



National Superconducting Cyclotron Laboratory at Michigan State University

MICHIGAN STATE
UNIVERSITY

Advancing Knowledge.
Transforming Lives.



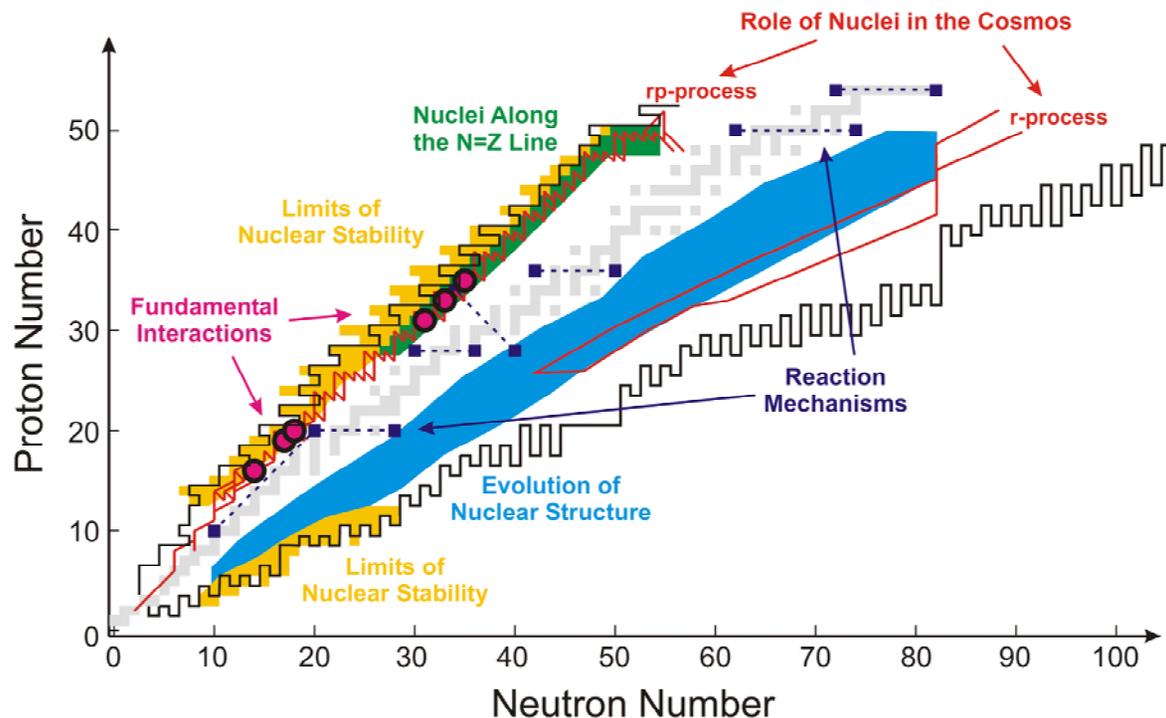
- (i) Science Highlights
- (ii) Facility Plan
- (iii) Reaccelerated Beams of In-flight Separated Rare Isotopes

