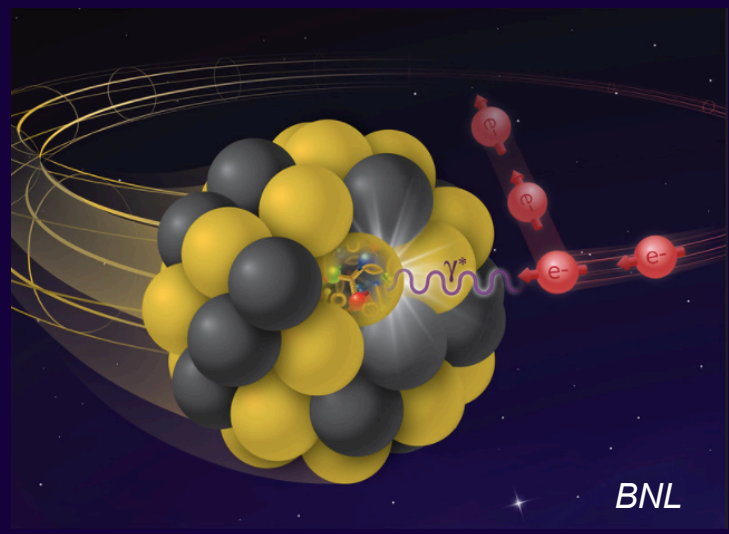
EIC: Overview and UK involvement

Daria Sokhan

CEA Saclay / Glasgow



Physics Opportunities at the Electron-Ion Collider
IPPP Durham (virtual) – 22 September 2021

Electron-Ion Collider

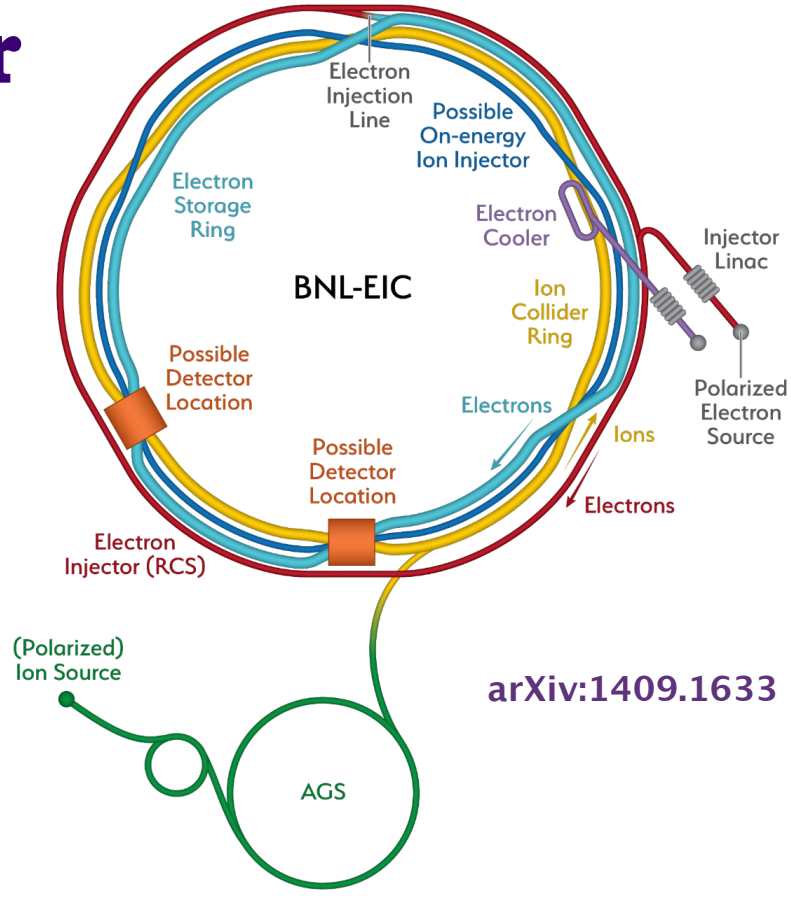
World's first polarized electron-proton/light ion and electron-Nucleus collider.

For e-N collisions at the EIC:

- ✓ Polarized beams: e, p, d/^{3}He
- ✓ e beam 3 – 10 (18) GeV
- ✓ Luminosity $L_{ep} \sim 10^{33-34}$ cm^{-2}s^{-1}
- ✓ 28 – 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



arXiv:1409.1633

Two sites were in play: Jefferson Lab and Brookhaven National Lab.

