RHIC/AGS Users Group: Report from the DOE

Ken Hicks

Office of Nuclear Physics, DOE

June 10, 2021

A bit about my background:

- **My research background is from Medium-Energy Physics:**
  - Chair of the CLAS Collaboration from 2012-2014
  - I know how large collaborations and large detectors work
- **NSF Program Director in Experimental Nuclear Physics**
  - 2014-2016: low-energy, medium-energy, heavy ions, etc.
- **Secretary-Treasurer for the APS Division of Nuclear Physics**
  - Elected position: 2018-2021.
  - Helped organize the April and Fall meetings of the DNP
- **Joined the DOE, Office of Science, in January 2021**
  - Currently I am Program Manager for Heavy Ion Physics.

Thanks, Richard!

- **Richard Witt was DOE Program Manager for HI during 2018-2020.**
  - He was on detail to DOE from the Navy.
  - Due to technical difficulties, his detail renewal had unexpected delays
  - Once past the legal deadline, it could not be renewed.
  - Bottom line: <u>a paperwork issue</u>.
- **Clearly, the HI program needed a Program Manager.**
  - Tim Hallman asked me to take on this role.
- **The HI program has been well run over many years**
  - I will continue to strongly promote the HI program within DOE/ONP.
  - Both university support and national lab research are keys to success.

New Leadership Team at the DOE

Jennifer M. Granholm

Secretary, U.S. Department of Energy

David M. Turk

Deputy Secretary, U.S. Department of Energy

Geraldine Richmond

Under Secretary for Science and Energy

Asmeret Berhe

Director, Office of Science

Nuclear Physics*

FY 2019 – FY 2021

Nuclear Physics *(NP: FY 2019 - $690M; FY 2020 - $713M; FY 2021 - $713M)**

- Advances experimental and theoretical research to discover, explore, and understand all forms of nuclear matter to understand why matter takes on the specific forms observed in nature and how that knowledge can benefit society in the areas of energy, commerce, medicine, and national security.

	FY 2019 Enacted		FY 2020 Enacted		FY 2021 Enacted	
	Dollars	Percentage	Dollars	Percentage	Dollars	Percentage
Nuclear Physics						
Research	229,426	33.25%	223,300	31.32%	225,191	31.58%
Facility Operations	357,521	51.81%	399,380	56.01%	414,545	58.14%
Projects	99,500	14.42%	86,720	12.16%	71,480	10.03%
Other	3,553	0.51%	3,600	0.50%	1,784	0.25%
Total, Nuclear Physics	**690,000**	**100.00%**	**713,000**	**100.00%**	**713,000**	**100.00%**

* Includes funding for the DOE Isotope Program ($78M in FY 2021)

NP - FY 2022 President's Request

(Dollars in thousands)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Enacted	FY 2022 Request	FY 2022 Request vs FY 2021 Enacted		FY 2022 Request vs FY 2020 Enacted	
Nuclear Physics								
Medium Energy, Research	66,800	65,479	41,110	54,083	12,973	31.56%	-11,396	-17.40%
Medium Energy, Operations	117,390	122,110	117,201	142,709	25,508	21.76%	20,599	16.87%
Medium Energy Physics	**184,190**	**187,589**	**158,311**	**196,792**	**38,481**	**24.31%**	**9,203**	**4.91%**
Heavy Ion, Research	37,354	37,661	36,313	48,059	11,746	32.35%	10,398	27.61%
Heavy Ion, Operations	187,465	187,131	181,625	183,943	2,318	1.28%	-3,188	-1.70%
Heavy Ion, Projects	5,660	19,520	30,180	10,213	-19,967	-66.16%	-9,307	-47.68%
Heavy Ion Physics	**230,479**	**244,312**	**248,118**	**242,215**	**-5,903**	**-2.38%**	**-2,097**	**-0.86%**
Theory, Research	55,327	51,862	61,129	60,781	-348	-0.57%	8,919	17.20%
Nuclear Theory	**55,327**	**51,862**	**61,129**	**60,781**	**-348**	**-0.57%**	**8,919**	**17.20%**
Low Energy, Research	63,690	60,398	61,763	74,341	12,578	20.36%	13,943	23.09%
Low Energy, Operations	30,215	55,739	79,379	107,831	28,452	35.84%	52,092	93.46%
Low Energy, Projects	6,840	10,600	16,000	18,040	2,040	12.75%	7,440	70.19%
Low Energy Physics	**100,745**	**126,737**	**157,142**	**200,212**	**43,070**	**27.41%**	**73,475**	**57.97%**
Isotopes Operations	22,451	34,400	36,340	...	-36,340	-100.00%	-34,400	-100.00%
Isotope - Research	9,808	11,500	26,660	...	-26,660	-100.00%	-11,500	-100.00%
Isotopes, Projects	12,000	3,600	3,000	...	-3,000	-100.00%	-3,600	-100.00%
Isotope Production and Applications	**44,259**	**49,500**	**66,000**	**...**	**-66,000**	**-100.00%**	**-49,500**	**-100.00%**
Program Subtotal	615,000	660,000	690,700	700,000	9,300	1.35%	40,000	6.06%
14-SC-50 Facility for Rare Isotope Beams FRIB	**75,000**	**40,000**	**5,300**	**...**	**-5,300**	**-100.00%**	**-40,000**	**-100.00%**
20-SC-51 Stable Isotope Production and Research Center SIPRC, ORNL	**...**	**12,000**	**12,000**	**...**	**-12,000**	**-100.00%**	**-12,000**	**-100.00%**
20-SC-52 Electron Ion Collider EIC, BNL	**...**	**1,000**	**5,000**	**20,000**	**15,000**	**300.00%**	**19,000**	**1,900.00%**
Construction Subtotal	75,000	53,000	22,300	20,000	-2,300	-10.31%	-33,000	-62.26%
Total Nuclear Physics	690,000	713,000	713,000	720,000	7,000	0.98%	7,000	0.98%

NOTE: This HI increase is misleading, as other items are grouped in here (e.g. QIS and SBIR). Only 12% to HI core.

