TRIUMF's current and future opportunities for radioactive ion source research and development

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ARIEL commissioning coordinator

2025-10-22

Discovery, accelerated

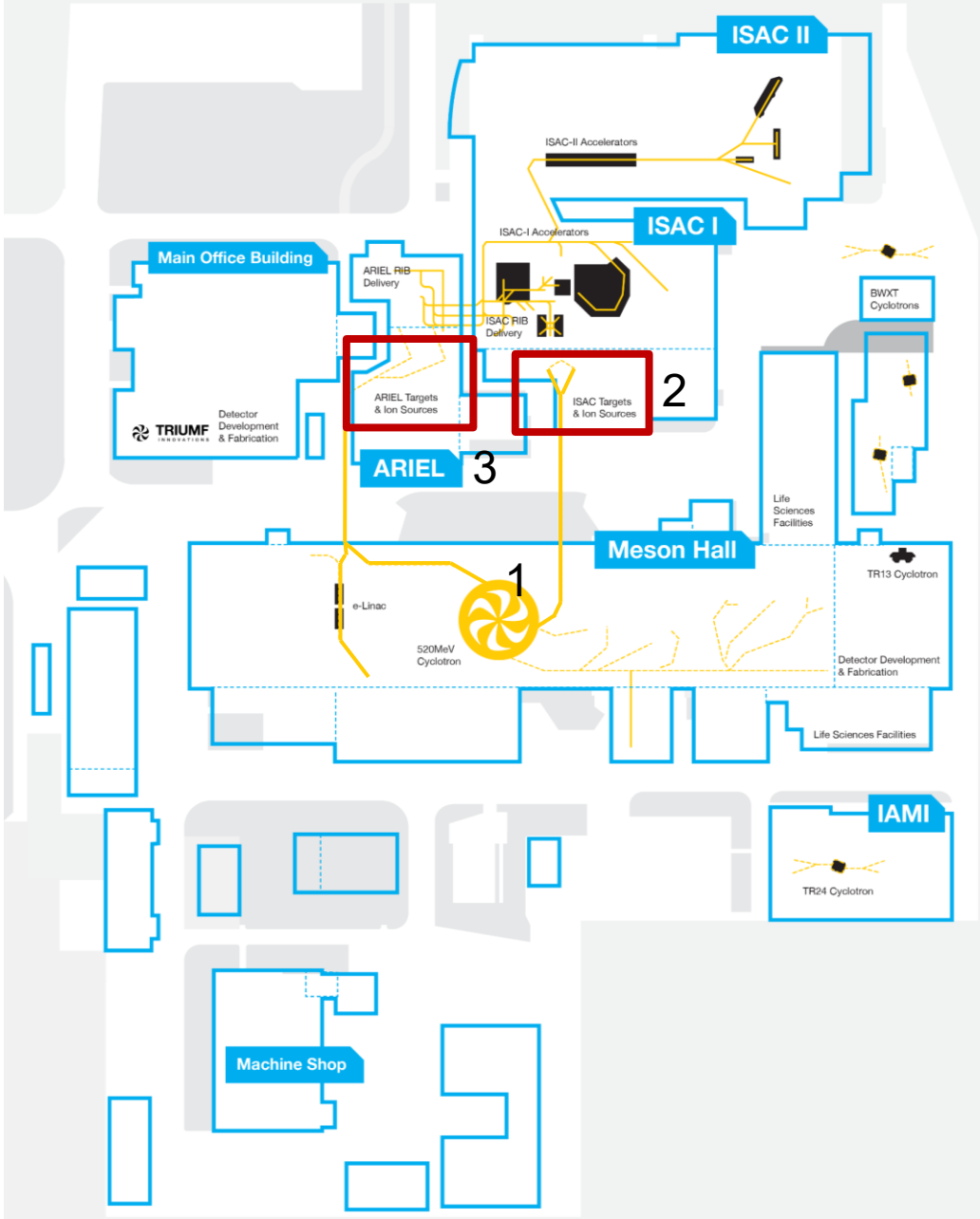
Roadmap

- Intro (more a recap)
- FEBIAD ion source (to link present and future)
- ARIEL new infrastructure and opportunities

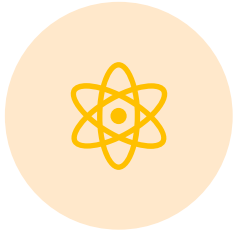
TRIUMF site recap

1. Main cyclotron produces protons up to 520 MeV.
2. Single beamline delivering protons either of the two ISAC target stations
3. New proton beamline for the ARIEL west station and electron beamline for the ARIEL east station. Both station can run simultaneously.

- Operating three simultaneous beam through a complex beamline switchyard increases the demand on the ion source's performance.



What is ion beam performance



AVAILABILITY:

IONIZING ATOMS AND/OR MOLECULES

EFFICIENCY:

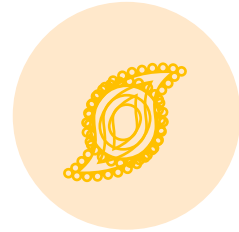
MORE CURRENT FROM MORE NEUTRALS*

SELECTIVITY:

REDUCE BACKGROUND FOR CLEANER BEAMS

RELIABILITY:

“BETTER INFRASTRUCTURE = MORE SCIENCE POSSIBILITIES”



BEAM QUALITY:

LOW ENERGY SPREAD, SMALL EMITTANCE

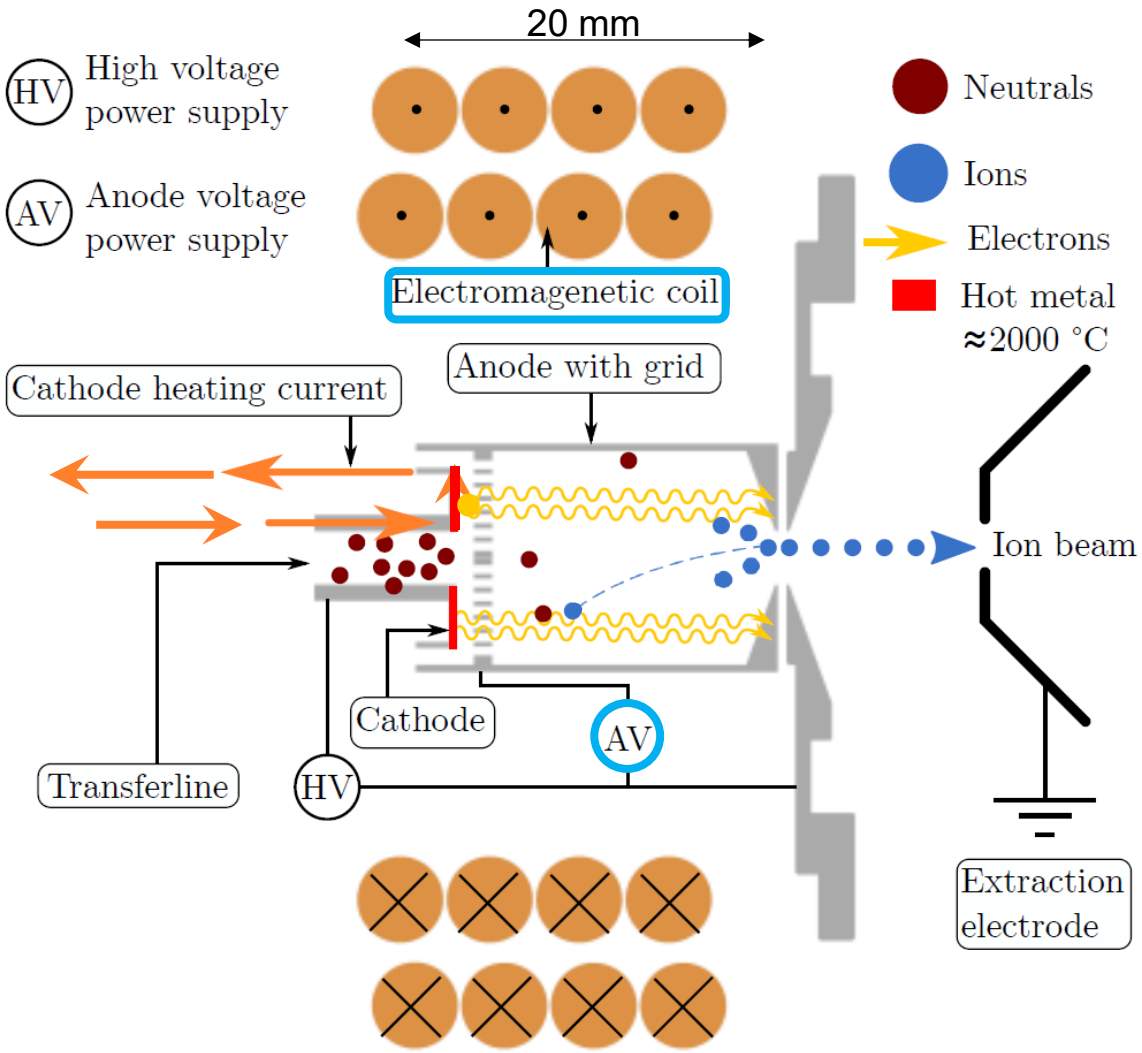
Systematic Measurements

Simulations

Collaboration

The
Forced **E**lectron **B**eam **I**nduced *Arc Discharge* source as the pathway of this talk

The FEBIAD ion source



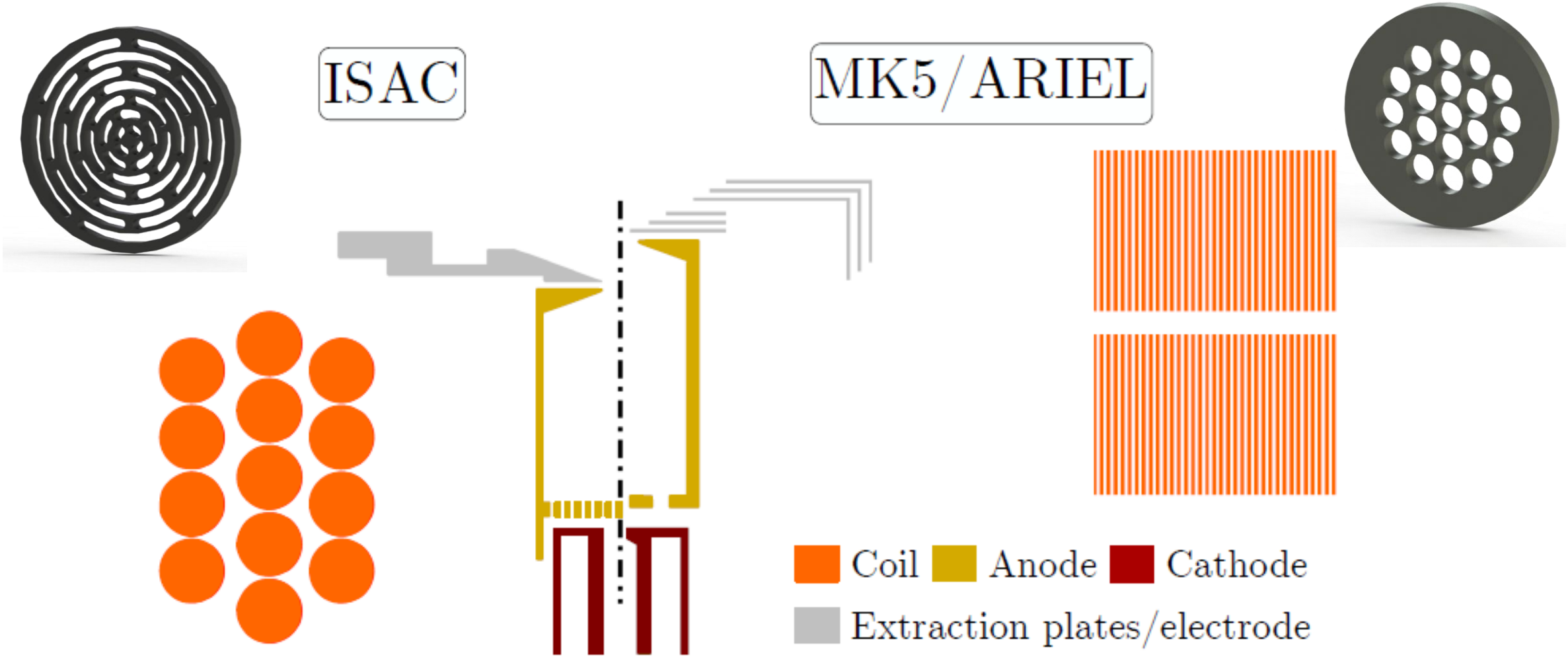
The FEBIAD ion source is typically used for noble gases*, halogens, and molecules.

- Hot cathode emits electrons.
- Electrons pulled into the anode volume.
- Magnetic field confines the electrons.
- Electron impact ionization.

Multidimensional parameter space available for operation.

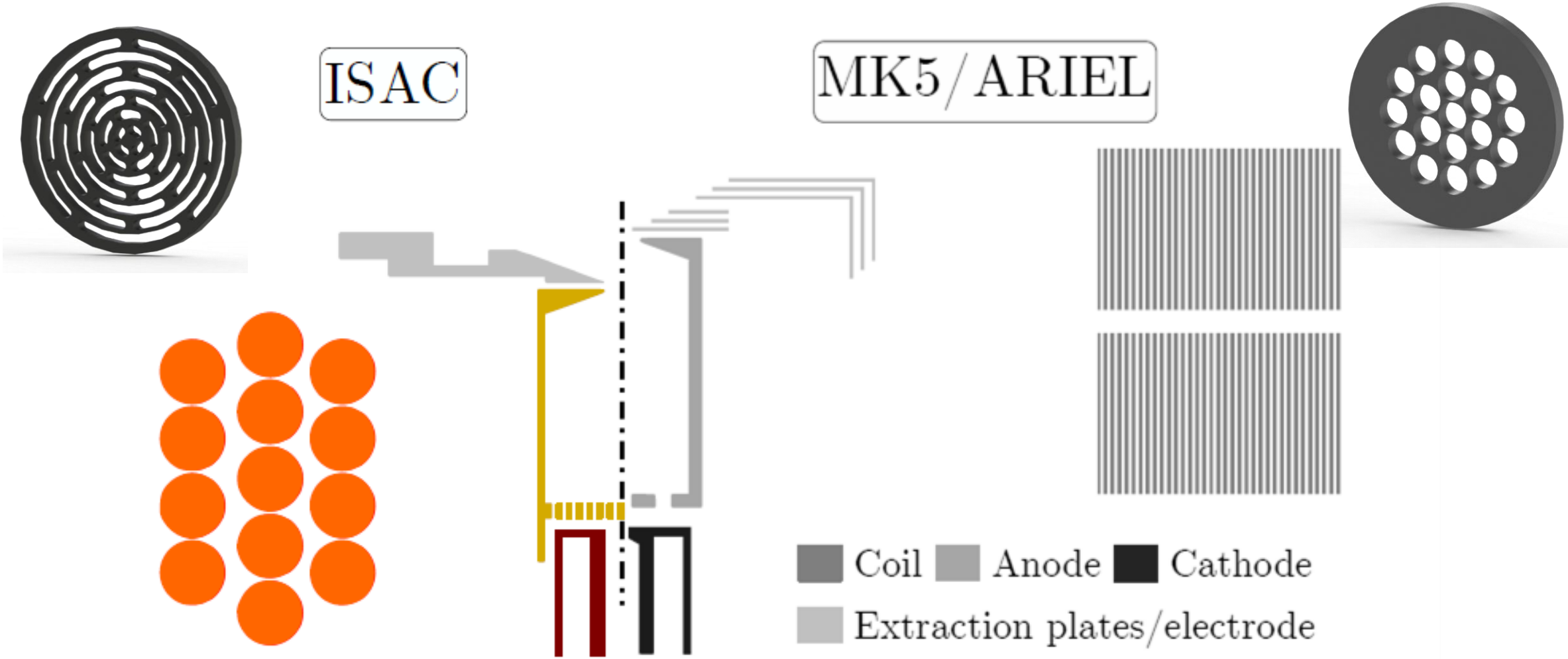
*Only source available for the high ionization potentials

