

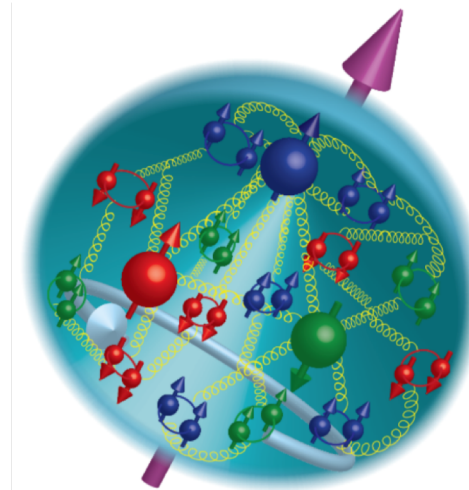
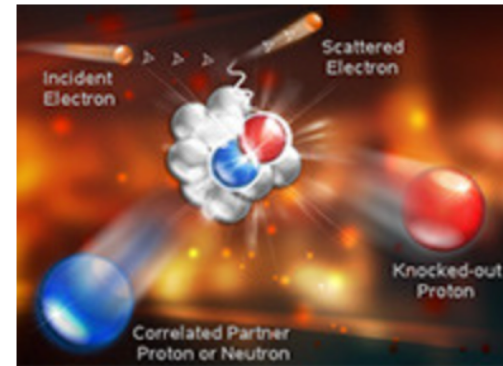
Improving Electron Source Performance by AI/ML

