ARIEL e-Linac

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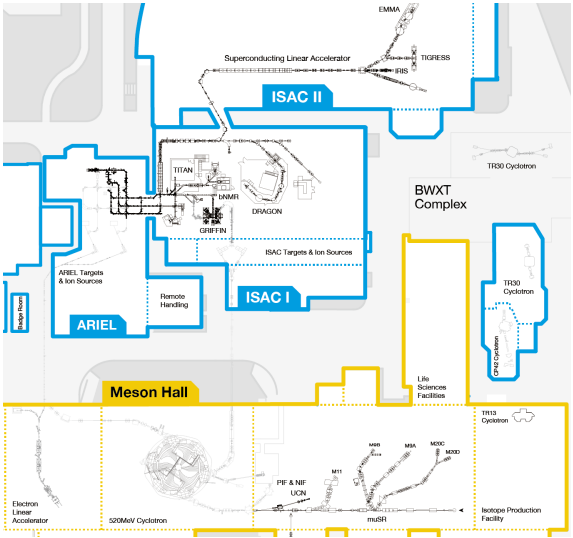
TRIUMF: Canada's particle accelerator centre



ARIEL e-linac:

- Second high-power driver to increase the capability of TRIUMF's Isotope Separator Online (ISOL) facility
- ARIEL electron target will be ready to take its first electron around the end of 2024.

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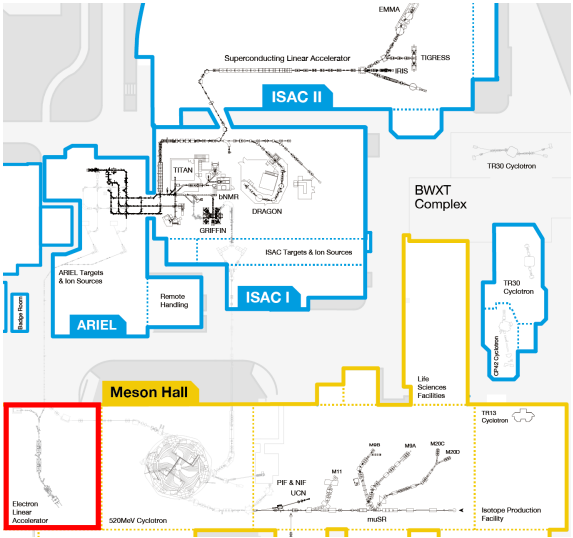

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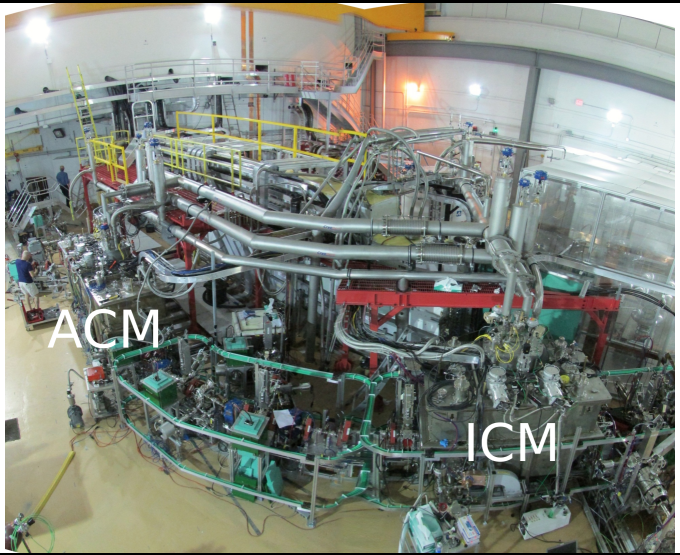
Fisheye view of the ARIEL e-linac



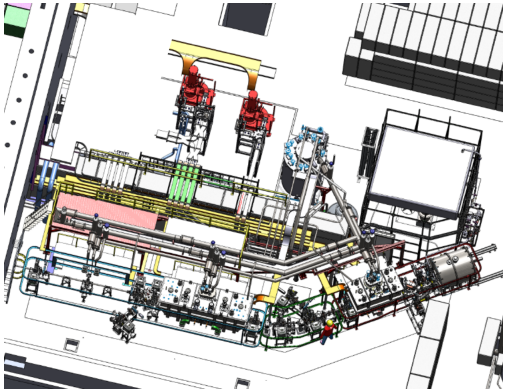
Layout of the existing facility

e-Gun: 300 kV thermionic gun, produces bunches at 650 MHz, delivers up to 10 mA average beam current in CW mode.

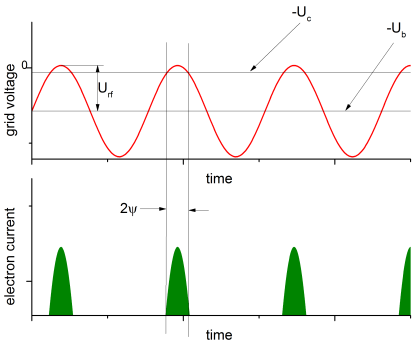
Linac: 3×9-cell 1.3 GHz niobium cavities working at 2K in 2 different cryomodules. 2×50 kW RF couplers per cavity

RF sources: 2×300 kW CPI klystrons. Use a single rf source for 2 cavities (second cryomodule).

