Report of the EIC Detector Advisory Committee
4th Meeting, December 13-14 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 December 13-14, 2012 the EIC Detector Advisory Committee met at BNL to review six progress reports that were presented concerning work from projects funded earlier; one of the reports also included a proposal for additional funding, submitted in response to the third solicitation. One further written report on a newly started project and one final report from a completed project were also considered. The Committee also heard reports on intersection region design and backgrounds from the two principle machine designs under development in the USA and a report on the recent EIC Simulation Workshop held to organize the general effort on detector simulations. 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 December meeting.

General Remarks

The proposers are congratulated on the generally good quality of the talks, the focus of the work reported on key problems, and in particular on the extensive efforts to obtain the many results reported. The reports demonstrated responsiveness to prior charges and comments as well as ongoing dialog among proponents of similar technical solutions.

Two informative talks were given by accelerator experts, one from RHIC to discuss the eRHIC concept and one from JLab to discuss the MEIC concept. These experts also attended the entire meeting and provided helpful commentary on various points that arose during discussion of detector ideas. This provided a significant step towards addressing the request by the Committee at the last meeting for input on machine and especially IR geometry, on backgrounds and expected losses, and on planned polarization patterns. It appeared that the understanding of beam loss backgrounds is more developed in the case of eRHIC. The Committee would still find benefit in a pedagogic exposition of the machine layouts and performance parameters.

A report on the EIC Simulation Workshop demonstrated that this effort is off to a good start with community support. The tools needed for specific detector simulations are being developed, with several examples discussed. The important efforts of dealing with data exchange formats and securing access to adequate computing resources are started. Further remarks are given below. The Committee notes that this as well as the event generator effort reported under RD 2012-5 (discussed further below) will be a "decadal" effort and will need sustained manpower. Those presently engaged in setting it up can be expected to move on to larger responsibilities as detectors are defined and their construction undertaken and as careers progress. A dialogue started now by Lab management with the funding agencies can ensure a stable source of support for this effort. This will need to include computing experts who can address robustness of code and examine the same from maintenance and continuing support points of view, more so since one can expect continued evolution of the available computing environment.

The Committee notes the broad interest expressed in GEM detector technology and offers the following comments.

The various groups should talk to each other even more.

Is GEM foil stretching causing a risk that some copper holes' edges develop cracks and cause breakdowns? One group demonstrated an automated CCD-based scanner for GEMs. Could this be used after foil stretching to inspect all holes? In this sense TGEM might be a safer and more long-lived technical choice as it is not stretched.

One should develop and then establish a standardized way to qualify GEMs for breakdown. One possible protocol could be to search for discharges using a 2D-scanning machine equipped with an alpha source; such an automatic machine would scan over all GEM holes, with the operator carefully monitoring current spikes.

We encourage groups to consider the use of at least 4-GEMs for single photo-electron detection in order to handle discharges better; initial studies of this by other groups were encouraging. Using 5-GEMs might yield even better performance; one might consider 5-fold GEMs in order to reduce the gain per stage, which would mitigate problems due to highly ionizing ions entering the chamber on occasion. An effort to study these issues with the simulation tools now being developed is of interest.

As an alternative to GEMs, one might consider using fast micro-channel plates. Recent development by H. Frisch, though still at an early stage, addresses 20cm x 20 cm MCPs which could have low cost/unit area. The advantages are that these are thick, can be coated, and have a precise hole pattern, which is potentially much "cleaner" for UV detection applications than G-10 or Kapton. Study is required to determine whether electrons could be extracted from the upper surface were it coated by e.g. CsI, else one might have to add a window coated by CsI and extract photoelectrons from that. A dialogue is encouraged.

A quick check might be done whether occupancies permit using, instead of a pad structure, a wire chamber with resistive wire readout and charge division.

This said, and in anticipation of proposals expected for the next meeting, the Committee does repeat a few statements from the May 2012 report. Proposals need to insure they state the 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 then discuss how their resulting detector specifications will produce a detector that meets 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. Proposals should note whether the concept can work at eRHIC and/or MEIC, since the crossing rates are markedly different, and should also note whether the IR designs proposed are presenting any particular challenges for proposed physics measurements. This discussion should expand in the future to encompass triggering needs, because these necessarily influence the design chosen. 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.

