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Towards 20 T accelerator magnets: a road to super-high energy colliding beams

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For a fixed size of a circular collider, its energy is limited by the strength of bending dipole magnets. Moreover, for both linear and circular machines, their maximum luminosity is determined (among other factors) by the strength of quadrupole magnets used for the final beam focusing. That is why there has been a permanent interest to higher-field and higher-field gradient accelerator magnets from the high-energy physics and particle accelerator community.
The highest fields in accelerator magnets have been achieved using superconducting electromagnets. The ultimate field of these magnets is limited by the superconductor critical parameters such as critical field Bc2, critical temperature Tc and critical current density Jc. There are two classes of practical superconducting materials suitable for accelerator magnets - so called Low-Temperature Superconductors (NbTi, Nb3Sn, Nb3Al) and High-Temperature Superconductors (BSCCO, YBCO). The maximum field of NbTi accelerator magnets used in all present high-energy machines including LHC is limited by ˜10 T at operating temperature ˜1.8 K. The magnetic fields above 10 T threshold became possible thanks to the Nb3Sn superconductor. Nb3Sn accelerator magnets can provide operating fields up to ˜15 T and significantly increase the coil temperature margin. Accelerator magnets with operating field above 15 T would require using high-field high-temperature superconductors, which have highest upper critical magnetic field Bc2. However, due to the substantially higher cost and lower critical current density in magnetic fields below 15 T, a hybrid approach with Nb3Sn superconductor in fields below 15 T is a quite attractive option even though the Nb3Sn and HTS materials require different coil processing. This paper discusses the status and main results of the state-of-the-art Nb3Sn accelerator magnets and outlines a roadmap towards the 20 T class magnets.

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