ePIC at the Upcoming EIC

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Stony Brook University

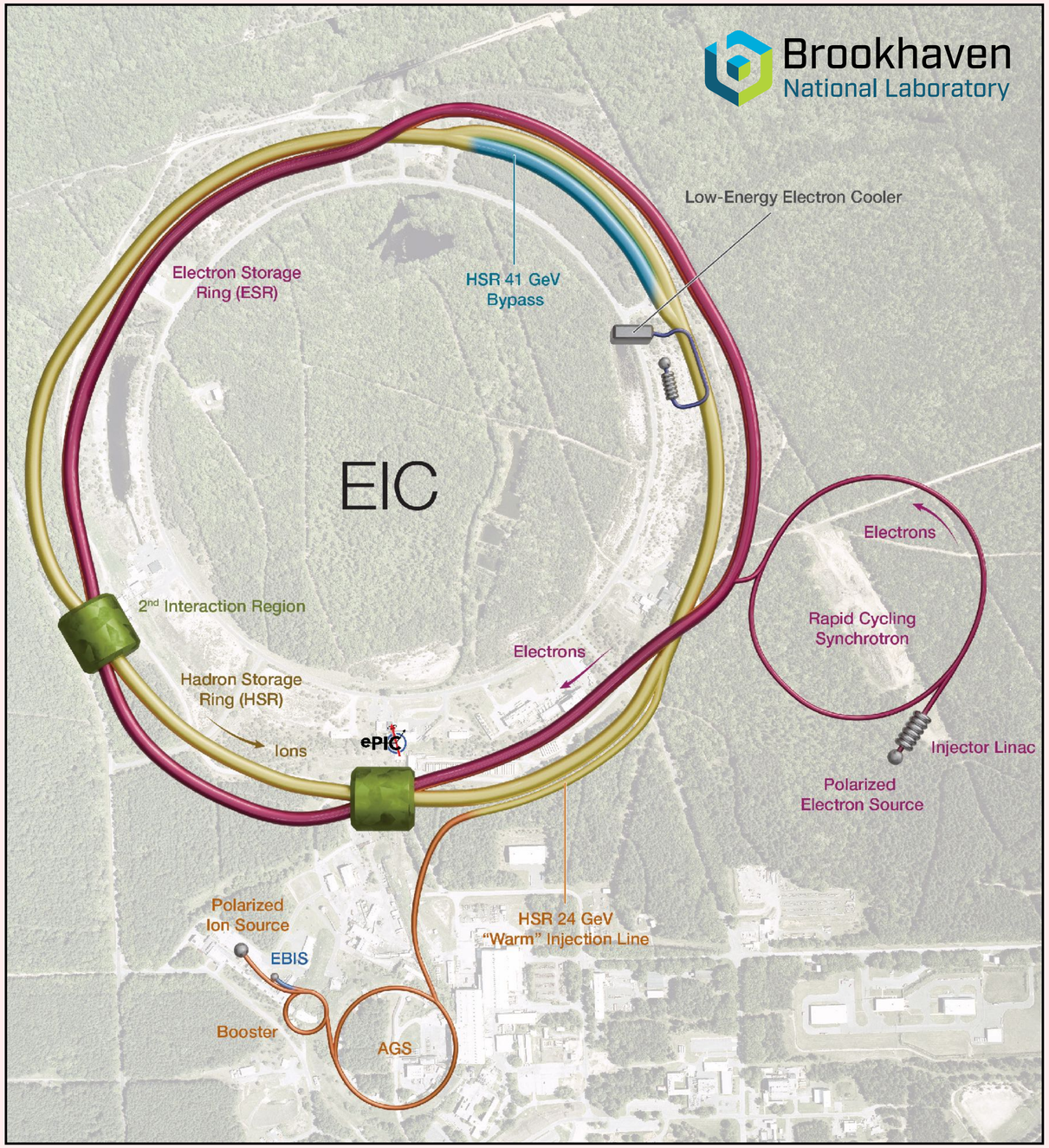
On Behalf of the ePIC collaboration

SPIN 2025

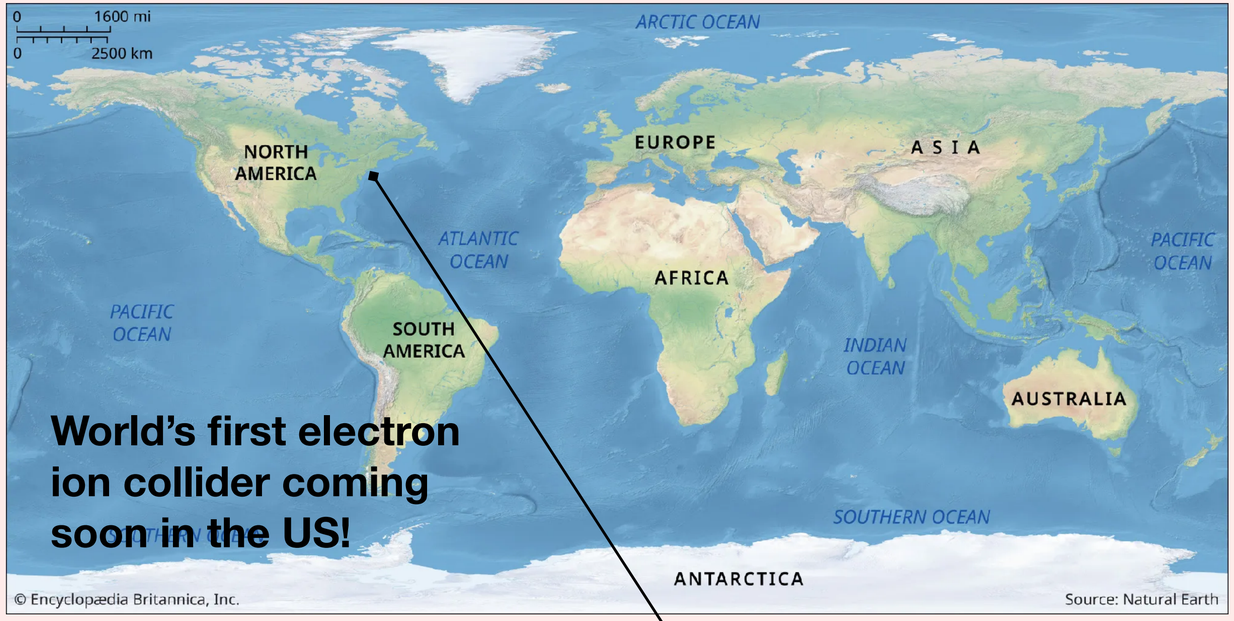
09/24/2025

Stony Brook University

Center for Frontiers in Nuclear Science

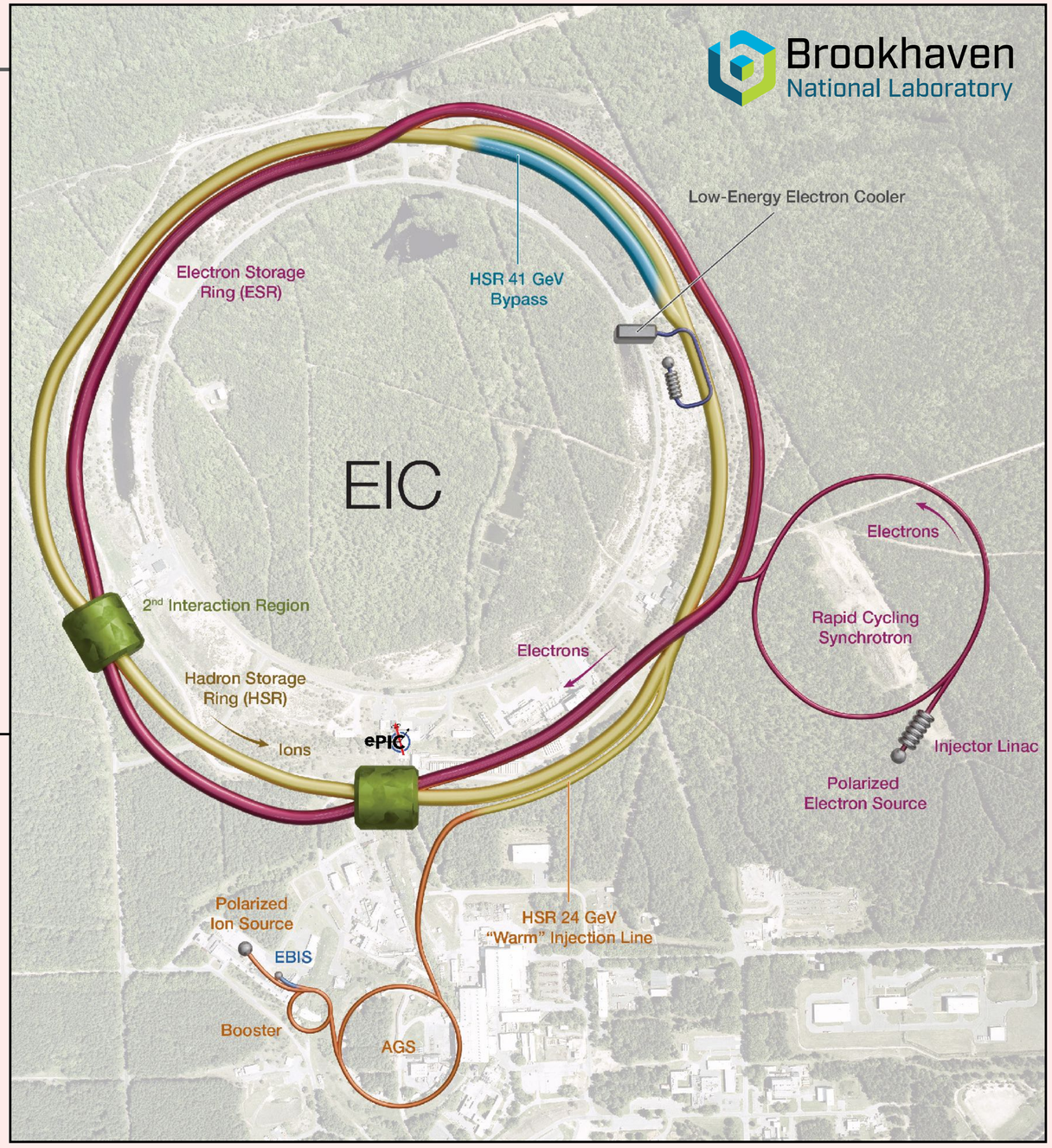


Electron Ion Collider (EIC)



World's first electron ion collider coming soon in the US!

