ERL – based circular Higgs factory

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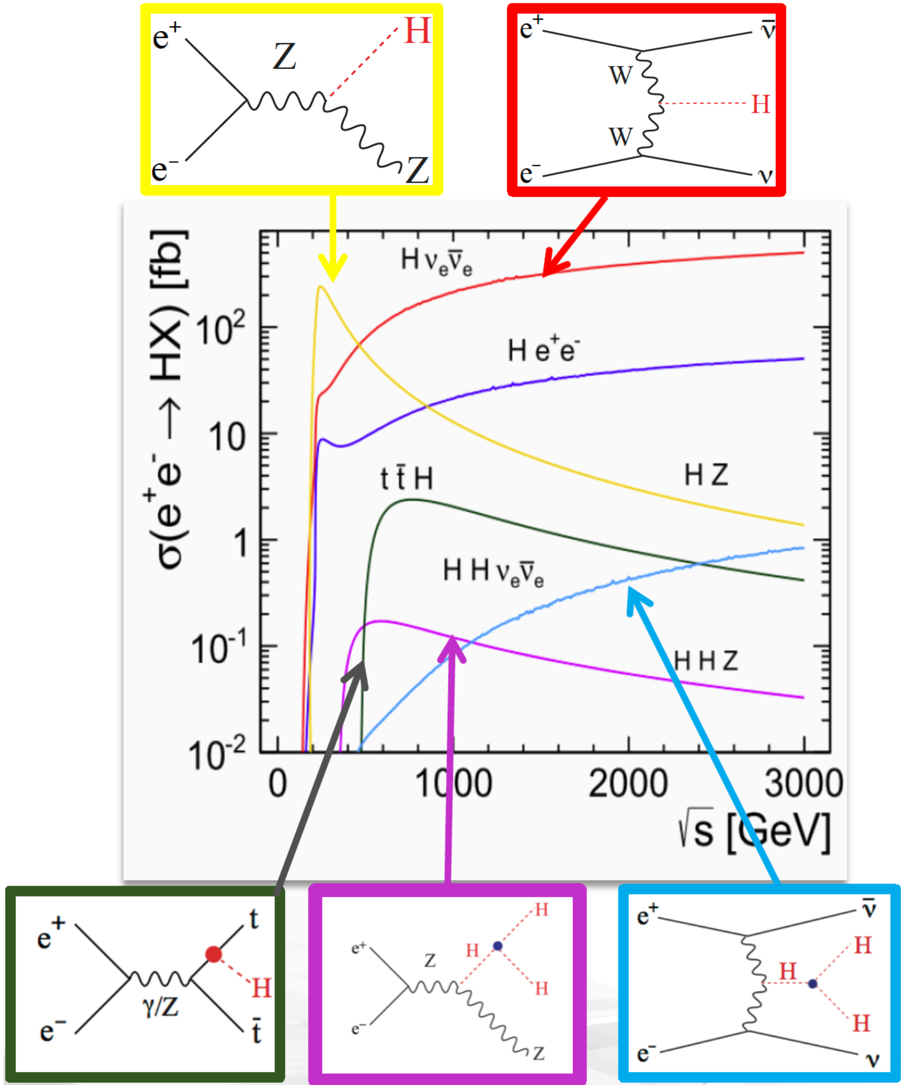
U.S. DEPARTMENT OF ENERGY

