Center for Frontiers in Nuclear Science

EICUG 2023

Electron-Ion Collider User Group Meeting 2023

Jul 23 – 31, 2023
Faculty of Physics, University of Warsaw
Europe/Warsaw timezone

"Introduction to EIC 2nd Detector"

EIC 2nd detector: vision and path to realization

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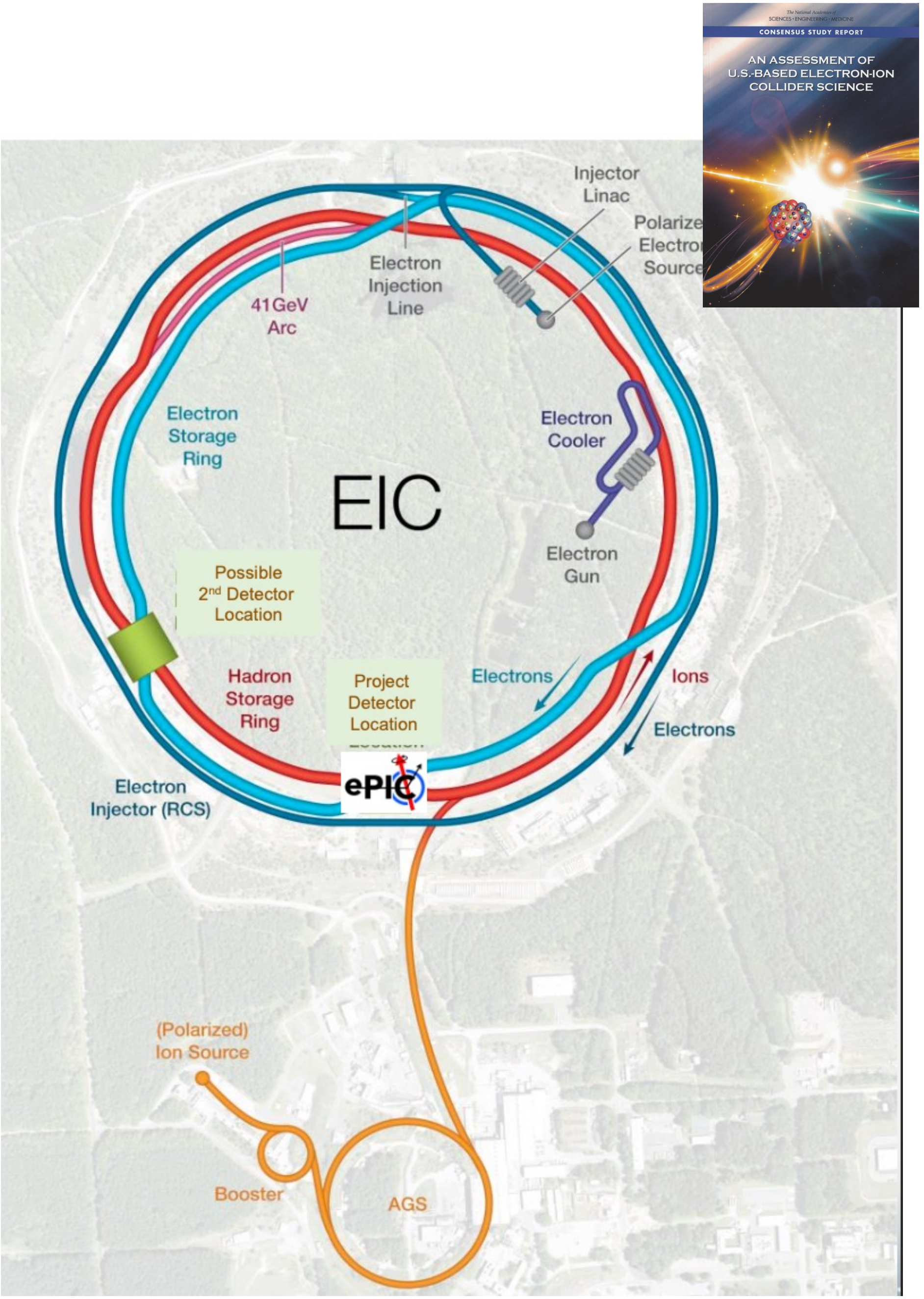
Electron Ion Collider Project: Accelerator & ~70% 1st detector

