Beam Dynamics Studies of CLIC DB Injector

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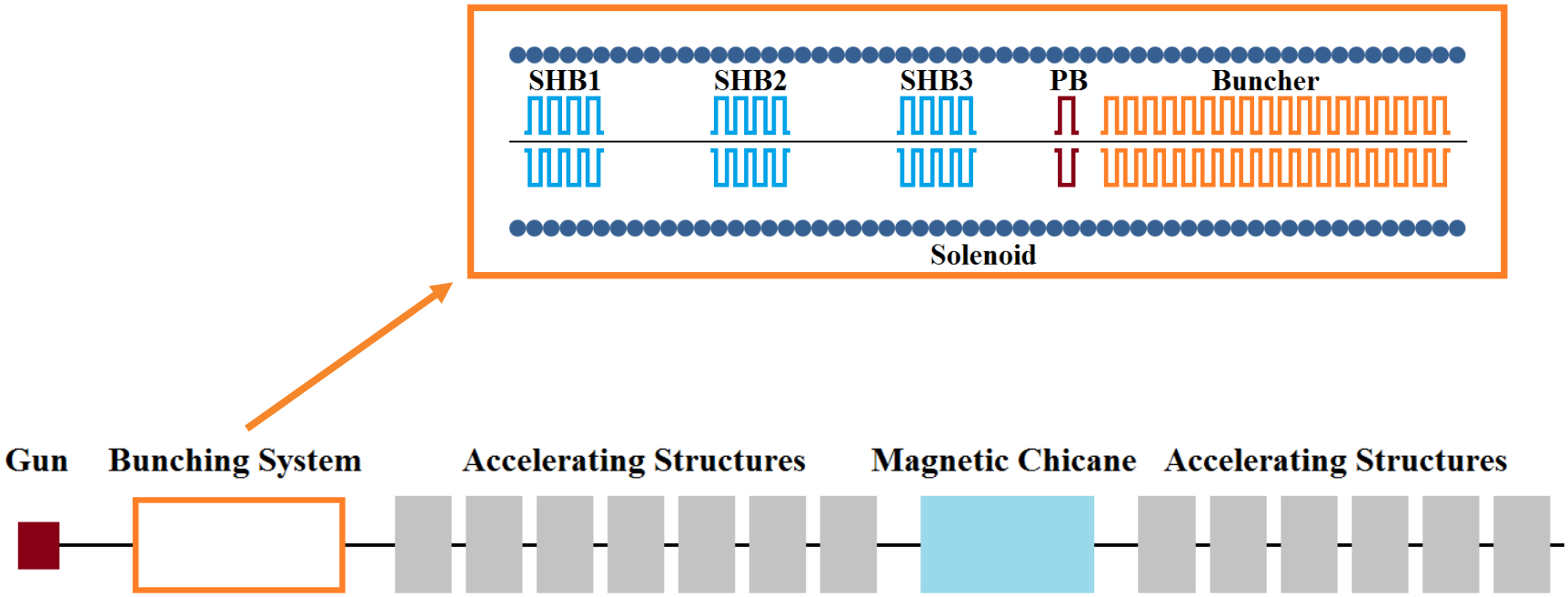
Contents

