Detector Commissioning Plan

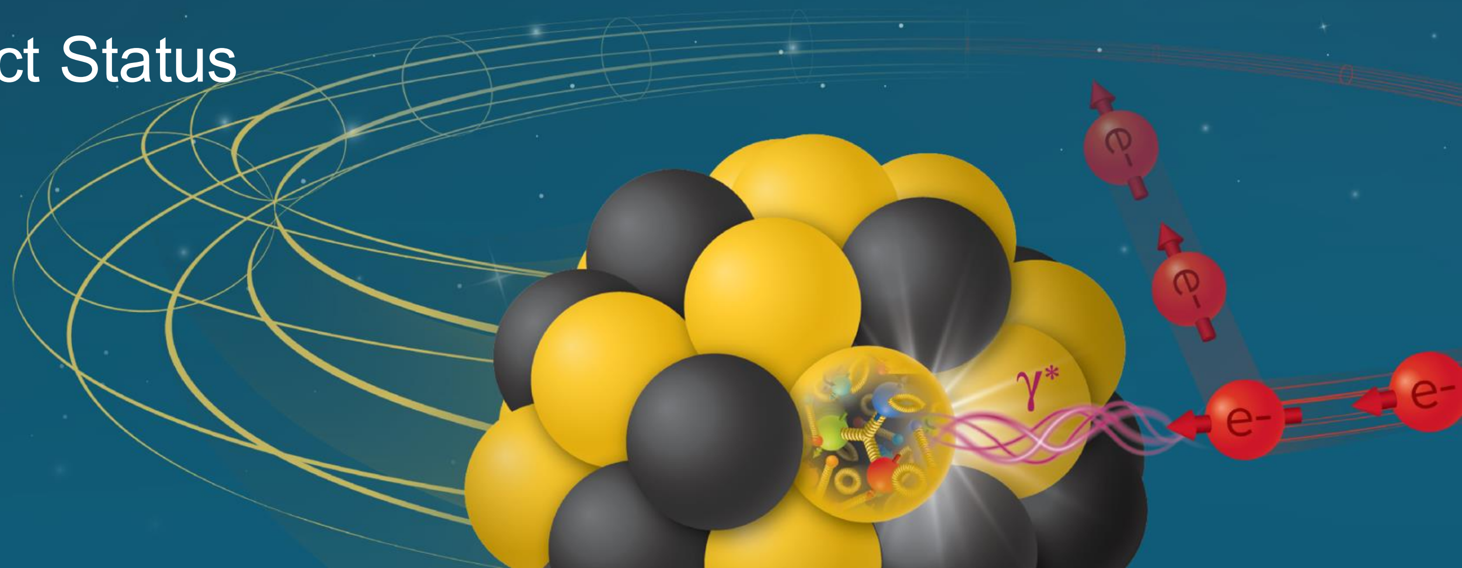
(SC4) Detector Parallel Session

E. Shulga

L3 CAM Detector Pre-Ops & Commissioning WBS 6.03.01.12

Director's Review of the EIC Project Status

March 9-12, 2026



Electron-Ion Collider

About Evgeny, Shulga

- EIC Current Role: L3 CAM Detector Pre-Ops & Commissioning
    - Assistant Physicist

- Experience:
    - 10+ years of detector physics experience at CERN and BNL
        - sPHENIX TPC, Commissioning and Upgrade
        - Broad detector systems engineering experience
    - Assistant Physicist @ BNL 2024 - present

- PhD Particle Physics, NRNU MEPhI, Moscow, Russia
- RHIC/AGS Merit Award 2023

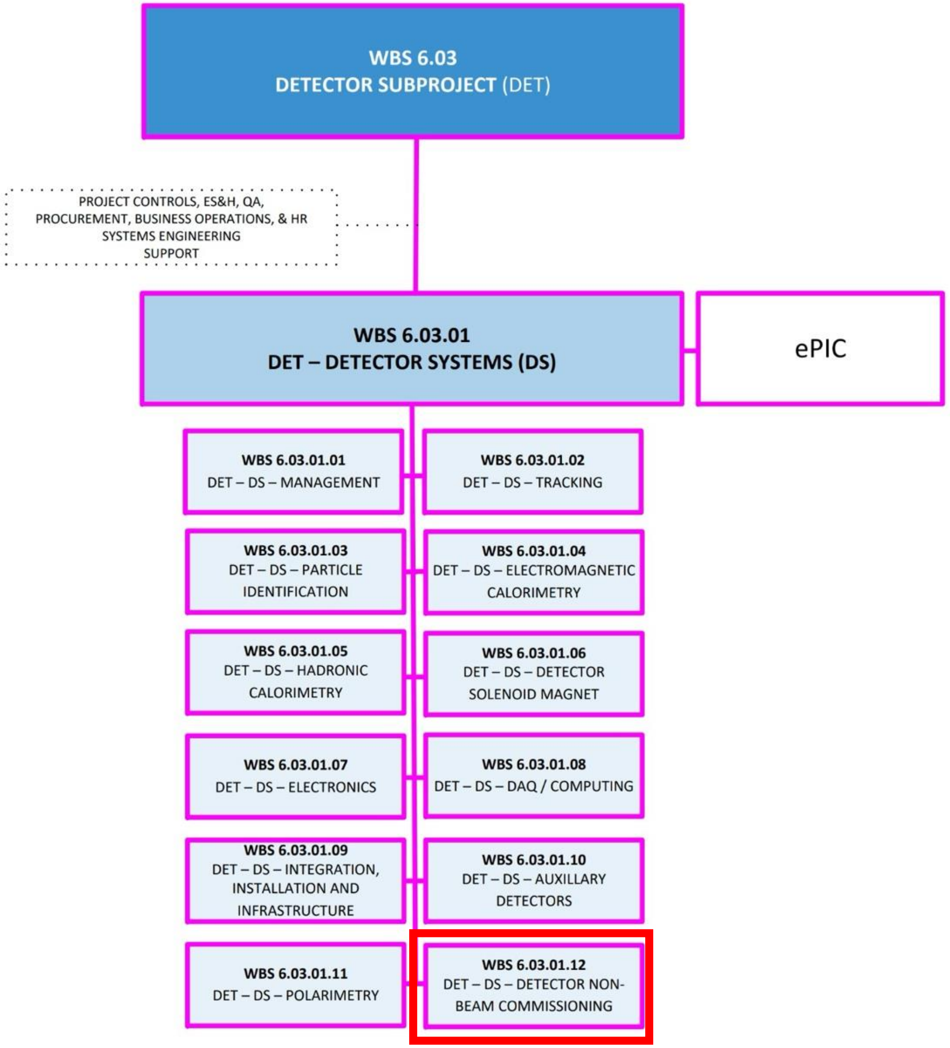
Charge Questions

Charge #

1. Is the project team effectively executing the work, including long-lead procurements? Is the project positioned to complete long-lead procurements within the established schedule and cost baseline? Are technical issues across all subprojects appropriately and proactively addressed?
2. Is the project team on track to present performance baselines for the first two subprojects it has proposed, the Accelerator Storage Rings and Detector subprojects, by the end of 2026? Is the team making adequate progress developing the performance baseline for the other subprojects it has proposed? Is each subproject scope well and logically defined? Are the subprojects ordered and phased optimally? Are subproject interfaces understood and clearly delineated at this stage of design? Are the schedules and cost estimates credible for the current stage of each subproject? Do plans include adequate scope, schedule, and cost contingency?
3. Are the key performance parameters and scope for each subproject well documented, traceable, reasonable, and justifiable? Does the roll-up of subproject scope unambiguously compose a complete and responsive Electron-Ion Collider facility? Would attainment of the key performance parameters of all subprojects indicate delivery of the mission need?
4. Are ES&H and QA properly addressed given the project's current stage of development?
5. 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?
6. Has the project team satisfactorily addressed recommendations from previous DOE SC reviews?

Scope Summary

Charge # 2, 3

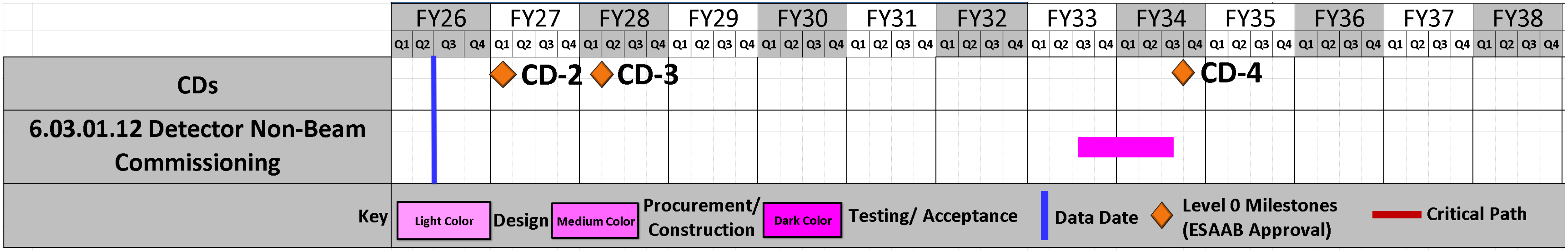


6.03.01.12	**DET - DS – Detector Non-Beam Commissioning**	**E. Shulga (BNL)**

Scope Description:
Includes all activities to commissions the central detector with cosmic sitting in the assembly hall, the forward and backward endcap calorimeters as well as the auxiliary detectors are also commissioned through cosmic data taking

Schedule

Charge # 2, 3



- Key Schedule Drivers/Assumptions: Integration complexity and service accessibility
- Key Take Away: Stable, integrated, and physics-ready ePIC detector prepared for beam operations and EIC science

