ERR for ALERT experiment

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1 Charge

1. What is the status of the ALERT detector? Please discuss in detail the system design and performance requirements. Also discuss in detail the present status and performances achieved, the completion and commissioning schedule of each component of the detector:
   - Drift Chamber
   - Target
   - TOF system
2. Has a down selection of the TOF readout electronics been made?
3. What are the trigger configuration and the DAQ requirements to run the ALERT experiments? Please discuss:
   a DC operation and calibration
   b reconstruction efficiency
   c Readout electronics (what is the event rate that can be handled?)
   d Computing requirements
4. Have the EHS&Q requirements been considered in the design, fabrication and operation of the equipment, including the pressure vessel design for the gas system?
5. What are the requirements to integrate ALERT into CLAS12?
6. What is the procedure for changing the different gasses during operation?

7. Are the beam commissioning procedures and machine protection systems sufficiently defined for this stage?

8. Are the responsibilities for carrying out each job identified, and are the manpower and other resources necessary to complete them on time in place?

9. Are the radiation levels expected to be generated in the hall acceptable? Is any local shielding required to minimize the effects of radiation in the hall equipment?

10. What is the simulation and data analysis software status for each experiment? Has readiness for expedient analysis of the data been demonstrated? What is the projected timeline for the first publication? Please provide, if possible, a documented track record from previous experiments.

11. What is the status of the specific documentation and procedures (COO, ESAD, RSAD, ERG, OSP's, operation manuals, etc.) to run the experiments?

2 Findings

- The ALERT detector system is designed to detect low momentum recoil particles from ^1H, ^2H, ^3H, ^3He to ^4He from various gaseous targets such as hydrogen, deuterium and helium. Because of the low recoil momenta the target is surrounded by a tracking detector based on wire chamber technology followed by a timing and energy detection based on scintillators. Discrimination of ^2H vs ^4He, which is critical to the physics program, requires additional information of the energy loss (dE/dx) from the TOF.

- The target has a diameter of 6 mm with the cell made from aluminized Kapton with a total wall thickness of 60 μm and aluminum end caps of 27 μm thickness. The target cell is pressurized at 5 atmospheres while the surrounding space is immediately occupied by the wire chamber gas with an operating pressure of about 100 pascal above atmospheric pressure.

- The wire chamber (Hyperbolic Drift Chamber, HDC) has 3026 wires, with one sense wire and 8 field wires forming one cell with a wire separation of 2 mm leading to a total of 8 cells in the radial direction. All wires are at stereo angles ±20° alternating in a cell configuration of 1-2-2-2-1 (-20°,+20°,-20°,+20°,-20°). The wires are located between the radii of 3 cm to 7 cm. The wires are all 30 μm diameter aluminum wires tensioned with 30 g. The vertex resolution of reconstructed tracks in combination with the forward track from Clas12 is expected to be of order 3 mm. The upstream end plate is PCB fiber glass while the downstream end is ceramic with a hyperbolic cone shape. This is surrounded by a carbon fiber end plate. The thickness of the downstream endplates is assumed to be 4 mm.

- Past the wire chamber in the radial direction is a cylinder of 60 scintillator paddles of 3 mm thickness with a width of 8 mm and length of 30 cm followed by scintillator wedges (10) of 3 cm length along the length of each scintillator paddle with a thickness of 2 cm. While the paddles are read out by a SiPM on either end, each wedge is read out by a single SiPM on the outer radius. The required timing resolution for the TOF is 150 ps.

3 Comments

1. ALERT Detector Components:

HDC A prototype detector demonstrates the feasibility of 2 mm cell size with 30 μm diameter aluminum wires holding the required high voltage on the sense wire. This prototype will be used in a test beam to determine its performance with regards to hadron particle identification. With a total of 8 sense wire layers it was not shown if this is sufficient to reach the required track reconstruction efficiency for the experiment. Detailed ideas for the construction and wiring have been presented but no feasibility test have been performed. This is particularly critical for the downstream endplate assembly with carbon fiber and ceramic materials with geometries that are not finalized. Details of the wire stringing have been discussed but no practical tests have been performed to demonstrate the feasibility of the procedure.

TOF No prototype of the detector exists to date. The performance of the detector was investigated with simulations based on Geant4. This includes the energy loss as well as the expected light output. The current design envisions a single SiPM for the scintillator wedges and the both ends of the paddles. It is very unlikely that a single SiPM in the readout will be sufficient to reach a timing resolution of better than 150 ps. This is based on the performance of the start counter detector and the tagger microscope detector in HallD. The resolution of the thin scintillator in TOF and dE/dx is critical to overall PID, and in particular to ^2H vs ^4He discrimination. The mechanical integrity of the proposed detector modules with four scintillator paddles and 40 scintillator wedges each has not been tested. According to the detailed schedule presented a full size prototype of the TOF should be ready by January 2020. This will not be feasible because neither the required scintillators nor the SiPM are on hand and a there is no readout available that uses the proposed electronics. A separate schedule in the TOF slides stated that prototyping would be done by March 2020, which also does not seem feasible.

