U.S. DEPARTMENT OF ENERGY | Office of Science

Topics from the Office of Nuclear Physics

2019 RHIC & AGS Annual Users' Meeting

Dr. Richard Witt
Program Manager for Heavy Ion Physics
Office of Nuclear Physics
DOE Office of Science

Perspective

Normandy coast, June 6th, 1944

Subprograms of Office of Nuclear Physics (NP)

- **Low Energy/Fundamental Interactions (ATLAS and FRIB)**

  Studies nuclear structure, nuclear astrophysics, and fundamental symmetries

  Investigates the properties of neutrinos, and uses cold neutrons and nuclei to test the Standard Model

- **Medium Energy (TJNAF 12 GeV Energy Upgrade, RHIC spin)**

  Studies the low temperature frontier of Quantum Chromodynamics (QCD)

  Search for parity-violating processes and the spin structure of the proton

- **Heavy Ion (RHIC and Heavy Ion Research at the LHC)**

  Studies at the high temperature frontier of QCD
  Investigating the properties of the Quark Gluon Plasma (QGP) across three orders of magnitude of center-of-mass energy, from RHIC to LHC

- **Theory**

  Explores all three frontiers of nuclear physics

  Encompasses the Nuclear Data Program, responsible for collection, evaluation, and dissemination of nuclear physics data for basic nuclear research and applied nuclear technologies

- **Isotope Production and Applications**

  Produces, prepares, and distributes isotopes for commercial applications and research

  Research and development relevant to isotope production

Office of Nuclear Physics (NP)

Timothy J. Hallman, Associate Director

Vacant, Administrative Specialist

Associate Director's Office Staff

- *Vacant*, Financial Advisor
- Brian Knesel, Financial Management Specialist
- *Vacant*, Program Assistant (OA) (Grants)
- Brenda May, Program Analyst

Physics Research Division

Vacant, Division Director

Christine Izzo, Program Support Specialist

- **Medium Energy Nuclear Physics** — Gulshan Rai
- **Heavy Ion Nuclear Physics** — *Vacant*; Richard Witt (Detailee)
- **Nuclear Structure and Astrophysics** — *Vacant*; Paul Sorensen (IPA)
- **Nuclear Theory** — George Fai
- **Nuclear Data and Nuclear Theory Computing** — *Vacant*; Fredrik Tovesson (Detailee)
- **Fundamental Symmetries** — *Vacant*; Paul Sorensen (IPA)

Facilities & Project Management Division

Jehanne Gillo, Director

Cassie Dukes, Program Analyst

Luisa Romero, Isotope Financial Management Specialist

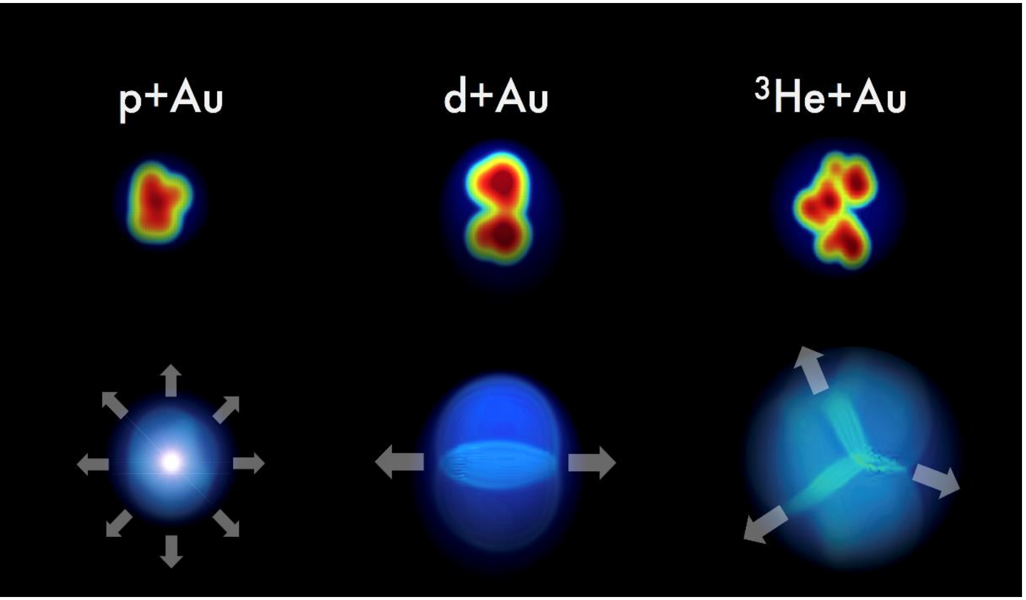
Latifa Elouadrhiri (Detailee)

- **Advanced Technology R & D** — Manouchehr Farkhondeh, Deputy
- **Nuclear Physics Instrumentation** — Elizabeth Bartosz
- **Nuclear Physics Facilities** — James Sowinski
- **Nuclear Physics Major Initiatives** — James Hawkins
- **Industrial Concepts** — Michelle Shinn

