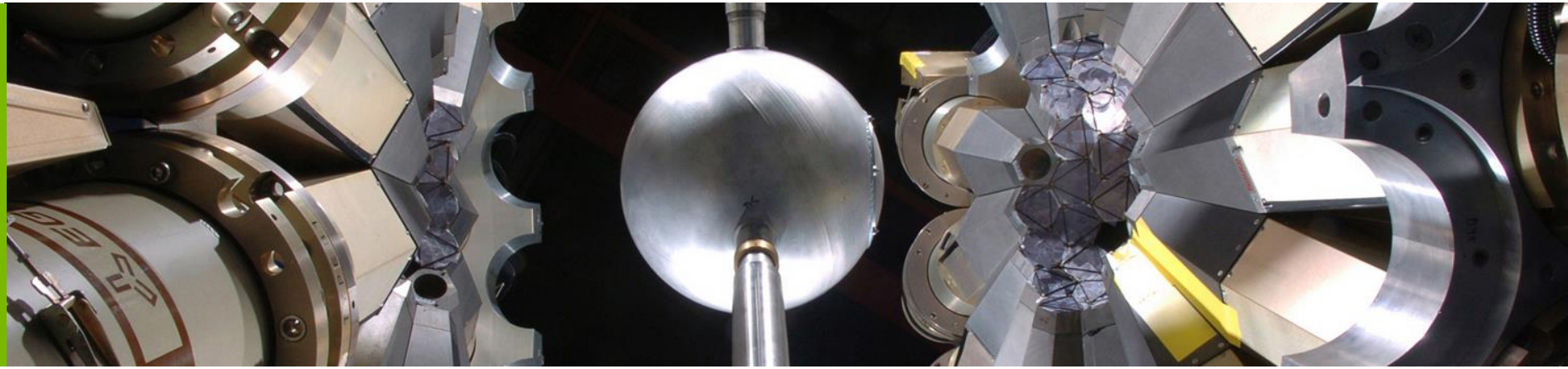
Argonne NATIONAL LABORATORY



OPPORTUNITIES FOR ML AT ATLAS

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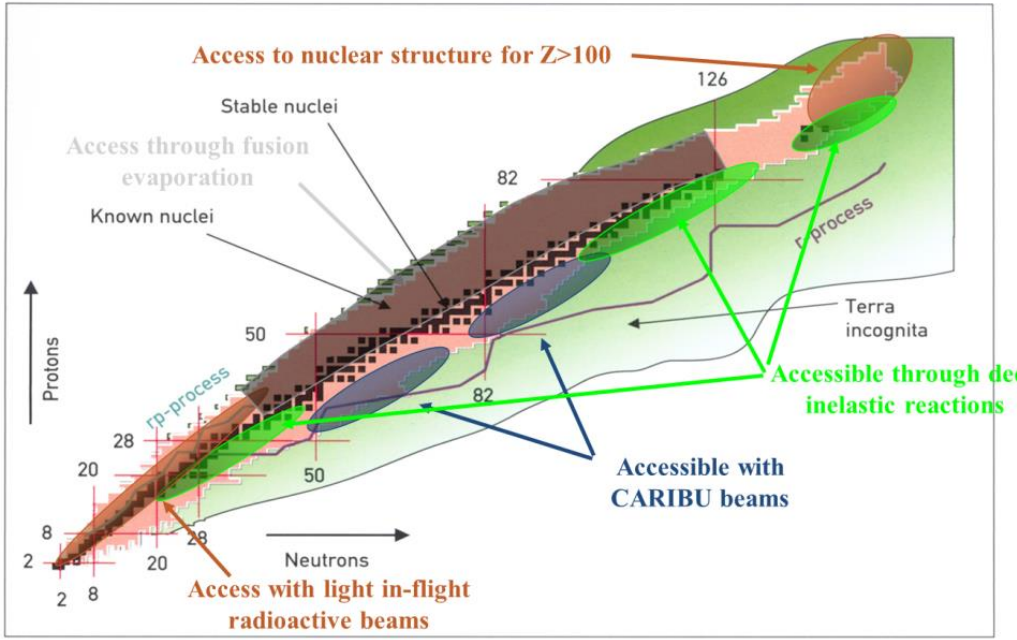
ATLAS Accelerator Physicist

