Request for Project Engineering and Design Support for EPIC TOF Detectors

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1 Introduction

A number of AC-LGAD detector system aspects which constitute project engineering will need to be addressed in time for the CD2/3a review. This includes preliminary mechanical and electrical engineering design of the far-forward and TOF barrel and endcap detector systems to be able to connect all electrical, optical and cooling services and provide a realistic plan of pre-assembling modules and services onto the mechanical structure, so that the assembled detectors can be integrated into EPIC with minimal post-assembly. Prototype mock-up structures will need be constructed to demonstrate the feasibility of production and assembly of individual parts where necessary. A detailed study of an appropriate cooling system will also be needed to quantify potential heating effects of surrounding detector systems, specifically the very temperature sensitive backwards ECAL crystals. Prototype production and testing of full scale service hybrid boards, firmware implementations of the downstream link towards the data aggregation modules are also needed to demonstrate the readiness of the concept at CD2/3a. The details of the plan and funding requests will be described in this Project Engineering and Design (PED) request.

2 Mechanical Engineering

2.1 Barrel TOF Engineering Design by Purdue/NCKU

Purdue is deeply involved in all aspects of the mechanical support structures of the CMS tracking detector upgrade for the HL-LHC, which provides extensive experience in engineering design, FEAs, manufacturing and integration aspects of light-weight composite structures. The Purdue/NCKU team will apply their knowledge and experience for the benefit of the EPIC TOF project.

For FY23 we propose to work on the mechanical support structure of the barrel TOF system, which includes a preliminary engineering design in time for the CD2/3a review. The design includes the “staves” supporting the detector/sensors itself and the support structure or mounting system for these staves able to support the barrel TOF including services (cooling, power, readout). All of which with minimal mass of the supports able to maintain envelopes and tolerances as required by the larger detector integration. The work includes studies of the thermal performance of the barrel TOF system and its demands on larger system aspects in terms of cooling power. Thermal and mechanical finite element analysis will guide the design work and use results of the R&D proposal submitted by the Purdue+NCKU team earlier.

The R&D proposal and the resources requested for the PED are highly connected and synergistic. The R&D work will use non-final materials to deliver a first prototype of a stave folded with limited thermal and mechanical FEAs to guide the work. The PED request relies on these results and further pushes these to a preliminary engineering design with final materials. Deliverables for the PED request are a prototype/mock-up of the larger mechanical stave support structure, which allows to test integration of the staves, as well as studying routing for cooling and other services.

2.2 Endcap TOF Mechanical Design by ORNL

The work proposed for FY23 includes preliminary mechanical engineering design of the TOF endcap discs to be used as a baseline design for the CD2 review. The work will focus on achieving a stable mechanical structure that fulfills all requirements on internal stiffness and deformation resistance that tracking detector as the EPIC TOF system demands while using a minimum amount of material. This will interface with the material R&D from Purdue/NCKU described the submitted eRD112 proposal for FY23. At the same time, the mechanical structure of the TOF endcap needs to be able to support all electrical, optical and cooling services and provide realistic means of pre-assembling modules and services onto the mechanical disc structure, so that the fully assembled endcap disc can be integrated into the full EPIC detector with minimal post-assembly. Prototype mock-up structures will be constructed to demonstrate the feasibility of production and assembly of individual parts where necessary.

The deliverables by CD2 include a realistic, validated, mechanical design for TOF endcap discs with partial mechanical mock-ups. A full, validated implementation of the resulting TOF detector geometry into the EPIC software framework and related studies will be contributed in-kind.

