Date: March 5, 2021

EIC Detector R&D Progress Report

Project ID: eRD17
Project Name: BeAGLE: A Tool to Refine Detector Requirements for eA Collisions
Period Reported: from July 2020 to March 2021
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Abstract

As a successful part of the EIC R&D program, the BeAGLE (Benchmark eA Generator for LEptoproduction) model code for simulating e+A collisions has evolved into a key element in the efforts to refine the detector and interaction region design for the EIC, particularly in the forward region in the ion-going direction. It has been used extensively to perform e+A studies which drove the forward detector/IR designs and highlighted possible tradeoffs. Following the successful Yellow Report process, and given the advanced state of the EIC project, development of new physics drivers for EIC is no longer the highest priority. Instead the priority has shifted to understanding the IR & detector design tradeoffs using already identified physics channels (such as those in BeAGLE) using a full GEANT simulation. In the near future (FY2021), therefore, the focus of eRD17 is shifting to three items: 1) Finalize, cleanup and debug the code; 2) Provide example control files for important processes; 3) Document the code, including publication of papers. In the longer term (FY2022 and beyond), we do not foresee BeAGLE development as falling under the EIC R&D scope, so the project will end in FY2021.

Past

What was planned for this period?

We planned to have three of the four benchmark processes available in time for the Yellow Report and contribute substantially to the Yellow Report. These processes were:

1. Incoherent diffractive J/ψ for e+Pb.
2. Fully tagged diffractive deuteron breakup, including the high-k SRC tail.
3. Double-proton-spectator-tagged e+^{3}He.

It should be noted that, due to reduced funding being available in FY2021 compared to the request, the fourth benchmark process, SRC-tagged e+A collisions (using GCF-DIS + BeAGLE) was postponed until the end of March, 2021.

What was achieved?

The achievements can be split into the overall accomplishments and the accomplishments during the reporting period.

Overall:

The main goal of eRD17 has been achieved. We established BeAGLE as a tool to refine detector and IR designs for e+A collisions at the EIC. At this point the tool is available and widely used and the focus is shifting to detailed GEANT simulations with BeAGLE and other models as inputs as the designs become less conceptual and more real.

The availability of BeAGLE during the last few years was essential. A few examples of some specific accomplishments include:

- Establishing the need for off-momentum charged particle detectors for forward proton detection in e+A collisions.
- Helping to clarify the detailed acceptance needs for the off-momentum detector and the B0 spectrometer.
- Highlighting the difficulty in vetoing incoherent diffractive events, which is still under study.
- Confirming the power of the ZDC in geometry tagging for e+A events.
- Establishing our acceptance for complete reconstruction, including all spectators, for e+D and e+^{3}He collisions.
- Establishing our ability to measure events with short-range correlations (SRCs).

Reporting Period:

We published a paper studying short-range correlations in the deuteron via incoherent diffractive J/ψ production with spectator tagging at the EIC[1].

The technical goal of having the three planned benchmark processes available was successful and all were used in the Yellow Report. In addition, the quasi-elastic SRC results (rather than DIS) were also available and used in the Yellow Report.

The goal of substantial contribution by eRD17 (BeAGLE) to the Yellow Report was successfully achieved. This was actually noted within the Yellow Report itself: "Besides hardware R&D the [EIC R&D] program has supported various vital projects such as machine background studies and simulation software developments to enable more accurate definition of the physics requirements. Sartre and Beagle are two examples of Monte-Carlo event generators whose development was substantially boosted by the program. Both were extensively used in the context of this report."[2]

Two examples involving BeAGLE + GEANT are enough to illustrate the type of result.

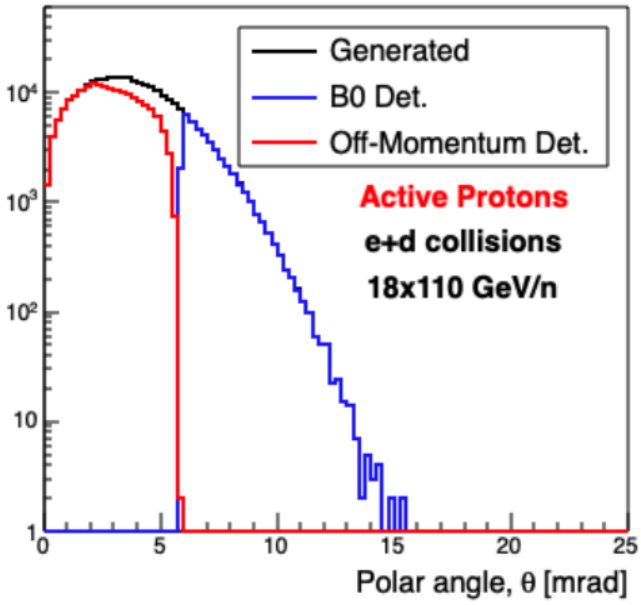

Figure 1. Acceptance in polar angle (θ) for protons in e+D→e'+p+n+J/ψ collisions for the active proton, spectator neutron case. The red and blue lines show the accepted protons in the off-momentum and B0 detectors, respectively. Plot taken from the draft Yellow Report Figure 11.101c[2].