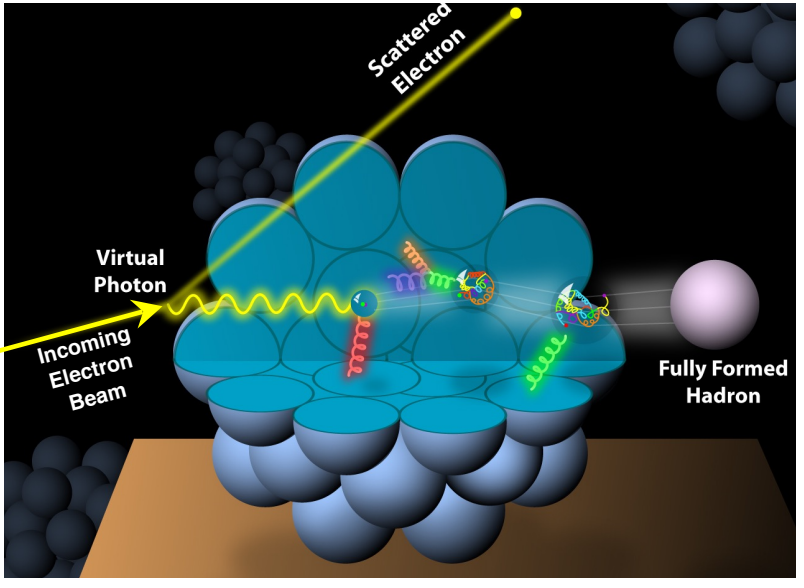
Early in 2020, Brookhaven National Lab was selected as the site.

Concurrently, **CD0 (Critical Decision 0)** was announced by the US Department of Energy: establishing mission need and formally launching the project.

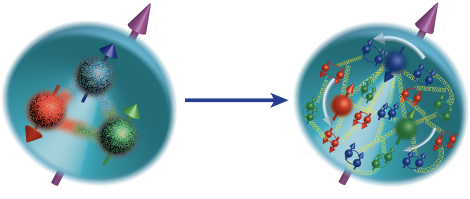
Cost range estimate: $1.6 – $2.6 billion.

Physics questions for the EIC

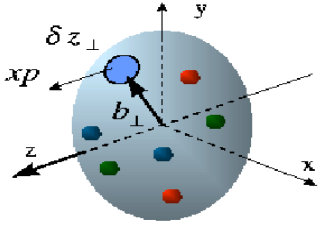
- How do hadrons and nuclei emerge from quarks and gluons?
- How does colour charge propagate through nuclear matter?
- What is the quark-gluon origin of the nuclear force?



Courtesy of E. Aschenauer



- What is the full composition of nucleon spin? How much do sea quarks and glue contribute?
- What is the origin of nucleon mass and what is the role of glue in it?

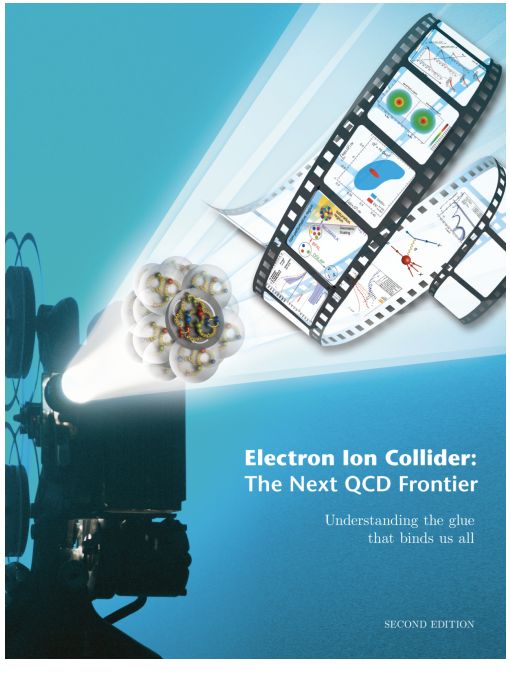


- Where does gluon saturation set in?

