Online Physics & ML Modelling

SLAC NATIONAL ACCELERATOR LABORATORY

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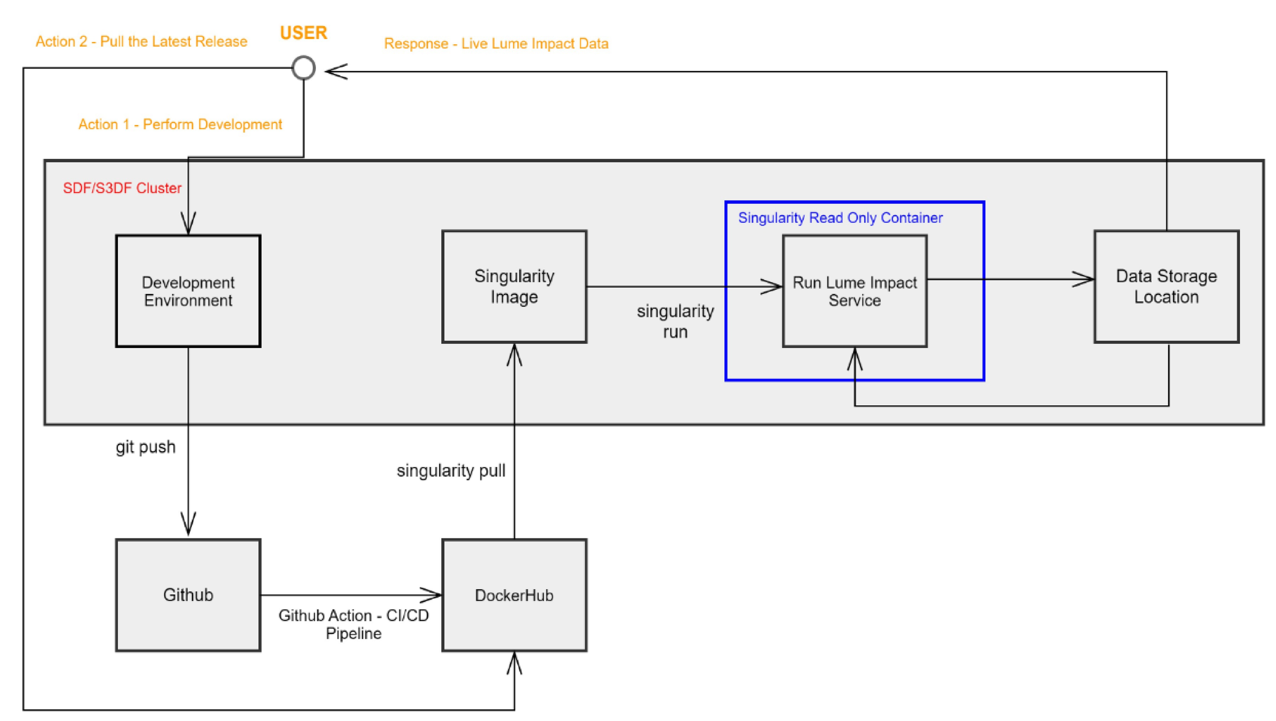
Introduction

