Options for Joint Developments

TRIUMF – CERN

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GUI
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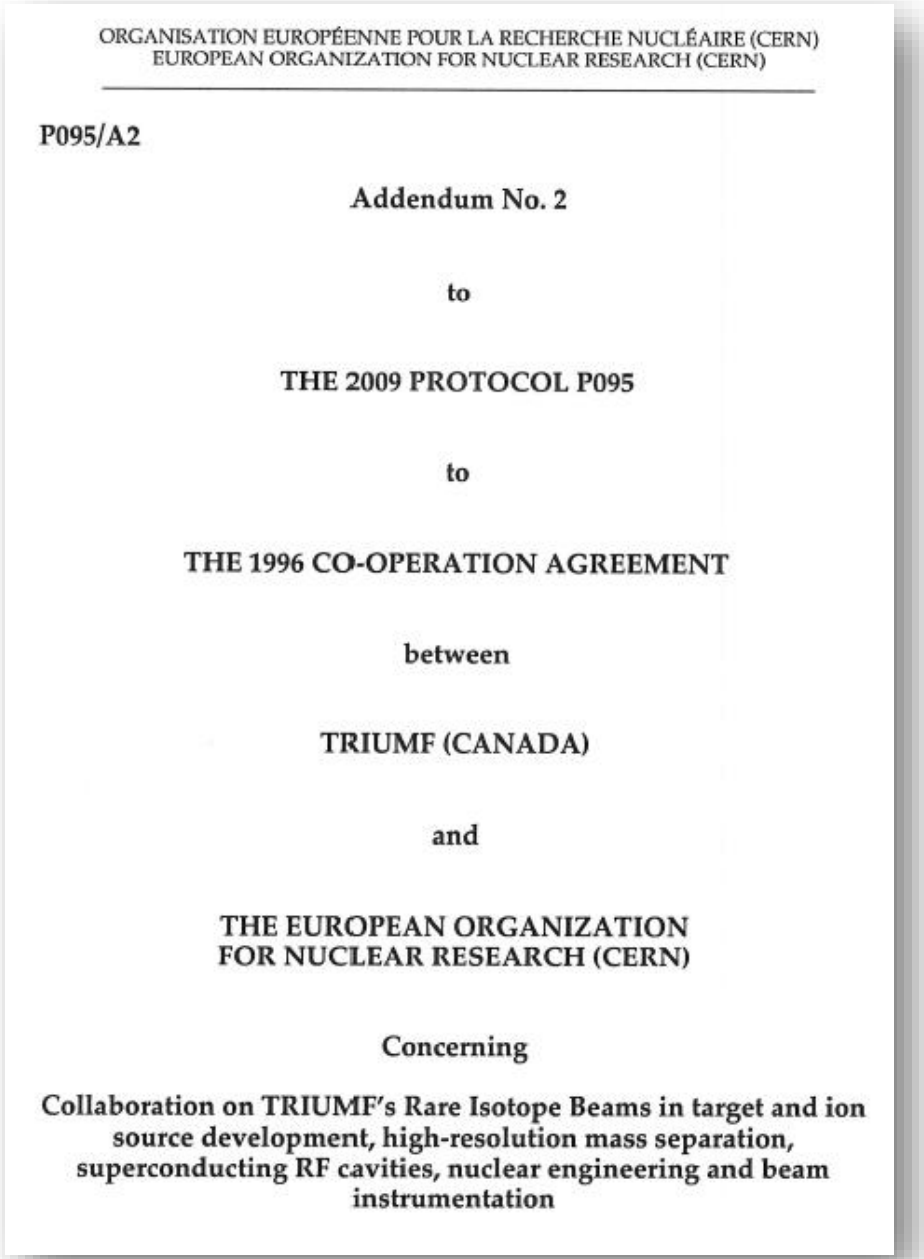
Areas of collaborations as defined by P095/A2:

- Operational experience
- Target material synthesis and development
- Ion source and transfer line development
- Target station infrastructure
- Remote handling

- Proton-to-neutron converter and online beamtime
- Ion optical extraction system
- Hermetic target vessel (vacuum feedthroughs, sealing technology, target oven, heat shields, …)

