KHuK Jahrestagung / Annual Meeting 2025

11.–13. Dez. 2025
Physikzentrum Bad Honnef

Deutsche Beteiligung am Electron-Ion-Collider

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Justus Liebig University Giessen

University of Connecticut

12/12/2025

EIC science questions

How do the **nucleon properties like mass and spin emerge** from their partonic structure?

Nucleon Spin:

- Spin is one of the fundamental properties of matter
- Proton has spin-1/2
- Proton is a composite system consisting of spin-1/2 quarks and spin-1 gluons

➔ Sum of the contribution of quarks and gluons together must be 1/2

Possible contributions …

$$\frac{\Delta\Sigma}{2} + \Delta G + \ell_q + \ell_g = \frac{\hbar}{2}$$

Quark spins — Gluon spins — Quark orbital angular momentum — Gluon orbital angular momentum

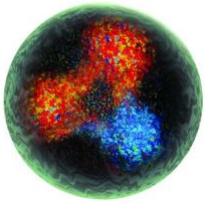
➔ **The EIC will unravel the different contributions from the quarks, gluons and orbital angular momentum**

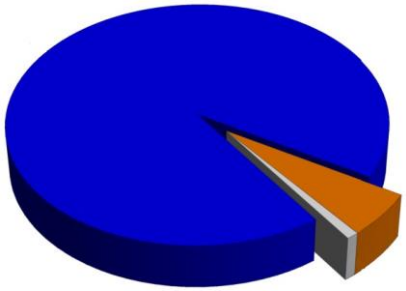
pictures: EIC yellow report

EIC science questions

Nucleon Mass:

- In a simple picture, the proton (m_p ~ 940 MeV/c²) consits of 2 up-quarks (m_u ~ 2 MeV/c²) and 1 down-quark (m_d ~ 5 MeV/c²) bound by gluons





Where is the proton mass coming from?

- Proton mass needs to be produced by the dynamics and interactions of quarks and gluons!
- How are the quarks and gluon distributed in space and momentum inside the nucleon?

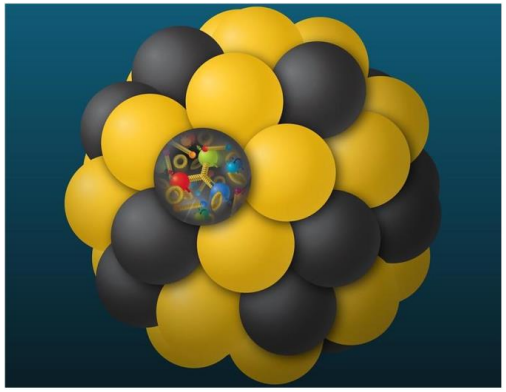
➔ **The EIC will determine an important term contributing to the proton mass, the so-called "QCD trace anomaly"**

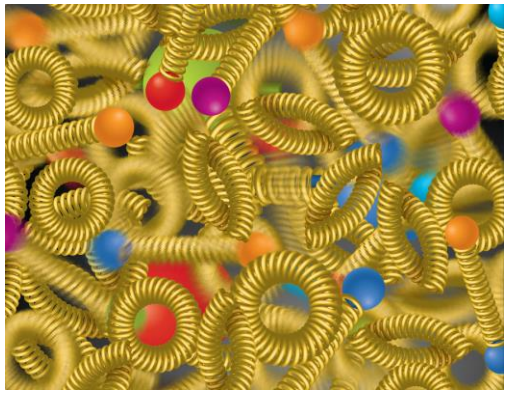
pictures: EIC yellow report

EIC science questions

What impact does a **high-density nuclear environment** have on the **interactions, correlations, and behaviors of quarks and gluons**?

- 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?



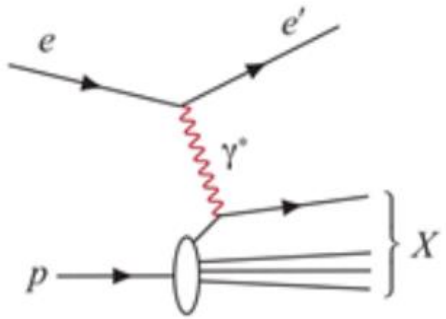


pictures: EIC yellow report

➔ **The EIC will provide the opportunity to have very high gluon densities in collisions of electrons and heavy nuclei**

