



BERKELEY LAB

Bringing Science Solutions to the World



U.S. DEPARTMENT OF
ENERGY

Office of Science

Nuclear Science at Berkeley Lab

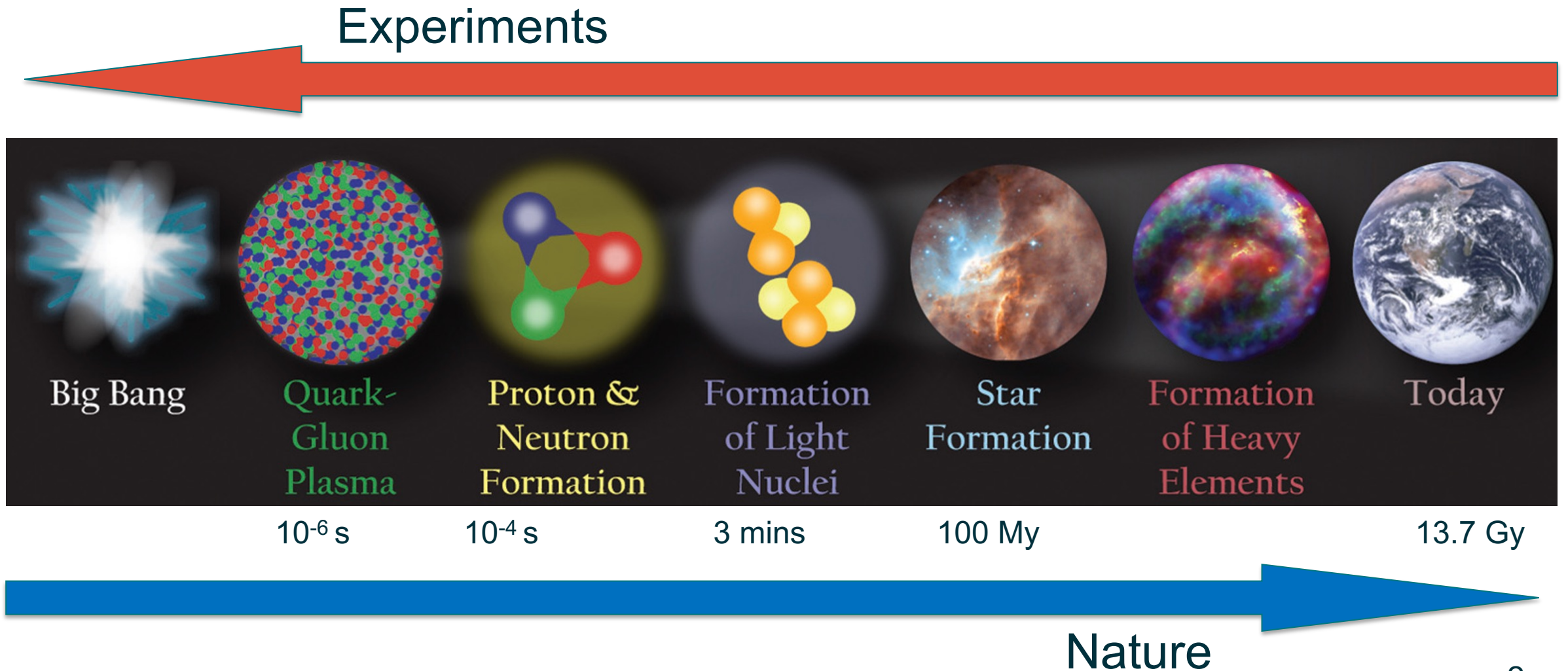
Reiner Kruecken

Nuclear Science Division

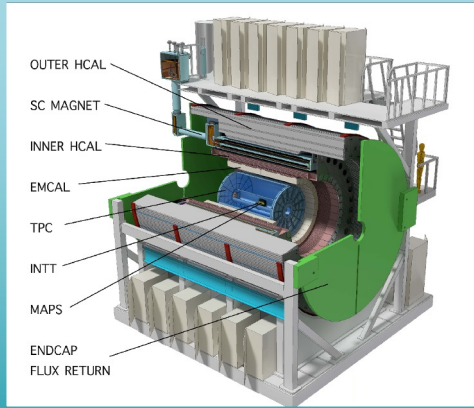
March 2024

Nuclear Science

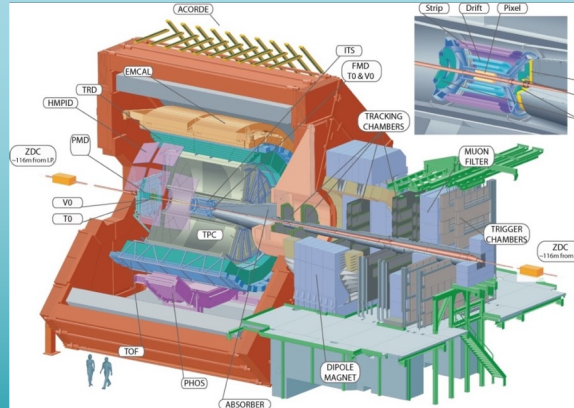
- Reaching back across the history of the universe -



