RadiaSoft Efforts for Modeling Strongly Tapered Undulators

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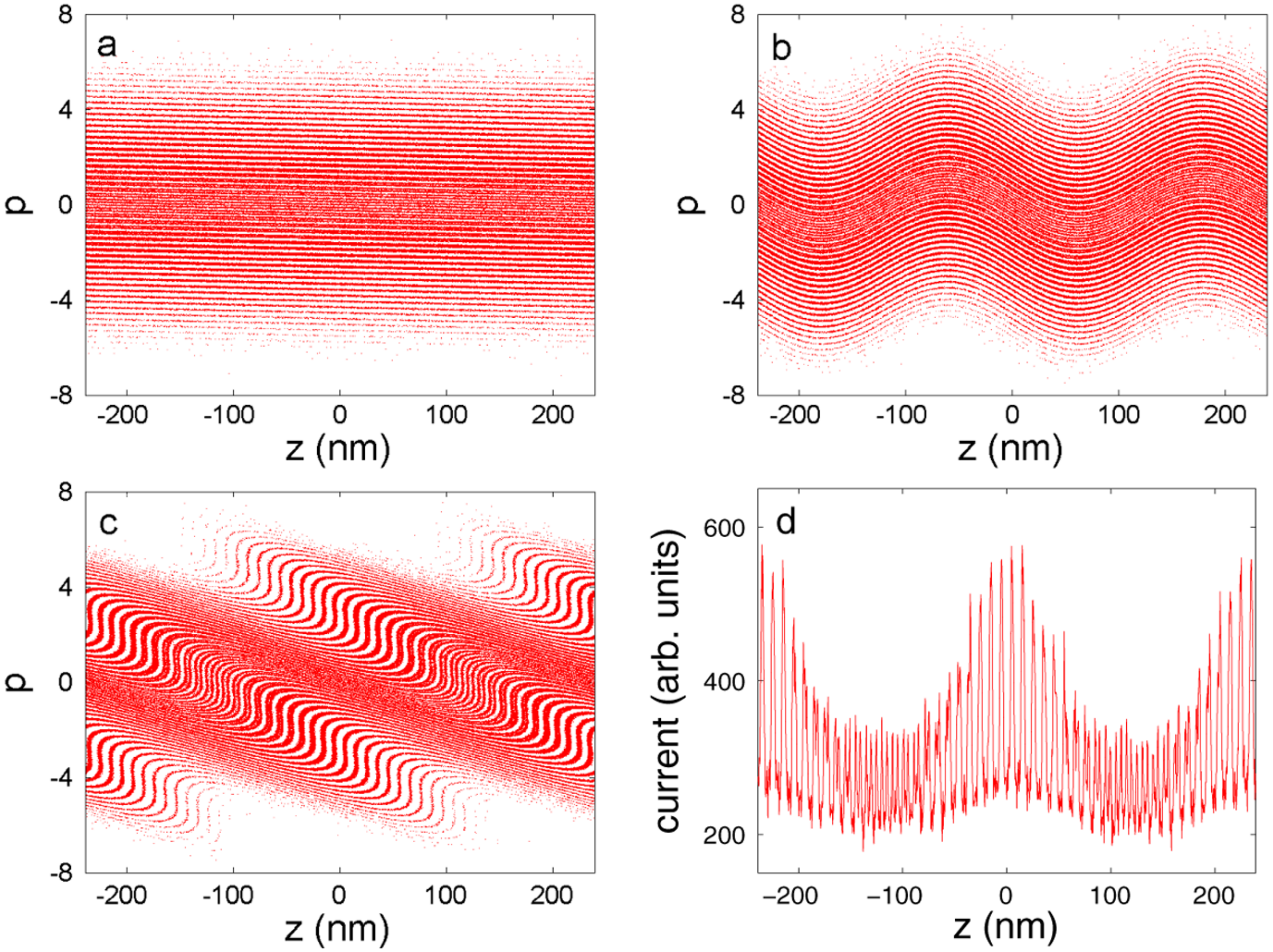
TESSA Presents some Unique Challenges for Modeling an FEL

- Requires flexible tapering schemes
- Potential for very large final energy spread

Other motivations for the Phase I
(why are you writing a Vlasov code?)

