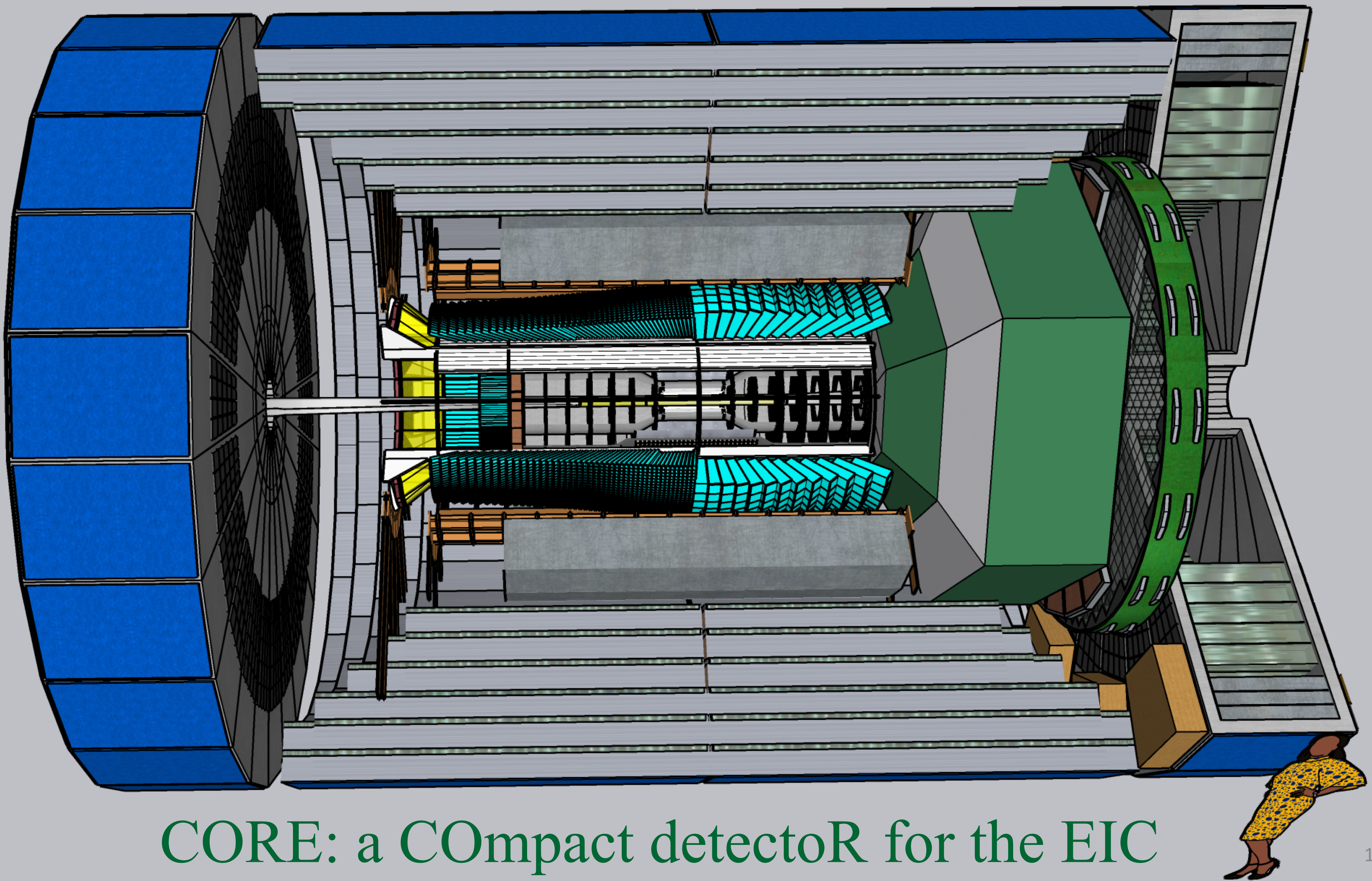


CORE: a COmpact detectoR for the EIC

Outline

- R&D needs and risks.
- Cost
- Proposed schedule
- Potential upgrade paths
- Collaboration

