ELECTRON-ION COLLIDER DETECTOR ADVISORY COMMITTEE

Report of the 8th Meeting held on Thursday and Friday, 22 and 23 January, 2015

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.

The EIC Detector Advisory Committee met at BNL on January 22 – 23, 2015, to hear progress reports from ten initiatives. For one additional project only the progress report was reviewed. No new proposals were considered at this meeting. Requests for funding of existing and new proposals will be handled during the June/July meeting. The Committee members are: M. Demarteau (ANL/Chair), C. Haber (LBNL), P. Krizan (Ljubljana), I. Shipsey (Purdue/Oxford), R. Van Berg (U. Pennsylvania), J. Va'vra (SLAC), G. Young (JLab). I. Shipsey was unable to attend the meeting due to unforeseen circumstances with the submission of the Oxford base grant application. Robert Klanner has retired from the committee. His contributions to the development of this program have been substantial. His insights, expertise and knowledge of detectors and EIC physics will be sorely missed. The committee welcomes Peter Krizan from the department for experimental particle physics at the Jožef Stefan Institute of the University of Ljubljana.

Thomas Ullrich, the manager for this program, reiterated in his opening remarks that the NSAC subcommittee on Scientific Facilities ranks an EIC as absolutely central to its ability to contribute to world-leading science in the next decade. The Long Range Planning process will converge by April and submit their recommendation to the office of Nuclear Physics. The EIC was ranked by the hadron and heavy ion physics communities as their highest priority construction project. He further noted that the current detector R&D program is very well received by the community and the Office of Science and that there are many outstanding R&D issues that remain to be addressed in order to achieve the physics performance metrics.

General Remarks

At the last meeting the EIC advisory committee adopted the proposal, put forward by Thomas Ullrich, to follow a different protocol. At the winter meeting progress of the consortia is reviewed. At the summer meeting progress will be reviewed and new proposals will be considered. This plan allows funding of new projects to be better synchronized with the funding cycle. New proposals can apply only for one year of funding and follow-up proposals are strongly encouraged. This was the first meeting of the committee following the new protocol. On the first day the panel heard progress reports from ten initiatives and evaluated in addition one progress report that was submitted, but not presented. No new proposals were considered.

Requests for funding of existing and new proposals will be handled during the June/July meeting.

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

To allow for an easier evaluation of the progress of the consortia in the future, the committee would like to ask the collaborations to succinctly summarize, in the progress reports as well as in their presentations, what was planned for the review period and what was achieved. An executive summary is most welcome. If not all tasks were completed, the reasons for the delay should be given and the corrective action taken. Also what is planned for the next funding cycle should be described, with milestones and deliverables and the critical issues should be highlighted.

The committee also notes that the intent of this R&D program is to provide seed funding for promising research proposals that after a couple of years can be sustained on independent external funding. Proponents are encouraged to explore opportunities for external funding once their research program has been established.

Over the course of the last five years a significant amount of support has been given to the detector research and development for an EIC. An often-used metric by the DOE to gauge the effectiveness of a program is the number of publications. The R&D carried out within the framework of this program is of high enough caliber to be published. **All R&D groups are strongly encouraged to publish their results in a timely way.**

The Committee notes that the Nuclear Physics Long Range Planning committee will converge on the timescale of a few months and a recommendation is expected in April 2015. If there is a positive decision with regard to the EIC it will move this program to another level. To date this program has been for generic EIC R&D. If there is a positive decision towards an EIC, it is very likely that directed R&D funds would be made available. This would provide each eRD group with a unique opportunity to enhance their current program. The committee encourages each eRD group to start an appropriate longer range planning process in anticipation of a positive recommendation. The groups are encouraged to anticipate the process of the formation of collaborations and a directed R&D program that will lead to the writing of technical design reports for the machine and detectors on a relatively short time scale.

