Questions Regarding the PANDA EMCAL TDR Update from the TDR Review Committee

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1) Cost and schedule

1.1) The current EMCAL schedule relies on Russian funding to acquire the additional PWO crystals needed for the barrel calorimeter and increasing the production rate at Crytur in order to meet your current schedule. As there is an inherent risk associated with this, please provide an alternative plan to meet the current project schedule in case the Russian funding does not become available, or describe the impact of not obtaining this funding on the current schedule.

1.2) With only one vendor Crytur to produce the additional PWO crystals for the barrel, please describe how you plan to control the cost and delivery schedule for the remaining crystals, both for the 12/16 slices that are planned to be completed by 2023, as well as all 16 slices. In the case of a cost increase due to the investment in additional ovens at Crytur, please provide an evaluation of other possible alternatives to obtain the additional needed crystals, such as the possibility to procure additional crystals from the alternative vendor SICCAS, using previously rejected spare crystals, and/or repurposing of other radiator material, and what impact this would have on the cost and schedule.

1.3) In the case that only up to ~75% of the barrel is instrumented on Day 1, please describe the impact this would have on the detector performance and physics capabilities and if there are ways to recover this performance.

1.4) Please provide clarification on the upgrade path to complete 100% barrel coverage and describe what impact this would have on the overall PANDA running schedule, including the need to recalibrate the calorimeter system in order to achieve the final overall physics performance.

2. Crystal Quality and Performance

2.1) The dk value of the Crytur PWO crystals after 30 Gy, shown in Fig. 2.15 of TDR update, seems significantly larger that the BTCP PWO-II crystals after 50 Gy, shown in Fig. 4.35 of the 2008 TDR. Please explain the nature of this difference and if there are any ways envisioned that this could be improved for the Crytur crystals.

2.2) It is known that hadrons can also cause radiation damage in PWO crystals beyond just ionization. Please provide the expected hadron fluence, including charged and neutral hadrons, and its effect on the performance of the crystals in the barrel and endcap calorimeters.

2.3) From Fig. 2.15, the measured ionization induced absorption coefficient at 420 nm (dk) is in the range from ~0.4 to 1.1 m^{-1} for accepted PWO crystals after 30 Gy at room temperature, which according to Fig. 2.16 corresponds to 35% to 70% light output loss at -25 degree C. Given this range of variability, as well as the variation in the radiation dose across the detector, what is the effect of these variations over the entire ensemble of crystals in the barrel and endcaps ?

2.4) The original TDR states that the energy resolution requirement for the EMCAL is to have a stochastic term < 2%/sqrt(E) and a constant term < 1%. The energy resolution was measured in several prototypes which gave 2.46%/sqrt(E) \oplus 0.16%/E \oplus 2.32% for the PROTO120 barrel prototype and 2.41%/sqrt(E) \oplus 0.86% for the Forward Endcap prototype, which are both slightly worse than the desired resolution requirement, and it is likely more difficult to achieve the desired resolution in the final full size detectors, especially given the added complication of radiation damage and recovery.

While the prospect of applying optical bleaching using a blue LED described in Section 2.5 would seem to provide a way to speed up recovery while the detector is at its -25 deg operating temperature, it seems that this would only be possible during short beam off periods, and that the main recovery process would take place only during the long 6 month shutdowns when the detector is warmed back up to room temperature. It is understood that the calibration and monitoring system is designed to achieve and maintain the desired energy resolution, but please provide further details as to how it will do this given the expected levels of ionizing radiation and hadron damage, its variability across the various parts of the detector, the control of thermal variations in the crystals and APDs, and the planned optical bleaching and thermal annealing procedures.

3. Photosensors, Electronics and Readout

3.1) Section 3.1.2.3 describes irradiation and annealing of the APDs but it is unclear what the conclusions are from these studies. Please summarize what the effects of irradiation to 37 Gy and subsequent annealing has on the APDs.

3.2) Please provide details on the expected nuclear counter effect in the large area APDs used in the barrel due to EM showers, charged hadrons and neutrons, and corresponding mitigation measures.

3.3) In addition to the nuclear counter effect, EM showers and hadronic interactions can potentially inject large amounts of charge into the front end charge sensitive preamplifier resulting in damage to the CSA. What precautions are there to mitigate this ?

3.4) In Section 4.3.1.7 it is mentioned that the MTBF for the combined system of FPGAs and SADCs is ~17 min. What is the recovery procedure and what is the impact on the live time ?

3.5) There is also a short discussion on proton and neutron irradiation studies for the SADC, but were any studies done using ionizing radiation, e.g. gammas from Co60 ?

3.6) Section 4.3.1.8 describes the post-production testing of the SADCs but does not mention any long term stability testing. Are any such tests being done as part of the acceptance and QA procedure ?

3.7) It is anticipated that it will be necessary to increase the gains of both the APDs and the VPTTs due to loss of light in the crystals resulting from radiation damage. The system to adjust the gains is described, but can you provide information on whether the available range of gain adjustment will be sufficient to compensate for the expected light loss. Also, increasing the gain in the APDs will also increase the noise. What effect will this have on the performance ?

4. Mechanical Systems

4.1) Structural

4.1.1) What are the maximum stresses and deflections for the operational conditions for the barrel and endcaps ? Please also include seismic and magnet quench loads.

4.1.2) Do the differences in the coefficients of thermal expansion cause increased stresses or is this accounted for in the assembly clearances and tolerances ?

Please provide appropriate FEA plots in your responses if possible.

4.2) Thermal

4.2.1) How long does it take for the cold region to get to its operating temperature (-25 deg C) and return to room temperature ?

4.2.2) What level of control of temperature stability and resolution is required and what do you think you can achieve ?

4.2.3) How are the sides of a slice thermally isolated from the environment ? How are gaps in thermal isolation between slices mitigated ?

4.2.4) How is potential air penetration mitigated ?

4.2.5) What is the anticipated additional heat load from the surrounding environment ? The TDR indicates 7W per slice, but what about the endcaps ?

4.2.6) What is the anticipated dewpoint in the surrounding environment ?

Please provide appropriate FEA plots in your responses if possible.