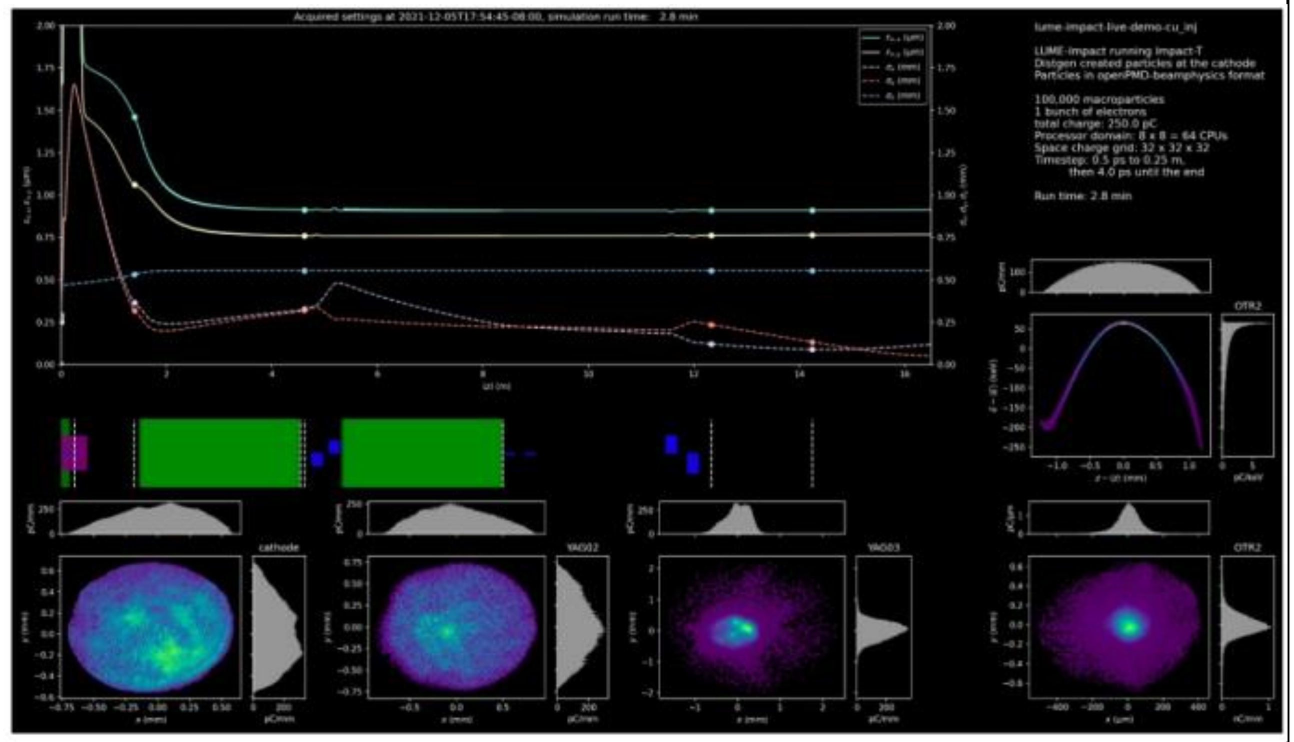
At the intersection of physics and machine learning, our mission revolves around online modeling. Simulations are executed seamlessly through the utilization of Containerized applications and autonomous jobs. This synergy aligns with the LUME Infrastructure, enabling real-time machine learning modeling and rapid HPC computing. These capabilities provide instant insights, revolutionize error analysis, deepen the understanding of beam behavior, and drive the future of modeling algorithms.

