

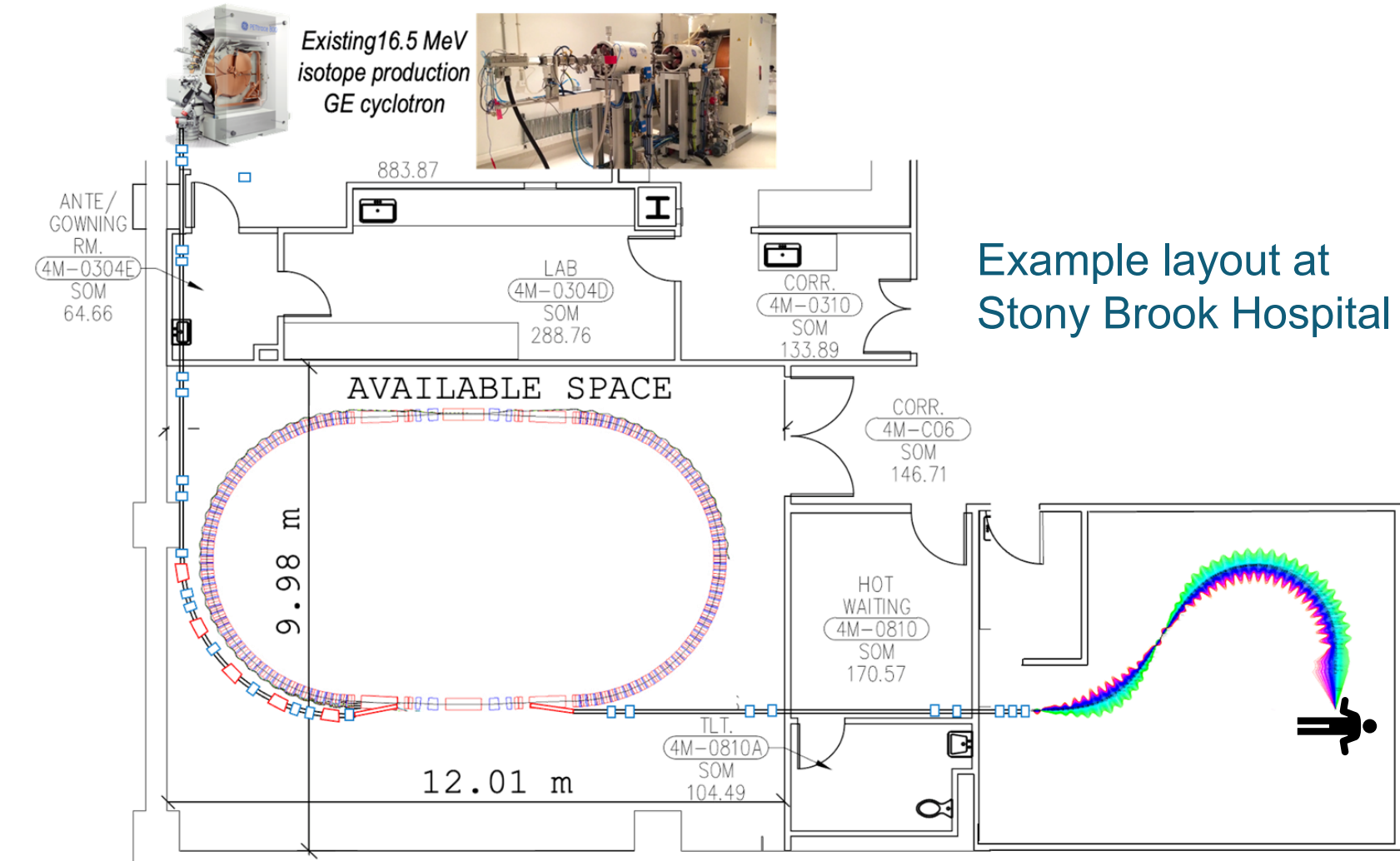
Advanced Accelerator Research at BNL

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LDRD 22-013 (Type B) High-Gradient Permanent Magnets for Emerging Accelerator Applications
LDRD 24-010 (Type B) Section of Fast-Cycling FFA Synchrotron

