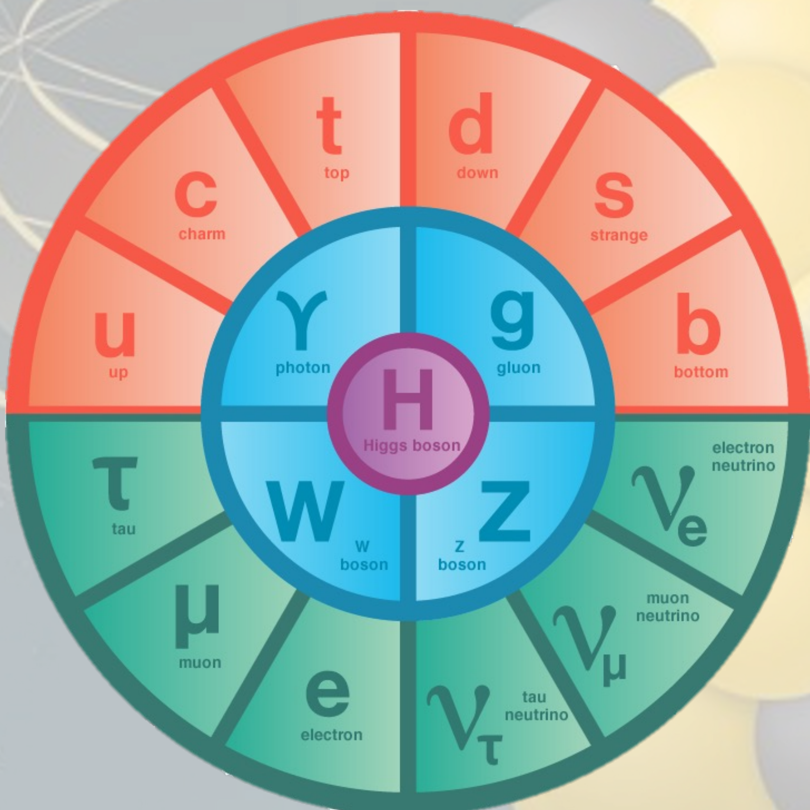
TIDC EIC Workshop
Welcome and Introduction

18 August 2022 @ NCKU

Yi Yang
National Cheng Kung University

Welcome from the College of Science of NCKU
Dean Prof. Chin-Chun Tsai

Standard Model of Particle Physics



Low energy (nuclear physics)
- Properties of proton, neutron
- QCD
- Dark matter
- …

TEXONO, ADMX,…

Intermediate energy (high energy nuclear physics)
- QCD
- QED
- …

RHIC, FAIR,…

High energy
- SM
- BSM
- …

LHC, Tevatron…

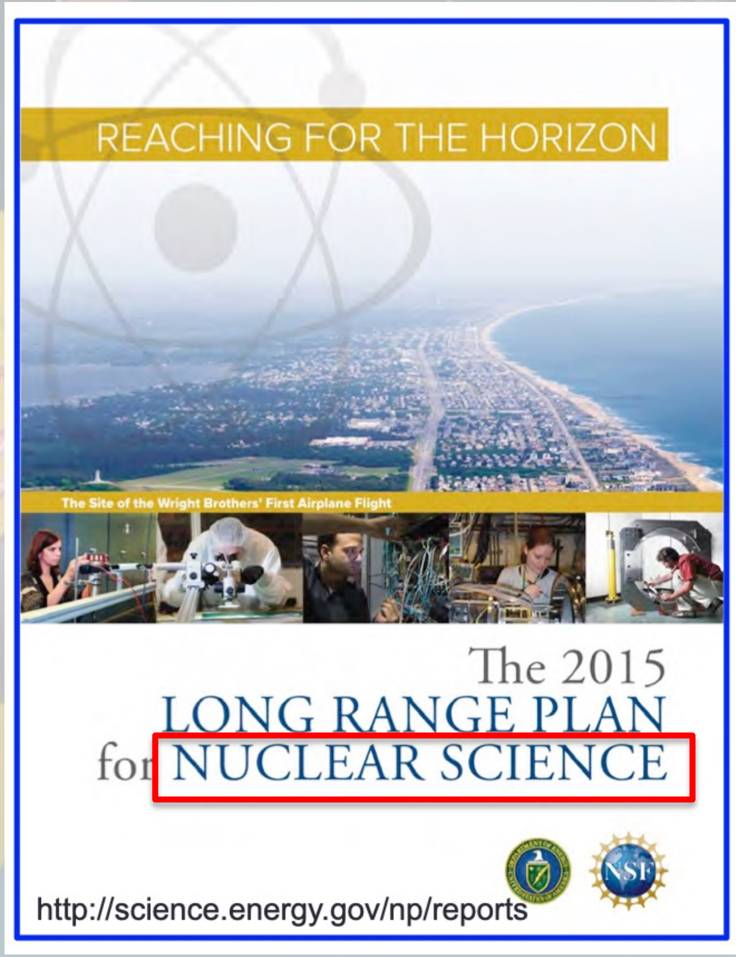
Ultra-high energy
- Cosmic ray
- Neutrino
- Dark matter
- …

AMS, IceCube, …

https://www.symmetrymagazine.org/standard-model/

Why EIC?

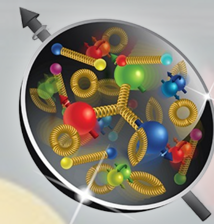
Gluons, the carriers of the strong force, bind the quarks together inside nucleons and nuclei and generate nearly all of the visible mass in the universe. Despite their importance, fundamental questions remain about the role of gluons in nucleons and nuclei. These questions can only be answered with a powerful new electron ion collider (EIC), providing unprecedented precision and versatility. The realization of this instrument is enabled by recent advances in accelerator technology.



We recommend a high-energy high-luminosity polarized EIC as the highest priority for new facility construction following the completion of FRIB.

FRIB: Facility for Rare Isotope Beams

Nobel Prizes and EIC



Hideki Yukawa (1949) "for his prediction of the existence of mesons on the basis of theoretical work on nuclear forces"
But the quark-gluon origin of the nuclear binding force remains an unknown.

Robert Hofstadter (1961) "for his pioneering studies of electron scattering in atomic nuclei and for his thereby achieved discoveries concerning the structure of the nucleons"
But the 3D quark-gluon structure of nucleons remains an unknown.

Jerome Friedman, Henry Kendall, Richard Taylor (1990) "for their pioneering investigations concerning deep inelastic scattering of electrons on protons and bound neutrons, which have been of essential importance for the development of the quark model in particle physics"
But the role of gluons in protons and bound neutrons remains unknown.

