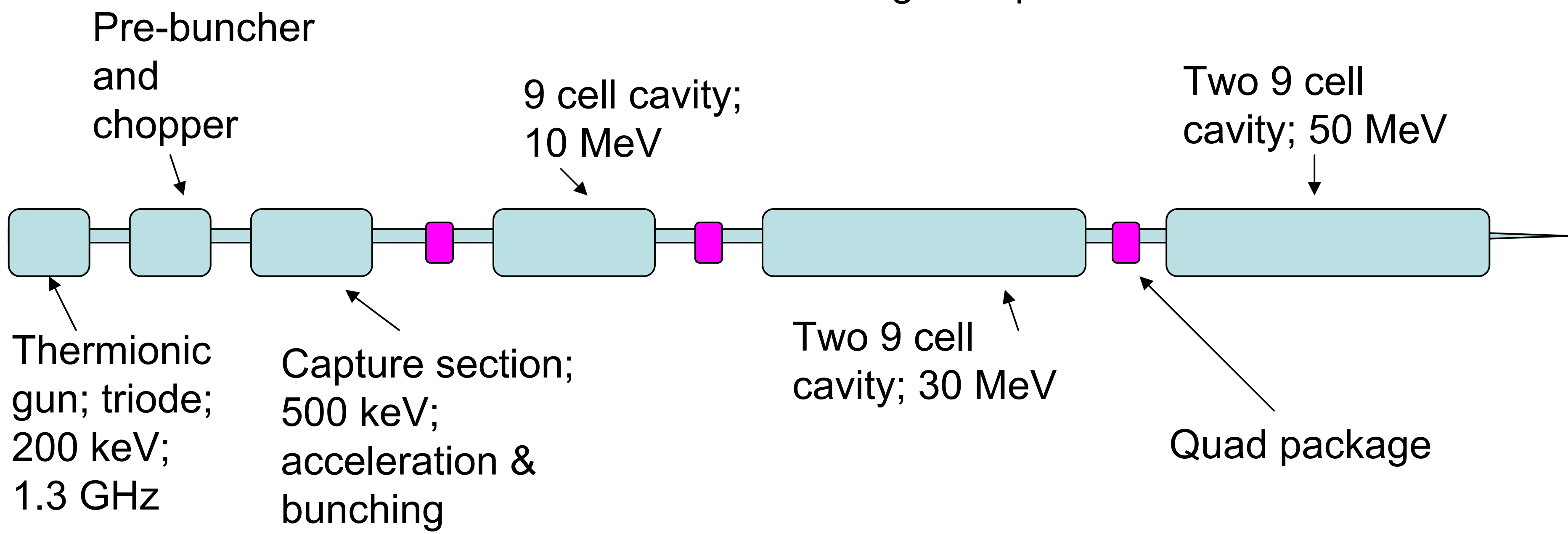
What is the strawman design?

- 0.5 MW: 10 mA, 50 MeV, c.w.
- RF: 1.3 GHz
- Bunch repetition frequency 1.3 GHz
- Charge/bunch 8pC
- Emittance 30μm normalized
- Energy spread <1% FW
- Bunch length 40 ps



How did we get there?

On the target side

On the target side

Bill Diamond (AECL) identified photo-fission initiated by 40-60 MeV energy range electrons for production of neutron radio-nuclides at rates of 10^{13}-10^{14} fission/s

Existing TRIUMF ISAC ISOL targets rated up to 50 kW (100µA, 500 MeV protons). Cyclotron tuning and beam dump targets up to 200 kW; shielding experience.

Factor of 10 in beam power (500 kW) will be sufficiently challenging.
Fission rate:

On the accelerator side

Based on existing fundamental mode power coupler (FPC) designs beam power per accelerating cavity is limited to 100 kW;

Based on 10 MV/m gradient, that is 10 mA.