- Heavy-ion SRF technology (cryomodules, ancillaries, operation and beam diagnostics)



ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE (CERN)
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)

P095/A2

Addendum No. 2

to

THE 2009 PROTOCOL P095

to

THE 1996 CO-OPERATION AGREEMENT

between

TRIUMF (CANADA)

and

THE EUROPEAN ORGANIZATION
FOR NUCLEAR RESEARCH (CERN)

Concerning

Collaboration on TRIUMF's Rare Isotope Beams in target and ion source development, high-resolution mass separation, superconducting RF cavities, nuclear engineering and beam instrumentation

Proposals – Overview

Target Materials
- Nano-fibrous target materials *
- UC_x ramp-up *

Ion Sources
- Multiphysics end-to-end simulations *
- IG-LIS, LIST improvements
- laser ionization scheme development
- Fundamental molecular beam formation studies
- Multi-stage electrostatic ion extraction
- Ion sources operated in cathode bias-mode

Infrastructure and Reliability under Irradiation
- TIS front end development *
- Rad-hard target vessel seals *
- 2400 A aluminum connectors *
- Remote handling (hot cell training, mockups) *
- Removal of water-to-vacuum interfaces
- High-voltage delivery systems (Boris tube)

Novel Target Concepts
- Proton-to-neutron converter *
- High-emissivity coatings *
- Protective TaC coatings *

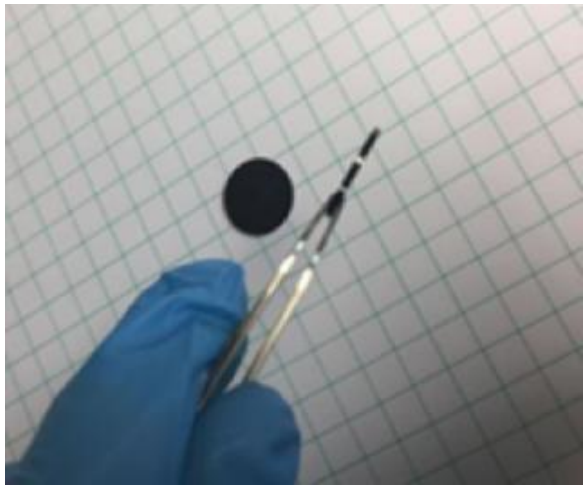
Join offline development capabilities to mitigate overbooking
- Offline separator *
- Thermal test stands
- Chemistry test stands

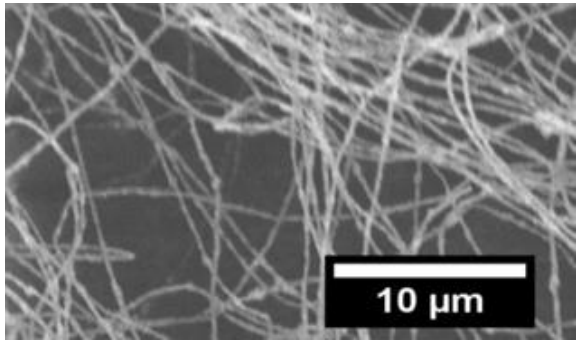
- **Joint access to online test beams during CERN LSX**

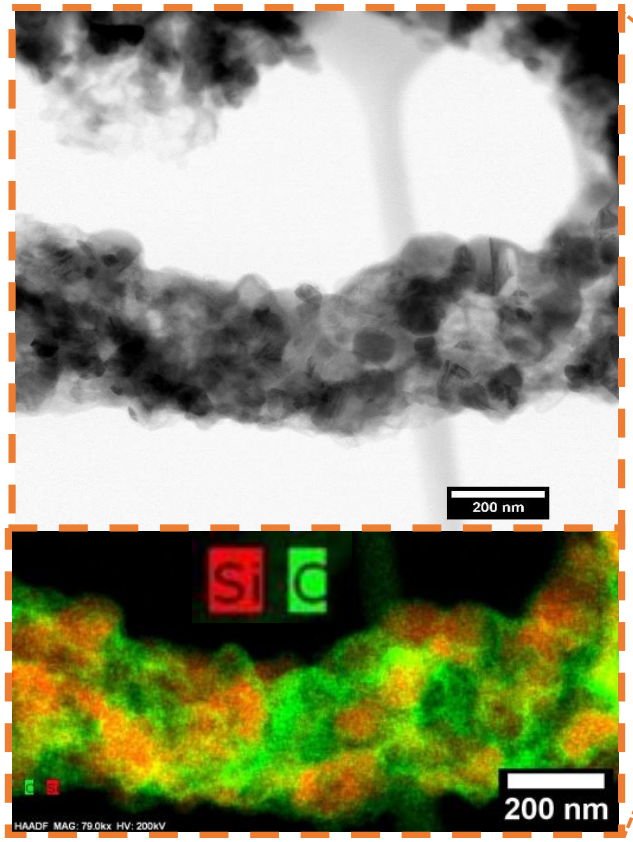
- **Collection of medically or industrially relevant isotopes**