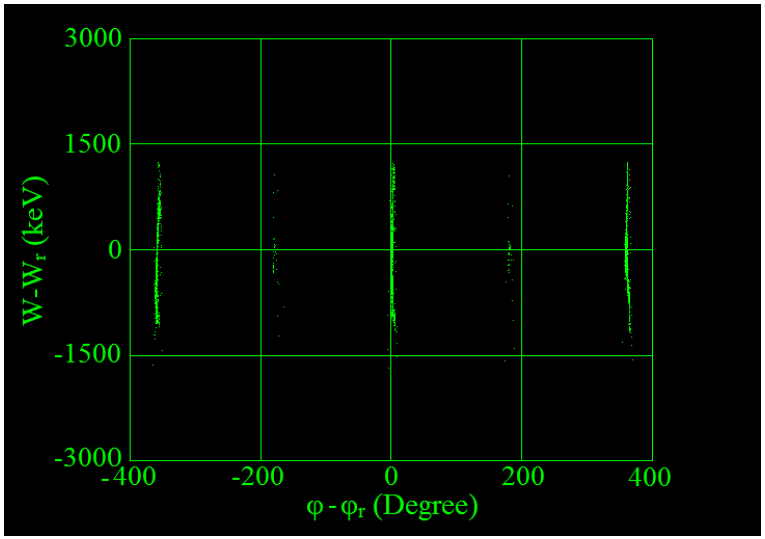
1. Introduction

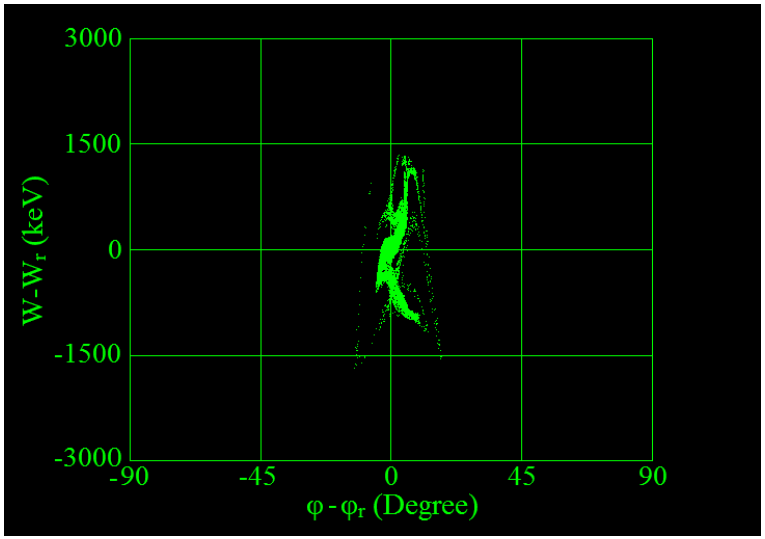
1.1 Injector Layout



2. Review of The Longitudinal Results

Parameter	Value	Target value
RMS bunch length (σ_b)	2.6 mm	3 mm
RMS energy spread (σ_E)	0.48 MeV	< 0.5 MeV
Satellite population	2.4 %	< 5%
Beam loss (chicane + satellite)	6.1 %	As less as possible





3. Transverse Beam Dynamics Studies

3.1 Envelop Equation

$$a'' + k_0^2 a - \frac{K}{a} - \frac{\epsilon_t^2}{a^3} = 0$$

Focusing term $\left(k_0 = \frac{eB}{2\gamma m\beta c}\right)$

$a = 2x_{rms}$

Emittance term $(\epsilon_t = 4\epsilon_{rms})$

Space charge term $\left(K = \frac{2eI}{4\pi\epsilon_0 mc^3\beta^3\gamma^3}\right)$

$$\begin{cases} a''(0) = a'(0) = 0 \\ k_0^2 a - \frac{K}{a} - \frac{\epsilon_t^2}{a^3} = 0 \end{cases} \xRightarrow{\text{Matched Beam}} B = \frac{2\gamma m\beta c}{e}\sqrt{\frac{2eI}{4\pi\epsilon_0 mc^3\beta^3\gamma^3 a^2} + \frac{\epsilon_t^2}{a^4}}$$

