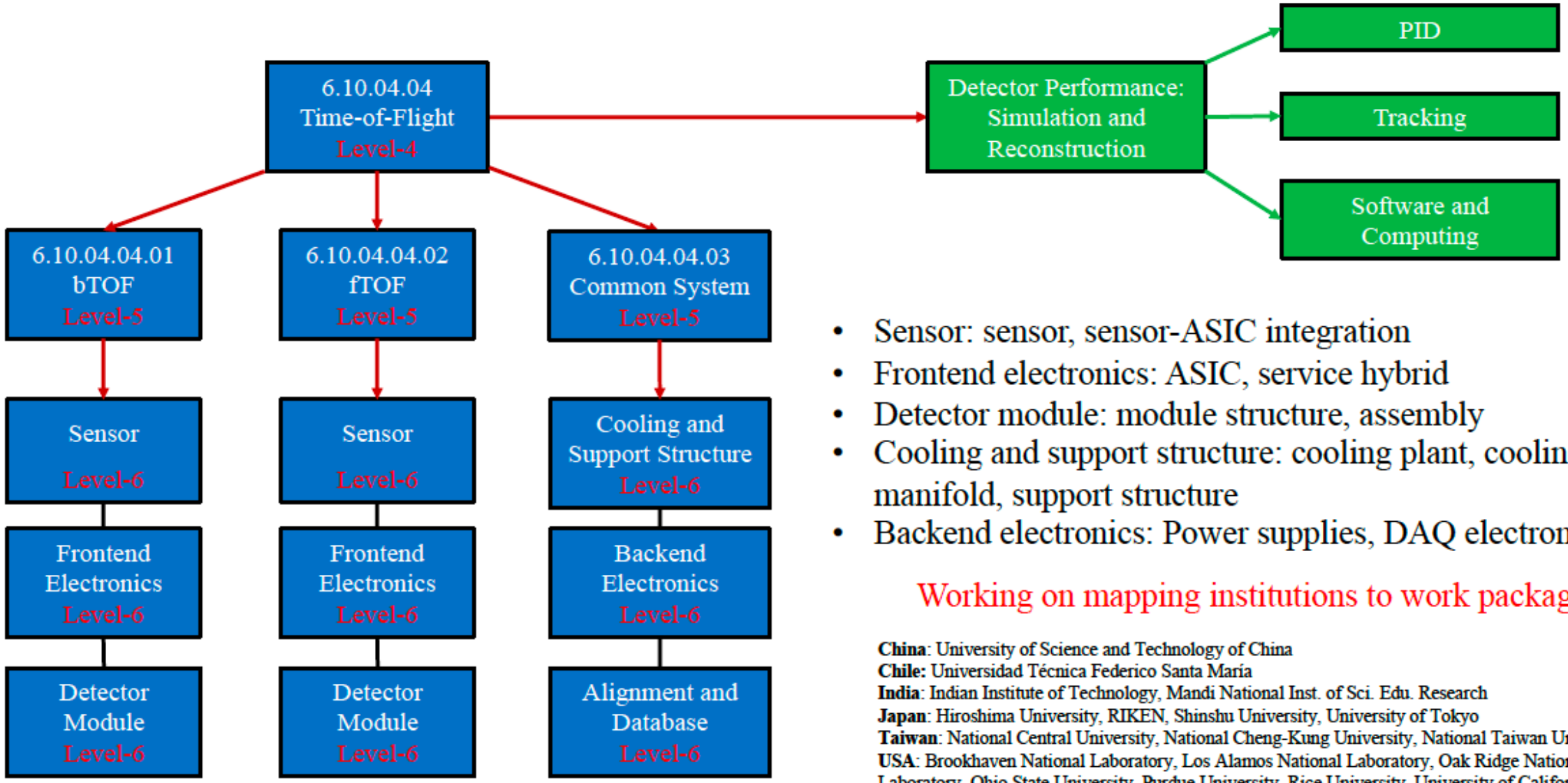
Common System

Andreas Jung (Purdue) and Zhangbu Xu (BNL)

Proposed Working Package Structure



- Sensor: sensor, sensor-ASIC integration
- Frontend electronics: ASIC, service hybrid
- Detector module: module structure, assembly
- Cooling and support structure: cooling plant, cooling manifold, support structure
- Backend electronics: Power supplies, DAQ electronics