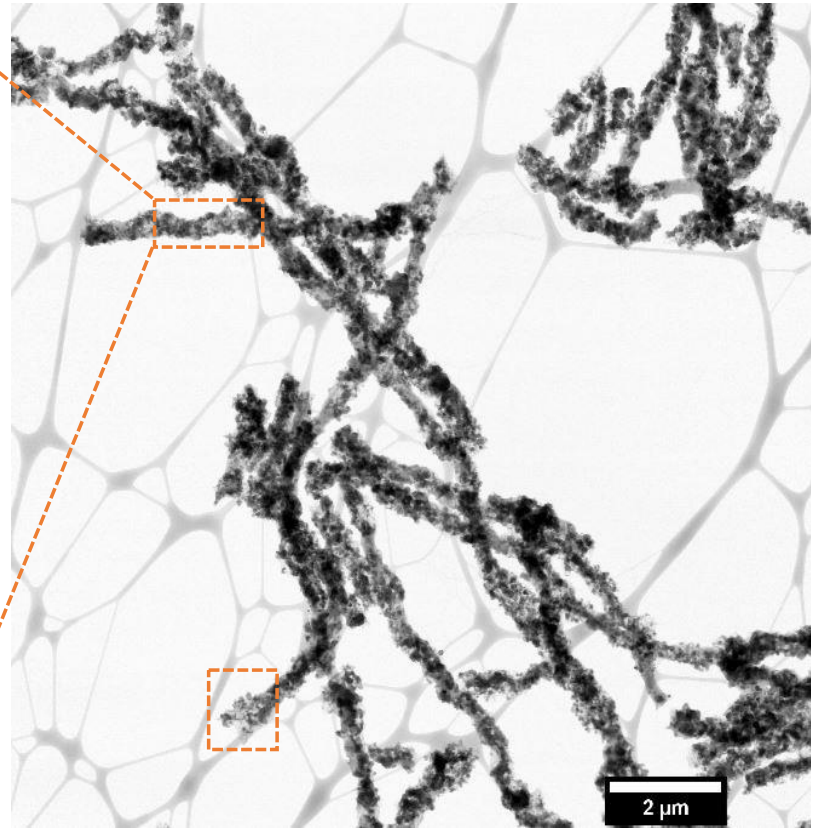
- **Isotope release studies using MEDICIS separator**

Target Materials – SiC Nanofibres









- Offline SiC material development done
- Material production ongoing
- Tests schedule September 25 to October 01

Discovery, accelerated

Target Materials – UC_x Ramp-Up

- **Previous material synthesis:**
  - Two-step production
  - UC_x in direct contact with Ta container
  - Demanding in terms of infrastructure, manpower, schedule
  - 10 weeks per target load
- **New production method:**
  - One-step production
  - Use of graphite intermediate container
  - Less than one week per target load
- **Material development to be concluded**
- **Online Tests in 2018**

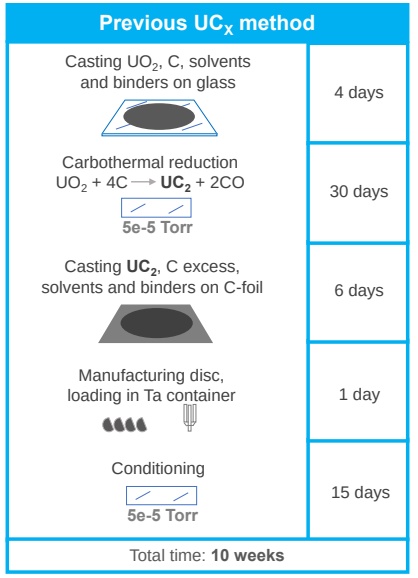


Fig. 3 Previous two-steps UC_x production method [1].

