**Report of the EIC Detector Advisory Committee**

**3rd Meeting, May 17-18 2012**

BNL, in association with Jefferson Lab and the 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 17-18, 2012 the EIC Detector Advisory Committee met at BNL to review seven proposals received in response to the second solicitation. The Committee members are:

M. Demarteau (ANL), C. Haber (LBNL), R. Klanner (Hamburg), I. Shipsey (Purdue), R. Van Berg (U. Pennsylvania), J. Va’vra (SLAC), G. Young (JLab, Chair). I. Shipsey was unable to attend the May meeting.

**General Remarks**

Most proposals did not have all the needed requirements to be addressed by the proposed detector concept; the Committee sees room for improvement.

Proposers need to include a discussion and tables of performance requirements and their resulting detector specifications to meet them. Development of reference detector designs by the community will help this by providing an agreed-upon set of requirements and how they change for different regions, e.g. barrel, e-endcap, h-endcap, and beamline regions. Proposers should also discuss specific responsibilities of personnel, more so since a specific R&D effort is often not the main activity of a given group.

The community needs to develop the understanding of the radiation dose and occupancy expected for each of the two machine proposals. Detector proponents need to note the radiation dose their proposed technology can withstand and discuss where further knowledge is needed. As a first step an analysis of the dose due to collision products alone is needed, not just as input to studies of overall dose but also to see if any technologies must be *a priori* ruled out.

A general understanding of bunch-to-bunch variations of polarization and luminosity is needed. A more widespread understanding by the experimenters of machine beam and crossing parameters as proposed by the two accelerator groups will be a must for further development of detector concepts. The presence at the meeting of an accelerator expert from each of the proposed machines would be most helpful to clarify upcoming issues efficiently.

**RD 2012-10: Silicon Based Tracking System for EIC Detector**

L. Elouadrhiri (PI), A. Yegneswaran (PI) Jefferson Lab, Moscow State University, University of New Hampshire

Considering the design of past detectors for asymmetric colliders, of experiments such as CLAS12 at JLAB, and also given general considerations for an EIC detector, the application of precision silicon layers at small and intermediate radii, in a barrel geometry, seems appropriate and relevant. One would therefore expect to see an R&D effort on a silicon based tracking system as part of a broad program in support of a future EIC experimental program. Silicon trackers now have a long history of application over a wide range of specifications and requirements. Their ability to function in high rate and high radiation environments is well documented and their capabilities are still improving, for example in application to the future high luminosity upgrade of the Large Hadron Collider.

The JLab, MSU, New Hampshire collaboration is well suited to pursue R&D on silicon based tracking for an EIC detector. This is due to its experience developing the present CLAS12 SVT upgrade, the available infrastructure and capabilities, and its established association with the SIDET facility at Fermilab.

In the application of silicon to tracking, there are a number of basic or fundamental issues and requirements which need to be understood. Critical among these are the radiation environment, the granularity and resolution, the data rate and front end response time, and the readout configuration. In turn, these issues then drive many technical choices including the operating temperature, cooling requirements, semiconductor materials and radiation hardness, choice of strip pitch, stereo angle, and/or pixel size, and the readout architecture.

The proposed research plan builds on the important experience of the CLAS12 upgrade project, which may, in the end, already represent a good model for many technical aspects of a future EIC detector. However, there remain at this time a considerable number of unknown parameters about an EIC which feed into the aforementioned issues and technical choices. Furthermore, there appear to be enough variables among the possible designs for an EIC itself and its IR, that focusing on a specific implementation at this time may be premature.

The Committee believes that a silicon tracking R&D effort should be an important part of the EIC detector R&D program and should be well supported. We recommend that an attempt be made first to address some fundamental issues in order to have later a better motivated program which can be strongly defended. In particular, the following aspects should be pursued first as part of an analytical, engineering, or simulation based study.

* What are the expected radiation levels at the position of a silicon tracker?
* How does this relate to the choice and/or design of the sensors and readout electronics?
* Does the silicon need to be cooled? If so, how?
* Considering the different collision modes and beam structures of possible EIC's are there issues around the choice of clock or data driven front end architectures?
* What sort of hit resolution is required and why?
* What sort of granularity is needed for tracking in this environment? Is stereo sufficient? Would some sort of pixel or large pixel structure be a better match?
* What amount of material can be afforded?
* Considering that this detector will be built and used in the 2020 decade, and the ever increasing capability of micro-electronics, are there ambitious designs (by today's standards) which would be a great match to the physics requirements at the EIC? Is an all pixel or MAPS design a good fit?

