Operation of the Coupled Cyclotron Facility at Michigan State University

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NSCL / Michigan State University

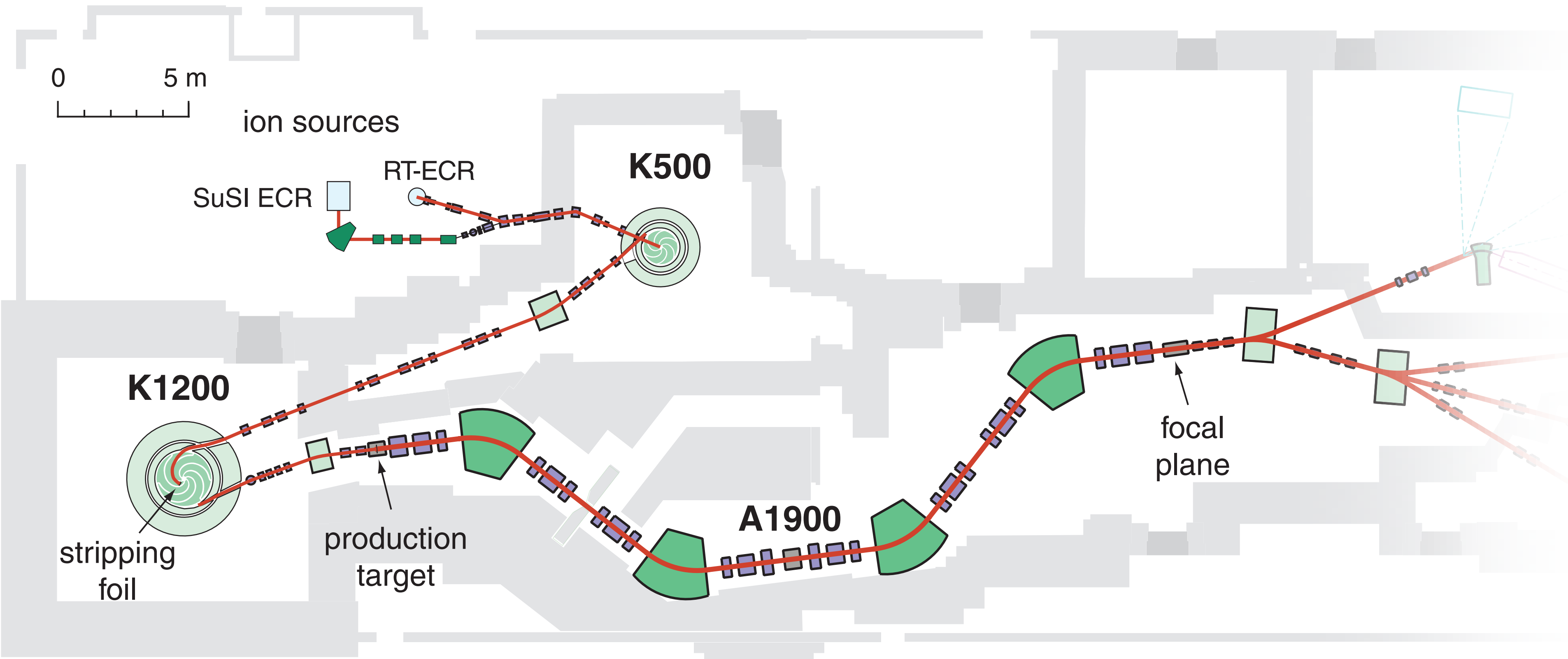
7th Workshop on Accelerator Operations

Daejeon, Korea, April 2010

National Superconducting Cyclotron Laboratory

- National user facility for rare isotope research and education in nuclear science, astro-nuclear physics, accelerator physics, and societal applications
- Located on the campus of Michigan State University in East Lansing
- 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 U.S. – 10% of U.S. nuclear science Ph.D.s
- 390 employees, incl. 69 graduate students, and 39 faculty – over 700 users
- Graduate program in nuclear physics ranked 2nd (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



2 coupled cyclotrons
primary beams: oxygen to uranium
K500: 8 - 12 MeV/u, 2-8 eμA
K1200: 100 - 160 MeV/u, up to 2 kW

A1900 fragment separator
to produce rare isotope beams

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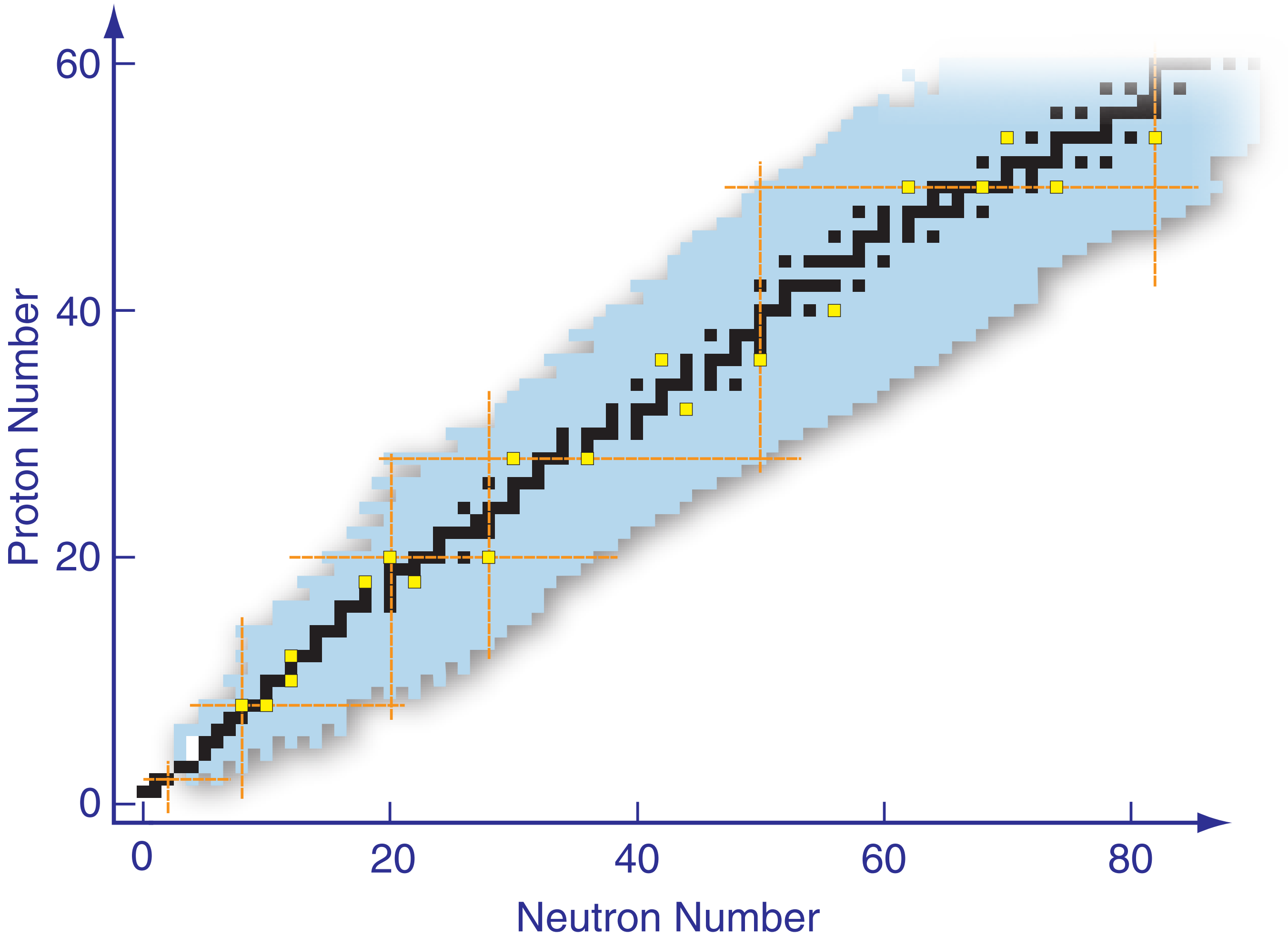
NSCL Primary Beam List



