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The RF H^- Ion Source Project at RAL

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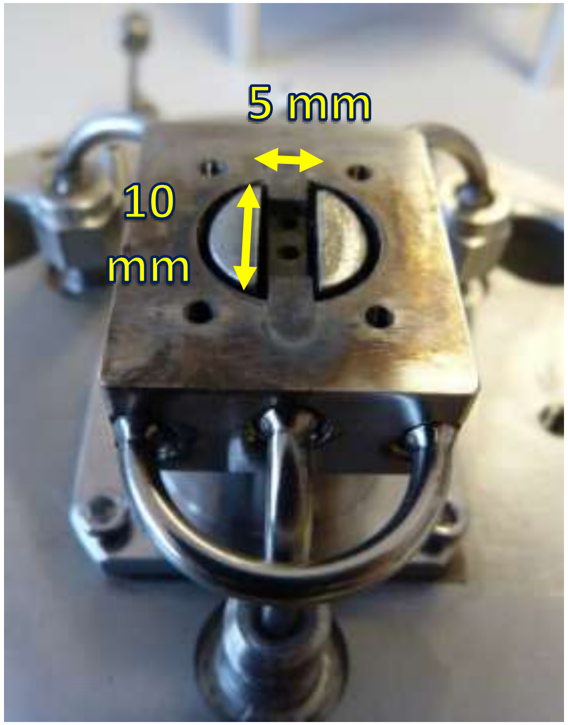
NIBS 2018, Novosibirsk Akademgorodok

Outline

- The Penning-type surface-plasma ion source at RAL
- MEBT upgrade
- Physics design of the RAL RF source
  - Magnetic field
  - Extraction
  - RF system
  - Plasma ignition

ISIS Penning ion source



55 mA of H^- current with a 1.5 % duty factor at 50 Hz (300 μs pulses)

Serving ISIS for more than 30 years

Relatively low cost and easy to operate

Requires the usage of Caesium and is fundamentally lifetime limited due to material erosion

Scheduled ion source replacement every 2-3 weeks

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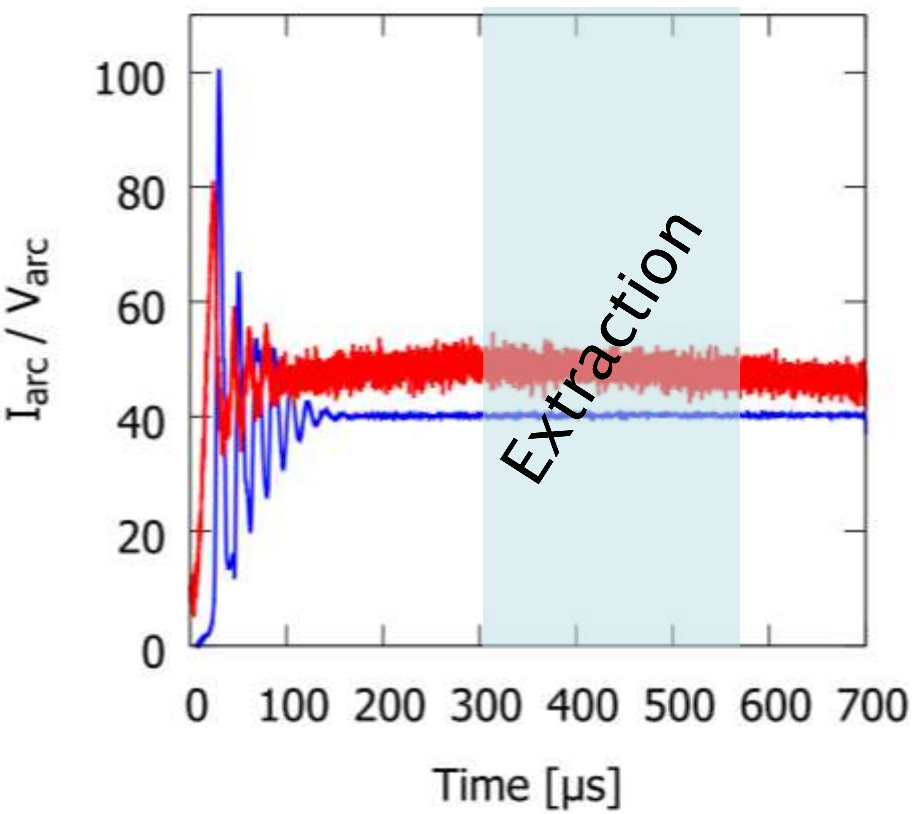
Penning source erosion



Relaxation oscillations, Cs^{2+} ions and backstreaming positive ions cause sputtering of the electrodes

