

The Electron-Ion Collider

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U. of Glasgow / CEA Saclay



EIC UK Meeting
7th December 2022

The EIC User Group

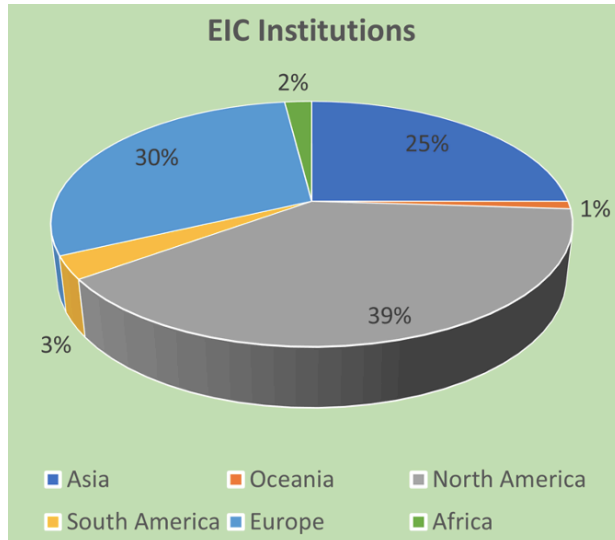
Formed in 2016, currently:

- 1369 members
- from 267 institutions
- in 36 countries

30% of institutions are European.

July 2022: EICUG meeting in Stonybrook (in person!)

Next meeting (July 2023): Warsaw.



EU Representative on Steering Committee (D. Sokhan)

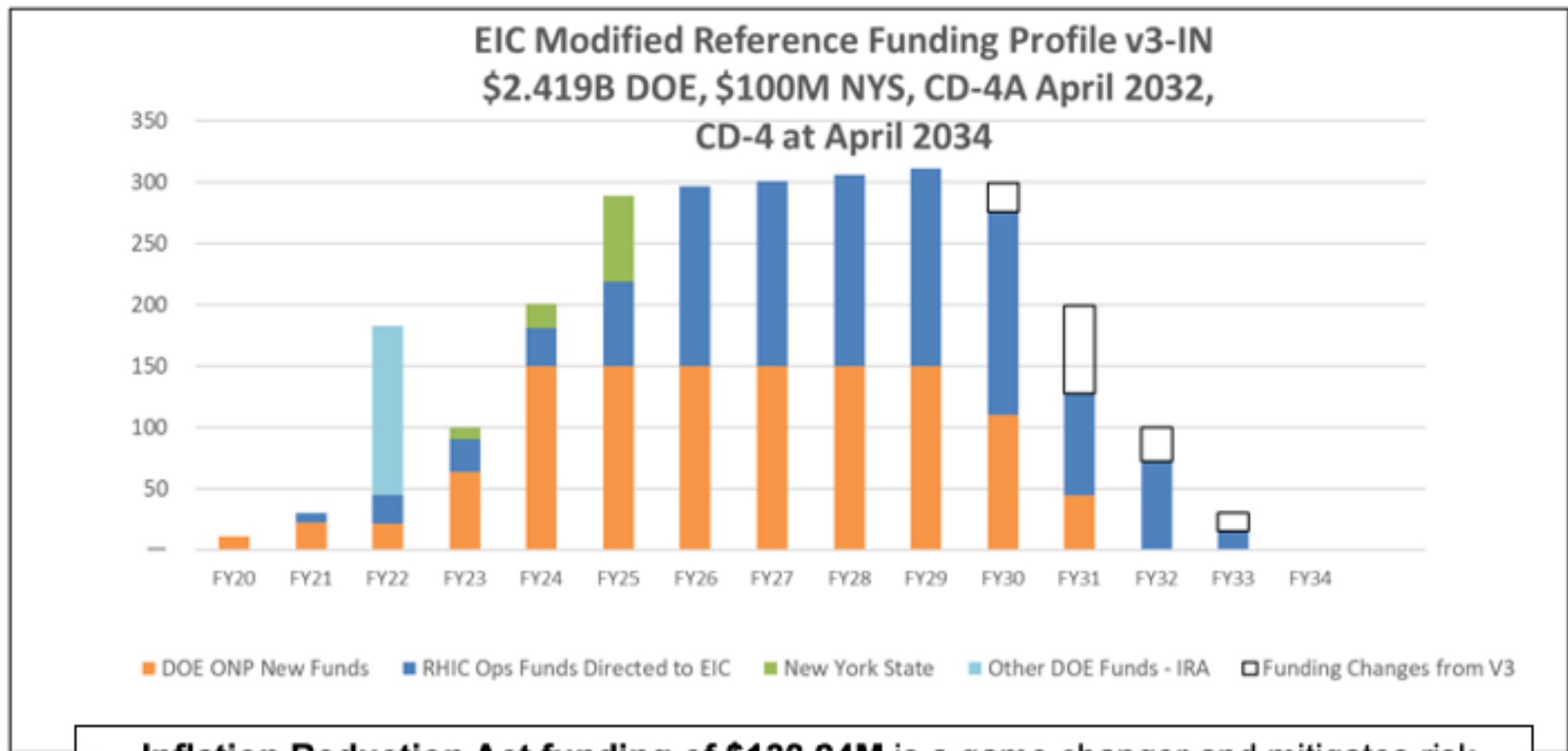
Monthly meetings between SC and EIC Project Management.

UK third-largest European member of EICUG (by individuals).

