Scaling FFAG Straight Line

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Outline

- Scaling FFAG law
- Study of Straight Scaling FFAG: experiment at KURRI
- Applications for muons: PRISM

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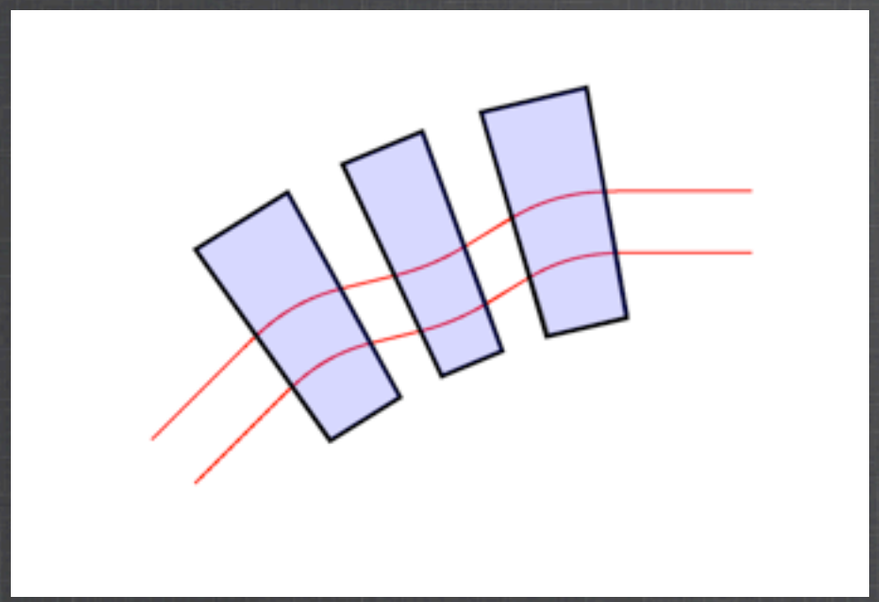
Scaling law: classical case



- Similarity of the closed orbits
- Invariance of the betatron oscillations

$$\rightarrow \quad \rho \propto r$$

& Magnetic field: $B_z = B_0 \left(\frac{r}{r_0}\right)^k$

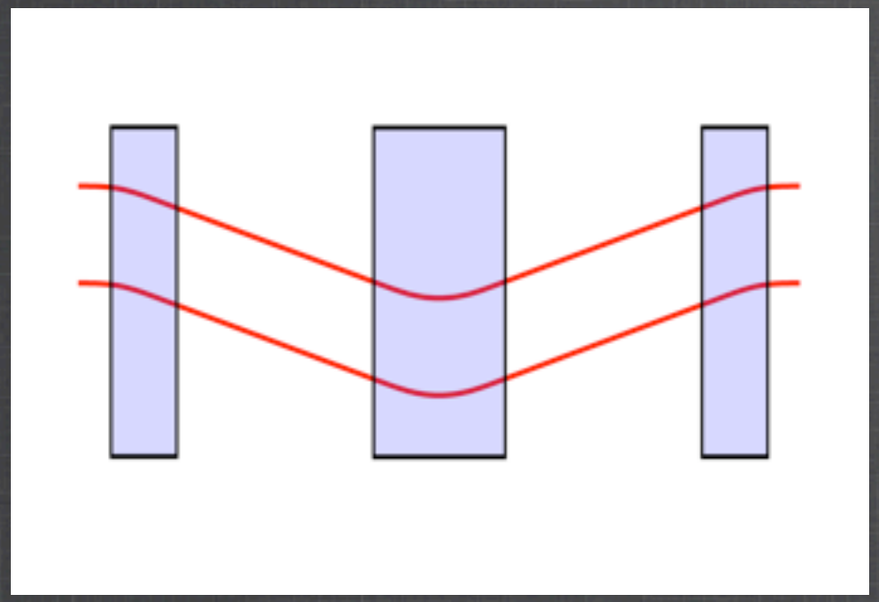
with $k = \frac{r}{B}\left(\frac{\partial B_z}{\partial r}\right)$

NB: In the linear approximation, $k = \frac{r}{\rho} n$

Momentum compaction factor: $\alpha = \frac{1}{k+1}$

Dispersion function: $D(p_0) = p_0 \left(\frac{\partial r}{\partial p}\right)_{p_0} = \frac{r}{k+1}$

Scaling law: straight case



- Similarity of the closed orbits
- Invariance of the betatron oscillations

$$\rightarrow \quad \rho = const.$$

& Magnetic field: $B_z = B_0 e^{m(x-x_0)}$

$$\text{with } m = \frac{1}{B}\left(\frac{\partial B_z}{\partial x}\right)$$

NB: In the linear approximation, $m = \frac{n}{\rho}$

Momentum compaction factor: $\alpha = 0$

Dispersion function: $D(p_0) = p_0 \left(\frac{\partial x}{\partial p}\right)_{p_0} = \frac{1}{m}$

Linear approx.: $\lim_{r_0 \to \infty} \left(\frac{r}{r_0}\right)^k = \lim_{r_0 \to \infty} \left[\left(1+\frac{x}{r_0}\right)^{\frac{r_0}{x}}\right]^{\frac{x}{r_0}k} = \left[\lim_{r_0 \to \infty} \left(1+\frac{x}{r_0}\right)^{\frac{r_0}{x}}\right]^{\frac{n}{\rho}x} = e^{\frac{n}{\rho}x} = e^{mx}$

