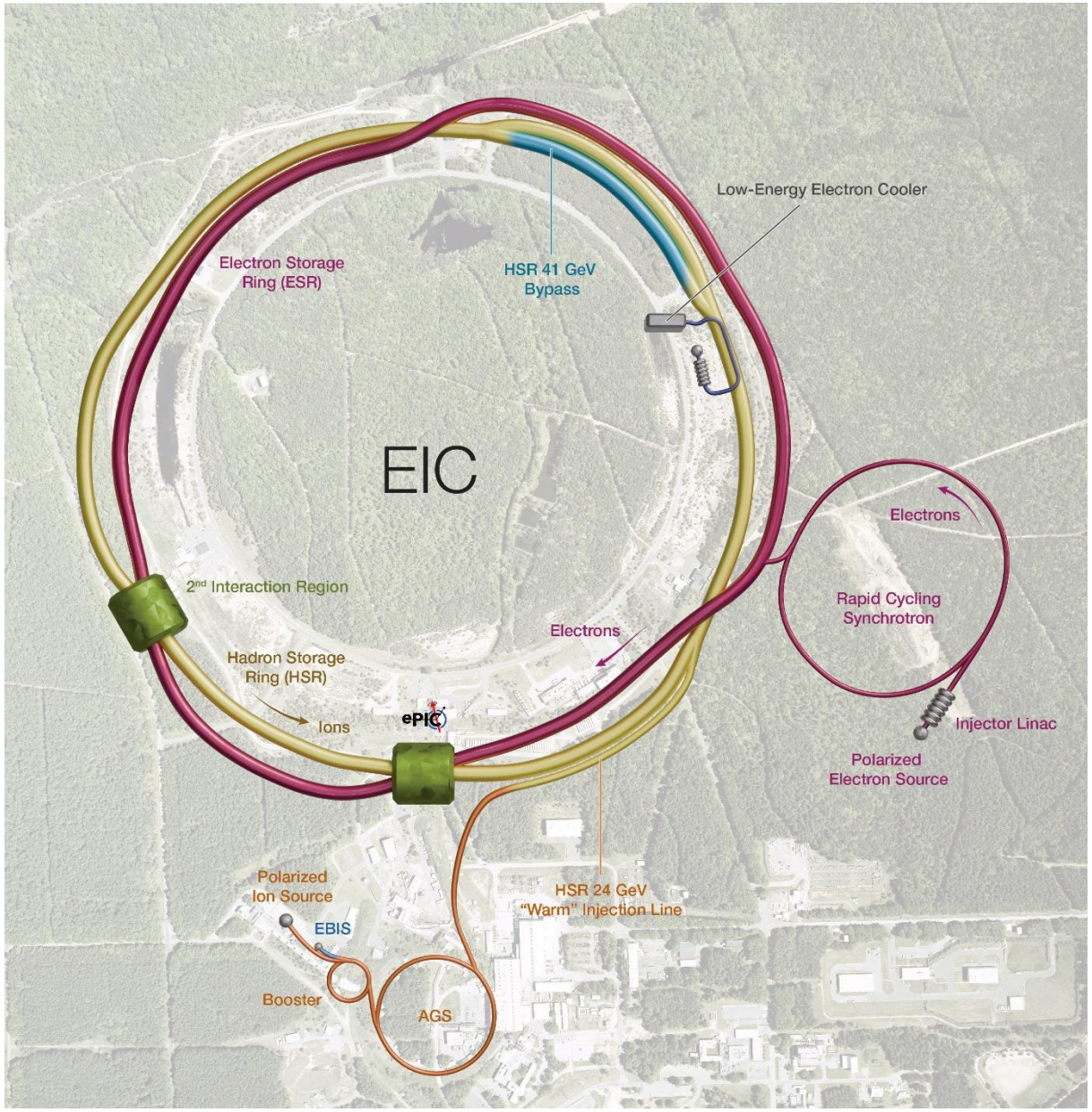


ePIC

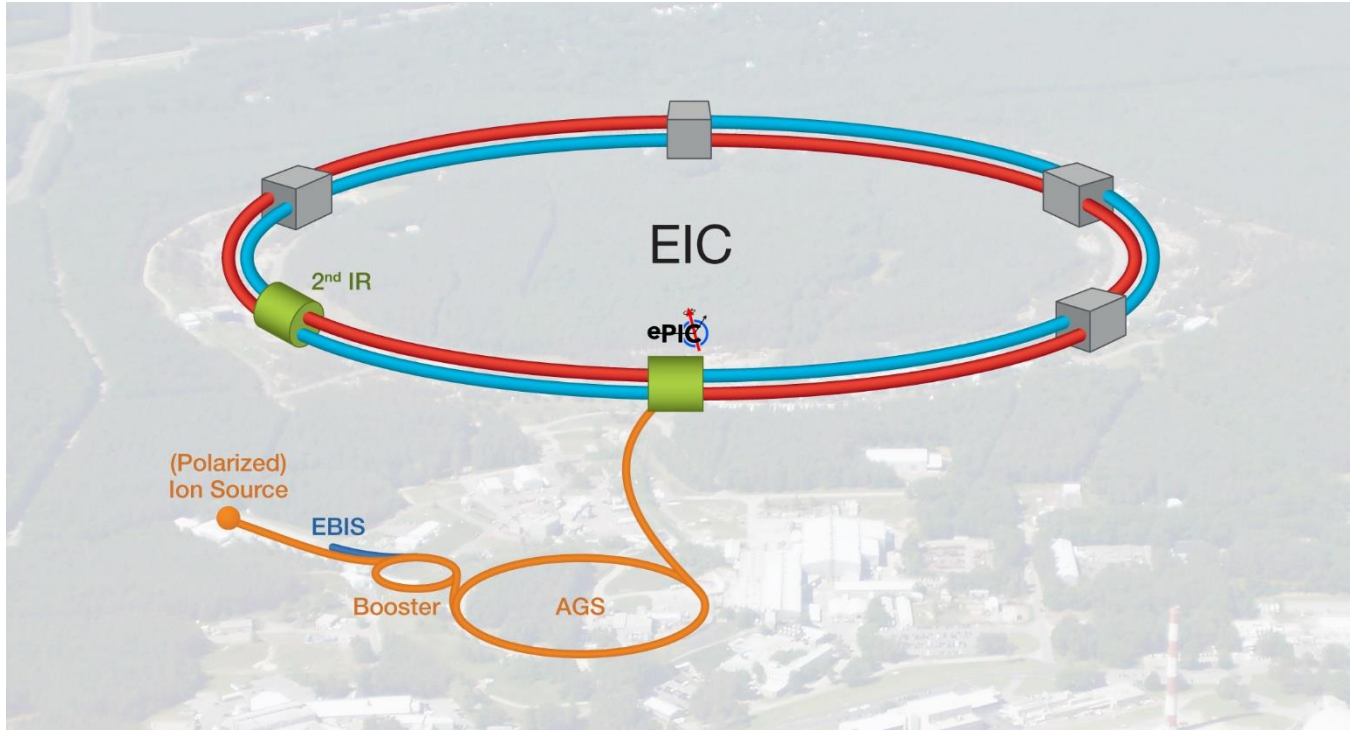
Carlos Muñoz Camacho
IJCLab

Workshop on high throughput heterogeneous computing

Orsay, 29/01/2026

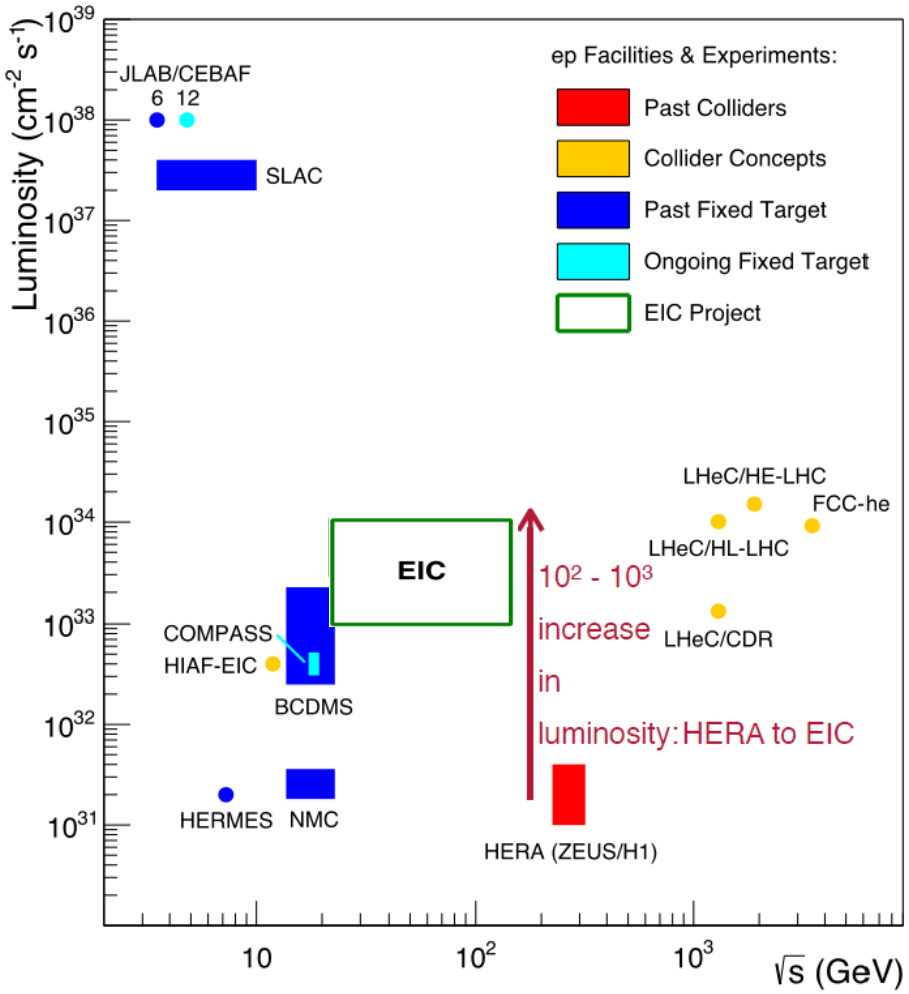
The EIC facility

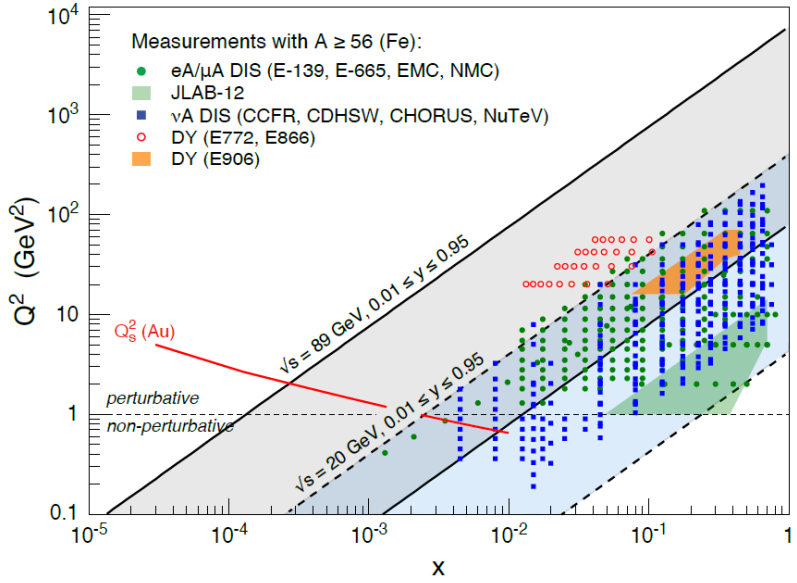
- Highly polarized electron / Highly polarized proton and light ions /Unpolarized heavy ions
- CME: ~ 20–140 GeV
- Luminosity: ~ $10^{33\text{-}34}$ $cm^{-2}s^{-1}$



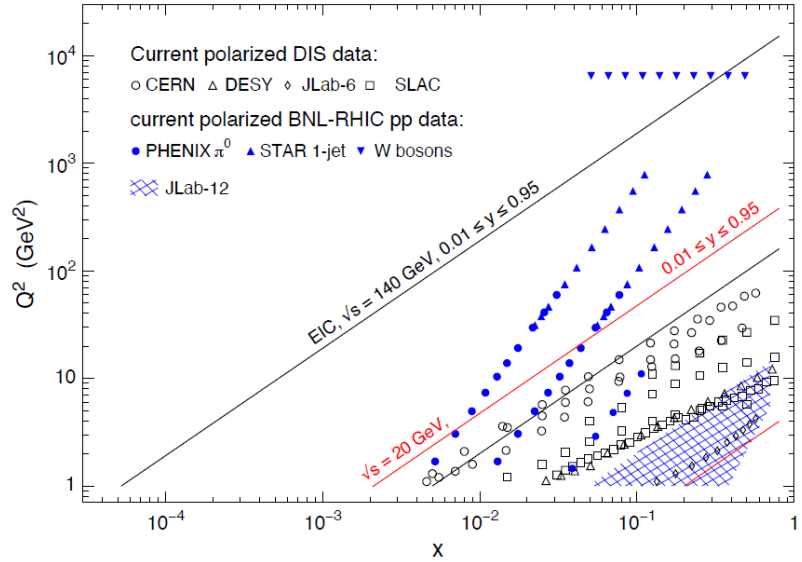
- ❑ Polarized electron source and 400 MeV injector linac to feed a rapid cycling synchrotron design to avoid depolarizing resonances up to the maximum e-beam energy of 18 GeV
