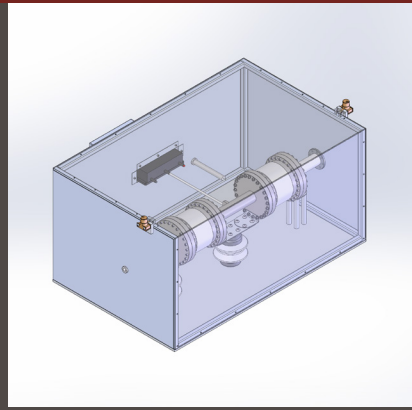
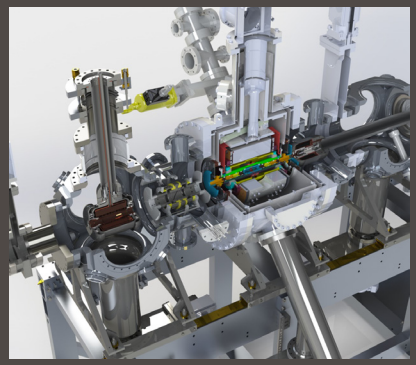
CANREB status

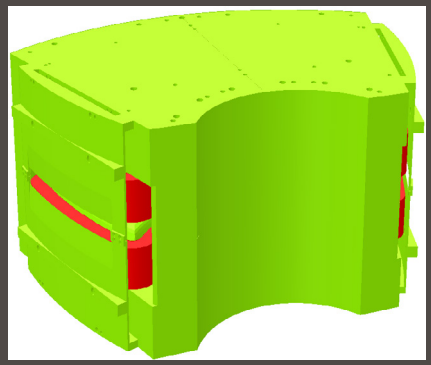
P0310

Friedhelm Ames

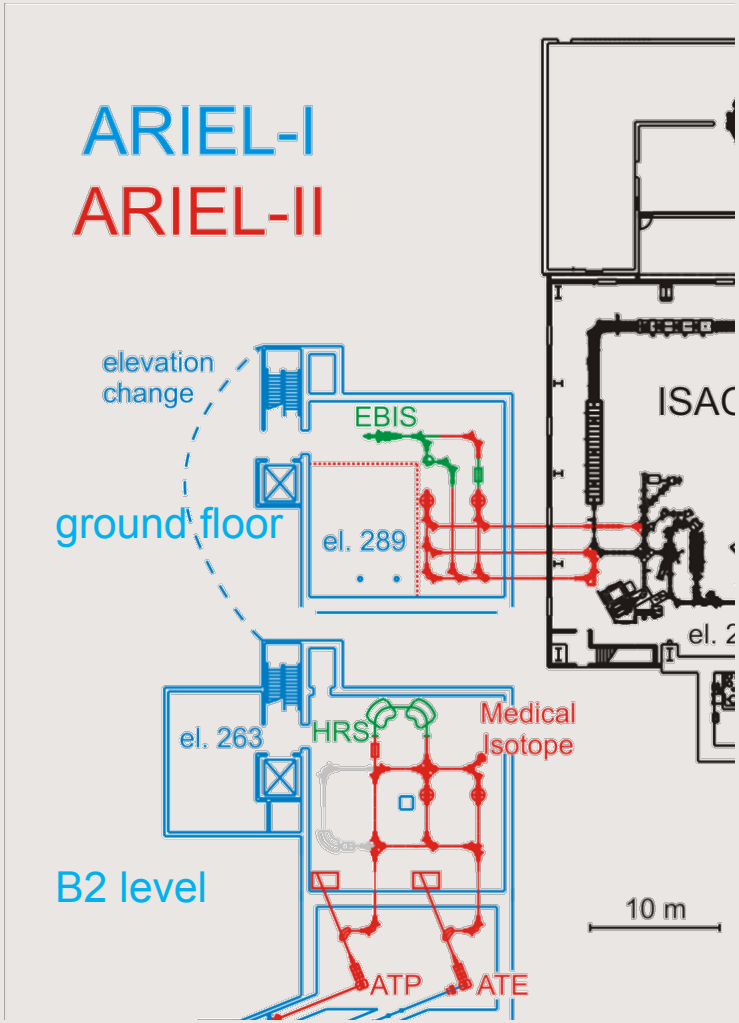
ARIEL town hall meeting, January 11, 2017







CANREB overview



main components of CANREB

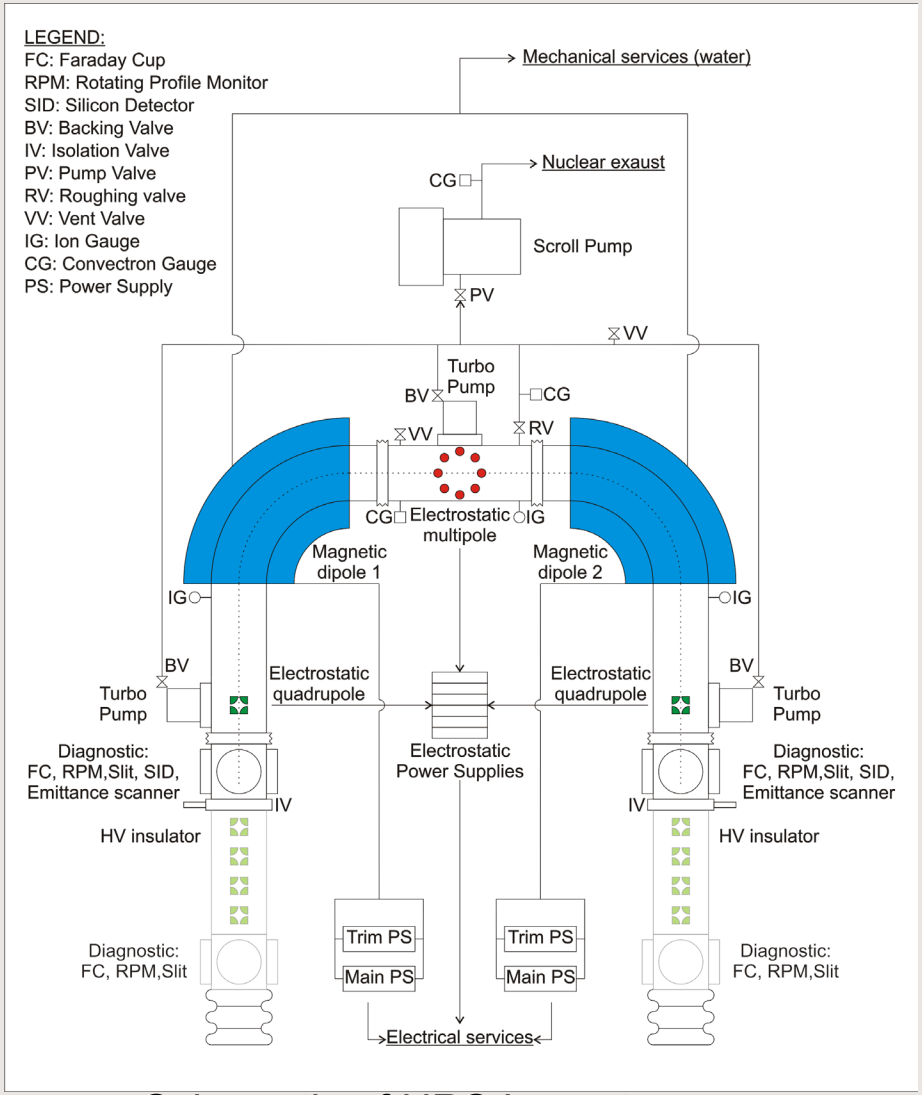
- high resolution mass separator M/ΔM = 20,000 for beams from ISAC and ARIEL
- charge state breeder A/q 5 - 7
  - RFQ cooler/buncher
  - EBIS charge state breeder
  - Nier spectrometer for highly charged ions
  - pulsed operation at 100 Hz

HRS requirements

- mass range up to A = 238
- beam energy 60 keV
- resolving power 20000 (no energy spread 3 μm emittance)
  10000 (6 μm emittance)

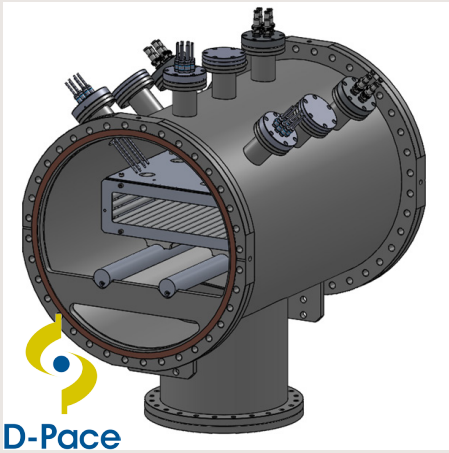
- stable operation over extended time (weeks)
- fast set-up
- low intensity beam diagnostics

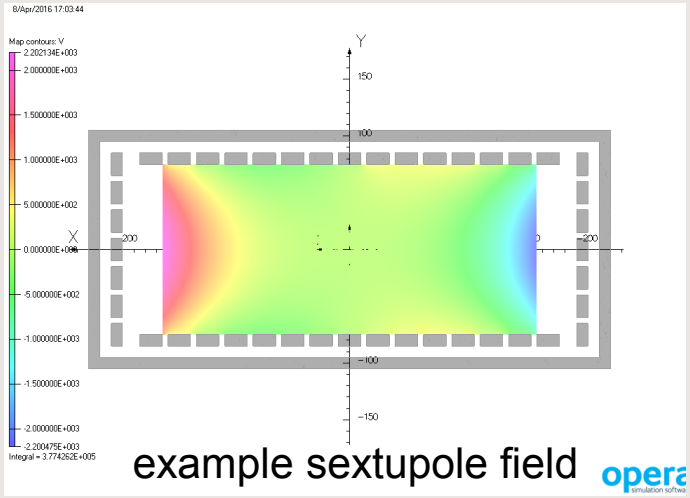
HRS - design



Schematic of HRS Layout

multipole corrector





example sextupole field

HRS - status

- ion optical design completed (TRI-DN14-06, TRI-DN-16-09)
- Concept design of high voltage platform completed
- Mechanical design of beamline components ongoing
- Conceptual design of Multipole completed (D-Pace); ECO released by the end of the January
- Final diagnostic requirements for selection slits, emittance rig and profile harps being included in document-121991

2 publications from EMIS 2015 and more to come!!!