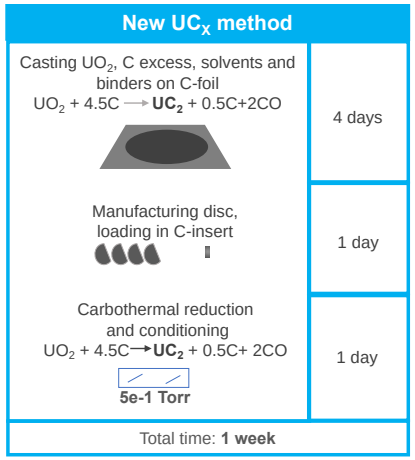


Fig. 4 New one-step UC_x production method, adopted from [2].

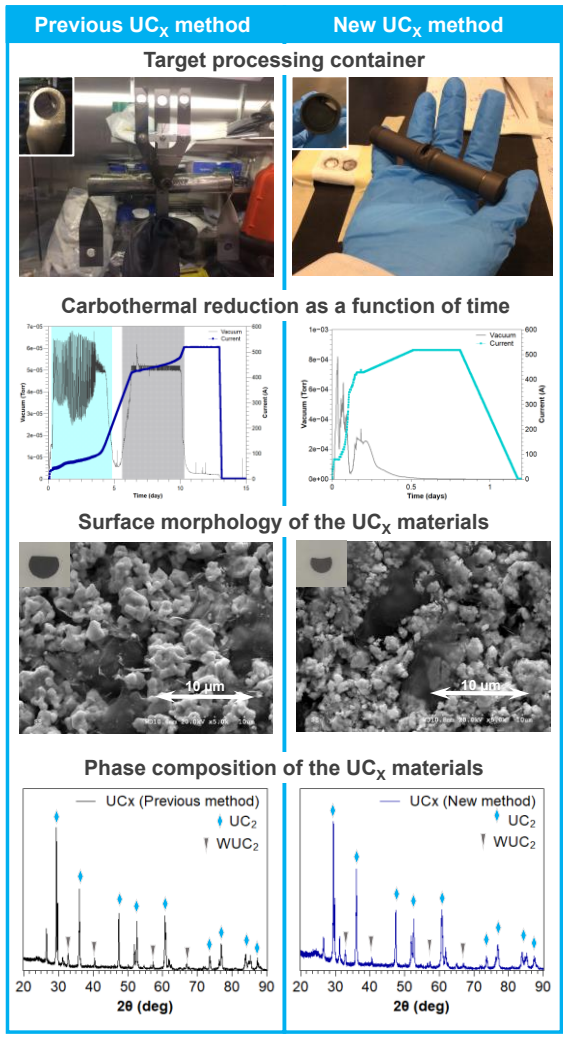
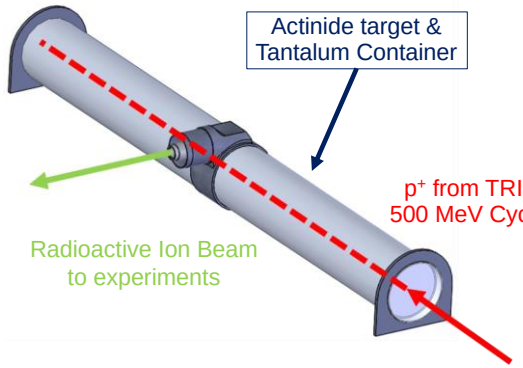


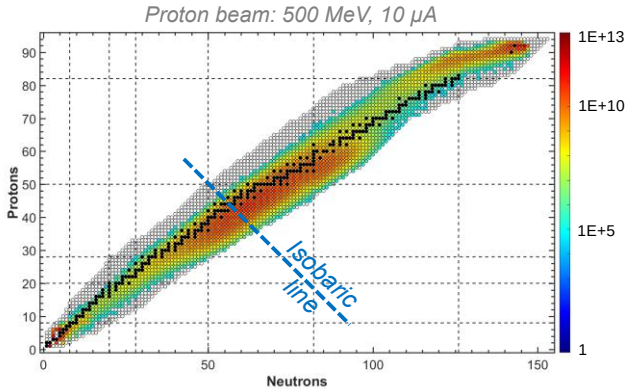
Fig. 5 Comparison of the previous (two-step) and new (one-step) UC_x target containers, carbothermal reduction, and morphological and crystallographic characteristics observed using SEM and XRD.