AI in the Accelerator Division

November 12, 2021

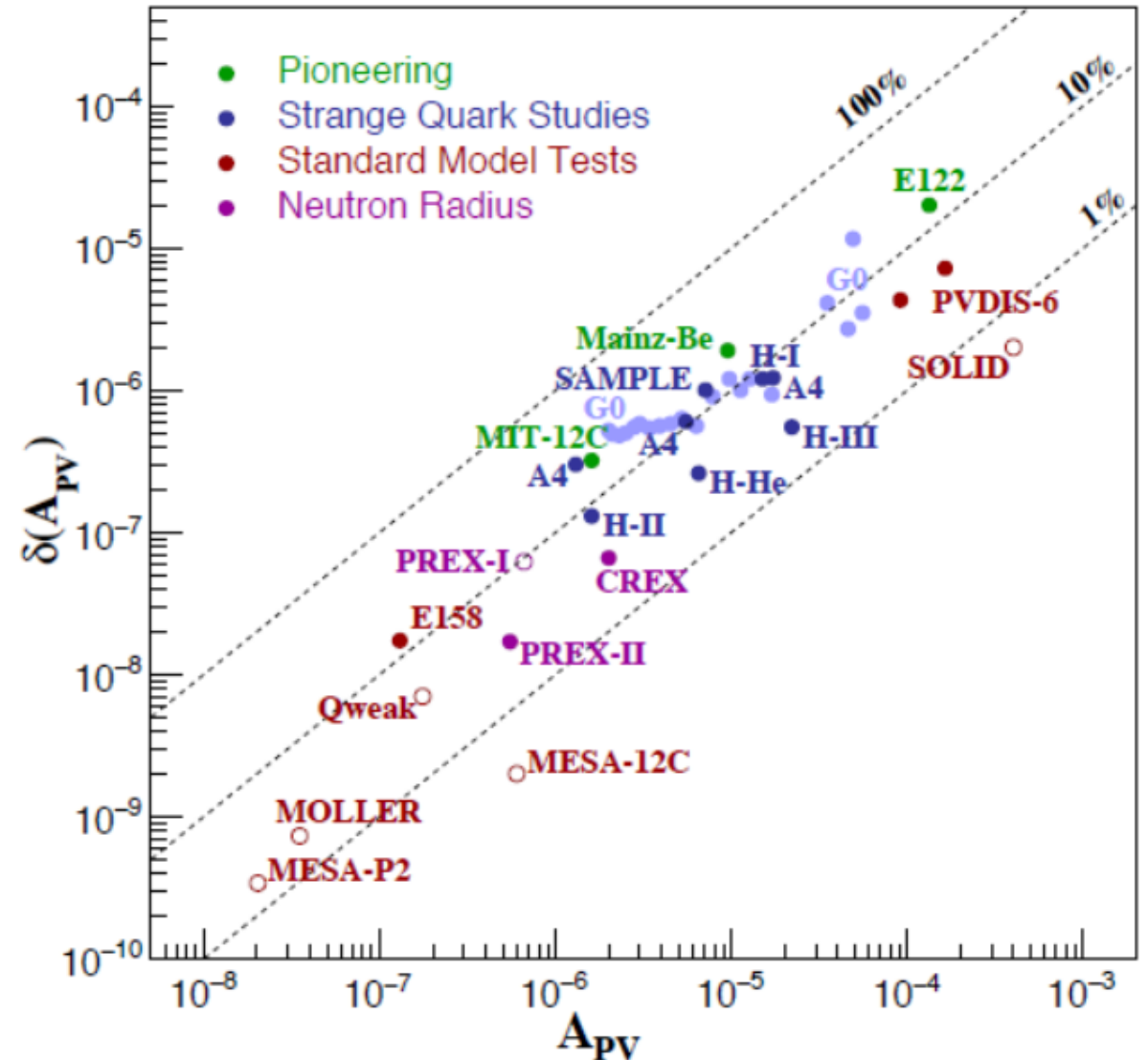
Shukui Zhang, CIS/ACC

 Jefferson Lab

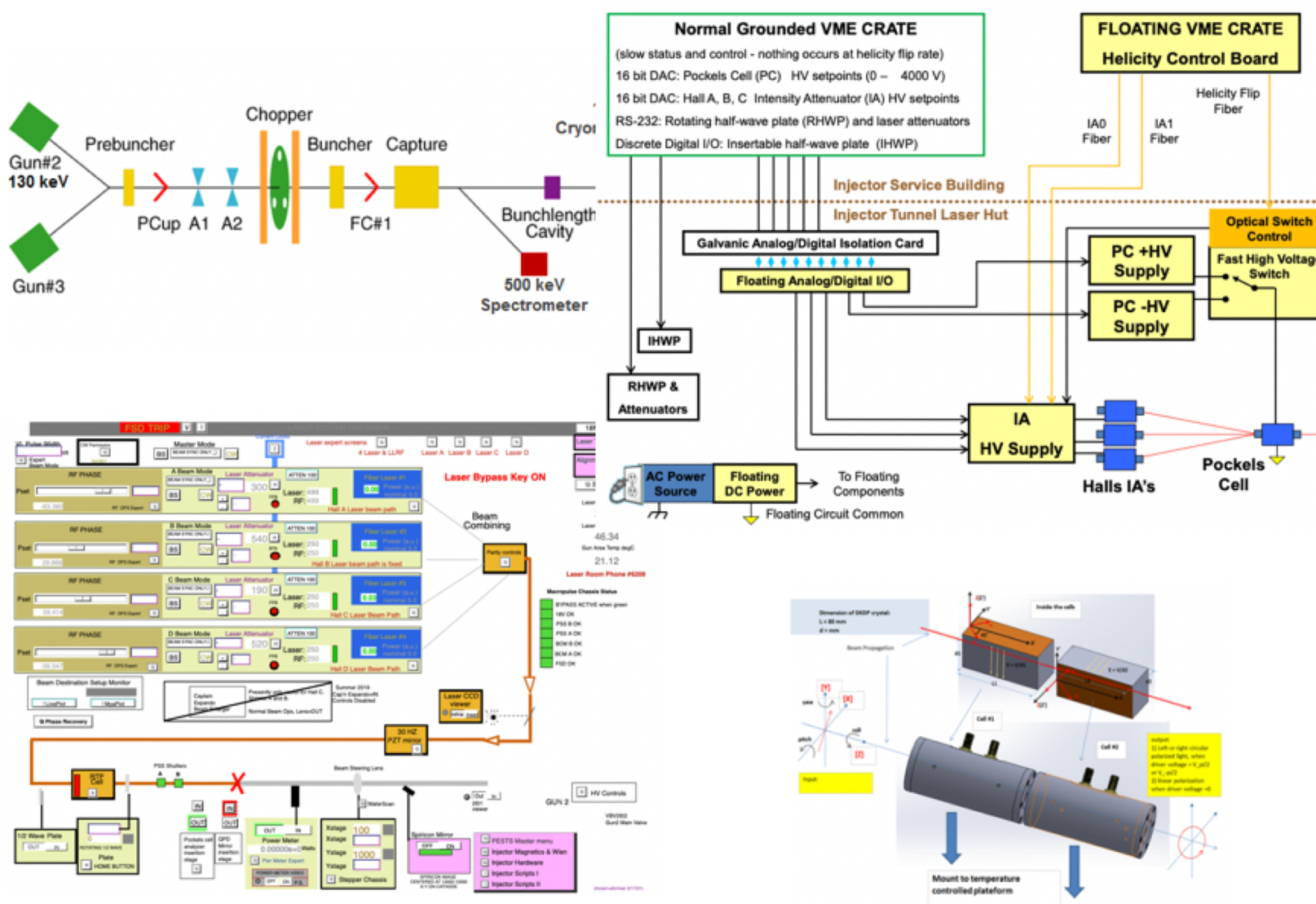


Challenges and the Needs

- 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



Laser Polarization & Parity Controls

INSERTABLE waveplate OUT IN
RETRACT / INSERT

ROTATING waveplate 0 → 8000 corresponds to 0 → 360 degrees

Pockels Cell POS HV adjust
DAC01 Pockels Cell +HV
COUNTS SET: 32768.00
COUNTS READ: 5.00007
VOLTS OUT: 5.00007

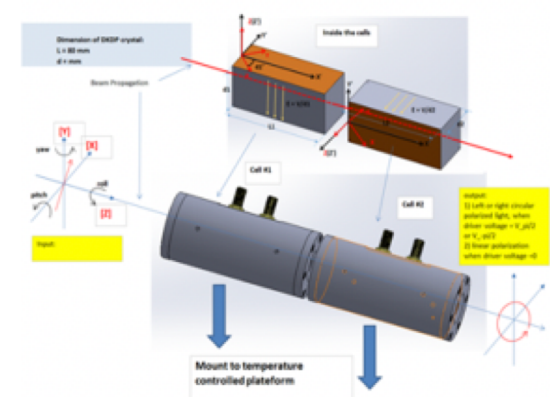
Pockels Cell NEG HV adj
DAC02 Pockels Cell -HV
COUNTS SET: 32768.00
COUNTS READ: 5.00007
VOLTS OUT: 5.00007

