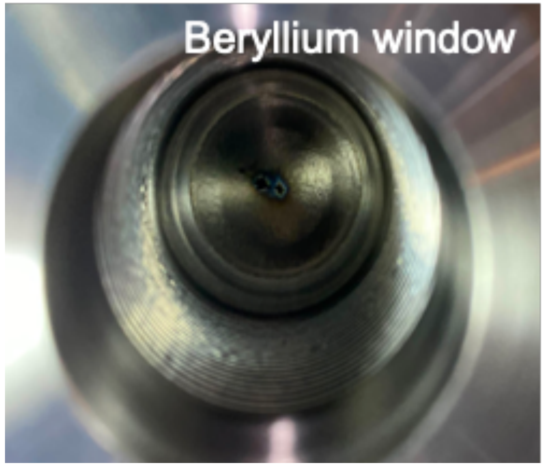
E326 Progress in FY 24 and Plans for FY25

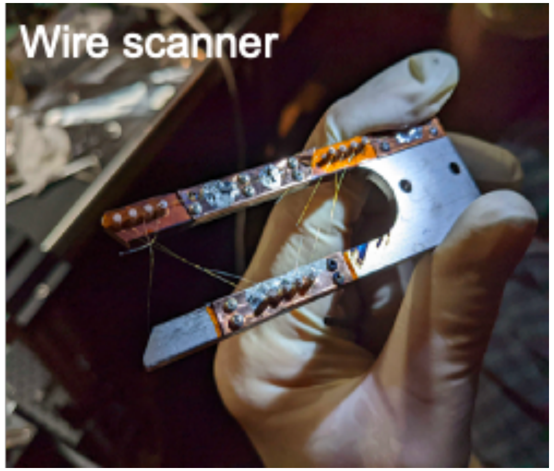
Brendan O'Shea / Lead Scientist / Advanced Accelerator Research Department Head

2024 FACET-II PAC & User Meeting

Fast beams, slow measurements

- The future is beams of unprecedented density
    - Short bunch length beams to reduce disruption in colliders
    - Nanometer scale bunch lengths
- Live diagnostics always get used
- Conventional beam diagnostics have limitations
    - Material in the beam path disturbs beam quality: can only measure one at a time, can not measure and perform experiments
    - High intensity beams may destroy the diagnostic

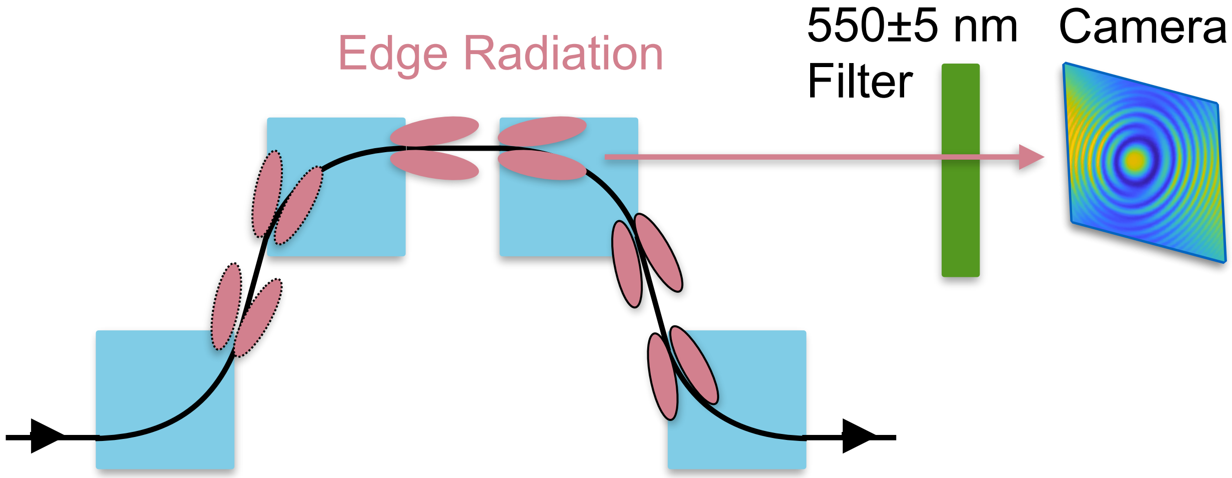




New diagnostics are required for high current beams

Edge Radiation as a Diagnostic

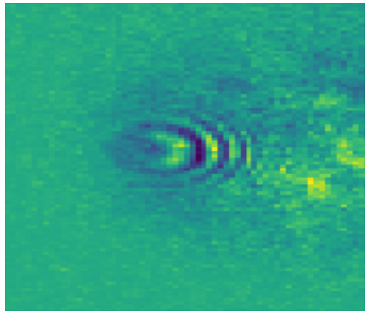
- Non-intercepting diagnostics are key for doing online analysis and control - more from Claudio
  - Measure emittance continually without intercepting the beam
- Beam information encoded in interference pattern (inverse problem)
- Developed a differentiable simulation code for computing synchrotron radiation
- Demonstrated single shot, non-intercepting diagnostic (image analysis), using conv. autoencoders, and a physics based loss function
- Partnered with Stanford Data Science to introduce non-physics undergraduates to SLAC