EIC - ePIC Commissioning

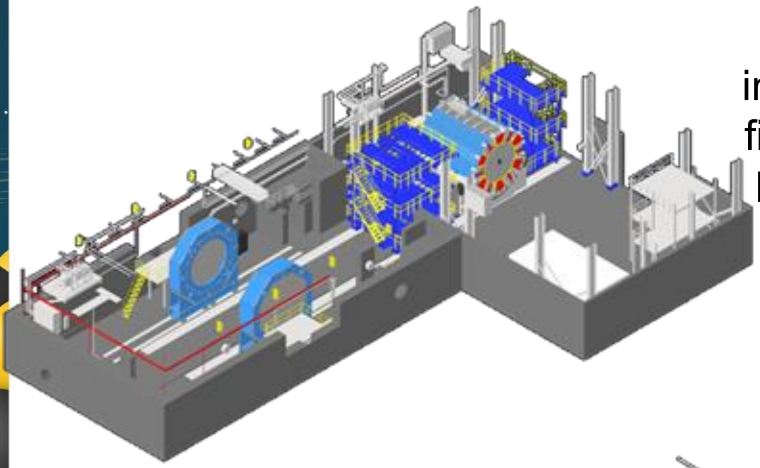
Q3/2033 | Q2/2034 | ~Q2/2035 (exact dates under development)

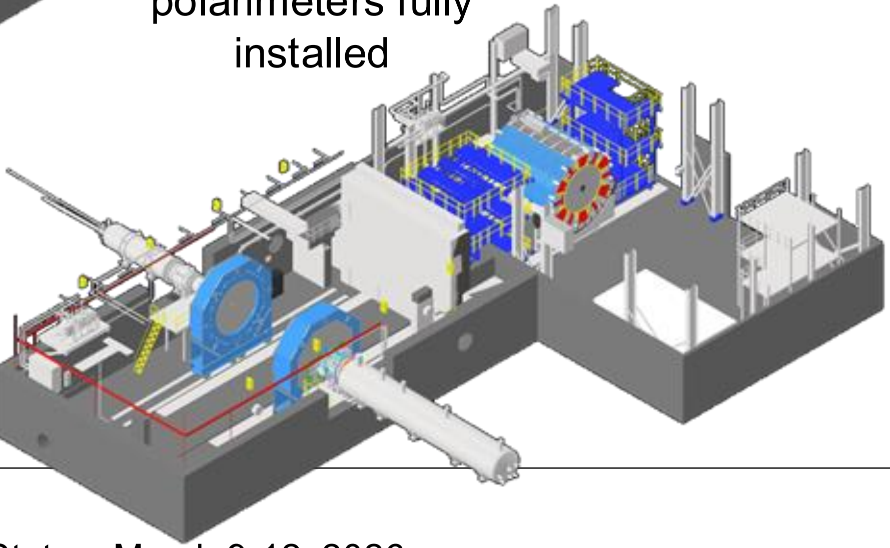
ePIC no-beam commissioning | ePIC commissioning with beam

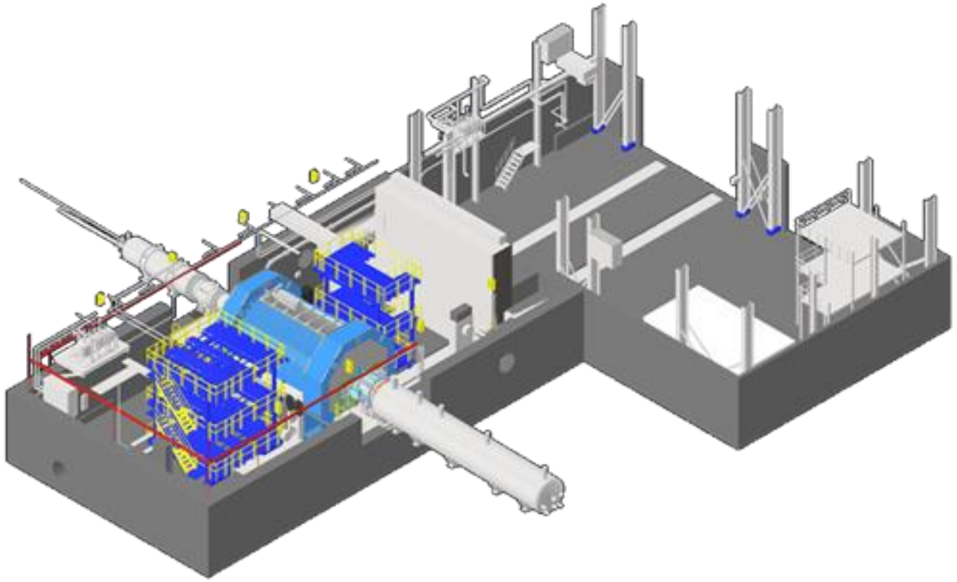
- ePIC fully assembled and Ready for Cosmic Data Taking
- EIC first beam commissioning central ePIC detector in assembly hall
- move central ePIC into wide-angle hall
- commission ePIC with beam
- Start of Science program

endcap calorimeters and beam pipe with instrumentation to have a first look on backgrounds Luminosity detector and hadron & electron polarimeters fully installed

After stable beam operations are achieved:
Off-momentum detectors will be installed





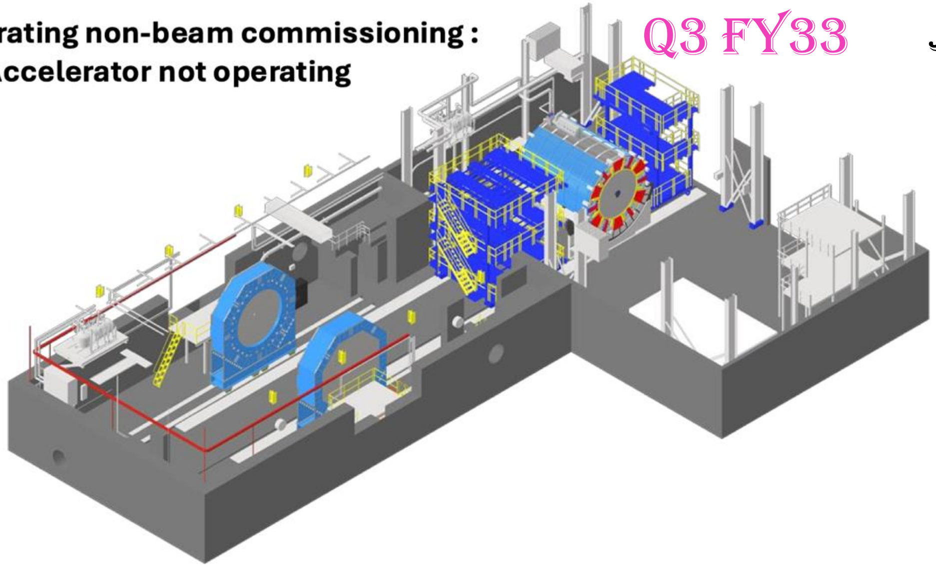


Commissioning stages

Strating non-beam commissioning :
- Accelerator not operating

Q3 FY33

1



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Q3 FY33

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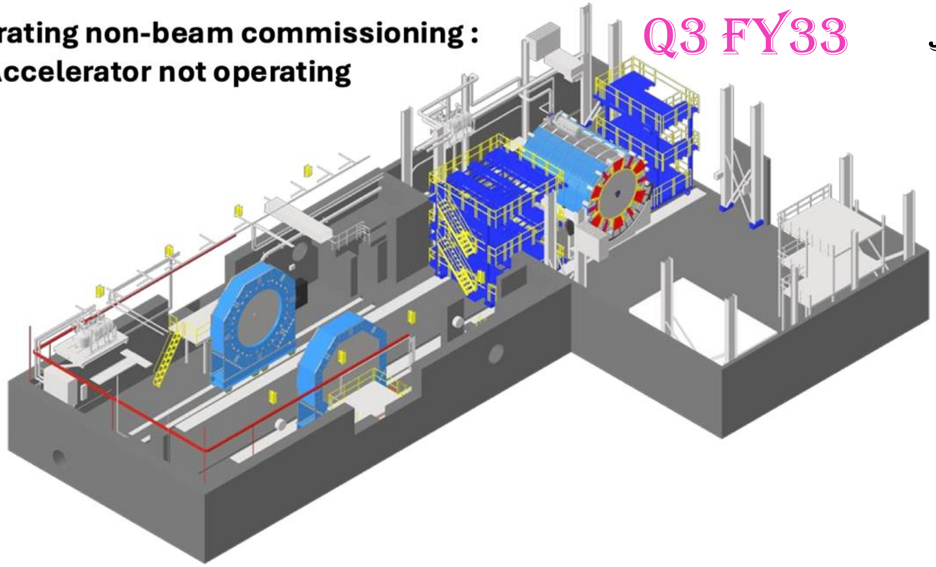
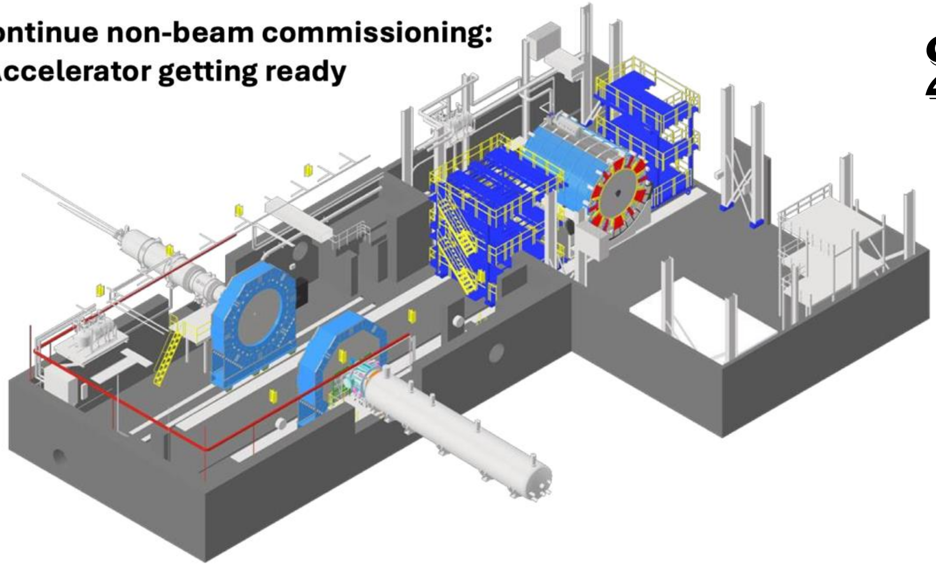