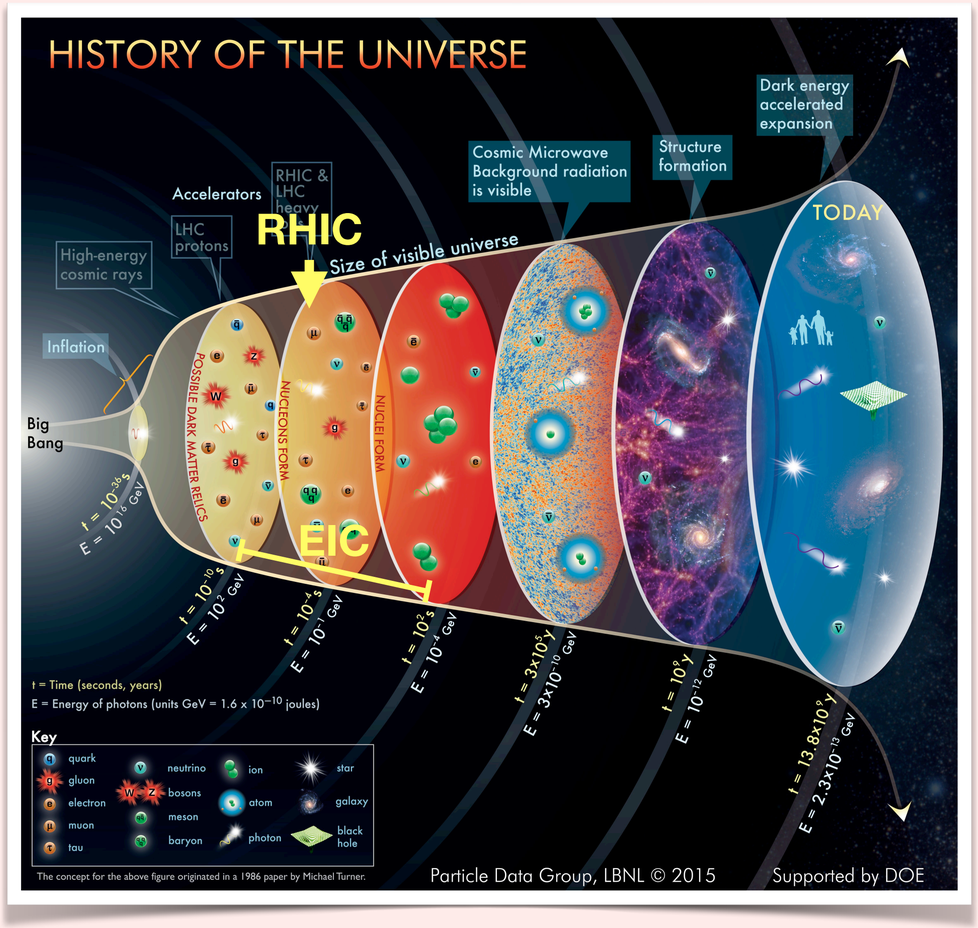
Long Island, NY

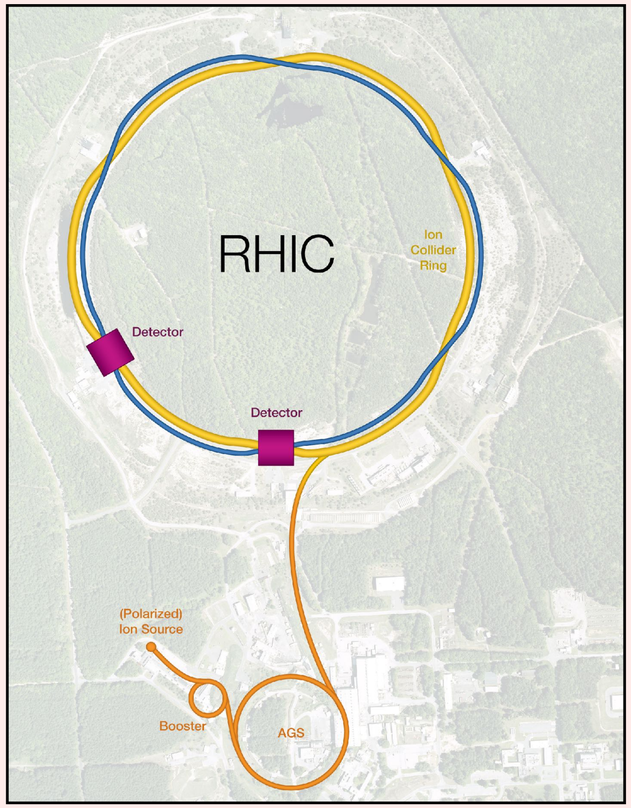


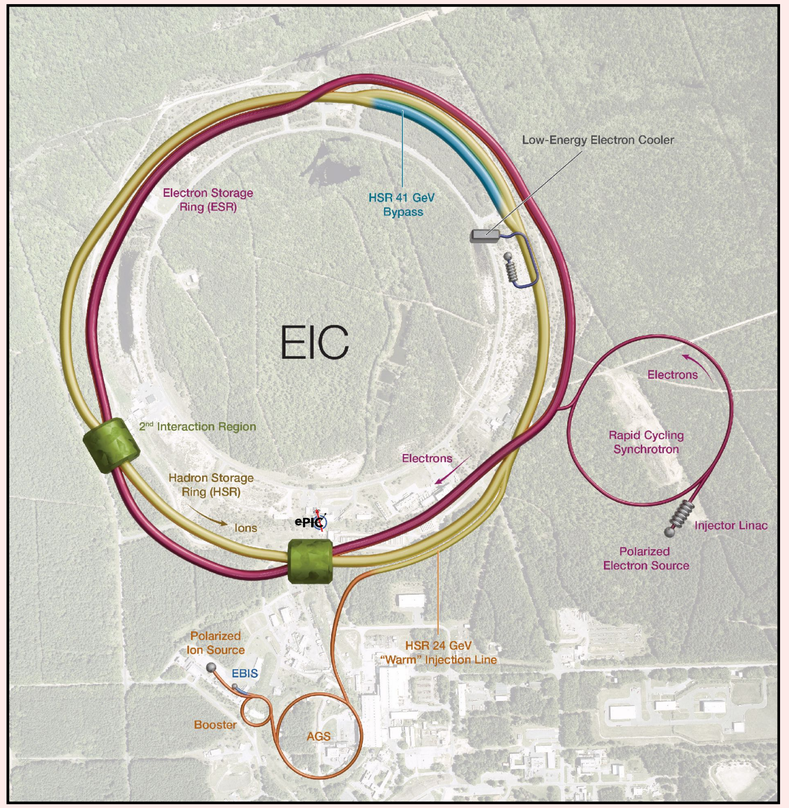
Electron Ion Collider (EIC)

To be built at BNL on RHIC complex

- Construction will start in 2026
- Experiments will start in ~ 2035







- Re-use existing tunnel
- Minimal modification to hadron beam complex
- New electron beam facility
- ~$2B investment

Electron Ion Collider (EIC)

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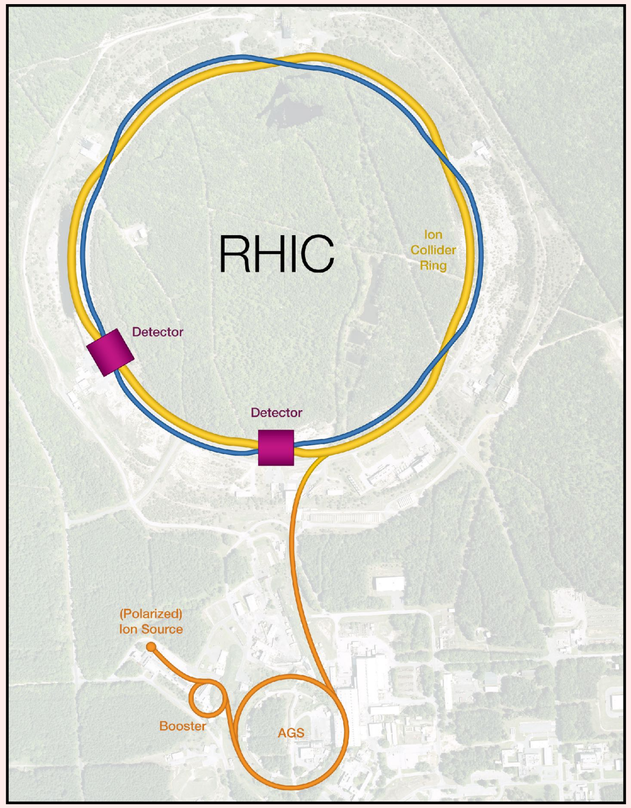

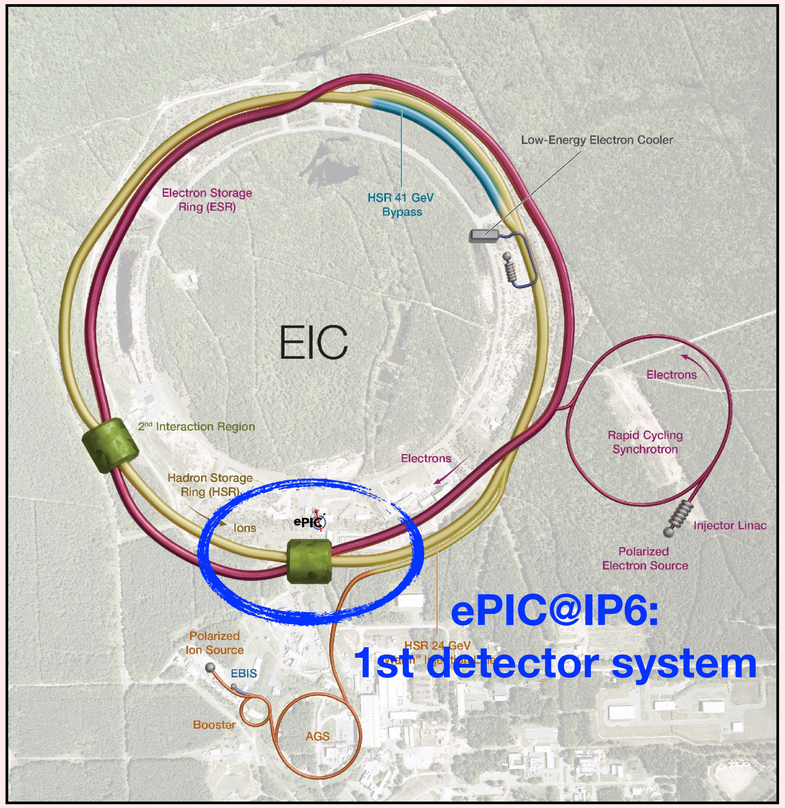

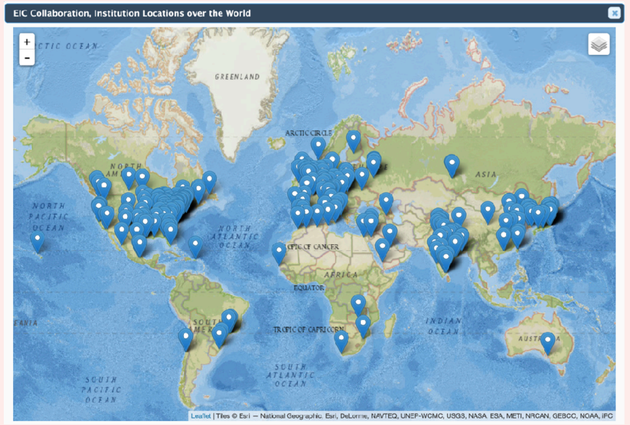

Collaboration was formed in July 2022

- Currently > 1050 collaborators
- 180 institutions in 4 world's region involved

Electron Ion Collider (EIC)

To be built at BNL on RHIC complex

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- Experiments will start in ~ 2035

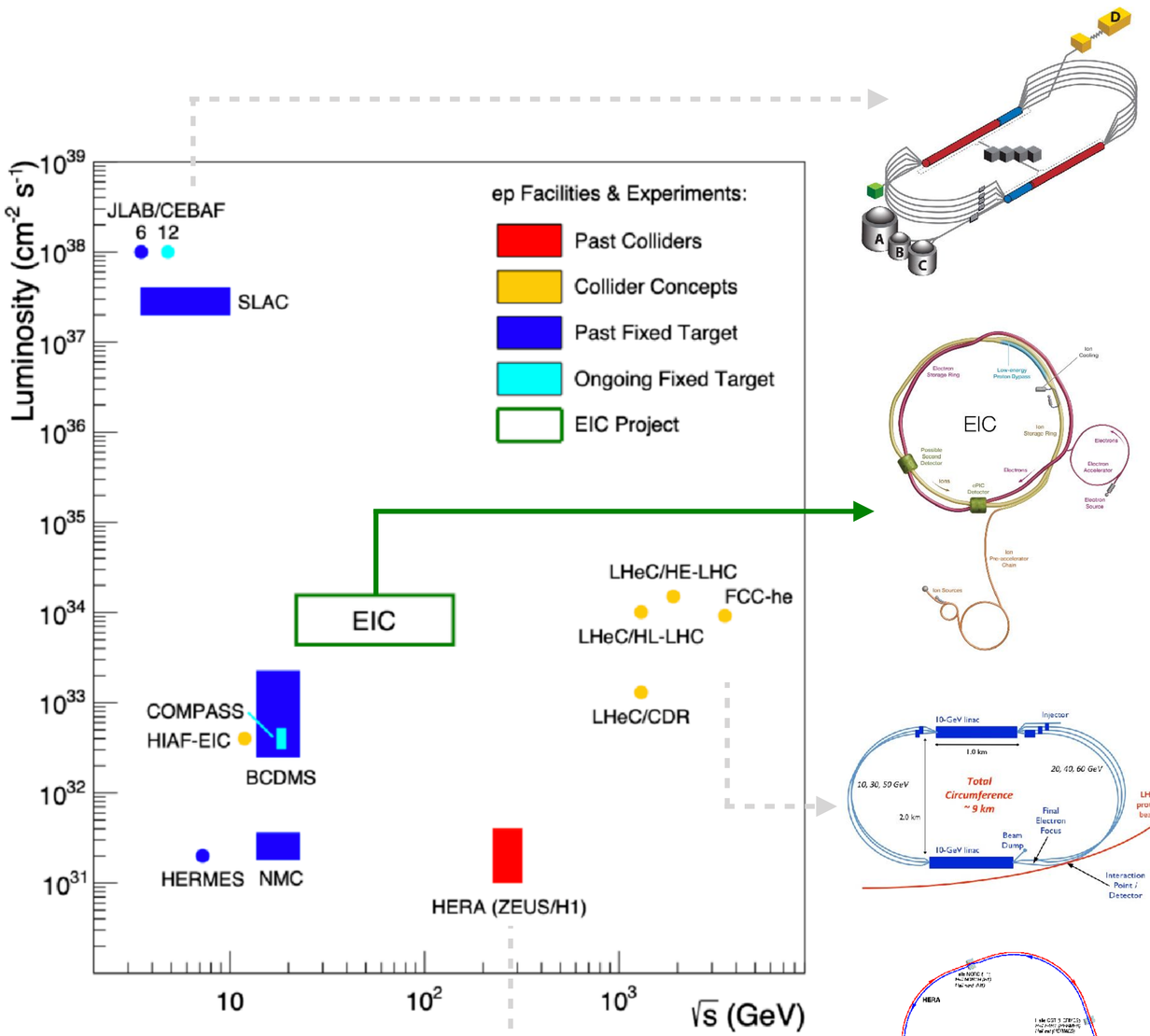
World's first polarized electron proton/ion and electron-nucleus collider!