Particle	Energy [MeV/u]	Intensity [pnA]
^{16}O	150	125
^{18}O	120	125
^{22}Ne	120	80
^{24}Mg	170	30
^{36}Ar	150	50
^{40}Ar	140	50
^{40}Ca	140	22
^{48}Ca	140	80
^{58}Ni	160	20
^{64}Ni	140	7
^{76}Ge	130	20
^{78}Kr	140	25
^{86}Kr	140	20
^{96}Zr	120	1.5
^{112}Sn	120	3
^{118}Sn	120	1.5
^{124}Sn	120	1.5
^{124}Xe	140	10
^{136}Xe	120	2
^{209}Bi	80	1
^{238}U	85	0.2

Primary beam list as offered for experiments (January 2010)

(some available beam energies not shown)

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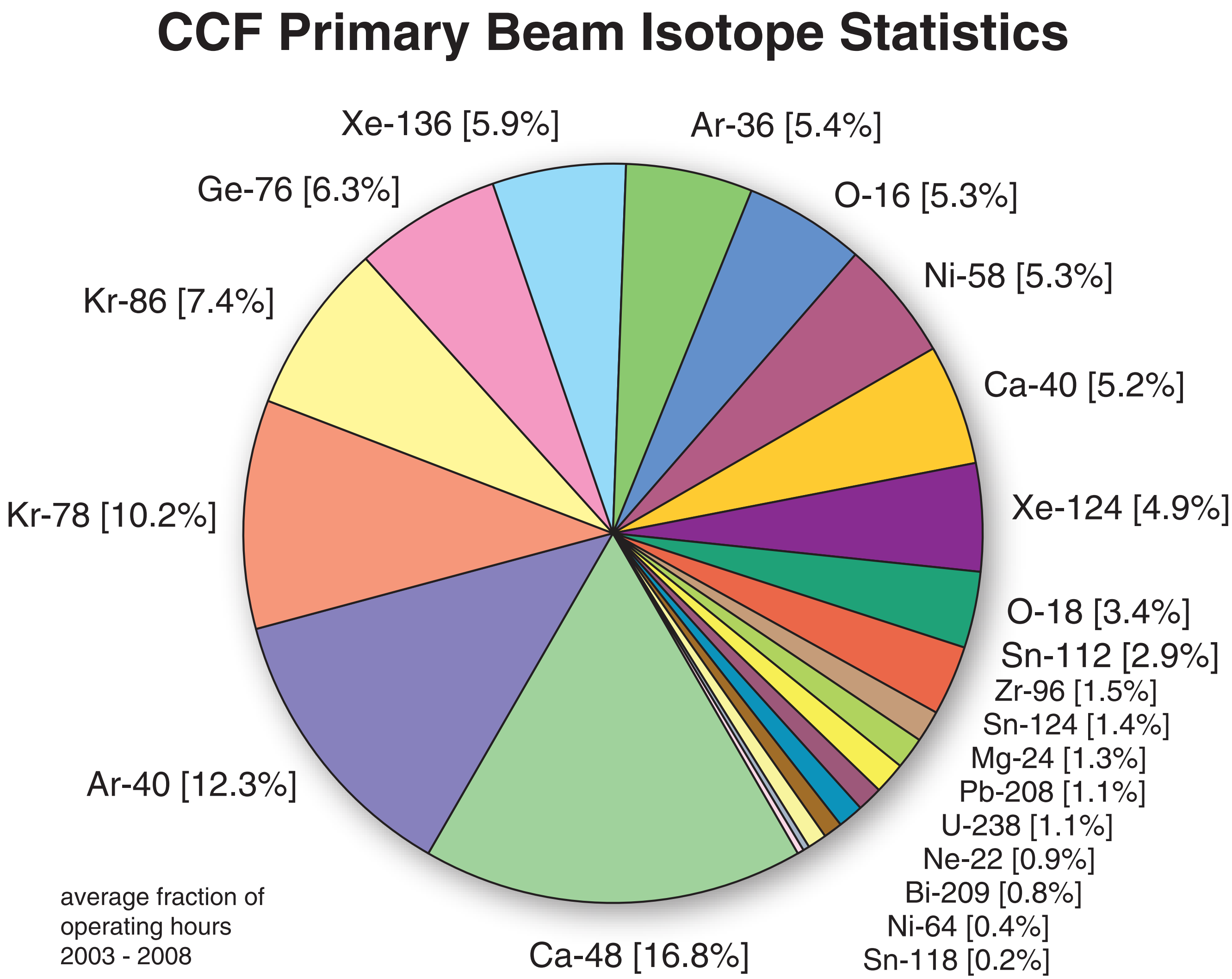
Primary Beam Statistics

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.