Hence 50 MeV requires five 9-cell cavities

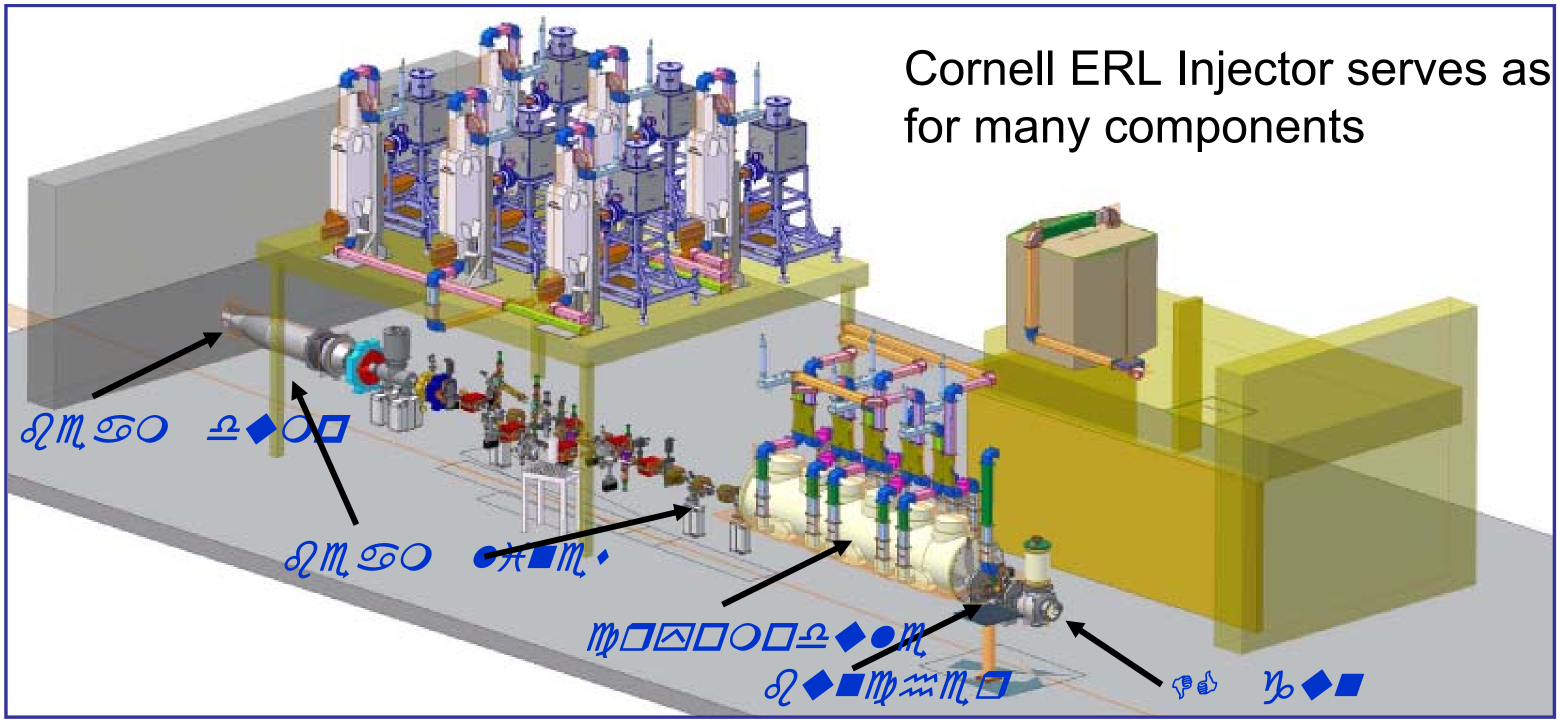
The tolerable HOM power also suggests a limit of 100 kW beam power/cavity – assuming 9-cell design and 1 absorber/cavity

International Linear Collider & Electron linac driver for photo-fission

SCRF

- ISAC-2 linac program has proven expertise in β«1, ≈ 0.1 GHz, 4 K, SCRF.
- Expanding that SCRF capability to β=1, ≈ 1 GHz, 2K opens way to several accelerator-based research-physics facilities.
- Examples include ILC at 1.3 GHz, CERN SPL at 0.7 GHZ, 4th Generation light source (e.g. ICS), and MW-class photo-fission driver.

MW-class electron linac will both leverage existing world-wide R&D for TTF/ILC 1.3 GHz and make a contribution to that technology development.