Working on mapping institutions to work packages

China: University of Science and Technology of China
Chile: Universidad Técnica Federico Santa María
India: Indian Institute of Technology, Mandi National Inst. of Sci. Edu. Research
Japan: Hiroshima University, RIKEN, Shinshu University, University of Tokyo
Taiwan: National Central University, National Cheng-Kung University, National Taiwan University
USA: Brookhaven National Laboratory, Los Alamos National Laboratory, Oak Ridge National Laboratory, Ohio State University, Purdue University, Rice University, University of California - Santa Cruz, University of Illinois at Chicago

Schedule and cost tasks for common system

- Mechanic structure
  - Support structures
  - Cooling systems
  - Cooling manifolds
- Alignment and Database
  - Computers and software
- Backend Electronics
  - High-Voltage Power Supplies
  - Low-Voltage Power Supplies
  - Patch Panels?
  - Cooling Infrastructures
  - Timing systems

Common systems

Detector Name		Specification/ requierments	Comments from BNL EE group
Sensor Type		AC-LGAD strip sensor	
Sensor Details		TBD. Current assumption is each sensor has a size of 3.2*4 cm2 with 64*4=256 strips. The strip pitch and length are 0.5 and 10mm, respectively.	
# Sensors		9216 assuming 144 BTOF modules, each with 64 sensors with a size of 3.2*4 cm2	
# Readout Channels		2359296 assuming 9216 sensors with 64*4=256 strips per sensor	1mW / chanel = 2400W. power / FEB? is there power conversion on FEB?
LC current /FEB or module		ASICs will consume 2.4kW/144=16.4W per module assuming 1mW per channel. ASICs will be biased at 1.2V. There will be DC-DC conversion from 11V to 1.2V on FEB/RDO (TBD) with ~66% efficiency. The power consumption will be 25W and current 25W/11V=2.3A per module. If the ASIC power consumption is 2mW/channel, the power consumption will be 50W and current 4.5A per module.	**System total: 50W / 0.7 = 10.8kw => 10.8kW/ 10Vin = 1,080A**
HV System(s)		TBD. Possible choices include CAEN SY4527 chasis and A1625 modules, or something similar	require 18x A1625 modules & 2x SY4527 crates => 18 unit rack space
HV current		<10 mA at 200-400V per detector module	
Readout ASIC		TBD. Candidates include EICROC modified for strip sensor readout, FCFD, HPSOC/ASROC/FAST	
ASIC details /requirements		TBD. Geometry match strip sensor design, zero suppression, digital output with TDC for signal time-of-arrival and ADC for signal amplitude measurements, power consumption <1mW/channel, jitter contribution from ASIC < 15ps for MIP signals, ASIC+Sensor+clock timing resolution < 35ps, spatial resolution < 30 microns.	
ASIC modes		Streaming readout, zero suppression with digital output with TDC and ADC info	
Front-End Board		Low mass kapton flexible PCB, mounted with AC-LGAD sensors and frontend ASICs	
FEB Data Transport		Electric Signals	LVDS over copper?
System Timing		clock jitter < 5ps	
Timing Requirements		clock jitter < 5ps, ASIC+Sensor+clock timing resolution < 35ps	
Readout Board		288 RDO with FPGA and Fibre links, mounted near the end of BTOF from both sides at z=+/-120cm (TBD)	
Patch Panel		TBD. If space near the ends of the BTOF is limited and RODs have to be placed at some distance, we may need to put PPs between BTOF modules and RDOs, with 144 PPs from each side of BTOF.	
Design Workforce		**ASIC:** EICROC by OMEGA/IJCLab/CEA-Irfu, FCFD by FNAL, HPSoC/ASROC/FAST by UCSC **FEB/ROB:** BNL/ORNL/OSU/Rice/UIC	