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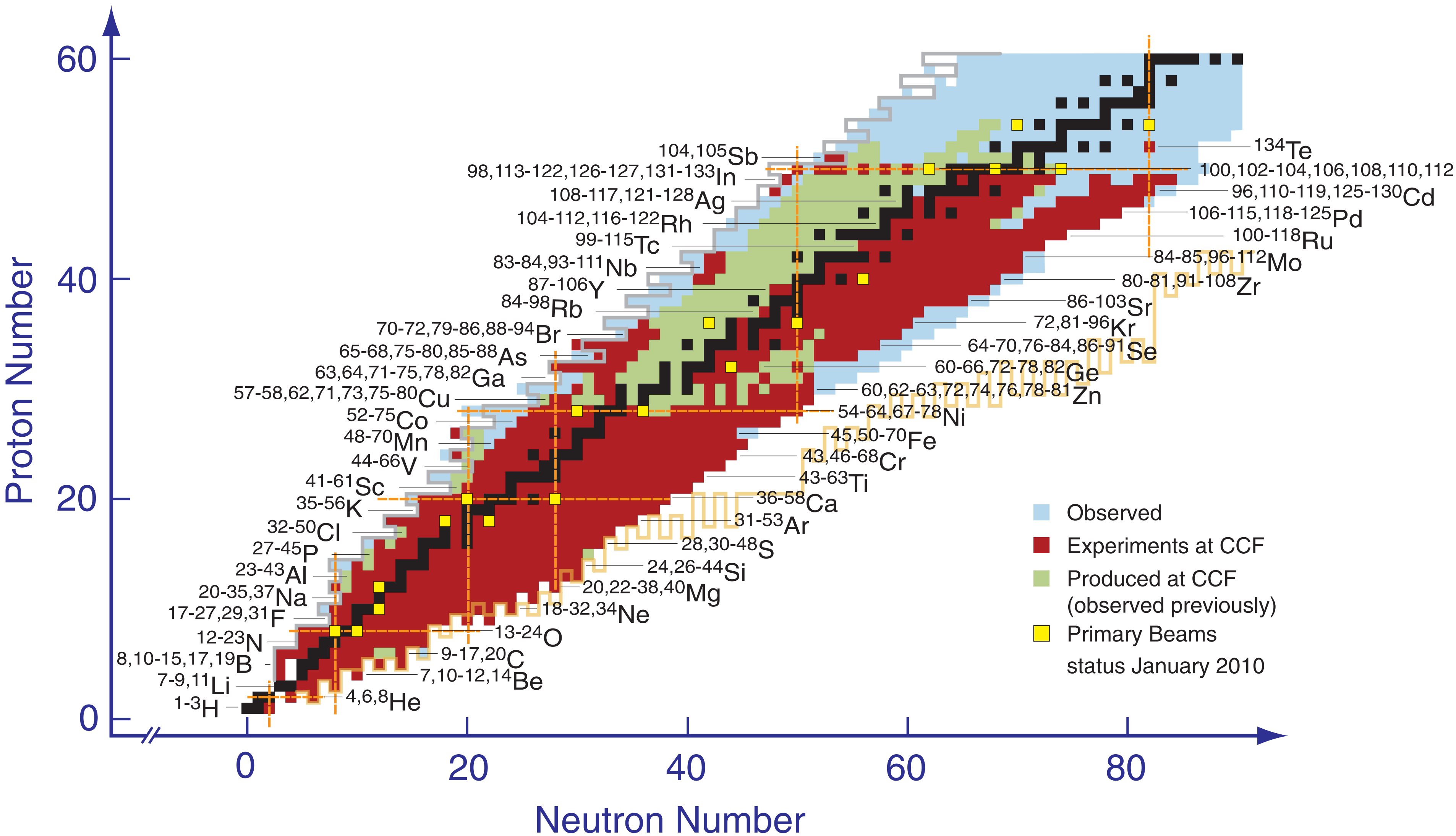
Rare Isotopes produced at NSCL

more than 1000 RIBs have been produced (2001-2010)
more than 830 have been used in experiments



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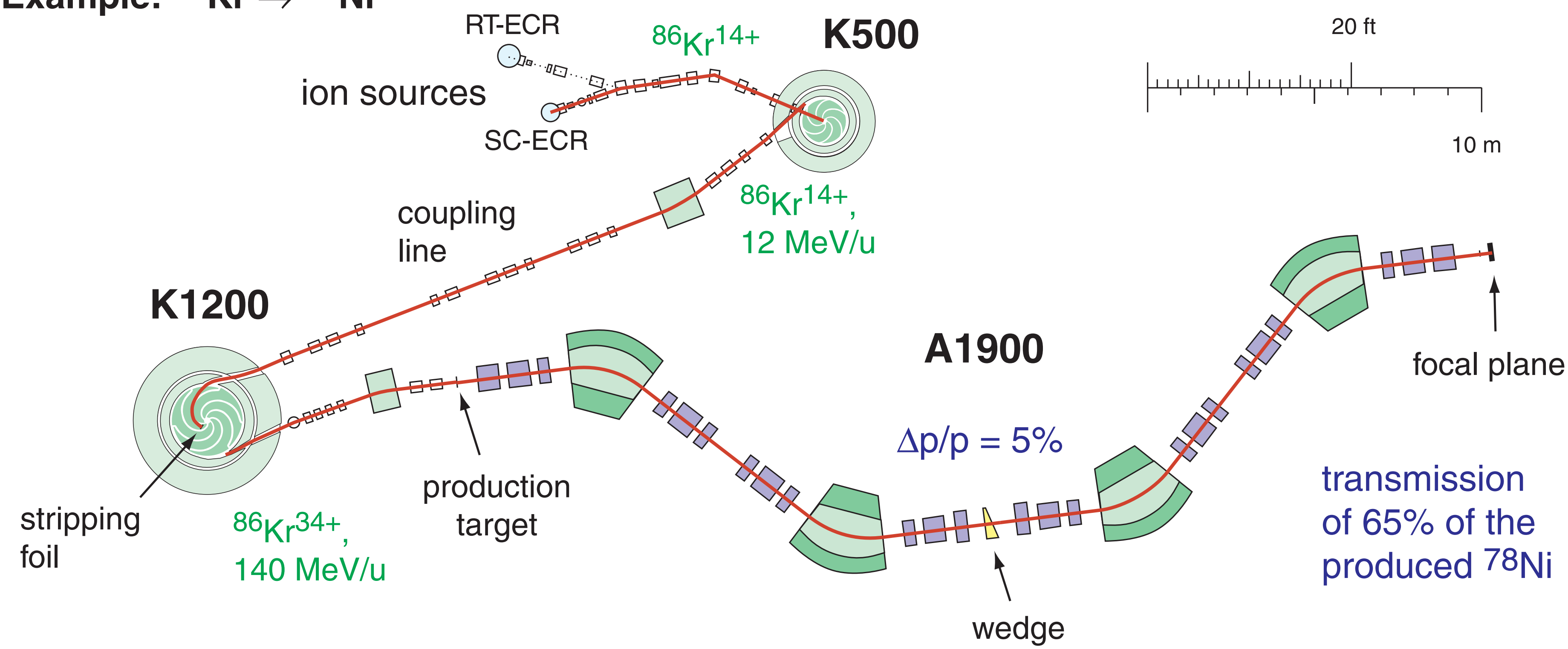
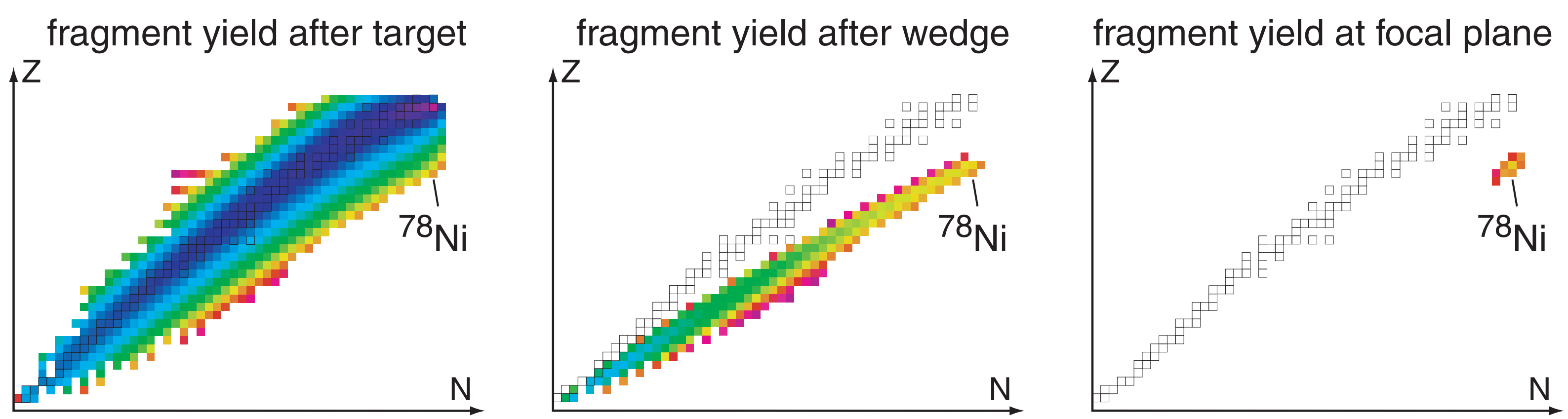
Overview of the Fragment Separation Technique

