Idea behind today's workshop

Morning:

- Presentation of the US EIC project to our Japanese and other international colleagues:
  - Potential scientific collaboration on EIC (science & machine) and
  - Awareness of the progress on the project in the US

Afternoon:

- Invited experts in fields outside the core QCD studies to explore the synergies between EIC science and their own primary research interests:
  - High energy physics, Very high energy cosmic rays, and neutrino science…
  - Beginning of a process to find concrete connections: to be followed up in future with dedicated workshops and activities.

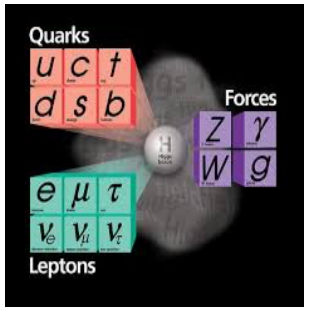
Center for Frontiers in Nuclear Science

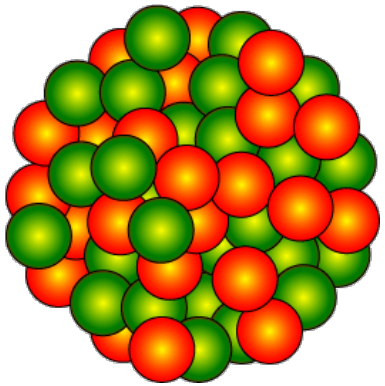
Center for Frontiers in Nuclear Science

Physics and the Status of the US Electron Ion Collider

Understanding the Glue that Binds Us All

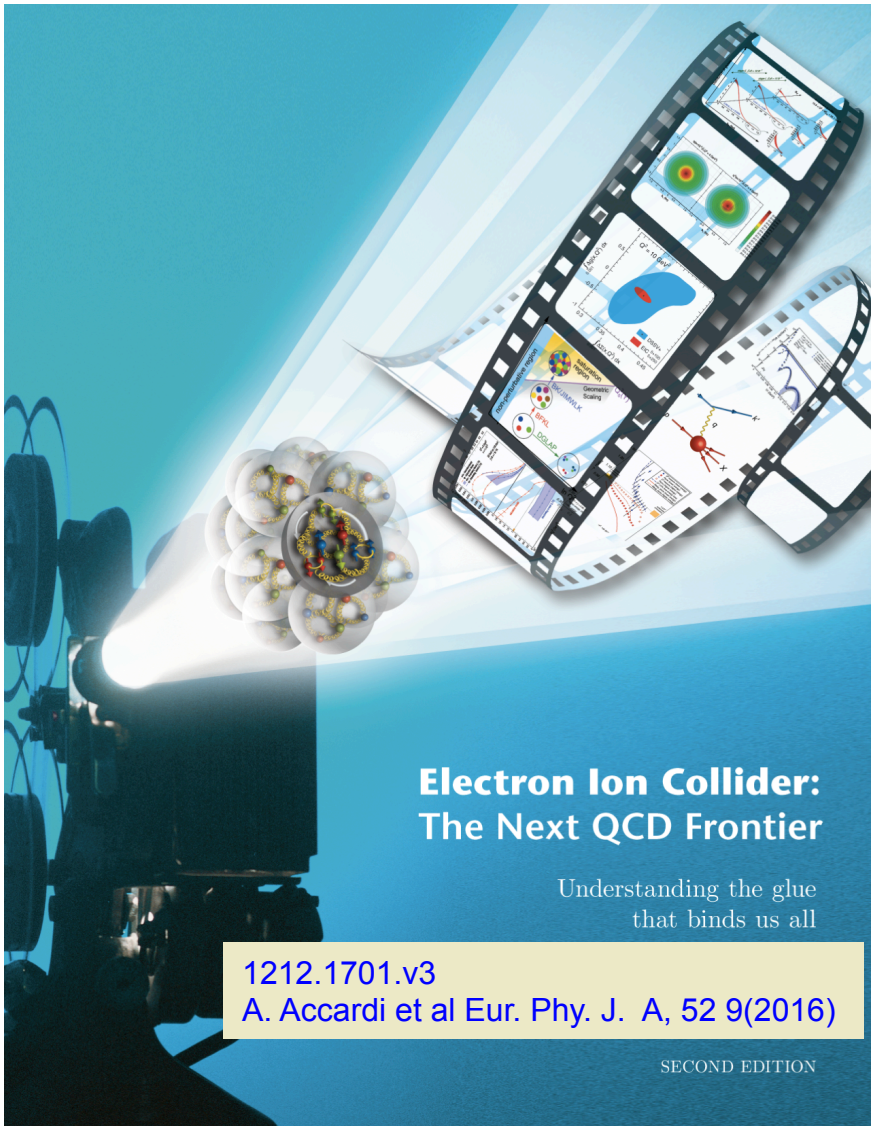
Why the EIC? ➔ "Gluon Imaging"
To understand the role of gluons in binding quarks & gluons into Nucleons and Nuclei

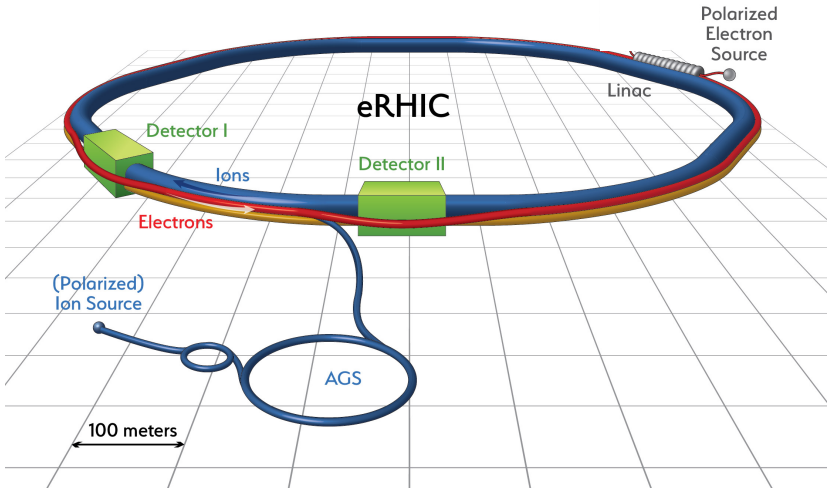




The Electron Ion Collider

Two options of realization!