Physics of EIC ➔ Elements of CD0 (Science Need) from DOE

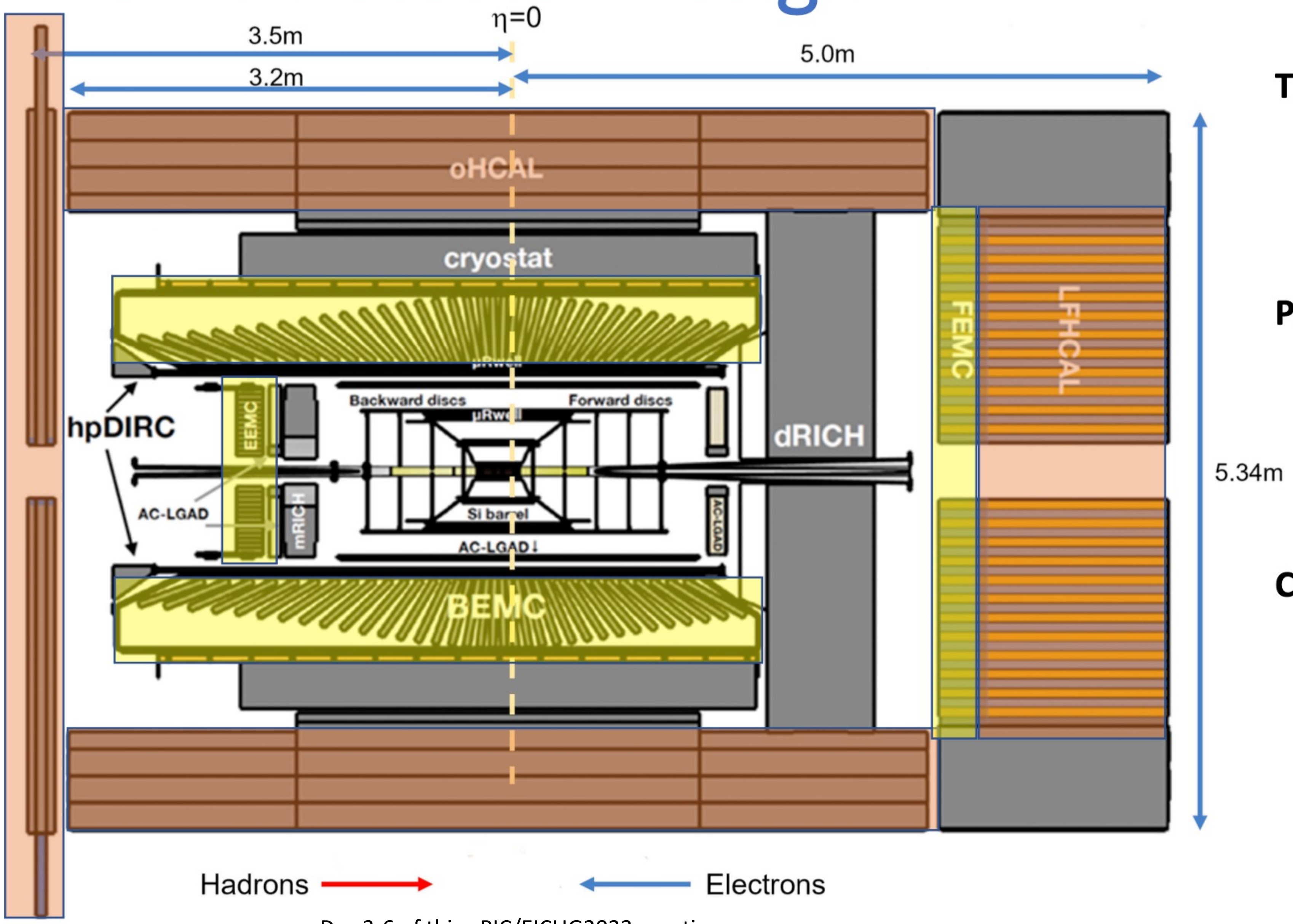
- Emergence of Spin
- Emergence of Mass
- Physics of high-density gluon fields