Snowmass Community Planning Meeting
Break out session 178
October 6, 2020

Physics of electron positron colliders

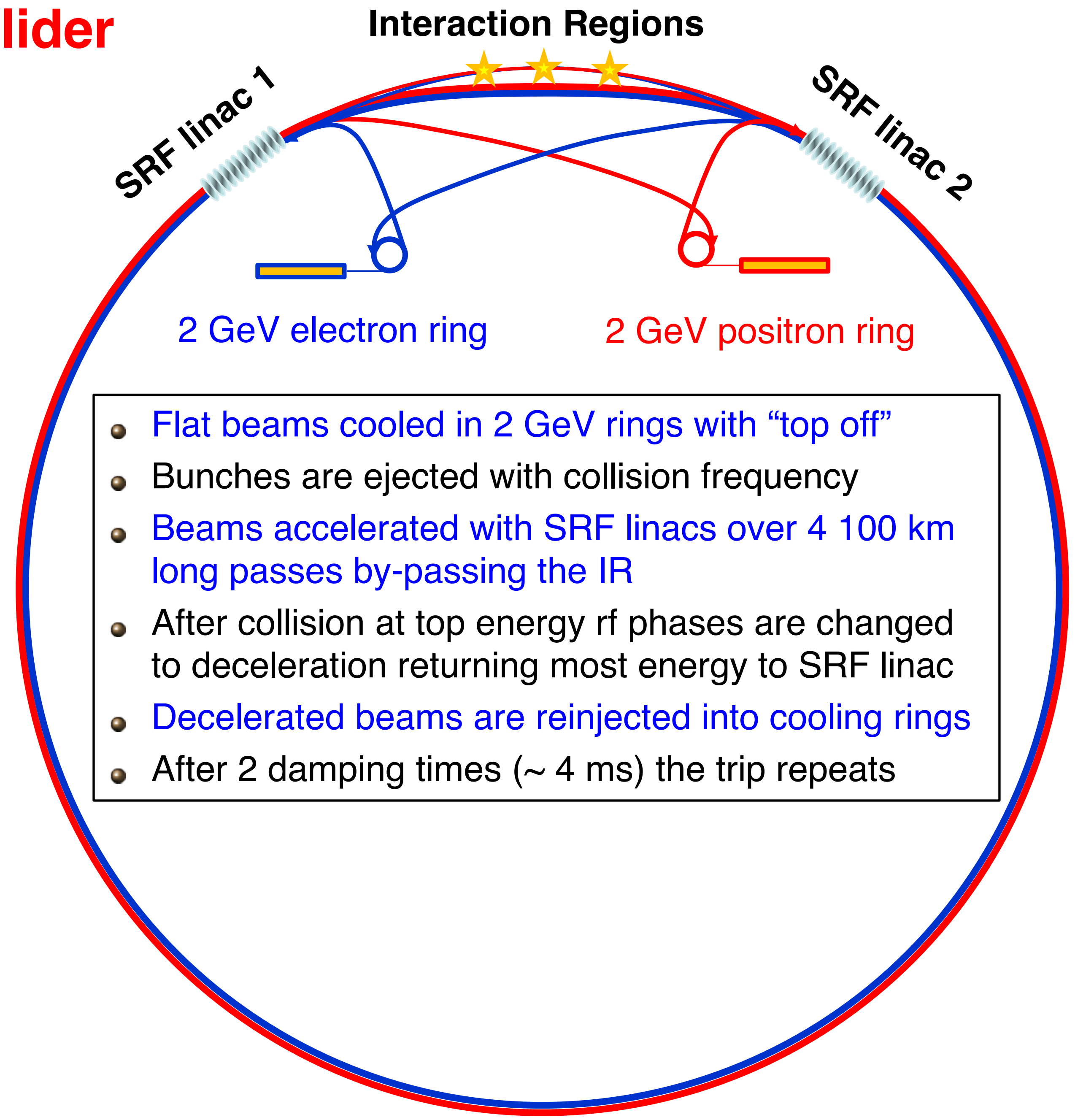
- Precision measurements
- Search for deviations from SM
  - Need high luminosity and high energy, beam polarization is also very useful

√s, GeV	Science Drivers
90-200	EW precision physics, Z, WW
240	**Single Higgs physics (HZ), H$\nu\nu$**
365	ttbar
500-600	**HHZ, Ht$\bar{t}$, direct access to H self-coupling, top Yukawa couplings**
1000-3000	HH$\nu\nu$, H self couplings



