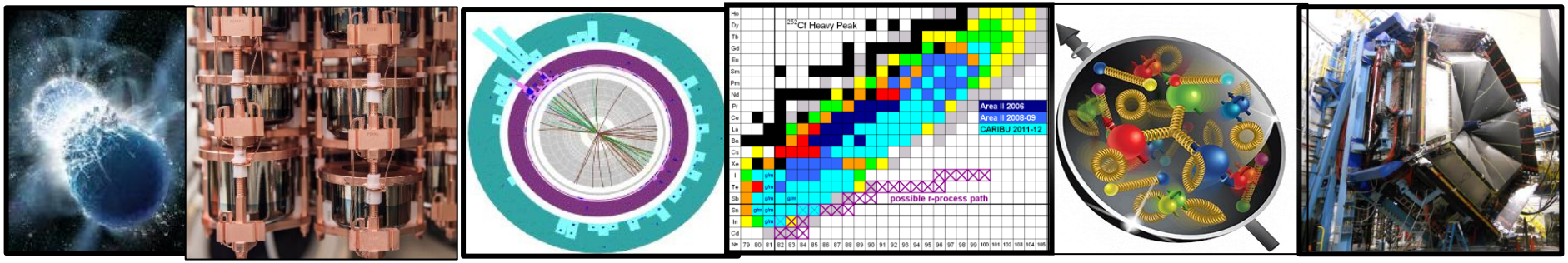
U.S. DEPARTMENT OF ENERGY | Office of Science

Perspectives from DOE Nuclear Physics

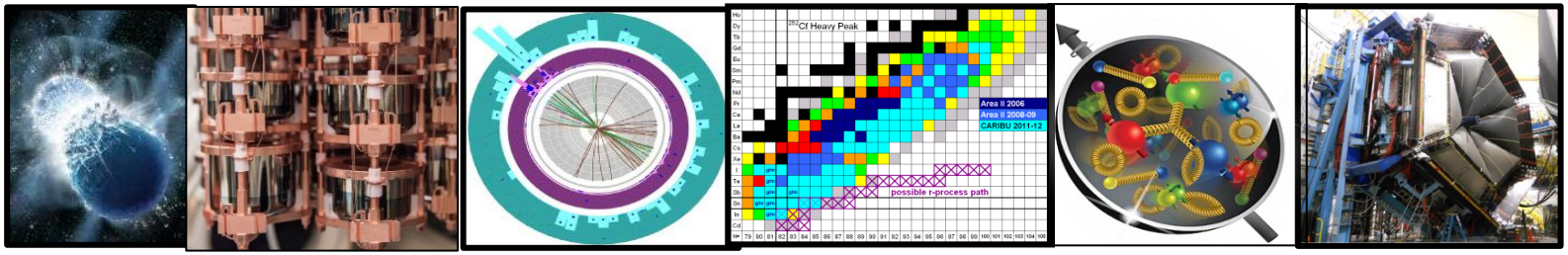
Nuclear Science Advisory Committee Meeting
November 16, 2021

Dr. Timothy J. Hallman
Associate Director of the Office of Science
for Nuclear Physics



Nuclear Physics
Discovering, exploring, and understanding all forms of nuclear matter

- Understanding why matter takes on the specific forms observed in nature and how that knowledge can benefit energy, commerce, medicine, and national security, by discovering:
  - How mass is created from energy in the interior of the proton using the future Electron-Ion Collider?
  - What are the properties of the novel quark-gluon plasma discovered at RHIC?
  - What is the mechanism underlying the confinement of quarks and gluons via CEBAF and RHIC?
  - The search for new exotic particles and anomalous violations of nature's symmetries at CEBAF
  - The limits of nuclear existence? How are heavy elements made in the cosmos via FRIB and ATLAS?
  - Is the neutrino its own anti-particle? Do the neutron's precise properties point to new physics?
  - The nature of the strong force in many-body systems via SciDAC?
  - Advanced Nuclear Data for Space, Energy, and Research.



Budget Matters

Summary of 2022 President's Request Changes Relative to FY 2021 Enacted

FY 2021 Enacted	FY 2022 President's Request
Core Research reduced 3.75% from FY20 Enacted (including COL, this is a 5.6% cut from constant effort in FY20). New ECA awards are made.	**Core research** in **Medium Energy, Heavy Ions, and Theory** is increased by 12% from FY21 Enacted. (After accounting for COL, this represents a ~10% increase over FY21 Enacted,.) **The Fundamental Symmetries and Nuclear Structure and Nuclear Astrophysics** portfolios are increased by 15% over FY21 Enacted.
LHC M&O commitments are met.	**LHC M&O** commitments are met.
FRIB Research flat with FY2020 and below the planned level.	**FRIB Research** is increased, but still below the planned level.
nEDM supported below planned profile.	**nEDM** supported significantly below planned profile, possibly impacting schedule.
SciDAC commitment are met.	**SciDAC** funding is increased to support SciDAC-5 (+$600k).
Nuclear Data slightly increased over FY20 Enacted.	**Nuclear Data** increased $3.5M from FY21 Enacted to support the expansion of experimental efforts.
Accelerator R&D subject to the 3.75% research reduction.	**Accelerator R&D** increased ~$1M over FY21 Enacted level.
QIS at $9.5M.	**QIS increased to** $10.5M.
NP ML/AI Initiative begins with $4M.	**AI/ML Initiative support flat** with FY21 Enacted ($4M).