Main Pockels Cell
OFF ON
On / Off
Green = ON

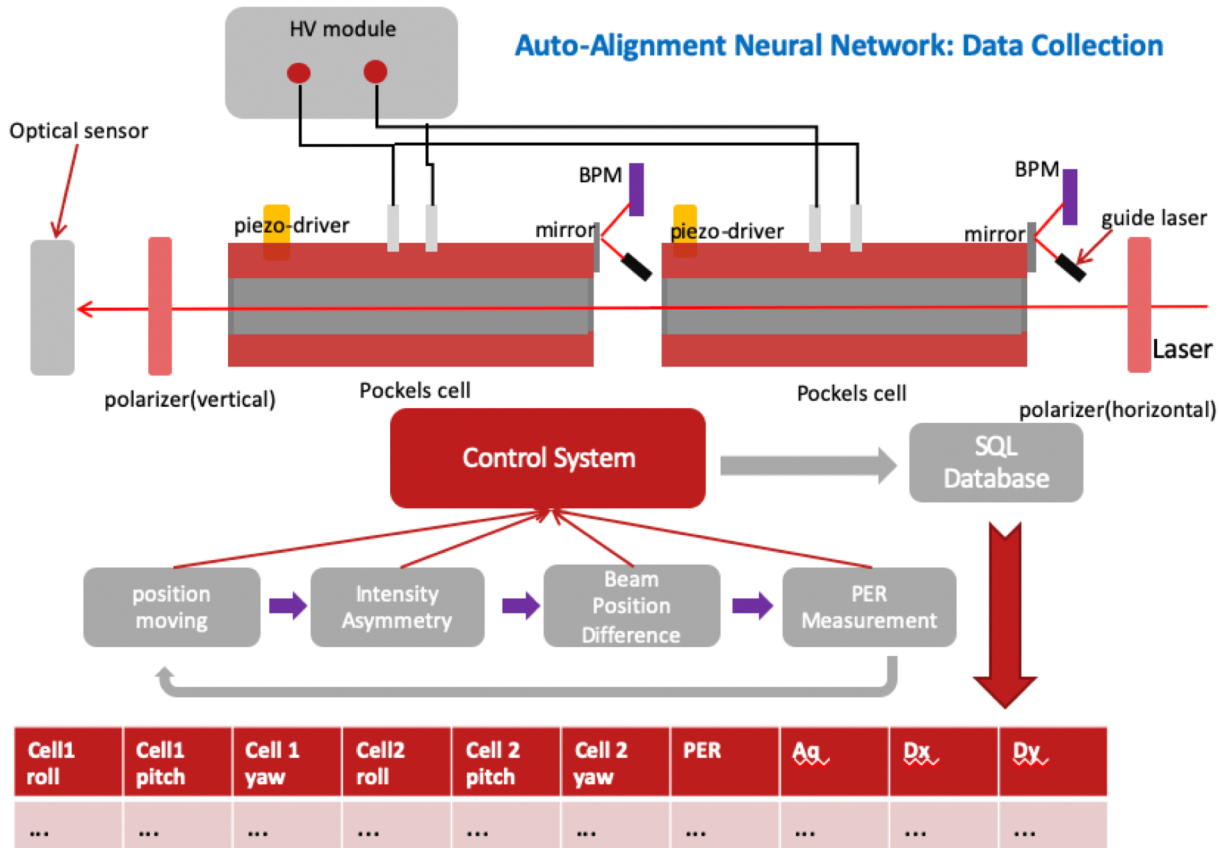
HALL A : IA	HALL B : IA	HALL C : IA
DAC03 Hall A QIA A0	DAC07 Hall B QIA A0	DAC11 Hall C QIA A0
COUNTS SET: 32768.00	COUNTS SET: 32768.00	COUNTS SET: 32768.00
COUNTS READ: 5.00007	COUNTS READ: 5.00007	COUNTS READ: 5.00007
VOLTS OUT: 5.00007	VOLTS OUT: 5.00007	VOLTS OUT: 5.00007
DAC04 Hall A QIA A1	DAC08 Hall B QIA A1	DAC12 Hall C QIA A1
COUNTS SET: 32768.00	COUNTS SET: 32768.00	COUNTS SET: 32768.00
COUNTS READ: 5.00007	COUNTS READ: 5.00007	COUNTS READ: 5.00007
VOLTS OUT: 5.00007	VOLTS OUT: 5.00007	VOLTS OUT: 5.00007
DAC05 Hall A QIA A2	DAC09 Hall B QIA A2	DAC13 Hall C QIA A2
COUNTS SET: 32768.00	COUNTS SET: 32768.00	COUNTS SET: 32768.00
COUNTS READ: 5.00007	COUNTS READ: 5.00007	COUNTS READ: 5.00007
VOLTS OUT: 5.00007	VOLTS OUT: 5.00007	VOLTS OUT: 5.00007
DAC06 Hall A QIA A3	DAC10 Hall B QIA A3	DAC14 Hall C QIA A3
COUNTS SET: 32768.00	COUNTS SET: 32768.00	COUNTS SET: 32768.00
COUNTS READ: 5.00007	COUNTS READ: 5.00007	COUNTS READ: 5.00007
VOLTS OUT: 5.00007	VOLTS OUT: 5.00007	VOLTS OUT: 5.00007

S2 Hall A IA rotation (IA Slope) S3 Hall B IA rotation (IA Slope) S1 Hall C IA rotation (IA Slope)

