Improving Electron Source Performance by AI/ML

AI in the Accelerator Division

November 12, 2021

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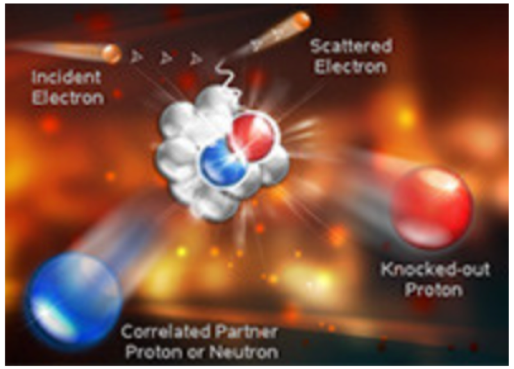
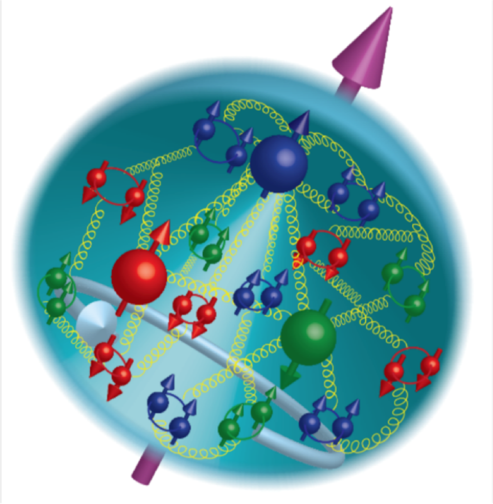
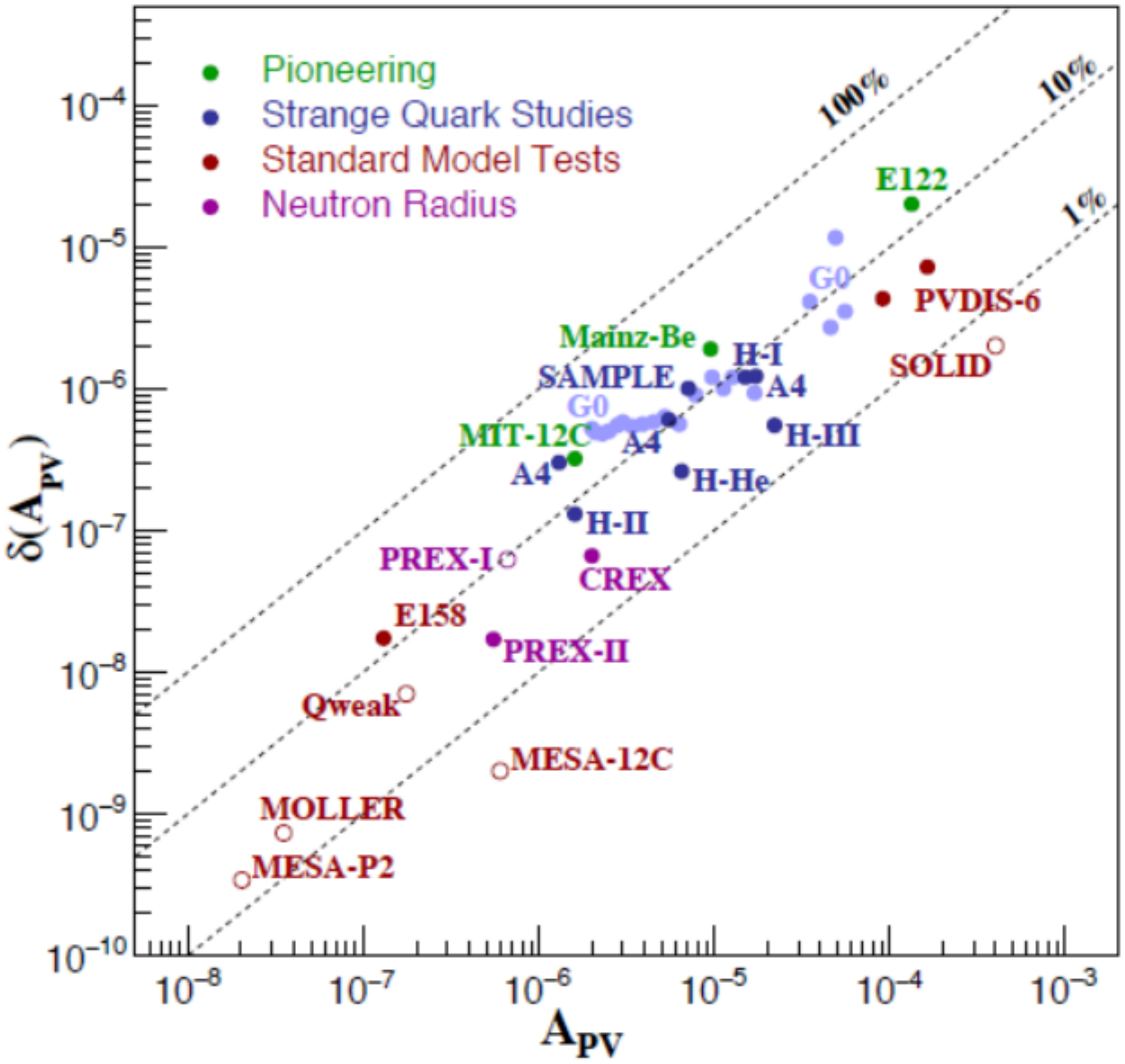




