EIC Status

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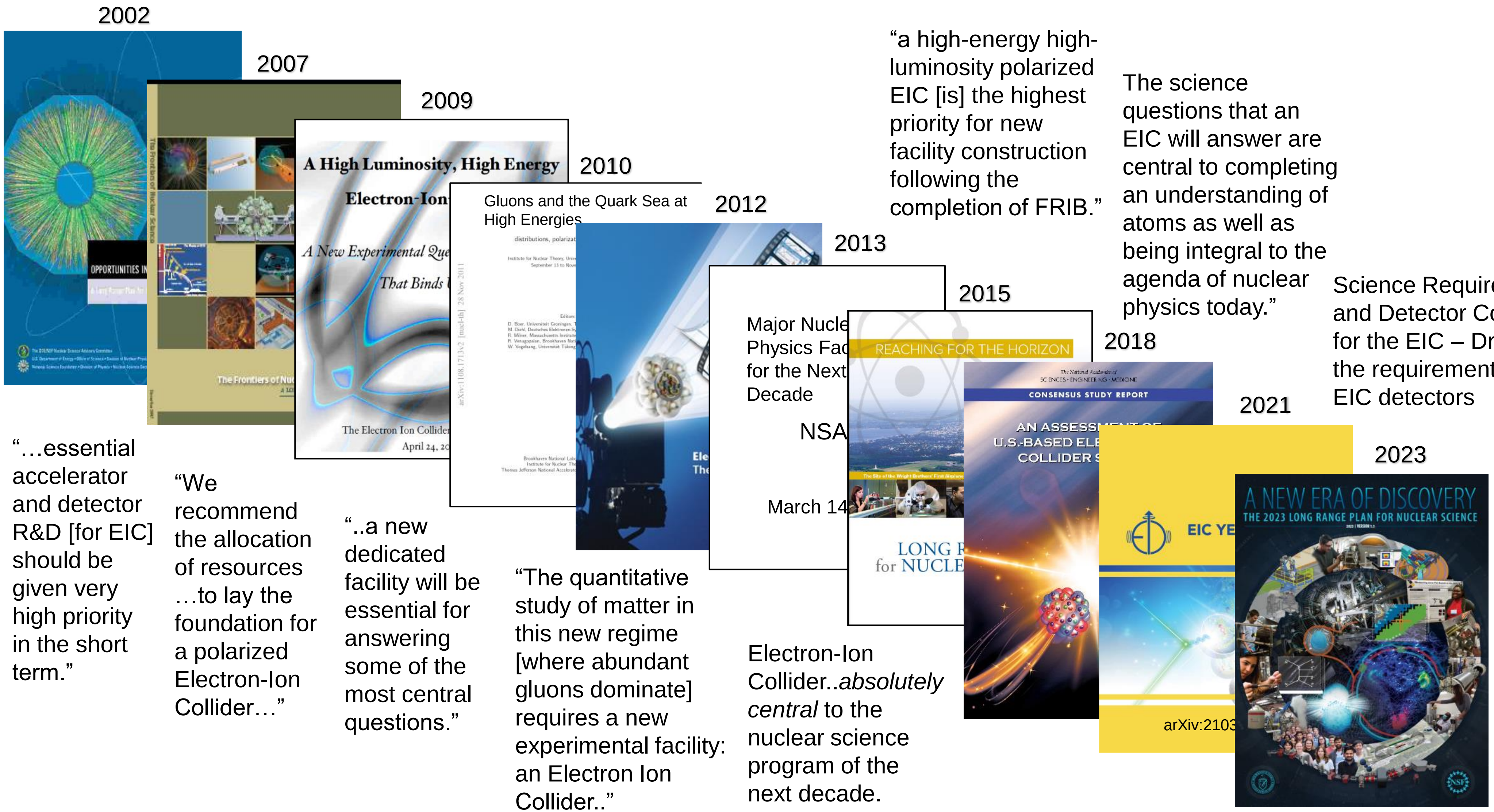
EIC Detector Leads

EIC-Asia Workshop
January 29-31, 2024
NCKU, Taiwan
Electron-Ion Collider

Outline

- High Level Overview & Requirements
- Schedule and Accelerator/Infrastructure Status
- Detector Scope
- Design Status and Progress - since CD-1
- CD-3A Long-Lead Procurement Overview
- Peer Review Summary
- Other Topics
  - Systems Engineering, Interfaces and User Accessibility
  - Backgrounds
  - Installation Schedule
- In-Kind/International Engagement
- Outlook to CD-2
- Summary

The Scientific Foundation for an EIC was Built Over Two Decades



"…essential accelerator and detector R&D [for EIC] should be given very high priority in the short term."

"We recommend the allocation of resources …to lay the foundation for a polarized Electron-Ion Collider…"

"..a new dedicated facility will be essential for answering some of the most central questions."

"The quantitative study of matter in this new regime [where abundant gluons dominate] requires a new experimental facility: an Electron Ion Collider.."

Electron-Ion Collider..*absolutely central* to the nuclear science program of the next decade.

"a high-energy high-luminosity polarized EIC [is] the highest priority for new facility construction following the completion of FRIB."

The science questions that an EIC will answer are central to completing an understanding of atoms as well as being integral to the agenda of nuclear physics today."

Science Requirements and Detector Concepts for the EIC – Drives the requirements of EIC detectors

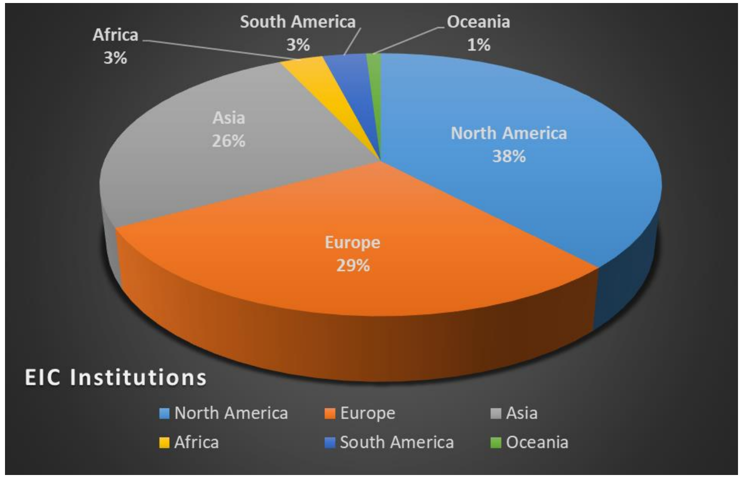
We recommend the expeditious completion of the EIC as the highest priority for facility construction.

EIC Community of Users

EIC User Group formed in 2016:
https://eicug.org/

Status January 2024:

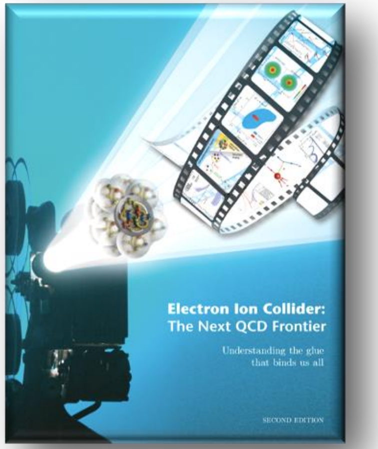
• Collaborators	1440
• Institutions	295
• Countries	40



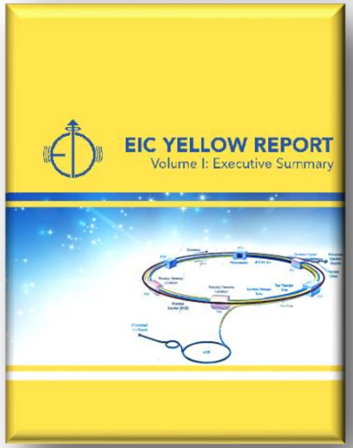
Annual EICUG meeting
2016 UC Berkeley, CA
2016 Argonne, IL
2017 Trieste, Italy
2018 CUA, Washington, DC
2019 Paris, France
2020 FIU, Miami, FL
2021 VUU, VA & UCR, CA
2022 Stony Brook U, NY
2023 Warsaw, Poland
2024 Lehigh U, PA

EIC Science is Well Known and Highly Cited

- EIC White Paper that guided the EIC science written following a 10-week program at the Institute for Nuclear Theory
  - Electron-Ion Collider: The Next QCD Frontier: understanding the glue that binds us all
  - arXiV:1212.1701 & Eur. Phys. J. A 52 (2016) 9, 268 – **1554 citations (01/28/2024)**



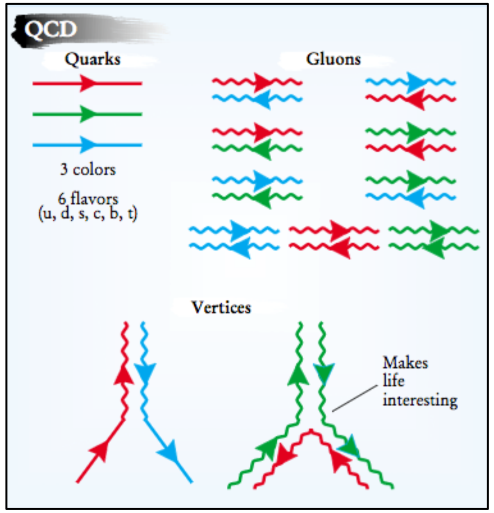
- Year-long EIC User Group driven EIC Yellow Report activity (December 2019 – February 2021)
  - Science Requirements and Detector Concepts for the EIC – The Yellow Report set the (*initial*) EIC detector requirements.
  - arXiv:2103.05419 & Nucl. Phys. A 1026 (2022) 122447 – **726 citations (01/28/2024)**

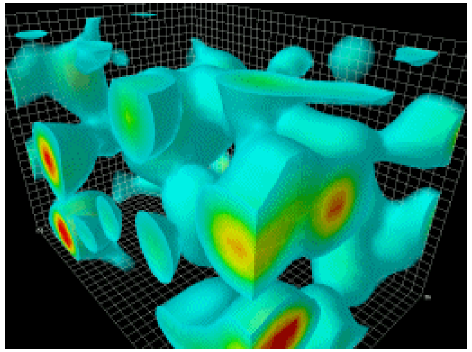


Requirements have then been further updated during proposal and follow-up processes

EIC: 21st Century Laboratory of Emergent Dynamics in QCD

- Massless gluons & almost massless quarks, *through their interactions,* generate most of the mass of the nucleons
- Gluons carry ~50% of the proton's momentum, a significant fraction of the nucleon's spin, and are essential for the dynamics of confinement
- Properties of hadrons – composite systems of quarks and gluons – are emergent phenomena and inextricably tied to the properties of the QCD vacuum. Striking examples besides confinement are spontaneous symmetry breaking and anomalies
- The nucleon-nucleon forces emerge from quark-gluon interactions: how this happens remains a mystery

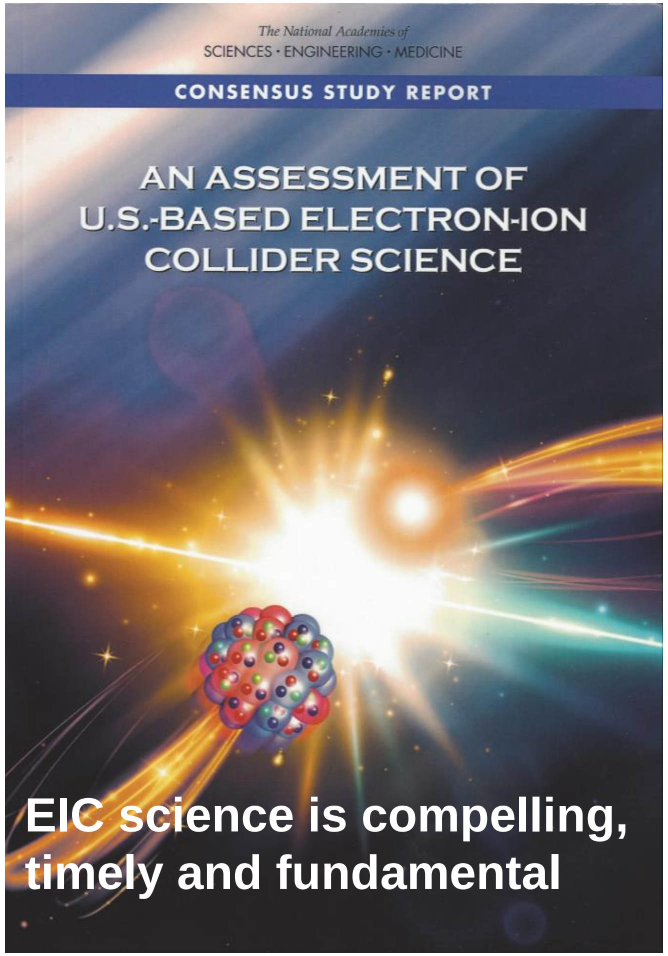




- The goal is to provide us with an understanding of the internal structure of the proton and more complex atomic nuclei that is comparable to our knowledge of the electronic structure of atoms, which lies at the heart of modern technologies

EIC Science – Findings of the NAS Committee

2018 The National Academies of SCIENCES · ENGINEERING · MEDICINE

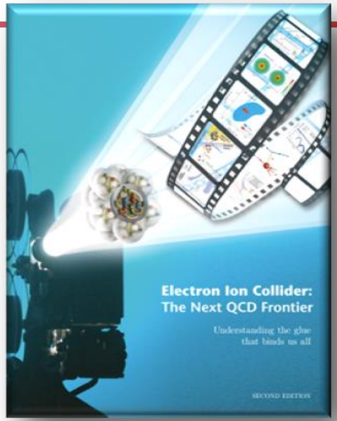


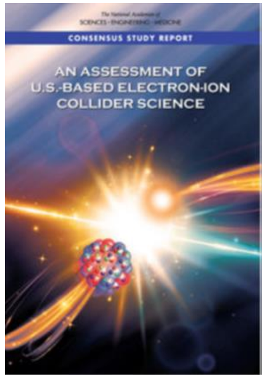
EIC science is compelling, timely and fundamental

Developed by NAS committee with broad science perspective

- **Finding 1:** An EIC can uniquely address three profound questions about nucleons — neutrons and protons — and how they are assembled to form the nuclei of atoms:
  - How does the **mass** of the nucleon arise?
  - How does the **spin** of the nucleon arise?
  - What are the **emergent properties** of dense systems of gluons?
- **Finding 2:** These three high-priority science questions can be answered by an EIC with **highly polarized beams** of electrons and ions, with sufficiently **high luminosity** and sufficient, and **variable**, center-of-mass **energy**.

NAS Report on EIC Requirements





In order to definitively answer the compelling scientific questions elaborated in Chapter 2, including the origin of the mass and spin of the nucleon and probing the role of gluons in nuclei, a new accelerator facility is required, an electron-ion collider (EIC) with unprecedented capabilities beyond previous electron scattering programs. An EIC must enable the following:

- Extensive center-of-mass energy range, from ~20-~100 GeV, upgradable to ~140 GeV, to map the transition in nuclear properties from a dilute gas of quarks and gluons to saturated gluonic matter.
- Ion beams from deuterons to the heaviest stable nuclei.
- Luminosity on the order of 100 to 1,000 times higher than the earlier electron-proton collider Hadron-Electron Ring Accelerator (HERA) at Deutsches Elektronen-Synchrotron (DESY), to allow unprecedented three-dimensional (3D) imaging of the gluon and sea quark distributions in nucleons and nuclei.
- Spin-polarized (~70 percent at a minimum) electron and proton/light-ion beams to explore the correlations of gluon and sea quark distributions with the overall nucleon spin. Polarized colliding beams have been achieved before only at HERA (with electrons and positrons only) and Relativistic Heavy Ion Collider (RHIC; with protons only).

The EIC requirements have remained consistent, see e.g., the 2012 white paper and 2015 NSAC Long Range Plan

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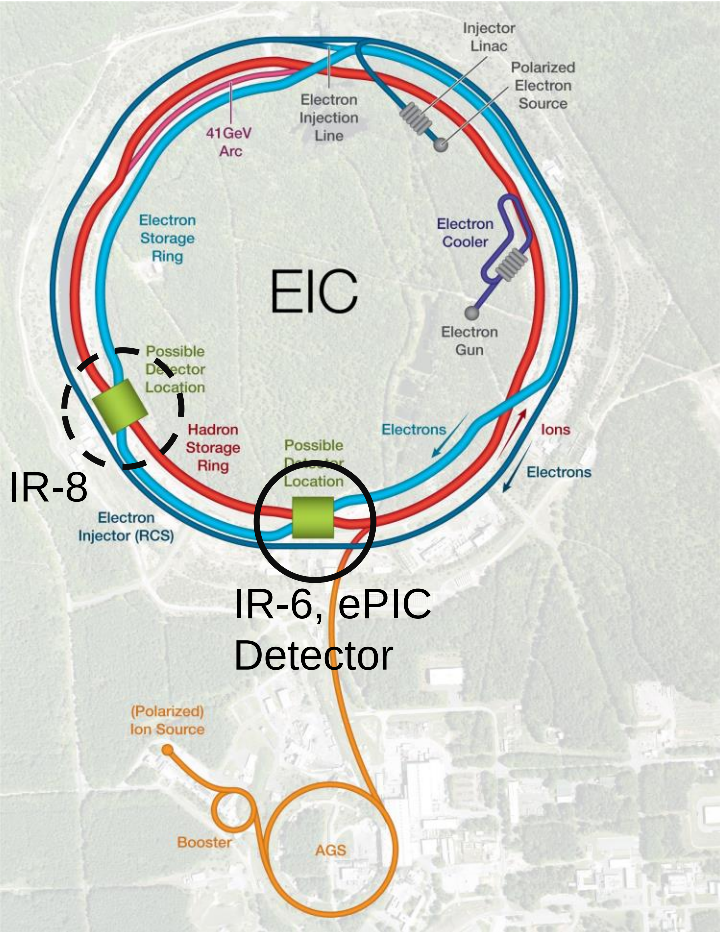
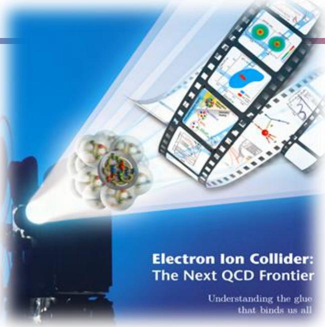
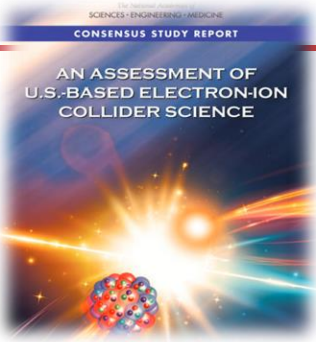
EIC Scope







Project Design Goals

- High Luminosity: L= 10^{33} – 10^{34} $cm^{-2}sec^{-1}$, 10 – 100 fb^{-1}/year
- Highly Polarized Beams: 70%
- Large Center of Mass Energy Range: E_{cm} = 29 – 140 GeV
- Large Ion Species Range: protons – Uranium
- Large Detector Acceptance and Good Background Conditions
- Accommodate a Second Interaction Region (IR)

IR-8

p: 41 GeV, 100 to 275 GeV p/A beam → ← e beam **e: 5 GeV to 18 GeV**

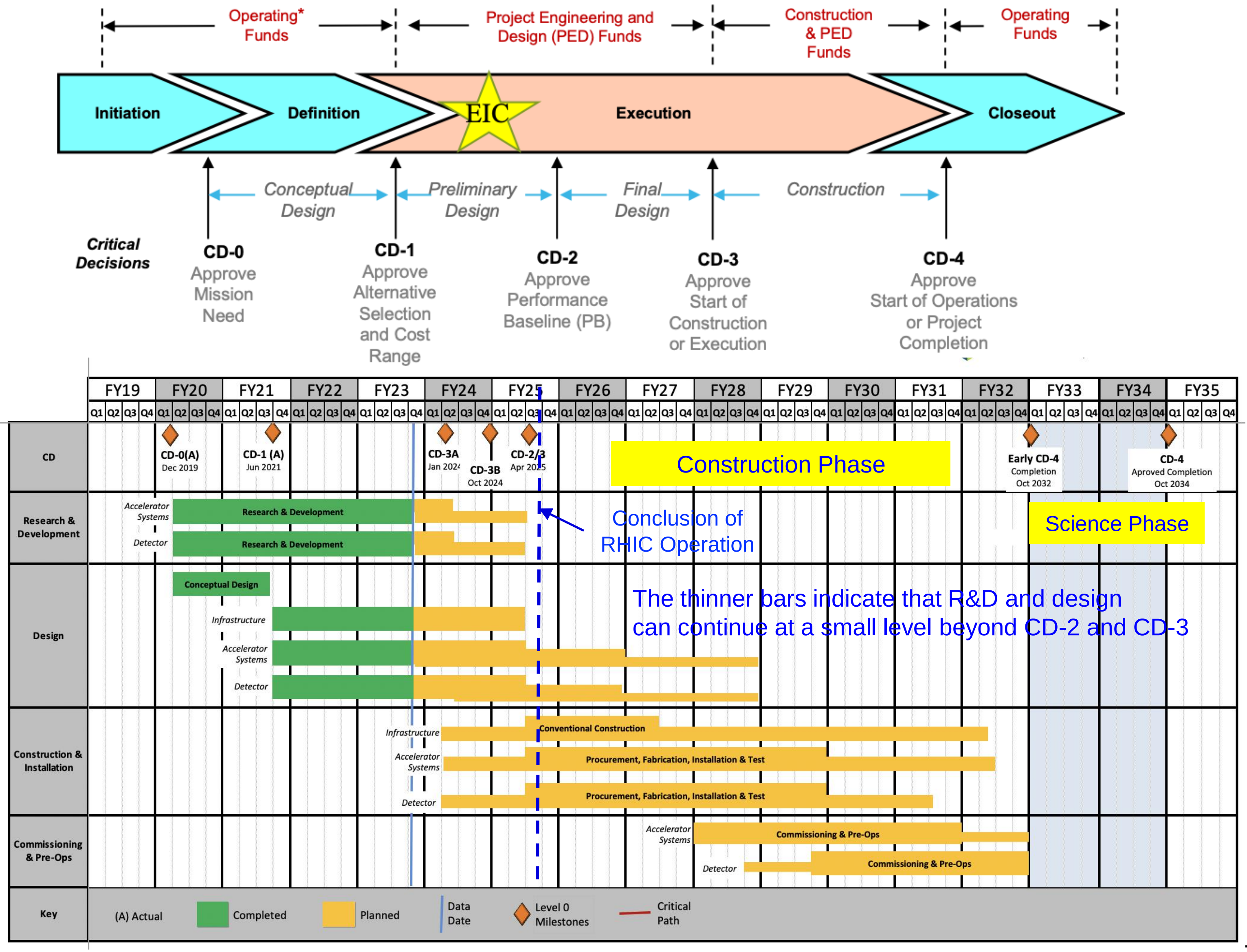
EIC Schedule

EIC Critical Decision Plan

CD-0/Site Selection	December 2019 ✓
CD-1	June 2021 ✓
CD-3A	January 2024
CD-3B	**October 2024**
CD-2/3	**April 2025**
early CD-4	October 2032
CD-4	**October 2034**

CD-2:
Approve preliminary design for all subdetectors
Design Maturity: >60%
Need "pre-"TDR (or draft TDR)
Baseline project in scope, cost, schedule

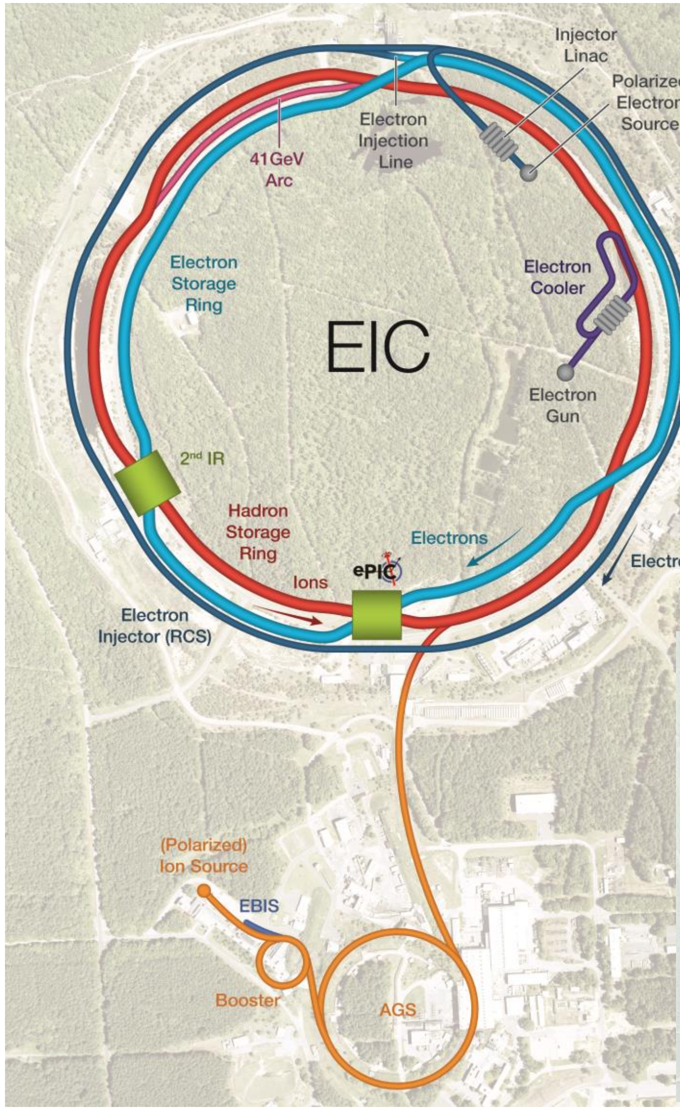
CD-3:
Approve final design for all subdetectors
Design Maturity: ~90%
Need full TDR

