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LLNL FESP Theory Highlights: August 2024

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Disclaimer

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Editor: Ben Dudson (Group Leader), on behalf of the LLNL Fusion Theory & Modeling group.

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2024 ABOUND SciDAC and BOUT++ workshop

The 2024 ABOUND SciDAC and BOUT++ combined workshop was held August 5-9th 2024 at the University of California Livermore Collaboration Center (UCLC) in Livermore. Bringing together leading scientists and researchers from across the globe, this pivotal event focused on advancing plasma physics and boundary plasma dynamics within the context of fusion energy research.

Key discussions throughout the meeting highlighted significant advancements in the BOUT++ framework, including enhanced simulations of small Edge Localized Modes (ELMs) and the initiation of integrating the integration of the 5D GEM gyrokinetic turbulence core code with the 2D SOLPS-ITER boundary transport code. These developments are crucial for managing heat loads in fusion reactors and supporting the longevity of plasma-facing components.

The event also featured a session on Inter-SciDAC Collaborations, where principal investigators from multiple U.S. FES SciDAC tokamak projects explored opportunities for cross-collaboration. Additionally, the meeting showcased cutting-edge advancements in GPU acceleration and AI/ML technologies, poised to drive the next generation of fusion research.

In his closing remarks, Dr. Xueqiao Xu emphasized the importance of the collaborative efforts and discussions that took place, noting their potential to shape future breakthroughs in fusion energy. The event underscored the global nature of the BOUT++ collaboration, with contributions from over 57 institutions worldwide.

The 2024 BOUT++ and ABOUND Joint Hybrid Meeting continues to drive forward the research and innovations needed to achieve fusion energy, setting the stage for future collaboration and discovery.

Workshop website: https://bout.llnl.gov/workshops/2024

Invited presentations

Invited Talk at the Platform for Advanced Computing (PASC) Conference, Zurich, Switzerland 6/3-5

Ilon Joseph, Ivan Novikau, Vasily Geyko, et al, “Exploration of Quantum Computing for Fusion Energy Applications”

Quantum computing promises to deliver large gains in computational power that can potentially benefit a number of Fusion Energy Science (FES) application areas. Ilon reviewed our recent efforts [1] to develop and extend quantum algorithms to perform both classical and quantum FES-relevant calculations, as well as to perform calculations on present-day quantum hardware platforms. We have developed and explored quantum algorithms that can compute nonlinear and non-Hamiltonian dynamics by simulating the Koopman-von Neumann and Liouville equations; perform eigenvalue estimation for generalized eigenvalue problems common in plasma physics and MHD theory; simulate nonlinear wave-wave interactions; and explore the chaotic dynamics of both quantum and classical systems. We have implemented models of these algorithms on state-of-the-art quantum computing architectures to test the fidelity of emerging quantum hardware capabilities including Grover's search, nonlinear three-wave interactions, and the chaotic dynamics of the quantum sawtooth map, a simple model for wave-particle interactions. The fidelity of the experimental results match noise models that include decay and dephasing processes and highlights key differences between state-of-the-art approaches to quantum computing hardware platforms.

[1] I. Joseph, Y. Shi, M. D. Porter, et al., Phys. Plasmas **30**, 010501 (2023).

Conference presentations

Contributed talk at the 5th International Conference on Data-Driven Plasma Science (ICDDPS-5). University of California, Berkeley, August 12, 2024

Ben Zhu, Menglong Zhao, Harsh Bhatia, **Xue-qiao Xu**, Peer-Timo Bremer, **Thomas Rognlien**, KyuBeen Kwon, Xinxing Ma, Anchal Gupta, David Eldon, Hyungho Lee, and Junghoo Hwang "**Overcoming challenges: leveraging machine learnings for efficient modeling of divertor plasmas"**