Example: $^{86}Kr \rightarrow {}^{78}Ni$





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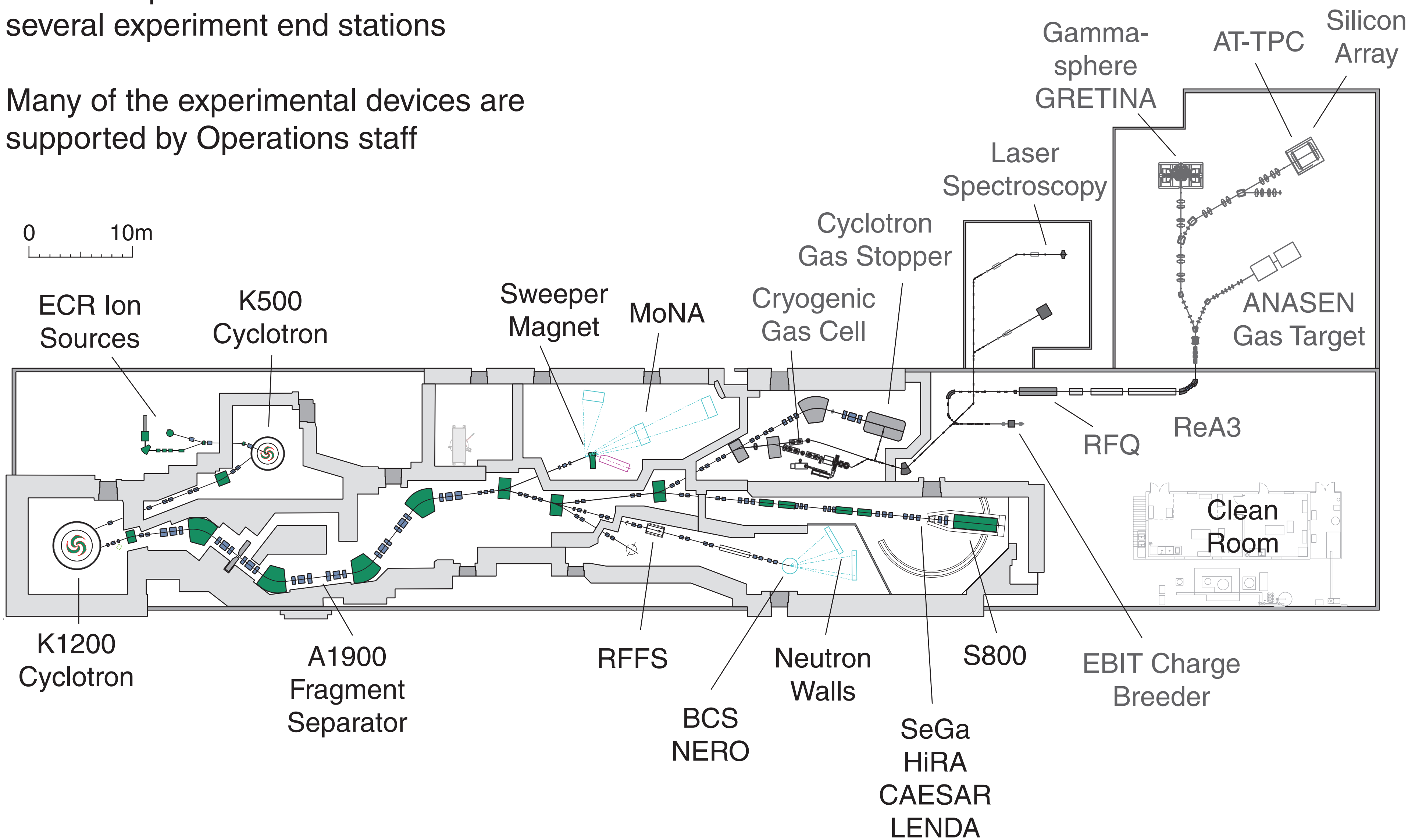
NSCL's Facility Plan

