TRIUMF

# TRIUMF e-Linac facility and ERL upgrade

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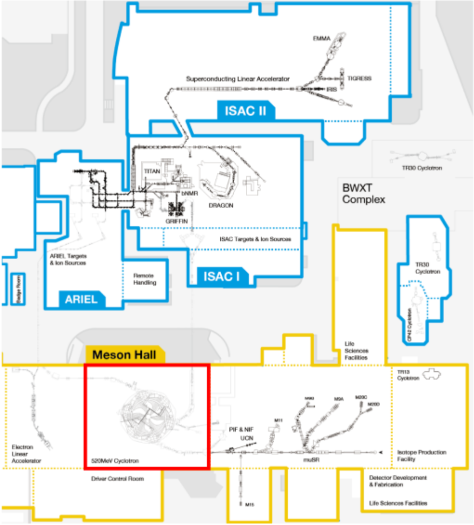
# Outline

1. TRIUMF overview
2. ARIEL and the e-Linac
3. ERL upgrade?
4. Multi-user facility
5. Reliability

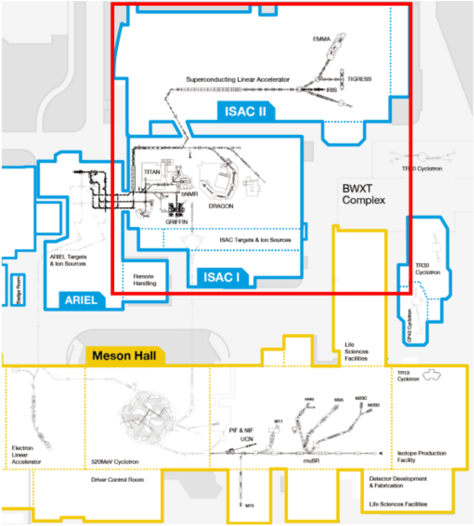
# TRIUMF - Canada's Particle Accelerator Centre

- **Cyclotron**
  - **520 MeV $H^-$ ions**
  - **Primary beam driver for isotope production**
- ISAC
- ARIEL
- Electron Hall



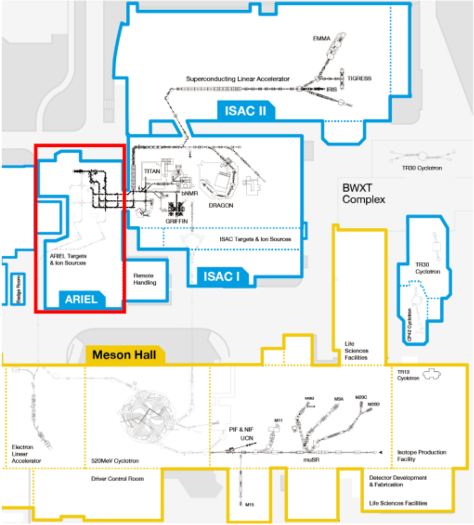
# TRIUMF - Canada's Particle Accelerator Centre

- Cyclotron
- **ISAC**
  - **Isotope separator and accelerator facility**
- ARIEL
- Electron Hall



# TRIUMF - Canada's Particle Accelerator Centre

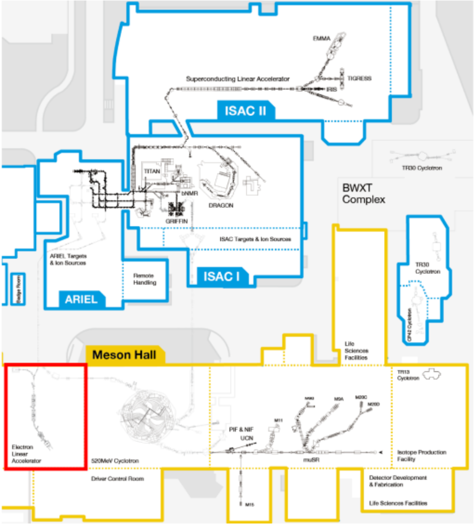
- Cyclotron
- ISAC
- **ARIEL (in progress)**
  - **Advanced rare isotope laboratory**
  - **Projected to triple isotope production**
- Electron Hall



