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Canada's national laboratory
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# Reliability enhancements for TRIUMF accelerators and ISAC targets

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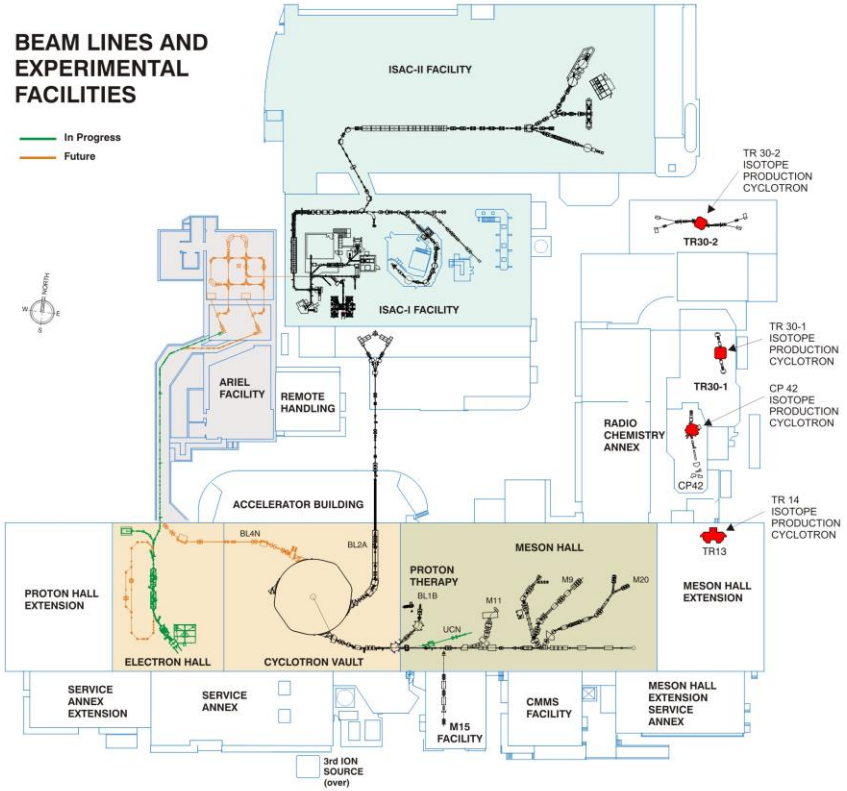
ARIEL Town Hall Meeting, January 11, 2017

# Outline

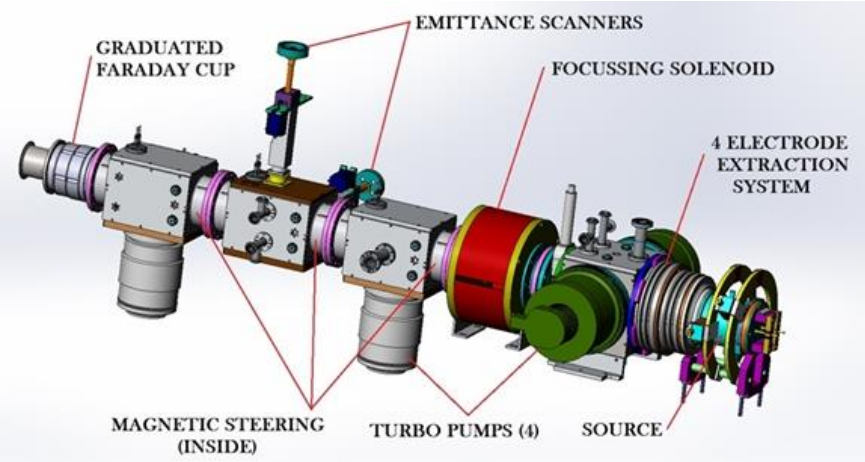
- Cyclotron and ISAC refurbishment
- ISAC target module status and strategy
- New Developments
  - Rotating beam operation
  - Beam tuning
  - Beam delivery and development



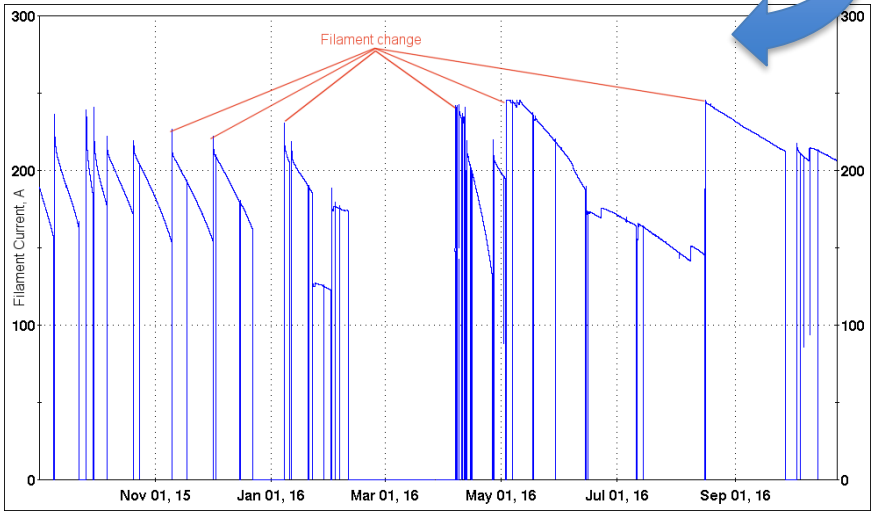
# Cyclotron , ISAC and beam line refurbishment