Energy Recovery Linac (ERL) collider

- New collider concept using existing accelerator technologies
- Combines advantages of existing collider concepts:
  - Storage ring collider: Recycling of beam energy (and particles)
  - Linear collider: efficient collisions (collisions per beam particles) using a large disruption parameter

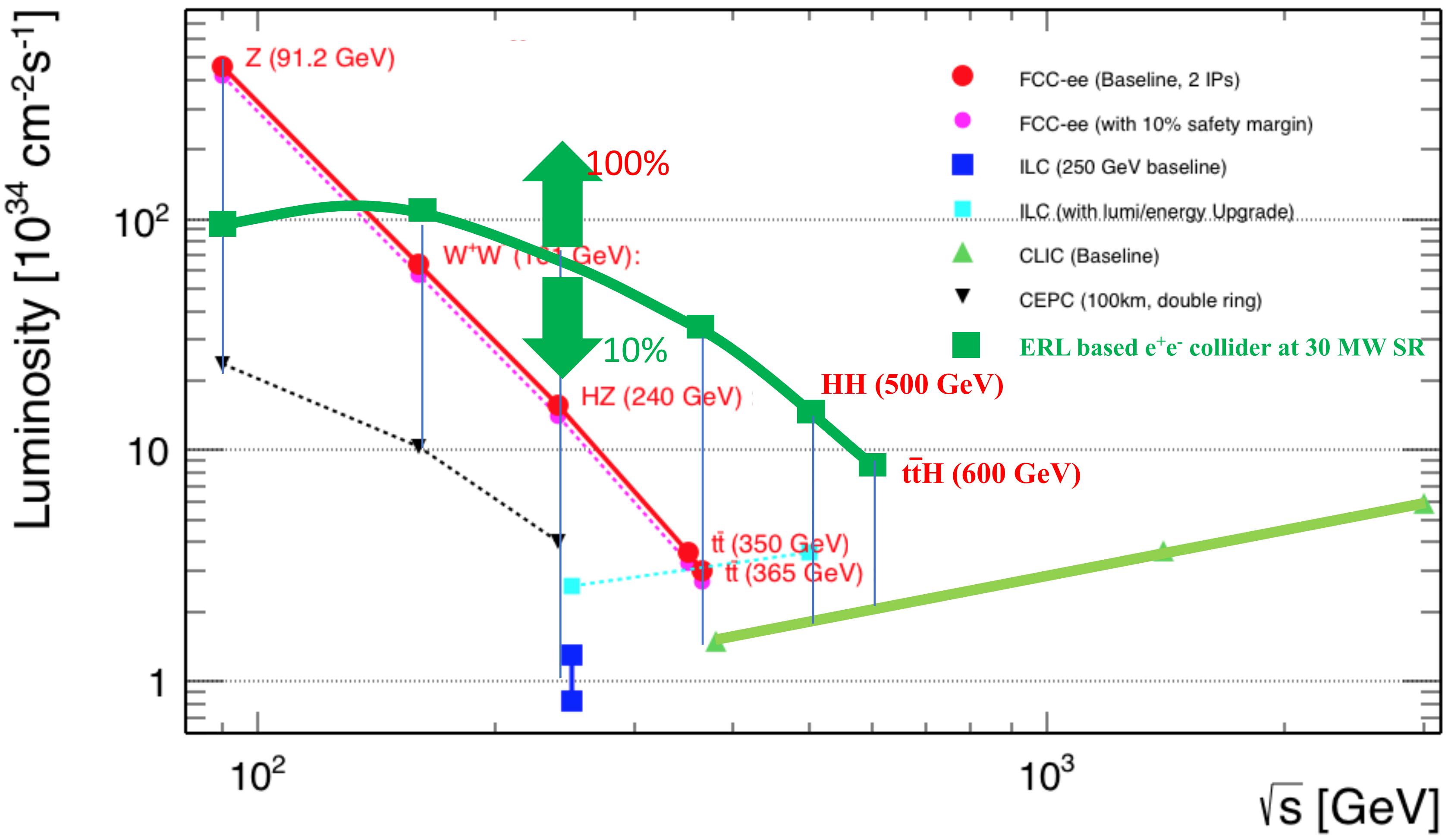


- Flat beams cooled in 2 GeV rings with "top off"
- Bunches are ejected with collision frequency
- Beams accelerated with SRF linacs over 4 100 km long passes by-passing the IR
- After collision at top energy rf phases are changed to deceleration returning most energy to SRF linac
- Decelerated beams are reinjected into cooling rings
- After 2 damping times (~ 4 ms) the trip repeats

"High-energy high-luminosity e^+e^- collider using energy-recovery linacs"
V.N. Litvinenko, T. Roser, M. Chamizo-Llatas
Physics Letters B 804 (2020) 13594

Luminosity vs Energy

- **ERL luminosity for 30 MW total synchrotron radiation power**; luminosity scales linear with SR power
- Luminosity can be shared (split) by multiple detectors/IR.
- Potential of increasing total luminosity further with smaller beta*; requires detailed simulations

