Particulate contamination in TRIUMF linear accelerators

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A. Mahon[1,2], T. Planche[1,2]

[1]TRIUMF, Vancouver, Canada | [2]UVic, Victoria, Canada

High energy requirements

The TRIUMF electron linear accelerator (**e-Linac**) requires reliable performance at **high accelerating gradient** for several upcoming projects:

- **ARIEL** ⇒ isotope photofission yield (fig. 3).
- **DarkLight** ⇒ X17 production cross-section.

Case Study: DarkLight

This experiment will investigate the **scattering products** from the incident electron beam on a tantalum target in the search for a **Dark Matter** candidate. The **beam optics** for this experiment present several challenges:

- **Highly scattered** beam transport.
- **Space constraint** from experiment detectors.

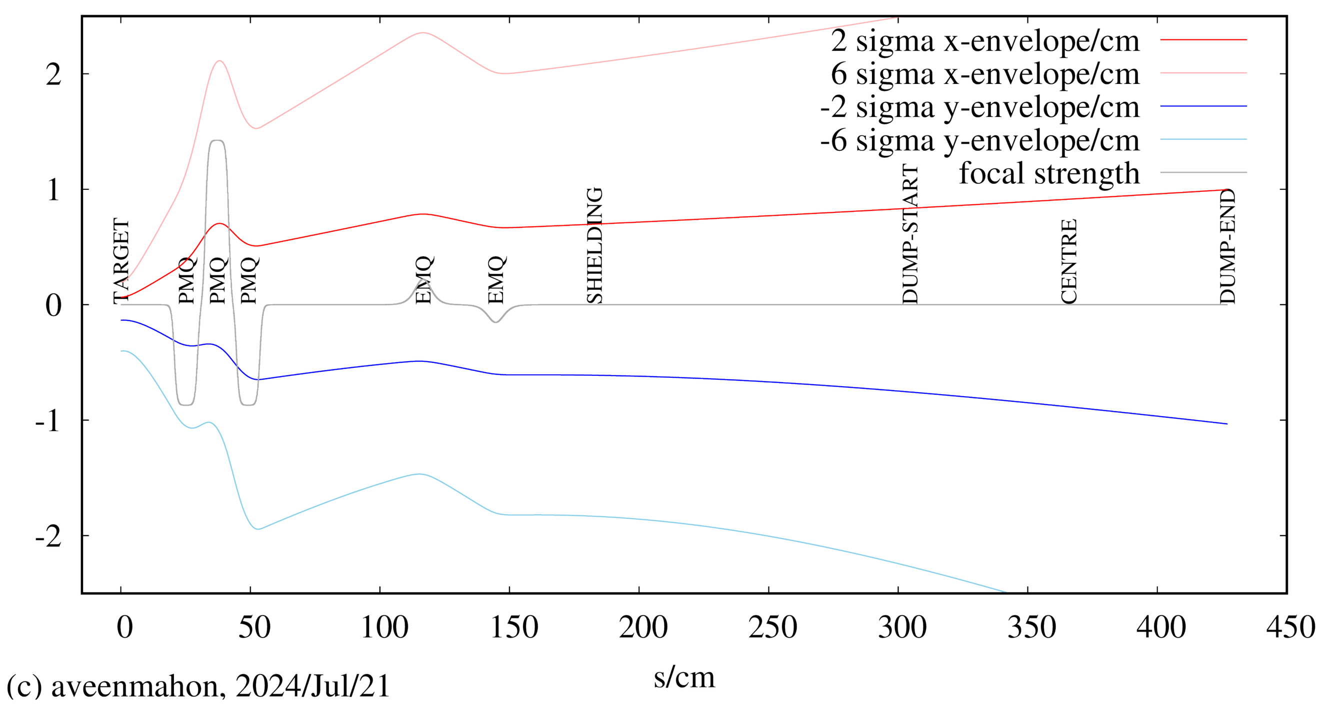

Figure 1. Beam envelopes simulated in TRANSOPTR from location of 1 µm tantalum target to beam dump for beam energy of 31 MeV.

Solution: use **permanent magnet quadrupoles** which are much more space efficient (fig. 1). However, these magnets have **fixed field strength** designed for a **specific beam energy** ⇒ rely even further on **stable RF performance**.