Machine Design Parameters:

- High luminosity: up to 10^{33}-10^{34} $cm^{-2}sec^{-1}$
    - a factor ~100-1000 times HERA
- Broad range in center-of-mass energy: ~20-140 GeV
- Polarized beams e-, p, and light ion beams with flexible spin patterns/orientation
- Broad range in hadron species: protons…. Uranium
- Up to two detectors well-integrated detector(s) into the machine lattice



ePIC Detector Design



Tracking:

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

PID:

- hpDIRC
- pfRICH
- dRICH
- AC-LGAD (~30ps TOF)

Calorimetry:

- Imaging Barrel EMCal
- PbWO4 EMCal in backward direction
- Finely segmented EMCal +HCal in forward direction
- Outer HCal (sPHENIX re-use)
- Backwards HCal (tail-catcher)

Day 3-6 of this ePIC/EICUG2023 meeting

Value of more than 1 detector

Two documents: with overlapping arguments

Ent and Milner et al for the EICUG SC

JLAB-PHY-23-3761

Motivation for Two Detectors at a Particle Physics Collider

Paul D. Grannis[*] and Hugh E. Montgomery[†]
(Dated: March 27, 2023)

It is generally accepted that it is preferable to build two general purpose detectors at any given collider facility. We reinforce this point by discussing a number of aspects and particular instances in which this has been important. The examples are taken mainly, but not exclusively, from experience at the Tevatron collider.

arXiv: 2303.08228v2 March 24, 20234

Case for two detectors being made from **Nuclear** and **Particle** Physics

History: Discoveries established with **more than one** detectors in Nuclear Science

- Discovery of gluon : TASSO, JADE, Mark J, and PLUTO @ DESY
- H1 and ZEUS at Rise of F_2 and hence the gluon dominance at low-x
- BRAHMS, PHOBOS, PHENIX and STAR Discovery and establishing the existence of Quark Gluon Plasma
- Measurements at DESY and JLab eventually led to “parton imaging”
- EMC discovered and then SMC/CERN and EXXX/SLAC established nucleon spin crisis (low-x)
- EMC discovered and then NMC established nuclear effects on nucleon PDFs (also low-x)

Two detectors (independent cross checks) builds trust in novel discoveries and prevents historical mistakes

Building Trust

- Quark Gluon Plasma: RHIC Experiments
- Discovery of Top Quark D0/CDF
- Discovery of Higgs Boson: ATLAS and CMS
- Gravitational Waves: LIGO and VIRGO
- Neutrino oscillations

Mistakes or misinterpretations:

- Cold fusion
- 17 KeV neutrinos in Tritium
- Superluminal neutrinos
- Leptoquarks
- Pentaquarks from the 2000’s