Comments on the FY22 President's Request

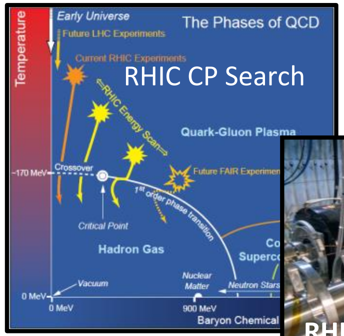
- **Research is prioritized**
  - Increases redress the reductions in recent years.
  - Almost back to FY19 levels of the research budget.
- **Operations at User facilities is prioritized**
  - All NP User Facilities operate at 90% or better of planned uptime.
  - FRIB starts in FY22 with its nominal full operation.
- **Projects (including EIC) continue, but below desired funding levels.**
  - Impacts of possible reduced funding are being drafted and sent along.
- **The President's Request is one step in the budget process.**
  - Congress will now deliberate and ultimately decide on the FY22 budget.
  - Given a traditional timeline, Congressional markups may be expected soon.

Nuclear Physics

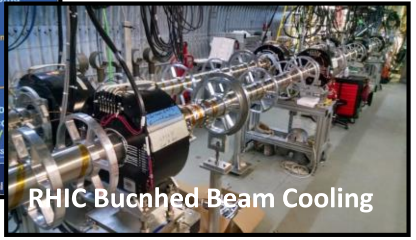
FY 2021 Highlights

Facility Operations:

- NP user facilities operated near or at full utilization.
    - RHIC operates for 3,130 hours (100% of maximum). RHIC completes the Beam Energy Scan II run utilizing bunched beam electron cooling.
    - CEBAF runs for 780 hours (41.3% of maximum) following completion of the CHL installation, with simultaneous 4-hall operation.
    - ATLAS operates for 5,350 hours (92.6% of maximum) and made significant progress towards a Multi-User Upgrade (MUU) and a new neutron-generator-based source for CARIBU
    - The Facility for Rare Isotope Beams (FRIB) recently accelerated an Argon-36 beam to 204 MeV/nucleon demonstrating the FRIB superconducting linear accelerator operates as intended



RHIC CP Search


RHIC Bucnhed Beam Cooling


CEBAF Hall B


CEBAF


FRIB


ATLAS

The Next Super High Current, Low Energy Microscope: The Facility for Rare Isotope Beams (>96% Complete)

FRIB will increase the number of known isotopes from ~2,000 to ~5,000 and will enable world-leading research on:

<u>Nuclear Structure</u>

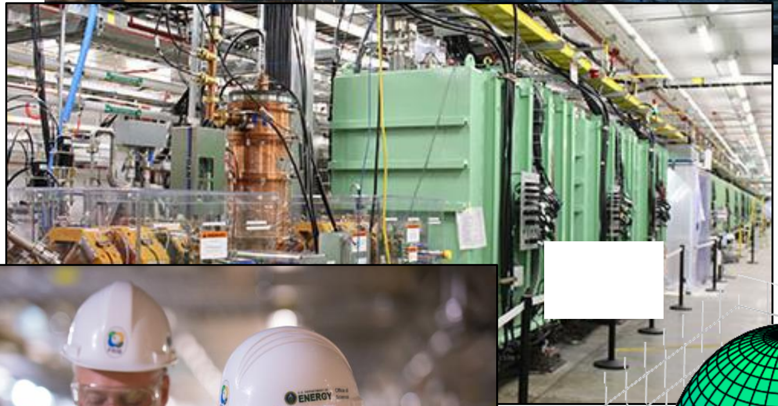
- The limits of existence for nuclei
- Nuclei that have neutron skins
- Synthesis of super heavy elements

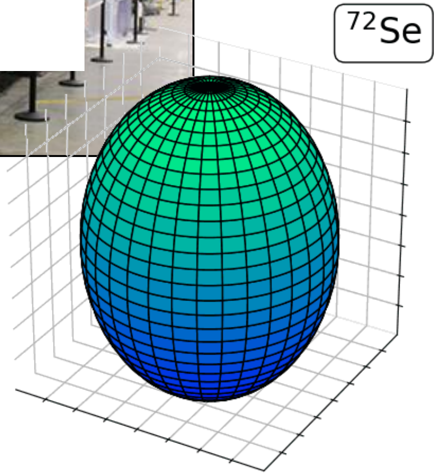
<u>Nuclear Astrophysics</u>

- The origin of the heavy elements and explosive nucleo-synthesis
- Composition of neutron star crusts

<u>Fundamental Symmetries</u>

- Tests of fundamental symmetries, Atomic EDMs, Weak Charge





FY 2021 Operating: $50M

82 proposals received requesting 9,800 hours. First PAC May,2021

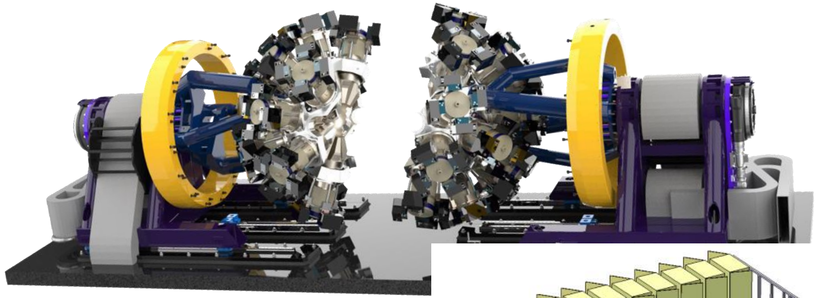
Nuclear Physics

FY 2021 Highlights

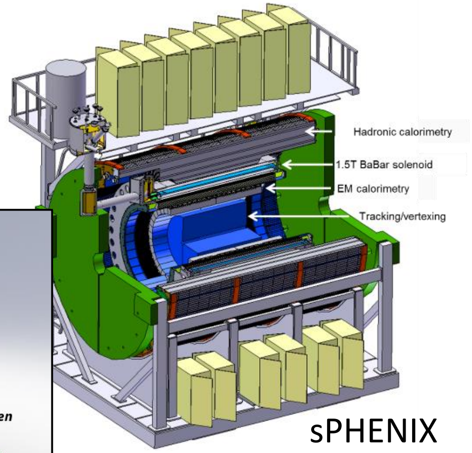
Projects: All MIEs and Construction

Projects are proceeding:

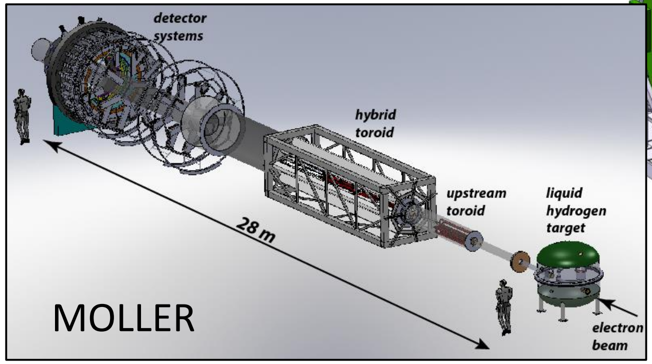
- GRETA procures additional detector modules. CD-2 ESAAB achieved Oct 2020; TPC \$58.3M; FY21 funding is \$6.6M, below planned baseline of \$12.5M
- sPHENIX continued detector component fabrication; TPC \$27M; FY21 \$5.5M consistent with baseline
- MOLLER TPC \$42M - \$61M; FY21 \$5M
- HRS received CD-1 in September 2020; TPC \$96.5M; FY21 \$3M



GRETA

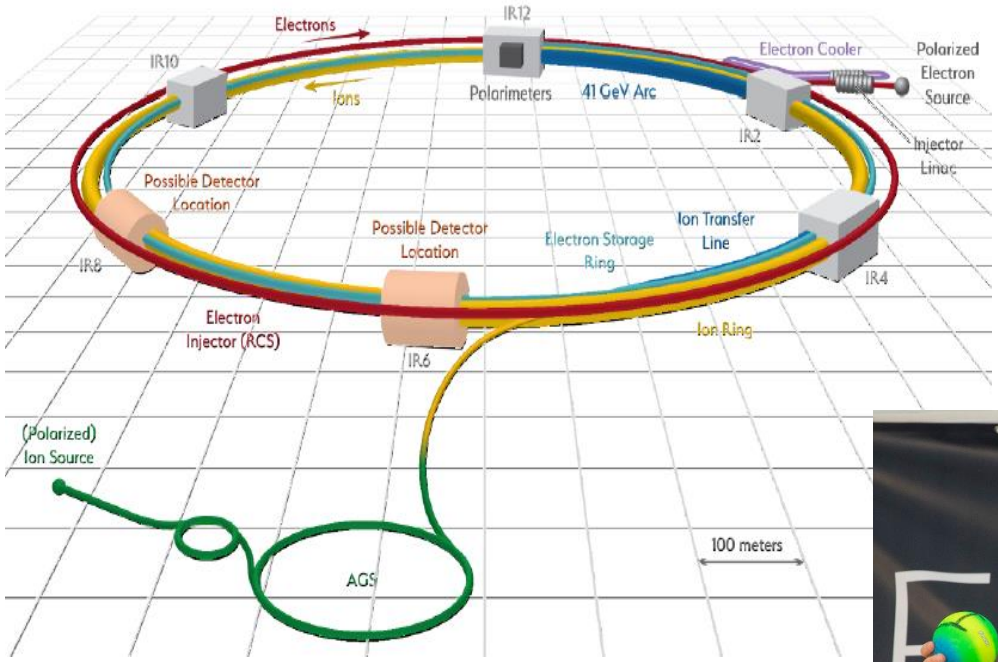


sPHENIX



sPHENIX Cradle (1 of 4) now mounted

EIC CD-0, Siting, Dedication in FY20; Projected CD-1 Q3 of FY 2021



The EIC will be located at BNL and with TJNAF as a major partner. The realization of the EIC will be accomplished over the next decade at an estimated cost between $1.7 and $2.8 billion.

Utilize existing operational hadron collider; add electron storage ring, cooling in existing RHIC tunnel and electron injector.

EIC scope includes the machine upgrade to RHIC asset and two interactions regions with one of the interaction regions outfitted with a major detector. Working towards CD-1 in Q3 FY 2021

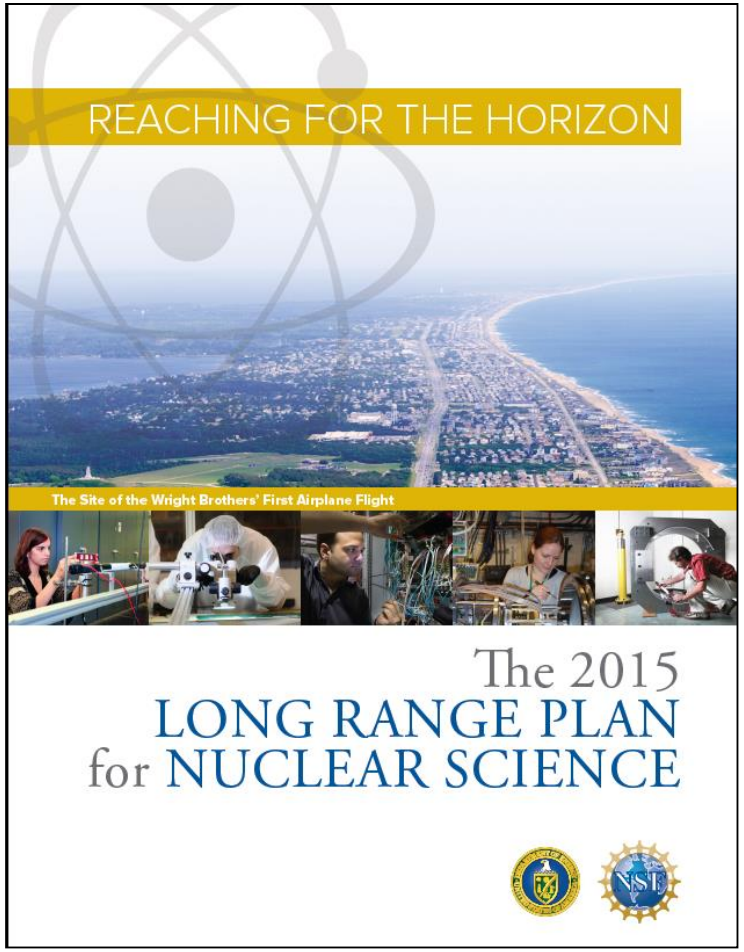
EIC Dedication September 18, 2020

<u>The EIC will be a game-changing resource for the international nuclear physics community.</u> *DOE looks forward to engaging with the international community and the international funding agencies about potential collaborations and contributions to the EIC effort, in nuclear, accelerator and computer science.*

The 2015 Long Range Plan for Nuclear Science

Recommendations:

1. Capitalize on investments made to maintain U.S. leadership in nuclear science.
2. Develop and deploy a U.S.-led ton-scale neutrino-less double beta decay experiment.
3. Construct a high-energy high-luminosity polarized electron-ion collider (EIC) as the highest priority for new construction following the completion of FRIB.
4. Increase investment in small-scale and mid-scale projects and initiatives that enable forefront research at universities and laboratories.