Common System Schedule/cost in the TOF Project

	Activity ID	Activity Name	OD	Start	Finish	START	STOP
2	**ECE06-10-04 EEW.10.04.04.03 TOF Common System**						
3	**EEW.10.04.04.03.01**	**TOF Support Structure and Cooling System**				**1-Oct-23**	**31-Dec-28**
4	**EEW.10.04.04.03.01.01**	**TOF Support Structure**				**1-Oct-23**	**31-Dec-28**
5		TOF Support Structure Design				**1-Oct-23**	**31-Mar-25**
6		TOF Support Structure Prototyping				**1-Apr-25**	**30-Sep-26**
7		TOF Support Structure Production				**1-Oct-26**	**31-Dec-28**
8	**EEW.10.04.04.03.01.02**	**TOF Cooling System**				**1-Oct-23**	**31-Dec-28**
9		TOF Cooling System Design				**1-Oct-23**	**31-Mar-25**
10		TOF Cooling System Prototyping				**1-Apr-25**	**30-Sep-26**
11		TOF Cooling System Production				**1-Oct-26**	**31-Dec-28**
12	**EEW.10.04.04.03.02**	**TOF Backend Electronics**				**1-Oct-23**	**31-Dec-28**
13	**EEW.10.04.04.03.02.01**	**TOF LV Power Supply**				**1-Oct-23**	**31-Dec-28**
14		TOF LV Power Supply Design				**1-Oct-23**	**31-Mar-25**
15		TOF LV Power Supply Prototyping				**1-Apr-25**	**30-Sep-26**
16		TOF LV Power Supply Production				**1-Oct-26**	**31-Dec-28**
17	**EEW.10.04.04.03.02.02**	**TOF HV Power Supply**				**1-Oct-23**	**31-Dec-28**
18		TOF HV Power Supply Design				**1-Oct-23**	**31-Mar-25**
19		TOF HV Power Supply Prototyping				**1-Apr-25**	**30-Sep-26**
20		TOF HV Power Supply Production				**1-Oct-26**	**31-Dec-28**
21	**EEW.10.04.04.01.02.03**	**BTOF Patch Panel and Cables (move to common)**				**1-Jan-24**	**30-Jun-28**
22		BTOF Patch Panel and Cable Design				**1-Oct-23**	**31-Mar-25**
23		BTOF Patch Panel and Cable Prototyping				**1-Apr-25**	**30-Sep-26**
24		BTOF Patch Panel and Cable Production				**1-Oct-26**	**31-Dec-28**
25	**EEW.10.04.04.03.02.04**	**TOF DAQ System**				**1-Jan-24**	**30-Jun-28**
26		TOF DAQ System Design				**1-Oct-23**	**31-Mar-25**
27		TOF DAQ System Prototyping				**1-Apr-25**	**30-Sep-26**
28		TOF DAQ System Production				**1-Oct-26**	**31-Dec-28**
29	**EEW.10.04.04.03.03**	**TOF Alignment System and Database**				**1-Oct-23**	**31-Dec-28**
30	**EEW.10.04.04.03.03.01**	**TOF Alignment System**				**1-Oct-23**	**31-Dec-28**
31		TOF Alignment System Design				**1-Oct-23**	**31-Mar-25**
32		TOF Alignment System Prototyping				**1-Apr-25**	**30-Sep-26**
33		TOF Alignment System Production				**1-Oct-26**	**31-Dec-28**
34	**EEW.10.04.04.03.03.02**	**TOF Database**				**1-Oct-23**	**31-Dec-28**

Backend Electronics and DAQ

E1008_05700	RQN: Peripheral Electronic Boards Procurement (TOF CTTL AC-LGAD)	1	02-Dec-26	02-Dec-26
E1008_05720	Prepare Award Documentation for Peripheral Electronic Boards (TOF CTTL AC-LGAD)	30	03-Dec-26	25-Jan-27
E1008_05740	AWARD: Peripheral Electronic Boards (TOF CTTL AC-LGAD)	1	26-Jan-27	26-Jan-27
E1008_05760	TR Effort for Peripheral Electronic Boards (TOF CTTL AC-LGAD)	363	27-Jan-27	10-Jul-28
E1008_05780	Vendor Effort for Peripheral Electronic Boards (TOF CTTL AC-LGAD)	363	27-Jan-27	10-Jul-28
E1008_05800	RCV: Peripheral Electronic Boards (TOF CTTL AC-LGAD)	1	11-Jul-28	11-Jul-28
E1008_05820	RQN: Fibers/Optical Connectors Procurement (TOF CTTL AC-LGAD)	1	02-Dec-26	02-Dec-26
E1008_05840	Prepare Award Documentation for Fibers/Optical Connectors (TOF CTTL AC-LGAD)	30	03-Dec-26	25-Jan-27
E1008_05860	AWARD: Fibers/Optical Connectors (TOF CTTL AC-LGAD)	1	26-Jan-27	26-Jan-27
E1008_05880	TR Effort for Fibers/Optical Connectors (TOF CTTL AC-LGAD)	363	27-Jan-27	10-Jul-28
E1008_05900	Vendor Effort for Fibers/Optical Connectors (TOF CTTL AC-LGAD)	363	27-Jan-27	10-Jul-28
E1008_05920	RCV: LV Fibers/Optical Connectors (TOF CTTL AC-LGAD)	1	11-Jul-28	11-Jul-28

