Integration, Installation and Infrastructure (I^3)

(SC4) Detector Parallel Session

Rahul Sharma

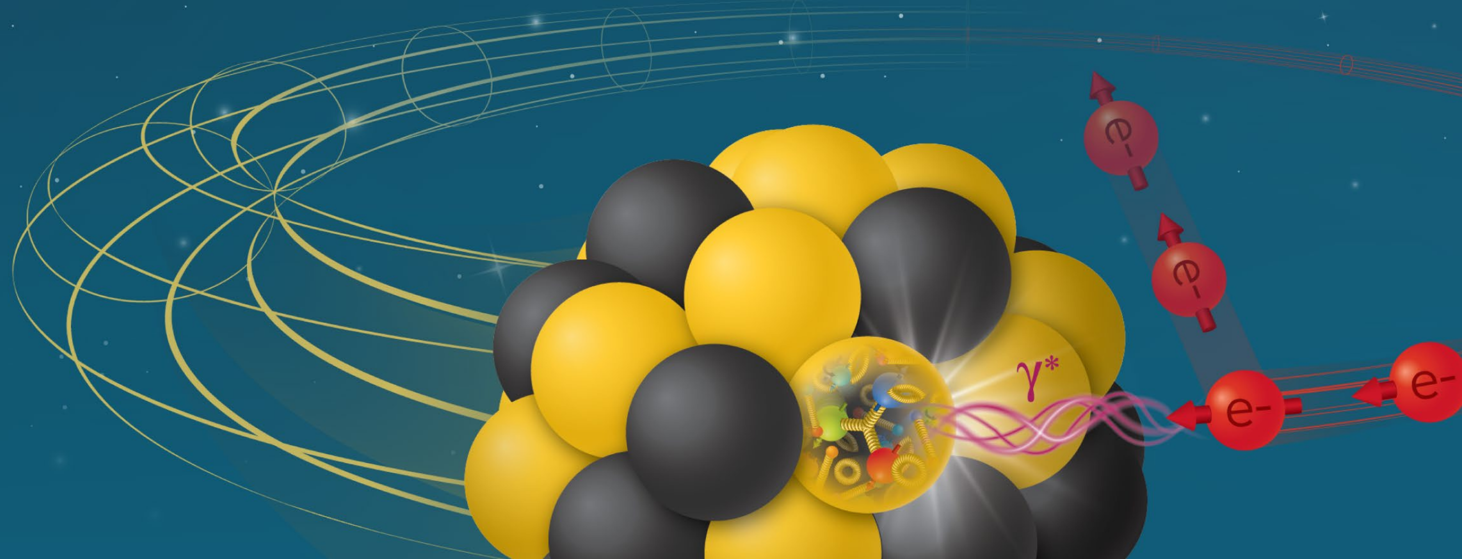
Chief Mechanical Engineer

L3 Manager WBS 6.03.01.09

OPA IPR of the EIC Project Status

September 15-18, 2026

Electron-Ion Collider



About Me-First Name, Last Name

Rahul Sharma

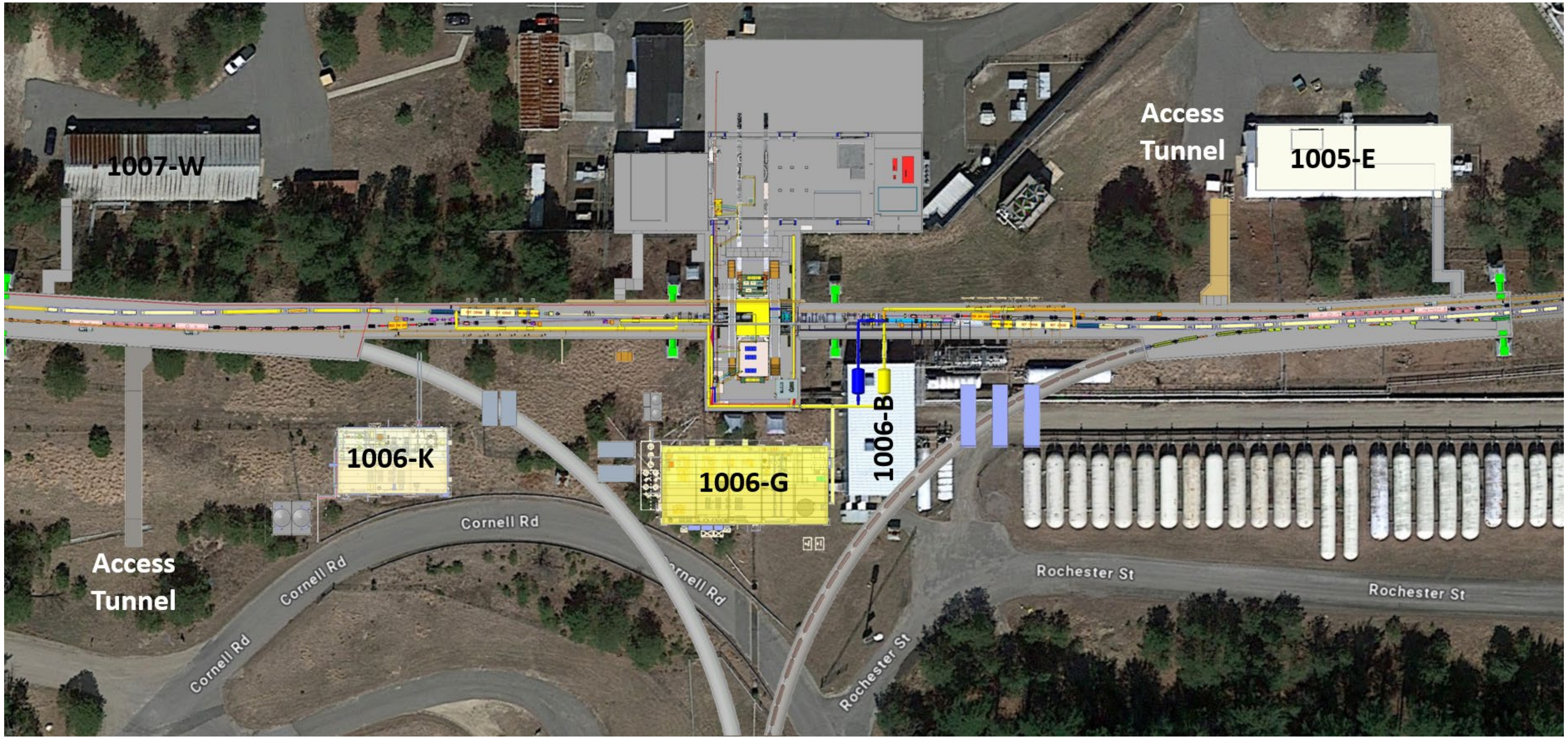
- Current Project Role
  - L3 Manager, Chief Mechanical Engineer, WBS 6.03.01.09 (Integration, Installation and Infrastructure)
- Relevant Experience
  - Over 18 years of Engineering Experience
  - 16+ Years at BNL
  - Design, analysis and construction of Daya Bay, DUNE, STAR
- Highest Degree
  - Masters of Science (Mechanical Engineering) from Stony Brook University
- Brookhaven Engineering Award 2021

Charge Questions Addressed

1. Has the project team developed a complete, technically credible preliminary performance baseline for this stage of the project and begun to effectively execute against it? Is the project positioned to complete approved long-lead procurements within the established schedule and cost baseline? Are technical issues appropriately and proactively addressed?
2. Is each proposed subproject scope defined well and logically? Are the subprojects ordered and phased optimally? Does the roll-up of the subprojects' scope unambiguously compose a complete and responsive EIC facility? Are the key performance parameters well documented and justifiable? Are subproject interfaces understood and delineated? Are the schedules and cost estimates and associated contingency plans credible for the current stage of each subproject?
3. Are the proposed CD-3C long-lead procurements appropriate and do they support project risk mitigation? Have the proposed CD-3C long lead procurements attained final design?
4. Are the schedule and cost for the first infrastructure subproject complete and credible? Do they include adequate scope, schedule, and cost contingency? Will the first infrastructure subproject likely achieve its performance baseline?
5. Has the first infrastructure subproject met all the CD-2 and CD-3 prerequisites and is the project team ready to request CD-2/3 approval?
6. Are ES&H and QA properly addressed given the project's current stage of development?
7. Is the project properly managed? Are risks being effectively managed? Is a management team in place to successfully execute the project including long-lead procurements? Are roles and responsibilities documented and understood?
8. Has the project team satisfactorily addressed recommendations from previous DOE SC reviews?

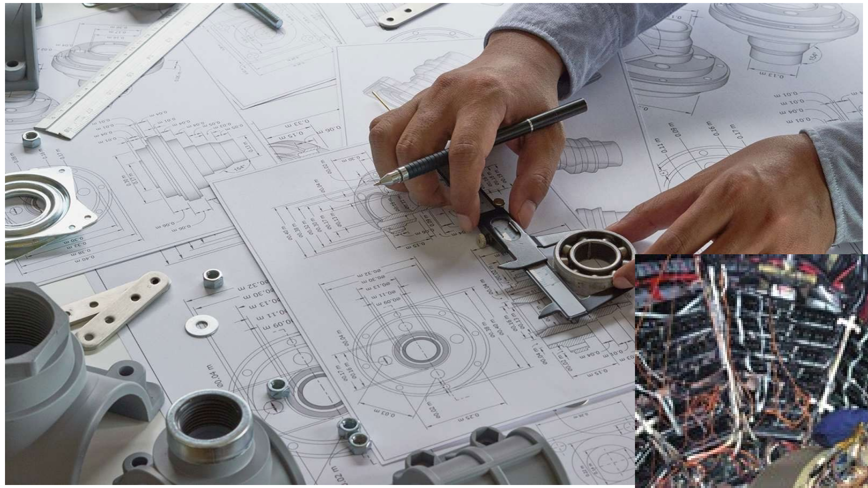
Outline

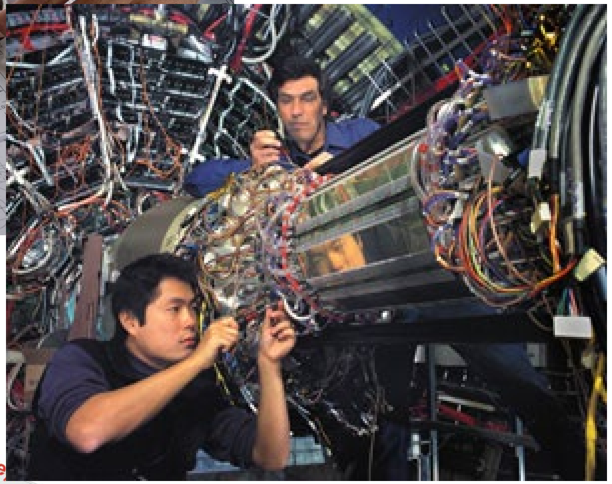
- ePIC I^3 Team
- Scope Summary
- Requirements
- Technical Progress
- Dependencies
- Alignment Requirement
- Major Interfaces
- ES&H
- Quality Assurance
- Major Procurement Planning
- Recommendation Tracker
- LLP CD-3B and CD-3C – Backup slides available.
- Schedule
- Costs
- Staffing
- Risks
- BOE Breakdown - Backup slides available
- Technical Summary
- Technical Path Forward

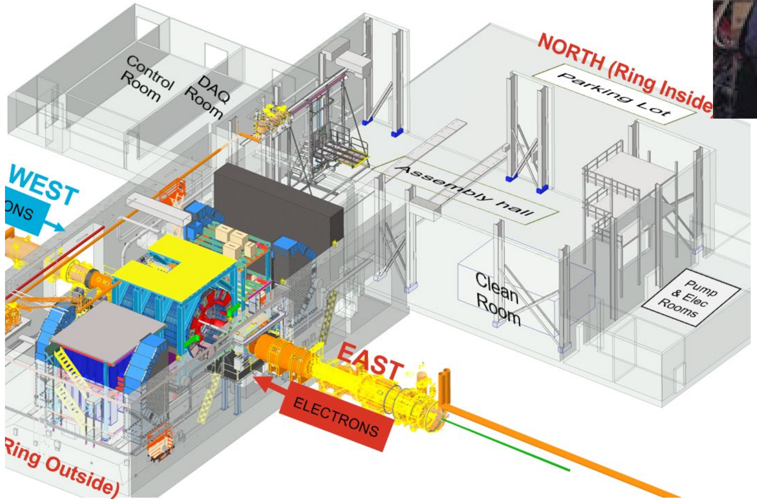


ePIC I^3 Team

- **Rahul Sharma (BNL) – Chief Mechanical Engineer**
- Walt Akers (JLAB) – Systems Integration
- Roland Wimmer (BNL) – Mechanical Engineer
- Dan Cacace (BNL) – Mechanical Engineer – Endcap Structures
- John Tuozzolo (BNL) – Mechanical Designer
- Nathaniel Speece-Moyer (BNL) – Mechanical Engineer
- Richard Porqueddu (BNL) – Mechanical Engineer
- Girish Gowda (BNL) – CFD and Thermal Analysis Engineer
- India Krehbiel (JLAB) – Mechanical Designer
- Karim Hamdi (BNL) – Mechanical Designer
- Alex Eslinger (JLAB) – Mechanical Engineer – pfRICH Design
- Alessandro Saputi (INFN/CERN) – dRICH Design and Installation
- Ron Lassiter (JLAB) – Forward Detectors – Mechanical Designer
- Johnathan Smith (JLAB) – Mechanical Designer
- Andreas Jung (Purdue University) – Detector Scientist
- Sushrut Karmarkar (Purdue University) – Mechanical Engineer
- Ben Denos (Purdue University) – Mechanical Engineer
- Seung Joon Lee (JLAB) – Detector Scientist
- Julien Bettane (IJC Lab – Orsay) – Mechanical Engineer
- Joshua Crafts (CUA) – Postdoc – EEEMCAL
- Tom O’Connor(ANL) – Barrel EMCAL Design
- Kevin Bailey (ANL) – Barrel EMCAL Design

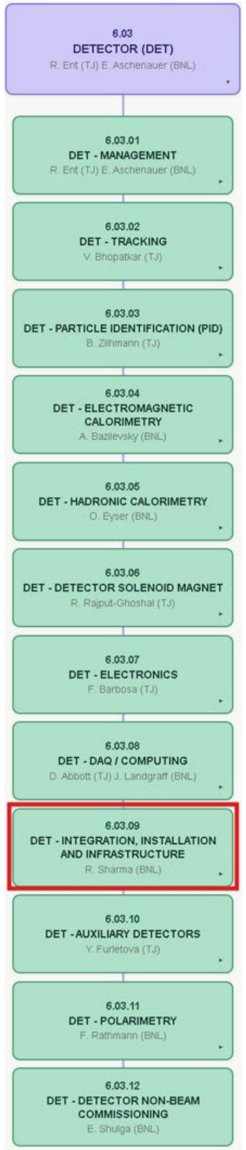






Charge # 1 & 7

Scope Summary



6.03.09	DET - DS -Integration, Installation and Infrastructure	R. Sharma (BNL)

Scope Description:

Includes the following: Effort needed to design and build new infrastructure, modify/repurpose existing infrastructure and Integration of various subdetectors for construction of ePIC detector in Bldg 1006 Assembly Hall and Experimental Hall.

- **Detector Integration**: Integration of sub-detectors and associated components into the ePIC detector, maintaining alignment, functionality, and overall system compatibility.
- **Interface Definition and Management:** Define and manage mechanical and services interfaces between experimental equipment, the central magnet, sub-detectors, other detector components, and the collider. Provide technical guidance to detector subgroups to ensure their designs are consistent with integration requirements.
- **Design, Fabrication, Assembly, and Installation:** Lead the design, manufacturing, assembly, and installation of support structures, installation tooling/access equipment and platforms for all sub-detectors, ensuring readiness for full installation prior to detector commissioning.
- **Utilities Coordination:** Coordinate and manage with EIC infrastructure subgroups to ensure provision and distribution of utilities—including power, water cooling (using existing MCW), air cooling, and HVAC—for both the ePIC detector and Building 1006. Please note that any special cooling units will be responsibility of subgroups.

