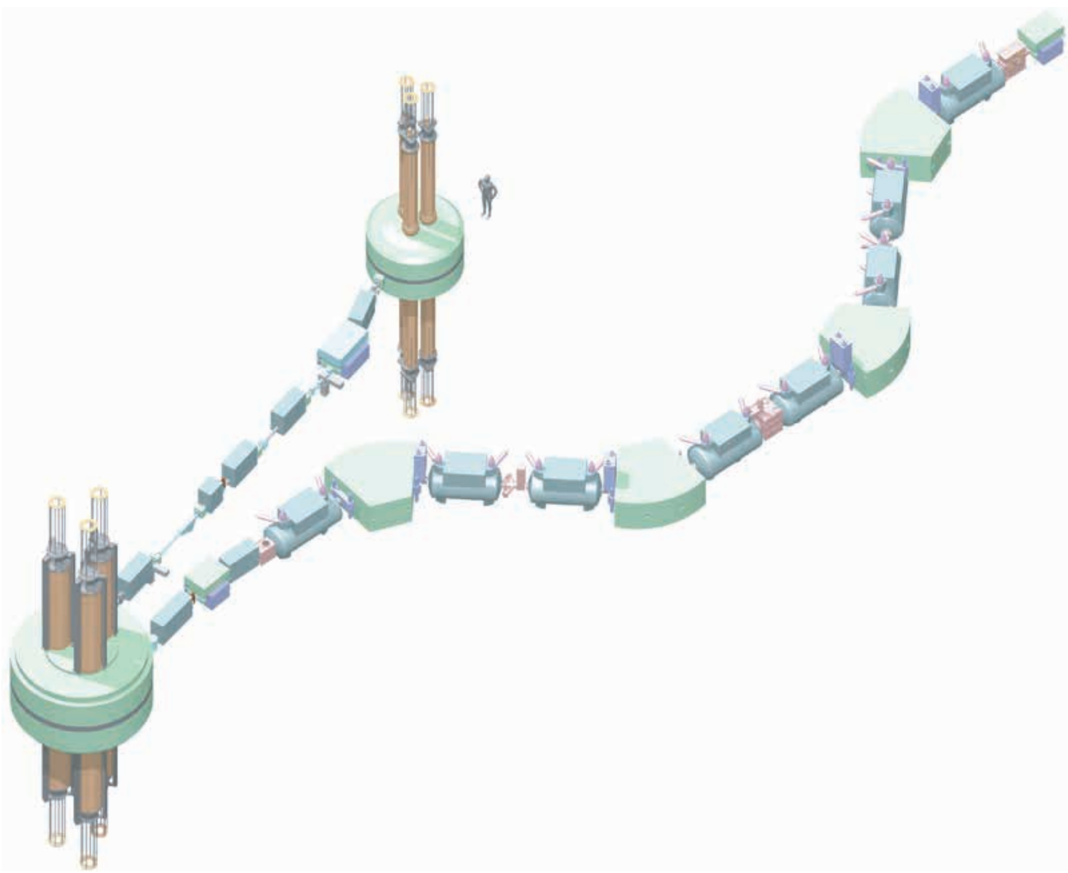
Operational Experiences with the A1900 Fragment Separator



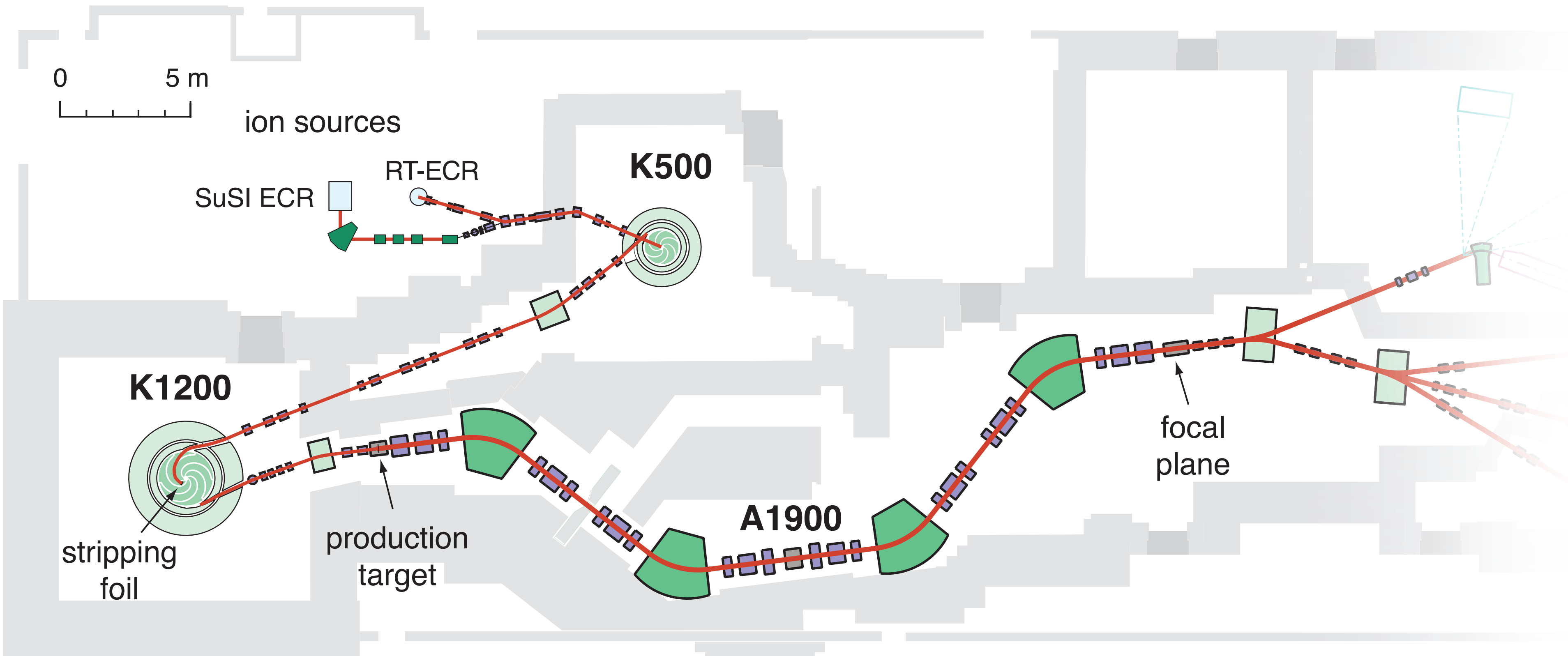
Andreas Stolz

NSCL / Michigan State University

Fragment Separator Expert Meeting

Grand Rapids, August 2016

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

power limit beam dump in first dipole: 4kW

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

Primary beam list intensities are based on operational experience and serve as planning basis for experiments.

Usually, beam intensities above these valuses are provided to experiment.

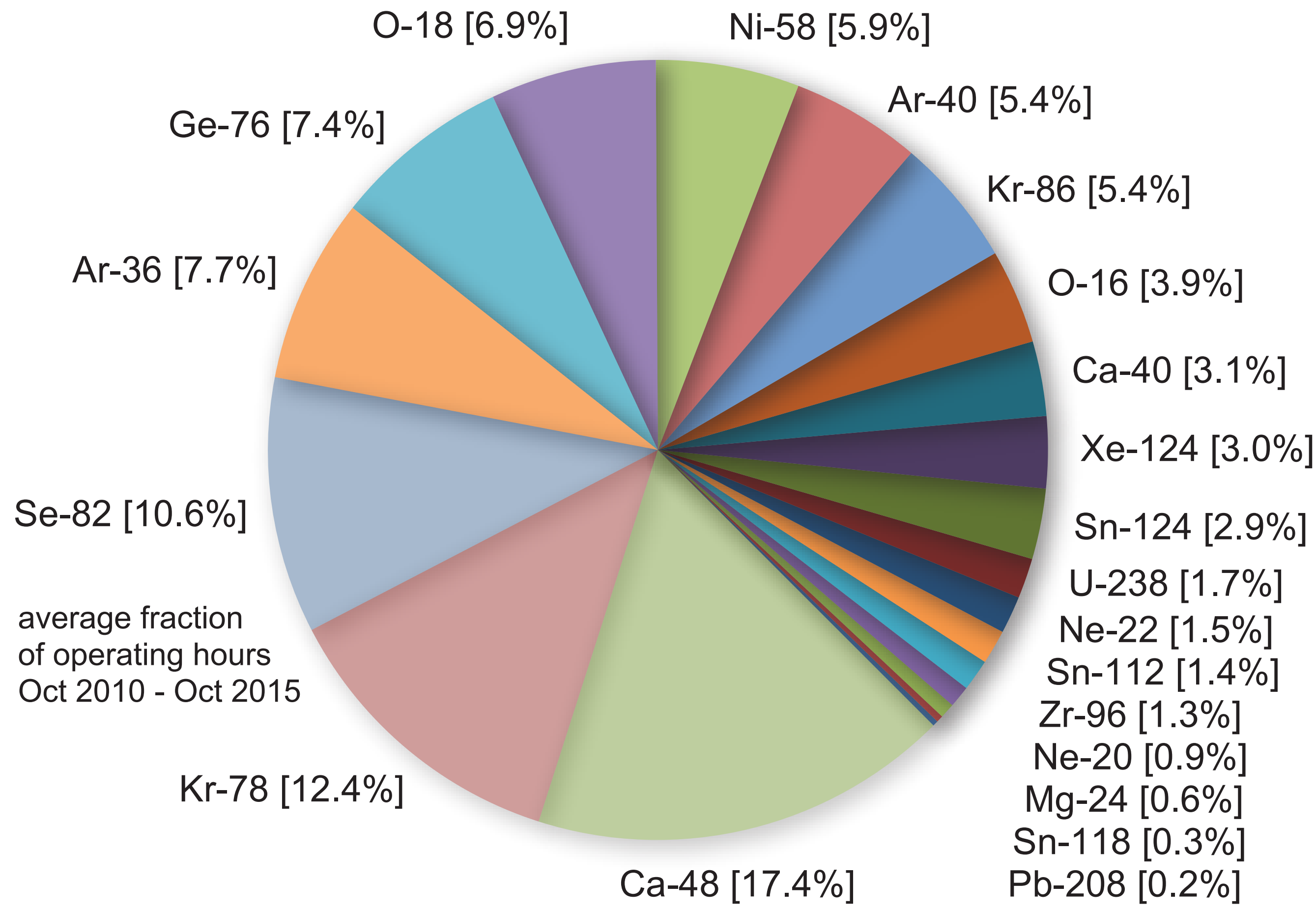
Beam power for Ca-48: 540 W

Primary Beam Statistics

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

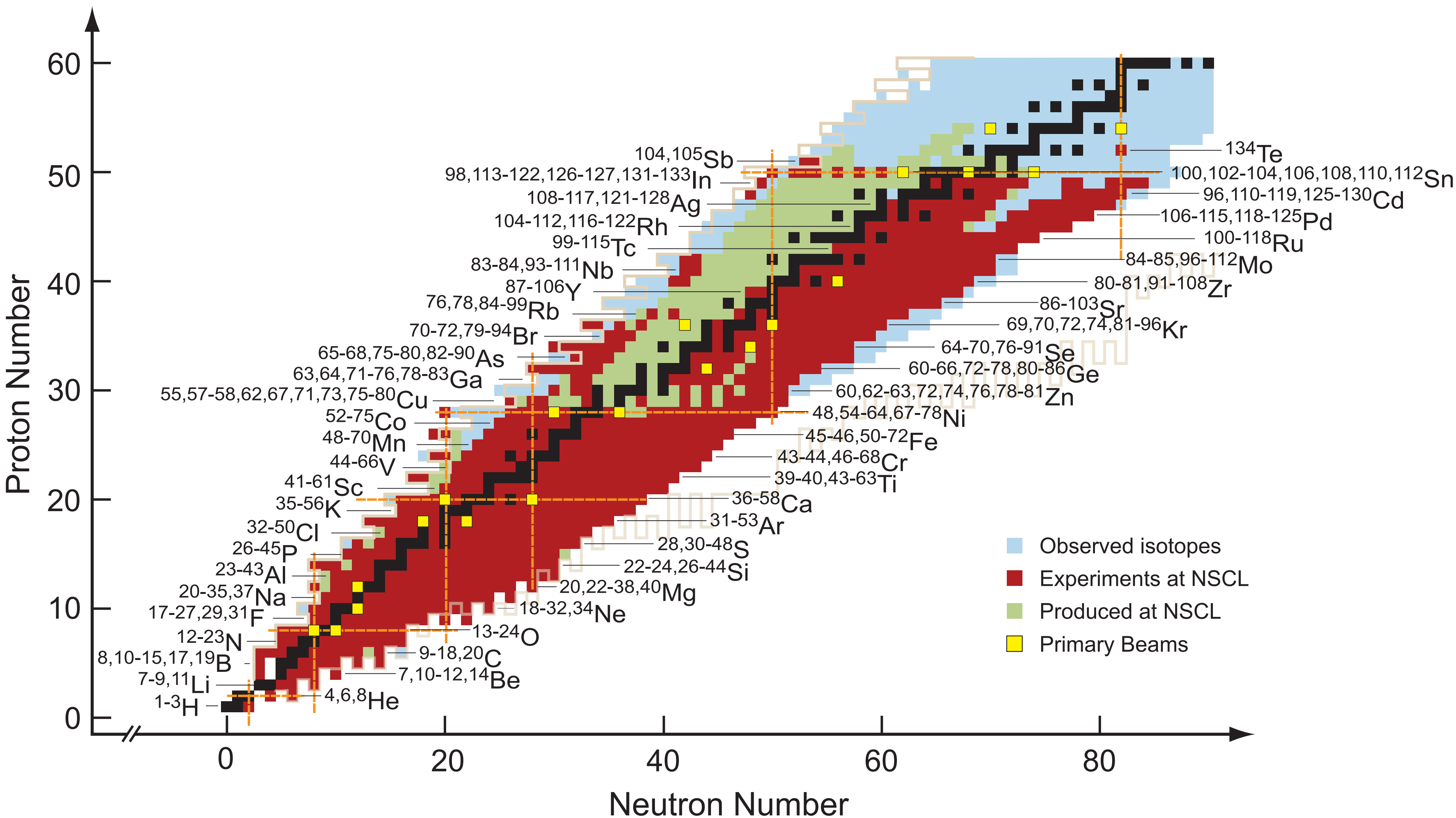
The development of new primary beams (isotope and energy) is driven by user demand.