ARTICLE IN PRESS

Nuclear Instruments and Methods in Physics Research B xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research B

journal homepage: www.elsevier.com/locate/nimb

Electrostatic potential map modelling with COSY Infinity ☆

J.A. Maloney *, R. Baartman, T. Planche, S. Saminathan

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ARTICLE INFO

Article history:
Received 11 August 2015
Received in revised form 20 November 2015
Accepted 2 December 2015
Available online xxxx

Keywords:
Electrostatic
Optics
COSY
Potential

ABSTRACT

COSY Infinity (Makino and Berz, 2005) is a differential-algebra based simulation code which allows accurate calculation of transfer maps to arbitrary order. COSY's existing internal procedures were modified to allow electrostatic elements to be specified using an array of field potential data from the midplane. Additionally, a new procedure was created allowing electrostatic elements and their fringe fields to be specified by an analytic function. This allows greater flexibility in accurately modelling electrostatic elements and their fringe fields. Applied examples of these new procedures are presented including the modelling of a shunted electrostatic multipole designed with OPERA, a spherical electrostatic bender, and the effects of different shaped apertures in an electrostatic beam line.

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1. Introduction

COSY Infinity (COSY) [1] is a differential algebra-based beam simulation code that allows calculation of transfer maps for beam optical systems to any arbitrary order. COSY models most elements by determining fields and potentials in the beam line midplane. COSY uses a curvilinear coordinate system where s is the forward trajectory of the reference particle, and x and y represent the horizontal plane, defined the Cartesian cian to be eq

$$\Delta V = \frac{1}{1+hx}$$

where h is the plane as a bou determine the

To specify sics package) nents, k_n and example, the pole in the m

$$V = V_m + (x/D$$

where V_m is the voltage at the poletip and D is the aperture (the radial distance from the optical axis to the poletip).

Most electrostatic elements are specified in COSY via the potential in the midplane in this manner [3]. Although useful, the analytic expressions for these elements are idealized. In practice, a "pure" quadrupole, is at best an approximation. To provide flexibility, COSY has a generalized function, GE, for specifying

* This project Trust (MRIT), University, and T
* Corresponde E-mail addre

http://dx.doi.org 0168-583X/© 20

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Nuclear Instruments and Methods in Physics Research B xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research B

journal homepage: www.elsevier.com/locate/nimb

New design studies for TRIUMF's ARIEL High Resolution Separator ☆

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ARTICLE INFO

Article history:
Received 15 August 2015
Received in revised form 9 November 2015
Accepted 15 November 2015
Available online xxxx

Keywords:
HRS
Mass separator
Aberrations
Optics
Matching

ABSTRACT

As part of its new Advanced Rare IsotopE Laboratory (ARIEL), TRIUMF is designing a novel High Resolution Separator (HRS) (Maloney et al., 2015) to separate rare isotopes. The HRS has a 180° bend, separated into two 90° magnetic dipoles, bend radius 1.2 m, with an electrostatic multipole corrector between them. Second order correction comes mainly from the dipole edge curvatures, but is intended to be fine-tuned with a sextupole component and a small octupole component in the multipole. This combination is designed to achieve 1:20,000 resolution for a 3 μm (horizontal) and 6 μm (vertical) emittance. A design for the HRS dipole magnets achieves both radial and integral flatness goals of <10 $^{-3}$. A review of the optical design for the HRS is presented, including the study of limiting factors affecting separation, matching and aberration correction. Field simulations from the OPERA-3D (OPERA) [2] models of the dipole magnets are used in COSY Infinity (COSY) (Berz and Makino, 2005) [3] to find and optimize the transfer maps to 3rd order and study residual nonlinearities to 8th order.

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1. Introduction

The ARIEL HRS is designed with the goal of separating rare isotope species with a fractional mass difference of 1:20,000 for an input beam width 3 μm (horizontal) and 6 μm (vertical) emittance. Mass separation is achieved by creating dispersion using bending magnets. Dispersion is a function of the bending radius and angle of the magnets. Isotopes of differing masses are transported to a shifted final horizontal position relative to the target isotope as they travel through the separator. Slit apertures can then be used to collimate the beam, allowing only the desired isotope to be transmitted through the HRS. The separation criterion can be expressed as a function of mass dispersion (D), resolving power of the separator (R = mass/Δmass), and the full width of the horizontal slit aperture ($2s$):

$$2s = D/R$$

In the case of the ARIEL HRS, dispersion is created using two 90° magnetic dipoles, each with a bending radius of 1.2 m. This creates dispersion at the exit to the separator of approximately 2.4 m. To achieve resolution of 20,000, the full width of the horizontal slit aperture, used for mass selection, is limited to 120 μm. For a 3 μm horizontal emittance, this horizontal beam size limit means the angular deviation in the beam would be up to ±50 mrad.

Energy spread within the beam and aberrations in the beam optics also directly affect resolution. These limitations are discussed later in this paper.

2. HRS dipole magnets

The dipole magnets for the HRS, like the one shown in Fig. 1, were designed using OPERA. The design requirements for the ARIEL HRS dipoles include both radial and integral flatness goals of <2.5·10^{-3}. Radial flatness is the fractional variation in magnetic field measured radially relative to the field felt along the reference trajectory. Integral flatness measures variation in the total integrated field felt by particles travelling along various trajectories from a hard edge model of the dipole's magnetic field. These goals are set for the 'good field' region of the magnet, where the beam is intended to travel and field quality must be the highest. This requirement is directly derived from the desired resolving power of 20,000. The specification requirements for integral field flatness, as well the radial field flatness at the center of the magnet, are met in the design model. The effective field edge is optimized in order to coincide with the curved field edge of an equivalent (same B_0 at the center of the dipole) hard edge magnet. The curvature was chosen from beam dynamics simulations to minimize second order aberrations in the beam optics. The saturation level in the iron is kept below 1.5 T in order to have reproducible fields at low excitation.

* This project is been supported by CFI, Nova Scotia Research and Innovation Trust (NSRIT), Manitoba Research and Innovation Fund, AAPS, Saint Mary's University, and TRIUMF.
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http://dx.doi.org/10.1016/j.nimb.2015.11.023
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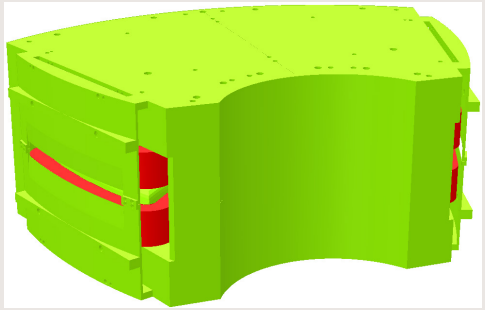
Please cite this article in press as: J.A. Maloney et al., New design studies for TRIUMF's ARIEL High Resolution Separator, Nucl. Instr. Meth. B (2015), http://dx.doi.org/10.1016/j.nimb.2015.11.023

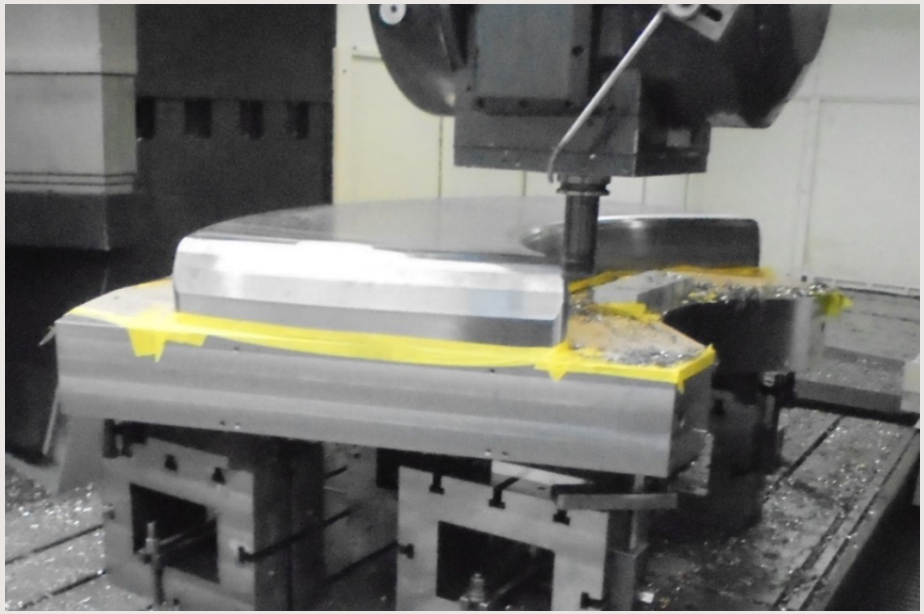
HRS – dipole status

- Design aspects of the ARIEL-II HRS Dipole Magnet included in TRI-DN14-06 and TRI-DN-15-28
- Final external design review February 27, 2015
- procurement document for manufacturing signed, delivery 2017
- First dipole steel manufacturing completed, second dipole to be completed by the end of January
- Steel manufacturing inspection by TRIUMF to occur in the second half of January
- procurement for vacuum chamber signed, manufacturing started