Cornell ERL Injector serves as model for many components

How did we get there? In more detail:

Existing β«1 program with λ/4 cavities (Nb, 4K, 100 MHz, microphonic regime)

Expanding expertise to β=1 structures open many opportunities (ILC, SPL, 4GLS, ERIBS)

Why 1.3 GHz and 9-cells?

Synergy with TTF/ILC:

- Grow local Vancouver-based producer of 9-cell Nb cavity for ILC, major achievement growing N. American vendor base
- Benefit from enormous worldwide R&D effort for 1.3 GHz SCRF and ancillary equipment

ILC cryomodule: 12 m long, 31 MV/m: 8 or 9 9-cell cavities giving 1/3 GeV energy gain.

Run half a cryomodule at 10 MV/m and get 50 MeV.

But its not so simple. The ILC is pulsed whereas ERIBS is c.w. Crucial distinction

Retrace the steps of the Cornell ERL; design diverges from ILC

ILC Main Linac module: "poster boy" for high-gradient, low average power

9 mA, 344 MeV energy gain 3 MW beam power/cryomodule	**BUT not c.w.** 1 ms pulse, 5 Hz
9 cavity/cryomodule; 9 cell/cavity 380 kW/cavity	Average current 0.04 mA
Two 250 kW input coupler per cavity; 31 MV/m gradient	Average power 16 kW/cavity
1 HOM damper/cavity	

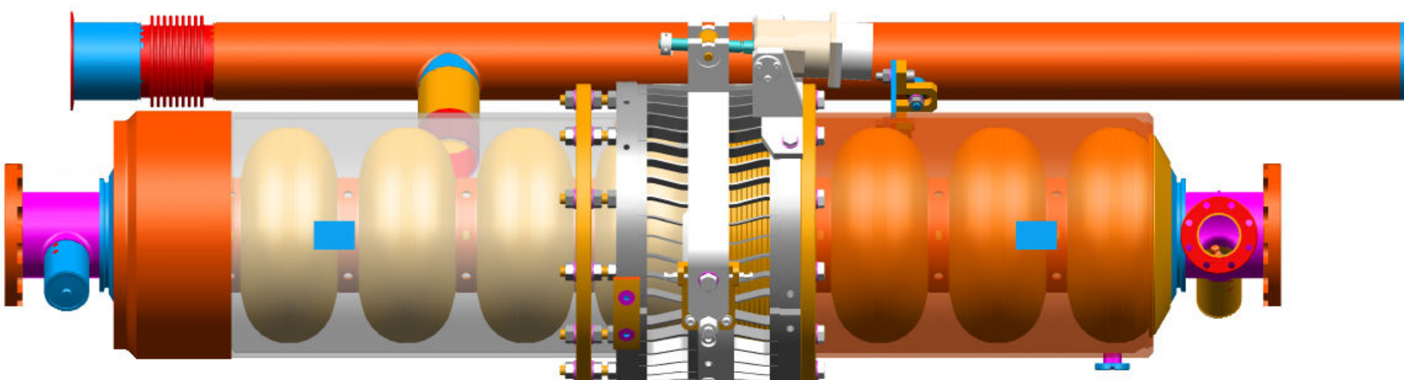
source

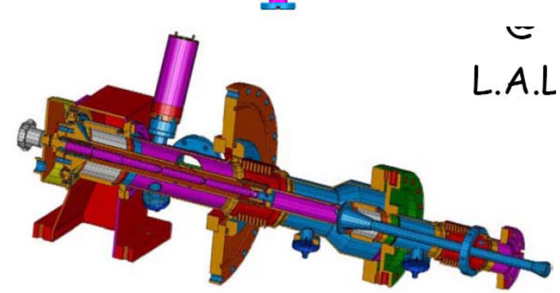
High brilliance r.f.-gun

3 MHz burst

3.2 nC per bunch

(9 mA)





Targets favour rep rates > few kHz and c.w. is ideal.

