Possible Application of Round-to-Flat Hadron Beam Creation Using 3rd Order Coupling Resonances for the Electron-Ion Collider

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Introduction

- The Electron-Ion Collider (EIC) will be built at the Brookhaven National Laboratory and will reuse many components of the existing BNL accelerator complex

- The luminosity scales as

$$L \propto \frac{1 + \frac{\sigma_y}{\sigma_x}}{\sqrt{\frac{\sigma_y}{\sigma_x}}} \left(\frac{1}{\beta^*_{xe}\beta^*_{ye}\beta^*_{xh}\beta^*_{yh}} \right)^{1/4}$$

- Flat beams with $\sigma_x^* \approx 10\sigma_y^*$ provide the optimum luminosity
- Achieved by having $\beta_y^* \ll \beta_x^*$ and $\epsilon_y < \epsilon_x$

Round-to-Flat beams

- Ion beams delivered by AGS are round and must be made flat
  - ϵ_x can be increased using kicker noise or injection mismatch

- Crossing the “Walkinshaw resonance” $\nu_x - 2\nu_y$ is known to create flat beams with $\epsilon_y > \epsilon_x$. Mainly driven by normal sextupoles.
  - Not only is ϵ_y increased, but ϵ_x is decreased

- We are interested in $\epsilon_y < \epsilon_x$, so how about $2\nu_x - \nu_y$?
  - Mainly driven by skew sextupoles

Resonance crossing of $2\nu_x - \nu_y$

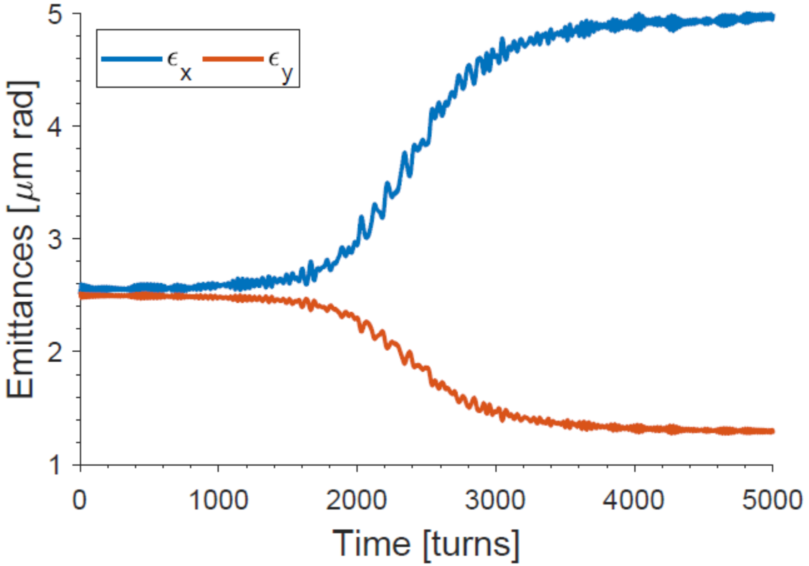
- A tracking example

- Simple tracking using one-turn maps followed by thin skew sextupole kick

Example:

$\beta_x = 8\ [m], \beta_y = 2\ [m], j_3\ell = 4.7\ [m^{-2}]$
$\alpha_x = \alpha_y = 0$

$\nu_y = 0.40, \nu_x = 0.225 \rightarrow 0.175$ over 5000 turns
$\epsilon_x = \epsilon_y = 2.5\ [\mu m\ rad]$

