Addenum to the proposal: DIRC-based PID for the EIC Central Detector

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The goal of this addendum to the proposal is to provide an initial response to the Advisory Committee's comments and suggestions, as well as presenting an updated plan for year 1, funded in FY11.

1. Suggestions from the Advisory Committee

The suggestions of the committee fall into three general categories.

1.1 Physics simulations

Part of this proposal is aimed at investigating the possibility to push the limit for 3σ separation between various particle combinations (e/π, π/K, K/p) in the DIRC detector to higher momenta. The possible improvement beyond state-of-the-art would vary somewhat for each combination, but potentially be up to 50% for π/K. Increasing the momentum range for 3σ separation is equivalent to increasing the separation for a fixed maximum particle momentum, as the separation between all particle species improves rapidly at lower momenta.
In this context, the committee specifically asked for three things.
The first was to provide specific examples of signal and background rates for some channels and kinematics, for instance the pion and proton backgrounds for kaon production in SIDIS, to determine whether the nominal 3σ separation criterion is adequate. The second was elaborate on the physics gain from increasing the momentum coverage in general, and the third to specifically look at the improvement in e/π identification at low pion momenta, which would be required for the measurement of F_L.

1.2 General detector questions

Two questions were raised in the context of the integration of the DIRC with the EIC detector, both related to the anticipated radiation dose.
The first was to ask for initiation of studies of the machine synchrotron background, which also is a source of neutrons, for both the JLab and BNL designs. Such studies would preferably be conducted in collaboration with experts from, for instance, SuperB or KEKB. The second request was to include an option for extending the DIRC bars through the electron-side endcap, penetrating the iron, and investigate its impact on the overall detector performance. Such a solution would reduce the requirements for

operations in high magnetic fields and improve accessibility, but potentially have a detrimental effect on the Cherenkov detectors and calorimeters in the endcap.

1.3 Work on the DIRC readout "camera"

The original proposal envisioned that preparations for the construction of a first, simple prototype for the DIRC readout "camera" (*i.e.*, expansion volume and sensors) would start in year 1, and that simulations, sensor tests, design work, and evaluation of the performance of the initial prototype would proceed in parallel and eventually be incorporated into a second, final prototype in year 3. The committee suggested to modify this schedule so that no prototyping work is carried out in the first year.

The simulation and design work is suggested to focus on studies of the requirements for achieving the best PID performance, and optimization of design parameters. The latter would, for instance, including pixel size, timing resolution, bar geometry, and the effects of a tracking point after the bar.

For the hardware, it was stated that G-APDs (SiPMs) are the only choice that is currently known to work at the upper end of the range for the maximum magnetic fields (2-4 T) anticipated for the EIC detector solenoid. It was thus suggested to put particular emphasis on the evaluation the performance of these sensors in the presence of a neutron background, taking advantage of other work done on this topic at JLab and GSI. In addition to radiation hardness, focus is put on cooling requirements and reduction of photon losses in the focusing optics by coupling the G-APD (SiPM) directly to the optics, minimizing the dead space between pixels.

2. Physics simulations

In the original proposal, the focus of the year 1 physics simulations was on pion backgrounds for the electrons in the EIC central detector to determine the need for supplementary e/π discrimination capabilities beyond those of the DIRC and the electromagnetic calorimeter. While this is already in line with the committee's recommendations, we will expand this effort to a broader range of signal / background combinations also including kaons and protons. For some of the latter we can perhaps utilize results from groups, both at the national labs and participating universities, who are working on simulations of various EIC processes.

Added to year 1 will be an effort to articulate the physics gains of extending the momentum coverage for particle identification in the central detector beyond what can be achieved with a state-of-the-art DIRC (or an aerogel RICH, which offers somewhat lower performance and thus faces similar challenges associated with supplementary detection requirements).

Combining these two efforts, it should be possible to present the background rejection requirements for a very limited number of golden channels.

