FRIB (Facility for Rare Isotope Beams) - Diverse Partnership Models in Nuclear Physics

Thomas Glasmacher
Michigan State University

APS April Meeting 2015 - Session S12
Models of International Partnership
Outline

- Path to International Partnerships
- Projects and one-of-a-kind scientific projects
- Different partnership models
- Examples of partnerships in Nuclear Physics
- RHIC
- Jefferson Laboratory
- FRIB
- Summary
Scientists make discoveries employing their creativity, ingenuity and tools
• Enabling discoveries is a complex and fragile endeavor

Public or private funds pay for scientists and their tools
• The funders have expectations and become stakeholders

Many tools are large and complex, scientists can no longer create them alone
• The tool creators become stakeholders

Projects are formed to create the large scientific tools
• Projects for one-of-a-kind scientific tools have special constraints relative to commercial projects

International partnerships are needed to support the most expensive one-of-a-kind scientific tools
• Creates opportunities a single country cannot afford, increases complexity and requires cross-cultural skills
Features of all Projects

- Projects
  - Have well-defined scope, cost and schedule
  - Have a beginning and an end

- Project success is delivery of the scope, on schedule, within budget, safely and with high quality
Features of one-of-a-kind Scientific Projects

- Must deliver scientific success
  - Mission goal is to enable discovery
    » How do you optimize? Harder to quantify than increasing shareholder value

- Must deliver project success
  - Deliver scope on cost, within budget, on schedule, safely with high quality
  - Expected by funders

- One-of-a-kind brings more risk
  - Interfaces need to be explicitly negotiated and sufficiently worked out
    » In mature industries (e.g. civil construction) there is a common understanding (e.g. civil construction)
    » In critical industries (e.g. nuclear power) everything is documented
      • Not enough resources to do in scientific projects
  - There is no collective experience on this particular project scope
    » There is however collective experience on other one-of-a-kind project scope that may be similar
How do one-of-a-kind Projects Work Out?

- Focus on the mission goal, enabling scientists to make discoveries
  - Involve scientists in requirements definition, keep science-driven upgrade paths open

- Work with parties and companies who can support the mission goal and get them emotionally engaged
  - Leverage the common mission goal and visualize success

- Manage the scientists, who always love scope, to respect schedule and cost (at least some)
  - Leverage the common mission goal and visualize success and discovery

- The key to one-of-a-kind project success are alignment on the mission goal and active management
Different Partnership Models

- Joint mission
  - Example: CERN, International Space Station, European Spallation Source, FAIR at GSI

- Part of a larger mission
  - Example: Polarized beams at RHIC

- Contributions to Projects or Experiments
  - Example: Jefferson Laboratory 12 GeV

- Topical Centers
  - Example: RIKEN BNL Research Center

- Participation in Experimental Collaborations
  - Many examples, this is how scientists work
Contributions to Experiments

- **RIPS**
  - 60~100 MeV/nucleon

- **GARIS**
  - ~5 MeV/nucleon

- **RILAC**
  - SHE (e.g., Z=113)

- **AVF**

- **fRC**

- **CRIB (CNS)**
  - several MeV/nucleon

- **IRC**

- **RRC**

- **SRC**

- **BigRIPS**
  - 350-400 MeV/nucleon

**Experimental facility**

**Accelerator**

**ZeroDegree**

**SAMURAI**

**SHARAQ (CNS)**

**Old facility**

**New facility**

Intense heavy ion beams (up to U) up to 345 AMeV at SRC
Fast RI beams by projectile fragmentation and U-fission at BigRIPS
In operation since 2007

T. Glasmacher, APS April 2015 S12, Slide 8
ISAC and ARIEL at TRIUMF in Canada

- Highest power ISOL facility: >50 kW
- Programs in nuclei, astrophysics, symmetry condensed matter, medical isotopes

www.triumf.ca/research/research-facilities/isac-facilities-for-rare-isotope-beams
Facility for Antiproton and Ion Research at GSI in Germany under Construction

Joint mission, > 10 countries

- Beams at 1.5 GeV/u
- $10^{12}/s$ Uranium

Research
- Compressed matter
- Rare isotopes
- Antiproton
- Plasma
- Atomic physics

www.fair-center.de
Jefferson Laboratory 12 GeV Upgrade Project

Contributions to project and experiments

Completion of the 12 GeV CEBAF Upgrade was ranked the highest priority in the 2007 NSAC Long Range Plan.