Thomas Glasmacher – Assoc Dir. for Operations, NSCL

Nuclear Science Advisory Committee
August 21, 2008

National Superconducting Cyclotron Laboratory Coupled Cyclotron Facility

- 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***



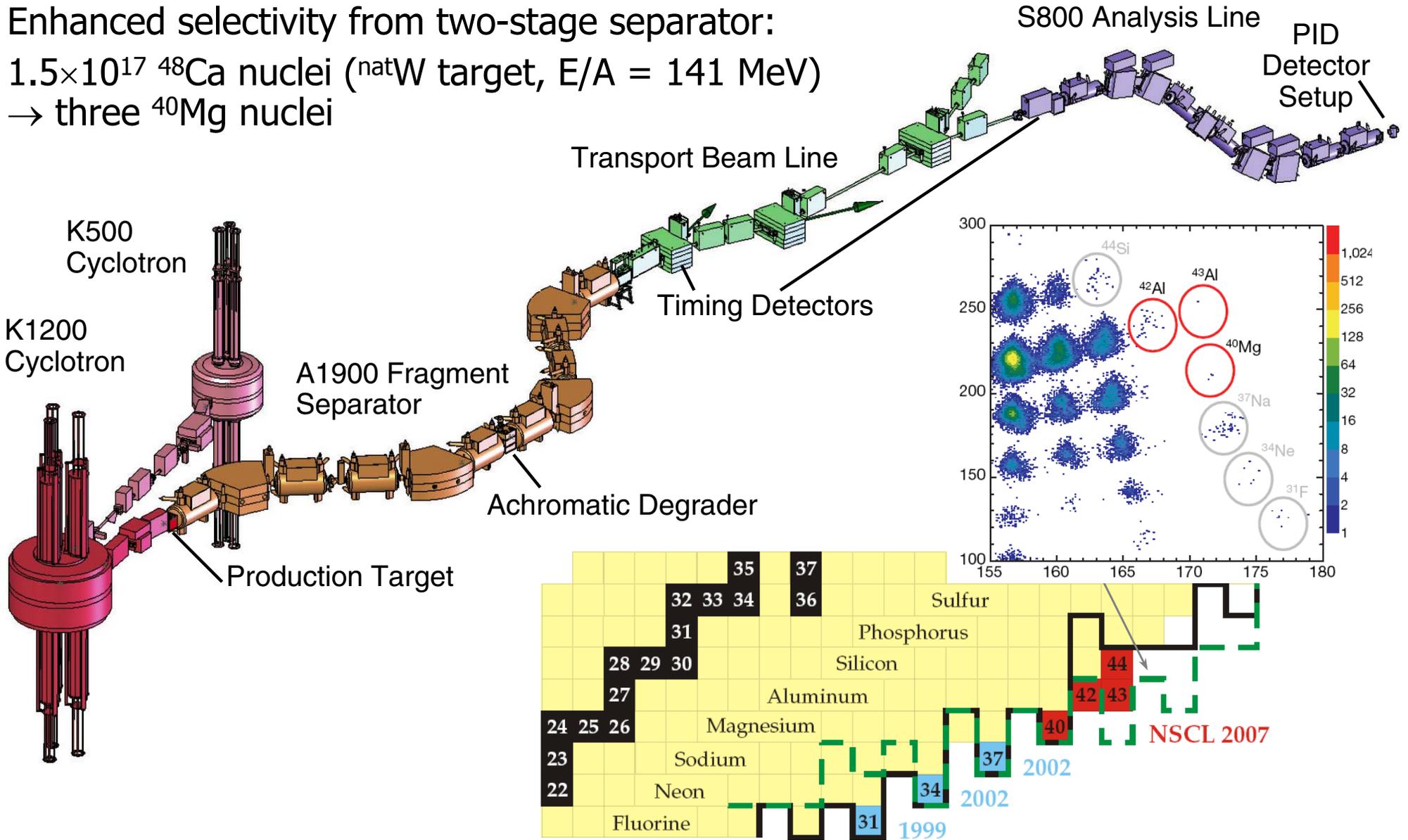
* Mesoscopic Theory Center at MSU
 ** JINA (Joint Institute for Nuclear Astrophysics, NSF Frontier Center)
 *** Member of USPAS (U.S. Particle Accelerator School)

- 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}Mg , $^{42,43}\text{Al}$, and ^{44}Si

Baumann *et al.*, Nature **449** (2007) 1022, Phys. Rev. **C 75** (2007) 064613

Enhanced selectivity from two-stage separator:
 1.5×10^{17} ^{48}Ca nuclei ($^{\text{nat}}\text{W}$ target, $E/A = 141$ MeV)
 \rightarrow three ^{40}Mg nuclei



