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Does the short pulse mode need energy recovery?

Rep. rate	Beam power @ 5GeV	
1nC @ 100MHz	**500MW**	**Absolutely**
1nC @ 10MHz	**50MW**	↓
		Maybe
1nC @ 1MHz	**5MW**	↓
1nC @ 100kHz	**0.5MW**	**No**

Most applications we have heard about need **MORE** photons per pulse and will do fine with **LESS** than 1MHz repetition rate (max ~100 kHz is OK).

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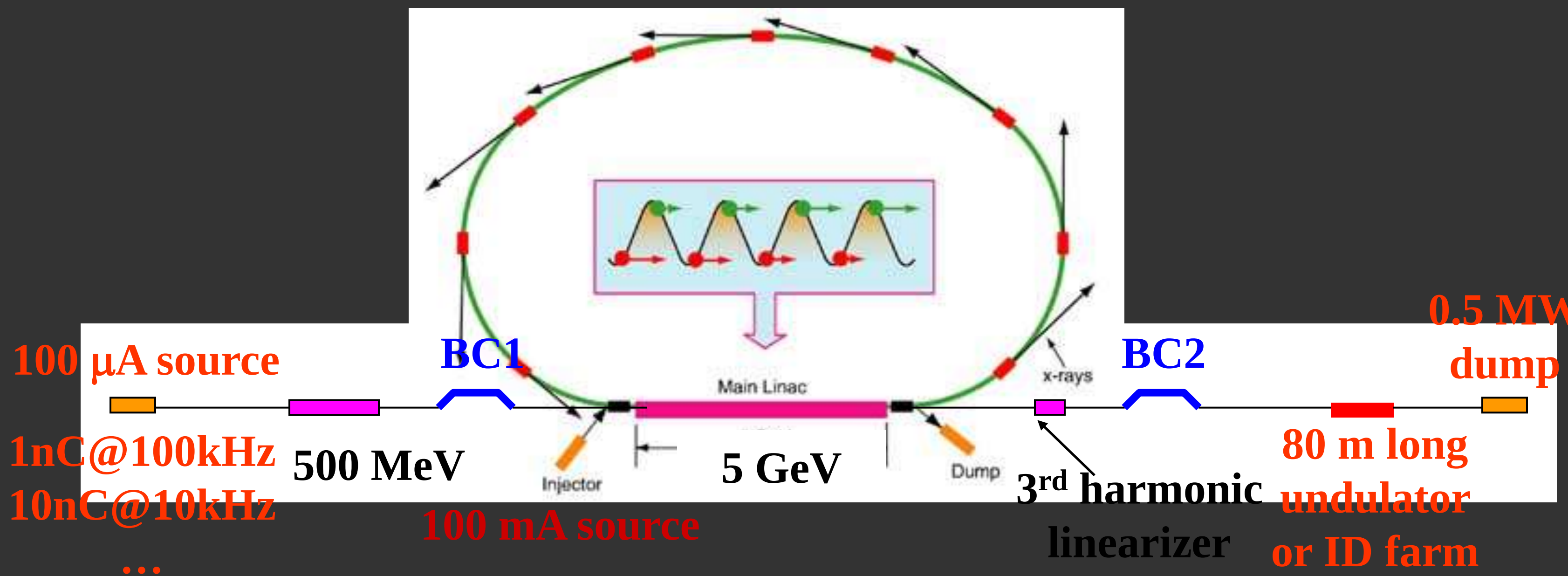
Compressing high ave current (ERL) bunches is a bad idea…