- **Isotope Program Operations** — Marc Garland, Deputy
- **Isotope R&D** — Ethan Balkin
- **Stable Isotopes** — Joel Grimm
- **Isotope Accelerator Facilities** — *Vacant*
- **Isotope Reactor Facilities** — *Vacant*
- **Other Isotope Facilities** — Joseph Glaser

March 11, 2019

RHIC Highlights



Credit: Javier Orjuela Koop, University of Colorado, Boulder

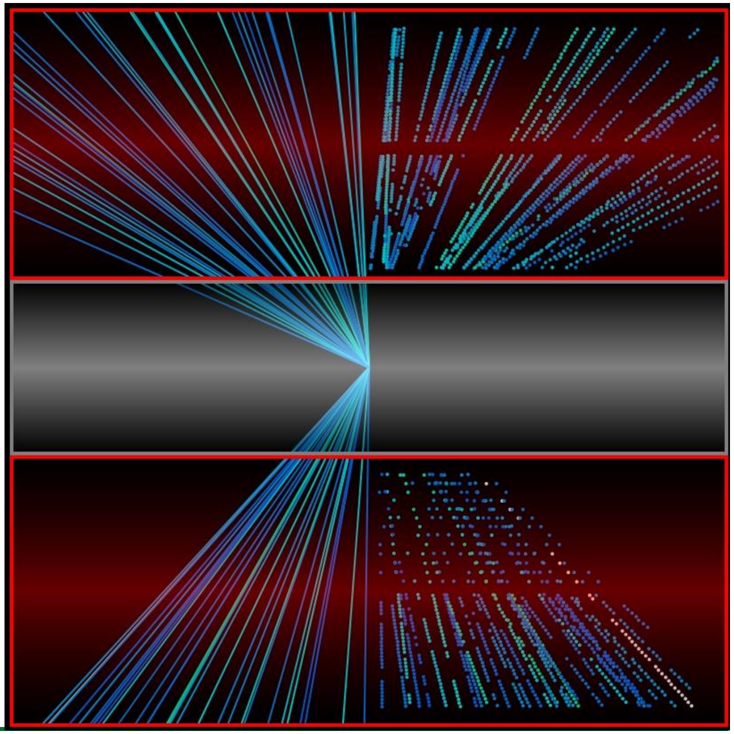
PHENIX Collaboration

Nature Physics **15**, 214–220 (2019)

- Elliptical and triangular flow patterns
  - small and asymmetric systems
  - p+Au, d+Au, ^{3}He+Au
  - strong constraint on hydro models

STAR Collaboration

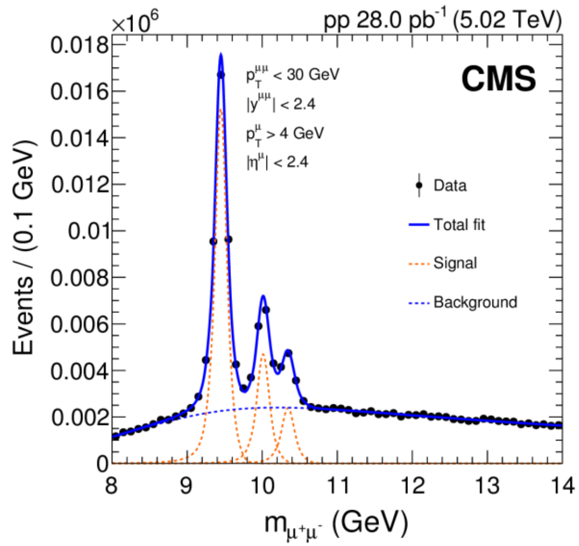
- iTPC: replace all 24 inner sectors, "success story"
- 13 padrows to 40 padrows
- Fully exploit BES II together with EPD and eTOF