Complementary detectors : 1 + 1 > 2

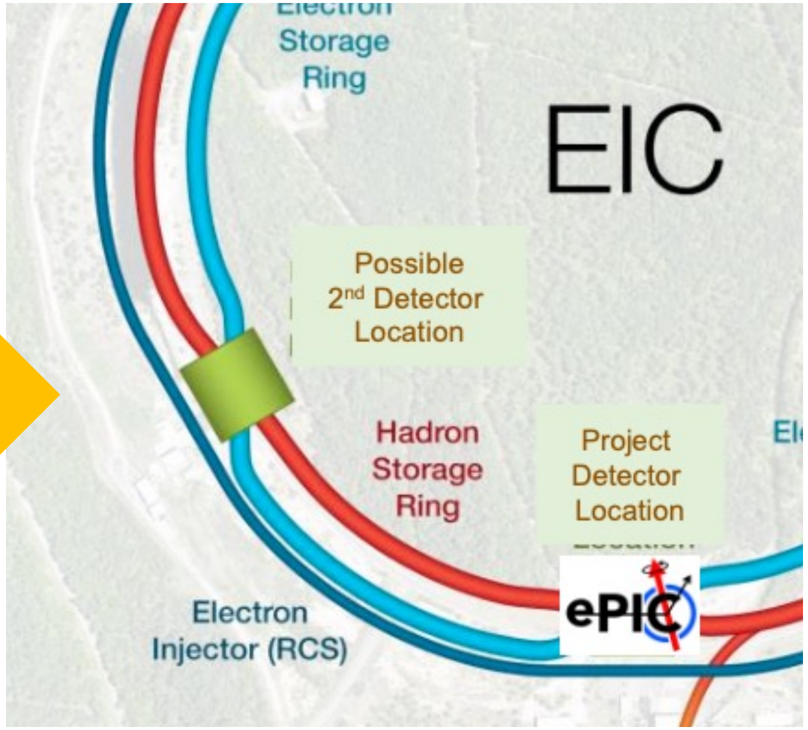
More than one detectors with different acceptances, optimizations and technologies:
Redundancy, cross-calibration and independent validation of important results

- Complementary acceptance -- confirming or refuting discoveries – studying from different “point of views”

- Complementary Technologies – multiple examples of systematic uncertainties improvement due to different Particle ID, Calorimetry, Tracking, magnetic field strengths and orientations.
  - H1/ZEUS, PHENIX/STAR, CDF/D0 and ATLAS/CMS vs. LHCb
  - Very important because most measurements at the EIC expected to be systematics limited

- Impact of different perspectives that different collaborators bring to the same problem.
  - Complementary analyses strategies build confidence in conclusions