Continue non-beam commissioning:
- Accelerator getting ready

2



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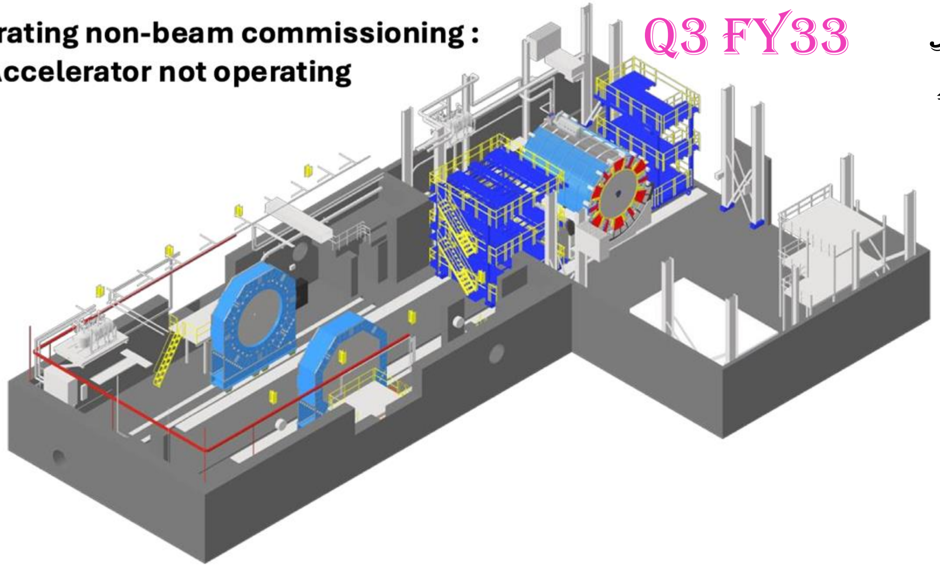
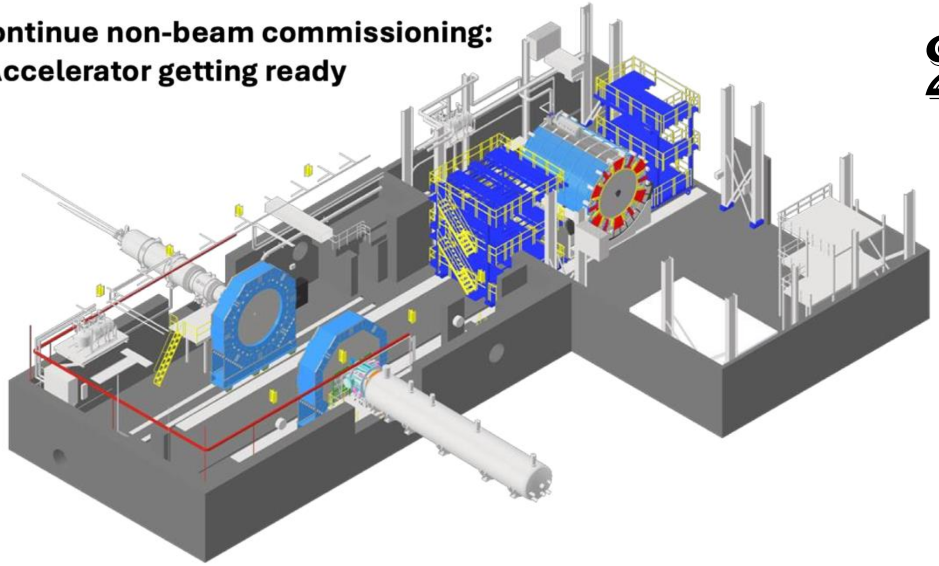


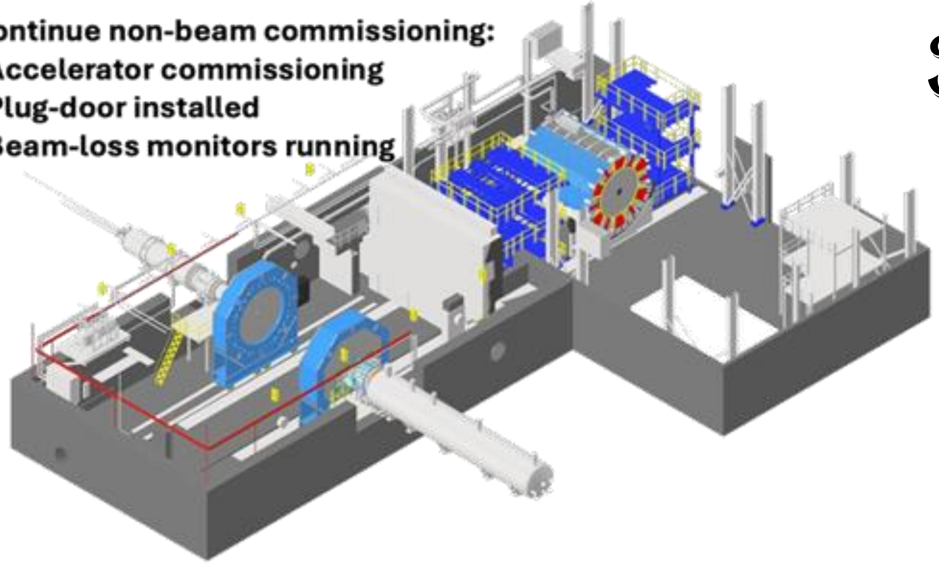
Continue non-beam commissioning:
- Accelerator getting ready

2



Continue non-beam commissioning:
- Accelerator commissioning
- Plug-door installed
- Beam-loss monitors running

3



Commissioning stages

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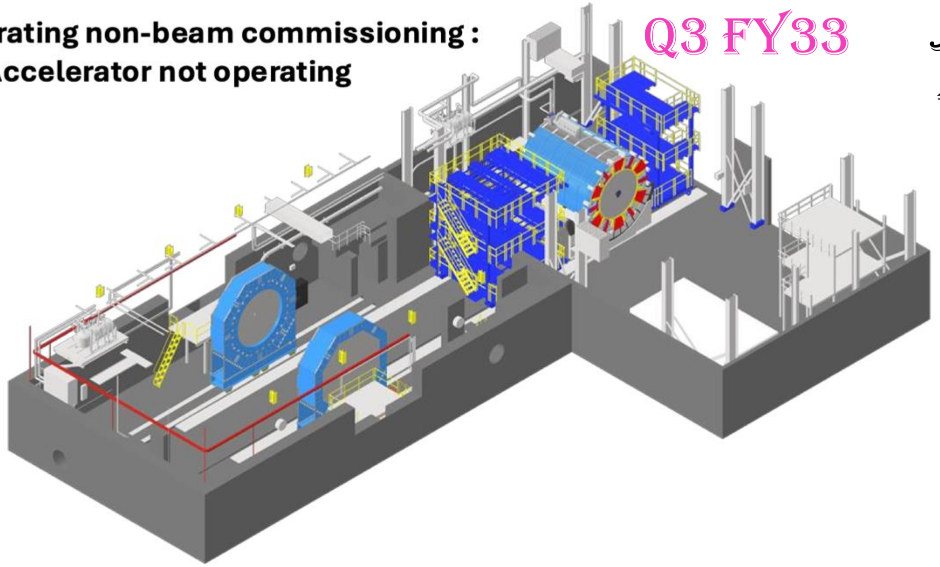
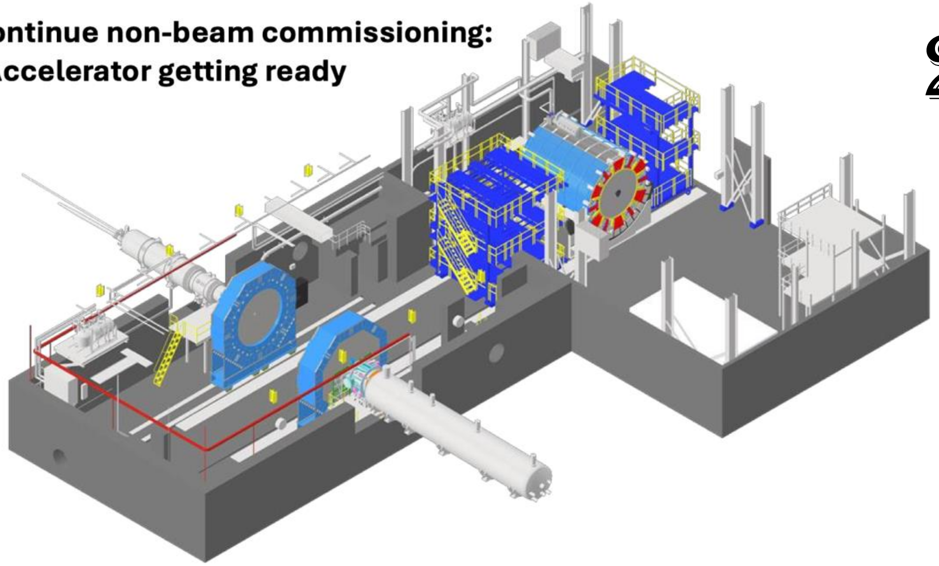


