The 2022 Workshop on Fixed Field Alternating Gradient Accelerators - FFA school

Zgoubi simulation code: vFFA keyword

FDF triplet vertical excursion FFA

The ring studied here comes from Ref. [1]. The ring comprises ten identical FDF triplet focusing cells whose magnets are aligned on a straight line. The bending angle is 36 degrees per cell. The magnets do not have vertical face angles. Their fringe field is described by a hyperbolic tangent function, with a fringe field extent of 20 cm. The main lattice design parameters are shown in table 1.

Parameters	
Kinetic Energy	3-12 MeV
Bend angle per cell	36^o
Number of cells	10
Cell length	2.5 m
Bd magnet length	0.24m
Bf magnet length	0.40m
Space between Bd and Bf	0.08 m
Fringe field extent	0.20 m
Field index	1.28 m^{-1}

TABLE 1 – Parameters of the vFFA example ring. The design parameters come from Ref. [1].

- **Closed orbits** - The closed orbit search is the first step before studying the optical properties of the lattice. Compute the closed orbits across a cell for several proton energies ranging from 3 to 12 MeV, and plot these orbits in the (x-y) and (x-z) planes (x, y, z being respectively the longitudinal, horizontal, and vertical coordinates). Compute the vertical orbit excursion and the momentum compaction factor.
- **Magnetic field seen by the particles** - Plot the magnetic field seen by a particle along the closed orbit at 3 MeV and show it scales with energy.
- **Transfer matrix and eigentunes** - Because of the skew quadrupolar and longitudinal field components, vFFAs have strongly transverse coupled optics. A simple way to compute the transverse eigentunes is to use the eigenvalues of the periodic transfer matrix. Compute the 4×4 transverse transfer matrix for a single cell and derive the transverse one-cell eigentunes. Compute and plot the momentum dependence of the tunes.

References

[1] S. Machida, D. J. Kelliher, J-B. Lagrange, and C. T. Rogers. Optics design of vertical excursion fixed-field alternating gradient accelerators. *Physical Review Accelerators and Beams*, 24(2) :021601, February 2021. `https://journals.aps.org/prab/pdf/10.1103/PhysRevAccelBeams.24.021601`.

The vFFA Zgoubi keyword definition with its associated parameters is as follows :

```
'vFFA'
IL,
N (Number of vFFA magnets), XL (Total length of the component),
XE, XS (Entrance/exit integration zones)
-----------For each vFFA magnet:------------------------------
  XM (Magnet start position), L (Magnet length), DYM,
    DZM (Magnet transverse offsets)
  B0 (Reference magnetic field), k (Field index),
  gap (Fringe field extent)
----------------------------------------------------------------
KIRD, Resol, (Only KIRD = 0 - analytical computation)
XPAS (Integration step),
KPOS, XCE, YCE, ALE (Positioning of the element)
```

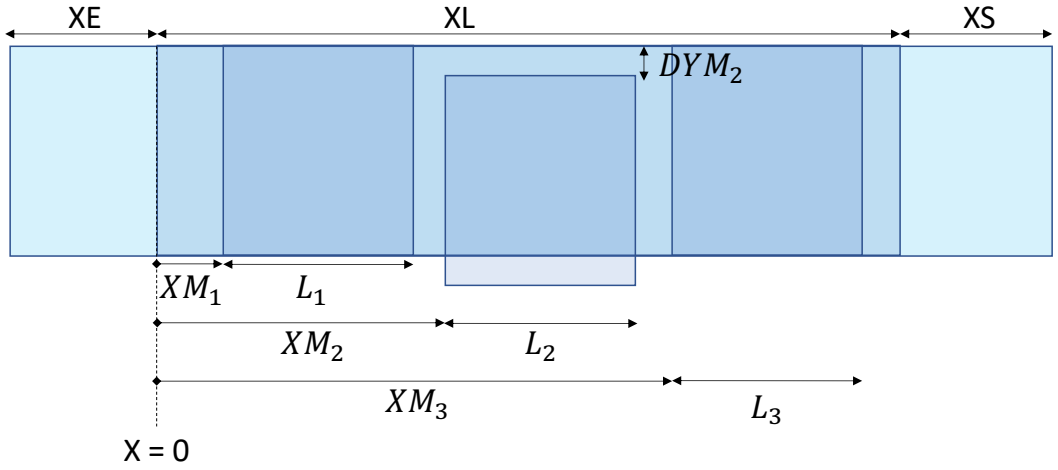

FIGURE 1 – The vFFA procedure implemented in Zgoubi.