NP continues to execute on the 2015 LRP Vision

Upcoming Portfolio Review

Three Front-Runner Technologies

- Scintillating bolometry (**CUPID**, ^{100}Mo enriched Li_2Mo_4 crystals)
- Enriched ^{76}Ge crystals (**LEGEND-1000**, drifted charge, point contact detectors)
- Liquid Xenon TPC (**nEXO**, light via APD, drifted ionization)

Background constraints are exceptionally challenging < 1 count/ton of material/year

Also, must choose between possible sites

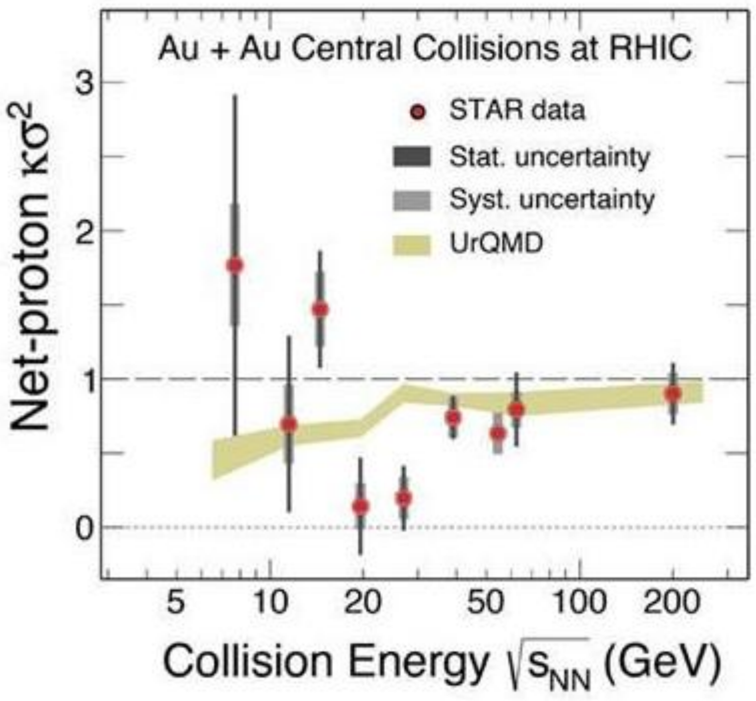
- SURF (SD)
- SnoLab (Canada)
- Gran Sasso (Italy)

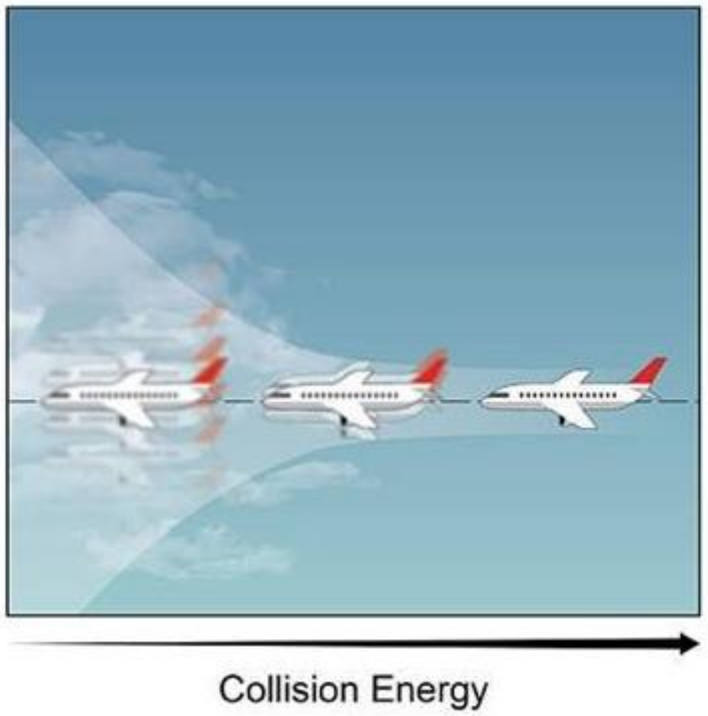
Challenges for the FY22 budget

- **During FY22, NP will be running 4 large facilities at >90% utilization**
  - RHIC, JLAB, FRIB and ATLAS
  - FRIB was Project funding, now Operations
- **Projects will be running "full steam ahead" within available funding**
  - sPHENIX being assembled.
  - $0\nu\beta\beta$ ton-scale on the horizon, plus other fundamental symmetry projects.
  - EIC R&D moving forward.
  - JLAB Moller detector starting construction.
  - A variety of project proposals in the works: SoLID (JLab), CMS-MTD (LHC), etc.
- **As always, there will be hard decisions in balancing the funding profiles**
  - Could an infrastructure bill help? Will Congress pass this bill?

