



**CLASSE**  
Cornell Laboratory for Accelerator-based Science & Education



# Cornell's ERL / EIC group

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Delegation from Japan and IDT @ Cornell

08/30/2023



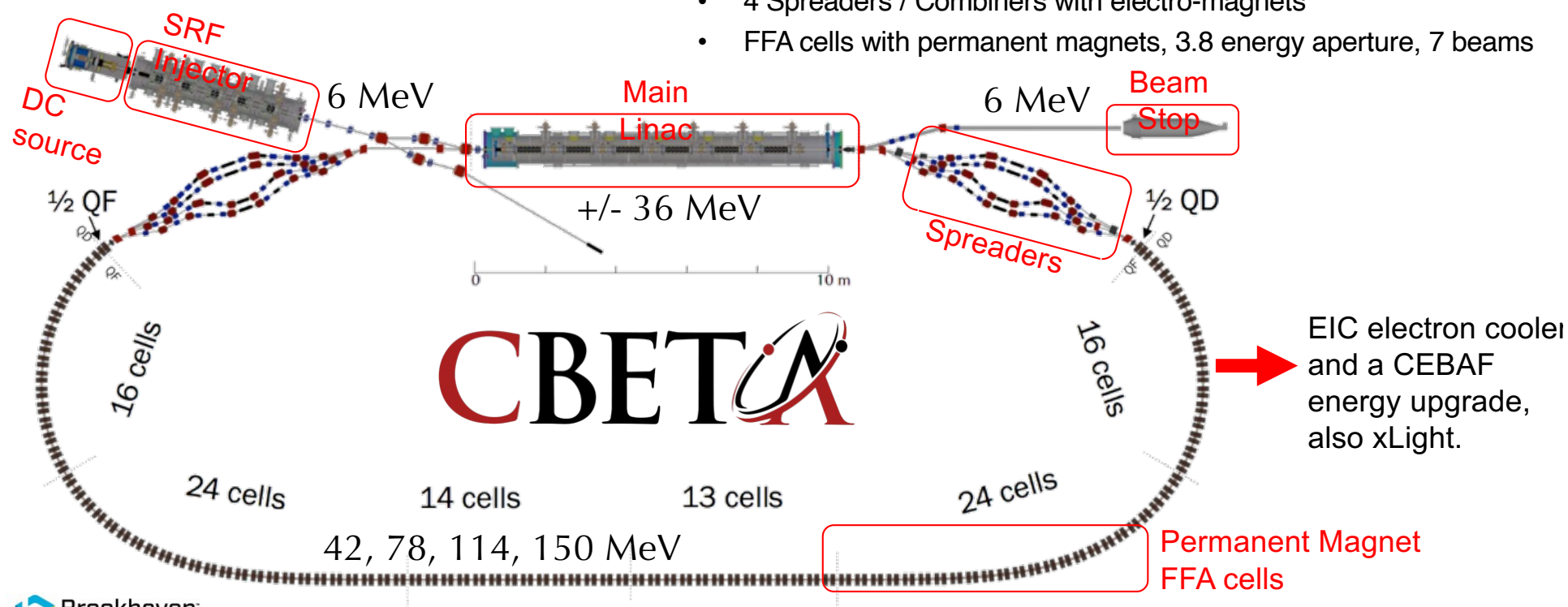
# CBETA installation at Cornell



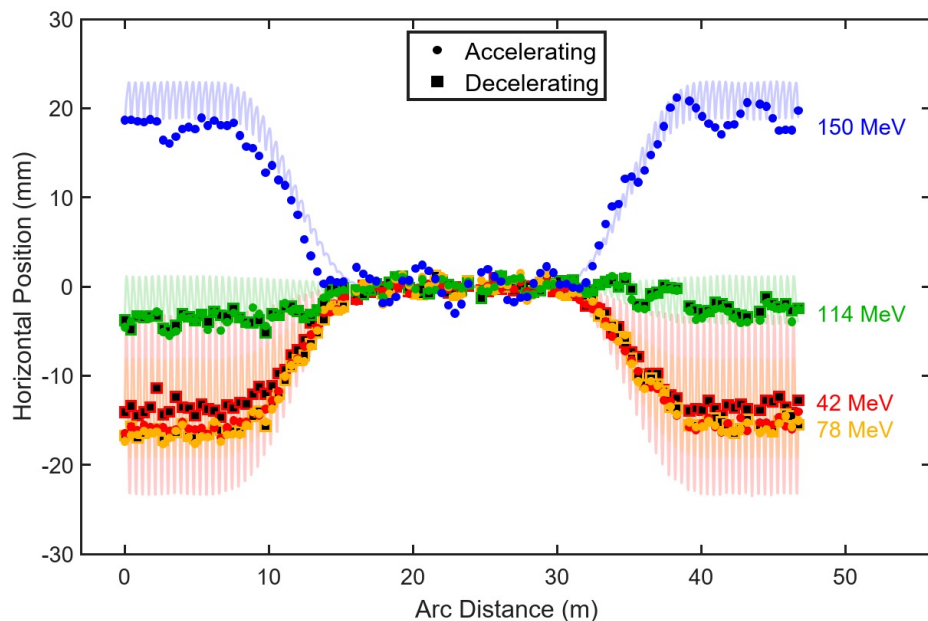
# Previous work: Cornell & BNL

- Cornell DC gun, 2nC peak
- 6MeV SRF injector (ICM), 1.3GHz
- 6-cavity SRF CW Linac (MLC), 1.3GHz
- 4 Spreaders / Combiners with electro-magnets
- FFA cells with permanent magnets, 3.8 energy aperture, 7 beams

## The Cornell-BNL ERL Test Accelerator



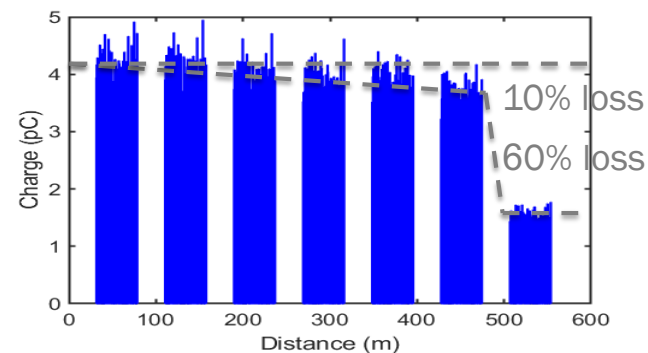
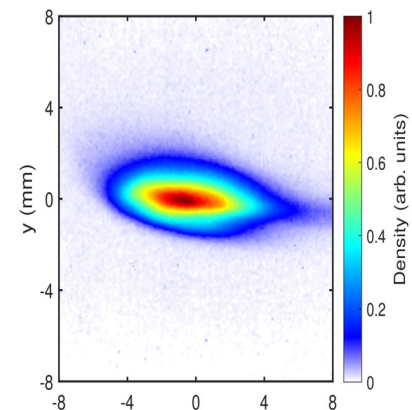
# First multi-turn ERL operation



**7 beams in the same FFA beamline, accelerated and energy-recovered.**

**Reports appeared in Nature, Phys. Rev. Letters, Forbes Magazine, EEE Spectrum, reddy.com, and others.**

## Beam in the beam stop after 8



**Before the 7<sup>th</sup> FFA pass, 60% loss**



## Design of the EIC – it's ERL and beyond



Brookhaven National Lab is constructing a 4km long accelerator complex to study basic nuclear physics, e.g.,

- Where do protons get their spin from?
- How did cosmic events produce the isotope distribution?
- How do gluons hold nuclei together

Designated the most pressing next NP project by DOE.  
The largest accelerator project in the US today.

Probably the most complex accelerator ever built:

- Polarized protons and electrons.
- Beam cooling (Rf, e, and photon based)
- Superconducting RF acceleration
- Superconducting magnets



Cornell Laboratory for  
Accelerator-based Sciences and  
Education (CLASSE)



# ML / AI for Accelerators

## Machine Learning Applications for Improving Accelerator Operations, CBETA, LEReC, CeC and Currently at the AGS and AGS Booster

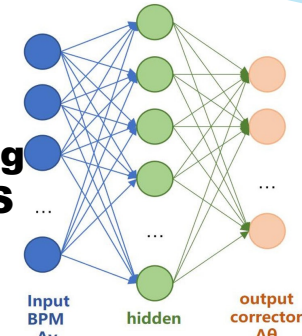
Need higher polarization for EIC!