- ❑ Polarized proton beams and ion beams based on existing RHIC facility
- ❑ 2 detector interaction points capability in the design

Luminosity and kinematic coverage





eA

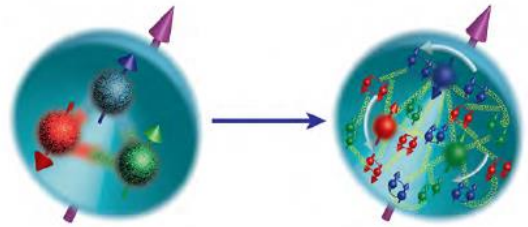


ep

Motivation – the EIC science program

Origin of spin:

How does the spin-1/2 of the nucleon arise from the spin of quarks, gluons and their orbital angular momenta?

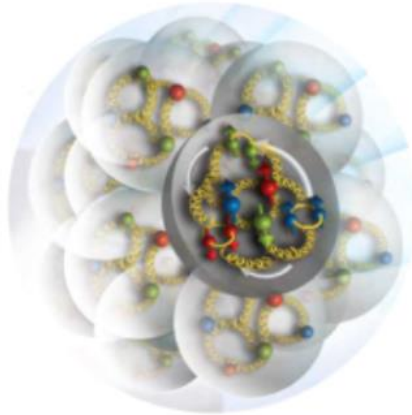


Origin of mass:

How do massless gluons make up for most of the nucleon mass?

Gluons in nuclei:

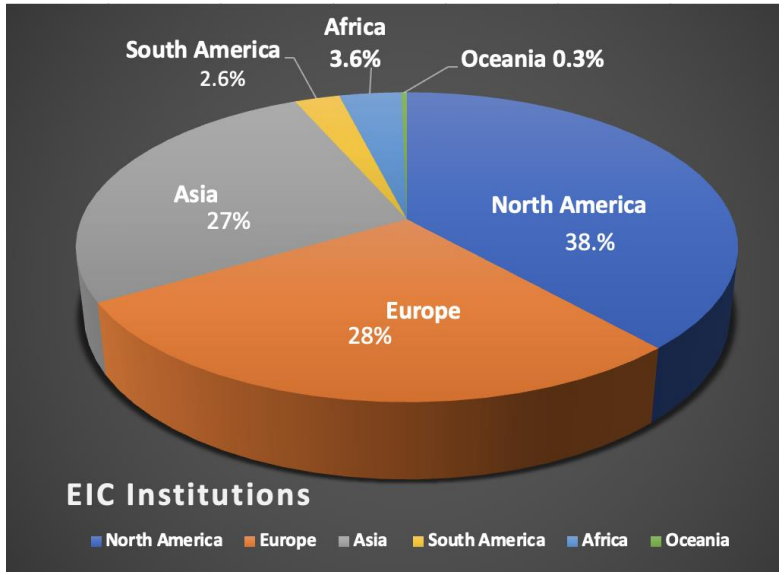
Does gluon density saturate at high energy giving rise to a new regime of matter?