NP Highlights: 1) Signs of "Turbulence" in Au+Au Collisions

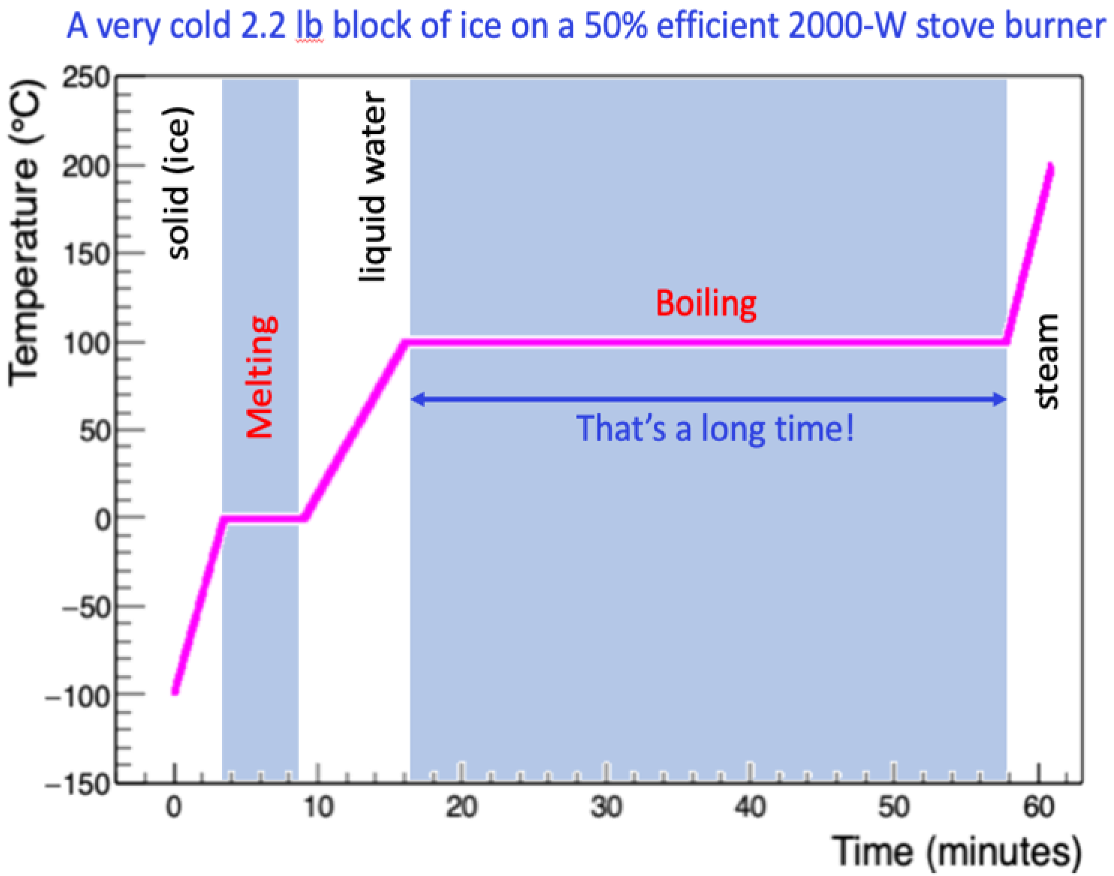
https://www.energy.gov/science/np/articles/signs-turbulence-collisions-melt-gold-ions

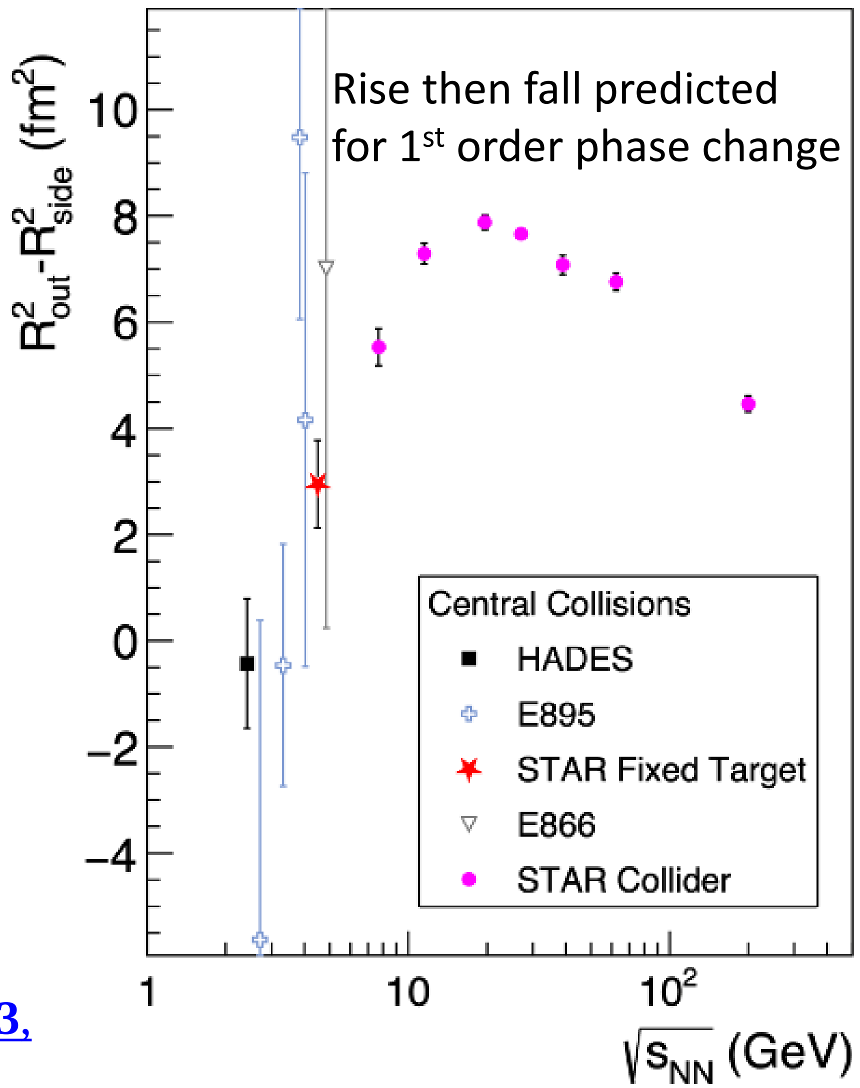




Adam, J., et al. (STAR Collaboration), Nonmonotonic energy dependence of net-proton number fluctuations. *Physical Review Letters* **126**, 092301 (2021). [DOI: 10.1103/PhysRevLett.126.092301]