Charge # 1

Requirements

- Requirements documentation for all sub-systems are provided in the pre-brief, including for Integration, Installation and Infrastructure.
- They are broken down and linked into General, Functional and Performance categories.
- An example of alignment requirement flow-down is shown here and how it is met is shown on slide 18:

G-DET-INF.9	The infrastructure systems will be functionally integrated with the other detectors, with the interaction region components, and with the facility infrastructure.	
F-DET-INF.4	The configuration of the infrastructure systems within the detector will be coordinated to ensure efficient operation and to minimize adverse interactions between sub-systems.	G-DET-INF.9, G-DET-INF.10
P-DET-INF-STD-SVCGAP.13	The positional tolerance of the beampipe shall be within ±1mm in the X,Y directions, and ±5mm in the Z direction.	F-DET-INF.4, F-DET-INF.5

General

GENERAL REQUIREMENTS	
Name	Description
Detector Infrastructure	
G-DET-INF.1	There will be distinct infrastructure requirements for the assembly hall, the collider hall, and the interaction region.
G-DET-INF.2	All components, equipment and assemblies will comply with standards established by the EIC project.
G-DET-INF.3	Infrastructure systems for the assembly hall shall include all power, water, environmental cooling, cryogenics, gas handling, clean compressed air delivery, space, fire protection, Helium Leak Detection, ODH Detection and any other Personnel Safety Systems, material handling and support systems required to assemble and maintain the central detector systems.
G-DET-INF.4	Infrastructure systems for the collider hall shall include all power, water, environmental cooling, cryogenics, gas handling, clean compressed air delivery, space, fire protection, Helium Leak Detection, ODH Detection and any other Personnel Safety Systems, Cryo Protection, material handling and support systems required to operate the entire detector systems.
G-DET-INF.5	Infrastructure systems for the interaction region shall include all power, water, environmental cooling, cryogenics, gas handling, space, material handling and support systems required to assemble, operate and maintain the far forward and far backward detector systems.
G-DET-INF.6	Infrastructure systems shall provide adequate space, environmental cooling, and distribution for DAQ and local computing.
G-DET-INF.7	Space and facilities for the experimental control room and operations shall be preserved.
G-DET-INF.8	Where feasible, existing infrastructure systems will be reused.
G-DET-INF.9	The infrastructure systems will be functionally integrated with the other detectors, with the interaction region components, and with the facility infrastructure.
G-DET-INF.10	The infrastructure systems must fit within the available space in the experimental hall, and be consistent with the available infrastructure and resources.

Functional

FUNCTIONAL REQUIREMENTS		
Name	Description	Parent
Detector Infrastructure		
F-DET-INF.1	All components, whether procured or manufactured, will, at a minimum, meet the standards specified by the EIC project AND meet the additional standards and specifications identified in these requirements.	G-DET-INF.2
F-DET-INF.2	Where not governed by specific standards, components will be implemented, installed, and utilized in a manner that is consistent with industry best practices.	G-DET-INF.2
F-DET-INF.3	The infrastructure systems will require adequate infrastructure resources (i.e. power, cooling, cryogens, etc.) to ensure it can function reliably during continuous operations.	G-DET-INF.9
F-DET-INF.4	The configuration of the infrastructure systems within the detector will be coordinated to ensure efficient operation and to minimize adverse interactions between sub-systems.	G-DET-INF.9 G-DET-INF.10
F-DET-INF.5	The infrastructure systems and its support systems must fit in the available space AND provide adequate plenums and pathways for the delivery of services, resources and communications, and for the removal of heat and waste during operations.	G-DET-INF.9 G-DET-INF.10
F-DET-INF.6	A structural support infrastructure must be provided that supports the weight of the infrastructure systems and peripheral equipment, and safely distributes that load to the ground.	G-DET-INF.9 G-DET-INF.10
F-DET-INF.7	Predefined detector envelopes shall not be infringed upon.	G-DET-INF.9 G-DET-INF.10

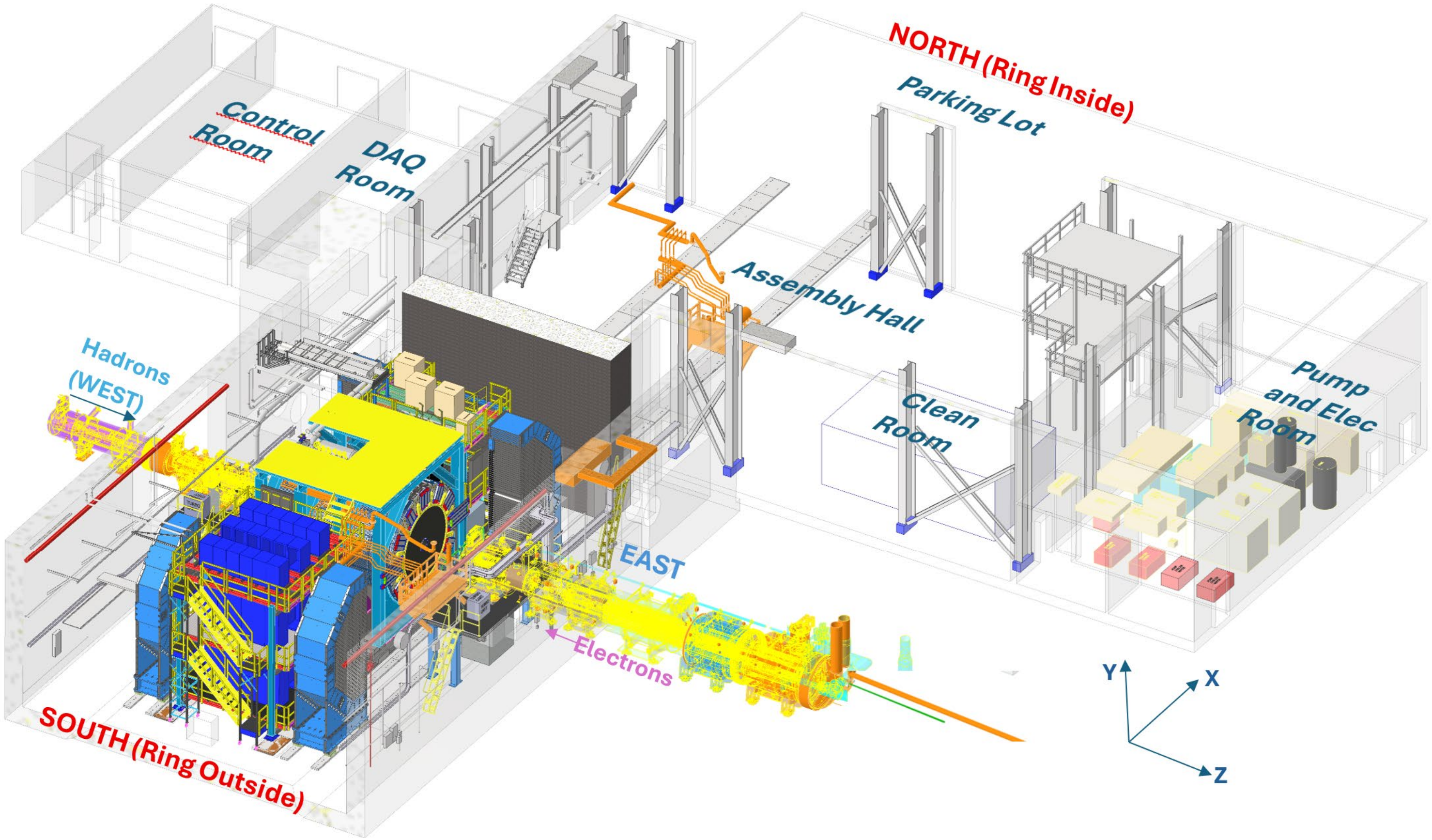
Performance

PERFORMANCE REQUIREMENTS		
Name	Description	Parent
Detector Infrastructure		
Standards		
Safety Factors		
P-DET-INF-STD-SAF.1	Safety factors will be calculated based off yield strength.	F-DET-INF.1 F-DET-INF.2
P-DET-INF-STD-SAF.2	Parts with a safety factor of 3 or greater will be generally accepted and will not require further review.	F-DET-INF.1 F-DET-INF.2
P-DET-INF-STD-SAF.3	Parts with a safety factor of 1.5 to 3 are required to be internally reviewed to determine if it's acceptable.	F-DET-INF.1 F-DET-INF.2
P-DET-INF-STD-SAF.4	Parts with a safety factor of 1.5 or less will be considered unacceptable.	F-DET-INF.1 F-DET-INF.2
P-DET-INF-STD-SAF.5	Bolts with a safety factor of 2 or greater will be generally accepted and will not require further review.	F-DET-INF.1 F-DET-INF.2
P-DET-INF-STD-SAF.6	Bolts with a safety factor of 1 to 2 are required to be internally reviewed to determine if it's acceptable.	F-DET-INF.1 F-DET-INF.2
P-DET-INF-STD-SAF.7	Bolts with a safety factor of 1 or less will be considered unacceptable.	F-DET-INF.1 F-DET-INF.2
P-DET-INF-STD-SAF.8	Engineering judgment will be used for identifying and disregarding any singularities which may go below these minimums.	F-DET-INF.1 F-DET-INF.2
Beampipe Clearances		
P-DET-INF-STD-PIPECLR.1	Inner Detectors will have a minimum clearance to the beampipe of 5mm all around.	F-DET-INF.5
P-DET-INF-STD-PIPECLR.2	For Inner Detectors that will be installed over flanges then the minimum clearance will be 5mm to the flange all around.	F-DET-INF.5
P-DET-INF-STD-PIPECLR.3	All other central detectors will have a minimum clearance to the beampipe of 10mm all around.	F-DET-INF.5
P-DET-INF-STD-PIPECLR.4	For all other central detectors that will be installed over flanges then the minimum clearance will be 10mm to the flange all around.	F-DET-INF.5
P-DET-INF-STD-PIPECLR.5	Endcaps will have a minimum clearance to the beampipe of 30mm all around.	F-DET-INF.5
Mechanical Adjustment Clearances		
P-DET-INF-STD-MECHCLR.1	Carbon Fiber Tube adjustments in the beampipe shall have an angular tolerance of ±1 mrad.	F-DET-INF.5
P-DET-INF-STD-MECHCLR.2	Carbon Fiber Tube adjustments in the Barrel EMCal will be within ±5m.	F-DET-INF.5
P-DET-INF-STD-MECHCLR.3	Carbon Fiber Tube adjustments in the STAR Cradle will be within ±~1/8" (4mm).	F-DET-INF.5
P-DET-INF-STD-MECHCLR.4	The Carbon Fiber Tube shall be able to be located within 12 mm.	F-DET-INF.5
P-DET-INF-STD-MECHCLR.5	The Barrel EMCal shall be able to be located within 5 mm.	F-DET-INF.5
P-DET-INF-STD-MECHCLR.6	The STAR Cradle shall be able to be located within 4 mm.	F-DET-INF.5

Charge # 1

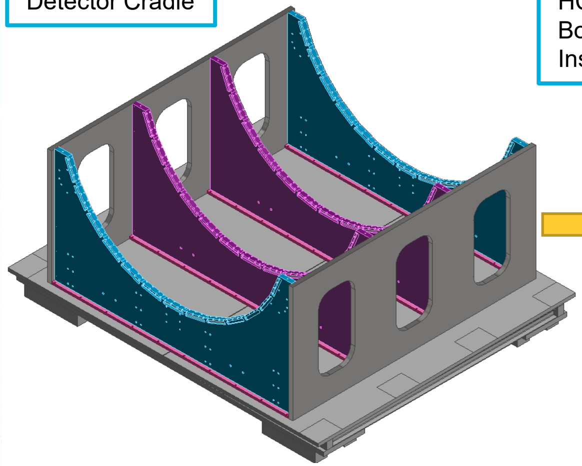
Technical Progress

- **ePIC Installation/Assembly Plan:** The ePIC barrel will be initially assembled in the Assembly Hall (and rolled between the Experimental Hall and Assembly Hall for maintenance shutdowns if needed), while the endcaps will be assembled and remain in the Experimental Hall.
- **Maintenance Plan (Details in backup slides):** The maintenance strategy is to maximize servicing in the Experimental Hall.
  - **In-situ maintenance:** Several major systems are not intended to be removed with electronics designed for external/accessible servicing.
  - **Removable-in-hall modules:** Many subsystems can be removed and serviced in the Experimental Hall.
  - **Roll-out drivers:** Some maintenance can require an extended shutdown and may drive full ePIC roll-out.
- **Building 1006 Modifications:** Facility modifications required for ePIC in the Experimental Hall and Assembly Hall are well understood and documented and incorporated into the Integrated Facilities CAD model such as structural platform layouts, and utilities etc.

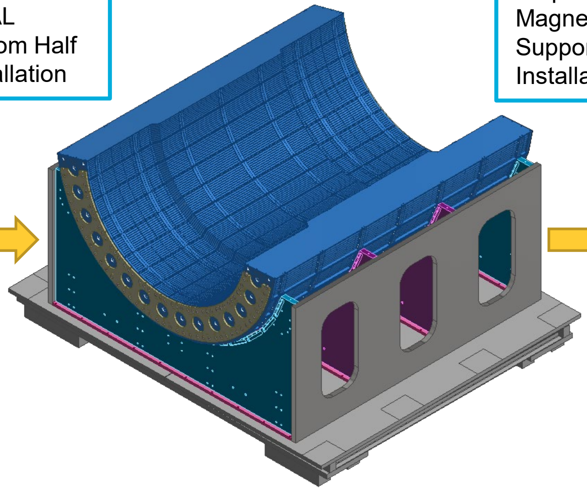


Technical Progress (ePIC Barrel Installation)

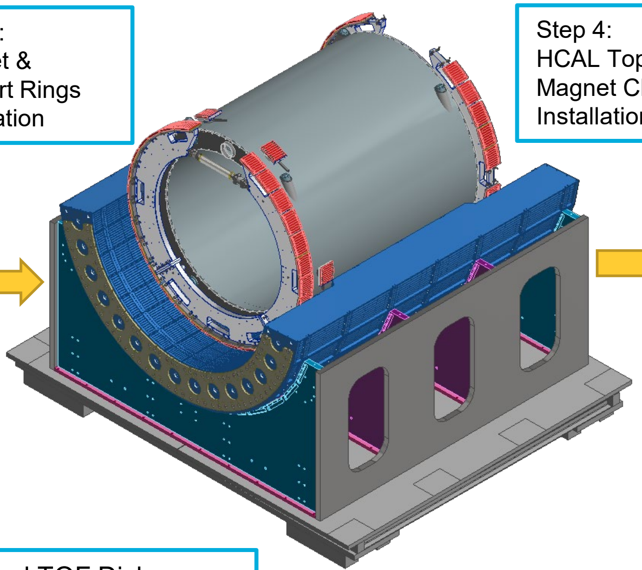
Step 1:
Detector Cradle



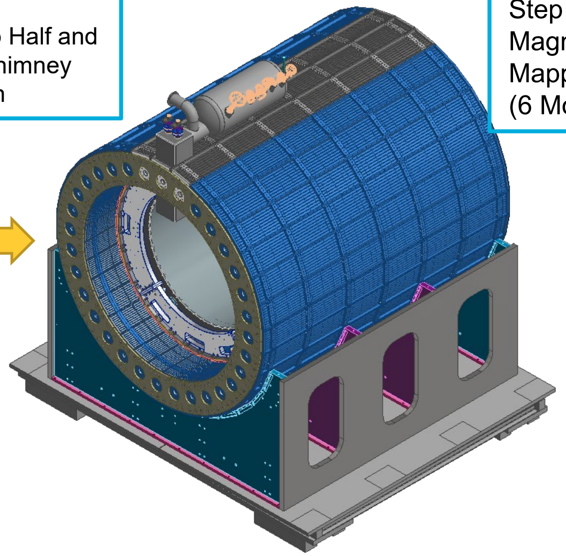
Step 2:
HCAL
Bottom Half
Installation



Step 3:
Magnet &
Support Rings
Installation



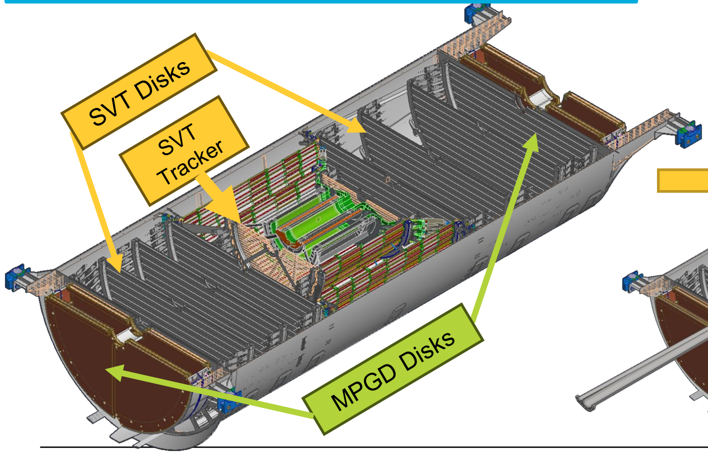
Step 4:
HCAL Top Half and
Magnet Chimney
Installation