Calibrate magnet strength model

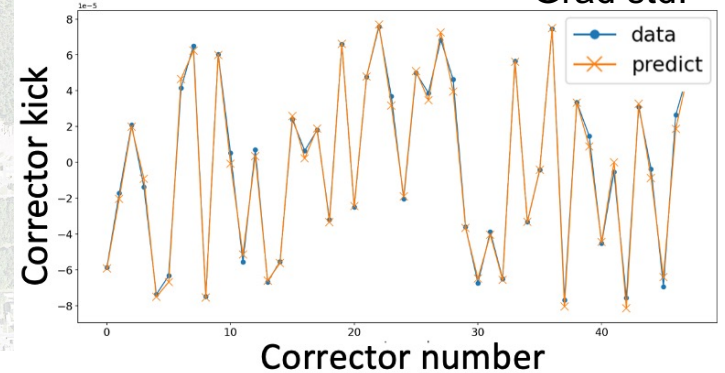
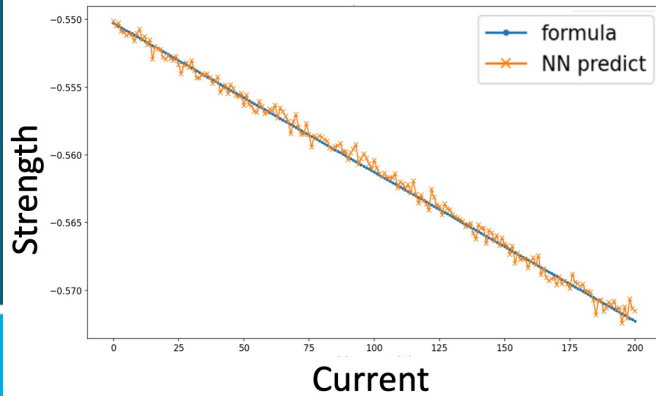
Machine Learning Applications for Improving Accelerator Operations at the AGS and AGS Booster



Automatic orbit correction and error identification



Lucy Lin  
Grad std.



# Enhancing Proton Polarization

BNL requested a study to understand polarization increase with broken Siberian Snake

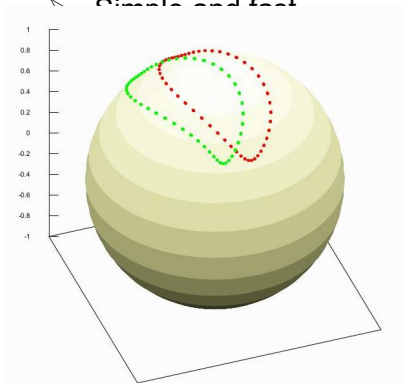
- Ideal (symmetric) snakes are generically effective against all traditional spin-orbit resonances
- Whereas simulations indicate asymmetry can be utilized against particular resonances

Developed simulations for high resolution tune-dependent polarization

- Calculating tune path for optimal final polarization
- Calculating width of spin-orbit resonances (to avoid)

Developed new method for calculating the Invariant Spin Field

- Nonperturbative
- Simple and fast

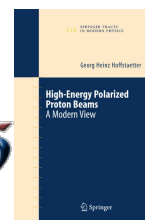


$$J_y = 10\pi \mu\text{m} \mid E = 201.6 \text{ GeV}$$

Invariant Spin Field



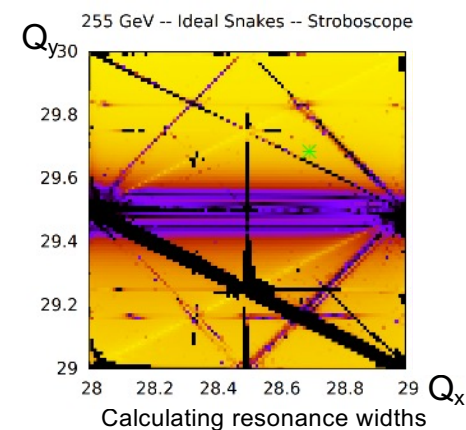
World-leading  
Computational  
Tools



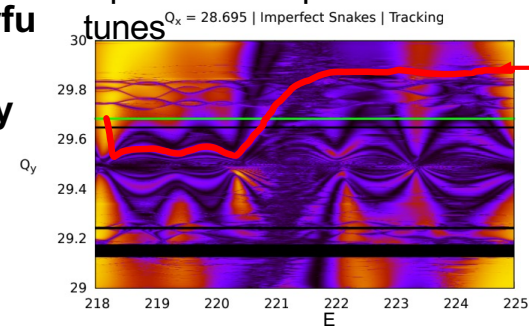
Powerful  
Theory

- Systematic analysis of dynamics
- Accurate and reproducible modeling
- Qualification & quantification of spin resonances