Inverse Problems

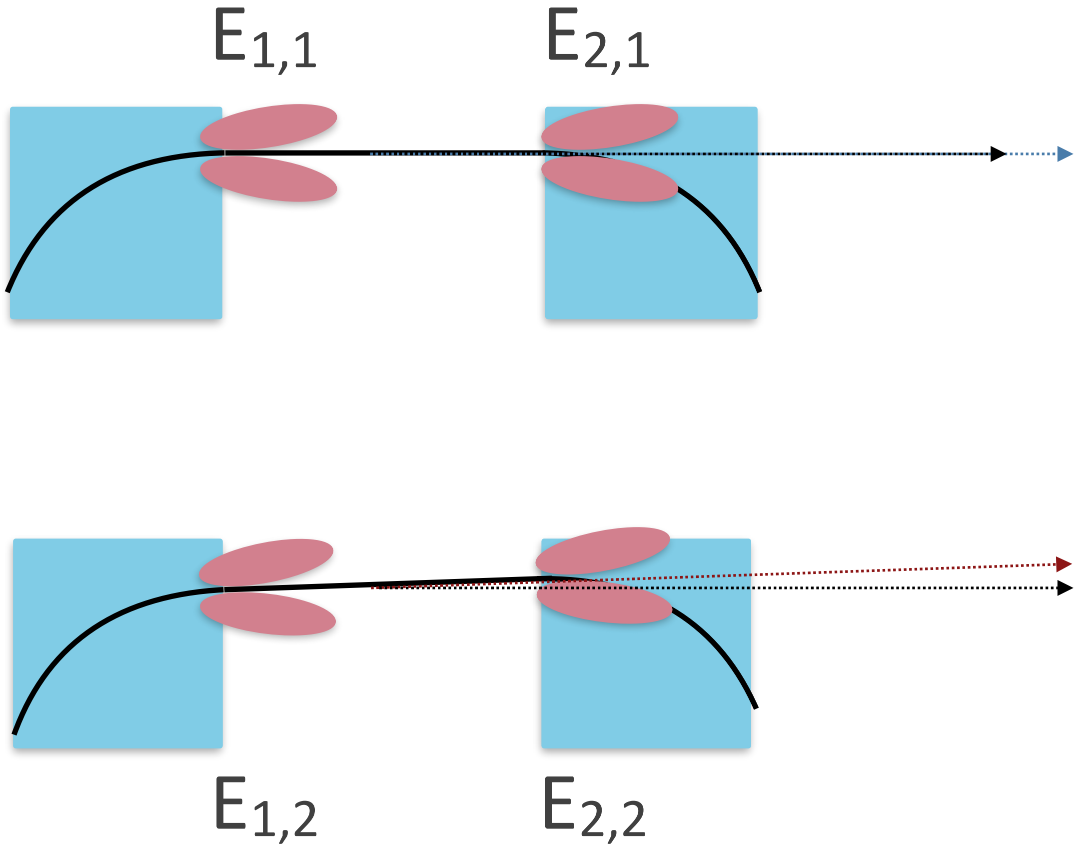
$$I(x) = \left| \int E(x - x')\rho(x)\mathrm{d}x \right|^2$$

