TRIUMF

Particulate migration at the TRIUMF e-Linac and ISAC II superconducting linac

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Natural Sciences and Engineering Research Council of Canada
Conseil de recherches en sciences naturelles et en génie du Canada
Canada

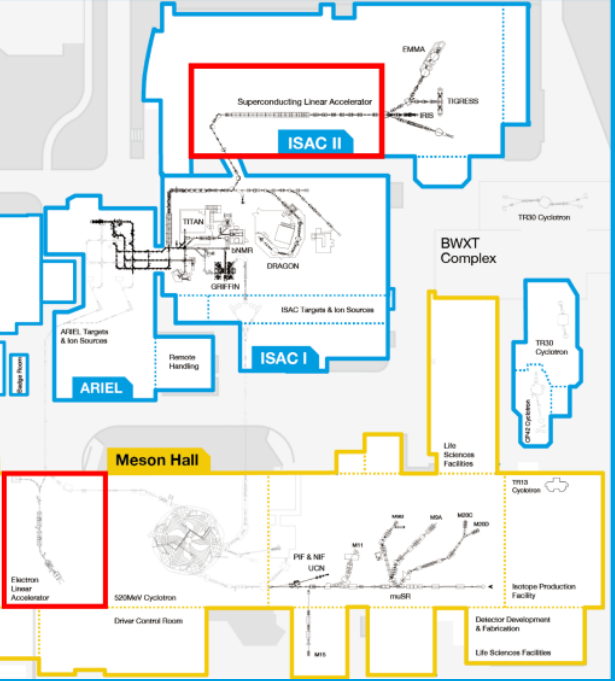
TRIUMF: Canada's particle accelerator centre

Founded in 1968 by 3 universities, TRIUMF has evolved into a multidisciplinary facility owned and operated by a consortium of Canadian universities from coast to coast.

TRIUMF is home to ~600 staff members and students.

Member Universities

University of Alberta
University of British Columbia
Carleton University
University of Calgary
University of Guelph
University of Manitoba
McMaster University
Université de Montréal
Queen's University
University of Regina
Simon Fraser University
University of Toronto
University of Victoria
York University



Main Superconducting RF Lines at TRIUMF:

ISAC II - heavy ions

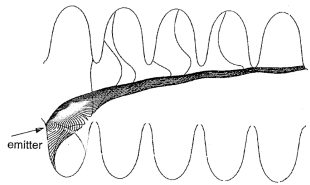
e-Linac - electrons

Dust in SRF Cavities $\rightarrow$ Field Emission (FE)

FE $\rightarrow$ emission of e^- from regions of $\uparrow$ surface E field.
Prevalent in SRF cavities due to high gradient.

Limits machine performance:

- Extra load on RF power $\rightarrow$ lower quality factor;
- Quench of SC state $\rightarrow$ downtime;
- X-rays $\rightarrow$ long term damage to equipment.



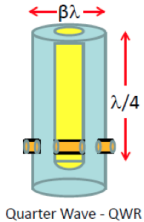
Padamsee, H., Knobloch, J., & Hays, T. (2008). RF superconductivity for accelerators.

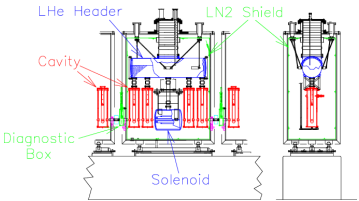
Emitters are commonly μm to sub μm sized contaminants $\rightarrow$ dust.

TRIUMF ISAC II SC Linac

RF parameters:

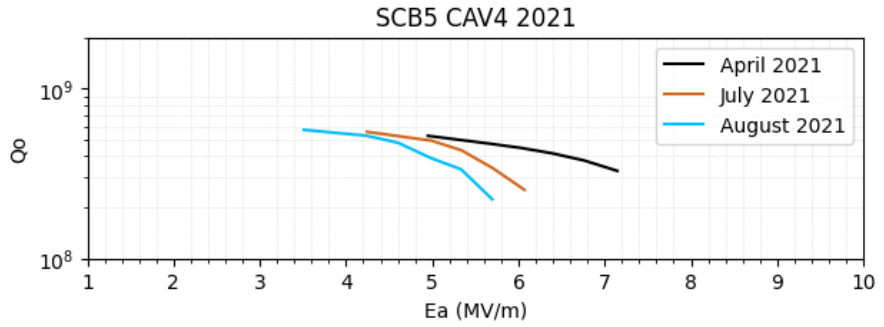
- 40 quarter wave resonator cavities interspersed with SC solenoids;
- Low β ($\approx$ 0.05-0.15);
- 4 degrees Kelvin;
- RF frequency $\approx$ 100 MHz.