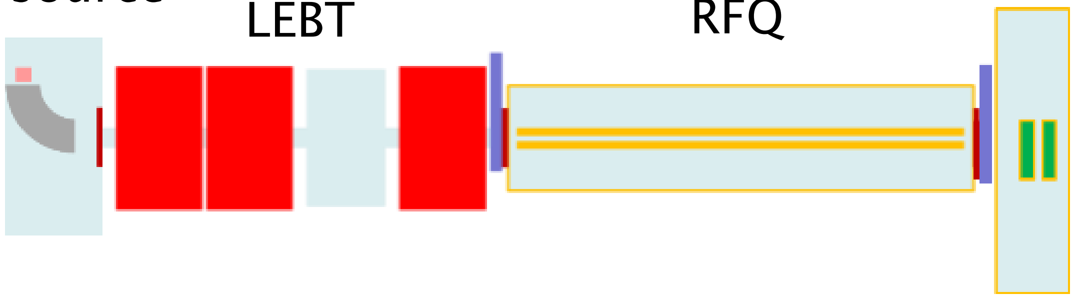
ISIS injector

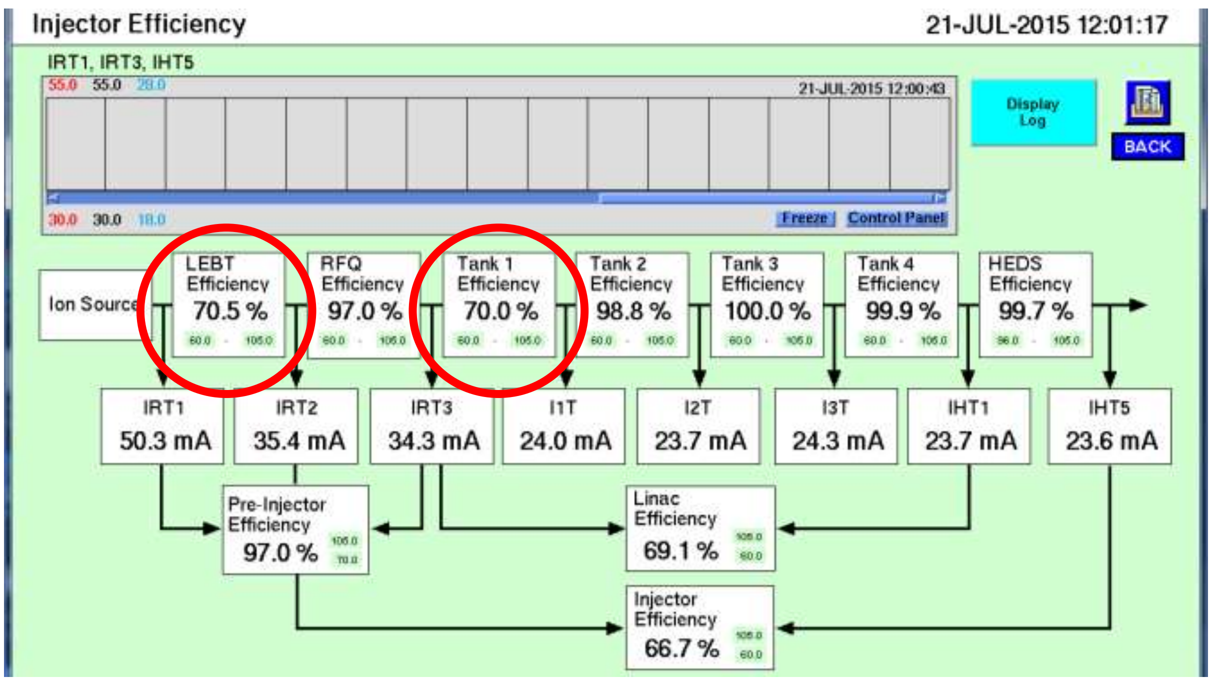
Ion source

LEBT

RFQ

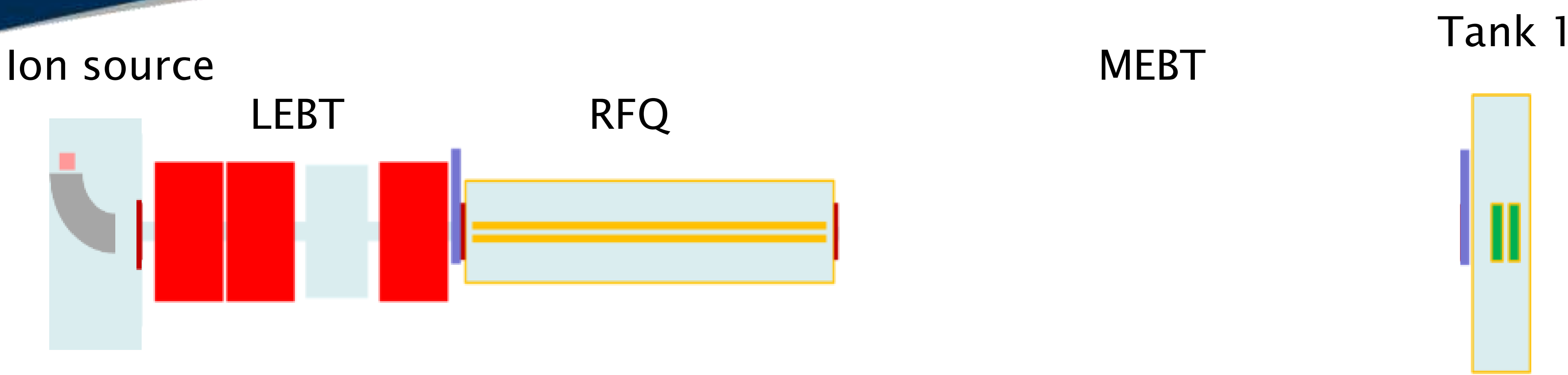
Tank 1 of the drift tube linac





Brute force to match divergent beam with tank 1 acceptance

New layout with the MEBT

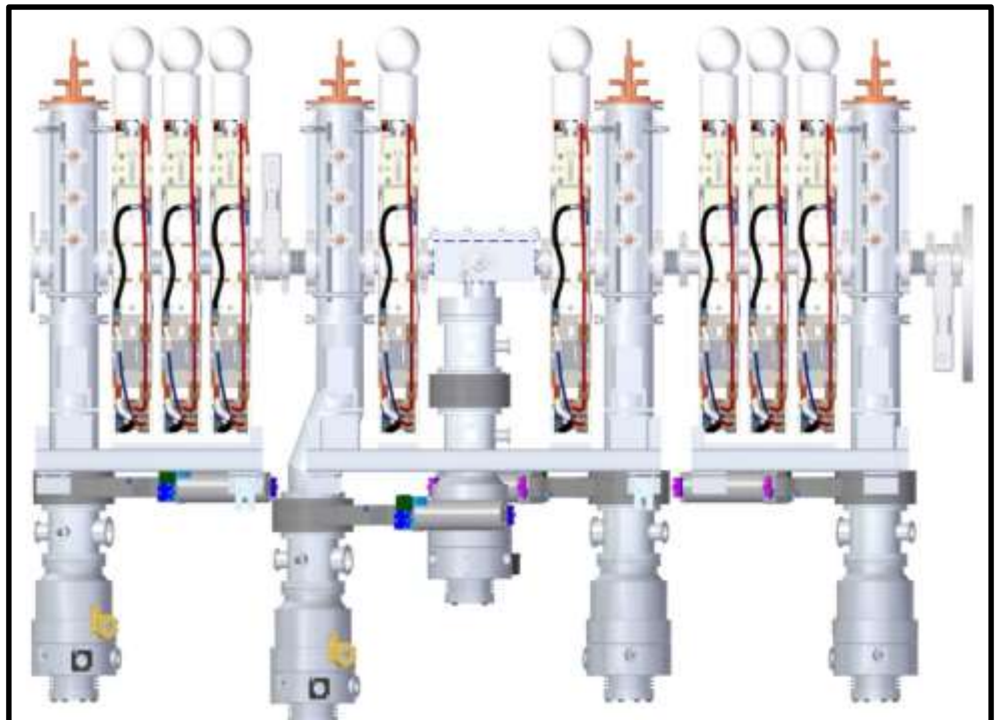


Quarter-wave resonators for longitudinal focusing

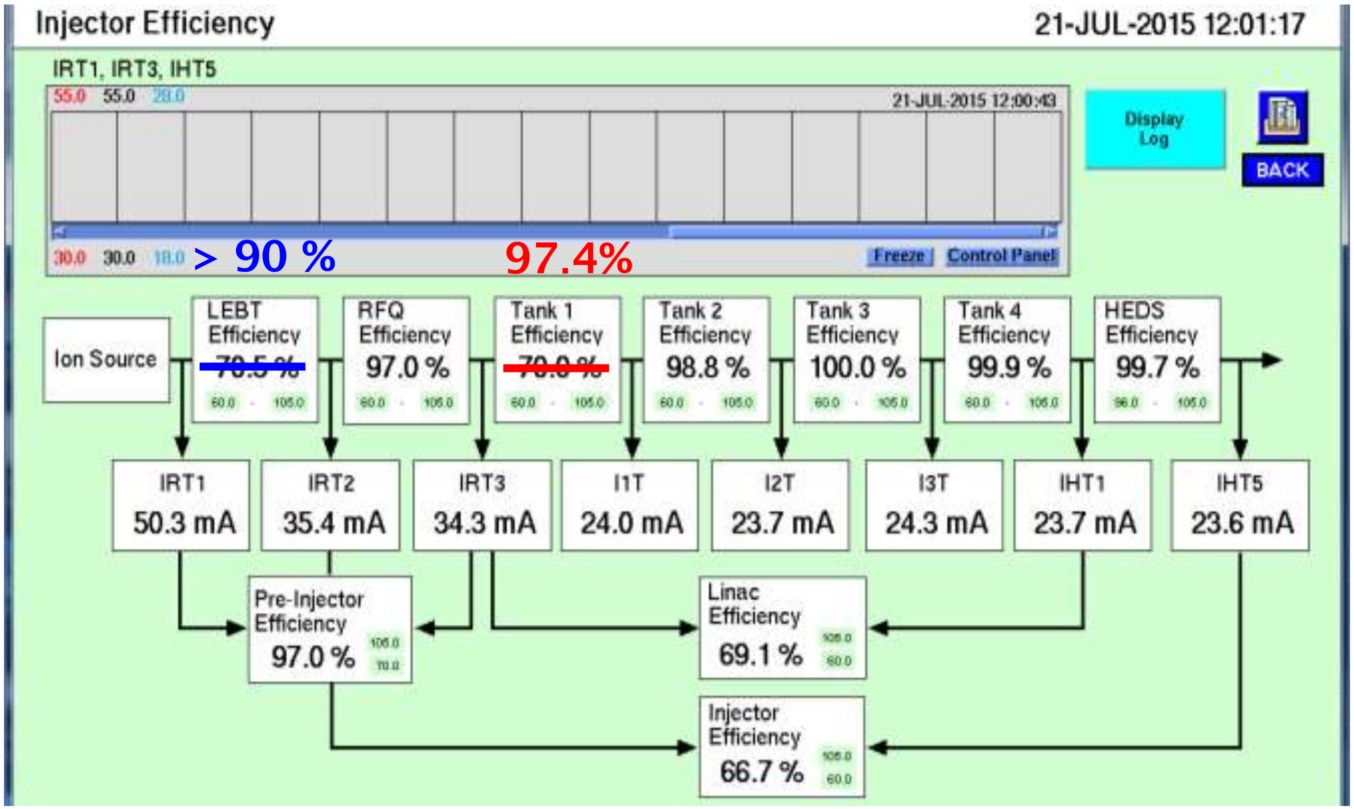
Quadrupole magnets for transverse focusing

Chopper filling the synchrotron RF buckets

Beam losses in tank 1 reduced from 30 % to 2.6 %



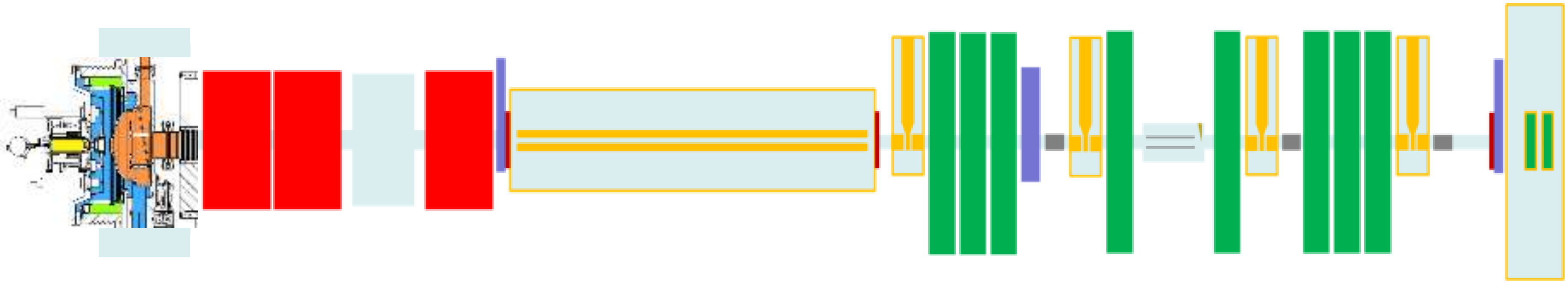
Transport efficiency math



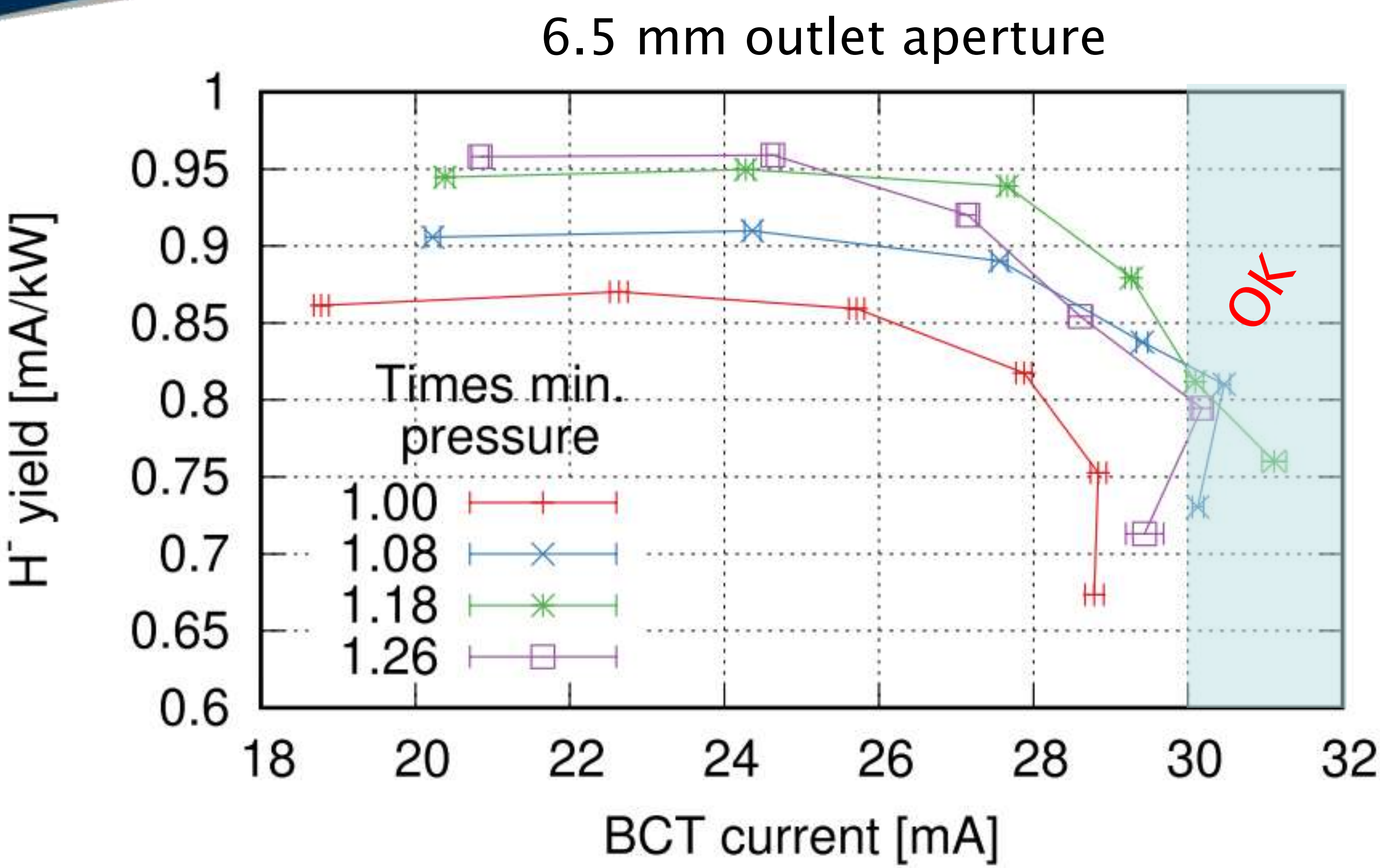
50.3 mA becomes 36.1 mA ...and finally 28.3 mA

