WORKSHOP FOR APPLIED NUCLEAR DATA ACTIVITIES (WANDA) 2026
FEBRUARY 11, 2026

RECENT DEPLOYMENT OF AI/ML TOOLS FOR (RADIOACTIVE) BEAM OPTIMIZATION AT ATLAS

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Argonne National Laboratory

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

Argonne NATIONAL LABORATORY
Argonne Tandem Linac Accelerator System

ATLAS BY THE NUMBERS

In FY25 served 400+ unique users

400+ unique users in a typical year

60% from U.S. national labs and universities

40% from international labs and universities

25% of users are students

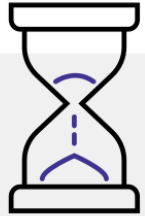
USERS FROM

15+ states

15+ countries

The ATLAS accelerator at Argonne National Laboratory is a DOE/SC/NP national user facility that supports forefront nuclear physics research, national security applications, and studies of the origin of chemical elements.

6,000+ hours of beam time delivered annually

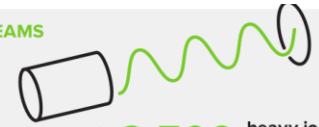


40% of requested beamtime approved as high priority

1–2 calls for proposals per year

30 scientific and user support staff

AVAILABLE PARTICLE BEAMS



250 heavy ion beams provided by ATLAS

2,500 heavy ion beams added through the N=126 Factory

500 heavy ion beams added through CARIBU and nuCARIBU

130 heavy ion beams added through RAISOR

Our heavy ion acceleration capability is **10–20%** the speed of light*

*Speed depends on the ion used.

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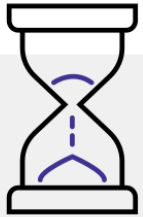

40%

1–2

4(

60%

To know more about ATLAS capabilities go to Thursday morning session on Instrumentation and Facilities for Nuclear Data

Speaker: Guy Savard

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ATLAS AI/ML EFFORTS FOR ACCEL OPERATIONS

First project (finished)

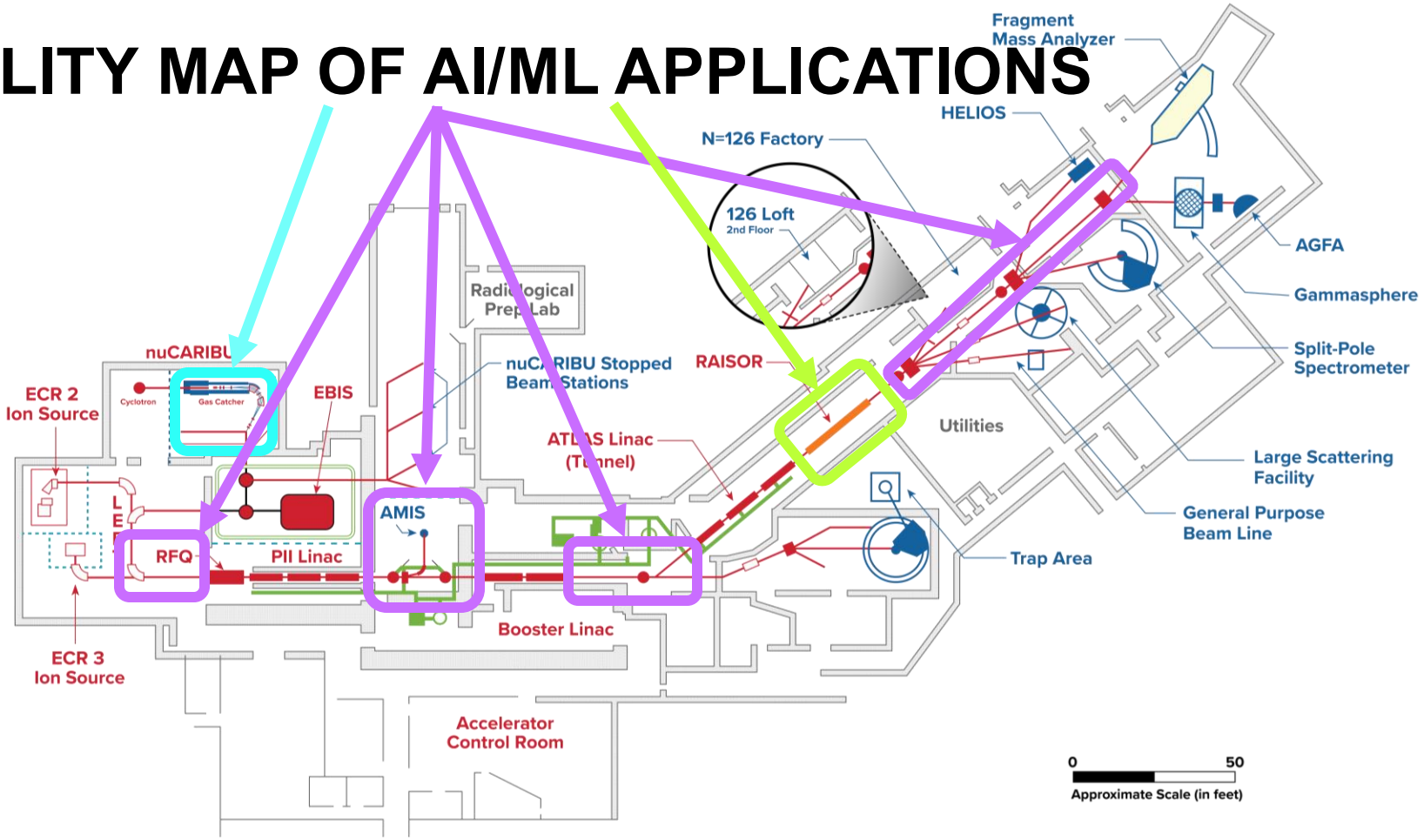
- PI B. Mustapha
- DOE Funds LAB-20-2261 [2020]
- Successful proof of concept
- Postdoc
  - Jose Martinez-Marin

