Study transmission efficiency in HCC w/wo helix quadrupole component

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Aim of this talk

- Some HCC model manipulates a helix quadrupole component but other one does not
  - Here, I named first HCC as “new HCC” and second one as “non-helix-quad HCC”
- Make a very simple test to see how the helix quadrupole component influences spec of channel
  - Use κ= 0.62 since I have data for this (see later slide)
- We observe transmission efficiency
  - From past HCC design study, one found that the momentum acceptance falls when the quad increases

Field parameter in non helix quad HCC (I)

- Optimized non helix quad HCC with wedge absorber by Balbekov

https://mctf.fnal.gov/meetings/2009/02_05/comments.ppt/view

$$B = 5.23\ \mathrm{T}$$
$$b_\psi = \text{-}1.075\ \mathrm{T}$$
$$b_\psi{}' = \text{-}1.03\ \mathrm{T/m}$$
$$\kappa = 0.62$$
$$\lambda = 1.0\ \mathrm{m}$$
$$p = 0.159\ \mathrm{GeV/c}$$

← This helix quad is generated from differentiation of helix dipole component (see next slide)

Field parameter in non helix quad HCC (II)

Field expression for non helix quad HCC

$$b_\psi = \frac{\lambda I_1\left(2\pi\rho/\lambda\right)}{\pi\rho} b_d$$

$$b'_\psi = \frac{\partial b_\psi}{\partial \rho} = \left(-\frac{\lambda I_1\left(2\pi\rho/\lambda\right)}{\pi\rho^2} + \frac{I_0\left(2\pi\rho/\lambda\right) + I_2\left(2\pi\rho/\lambda\right)}{\rho}\right) b_d$$

$$B = \frac{2\Box}{\Box}\frac{3.3356p}{\sqrt{1+\Box^2}} + \frac{1+\Box^2}{\Box} b_\psi$$

A new variable, b_d can be fixed to satisfy the required field that is shown in previous slide

b_d = *-1.025 T*

Transverse phase space stability condition in non quad HCC

Phase space stability condition in helical magnet is given in Derbenev and Johnson paper based on linear dynamics of motion

This analysis must be general

$$0 < \quad {}^{2}$$

$0 < 0.563 < 0.576$

$$G = \left(\frac{2q+\kappa^2}{1+\kappa^2} - \hat{D}^{-1}\right)\hat{D}^{-1}$$

$= 0.563$

$$R = \frac{1}{2}\left(1 + \frac{q^2}{1+\quad{}^2}\right)$$

$= 0.759$

$$\hat{D}^{-1} = \frac{\kappa^2 + (1-\kappa^2)q}{1+\kappa^2} + g$$

$= 0.734$

$$q = \frac{B\sqrt{1+\kappa^2}/3.3356p}{k} - 1$$

$= 0.847$

$$g = -\frac{\left(1+\kappa^2\right)^{3/2}}{3.3356pk^2}b'_{\psi}$$

$= 0.0813$

Design optics is near the boundary of transverse stability condition

Field parameter in new HCC (I)

- Optimized new HCC with continuous absorber by Yonehara

There are many references.
For instance, http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/TPPP052.PDF

$$B = 4.66\ \mathrm{T}$$
$$b_\psi = -0.818\ \mathrm{T}$$
$$b_\psi{}' = -3.94\ \mathrm{T/m}$$
$$\kappa = 0.62$$
$$\lambda = 1.0\ \mathrm{m}$$
$$p = 0.159\ \mathrm{GeV/c}$$

Field parameter in no helix quad HCC (II)

Field expression for non helix quad HCC

$$b_\psi = \frac{\lambda I_1\left(2\pi\rho/\lambda\right)}{\pi\rho} b_d + \frac{\lambda I_2\left(4\pi\rho/\lambda\right)}{\pi\kappa\rho} b_q$$

$$b'_\psi = \left(-\frac{\lambda I_1\left(2\pi\rho/\lambda\right)}{\pi\rho^2} + \frac{I_0\left(2\pi\rho/\lambda\right) + I_2\left(2\pi\rho/\lambda\right)}{\rho}\right) b_d + \left(-\frac{\lambda I_2\left(2\pi\rho/\lambda\right)}{\pi\kappa\rho^2} + \frac{2\left(I_1\left(4\pi\rho/\lambda\right) + I_3\left(4\pi\rho/\lambda\right)\right)}{\kappa\rho}\right) b_q$$

$$B = \frac{2\Box}{\Box}\frac{3.3356p}{\sqrt{1+\Box^2}} + \frac{1+\Box^2}{\Box} b_\psi$$

A new variable, b_d and b_q can be fixed to satisfy the required field that is shown in previous slide

$$b_d = -0.393\ T$$
$$b_q = -0.478\ T$$

Transverse phase space stability condition in new HCC

$0 < \quad {}^{2}$ 0 < 0.295 < 0.423

$G = \left(\frac{2q + \kappa^2}{1 + \kappa^2} - \hat{D}^{-1} \right) \hat{D}^{-1}$ = 0.295