Installation of the new MEBT and improvements of the LEBT relax the ion source beam current requirement to 30 mA

This is in the realms of state-of-the-art caesium-free RF ion source technologies

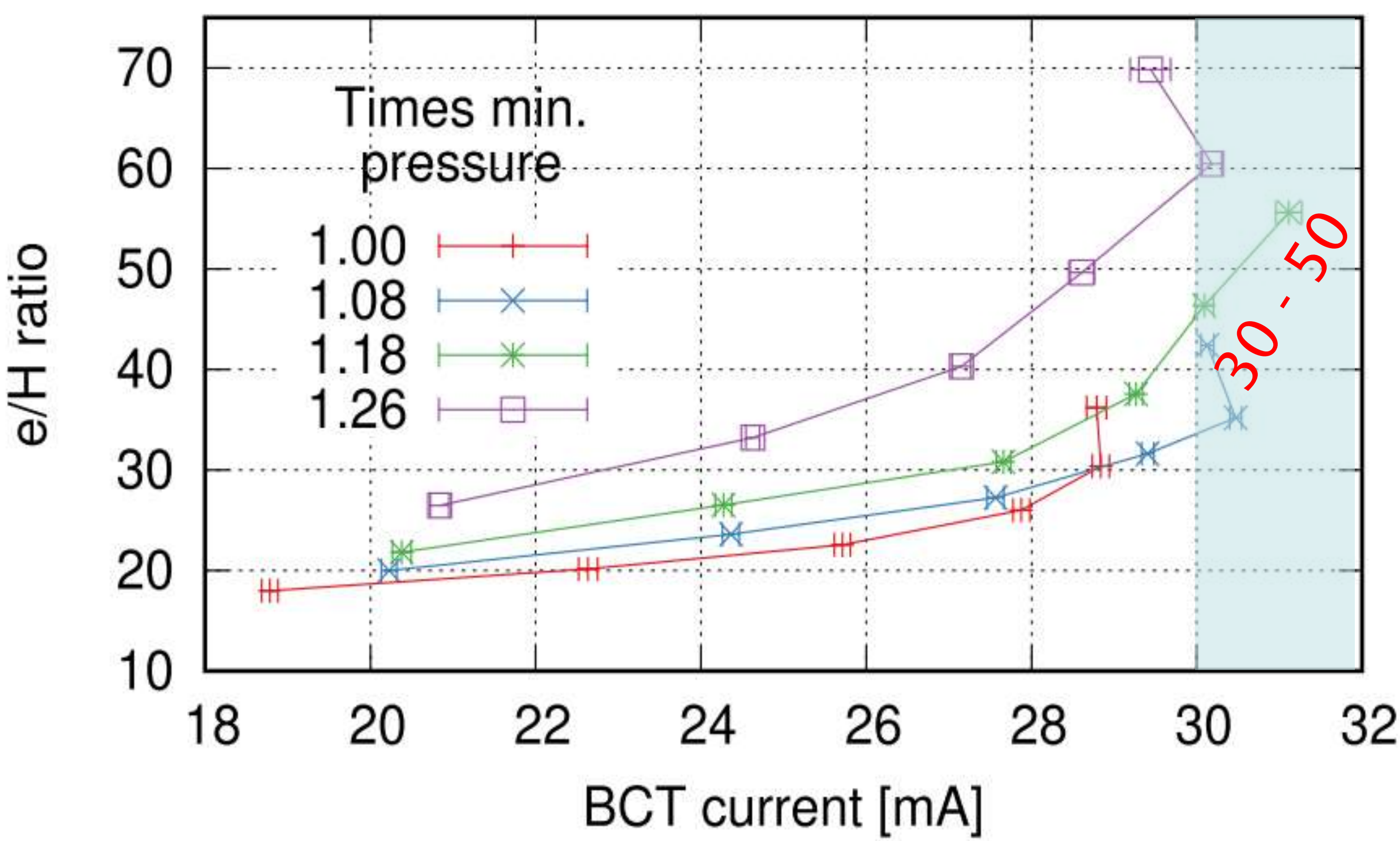


CERN Linac4 ion source – uncaesiated



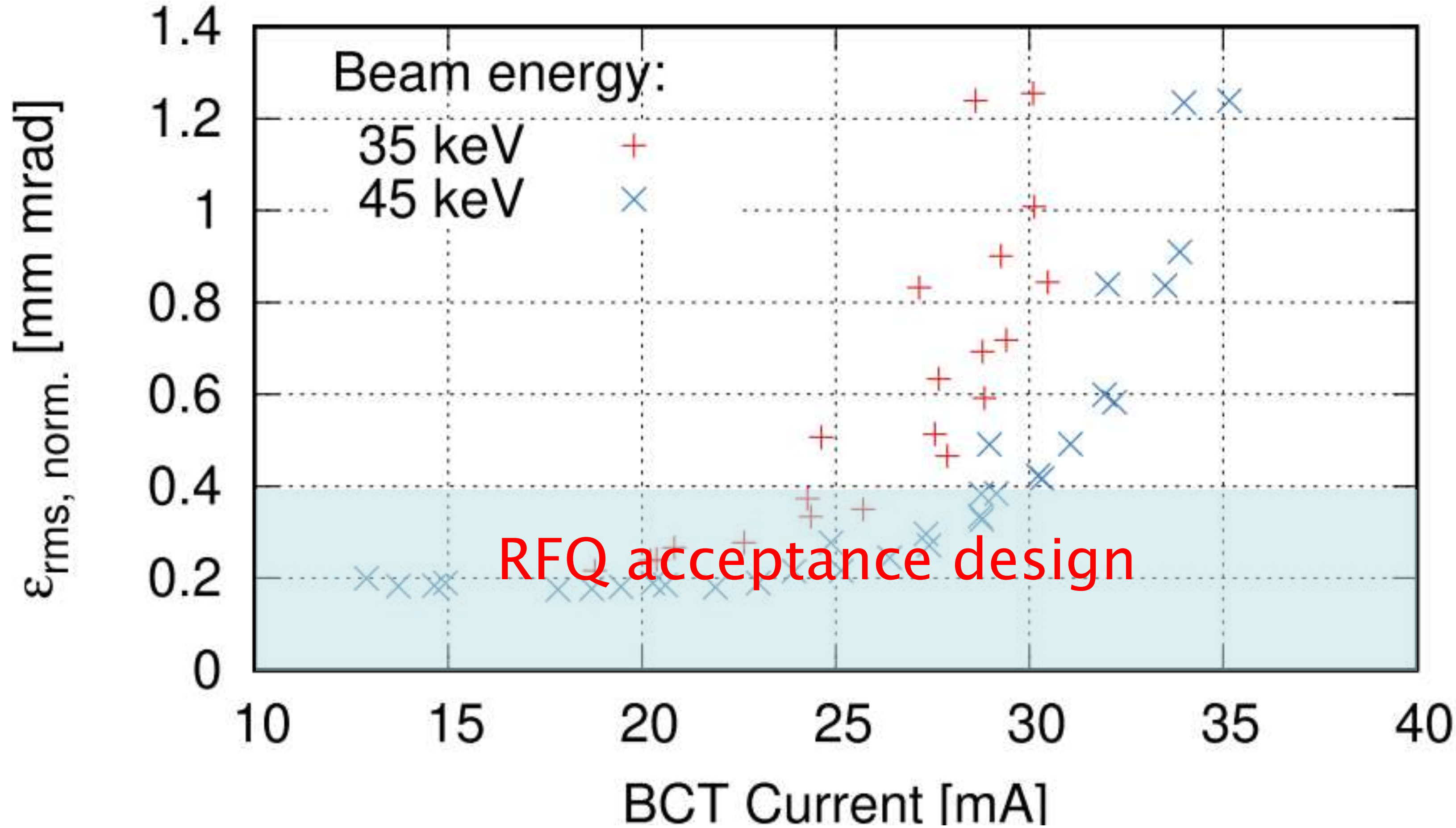
Data by Daniel Noll

CERN Linac4 ion source – uncaesiated



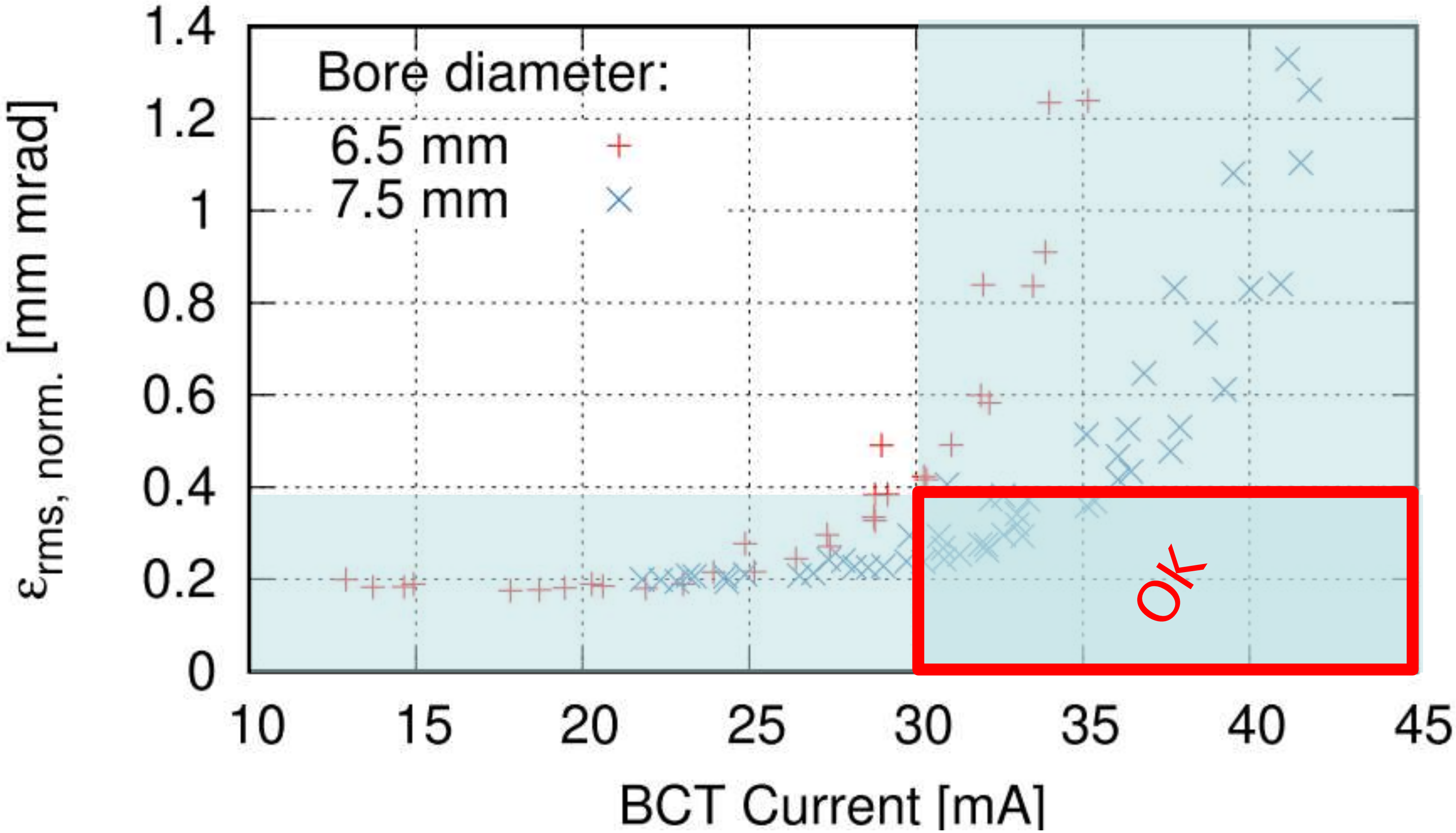
Data by Daniel Noll

CERN Linac4 ion source – uncaesiated



Data by Daniel Noll

CERN Linac4 ion source – uncaesiated



Data by Daniel Noll

RAL RF ion source project statement