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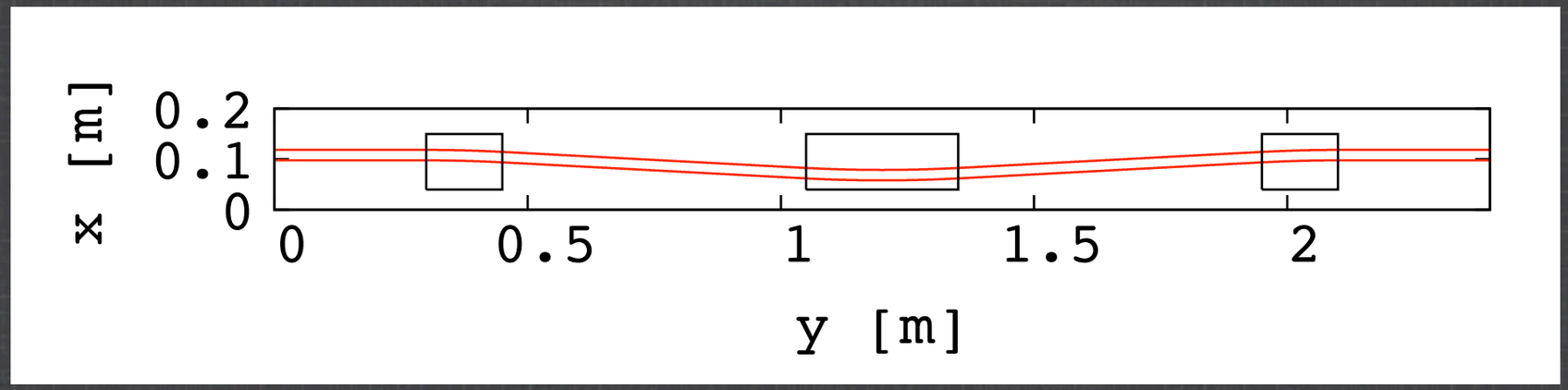
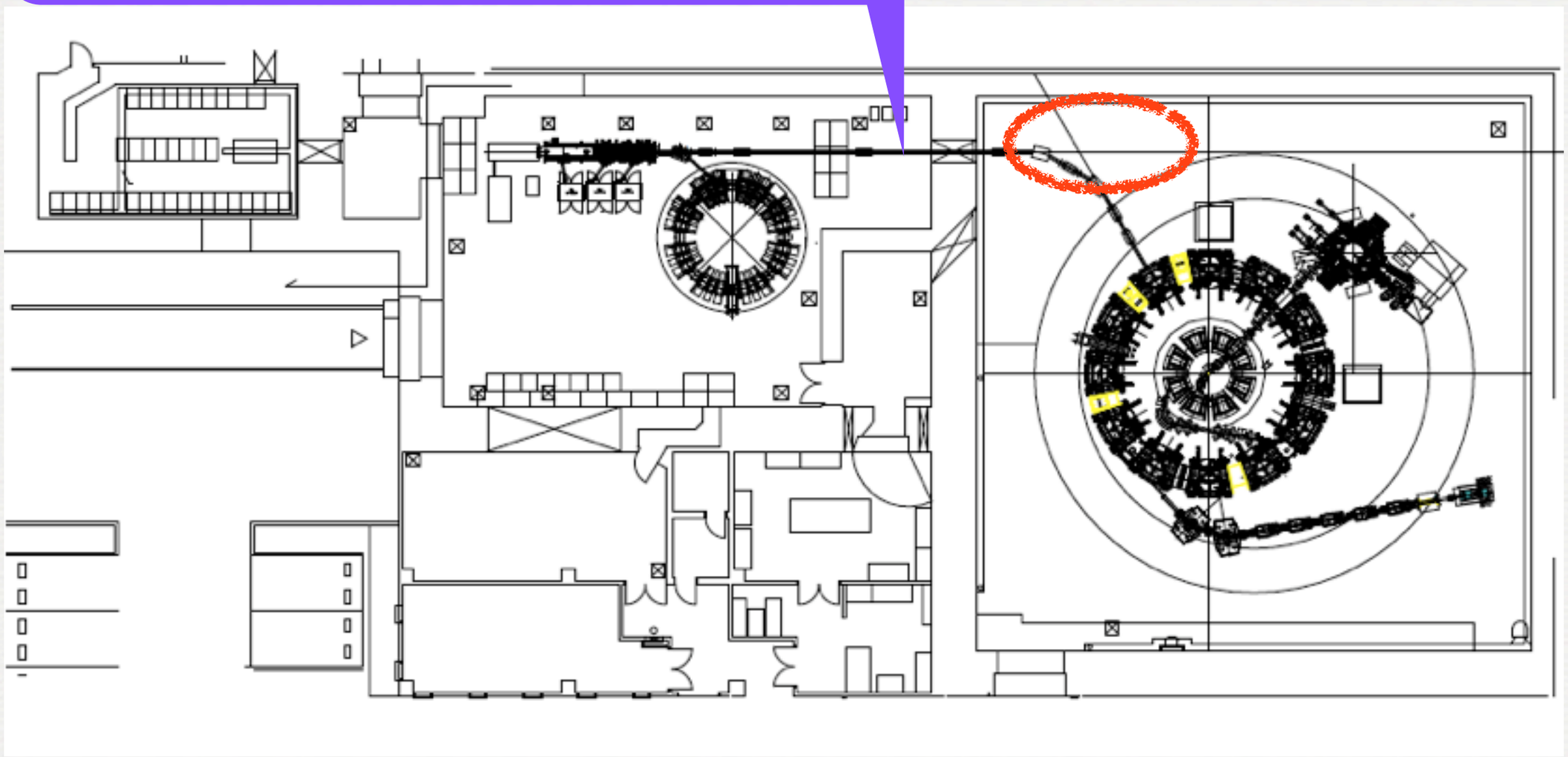
Study of Straight Scaling FFAG

In Kyoto University, an experiment is
under construction to verify the straight field law.