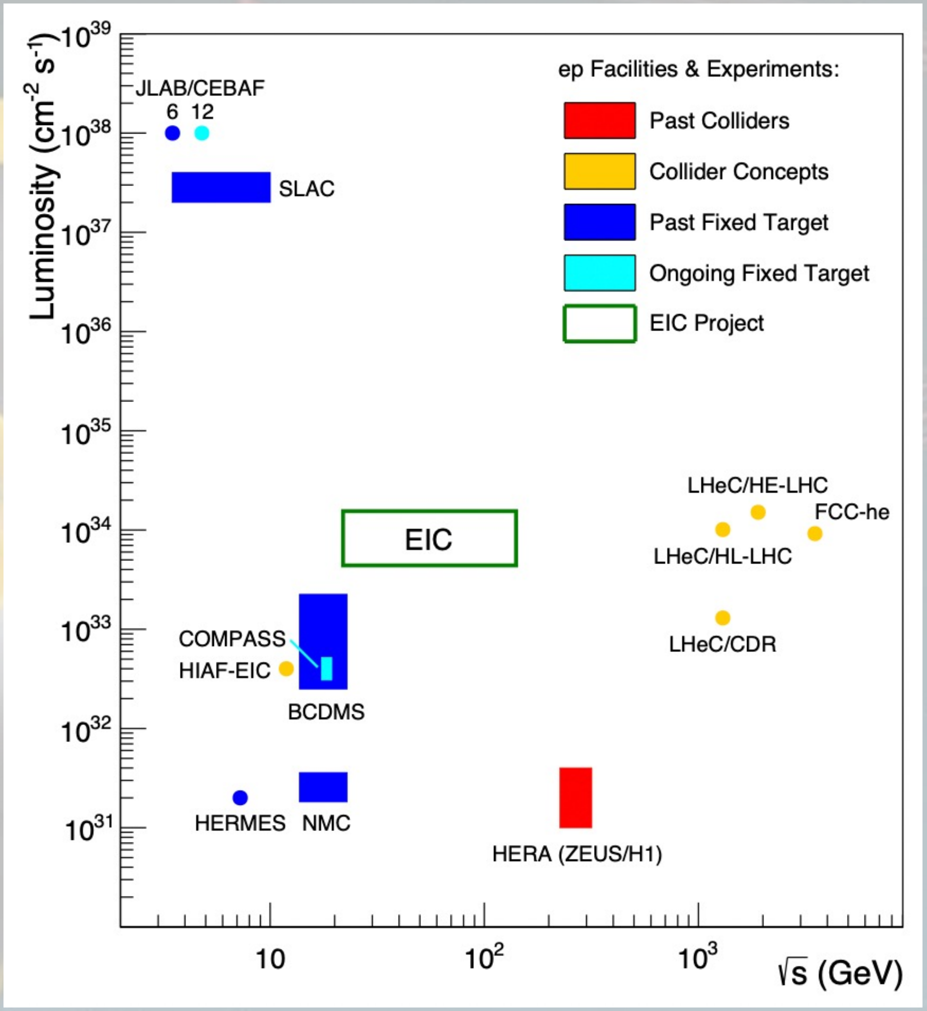
David Gross, David Politzer, Frank Wilczek (2004) "for the discovery of asymptotic freedom in the theory of the strong interaction"
But the confinement aspect of the theory remains unknown.

Yoichiro Nambu (2008) "for the discovery of the mechanism of spontaneous broken symmetry in subatomic physics "
But how dynamical chiral symmetry breaking shapes the mass and structure of quark-gluon systems remains unknown.

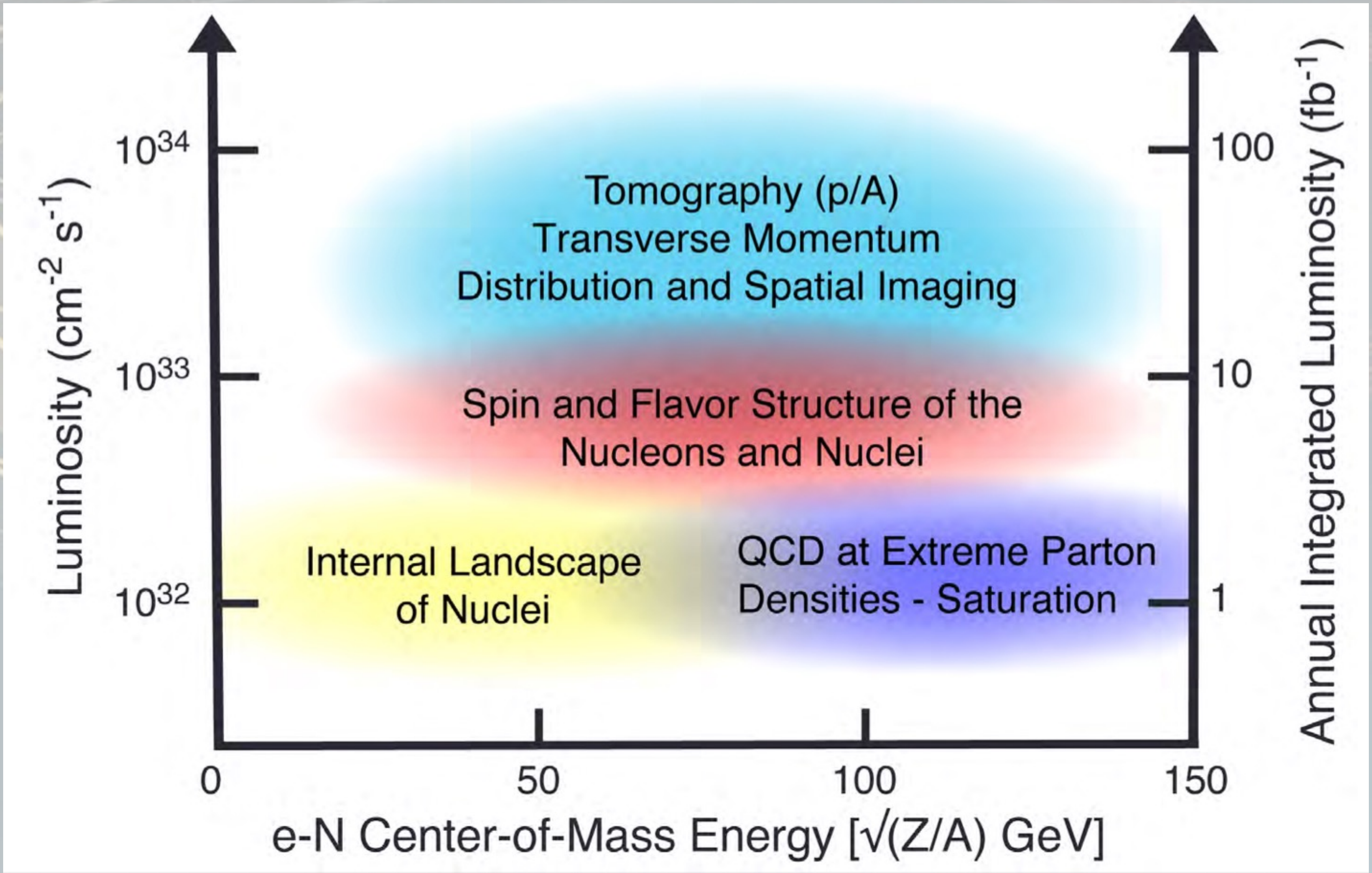
https://indico.fnal.gov/event/24231/contributions/75845/attachments/47256/56730/Diefenthaler-EIC-OSG.pdf