Recent Developments

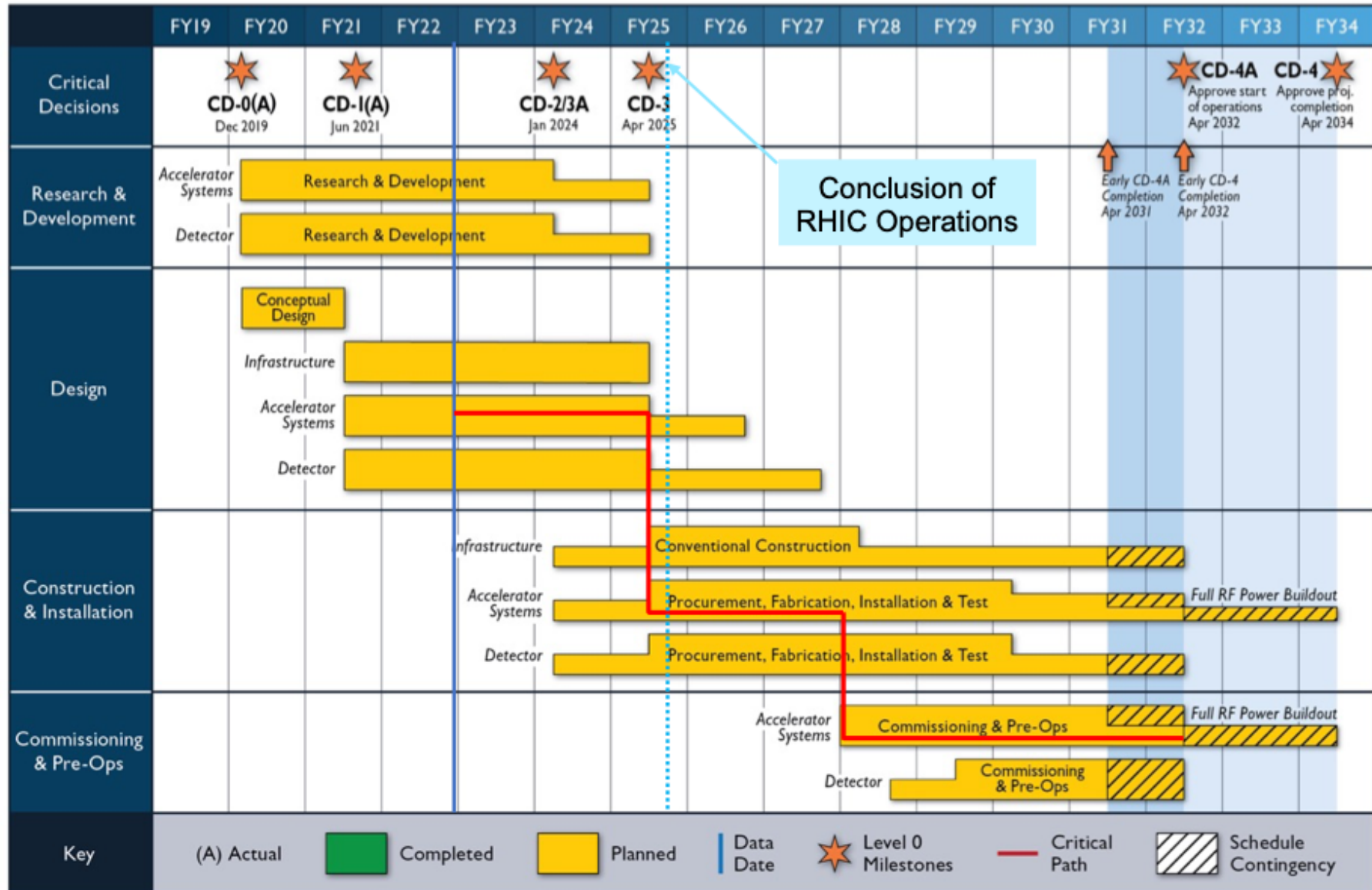
- * **EPIC (ePIC?)** collaboration formed in Summer 2022: detector 1 at IP6.
- * **Inflation Reduction Act:** \$138M to EIC (out of a total 200-something to DOE overall). To be spent within a few years. NOT extra funding – this is effectively an advance.
- * Two dedicated documents provided from EIC community as input to **NuPECC Long Range Plan** (one by the EICUG Steering Committee, one by the Project) – *plus separate contributions made by UK, France, Italy, etc.*
- * 17 Nov – DOE hosted meeting, in DC, with international funding agencies: Mark Thomson attended from STFC, very positive feedback from both sides.
- * Pre-RRB (**Resource Review Board**) meeting held online in October – solicited summaries of prospective contributions from international community. **RRB** meeting to be held in April 2023.
- * **Schedule.** CD-3a (procurement): review in Nov 2023, expected Jan 2024 (no change). CD-2 (baseline approval) delayed by ~ a year: spring 2025. CD-3 expected in April 2025 (just before RHIC shutdown, no change).

DOE Funding Plan



- **Inflation Reduction Act funding of \$138.24M** is a game changer and mitigates risk of slower than optimum ramp of new funding to the \$150M/year needed.
- Possibility of significant package of long lead procurement items (CD-3A) helping to mitigate risks including procurement, supply chain, inflation and schedule.

EIC Reference Schedule - V3



A vibrant field of sunflowers with bright yellow petals and dark brown centers, set against a clear blue sky with scattered white clouds. The sunflowers are in the foreground, and their green leaves are visible. In the background, there are dark green trees.

Thank you!

Any questions?

Electron-Ion Collider

World's first polarized electron-proton/light ion and electron-Nucleus collider.

For e-N collisions at the EIC:

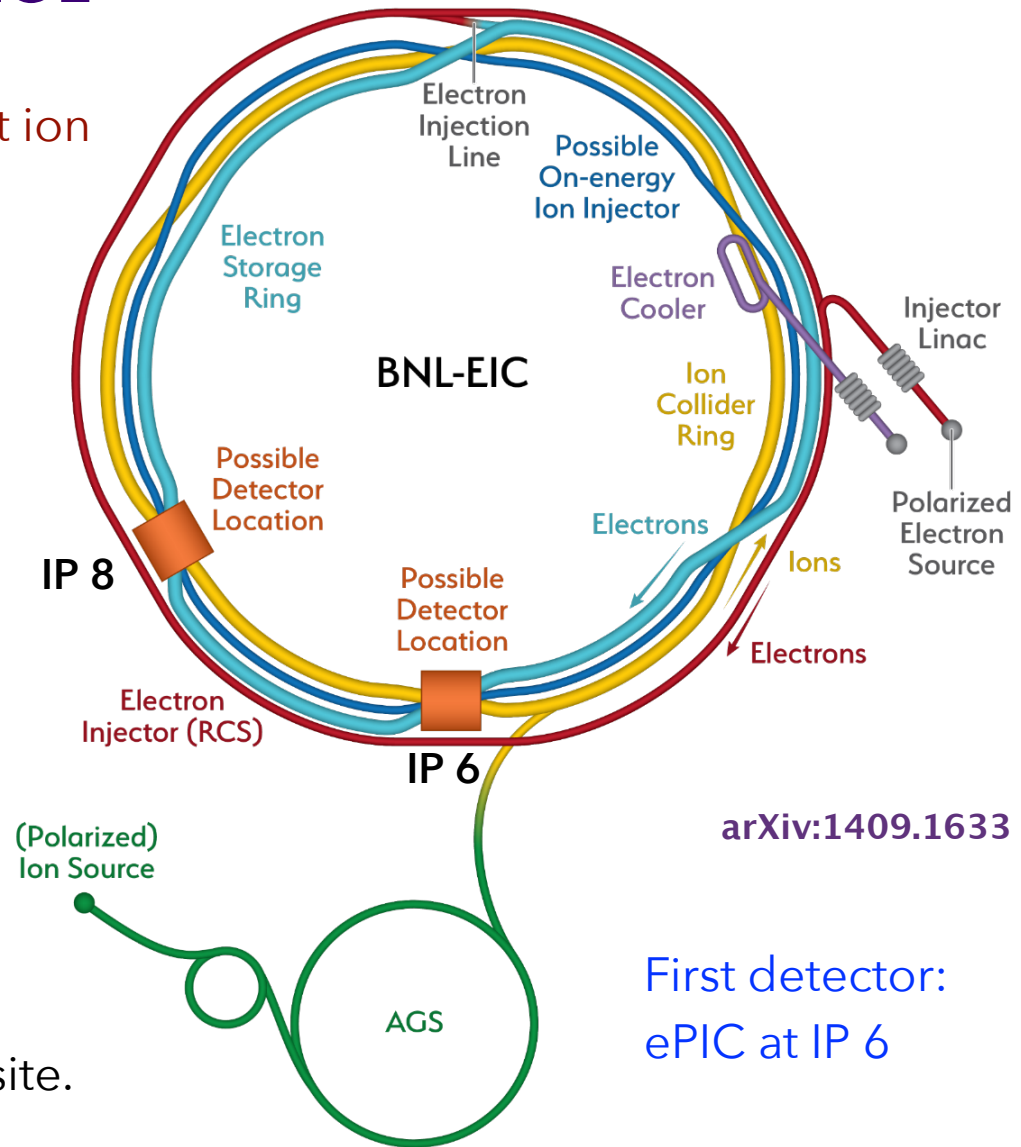
- ✓ Polarized beams (70%): e, p, d/³He
- ✓ e beam 3 - 10 (18) GeV
- ✓ Luminosity $L_{ep} \sim 10^{33-34} \text{ cm}^{-2}\text{s}^{-1}$
- ✓ 20 - 100 (140) GeV Variable CoM