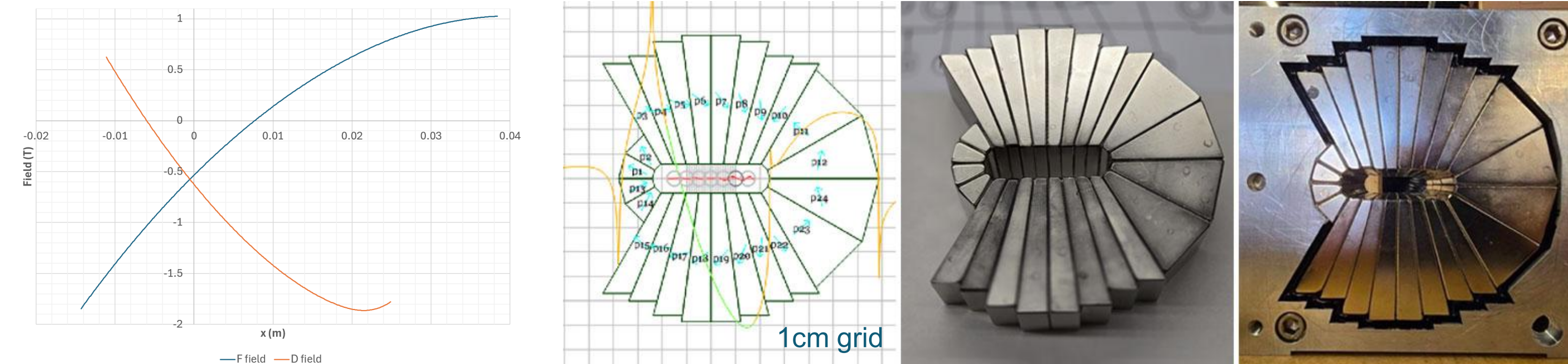
Permanent Magnet Accelerator Design for Fast Hadron Therapy Treatments

Fixed-field accelerators (FFAs) allow the acceleration of beams without ramping magnetic fields: the orbit shifts to higher field regions instead. This avoids limits on machine cycle rate from magnetic inductance and forms the basis of the very-rapid-cycling medical accelerator facility shown below, producing high dose rates required for FLASH therapy as well as rapid energy scanning for 3D coverage of the tumor.

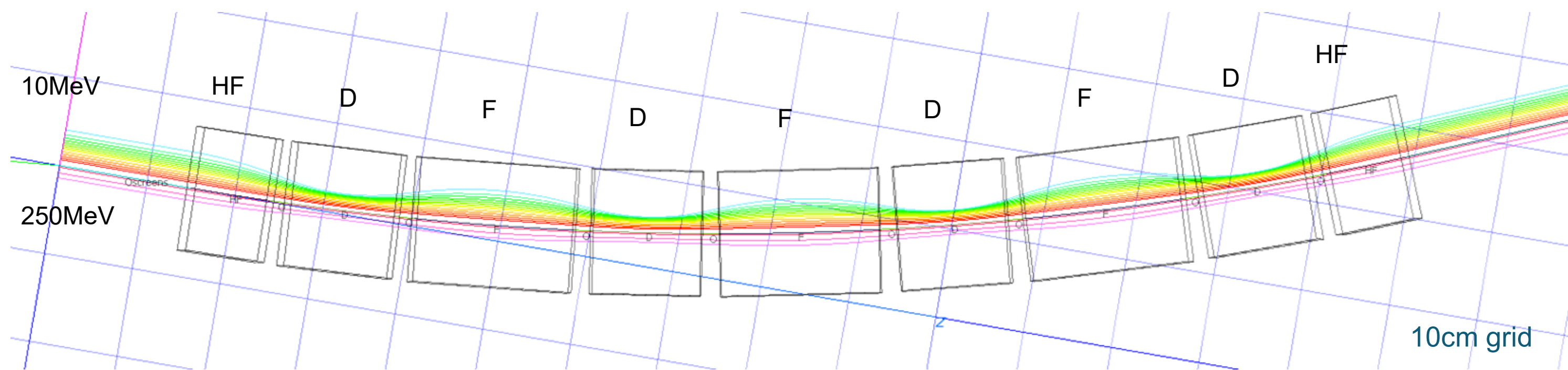


Parameter	Value	Unit
Injection E_k	10-30	MeV
Extraction E_k range	65-250	MeV
Arc radius	3.5	m
Machine cycle rate	500-800	Hz
Energy gain / turn	30-45	kV
Treatment charge	60	nC
Treatment time	75-250	ms