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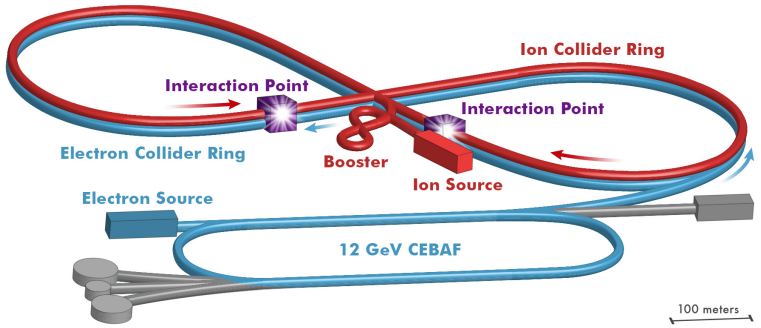


The Electron Ion Collider

Two options of realization!

For e-N collisions at the EIC:

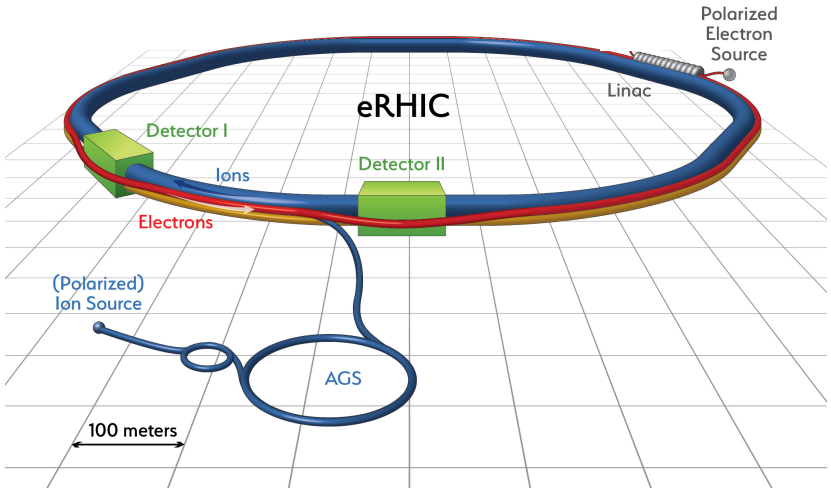
- ✓ Polarized beams: e, p, d/^{3}He
- ✓ e beam 5-10(20) GeV
- ✓ Luminosity $L_{ep} \sim 10^{33\text{-}34}$ cm^{-2}sec^{-1}
  100-1000 times HERA
- ✓ 20-100 (140) GeV Variable CoM

For e-A collisions at the EIC:

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

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

Both designs use DOE's significant investments in infrastructure



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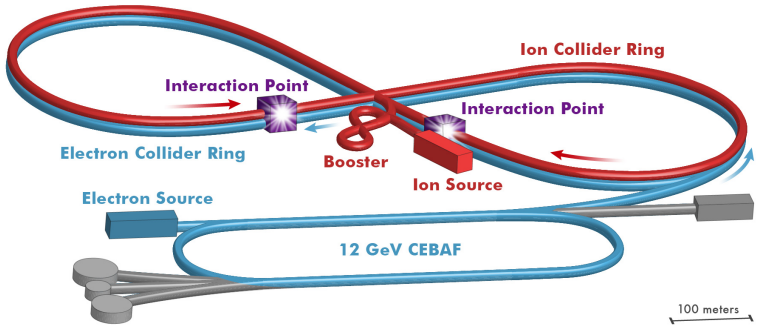
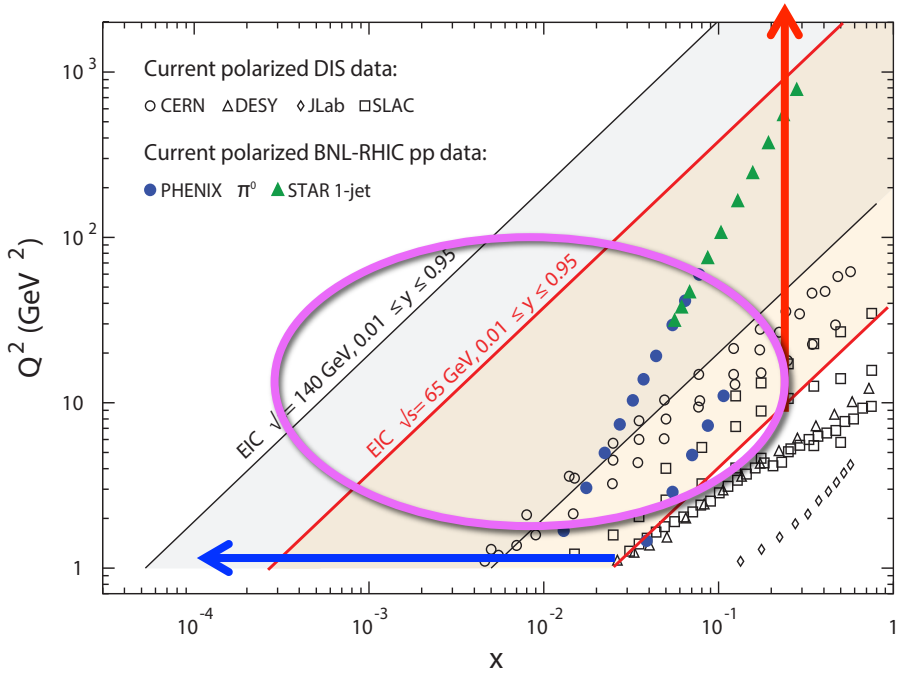