R&D needs and risks - costs

- Most R&D needs for CORE are addressed by the targeted R&D supported by the EIC project. This includes:
  - eRD102 (dRICH), eRD103 (hpDIRC), eRD104 (silicon service reduction), eRD109 (electronics), eRD110 (photosensors), eRD111 (Si-vertex), and eRD112 (AC-LGAD)
- Additional CORE-specific R&D needs include the
  - W-shashlyk. KLM, and μRWELL MPGD
- The R&D costs for each system are:
  - Silicon tracker: $12,804k
  - AC-LGADs: $668k
  - W-shashlyk: $450k
  - DIRC: $305 (of which $120k is in-kind)
  - dRICH: $234k
  - KLM: $200k
  - MPGD: $100k

TOTAL: $14,761k

Cost to project: $14,641k

R&D needs and risks - costs

- We assume that no R&D is needed for the $PbWO_4$ Emcal and the STAR FCS-like Hcal.
  - However, we note that if developed, the compensation scheme pursued by eRD107 could be applied to the new CORE Hcal modules.

- The total R&D cost is $14,761k.
  - However, since the targeted R&D is already ongoing for Detector 1 most of it will be completed by FY24 when the Detector 2 R&D timeline starts.
  - We estimate that the R&D need for CORE from FY24 onwards would be $1,957k

CORE technologies

Component	Baseline Technology	Basis for Tech.	Risk	Alternative	Alternative seen as
compact solenoid	NbTi	widespread use	medium	lower field	fallback
silicon tracker	MAPS (10 μm pixels)	ITS3, eRD25	medium	as for ALICE	fallback
MPGD tracker	μRWELL	eRD6	medium	GEM	fallback
LGAD TOF	AC-LGAD	eRD112	medium	resistive LGAD	lower fill factor
dRICH PID	gas + aerogel	eRD14, HERMES	medium	non-CFC gas	eco friendly
DIRC PID	hpDIRC	eRD14, PANDA, BaBar	low	thin bars	improved e/π ID
EMcal $\eta < 0$	$PbWO_4$	PANDA, CMS, etc	low	W-shashlyk	fallback
EMcal $\eta > 0$	W-shashlyk	similar to Pb-shashlyk	low	W/SciFi	fallback
HCal $\eta > 1.2$	Fe/Sci towers	STAR FCS, eRD1, etc	low	eRD107 compensation	improved resolution
KLM $\eta < 1.2$	Fe/Sci 2D layers	Belle II	low	sPHENIX HCal	traditional HCal

TABLE II. Summary of detector technologies.

R&D needs and risks - comments on assessment

- CORE does not use any emerging or high-risk technologies.

- The CORE solenoid is small and none of the specs are particularly demanding. However, construction of a solenoid is never low-risk, which is why we consider the risk to be moderate.

- The R&D for the ITS3-based silicon tracker is quite challenging, but given the support at CERN (RD50, RD53) and the experience within the silicon consortium, we believe that the overall risk of developing the silicon tracker is moderate.

- The baseline technology for the MPGD tracker is μRWELL. In principle, fabrication, operation, and maintenance risks for the μRWELL technology should be lower for than for GEMs (our low-risk fallback option). However, since μRWELL is a new technology, we nevertheless assigned it a moderate risk.

R&D needs and risks - comments on assessment

- The design of the dual-radiator RICH is sound, but the ongoing R&D is still addressing some key design features. Thus, while we are confident that the R&D will be successful, we consider the risk to be moderate.

- The hpDIRC R&D is currently focusing on validation of the performance and cost reduction. The overall technical risk is thus low.

- The four calorimeter technologies all have low risk. Suitable PbWO4 EMcal modules are currently produced in quantity for PANDA, STAR FCS Hcal modules were recently produced, the W-shashlyk can be procured from commercial sources, and the CORE KLM is a straightforward adaptation of the one used by Belle II.

- There is also a non-technical risk associated with the rate of production of $PbWO_4$ modules.

Cost – main detector

- Total cost and cost to project.
  - Escalation is not shown in the table.
- Our estimate of the electronics cost is compatible with the official YR detector estimate.
- The total cost of the R&D for CORE is $14.8M.
  - For Detector 2, only $2M of R&D would be required, which has been included for the respective system.
  - For Detector 1, an additional $12.8M would be added to the tracker.

