Optimal compensation of the Earth's magnetic field while changing the energy at FLASH

Martin Nuss[1]

TU Graz, Austria

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[1]Thanks to my supervisor Dr. Pedro Castro

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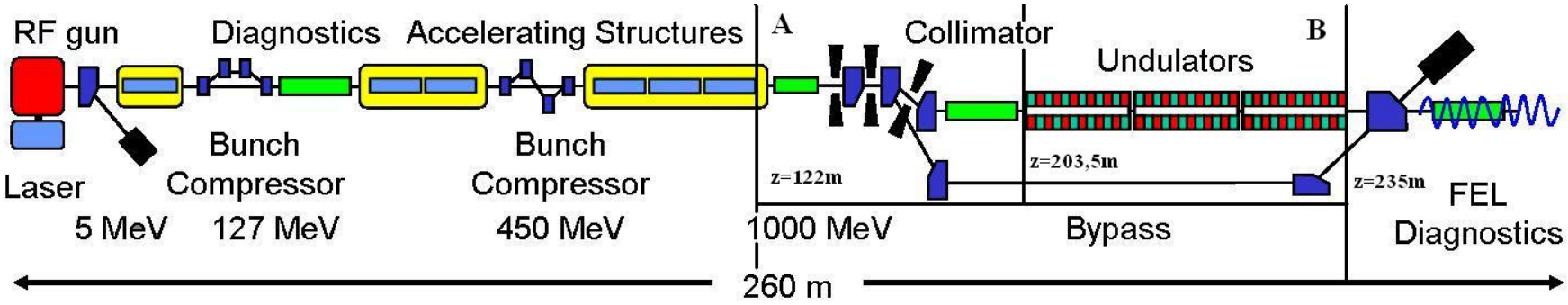
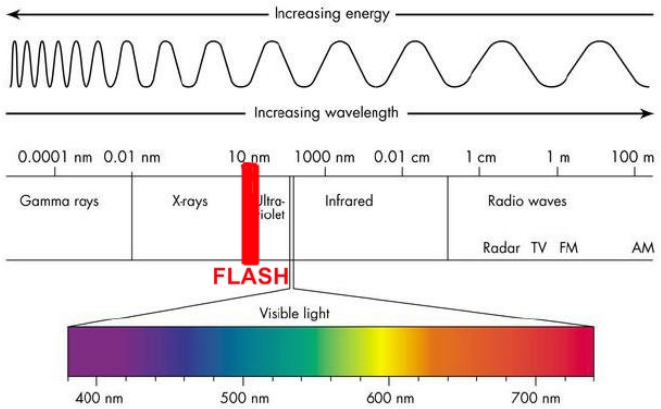
FLASH