- A very nice letter from Tor Raubenheimer
- Study SASE effects in EEHG (LCLS-II)
- Impossible using Fawley loading

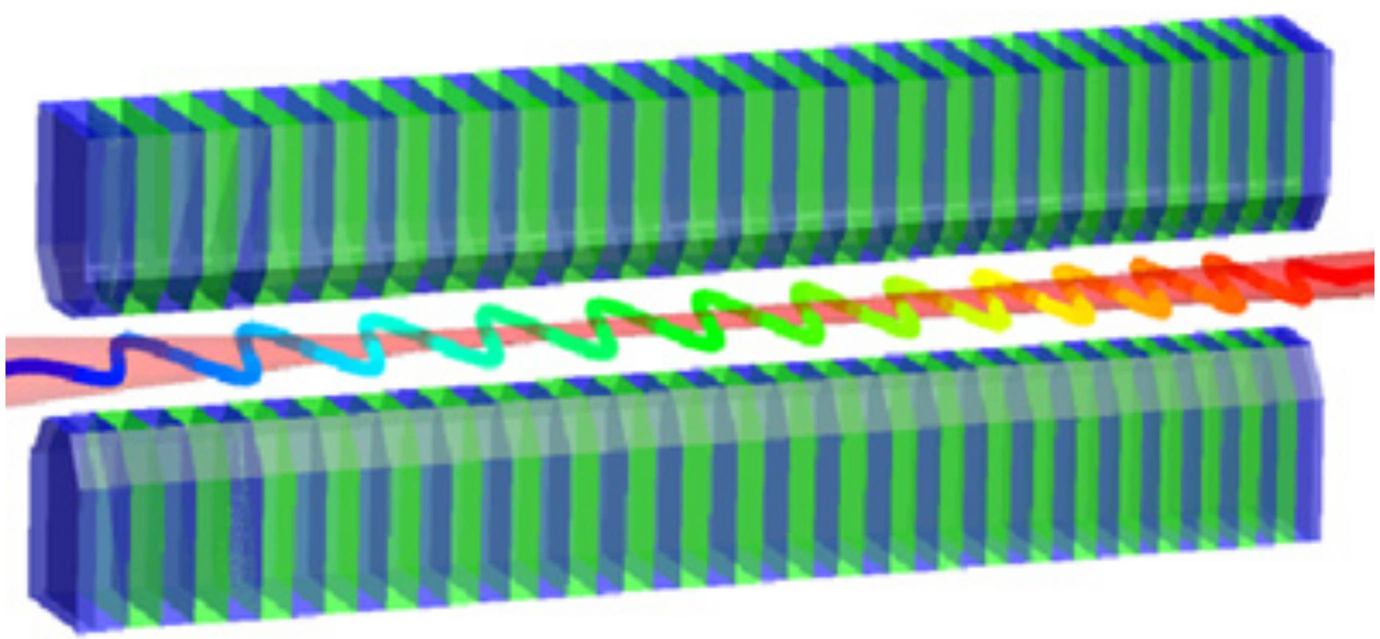


from D. Xiang and G. Stupakov PRSTAB **12**, 030702 (2009)

How to deal with tapering

$$(\theta_{fin.}, \gamma_{fin.}) = \mathscr{M}_u \circ (\theta_{in.}, \gamma_{in.})$$