3. Transverse Beam Dynamics Studies

3.2 Emittance Growth

$$a'' + k_0^2 a - \frac{K}{a} - \frac{\epsilon_t^2}{a^3} = 0$$

$$\epsilon_{rms} = x_{rms} x'_{rms} = \frac{a}{2} \frac{\tilde{v}_x}{\beta c}$$

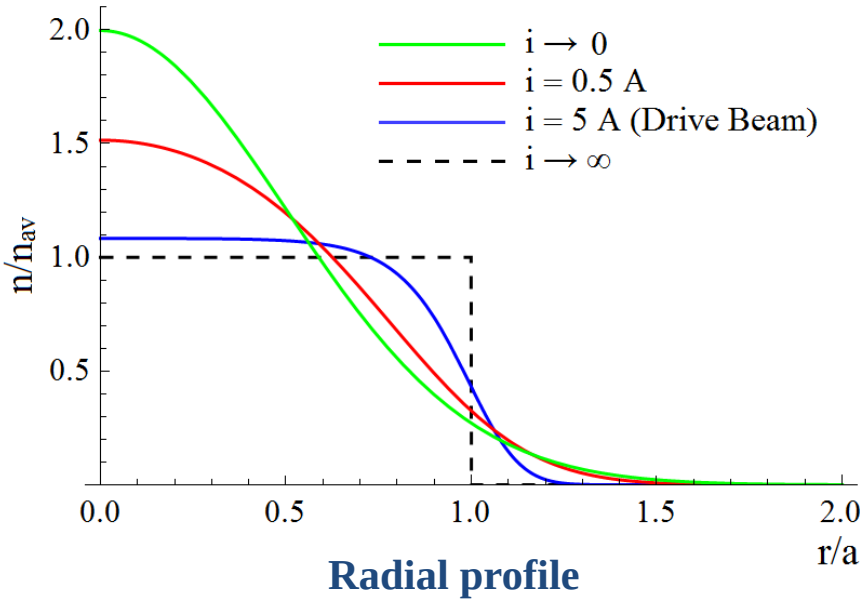
$$T_\perp = \gamma m \tilde{v}_x^2$$

Sources of the emittance growth

- Non-stationary initial distribution
- Beam mismatching

3. Transverse Beam Dynamics Studies

3.2.1 Non-Stationary Initial Distributions



Radial profile

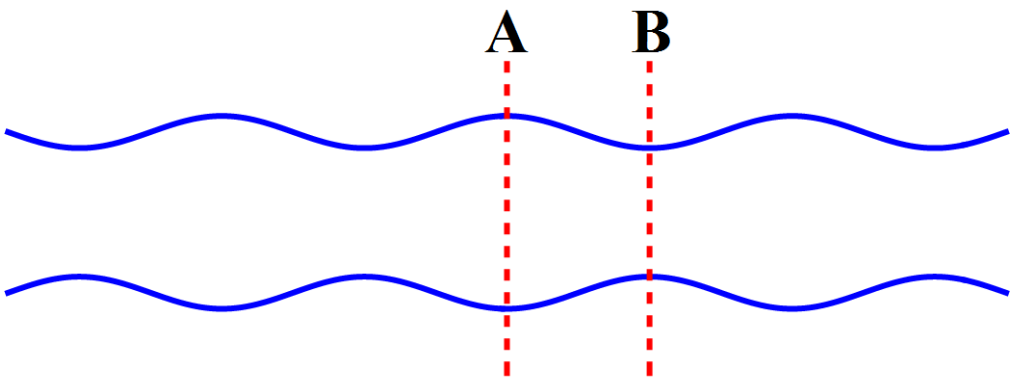
$$n(r) = n(0)e^{-\frac{\beta^2 c^2 k_0^2 r^2}{2\tilde{v}_x^2} - \frac{q\varphi_s}{m\gamma^3\tilde{v}_x^2}}$$

$$\frac{1}{r}\frac{d}{dr}\left(r\frac{d\varphi_s}{dr}\right) = -\frac{q}{\epsilon_0}n(r)$$

Reiser's formula: $(\Delta\epsilon^2)_{max} = \frac{1}{2}Ka_i^2\frac{U_i}{w_0}$

3. Transverse Beam Dynamics Studies

3.2.2 Beam Mismatching



Wangler's formula: $\frac{d\epsilon^2}{dz} = -\frac{1}{2}Ka^2\frac{d}{dz}\left(\frac{U}{w_0}\right)$