Microscopes into early universe, nucleon & nucleus



**sPHENIX @ RHIC,
BNL**



**ALICE @ LHC,
CERN**

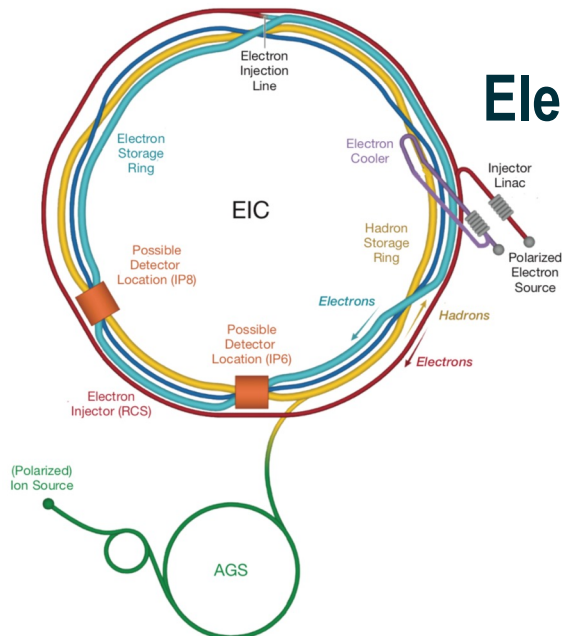


**Hall-A & C @CEBAF,
Jefferson Lab**

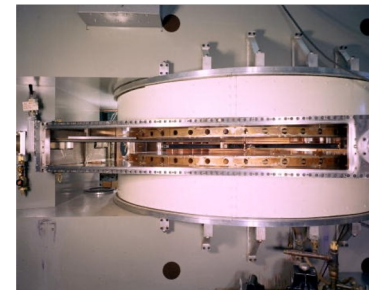


FRIB @ MSU

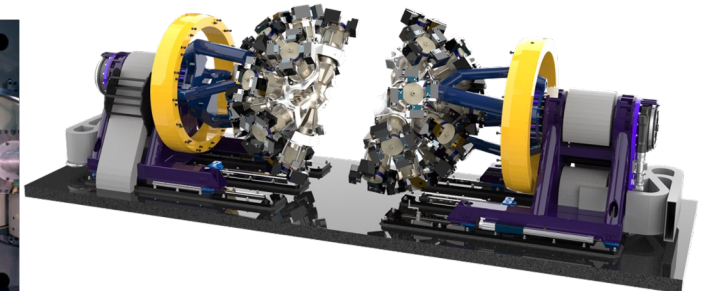
**Future:
Electron Ion Collider (EIC)
BNL**



88-Inch Cyclotron



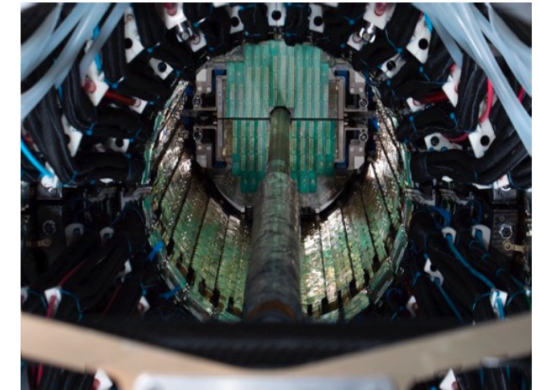
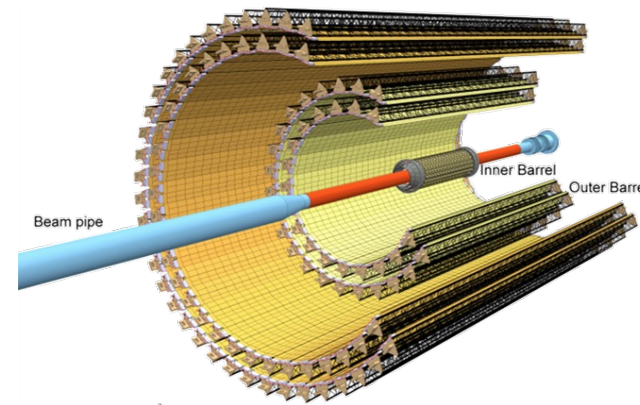
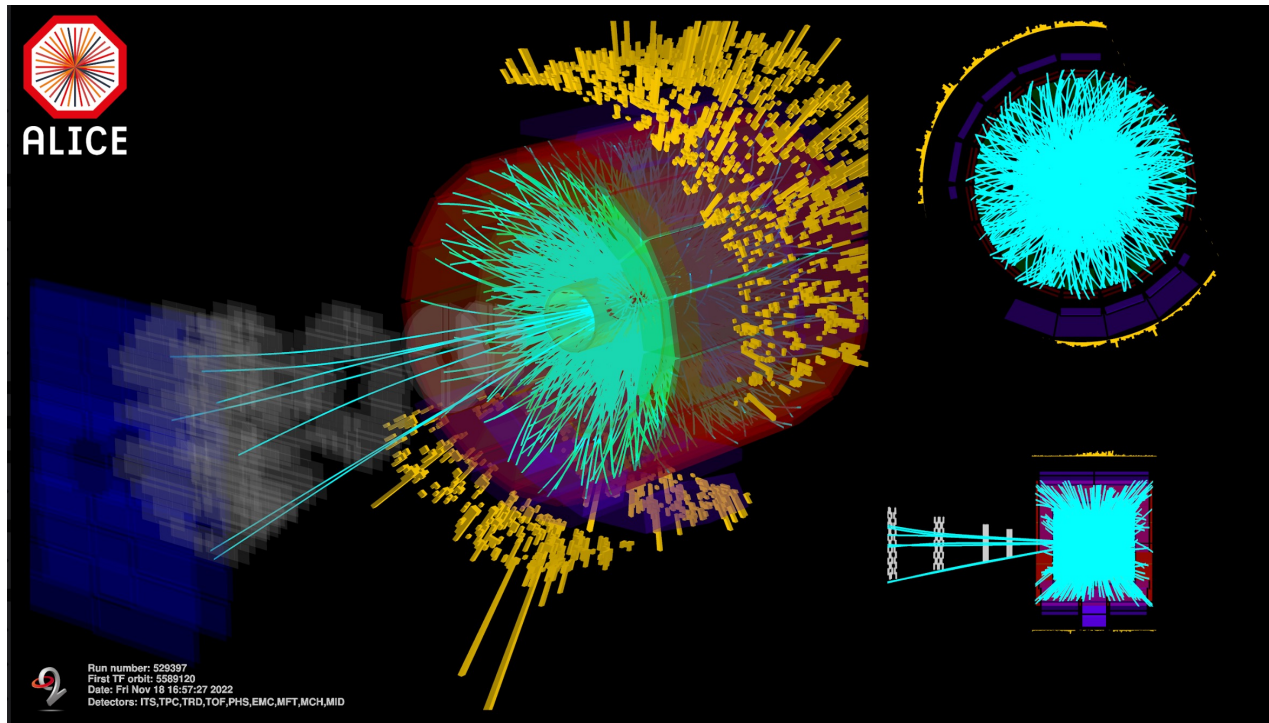
GRETA