Consolidated project

- **PIs: B. Mustapha, C. Hoffman, D. Santiago**
- DOE Funds DE-FOA-0002875 [2023]
- 3 sub-projects:
  - Main accelerator
  - RAISOR (rad. beams)
  - CARIBU/nuCARIBU (rad. beams)
- PDs and students
  - Adwaith Ravichandran
  - Sergio Lopez-Caceres
  - Anthony Tran, et al.

Final phase: Deploy practical AI/ML applications to increase operational efficiency

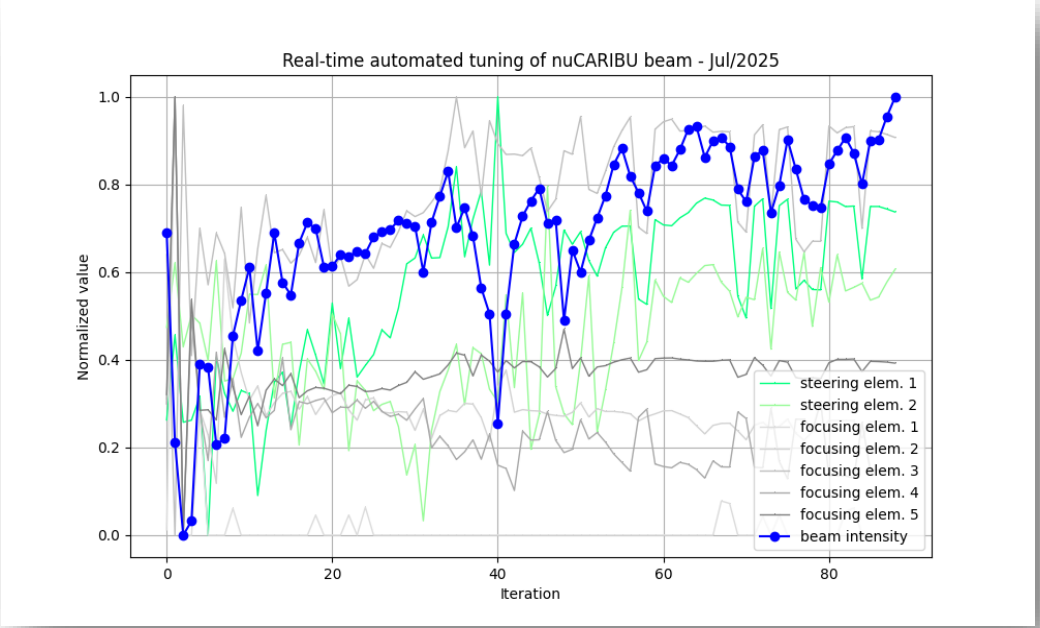
FACILITY MAP OF AI/ML APPLICATIONS



AI/ML TOOL DEPLOYED FOR NUCARIBU

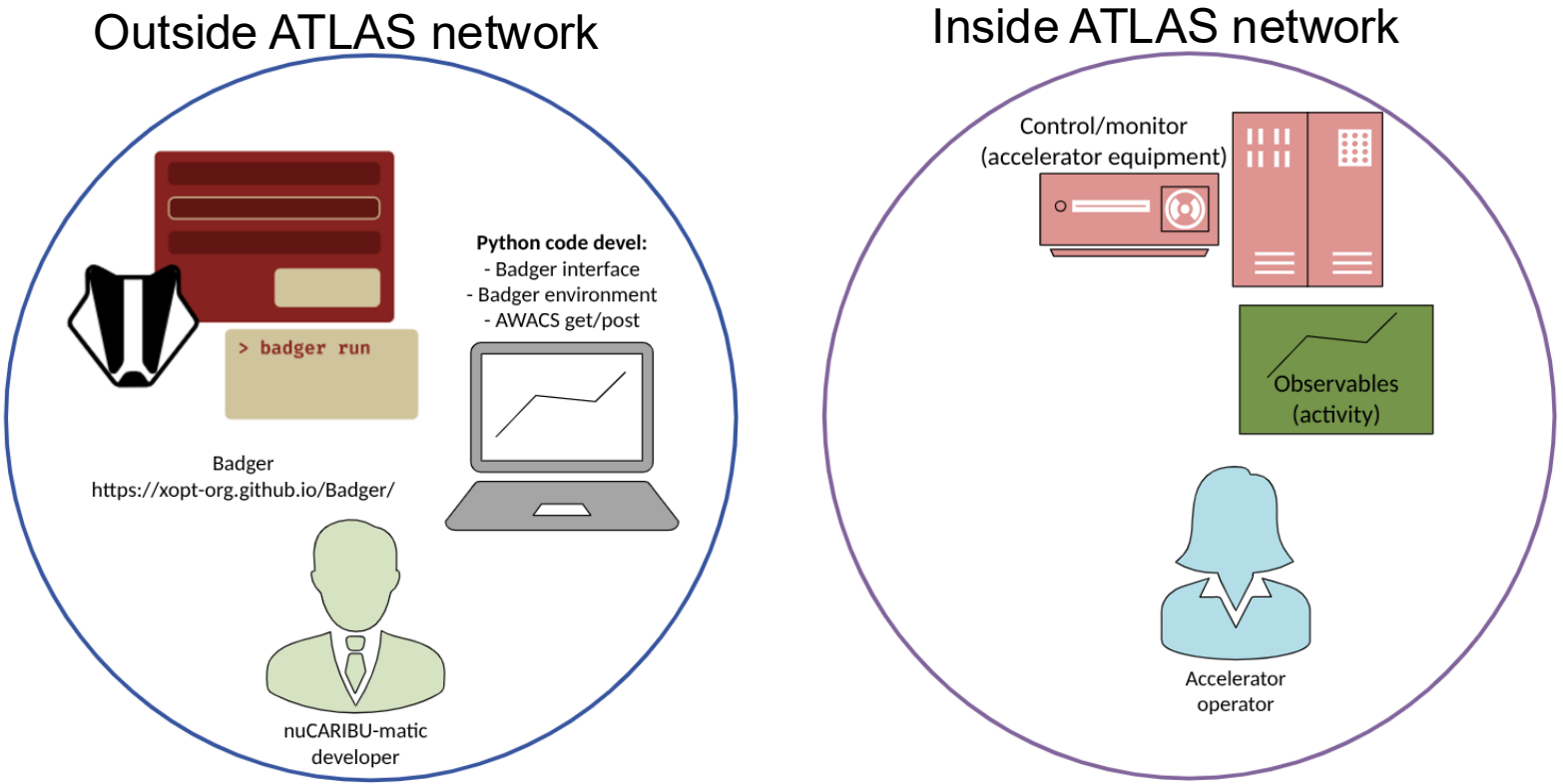
Used online during nuCARIBU commissioning operations in 2025

