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 engineering design of the barrel and endcap TOF detector systems including its support mechanics 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. 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, as well as R&D activities for support structures with integrated services for future colliders. Further details can also be found on this web page: Purdue Detector R&D. All of these activities provide extensive experience in engineering design, FEAs, manufacturing and integration aspects of light-weight composite structures supporting sub-detectors. On the other hand, National Cheng Kung University (NCKU) is also heavily involved into the mechanical support for the STAR Forward Silicon Tracker and the new cooling system (radiator) for the upgrade of the AMS-02 detector. The Purdue/NCKU team will apply their knowledge and experience for the

benefit of the EPIC TOF project. Figure 1 shows examples of the work carried out at Purdue related to the upgrade of the CMS tracking detector for the HL-LHC.

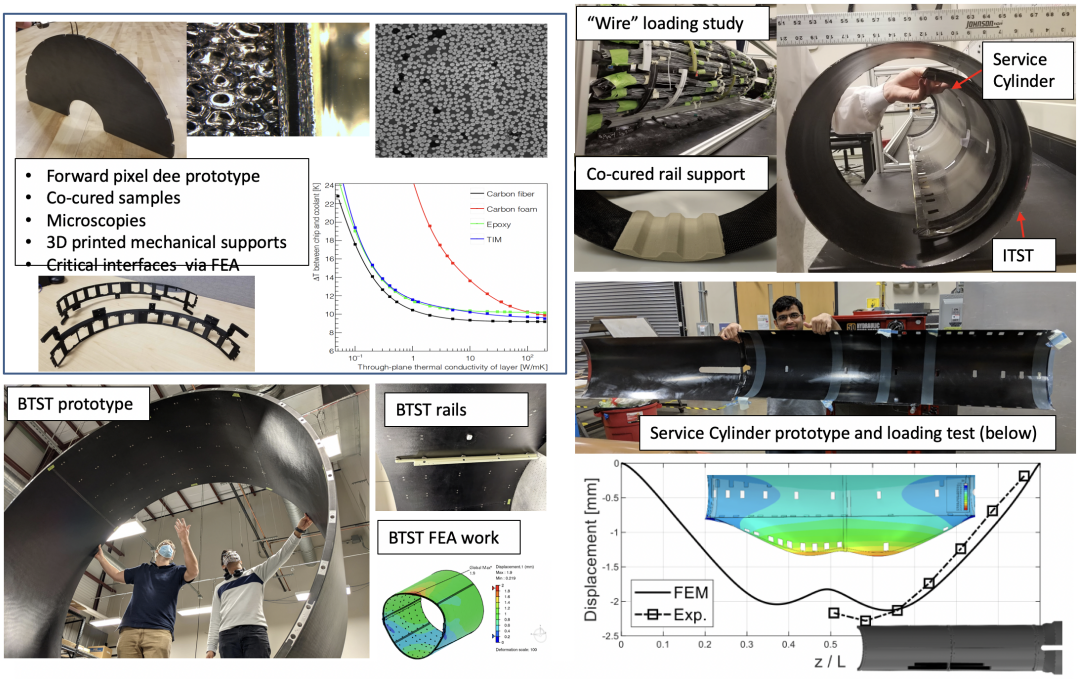

Figure 1: Examples of the efforts at Purdue University related to light-weight and radiation hard composite support structures for the upgrade of the CMS tracking detector.

For FY24 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 minimal mass "staves" supporting the detector/sensors itself, as well as the support structure or mounting system for these staves to be able to support the barrel TOF including services (cooling, power, readout) within the envelopes and tolerances required by the larger detector integration. Staves will ideally have full length to increase coverage by LGADs and supported by either a system of composite carbon fiber rings or thin-walled cylinder, see Figure 2. We follow recent discussions that suggest to mount/support the endcap LGAD system to the dRICH rather than directly to the structure of the LGAD barrel detector. That way easier access to the tracking systems is possible - we foresee the potential support of the tracking systems by means of a top and bottom rail or cylinder supported by the barrel LGAD system with the tracking detectors itself being mounted inside of "half-cylinders". Figure 3(right) shows only support structures and indicates inner and outer "engagement rings" which can support MPGDs and tracking system on the inner side as briefly discussed previously.