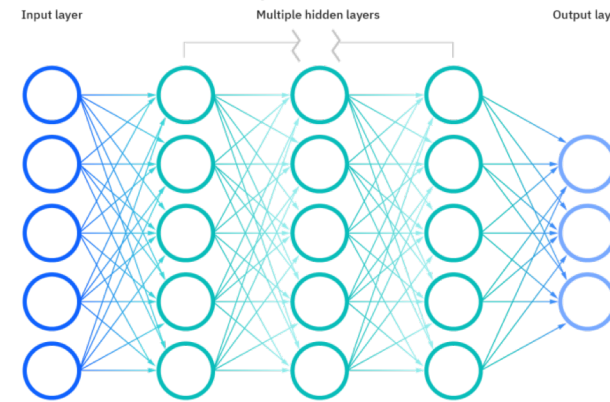
IA Slope control. Verify red surrounds the S1, S2, or S3 above before adjusting slope. This is a dynamic adjustment, so system response must be charted as change is made.



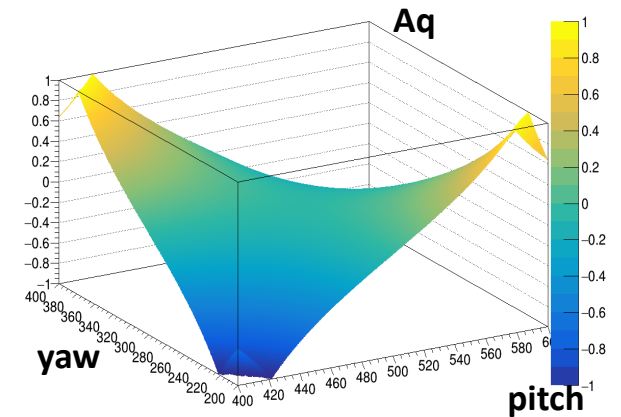
Attempt towards Polarization Control by ML



- 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



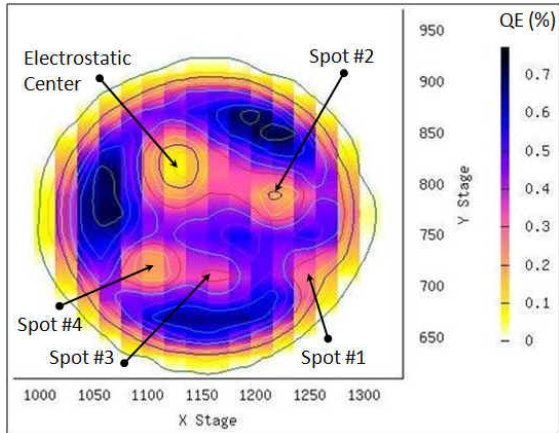
- Initial state PER = 289, intensity asymmetry A_q/0.134, Beam position diff: D_x /121 um, D_y /150 um,
- Optimal position reached after 28 steps with PER = 512, A_q/0.005, D_x /2 um, D_y / 5 um.
- The total auto-alignment process takes ~ 30 min.
- Promising tool for maintaining and fast control of polarization!

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

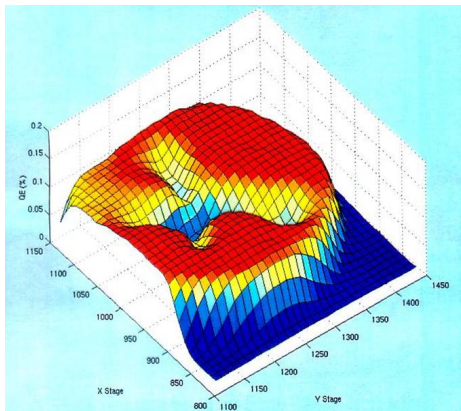
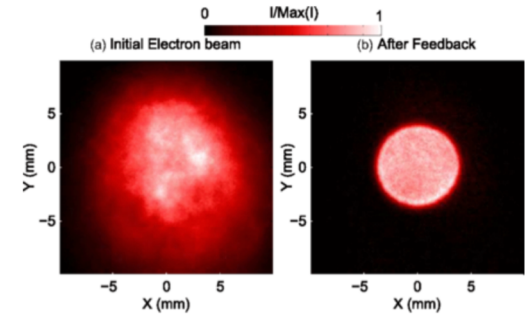
Beam instability and emittance growth may be induced by photocathode parameter variation including QE depletion and non-uniformity during long-term or high-current operation. Beam polarization degradation?



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](#)

