Future work on the X-ray source

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SAC meeting, Uppsala

Future work

Strategic actions:

- Procure a 100 keV DC gun and a fs laser
- Hire a laser specialist
- Build a test stand for beam dynamics studies

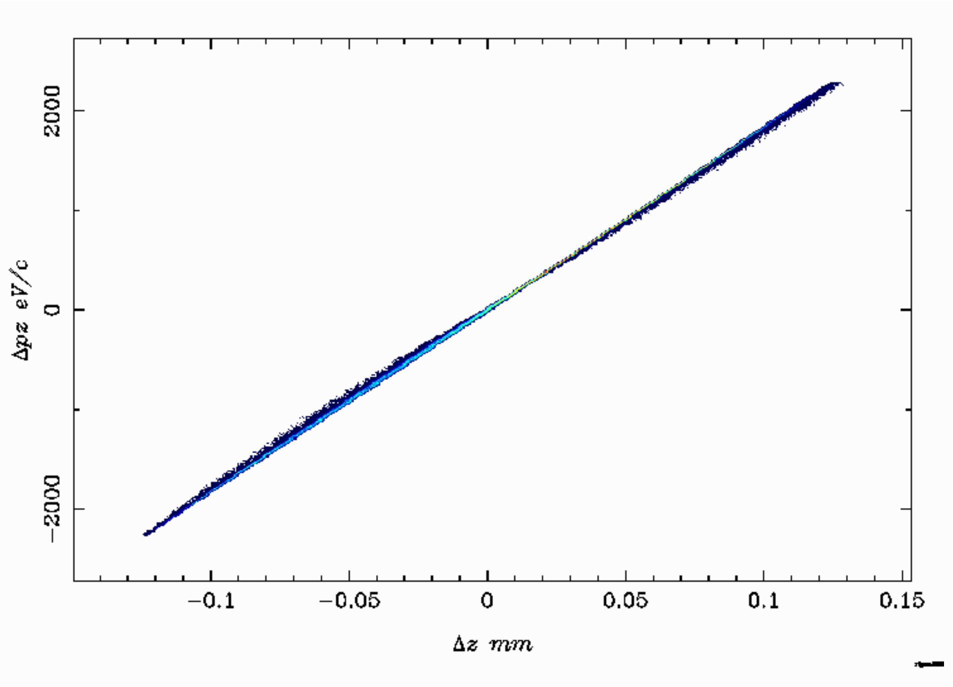
Theoretical work:

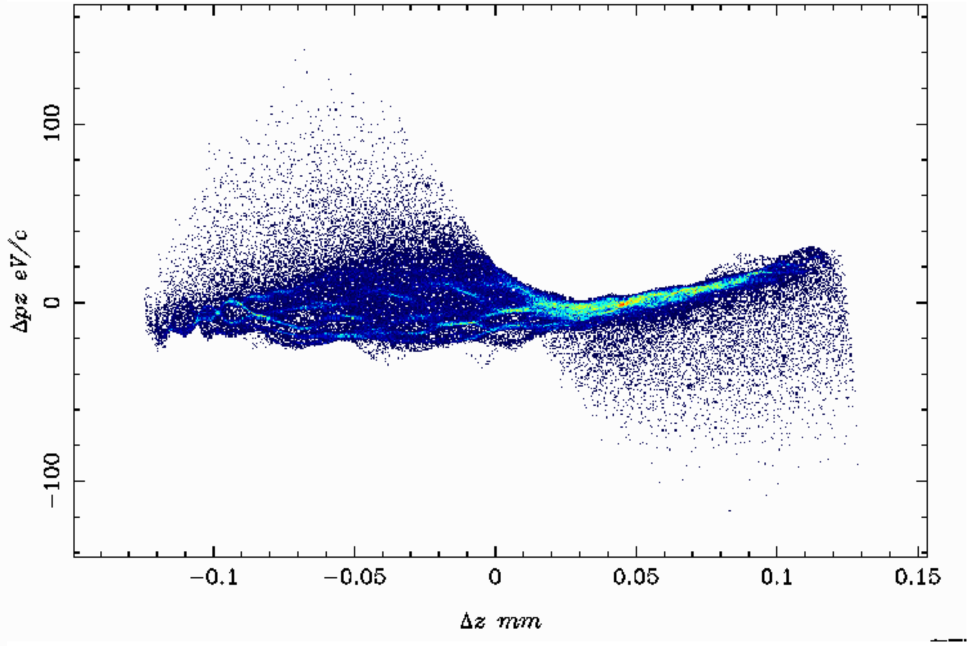
- Complete the model of the emittance exchange line
- Optimize electron optics for the nominal charge (16 and 1.6 pC)
- Investigate the regime of small-period structuring of the bunch
- Design the optical system (will answer many questions)
- Quantum simulations of electron diffraction on the crystal

Experimental work

- Get experience with low-emittance electron bunches
- Fabrication of a perforated crystal for diffraction
- Formation of transversely-structured electron bunches