Uniqueness of EIC

- **World's first polarized electron-proton/light ion and electron-Nucleus collider**
- **For e-N collisions at the EIC:**
  - Polarized beams: e, p, d/^{3}He
  - e beam 5-10(20) GeV
  - Luminosity L_{ep} ~ $10^{33\text{-}34}$ $cm^{-2}sec^{-1}$ (100-1000 times HERA)
  - 20-100 (140) GeV Variable CoM
- **For e-A collisions at the EIC:**
  - Wide range in nuclei
    Luminosity per nucleon same as e-p
  - Variable center of mass energy

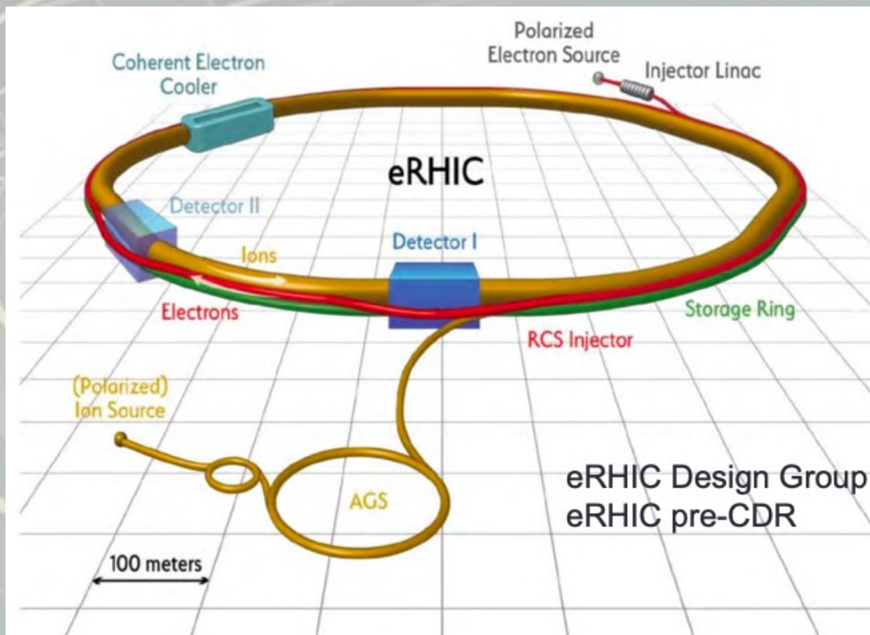


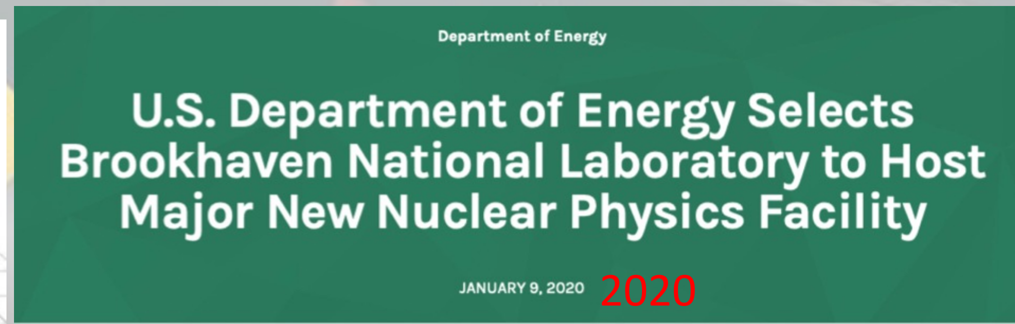
EIC Physics


Luminosity (cm^{-2} s^{-1})
10^{34}
10^{33}
10^{32}
Tomography (p/A)
Transverse Momentum
Distribution and Spatial Imaging
Spin and Flavor Structure of the
Nucleons and Nuclei
Internal Landscape
of Nuclei
QCD at Extreme Parton
Densities - Saturation
100
10
1
Annual Integrated Luminosity (fb^{-1})
0
50
100
150
e-N Center-of-Mass Energy [√(Z/A) GeV]