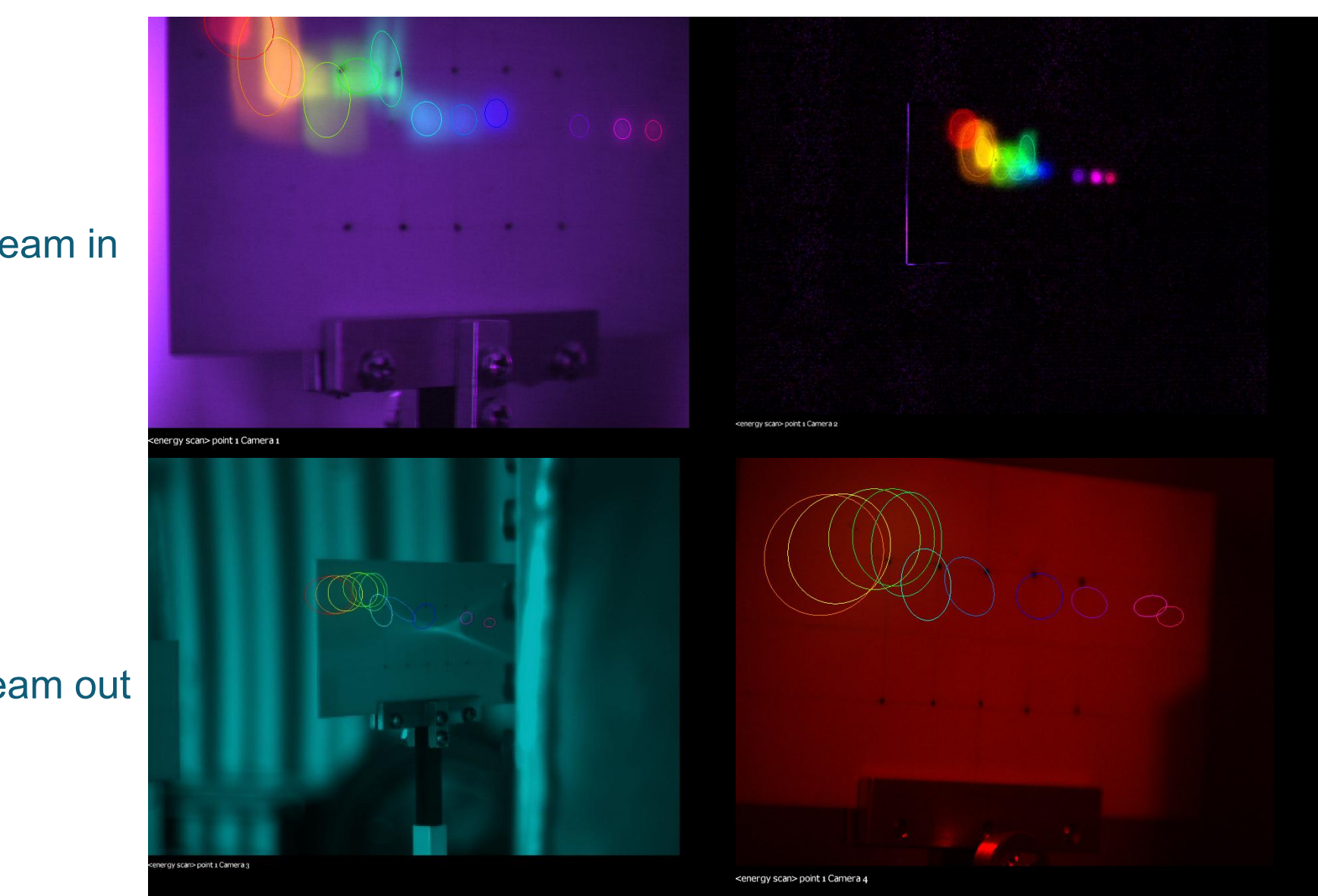
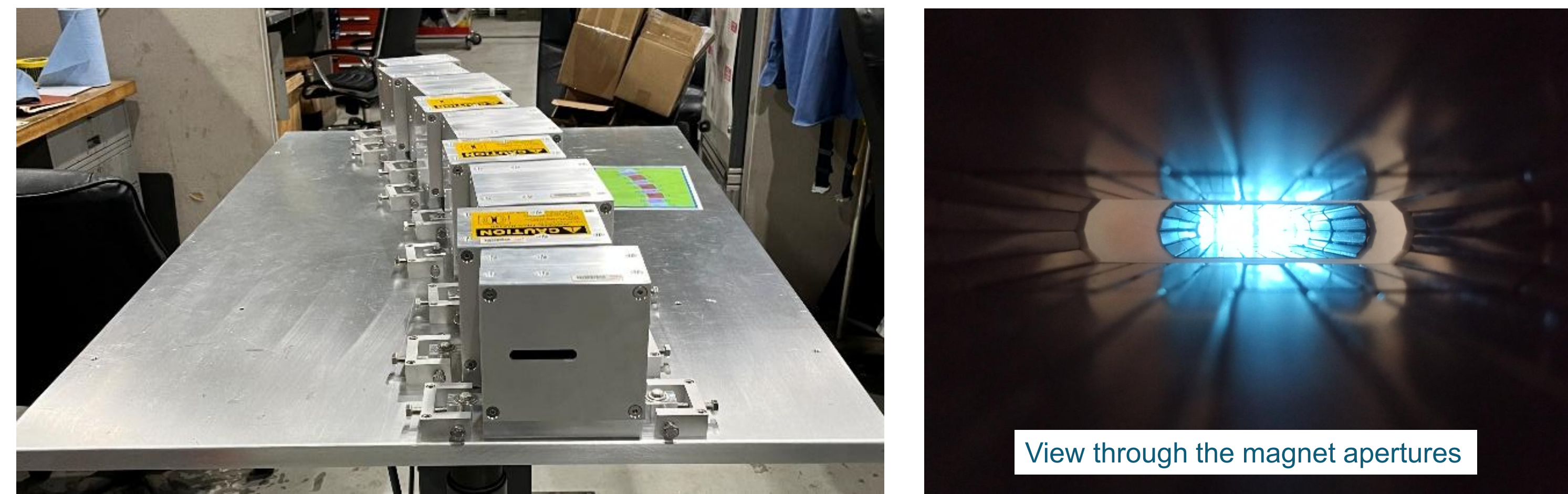
The wide 10-250MeV energy range of the accelerator is allowed by NdFeB permanent magnets with a peak field of 1.85T, shown below. The specially-designed nonlinear field profile keeps the machine tune constant throughout acceleration.



