U.S. DEPARTMENT OF ENERGY | Office of Science

Perspectives from DOE Nuclear Physics

Nuclear Science Advisory Committee Meeting
December 1, 2011
Gaithersburg, MD

Timothy J. Hallman
Associate Director for Nuclear Physics
Office of Science, U.S. Department of Energy

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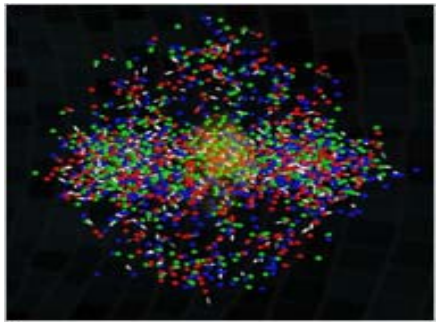
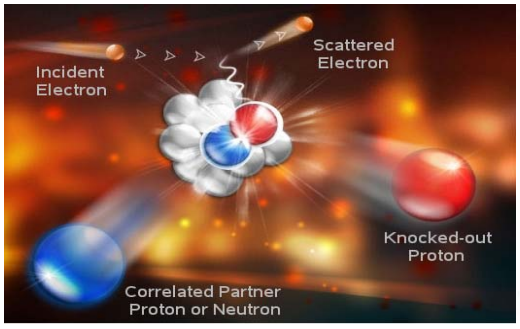
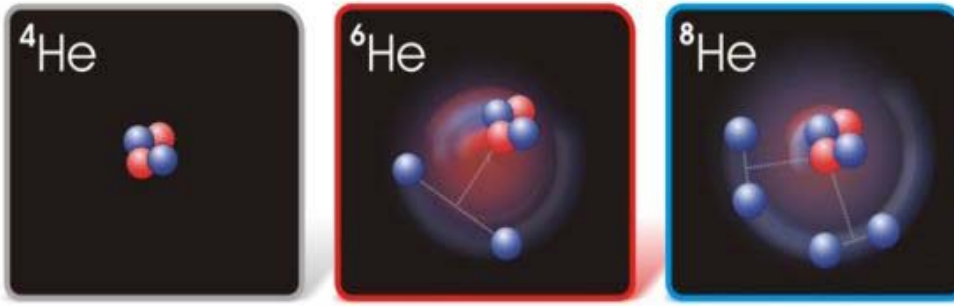
Nuclear Physics Vision

- To enable U.S. world leadership in discovery science illuminating the properties of nuclear matter in all of its manifestations
- To provide the tools necessary for scientific and technical advances which will lead to new knowledge, new competencies, and groundbreaking innovation and applications
- To make strategic investments in facilities and research to provide the U.S. with the premier facilities in the world around the end of the decade for research on:
  - New states of matter 100 times more dense than “normal’ nuclear matter at the Relativistic Heavy Ion Collider
  - The force which binds quarks and gluons in protons and neutrons at the 12 GeV Continuous Electron Beam Accelerator Facility
  - The limits of nuclear existence for neutron and proton rich nuclei at the Facility for Rare Isotope Beams and the Argonne Tandem Linac Accelerator System
  - Innovative, effective and reliable isotope production with a new dedicated isotope facility







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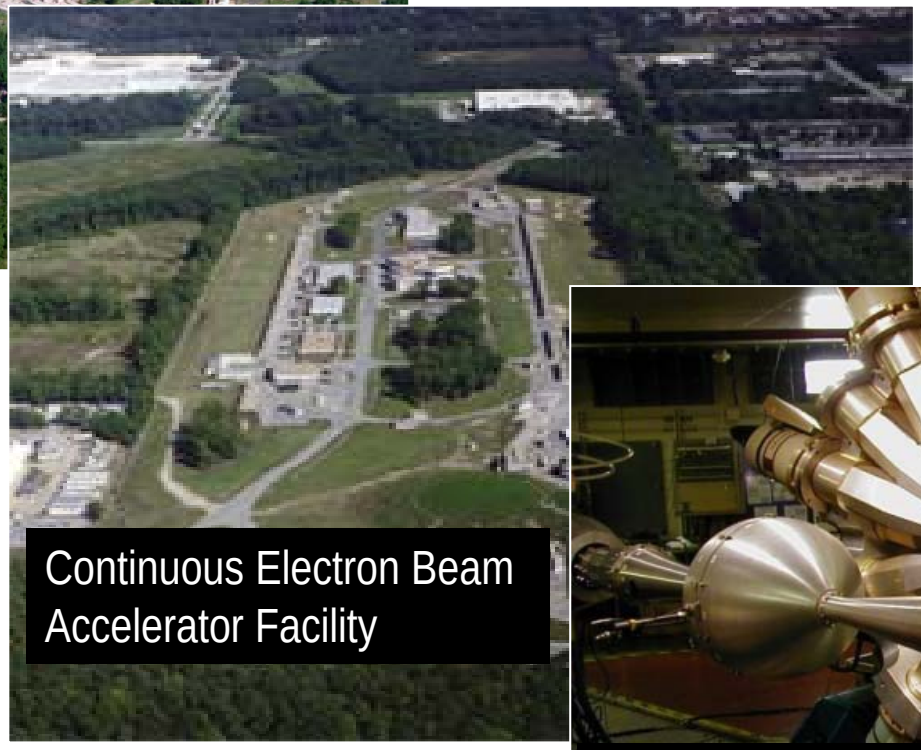
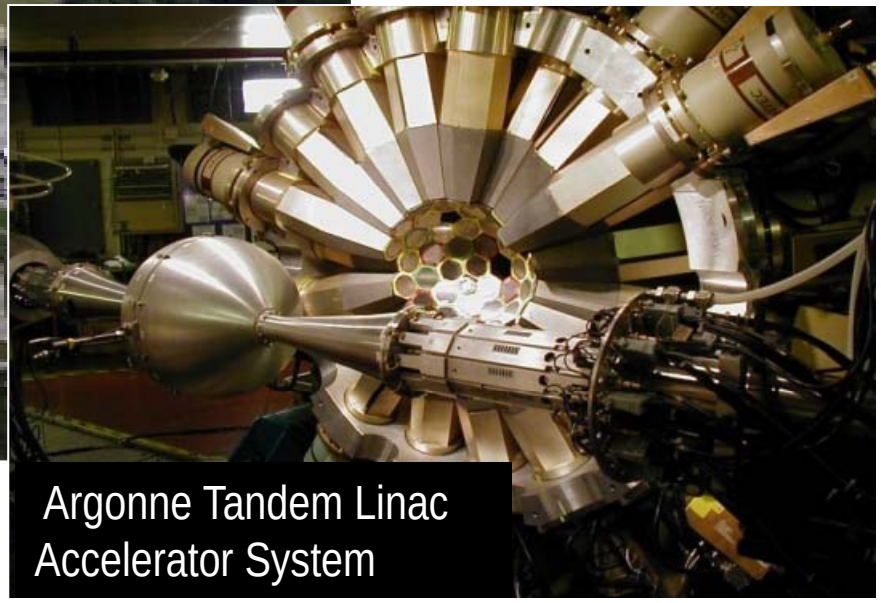
NP National User Facilities Beyond FY 2012

"Microscopes" pursuing groundbreaking research

Relativistic Heavy Ion Collider



Continuous Electron Beam Accelerator Facility



Argonne Tandem Linac Accelerator System

Planned Facility Closure in FY2012

Holifield Radioactive Ion Beam Facility

HRIBF Terminated in FY2012

D&D begins in FY2012 and continues
In FY2013 and the out years

Impacts:

RIF of ~ 50 scientific and technical staff

Need to transition sizeable user community

No U.S. ISOL capability

Some isotopes for NP research unavailable in the U.S. until FRIB

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New Capabilities and Tools: 12 GeV Upgrade – Highlights

- Hall D Complex – civil construction nearly complete

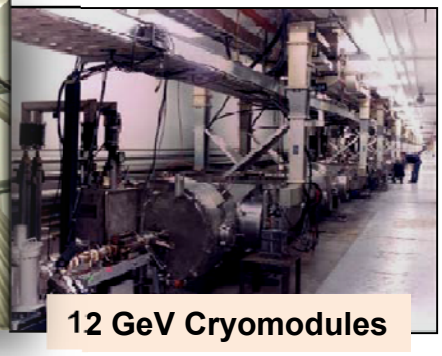

Hall D & Counting House

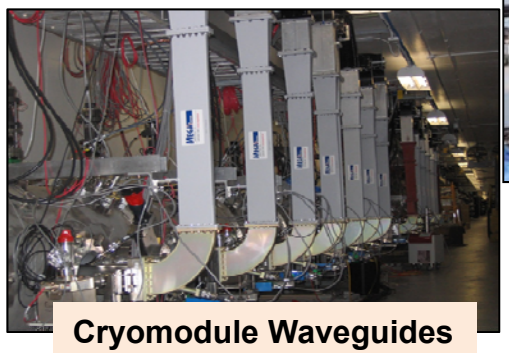

Hall D Interior

- First major installation period (6 months) very successful
  - Accelerator tunnel connection to Hall D complete
  - Arc Magnet rework exceeded plan
  - Two (of 10) high gradient 12 GeV cryomodules installed