EIC: Kinematic reach & properties

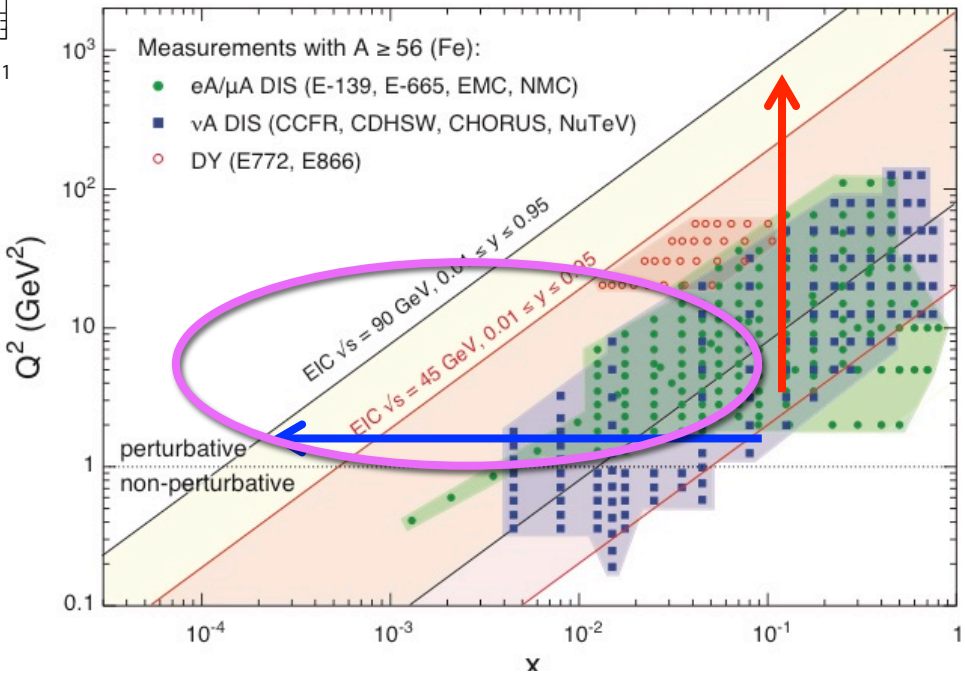


For e-N collisions at the EIC:

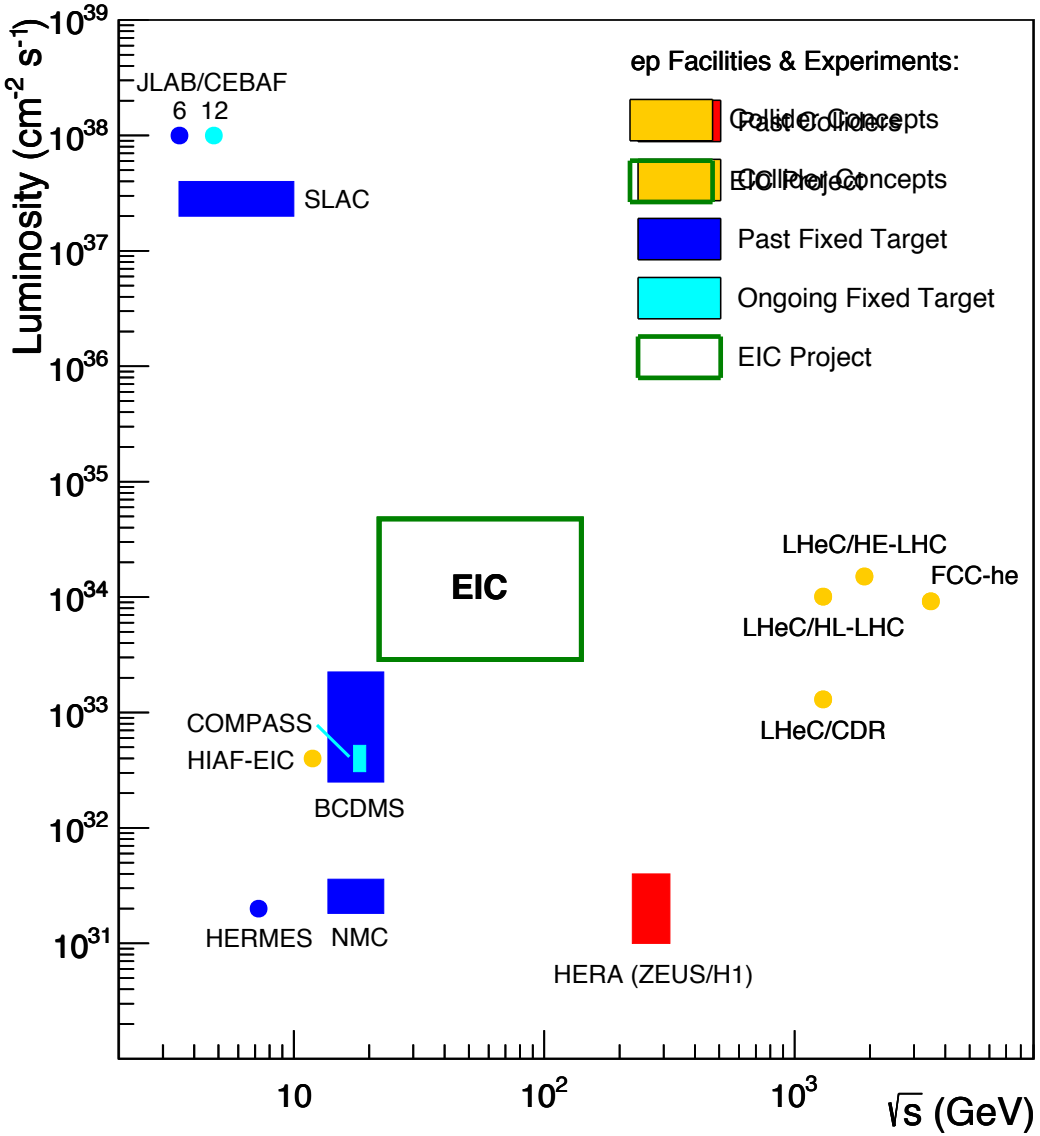
- ✓ **Polarized** beams: e, p, d/^{3}He
- ✓ Variable center of mass energy
- ✓ Wide Q^2 range → evolution
- ✓ Wide x range → spanning valence to low-x physics