WBS	**$M** (total cost)	**$M** (cost to project)
fwd MPGD-tracker	*0.95*	*0.95*
Silicon tracker	*20.52*	*20.52*
Tracking Total	**21.47**	**21.47**
AC-LGAD	*3.86*	*3.35*
DIRC	*12.81*	*7.47*
Dual-radiator RICH	*7.72*	*7.72*
PID Total	**24.39**	**18.54**
$PbWO_4$ - *barrel*	*17.79*	*17.47*
$PbWO_4$ - *e-endcap*	*2.68*	*1.16*
W-Shashlyk - barrel	*2.22*	*2.20*
W-Shashlyk - h-endcap	*4.46*	*4.42*
EMcal Total	**27.14**	**25.25**
Hcal - new modules	*5.48*	*5.48*
Hcal - STAR FCS	*1.17*	*0.29*
Neutral hadron & μ (KLM)	*8.52*	*8.52*
Hcal Total	**15.17**	**14.29**
Magnet	**15.84**	**15.84**
Electronics	**17.1**	**17.1**
TOTAL (Main Detector)	**121.10**	**112.49**

Cost - total

- Total cost and cost to project.
  - Escalation is not shown in the table.
- The estimates for Detector Infrastructure, Detector Pre-Ops, and Detector Management were provided by the project.

WBS	\$M (total cost)	\$M (cost to project)
Main Detector	121.10	112.49
IR Integration & Auxiliary Detectors	8.1	8.1
DAQ Computing	8.7	8.7
Detector Infrastructure	26.4	25.4
Detector Pre-Ops & Commissioning	8.7	8.7
Detector Management	7.4	7.4
TOTAL	180.40	170.79

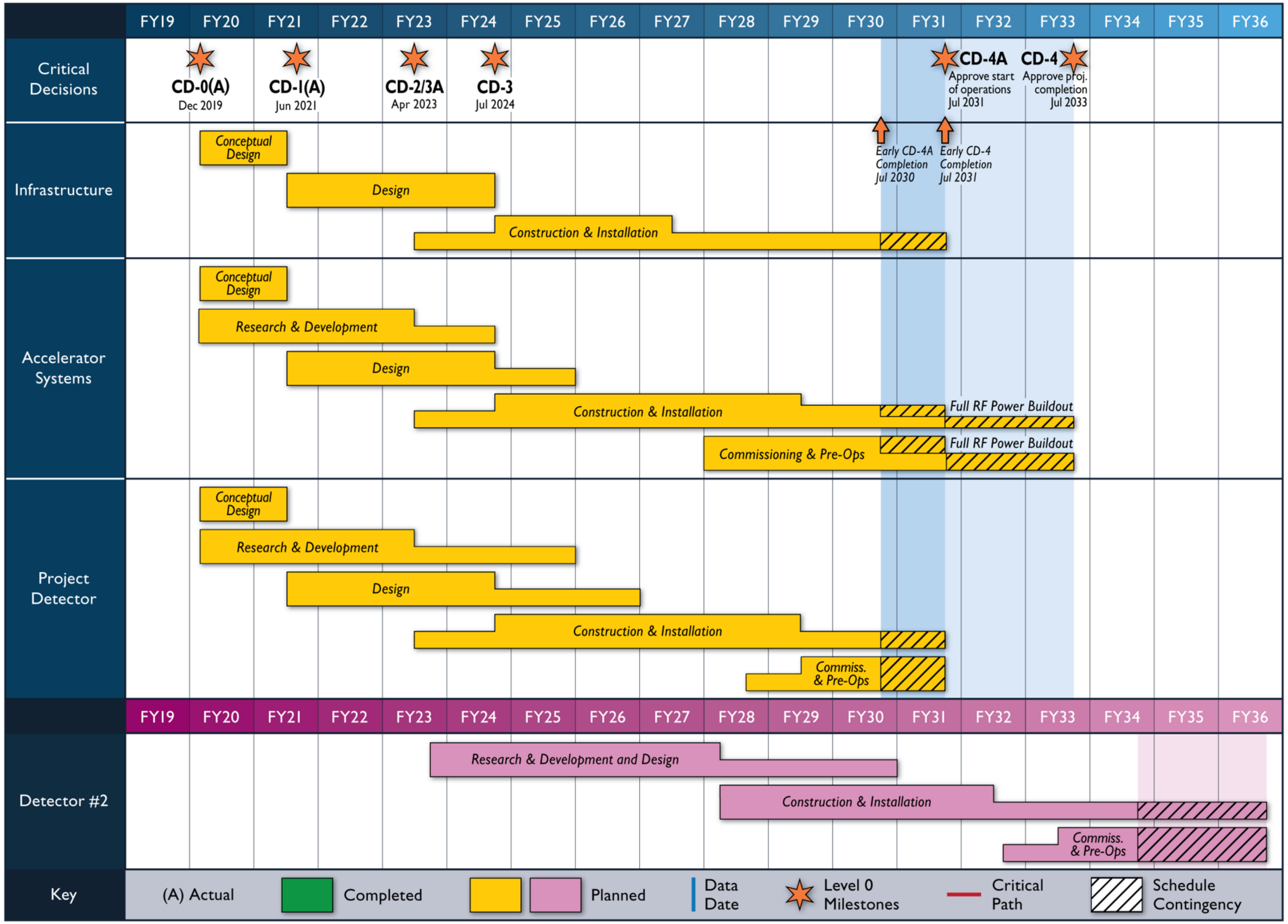
- Our estimates for DAQ computing are compatible with those done for the YR detector.
- The YR estimate for the IR Integration & Auxiliary Detectors is also generally representative of the cost for either IR6 and IR8. However, costs for the latter may change as the design evolves, and there may be additional opportunities for in-kind contributions associated with new opportunities (*e.g.,* rare isotopes).

