# **1 Abstract**

The ALICE Collaboration together with the ALICE-USA group of research institutions have developed a state-of-the art silicon-based Inner Tracking System (ITS) to be used in future runs of the Large Hadron Collider (LHC) at CERN. Brookhaven National Laboratory (BNL) is very interested in utilizing this silicon technology in future projects such as a potential Electron Ion Collider (EIC) detector, a possible upgrade to the sPHENIX detector as well as other vertex detector applications. components of the ALICE ITSkey parts of a. It is also a purchase that is time critical because ALICE is currently producing the ITS components of interest, and it may be impossible to produce these components in the near future because of the redirection of production facilities to other tasks.

As part of the effort to development modern silicon detector capabilities for use at the Relativistic Heavy Ion Collider (RHIC) and EIC, we propose to purchase from CERN components identical to those of the ALICE Inner Tracking System. Because the ALICE Collaboration and the ALICE-USA group of research institutions within the ALICE collaboration have developed the expertise and technology for building this ITS system, it is a natural extension of the ALICE-USA BTU grant to apply for the supplemental funding for nearly identical ITS system components. The University of Tennessee is a member of the ALICE collaboration, the sPHENIX Collaboration and a potential collaborator on a future EIC experiment.

# **2 Proposal**

# **2.1 Overview**

The ALICE ITS is a multi-layer silicon tracking device with silicon sensors based on the latest Monolithic Active Pixel Sensor (MAPS) technology, developed for the ALICE experiment. The ALICE ITS will bring a number of capabilities to the experiment including precision measurements of b-quark observables, therefore providing access to a qualitatively new QGP signature. This proposal would allow for the purchase of copies of key components of the inner three layers of the ALICE ITS for use in a future detector at either RHIC or EIC. The inner three layers of the ALICE ITS consist of cylindrical hermetic layers of MAPS staves covering 2π in azimuthal angle and pseudorapidity η between -1 and 1. They are composed of 48 staves of sensors. Each stave is composed of 9 ALICE ALPIDE sensors thinned to 50 um and arranged in a linear array covering approximately 15 mm x 270 mm of active area with 1024 rows x 512 columns of pixels per sensor giving approximately 4.5M pixels per stave. These sensors are mounted onto a carbon fiber cold plate that contains embedded cooling tubes. The structural strength of the stave is provided by the use of a carbon fiber truss structure that supports the cold plate. Sensors are glued and wire bonded to an aluminum conductor flexible PCB that provides bi-directional signal paths for configuration and control, signal paths-out for data, and the necessary power and ground connections. In addition to the 48 staves required, we will also produce a full spare set of staves for the inner two layers (12+16), plus 10% spares, thus a total of 84 staves.



Figure 1 Assembled ALICE ITS stave showing the top and bottom views with the space frame visible in the upper stave. Flex power extension cables are not shown.

The readout system for the staves will use Readout Units (RUs) developed for the ALICE ITS upgrade, one RU for each stave. We will produce 48+12(spares, 25%) RUs, a total of 60.

## **2.2 Barrel Staves Technical Details**

The ALICE ITS Upgrade Inner Barrel Pixel Stave is the complete detector element that has been developed for the ALICE Inner Tracking System Upgrade. It contains the following main components:

· Space Frame: a carbon fiber structure providing the mechanical support and the necessary stiffness;

· Cold Plate: a sheet of high thermal-conductivity carbon fiber with embedded polyimide cooling pipes, which is integrated into the Space Frame. The Cold Plate is in thermal contact with the Pixel Chips to remove the generated heat;

· Hybrid Integrated Circuit: an assembly consisting of a polyimide Flexible Printed Circuit (FPC) on which nine Pixel Chips and some passive components are bonded. The flex power extension cables will be modified to extend their length from 15 cm to 40 cm long for better adaptability to potentiasl future projects.

Detailed technical specifications of the Inner Barrel Pixel Stave for the ALICE ITS Upgrade, including construction, assembly and qualification procedures can be found at the following link:<https://indico.cern.ch/event/631636/>.