- High luminosity:

  up to $10^{33} - 10^{34}\ \mathrm{cm}^{-2}\,\mathrm{s}^{-1}$

  a factor ~100 - 1000 times > HERA
- Broad range of center-of-mass energy:

  ~20 - 100 GeV; upgradable to 140 GeV



Paul N. Imperial College Seminar, 23 May 2025

Electron Ion Collider (EIC)

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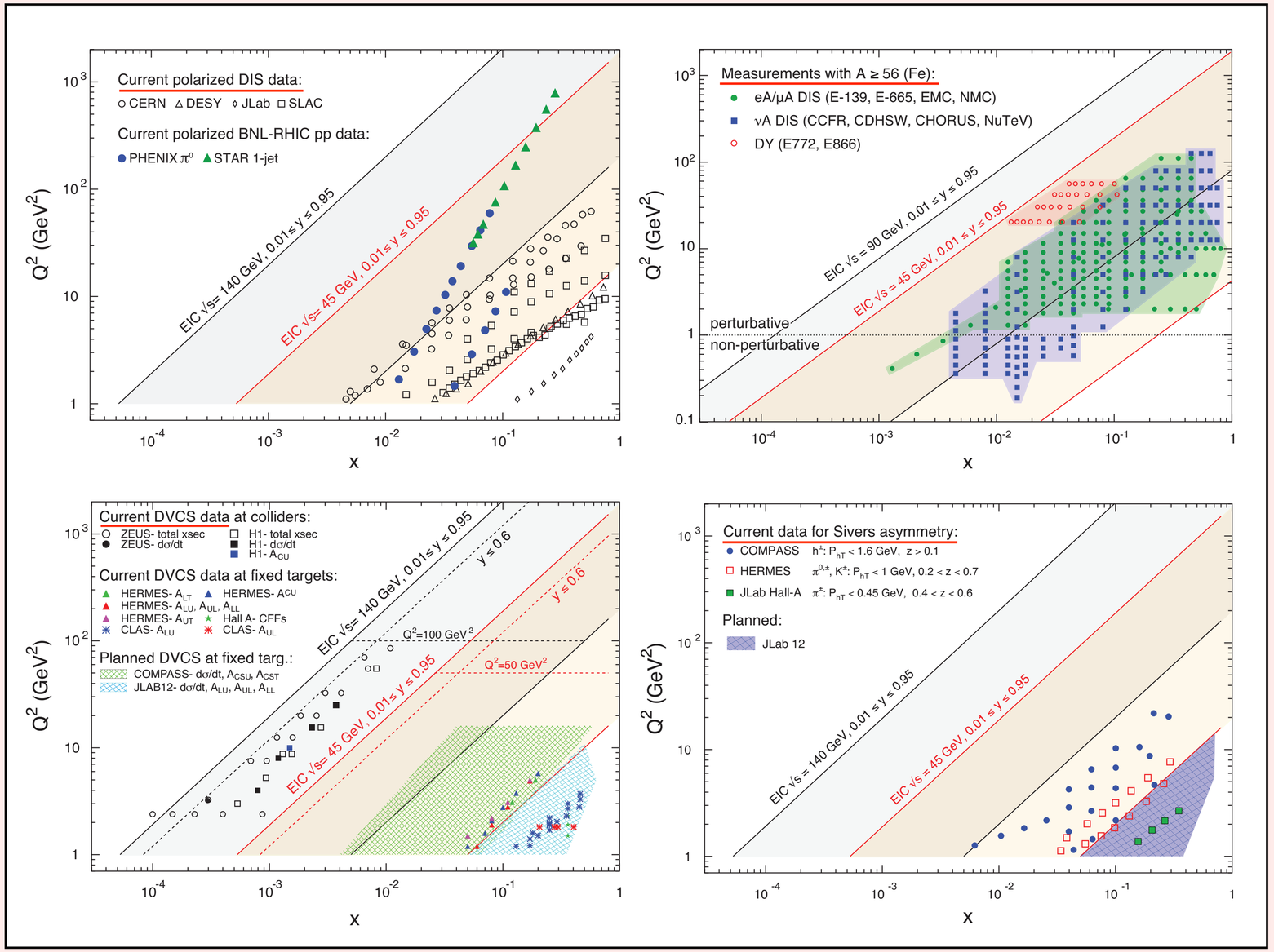
  up to $10^{33} - 10^{34}\ \mathrm{cm}^{-2}\,\mathrm{s}^{-1}$

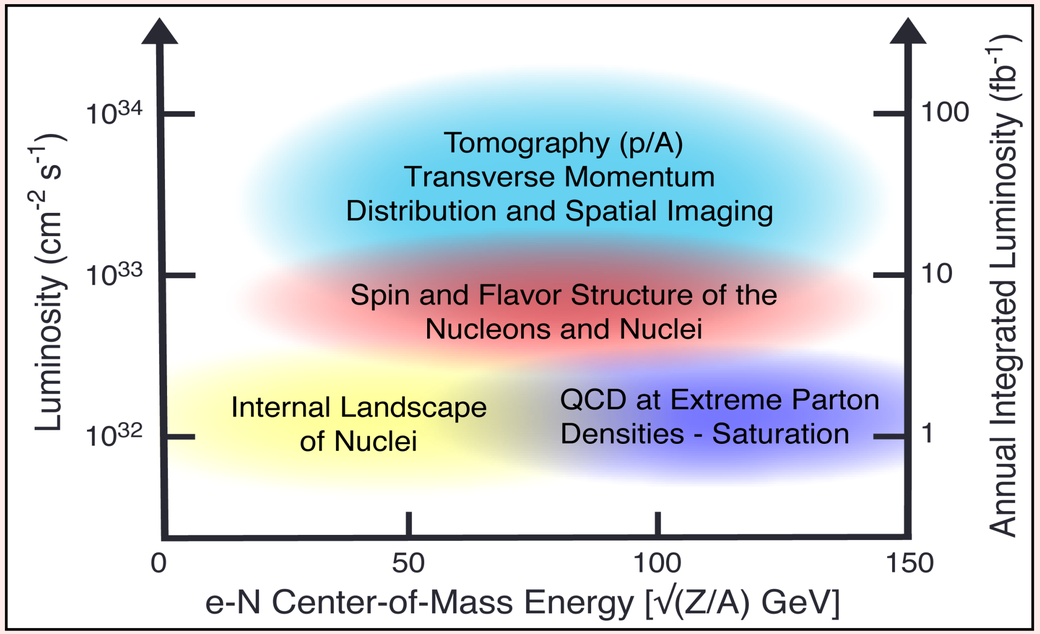
  a factor ~100 - 1000 times > HERA
- Broad range of center-of-mass energy:

  ~20 - 100 GeV; upgradable to 140 GeV
- Polarized e-, p, and light ion beams with flexible spin patterns/orientation
- Broad range of particles: p, d … Au .. U

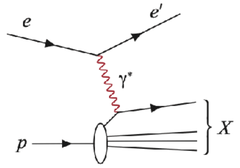


https://doi.org/10.48550/arXiv.1212.1701

EIC Physics Opportunities

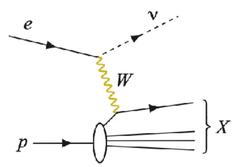


Different categories of processes measured at an EIC



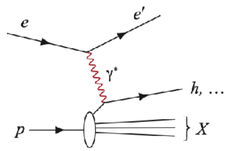
NC Inclusive DIS:

$e + p/A \rightarrow e' + X$



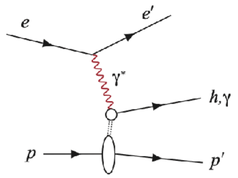
CC Inclusive DIS:

$e + p/A \rightarrow \nu + X$



Semi-inclusive DIS:

$e + p/A \rightarrow e' + h^{\pm,0} + X$



Exclusive DIS:

$e + p/A \rightarrow e' + p'/A' + \gamma/h^{\pm,0}/\mathrm{VM}$

Origin of nucleon spin

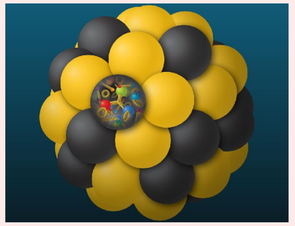
- $\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L^q + L^g$
- What are the spin contributions from each constituent?

Origin of nucleon mass

- Mass of proton mass < Sum of constituents' mass
- Does the mass of visible matter emerge from quark-gluon interactions?

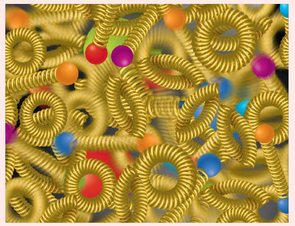
Nucleon tomography

- How are the quarks and gluon distributed in space and momentum inside the nucleon & nuclei?
- How do nucleon properties emerge from them and their interactions?



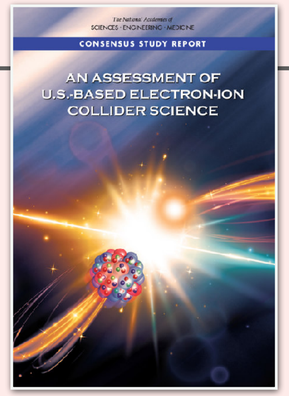
Nuclear modifications of parton distribution

- Is the structure of a free and bound nucleon the same?
- How do quarks and gluons interact with a nuclear medium?
- How do the quark-gluon interactions create nuclear binding?



Gluon saturation

- How many gluons can fit in a proton?
- How does a dense nuclear environment affect the quarks and gluons, their correlations, and their interactions?



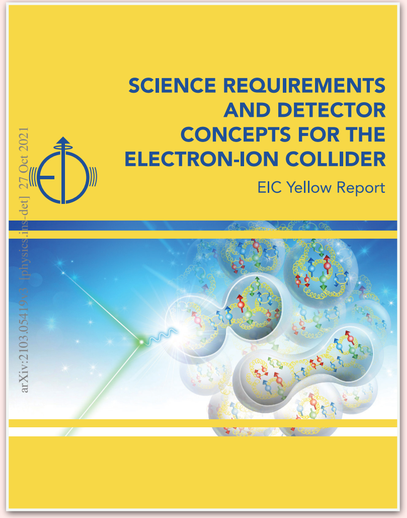
https://doi.org/10.17226/25171

The ePIC Detector System

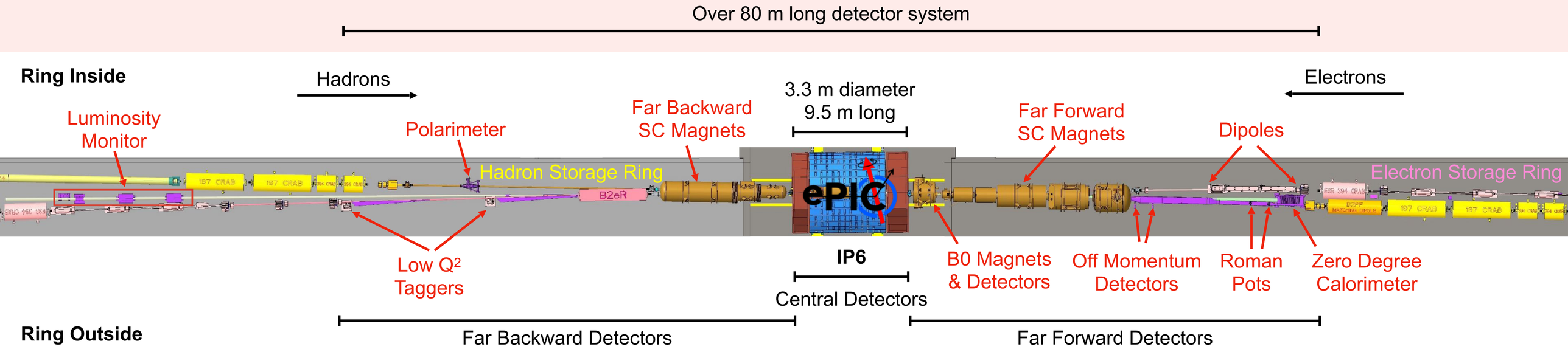
Requirement summarized in EIC Yellow Report:

- 4π hermetic detector
  - Primary detector covering $-4 < \eta < 4$
  - Auxiliary detectors in the far backward and far forward region
- Low material budget high spatial resolution inner tracking
- Components close to the beamline might see high occupancies
- PID seperation for $\pi/K/p$:
  - Central: 3σ up to 10 GeV/c
  - Backward: 3σ up to 1 GeV/c
  - Forward: 3σ up to 50 GeV/c

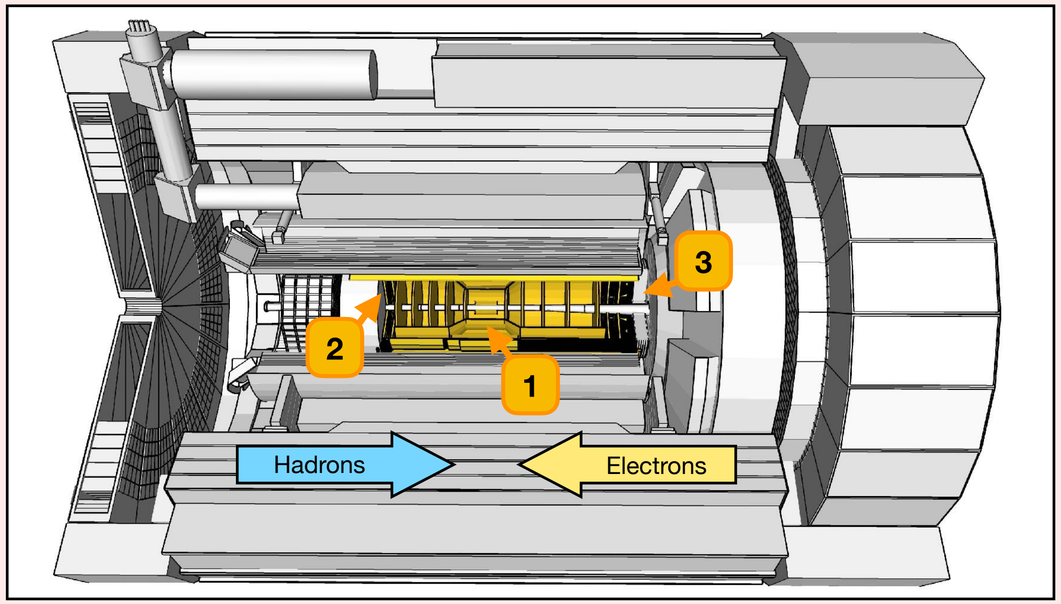
- Impact parameter resolution for heavy flavor:
  - $\sigma_{xy} \approx 20/p_T \otimes 5\,\mu\mathrm{m}$
- Momentum resolution:
  - Central: $\sigma_{p_T}/p_T(\,\%\,) \approx 0.05 p_T \otimes 0.5$
  - Backward: $\sigma_{p_T}/p_T(\,\%\,) \approx 0.1 p_T \otimes 0.5$
  - Forward: $\sigma_{p_T}/p_T(\,\%\,) \approx 0.1 p_T \otimes (1-2)$
- Calorimeter resolution:
  - Central EM CAL: $\sigma(E)/E \approx 10\,\%/\sqrt{E} \otimes (1-3)\,\%$
  - Backward EM CAL: $\sigma(E)/E \approx 2\,\%/\sqrt{E} \otimes (1-3)\,\%$
  - Forward HCAL: $\sigma(E)/E \approx 50\,\%/\sqrt{E} \otimes 10\,\%$