Final Decision from DoE

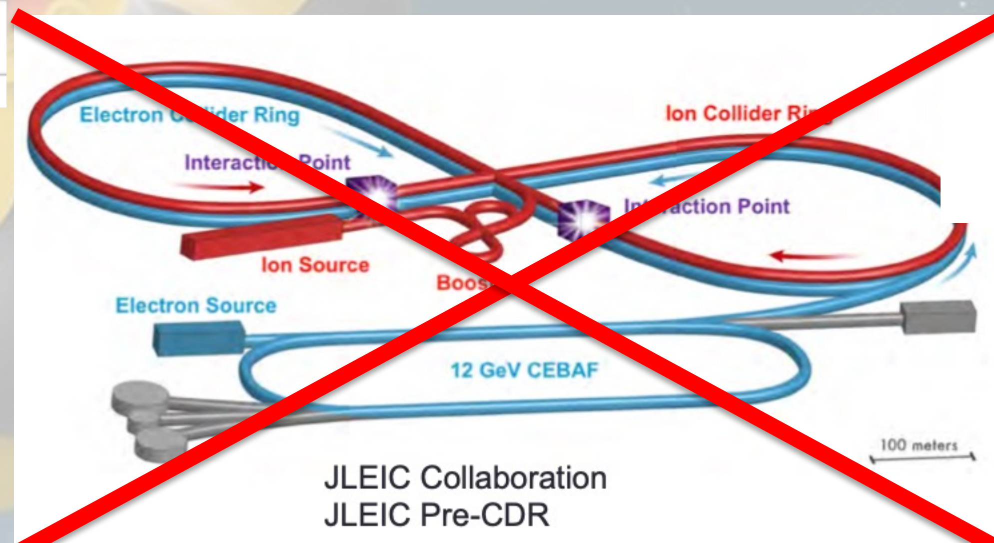
Brookhaven National Lab





2020

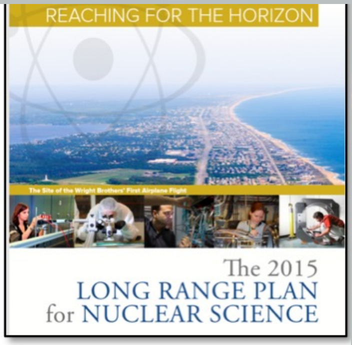
Jefferson Lab

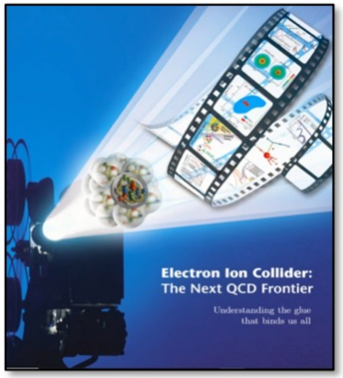


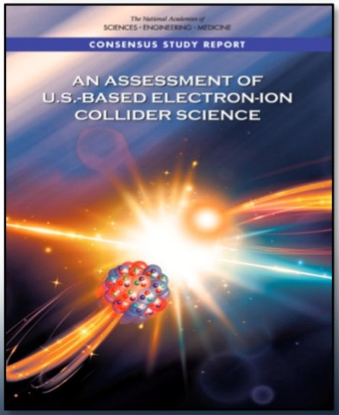
Accelerator Requirements

Requirements

- EIC Design Goals
  - High Luminosity: $L = (0.1\text{-}1)\cdot10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1} \rightarrow 10\text{-}100\ \mathrm{fb}^{-1}$
  - Collisions of highly polarized e and p (and light ion) beams with flexible bunch by bunch spin patterns : 70%
  - Large range of center of mass energies: E_{cm} = 20-140 GeV
  - Large range of Ion Species: Protons – Uranium
  - Ensure accommodation of a second IR
  - Large detector acceptance
  - Good background conditions
    - acceptable hadron particle loss and synchrotron radiation in the IR
- Goals match or exceed requirements of Long-Range Plan & EIC White Paper, endorsed by NAS
- EIC Design meets or exceeds goals and requirements







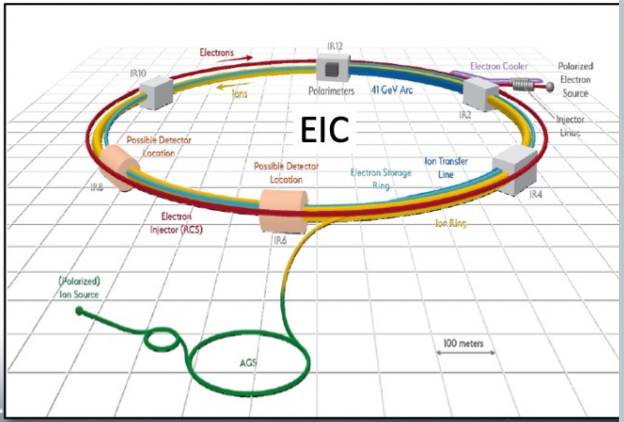
https://indico.bnl.gov/event/15342/contributions/64650/attachments/42380/70993/2022-07-26-EICUG-Satogata-AcceleratorDesign.pdf

Accelerator Design Overview

EIC Design Overview

Design based on **existing RHIC Complex**
RHIC is well-maintained, operating at its peak

- **Hadron storage ring (HSR): 40-275 GeV (existing)**
  - up to 1160 bunches, 1A beam current (3x RHIC)
  - bright vertical beam emittance 1.5 nm
  - strong cooling (coherent electron cooling, ERL)
- **Electron storage ring (ESR): 2.5–18 GeV (new)**
  - up to 1160 polarized bunches
    - high polarization by continual reinjection from RCS
  - large beam current (2.5 A) ➔ 9 MW SR power
  - superconducting RF cavities
- **Rapid cycling synchrotron (RCS): 0.4-18 GeV (new)**
  - 1-2 Hz; spin transparent due to high periodicity
- **High luminosity interaction region(s) (new)**
  - $L = 10^{34}\ cm^{-2}s^{-1}$, superconducting magnets
  - 25 mrad crossing angle with crab cavities
  - spin rotators (produce longitudinal spin at IP)
  - forward hadron instrumentation



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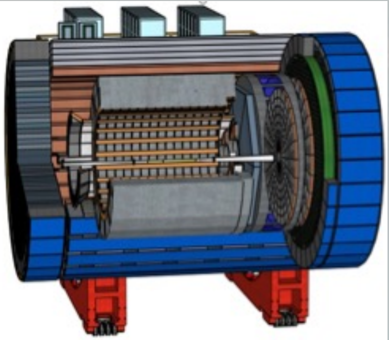
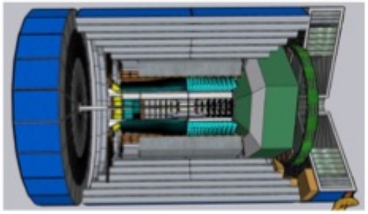
Proposals for EIC Detector

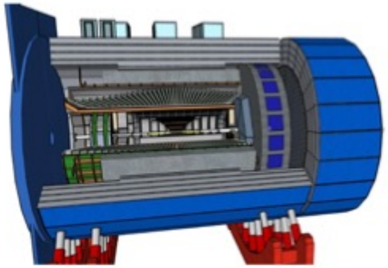
- **ATHENA**
  - A Totally Hermetic Electron-Nucleus Apparatus
  - Concept: General purpose detector inspired by the YR studies based on a new central magnet of up to 3T



- **CORE**
  - COmpact detectoR for the EIC
  - Concept: Nearly hermetic, general purpose compact detector, 2T baseline



- **ECCE**
  - EIC Comprehensive Chromodynamics Experiment
  - Concept: General purpose detector based on 1.5T BaBar magnet

