# Near-Infrared Noise in Intense Electron Beams

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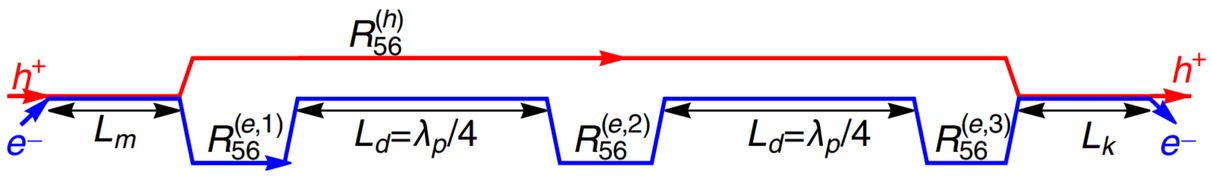
## Background

- Beam noise ≡ density fluctuations
- Important in SASE/externally seeded FELs, Coherent Electron Cooling



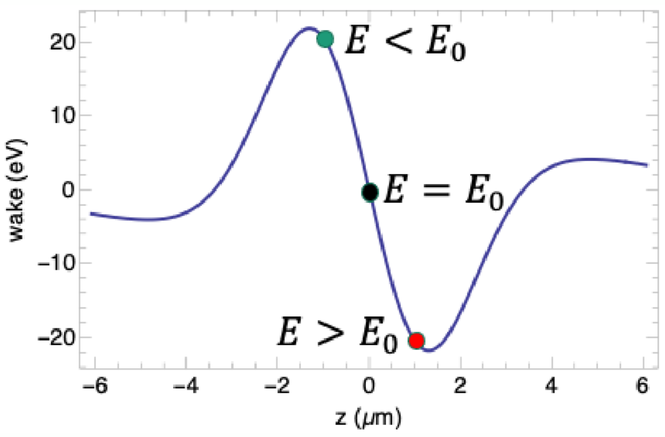

Coherent Electron Cooling at EIC

- CEC is an optical stochastic cooling with electron beam as transmitter
- Noise in electron beam → heating diffusion
- Quiet beam: diffusion is ~700 times weaker

$$\frac{D_{\text{diff}}}{D_{\text{cool}}} = 0.0013\,F$$

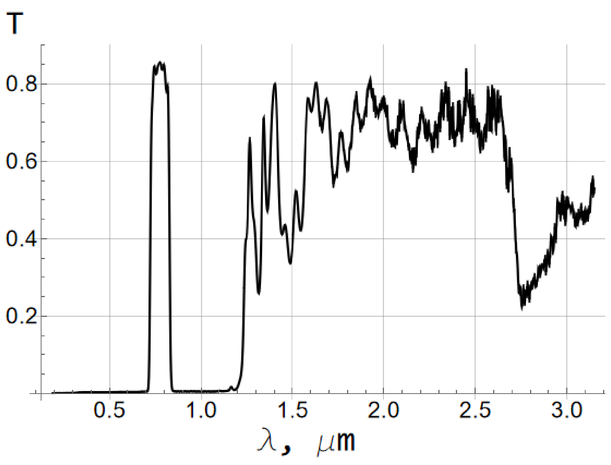
$$\frac{D_{\text{diff}}}{D_{\text{cool}}} = r_2 \frac{\int_{-\infty}^{\infty} |Z_{e,2}(k)|^2 \boxed{|\delta\rho_e(k)|^2}\, dk}{\int_{-\infty}^{\infty} |Z_{e,2}(k)|^2 \boxed{\frac{1}{n_e}}\, dk}$$