# TRIUMF - Canada's Particle Accelerator Centre

- Cyclotron
- ISAC
- ARIEL
- **Electron Hall**
  - **Superconducting electron linac**
  - **Second driver beam for the ARIEL facility**

**Focus of today's talk!**



# ARIEL: Advanced Rare Isotope Laboratory

- New Isotope Separator Online (ISOL) facility.
- Projected to triple the yield of rare isotopes at TRIUMF.
- Two additional production targets respectively driven by:
  - 500 MeV cyclotron beam
  - 30-50 MeV electron beam

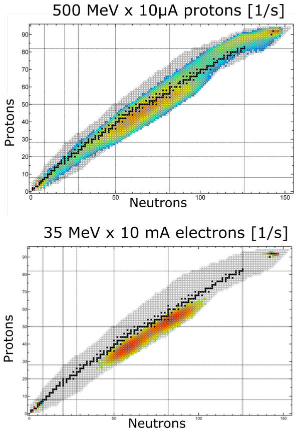
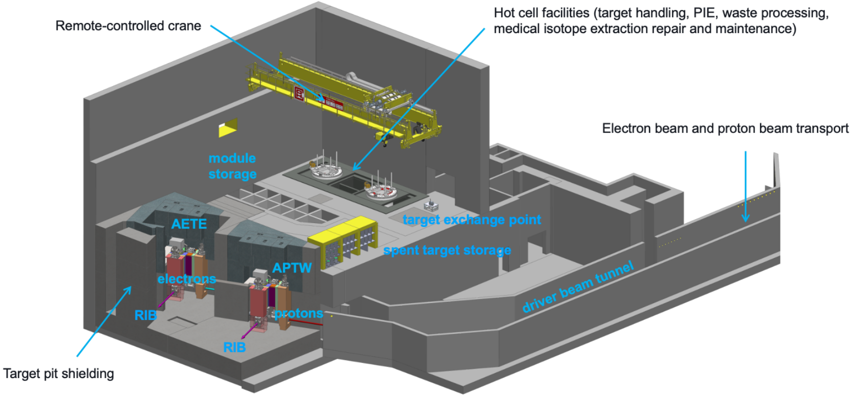