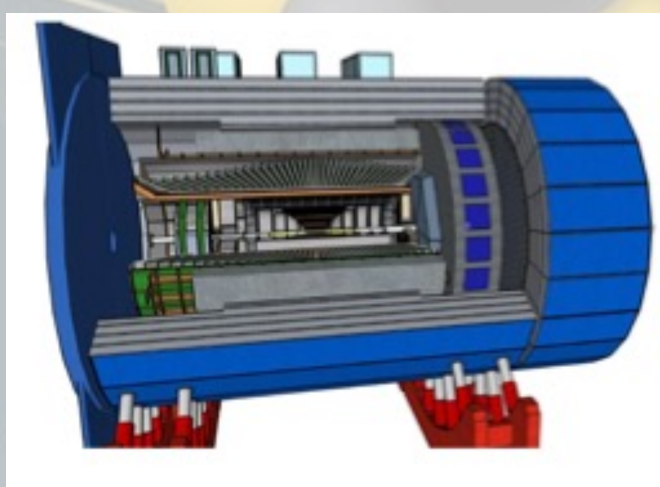


DPAP Recommendations

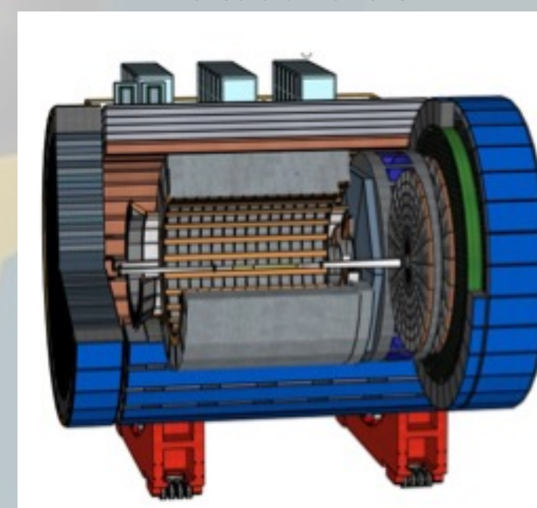
- DPAP: Detector Proposal Advisory Panel

"The EIC Project recognizes that the panel recommended ECCE as the Project Detector. As described in the panel report, we will urge the proto-collaboration to: (1) ***integrate new collaborators*** *in a manner that enables them to make contributions that impact the capabilities and success of the experiment in significant ways, including new collaborating individuals and groups into positions of responsibility and leadership; and (2)* ***integrate new experimental concepts*** *and technologies that improve physics capabilities without introducing inappropriate risk.* ***ECCE is the reference design for this optimization and consolidation so that the Project Detector can advance to CD2/3a in a timely way"*** – email communication from the EIC Project Team on 13 March 2022.

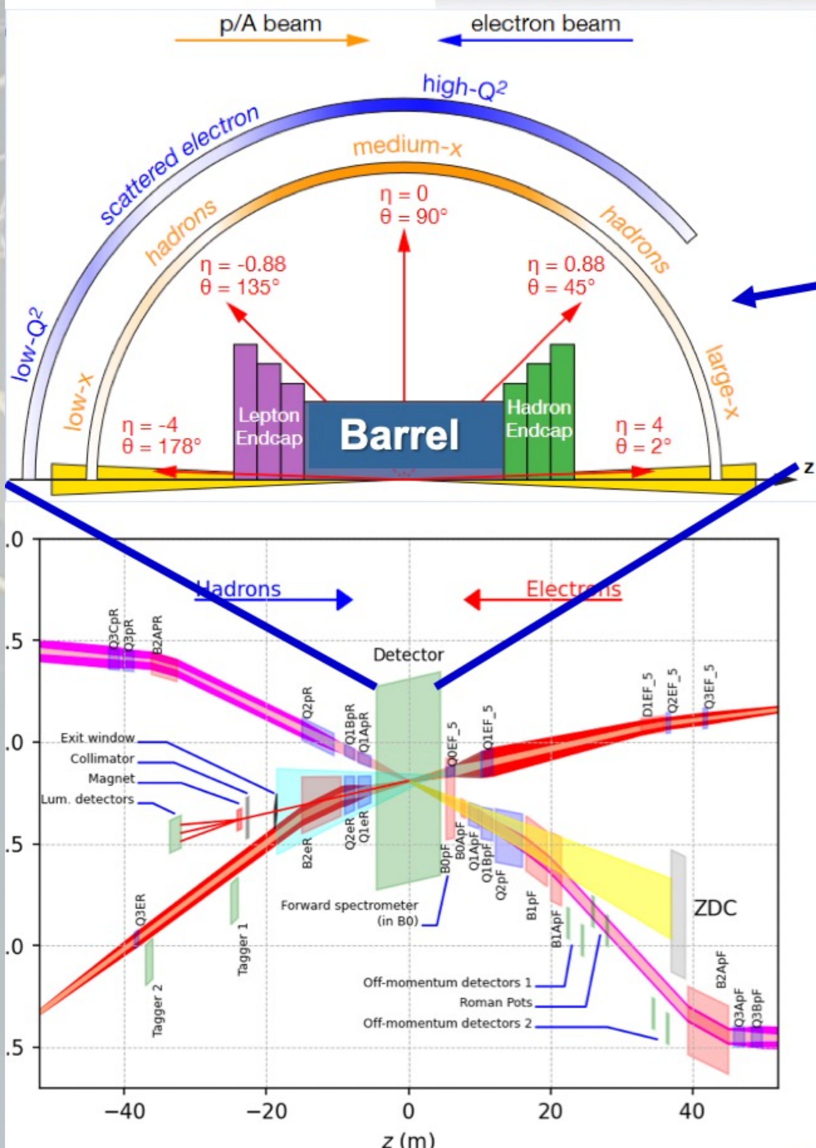
ECCE

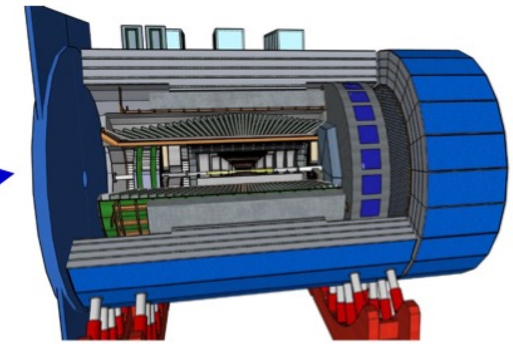


ATHENA



Detector-1: Central





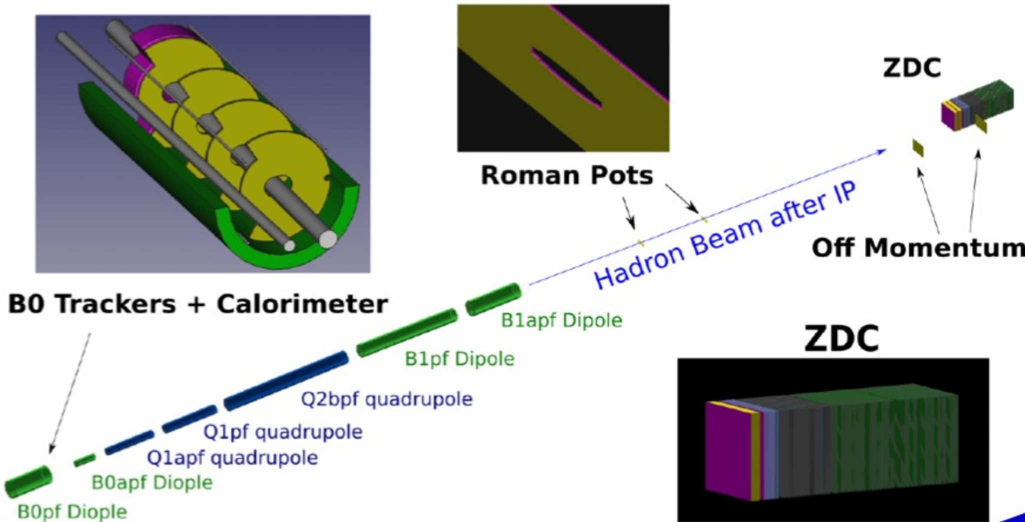
Central Detector (CD)

Total size detector: ~75m
Central detector: ~10m
Backward electron detection: ~35m
Forward hadron spectrometer: ~40m

Auxiliary detectors needed to tag particles with very small scattering angles both in the outgoing lepton and hadron beam direction (B0-Taggers, Off-momentum taggers, Roman Pots, Zero-degree Calorimeter and low Q2-tagger).