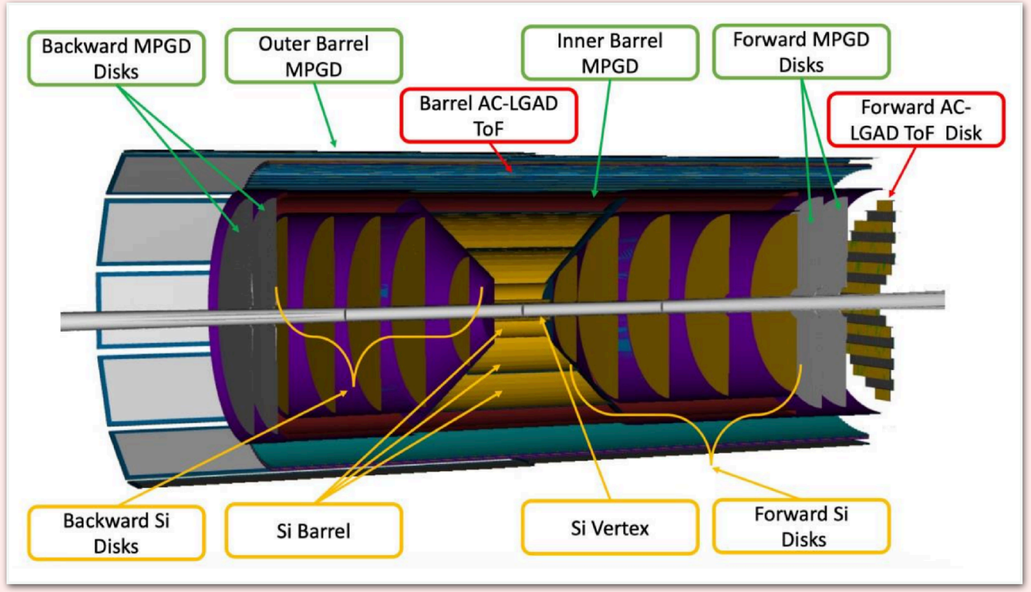


https://arxiv.org/abs/2103.05419



The ePIC Detector - Tracking





1 - Silicon Vertex Tracker (SVT)

- Monolithic Active Pixel Sensors (MAPS)
- 20 μm pixels
- 0.05% - 0.55% X/X_0 per layer
- ITS3 curved wafer-scale sensor (inner)
- ITS3 based large area sensors (outer and endcaps)

2 - Micro Pattern Gas Detectors (MPGD)

- Cylindrical MicroMegas Barrel tracker (CyMBaL)
- GEM-μRWell Barrel and endcap tracker
- 10 ns timing resolution, 150 μm tracking resolution

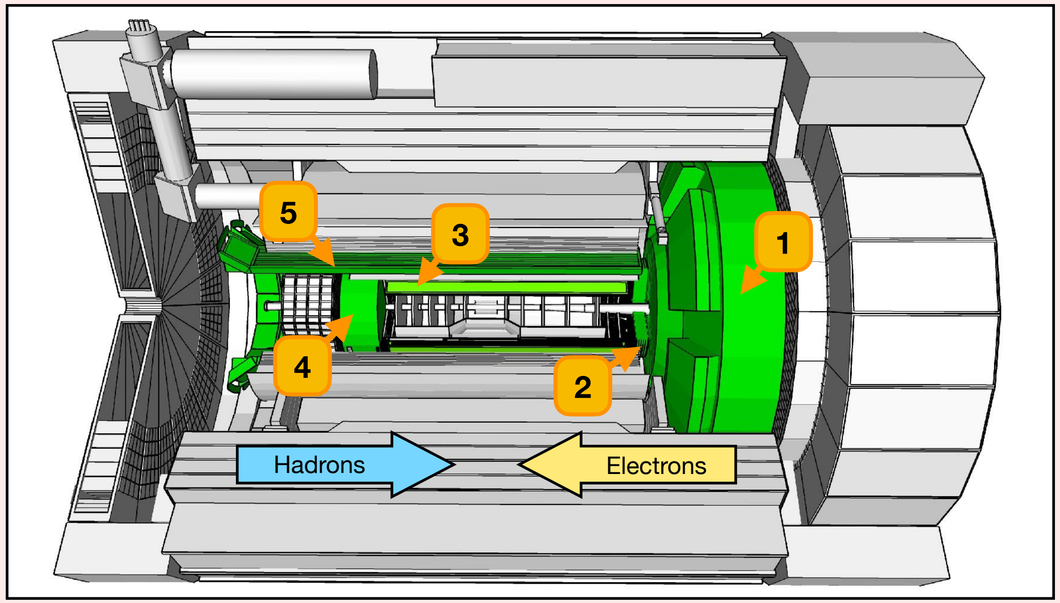
World's first at ePIC

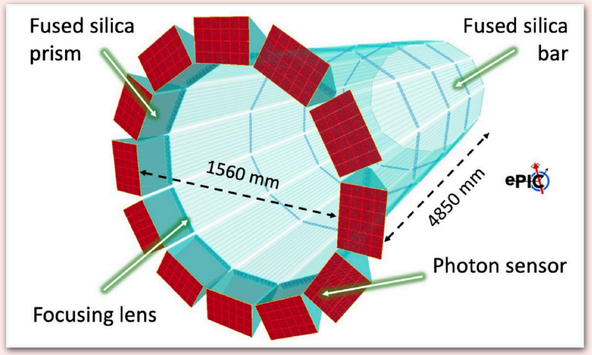
2 - AC-coupled Low Gain Avalanche Diode (AC-LGAD)

- 4D (timing + position) readout
- Fast detector response
- ~35 ps timing resolution
- 30 μm resolution tracking point

World's first at ePIC

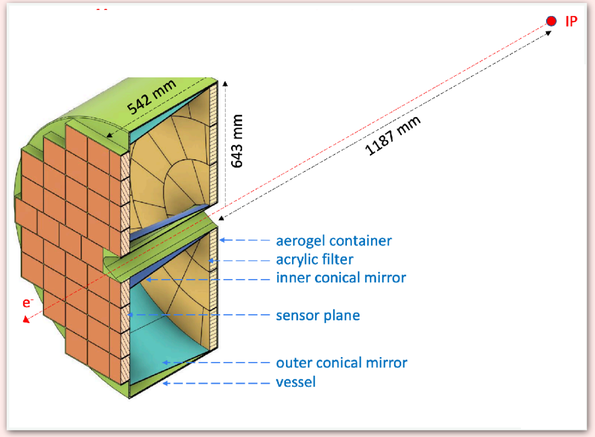
The ePIC Detector - Particle ID





5 - High-Performance DIRC (hpDIRC)

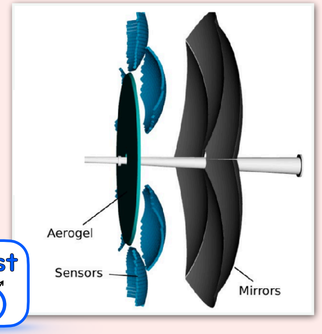
- Quartz bar radiator
- MCP - PMTs sensors
- π/K separation up to 6 $\mathrm{GeV/c}$



4 - Proximity-Focusing RICH (pfRICH)

- Long Proximity gap (~40 cm)
- HRPPDs sensors
- ~20ps timing resolution
- π/K separation up to 10 $\mathrm{GeV/c}$
- e/π separation up to 2.5 $\mathrm{GeV/c}$

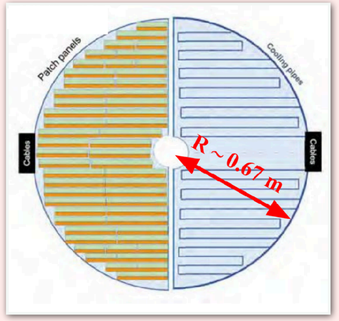
World's first at ePIC



World's first at ePIC

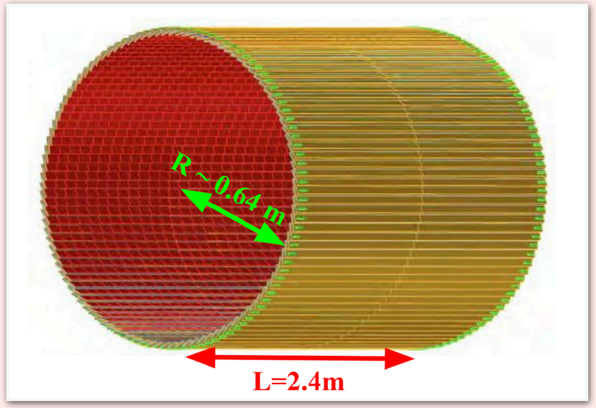
1 - Dual-Radiator Rich (dRICH)

- C_2F_6 gas volume and aerogel
- SiPM tile on spheres
- π/K separation up to 50 $\mathrm{GeV/c}$