- **Task**
  - Extract and transport radioactive beam (^{100}Zr) from source to charge breeder
  - Perform online optimization of 100+ beam line elements divided in sections of 5-10 elements
- **Transport efficiency**
  - ~35% from source to charge breeder
  - In some sections demonstrated significant improvements in transport efficiency compared to initial tune performed by human experts
- **Optimization time**
  - 5-10 minutes per section (21 sections)
  - ~3 hours from source to charge breeder



OUR APPROACH

The biggest obstacle is infrastructure (controls / networking)



References

[1] https://xopt-org.github.io/Badger/

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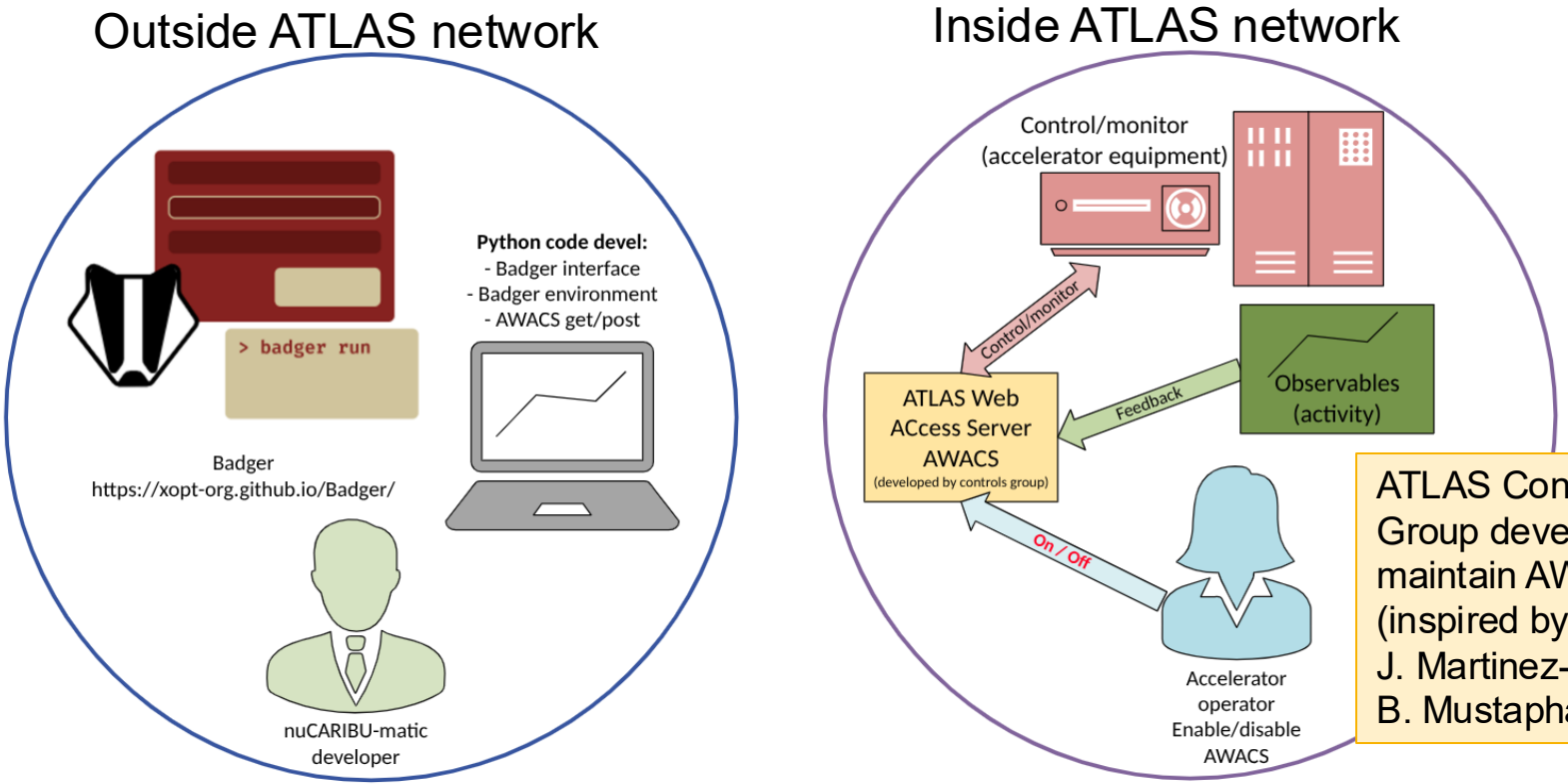