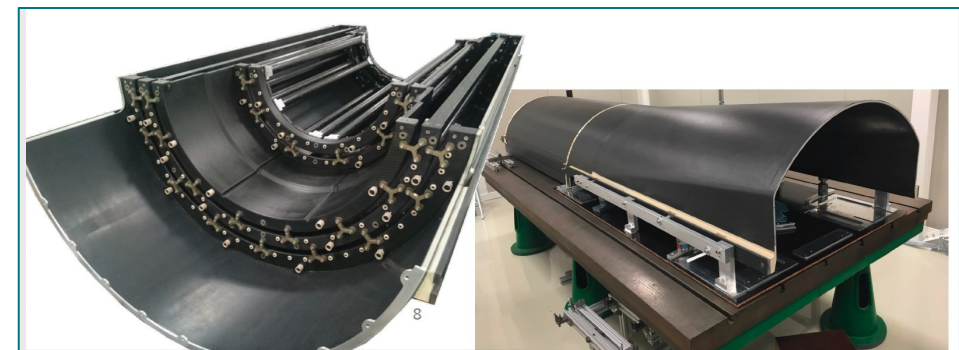
**HPC for analysis
and theory**

Silicon Vertex Detectors for Colliders

Single Lead – Lead collision at CERN LHC

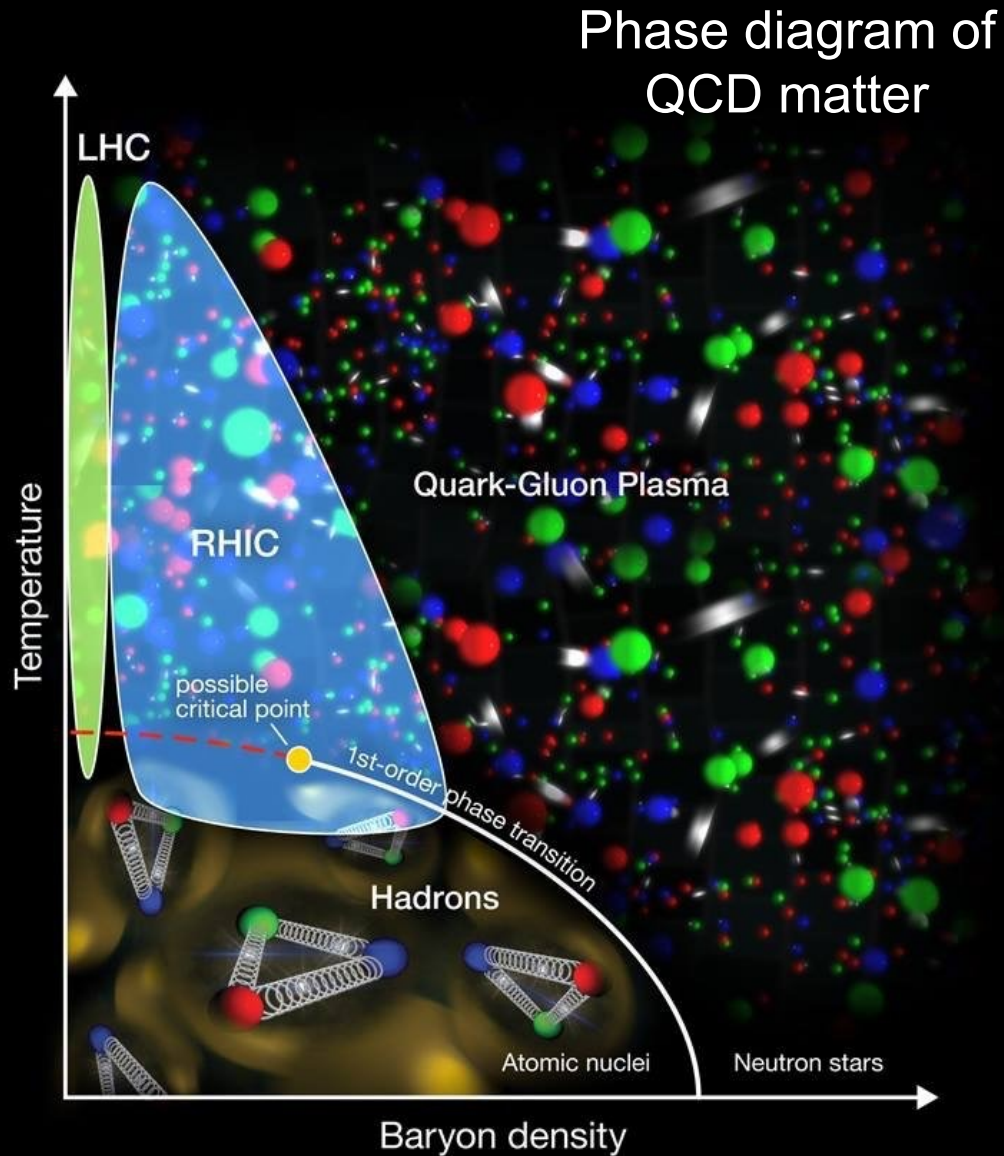


ALICE ITS2 Upgrade

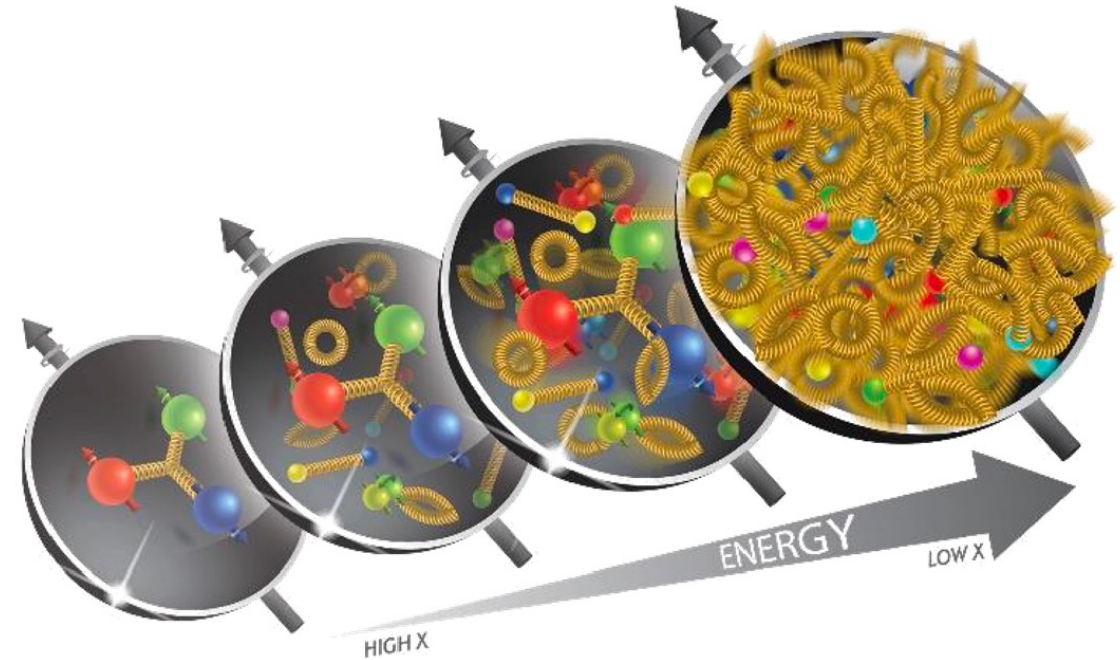