Strongly tapered undulator



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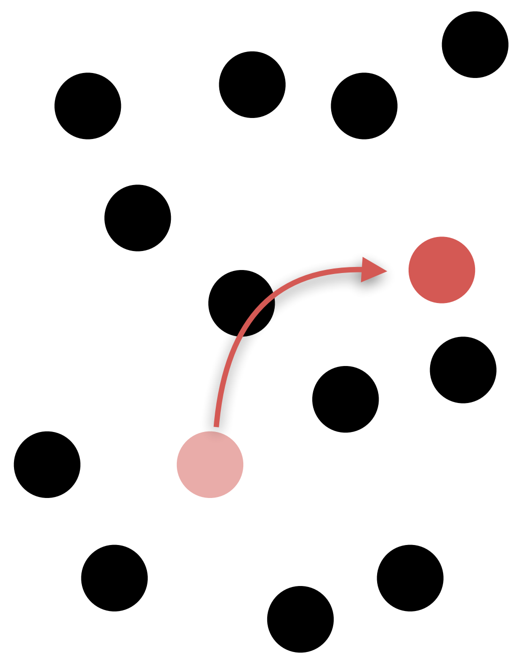

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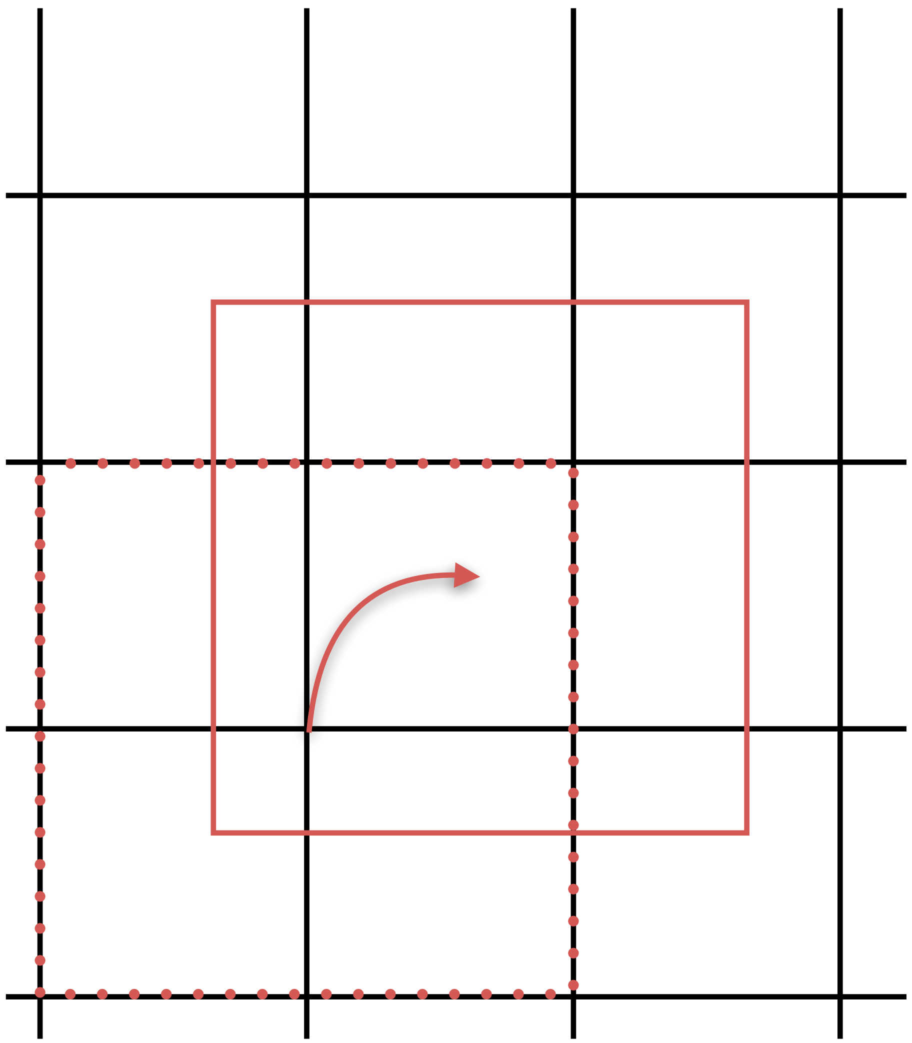
