HELEN: A Linear Collider Base on Advanced SRF Technology

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Abstract
This contribution discusses recently proposed Higgs-Energy e+e− linear collider based on advances in superconducting radio frequency technology. The collider offers cost and AC power savings, smaller footprint (relative to the ILC), and could be built at Fermilab with an interaction region within the site boundaries. After the initial physics run at 250 GeV, the collider could be upgraded either to higher luminosity or to higher (up to 5900 GeV) energies.

Introduction
• One of the highest priorities for the particle physics community is to make precision measurements of the Higgs boson properties and look for any deviations from the Standard Model using an e+e− collider at the center-of-mass energy of 250 to 360 GeV (Higgs factory).
• ILC remains the prime candidate for such a machine. It is based on a mature, “shovel ready” SRF technology, which has been used already to build such linacs as European XFEL and LCLS-II.
• However, the community continues to make progress improving the performance of SRF cavities. Recent advances in the SRF technology can be applied to a more compact and cost-effective e+e− linear collider.
• If the ILC cannot be realized in Japan in a timely manner, we proposed a Higgs-Energy Lepton (HELEN) collider based on the traveling wave (TW) SRF structures.
• HELEN could be built at relatively short period of dedicated R&D efforts.

Promise of traveling wave SRF
Advantages wrt TESLA cavity:
• Substantially lower Hq/E0 and lower Ea/E0, compared to TESLA cavity [28.8 Oe/(MV/m) and 1.73 vs. 42.6 Oe/(MV/m) and 2.0 respectively] → can potentially reach E0 ≥ 70 MV/m if we can utilize the state-of-the-art surface treatment.
• Factor of 2 higher R/Q.
• Higher group velocity (2.3% vs. 1.8%) → TW structures are less sensitive to cavity detuning errors, making tuning easier, despite the larger number of cells. The high stability of the field distribution along the structure allows for much longer (e.g., 2-meter long) accelerating structures than TESLA cavities.
• Cell shape can be fine-tuned to avoid multipacting.
• Preliminary results indicate that the first 10 monopole modes up to 7 GHz show no trapping.

Disadvantages:
• More cells per meter + feedback waveguide → more expensive fabrication and surface treatment.
• The feedback waveguide requires tuning to compensate reflections along the TW ring and thus obtain a pure traveling wave regime.
• Lower geometry factor (196 Ohm vs. 270 Ohm), but still gaining in cryogenic performance overall.

R&D program
TW SRF technology:
• Test proof-of-principle 3-cell TW cavity and demonstrate accelerating gradient of ∼ 70 MV/m.
• Adapt an advanced cavity treatment technique to achieve high Q ∼ 1010 at high gradient.
• Design, build and test full-scale prototype cavities; demonstrate performance needed for the HELEN collider.
• Design and build a prototype cryomodule (CM) for TW SRF cavities.
• Verify the CM performance on a test stand and with beam at Fermilab’s FAST facility.

Other tasks:
• Design and optimization of the HELEN linear collider accelerator complex.
• Confirm the physics reach and detector performance for the HELEN beam parameters.
• Publish CDR as modification of the ILC design in 2–3 years.
• Prepare TDR after demonstrating the cryomodule performance, in ~5 years

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