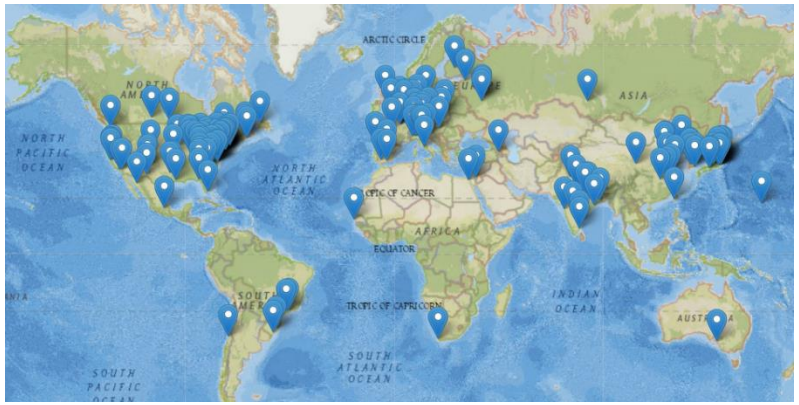


The EIC Users Group and ePIC

Formed in 2016, currently:

- 1550 collaborators,
- 41 countries, 305 institutions as of today





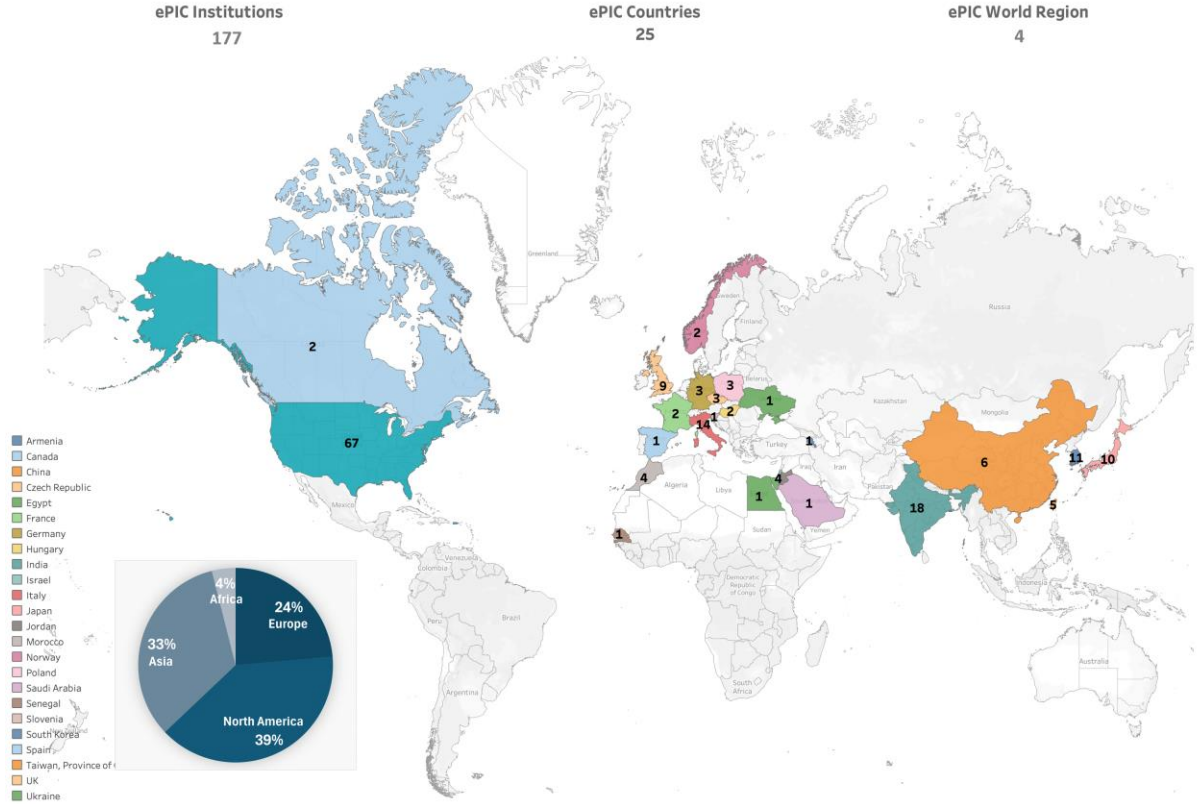
ePIC Collaboration

https://www.epic-eic.org

Formed in 2022 → Now

~1050 collaborators, 25 countries, 182 institutions

US: 8 National Labs + 59 Universities



The ePIC detector design

Tracking:

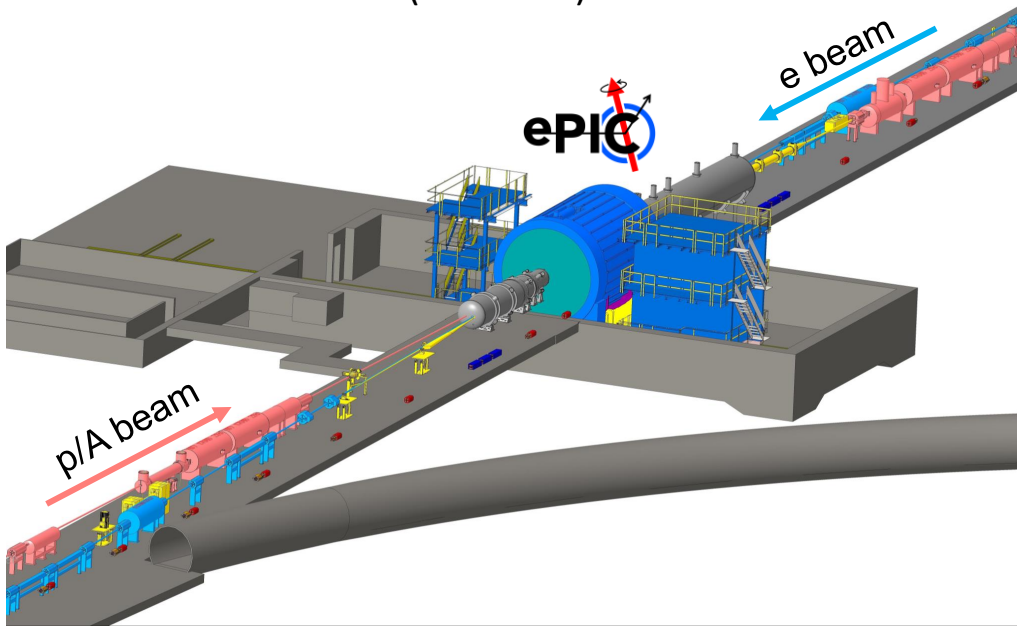
- New 1.7T solenoid
- Si MAPS Tracker
- MPGDs (µRWELL/µMegas)

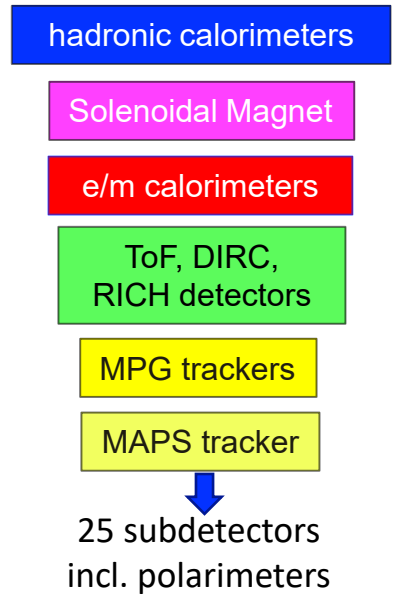
PID:

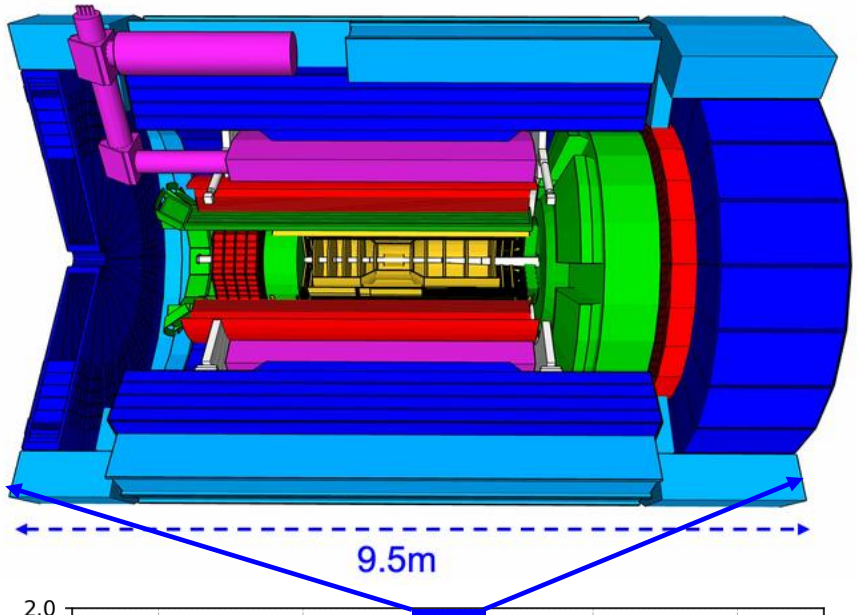
- Backward pfRICH
- Barrel hpDIRC
- Forward dRICH
- Barrel & Forward TOF (AC-LGAD)