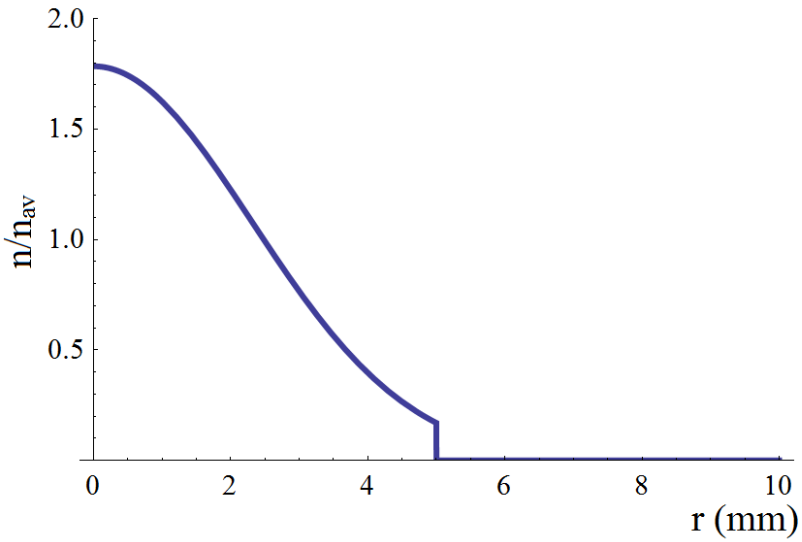
3. Transverse Beam Dynamics Studies

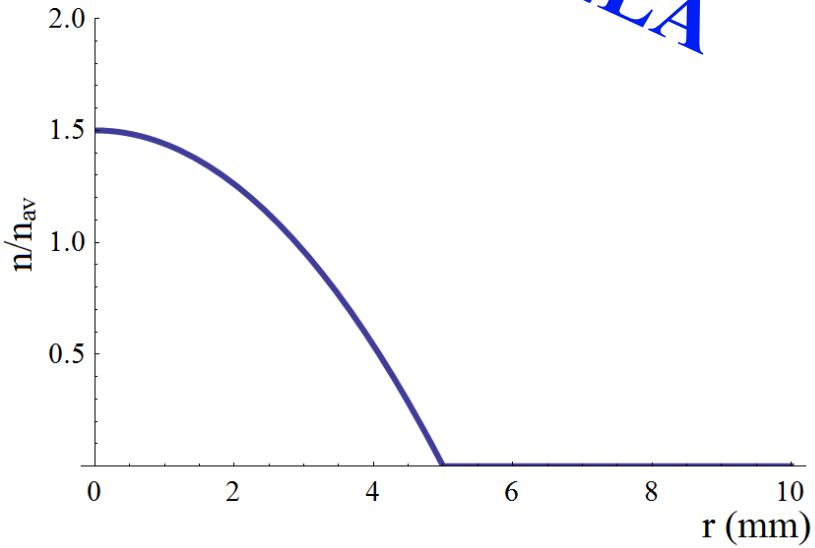
3.3 Simulations

3.3.1 Beam Initial Conditions

$x_{rms} = 2mm$
$\epsilon_n = 10\ mm - mrad$

PARMELA

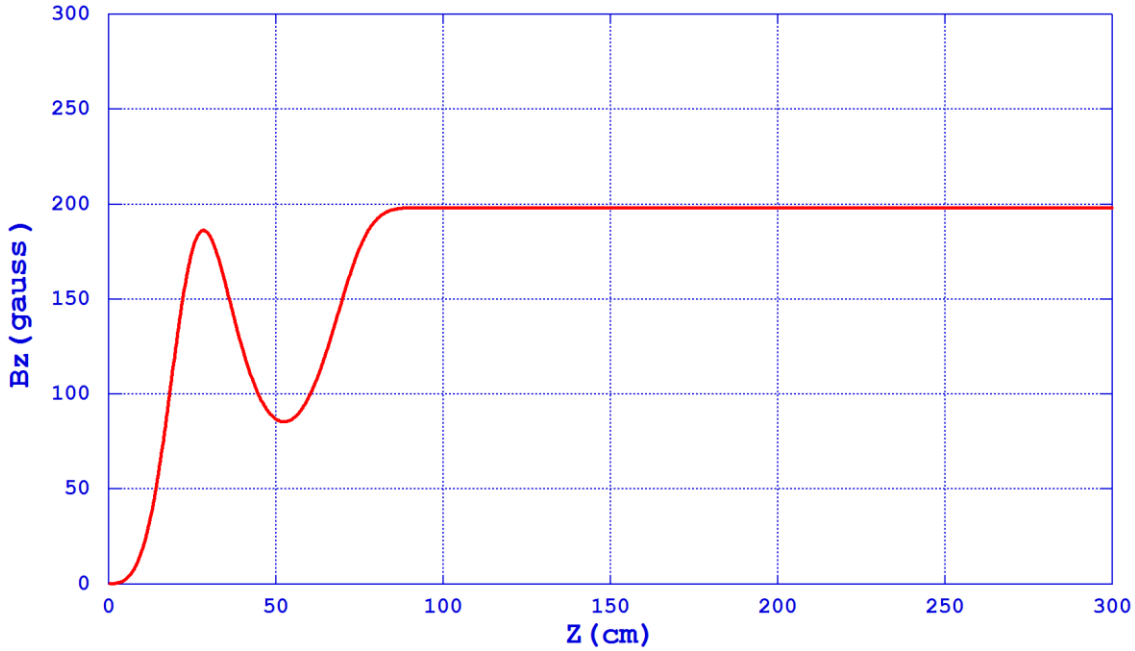




3. Transverse Beam Dynamics Studies

3.3 Simulations

3.3.2 Matched Beam

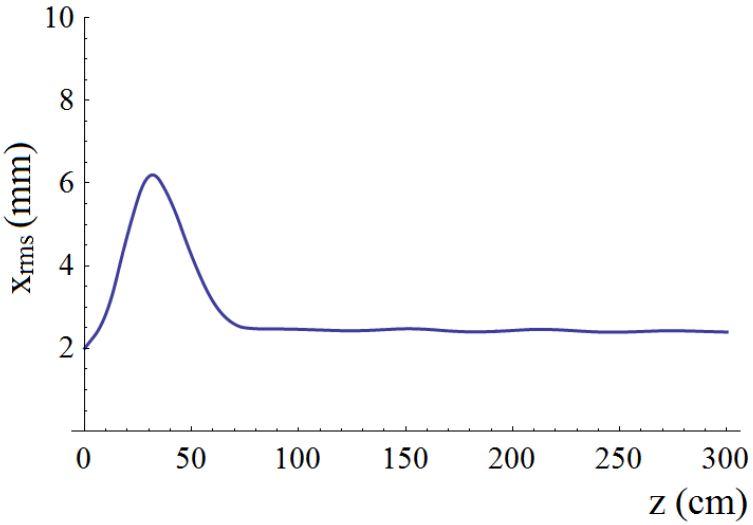


Magnetic field map

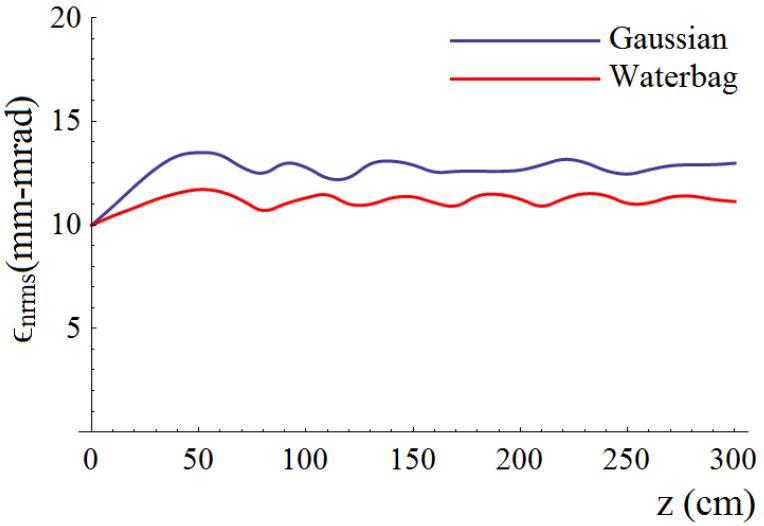