In EIC Project

In TOF Project 

21	**EEW.10.04.04.01.02.03**	**BTOF Patch Panel and Cables (move to common)**				**1-Jan-24**	**30-Jun-28**
22		BTOF Patch Panel and Cable Design				**1-Oct-23**	**31-Mar-25**
23		BTOF Patch Panel and Cable Prototyping				**1-Apr-25**	**30-Sep-26**
24		BTOF Patch Panel and Cable Production				**1-Oct-26**	**31-Dec-28**
25	**EEW.10.04.04.03.02.04**	**TOF DAQ System**				**1-Jan-24**	**30-Jun-28**
26		TOF DAQ System Design				**1-Oct-23**	**31-Mar-25**
27		TOF DAQ System Prototyping				**1-Apr-25**	**30-Sep-26**
28		TOF DAQ System Production				**1-Oct-26**	**31-Dec-28**

Cooling infrastructure

ETL.03.02.04 Cooling Infrastructure	
ETL.03.02.04.01 Cooling Infrastructure Procurement	
ETL105	Milestone: Procurement of CO2 Cooling Infrastructure Start
ETL106	Rice Prepare and Issue PO: CO2 Cooling Infrastructure
ETL106	SVT Lead Time: CO2 Cooling Infrastructure
ETL106	Receive CO2 Cooling Infrastructure
ETL109	Milestone: Procurement of CO2 Cooling Infrastructure Complete

HV and LV Power Supplies

E1008_05580	RQN: Low and High Voltage System Procurement (TOF CTTL AC-LGAD)	1	02-Dec-26	02-Dec-26
E1008_05600	Prepare Award Documentation for Low and High Voltage System (TOF CTTL AC-LGAD)	30	03-Dec-26	25-Jan-27
E1008_05620	AWARD: Low and High Voltage System (TOF CTTL AC-LGAD)	1	26-Jan-27	26-Jan-27
E1008_05640	TR Effort for Low and High Voltage System (TOF CTTL AC-LGAD)	363	27-Jan-27	10-Jul-28
E1008_05660	Vendor Effort for Low and High Voltage System (TOF CTTL AC-LGAD)	363	27-Jan-27	10-Jul-28
E1008_05680	RCV: Low and High Voltage System (TOF CTTL AC-LGAD)	1	11-Jul-28	11-Jul-28

In EIC Project

In TOF Project

12	**EEW.10.04.04.03.02**	**TOF Backend Electronics**				**1-Oct-23**	**31-Dec-28**
13	**EEW.10.04.04.03.02.01**	**TOF LV Power Supply**				**1-Oct-23**	**31-Dec-28**
14		TOF LV Power Supply Design				**1-Oct-23**	**31-Mar-25**
15		TOF LV Power Supply Prototyping				**1-Apr-25**	**30-Sep-26**
16		TOF LV Power Supply Production				**1-Oct-26**	**31-Dec-28**
17	**EEW.10.04.04.03.02.02**	**TOF HV Power Supply**				**1-Oct-23**	**31-Dec-28**
18		TOF HV Power Supply Design				**1-Oct-23**	**31-Mar-25**
19		TOF HV Power Supply Prototyping				**1-Apr-25**	**30-Sep-26**
20		TOF HV Power Supply Production				**1-Oct-26**	**31-Dec-28**

Alignment and Database

E1004_07700	TOF Alignment System - Final Design (TOF)	366	15-Jan-25	06-Jul-26
E1004_07720	TOF Alignment System - Production (TOF)	928	07-Jul-26	05-Apr-30
E1004_07740	TOF Alignment System - Delivery (TOF)	0		05-Apr-30
E1004_07760	TOF Database - Final Design (TOF)	366	15-Jan-25	06-Jul-26
E1004_07780	TOF Database - Production (TOF)	928	07-Jul-26	05-Apr-30
E1004_07800	TOF Database - Delivery (TOF)	0		05-Apr-30

In EIC Project

In TOF Project 

29	**EEW.10.04.04.03.03**	**TOF Alignment System and Database**				**1-Oct-23**	**31-Dec-28**
30	**EEW.10.04.04.03.03.01**	**TOF Alignment System**				**1-Oct-23**	**31-Dec-28**
31		TOF Alignment System Design				**1-Oct-23**	**31-Mar-25**
32		TOF Alignment System Prototyping				**1-Apr-25**	**30-Sep-26**
33		TOF Alignment System Production				**1-Oct-26**	**31-Dec-28**
34	**EEW.10.04.04.03.03.02**	**TOF Database**				**1-Oct-23**	**31-Dec-28**