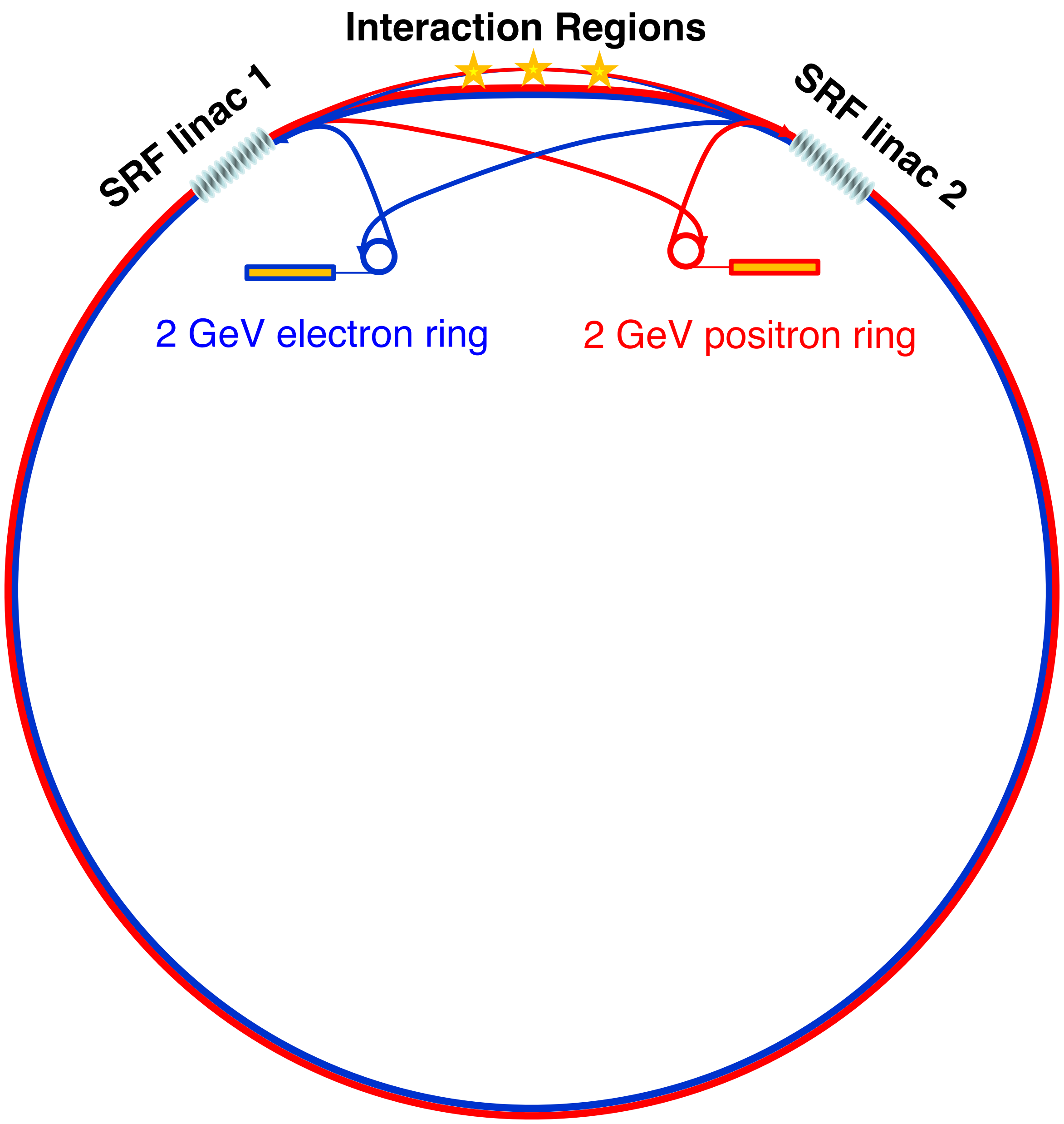


ERL collider recycles (polarized) electrons and positrons

- After acceleration, collision, and deceleration all electrons and positrons are reinjected into the cooling rings. Only beam losses must be made up through top-off injection.

- Depolarization during acceleration, collision, and deceleration is expected to be minimal.

- If this depolarization is less than the polarization build-up during the 4 ms time in the cooling rings, the electron and positron beams will eventually be polarized.



Facility "Standard Table"

ERL collider / Thomas Roser	electron/positron	vl@bnl.ogv , roser@bnl.gov, mchamizo@bnl.gov	
Beam Energy	GeV	300 (Httbar)	120 (HZ)
Peak Luminosity	10^{34} cm^{-2} s^{-1}	8.3	73
Int. Luminosity	ab^{-1}/year	1.0	8.8
Beam dE/E at IP	%	0.32	0.23
Transv. Beam sizes at IP x/y	um	3.7 / 0.0052	5.0 / 0.0058
Rms bunch length / betay*	cm	0.2 / 0.2	0.1 / 0.1
Crossing angle	urad	0	0
Rep./Rev. frequency	Hz	9,000	99,000
Bunch spacing	ns	110,000	10,000