Calorimetry:

- Backward HCal (Steel+scint)
- $PbWO_4$ EMCal in backward direction
- Sampling & Imaging Barrel EMCal
- Outer HCal (sPHENIX re-use)
- Finely segmented EMCal +HCal in forward direction





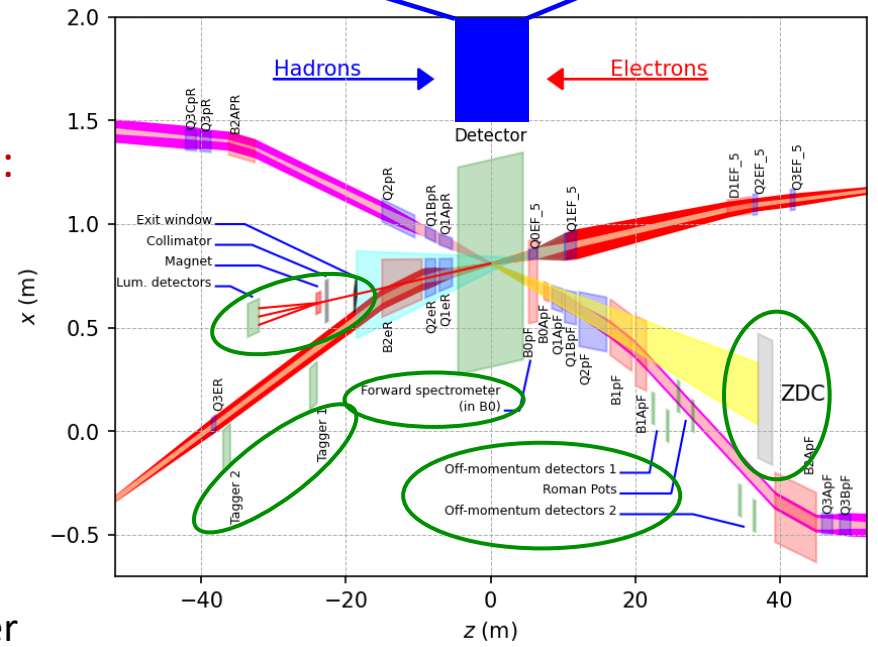


Far-Backward Detectors:

- Luminosity monitor.
- Low-Q^2 Tagger

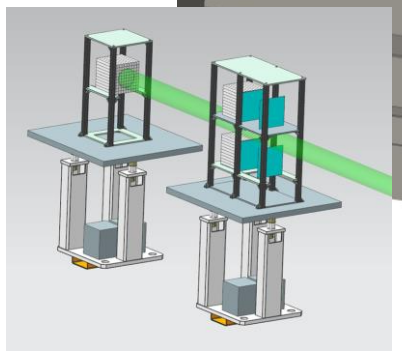
Far-Forward Detectors:

- B0 Tracking and Photon Detection
- Roman Pots and Off-Momentum Detectors.
- Zero-Degree Calorimeter



ePIC Far-Forward/Far-Backward detectors

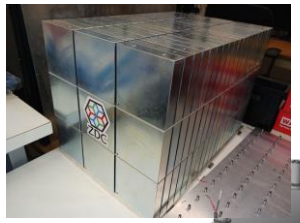
Main Function:
measure bunch-by-bunch luminosity through Bethe-Heitler process
Technology:
Pair-spectrometer: each with
2 tracking layers of AC-LGAD / FCFD
Calorimeter: Tungsten-powder + SciFi SPACAL

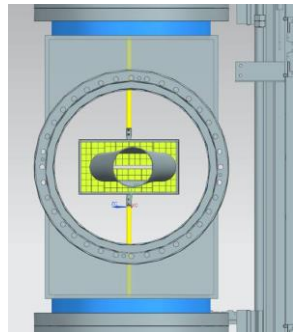


Luminosity System

Main Function:
detection of forward scattered neutrons and γ
Technology:
EMCAL: 2x2x20 cm^3 $PbWO_4$ calorimeter
HCAL: Steel-SiPM-on-Tile

Zero Degree Calorimeter





Roman Pots and Off-Momentum

Main Function:
detection of forward scattered protons and nuclei
Technology:
2 stations with 2 tracking layers each
AC-LGAD / EICROC (500x500 μm^2 pixel)

B0 Magnet Spectrometer

Main Function:
detection of forward scattered protons and and γ
Technology:
4 tracking layers each
AC-LGAD / EICROC (500x500 μm^2 pixel)
EMCAL: 2x2x20 cm^3 $PbWO_4$ calorimeter

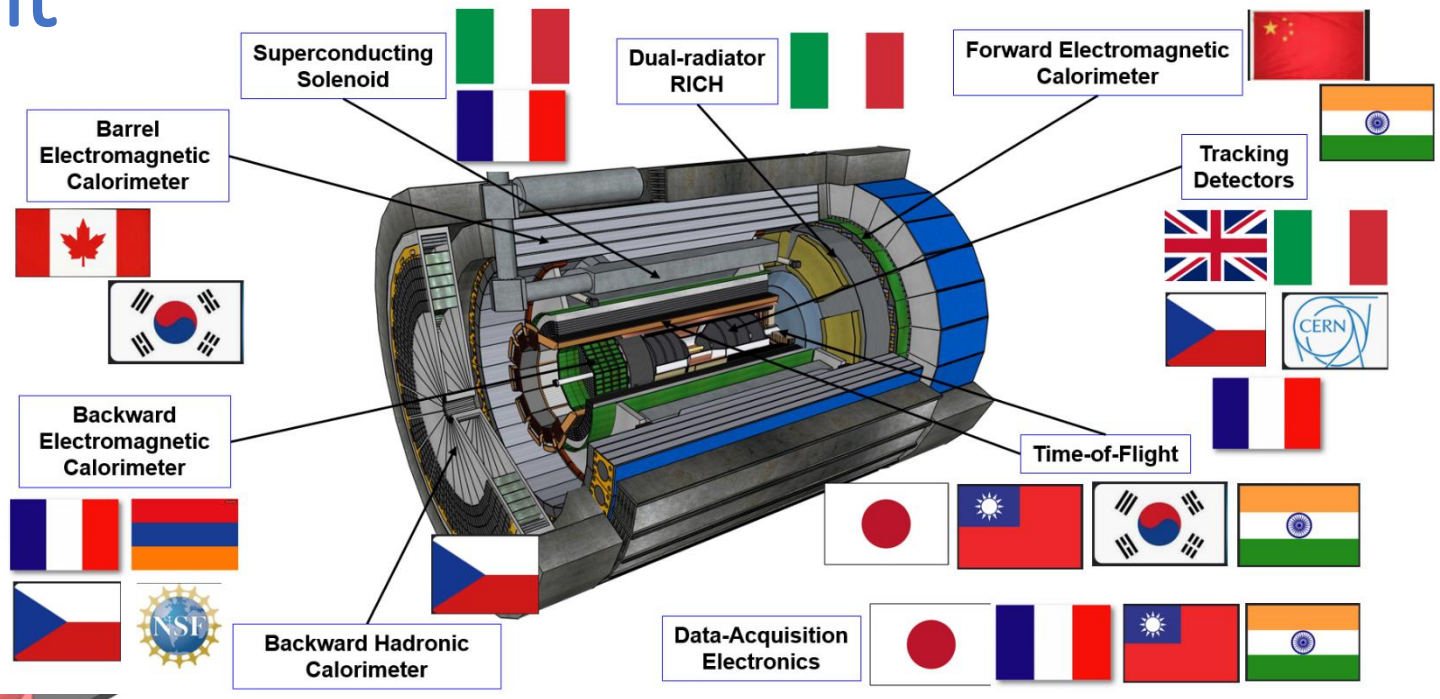
Low-Q2 Taggers

Main Function:
detection of scattered electrons
Technology:
2 stations with 4 tracking layers each ($16x18cm^2$)
Si / Timepix4
Calorimeter: Tungsten-powder + SciFi SPACAL