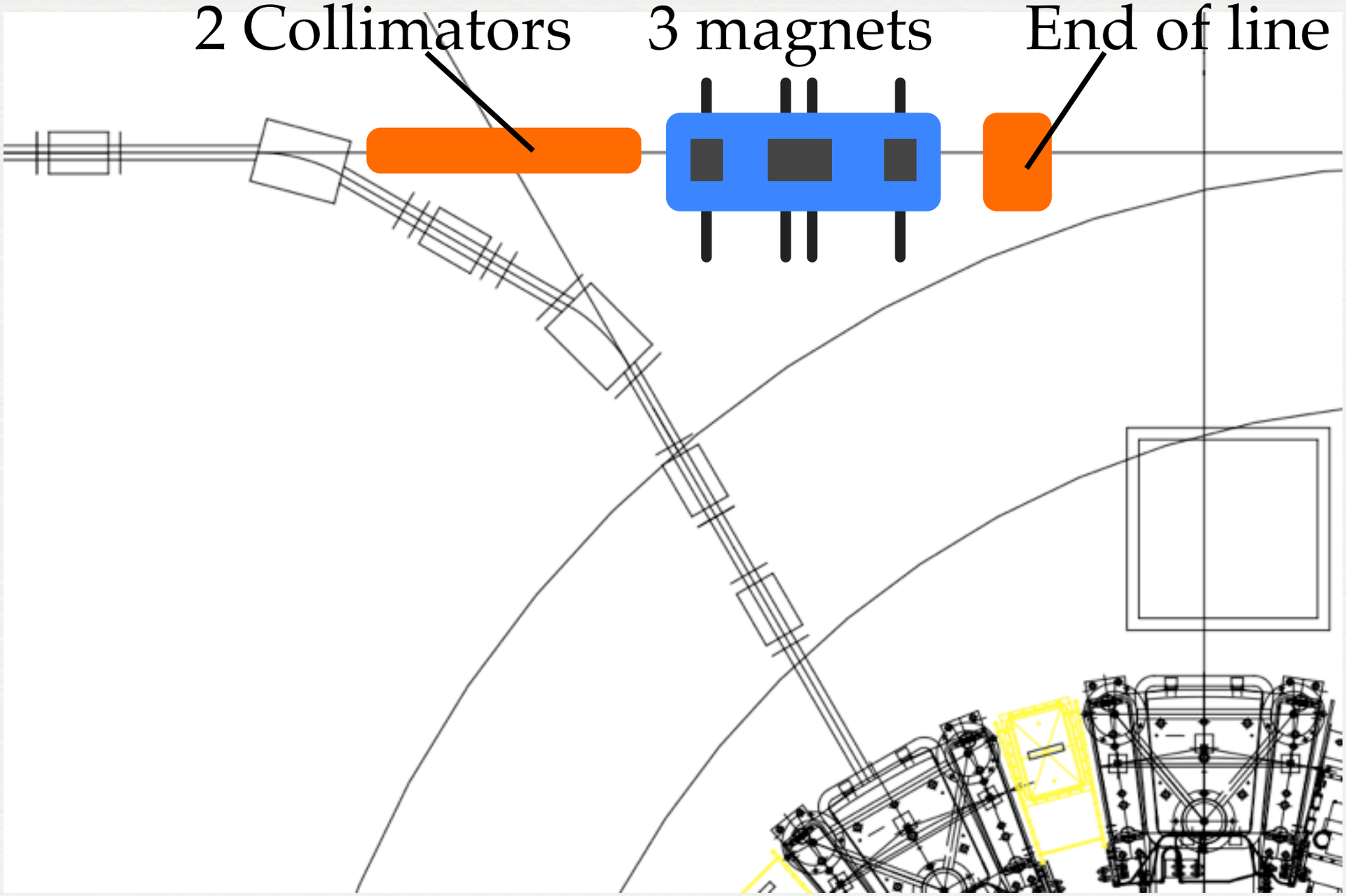
Experiment

Layout of the experiment



Use of 2 energies: 7 MeV and 11 MeV.