3. Transverse Beam Dynamics Studies

3.3 Simulations

3.3.2 Matched Beam



RMS Beam Size

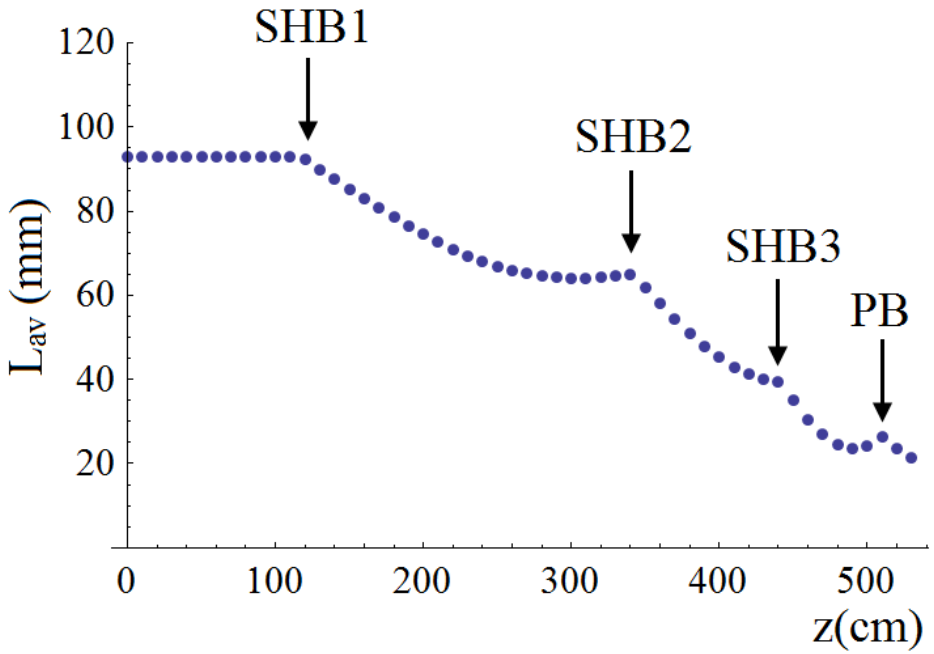


RMS Normalised Emittance

3. Transverse Beam Dynamics Studies

3.3 Simulations

3.3.2 Bunching Effect



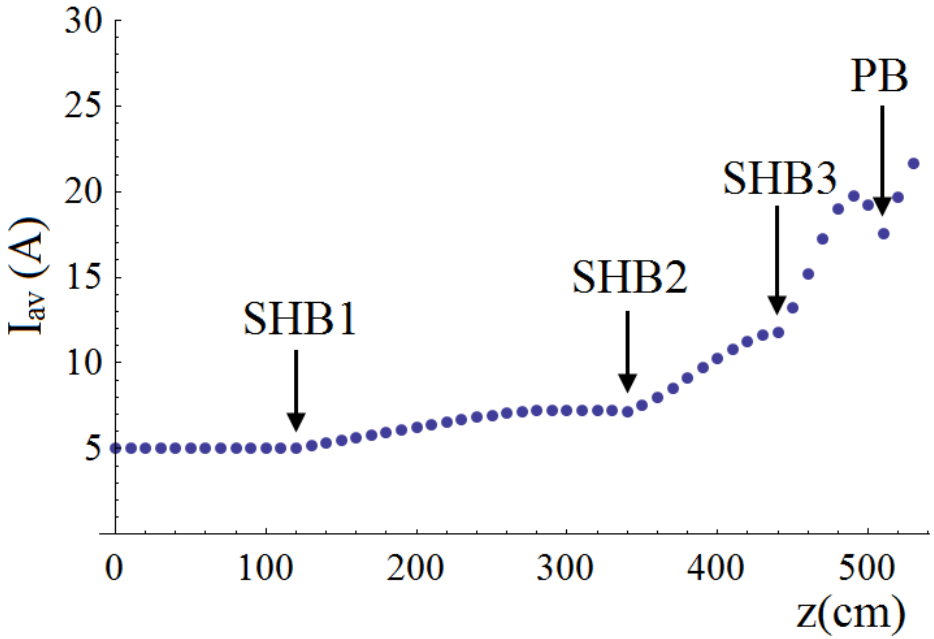
Average bunch length

$$I_{av} = I_0 \frac{(L_{av})_0}{L_{av}}$$

3. Transverse Beam Dynamics Studies

3.3 Simulations

