VFFA magnet for muon acceleration

J.B. Lagrange
ISIS, RAL, STFC

Why VFFA for muon acceleration?

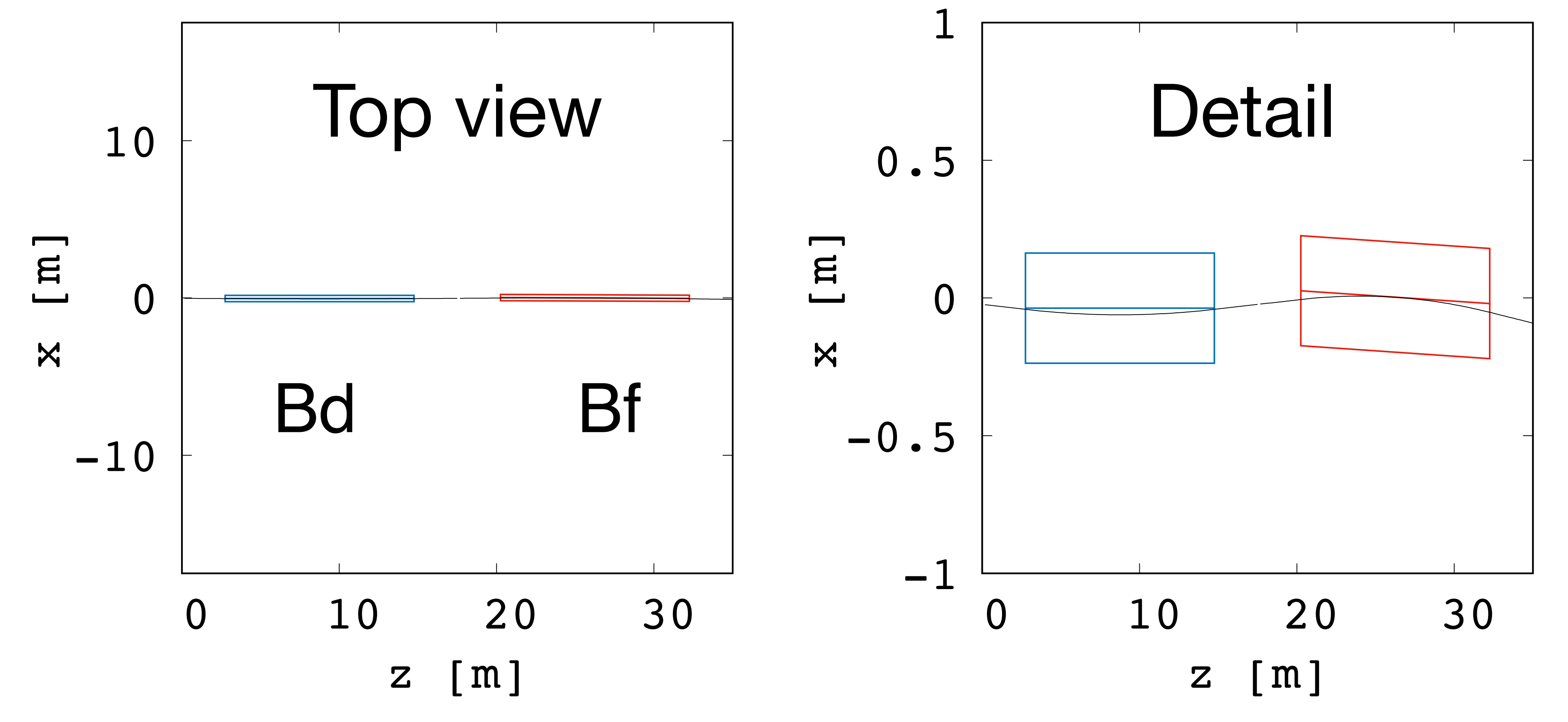
- Muon unstable particle, need for fast acceleration.
- FFA free from magnet ramping: acceleration only depends on RF.
- VFFA has a path length independent of momentum (quasi-isochronism at high energy), constant RF frequency acceleration.