Support structure examples from ALICE ITS2

Phases and Structures of Strongly Interacting Matter



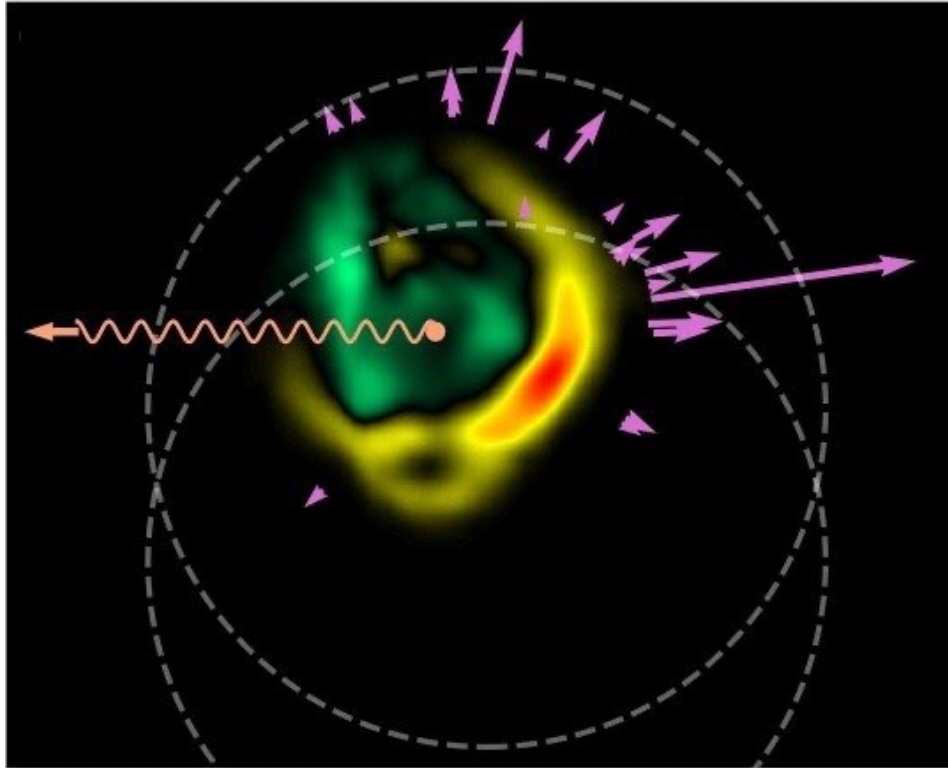
Structure of the nucleon



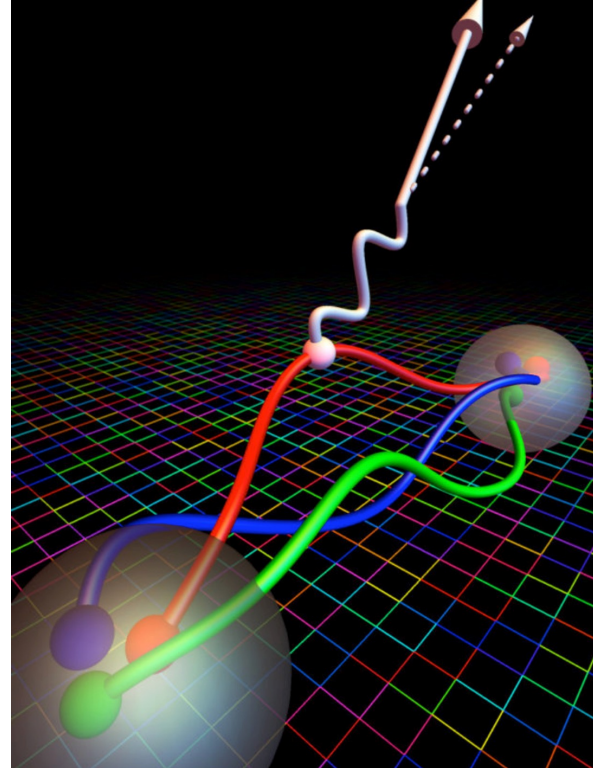
e.g. Origin of the Nucleon Mass and Nucleon Spin