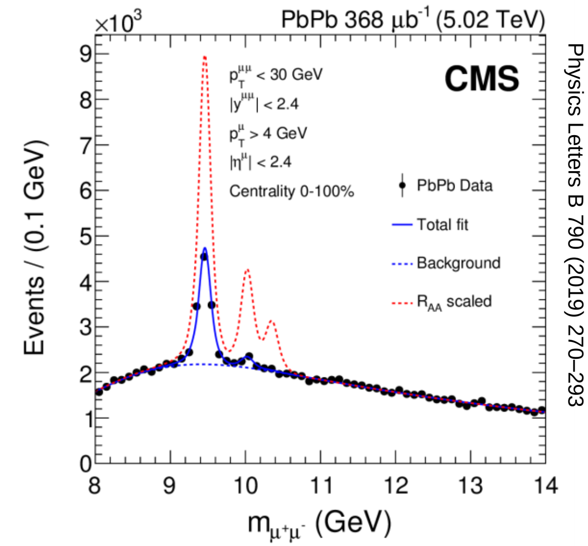


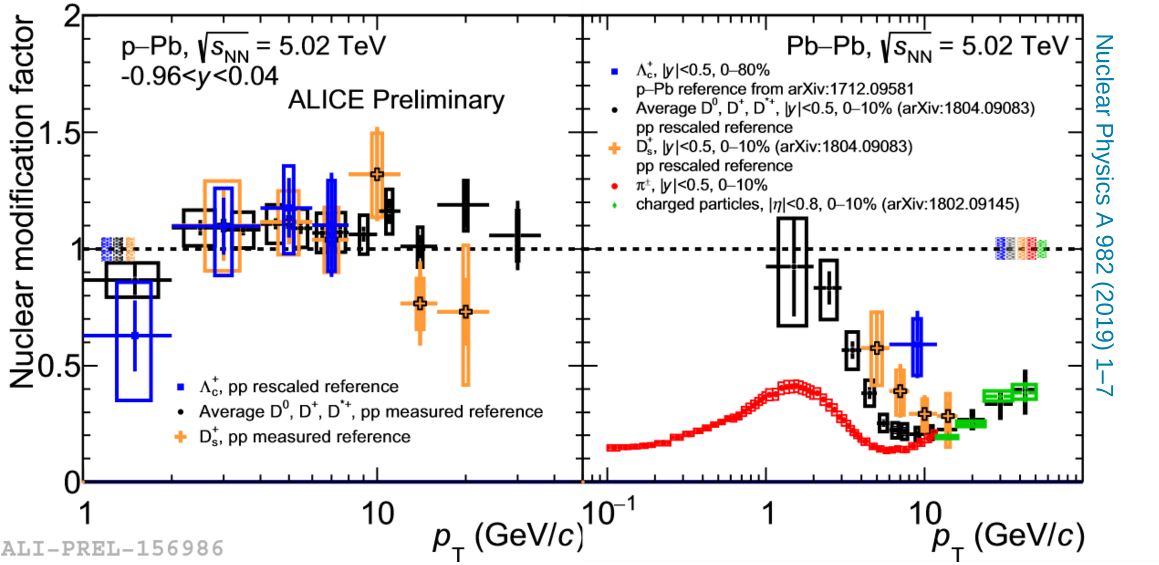
LHC Highlights

CMS

- Upsilon sequential melting
- Υ(1s), Υ(2s), Υ(3s) clear in pp
- No visible Υ(3s) in PbPb
    - Υ(3s) R_{AA} less than 0.096 to 95% CL





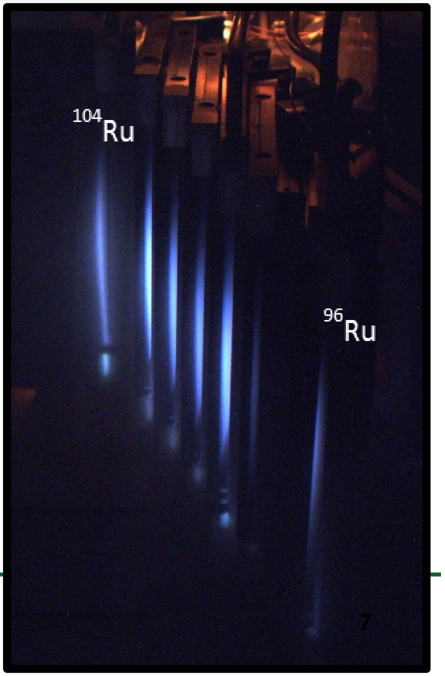


ALICE

- Weaker low-pt J/ψ suppression than at RHIC
    - c c-bar recombination
- Λc / D higher in PbPb than pPb
- Λ_c, D_s, D ordering

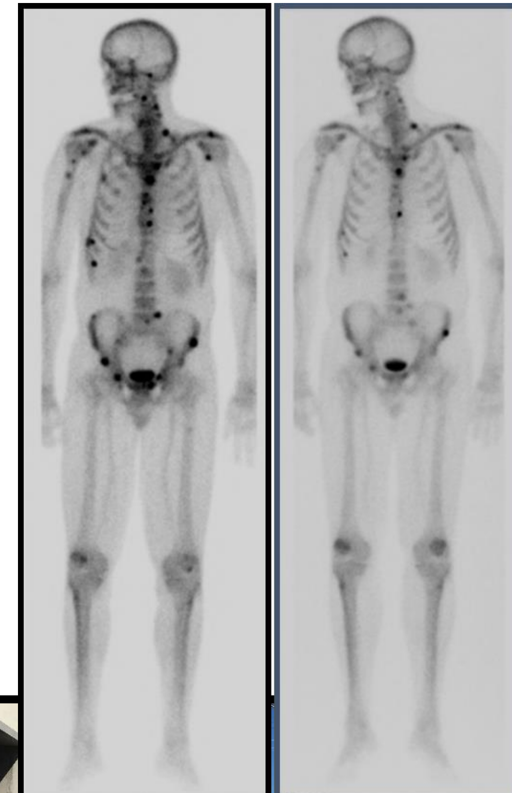
Stable Isotope Enrichment and Distribution

- DOE Isotope Program manages the Nation's inventory of stable isotopes
- Re-established enriched stable isotope production in the United States – Enriched Stable Isotope Prototype Plant
  - Electromagnetic separation and gas centrifuge
  - Produced 500 mg of Ru-96 for RHIC
- Stable Isotope Production Facility MIE - ongoing
  - Increase production capacity to kg quantities
  - Basic research, applications, industry
  - Quantum Information Science
- Xe-129, Mo-98, Mo-100, Yb-176