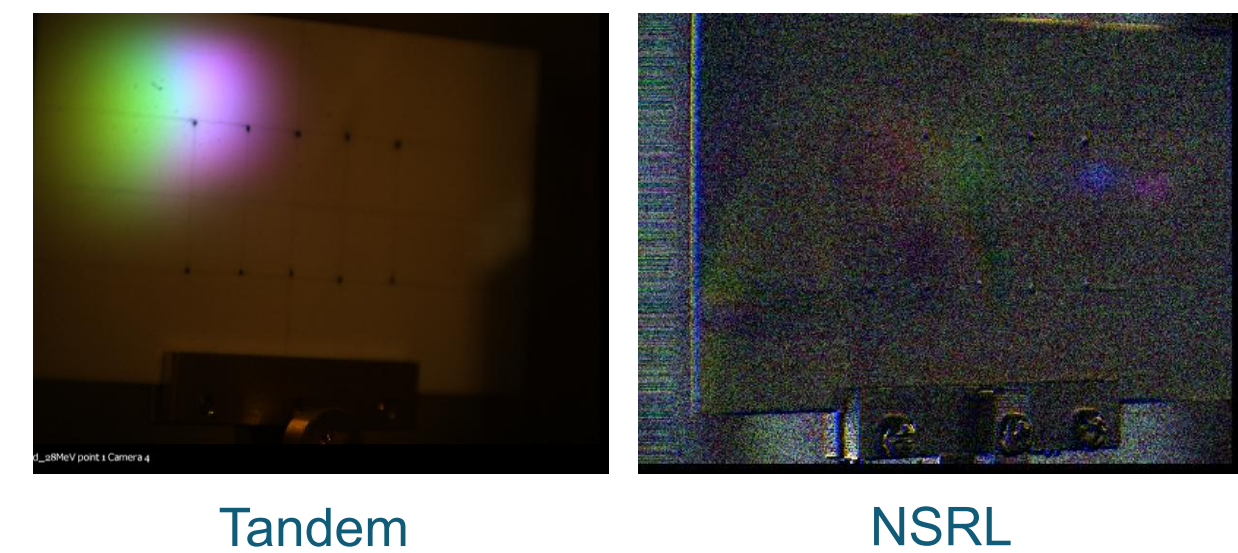
Beamline Tested at NSRL and Tandem



A 100% scale, full-field section of the arc with nine magnets (22.5°) was built and tested for beam transmission across the entire energy range: 50-250MeV protons at NSRL and 10-50MeV at BNL Tandem.