In-kind contributions

- Items at DOE labs (BNL and JLab):
  - Detector cradle at IP8 (detector infrastructure),
  - ~1,000 non-projective $PbWO_4$ crystals for the endcap
  - 520 STAR FCS Hcal modules
  - BaBar DIRC bars. Since each bar has 4 segments, fewer than 80 would be required

- Contributions from collaborators
  - The table includes labor contributions to the DIRC and EM calorimeters
  - As the collaboration grows, we expect more such in-kind contributions

EIC project schedule



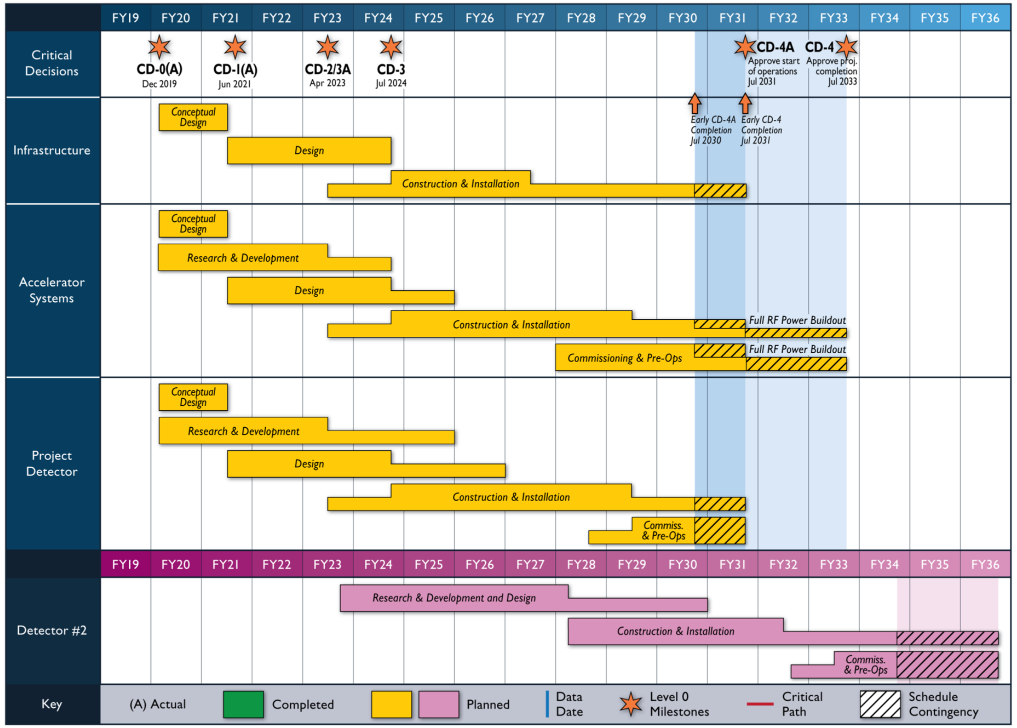
- The CORE detector can be completed by CD-4A.
- The estimated Detector 2 construction schedule is also compatible with achieving detector completion by CD-4.
- Critical issues are deliveries of $PbWO_4$ crystals and solenoid construction.
- Several systems including the MPGD, LGAD TOF, W-shashlyk EMcal, and Fe/Sci Hcal, can be built relatively quickly.