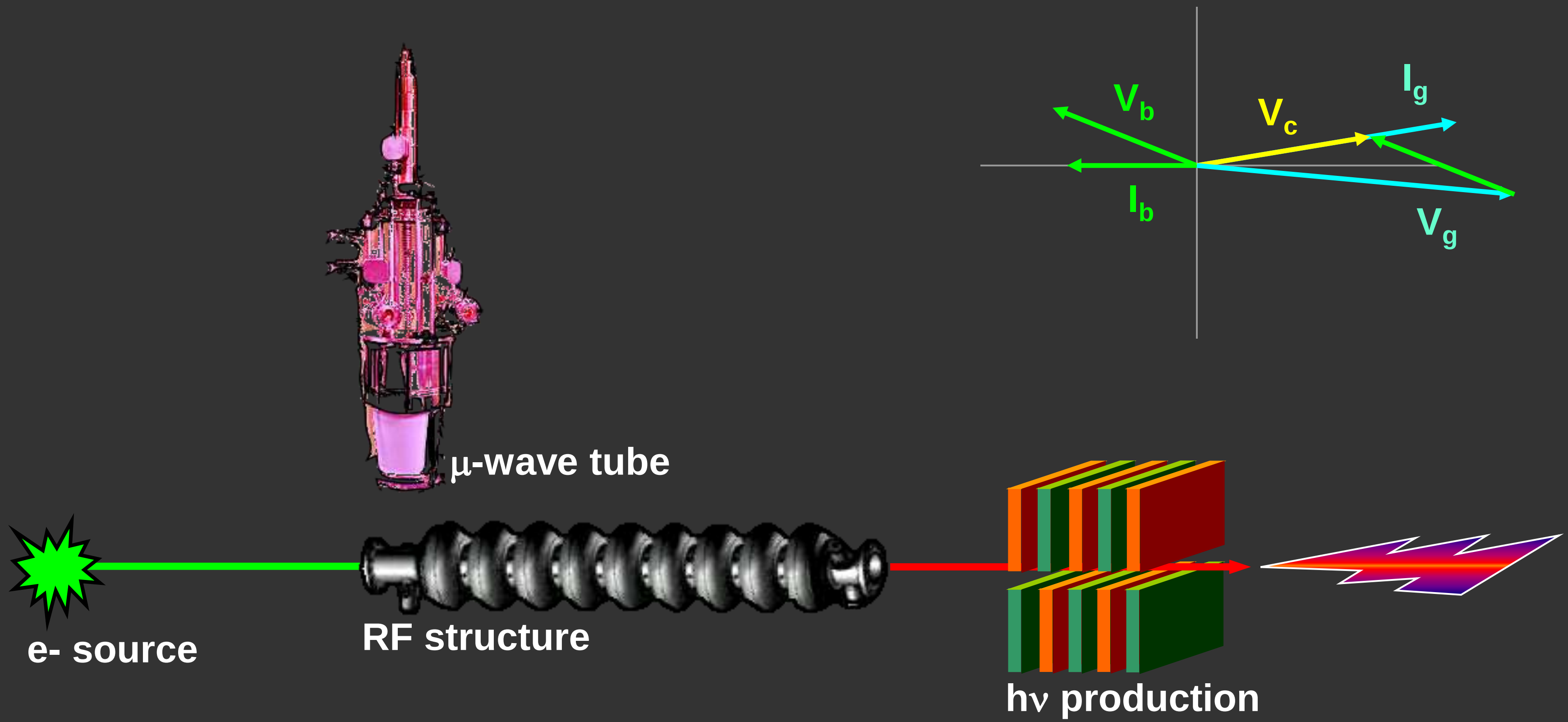
- ERL is a single stage compressor $\rightarrow$ must have large energy chirp imposed by the 5 GeV linac $\rightarrow$ increases energy spread by > **×10**.
- Emittance growth due to CSR is penalty one has to pay when bunches are being compressed (easily ~ **×10** degradation).
- The current will ***have*** to be reduced (e.g. 1nC@1MHz) anyway due to problems with resistive heating and wakefields in the arc.
- As a result, the high brightness users will ***abhor*** the short pulse people.