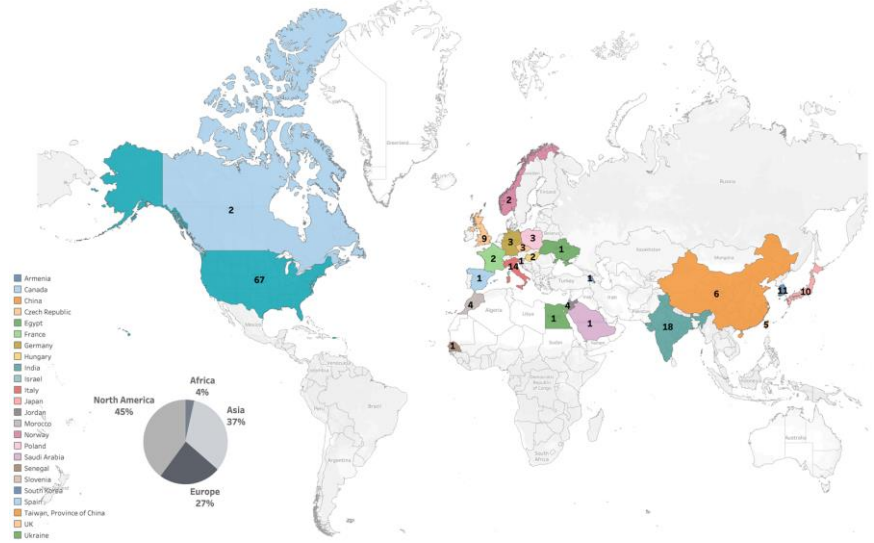
International engagement

- Large involvement from non-US institutions in ePIC central & far-forward/far-backward detectors
- Also contributions to EIC accelerator (magnets, cryomodules…)

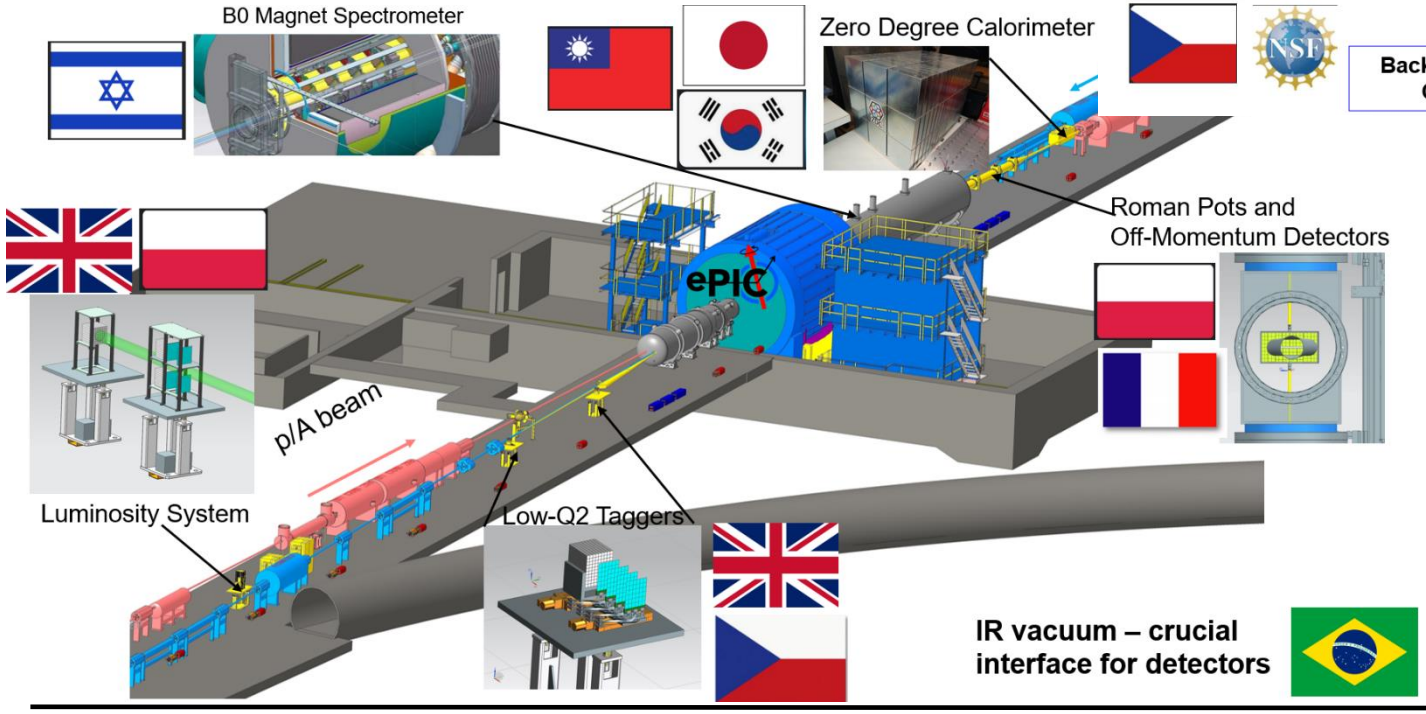
Central detector



ePIC Institutions 173 | ePIC Countries 25 | ePIC World Region 4



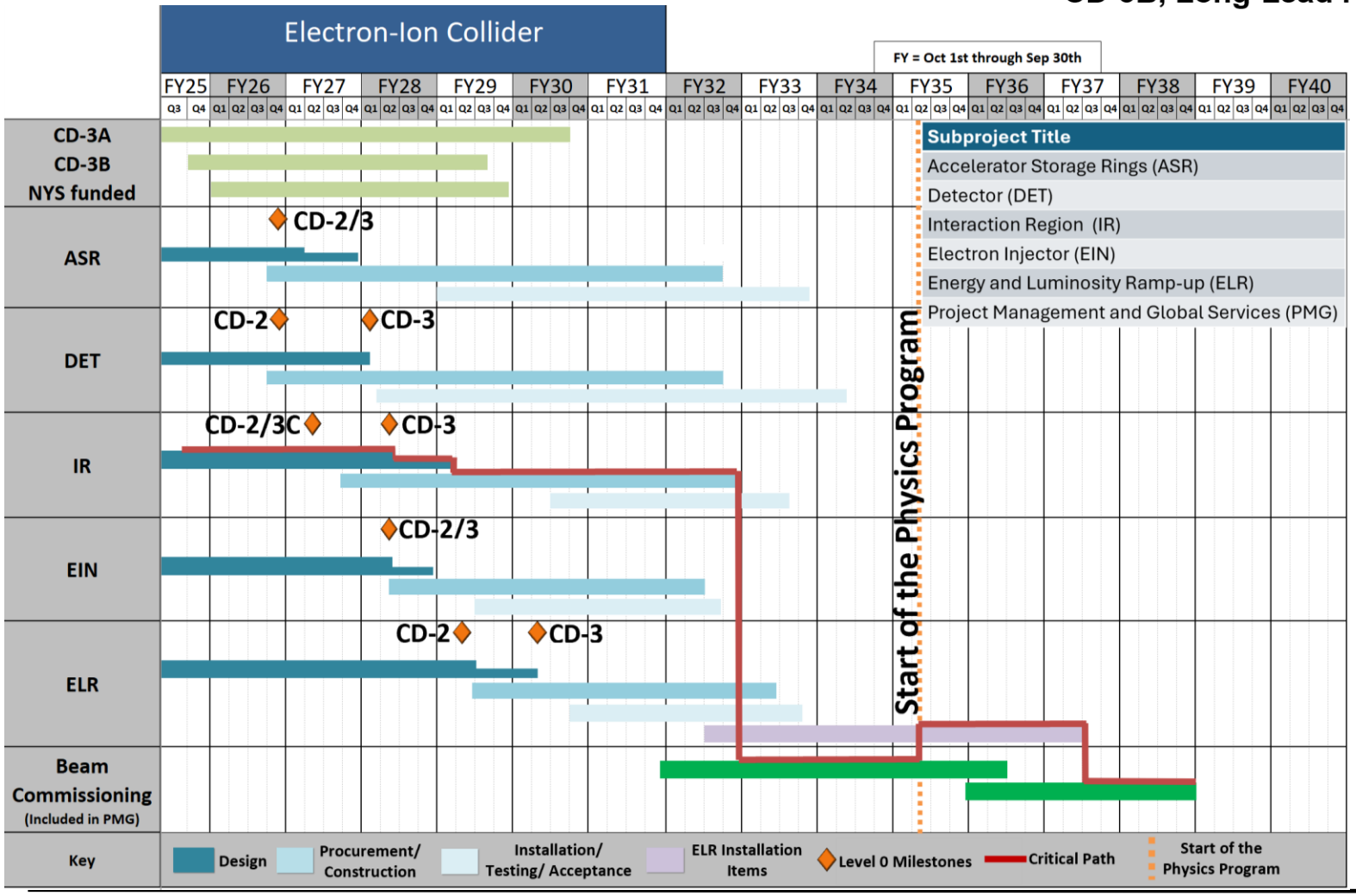
Far-forward/far-backward detectors



IR vacuum – crucial interface for detectors

EIC reference schedule

CD-0, Mission Need Approved	December 2019
DOE Site Selection Announced	January 2020
CD-1, Alternative Selection and Cost Range Approved	June 2021
CD-3A, Long-Lead Procurement Approved	**March 2024**
CD-3B, Long-Lead Procurement Planned Approval	**March 2025**