How do the TRIUMF FEBIADs look like?



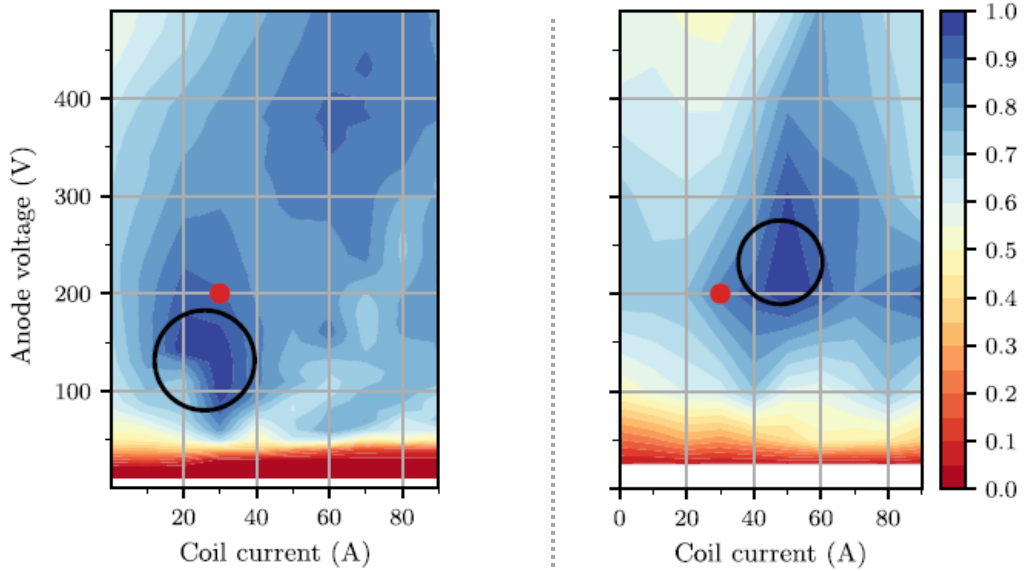
The anode length, grid openings and coil construction are noticeable different

How does the TRIUMF FEBIAD look like

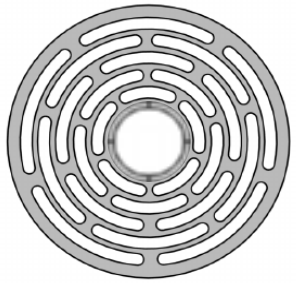


The anode length, grid openings and coil construction are noticeable different

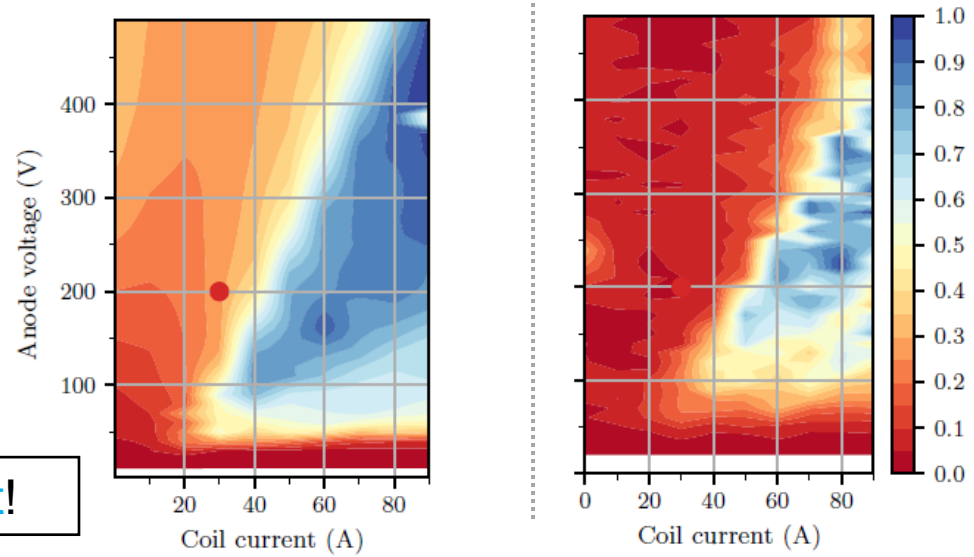
Normalized $^{40}Ar^{+}$ ionization efficiency as a function of anode voltage and electromagnet current



- No dominant effect with electromagnet current
- Blue hue in most of the map (> 0.6)
- Higher efficiency island near operation point
- Simulated ion extraction qualitatively agrees



2x more efficient!



- Dominant effect with electromagnet current
- Red hue in most of the map (< 0.4)
- Simultaneous increase with voltage and current
- Simulated ion extraction qualitatively agrees

Measured

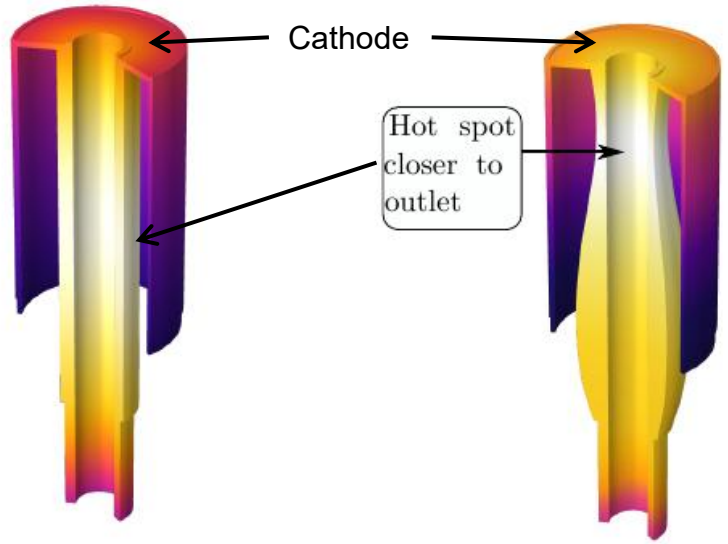
Simulated ion extraction

F Maldonado (PhD Thesis) http://hdl.handle.net/1828/14082

Using COMSOL Multiphysics for all simulation during my PhD.

