

# NSAC LONG-RANGE PLAN TOWN HALL MEETING ON NUCLEAR STRUCTURE, REACTIONS AND ASTROPHYSICS

## AI-ML FOR ACCELERATOR OPERATIONS AND RADIOACTIVE BEAM PRODUCTION



**BRAHIM MUSTAPHA**

Physics Division  
Argonne National Laboratory

November 15th, 2022  
APS Conference Center  
Argonne National Laboratory

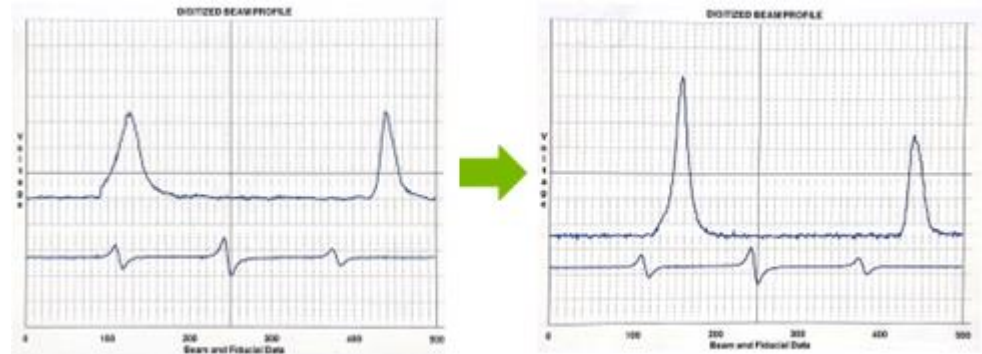
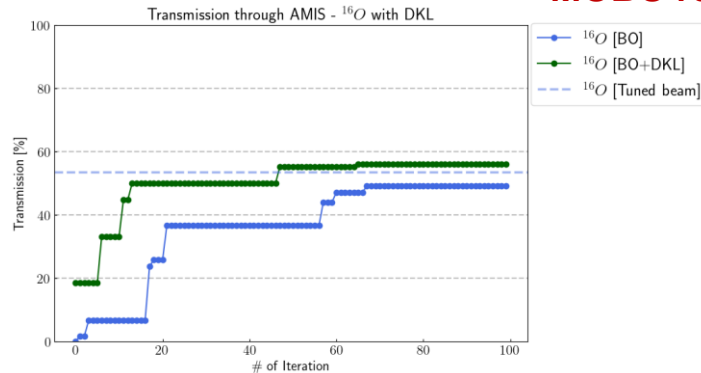
# AI-ML FOR ACCELERATOR OPERATIONS & RADIOACTIVE ION BEAM PRODUCTION

- ❑ At a heavy-ion linac facility such as ATLAS, a new ion beam is tuned once or twice a week. The use of AI-ML is being leveraged to streamline the tuning process, reducing the time needed to tune a given beam and allowing more beam time for the experiment.
- ❑ This will also allow better understanding of existing machines, which would lead to improving their overall performance and designing better accelerators in the future.
- ❑ The production and delivery of radioactive ion beams is very critical to the field. AI-ML could play a significant role in improving and optimizing these processes to maximize the number and throughput of RIB experiments.

# WHAT HAS BEEN ACHIEVED SO FAR

- At ATLAS, we were able to: (NP funded ATLAS AI-ML Project)
- Digitize crucial beam data and establish automatic data collection for both machine records and AI-ML modeling
  - Trained online and deployed ML models to tune and control sub-sections of the machine, including the commissioning of a new beamline
  - Demonstrated transfer learning from a simulation-based model to an online model, successfully used for multi-objective Bayesian optimization (MOBO)
  - Demonstrated transfer learning and fast switching from one ion beam to another