Arc Magnets


Hall D Drift Chamber

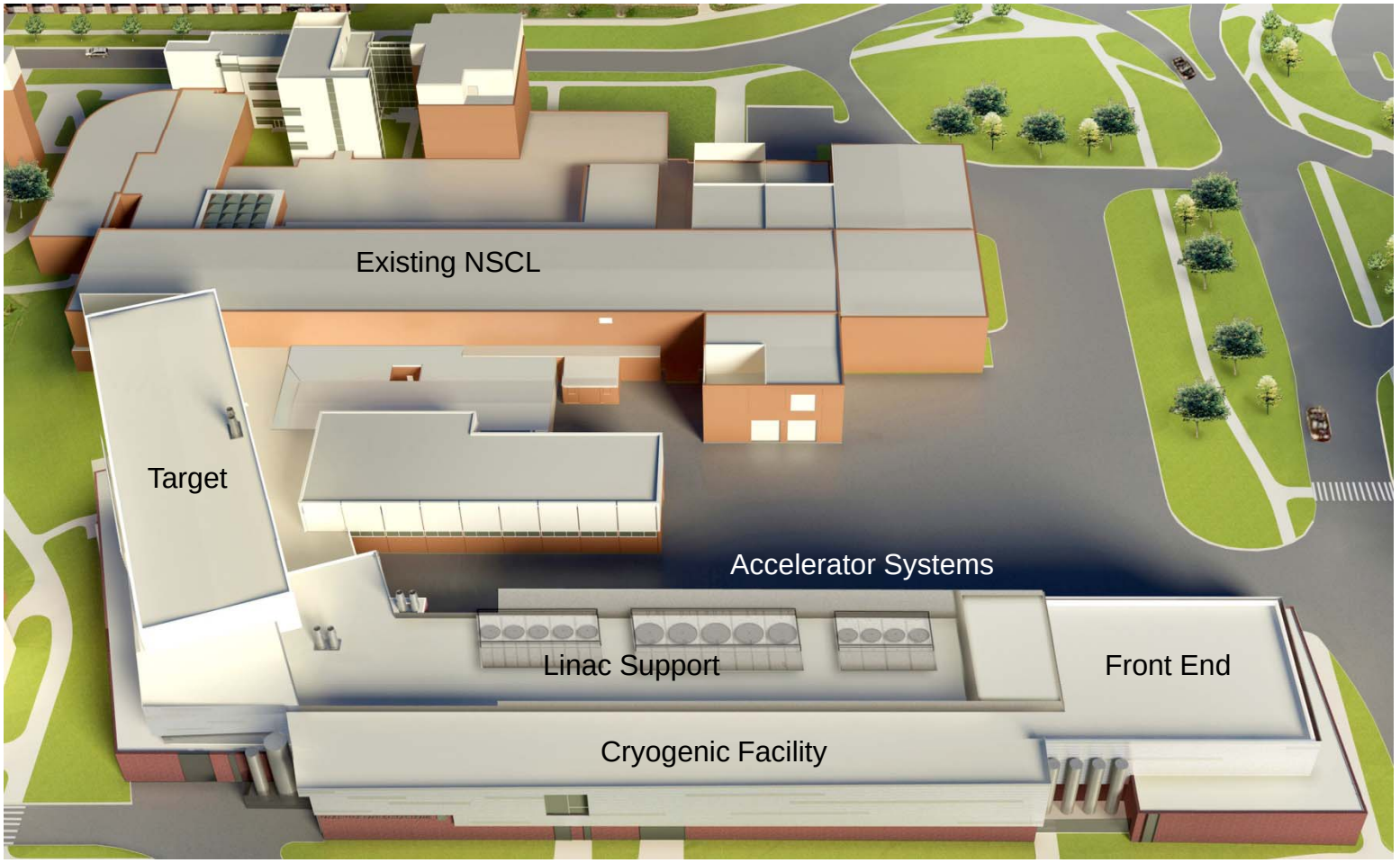

12 GeV Cryomodules


Cryomodule Waveguides

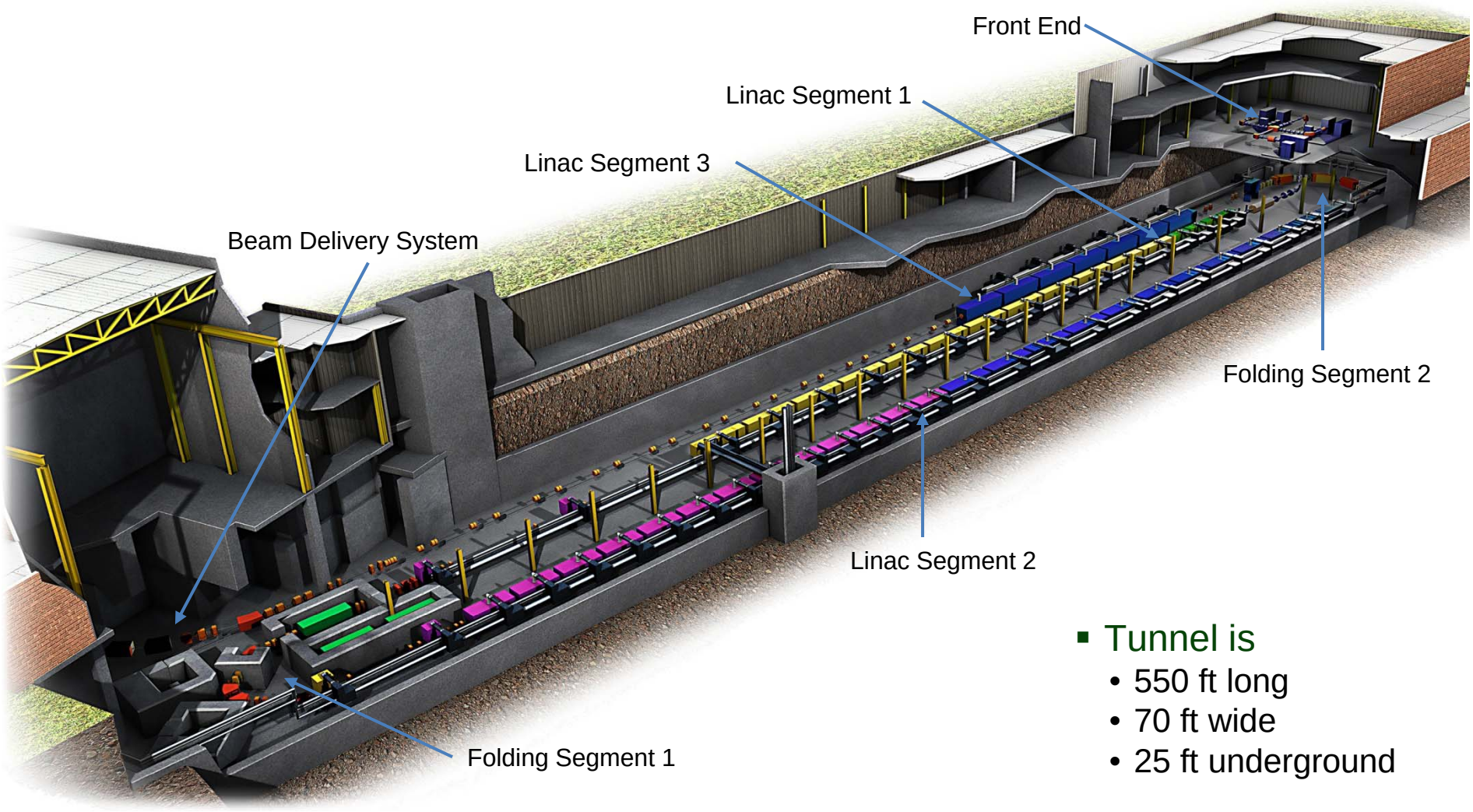
- Hall D Solenoid Magnet tested and installed
- All major detector systems under construction

Physics Running Resumed Nov19th !

Facility for Rare Isotope Beams: Preliminary Civil Design Complete & Integrated with Technical Systems; Final Design Started



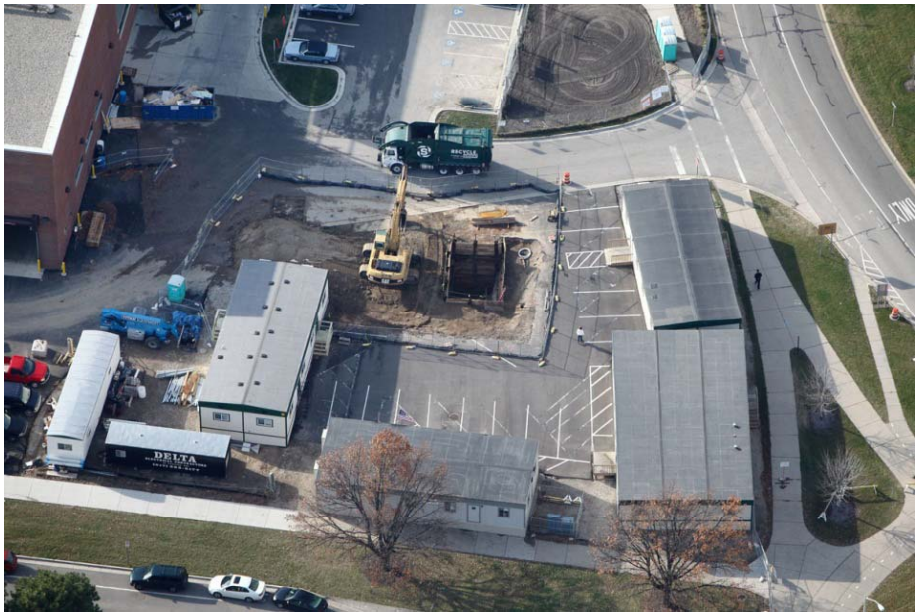
Driver Linear Accelerator Lattice Frozen; Design Integrated with Civil Design

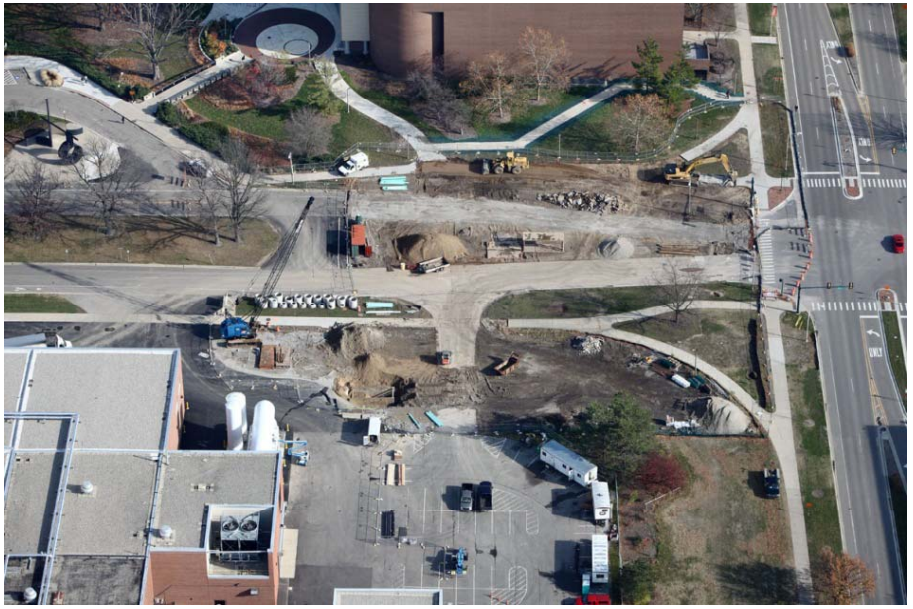


- Tunnel is
  - 550 ft long
  - 70 ft wide
  - 25 ft underground

FRIB Ready to Start Civil Construction in May 2012

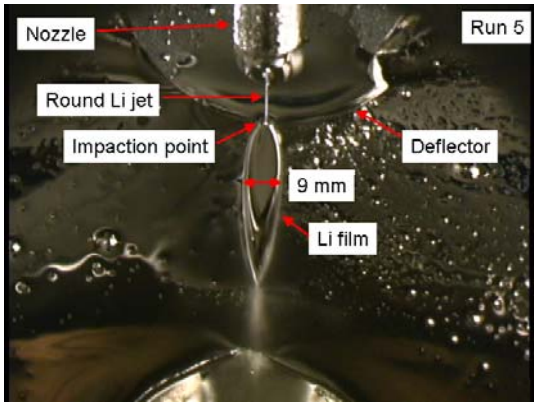
- Advanced civil construction by one year rel. to CD-1 to reduce cost risk
  - MSU cost share funding advanced while keeping DOE profile the same
- Ready to start civil construction
  - Site clearing and site preparation starts in January 2012
  - Excavation starts in May 2012 assuming successful Lehman Review in April
- Utility relocation proceeding now





Leveraging Prior Investments by DOE and Office of Nuclear Physics

- ANL
  - Successfully demonstrated stability of liquid lithium film for charge stripping
  - Collaborates on SRF work and fragment separator
- BNL
  - Successful R&D on high-temperature superconducting radiation resistant magnet allows R&D magnet to become part of FRIB baseline
  - Develops plasma windows for gas charge stripper
- JLab
  - Designs liquid helium plant
  - Collaborates on SRF work and processes SRF cavities
- LANL
  - Provides LEDA ion source for tests
- LBNL
  - VENUS ion source produces brightest uranium beam (440 emA in 33^{+} and 400 emA in 34^{+})
  - For 400 kW beam, FRIB needs 432 emA in 33^{+}
  - Eliminates need to simultaneously accelerate two charge states before stripping
- ORNL
  - Collaboration on design of beam dump, remote handling and non-conventional utilities in target area



FRIB Project On Track for CD-2/3A in Spring 2012

- Lehman Reviews
  - March 2011 "*The Review Committee supports the combined CD-2/3A strategy and the advancement of MSU funding in FY-11 and FY-12 to accelerate the conventional facilities design and construction.*"
  - September 2011 "*Schedule a CD-2/3A review to be conducted in April 2012.*"

1,000 FRIB Users Ready to Make Discoveries

FRIB Users Organization
FACILITY FOR RARE ISOTOPE BEAMS

fribusers.org

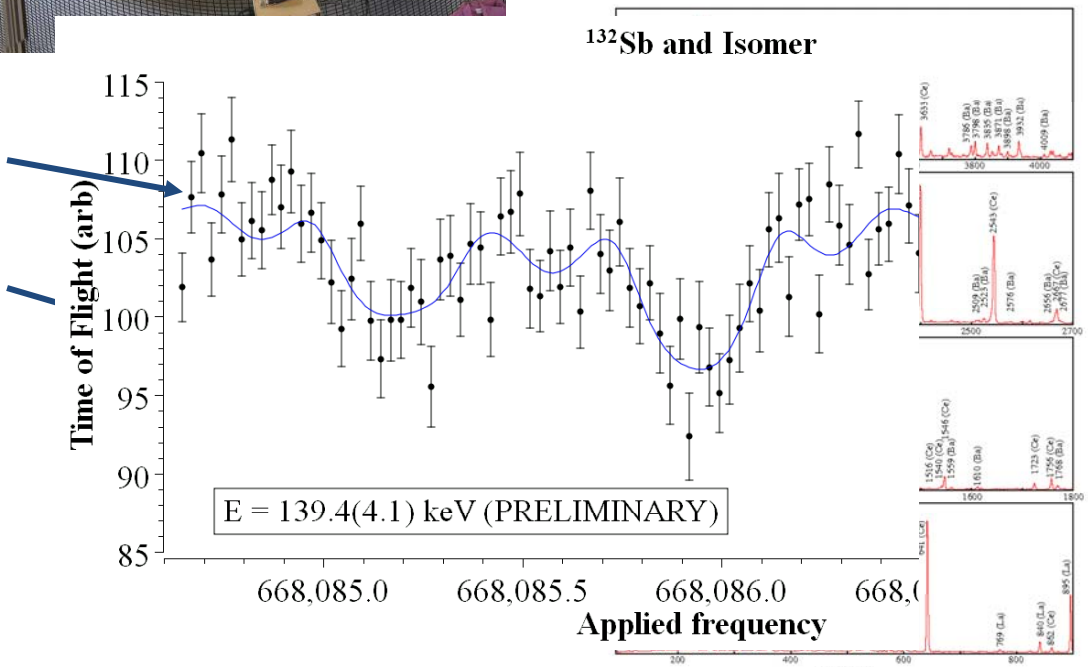
- 1,050 users in FRIB Users Organization
- 20 working groups on experimental equipment
- Seven meetings and workshops since May 2009
  - Joint ATLAS-HRIBF-NSCL-FRIB Users Meeting, August 2011 in East Lansing
  - SAC Review of Equipment Initiatives, February 2011 in East Lansing
  - Advances in Nuclear Radiation Detectors and Technologies, January 2011 at Rutgers University
  - Reaction Theory for FRIB, November 2010 at DNP meeting in Santa Fe
  - Radiochemistry at FRIB, August 2010 in Boston
  - FRIB Equipment Workshop, February 2010 in East Lansing
  - Step Forward to FRIB, May 2009 at Argonne National Laboratory
- Users poised for discoveries when FRIB turns on

Joint Users Meeting, August 2011

CARIBU status

- Project completed: All commissioning milestones achieved

- First measurements have been made
  - New and improved masses at the CPT mass spectrometer
  - Decay spectra at Gammasphere



- Working on improving yield, transmission and beam purity
- CARIBU beams available in next PAC cycle (2012)