Continue non-beam commissioning:
- Accelerator getting ready

2



Continue non-beam commissioning:
- Accelerator commissioning
- Plug-door installed
- Beam-loss monitors running

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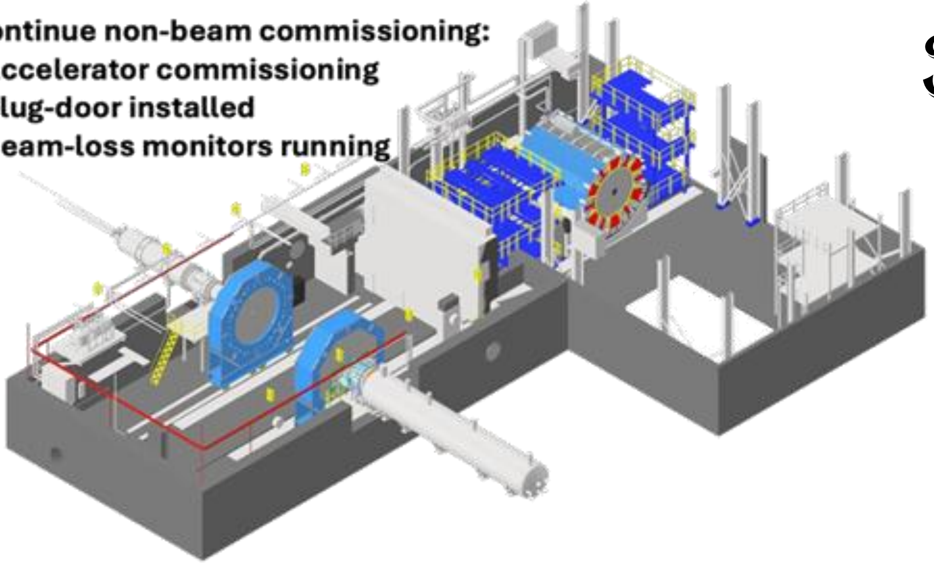
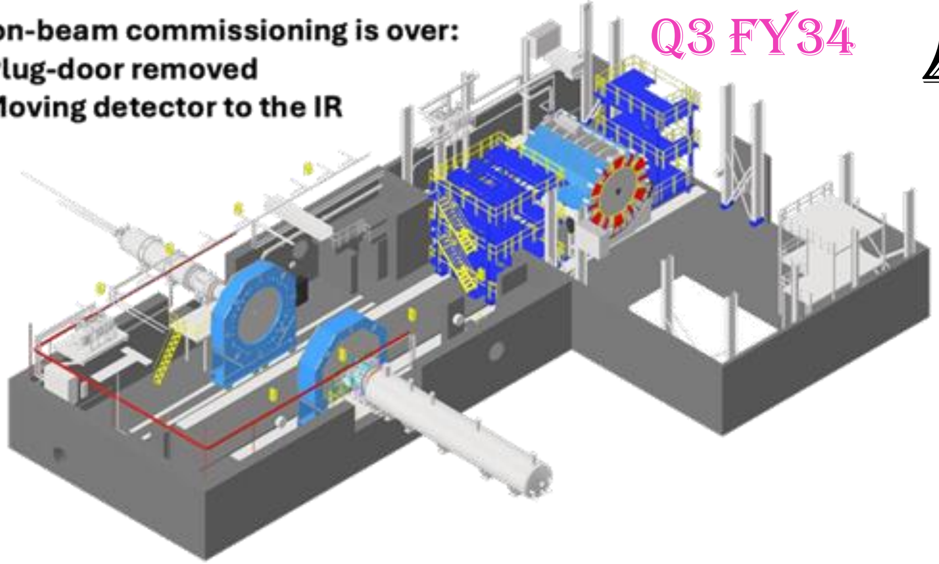


Non-beam commissioning is over:
- Plug-door removed
- Moving detector to the IR

Q3 FY34

4

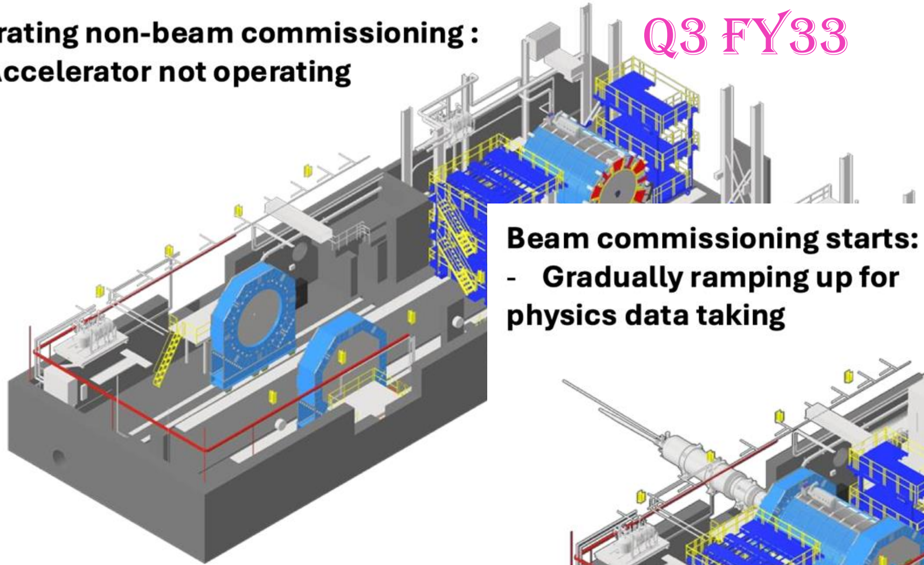


Commissioning stages

Strating non-beam commissioning :
- Accelerator not operating

Q3 FY33

1



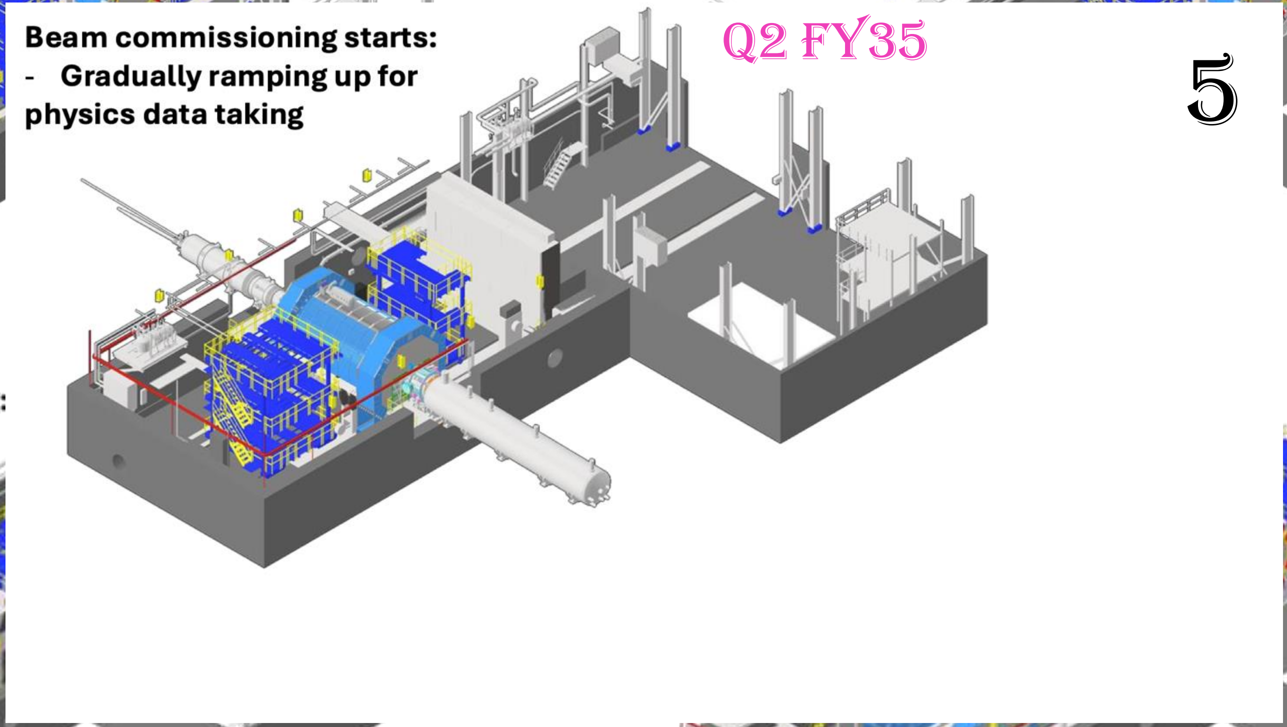
Continue non-beam commissioning:
- Accelerator getting ready

2

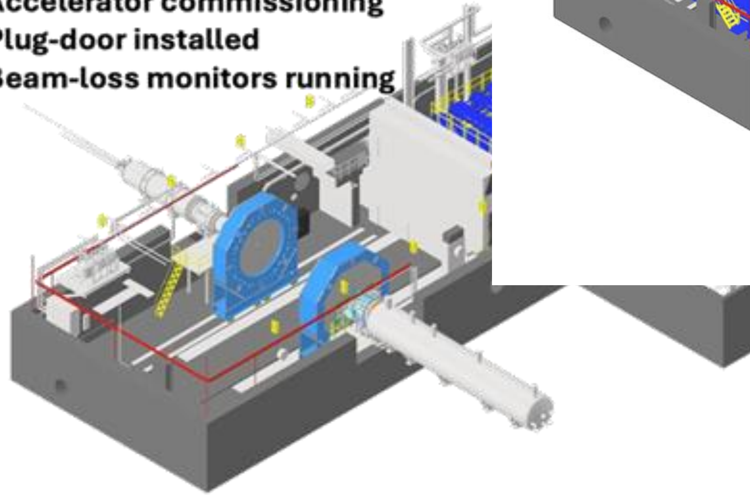
Beam commissioning starts:
- Gradually ramping up for physics data taking