CCF Primary Beam Isotope Statistics

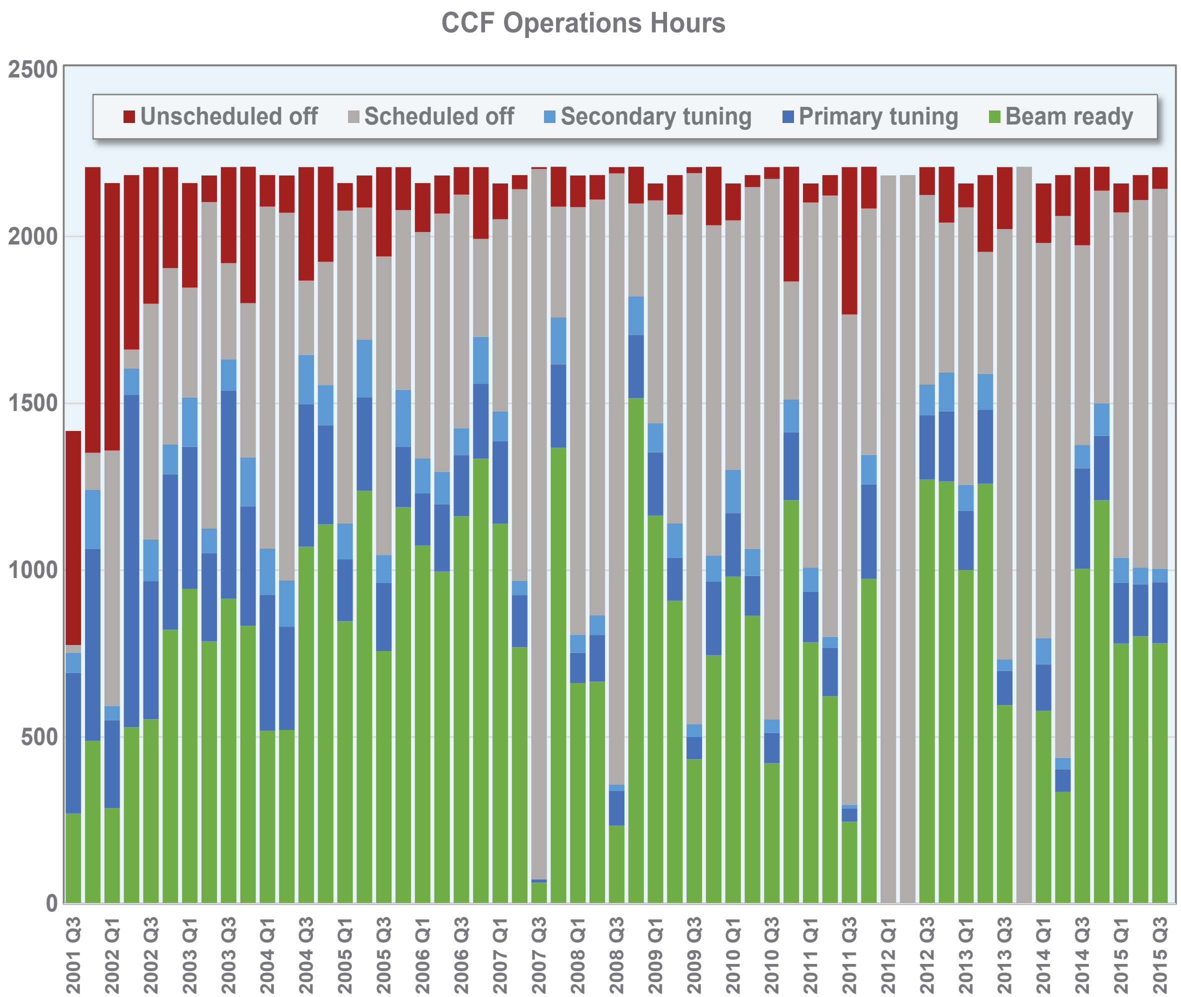


Rare Isotope Beams produced at NSCL

more than 1000 RIBs have been produced (2001-2016)
more than 900 have been used in experiments



CCF Operations Statistics



NSCL operations hours: typically: 4500 hours/year

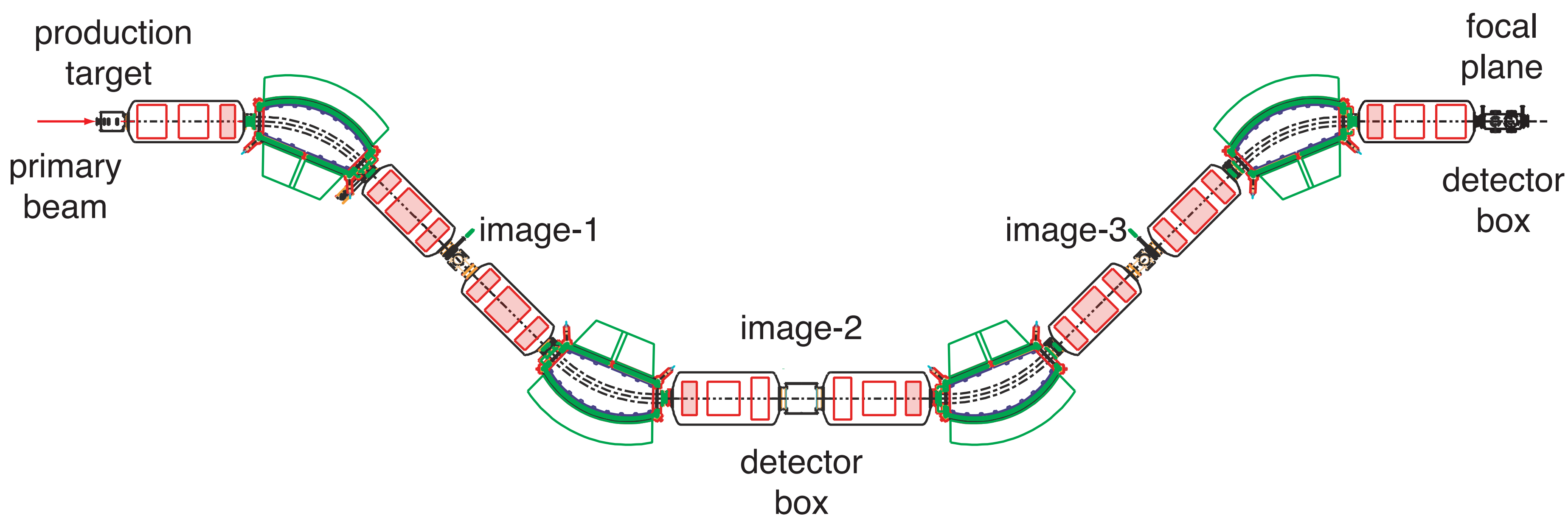
up to 6000 hours/year possible

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

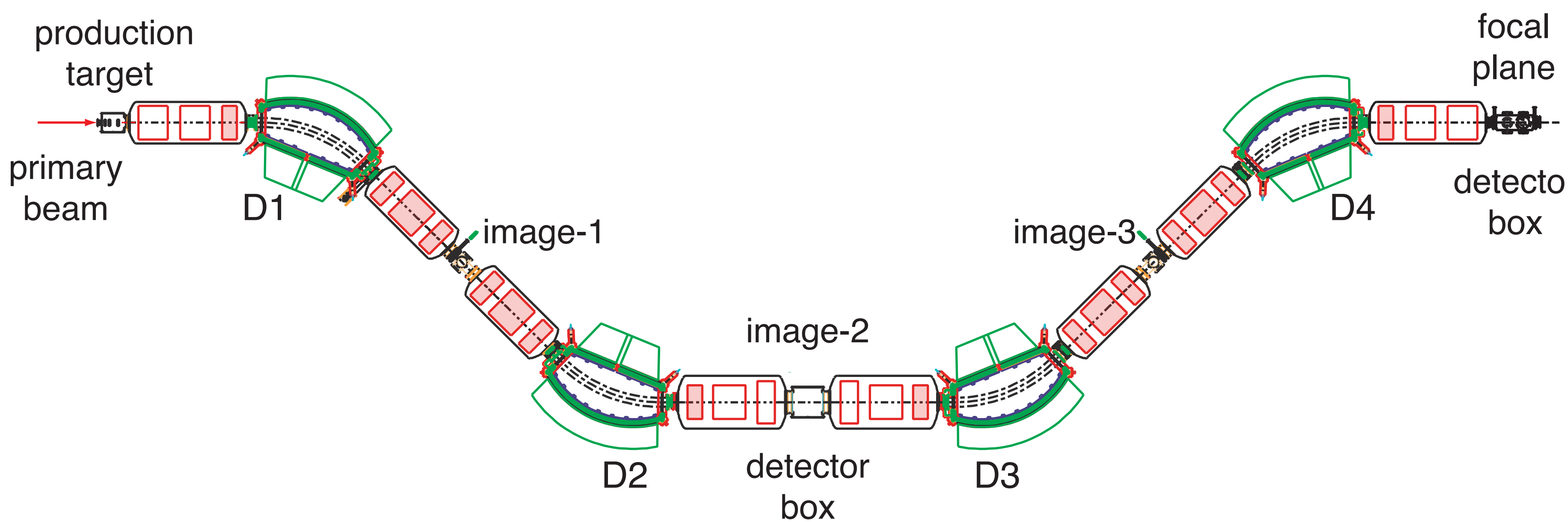
A1900 Fragment Separator



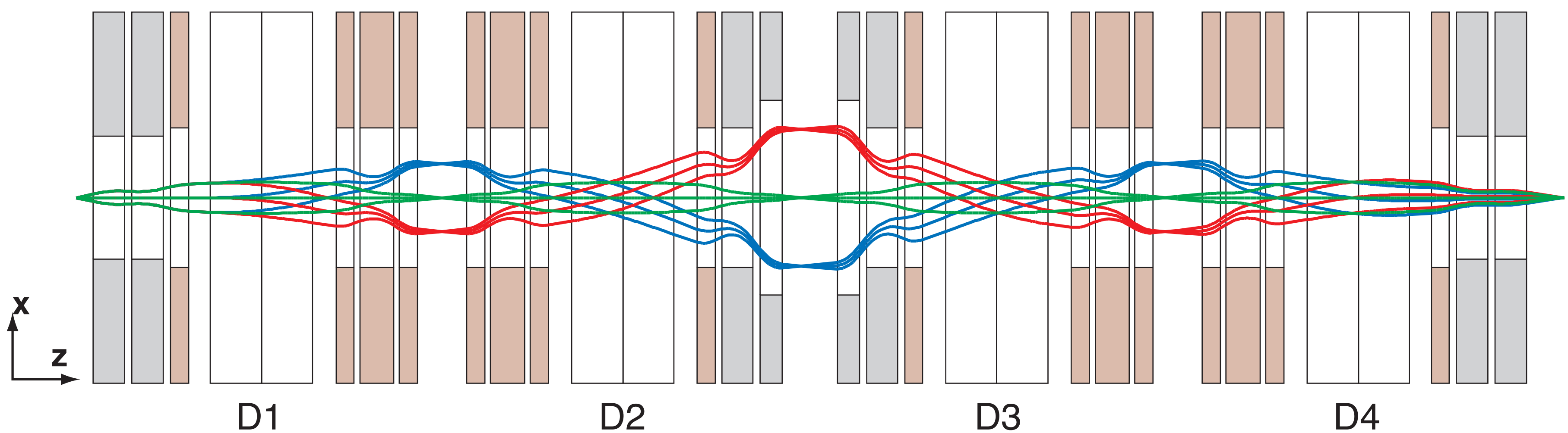
- superconducting magnets (NSCL design)
- four 45° dipoles
- 24 quadrupole magnets (5 different designs)
- 16 quadrupoles with hexapole and octupole coils
- high degree of symmetry to minimize aberrations

Parameter	**A1900**
moment. accept. $\Delta p/p$	5%
angle accept. [mrad]	60 x 40
$B\rho_{max}$ [Tm]	6
resolving power	~2900

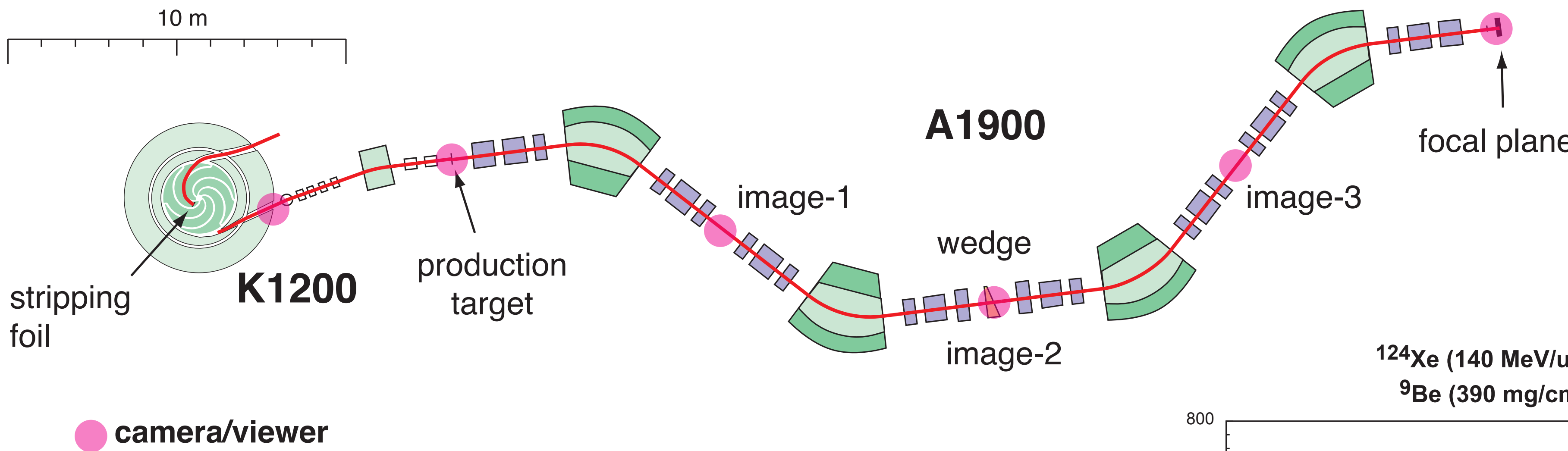
A1900 Fragment Separator Standard Ion Optics