ATLAS Controls Group developed and maintain AWACS (inspired by efforts of J. Martinez-Marin and B. Mustapha)

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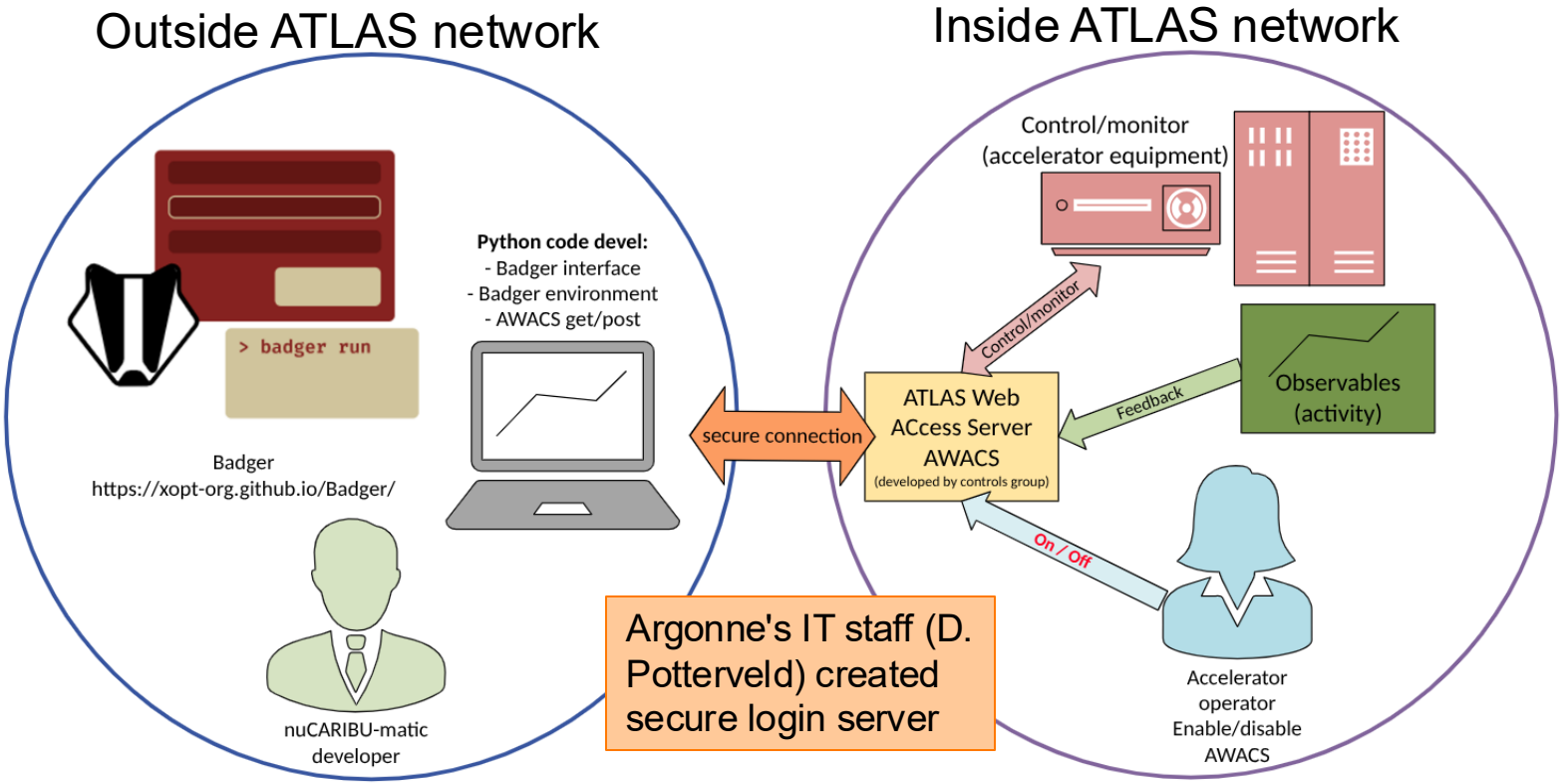


Argonne's IT staff (D. Potterveld) created secure login server

CONCLUSION

Suggestions on using BO for facility ops

- It can help with automation of time-consuming tasks that are difficult / costly to simulate / calculate but have well-defined controls and observables
- Think of non-human errors your AI app can make and limit them
- Use the data / knowledge you already have
- **The codes are there but you'll likely need to work on your infrastructure**