Rare isotope beams can be delivered to several experiment end stations

Many of the experimental devices are supported by Operations staff



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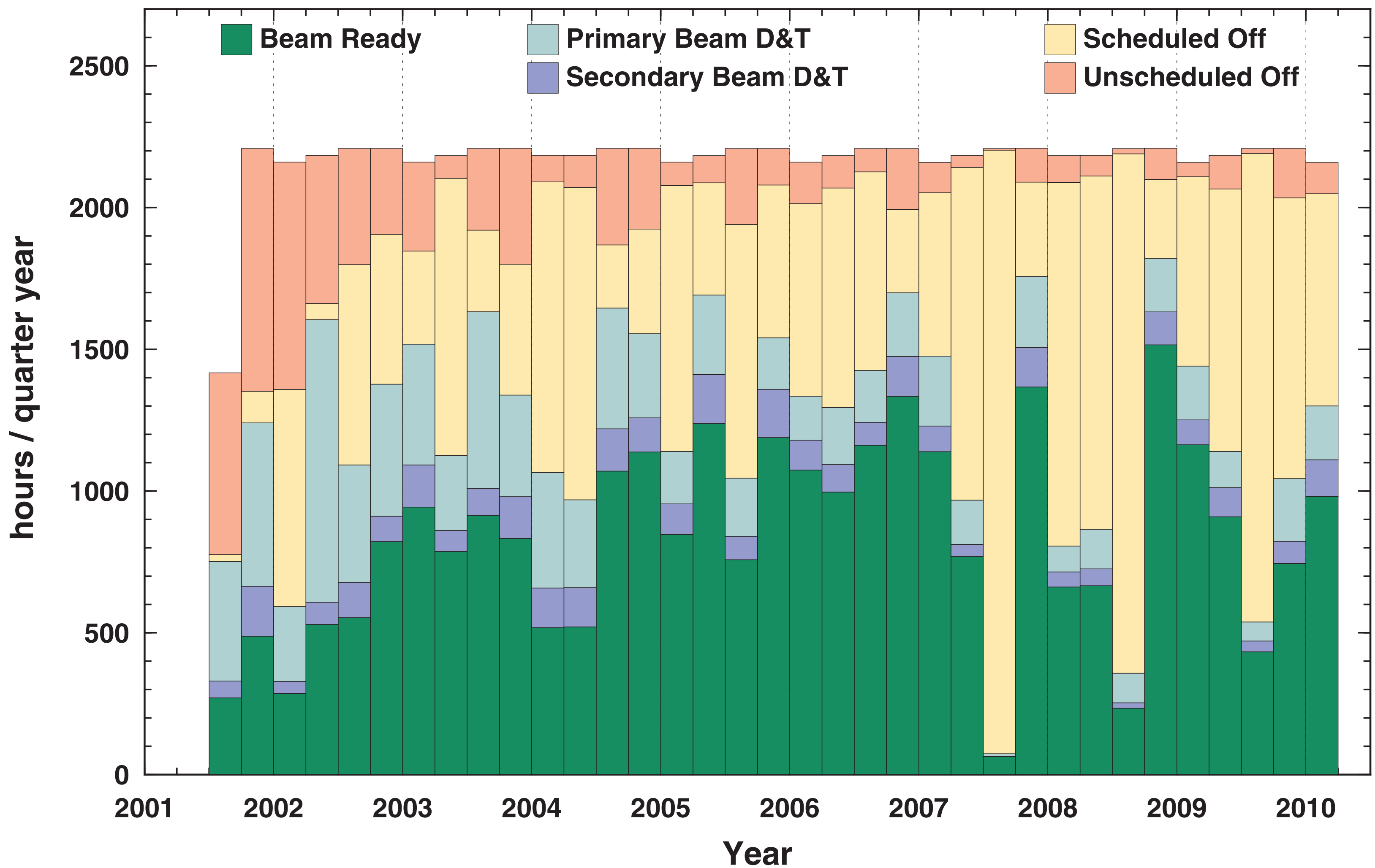
CCF Operations Statistics



NSCL ist currently funded for 4200 operations hours per year

Coupled Cyclotron Facility (CCF) operates 24/7 during beam delivery periods

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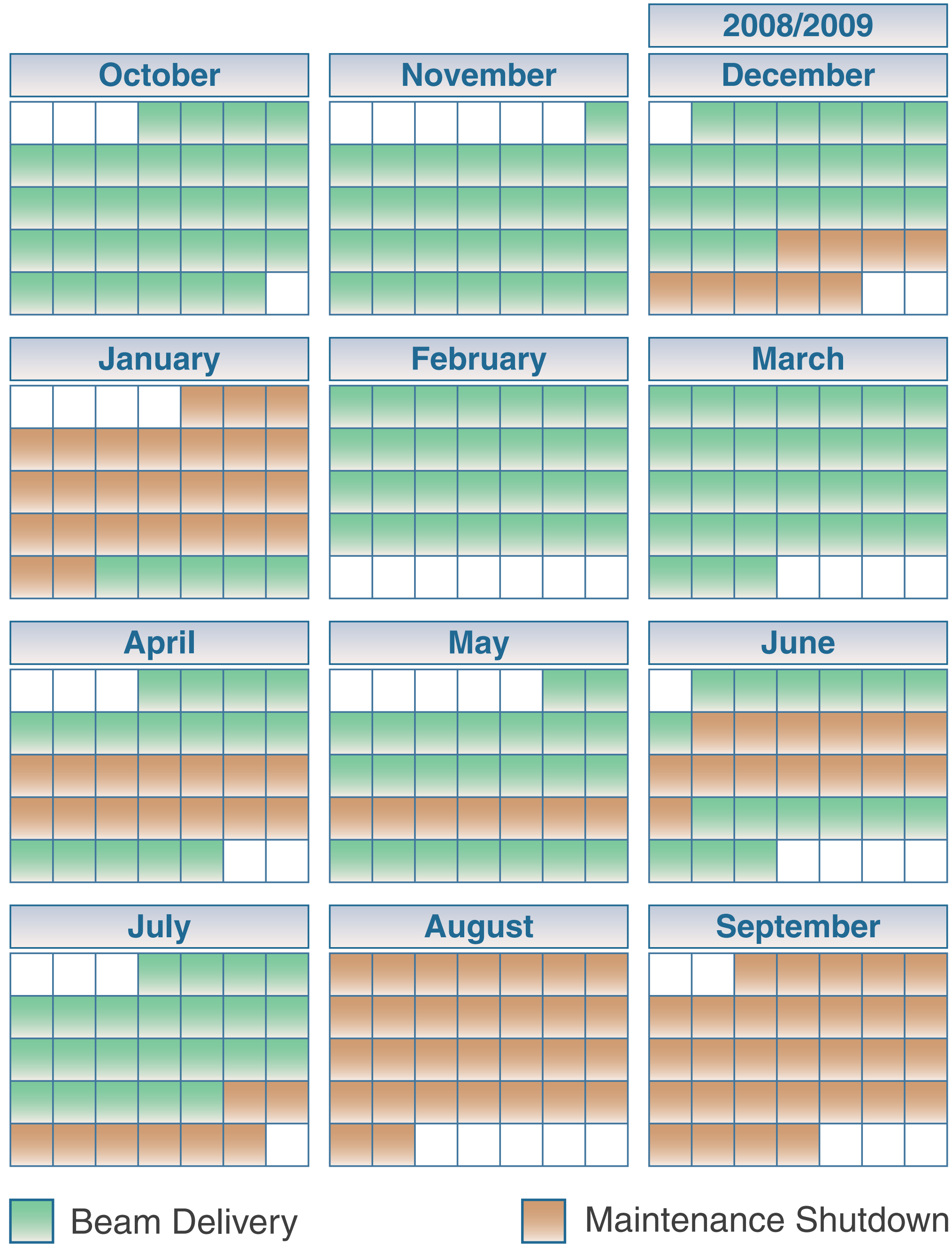
Operations Schedule