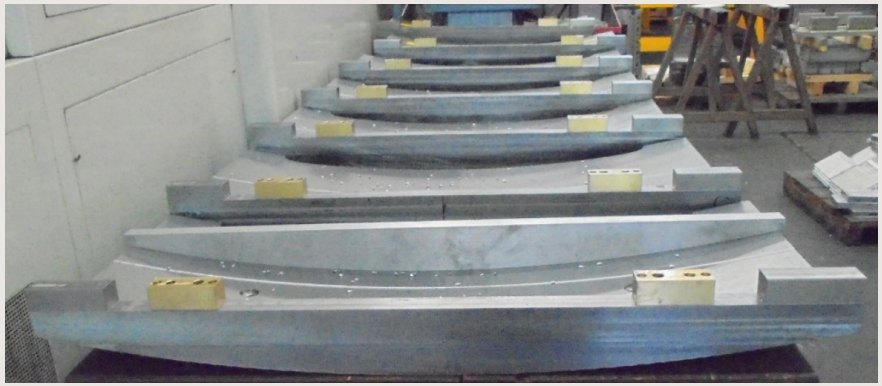


OPERA model of
HRS Dipole Magnet

HRS – dipole status



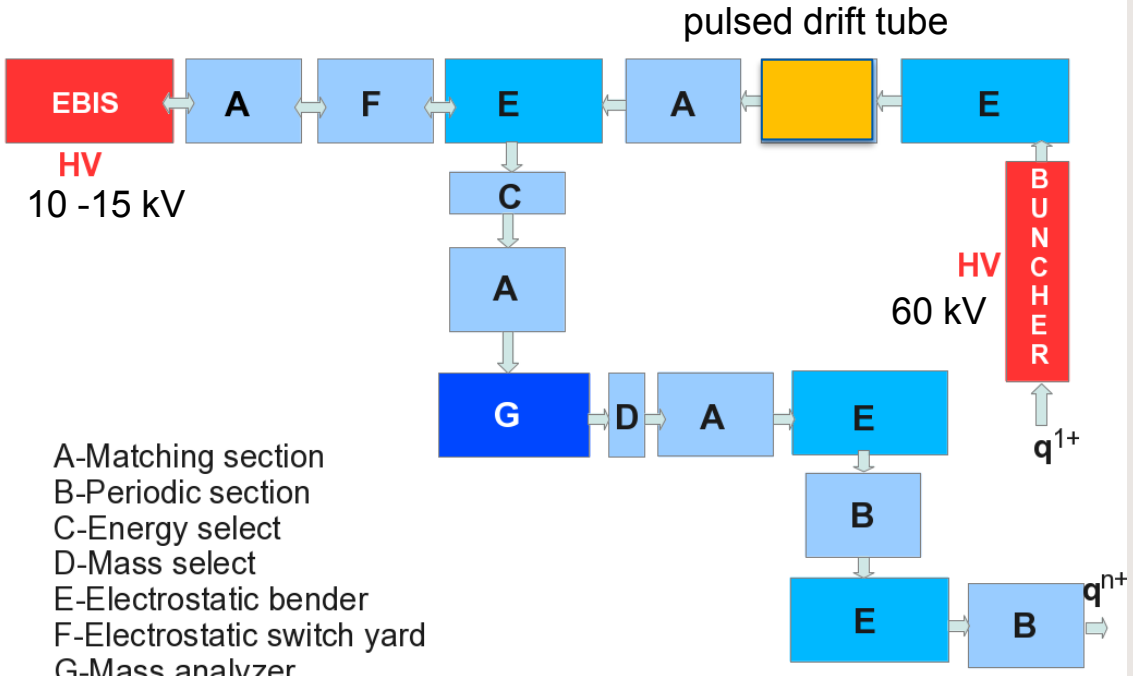
pole on top of yoke

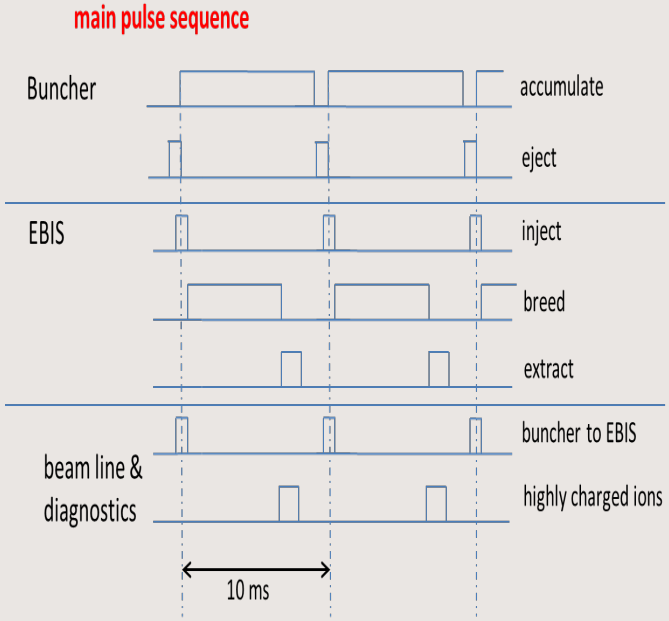


field clamps

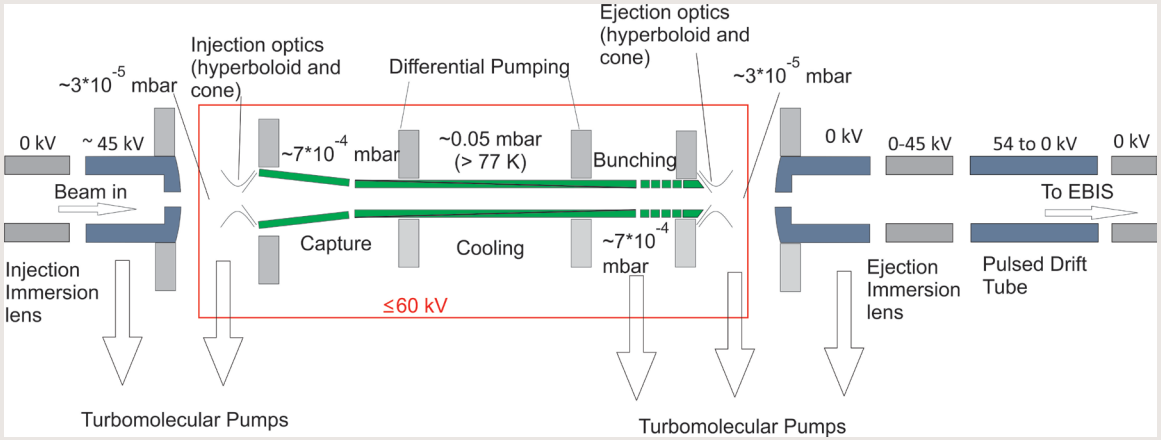
coil winding and wrapping

charge breeding system





RFQ buncher



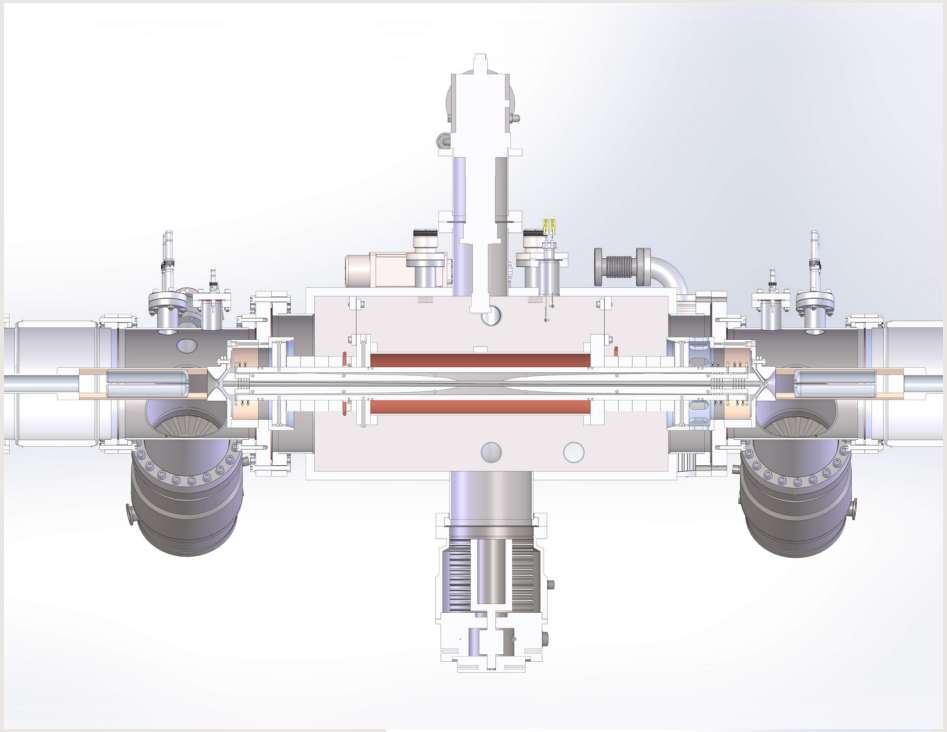
- gas filled radio frequency quadrupole (1-3 MHz)
- capturing of singly charged ions at 60 keV
- accumulating section
- release as ion bunches
- pulsed drift tube for energy matching to accelerator

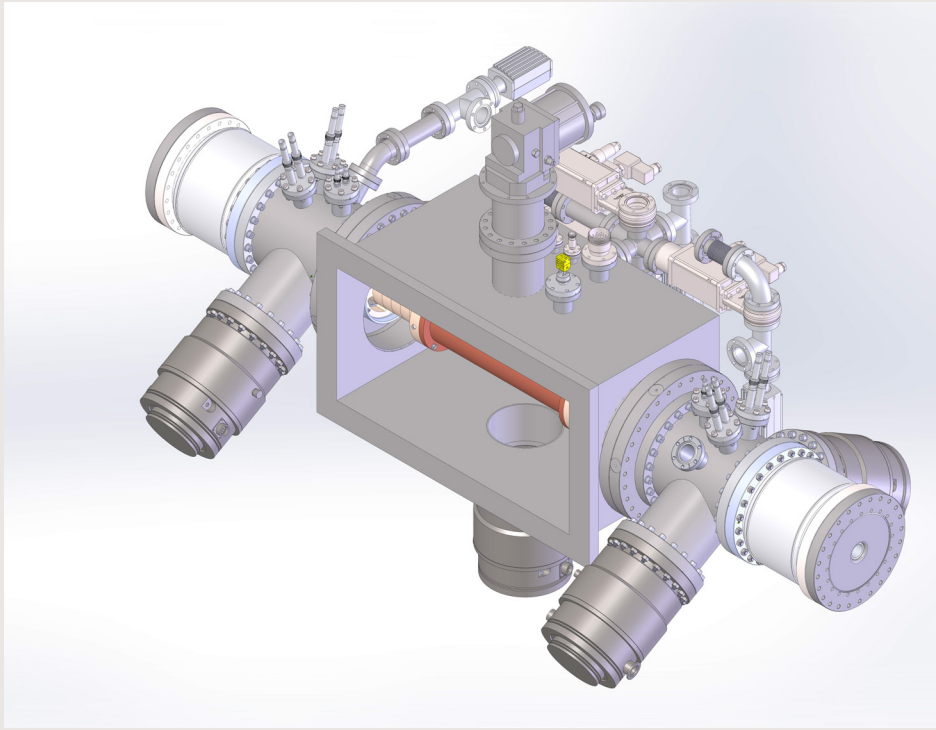
external design review June 14, 2016

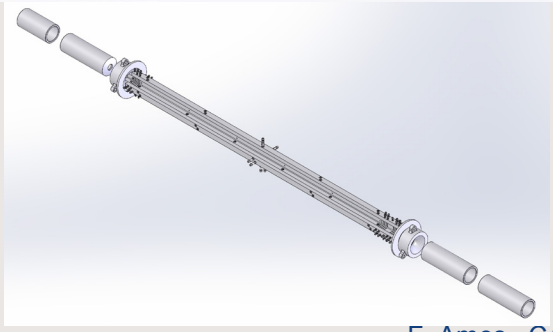
- detailed design nearly finished
- manufacturing of parts started
- prototype testing for pulsed drift tube done