Summary of 2022 President's Request Changes Relative to FY 2021 Enacted

FY 2021 Enacted	FY 2022 President's Request
	Four new initiatives are supported: • Reaching a New Energy Sciences Workforce (RENEW) - $3M • Accelerator Science and Technology - $2M • Integrated Computational & Data Infrastructure - $1M • Microelectronics - $500k
Facility operations funding reduced by 3.75%. - **RHIC** operates 24 weeks (100 % maximum) - **CEBAF** operates 7 weeks (41 % maximum) - **ATLAS** operates 39 weeks (93 % optimal)	**Facilities operations supported at >90% of optimal.** - **RHIC** operates 18 weeks (90 % maximum) - **CEBAF** operates 31 weeks (90 % optimal) - **ATLAS** operates 39 weeks (93 % optimal) - **FRIB** operates 12 weeks (100% of optimal)
FRIB operations supported at $50M.	**FRIB Operations increased,** but still slightly below planned levels ($77M in PR vs $82M planned)
FRIB construction at baselined $5.3M in final funding year.	
EIC construction at TEC of $5M and OPC of $24.65M	**EIC construction** at TEC of $20M and OPC of $10M
Major Items of Equipment: - **GRETA** reduced below planned levels ($6.6M) - **sPHENIX** at planned baseline level ($5.53M) - **MOLLER** at $5M TEC - **TSNLDBD** at $1.4M TEC - **HRS** at $3M TEC	**Ongoing Major Item of Equipment:** - **GRETA** below planned levels ($6.6M) - **sPHENIX** at baseline level ($0.2M) - **MOLLER** at $7M TEC - **TSNLDBD** at $1.44M TEC - **HRS** at $3M TEC
Isotope Program embedded within NP budget	**Isotope Program no longer embedded within NP budget**

Nuclear Physics – FY 2022 Highlights (cont.)
Discovering, exploring, and understanding all forms of nuclear matter

Research

- Funding is strengthened at national labs and universities conducting research in relativistic nuclear collisions, hadron physics, nuclear structure and nuclear astrophysics, fundamental symmetries and nuclear theory.

- NP participates in six crosscutting scientific initiatives:
  - **Accelerator Science and Technology Initiative** – strengthening U.S. supply chain robustness to steward key technologies such as electron ion source developments and advanced approaches in SRF technology
  - **Artificial Intelligence and Machine Learning** – R&D for automated optimization of accelerator performance and operation as well as algorithm development for data-analytics-driven discovery.
  - **Integrated Computational & Data Infrastructure** – Cross-cutting cloud solutions to Big Data storage challenges in Nuclear Physics
  - **Microelectronics** – R&D on detector materials, devices, advances in front-end electronics, and integrated sensor/processor architectures
  - **Quantum Information Science** – leveraging discovery opportunities in sensing, simulation, and computing at the intersections of nuclear physics and QIS
  - **Reaching a New Energy Sciences Workforce (RENEW)** - advancing a diverse, equitable, and inclusive research community

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%**

	FY 2020	FY 2021	DELTA
Total, NP FY21 – FY20 (non-isotope)	**651,500**	**635,000**	**-16,500**
FY21 NP Appropriation	**713,000**	**713,000**	

FY 22 House Mark $665; Senate Mark $744M

General Outlook

- The budget uncertainty continues.
- We need to stay focused and continue to deliver important outcomes for the nation.
- Delivering exciting discoveries, important scientific knowledge, technological advances, and workforce training is what we do.
- We need to keep up the good work!

A Long Tradition of Partnership and Stewardship

There has been a long tradition in Nuclear Science of effective partnership between the community and the agencies in charting compelling scientific visions for the future of nuclear science.

Key factors:

1) Informed scientific knowledge as the basis for recommendations and next steps
2) Mutual respect among scientific sub-disciplines
3) Commitment to the greater good of nuclear science as a discipline
4) Meticulously level playing field leading to respect for process and outcomes
5) Deep appreciation for the wisdom of Ben Franklin

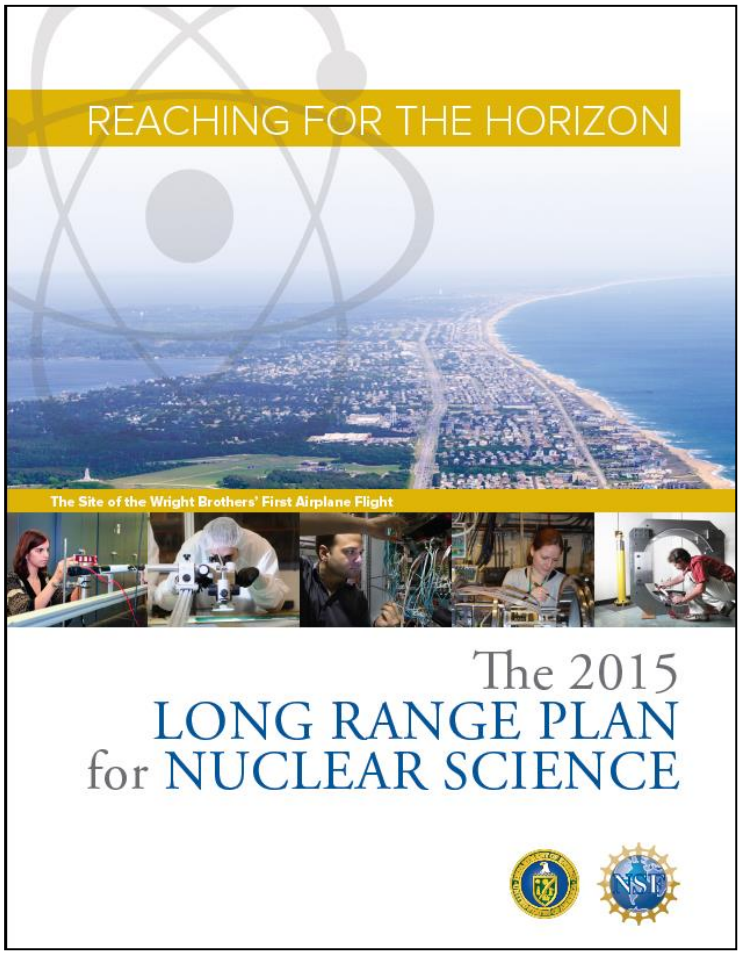
Staying united we can accomplish great things together