Theoretical Nuclear Physics and Astrophysics

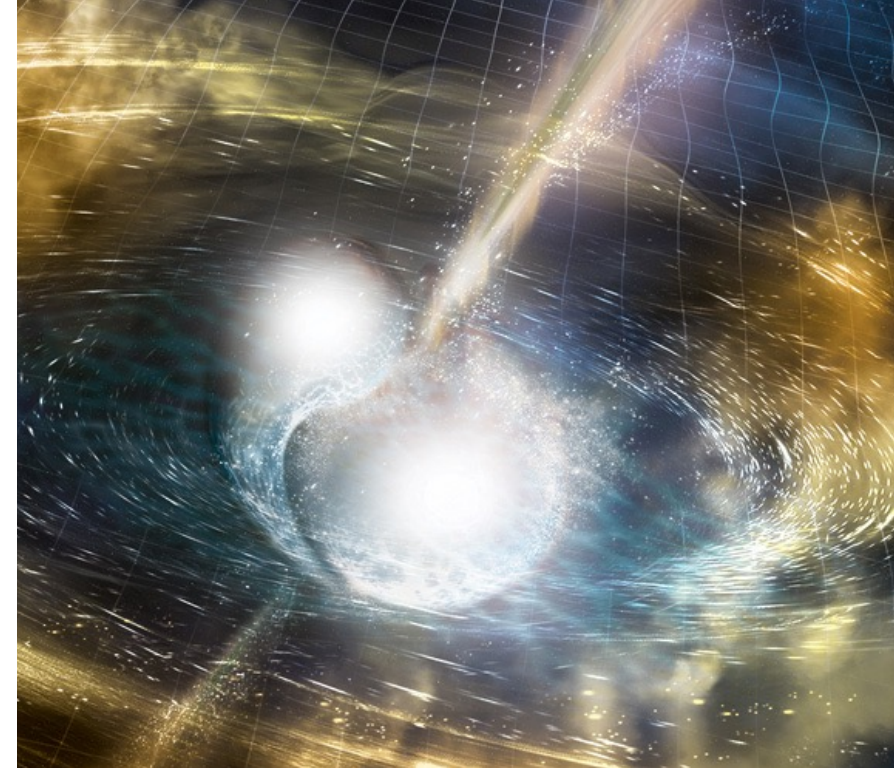
Mach waves in the perfect liquid –
Quark Gluon Plasma



Lattice QCD calculations
of the neutron decay



Neutron star mergers and
nucleosynthesis of heavy elements



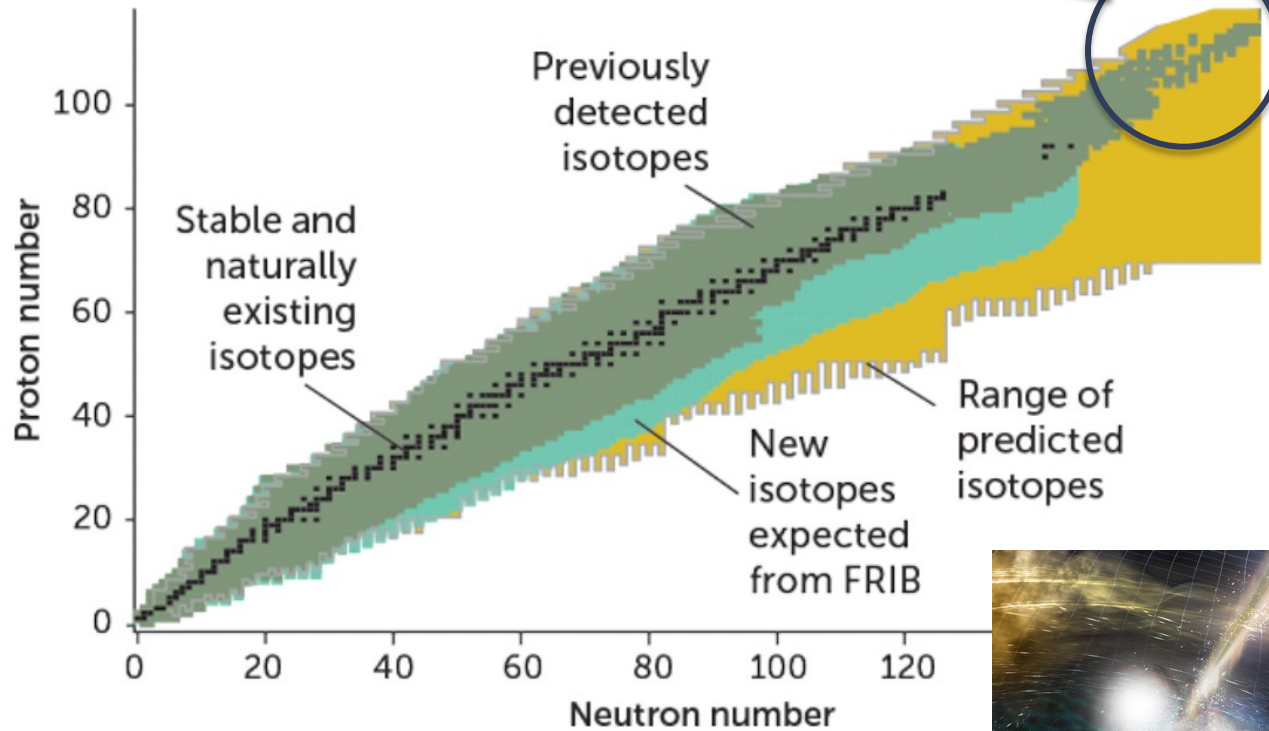
Leveraging LBNL high-performance computing resources

