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SNETP Forum

Deep Learning Surrogate Models for Neutronic Irradiation Optimisation in IFMIF-DONES

HI IBERIA

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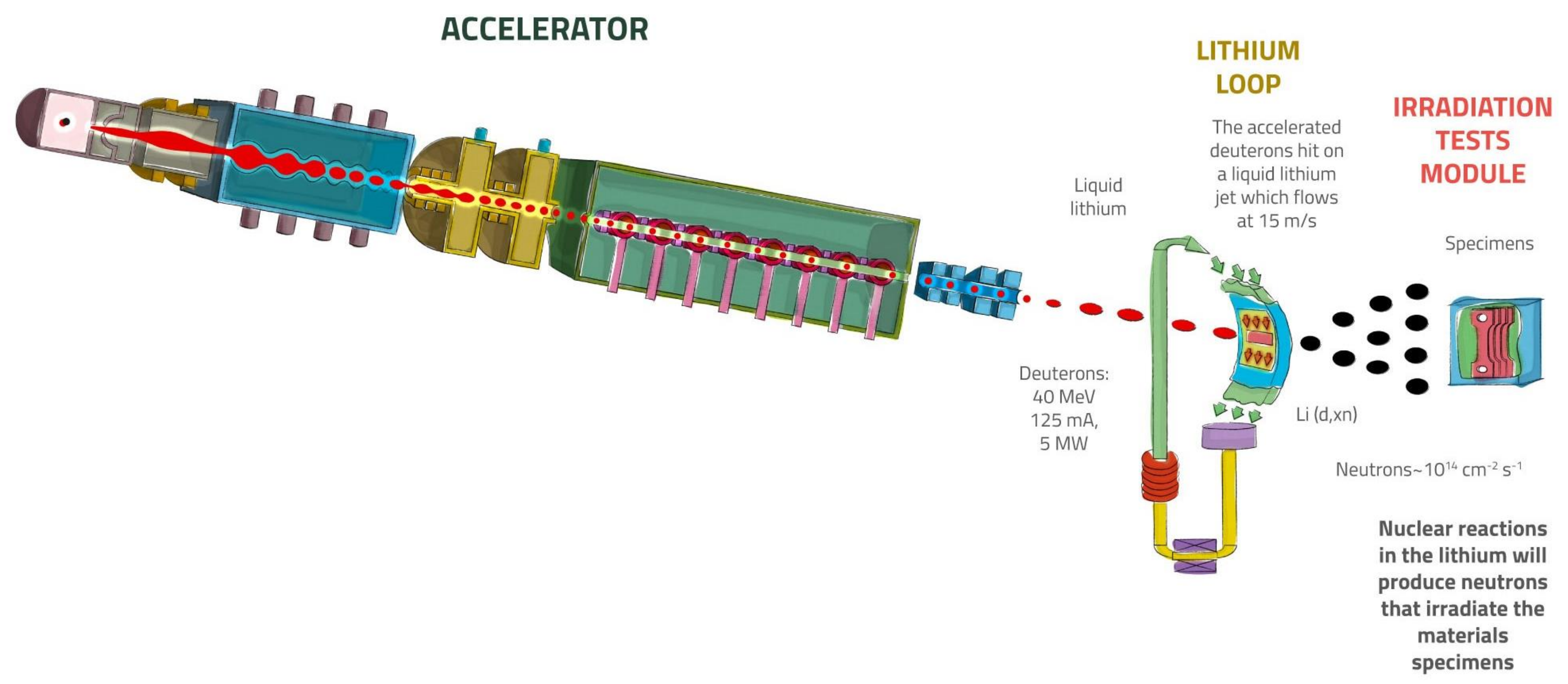
INTRODUCTION

The **IFMIF-DONES** project, which aims to pave the way for understanding the effects of high-energy and high-flux neutronic irradiation on materials, is a crucial step for the future of fusion reactors.