For e-A collisions at the EIC:

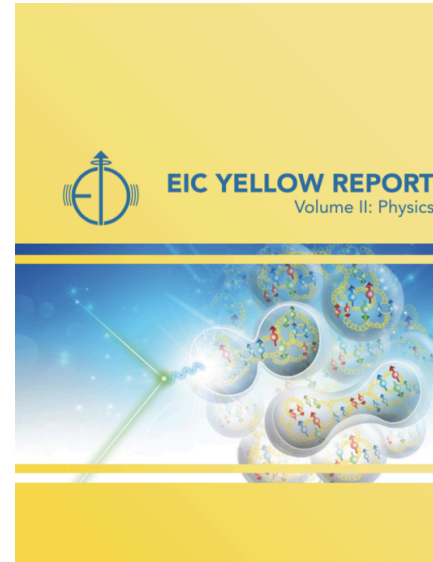
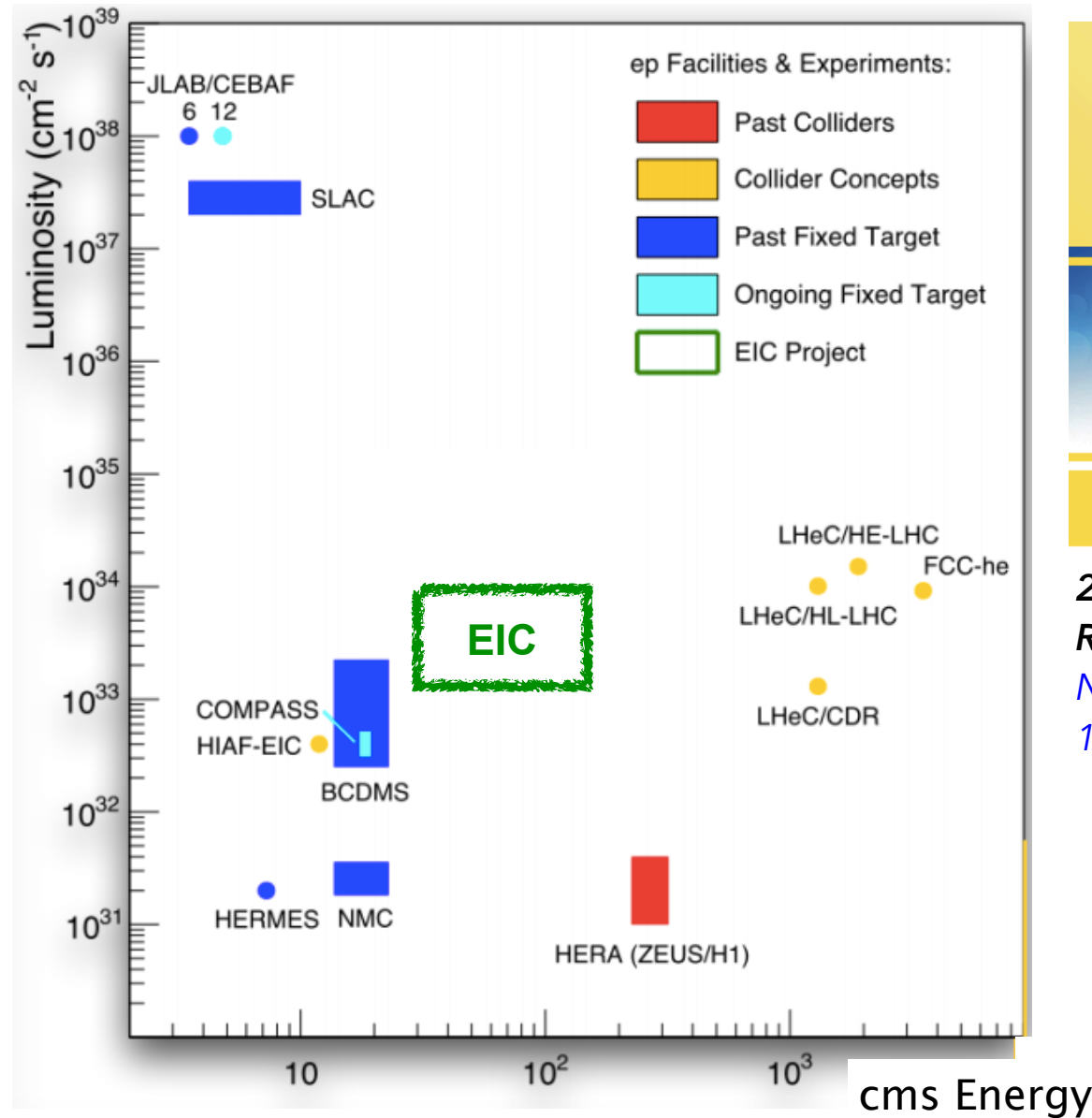
- ✓ Wide range of nuclei
- ✓ Luminosity per nucleon same as e-p
- ✓ Variable centre of mass energy

Brookhaven National Lab selected as the site.

Expected start of operations: early 2020s.

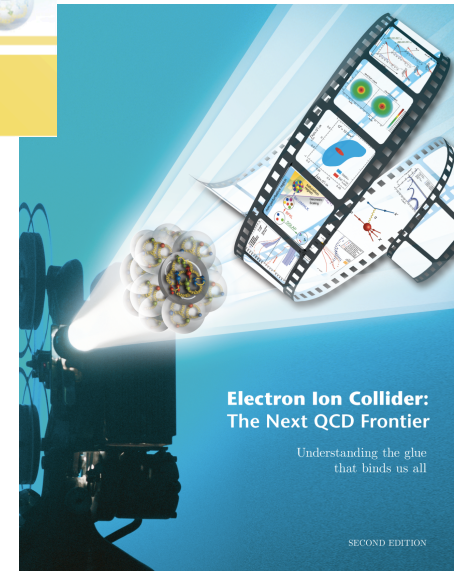


EIC landscape



2020 EIC Yellow Report,
Nuc. Phys. A 1026,
122447 (2022)

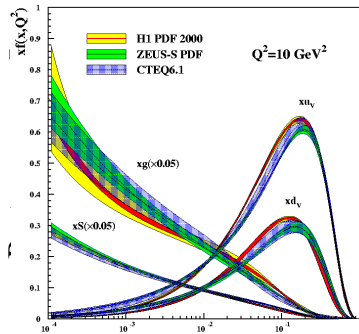
Dedicated studies of EIC physics and design:



2012 EIC White Paper,
Eur. Phys. J. A 52, 9 (2016)

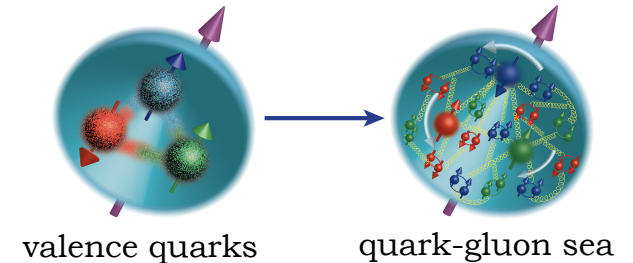
What is the EIC for?

* Designed primarily for the study of hadron physics:



- ⌘ What is the origin of nucleon mass and what is the role of glue in it? How is it generated from the almost massless quarks and massless gluons?
- ⌘ What is the quark-gluon origin of the nuclear force?
- ⌘ How do hadrons and nuclei emerge from quarks and gluons? What is the nature of confinement?