EIC detector milestones

- *Currently: Finalizing detector design*
- 2026: TDR completed (CD-2/3)
- 2027: Detector construction
- 2033/4: Installation/commissioning
- 2035: Start of physics program

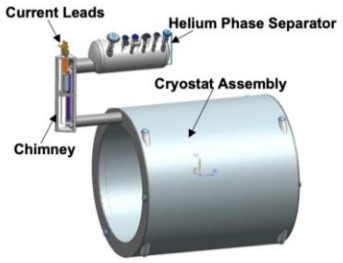
DOE project phases:

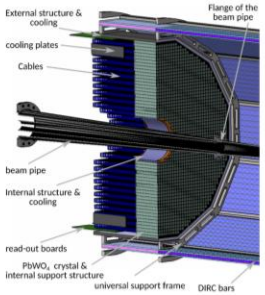
- CD-0: Approve mission need
- CD-1: Approve Alternative Selection and Cost Range
- CD-2: Approve performance Baseline
- CD-3: Approve Start of Construction
- CD-4: Approve Start of Operations

ePIC detector construction has started

- CD-3A enables procurement of long lead items
- Several contracts have already been awarded
- First items already received (eg. part of PWO crystals) and other expected by the end of the year (eg. first batch of SiPMs)

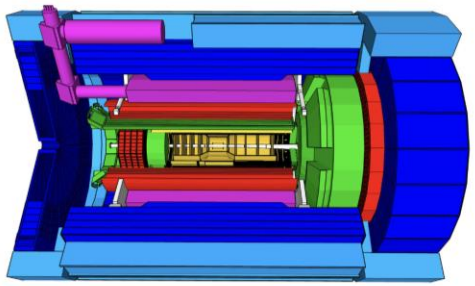
Detector LLPs

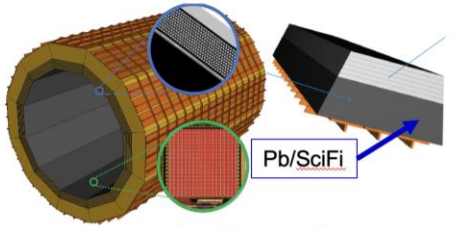




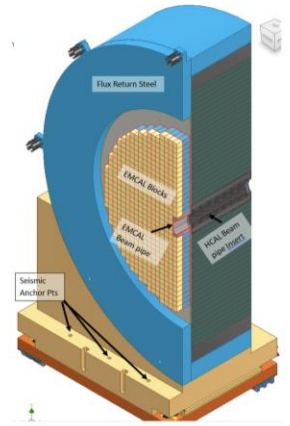
Backward Ecal
PbWO4-crystals

2T Solenoid
Design – built contract for magnet and Conductor
(Rutherford cable in Copper channel)





Barrel ECal: Pb/**Scintillating Fiber matrix**
with a hybrid imaging part



Forward ECal
High granularity
Tungsten-Powder/
Scintillating Fibers matrix

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

1. Lead Tungstate Crystals for the Detector Backward Electro-Magnetic (EM) Calorimeter
2. Scintillating Fibers for the Detector Barrel and Forward EM Calorimeters
3. Silicon Photomultipliers for the Detector Forward Hadronic Calorimeter
4. Steel and Tungsten for the Detector Forward Hadronic Calorimeter
5. Detector Solenoid Magnet Design and Fabrication and Conductor

EIC early science matrix

- Based on machine capabilies and evolution over the first years
- Goal of producing meaning and impacting science while commissioning different machine and detector systems
- Still under discussion within ePIC and the EIC project

	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

NB: ePIC installation plan calls for the full ePIC to be installed year-1 (exception for Roman Pots and Off-Momentum Detectors)

Proposal for the Science Program in the first years of ePIC

Year - 1

Start with Phase 1 EIC

New Capability:
Commission electron polarization in parallel

Run:
10 GeV electrons on 115 GeV/u heavy ion beams (Ag or Nb or Cu or Ru)

Physics:
Add your preferred science topic

Year - 2

Phase 1 EIC
+ long. electron polarization

New Capability:
Commission proton polarization in parallel

Run:
10 GeV long. polarized electrons on 130 GeV/u Deuterium

Physics:
Add your preferred science topic

Run:
Last weeks 10 GeV long. polarized electrons and 130 GeV polarized protons

Physics:
Add your preferred science topic

Year - 3

Phase 1 EIC
+ long. electron polarization
+ proton polarization

New Capability:
Commission running with hadron spin rotators

Run:
10 GeV long. polarized electrons on 130 GeV transverse polarized protons

Physics:
Add your preferred science topic

Run:
Last weeks switch to longitudinal proton polarization

Physics:
Add your preferred science topic

Year - 4

Phase 1 EIC
+ long. electron polarization
+ proton polarization
+ operation of hadron spin rotators

New Capability:
Commission hadron accelerator to operate with not centered orbits

Run:
10 GeV long. polarized electrons on 100 GeV Au

Physics:
Add your preferred science topic

Run:
10 GeV long. polarized electrons on 250 GeV transverse and longitudinal polarized protons

Physics:
Add your preferred science topic

Year - 5

Phase 1 EIC
+ long. electron polarization
+ proton polarization
+ operation of hadron spin rotators
+ operation of hadron beams with not centered orbits

Run:
10 GeV long. polarized electrons on 100 GeV Au

Physics:
Add your preferred science topic

Run:
10 GeV long. polarized electrons on 166 GeV transverse and longitudinal polarized He-3

Physics:
Add your preferred science topic

Time to install additional ESR RF and HSR PS to reach design Current and max. Energies

Proposal for the Science Program in the first years of ePIC

Year - 5

Phase 1 EIC
+ long. electron polarization
+ proton polarization
+ operation of hadron spin rotators
+ operation of hadron beams with not centered orbits

Run:
10 GeV polarized electrons on 100 GeV Au

Physics:
Add your preferred science topic

Run:
10 GeV long. electrons on 166 GeV transverse and longitudinal polarized He-3

Physics:
Add your preferred science topic

Year - 6

Phase 1 EIC
+ long. electron polarization
+ proton polarization
+ operation of hadron spin rotators
+ operation of hadron beams with not centered orbits

New Capability:
Commission ESR & HSR at max. energy and beam currents

Run:
18 GeV long. polarized electrons on 275 GeV/u polarized (longitudinal & transverse) proton beams

Physics:
Add your preferred science topic

Year - 7

Phase 1 EIC
+ long. electron polarization
+ proton polarization
+ operation of hadron spin rotators
+ operation of hadron beams with not centered orbits
+ operation of ESR & HSR at max. energy and beam currents

New Capability:
Operate HSR with 41 GeV bypass

Run:
5 GeV long. polarized electrons on 41 GeV transverse polarized proton beams

Physics:
Add your preferred science topic

Full EIC Capabilities

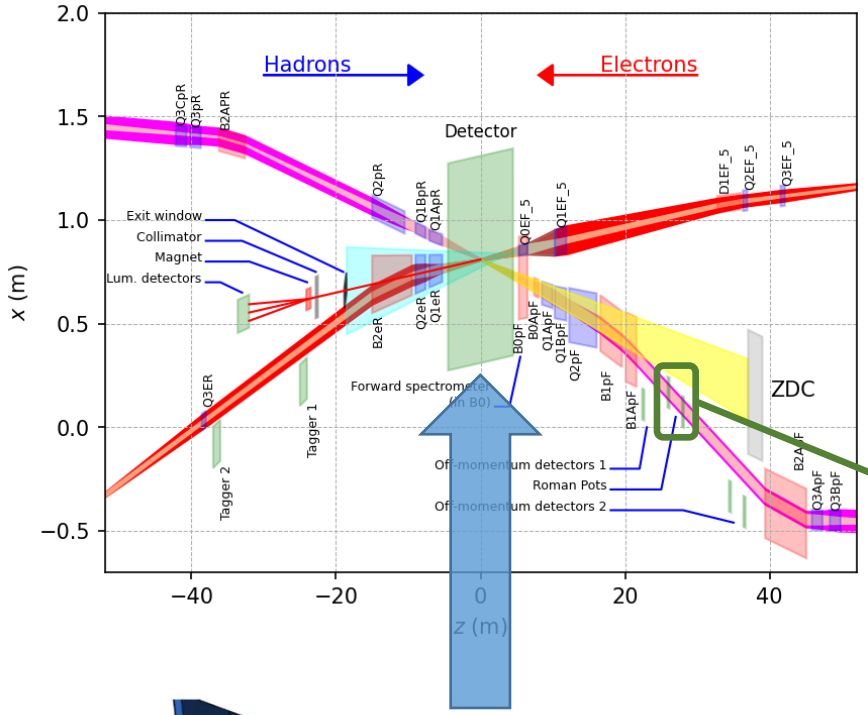
Interests of IN2P3 (IJCLab, LLR, OMEGA) - detector