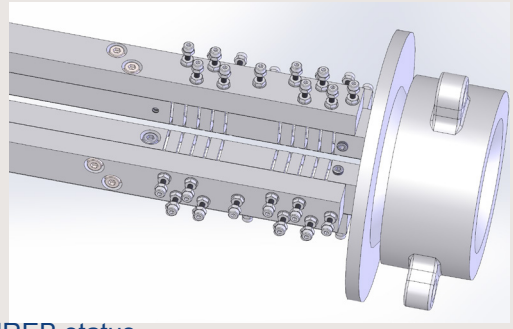
RFQ buncher

detailed design for RFQ structure







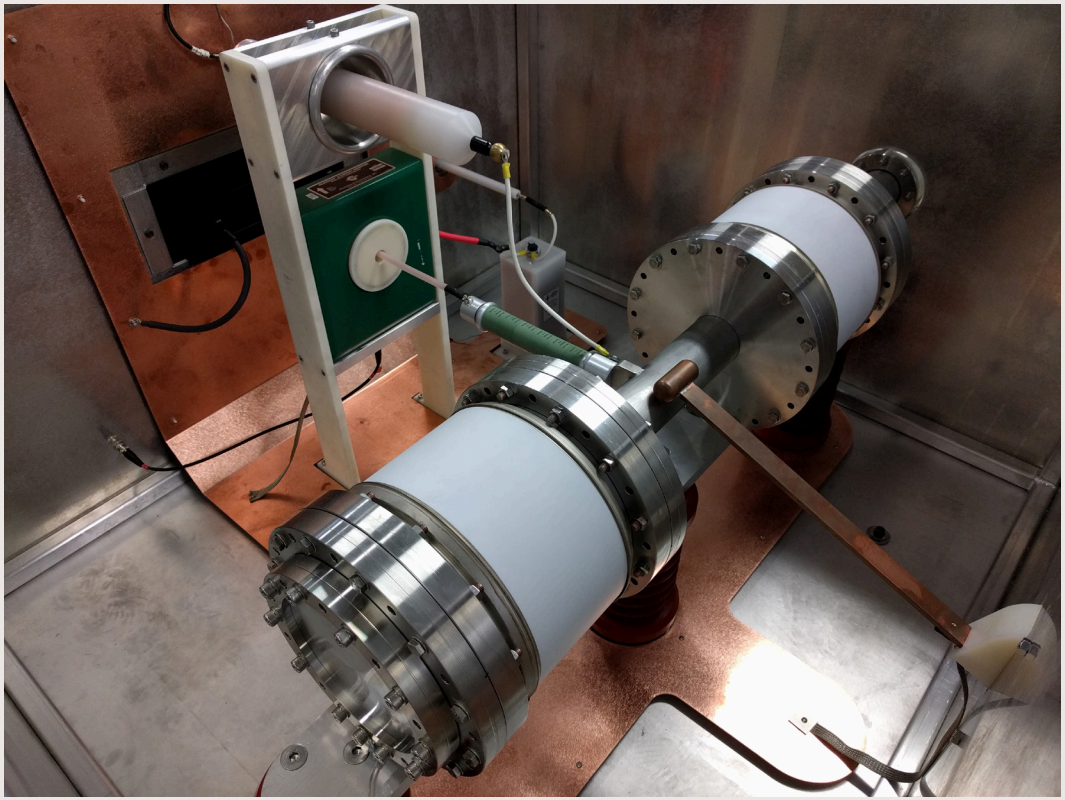


RFQ electrodes parts

- Design drawings for RFQ structure, surrounding optics released to shop
- Differential pumping and RFQ electrode parts are being manufactured

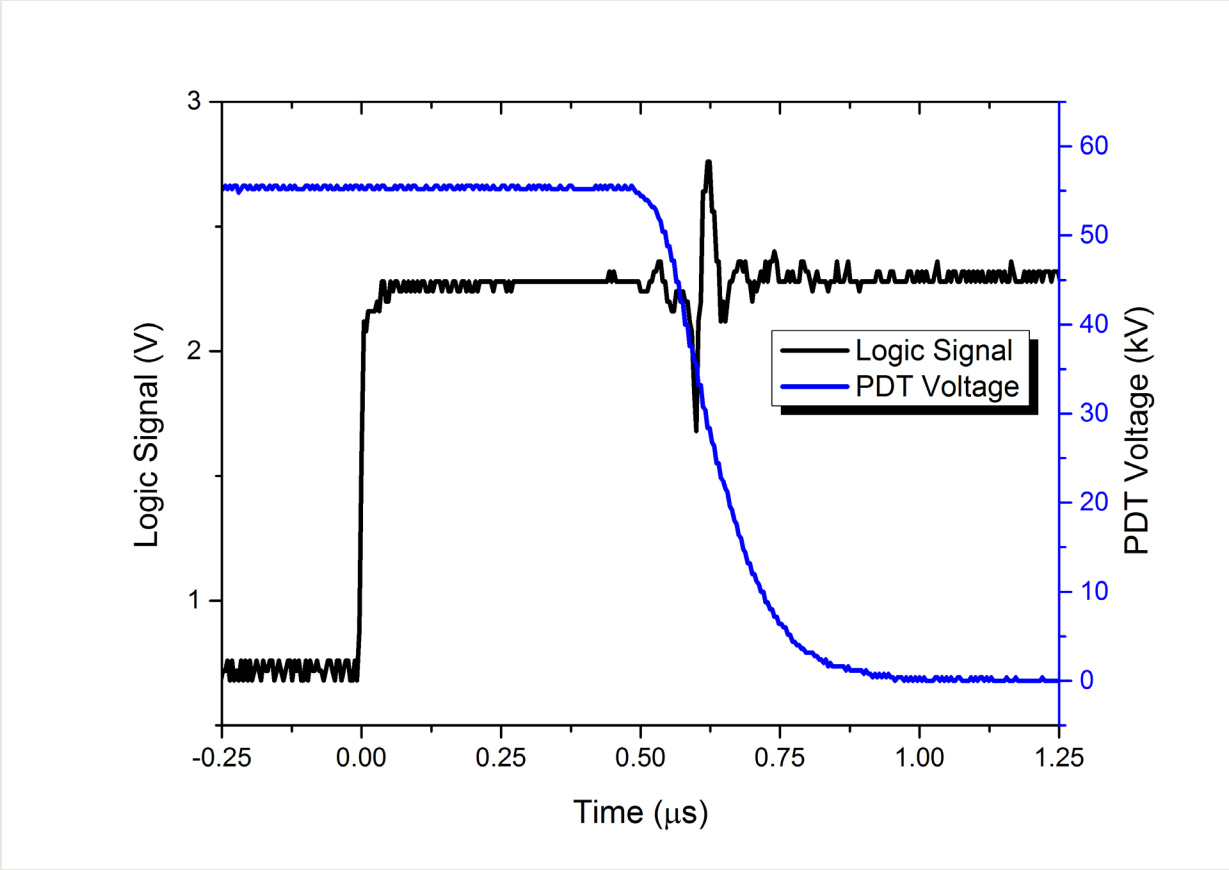
pulsed drift tube

prototype test set up



pulsed drift tube (PDT) test results

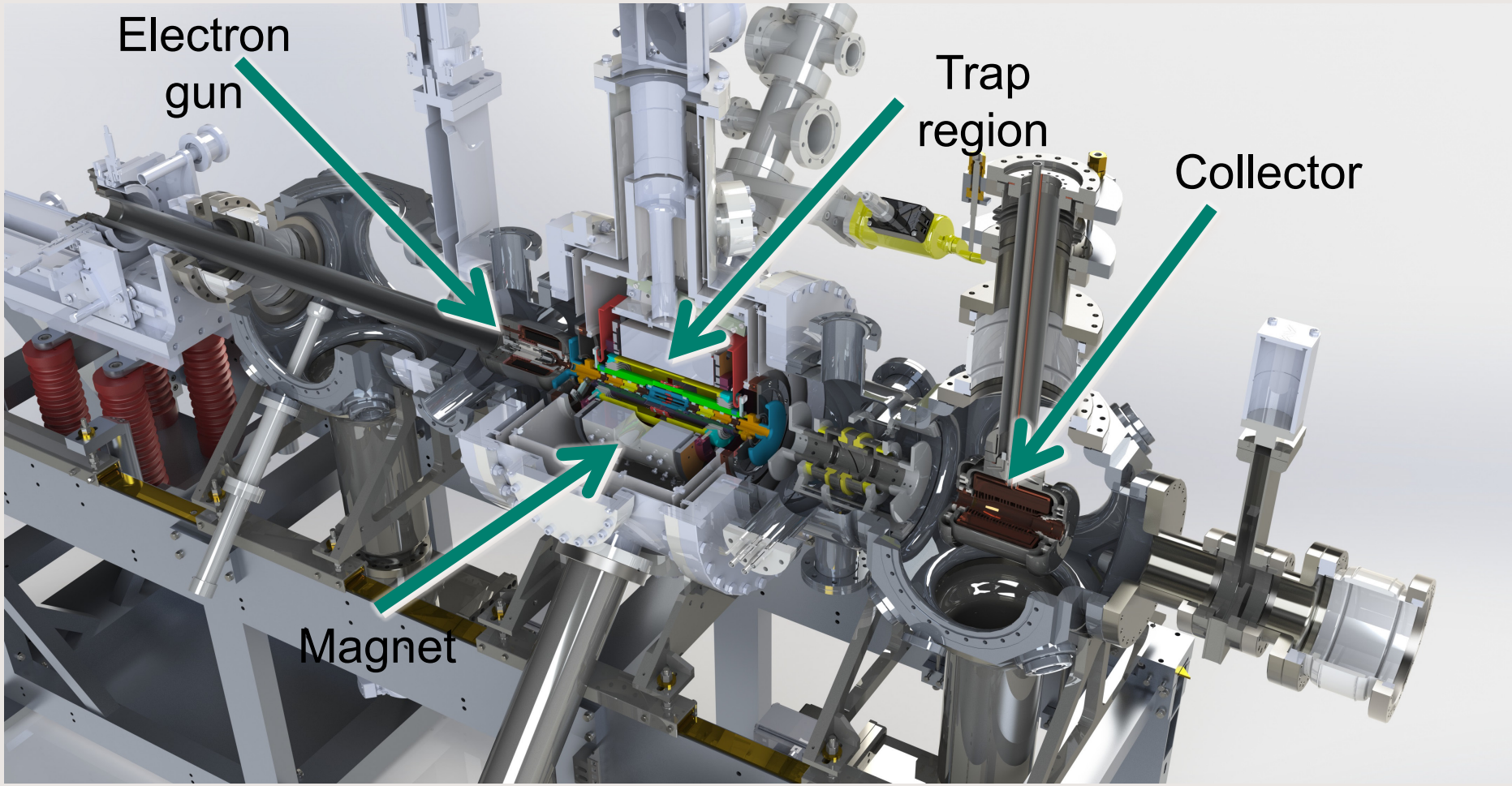
- Desired voltages, rise time reached – PDT design concept validated
- Results will inform improved enclosure design to reduce discharge