Division will setback the entire field and is the last thing needed right now

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. ✓



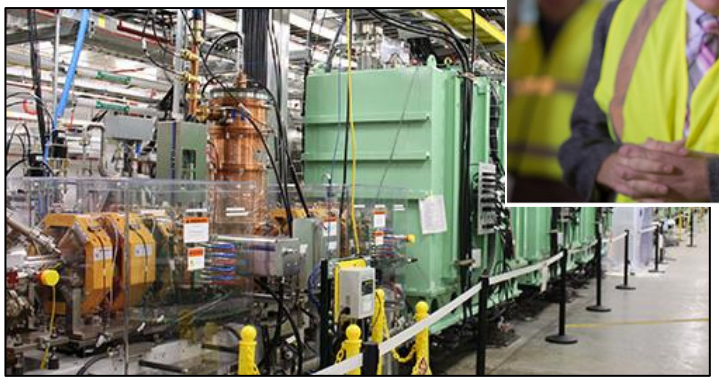
A New LRP is Warranted Once the Smoke Clears on FY 2022

$0\nu\beta\beta$ Progression

- Ongoing interactions with potential international collaborators to introduce U.S. perspectives, hear European perspectives, and suggest a global approach to investment in DBD science
- DBD Portfolio Review was held July 13-16, 2021 to inform U.S. investment strategy. Instructions published by April 15, 2021.
- North American – European Summit was held September 29 to October 1, 2021. Common ground exists for an international approach to DBD investment and the mounting of two ton-scale experiments in Norther America and Europe respectively.
- Funding for ton-scale $0\nu\beta\beta$ is going to be challenging

The Fourth, Newest Microscope: Facility for Rare Isotope Beams (FRIB)

- FRIB issued a call for proposals to its 1500 member user group.
- 82 proposals received from 130 institutions in 30 countries requesting 9,784 hours of beam time
- FRIB Program Advisory Committee Meeting held in May 2021.
- First science in spring of 2022



World Leadership in Nuclear Structure & Nuclear Astrophysics Research

Exciting and Challenging News:

EIC CD-1 is Approved, June 29, 2021

Preliminary Costs at CD1

WBS	Description	WBS Manager	Total M$	DOE M$
6	**Electron-Ion Collider**	**J. Yeck**	**$ 1,848**	**$ 1,606**
6.01	Project Management	D. Hatton	$ 103	$ 103
6.02	Accelerator Dev & R&D	M. Blaskiewicz	$ 70	$ 70
6.03	Electron Injector	V. Ranjbar	$ 195	$ 171
6.04	Electron Storage Ring	C. Montag	$ 310	$ 285
6.05	Hadron Ring	V. Ptitsyn	$ 199	$ 199
6.06	Interaction Regions & Detector Interface	G. McIntyre	$ 195	$ 195
6.07	Accelerator Support Systems	J. Tuozzolo	$ 230	$ 230
6.08	Infrastructure	C. Folz	$ 210	$ 110
6.09	Pre-Operations	W. Fischer	$ 80	$ 80
6.10	EIC Detector	R. Ent	$ 255	$ 162

(Costs do not include contingency)

$ ~90M anticipated detector in-kind (~30%)
$ ~50M anticipated accelerator in-kind (~5%)
$100M grant from New York State

- Funding guidance revised after OPA & ICR CD-1 Reviews
- Preliminary Point Estimate = $2.249B (DOE only); $2.389B (total)
- Contingency = $643M (40% of DOE TPC)

Estimated cost-to-go to CD-2 is $123.3M
Current outlook suggests that the planned CD-2 date of Q2 FY 2023 may need to be stretched

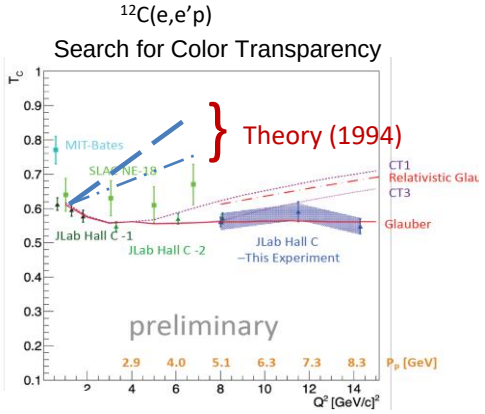
12 GeV Science Continues Successfully

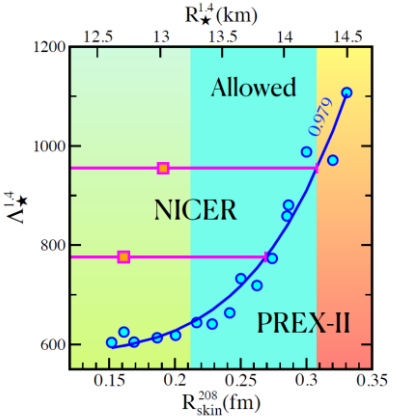
- **Hall A:**
  - Tritium family of experiments – all 4 complete!
  - PREX-II published in PRL, CREX complete
  - SBS installed for FY22 run