As a subsidiary item, the proposal raised the issue of interference between silicon readout and nearby gas filled tracking systems. It would seem that this can already be addressed in the context of CLAS12. It was not clear why a separate test was required at this early stage.

*The Committee does not recommend funding at this time but strongly encourages the collaboration to address the questions listed above and return with a revised proposal at the Committee’s next meeting.*

## RD2012-11: Development of a Spin-Light Polarimeter for the EIC

Dipangkar Dutta (PI), James Dunne, Edward Leggett, Prajwal Mohanmurthy, Mitra Shabestari (Mississippi State), Wouter Deconinck, Valerie Gray (William and Mary), Abhay Deshpande (Stony Brook), Frank Maas (Johannes Gutenberg) Kent Paschke (Virginia), Paul Reimer (ANL), Dave Gaskell (Jefferson Lab)

The proponents are to be congratulated for presenting a much clearer picture of the underlying physics of the spin-light process and the way a differential ionization chamber might be used to measure the degree of beam polarization. This clearly could be an interesting and significant new tool.

However, while the proponents have greatly clarified their case in many areas, there still seem to be several remaining lacunae, at the very least, in terms of other systematic effects (beyond the vertical beam movements considered in the proposal) and signal characteristics. The expected effect is small enough (~10-4 or less) that careful cataloging of other known systematic effects is advisable before launching a construction project even of modest magnitude. During the discussion a number of possible effects (matching of spin-light defining collimators between the beams, small machine instabilities, bunch to bunch differences in polarization or intensity, etc.) as well as other purely instrumental effects might be imagined (e.g. collection of electrons from the one and ions from the other side, left right differences in gas mixture or gas impurities affecting electron or ion lifetime, temperature stability of the gas and electrodes in the differential ionization chambers, temperature or power supply sensitivities in the electronics chain, etc.). A more exhaustive list of possible effects should be made, and then each candidate effect needs to be either shown to be very much less than the expected signal or included in a more sophisticated model of the final signal that includes all known significant systematic. In addition it was clear from the discussion that the possible usage of the information provided was not crisply understood – is a continuous or near continuous knowledge of the polarization required, what is the correct time scale for such knowledge, even, what is the possible time scale for such knowledge – some of this is clearly due to the different underlying structure of the competing machine designs and so consultation between the proponents and machine designers at JLAB and BNL could be of benefit and could help ascertain whether the proposed design can function in both environments or is particularly suited to only one..

Also missing from the proposal and presentation was a crisp description of photon beam intensity, chamber gas (liquid?) density, interaction rates and thus the resulting drift chamber currents. A description of ion chamber currents and measurement scheme needs to be developed. In addition, it would be helpful to review the equipment list in the proposal and provide justification of the choices made and more detail on minimum requirements. We encourage the proponents of this novel idea to consult not only with the designers of the two proposed machines but also other experts in polarization measurements to help clarify challenges and opportunities and as part of moving forward on the examination of overall systematic effects and details of ionization chamber performance forward.

*The Committee recommends modest funds to support travel to help develop the idea further.*

**RD2012-12: RICH detector for forward direction**

V. Kubarovski (co-PI), P. Rossi (co-PI)

Jefferson Lab, INFN- Frascati, INFN- Sezione di Ferrara, Christopher Newport University, Univ. Tecnica Federico Santa Maria (Chile)

The detector concept is a reasonable idea. Some initial requirements were stated; these need to be further elaborated. It would help to know better where the proposed detector can perform K/π and p/K separation and how well it would do this. Much of the R&D on the SiPM concept and light collectors was done by Krizan group (RICH2010), and R&D on graded aerogel was done by the Novosibirsk group. Belle-II collaborators also push this concept for the forward detector (I. Adachi, NIM**A639**(2011)103). One should know, however, that they have decided to use Hamamatsu pixilated HAPD (Hybrid Avalanche Photo Detector) detectors because they believe that SiPMs would not survive in the environment at the Belle-II detector, which is expected to get a total dose equal to or even above 1010n/cm2.

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Therefore the Committee suggests to concentrate on (a) simulation of expected background at eRHIC, (b) study of SiPM aging, (c) collaborative work with other people who are doing similar aging studies, and (d) study of an alternative detector: Hamamatsu HAPD.

The background simulation should be done together with the rest of the EIC collaboration to make a coherent study as noted earlier in the General Remarks section.

