

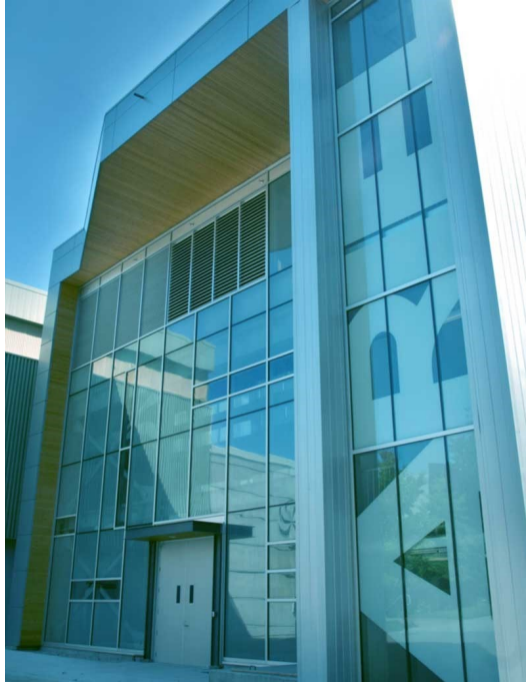


Locked in a Dark and Dusty Basement:

Field Emission and Particulate Contamination in the TRIUMF e-Linac

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Department of Physics and Astronomy, UVic
Accelerator Division, TRIUMF

February 14th, 2025
WNPPC 2025, Banff



Discovery,
accelerated

TRIUMF is located on the traditional, ancestral, and unceded territory of the Musqueam people.

<https://native-land.ca/>



Outline:

- Electron Linear Accelerator
- DarkLight
- Field Emission
- Particulate Collection and Analysis



Accelerator Complex

Cyclotron

ISAC

e-Linac

**Discovery,
accelerated**



Accelerator Complex

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ISAC

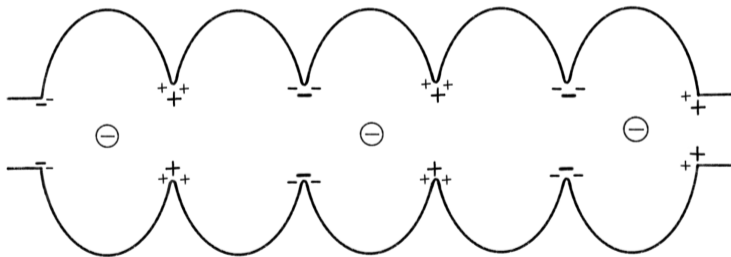
e-Linac!!

Discovery,
accelerated

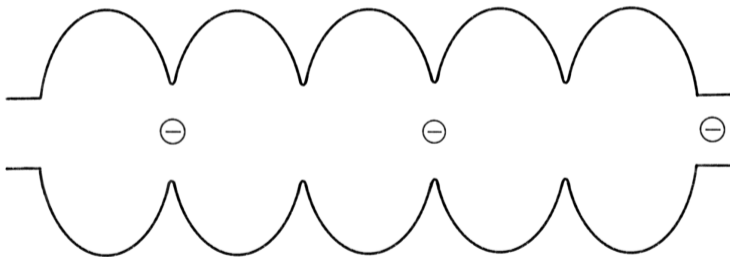




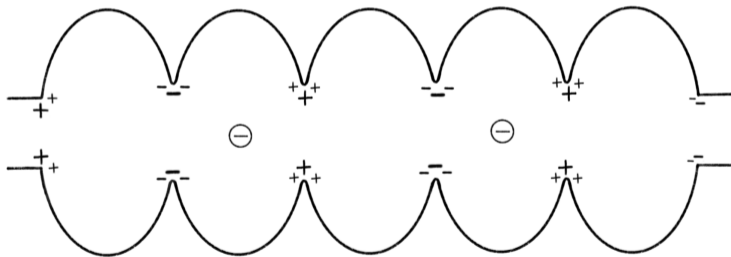
- Time varying electromagnetic (EM) fields
- Cavity design resonates at frequency in sync with passage of particles



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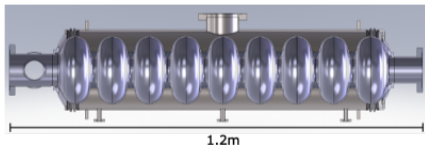


