Simulation Studies on the **F8SR** Injection

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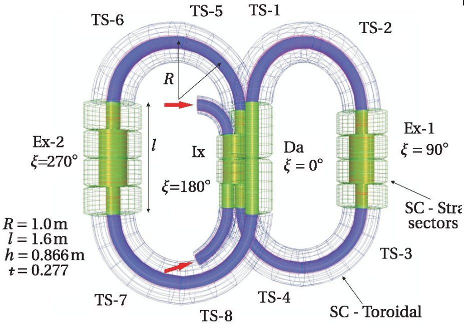
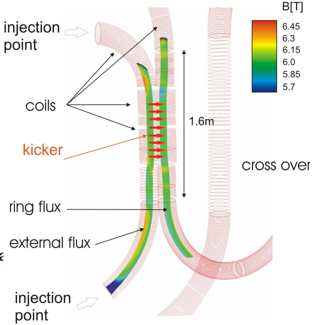
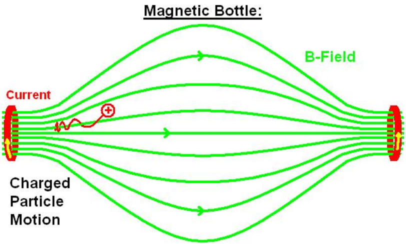
F8SR Injection Area

- Magnetostatic $|\vec{B}| \approx 6\,\mathrm{T}$
- Beam Energy: $W = 150\,\mathrm{keV}$-$1\,\mathrm{MeV}$
- Beam Current: $I = 1$-$10\,\mathrm{A}$





The Adiabatic Invariant

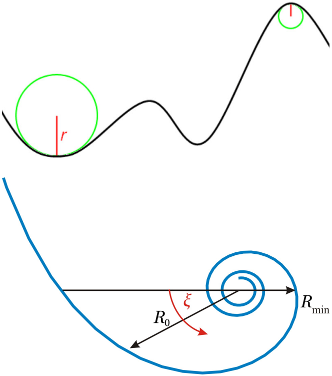


magnetic moment $\mu = \frac{mv_\perp^2}{2B}$ must be constant
$\rightarrow$ adiabatic invariant $\mu_m(B_{\mathrm{max}} - B_1) = \Delta W_\perp$

$$\frac{\mathrm{d}B}{\mathrm{d}t} = \underbrace{\frac{\partial B}{\partial t}}_{=0} + v_z\frac{\partial B}{\partial z} < B\frac{\omega_c}{2\pi} = \frac{qB^2}{2\pi m} \rightarrow v_\parallel \frac{\Delta B}{\Delta s} < q\frac{B^2}{2\pi m}$$

first order approximation with $150\,\mathrm{keV}$ leads to ${}^{5.8\,\mathrm{T}}/_{4\,\mathrm{m}}$

Geometry of a Plane Curve



tangent vector: $\vec{t} = \frac{\mathrm{d}\vec{r}}{\mathrm{d}s}$

curvature: $\kappa = \left|\frac{\mathrm{d}^2\vec{r}}{\mathrm{d}s^2}\right|$

radius of curvature: $R_\mathrm{C} = \frac{1}{\kappa}$

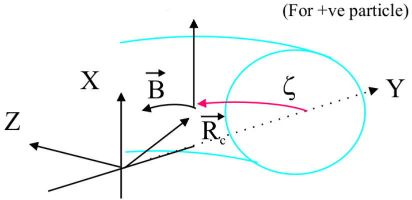
For a circle: $R_\mathrm{C} = R = \mathrm{const.}$
and $\kappa = \mathrm{const.}$

Concerning for ex. a hyperbolic spiral:

$R_\mathrm{C} \neq R \ , \quad R = \frac{1}{\theta} \ ,$

$R_\mathrm{C} = \frac{1}{\kappa} = \frac{a}{\theta}\left(1 + \frac{1}{\theta^2}\right)^{\frac{3}{2}}$

The RxB Drift



there is a need for a off curvature-plane drift velocity to provide the necessary centripetal force F_C

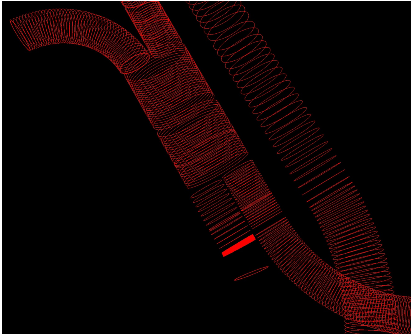
$$\vec{F}_c = \frac{mv_{\parallel}^2}{R_c}$$

$$\vec{v}_d = \frac{1}{q}\frac{\vec{F}\times\vec{B}}{B^2}$$

$$\rightarrow \vec{v}_d = \frac{mv_{\parallel}^2}{qB^2}\frac{\vec{R}_c\times\vec{B}}{R_c^2}$$