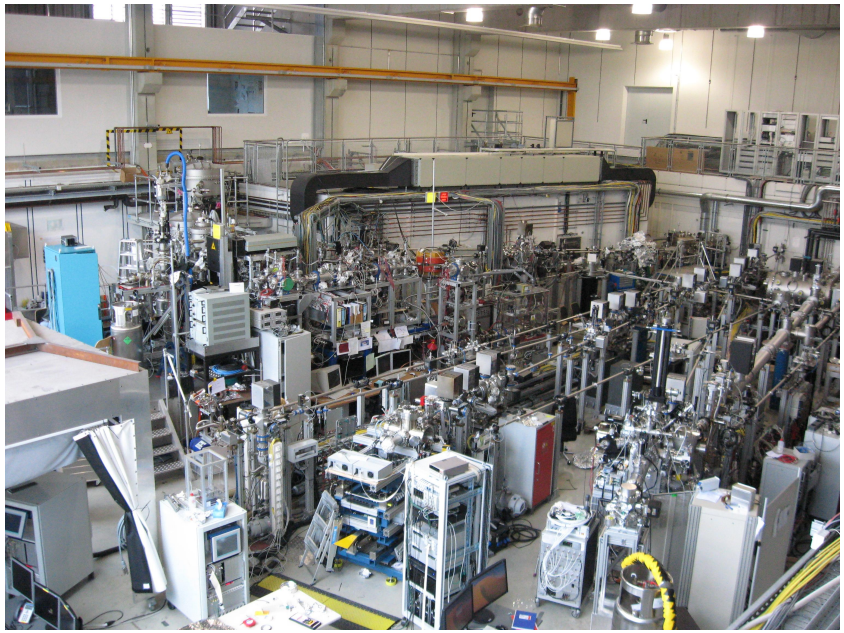


FLASH data

- Free Electron Laser: SASE
- length: $\approx 260m$
- electron beam energy: $0.3GeV$ to $1.0GeV$
- synchrotron radiation: VUV and soft X-ray



Experimentalists work with different wavelengths



$$\lambda_{photons} = \frac{\lambda_u}{2\gamma^2}(1 + \frac{K}{2})$$

γ ... relativistic γ factor

K, λ_u ... undulator constants

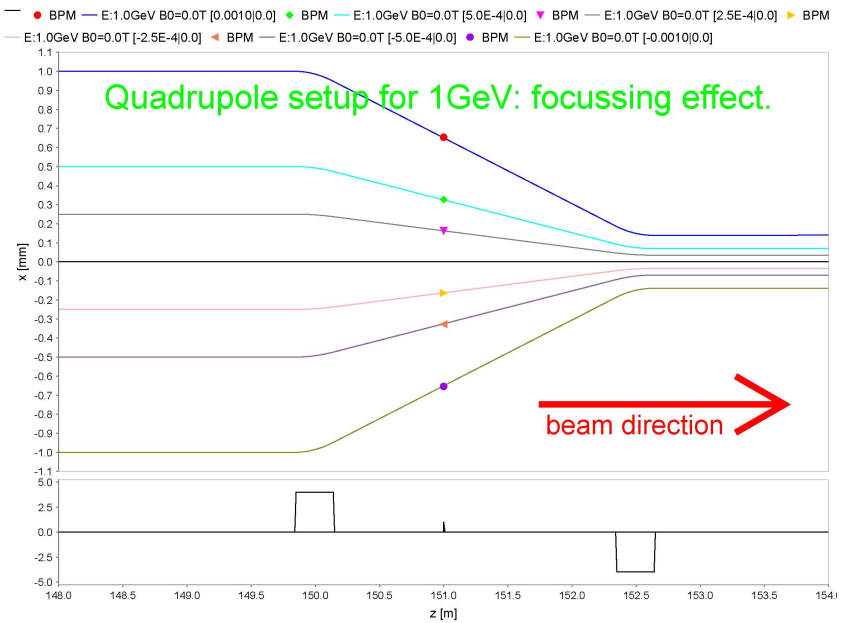
FLASH has to tune energy of e^- beam to change λ

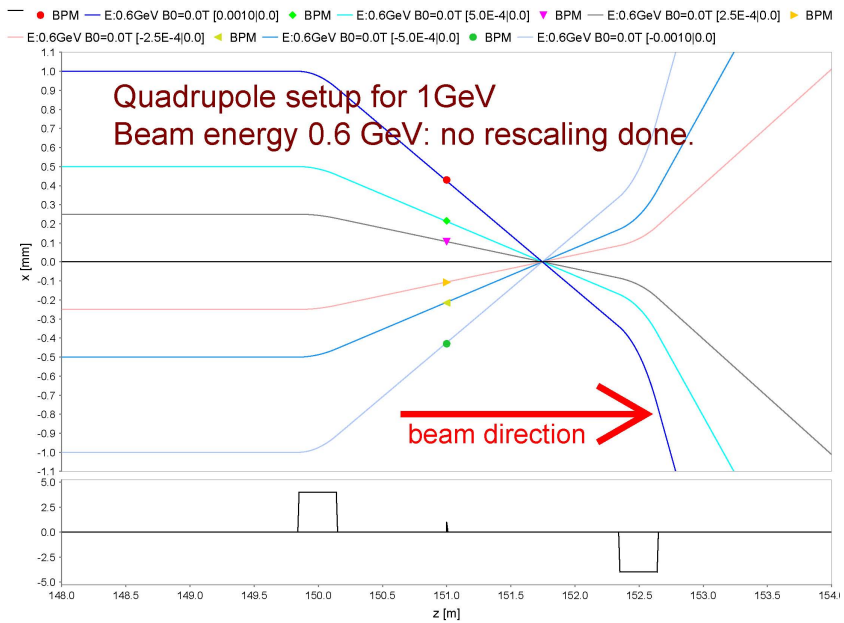
- $E = 0.3GeV \Rightarrow \lambda = 70.0nm$
- $E = 1.0GeV \Rightarrow \lambda = 6.3nm$