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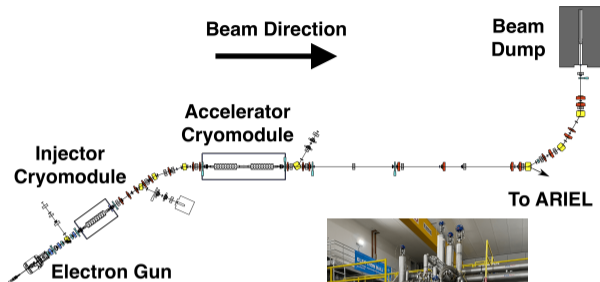


Parameters:

Total beam energy	30 MeV
Nominal beam current	10 mA
Power rating of dump	10 kW
RF frequency	1.3 GHz
Cavity type	Elliptical (9-cell)
Cavity material	Bulk Niobium
Cavity temperature	2 K

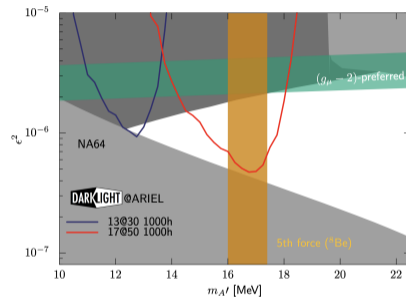
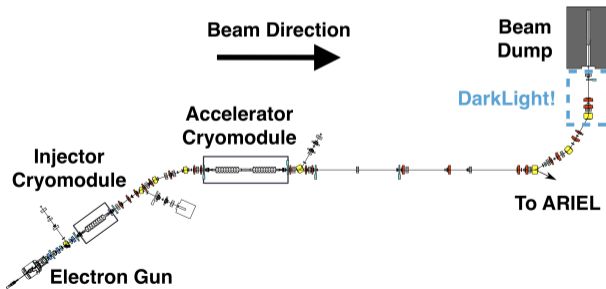


Operate (quasi) CW or at reduced duty factor.



What is DarkLight?

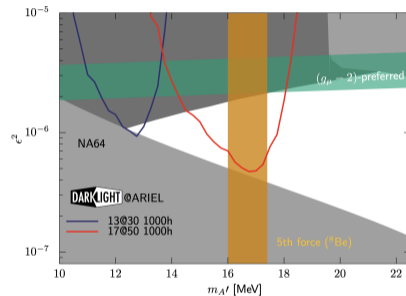
- Scattering of e^- beam on tantalum target.
- Pair production of e^-/e^+ to search for mass resonance of new interaction boson.



Projected exclusion plot for 2-phases of DarkLight by L. Miller.







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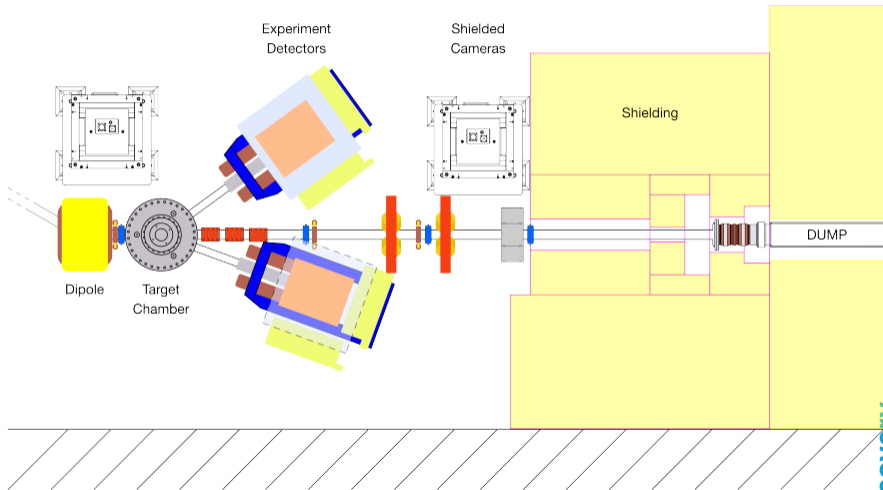
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Discovery,
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- Legend
-  Steerer
 -  BPM
 -  PMQ
 -  EMQ
 -  Diagnostics Box
 -  Collimator

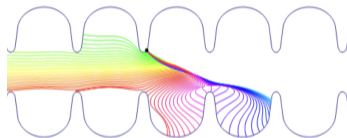


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Prevalent in SRF cavities due to high gradient.