3.3.2 Bunching Effect



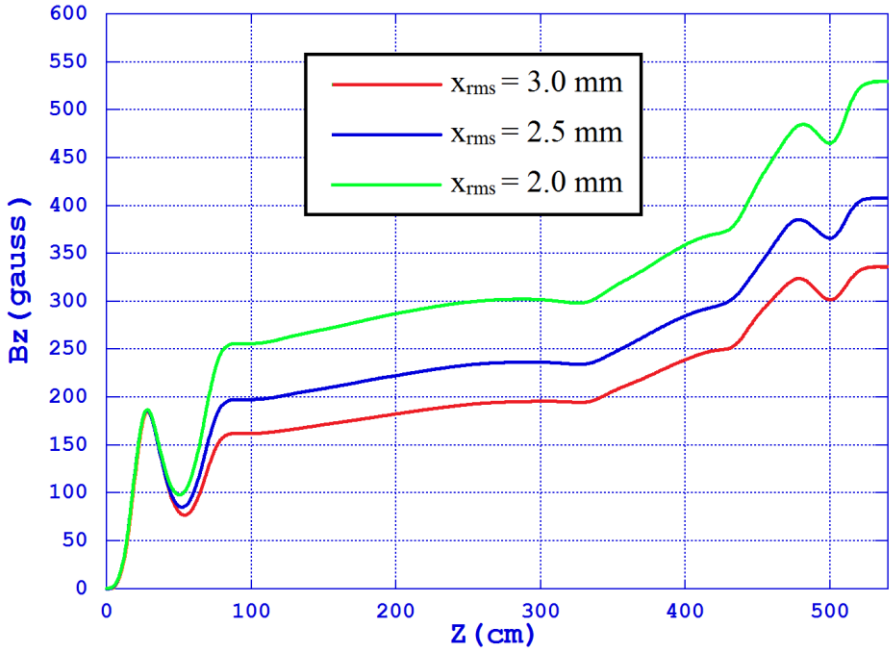
Average bunch current

$$I_{av} = I_0 \frac{(L_{av})_0}{L_{av}}$$

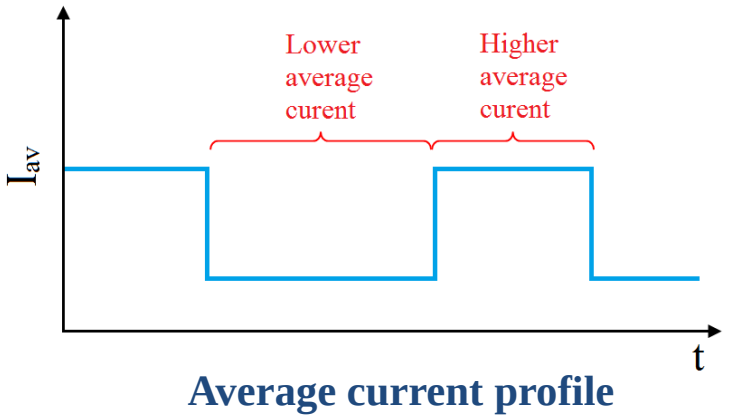
3. Transverse Beam Dynamics Studies

3.3 Simulations

3.3.2 Bunching Effect



Magnetic field map

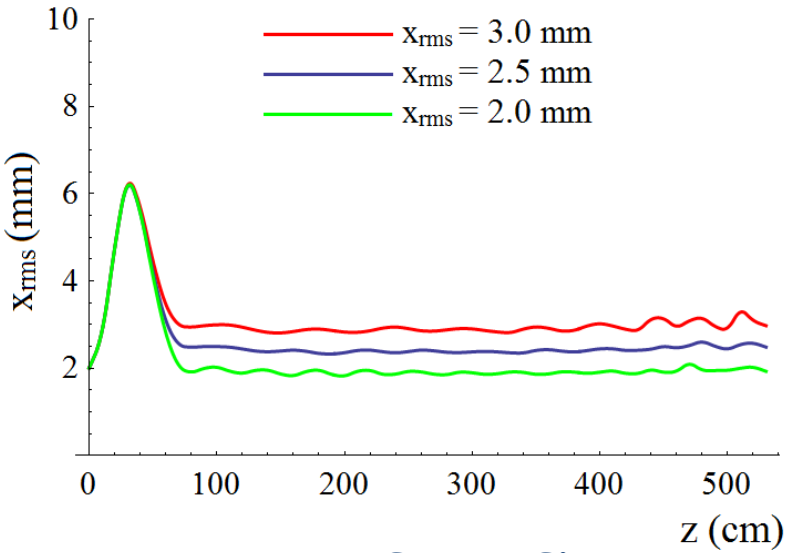


Average current profile

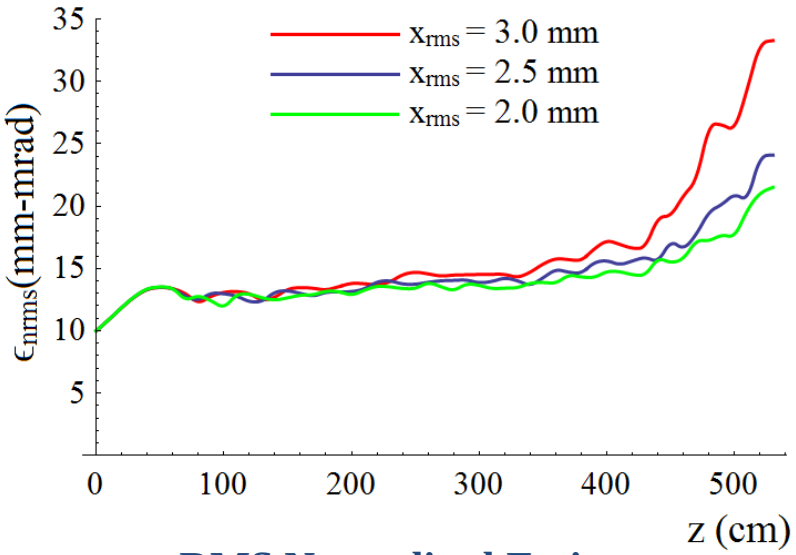
3. Transverse Beam Dynamics Studies

3.3 Simulations