Simultaneous short pulses and generic ERL running

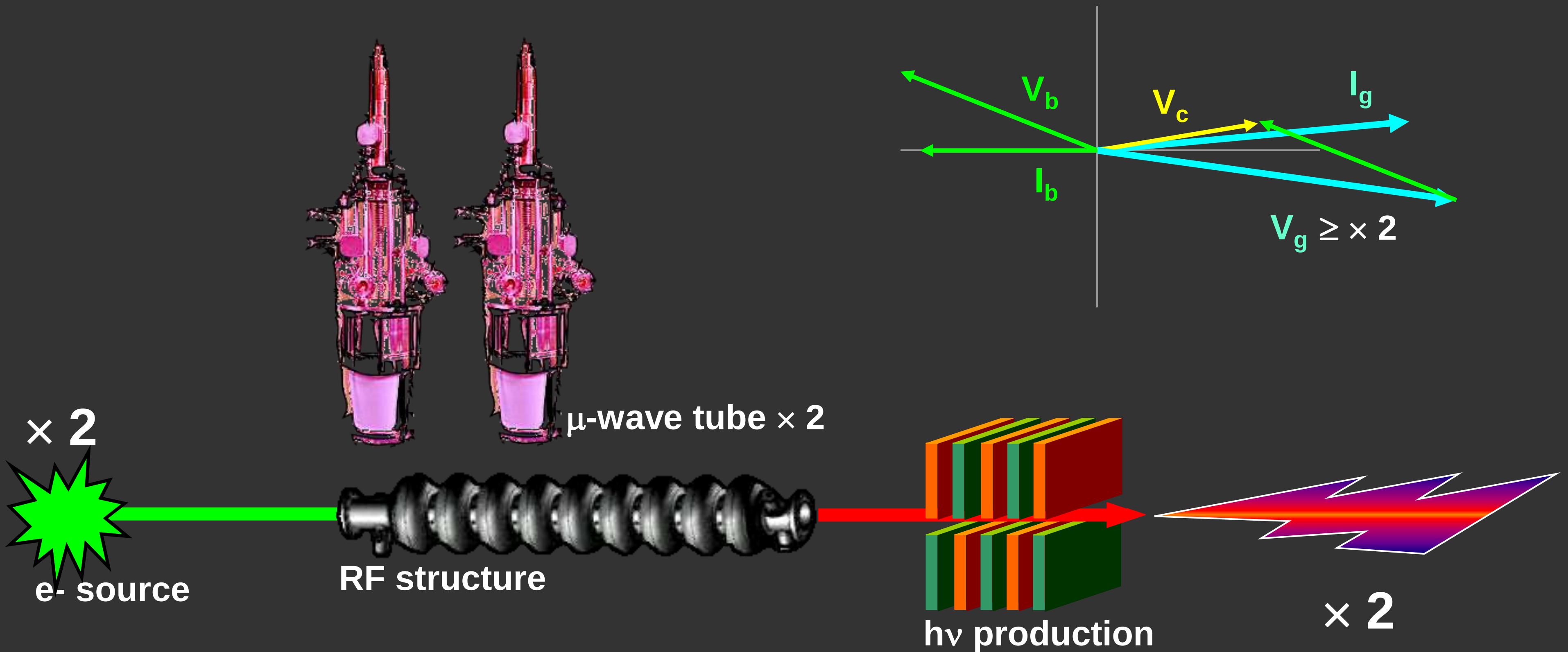


- 10% energy difference between 100 mA and 0.1 mA beams is plenty to separate the beams
- Multiple stage bunch compression