EIC beginnings

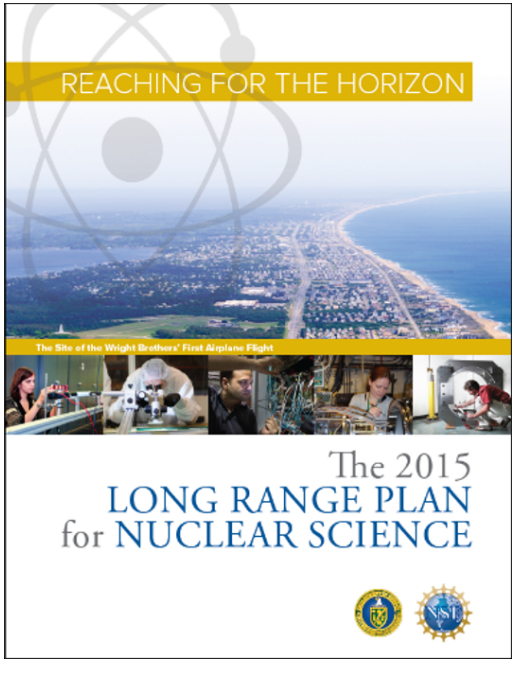
- **2007 Nuclear Physics Long Range Plan** "*The EIC is embodying the vision of reaching the next QCD frontier*"

- **EIC generic detector R&D funds**: since 2011. Consortia formed (eg: PID, software). UK project: *"Precision Central Silicon Tracking and Vertexing", Laura Gonella et al., Birmingham (2017-20), now "Silicon Tracking and Vertexing Consortium" in collaboration with RAL and LBNL.*



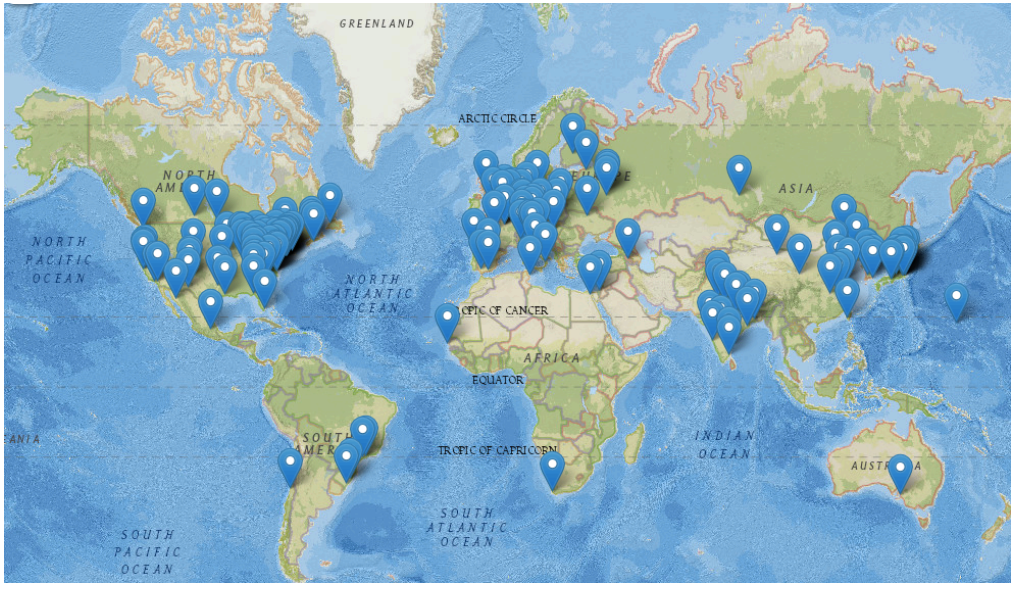
- **2012 EIC White Paper,** *Eur. Phy. J. A 52, 9 (2016)*

- **2015 Nuclear Physics Long Range Plan** "*high-energy, high-luminosity polarised EIC as the highest priority for new facility construction following completion of FRIB*"

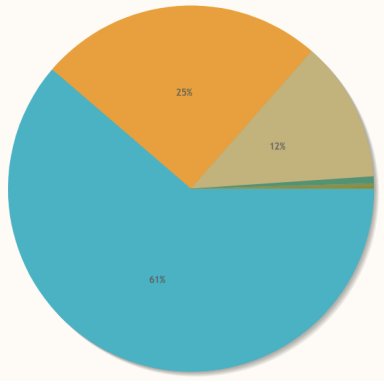


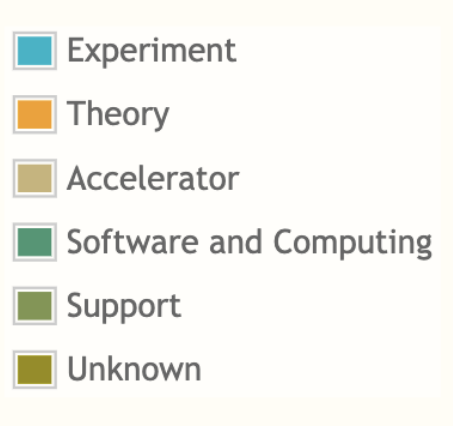
EIC Users Group

http://www.eicug.org



- 263 institutions in 35 countries,
- 1299 members (25% in Europe):





✦ 2016: **EICUG** acquires formal charter and a board of elected representatives.