- **Hall B:**
  - First phase of CLAS12 Run Groups A & B complete
  - PRad results published in Nature
  - Bonus experiment completed phase 1
  - Heavy Photon Search started production run for FY22

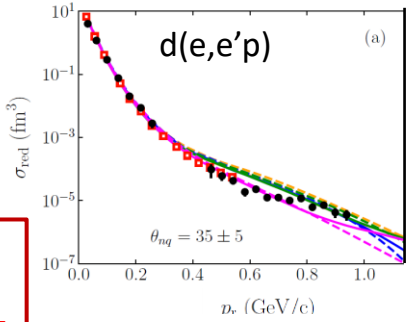
- **Hall C:**
  - Deuteron electrodisintegration published - PRL
  - Color Transparency published - PRL
  - Search for LHCb pentaquark complete
  - A_1^n running complete, d_2^n partially completed

- **Hall D:**
  - GlueX phase I complete
  - Threshold J/y published in PRL
  - DIRC enhancement complete
  - Phase II started
  - Search for dark sector particles submitted

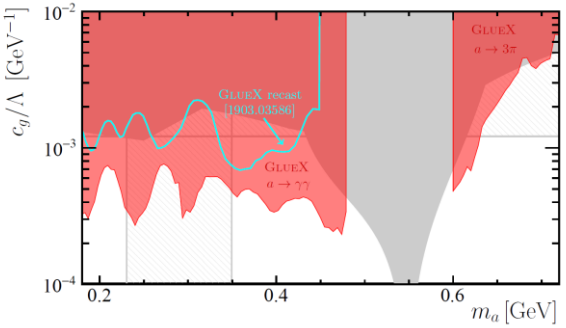


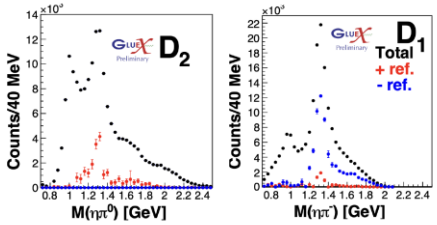


Observation of Beam Spin Asymmetries in the Process ep -> e'pi+pi- with CLAS12 → PRL



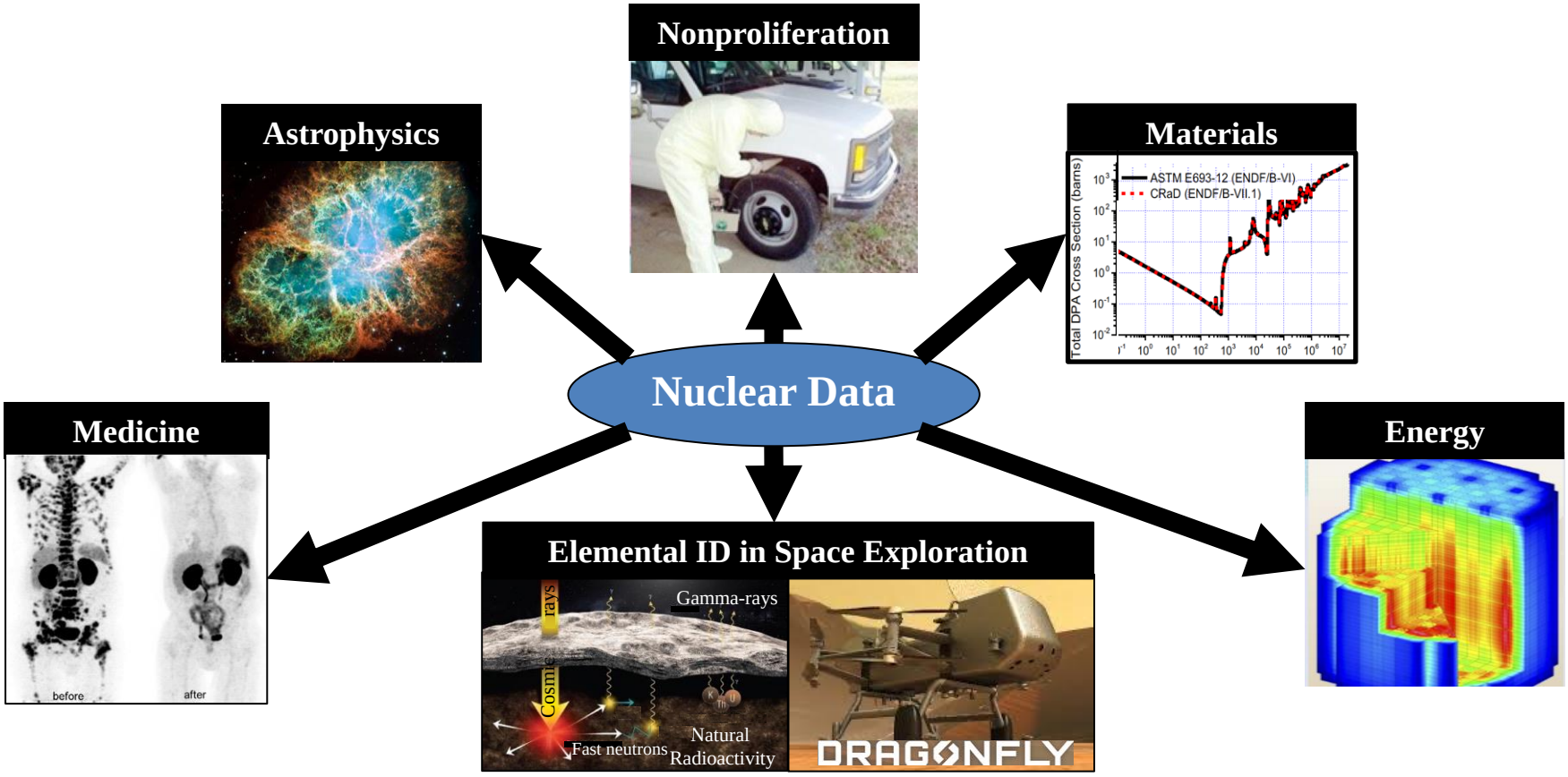
First multidimensional, high precision measurements of semi-inclusive pi+ beam single spin asymmetries from the proton → PRL