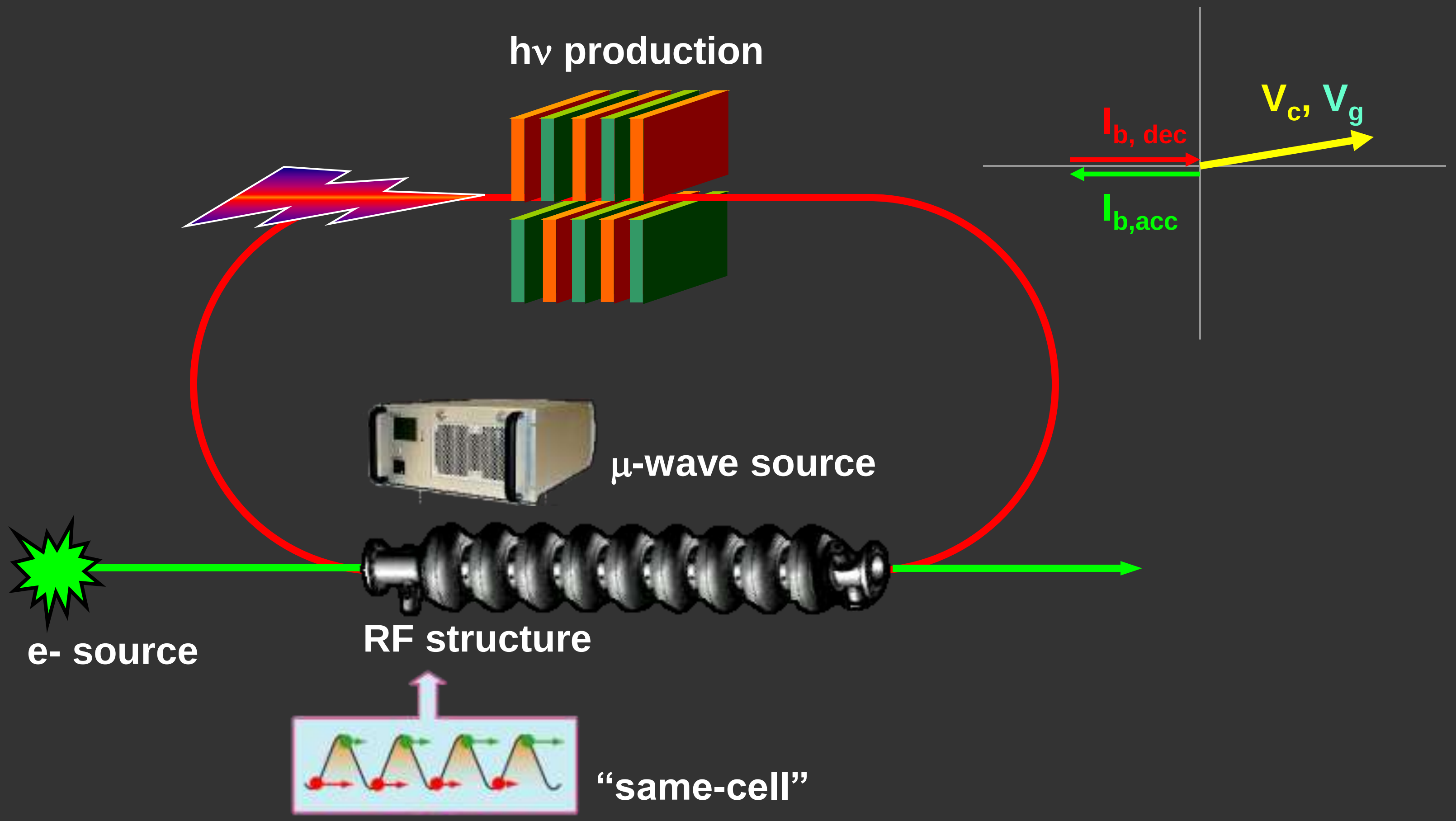
ERL Concept: conventional linac



ERL Concept: conventional linac



ERL Concept: energy recovery linac