Simulation-based optimization

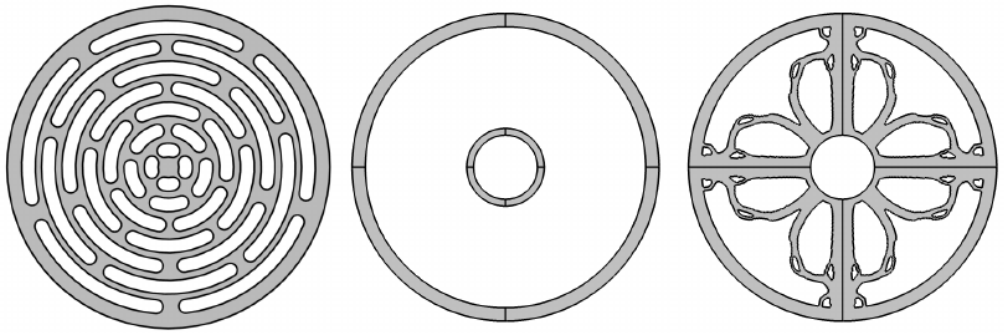
Transferline shape-optimization



(a) Nominal geometry (b) Optimized geometry

Provides reliability. Prevents cathode-anode short due to thermal deflections while moving the hotter temperature towards the emitting face.

Grid generative-design-optimization



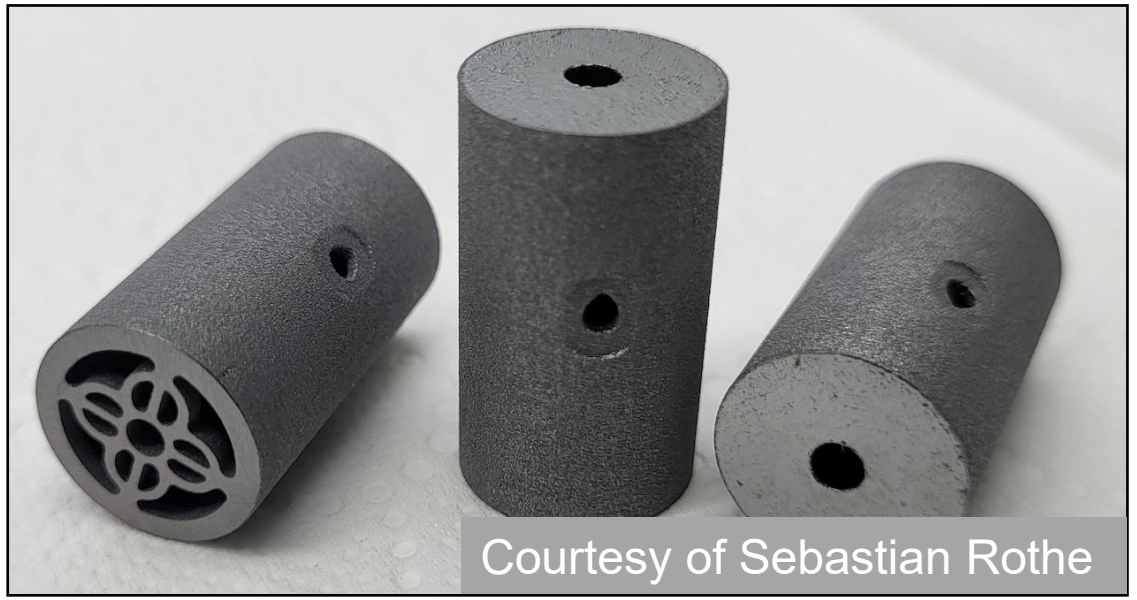
(a) Nominal geometry (b) Initial geometry (c) Optimized geometry

Resilient to electron bombardment. Increases electron into the anode volume and hence increases the ionization efficiency.

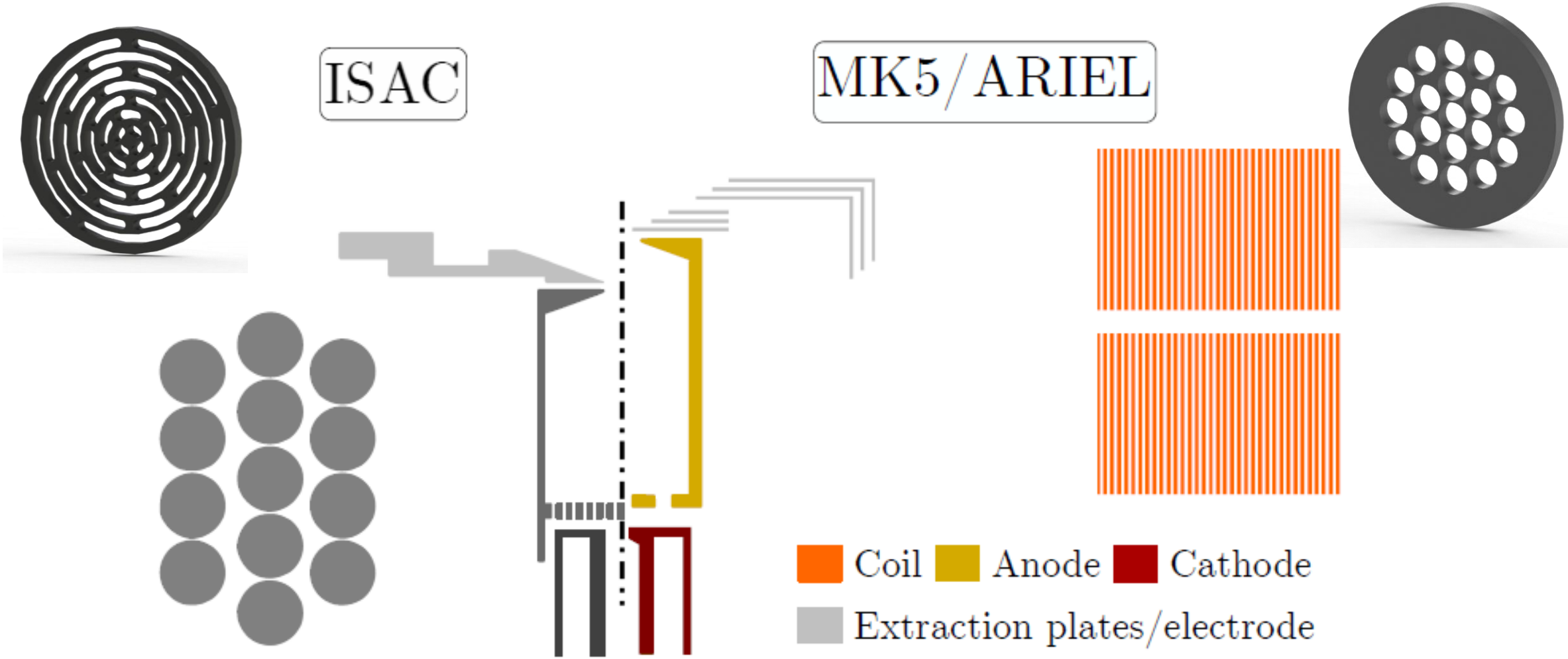
10.1016/j.nimb.2023.05.056

Manufacturing Novel Grid Geometry:

- Additive manufacturing of Ta
  - A standard geometry tested at ISOLDE in 2023 as part of a collaboration with SPES.
- Monolith geometry for ARIEL manufactured including anode body
  - To be tested next year at ISOLDE as part of a collaboration



