A.I. for Nuclear Physics

Accelerator Science and Operations
Recap of the week’s sessions

• ~40-50 participants!

• Wednesday
  • Accelerator science that uses and can benefit from AI support

• Thursday
  • Accelerator operations that can be improved from AI methodologies
Applications - Accelerator Science

• **Optics and lattice design**
  • "Experiments on Improving Cooling Results in the LEReC system using Machine Learning Techniques”, Y. Gao  **Bayes Reinforcement Learning (RL)**
  • ML techniques applied to 6D phase space evolution and equilibria (higher dimensional frequency maps, beam-beam effects in EIC). Identify working points.  **Unsupervised learning**

• **Beam instrumentation design and optimization**
  • “EM structure optimization”, B. Mustapha  **Surrogate Models**
  • Interpolation of high dimensional beam phase space data – virtual diagnostics

• **Reinforcement Learning for Controls**
Applications - Accelerator Operations

- **Optics and lattice optimization**
  - “Bayes analysis of beamline optimization” Y. Hao  **Bayesian GP**
  - "Online Optimization Strategies at the Argonne Wakefield Accelerator", Ryan Roussel  **GP Surrogate+NN RL**
  - “Autonomous On-line Beam Optimization”, Matt Amthor  **Particle swarm**

- **Target, charge stripper, collimation systems**
  - ML/HPC to investigate high power target damage, material properties

- **Anomaly detection and mitigation**
  - LLRF trip events, beam loss monitoring  **Random Forest DL PCA**

- **Other operational aspects**
  - Cryoplant operations, component maintenance prediction
Synergies with many accelerator labs

• NP
  • RHIC, EIC
  • 88” cyclotron, VENUS source
  • ATLAS, TAMU

• HEP/BES and Others
  • SNS, ESS, GSI
  • LCLS, Argonne Wakefield Accelerator
  • Swiss FEL, EU-XFEL
  • FNAL
Data Science Uses and Needs

• Gaussian processes, optimization
• Supervised, unsupervised learning
• Reinforcement learning, design of agents
• Centralized and distributed computing
  • Network, hardware, and software architecture for data
• Example workflow:
Challenges and Opportunities

• **Optimized design of linacs, synchrotrons, transport lines**
  • Development and validation of virtual diagnostics (eg. long. phase space)
  • Design and simulation of novel accelerators; advanced engineered materials
  • Optimized diagnostic deployment

• **Improving facility performance and user experience**
  • Data-driven beam generation, transport, delivery optimization
    • Automated learning for operator support
    • Hardware acceleration of ML in distributed control systems
  • Anomaly detection and mitigation (eg. LLRF, beam diagnostics)
  • System health monitoring (eg. targets, cryoplant); data driven system maintenance

• **Create/deploy data standards for integration to ML workflows (big, small)**
  • Aggregated and distributed computing resources

• **Benchmark techniques on standard models; dedicated accelerator studies**
  • Dedicated studies on machines and diagnostic support?
  • AI Cookbook of techniques, Data Science training (for humans)
Thank you to all of the session speakers and participants and to Jlab and DOE/NP for organizing the workshop.