Composite image of the 12 input beams from 10MeV (left) to 250MeV (right) at both facilities. Lower plots show ellipses fitted to the output beams.



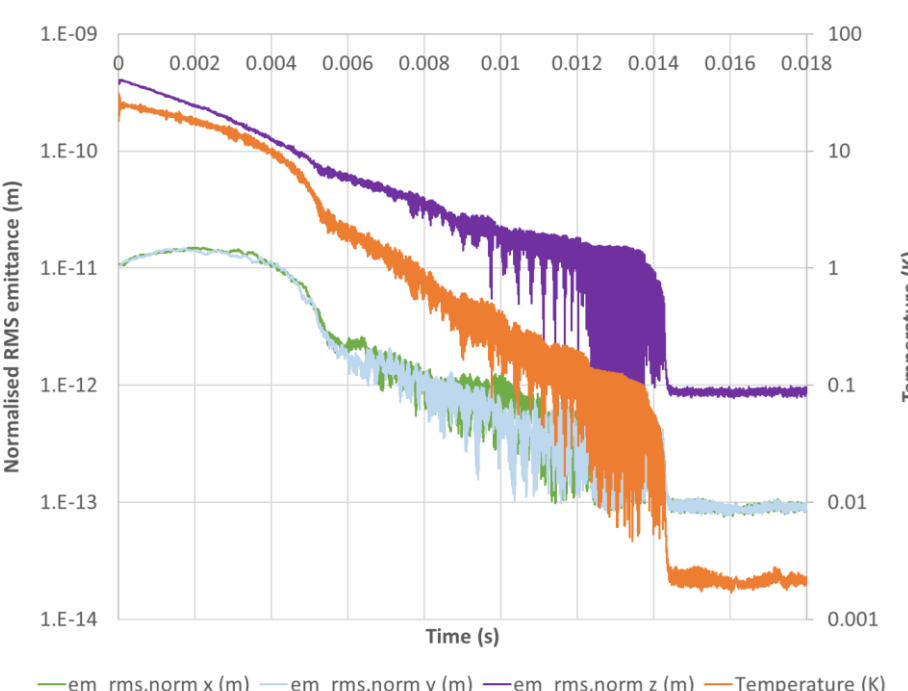
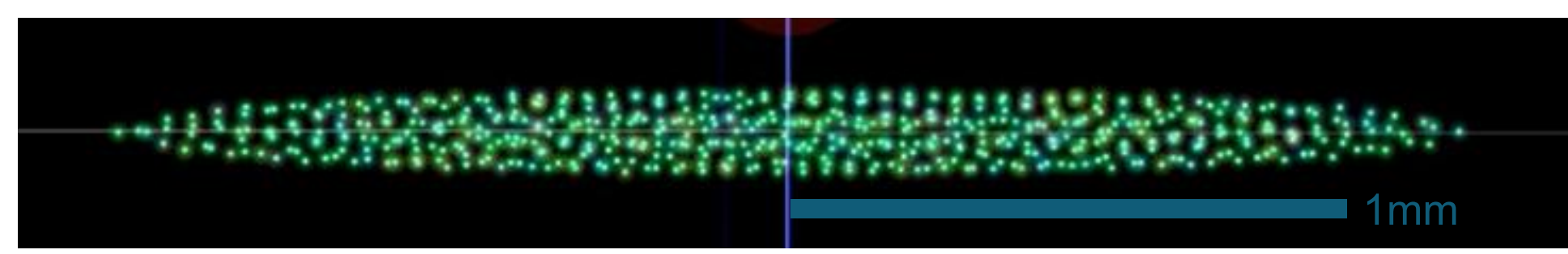
Tandem