# H- Ion Source Advances

- Powerful H- source test stand is essential for hardware and beam development:
  - Filament lifetime studies resulted in running time increase from 3 weeks to 4 months
  - High performance demonstration: 25 mA cw
  - New efficient source development for 500 MeV cyclotron
- Future: New operational source will be installed in the spare HV terminal (I2)




H- source test stand




Source filament current evolution

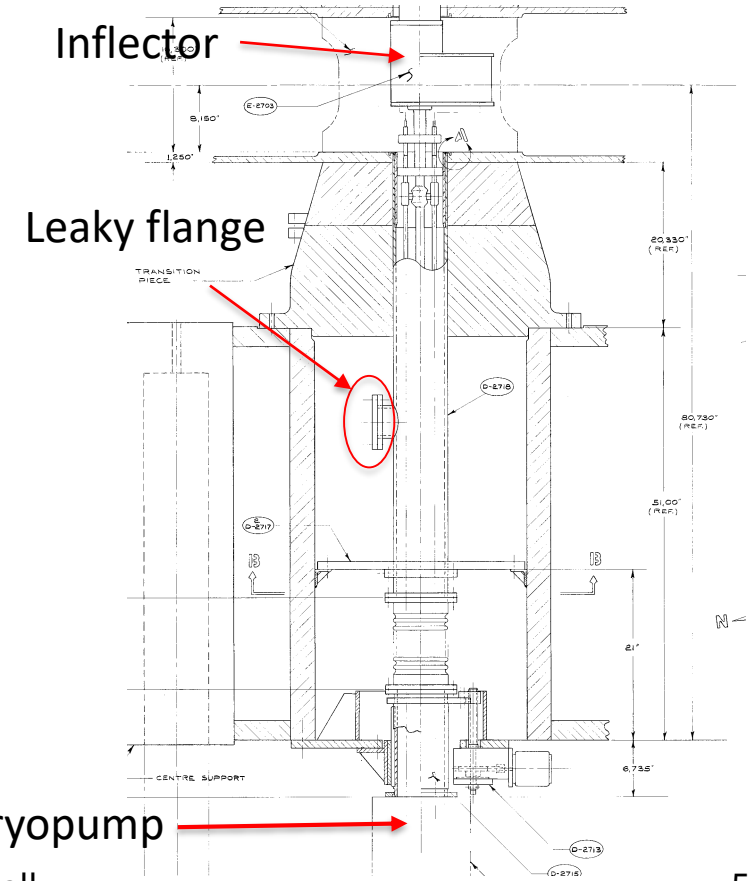
# Inflector vacuum

Inflector vacuum leak repair & upgrade

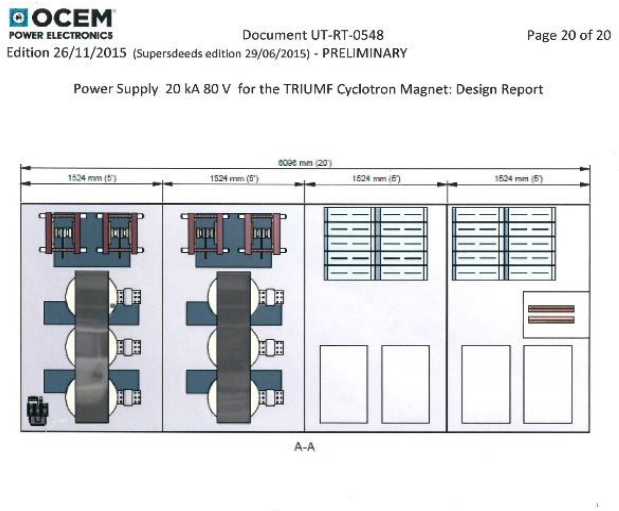
- Nominal pressure $10^{-7}$ Torr
- Present pressure $10^{-6}$ Torr (trips at $2*10^{-7}$ Torr)
- Good vacuum is critical for HV electrostatics
- Identified leak at old ion gauge joint

Scope of upgrade

- Replace 3 elastomer gaskets with Helicoflex metal seals
- Install extension tube and relocate ion gauge to an accessible area



# Cyclotron Main Magnet Power Supply Upgrade


OCEM
POWER ELECTRONICS
Document UT-RT-0548
Page 20 of 20
Edition 26/11/2015 (Supersdeeds edition 29/06/2015) - PRELIMINARY

Power Supply 20 kA 80 V for the TRIUMF Cyclotron Magnet: Design Report

6096 mm (20')
1524 mm (5')
1524 mm (5')
1524 mm (5')
1524 mm (5')
A-A

*Figure 6 - Upper view of the four sections*

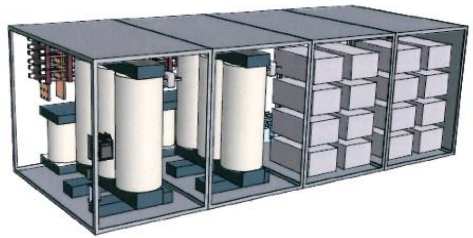


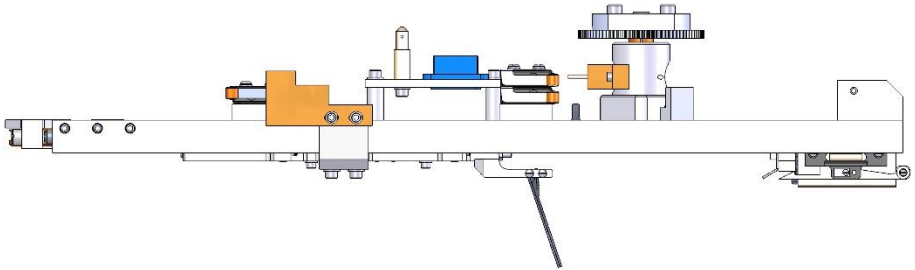
*Figure 7 - Front 3D view of the four sections*