- Only $\lambda < 10\mu\text{m}$ is important

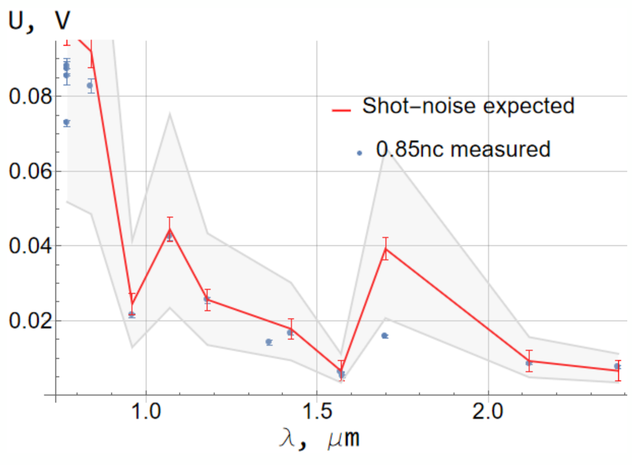



Proton energy kick in the EIC CEC

## Low-level Noise



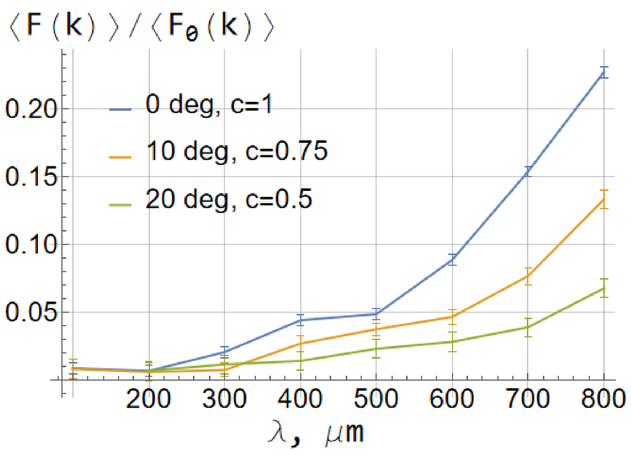

770nm filter transmission



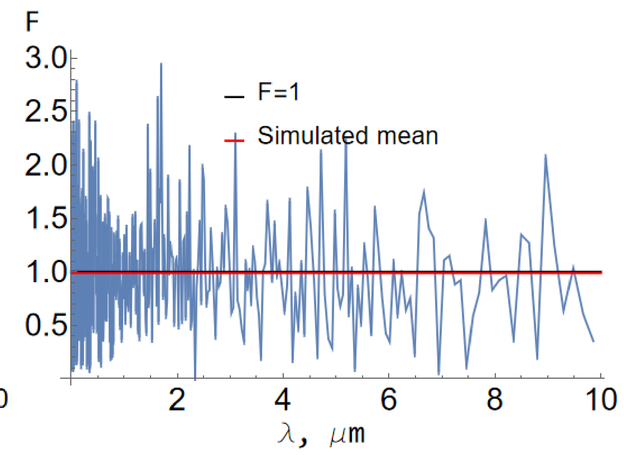

Predicted and measured OTR energy for each filter

- Errors are mainly from the optical transport line

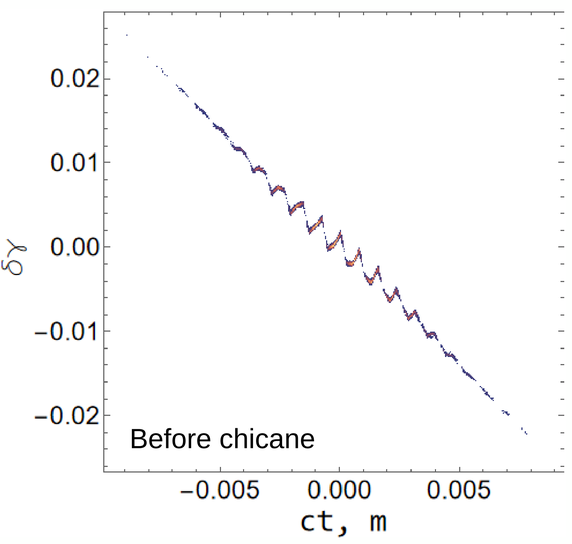
## Simulations

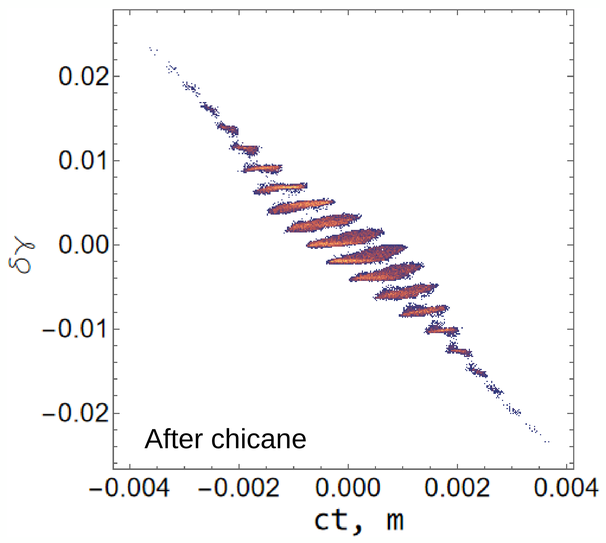



Microbunching gain dependence on initial perturbation wavelength




Beam spectrum at x121 cross. Initially modulated at $6\mu\text{m}$



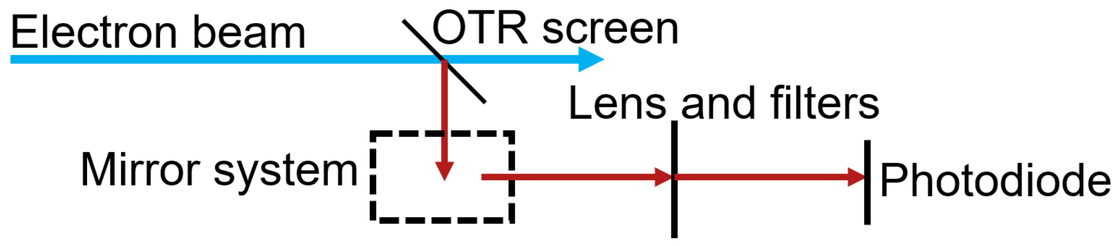