Cooling System

Detector	Type	Front End	HV Bias	LV Power S	HV Power S	Power Sup	LV Power F	LV Feed Cables (Tray Rated)	Cooling (Board Electronics)
Barrel TOF	AG-LGAD	7.2kW	4W@400V	PL506	CAEN A162	S. Platform	10V @ 900	30x 8AWG	Liquid
HE TOF	AG-LGAD	16.0kW	4W@400V	PL506	CAEN A162	S. Platform	10V @ 2,0(	60x 8AWG	Liquid

E1004_07580	TOF Support Structure - Final Design (TOF)	366	15-Jan-25	06-Jul-26
E1004_07600	TOF Support Structure - Production (TOF)	928	07-Jul-26	05-Apr-30
E1004_07620	TOF Support Structure - Delivery (TOF)	0		05-Apr-30
E1004_07640	TOF Cooling System - Final Design (TOF)	366	15-Jan-25	06-Jul-26
E1004_07660	TOF Cooling System - Production (TOF)	928	07-Jul-26	05-Apr-30
E1004_07680	TOF Cooling System - Delivery (TOF)	0		05-Apr-30

In EIC Project

8	**EEW.10.04.04.03.01.02**	**TOF Cooling System**					**1-Oct-23**	**31-Dec-28**
9		TOF Cooling System Design					**1-Oct-23**	**31-Mar-25**
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11		TOF Cooling System Production					**1-Oct-26**	**31-Dec-28**

In TOF Project 

Support Structure – FTOF

- In TOF Project

TOF LGAD endcap (for now standard sandwich structure)			
	Milestones	**Plan start**	**Duration**
	Pre-production & Prototype, earliest for 1st wegde available	9/3/25	4
	Finalize loads/BCs	1/1/26	0.5
	Current Design Review	1/16/26	0.5
	Final FEA & Coolant pipe layout	1/31/26	0.5
	Tool Preparation & Machining	2/15/26	1
	Practice Layup	3/17/26	0.25
	Final Manufacturing FEA	3/24/26	1
	3D print sub-parts	4/23/26	1
	Final adjustments to manufacturing	5/23/26	1
	First wedge layup	6/22/26	1
	First wedge part prep	7/22/26	0.25
	Tool Preparation & Machining	7/30/26	1
	Remaining wedges layup	8/29/26	2
	Remaining wedges	10/28/26	2
	Endcap assembly	12/27/26	2
	QA/QC + loading	2/25/27	1
	Total	3/27/27	19

Support Structures – Staves

- In TOF project

TOF LGAD staves (cost savings via NCKU machine shop possible)			
	Milestones	**Plan start**	**Duration**
	Pre-production & Prototype, earliest for final stave available	1/1/25	3
	Finalize design & choice	4/1/25	2
	Purchase Consumables	5/31/25	0.5
	Practice Layup	6/15/25	0.5
	QA/QC	6/30/25	0.25
	Layups 1 to 72	7/7/25	2
	Layups 72 to 144	9/5/25	2
	Layups > 144 (spares)	11/4/25	2
	Pipe preparation	1/3/26	2
	Assembly/Gluing	3/4/26	2
	QA/QC	5/3/26	0.75
	Total	5/26/26	17