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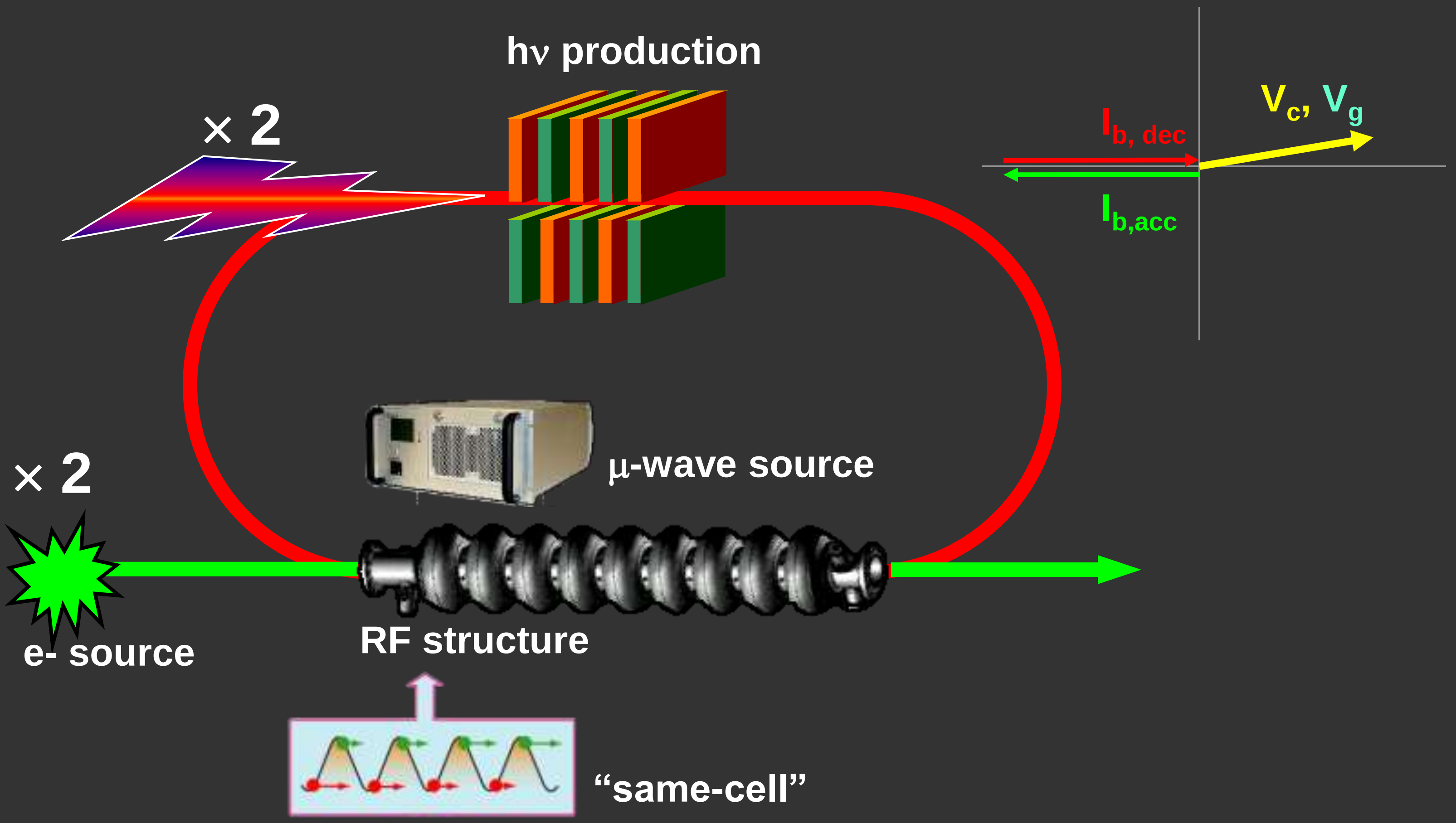
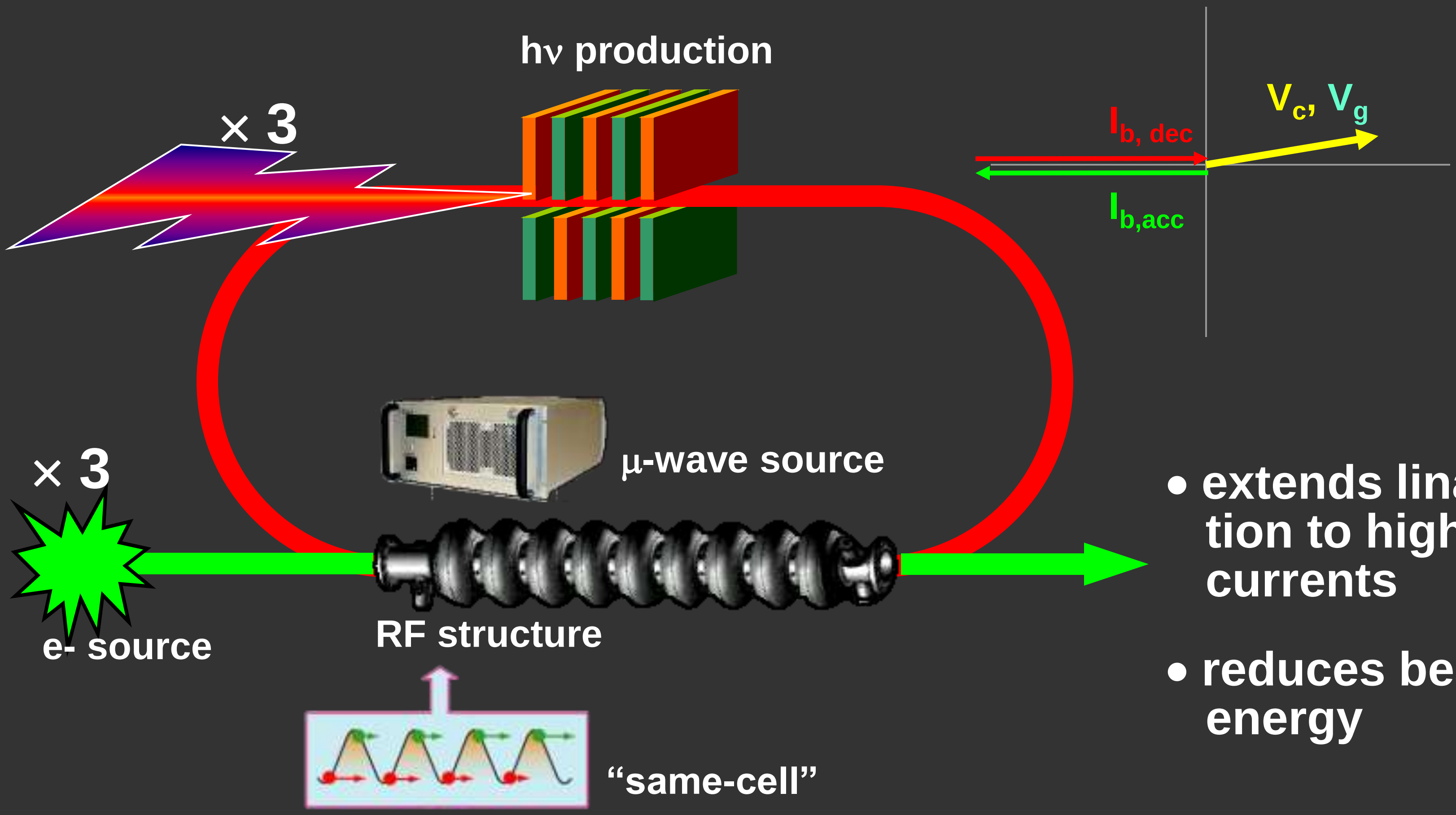
ERL Concept: energy recovery linac