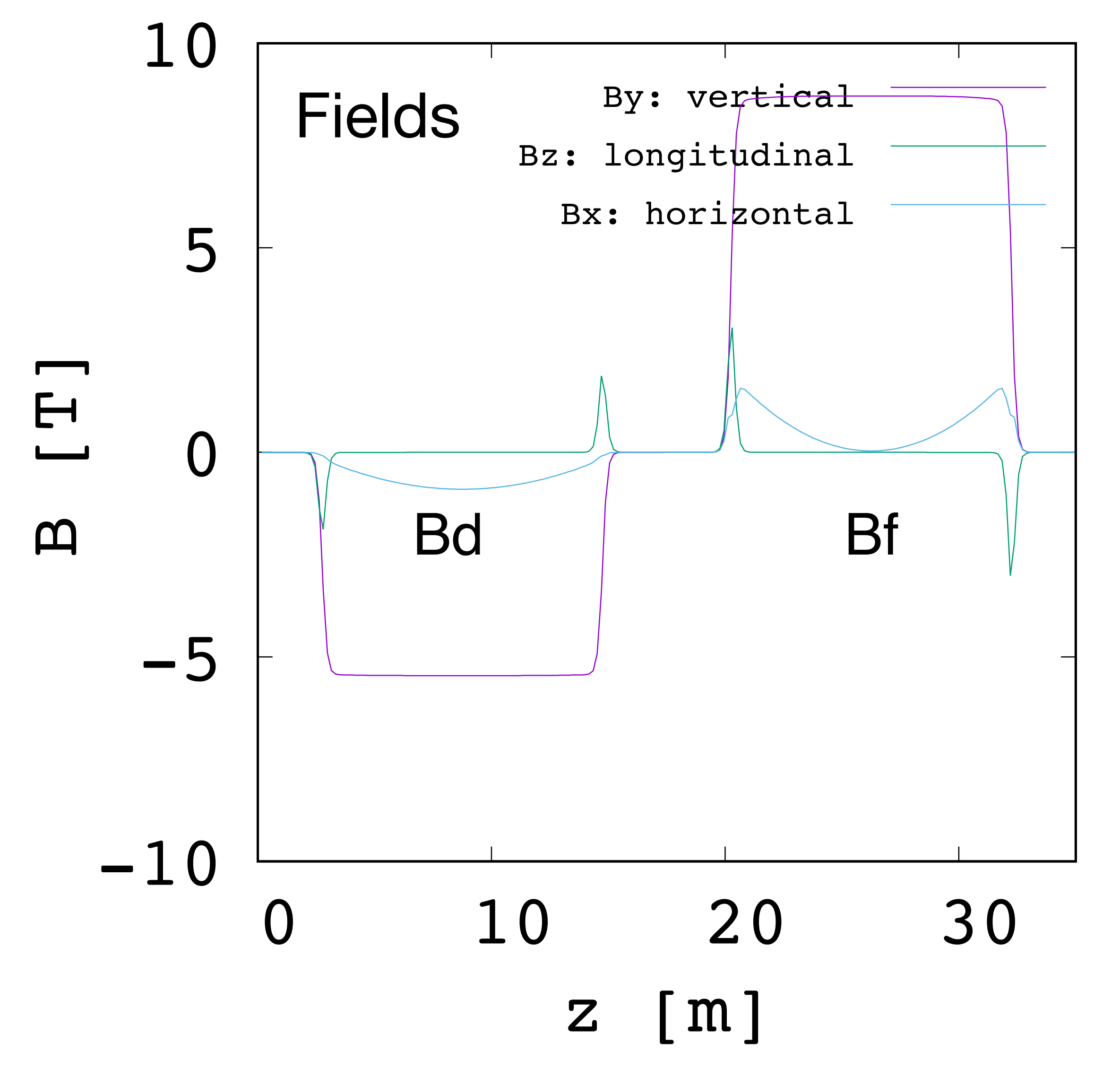
→ VFFA good candidate for muon acceleration

VFFA lattice for muon acceleration

Design constraints:

- LHC circumference,
- Final energy 1.5 TeV,
- Momentum multiplicator is 30,
- Maximum magnetic field is 10 T,
- Orbit excursion less than 0.5 m.





	FODO design
Energy	50 GeV to 1.5 TeV
Cell length	35 m
Number of cells	810
Packing factor	86%
Maximum field	8.7 T
Normalised gradient m^*	6.8 m^{-1}
Orbit excursion	0.50 m
Cell tune	0.3957/0.0861

$$^*m = \frac{1}{B}\frac{dB}{dy}$$ (y: vertical direction)