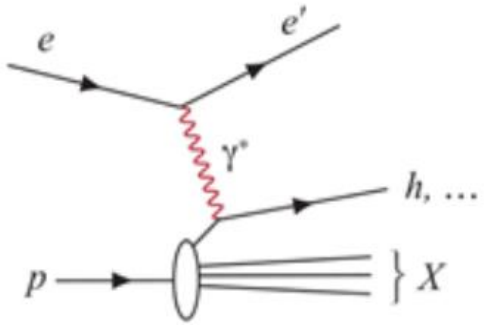
➔ **Map the transition from a linear to a non-linear QCD regime**

EIC main physics processes



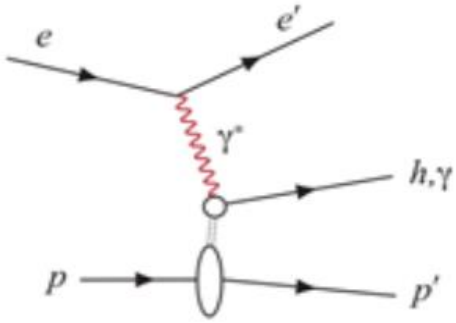
Deep-inelastic scattering (DIS)

- Detection of the scattered electron only



Semi - inclusive DIS

- Detection of the scattered electron and at least 1 hadron (or a jet)



Deep - exclusive processes

- Detection of all final state particles

Parton distributions in nucleons and nuclei

3D momentum distributions of partons (TMDs)

Spatial imaging of partons (GPDs)

Spin and flavor structure of nucleons and nuclei

QCD at extreme parton densities (saturation)

EIC overview

Planned at Brookhaven National Laboratory (Upton, New York, US)

- **Construction start in 2026**

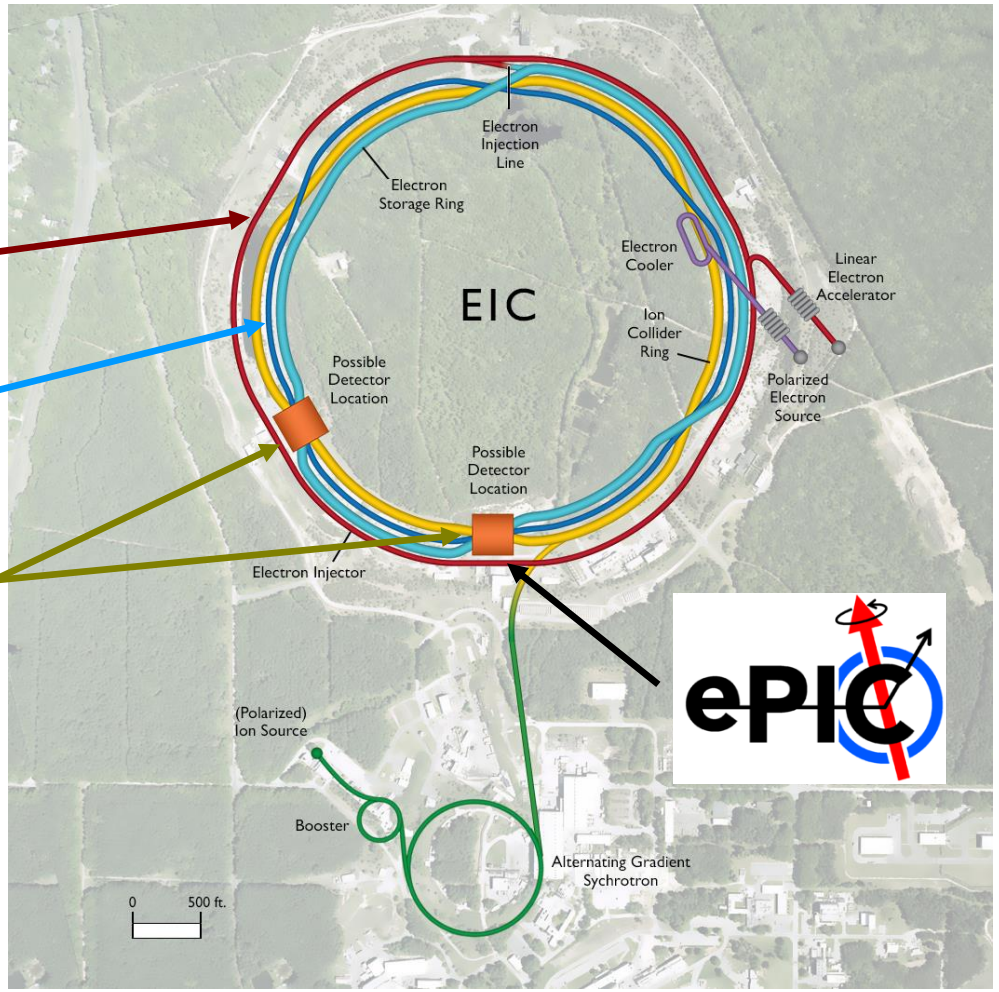
Hadron storage ring (RHIC Rings)
41 - 275 GeV