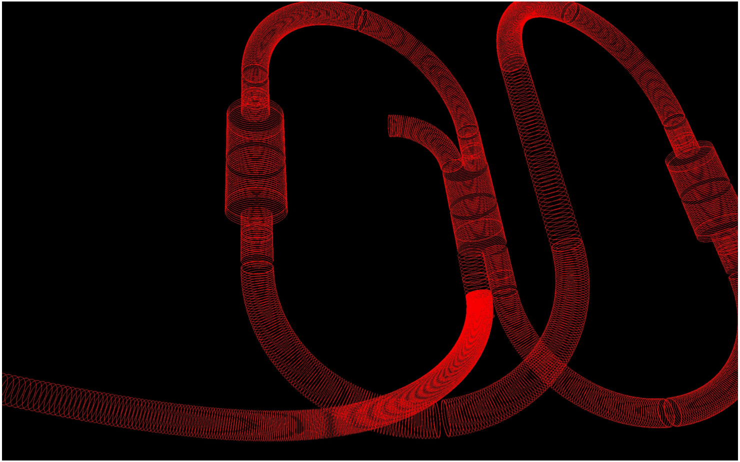
Injection Channel Constraints

- due to neighboring toroid coils
  $\rightarrow$ field distortion
  $\rightarrow$ particle kick
  $\rightarrow$ **channel must be bend**
  $\mathbf{R < 0.6\,m}$
- adiabatic invariant $\rightarrow$ small $\frac{\Delta B}{\Delta s}$
  $\rightarrow$ leads to certain channel length $\approx 4\,\mathrm{m}$
  $R = \mathrm{const.}$ not possible ($2\pi R < 4\,\mathrm{m}$)
  $\rightarrow$ **R must vary** $\rightarrow$ **spiral shape**
- concerning the $\vec{R} \times \vec{B}$-Drift
  $\rightarrow$ the curvature $\kappa = {}^{1}/_{R_{\mathrm{C}}}$ shall start slowly for technical feasibility $\rightarrow$ **spiral shape**

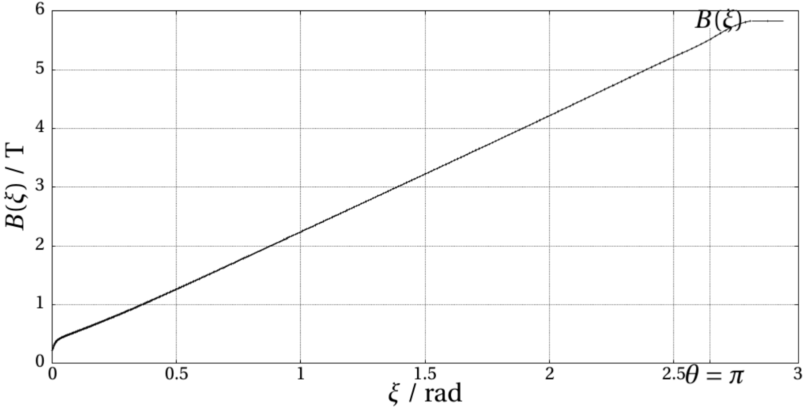


Injection Channel Design

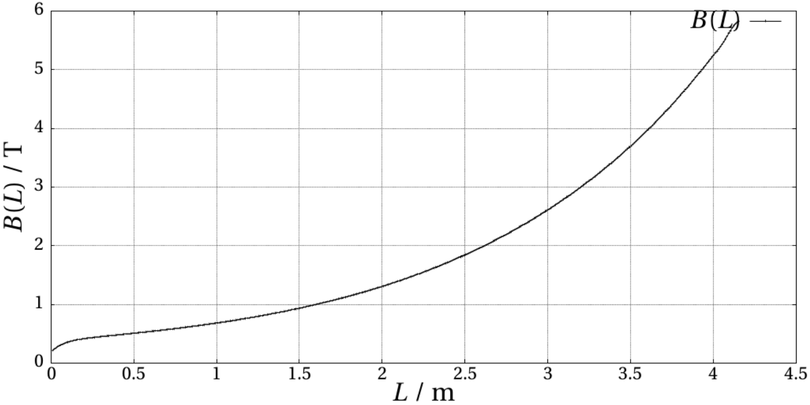
hyperbolic spiral shape was chosen and implemented in *Segments* (design program by M.Droba)