- Replacement of the original power supply to guarantee a high availability
- Output: 80 V dc / 20 000 Amps
- Magnetic Field Stability: $<10E^{-6}$
- Manufacturer: OCEM, Bologna, Italy
- Expected delivery date of mid December 2016 will not be met because of CSA certification
- Delivery is delayed to May 2017, installation will be in winter shutdown 2018

# BL2A Extraction Foil

New concept of foil holder

- Now: foil at straight vertical position – multi-turn interaction of stripped electrons with foil due to their spiral motion in strong magnetic field
- New: foil tilted at 20 deg. along beam path
- Benefit: 2 stripped electrons prompt escape; low energy loss in foil
- Expected outcome:
  - foil temperature reduction
  - foil life time extension
  - 7Be release mitigation
- Plan is to implement it in this shutdown

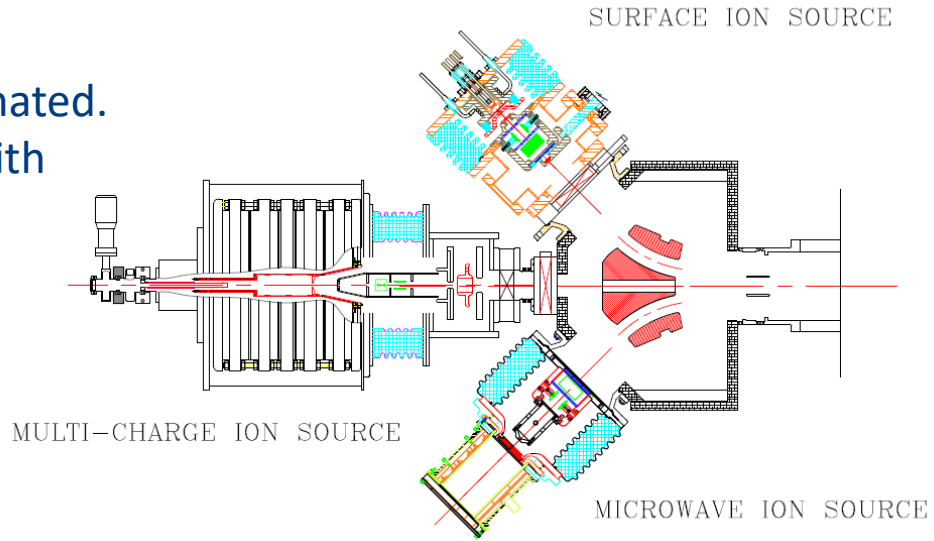


# Stable ion sources ISAC – OLIS and $H^-$ source

- All three ion sources (microwave ion source, surface ion source and multi-charge ion source) are fully functional.
- To date we have delivered 78 different isotopes to ISAC experiments including rare isotopes such as $^{3}He$, $^{13}C$, $^{15}N$, $^{17}O$, $^{33}S$, and $^{76}Se$ from enriched samples.

Recent upgrades:

- Microwave ion source is now fully automated.
- Surface source can run independently with its own Vacuum system and a dedicated faraday cup.
- Multi-charge ion source has been upgraded with dual frequency RF system → higher beam intensity



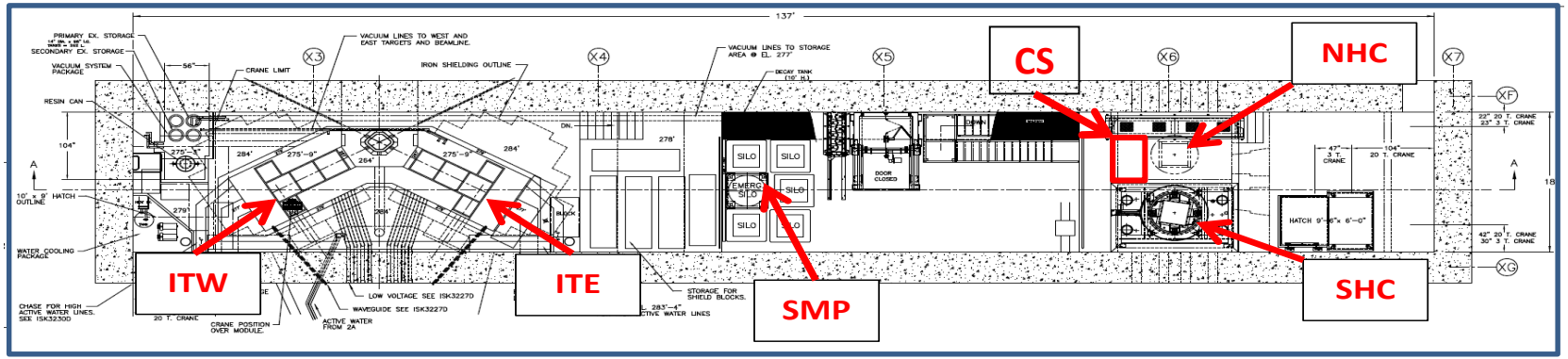
# ISAC reliability upgrade and Target Module strategy