New & Traditional Frontiers Requiring Accurate Nuclear Data

Many types of nuclear data are "crosscutting" to numerous applications



NP Leads a Nuclear Data Interagency Working Group (NDIAWG) that has published 4 FOAs

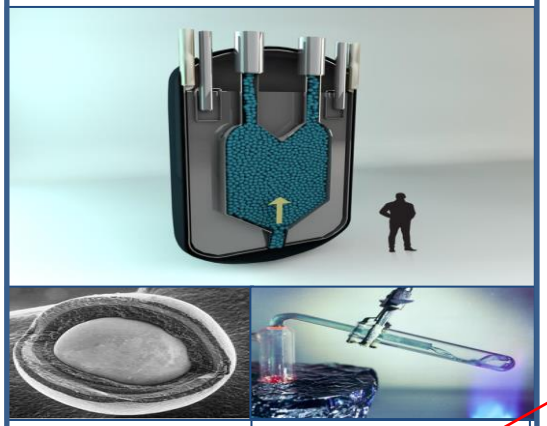
Nuclear Data In Support of Clean Energy Goals

Next generation reactors use faster neutrons, different fuels, and coolants to achieve greater safety and modularity

$$k = \eta f p \epsilon P_{FNL} P_{TNL}$$

- η: neutron multiplication factor
- f: Thermal fision factor
- p: Thermal utilization factor
- ϵ: Resonance escape factor
- P_{FNL}: Fast Non – leakage factor
- P_{TNL}: Thermal Non – leakage factor

Kairos FHR

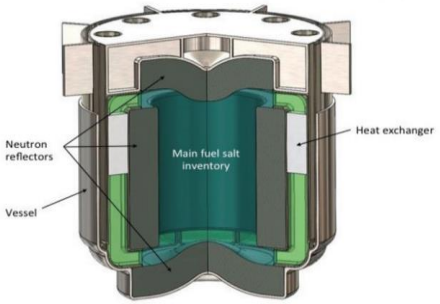


TRISO Pebble Fuel (U,C,Si)

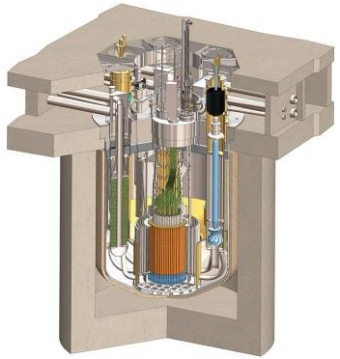
Molten Salt Coolant (Flibe)

Non-existent or uncertain Nuclear Data needs to be redressed for new materials and fuels in order to correctly understand/model the neutronics in new designs at a high level of confidence

Terrapower



MCFR (Cl)



SMR (Na)

Continued NP Progress on RENEW Is A Strong Priority

- NP received 36 proposals requesting funding to support 110 traineeships across the country.

- The proposed collaborations involve 91 potential participating institutions including
  - 9 National Labs,
  - 44 MSIs of which 18 are HBCUs and 2 are PBIs,
  - 9 Community Colleges, and
  - 2 Women's Colleges.

Congressional interest garnered as well

Traineeships thus far 40% Hispanic, 40% African American, 5% White, 5% Other

Serious Issue for Gender DEI Based on Community Feedback

- Continued dismissive behavior based solely on gender
- Continued inappropriate or nonprofessional remarks based on gender
- Continued micro-aggressions based on gender
- Continued attempts to elicit a relationship/sex through inappropriate banter
- Continued attempts to elicit sex through inappropriate use of position/intimidation
- Continued failure to take action when inappropriate behavior is reported
- Inappropriate unwanted touching
- Inappropriate (criminal?) physical assault
- Behavior bordering on attempted sexual assault

NB: As egregious/appalling as the bottom bullets are, the top three bullets may in the end be much more damaging to the community's goals for DEI

I am hearing events related to gender. I suspect the infractions related to race and ethnicity are worse but are not being reported

For Whom it May Concern

THIS STOPS NOW

This is not who we are and aspire to be as a society of talented professionals/intellectuals

Given our collective aspiration it is hard to see how those who may continue to speak and behave inappropriately have a future in nuclear science