Eiad Hamwi



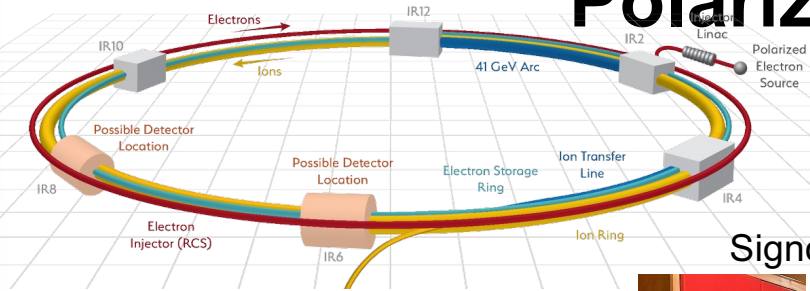
Optimized ramp  
tunes



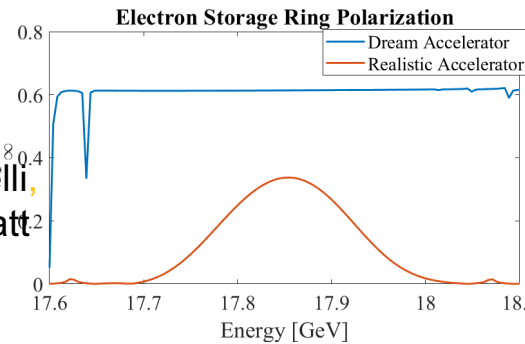
Simulating polarization during energy ramping process



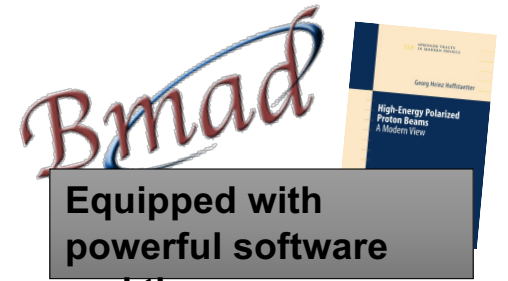
# Polarization in the EIC



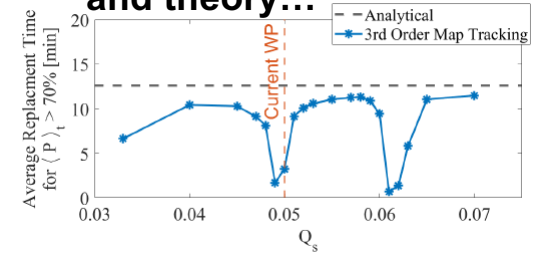
Signorèlli,  
Matt



...but polarization is hard

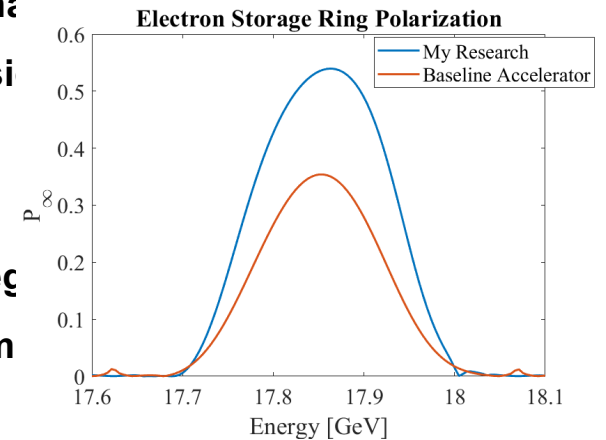


Equipped with powerful software and theory...