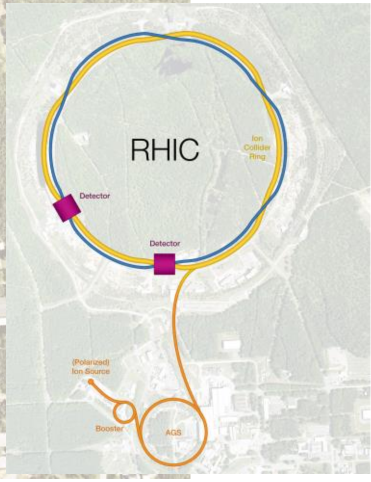


Facility layout

Slide from Christoph Montag

- Hadron Storage Ring comprised of “Blue” and “Yellow” RHIC arcs
- Layout breaks RHIC symmetry
- Retaining RHIC injector chain, using “Blue” arc as transfer line
- Strong Hadron Cooling in IR12
- Electron complex to be installed in existing RHIC tunnel – cost effective



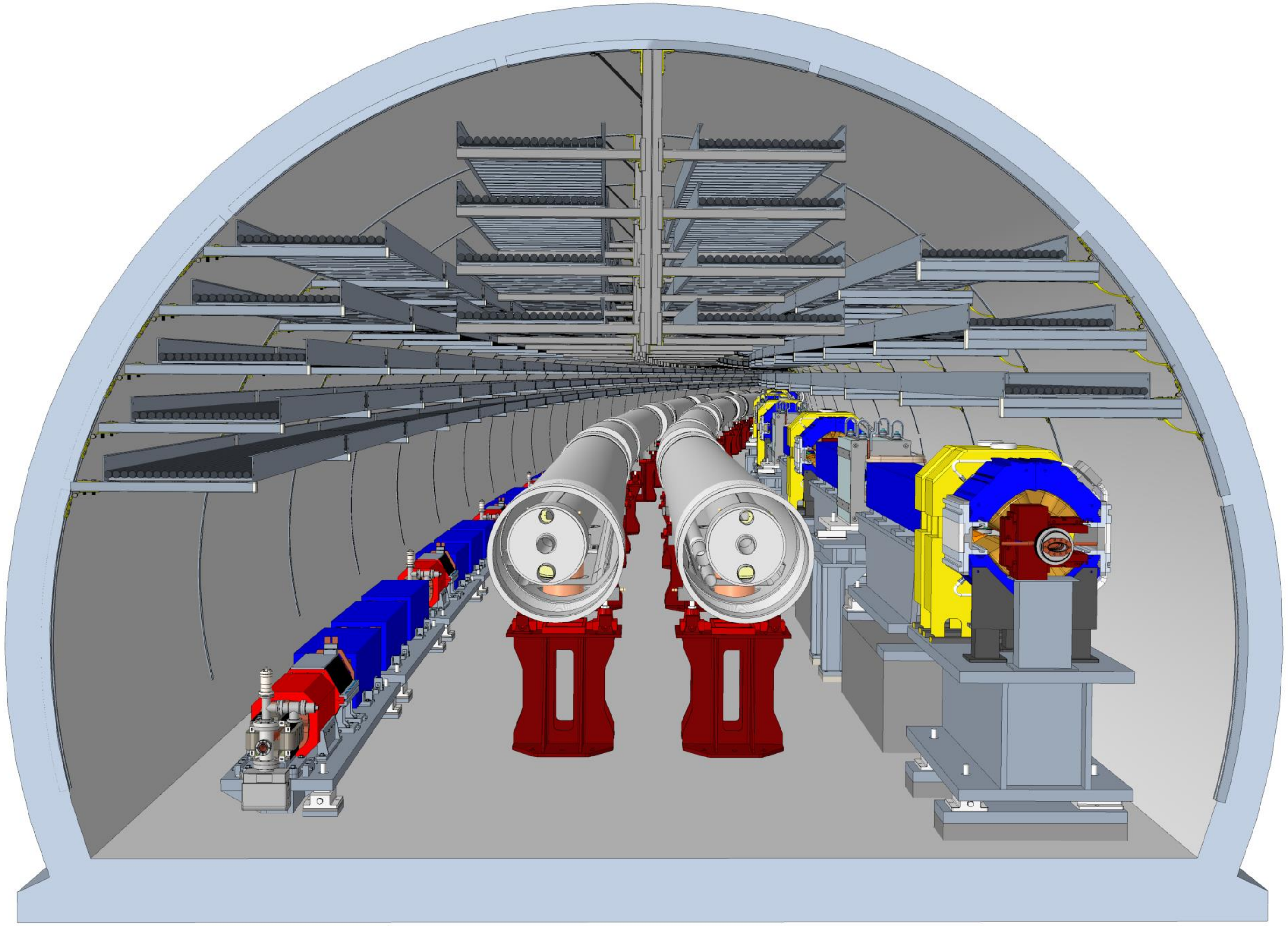


Tunnel Cross Section

Slide from Christoph Montag

All accelerators fit into the existing tunnel

- ESR at same height as RHIC, tilted by 200 μrad around axis through IPs 6 and 8 to simplify cross-overs in IRs 4 and 12
- RCS at ~60 cm above tunnel floor, underneath ESR in three arcs (not shown here)



Recycling APS Magnets for the ESR

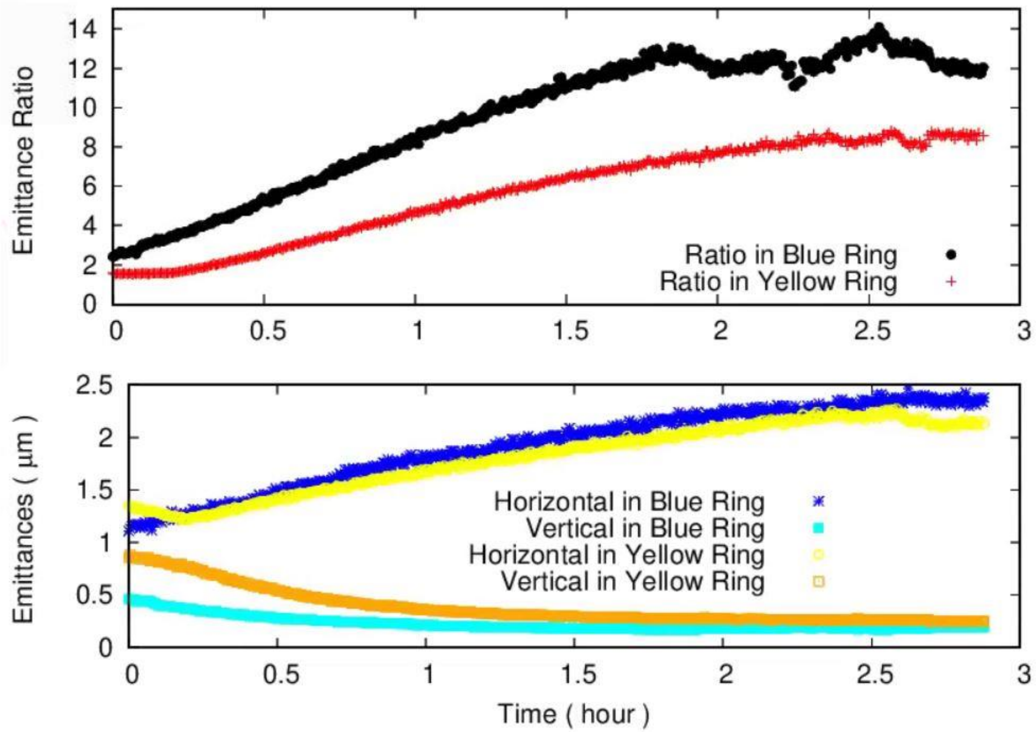
- 400 Quadrupoles and 280 Sextupoles from the Advanced Photon Source at ANL to be repurposed for ESR
- ~ $7M cost savings
- All girders have been shipped to BNL and TJNAF
- Disassembly well underway at BNL, recently started at TJNAF

Demonstration of Flat Beams in RHIC

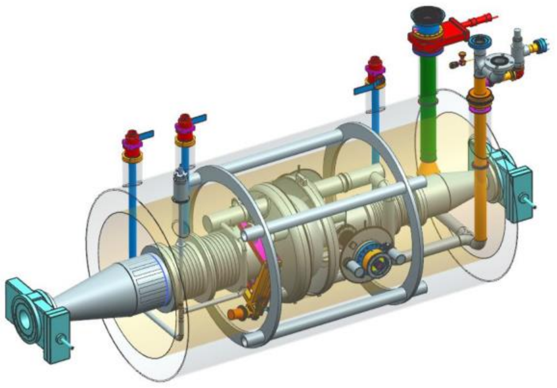
Slide from Christoph Montag

- To achieve maximum luminosity performance, EIC needs “flat” hadron beams with unequal emittances
- Required emittance ratio: $\frac{\varepsilon_y}{\varepsilon_x} = 0.1$
- Hadron beams with unequal emittances are a novelty – SppS, TEVATRON, HERA, RHIC, LHC, … all had “round” hadron beams
- Achieving unequal emittances requires careful decoupling of the two transverse planes
- Demonstrated during APEX in RHIC in 2023 – great achievement!

Feasibility of EIC Design Parameters: Generation of & collisions with flat hadron beam demonstrated in RHIC, emittance ratio $\frac{\varepsilon_y}{\varepsilon_x} = 0.09$

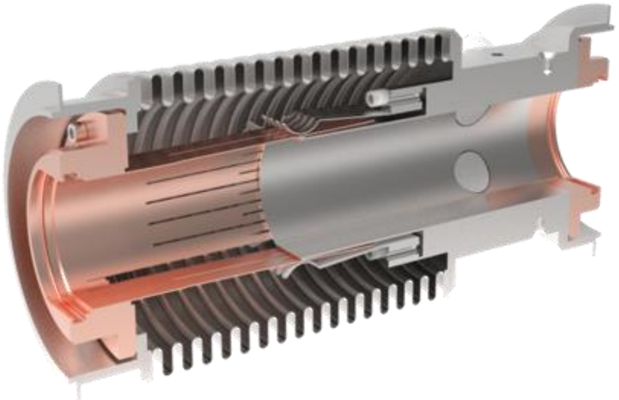


Accelerator 5 Long-Lead Procurement (LLP) Items

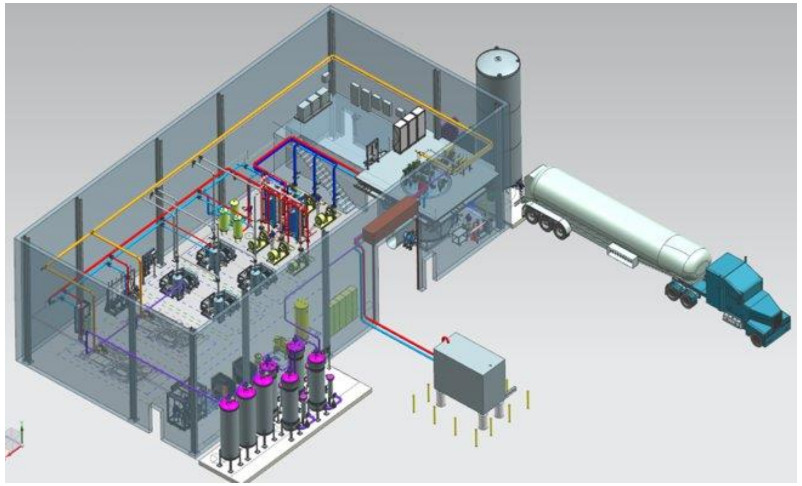


591 MHz Single Cell Cryomodule First Article

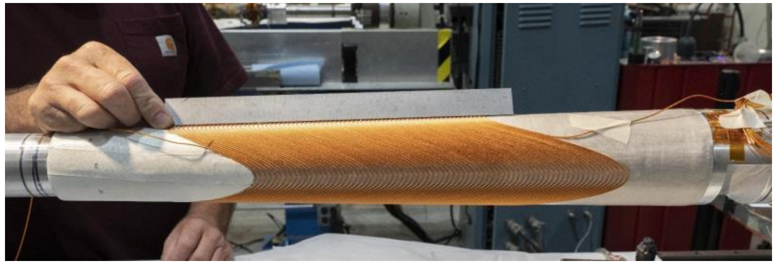
HSR Beam Screen Material



HSR BPM Buttons at Cryogenic Temperatures



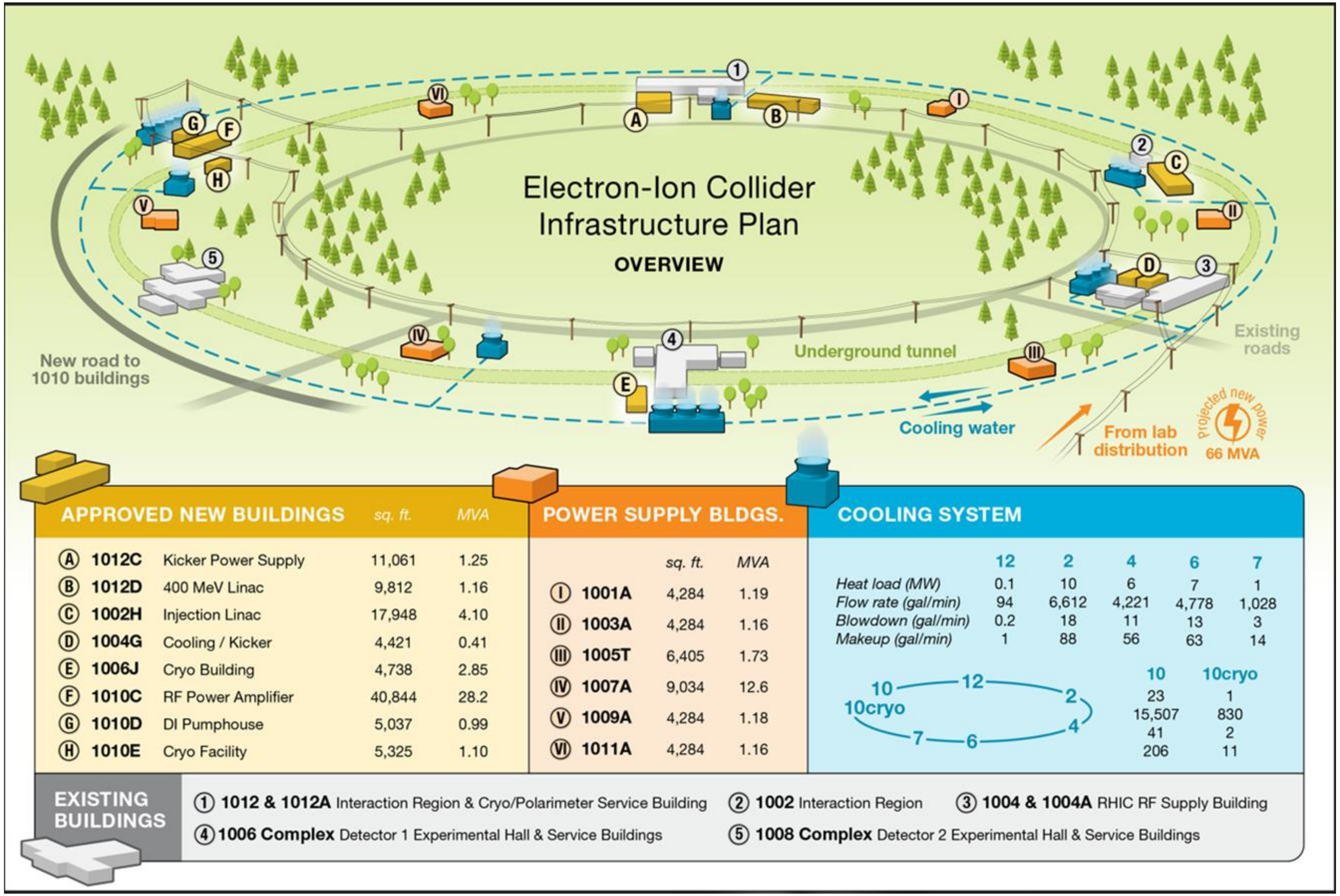
Cryogenic 2K Satellite Plant for IR 10



Strands for Superconducting IR Magnets

Scope WBS 6.11 Infrastructure

Slide from Charles Folz



APPROVED NEW BUILDINGS			sq. ft.	MVA
Ⓐ	1012C	Kicker Power Supply	11,061	1.25
Ⓑ	1012D	400 MeV Linac	9,812	1.16
Ⓒ	1002H	Injection Linac	17,948	4.10
Ⓓ	1004G	Cooling / Kicker	4,421	0.41
Ⓔ	1006J	Cryo Building	4,738	2.85
Ⓕ	1010C	RF Power Amplifier	40,844	28.2
Ⓖ	1010D	DI Pumphouse	5,037	0.99
Ⓗ	1010E	Cryo Facility	5,325	1.10

POWER SUPPLY BLDGS.		sq. ft.	MVA
Ⅰ	1001A	4,284	1.19
Ⅱ	1003A	4,284	1.16
Ⅲ	1005T	6,405	1.73
Ⅳ	1007A	9,034	12.6
Ⅴ	1009A	4,284	1.18
Ⅵ	1011A	4,284	1.16

COOLING SYSTEM

	12	2	4	6	7
Heat load (MW)	0.1	10	6	7	1
Flow rate (gal/min)	94	6,612	4,221	4,778	1,028
Blowdown (gal/min)	0.2	18	11	13	3
Makeup (gal/min)	1	88	56	63	14

10	10cryo
23	1
15,507	830
41	2
206	11

EXISTING BUILDINGS

① 1012 & 1012A Interaction Region & Cryo/Polarimeter Service Building
② 1002 Interaction Region
③ 1004 & 1004A RHIC RF Supply Building
④ 1006 Complex Detector 1 Experimental Hall & Service Buildings
⑤ 1008 Complex Detector 2 Experimental Hall & Service Buildings

LLP Scope

- Scope:
  - Procure 15 Secondary Unit Substations, 13.8kV to 480V.
  - Primary power to EIC equipment support buildings.
  - Installation is not part of the CD-3A scope

- Current industry outlook indicates extremely long lead times – typically 2.5 yrs. and up.
- Substations are required to complete BOREs (Building Occupancy Readiness Evaluations) in support of accelerator equipment installation.
- Minimize or eliminate need for temporary power

OPA CD-3A Review recommendation: Proceed to CD-3A.
Anticipating ESAAB in March 2024

Detector Scope

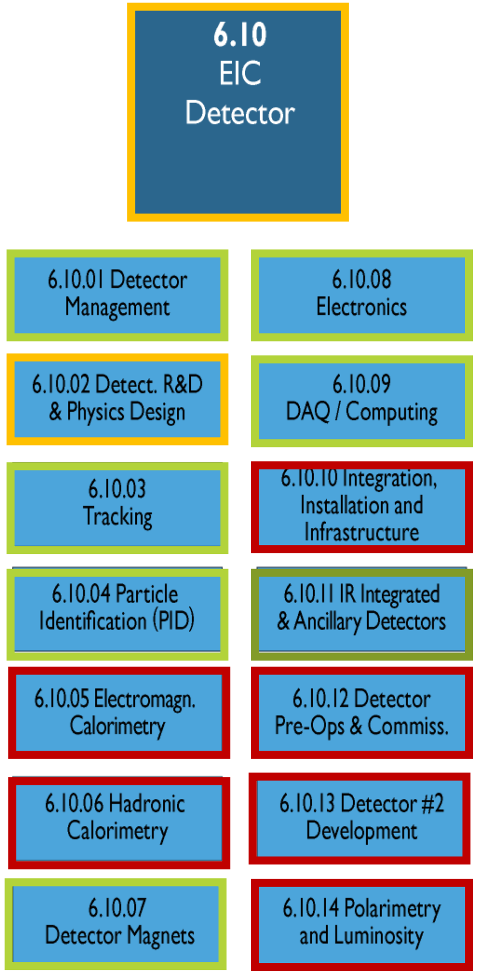
WBS View – Detector

Detector

6.0 Electron-Ion Collider

- **6.01 Project Management**
  - 6.01.01 Project Management
  - 6.01.02 ESH
  - 6.01.03 Project & Mission Support
  - 6.01.04 Quality Assurance
- **6.02 Accelerator Development & R&D**
  - 6.02.01 Accel. Devel. & R&D Mngmt.
  - 6.02.02 Accel. Physics & Design
  - 6.02.03 Accel. Systems R&D
- **6.03 Electron Injector**
  - 6.03.01 Electron Injector Mngmt.
  - 6.03.02 Rapid Cycling Synch. (RCS)
  - 6.03.03 Transf. Lines & Inj./Extr. Elements
  - 6.03.04 Electron Pre-Injector
- **6.04 Electron Storage Ring**
  - 6.04.01 Electron Storage Ring Mngmt.
  - 6.04.02 Elect. Strg. Ring Magnets - Dipole, Sextupole
  - 6.04.03 Elect. Strg. Ring Magnets - Quadrupole, Corrector
  - 6.04.04 Electron Strg. Ring Pwr. Sup.
  - 6.04.05 Elect. Strg. Ring Vacuum System
  - 6.04.06 Electron Strg. Ring Instrum.
- **6.05 Hadron Ring**
  - 6.05.01 Hadron Ring Management
  - 6.05.02 Hadron Ring Strght. Sect. Modif.
  - 6.05.03 Hadron Ring Inject. Syst. Upgrade
  - 6.05.04 HR SC Magn. Beam Pipe Upgrade
  - 6.05.05 Hadron Ring Beam Instr. Upgrade
  - 6.05.06 Hadron Ring Additional Snakes
  - 6.05.07 Hadron Cooling
  - 6.05.08 SHC Energy Rcvry Linac (ERL)
- **6.06 Interaction Regions & Detector Interface**
  - 6.06.01 IR & Detect. Interface Mngmt.
  - 6.06.02 Interaction Region (IR)
  - 6.06.03 Machine-Detector Integration
  - 6.06.04 IR#2 Development
- **6.07 Accelerator Support Systems**
  - 6.07.01 Acc. Sup. Sys. Mngmt. & Infrastruct.
  - 6.07.02 Control System
  - 6.07.03 EIC Acc./Strg. Ring Systs. Installations
  - 6.07.04 EIC Acc./Strg. Ring Systems Removals
- **6.08 RF Systems**
  - 6.08.01 RF Systems Mngmt & Integr.
  - 6.08.02 SRF R&D
  - 6.08.03 SRF First Article Cryomodules
  - 6.08.04 SRF Cryomodules
  - 6.08.05 NCRF Cavities
  - 6.08.06 High Power RF Systems
  - 6.08.07 RF Controls
  - 6.08.08 Facilities Modifications
- **6.09 Cryogenics**
  - 6.09.01 Cryogenics Management
  - 6.09.02 2K Satellite Plants IR02, IR06, IR10
  - 6.09.03 Reconfig. of Exist. & New 4K Dist.
  - 6.09.04 2K Cry. Dist. & 4K HSR Conn.
  - 6.09.05 Cryogenic Controls
- **6.10 EIC Detector**
  - 6.10.01 Detector Management
  - 6.10.02 Detect. R&D & Physics Design
  - 6.10.03 Tracking
  - 6.10.04 Particle Identification (PID)
  - 6.10.05 Electromagn. Calorimetry
  - 6.10.06 Hadronic Calorimetry
  - 6.10.07 Detector Magnets
  - 6.10.08 Electronics
  - 6.10.09 DAQ / Computing
  - 6.10.10 Integration, Installation and Infrastructure
  - 6.10.11 IR Integrated & Ancillary Detectors
  - 6.10.12 Detector Pre-Ops & Commiss.
  - 6.10.13 Detector #2 Development
  - 6.10.14 Polarimetry and Luminosity
- **6.11 Infrastructure**
  - 6.11.01 Infrastr. Mngmt. & Engnrng.
  - 6.11.02 Civil Construction
  - 6.11.03 Electrical Power Systems
  - 6.11.04 Cooling Systems
- **6.12 Pre-Operations**
  - 6.12.01 Pre-Ops Planning & Mngmt.
  - 6.12.02 Systems Commissioning
  - 6.12.03 Beam Commissioning
  - 6.12.04 Spares

Scope: WBS 6.10



WBS 6.10	EIC Detector	R. Ent, E. Aschenauer

-Description: This WBS covers the cost for R&D, PED and construction of a general-purpose reference detector capable of the physics program detailed in the NAS review at full center-of-mass energy range (20 GeV and 140 GeV) and luminosity (10^{33-34} $cm^{-2}s^{-1}$). The detector consists of a solenoidal magnet, the central detector with 5 subsystems and a lepton and hadron endcap with each 5 subsystems. Further data-acquisition and trigger, infrastructure and integration as well as online and offline software efforts are included in the scope. In addition, the auxiliary detectors needed to tag particles with very small scattering angles both in the outgoing lepton and hadron beam direction (Roman Pots, Zero-degree Calorimeter and low Q^2-tagger).