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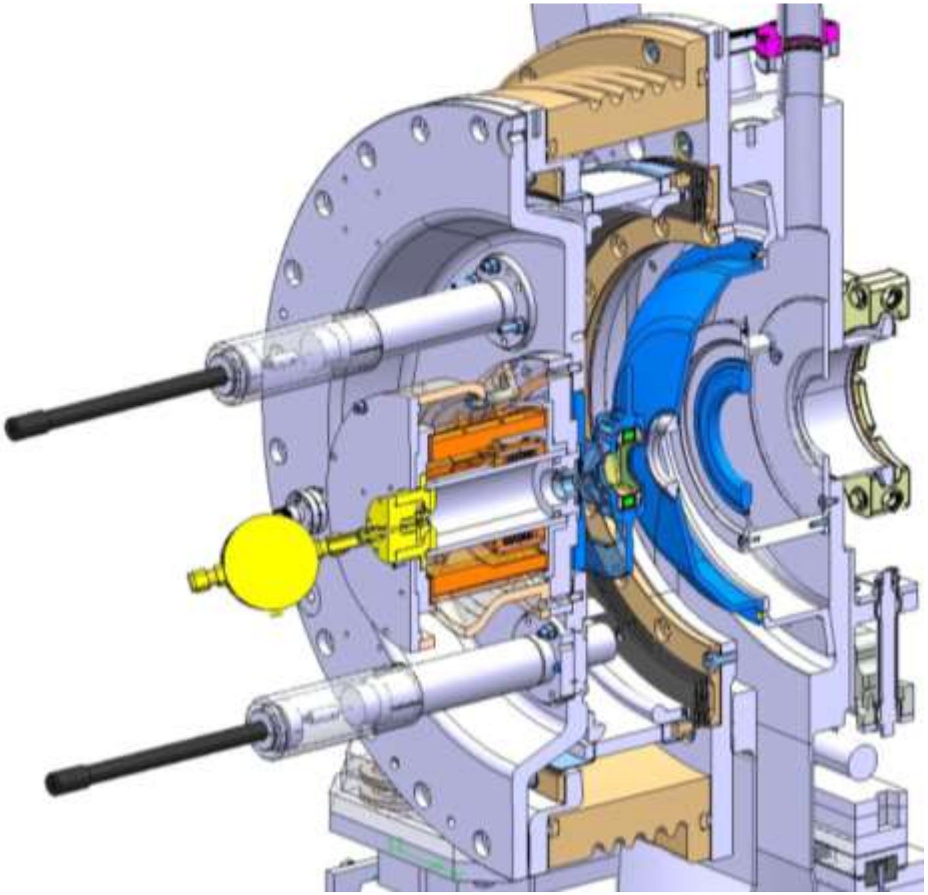
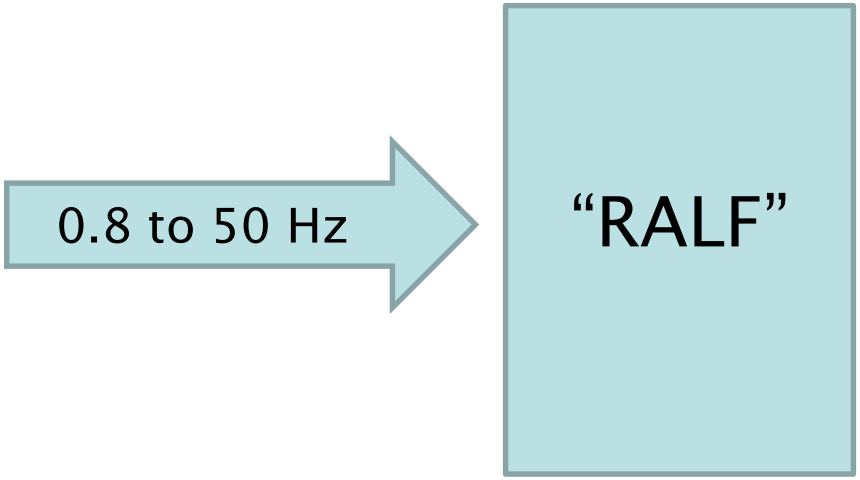
The goal of the project is to develop a long lifetime caesium free 30 mA RF H- ion source operating at 50 Hz pulse repetition rate, allowing unbroken neutron user cycles and increasing overall machine availability at ISIS

RAL RF ion source physics design

CERN Linac4 ion source



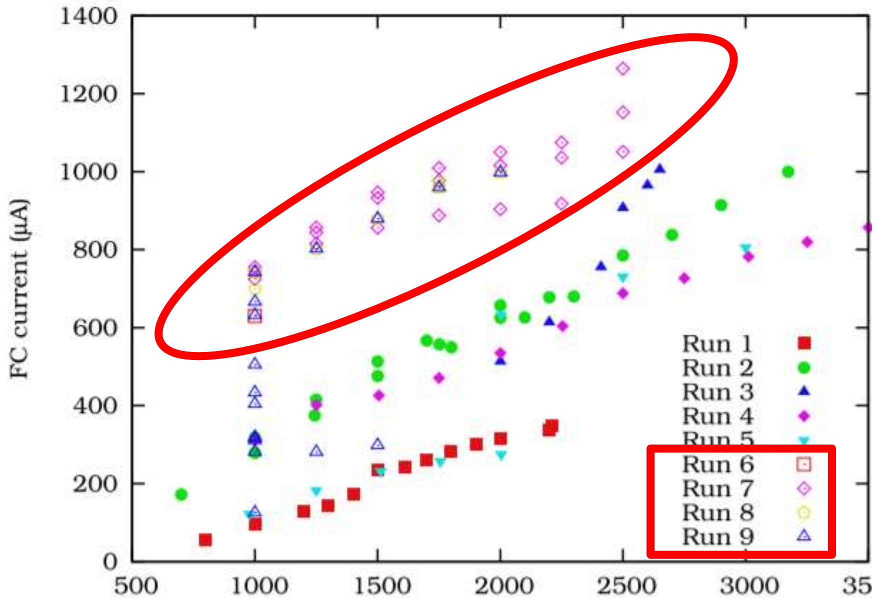


Magnetic field

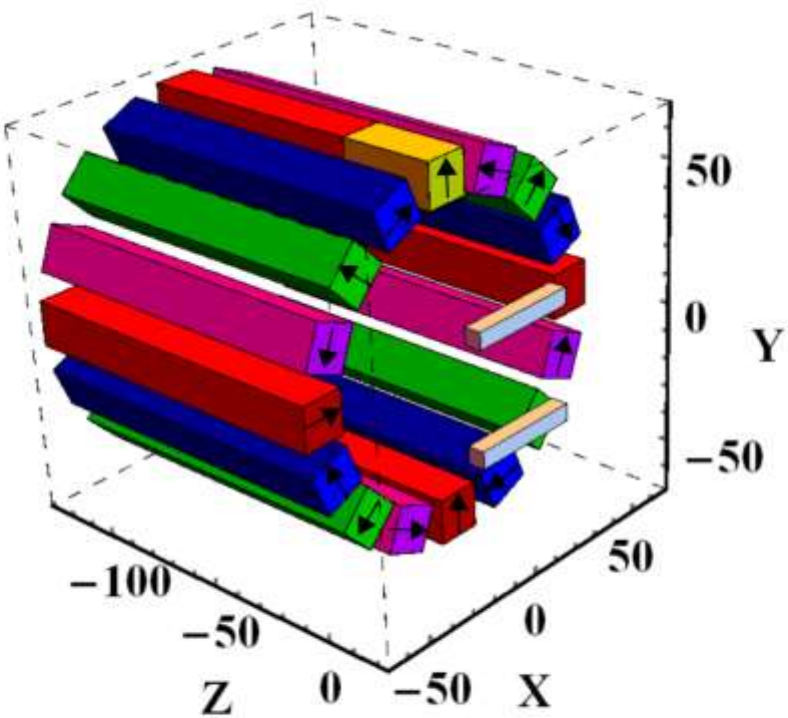
Power efficiency improvements with the radio frequency H− ion source