## MOBO results: transmission and beam profiles

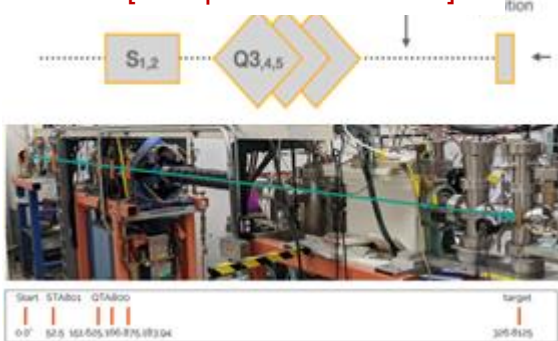


# OPTIMIZATION OF SECONDARY BEAM PRODUCTION & DELIVERY

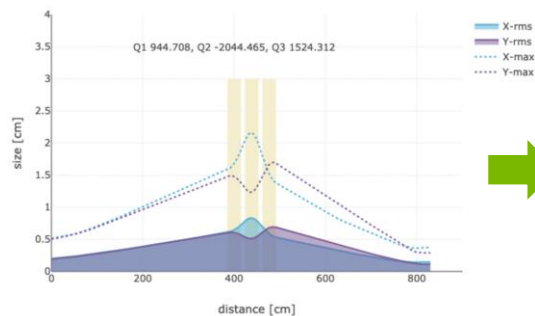
## OptSB focuses on secondary beams produced in-flight at RAISOR

- NP/FOA funded Project [Hoffman (PHY), Larson (MCS)]
- Goals: Fast & reliable optimization of the secondary in-flight beam transmission & focusing on target
- Leverages work from ATLAS project
  - Frameworks for offline data generation & online data collection
  - FC -> Si Detectors, Beam scanner profiles -> position info from MCP system
- Unique challenges for in-flight beams
  - Variations on the input profiles due to production reaction [physics]
  - Varying optimization goals [transmission, rate, energies, &/or purity]

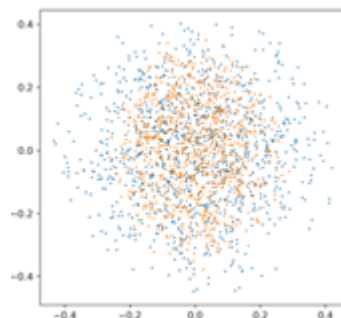
### TRACK [ion optics calculations]



### “Simulated” observables & reward values



### Experimental results: RL Optimization



XY position [cm]  
at target

- Before optimization
- After optimization

# CHALLENGES & OPPORTUNITIES → ACTIONS

## □ Challenges & Opportunities

- The recent success shows proof of concept for short linac sections with limited number of parameters, need scaling to other sections and more parameters
- Not enough diagnostics and data to characterize the initial beam distribution from the source
- Need to limit the number of random or non-physical settings to avoid unintentional damage to beamline components, power supplies, ...
- Need faster data acquisition and collection to speed-up the process
- What we showed is only the tip of the iceberg, a lot more can be done!

## □ Recommend/Suggested Actions:

- Continue investments in AI-ML for Accelerators and Detectors
- The recent NP/FOA call is very encouraging, a good step forward ...

# RECENT REFERENCES

- “Reinforcement Learning and Bayesian Optimization for Ion Linac Operations”, J. Martinez, B. Mustapha et al, Invited talk at the Heavy Ion Accelerator Technology (HIAT) Conference, Darmstadt, Germany, June 27 - July 1 2022
- “Machine Learning to support the ATLAS Linac Operations at Argonne”, B. Mustapha et al, Poster & Paper at the North American Particle Accelerator Conference, NAPAC’22, August 7-12th, 2022, Albuquerque, New Mexico & ICFA Workshop on Machine Learning for Accelerators, Nov. 1-4, Chicago, Illinois
- “Machine Learning Tools to support the ATLAS Ion Linac Operations at Argonne”, J. Martinez, B. Mustapha et al, Talk at the ICFA Workshop on Machine Learning for Accelerators, Nov. 1-4, Chicago, Illinois



# THANK YOU



Argonne National Laboratory is a  
U.S. Department of Energy laboratory  
managed by UChicago Argonne, LLC.