BNL Highlights: Flow and interferometry results from Au+Au collisions

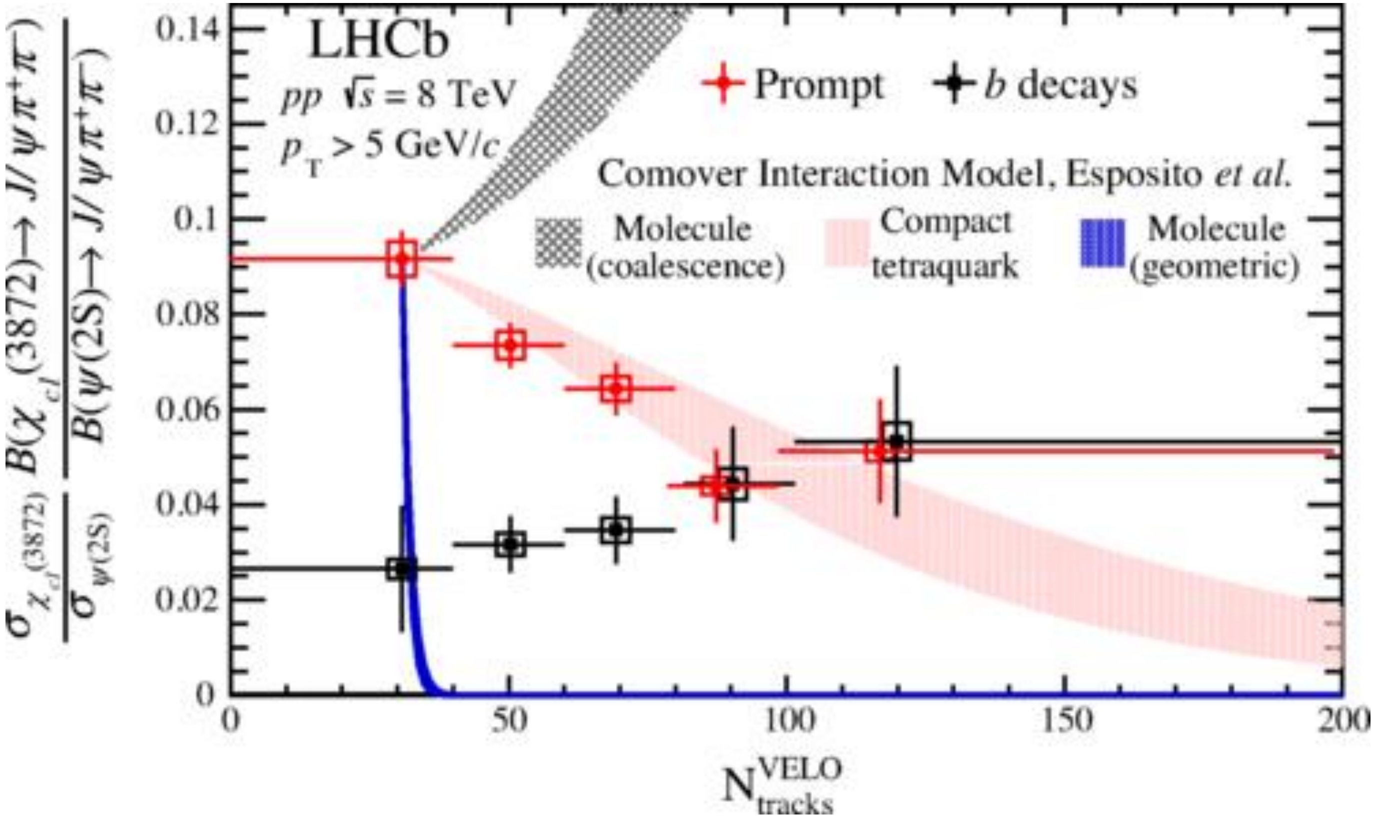


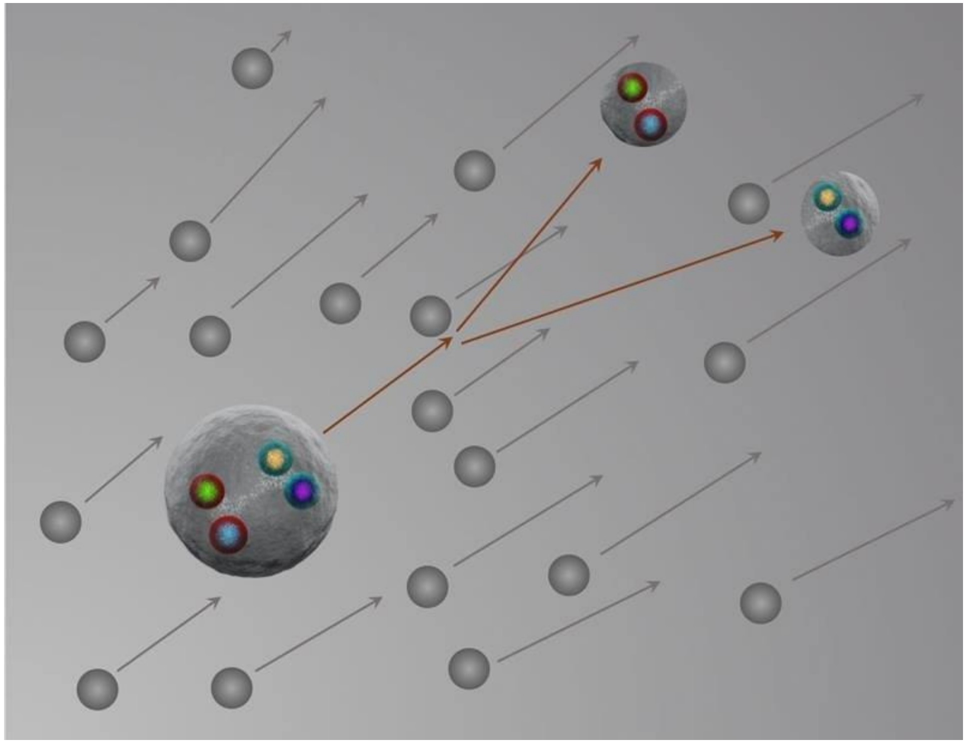


The STAR Collaboration published "Flow and interferometry results from Au+Au collisions at √sNN = 4.5 GeV" in [Physical Review C **103**, 034908](https://doi.org/10.1103/PhysRevC.103.034908).