ACKNOWLEDGMENTS

Brahim Mustapha
Calem Hoffman
Adwaith Ravichandran (PD)
Sergio Lopez-Caceres (PD)
Khushi Bhatt (PD)
Anthony Tran (student)
ATLAS operators
ATLAS controls group

FUNDS

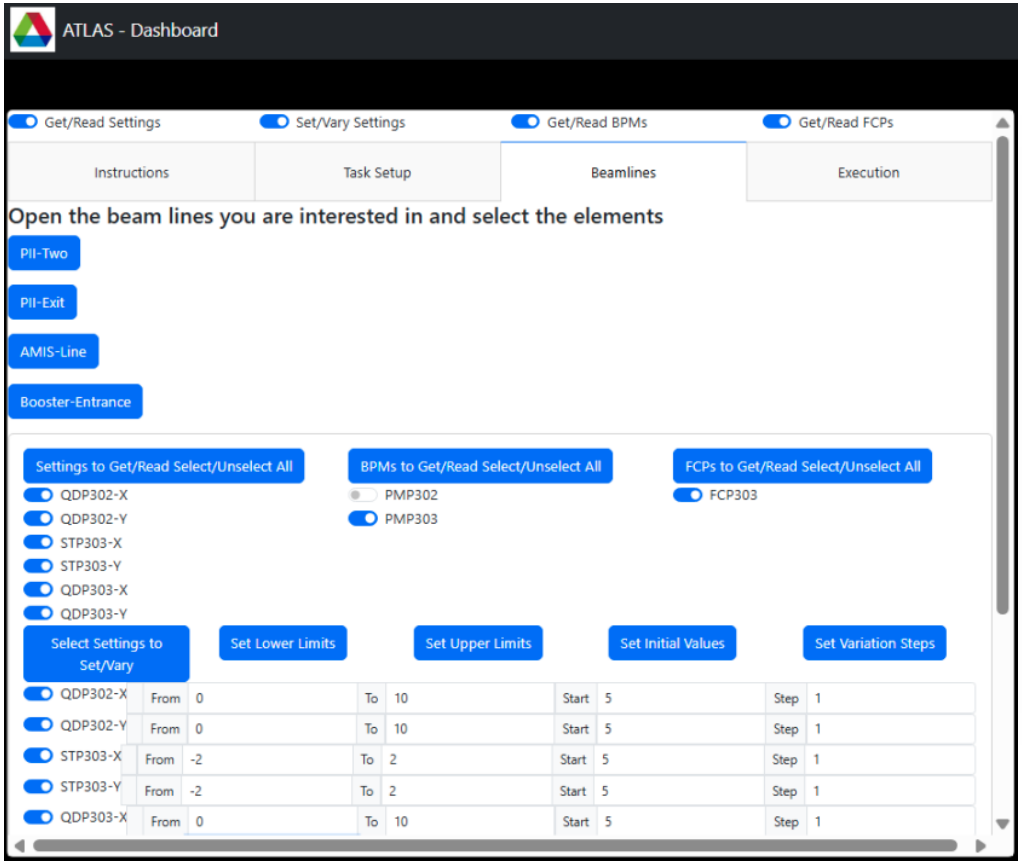
DOE LAB-20-2261 [2020]
DOE DE-FOA-0002875 [2023]

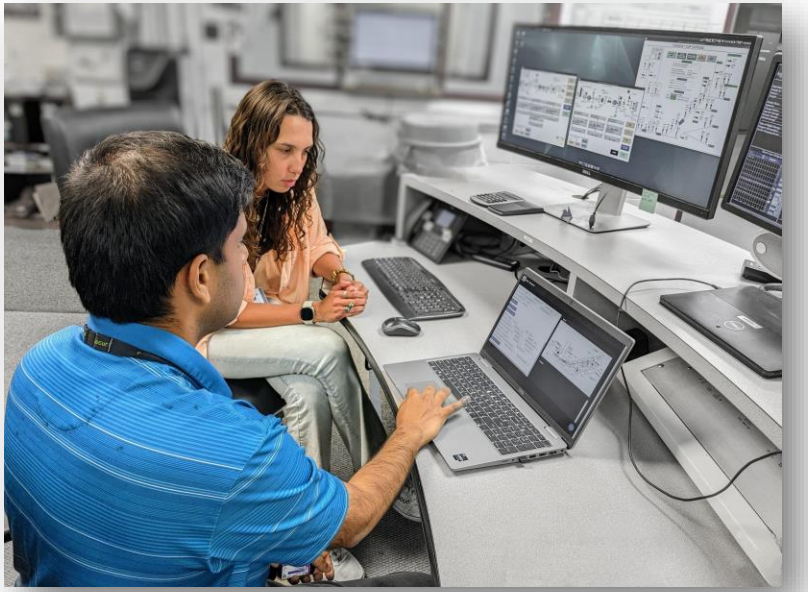
THANK YOU FOR YOUR ATTENTION

FEEL FREE TO REACH OUT IF YOU HAVE QUESTIONS
DASAGO@ANL.GOV

BACKUP SLIDES

OPERATOR AI INTERFACE





PRACTICAL APPLICATIONS OF AI

Established in consultation with accelerator operators

Automate tuning following a large beam intensity increment

Simultaneously tune beamline elements for transmission and beam shape

Automate tuning following a large energy change (across cryostats)

Assist with tune of radioactive beams (nuCARIBU, RAISOR)

LIST OF PUBLICATIONS

From our work on AI

Journal papers

"AI-Assisted Transport of Radioactive Ion Beams", S. Lopez-Caceres, D. Santiago-Gonzalez, Phys. Rev. Accel & Beams (2025, under review). Preprint available at: https://arxiv.org/abs/2504.06469

“Bayesian optimization algorithms for accelerator physics”, R. Roussel et al, Phys. Rev. Accel. & Beams 27, 084801 (2024).