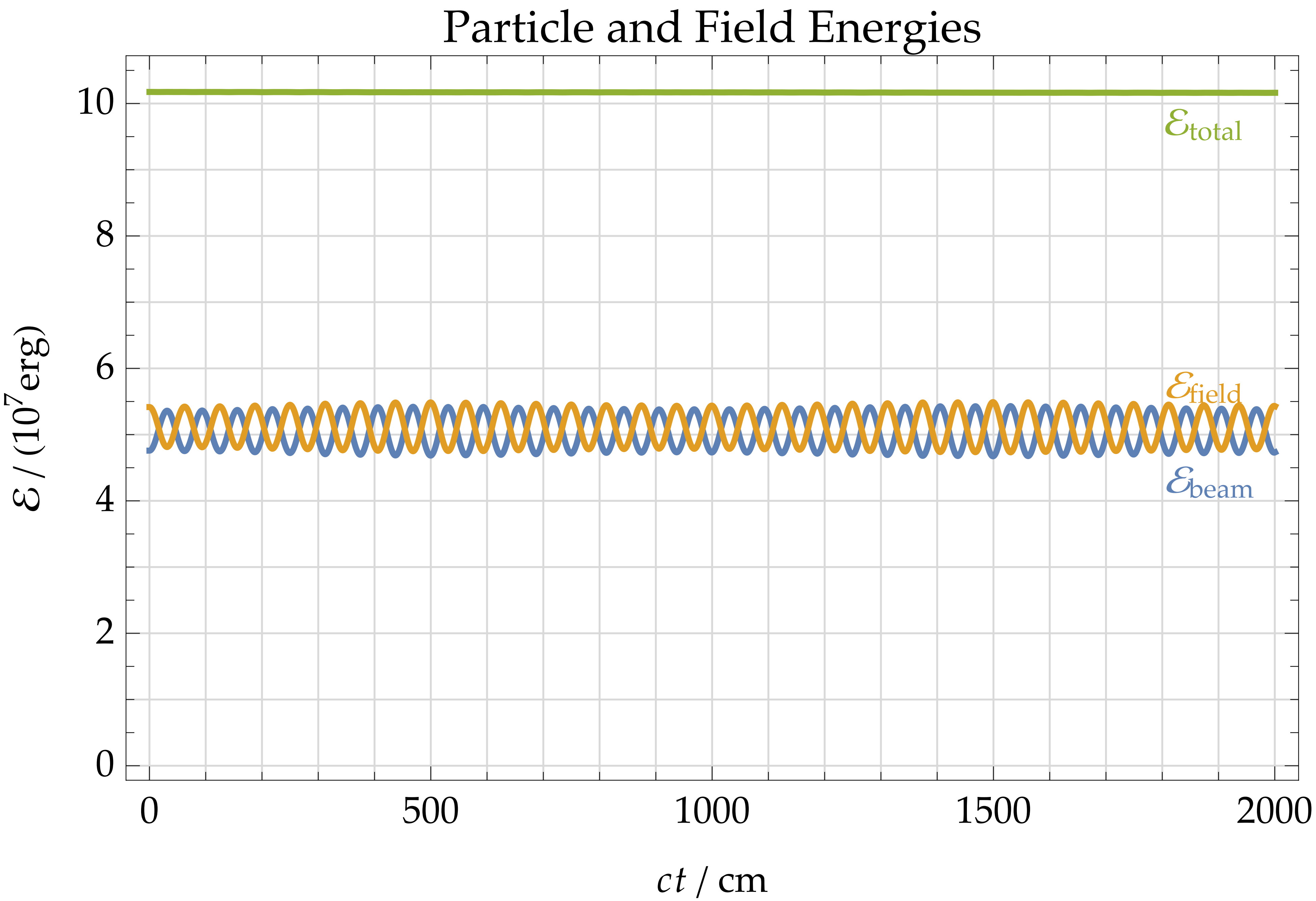
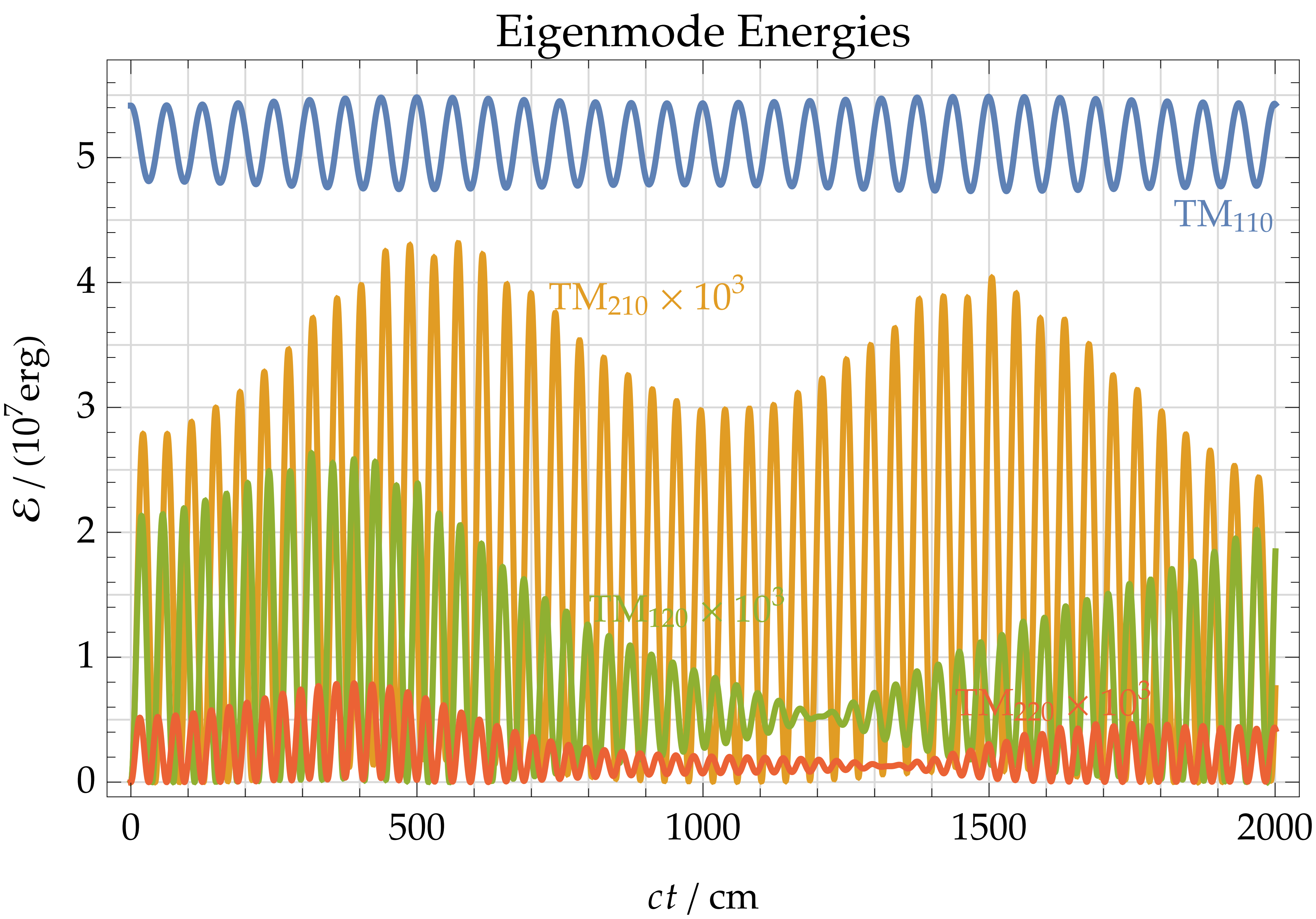