30-Jan-2020

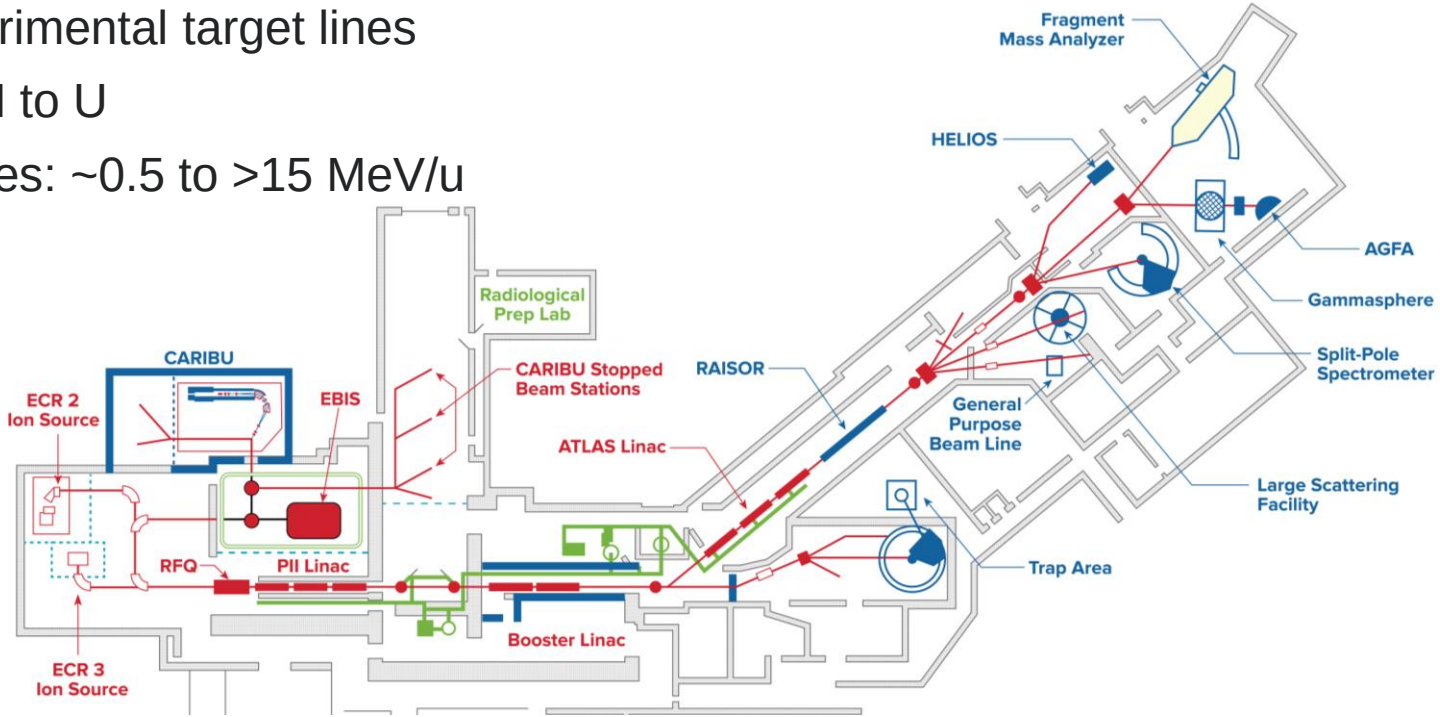
ATLAS/CARIBU FACILITY

- Stable beams up to, ~10pμA, typically 10 pnA and energy from ~0.5 to 15 MeV/u
- CARIBU (CAlifornium Rare Isotope Breeder Upgrade) beams
  - heavy n-rich from Cf fission, no chemical limitations, low intensity, ATLAS beam quality, energies up to 10 MeV/u
- In-flight radioactive beams with RAISOR
  - light beams (A<50), no chemical limitations, close to stability, acceptable beam properties
- State-of-the-art instrumentation for Coulomb barrier and low-energy experiments
- Operating ~6000 hrs/yr (+ 2000 hrs/yr CARIBU low energy)