IMPACT-T Physics Simulation



Running Containerized Applications on HPC

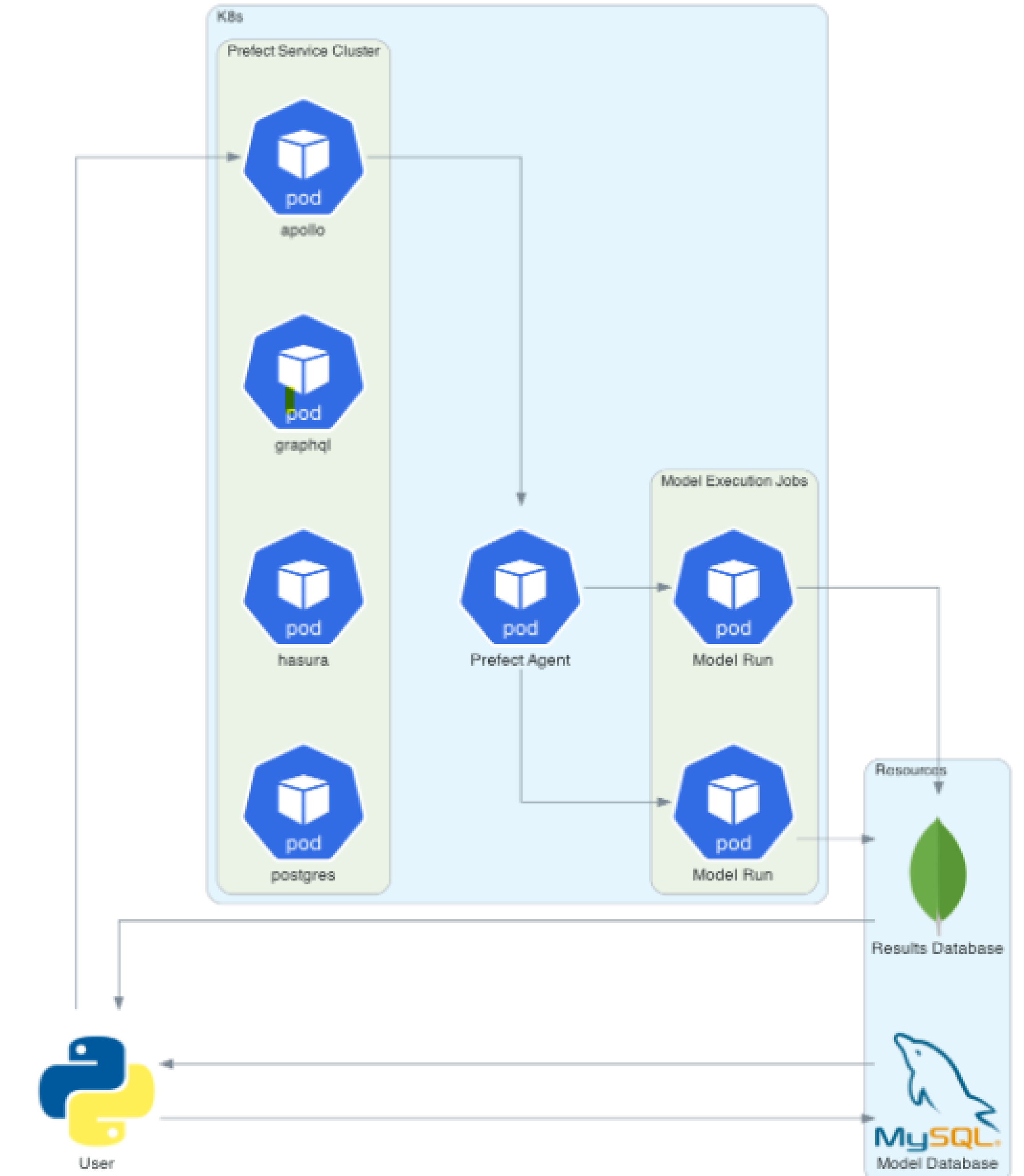
- Advanced three-dimensional physics simulation that proficiently traces and graphs the trajectories of relativistic charged particles.
- Albeit slower than Neural Network, It provides physicists insights into beam trajectory.
- Transformed into an active service running on S3DF HPC using Dockerized Singularity Containers.



Impact-T Dashboard

LUME Orchestration

- Runs containerized applications, accessible through Kubernetes on the ARD GPU Box.
- Saves model registration and outputs in PostgreSQL and Mongo DB.
- Standardized set of services for composing applications
- Advanced online visualization