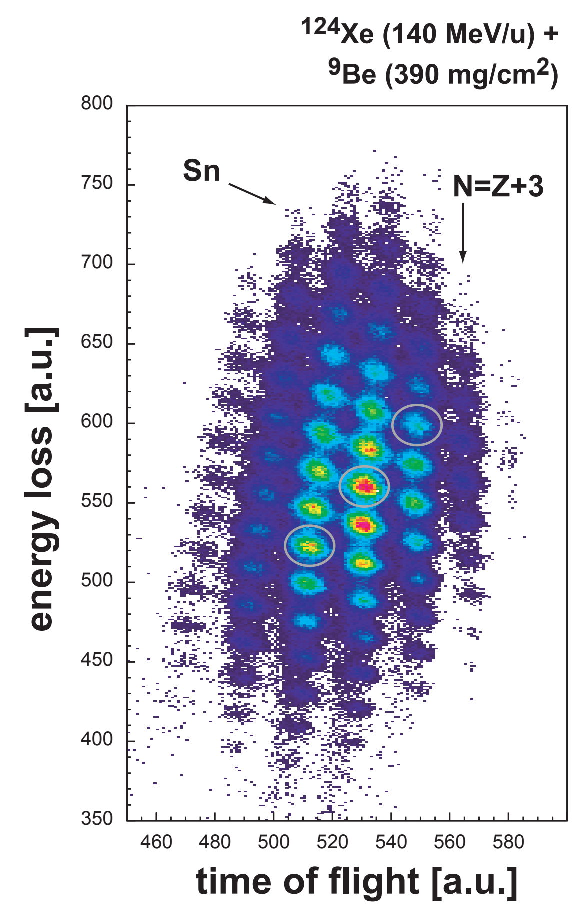


1st order calculation

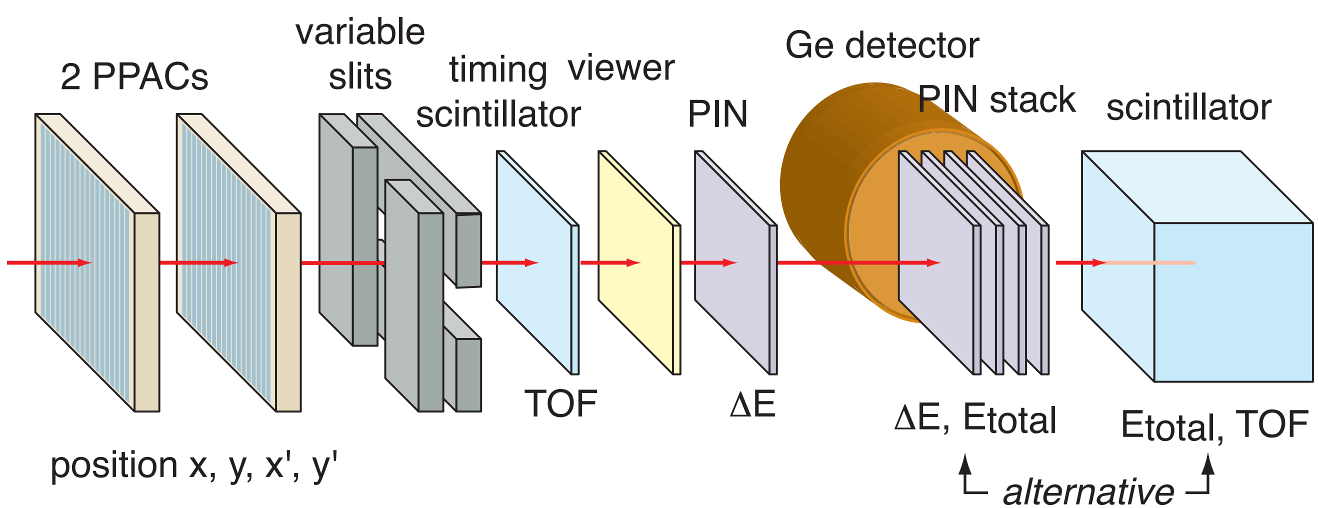


A1900 Diagnostics Setup and Particle Identification





Detector Setup in Focal Plane Box



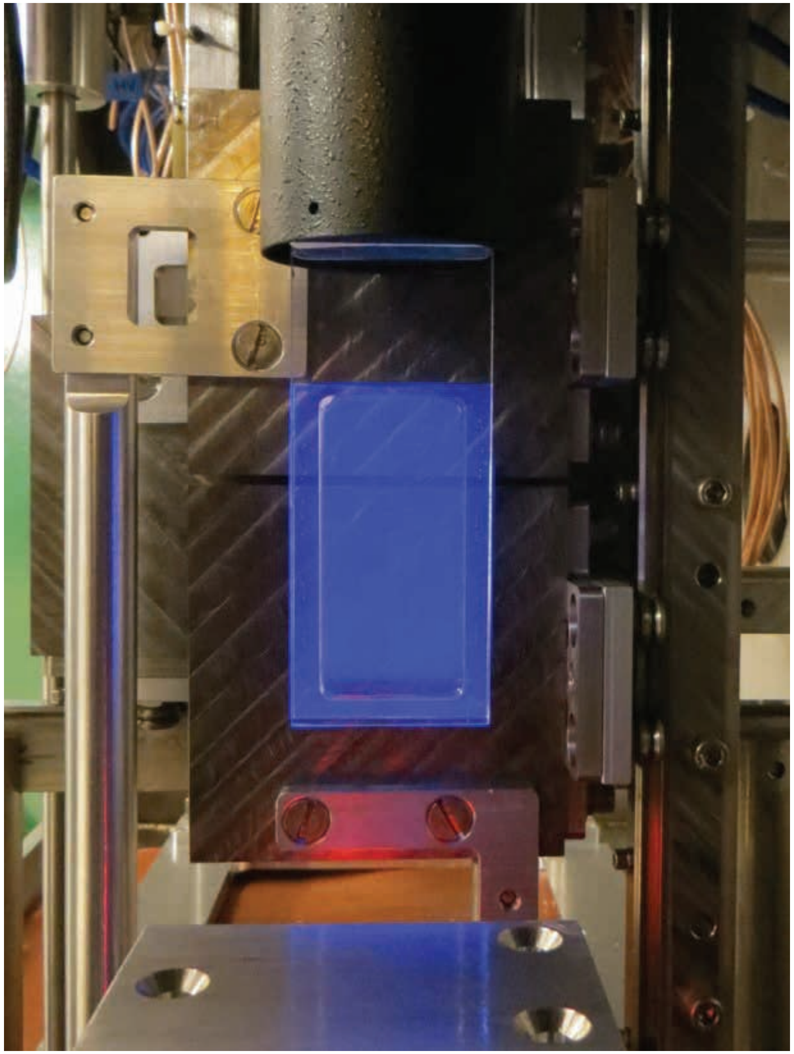
A1900 timing scintillator

Thin timing scintillators (BC-400) that are used throughout beam delivery have a limited life time. Material degradation affects timing resolution and detection efficiency.

Life time depends on particle and beam intensity. For higher Z and high intensities useful life can be less than 24 h.

A 2-position pneumatic drive was replaced with linear stepper motor drive:

Up to 10 pre-programmed positions can be used, enabling the switch to a fresh detector position with virtually no down time.



Irradiation of Diamond with Heavy Ions at NSCL

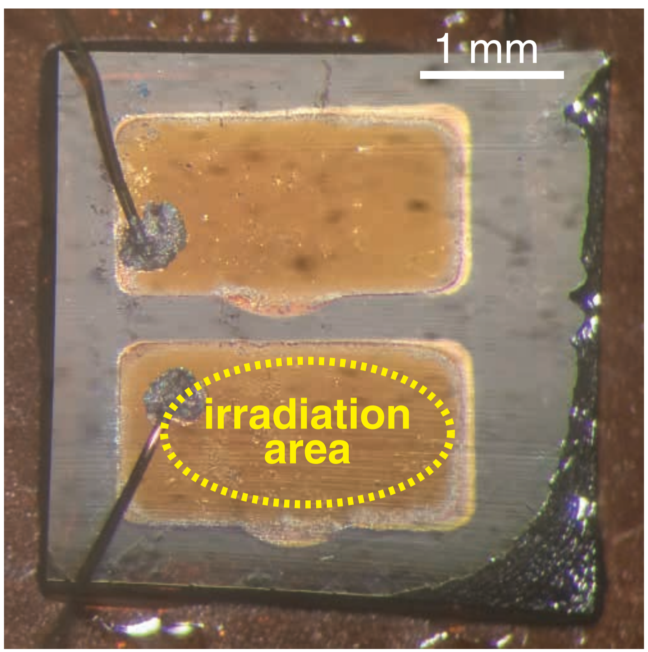
MSU-grown single-crystal diamond

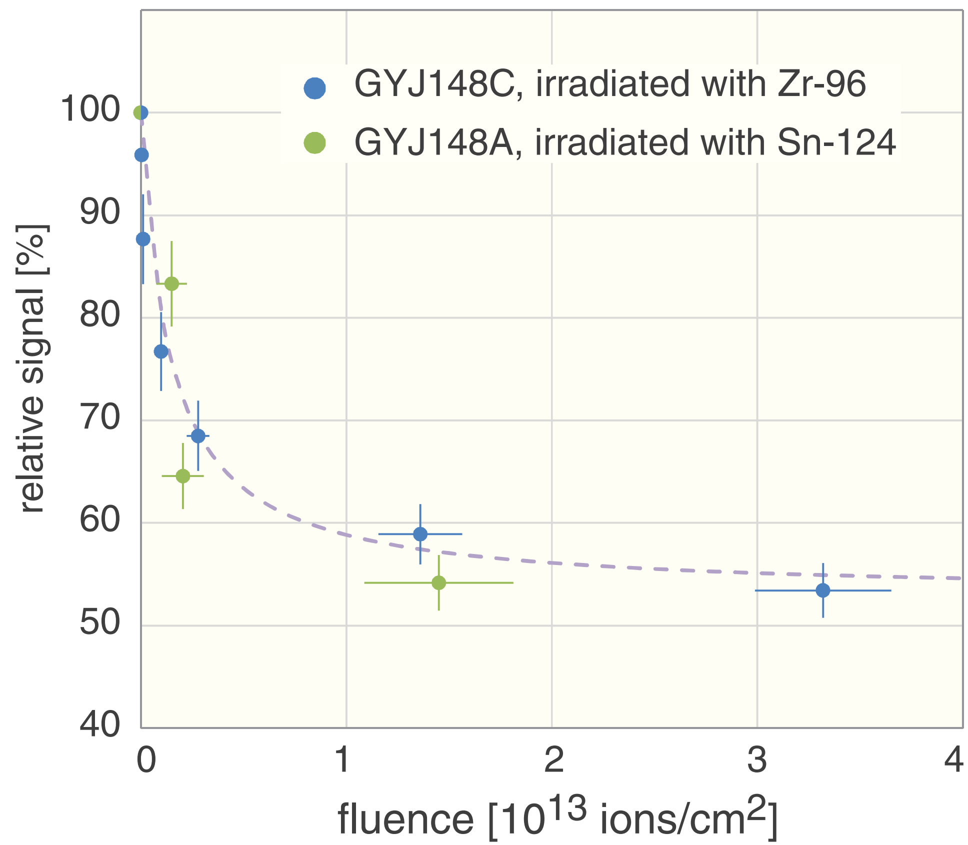
sample size: ~ 4 mm x 4 mm

irradiation area: ~ 2 mm x 1 mm

2-fold segmented electrodes allows for non-irradiated reference sample area

irradiated with ^{96}Zr and ^{124}Sn @ 120 MeV/u





$3 \cdot 10^{13}$ ions/cm^2 = 1 MHz/cm^2 for 1 year

Irradiation of Diamond with Heavy Ions at NSCL

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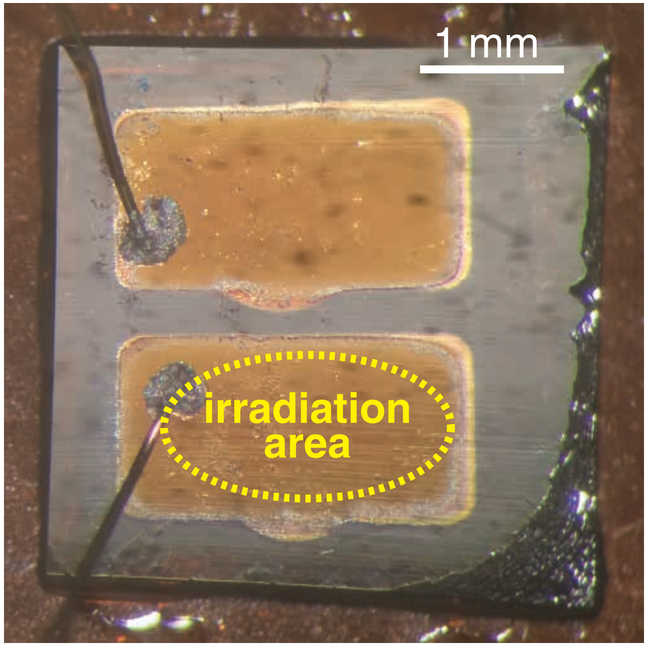
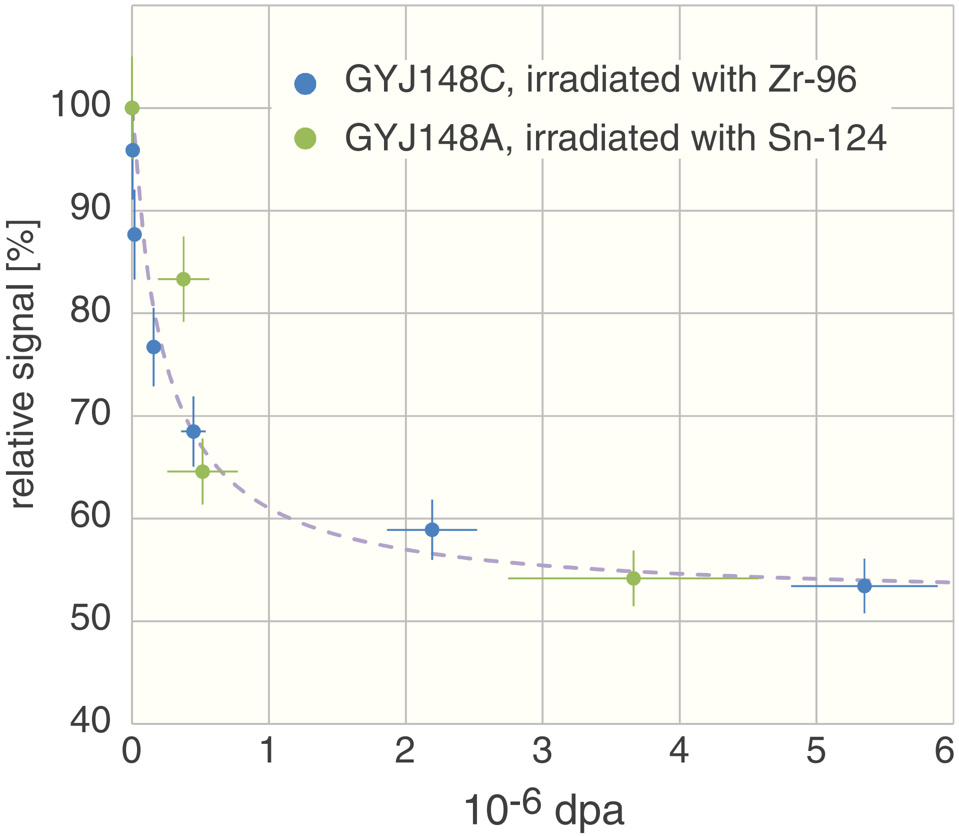


Damage calculation with SRIM



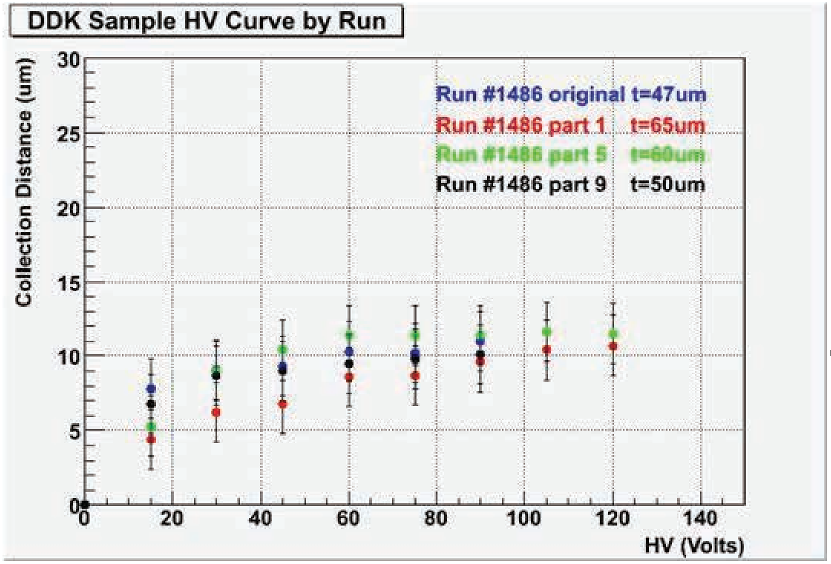
10^{12} Zr-ions/cm^2 = 1.6 · 10^{-7} dpa

10^{12} Sn-ions/cm^2 = 2.5 · 10^{-7} dpa

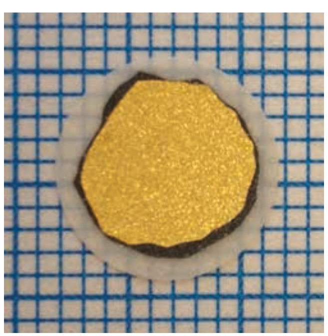
dpa = displacements per atom

Thin Diamond Detectors

Collaboration with Applied Diamonds (Wilmington, DE, USA) and Ohio State University (H. Kagan)

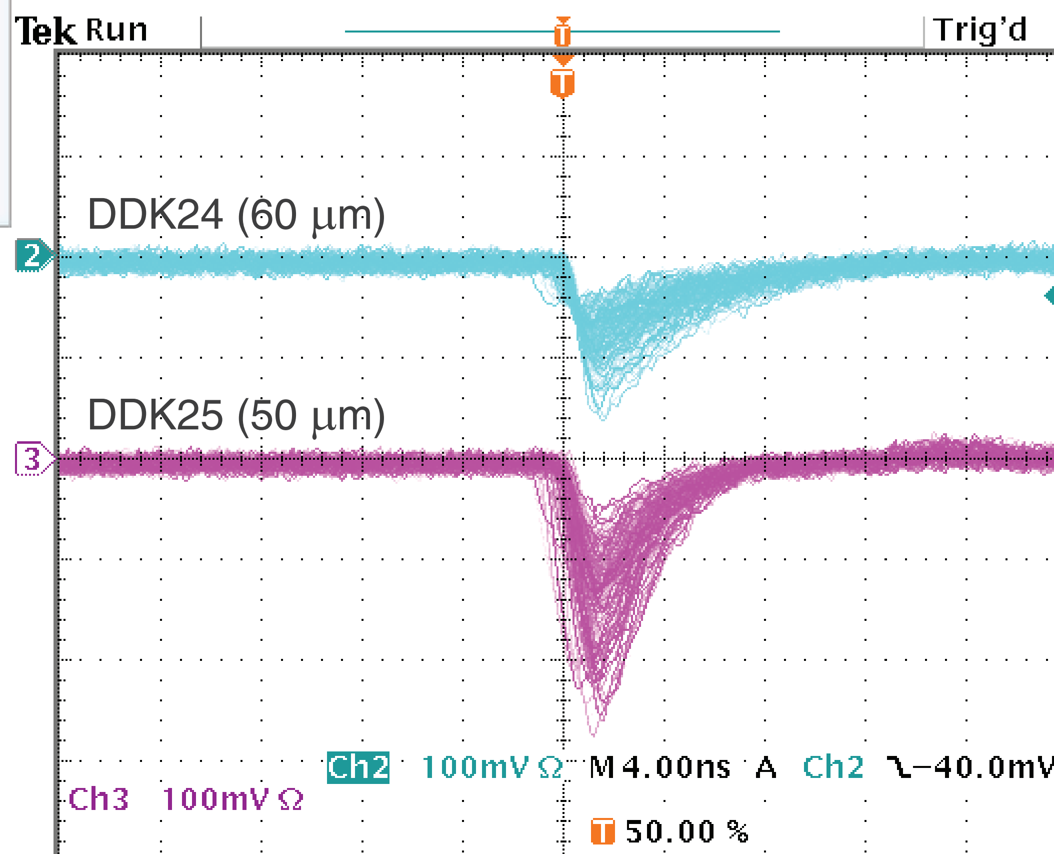


Free-standing polycrystalline diamond
with thicknesses between 30 - 60 μm
grown by Applied Diamond, Inc.