As consortia move towards the formation of collaborations and lay out a full detector with its preferred technology choices, some consideration should be given to the trigger architecture and the readout for each technology choice, in particular the electronics. A survey of the field for existing trigger architectures and front-end electronics designs, including but not limited to available ASICs, is encouraged to judge how well current solutions are matched to achieved detector performance. It is advisable to consider whether ASICs and front-end designs that are currently available, including the implied power, cooling and data connection requirements, allow realization of the full detector performance. Development, either incremental or new, of systems could be required to ensure the detector and not the downstream architecture and its implementation limits detector performance. One can envision a future R&D effort assessing

whether existing designs, that appear applicable, can still be produced, or if new versions are needed to address likely production, process or paradigm constraints circa 2023-2027, which appears to be a likely period for large-scale detector and electronics production. This study could take into account technology road maps that exist for silicon foundries, recognizing that not all processes are suitable and any process has a design and production lifetime. Such a study could lead to suggested areas for targeted R&D for electronics tailored to an EIC.

eRD1: Status Report and Proposal for EIC Calorimeter Development
C. Woody reporting

A detailed written status report has been submitted, and C. Woody gave an oral presentation. In the presentation, the following four topics have been covered.

1) Development of an electromagnetic calorimeter based on a matrix of tungsten powder and epoxy with embedded scintillating fibers (W/SciFi)

   The main efforts developing this technology have been focused on improving light collection uniformity within the modules, developing a high resolution version of the modules that could achieve an energy resolution about 6%/√E, developing a cost effective mass production method for producing the huge quantity of modules needed for the barrel calorimeter, and developing a method for producing fully projective modules. A possible industrial partner was identified, and looks promising.

   Since the last report, the BNL PHENIX team has joined the UCLA team in developing the W/SciFi calorimeter, because of the synergy between the central electromagnetic barrel calorimeter for the upgrade to the PHENIX experiment (sPHENIX) and the calorimeter for a detector for eRHIC.

   The Committee finds the progress on the project very promising, in particular the development of the possibility to use a commercial producer. The Committee would like to understand how different the calorimeter would be if it were optimized for ePHENIX rather than sPHENIX.

2) The study of radiation damage in silicon photomultipliers (SiPMs)

   The study of radiation damage in SiPMs focused on neutron induced damage and investigate ways to deal with the large increase in dark current that is produced by irradiation. The MC based estimate of the neutron fluence was benchmarked against a thermal neutron flux measurement in the STAR hall, and good agreement was found. The committee suggests to test each batch of SiPMs using a source of thermal neutrons.

   The Committee is worried about the impact of thermal neutrons. In particular, what is needed is a reliable estimate of their fluence, together with results of studies of thermal neutron effects in SiPMs for different SiPM types.

3) Development of scintillating crystals for an electromagnetic calorimeter in the forward electron going direction at EIC

   The effort on scintillating crystals for use in a high resolution electromagnetic calorimeter in the forward electron direction consisted of two parts. The main activity was devoted to developing a viable source of $PbWO_4$ crystals. While the producer of the crystals for CMS has gone out of business, the Shanghai Institute for Ceramics (SIC) has quality assurance problems. A new potential vendor was found, Crytur, who is a potential supplier for the

crystals for the PANDA calorimeter, and is under consideration. Having a second qualified crystal grower would be a benefit to the community. Crystals delivered by SIC are under study, and will be tested for radiation hardness. It is not clear whether the group wants to operate the calorimeter at low temperatures (~ -25 ^{0}C) or not.

The second activity was the continued investigation of BSO crystals as a low cost alternative to $PbWO_4$. The R&D for large-scale production is carried out at SIC. A beam test of a 3x3 matrix is planned for early 2015. A small team plans to carry out this study, and it is not clear whether the group is subcritical.

