Facility Overview and Future
National Superconducting Cyclotron Laboratory
at Michigan State University

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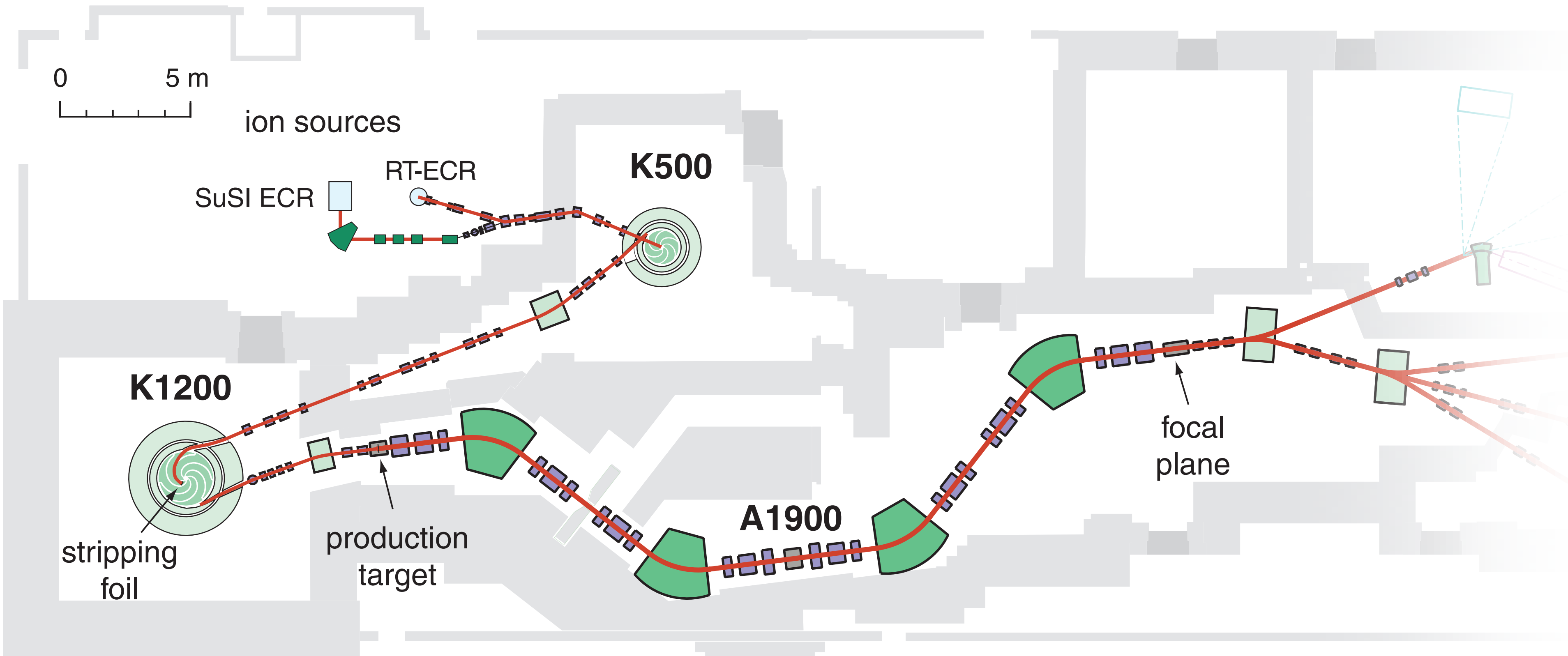
National Superconducting Cyclotron Laboratory

- Located at Michigan State University in East Lansing, Michigan, USA
- National user facility for rare isotope research and education in nuclear science, astro-nuclear physics, accelerator physics, and societal applications
- One of the three nuclear-science flagship facilities in the US: RHIC at BNL, CEBAF at JLAB, NSCL at MSU
- Largest university-based nuclear physics laboratory in the United States: 10% of U.S. nuclear science Ph.D.s
- Over 600 employees (NSCL+FRIB), incl. 110 graduate students, and 47 faculty – user group with 1300+ members
- Graduate program in nuclear physics ranked 1st [U.S. News and World Report]
- NSCL provides accelerated beams of heavy ions from oxygen to uranium, including rare isotope beams
- Michigan State University has been selected to establish FRIB, the Facility for Rare Isotope Beams

Coupled Cyclotron Facility at NSCL



2 ECR ion sources
2 coupled cyclotrons: K500 + K1200
primary beams: oxygen to uranium
K500: 8 - 14 MeV/u, 2-8 eμA
K1200: 100 - 170 MeV/u, up to 2 kW

A1900 fragment separator
to produce rare isotope beams
by projectile fragmentation

NSCL Primary Beam List

Isotope	Energy [MeV/u]	Intensity [pnA]		Isotope	Energy [MeV/u]	Intensity [pnA]
^{16}O	150	175		^{82}Se	140	35
^{18}O	120	150		^{78}Kr	150	25
^{20}Ne	170	80		^{86}Kr	100	15
^{22}Ne	120	80		^{86}Kr	140	25
^{22}Ne	150	100		^{96}Zr	120	1.5
^{24}Mg	170	60		^{112}Sn	120	4
^{36}Ar	150	75		^{118}Sn	120	1.5
^{40}Ar	140	75		^{124}Sn	120	1.5
^{40}Ca	140	50		^{124}Xe	140	10
^{48}Ca	90	15		^{136}Xe	120	2
^{48}Ca	140	80		^{208}Pb	85	1.5
^{58}Ni	160	20		^{209}Bi	80	1
^{64}Ni	140	7		^{238}U	45	0.1
^{76}Ge	130	25		^{238}U	80	0.2

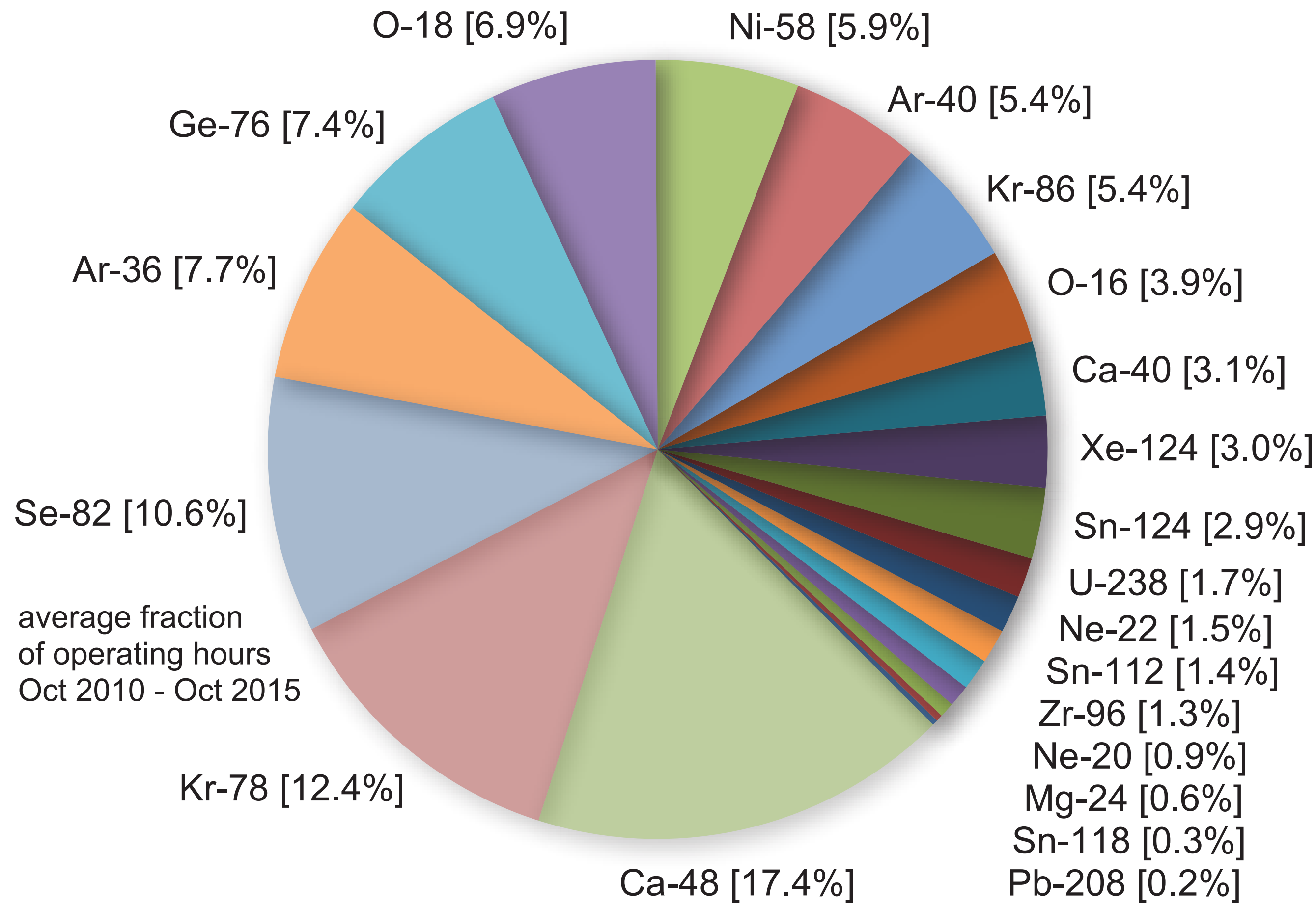
Beam list intensities are typical intensities for experiment planning purposes and are maintainable for extended time periods.