Solve for ρ

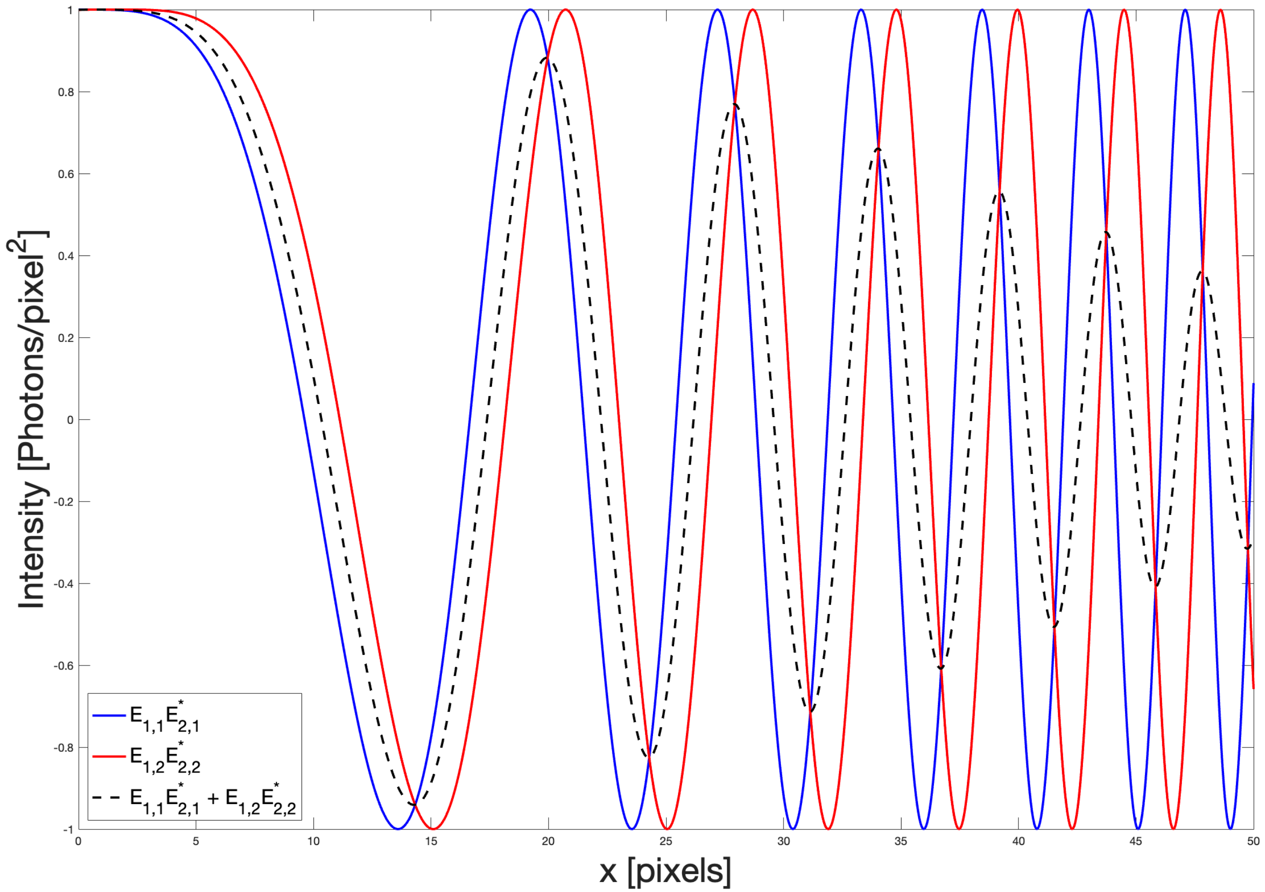


Edge radiation diagnostic meets previously listed challenges

How is information encoded in interference