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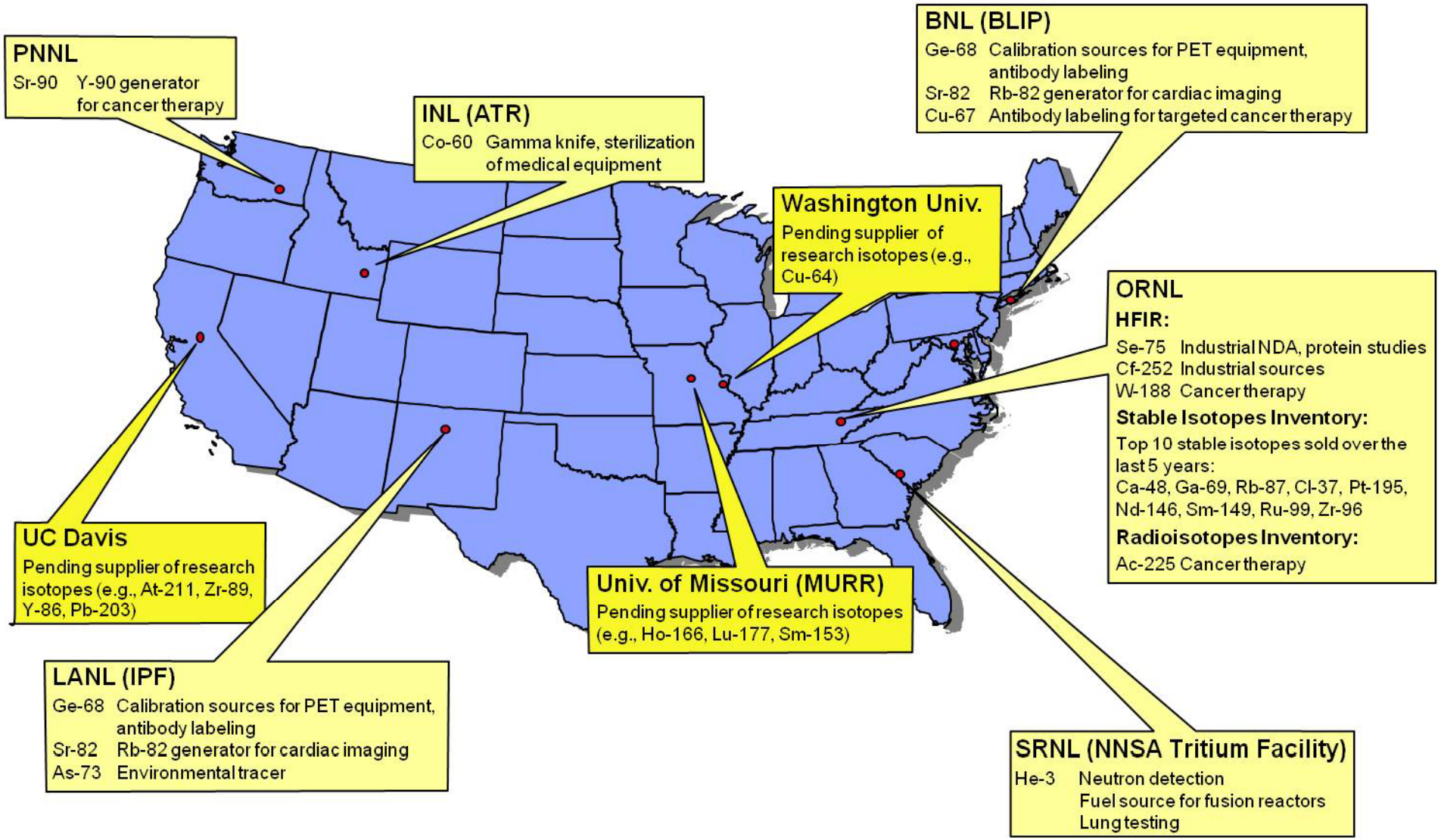
Other NP Capabilities: Production Sites Presently Integrated into the Isotope Program



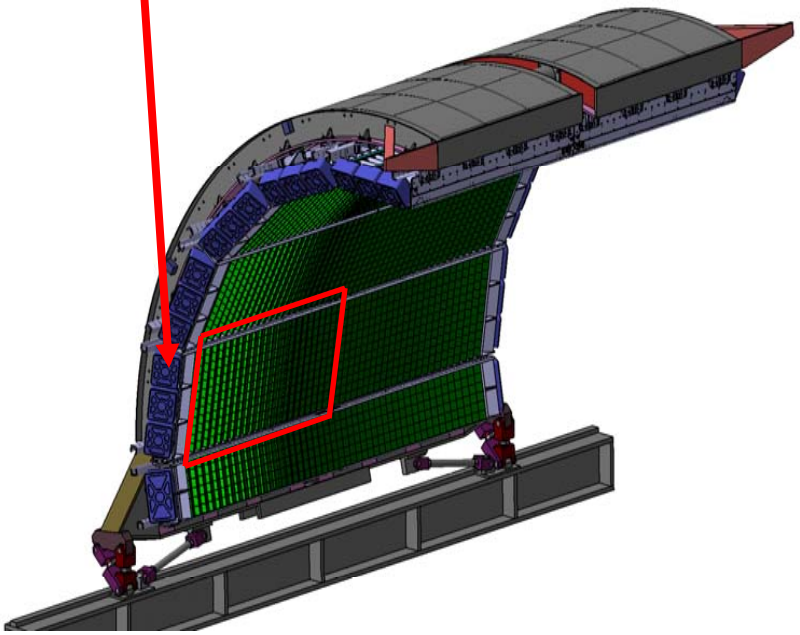
EMCal for ALICE to study LHC Heavy Ion Collisions

U.S. Heavy Ions at the LHC
DOE TPC: $13.5 Million
FY 2007-FY 2011 CD-2/3 in February 2008

- Joint U.S., French, and Italian project

Project Deliverables:

- US Scope: 7 2/3 Supermodules
- EU Scope: 3 Supermodules

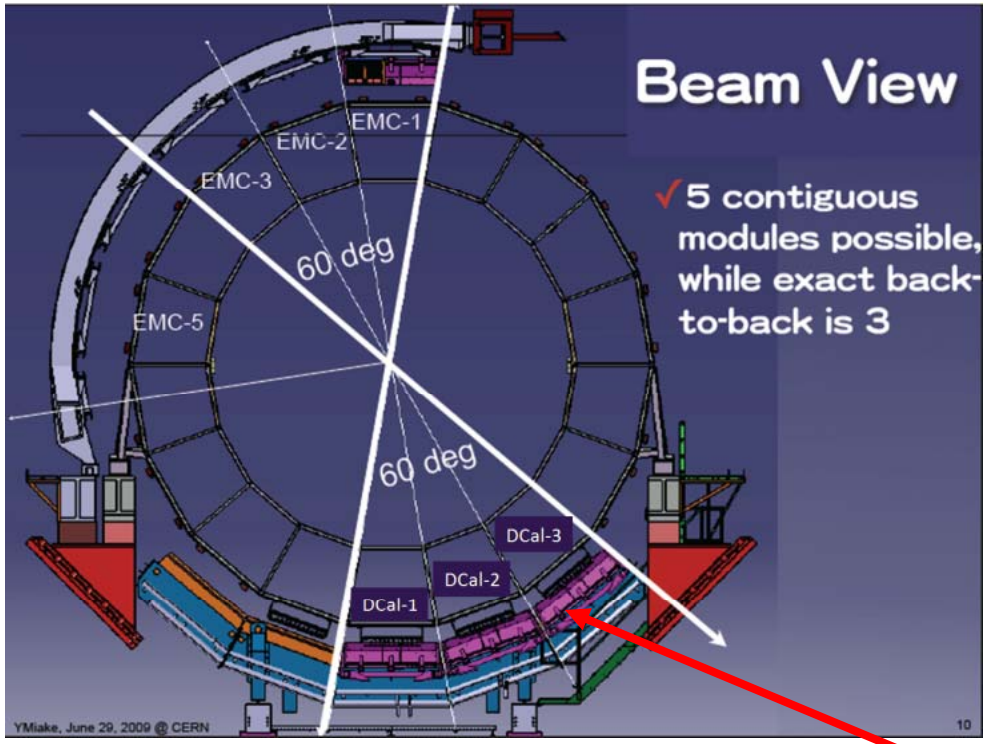


Science:

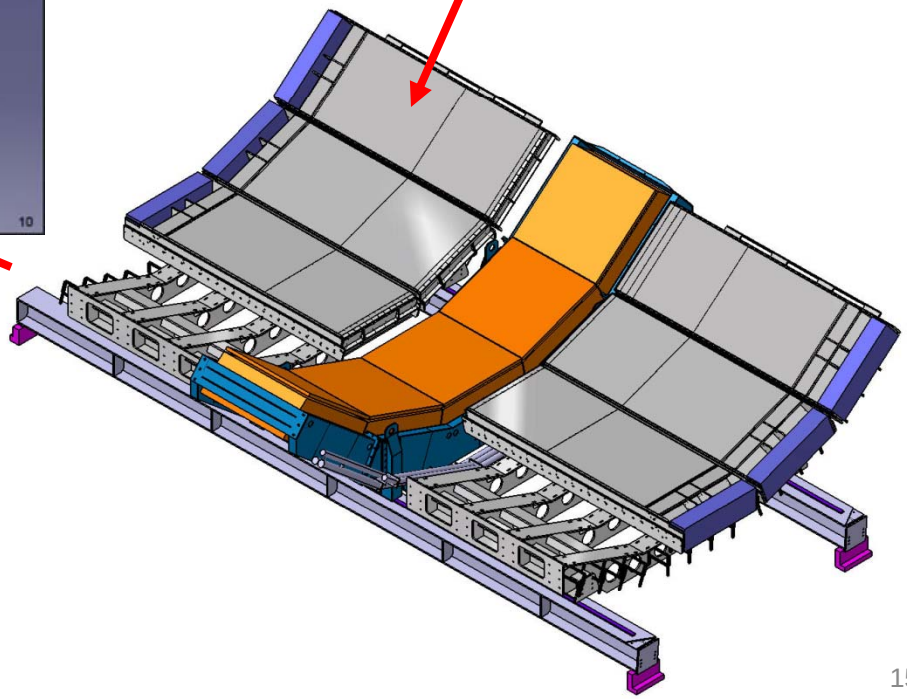
- Triggering on high p_T π_0, gammas and electrons to study jet quenching via suppression of leading particles
- Hard processes modified by the nuclear medium
- Jet correlations and jet reconstruction

	FY06	FY07	FY08	FY09	FY10	FY11
DOE TPC $ in 000s	295	1,000	2,000	4,000	5,000	1,205

DCAL "Away Side" Acceptance Upgrade



Concept: 6 DCal super modules (2/3 length EMCal + Electronics, Trigger, Controls)



EMCAL project so successful that DCAL scope enhancement is possible within the original TPC ($13.5M)

USA-China-France-Finland-Italy-Japan Collaboration

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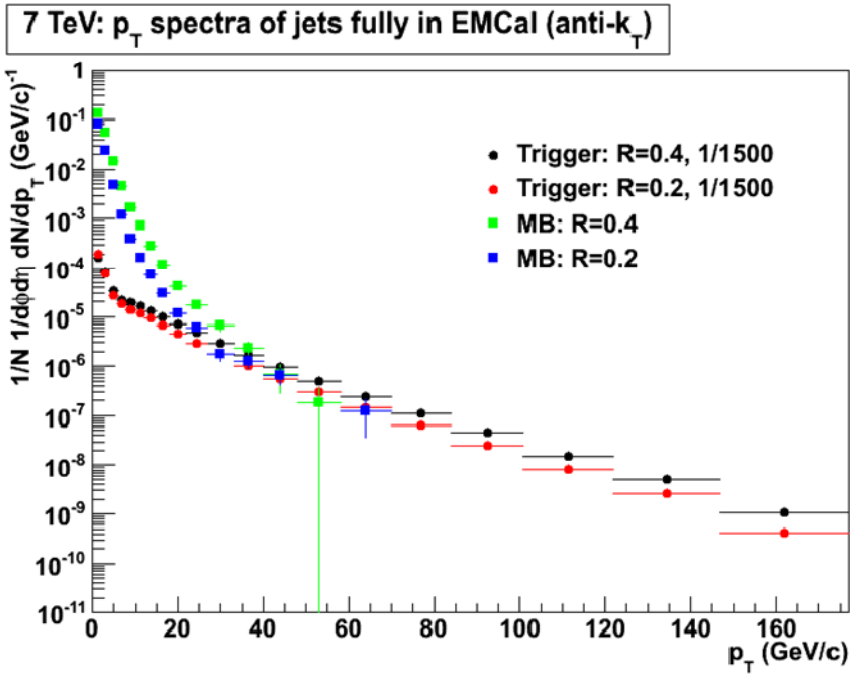
Completion of the ALICE EMCal detector

A major milestone was reached in January, 2011, by US collaborators in the ALICE experiment at the Large Hadron Collider in Geneva, Switzerland, with the completion of the EMCal, a large electromagnetic calorimeter. The EMCal was built by an international group of institutions from the US, France, and Italy, as well as CERN. It was led by the US, with support from DOE/NP for a total project cost of $13.5 M.