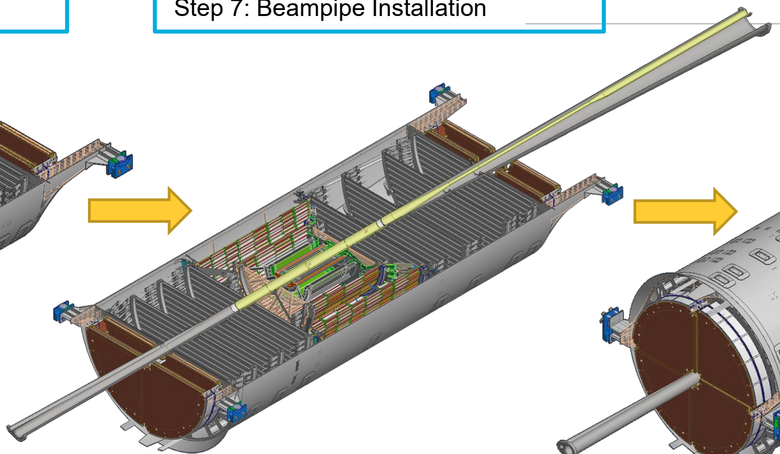
Step 5:
Magnet
Mapping
(6 Months)

While Magnet Mapping Takes place, We can Assemble PST with Silicon Detectors, MPGD Disks and TOF Disks

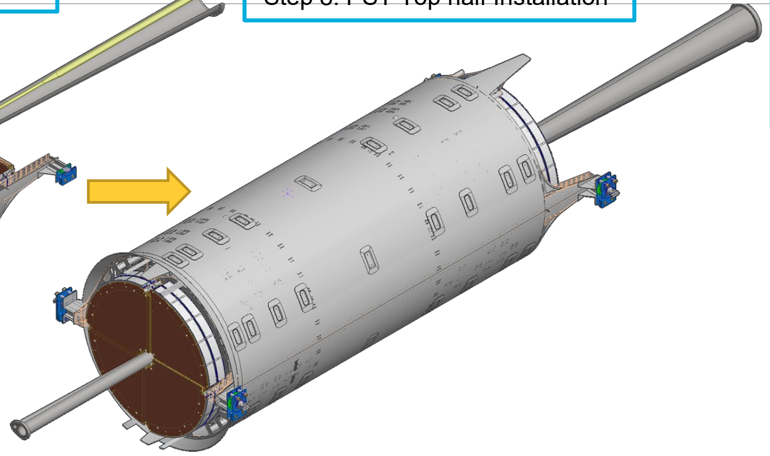
Step 6: PST Bottom half assembly



Step 7: Beampipe Installation



Step 8: PST Top half Installation

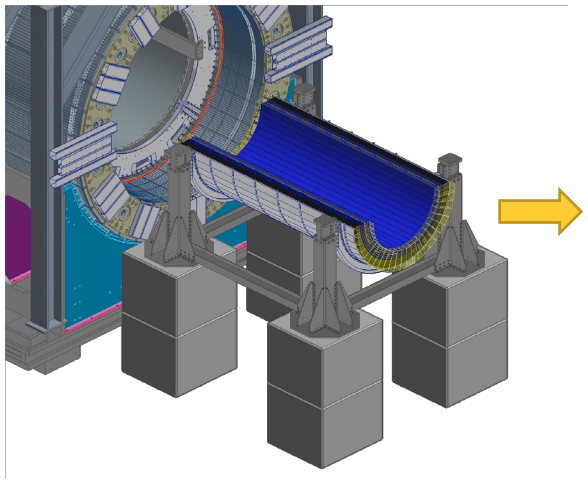


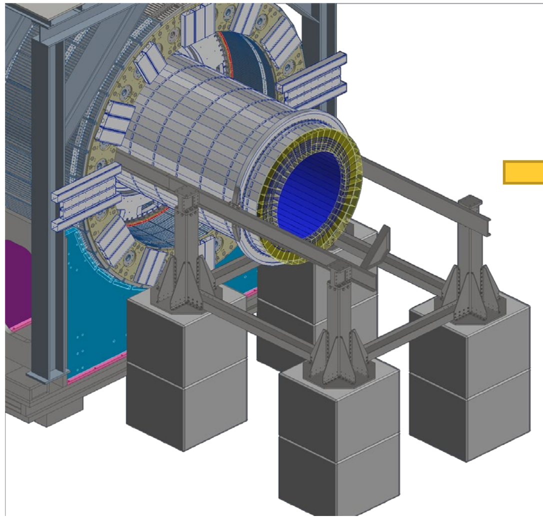
Barrel HCAL + cradle plates reused from sPHENIX with proven installation approach.

Charge # 1

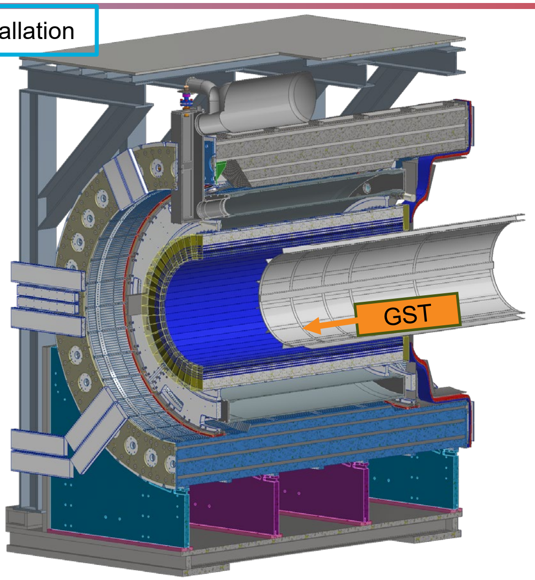
Technical Progress (ePIC Barrel Installation)

Step 9:BEMCAL Assembly and Installation

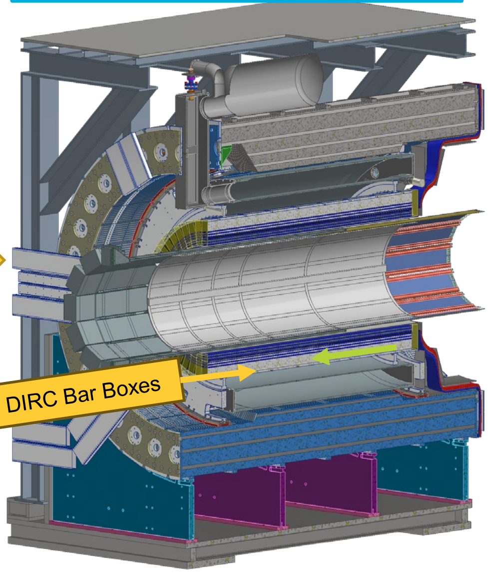




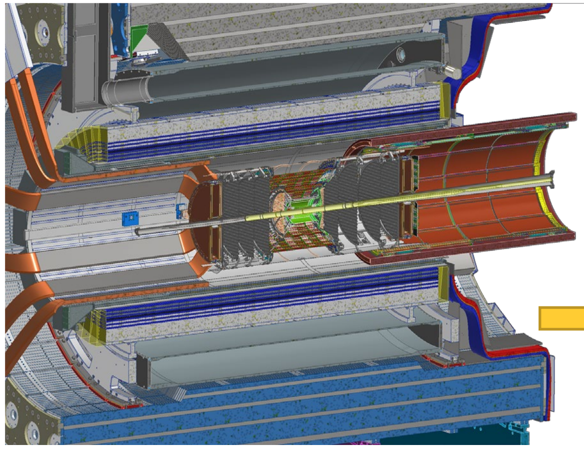
Step 10: GST Installation



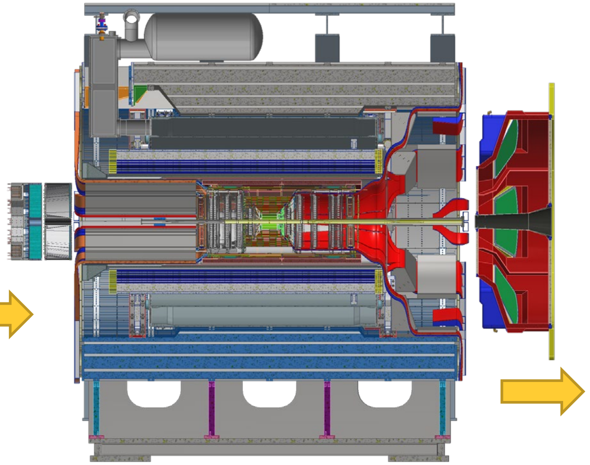
Step 11: MPGD and DIRC Installation



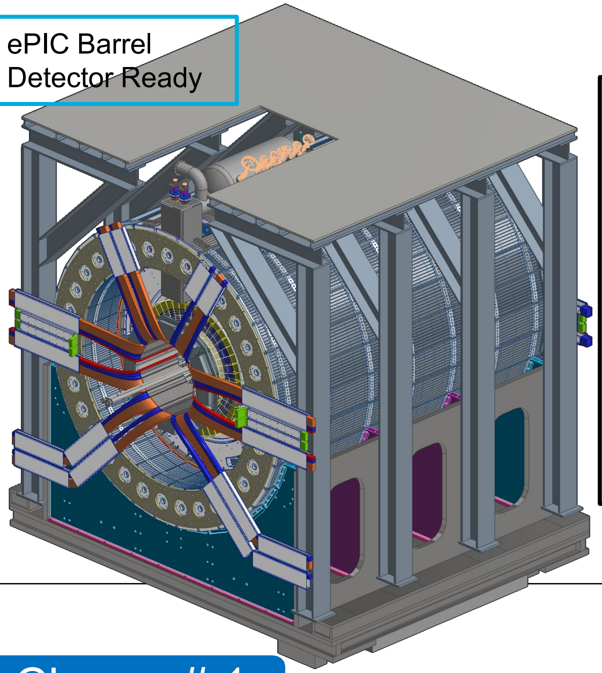
Step 12: PST, TOF and Cymbal Installation



Step 13: EEEMCAL, pfRICH and dRICH



ePIC Barrel
Detector Ready



Barrel Detector Components (support structures + installation tooling + procedures):

The Dec 8–9, 2025 PDR/Safety Review explicitly covered the scope of support structures, platforms, installation tooling/access equipment, and installation readiness for all subdetectors.

Technical Progress (ePIC Endcaps Installation)

1. Base shimmed to height and anchored FE: 11.25ton BE: 9.5ton

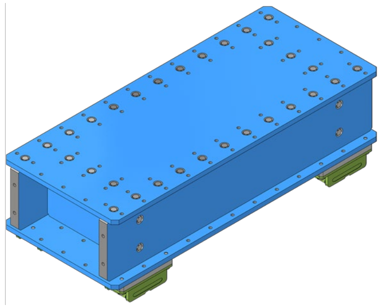
2. Flux return support attached FE: 15ton BE: 13.25ton

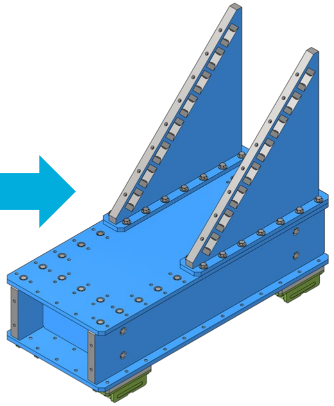
3. First flux return module attached FE: 28.25ton BE: 23.5ton

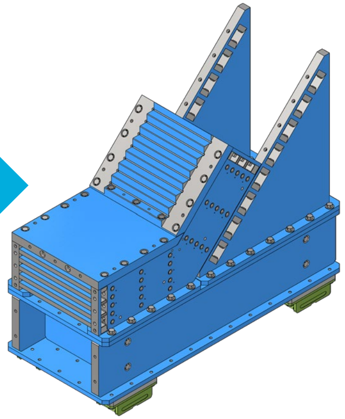
4. Second module attached FE: 41.5ton BE: 33.75ton

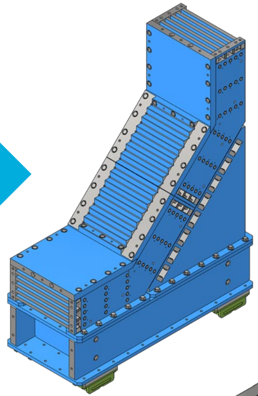
5. Pole tip and half annulus attached FE: 51.5ton BE: 60.5ton

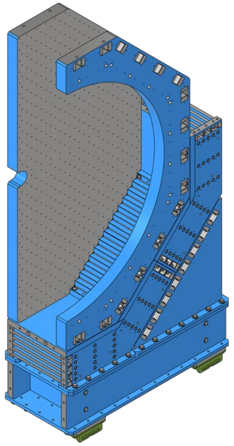
6. Detector installed FE: 151.5ton BE: 90.5ton



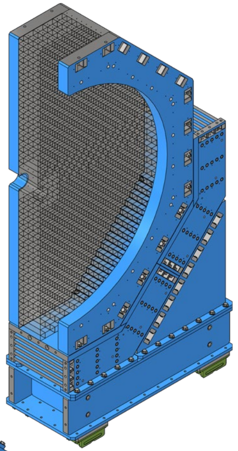


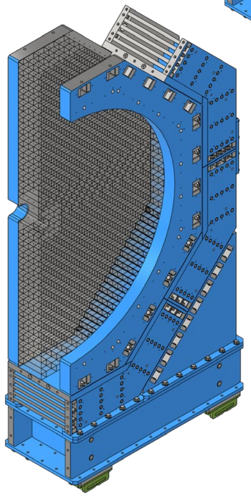


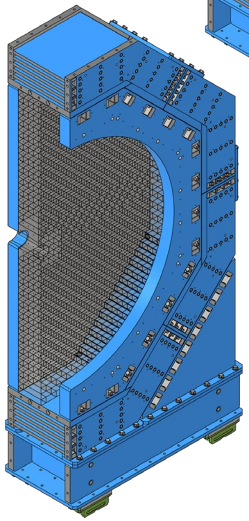




HCAL Installation (100d)