Search for di-proton Decay

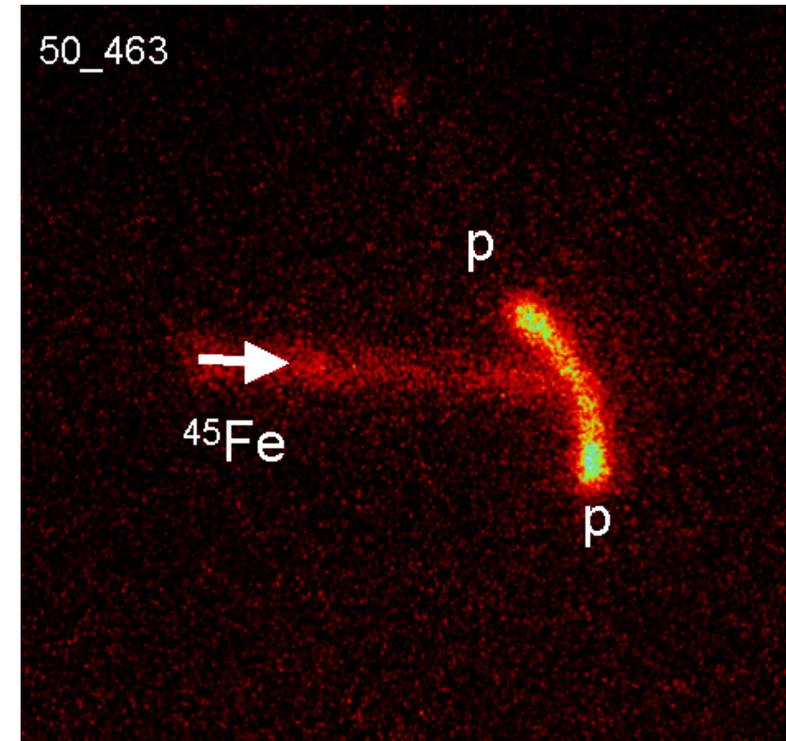
K. Miernik *et al.*, Phys. Rev. Lett. **99** (2007) 192501

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

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

Experiment with optical time projection chamber

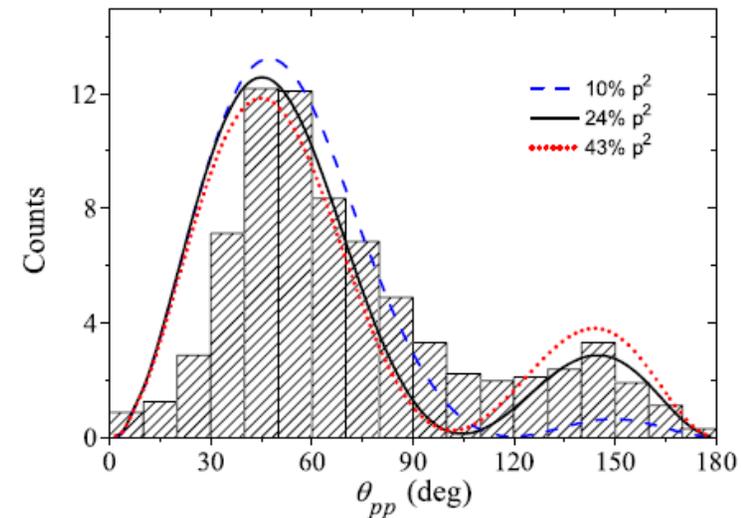
- First direct angular and energy correlation measurement in 2-proton decay
- First observation of β -delayed 3-proton decay



M. Pfützner (Warsaw) *et al.*

$\beta 3p$ event

- 87 2p-events
- 38 β -delayed events
 - Good agreement with 3-body model of Grigorenko, Zhukov