T. Kalvas, O. Tarvainen, J. Komppula, H. Koivisto, J. Tuunanen, D. Potkins, T. Stewart, and M. Dehnel

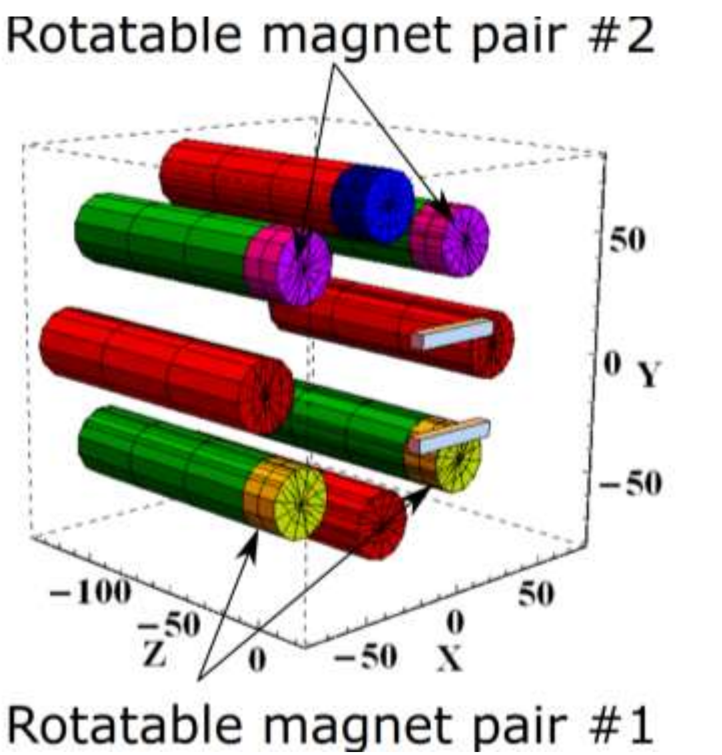
Citation: Review of Scientific Instruments **87**, 02B102 (2016); doi: 10.1063/1.4932008