“Predicting beam transmission using 2-dimensional phase space projections of hadron Accelerators”, A. Tran et al, Front. Phys. 10:955555 (2022), doi: 10.3389/fphy.2022.955555

Conference papers

“Beam Tomography using MCMC”, A. Tran et al, in Proceedings of IPAC’24 Conference, Nashville, Tennessee, May 2024.

“Real-time Bayesian Optimization with Deep Kernel Learning and NN-Prior Mean for Accelerator Operations”, J. Martinez and B. Mustapha, in Proceedings of IPAC’23 Conference, Venice, Italy, May 2023.

“Beam Tomography with Coupling using Maximum Entropy Technique”, A. Tran and Y. Hao, in Proceedings of IPAC’23 Conference, Venice, Italy, May 2023.

“Machine Learning to support the ATLAS Linac Operations at Argonne”, B. Mustapha et al, 3rd ICFA Workshop on Machine Learning for Accelerators, Chicago, Illinois, November 2022.

“Relating Initial Distribution to Beam Loss on the Front End of a Heavy-Ion Linac using Machine Learning”, A. Tran et al, in Proceedings of NAPAC’22, Albuquerque, New Mexico, August 2022.

“Model-based Calibration of Control Parameters at the Argonne Wakefield Accelerator”, I. Sugrue et al, in Proceedings of NAPAC’22, Albuquerque, New Mexico, August 2022.

“Reinforcement Learning and Bayesian Optimization for Ion Linac Operations”, J. Martinez et al, in Proceedings of HIAT’22 Conference, Darmstadt, Germany, June 2022.

“AI-ML Developments for the ATLAS Ion Linac Facility”, B. Mustapha et al, in Proceedings of IPAC’21 Conference, Campinas, Brazil, May 2021.

IN THE NEWS

FEATURE STORY | ARGONNE NATIONAL LABORATORY

The next frontier in nuclear physics

How AI is supporting operations and revolutionizing research at ATLAS

News | Media Contacts | Experts Guide | Press Releases | Feature Stories | In the News | Soc

BY AMBER ROSE | MAY 8, 2025

Recent advancements at the ATLAS user facility are enhancing operations and efficiency to help unlock new insights into the universe's fundamental forces.

In the quest to solve fundamental mysteries about the universe, nuclear physics stands at the forefront, probing the very building blocks of matter and the forces that govern their interactions. At the U.S. Department of Energy's (DOE) Argonne National Laboratory, a prominent fixture in this exploration is the Argonne Tandem Linac Accelerator System (ATLAS), a DOE Office of Science user

DOE Office of Science Research News Update

US Department of Energy Office of Science sent this bulletin at 05/27/2025 10:25 AM EDT

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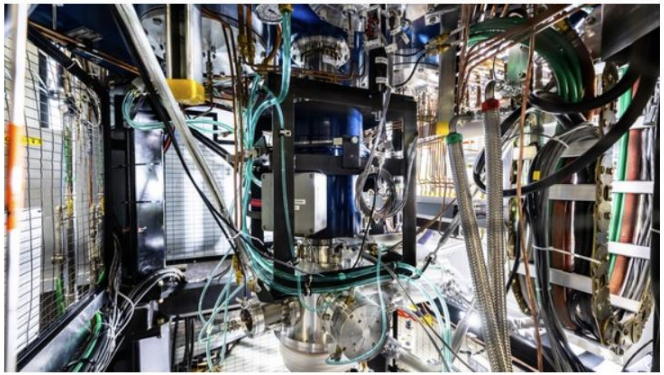
U.S. DEPARTMENT of ENERGY | Office of Science

RESEARCH NEWS UPDATE

27 May 2025

The Next Frontier in Nuclear Physics



Nuclear physics examines the very building blocks of the matter that makes up everything we can detect. It also studies the fundamental forces of physics. Researchers investigate which forces bind protons and neutrons together in atoms, how these interactions result in elements, and what rare nuclei can show us about the origin of matter. Researchers at DOE's Argonne National Laboratory use the Argonne Tandem Linac Accelerator System (ATLAS), a DOE Office of Science user facility, to explore these issues. The team of researchers is exploring new ways to make ATLAS ever more effective, from using AI to creating a "digital twin" where scientists can test beam settings in a virtual space.