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Limits cavity performance:

- Extra load on RF power
 → lower cavity gradient;
 → consequences for
 delivery to experiments.

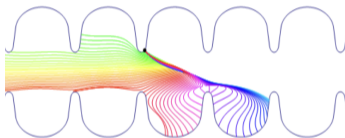


[1]

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 → long term damage to equipment.

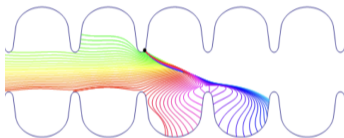


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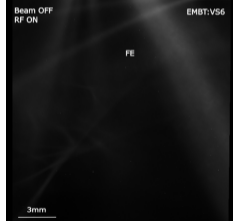
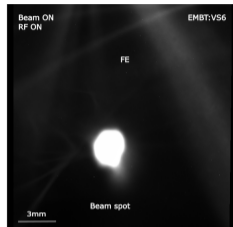
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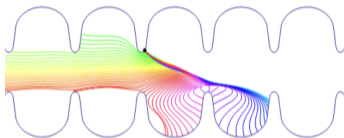


FE seen on e-Linac view screen.

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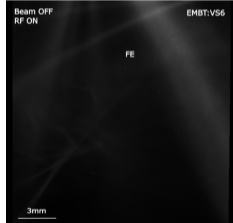
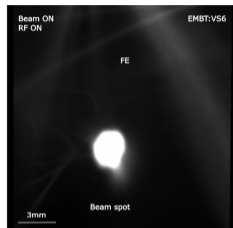
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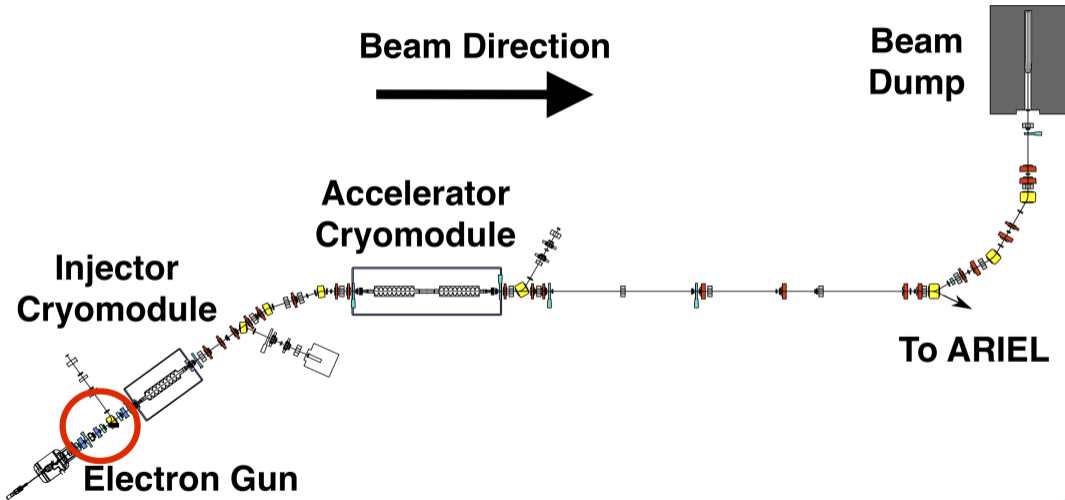
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Emitters are μm to sub μm sized contaminants ⇒ **dust!**

Migrate back into SRF cavities during operation...