Electron storage ring **5 - 18 GeV**

High luminosity interaction region(s)

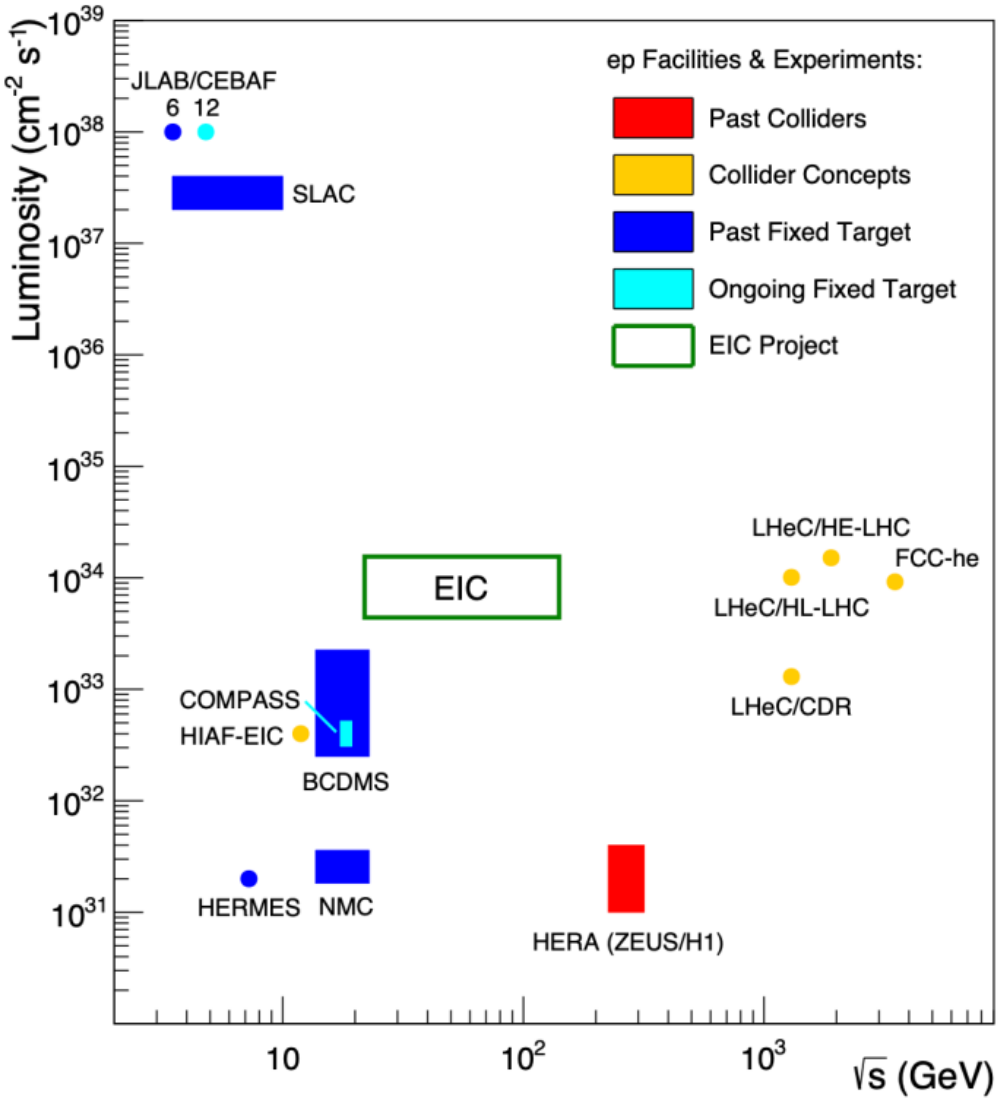
- **Luminosity:** L= 10^{33} - 10^{34} $cm^{-2}s^{-1}$
  → 10 - 100 fb^{-1}/year

