High-energy high-luminosity ERL-based e^+e^- collider

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Abstract. The study of the properties of the Higgs boson and looking for signs of new physics through deviations from the standard model prediction is one of the main topics in particle physics today. Future electron-positron colliders provide a powerful tool to perform high precision measurements of the Higgs and electroweak parameters and search for signs of new physics. An electron-positron collider with center of mass energy reach up to 600 GeV would enable double Higgs and $t\bar{t}H$ production, allowing access at tree level to the Higgs self-coupling and top Yukawa coupling, complementing the measurements at HL-LHC and other lower energy e+e- colliders. The high luminosities delivered by the proposed ERL e+e- collider and the center of mass energy reach (see Fig. 1), would allow to reach these goals.

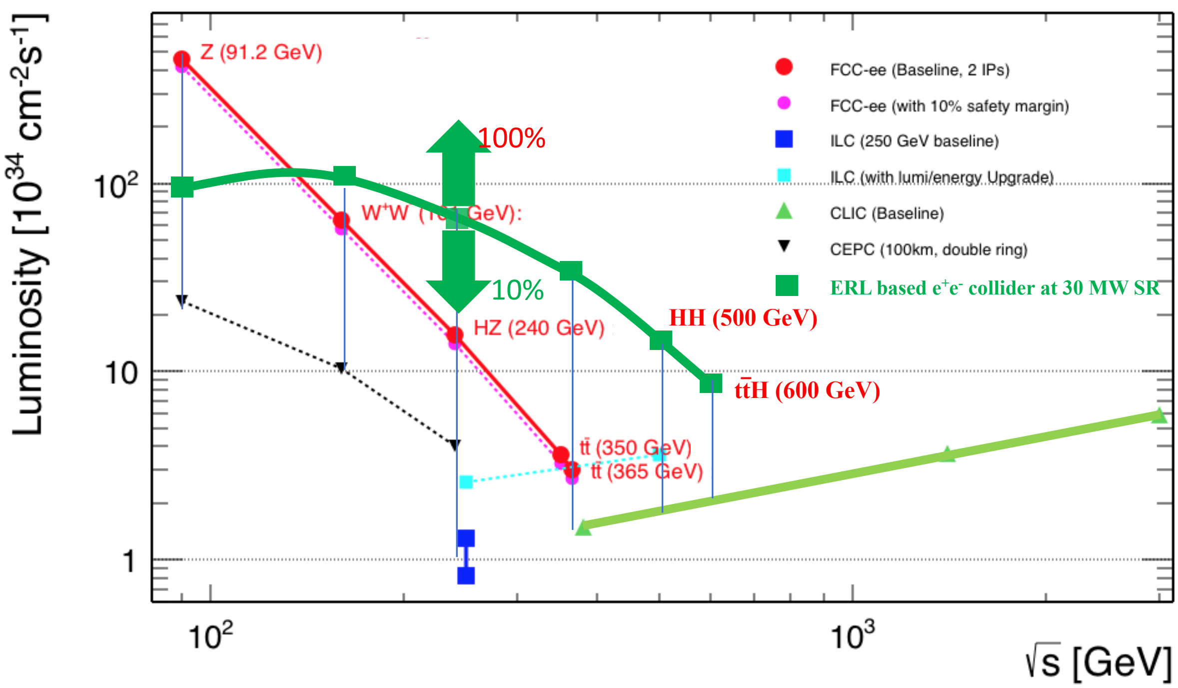

Fig. 1. Luminosities for various options for high-energy e^+e^- collider. We added the luminosity curve for our design to a plot taken from reference [2]. The thick green line and green squares show our estimated luminosities for the ERL-based collider with 30 MW of synchrotron radiation power. The luminosities of e^+e^- colliders scale proportionally to the synchrotron radiation power: green arrow shows where the ERL luminosity curve would be at 10 MW and 100 MW of synchrotron radiation power (10% and 100% percent of that proposed for FCC ee).

ERL-based e^+e^- collider. The purpose of this letter is to explore an alternative approach for a high-energy high-luminosity electron-positron collider [1]. Present designs for future high-energy electron-positron colliders are either based on two storage rings with 100 km circumference with a maximum CM energy of

365 GeV or two large linear accelerators with a high energy reach but lower luminosity, especially at the lower initial CM energies. A shortcoming of the collider based on storage rings is the high electric power consumption required to compensate for the beam energy losses from the 100 MW of synchrotron radiation power [2-4]. We propose to use an Energy Recovery Linac (ERL) located in the same-size 100 km tunnel to mitigate this drawback. Using an ERL would allow for a large reduction of the beam energy losses while providing higher luminosity in this high-energy collider (see Fig. 1). Furthermore, our approach would allow for colliding highly polarized electron and positron beams and for extending the CM energy to 600 GeV, which would enable double-Higgs production and measurements of the top Yukawa coupling.

Our proposed e^+e^- collider design is based on an ERL and two damping rings that are also used for particle recycling. It will consume about one third of RF power while extending the CM energy reach to 600 GeV and providing significantly higher luminosity at CM energies above 140 GeV when compared to the Storage Ring (SR) e^+e^- collider [2-7].

Current status and Future steps

In our preliminary studies we showed that an ERL-based high-energy e^+e^- collider promises significantly higher luminosities at CM energies above 140 GeV while emitting a fraction – 30% in these studies - of synchrotron radiation power in a corresponding SR e^+e^- collider design, and also extends the CM energy reach to 600 GeV. These features of the ERL-based collider are unique in this energy range. It promises to outperform the ring-ring design - by colliding beams only once - and linear colliders by using the energy recovery and recycling of the particles.

In principle, the ERL scheme described in this letter should be capable of colliding longitudinally polarized electron and positron beams, but further studies are needed to define the level of attainable polarization and its usefulness for physics experiments. Our estimations indicate that for top collision energies the beam depolarization can be as little as 5 ppm per pass, resulting in 72% polarization at collision. For the electron beam even higher polarization could be reached by using fully polarized electron bunches from a modern polarized electron gun to replace bunches with low polarization in the damping ring.

A detailed in-depth study, similar to those done for the ILC/CLIC and FCC ee designs, is needed to fully develop this concept. There is a number of important design challenges for our proposed ERL-based collider, which we propose to include in the future development of this extremely potent design: Full 3D beam-beam simulations; Transport beamline lattice preserving a small vertical emittance; Using small gap magnets to reduce power consumption of these beamlines; Spreaders and combiners to propagate beams through the SRF linacs; High-order mode (HOM) damping of the SRF cavities to avoid transverse beam-breakup instability (TBBU); Absolute beam energy measuring systems with accuracy ~ 10^{-5} (similar to that implemented for CEBAF [5]) at IRs; Attaining a high degree of longitudinal polarization of colliding beams; 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.

References:

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