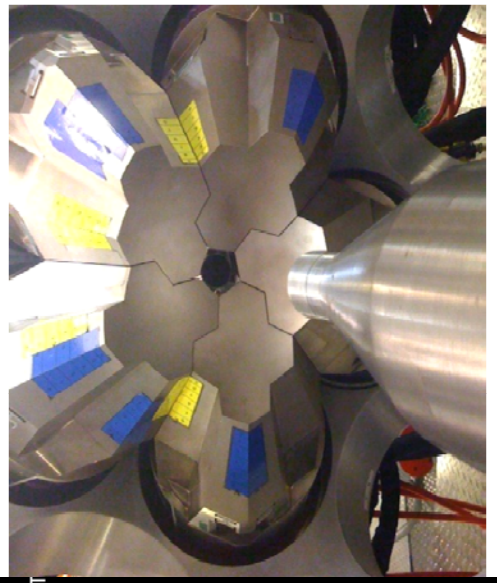
The photo shows the EMCal installation fixture (yellow), loaded with a supermodule and being positioned for installation. The plot shows the preliminary inclusive jet spectrum measured by the EMCal during the 3-day LHC run in March 2011 (two months after installation), with proton collisions at an energy of 2.78 TeV, the same as that of LHC heavy ion collisions. The plot shows the large kinematic reach of jet measurements in the EMCal, as well and the good performance of the EMCal trigger system.

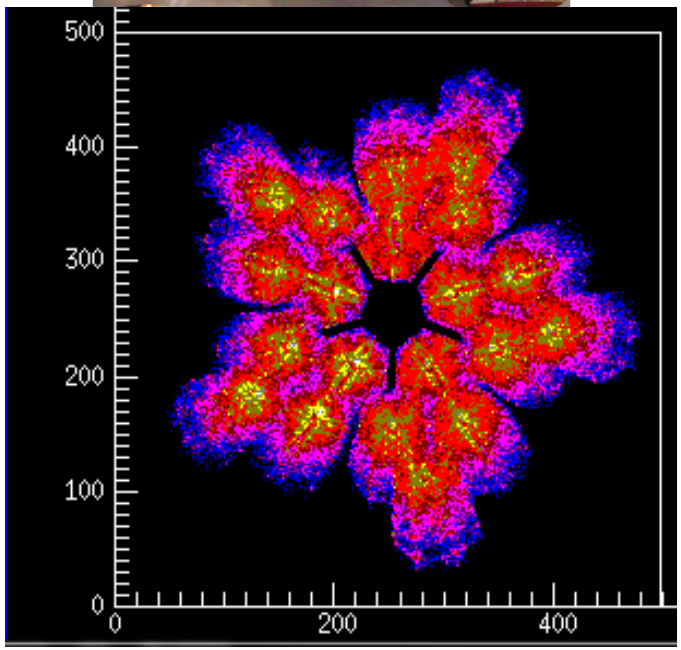


Completion of the GRETINA detector

- On March 22nd 2011, the Department of Energy approved the start of operations for GRETINA (Critical Decision 4, CD-4). The project has been completed on time, on budget, and exceeded many of the key performance parameters. GRETINA now enters the operations phase with scheduled engineering runs taking place in April, May, and July in Cave 4C of the 88-Inch Cyclotron. It will then be moved and coupled with the BGS for a series of commissioning runs from September 2011 through March 2012. Then it will move to the NSCL at MSU to begin physics campaigns at the national laboratories.

- The first engineering run was successfully April 5-6. The reaction used was $^{122}Sn(^{40}Ar,4n)^{158}Er$ with a 170 MeV Ar beam from the 88-Inch cyclotron. We completed all planned tests and collected about 1 Tbyte of data. Results from an on-line analysis are shown in the figure Members of the Users Community representing ANL, FSU, ORNL, Richmond and Rochester participated of this run.





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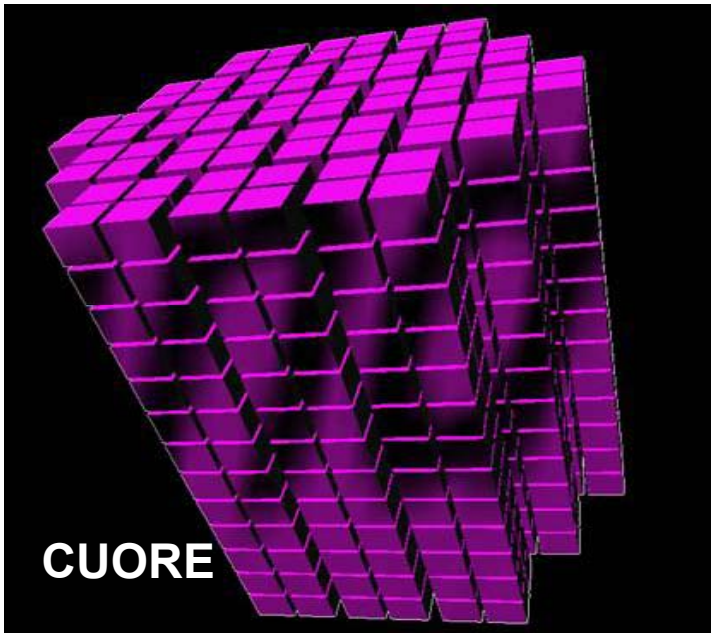
Major Activities in Neutrinos, and Fundamental Symmetries

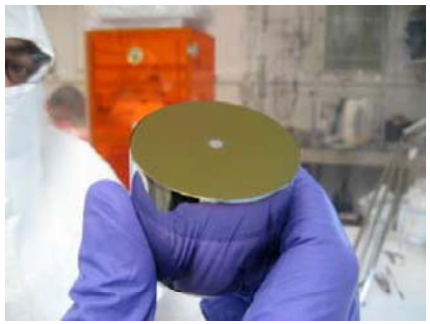
Grand Challenge — Nobel Class — question being tackled:

Is the neutrino its own anti-particle ?



U.S. – Italian international Collaboration using Te crystal technology at Gran Sasso. Joint DOE/NSF project funding

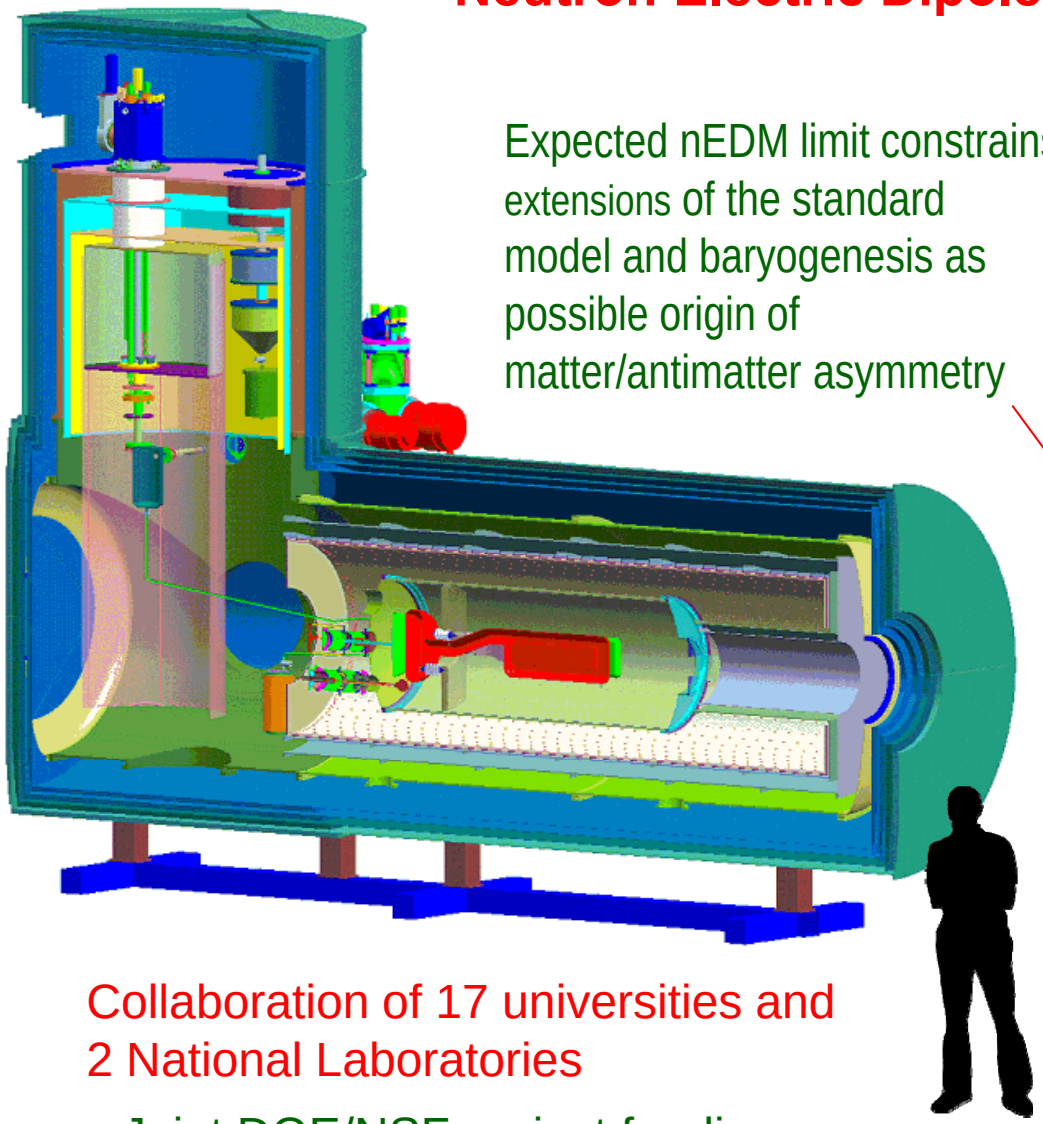
U.S. – Technology Demonstration prior to technology choice and planned US-German Collaboration



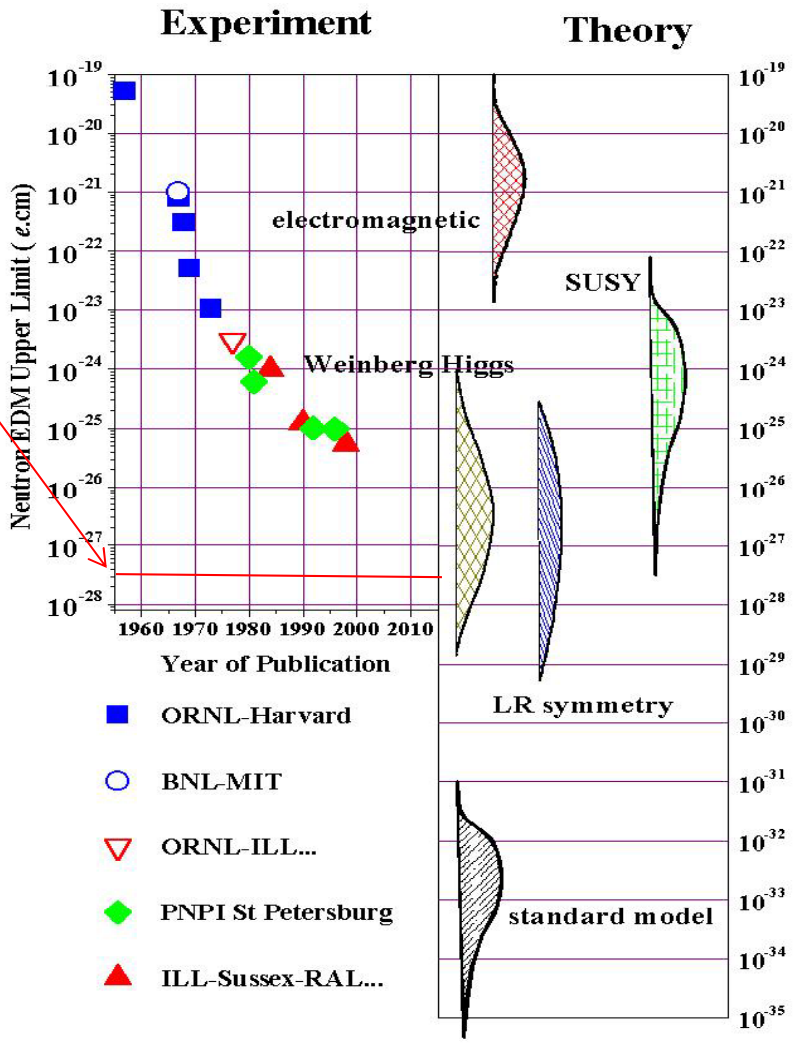
Germanium detector and the cryostat for Majorana Demonstrator.