RF reliability challenges

Field Emission is a key limitation to the performance of superconducting rf cavities used in the e-Linac. This is a phenomenon wherein **rogue electrons** are emitted from regions of high surface electric field in the cavities (fig. 2), causing:

- Extra load on RF power ⇒ **Lower cavity gradient**.
- **Quench** of superconducting state from localized heating.
- **X-rays** ⇒ long term damage to equipment.

Emitters identified as **dust particulates!**

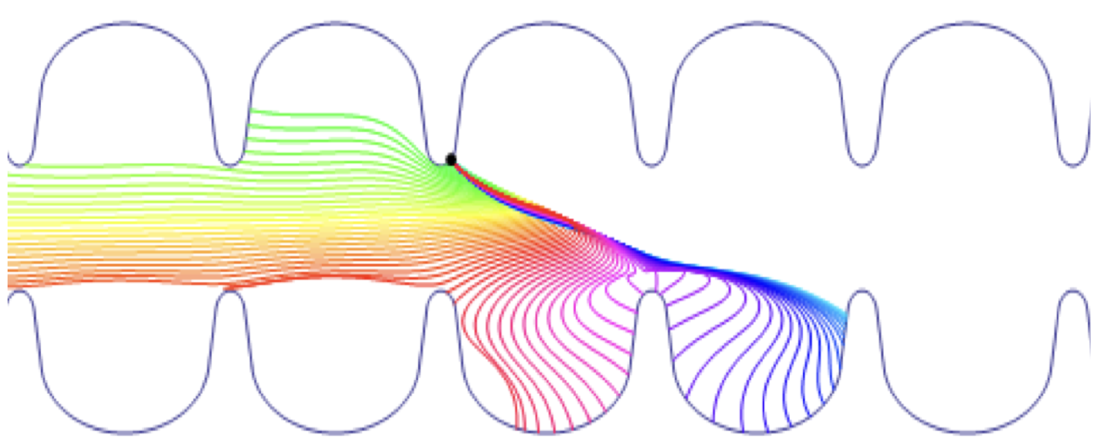

Figure 2. Simulated trajectories of field emission electrons in a 5-cell rf cavity. Each line corresponds to a different RF phase. [1].

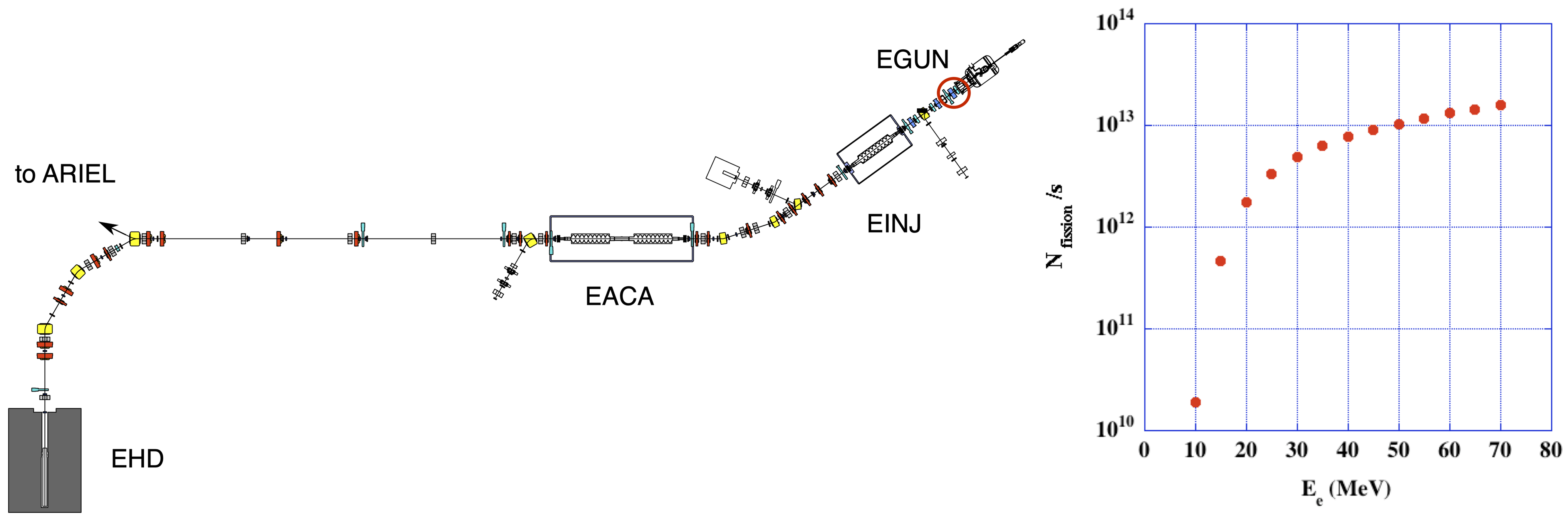

Figure 3. Left: Schematic of TRIUMF e-Linac. Right: Isotope photfission yield as a function of beam energy at ARIEL [2].