Prior success: beam loading

arXiv:1611.00343, “Symplectic Modeling of Beam Loading in Electromagnetic Cavities”



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1D FEL Example

$$\mathscr{P}_z = \sum_j \left\{ -p_\tau^{(j)} + \frac{1}{2}\frac{m^2c^2}{p_\tau^{(j)}} + \frac{1}{2}\frac{e^2}{c^2}\frac{|\mathbf{A}_w(z)|^2}{p_\tau^{(j)}} + \frac{1}{2}\frac{e^2}{c^2}\frac{\mathbf{A}_w \cdot \mathbf{A}_r}{p_\tau^{(j)}} \right\} + \frac{1}{2}\left(\mathcal{P}_r^2 + k_0^2 \mathcal{Q}_r^2\right)$$

$$\mathbf{A}_r = \mathcal{Q}_r e^{ik_0\tau}\mathbf{e}_r$$

Factored Map Formalism

$$\mathscr{M} = \mathscr{M}_I \mathscr{M}_0$$

$$\dot{\mathscr{M}}_0 = -\mathscr{M}_0 \, {:}{-p_\tau} + \frac{m^2 c^2}{2 p_\tau} + \frac{e^2}{c^2} \frac{\left|\mathbf{A}_w(z)\right|^2}{2 p_\tau} + \frac{1}{2}\left(\mathcal{P}_r^2 + k_r^2 \mathcal{Q}_r^2\right){:}$$

Interaction Map

$$\dot{\mathscr{M}}_I = -\mathscr{M}_I \left\{ \mathscr{M}_0 : \frac{e^2}{c^2} \frac{\mathbf{A}_w \cdot \mathbf{e}_r \mathcal{Q}_r e^{ik_r\tau}}{2p_\tau} : \mathscr{M}_0^{-1} \right\}$$

$$\mathscr{M}_0 : \frac{e^2}{c^2} \frac{\mathbf{A}_w \cdot \mathbf{e}_r \mathcal{Q}_r e^{ik_r\tau}}{2p_\tau} : \mathscr{M}_0^{-1} =$$

$$: \frac{e^2 B_w}{2k_w c^2} \cos(k_w z) \frac{\mathcal{Q}_r \cos(k_r z) - \mathcal{P}_r \sin(k_r z)}{p_\tau} \exp\left[ik_r \left(\tau + (z - z_i) - \frac{m^2 c^2}{p_\tau^2}(z - z_i) - \frac{e^2}{2c^2} \frac{\int_{z_i}^{z} dz \, |\mathbf{A}_w(z)|^2}{p_\tau^2} \right) \right] :$$