Discovery, accelerated

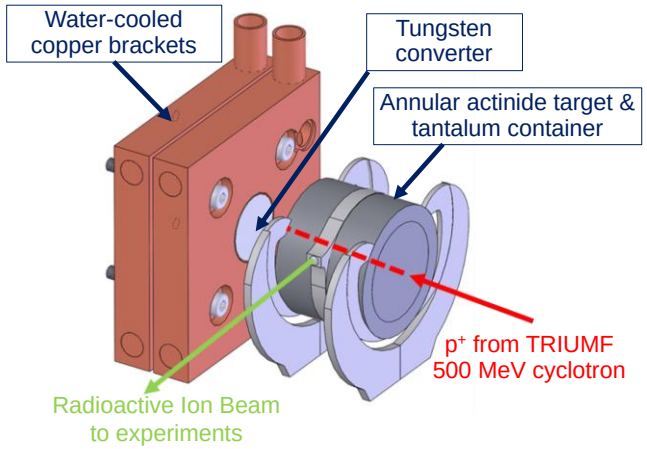
Novel Target Concepts – Proton-to-Neutron Converter



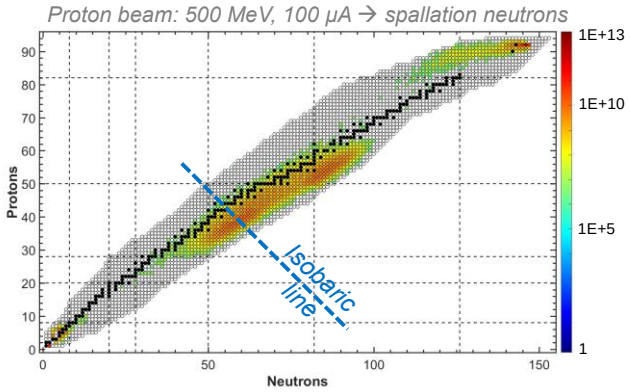
- Many nuclides are produced from the same actinide target ✓
- Experiments often suffer from **isobaric contamination** ✗
  Selective production is needed.
- Direct proton beam on target creates **cold spots** detrimental for isotope extraction ✗



New proton-to-neutron converter target



- Match or increase the standard production of neutron-rich fission fragments ✓
- Reduce by a factor 100 the contamination from neutron deficient isobaric nuclides ✓
- Avoid proton beam induced cold spots for more efficient isotope extraction ✓

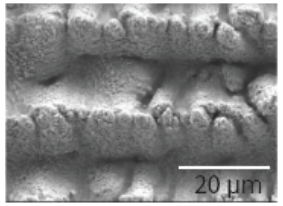


- Development in collaboration with ISODE and SCK-CEN
- Offline development advanced but ongoing
- Online tests in 2018, beamtime approved, schedule to be release

Novel Target Concepts – Coatings

High-emissivity coatings

Laser micro-machining

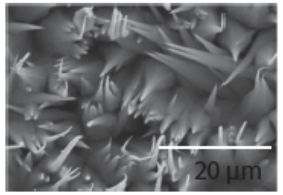


SEM view of a copper surface following micro-machining [5].

Pulsed lasers have proven capable of micro-machining metals to increase their effective emissivity [5].

Work is ongoing to asses the applicability of the technique to tantalum and the survival of the micro-structures at >2000 °C

Black rhenium coating

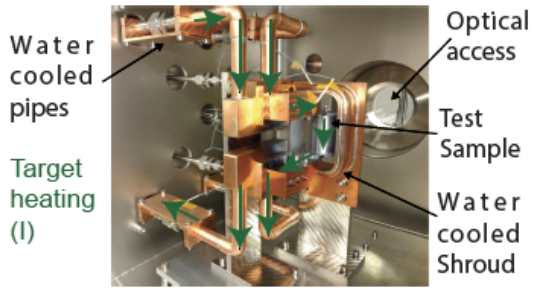


SEM view of a black rhenium coating [6].