As an example of the type discussion the Committee seeks, consider detection of transition radiation photons in an end-cap situated behind a TPC. Is the multiplicity and pixel occupancy for e.g. e-U collisions such that TR photons can be spotted and associated with little ambiguity with the correct track? Can this be done for the full range of “golden” measurements or is it best suited to a select subset? What is the rate of false positives and what arrangement including the number of layers of TR foils is needed to obtain a purity and efficiency sufficient to perform the proposed measurement(s)?

Initial estimates of neutron dose were discussed, notably by the calorimetry group and those planning use of SiPM readout; this can serve as a first threshold to rule out technologies that are especially radiation-soft. This is an encouraging start on a problem that will need sustained study. The community needs to develop the understanding of the radiation dose and occupancy expected for each of the two machine proposals. Simulations must eventually include the full environment, including all detectors, shielding walls and the accelerator structure for up to ±100m, to fully understand the dose. Detector proponents need to note the radiation dose their proposed technology can withstand and discuss where further knowledge is needed.

A general understanding of bunch-to-bunch variations of polarization and luminosity is still needed. Some further discussion of this is needed.

Report on the EIC Simulation Workshop
(E.-C. Aschenauer, reporting)

The main results from an EIC Detector R&D Simulation Workshop were reported in an impressive talk:

- Golden processes for inclusive, semi-inclusive and exclusive eA scattering have been defined as bench marks for the detector performance.
- FairRoot will be used as the framework for the detailed detector simulation
- On the basis of simulations (mainly "fast" simulations to date) the most challenging performance parameters for the different detector regions have been identified.

The Committee takes note of the excellent progress and strongly supports the idea of further workshops to discuss and plan the simulation work.

The Committee notes that the trigger concept(s) for EIC detectors should be developed, as they will have a significant impact on the detector design. It also encourages the development of first-order analysis tools for the simulated data in order to quantify the relation between detector performance and knowledge thereof (acceptance, resolution, background and misidentification) and the achievable precision of the physics measurements.

The Committee also notes that ideas on how to assure the long-term maintainability of the MC programs, to perform the code management and to do the quality control of the code must be developed. An important role of the EIC host laboratories is foreseen for this area, and a timely engagement of the funding agencies is needed.

RD-1 (RD 2011-1, RD 2012-14) Calorimeter Development for EIC
(O. Tsai and C. Woody, reporting)

Presentation and request by O. Tsai

The proposal section for the tungsten powder and fiber calorimeter addressed mechanical aspects and readout uniformity, including angular divergence of light, for various mans of coupling the light out. A conceptual design for the interface between W-ScFi, light guides, calibration fiber, photo detector and front-end electronics was shown.

The results on the energy resolution of the first W-ScFi prototype and comparison to simulations were shown. Measured and predicted energy resolutions agree within 10%. Parametric resolution studies of the device were made to establish contributions over the electron energy range from 1-100 GeV. However, given that the maximum energy was only 8 GeV, that the test beam had a significant momentum spread, and that the precise impact point had not been measured, the results are encouraging, however not completely convincing. Results from readout tests and considerations on calibration were presented.

A first estimate of the neutron background (10^{10} cm^{-2} at mid-rapidity, and $5x10^{10}$ cm^{-2} for higher rapidities for an integrated luminosity of 10^{41} cm^{-2}) has been presented. On the basis of this estimate, no major issue of radiation damage for the optical fibers was seen, and MPPCs (SiPMs) were considered adequate as light-sensors. The Committee appreciates this first estimate; however, the Committee is of the opinion that a more detailed estimate which takes into account the effect of halo electrons and halo hadrons is still required. This estimate appears to be for one year's running at full nominal luminosity and thus may correspond to several year's actual integrated luminosity. It is certainly for one major source of background (tunnel electrons hitting the beampipe) but is not the only source possible. The entire experiment boundary needs to be defined and included, i.e. all other detectors and walls need to be in the simulation, as neutrons can bounce back and forth. The Committee notes that while the physics groups tend to use GEANT4 for these simulations, the radiation safety groups will use either FLUKA or MARS in order to get normalizations correct. Some effort to explore this will be needed in the future.