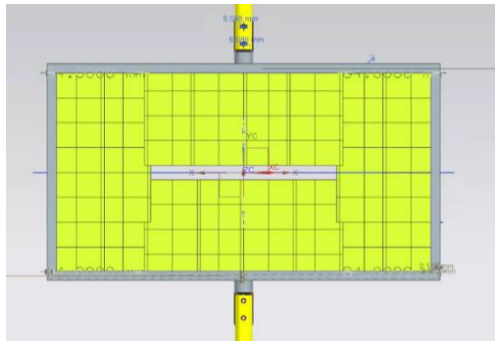
Phenomenology and software:

- Development of *eA* and *ep* event generators
- Detector simulation and analysis software development

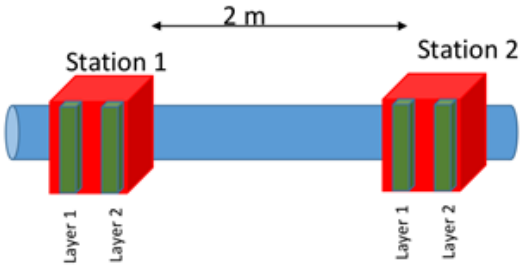
TOPEG
Project ID: 9292

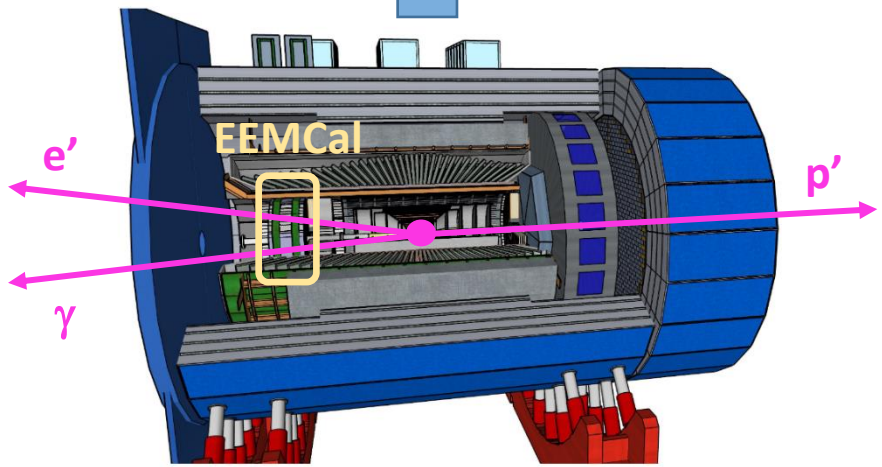
[The Orsay-Perugia Event Generator]





Roman Pots

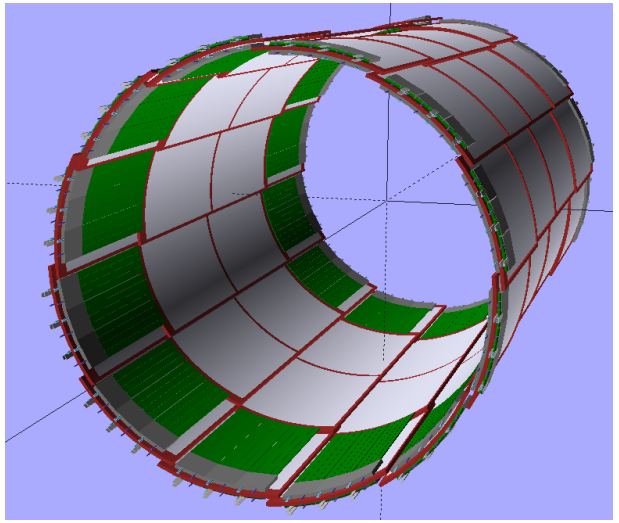


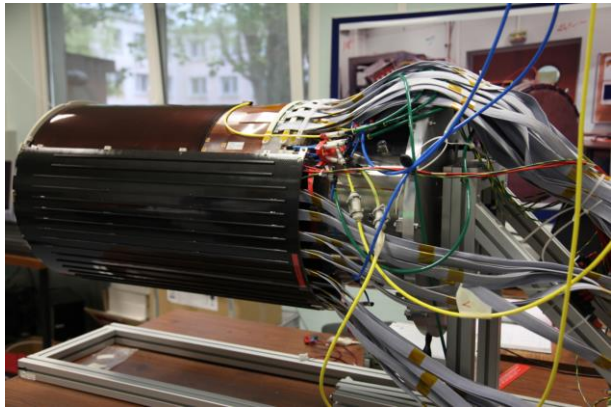


EEMCal:
- PWO crystals
- SiPM readout

Roman Pots:
- AC-LGAD sensors
- Readout ASIC under development

Interests of IRFU (DPhN) - detector





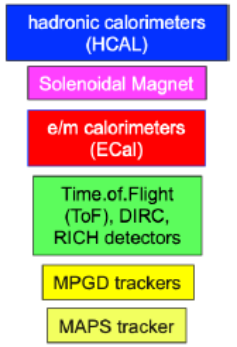
- **Micromegas barrel layer for ePIC**
  - Low material budget Micromegas 2D detectors
  - Based on the technology developed for the CLAS12 experiment at JLab
  - Experience in large projects : CLAS12 MVT, ATLAS NSW, T2K and more
- **ASIC for MPGD readout**
  - Development of a new versatile ASIC for Micromegas and µRWELL readout
  - Partnership with Sao Paolo University
  - Close synergy with the detector development
- **ASIC for AC-LGAD**
  - Collaboration: IJCLab, OMEGA, CEA, BNL
  - CEA's contribution on high precision TDC

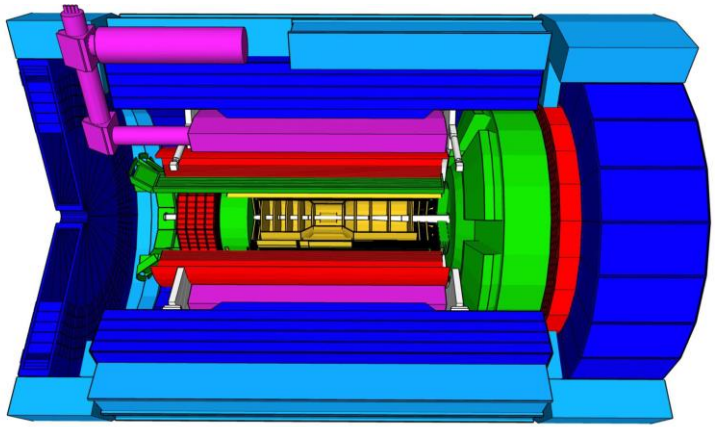
The MARCO solenoid for ePIC

- The design of a new superconducting 1.7 T solenoid
- Collaborative effort with INFN, JLab and BNL
- Irfu's long experience in large detector magnets (Cello, CMS, ATLAS, R3B/GLAD…)

Software and simulation

- PARTON framework for phenomenology of 3D hadron structure
- EpIC event generator
- Simulation and reconstruction software for MPGDs.