The proposed 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 as part

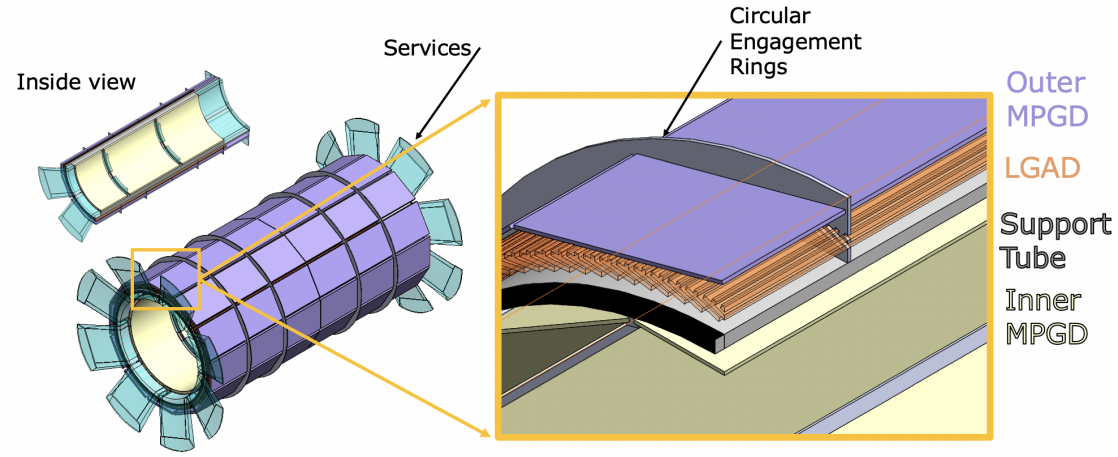

Figure 2: Simple sketch of potential support structures for the TOF-LGAD barrel staves (horizontal blue structures) including endcap and MPGDs. The staves could be supported by “rings" (called engagement rings) and feed-through for services exists as well.

of eRD112 by the Purdue/NCKU team, which was approved and is currently being carried out.

The already approved R&D proposal for eRD112 (“") and the resources requested for this PED request here are highly connected and synergistic. The ongoing R&D work funded by eRD112 in FY23 will use non-final materials to deliver a first prototype of a stave folded with limited thermal and mechanical FEAs to guide the work and we expect this to wrap up by end of 2023. This PED request relies on these results and further pushes these to a preliminary engineering design with materials selected to match desired performance as much as possible at this current state of the engineering design of the surrounding systems. Deliverables for the PED request are a prototype/mock-up of the larger mechanical stave support structure (likely a 45 degree section/wedge), 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 Purdue - started by ORNL

The work proposed for FY24 includes preliminary mechanical engineering design of the TOF endcap discs to be used as a baseline design for the CD2/3a review. The work will focus on achieving a stable mechanical structure that fulfills all requirements on internal stiffness and deformation resistance that a tracking detector as the EPIC TOF system demands, while using a minimum amount of material. This work naturally extends and integrates the material R&D for the barrel part from Purdue/NCKU as described above and in the submitted and approved 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. Especially, the material budget of the endcap has been shown to be critical and in need of optimization, see Figure 3(left) by Nicholas Schmidt [TOF PID indico agenda].

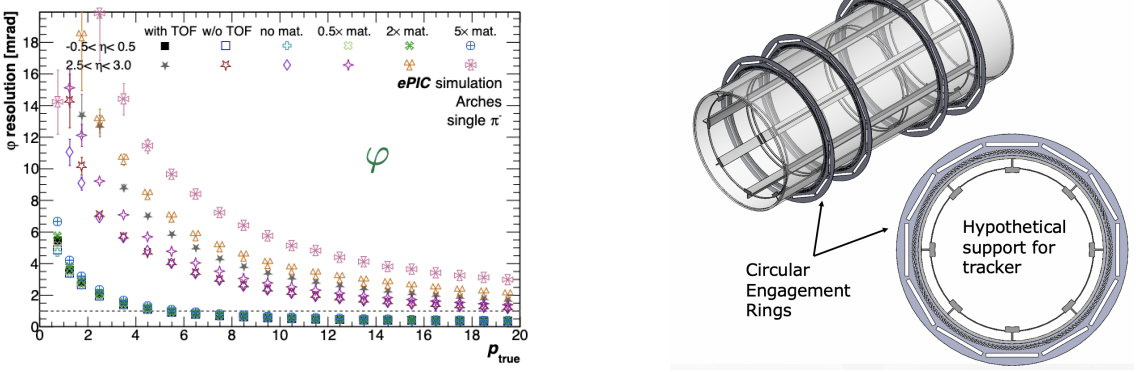

Figure 3: The angular resolutions in ϕ is shown on the left with multiple material budget variations from only sensors (no material) to factor 5 in overall material budget, which shows a strong material budget dependence for ϕ in forward directions [TOF PID indico agenda]. The right shows a sketch of only the support mechanics for the TOF LGAD barrel detector with potential support for tracking, MPGDs as well - more details in the text.

A prototype mock-up structure of the endcap support discs will be constructed to demonstrate the feasibility of production and assembly of individual parts where necessary - naturally, the endcap disc potentially uses some of the outcomes of the R&D activities (supported by the DOE BlueSky R&D program, not by EIC) presented in past eRD112 meetings.