* 3D tomography of the nucleon: distributions of partons from the valence quark region to the quark-gluon sea.

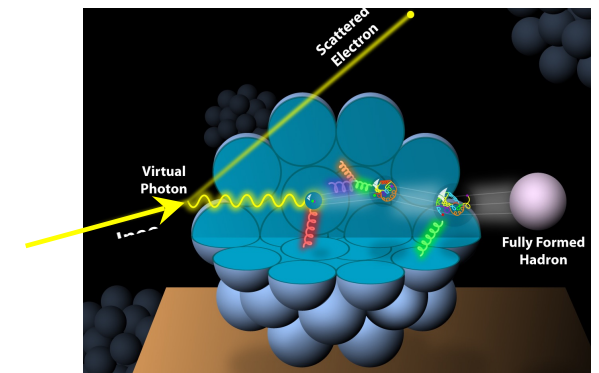


* Decomposition of nucleon spin — contribution of sea quarks and gluons.

$$J_q = \frac{1}{2} \Delta\Sigma + L_q + J_g$$

* Effect of nuclear medium on the propagation of a colour charge: insight into hadronisation and the EMC effect.

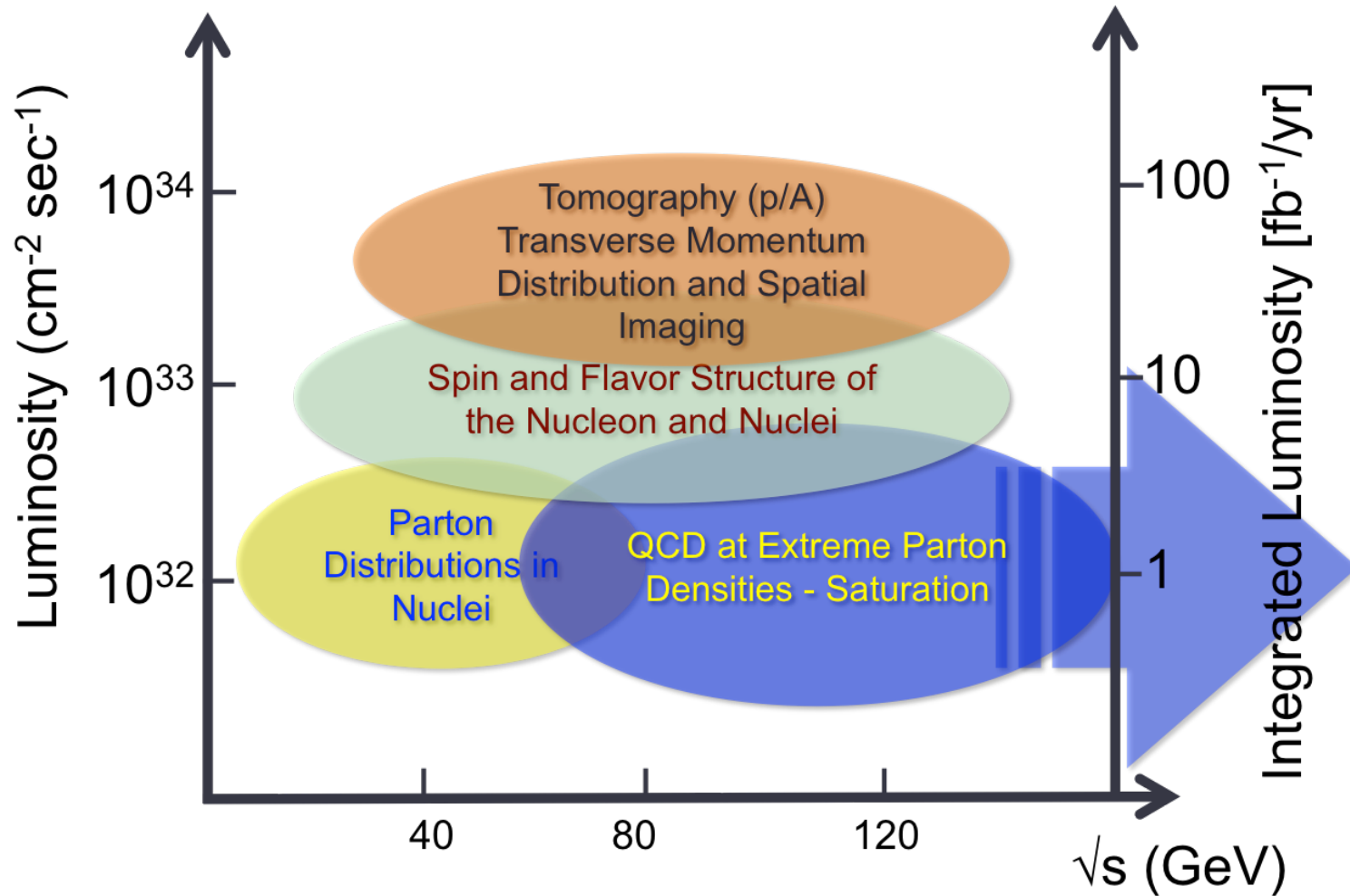
* Search for gluon saturation: a new form of matter.



Courtesy of E. Aschenauer

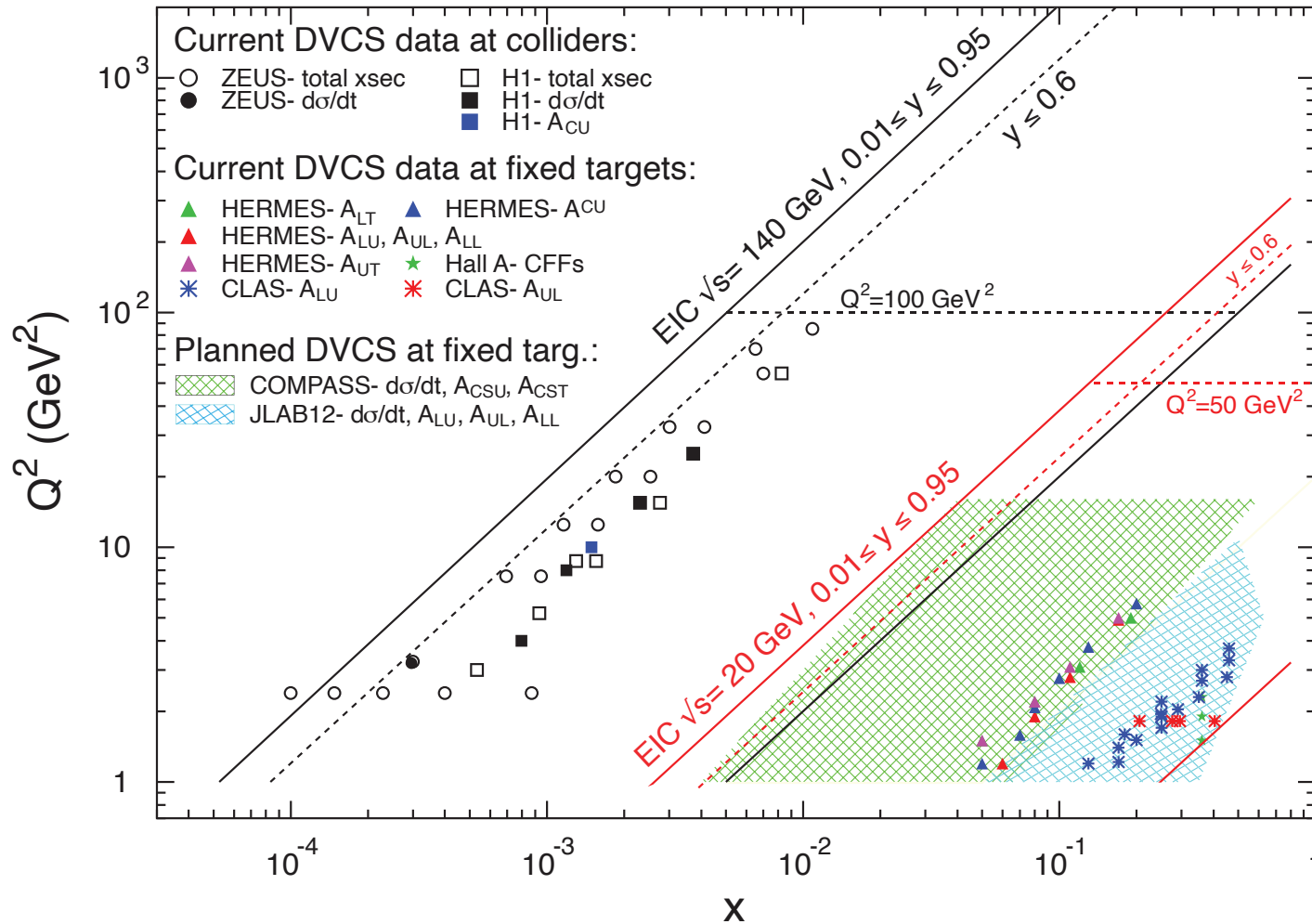
and much more...