Cryo: 800 W (@4 K) He liquefier. 2 K Busch sub-atmospheric pumps, 3 in operation, 1 'spare'.



300 kV DC e-gun



The cathode has a grid with DC suppressing voltage and rf modulation that produces electron bunches at 650MHz.

Cryo

ALAT LL Cold Box, KAESER (FSD571SFC) main compressor (112g/s), Cryotherm - distribution

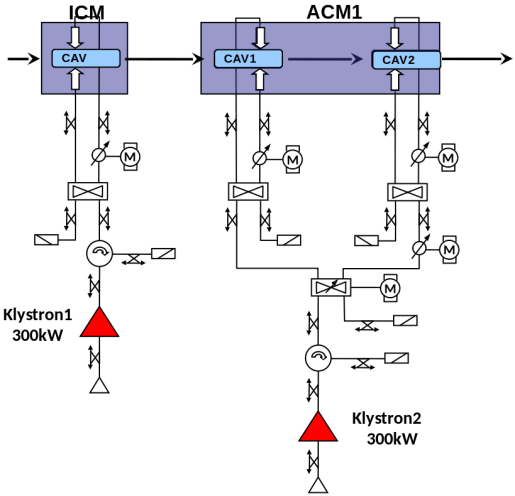
4 Busch combi DS3010-He pumping units specified and installed (1.4g/s @ 24mBar each)

Klystrons

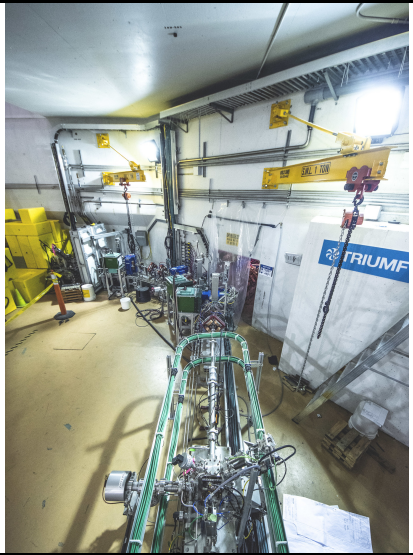
Two CPI 290 kW cw 1.3 GHz klystrons in the e-hall

Klystrons' 600 kW 65 kV power supplies (Ampegon) on the e-hall roof

The second Klystron provides power to two cavities



10 kW tuning dump

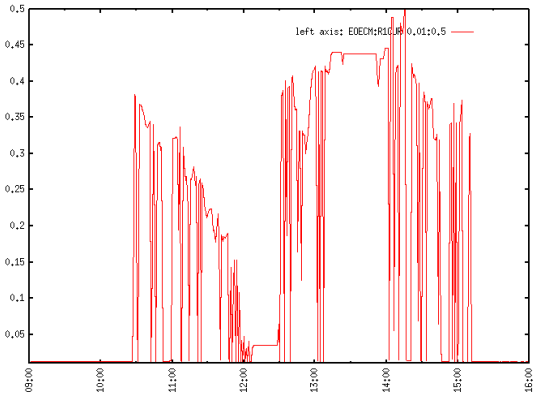


Since September 2021

BEAM	ON
PATH	EHD:DUMP
PEAK CUR.	498 µA
ENERGY	30.2 MeV
POWER	10.0 kW

In this case the duty factor was 66%.

Typical day of 10 kW beam delivery



Peak beam current in mA along the day: shows instability and multiple beam trips. The system is not yet ready for reliable operations.

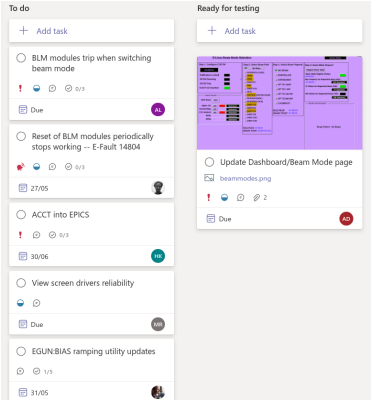
Roadmap towards reliability

Top 4 issues that case downtime:

- **e-Gun**: high-voltage and beam current stability
- **Tunability**: many procedures depend on tedious manual interventions. This also complicates the training of Operators.
- **Spurious trips**: complex interlock chains and unreliable diagnostics cause many beam interruptions
- **Lack of spare parts**: simple failures cause long delays

We have established a strategy to address these issues over the coming year, but we would like to discuss some of the most critical aspects with you during this workshop.

Implemtation of the Roadmap



We track the resolution of issues every week in a meeting where all the key service groups are represented.

