TRIUMF ARIEL e-Linac strategy for 50 MeV

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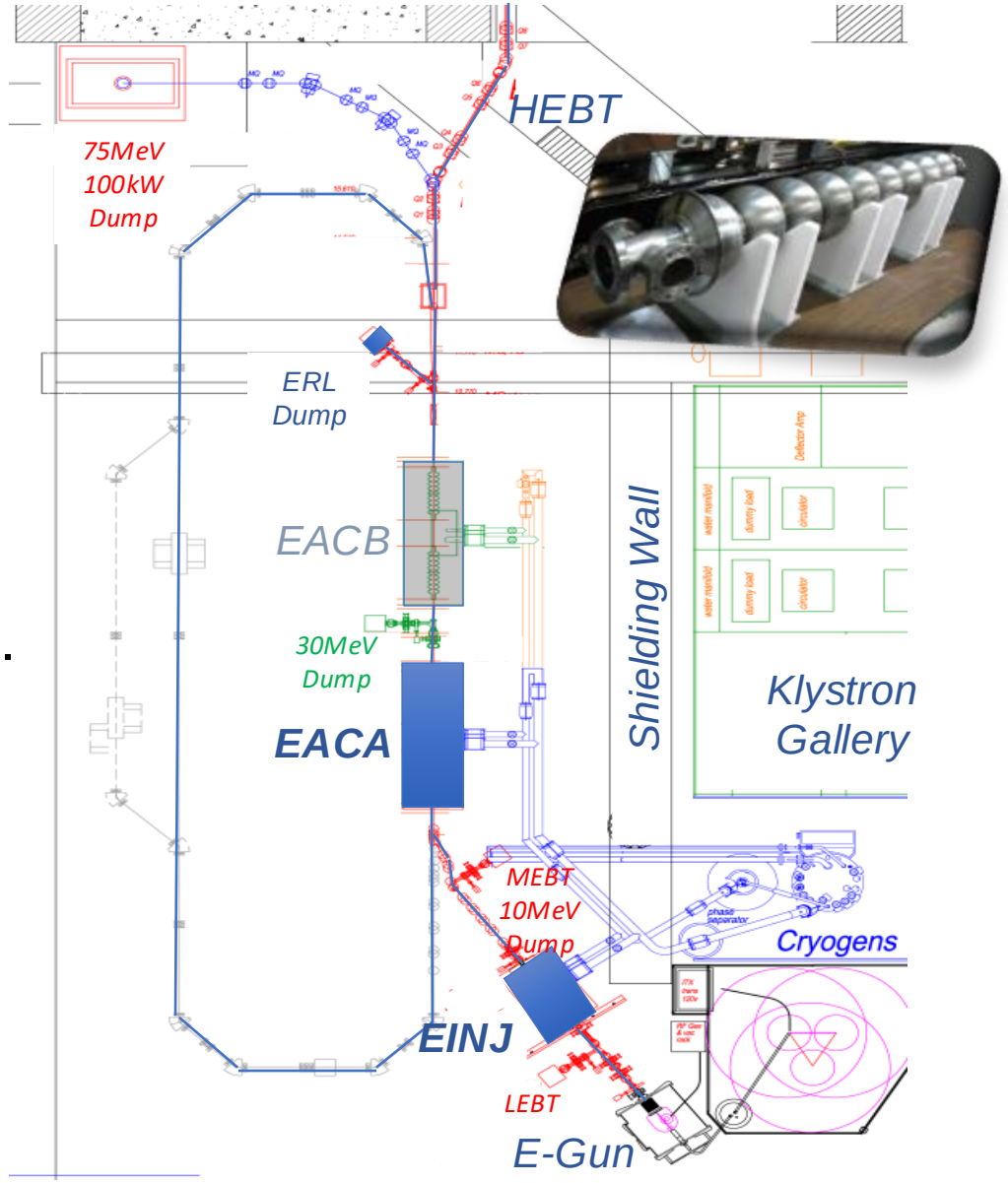
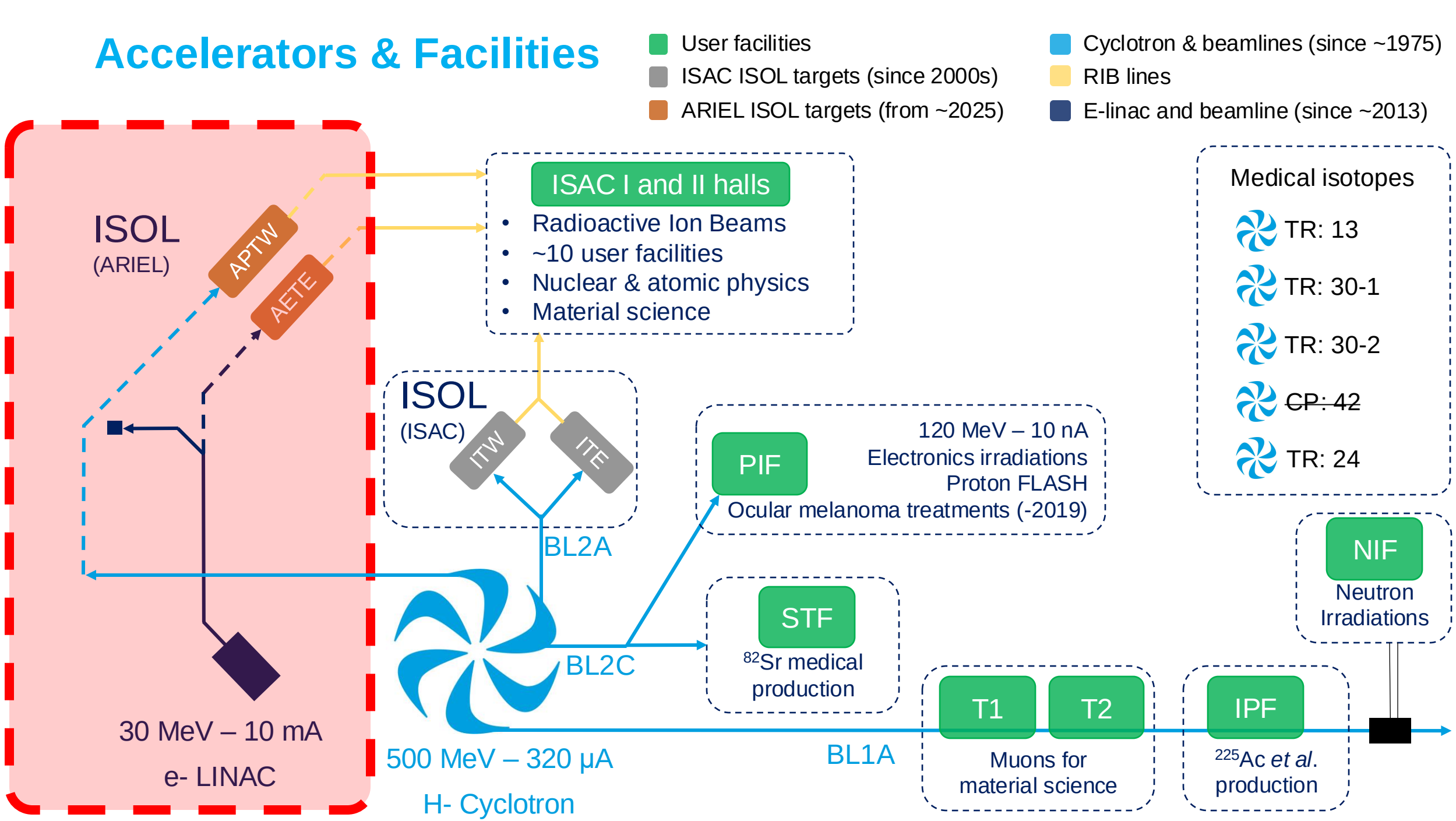
Discovery, accelerated