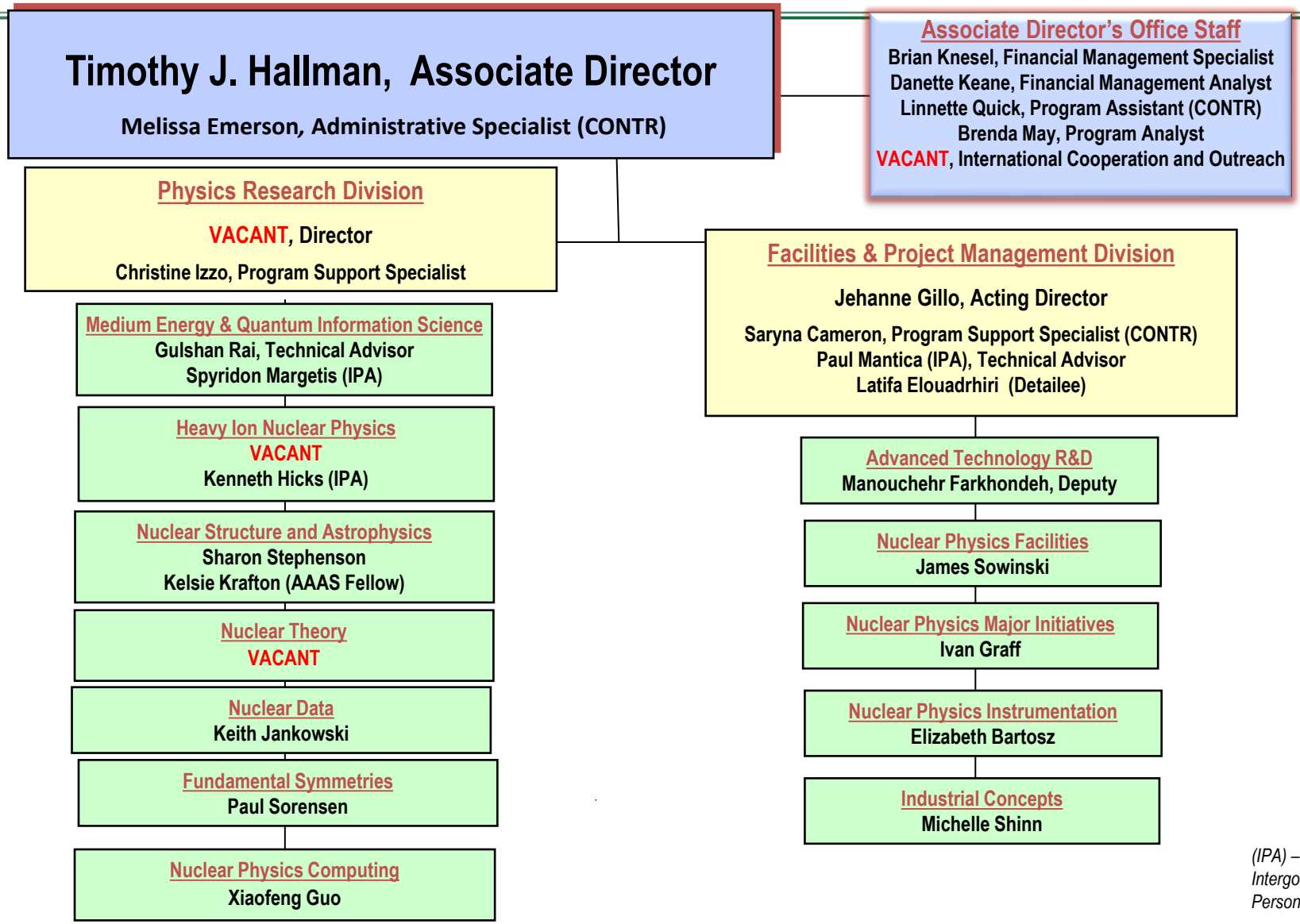
The message is simple: treat all people with the same dignity and respect you expect to be treated with yourself and “keep it professional”.

For the Rest of Us

The only thing it takes for bad-behavior to continue is for people of good conscience and integrity to do nothing

Let’s make the Nuclear Physics community the gold standard.

Office of Nuclear Physics



(IPA) – Intergovernmental Personnel Act

Other Items in the News

Planned FY22 FOAs:

- Topical Theory Collaborations
- Quantum Horizons
- SciDAC5
- Interagency Nuclear Data
- FY 2020 R&D for Next Generation Nuclear Physics Accelerator Facilities

A new white paper based on a JLAB sponsored workshop is available: *Accelerating Innovation in Medical Care through Discovery in the Physical Sciences (AIMDPS): A New Crosscutting Architecture for Leveraging DOE-NIH Collaboration* (Thia Keppel)

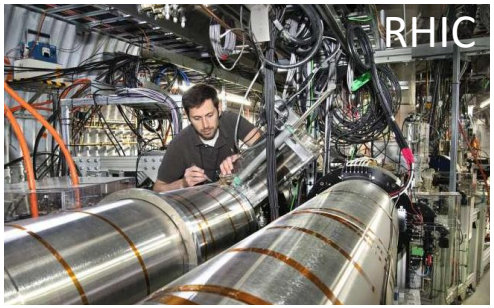
No official word yet on SC/DOE return to HQ; SC still in max telework mode; only mission critical travel

Under Secretary for Science and Energy confirmed

NERSC allocations are in; NP usage will increase. INCITE requests are under consideration.