Fundamental Symmetries (cont'd)

Neutron Electric Dipole Moment (nEDM)



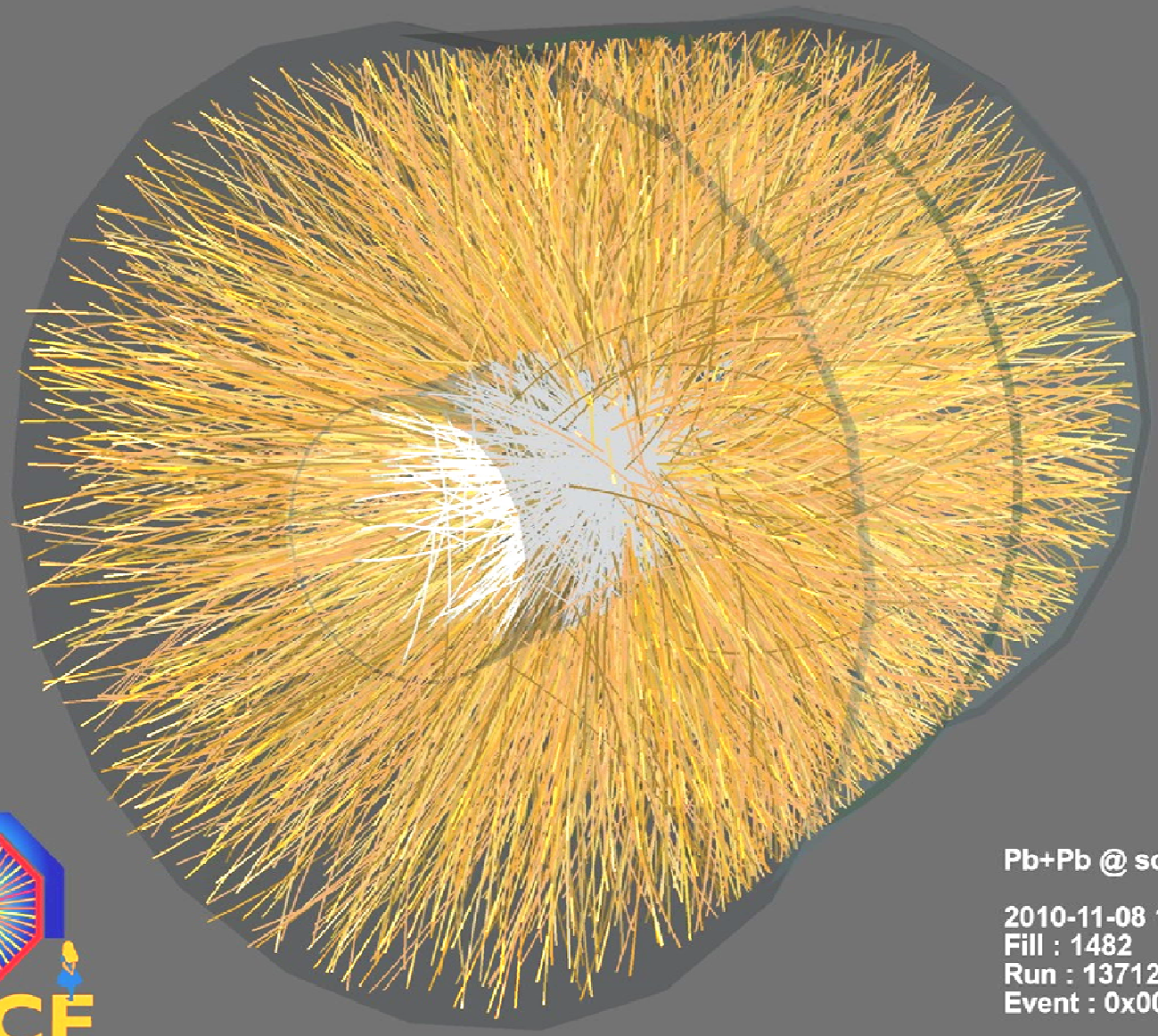
Expected nEDM limit constrains extensions of the standard model and baryogenesis as possible origin of matter/antimatter asymmetry



Collaboration of 17 universities and 2 National Laboratories

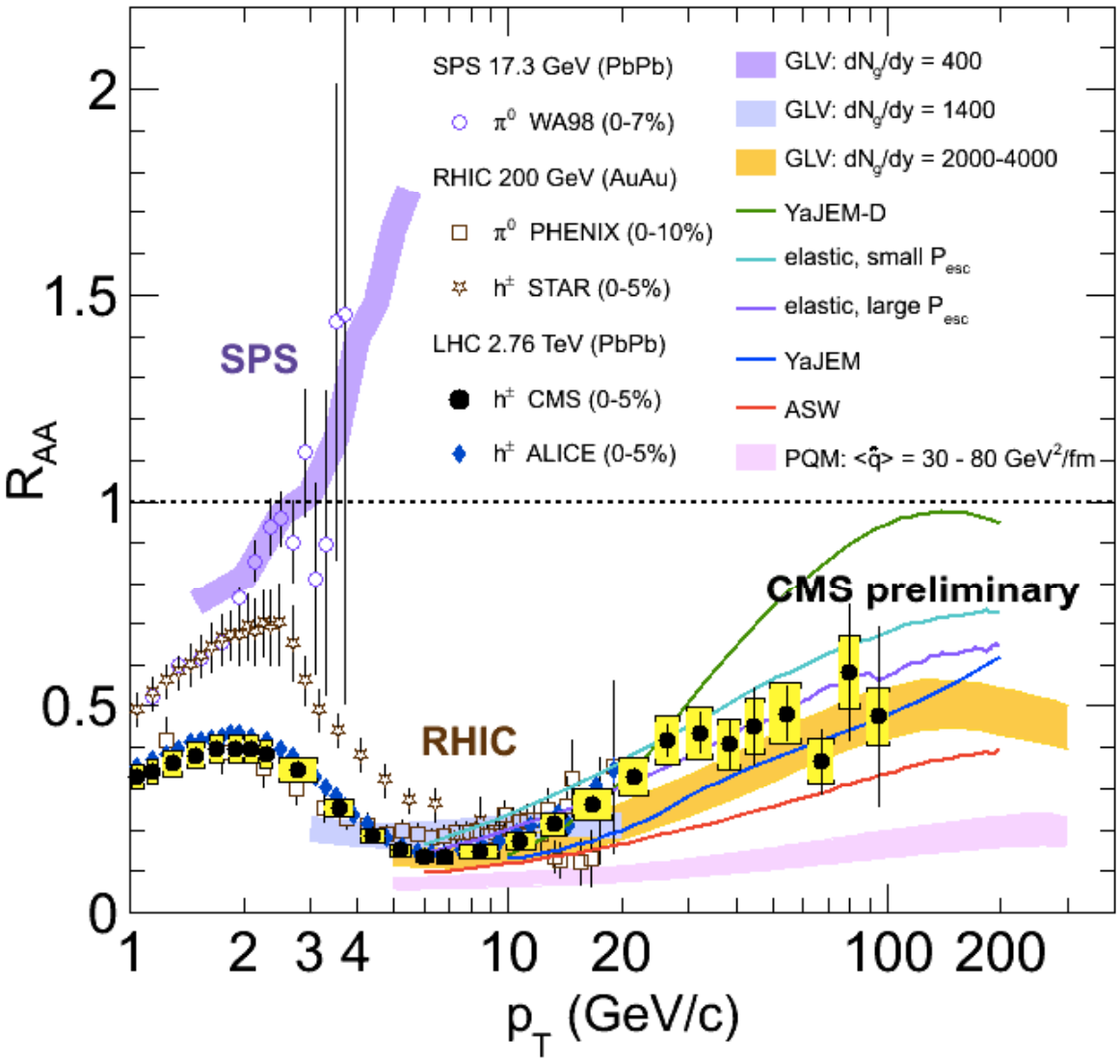
Joint DOE/NSF project funding

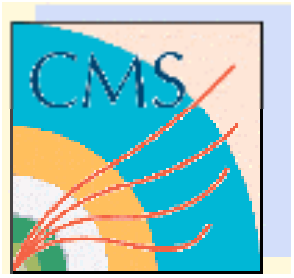
First Heavy Ion Pb+Pb collisions at 2.76 TeV in November 2010.



ALICE

First Physics Results (< 6 months)





R_{AA} to 100 GeV/c!

Large quenching!

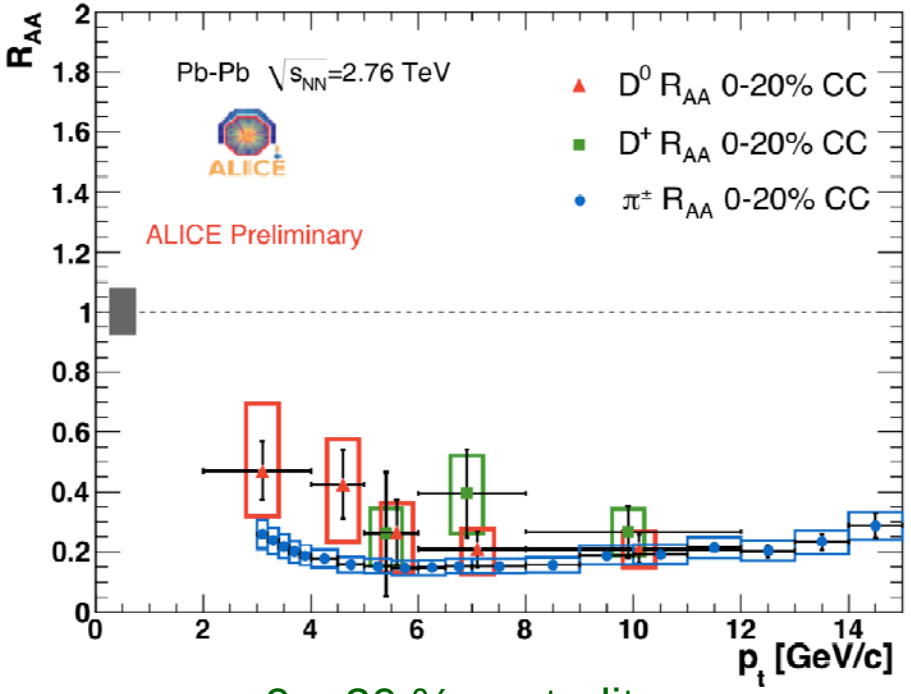
For colorless probes (direct photons) initial results consistent with no suppression

CMS, Wyslouch QM 2011

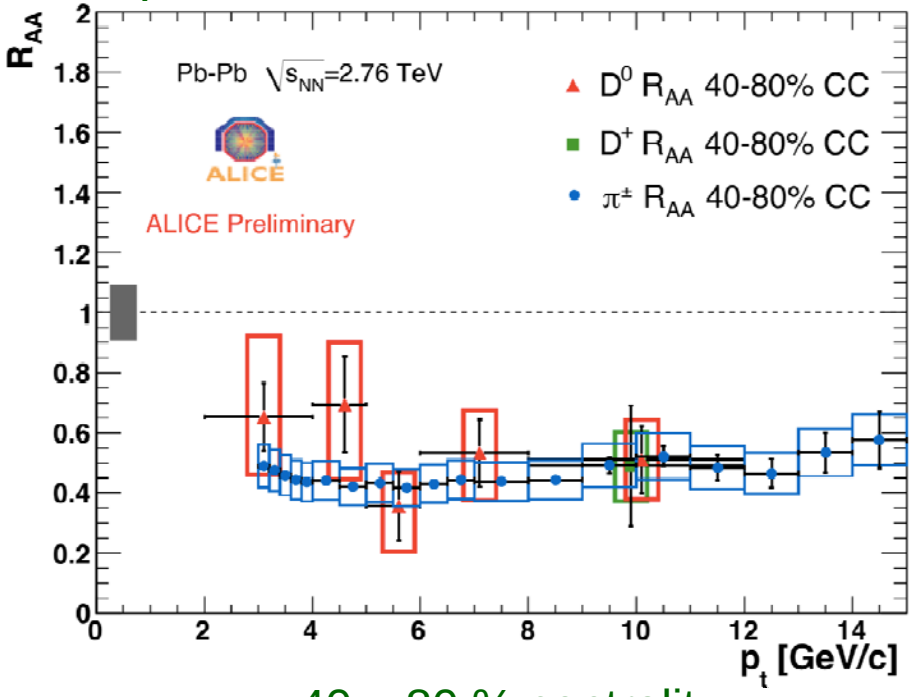
R_{AA} at SPS, RHIC, LHC, & Theory

First Physics Results (< 6 months)