$R = \frac{1}{2} \left(1 + \frac{q^2}{1 + \quad {}^{2}} \right)$ = 0.650

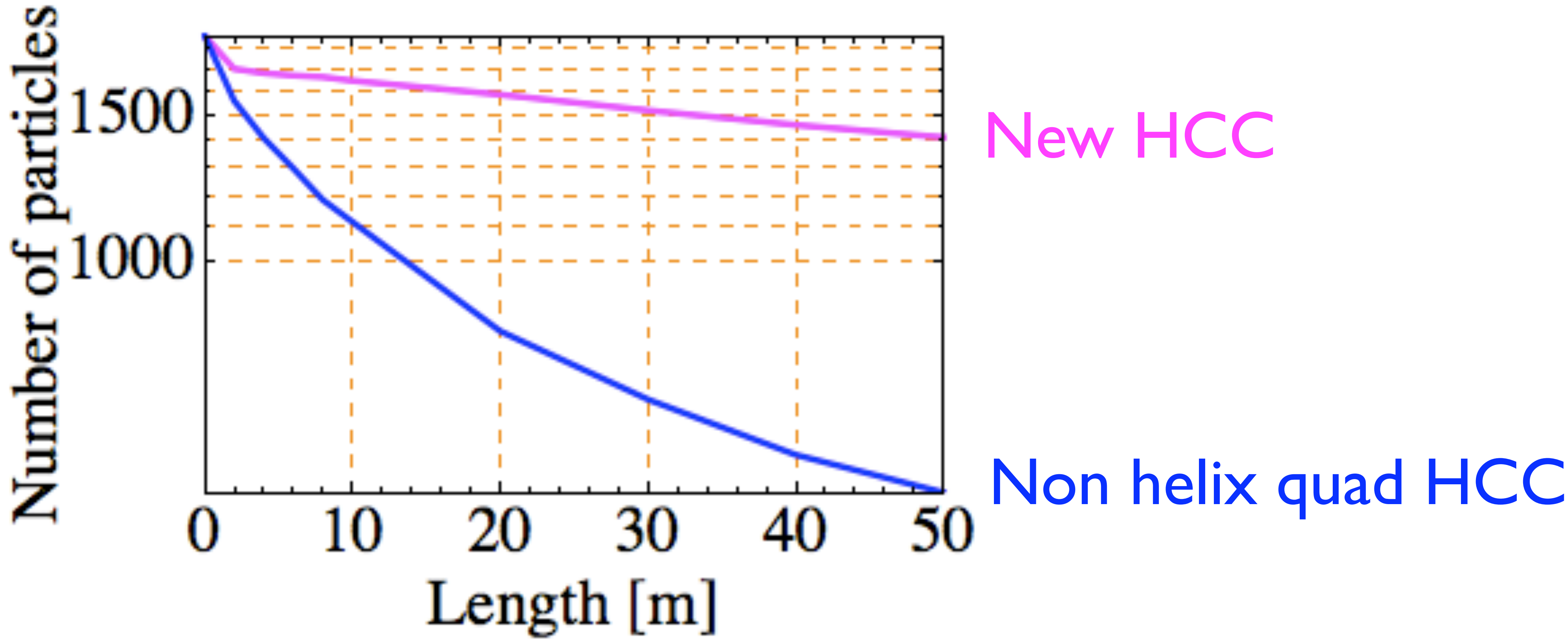
$\hat{D}^{-1} = \frac{\kappa^2 + (1 - \kappa^2) q}{1 + \kappa^2} + g$ = 0.871

$q = \frac{B\sqrt{1 + \kappa^2}/3.3356p}{k} - 1$ = 0.645

$g = -\frac{\left(1 + \kappa^2\right)^{3/2}}{3.3356pk^2} b'_{\psi}$ = 0.306

Design optics is center of the boundary of transverse stability condition

Numerical simulation



- For simplicity, no absorber + no RF
  - Much less simulation code dependence
- Initial beam parameters
  - $\sigma x,y$ = 80 mm, $\sigma x',y'$ = 0.8, σp = 80 MeV/c
- 1867 particles injected in both channels and 1411 and 529 particles survived in new and non-helix-quad HCCs

Conclusion

- Transmission efficiency was tested in new HCC and non-helix-quad one
- Design field in optimized non-helix-quad satisfies the transverse stability condition but near the boundary
- Design field in optimized new HCC is the center of the transverse stability condition
- Numerical result supports above analysis
- Probably, a wedge absorber stabilizes the phase space by its effective dispersion
- Or, I believe that the past HCC designed with very low κ, hence helix quad makes destructive (or useless) for phase stability