Period-Averaging from a Hamiltonian Perspective

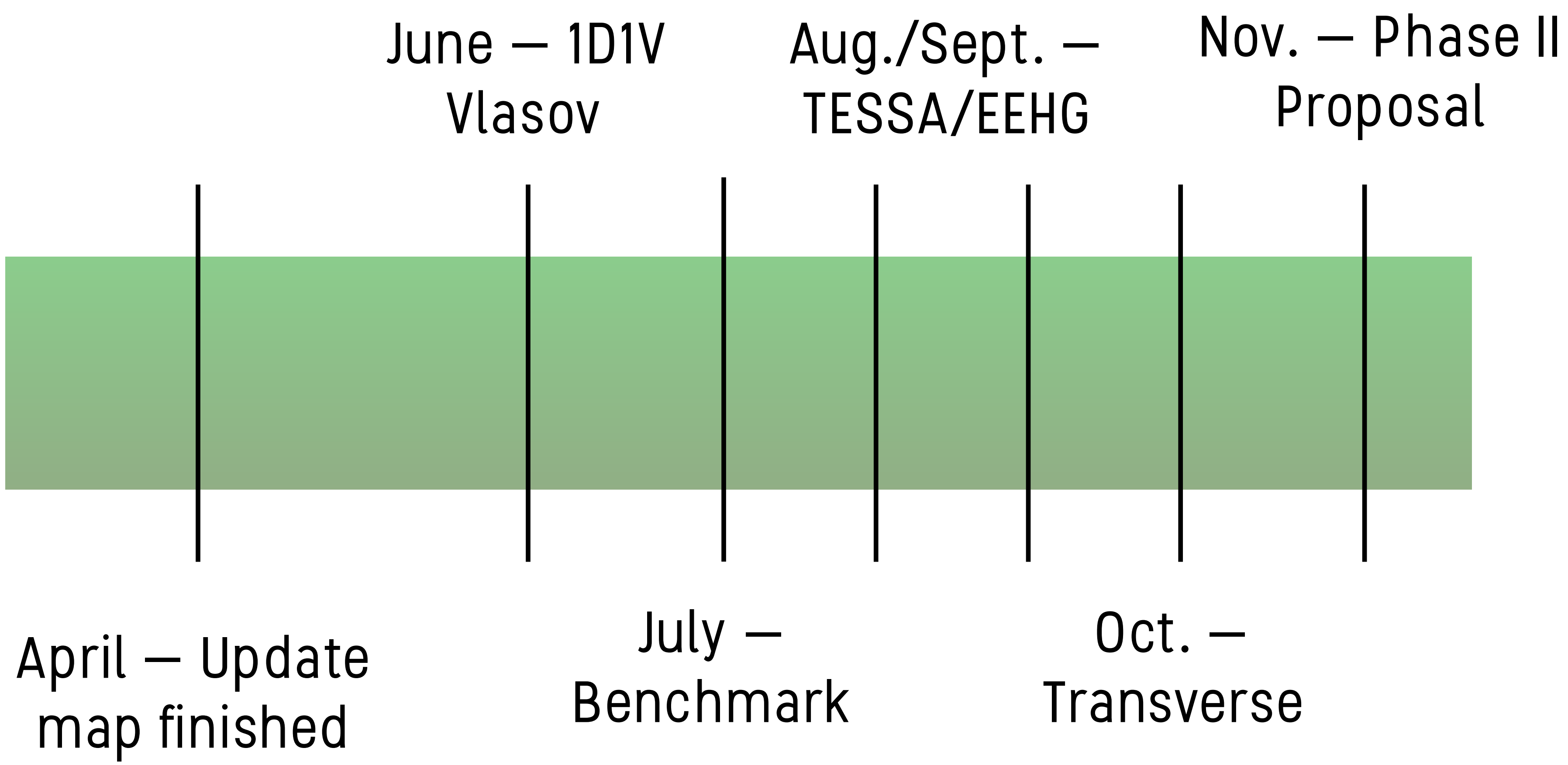
$$\mathscr{M}_I(z_i \to z_i + L_w) \approx \exp\left\{ - : \int_{z_i}^{z_i + L_w} \mathscr{P}_z^{(I)}(z') dz' : \right\}$$

$$= \exp\left\{ - : L_w \left\langle \mathscr{P}_z^{(I)}(z) \right\rangle_z : \right\}$$

Phase I Goals

- 1D1V Vlasov algorithm & implementation
- Benchmark to data (LCLS, Genesis, etc.)
- TESSA simulations (w/ us)
- EEHG simulations (w/ SLAC)
- Ideas about hybrid Vlasov-macroparticle

Phase I Timeline



Long term vision

- 3D hybrid Vlasov-macroparticle code for next-generation FELs
- Benchmarked to early TESSA experiments and used for design of TESSA FEL
- Small user group for code here & for LCLS-II