Energy scaling procedure

Magnets (quadrupoles and corrector dipoles) are scaled by

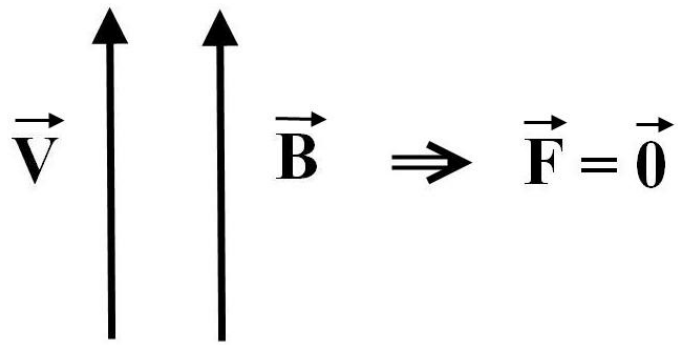
$$\vec{I}_{new} = \frac{E_{new}}{E_{initial}} \vec{I}_{initial}$$





Why does the trajectory change?

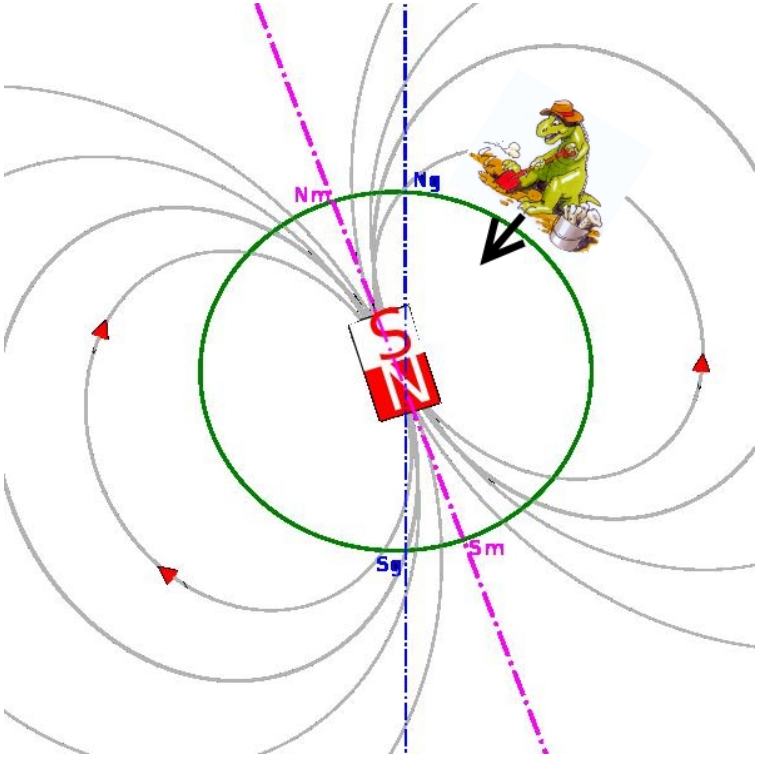
$$\vec{F}_L = q(\vec{E} + \vec{v} \times \vec{B})$$



Location of FLASH

- FLASH is situated almost in south-north direction
- $\vec{B}_{earth} || south - north$
- $\Rightarrow$ no influence of Earth's magnetic field
- But what about vertical component of $\vec{B}_{earth}$?