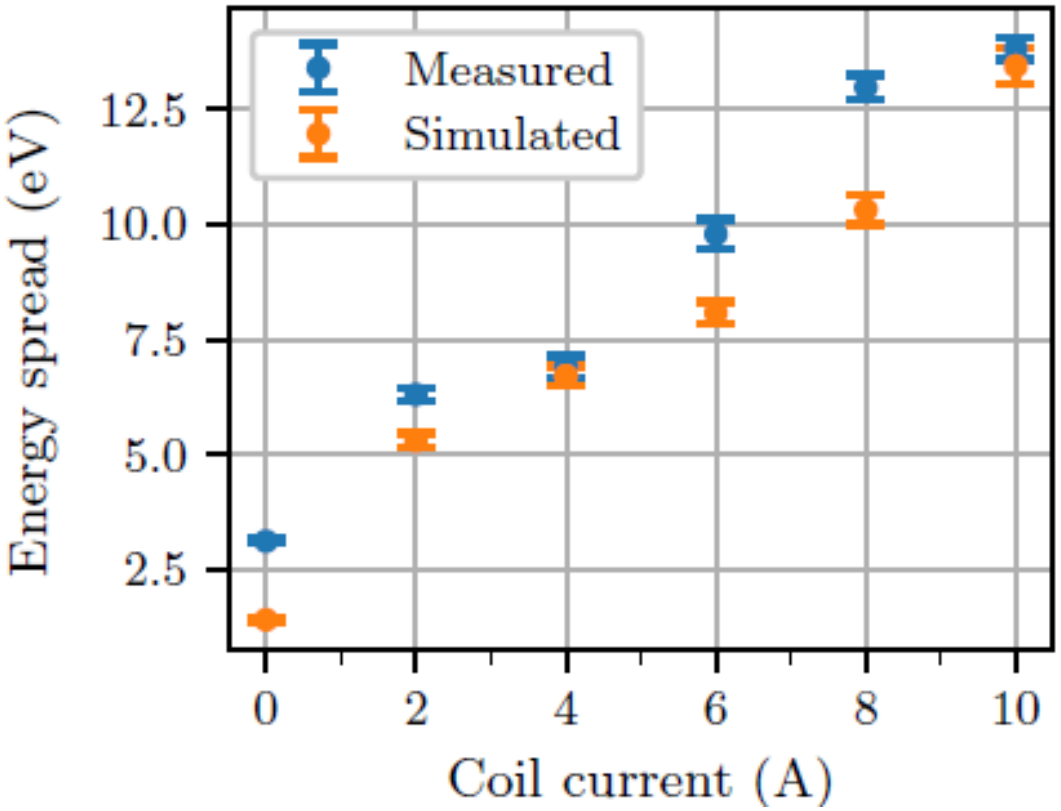
How does the TRIUMF FEBIAD look like



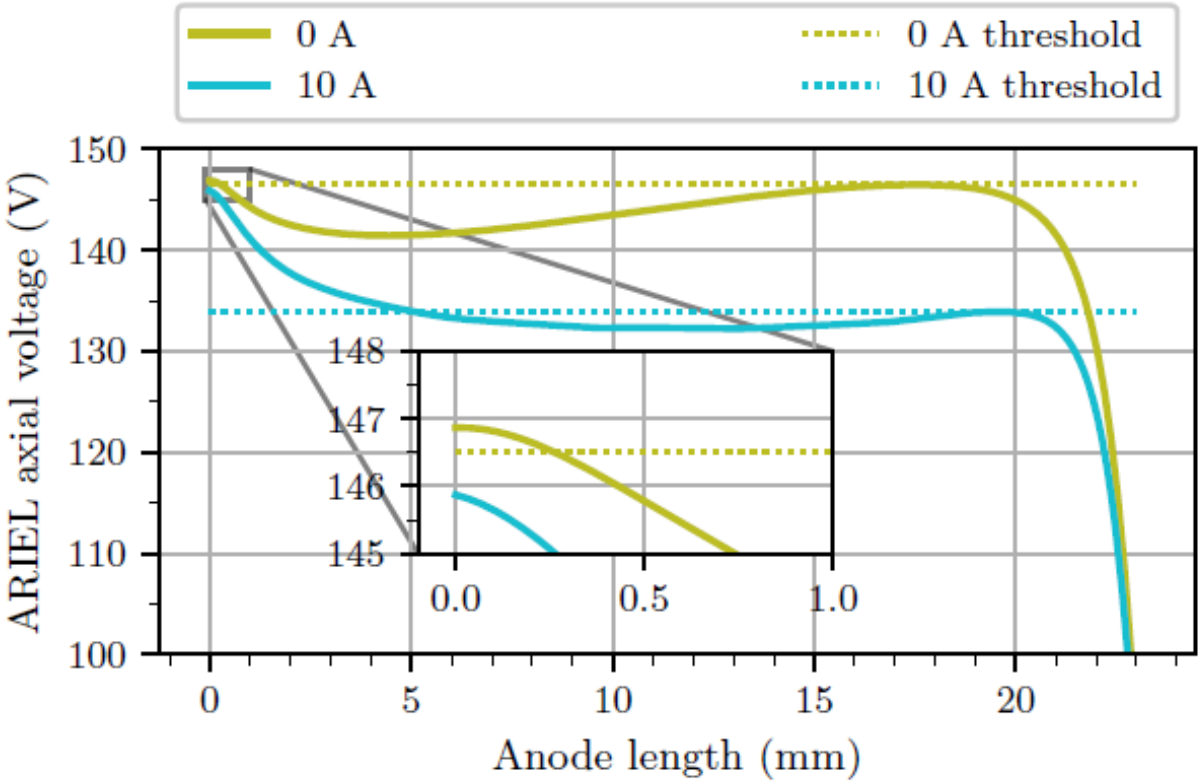
The anode length, grid openings and coil construction are noticeable different

Ion energy spread explained from electric potential and spatial distribution of the ionization