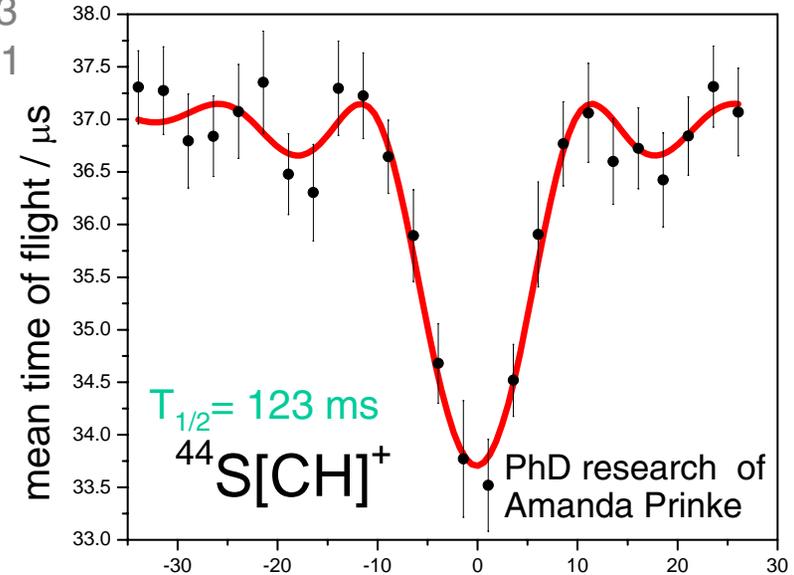
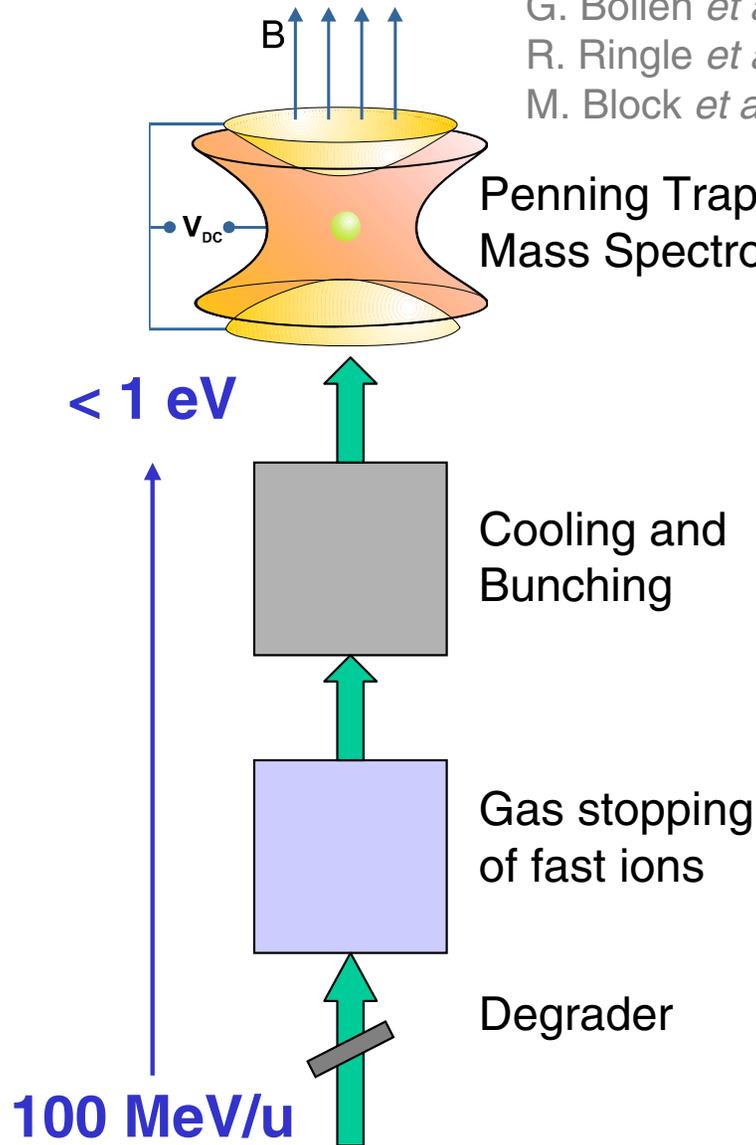
Low Energy Beam Ion Trap (LEBIT)

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:

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

G. Bollen *et al.*, PRL 96 (2006) 152501; P. Schury *et al.*, PRC 75 (2007) 055801;
R. Ringle *et al.*, PRC 75 (2007) 055503
M. Block *et al.*, PRL 100 (2008) 132501



f_{RF} [Hz] -2528609.5

^{44}S :

$ME_{\text{LEBIT}} = -9205(5)\text{ keV}$

– 25-fold improvement over SPEG 2007:

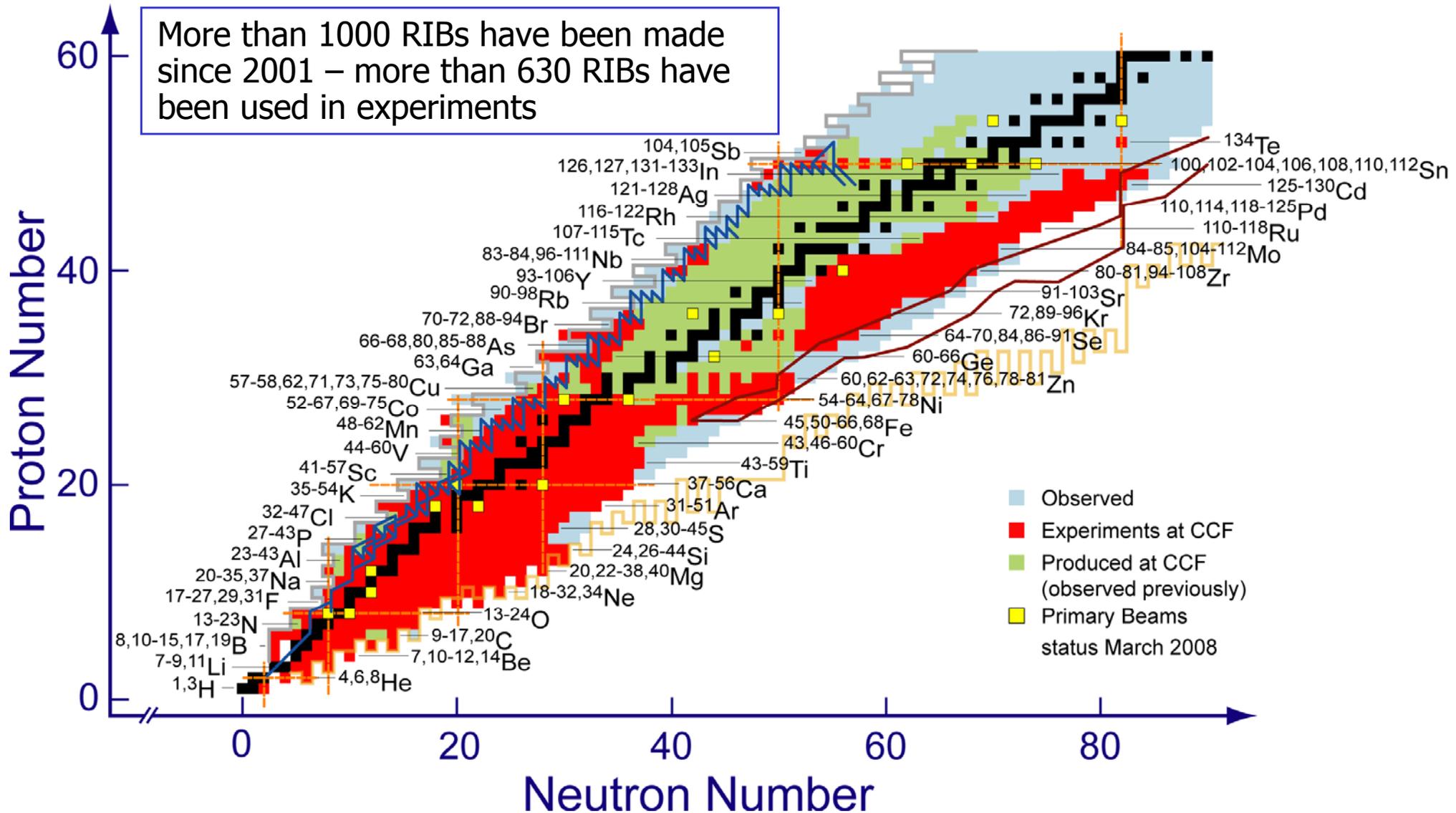
$ME = -9100(130)\text{ keV}$

– Disappearance of $N = 28$ magic number?

