CBM TRD review, GSI, March 14th & 15th 2017

Reviewers:
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The CBM TRD collaboration is preparing the Technical Design Report for the project in view of submission during mid 2017. The review panel was asked to assess the status of the project and the draft of the TDR document. This text is prepared as an 'informal' document for internal discussion in the CBM TRD collaboration.

The reviewers would like to congratulate the CBM TRD collaboration for a clear and concise presentation of the project status.

Overall feasibility
The CBM TRD project draws heavily from the ALICE TRD that is operational since several years. Most institutes and many individuals of the CBM TRD collaboration were involved in the development and the construction of the ALICE TRD. Good expertise does therefore exist in this collaboration that ensures a successful execution of this project.

Cavern access and reliability
When discussing aspects of failure modes and reliability of detector elements and systems, the difference of detector accessibility between ALICE and CBM was pointed out in order to argue for less stringent requirements. The reviewers do strongly discourage the CBM collaboration to think along such lines.

The CBM detector is a large scale installation that does not allow easy access to all elements. Moving detector structures to access subsystems will pose some risk of damage to other systems, it will cause detector misalignment etc., so it is evident that such interventions would only be decided in case of serious performance degradation, which will already affect the data quality. Data sets with different quality, acceptance etc. are difficult to combine into a coherent analysis, so this situation clearly has to be avoided from the outset.

Concerning the overall operation, a loss of beamtime due to frequent needs for access is clearly connected with a loss of physics operation time and issues of quality and many access requests can quickly lead to a significant degradation of scientific output.

The reviewers therefore encourage the CBM TRD collaboration to make the minimization of access requirements a central requirement for the overall detector concept and ensure reliable operation of the system by stringent QA, robust solutions and by avoiding single point failures. In many cases this is not necessarily a cost driver, but it is more a question of a proper engineering effort.

Physics discussion
The TDR describes rather detailed studies of the physics performance for observables which would profit from the presence of a TRD. These include the detection of a thermal dielectron signal in the Intermediate Mass Region (IMR), the study of J/psi production in p-A collisions, and the detection/identification of nuclear fragments.

For the first two items, a discussion of the respective merits of the dielectron vs dimuon channel is somewhat missing. Since the most accurate data collected up to now on thermal dilepton production have come from a dimuon experiment (NA60 at CERN SPS), it would be useful if the Collaboration could discuss in some detail the specific advantages of a dielectron measurement for this observable, which represents, in our opinion, the flagship measurement for the CBM TRD.

Concerning the results of the physics performance study for intermediate mass dileptons, it would be good if the study of the invariant mass could be extended up to ~3 GeV/c^2 (now studies run out of statistics at ~2 GeV/c^2). Since the TRD becomes crucial for electron ID for p>8 GeV/c, we expect the region beyond 2 GeV/c^2 to be the one where the benefits of such a detector becomes more appreciable.

Connected with this observation, it is shown, when discussing the origin of the combinatorial background, the breakdown in e-e, e-pi, pi-pi. Up to 2 GeV/c^2, this background, which accounts for 99% of the measured yield, looks dominated from e-e rather than from misidentified pions. One might even wonder if there is a real necessity, for this measurement in the IMR, to have the pion rejection factor ensured by 4 TRD planes. It would be good if it could be shown what happens with just 3 or 2 TRD planes, to evaluate the necessity of having 4 as in the current design.

Possibly, also the other observables mentioned (J/psi production in p-A, identification of fragments) would be feasible with a smaller number of detector planes.

Concerning the simulation and reconstruction procedures, they are discussed in detail and convincing evidence for the efficient electron identification is brought forward. It would be interesting if performance plots for the ordered statistics and boosted decision tree could be shown. Also, for the two methods which are described in more detail, and in particular the neural network approach, it would be interesting to give details about the foreseen training procedures to be used for real data taking.

Simulation
Simulations of rates, channel occupancies, radiation levels were presented, but the proper conclusions and documentation of the resulting specifications is missing in several places. In order to get a more concise idea about the

integration of the TRD inside the CBM experiment, e.g. a 2D map of the radiations length and nuclear interaction length that is sitting in front of the TRD chambers would be very instructive. This should of course include the relevant support structures. A description of the interaction region will also be very useful.

Radiation levels in key areas should be tabulated, safety factors applied and the specifications for radiation tolerance for electronics components and radiation numbers for chamber ageing tests should be derived. These numbers can then also be compared to the ALICE TRD or experience with other geometries. The overall specification of the detector has to be presented in a more clear way.

Integration

The system integration of the TRD has to be worked out in more detail. E.g. the flow of Xenon through the chambers, considering height differences, gas pockets, single point failures etc. must be studied. The chamber leak rate, maximum chamber overpressure and the system aspects that ensure the protection against overpressure and loss of large amounts of Xenon must be worked out.