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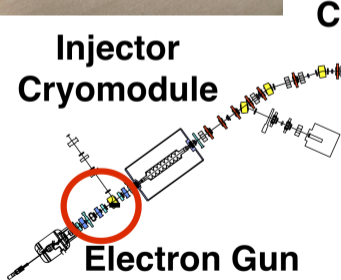


Beam Direction



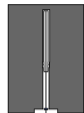
Accelerator
Cryomodule

Injector
Cryomodule



Electron Gun

Beam
Dump

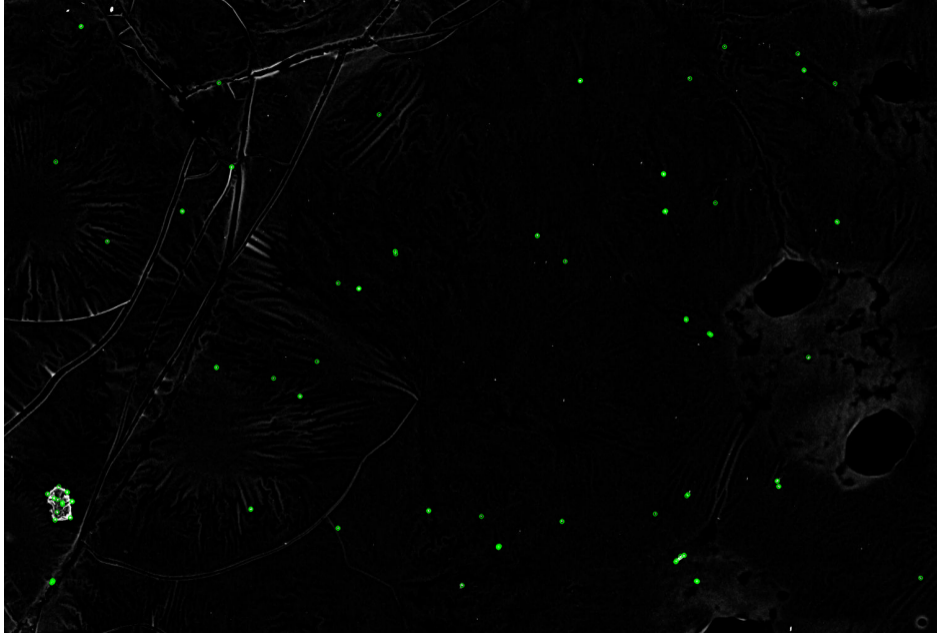


To ARIEL

Analysis tools:

Scanning
Electron
Microscope
(SEM)

Energy-
dispersive X-ray
Spectroscopy
(EDX)



4/25/2024
12:42:55 PM

HV
20.00 kV

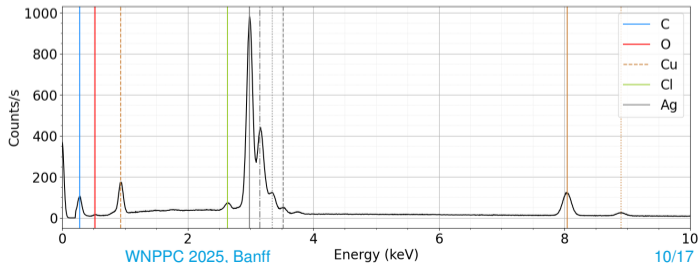
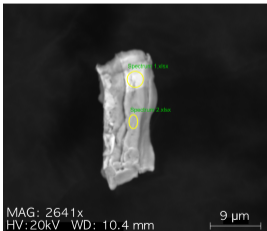
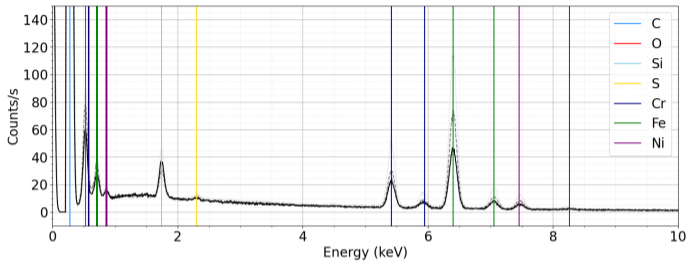
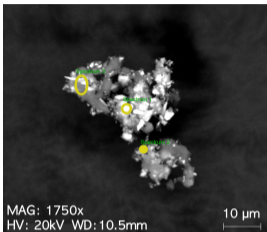
HFW
1.27 mm