Energy spread for a 6 keV argon beam



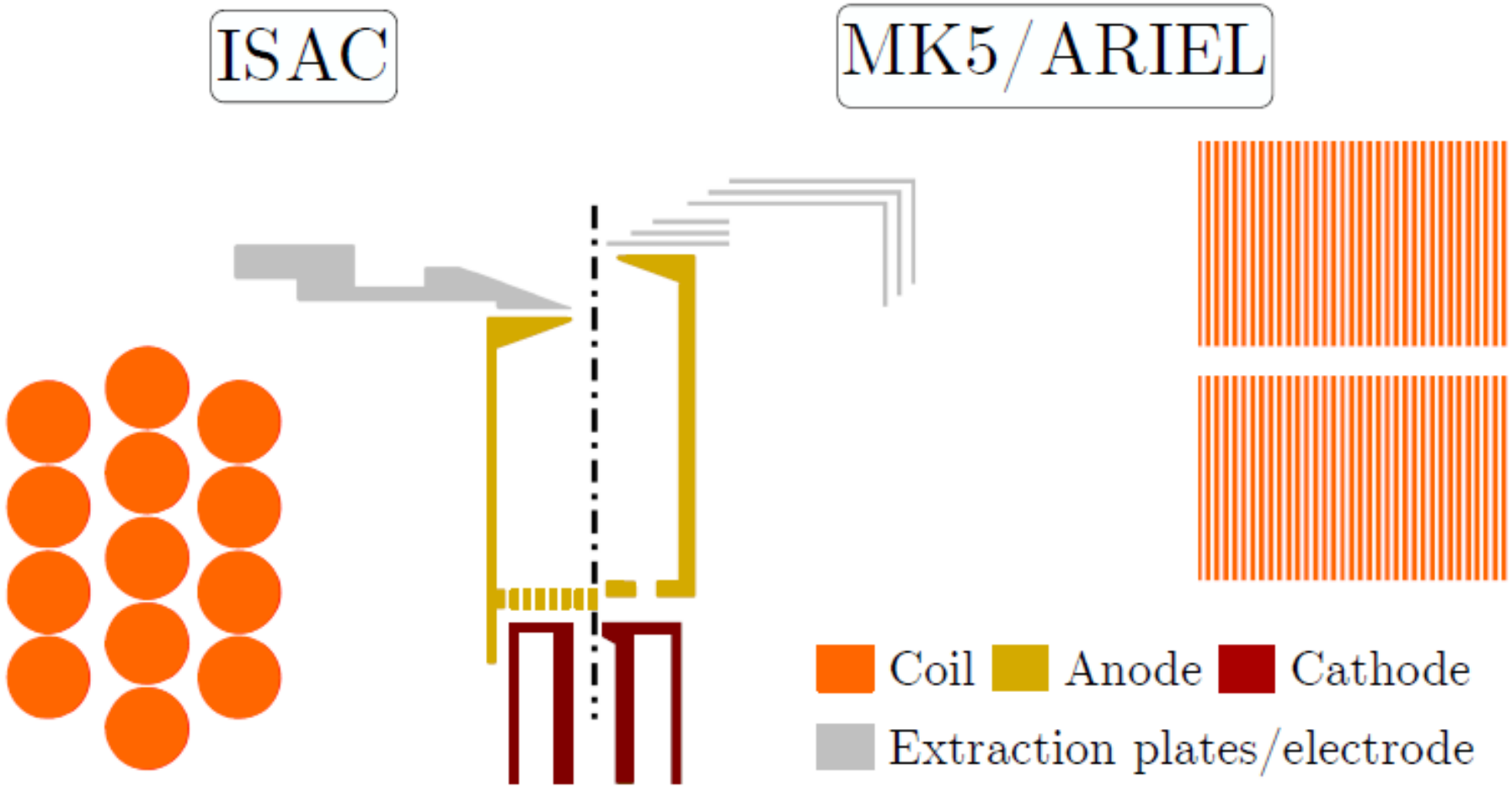
Electric potential on-axis



Values measured at GANIL for a MK5/**ARIEL** geometry. Quantify the beam quality for the ARIEL FEBIAD

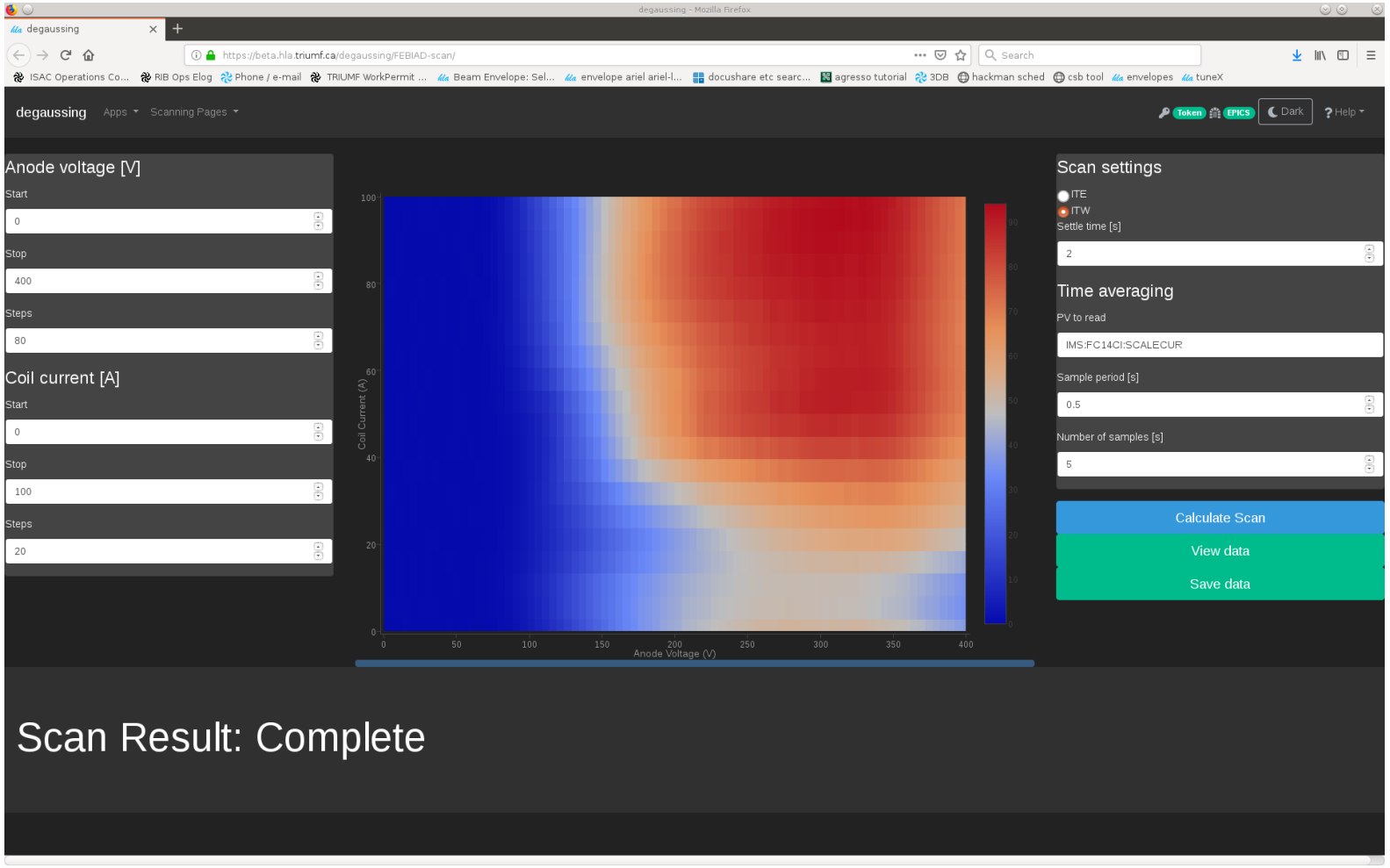
http://hdl.handle.net/1828/14082

How do the TRIUMF FEBIADs look like?



Web-app for automatic contour parameter scans

Please check Omar's talk Thu 13:30
And Santiago's at 14:00



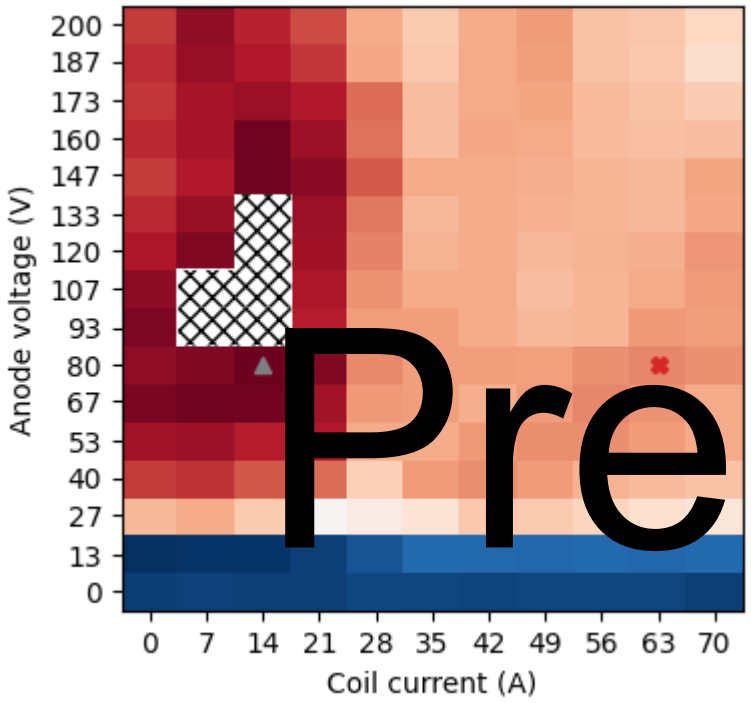
- Thesis data measured locally via HLA libraries.
  - i.e., not user friendly.
- The new paradigm enables any expert to run automatic scans.
  - i.e., user friendly.
- **Significantly reduces workload** considering manual tapping in EPICS.