Black rhenium coatings have been tested for solar probes with an emissivity of 0.8 at 1400 °C [6].

Work is ongoing to asses the durability of the structures at >2000 °C

The ARIEL thermal test stand

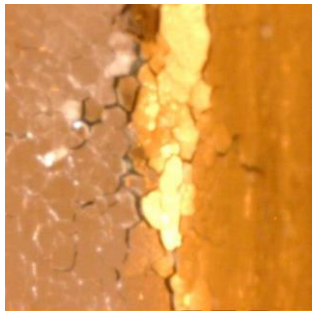


A thermal test stand capable of delivering 2400 A (12.5 V) to test components has been commissioned.

There is optical access from two sides and 12 thermocouple feedthroughs.

Results are used to validate simulations and for component testing.

Protective coatings



- ISAC container material thickness is only 350 µm to allow sufficient cooling
- Chemistry and formation of brittle TaC has been the dominant failure mode for all carbon-container targets (UC_x, SiC, TaC)
- Protective coating of TaC has been developed and mitigated this failure mode

Ion Sources – End-to-End Simulations

ISAC FEBIAD

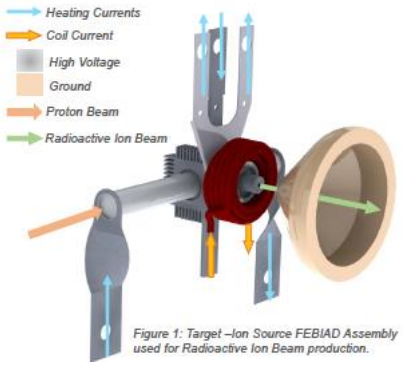
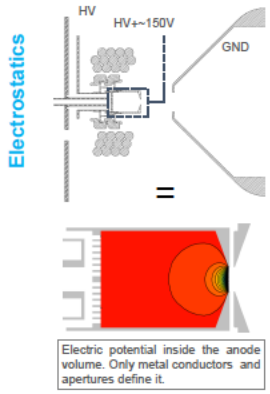
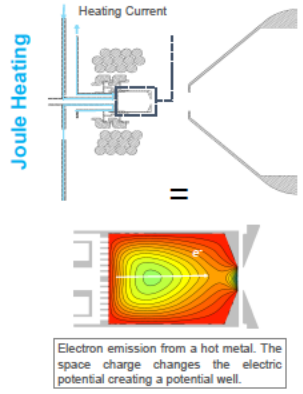


Figure 1: Target –Ion Source FEBIAD Assembly used for Radioactive Ion Beam production.

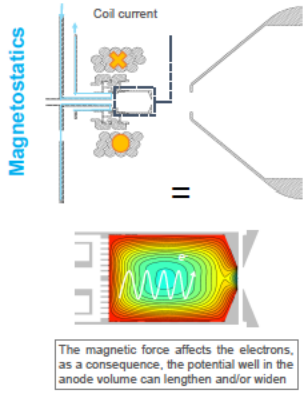
Input parameters



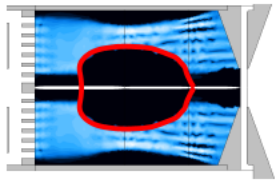
Electric potential inside the anode volume. Only metal conductors and apertures define it.

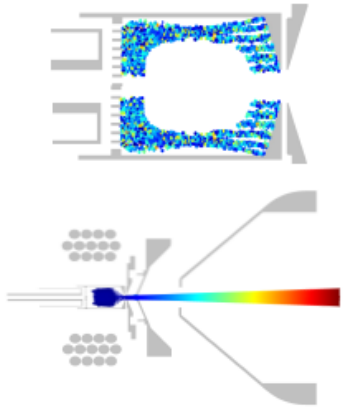


Electron emission from a hot metal. The space charge changes the electric potential creating a potential well.