EBIS requirements

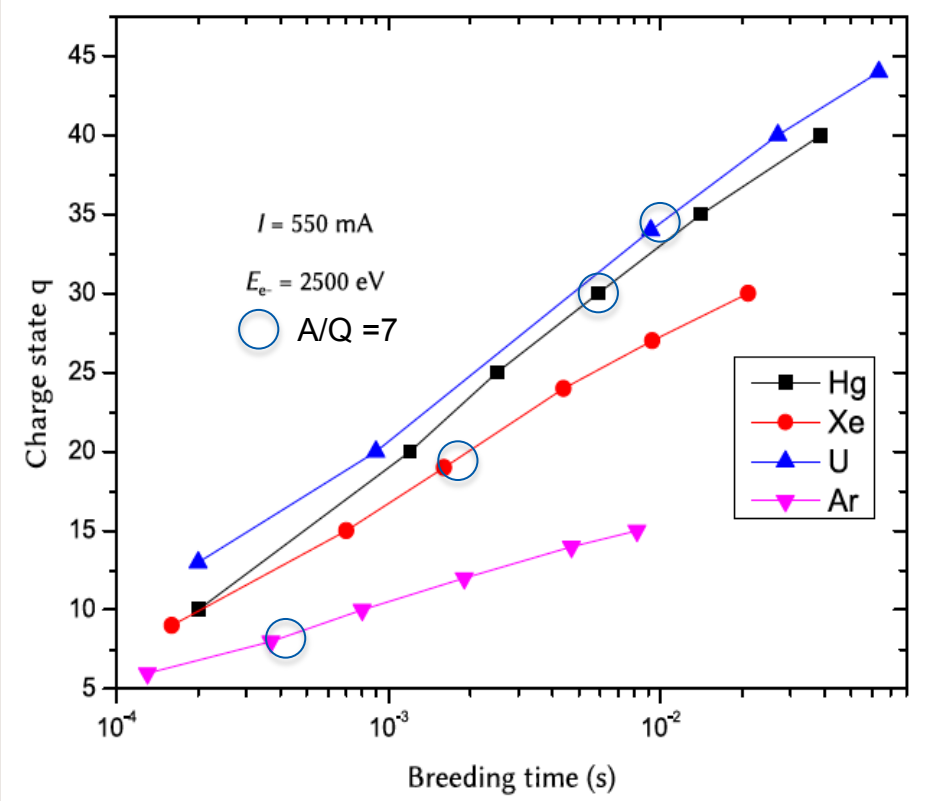
- beam acceptance
  - singly charged ions
  - 10^6 ions per bunch
  - E 10 -14 keV
  - transversal emittance 5 μm
  - bunch length 1 μs
- charge state breeding
  - A/Q 5 -7,
  - 10-20% in the desired charge state
  - 100 Hz repetition rate
- highly charged ion beam properties
  - E 10 - 14 keV x Q
  - δE <= 100 eV x Q
  - transversal emittance <= 20 μm
  - bunch length up to 1 ms
- background ions
  - minimize contaminations
  - ultra high vacuum 5 x 10^{-12} mbar in trapping region

EBIS design



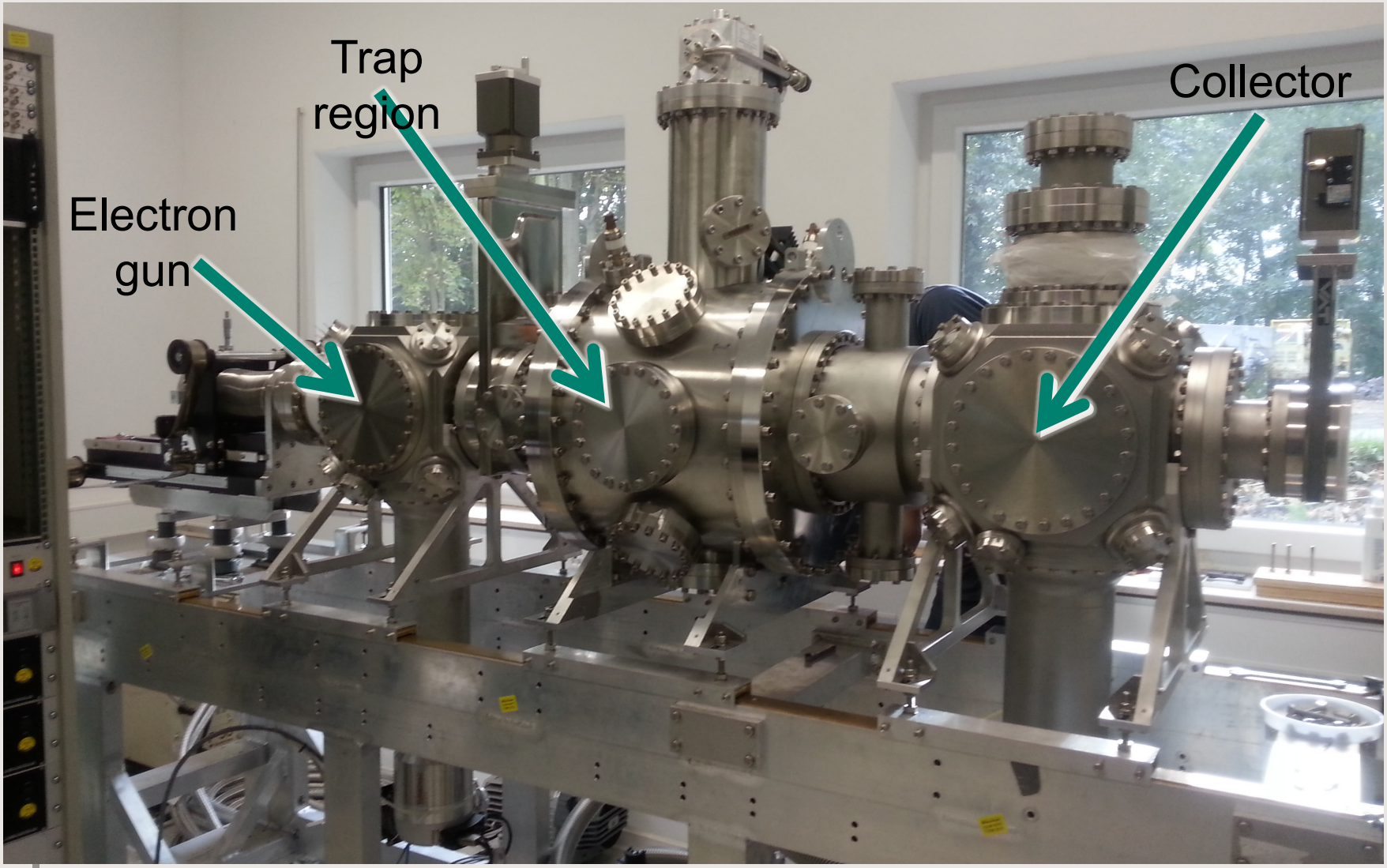
EBIS design specifications

- magnet
  - superconducting 6 T
  - dB/B < 10^{-4}
- electron beam
  - I_{max} = 550 mA
  - electron beam density in trap region 20 000 A/cm^2
  - effective density (seen by ions) 1300 A/cm^2
  - beam diameter in trap region 60 µm



