(i) Science Highlights
(ii) Facility Plan
(iii) Reaccelerated Beams of In-flight Separated Rare Isotopes

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Nuclear Science Advisory Committee
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- Production and properties of nuclei far from stability – connection to mesoscopic science*
- Nuclear processes responsible for the chemical evolution of the universe – connection to astrophysics**
- Equation of state (EOS) of neutron-rich nuclear matter – connection to astrophysics**
- Beam dynamics and accelerator physics: superconducting cyclotrons, linacs, and magnets***

* Mesoscopic Theory Center at MSU
** JINA (Joint Institute for Nuclear Astrophysics, NSF Frontier Center)
*** Member of USPAS (U.S. Particle Accelerator School)

- Primary beams He–U E/A < 200 MeV
- Fast and stopped rare isotopes beams
- Experiments with reaccelerated beams of rare isotopes in 2010
Discovery of $^{40}\text{Mg}$, $^{42,43}\text{Al}$, and $^{44}\text{Si}$


Enhanced selectivity from two-stage separator:

$1.5 \times 10^{17}$ $^{48}\text{Ca}$ nuclei (natW target, E/A = 141 MeV) → three $^{40}\text{Mg}$ nuclei

FRDMHFB-8
Search for di-proton Decay


$^{45}$Fe is a known 2-proton ground-state emitter

- What is the correlation between the two emitted protons
  - Di-proton ($^2$He) or p+p?

Experiment with optical time projection chamber

- First direct angular and energy correlation measurement in 2-proton decay
- First observation of $\beta$-delayed 3-proton decay

M. Pfützner (Warsaw) et al.

- 87 2p-events
- 38 $\beta$-delayed events
  - Good agreement with 3-body model of Grigorenko, Zhukov
Low Energy Beam Ion Trap (LEBIT)

stop fragments in helium-gas cell, extract, purify, and store in Penning trap

Since 2005: accurate masses for more than 30 isotopes of more than 10 elements:

\begin{itemize}
  \item \(^{32,33}\text{Si}\), \(^{29,34}\text{P}\), \(^{37,38}\text{Ca}\), \(^{40-44}\text{S}\), \(^{63-65,65\text{m}}\text{Fe}\), \(^{64-66}\text{Co}\), \(^{63-64}\text{Ga}\), \(^{64-66}\text{Ge}\), \(^{66-68,80}\text{As}\), \(^{68-70,81,81\text{m}}\text{Se}\), \(^{70\text{m},71}\text{Br}\)
\end{itemize}


\(\text{f}_{\text{RF}} = [\text{Hz}] -2528609.5\)

\(\text{ME}_{\text{LEBIT}} = -9205(5) \text{ keV}\)

- 25-fold improvement over SPEG 2007:
  \(\text{ME} = -9100(130) \text{ keV}\)

- Disappearance of N = 28 magic number?

\(T_{1/2} = 123 \text{ ms}\)

\(44\text{S}\):

\[\text{s}\]
On average, an experiment lasts 4 days. Research program requires large number of beam tunes and, hence, reliable and predictable operations (availability > 90%).

More than 1000 RIBs have been made since 2001 – more than 630 RIBs have been used in experiments.
Ongoing Developments

New experimental apparatus

- Digital electronics for enhanced resolution with SeGA (Starosta) – completion in 2008
- High-efficiency gamma-ray detector array (Gade) – completion by early 2009
- Low-energy neutron array for charge exchange reactions in inverse kinematics (Zegers) – tests with prototype modules in summer 2008, full array complete late 2009 (delayed by NSF budget shortfall)
- Laser spectroscopy area (Mantica) – completion by 2011
- Time projection chamber: dual use as active target for low energy experiments and for fast beam nucleus-nucleus collision experiments (Bickley) – pre-proposal to DOE
- Si-detector array for low-energy astrophysics experiments (Blackmon) – MRI-proposal accepted for funding
- Two beam lines with monochromators for gas stopping – cryogenic linear cell and cyclotron gas stopper (Bollen, Morrissey) – first line complete by 2009

ReA3 – 3.2 MeV/u reacceleration facility (easily upgradeable to higher energy)

- Advanced EBIT charge breeder (collaboration with MPI Heidelberg, TRIUMF) – construction started, ongoing refinements of e-beam optics
- RFQ – being built at U. of Frankfurt
- 3.2 MeV/nucleon SC linac – long-lead items ordered, cavity construction started
- Construction of mezzanine for reaccelerator – completed
- Commissioning of reaccelerator expected to start in 2010
NSCL Facility Plan
(next 3 years)

- Existing state-of-the-art experimental apparatus
  - A1900 fragment separator, 92-inch chamber, S800 magnetic spectrograph, large aperture sweeper magnet spectrograph, large area position sensitive neutron detectors, segmented Ge and Si-strip-CsI arrays, β-NMR and β-counting station, Gas cell (1 bar He) for stopping rare isotopes, 9.4 Tesla Penning Trap, RF fragment separator...

- The NSCL is currently developing an innovative facility for efficiently stopping and accelerating rare isotopes produced and separated in flight
  - Ongoing design and construction of gas stopper, EBIT charge breeder, RFQ, ReA3 (3.2 MeV/nucleon SC linac)
  - Easily upgradeable to higher energy

- World-unique capability by 2010: Reaccelerated beams of in-flight separated, gas-stopped rare isotope beams
  - Detectors for science program at conceptual stage e.g., $^{30}\text{P}(p,\gamma)^{31}\text{S}$; $(p,\alpha)$ reactions ...
NSCL EBIT Charge-Breeder

Breeder requirements: breeding times ~ 10 ms, beam intensity $10^9$ ions/s

NSCL’s EBIT Project:

Started from TITAN-EBIT at TRIUMF
- $10^4$A/cm$^2$, 6 T, 60 kV

Modified design for increased acceptance
- larger trapping region (40 cm)
- variable B-field configuration (2T + 8T)
- higher current density ($<10^5$A/cm$^2$)

Collaboration with MPI-K Heidelberg, TRIUMF
NSCL Ongoing MSU-funded Building Additions

- New Office Wing
- Experimental area for reaccelerated beams