The Committee is looking forward to learning about the crystal quality of the PWO_4 production for PANDA and would like to learn more about the experience of Crytur in crystal production, notably for the scientific community, such as the LHC experiments. The radiation damage studies of $PbWO_4$ crystals from Crytur should be made as soon as possible. The Committee would like to recommend that the group complete the test beam studies of the BSO 3x3 matrix, but then give this option lower priority given that the effort seems subcritical and would require substantial resources over a prolonged period.

4) Simulations on calorimetry and related detector systems for an overall EIC detector.

The effort on simulations has provided valuable guidance to other activities as to the requirements and expected performance of the various detectors. Many of these simulation results are presented in the newly released eRHIC Design Study. The simulation of calorimeter modules tested in the beam has shown a good agreement with the data.

The Committee appreciates the good progress in the area of Monte Carlo simulations for the detector design as well as physics performance in developing detector performance specifications and physics capabilities for a comprehensive detector at an EIC. These are of great help and will guide the R&D efforts. The Committee finds the report very useful, and an excellent starting point for further studies.

eRD2: Status Report on A Compact Magnetic Field Cloaking Device
N. Feege reporting

The committee finds this a good project, with very good, concrete results and of potential high value to the community. There has been considerable progress in optimizing the fabrication techniques and testing methodology. The long prototype is fully commissioned and ready for the test beam. Epoxy-steel mixture is a viable option for the ferromagnetic material choice. We appreciate the strong involvement of students and the committee supports this program enthusiastically. It would be nice to see these results summarized in a publication.

The committee reminds the authors of the report that some of the questions from earlier reviews are still open:

- Thermal effects due to accidental beam dumps in view of structural damage.
- Radiation hardness of the ferromagnetic and superconducting materials. For example, the sensitivity of magnesium boride (MgB_2) to thermal neutrons should be tested.
- Effect of a possible cryostat and its flanges on the detector acceptance and performance at small angles.
- Quantitative study of the physics benefit for a conceptual forward dipole spectrometer.

While the first of the above-mentioned two efforts focus on technical needs before deployment and thus have to be settled before then, the latter two would be good projects for new students and give the group a basis for active involvement in future EIC collaborations, in particular for planning detector layouts and making the major choice regarding magnetic configuration.

eRD3 - Design and assembly of fast and lightweight barrel and forward tracking prototype systems for an EIC
B. Surrow and M. Posik reporting

The consortium has made good progress on both forward GEM and barrel MicroMegas detectors for a future EIC experiment. The GEM work is centered at Temple University with strong contributions from FIT and UVa while the MicroMegas work is centered at CEA, Saclay.

The commercialization of large area GEM foil production fostered by the collaboration is especially impressive and the detailed QA tests developed for checking both CERN fabricated and Tech Etch produced foils for leakage current and hole size and pitch are well designed. The ability to provide very detailed technical feedback to both the CERN shop and Tech Etch will surely be helpful in improving the uniformity and reliability of these basic building blocks of a GEM detector. The collaboration has, in addition, benefitted from the initial QA efforts to allow improvements and refinements to their own processes for the larger foils now being produced commercially.

The consortium is also in the process of assembling and testing a number of smaller (10cm) triple GEM test chambers. The plan is to characterize their performance with both sources and cosmic rays. Work is underway to finish the design and then construction of larger, 40 cm, scale chambers at all three sites using somewhat different techniques to position and stabilize the foils. The collaboration has produced a common design for an EIC scale end cap tracker and the foil for that design will soon go into commercial production.

The work on MicroMegas at Saclay has produced a 120 degree section large scale cylindrical chamber with Z readout that has been tested with cosmics. In an impressive feat of diagnosis and repair a short occurring part way through the test, caused by “dust”, was located and removed by the Saclay team.

The consortium has also been working on simulating the forward GEM / barrel MicroMegas solution for an EIC detector and is now able to make detailed estimates of material for this solution versus a TPC solution for central tracking in an EIC detector.