Intermediate milestones:

#1 **Jan. 2022** Startup in less than 30 min: lock up to beam ON.

#2 **Jun. 2022** Energy stability better than 0.1%.

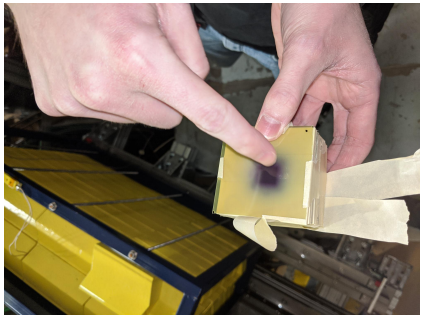
#3 **Dec. 2022** 8-hour continuous beam delivery.

#4 **Mar. 2023** 3-day continuous beam delivery.

2022: first users

Beam delivery to FLASH:

Life science experiment at our 10 MeV beam dump to explore high dose rate radiotherapy (X-rays)



Impact on the e-linac development:

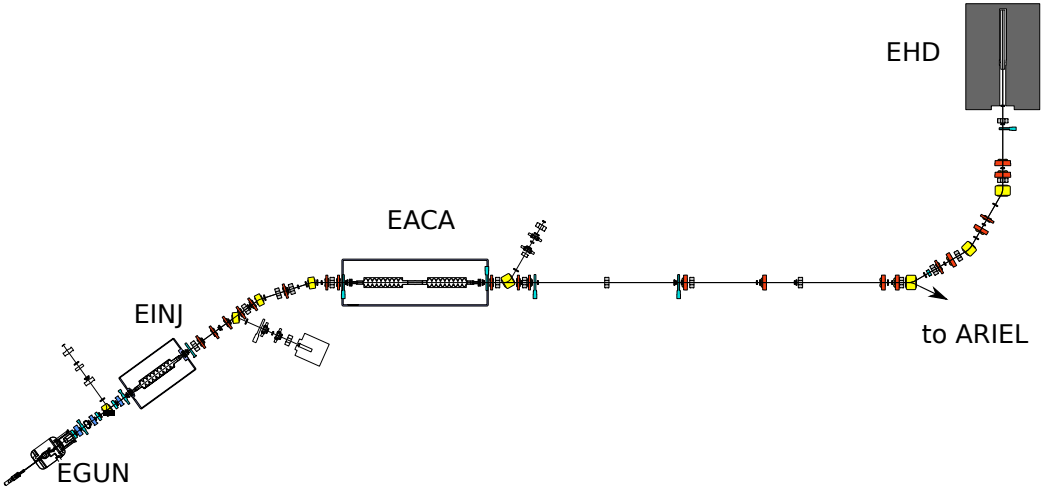
- **Reliability**: practice reliable beam delivery
- **Motivation**: early science from e-linac
- **Training**: train operators to support e-linac operations as other accelerators on campus

Need to find the right balance between beam time given to users, and beamtime dedicate to machine development. Current weekly plan: $>$3 days for development + training + maintenance, $<$2 day for users.

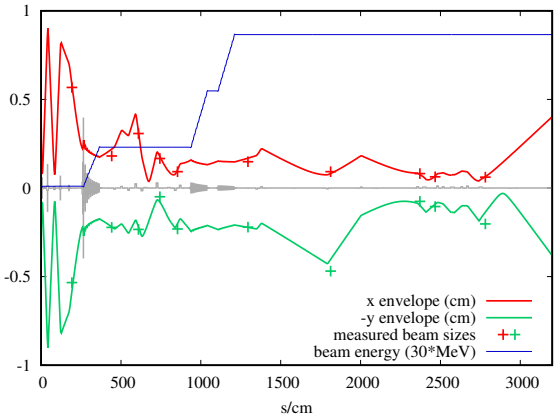
Questions for the discussion session

- How reliable are your electron linacs?
- How did you get there?
- What worked for you and what did not?
- What limits the performance of your machines?
- What are the main sources of downtime?

Layout of the existing facility



Beam optics model



Comparison between optics model and measured beam size, from 300 keV to 26 MeV.

Beam loading effect in pulsed beams

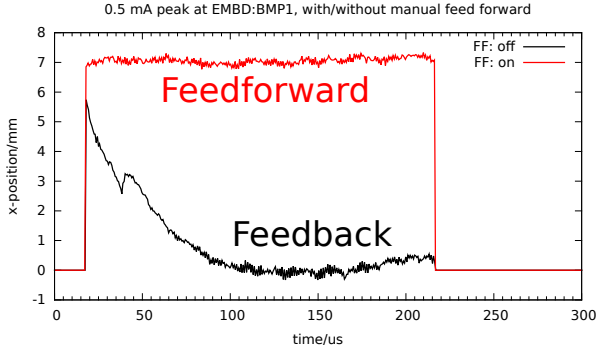


Illustration of the effect of beam loading: the cavity feed back system is not fast enough to cope with the front of the beam pulse. Need feed forward.