Answer to TDIS update document titled

"Request for full approval of Hall A experiment C12-15-006:"

B. Zihlmann (chair), P. Rossi (co-chair), J. Benesh, D. Mack, D. Meekins, S. Stepanyan

Introduction:

To give some context we discuss shortly the history of the experiment proposal.

- Originally this proposal, C12-15-006, was presented to the PAC43 in 2015
- The PAC43 conditionally approved this proposal with the following recommendation: *"that the collaboration seriously consider the tradeoffs in physics reach vs. reliability inherent in the cryogenic design and that the laboratory convene a rigorous technical review of the resulting optimized design before going forward with construction of this experiment. "*
- Such a review was organized in 2019.
- Between 2015 and 2019 the proponents of this experiment considerably modified the conceptual design of the target and recoil detector before presenting the new work to the review committee.
- The report from this review emphasized the need for more detailed studies with regards to the design of the target and recoil detector regarding mechanical stability and safety margins regarding the gas pressure in the target cell. The other major concern at the time was the high track multiplicity in the mTPC modules and the challenge to find and reconstruct all the tracks within a given trigger event. This led to three recommendations:
  - Proceed with more realistic detector design incorporating mechanical details such as support structures
  - Perform full simulations, including timing of signals
  - Present an effective and tested tracking algorithm in a simulated high background environment (150 tracks/module/trigger).
- Current document: "Request for full approval of Hall A experiment C121-15-006:" addressing the comments and recommendations of the review.

Overview:

In the following we will start "backwards" with the section *conclusion* regarding the review of this latest TDIS document followed by the section *assessment* addressing various questions that arose during our review process and discussions to illustrate our thoughts.

Conclusion:

Based on the document titled "Request for full approval of Hall A experiment C121-15-006:" alone, we feel we cannot conclude that this experiment will have a successful outcome. Too many questions arose in reviewing this document than cannot be answered by simple email exchanges. They require a dedicated review process. We therefore propose a new review of a new modified experimental proposal C12-15-006 addressing the following main topics:

- Experimental conditions:
  - What is the envisioned luminosity: e-beam current, target thickness?
- Target:
  - It is strongly recommended that a JLAB Design Authority be assigned to this system.
  - What are the safety margins regarding target operation (pressures/temperatures)?
  - What safety mitigations are planned if the pressure margin requirements cannot be met?
  - What is the impact of the downstream flange material on the scattered electron trajectory?
  - What is the impact of beam-heating on the aluminum entrance and exit windows? Is active cooling required?
  - What is the impact of the heat and radiation environment on the target flange seal o-rings? Are special/dedicated materials needed?
- Solenoid / SBS Dipole:
  - What is the interaction between the solenoid field and the SBS Dipole iron?
  - What are the forces between these magnets?
  - Are additional support structures required to mitigate the forces on the magnets?

- Recoil Detector (mTDR):
  - Is the structural design of the mTDR sound? Is the inner tube strong enough to support the lateral loads of the individual cells keeping them aligned?
  - Is the diffusion of the Helium gas into the target cell understood and within the tolerances of the experiment?
  - What is the double peak timing resolution in a readout cell? How far do two pulses have to be apart to be detected as individual hits in the same pad?
- Tracking:
  - How can tracks be identified and reconstructed given the expected high occupancy, in particular in the first few layers/rings of a single detector module? The hit multiplicity is expected to be much higher than for the BONuS12 or VELO detector.
  - What is the yield of "false"/"fake" tracks given the high hit multiplicity?
  - Can either algorithm be run from the outer ring in, reducing the effect of the inner ring occupancy?