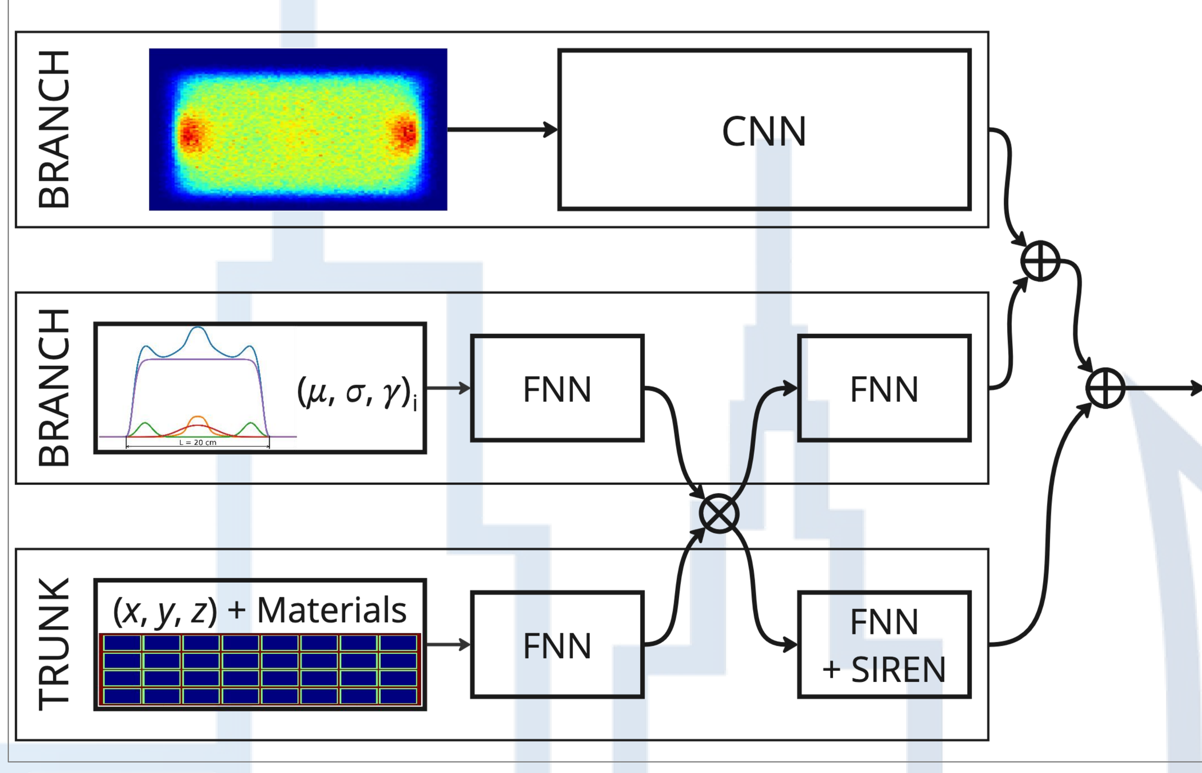


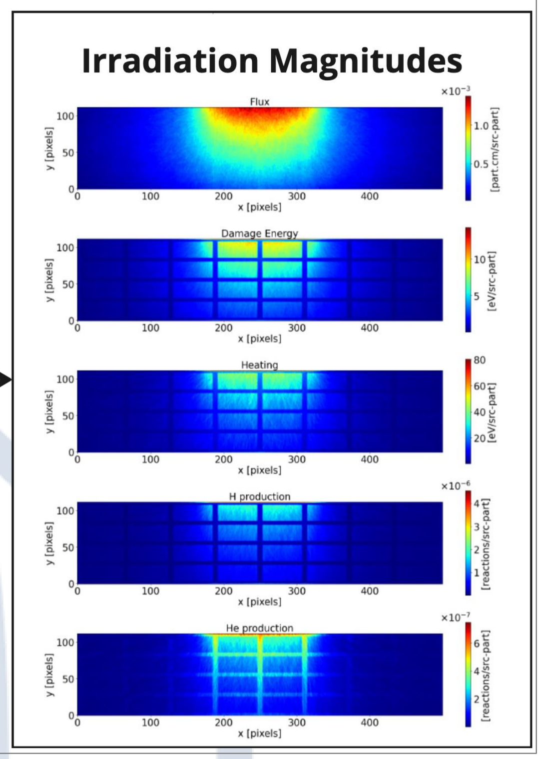
DESCRIPTION OF THE RESEARCH PROBLEM

Monte Carlo simulations are traditionally used to study neutronic transport studies; however, their computational cost limits the ability to optimise and control elements such as geometry or accelerator configuration, in the case of IFMIF-DONES. To alleviate this problem, the usage of differentiable **Deep Learning Surrogate Models** (DLSM) are employed.