For e-A collisions at the EIC:

- ✓ **Wide range in nuclei**
- ✓ Lum. per nucleon same as e-p
- ✓ Variable center of mass energy
- ✓ Wide x range (evolution)
- ✓ Wide x region (reach high gluon densities)



Uniqueness of EIC among all DIS Facilities



All DIS facilities in the world.

However,
if we ask for:

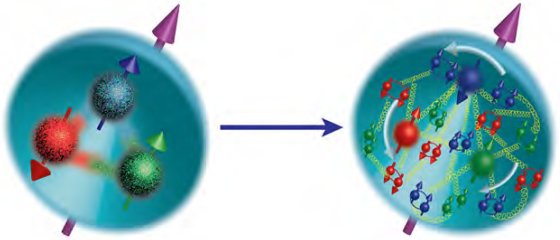
- high luminosity & wide reach in √s
- polarized lepton & hadron beams
- nuclear beams

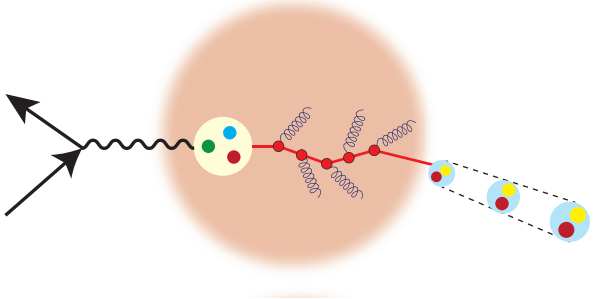
EIC stands out as unique facility …

A new facility is needed to investigate, with precision, the dynamics of gluons & sea quarks and their role in the structure of visible matter

How are the sea quarks and gluons, and their spins, distributed in space and momentum inside the nucleon?

How do the nucleon properties emerge from them and their interactions?

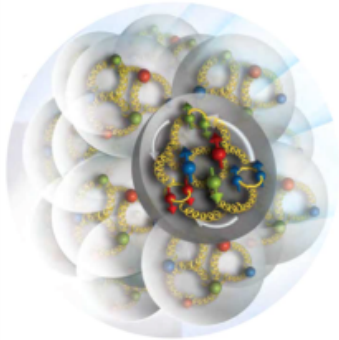




How do color-charged quarks and gluons, and colorless jets, interact with a nuclear medium?

How do the confined hadronic states emerge from these quarks and gluons?

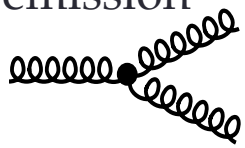
How do the quark-gluon interactions create nuclear binding?



How does a dense nuclear environment affect the quarks and gluons, their correlations, and their interactions?

What happens to the gluon density in nuclei? Does it saturate at high energy, giving rise to a gluonic matter with universal properties in all nuclei, even the proton?