Phase space for maximum modulation amplitude, $\lambda_0 = 0.8\text{mm}$, $q = 1nC$

## Methods

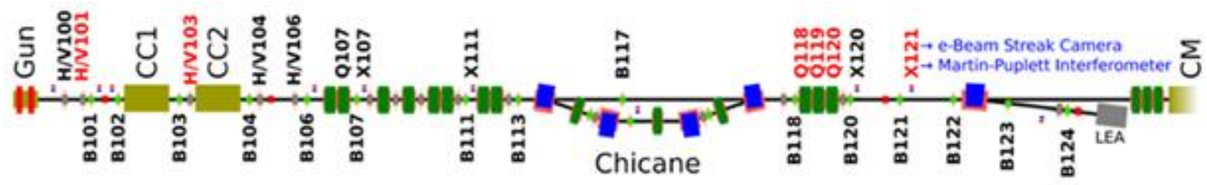
- Can be measured with Optical Transition Radiation (OTR)
- Energy per 100nm ~2pJ
- Scan the OTR spectrum with a set of BP filters

| Parameter | FAST | EIC |
|---|---|---|
| $E_p$, GeV | | 100 - 275 |
| $E_e$, MeV | 40 - 300 | 50 - 150 |
| $Q$, nC | 0 - 3 | 1 |
| $\epsilon_{\text{norm}}$, $\mu$m | 3 (at 1 nC) | 2.8 |
| $\sigma_z$, mm | 0.3 - 10 | 12 - 8 |
| $L_{\text{drift}}$, m | 80 | 100 |

- OTR intensity: $\frac{d^2I}{dwd\Omega} = \frac{d^2I_1}{dwd\Omega} N^2 |\rho(w)|^2 \propto N + \sum_{m,n,\, m\neq n} \exp(iw(t_n - t_m)/\lambda)$