Timelines for the tracker, DIRC, and dRICH

Task	Start Time	Quarter	End Time	Quarter	Duration Q
Tracking: R&D	01/01/2022	1	10/01/2025	1	12
Tracking: Staves & Discs	26/03/2025	1	27/03/2026	1	4
Tracking: Mechanics	02/10/2024	4	10/11/2026	4	8
Tracking: Power Systems	02/10/2024	4	16/09/2025	3	4
Tracking: Silicon	02/10/2024	4	25/11/2025	4	4
Tracking: Services routing	17/09/2025	3	03/03/2026	3	4
Tracking: Assambly	11/11/2026	4	31/12/2028	4	8
Tracking: Test	01/07/2025	3	31/05/2029	2	15
Tracking: Installation	31/05/2029	2	31/12/2029	4	2

Task	Start Time	Quarter	End Time	Quarter	Duration Q
PID hpDIRC: R&D	01/01/2022	1	10/01/2025	1	12
PID hpDIRC: Procurement	01/01/2024	1	31/12/2026	4	12
PID hpDIRC: Assembly	01/01/2027	1	31/12/2028	4	8
PID hpDIRC: Test	01/07/2025	3	31/05/2029	2	15
PID hpDIRC: Installation	31/05/2029	2	31/12/2029	4	2

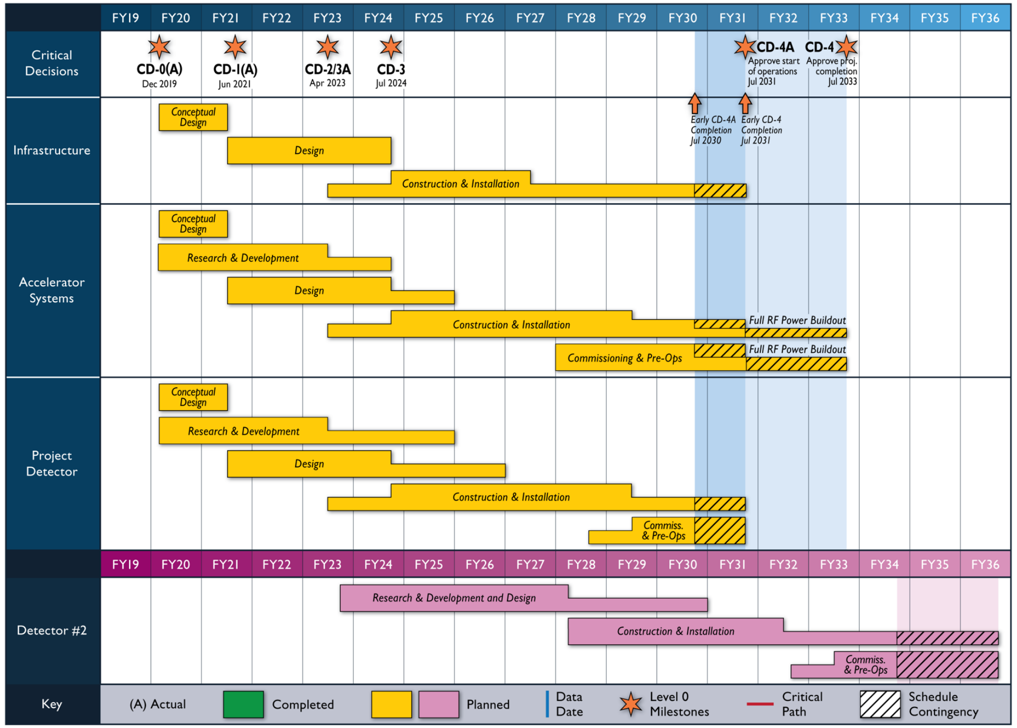
Task	Start Time	Quarter	End Time	Quarter	Duration Q
PID dRICH: R&D	01/01/2022	1	10/01/2025	1	12
PID dRICH: Procurement	01/01/2024	1	31/12/2026	4	12
PID dRICH: Assembly	01/01/2027	1	31/12/2028	4	8
PID dRICH: Test	01/07/2025	3	31/05/2029	2	15
PID dRICH: Installation	31/05/2029	2	31/12/2029	4	2



- The schedule shows a Detector 1 scenario. For Detector 2, the it would be shifted and the R&D phase would be shorter.