The ARIEL superconducting e-Linac – big picture

- The ARIEL e-Linac was designed to provide electron beams to an ISOL target station with a maximum of 50 MeV beam energy and of 10 mA beam current.
- The main goal of the ARIEL e-Linac is to provide an intense driver beam for photo-fission using actinide targets to produce rare isotope beams (RIB) primary for nuclear physics, and for materials science research.
- The design foresees one TESLA type cavity in the injector cryomodule (gain of 10 MeV), and two are housed in the accelerator cryomodules (gain of 20 MeV).
- Due to the available budget only one accelerator cryomodule was build and installed, but both high power (300 kW) klystrons were installed.
- A future extension of the electron linac was planned that includes the addition of a recirculation arc that can be tuned either for energy recovery (ERL) operation or for energy doubling (RLA).



Accelerators & Facilities



e-Linac stake holders and boundary conditions

The ARIEL e-Linac will need to accommodate several user groups that will share the e-beam. These are:

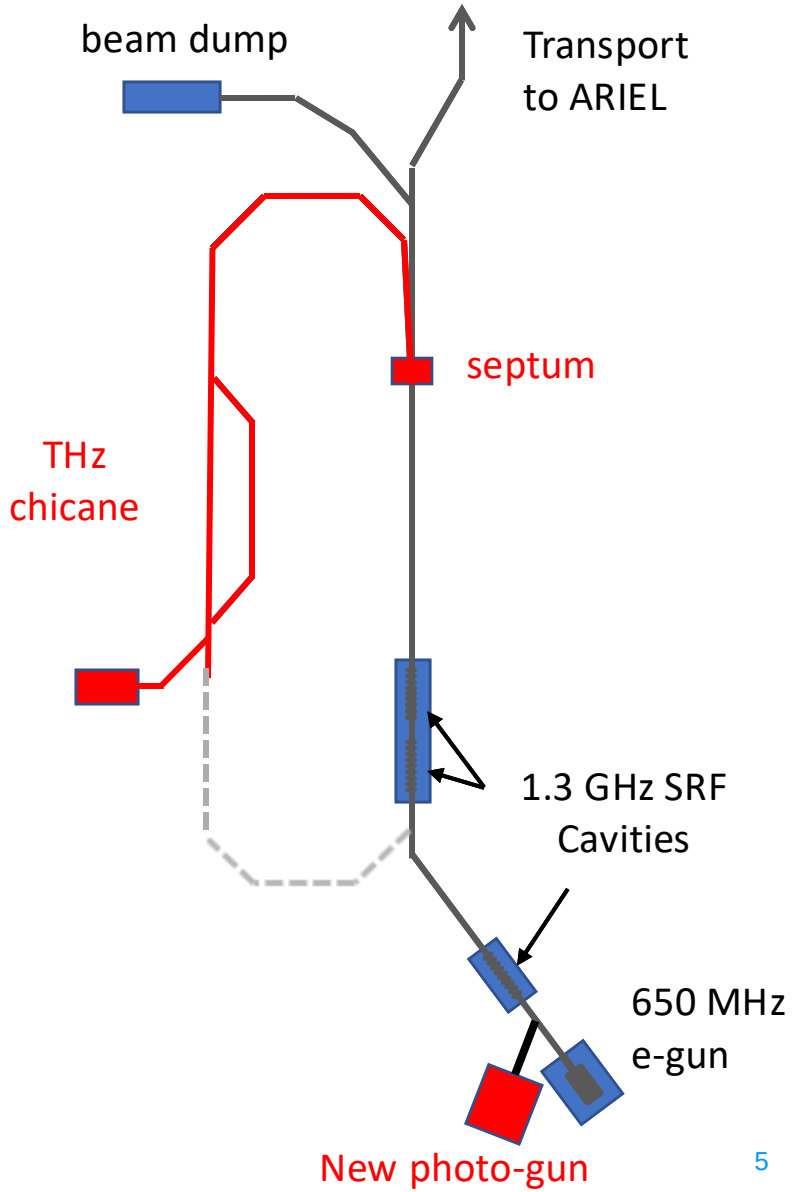
- ARIEL Electron Target station East (AETE) – highest priority
- DarkLight experiment which need to be located close to a high-power beam dump
- High field THz radiation facility – proof of principle system
  (but not the final user's facility)