Experiment schedule is finalized
3 months in advance

Experiments are typically 5-7 days long,
1 primary beam from cyclotrons
1-3 different rare isotopes

Shorter quarterly shutdowns for
preventative maintenance

Longer shutdowns for upgrade or
larger repairs
(e.g., summer 2009: installation of new
superconducting ion source)



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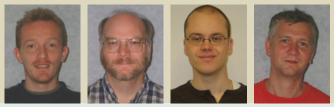
Organizational Structure

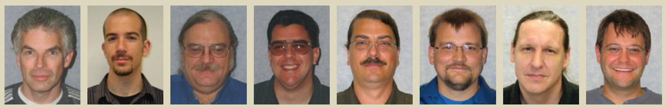
Operations

Ion Source Group (5 FTE)



ion source support,
weekdays 08:00-17:00 on-site,
call-in support at other times

Operations Engineers Group (8 FTE)



Maintenance Engineers Group (4 FTE)

cyclotron operations
(+ maintaining ion source tune),
24/7 on rotating shift
weekdays 08:00-17:00 during maintenance

Beam Physicist Group (3 FTE)

beam delivery support, weekdays 08:00-17:00 on-site,17:00-24:00 and weekend on-demand, call-in support at other times

Development Group (5 FTE)

weekdays 08:00-17:00 on-site, on-demand and call-in support at other times

Electronics
Facilities
Computer
Mechanical Design
Fabrication&Assembly

day time on-site technical support,
call-in support at other times
for RF systems, power supplys,
cryogenics, vacuum systems,
control system, computer,
mechanical repair, ...

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Cyclotron Operator Group

Cyclotron Operator Responsibilities:

Tuning of two cyclotrons and beam lines from ion source to production target, maintaining ion source tune, monitoring of all production systems, “first responder” for alarms, operator will call-in technical support if needed, first contact for experimenter support during off-hours

Primary beam development takes 8-10 hours (12 hours scheduled: 16:00 - 08:00)

Operator Shift Schedule

	Crew	Monday			Tuesday			Wednesday			Thursday			Friday			Saturday		Sunday		hours
week 1	A	8			8			8			8			8			12		12		64
	B											8			8						16
	C					8			8									12		12	40
	D			8			8			8			8			8					40
	E		8																		8
week 2	A		8			8															16
	B	8			8			8			8			8			12		12		64
	C			8			8			8			8			8					40
	D											8			8			12		12	40
	E								8												8

Cyclotron Operator is only group on rotating shift schedule
2 operators per shift crew, 1 OIC = “operator in charge”
three 8-hour shifts during weekdays (shift change at 07:00, 15:00, 23:00)
two 12-hour shifts during weekend (shift change at 11:00 and 23:00)
crew rotates only through 2 out of 3 shifts

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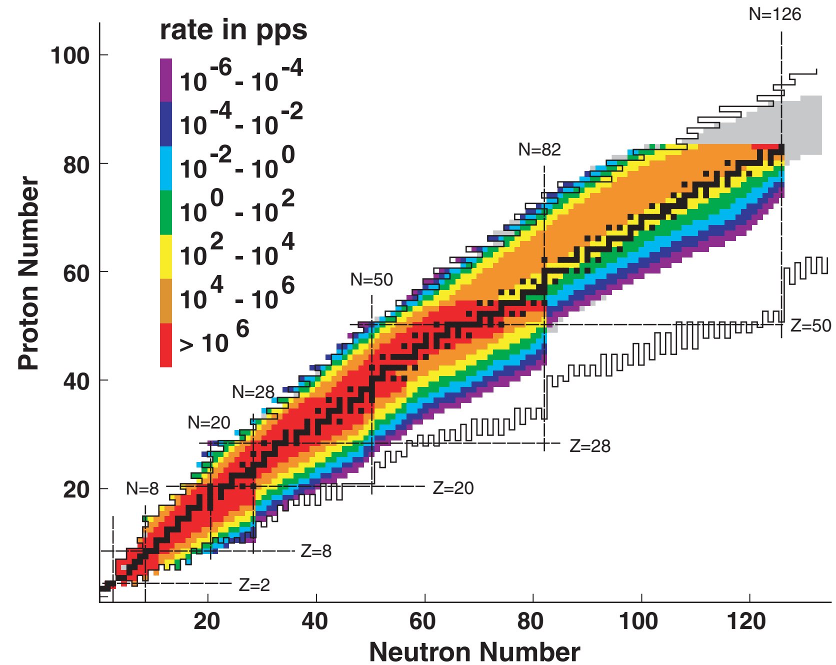
Beam Physicist Group

Rare Isotope Production and Delivery:

Task is similar to Ph.D.-level nuclear physics experiment

Difficulty is correlated with production rate,
which can vary over more than ten orders of magnitude:
many million particles per second to
a few particles per week

Development time: 2 - 24 hours
Delivery time: 3 hours to experiment after development

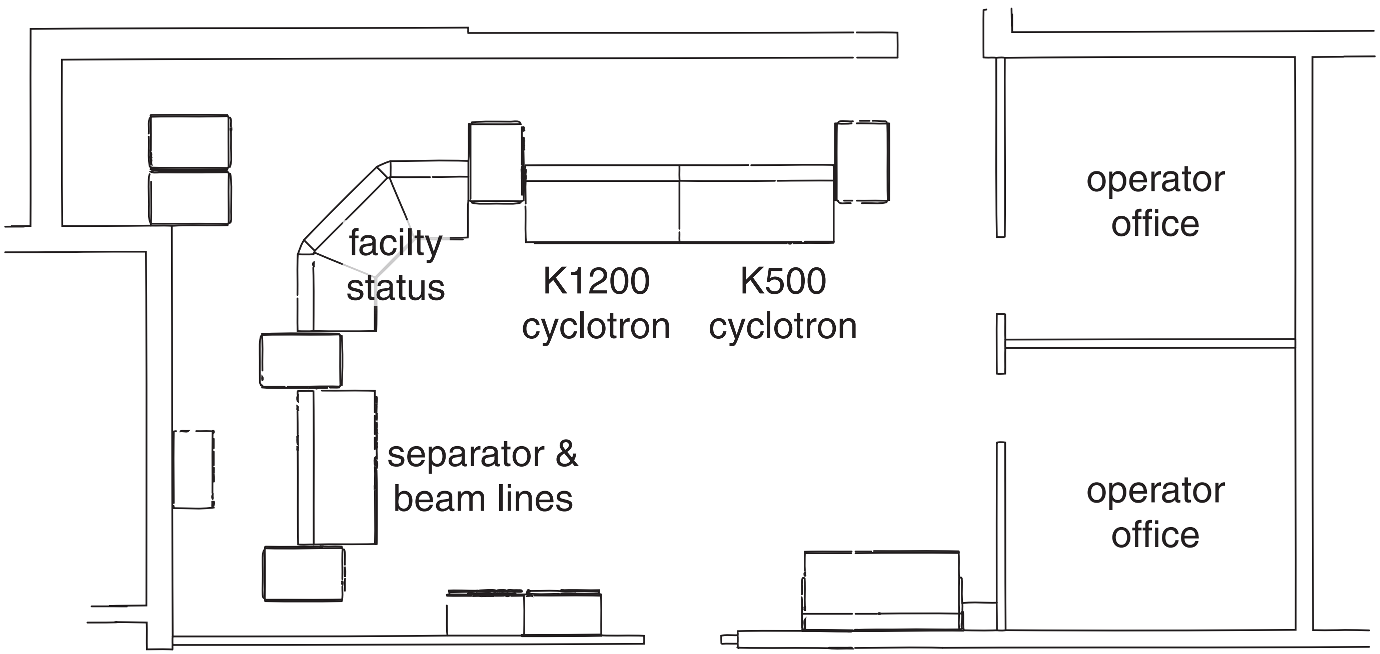


1 group leader and 4 beam physicist (50% beam delivery, 50% research)