Target The cell design and prototype tests were presented demonstrating that it is necessary to use aluminized kapton to reduce the helium leakage into the wire chamber volume at acceptable levels of 1 psi/h. A radius of 3 mm for the target cell corresponds to about 10 σ with regards to the size of the electron-beam. This requires the taget cell to be straight and the beam to be at nominal position at all times.

2. The readout electronics for the TOF is proposed to be based on the Petiroc2A ASIC chip. This chip is designed for use with SiPM detectors. However this chip has never been used in any application at Jefferson Lab. Therefore the design of the electronics boards to use such chips will have to start from scratch and has not yet begun. The electronics board to read out the ASCI is proposed to be the JLAB FPGA ROC. The interface to this module also needs to be designed from scratch. The current design concept of the detector itself envisions no electronics close to the SiPM sensors. This will have an adverse impact on the noise level in the signal lines and will degrade the detector performance with regards to timing and energy resolution. An further caveat is the latency of the Petiroc2A chip when operated in "digital"-mode where the high resolution TDC and ADC is used. In this mode it takes $25\mu s$ for a signal to be processed and during this time no further signals can be accepted due to a lack of any buffers. This immediately translates into a $25\mu s$ intrinsic dead time for a trigger to be processed. This will lead to a DAQ dead time of 25% at a 10 kHz trigger rate.
   Operating the chip in "analog" mode as is done in a similar way for the CLAS12 RICH detector using the MAROC ASIC, will result in a timing resolution of about 1 ns which is not sufficient for the required timing resolution of 150 ps.

3. The ALERT recoil detector is not envisioned to be part of the CLAS12 trigger.

4. Yes, the gas system has been designed and approved for another experiment (BONus12) already and is currently in operation.

5. The physical dimensions of the ALERT recoil detector with a diameter of about 47 cm as a whole fits into the space currently occupied by the Clas12 central tracking

system. There is however no final design on the gas volume enclosure nor are there details available on how the signal cables from the TOF are transferred outside of this volume. The effect of the downstream endplate made of carbon-fiber and ceramic on multiple scattering and its the resulting effect on track reconstruction has not been discussed, also because the detailed thickness and material choices appear not to be fixed at the time.

6. The gas system presentation detailed the procedure of how to purge and fill the target with the required gas and operating pressures.
7. see 5
8. Each sub detector system has an associated manager and man power assigned. However based on the comments of 1 and 2 in particular the TOF will not be ready within the next 18 months as a successful ERR requires. Also for the HDC this time frame of 18 months is questionable given that the stringing of the cylindrical hyperbolic structure has been conceptual only and requires extensive feasibility tests.
9. Running the ALERT experiment is not expected to bring radiation levels in the Hall above typical Hall B conditions. All regular radiation safety measures will be implemented. However, the use of SiPMs close to the beam line and target are very sensitive to neutron radiation. This potential problem was assessed to be not an issue based on other studies but have not been discussed in detail. Positioning a SiPM close to the envisioned location during CLAS12 running with comparable beam/target conditions would lead to a direct assessment of this question.
10. The coherent DVCS analysis is expected to be ready for publication 3 years after data taking as the analysis procedures have been established with previous DVCS experiments in CLAS6. Tagged EMC and coherent meson production require a longer time as PID and precise ALERT calibrations are required.
11. Basic drafts of the documents are available.

4 Recommendations

1. Construct a prototype of one TOF wedge (preferentially with all four 30 cm long scintillator paddles and 40 scintillator wedges) with all the SiPM readouts and associated electronics in place and demonstrate that the required timing resolution of 150 ps or better can be achieved. This requires prior design and construction of the readout system based on SiPMs and associated electronics.

2. Determine whether the choice of Petiroc2A ASIC chips operated in "digital" mode is the best choice for the TOF and that the $25 \mu s$ dead time is acceptable for the experiment or whether a more direct approach, similar to what is used in the HallD start counter, is more favorable.

3. Finalize the design of the downstream endplate with regards to the material choices and thicknesses and determine its impact on multiple scattering and tracking resolution to the Clas12 tracking detectors downstream with regards to the experimental requirements.

4. Build a prototype of the HDC preferentially with the full dimensions and demonstrate the stringing procedure by wiring it one cell deep all around $360°$ in ϕ.

5. Develop a complete design for the gas volume with all the required feed-through connections to get the detector signals/data out of the gas volume.

6. All materials for the detector and support systems must be non magnetic. Calculate the eddy current forces on all electrically conductive materials due to a solenoid magnet quench. Verify that all supports are analyzed to handle the eddy current forces. The Jefferson lab magnet engineering manager, Ruben Fair, can be of assistance.