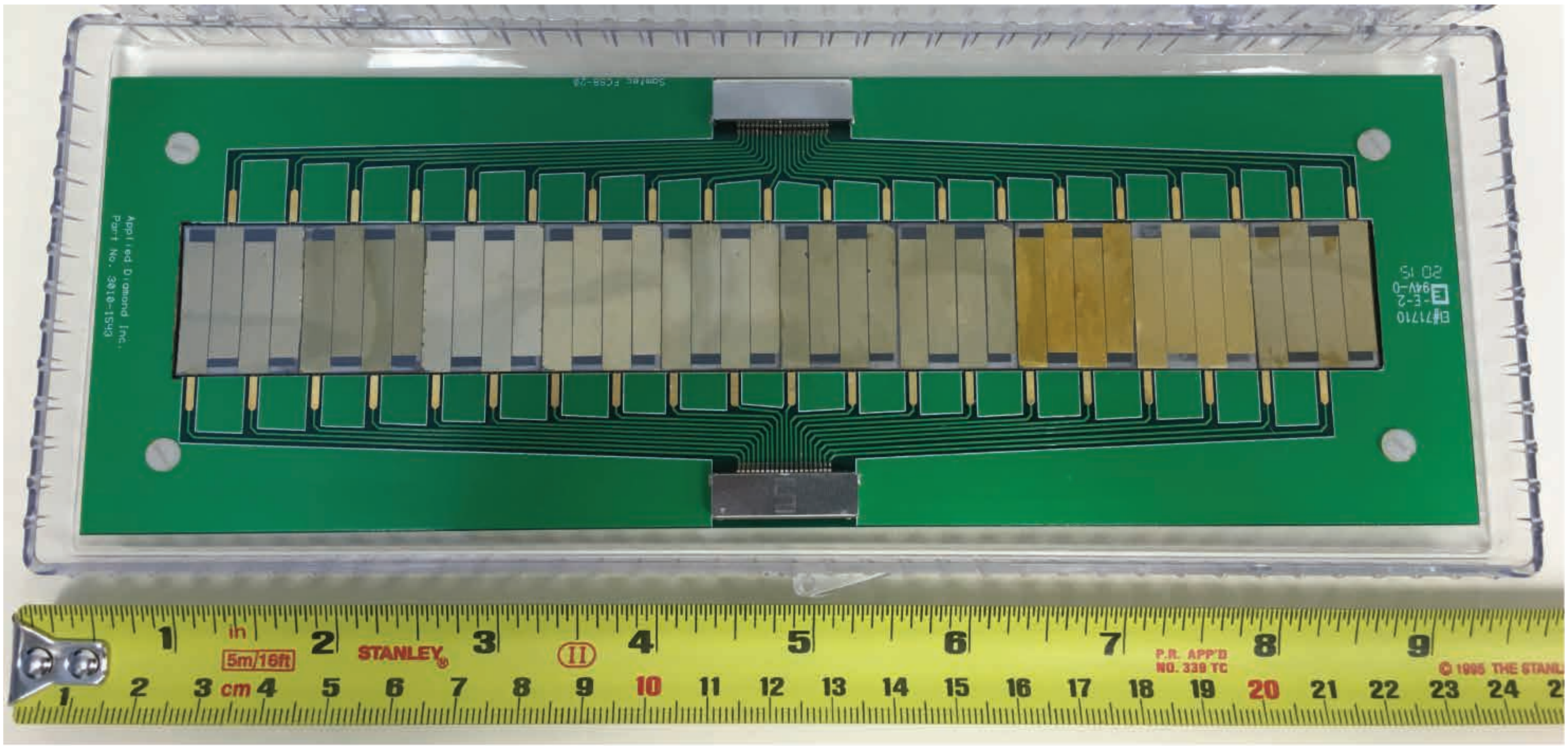
Test Sample Size:
10 mm diameter

Beam test with ^{40}Ca, 140 MeV/u with two detectors in transmission mount



Thin Diamond Tracking Detector Prototype

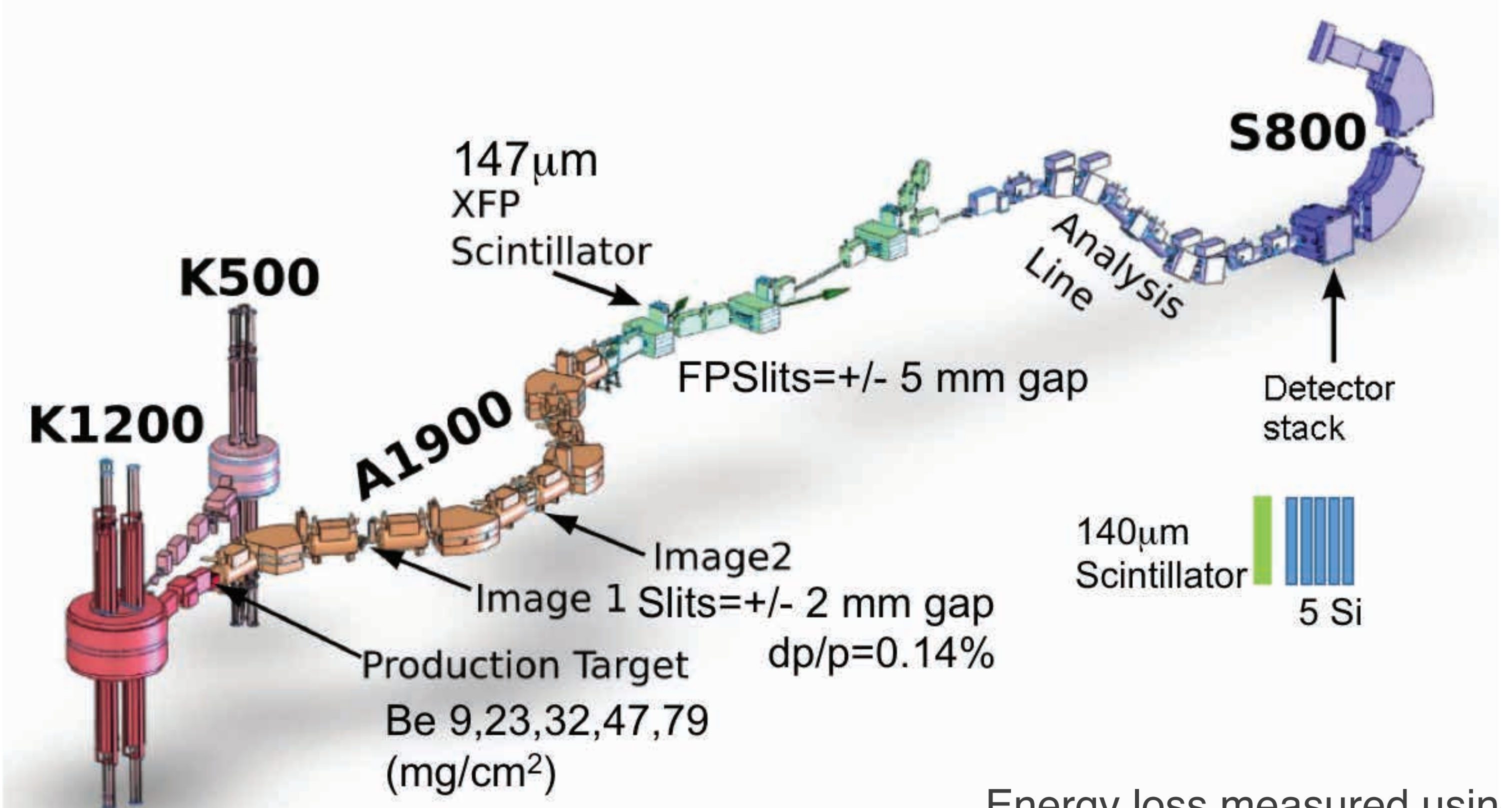
Collaboration with Applied Diamonds (Wilmington, DE, USA)



Active area: 200 mm x 20 mm
Thickness: 50 μm
Segmentation: 40 strips

Fragmentation of U-238 at 80 MeV/u

Primary Goal: Produce and identify fragmentation products around Z~92



Energy loss measured using Si stack detectors range of products near U ~ 1000 μm

Experiment ran June14-17, 2016
Target scan done at two production settings:
$B\rho$ = 3.1853&3.1748 Tm before XFP scintillator
$B\rho$ = 3.0830 Tm after XFP scintillator

Stack 1: Ortec Si Surface barrier with cooling down to –4°C
305, 306, 997, 998, 2000 μm

TOF measured with RF frequency and between two ~140 um H2C10 scintillators

Stack 2: Micron Si PIN at room temperature
508, 509, 1036, 1000, 1000 μm

Fragmentation of U-238 at 80 MeV/u

New A1900 DAQ module test:

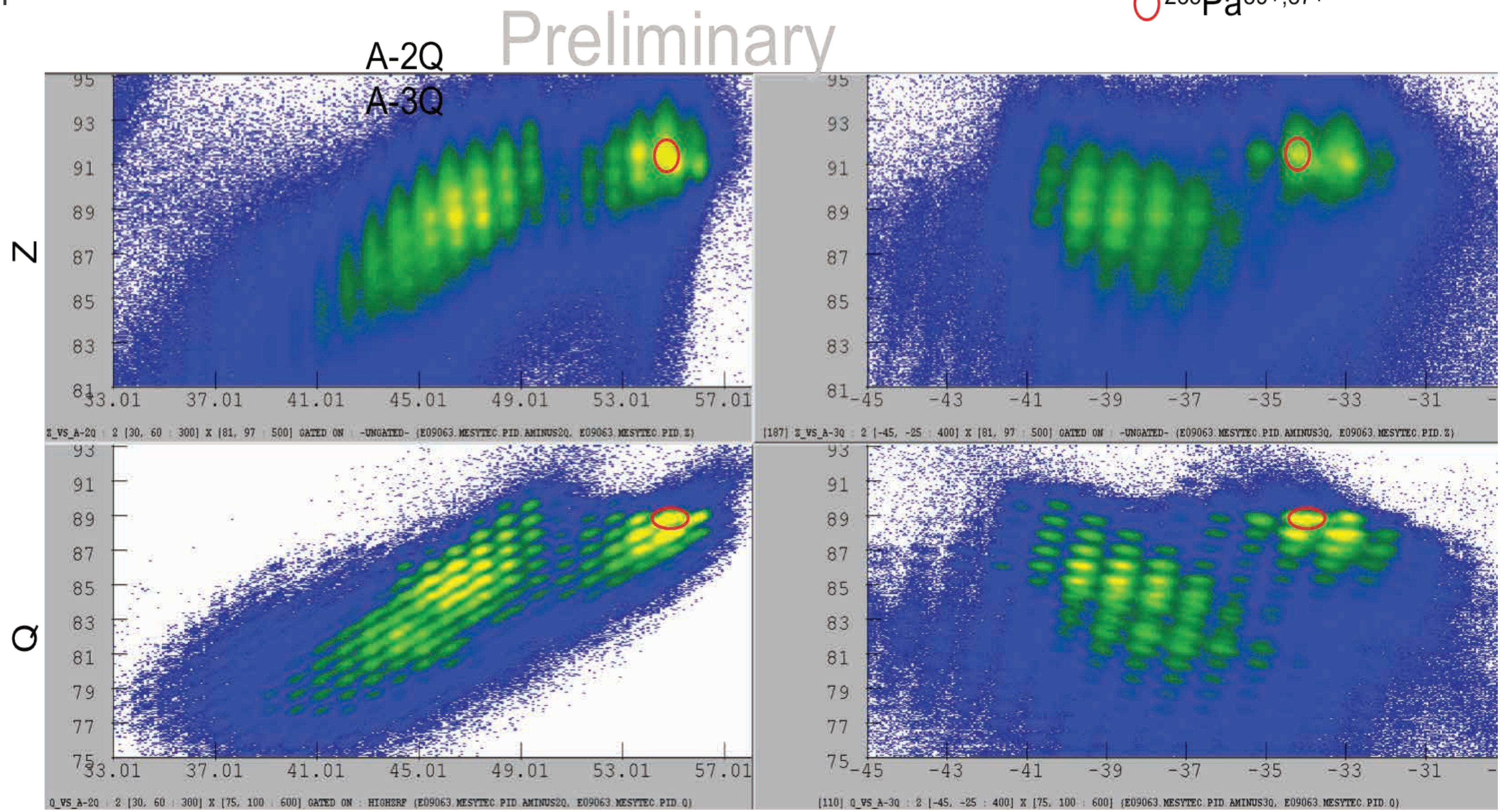
Mesytec MADC-32 & MTDC-32 modules allow up to 13 bit channel resolution

Micron Si PIN, Resolution of energy peak from primary beam FWHM~4.5-6.0% with no cooling