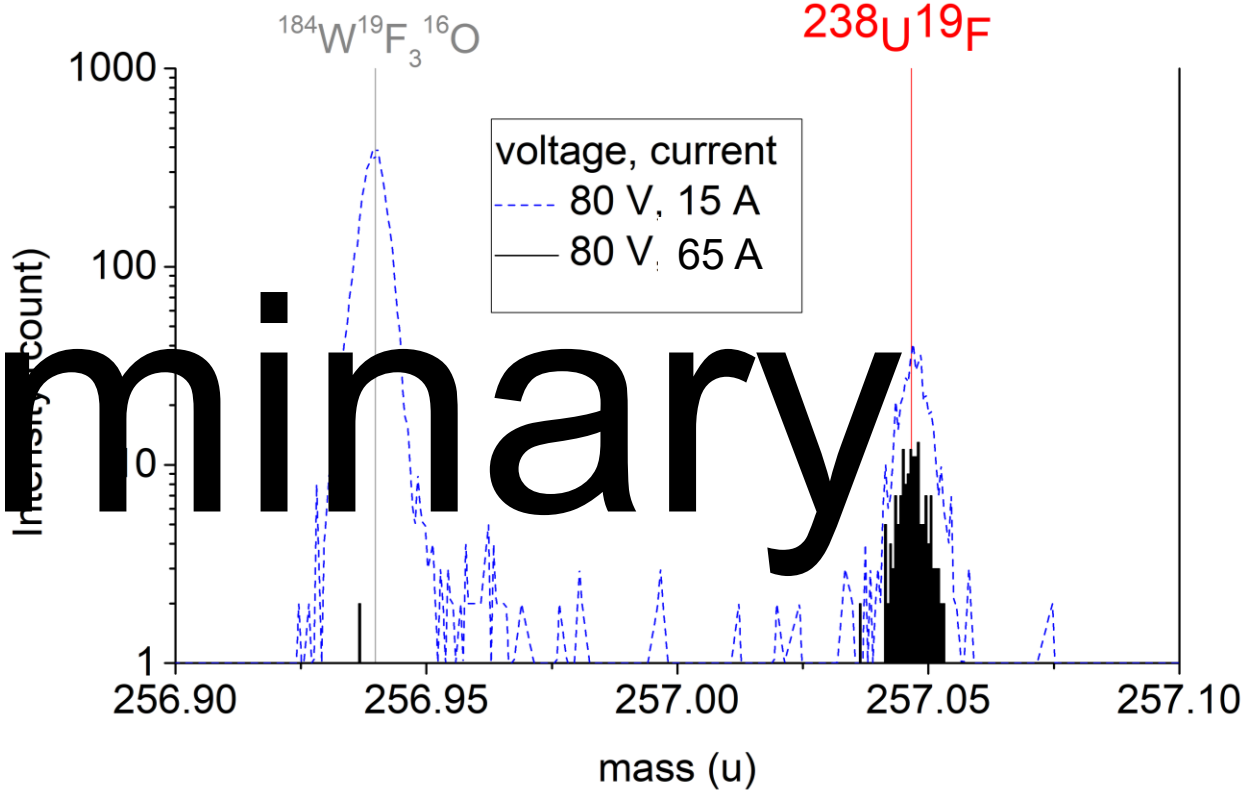
*$^{20}Ne^{++}$ measurement at **ITE,1600** data points automatically measured in just **under two hours**. Support reliability*

10.1088/1742-6596/2743/1/012069

Molecular selectivity for $^{238}U^{19}F^{+}$

Please see poster 147,
Pavi's talk on Thu at 09:40
Wiktoria's talk on Thu at 16:10



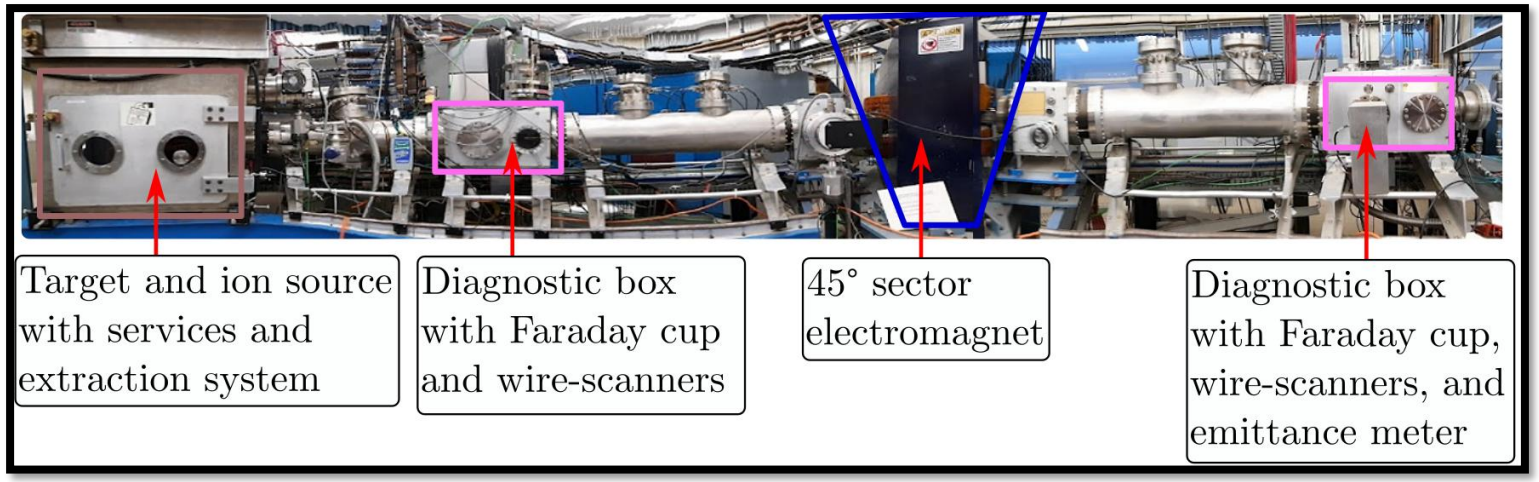


Map in log scale. *Hatch indicates readback error*

- The FEBIAD can be selective by reducing unwanted isobaric molecules. Provides selectivity
- Methodology needs refinement if/when we want to produce in-target radioactive molecules fluorides of interest