## **2.3 RDO Technical details**

ALICE ITS Upgrade Readout Unit (assembled motherboard only). This is the main component of the new readout system for the ALICE ITS Upgrade. It is a radiation tolerant electronic board, which provides detector data readout, control, and triggering. It supports up to 28 input electrical links (at 400Mbit/s, 600Mbit/s or 1.2 Gbit/s) and 3 output (and 2 input) optical links for a total bandwidth of 10 Gbit/s. The board is based on Commercial Off–the-Shelf (COTS) components as well as custom-made components to drive the optical links, the so-called GBT chip set, developed by CERN.

Detailed technical specifications of the Readout Unit for the ALICE ITS Upgrade, including technical drawings, characterization procedures and results can be found at the following link:<https://indico.cern.ch/event/698929/>.

## **2.4 Testing, Shipping, and Acceptance**

The ITS Stave and RU Testing, Shipping, Acceptance/Detector Construction are the responsibility of LBNL and UT-Austin, respectively. The ITS stave and RU production will be carried out at CERN under the supervision of the ALICE ITS technical staff there. Any quality problems identified will be resolved by consulting with the ALICE ITS upgrade project manager, and silicon experts at BNL and LBNL.

The ALICE/CERN Team, which is responsible for the construction of the Inner Barrel for the ALICE ITS Upgrade, will

· build and test 84 ALICE ITS Upgrade Inner Barrel Pixel Staves, which meet the ALICE Gold/Silver QA standards; Only staves that are fully qualified with Gold/Silver will be invoiced.

· build 60 ALICE ITS Upgrade Readout Units (fully assembled motherboards only);

and supply them to Brookhaven National Laboratory (BNL) as components of a future silicon vertex project.

Detailed Detector-Specific Quality Assurance Plans (DQAP) have been developed for stave and RU production.

**Staves:**

LBNL will be the responsible organization for shipping and implementing the QA requirements for all ITS staves delivered from CERN

At CERN, all relevant stave QA parameters related to the assembly, electrical bonding, metrological analysis, thermal and electrical tests of each fully assembled stave, as well as of each individual component (pixel chip, support structure, electrical substrate, etc.) will be stored in the ALICE construction database, to which BNL will be granted access for its information purposes.

Staves will be hand-carried from CERN to LBNL with special containers being designed by LBNL and CERN engineers. After receiving staves, LBNL personnel will perform the same ALICE ITS upgrade stave QA procedures to check the integrity of all 84 staves, and log all relevant parameters into a database. Additional ITS stave QA procedures will be developed, as necessary, if early production experience indicates they are warranted. Similarly, the QA procedures listed herein may be modified or improved, as experience dictates. All such additions and modifications will be captured in a formal revision to the DQAP for the staves.

**RUs:**

The Readout Unit module consists of a motherboard, mezzanine interface boards and a cooling plate. ALICE CERN Team will procure fully assembled motherboards, without mezzanine interface board and without cooling plate, and will make them available to BNL untested.

UT-Austin Physics will be the responsible organization for shipping and implementing the QA requirements for all Readout Unit production activities through completion of testing and subsequent shipment to BNL. After receiving RUs at Univ. of Texas at Austin, UTA personnel will perform the same ALICE ITS upgrade RU QA procedures to check the integrity of all 60 RUs, and log all relevant parameters into a database. Additional Readout Unit production QA procedures will be developed, as necessary, if early production experience indicates they are warranted. Similarly, the QA procedures listed herein may be modified or improved, as experience dictates. All such additions and modifications will be captured in a formal revision to the DQAP.

