A Simulation Resource Team for Innovative Fusion Concepts in the BETHE program

P. Tzeferacos[1,2], R. Betti[1,2,3], J. R. C. Davies[1], F. García-Rubio[1,3], E. C. Hansen[2], D. Michta[2], C. Ren[1,2,3], A. C. Reyes[2], W. Scullin[1], A. B. Sefkow[1,2,3], J. G. Shaw[1], H. Wen[1], K. M. Woo[1]

1 Laboratory for Laser Energetics, 2 Department of Physics and Astronomy, 3 Department of Mechanical Engineering
University of Rochester

Abstract

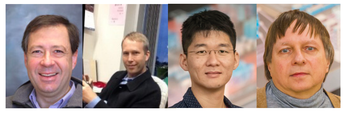
Computer simulations are indispensable tools in the development of all areas of science and engineering. For any innovative fusion scheme, simulations are essential to help interpret data and to extrapolate from the first experiments to a prototype design.

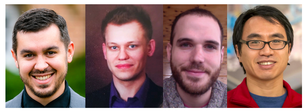
Here we present a project that assembles a theory/modeling Capability Team at the University of Rochester to provide, under the auspices of the DOE ARPA-E BETHE program, simulation support for Concept Teams and independent theoretical analysis of the physics underlying leading Concepts.

We discuss the suite of simulation codes – fluid, hybrid, and kinetic – we will use in this effort, and how they will be applied to engage with Concept Teams that focus on Plasma-Jet-Driven Magneto-Inertial Fusion, Field-Reversal Configurations, and the staged Z-pinch. The codes central to this project are FLASH, TriForce, and OSIRIS, chosen because they are flexible, high-performance computing codes, capable of one-, two-, and three-dimensional simulations, and can be used by Concept Teams to sustainably continue their modeling efforts. The Capability Team also leverages OSHUN, a Fokker-Planck code to develop models of magnetized transport.

Meet the Team at the University of Rochester!

- **Petros Tzeferacos** - PI, project lead, FLASH lead
- **Adam Sefkow** - co-PI, TriForce lead
- **Chuang Ren** - co-PI, OSIRIS lead
- **Riccardo Betti** - co-PI, theory & simulations support
- **Jonathan Davies** - co-PI, theory & liaison
- **Han Wen** - co-PI, OSHUN & OSIRIS simulations
- **John Shaw** - Scientist, TriForce simulations
- **Eddie Hansen** - Postdoc, FLASH simulations
- **David Michta** - Postdoc, FLASH simulations
- **Fernando García-Rubio** - Postdoc, theory
- **Ka Ming (Jack) Woo** - Postdoc, theory & simulations
- **Graduate student** - open position, HPC support

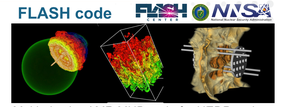




UR Theory & Modeling Capability Team to provide simulation support for Concept Teams and assess leading Concepts

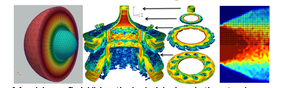
- Four components:
  - (1) Carry out simulations for Concept Teams;
  - (2) Independent simulations of key fusion Concepts;
  - (3) Assist Teams in the use of simulation codes;
  - (4) Modest development to enhance fidelity.
- A suite of simulation codes – fluid, hybrid, and kinetic: Principal codes are **FLASH**, **TriForce**, and **OSIRIS**. **OSHUN** to develop models of magnetized transport.
- Engage with Concept Teams that focus on Plasma-Jet-Driven Magneto-Inertial Fusion **(PJMIF)**, Field-Reversal Configurations **(FRC)**, and the staged Z-pinch **(SZP)**.

FLASH code



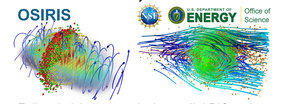
Multi-physics AMR MHD code for HEDP and plasma astrophysics

TriForce



Meshless fluid/kinetic hybrid simulation tool

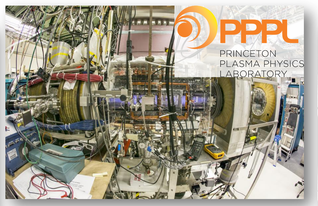
OSIRIS



Fully relativistic, massively parallel PIC code

Fusion Concepts

PLX device at LANL



Princeton Field Reversed Configuration device, the PFRC-2

COMPACT FUSION SYSTEMS

Staged Z-Pinch concept of MIFTI

Major Milestones and Outcomes

Major Milestones

- FLASH and OSIRIS integrated simulations of **PJMIF** Concept. Evaluate perturbation effects on energy-gain, fluid/kinetic effects
- Provide independent integrated assessment of the **SZP** Concept based on theory and FLASH and TriForce simulations
- Assessment of energy-gain potential of **PFRC** Concept at 10x density, 4x volume, and 100x timescale with TriForce simulations
- State-of-the-art FLASH and TriForce **transport coefficients** from OSHUN

Major Outcomes

- **Sustainable simulation support** for OPEN, ALPHA, and BETHE projects
- **Assist multiple Concept Teams** and provide **independent assessments**
- **Sustainable simulations support** for the broader HED, ICF, and plasma physics communities

Key techno-economic impact of the project

- Numerical simulations are critically important for the design and interpretation of Innovative innovative fusion schemes. However, **establishing adequate simulation capabilities** for new fusion concepts can easily be **more expensive** and **time-consuming** than building the first experiment.
- The Simulation Resource Team overcomes this “entry-barrier” in a **cost-effective manner** by developing a flexible, multi-purpose, multi-physics simulation capability suitable for many innovative fusion concepts.
- The **broad availability** of the simulation codes involved and the **training** the Simulation Resource Team will provide will ensure a **sustainable simulation resource** for the ARPA-E BETHE Program to enable **novel disruptive technologies**.

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