We have to accommodate several main objectives of the stake holders

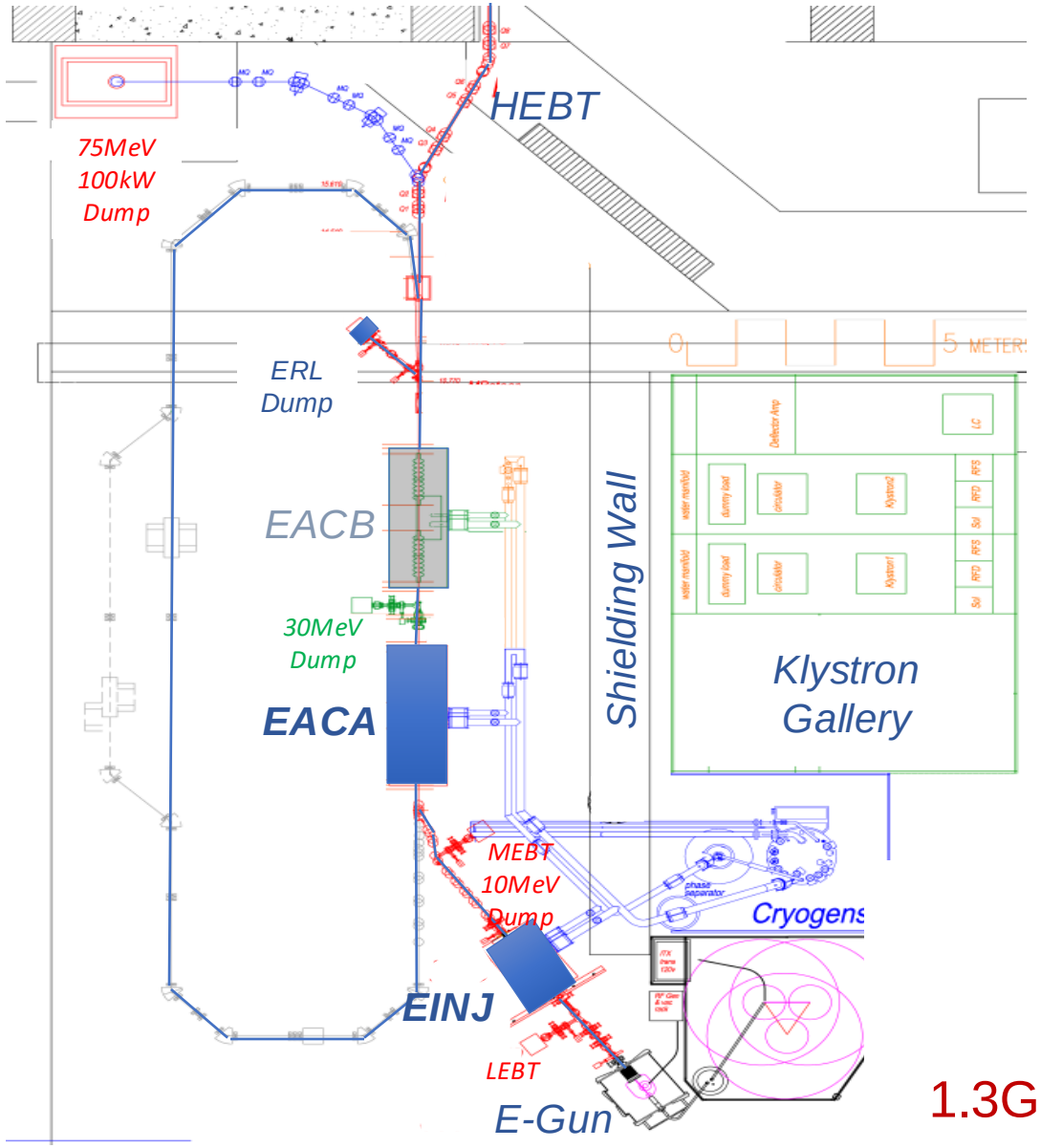
- Next TRIUMF five year plan:
  A potential acceleration of the ARIEL schedule with a one-year shutdown in 2026 and ARIEL operation start in 2027. Parallel operation will be required in 2028.
- DarkLight does need the increase of the e-Linac beam energy to 50 MeV
- High field THz radiation will need a SRF photo gun to produce the required bunch charges, a chicane for bunch compression and will use one linac cavity for pre-bunching.

e-Linac with re-circulation lines

- The first idea for a fast track to 50 MeV beam energy was a re-circulation to increase the beam energy and provide a home for the THz radiation facility (RLA mode).
- The re-circulation also allows the operation in the Energy Recovery Linac (ERL) mode and perform tests for EIC and a future LHeC for instance.
- A fast kicker of an RF-deflector cavity must be added to run experiments in the recirculation in parallel to ARIEL RIB production.
- A proper merging of the re-circulated beam into the linac that does not affect the required beam quality is a challenge.
- There are more beam dynamics challenges related to the intense space charge forces in particular for the high bunch charges required for the THz radiation facility.
  A feasibility study about using the first arc for bunch compression will require a significant simulation effort.



Recirculating modes

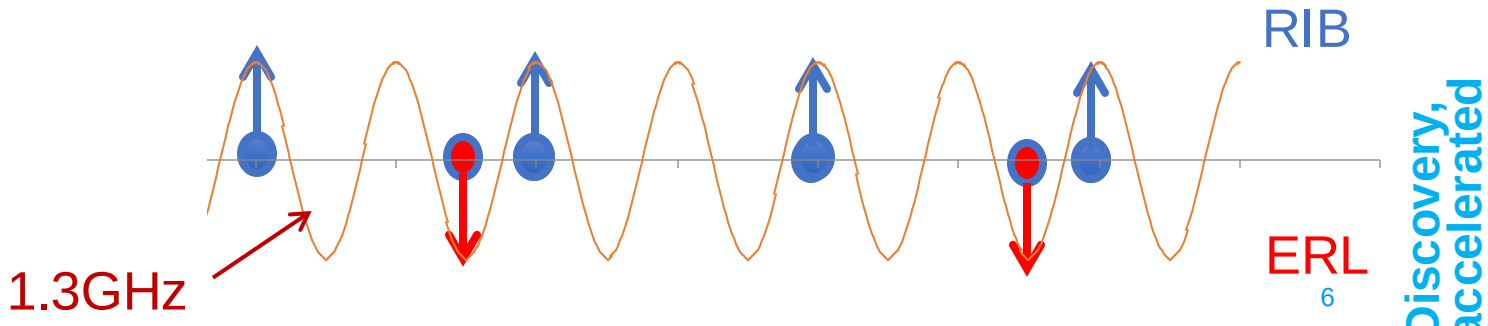


Re-circulation (energy doubler)