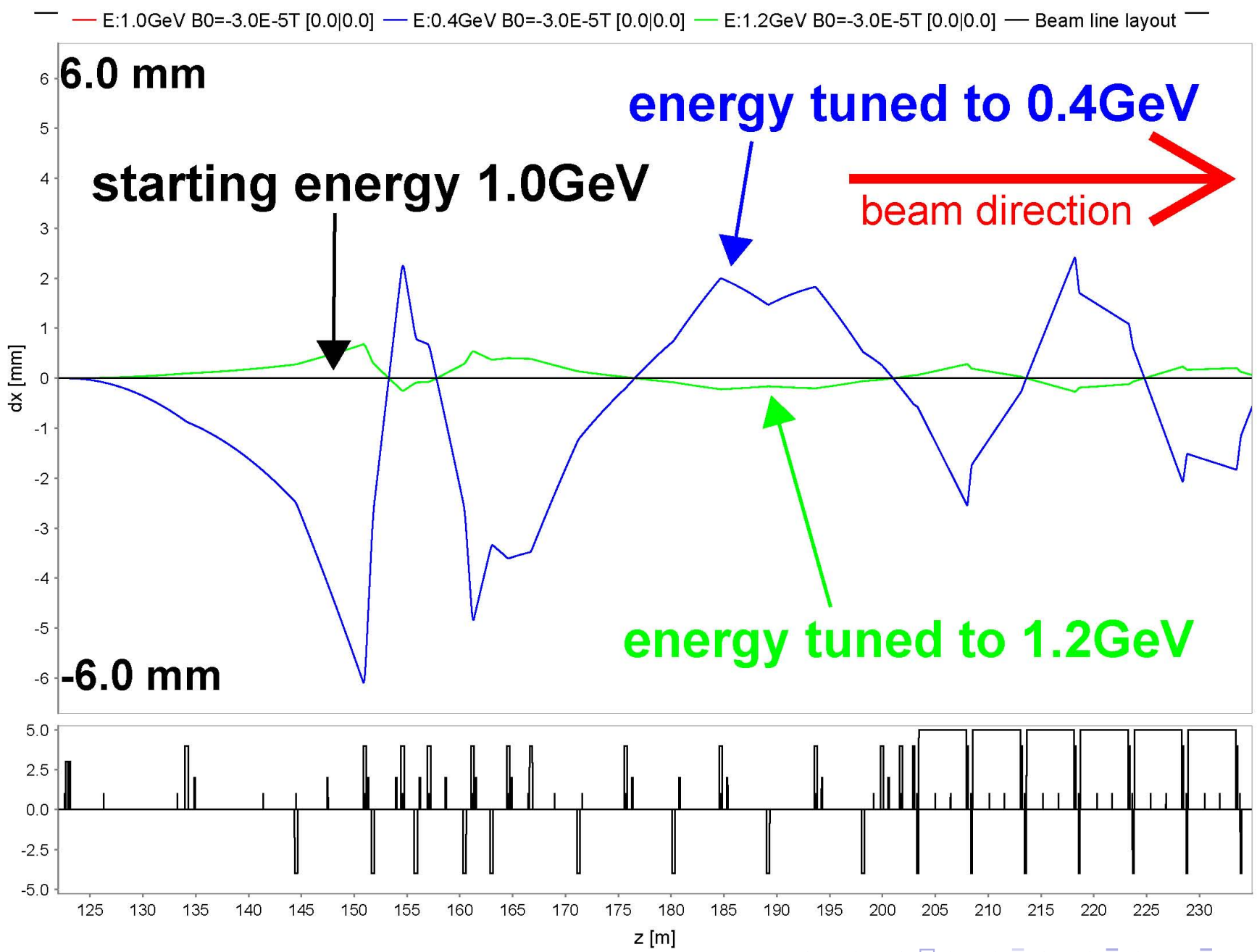
Effect of Earth's magnetic field



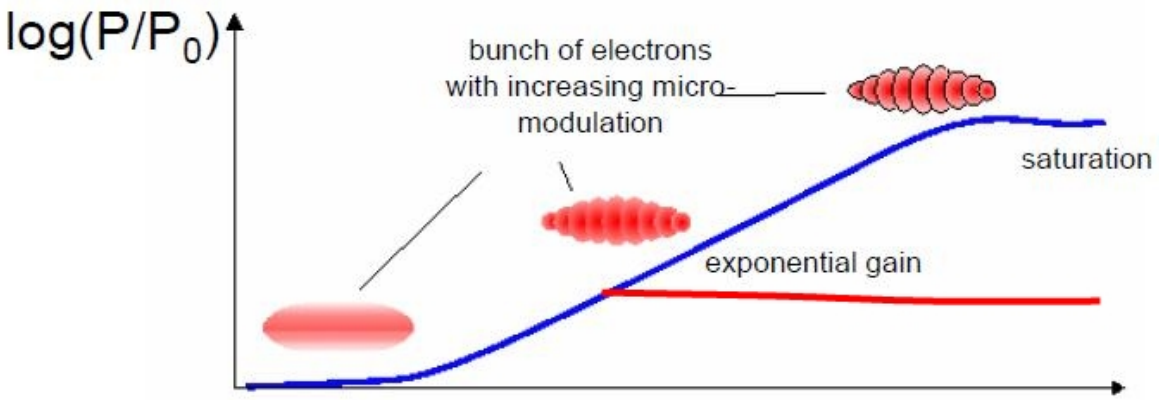
Hamburg (53°37'59"N/9°58'59"E)