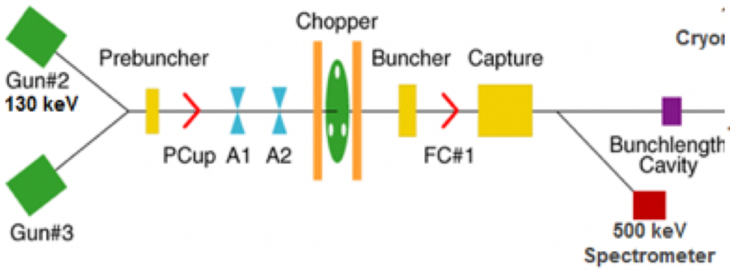
Challenges and the Needs

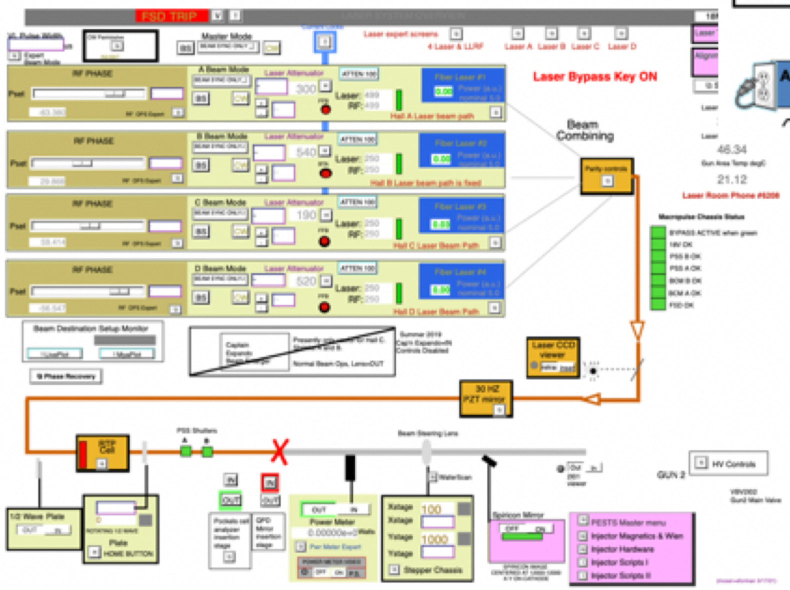
- JLab *PV Physics Programs* put stringent requirements on beam polarization & measurements
  - MOLLER and SOLID, **<0.5%** precision
- E-beam polarity must remain constant while flipping the the sign of polarization, which can be affected by various factors
  - Environmental, e.g. temperature, EM interface, vibration,…
  - Optical limitation
- **AI/ML could help to quickly detect/minimize the error and keep the system in optimal condition**