Deliverables:

EIC detector designed, constructed and commissioned.

BNL JLab Joint Lead

The ePIC Detector

- Asymmetric beam energies
  - requires an asymmetric detector with electron and hadron endcap
  - tracking, particle identification, EM calorimetry and hadronic
    calorimetry functionality in all directions
  - very compact Detector, Integration will be key
- Imaging science program with protons and nuclei
  - requires specialized detectors integrated in the IR over 80 m
- Momentum resolution for EIC science
  - requires a large bore 2T magnet
    (1.7 T magnet operation point, stretch goal 2T
    that has same geometry as the BaBAR magnet).
- Highest scientific flexibility
  - requires Streaming Readout electronics model

hadronic calorimeters (HCAL)

Solenoidal Magnet

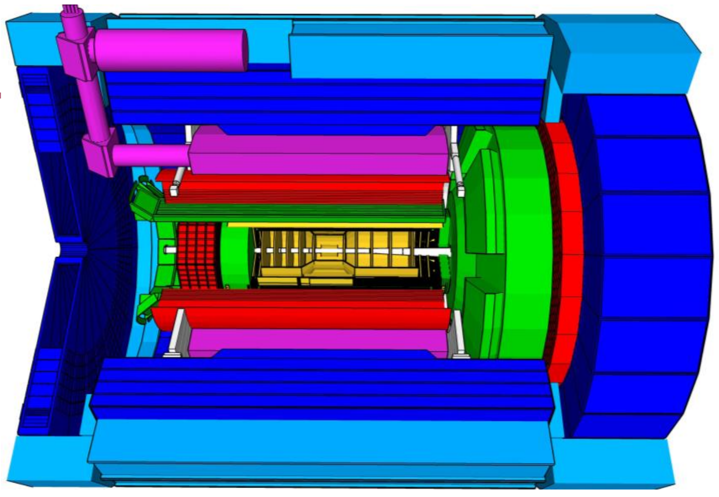
e/m calorimeters (ECal)

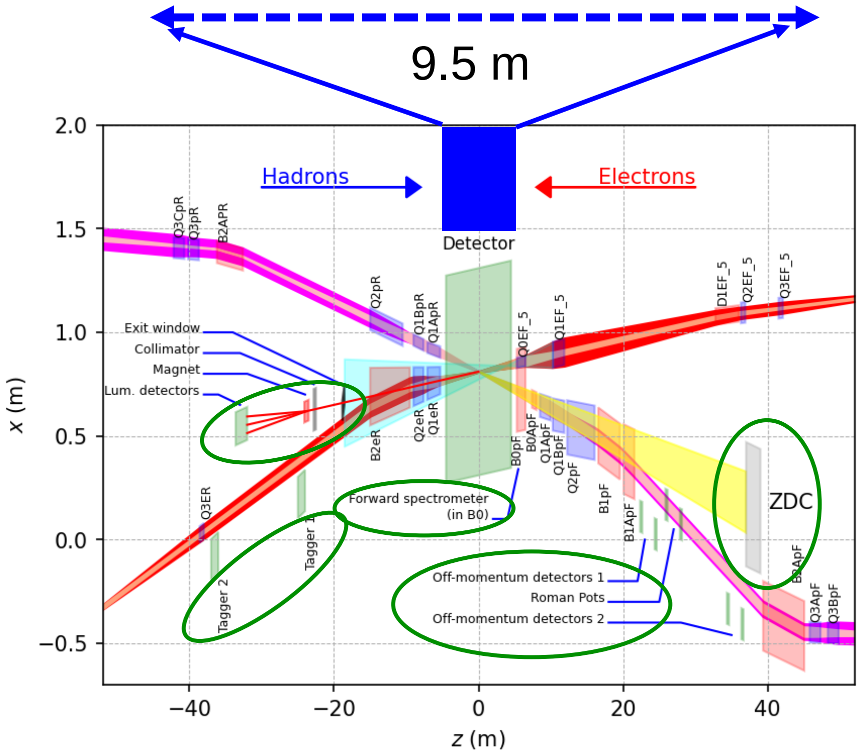
Time.of.Flight (ToF), DIRC, RICH detectors

MPGD trackers

MAPS tracker

23 Subdetectors incl. Polarimeters + Electronics + Data Acquisition





Design Status and Progress – Since CD-1

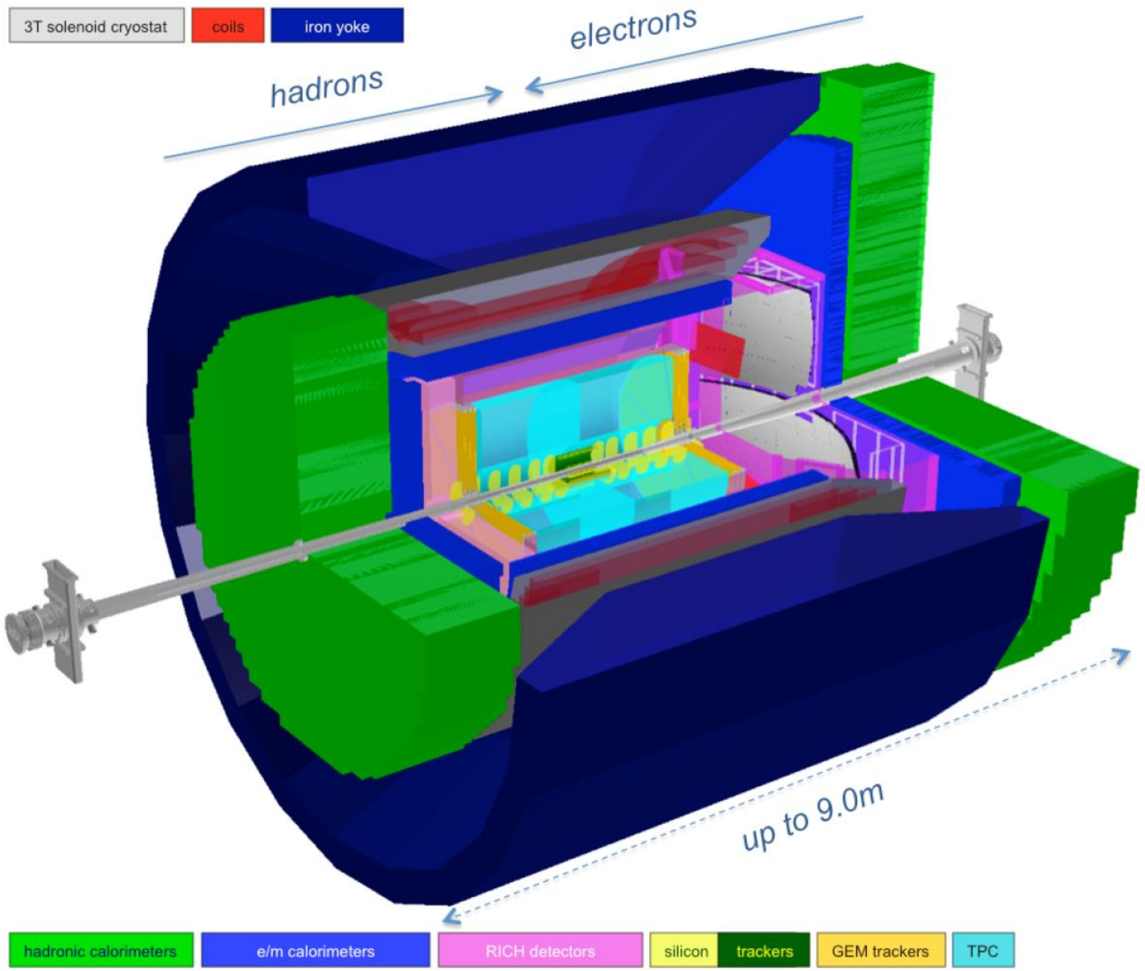
Experimental Program Progress Since CD-1

BNL and TJNAF Jointly Leading Efforts Towards Experimental Program		
2021	EIC Yellow Report (https://arxiv.org/abs/2103.05419)	February 2021
	Call for Collaboration Proposals for Detectors https://www.bnl.gov/eic/CFC.php	March 2021
	Collaboration Proposals for Detectors Submitted	December 2021
2022	Decision on Project Detector – "ECCE"	March 2022
	Process to consolidate ECCE & ATHENA to the EIC Project Detector ePIC	Spring 2022
	ePIC Collaboration Formed – 160 institutions	July 2022
2023	ePIC Charter ratified & elected Leadership Team	February 2023
	All subdetector technologies defined	April 2023

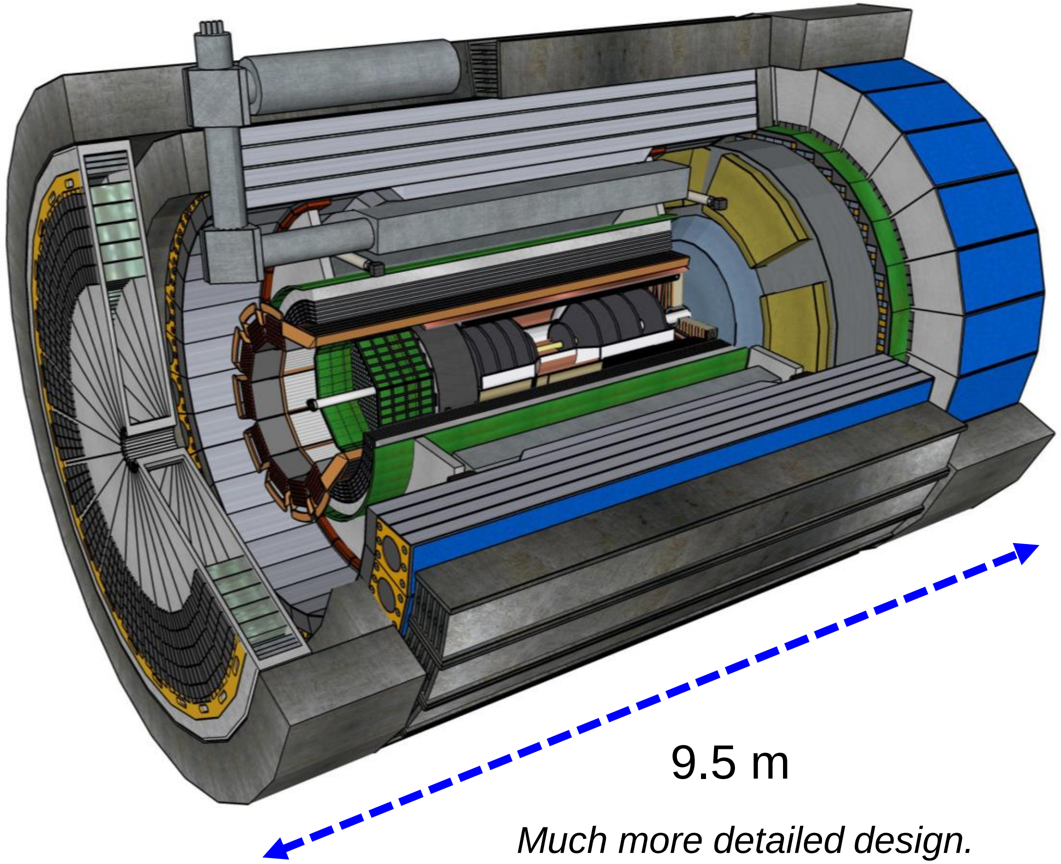
- EIC Project central detector fully defined by 04/2023
- Some final decisions to make for far-forward/far-backward detectors where scope is correlated with accelerator → design review 02/12/24

Design Progress Since CD-1

CD-1: Reference General-Purpose Detector

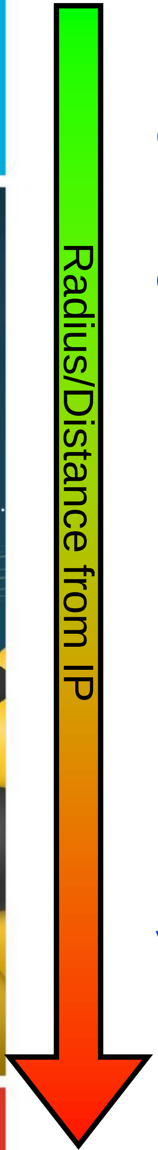


CD-3A: ePIC Detector



Much more detailed design.
Most subsystems had PDR.
Much attention to integration & services.

ePIC Baseline Technologies



Vertex detector → Identify primary and secondary vertices,
- Low material budget: 0.05% X/X_0 per layer;
- High spatial resolution: 10 mm pitch CMOS Monolithic Active Pixel Sensor

Central tracker → Measure charged track momenta
- MAPS – tracking layers in combination with micro pattern gas detectors
- MPGD: μRWell or MicroMegas

world's first at ePIC

electron and hadron endcap tracker → Measure charged track momenta
- MAPS – disks in combination with micro pattern gas detector disks

world's first at ePIC

Particle Identification → pion, kaon, proton separation on track level
- RICH detectors (modular and dual radiator RICH, DIRC) & Time-of-Flight
- high resolution timing detectors (LAPPS, LGAD) 10 – 30 ps
- novel photon sensors for RICHs: LAPPD & SiPMs

world's first at ePIC

Electromagnetic calorimeter → Measure photons (E, angle), identify electrons
- $PbWO_4$ Crystals (backward) with SiPM readout,
- W/SciFi Spacal (forward), Barrel: Pb/SciFi+imaging part using ASTROPIX

world's first at ePIC

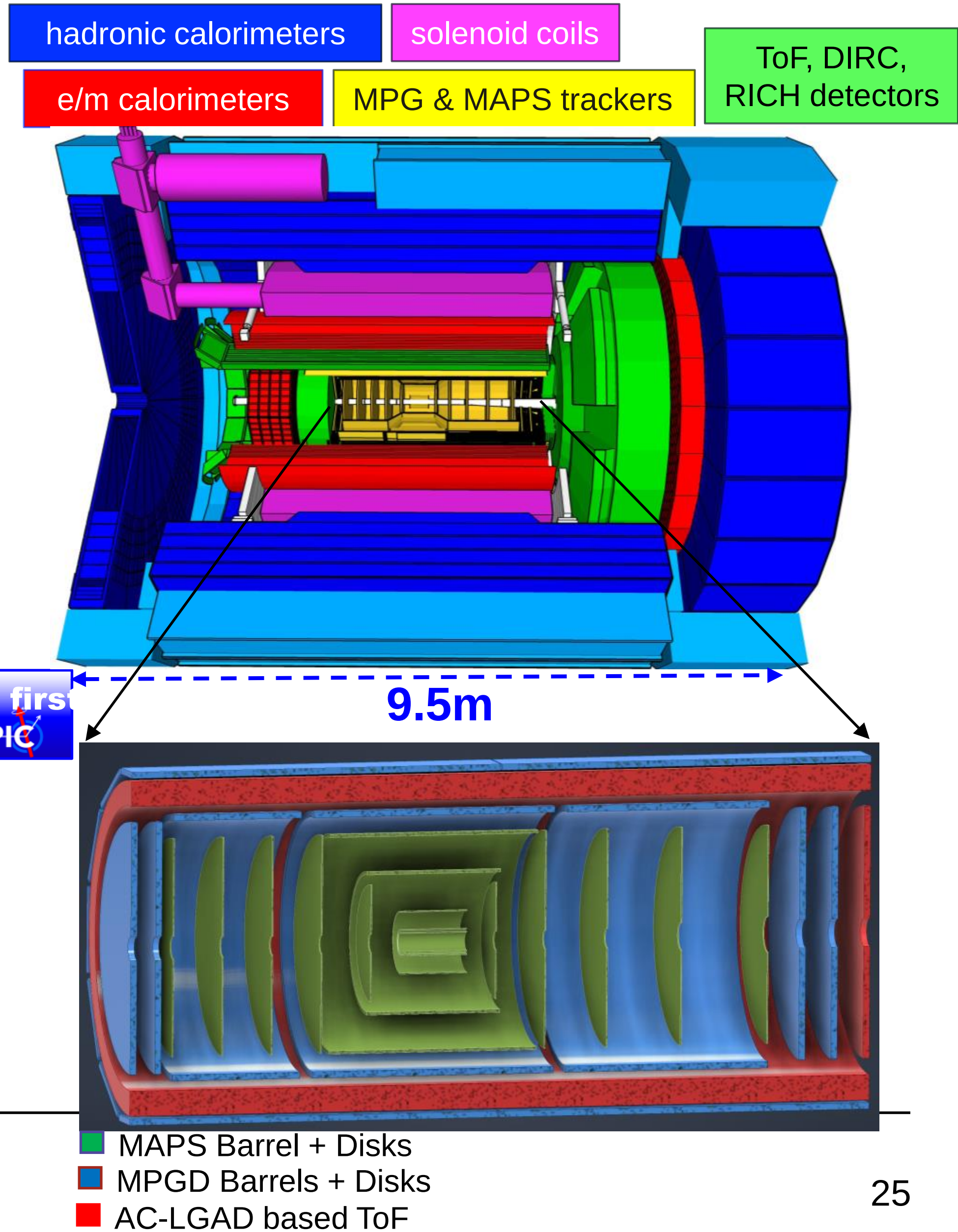
Hadron calorimeter → Measure charged hadrons, neutrons and K_L^0
- challenge achieve ~50%/√E + 10% for low E hadrons (<E> ~ 20 GeV)
- Steel/Sc & W/Sc sandwich sandwich with longitudinal segmentation & SiPM readout

world's first at ePIC

DAQ & Readout Electronics: trigger-less / streaming DAQ
- Integrate AI into DAQ → cognizant Detector

Very forward and backward detectors → scattered particles under very small angles
- Silicon tracking layers in lepton and hadron beam vacuum
- Zero – degree high resolution electromagnetic and hadronic calorimeter

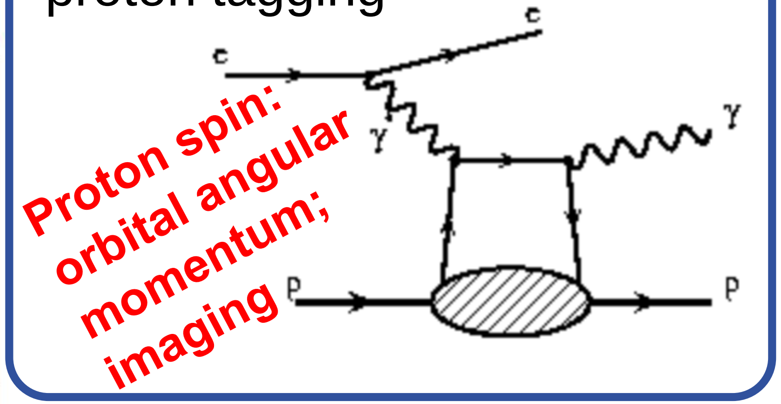
Polarimetry
- Lepton: integrated transverse and longitudinal Compton polarimeter
- Hadron: absolute and relative hadron polarimetry in the CNI region



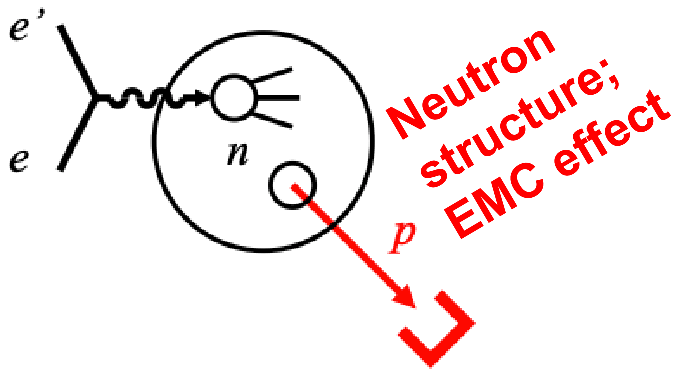
Far-Forward physics overview

Lots of important final-states in the Far-Forward detectors

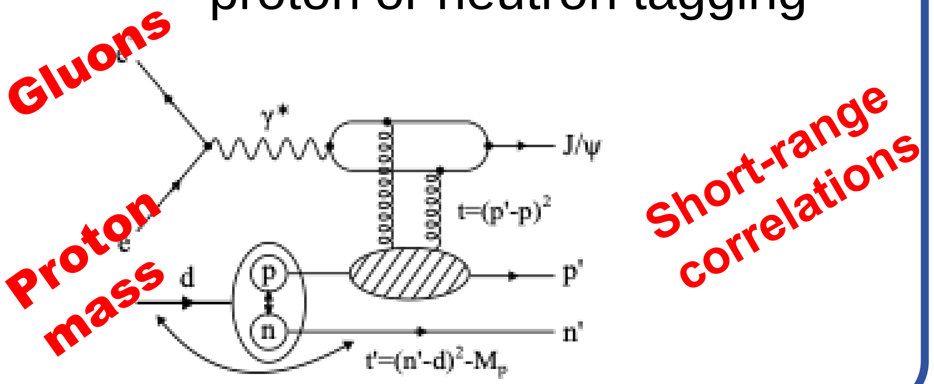
e+p DVCS events with proton tagging



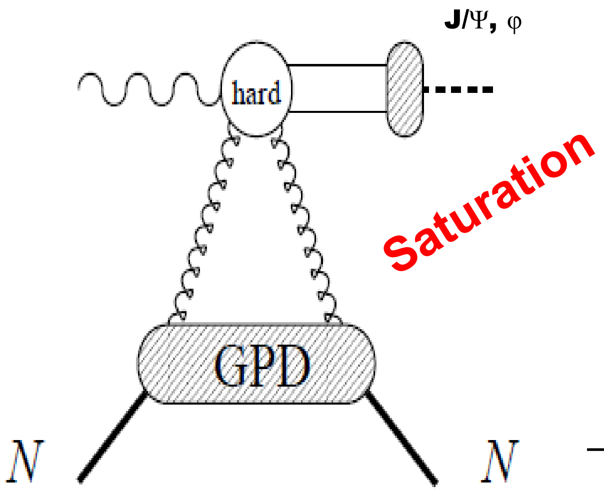
DIS on the deuteron



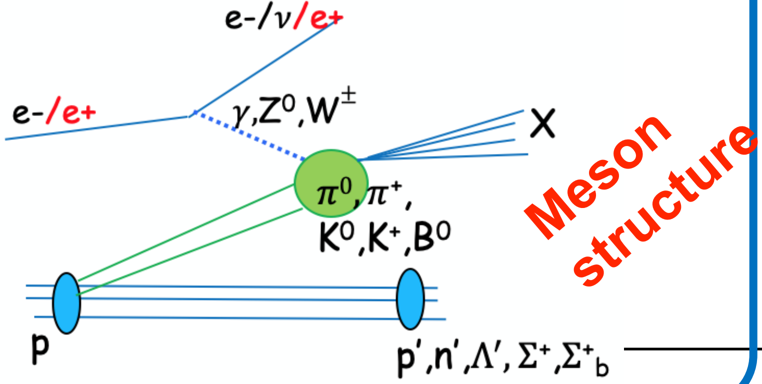
e+d exclusive J/Ψ events with proton or neutron tagging



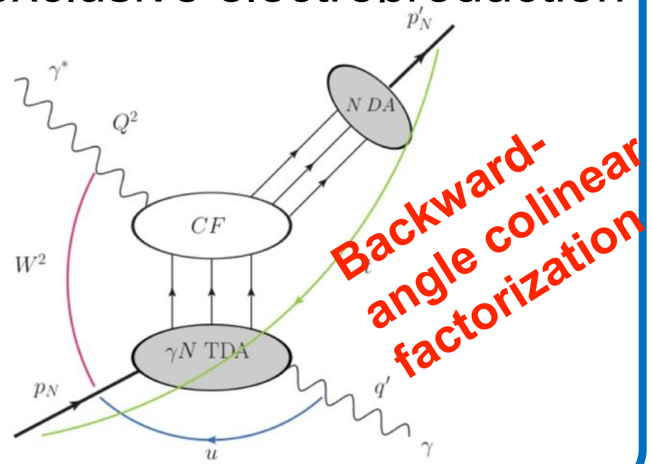
coherent/incoherent J/Ψ production in eA