ERL Concept: energy recovery linac



- extends linac operation to high average currents
- reduces beam dump energy

Can ERL 0.1 A beam co-exist with 0.1 mA?

• currently, each SRF cavity in the main linac is spec’ed for roughly 15 MV voltage, each powered by a klystron of 15 kW

• Beam loading due to 100 microAmps beam is only 1.5 kW – 10% of the klystron power

• HOM problems in the linac should be addressable as well: *low* average current; bunch is real short *only* after BC2

• 0.1 mA bunches can have arbitrary RF phase – can be used to one’s advantage

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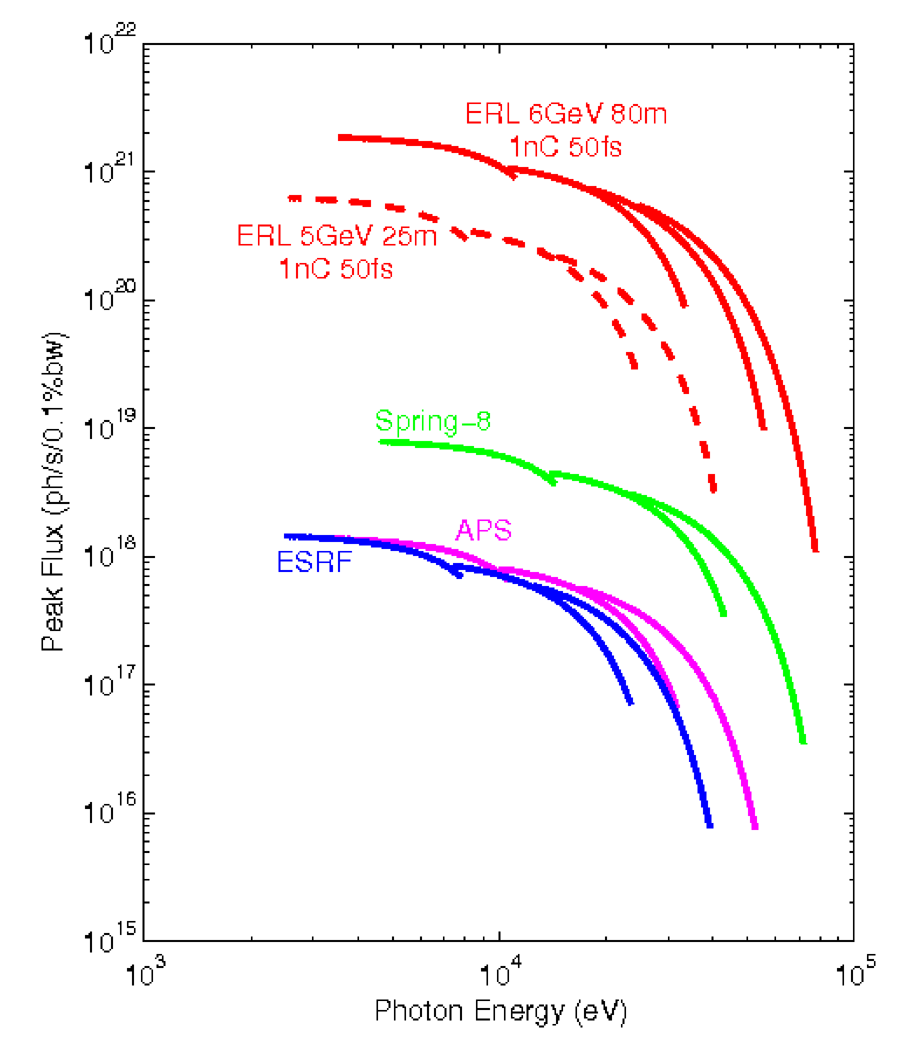
Performance of 80 m long undulator