NSRL

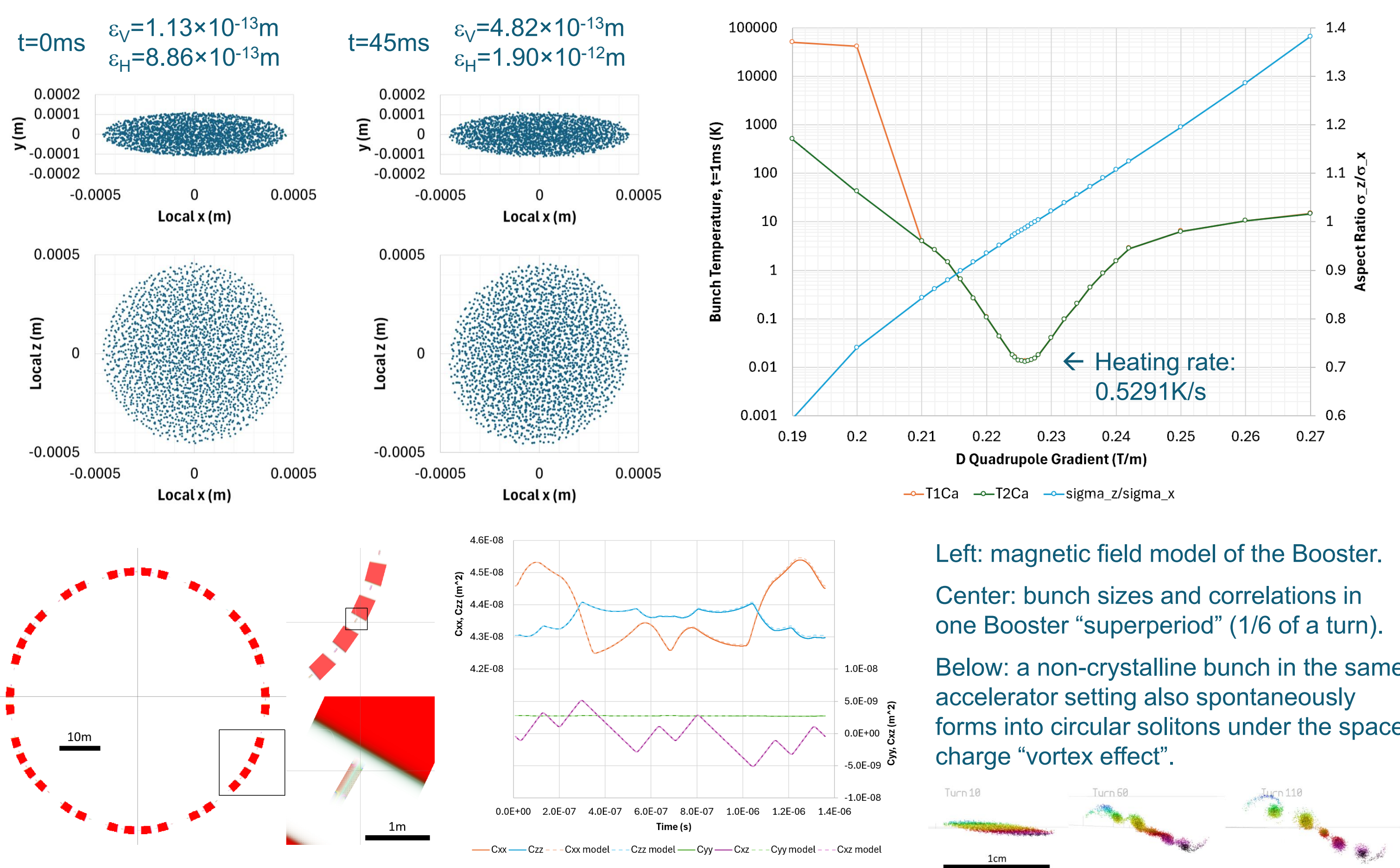
LDRD 24-006 (Type B) Ion trap test stand and laser cooling studies of ultra-low emittance bunches for high luminosity
LDRD 26-055 (Type C) Laser System for Doppler Ion Cooling

Simulations of Crystalline Beam Stability in the BNL Booster

Laser Doppler cooling can cool ion bunches into solid “Coulomb crystals”, for example this simulated Ca^+ crystal at 2mK temperature.