Q-degradation at TRIUMF - ISAC II

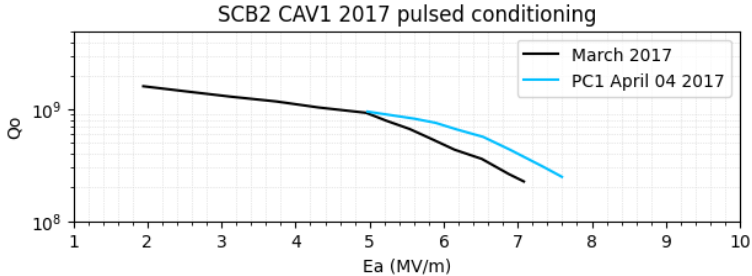
Observed when plotting quality factor (Q) VS accelerating gradient (Ea):

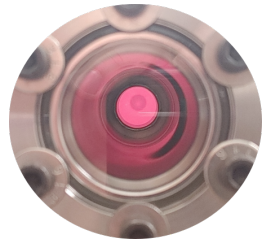


Steady drop in Q with prolonged operation $\rightarrow$ onset of FE at lower gradients.
BUT not necessarily due to dust migration from outside cryomodules.

Current Mitigation Techniques

Pulsed conditioning → process emitters with short bursts of high field.





Ignited Ar plasma inside 1-cell cavity test setup at TRIUMF. (*D. Hedji*)

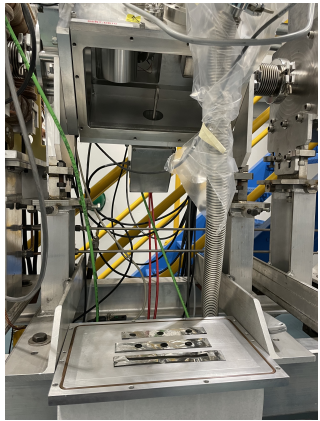
Other in situ techniques in development at TRIUMF:

- Plasma conditioning: requires room temperature conditions.

Sample Installation ISAC II SC Linac

Long term sample installation:

- Quantify particulate migration;
- Retrieval planned for Jan 2024.



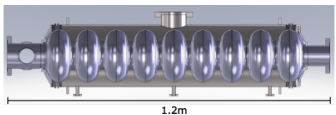
DB10

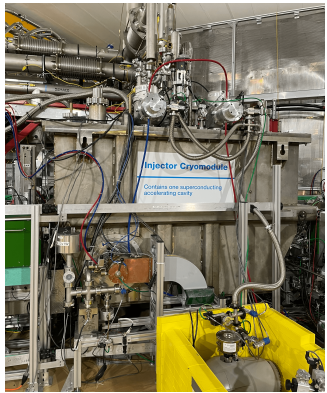
DB2B

TRIUMF e-Linac

RF parameters:

- Elliptical 9-cell cavities;
- $\beta \approx 1$;
- 2 degrees Kelvin;
- RF frequency 1.3 GHz.

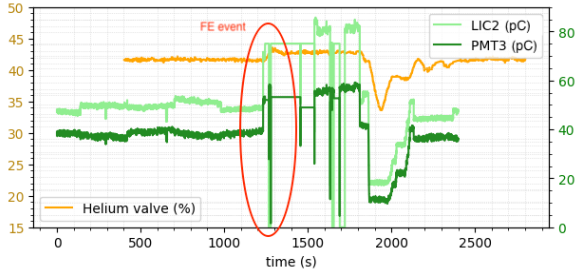


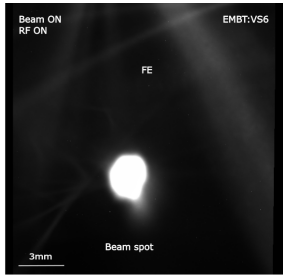


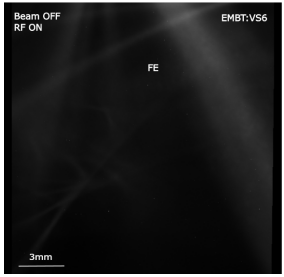
Field Emission at TRIUMF: e-Linac

Most easily observed on viewscreen diagnostics ⇒ When beam is off Field Emission REMAINS!

Field emitter events registered by RF and cryogenics readback (June 2023):



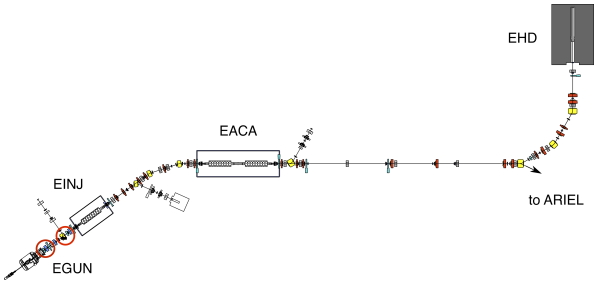




Dynamic process → degradation of new system is a stronger indication of dust migration.