- Prefers single user mode
- Doubles beam loading so limits maximum beam intensity

Energy Recovery LINAC (ERL)

- Dual-use possible with two interleaved bunch trains into 1.3 GHz buckets
- 650 MHz pulse train - single pass acceleration for RIB production – low brightness
- 650 MHz/n pulse train for ERL – high brightness
- 650 MHz rf separator used to separate the beams.

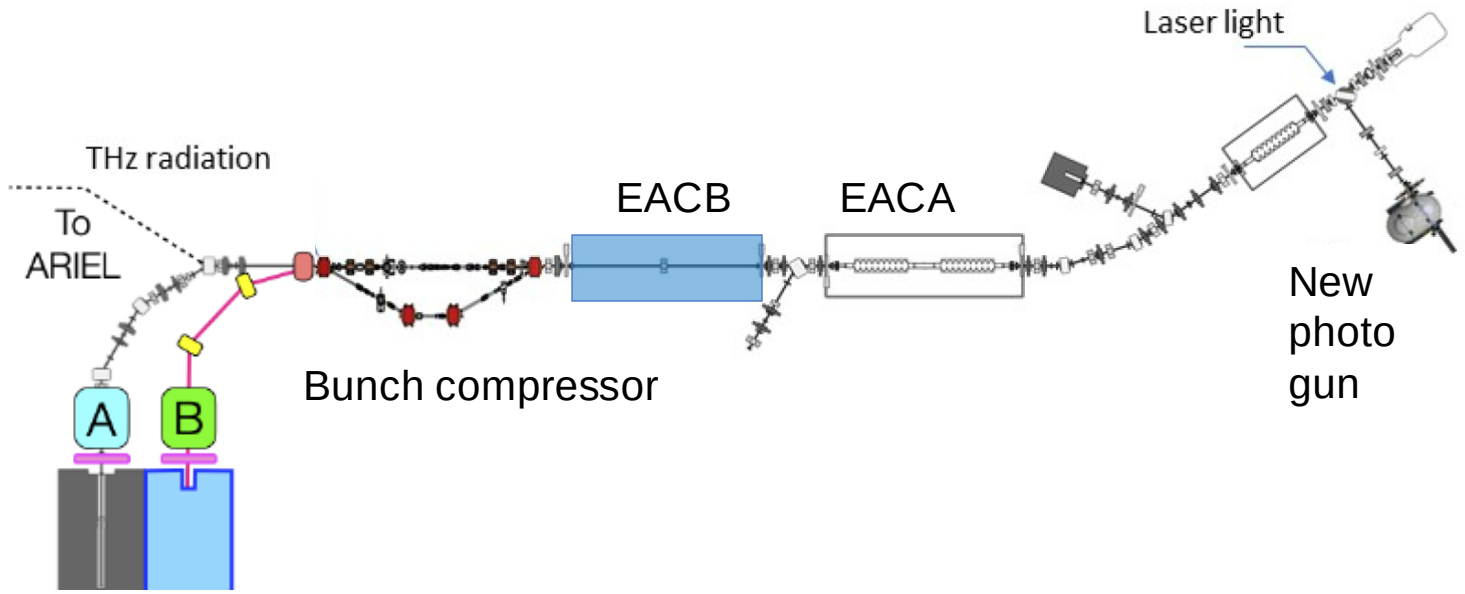


Challenges to establish the re-circulation

- The originally path of using the RLA to increase the beam energy and provide a home for the THz radiation facility turns out to be costly, work intense and will not mitigate any operation's risks, but will add risks.
- The e-Linac team will not have the bandwidth to perform the intense beam optics simulation in due time to be ready for the design and procurement of all components required for the re-circulation in a two years period.
- In addition, it will not be possible to establish the ring in the accelerated scenario for ARIEL operation assuming a long shut down in 2026. Service groups will not be available before 2027 to work on the required infrastructure (electrical and mechanical services, beam lines etc.).