Layout of the experiment



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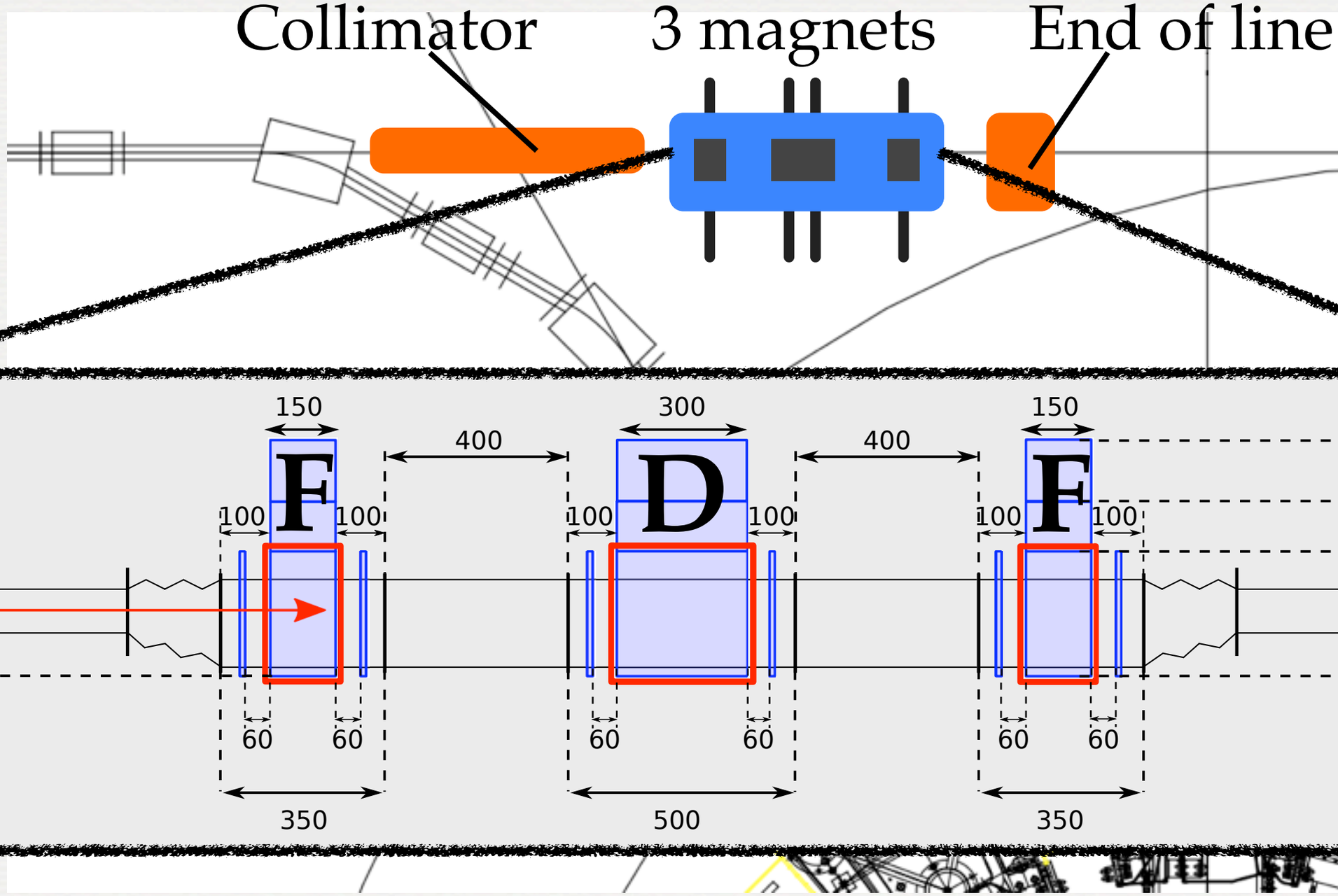
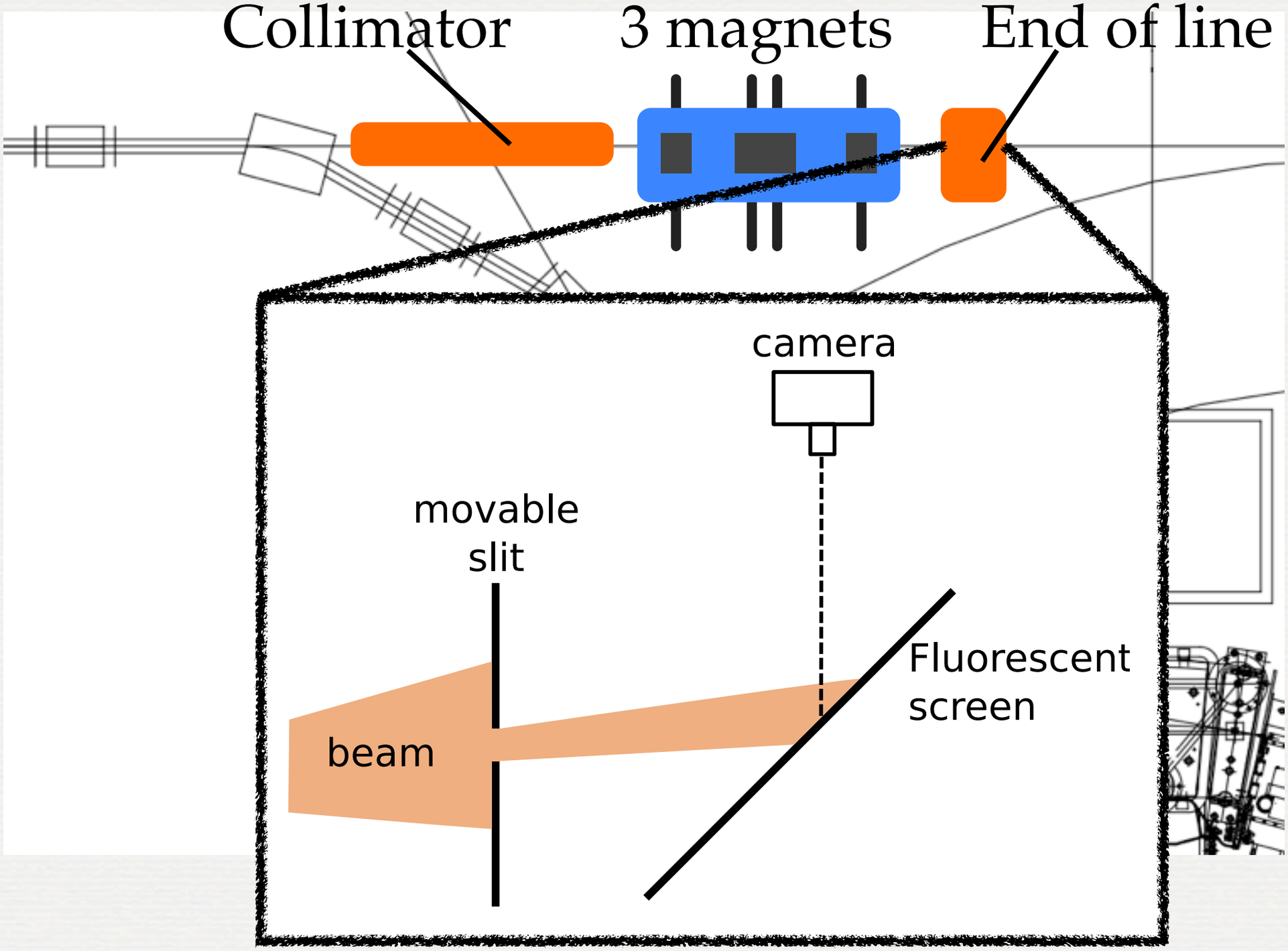
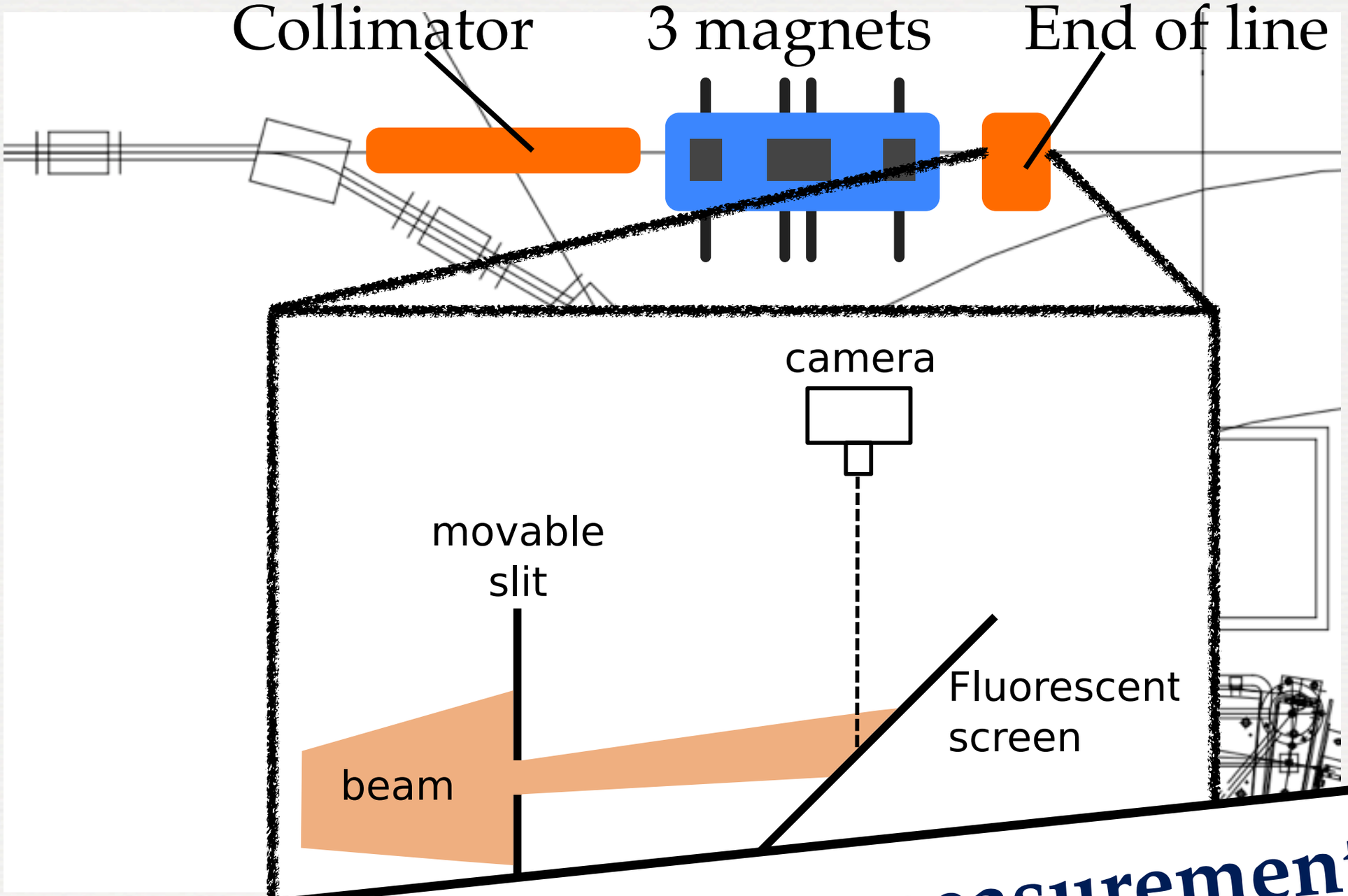