gluon emission



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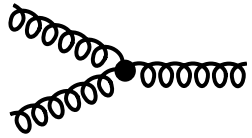
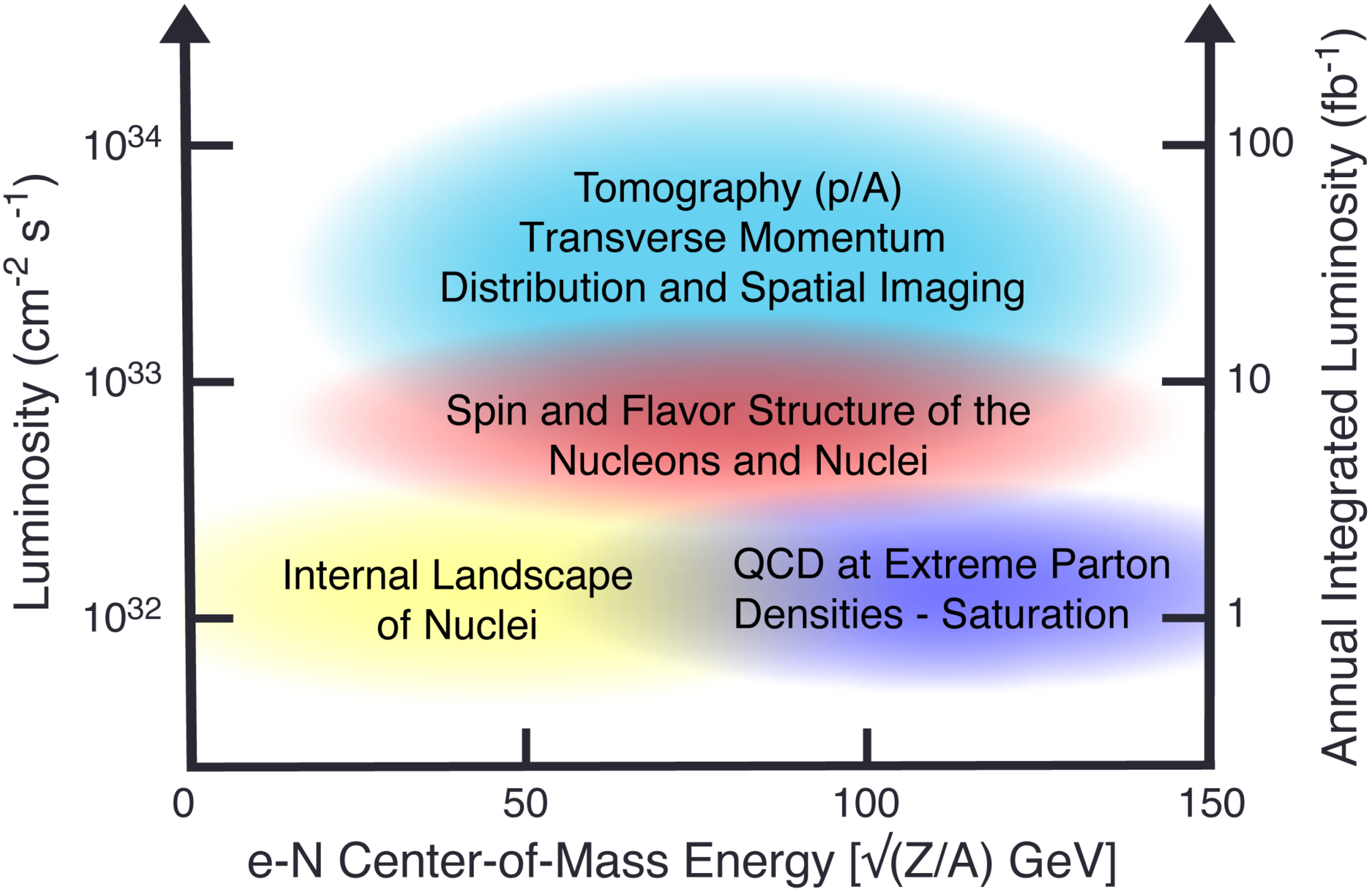
gluon recombination

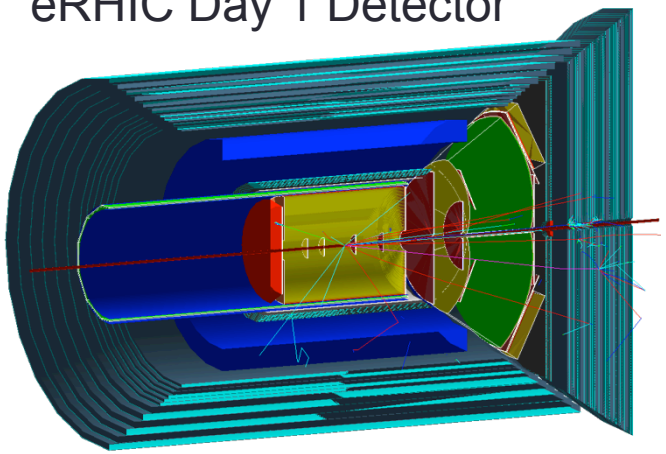


Summary: EIC Physics: CM vs. Luminosity vs. Integrated luminosity

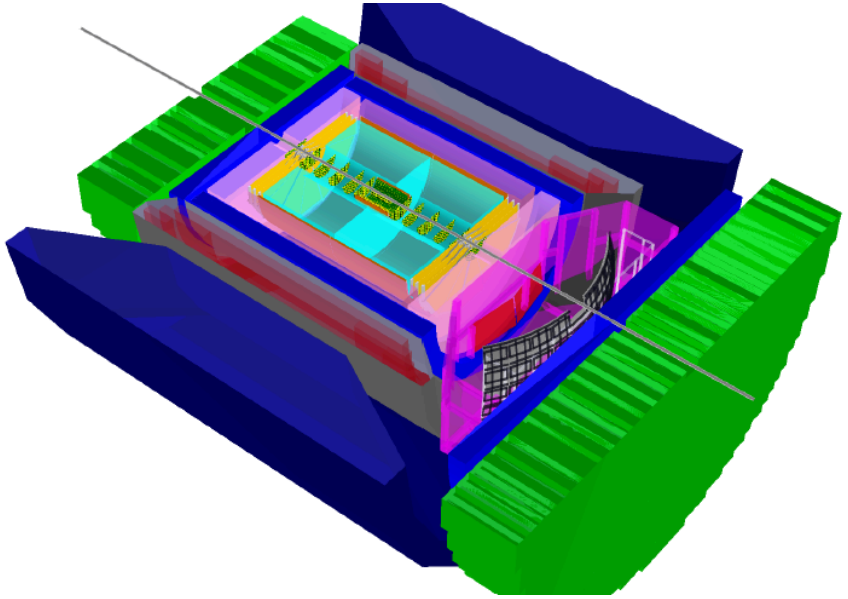


EIC Detector Concepts

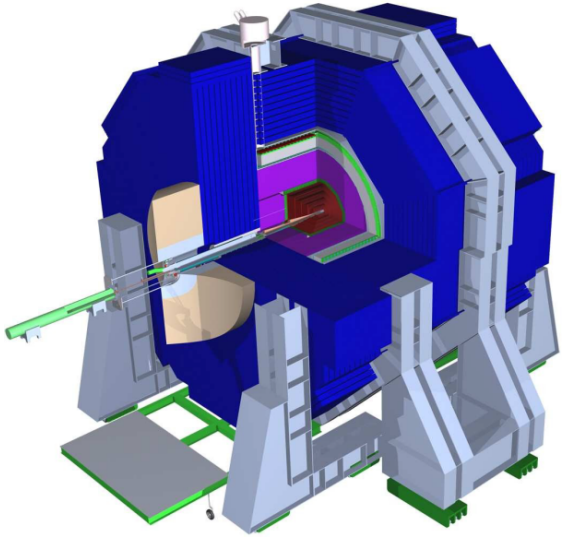
"eRHIC Day 1 Detector "