ALICE, A. Dainese OM 2011



0 – 20 % centrality



40 – 80 % centrality

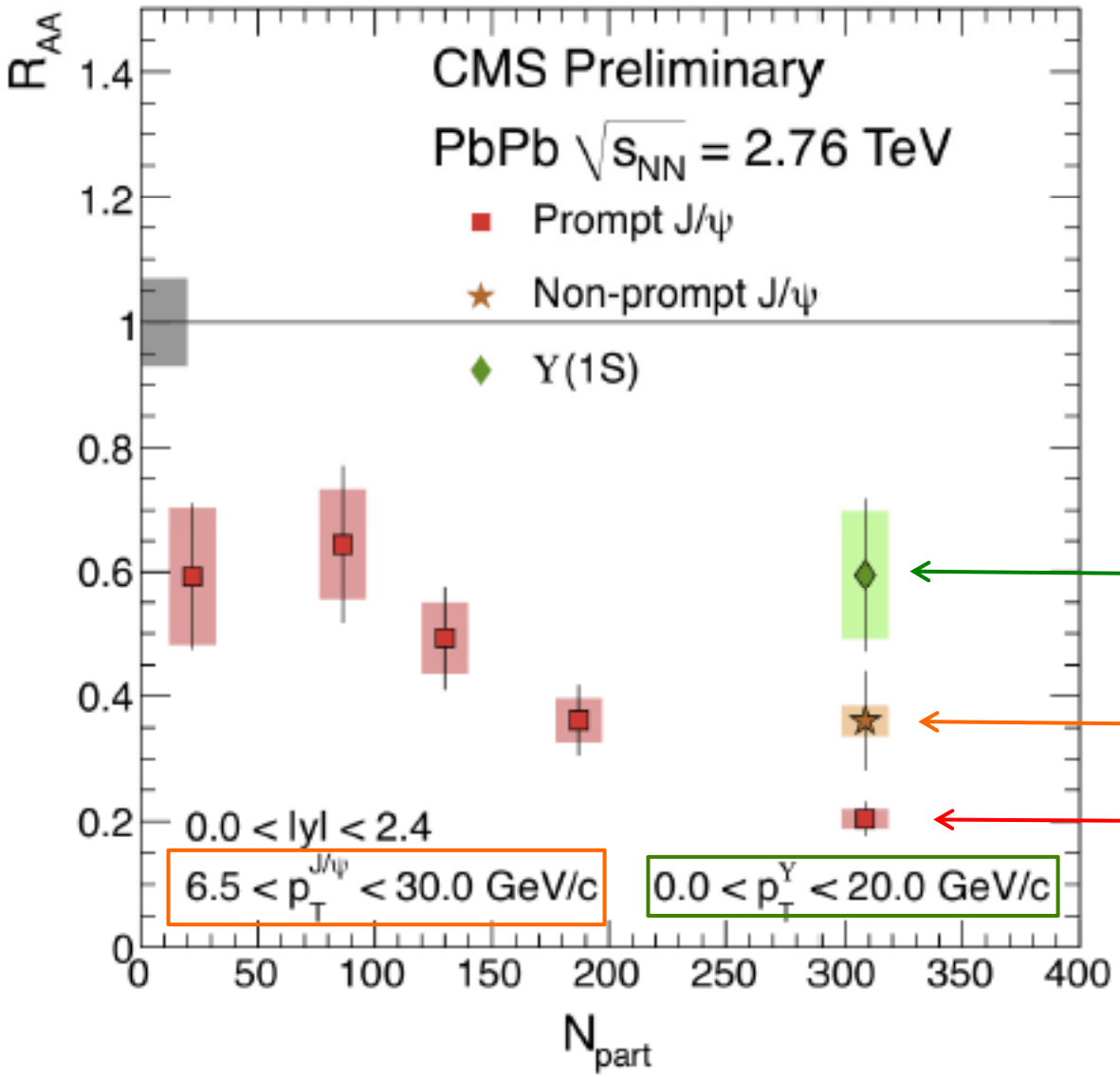
R_{AA} Centrality Dependence – D and π

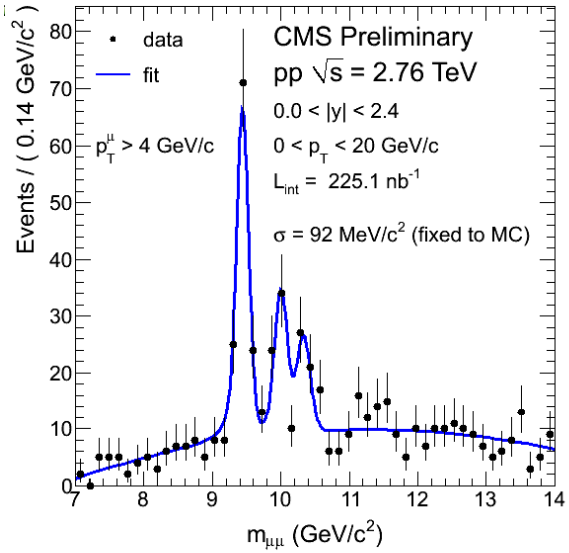
~ 4-5x suppression for charm for $p_T > 5$ GeV/*c*

R_{AA} (D) ~ R_{AA} (π) for $p_T > 5$ GeV/*c*

R_{AA} (D) slightly larger than R_{AA} (π) for $p_T < 5$ GeV/*c*

First Physics Results (< 6 months)





Inclusive Υ (1s) suppressed

Non-Prompt J/ψ from B-decays

Prompt J/ψ suppressed

CMS, C. Sylvestre, B. Wyslouch QM 2011

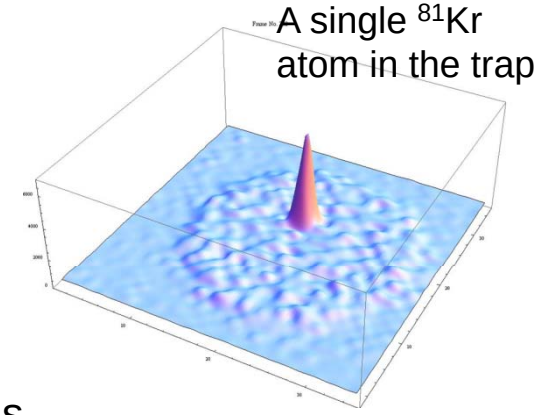
R_{AA} Centrality Dependence – J/ψ and Υ

Atom Trap Trace Analysis (ATTA)

Developed ATTA-3 instrument with greatly improved sensitivity and selectivity

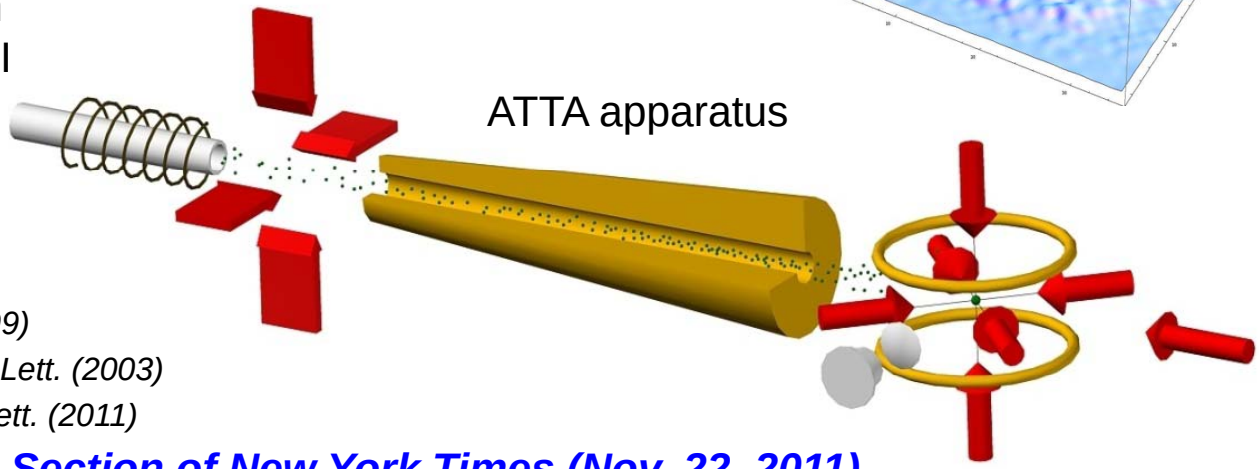
- Sensitivity: Capable of ^{81}Kr-dating with a sample of 10 micro-liter (STP) of krypton gas;
- Selectivity: Analyzed ^{39}Ar in environmental samples with exquisite isotopic abundance sensitivity

^{81}Kr-dating has been achieved. This opens up range of applications in Earth & Environmental sciences



Samples to be analyzed in 2011-2012

- Done: Yellowstone National Park, WIPP sites (with Sandia);
- In progress: Great Artesian Basin, Australia;
- Planned: Participation in world-wide aquifers (with I



References

- ATTA-1: *Chen et al., Science (1999)*
- ATTA-2: *Du et al., Geophys. Res. Lett. (2003)*
- ATTA-3: *Jiang et al., Phys. Rev. Lett. (2011)*

- ***Featured in the Science Section of New York Times (Nov. 22, 2011)***

NP Science "In The News"

The New York Times SCIENCE

A Rare Isotope Helps Track an Ancient Water Source

By FELICITY BARRINGER
Published: November 21, 2011

DEA/C. SAPPA/De Agostini/Getty Images

The Dakhla Oasis in western Egypt is fed by the Nubian Aquifer.

Knowing how long water has been underground helps researchers understand how fast aquifers are recharged by surface water and how fast they move, leading to more accurate geological models. Groundwater is becoming an increasingly crucial component of the world's available fresh water, and the findings could significantly increase understanding of how it behaves. …

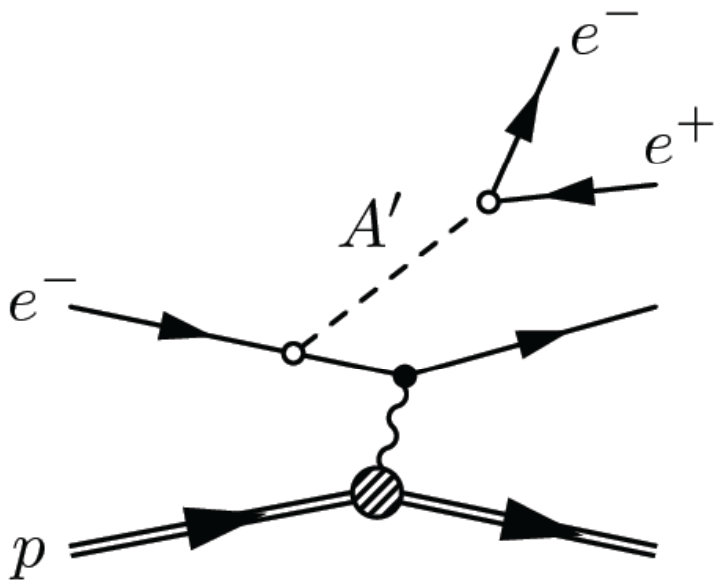
The Nubian Aquifer, the font of fabled oases in Egypt and Libya, stretches languidly across 770,000 square miles of northern Africa, a pointillist collection of underground pools of water migrating, ever so slowly, through rock and sand toward the Mediterranean Sea.

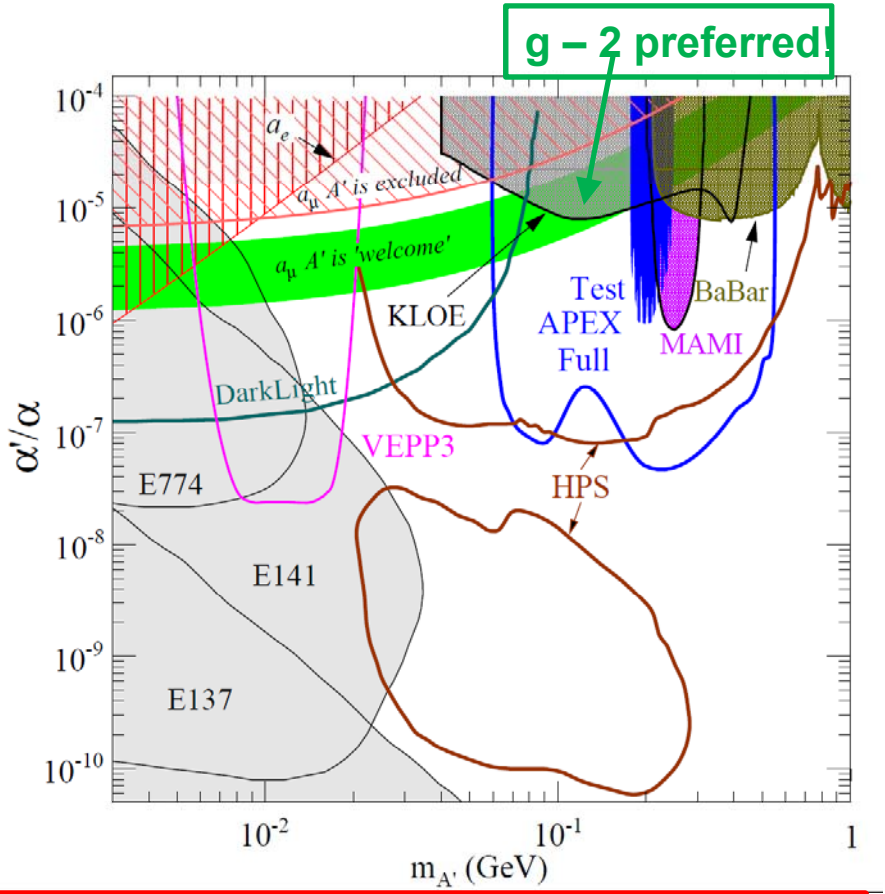
The aquifer is one of the world's oldest. But its workings — how it flows and how quickly surface water replenishes it — have been hard to understand, in part because the tools available to study it have provided, at best, a blurry image. Now, to solve some of the puzzles, physicists at the Department of Energy's Argonne National Laboratory in Illinois have turned to one of the rarest particles on earth: an elusive radioactive isotope usually ricocheting around in the atmosphere at hundreds of miles an hour.

Their first success was in distilling these elusive isotopes, krypton 81, from the water in the huge Nubian Aquifer, part of which lies two miles below the oases of western Egypt where temples honor Alexander the Great. Their second was in holding these isotopes still and measuring how much they had decayed since they last saw sunlight. …..

New Opportunity: Search for A' at JLAB

Search for new forces mediated by ~100 MeV vector boson A' with weak coupling to electrons:





Irrespective of astrophysical anomalies:

- New ~GeV–scale force carriers are important category of physics beyond the SM
- Fixed-target experiments @JLab (FEL + CEBAF) have unique capability to explore this!