Q2 FY35

5

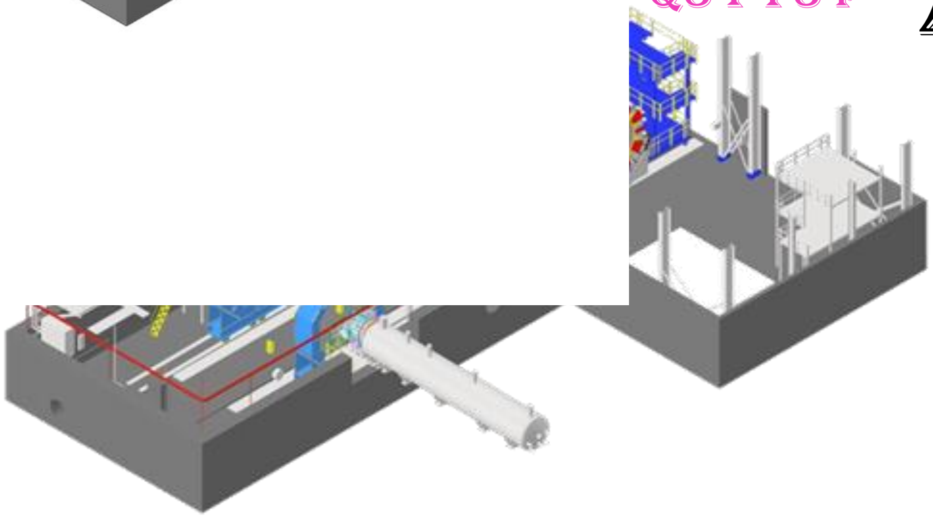


Continue non-beam commissioning:
- Accelerator commissioning
- Plug-door installed
- Beam-loss monitors running



Q3 FY34

4



EIC Commissioning: Draft KPPs

Charge # 3

Q3 FY34 — end of DET subproject

move ePIC from Assembly Hall into beam position

Q2 FY36 — Early CD-4 Project

Detector (DET) Subproject **WBS 6.03**		
Performance Measure	**Threshold KPP**	**Objective KPP**
Central Detector & Auxiliary Systems	Record signals from cosmic rays in all individual ePIC detector subsystems to test the full readout chain and determine that above 80% of the channels in all detector subsystems are functional.	Record signals from cosmic rays in all individual detector subsystems and assembled into the EIC detector, ePIC, to validate channel mapping and data collection for 90% of the channels.
Detector Magnet	Magnet operated at 1.7 T field	Magnet operated at 2 T field

Full Project		
Performance Measure	**Threshold KPP**	**Objective KPP**
Detector		Record signals of e-h collisions in the different ePIC subsystems and separate electrons and hadrons.

Path from Threshold to Objective to Ultimate:

- increased integrated luminosity per system (ep & eA) and √s
- gradually improve understanding of detector
- gradually improve calibrations and systematic uncertainties
- develop more sophisticated analysis methods

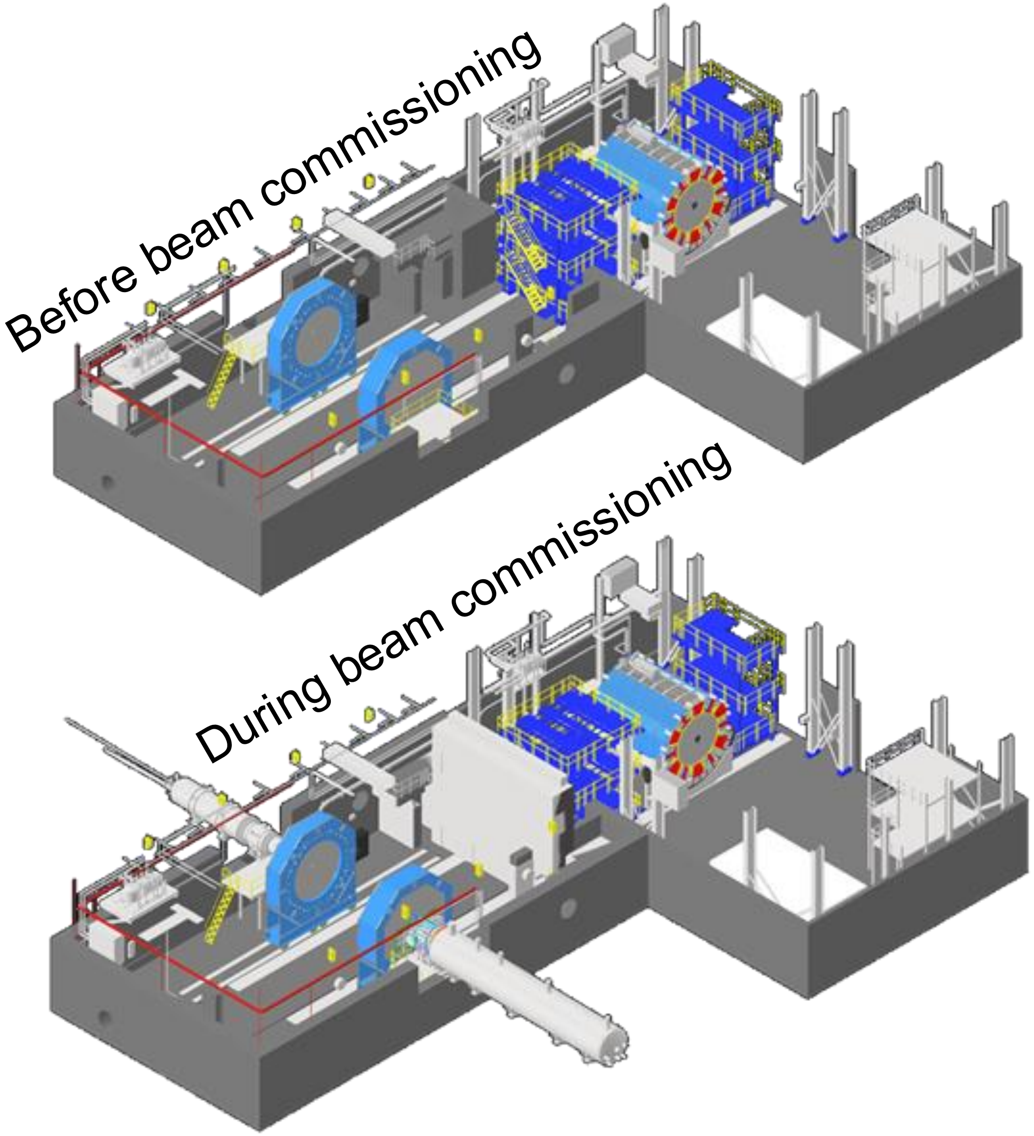
Objective KPP, the same as CD-1 threshold KPP, just more detailed wording

KPP	Performance Measure	Threshold KPP
DET-4	Detector	Detector installed and ready for beam operations.

Threshold KPP, the same as CD-1 objective KPP with Lumi requirement added

KPP	Performance Measure	Threshold KPP	Objective KPP
DET-4	Detector	Detector installed and ready for beam operations.	Inelastic scattering events in e-p and e-A collisions measured in Detector.

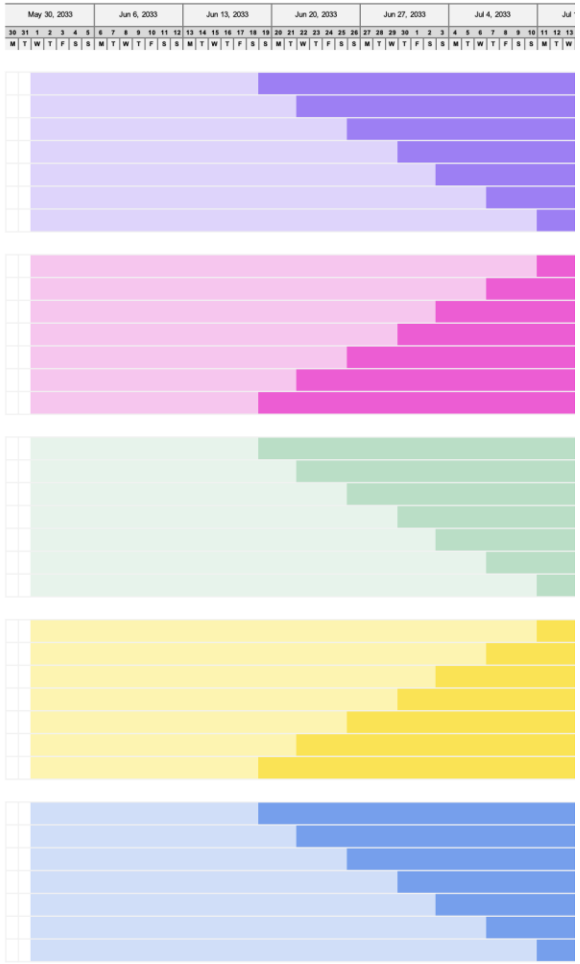
Requirements to start commissioning



- Infrastructure:
  - Electric lines set and connected at the detector.
  - Cooling ready to be up and running.
- Magnet:
  - Magnet should be fully accepted and mapping completed.
- All detectors installed and connectorized (LV/HV/DAQ):
  - Installed Beam-Loss Monitoring
  - Tracking detectors (gas, temperature, pressure)
  - PID
  - Calorimeters
- DAQ/Slow controls/Electronics:
  - LV (mapping, monitoring)
  - Fibers (mapping)