The decision to select SiPM readout seems taken a bit early at this point. Continued improvement in understanding of their long-term behavior is still needed as is evaluation of improved versions now appearing. Consultation with the CMS group at FNAL and the GlueX group at JLab is encouraged given their extensive evaluation of issues associated with SiPM use. This effort might benefit from learning about and maybe adopting some of the electronics that has already been developed for these experiments. More broadly, the Committee encourages the proponents to acquire more details about ongoing projects using SiPMs for the readout of scintillators and calorimeters, and consider using their readout electronics for the R&D.

The budget proposal covered a number of small scale items to support completing and testing a prototype in beam in late 2013. The Committee is reluctant at this point to recommend funding another electronics project for reading out the powder calorimeter and encourages exploring whether electronics already developed for sPHENIX, CMS or GlueX could be used instead.

The Committee recommends funding for the other elements of the proposal requested at this time.

Presentation by C. Woody

First experiences and further plans for accordion W-SciFi calorimeters using W plates and SciFi embedded in W-powder epoxy were presented. In addition, various measurements on fiber-attenuation lengths were shown, the different types of SiPMs and read-out electronics presently under investigation discussed, and the R&D goals for 2013 were presented.

The accordion proposal addressed mechanical issues in forming the required tungsten plates and noted a shift to considering tapered core plates was underway. Light output vs. depth and uniformity over the transverse extent was studied. A readout architecture is under development, drawing from work on the sPHENIX proposal. This does address temperature monitoring and the necessary compensation feedback to the bias voltage.

The Committee needs further understanding of the accordion structure in the proposed setup. It can be difficult to determine the shower center, shape and direction if the shower is very small. Variations in sampling fraction in an accordion geometry should be studied for their effect on position and energy resolution plus shower shape (e.g. distinguishing two nearby photons from decay of a neutral pion from a single photon). Similar comments apply to a fiber-plus-powder projective geometry, in particular if towers are inclined by several degrees, up to as many as ten degrees, with respect to the interaction point to avoid long traversals of fibers by primary reaction products.

The efforts addressing uniformity of response by adjusting various readout elements (e.g. light guides vs. WLS plates) and testing various treatments are yielding useful systematic information and should continue.

The Committee supports the program.

General remark on Tungsten Calorimeter program

Once the planned programs are carried out, a report comparing the relative merits of the two tungsten approaches should be prepared and used as input to guide further development. Both groups should come to a decision which calorimeter design to pursue, and lay out the reasons for the decision taken.

Report on Scintillating Crystals by USTC

The written report also discussed efforts at USTC with dense crystalline calorimeters, in particular two types of BSO and PWO. The large light output from BSO at room temperature is of particular interest, more so if it allows a design that operates at room temperature. The Committee takes note of the progress reported and looks forward to further results once larger BSO crystals are available.

RD-3 (RD 2011-3, RD 2012-7) DIRC-Based PIC for EIC
(P. Nadel-Turonski reporting)

The Committee enjoyed the nice presentation from this ongoing project of very interesting work and the various choices and technical options considered. The Committee notes that to push DIRC PID performance to 5-6 GeV/c is hard in practice. Does one really need it for the physics program? One needs to ask what detector performance is needed to achieve the physics goals. It is recommended to initiate an evaluation of the impact of the physics requirements on the detector specifications. For example, a slightly worse but more uniform Cherenkov angle resolution might be preferable from a physics perspective. This is a good example of where effort using the experiment simulation tools now being developed would help answer what performance is required to reach the stated physics goals.

Before adopting a readout solution with SiPMs, one needs to estimate the neutron background correctly. This is difficult at this stage. One must include the machine background. For example, Belle-II is simulating the machine +-90 meters on either side of IP, whereas SuperB was simulating +-15 meters on either side of IP, which is not likely to be enough. The entire experiment boundary needs to be defined and included, i.e. all other detectors and walls needs to be in the simulation, as neutrons can bounce back and forth. The Committee notes that while the physics groups tend to use GEANT4 for these simulations, the radiation safety groups will use either FLUKA or MARS in order to get the normalizations correct.

A DIRC solution having the photon camera placed inside the magnet presents a real constraint on available space and the detector choice becomes very limited, perhaps even defaulting to SiPM at present, and access to the detector is constrained. Having a photon camera outside makes it possible to use longer bars which in turn allow chromatic corrections by timing, resulting in a much wider choice of detectors and no sensitivity to magnetic field.