- **Highly polarized beams:** ~ 70%



https://www.bnl.gov/today/body_pics/2020/01/EIC-satellite-HR.jpg

EIC in comparison to other experiments



The EIC will be the first …

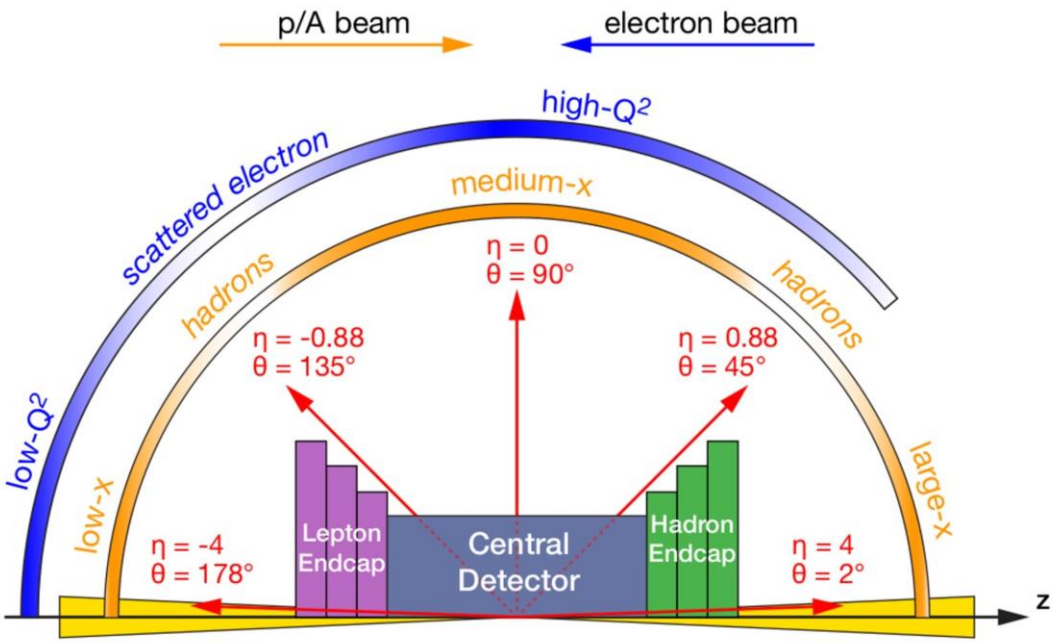
- High-luminosity e-p collider
- Polarized beam collider
- Electron-nucleus collider

EIC cm energy range:

$$29 < \sqrt{s} < 141\ GeV$$

EIC detector challenges

p, A: 41 - 275 GeV **e:** 5 - 18 GeV



$$\eta = -\ln\tan(\theta/2)$$

Large center-of-mass energy range:
29 - 141 GeV

- Large detector acceptance

Asymmetric beams

- **Asymmetric detector**: Barrel + electron and hadron end-caps
- Large central coverage ($-4 < \eta < 4$) in **tracking**, **particle identification**, em and hadronic **calorimetry**
  - High precision low mass tracking
  - Good e/h separation critical for scattered electron ID
  - Good separation of e, p, π, K over a wide momentum range