Physics reach of the EIC

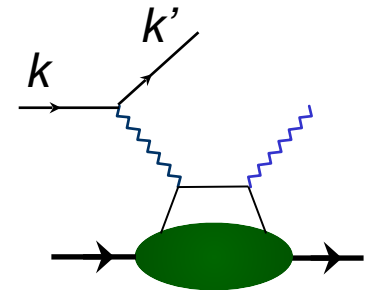


year = 10^7 sec

Kinematic reach of the EIC



DVCS:
Deeply Virtual
Compton Scattering



$$Q^2 = -(\mathbf{k} - \mathbf{k}')^2$$

Four-momentum transfer
in the scattering

$$x_B = \frac{Q^2}{2\mathbf{p} \cdot \mathbf{q}}$$

Bjorken- x

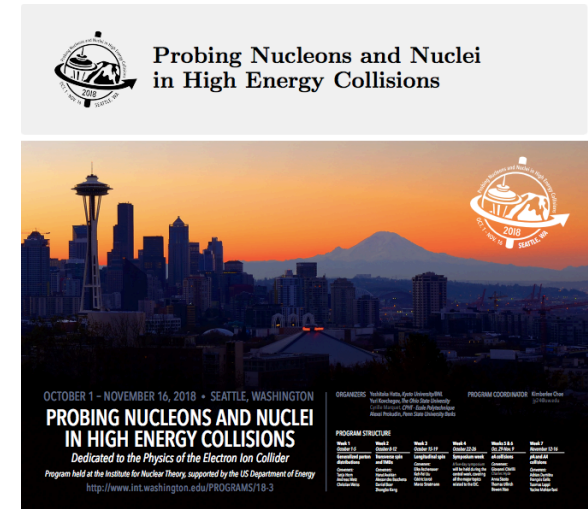
y : inelasticity

EIC in the making

- ◆ **2007 Nuclear Physics Long Range Plan** "*The EIC is embodying the vision of reaching the next QCD frontier*"
- ◆ **2011:** US DOE starts to fund generic R&D (**eRD programme**)
- ◆ **2012:** **EIC White Paper**
- ◆ **2015 Nuclear Physics Long Range Plan** "*high-energy, high-luminosity polarised EIC as the highest priority for new facility construction following completion of FRIB*"
- ◆ **2016: Users Group** acquires formal charter / elected board of representatives (eicug.org)
- ◆ **2017-18 National Academies of Science (NAS) Review:** "*the science questions that an [EIC] would answer are central to completing our understanding of atomic nuclei... An EIC can **uniquely** address three profound questions about nucleons ... and how they are assembled to form the nuclei of atoms*"

EIC in the making

- ◆ **2018: “Probing Nucleons and Nuclei in High Energy Collisions”**: 7-week workshop programme at INT, Seattle.
<https://arxiv.org/abs/2002.12333>
- ◆ **2019: DOE Independent Cost review Exercise**, DOE-led meetings with international funding agencies / government representatives.
- ◆ **Dec 2019: CD0 (Critical Decision 0) status granted by US DoE**: establishes “mission need” & formal launch of project. Funding envelope: \$1.6 - \$2.6 billion.
- ◆ **2020: EIC Yellow Report**
- ◆ **2020: Expressions of Interest** from the international community
- ◆ **2021: Development of detector proposals: ATHENA, ECCE, CORE**
- ◆ **2021: Conceptual Design Report**
- ◆ **June 2021: CD1 status granted by DOE**: “approve alternative selection and cost range”
- ◆ **2022: Formation of the ePIC Collaboration**, design of the “project detector” (detector 1).



EIC accelerator

Hadron storage ring (HSR): 41-275 GeV (based on RHIC)

- 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)

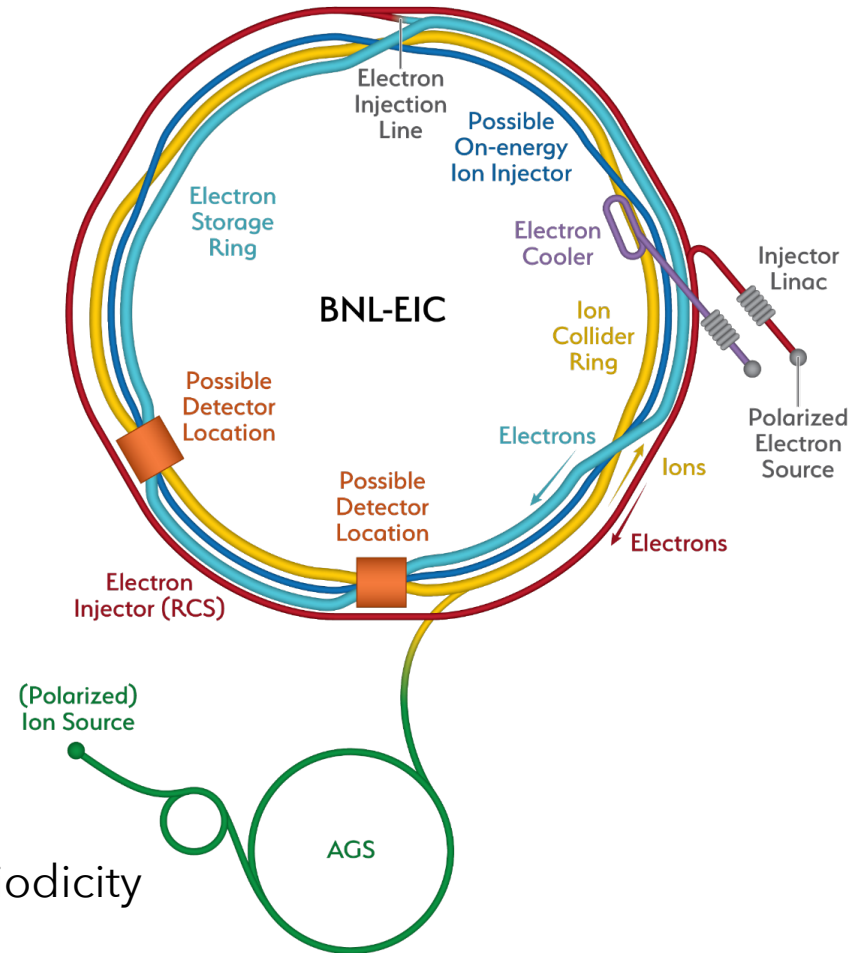
- up to 1160 bunches
- high polarization by continual reinjection from RCS
- large beam current (2.5 A) → 9 MW SR power
- superconducting RF cavities