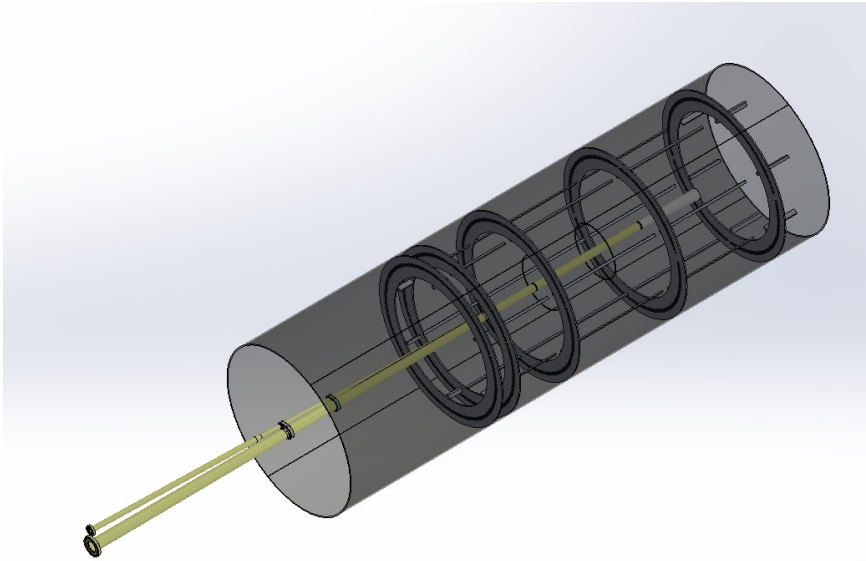
Support Structures – BTOF

- In Common projects
- Currently also implemented in tracker, may stay there
- See next slide, more up-to-date then this one!

TOF LGAD support + interfaces (for now assume half cylinders)			
	Milestones	**Plan start**	**Duration**
	Pre-production & Prototype, earliest for final parts of supports available	7/5/25	6
	Finalize BCs, Loads, design	1/1/26	1
	Sched. CNC Time	1/31/26	1
	Purchase Consumables	3/2/26	1
	Practice Layup	4/1/26	2
	Final prototype, final design for insertion tests	5/31/26	2
	Final Manufacturing FEA	7/30/26	2
	Final adjustments to manufacturing	9/28/26	2
	3D print sub-parts	11/27/26	1
	Tool Preparation & Machining	12/27/26	2
	Half-cylinder layup	2/25/27	1
	Cylinder Assembly	3/27/27	0.5
	QA/QC + loading	4/11/27	1
	Half-cylinder layup & Assembly	5/11/27	2
	QA/QC + loading	7/10/27	1
	Total	8/9/27	25.5

Support Structures – BTOF

- WBS 6 on Global Mechanics for tracker SVT side
- Just discussed and separated out with WBS 4 on SVT (Mechanics)



6.1	Global Mechanics - Support structure	
6.1.1	Definition of SVT system parameters	
6.1.1.1		Envelope model (incl. service volumes)
6.1.1.2		Support hierarchy
6.1.1.3		Mechanical interfaces to outside
6.1.1.4		Global SVT CAD model (incl. services)
6.1.1.5		Global SVT thermo-mechanical FEA model (incl. services)
6.1.2	Outer support cylinder design & prototyping	
6.1.2.1		Finalize BC, Loads, Design
6.1.2.2		CNC time schedule, Procure long lead items
6.1.2.3		Final manufacturing FEA based on global FEA
6.1.2.4		3d print sub-components
6.1.2.5		tool preparation & machining
6.1.2.6		Practice Layup
6.1.2.7		Prototype manufacturing
6.1.2.8		QA/QC + loading tests
6.1.3	Global SVT mechanics test (inc. cooling)	
6.1.4	Outer support cylinder production	
6.1.4.1		Adjustment to design based on prototype
6.1.4.2		Product Readiness Review and go-ahead
6.1.4.3		Finalize BC, Loads, Design
6.1.4.4		Final manufacturing FEA based on global FEA & Prototype
6.1.4.5		3d print sub-components
6.1.4.6		Tool preparation & machining
6.1.4.7		Practice Layup
6.1.4.8		Prototype manufacturing
6.1.4.9		QA/QC + loading tests
6.1.5	Mechanical interface to beam pipe	

Support Structures – BTOF

- WBS 6 on Global Mechanics for tracker SVT side
- Just discussed and separated out with WBS 4 on SVT (Mechanics)

6.2	Integration	
6.2.1	Dry-assembly (simulated and prototype based)	
6.2.2	Define mounting systems and adjustment options (alignment ?)	
6.2.3	IB integration test	
6.2.4	OB integration test	
6.2.5	Dee integration test	
6.3	Services	
6.3.1	Mapping	
6.3.2	Service support cones	
6.3.3	Services from end of subsystem to TOF	
6.3.3.1		Design
6.3.3.2		Installation
6.3.4	Service Distribution Patch Panel (at outer cylinder)	
6.3.4.1		Design
6.3.4.2		Installation

Common System: most are on EIC project side

- Support structure:
  Andy and Rahul
- Cooling infrastructure:
  Rahul
- HV and LV PS:
  Tim Camarda
- DAQ and Fiber:
  Jeff and Fernando
- Alignment and Database?

- Follow up with engineers from EIC project to work on the requirements and schedule, make sure that everywhere in TOF project and EIC project schedule/cost are consistent