Beam delivery scheduled during daytime, weekend support with prior arrangement

Beam physicist group also supports initial tuning of experimental devices

Control Room Layout



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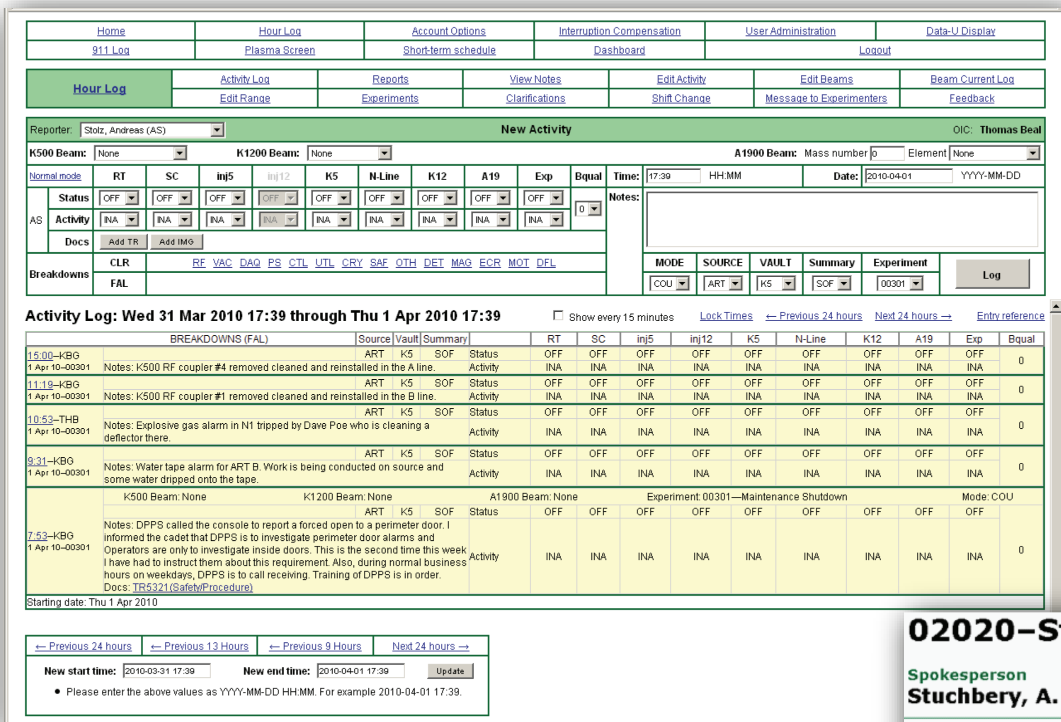
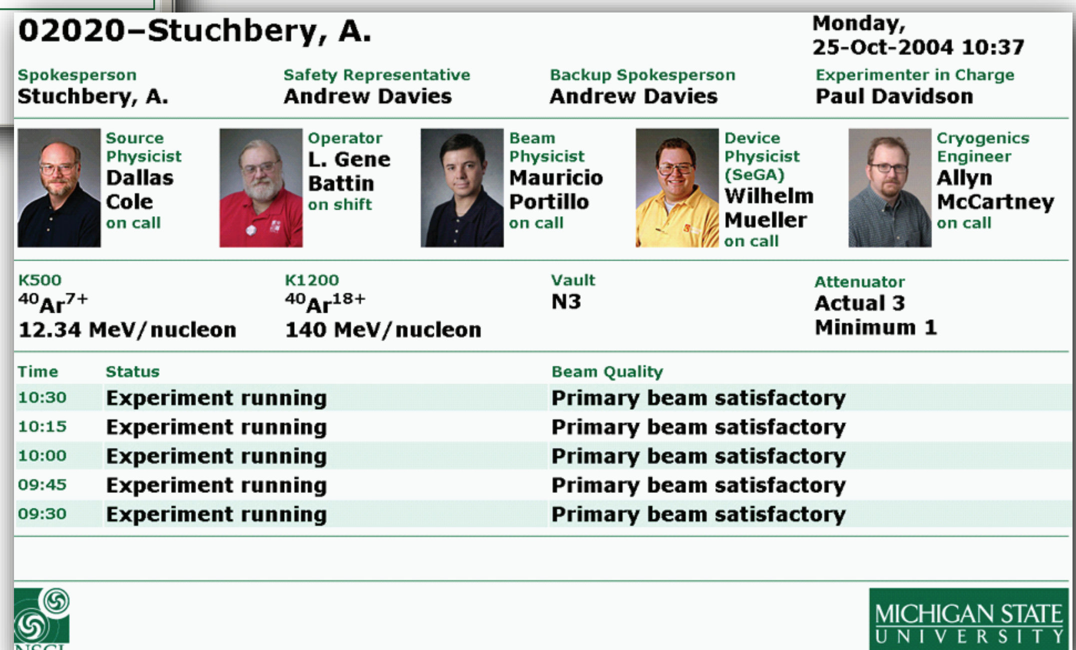
Facility Logbook



Display facility status for experimenters in Data-U areas, invite corrections



Facility status is captured in Hourlog database by operator

All operations data, including experiment statistics, breakdown statistics and availability can be extracted from Hourlog database

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Facility Availability

High availability is essential to maintain experiment schedule (defined 3 months in advance)

Availability is product of all system availabilties

Availability A relates to Mean Time Between Failures (MTBF) and Mean Down Time (MDT):