The committee notes that Temple University, with the funding obtained through this program and additional support from the university, has established strong expertise in micro-pattern gas detector development. The Temple group is in an excellent position to establish itself as a center of excellence for micro-pattern gas detectors in the country and is encouraged to explore this possibility.

Recommendation:
The infrastructure now available for QA and assembly at Temple (and already long available at Saclay), seems well poised to allow the consortium to move into large-scale prototyping for a future EIC detector. The consortium should develop a plan to map this capability into an actual detector design satisfying the constraints that may be imposed by a large collaboration, which may have complementary but also conflicting physics goals. This will be a challenge for the next phase.

eRD4: DIRC Based PID for EIC
P. Nadel-Turonski reporting

The committee notes that there is steady progress in the overall understanding of the DIRC. The group has developed the experimental setup to evaluate MCP-PMTs in a large magnetic field, and has begun to evaluate several MCP-PMT tubes in it. This will prove to be a very valuable investment. We point out that the phase space for the DIRC detector optical design is huge if no constraints are applied, i.e., at some point one should concentrate on the EIC-related design. To guide these studies, the committee suggests that studies of the performance for single particles as a function of phase space variables, such as various specific track orientations, be carried out as function of background conditions. This will provide insight into the limitations of the detector performance and indicate if the detector is able to handle backgrounds that are, say an order of magnitude worse than expected. These studies will also highlight regions of phase space where the performance deteriorates either at zero background or higher backgrounds and will lead to quantitative comparison of various designs. Once these studies have been carried out, the consortium should be in an excellent position to study its physics performance for the crucial physics processes versus backgrounds.

The committee reminds the authors, that some questions from the previous review are still open:

- Since the lens uses complex glasses at present to achieve a higher refraction index compared to the silica, we encourage the group to take a few samples of these glasses and subject them to 5-10krad of ^{60}Co radiation in order to weed out wrong paths as early as possible.

Recommendation:
The committee would like to see a demonstration that the lens design does not introduce some unintended distortion effects. Specifically it would be nice to see its performance in the reconstruction program, which includes a realistic background, and to compare it to (a) the BaBar DIRC with its pin hole focusing, (b) SuperB FDIRC with DIRC bar boxes and 3mm pixels, and (c) a new EIC FDIRC with a cylindrical mirror and 2 mm pixels. The committee hopes that a quantitative comparison can be presented at the next meeting, or at least a plan to make such a comparison.

eRD6: Proposal for detector R&D towards an EIC detector
T. Hemmick reporting

This proposal reviewed well in July of 2014. The team is comprised of members from BNL, Florida Tech, Stony Brook, the University of Virginia, and Yale. The team has continued to make good progress, generally following the committee's recommendations, and has been forthcoming with details and expositions of the status of the work.

Efforts have covered simulation and performance studies, data analysis, laboratory tests, fabrication, and continued design work. The goals and recommendations of July 2014 were focused on the full year of effort so the six-month status seems reasonable.

Specific activities include test beam analysis from the mini-drift detector, design of the TPC/Cerenkov detector and component fabrication, tracking algorithms and resolution studies for GEMs, tracking simulation for the test beam, forward GEM design and assembly, RICH beam tests and analyses, and a variety of GEM and hybrid readout structure studies.

The common work of UVa and FIT with B. Sorrow of eRD3 is an excellent development and should be continued enthusiastically.

The committee commends the consortium for submitting results of this work for publication and sees this achievement as an important example for the other consortia to follow!

The committee recommends to certainly continue the planned efforts and complete the tasks, which have been delayed due to funds allocation, procurements, staffing priorities, workflow, or task complexity.