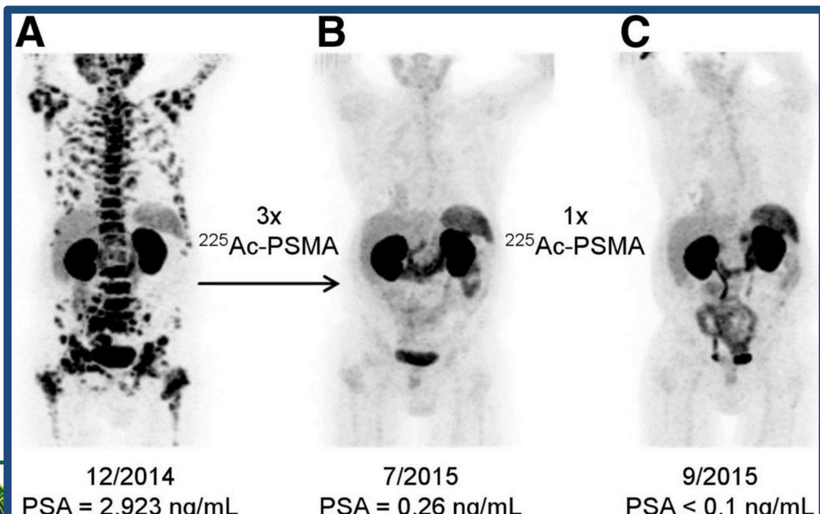
Ac-227 Production Development

- Bayer drug Xofigo® (Ra-223 dichloride) treats prostate cancer that has spread to the bone.
- Recover Ra-226 from waste medical devices secured by the DOE IP before disposal as rad waste. Ra-226 targets irradiated in HFIR to produce Ac-227.
- Chemically separate and purify the Ac-227– shipped to Bayer in Norway where they extract Ra-223 and ship it around the world for immediate use as a cancer therapy.
- DOE IP is the sole worldwide producer of Ac-227 for Bayer.



Actinium-225 Production

- **High priority of NIH for decades to develop alpha-particle targeted radiotherapy agents for cancer and other diseases**
- **DOE IP is world leader in production R&D**
- **ORNL extracts Ac-225 from Th-229 recovered from U-233**
  - 1,200 mCi/year - entire U.S. supply and more than half the worldwide supply
  - Supply cannot support adequate clinical trials or therapy
- DOE IP has developed accelerator production route
  - BNL/LANL/ORNL collaboration (Tri-Lab Project)
  - Full-scale production will be able to meet clinical and therapy demands
  - Initial production began in 2017
  - Tri-Lab Project continuing scale-up of production quantities
  - Accelerator product now routinely available



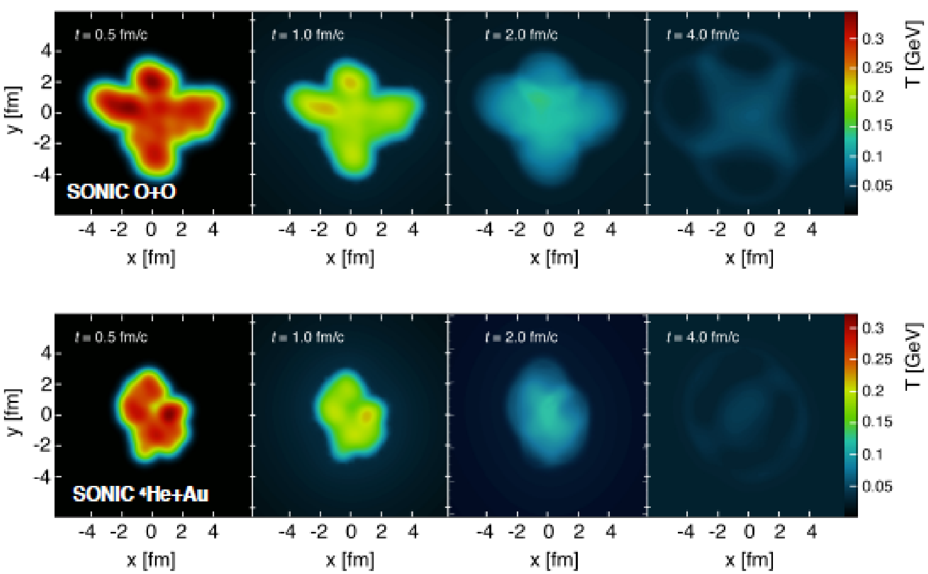
Exploring new small system geometries in heavy ion collisions

U.S. DEPARTMENT OF ENERGY | Office of Science

NUCLEI — Nuclear Computational Low-Energy Initiative

Objectives

- We explore various new collision geometries in the context of the publicly available hydrodynamic model SONIC.
- We incorporate full *A*-nucleon configurations for ^{4}He, ^{12}C, and ^{16}O obtained from quantum Monte Carlo calculations with realistic nuclear potentials, and use a Monte Carlo Glauber calculation for the initial conditions.