Detector-1: Far For/Backward

Far Forward



Far Backward

Figure: Low-Q^2 taggers

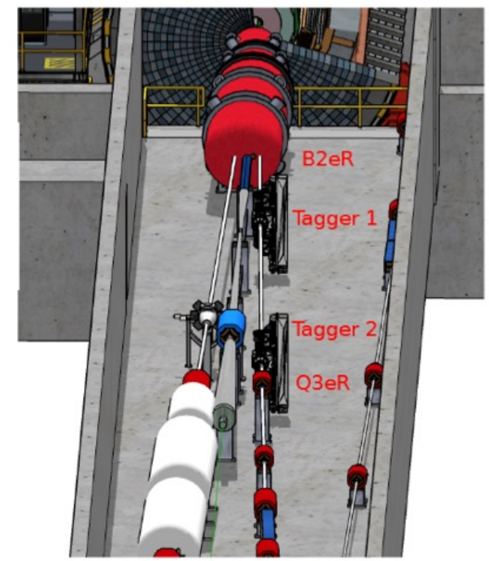
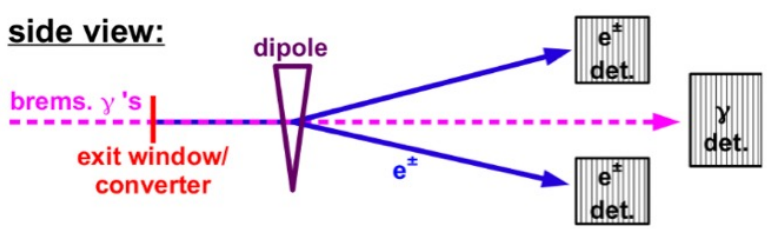