Rapid cycling synchrotron (RCS): 0.4-18 GeV (new)

- 2 bunches at 1 Hz; spin transparent due to high periodicity

High luminosity interaction region(s) (new)

- $L = 10^{34} \text{ cm}^{-2}\text{s}^{-1}$
- 25 mrad crossing angle with crab cavities
- superconducting magnets
- spin rotators (produce longitudinal spin at IP)

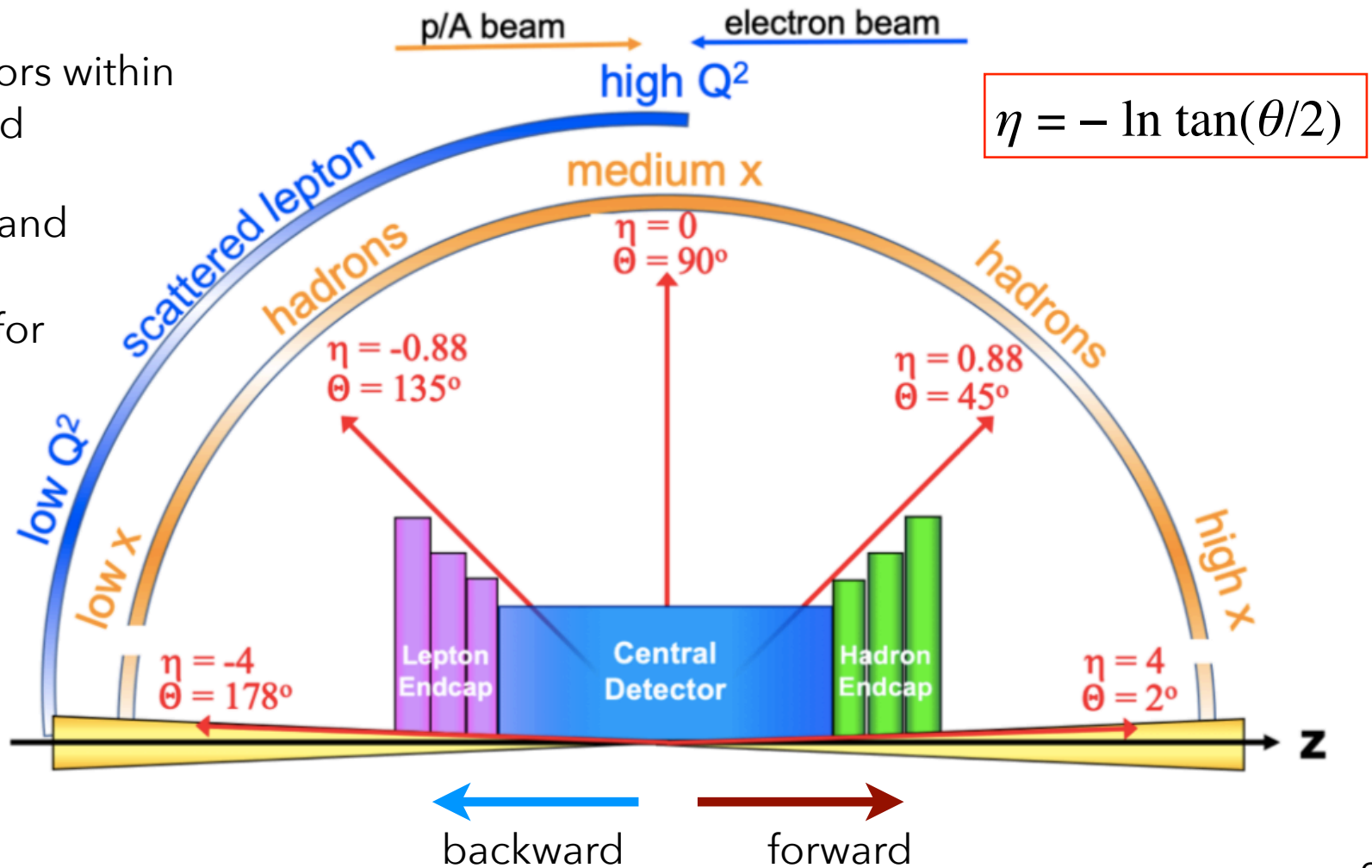


Detector configuration

Very asymmetric beams

Hermetic detectors within a central solenoid

Very far-forward and far-backward instrumentation for lowest scattering angles.



The ePIC detector

Electron-Proton and -Ion Collider detector

Result of the merging of ECCE and ATHENA collaborations.

electron beam



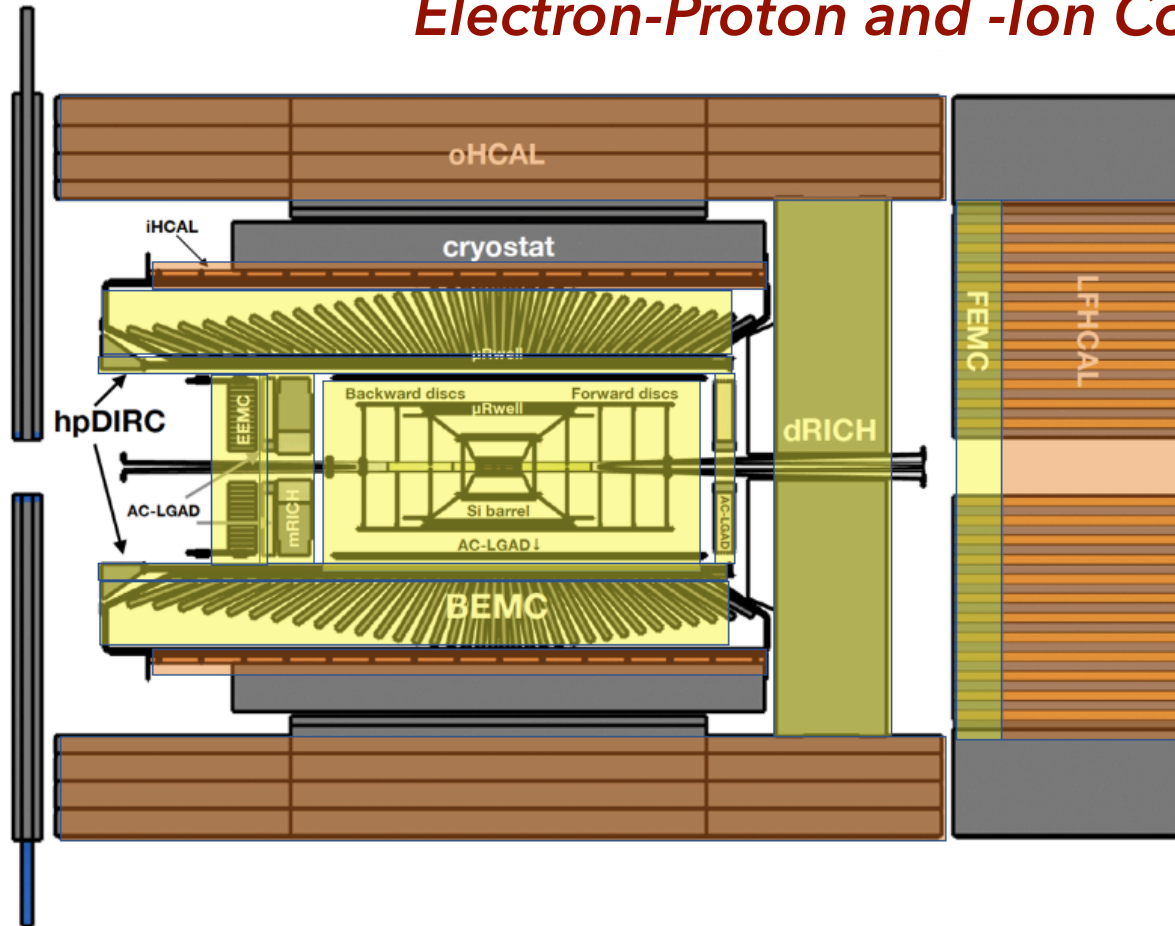
The "project detector" to be constructed at IP 6