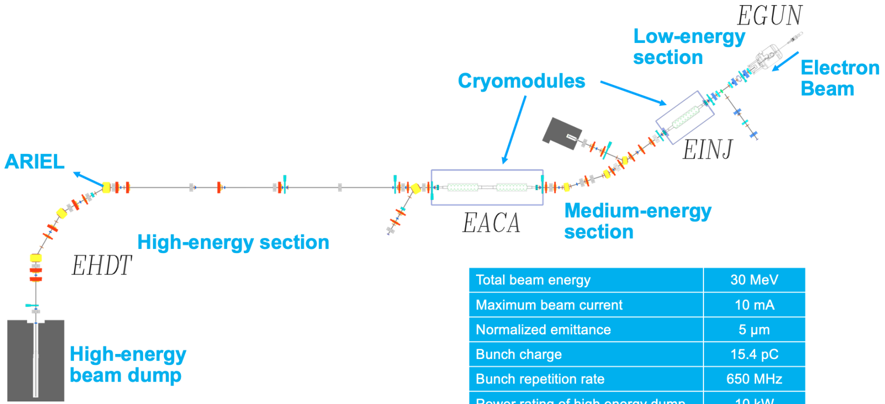

**Figure:** Projected isotope production from proton and electron beams on $^{238}UC_x$ targets at ARIEL.

# ARIEL: Advanced Rare Isotope Laboratory



# E-Linac: second driver beam for ARIEL

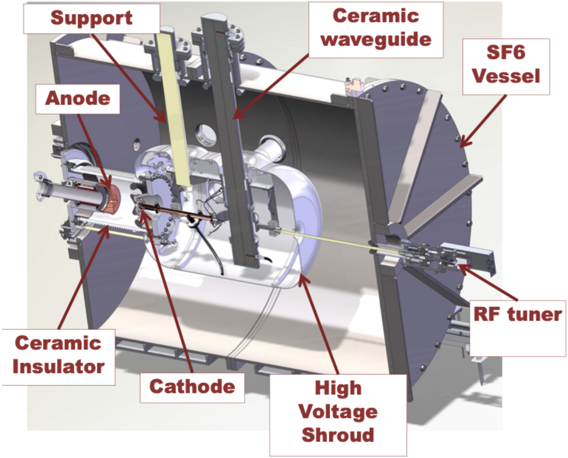
# E-Linac Layout and properties




| | |
|---|---|
| Total beam energy | 30 MeV |
| Maximum beam current | 10 mA |
| Normalized emittance | 5 μm |
| Bunch charge | 15.4 pC |
| Bunch repetition rate | 650 MHz |
| Power rating of high energy dump | 10 kW |

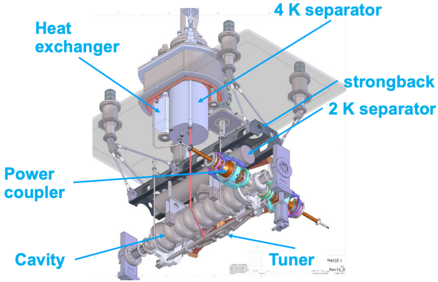
# Electron Gun

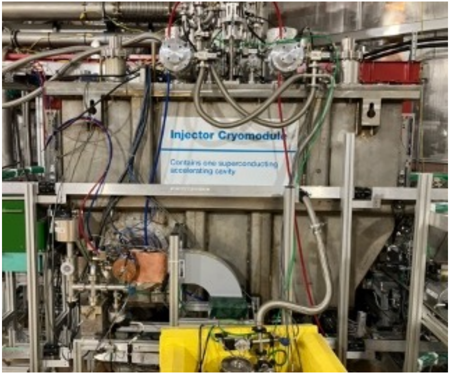
- 300 kV thermionic electron gun
- Contained in a pressurized $SF_6$ vessel
- RF frequency 650 MHz



# Injector Cavity EINJ

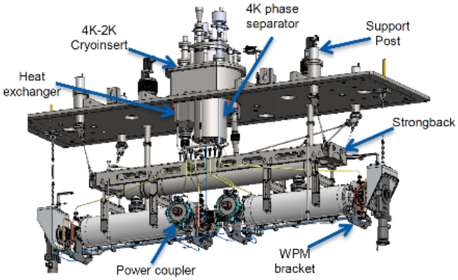
- Accelerates 300 kV beam from gun to 10 MeV.
- One 9-cell elliptical superconducting niobium cavity with RF frequency of 1.3GHz operated at 2K.

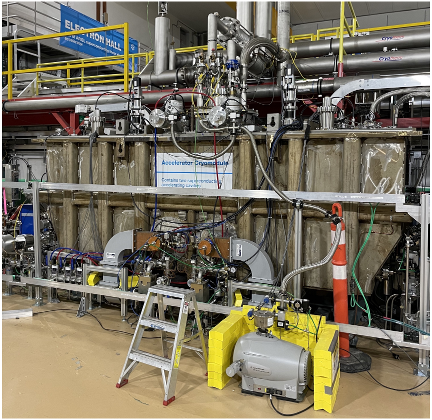


# Accelerator Cavity EACA

- Further accelerates beam to 30 MeV.
- Two 9-cell elliptical superconducting niobium cavities with RF frequency of 1.3GHz operated at 2K.