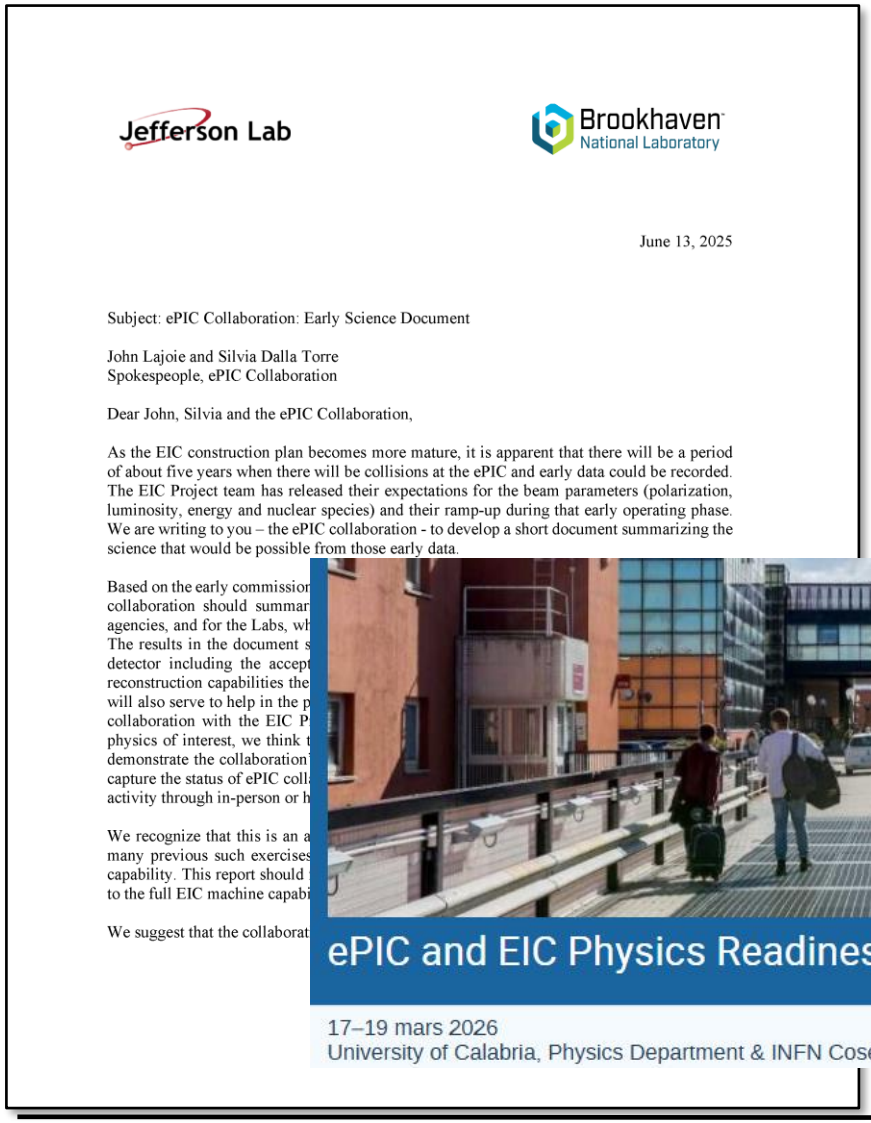


Strong synergy with theory activity in France

- Our physics interests have a large overlap with theory activities at France (IN2P3, INP, CEA)
- Field of GPDs has had strong contributions by French theorists from the start
- Theory interests include:
  - Saturation physics
  - GPDs (through DVCS, DVMP and other processes)
  - TMDs (gluon TMDs in particular)
  - Nuclear PDFs
  - Quarkonia

Series of workshops & upcoming report on early science

Charge from BNL/JLab to the ePIC collaboration to outline (by **May 1, 2026**) the science that could be produced before the ramp-up to the EIC full capability



Jefferson Lab

Brookhaven National Laboratory

June 13, 2025

Subject: ePIC Collaboration: Early Science Document

John Lajoie and Silvia Dalla Torre
Spokespeople, ePIC Collaboration

Dear John, Silvia and the ePIC Collaboration,

As the EIC construction plan becomes more mature, it is apparent that there will be a period of about five years when there will be collisions at the ePIC and early data could be recorded. The EIC Project team has released their expectations for the beam parameters (polarization, luminosity, energy and nuclear species) and their ramp-up during that early operating phase. We are writing to you – the ePIC collaboration - to develop a short document summarizing the science that would be possible from those early data.

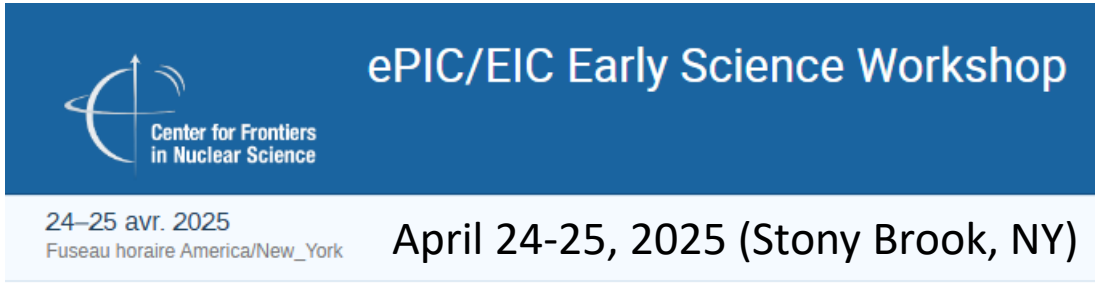
Based on the early commissio
collaboration should summar
agencies, and for the Labs, wh
The results in the document s
detector including the accept
reconstruction capabilities the
will also serve to help in the p
collaboration with the EIC P
physics of interest, we think t
demonstrate the collaboration
capture the status of ePIC coll
activity through in-person or h

We recognize that this is an a
many previous such exercises
capability. This report should
to the full EIC machine capabi

We suggest that the collaborat

March 17-219, 2026 (Calabria, IT)
https://indico.bnl.gov/event/30283/

https://indico.cfnssbu.physics.sunysb.edu/event/410/



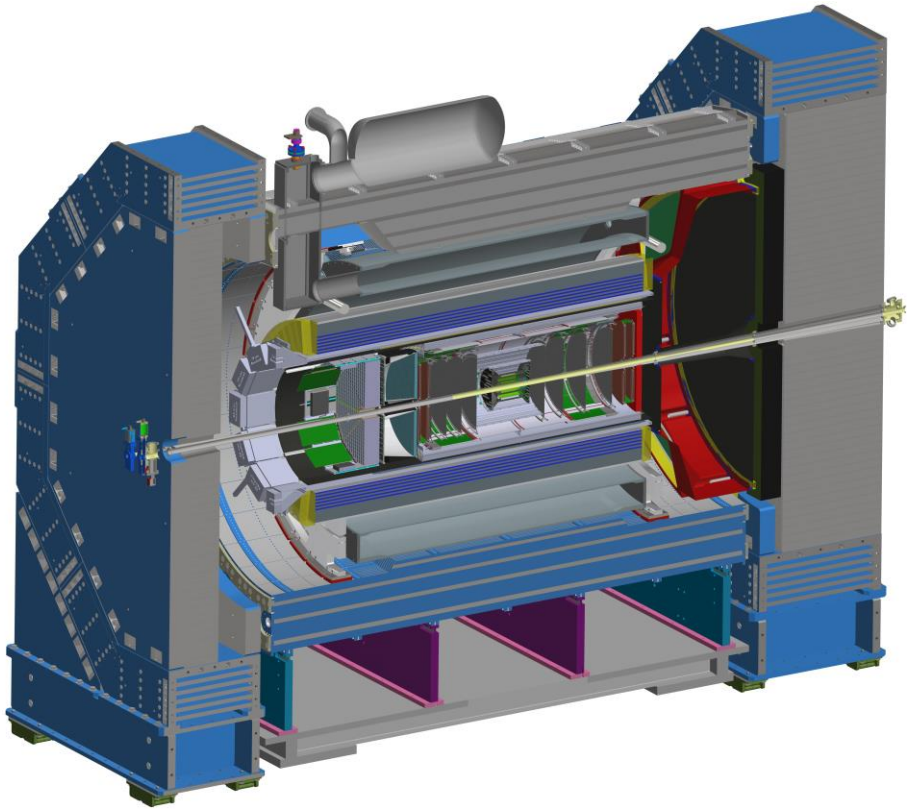
April 24-25, 2025 (Stony Brook, NY)

https://indico.global/event/15249/

September 17-18, 2025 (London, UK)

Summary

- The ePIC detector at the EIC will address fundamental questions on the structure and dynamics of nucleons and nuclei in terms of quarks and gluons, including
  - Parton distributions in nuclei/QCD at extreme parton densities – saturation
  - Spin and flavor structure of the nucleon and nuclei
  - Tomography (p/A) Transverse Momentum Distributions and Spatial Imaging
  - *Synergies with pA and AA (PDFs, nPDF, FFs…)*
  - *Many important measurements to understand initial conditions in HIC*



- The EIC project has achieved CD-3B and started procurement of long-lead ePIC detector components, and construction will continue through 2032/3 and commissioning will start

- Early physics program expected to begin as soon as 2034 with EIC reaching full capability ≈5 years later

- Exciting opportunities to increase French involvement and contributions towards the realization of the EIC detector ePIC