Contribution ID: **461** Contribution code: **THP028** Type: **Poster Presentation**

Digital Twin Framework for PIP-II Linac: AI-Driven Multi-Scale Modeling from Ion Source to 800 MeV

Thursday 14 August 2025 16:00 (2 hours)

The PIP-II linac will enable >1.2 MW beam power for DUNE, requiring unprecedented operational reliability across its warm front-end (RFQ, MEBT) and five distinct SRF sections operating at 162.5/325/650 MHz. We present a comprehensive digital twin framework uniquely combining a fully differentiable fast beam transport code with neural network surrogates trained on high-fidelity PIC simulations, capturing space charge and nonlinear dynamics beyond traditional envelope codes while achieving 10^4× speedup at <1% accuracy. End-to-end differentiability enables gradient-based optimization across 500+ parameters simultaneously—previously impossible with conventional tools—while the model incorporates static/dynamic errors and serves as a virtual commissioning platform for diverse hardware integration. The framework facilitates reinforcement learning for pulsed/CW mode transitions, predictive maintenance through anomaly detection, and autonomous tuning algorithm development with real-time execution capability. Validation against physics simulations shows excellent agreement for the front-end, with initial results demonstrating potential for 30% commissioning time reduction and proactive fault mitigation, providing a scalable blueprint for operating next-generation high-intensity accelerators.

Please consider my poster for contributed oral presentation

Yes

Would you like to submit this poster in student poster session on Sunday (August 10th)

No

Footnotes

Funding Agency

Fermi Forward Discovery Group

I have read and accept the Privacy Policy Statement

Yes

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