2- Endcap AC-LGAD TOF

- ~25 ps timing resolution
- Also provide 30 μm resolution tracking point

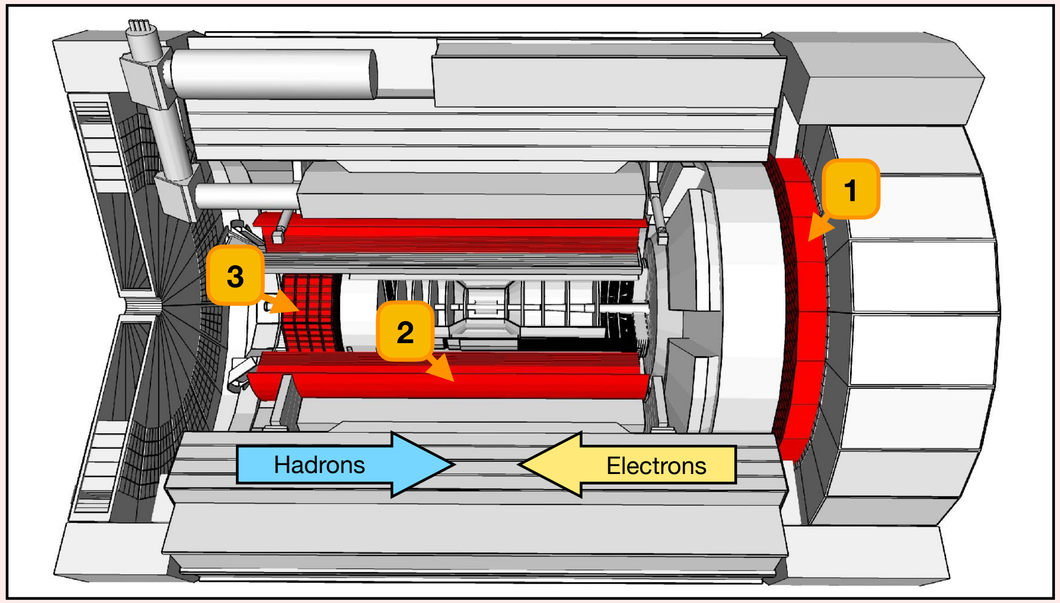


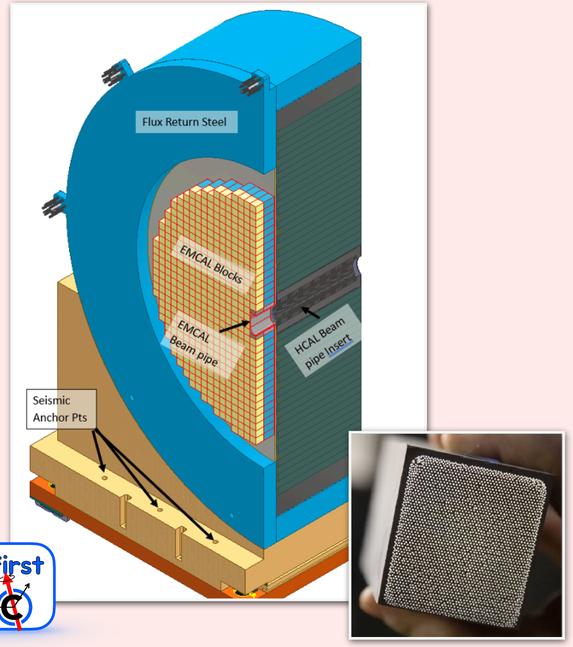
3 - Barrel AC-LGAD TOF

- ~35 ps timing resolution
- Also provide 30 μm resolution tracking point

World's first at ePIC

The ePIC Detector - Electromagnetic Calorimeter

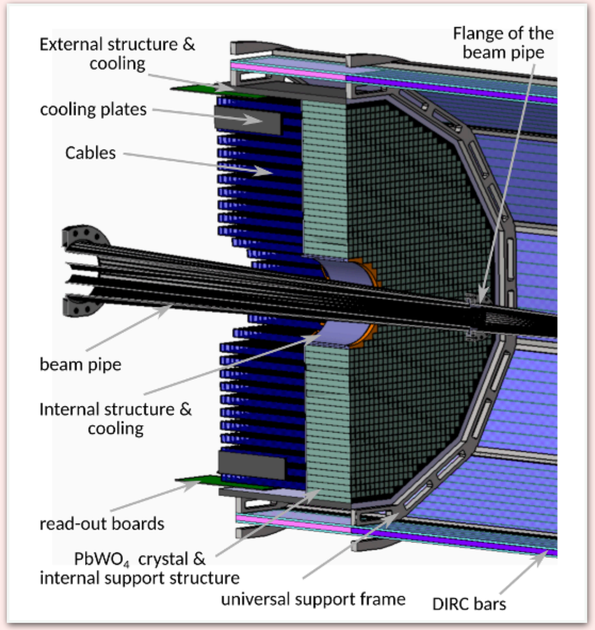




World's first at ePIC

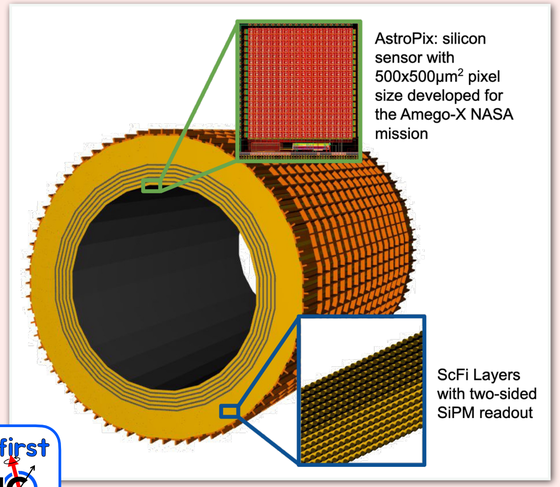
1 - Forward EM Calorimeter

- High granularity Tungsten powder + scintillating fiber EMCal
- SiPM sensor



3 - Backward EM Calorimeter

- $PbWO_4$ crystals
- SiPM sensor

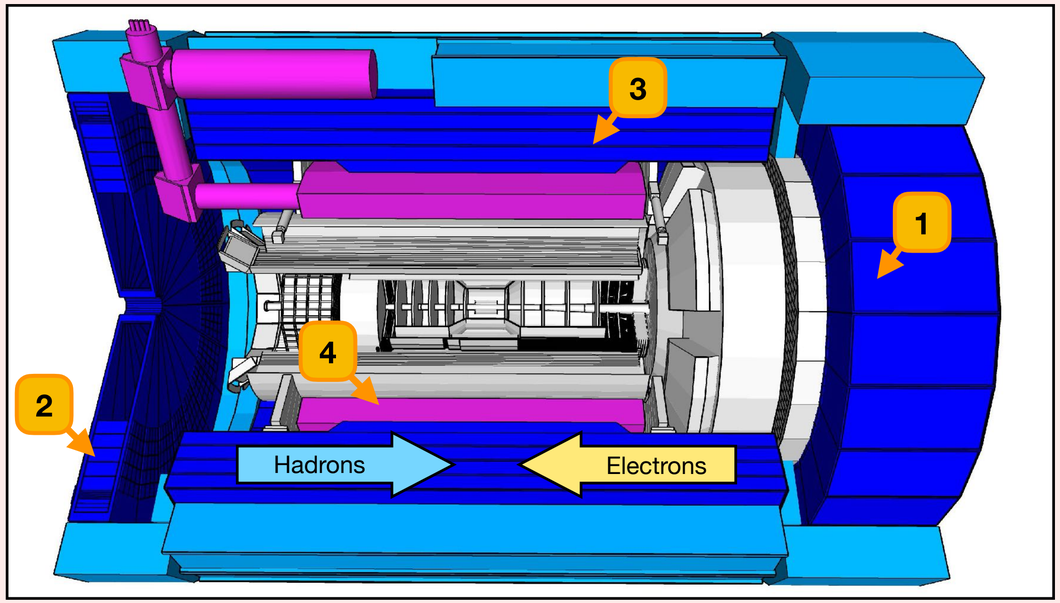


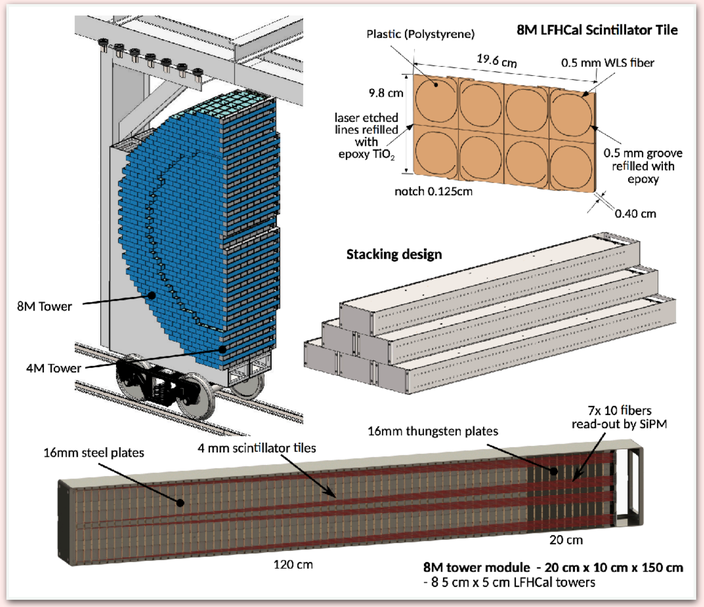
World's first at ePIC

2 - Barrel imaging calorimeter

- AstroPix monolithic silicon sensors
- 6 layers of imaging Si sensors
- 5 Pb scintillator fiber layers
- Large chunk of Pb scintillator fiber
- Covers $-1.7 < \eta < 1.3$
- Pixel size position resolution
- $5.3\,\%/\sqrt{E} \oplus 1.0\,\%$ energy revolution

The ePIC Detector - Hadronic Calorimeter

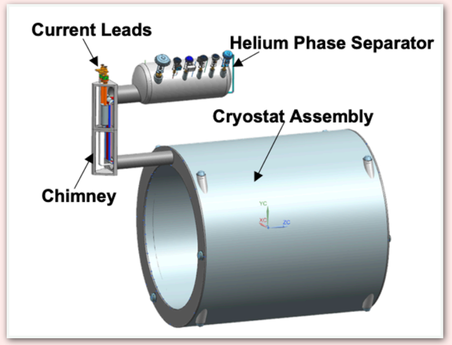




1 - Longitudinally segmented Forward HCal (LFHCal)

- Longitudinal steel/scintillator segments
- SiPM-on-tile readout
- High-granularity insert to aid in reconstruction of HFS
- Identification of muons

World's first at ePIC

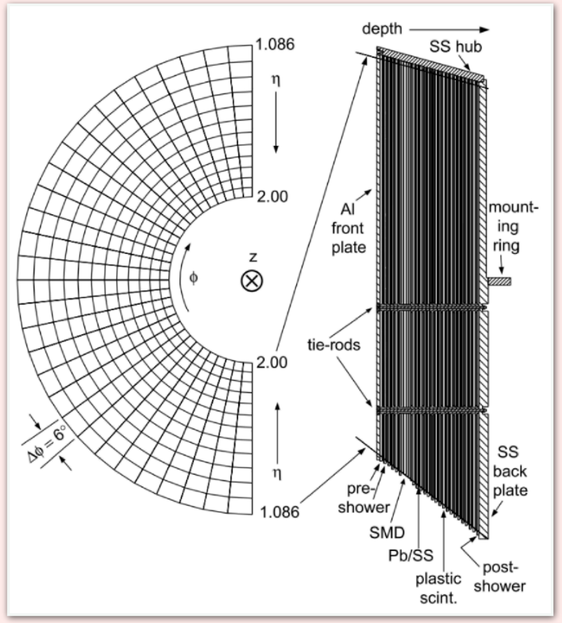


4 -MACRO solenoid magnet

- 2T super conducting solenoid

3 - Barrel HCAL

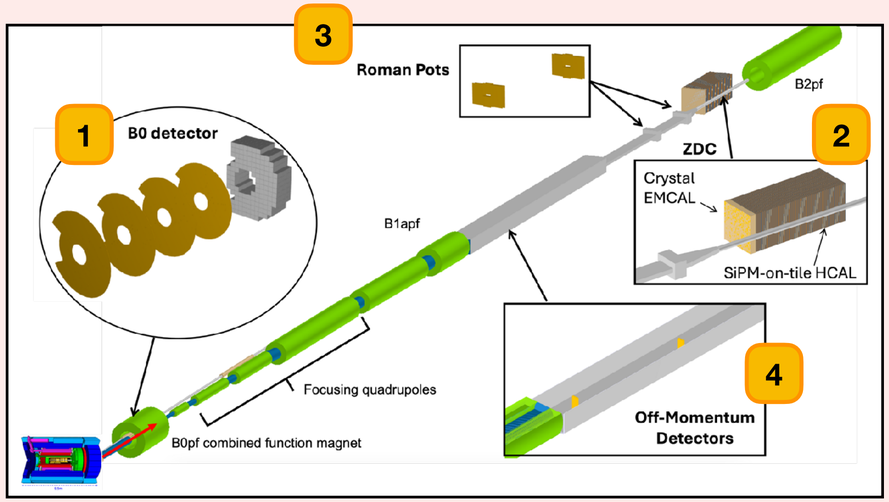
- sPHENIX calorimeter
- with new SiPMs

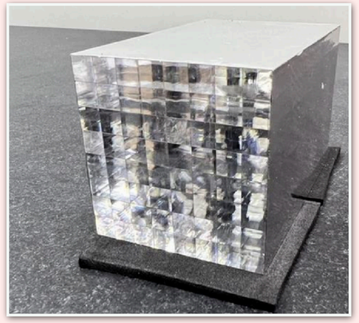


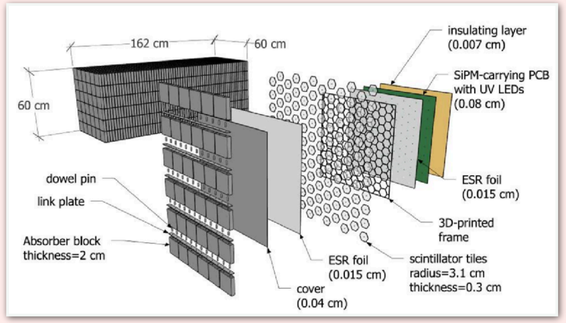
2 - Backward HCal

- Steel/Scintillator sandwich (10 layers)
- STAR scintillator tiles

The ePIC Detector - Far Forward

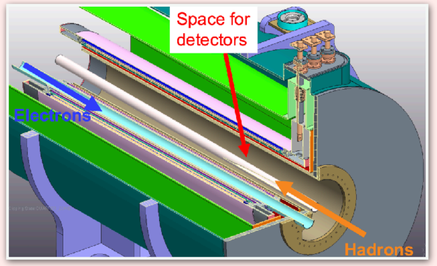


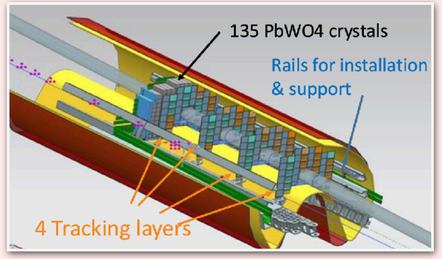




2 - Zero Degree Calorimeter (ZDC)

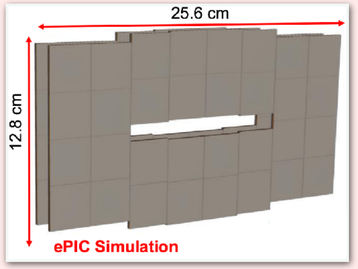
- PbWO4 ECAL + Steel/Sc. HCAL
- Covers $0 < \theta < 5\,\mathrm{mrad}$





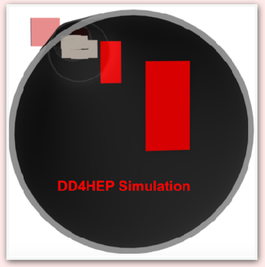
1 - B0 tracker

- Fully embedded in machine dipole
- AC-LGADs based silicon tracker
- PbWO4 calorimeter
- Covers $5.5 < \theta < 20\,\mathrm{mrad}$



3 - Roman Pots (RP)

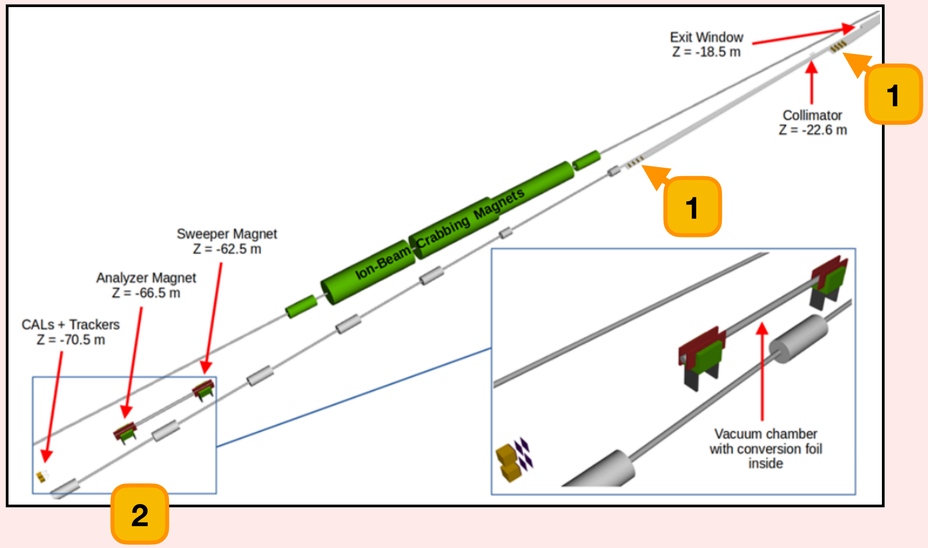
- AC-LGADs detectors
- Position changes for different beam optics
- 10σ from beam center, 1σ ~ 1 mm
- Low-pT cutoff
- Covers $0 < \theta < 5\,\mathrm{mrad}$