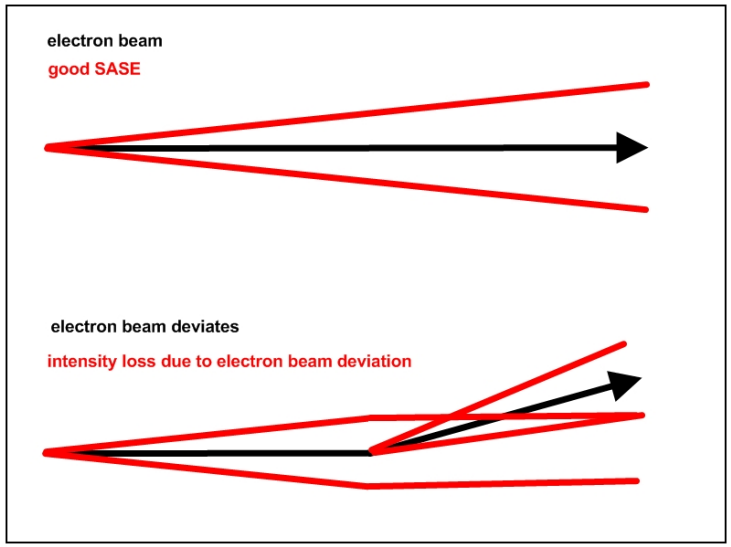
- $\vec{B}_{earth,vertical} \approx -30\mu T$
- $\Rightarrow$ vertical component affects horizontal trajectory