Fragments change charge state in 147 μm scintillator

dp/p=0.14% -- no tracking detectors

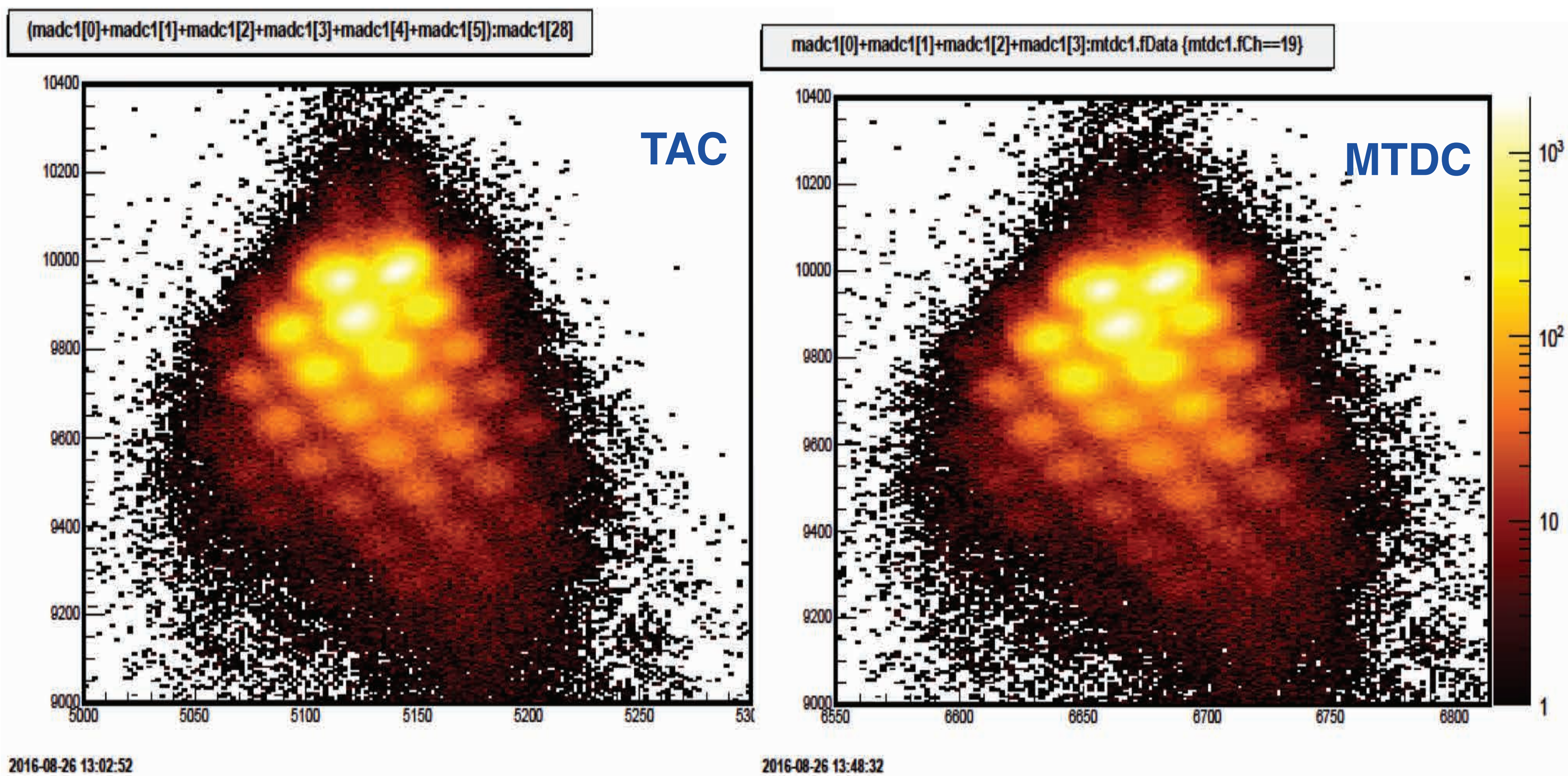
particle rate<1 kHz



Fragmentation of U-238 at 80 MeV/u

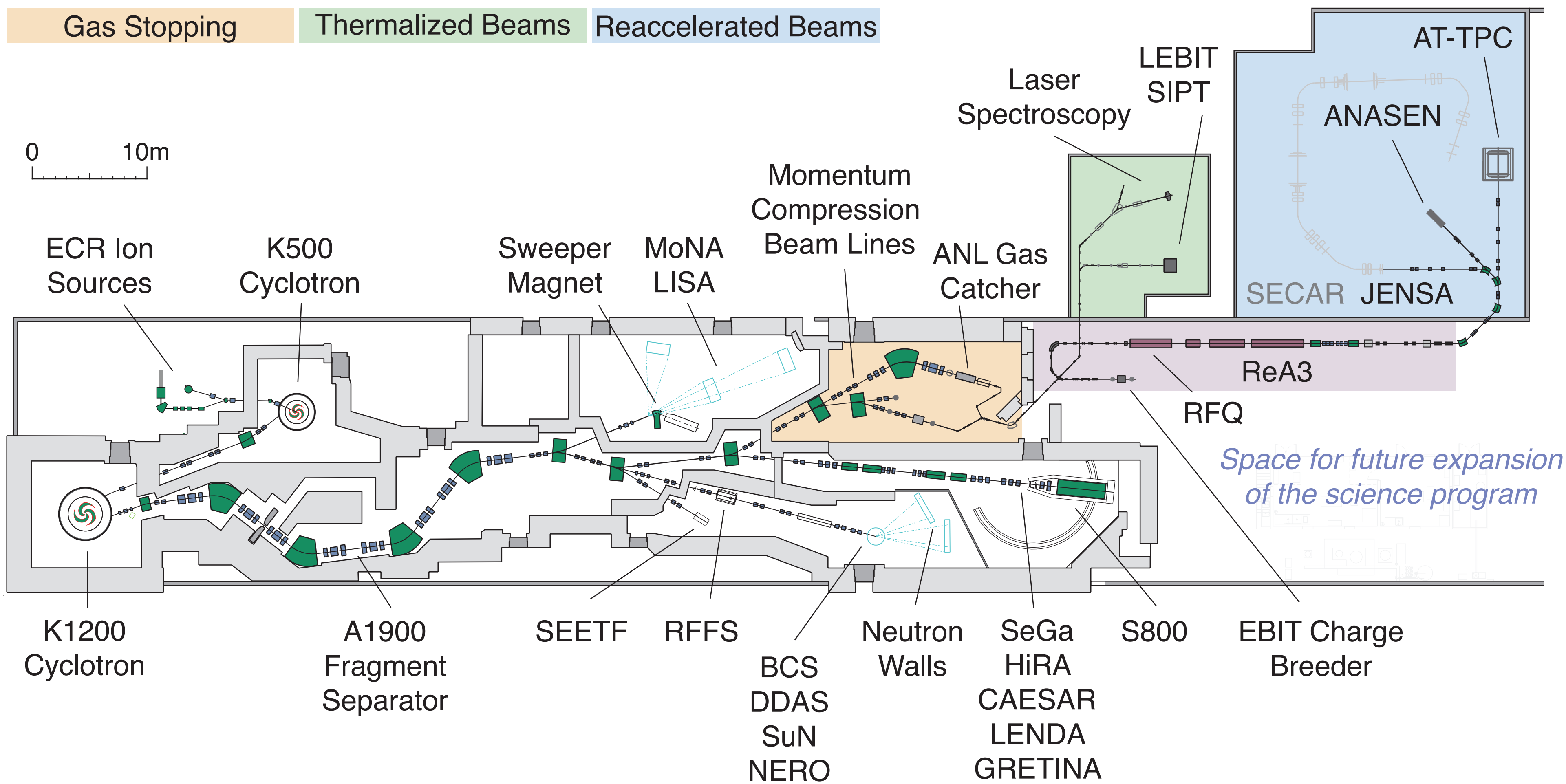
New A1900 DAQ module test:

The multihit Mesytec MTDC-32 has with adjustable time resolution from 3.9-500 ps.
The TKE vs TOF spectrum using data from the MTDC adjusted to a 62.5 ps resolution is as good as the one from a TAC with a range of 1000 ns.
Mesytec CFD-16 designed to provide fast timing with MTDC with remotely adjustable parameters. This module can provide an ECL & analog output directly to a TDC/QDC/ADC



NSCL's Experimental Facility Plan

NSCL is the only facility in the world that can provide fast, thermalized, and reaccelerated beams of rare isotope.

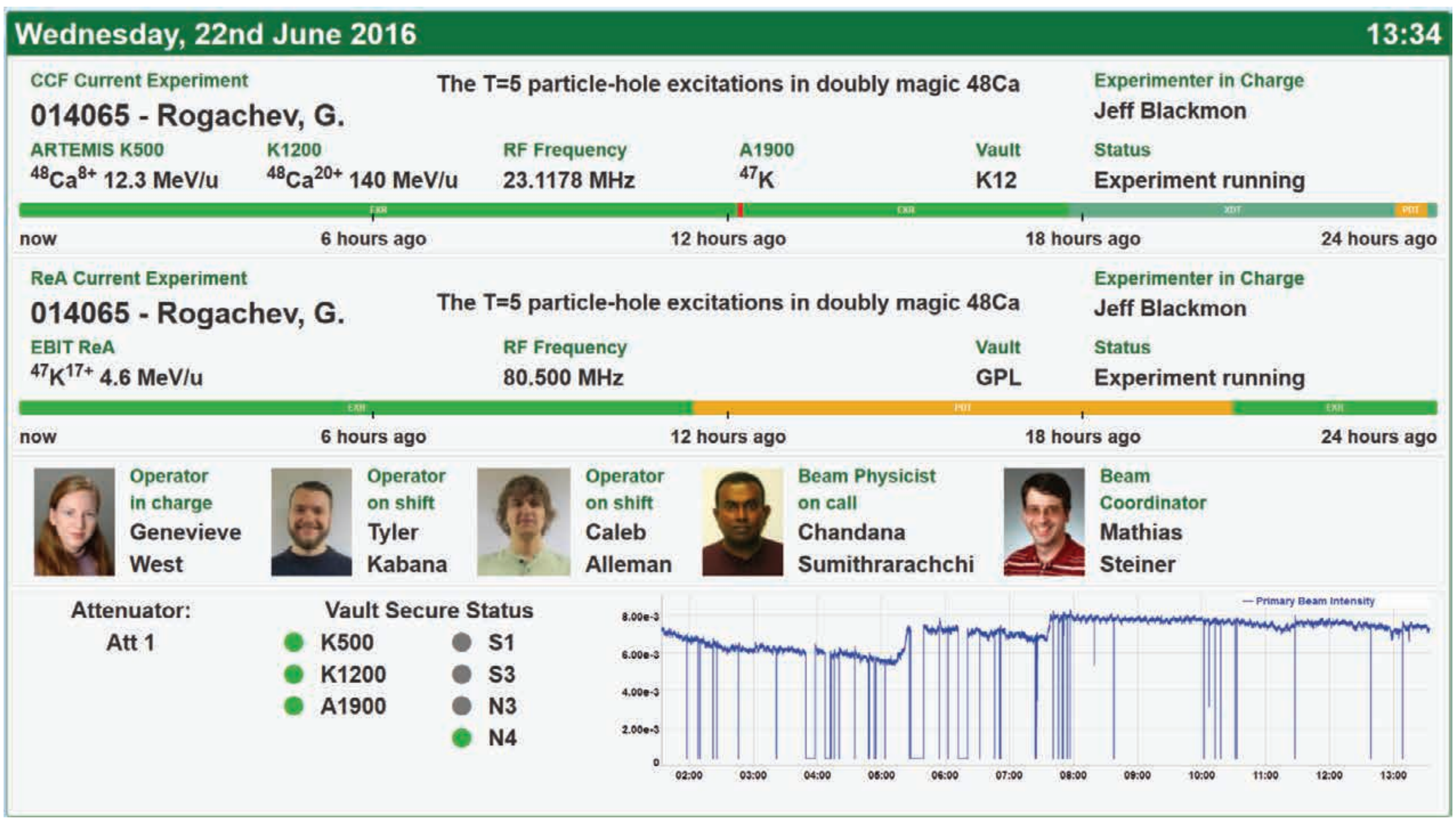


Scheduled Operation with Two Accelerators in FY16

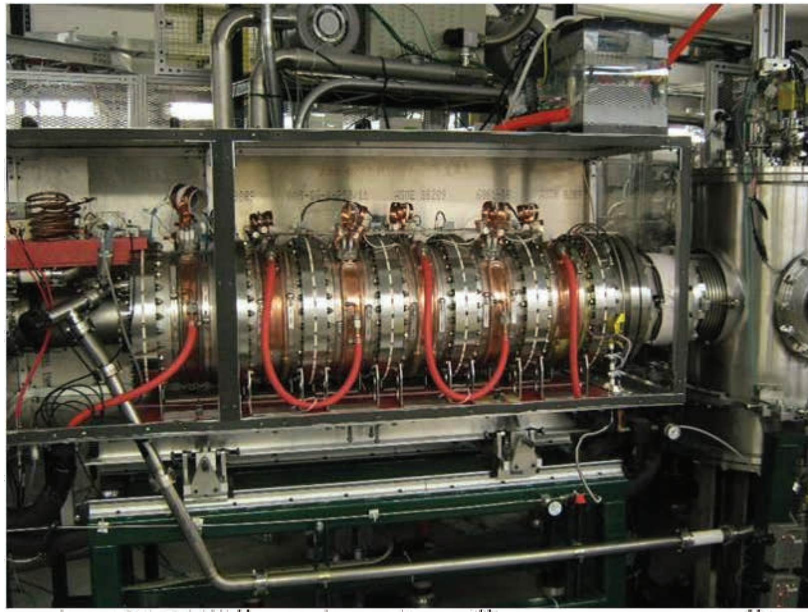
In FY16 (10/01/2015-07/23/2016) the NSCL carried out a user program with scheduled operations of CCF and ReA3 for the first time.

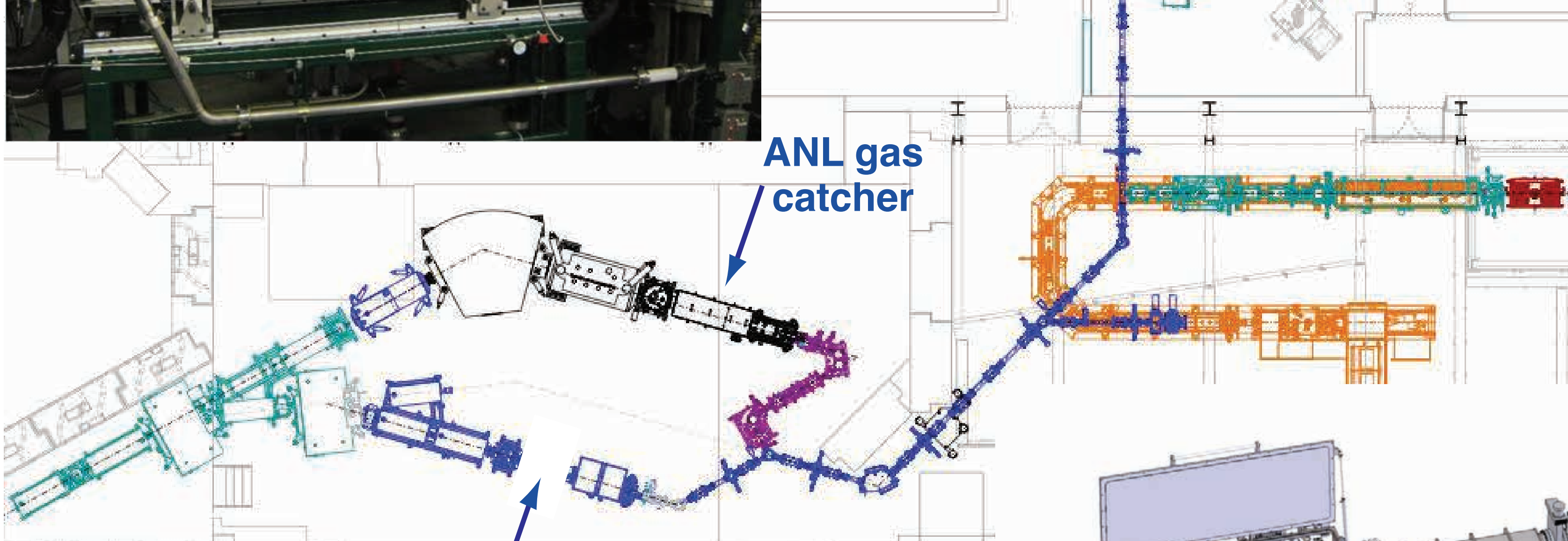
Total Operating Hours: 4727 hours

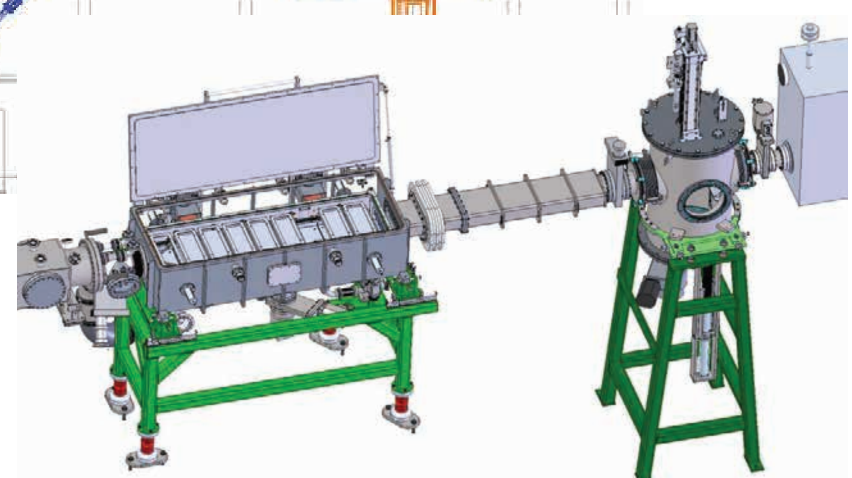
3900 hrs beam delivery to 23 PAC approved experiments:
15 CCF RIB experiments (11 with GRETINA)
3 stable beam experiments
5 CCF-ReA3 coupled RIB experiments