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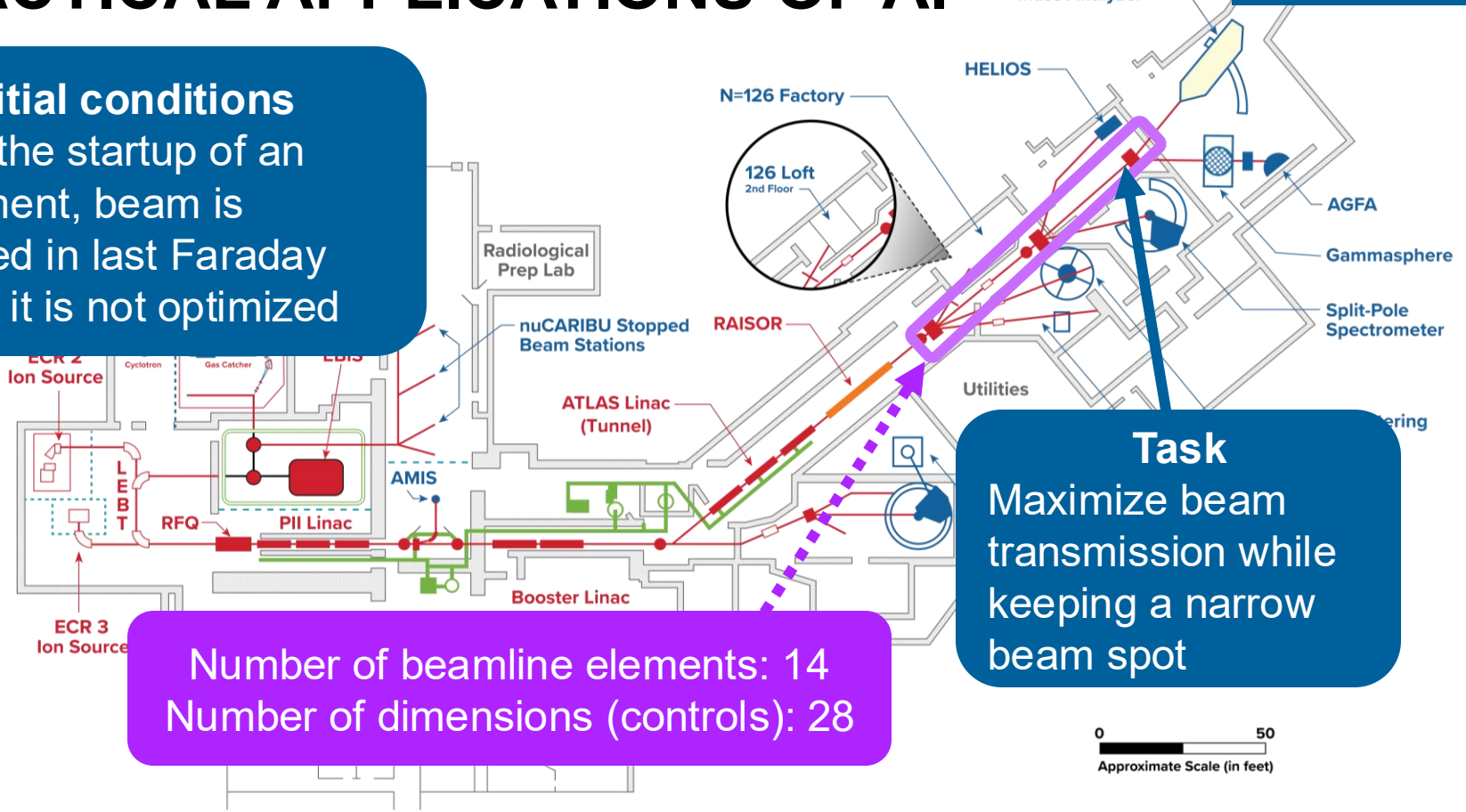
PRACTICAL APPLICATIONS OF AI

Initial conditions

During the startup of an experiment, beam is observed in last Faraday cup but it is not optimized



Task

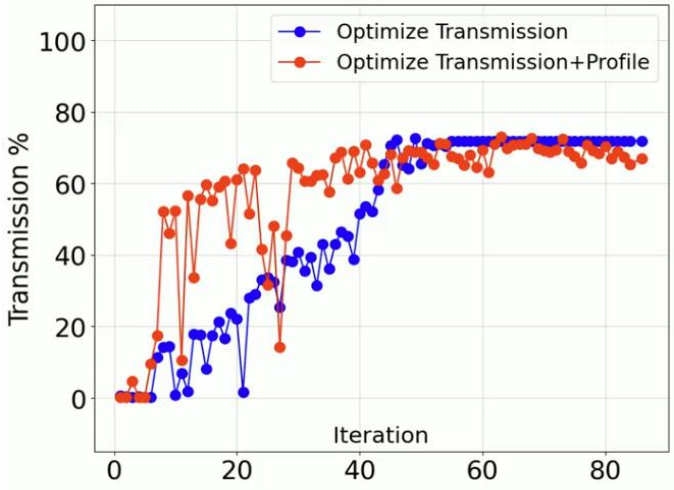
Maximize beam transmission while keeping a narrow beam spot

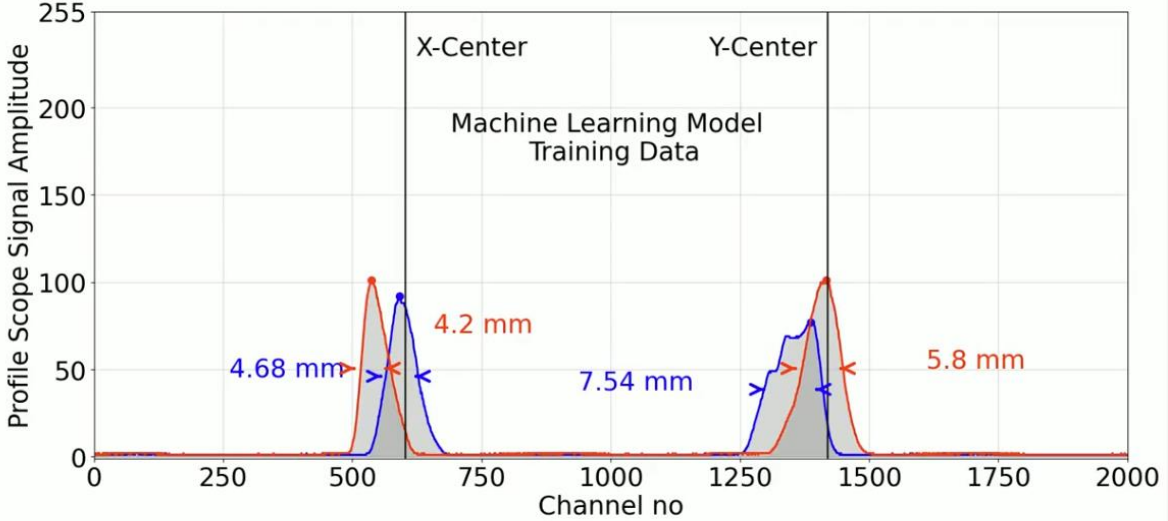
Number of beamline elements: 14
Number of dimensions (controls): 28