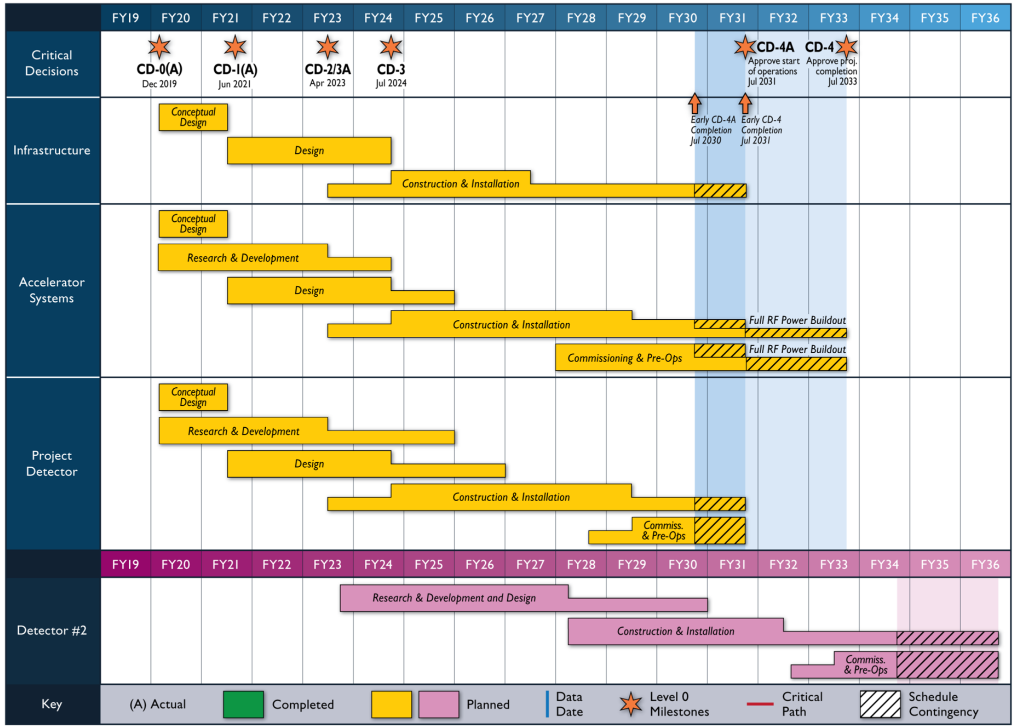
Solenoid timeline

- The timeline for the CORE solenoid assumes a 4-year contract for construction followed by a year of installation and commissioning at BNL
- This would be preceded by one year of Engineering & Design and procurement.
  - Preliminary E&D would start earlier.
- If funding becomes available at CD-3, there should be sufficient time until CD-4A for construction, installation, and commissioning
- The proposed timeline is also compatible with completion by CD-4 for Detector 2



$PbWO_4$ timeline

- There are two established producers of $PbWO_4$ crystals: Crytur and SICCAS
  - Crytur supplies crystals for PANDA and has in recent years had better QA
- CORE needs 11,200 - 12,200 crystals
  - Re-use of 1,000 crystals is assumed.
- With a production rate of 200 / month all crystals could be delivered within 5 years
  - This rate is reasonable for Crytur and could be supplemented by SICCAS.
  - Crystals would be prepared for use in parallel with new deliveries
- To minimize risk of production delays, $PbWO_4$ would be a good candidate for CD-3A, early procurement.



- In case of delays, the fallback plan would be to extend the W-shaskyk coverage. Since Uniplast can build all baseline CORE modules (barrel and endcap) in six months, a decision on a small increase can be made fairly late without affecting timelines.