3.3.2 Bunching Effect



RMS Beam Size



RMS Normalised Emittance

Wangler's formula: $\frac{d\epsilon^2}{dz} = -\frac{1}{2}Ka^2\frac{d}{dz}\left(\frac{U}{w_0}\right)$

3. Transverse Beam Dynamics Studies

3.3 Simulations

3.3.2 Bunching Effect

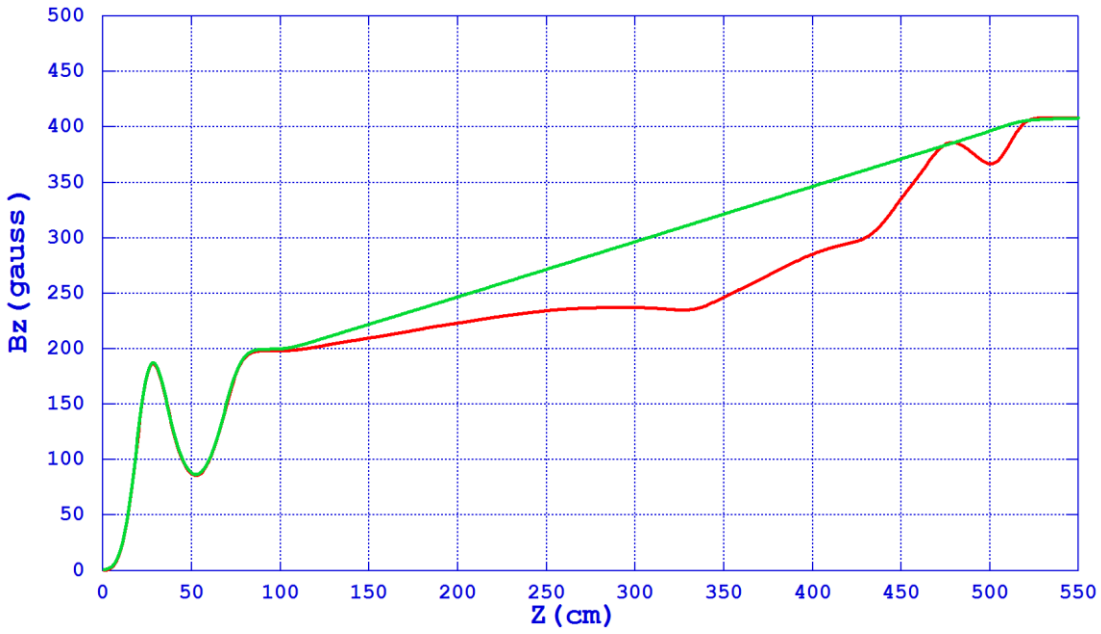
Target beam size (mm)	**2.0**	**2.5**	**3.0**
$\gamma\beta\epsilon_{rms}$(mm − mrad)	21.5	24.1	33.3
Maximum magnetic field (G)	529	409	336