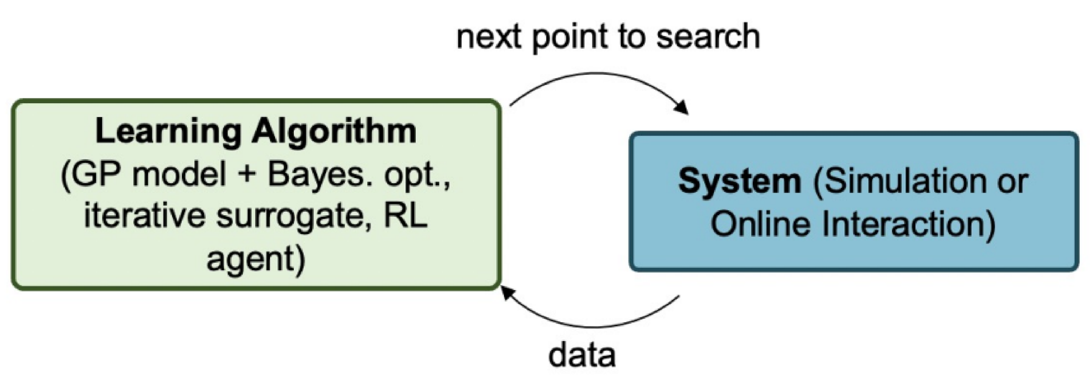


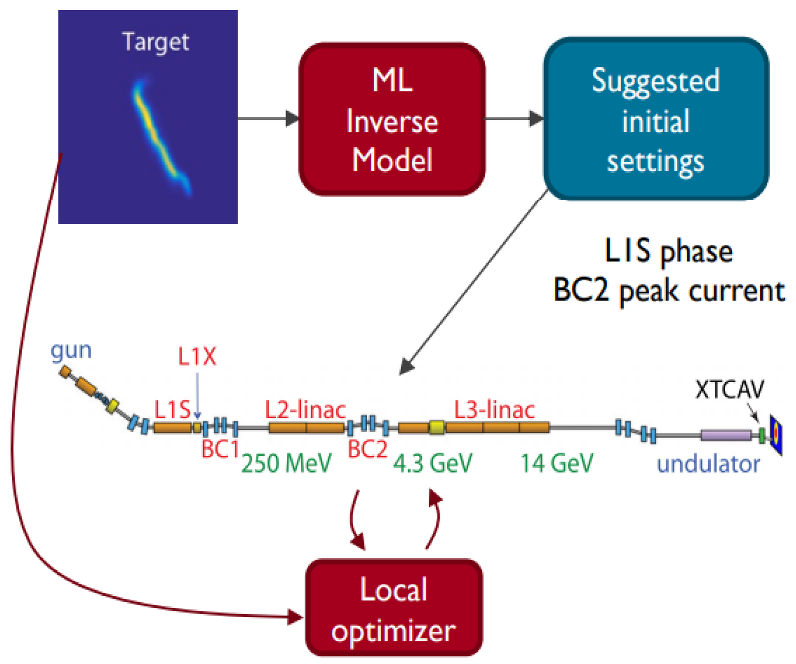
Kubernetes Architecture

Online Machine Learning Modelling

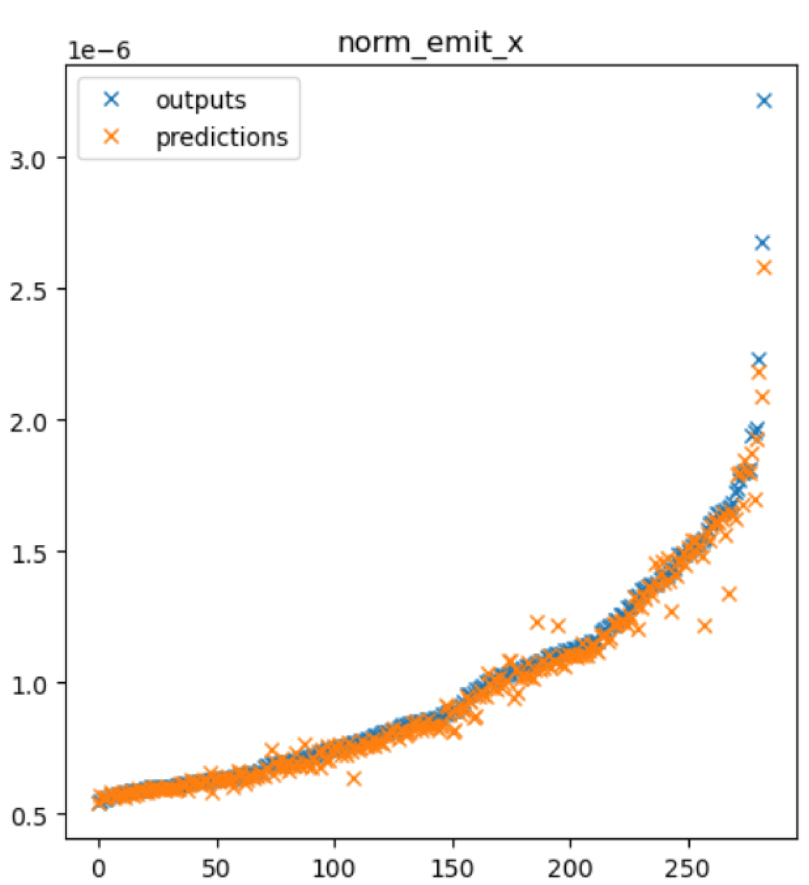
By employing Online ML Modeling, we can offer an initial guess (using NN/Simulation output) and then refine our experiments according to our model, or vice versa. This approach assists in establishing precise prototypes for upcoming experiments.