Particulate collection and characterization

To understand the conditions at the **e-Linac**, samples of **dust particulates** were collected. Their **morphology and composition** were analysed using Scanning Electron Microscopy **(SEM)** and Energy-dispersive X-ray Spectroscoy **(EDX)**:

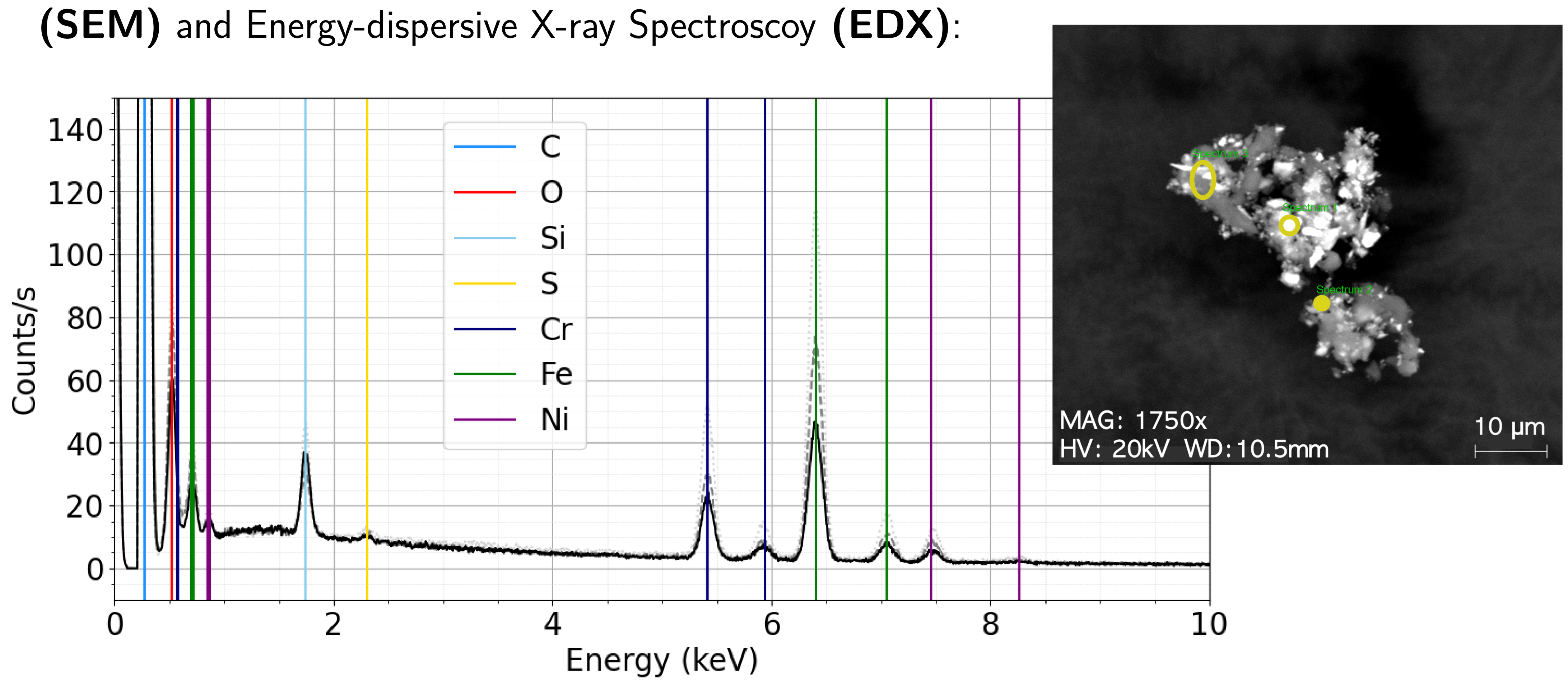

Figure 4. SEM image and EDX spectrum of e-Linac particulate. Areas within yellow circles are used for EDX analysis. Characteristic x-ray energies obtained from LBNL data booklet [3].