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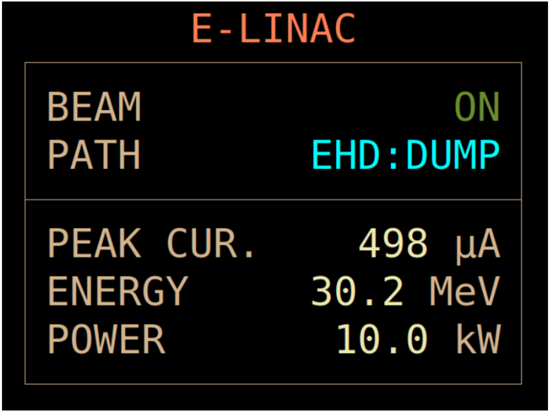
# High Power Dump

- 10 kW tuning dump.

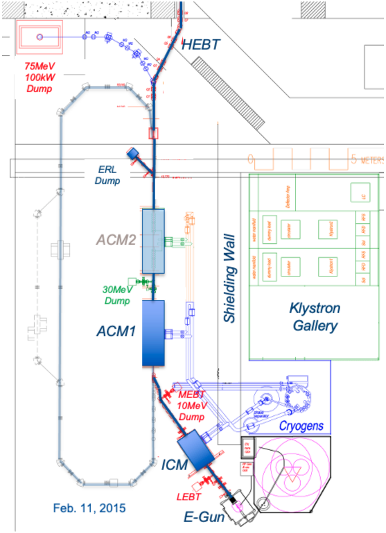
# Current Status




- Initial commissioning completed September 2021.
- 10 kW beam at 30 MeV for the first time.

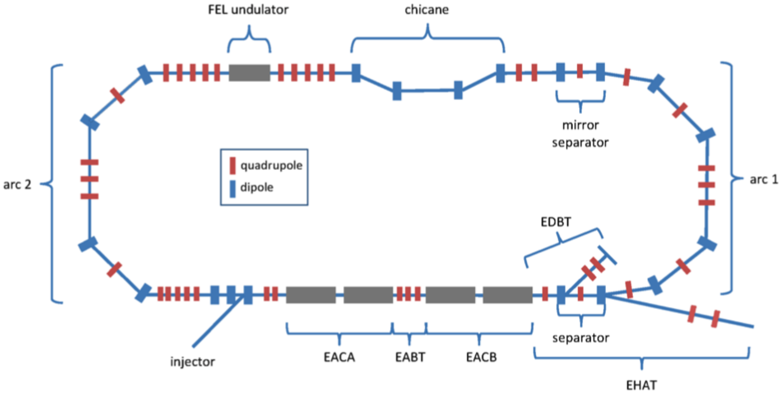
# Energy Recovery Linac (ERL) Upgrade

- E-Hall configured to eventually allow a recirculating ring.
- Multi-pass ‘energy doubler’ mode.
- Operate as an energy recovery linac for accelerator studies and applications.



# ERL Upgrade

- Preliminary design by former PhD student Chris Gong. (Gong,2015)



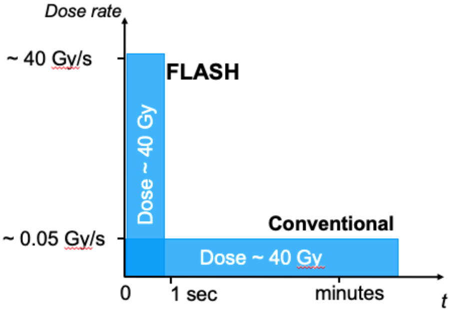
# ERL Upgrade: Current status

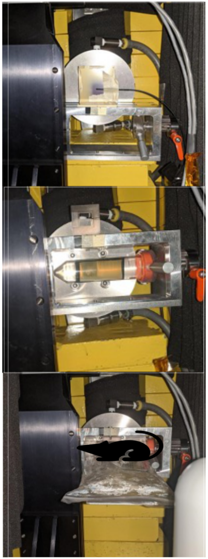
Phase 1: High-Brightness THz/IR photon source:

- New electron gun required to produce the sub-mm high charge electron bunches needed for THz light.
- Submitted to this year's round of CFI funding - ERL follow suit.