# of IPs		Multiple with shared luminosity	
# of bunches		Continuous beam	
Length/Circumference	km	100	
Facility site power	MW	30 MW of synchrotron radiation power	
Cost range	$B US	(day 2 speakers – feel free to skip)	
Timescale until operations		10 – 15 years	

(1.2×10^{7} s/year)

Summary: challenges and opportunities of an ERL collider

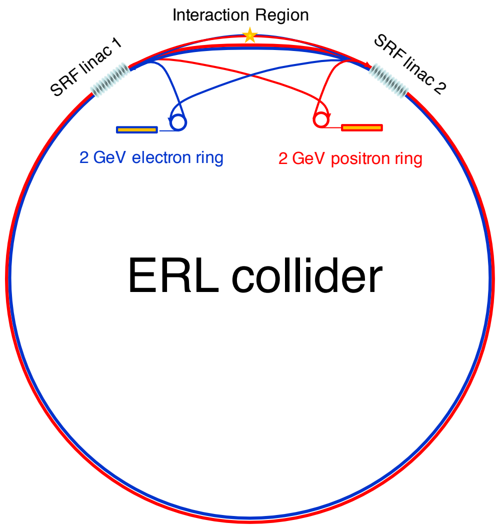
- Design challenges and R&D
  - Multi-pass, high energy ERL R&D
  - Transport beamline lattice preserving a small vertical emittance with large beam aspect ratio
  - Full 3D simulation of electron-positron collisions with flat beams and high disruption parameter
  - Using small gap magnets to reduce power consumption and cost of the multiple 100 km beamlines
  - Absolute beam energy measuring systems with accuracy $\sim 10^{-5}$ at IRs as pioneered at CEBAF
  - High repetition rate ejection and injection kickers for 2 GeV damping rings
  - Compressing and de-compressing electron and positron bunches to match energy acceptance of the 2 GeV damping rings