Layout of the experiment



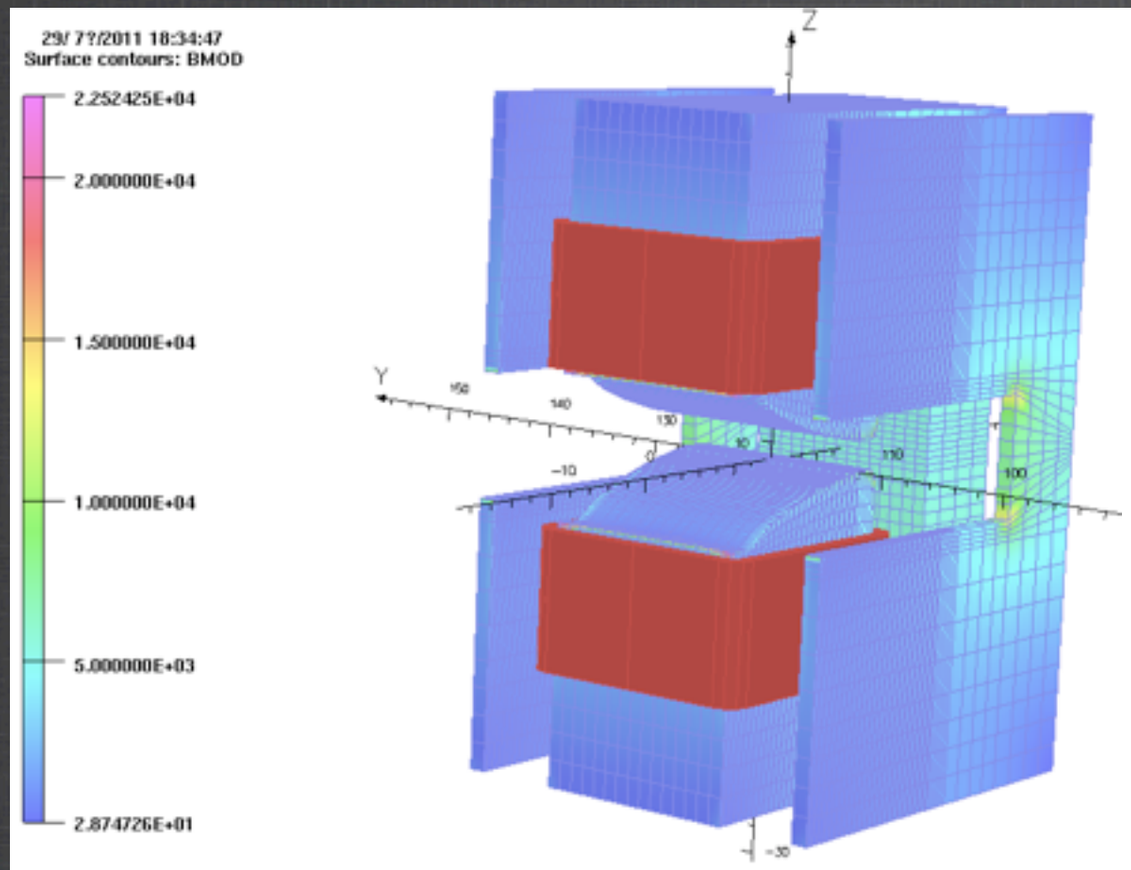
Layout of the experiment



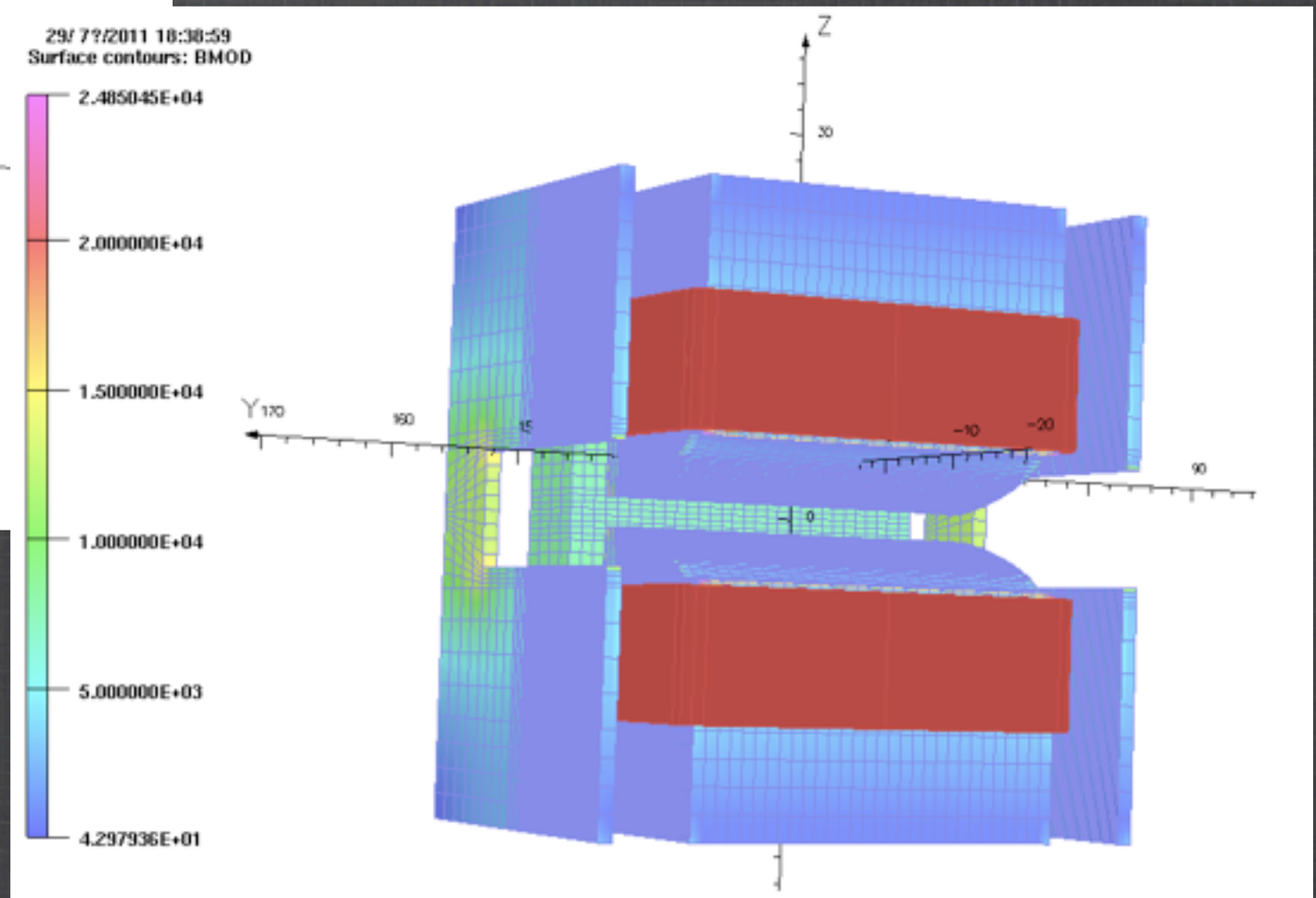
Twiss parameters measurement

Magnet design

Pole shape configured with TOSCA.