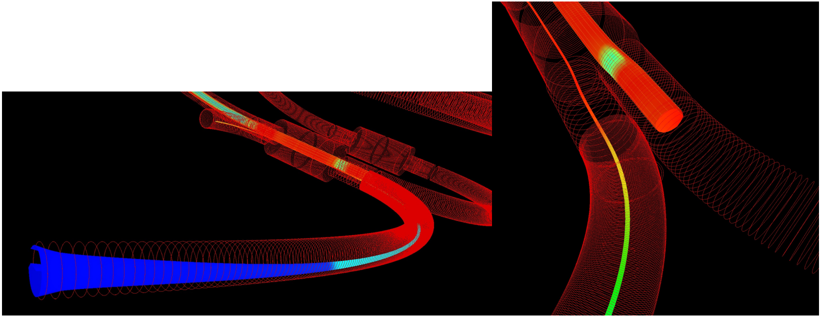
Magnetic field on axis



Magnetic field on axis

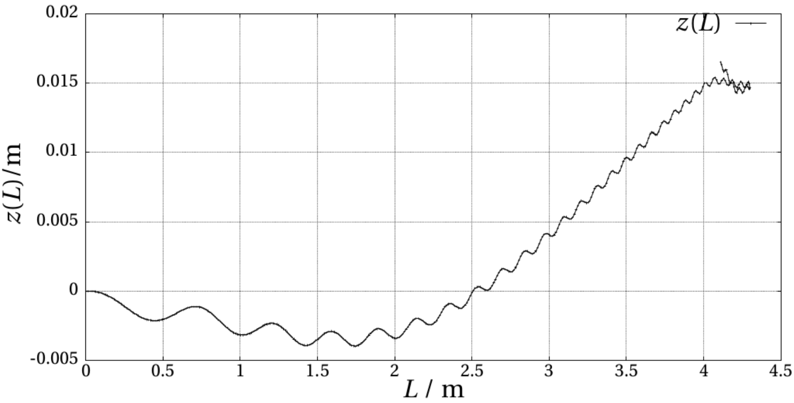


Mapped Magnetic Surface

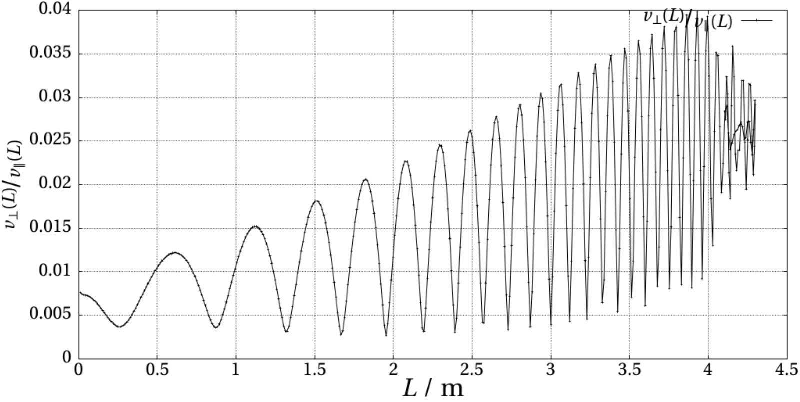


channel entrance kicker area

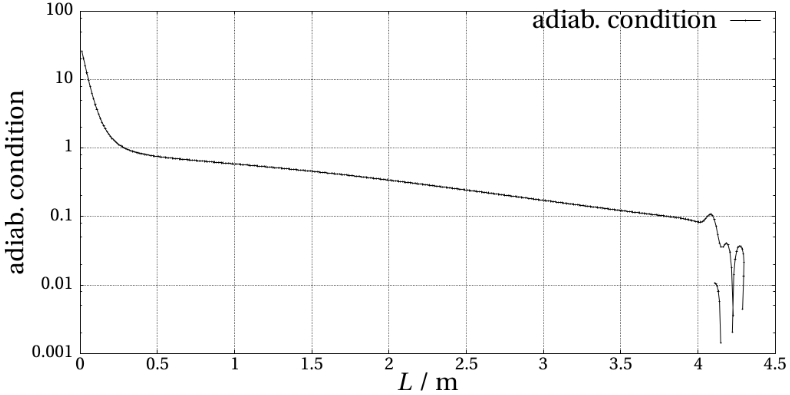
Single Particle Tracking



Single Particle Tracking

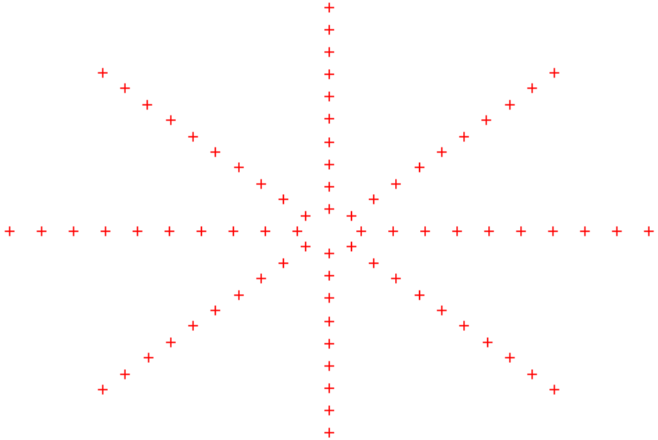


Single Particle Tracking



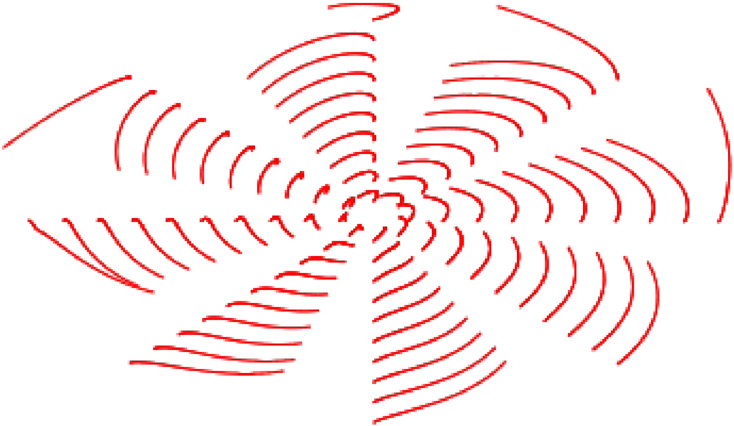
Adiabatic Invariant: $v_s \frac{\Delta B}{\Delta s} \cdot \frac{2\pi m}{qB^2} < 1$

Acceptance - Particle Tracking



$r[1\,\mathrm{cm} : 10\,\mathrm{cm}]$ $1\,\mathrm{cm}$ steps, $\alpha =$ every 45 degree