Strategy for the 50 MeV route

- Add a second accelerating cryo-module that will allow the higher (>50 MeV) beam energy and a fast kicker magnet (and maybe a septum) to secure parallel beam operation with ARIEL.
- The second cryo-module will provide a higher availability of the machine in case of a cavity/module failure.
  It will also allow pre-bunching with a linac cavity for the generation of THz radiation.
- Will allow parallel operation scenarios with ARIEL. Need to investigate if there is a scenario in which all three users can get beam in parallel by using the new photo gun.



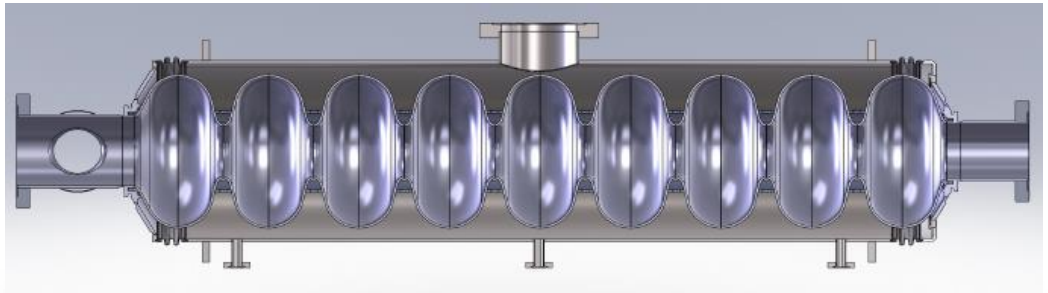
Challenges to get a second cryomodule in place

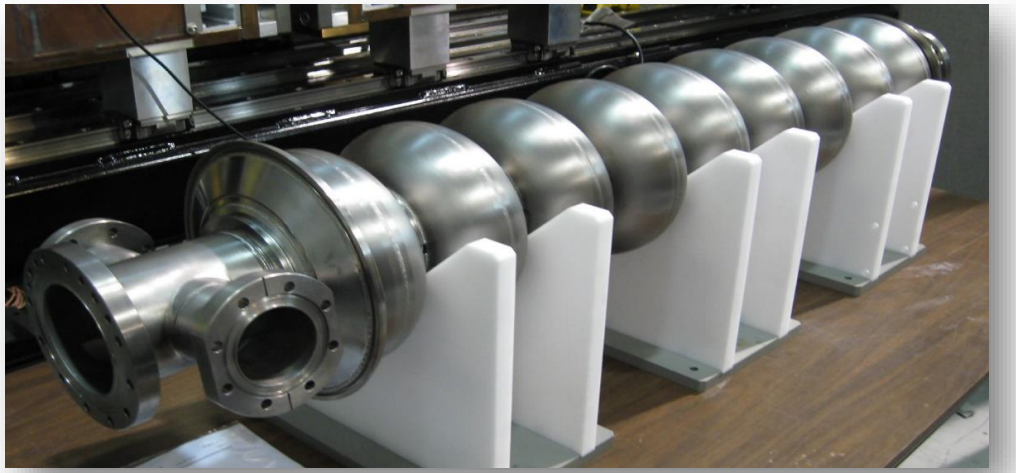
- A second cryomodule costs about $3M and a 100 kW solid state amplifier for the EINJ ($500k) will be required (to make the second klystron available for EACB)
- On the positive side:
  - The SRF group will have capacity to do the construction after the HL-LHC crab cavity cryomodules will be completed in 2026. Long lead items can be purchased in advance.
  - Al lot of the infrastructure for a second module has already been prepared.
  - Some money is available from the THz radiation CFI project, the DL RTI and divisional funds
- Will require some support from JLab by providing two dressed cavities (with He-reservoir, power coupler and HOM damper etc.).
  We are moving towards an MoU with Jlab on SRF collaboration. We will need the help from the DL collaboration to the money for modification of existing cavities at JLab.

Dressed cavities – 1.3 GHz TESLA type

1.3 GHz nine-cell elliptical cavities not the original TESLA type cavities → End groups modified to accommodate two 50kW couplers and to reduce trapped (higher order) modes.

Collaboration with Jlab where cavities are available, but money is required to modify the cavities and dress the cavities (He-reservoir, power couplers, HOM dampers etc.)