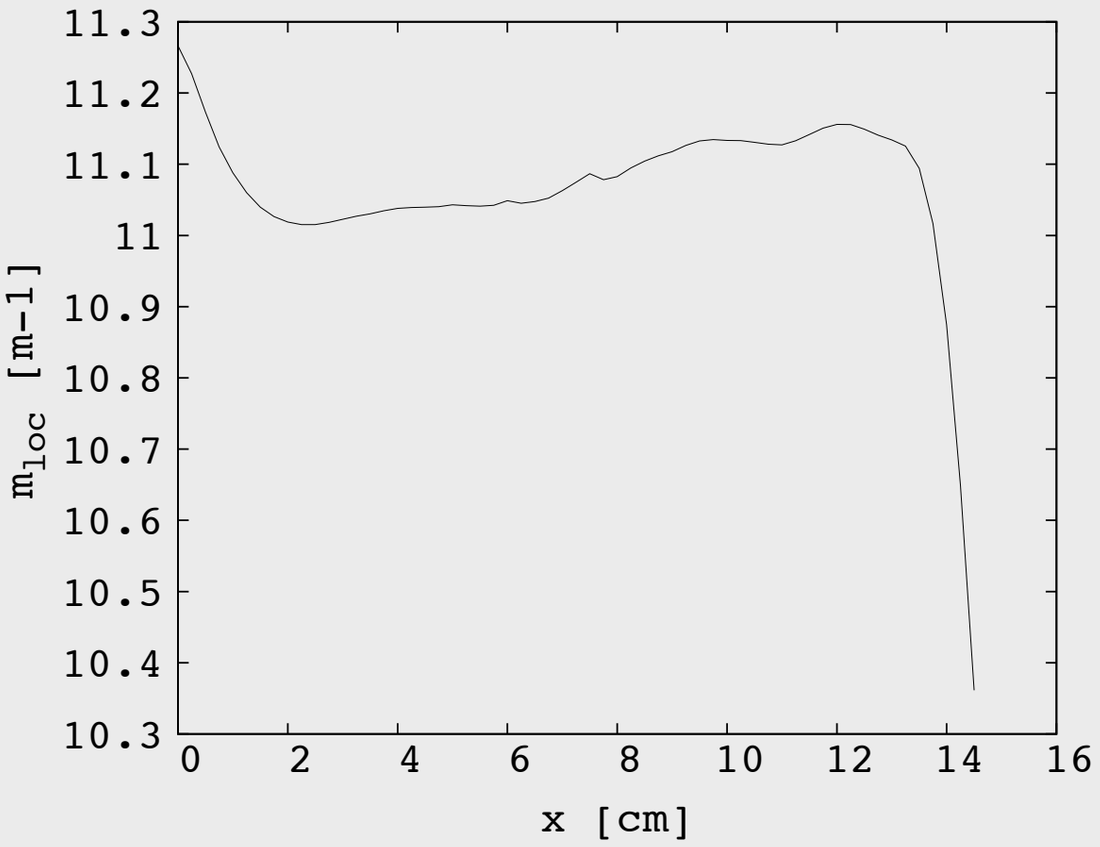


Magnetic field in
F magnet (15 cm long)

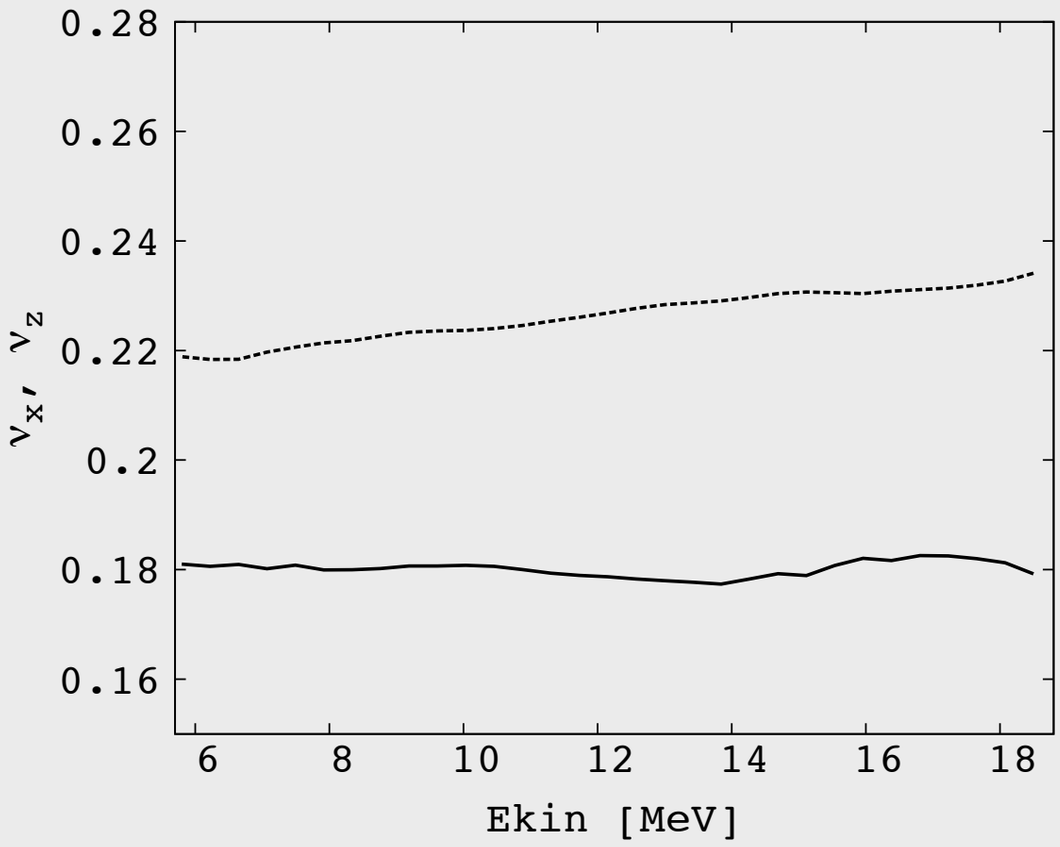


Magnetic field in
D magnet (30 cm long)