The sensitivity of the TRD performance to pressure and temperature variations must be established. The issue of electronics cooling (air cooling vs. water cooling) must be evaluated in detail.

The global support structure and fixation of the chambers on this structure also has to be presented in to sufficient detail.

It seems that the radiator is operated in the 'cavern atmosphere'. Are there issues related to this? What are the specifications on the cavern environment with respect to temperature and humidity?

An overall idea for the detector control system should also be presented, e.g. where will temperature sensors be placed, will the DCS operate through the GBT or is it an independent system through e.g. Ethernet that does not rely on the readout system being operational etc.

Chambers and Testbeam

Some details on the HV system should be presented, in terms of number of wire groups connected together, the estimated capacitance for one wire group, the choice for the value of the decoupling capacitor, the type and reliability of the decoupling capacitor.

The overall calibration strategy for the wire chambers should be discussed. The operation point also has to be defined properly, sensitivity to temperature and pressure variations, the nominal operating gas gain, the specified noise in terms of ADC counts, the ADC bin position where the MIP peak is placed, what is the dynamic range with …

3 types of FE boards and 3 types of RO boards were presented, with the prospect of reducing to 2 types of FE boards and just one type of RO board. Clearly it is strongly recommended to aim for the smallest possible number of boards types.

The pad planes and the signal connectors do not contain any ground connections, all the grounding of the FE board and readout board is referred to the aluminum chamber structure. The electrical scheme for this overall system should be presented and discussed in some detail.

The results of the large scale testbeam together with other CBM subsystems are of course an important steps, they should however not replace tests that are dedicated and optimized for very chamber specific tests. E.g. a test at the GIF++ that should simulate the performance under global chamber illumination at realistic rates is very important. A setup to assess position resolution in a better way will also be helpful.

The detector performance in terms of resolution and rejection power should be compared to simulations and be properly implemented in the overall CBM simulation in order to guarantee consistent performance studies.

The test under full illumination is also important to verify that the system of triggering neighboring channels for the readout, either on the same chip or even on the neighboring chip, does still operate properly in an environment with a large overlap of 'self triggering' and 'neighbor triggering' channels and the system shows 'graceful degradation' when put to rates beyond the nominal ones.

In general, the tests for the 'baseline chamber & electronics' solution should come at least to the level of completeness and clarity that was presented for the 'alternative chamber & electronics' solutions.

Electronics

For the SPADIC specification, a Qmax of 75fC is quoted. The full linear range of the analog fronted should be measured and presented. The reaction of the frontend to highly ionizing events of 10, 100, 1000x the average charge should be measured and studied. The recovery time of the shaper output is one measure of the related deadtime. By injecting a sequence of very large and small pulses one can assess whether the preamp shows saturation and deadtime that would not be visible at the shaper output.

It should also be verified whether the preamp/shaper stays in the operational regime for the effective persistent input current represented by the actual charge that is flowing onto the readout pad. This situation can be easily overlooked in lab tests and testbeams with short spills.

The radiation requirement including safety factors should be specified and related to the used technology. Are radiation tests to the expected levels planned for TID and 1MeVneq fluence?

The specification of the shaping time with respect to both, Argon and Xenon operation, should be discussed.

For commissioning and calibration purposes it would be extremely useful to have a mode that allows the readout of a continuous sampling of the baseline for the individual channels on the chip (of course not at the same time).

The baseline correction is now postponed to the FPGA (Feature Extraction). However much more information about the baseline is available in the SPADIC chip itself. Please consider as option (which can be turned off) a simple baseline correction circuit in the SPADIC 2.1, e.g. like in the TRAP chip.

It also has to be guaranteed that a single noisy channel on the chip does not fully occupy the output buffers. Can an individual noisy FE channel be switched off ? Clock gating of the unused digital filter stages could save power.

Decision on alternative solutions

Assuming an optimistic TDR timeline with approval by the end of 2017, the milestones as presented to the referees are not maintainable. Engineering Design Reviews and Production Readiness Reviews have to be included in the list of milestones. System developments and final design considerations for EDR and PRR typically take at least one year, which will move start of production to 31.12. 2018 at best.

The alternative chamber design is certainly very elegant and innovative, and the level of evaluation and tests is very impressive. The performance of the alternative electronics is also demonstrated to work well, it is however not yet on a level that is integrated in the system – digitization and readout logic development are still ahead which takes significant time and effort.

Unless a significant improvement in overall performance for the CBM physics program can be demonstrated for the alternative solutions, the referees recommend to base the project on a uniform system using the presented baseline. In view of the presented timeline, the time for a decision has long passed and all efforts must now be focused on the development of the system aspects of the TRD project.