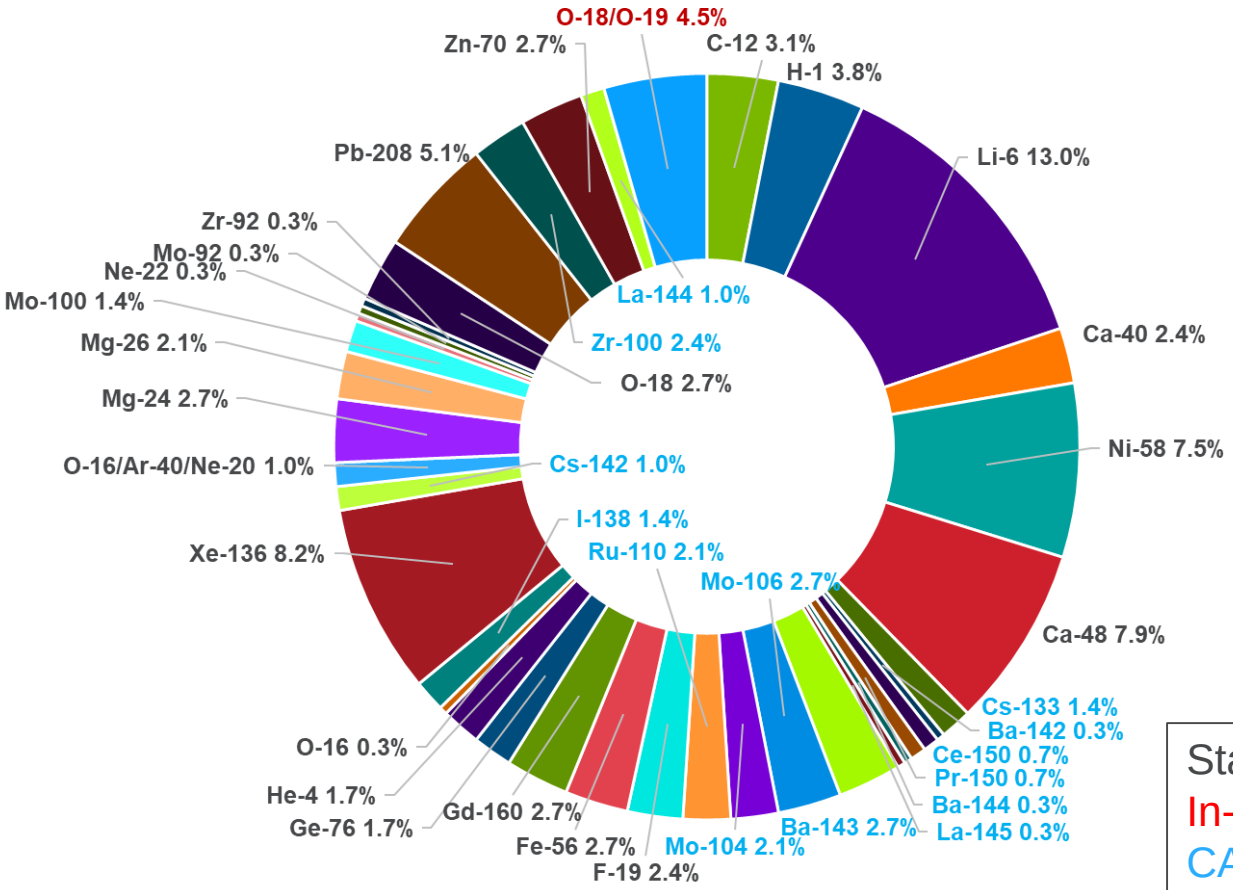
ATLAS FLEXIBILITY

- 3 ion sources
- 6 experimental target lines
- Ions: H to U
- Energies: ~0.5 to >15 MeV/u



Beam Species at ATLAS for Fiscal Year 2018

(percentage of beam hours delivered)