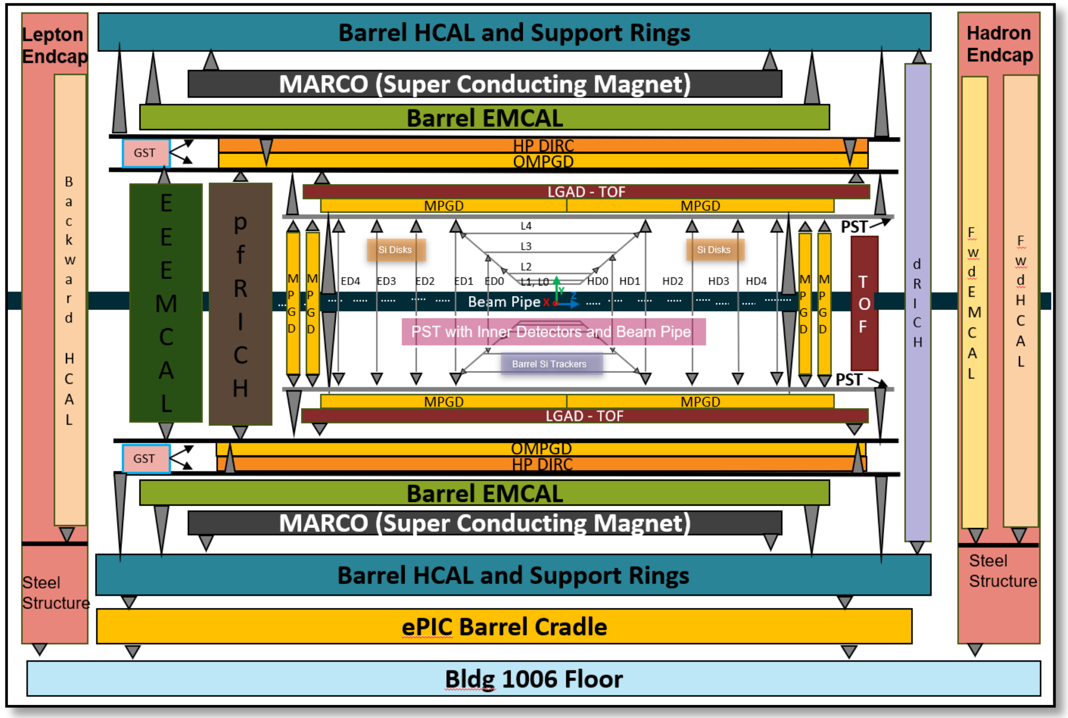


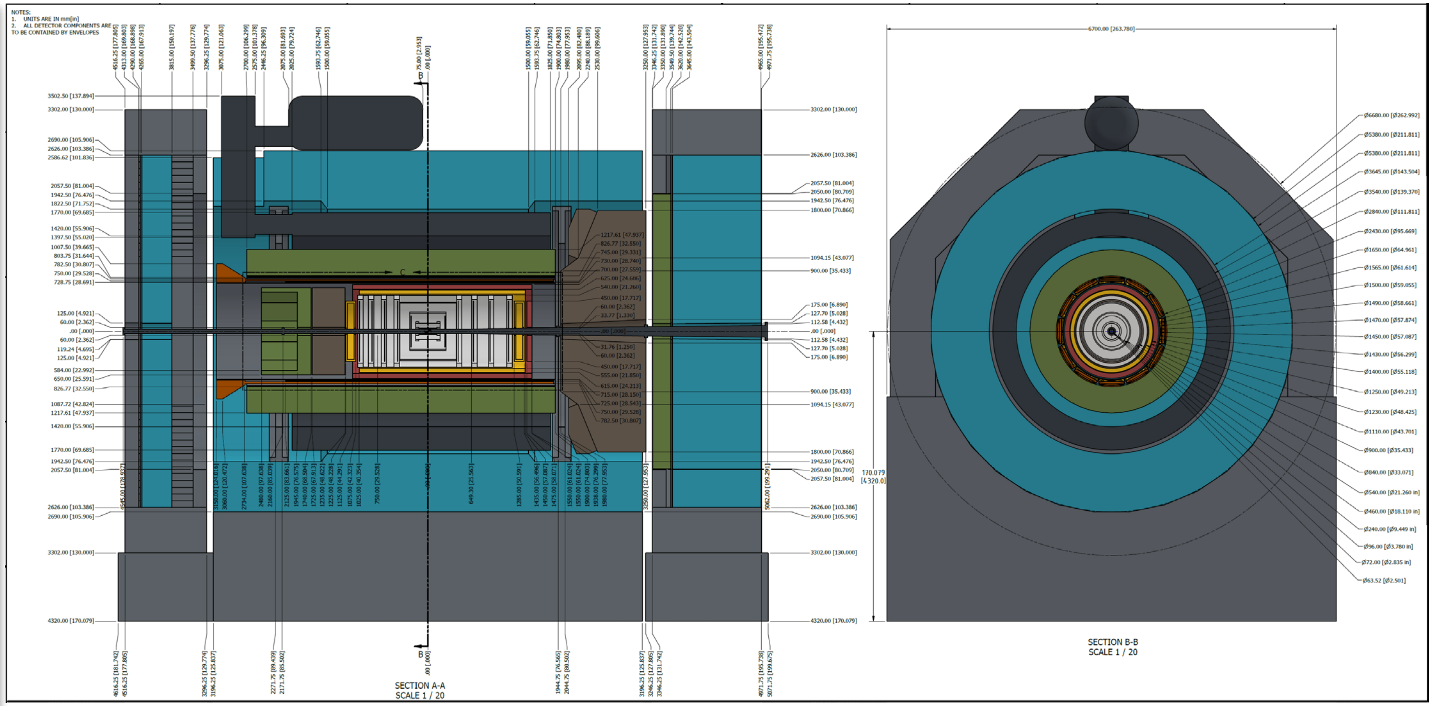
Endcap structures supporting detectors and flux-return steel are part of **CD-3B** (forward) and **CD-3C** (backward)

7. Third flux return module attached FE: 65.5ton (+100ton) BE: 71.25ton (+30ton)

8. Forth flux return module attached FE: 79.5ton (+100ton) BE: 82ton (+30ton)

Technical Progress (Configuration Control & Envelopes)



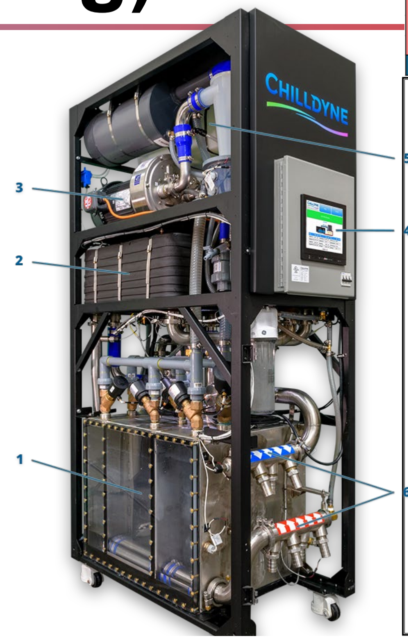


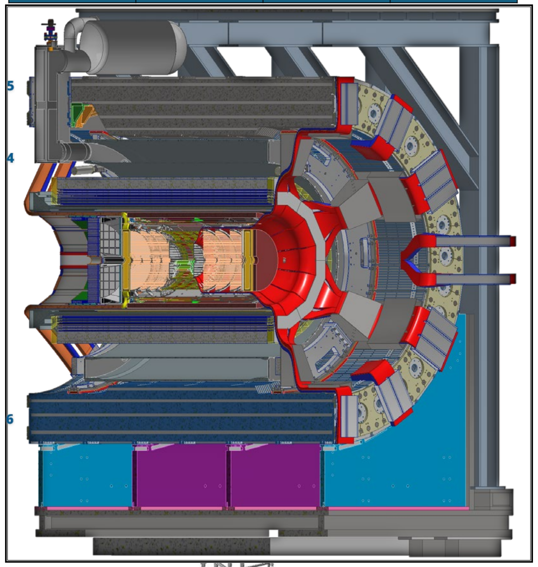
- **Mechanical integration model established:** Envelopes model + official envelope drawings in place; detector teams are required to stay within envelopes and follow integration routing guidance.
- **Support hierarchy + load paths defined:** Documented mechanical support chain (PST→GST→HCAL rings→HCAL→Cradle) and endcap clearances/seismic link concept.
- **Configuration control + QA governance implemented:**
  - Master integration CAD is Primary Reference Model and Vault-based configuration control.
  - Interfaces controlled via ICDs.

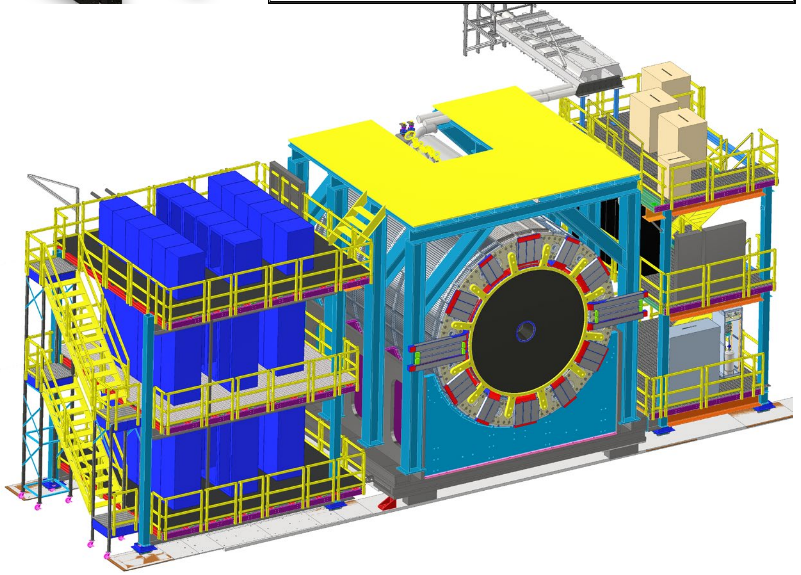
Technical Progress (Services + Cooling)

Direction	Service Type	Sub Total	Total
Forward	Power	3946	6270
	Signal	1624	
	Cooling	700	
Backward	Power	1547	7547
	Signal	5458	
	Cooling	542	
		Total	13817

- **Baseline services architecture defined and quantified:**
  - 7,500 cables/lines (backward) and
  - 6,300 cables/lines (forward)
  - Electronics Platform (Clean Power): Houses sub-detector electronics racks,
  - Utilities platform (Dirty Power): Gas racks, Air/Liquid cooling units, Transformers).
  - Independent tray segmentation supports partial removal/maintenance.
- **Cooling Baseline architecture defined:**
  - Facility primary loop Modified Chilled Water (MCW)
  - Secondary loop using Cooling Distribution Units (CDUs - negative-pressure circulation units) cooled by MCW
  - Aluminum Compatible Water (ACW) for aluminum manifolds/tubing.
  - Convective air cooling used where appropriate.
  - Special closed-loop cooling identified detectors that need it (eg dRICH).
  - Building 1006 environmental control requirements are defined for key areas (WAH and Assembly Hall temperature/RH bands).
- **Work-in-progress and next steps:**
  - Physical mockups of tight service regions
  - Global thermal model development is underway; next actions are to refine cooling calculations, finalize manifold sizing/locations, confirm subsystem temperature/flow/tubing requirements, and close remaining cooling interface details.



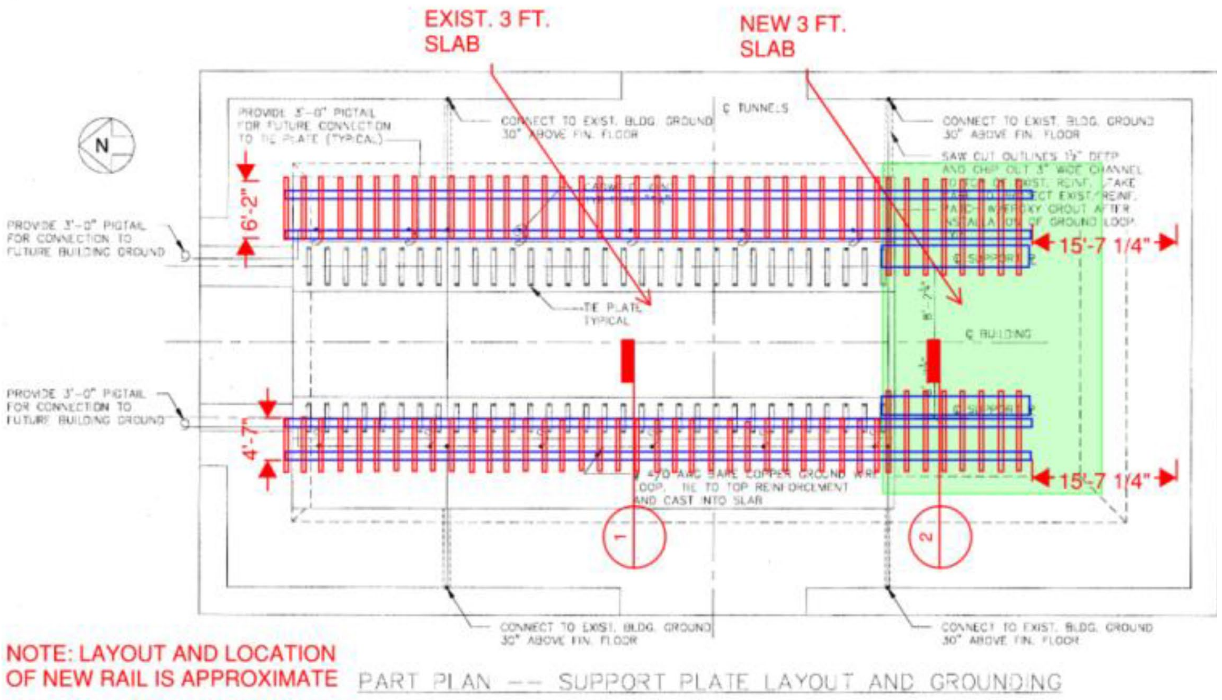




Charge # 1

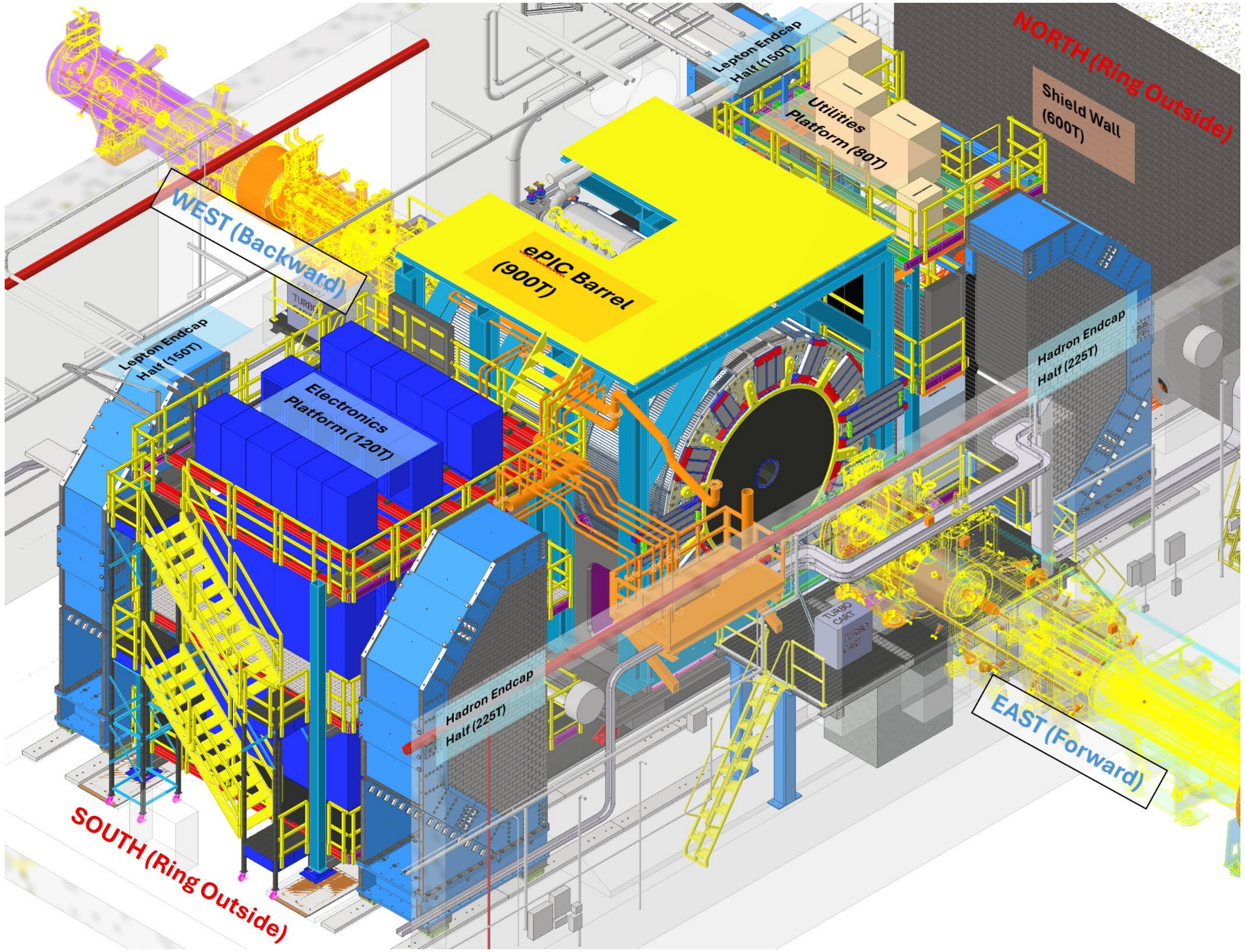
Technical Progress (Experimental Hall Concrete Slab Analysis)

- Structural evaluation completed for ePIC detector loads and rail movement scenarios
- **Records reviewed:** 1979 B-1006 drawings, 1994 STAR slab/rail modifications, 2024 ePIC layout, 1993 base slab analysis, and 2013 floor loading report.
- **Field/material checks:** site observations, slab condition survey, concrete core review, and rebound-hammer strength verification.
- **ePIC load mapping:** barrel, north/south platforms, hadron and lepton endcap halves, shield blocks, rollers, rails, and maintenance positions.
- **Structural evaluation:** load path through rails/slab/soil; concrete bearing, punching shear, soil bearing, and settlement assumptions.
- **Seismic + constructability:** ASCE 7-16 lateral force check; anchor / shear-key concepts; two slab replacement options and ROM construction cost.
- **Conclusion:** The existing back/south 12-inch concrete slab is structurally inadequate for new ePIC endcap/rail loads. Upgrade the affected zone to a 3-ft-thick slab / 3-ft-deep grade beams; existing 3-ft WAH slab and 3-ft-6-in Assembly Hall rail slab are adequate. Quote received for detailed design — pursue in FY 2027.