How would this be different with ARIEL

- Two Offline test stands



ISAC offline test stand

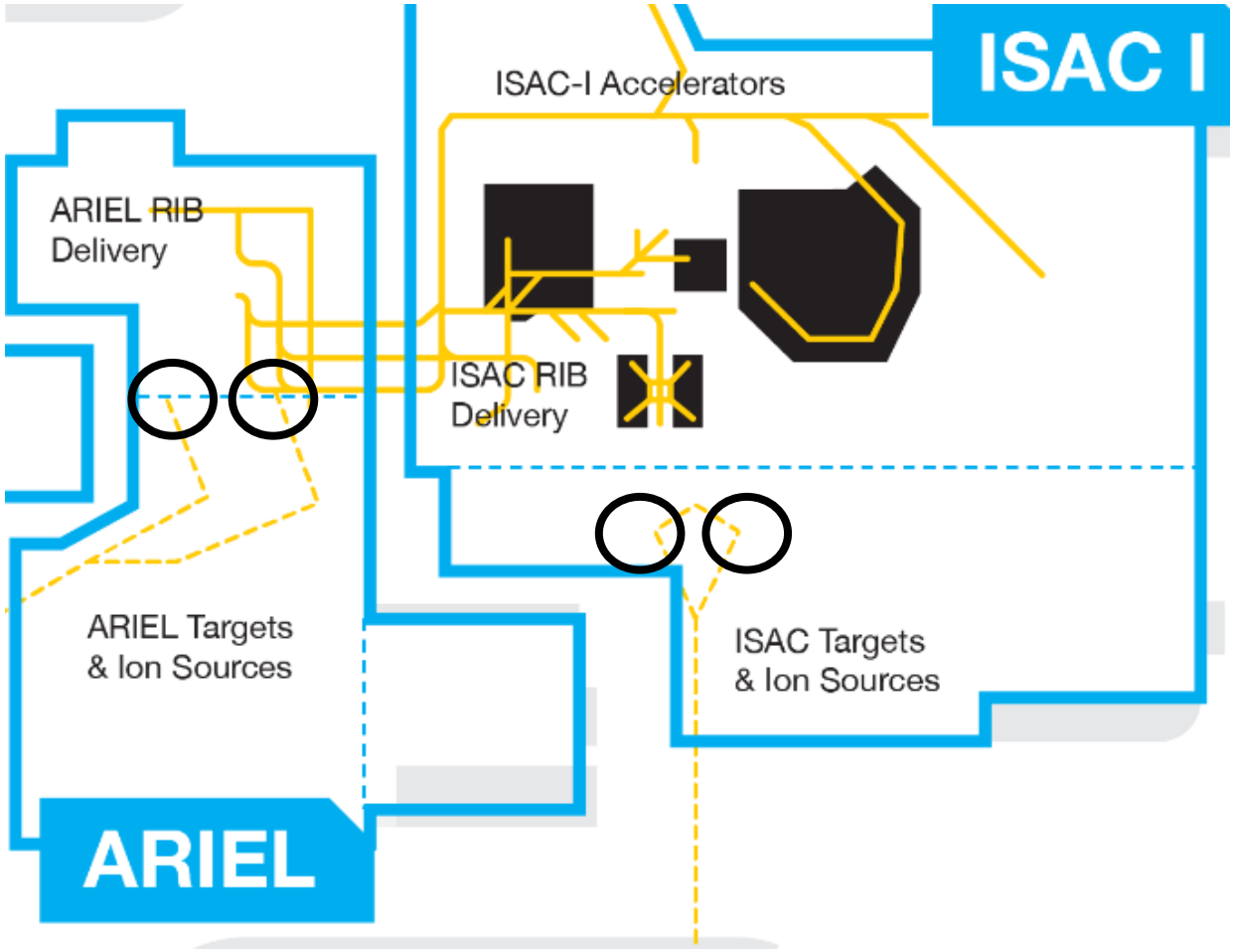
Please Dave's poster 144

ARIEL offline test stand

Please Navid's poster 59

ARIEL: new infrastructure, new opportunities

- Two Offline test stands
- Four target stations



What needs to be answered for ARIEL ion source

Ion beam properties

- Extraction electrode position vs: intensity, beam size, emittance

Isobaric comparison

- With an advanced diagnostic, e.g., an MR-TOF MS, measure production ratios

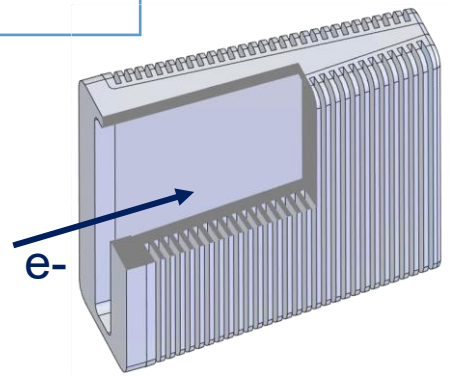
Pulsed electron beam and release efficiency

- Could there be a first step with a pulsed gas injection at an offline test stand to understand better the ion source and with that help understand the target release

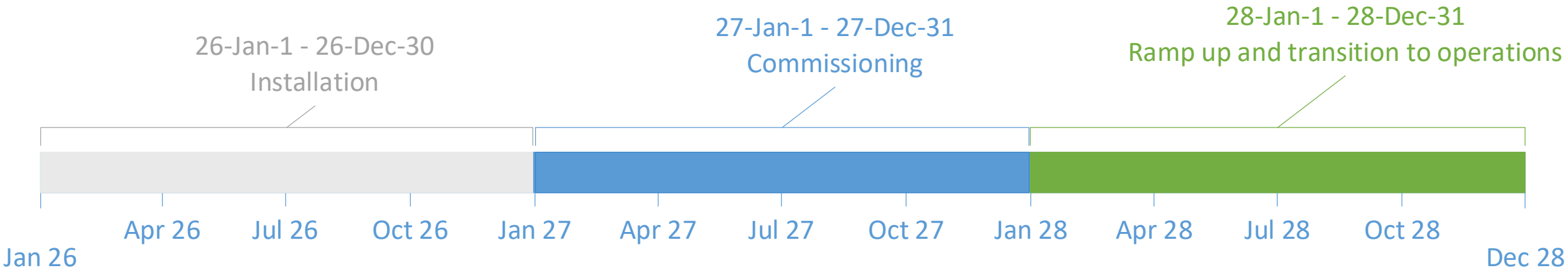
Optimum rastering

- When rastering our electron beam, is there an optimum way for increasing the release, does this affect the ion source

In other words, create a baseline measurement campaign to inform the developments to come



Timeline



- Ready for commissioning by 2027
- 5000 h of RIB to ISAC during the 2029 operational year

Operations mode, and windows for development

Week	Exchange	Unused station	Offline ISAC	Offline ARIEL
1	ITE	ITW		
2	APTW		available	
3	AETE			available
4	ITW	ITE		
5	APTW		available	
6	AETE			available
7	ITE	ITW		
8	APTW		available	
9	AETE			available
10	ITW	ITE		
11	APTW	AETE		available

Bound to :

- Target material production
- Target and Ion Source unit assembly
- Target and Ion Source unit assembly for R&D
  - Pyrophoric materials

Please Marla's poster 148

- ARIEL FEBIAD
- ARIEL IGLIS

ARIEL: new infrastructure, new opportunities

- **Two different geometries would allow us, as with the FEBIAD, to better understand what is happening with the ion sources and make them better.**
- After ARIEL commissioning
  - Standard radioactive ion sources implementation for ARIEL.
  - Students needed for modelling and take current framework beyond what it can do now.
  - Streamline novel ion source geometries prototyping and testing by strengthening international collaboration with our R&D program

How does the future target and ion source look like, how things will look in EMIS40?

Hard to say, but at TRIUMF this starts with more infrastructure to support the ideas to come. Ideas that we need to discuss now and plan as best as we can for their implementation.

Summary

- Numerical and experimental campaign on different geometries provides more insight into what is happening inside the sources.
- The ISAC FEBIAD has a benchmarked model that allows multiple avenues for R&D and supports new developments.
- Creating time for ion source development is difficult with the imminent ARIEL commissioning. During operations we need to be smart about planning and executing R&D.

Thank you!

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Special thanks to the ARIEL team, Alexander Gottberg, Tom Day Goodacre, Carla Babcock, Anders Mjos, Aaron Schmidt, Spencer Kiy, Dan Rowbotham, ACCDIV, the TIS department, RIB ops, HLA, TITAN, Controls, and all the people helping towards ARIEL success.

To Sebastian Rothe, Pierre Delahaye, Mia Au, Wiktoria Wojtaczka, Alberto Monetti, Alberto Girotto, and Michele Ballan for discussions