Finally, last but not least, the SuperB project was recently cancelled by the Italian government. There is some effort to propose a tau-charm factory instead. Evidently FDIRC is not the preferred option for it, as FDIRC is too expensive. Instead the latest news from their collaboration meeting is that they may chose a simple TOF system. That means that the DIRC bar boxes and "know how" how to build the FDIRC photon camera are available. One can even join the present on-going FDIRC test in a cosmic ray telescope to gain immediate experience with such hardware.

The Committee adds a series of specific questions for the proponents' consideration.

> Does the simulation have realistic resolution for tracking, timing and noise from SiPMs? Did you get a reasonable single photon Cherenkov angle resolution with a good S/N? The additional side reflections in a photon camera cause additional combinatorial solution background, which makes the S/N worse. This needs to be studied very carefully.
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> Based on prior experience, a good dTOP = $TOP_{measured} - TOP_{expected}$ resolution may be important to resolve many solutions for a given pixel. A good dTOP resolution was thought initially to be necessary to remove background and correct for chromatic error. It

may be most important for limiting the number of ambiguities. For example, the SuperB FDIRC has a total of 8-20 ambiguities/pixel. This is a potentially important issue, which may require developing new methods of analysis (ring fitting, PID likelihood methods, etc.) as the usual pixel dictionary techniques to determine θ_c-distributions may not work.

Wider plates result in more ambiguities for multiple tracks., The analysis needed may become more complicated and time consuming.

Finally, a technical question - do you have already a mother board for the R11265-100-M64 tube or must one be developed?

RD-5 Radiation Damage to SiPMs
(C. Zorn et al., final written report)

The Committee notes the report by this group to the 2012 IEEE Medical Imaging Conference, reporting work partially supported by these R&D funds and thanks the group for their report to this Committee. The results therein form a useful addition to the nascent literature on long-term performance of SiPMs in environments likely to be encountered in experiments.

The Committee would be interested to see an addendum to the report, for example in tabular form that noted all of the environmental conditions and parameters for each of the several runs performed. This could aid the interested researcher in knowing in detail how well the measurements reported corresponded to their own situation.

RD-6 (RD 2011-6, RD 2012-9, RD 2012-16) Tracking and PID for an EIC Detector (T. Hemmick reporting)

This large and active collaboration presented progress on multiple interrelated tracking projects:

- A central arm TPC plus HBD using GEMs
- Forward large area planar GEM detectors
- CsI photocathode RICH large area mirror also using GEMs

The TPC & HDB detector thrust is concentrating on solving several fundamental problems in field sensitivity and gas choices and presented encouraging early results. The Forward Tracker effort has made progress in foil stretching and conceptual design of very large area readout schemes and has reconstructed tracks from small GEM chambers as well as tracks from a GEM with a novel "zigzag" readout scheme, both operated in a CERN test beam. On the RICH front the collaboration has designed new pad readout planes and has developed a promising method of making high quality UV mirror coatings.

In addition over the past six months the collaboration has worked on simulations of detectors and worked with the calorimeter collaboration – all activities directed towards the eventual design of a complete EIC detector. The progress over the past period has been impressive and the results generally very encouraging. Nevertheless, as funding grows tighter it would probably be wise to make every effort to ensure that both within this collaboration and within the larger EIC community that the R&D efforts are complementary rather than duplicative. For instance, GEMs play a central role not only in this work, but also figure heavily in several other efforts. At the moment, most of the research seems suitably complementary, but it is clear that it would be possible to engage in significant duplication of effort if communication within and between R&D collaborations is not maintained at a high level.

RD 2012-3 Fast and Lightweight Tracking Systems
(B. Surrow and M. Vandenbroucke reporting)

The Committee heard a progress report on the development of Fast and lightweight tracking systems and the design of large forward Triple-GEM chambers. The report focused on the activities at Temple University, which include the setup of lab space at the university, the start of simulation work and the design of a full prototype. An automated GEM foil scanning system has been commissioned. The group has also invested considerable effort in establishing commercial fabrication of large GEM foils with the company Tech-Etch Inc. The Committee is very pleased with the activities and that the group is becoming well-established at Temple University. The near term plan includes completing the labs and starting the measurements on prototype parts and starting the simulations. The design of a triple-GEM prototype will be completed. The Committee looks forward to further results on the mechanical design and analysis of these large structures and the ensuing prototyping program. The Committee is looking forward to the request from the group in the Spring of 2013.