External Dependencies

- Internal Dependencies: None
- External Dependencies
  - RHIC Removal and Repurposing - STAR and sPHENIX. Access Tunnel sector 5 and 6 to install the IR magnets not through the IR.
  - Work to be done before beneficial occupancy (March 2030):
    - Facility & Workspace Upgrades
    - HVAC & Environmental Controls
    - Cooling & Utility Infrastructure
    - Electrical Infrastructure Evaluation and Refurbishment where needed.
    - Detector Platform Modifications
    - Safety Systems: VESDA, ODH monitoring etc.
    - Civil & Structural Modifications: Concrete Slab Reinforcement.



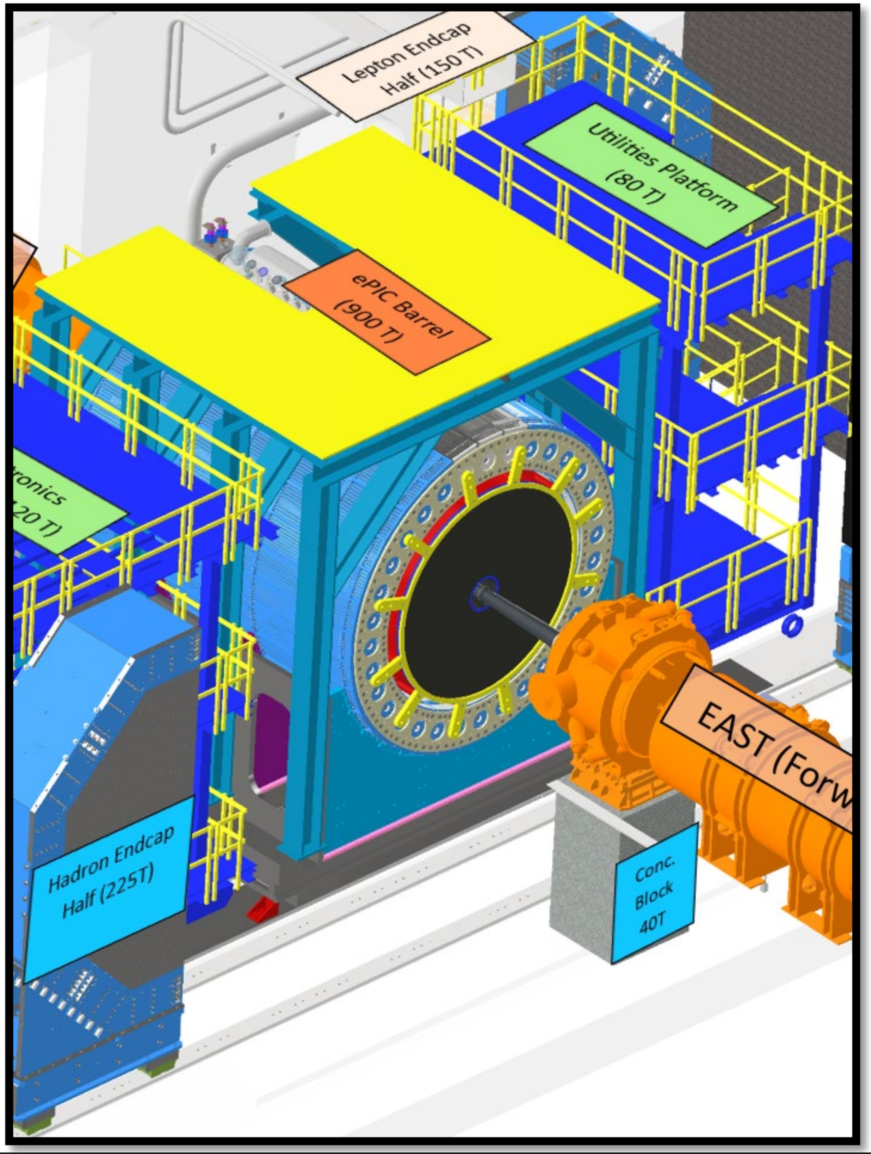
Charge # 1

Alignment Requirement

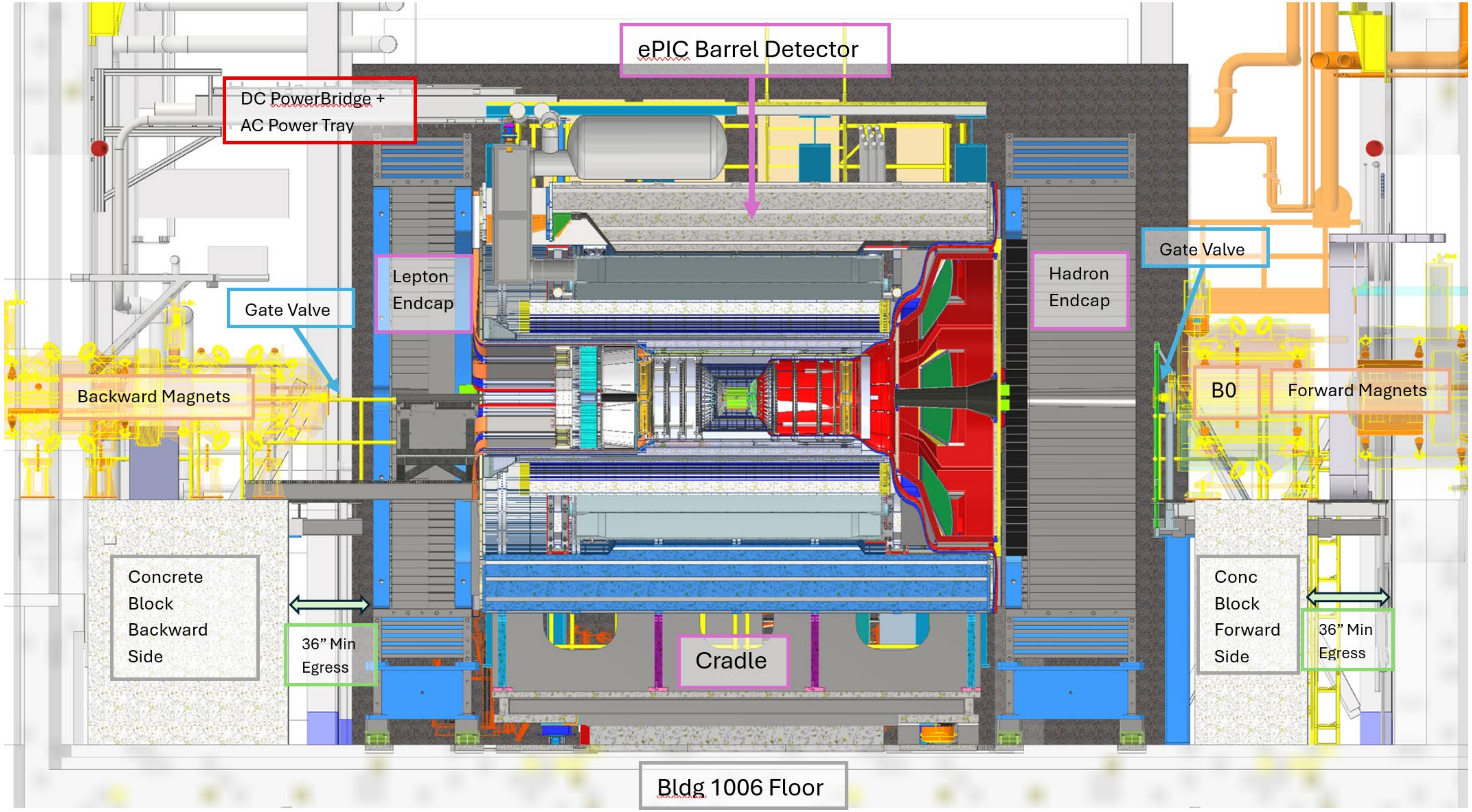
- P-DET-INF-STD-SVCGAP.13 **The positional tolerance of the beampipe shall be within ±1mm in the X,Y directions, and ±5mm in the Z direction.**
- Primary constraint is the **central beryllium section of the beam pipe at the IP**.
- Applies to the fully assembled detector at its final operating position.
- Other sub-detectors and supports may have looser tolerances as long as they assemble cleanly, maintain clearances, and can be accurately surveyed and reconstructed.

Baseline Solution

- **Hierarchical adjustment chain (Baseline)**
  - Cradle: Coarse positioning with ±2 mm in X, Y, Z using precision blocks, shims, and adjustment mechanisms.
  - GST: Intermediate adjustment with ±3 mm relative to cradle to center the PST/central region.
  - PST (fine alignment host): ±3 mm travel, used to set the central Be beam pipe to ±1 mm (X/Y) and ±5 mm (Z) at the IP. This is not part of the design yet, but under investigation.
- **Survey-driven implementation**
  - Central detectors and beam pipe precisely surveyed with respect to PST during assembly.
  - PST/GST remain surveyable after installation, while the central Be section is not directly visible.
  - Final adjustment settings (cradle, GST, PST, and possibly beam pipe supports) are tuned from survey data so the Be section meets ±1 mm / ±5 mm while keeping ends/flanges compatible with short bellows and the rest of the beam line.



Major External Interfaces

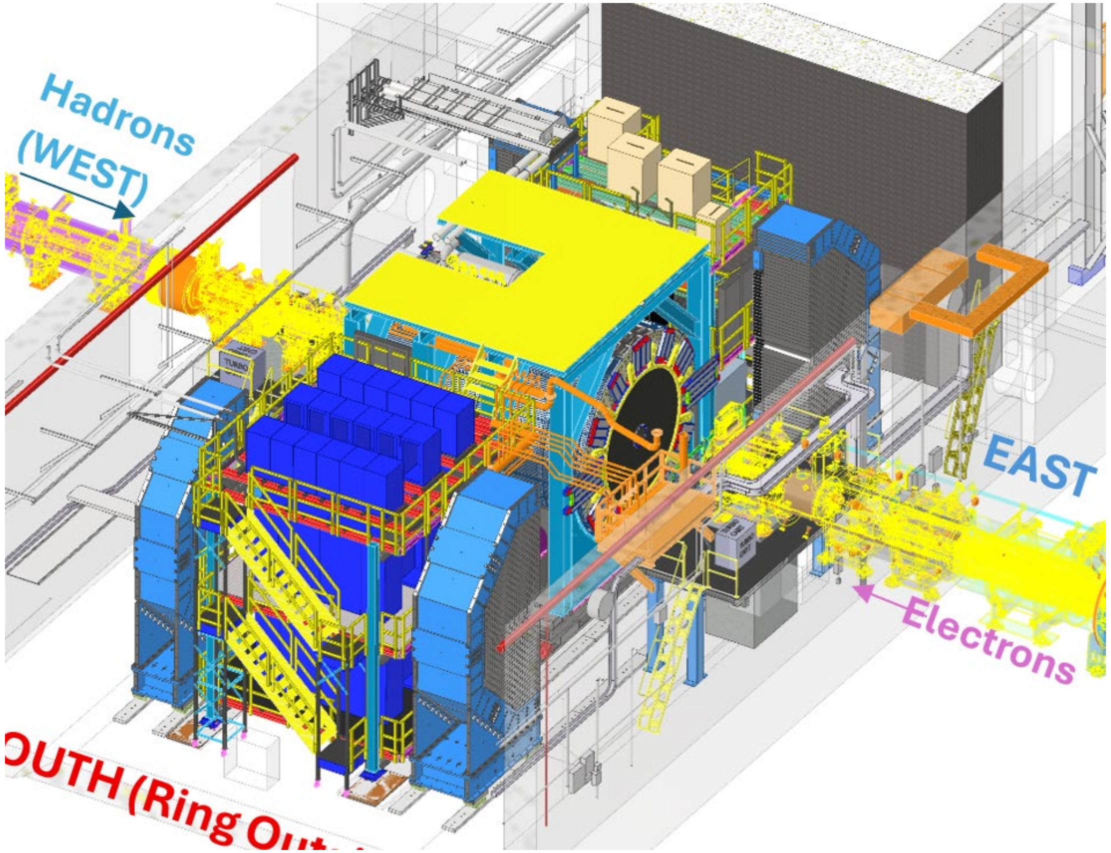


External/facility interfaces advanced: Interface scope documented across Detector/ Building /Magnets /Vacuum /Power /Water/Cryo/Safety

Charge # 1

Major External Interfaces

- **External Interface Control Document is complete and posted.**
- **Building 1006 / Detector Interface:** Covers the Assembly Hall, Experimental Hall, rail path, cranes, HVAC, facility access, and survey/alignment support needed for detector assembly, movement, and installation.
- **Magnet Interface:** Defines how the forward and rear magnets interface with detector envelopes, beam pipe, platforms, supports, alignment, vibration control, service routing, and non-magnetic platform requirements.
- **Vacuum / Beam-Pipe Interface:** Controls the beam-pipe vacuum envelope through the detector and magnet regions, including required clearances, B0 access, shared platforms, pump-down, leak-checking, instrumentation, and interlocks.
- **Power / Grounding Interface:** Covers facility power for the detector, MARCO magnet, DAQ/control areas, platforms, vacuum equipment, grounding segregation, E-Stops, and electrical interlocks.
- **Modified Chilled Water Interface:** Defines the MCW cooling interface, including detector cooling loads, flow/temperature needs, water quality, monitoring, leak testing, and chiller capacity evaluation.
- **Cryogenic Interface:** Covers cryogenic supply to the MARCO superconducting magnet, including Experimental Hall cryostat, South platform manifold, Assembly Hall standby cooling, building penetrations, and ODH/safety coordination.
- **Safety / ES&H Interface:** Captures egress, lifting and detector movement safety, electrical safety, fire protection, hot work, ODH/cryo safety, and readiness controls required before installation or operation.