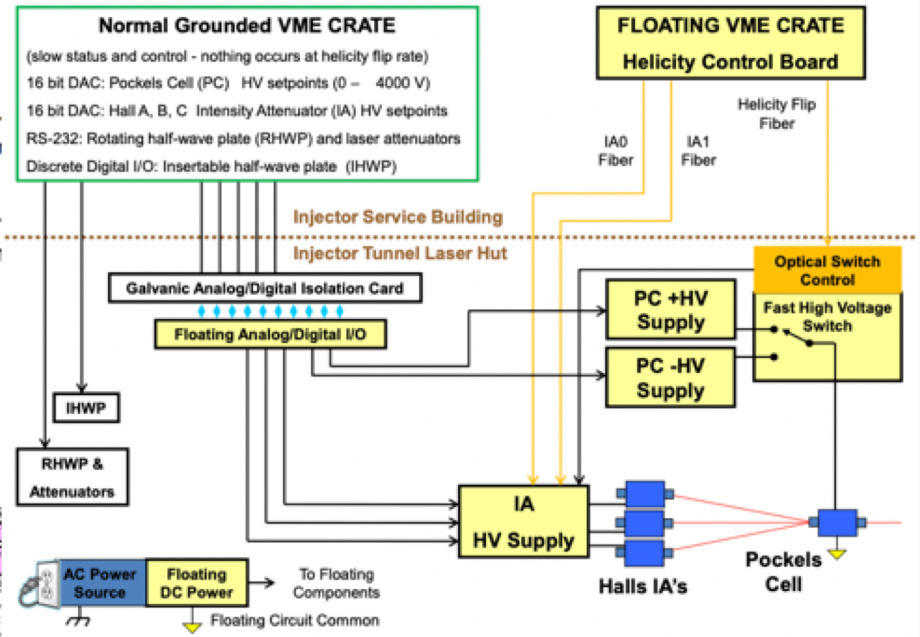


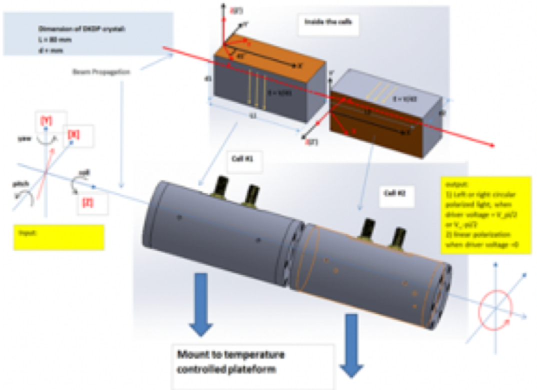
CEBAF Polarized Electron Source

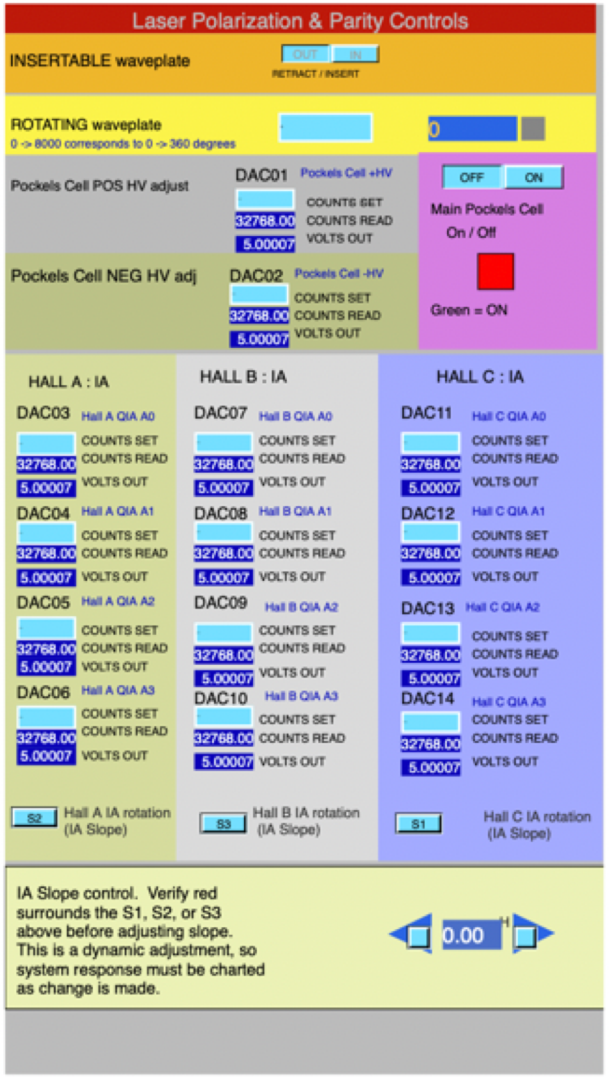
Jefferson Lab
Exploring the Nature of Matter



