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
  • 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: a paperwork issue.

• 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 (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.

<table>
<thead>
<tr>
<th></th>
<th>FY 2019 Enacted</th>
<th>FY 2020 Enacted</th>
<th>FY 2021 Enacted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dollars</td>
<td>Percentage</td>
<td>Dollars</td>
</tr>
<tr>
<td>Research</td>
<td>229,426</td>
<td>33.25%</td>
<td>223,300</td>
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<tr>
<td>Facility Operations</td>
<td>357,521</td>
<td>51.81%</td>
<td>399,380</td>
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<tr>
<td>Projects</td>
<td>99,500</td>
<td>14.42%</td>
<td>86,720</td>
</tr>
<tr>
<td>Other</td>
<td>3,553</td>
<td>0.51%</td>
<td>3,600</td>
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<tr>
<td>Total, Nuclear Physics</td>
<td>690,000</td>
<td>100.00%</td>
<td>713,000</td>
</tr>
</tbody>
</table>

* Includes funding for the DOE Isotope Program ($78M in FY 2021)
<table>
<thead>
<tr>
<th>Nuclear Physics</th>
<th>FY 2019</th>
<th>FY 2020</th>
<th>FY 2021</th>
<th>FY 2022</th>
<th>FY 2022 Request vs FY 2021 Enacted</th>
<th>FY 2022 Request vs FY 2020 Enacted</th>
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<tbody>
<tr>
<td>Medium Energy, Research</td>
<td>66,800</td>
<td>65,479</td>
<td>41,110</td>
<td>54,083</td>
<td>12,073</td>
<td>31.56%</td>
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<td>117,201</td>
<td>142,708</td>
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<td>Medium Energy Physics</td>
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<td>196,792</td>
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<tr>
<td>Heavy Ion, Research</td>
<td>37,354</td>
<td>37,661</td>
<td>36,313</td>
<td>46,059</td>
<td>11,746</td>
<td>32.35%</td>
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<tr>
<td>Heavy Ion, Operations</td>
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<td>19,520</td>
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<td>Heavy Ion Physics</td>
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<tr>
<td>Theory, Research</td>
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<td>51,662</td>
<td>61,129</td>
<td>60,781</td>
<td>-340</td>
<td>-0.57%</td>
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<tr>
<td>Nuclear Theory</td>
<td>55,327</td>
<td>51,862</td>
<td>61,129</td>
<td>60,781</td>
<td>-348</td>
<td>-0.57%</td>
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<tr>
<td>Low Energy, Research</td>
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<td>60,398</td>
<td>61,763</td>
<td>74,341</td>
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<td>Low Energy, Operations</td>
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<td>Low Energy, Projects</td>
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<td>10,600</td>
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<td>16,040</td>
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<td>36,340</td>
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<td>-100.00%</td>
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<tr>
<td>Isotope - Research</td>
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<td>11,500</td>
<td>26,660</td>
<td>26,660</td>
<td>-26,660</td>
<td>-100.00%</td>
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<tr>
<td>Isotopes, Projects</td>
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<td>3,600</td>
<td>3,000</td>
<td>3,000</td>
<td>-3,000</td>
<td>-100.00%</td>
</tr>
<tr>
<td>Isotope Production and Applications</td>
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<td>66,000</td>
<td>66,000</td>
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<tr>
<td>Program Subtotal</td>
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<td>660,000</td>
<td>690,700</td>
<td>700,000</td>
<td>9,300</td>
<td>1.35%</td>
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<tr>
<td>14-SC-50 Facility for Rare Isotope Beams FRIB</td>
<td>75,000</td>
<td>40,600</td>
<td>5,300</td>
<td>5,300</td>
<td>-5,300</td>
<td>-100.00%</td>
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<tr>
<td>20-SC-51 Stable Isotope Production and Research Center SPRC, ORNL</td>
<td>...</td>
<td>12,000</td>
<td>12,000</td>
<td>12,000</td>
<td>-12,000</td>
<td>-100.00%</td>
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<td>20-SC-52 Electron Ion Collider EIC, BNL</td>
<td>...</td>
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<td>5,000</td>
<td>20,000</td>
<td>15,000</td>
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<tr>
<td>Construction Subtotal</td>
<td>75,000</td>
<td>53,000</td>
<td>22,300</td>
<td>20,000</td>
<td>-2,300</td>
<td>-10.31%</td>
</tr>
<tr>
<td>Total Nuclear Physics</td>
<td>690,000</td>
<td>713,000</td>
<td>713,000</td>
<td>720,000</td>
<td>7,000</td>
<td>0.98%</td>
</tr>
</tbody>
</table>

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

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

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

**Fundamental Symmetries**
- Tests of fundamental symmetries, Atomic EDMs, Weak Charge

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

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

FY 2021 Operating: $50M
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
sPHENIX Cradle (1 of 4) now mounted
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

The EIC will be a game-changing resource for the international nuclear physics community. 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.
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$_2$Mo$_4$ 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.
  – 0νββ 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


The STAR Collaboration published “Flow and interferometry results from Au+Au collisions at $\sqrt{s_{NN}} = 4.5$ GeV” in Physical Review C 103, 034908.
SQM2021 Highlight: Hyperon-nucleon femtoscopy at ALICE

Previous cross section data
Theory predicts cusp effect.

Attractive potential
Cusp effect

Correlation function

Attractive
Repulsive
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)
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.
Research:

FY 2021 Highlights

- **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.