Figure 1 shows the distribution in polar angle for the outgoing proton in a diffractive e+D collision. This plot shows the delicate complementarity between the off-momentum detector for detecting very forward protons (θ<6 mrad) and the B0 spectrometer for detecting forward protons with θ > 6 mrad.

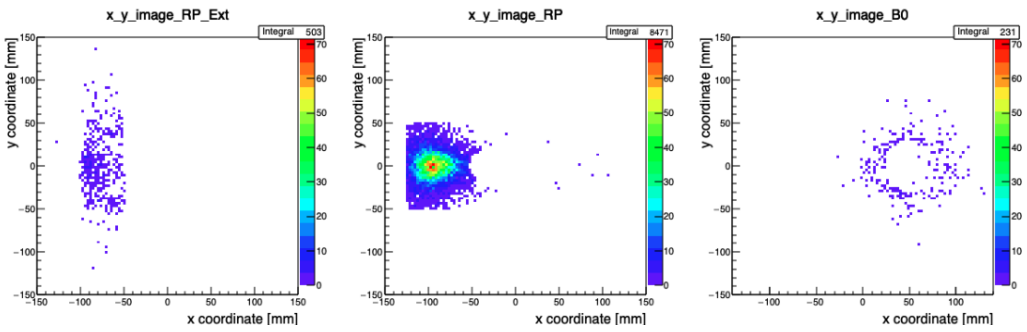

Figure 2. Occupancy plots of far forward (FF) detectors due to spectator protons from 5x41 GeV e+^{3}He inelastic events with a struck neutron from BeAGLE. The left column shows protons incident on the off-momentum detectors, the middle column shows the Roman Pots, and the right column shows the sum of the 4 individual planes of the B0 detector used in this simulation. All plots show the local coordinate system for the particular detector. Plot taken from the draft Yellow Report Figure 11.104a-c[2].

Figure 2 shows the occupancy of the three main far forward charged-particle detectors for the e+^{3}He inelastic events. This was part of a series of plots in the Yellow Report which indicate that double-proton-spectator tagging of these events is feasible, allowing us to reduce the model-dependence of the extraction of neutron structure functions (including spin structure functions) using ^{3}He.

What was not achieved, why not, and what will be done to correct?

All of the important goals of the project are on track.

How did the COVID-19 pandemic and related closing of labs and facilities affect progress of your project?

Travel restrictions reduce efficiency of collaboration, but this was factored into our plans for the reporting period.

How much of your FY20 funding could not be spent due to pandemic related closing of facilities?

We will be able to spend all FY20 funding.

Do you have running costs that are needed even if R&D efforts have paused?

No. In any case, the efforts have not paused.

Future

What is planned for the next funding cycle and beyond? How, if at all, is this planning different from the original plan?

There are four main goals for the remainder of FY2021. The immediate technical goal is to implement the SRCs in DIS events using GCF+BeAGLE. A second goal is to clean up the code, fix any minor bugs and improve the documentation, including publishing more papers. A third goal is to provide example control files for the most common processes, also establishing the preferred BeAGLE tune. Finally, we will support the ongoing efforts to study specific detector designs and the design of the 2nd IR.

With regard to the second goal, it should be noted that we have already started work on a few papers – primarily based on results in the Yellow Report.

The formal eRD17 project is expected to be complete by the end of FY2021 and technical support will be provided by Zhoudunming Tu of BNL in the out years.

What are critical issues?

None.

Manpower

Include a list of the existing manpower and what approximate fraction each has spent on the project. If students and/or postdocs were funded through the R&D, please state where they were located, what fraction of their time they spend on EIC R&D, and who supervised their work.

Baker is the only directly funded person on the project, working 0.37 FTE on average. Aschenauer, Chang, Jentsch and Tu have been actively involved in the project in the past reporting period, while Lee continues to provide valuable advice.

External Funding

Describe what external funding was obtained, if any. The report must clarify what has been accomplished with the EIC R&D funds and what came as a contribution from potential collaborators.

Brookhaven National Laboratory Physics Department funding supported the salary of Aschenauer, Jentsch, Lee and Tu. China University of Geosciences (Wuhan) supports Liang Zheng's salary and China Central Normal University supports Wan Chang’s salary and tuition.

Publications

Please provide a list of publications coming out of the R&D effort.

The following publication appeared in December 2020:

Z. Tu, A. Jentsch, M. Baker, L. Zheng, J.-H. Lee, R. Venugopalan, O. Hen, D. Higinbotham, E.-C. Aschenauer, and T. Ullrich, "Probing short-range correlations in the deuteron via incoherent diffractive J/ψ production with spectator tagging at the EIC," Physics Letters B 811 (2020) 135877.

A few more publications are being prepared.

References

[1] Z. Tu, A. Jentsch, M. Baker, L. Zheng, J.-H. Lee, R. Venugopalan, O. Hen, D. Higinbotham, E.-C. Aschenauer, and T. Ullrich, "Probing short-range correlations in the deuteron via incoherent diffractive J/ψ production with spectator tagging at the EIC," Physics Letters B 811 (2020) 135877.

[2] A. Accardi et al., "EIC Yellow Report" - January 13, 2021 draft version.