Acceptance - Particle Tracking



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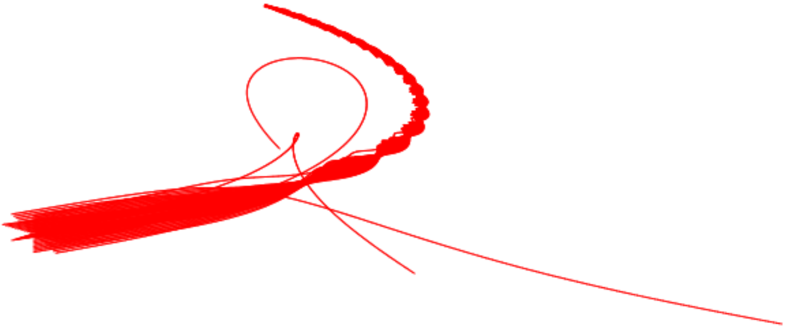

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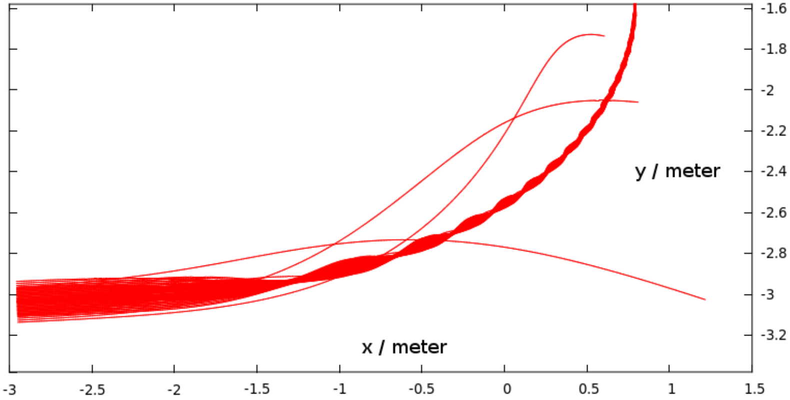

Particles within $r \leq 9\,\mathrm{cm}$ all α had been trapped. The *beam radius* decreased from $9\,\mathrm{cm}$ to $1.8\,\mathrm{cm}$

Outlook

- export designed coil geometry to *bender* to perform full beam simulations with space charge
- continue the ExB-kicker simulations and combine them with the channel simulations
- get ready for multi turn injection

Thank you for listening!