Primary Beam Statistics

CCF Primary Beam Isotope Statistics

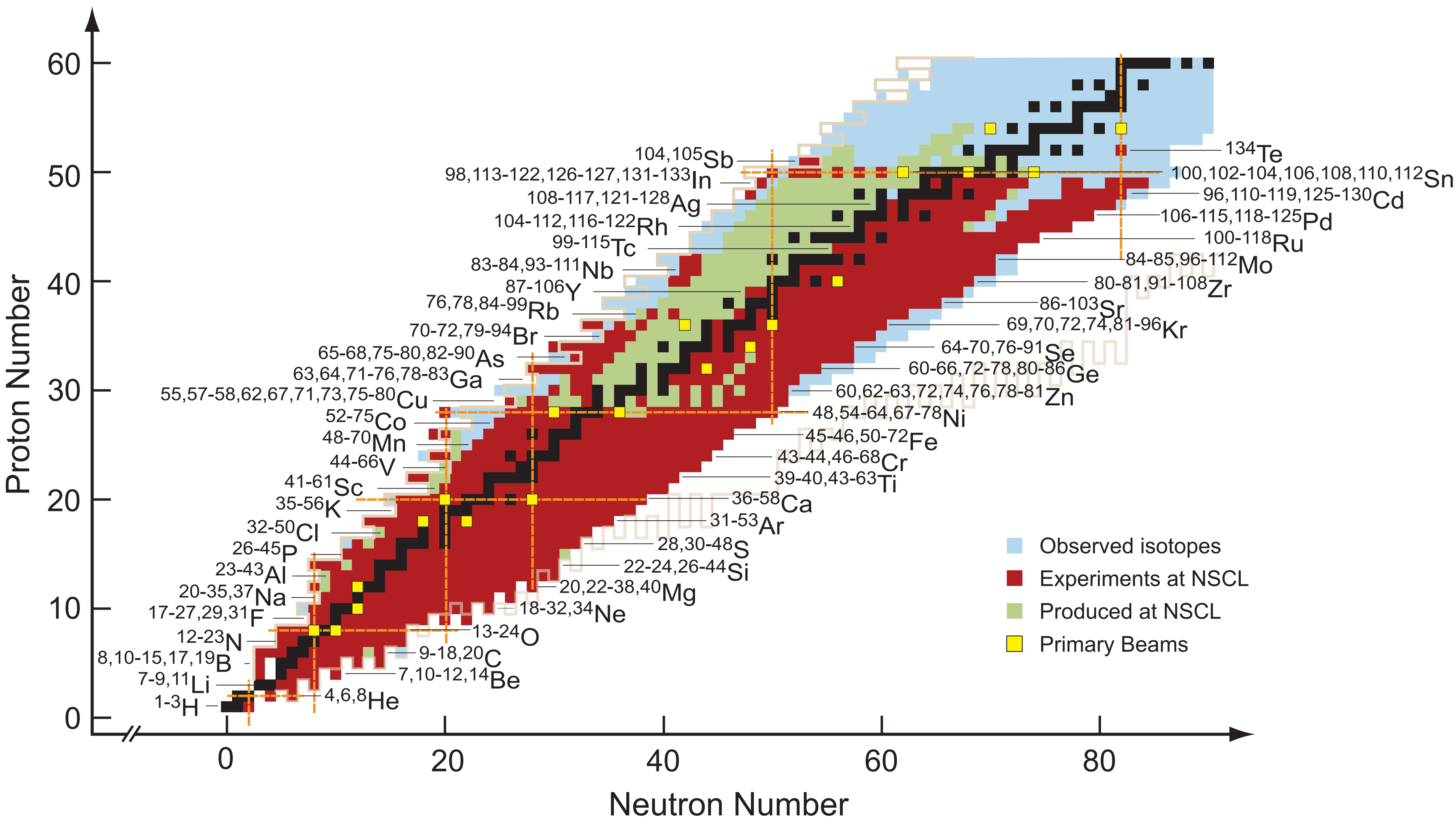
Coupled Cyclotron Facility (CCF) delivers a different primary beam every 5 to 7 days, typically 30 beam changes per year.

The development of new primary beams (isotope and energy) is driven by user demand.