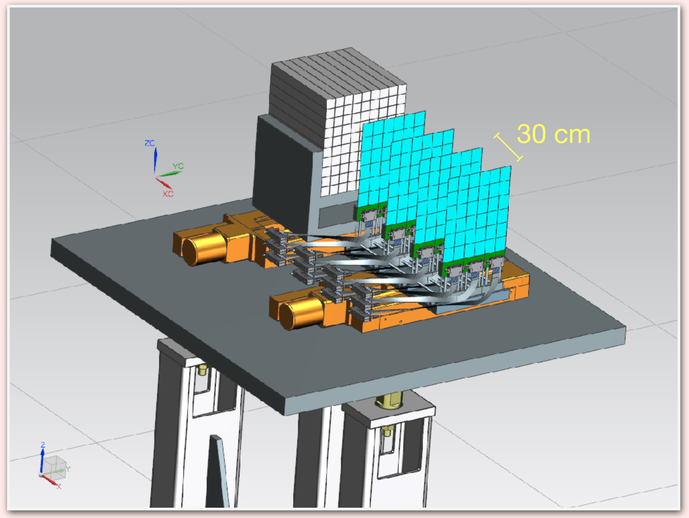


4 - Off-Momentum Detector (OMD)

- Same technology as the RF
- Covers $0 < \theta < 5\,\mathrm{mrad}$

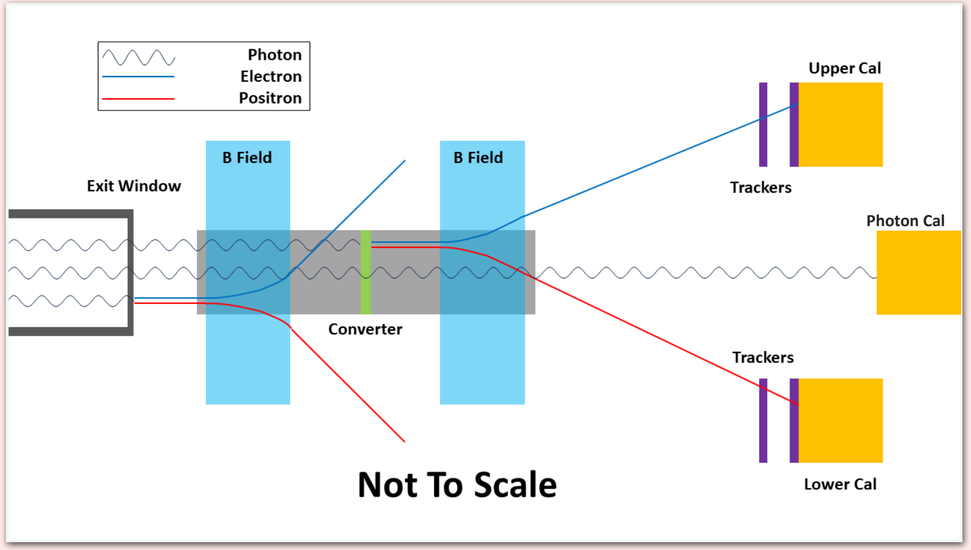
The ePIC Detector - Far Backward





1 - Low Q2 electron taggers

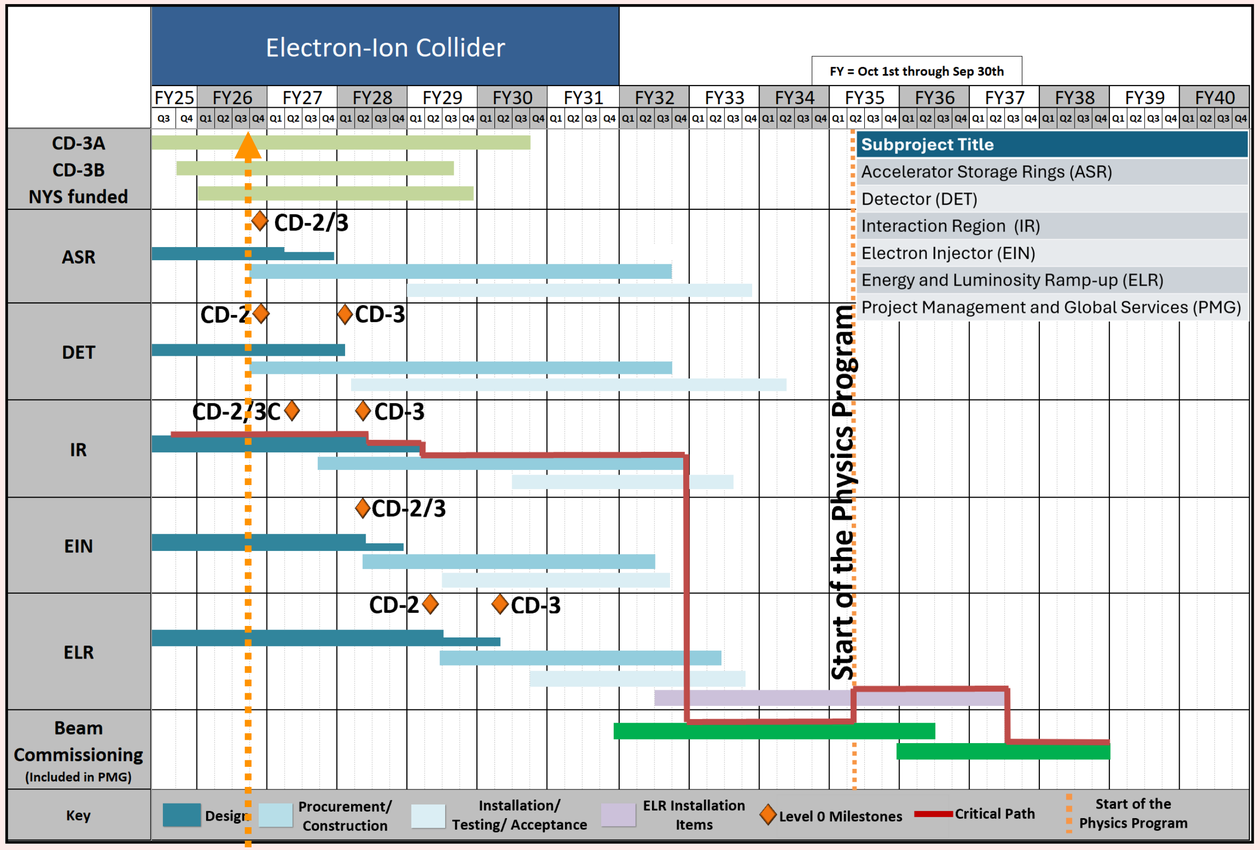
- 2 station, each with 4 tracking layers and calorimeter
- Timepix4 ASIC + Si Sensor
  - 2 ns timing resolution
  - High rate capability



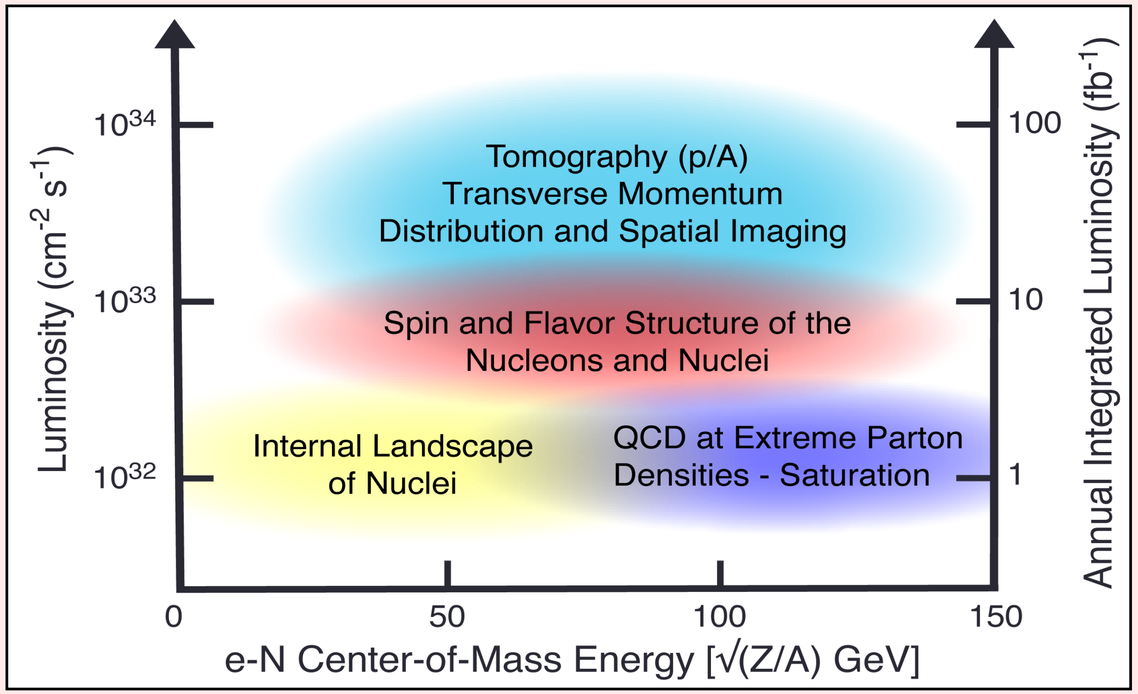
2 - Luminosity monitors

- Similar to HERA design
- Direct photon detector on $0°$ line
  - Tungsten scintillating fiber calorimeter (WSciFi)
- Complimentary Pair spectrometer
  - AC-LGAD strip tracker
  - WSciFi calorimeter

