An understanding of compensation and low energy hadronic response with this technique would be useful for the EIC environment.

The committee recommends funding this proposal in full.

Proposal #2: Front end readout module for detector data acquisition and trigger system
C. Cuevas (Jefferson Lab).

The proposal outlines a path towards a generic Front End Readout Module for the EIC R&D phase that takes advantage of JLab's expertise in digital electronics. The proposed generic design builds on the successful JLab VXS project which provides separate high speed serial trigger data and lower speed VME parallel readout data paths. The proposed Front End Readout Module would provide more physical space and higher trigger bandwidth but would otherwise duplicate most of the features of the previous work. Users would design custom daughter boards that would interface to the large FERM FPGA for both the data and trigger paths. The general design mirrors other current high speed digital DAQ projects in other labs and shows a good grasp of the necessary technologies. On the other hand, there are no clearly defined "users" for this development in the present EIC R&D community and it would be easy to miss features that would be important for future users without critical user input. In addition, speeding up the serial trigger path may not be critical in this near term R&D phase if the data path remains based on the (relatively) slow VME parallel bus – a bus that is no longer being proposed for many new designs. It is also possible that if only one or two "users" come forward in the near term that it would make more sense to use the JLab expertise working in collaboration with the user community to design and fabricate one or more boards in the present 6U format using the present data and trigger paths. In light of this, the Committee makes the following suggestions:

- Investigate joining one or more general EIC R&D collaborations to provide electronics support for those near term R&D efforts.
- Investigate other emerging data movement standards and methods with the aim of being in a position to contribute to the development of an EIC oriented DAQ /Trigger fabric when that becomes appropriate – engaging with efforts directed at SLHC and other ongoing very high bandwidth projects could be valuable.

The Committee recommends that this project not be funded at this time.

Proposal #3: DIRC-based PID for the EIC Central Detector
T. Horn (Catholic University of America), C. Hyde (Old Dominion University), P. Nadel-Turonski (Jefferson Lab), K. Peters, C. Schwarz, J. Schwiening (GSI, Darmstadt).

The presented proposal is a very good start. It is very much appreciated that as a first step the kinematics of particle production for the different beam energies has been presented. This type of work should be further pursued and the required efficiency and rejection power should be evaluated for a very limited number of "golden channels". In addition the physics gain of pushing the DIRC performance beyond today's state of the art should be understood. It also would be interesting to know how much the DIRC can help in the identification of low energy electrons, required for the F_L measurement.

Before any prototype is actually built, one should do more detector simulations to be sure that the prototype makes sense. This is important so one can judge what variables are relevant to achieve the best PID performance. For example, which variables control the PID performance limit, what size of pixel is relevant, what timing resolution is necessary to achieve the best possible chromatic correction by timing, what is the expected background, can bars penetrate the iron, what is the optimal geometry of the photon camera, what thickness of bars is important, what bar width to choose, does one need to have a tracking point after bars to reach the optimum Cherenkov resolution, etc. This will easily take 12 additional months before one can start prototyping.

To answer the question what is the accelerator-triggered photon background, one needs a detailed MC simulation of the accelerator components and bring it some distance from the IP. This is a significant amount of work. We suggest contacting people, for example from SuperB or KEKB, to see how this is done in practice.

The high magnetic field will limit the possible choice of the photon detector.
Probably a Silicon PM, otherwise known as Geiger mode APD (G-APD), is the only choice at present if one insists on a magnetic field of 4T. This requires finding out and evaluating what is the experience with these types of detectors in the presence of the neutron background. We also suggest getting involved initially in the aging tests proposed in Jlab, get hands-on experience with the work done at GSI and, in parallel, study what has been done elsewhere, e.g. to learn more about what is a minimum temperature to run G-APDs, what is the effect of annealing, etc. One additional point to stress is that DIRC photons have a large span of angles when exiting the bar, and therefore any use of optics to concentrate photons onto the active area of the G-APD will cause a loss of photons. This means that one has to couple the G-APD directly to the camera optics, and therefore the G-APD array has to have a minimum dead space between pixels.

If one would penetrate the iron, many options will open up for the photon detector choice. This should be investigated as part of an overall detector design to see if there is a way to do it.

The technology of the detectors is expected to change several times before the EIC detector will be built. There is no need to rush to prototyping at this stage, unless it is well thought out, it is a very new idea, and it is supported by a detailed simulation.

Conclusions and Recommendations:
The proposal addresses an important R&D topic for experimentation at the EIC. It should be funded for an initial period of one year. The authors then should come back with a concrete proposal on the bases of answers to questions raised.

Proposal #4: Liquid scintillator calorimetry for the Electron Ion Collider
J. Frantz and D. Kotchetkov (Ohio University).

The authors propose to investigate the properties of a series of liquid paraffin based scintillators to be contained in an inexpensive extruded polycarbonate structure to form up the active cells of a sampling-type calorimeter. This would be useful in sections of the calorimetry planned for an EIC particularly where large volume coverage and radiation resistance are important. Calorimeters based on liquid scintillator may provide an attractive alternative to homogeneous devices, such as crystal-based devices, which are expensive, or lead-glass based devices which have radiation-tolerance issues, to shashlik-style and other fiber-based calorimeters which require much custom assembly. Large-scale use of liquids in collider detector calorimeters to date has been focused on cryogenic liquids used in ionization mode, which permits customizing the segmentation of the readout. The authors seek to find an inexpensive solution to both the high cost per unit volume for commercially-available liquid scintillators with fast response time and high light yield per unit energy deposited, and to the cost of containing liquids in thin enough layers that the contribution to the energy resolution due to sampling fluctuations are kept to an acceptable level. The authors propose ambitious program of measuring response to ionizing radiation, for example from beta and x-ray sources, of various mixtures of primary scintillator and the primary and secondary dyes added to obtain adequate Stokes shift to detect the emitted light with optical light sensors. The proposal does not address issues of light sensor choice or use of wavelength-shifting light-extraction elements, fiber-based or other, instead leaving those for a later proposal.