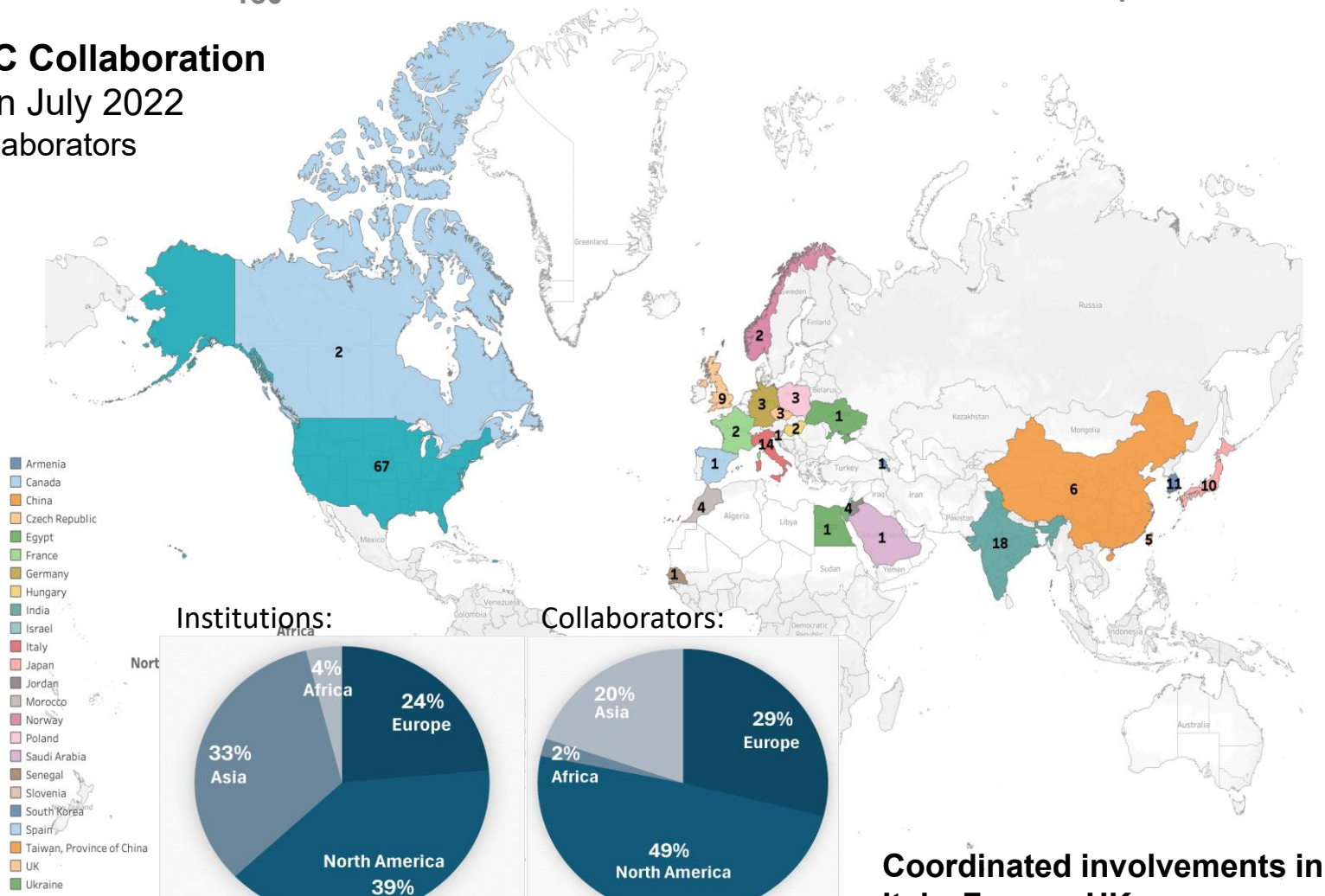
The ePIC collaboration

ePIC Institutions
180

ePIC Countries
25

ePIC World Region
4

The **ePIC Collaboration**
formed in July 2022
> 850 collaborators