Planning and following the progress

TASK/DETECTORS	DESCRIPTION	IRED MATERIALS/SER'	PI	ROGRES	START	WEEKS	END
Mechanical & Alignment							
Silicon Vertex & Tracking (MAPS + A	Verify support structures, alignment wrt beam pipe	servey	J Doe	5%	6/1/33	52.00	#####
MPGD Trackers	Chamber integrity, mechanical positioning		J Doe	6%	6/1/33	52.00	#####
dRICH (Dual Radiator RICH)	Optical alignment of mirrors, photon detectors		J Doe	7%	6/1/33	52.00	#####
Backward RICH	Alignment of optics & sensors		J Doe	8%	6/1/33	52.00	#####
Electromagnetic Calorimeters (EMCal	Module installation, mechanical survey		J Doe	9%	6/1/33	52.00	#####
Hadronic Calorimeters (HCal)	Module integrity, absorber/tile positioning		J Doe	10%	6/1/33	52.00	#####
Superconducting Solenoid Magnet	Field map survey, cryostat integrity		J Doe	11%	6/1/33	52.00	#####
Services (Power, Cooling, Gas)							
Silicon Vertex & Tracking (MAPS + A	Power stability (low-voltage + high-voltage), cooling loops fun	Cooling	J Doe	11%	6/1/33	52.00	#####
MPGD Trackers	Gas system (flow, pressure, purity), HV stability	Working gas mixture, cc	J Doe	10%	6/1/33	52.00	#####
dRICH (Dual Radiator RICH)	Cooling of photon detectors, HV checks	Cooling	J Doe	9%	6/1/33	52.00	#####
Backward RICH	HV stability for photon detectors	Cooling	J Doe	8%	6/1/33	52.00	#####
Electromagnetic Calorimeters (EMCal	HV for SiPMs, cooling loops	Cooling	J Doe	7%	6/1/33	52.00	#####
Hadronic Calorimeters (HCal)	HV, cooling checks	Cooling	J Doe	6%	6/1/33	52.00	#####
Superconducting Solenoid Magnet	Cryogenic systems, quench protection, power supplies	Cooling	J Doe	5%	6/1/33	52.00	#####
Readout & DAQ							
Silicon Vertex & Tracking (MAPS + A	Check chip readout, hit/noise maps, timing		J Doe	5%	6/1/33	52.00	#####
MPGD Trackers	Front-end electronics noise check, gain uniformity		J Doe	6%	6/1/33	52.00	#####
dRICH (Dual Radiator RICH)	Photon sensor readout noise test, dark current		J Doe	7%	6/1/33	52.00	#####
Backward RICH	Pedestal runs, electronic noise level		J Doe	8%	6/1/33	52.00	#####
Electromagnetic Calorimeters (EMCal	Pedestal runs, electronic noise level		J Doe	9%	6/1/33	52.00	#####
Hadronic Calorimeters (HCal)	Pedestal stability, timing tests		J Doe	10%	6/1/33	52.00	#####
Superconducting Solenoid Magnet	Field readout sensors operational		J Doe	11%	6/1/33	52.00	#####
Calibration / Performance							
Silicon Vertex & Tracking (MAPS + A	Pedestal & noise calibration, cosmic tracks		J Doe	11%	6/1/33	52.00	#####
MPGD Trackers	Cosmic ray runs for efficiency maps, gain calibration		J Doe	10%	6/1/33	52.00	#####
dRICH (Dual Radiator RICH)	LED/laser calibration		J Doe	9%	6/1/33	52.00	#####
Backward RICH	Light source calibration, reconstructed ring resolution		J Doe	8%	6/1/33	52.00	#####
Electromagnetic Calorimeters (EMCal	Energy calibration with LEDs, cosmic muons		J Doe	7%	6/1/33	52.00	#####
Hadronic Calorimeters (HCal)	Muon/calorimeter cosmic runs, energy response uniformity		J Doe	6%	6/1/33	52.00	#####
Superconducting Solenoid Magnet	Field uniformity measurement, Hall probe mapping		J Doe	5%	6/1/33	52.00	#####
Integration / Global							
Silicon Vertex & Tracking (MAPS + A	Synchronization with trigger, clock, DAQ throughput		J Doe	5%	6/1/33	52.00	#####
MPGD Trackers	Timing alignment, DAQ data format validation		J Doe	6%	6/1/33	52.00	#####
dRICH (Dual Radiator RICH)	PID algorithm integration in software framework		J Doe	7%	6/1/33	52.00	#####
Backward RICH	Synchronization with central tracker & EMCal		J Doe	8%	6/1/33	52.00	#####
Electromagnetic Calorimeters (EMCal	Synchronization with central tracker & EMCal		J Doe	9%	6/1/33	52.00	#####
Hadronic Calorimeters (HCal)	Synchronization with central tracker & EMCal		J Doe	10%	6/1/33	52.00	#####
Superconducting Solenoid Magnet	Verify tracking B-field map matches reconstruction software		J Doe	11%	6/1/33	52.00	#####



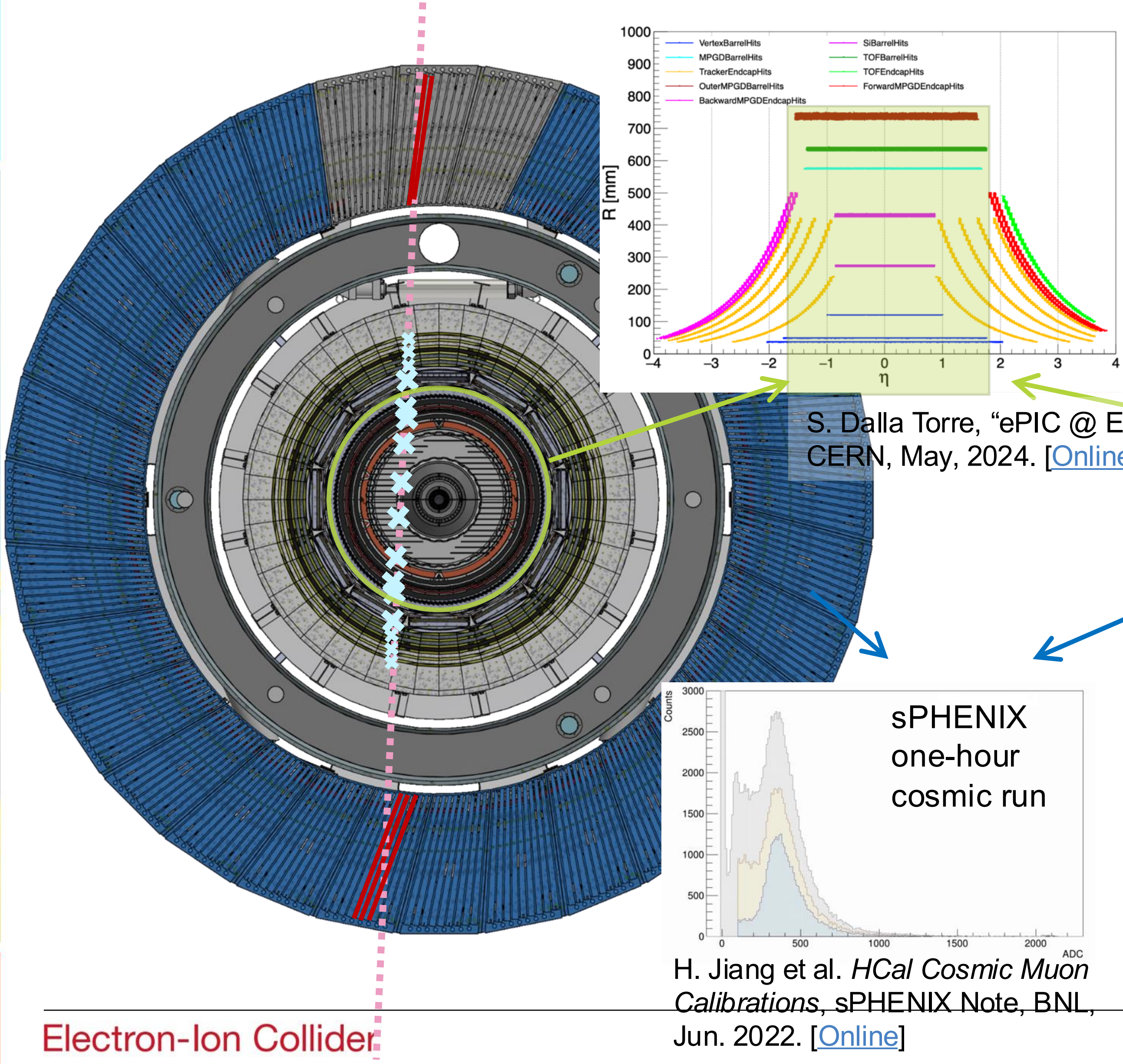
- Non-beam commissioning is under development, will require contribution from detector subsystems not to miss anything
- Step by step planning will be set up to have flexibility for the positive progress

Number of channels, cooling and gas in ePIC

Detector Group	Channels					Det Fiber Down	Det Fiber Up	RDO	Fiber Pair (DAQ)	Cooling Electronics/LV	Gas
	MAPS	AC-LGAD	SiPM/PMT	MPGD	HRPPD/ MCP-PMT						
Tracking (MAPS)	16B					183	5863	183	183	550 (liquid/CO_2 cooling disks) + 356 +TBD	-
Tracking (MPGD)				164k		640	2560	160	160	24 (Barrel) + TBD	24 (Barrel) + 12
Calorimeters	500M		100k					522	522	2(CO_2) HCal + 36 (water) EMCal	-
PID (TOF)		6.1M				500	1364	500	500	144 + 4	-
PID Cherenkov			318k		143k			1283	1283	24 dRICH + 12 (N_2) + 12 (water) DIRC	36 (N_2 dRICH)
TOTAL	**16.6B**	**7.7M**	**432k**	**164k**	**143k**	**843**	**9,787**	**2,788**	**2,810**	**>1700 lines**	**>70 lines**