Stable
In-flight
CARIBU/EBIS

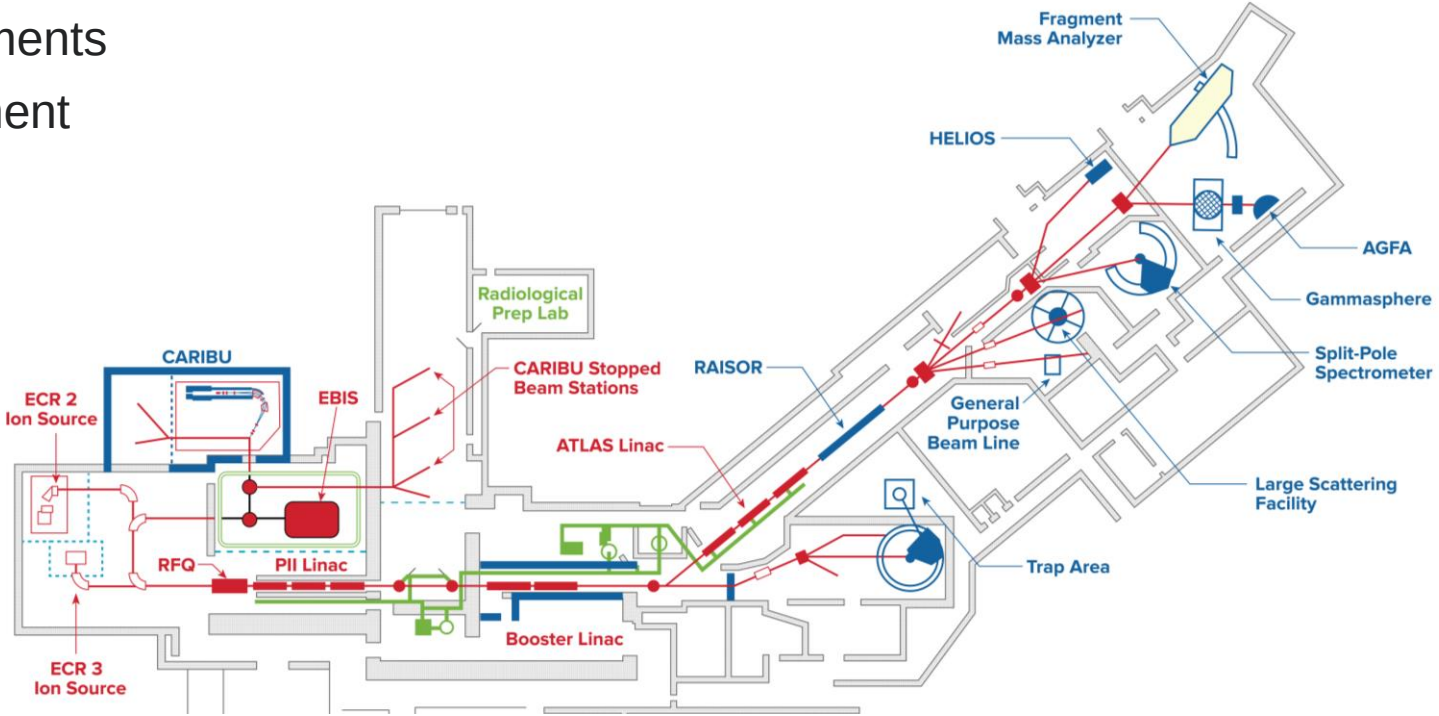
TYPICAL OPERATION

- Operating hours
  - ~6000 hrs/yr
  - ~40 experiments/yr
  - 6770 hrs in FY19
- >90% availability
- ~1 new accelerator configuration per week
  - 8 – 24 hrs to tune stable beams
  - 24 – 48+ hrs to tune RIBs
- ~25% of beams are more challenging radioactive (CARIBU or In-flight)

How much time can we convert from startup to physics?