## **3 Budget and Budget Explanation**

**List and Cost of CERN Deliverables for future silicon vertex development at BNL, plus Additional Expenses**

**1)**  84 Pixel Staves = 11850 CHF/units, 84 units = **995400 CHF**

**2)** 84 Pixel Stave flexible power cables, with a length extension from 15 cm (ALICE) to 40 cm (BNL), has an extra total cost = **14000 CHF**

**3)** 84 stave carrier/storage plates = 238 CHF / unit \* 84 units = **20000 CHF**.This carrier plate will be a modified version of the one used for ALICE. The modification is needed in order to accommodate the length extension of the flexible power cable. The cost quoted above includes the design change, the development and qualification of a prototype and the production of 84 units.

**4)** 60 Readout Units = 2500 CHF/unit ∗ 60 units = **150000 CHF**

All costs are net, with no taxes and custom duties included. CERN will not cover any taxes and custom duties. All costs are FOB CERN. CERN is not responsible for the transport of the CERN contributed items from CERN to BNL. CERN will not cover any associated transportation costs, including the development of suitable transport boxes and packaging.

**UTK management Cost**

Dr. Tom Cormier will work on this project 10% of his time for a 12-month period. As a Joint Faculty Member with home institution at ORNL, he is required to charge the appropriate part of his work effort to this project in accordance with the “Guide for ORNL Joint Faculty (JF) Participating in University Proposals”. The salary is based on the ORNL JFO Wage Pool.

**F&A**

For the salary for Tom Cormier we will use the on-campus rate of 51% in accordance with the “Guide for ORNL Joint Faculty (JF) Participating in University Proposals”.

The ITS system is complete integrated piece of research equipment that will be purchased from CERN. We are therefore requesting that it will be treated as capital equipment for F&A calculations.

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| **Proposal Budget \*** | **CHF** | **USD** |
| **Readout Units** | **150,000** | **$151,254** |
| **Staves** | **995,400** | **$1,003,722** |
| **Power extension cables** | **14,000** | **$14,117** |
| **Modified fixtures for assembly** | **20,000** | **$20,167** |
| **Total Capital Equipment Cost for ITS system** | **1,179,400** | **$1,189,260** |
| **UTK management cost** |  | **$30,290** |
| **USD/CHF exchange rate fluctuation 10% of Capital Equipment Cost (Contingency)** |  | **$118,926** |
| **Total (before F&A)**  |  | **$1,338,476** |
| **F&A (51% of Management Cost)** |  | **$15,448** |
| **Total Requested Amount** |  | **$1,353,924** |

 **\*** Calculated using 1 CHF = 1.00836 USD

# **4 Biographical Information**

**Tom Cormier (PI):** Tom has participated in search for and study of Quark Matter from the earliest experiments in the ultra-relativistic energy regime at the Brookhaven AGS: Experiments E814, E877 and E866. In the latter experiment he was the project leader of the large Hadronic Calorimeter that enabled a very sensitive search for neutral strangelets and provided other rare, high mass, triggers. He was one of the founding member of the STAR experiment at the Relativistic Heavy Ion Collider (RHIC) where he was the project leader of the Barrel Electromagnetic Calorimeter and lead the group that developed the methods for heavy ion jet physics and single, non-photonic, electrons for heavy flavor physics. Currently, as a member of the ALICE experiment he is project leader of the ALICE Electromagnetic Calorimeters and the Barrel Tracking Upgrade Project. The former was constructed and available for LHC Run-1 and provides the high PT trigger and jet, electron and photon analysis for the experiment, while the latter is under preparation for high luminosity running in LHC Run-3.

**Soren Sorensen (Co-PI):** Soren has done most of his research within the WA80/93/98 collaboration (transverse energy production, nuclear stopping power, etc.), the PHENIX collaboration (Muon Arm system, responsible for offline computing, heavy flavor physics), and the ALICE collaboration. During the period 2013-2015 he was Coordinator of ALICE-USA and is now chair of the ALICE-USA Council. His research within ALICE has been focused on a) heavy flavor suppression at high pt as measured through single electrons from open heavy flavor decay, b) transverse energy production, and c) the construction of Inner Read-Out Chambers (IROCs) for the upgrade of the TPC.