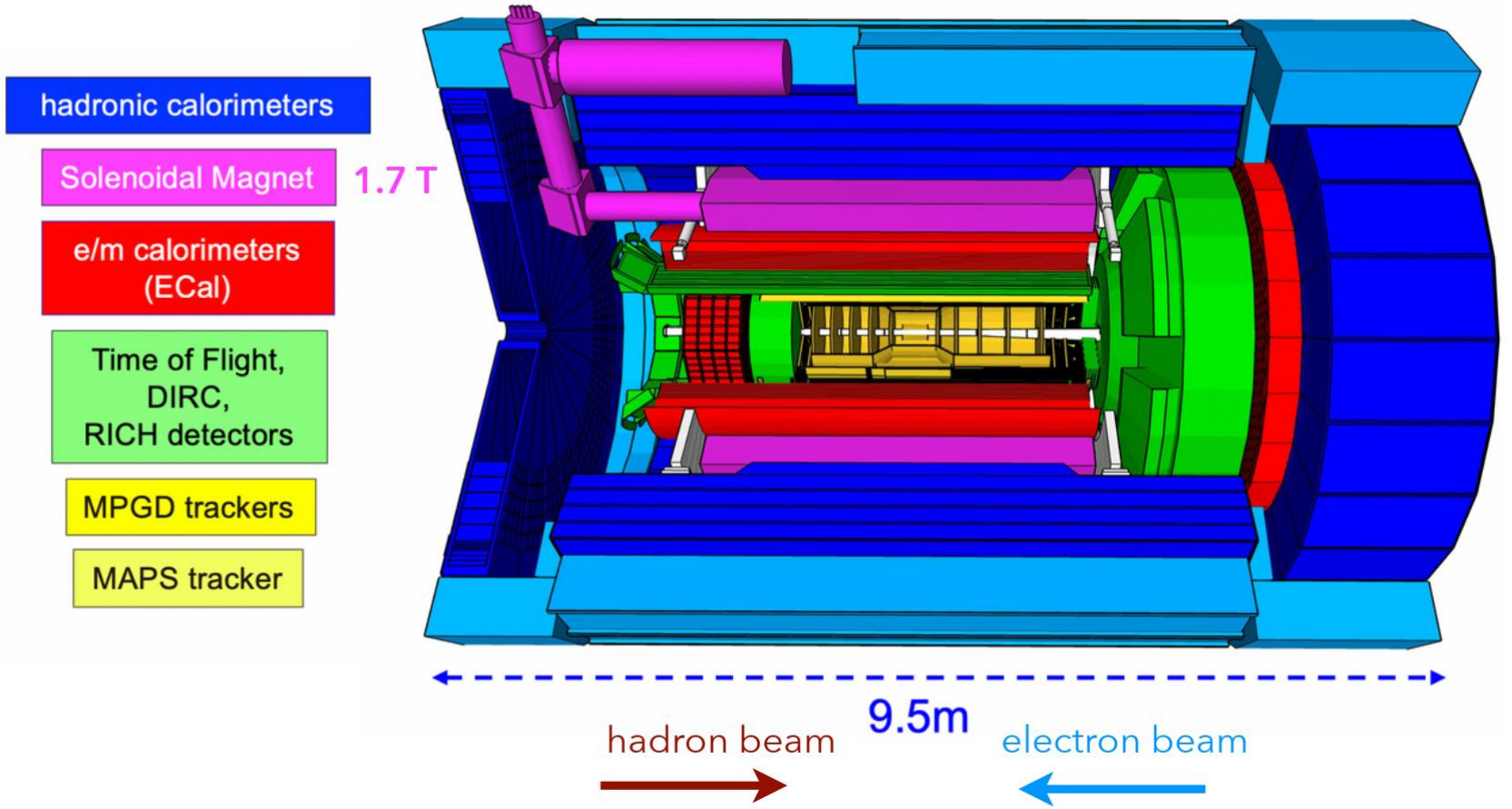


Coordinated involvements in:
Italy, France, UK, …

The ePIC detector

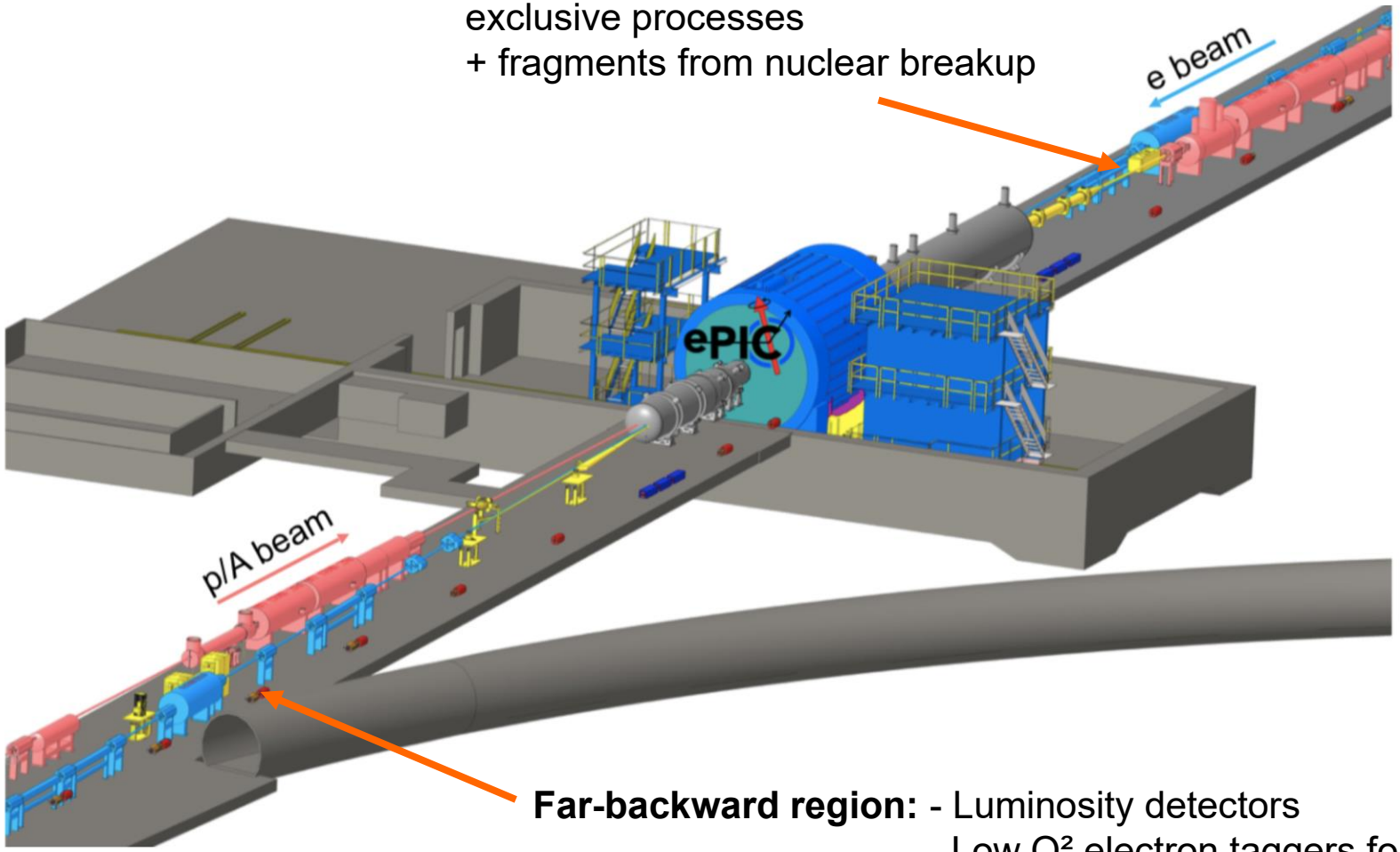
Electron-Proton and -Ion Collider detector