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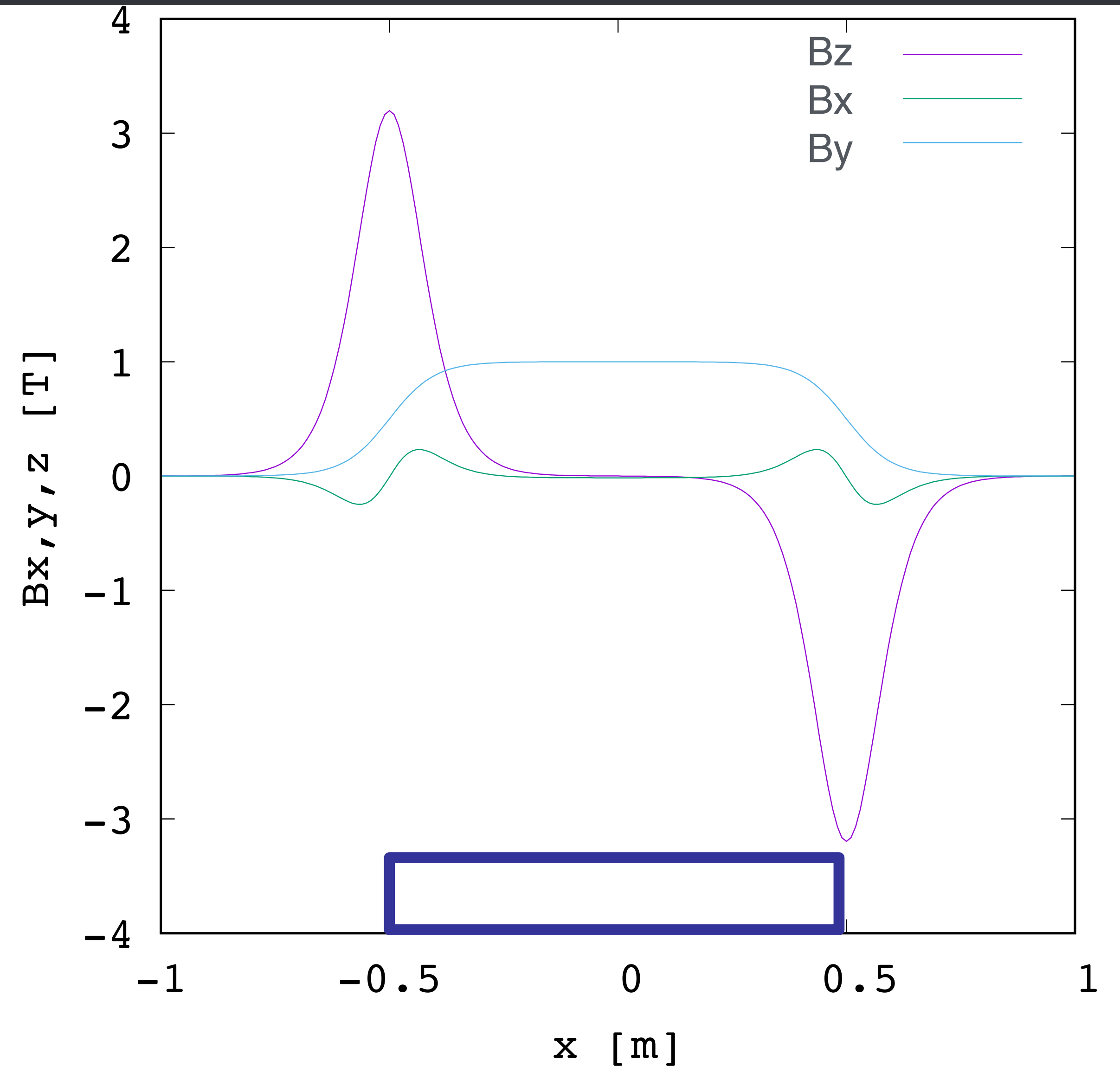
Magnetic field in VFFA

- Exponentially increasing magnetic field to satisfy zero-chromatic conditions.

  Cartesian coordinates *x* (hor.),*y* (vert.),*z* (long.)

$$\begin{cases} B_x(x,y,z) = B_0 e^{m(y-y_0)} \sum_i b_{xi}(z)(x-x_0)^i \\ B_y(x,y,z) = B_0 e^{m(y-y_0)} \sum_i b_{yi}(z)(x-x_0)^i \\ B_z(x,y,z) = B_0 e^{m(y-y_0)} \sum_i b_{zi}(z)(x-x_0)^i \end{cases}$$



- Non-zero longitudinal field on median plane.