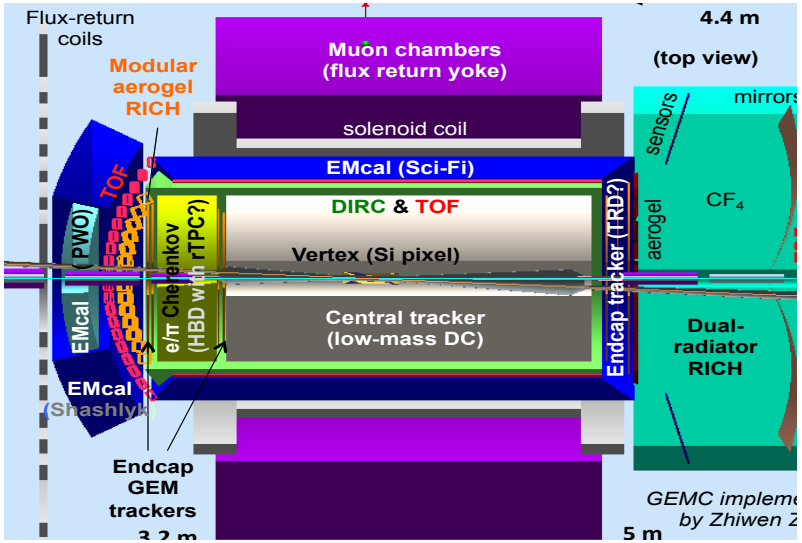
eRHIC Detector



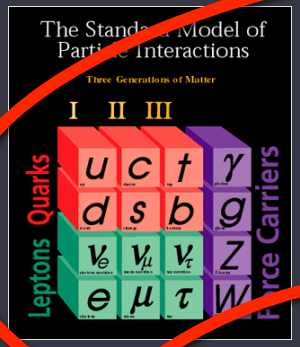
ANL's: "SiEIC Detector" Si-tracker &
Precision calorimetry: particle flow detector

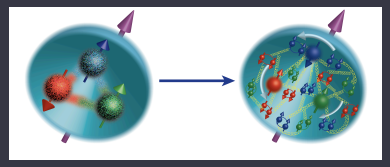


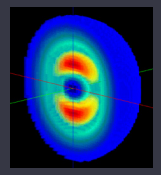
JLEIC Det

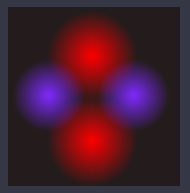


21st Century Nuclear Science: Probing nuclear matter in all Its forms & exploring their potential for applications



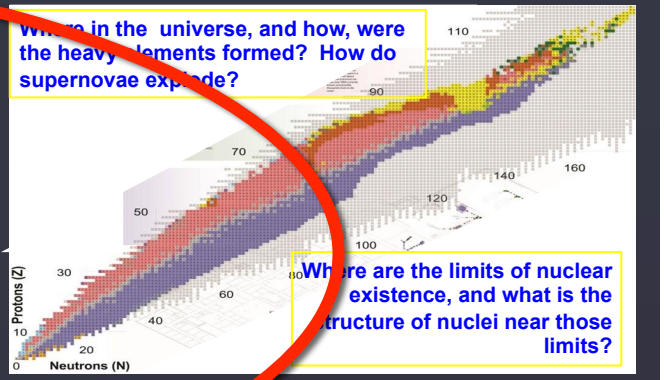




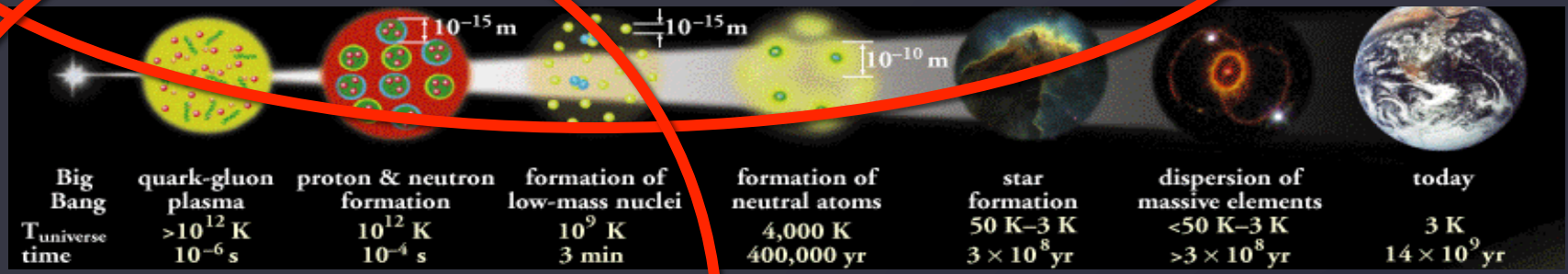


How are the properties of protons and neutrons, and the force between them, built up from quarks, antiquarks and gluons? What is the mechanism by which these fundamental particles materialize as hadrons?

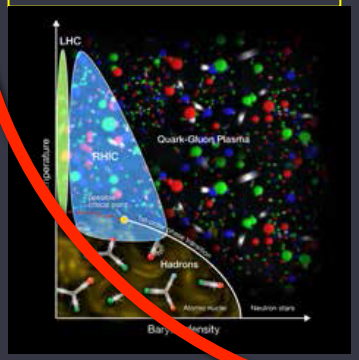
Where in the universe, and how, were the heavy elements formed? How do supernovae explode?