✦ UK representation:

- Paul Newman (Birmingham): Elections & Nominating Committee 2019-20.
- Daria Sokhan (Glasgow/Saclay): European Representative on the Steering Committee (2021-), charter re-writing committee.

✦ Annual EICUG meetings, held in Europe every two years: Trieste (2017), Paris (2019), Warsaw (postponed to 2022).

UK Workshops on the EIC

- Oct 2016: First UK workshop on opportunities at the EIC, held at Loch Lomond:

Workshop on Physics & Engineering
Opportunities at the Electron-Ion Collider 2016

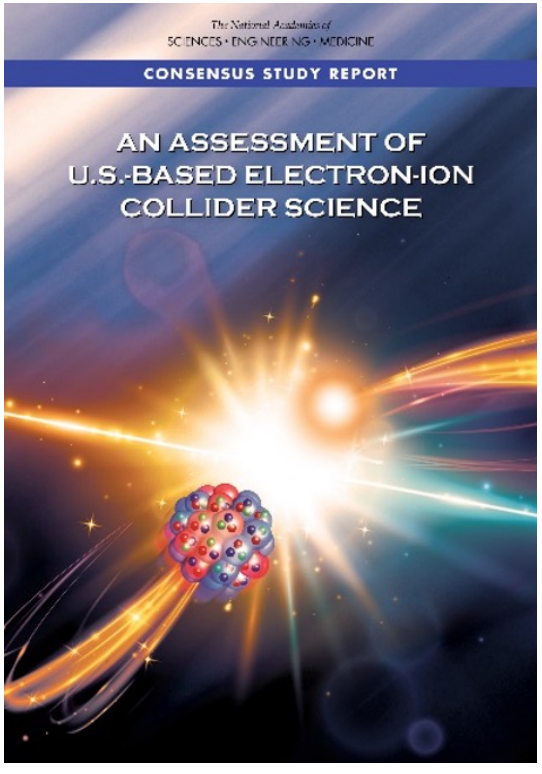
https://indico.cern.ch/event/565879/

- Workshop on Physics, Detector and Accelerator Opportunities at the EIC: July 2020

https://indico.cern.ch/event/934314/

Closer to approval

- **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*"



- **2018 "Probing Nucleons and Nuclei in High Energy Collisions"**: 7-week workshop programme @ INT, Seattle, to address the physics of EIC (https://arxiv.org/abs/2002.12333).

- **DOE funds for accelerator R&D**: $9-11M / year for FY18 and FY19. Ramping up since then.

- Aug 2019 DOE-led EIC meeting with **international funding agencies** / government representatives in London. DOE cost and site-review during 2019.

2020: EIC gets the green light

- 9th Jan 2020: EIC granted **CD0 status** (mission need approved) and **BNL has been selected as the site.** Cost range estimate: $1.6 - $2.6 billion. DOE funding to cover ~80% of one interaction region and associated detector.

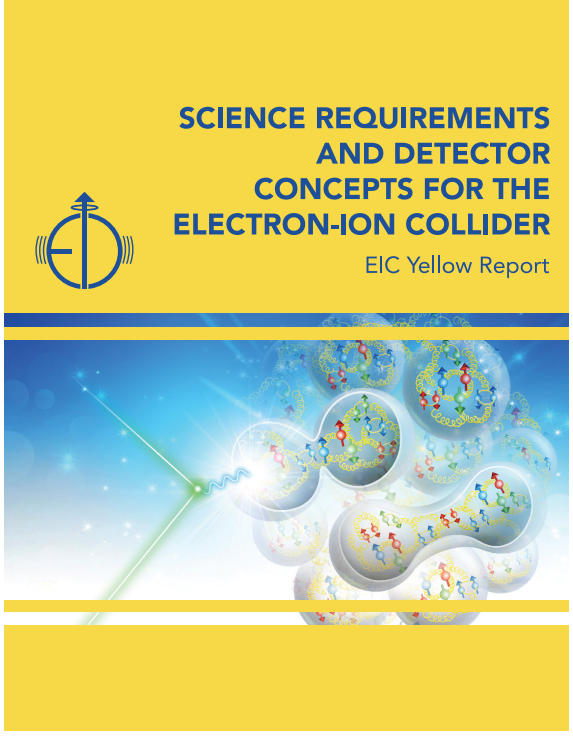
- Independent EIC Conceptual Design Review (CDR): Nov 2020.