# ISAC Reliability Upgrade and ISAC Ramp-Up Towards ARIEL

Single hot cell for 1) ISAC target exchange, 2) module move (landing redundancy for target hall crane)
→ no extended maintenance, repair or investigation processes possible in hot cell during operation

**ISAC infrastructure upgrade**:

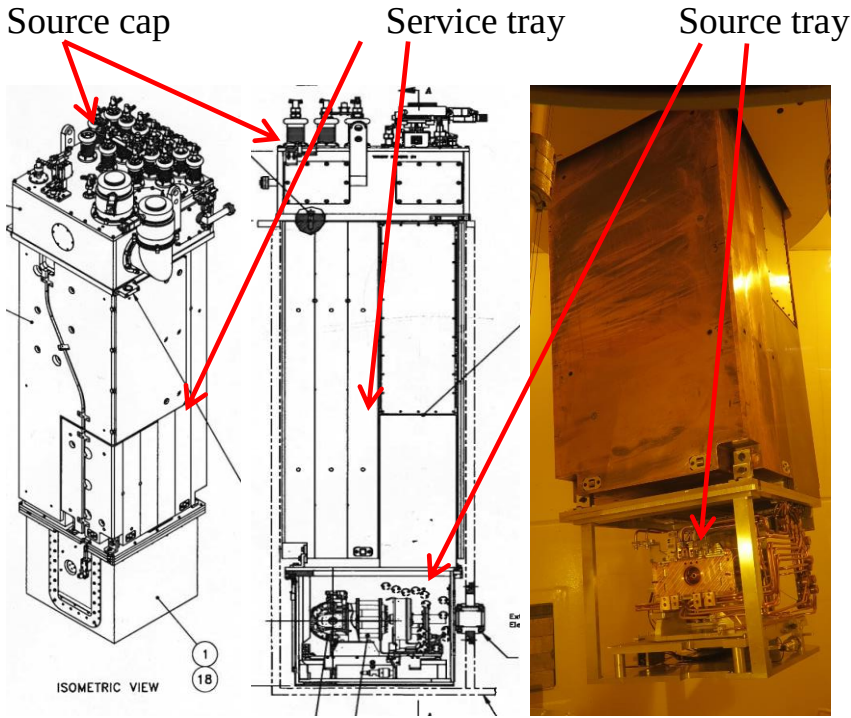
- North Hot Cell (NHC) for routine ISAC target exchange, installation ongoing, commissioning in 2018/2019 shutdown → extended maintenance and repair during standard operation
- Safe Module Parking (SMP) for crane rotation redundancy, installation ongoing, commissioning in 2018/2019 shutdown → increased operational flexibility
- Increase target production efficiency, ongoing for Ucx → additional operational efficiency, freeing up resources for development



# ISAC Target Modules

- Presently four Target Modules (TM) in ISAC
- TM1 highly limited, unique in design
- TM2-4 are similar – investing in refurbishment
- Only TM4 can presently run IGLIS, only TM2 can run the Febiad
- TM3 investigations → HV level, water leaks, EE shorts

Four modules allow for reliable and sustainable operation assuming at any point in time one module is in refurbishment, one is in operation, one is waiting in the other target station and one is being prepared for upcoming installation or back-up



# TM3 Investigation - 2016

TM3 is now out of the Target Module rotation and is being investigated

2016 Summary:

- investigate module assembly & components: replaced/removed parts (insulators/cooling lines)

  showing sparking marks -> still sparking at 22.5kV

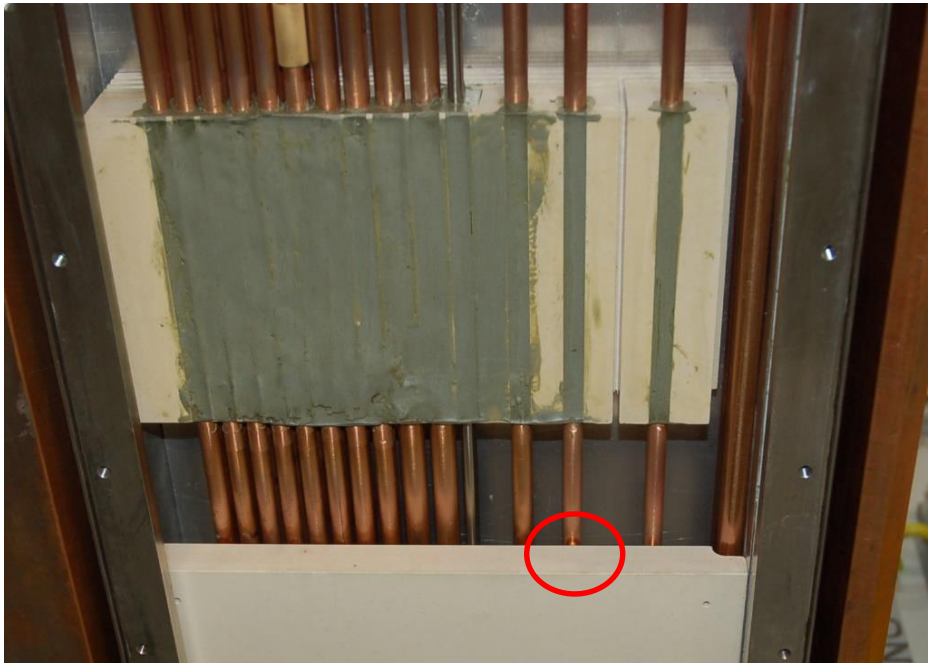
- initiated 3D CAD Model and drawing package for TM3 as built