2.3 Cooling System Engineering by ORNL

The work proposed for FY23 includes preliminary engineering design of an appropriate cooling system integrated into the TOF endcap disc engineering design to be used as a baseline design for the CD2 review. The work will focus on the design and simulation of a low material ambient temperature water cooling system and the temperature impact on the surrounding sub-detectors. Since the exact heat load of the TOF endcaps depends on the targeted AC-LGAD segmentation which is yet to be finally determined, The ORNL mechanical engineering group holds extensive expertise in fluid cooling systems from a wide array of previous projects in ITER and other nuclear fusion experiment. This includes detailed simulations with state of the art computational fluid dynamics (CFD) simulation tools such as Solidworks Flow Simulation and Ansys. The same ORNL mechanical engineers are already involved in the mechanical design of the EPIC LFHCAL structure and preliminary studies on the EPIC inner tracker mechanics. Figure 1 shows an example of a cooling flow simulation performed at ORNL.

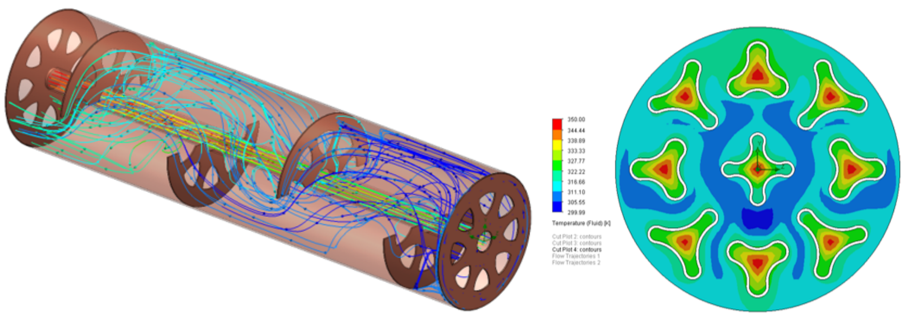

Figure 1: Example results of Solidworks fluid cooling simulations, kindly provided by Eliott J. Fountain, ORNL Nuclear Fusion Energy Division, Remote Systems Group.

The deliverable by CD2 includes a realistic, preliminary design for a low material cooling system based on circulating water at close to ambient temperature. The proposed cooling system will be fully integrated into the mechanical design proposed in subsection 2.2. Extensive CFD simulations will provide the required water flow rates and cooling plant power, as well as the resulting temperature gradients, both within the endcap and towards neighboring sub-detectors. The simulation will be designed to be parametric in the assumed heat load from the TOF system to easily adapt to varying assumptions and realities in the power consumption of the AC-LGAD system.

3 Resource Request

3.1 Purdue/NCKU

Workforce at Purdue/NCKU on EPIC includes: a combined 0.5 Faculty at Purdue and NCKU (20% FTE), 1 staff senior engineer at Purdue (20% FTE), TBC: 1 postdoc at NCKU (20% FTE), and part time of undergraduate students at Purdue. Tab. 1 contains resource allocation on preliminary engineering design for barrel TOF.

Resource	FTE (%)	Budget (k$)
Manufacturing Design of pre-production		
Mechanical Engineer + Technician, Purdue	20	60
UG students, Purdue	20	0 (in-kind)
Postdoc, NCKU	20	0 (in-kind)
G/UG students, NCKU	20	0 (in-kind)
Materials and Supplies (staves, etc.)	-	20
Integration aspects / Services		
Mechanical Engineer, Purdue	10	20
Total	-	100

Table 1: Purdue/NCKU budget request on engineering design for barrel TOF in FY23. All entries in thousands of dollars.

3.2 ORNL

Workforce at ORNL on EPIC include: 0.5 Faculty (20% FTE) + 4 staff scientists (20% FTE), 2 technical staff, 1 postdoc (50% FTE), and part time of 1-2 graduate students. Tab. 2 contains resource allocation on preliminary engineering design for endcap TOF.

Resource	FTE (%)	Budget (k$)
Mechanics Prototype Engineering		
Mechanical Engineer	20	60
Staff Scientist	5	0 (in-kind)
Postdoc	5	0 (in-kind)
Materials and Supplies	-	15
Cooling System Engineering		
Mechanical Engineer	15	40
Staff Scientist	5	0 (in-kind)
Total	-	115

Table 2: ORNL budget request on engineering design for endcap TOF in FY23. All entries in thousands of dollars.