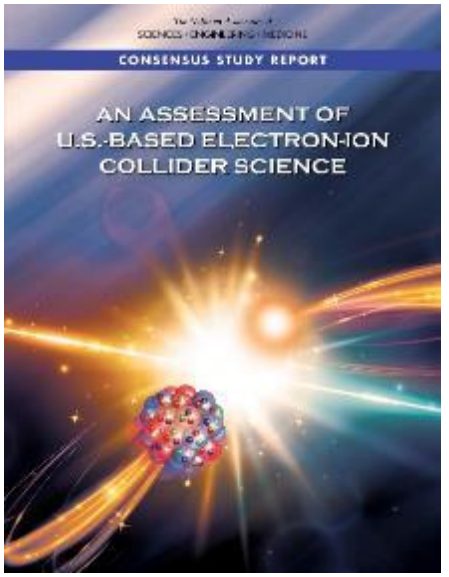
SECAR successfully completed; GRETA preparing to re-baseline; HRS and MOLLER implementation continuing

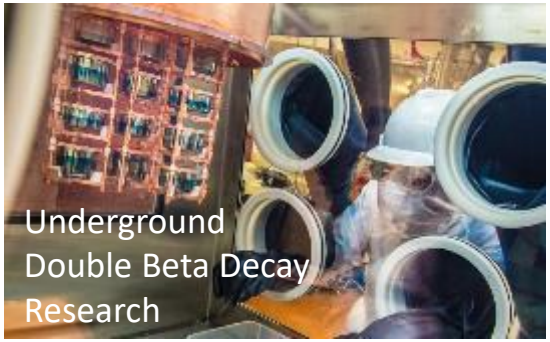
Overall, Progress in Implementing the LRP Has Been Good



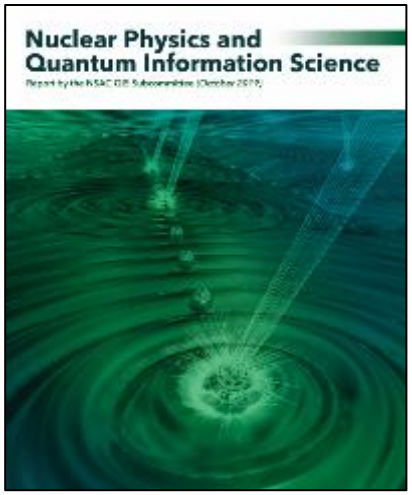
World leading research supported at state-of-the-art NP National User Facilities

The vision to maintain U.S. leadership continues to be implemented: EIC construction; FRIB construction





Pioneering experiments and research tools (MIEs) are created



Groundbreaking contributions to national cross-cutting priorities continue

Additional Information

Nuclear Data & Space Nuclear Propulsion

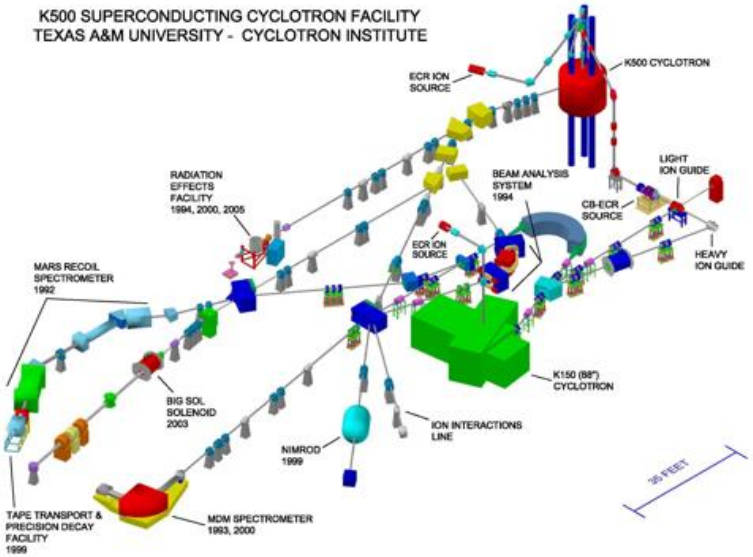
Presented to: Workshop on Applied Nuclear Data Activities (WANDA) 2021

Space Technology Mission Directorate
Technology Demonstration Mission Program
Space Nuclear Propulsion Project
Kelsa Palomares, AMA Inc. | January 25, 2020

Two NP Centers of Excellence at TUNL and Texas A&M

50 YEARS OF BEAM — exploring the nuclear frontier

CYCLOTRON INSTITUTE
TEXAS A&M UNIVERSITY

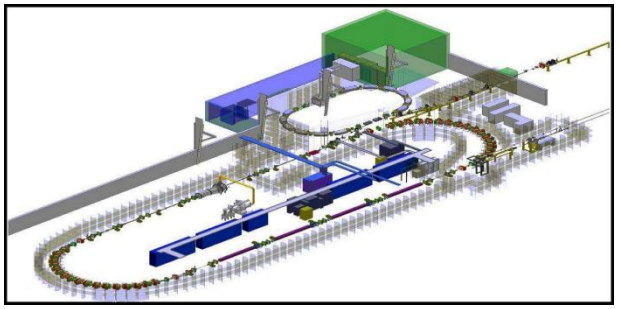


The Texas A&M University Cyclotron Institute jointly supported by DOE and the State of Texas focuses on conducting basic research, educating students in accelerator-based science and technology, and providing technical capabilities for a wide variety of applications in space science, materials science, analytical procedures and nuclear medicine.

The 88 inch cyclotron also plays a crucial role in space radiation effects chip testing for the Air Force

TRIANGLE UNIVERSITIES NUCLEAR LABORATORY
Durham, North Carolina
A US Department of Energy Center of Excellence in Nuclear Physics

The Triangle Universities Nuclear Laboratory (TUNL) is Center of Excellence that focuses on low-energy nuclear physics research. TUNL is a consortium Duke University, North Carolina State University, and the University of North Carolina at Chapel Hill comprising about 30 faculty members, 20 postdocs and research scientists, and 50 graduate students.