3. Detector design and integration

As presented in the original proposal, the design work will focus on studies of the performance of different bar geometries and expansion volume (EV) sizes, shapes, focusing designs, and radiator shapes, in terms of single photon resolution and light yield. The effect of including additional tracking after the DIRC will also be looked into. However, following the recommendations of the Committee, the goal will shift from finalizing the design of a first prototype, to a more general study of how to build a readout “camera” suitable for the EIC that would push the DIRC performance limits. The simulation work will comprise:

1. Implementation of the readout “camera” in GEANT, including:
    a. Polished fused silica bar/plate
    b. Small expansion volume (approximately 30 cm deep)
    c. Focusing lens
    d. Multi-pixel readout
2. Development of reconstruction algorithm for the bar/plate geometry.

The option of having very long DIRC bars penetrating the iron, allowing the readout to be placed outside of the solenoid field, will also be included, and the impact on the electron encap detectors will be evaluated.

In the original proposal, the bulk of the work on the integration of the DIRC into the EIC detector was planned for year 2. However, once the design options and requirements for the readout “camera” have been identified, an attempt will be made to evaluate the interaction of the DIRC with other detector components, even if a full GEANT simulation would not be ready by the end of year 1. The integration work will also include optimization of the location within the EIC detector and a materials budget. Although the evaluation of synchrotron radiation backgrounds from the accelerator falls outside the competence of the proponents, efforts will be made to obtain this information by interacting closely with the accelerator groups at both JLab and BNL. At JLab, where the storage ring will not constrained by legacy hardware, efforts have already been made to incorporate background reduction into the design. This includes, for instance, an electron beam line aligned with the solenoid axis with no bends in the straight section to suppress synchrotron radiation, and an ion beam geometry minimizing hadronic backgrounds from interactions with residual gas. A first look at the synchrotron radiation from the IR quads by Mike Sullivan (SLAC) suggested that this contribution will be very small. He has promised to do more detailed studies, with results expected in the fall of 2011.

4. Sensor studies

The focus of the first year hardware activities will be on studying several types of photon detectors for potential use in the EIC DIRC. The work will include:

1. Set up a station for measuring the single photon detection uniformity and timing properties of different sensors.
2. Set up DAQ system for readout.
3. Test of sensors using fast laser pulser.
4. Study magnetic field tolerance of SiPM and MCP-PMT (up to about 2 T)

The year 1 sensor testing will provide input on sensor performance needed for a realistic simulation and design of the DIRC readout “camera”. The plan includes tests in magnetic field at up to 2 T, thus reaching the lower limit of the maximum solenoid field considered for the EIC. This will, in particular, make it possible to assess the performance of the latest 6 micron MCP-PMTs. An effort will also be made to identify or create a facility suitable for conducting such test at up to 4 T.

5. Updated procurement plan for year 1

1. Materials for CUA undergrad student (computer, etc): $1.5k
1. Dark box for sensor tests: $2k
2. One multi-pixel PMT: $11k
    a. option A: Hamamatsu H9500-03 (256 pixels)
    b. option B: Photonis XP85022 (1024 pixels)
3. Two digital SiPMs, Philips: $4k
4. One 6 micron MCP-PMT, round, single anode, BINP, Novosibirsk: $2k
5. Readout electronics: $5k
    a. option A: HADES TRBv2 with TOF-addON, 128 channels with fast TDC (100ps/count) and time-over-threshold
    b. option B: new, faster version (TRBv3) expected in late 2011 (~10ps/count, more channels per board), similar cost per channel
6. Cabling for 128 channels: $2.5k
7. Temperature-controlled cool box for SiPM tests: $2k

Total: $30k

Comments

The costs listed above are direct, assuming an exchange rate of 1.4 USD per Euro.

6. Budget

The budget request of $115k for the first year was approved as requested. Compared with the original request, slight adjustments have been made do the postdoc salary due to additional health insurance costs. However, following the committee's recommendations, this has been partly offset by reductions in the planned hardware procurement (and travel). The tables below list the budget broken down by recipient and category.

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Old Dominon University (ODU)	$53,290
Catholic Univesity of America (CUA)	$9,800
JLab (and GSI through a MoU)	$51,910
Total	*$115,000*

Postdoc (50%)	$53,290

Undergrad	$8,300
Hardware	$41,970
Travel	$11,440
Total	*$115,000*

Comments

All budget items include overhead. Matching funds are available for the postdoc.