FREQUENT CHANGES

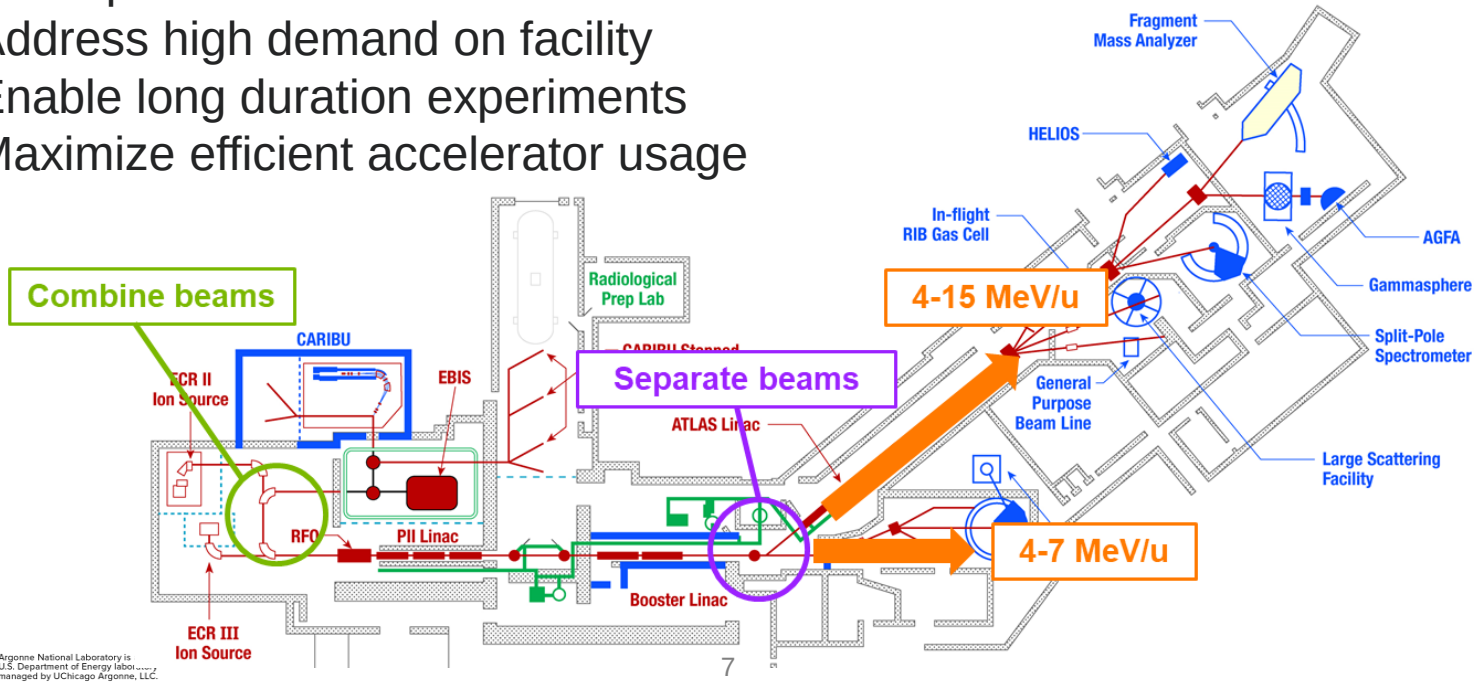
- New experiments
- New equipment
- Upgrades
- Failures



TIGHTER CONSTRAINTS TO COME

Multi-user upgrade

- EBIS beams represents 1-3% duty factor
- Combine pulsed EBIS beam with stable ECR beam
  - Address high demand on facility
  - Enable long duration experiments
  - Maximize efficient accelerator usage