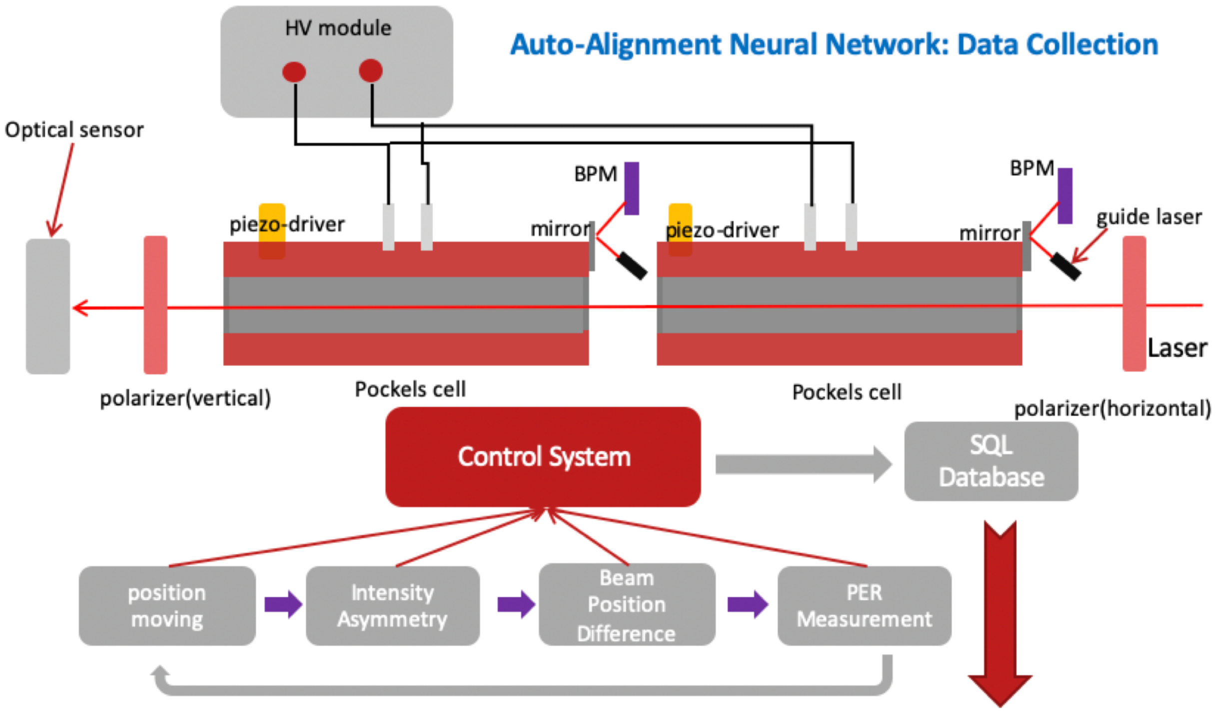






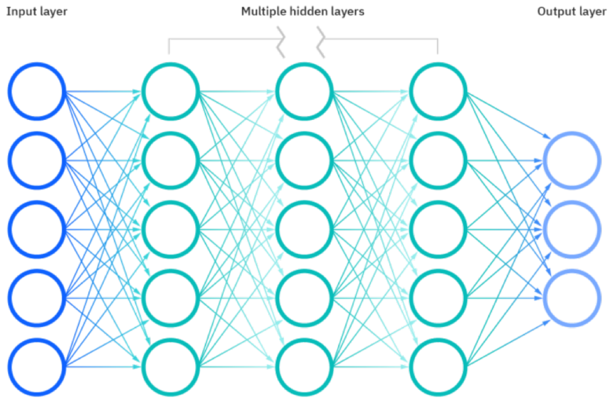


Attempt towards Polarization Control by ML

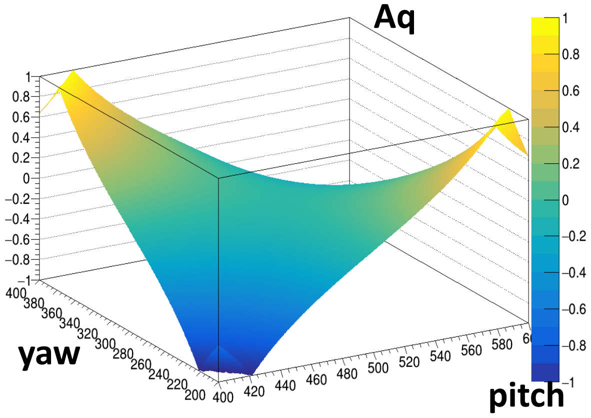


Cell1 roll	Cell1 pitch	Cell 1 yaw	Cell2 roll	Cell 2 pitch	Cell 2 yaw	PER	Aq	Dx	Dy
...	...	...	...	...	...	...	...	...	...

- Scan through different yaw/pitch/roll angles of Pockels cells, characterize measurement at each orientation angle, and store data in database.
- A 3 layer NN with very good precision can be built based on collected data.



3 layers, 32,32,16 neurons



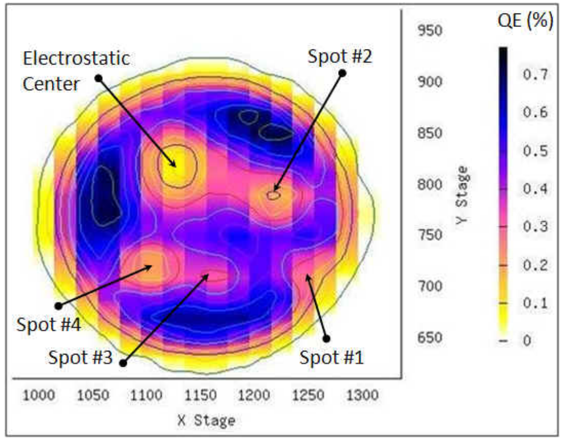
- Initial state PER = 289, intensity asymmetry Aq/0.134, Beam position diff: Dx /121 um, Dy /150 um,
- Optimal position reached after 28 steps with PER = 512, Aq/0.005, Dx /2 um, Dy / 5 um.
- The total auto-alignment process takes ~ 30 min.
- Promising tool for maintaining and fast control of polarization!

- Courtesy: Raytum

More for Consideration

- Photocathodes & beam performance affected by
  - QE depletion
  - Damage from Ion bombardment