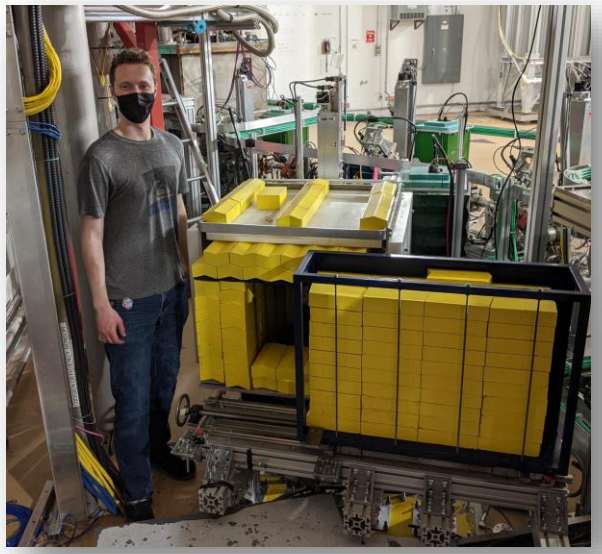


* P. Kolb, `The TRIUMF nine-cell SRF cavity for ARIEL', PhD thesis, University of British Columbia, DOI: 10.14288/1.0300057, April 2016.