ML FOR DATA ANALYSIS

- Daniel Santiago-Gonzalez, Melina Avila-Coronado, Prassana Balaprakash

MUSIC MACHINE LEARNING PROJECT

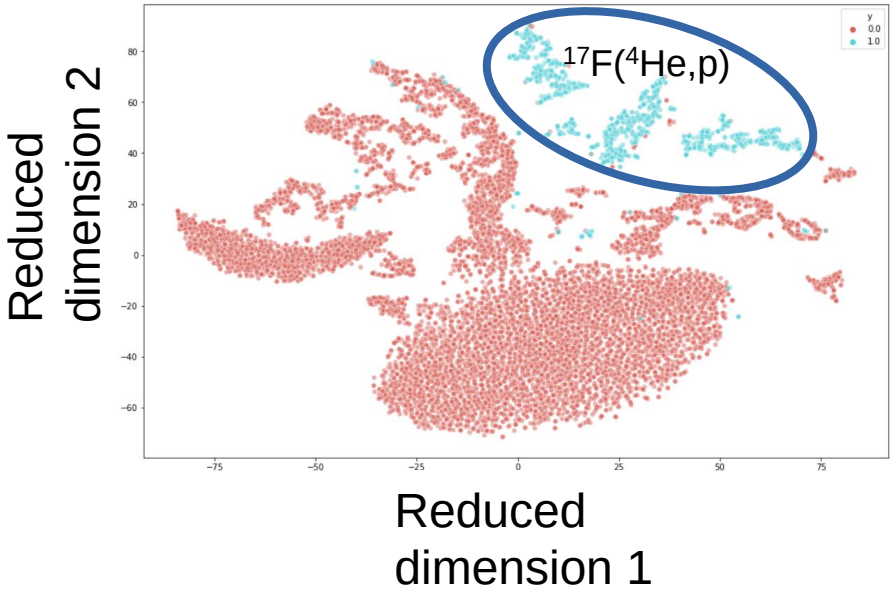
Introduction

- MUSIC is an active target detector system located at the ATLAS accelerator facility used for measuring nuclear reaction cross sections as a function of energy (i.e. excitation functions)
- Results obtained with MUSIC detector have impact in fields of Nuclear Astrophysics and Nuclear Reactions. Selected publications:
  - https://www.sciencedirect.com/science/article/pii/S0168900217304187
  - https://journals.aps.org/prc/abstract/10.1103/PhysRevC.94.065804
  - https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.112.192701
- Standard data analysis techniques take months to identify relevant events from the rest of the saved data
- AI techniques (e.g. supervised/unsupervised learning) can be used to improve data analysis technique and reduce analysis time
- Scientists from ANL's PHY and MCS divisions are working together to address this challenge

MUSIC MACHINE LEARNING PROJECT

Goals (to potentially increase scientific throughput)

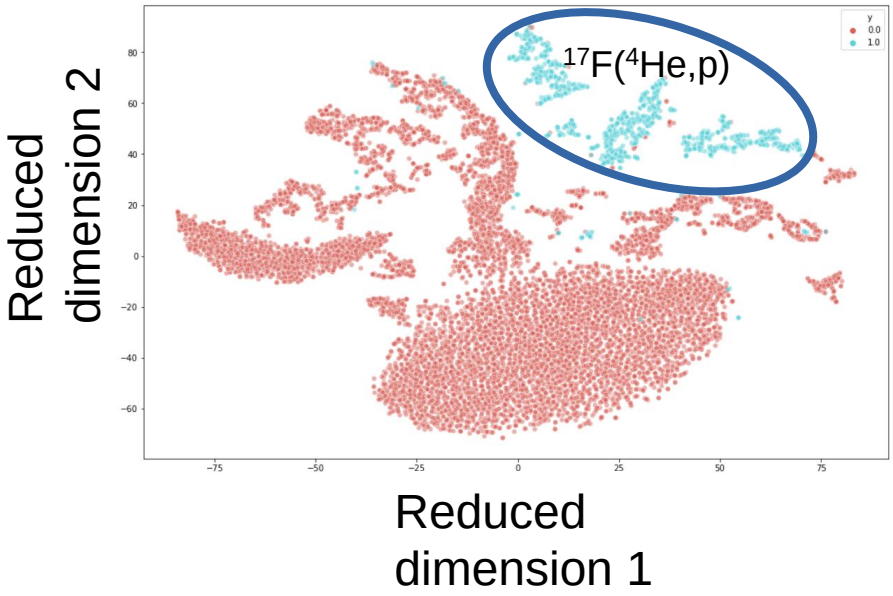
- Short term (6-12 months)
  - Reduce analysis time (from months to hours)
  - Enable simultaneous analysis of more than 1 reaction per experiment (structures in figure may correspond to different nuclear reactions)
- Long term (2-3 years)
  - Use AI techniques for online analysis (while experiments are running)
  - Apply these techniques to other detector systems at ATLAS (e.g. HELIOS, Gammasphere, etc.)



MUSIC MACHINE LEARNING PROJECT

Project status

- AI techniques applied to MUSIC data from $^{17}F+^{4}He$ reactions (experiment done at ATLAS)
- Example of results from unsupervised learning (see figure):
  - Raw data is passed through an algorithm
  - Algorithm finds clusters corresponding to different reactions
  - Relevant data (blue points) from $^{17}F(^{4}He,p)$ reactions, previously identified with standard analysis technique, is clearly separated from other clusters
- For data visualization a dimension reduction technique is used: 35 dim → 2 dim



SUMMARY

OPPORTUNITIES FOR ML

- Simplifying accelerator configurations
  - Transport systems
  - Resonator amplitude and phasing
- Simplifying in-flight configurations – unique reaction kinematics
- Recovering from equipment failures
- Improving stability for multi-user operation
- Data analysis
- Experiment planning and prediction

RESOURCES AT ANL

Machines and expertise

- Accelerators
- Supercomputers