Figure: Luminosity detector

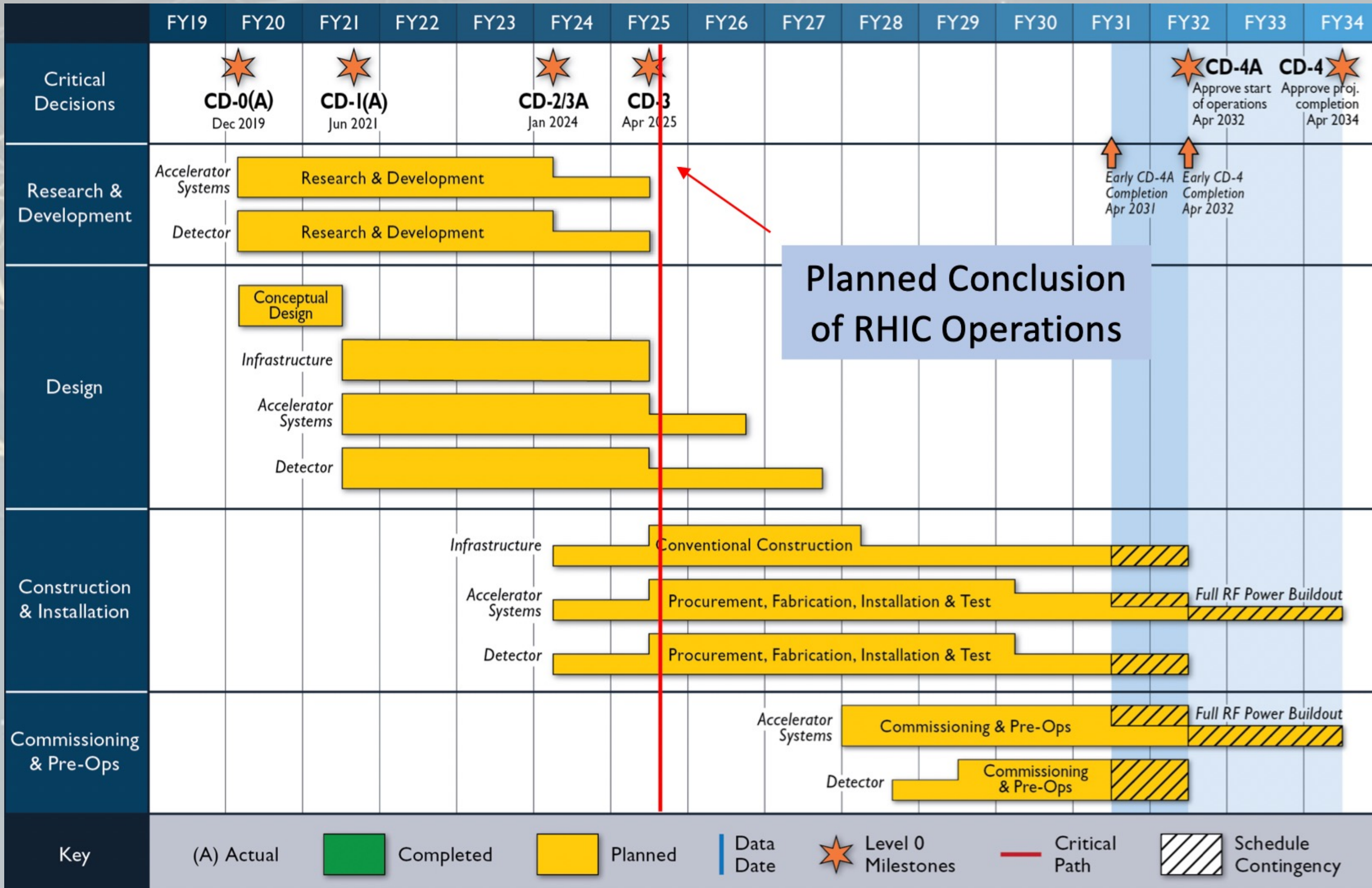


Working Groups

	WG	Conveners			
Transversal WGs	Global Detector Optimization	Richard Milner	Jin Huang	Thomas Ullrich	Silvia Dalla Torre
	Simulation production and QA	Joe Osborn	Wenliang (Bill) Li	Zhoudunming (Kong) Tu	Wouter Deconinck
	Computing and Software	Cristiano Fanelli	David Lawrence	Sylvester Joosten	Andrea Bressan
	DAQ / Electronics / Readout	Chris Cuevas	Jo Schambach	Alexandre Camsonne	Landgraf Jeff
Detector WGs	Tracking	Xuan Li	Kondo Gnanvo	Laura Gonella	Francesco Bossu
	Calorimetry	Friederike Bock	Carlos Munoz Camacho	Oleg Tsai	Paul Reimer
	PID Cherenkov	Xiaochun He	Grzegorz Kalicy	Tom Hemmick	Roberto Preghenella
	PID ToF	Wei Li	Constantin Loizides	Franck Geurts	Zhenyu Ye
	Far Forward	Michael Murray	Yuji Goto	Jentsch Alex	John Arrington
	Far Backward	Igor Korover	Nick Zachariou	Krzyzstof Piotrzkowski	Adam Jaroslav
Physics WGs	Inclusive Physics	Tyler Kutz	Claire Gwenlan	Barak Schmookler	Paul Newman
	Jets and Heavy Flavor	Cheuk-Ping Wong	Wangmei Zha	Miguel Arratia	Page Brian
	Exclusive, Diffraction, & Tagging	Axel Schmidt	Rachel Montgomery	Spencer Klein	Daria Sokhan
	Semi-Inclusive Physics	Ralf Seidl	Charlotte Van Hulse	Anselm Vossen	Marco Radici
	BSM & precision EW	Xiaochao Zheng	Sonny Mantry	Furletova Yulia	Ciprian Gal

Mailing list: https://lists.bnl.gov/mailman/listinfo/

Schedule


FY19 FY20 FY21 FY22 FY23 FY24 FY25 FY26 FY27 FY28 FY29 FY30 FY31 FY32 FY33 FY34
Critical Decisions
CD-0(A) Dec 2019
CD-1(A) Jun 2021
CD-2/3A Jan 2024
CD-3 Apr 2025
CD-4A Approve start of operations Apr 2032
CD-4 Approve proj. completion Apr 2034
Early CD-4A Completion Apr 2031
Early CD-4 Completion Apr 2032
Research & Development
Accelerator Systems
Research & Development
Detector
Research & Development
Planned Conclusion of RHIC Operations
Design
Conceptual Design
Infrastructure
Accelerator Systems
Detector
Construction & Installation
Infrastructure
Conventional Construction
Accelerator Systems
Procurement, Fabrication, Installation & Test
Full RF Power Buildout
Detector
Procurement, Fabrication, Installation & Test
Commissioning & Pre-Ops
Accelerator Systems
Commissioning & Pre-Ops
Full RF Power Buildout
Detector
Commissioning & Pre-Ops
Key
(A) Actual
Completed
Planned
Data Date
Level 0 Milestones
Critical Path
Schedule Contingency

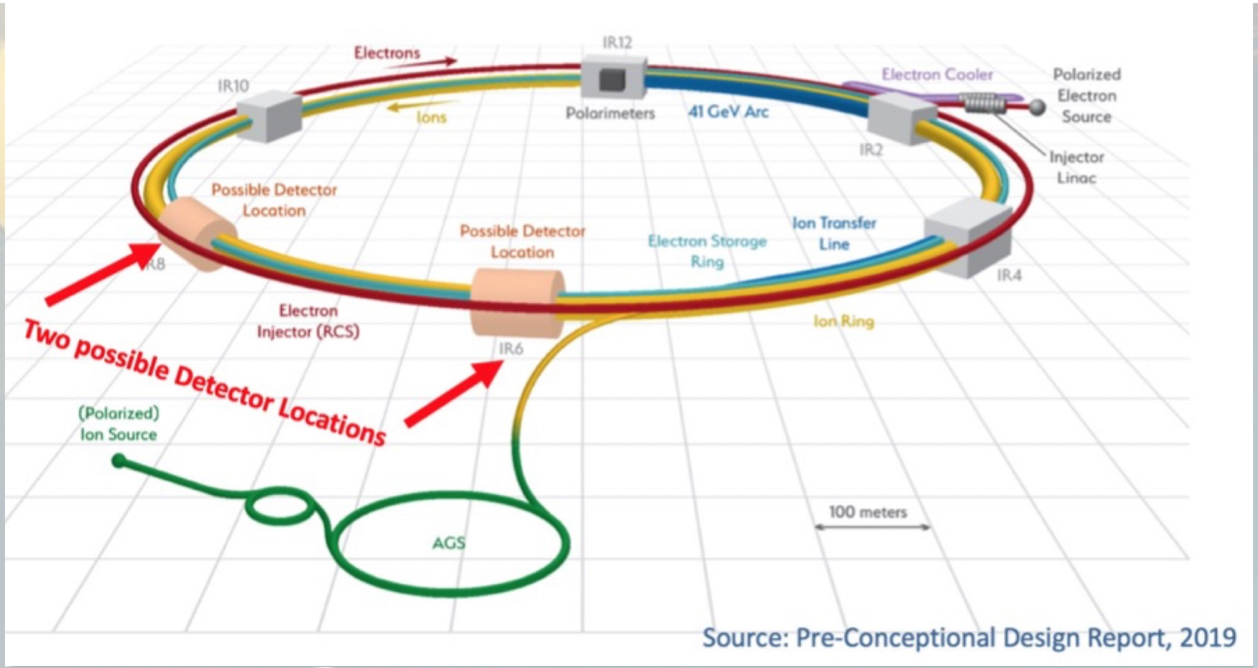
CD2/3A Planning Dates

• DOE OPA Status Review (Remote)	October 19-21, 2021(A)
• Funding Discussion at DOE ONP (In-Person)	April 26, 2022 (A)
• FPD Status Update at BNL (Hybrid)	June 28, 29, 30 2022
• Cost and Schedule Scrutiny Meetings	July - August 2022
• Project Detector Meetings	Fall 2022
• DOE OPA Status Review - Confirm CD-2/3A Plans	January 2023
• Preliminary Design and Director's Reviews	June 2023
• DOE CD 2/3A OPA Review and ICR	October 2023
• DOE CD 2/3A ESAAB Approval	January 2024

Detector-2?