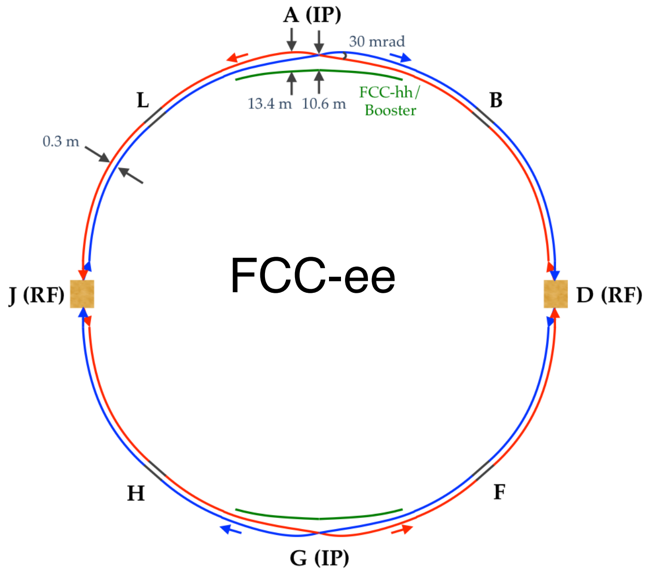
- Opportunities
  - Building the next generation high luminosity particle collider as a sustainable facility
  - A high degree of longitudinal polarization of electron and positron beams
  - Alternate locations with different circumference: very preliminary estimate for an ERL collider in the LHC tunnel indicates that it could reach $\sqrt{s}$ = 240 GeV (HZ) with 40 x 10^{34} $cm^{-2}s^{-1}$ luminosity and 30 MW SR power.

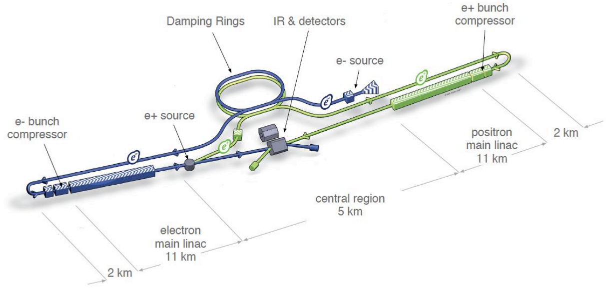
Back-up slides

Why is the power consumption of an ERL collider lower?

- In an ERL collider beam bunches collide only once (like in a linear collider). This allows much larger disruption of the bunches by the beam-beam interaction and therefore much more luminosity for a given bunch intensity. This is a more efficient use of the beam particles.
- This allows to either lower the beam current (and synchrotron radiation power) for the same luminosity or increase the luminosity for same current or some of both.
- A linear collider can make the same efficient use of the beam particles, but the beam is dumped after use and all the beam energy is lost.
- In an ERL all the beam energy is recovered during deceleration except for the radiated synchrotron light. A high energy ERL collider can be much more energy efficient than a linear collider for a large enough circumference, about 100 km for 250 - 300 GeV beam energy.







ILC (Japan)

same scale

Strong-strong collisions of flat beams

- Using very flat beams minimizes beamstrahlung by minimizing the EM fields, similar to linear colliders. Flat beams allow for using 2D calculations to estimate beam-beam effects.
- Below is vertical phase space of beam after the collision. Top is for the middle of the bunch; bottom is for 10 slices covering the whole bunch length.
- Vertical emittance grows by about a factor of 5. This is well within acceptance of the deceleration beam line
- There is little disruption and emittance growth in the horizontal direction
- Full 3D simulations requiring intensive computations are needed