- **EIC Yellow Report** (YR) Dec 2019 - March 2021.

Intensive study of the diverse physics case & the detector concepts to enable it. Two main working groups:

- Physics (*Daria Sokhan (Glasgow/Saclay), sub-convener for Exclusive Processes*),
- Detector (*Peter Jones (Birmingham), one of four main conveners, Paul Newman (Birmingham), sub-convener of Detector Complementarity*).

- YR made strong case for two interaction regions (IR), defined a reference detector which would achieve the physics programme and identified the possible technologies for it.



http://www.eicug.org/web/content/yellow-report-initiative

2021: Detector Proposals

- Nov 2020: call for Expressions of Interest for Potential Cooperation on the EIC Experimental Programme: **UK submits a joint EoI from Birmingham, Brunel, Daresbury, Glasgow, Lancaster, Liverpool, RAL & York.**

- March 2021: **call for full detector proposals,** deadline: 1st December.

- Spring 2021: gradual formation of three **proto-collaborations**: ATHENA, CORE and ECCE.

ATHENA

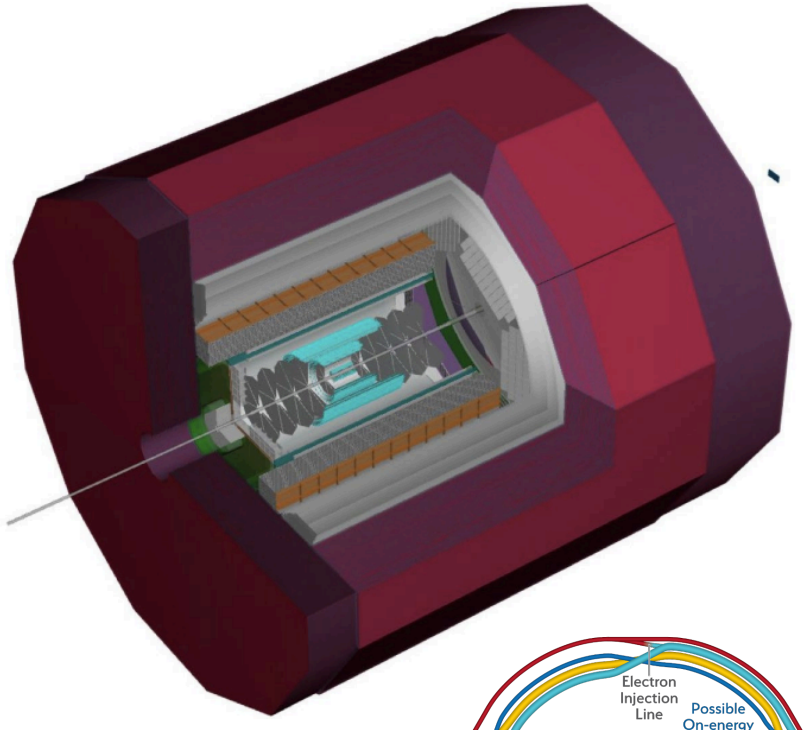
- Peter Jones (Birmingham): member of proposal writing committee
- Paul Newman (Birmingham): Inclusive Processes WG co-convener
- Daria Sokhan (Glasgow/Saclay): Exclusive / Tagging WG co-convener, member of charter committee

ECCE

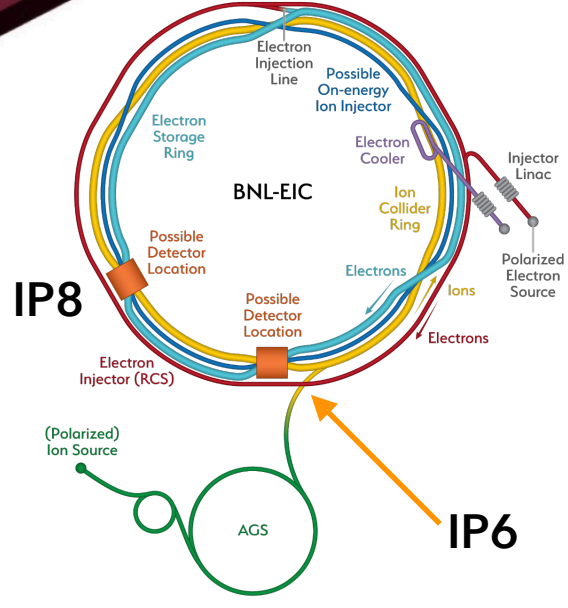
- Claire Gwenlan (Oxford): Inclusive Processes WG co-convener
- Rachel Montgomery (Glasgow): Exclusive Processes WG co-convener
- Nick Zachariou (York): Far-forward/Far-backward WG co-convener