hadron beam



Particle ID (PID):

High time-resolution Si (AC-LGAD), Cherenkov detectors: RICH, DIRC.



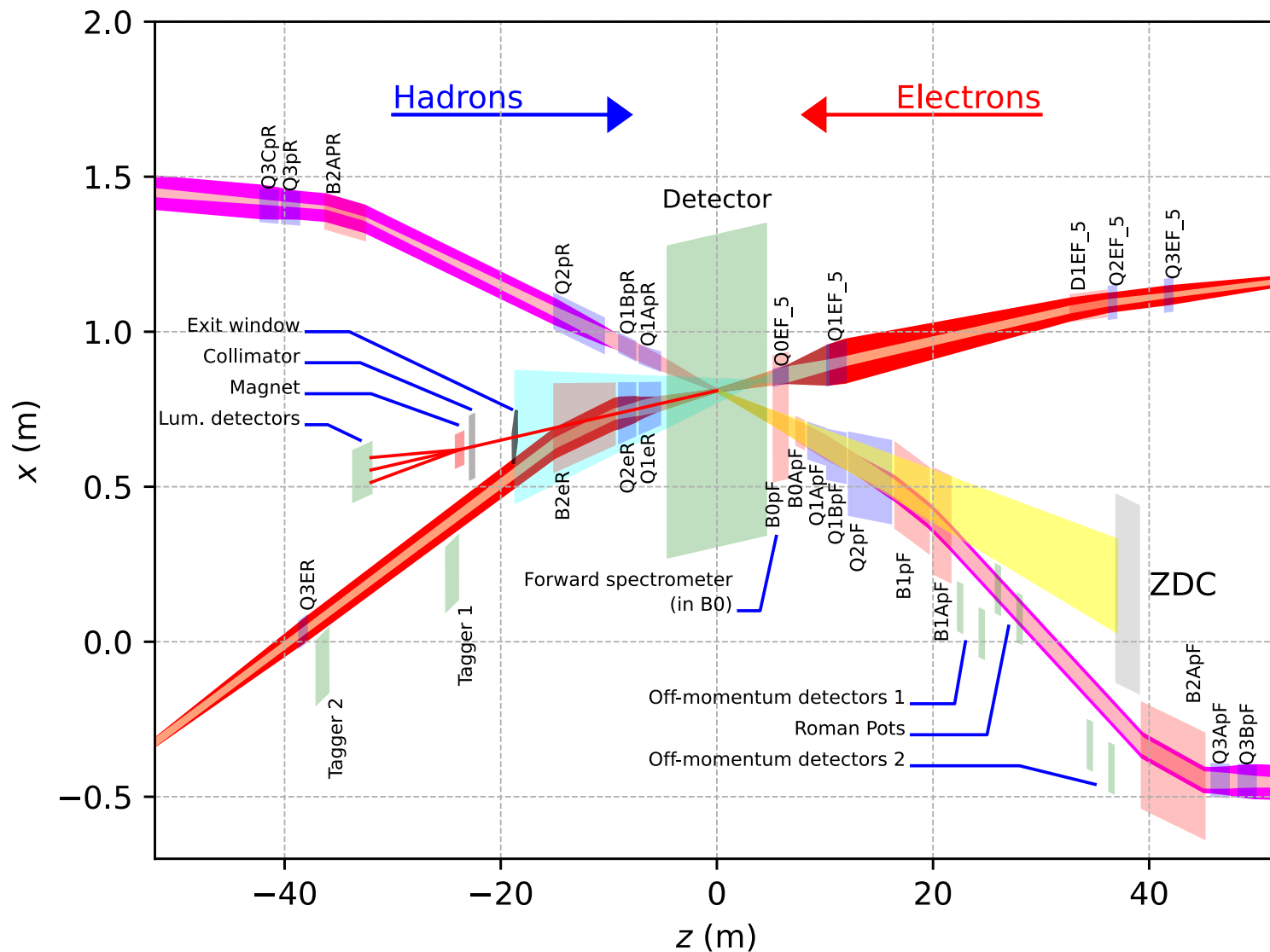
Calorimetry:

Range of EM and hadron calorimeters.

Tracking: New 1.7 T magnet (MARCO), to be built by Saclay.

Light-weight Si tracking (65nm MAPS), micro-pattern gaseous detectors (MPGDs).

The Interaction Region @ IP6



Crossing angle for the beams:
25 mrad.