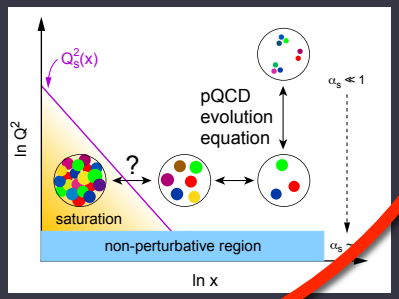
Where are the limits of nuclear existence, and what is the structure of nuclei near those limits?



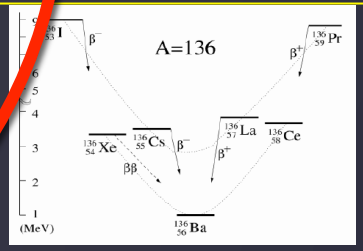
What is the nature of the different phases of nuclear matter through which the universe has evolved?



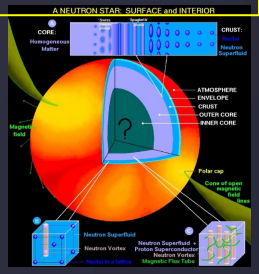
Do nucleons and all nuclei, viewed at near light speed, appear as walls of gluons with universal properties?



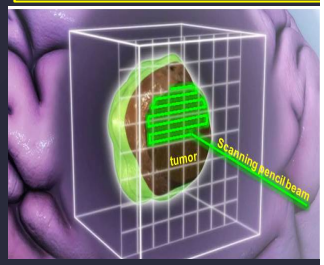
How can the properties of nuclei be used to reveal the fundamental processes that produced an imbalance between matter and antimatter in our universe?



How are the nuclear building blocks manifested in the internal structure of compact stellar objects, like neutron stars?

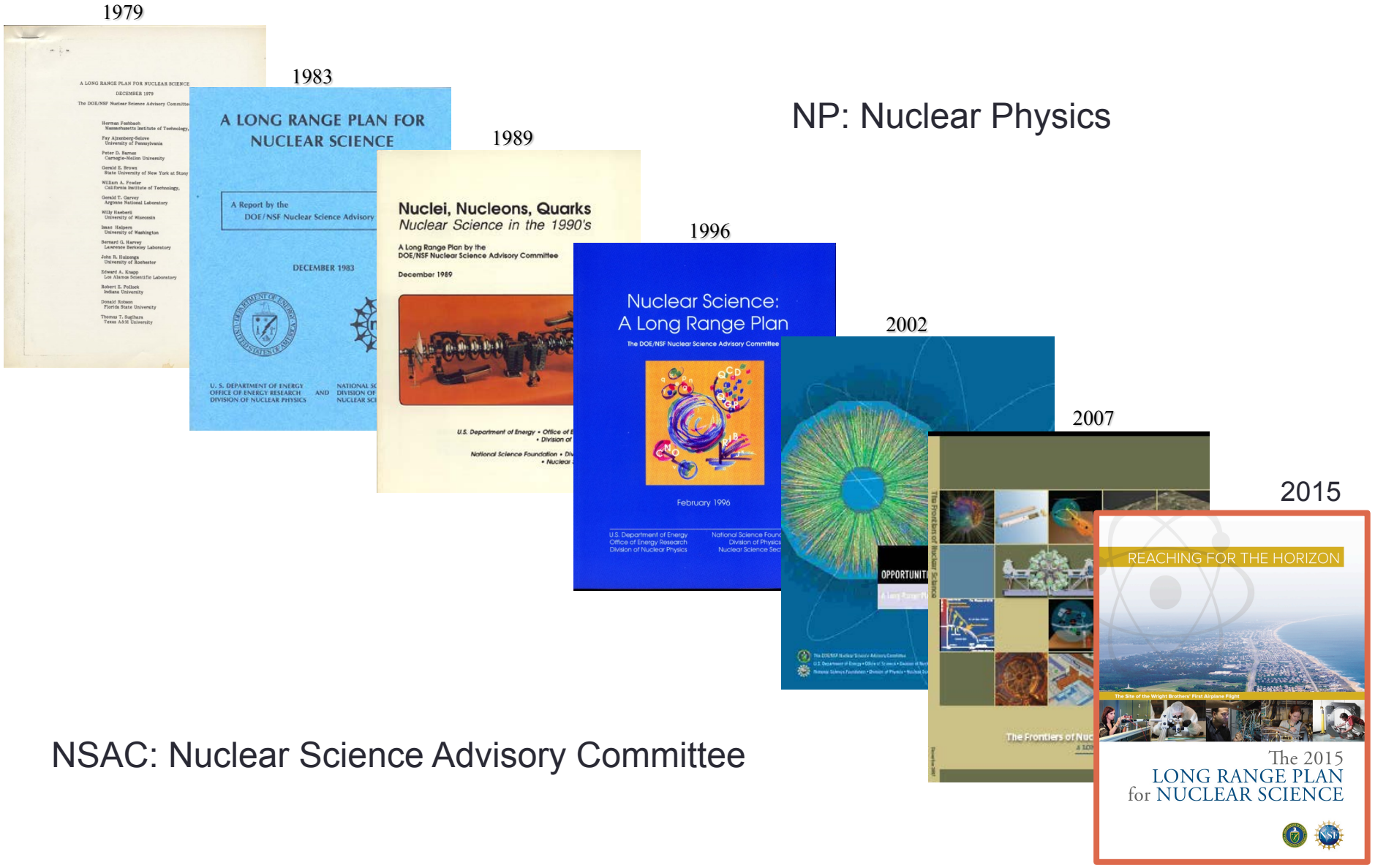


How can technologies developed for basic nuclear physics research be adapted to address society's needs?