- started complex thermal/structural analysis for the Target & Ion Source to determine the required cooling lines – not all lines are required but all water joints represent potential leaks

# TM3 Investigation – 2017

2016 Summary:

- Epoxy deteriorates, flakes (see pictures)
- showing extensive sparking marks



- HV tests with cameras inserted in the module to localize the sparks
- complete 3D CAD Model and drawing package
- Full thermal simulations of source tray to identify cooling requirements

# ISAC Target Module Strategy

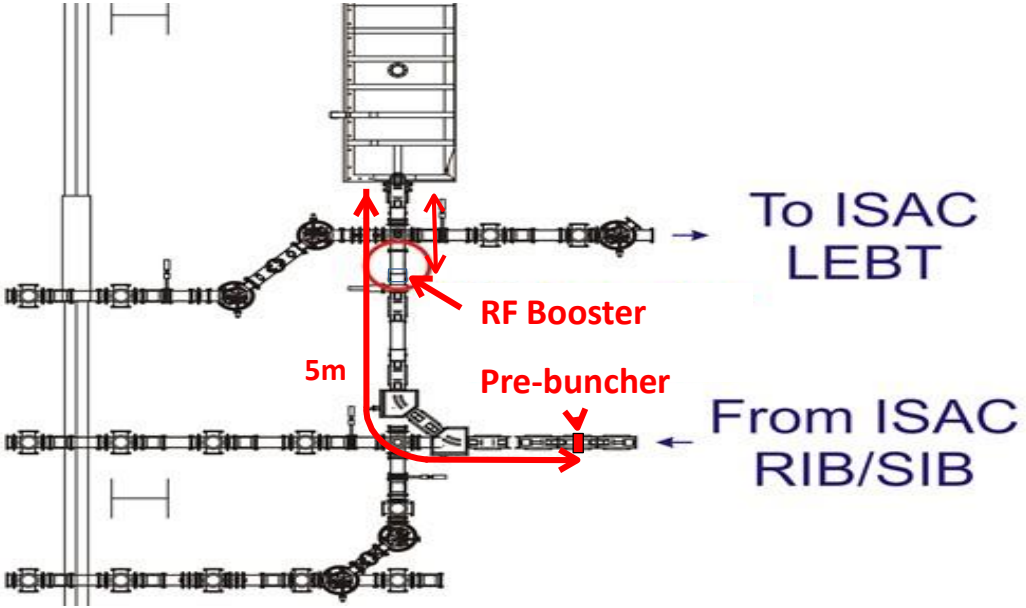
- Additional target module (cold TM) to reach optimum number of target modules in rotation
  - New TM project launched, Gate 0 approval, about 0.9 $M invest
  - Some modifications will be incorporated that improve the reliability and performance of the TM based on investigations of TM3, without a major re-design
  - The design must be compatible with SIS, FEBIAD, IGLIS, HP, LP, and 60 kV operations on ITE and ITW.

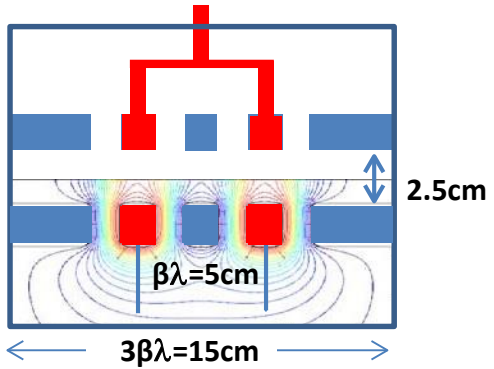
- Planning for overall target module refurbishment with approx. 1 refurbishment / year
  →Goal: 4 modules (as identical as possible to have common spares and common refurbishment steps, fulfilling all requirements)

- Module waste disposal plan

# LEBT RF Booster

- RF Booster to mitigate limited target module extraction voltage
- Effective voltage ≤16 kV at 11.78 MHz to be installed before ISAC-I RFQ to accelerate heavy ions when ISAC bias is below specification




- Aperture=25mm
- Gap=12mm

# New developments

# Beam Rastering on ISAC Target

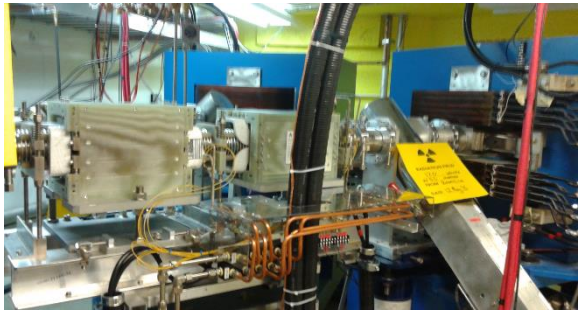
Components and parameters:

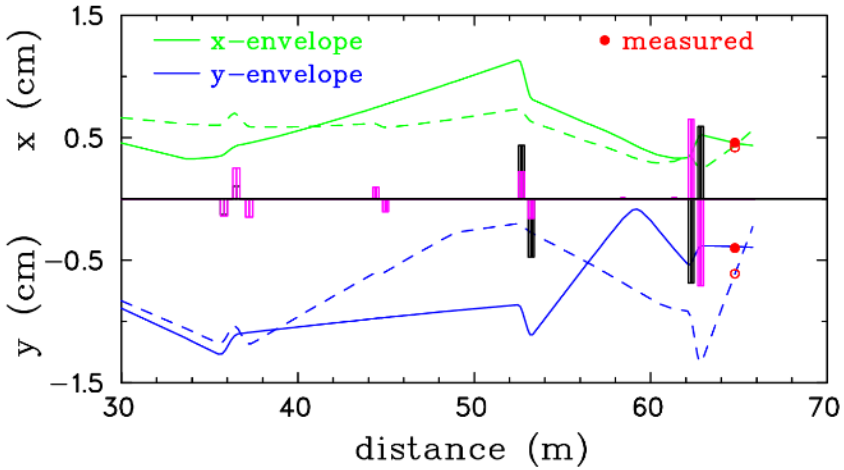
- two magnets (X,Y) for beam movements on target
- two power supplies with adjustable frequencies: up to 400 Hz.

By adjusting the phases and amplitudes of the X and Y magnets a variety of rastering patterns can be achieved

New tune feature – beam is parallel in the last drift!

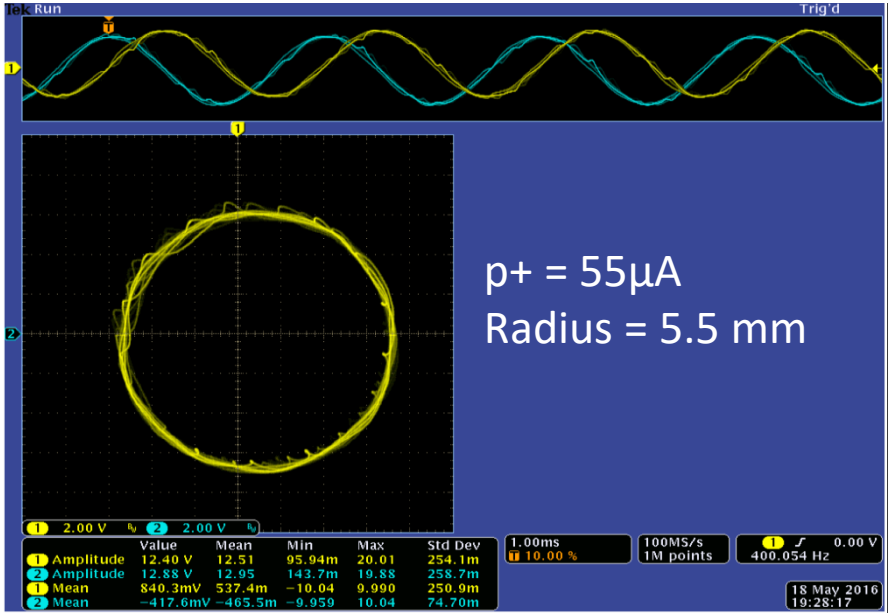
**Raster magnet is a ferrite H-frame type magnet**



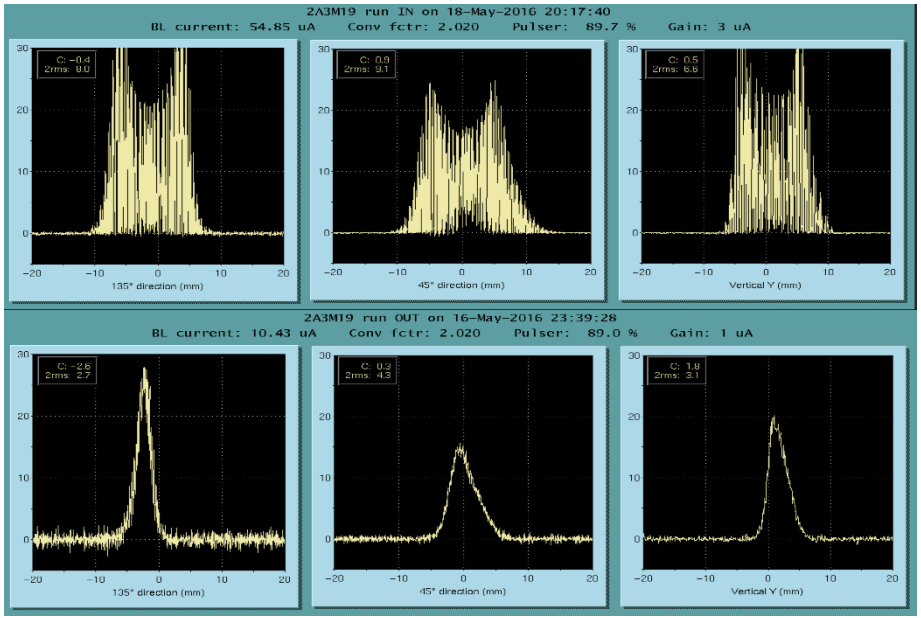



Dashed line – old tune; solid line – new tune

Diagnostics: BPM, Protect (Halo) Monitor and Wire Scanner are all used to set-up and deliver a centered beam on target