NP Highlights: 2) Structure of Exotic (Tetraquark) Mesons

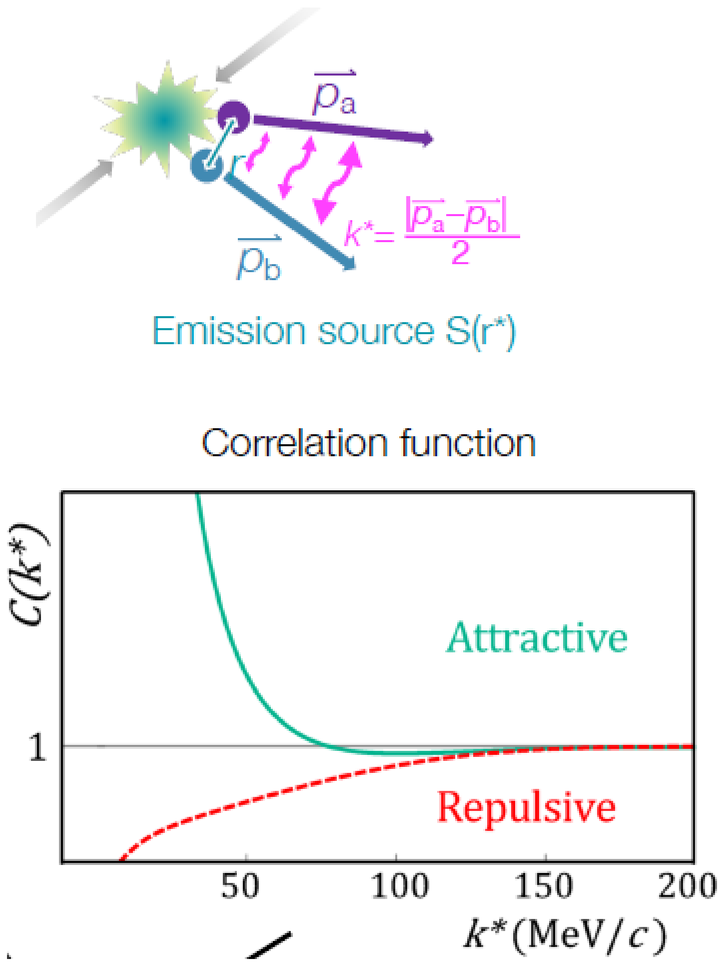
https://www.energy.gov/science/np/articles/new-technique-studies-structure-exotic-hadrons

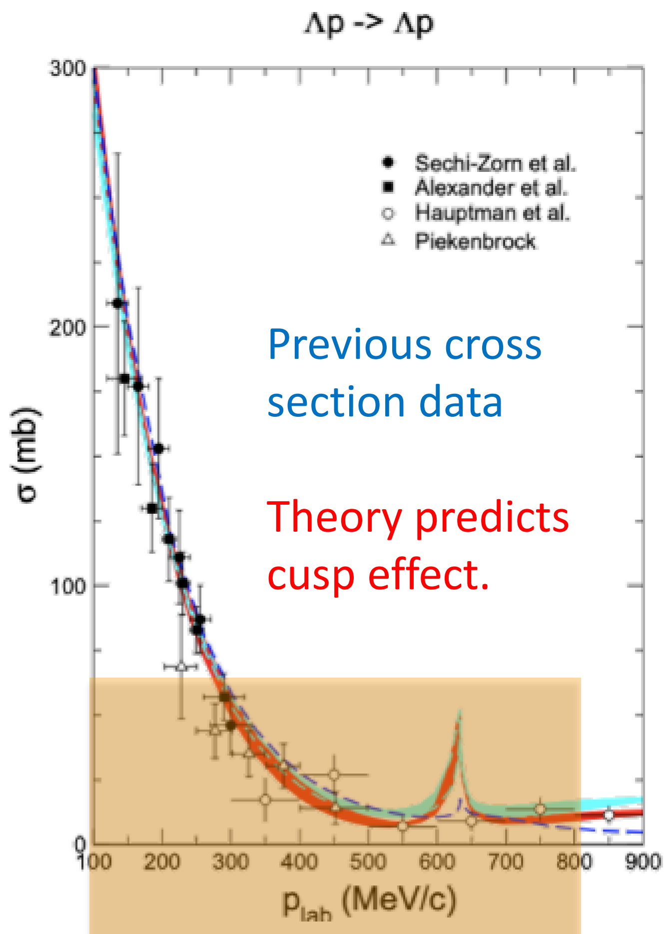


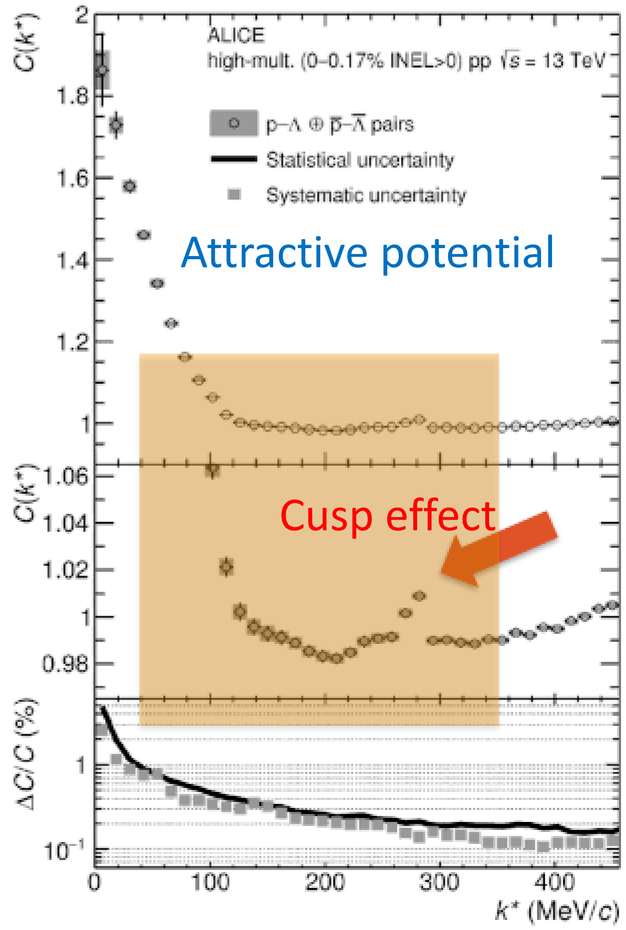


Aaij, R., *et al.*(LHCb Collaboration), Observation of Multiplicity Dependent Prompt χc1(3872) and ψ(2S) Production in pp Collisions, *Physics Review Letters* 126, 092001 (2021). [DOI: 10.1103/PhysRevLett.126.092001]

SQM2021 Highlight: Hyperon-nucleon femtoscopy at ALICE







ALICE Coll. arXiv:2104.04427

Summary

- **New Leadership Team in place at the DOE**
  - Also many new faces at the Office of Nuclear Physics
- **FY22 budget: President's Request released last week**
  - Now we wait for Congressional markups
- **NP is a vibrant field, with many new projects and ideas**
  - EIC is on the horizon; let's start planning for it now.
  - No lack of good ideas to pursue if funding allows!
  - "A rising tide floats all boats"
- **Lots of new results from the HI community**
  - RHIC accelerator is performing incredibly well.
  - New data from BES and Isobar runs bring exciting prospects.
  - Femtoscopy and other new techniques bring discovery potential.