RD 2012-5 Physics Simulations
(Th. Ullrich reporting)

Th. Ullrich gave a high-quality status report on the recent progress on the developments of Monte Carlo generators for the EIC and their use for the detector design:

- Sar*t*re for exclusive eA reactions with and without saturation effects.
- eA-hybrid for semi-inclusive deep-inelastic scattering (so far without saturation).
- eA-cascade for inclusive eA scattering using un-integrate parton distributions.

The Committee appreciates the significant progress made. It supports the proposal to give priority at present to using existing ep Monte-Carlo (MC) generators for optimizing the layout and performance of the central detector.

The Committee also notes that ideas on how to assure the long-term maintainability of the MC programs, to perform the code management and to do the quality control of the code must be developed. An important role of the EIC host laboratories is foreseen for this area, and a timely engagement of the funding agencies is needed.

RD 2012-15 GEM-based TRD and Identifying Electrons in EIC
(Z. Xu reporting)

This proposal addresses the development of detectors for electron ID in the forward direction using transition radiation in GEM chambers coupled with TOF and upstream tracking in the TPC. In May 2012 the Committee made the following recommendations:

"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."

The collaboration has largely succeeded in following this recommended plan. We note the establishment of a test stand at BNL using four GMT chambers. Strong connections with established GEM infrastructure and resources have been developed. Results were shown for gain, gain uniformity, CR tracking, and time development. The system included a TGEM. The GEM chambers were operated along with wire chambers using STAR readout electronics. The GEMs were read with the faster APV electronics. Plans are underway for a test beam in 2013 which will presumably look at tracklet resolution and actual TR detection.
Open questions remaining concern also the overall system and tracking performance aspects. The collaboration states therefore:

" In addition, we plan to carry out simulations including a realistic simulation for a combination of TPC and TRD tracking, TOF with converter for identifying scattering electrons at the level of better than 1000 hadron rejection and for detecting large background photons in a possible first-stage EIC detector."

The Committee looks forward hearing the results of this (and the beam tests) in Spring of 2013. Further second phase plans/goals include
1. Complete TRD prototype with radiator and tracking capability;
2. TOF prototype detector with the necessary radiation and rate capabilities;
3. Stage II TRD electronics design and new TOF electronics options.
4. Install the prototype in realistic magnetic field and radiation environment.

The Committee may support these goals contingent upon successful completion of the Phase-1 program and satisfactory results from the above mentioned simulation program.

In terms of questions and comments on the present status of work, the Committee makes the following points:

1) Future presentations on this work would benefit from a written text summarizing the results and referencing the prior reports and milestones.

2) The Committee heard a number of proposals for forward tracking and PID, some using GEMs in a number of functions. It would be good to understand the extent to which these various efforts are in synergy, are mutually exclusive, utilize overlapping technology, or are in some sort of collaboration already.

3) To what extent is the TPC tracking sufficient for this as part of an electron ID system? Would additional tracking layers, as part of a larger GEM (or other) system, have some advantage? Is there room for such additional layers?

4) What is the optimization of TRD, including the number of measurements, efficiency vs rejection, and use of other tracking layers in the available space?

5) The ATLAS tracking uses silicon followed by a straw tube/TR system. Conceptually there is some relationship to the present proposal. Can you learn anything from the ATLAS experience to help you better understand the usefulness or design of the system proposed here?

RD 2012-13 Pre-Shower Detector for Forward EM Calorimeters
(S. Kuleshov and W. Brooks, written progress report)

The report addressed startup efforts for this project. The ^{22}Na tagging detector has been built and characterized and the ability demonstrated to detect triple coincidences among the $LaBr_3(Ce)$ viewing the ^{22}Na and the two sides of a single LYSO crystal read out by SiPMs. Engineering work has progressed to design the housing for the LYSO array which will be read out by crossed fibers. Simulation work is still being organized at this time. The other ongoing projects at the UTFSM were briefly described regarding how they help develop technical capability that will benefit this effort. The Committee is encouraged by the progress to date and looks forward to a more extensive report at its next meeting. A part of the May 2012 report from the Committee is repeated below in anticipation of further work by the group.

(From the May 2012 report)
"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."