METHODOLOGY

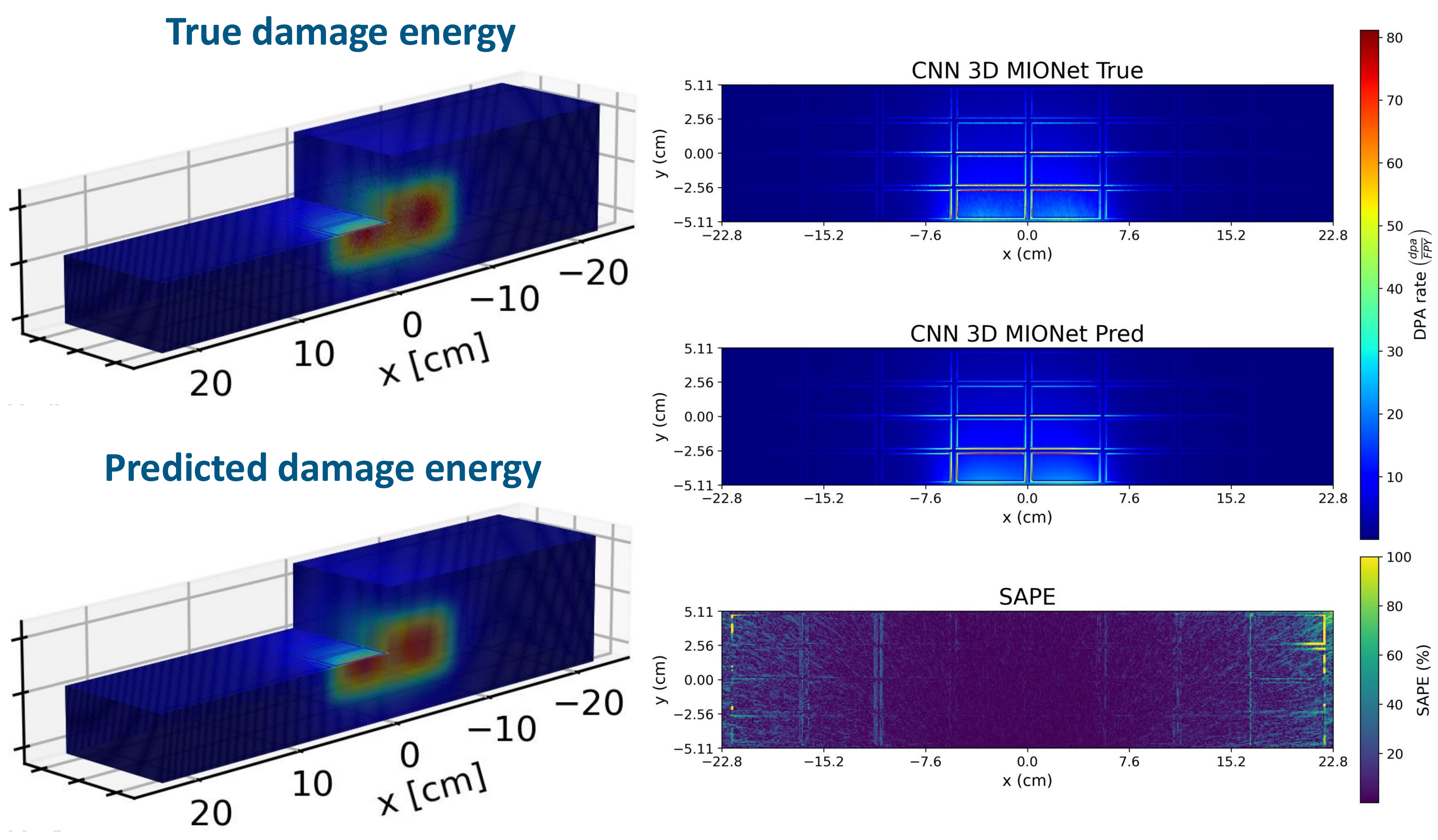
1. Create a **soft-coupled Monte Carlo simulator** of the stripping reaction and neutron transport to predict neutron flux, damage energy, H and He production and heating.
2. Generate simulations for different inputs → deuteron beam lengths (*L*) and Gaussian parameters (σ_i, μ_i, γ_i)
3. Train a **MIONet** (Trunk: geometry and materials, Branches: Gaussian parameters + footprint image)
4. Test predictions and their inference time
5. Use the nets differentiability to perform **Gradient Descent** (GD) and inverse design the Gaussian parameters



