FRIB Project Status and Plans for Initial Operation
2016 Low Energy Community Meeting

Thomas Glasmacher, FRIB Laboratory Director
12 August 2016
Facility for Rare Isotope Beams
A Future DOE-SC Scientific User Facility for Nuclear Physics

- Funded by U.S. Department of Energy Office of Science (DOE-SC) supporting the mission of the Office of Nuclear Physics in DOE-SC

- Serving over 1,400 users

- Key feature is 400 kW beam power for all ions \(5 \times 10^{13} \, ^{238}\text{U}/\text{s}\)

- Separation of isotopes in-flight
  - Fast development time for any isotope
  - Suited for all elements and short half-lives
  - Fast, stopped, and reaccelerated beams
Civil Construction Progressing Well
Ten Weeks Ahead of Baseline Schedule

FRIB construction site on August 12, 2016
Web cameras at [www.frib.msu.edu](http://www.frib.msu.edu)
Civil Construction Progressing Well
Ten Weeks Ahead of Baseline Schedule

Mechanical piping in lower second floor
Remote handling gallery painted (looking north)
Cryogenic transfer lines being installed in the linac tunnel for linac segment 1

DC cables being installed for folding segment 1

Civil Construction Progress Allows Technical Construction to Advance Ahead of Beneficial Occupancy

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4K Upper Cold Box Lifted Off 150ft Trailer and Placed in Cryogenic Plant
FRIB Accelerator Systems
Superconducting RF Driver Linac

- Accelerate ion species up to $^{238}\text{U}$ with energies of no less than 200 MeV/u
- Provide beam power up to 400kW
- Energy upgrade to 400 MeV/u for $^{238}\text{U}$ by filling vacant slots with 12 SRF cryomodules
- Provisions for ISOL upgrade
Experimental Area Expansion and New Scientific Instruments

- 47,000 sq ft operational when FRIB starts, upgrade space of more than 60,000 sq ft

- Experimental Equipment
  - Equipment at NSCL (existing or under development): S800, SeGA, MoNA, MoNA-LISA, LENDA, NSCL-BCS, LEBIT, BECOLA, AT-TPC, CAESAR, SUN, ...
  - Equipment available in the community and movable (existing, under development, or planned): GRETINA, ANASEN, CHICO, Nanoball, ORRUBA, JANUS, ...
  - Science-driven new equipment developed by FRIB user community: SECAR, GRETA, HRS, Decay Station, ISLA, ...

T. Glasmacher, Low Energy Community Meeting, August 2016, Slide 9
- Three-stage fragment separator for production and delivery of rare isotope with high rates and high purities to maximize FRIB science reach
- Primary beam power of 400 kW and beam energies of $\geq 200$ MeV/u
Fabrication is making good progress

- **Target**: Final assembly 93% complete
- **Beam dump**: Upper half 7% complete; Lower half 24% complete
- **Wedge**: Wedge vessel shipped to machine shop in Cincinnati, OH, final machining underway; machining to be completed by end of August

Preparing for vacuum tests at Cincinnati machine shop
$2^{nd} \beta = 0.085$ Cryomodule Being Tested; $1^{st} \beta = 0.041$ Cryomodule Being Assembled
Four Cryomodules Being Assembled in Parallel

Bay #1 SCM803
Bay #2 SCM802
Bay #3 SCM401
Bay #4 SCM501

$\beta = 0.53$ preproduction cryomodule being assembled

$\beta = 0.085$ preproduction cryomodule (FRIB-1) under test
RFQ Segments Assembled and Tested
In Transit to FRIB - Arriving Early September

RFQ assembly at supplier

RFQ amplifier assembly at FRIB

T. Glasmacher, Low Energy Community Meeting, August 2016, Slide 14
FRIB Project is on Schedule for Completion in FY2021 and on Budget

<table>
<thead>
<tr>
<th>Date</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>01-Aug-16</td>
<td>Early Completion</td>
</tr>
<tr>
<td>Data Date</td>
<td>01-Aug-16</td>
</tr>
<tr>
<td></td>
<td>CD-1 ◆</td>
</tr>
<tr>
<td></td>
<td>CD-2/3A ◆</td>
</tr>
<tr>
<td></td>
<td>CD-3B ◆</td>
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<tr>
<td></td>
<td>CD-4 ◆</td>
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<tr>
<td></td>
<td>Baseline</td>
</tr>
<tr>
<td></td>
<td>Forecast/Complete</td>
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<tr>
<td></td>
<td>Critical Path</td>
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<td>▲ Milestone</td>
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Facility for Rare Isotope Beams, Schedule Data Date: 01-Aug-16

FRIB Schedule to Support the PMB - T10201-BL-000042-R037

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NSCL-FRIB Integration Plan in Place and Being Executed by all Parties

- FRIB project managing towards early completion in FY21
- NSF National Science Board approved cooperative agreement for NSCL operation FY17 - FY21
  - NSCL operations completes in FY2021
- DOE-SC NP reviewed FRIB operations cost in January 2016
- Transition to FRIB operations is planned for less than a year
  - Plan optimizes continuity of nation’s world-class science endeavor in low-energy nuclear science
Users are organized as part of the independent FRIB Users Organization (FRIBUO)

- Chartered organization with an elected executive committee
- 1,400 members (107 U.S. colleges and universities, 12 national laboratories, 51 countries) as of August 2016
- 19 working groups on instruments

Science Advisory Committee

- Review of equipment initiatives (February 2011)
- Review of FRIB integrated design (March 2012)
- Review of equipment working group progress (October 2013)
- Review of experimental equipment plans (March 2015)
- Next meeting December 2016
A meeting marking the creation of the FRIB Theory Alliance was held on March 31 and April 1 at Michigan State University. It was very well attended (around 100 participants), with many FRIB-TA members present and others observing by videocast.