Thanks for your attention

Additional slides

Early science supported by the ARIEL e-Linac

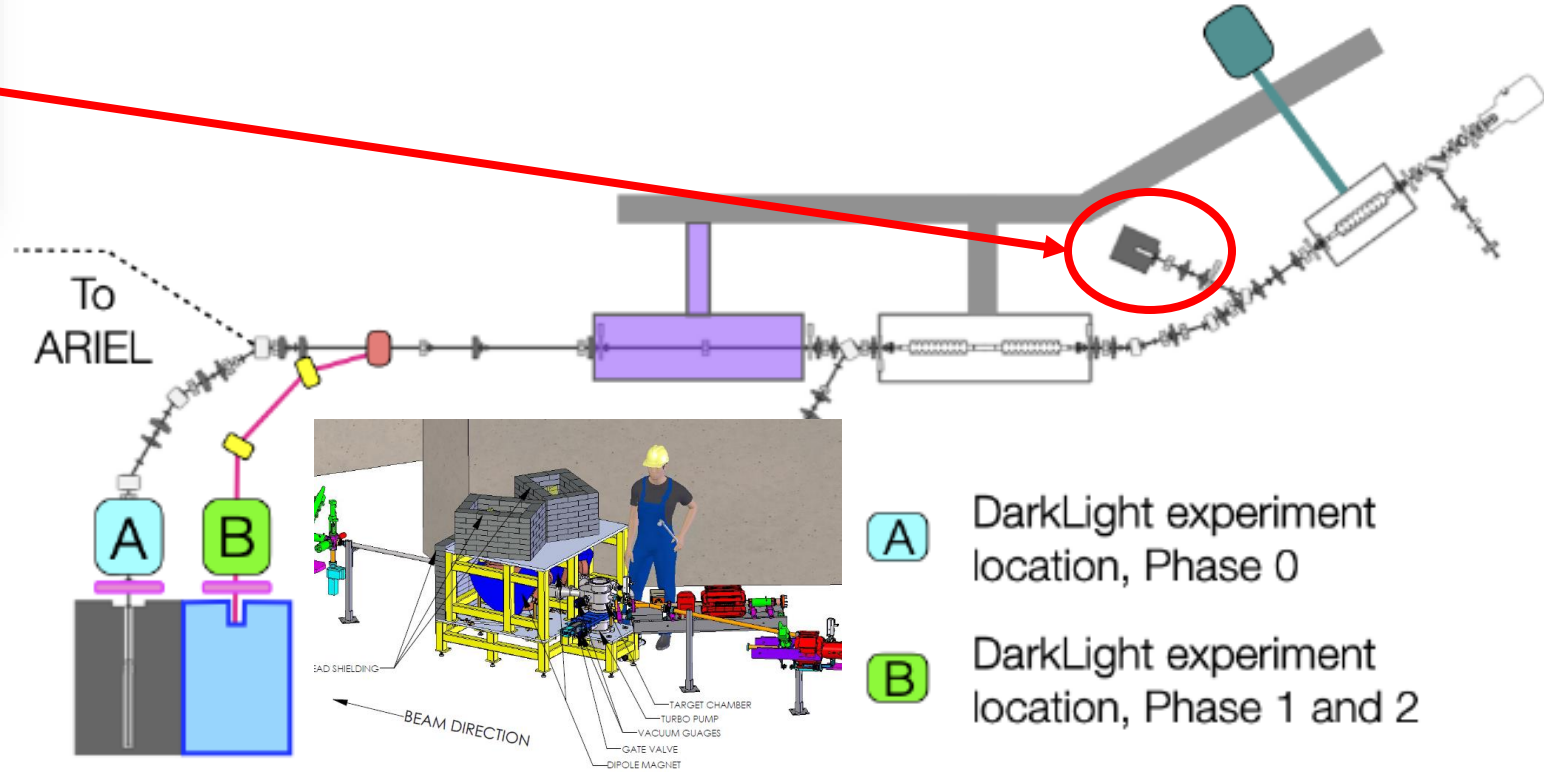


PhD Nolen Esplen, UVic

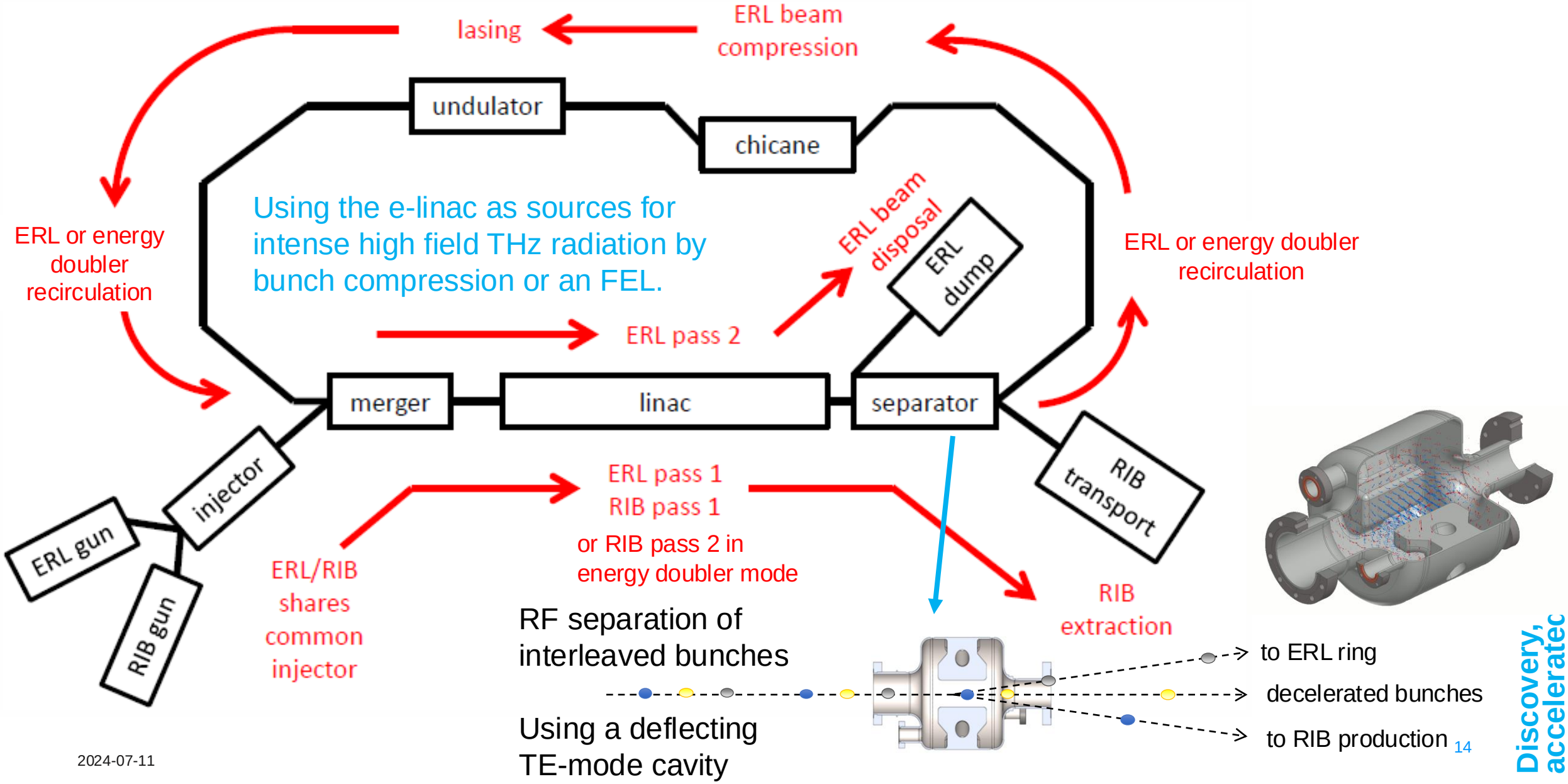
FLASH irradiation test involve the ultra-fast delivery of radiation. It is enabled by the new ARIEL convertor technology:

- Studies comparing response to identical dose deposited with FLASH and conventional rates in mice, fruit flies and DNA samples have been completed.
- FLASH does rates about 100 Gy/s, conventional 0.1 Gy/s

- Dark matter search – DARK LIGHT experiment looking for a 5th force (dark photons) at a low energy e-linac
- First target test at 30 MeV and 10 nA completed
  → test of radiation background, target foil integrity etc.



Future dual use ERL/Linac



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