Boundaries of existence of atomic nuclei

88-Inch Cyclotron

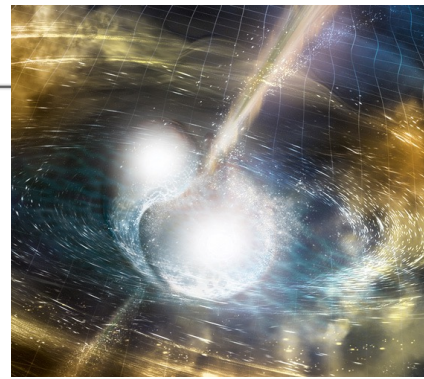


Landscapes of isotopes

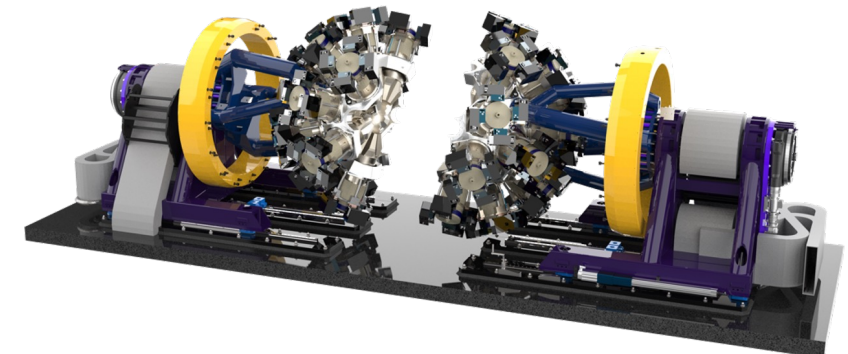


FRIB

Short-lived neutron-rich nuclei are key to heavy element nucleosynthesis



Facility for Rare Isotope Beams (FRIB) at Michigan State University

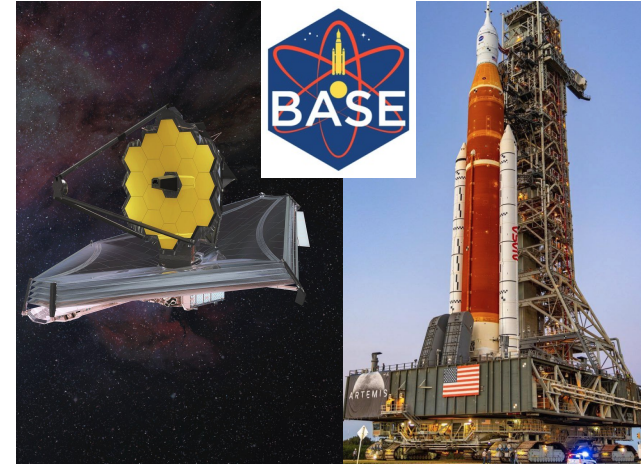
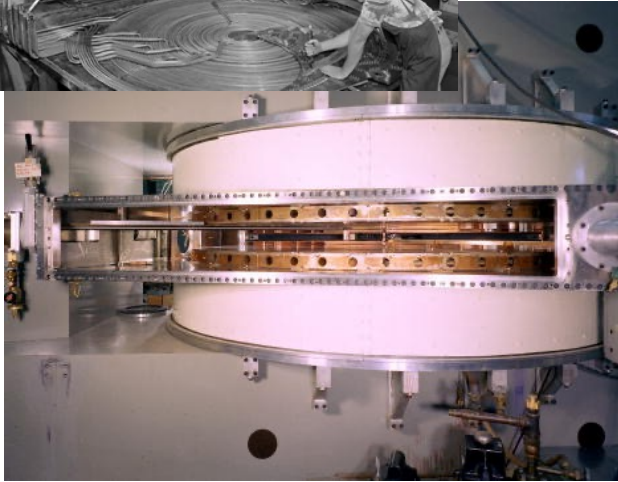


Berkeley Lab is building the most advanced **microscope into the atomic nucleus**: Gamma-Ray Energy Tracking Array (GRETA) ~\$50M

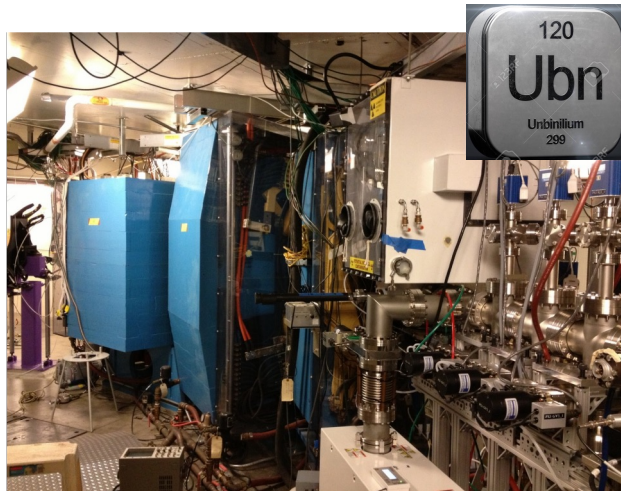
88-Inch Cyclotron



The 88-Inch Cyclotron, producing heavy ion beams since 1961 and is a development center for world-leading ion sources.



The Berkeley Accelerator Space Effects (BASE) facility enables tests of components of the JWST and most other U.S. space missions.