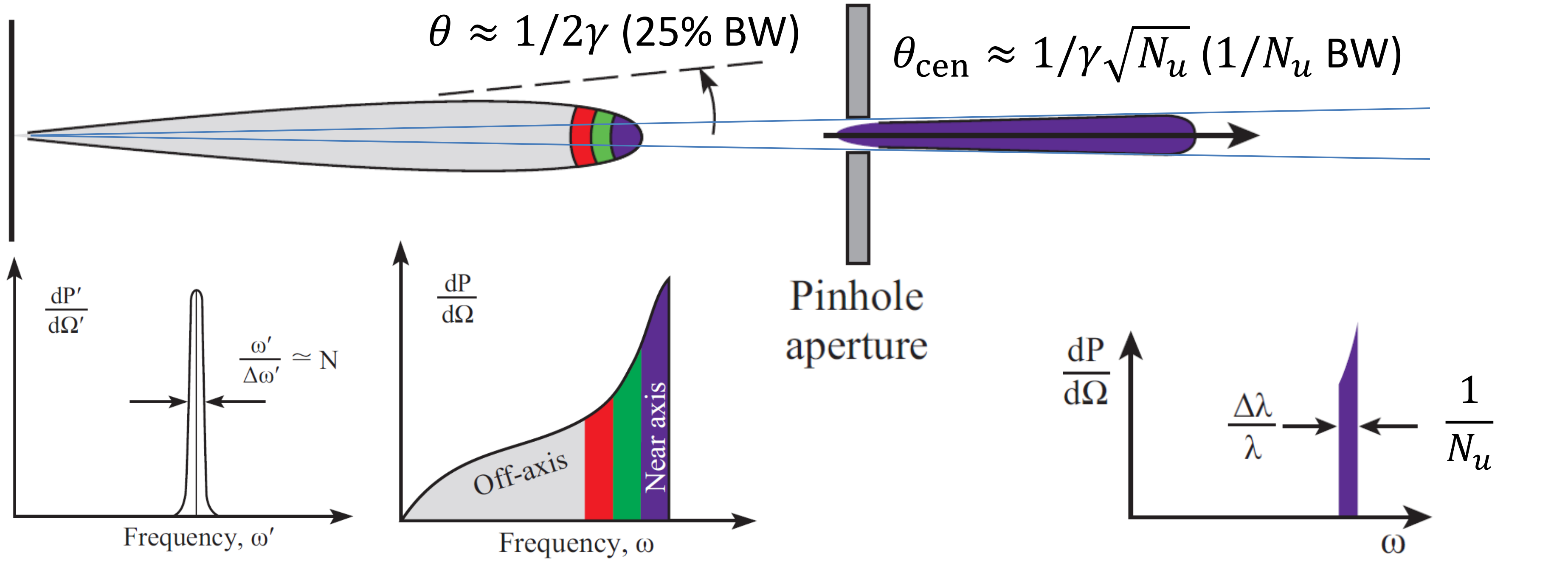
Comment on the longitudinal phase space





Correct bunch distribution from Zoltan and Kevin

Design of Compton source: idealized case



$$N_{\text{X-ray}} \approx N_e \pi \alpha \frac{\mathcal{K}^2}{(1+\mathcal{K}^2)} \approx N_e \pi \alpha \mathcal{K}^2$$

$$\mathcal{K}^2 = \frac{2 r_e I_L}{\pi m c^3} \lambda_L^2$$

Number of X-ray photons into the central cone for a **zero-emittance** electron beam and a **uniform** laser beam

Design of Compton source: realistic case

$$N_{\text{X-ray}} \approx N_e \pi \alpha \mathcal{K}^2 \frac{\text{BW}}{\Delta\omega/\omega} \frac{1}{1+\frac{\sigma_b^2}{\sigma_L^2}}$$

$$\mathcal{K}^2 = \frac{2 r_e I_L}{\pi m c^3} \lambda_L^2$$

$$\frac{\Delta\omega}{\omega} = \sqrt{\frac{1}{N_u^2} + \frac{\gamma^4 \Delta\theta_e^4}{4} + \left(\frac{\Delta\theta_e^2 + \Delta\theta_L^2}{8}\right)^2 + 4\frac{\Delta\gamma^2}{\gamma^2} + \frac{\Delta\omega_{\text{pon}}^2}{\omega^2}}$$

Intrinsic laser BW

broadening from e-beam divergence

broadening from laser beam divergence

broadening from e-beam energy spread

ponderomotive broadening

- Maximize $\mathcal{K}$
- Balance different contributions to $\Delta\omega/\omega$ to minimize broadening
- Maximize the number of electrons N_e (constrained by the laser pulse volume and ponderomotive broadening)

Comment on a higher charge operation

$$N_{\mathrm{x-ray}} \approx N_e \pi \alpha \mathcal{K}^2 \frac{\mathrm{BW}}{\Delta\omega/\omega} \frac{1}{1+\frac{\sigma_b^2}{\sigma_L^2}}$$

$$\mathcal{K}^2 = \frac{2 r_e I_L}{\pi m c^3} \lambda_L^2$$

- Number of electrons $N_e \propto \sigma_0^2$
- Thermal emittance $\varepsilon_t \propto \sigma_0$
- Normalized emittance after the gun $\varepsilon_n \propto \sigma_0^{1+\delta}$, $\delta = 0.3 - 0.5$
- $\sigma_L > \sigma_e$ to mitigate the ponderomotive broadening
- Scaling of the number of photons $N_{\mathrm{x-ray}} \propto N_e \frac{\mathcal{E}_L}{\sigma_L^2} \propto \frac{\sigma_0^2}{\sigma_0^{2+2\delta}}$