ES&H

- **Safety Integration in Engineering & Design**
  - ES&H representatives participate in regular engineering and integration meetings to provide ongoing safety input as designs, interfaces, installation methods, and work plans are developed. Safety considerations are incorporated early in the design process, including constructability, access, lifting/handling, work-at-height and operational hazards.
  - The **ePIC I³ Design Guide** has been developed with input from ES&H and provides common safety-related design requirements and guidance for detector systems, supports, platforms, tooling, utilities, and installation activities.
  - Safety comments and lessons learned are tracked through design reviews and incorporated into drawings, procedures, and installation planning as the design matures.
- **Fire Protection, ODH & Safety**
  - Existing fire protection systems will be re-evaluated for ePIC needs and refurbished/upgraded as required
  - Bldg. 1006 will be reclassified as an ODH-0 area in support of ePIC's cryogenically cooled superconducting magnet. Operational safety controls and interlocks will be implemented and integrated into facility/detector systems as required
- **Primary I³ ES&H Risk Areas**
  - Heavy handling: rigging/lifting/moving barrel & endcaps, large steel and assemblies
  - Work at height: platforms, temporary structures, floor modifications, installation fixtures/tooling
  - Utilities/services: cooling water, gases, electrical power, commissioning and testing
- **Controls, Oversight & Continuous Improvement**
  - Approved work plans/permits; training & qualifications verified for BNL, vendors, and in-kind partners
  - Pre-job briefings and coordinated access control in Assembly/Experimental Halls
  - Standard procedures for rigging, LOTO, stored energy, pinch/crush hazards, and area control/signage
  - Task-based hazard analyses (AHA/JHA) and defined hold points for high-risk activities
  - Routine walkdowns/inspections, readiness reviews before major lifts and installations
  - Incident/near-miss reporting and corrective-action tracking; lessons learned fed back into plans/procedures

Quality Assurance

- **QA governed by the ePIC Global QA Document:** PQCPs required to verify all requirements/specifications per the EIC Requirements Management Plan.
- **ePIC I³ Design Guide:** Establishes common mechanical design, documentation, CAD, review, and configuration-control requirements to ensure consistent and traceable engineering across ePIC systems.
- **Generic (Inspection Test Plan) ITP:** Establishes common mechanical test plans and generic inspection procedures for typical mechanical devices.
- L3 Manager (CAM) owns QC: develop/maintain QC plans, ensure compliance, and regularly review to support procurements/acquisitions.
- I³ production spans vendors + institutional partners; component acceptance criteria defined in specs, including in-kind contributions.
- QC scope covers major I³ hardware: flux return steel, cradle, HCAL/magnet supports, all inner-detector supports, installation tooling/fixtures, lifting/motion systems, and utilities (cooling/gas) + platform/floor mods.
- Verification & records: acceptance inspections/tests; dimensional/performance testing; travelers/checklists and test data archived in central repositories and indexed in the EIC SE Portal.
- Nonconformances: recording/reporting/tracking quality issues

Major Procurement Planning

1. Procurement Objectives

- Ensure all procurements are backed by reviewed and approved engineering documentation (PRR-level).
- Maintain compliance with BNL Procurement QA and DOE project control procedures.

2. Key Procurements Under WBS 6.03.01.09 (I^3)

- **Cradle Assembly** – structural steel fabrication, motion system, and alignment jacks.
- **Installation Tooling, Fixtures and Access Equipment** – For Sub-Detector transport and Installation.
- **Support Structures**– For various subdetectors integrated into the design.
- **Endcaps and Moving & Control Mechanisms** – flux return steel, actuators, guide rails, and interlocks.
- **Cooling and Service Hardware** – manifolds, piping, flexible lines, and cable trays.

3. Procurement Readiness Activities

- Finalize technical specifications and fabrication drawings.
- Initiate RFQs and vendor pre-qualification and cost validation for large structural components.
- Coordinate procurement planning with Project Controls and Procurement Office.

Charge # 1 & 6

Recommendation Tracker

there are no open DOE recommendations for this WBS

Incremental Preliminary Design and Safety Review of the ePIC Outer and Inner Support Structures:

The Dec 8–9, 2025 PDR/Safety Review explicitly covered the scope of support structures, platforms, installation tooling/access equipment, and installation readiness for all subdetectors. We were given following recommendations (documented in recommendation tracker) by the review committee.

Status	Recommendation	Action Taken
Open	The status of the Cradle, Moving Mechanism and Barrel Access Platforms subsystem is still in a very preliminary state. It is important that the project address this issue by providing additional staff to the engineering lead. 1. Assign additional help to complete the design and analysis of the cradle system 2. Moving the detector assembly from the IR to the assembly hall after initial magnet testing will have a time critical element to keep the MARCO magnet cool. Consider adding redundancy in the air castor system.	1. We have been succesful to find additional Engineering help to work on cradle and platform design. 2. We were able to find different system more suitable for ePIC needs.
Open	Mock up a portion of the services runs to ensure there is enough space to install all services as soon as reasonably possible.	Prototype for a section mockup for Internal detector services built and to be populated by right cable/services volume. Next phase: Complete mockup of a section inside GST showing sliding cable trays and services.
Closed	Expedite the analysis and modifications to the floor structure. Ensure a POC is identified to coordinate and lead this deliverable.	Floor Analysis work Complete. We need to reinforce the concrete floor in the back of the experimental hall. Quote received from vendor for detailed design work. Work will start in FY 2027. POC: Rahul Sharma

Charge # 8

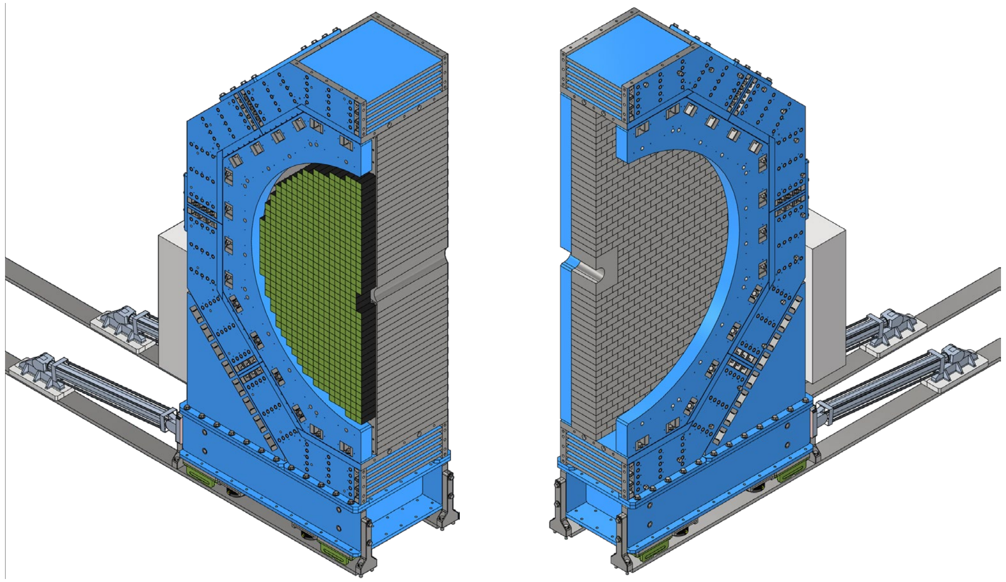
LLP for CD-3B and CD-3C Scope and Status

Electron and Hadron Endcap Structures for the ePIC Detector

- CD-3B and CD-3C scope FDR completed: 10/2024
- Scope includes design, analysis, and procurement of:
  - **Hadron** (forward, **CD-3B**) steel structure and flux return
  - **Electron** (backward, **CD-3C**) steel structure and flux return
  - Material certifications
  - Associated tooling
- Status:
  - Drawings – Done
  - SOW – Done
  - Tech Spec – Done
  - RFI – Done
  - APP – Done
  - Acquisition Plan – Nearly Completed
  - RFQ – Imminent (pending AP)
- **CD-3B** order to be place by end of Calander year
- **CD-3C** order will be an option of CD-3B contract

WBS	WBS Name	CD	Budget at Completion DOE Funded Only (Burdened & Escalated)
6.03.09.02	**DET - Detector Integr., Install. and Infra. - Forward and Backward Endcap Steel Structures and Moving Mechanisms**	**CD-3X**	$ 6,562,742.26
6.03.09.02.02	Forward Endcap Steel Structure	CD-3B	$ 3,318,678.18
6.03.09.02.03	Backward Endcap Steel Structure	CD-3C	$ 3,244,064.08

CD-3B (Half Shown) Forward Endcap (Blue Parts)	CD-3C (Half Shown) Backward Endcap (Blue Parts)



CD-3C Risk and Justification

Risk ID	Title	System	Owner	Overall Category
RT-6-010-XXX5-LLP-CD3C	Electron Endcap Detector Magnet Flux Steel Delivery Delay	DET	R. Ent	Low

Risk Statement (If/Then)	P6 Milestone affected		
If electron endcap magnet flux return steel is delivered late due to tight steel market and Buy American reqs, then a new procurement contract will be required and additional cost and delays will occur and the acceptance of the detector solenoid can not be completed and there will be schedule delays for installation of accelerator components.	E1007_03060	Residual Probability	20%
		Residual Cost Category	Marginal
		Resid. Schedule Category	Significant
		Technical Category	Negligible

Risk Mitigations
Get CD-3C approval to ensure procurement starts early to be able to run magnet at full current early and move magnet to Assembly Hall for continued subsystem installation.

Cost Impacts ($K)		Schedule Impacts (Months)	
Expected Value (calculated)	200		
Average EV (calculated)	200		
Low Cost	500	Low	6
Likely Cost	1,000	Likely	12
High Cost	1,500	High	18

Basis of Impact Estimates (Cost & Sched.):
Probability is estimated very low. Delays are due to worldwide vendor competition. Costs are a combination of vendor incentives to expedite schedule.

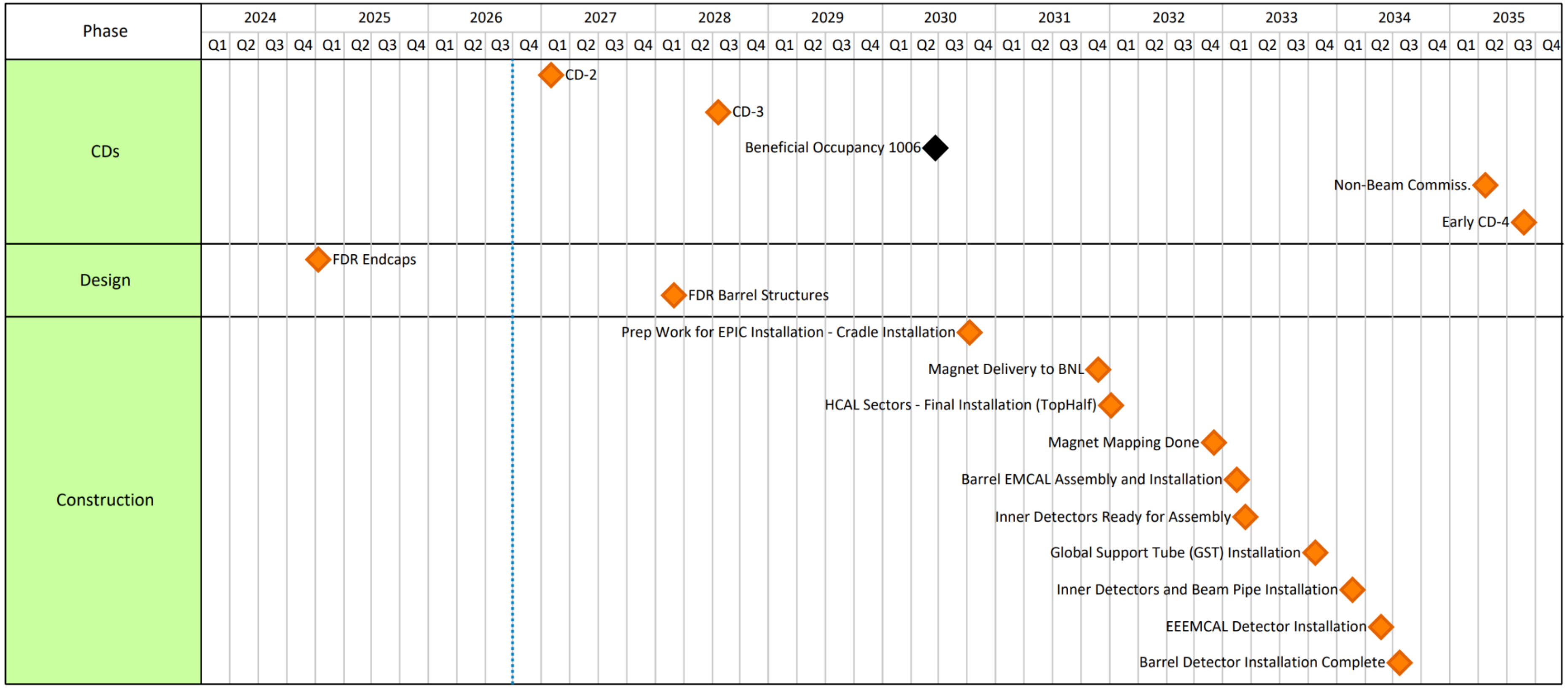
Risk Handling Schedule (Triggers, Milestones, Due Dates)
Q2 FY27

Pre-Mitigated Overall Category	Post-Mitigated Overall Category
Moderate	Low

- Delaying procurement of the electron endcap magnet flux return steel increase cost and schedule risk, including delaying detector solenoid acceptance and installation activities.
- CD-3C approval mitigates this risk by enabling early procurement under the existing contract option.

Schedule

DET 6.03.09 Subsystem Technical Milestone Schedule



Key Schedule Drivers/Assumptions:
Detector installation, MAPS Design and Magnet Delivery are on the project critical path. For Installation schedule, Support structures, installation tooling, and interface definitions can only be finalized once each subdetector reaches FDR-level design maturity. Any delay in subdetector design completion will therefore delay tooling/support design and cascade into production and installation schedule impacts.

Key Milestones:

- CD3 : Q3 2028
- Beneficial Occupancy : March 2030
- Cosmic Data Taking : Summer 2033
- CD4 : Q3 2035
- Magnet Delivery to BNL : Aug 2031
- Magnet Mapping Complete : Sept 2032
- Inner Detectors Ready for Assembly : Dec 2032
- Barrel Installation Complete : Apr 2034

Charge # 1

Costs: Budget at Completion

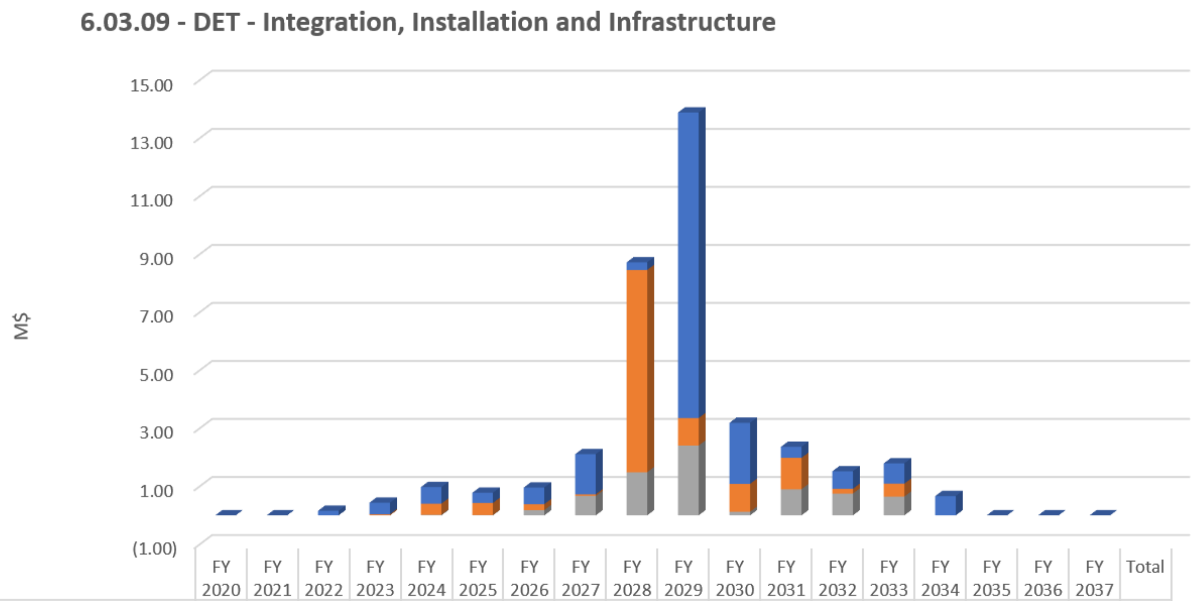
WBS	WBS Name	Budget at Completion (Burdened & Escalated)	In-Kind Contributions
6.03.09	**DET - Integration, Installation and Infrastructure**	**$ 37,543,115**	**$ 4,090,701**
6.03.09.01	DET - Detector Integr., Install. and Infra. - Barrel Detector Structures	$ 18,682,972	$ 1,240,159
6.03.09.02	DET - Detector Integr., Install. and Infra. - Forward and Backward Endcap Steel Structures and Moving Mechanisms	$ 11,668,421	$ -
6.03.09.03	DET - Detector Integr., Install. and Infra. - Detector Infrastructure and Utilities Integration	$ 7,191,722	$ 2,850,542

- Major In Kind Contributions/Reused by Design Components:
  - Reusing Existing detector platforms (Utilities and Electronics) from STAR.
  - Reusing HCAL detector and cradle/support plates from sPHENIX.
  - Support structure of Backward EMCAL from IN2P3 France.