The magnetic force affects the electrons, as a consequence, the potential well in the anode volume can lengthen and/or widen

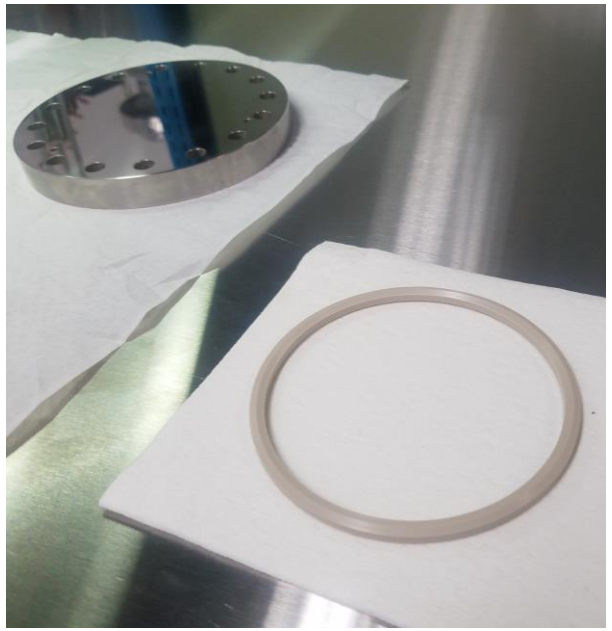




- Input: current (cathode heating, magnet), voltage (cathode, extraction electrode, ground electrode), influx of atomic species
- Output: ionization maps, ion beam (emittance, intensity, time structure, shape)
- Development ongoing, in qualitative agreement with experimental data

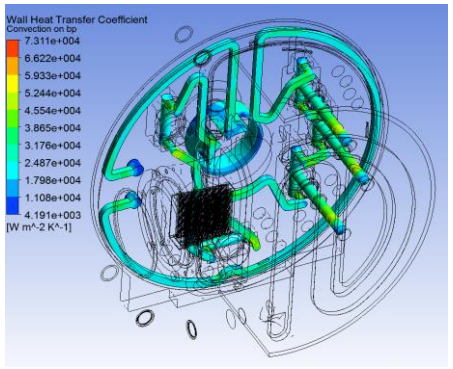
Infrastructure

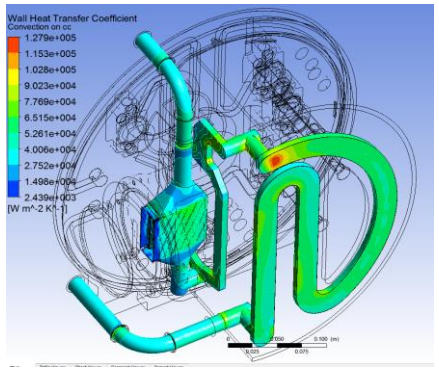
Rad-hard vacuum seals



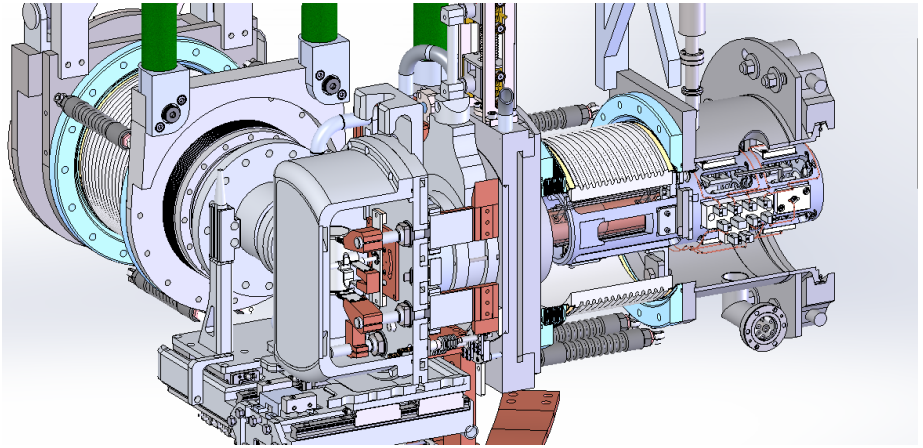
- EPDM (RH_{EPDM}) acceptable for low-power ramp up
- At 100 kW, ARIEL requires 20x RH_{EPDM}
- PEEK seals being tested now (comparable forces, 50x RH_{EPDM}
- Polyimide (600 RH_{EPDM}) and metal seals under consideration