Tracking in Field map

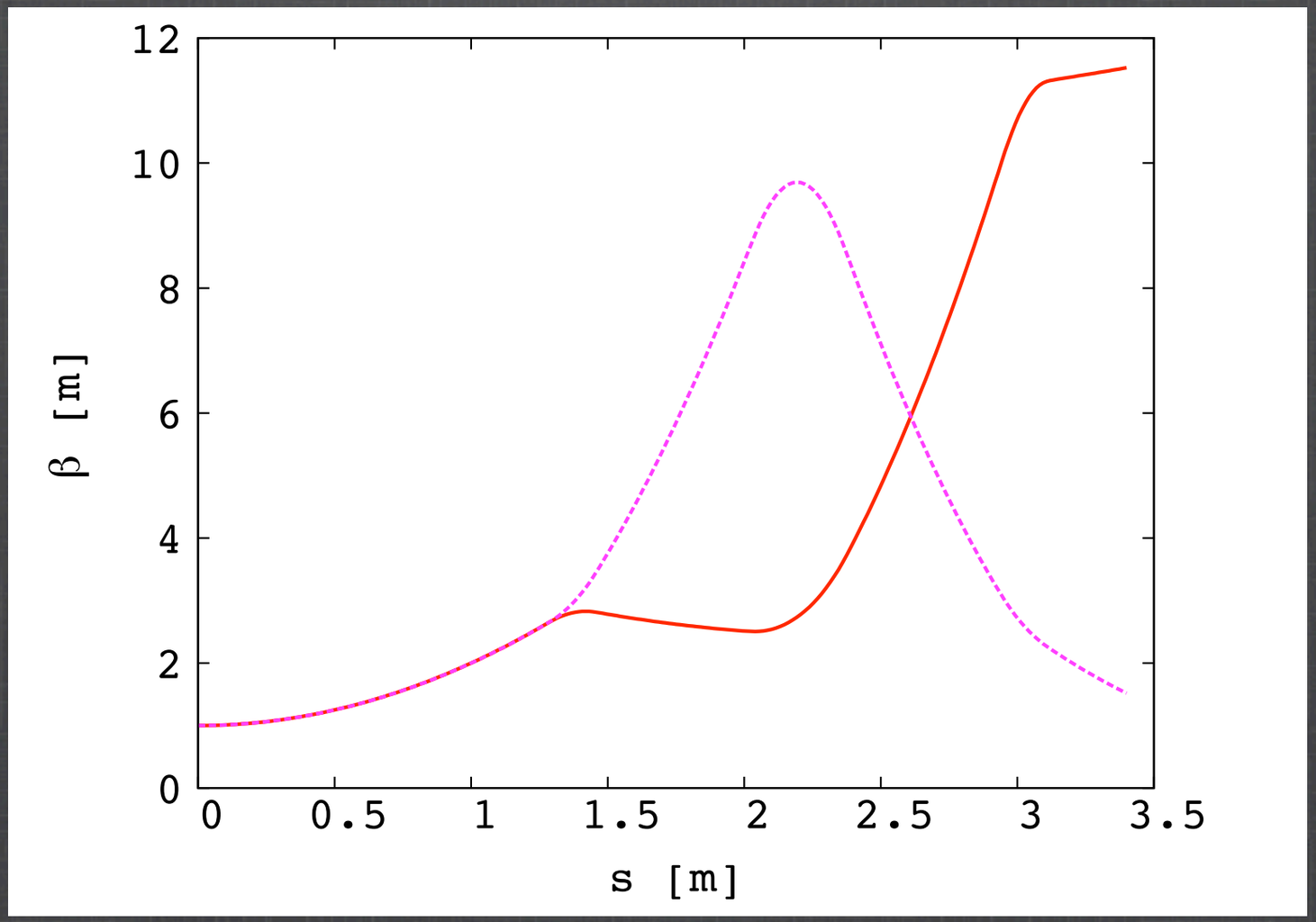


Local m value vs horizontal abscissa



Horizontal (plain) and vertical (dot) phase advances vs kinetic energy

Tracking in Field map



Horizontal (plain red) and vertical (dotted purple) betafunctions in the straight FFAG line

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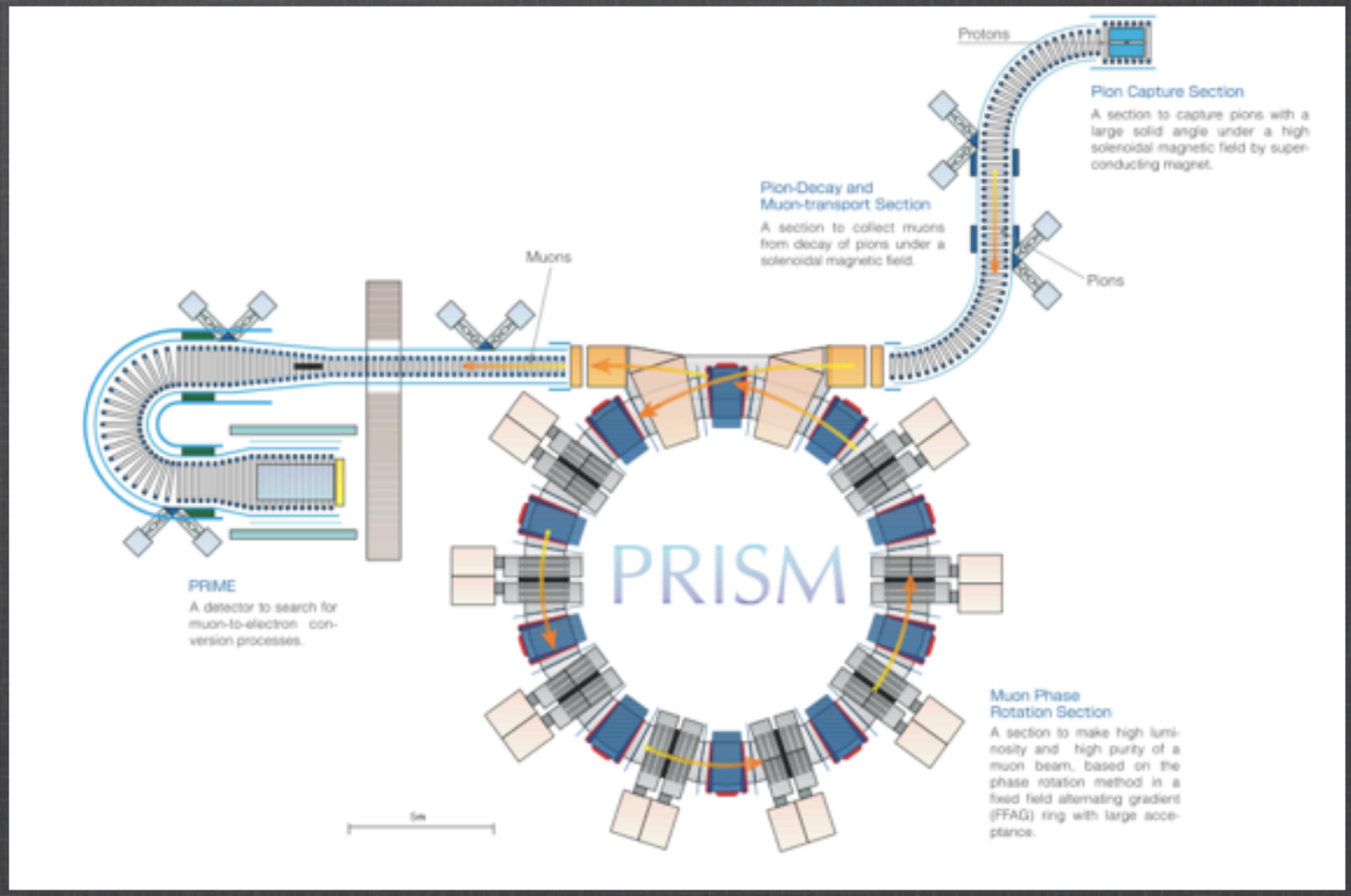
Applications