The first day contained talks by MSU, DOE, and NSF representatives, and presentations from past and present FRIB Theory Fellows. An overview summary of the FRIB-TA goals and initiatives led into a general open discussion and the ratification of the FRIB-TA Charter.

The second day was devoted to an excellent series of talks covering the full depth and breadth of FRIB-related science. Slides for the talks are available at: http://fribtheoryalliance.org/content/meetings/TA_Inaugural_talks.php.

The FRIB-TA Managing Director (Filomena Nunes) has been appointed by the FRIB Laboratory Director in coordination with DOE.

The first elections for the two open seats held: Rebecca Surman and Chuck Horowitz joined the FRIB-TA Executive Board.
Balance Between Science and Machine Advancement to Enhance Discovery Potential

- After CD-4, adequate time allocated for maintenance and tuning to assure machine integrity and path towards mission goal while enabling world-class science.

- Time allocation optimized for efficient integration assuming more extensive maintenance/tuning to reach 400 kW for early years.

- Detailed operation cycle is under discussion, trade-offs will be discussed with Accelerator Systems Advisory Committee (Machine Advisory Committee once FRIB in operation) and Science Advisory Committee (Program Advisory Committee once FRIB in operation).

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**Tentative Operation Cycle**

<table>
<thead>
<tr>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
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<tbody>
<tr>
<td>User operation</td>
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<td>User operation</td>
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<tr>
<td>Tuning</td>
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<td>Tuning</td>
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- Maintenance

**Optimize time for science**

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T. Glasmacher, Low Energy Community Meeting, August 2016, Slide 19
Accelerator Operations on Day-one

- **Primary beams**
  - See tables to right

- **Beam power**
  - Year One – 10 kW
  - Year Two – 50 kW

- **Secondary beams**
  - See reference to scientific benchmarks
  - Initial studies for all benchmarks enabled by year two

- **Experimental end stations**
  - Existing NSCL instruments
  - GRETA
  - SECAR

- **Early operations funding** ensures that key staff are available to deliver primary and secondary beams for science

<table>
<thead>
<tr>
<th>Beam</th>
<th>Notional Weeks/Year</th>
<th>RISAC Benchmarks</th>
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<tbody>
<tr>
<td>$^{238}$U</td>
<td>12</td>
<td>7,10,12,15</td>
</tr>
<tr>
<td>$^{48}$Ca</td>
<td>6.34</td>
<td>2,14</td>
</tr>
<tr>
<td>$^{78}$Kr</td>
<td>2.21</td>
<td>3,8,9,16,17</td>
</tr>
<tr>
<td>$^{124}$Xe</td>
<td>1.3</td>
<td>1,11,17</td>
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<tr>
<td>$^{18}$O</td>
<td>0.86</td>
<td>2,8</td>
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<tr>
<td>$^{86}$Kr (CD-4)</td>
<td>0.63</td>
<td>1,3,4,6,14,15</td>
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<tr>
<td>$^{16}$O</td>
<td>0.44</td>
<td>2,8</td>
</tr>
<tr>
<td>$^{36}$Ar (CD-4)</td>
<td>-</td>
<td>8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>23.8</strong></td>
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$^{86}$Kr and $^{36}$Ar used to demonstrate FRIB Project’s Key Performance Parameters

<table>
<thead>
<tr>
<th>Beam</th>
<th>Notional Weeks/Year</th>
<th>RISAC Benchmarks</th>
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<tbody>
<tr>
<td>$^{82}$Se</td>
<td>5.25</td>
<td>1,3,4,5,6,13,14,15</td>
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<tr>
<td>$^{92}$Mo</td>
<td>2.45</td>
<td>1,3,9,11,16,17</td>
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<tr>
<td>$^{58}$Ni</td>
<td>1.64</td>
<td>1,3</td>
</tr>
<tr>
<td>$^{22}$Ne</td>
<td>0.54</td>
<td>2</td>
</tr>
<tr>
<td>$^{64}$Ni</td>
<td>0.5</td>
<td>1,13,14</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>10.4</strong></td>
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FRIB Project is on Track

- 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)
- Jan 2016 DOE NP operations cost review
- June 2022 – CD-4, managing to early completion in FY21
  - First beam from ECR in 2016
  - Liquid helium in 2017
Summary

- FRIB project is making good progress
- Plan to ensure nation’s leadership in low-energy nuclear science in place, on track and supported by all parties
  - NSF National Science Board has approved NSCL Cooperative Agreement to operate NSCL FY17-21
  - DOE-SC Office of Nuclear Physics has held FRIB operations cost review
  - MSU ensures FRIB on track for completion in FY2021 with DOE funding and MSU funding
- Users engaged and planning for day-one scientific program
- Instruments under construction and more planned
- Theory Alliance inaugural meeting held
- Will need to balance science experiments (realization of discovery potential afforded by FRIB) with machine development (which increases discovery potential)