- Major cost drivers:
  - Cradle : $ 3 million
  - Cradle Moving Mechanism : $ 2 million
  - Endcaps Flux Return Steel Structures : $6.2 million (Half of this is CD3B Item)
  - GST+PST : 2.59 million

Charge # 1

Costs: Budget Profile

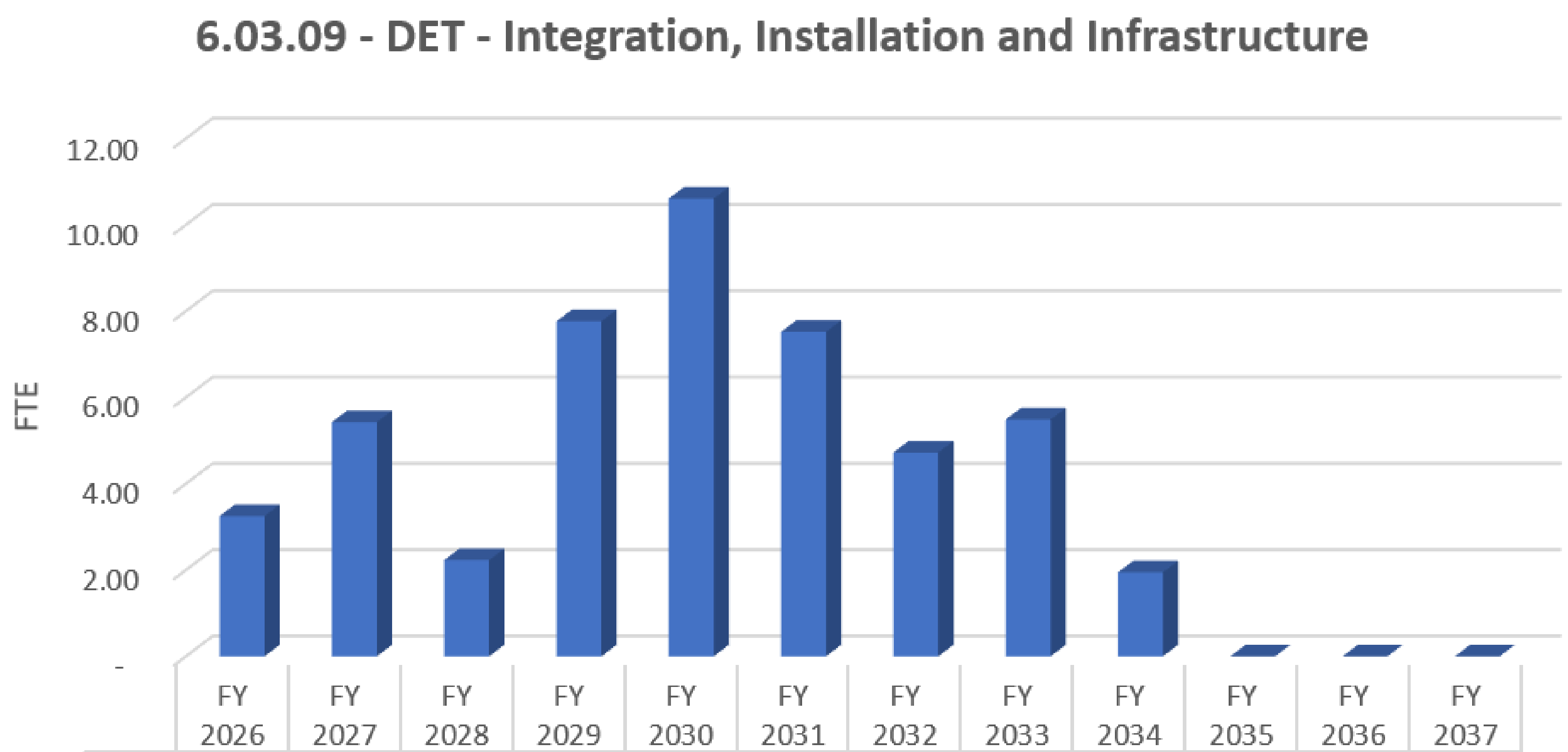


	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024	FY 2025	FY 2026	FY 2027	FY 2028	FY 2029	FY 2030	FY 2031	FY 2032	FY 2033	FY 2034	FY 2035	FY 2036	FY 2037	Total
6.03.09.01 - DET - Detector Integr., Install. and Infra. - Barrel Detector Structures	-	-	0.16	0.40	0.57	0.35	0.57	1.39	0.26	10.53	2.11	0.38	0.60	0.70	0.66	-	-	-	18.68
6.03.09.02 - DET - Detector Integr., Install. and Infra. - Forward and Backward Endcap Steel Structures and Moving Mechanisms	-	-	-	0.04	0.38	0.42	0.21	0.05	6.97	0.95	0.96	1.08	0.16	0.44	-	-	-	-	11.67
6.03.09.03 - DET - Detector Integr., Install. and Infra. - Detector Infrastructure and Utilities Integration	-	-	-	-	0.02	0.01	0.18	0.67	1.49	2.41	0.12	0.90	0.75	0.65	-	-	-	-	7.19

Trends:

- FY 2028 shows procurement of Endcaps flux return steel roughly $6.3 mil in orange color. Makes it the second most
- The budget peaks in FY2029, representing the main period of large-scale fabrication/procurement and installation preparation.
- Another major funding year occurs in FY2030, driven largely by installation.
- Barrel structures are the primary cost driver followed by Endcaps throughout the profile.
- After FY2030, costs decline steadily through FY2033, reflecting completion of major fabrication and transition to final installation/closeout activities.

Staffing and Organization



	FY 2026	FY 2027	FY 2028	FY 2029	FY 2030	FY 2031	FY 2032	FY 2033	FY 2034	FY 2035	FY 2036	FY 2037
FTE	3.25	5.43	2.23	7.76	10.61	7.52	4.73	5.49	1.95	-	-	-

Trends

- Peak labor will occur in FY2030 at ~10 FTE, aligning with the most labor-intensive period of fabrication oversight, installation tooling readiness, and detector installation execution.

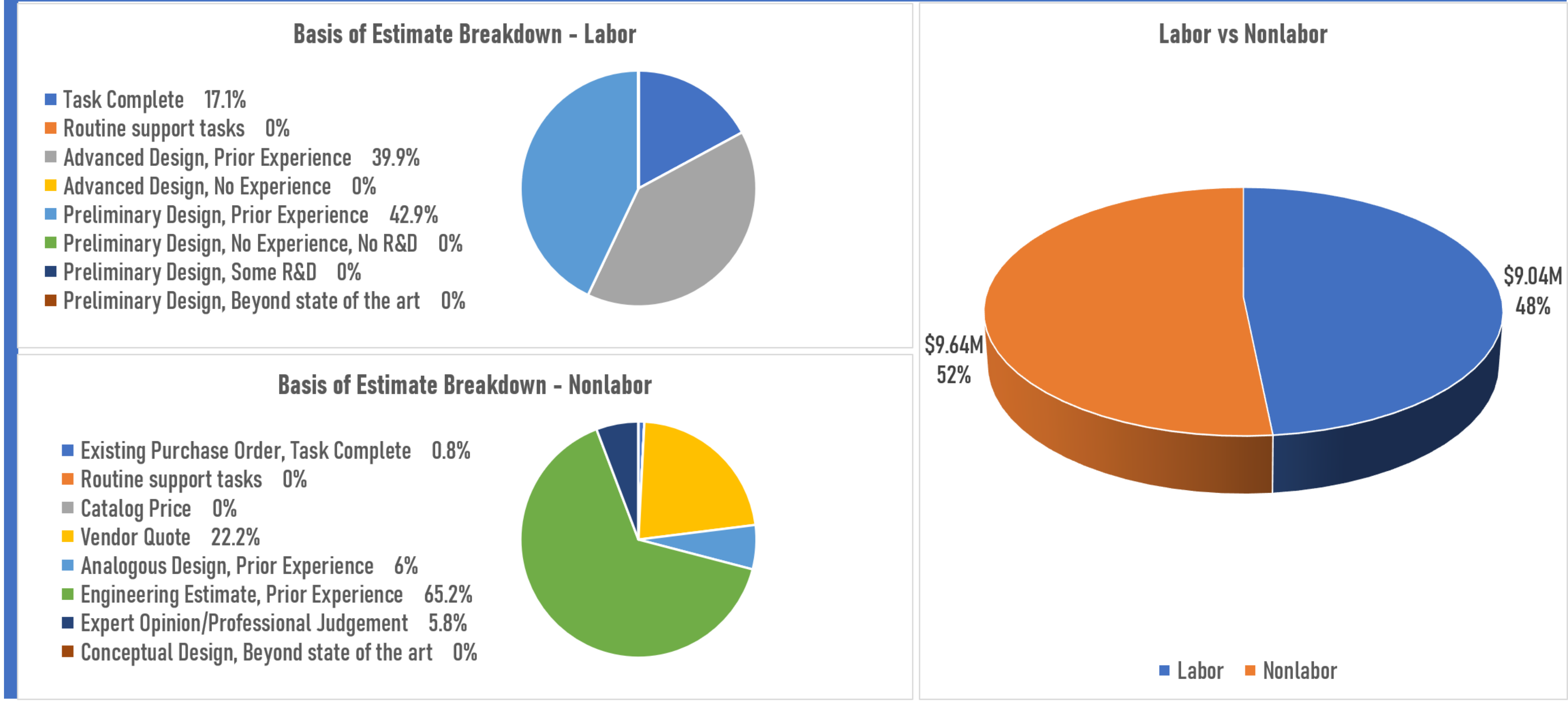
Risks

Top Risks	Handling Strategy	Residual Risk Rating
R&R for STAR, IP6 and sPHENIX is not done in time for starting construction of ePIC	Develop a reliable schedule, cost and workforce needs for the R&R of STAR, sPHENIX and IP-6. Ensure deinstallation of STAR and the IR-6 accelerator components are possible in parallel. The sPHENIX R&R needs to be planned in equal detail as STAR.	Low
Delay in Off- Project Activities	Work closely with BNL and NPP management to coordinate the off-project dependencies.	Low
Delay in subsystem installation into ePIC	Enhance presence of engineers and scientists in the assembly and wide-angle Halls during assembly and installation phases to expedite and find problems and mitigation solutions early. Find additional workforce technicians and mechanical engineers to work extra shifts and resolve the installation issues	Low
Detector Magnet Flux Steel Delivery Delay	Get CD-3B approval to ensure procurement starts early to be able to run magnet at full current early and move magnet to Assembly Hall for continued subsystem installation.	Low
Electron Endcap Detector Magnet Flux Steel Delivery Delay	Get CD-3C approval to ensure procurement starts early to be able to run magnet at full current early and move magnet to Assembly Hall for continued subsystem installation.	Low

Charge # 7

6.03.09.01

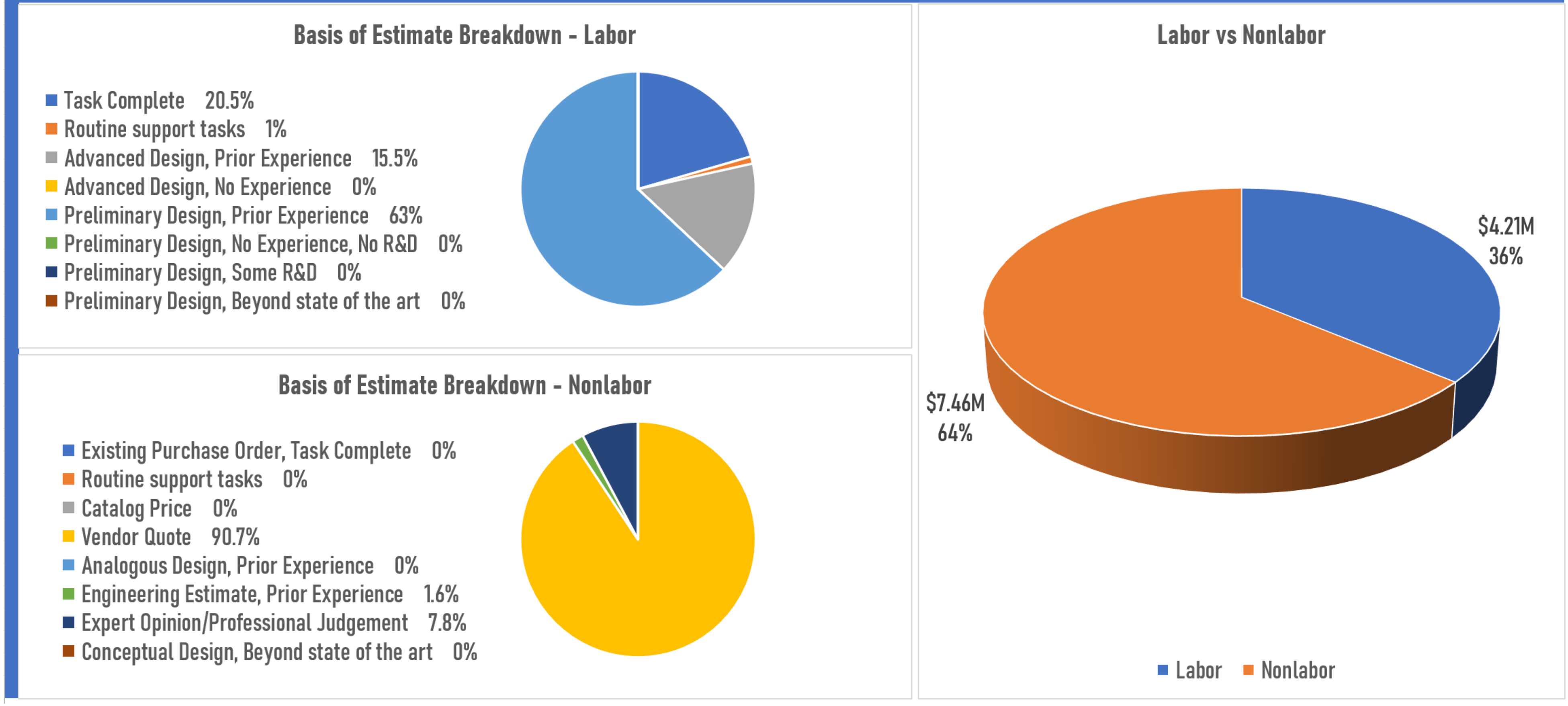
SUMMARY: 6.03.09.01 - DET - Detector Integr., Install. and Infra. - Barrel Detector Structures **BUDGETED TOTAL: $18.68M**



- For both Labor and Non Labor Most of the costs are Engineering Estimates.
- Some costs such as moving mechanism for cradle are vendor estimates.