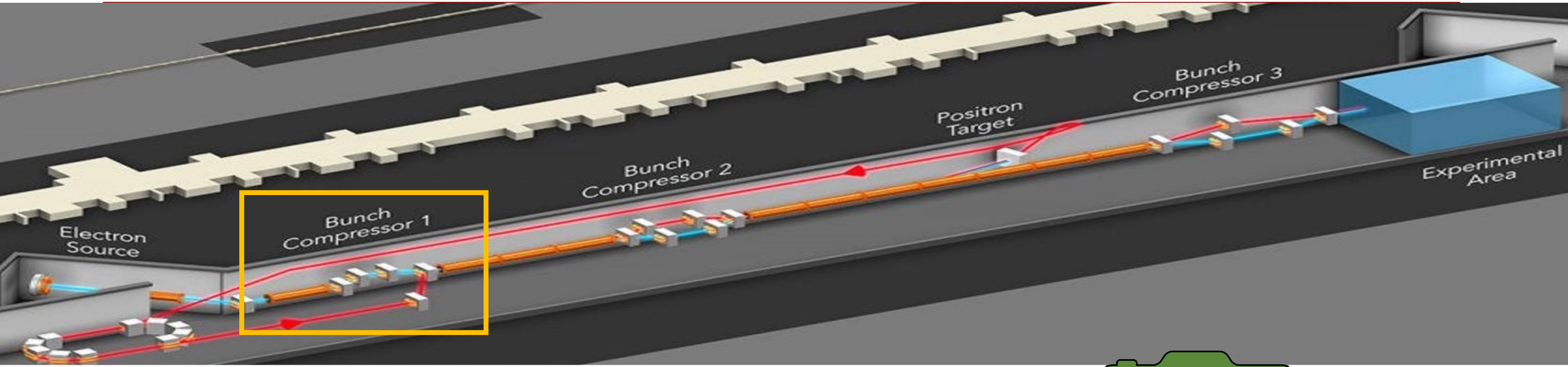


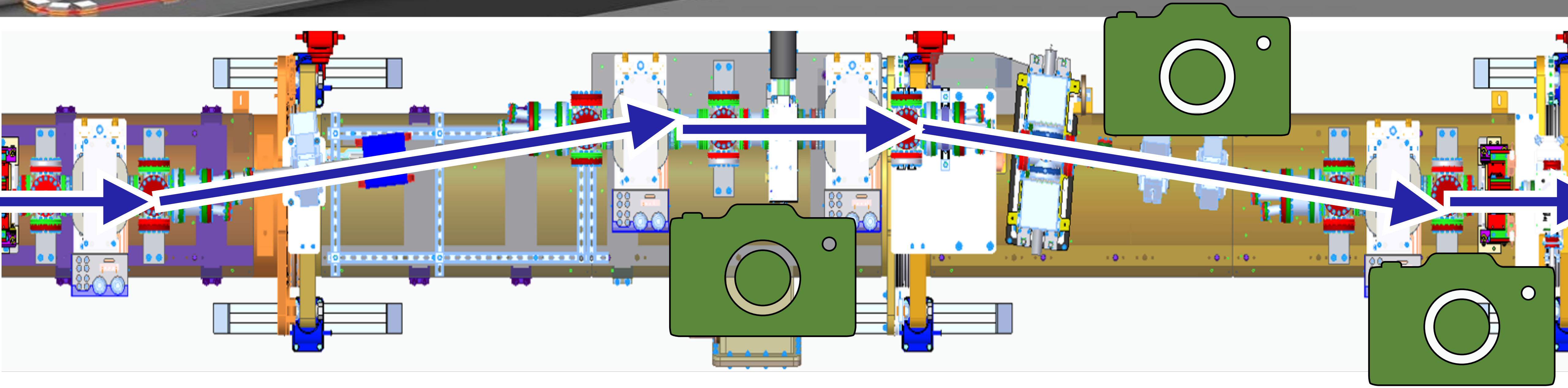
$$\frac{d^2 I}{d\Omega d\omega} = (E_1 + E_2)(E_1 + E_2)^* = |E_1|^2 + |E_2|^2 + 2E_1 E_2^*$$