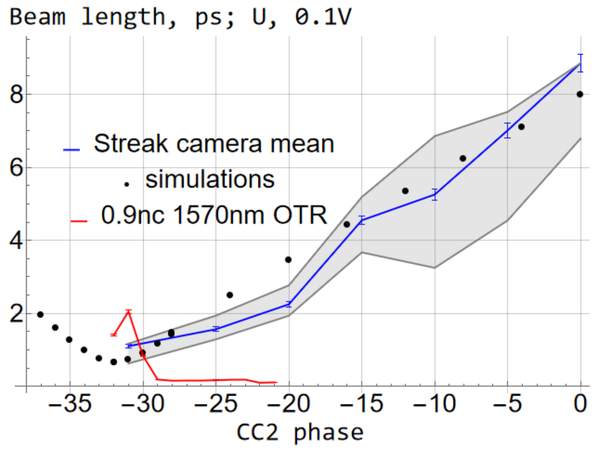

Principle experiment scheme



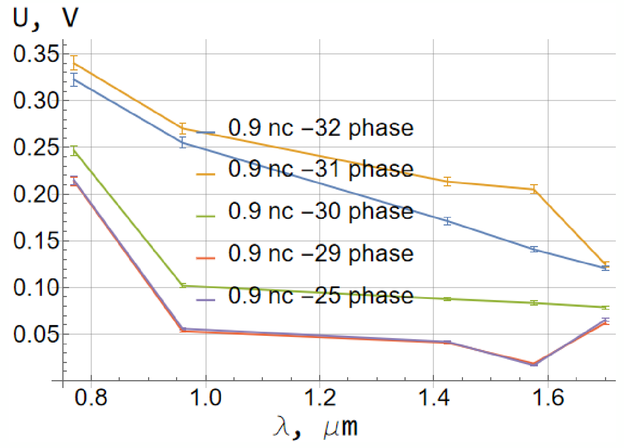

FAST layout. The NEB measurement system is installed at x121 cross

## Elevated noise

- Expected: broad-band noise elevation, increasing with wavelength

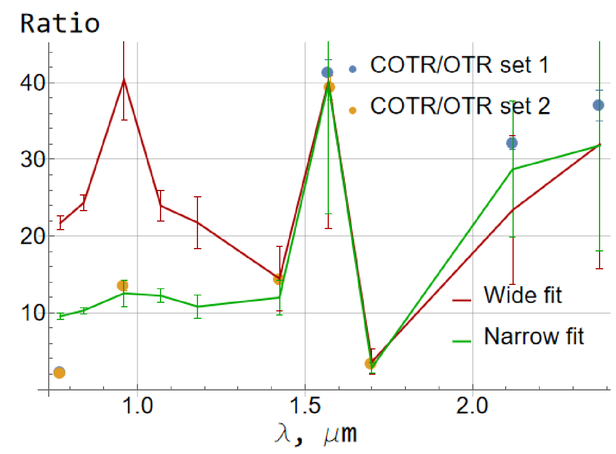



Beam size from streak camera, OTR and simulations

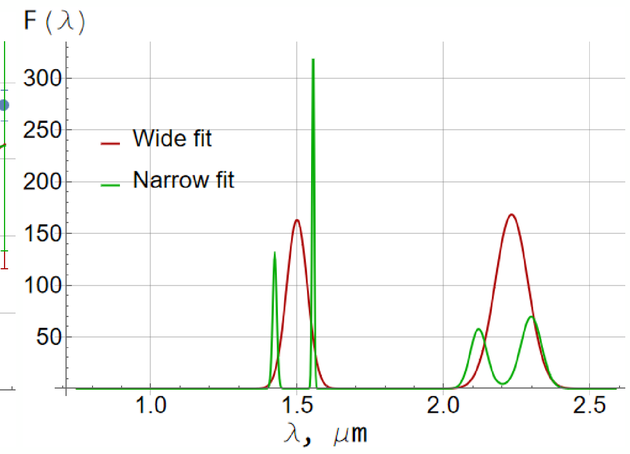



OTR signal increase with beam length decrease

- Broad-band fit: does not work; delta-functions: do not fit 770nm filter
- No radiation in $\lambda < 1.5\mu\text{m}$ region for compression factor $c = 0.1$




Elevated noise fit with a guessed beam spectrum




Beam spectrum that fits the data

## Discussion

- No noise above shot level in the region $\lambda < 10\mu\text{m}$ for uncompressed ($l > 2\text{ps}$) beam: $F = 1 \div 1.7$: $\frac{T_{diff}}{T_{\text{cool}}} > 200$ in $F = 3.1$ $(3\sigma)$
- $1\text{ps}$ short beam: $\frac{T_{\text{diff}}}{T_{\text{cool}}} \sim 5$ if no transverse size effects taken into account
- Checked for CSR: $I_{\max} \sim 1\text{kA}$, $\left.\frac{w\sigma_z}{c\sqrt{\ln N}}\right|_{\min} \sim 130$

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