The larger the focusing field the smaller the beam size and the lower the emittance growth

3. Transverse Beam Dynamics Studies

3.3 Simulations

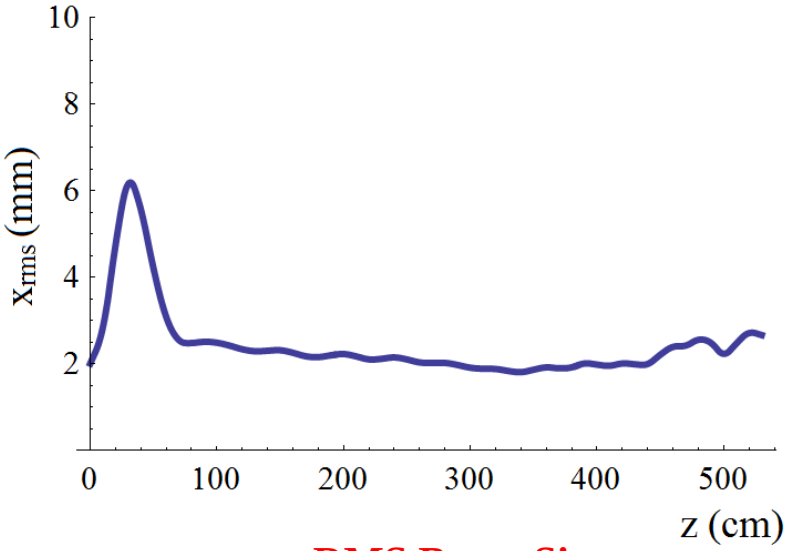
3.3.3 Sensitivity to The Ideal Filed



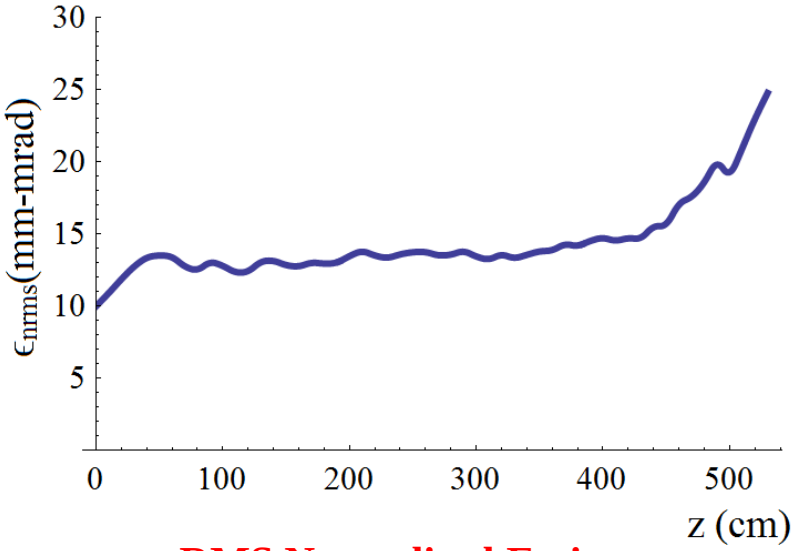
3. Transverse Beam Dynamics Studies

3.3 Simulations

3.3.3 Sensitivity to The Ideal Filed



RMS Beam Size



RMS Normalised Emittance

$\gamma\beta\,\epsilon_{rms}(\mathrm{mm-mrad})$: 24.1 ⟶ 24.8

Thanks for your attention