Gas Thermalization



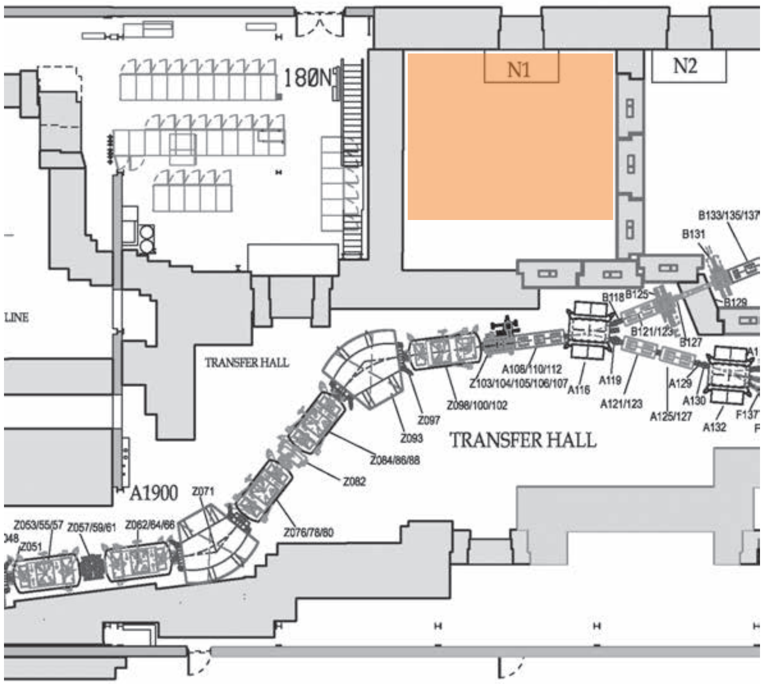


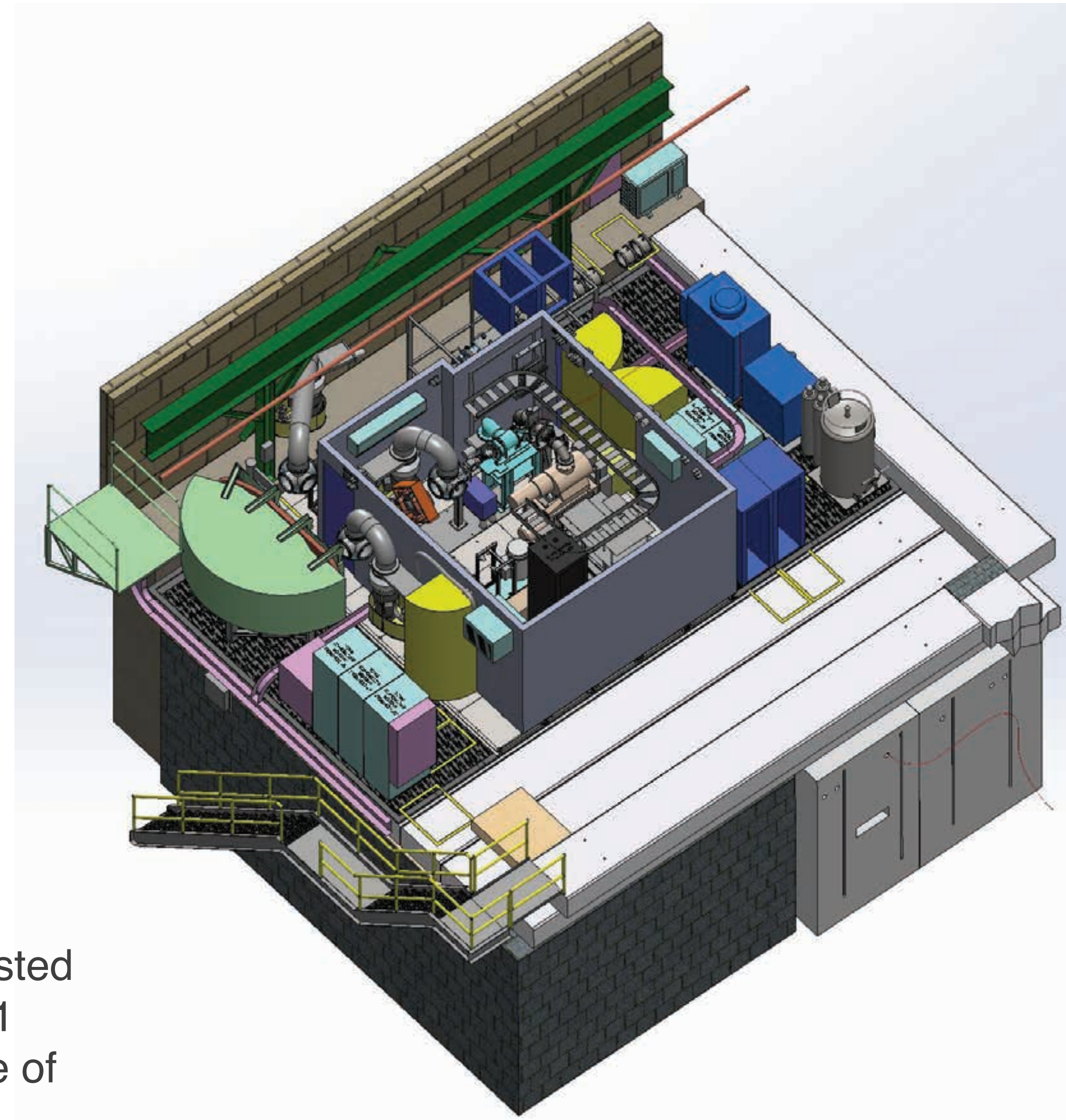


Advanced Cryogenic Gas Stopper is being fabricated for installation on a second line next to ANL gas catcher.

☞ **Thursday 9:00 (Sumithrarachchi)**

Helium Jet Ion Guide System



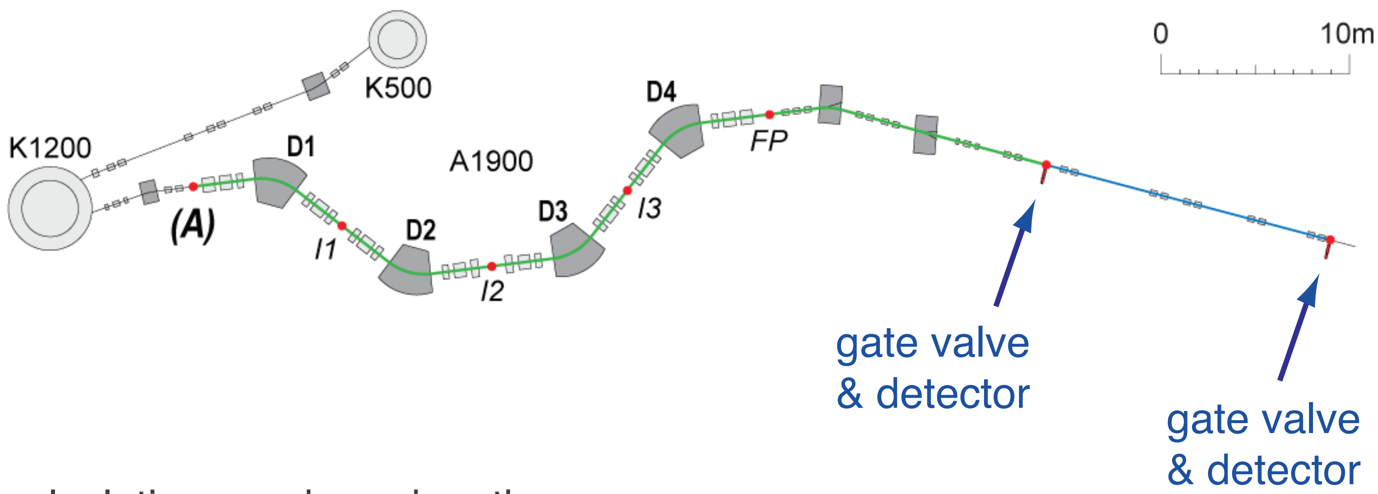


Helium-Jet Ion Source was constructed/tested at ORNL, now being installed on roof of N1 vault. Catcher cell will be at the focal plane of the A1900 fragment separator.

Thermalized ion will be transported using a wax aerosol in Helium gas through a thin capillary.

This system will allow for the harvesting of rare isotopes that would otherwise be lost on focal plane slits.

A1900 Rigidity Calibration



Old rigidity calculation was based on the assumption of a constant dipole radius.

This (obviously flawed) assumption lead to problems with energy loss and stopping range calculations for thermalized beam experiments.

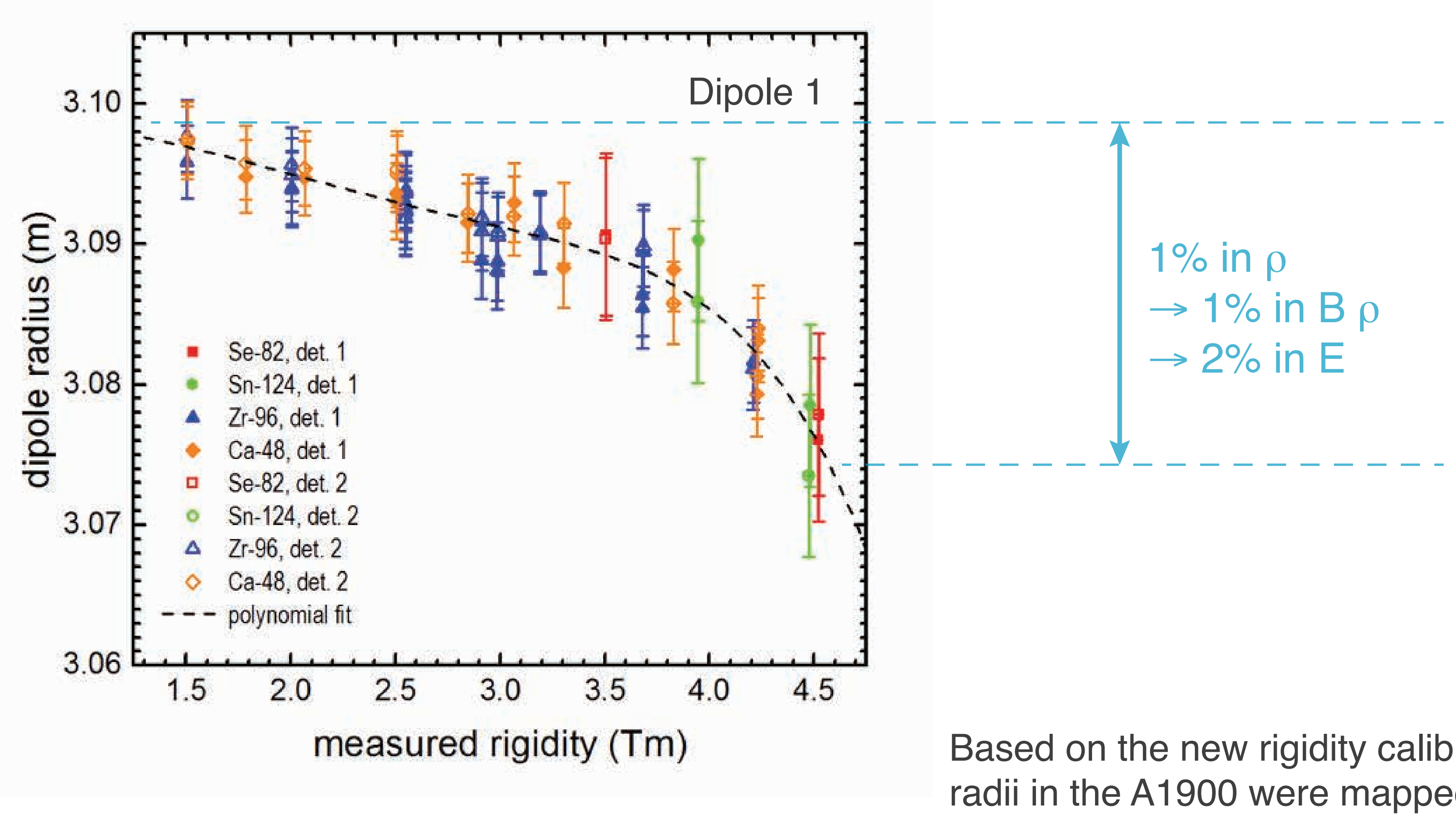
An absolute rigidity and energy calibration was performed using a time-of-flight (TOF) technique along a straight beam line section in the S2 vault.

Beam TOF was measured with a gamma detector placed at two different gate valves along beam line with RF as a reference.

A1900 rigidity now calibrated with accuracy of ±0.1%

☞ **Tuesday 11:30 (Ginter)**

A1900 Rigidity Calibration



Based on the new rigidity calibration dipole radii in the A1900 were mapped as a function of rigidity.

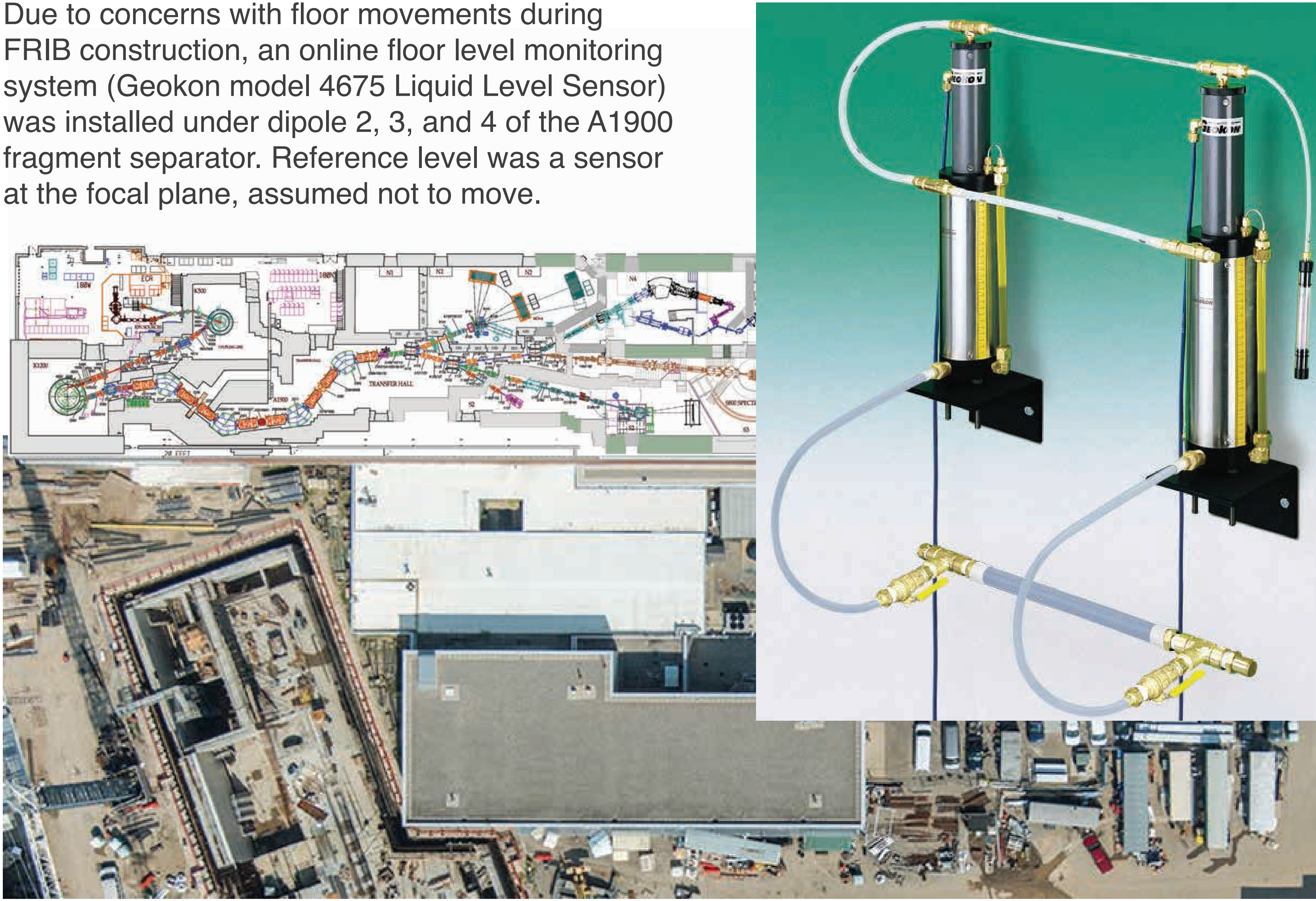
Different degraded primary beams were used over a range between 1.5 and 4.5 Tm.