SELECTED RESULTS - REAL BENEFITS

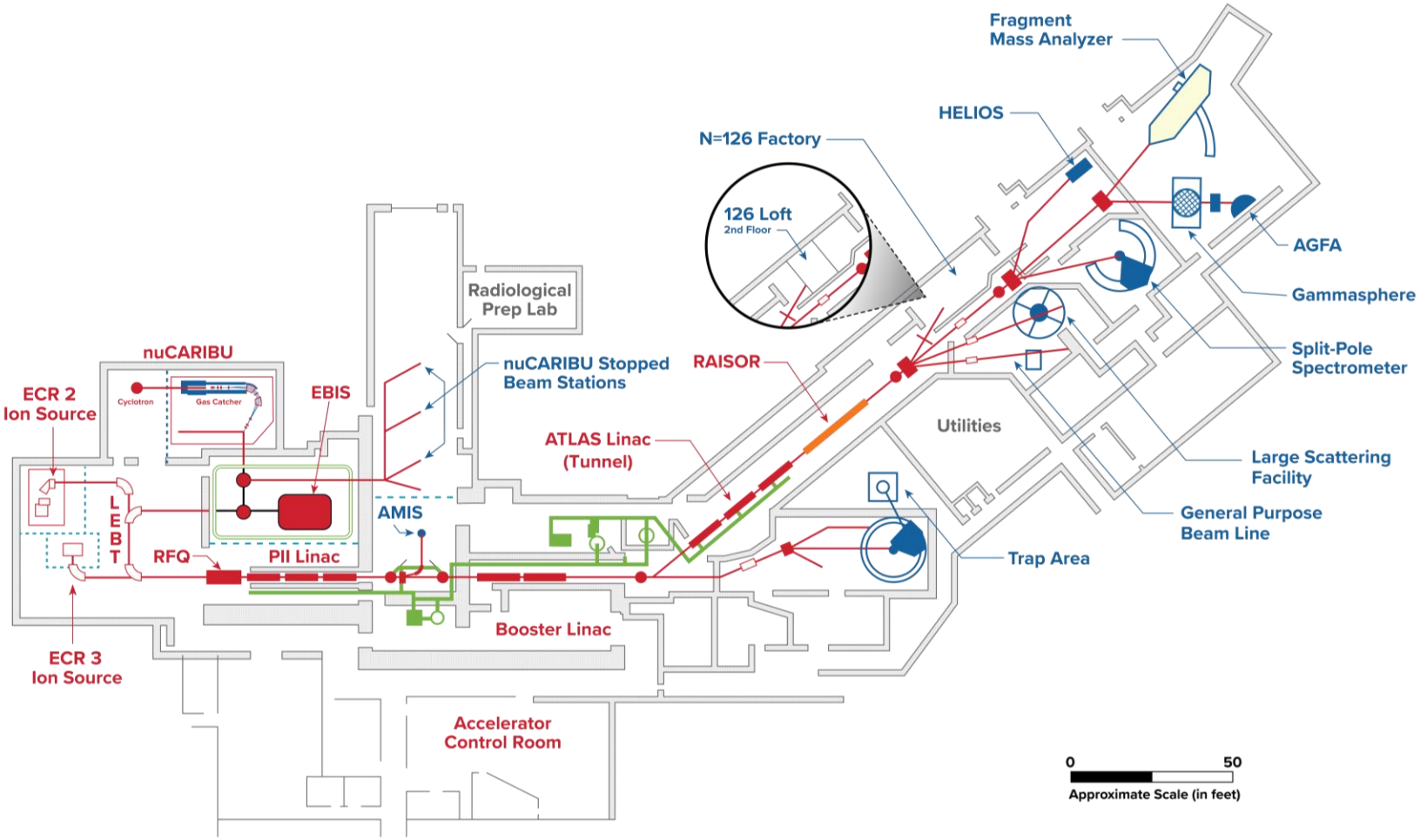
Simultaneous transmission + beam shape optimization

Final configuration





Optimization time: ~7 minutes


Fragment
Mass Analyzer
HELIOS
N=126 Factory
126 Loft
2nd Floor
AGFA
Gammasphere
Split-Pole
Spectrometer
Radiological
Prep Lab
nuCARIBU
nuCARIBU Stopped
Beam Stations
RAISOR
ECR 2
Ion Source
Cyclotron
Gas Catcher
EBIS
ATLAS Linac
(Tunnel)
Utilities
Large Scattering
Facility
General Purpose
Beam Line
LEBT
AMIS
RFQ
PII Linac
Trap Area
Booster Linac
ECR 3
Ion Source
Accelerator
Control Room
0
50
Approximate Scale (in feet)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