charge state breeding for various elements simulation with DITHER

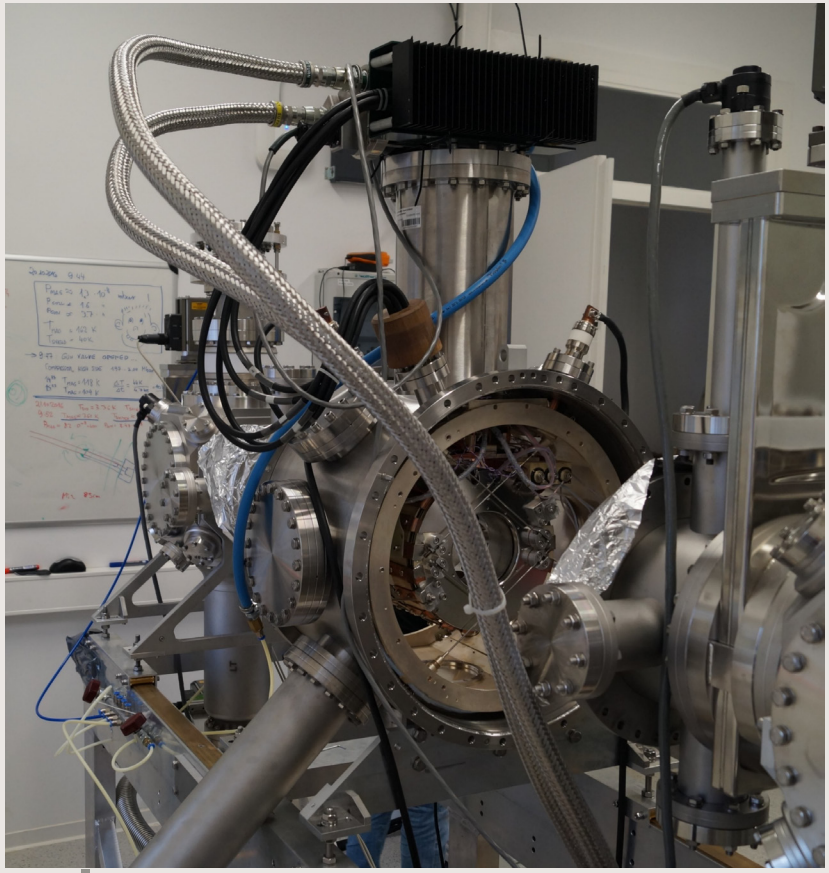
EBIS setup

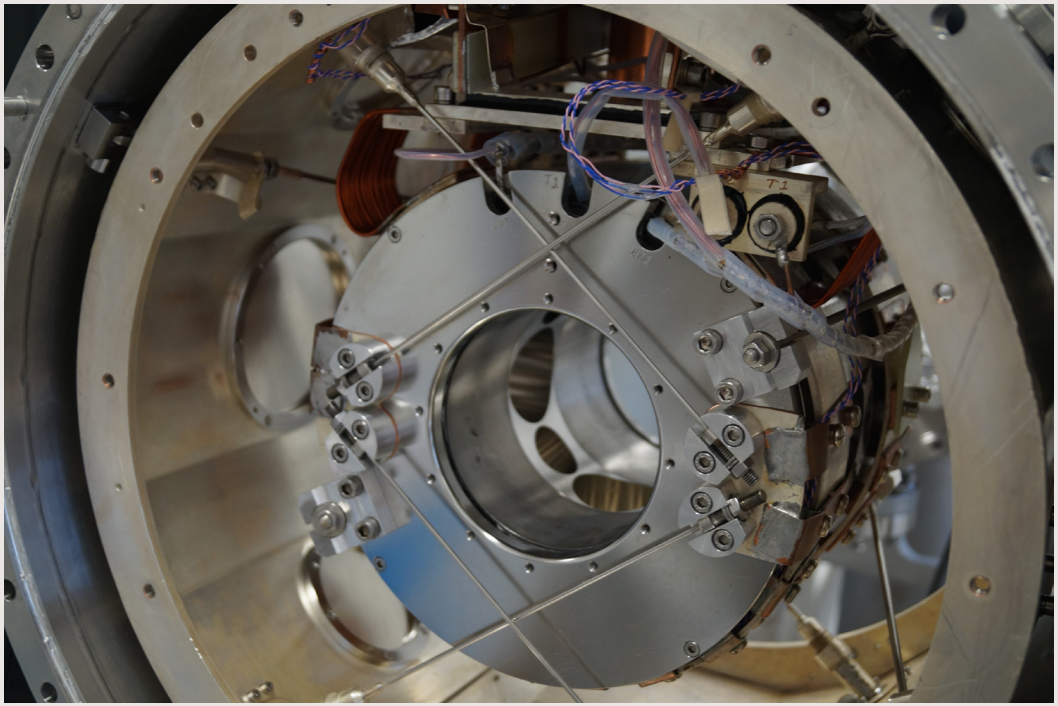


EBIS superconducting magnet

The superconducting magnet arrived in Heidelberg in May.

It was damaged during a quench in June and send back to the manufacturer.



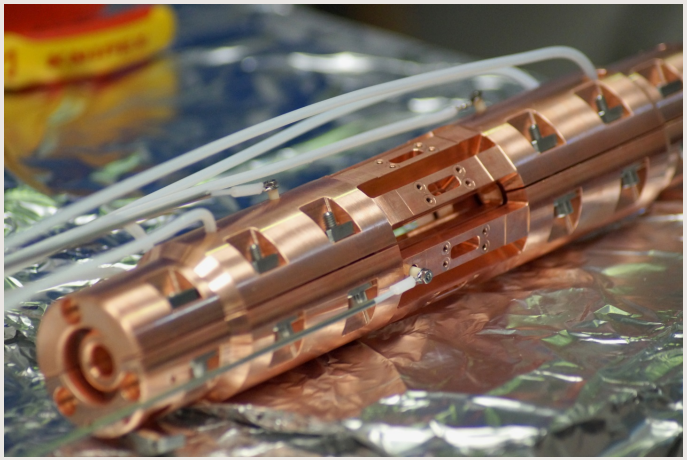


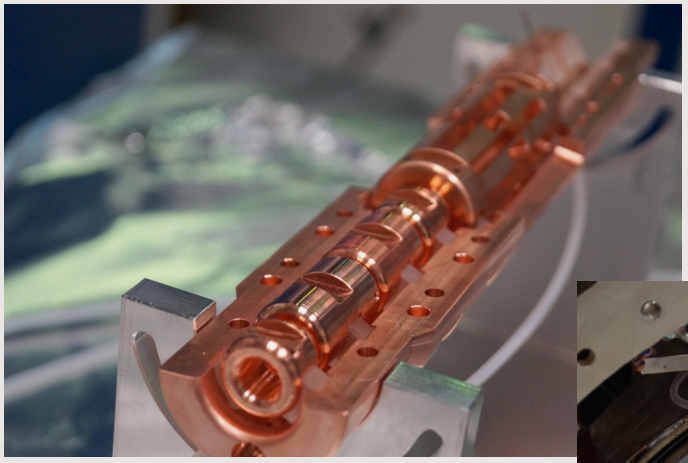
The magnet arrived back in Heidelberg in October. It was thoroughly tested (several induced quenches) and is working fine.

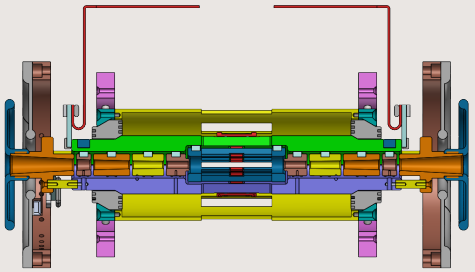
To prevent future damages the steel rods supporting the magnet were made with a larger diameter, among other repairs.