Beam distribution reduces contrast of high frequency interference

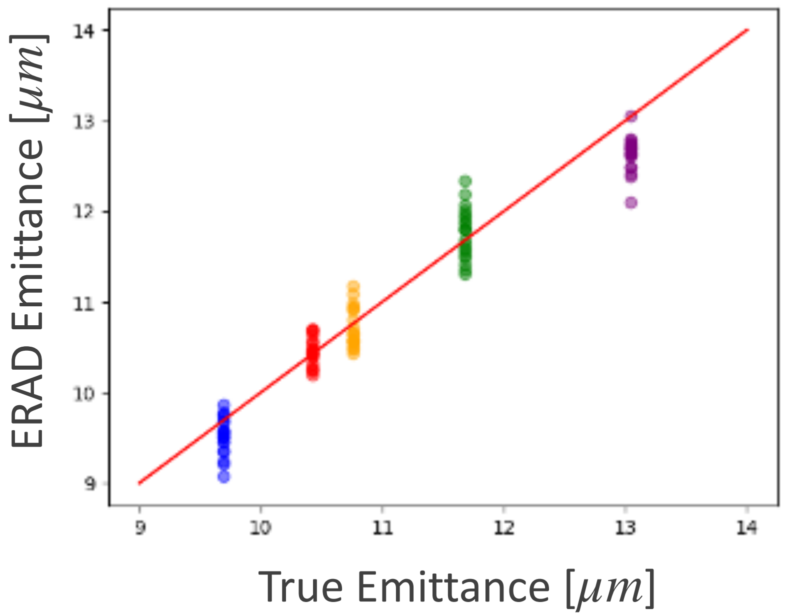
Diagnostic located in BC11

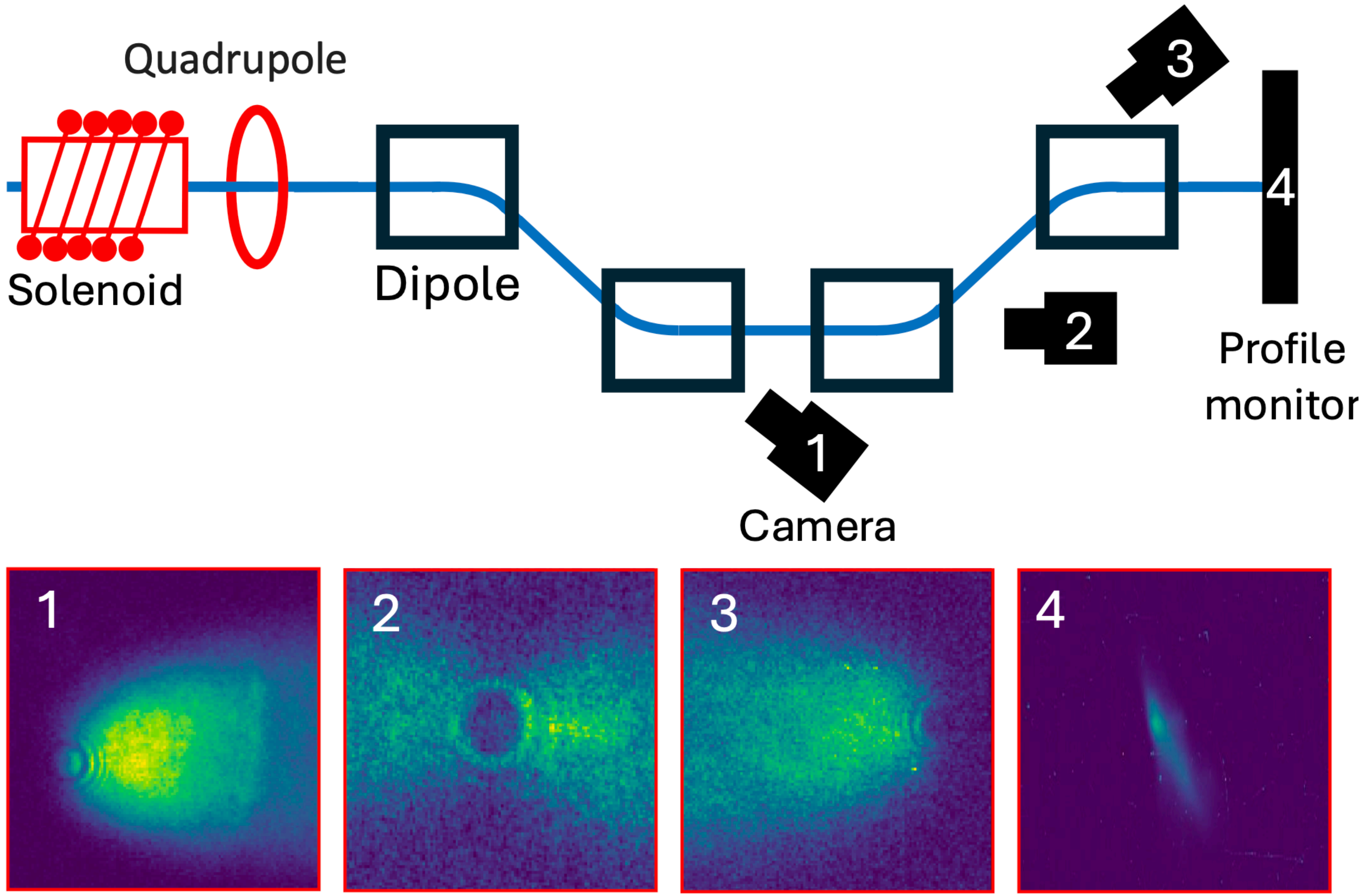




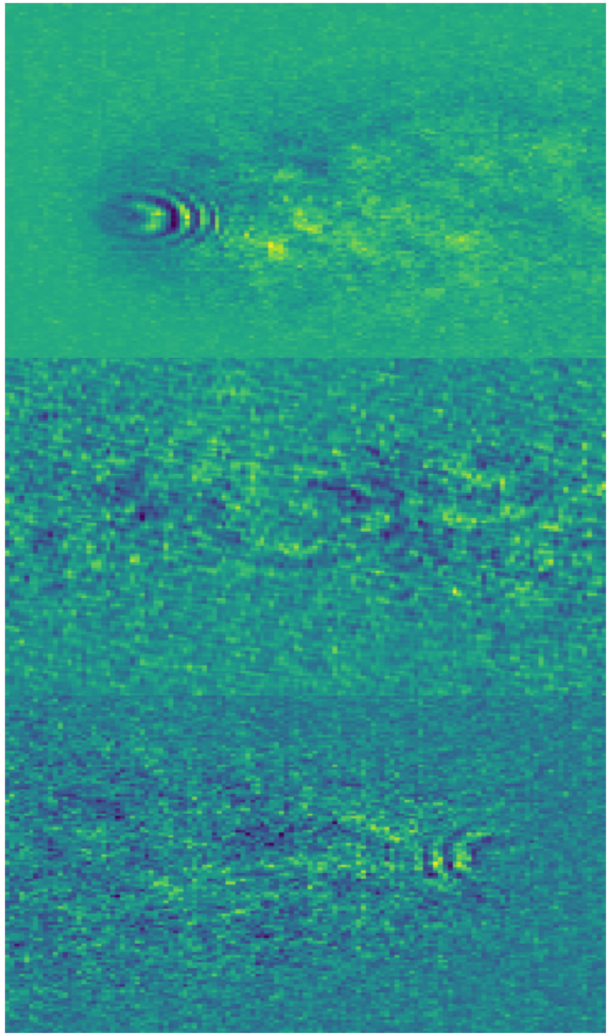
Results in a nutshell

- Measurements made at 3 nC
- Solenoid used to change emittance
- Quad scan used to collect data