**Rotating beam and static beam profile**



# 2016 - Rotating p+ beam experiments in ISAC

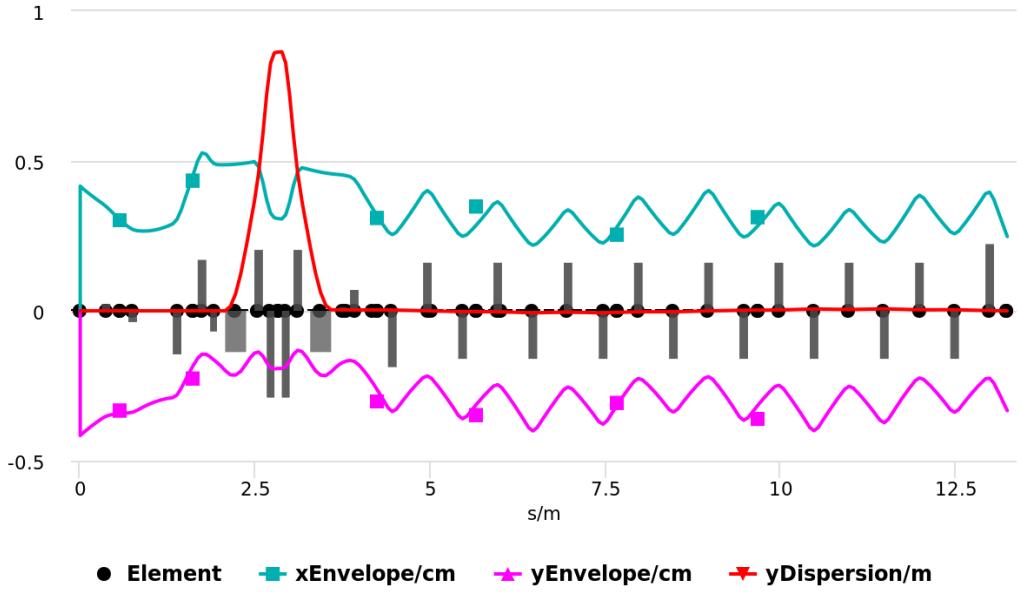
**Ta#47 and Ta#50 Low Power rotating beam experiments:**

- Checked **consistency** of the: yields and the optimal rotating settings
  Yield doubled compared to the values of a static p+ beam
- Measured and mapped isotopes for the Rotating Beam vs. Stationary Beam for:
  Li, Cs, Be, K, Rb, Na, Ca
- Longer runs – to check hardware reliability and yields released over time
- 2 weeks delivery of RIBs to experiments: Griffin (Ca50), and OSAKA & βNMR (Li9, Li8)
- Started the transition **towards Operational Mode** for the Rotating Beam: operation procedures, training, instructions.

**Future objectives:**

- move to **Operational Mode** for the Rotating Beam
- to develop optimized targets for the Rotating Beam

# Injection Beam Transport Modelling




Beam envelope from H- source to buncher.
Squares represent measured beam size (2 rms)

- Quadrupole effects from source electrostatic steerer were removed by balanced bias
- Accurate model of beam optics from source to cyclotron was validated
- Good matching achieved
- High Level Application (HLA) of injection line was created and actively used – one of the first at TRIUMF!

# Beam delivery and development – tuning tools

- Web-based interactive GUI for envelope calculations (live app)

- Top section is scrollable, sliders for each controllable input like solenoid and quad currents, linac voltage and phase etc.

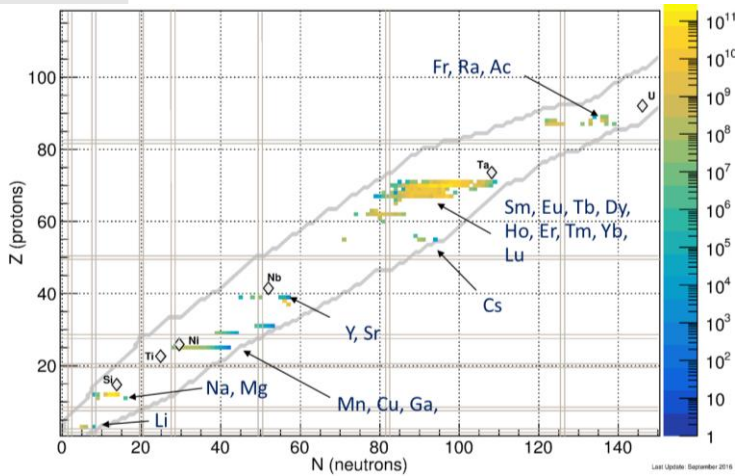
- Plotted are transverse beam sizes, bunch lengths, energy spread, energy, etc.

- Does optimizations such as matching, minimizing energy spread, etc.
  →Continuous development for all sections of beamlines.

# 2016 Yield Assessment and LIS development

| Year | Yield measurements (total) | New entries in yield database | Improved yields | New Isotopes |
|---|---|---|---|---|
| 2001-2011 | | 1458 | | |
| 2012 | 702 | 632 | 107 | 142 |
| 2013 | 681 | 220 | 46 | 29 |
| 2014 | 985 | 425 | 29 | 19 |
| 2015 | 589 | 309 | 31 | 9 |
| 2016 | 909 | 813 | 90 | 94 |