Upgrade is designed to build on existing facility: vast majority of accelerator and experimental equipment have continued use.

Add arc

Add 5 cryomodules

20 cryomodules

CHL upgrade

Add 5 cryomodules

20 cryomodules

New Hall

Upgrade arc magnets and supplies

TPC = $338M
ETC = ~$26M

Project Scope (~92% complete):

- Doubling the accelerator beam energy - DONE
- New experimental Hall D and beam line - DONE
- Civil construction including Utilities - ~97%
- Upgrades to Experimental Halls B & C - ~80%

Maintain capability to deliver lower pass beam energies: 2.2, 4.4, 6.6....
12 GeV Scientific Capabilities

*Hall B* – understanding nucleon structure via generalized parton distributions

*Hall D* – exploring origin of confinement by studying exotic mesons

*Hall A* – form factors, future new experiments (e.g., SoLID and MOLLER)

*Hall C* – precision determination of valence quark properties in nucleons/nuclei
Equipment Provided for 12 GeV Program by an Active International User Community

- Hall A DVCS Calorimeter (France - Orsay) **installed**
- Hall A SBS – ongoing (CE)
- Hall A SBS GEMs (Italy INFN, UK), Hadron Cal. (CMU+INFN) ongoing (ops)
- Hall A pre-R&D toward PV (magnet concept, with MIT) ongoing (ops)
- Hall A SOLID (China, Temple, Duke, ANL, …) ongoing (magnet - CE)
- Hall A APEX septum magnet (Canada, Stony Brook) **complete**
- Hall B longitudinally polarized target (NSF/MRI) ongoing (infrastr. - CE)
- Hall B forward tagger (Italy INFN & NSF/MRI) **near-complete**
- Hall B RICH sector(s) (Italy INFN) ongoing (PMTs, materials - CE)
- Hall B MicroMegas (France - Saclay) ongoing
- Hall B Central Neutron Detector (France - Orsay) **near-complete**
- Hall B Heavy Photon Search (HPS) (DOE HEP, France, INFN) **installed**
- Hall B H Gas Target for Proton Charge Radius (NSF/MRI) **near-complete**
- Hall C Kaon Detection System (CUA …, NSF/MRI) **complete**
- Hall C Backward nucleon detection system (Israel/ODU) ongoing
- Hall C Neutral-Particle Spectrometer (US/France/UK/Armenia) planning
- Hall D PID/Cherenkov system (US) pre-R&D/planning (CE)
- Hall D Discussions with China on calorimeter upgrades planning
International Users at Jefferson Lab

~1400 Users, 1/3 from about 30 foreign countries
RIKEN BNL Research Center (RBRC)
Purpose

The activities of the Center are dedicated to the study of the strong interactions, including spin physics, the study of high density and temperature nuclear matter (RHIC), and lattice gauge theory, non-perturbative QCD. The Center also serves as RIKEN’s local base for the Spin Physics Program at RHIC. A major goal of RBRC is the training and nurturing of a new generation of young physicists. In order to carry out this task, it was deemed important that there be no permanent positions at RBRC, appointments being term and consisting of Fellows for five years and Research Associates for two years.
RIKEN BNL Research Center (RBRC)  
History

- Established April 1997 at BNL
- Funded by “Rikagaku Kenkyusho” (RIKEN)  
  - The Institute of Physical and Chemical Research of Japan  
- During the first year, the Center had only a Theory Group
- In the second year an Experimental Group was also established as the major local team to carry out the PHENIX RHIC Physics Spin Program
- In the third year, a new Tenure Track University Fellows Program was initiated whereby such Fellows would spend equal time at RBRC and their university  
  - Limited to approximately 25 fellows and postdocs, allowing for maximum interaction among its members  
  - 2001 – RIKEN Spin Program (RSP) – RSP Researchers and RSP Research Associates  
  - Activities have been very much reinforced by long term residents and frequent visitors from the Radiation Laboratory in RIKEN Wako  
  - 2010 – Foreign Postdoc Researchers (FPR)  
  - Special Postdoc Research (SPDR)
RIKEN BNL Research Center (RBRC)
Impact