APEX – Hall A test run, published: arXiv:1108.2750, PhysRevLett.107.191804

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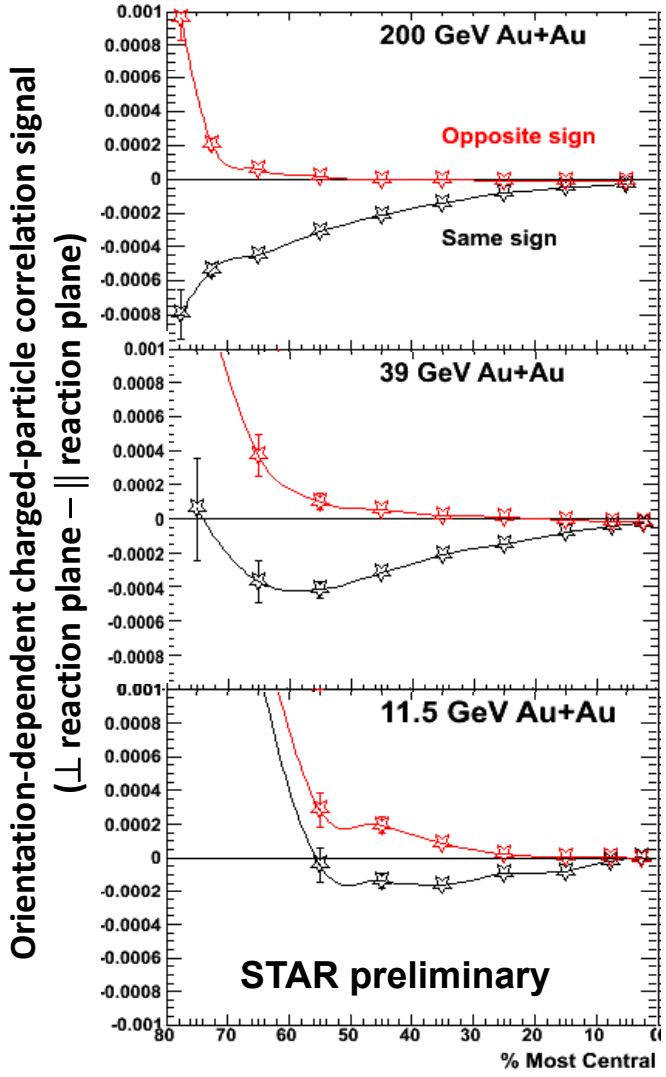
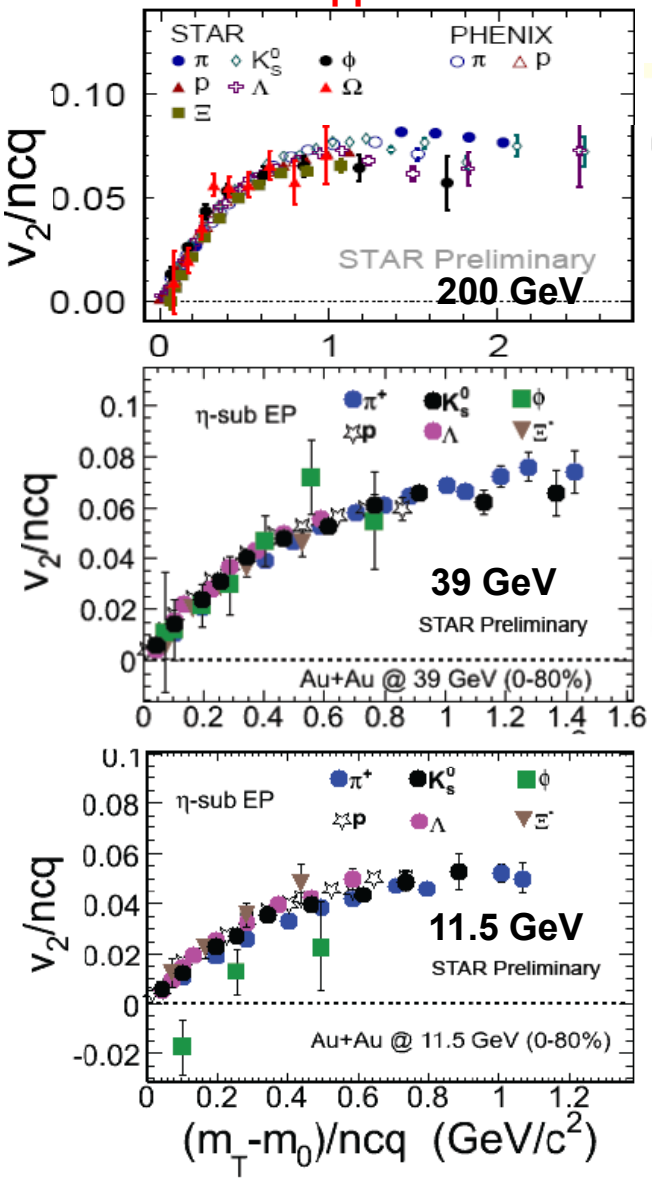
New RHIC Data ⇒ Behavior Changes Below $\sqrt{s_{NN}}$ = 39 GeV
Signal of Onset of Deconfinement?

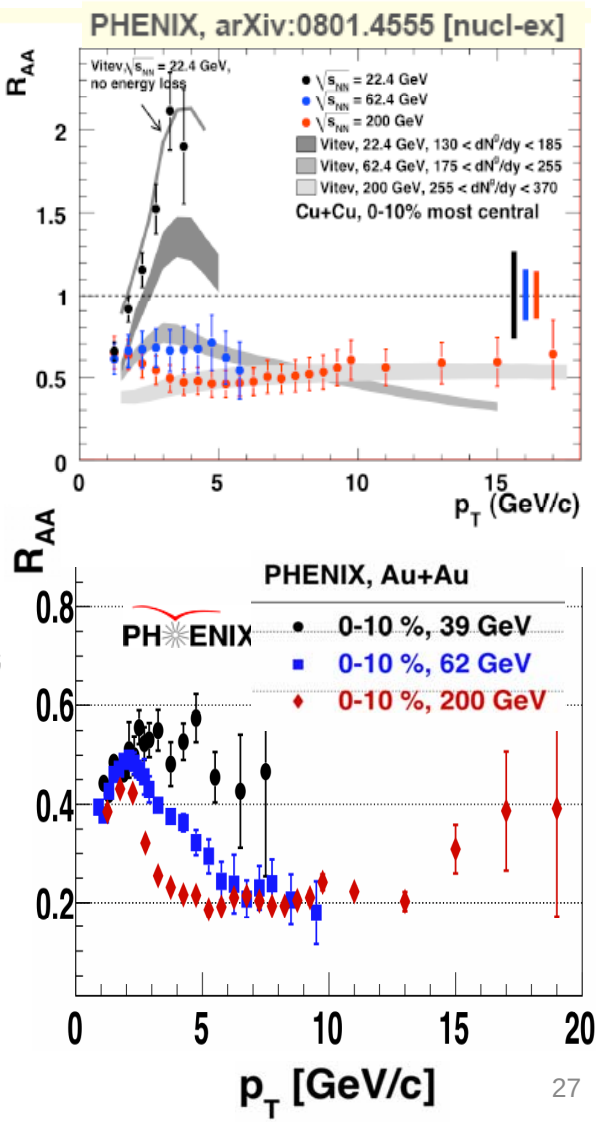
Charge-dependent correl'n consistent with Local Parity Violation tends to vanish below 39 GeV



Constituent-quark scaling of elliptic flow less apparent < 39 GeV



High-p_T hadron suppression → enhancement < 39 GeV



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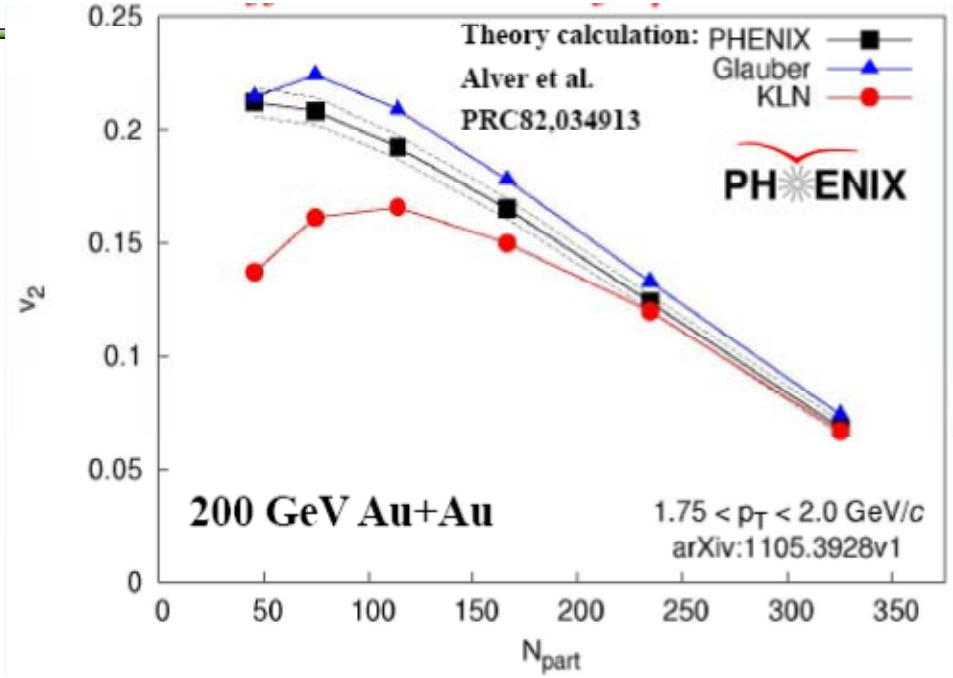
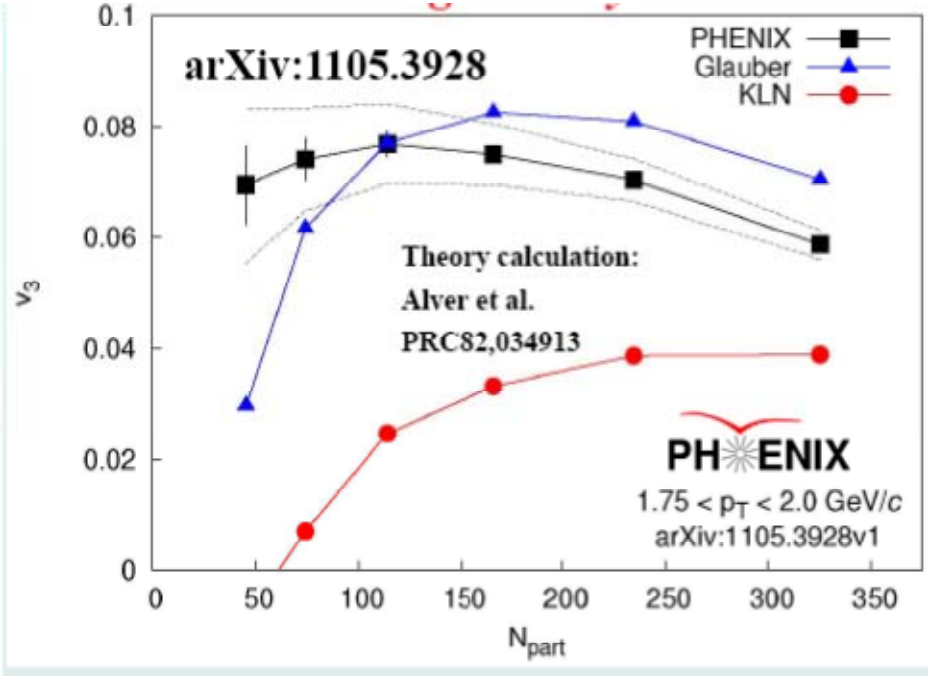
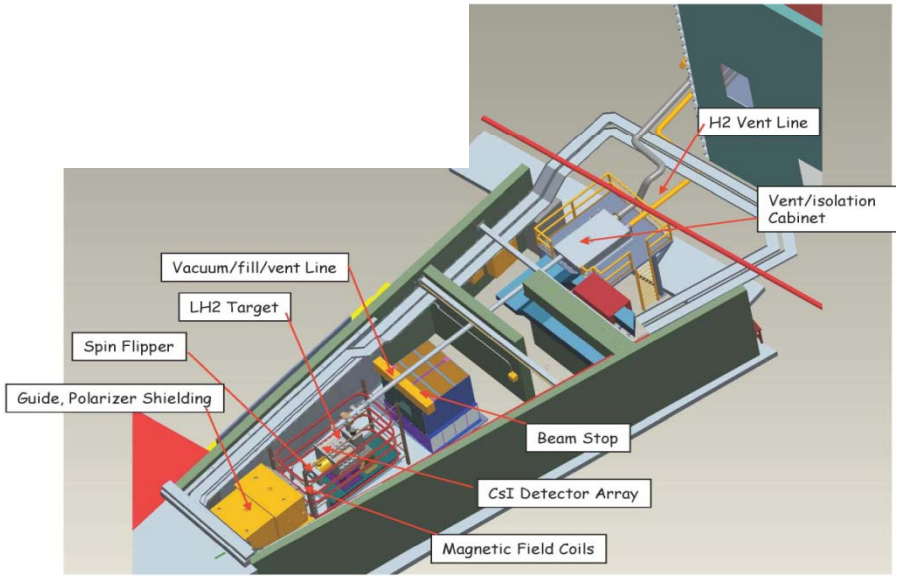
Measurement of Higher Harmonics of Collective Flow ⇒ Path to Quantify How Perfect is the 'Perfect Fluid'