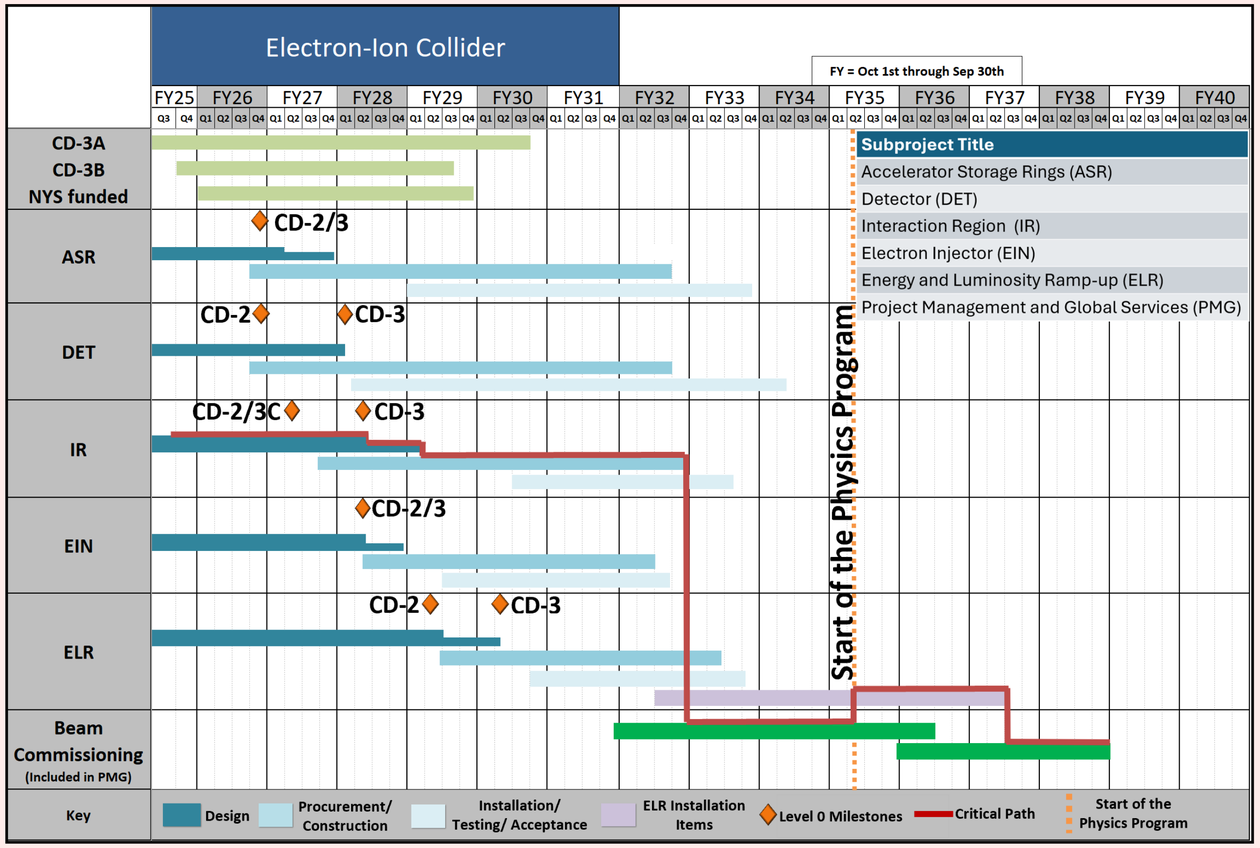
EIC Physics and Timeline

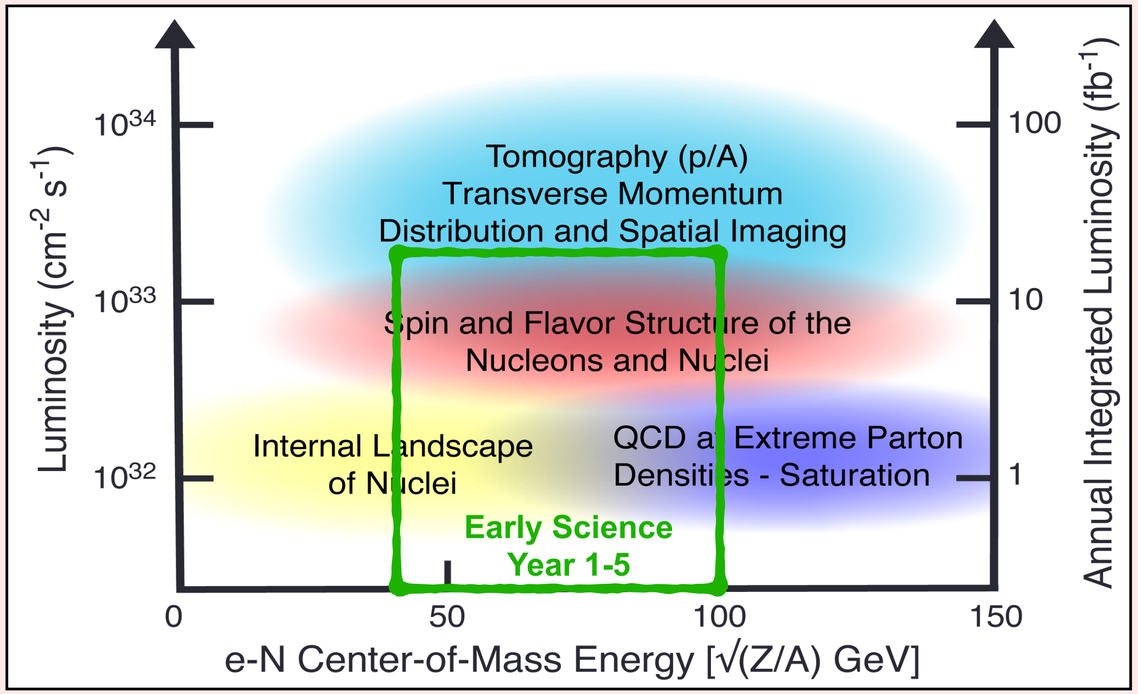


Construction phase start



EIC Physics and Timeline



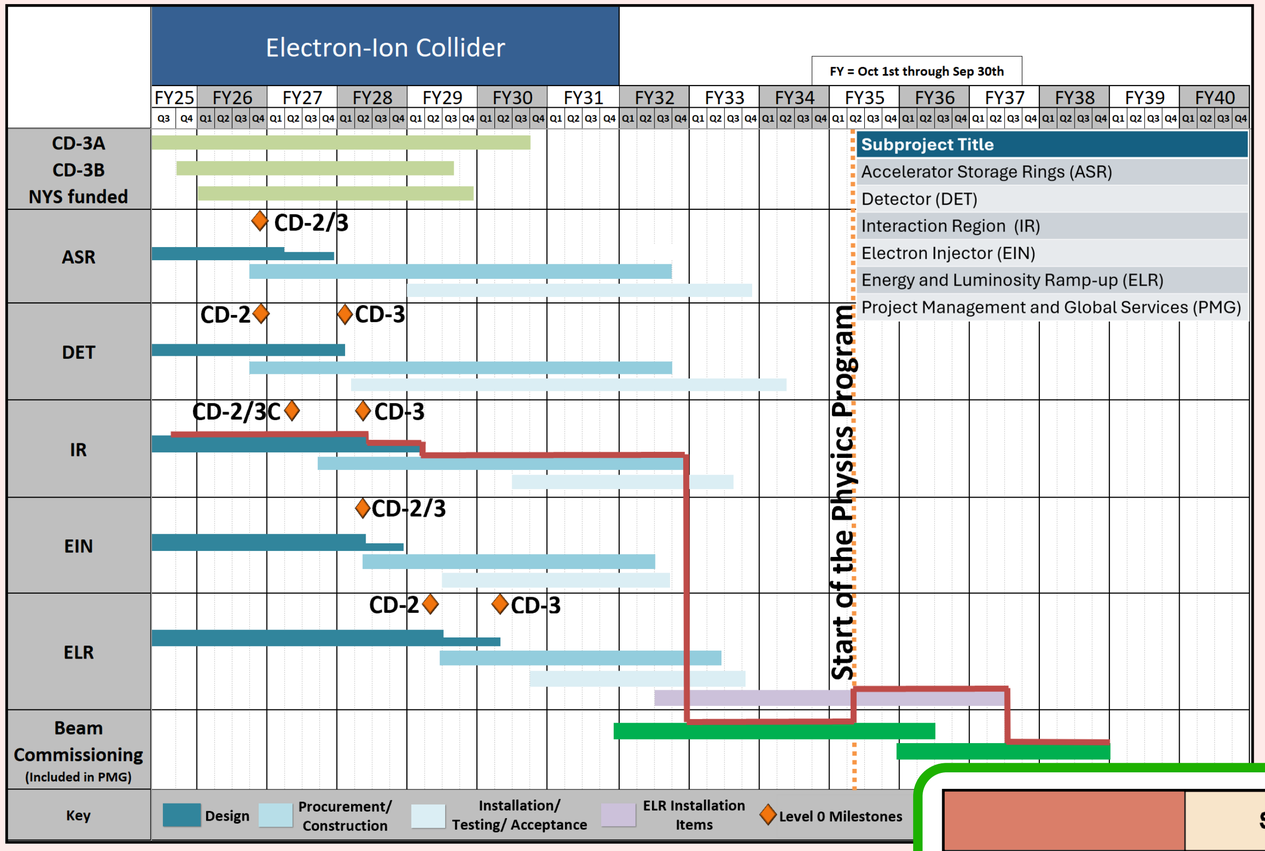


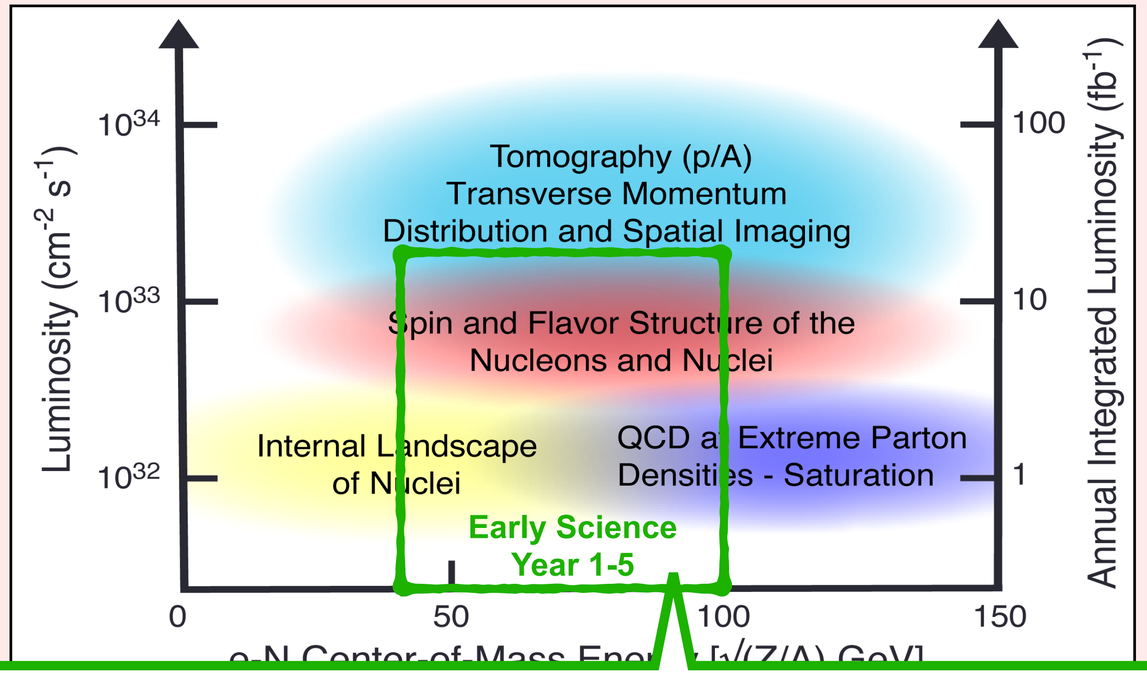
7 nC / bunch
Pre-cooling at injection

5 - 10 GeV polarized e-

100 - 250 GeV polarized p
100 GeV/u nuclear beams

EIC Physics and Timeline





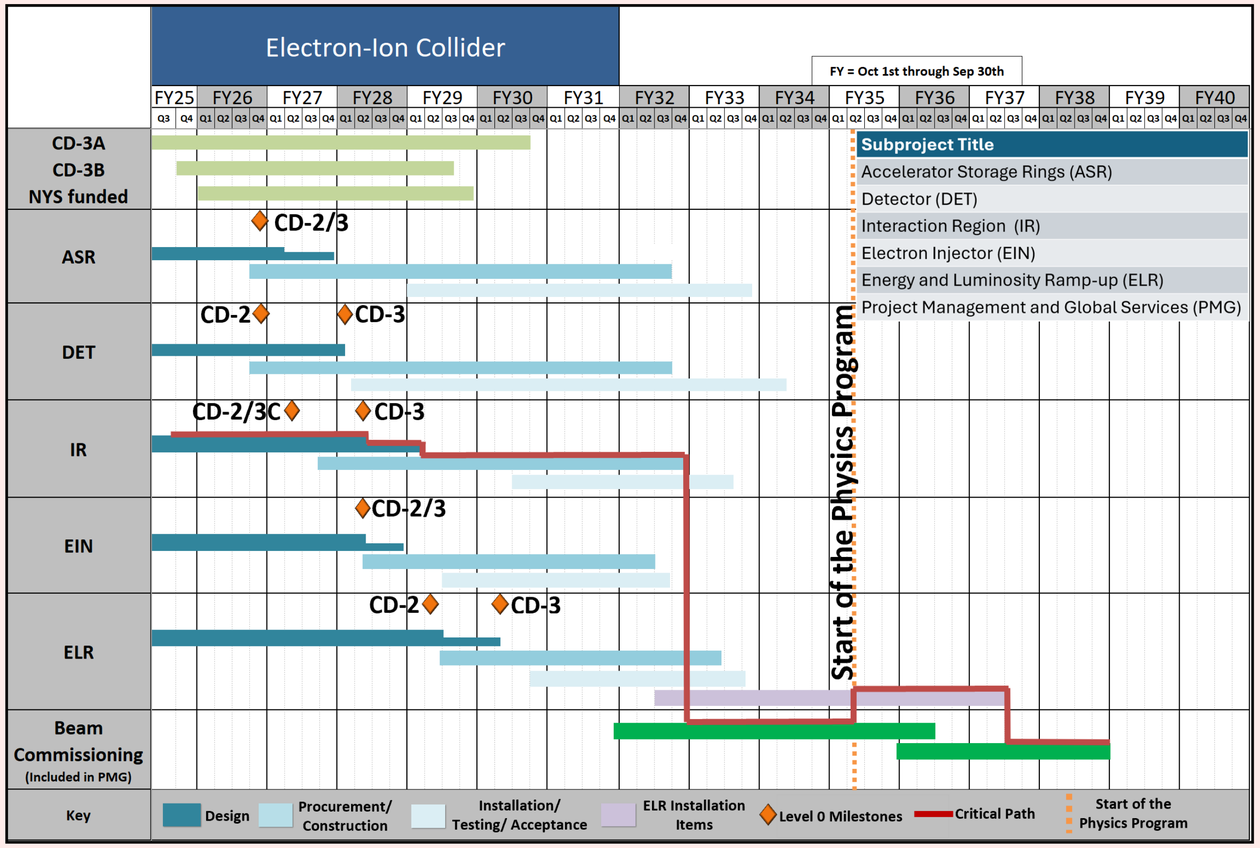
7 nC / bunch
Pre-cooling at injection

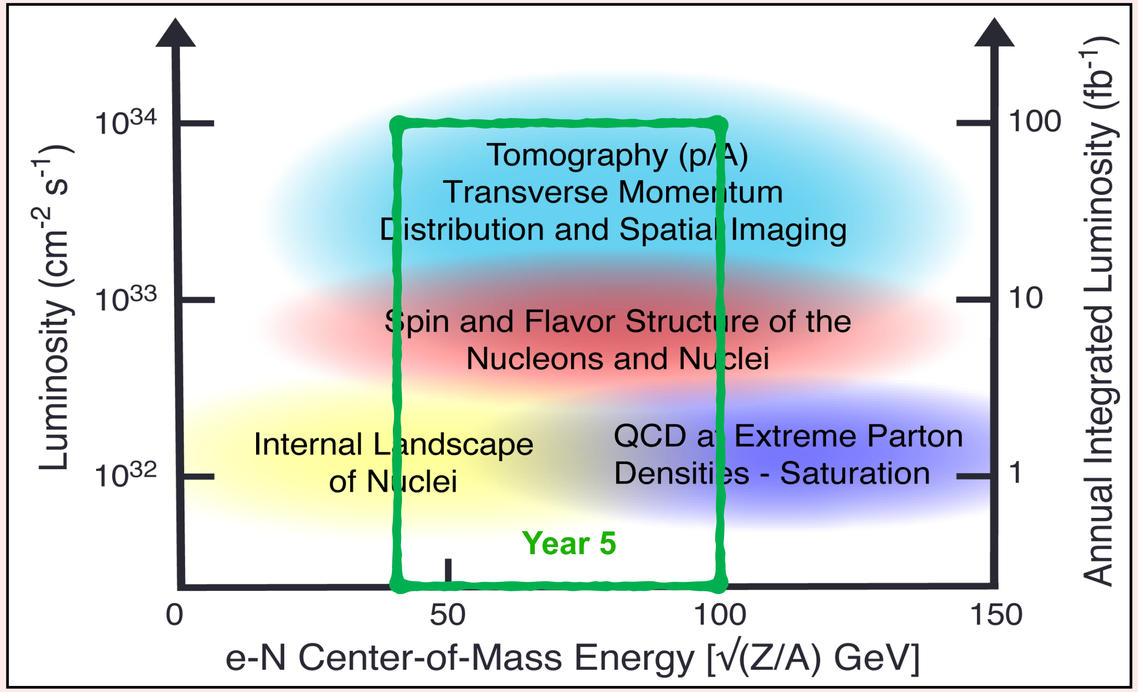
5 - 10 GeV

	Species	Energy (GeV)	Luminosity/year (fb-1)	Electron polarization	p/A polarization
YEAR 1	e+Ru or e+Cu	10 x 115	0.9	NO (Commissioning)	N/A
YEAR 2	e+D e+p	10 x 130	11.4 4.95 - 5.33	LONG	NO TRANS
YEAR 3	e+p	10 x 130	4.95 - 5.33	LONG	TRANS and/or LONG
YEAR 4	e+Au e+p	10 x 100 10 x 250	0.84 6.19 - 9.18	LONG	N/A TRANS and/or LONG
YEAR 5	e+Au e+3He	10 x 100 10 x 166	0.84 8.65	LONG	N/A TRANS and/or LONG