- June 2021: **CD1 status granted** (approval of alternative selection and cost envelope)

ATHENA

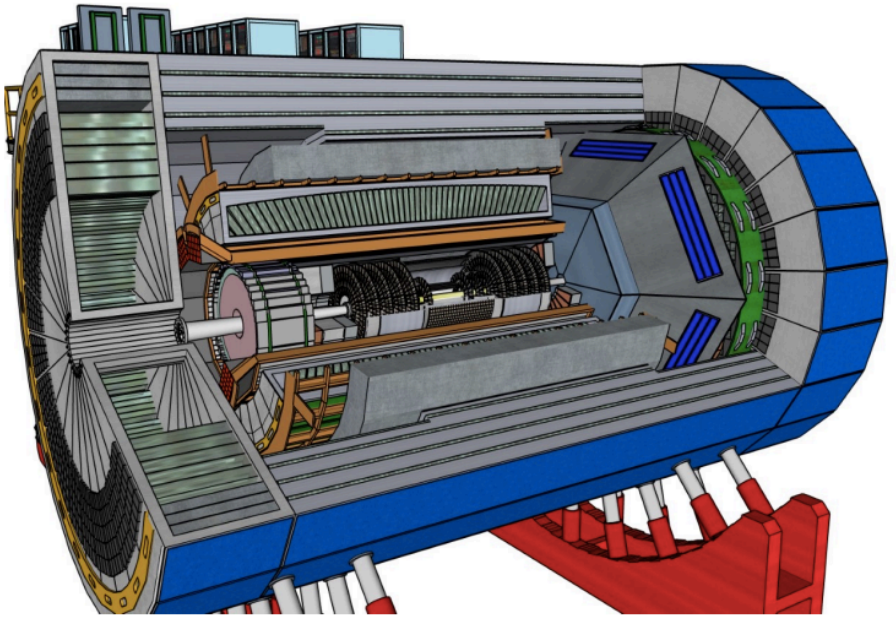


- A Totally Hermetic Electron-Nucleus Apparatus.
- Intended to cover the whole physics programme defined in the EIC White Paper, NAS Report and Yellow Report.
- Design based on the Reference Detector defined in the YR and the CDR.
- Built around a new 3T variable-field solenoid with a large internal bore.
- Intended for IP6, which is the primary interaction region for the EIC.



https://sites.temple.edu/eicatip6/

ECCE

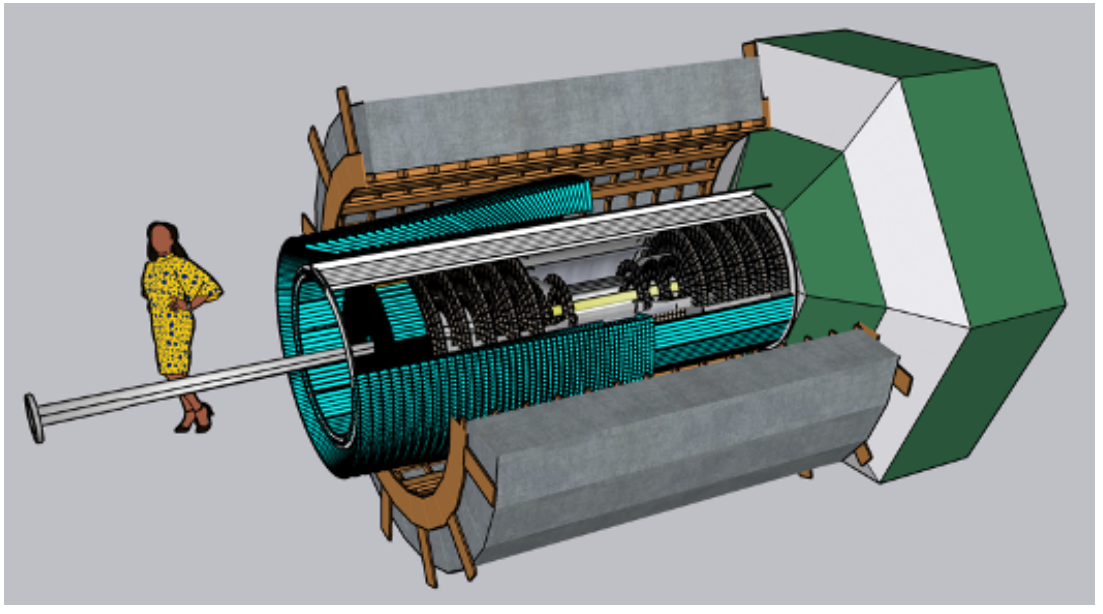


- Eic Comprehensive Chromodynamics Experiment
- Also intends to cover the whole physics programme defined in the EIC White Paper, NAS Report and Yellow Report.
- Low-risk, cost-effective and flexible.