Considering the upcoming milestones in a process, which will hopefully lead to a real EIC project, and the likely schedule, leading to physics in about 10 years, the committee strongly encourages the consortium to begin an appropriate longer range planning process. It may be time to converge on technical choices and merge efforts where appropriate with other consortia. The committee would like to see this reality addressed in future presentations.

eRD10: Status Report on Fast Timing Detectors using mRPCs
M. Chiu reporting

The group has made definite progress, constructing a first version of an mRPC, diagnosing its behavior and incorporating what was learned in a second version, which is now well along in construction. Specific choices about glass substrate and PCB dimensions, cathode coating, orientation of various cells and biasing, and extraction of signal have been made. Suitable fast electronics and DAQ have been identified. The ringing observed on scope traces, however, shown in the presentation (but less apparent in the write-up) suggests improvements are possible in the coupling of the electronics to the detector. Test beam data were taken at FNAL and progress is being made to set up a cosmic-ray test stand at UIUC for long-term and parametric studies.

The Committee reminds the proposers of the following issues, made in the previous review in June 2014, many of which are still open:

- General detector and optimization studies should be done.
- Collaborate with RICH/JLab group on basic LAPPD characterization studies
- Post-doc efforts towards the eventual application of new photocathode materials.
- At a somewhat lower priority look into the pad readout options for LAPPDs – because the technical modifications needed are likely to lag behind the photocathode work.
- Theoretical studies of RPCs are viewed very favorably but the group is encouraged to seek additional funding for this.
- Make best use of the post-doc already in place at UIUC to balance the proposed work on mRPCs and efforts towards the LAPPD aspect.

The Committee does take note that the LAPPD items are pursued by RD11 and that the RD10 group has made contact with them and started discussions about a broader "PID" R&D consortium. The postdoc at UIUC evidently will focus now on mRPC work.

A basis of reproducible results is needed before starting systematic studies of the variables affecting the timing resolution. The committee suggests focusing on completing and operating the current prototype with the glass plates, to gain operating experience and produce a data set to form a basis of comparison for data to be taken from future parametric studies or with altered detector construction. This should be done before moving to different substrates such as Kapton. An early program of studies to obtain timing resolutions under known conditions for comparison with published state of the art of such detectors is needed before proceeding with a program of e.g. parametric studies of this behavior.

- The group should invest into the construction of a cosmic-ray telescope (CRT) with good tracking capability and thick enough shielding to ensure that muons of above 1, and preferably 2 GeV, are tagged. They should discuss the design of this CRT with DIRC proponents as it might be useful for them as well at some point.

- It was expected by the committee that the theoretical studies of mRPC performance, e.g. of avalanche formation, would proceed forthwith. While the Committee is pleased to see the progress in setting this up, we encourage its timely pursuit.

eRD11: Forward RICH Detector
C. Zorn reporting

The group has been funded to test LAPPD MCP-based photodetectors and to carry out detailed detector simulations, in particular the implementation of optical components in an MEIC-GEMC with simulations in standalone mode to study the requirements on the optical quality of aerogel and the Fresnel lens.

The group has made good progress setting up the infrastructure for photodetector testing and first results were shown. Magnetic field sensitivity will be an important study and the group is ready to start these measurements.

Progress was also reported in the area of simulation; detector non-uniformities and non-flatness effects have been implemented. The simulations have been extended to include gas radiators and realistic detector performance has been implemented. Studies of PID requirements of angular and momentum coverage have begun. The committee hopes to see the full realistic and detailed MC simulation of the Cherenkov angle resolution as a function of various forward RICH detector options completed by the next meeting. As stated previously this simulation should focus on a few examples, which are closest to a likely geometry choice of the EIC detector. This should be coordinated among other participants in the EIC development. The MC simulation of the Cherenkov angle resolution should include modeling of the state of the art of various technologies, including several Aerogel options, the DIRC-like option à la forward Panda RICH, various gaseous radiator choices, as well as various detector options. The people involved in the MC simulation should contact corresponding experts in other experiments doing similar work in Belle-II, Panda, and other experiments.

The committee is worried about the impact of the imminent departure of Yi Qiang, who has been leading this effort to date. Identifying a co-leader, together with Hubert van Hecke, should be a high priority. Very little progress has been made to date on the formation of a PID consortium.