The authors presented expected radiation dose levels at EIC after 5 years of operation and some remarks on radiation tolerance for a few liquids. The calculated doses for forward calorimeters range from 8 mGy (0.8 Mrad) and 2.2 Gy (220 Mrad) for pseudorapidity 3 and 5, respectively, values that are large enough to make investigation of radiation-tolerant technologies of interest. It would be useful also to have information on requirements, and likely choices, related to energy resolution and thus sampling fraction and perhaps choice of inert absorber material, to electron-hadron compensation, to required transverse position resolution, and to speed of overall response and whether the device was a primary ingredient in the experiment trigger, which could well be expected at an EIC. Such requirements could come from a program of physics and detector simulation which might be carried out as part of a larger effort concerning calorimetry at EIC. This larger effort could also posit a possible detector design, from which practical aspects of calorimeter size, segmentation and space for readout could be determined and used to guide development of specific devices.

The proposal is broadly written concerning the investigation of scintillator properties. It would benefit from enlarged discussion of the practical aspects of setting up the test cell, including materials and choice of cell dimensions, reflector or diffuser if any, primary light yield, signal attenuation, light transport and extraction, sealing, choice of photo-sensor and its peak wavelength response, and results to be collected during a test program. The immediate test program makes several practical choices, such as the Hamamatsu H3878 PMT directly coupled to a sealed cell, chosen for broad wavelength response peaked at 420 nm. An evaluation of various primary scintillator and dye mixtures would be useful, including likely costs for bulk production, with then a focused selection of a few for laboratory evaluation of response and radiation tolerance. The authors do propose a few specific choices of scintillator and dyes for initial work; a rationale and criteria for selecting further scintillator-dye combinations for future study would be useful.

The committee does not recommend funding this proposal. We recommend that the proponents consider joining with a broader effort to explore calorimeter needs and techniques for physics at the EIC.

Proposal #5: Proposal to test improved radiation tolerant silicon photomultipliers
F. Barbosa, J. McKisson, Y. Qiang, E. Smith, D. Weisenberger, C. Zorn (Jefferson Lab).

The proposal to test improved radiation tolerant silicon photomultipliers (Geiger mode APD (G-APD)) outlines a plan to gain information useful for EIC planning by characterizing the radiation hardness of new Hamamatsu G-APDs for the barrel calorimeter of the GlueX detector.

A batch of 80 4x4 SiPMs has been characterized at JLab and mostly meet the requirements of the experiment. The only characteristic that raised any doubt concerning the use of these devices was the radiation tolerance to high energy neutrons. The proposal calls for obtaining more radiation hard samples from Hamamatsu and characterizing their radiation hardness. The group has built a very nice setup for the characterization of these devices and that work is very much supported.

However, samples from only two vendors have been tested and it is proposed to obtain new samples from only Hamamatsu. There are a lot of other groups who have studied in great detail the radiation hardness of G-APDs from a wide range of vendors, such as Zecotek in Singapore, ST Microelectronics in Catania, RMD in Boston, IRST-FBK in Trento, to name a few.

It is recommended to contact experiments that use, or intend to use, G-APDs in large quantities, such as CALICE, T2K and CMS, and obtain a broad overview of the state of the art.

The Committee recommends that the requested funds be provided to procure the new Hamamatsu samples.

Proposal #6: Letter of intent for detector R&D towards an EIC detector
C. Aidala et al. (BNL, Florida Inst. of Technology, Iowa State Univ., LBNL, LANL, MIT, RIKEN/BNL Research Center, Stony Brook Univ., Univ. of Virginia, and Yale Univ.).

The collaboration emphasized their intention to carry out extensive physics simulations to shape the direction of future detector R&D proposals. It is presumed that the multiple institutions in this collaboration not requesting funding at this time would be committing to the simulation activity and hopefully in a mutually supportive manner. The committee appreciates and encourages this approach. Only after the demanding simulation effort progresses can detector R&D proceed with the desired focus. The choice of the longitudinal structure function F_L as a benchmark measurement for resolution and the contribution of the strange quark to the spin of the proton, Delta(s), for particle identification are considered good choices.

The committee also strongly endorsed the early coalescence of multiple institutions working together to develop the EIC detector program.

The collaboration selected several detector programs, all related to tracking, for seed development:

- Measurement of fast TPC characteristics
- Improved pad readout structures for GEMs
- Development of lager area GEMs and minimized electronic gaps
- Development of GEM based CsI photo cathode detectors
- Development 3D strip readouts for GEMs

These programs could well lead to improved technologies suitable for an EIC detector. In particular the 3D strip GEM readout could reduce the electronics count required for the GEM readout plane. The fast drift TPC, while interesting, may turn out not to be necessary as the track rate for the EIC is significantly lower than is handled with slow TPCs used for heavy ion collisions. The study of the feasibility and its advantages to other tracking detectors should be evaluated. The committee would like to see a calculation/simulation of handling multiple interactions per TPC memory time. The institutions are well-positioned in experience and equipment to carry out the proposed development work.

The one concern that the committee had was that while the letter of intent stated the strong need for simulations, there was actually very little discussion or identification of resources that would be devoted to this important activity. The plans for hardware R&D were discussed and requests for associated funds were made. But, there were no similar plans outlined for simulations other than a brief mention by LBNL. It was suggested that a funding request for post docs in support of simulations would be reasonable. It was also suggested that machine related backgrounds should be included in the simulations.

The full funding is recommended and the committee is looking forward to proposals, based on the work described in this LoI.