The trajectory while the beam energy changes



Effect of the electron trajectory on SASE





Procedure

Procedure

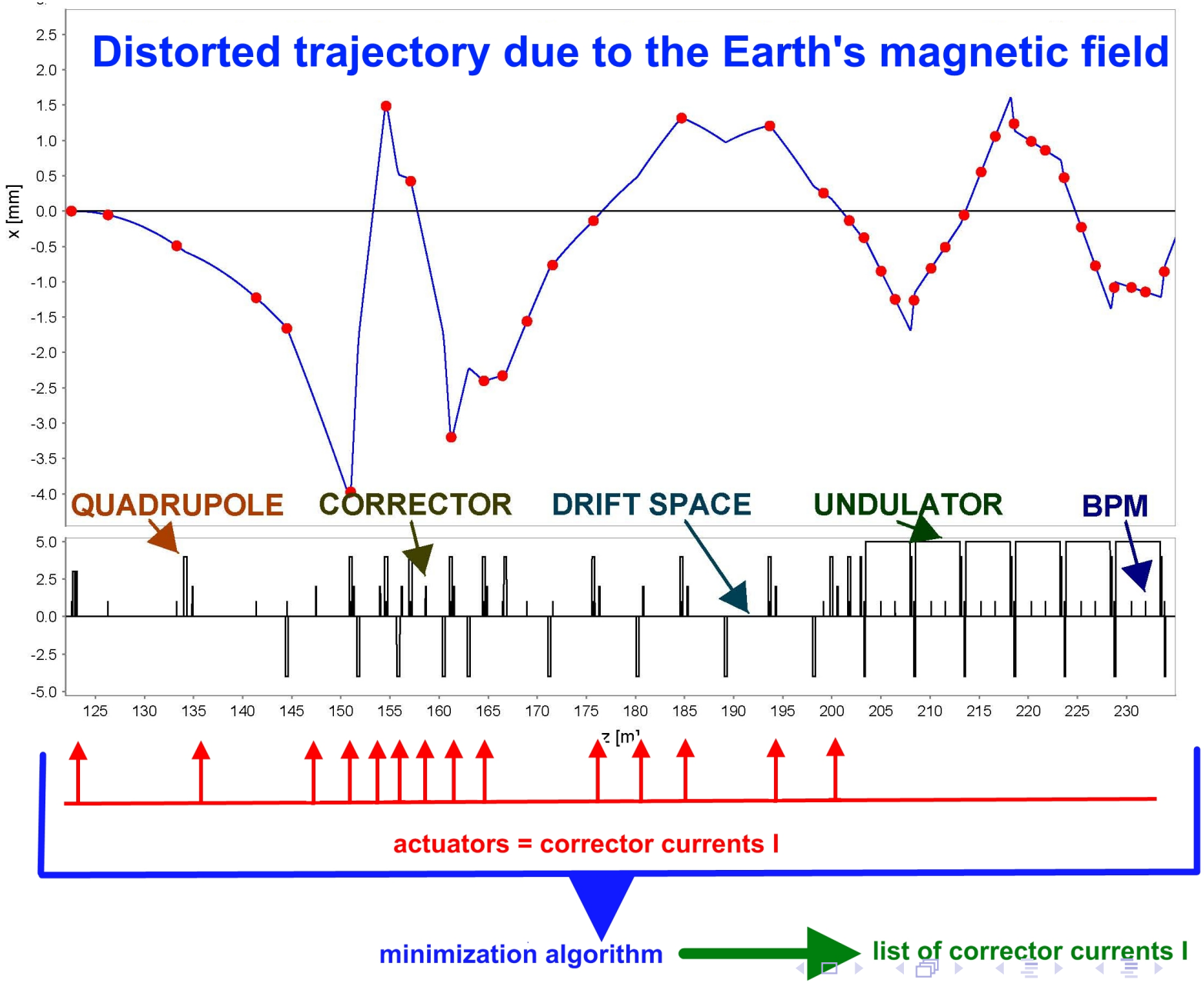
- Simulate the effects of the Earth's magnetic field
- Find a compensation scheme

Methods

Tools

- Computer simulation
- Single particle motion in EM-fields
- Transport Matrix Formalism
- Numerical Optimization

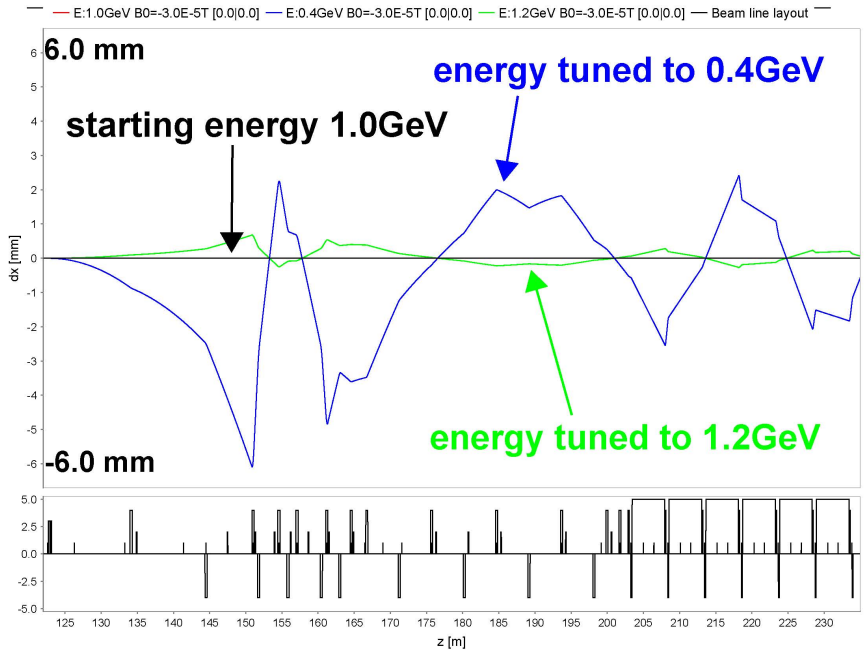
Calculation of the compensation for the Earth's magnetic field