Assessment:

- The BOnuS12 experiment had a 4-bar pressurized gas target with 250nA e-beam current resulting in a luminosity of order 3e34 while this experiment wants to reach two orders of magnitude higher luminosity with a similar target thickness. We assume this means the beam current will be of order 25uA.
- What are the heat loads of high beam currents (25uA) on the target windows? Does it require active cooling and beam raster?
- What kind of o-ring seals around the target entrance and exit can operate at the expected temperatures and radiation environment?
- JLAB safety margin for a pressurized vessel needs to be assessed. The proposed operating pressure is 3 to 4 bars while the burst pressure of the target cell was tested to be 4.5 bar. What are the safety mitigations to address the lack of burst pressure safety margins?
- The downstream target/detector flange coupling is massive and will impact the scattered electron trajectory and its reconstruction. What is the impact of this to the vertex reconstruction of the scattered electron?
- The 4 Tesla solenoid is rather close to the dipole magnet of the SBS. What are the forces associated with such a setup? Are additional mechanical structures required to keep the magnets from moving?
- Several different drift velocities for the mTPC are quoted in the text. On page 10 the electron drift velocity is quoted to be 2.1um/ns. On page 16 drift velocity of 50um/ns is used while from figure 12 a drift velocity of 31um/ns is deduced using the 5cm drift distance for a 1600ns drift time. What is the correct drift time and associated with it the operating gas mixture?
- Figure 12 leads to the conclusion that transverse (perpendicular to z) drifts of the electrons in the mTPC are not an issue. The pad sizes are significantly larger than those drifts given 4T field and momenta. True?
- The track search algorithm looks for "neighboring" pads being hit with a close enough time signature as the current pad hit. This search is continued till no adjacent pad hits are found. It is not clear how this can work because the ionization centers along a particle trajectory are not uniformly distributed but are rather random. This means that hits on the pads are not contiguous and there may be larger gaps between pads that see a hit. This can actually be seen in figure 15 that shows 50 tracks in a mTPC module. This may be also the reason why we do not understand figure 16 showing the track finding efficiency which quoted as the fraction of original tracks begin found. In the limit of very few tracks

this efficiency is expected to be close to 100% and should stay more or less constant close to a 100% slowly degrading up to some multiplicity at which point this efficiency should decrease at a faster rate. Also, why should this efficiency level out at high track multiplicity?

- The SAMPA FEC with its associated signal processing capability on the FPGA needs to be able to resolve more than one hit in single channel since a pad could be hit more than once given the expected track/hit multiplicity. What is the expected double pulse resolution? Not only is the maximum sampling value and its time stamp of a pulse needed but the associated base line (pedestal). Since a shaper amplifier is used the Integral of the pulse is highly correlated with the maximum sample value and not needed however double pulse identification is. Given the known signal shaping/amplification behavior and the known band width acceptance of the ADC down sampling of the digitized data is possible to improve the effective time resolution similar to the fADC125 used in GlueX.
- Both the BOnuS12 and the VELO detector, while in a high-rate environment, still have moderate hit occupancies of order 1% while the mTPC is expected have a much higher hit occupancy (which is not given in this document) based on the proposed luminosity. Therefore, the mTPC detector cannot be easily compared with the former. What is the expected hit occupancy in a single mTPC module for an expected track multiplicity of 200? Peak luminosity in LHCb is 400 Hz/μb during the 2022 run as of 9/3/22, is far less than is anticipated in this experiment. https://bpt.web.cern.ch/lhc/statistics/2022/
- The analysis timing window is quoted to be from –250ns to 1250ns with respect to the trigger. However, from figure 12 the maximum expected drift time is 1600ns which would result in a loss of hits at larger drift distances.
- In the original proposal the region of interest with regards to angle and momenta of the recoil protons is 150MeV/c to 400MeV/c in and angular region between 30 and 70 degrees. This could be taken as an “input parameter”. It is not necessary to find and reconstruct all tracks but all tracks of interest.
- While it is quoted that the vertex resolution of the scattered electron detected in the SBS is very good no numbers are given. What is the vertex resolution, and can it be used to limit the search for the recoil hadrons to a smaller region in the mTPC?
- What are the required computing resources to analyze the data from the mTPC and do the track finding and fitting? Similarly, what is the expected data volume per event that needs to be recorded by the DAQ?