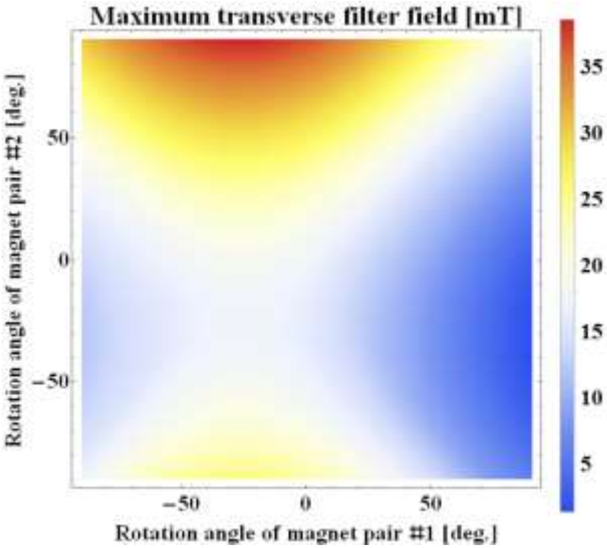
Magnetic field

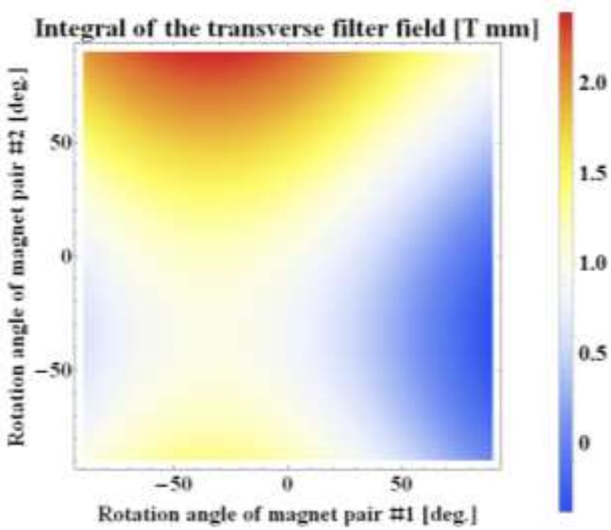


Magnetic field



Magnetic field

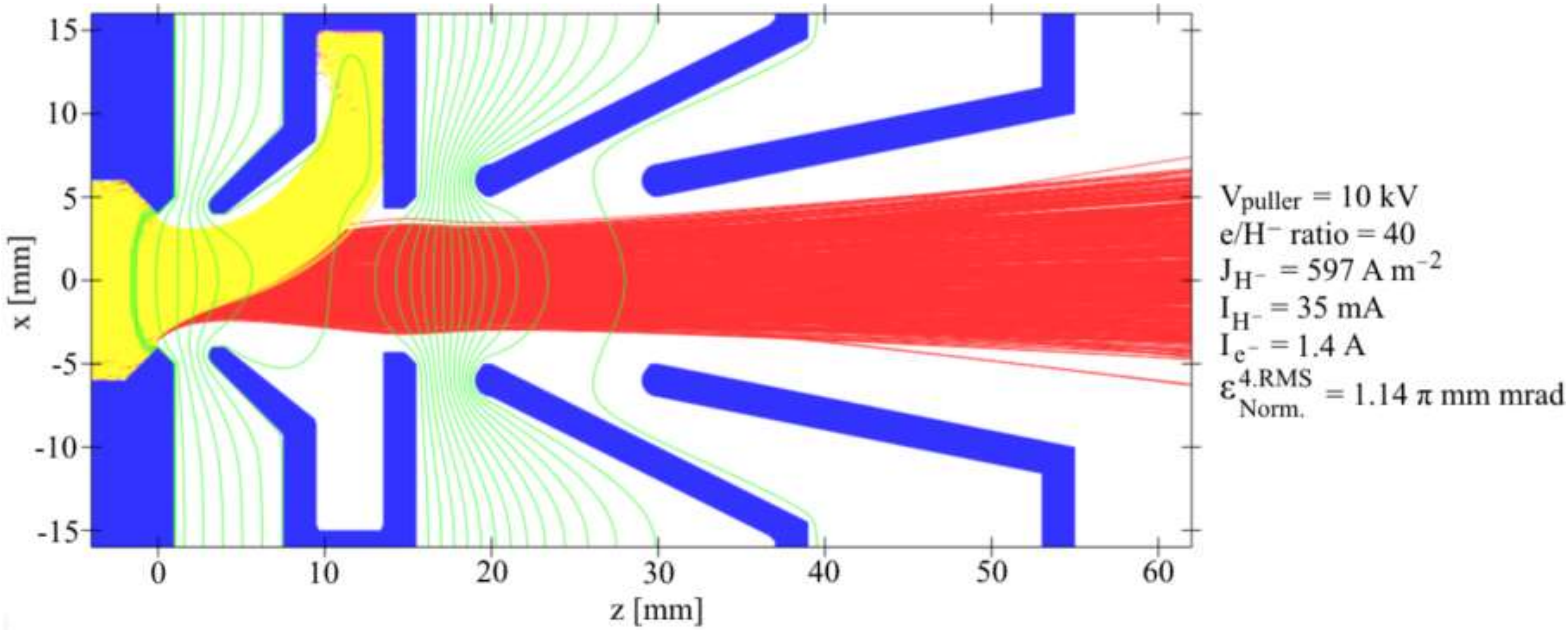




Extraction

Co-extracted electrons dumped into the puller electrode

No Einzel lens – diverging beam into two solenoid LEBT



IBSimu simulations by Scott Lawrie

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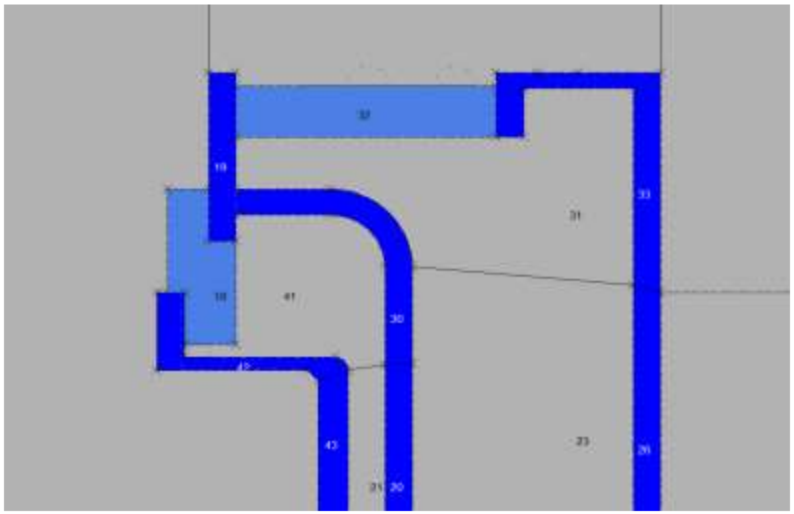
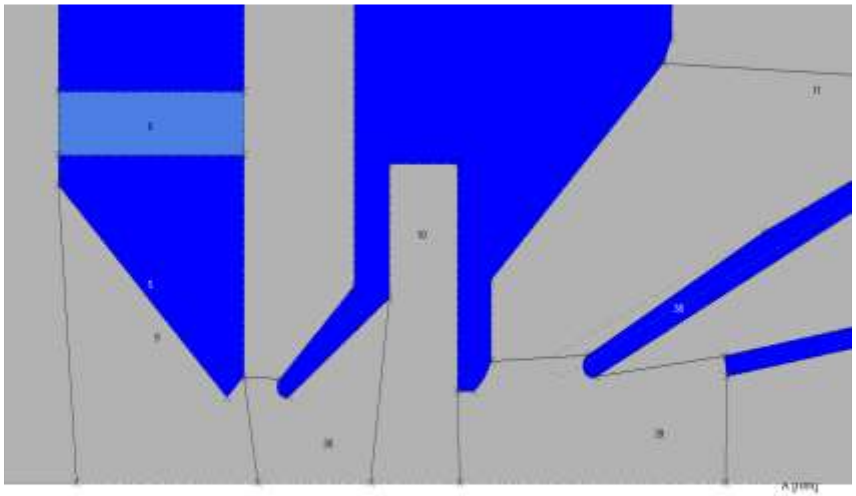
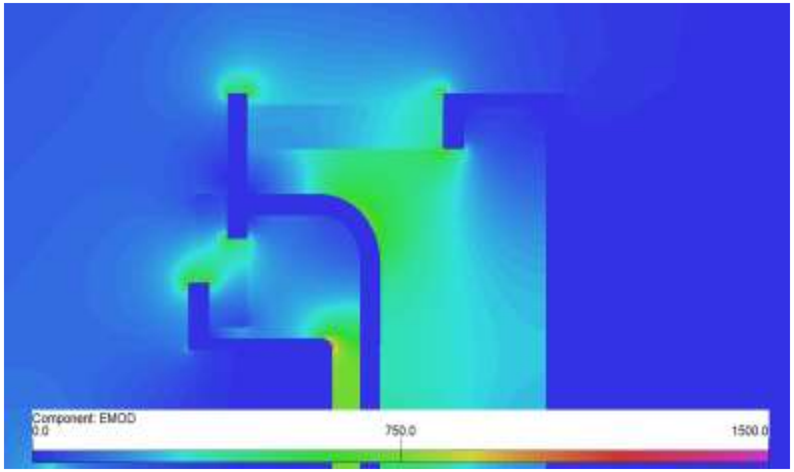
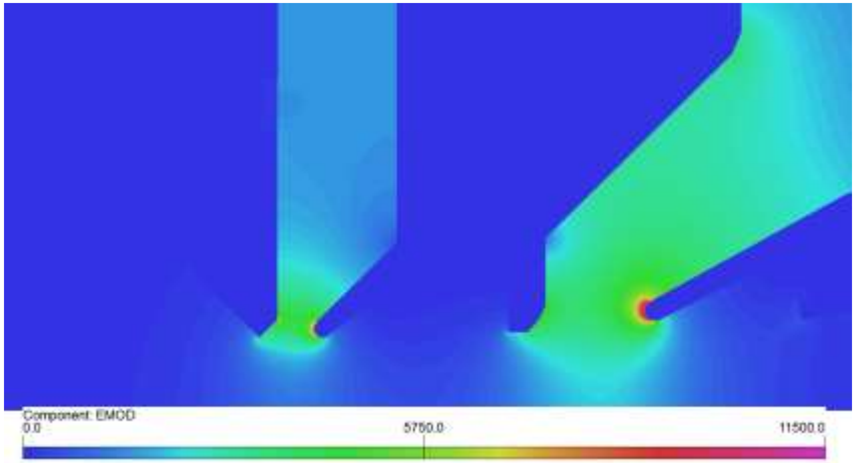
Extraction