The 2nd detector



NSAC documents talk about possibly ~4 detectors

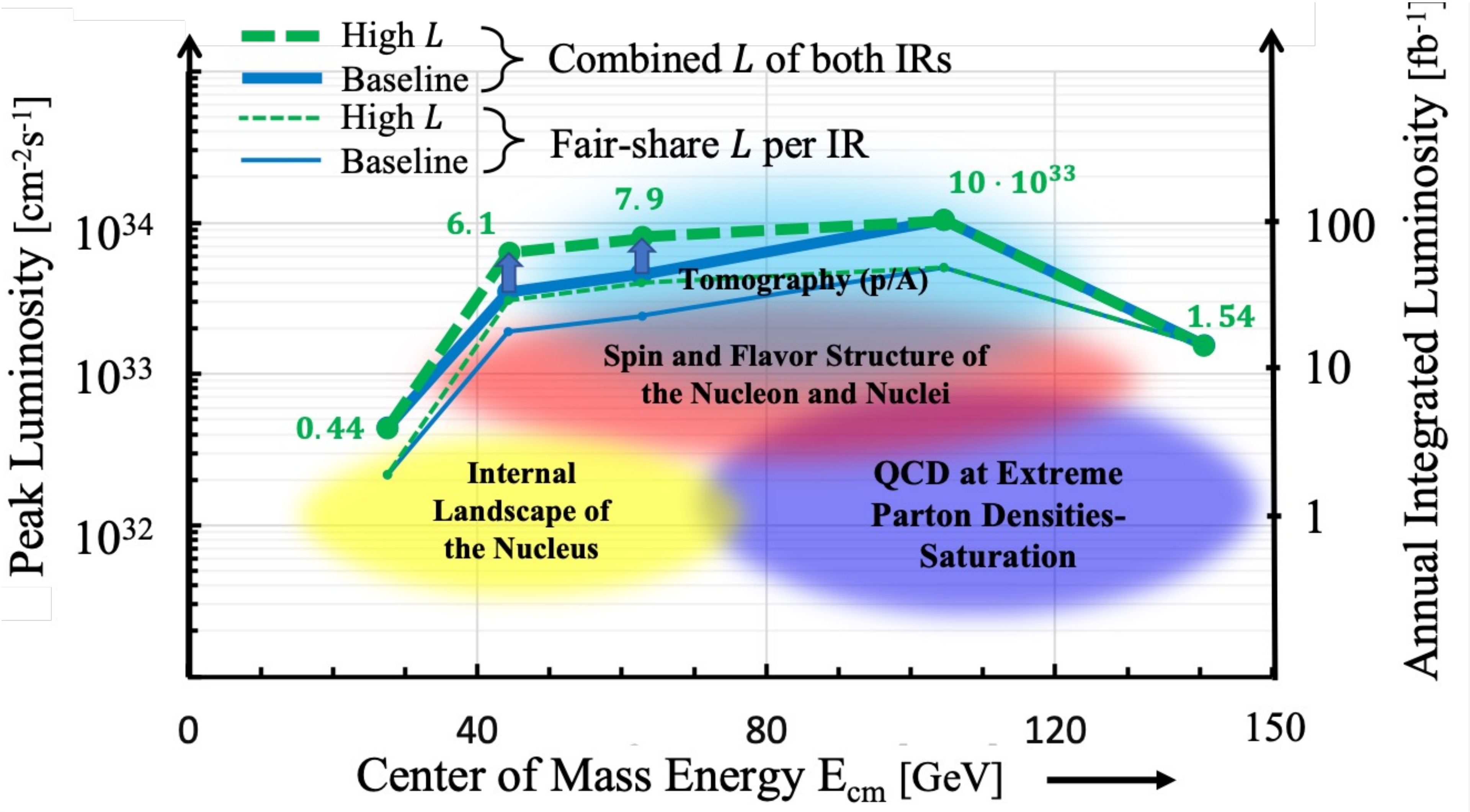
NAS Report: planning for up to 2 well-integrated detectors

EICUG desires 2 Detectors

EIC Project has 1 Machine, 1 IR and ~1 Detector

without negating the possibility of the 2nd IR/Detector

Adding IRs : Luminosity gets shared
(at beam-beam limit)



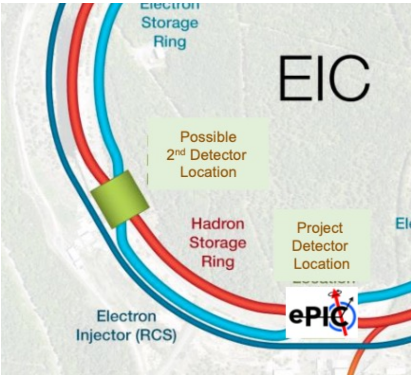
EIC project (machine and 1st detector) *have to* succeed….

At the same time, we need to sow the seeds for the eventual success of 2nd detector

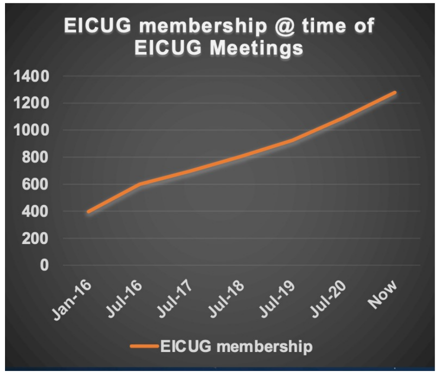
Neither of the above are trivial and hence a balance between them is bound to be challenging.

Opportunity for more than one detector already exists

EIC Layout and International EIC Users Group



- EIC layout allows for more than one interaction point
- EIC Users Group is large & growing
  - 700 in 2016 to 1400 in 2023 – potential to grow further

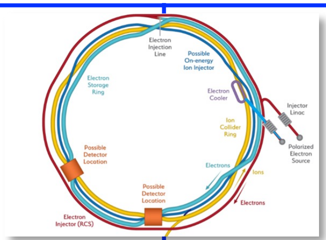


- Have we explored the potential of all countries and subgroups in the UG?
- Is there (not) significant potential growth in international contribution?