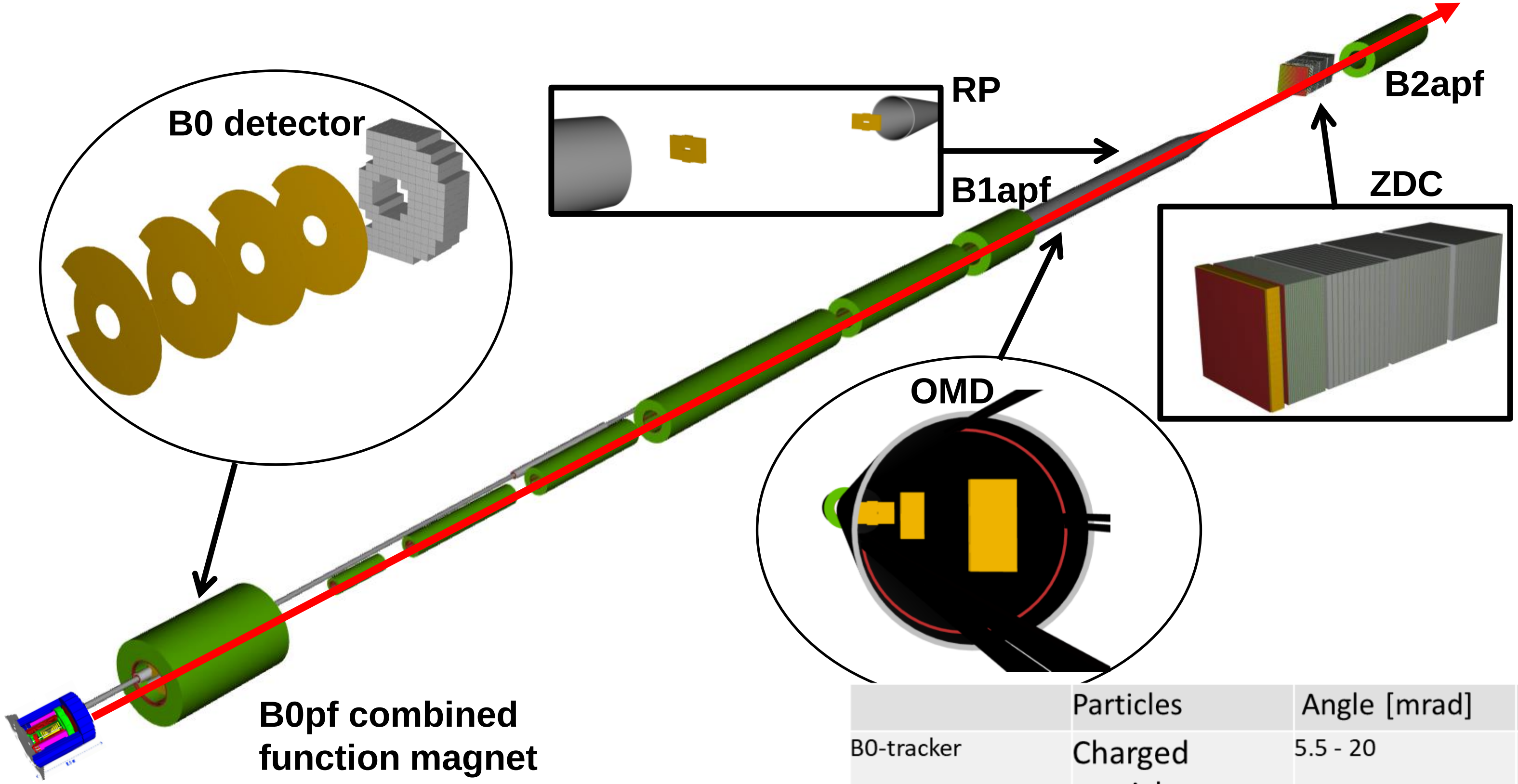
Sullivan process: With neutron tagging (ep→ (π)e' n X) and Λ decays (Λ → pπ⁻ and Λ → nπ⁰)



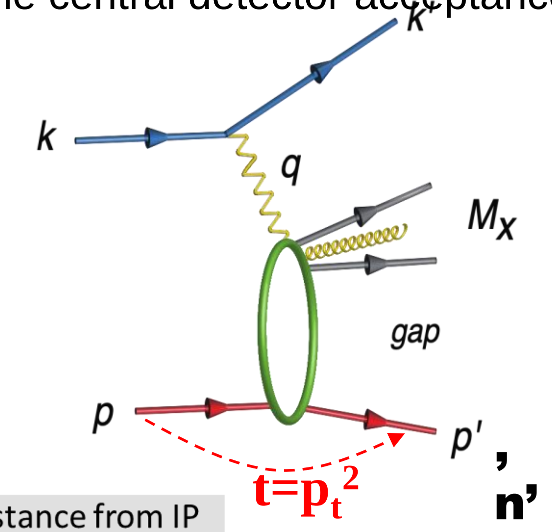
u-channel backward exclusive electroproduction



Far-Forward detectors (hadron outgoing)



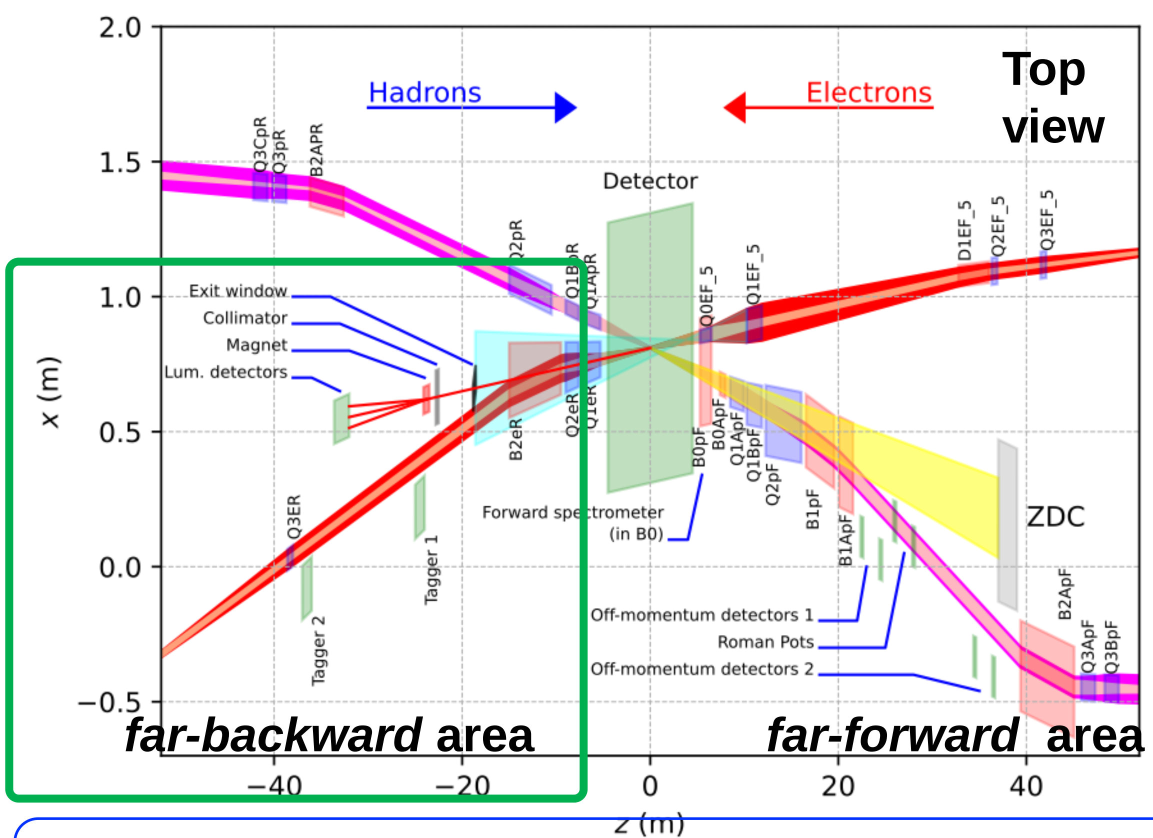
Exclusive /diffractive reactions driving the design of FF area -> reconstruction of particles outside of the central detector acceptance

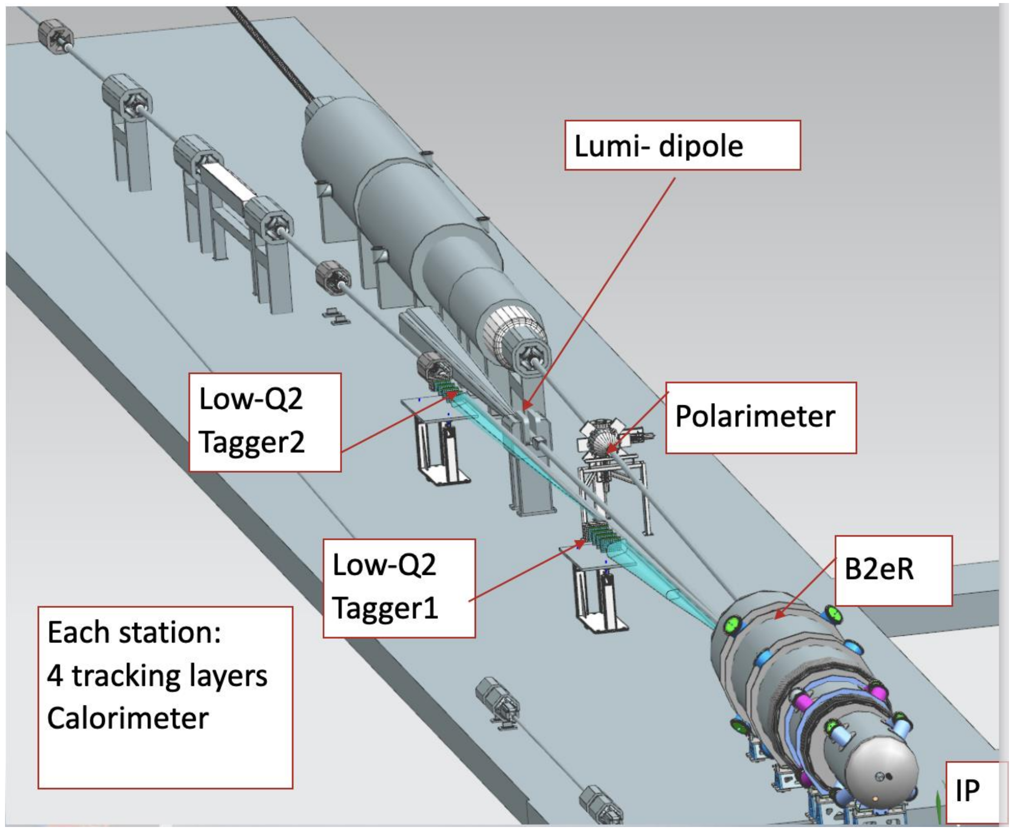


	Particles	Angle [mrad]		Distance from IP
B0-tracker	Charged particles Photons (tagged)	5.5 - 20		ca 6-7 m
Off-momentum	Charged particles	0-5.0	0.4< xL< 0.65	ca 23-25 m
Roman Pots	Protons Light nuclei	0*-5.0	0.6 < xL< 0.95	ca 27-30 m
ZDC	Neutrons Photons	0-4.0 (5.5)		ca 35 m

√protons at wide range of p_T^2
√protons with **different rigidity**
√**neutrons and photons**

Far-backward (electron-outgoing) region





- ➢ This area is designed to provide coverage for the low-Q² events (photoproduction, $Q^2 <\sim 1GeV^2$) . Need to measure a scattered electron position/angle and energy
- ➢ And luminosity detector (ep → e'pγ bremsstrahlung photons)

Experimental Program Progress Since last year January

- ePIC leadership elected and working group structures established
- ePIC well integrated in EIC detector project
- Final central detector technology decisions made
- Major progress on integration
- Established change control process with initial phases linked to ePIC
- Resource Review Board meetings started
- Productive CERN visit to discuss ALICE/ITS3 and particle identification detector synergies. Follow-up to define ePIC tracking layout.
- EIC-Asia meeting in Japan, EIC User Group meeting in Poland, two meetings in Brazil, in Taiwan, EIC schools hosted all over the world
- EIC folded in US and Europe Long-Range Planning exercises
- Various proposals submitted by EIC users to secure in-kind contributions (UK-STFC, INFN, NSF, …)
- Implemented interface definitions
- Various preliminary and final design reviews
- Comprehensive design review by DAC
- CD-3A review recommends to proceed to CD-3A approval of Long-Lead Procurement items
- Baseline decisions in Far-Forward/Far-Backward detectors made to feed into design review in February

Detector Technical Baseline Proposal

- Central Detector Baseline Technology choices were completed in 2023 before the DAC Comprehensive Design Review and folded into the CD-3A review
  - ➢ P6 is fully up-to-date
- Far-Forward/Far-Backward Baseline Technology choices are completed and will be presented at the February 12thy IR Integration and Auxiliary Detectors preliminary design review
  - ➢ These are more to align the international ePIC collaboration than technical-driven
- There are no outstanding technology decisions; emphasis has shifted to documenting what-if alternate detector choices to mitigate risk caused by R&D delays and/or dependencies.

CD-3A Long Lead Procurement Overview

CD-3A Scope Overview for Detector Systems

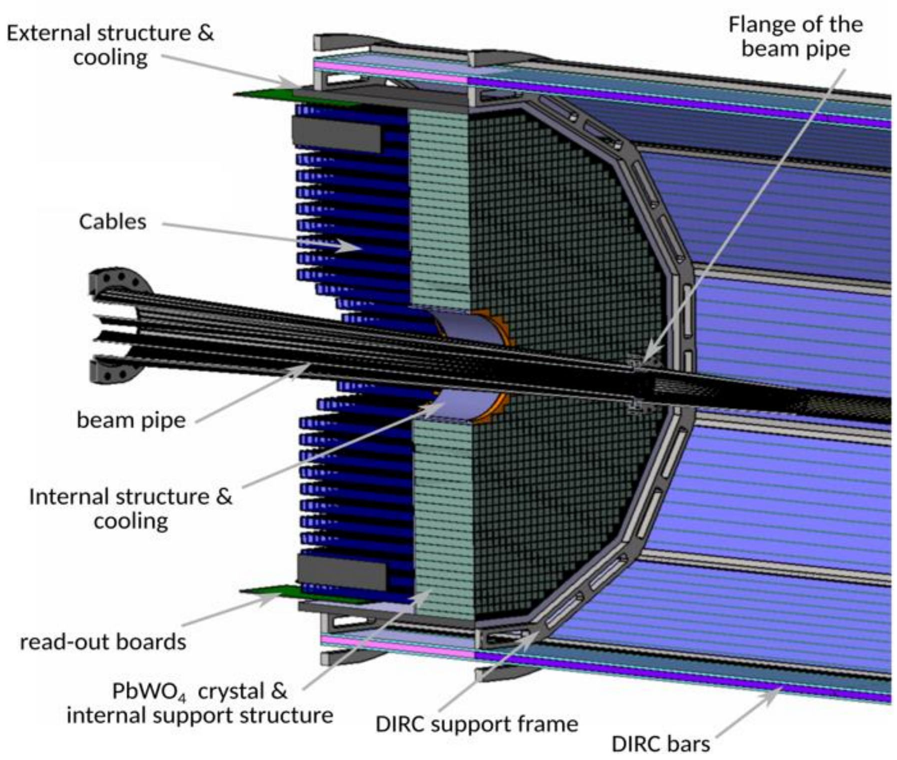
- Detector Systems CD-3A Scope
  - WBS 6.10.05: Lead Tungstate Crystals for the Detector Backward EM Calorimeter
    - CD-3A scope is first two years of procurements (1500 pieces)
  - WBS 6.10.05: Scintillating Fibers for the Detector Barrel and Forward EM Calorimeters
    - CD-3A scope is 1875 km first of four phases
  - WBS 6.10.06: Silicon Photomultipliers for the Detector Foward Hadronic Calorimeter
    - CD-3A scope is one phase (320K SiPMs) out of two for the forward Hadron Calorimeter
  - WBS 6.10.06: Steel and Tungsten Plates for the Detector Forward Hadronic Calorimeter
    - CD-3A scope is first of two phases (~50%)
  - WBS 6.10.07: Detector Solenoid Magnet Design and Fabrication and Conductor
    - CD-3A scope is for the conductor and the full magnet construction.

- Designs driving CD-3A Detector Systems scope are stable – final design reviews are completed for all LLP scope. Review committees concurred there is minimal risk of change that could impact CD-3A LLPs following contract award.

- CD-3A Detector System scope justifications are based on:
  - Reduction of cost and technical risk
  - Limited world-wide vendors
  - Production times and capability and/or labor-intensive manufacturing tasks
  - Evade competition by other projects around the world

LLP Scope

- Scope:
  - The electromagnetic calorimeter in the backward (outgoing electron) direction provides high-resolution measurements to determine the electron scattering process kinematics. It is based on lead-tungstate (PbWO4) crystals.
  - The CD-3A request includes two years of PbWO4 crystal production (~1500 pieces). The quantity of crystals with the required quality that are needed by the EIC detector requires 4-5 years of full production capability, since there is only one vendor worldwide.

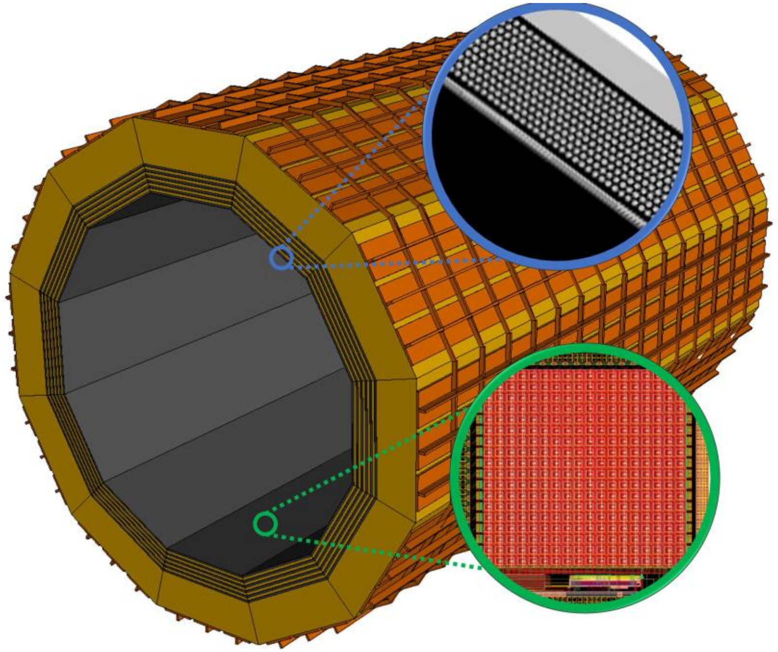


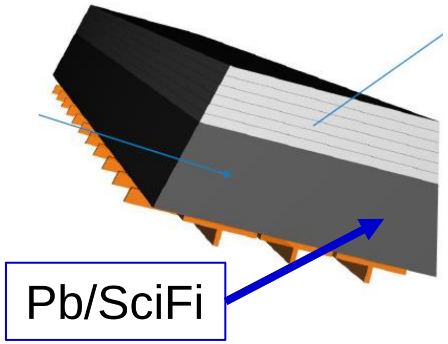
- Reduces the supply chain (single-vendor) risk exposure for PbWO4 crystals.
- Reduces impacts that could arise from competing customers or vendor equipment failures.
- Delay of procurement can potentially lead to the vendor to shutting off its ovens resulting in long start-up times and cost increases when orders are placed later.
- The impact of delaying this CD-3A item can be evaluated as 24 months and a cost increase of $10M to evade large escalation due to power cost increases and to expand vendor capability.

LLP Scope

- Scope:
  - The CD-3A request includes the first batch of the scintillating fibers for forward and barrel EM calorimeters. The quantities of materials needed for the EIC detector would consume the known vendor's capacity for many years.

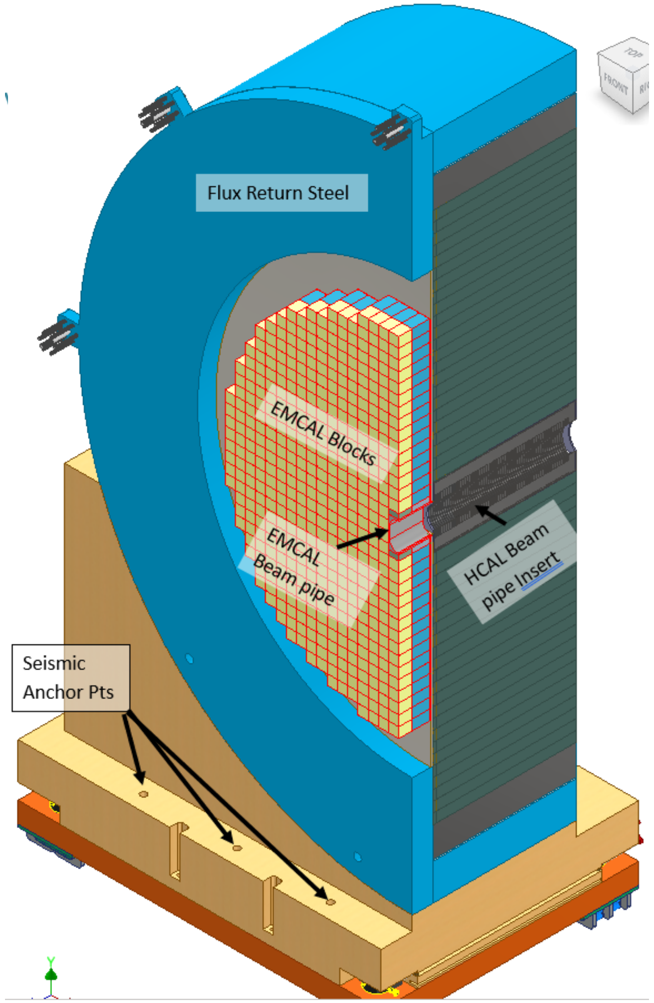
- Forward Ecal: High granularity Tungsten-Powder/SciFi matrix
- Barrel Ecal (this graphics): Pb/SciFi with a hybrid imaging part





- Reduces the limited-vendor supply chain risk and reduces potential schedule impacts that could arise from competing customers.
  - Only two known vendors may be able to meet the specifications of the required scintillating fibers. The EIC detector system needs a total of 7,500 km.
- Reduces the risk to the EIC Project of untimely delivery of high-quality scintillating fibers required by the EM calorimeter.
- The impact of delaying this CD-3A item can be evaluated as 12 months and a cost increase of $2M to expedite vendor production and mitigate reduced time for quality control.

LLP Scope

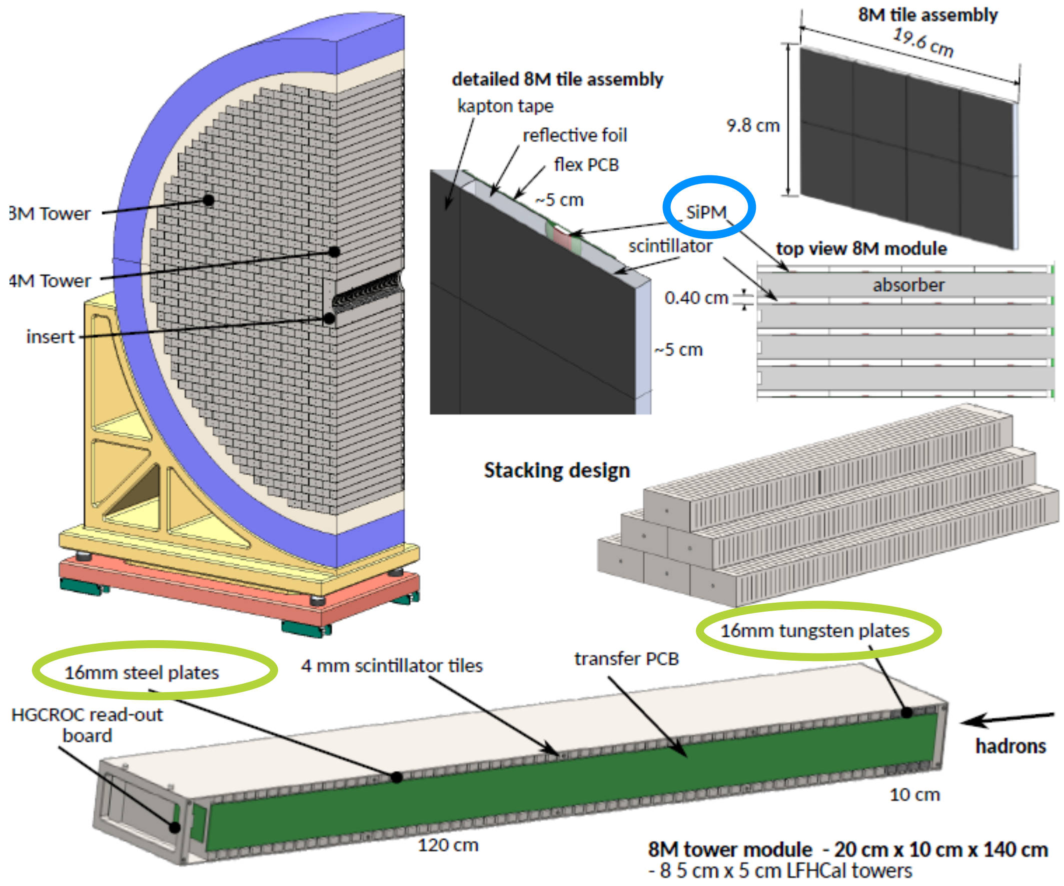


- Scope:
  - The CD-3A request includes the first batch of the steel and tungsten plates and all the casing steel for the forward hadronic calorimeter. These detector subsystems must be integrated with the detector solenoid magnet early on for magnet high-field tests and acceptance.