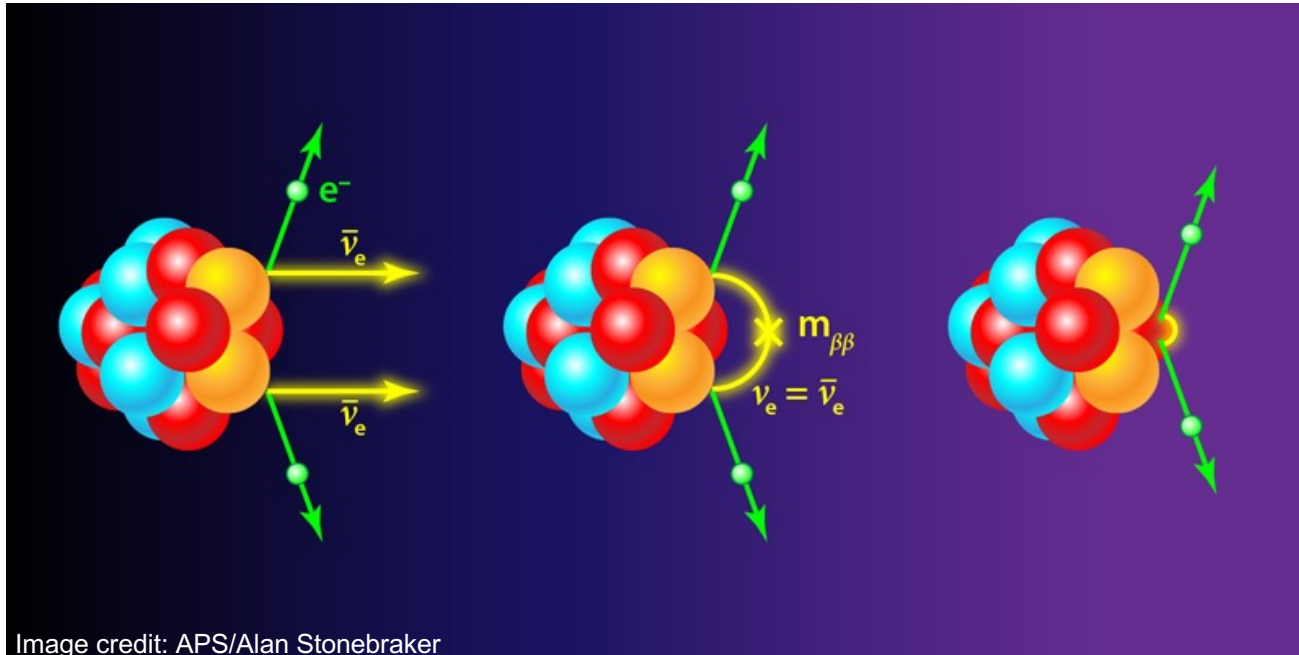
The Berkeley Gas-Filled Separator (BGS) is a key instrument of a national center for heavy and super-heavy element research.



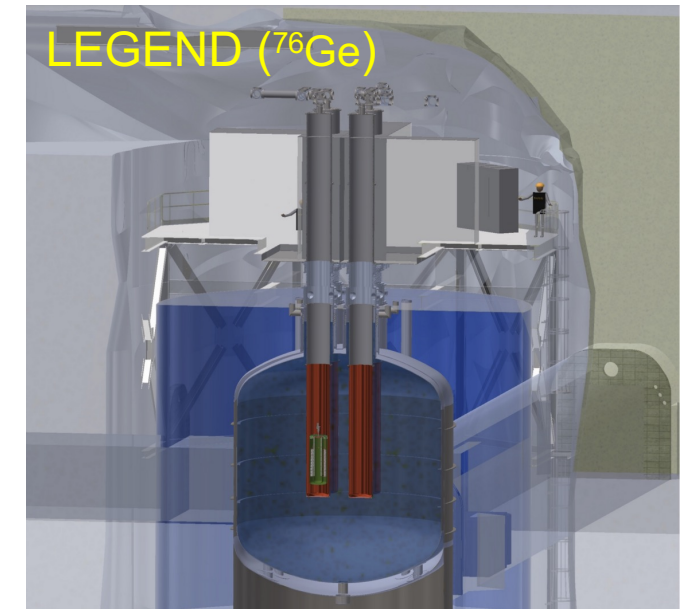
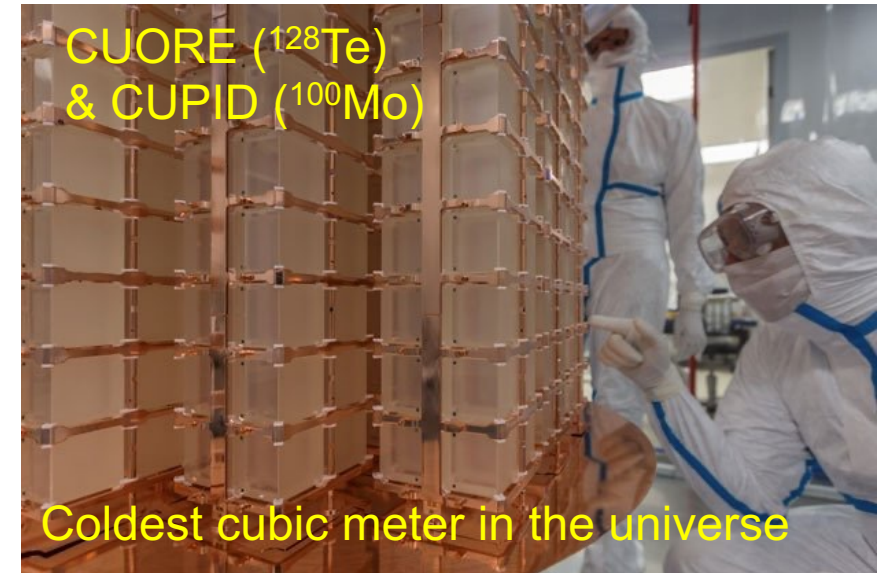
Nuclear Data from the 88-Inch supports national priorities in basic nuclear science, medical isotope production, nuclear energy, and nuclear security.

Nuclei as Laboratories for testing the Standard Model

Search for neutrinoless double-beta decay



- Observation would mean that neutrino is its own antiparticle
→ violates lepton number conservation
- Very rare process: Half-life limit $>10^{26}$ years
- Ton-scale detectors built of candidate isotopes (^{128}Te , ^{100}Mo , ^{76}Ge , ^{136}Xe)
- Deep underground (e.g. Gran Sasso, Italy) to reduce cosmic ray signals

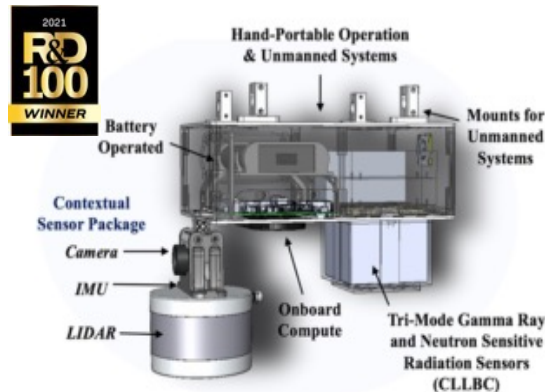


Applied Nuclear Physics

Radiation detection and imaging for security, environment, health, and space missions