(Avoid thermal cycling/ shocking of target)

c.w. has many benefits for beam:

- lower bunch charge
- No periodic beam-load transients, no periodic Lorentz-force detuning; LLRF simpler in principle; little or no need for piezo actuators

Advantages of 1.3 GHz

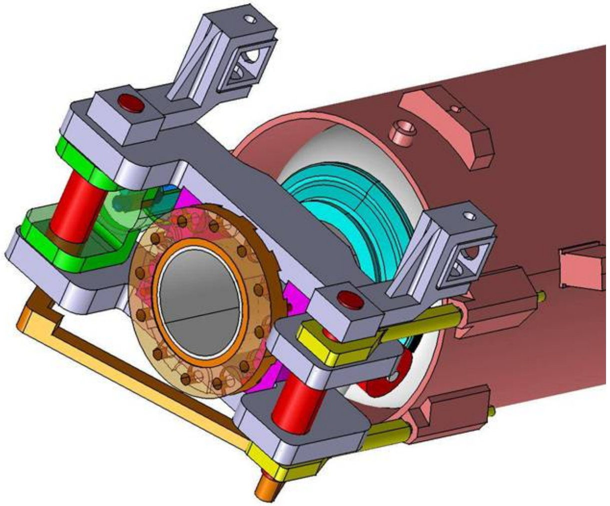
There are cell, cavity, input coupler, HOM damper, tuner, klystron, IOT, cryostat and BPM designs all pre-existing – eliminates substantial R&D

Cost optimization: at lower gradient the cost minimum w.r.t. frequency and temperature is less pronounced than for ILC, but ancillary benefits of 1.3 GHz enormous.

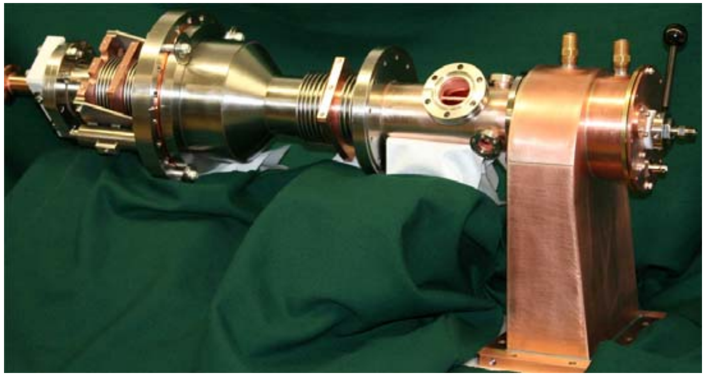
Elinac will both leverage existing world-wide R&D for TTF/ILC 1.3 GHz and make a contribution to that technology development.

Elinac will use/adapt existing equipment designs wherever possible

- TTF/ILC 9-cell cavities
- ILC/Saclay-style tuner
- TTF/ILC LLRF "SIMCOM"
- Cornell power couplers – c.w. variant of ILC/Orsay coaxial couplers
- Cornell cryostat – c.w. variant of TTF cryostat
- Cornell-type HOM dampers - probably
- 100 kW klystrons from e2V



SACLAY tuner (type III)



Why not push accelerator design to 1 MW?

It is instructive to look at the ½ MW scenario.

½ MW @ 50 MeV → 10 mA

Gradient 10 MV/m in 9-cell cavity → 100 kW/cavity c.w.

Power coupler: (2×50 kW) TTF-style coaxial couplers/cavity

> Waveguide couplers have many advantages and could go to higher power (e.g. Rimmer @ Jlab explores 100-200 kW, but not at 1.3 GHz)
>
> BUT small coupling range and large heat leak c.f. coaxial type.

HOM losses: HOM damper and absorber designs (XFEL) are good to 100 kW c.w. for 9-cell cavity – may push further with Cornell absorber design.

With these assumptions (couplers, 9-cell) higher beam power not possible

Unless utilize cavities with fewer cells, e.g. 7, 5, 2 – this is only option!

Note: lowering gradient (e.g. 5MV/m and 2× # cavities) does not cure the HOM problem – but it does solve coupler issue.

Corollary: if above assumptions are correct, linac with five 9-cell cavities will not operate much above ½ MW – except, perhaps, with waveguide FPCs.

Note: we are wedded to a 9-cell design to build ILC production capability in Canada; it would be a significant political miscalculation to say that we abandon baseline of 9-cell cavities.

Choice of electron gun

First choice: it’s a DC gun, RF guns still immature and costly technology

Second choice: between thermionic & photocathode.