new and improved beams in 2016

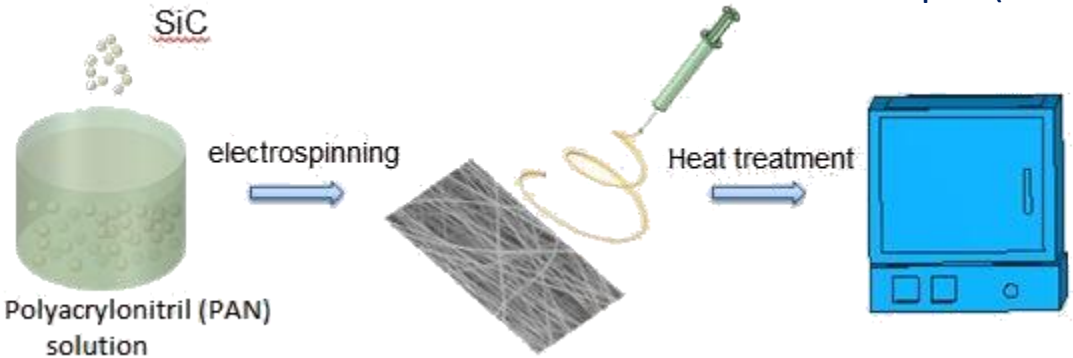


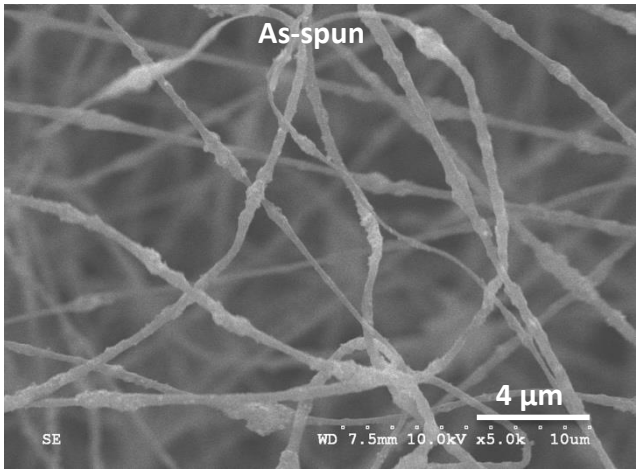

Beam development according to Science/EEC priorities 32 on-line elements by TiSa RILIS

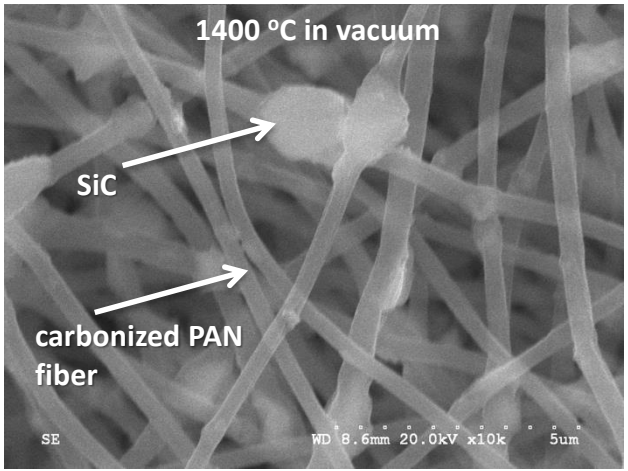
new beam development on-line:
Tl, Er, Yb, Sm, Y, Lu, Ho, Cu, Cd, U, Mn, Mg, Be
→ 5 new TRILIS beams & yield

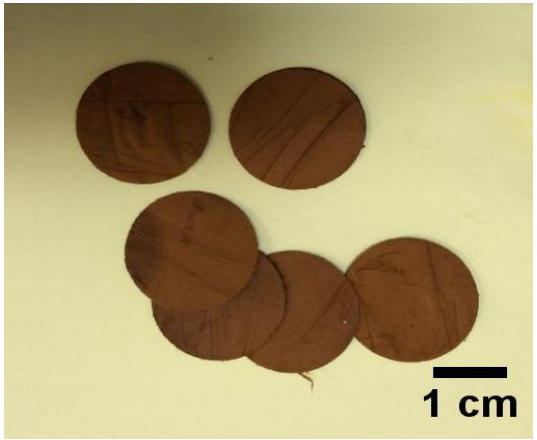
# SiC Nanofiber Target Materials

Nanofibers for enhanced release of diffusion limited isotopes (work in progress, online tests in 2018)




SiC/PAN nanofibers after stabilizing at 250 °C in air and cutting

# Beam delivery and development

Beam delivery and development group in collaboration with the beam physics department:

- Harmonize high level applications, new GUIs for beam tuning
  These high level applications and GUI's will be essential for beam delivery in ARIEL for multiple driver beams and RIBs
- Optimization of the extraction system of the ISAC and ARIEL target ion sources
  Simulations, measurements of beam properties (starting with FEBIAD)
  Emittance meter for the whole intensity range available
- PHOENIX Charge state booster improvements (injection)
  Future: CANREB - EBIS, energy matching, cooling
- Mass separator commissioning
- Transfer of expert knowledge to operators

# Summary

- Cyclotron and ISAC refurbishment
  - Stable ion source development towards higher intensity and availability
  - Improvements in vacuum, diagnostics and extraction foil lifetime
  - Main Magnet PS replacement
  - OLIS improvements

- ISAC target module strategy
  - ISAC target module infrastructure (NHC and SMP)
  - Investigations on existing TM3
  - Plan for a `cold module' copy of an existing operational TM – brings us to four similar modules

- New developments
  - Rotating beam operation
  - New tools – high level applications, beam tuning tools
  - New beam development (TIS and target material)

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