- Hermetic detectors within a central solenoid



ePIC far forward and backward detectors

Far-forward region: Detection of low -t protons from exclusive processes
+ fragments from nuclear breakup



Far-backward region: - Luminosity detectors
- Low Q^2 electron taggers for **quasi-real photo-production**

Spectroscopy

EIC schedule and timelines

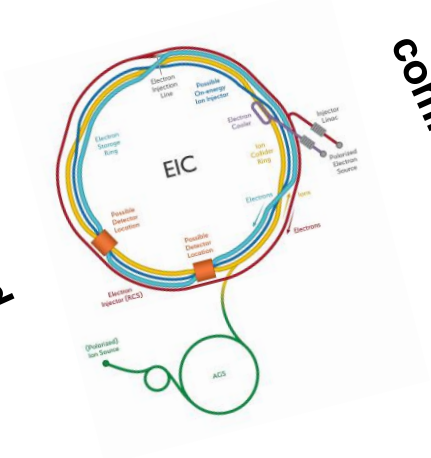
planned DFG application (October)

decision by DFG (March)

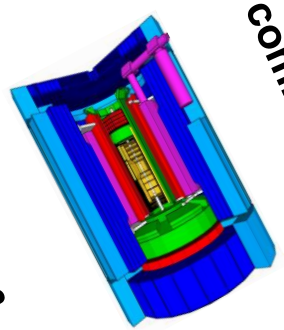
potential DFG Schwerpunktprogramm

2026 2027 2028 2029 2030 2031 2032 2033 2034

Start of EIC and ePIC construction

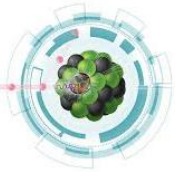


Start of EIC beam commissioning

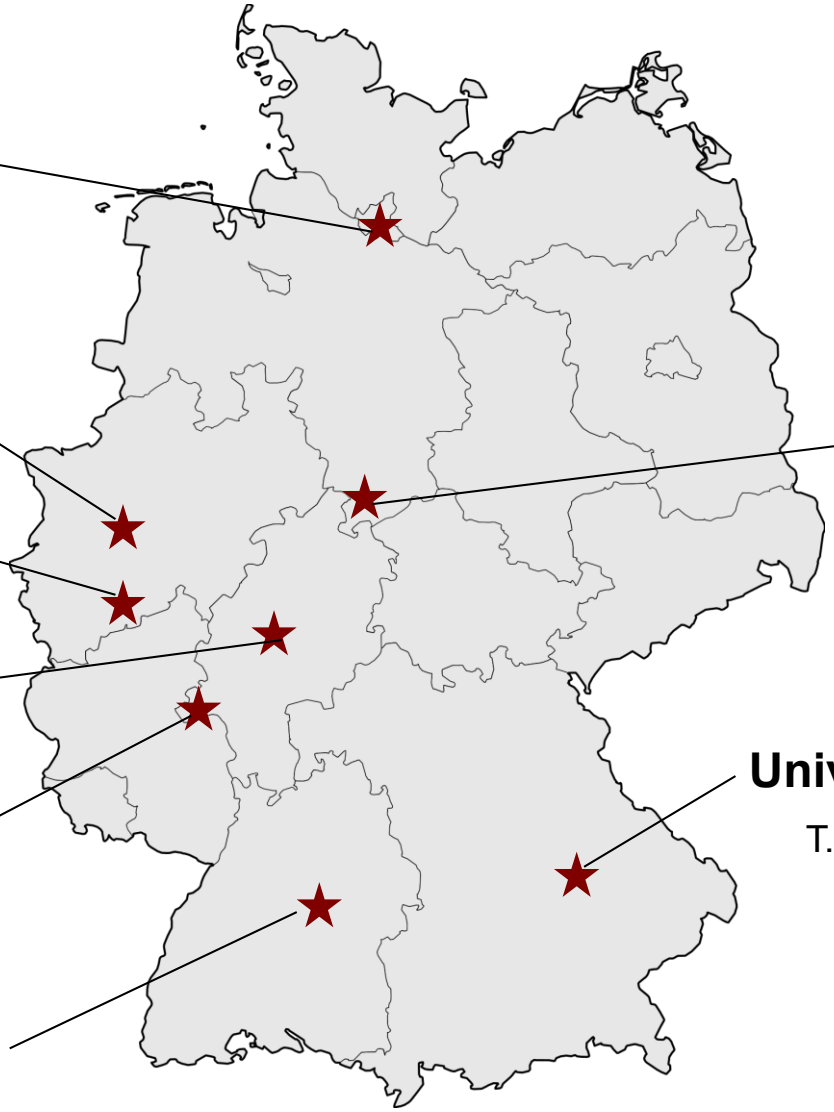


Start of ePIC commissioning

Start of data taking



Currently involved EIC Germany institutions



DESY, Hamburg
M. Diehl, S. Moch

Universität Wuppertal
F. Ellinghaus

Universität Bonn
T. Jude, J. Kaminski, M. Mai

JLU Gießen
K. Brinkmann, **S. Diehl, A. Thiel**

JGU Mainz
T. Kutz, M. Vanderhaegen

Universität Tübingen
W. Vogelsang

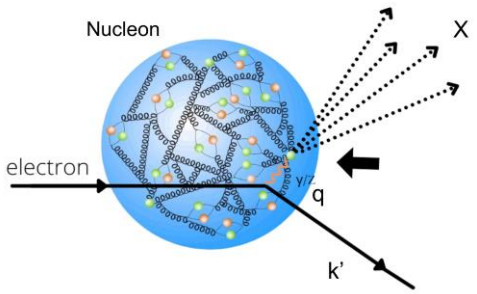
Universität Göttingen
S. Schumann

Universität Regensburg
T. Ahmed, A. v. Manteuffel
G. Bali, S. Collins