Note: the eA luminosity is per nucleon

EIC Physics and Timeline



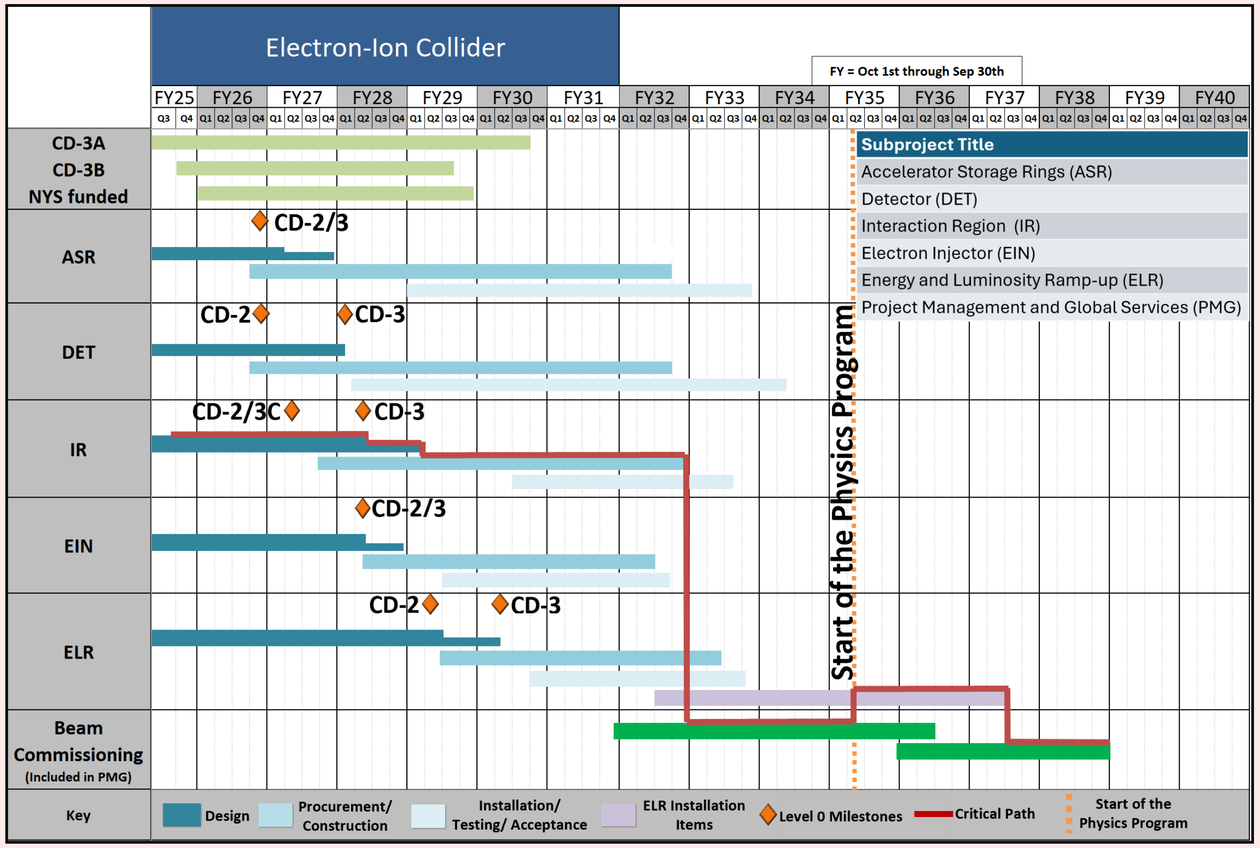


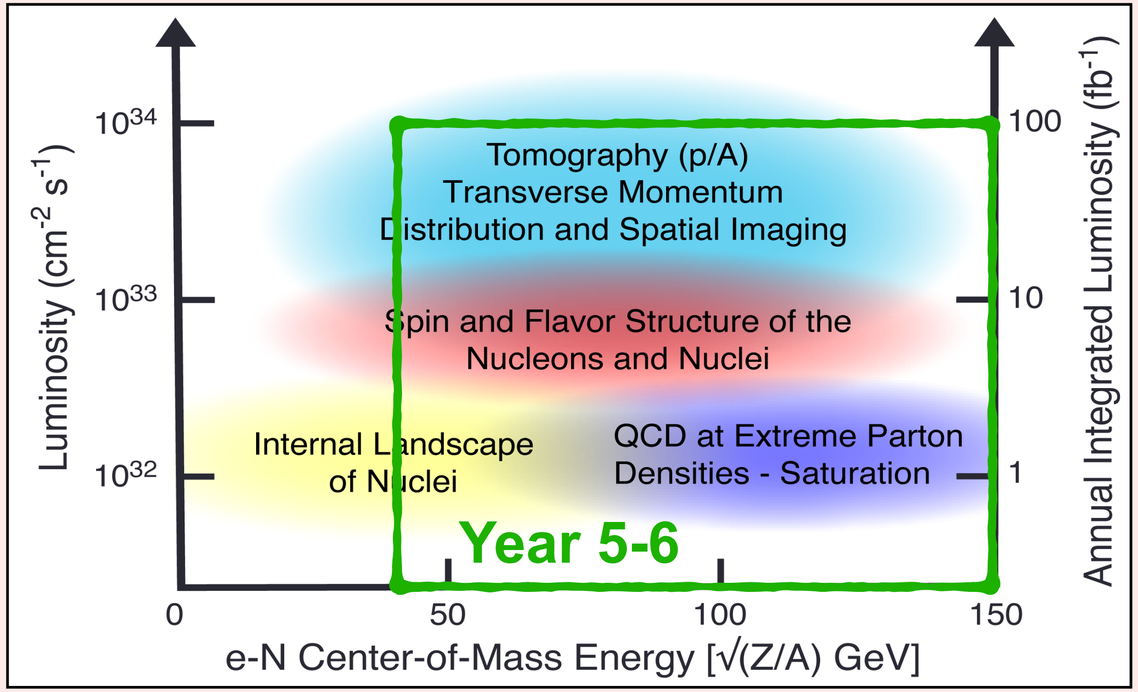
28 nC / bunch
Low energy hadron cooling

5 - 10 GeV polarized e-

100 - 250 GeV polarized p
100 GeV/u nuclear beams

EIC Physics and Timeline



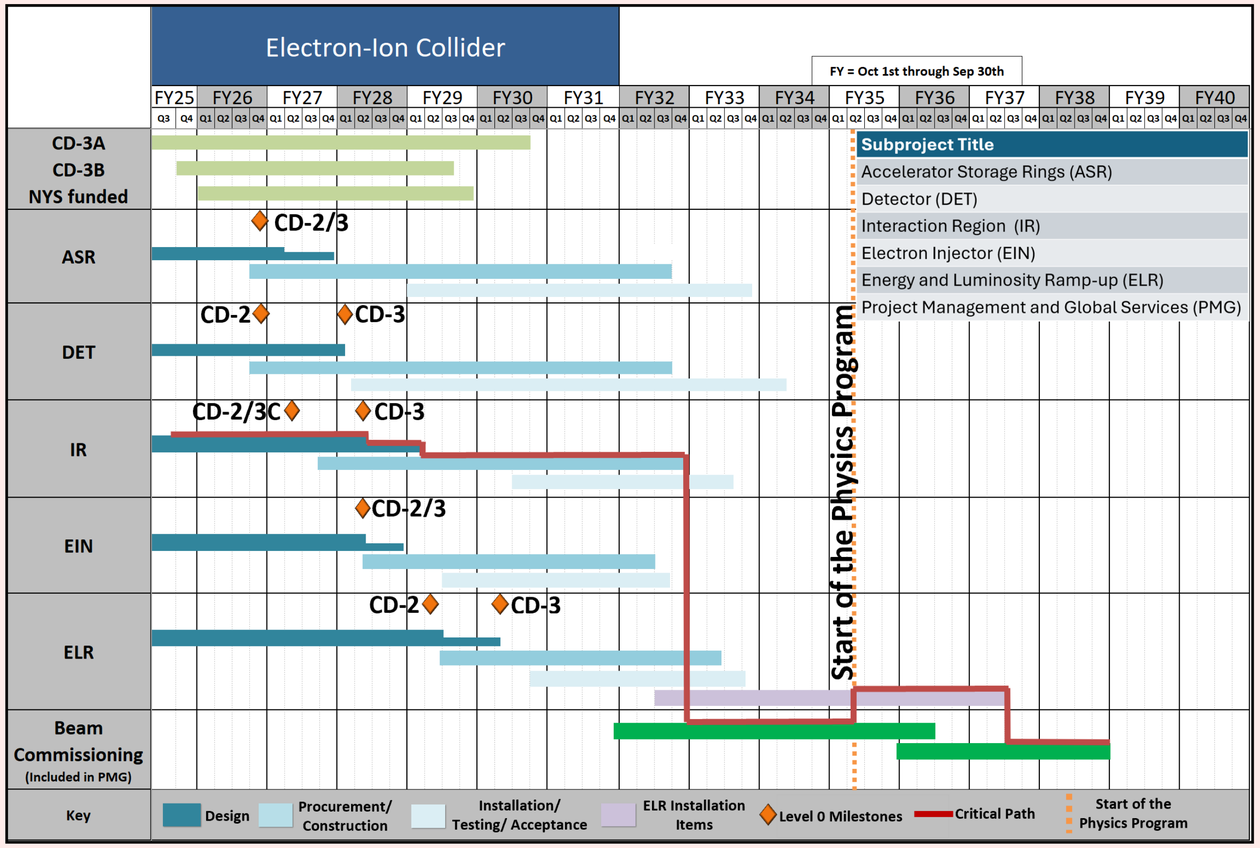


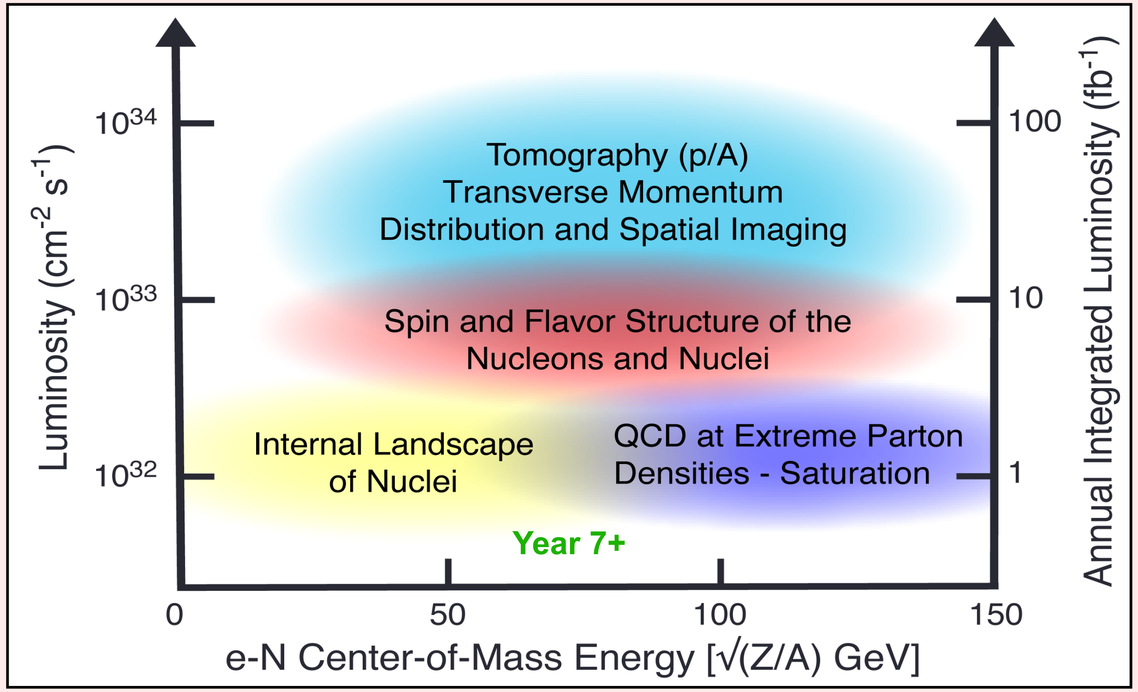
28 nC / bunch
Low energy hadron cooling

More RF cavities
18 GeV e-

100 - 250 GeV polarized p
100 GeV/u nuclear beams

EIC Physics and Timeline





28 nC / bunch
Low energy hadron cooling

More RF cavities
18 GeV e-

Hadron low-energy bypass

Full science potential will be unlocked

Summary

- EIC will be the first polarized electron proton/ion and electron nucleus collider providing high luminosity beams with wide range of energies
- EIC will enable opportunities for many important QCD studies
- The ePIC collaboration is dedicated to build the first detector system at IP6 with many world's first technologies to provide high coverage for nuclear physics programs
- EIC construction phase is starting soon!