Photocathode (ILC, 4GLS, etc)

Advantages: high brilliance (HB), short bunch (SB); beam bunched at source at 1.3 GHz – eliminate chopper and buncher

Disadvantages: cost at least 3× thermionic gun; high vacuum, high maintenance; HB and SB lead to strong space-charge forces

Thermionic (SLAC, LEP, FELIX, MIT-Bates, NIST, etc)

Low brilliance, long bunch, not polarized – perfectly adequate for ERIBs

Disadvantage: need bunching system; at high-power c.w. chopper turns into beam dump! (E.g. 500 keV, 10mA, 50% efficient, 2.5kW, power density 50 kW/cm^2)

Gun voltage

Photocathode & high space-charge favours HV, e.g. » 400 kV & SF_6

Thermionic & chopping favours lower voltage e.g. < 200 kV & air or N_2

Triode gun for FELIX at NIKHEF

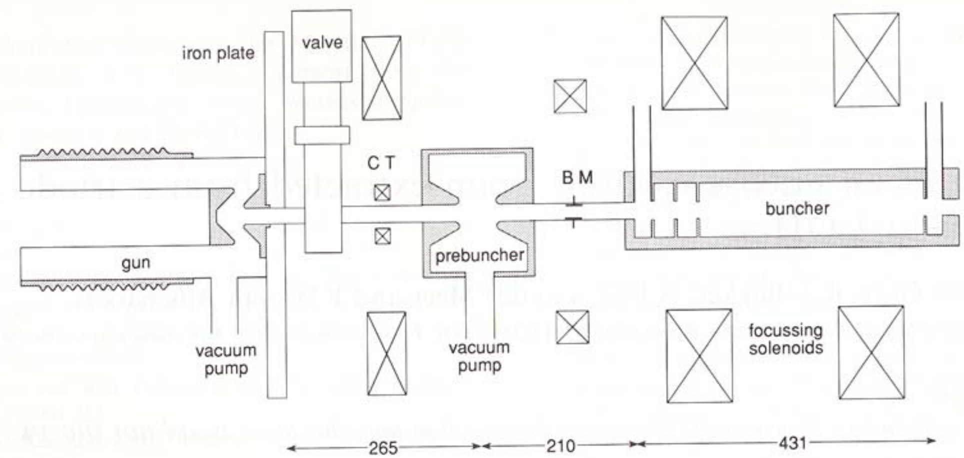


Fig. 1. Schematic view of the FELIX injector. Dimensions are in mm. CT: current transformer for measuring the beam current. BM: button monitor for measuring the beam position and bunch length.

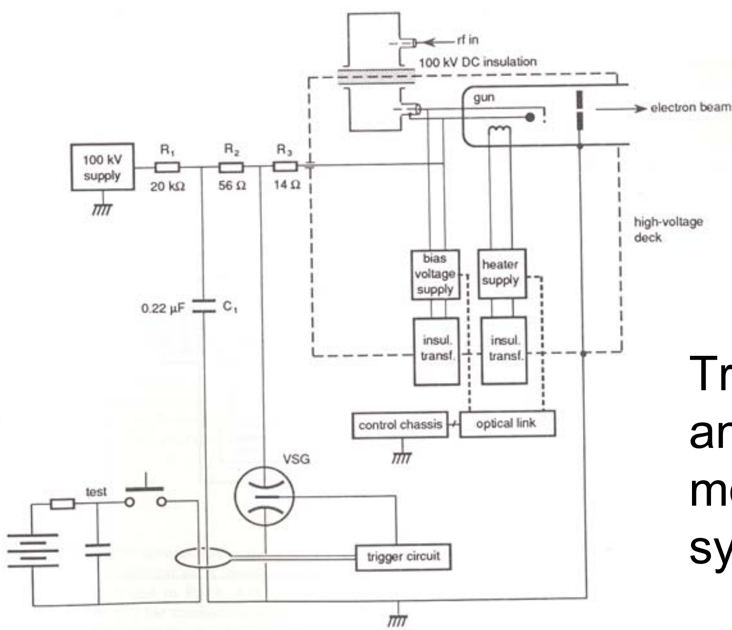


Fig. 3. High-voltage system for the electron gun. VSG: vacuum spark gap.

Triode biasing and RF modulation system