- **Publications**
  - ~1,000 Theoretical
  - ~300 Experimental

- **Awards**
  - 12 DOE OJI/ECA awards
  - 3 A.P Sloan Fellowships

- **44 Fellows graduated**
  - 41 tenured world-wide

- **53 Postdocs graduated**
  - 27 tenured world-wide and still counting
Facility for Rare Isotope Beams at MSU under Construction

- DOE Office of Science national user facility supporting the mission of the Office of Nuclear Physics
- Key Feature is 400 kW beam power (5 x10^{13}^{238}U/s)
- Separation of isotopes in-flight
  - Fast development time for any isotope
  - Suited for all elements and short half-lives
  - Fast, stopped, and reaccelerated beams
- CD-4 June 2022, managing to early completion in Dec 2020
FRIB Enables Scientists to Make Discoveries
DOE Office of Science Scientific User Facility


Properties of nuclei
• Develop a predictive model of nuclei and their interactions
• Many-body quantum problem: intellectual overlap to mesoscopic science, quantum dots, atomic clusters, etc.

Astrophysical processes
• Origin of the elements in the cosmos
• Explosive environments: novae, supernovae, X-ray bursts …
• Properties of neutron stars

Tests of fundamental symmetries
• Effects of symmetry violations are amplified in certain nuclei

Societal applications and benefits
• Bio-medicine, energy, material sciences
• National security
Integrated Laboratory Building Plan: MSU is a Committed Partner

- FRIB Linac and cryoplant
- Office Tower 3 (by summer 2016)
- NSCL Highbay
- SRF Cleanrooms and Assembly
- Shops 2004
- ReA12 2013
- FRIB Target Complex

Green shade: new FRIB construction (220,000 gsf)
FRIB Civil Construction 55 weeks after Groundbreaking - 8 Weeks Ahead of Schedule

Inside tunnel with form work for ceiling
On top of tunnel with conduit shafts
Storage tanks on bottom of tunnel

11 April 2015
FRIB Technical Construction on Track

- Master slave manipulators
- Cryomodule
- Bottom loading port
- 4.5 K cold box
- Non-conventional utilities tanks
- Cold beam-position monitor
- Embrds
- SRF cavity processing
- SRF cavity
- Superconducting magnet fabrication
Radio-frequency (rf) quadrupole provides first 500 keV of acceleration beyond ion source

Copper resonator structure made of five large (1.5 m x 1 m) sections of brazed copper, vacuum tight, with water cooling channels in copper

Machining and brazing are key to precise rf structure

Manufacturing managed for FRIB by Tsinghua University, Department of Engineering Physics

<table>
<thead>
<tr>
<th>Objective Measures</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contract awarded; three party engaged</td>
<td>Done, 03/2013</td>
</tr>
<tr>
<td>Full cross section prototype tested</td>
<td>Done, 02/2014</td>
</tr>
<tr>
<td>Segment 1 (total 5) completed</td>
<td>Done, 11/2014</td>
</tr>
<tr>
<td>Fabrication, low-power tuning complete</td>
<td>01/2016</td>
</tr>
<tr>
<td>Installation followed by test in FRIB tunnel</td>
<td>03/2016</td>
</tr>
</tbody>
</table>
Collaborations Make FRIB Successful