*The Committee recommends that the proposal be supported at a small level to enable buying SiPM and HAPD hardware and performing software simulation.*

**RD 2012-13: A Pre-Shower Detector for Forward Electromagnetic Calorimeters**

S. Kuleshov and W. Brooks

Univ. Tecnica Federico Santa Maria, Valparaiso, Chile

The aim of the proposal is to study the performance of a 25x25 matrix of LYSO crystals read out through a novel technique of a grid of x-y WLS fibers. The proposal is concise and focused. The group has possession of the crystals. A request is made for the purchase of a full complement of SiPMs from Hamamatsu, WLS fibers, mechanical support and readout. Funding for support of a graduate student is also requested.

The presentations were clear and well received. The concept appears interesting and the Committee supports further development. The request is for a modest startup effort and we would like to see a timeline how this project evolves into a realistic concept for a component of an EIC detector.

The Committee notes, that the layout of the crossing fibers still may have to be optimized (minimize shadowing of the fibers) and that a conceptual design for tiling is missing. The question of ambiguities has not been addressed and it is unclear if the concept can be developed into a large area pre-shower detector. Furthermore, the concept of "3D spatial resolution" has not been explained and is not understood. The group is encouraged to revisit their priorities with more emphasis on the performance of the concept in a real physics environment with emphasis on the shower separation in the presence of ambiguities. This should reference the more general detector requirements noted above under General Remarks. The development of a realistic tiling design that minimizes dead space for realistic EIC running conditions is encouraged.

The Committee notes that a timeline for the R&D is missing.

*The Committee recommends funding the proposal at the requested level. At the same time the Committee encourages the group to study with moderate to high priority the separation of showers in the context of large hit multiplicities through simulations and develop a viable tiling concept for an EIC detector.*

**RD 2012-14: Joint Proposal to Develop Calorimeters for EIC**

H. Huang (co-PI), C. Woody (co-PI)

BNL, Penn. State Univ., Texas A&M Univ., UCLA, USTC (China)

The Committee welcomes these first steps to form a collaboration on calorimetry and encourages its expansion and efforts. The Committee strongly recommends contact with other calorimeter R&D groups and also read with interest the specific simulation results, their connection to proposed physics measurements, and the resulting requirements for calorimeter performance in terms of energy and angular resolution and e/h discrimination.

The ongoing R&D effort on powder calorimetry discussed in the first part of the proposal has resulted in construction of two tungsten-powder plus scintillating fiber test calorimeters and their testing in-beam. Energy resolution and light yield have been measured in a test beam; a choice was made to deviate from optimum e/h compensation to focus on light yield and resolution. Fine sampling has been studied and first limits due to inefficiency of light extraction established. The group proposes to continue the development with focus on compact readout structure and choice of photosensors, to study mechanical properties of the powder device, and to develop a ‘wedge’ geometry for a barrel calorimeter. There were concerns about proposal completeness, and the elucidation of calorimeter requirements was lacking, specifically resolution, uniformity, calibration, rate capability, mechanical tolerances and radiation requirements. The Committee would like to understand transverse uniformity and spatial resolution of the test devices; it was not clear whether the in-beam measurements had been made with adequately fine determination of the position of the incoming particle and whether e.g. variation of the total energy response with incident particle transverse position could be determined.

*For the first part, the Committee recommends the proposers return with a more developed request and that partial support be provided for a staff member to prepare this.*

The second part of the proposal concerning accordion structures is well-motivated, although the need for an accordion structure versus just a few-degree tilt for an EM calorimeter is not clear. However the development of accordion structures is underway, does not appear to pose a manufacturing issue for the tungsten vendor, and could be useful for hadron calorimeters. The assignment of responsibilities among the collaborators was not clear, and the relationship to the powder structure above needs to be clarified.

*For the second part, the Committee recommends the first year’s effort be supported now and that the proponents return with initial results to discuss the second year’s funding at a future meeting.*

**RD 2012-15: Endcap TOF and TRD for Identifying Electrons at EIC**

Tonko Ljubicic, Bob Scheetz, Gene van Buren, Lijuan Ruan, Zhangbu Xu (co-PI) (BNL) Gerard Visser, (Indiana CEEM) Cheng Li, Hongfang Chen, Ming Shao (co-PI) (USTC/China) Subhasis Chattopadhyay (VECC), Richard Majka, Nikolai Smirnov (Yale), Dave Underwood, Hal Spinka (ANL)

The goal of the proposal is to develop a TRD for use in the forward region at an EIC to tag electrons and serve as part of an extended structure consisting of a central tracker, TRD, TOF, pre-shower and calorimeter. The TRD would use triple GEMs for signal amplification and a TPC-style readout of a following ion chamber. The proponents brought forward results from on-going work on GEMs and their readout electronics since the last meeting and gave through answers to the questions asked at that time. The first year would use existing GEM devices being built for STAR, modify the electronics to allow taking up to 100 time samples and operation at up to 15 MHz (the crossing frequency for eRHIC). Different type GEM structures would be examined – thin vs thick GEMs, for example. Measurements of dE/dx and position resolution would be made, followed by later fills with Xe + CO2 and study of the TR emission. Later efforts would explore and develop electronics and pad-planes options for the readout. The group appears capable of carrying out the effort and to have already much relevant experience.