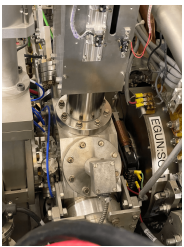
e-Linac Dust Collection

Samples collected on Jan 25th, 2023 from ELBT section and August 31st, 2023 from EGUN section.



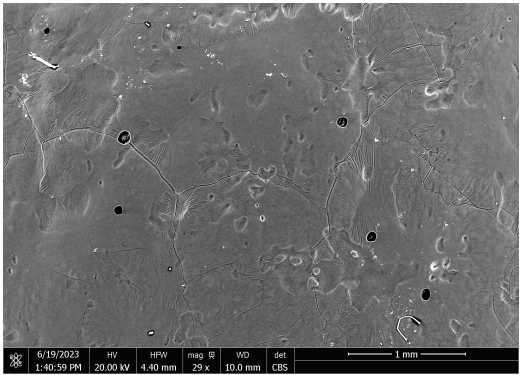
ELBT

EGUN:DB1

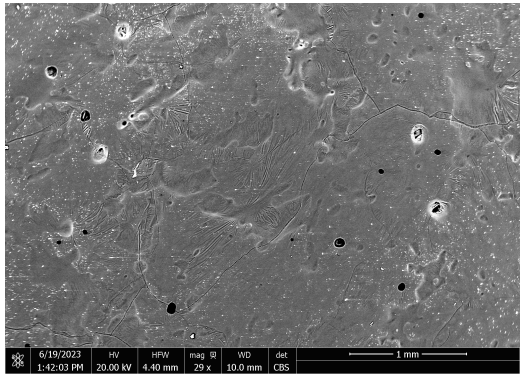


e-Linac Dust Collection

Analysis via Scanning Electron Microscopy (SEM) and X-ray spectroscopy (EDX).



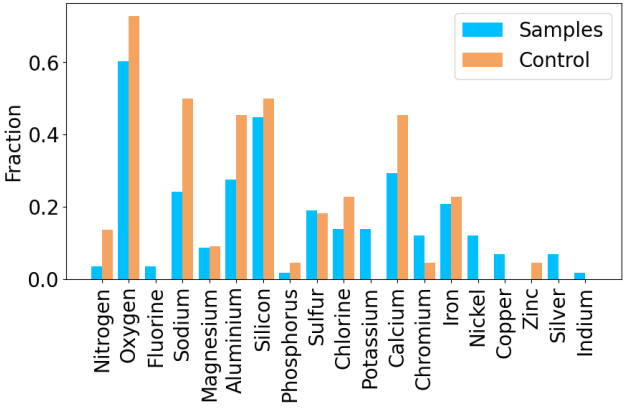
Control sample

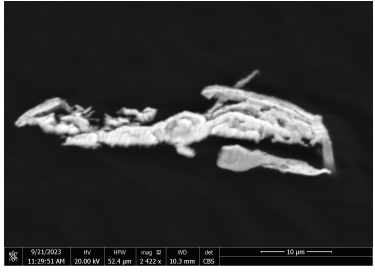


Dust sample

e-Linac Dust Collection

Analysis in progress - low statistics: 58 dust grains and 22 control grains.
Summary of elemental analysis thus far:



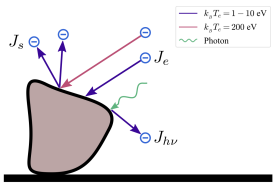


Example of silver-copper dust grain identified and analysed via SEM/EDX.

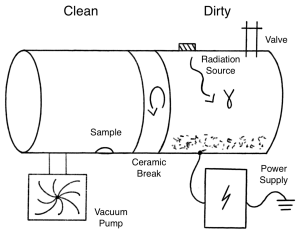
TRIUMF Study

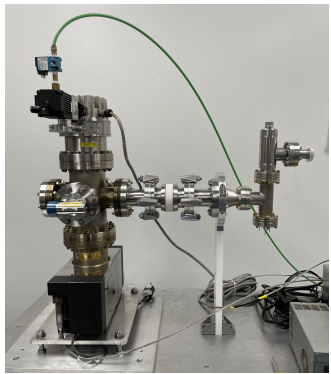
Goal: Investigate dust migration mechanism and test mitigation technique:

- Potential Barrier $\rightarrow$ Block charged particulates from migrating



Bélanger, P., et al. (2022). Charging mechanisms and orbital dynamics of charged dust grains in the LHC.





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Thank you
Merci

References

P. Bélanger, R. Baartman, G. Iadarola, A. Lechner, B. Lindstrom, R. Schmidt, and D. Wollmann. Charging mechanisms and orbital dynamics of charged dust grains in the lhc. *Physical Review Accelerators and Beams*, 25(10):101001, 2022.

Hasan Padamsee, Jens Knobloch, and Tomas Hays. *RF superconductivity for accelerators*. John Wiley & Sons, 2008.

Appendix - ISAC II