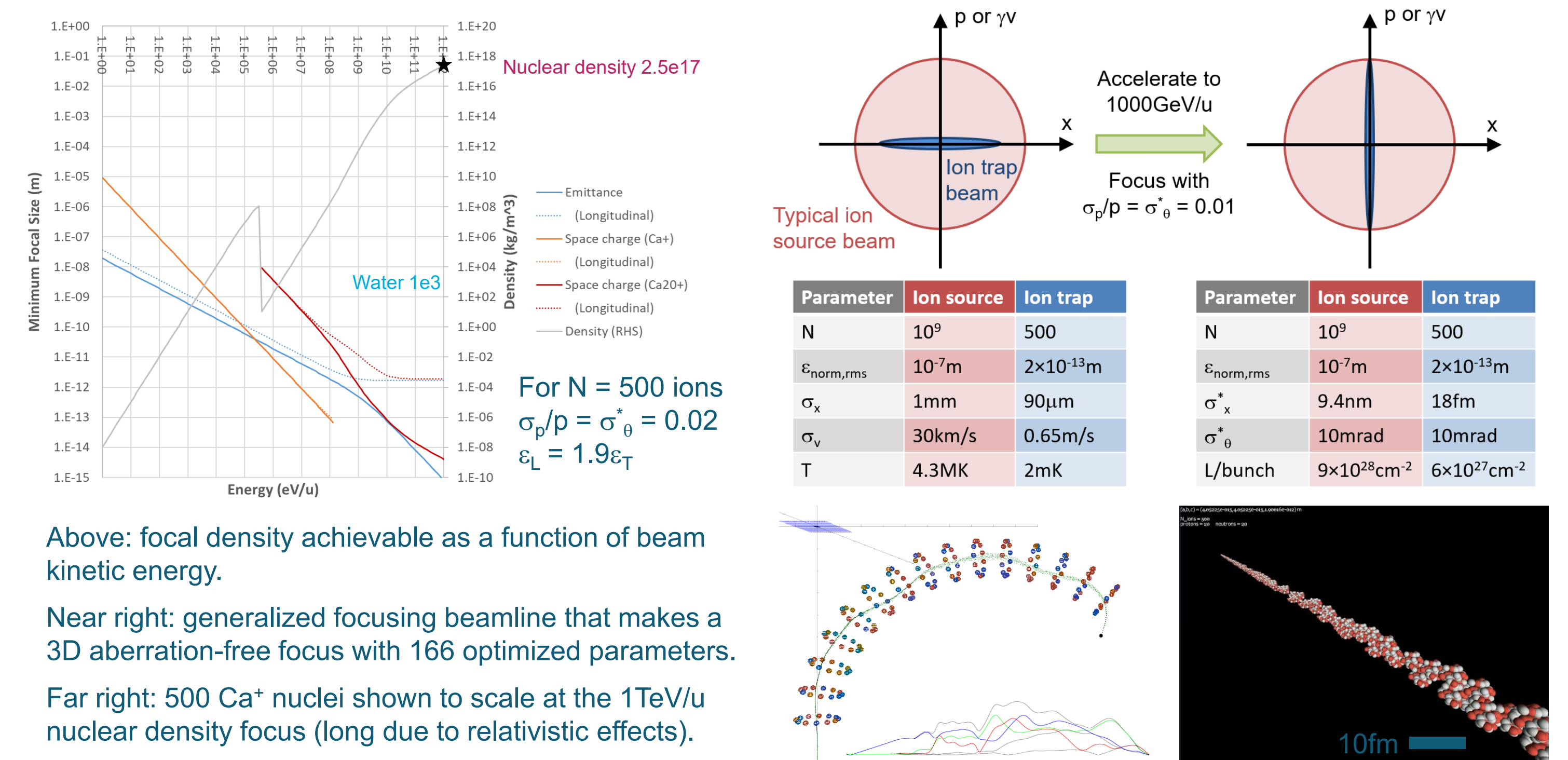


Such a crystal distribution was placed into a magnetic field model of the BNL Booster synchrotron for 5500 turns (45ms). Quadrupole settings were found that reduced heating rates to less than 1K/s and preserve the solid state, even without additional laser cooling.



Nuclear Density Focal Point Formation

The 10^5 times smaller velocity spread of a crystalline beam compared to a typical plasma source can be converted into a 10^{15} -fold increase in density of a final focus, achieving the nuclear density around 1TeV/u.



Ion Trap Test Stand at BNL

Hardware for a Ca^+ ion Paul trap with laser Doppler cooling has been purchased at BNL. This system will be a source of ultra-low emittance crystalline bunches and allow studies of their beam dynamics.