The deliverables by the time of CD2 include a realistic and 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 Purdue

In general, a system/detector-wide cooling system is to be discussed and designed by all stakeholders of the relevant detectors. The work proposed for FY24 includes preliminary studies to understand the specifics of an appropriate cooling system integrated into the TOF barrel and endcap disc engineering design to be used as a baseline design for the CD2/3a review. The work will focus on the simulation of a low material cooling system and the temperature impact on the surrounding sub-detectors. Since the exact heat load of the TOF barrel and endcaps depends on the targeted AC-LGAD segmentation which is yet to be finally determined, these studies will be parametric in assumed heat load.

The Purdue mechanical engineering group holds extensive expertise in fluid cooling systems from a wide array of previous projects in the CMS experiment on the silicon pixel tracker as well as outer silicon tracker (strip devices). This includes detailed simulations with state of the art computational fluid dynamics (CFD) simulation tools such as Solidworks Flow Simulation and Ansys. The same Purdue mechanical engineers are already involved in the mechanical design of the EPIC TOF/LGAD barrel structure and potentially engaged in other EPIC mechanics projects. Figure Figure 4 shows

an example of a thermal FEA performed at Purdue.

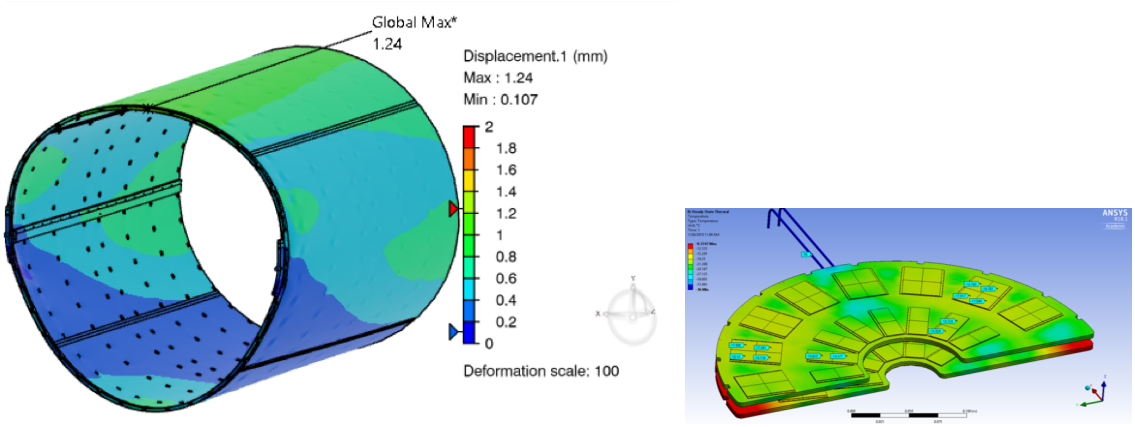

Figure 4: Examples of mechanical and cooling simulation expertise at Purdue. The right shows the large Barrel Timing Layer and Tracker Support Structure of CMS detector which has a warm and a cold side while supporting roughly 5 tons. The left shows a dedicated thermal FEA for the dee structure of the forward silicon pixel system cooled by two-phase CO2.

The NCKU HEP group also has experience on thermal analysis and testing on the mechanical structure for STAR Forward Silicon Tracker and AMS-02 experiment, as shown in Fig. 5. It is also worthwhile mentioning that NCKU group also built the UTTPS radiator for the previous AMS-02 upgrade with Aerospace Industrial Development Corporation (AIDC) which has strong capability and experience on composite material and structure design and manufacture.

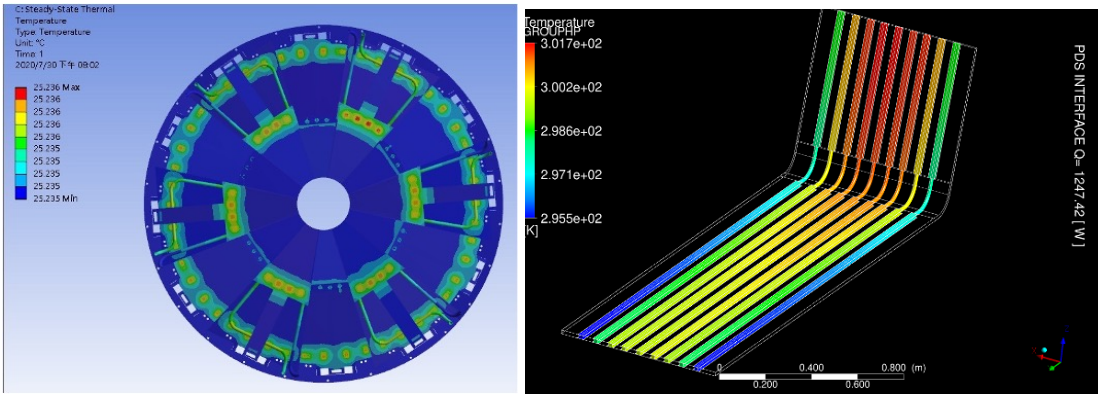

Figure 5: The thermal analysis for the STAR Forward Silicon Tracker (left) and the PDS radiator for the AMS-02 upgrade (right).

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