STATUS OF EIC

NP's long history of Long Range Plans (LRP)



NP: Nuclear Physics

NSAC: Nuclear Science Advisory Committee

The 2015
LONG RANGE PLAN
for NUCLEAR SCIENCE

http://science.energy.gov/np/reports

RECOMMENDATION:

We recommend a high-energy high-luminosity polarized EIC as the highest priority for new facility construction following the completion of FRIB.

Initiatives:

Theory

Detector & Accelerator R&D

Detector R&D money ~1.3M/yr since 2011; significant increase anticipated soon.

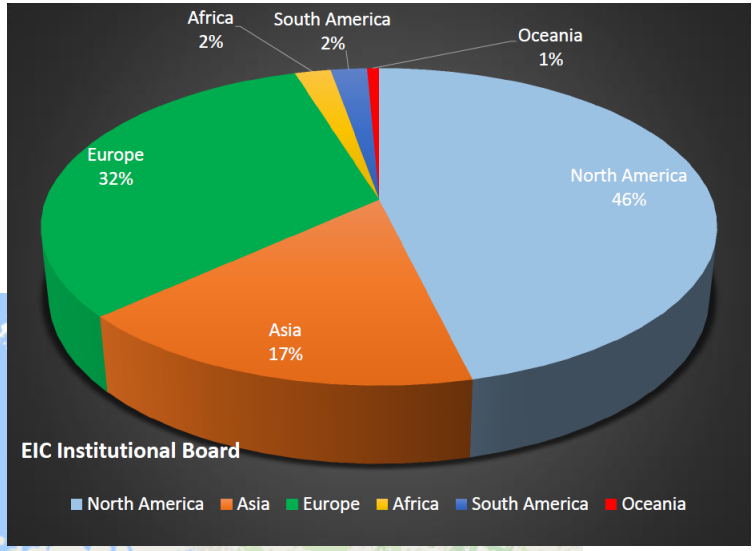
Anticipated Now:
Money for EIC Accelerator R&D already assigned $7m/yr

The EIC Users Group: EICUG.ORG

(no students included as of yet)

738 collaborators, 29 countries, 169 institutions... (January 2018)

Map of institution's locations



Next meeting: July 31-August 4, 2018
Catholic University of America, Washington DC

New Users → New Physics → Lots of activities

Highly Active EIC Community has evolved

- In view of new discoveries of multi-quark

Critical Decision Process DOE

PROJECT ACQUISITION PROCESS AND CRITICAL DECISIONS					
Project Planning Phase		Project Execution Phase			Mission
Preconceptual Planning	Conceptual Design	Preliminary Design	Final Design	Construction	Operations
CD-0 Approve Mission Need	**CD-1** Approve Preliminary Baseline Range	**CD-2** Approve Performance Baseline	**CD-3** Approve Start of Construction	**CD-4** Approve Start of Operations or Project Closeout	

CD-0	CD-1	CD-2	CD-3	CD-4
Actions Authorized by Critical Decision Approval				
• Proceed with conceptual design using program funds • Request PED funding	• Allow expenditure of PED funds for design	• Establish baseline budget for construction • Continue design • Request construction funding	• Approve expenditure of funds for construction	• Allow start of operations or project closeout

PED: Project Engineering & Design

Path forward for the EIC:

- DOE sanctioned a science Review by National Academy of Science of EIC
  - Expect report **by June/July 2018(?)**

- Positive NAS review will trigger the DOE's CD process
  - CD0 (acceptance of the critical need for science by DOE) likely FY19
  - EIC-Proposal's Technical & Cost review → FY20 (site selection)
  - **Major Construction funds ("CD3") by 2022/23" (according to LRP2015)**
    - Assuming 1.6% sustained increase over inflation of the next several years (Long Range Plan)
    - Consistent with the past 10 years of NP funding increases in the US

- First collisions sometime between 2025-2030

INT Program 2010 → EIC in the LRP2015

- 2010 INT workshop on the Science of EIC critical to making the case in the 2015 LRP. (500+ page document, 150+ participants and 500+ authors) : **arXiv:1108.1713**, D. Boer et al.

- Next LRP in ~2020/21, just before EIC Construction could begin ➔ We will EIC physics case with additional details and new physics input….

INT Program Approved: 2018

A 7-week program "Probing Nucleons and Nuclei in High Energy Collisions" dedicated to the **physics of the Electron Ion Collider has been approved by the Institute for Nuclear Theory** in Seattle with the tentative dates of **October 1 - November 16, 2018**. The topics to be covered include Spin and Three-Dimensional Structure of the Nucleon (GPDs, TMDs, longitudinal spin) and QCD in a Nucleus (small-x physics and saturation, connections to heavy ions, large-x physics in a nucleus).

The program organizers will be **Yoshitaka Hatta, Yuri Kovchegov, Cyrille Marquet, and Alexei Prokudin.** They plan to have ample discussion time and lectures aimed at young researchers. Both **theorists and experimentalists** are welcome to participate in the program. Young researchers, women and underrepresented minorities are strongly encouraged to apply.

INT: Institute of Nuclear Theory @ U. of Washington

Concluding thoughts & perspective:

The EIC (with its precision and control) will profoundly impact our understanding of QCD:

- *The bridge between sea quark/gluons to Nuclei by* Imaging of quarks and gluons in 3D in nucleons and nuclei

EIC: Pushes the boundaries of our knowledge on Accelerator Science

- A magnet of the best and brightest of the accelerator scientists

EIC Users Group: eicug.org → Seeds for Detector Collaborations

Positive National Academy Science report (April/May 2018)

→Critical Decision process of the DOE to start → 1st collisions ~10 years

Today's meeting: exploratory : EIC science to other fields.

Exciting times for scientists, particularly young researchers, who will be in " the driver's seat at the EIC "