Mechanical design of water cherenkov test experiment (WCTE) at CERN

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On behalf of the WCTE collaboration

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Abstract: The Water Cherenkov Test Experiment (WCTE) is an experiment proposed at CERN to measure the response of a Water Cherenkov Detector for charged particles such as π±, p+, e±, etc. The data obtained from WCTE will be used in future neutrino experiments. WCTE consists of a sealed cylindrical tank filled with ultrapure water. 128 multi-PhotoMultiplier Tubes (mPMTs) are mounted on a cylindrical support structure facing inwards to map out the Cherenkov radiation with high granularity. This work presents the mechanical design and analysis of the support structure for WCTE. It is designed to sustain the load of 128 mPMTs, arrangement of Photogrammetry system Cameras & lights and Calibration arm without significant change in the position / geometry of the structure. SS304 is identified as a suitable material to ensure the compatibility with the ultrapure water and Gd-loaded water. The structure is robust against stresses during handling and subsequent transport with and without water.

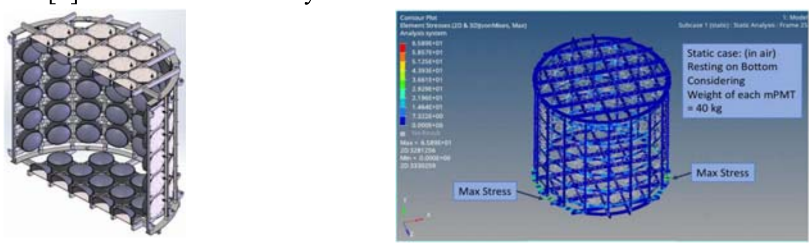
1. Introduction
The WCTE is an experiment to quantify the interaction cross sections of the particles typically produced in water Cherenkov based investigations of neutrinos.

Figure 1. CAD image of fully assembled WCTE detector with calibration system and roller system.

The WCTE will be carried out in the T9 Beam area at CERN from 2023. The support structure is designed considering the possible loads on the support structure including the loads during experimentation and transport. The calibration system is developed for handling sources for calibration of the detector. Two separate beam windows are designed to inject the particles from secondary and tertiary beams into the tank of the WCTE detector. The fully assembled detector section view is shown in Figure 1.

2. Support Structure

The support structure is designed for mounting 128 mPMTs. Stainless steel 304 is chosen for the design as it is compatible with ultrapure water and Gd-loaded water. The support structure is designed using hollow standard rectangular and square beams. The square beams with the dimensions of 60 x 60 x 5 mm^3 are used in the barrel part and partially at the bottom end cap. The rectangular beams with dimensions 120 x 120 x 5 mm^3 are used in the end caps which are installed in the higher modules for bending. The support structure is shown in Figure 2a.
Figure 2b shows the stress analysis of the support structure for one of the most critical cases - resting on the bottom. The mass of each mPMT is considered as a point mass of 40 kg. The analysis shows that the maximum equivalent stress[1][3] is 65 MPa at the bottom ring of the support structure. The structure can be considered as safe[2] as the factor of safety is 3.2.



[a] **[b]**

Figure 2. Section view of WCTE structure with mPMTs and its stress analysis

3. Beam Windows

The beam windows are the entry point of the beam inside the detector. There are two separate beam windows for tertiary and secondary particles as shown in Figure 3. Both the beams are facing radially towards the centre at an angle of 450 mrad from each other. The beams are located at the central location in terms of height of the support structure. The room for the beam is obtained by removing two adjacent mPMTs from the central ring of the support structure.

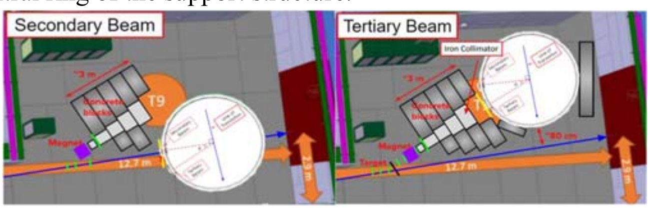


Figure 3. Transportation between two Beam Location

3.1 Secondary Beam

The secondary beam has a diameter of ~100 mm and the beam window can be moved radially towards the centre to study the interaction of the secondary beam particles at various locations inside the detector. The secondary particles enter the water through a 2mm thick plate which is mounted on a flexible bellow which in turn is sealed on a flange welded to the tank wall. The beam window can be thrust forward by extending the bellow using a modular rigid thruster. The stiffness to restrain the beam at the desired location can be achieved by using removable hollow solid components. The stiffer components are made short and removable to overcome the limitation of the space in the experimental area and make it modular. Figure 4 shows both the components of the secondary beam and fully assembled beam.