ARIEL front end and target development



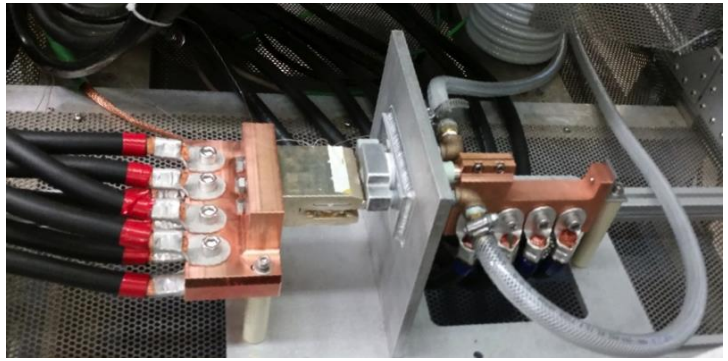


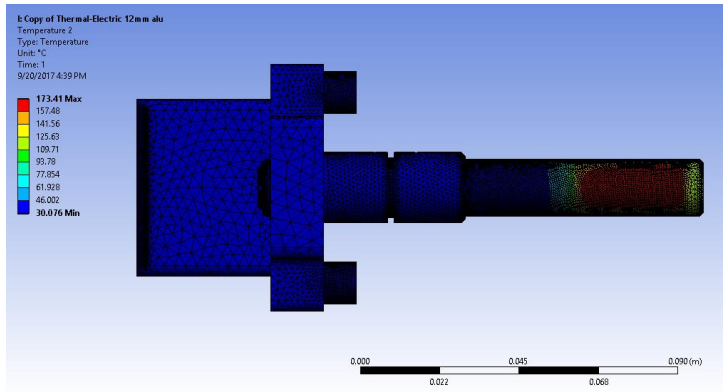
Cooling water architecture & welding technology



- Novel rad-hard materials
- Further development on:
  - Extraction electrode mechanism
  - Pneumatic all-metal piston
  - …
- Fully compliant to remote handling standards
- Vacuum and services remote quick disconnects

2400 A Al connectors

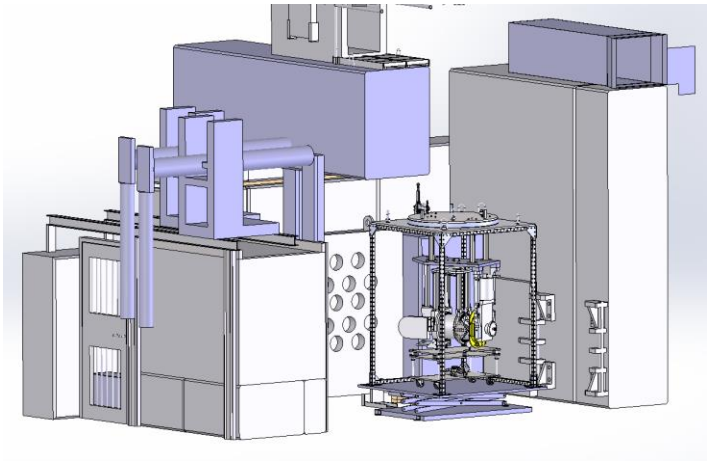




- All Al design to limit waste rad inventory and weigh
- Reliable up to 2400 A, 100 coupling repetitions
- Removal of all water to vacuum interfaces

Remote Handing

- Hot cell technology
- Remote handling practice
- Nuclear waste handling
- Operator training
- RH friendly design and validations



Collaboration Framework

- Lots of great ideas on all sides but manpower, infrastructure, skill and beam time limits
- Collaboration where interests overlap significantly AND where above limits are detrimental to conduct development
- What was presented are ideas where TRIUMF has significant interest and/or is significantly engaged
- Foster open communication on all levels
- Mutual benefit and fairness is absolutely required

The problems in all ISOL systems are widely identical, so are most of the solutions

TRIUMF

Thank you!
Merci!