Time evolution of a O+O event (top panel) and ^{4}He+Au event (bottom panel) from SONIC. The color scale indicates the local temperature.

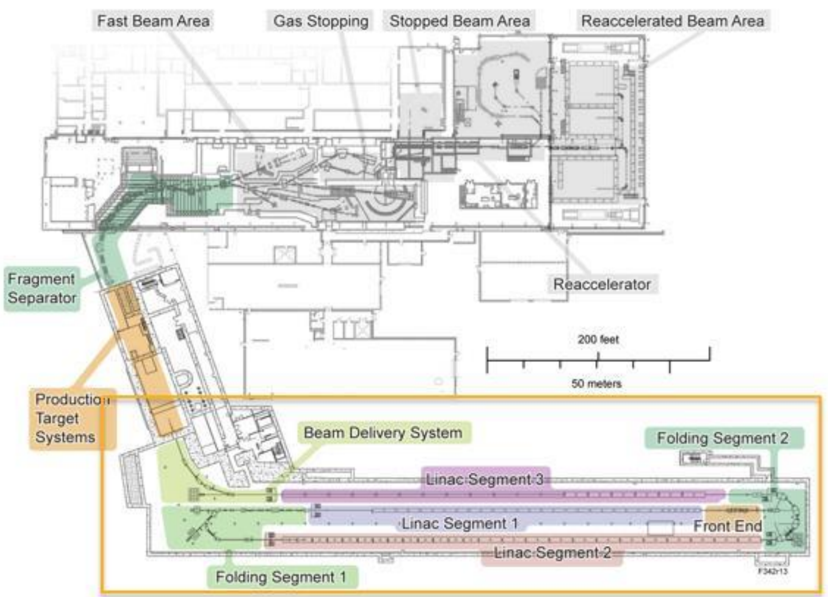
Impact

- New collision geometries are investigated, with particular focus on p+O and O+O, proposed for running at the Large Hadron Collider (LHC), as well as ^{4}He+Au, C+Au, O+Au, and ^{7,9}Be+Au, proposed for running at the Relativistic Heavy Ion Collider (RHIC).
- Hydrodynamic calculations with SONIC indicate flow anisotropies that approximately scale with initial eccentricities, and have an additional dependence on the compactness of the initial geometry (the more compact the source, the larger the flow).
- The comparison between the nucleon distributions obtained from the full 16-nucleon configurations in oxygen and from the α-cluster tetrahedron model shows significant changes in both p+O and O+O events, suggesting that the new experimental data at LHC should easily be able to discriminate the two cases.

Accomplishments

S. H. Lim, J. Carlson, C. Loizides, D. Lonardoni, J. E. Lynn, J. L. Nagle, J. D. Orjuela Koop, and J. Ouellette, Phys. Rev. C 99, 044904 (2019)

Facility for Rare Isotope Beams (FRIB)



FRIB will increase the number of isotopes with known properties from ~2,000 observed over the last century to ~5,000 and will provide world-leading capabilities for 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

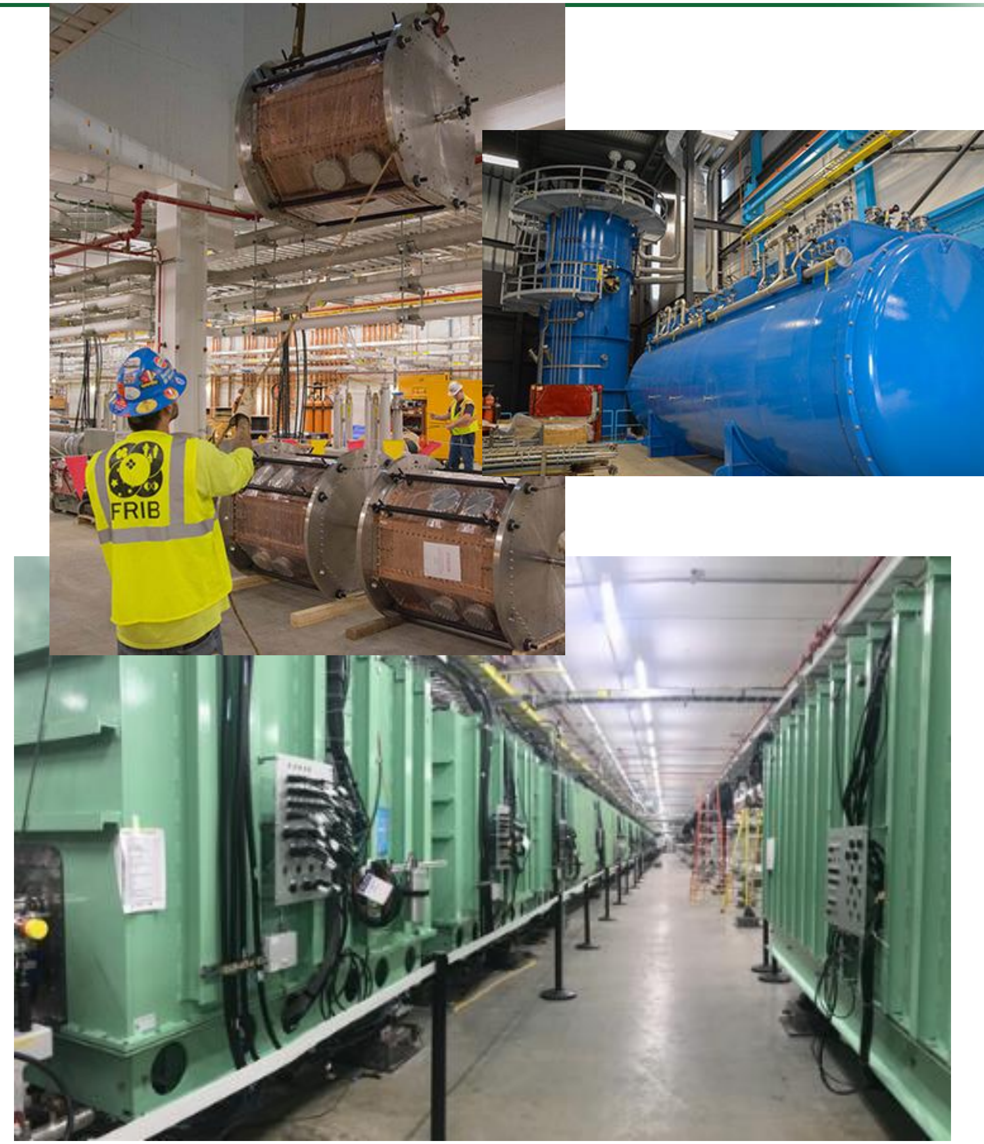
- Tests of fundamental symmetries, Atomic EDMs, Weak Charge