Rare Isotope Beams Produced Reliably and Predictably at NSCL

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

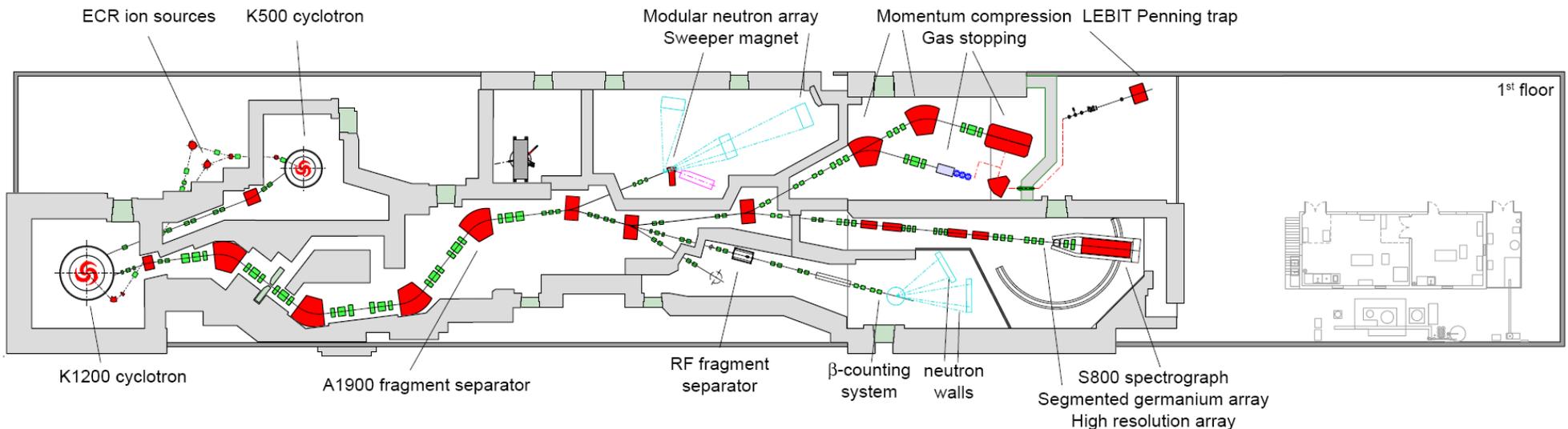
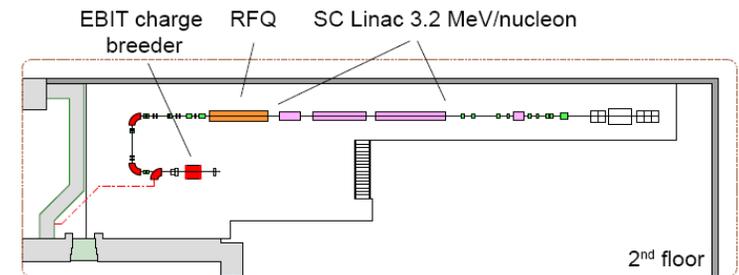
- Digital electronics for enhanced resolution with SeGA (Starosta) – completion in 2008
- High-efficiency gamma-ray detector array (Gade) – completion by early 2009
- Low-energy neutron array for charge exchange reactions in inverse kinematics (Zegers) – tests with prototype modules in summer 2008, full 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)

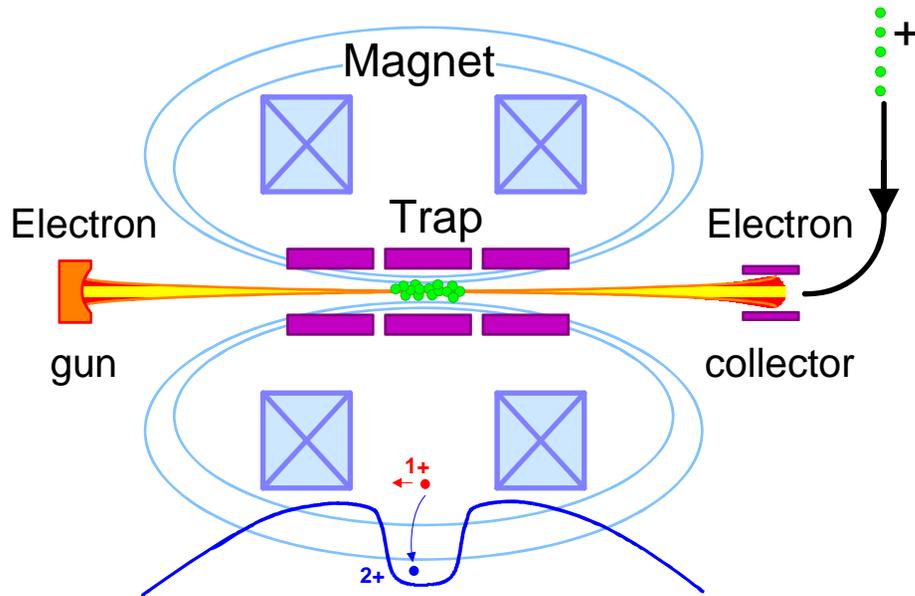
- Advanced EBIT charge breeder (collaboration with MPI Heidelberg, TRIUMF) – construction started, ongoing refinements of e-beam optics
- RFQ – being built at U. of Frankfurt
- 3.2 MeV/nucleon SC linac – long-lead items ordered, cavity construction started
- Construction of mezzanine for reaccelerator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