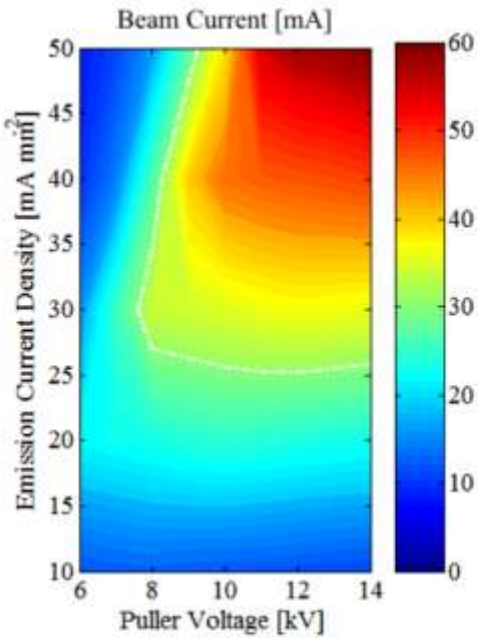




OPERA simulations by Dan Faircloth

Extraction

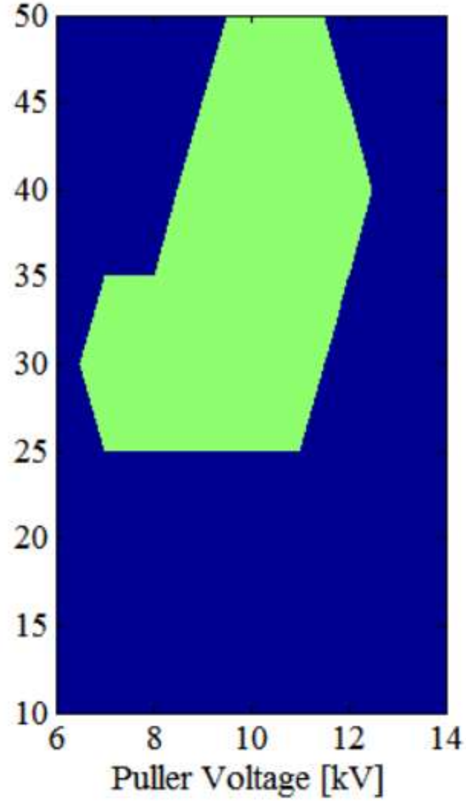
e/H^- -ratio set to 30



> 30 mA

IBSimu simulations by Scott Lawrie

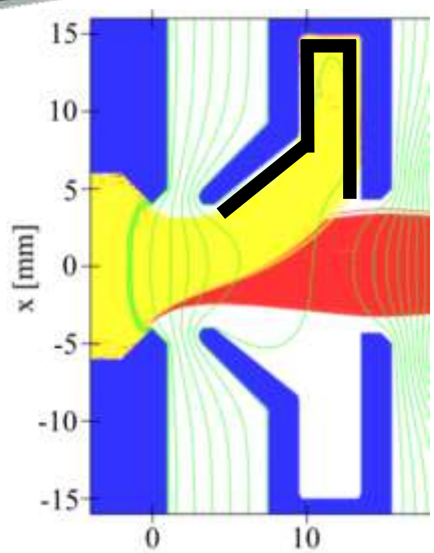
Island of operation

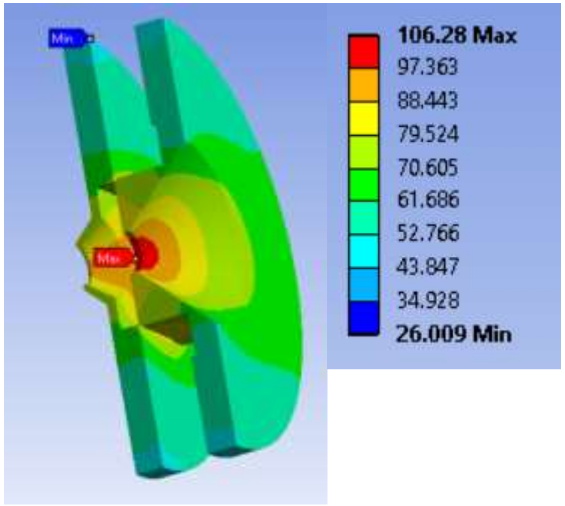


(b) 16 mT

IBSimu simulations by Scott Lawrie

Extraction



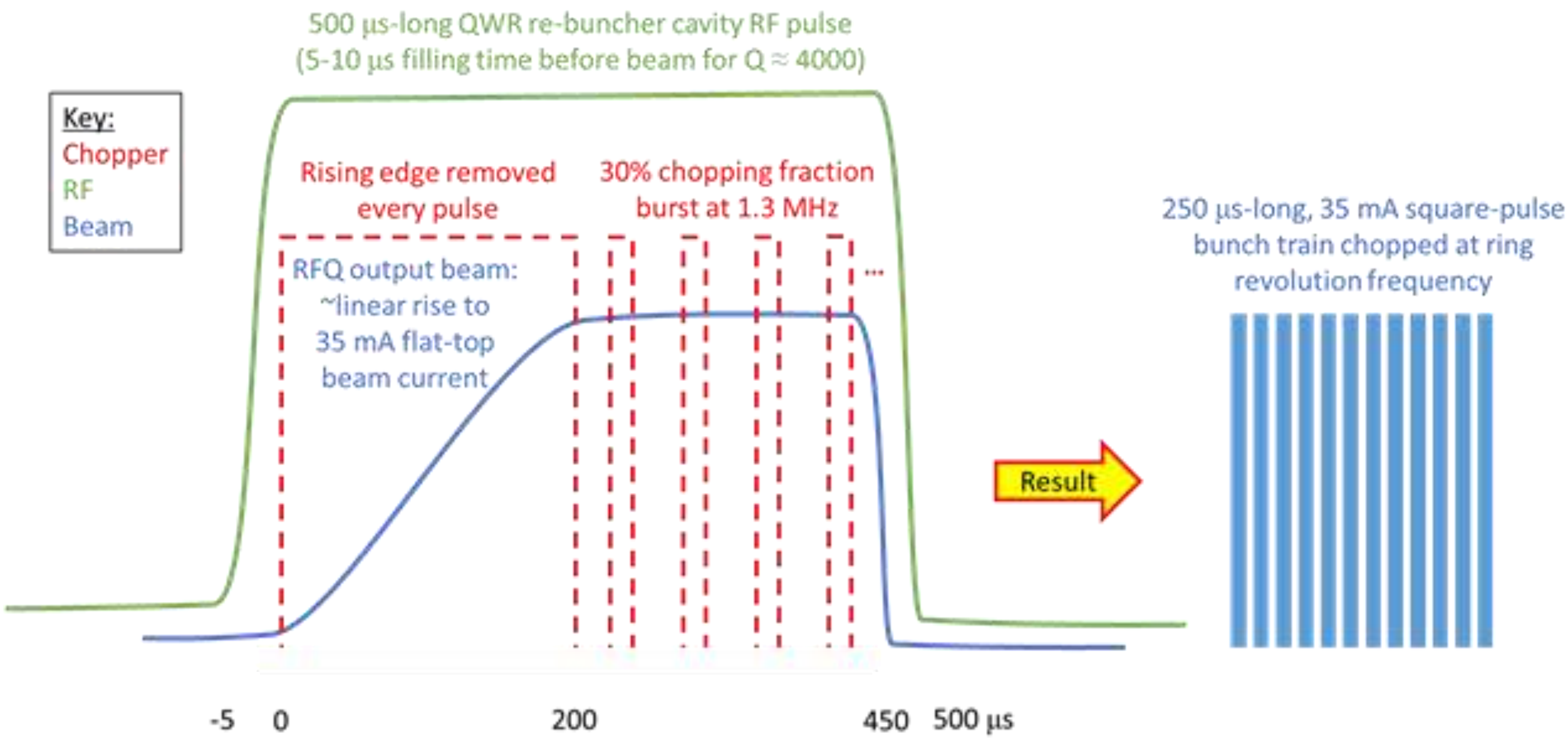


The average power depends on the extraction pulse length

... which is determined by the space charge compensation time

IBSimu simulations by Scott Lawrie

Space charge compensation



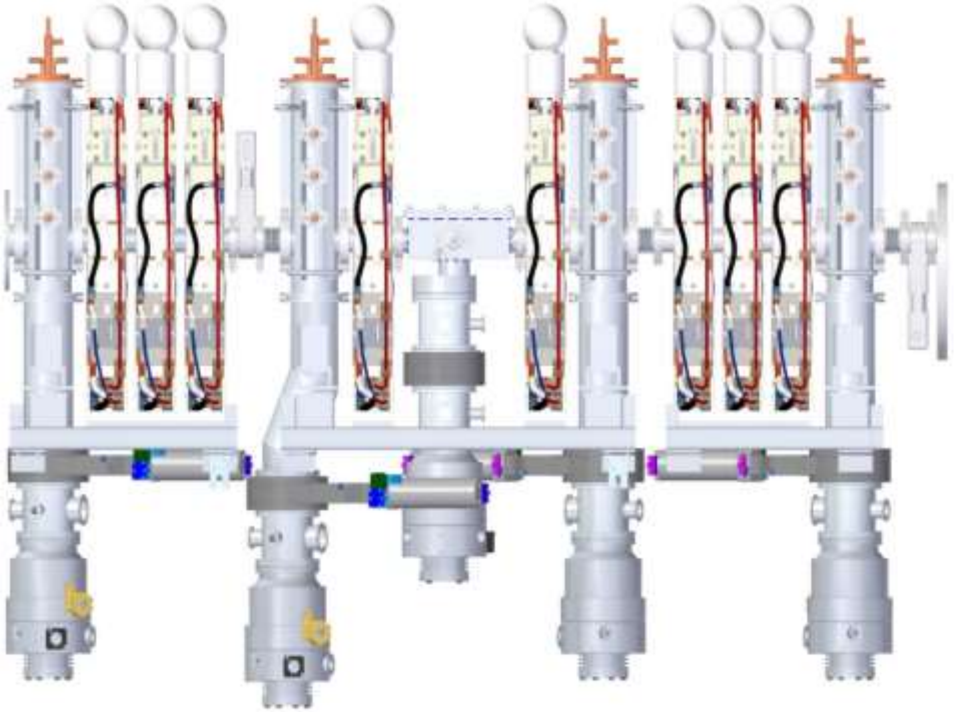
The slope depends on the beamline pressure

How to deal with the "unknown" pulse length?

Space charge compensation

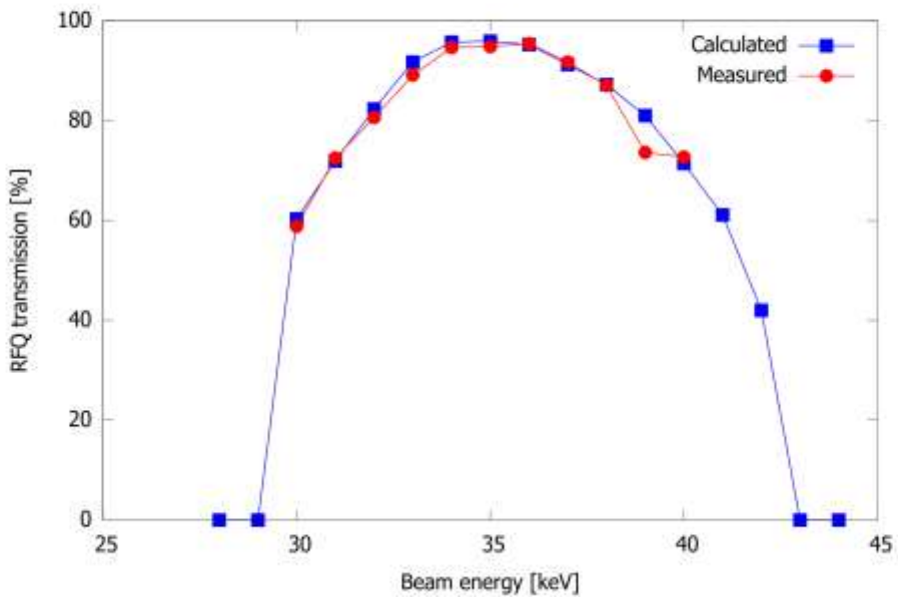
Increase the cooling capacity of the MEBT and/or trust that the LEBT setting mismatch reduces the pulse length out of the RFQ

Cooling!



Space charge compensation

Energy acceptance of the ISIS RFQ



Data by Alan Letchford

Create the space charge compensation at ~25 keV and then switch the platform voltage to 35 kV to reduce the pulse length through the RFQ?

Space charge compensation

Typical LEBT consists of two solenoids

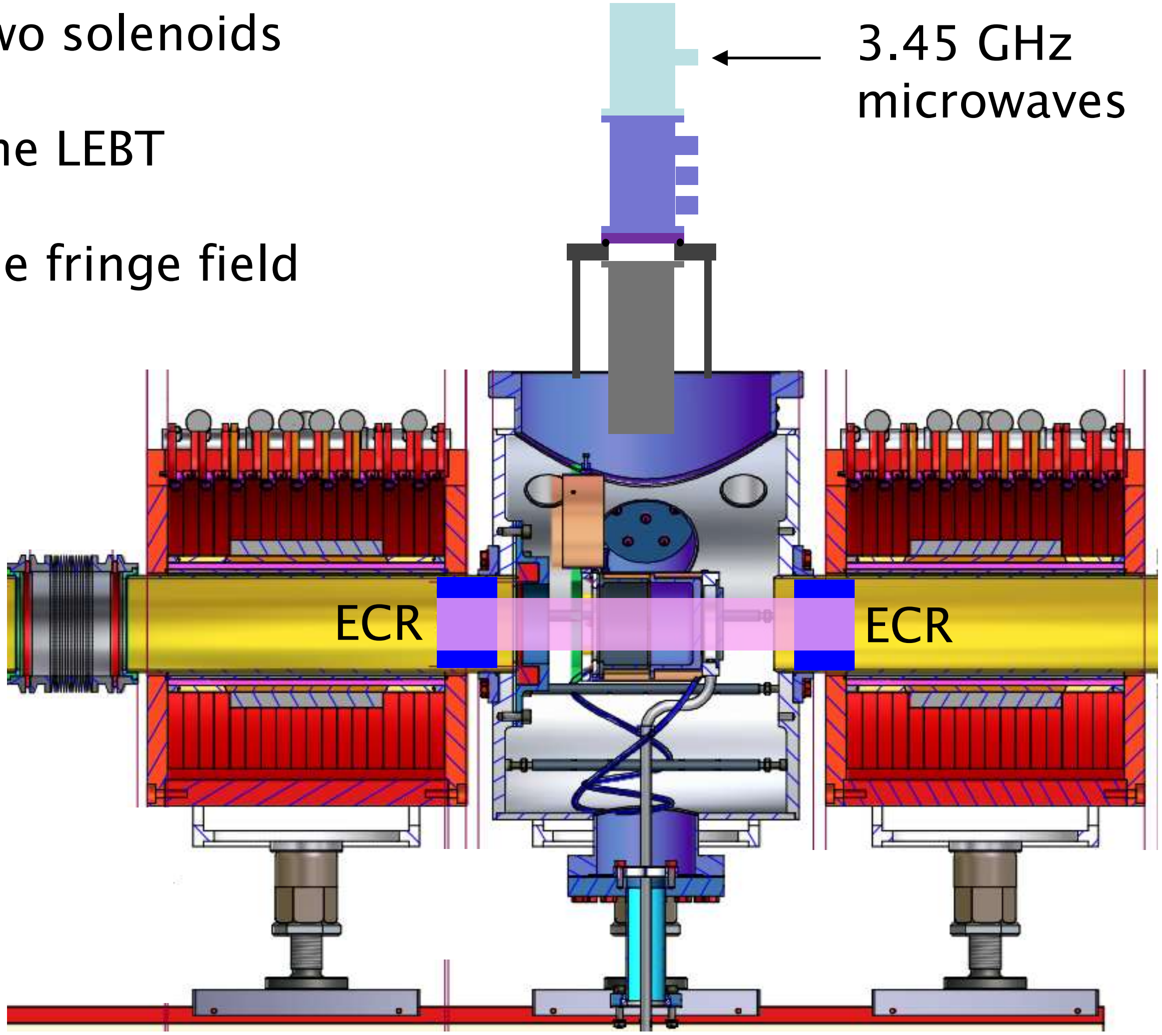
Launch microwaves into the LEBT

Ignite an ECR plasma in the fringe field of the solenoid(s)?

Reduce SCC time?

Reduce pulse length?