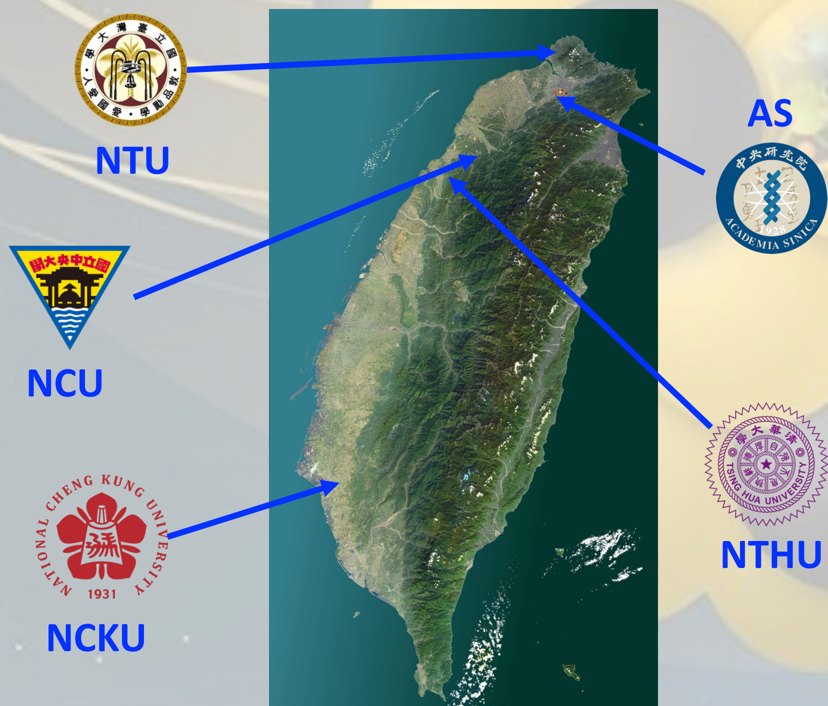
Comments from the DPAP report

- "A strong case for ***two complementary general-purpose detectors*** has been made during the panel review"
- "…requires a ***well-chosen balance between optimization as general-purpose detector versus partial specialization*** and the ability to cross check the other detector for a broad range of measurements. The design of a second detector should be chosen with these criteria in mind."
- "The time required for its design and construction may offer ***opportunities for benefiting from technological progress***."
- "As laid out in the section 2.1 on physics performance, ***an IR with a secondary focus can significantly broaden the physics scope and output of the EIC***."

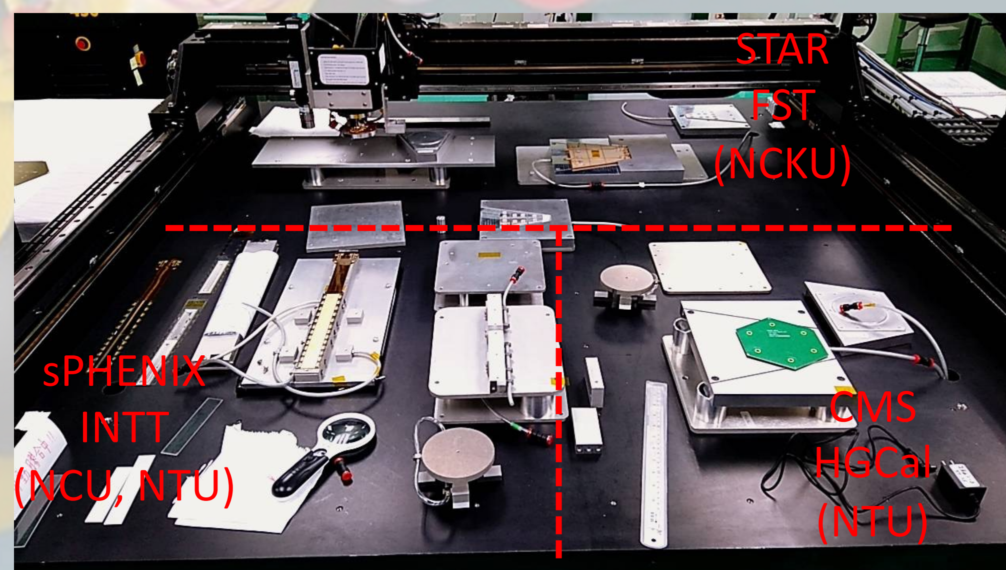


Electron-Ion Collider @ Taiwan

- 5 institutes (AS, NCU, NTHU, NCKU, NTU) in Taiwan have the consensus to form a strong team to participate the EIC in the coming future
- Mainly focus on physics, silicon-based detector (sensor development and mechanical structure design)



TIDC



1st EIC Workshop in Taiwan

The aims for this workshop are bringing all QCD enthusiasts in Taiwan together, discussing the physics topics and potential detector developments for EIC, educating ourselves to have a smooth transition from “high energy physics” to “nuclear physics”.

Agenda - Day 1

Thursday, August 18

Time	Session	Duration
11:00 AM → 1:00 PM	**Registration** Lunch box	2h
1:00 PM → 1:40 PM	**Opening/Welcome and Overview of EIC** **Speaker**: Yi Yang (NCKU)	40m
1:40 PM → 2:40 PM	**PDFs/TMDs/GPDs for EIC (theory)** **Speaker**: Chung-Wen Kao (CYCU)	1h
2:40 PM → 3:40 PM	**PDFs/TMDs/GPDs for EIC (experiment)** **Speaker**: Wen-Chen Chang, Po-Ju Lin (AS)	1h
3:40 PM → 4:10 PM	**Coffee break**	30m
4:10 PM → 4:50 PM	**CGC for EIC (theory)** **Speaker**: Hsiang-nan Li (AS)	40m
4:50 PM → 5:30 PM	**CGC for EIC (experiment)** **Speaker**: Chia-Ming Kuo (NCU)	40m
6:00 PM → 8:00 PM	**Dinner**	2h

Agenda - Day 2

Friday, August 19

9:30 AM → 10:30 AM	**What we would like to learn from EIC**	**Speaker**: Jen-Chieh Peng (UIUC)	1h
10:30 AM → 11:00 AM	**AC-LGAD in US**	**Speaker**: Zhenyu Ye (UIC)	30m
11:00 AM → 11:30 AM	**DC-LGAD in Taiwan**	**Speaker**: Rong-Hwei Yeh (Asia Univ.)	30m
11:30 AM → 12:00 PM	**Optical readout**	**Speaker**: Suen Hou (AS)	30m
12:00 PM → 1:00 PM	**Lunch**	lunch box	1h
1:00 PM → 1:30 PM	**Detector and Physics opportunities for Taiwan EIC team - I**	**Speaker**: Chia-Ming Kuo (NCU)	30m
1:30 PM → 2:00 PM	**Detector and Physics opportunities for Taiwan EIC team - II**	**Speaker**: Rong-Shyang Lu (NTU)	30m
2:00 PM → 2:30 PM	**Detector and Physics opportunities for Taiwan EIC team - III**	**Speaker**: Yi Yang (NCKU)	30m
2:30 PM → 3:00 PM	**Coffee break**		30m
3:00 PM → 4:00 PM	**Discussion and closing**	**Speaker**: Wen-Chen Chang (AS)	1h

Thanks to TIDC and hope you will enjoy your stay in Tainan