- Reduces schedule risks related with the integration of the forward calorimeter system that needs significant labor-intensive assembly work.
  - Assembly requires multiple items to arrive for system integration.
  - Currently, the lead times for receipt of steel and tungsten plates and casing steel are long, due to not only the material production but also to the machining of the steel requested time.
  - Beyond, significant labor-intensive assembly work is required when all items are ready, and quality tested.
- Reduces exposure of the EIC Project to the risk of a delay to the detector solenoid magnet acceptance.
  - The detector solenoid cannot be operated at its design field for acceptance testing without the hadron calorimeters that form the magnet return yoke.
- The impact of delaying this CD-3A item can be evaluated as 12 months and a cost increase of $4M to recover impact on magnet acceptance and interaction region installation work with double shifts.

LLP Scope

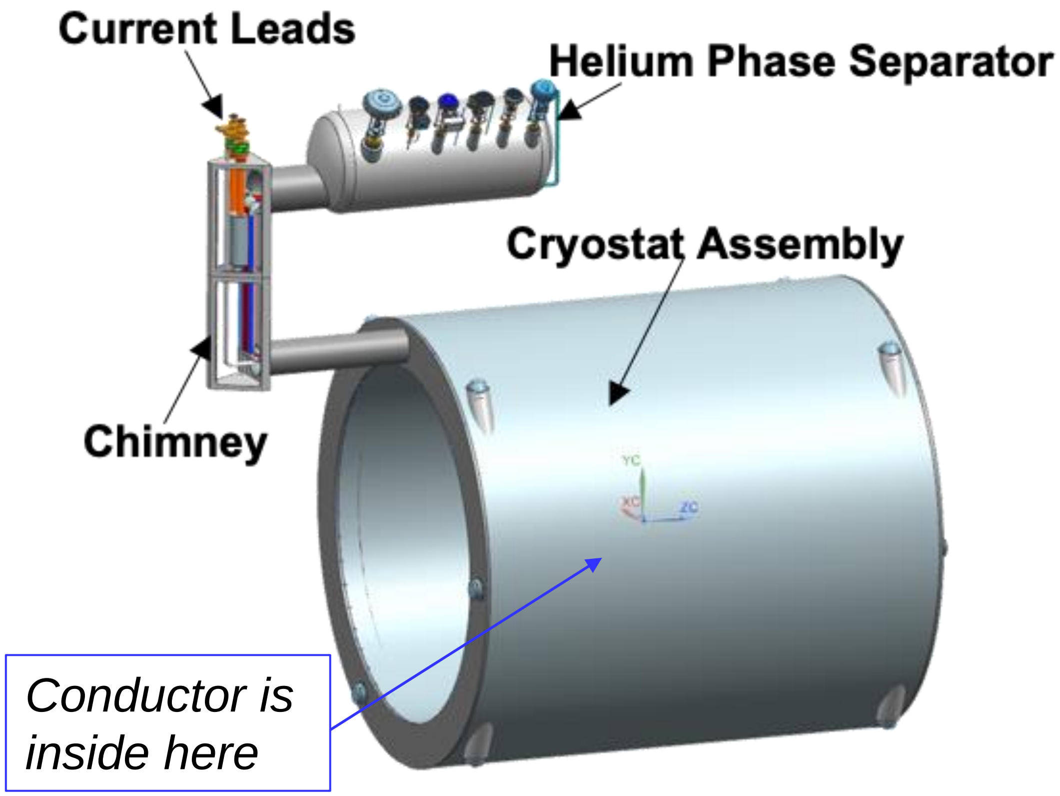
- Scope:
  - The CD-3A request includes the first batch of the silicon photomultipliers (SiPM) for the forward hadronic calorimeter. For the forward hadronic calorimeter, these silicon photomultipliers are embedded in the detector assembly, without them a complex and lengthy process cannot start. The silicon photomultipliers are currently the only possible photo-sensor technology for various detector subsystems.



- The total quantity of SiPMs required for the EIC detectors may consume the known qualified vendor production capacity for order of 4 years in a row.
- Reduces limited vendor supply chain risk and reduce potential schedule impacts that could arise from competing customers.
- The SiPMs are embedded in the forward hadronic calorimeter, a system needed as flux return for the detector solenoid.
- The impact of delaying this CD-3A item can be evaluated as 12 months and a cost increase of $2M to speed up vendor production and evade impact on magnet acceptance and interaction region installation schedule.

LLP Scope

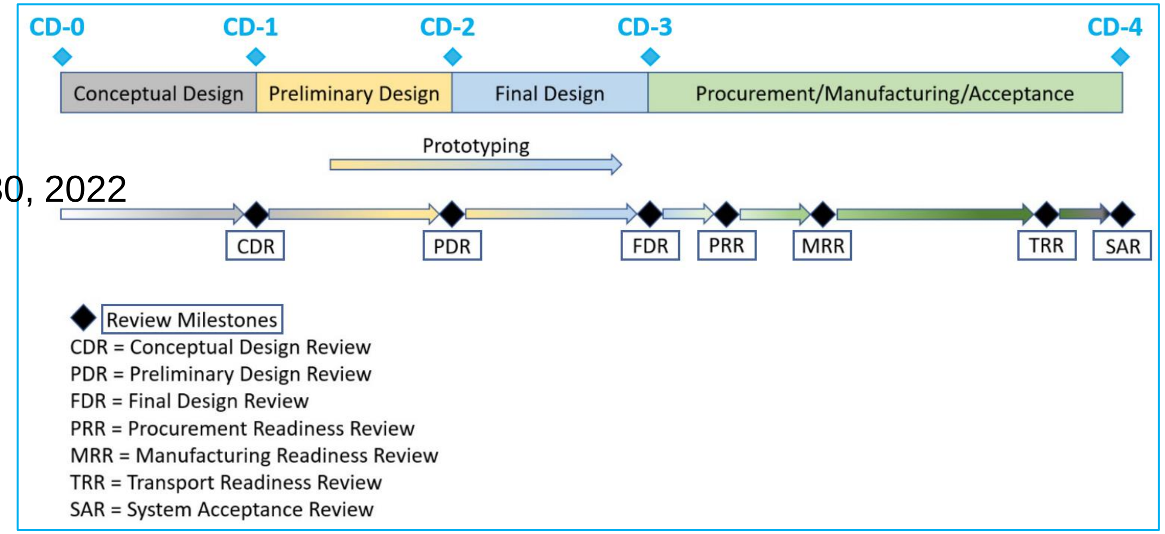
- Scope:
  - Lessons learned on large-scale detector superconducting magnets have demonstrated that they have experienced vendor production delays and technical challenges during fabrication. This applies both to acquiring the proper quality-tested conductor that is essential for such magnets, and the magnet coil construction itself that requires several critical fabrication steps carrying technical, cost and schedule risk.



- Manufacturing time is 5 years and needs the conductor early.
- There is only a limited viable vendor base worldwide, and only one known vendor for the conductor.
- There are several critical fabrication steps during conductor production and further magnet assembly carrying technical, cost and schedule risk.
  - The magnet stays high risk until low-current tests.
- The magnet has to arrive on site early to be integrated with hadron calorimeter detectors that also act as field flux return before its full-magnetic field commissioning and acceptance.
  - Magnet availability drives the rest of the detector assembly schedule.
- The impact of delaying this CD-3A item can be evaluated as 12 months and a cost increase of $2M to speed up vendor production and evade impact on magnet acceptance and interaction region installation schedule.

Peer Review Summary

Design Review Progress



- Preliminary Design Reviews:
  - Magnet (6.10.07) – 30% design, Feb. 23, 2022
  - IR Integration and Ancillary Detectors (6.10.11) – April 27, 2022
  - Electronics/Computing Subsystems (6.10.08 & 6.10.09) – August 29-30, 2022
  - Magnet (6.10.07) – 60% design, October 18-19, 2022
  - Calorimetry (6.10.05 & 6.10.06) – December 6-8, 2022
  - Polarimetry (6.10.14) – January 17-18, 2023
  - Particle Identification Detectors (6.10.04) – July 5-6, 2023
- Final Design Reviews (for CD-3A scope):
  - PbWO4 Crystals (6.10.05) – July 14, 2023
  - Scintillating Fibers (6.10.05) – September 13, 2023
  - Silicon Photomultipliers (6.10.06, 6.10.05, 6.10.04) – September 14, 2023
  - Forward Hadron Calorimeter Steel and Tungsten (6.10.06) – September 25, 2023
  - Magnet (6.10.07) – October 5-6, 2023
- Project detector R&D (6.10.02) is annually reviewed by the DAC
  - Last one was August 28+31, 2023; Details: https://indico.bnl.gov/event/20113/
- Scientific computing & associated infrastructure is a dependency for the EIC
  - EIC Detector Software Infrastructure Review, in collaboration with host labs (https://indico.bnl.gov/event/16676/) – August 22-23, 2022
  - ePIC Computing & Software review by host labs (https://indico.bnl.gov/event/20481/) – October 19-20, 2023

Detector Advisory Committee

- We assembled the DAC in 2020
- Per the charter, 1/3 of the committee was replaced early 2023

Edward Kinney	Boulder CO
Ewa Rondio	Warsaw
Werner Riegler	CERN
Greg Rakness	FNAL
Peter Krizan	U Ljubljana
Ana Amelia Machado	University of Campinas, Brazil
Heidi Schellman	Oregon State
Brigitte Vachon	McGill
Glenn Young	BNL
Etiennette Auffray	CERN
Andrew White	U. Texas Arlington
Chi Yang	SDU China

→

Edward Kinney (Chair)	Boulder CO
Ken Wyllie	CERN
Petra Merkel	FNAL
Antonis Papanestis	Rutherford Appleton Laboratory
Peter Krizan	U Ljubljana
Ana Amelia Machado	University of Campinas, Brazil
Heidi Schellman	Oregon State
Brigitte Vachon	McGill
Stefano Miscetti	INFN Frascati
Etiennette Auffray	CERN
Andrew White	U. Texas Arlington
Chi Yang	SDU China

- In 2024: Transition Chair from Ed Kinney to Andrew White, replace 3 members (Heidi, Etiennette, Chi)
- Meetings to date:
  - September 28-29, 2020. Bring the DAC up to speed and prepare them for upcoming charges, e.g., related to input on assessment of the call for Expressions of Interest (EoI).
  - December 18, 2020. Update DAC on the EIC Project and Yellow Report status, the EoI assessment, international engagement, and planning for call for detector proposals.
  - March 24-26, 2021. Transition from the generic EIC detector R&D to the Project detector R&D.
  - Dec. 2021 – Jan. 2022. Evaluation of detector technologies, cost and schedule as input to the Detector Proposal Advisory Panel.
  - October 19-21, 2022. Review the ongoing project detector R&D. Advise for the FY23 detector R&D.
  - **August 28-31, 2023: Review next phase of Project Detector R&D and status of ePIC design**

DAC – Comprehensive Design Review (Aug. 2023)

- “Amazing progress in the last two years, congratulations to all working on the EIC for this enormous achievement.”
- “Congratulations on rapid development of a nearly complete design for the EIC detector. This was extremely impressive to the committee, especially in the organization of the many different project components and tasks. This inspired confidence in the successful completion of this incredibly complex facility.“
- “Enormous progress in developing a coherent design for detector to carry out EIC research goals, with minimal open technology choices.”

Our retrospect:

- *This was nice feedback!*
- *Tremendous progress over last two years*
- *Need to keep insuring progress on magnet, Si/MAPS, AC-LGAD, integration, …*
- *Far-forward detectors still at a less advanced stage of design, with still some open technology choices being investigated.*
- *Dual RICH flagged as one system that is less advanced in design.*
- *MPGDs flagged in many areas – need detailed technology choice.*

Design Review Progress

- Global Project Reviews:
  - DOE CD-3A Design Review by DAC August 29 + 30, 2023
  - DOE CD-3A Director's Review October 10-12, 2023

    Integrated Design Review reports of DAC, MAC, Infrastructure Committee, Focus on CD-3A Long Lead Procurement Items
  - **DOE CD-3A Independent Project Review November 14-16, 2023**

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2.4 Detector
A. Lankford, UCI / Subcommittee 4
D. Christian, FNAL

1. Is the project team effectively executing the work? Are technical issues proactively being addressed?
   YES & YES
2. Are R&D and design efforts yielding sufficiently advanced designs and
   YES
   Are the proposed CD-3A long-lead procurements appropriate and do the mitigation? Have the proposed CD-3A long-lead procurements attained
   YES & YES
6. Has the project satisfactorily addressed recommendations from previous
   YES
   - Pursue formal commitments for IKC before CD-2. – satisfac
   - **Advance detector integration and assembly planning for**
   - Develop interface definitions for services for this review. – o
   - **Prioritize completing R&D of all technical options. – opti**
7. Is the project ready for CD-3A approval?
   YES

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2.4 Detector
A. Lankford, UCI / Subcommittee 4
D. Christian, FNAL

- **Comments - I**
  - **The detector subproject is well-organized. It has a strong engineering team including system engineer and chief mechanical and electronics engineers. Integration of project and ePIC collaboration is very good. Final technolog choices for all central detector subsystems are complete, and detector is proceeding well towards CD-2/3.**
  - **EIC physics requires a complex detector, with many subsystems. Integratio subsystems, coordination of common elements, and management will requi great attention in order to keep all the subprojects on track for CD-4.**
  - **Investment in years of EIC detector R&D and project R&D has resulted in mature detector technologies and in subdetector designs of appropriate ma for this stage of the project. Plans for remaining detector R&D are sound. Remaining R&D followed by engineering test articles and full-chain tests sl continue apace in order to allow time to resolve any unforeseen issues.**
  - **Studies of beam pipe bake-out procedure are reasonable and systematic, ar should be continued to ensure safety of MAPS microvertex tracker.**
  - **Systems engineering of detector electronics now needs to advance, includin development of guidance/policies for detector subsystems regarding locatio electronics, grounding, shielding, and cooling.**

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2.4 Detector
A. Lankford, UCI / Subcommittee 4
D. Christian, FNAL

- **Comments - II**
  - **ePIC depends on development of five ASICs. Timely development of ASICs should be followed closely. Groups developing ASICs upon which the project depends should be well aware of the project's needs and schedule. ePIC's partnership with ALICE on MAPS development could be considered as a model for working closely with ASIC development teams.**
  - **All long-lead procurements on the CD-3A list are well-motivated and have appropriately mature designs.**
  - **A set of high-level milestones for each level-4 WBS element should be prepared for presentation at future reviews. The same set should be used consistently at future reviews in order to facilitate tracking detector progress for review committees.**
- **Recommendations**
  - **Proceed to CD-3A.**
  - **Advance system engineering of detector electronics subsystems. Prioritize issues that impact space requirements within ePIC detector volume for the next review, including location of electronics as well as cooling and cables.**

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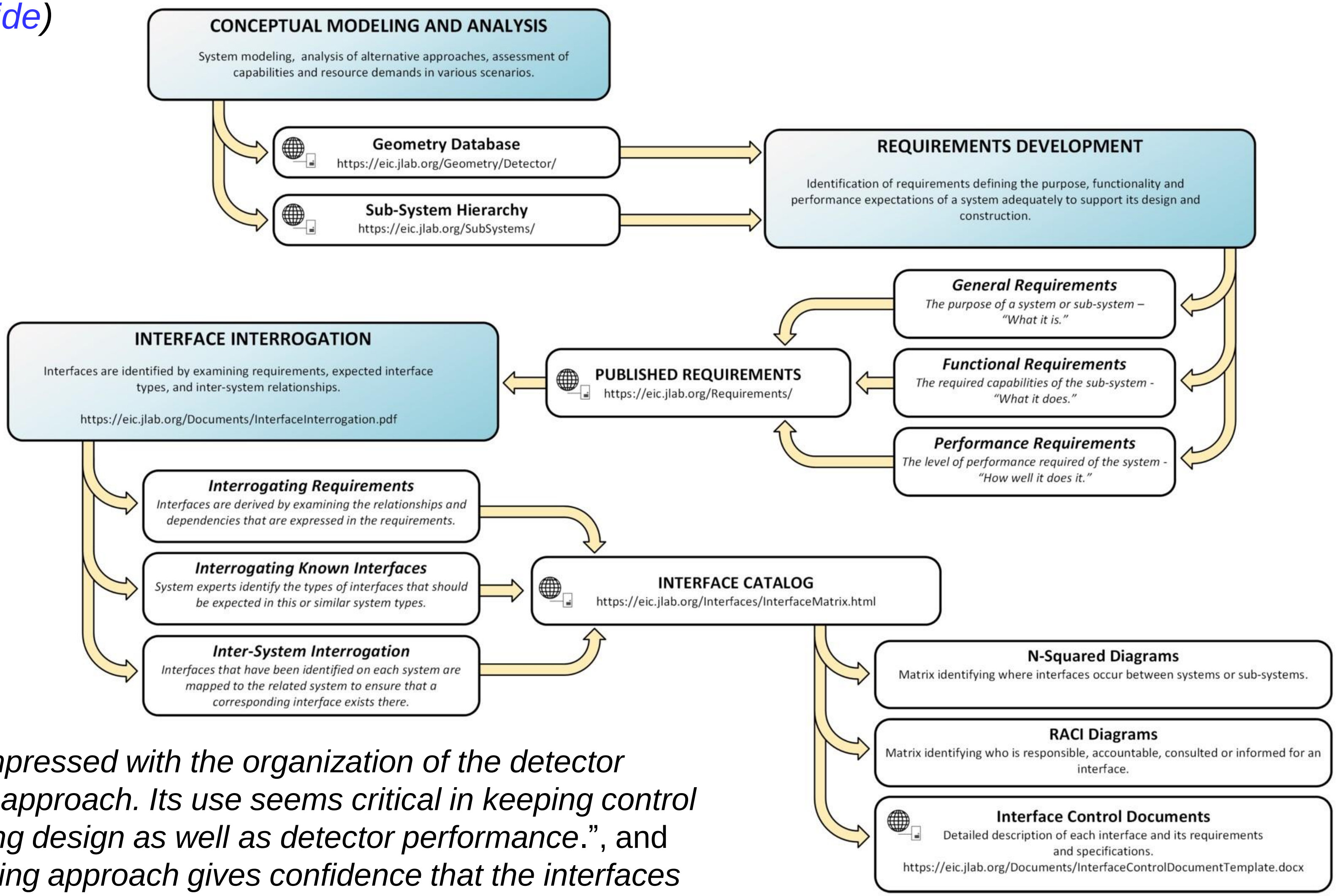
Other Topics

EIC ~~Detector~~ Systems Engineering

(*not just for detector, this is done system-wide*)

- Crucial to invest in systems engineering given the high integration level of EIC
- Similar, need to provide easy access to requirements and interfaces for the large EIC user community
- For requirements, see https://eic.jlab.org/Requirements/
- For Interface Definitions see https://eic.jlab.org/Documents/InterfaceInterrogation.pdf
- For interfaces (in progress) see https://eic.jlab.org/Interfaces/Interfaces.html



DAC Design Review: "*The committee was very impressed with the organization of the detector development using a formal systems engineering approach. Its use seems critical in keeping control on the myriad requirements needed for engineering design as well as detector performance*.", and "*Once again, the demonstrated systems engineering approach gives confidence that the interfaces are sufficiently well defined that the long-lead items can be procured with small risk*."

Beam Background and Detector Performance

Accelerator Changes impacting Beam Background

- new incoming and outgoing electron beam lattice → SR and electron beam gas
- potential changes in injection scheme of leptons → SR

Impact on Detector Performance:

- Background hits will impact the track finding and reconstruction
  - Embedding of beam background events in DIS signal event in MC simulations
  - Impact depends on speed of subdetector readout speed, MAPS 2 μs AC-LGAD 30 ps
- Background will impact of energy reconstruction in calorimeters
- Need to know the total rate per readout channel (== Background + DIS) for DAQ
  - impact needed data rate capabilities
- Total Radiation (== Background + DIS) impact subdetector lifetimes

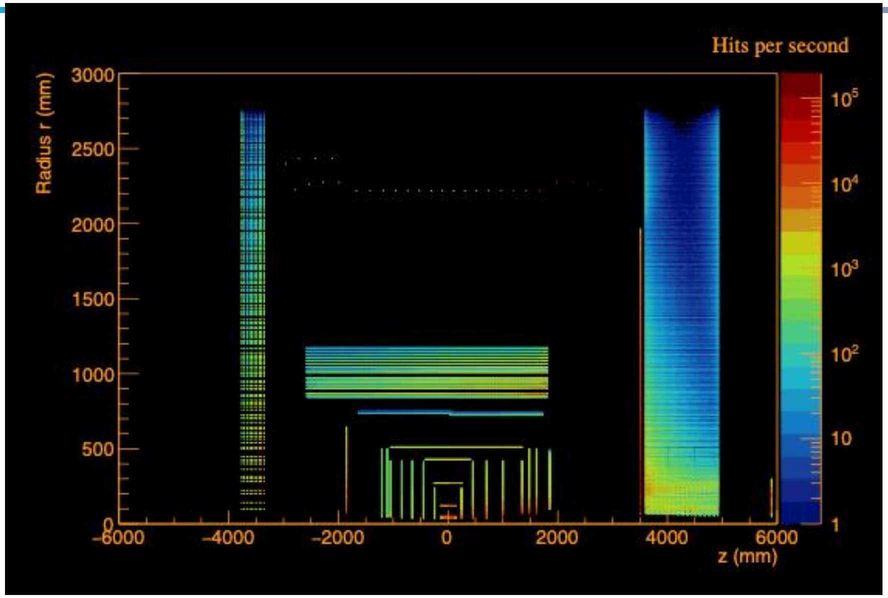
→ need the thresholds per subdetector on hit level and summed energy,
see EPIC Detector DigitizationModel.09.2023.xlsx, to get the correct rates

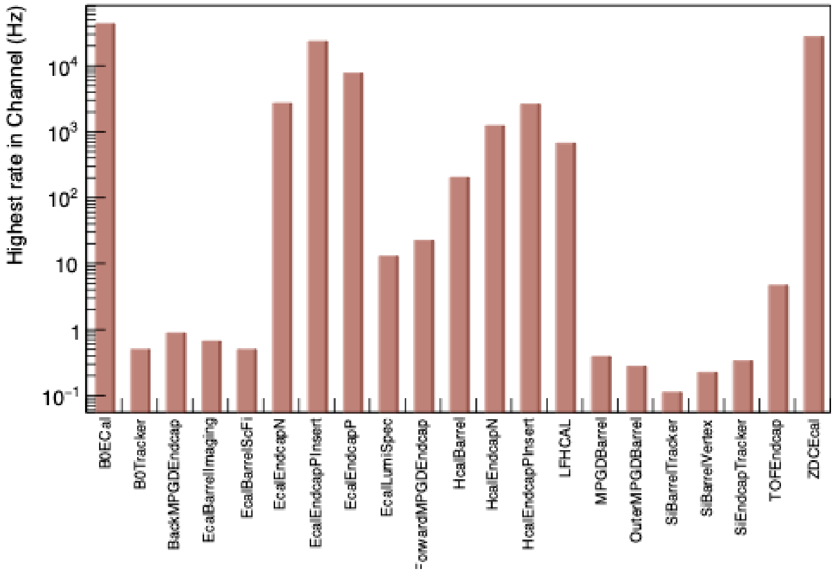
→ All implemented in December campaign

→ Impact on backgrounds currently actively analyzed

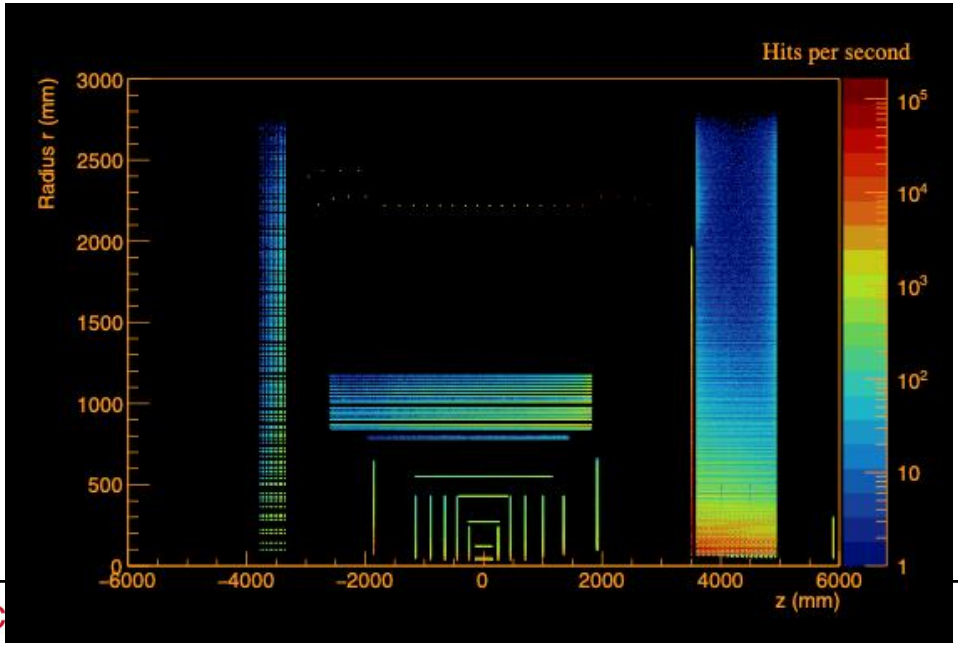
→ https://wiki.bnl.gov/EPIC/index.php?title=Background will be updated