- EIC project is charged to keep the possibility of the 2nd detector at the EIC

Opportunity for complementary detector designs or (even) thinking out-of-the-box for different IRs exists!

	1st IR (IP-6) ePIC	2nd IR (IP-8)
Geometry:	ring inside to outside tunnel and assembly hall are larger Tunnel: ⃠ 7m +/- 140m	ring outside to inside tunnel and assembly hall are smaller Tunnel: ⃠ 6.3m to 60m then 5.3m
Crossing Angle:	25 mrad	35 mrad **secondary focus**



different blind spots
different forward detectors and acceptances
different acceptance of central detector

Luminosity:

Optimize Doublet focusing FDD vs. FDF
→ impact of far forward p_T acceptance

Experiment:

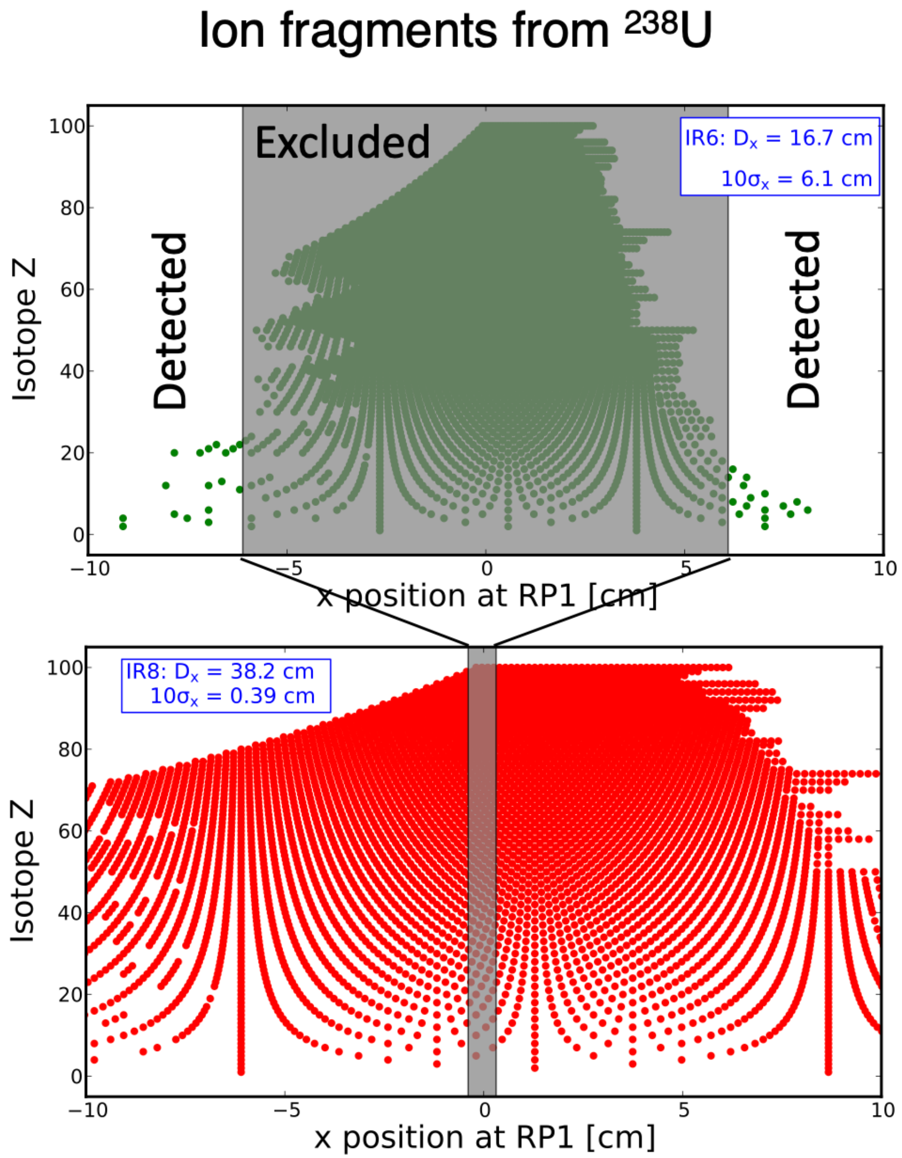
1.7 Tesla or 3 (?) Tesla solenoidal field? Other field Geometries?
different subdetector technologies