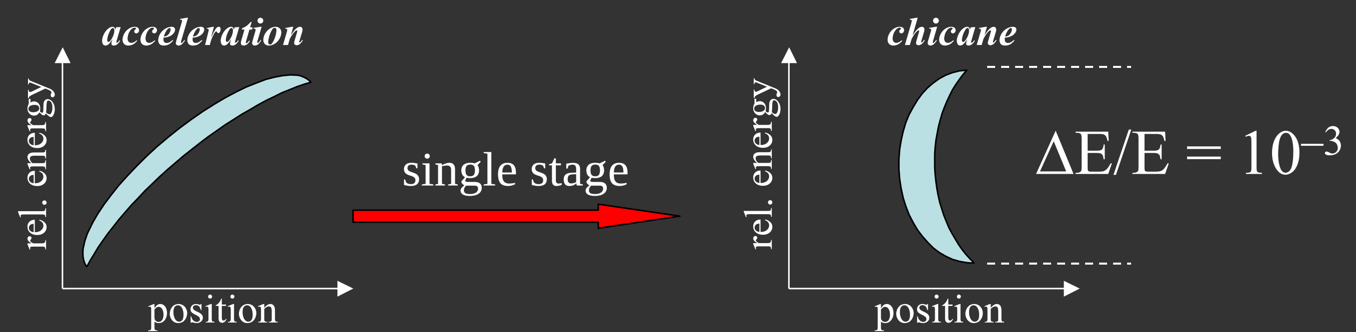


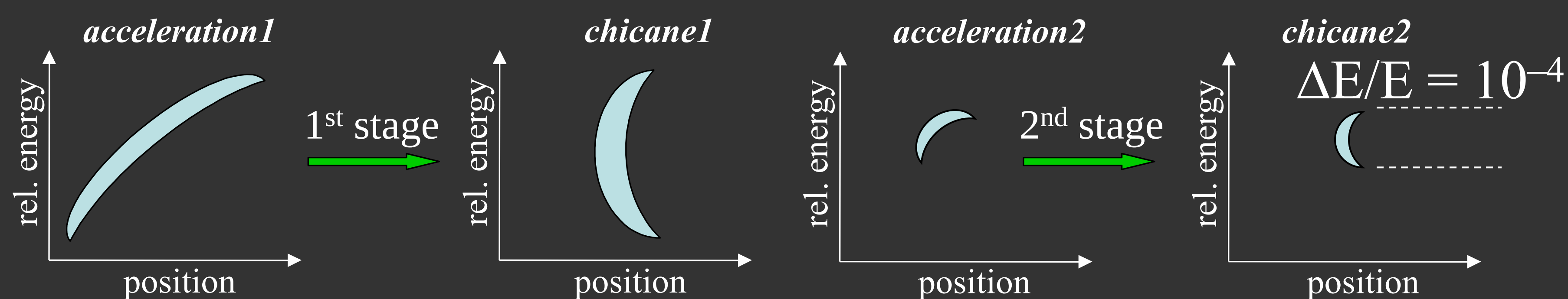
- Hybrid (vanadium permendur), 2.3 cm period; min gap 5 mm

- **10^9 Photons/pulse/0.1%BW** for 1nC bunch

Multiple stage compression

- TESLA XFEL: 3 stages; LCLS: 2 stages; BESSY XFEL: 2 stages
- Vanilla ERL: ***1 stage***
- Proposed short pulse line in ERL: ***2 stages***





Parametrized 3D FEL simulations applied to the short pulse line specs

Case 3

Beam energy	5 *GeV*
Charge per bunch	770 *pC*
Normalized slice emittance (rms)	1 *mm-mrad*
Bunch length (rms)	0.03 *mm*
Peak current	3 *kA*
Average beta-function	7 *m*
Slice fractional energy spread	2.9×10^{-4}
Total fractional energy spread	9.0×10^{-3}