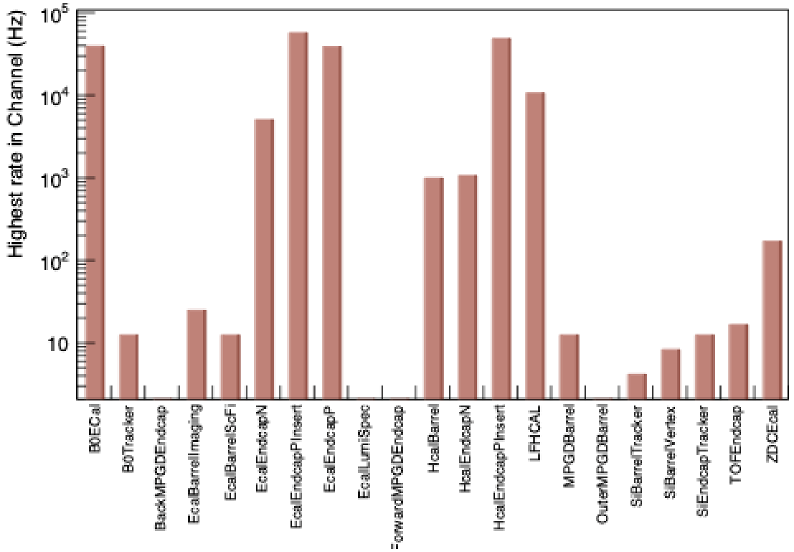
Rates per Channel – first Results





eP





Hadron Beam Gas – 275 GeV

High Level Installation Schedule

Note that this assumes the present best-known schedule, dates may shift with schedule/funding actuals

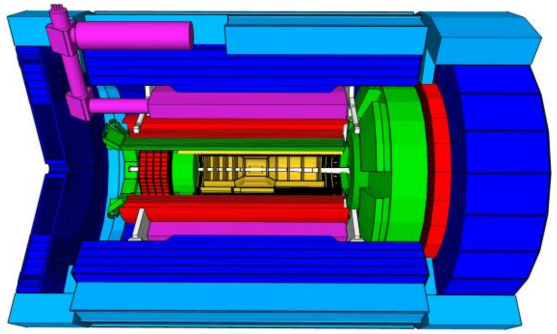
- CD-3 04/2025
- Construction
- Oct 2028 — IR-6 ready for installation
- Jan 2029 — lower half barrel Hcal installed Solenoid delivered
- April 2029 — Barrel Hcal & Solenoid installed followed by low power test
- Dec 2029 — Endcap HCals completed Solenoid Field mapping
- Barrel Ecal ready for installation
- June 2030 — Barrel Detectors installed ECal, DIRC, ToF, Trackers
- Oct 2030 — Hadron Endcap Detectors installed Trackers, dRICH ECal
- Jan 2031 — Lepton Endcap Detectors installed Trackers, bRICH ECal
- Milestone PO_0305_0900 Apr. 2031 — Detector Assembled and Ready for Cosmic Data Taking
- Pre-OPS
- early CD-4 10/2032 — Early start of Operations & Science
- CD-4 10/2034 — Start of Operations & Science

done in beam position

done in Assembly Hall

Take Away:

- Solenoid and Barrel HCal need to be ready by Jan 2029
- all other subdetectors need to be ready between 06/29 to 06/30 depending on their location in the detector



In-Kind and International Engagement

High-Level Summary for In-Kind

- Slides that indicate country interest provided by the primary scientists of each country to us to ensure foreign agencies and DOE have similar information:
  - https://www.dropbox.com/sh/qfkl5q8lf717b34/AACl0o7IxsTPRbP8RjY0qGcSa?dl=0
- We summarize interest of non-DOE funded groups at high level in a table (see later slide).

- From the start of the EIC Project (CD-0), the DOE assumption was that there would be in-kind contributions to the detector of order $100M (corresponding to ~30% of the detector cost).
- Present In-Kind Status:
  - Large In-Kind Component of EIC Project Detector R&D
  - Excellent progress on PED – designs moving rapidly with help of many friends (see backup slide for in-kind examples)
  - We defined three categories in P6, *confirmed* (includes reuse and ~$5M PED contribution), *likely* (still needs formal in-kind agreement) and *possible* (subject of recent proposals to agencies)
  - $60+M of in-kind scope seems secured (*confirmed, likely*) and $80M seems within near-term reach (includes *possible*).
  - The 30% (~$100M) in-kind EIC detector scope remains within reach. E.g., recent Korea and Taiwan interests need to be folded in the P6 assumptions. We continue to work to further develop international EIC detector engagement.

International Engagement: Resource Review Board (RRB) Meetings

DOE and the host labs promoting the EIC as a facility "fully international in character."

Initial RRB Co-Chairs:

- Haiyan Gao (BNL)
- Diego Bettoni (INFN)

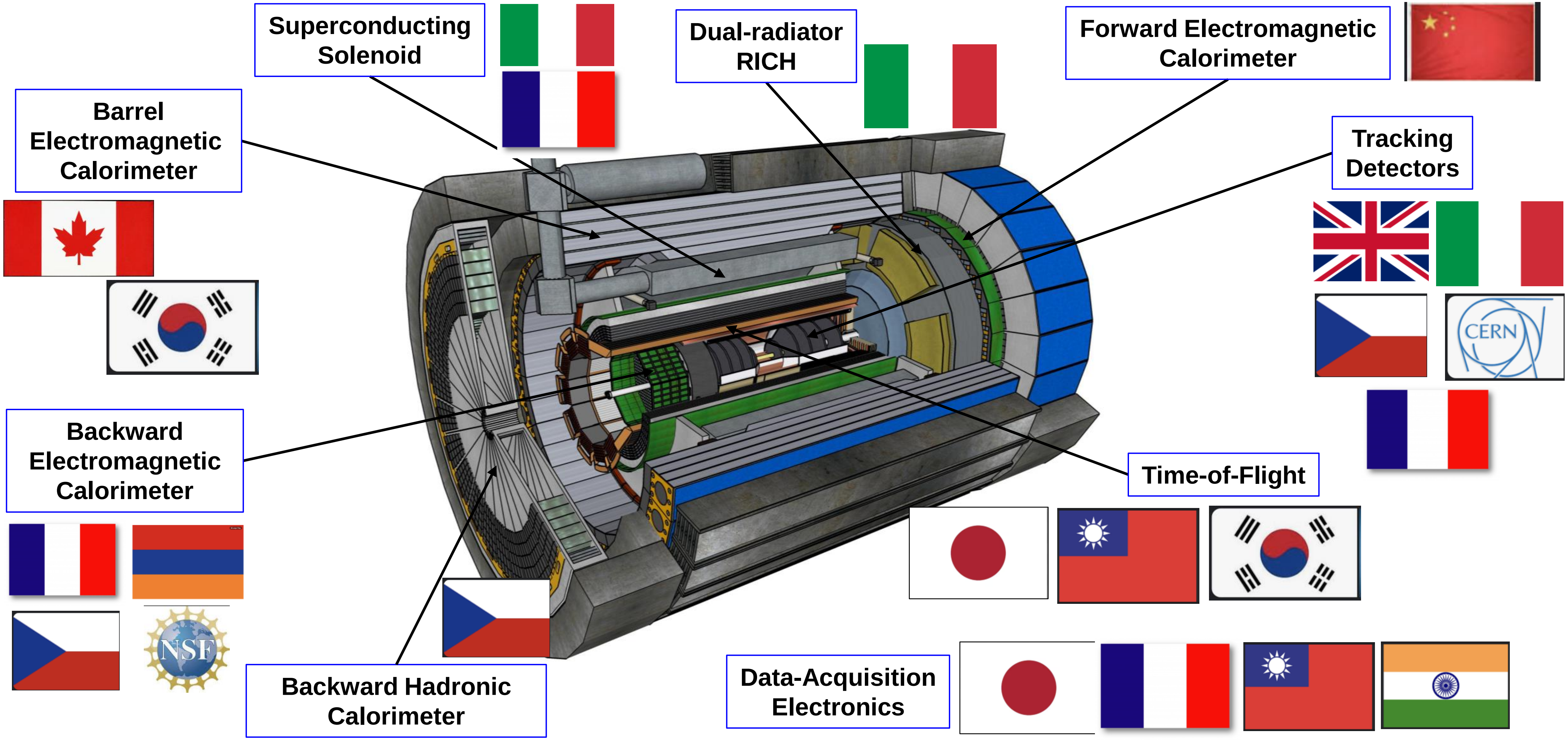
https://www.bnl.gov/eic-rrbmeeting/

1st RRB meeting on April 3-4, 2023 at Stony Brook University.

2nd RRB meeting on December 7 + 8 at Catholic University of America.

3rd RRB meeting planned for May 6 + 7 hosted by INFN/Italy

Central Detector Non-DOE Interest & In-Kind



US National Laboratory (Main) Involvement – not including BNL and JLab

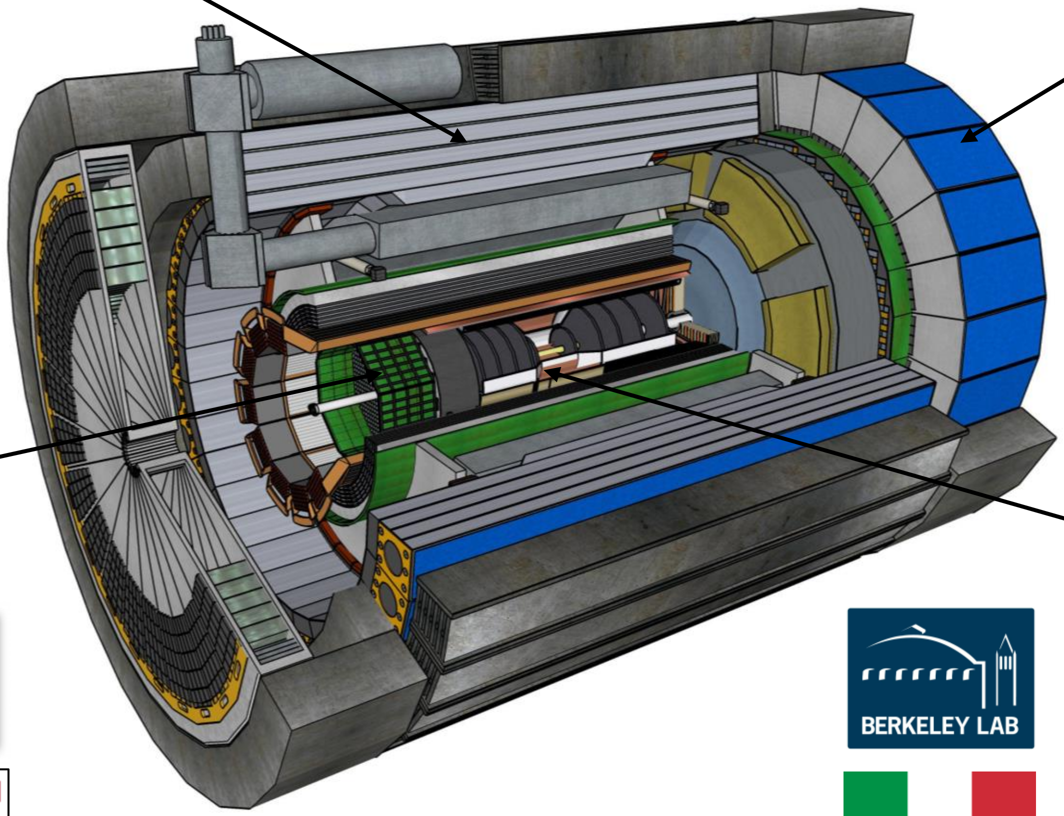
Barrel Electromagnetic Calorimeter

Argonne NATIONAL LABORATORY

Forward Hadron Calorimeter

OAK RIDGE National Laboratory

(ORNL also large involvement in DAQ/electronics)



Backward Electromagnetic Calorimeter

NSF

MIT

Silicon/MAPS Tracking Detectors

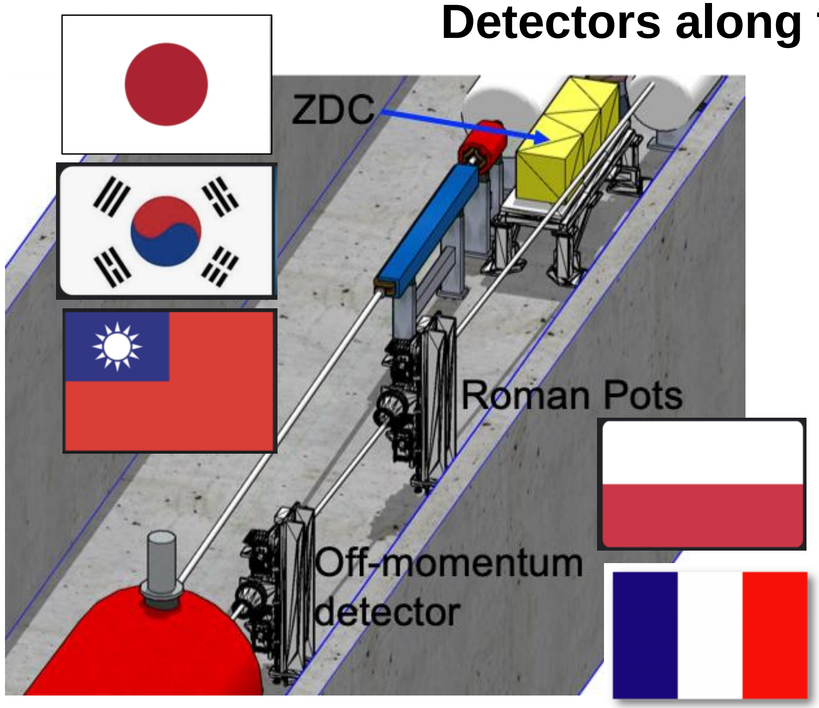
BERKELEY LAB

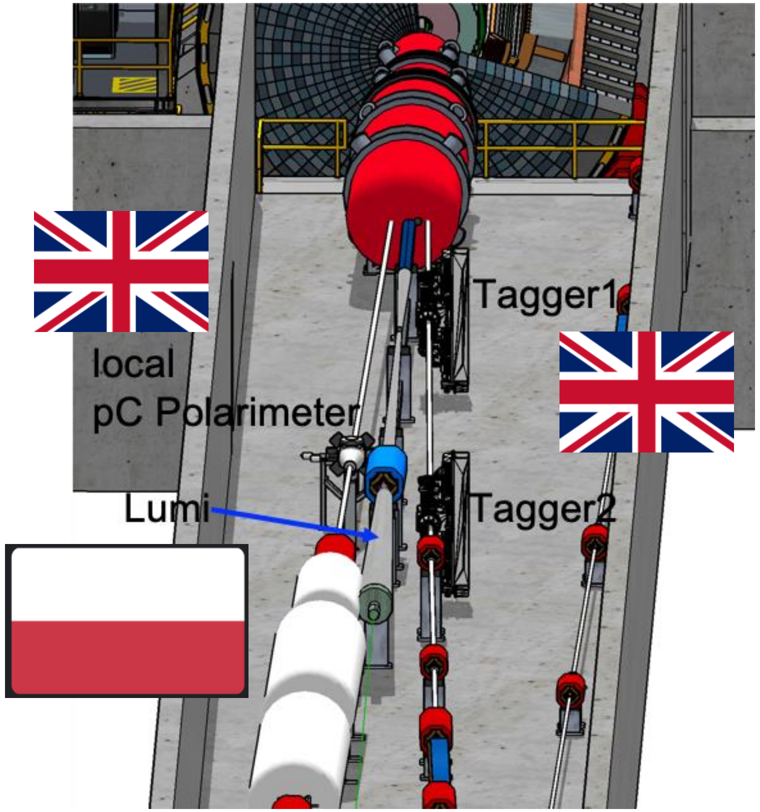
CERN

Los Alamos NATIONAL LABORATORY

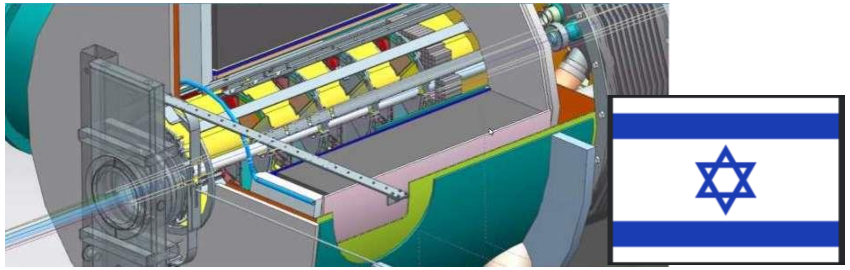
Far-Forward/Far-Backward Detectors Non-DOE Interest & In-kind

Detectors along the hadron and electron beam-lines





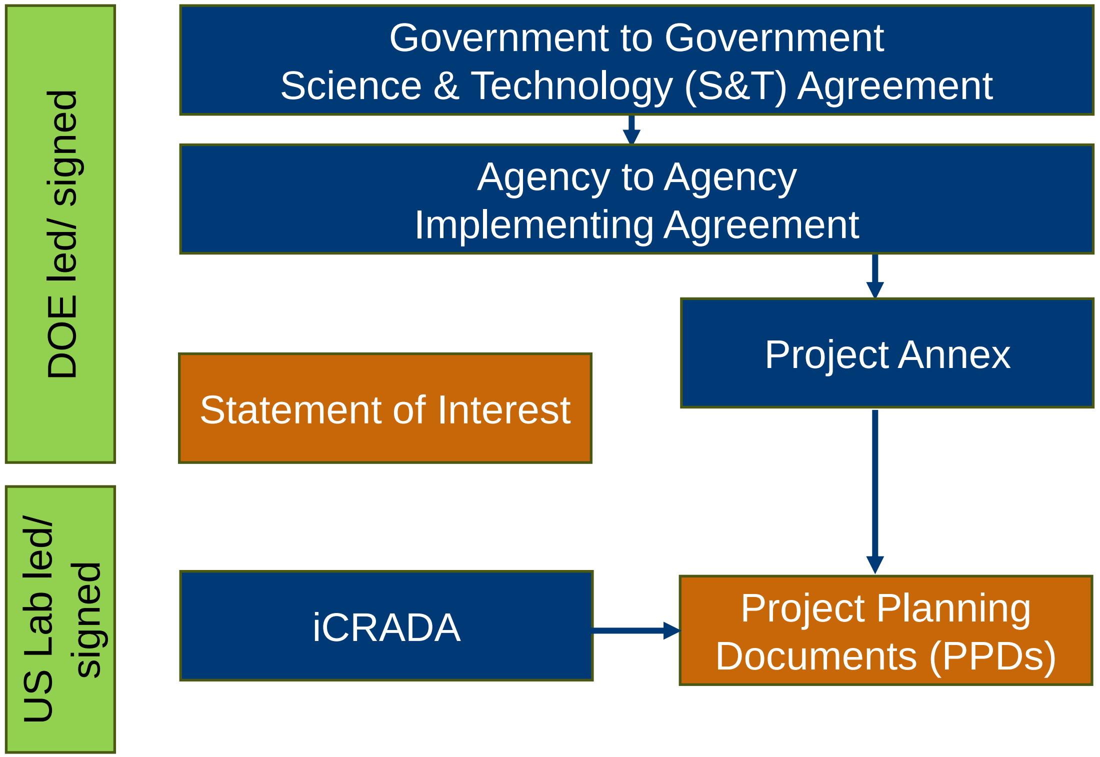
B0-Tracker & Electromagnetic Calorimeter



Detector Non-DOE Interest & In-Kind

Entity	Interest and Important Facts
NSF	NSF-MSRI pre-proposal submitted by 10 US universities – aims at full scope of backward EM calorimetry (eECal). Armenia, Czech, France/IN2P3 as unfunded contributors. Invited to submit proposal. Moved within NSF to consider in MPS directorate. Final internal NSF review is ongoing.
CERN	MAPS sensor design developed by CERN/ITS-3 Group providing synergy with ALICE. Synergy of gaseous-based Cherenkov detectors and photon-sensors with ALICE & LHCb. Synergy of Forward AC-LGAD design with CMS endcap timing layer.
Armenia	Contributions, mainly labor to eECal and many EM calorimetry and particle id detectors component tests.
Canada	EIC included in 2022 Canadian Subatomic Physics Long-Range Plan; Interested in Compton Polarimetry, Barrel Electromagnetic Calorimetry and Software
China	Interested in Forward EM Calorimeter – working on NSF-China proposal.
Czech	Working with funding agency; Interested in eECal (PbWO4 crystals and glass) and Silicon
France/IRFU	Interested in MPGD/racking, electronics. Provided in-kind contributions to SC magnet design and interested to continue labor oversight during magnet construction.
France/IN2P3	International contribution to backward EM calorimetry (including in-kind design) and to readout electronics (two ASICs for AC-LGAD detectors and Calorimetry). IRFU & IN2P3 discussing together for higher-level contributions.
India	Consortium is working with Funding agency; Interested in detector software (non-project scientific contribution), contributions to DAQ/slow controls. Investigating further hardware contributions (including possible links with Si groups and plants).
Italy/INFN	Aims at major scope of forward particle identification detector (dRICH), at (part of) the Si/MAPS tracker scope, and at photo-sensor contributions as well as contributions to the μRwell. tracker. Further investigating possible interest in EIC detector magnet scope.
Israel	B0 Detectors (Si tracking and PbWO4)
Japan	Interested in a US-Japan agreement; Aims at full scope of Zero-Degree Calorimeter in collaboration with Taiwan/Korea. Pursuit of full scope of barrel AC-LGAD detector as EIC-Asia consortium. Contribution to DAQ/streaming.
Korea	Aims at major scope for fiber-based barrel EM calorimeter, Also work packages for barrel AC-LGAD and Si-based hadronic calorimetry for ZDC.as part of EIC-Asia consortium (includes also Japan,Taiwan), Collaboration on Si tracking detector. Proposal submitted to MSIT.for M&S for barrel EMCal and support for labor for all interests.
Poland	Actively working with ministry/funding agency; Interested in detectors along the beam line (luminosity detector, Roman Pots)
Taiwan	Pursuit of full scope of barrel AC-LGAD as part of EIC-Asia consortium. LYSO-based EM calorimeter for ZDC, Also optical readout/fiber. Possible later interest in PCBs. Computing.
UK	STFC seed funding for UK detector R&D (3M£). Interest in Si/MAPS tracker, polarimetry and detectors along the beams (Low-Q2/TimePix). Follow-up STFC/UKRI request for 5-7 years submitted early 2023 (includes accelerator part).

EIC In-Kind CD-2 Expectations



binding (contractual)

not-binding

Templates posted on the RRB indico page

- DOE agreements do not contain EIC Project IKC scope details.
- Project Planning Documents (PPDs) contain IKC scope details.
- PPDs are not required for all IKC. EIC will have ~ 5-10.
- Laboratory (BNL or JLab) iCRADA binding agreements are suggested for IKC items requiring a PPD.