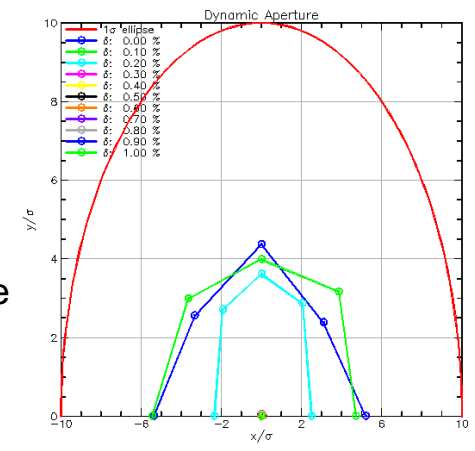
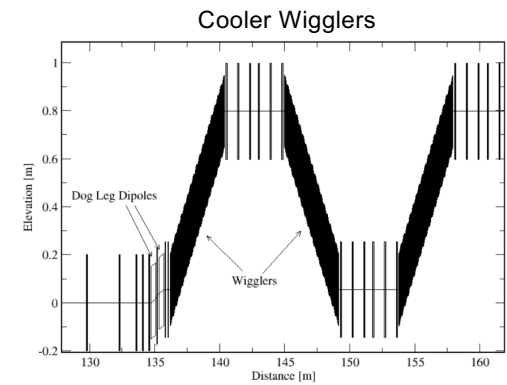
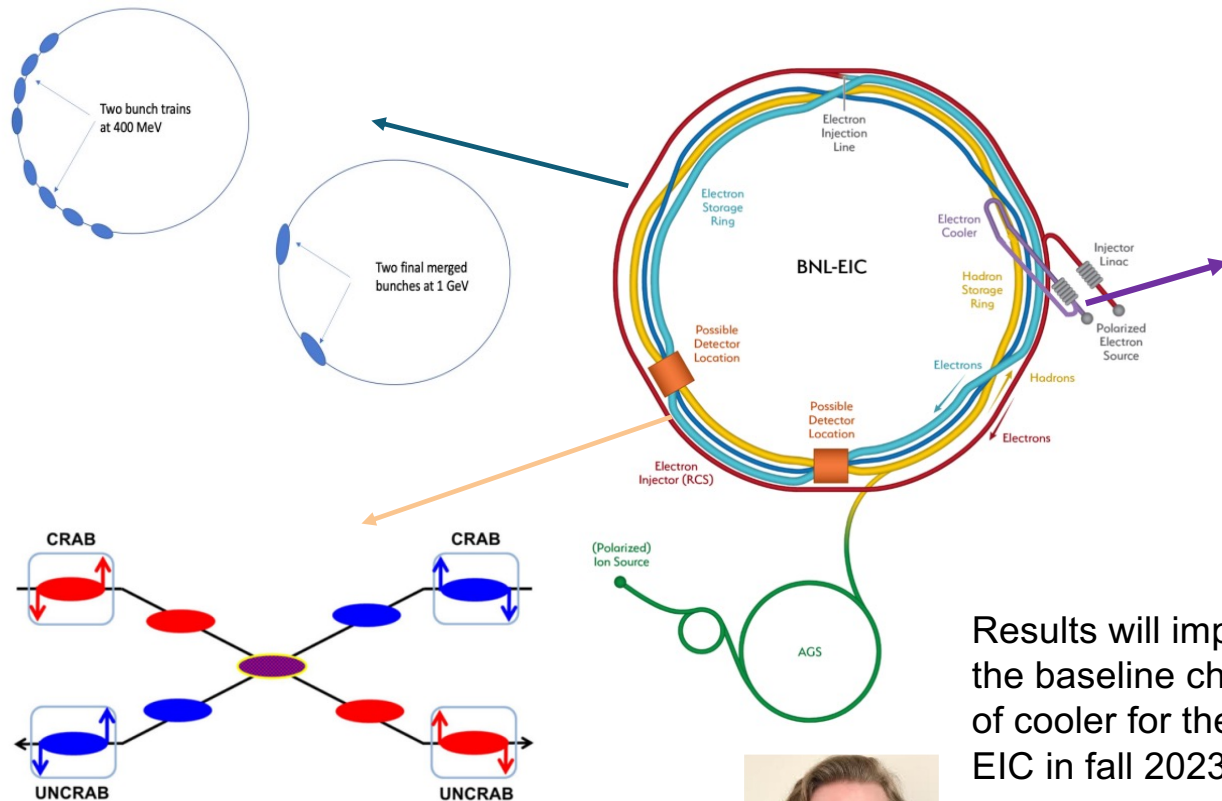
Polarized e- and light ion collisions at *many COM energies*