Potential upgrade paths

The baseline CORE detector has all the subsystems required to execute the full EIC physics program. There are, however, some short- and long-term opportunities for upgrades

- Short term: an LGAD TOF layer can be added behind the last MAPS disk on the hadron side.

- Mid-life upgrade: photosensors used by the DIRC and dRICH are quickly evolving technologies. In the future, it may be possible to improve performance by only replacing the photosensors and electronics. For the DIRC, better timing could improve the momentum reach, and for the dRICH lower noise levels could reduce noise cooling requirements.

- Mid-life upgrade: Si-tracking is another rapidly evolving technology. A future tracker could further reduce the mass, which would improve dp/p at low momenta.

- There are also more speculative upgrade paths. For instance, a breakthrough in the use optical metamaterials as Cherenkov radiators could make it possible to replace the dRICH with a much more compact system, which would enable moving the accelerator magnets even closer to the IP.

The CORE proto-collaboration - structure

- The CORE proto-collaboration currently includes 25 institutions, of which 8 are foreign.

- Since there are three proposals presented for at most two detectors, we expect that a consolidation will occur after the review is completed.

- CORE has thus taken its role as a proto-collaboration seriously, and avoided to set up permanent structures before proposal submission to ensure that both current and future members can participate equally in shaping the collaboration.
    - This consideration would be particularly important for a Detector 2 collaboration, which needs to be as broad as possible.

- The CORE proto-collaboration developed the proposal as a group of interested parties, with a direct participation by all its members, without (as of yet) establishing a formal collaboration structure - although topical working groups naturally emerged.

The CORE proto-collaboration

- An important role the proto-collaboration was also to establish close links with the various technology-focused consortia that the EIC community has self-organized into.
- We also expect that the collaboration will benefit from the support from major laboratories, particularly for major procurements, such as the solenoid magnet and silicon tracker.
- We do not claim that the signatories of this proposal at this time have the resources to alone build the CORE detector, but the proto-collaboration forms a strong basis for a full collaboration and its current members can take the lead in designing and building key components of the detector.
- We believe that our proposal is innovative and contains numerous opportunities for participation in providing the major sub-systems of the experiment. We expect additional support to emerge quickly if CORE receives encouragement from the EIC Detector Proposal Advisory Panel.

Construction

Participation and preliminary commitments to construction.
Potential Source of Support are not committed.

- We have had in-depth discussions with a broad range of people in the "Potential Source of Support" column throughout the preparation of this proposal.

Sub-system	Primary Responsibility	Key Participants	Potential Source of Support
Solenoid	P. Brindza (ODU/JLab)		JLab/BNL Magnet Groups
Silicon tracker	S. Bueltmann (ODU)		EIC Silicon consortium
MPGD	M. Hohlmann (FIT)	K. Gnanvo (JLab)	JLab Detector Group
DIRC	G. Kalicy (CUA)	J. Schwiening (GSI)	PANDA DIRC Group (GSI)
dRICH	K. Joo (UConn)		CFNS @ Stony Brook, PID consortium
LGAD			LGAD consortium
$PbWO_4$ EMcal	C. Muñoz Camacho (IJCLab)	C. Hyde (ODU)	Electron Endcap EMcal consortium
W-shashlyk EMcal		LLC Uniplast	
Forward Hcal			Calorimeter consortium
KLM	W. Jacobs (IU)	A. Vossen (Duke)	
Pair spectrometer	M. Dugger (ASU)		
Low-Q^2 tagger	L. Guo (FIU)		
ZDC	M. Murray (KU)		
Forward Tracking	M. Murray (KU)		
Electronics	G. Varner (UH)	I. Mostafanezhad (Nalu)	JLab/BNL Electronics Groups

- Some of the "gaps" correspond to topics that are of the natural scale for recruiting University research groups.

Next steps towards a CORE collaboration

Presuming CORE is endorsed by BNL & JLab, as well as the EIC Project as an EIC Detector:

- We expect broad interest in the international EIC community to join CORE.
- We will aggressively recruit in critical areas of expertise and capacity.
- All will be welcome, without distinction to "originals" vs. "newcomers."
- CORE is ready to move quickly on Long-Lead-Time items.
- We will recruit a Charter committee broadly across all interested parties and move quickly to develop a structure and elect officers consistent with our principles of Diversity & Inclusion.

Thank you!