☞ **Tuesday 11:30 (Ginter)**

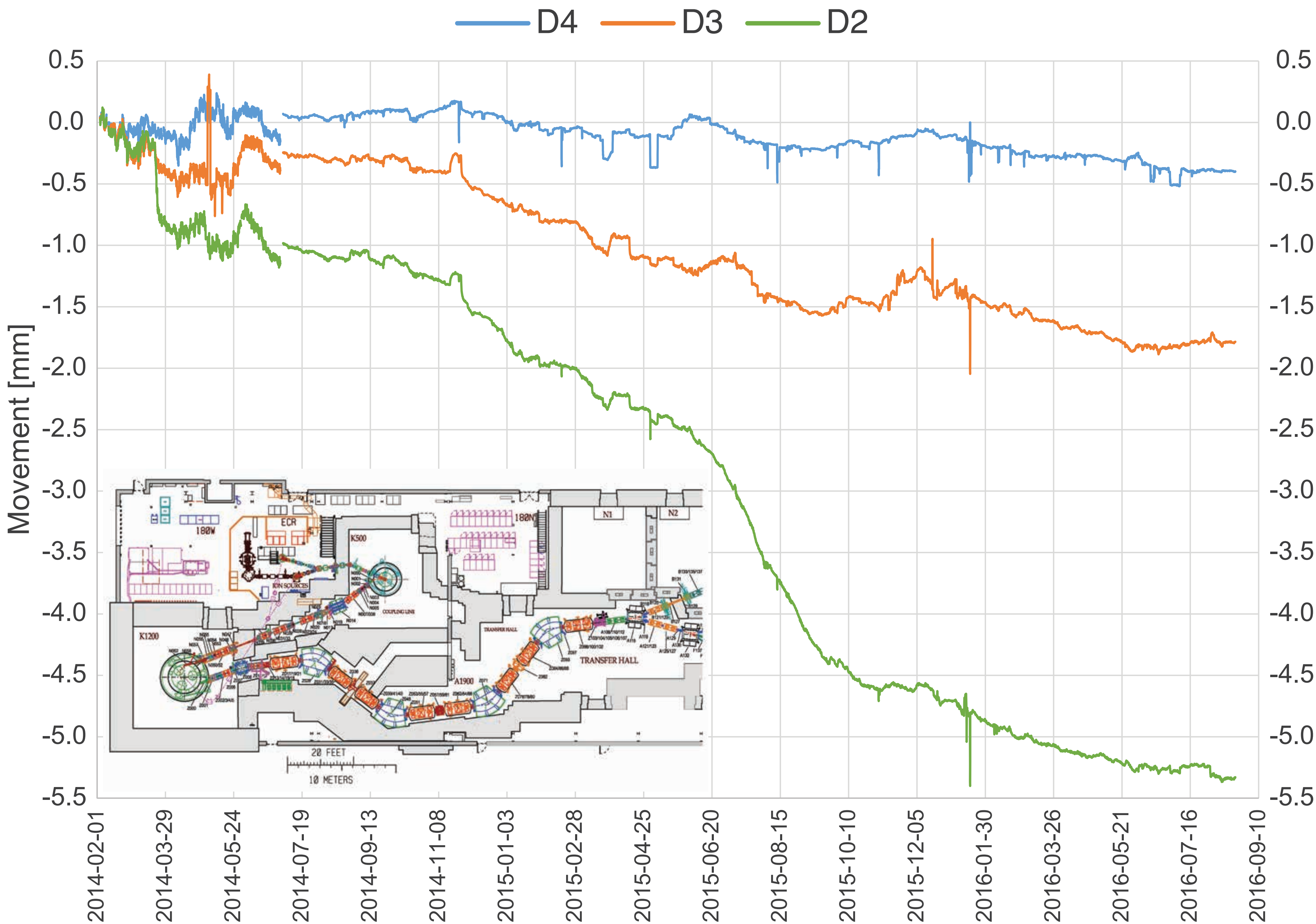
NSCL

FRIB Construction and Alignment of the A1900

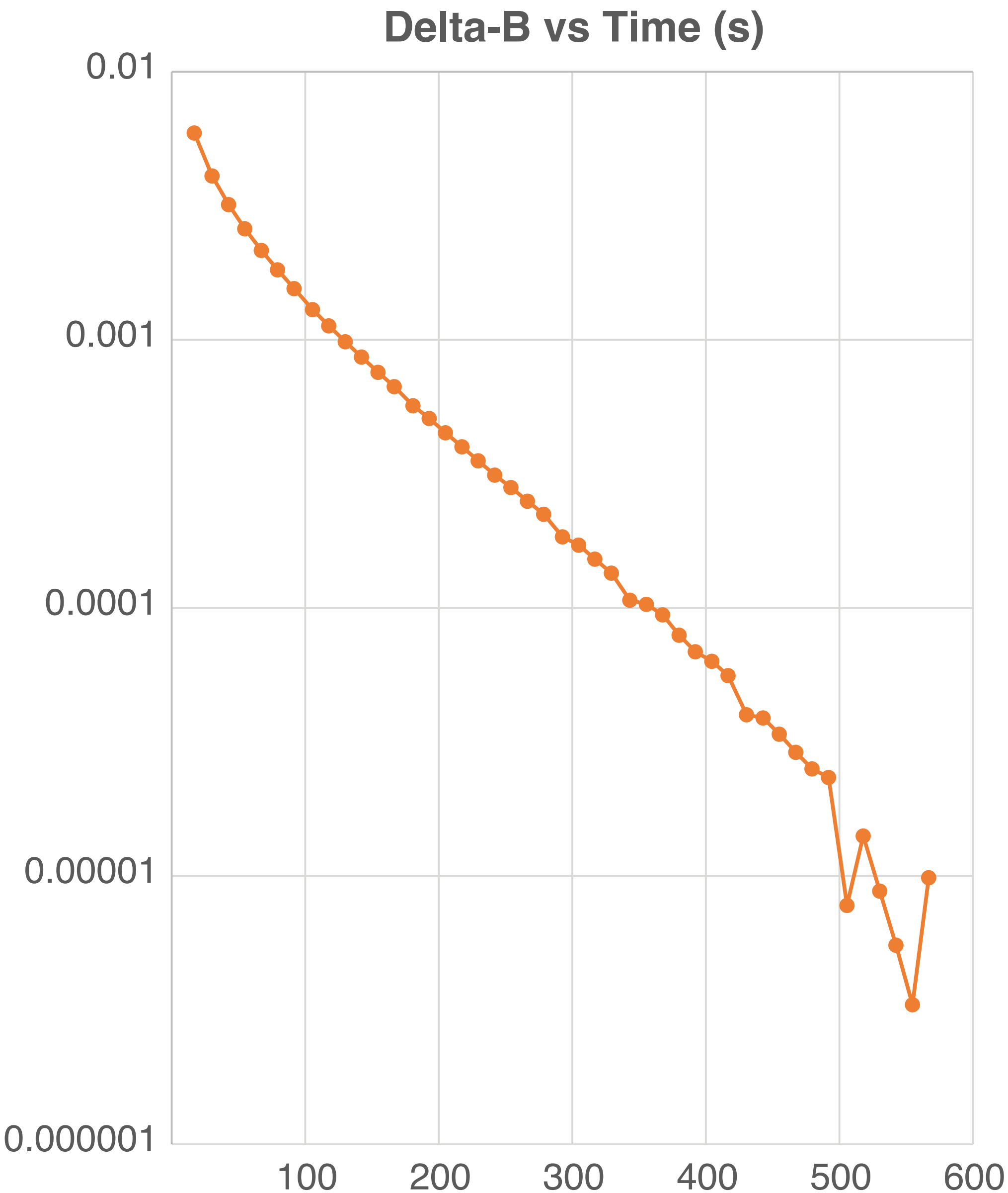
Due to concerns with floor movements during FRIB construction, an online floor level monitoring system (Geokon model 4675 Liquid Level Sensor) was installed under dipole 2, 3, and 4 of the A1900 fragment separator. Reference level was a sensor at the focal plane, assumed not to move.



FRIB Construction and Alignment of the A1900



Automated A1900 Dipole Matching



Dipoles have a long field settling time

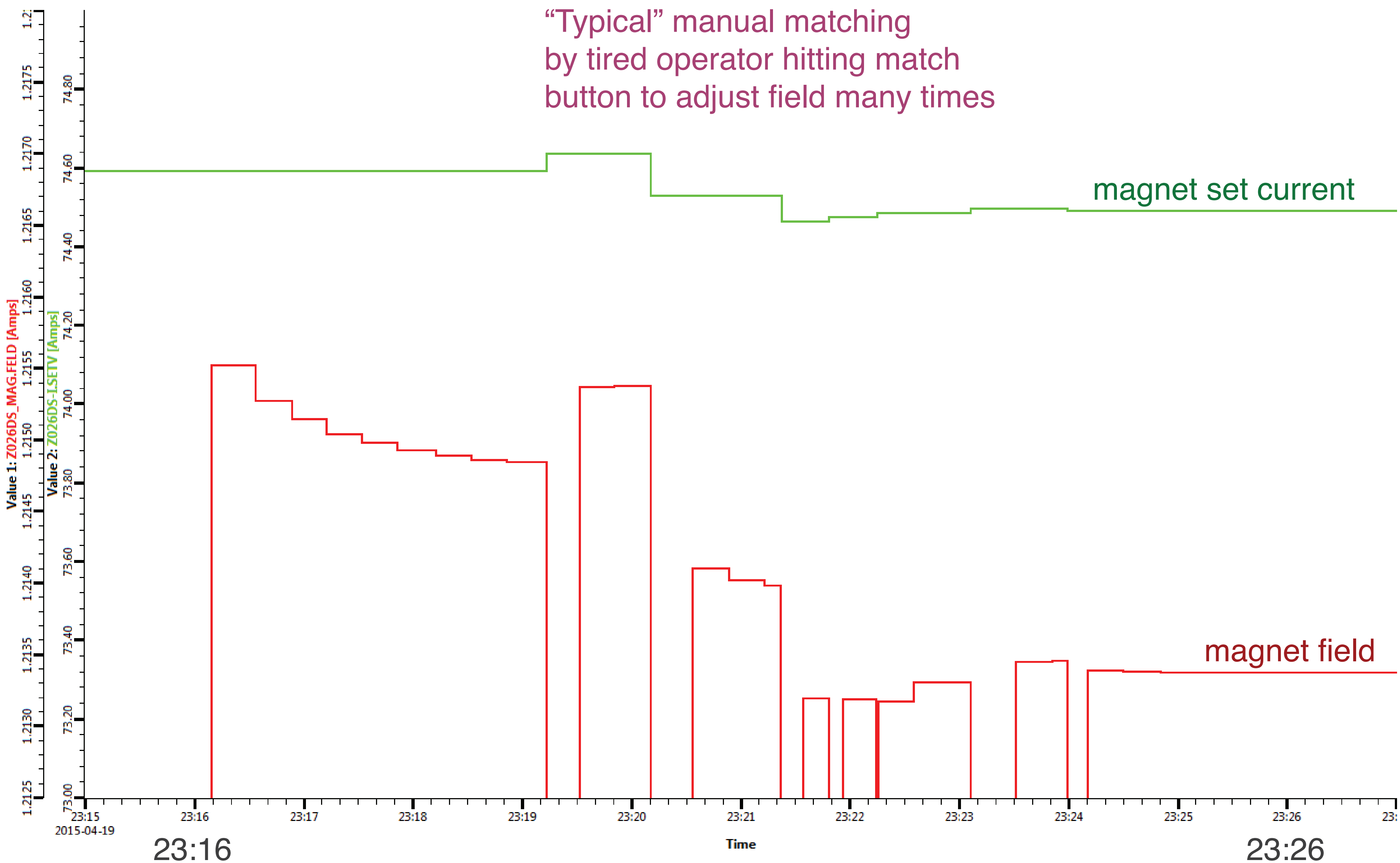
Achieving correct final field required several adjustments

Manual matching requires operator attention

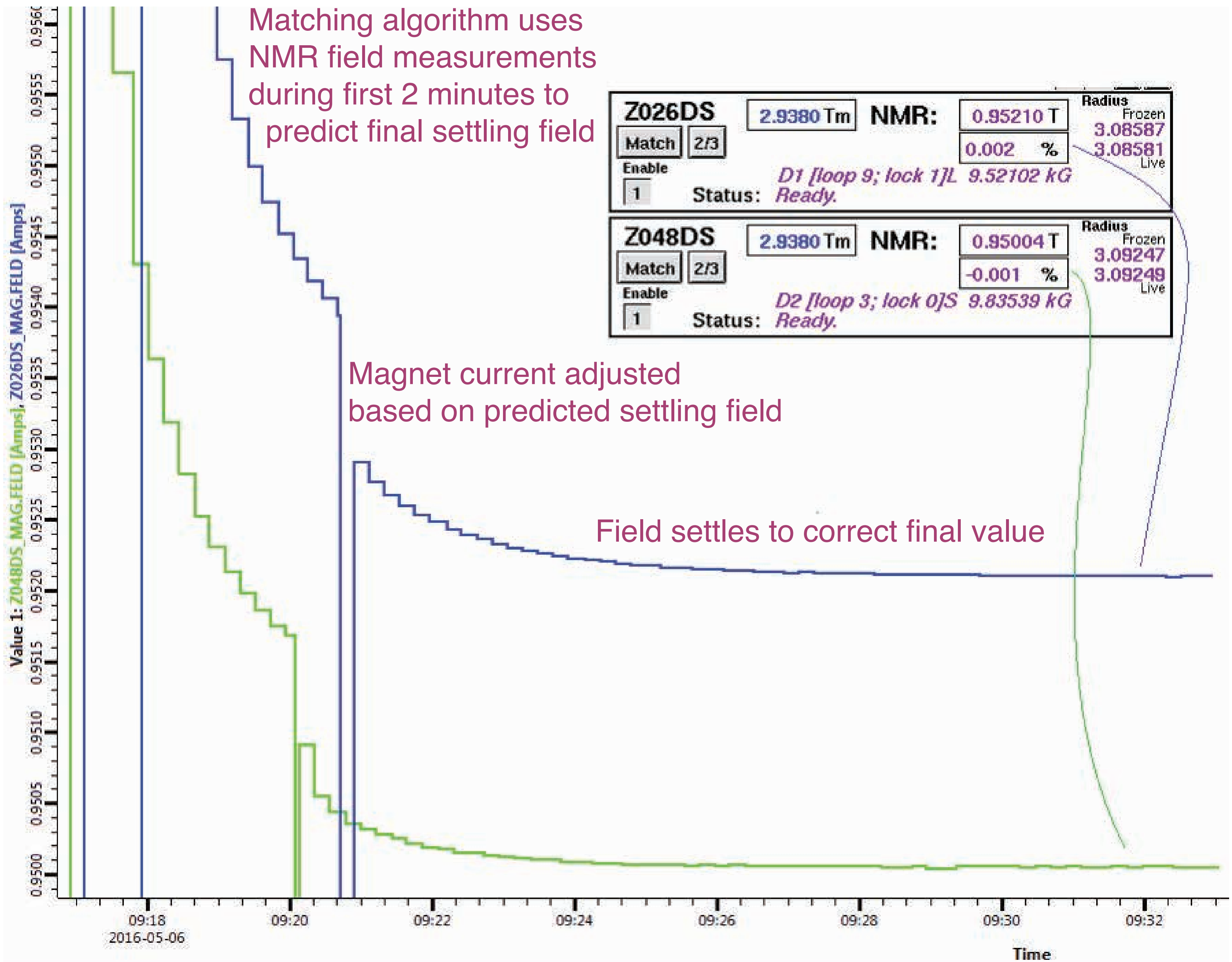
➥ **Development of predictive matching using B(t) analysis**

