

AF4 (Multi-TeV Colliders) Executive Summary

The ongoing Snowmass process has emphasized the need to explore the Energy Frontier with particle collisions where the constituent center-of-mass energy is $E_{cm} > 10$ TeV. Thus, a principal focus of AF4 has been a review of the machine options for hadron and lepton colliders that may provide a path to this threshold. A consensus is emerging that the earliest timescale for making a construction decision for such a discovery machine will be sometime in the next decade. Thus, our evaluation has focused heavily on the maturity of the various concepts and the type of support that will be required to provide the high energy physics (HEP) community with the design inputs required for a machine decision on that timescale.

In addition to the frontier discovery machine concepts just described, various submissions were received describing lepton colliders that could operate in the 1-few TeV range. Furthermore, interest remains in the possibility of alternative paths exploring the TeV-scale including lepton-ion and $\gamma\text{--}\gamma$ colliders.

Figure 1 shows our evaluation of the current maturity of various concepts. Designs in the green-shaded region are considered sufficiently mature to enable an informed decision about the proposed approach for physics performance, cost, and risk. Designs in the yellow-shaded region will require both significant technology R&D as well as more detailed design studies to fully evaluate their realistic physics potential and to understand both the risks and costs of the approach. Designs in the red-shaded region are very preliminary concepts that cannot be qualitatively compared with other designs. A detailed discussion of the evaluation criteria can be found in the section on “Concept Assessments.”

It should be noted that the concepts shown in yellow-shaded region have the potential to achieve sufficient maturity within the next decade for evaluation by the HEP community. It is important to note that the necessary technical maturity for these concepts, and hence the ability to evaluate both the overall physics performance as well as cost scale, cannot be delivered without dedicated Collider R&D research investment over the next several years.

Collider Concepts	<div> <div>Collider-in-Sea</div> <div>MuIC</div> <div>Multi-TeV ILC (Nb₃Sn)</div> </div>	<div> <div>WFA</div> <div>ReLIC (≤3 TeV)</div> <div>CCC (TeV)</div> </div>	<div> <div>MuC</div> <div>SppC</div> <div>FCC-eh</div> </div>	<div> <div>FCC-hh</div> <div>CLIC</div> <div>TeV ILC (Nb)</div> </div>
Technical Maturity	<ul style="list-style-type: none"> • Low maturity conceptual development. • Proof-of-principle R&D required. • Concepts not ready for facility consideration. 	<ul style="list-style-type: none"> • Emerging accelerator concepts requiring significant basic R&D and design effort to bring to maturity. 		<ul style="list-style-type: none"> • Designs have achieved a level of maturity to have reliable performance evaluations based on prior R&D and design efforts. • Critical project risks have been identified and sub-system focused R&D is underway where necessary.
Funding Approach	<ul style="list-style-type: none"> • Funding for basic R&D required. • Availability of "generic" accelerator test facility access often necessary. 	<ul style="list-style-type: none"> • Efforts would benefit from directed R&D funding to mature collider concepts. • Availability of test facilities to demonstrate a broad range of technology concepts required. • Some large-ticket demonstrators are generally necessary before a detailed "reference" design can be completed. 		<ul style="list-style-type: none"> • Funding approach typically transitions to "project-style" efforts with significant dedicated investment required.

Figure 1 The AF4 evaluation of the maturity level of various concepts. Further details for the evaluation of the various concepts can be found in the “Concept Assessments” Section. The color code is that the concepts shown in blue offer a path to constituent center-of-mass energies >10 TeV, while those shown in orange are electron-hadron machines, and those shown in black are lepton collider concepts which will reach only into the 1-few TeV range.