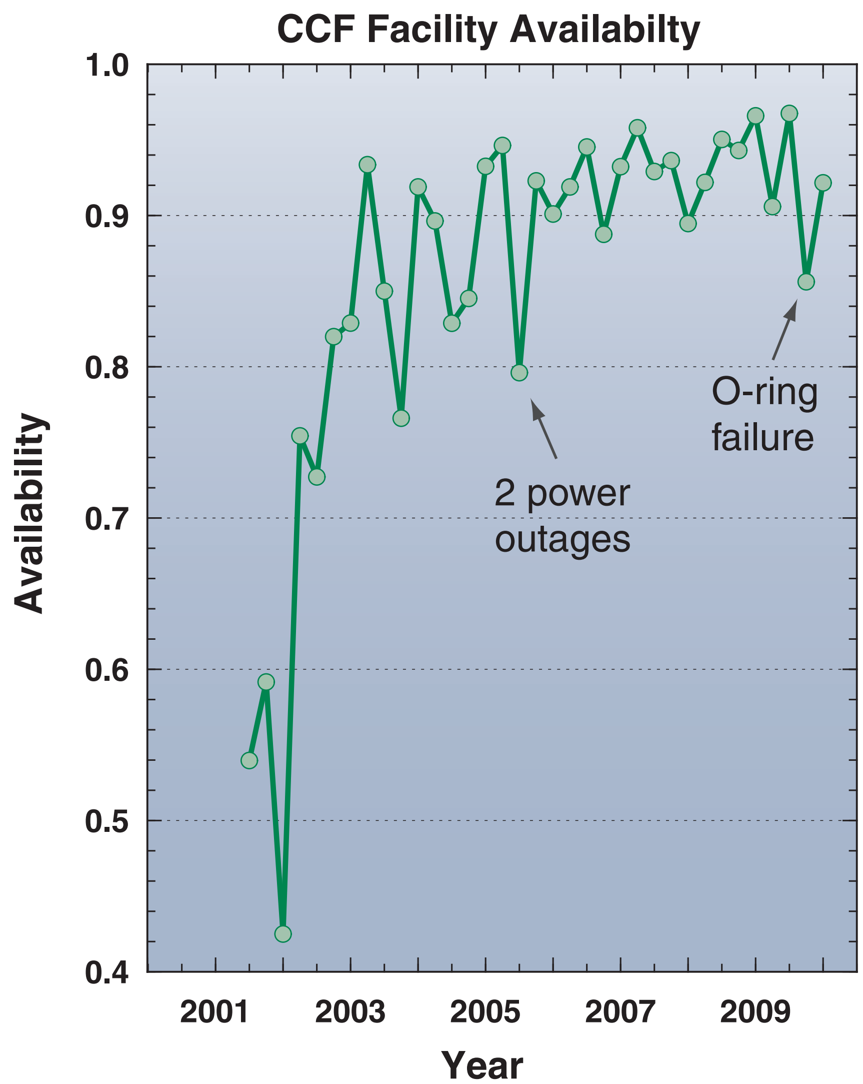
$$A = MTBF / (MTBF + MDT)$$

Increase MTBF and decrease MDT

Mean Down Time MDT is sum of many components:
Recognize a problem exists, diagnose problem, repair strategy, get parts, install, test, check quality, recover operations
MDT can be decreased by reducing time for each step

Mean Time Between Failures MTBF depends on quality
Design, parts, work, procedures
Quality engineering and quality officer, project teams

Track failures by system, root cause analysis, preventive action, value engineering



Availability on Hallway Displays

Staff members are informed on-line about availability in 10 Hallway Displays

Thursday, 1 Apr 2010 **10:44**

now | 6 hours ago | 12 hours ago | 18 hours ago | 24 hours ago

Current Experiment

02020-Stuchbery, A.

K500	K1200	Vault	Status
$^{40}Ar^{7+}$ 12.34 MeV/nucleon	$^{40}Ar^{18+}$ 140 MeV/nucleon	N3	Experiment running

	1 day		7 days		30 days		180 days	
Availability	**86.5 %**		**91.0 %**		**80.2 %**		**83.7 %**	
Scheduled Off	0.0 hrs	0.0 %	1 hrs	1 %	125 hrs	17 %	1,276 hrs	30 %
Unscheduled Off	3.3	13.7 %	15	9 %	118	16 %	496	11 %
Development	0.8	3.3 %	15	9 %	167	23 %	875	20 %
Experiment	20.0	83.3 %	137	82 %	301	42 %	1,633	38 %

Utility Shutdowns

Tour (Today 17:45-18:45)

Access Restrictions

K500 vault, K1200 vault, Transfer Hall, N3 vault secured

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Quality Management System

NSCL introduced Quality Management System to achieve and maintain high availability (third-party certification to ISO 9001 in 2008)

Every system or process failure triggers “Trouble Report”

Root cause analysis, corrective and preventive action

Labwide Preventive Maintenance Database

Scheduled Maintenance with Reminder Emails

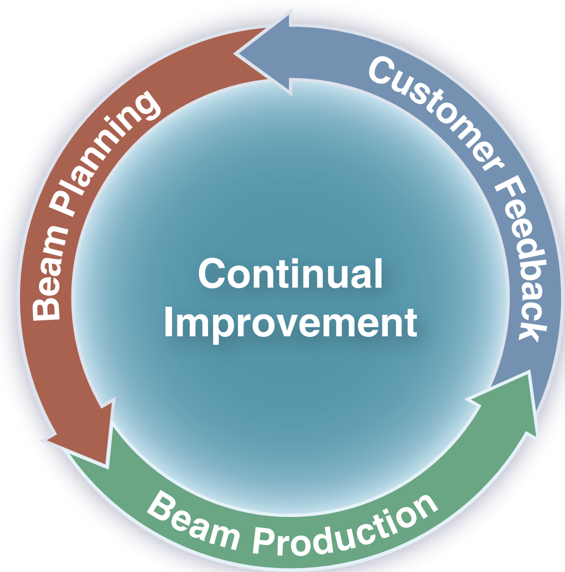
Maintenance Records to document maintenance history

Experimenter Feedback Survey to analyze “Customer Satisfaction”

Experimenter feedback helps to improve beam delivery

Employee Training

Online Training modules can be taken any time, training database to document successful training



similar management systems for Integrated Safety (OHSAS 18001certification) and Environmental Management (ISO 14001 certification)

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Future Challenge

system	group	Operations FTEs	support ratio	Total FTEs
ion source	ion source group	1.5	2	3
cyclotrons	operator group	10	1.5	15
A1900 +HE beam line	beam delivery group	1.5	2	3
gas stopping	beam delivery group	1	2	2
60keV beam transport + analysis	beam delivery group			
EBIT + Q/A separator	ion source group	1	2	2
LEBT RFQ SRF linac	LINAC group LINAC group	5	1.5	7.5
beam line to experiment	beam delivery group	0.5	2	1
diagnostics	LINAC group			
	CCF	**13**		**21**
	CCF+ReA3	**20.5**		**33.5**

Expansion:
Stopped and reaccelerated beams

cryogenic linear gas stopper
cyclotron gas stopper
EBIT charge breeder
superconducting RF linear accelerator
(0.3-3.2 MeV/u, 12 MeV/u upgrade)
new experiment halls

increase in Operations staff by 60%