<table>
<thead>
<tr>
<th>Institution</th>
<th>Contributions</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANL</td>
<td>• Liquid lithium stripper &lt;br&gt; • Beam dynamics verification; $\beta=0.29$ HWR design; SRF tuner validation</td>
</tr>
<tr>
<td>BNL</td>
<td>• Plasma window &amp; charge stripper, physics modeling, database</td>
</tr>
<tr>
<td>FNAL</td>
<td>• Diagnostics, SRF processing</td>
</tr>
<tr>
<td>JLab</td>
<td>• Cryoplant; cryodistribution design &amp; prototyping &lt;br&gt; • Cavity hydrogen degassing; &lt;br&gt; • QWR and HWR cryomodule design</td>
</tr>
<tr>
<td>LANL</td>
<td>• Proton ion source</td>
</tr>
<tr>
<td>LBNL</td>
<td>• ECR coldmass design; beam dynamics**</td>
</tr>
<tr>
<td>ORNL</td>
<td>• Diagnostics, controls</td>
</tr>
<tr>
<td>SLAC**</td>
<td>• Cryogenics, SRF multipacting, physics modeling</td>
</tr>
<tr>
<td>RIKEN</td>
<td>• Helium gas charge stripper</td>
</tr>
<tr>
<td>TRIUMF</td>
<td>• Beam dynamics design, physics modeling**</td>
</tr>
<tr>
<td></td>
<td>• SRF, QWR etching*</td>
</tr>
<tr>
<td>INFN</td>
<td>• SRF technology</td>
</tr>
<tr>
<td>KEK</td>
<td>• SRF technology, SC solenoid prototyping</td>
</tr>
<tr>
<td>IMP</td>
<td>• Magnets</td>
</tr>
<tr>
<td>Budker Institute, INR Institute</td>
<td>• Diagnostics</td>
</tr>
<tr>
<td>Tsinghua Univ. &amp; CAS</td>
<td>• RFQ</td>
</tr>
<tr>
<td>ESS</td>
<td>• AP*</td>
</tr>
</tbody>
</table>

* Under discussion or in preparation  
** Completed  

T. Glasmacher, APS April 2015 S12, Slide 25
FRIB Construction Tracking to Plan

- 8 June 2009 – DOE-SC and MSU sign Cooperative Agreement
- September 2010 – CD-1 approved, DOE issues NEPA FONSI
- April 2012 – Lehman review, baseline and start of civil construction
- August 2013 – CD-2 approved (baseline), CD-3a approved (start civil construction pending FY2014 federal appropriation)
- March 2014 – Start civil construction
- August 2014 – CD-3b approved (technical construction)
- 31 March – 2 April 2015 DOE-SC OPA progress review
- December 2020 – Early completion goal
  - Tunnel and first surface buildings (ECR and frontend) complete in 2015
    » First beam from ECR in 2016
    » Install and test RFQ in CD-4 position and configuration (avoids moving RFQ)
- June 2022 – CD-4 (project completion)
1400 Users Engaged and Ready for Science
www.fribusers.org

- Users are organized as part of the independent FRIB Users Organization (FRIBUO)
  Chartered organization with an elected executive committee
  - 1,418 members (92 U.S. colleges and universities, 10 national laboratories, 51 countries) as of February 2015
  - 19 working groups on instruments

- Annual low-energy nuclear science community meetings
  - At MSU August 2011: “The progress made on ReA3 is important, and we support further increases in energy and preparations for the experimental program in the near term”
  - At Argonne National Laboratory August 2012: “We reaffirm in the strongest possible terms the scientific vision of FRIB …”
  - At MSU August 2013: “The Low Energy Nuclear Physics Community recommends that agencies support operation[s] … We endorse efforts to explore multi-user capabilities…”
  - At Texas A&M University August 2014: “The highest priority in low-energy nuclear physics and nuclear astrophysics is the timely completion of the Facility for Rare Isotope Beams and the initiation of its full science program.”
  www.lecmeeting.org/preambleAndResolutionsTAMU2014.pdf
Integration Plan Optimizes Science
Minimal disruption of world-class science and education programs

- Users form collaborations, commission detectors and first science with beams from CCF
  - World-class FRIB program on startup

- Transition from CCF to FRIB operations can be accomplished in less than a year
  - Important for graduate program in experimental nuclear science
NSCL: Cutting-Edge Equipment Enables Continued World-Class Science

- Scientific users do experiments and form collaborations at NSCL
- NSCL to FRIB transition in less than one year
Summary

- Cost and complexity of scientific facilities lead naturally to partnerships
- Projects establish one-of-a-kind scientific user facilities
  - Partnerships add complexity and make large facilities possible
- Partnership models range from very formal (multilateral agreements between governments) to informal
- Nuclear physics community successfully executes partnerships based on contributions – RHIC, Jefferson Laboratory 12 GeV
- FRIB under construction and on track with partnerships in project, planning for partnerships around experiments