NSCL Facility Plan (next 3 years)

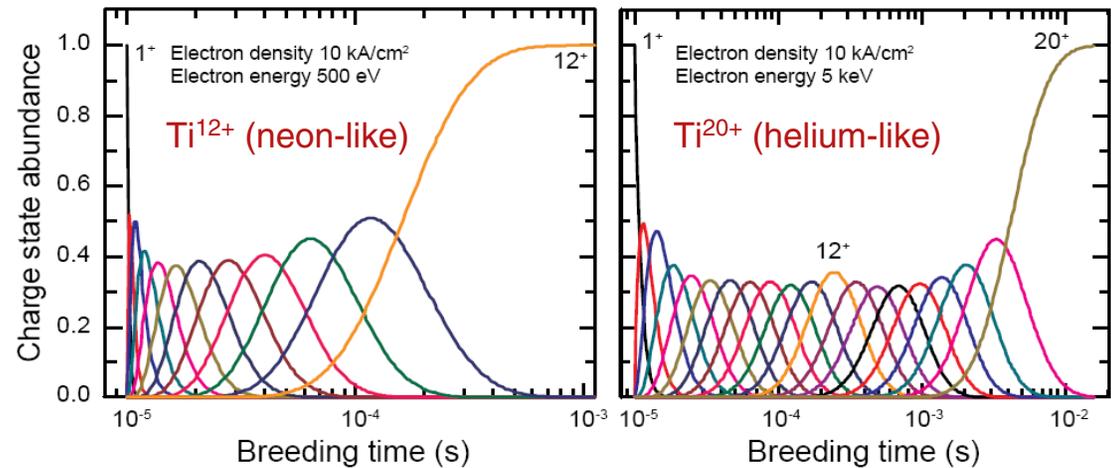
- Existing state-of-the-art experimental apparatus
 - A1900 fragment separator, 92-inch chamber, S800 magnetic spectrograph, large aperture sweeper magnet spectrograph, large area position sensitive neutron detectors, segmented Ge and Si-strip-CsI arrays, β -NMR and β -counting station, Gas cell (1 bar 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,p) excitation functions, (p,α) reactions ...



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



High-intensity EBIT \rightarrow fast and selective breeding



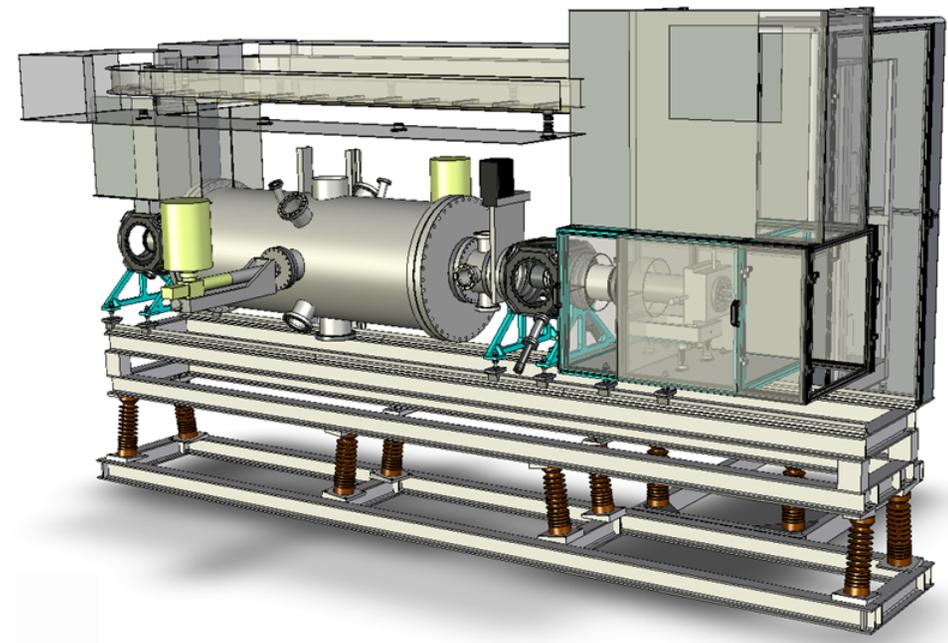
NSCL's EBIT Project:

Started from TITAN-EBIT at TRIUMF

- 10^4 A/cm², 6 T, 60 kV

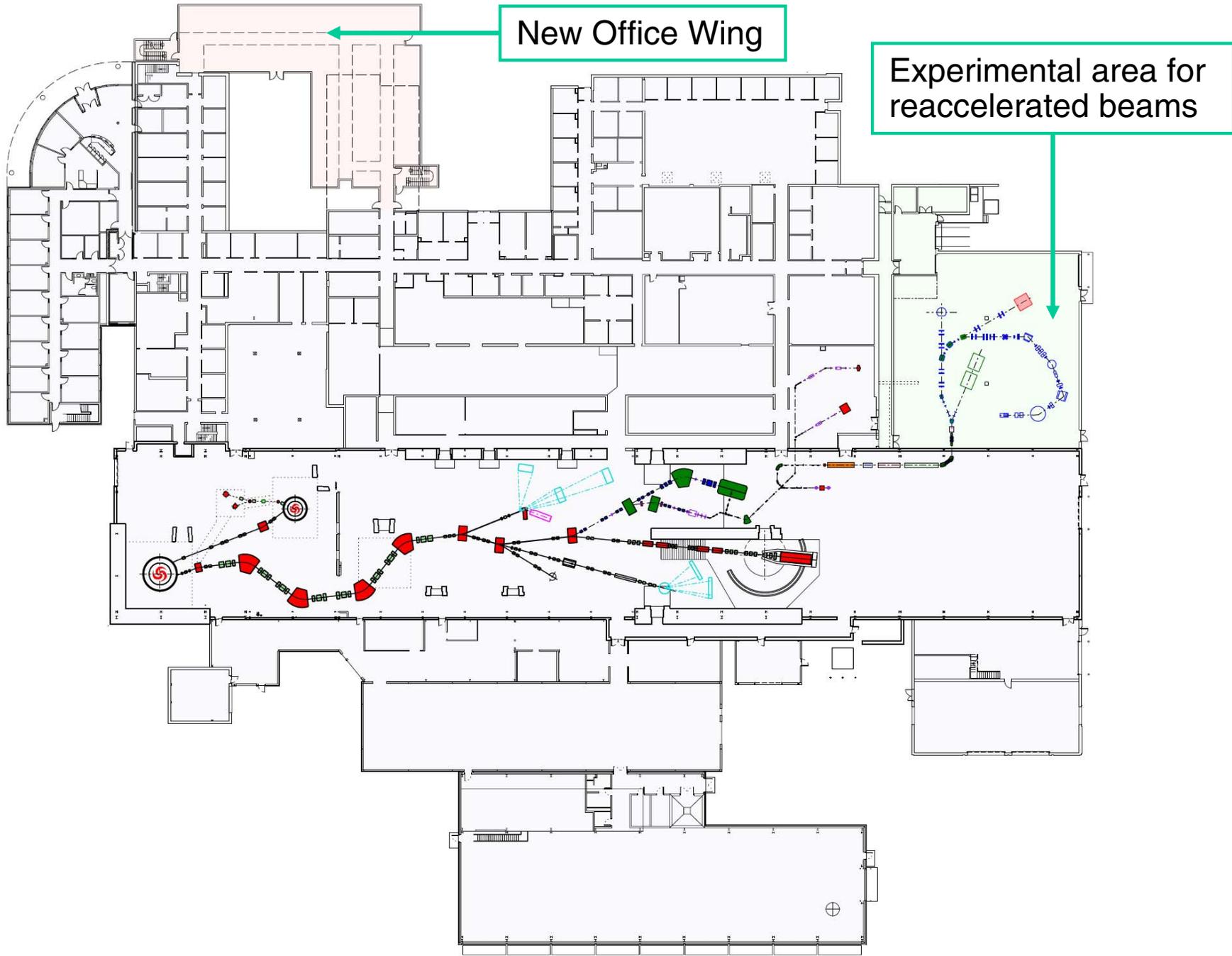
Modified design for increased acceptance

- larger trapping region (40 cm)
- variable B-field configuration (2T + 8T)
- higher current density ($< 10^5$ A/cm²)



Collaboration with MPI-K Heidelberg, TRIUMF

NSCL Ongoing MSU-funded Building Additions





NSCL by July 2009

Experimental area for
reaccelerated beams

New Office Wing