The committee fully supports the simulation studies and is looking forward to a comprehensive presentation at the next meeting. The testing of LAPPD tubes is encouraging. Especially measurements in high magnetic fields are strongly encouraged. The committee would like to see progress towards the formation of a PID consortium at the next meeting.

eRD12: Status Update on Polarimeter, Luminosity Monitor and Low Q^2-Tagger for Electron Beam
E. Aschenauer reporting

The collaboration successfully added a postdoc last August and significant progress has been made on understanding and detailing the IR design. The collaboration has also managed to integrate the computer aided design (CAD) files and magnetic field maps from the BNL collider accelerator division (CAD) into the EICRoot framework, thus greatly enhancing the ability of the detector designs to provide feedback to the machine design.

The interaction with the machine design group at BNL seems to be very productive and several significant changes in magnet orientation and position have resulted from feedback provided by the simulations. This ability to optimize the overall design is highly valuable and is to be commended.

The collaboration has begun the detailed design of the low-Q^2 tagger with the intent of moving on to polarimeter and luminosity detector design in the next phase followed by integration and re-optimization of all those devices. These efforts will, naturally, involve additional (and continual) collaboration with the machine designers but the interactions to date give every indication that reasonable compromises will be arrived at giving a near optimal final design. The work with the eRHIC accelerator team is clearly advancing well and bearing significant fruit. As of yet, however, the committee is unaware of an equivalent collaborative effort with the MEIC design team.

Recommendation:
The group is to be commended for the progress made over the course of the last six months and is highly encouraged to continue these studies and maintain the close feedback with the accelerator design team. The committee recommends that a presentation of the status of the work for the MEIC design is presented at the next meeting and encourages a dialogue between the two efforts.

eRDx: Compton Electron Detector

A. Camsonne reporting

There has been considerable progress in the understanding of the different requirements of eRHIC and MEIC for a Compton polarimeter. This includes noting eRHIC has a given ion bunch always colliding with the same electron bunch, whereas MEIC has each ion bunch colliding in succession with all electron bunches. The different RF structures of the machines were taken into account. An evaluation was given of the expected rate of electrons as a function of electron kinetic energy per Watt of laser power and per Ampère of beam. It was shown that acquiring adequate counting statistics can be done in a few seconds for the various cases.

The group has studied a particular magnetic chicane layout (Hall A at Jefferson Lab) and a particular layout for laser, crossing angle and detector location. There are possibilities for preparing a chamber to allow testing of various detector ideas. The chicane can operate any time the Hall is operating, giving regular possibilities for scheduling tests.

The group has recognized that relevant rates dictate detectors with good time response and may require detectors and perhaps electronics with a good degree of radiation hardness. Options for detectors were discussed; the Committee encourages further contact with colleagues with experience with fast radiation hard devices and development of specific concepts for trials.

The group is encouraged to proceed to development of a proposal.

eRDx: Development of a Spin-Light Polarimeter for the EIC: an UpdateDetector D. Dutta written report submission

D. Dutta provided a written status report on the development of the spin-light polarimeter. In consultation with the MEIC accelerator team a lattice location has been identified for a spin-light polarimeter near the interaction region. Furthermore, members of the MEIC design team have joined him to study the feasibility of the spin-light polarimeter. A set of 8 dipole magnets, that are already part of the lattice design, have been identified as a possible source for the spin-light polarimeter. The field strength of the magnets is significantly lower, however, than the original design, making this challenging measurement even more challenging. With the new configuration the asymmetry is too small to be measured precisely using existing detector technology. Studies have also been carried out for the eRICH design. It has been concluded that a longitudinal polarimeter is not feasible for either the current MEIC or the eRHIC lattice designs. The asymmetry for transversely polarized electrons is at least an orders of magnitude larger than the asymmetry for the longitudinally polarized electrons and this option is currently being studied.

The group is encouraged to continue their studies.