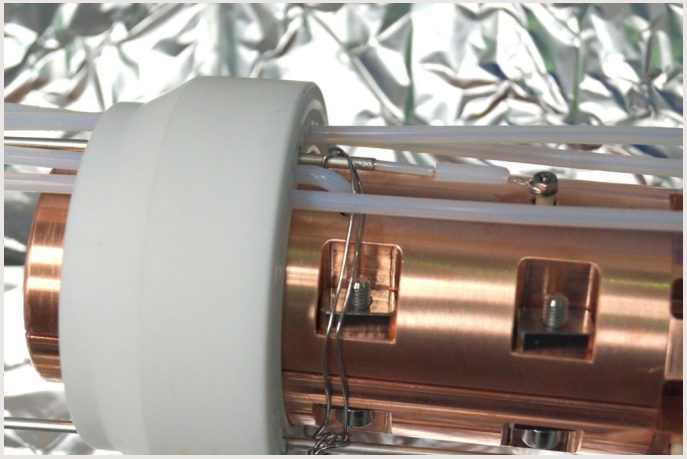
TRIUMF

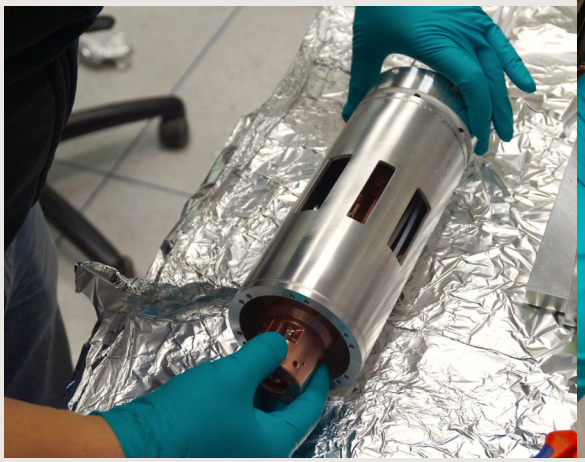
EBIS trap electrodes assembly

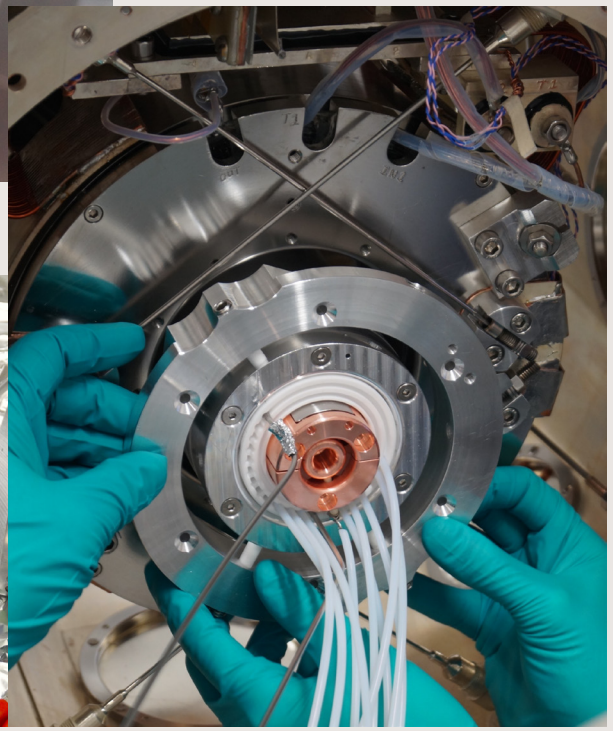






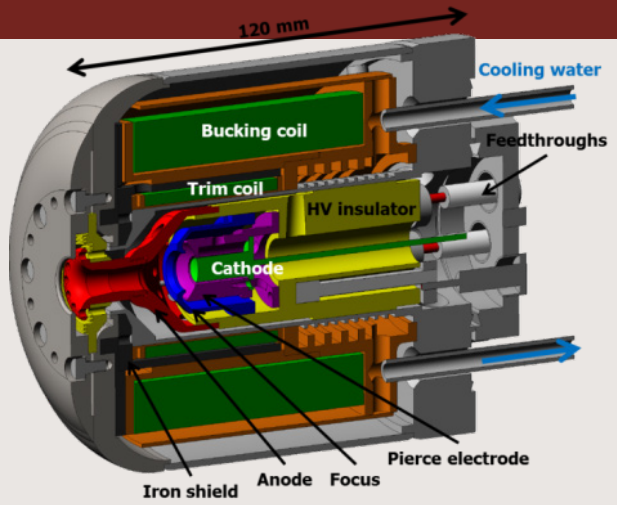


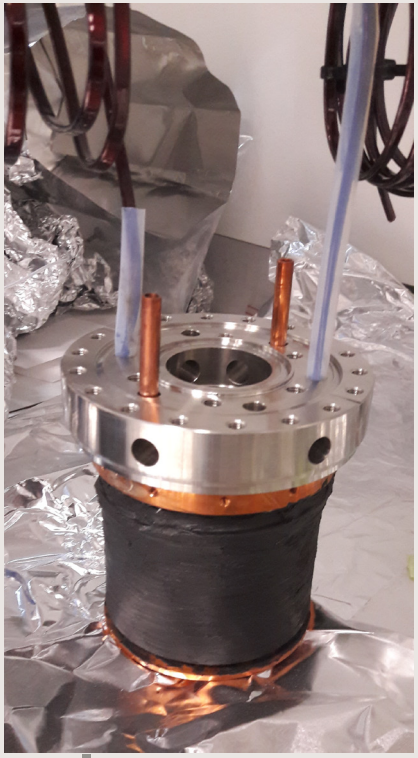


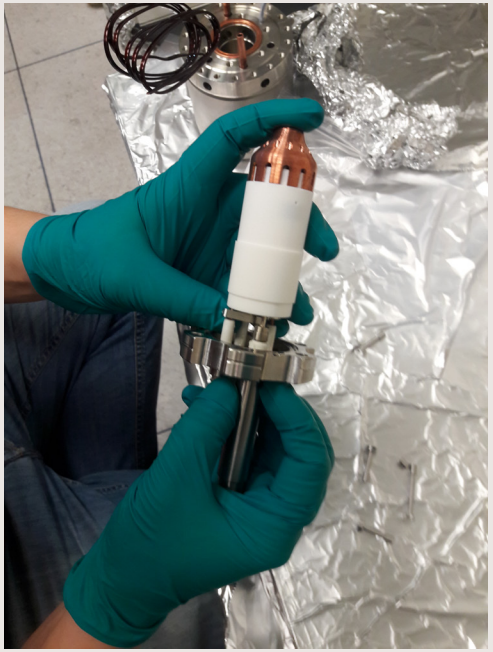


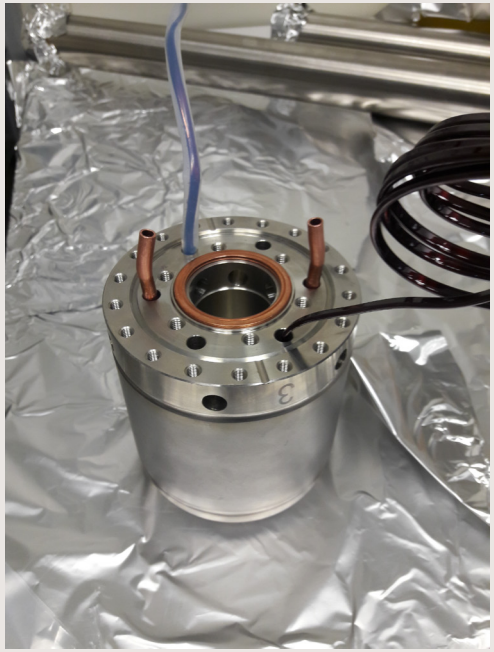
EBIS electron gun

Electron gun is in assembly, some small parts need to be altered by the workshop

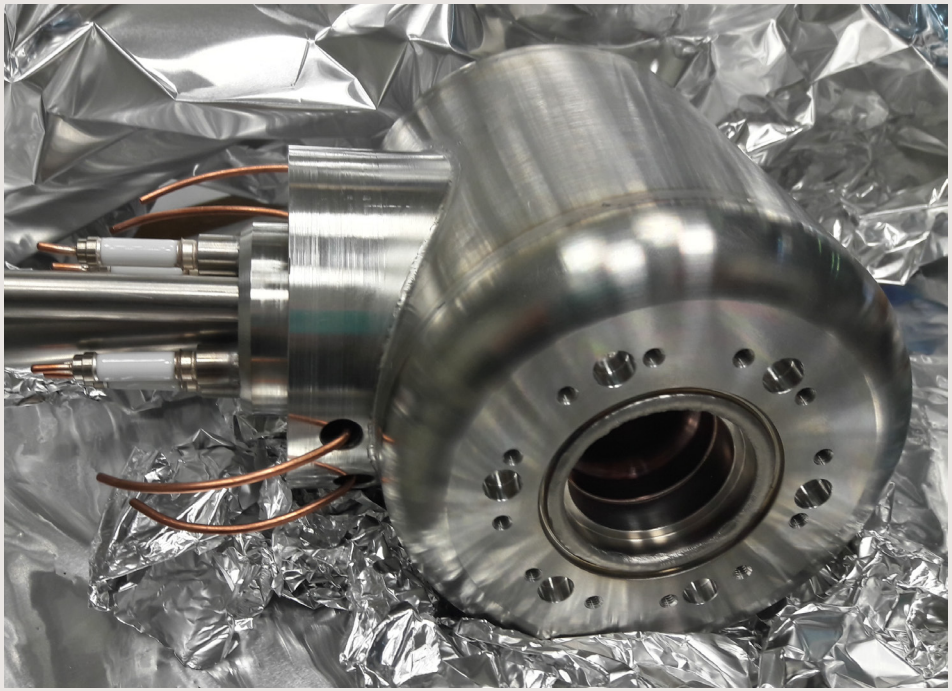




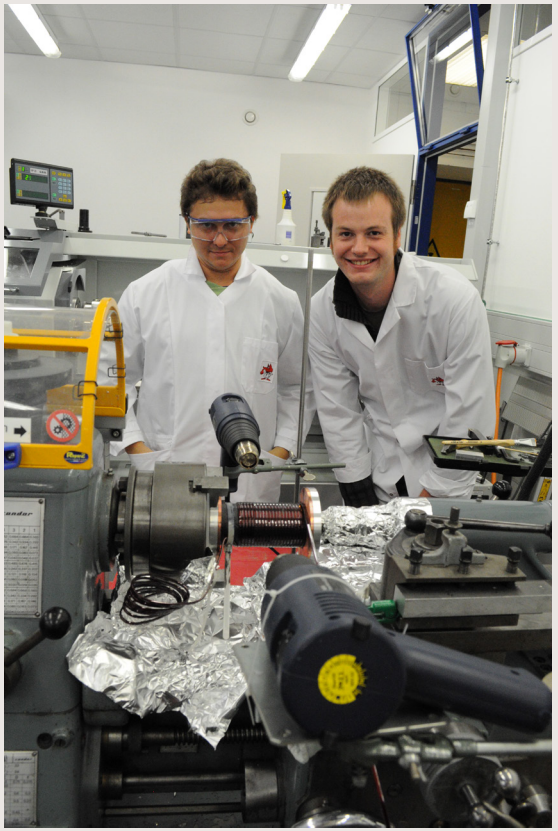




EBIS electron collector



collector assembly ready for installation

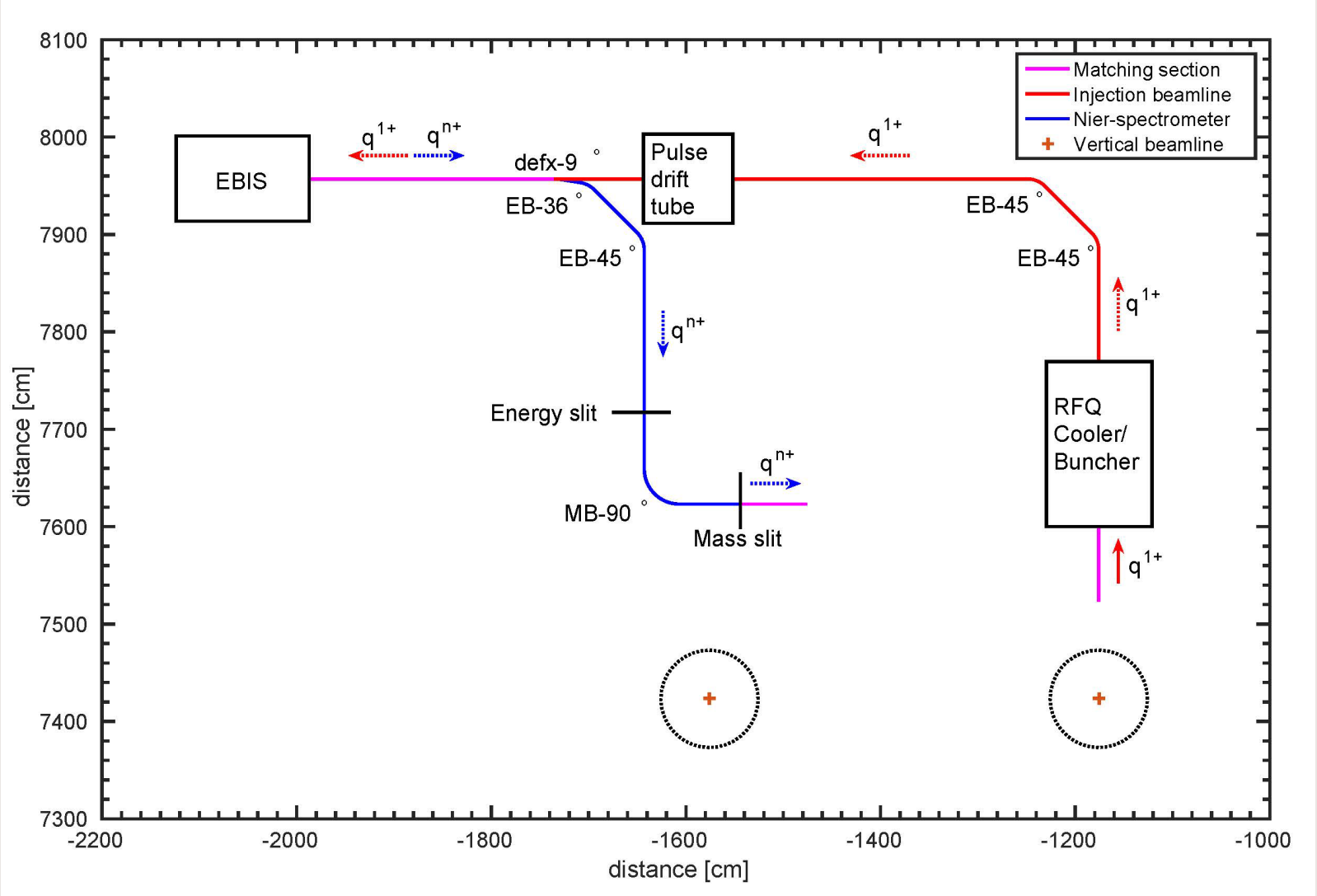


The magnetic coils for electron gun and collector needed to be wound and glued manually