This research will provide the basis for a predictive model of nuclei and how they interact.

Facility for Rare Isotope Beams is > 89% Complete

Recent Progress:

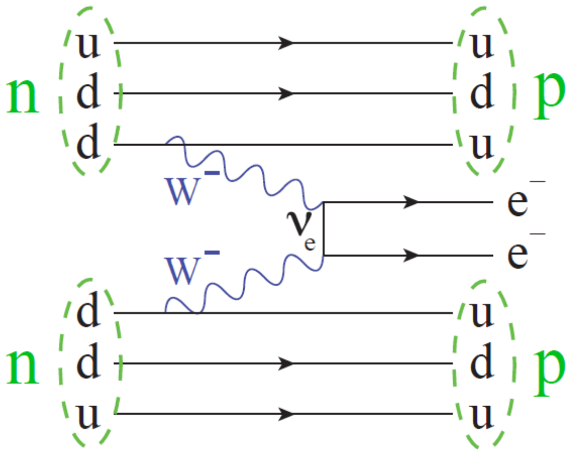
- Ion source through first straight section have had beam (krypton and argon), cryoplant RF, modules and controls working together
- Have installed all 14 accelerating quarter-wave cryomodules in tunnel and are preparing to accelerate beam in them early next year
- Constructing and testing remaining half-wave cryomodules at a rate of 1.5/month (18/yr), will be done with cryomodule
- First separator magnet is in place
- Operations has started developing beams beyond KPPs to be ready for experiments
- Early finish planned for end of CY 2021 construction in 2019.



R&D "Demonstrators" Leading Up to a Ton-Scale $0\nu\beta\beta$ Decay Experiment

How can it be determined whether the neutrino is a Majorana Particle?

Search for Neutrino-less Double Beta Decay ($0\nu\beta\beta$): in a selected nucleus, two neutrons decay into two protons and two electrons, with no neutrinos being emitted.



It can only happen if the two neutrinos from the two W^- particles annihilate internally because the neutrino is its own anti-particle

Scientists have been eagerly working to demonstrate the necessary sensitivity

TeO_2 from CUORE and CUOREcino

1.5×10^{25} years, 90% CL

Ge^{76} from Majorana Demonstrator

1.9×10^{25} years, 90% CL

Ge^{76} from GERDA

8.0×10^{25} years, 90% CL

Xe^{136} from EXO-200

1.8×10^{25} years, 90% CL

Xe^{136} from Kamland-Zen

1.1×10^{26} years, 90% CL

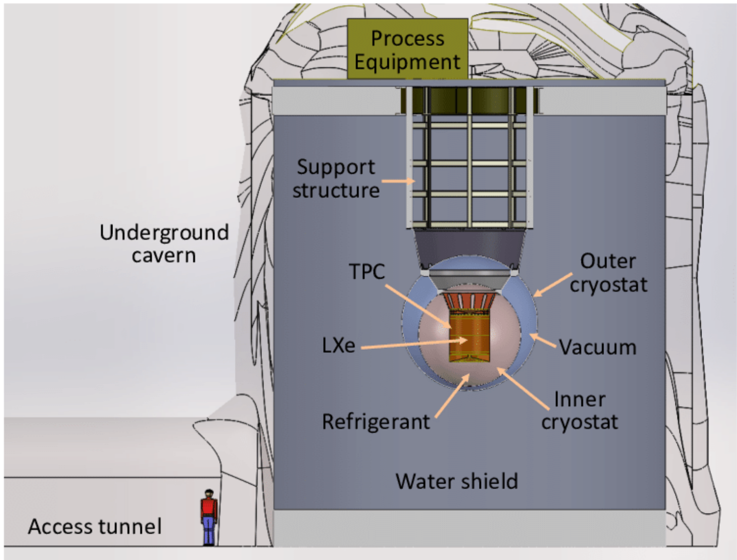
NP | HEP | Support through demonstrator phase