A total of **5 control** and **87 sample** particulates were analysed, with the **composition** summary shown in fig. 5. The elements found via EDX were **normalized** with respect to the **number of grains** analyzed, as well as the **density** of the grains on the samples.

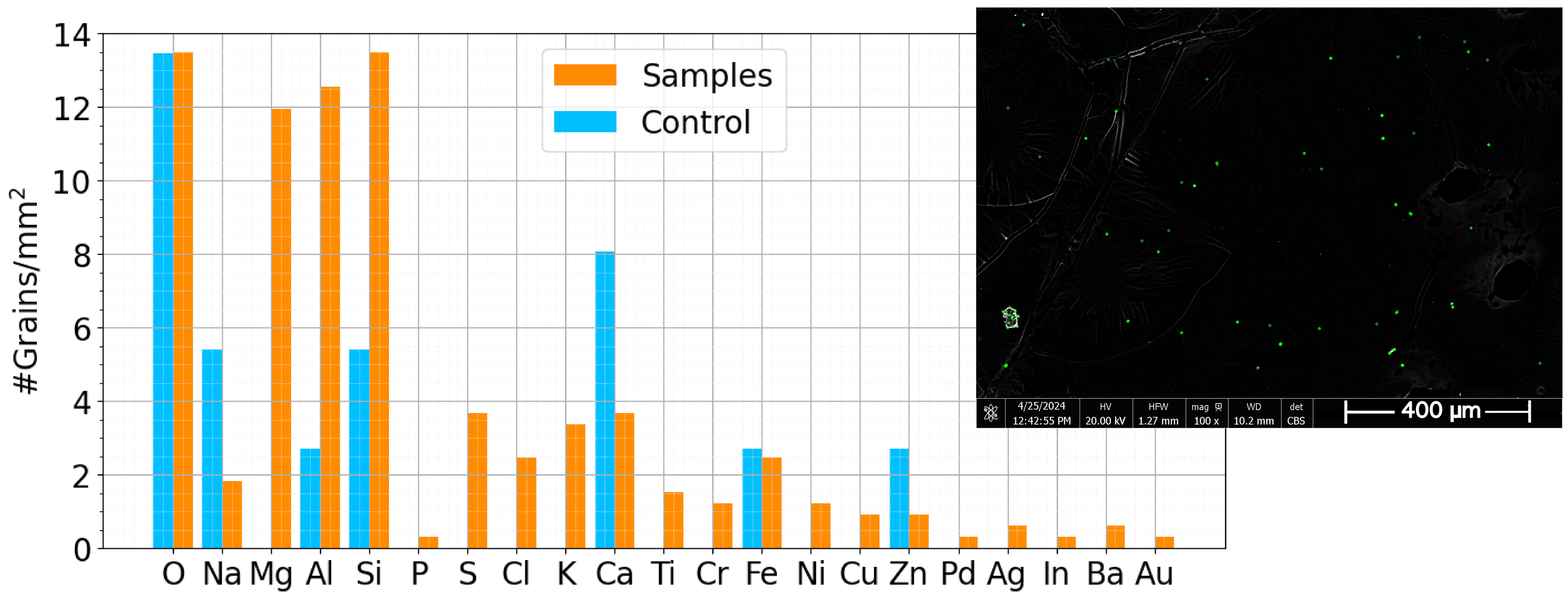

Figure 5. Summary of elemental composition of particulates collected from the e-Linac.

The **key takeaways** are:

- The **size** of particulates varies considerably, from a few micrometers to several hundred.
- **Conducting elements** have been identified which are not present on control samples.

Further studies are currently being conducted to investigate the **mechanisms** behind **charging, detachment and migration** of dust inside accelerators.

References

[1] Rongli Geng. Root causes of field emitters in srf cavities placed in cebaf tunnel. Technical report, Thomas Jefferson National Accelerator Facility (TJNAF), Newport News, VA , 2016.

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[3] Lawrence Berkeley National Laboratory Center for X-ray Optics and Advanced Light Source. *X-RAY DATA BOOKLET*, 10 2009. Rev. 3.

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