# Multi-user facility: FLASH Radiotherapy Research

- Sub-second irradiation treatments at 10 MeV to reduce normal tissue toxicity compared to low dose rate (conventional) treatments.
- First successful irradiation of mice March 2022.



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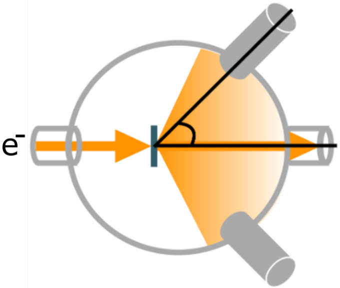
# Multi-user facility: DarkLight Dark Matter Research

- Motivated by Atomki experiment.
- Scattering of 50 MeV $e^-$ beam on thin tantalum target.
- Goal: measure energy spectrum of $e^-/e^+$ pairs created by $\gamma$ or... X17?

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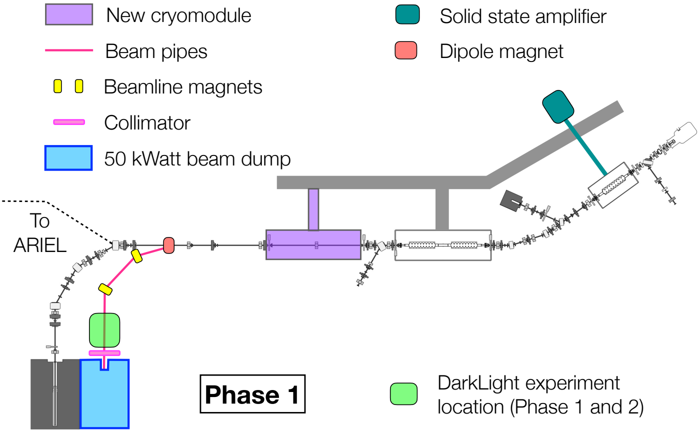
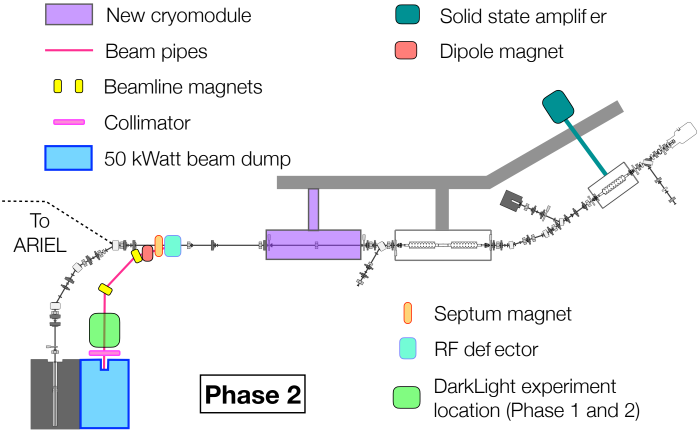
# Multi-user facility: DarkLight Phase 1



# Multi-user facility: DarkLight Phase 2



# e-Linac Reliability

Next milestone: 3-day continuous beam delivery by March 2023.

$\Rightarrow$ Reliability:

- e-Gun stability
- Diagnostics tools
- **SRF cavity performance**

# Field Emission

Emission of $e^-$ from regions of high surface electric field.

In SRF cavities can cause:

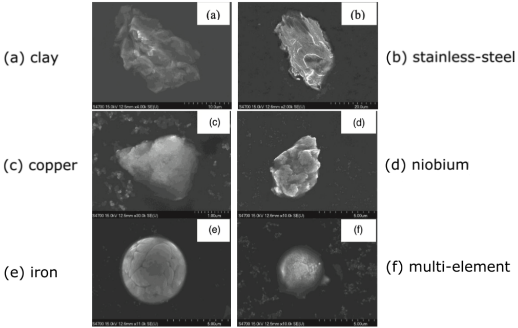
- beam losses
- emittance growth
- pressure bursts
- quenches

Emitters are $\mu$m to sub $\mu$m sized contaminants $\rightarrow$ dust.