Applied corrector currents to compensate the Earth's magnetic field

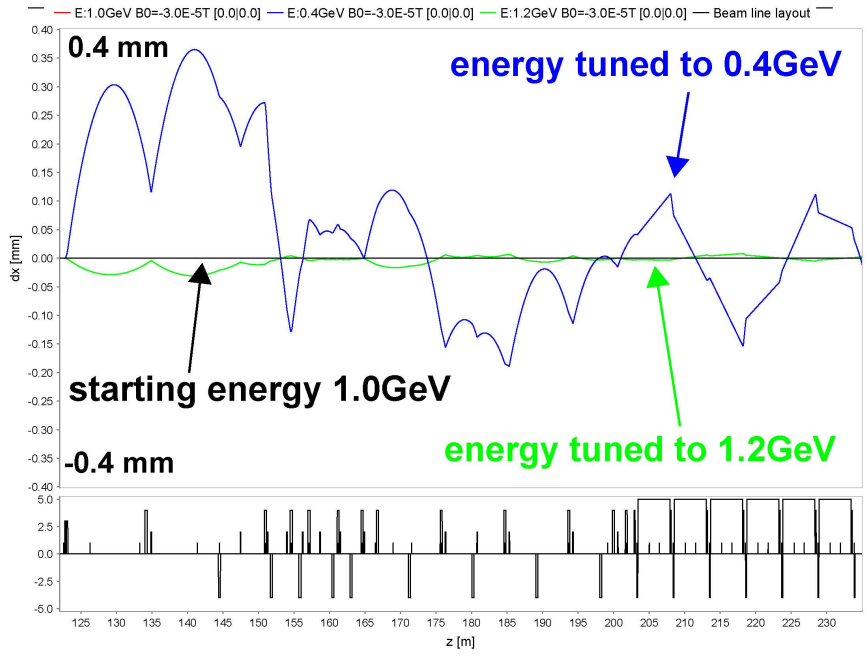
Corrector	Current
H9ACC6	530.9
H10ACC6	530.9
H10ACC7	590.9
H4TCOL	33.7
H9TCOL	-4.4
H2ECOL	57.7
H4ECOL	25.6
H6ECOL	89.3
H3MATCH	5.5
H6MATCH	18.7
H5SUND2	25.7
H4SUND3	8.1

Result, (Δx) - z is shown in the graph



$$\vec{I}_{c,new} = \frac{E_{new}}{E_{initial}} \vec{I}_{c,initial}$$

- $RMS(0.4GeV) = 1.9mm$
- $RMS(1.2GeV) = 0.21mm$



$$\vec{I}_{c,new} = \frac{E_{new}}{E_{initial}} (\vec{I}_{c,initial} - \vec{I}_c^{EARTH}) + \vec{I}_c^{EARTH}$$

- $RMS(0.4GeV) = 0.2mm$
- $RMS(1.2GeV) = 0.01mm$

Conclusion

- An optimal compensation of the Earth's magnetic field has been found.
- A new scheme for changing the energy has been developed.
- The compensating currents $\vec{I}_c^{EARTH}$ have been calculated.

Thank You!

Thank you for your attention!

If you have any questions feel free to ask them.