Online Modeling Workflows



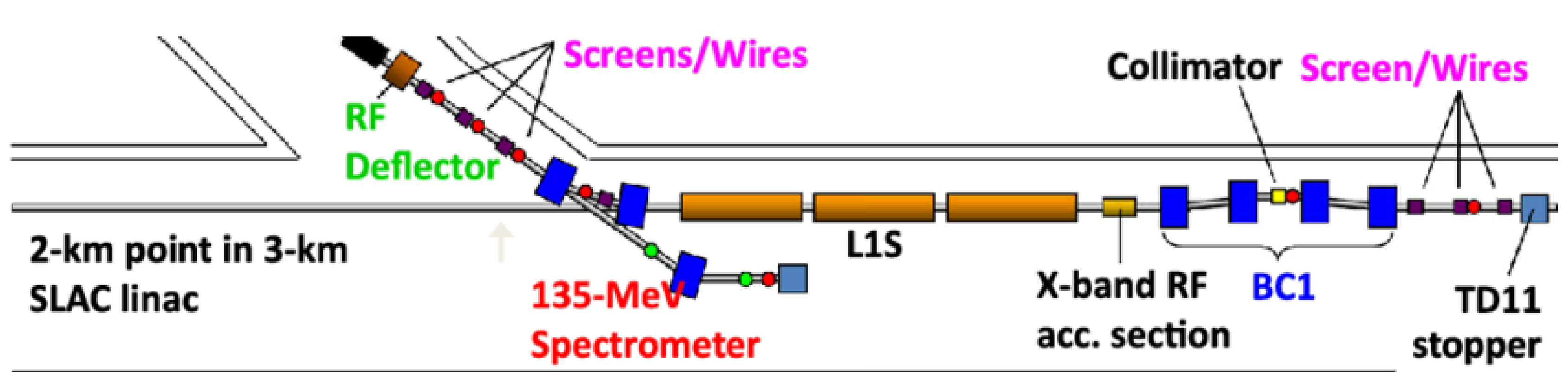


LCLS Injector Neural Network



LCLS Injector X-Axis Beam Emittance Prediction

- Trained using inputs from IMPACT-T simulations sampled across wide range of beam settings
- Currently, It's used to prototype new algorithms before testing live on FACET-II & LCLS and provides input parameters for downstream online modelling.
- LCLS Injector Neural Network runs with 10 Linear Layers with ELU activation function



Schematic Layout of LCLS Injector

Conclusions & Future Scope

In conclusion, The Online Modeling of the LCLS Injector and IMPACT-T provides immediate insights and improved error analysis, further enhancing our comprehension of beam behavior. The most significant advantage lies in the availability of immediate NN suggestions, in contrast to waiting 3-8 minutes for the completion of physics simulations.

In future, We hope to leverage this infrastructure to build dynamic ML models and expand to other parts of the Accelerator.

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