1st Wave of Milestones for Detector IKC

Agency	Milestone	Target Date
Italy-INFN	Outcome on detector solenoid funding (CD-3A scope)	December 2023
US-NSF	Outcome on MSRI funding (CD-3A scope)	January 2024
UK	UKRI outcome on funding proposal	January 2024
Italy-INFN	JLab iCRADA draft on magnet	February 2024
Italy-INFN	BNL iCRADA draft on magnet	March 2024
Italy-INFN	iCRADAs on magnet signed	May 2024
France-IN2P3	PPD draft	May 2024
France-CEA	PPD draft	June 2024
UK	PPD draft	August 2024
Italy-INFN	JLab iCRADA signed (excluding magnet scope)	August 2024
Italy-INFN	PPD draft / excluding magnet scope	August 2024
France-IN2P3	JLab iCRADA and BNL iCRADA signed (draft in Jun/Jul)	September 2024
France-CEA	JLab iCRADA signed (draft in Jun/Jul)	September 2024
UK	JLab iCRADA signed (draft in Jun/Jul)	September 2024
	CD-2/CD-3 Director's Review / All PPDs signed	**November 2024**
	CD-2/3 OPA review	**January 2025**
	CD-2/3 ESAAB	**April 2025**

There will be amble opportunity to make in-kind contributions after CD-2 as fits best with your funding agency cycle.

To achieve these timelines, it will be critical to have a dedicated team from the in-kind partner and the project team working in sync to get the documents done and signed.

Would appreciate to get contact persons defined asap.

Note after review:
for magnet it makes more sense to constrain to:
- JLab-INFN iCRADA
- JLab-CEA iCRADA
- Magnet PPD

IKC Not Addressed in iCRADA / PPDs

At the time of the DOE CD-2/3 Review, currently planned for early 2025, scope without identified IKC partners will be assumed as DOE scope, and pursued as opportunities.

IKC are expected to be identified and agreed upon at all stages of the EIC project, e.g., detector upgrades, accelerator installation and commissioning, and the timing of approval cycles in different countries (for example in the detector area, we would like to mention in this categories Countries with which we are already working such as Canada, Japan, Korea, Taiwan, etc.).

Outlook to CD-2

Goals for 2024 (towards CD-2!)

- DAC meetings in ~April (topics: detector status, international engagement, R&D status) and ~August (topic: Detector R&D advise)
  - Completion of Non-Si R&D
  - Advise on follow-up of MAPS/ITS3, ASICs, and AC-LGAD
- Quantify (time, cost, performance) and document, before CD2, mitigation plans for the possibility that some R&D components will not meet expectations
  - Tracking layout with branching points defined and documented
  - HRPPD backup option documented, etc.
- Ensure good project progress
  - Implement procurements for CD-3A scope and manage progress
  - Continue work on design maturity for all (non-CD-3A) systems.
  - Define CD-3B needs: next phases of CD-3A, magnet power supply, perhaps VTRx+ optical transceivers, perhaps magnet steel
  - PDRs of Tracking, Far-Forward/Far-Backward, Electronics/DAQ, Particle Identification
  - FDRs of Magnet Power Supply, Calorimetry
- Continue work on integration aspects, e.g., service needs of various detectors, cable routing, electronic rack layouts, survey & alignment planning, monitoring systems, controls needs.
  - System engineering for electrical and services (per DOE/OPA recommendation)
  - Document controls needs
  - Collect interfaces beyond CD-3A scope, and document towards ICDs
- Simulations with Full Materials, Background and Reconstruction
- Draft Technical Design Report in collaboration with ePIC
- Formalize in-kind agreements in form of high-level agreements and project planning documents, as appropriate: Italy/INFN (Detector, Magnet), France/IN2P3, France/IRFU, UK/STFC, perhaps NSF, other

2024 Design Review Plans

- Design Reviews
  - PDR2: IR Integration and Auxiliary Detectors – February 12, 2024 – main emphasis on baseline choices and progress
  - PDR1: Tracking Detectors – 2nd half of March 2024 – main emphasis on baseline tracking layout, if we are on track and plans
  - PDR2: Electronics/DAQ – May 2024? – continuation of PDR1 to ensure we are on track and show progress
  - PDR: Integration, Infrastructure and Installation – Summer/Autumn 2024? – includes detector support structures
  - PDR2: Particle Identification Detectors – Summer 2024?
  - PDR2: Barrel EM Cal – Summer/Fall 2024 – emphasis on mechanical design & AstroPix readiness
  - FDR: Backward & Forward EM Calorimetry, Barrel & Forward HCAL – Fall 2024
  - PDR2: Polarimetry – timescale TBD (but before CD-2)
  - FDR for any potential CD-3B scope: Magnet Power Supply, perhaps VTRx+/lpGBT, perhaps magnet steel – see NOTE
  - FDR Magnet Power Supply – Spring 2024; Magnet Steel perhaps Summer 2024; VTRx+/lpGBT add ½ day to electronics/DAQ PDR2
- Detector R&D Day - late March/early April? – check R&D progress and outlook to FY25
- DAC-Meetings 2024 under planning:
  - ~April 2024: Project Status, Baseline Detector, International Engagement, Detector R&D progress (expect 1+ day)
  - ~August 2024: Detector R&D annual review (expect 2 days) – deadline for submission July 1, 2024
- Next ePIC Computing & Software review by host labs – Late Summer 2024?

NOTE: CD-3B for detector will include continuation phases for SiPMs, SciFi, PbWO4, Forward HCAL. Further scope has to be known essentially now and needs FDRs.

Challenges

- Completion of project detector R&D and expediting PED
  - Setting up procurements at national labs causes often long delay of detector R&D contracts (and thus) milestones. Similar for PED work and contracts.
  - ITS3 sensor dependency is a single point of failure vulnerability. Tracking alternatives will imply significant implications on the realization of the EIC science reach.
- Formalizing interest of international EIC user community into in-kind agreements.
- Ensuring IR and detector scope remain to go hand in hand and in phase.
- The lack of high energy hadron test beam in the years after 2025
  - We collect current ePIC current test beam needs at TestBeamNeeds
- Familiarizing the international ePIC collaboration with work in DOE Project mode.
- Continued vigilance about user-provided equipment and US/DOE safety codes and equipment requirements.

Summary

Summary

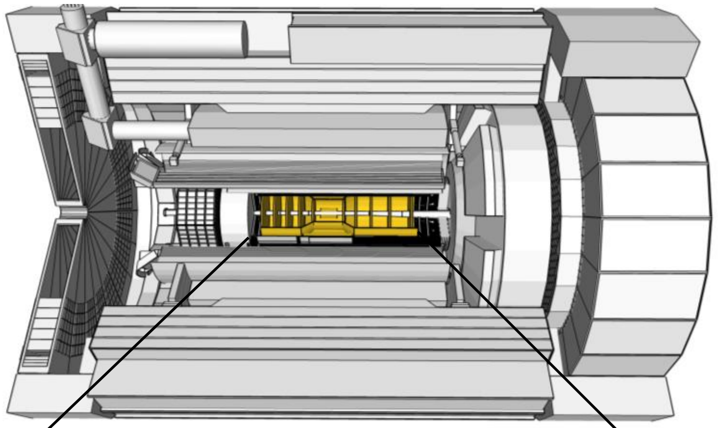
- Successful transition to ePIC detector collaboration.
  - Excellent working mode. *(More on this in John Lajoie's talk tomorrow)*
- Final central detector technology changes after transition to ePIC were made.
  - Finalized exact gaseous-based tracking (MPGD) implementation (barring risk-mitigation strategies).
  - Working to finalize detailed technology choices in far-forward/far-backward – review February 12.
- Project detector R&D started Q3/FY22. Benefits from large in-kind component.
  - Milestones defined and included in P6.
  - DAC reviewed FY23 progress + FY24 detector R&D plans in August 2023. FY24 contracts in procurement.
  - DOE initiated generic EIC detector R&D program in FY22, hosted by JLab.
- Excellent progress on PED – designs are maturing with help of our many friends.
  - This constitutes a ~$5M in-kind non-DOE PED contribution.
  - DAC was very complimentary about design maturity in the comprehensive design review.
  - Detector remains on track for CD-2.
  - **All CD-3A scope had FDRs; All FDRs pointed to appropriateness of LLP items for CD-3A; and the urge to start them; DOE/Office of Project Assessment review recommended to proceed to CD-3A approval.**
  - **Formal CD-3A approval by DOE imminent.**
- Remaining high risk is with the SC detector magnet.
- Much emphasis on international engagement.
  - 1st and 2nd Resource Review Board meetings were successes, 3rd meeting scheduled for May 6 + 7 hosted by Italy.
  - Multiple international meetings and visits; In-kind goal of 30% of detector scope still remains within reach.

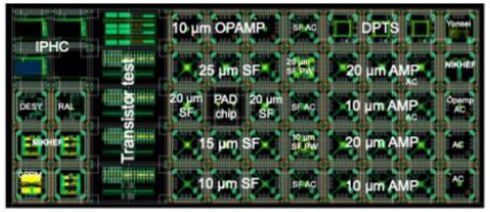
Backup Material

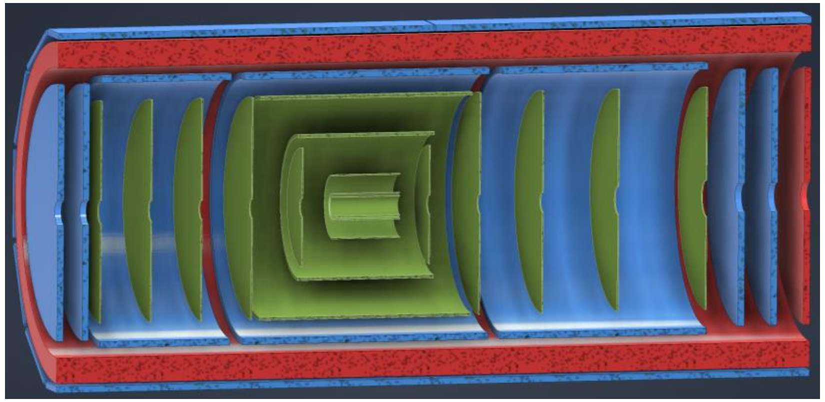
ePIC Tracking Detectors

Monolithic Active Pixel Silicon Tracker:

- 1 single technology: 65-nm MAPS
  - small pixels (~18 μm) and power consumption (<20 mW/cm^2)
    low material budget
    (0.05% to 0.55% X/X_0 / layer)
  - based on ALICE ITS3 development
  - MAPS Vertex layers
  - MAPS Barrel, forward and backward disks



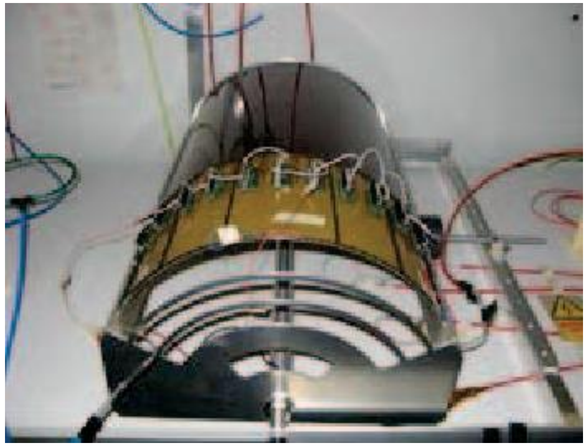




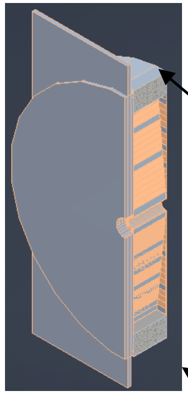
- MAPS Barrel + Disks
- MPGD Barrels + Disks
- AC-LGAD based ToF

Multi Pattern Gas DetectorS:

- additional space points at large radii
- Cylindrical microMEGAS
  - → Additional space point for pattern recognition / redundancy
  - → Ongoing geometry optimization
- μRWELL planar layer just before hpDIRC
  - → Impact point and direction for the ring seeding of hpDIRC
  - → Additional space point for pattern recognition / redundancy
- Two MPGD disks each beyond Si disks in forward and backward direction
  - → To provide sufficient hits under large backgrounds to compensate for large Si time integration frame

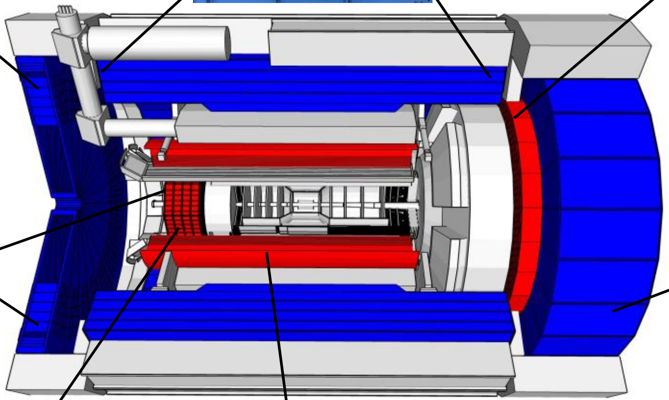


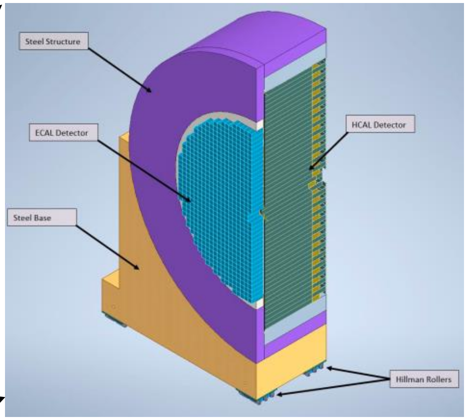
ePIC Calorimetry



Backwards HCal
Steel/Sc Sandwich
tail catcher

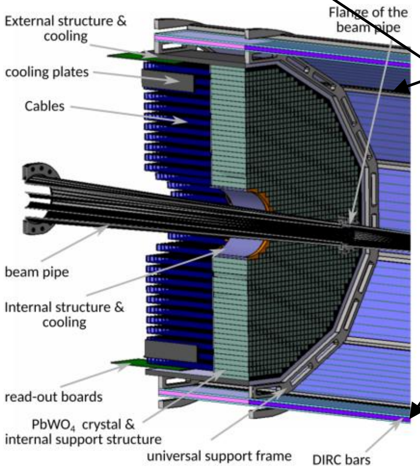
Barrel HCAL
(re-used from
sPHENIX)



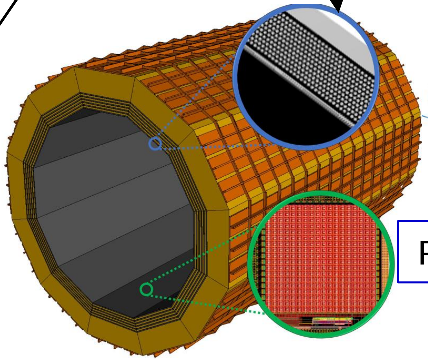


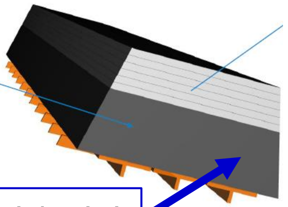
Forward ECal
High granularity
Tungsten-Powder/**SciFi** matrix
SiPMs as photonsensors

ForwardHCAL
Longitudinally separated **Steel**/Sc &
Tungsten/Sc sandwich
with **SiPMs** embedded in Scintillator



Backward Ecal
High-precision, **PbWO4**
SiPMs as photonsensor

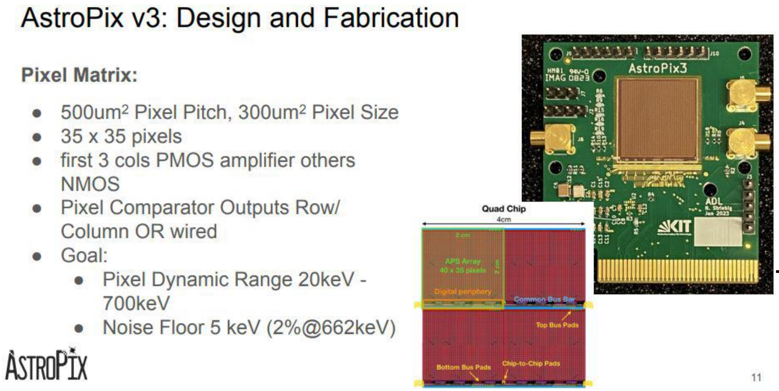




Pb/SciFi

Long Lead Procurement Items

Barrel ECal: Pb/**SciFi** with a hybrid imaging part (using 6 layers of ASTROPIX)



ePIC Particle Identification Detectors

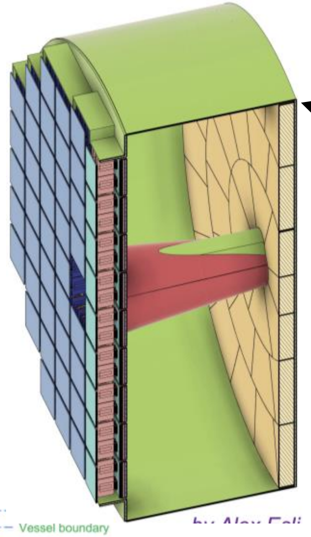
Backward RICH:

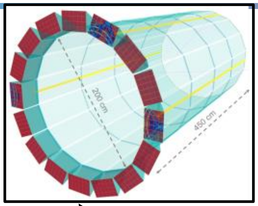
- Aerogel Cherenkov Det.
- e, π, K, p separation

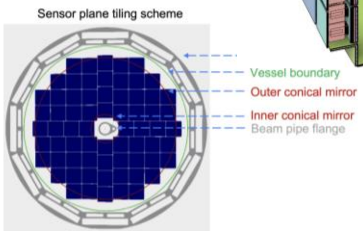
→ π/K 3σ sep. at 10 GeV/c

- Photon-sensor:
  LAPPDs to include TOF

Single volume proximity focusing aerogel RICH with long proximity gap (~30 cm)

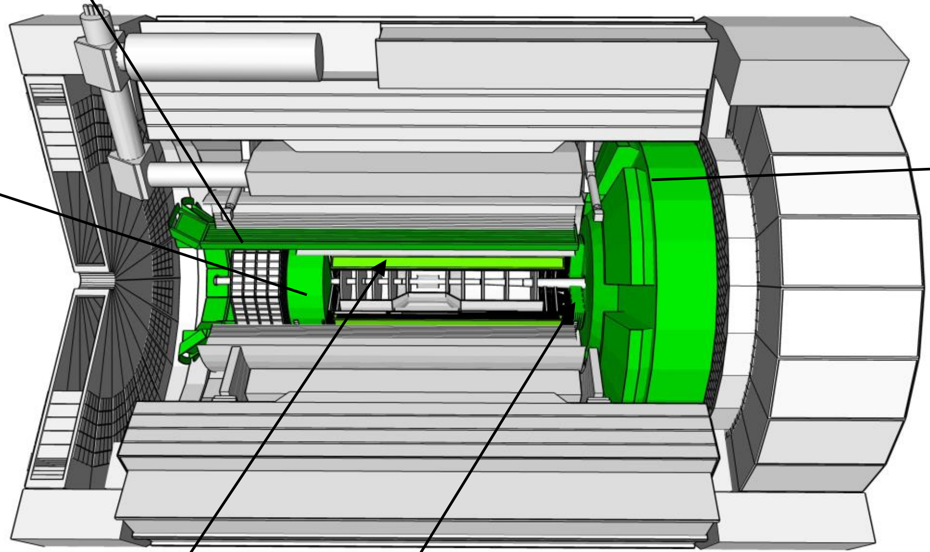






hpDIRC (High Performance DIRC)

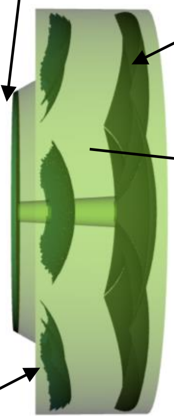
- Quartz bar radiator → Reuse of BaBAR DIRC bars
- light detection with MCP-PMTs
- Fully focused
- p/K 3σ sep. at 6 GeV/c



dual Radiator RICH

Aerogel
z: 4cm radius: 110 cm
air gap
0.3 mm acrylic filter

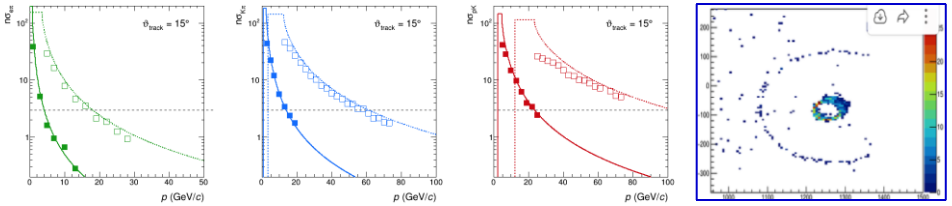
Spherical Mirrors
6 Azimuthal Sectors



C_2F_6 Gas Volume
120 cm length
radius: 185 cm
Tapered bore radius
Al vessel

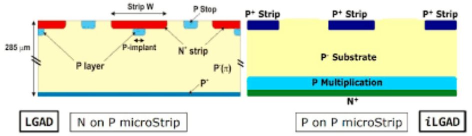
Sensors tiled on spheres
→ SiPMs as Photonsensors

π/K 3σ sep. at 50 GeV/c



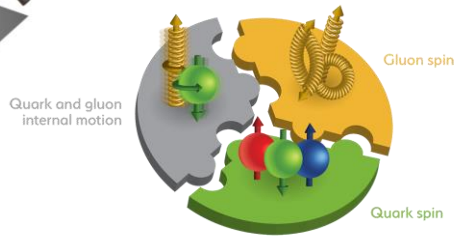
ToF AC-LGAD (Low Gain Avalanche Detector)

- 20-35 psec
- Accurate space point for tracking
- forward disk and central barrel
- R&D and PED by International consortium HEP & NP



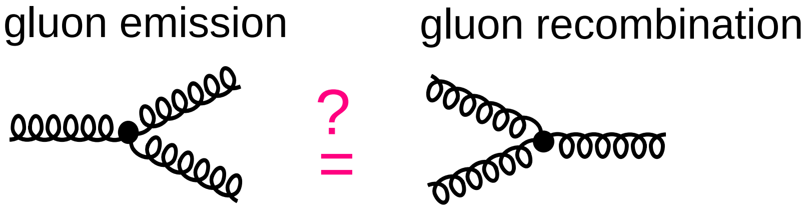
Accelerator Performance Needs for NAS Science

wide center-of-mass energy √s: 20 – 140 GeV :
- map the out nucleon and nuclei structure from high to low x



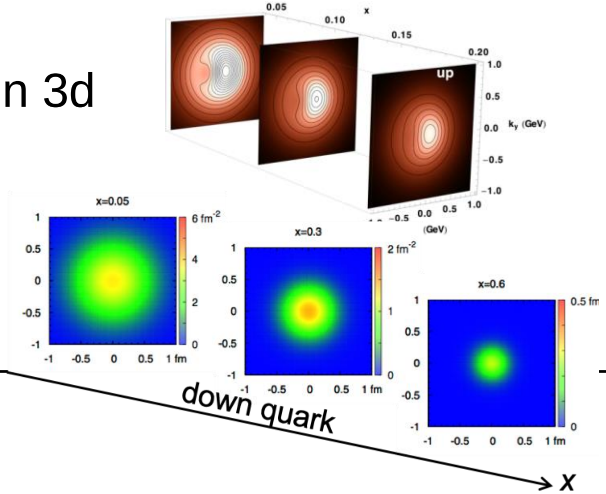
polarized electron and hadron (p, He-3) beams:
- access to spin structure of nucleons and nuclei
- Spin vehicle to access the spatial and momentum structure of the nucleon in 3d
- Full specification of initial and final states to probe q-g structure of NN and NNN interaction in light nuclei

nuclear beams: d to Pb
- accessing the highest gluon densities → saturation
- quark and gluon interact with a nuclear medium



high luminosity 10^{33}-10^{34} $cm^{-2}s^{-1}$:
- mapping the spatial and momentum structure of nucleons and nuclei in 3d
- access to rare probes, i.e. Ws

large acceptance (0.2 – 1.3 GeV) through forward focusing IR magnets
- spatial imaging of nucleons and nuclei

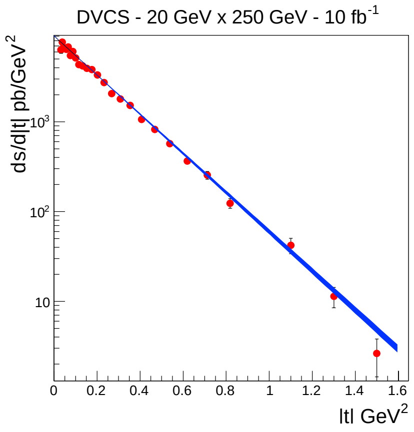


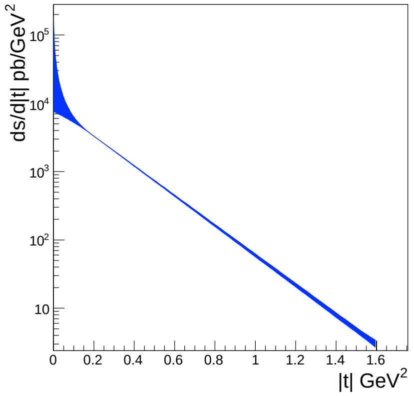
Accelerator Performance Needs for NAS Science