☞ **Wednesday 12:00 (Steiner)**

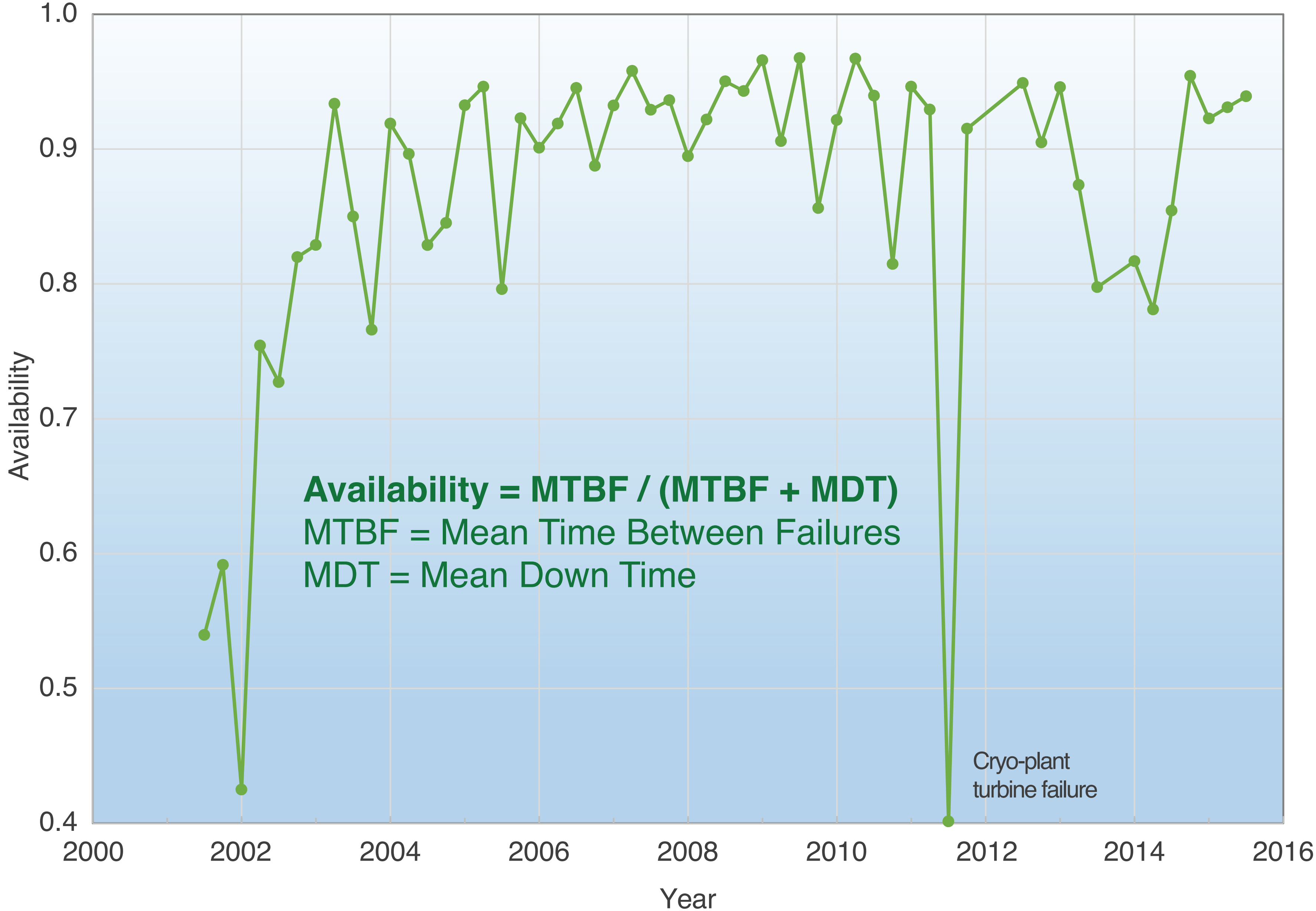
Automated A1900 Dipole Matching



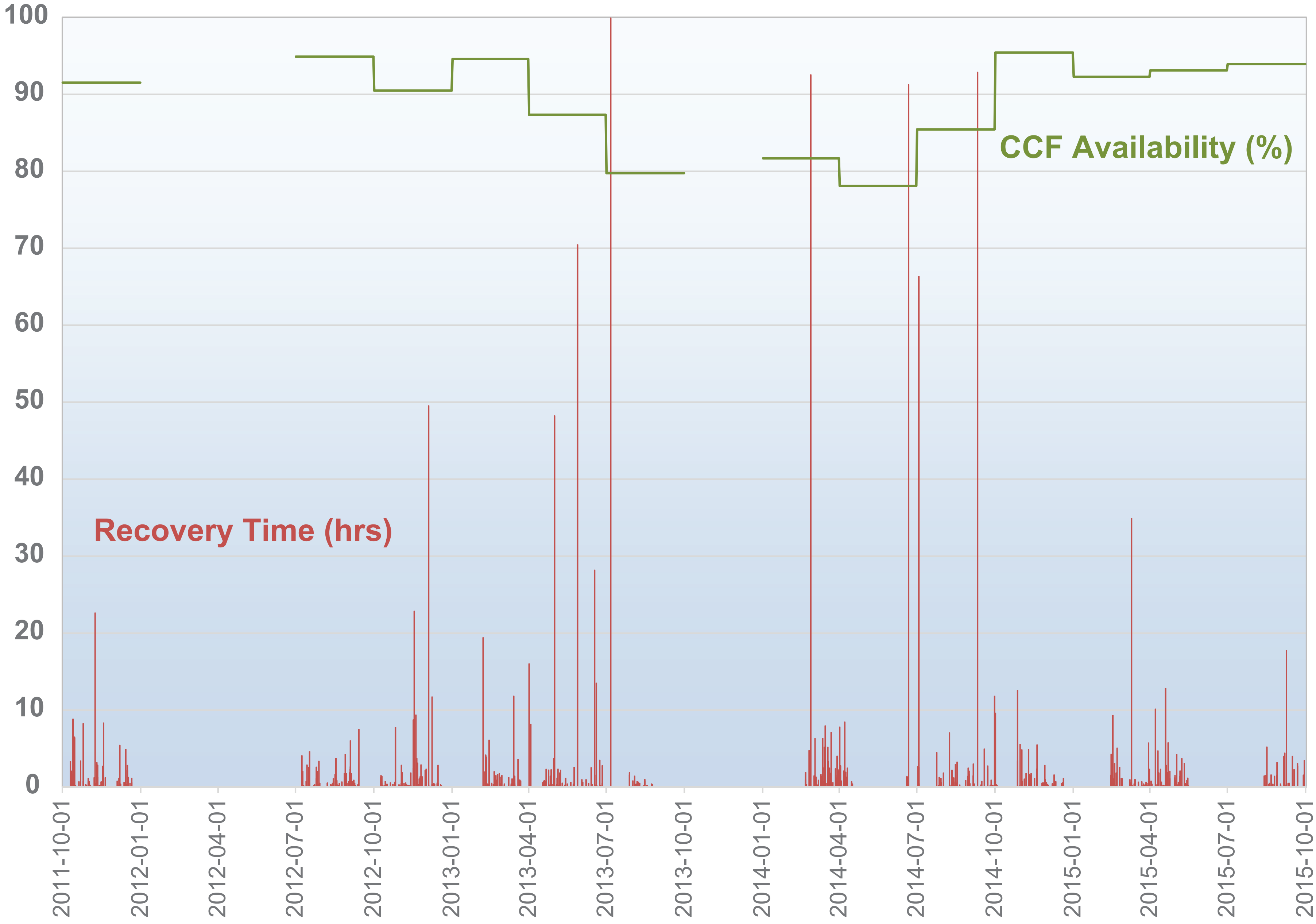
Automated A1900 Dipole Matching



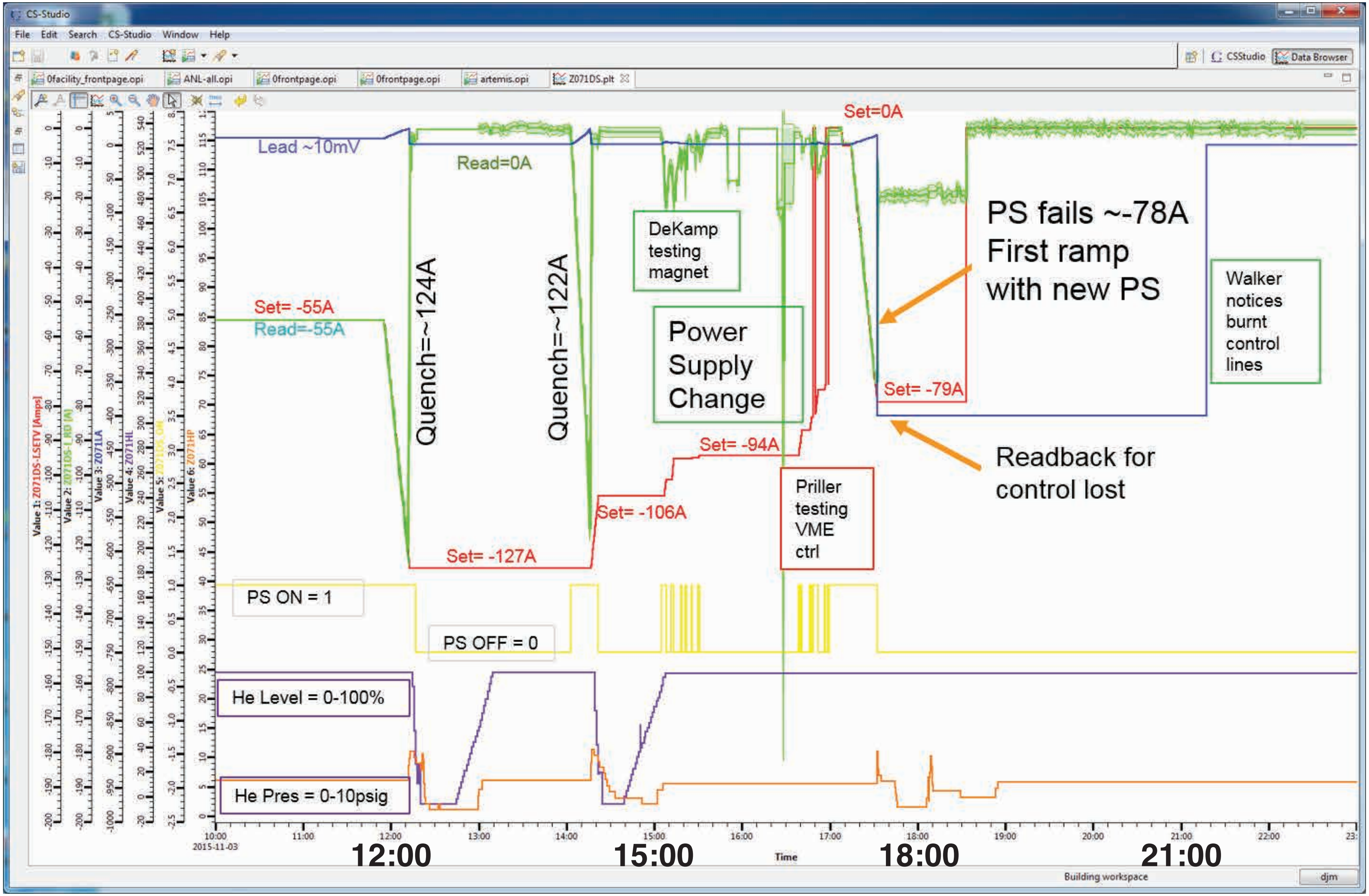
CCF Operations Availability



CCF Operations Availability

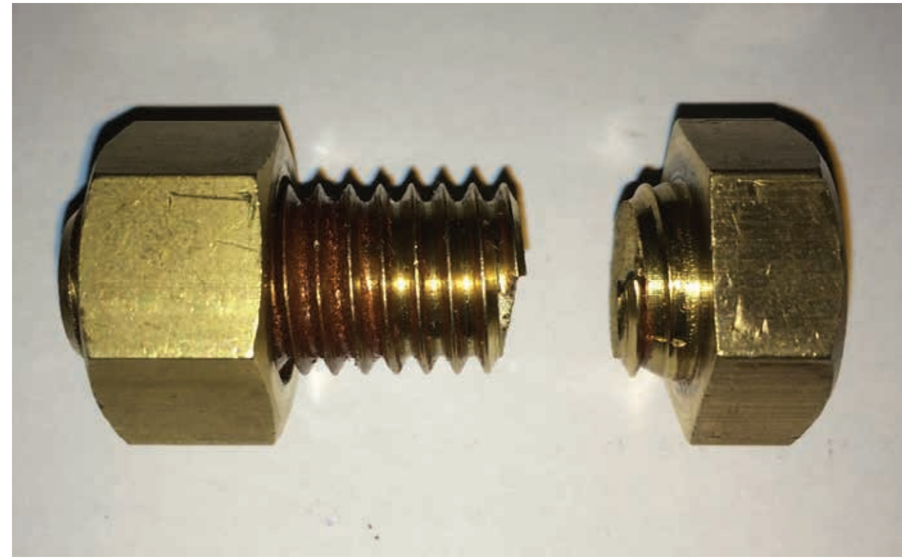


A1900 Dipole 3 Failure



A1900 Dipole 3 Failure

Back of the power supply

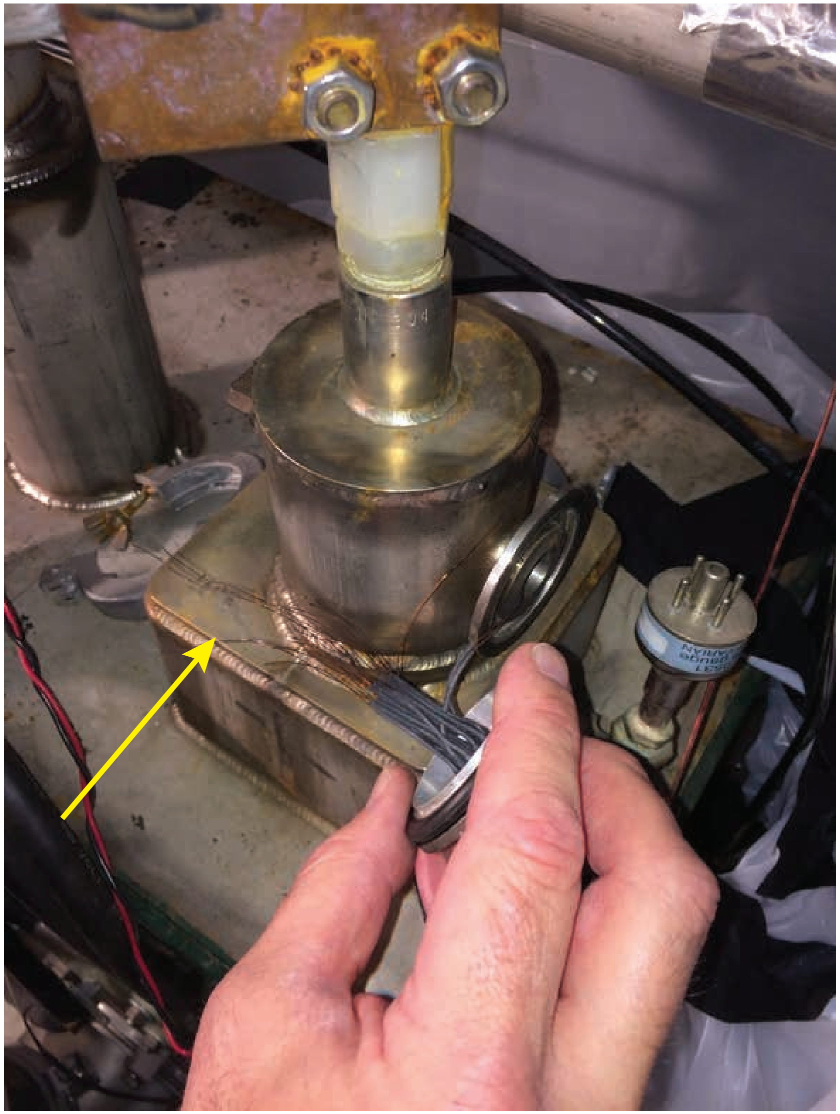


During power supply replacement original stain-less steel bolt was replaced with brass bolt in order to increase conductivity.

This bolt was found broken inside the power supply rack.

A1900 Dipole 3 Failure

Broken/melted diagnostic wires



After removing the lead can it became obvious that superconducting lead wires were significantly damaged.

A1900 Dipole 3 Failure

Damaged coil package was replaced with spare one (4 weeks repair).

New work instructions for electrical lead connection:

- silicon-bronze bolts (manufactured according to ASTM B99) from approved vendor
- specified torque during installation
- verify conductivity with milli-Ohm meter

Checked all magnet lead connections in the laboratory with milli-Ohm meter and thermal imaging under load.

A1900 Dipole 3 Failure

Time Line

11/03/2015	Magnet failure
11/04/2015	Extent of damage realized, decision to warm up magnet Decision to turn off all superconducting magnets to inspect bolt connections
11/05/2015	Project plan with two options: Magnet Repair / Magnet Replacement
11/06/2015	Decision to start winter maintenance shutdown 5 weeks early
11/09/2015	Decision to replace magnet
11/25/2015	Old magnet removed, new coil package and iron yoke installed
12/10/2015	Cryo-welding completed
12/29/2015	Magnet filled with liquid Helium
01/05/2016	Magnet tested at 160 Amps
01/18/2016	Magnet tested with beam, rho calibration

➥ **A $3 item used in the wrong way can cost you easily $3,000,000**