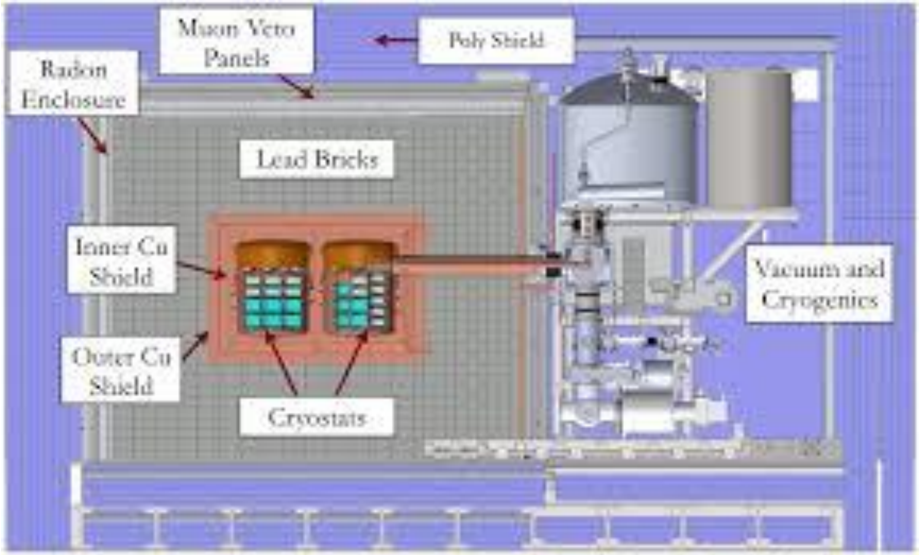
Status of Ton-scale 0νββ

TEC construction start for a ton-scale 0νββ experiment requested in the FY2020 President's Budget Request

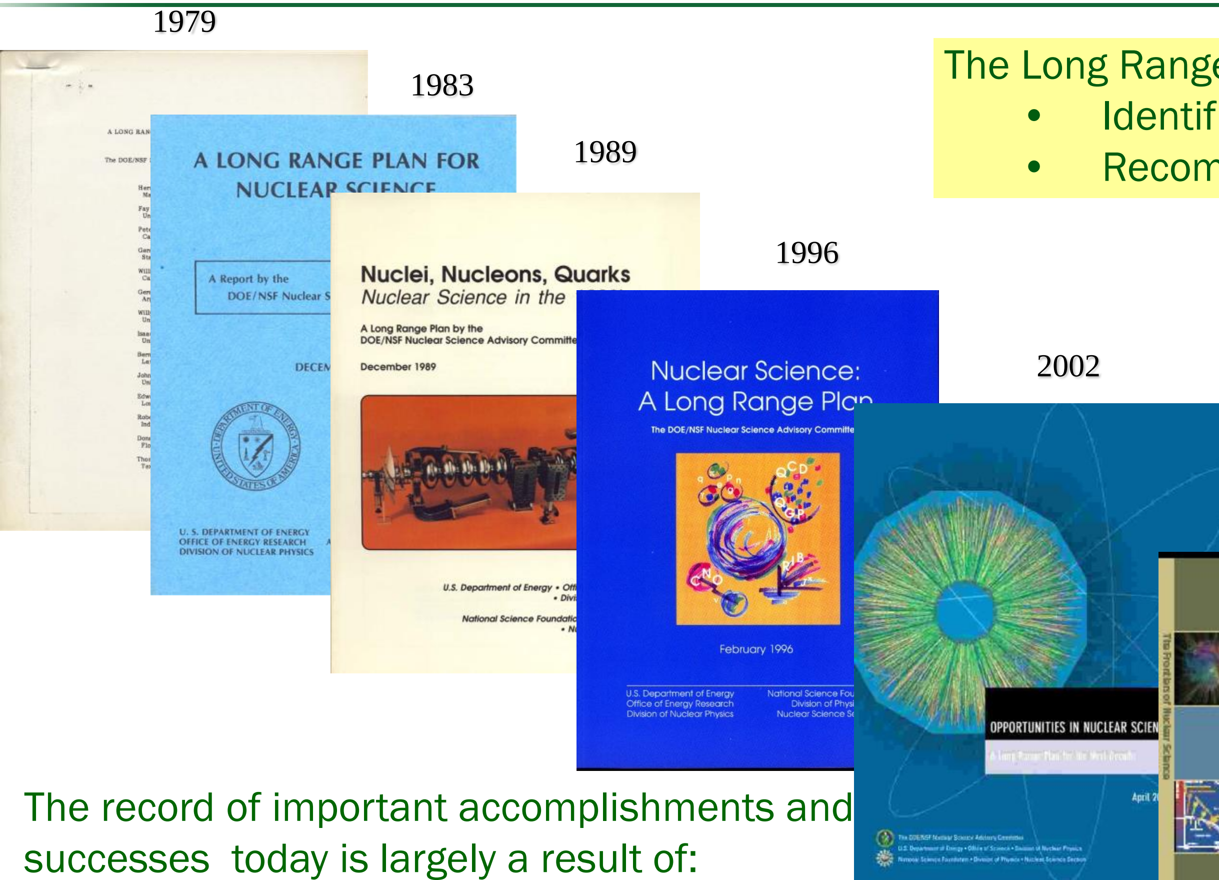
Meeting on the margins of IUPAP WG9 Meeting in London (8/2019) to discuss possible international collaboration