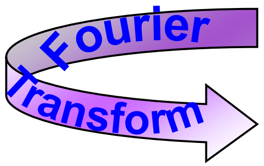
The special role of SHC for the spatial imaging program

→ SHC is not just about luminosity but **even more critical** minimizes emittance blow up of hadrons

Measurement

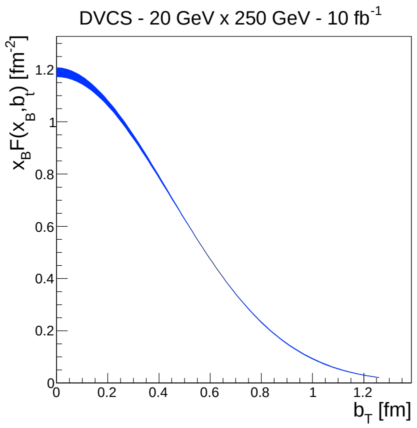


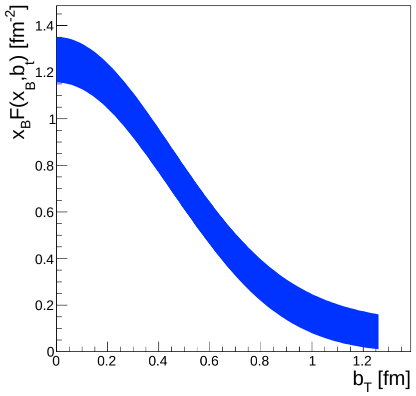




Plots with reduced lower p_t-acceptance cause: emittance blow up reduced Roman Pot acceptance

Physics Observable





Physics Requirement:

$\int L_{int} = 10 fb^{-1}$

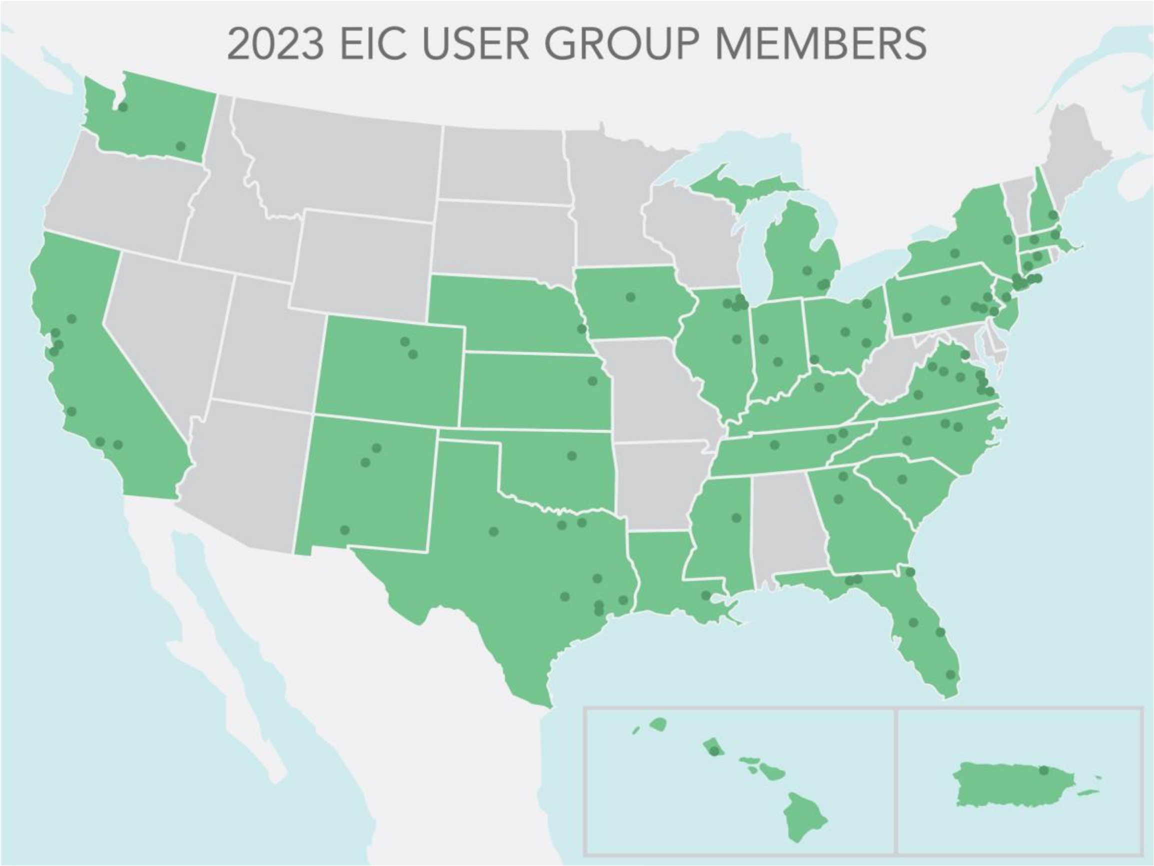
$0.18 < p_t$ (GeV) < 1.3

$0.03 < |t|$ (GeV^2) < 1.6

$\int L_{int} = 10 fb^{-1}$

$0.44 < |p_t|$ (GeV) < 1.3

Detector Domestic Interest in EIC and Diverse Workforce Development



- The growing EIC user community currently comprises **98** US institutions including 7 National Laboratories
- 12 of these are MSIs:
  - Dillard University
  - Florida A&M University
  - Florida International University
  - Georgia State University
  - Hampton University
  - New Mexico State University
  - University of Illinois Chicago
  - University of Houston
  - University of Puerto Rico, Rio Piedras
  - Virginia Union University
  - Univ. of CA, Riverside
  - Texas A&M

The broad US interest in EIC provides opportunities for further diverse workforce development

Far-Forward/Far-Backward Detectors Review

- Preliminary Design Reviews:
  - IR Integration and Auxiliary Detectors (6.10.11) – April 27, 2022

    Main emphasis: check progress ensure no scope or interface is forgotten.
  - **IR Integration and Auxiliary Detectors– February 12, 2023**

    Main emphasis: baseline detector choices
  - IR Integration and Auxiliary Detectors – Future before CD-2 with as main emphasis the designs

You are asked to address the following questions:

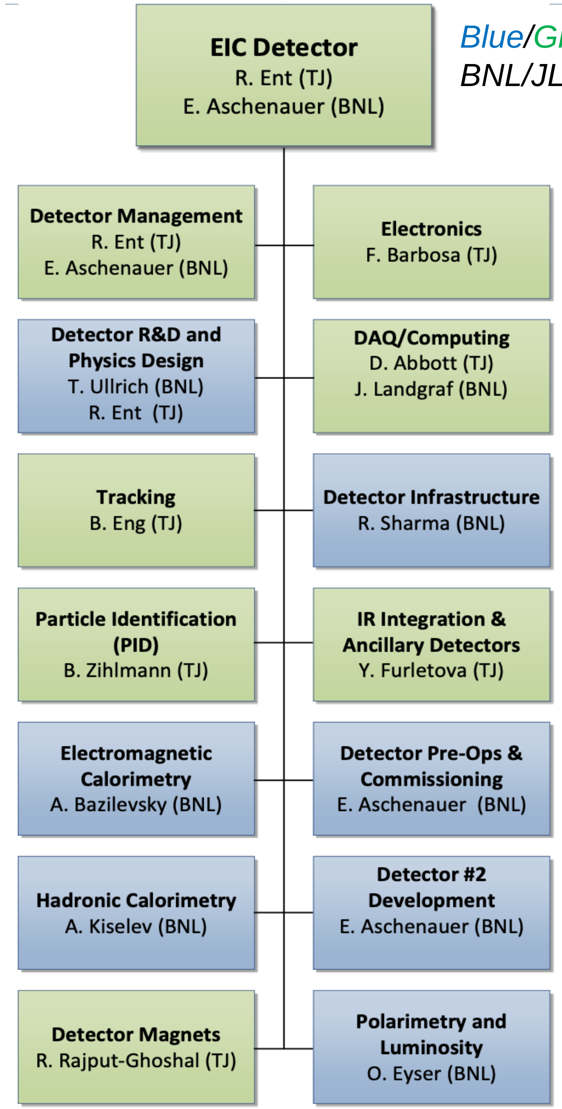
1. Are the technical performance requirements appropriately defined and complete for this stage of the project?
2. Are the plans for achieving detector performance and construction sufficiently developed and documented for the present phase of the project?
3. Are the current designs and plans for detectors and electronics readout likely to achieve the performance requirements with a low risk of cost increases, schedule delays, and technical problems?
4. Are the fabrication and assembly plans for the various detector systems appropriately developed for the present phase of the project?
5. Are the plans for detector integration in the interaction region appropriately developed for the present phase of the project?
6. Have ES&H and QA considerations been adequately incorporated into the designs at their present stage?

Please address these questions point-by-point.

Tentative agenda (Suggested, times in Eastern Standard Time, to be adjusted):

08:00 – 08:30	Executive Session (Closed Session)
08:30 – 09:00	Far-forward/far-backward overview and requirements – Yulia Furletova (JLab)
09:00 – 09:15	Summary of accelerator integration – Karim Hamdi (BNL)
09:15 – 09:45	Summary of Vacuum, Backgrounds and Beam Collimation and Abort Systems – Elke
09:45 – 10:15	Roman Pots and Off-Momentum Detectors – Alex Jentsch (BNL)
10:15 – 10:30	Break
10:30 – 11:00	Zero-Degree Calorimeter – Yuji Goto / Michael Murray
11:00 – 11:30	B0 Detectors – Zvi Citron / Michael Pitt
11:30 – 11:50	Luminosity Detector Pair spectrometer – Nick Zachariou (York, UK) / Dhevan Gangadharan
11:50 – 12:10	Luminosity Detector : direct photon calorimeter – Krzysztof Piotrzkowski /Mariusz Przybycien
12:10 – 12:30	Break
12:30 – 13:00	Low Q2 detector – Ken Livingston (Glasgow, UK) - keep after 12.
13:00 –13:15	DAQ and synchronization – Jeff Landgraff (BNL)
13:15 – 13:30	Engineering design and mechanical support structures – Ron Lassiter (Jlab)
13:30 – 14:00	(as needed) Further Questions
14:00 – 15:30	Executive Session (Closed Session)
15:30 – 16:00	Closeout

WBS 6.10 EIC Detector & 6.10.01 Management



Blue/Green show nominal BNL/JLAB responsibility

How We Work:

The highest-level detector management consists of:

Elke & Rolf L2 Leads
Walt Akers 6.10 Systems Engineer
Fernando Barbosa Chief Electrical Engineer
Rahul Sharma Chief Mechanical Engineer

Do not use this CAM responsibility organization as Black and White, we work together as a scientific collaboration and use expertise from each lab as it fits independent of high-level responsibility
We include user efforts where it makes sense, and lean to more

We have
- Weekly meetings with ePIC spokesperson and deputy
- Weekly meetings with the mechanical engineering team
- Biweekly meetings with the electrical engineering team
- Weekly meetings with the Detector Control Account Managers
- As needed meetings with various detector subsystems
- Walt, Fernando and Rahul have also separate meetings, for Walt with the Systems Engineering Group, for Rahul with also various non-BNL/non-Jlab engineers/designers, etc.

We report at the biweekly ePIC meetings and many other meetings on general detector progress or requested topics

Integrating ePIC collaboration in Project WBS

6.10 EIC Detector

- 6.10.01 Detector Management
- 6.10.02 Detect. R&D & Physics Design
- 6.10.03 Tracking
- 6.10.04 Particle Identification
- 6.10.05 Electromagn. Calorimetry
- 6.10.06 Hadronic Calorimetry
- 6.10.07 Magnets
- 6.10.08 Electronics
- 6.10.09 DAQ / Computing
- 6.10.10 Detector Infrastructure
- 6.10.11 IR Integration & Auxiliary Detectors
- 6.10.12 Detector Pre-Ops & Commiss.
- 6.10.13 Detector #2 Development
- 6.10.14 Polarimetry and Luminosity

Detector Subsystem Work Packages

need to be integrated in WBS

SPOKESPERSON'S OFFICE
J. Lajoie (ISU), Spokesperson
S. Dalla Torre (INFN), Deputy Spokesperson

TECHNICAL COORDINATOR
Silvia Dalla Torre *(interim)*

DSL:
Detector Subsystem Leader
DSTC:
Detector Subsystem Technical Coordinator

dRICH
DSL/DSTC: Marco Contalbrigo (INFN)

hpDIRC
DSL/DSTC: Greg Kalicy (CUA)

BACKWARD RICH
DSL/DSTC: Alexander Kiselev (BNL)

FAR FORWARD
DSL: Alex Jentsch (BNL)
DSTC (B0): Zvi Citron (Ben-Gurion)
DSTC (Roman Pots/OMD): Alex Jentsch (BNL)
DSTC (ZDC): Yuji Goto (RIKEN)

LUMINOSITY
Co-DSL: Nick Zachariou (York)
Co-DSL: Krzysztof Piotrzkowski (AGH Krakow)
DSTC (Pair Spectr.): Dhevan Gangadharan (Houston)

FAR BACKWARD HIGH RATE TRACKER
DSL: Jaroslav Adam (CTU)
DSTC: Simon Gardner (Glasgow)

Si TRACKERS
DSL: Ernst Sichtermann (LBL)
DSTC: Laura Gonella (Birmingham)

BACKWARDS ECAL
DSL: Tanja Horn (CUA)
DSTC: Carlos Munhoz (IJCLab)

BACKWARDS HCAL
DSL/DSTC: Leszek Kosarzewski (OSU)

BARREL ECAL
Co-DSL: Sylvester Joosten (ANL)
Co-DSL: Hwidong Yoo (Yonsei)
Deputy DSL: Maria Zurek (ANL)
DSTC (Si): Jessica Metcalfe (ANL)
DSTC (SciFi/Pb): Zisis Papandreou (Regina)

BARREL HCAL
Co-DSL: Stefan Bathe (Baruch)
Co-DSL: Megan Connors (GSU)

FORWARD ECAL
Co-DSL/DSTC: Oleg Tsai (UCLA)
Co-DSL: Huan Huang (UCLA)

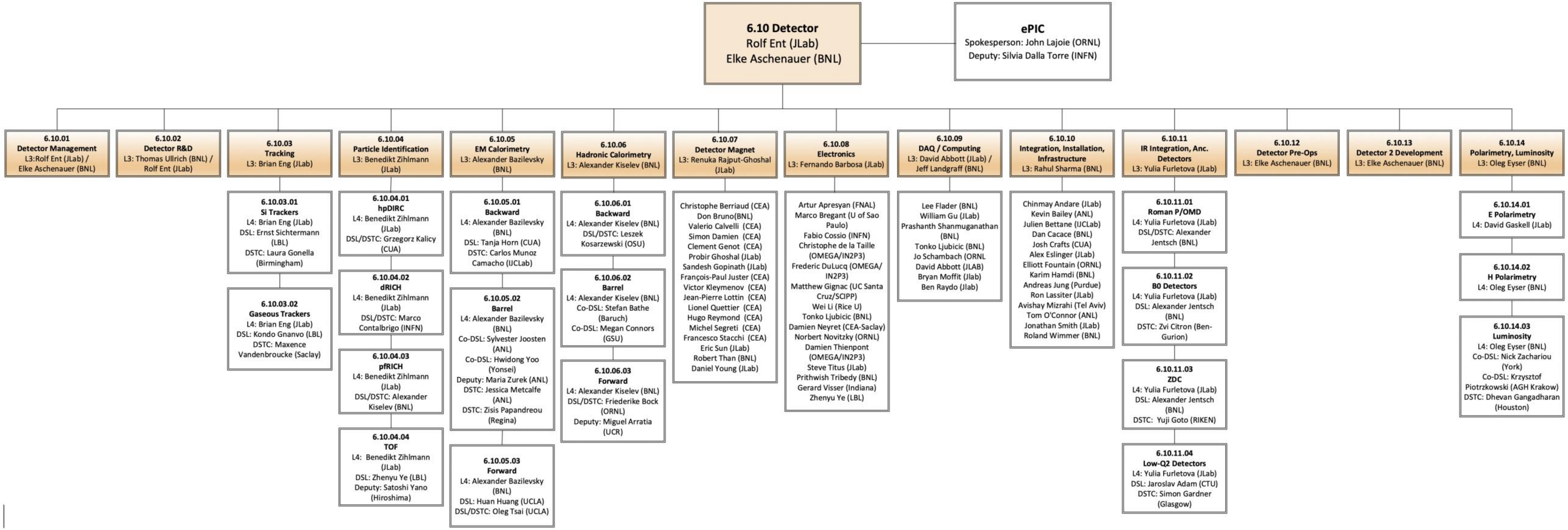
FORWARD HCAL
DSL/DSTC: Friederike Bock (ORNL)
Deputy DSL/DSTC: Miguel Arratia (UCR)

AC-LGAD TOF
DSL: Zhenyu Ye (LBL)
Deputy DSL: Satoshi Yano (Hiroshima)

GASEOUS TRACKERS
DSL: Kondo Gnanvo (LBL)
DSTC: Maxence Vendenbroucke (Saclay)

ePIC Detector Subsystem Collaborations

Integrating ePIC collaboration in Project WBS



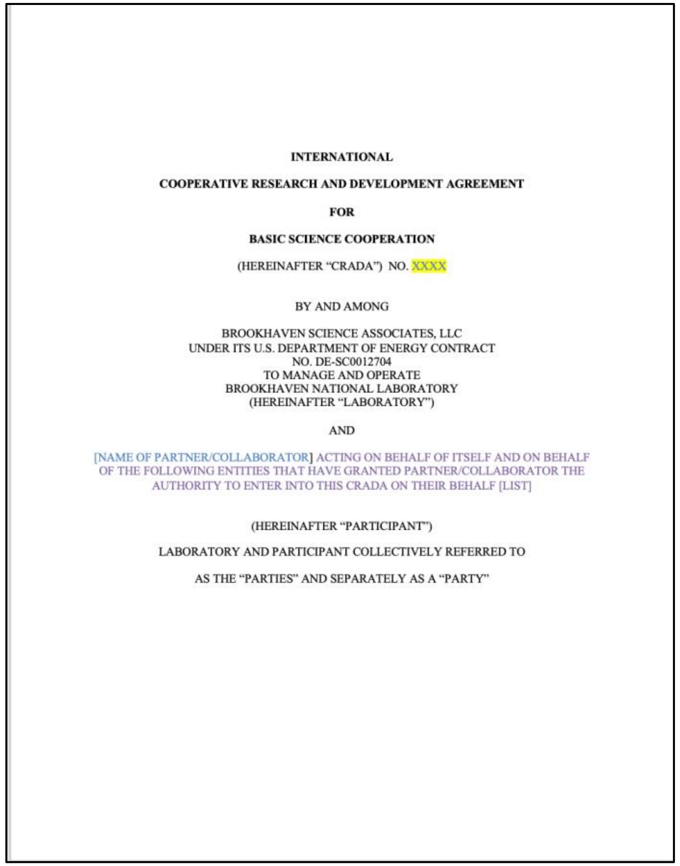
Work packages are implemented at L5 or lower

1st Wave of Milestones for Accelerator IKC

Agency	Milestone	Target Date
France – IN2P3	Proposed scope accelerator	End December 2023
UK	UKRI outcome on funding proposal	January 2024
France – CEA/IN2P3	Joint Proposal submitted to French Ministry	February 2024
Canada – TRIUMF	JLab iCRADA draft	February 2024
Canada – TRIUMF	BNL iCRADA draft	March 2024
Canada – TRIUMF	iCRADAs signed	May 2024
Canada – TRIUMF	PPD draft	June 2024
France – CEA	BNL iCRADA draft	June/July 2024
UK	Jlab iCRADA draft	June/July 2024
France – CEA	PPD draft	August 2024
UK	PPD draft	August 2024
France-CEA	BNL iCRADA signed	August 2024
UK	JLab iCRADA signed	August 2024
	CD-2/CD-3 Director's Review / All PPDs signed	**November 2024**
	CD-2/3 OPA review	**January 2025**
	CD-2/3 ESAAB	**April 2025**

Why iCRADA?

iCRADA = international Cooperative Research And Development Agreement.



INTERNATIONAL

COOPERATIVE RESEARCH AND DEVELOPMENT AGREEMENT

FOR

BASIC SCIENCE COOPERATION

(HEREINAFTER "CRADA") NO. XXXX

BY AND AMONG

BROOKHAVEN SCIENCE ASSOCIATES, LLC
UNDER ITS U.S. DEPARTMENT OF ENERGY CONTRACT
NO. DE-SC0012704
TO MANAGE AND OPERATE
BROOKHAVEN NATIONAL LABORATORY
(HEREINAFTER "LABORATORY")

AND

[NAME OF PARTNER/COLLABORATOR] ACTING ON BEHALF OF ITSELF AND ON BEHALF OF THE FOLLOWING ENTITIES THAT HAVE GRANTED PARTNER/COLLABORATOR THE AUTHORITY TO ENTER INTO THIS CRADA ON THEIR BEHALF [LIST]

(HEREINAFTER "PARTICIPANT")

LABORATORY AND PARTICIPANT COLLECTIVELY REFERRED TO

AS THE "PARTIES" AND SEPARATELY AS A "PARTY"

Template posted on the RRB indico page

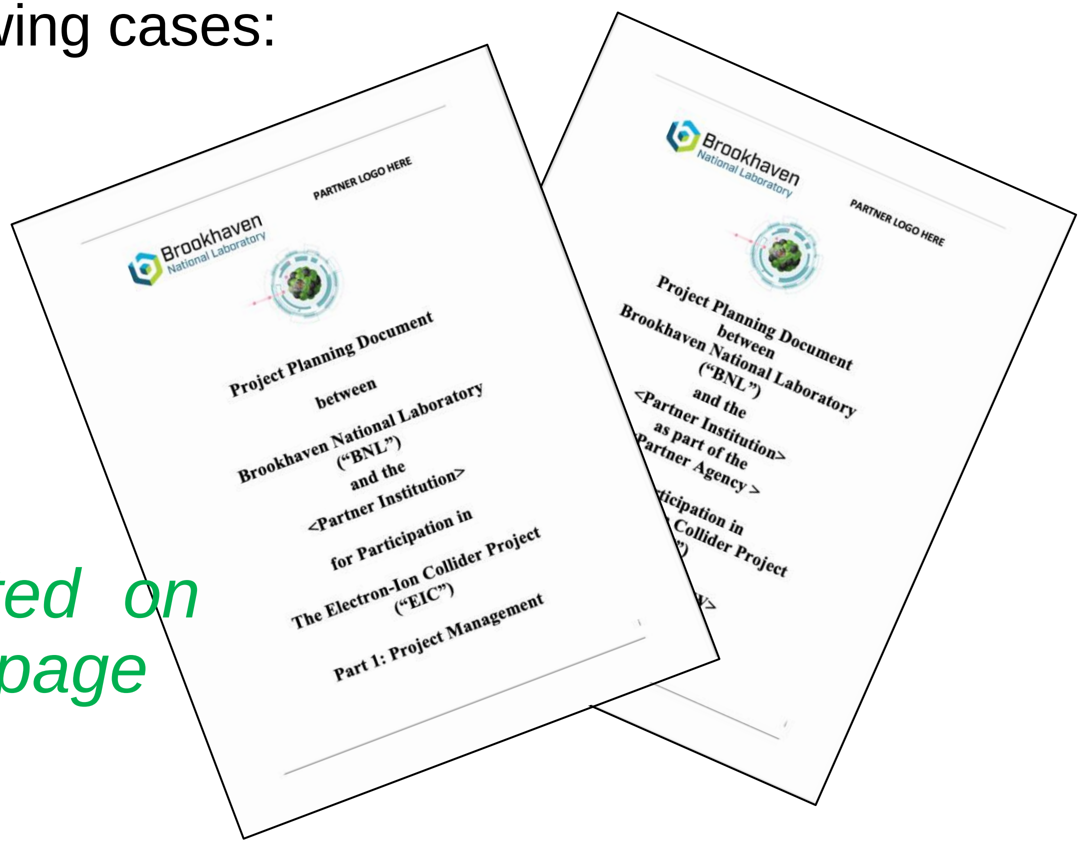
- iCRADA is needed to carry out the cooperative activities set forth in the Annex.
- iCRADA first 8 pages can not be modified by the Parties i.e. the first 8 pages are not negotiable (Please note that the first 8 pages might look familiar too many of you.)
- iCRADA Annex need to be develop with each EIC Partner with a preference to maintain separate the Detector and Accelerator scope.
- iCRADA Annex contains a high level description of the EIC specific IKC scope from a EIC Partner.
- iCRADA Annex contains an estimation of the IKC work "up to/do not exceed" US $ calculated as the IKC work will be performed by DOE $.

Why are PPDs needed

The EIC Project requests PPDs for the following cases:

- Technical complex items;
- Critical technical items;
- High-risk items;
- High-cost items;

Templates posted on the RRB indico page



PPDs are needed to align step by step the IKC scope/expectation to the project requirements.