14th International Computational Accelerator Physics Conference

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Integration of magnetic measurement data in magnetic field simulations by BEM-based discrepancy modeling

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Magnetic measurement data is collected at various points in an accelerator magnet's life cycle. It is used, for example, to calibrate model parameters in the prototyping phase, for quality assurance and fault detection in the production phase, and for state observation and prediction during magnet operation. In all cases, the numerical model of the accelerator magnet is at the center of the analysis.

Although magnetic measurement data is highly accurate, it is typically incomplete, i.e., the state space is not observable by a finite number of magnetic field sensors. On the other hand, numerical field simulations can predict the magnet state but are limited in accuracy and often fall short of the stringent requirements for magnet operation. For this reason, measurement data must be integrated with numerical field calculations to enable predictions with the required accuracy of one unit in 10^4 to 10^5.

We are developing application-specific hybrid models in all stages of the accelerator magnet lifecycle based on the principles of Model-based systems engineering, which focuses on models and simulations rather than documents for operation, performance evaluation, maintenance, and information exchange.

In this talk, we will focus on developing delta models, where boundary element methods (BEM) are used to model the discrepancy between measurements and observations using fictitious density functions at the iron air interface. Determining the discrepancy function from measurement data is an ill-posed inverse problem that requires a suitable regularization. For this purpose, deterministic methods (minimal energy solutions and truncated singular value decompositions) and stochastic methods such as Bayesian inference are compared.

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