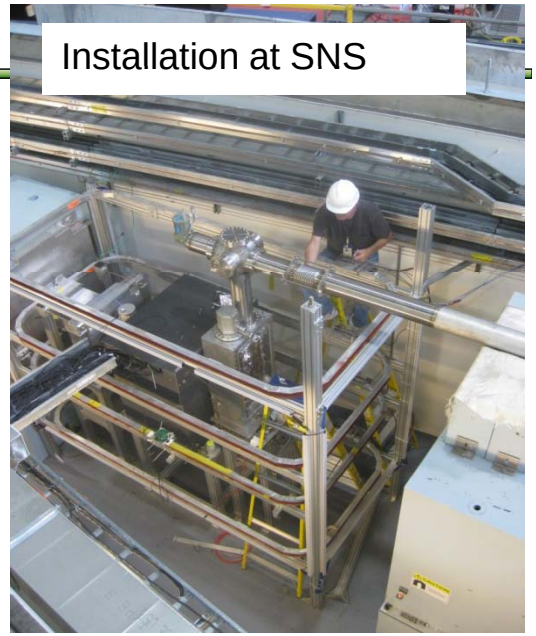




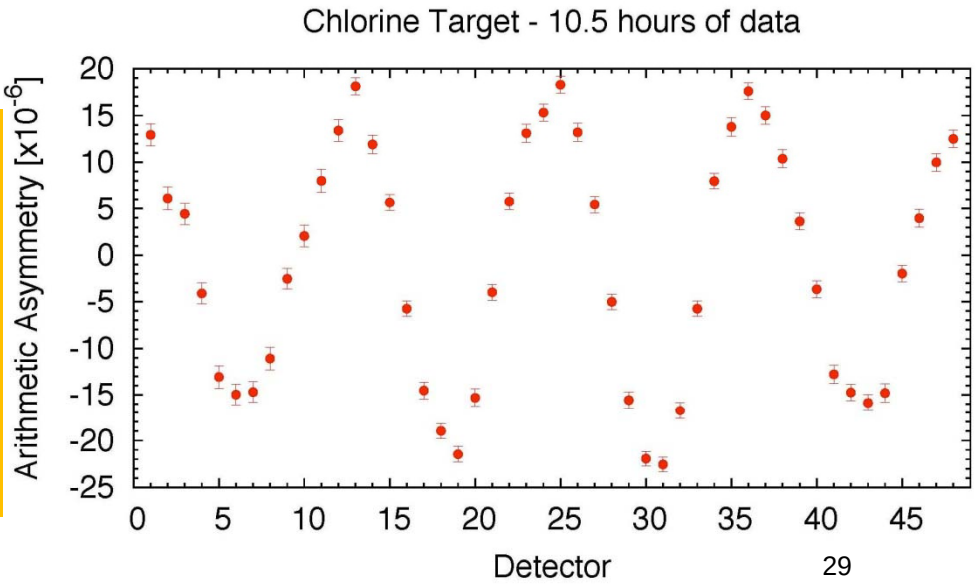
- Elliptic flow v_2 is sensitive to centrality (impact parameter), shear viscosity/entropy density (η/s), initial-state geometry + fluctuations
  - Red and blue theory curves use different models of initial-state matter densities and fluctuations, can ~fit v_2 with η/s values differing by factor ~2
- Odd flow harmonics would vanish if nuclear overlap were perfectly left-right symmetric, but v_3 arises (primarily) from geometry fluctuations
  - For given η/s, different models yield quite different v_3 vs. v_2 ⇒ new data will better constrain η/s vis-à-vis String Theory quantum limit $\eta/s \geq \frac{1}{4\pi}$
- Still higher v_n should be more sensitive to viscosity damping ⇒ constrain η/s even further by measuring v_n for various colliding species and energies

NPDGamma Commissioned at the SNS



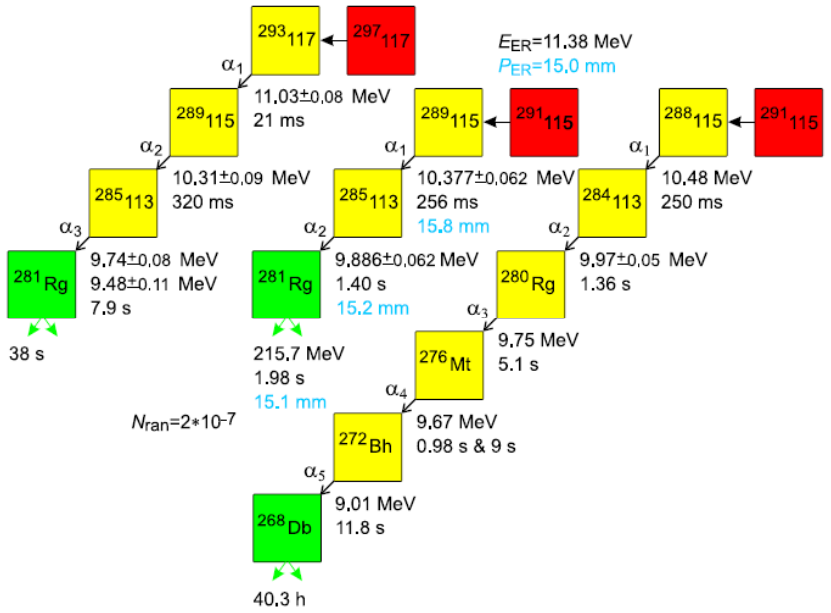


- Beamline and detector installed
- DAQ operational
- Polarization measured
- Commissioning runs with Cl complete
- LH_2 target installed
- Initial cool-down with Neon successful



Ramping Up in Super Heavy Science at ORNL

- For the first time, over twenty decay chains of super heavy nuclei, ^{288}(115) and ^{289}(115), were observed during one experimental campaign by the Russia-US collaboration (Dubna-Oak Ridge-Livermore-Vanderbilt).
- Creating new chemical elements are among the most challenging scientific endeavors. These investigations capture the imagination, provide sensitive tests of nuclear theories and chemistry and expand the Periodic Table to atomic numbers that seemed unreachable a decade ago.
- However, these studies have required months to several years, and despite such efforts, a successful campaign typically yielded only a few nuclei of a superheavy element.
- In summary, the newly identified decay chains greatly expand earlier observations of a few ^{288}(115) and ^{284}(113) nuclei identified at Dubna in 2004-2005. In addition, ^{289}(115) nuclei were produced in the same reaction [1]. These nuclei share common properties with the decay daughter of the mass 293 isotope of the newly-discovered element 117, providing an additional evidence for that discovery.

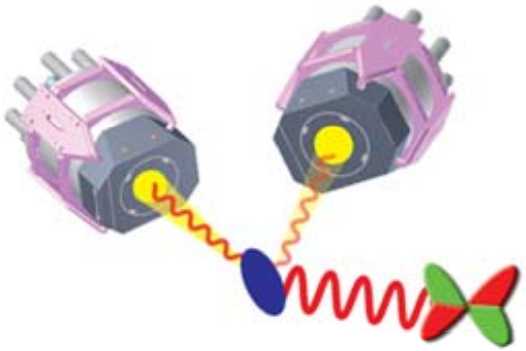


Decay properties of Z=117 and Z=115 isotopes averaged over observed five ^{293}(117) chains and twenty four ^{288}(115) chains [1]. The decay pattern of directly produced ^{289}(115) isotope provides an additional evidence for the recent identification of 293(117) nucleus [2].

Contact: K. Rykaczewski, 865-576-2636, rykaczewskik@ornl.gov
Funding sources: DOE Office of Science, Office of Nuclear Physics
Resources: High Flux Isotope Reactor, Radiochemical Engineering Development Center, Holifield Radioactive Beam Facility, ORNL

[1] Y. Oganessian et al, Phys. Rev. Lett., 2011, in press.

[2] Y. Oganessian et al., Phys. Rev.Lett. 104, 142502, 2010.



Courtesy Seth Henshaw, Duke University

New Method for Precise Determination of the Isovector Giant Quadrupole Resonances in Nuclei

S. S. Henshaw, M. W. Ahmed, G. Feldman, A. M. Nathan, and H. R. Weller

Phys. Rev. Lett. **107**, 222501 (2011)

Published November 23, 2011

Neutrons and protons in a nucleus can collectively oscillate against one another in what are called giant multipole resonances, a bit like the vibrational modes of a bell struck by a hammer. Researchers need to gather detailed and precise information on each of the multipole resonances to formulate a reliable equation of state for nuclear matter. The first two modes in the series, the isovector (when neutrons and protons oscillate out-of-phase) dipole resonance and the isoscalar (when neutrons and protons oscillate in phase) quadrupole resonance have already been systematically studied for a range of nuclear masses. The isovector giant quadrupole resonance has been much harder to tackle owing to the higher energies and low cross sections for exciting this mode.

Writing in *Physical Review Letters*, Seth Henshaw at Duke University, North Carolina, and colleagues report their measurements of the isovector giant quadrupole resonance in bismuth-209. The team developed a novel technique to measure Compton scattering of linearly-polarized monoenergetic gamma rays from the High Intensity Gamma Source at Duke. Measuring the asymmetries between horizontally and vertically scattered gamma rays allowed for precise determination of the resonance parameters (energy, width, and strength).

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Other Office of Science News

Early Career Selection process is ongoing

Lindau Fellowship application process is ongoing

Solicitation out for a new cohort of SC Graduate Fellowships which would begin fall of 2012

Now Accepting Applications for Summer 2012 SULI Internships
Applications Due Tuesday, January 10, 2012 (11:00pm ET)

Currently Accepting Applications for Spring 2012 SULI Internships
Applications Due November 30, 2011

Now Accepting Applications for Summer 2012 CCI Internships
Applications Due Tuesday, January 10, 2012 (11:00pm ET)

Initiation of the Visiting Faculty Program (Formerly called FaST)

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NP's Vision for U.S. Nuclear Science

- **Transformative discovery science on the hot QCD Matter, quark structure, and limits of nuclear existence frontiers — Recent accomplishments**
  - Evidence for local symmetry breaking in the nearly perfect quark-gluon liquid at RHIC & LHC
  - Discovery of anti-Helium 4 and the anti-hyper triton at RHIC
  - Suppression of jets and quarkonia at the LHC and RHIC
  - Groundbreaking data on neutron-rich nuclei which are central to stellar explosions
  - New insight on how quarks are bound in mesons by calculating masses of states with exotic quantum numbers in dynamical QCD
  - Observation of a neutron skin in heavy nuclei (Pb 208)

- **Going forward, around end of the decade, 4 Leadership class facilities for U.S. science**
  - Relativistic Heavy Ion Collider (RHIC)
  - Continuous Electron Beam Accelerator Facility (CEBAF) with 12 GeV Upgrade
  - Facility for Rare Isotope Beams (FRIB)
  - Argonne Tandem Linac Accelerator System (ATLAS)

- **Targeted High Science Impact MIE's**
  - STAR Heavy Flavor Tracker
  - Majorana
  - Items yet to be submitted

- **Leading applications and technological advances — Recent examples**
  - Development of SRF cavities for high power linacs for research, defense, and energy production
  - Restart of americium production (Am 241) for commerce
  - Important new nuclear data on decay heat in nuclear fuel

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The Big Picture for the NP Budget in 2012

- At the time the 12 GeV upgrade and FRIB were started, the goal for SC funding was a doubling curve
- Assuming for the sake of argument, the FY2012 Presidential budget only requested the planned profile for the 12 GeV upgrade and FRIB, with the rest of the program remaining flat at the FY 2011 level, the NP increase requested would have been ~$50,000,000 relative to FY2011.
- The House mark provides for an overall increase of $11,886,000 over FY 2011 and includes direction that increased funding of $18,072,000 will go to 12 GeV and FRIB
- The Senate mark provides for an overall increase of $10,000,000 and includes direction that increased funding of $33,072,000 will go to 12 GeV and FRIB
- Both the House and Senate recognize the importance of these new research tools for U.S. scientific leadership and direct that significantly increased funding will be provided
- Both the House and the Senate marks direct that the increases for the projects will be provided in large measure from the existing NP base.
- NP has a very “heavy lift”, which is already requiring significant cuts and terminations to its base; despite these measures, the projects will be delayed and will undergo cost growth for either mark

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Outlook Beyond 2012

Can not speak to details about the FY2013 OMB pass back

The FY 2013 budget formulation process will continue to be dynamic until the President's request is released

The initial OMB guidance for Nuclear Physics is very challenging

If that is how things turn out, the budget will most certainly not support the nuclear science vision articulated in the 2007 Long Range Plan

In that case one would anticipate some kind of community exercise early in 2012 to seek input on how to implement the program in light of the constraints

One can also imagine an additional exercise across the field to gauge the strengths and unique capabilities of NP supported research groups taking into account revised priorities and plans within the field

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Outlook

- NP continues, and will continue to support a high impact world-class research effort with world leading facilities and research tools
- Nuclear Physics, similar to all Federally supported programs, is potentially facing very challenging budgets. Our Office will work with the community to mitigate impacts and ensure continuation of the highest priority, highest impact nuclear science research