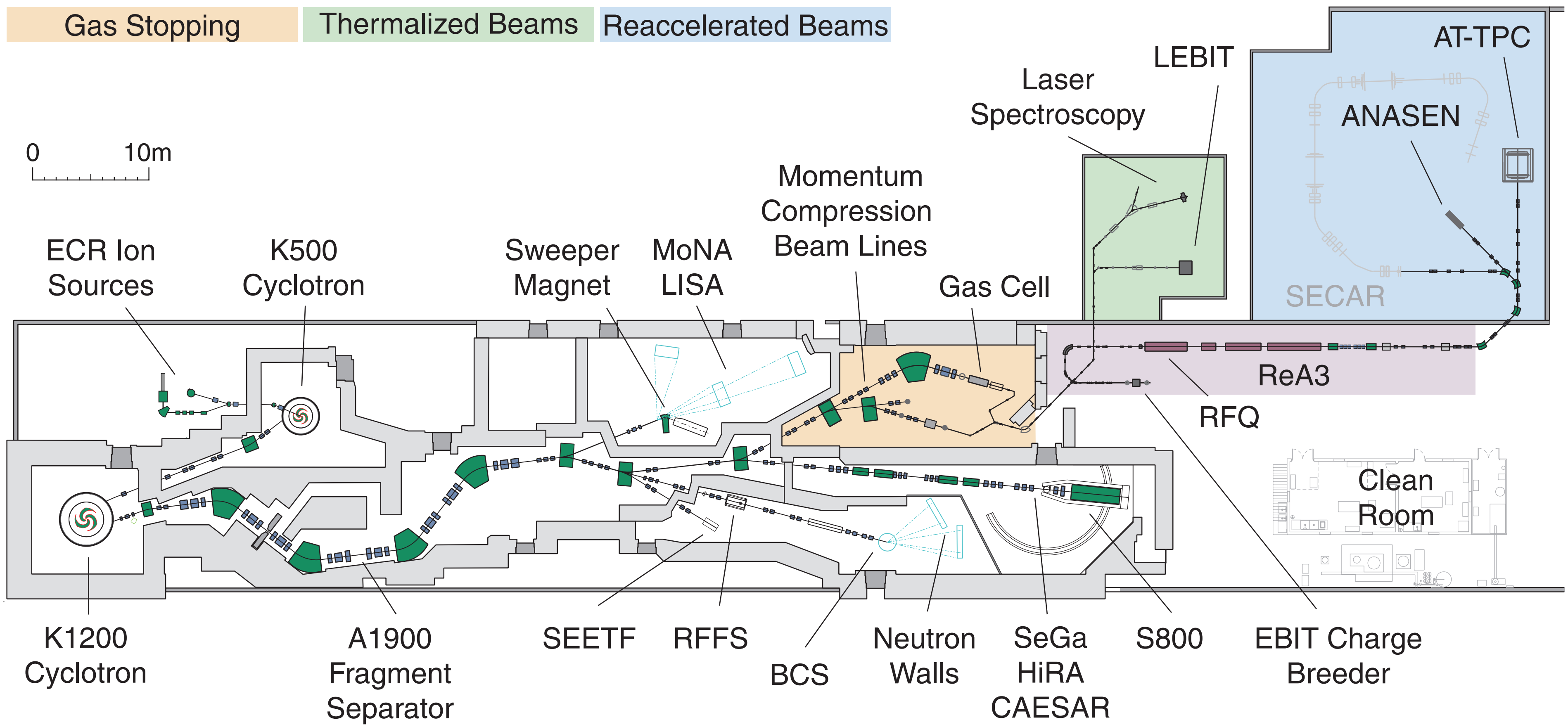


Rare Isotope Beams produced at NSCL

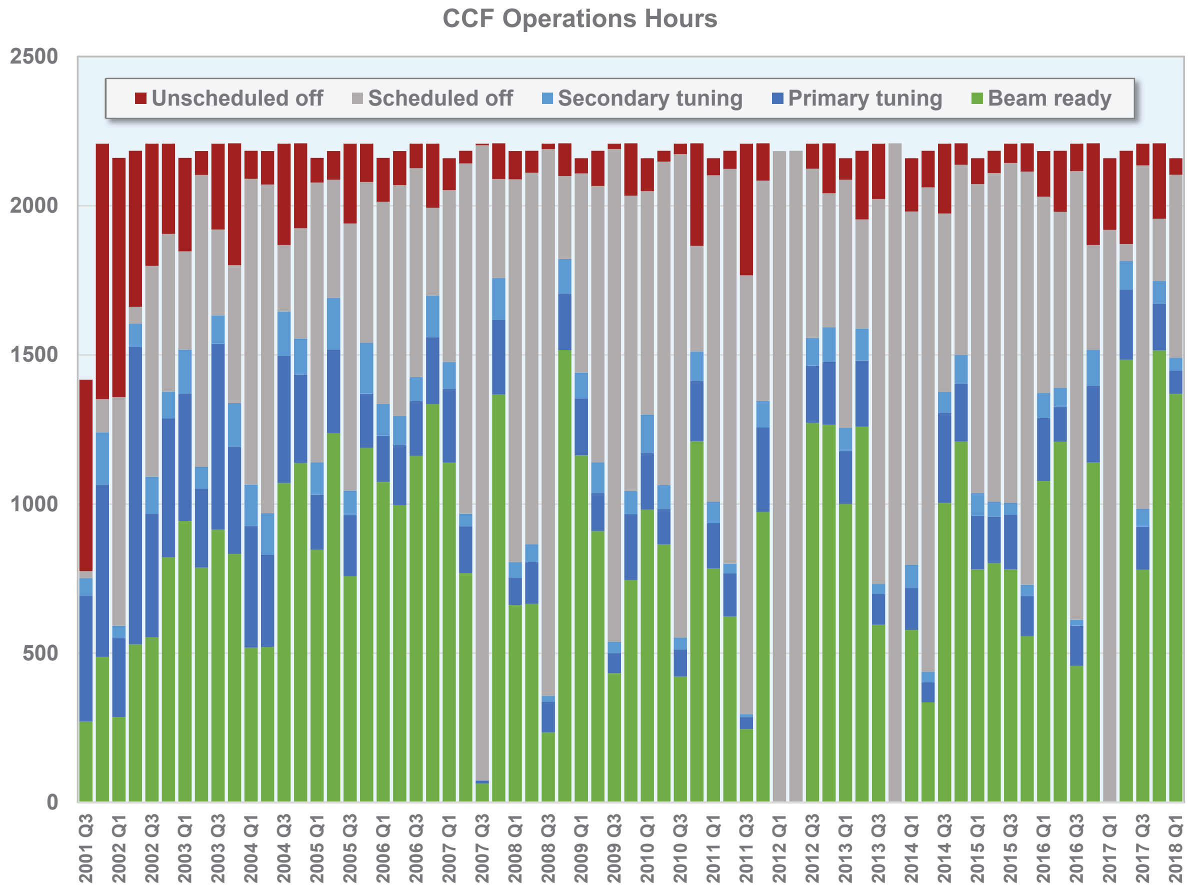
more than 1000 RIBs have been produced (2001-2018)
more than 900 have been used in experiments



NSCL's Experimental Facility Plan



CCF Operations Statistics



NSCL operations hours: typically: 4500 hours/year

up to 6000 hours/year possible

During scheduled facility operations NSCL operates on a 24/7 schedule.

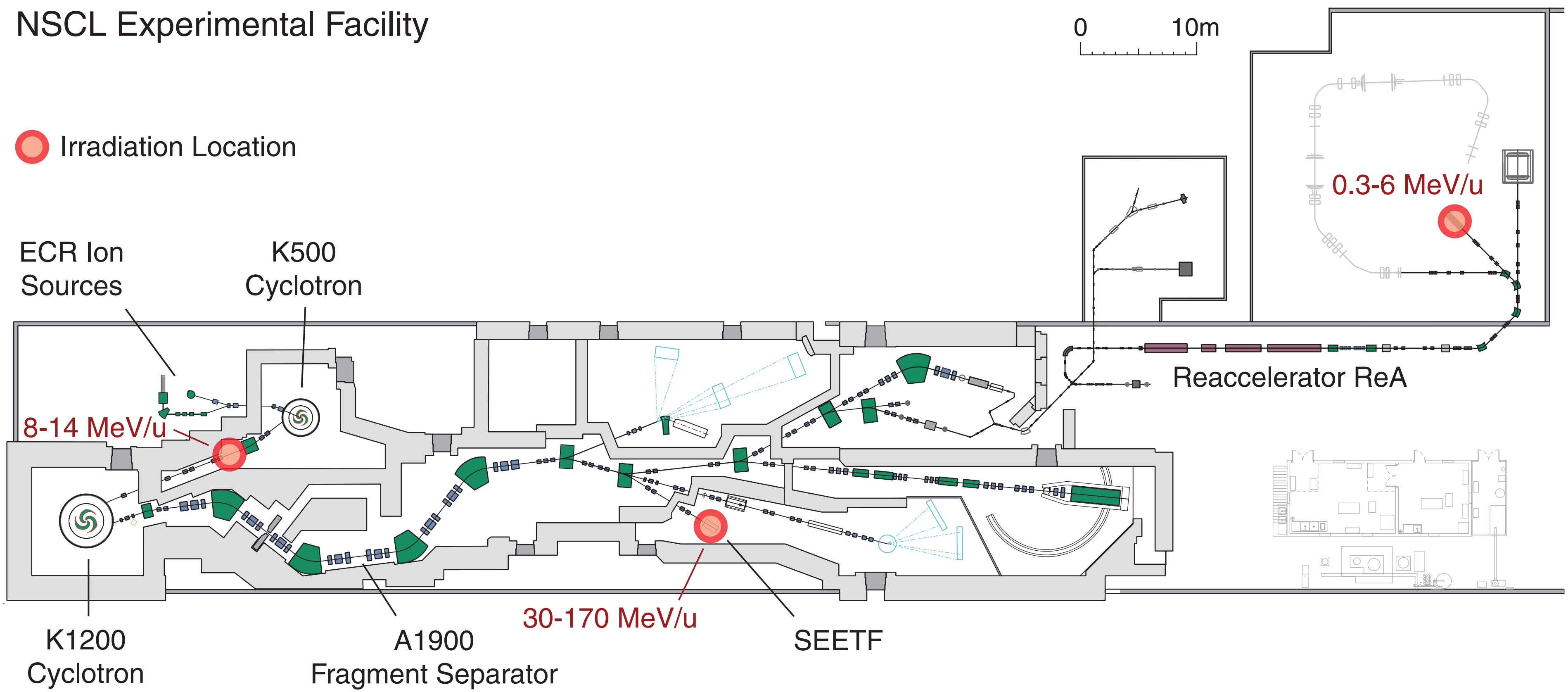
Facility availability of more than 90% allows for reliable schedule and high user satisfaction