A TRD clearly helps TPC tracking resolution in the forward direction. However, there is presently a discussion whether a thick GEM is suitable for the dE/dx measurements because of (a) gain non-uniformities, (b) long-term stability (charging and drying). In addition, there are questions whether the TRD concept can work successfully behind thick TPC endplates. The Committee supports R&D activity to address the GEM questions (should one use "classical thin GEM" vs. "various types of thick GEM"), and background simulation effort addressing TRD and dE/dx performance in the forward direction.

*The Committee recommends the first year be funded with a concentration on resolving whether various GEM structures can work in the proposed environment (behind a TPC endcap) and whether GEMs have acceptable gain uniformity and resolution. Background simulation should be part of this effort. Later in the year once chamber performance is understood, a fill with Xe + CO2 and study of TR emission should be done. The Committee would like to learn the progress before proceeding to the second year’s funding.*

**RD 2012-16: Detector R&D for EIC Detector**

E. Aschenauer, B. Azmoun, T. Burton, B. Christie, S. Fazio, A. Franz, M. Lamont, R. PaK, R. Pisani, S. Stoll, T. Ullrich, C. Woody (BNL) M. Hohlmann, M. Staib (FIT) A. Lebedev, M. Rosati (Iowa State), E. Sichtermann (LBNL), A. Deshpande (Riken-BNL & Stony Brook) K. Dehmelt, A. Drees , C. Gal, H. Ge, T.K. Hemmick, B. Lewis (Stony Brook) Z-E. Meziani, B. Surrow, T. Videbaek, S. Yalcin (Temple), K. Gnanvo, N. Liyanage (Virginia) ), H. Caines, J. W. Harris, R. Majka, N. Smirnov (Yale)

The collaboration presented in an excellent and convincing talk the progress towards forming a strong proto-collaboration for an EIC experiment, its physics priorities, a first order estimation of the detector performance requirements based on two “golden” physics channels, and proposals for two specific detector R&D programs.

There have been some changes in the collaboration: The size of the collaboration has further increased and the different members (presently totaling 10 institutions) have reaffirmed their commitment. In addition, further common efforts on R&D have been established. *The Committee is very pleased with these developments.*

Using two “golden” physics topics, namely the precision measurement of the longitudinal structure function, FL, and the strange spin-structure of the proton, Delta(s), generic detector performance requirements have been derived. *The Committee strongly supports the approach, however it notes that this is just a first step.* In addition to detector resolutions, detailed studies of the impact of uncertainties of acceptance, background and possible biases on the measurements are required. In addition, the issue of triggering will have to be addressed. Finally, this first order approach has to be extended to detailed simulations, once the detector layout including the interaction region, occupancy and radiation background is better known. Also the complex issue of radiative effects has to be simulated in detail. The collaboration is fully aware of this.

The concept of an optimized EIC detector has been presented. For the tracking detectors, where MAPS (Monolithic Active Pixel Sensors) and a fast TPC are proposed, the emphasis is on minimal material at the expense of integration time. In order to assign tracks to the proper bunch crossing, additional detector layers with precise timing are foreseen. It still has to be verified that this detector concept is compatible with the occupancy at the highest luminosities. The idea of a combined TPC and a HBD (Hadron Blind Detector) appears very appealing. This concept should be further developed and eventually its feasibility demonstrated. A micro-drift chamber based on GEM foils, which is expected to show a good spatial resolution also for inclined tracks, is also under consideration. For the forward tracking large area GEM chambers, possibly with 3-coordinate single plane readout, are under development. Results from various prototype tests have been shown. *The Committee considers the progress on the tracking detectors very good and the on-going and proposed R&D program important and realistic.*

For the forward region, which represents the biggest challenge with respect to particle identification using Cerenkov counters, a RICH is proposed. A test of a prototype with pure CF4, CsI cathodes on a GEM detector aided with a mirror having reflectivity in the VUV is under way. *The Committee is pleased to see this important R&D effort by the Collaboration.*

*The Committee strongly encourages stronger collaborative efforts with other groups on the different R&D projects.*

The budget, which clearly shows both a distribution among the different R&D items as well as among the several institutions, appears well justified. The financing of the post-doc, expected to play the role of a gluon for the detector R&D, is of particular importance.

*The Committee recommends full funding.*