$\Rightarrow$ **Critical issue for ERLs.**

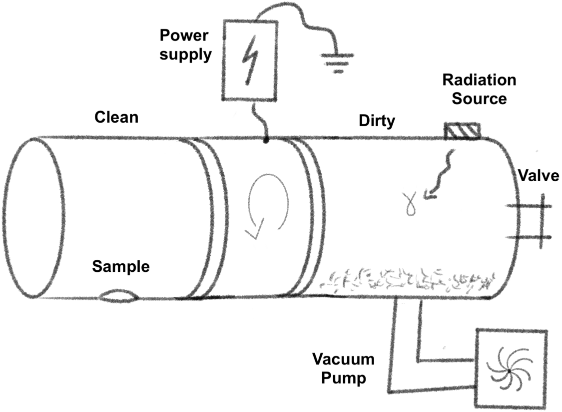
# Previous studies

- Abundance, size and distribution indicate dust migrates. (Geng et al.,2015)
- Beam loss time scale at LHC indicate dust is charged. (Goddard et al.,2012)



# Potential Barrier Experiment

- Implement potential barrier to suppress dust migration and tackle field emission problem at its source.



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# NON-EVAPORABLE GETTER-BASED DIFFERENTIAL PUMPING SYSTEM FOR SRILAC AT RIBF

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RIKEN Nishina Center for Accelerator-based Science, Saitama, Japan
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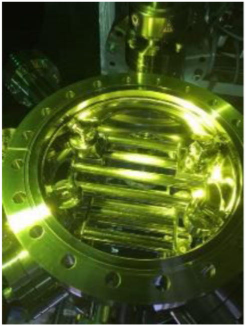
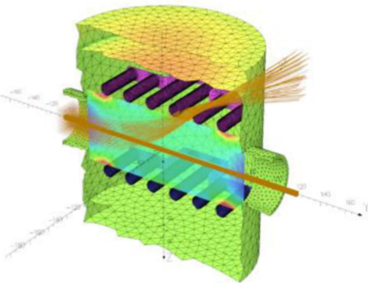




# Current Status

- Assembly in progress.

# Summary

- TRIUMF e-Linac commissioned to 30 MeV at 10kW.
- ERL upgrade envisioned in the future.
- Reliability study centered on field emission in progress.