NSCL operations is certified according to ISO 9001, ISO14001, and ISO 18001

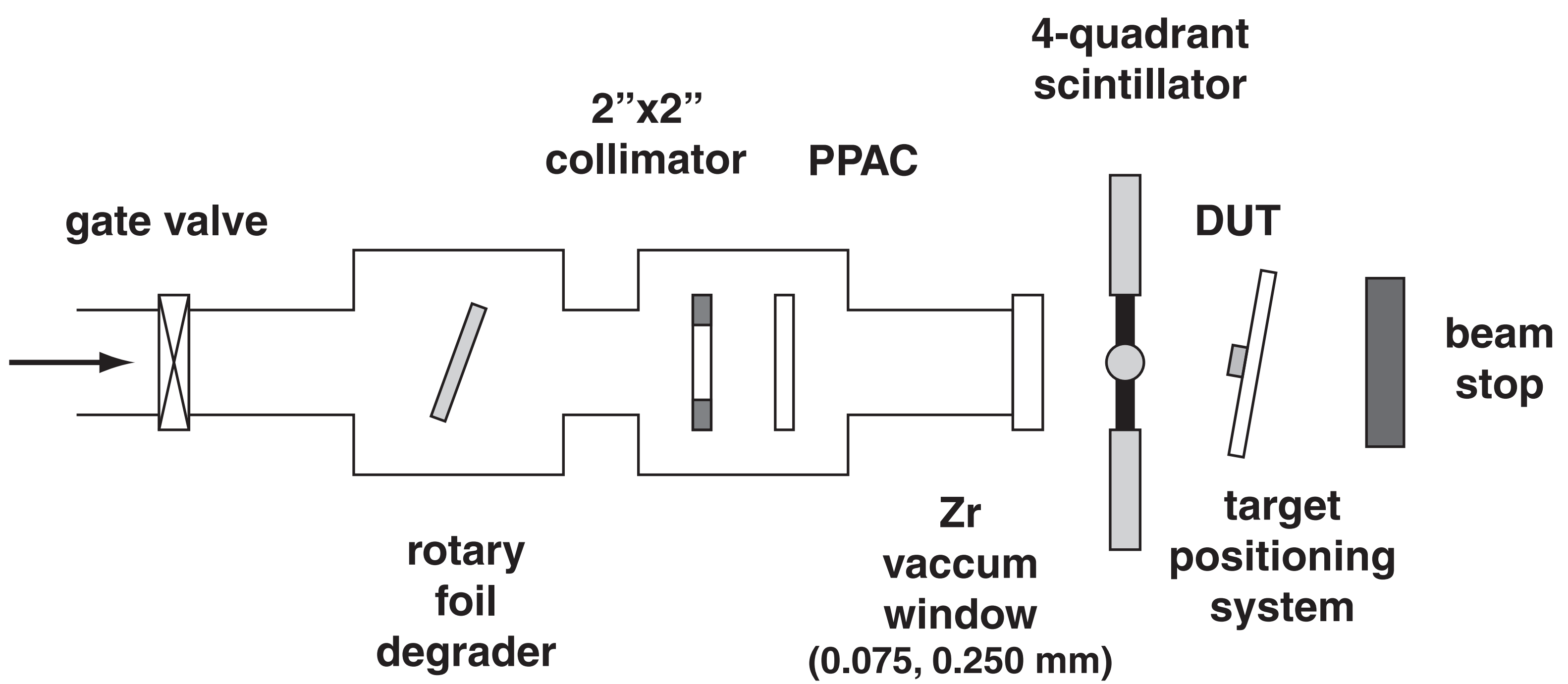
NSCL science operations is funded by National Science Foundation through 5-year cooperative agreement FY17 – FY21.

Up to 500 hours/year are available for SEE testing

Irradiation Stations



Schematic Layout of the SEETF

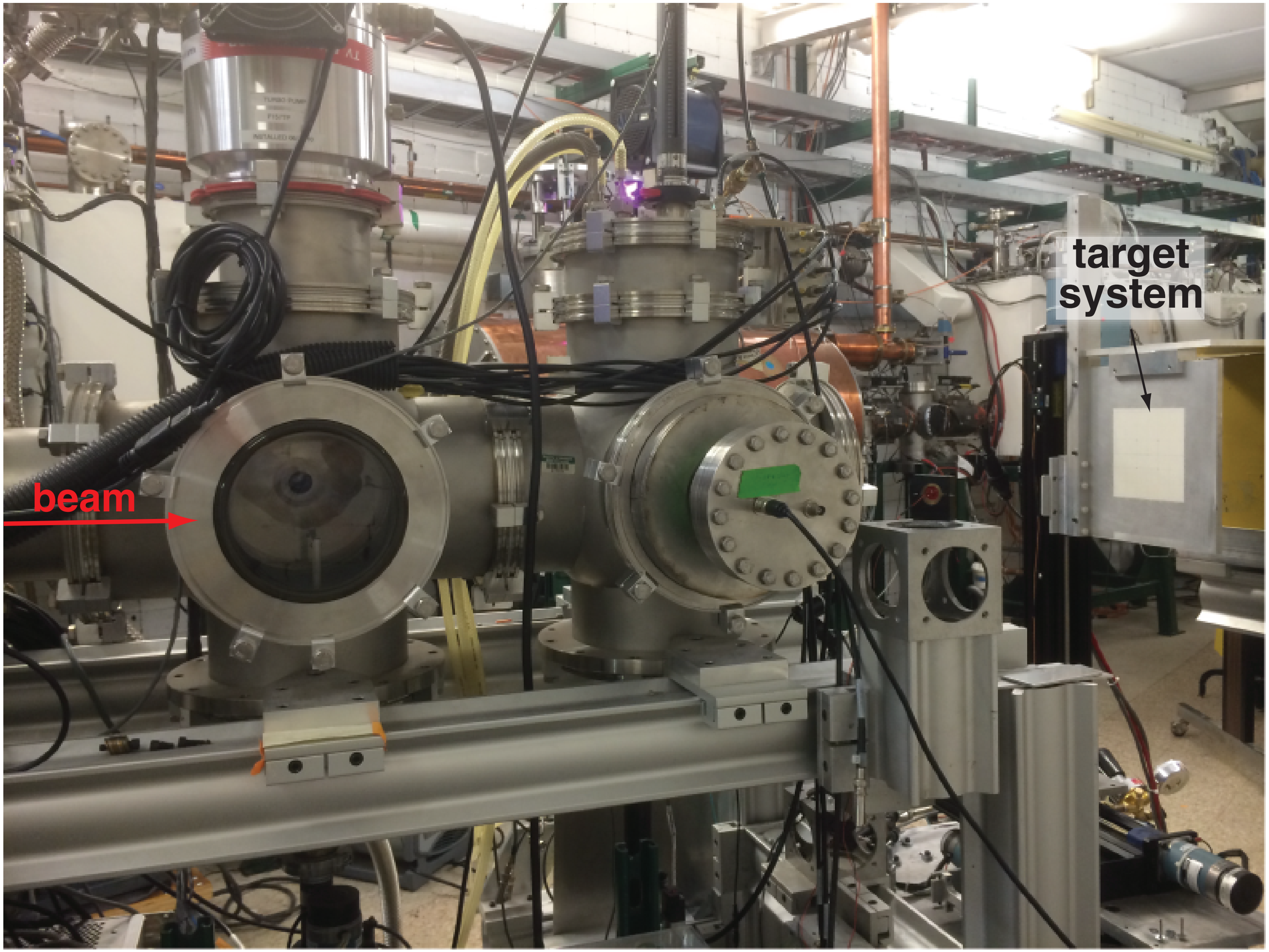


rotary degrader:

Al plate (100x100 mm^2, 0.1 - 2 mm thick),

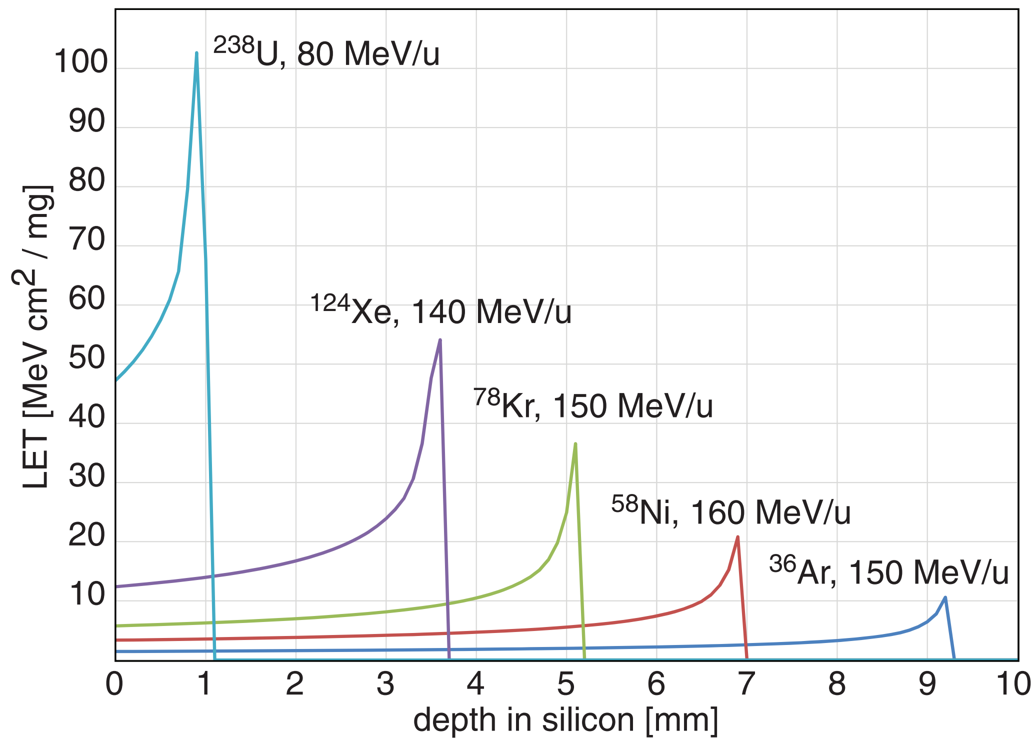
quick adjustment of energy, controlled by user

SEE Test Facility



Beams available at the SEETF

Isotope	Energy [MeV/u]	@100mm air [MeV/u]	LET(Si) [MeV cm2/mg]	range(Si) [mm]
16O	150	149	0.3	21.1
18O	120	119	0.3	16.1
20Ne	170	169	0.4	21.0
22Ne	150	149	0.4	18.6
24Mg	170	169	0.6	17.4
36Ar	150	148	1.4	9.3
40Ar	140	138	1.5	9.2
40Ca	140	138	1.9	7.5
48Ca	140	138	1.9	9.0
58Ni	160	157	3.3	7.0
64Ni	140	137	3.7	6.2
76Ge	130	127	5.0	5.0
82Se	140	137	5.4	5.5
78Kr	150	147	5.8	5.2
86Kr	140	137	6.0	5.1
96Zr	120	116	8.2	3.6
92Mo	120	116	9.1	3.1
100Mo	120	116	9.1	3.4
112Sn	120	115	12.7	2.8
124Sn	120	115	12.7	3.1
124Xe	140	135	13.3	3.5
136Xe	120	115	14.6	3.0
208Pb	85	77	37.9	1.3
209Bi	80	72	40.0	1.2
238U	80	71	47.2	1.1



Beam Spot Homogenity

ion beam: ^{78}Kr, 123 MeV/u

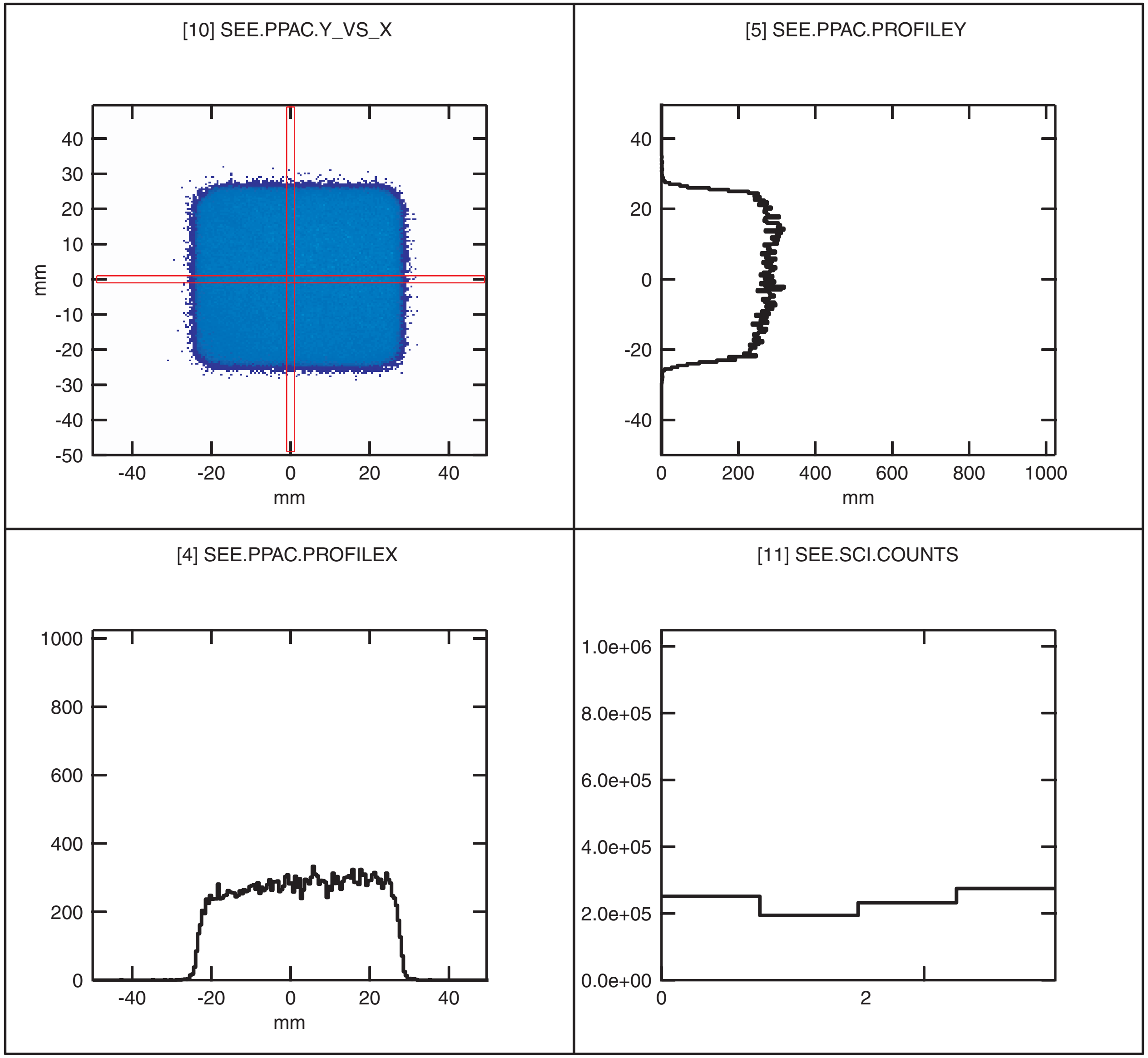
aperture inserted

beam spot characteristics:

beam spot size:
50 x 50 mm^2

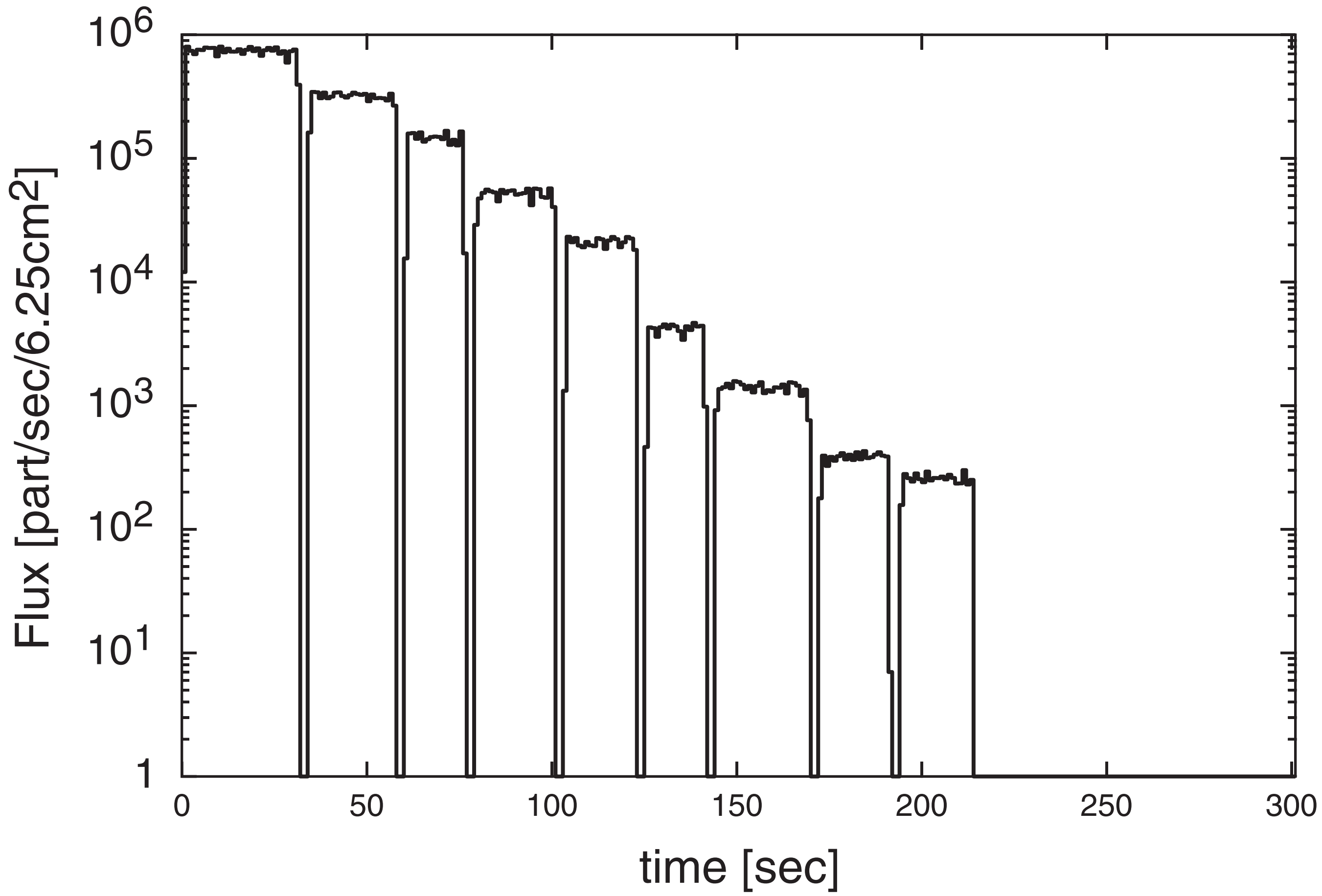
beam spot homogeneity:
> 50% (specification)
> 85% (typical)

isotopic purity:
> 99%



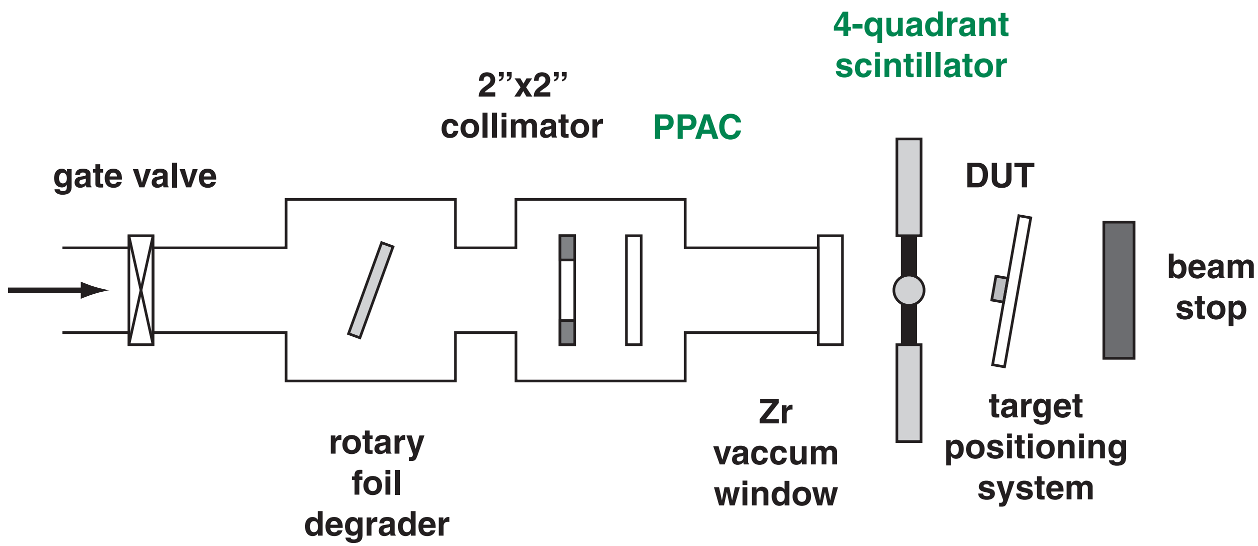
Beam Flux Adjustments

Flux adjustments with attenuator grids in K500 cyclotron injection line



adjustments in steps of factor of 3 from 1 to 10^6,
fine adjustments with variable slits
possible within 30 seconds

Beam Diagnostic and Dosimetry



PPAC (parallel plate avalanche counter)

2-dim position resolution: 1mm

active area: 100x100 mm^2

max counting rate: 10 kHz

max flux: $4 \cdot 10^2$ cm^{-2} s^{-1}

equivalent thickness: 5 mg/cm2 Al

detector rectractable

Four-quadrant scintillator

4 quadrants

active area: 100x100 mm^2

max counting rate: 1 MHz per quadrant

max flux: $1.5 \cdot 10^5$ cm^{-2} s^{-1}

thickness: 0.25 mm BC-400

detector mounted in air, non-retractable

SEE Test Facility Control

SEETF can be controlled from any user control area:

System controls program (Windows based):

- target positiong
- SEETF degrader
- start/stop of irradiation runs

Data acquisition system (Linux based):

- control of beam monitoring equipment and dosimetry
- storage of facility data

Beam control (flux, uniformity, tuning):