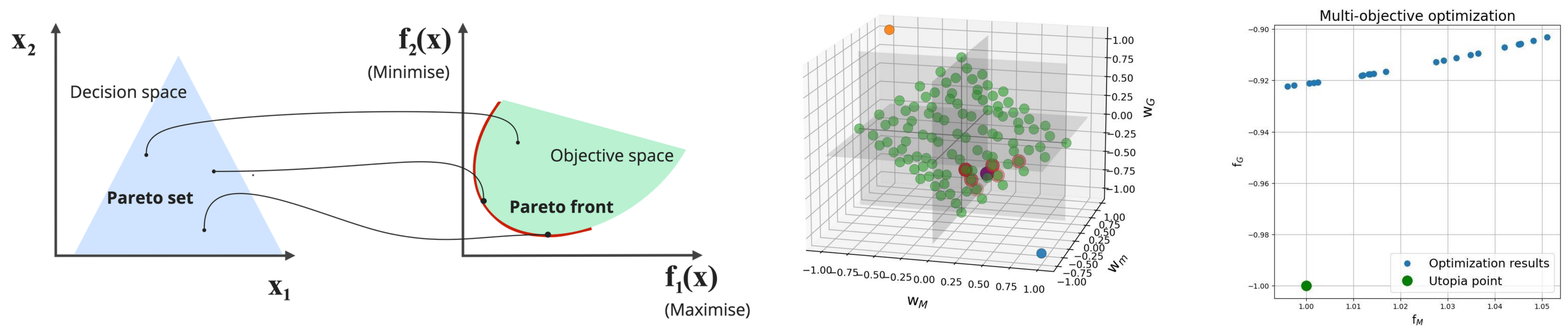


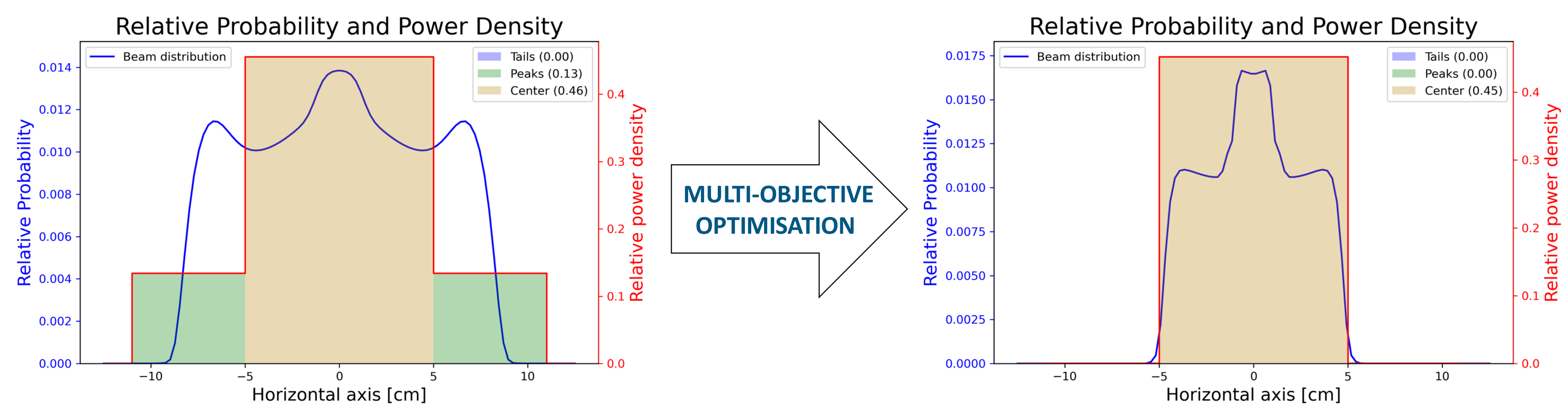
RESULTS

- **Speed**: speedup ≥10^6, compared with the simulator
- **Accuracy**:
  - R^2 = 0.994 ± 0.00158
  - sMAPE (%) = 8.74 ± 1.08



- **Optimisation**: GD, by leveraging differentiable model





CONCLUSIONS

- Computational efficiency of DLSM
- Potential for real-time control and design optimisation in fusion facilities
- **Future work**:
  - Improve training configuration with complete CLC geometric models
  - Couple with the accelerator's DRL control

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Plan de Recuperación, Transformación y Resiliencia

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