Backup Slides

Planned NP Pilot on Diversity: Varied Expertise and Backgrounds

Mentoring, Diversity & Inclusion, MSI/HBCU, Undergrad Research, Nuclear Physics

Tan Ahn *(Notre Dame, Nuclear Experiment, Experienced Undergrad Mentor)*
Stephon Alexander *(Brown, Cosmology Theory, Author, National Society of Black Physicists)*
Ketevi Assamagan *(BNL ATLAS Experiment, NSBP, Outstanding Mentor Award, co-founder of African School of Physics)*
Brian Beckford *(DOE, HEP Intensity Frontier Program Manager, AIP Team-up Task Force)*
Tommy Boykin II *(UMD, Condensed Matter Exp., APS Bridge Program Grad, Inclusive Grad. Ed. Network Advisory Board)*
Jason Detwiler *(UW Nuclear Experiment, Early Career Award, Physics Dept. Mentoring Award, Breakthrough Prize)*
Paul DeYoung *(Hope College, APS Outstanding Research and Mentoring at an Undergrad Inst.)*
Evangeline Downie *(GWU, Nuclear Experiment, Muse, Committee on the Status of Women in Physics)*
Renee Fatemi *(UK, Nuclear Experiment, STAR, g-2, Excellent Undergraduate Research Mentor Award)*
Roy Lacey *(Stony Brook, Chemistry Dept., Nuclear Experiment, STAR, AAPT, NSTA)*
Dina Myers-Stroud *(Executive Director Fisk-Vanderbilt Bridge Program)*
Jesus Pando *(DePaul U, Nuclear Experiment, National Society of Hispanic Physicists, SACNAS)*
Diana Parno *(Carnegie Mellon, Nuclear Experiment, Organizer LGBT+ Physicists advocacy group, Best Practices Guide)*
Carol Scarlett *(Florida A&M, Nuclear Theory, Axion Tech LLC.)*
Yolanda Small *(York College/CUNY, Theoretical Chemist, Chair Undergraduate Research Symposium)*
Daniel Tapia Takaki *(Kansas, Nuclear Experiment, ALICE and CMS Collaborations)*

Nuclear Physics

FY 2020 Highlights

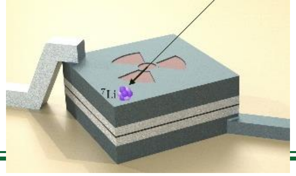
Research:

In FY 2020 NP supported over 263 financial assistance awards (including 123 new, renewal, or supplemental awards) and research at 10 national labs, supporting the goal of discovering, exploring, and understanding all forms of nuclear matter.

- ***A Landmark Advance on the Road to Quantum Computing***— Nuclear physicists from MIT, PNNL discover that ionizing radiation from environmental radioactive materials, contaminants and cosmic rays can limit superconducting qubits to coherence times in the millisecond regime—far too short for practical quantum computing. This indicates the need to mitigate such effects.
- ***Computing the structure of Nuclei—Faster is a lot Better*** Nuclear physicists at Oak Ridge National Laboratory have developed a new method that accurately emulates the quantum properties of atomic nuclei within a few milliseconds of computing. After an initial training stage using the Oak Ridge Leadership Computing Facility, millions of predictions can now be generated in a couple of hours on a standard laptop using statistical methods.
- ***Mass Limits on the Elusive Neutrino Cut in Half***— Nuclear physicists working on the KATRIN experiment (UW, UNC, MIT, CMU, LBNL) cut the upper bound on the neutrino mass in half, demonstrating that the wispy neutrino mass is no more than the energy equivalent of one electron volt (eV). As the existence of neutrino mass contradicts a prediction of the Standard Model of particle physics, knowing its value opens a window to discover new physics. Over the next 5 years, KATRIN is expected to further improve its sensitivity by a factor of five.

Nuclear Physics

FY 2021 Highlights



Research:

- ***Search for New Particles in Nuclear Decays Gets a Boost from Quantum Sensors*** — A team of nuclear physicists at Lawrence Livermore National Laboratory and Colorado School of Mines adapted quantum sensors to search for exotic particles and have already set world leading limits. This technique has achieved ten times better sensitivity at a fraction of the cost.
- ***Nickel-64: A Shape Shifting Nucleus***— Results from four experiments at nuclear facilities around the world, including ANL and TUNL, have established so-called triple shape coexistence in the stable nuclei of nickel-64. This triple shape coexistence indicates profound changes in the way protons and neutrons can arrange themselves,—even in the same stable nucleus—depending on how "excited" the nucleus is.
- ***Unraveling Cosmic Mysteries*: **Nuclear physicists from Los Alamos National Laboratory in collaboration with other scientists, including LIGO scientists, have combined state-of-the-art nuclear-theory computations with multi-messenger observations of neutron stars to obtain the most stringent constraints on the dense-matter equation of state and measurement of the Hubble constant.
- ***Accelerating Discovery with AI Image classification technology*** Nuclear physicists (LBNL, ORNL, PNNL, MSU, U of Maryland, Catholic U., JLab, etc) have used AI image classification technology to characterize the quality of thousands of plot images two orders of magnitude faster than possible by hand
- ***Critical beam studies for the EIC initiated* -** The proof of principal Coherent Electron Cooling (CEC) accelerator experiment at RHIC is taking data critical to demonstrate cooling of ion beams essential for achieving and sustaining the high luminosities planned for the Electron Ion Collider. The electron beam for CeC is generated by an advanced superconducting radiofrequency photocathode gun with the electrons accelerated to velocities that exactly match that of the ion beam that needs to be cooled