3.2 Tertiary Beam

The tertiary beam window has a diameter of ~500 mm and is at the same height as the secondary beam. The tertiary beam window is stationary at the circumference of the tank as shown in Figure 4. The tertiary beam window can be installed from the outside so that the waterproofing can be done using a simple gasket. The area of the tertiary beam window is quite large and hence the design of the material of the actual beam window is underway.

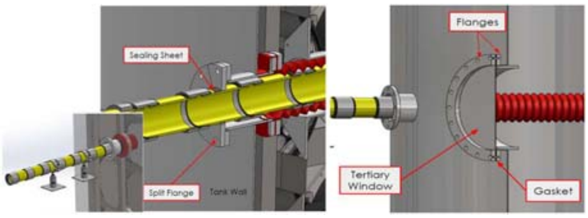


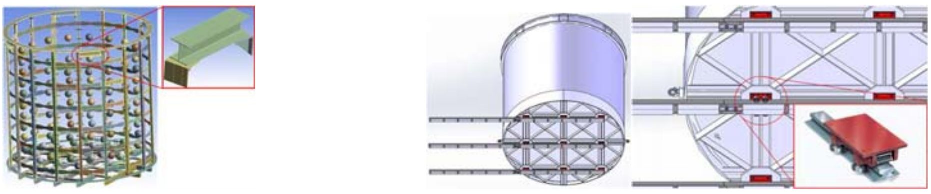
Figure 4. Detailed view of secondary beam window and two beam windows on the tank cross section

4. Lifting Lugs

The lifting lugs are important components used for the safe handling and assembly of the detector. The lug design for the WCTE support structure has gone through several iterations and the desired design is close to its final version. The single vertical column of the support structure is not capable of sustaining the whole load. To overcome this issue, a set of two beams is used for each lifting point. Four lifting points were selected for easy and convenient lifting and handling of the support structure as shown in Figure 5a.

5. Roller System

A roller system, which can withstand the load of the support structure, mPMTs, tank and other equipment, is required for the movement of the whole detector from tertiary beam location to secondary beam location. Apart from the roller system, the moving system consists of a mechanised cable pulley arrangement as shown in Figure 1. The detailed view of the roller system for the WCTE is shown in Figure 5b.



[a] **[b]**

Figure 5. a) Lifting lug on support structure without end cap including zoomed image and b) Roller system for the motion of the tank, zoom view of the rollers & image of actual roller

6. Photogrammetry

Photogrammetry is used to map out the location of each mPMT in the fully assembled detector. Cameras and light sources are mounted on the support structure with well defined positions and orientations.

Machine learning will be used to map the orientations and positions of mPMTs. The prototype of the camera housing is shown in Figure 6.

7. Calibration System

Calibration system consists of a calibration arm which is supported on the lid and has the capability to move the calibration source to any location inside the detector. Special installation and retrieval mechanisms will be used to change the calibration source. The calibration system and other accessories are shown in Figure 6.

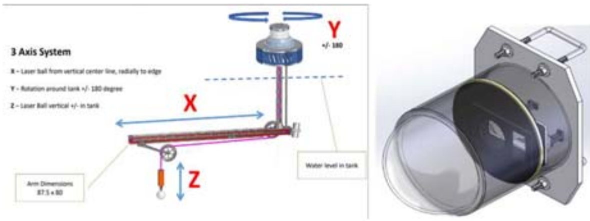


Figure 6. Schematic configuration of calibration arm and camera housing

8. Tank Lid

The detector needs to be closed by a lid to avoid entry of air and light. CO2 in the air can aid organic growth in the ultrapure water and stray light amounts to noise in the signal. The lid is made of the SS304 to maintain the compatibility with ultrapure water. The lid is designed to withstand the weight of the calibration system and accessories. The lid has several sealed holes for the water system and feedthrough cables. The schematic layout is shown in Figure 7.

Figure 7. Position of various components (ports for water circulation, cover gas circulation, cables and other accessories) on the lid of WCTE detector

9. Conclusion

The design of the support structure, with the best suited material as SS304 for ultrapure water, is verified to be safe for the static load. The analysis of the effect on the structure of dynamic load without water and static / dynamic load with water is underway. The conceptual design of the beam windows and lifting lugs are done and final design is underway. The design of the roller system and the calibration system are in the final stage of design.

References

[1] Timoshenko, Stephen, and Donovan Harold Young. Element of Strength of Materials. Van Nostrand, 1962.
[2] Eurocode 3: Design of Steel Structures. London: BSI, 2005.
[3] Timoshenko, S. P. and Goodier, J. N., 1970, Theory of Elasticity, 3rd ed.,McGraw-Hill, New York.