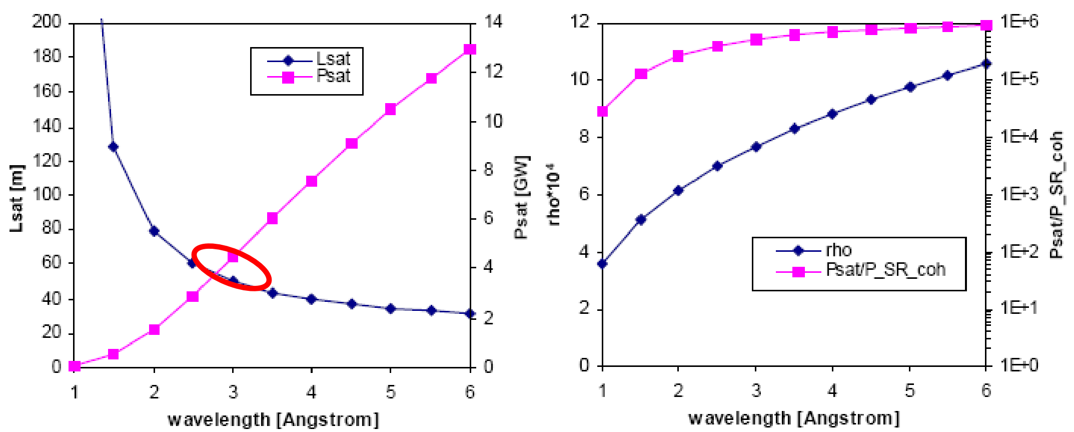


Fig. 4. Case 3: saturation length and peak power (left); ρ and ratio of SASE coherent power to spontaneous SR coherent power as given by (8) (right).

- 80 m undulator should lase at ~3-4 keV;
- Undulator K is large (2.7) → 3rd harmonic lasing will happen

3–4 keV: 10^{12} ph/pulse
10–12 keV: $>10^{10}$ ph/pulse
rep rate: up to 0.1 MHz

ERL TN 02-5

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Is there an electron source capable of 100 kHz 1nC emittance <1mm-mrad?

• not at the moment

• ***but***, a source similar to the one currently being built at Cornell has been simulated to be up to the challenge

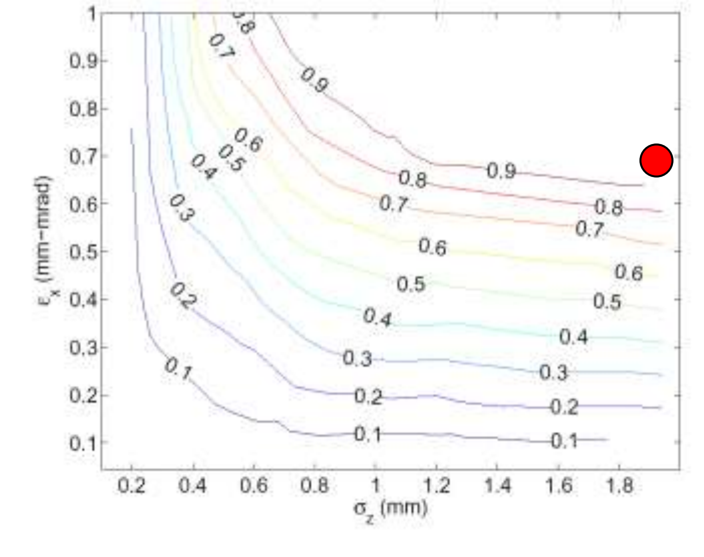

FIG. 10: Transverse emittance vs. bunch length for various charges in the injector (nC).

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1nC, 0.7 mm-mrad,
66 A peak current

Summary

- The proposed short pulse beamline takes advantage of two unique to ERL technologies (hi rep rate photoinjectors, SRF);
- Multiple stage compression will enable small energy spread, resulting in saturation length of ~60-80 m with parameters that we believe are achievable;
- Simultaneous running of ERL and the short pulse experiments appear feasible;
- Will put the accelerator to the frontiers of light source development & performance for many years to come.

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Additional thoughts

- High bunch charge injector is needed in any event to provide optimal fat bunches for timing exp.;
- Only 10% of additional linac is required, i.e. cannot be “make it or break it” from monetary point of view;
- Initially, non-XFEL option can be pursued with a long undulator (but not 80 m necessarily) producing 10^9 photons/pulse @ 0.1 MHz;
- Upgrade with 3rd harmonic linearizer linac (if required) and extended undulator will move the ERL accelerator into the new regime of high rep rate XFELs.