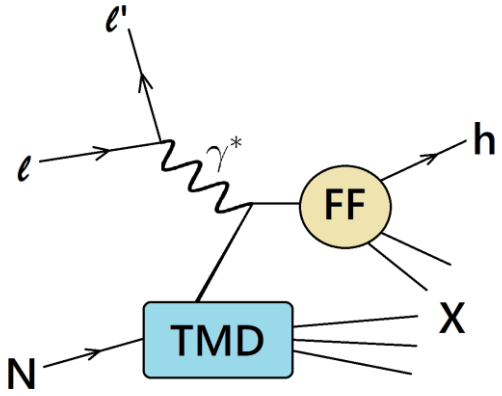
https://de.wikipedia.org/wiki/Datei:Karte_Deutschland.svg

Interests of German groups

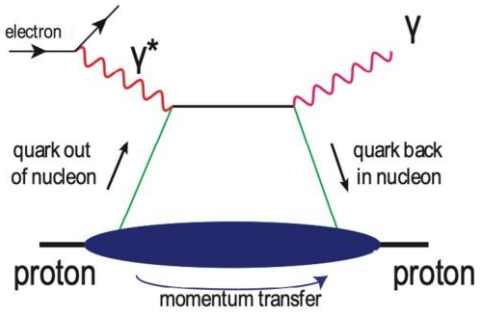
- Structure of the free and bound nucleon (PDFs, TMDs, GPDs, transition GPDs)



DIS



SIDIS



DVCS / DVMP

- Spectroscopy (exotica, quarkonia, production in nuclei)

➔ Theory developments ➔ MC based feasibility / benchmark studies

Theory ⟺ Development of MC generators ⟺ Experiment

- Software- and Hardware contributions → Calorimetry, readout, slow control, …

Join us!

- **Planed application: DFG „Schwerpunktprogramm“ for a German EIC involvement**
  - Currently ~ 15 people from 8 Universities / Institutes (theory + experiment)
  - Hadron structure, hadron spectroscopy, MC-, software-, detector- development

DFG application deadline: October 15th 2026

Ongoing: Monthly zoom-meetings to coordinate the application

DFG Rundegespräch (to be approved): March 3 - 4 2026 at JLU Gießen

https://de.wikipedia.org/wiki/Datei:I_want_you.jpg

Evrybody with interest in the EIC is welcome to join the effort!

Contact: Stefan Diehl, JLU Gießen, stefan.diehl@exp2.physik.uni-giessen.de
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