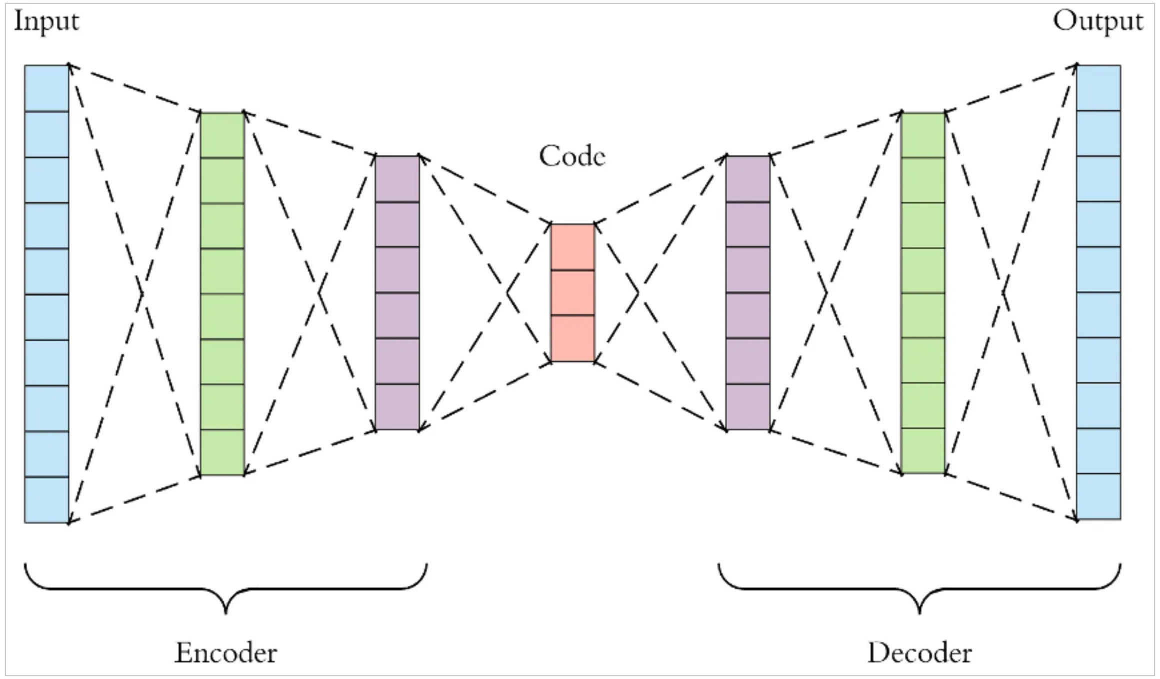




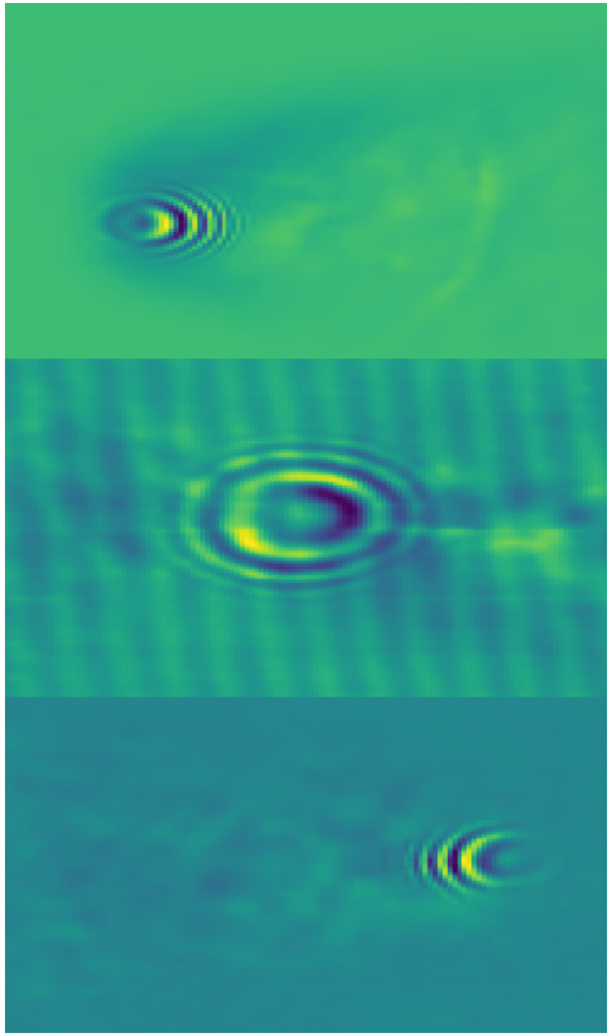
Latent representation of images



- Autoencoder learns to focus on interference
- Noise is not propagated downstream