- All channels must be mapped, validated and monitored
- Temperature and flow monitoring must be up and running

Commissioning & cosmic events



S. Dalla Torre, “ePIC @ EIC”, CERN, May, 2024. [Online].

H. Jiang et al. *HCal Cosmic Muon Calibrations*, sPHENIX Note, BNL, Jun. 2022. [Online]

Main goals of the commissioning

- All systems timed in and readout simultaneously
- All subsystems monitored and under control

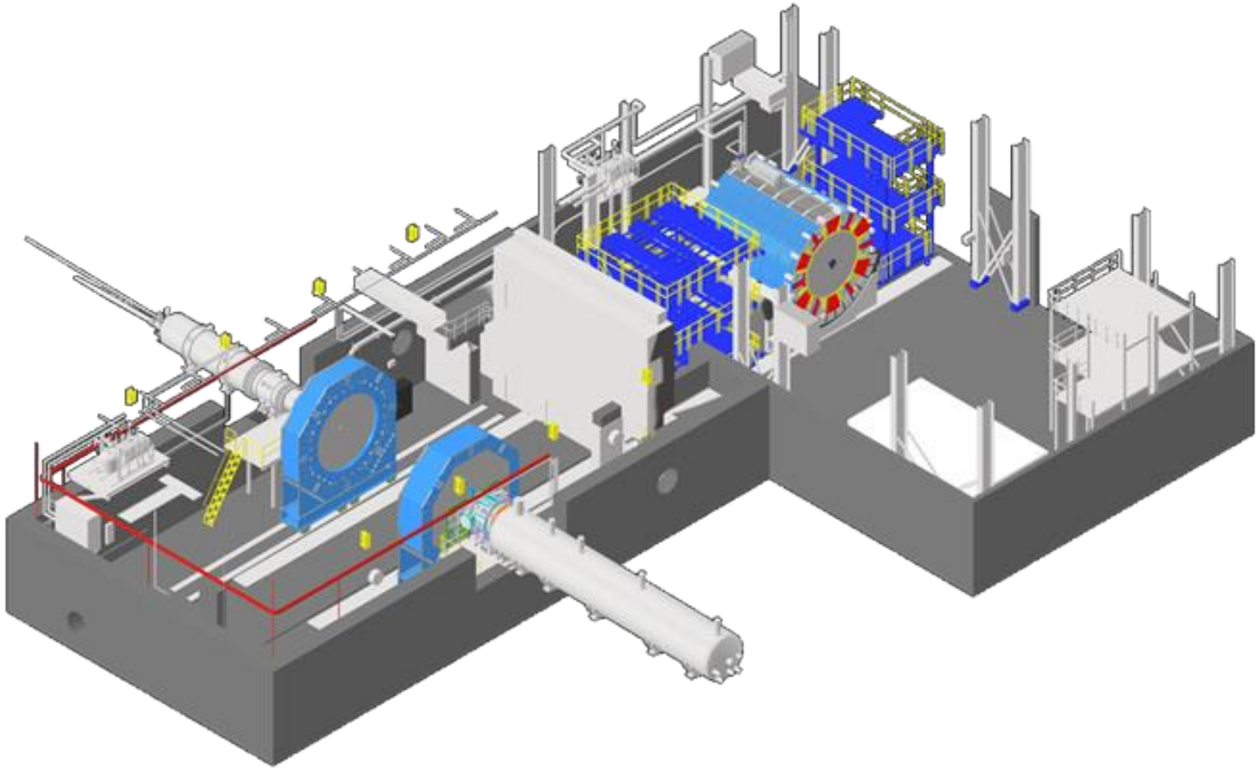
Main goals with cosmic data:

- Initial alignment of tracking detectors and all the systems by utilizing cosmic track reconstruction (relying on reconstruction SW).
- HCal tower-by-tower absolute calibration of energy scale, by comparing the data to Geant4 simulations.

Requirements

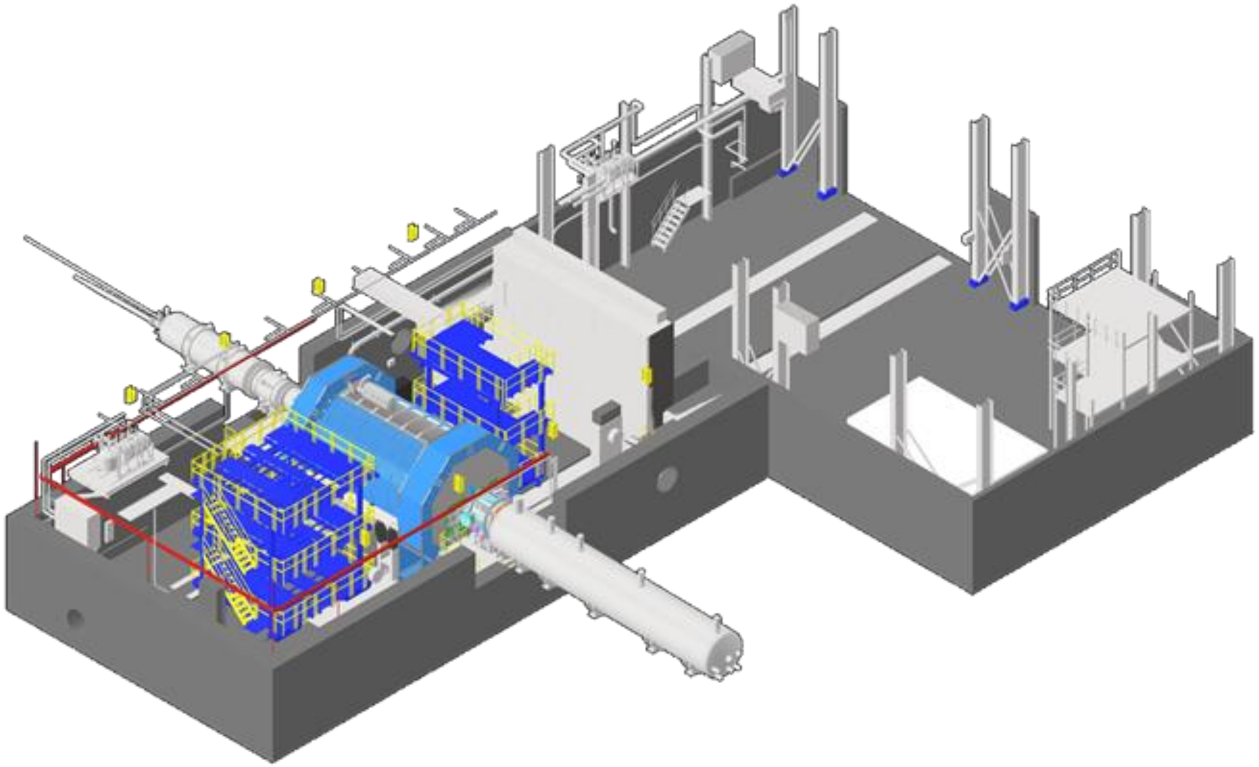
- Cosmic data acquisition mode is included in DAQ/Computing
- All systems (HV, cooling, DAQ) running

To Do with the beam: Detector in the Assembly hall



- Develop detector beam-dump triggers scheme with BLM detectors
- Synchronize DAQ system:
  - With C-AD clock
  - Internal clocks
- Start background measurements
  - Improve beam conditions in collaboration with C-AD
- Test slow controls and monitoring of environmental parameters gradually increasing beam-load

Outlook: Detector commissioning with the beam



- Develop detector beam-dump triggers scheme with BLM detectors
- Synchronize DAQ system:
  - With C-AD clock
  - Internal clocks
- Get background effects “under control”
  - Improve beam conditions in collaboration with C-AD
  - Tune detector gains
- Test slow controls and monitoring of environmental parameters gradually increasing beam-load

ESH and Quality Assurance

Detector commissioning

ESH and QA-related issues:

- All detector subsystems have their own ESH and QA which must be satisfied before start of the commissioning.
- Safety review (mini-IRR*) for the magnet operation for the acceptance checking and mapping
- Detector IRR* will be executed before commissioning.
- Partial contribution during initial ARR* for taking data during accelerator commissioning

Critical components requiring quality control:

- Cooling
- HVAC
- gas-systems
- HV, LV
- DAQ
- Slow controls

* Definitions:
IRR – Independent Readiness Review is a formal review conducted by an independent committee to assess whether a project or subsystem is ready to proceed to the next phase. It evaluates technical maturity, risks, resources, and plans before authorizing advancement.
ARR – Accelerator Readiness Review is a safety-focused review required before operating or commissioning accelerator equipment. It ensures that personnel, procedures, controls, and systems are in place to safely operate the machine or a subsystem of it.