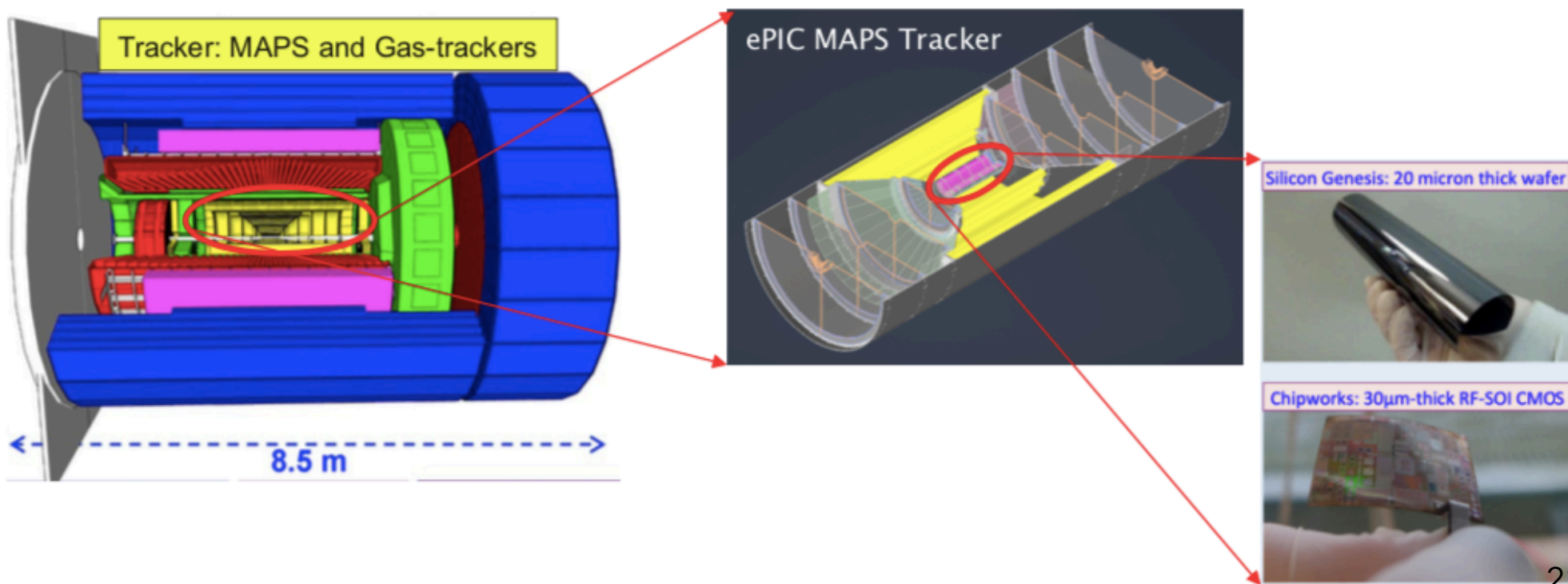
UK

- ◆ Participation in the 2018 **INT programme**,
- ◆ **Yellow Report**: co-conveners of Detector WG, Exclusive Processes WG and Detector Complementarity WG.
- ◆ **ATHENA proposal**: co-conveners of Tracking, Exclusive and Inclusive WGs, editor of proposal writing committee
- ◆ **ECCE proposal**: co-conveners of Far-Backward, Inclusive and Exclusive WGs.
- ◆ **EIC Users Group**: UK has third largest European involvement (after Italy and France). EU representative on Steering Committee, member of Charter Committee
- ◆ **ePIC detector**: co-conveners of Inclusive, Exclusive, Tracking and Far-Backward WGs.
- ◆ **EIC Silicon Consortium**: two members of the leadership team
- ◆ **EIC R&D programme**: participation in eRD18/25 – Precision silicon vertexing and tracking for the EIC (2016 – 2021)

Aspiration for the Construction Phase

- Three detector WPs: [MAPS](#), [Timepix](#) and [Polarimetry](#)
- [MAPS](#): 65 nm wafer-scale sensors; co-development with ALICE-ITS3. Build 33% of central tracker – vertex and barrel layers, plus possible contribution to forward / backward disks. Technology already adopted in baseline detector.

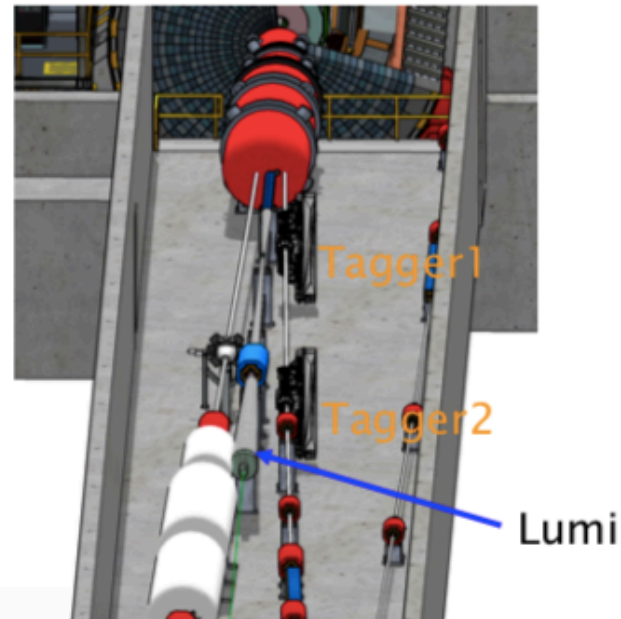
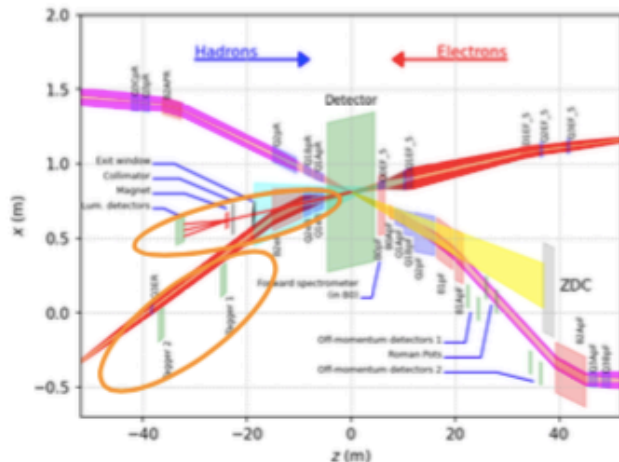
Institutes: [Birmingham](#), [Brunel](#), [Lancaster](#), [Liverpool](#), [STFC RAL \(PPD and TD\)](#), [STFC DL](#)



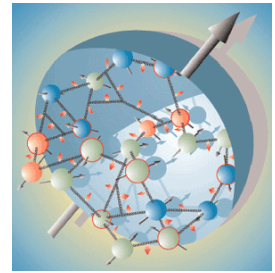
Aspiration for the Construction Phase

- Three detector WPs: **MAPS**, **Timepix** and **Polarimetry**
- Timepix**: **low- Q^2 tagger** using Timepix4 pixel sensors. Build two tracking stations in far backward region. Detector is baseline. Timepix is a candidate technology.
- Institutes: **Glasgow**, **STFC DL**
- Polarimetry**: current activity is exploring use of novel polarised scattering media using chemical hyperpolarization. Nucleon polarimeter is not currently in baseline detector. Also, leading design of electron beam **luminosity monitor**.

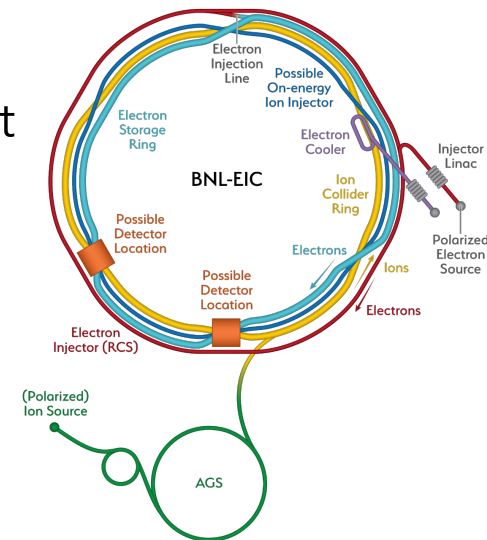
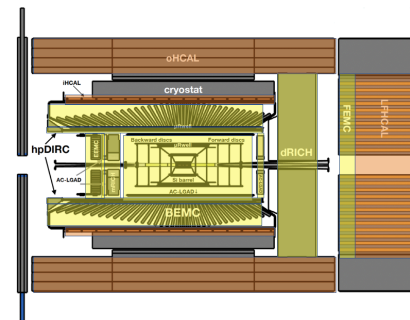
Institutes: **York**



Summary



- * Electron-Ion Collider to be built at Brookhaven National Laboratory, start operation in 2032.
- * Large range of CoM energies (20 - 140 GeV), high luminosity ($10^{33-34} \text{ cm}^{-2}\text{s}^{-1}$): high precision measurements across a wide range of phase space from the gluon sea to the valence quark region.
- * Design of the first detector being finalised this year: the ePIC collaboration.
- * Europe provides 30% of the institutions involved in the EIC Users Group, with significant, sustained leadership throughout the physics and detector development stages, in the EIC community and the ePIC collaboration.



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