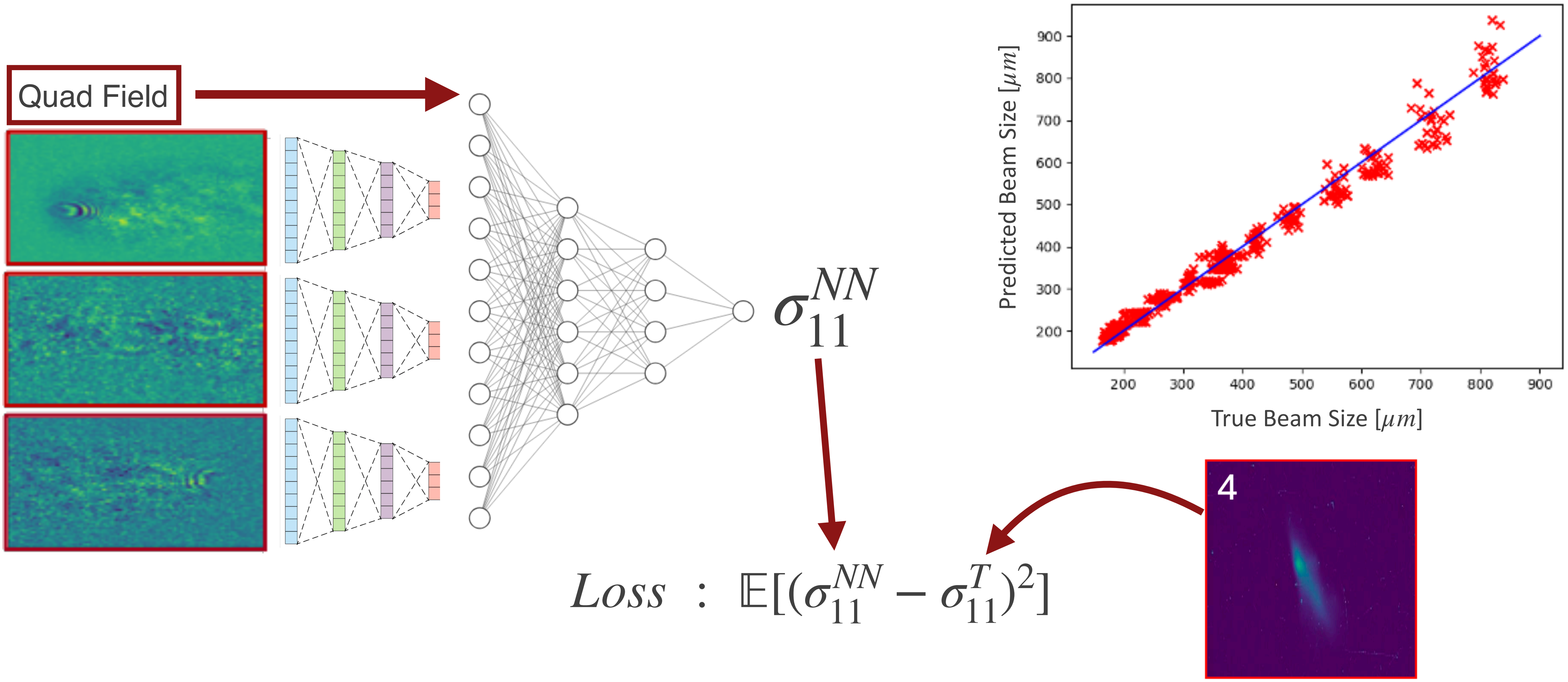


- Latent space of 5 parameters



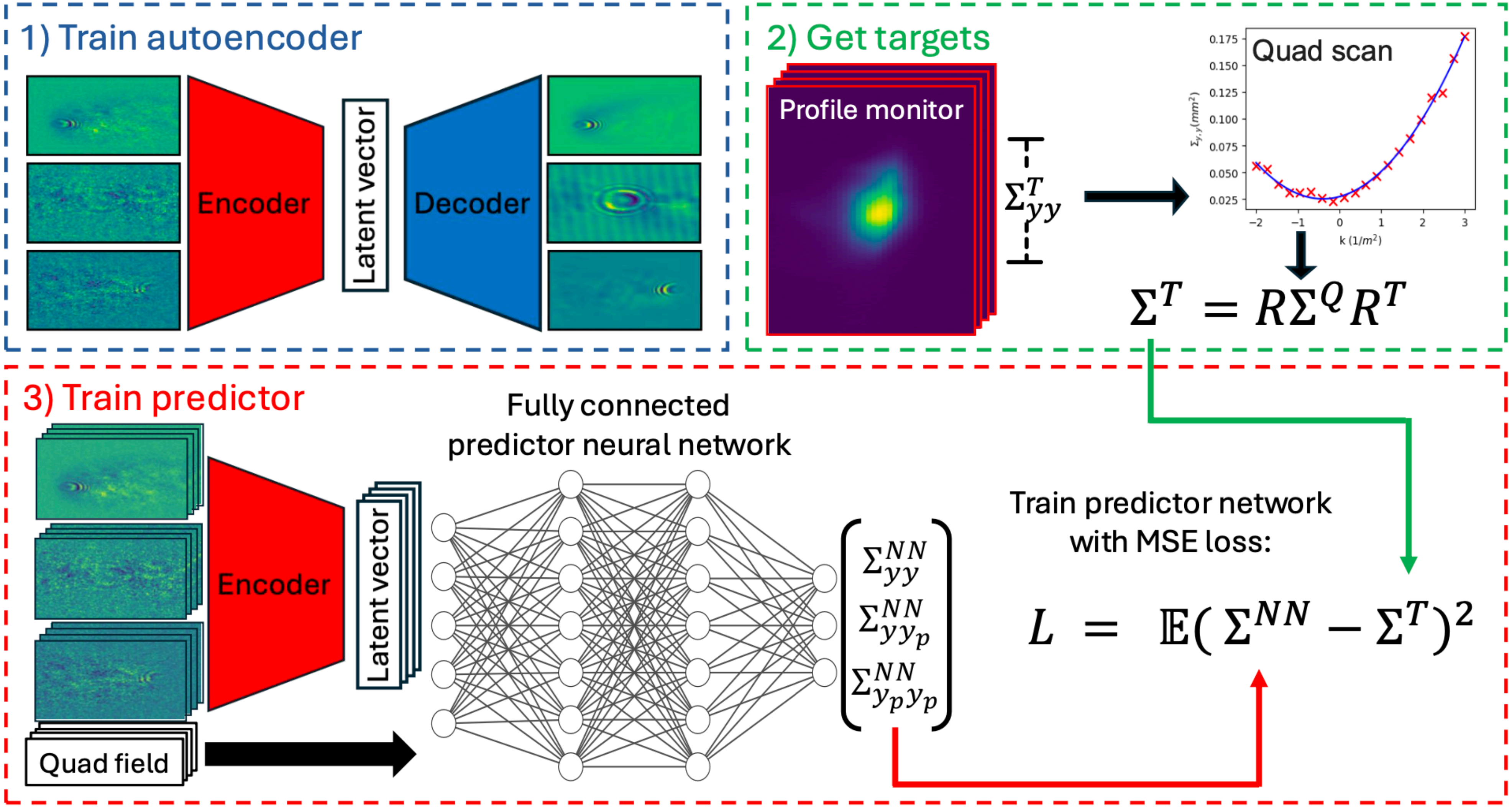
Latent representation converts noisy images to robust scalars

Convert latent images into real beam parameters



Transform latent space into beam size

We can do better than physical rms

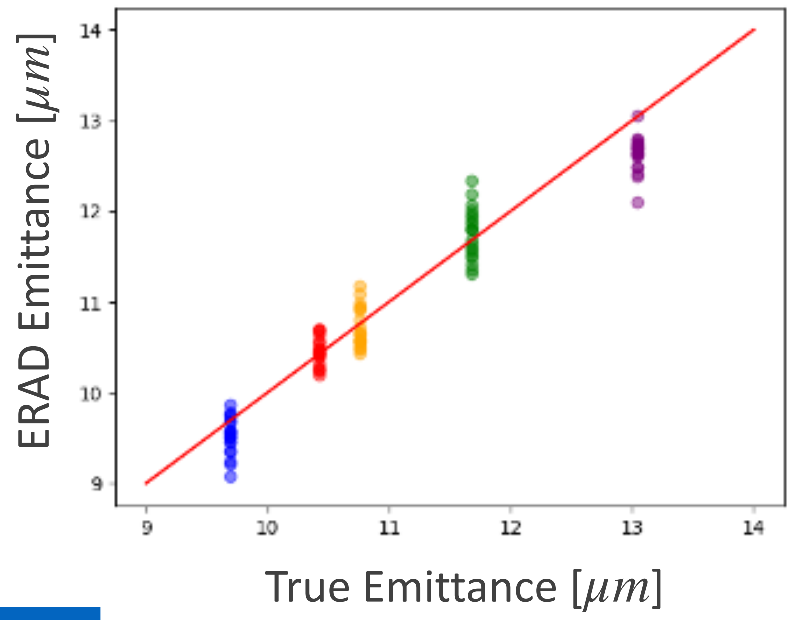


Transform latent space into emittance

Plans for FY25

$$\varepsilon_n^{NN} = \gamma\sqrt{\sigma_{11}^{NN}\sigma_{22}^{NN} - (\sigma_{12}^{NN})^2}$$

- Demonstrated operation principal!
- Improvements to be made in light collection
- Goal: Run E326 at the same time as other experiments



$$\frac{c_2}{c_1} \propto \left(\frac{f_1}{f2}\right)^2 \left(\frac{p_2}{p_1}\right)^2 \left(\frac{QE_2}{QE_1}\right) \left(\frac{fNum_1}{fNum_2}\right)^2$$

Camera	*Pixel size p [um]*	*QE @ 490 nm*	*f [mm]*	*f#*	*c2/c1*
Mako G-125	*3.75*	*0.55*	*50*	*1.4*	*1.00*
Mako G-40	*6.9*	*0.70*	*50*	*1.2*	*5.86*
Hamamatsu ORCA FLASH V4	*6.5*	*0.75*	*50*	*1.2*	*5.58*

- Strong synergy with injector tuning (E331) and GPSR (New Proposal)

In FY25 transition from demonstration to diagnostic