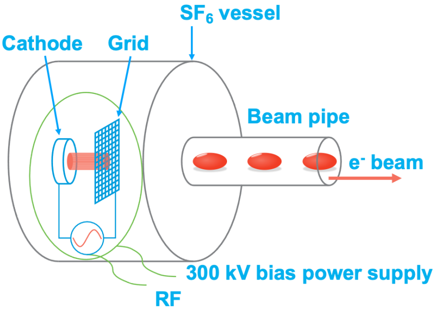
TRIUMF

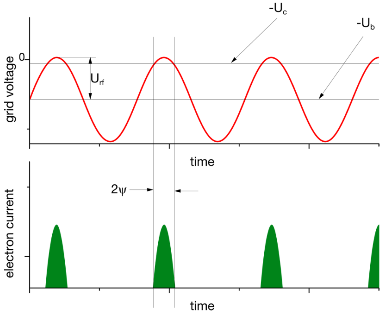
Thank you

Merci

# Electron gun

- Cathode has grid with suppressing voltage and RF modulation



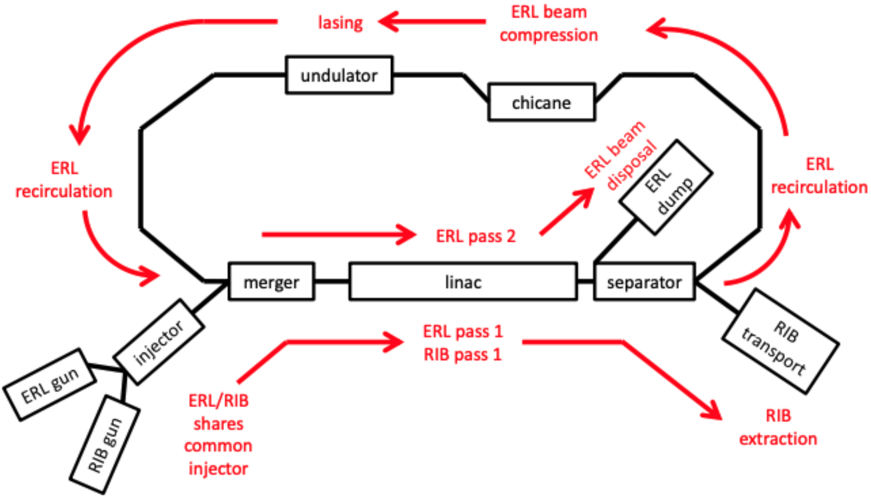
# High Power RF

- SRF cavities powered by two CPI 290 kW cw 1.3 GHz klystrons.
- Second klystron powers both EACA cavities.

Klystrons in the e-Hall.


Power supplies on e-Hall roof.

# ERL backup



lasing
ERL beam compression
undulator
chicane
ERL recirculation
ERL beam disposal
ERL dump
ERL recirculation
ERL pass 2
merger
linac
separator
injector
ERL gun
RIB gun
ERL pass 1
RIB pass 1
RIB transport
ERL/RIB shares common injector
RIB extraction

# ERL backup

Table 6.1: ERL baseline parameters.

| Parameter | Value |
|---|---|
| Gain | $0.5\ \text{m}^{-1}$ |
| Initial momentum | 7.5 MeV |
| EDBT momentum | 7.7 MeV |
| $\sigma_x$ | $\leq 3$ mm everywhere |
| $\sigma_y$ | $\leq 3$ mm everywhere |
| EDBT energy spread | 0.029 |
| EDBT max $\sigma_x$ | 3.0 mm |
| EDBT max $\sigma_y$ | 1.9 mm |
| Dump $\sigma_x$ | 5.5 mm |
| Dump $\sigma_y$ | 6.0 mm |
| Beam loss | $\leq 10^{-5}$ |

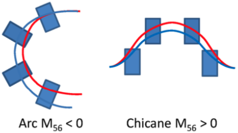
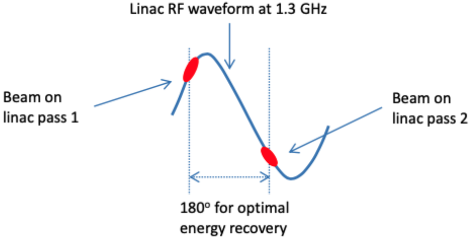



Figure 4.5: $M_{56}$ of the linac-to-undulator transport is determined by arc 1 and the chicane. Due to the layout of the dipoles, arc 1 has a natural $M_{56} < 0$. A particle with less energy (red) takes a shorter path in arc 1 than a particle with more energy (blue). The chicane has $M_{56} > 0$. A particle with less energy (red) takes a longer path in the chicane than a particle with more energy (blue). The total $M_{56}$ determines bunch compression at the undulator.



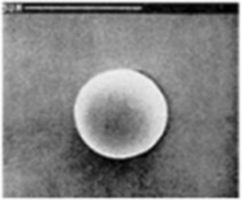
# Particulate Characterization

Particulates are the principal cause of field emission, BUT not all particles emit.

Influenced by:

- geometry
- conductivity

Where β = field enhancement factor. (Antoine, 2015)



$\beta \sim 3$

$\beta \sim 100\text{-}500$