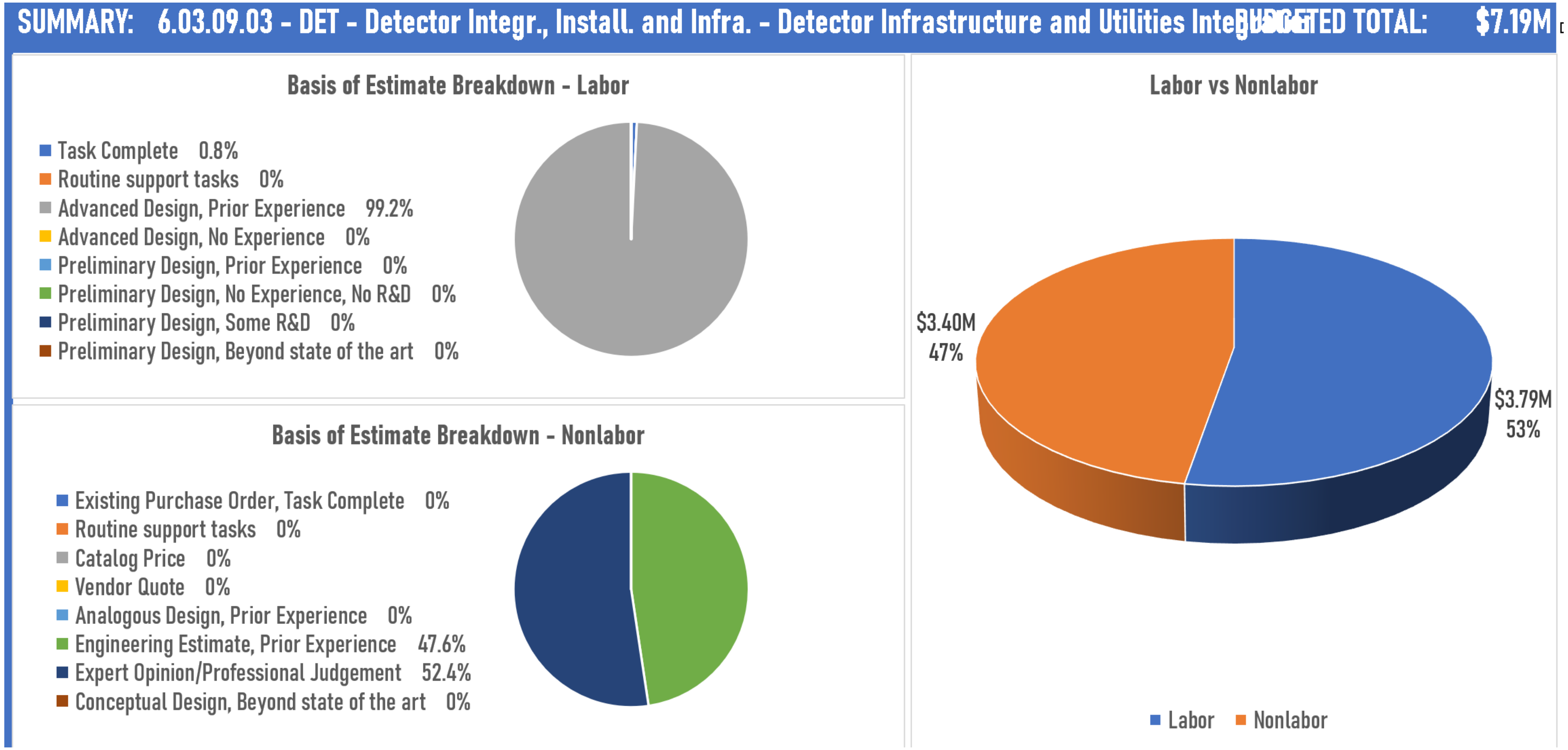
6.03.09.02

SUMMARY: 6.03.09.02 - DET - Detector Integr., Install. and Infra. - Forward and Backward Endcap Steel St BUDGETED TOTAL: $11.67M



- For Non Labor most of the costs are Vendor Quotes.
- Some costs such as moving mechanism for are vendor estimates.

6.03.09.03



- **Cost Basis:** Most infrastructure costs are based on engineering estimates and professional judgment at the current level of design maturity.
- **Primary Cost Drivers:** A significant portion of the infrastructure cost is associated with modifications and upgrades to existing facilities by external contractors, including detector electronics/utility platforms, plumbing, electrical systems, and other supporting infrastructure.

Technical Summary

Subsystem / Area	Status	Key Notes
Barrel Systems (Cradle, Platforms, Support Rings, All subdetector Support structures and Installation Tooling)	**PDR Completed**	Design progressing toward PDR readiness; integrated model under refinement. Subdetector installation tooling design and procedures also under refinement.
Endcap Structures (Flux Return Steel, Support Frames)	**FDR Completed**	Fabrication packages and drawings approved
Endcap and Barrel Motion & Control Systems	**PDR Completed**	Mechanisms and control integration validated in model
Services Integration (Cooling, Power, Signal Routing)	**PDR Completed**	Service envelopes defined; routing documented and verified
Cooling Systems	**Global PDR Completed in I3 Detectors PDR Completed subsystem reviews**	Concepts maturing with detector designs; Facilities 18 °C water baseline. Air Cooling or Convection Cooling as a second preference. Special cooling like Glycol cooling system is only used for dRICH detector.
Building 1006 Modifications (Experimental & Assembly Halls)	**PDR Completed**	Reuse of existing STAR infrastructure provides major schedule and cost advantage

Technical Path Forward

- **1. Design Reviews and Finalize Engineering Details**
  - Develop detailed installation tooling designs and procedures.
  - Perform mock-up/prototype studies for detector insertion and service routing validation.
  - Integrate all facility changes in the ePIC Facilities CAD model for construction release.
  - Finalize service routing documentation and interface details for all subdetectors.
  - Detailed cooling simulations.
  - Complete cooling design that includes air ducts, water manifold and distribution and any special cooling system designs.
  - Finalize detailed outline-interface drawings for all subsystems (Subdetectors and Support Structures).
  - Advance designs and FEA to FDR readiness and conduct FDR.

- **2. Advance Procurement and Fabrication Readiness**
  - Prepare fabrication drawing packages and conduct PRR.
  - Initiate RFQs and vendor pre-qualification and cost validation for large structural components.
  - Coordinate procurement planning with Project Controls and Procurement Office.

Backup

CD-3C Justification for each item

Summary

- The Electron (Backward, CD-3C) steel structure and flux return procurement is an option from the same contract as the Hadron (forward, CD-3B) steel structure and flux return.
- This CD-3C request is needed to authorize procurement of the long-lead backward endcap magnet flux return steel, reducing technical and schedule risks while ensuring the detector solenoid magnet can be tested and operated at its full design field.
- Delaying this CD-3C scope would likely delay detector solenoid magnet acceptance by up to 18 months, increase costs by approximately $1.5 million, and impact the overall installation schedule.

Why is this CD-3C scope necessary?

Detector Endcap Structures – Flux Return Steel (WBS 6.03.09.02.03)

DOE approved CD-3B in January 2026. Subsequentially, the Project works on an RFP for more than the approved CD-3B scope, to include an option for the flux return steel also for the rear endcap. The magnet flux return steel is critical for the operation of the detector solenoid magnet at its design field. A full field test is required for the magnet acceptance. Acquisition time for the machined magnet flux return steel is approximately 3 years. The CD-3C request is to exercise the contract option for the final flux return steel for the rear endcap. This LLP would mitigate schedule risk due to the worldwide steel demand. Inquiries have indicated production times of up to 5 years. Operating the magnet at design field requires the magnet (an approved CD-3A item), its power supply (a proposed CD-3B item), the steel of the forward hadron calorimeter (an approved CD-3A item), and the magnet flux return steel of the forward endcap (an approved CD-3B item). This CD-3C LLP request reduces technical risk to start operation of the detector solenoid magnet and schedule risks due to the production long-lead procurement exposition with limited vendors. It allows the contract option to be exercised for completion of this scope.

Can this CD-3C scope be delayed?

Detector Endcap Structures – Flux Return Steel (WBS 6.03.09.02.03)

No, not approving this CD-3C request would delay the detector solenoid magnet acceptance. Current lead times for receipt of steel are long, due to not only the material production but also to the machining of the steel. Approving this CD-3C request will allow exercise of a contract option with known costs and complete this scope. The most severe estimated impact can be an 18-month delay and a cost increase of $1.5M to fund double shifts for magnet acceptance and installation work to build the electron endcap flux return structure in the experimental hall, which will impact the interaction region installation if delayed.

CD-3C Risks for each LLP request

Risk ID	Title	System	Owner	Overall Category
RT-6-010-XXX5-LLP-CD3C	Electron Endcap Detector Magnet Flux Steel Delivery Delay	DET	R. Ent	Low

Risk Statement (If/Then)	P6 Milestone affected		
If electreon endcap magnet flux return steel is delivered late due to tight steel market and Buy American reqs, then a new procurement contract will be required and additional cost and delays will occur and the acceptance of the detector solenoid can not be completed and there will be schedule delays for installation of accelerator components.	E1007_03060	Residual Probability	20%
		Residual Cost Category	Marginal
		Resid. Schedule Category	Significant
		Technical Category	Negligible

Risk Mitigations	Cost Impacts ($K)		Schedule Impacts (Months)	
Get CD-3C approval to ensure procurement starts early to be able to run magnet at full current early and move magnet to Assembly Hall for continued subsystem installation.	Expected Value (calculated)	200		
	Average EV (calculated)	200		
	Low Cost	500	Low	6
	Likely Cost	1,000	Likely	12
	High Cost	1,500	High	18

Basis of Impact Estimates (Cost & Sched.):

Probability is estimated very low. Delays are due to worldwide vendor competition. Costs are a combination of vendor incentives to expedite schedule.

Risk Handling Schedule (Triggers, Milestones, Due Dates)

Q2 FY27

Pre-Mitigated Overall Category	Post-Mitigated Overall Category
Moderate	Low

- Delaying procurement of the electron endcap magnet flux return steel increase cost and schedule risk, including delaying detector solenoid acceptance and installation activities.
- CD-3C approval mitigates this risk by enabling early procurement under the existing contract option.

CD-3C Schedule in P6

EIC_WBS_Temp_H	Activity ID	Activity Name	At Completion Duration	Start	Finish	Total Float	Budgeted Total Cost	Budgeted Labor Cost	Budgeted Nonlabor Cost	BNL_CAM	BNL_PMC Rep	EIC_LLP
6.03.09 DET - Integration, Installation and Infrastructure			375d	29-Jan-27	31-Jul-28	1726d	$3,258,169.27	$14,105.18	$3,244,064.08			
6.03.09.02 DET - Detector Integr., Install. and Infra. - Forward and Backward Endcap Steel Structures and Moving Mechanisms			375d	29-Jan-27	31-Jul-28	1726d	$3,258,169.27	$14,105.18	$3,244,064.08			
6.03.09.02.01 DET - Detector Integr., Install. and Infra. - Forward and Backward Endcap Steel Structures and Moving Mechanisms			375d	29-Jan-27	31-Jul-28	1726d	$3,258,169.27	$14,105.18	$3,244,064.08			
6.03.09.0	E1010_08952	Hadron and Lepton Endcaps Structures - Flux Return Steel - AWD - Award Option	0d		29-Jan-27	1726d	$0.00	$0.00	$0.00	Sharma	tlewis	CD3C.SCOPE
6.03.09.0	E1010_08954	Hadron and Lepton Endcaps Structures - Flux Return Steel - Vendor Effort	375d	01-Feb-27	31-Jul-28	1726d	$0.00	$0.00	$0.00	Sharma	tlewis	CD3C.SCOPE
6.03.09.0	E1010_08955	Hadron and Lepton Endcaps Structures - Flux Return Steel - TR effort	375d	01-Feb-27	31-Jul-28	1726d	$14,105.18	$14,105.18	$0.00	Sharma	tlewis	CD3C.SCOPE
6.03.09.0	E1010_08959	Hadron and Lepton Endcaps Structures - Flux Return Steel - RCV - Phase 2	1d	31-Jul-28	31-Jul-28	1726d	$3,244,064.08	$0.00	$3,244,064.08	Sharma	tlewis	CD3C.SCOPE

Contract award date for CD-3B Scope: 12/2026
Contract award date for CD-3B Scope: 12/2026
(Assuming funding available)

Basis of Estimate (Endcaps)

The cost estimates are based on the average of three vendor quotes from 11/2025

RFI # 00585-CAB (APP# 00585)								
EIC Electron and Hadron Endcap Structures for the ePIC Detector Preliminary Estimated Cost Analysis								
Bidders:			DAL BEN S.P.A (Man	Streck's , Inc. (Mar	MERRILL TECHNO	Steel Tide Const	Average	
Production:								
Forward Endcap Structure	EPC-FWD-FLX-SUP-ASM-100	1	$2,557,817.20	$2,893,499.50	$3,590,649.00		$3,029,902.63	CD-3B
Forward Endcap Tooling	EPC-FWD-FLX-FIX-ASM-350	1	$8,878.20	$18,522.00	$20,342.00			
Option No. 1 Production:								
Backward Endcap Structure	EPC-BWD-FLX-SUP-ASM-100	1	$2,380,793.60	$2,783,824.25	$4,146,417.00		$3,119,592.35	CD-3C
Backward Endcap Tooling	EPC-BWD-FLX-FIX-ASM-350	1	$8,878.20	$18,522.00	$20,342.00			
Total Cost=			$4,956,367.20	$5,714,367.75	$7,777,750.00		$6,149,494.98	Total

Basis of Estimate (GST+PST Engineering Estimate)

GST	Comments	Option A (GST differs	Option B (GST differs)	Explanation
Cylinder	HM63 (stiff)	$ 80,000.00		Sandiwch core with 1mm skins
	HM63 (stiff) also supporting oMPGD, DIRC		$ 400,000.00	Massive shells 5mm and no core
Core material		$ 20,000.00	$ -	no core in B
NRE tooling, mold etc.		$ 80,000.00	$ 100,000.00	
Consumables		$ 25,000.00	$ 25,000.00	
Autoclave time		$ 10,000.00	$ 10,000.00	
Limited prototyping and verifcations of design		$ 50,000.00	$ 50,000.00	
Material cost		$ 265,000.00	$ 585,000.00	
Labor cost Manufacturing	no split, assumes engineer (Sushrut), Tech (Archie, others), and lots of "cheap" UG labor to support	$ 400,000.00	$ 350,000.00	Manufacturing Design only (Purdue only)
Labor cost Engineering	FEA work, design, tolerances, drawings, SOP and so on	$ 750,000.00	$ 850,000.00	Engineering design (mix and team effort)
TOTAL GST		**$ 1,415,000.00**	**$ 1,785,000.00**	
PST				
Materials, NRE, Tooling (Same approach as for GST)	PST is a one shell, 2 half cylinder structure with maybe same material for fire safety or lower strength material for now assumed same material	$ 160,000.00	$ 160,000.00	
Labor cost Manufacturing		$ 160,000.00	$ 160,000.00	
Labor cost Engineering		$ 160,000.00	$ 160,000.00	
TOTAL PST		**$ 480,000.00**	**$ 480,000.00**	
Installation tools				
Brackets for GST, rails for PST		$ 75,000.00	$ 75,000.00	
Eifeltower, Service supports, other support items		$ 150,000.00	$ 150,000.00	
Engineering Interface cost		$ 100,000.00	$ 100,000.00	
TOTAL Installation		**$ 325,000.00**	**$ 325,000.00**	
Total Cost		**$ 2,220,000.00**	**$ 2,590,000.00**	

- Backup for Slide 30

Basis of Estimate – CD-3C 6.03.09.02

SUMMARY: 6.03.09.02 - DET - Detector Integr., Install. and Infra. - Forward and Backward Endcap Steel Structures and Moving Mechanisms

BUDGETED TOTAL: $3.26M