mag 貝
100 x

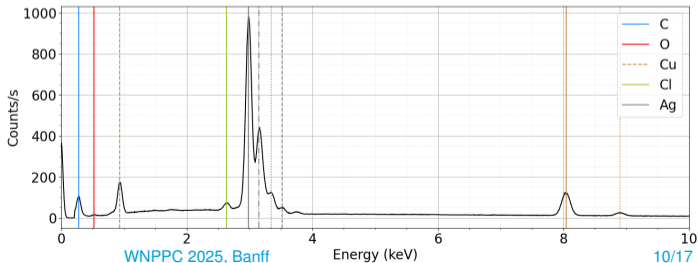
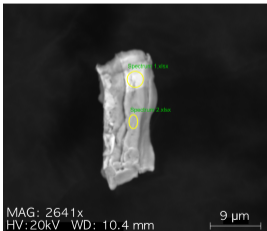
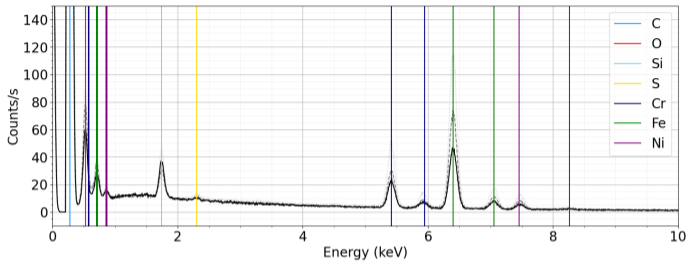
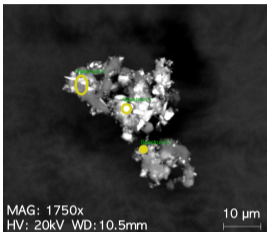
WD
10.2 mm

det
CBS

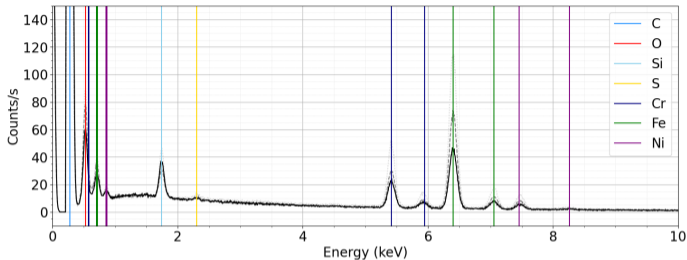
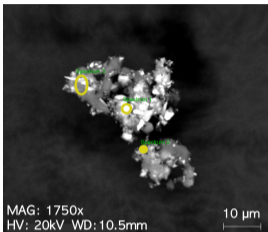
400 μm



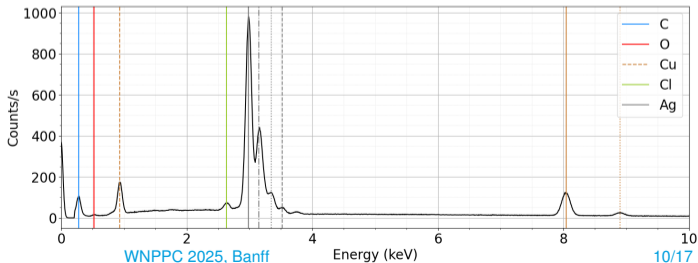
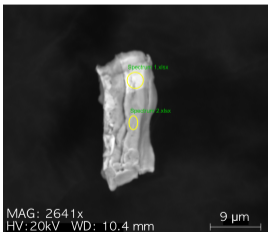
Stainless steel



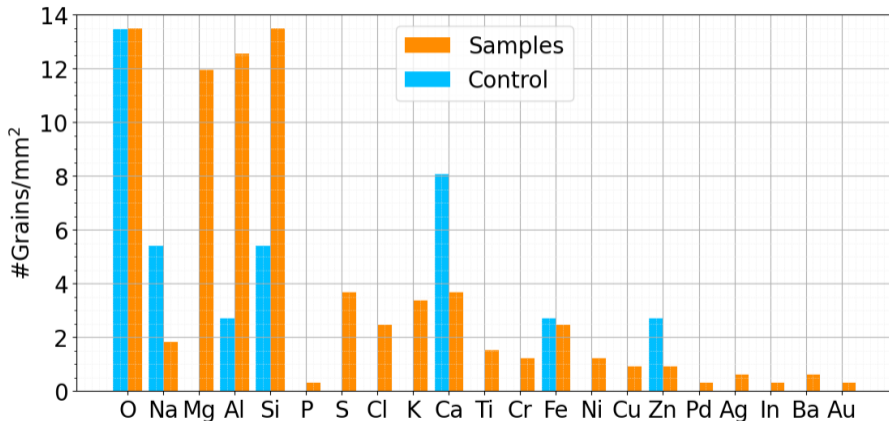
Stainless steel



Copper-silver alloy



Grain statistics: 87 beamline grains & 5 control grains analyzed.