- QE can be restored, but takes time and effort

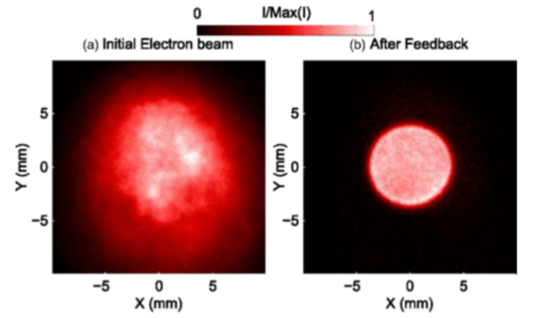
Beam instability and emittance growth may be induced by photocathode parameter variation including QE depletion and non-uniformity during long-term or high-current operation. Beam polarization degradation?

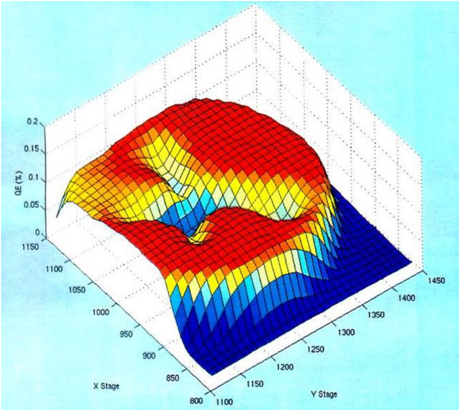


QE non-uniformity can be compensated to mitigate the associated effects by control of laser beam (intensity distribution & phase)

This is where AI/ML may play a big role!

"Adaptive electron beam shaping using a photoemission gun and spatial light modulator", Phys. Rev. ST Accel. Beams **18**, 023401





- Photocathode preparation/fabrication:
  - Automated growth of photocathode films: from the basics of process control towards artificial intelligence, Vitaly Pavlenko, "We utilize machine learning methods for instantaneous and accurate work function predictions"
  - Novel Ultrabright Photocathodes Discovered from Machine Learning and Density Functional Theory Driven Screening Evan R. Antoniuk, Stanford University