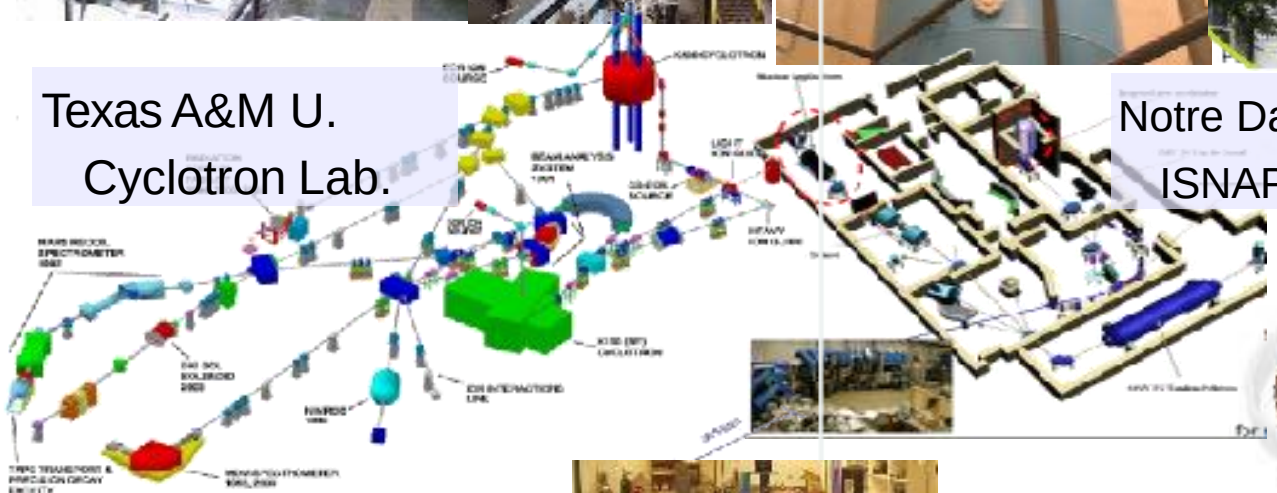


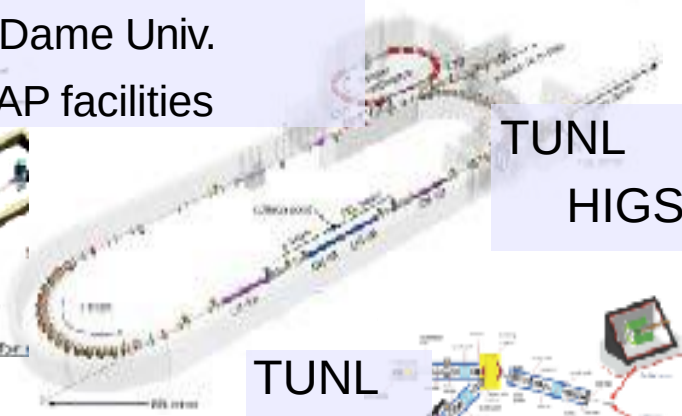
http://aruna.physics.fsu.edu

10 members

~200 users

ARUNA- Association for Research at University Nuclear Accelerators





Continued Landmark Progress in QIS is a Priority

Article

Impact of ionizing radiation on superconducting qubit coherence

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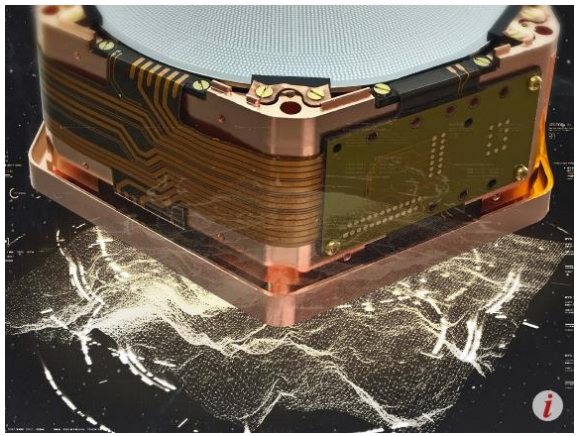

Naturally occurring radiation produced by environmental radioactive materials and cosmic rays is enough to limit the useful lifetime of superconducting qubit state to just a few milliseconds… Identifying ionizing radiation as a dominant source of excess quasiparticles… is a first step towards developing to mitigate its impact on superconducting circuits, including those used for quantum computation and quantum sensing.

Popular press coverage: ***PNNL "Natural Radiation Can Interfere with Quantum Computers "and MIT Technology Review "Cosmic rays could pose a problem for future quantum computers "*** https://www.pnnl.gov/news-media/natural-radiation-can-interfere-quantum-computers
https://www.technologyreview.com/2020/08/26/1007688/cosmic-rays-could-pose-a-problem-for-future-quantum-computers/

***Independent*, Future of Quantum Computing Could Be Disrupted by Space**
https://www.independent.co.uk/life-style/gadgets-and-tech/news/quantum-computer-cosmic-rays-radiation-space-a9689946.html

***The Vice*, Particles From Space Are Messing With Our Quantum Computers, Scientists Discover**
https://www.vice.com/en_us/article/wxqy5x/particles-from-space-are-messing-with-our-quantum-computers-scientists-discover

New Scientist, Quantum computers may be destroyed by high-energy particles from space
https://www.newscientist.com/article/2252933-quantum-computers-may-be-destroyed-by-high-energy-particles-from-space/

"Natural Radiation Can Interfere with Quantum Computers"