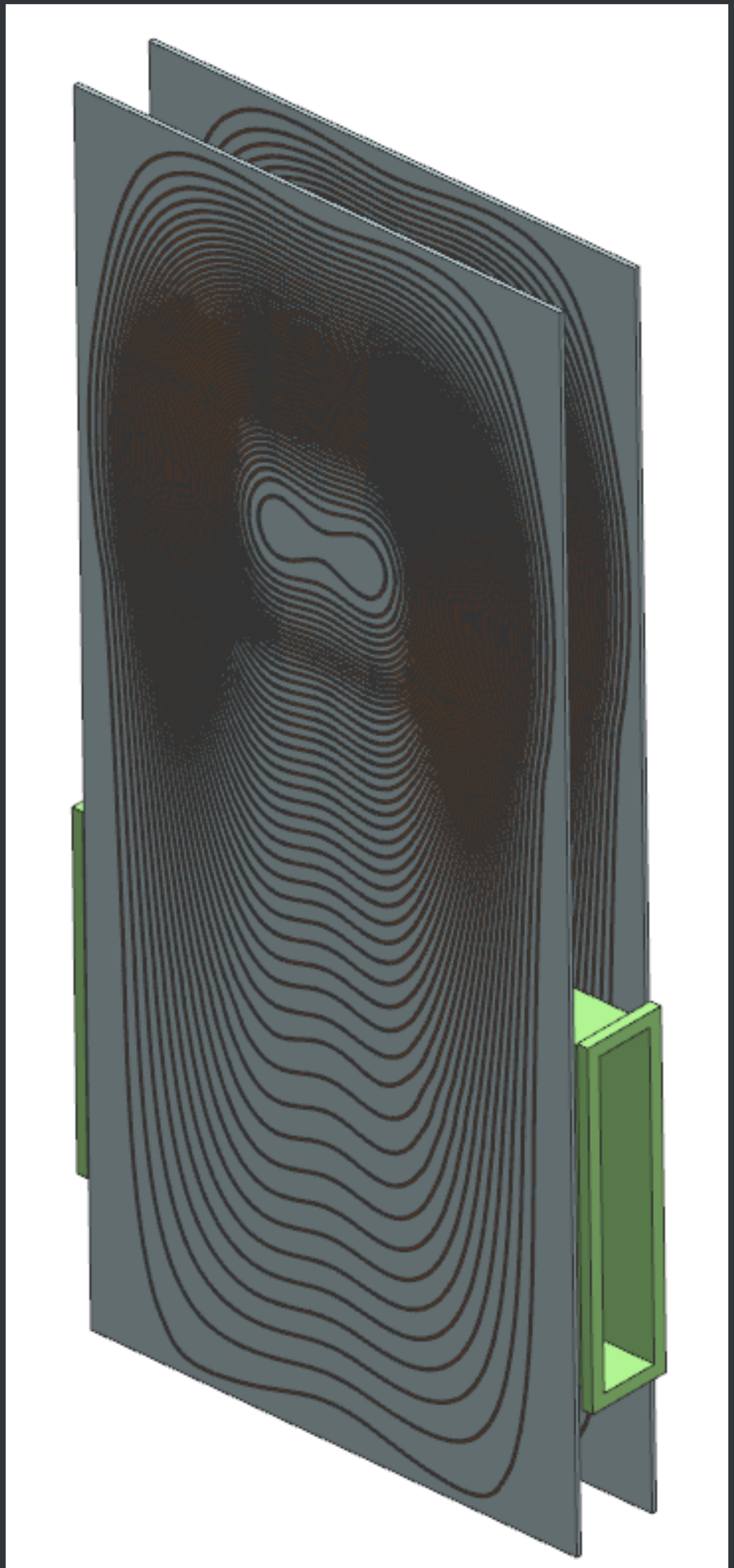
- Importance of fringe field modelling, (more in small machines).

- Expansion of the field in the magnet shows alternance of normal and skew components.