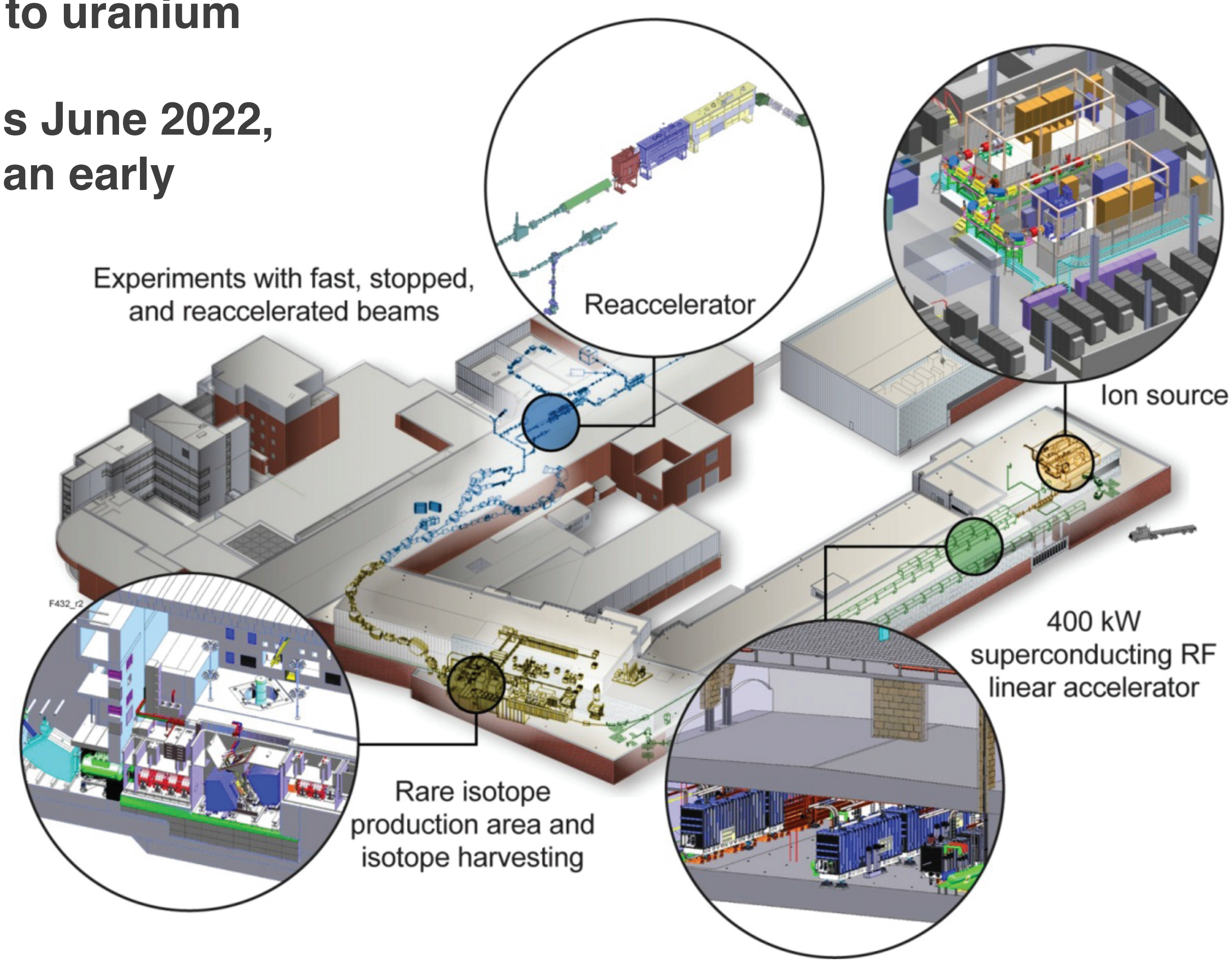
- exercised by accelerator operators
- communication by phone

Facility for Rare Isotope Beams

A DOE National User Facility, funded by U.S. Department of Energy Office of Science (DOE-SC), Michigan State University and the State of Michigan

Replaces the NSCL cyclotrons with a 400 kW superconducting RF linear accelerator for all ions up to uranium

Planned completion date is June 2022, the project is managed to an early completion in 2021