- Identified a nonlinear resonance and **changed the tunes of the electron ring**
- Changed the energies and spin rotator settings of electron ring for many energies**
- Devised and verified solenoid settings that **allow for 2-IP polarized collisions**
- Verified sufficient polarization with each new geometry
- Determined possible method to increase polarization significantly**
- Implementing vertical beam size creator with minimal polarization degradation**
- Determined exact depolarization for protons and helions through ram**





# Long Term Stability in Electron Rings



Results will impact the baseline choice of cooler for the EIC in fall 2023.

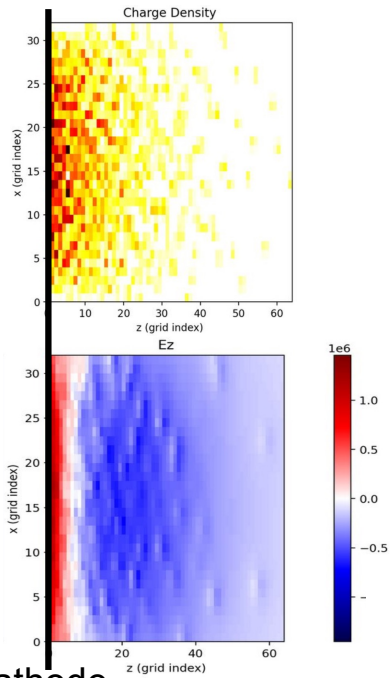


Jonathan Unger



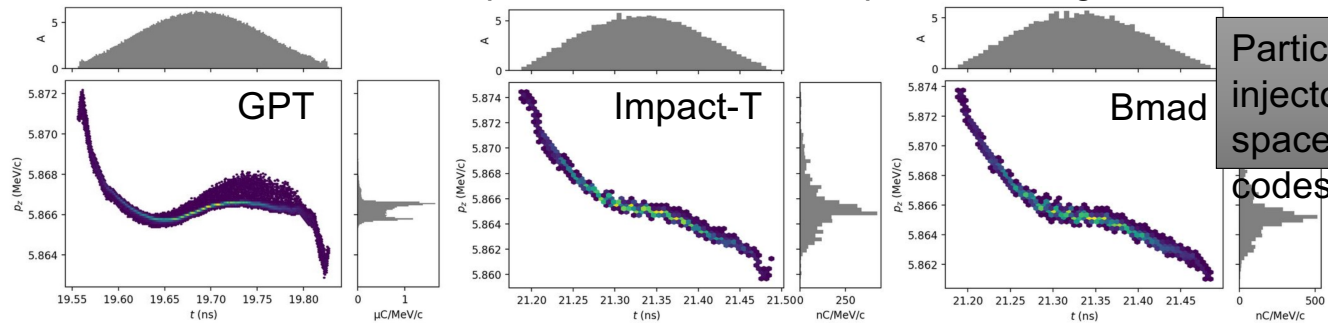
# Low energy space charge in Bmad

- Space charge describes the interaction of electric charges in a charge particle bunch. This effect is especially important in **high brightness** beams and at **low energy**.
- I implemented cathode space charge tracking in Bmad, enabling accurate simulations of particles near the cathode.
- Continuing code developments for CBETA, Bmad is the basis of optics design for the EIC ERL-cooler.
- I was selected for a SCGSR fellowship and spend '23-'24 at BNL to optimize the EIC ERL-cooler's laser shape at the cathode for optimal cooling.

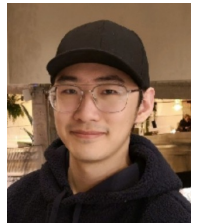


cathode

Particles coming out of the cathode and their space charge field



Particles out of injector in three space charge codes



Ningdong Wang





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The Center for  
**BRIGHT  
BEAMS**  
A National Science Foundation  
Science & Technology Center



**Brookhaven™**  
National Laboratory



U.S. DEPARTMENT OF  
**ENERGY**

# Questions?



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