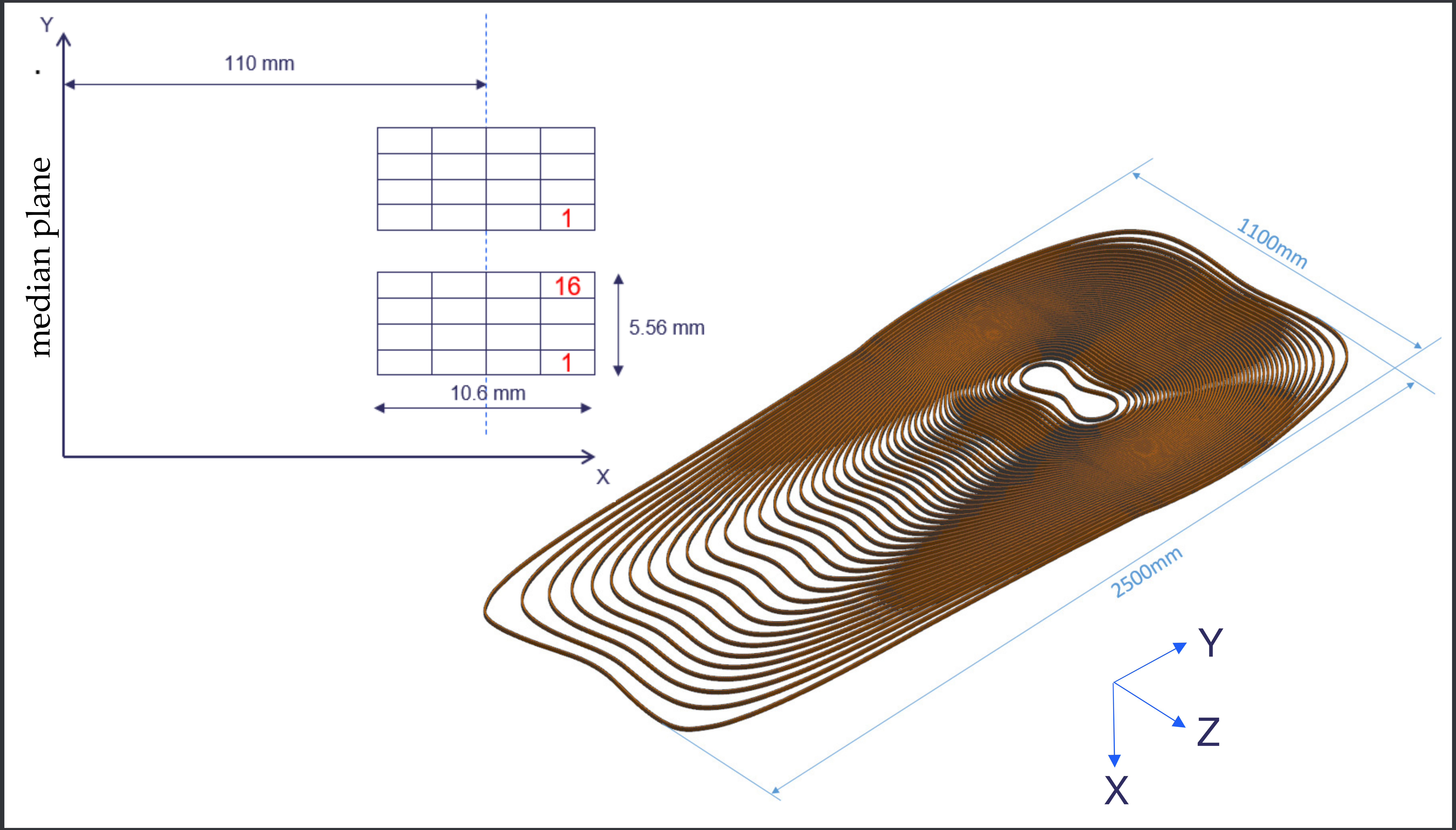
→ Strongly coupled optics

Magnet prototype at ISIS

- VFFA also considered for ISIS-II.
- Proof-of-principle ring (3-12 MeV proton) to be built by 2027.
- Prototype magnet under development:
- First prototype normal conducting with SC winding method.
- 1 m-long magnet.
- Normalised gradient m=1.3 m^{-1}.
- Vertical beam excursion 0.6 m.



Coil winding geometry



R&D for VFFA magnet

	1st NC prototype	12 MeV proton	1.2 GeV proton	1.5 TeV muon
Aperture H [mm] x D [mm]	600 x 220	700 x 300	700 x 300	700 x 200
Length [m]	1	0.5 ~ 1	2 ~ 3	10 ~ 20
Max Field [T]	0.01	3	6	9
Normalised gradient m^* [m^{-1}]	1.3	1.3 ± 25 %	1.3 ± 25 %	6.8
Momentum ratio	2	2	2	30

$^*m = \frac{1}{B}\frac{dB}{dy}$ (y: vertical direction)

(PRELIMINARY NUMBERS)

Summary

- VFFA good candidate for muon acceleration.
- Preliminary design for lattice from 50 GeV to 1.5 TeV.
- Magnet prototype at ISIS under development, strong synergy with muon collider.

Thank you for your attention