Combining

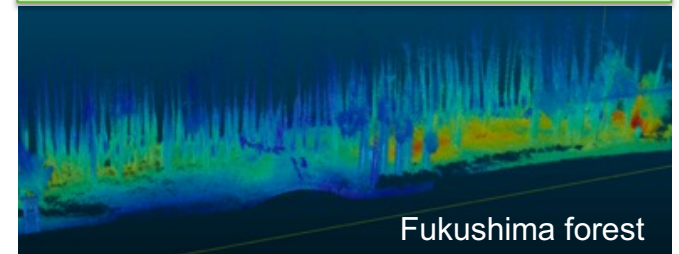
- Advanced radiation detection techniques
- Virtual and augmented reality
- Machine learning and artificial intelligence, robotics



Localization and Mapping Platform
(Deployed across U.S., Fukushima, and Chornobyl)



Making radiation visible in 3D and real time



Nuclear Street View



Clearing of public events



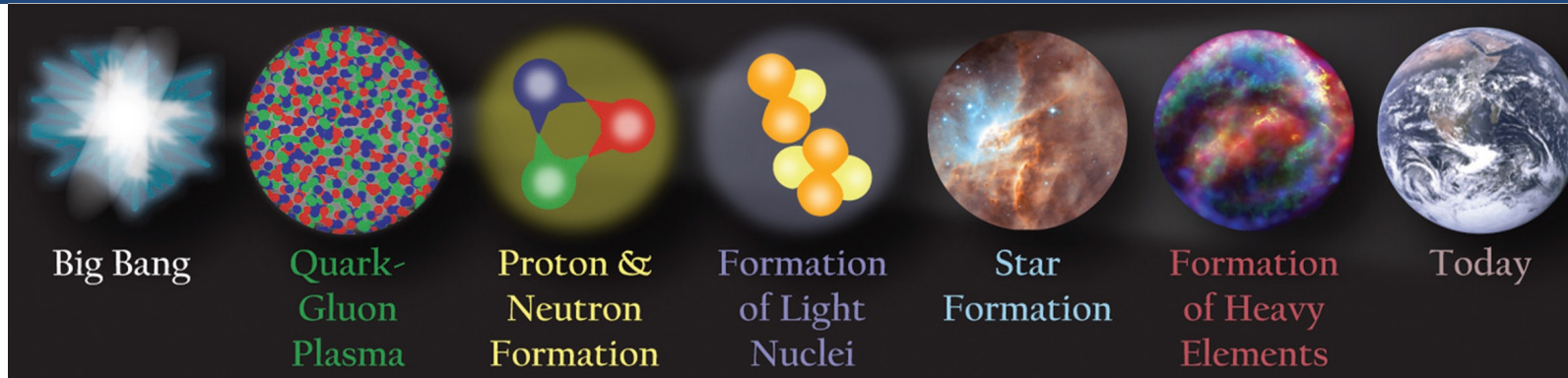
Cancer therapy verification



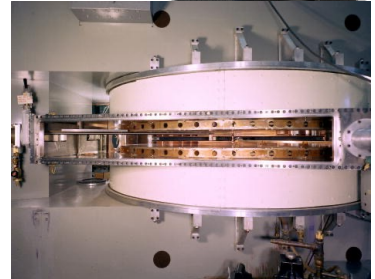
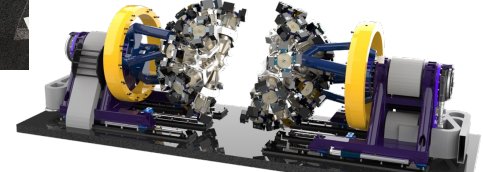
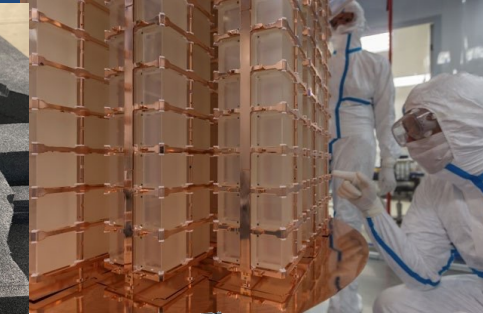
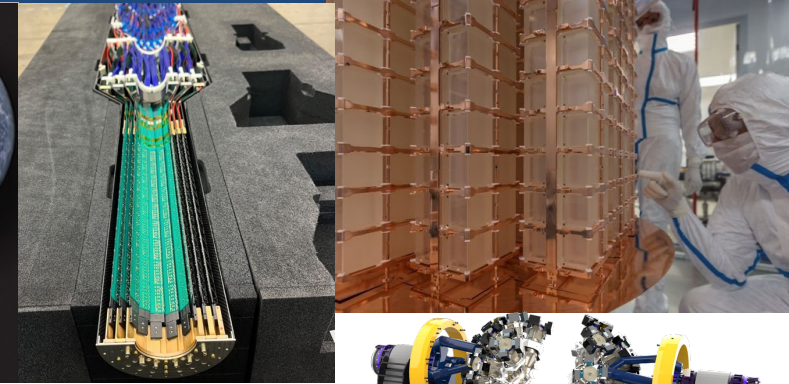
Nuclear Compton Telescope & Compton Spectrometer and Imager (COSI)



Summary



- The Nuclear Science Division leads discovery and innovation in nuclear science and technology across a broad portfolio.
- We advance the understanding of all facets of nuclear matter and forces through experiment and theory.
- We drive innovation in instrumentation and computing for fundamental research and applications for societal benefits.
- We inspire and train the next generation and we foster a diverse, inclusive, and safe environment with opportunity for everyone to thrive.





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Thank you