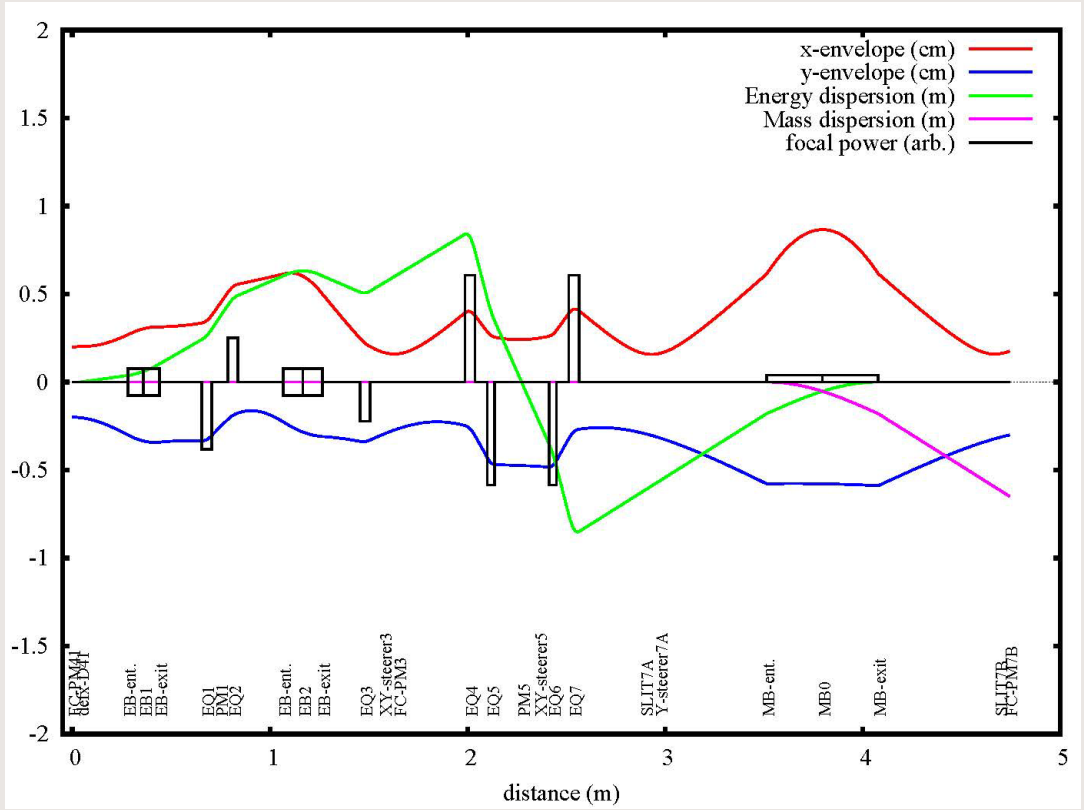
EBIS status

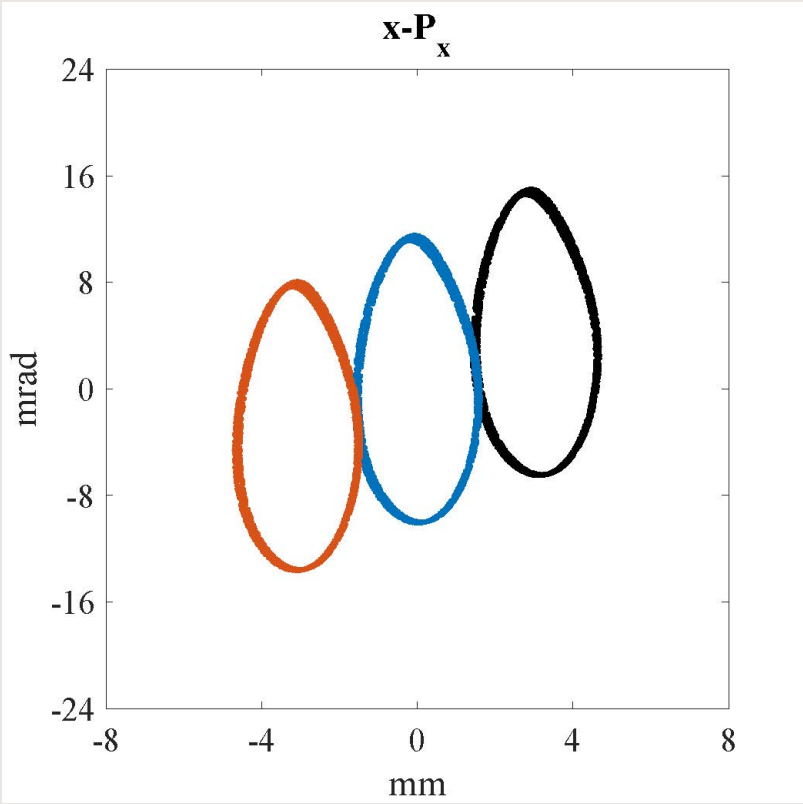
- Superconducting magnet repaired, redelivered, installed and thoroughly tested-works
- Last components are produced and altered in the MPIK workshop
- Trap electrodes are installed inside magnet
- Collector and e-gun are nearly finished, will be installed in the next days/week
- Lab infrastructure (cooling water supply, pressurized air, …) have been installed
- Ongoing simulations on injection/extraction/charge breeding

Nier spectrometer and beam lines



Nier spectrometer optics simulation

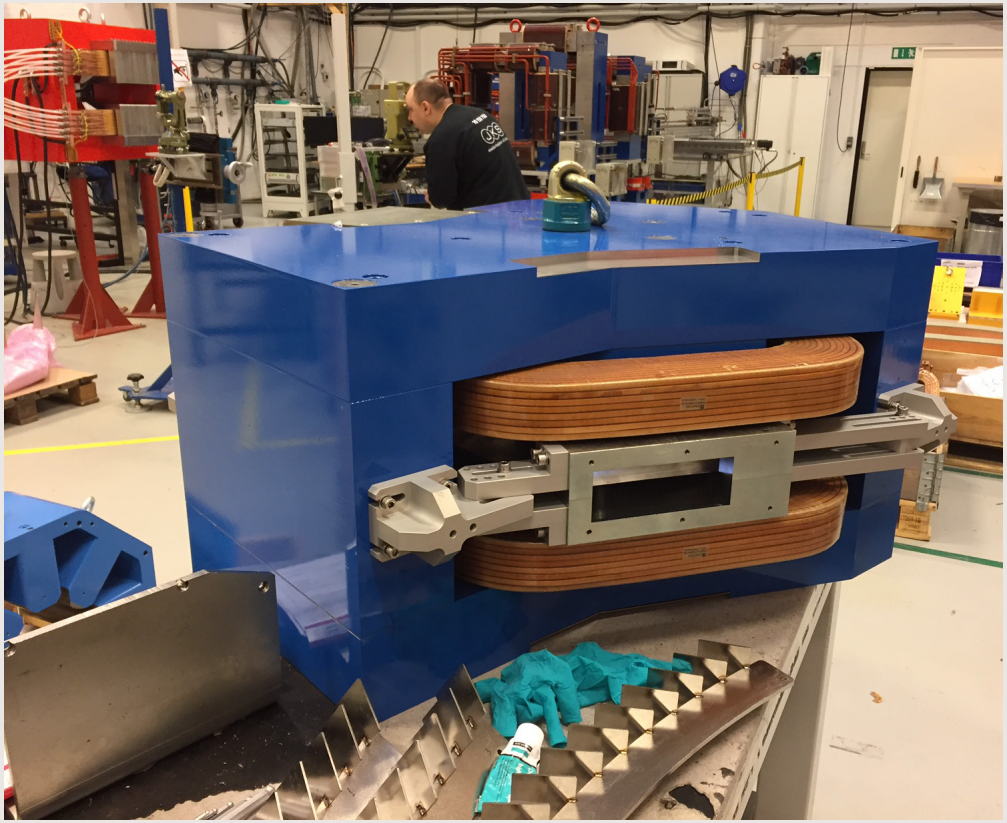


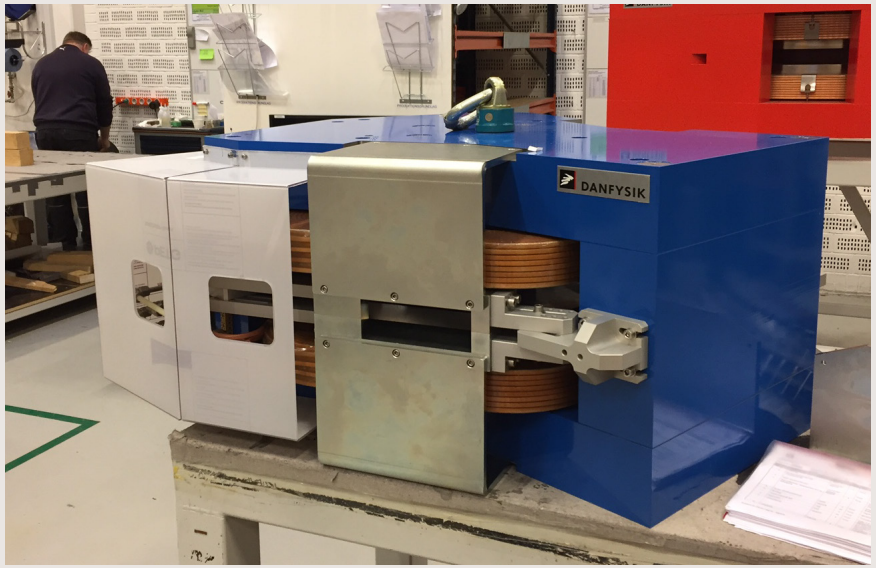


beam envelop for $^{133}Cs^{19+}$ @266 keV
(A/Q =7@ 2 keV/A)

phase space at mass slit
δE = ±0.25%, δM = ±0.5%

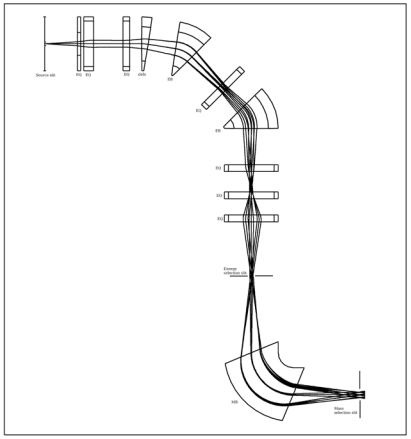
Nier spectrometer magnet





magnet assembly and testing at manufacturer
delivery to TRIUMF in February 2017

Nier spectrometer and beam lines



Nier spectrometer optics

- optics lay out for Nier spectrometer done
- will use standard ARIEL RIB beam transport elements
- electrostatic elements in front of EBIS to be switched
- matching of RFQ beam to pulsed drift tube and EBIS to be finalized

CANREB schedule

HRS	• magnet delivery to TRIUMF	April 2017
	• magnet tested (field mapping)	January 2018
	• Installation finished	June 2018
RFQ	• parts ready for installation	May 2017
	• installation finished	April 2018
EBIS	• shipment to TRIUMF	September 2017
	• installation finished	May 2017
Nier spectr beam lines	• magnet delivery to TRIUMF	February 2017
	• installation finished	June 2018
Commissioning	• with stable beam (CFI deliverable)	July to October 2018
	• with beam from ISAC	2019

TRIUMF

Canada's national laboratory for particle and nuclear physics
Laboratoire national canadien pour la recherche en physique nucléaire
et en physique des particules

Thank you!
Merci

F.A., Rick Baartman, Carla Barquest, Brad Barquest, Michael Blessenohl, George Clark, Jose Crespo, Jens Dilling, Stepan Dobrodoy, Leigh Graham, Renate Hubele, Rituparna Kanungo, Reiner Kruecken, Jim Maloney, Marco Marchetto, Norman Muller, Matt Pearson, Mike Rowe, Suresh Saminathan, Brad Schultz, David Wager

+ TRIUMF service groups

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