Processes for technology down-select and site selection for a 1 ton experiment under discussion





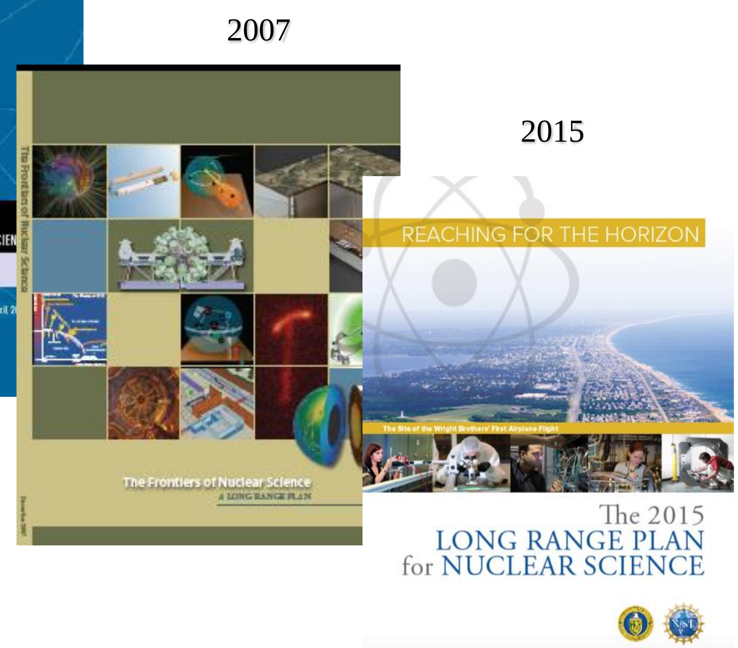
NSAC Long Range Plans



The Long Range Plans have:

- Identified the scientific opportunities
- Recommended scientific priorities

The plans have been informed by a number of sources including important National Academy Studies



The record of important accomplishments and successes today is largely a result of:

- The responsible/visionary **strategic planning** embodied in the NSAC Long Range Plans
- Federal government's decision to utilize the guidance and provide the needed resources

Major Recommendations of the 2015 NSAC LRP

- The progress achieved under the guidance of the 2007 Long Range Plan has reinforced U.S. world leadership in nuclear science. The highest priority in this 2015 Plan is to capitalize on the investments made

  Investments made since 2007 continue to bear fruit. Successes are due to YOUR efforts.

- We recommend the timely development and deployment of a U.S.-led ton-scale neutrinoless double beta decay experiment.

  The demonstrators have been delivered; further scientific progress awaits a ton scale experiment. This is a global campaign with a number of international efforts ongoing.

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

  FRIB is well on the way to completion. Stay tuned.

- We recommend increasing investment in small-scale and mid-scale projects and initiatives that enable forefront research at universities and laboratories.

  Priority for programs across NP. Detector subsystem development in HI for example.

FY 2020 Budget Status

FY20 DOE Office of Science Appropriations ($ millions)							
Account	FY18 Enacted	FY19 Enacted	FY20 Request	Change 19-20	House	Change 19-20	Senate
Office of Science	**6,260**	**6,585**	**5,546**	**-16%**	**6,870**	**4%**	--
Advanced Scientific Computing Research	810	936	921	-2%	957	2%	--
Basic Energy Sciences	2,090	2,166	1,858	-14%	2,143	-1%	--
Biological & Environmental Research	673	705	494	-30%	730	4%	--
Fusion Energy Sciences	532	564	403	-29%	688	22%	--
High Energy Physics	908	980	768	-22%	1,045	7%	--
Nuclear Physics	**684**	**690**	**625**	**-9%**	**735**	**7%**	--

Source: American Institute of Physics

All figures are in millions of nominal U.S. dollars and are rounded to the nearest million. Percentages are rounded to the nearest percent.

Thanks To Dr. James “Jim” Sowinski

- PM for Heavy Ions since 2012
- PM for Nuclear Physics Facilities since ~2016
- Great mentor
- Success and state of HI due in large part to Jim’s stewardship.
- On behalf of myself and the HI community:

Thanks Jim!