EIC Commissioning: Summary

Scope: Transition from detector installation to full operational , ensuring stability
Readiness Drivers: Infrastructure (power, cooling), fully installed and connectorized detectors, validated magnet (mapping + quench), integrated DAQ and slow controls.
Non-Beam & Cosmic:
- Full-system integration and timing across all subsystems
- Initial tracking alignment and calorimeter energy calibration using cosmic muons
- Requires stable services, cosmic DAQ mode, and mature reconstruction software

Beam:
- DAQ synchronization with accelerator timing
- Background characterization and mitigation with C-AD
- Gain tuning, slow-control validation under increasing beam load

KPP Alignment:
- Supports DET Subproject Threshold → Objective KPPs (cosmic-tested, integrated detector)
- Enables CD-4 transition to a physics-ready

Key Risks & Mitigation: Integration complexity and service accessibility addressed via stepwise, flexible commissioning and early monitoring
Outcome: Stable, integrated, and physics-ready ePIC detector prepared for beam operations and EIC science

Back Up

Costs: Budget at Completion

Charge # 2

WBS	WBS Name	Budget at Completion DOE Funded Only (Burdened & Escalated)	In-Kind Contributions
6.03.01.12	DET - Detector Non-Beam Commissioning	$ 8,145,929	$ -

Role		FTE [FTE/year] Commissioning 1 year and 3 months + Tests before commissioning:	Period [hours]	Cost [$/hour]	Total	Total X Factor
Safety	safety IRR	1	2080	$250.00	$520,000.00	$650,000.00
	with beam ARR	0.25	520	$250.00	$130,000.00	$162,500.00
Shift	Post Doc (BNL)	1.25	2600	$250.00	$650,000.00	$812,500.00
	Scientist_Low	1.25	2600	$250.00	$650,000.00	$812,500.00
	Scientist_Med	1.25	2600	$250.00	$650,000.00	$812,500.00
DAQ	Post Doc (BNL)	1.25	2600	$250.00	$650,000.00	$812,500.00
	Scientist_Low	1.25	2600	$250.00	$650,000.00	$812,500.00
	Scientist_Med	1.25	2600	$250.00	$650,000.00	$812,500.00
Detector experts	Magnet	1.25	2600	$250.00	$650,000.00	$812,500.00
	Tracking	1.25	2600	$250.00	$650,000.00	$812,500.00
	PID	1.25	2600	$250.00	$650,000.00	$812,500.00
	Calo	1.25	2600	$250.00	$650,000.00	$812,500.00
	Far detectors	1.25	2600	$250.00	$650,000.00	$812,500.00
Tech	Misc	1.25	2600	$250.00	$650,000.00	$812,500.00
	Misc	1.25	2600	$250.00	$650,000.00	$812,500.00
					Total manpow	$10,562,500.00

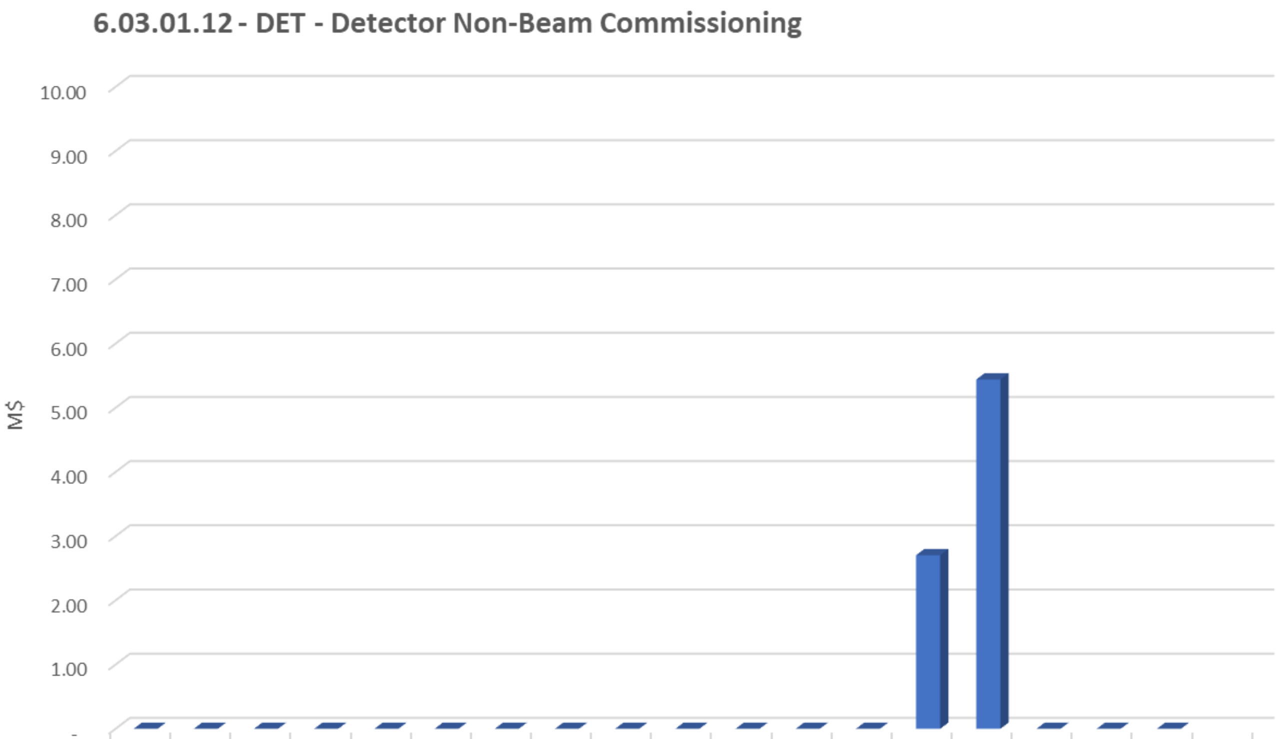
	Volume [L/day]	Cost [$/L]	Cost [$/day]	Gas	Cost [$/K bottle]	Volume [CF]	Volume [L]	Dduration [days/bottle]	Bottles [1/year]
MPGDs:									
- MPGD-BOT	330	$0.15	$48.75	Ar:iso 95:5	$260.00	62.00	1760.00	5.3	68.3
- CyMBaL	150	$0.15	$22.16	Ar:iso 95:5	$260.00	62.00	1760.00	11.7	31.0
- uRWELL ECT	768	$0.15	$113.45	Ar:iso 95:5	$260.00	62.00	1760.00	2.3	158.8
dRICH									
C2F6	80	$0.61	$49.14	C2F6	$3,440.00	62.00	5600.00	70.0	5.2
All:									
N2	310	$0.01	$3.88	N2	70	62	5600.00	18.1	20.2
		Total per day	237.38						
	Code value	Factor	Days of running	Running period	Total	Total X Factor			
Total estimated gas costs	M06_EEB	1.25	300		$71,214.45	$89,018.06			

DAQ yearly estimates for discs/computers/cables
$10,000.00
Misc: gas tubing, controllers, cooling fluids:
$20,000.00

- Major cost drivers:
  - Labor for commissioning the detector
  - All other costs are low

Costs: Budget Profile

Charge # 2

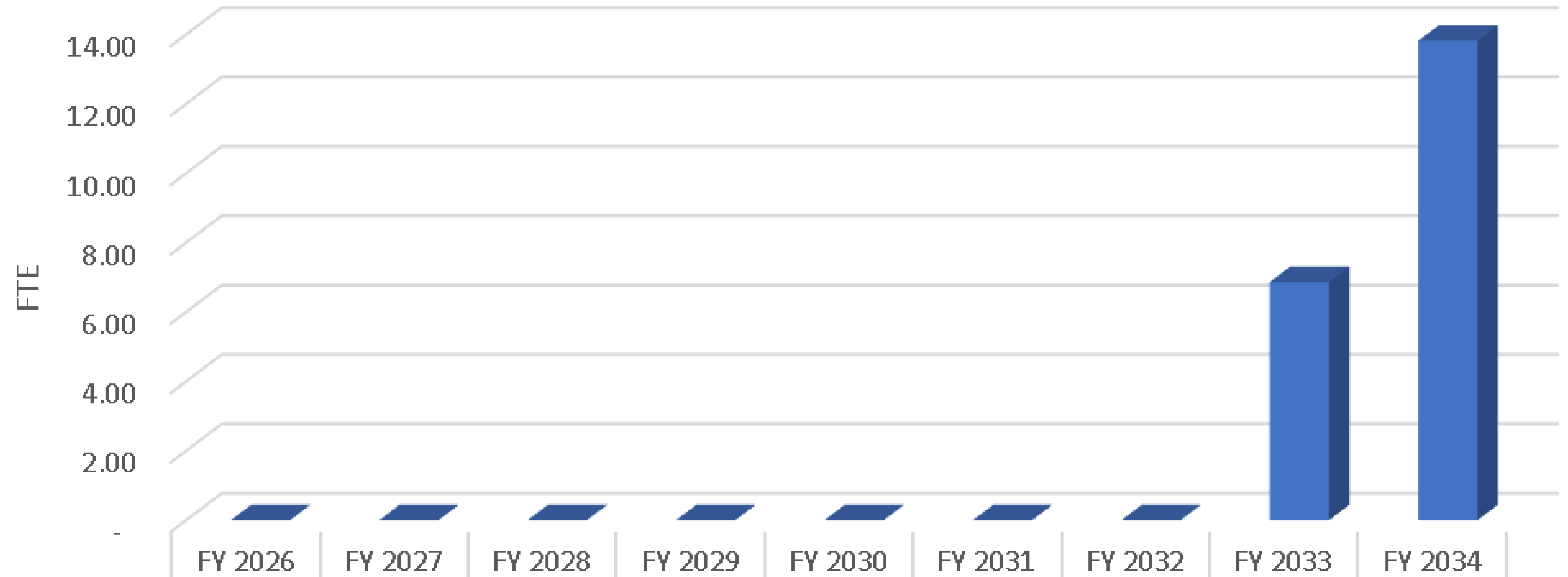


	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024	FY 2025	FY 2026	FY 2027	FY 2028	FY 2029	FY 2030	FY 2031	FY 2032	FY 2033	FY 2034	FY 2035	FY 2036	FY 2037	Total
6.03.01.12 - DET - Detector Non-Beam Commissioning	-	-	-	-	-	-	-	-	-	-	-	-	-	2.70	5.44	-	-	-	8.15

- Trends:
  - Tracks manpower needed for the commissioning of all the systems

Staffing and Organization

Charge # 2



	FY 2026	FY 2027	FY 2028	FY 2029	FY 2030	FY 2031	FY 2032	FY 2033	FY 2034
FTE	-	-	-	-	-	-	-	6.87	13.82

- Trends
  - 2033-2034: workforce needed to commission all the systems
  - Costed labor per year varies to match workforce and experience needed