Based on a slide by ECA & RE

See more in Pawel N-T's talk

Complementary IR design : impact of 2nd "focus"

- Far forward acceptance improves dramatically with the 2nd focus.
- Knowing this, what compelling physics topics could one think of?
- Brainstorming beyond (just) this example is needed.



Potential Physics topics beyond Core EPIC detector's mandate exist

Focus first on Physics beyond the EIC's core (CD0) science

(there will be others: some overlapping, some exclusive due to different IR design)

Physics with nucleons and nuclear targets:

- Quark **Exotica**: 4,5,6 quark systems…? Much interest after recent **LHCb** led results.
- **Nuclear Fragments** from light and heavy nuclei : e-A – Connecting to low energy nuclear physics (exotic nuclei), studying the shapes of nuclei and their internal substructure; entanglement, entropy, fragmentation, hadronization and such phenomena

Precision electroweak and BSM physics:

- Electroweak physics & searches beyond the SM: Parity, charge symmetry, lepton flavor violation
- LHC-EIC Synergies & complementarity: (**muon detectors** were of particular interest)

New Studies with proton or neutron target: (mostly overlapping?)

- Impact of precision measurements of unpolarized PDFs at high x/Q^2, on LHC-Upgrade results(?)
- Precision calculation of α_S : higher order pQCD calculations, twist 3
- Heavy quark and quarkonia (c, b quarks) studies with 1000 times lumi of HERA (and polarization)

Vision for the 2nd detector: C²C

- Complementary (IR, detector technologies & design)
  - Continue to explore complementary ready and not-yet-ready technologies
  - Generic detector R&D program – Run through Jlab

- Complementary (physics)
  - A significant list of physics topics exists (some-exclusive to 2nd IR, some-overlapping): drill down and see which of those can *develop into strong pillars of science for the 2nd detector.*
  - New physics developing around the world: we need to monitor constantly

- Complementary (people)
  - New non-US/outside groups who may bring new interests & funding in future
  - New US groups – other than those with significant responsibilities in ePIC

Path forward to D2 ~2025

✓Focused workshops, detector simulations with new (and some old) physics topics

✓Look at **complementary detector technologies** (to ePIC) and attract (those/new) groups

✓Focused discussions on **new physics topics** to try to make a unique case (at least partially) complementary to ePIC/EIC White Paper

✓**New community** – at least **some new** groups/faces/resources need to take leadership in D2

Resources:

EICUG ➔ has formed a "task force" and a "theory support" group

Generic detector R&D – supported by DOE administered from JLab & EIC^2 Center

Center for Frontiers in Nuclear Science CFNS @ Stony Brook (& EIC – Theory Institute at BNL)

Concluding Remarks:

- EIC project's path (Collider and the ePIC) is well understood. Its success is paramount. *Nothing can obstruct that.*

- 2nd detector is essential for completing the Vision of EIC
  - C^2C : Complementary physics, technology and people
- It is time to move forward developing a design and case for the 2nd detector:
  - Detailed studies through series of workshops, outreach and critical evaluation for each developing argument
  - Plan an INT- Program (~3 month) in ~2025 like we had in 2010.

I look forward to supporting the discussions, workshops, and activities of the EICUG