https://www.ecce-eic.org/

- Re-use 1.5T BaBar solenoid magnet, previous detectors as much as possible.
- Considering both interaction points (IP6 and IP8).

CORE



https://eic.jlab.org/core/

- COmpact detectoR for the Eic
- An affordable second detector, to be placed at IP8, with a compact 2.5T solenoid magnet.
- Optimised for high-luminosity and acceptance in the forward region.
- Tracking and PID based on the work of the "Generic Detector R&D for an EIC" programme 2011-2021:
  - all-Si tracker (MAPS),
  - DIRC in barrel,
  - dual-RICH for far-forward direction,
  - $PbWO_4$ / W-shashlik EMCal.

Second IR initiative

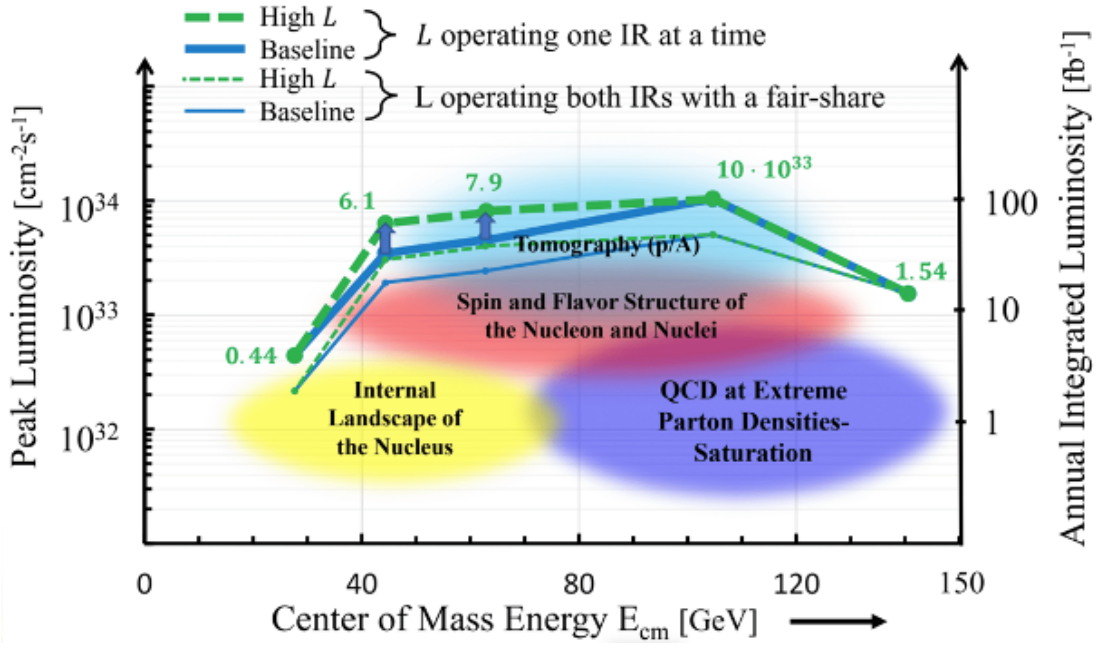
- A series of workshops focussed on the physics of a high-luminosity, low-to-medium centre of mass energy (25-65 GeV) second interaction region.

- At first called IR2@EIC, later renamed to PSQ@EIC (Precision Studies in QCD @ EIC).

- Two workshops held:
  - March 2021: https://indico.bnl.gov/event/10677/
  - July 2021: https://indico.bnl.gov/event/11669/

- Will culminate in a White Paper, soon to begin preparation.