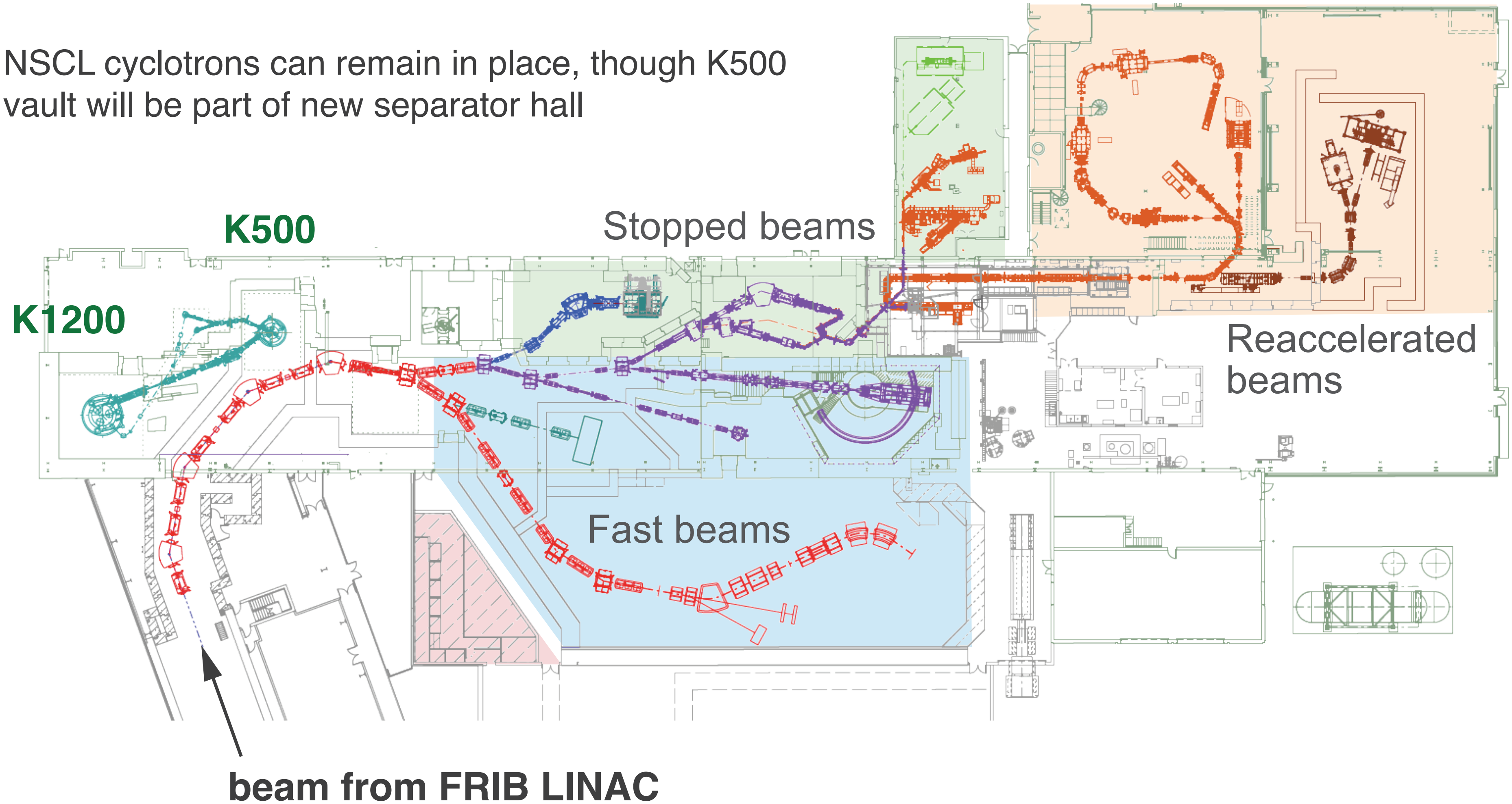


Future FRIB Experimental Facility

FRIB will reuse NSCL Experimental Facility

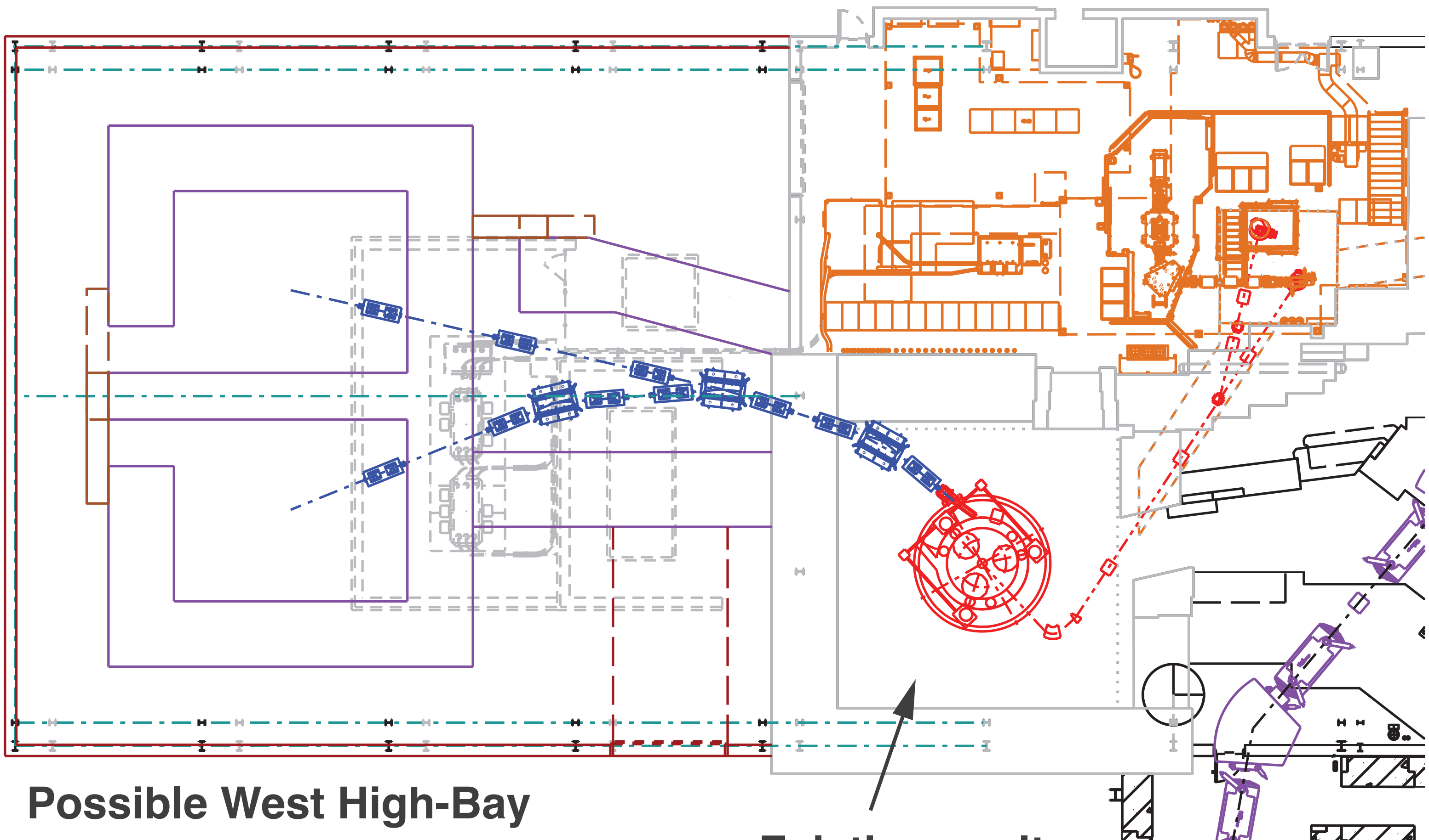
Reconfigured Fragment Separator beam line will connect to FRIB Linear Accelerator

NSCL cyclotrons can remain in place, though K500 vault will be part of new separator hall



Potential Future Use of K1200 cyclotron

K1200 cyclotron could be disassembled, refurbished, reassembled rotated by 120° pointing toward a new experimental area, and again operated in a standalone mode



Possible West High-Bay extension

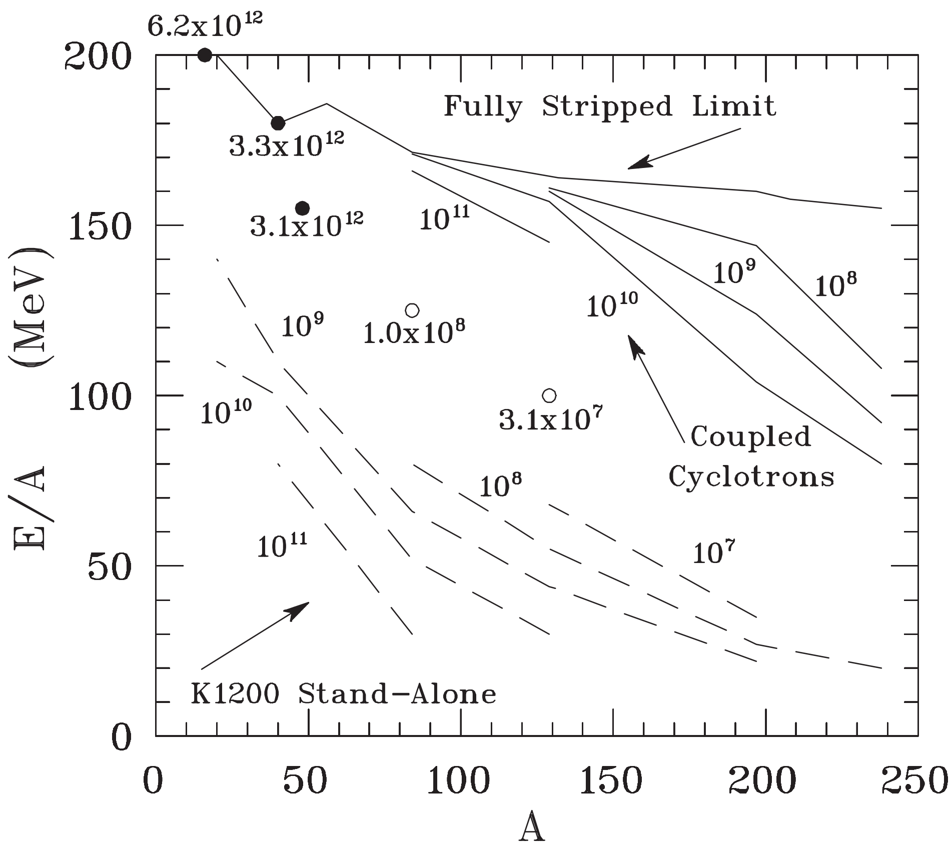
Existing vault with K1200 rotated by 120°

K1200 Cyclotron Standalone Operations

Operating Diagram for K1200 Standalone

compared with Coupled Cyclotron System

K1200 can provide ions from hydrogen to uranium including cocktail beams



Selected K1200 Standalone Beams

April 1998

Ion	E (MeV/A)	I (pnA)	I (part/sec)
2 H-H 1+	200	2	1.3E+10
12 C 5+	150	10	6.3E+10
12 C 6+	200	0.1	6.3E+08
20 Ne 9+	125	0.3	1.9E+09
20 Ne 10+	170	0.08	5.0E+08
36 Ar 15+	150	2.2	1.4E+10
36 Ar 17+	180	0.003	1.9E+07
58 Ni 17+	90	0.35	2.2E+09
58 Ni 18+	105	0.1	6.3E+08
86 Kr 27+	100	0.02	1.3E+08
86 Kr 29+	120	0.0002	1.3E+06
129 Xe 30+	60	0.1	6.3E+08
129 Xe 32+	70	0.002	1.3E+07
197 Au 42+	50	0.0017	1.1E+07
197 Au 44+	59	0.0002	1.3E+06
238 U 35+	20	0.04	2.5E+08
238 U 39+	25	0.0004	2.5E+06

Summary

NSCL Coupled Cyclotron Facility

NSCL science operations is funded until FY21
Facility will transition to FRIB operations
Until then, up to 500 hours/year available for SEE testing

Potential future use of K1200 cyclotron

K1200 cyclotron could be used in standalone mode for future SEE testing
K1200 can provide ions from hydrogen to uranium
light ions up to 200 MeV/u, uranium up to 25 MeV/u