Where do these come from??

Potential origins of elements:

Element	Source
Al/Pd/Au	Test stand or electrical connectors
K	Human contamination
Ti	Cathode electrodes
Stainless Steel (Fe+Ni+Cr)	Most beamline elements
Cu/Ag	Braising, anode electrodes
In/Ba	Cathode material

Conceived an **off-line test setup** to reproduce the accelerator environment, with control on key parameters.

Goal: study each step in dust migration process:

- **Charging** $\Rightarrow e^-$ & γ
- **Detachment** \Rightarrow baking
- **Migration** \Rightarrow mechanism unknown...





Thank you
Merci



-  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.

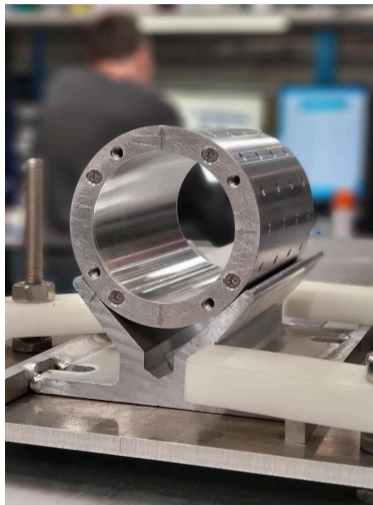
Beam optics for DarkLight present challenges:

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

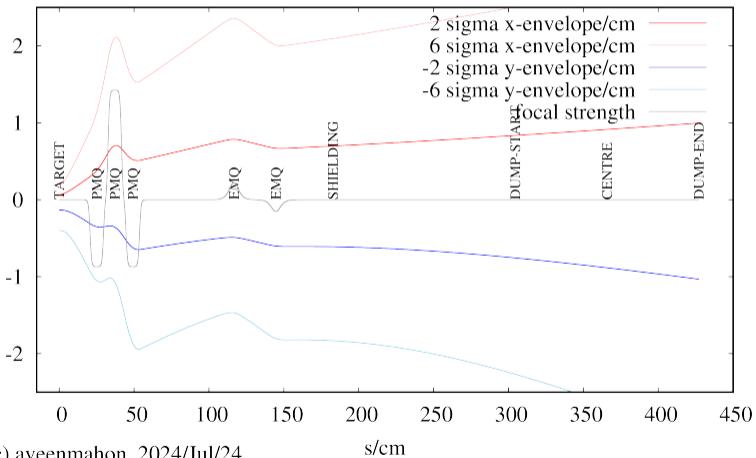
Combination of electromagnets and permanent magnets:

- Pros: space efficient
- Cons: cannot vary field strength

Optics designed for a specific beam energy
⇒ rely on stable RF performance.

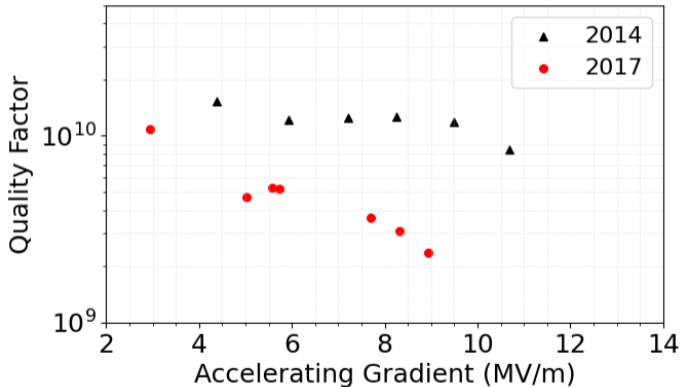


Optics design optimized in envelope code TRANSOPTR



(c) avenmahon, 2024/Jul/24

Quality factor (Q) vs Acceleration Gradient (E_a) of e-Linac cavity over time.
(Power Stored/Dissipated)



If we cannot deliver required energy for DarkLight, there is no experiment!