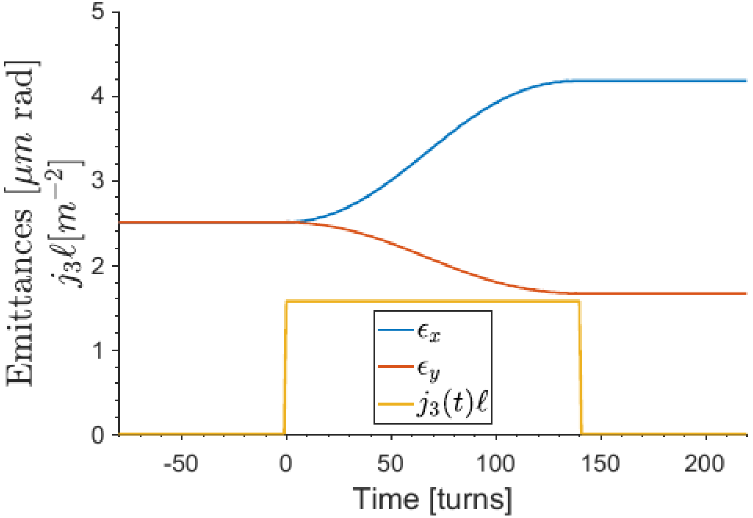


- After the crossing: $\epsilon_x/\epsilon_y = 3.9$
    - Theory suggests 4.0 as maximum

Alternative methods:
Pulsed skew sextupole

- Working point directly on (or close to) $2\nu_x - \nu_y$ which is normally weakly excited
- Pulse skew sextupole to let stop-band overlap working point
  ➔ emittances start exchanging
- Turn off magnet when best exchange achieved

- $\epsilon_x/\epsilon_y \approx 2.5$ achieved, consistent with existing theory
  – No tune-changes needed!



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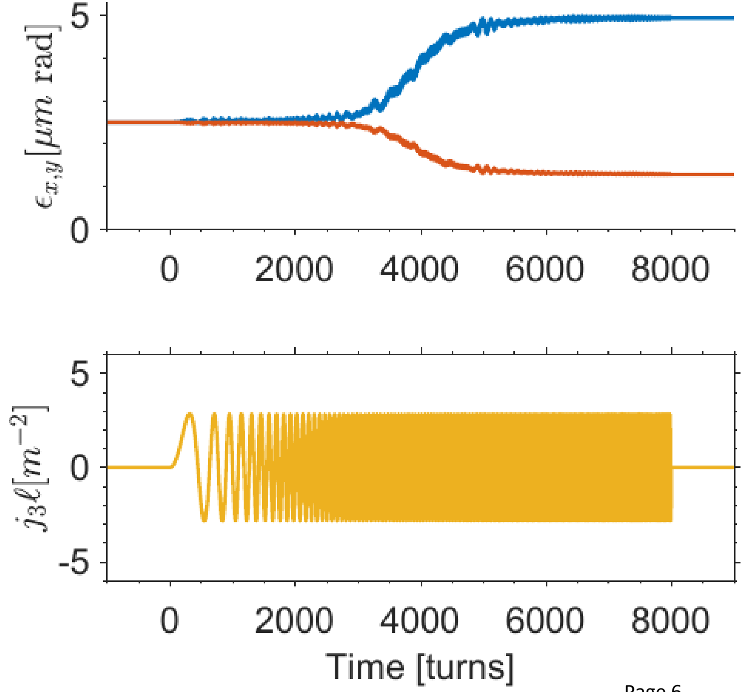
Alternative methods:
swept-frequency AC skew sextupole

- Resonance crossing and pulsed skew sextupoles require working point close to $2\nu_x - \nu_y$ which limits applicability

- Alternative: fix working point far away from resonance, but induce resonance by AC skew sextupole
  Resonance condition: $2\nu_x - \nu_y - \nu_{osc} - \ell = 0$
- Sweeping across the resonance condition creates a resonance crossing



Example:

- Select $\nu_x = 0.20, \nu_y = 0.42 \Rightarrow \nu_{osc} = 0.02.$
- Sweep $\nu_{osc} = 0.01 \rightarrow 0.03$ in 8000 turns
- Result: $\epsilon_x / \epsilon_y = 3.9$

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Conclusions

- Three methods for creating round-to-flat ion beams for the EIC using the $2\nu_x - \nu_y$ resonance has been considered
  - Resonance crossing: $\epsilon_x/\epsilon_y \approx 4$
  - Pulsed skew sextupole: $\epsilon_x/\epsilon_y \approx 2.5$
  - Swept frequency AC skew sextupole: $\epsilon_x/\epsilon_y \approx 4$

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