Experiment at FETS in October - December

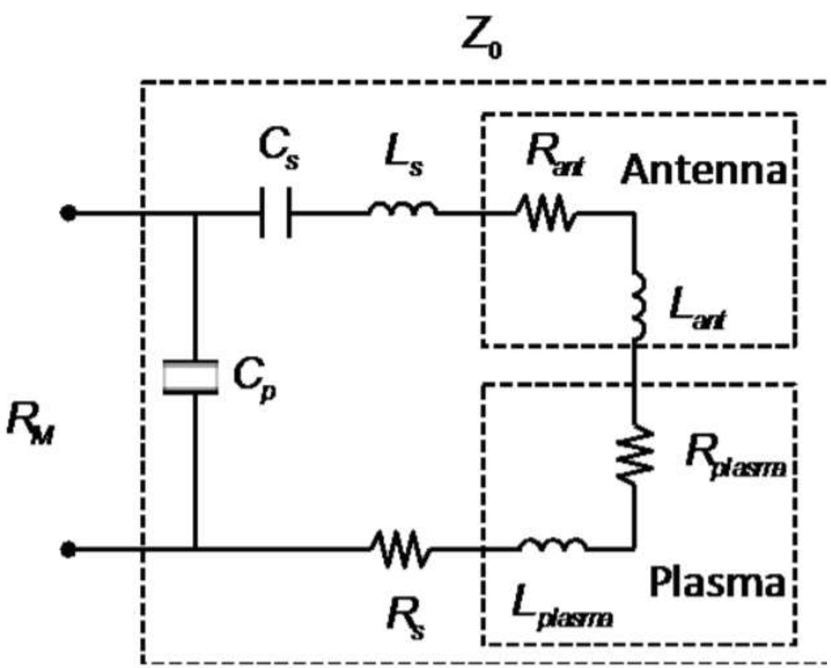


RF system

RF low-level control for the Linac4 H⁻ source

A. Butterworth, A. Grudiev, J. Lettry, K. Nishida, M. Paoluzzi, and C. Schmitzer

Citation: AIP Conference Proceedings **1655**, 030007 (2015); doi: 10.1063/1.4916434



Tendering process initiated for

2 MHz

100 kW

solid state

RF amplifier preferably with

“hot swappable” modules

Plasma ignition

Optimizing the ion source pressure for reliable plasma ignition and H^- production at high repetition rate requires an ignition method

Recent Performance of and Plasma Outage Studies with the SNS H^- Source[a)]

M.P. Stockli[b)], B. Han, S.N. Murray, T.R. Pennisi, C. Piller, M. Santana, R. Welton

Spallation Neutron Source, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830, USA

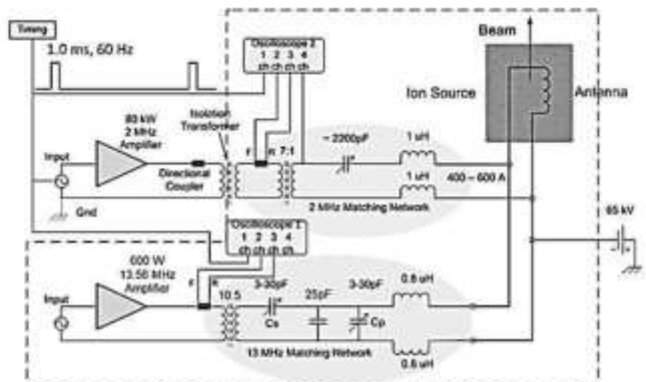


FIG. 4. The 2 and the 13 MHz RF systems powering the plasma antenna.

Status of the plasma generator of the superconducting proton linac[a)]

M. Kronberger,[1,b)] D. Faircloth,[2] J. Lettry,[1] M. Paoluzzi,[1] H. Pereira,[1] J. Sanchez Arias,[1] C. Schmitzer,[1] and R. Scrivens[1]

[1]*European Organization for Nuclear Research, CERN, 1211 Geneva 23, Switzerland*
[2]*STFC, Rutherford Appleton Laboratory, Chilton, Oxon OX11 0QX, United Kingdom*

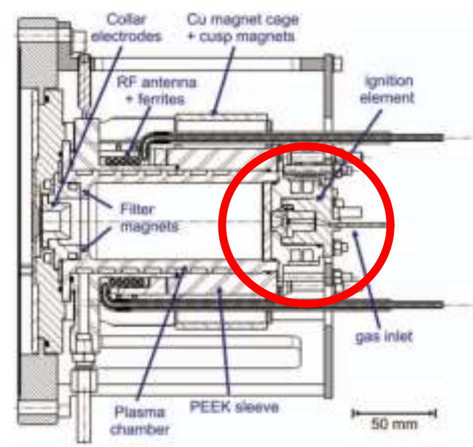


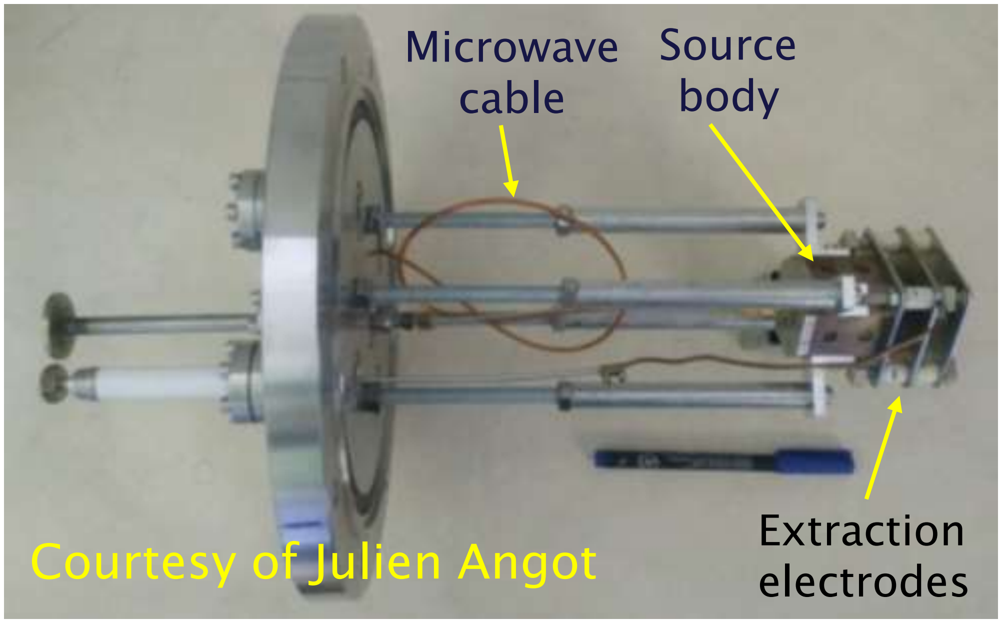
FIG. 1. (Color online) View of the SPL plasma generator (version 09/2011).

Arc discharge
"Spark Plug"

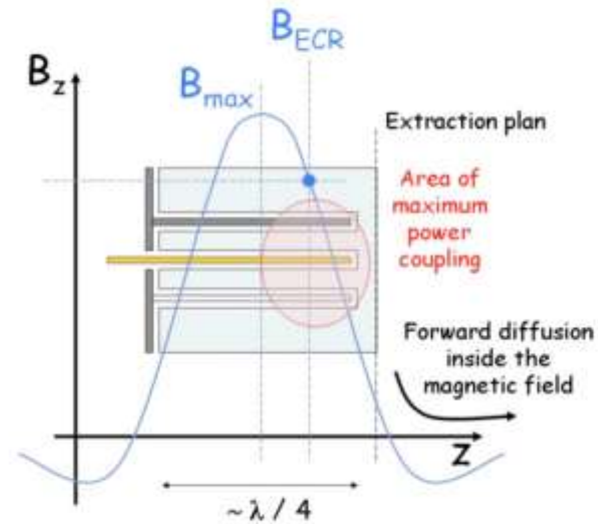
Plasma ignition

The COMIC ion source

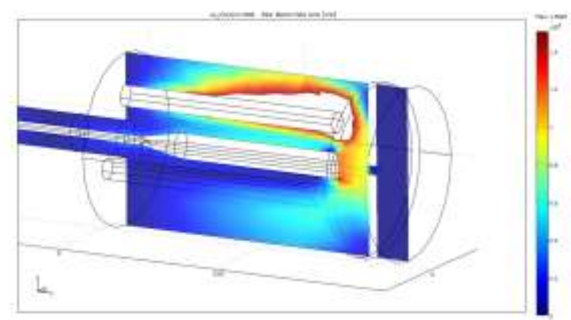
COmpact MIcrowave and Coaxial – P. SORTAIS – LPSC



Axial magnetic field in the cavity



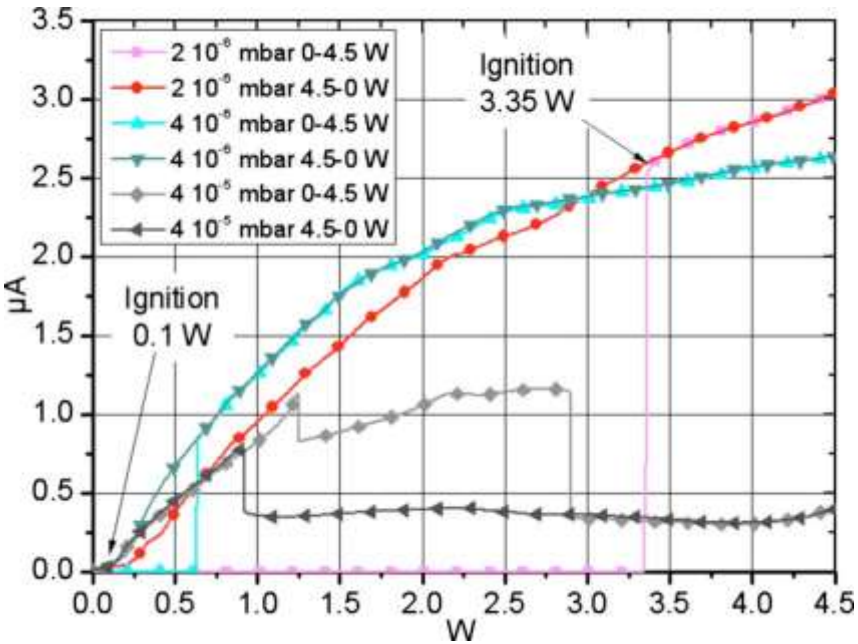
- Compact 2.45 GHz ECR ion source
- Magnetic field created with permanent magnets
- Strong microwave electric field at low power < 20W



Electric field amplitude

Plasma ignition

1 μA of Ar^+ with 1 W power
(20 kV, 0.3 mm aperture)



Experiments at LPSC scheduled in October 2018 to determine the power, pressure and geometry for the RAL RF ion source COMIC igniter

Courtesy of Julien Angot

RF ion source project status

Project officially approved by ISIS Management Committee in April 2018

Engineering effort based on the physics design is ongoing

Space reserved for a complete injector test stand in new laboratory building (May 2018)

Thank You!

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 665593 awarded to the Science and Technology Facilities Council.