  Derek Glazier (Glasgow): spectroscopy task force



F. Willeke (PSQ@EIC July meeting)

UK involvement

✦ **Horizon-2020 European Integrating Initiative in Hadron Physics funds: 325k€** ***(2019-23), half of the funds to UK***

"Challenges for next-generation DIS facilities"

Spokespeople: Daria Sokhan (Glasgow/Saclay) and Francesco Bossu (CEA Saclay, France)

Glasgow, Birmingham, York, INFN, Saclay, CNRS, …

A collaborative European effort focussed on EIC detector R&D (tracking, vertexing and PID) and simulations. One PDRA post (Glasgow).

✦ **DoE funds through EIC detector R&D programme: ~$270k over past 5 years.**

"Precision Central Silicon Tracking & Vertexing for the EIC"/ "Silicon Tracking and Vertexing Consortium"

Birmingham: Laura Gonella, Peter Jones, Paul Newman, S. Maple, H. Wennlöf, Phil Allport

Successful collaboration of nuclear, particle and instrumentation groups, synergies with existing R&D projects. Collaboration with RAL and LBNL on the development of a silicon vertex and tracking detector with MAPS sensors in a commercial 65 nm CMOS imaging technology.

✦ **Accelerator R&D** in ERL technology: synergies with currently funded projects (UK-FEL), direct relevance for EIC. **3 PhD projects funded in 2018** (Cockcroft), SOIs in preparation.

Bidding for funding from UKRI

✦ EIC: one of the 52 priority projects in the **UKRI Developing a World Class Research Programme** initiative (2019).

✦ STFC solicited an **expressions of interest in EIC** document – submitted in summer 2020, on behalf of 15 institutions.

✦ Invited to submit a bid to the **UKRI "Creating world-class Research and Innovation infrastructure" funding call**, launched in 2020:

a 3-year £3M preliminary activity in detector R&D, followed by a 7-year full implementation phase (as a future proposal): detector and accelerator R&D and construction.

Co-PIs: Peter Jones (Birmingham), Daria Sokhan (Glasgow/Saclay)

Preliminary Activity institutions: Birmingham, Brunel, Daresbury, Glasgow, Liverpool, Lancaster, RAL, York.

Selected by STFC as one of the projects to submit to UKRI, asked to de-scope twice. Positive outcome from UKRI, STFC Peer Review in August 2021 – awaiting outcome.

Bidding for funding from UKRI

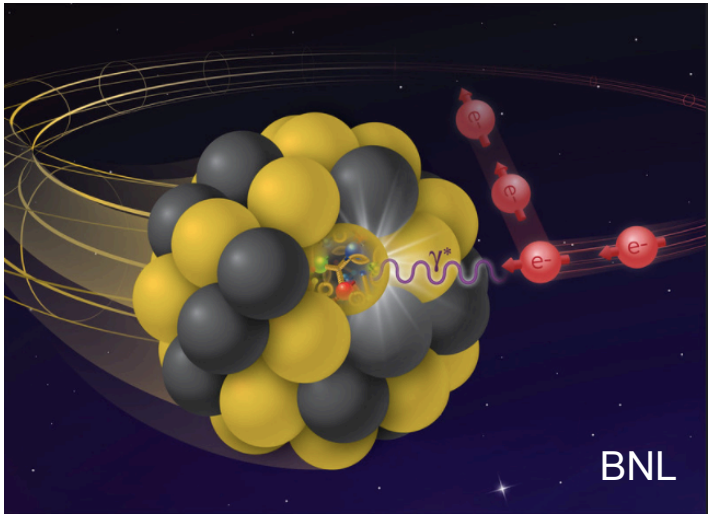
Preliminary Activity (3 years) part of the UKRI bid built around 3 detector R&D work packages:

- ✦ MAPS for vertexing and tracking: led by Laura Gonella (Birmingham). Institutes: Birmingham, Brunel, Daresbury, Lancaster, Liverpool and RAL.
- ✦ Timepix-based detectors for far-backward / far-forward region: led by Ken Livingston (Glasgow)
- ✦ Polarimetry: led by Dan Watts (York).

See the dedicated talks in this morning's session!

Final remarks

- The EIC project is advancing extremely fast, meeting deadlines.
- Spring 2022 will see the selection of the detector proposal for the first interaction region — probable restructuring of collaborations.
- CD2 (approve performance baseline) expected at the start of 2023, CD3 (approve start of construction) in spring 2024. Full CD4 (approve start of operations): expected summer 2033.
- Numerous detector-agnostic **working groups** exist, eg: Spectroscopy (contact Derek Glazier, Glasgow) and a newly set-up Crossing-Angle Task Force. Check the EICUG webpages or get in touch with us!
- **This is the time to get involved!**




Thank you!
Loch Lomond