PRISM project

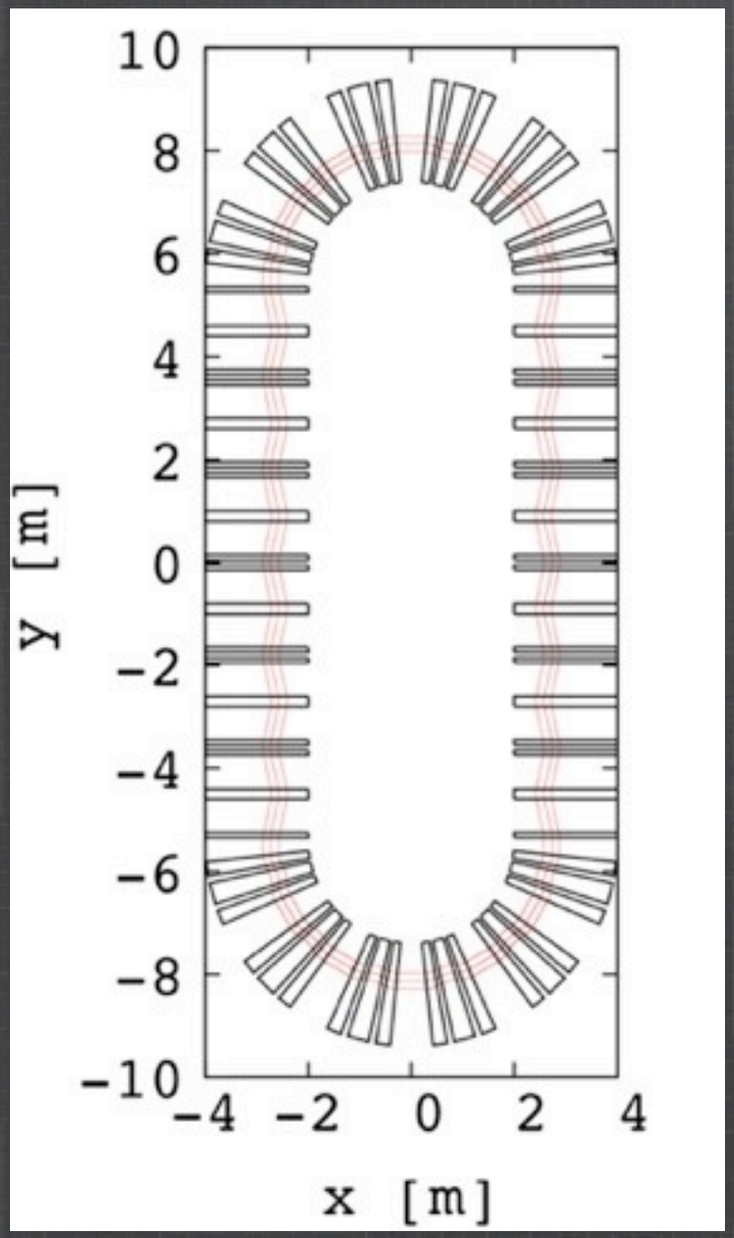
Muon phase rotator
(at Osaka University)

- Momentum acceptance:
  68MeV / c ± 20%
- Transverse acceptance:
  - hor.: 30 000π mm.mrad
  - vert.: 3 000π mm.mrad



Applications

Race-track scaling FFAG PRISM

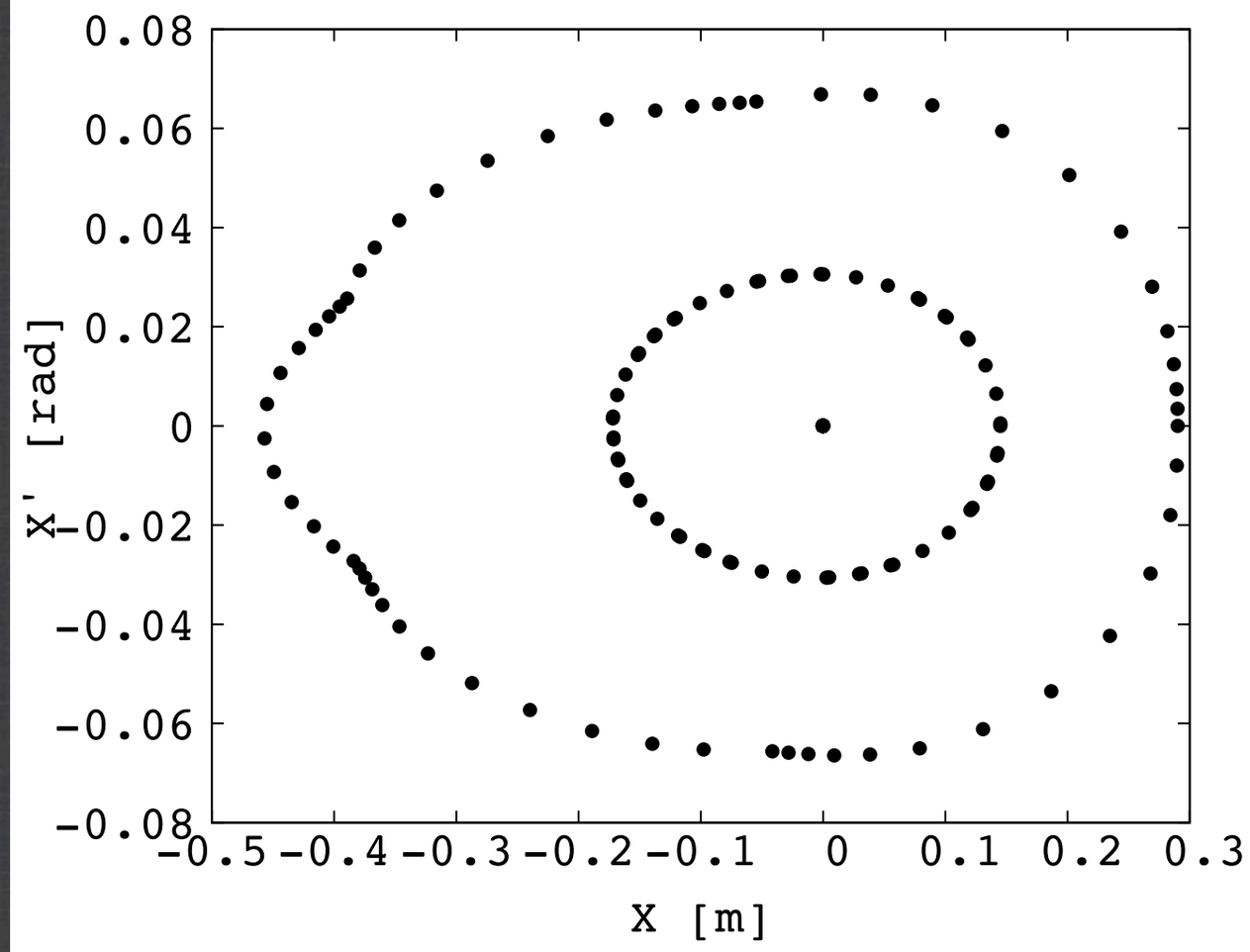


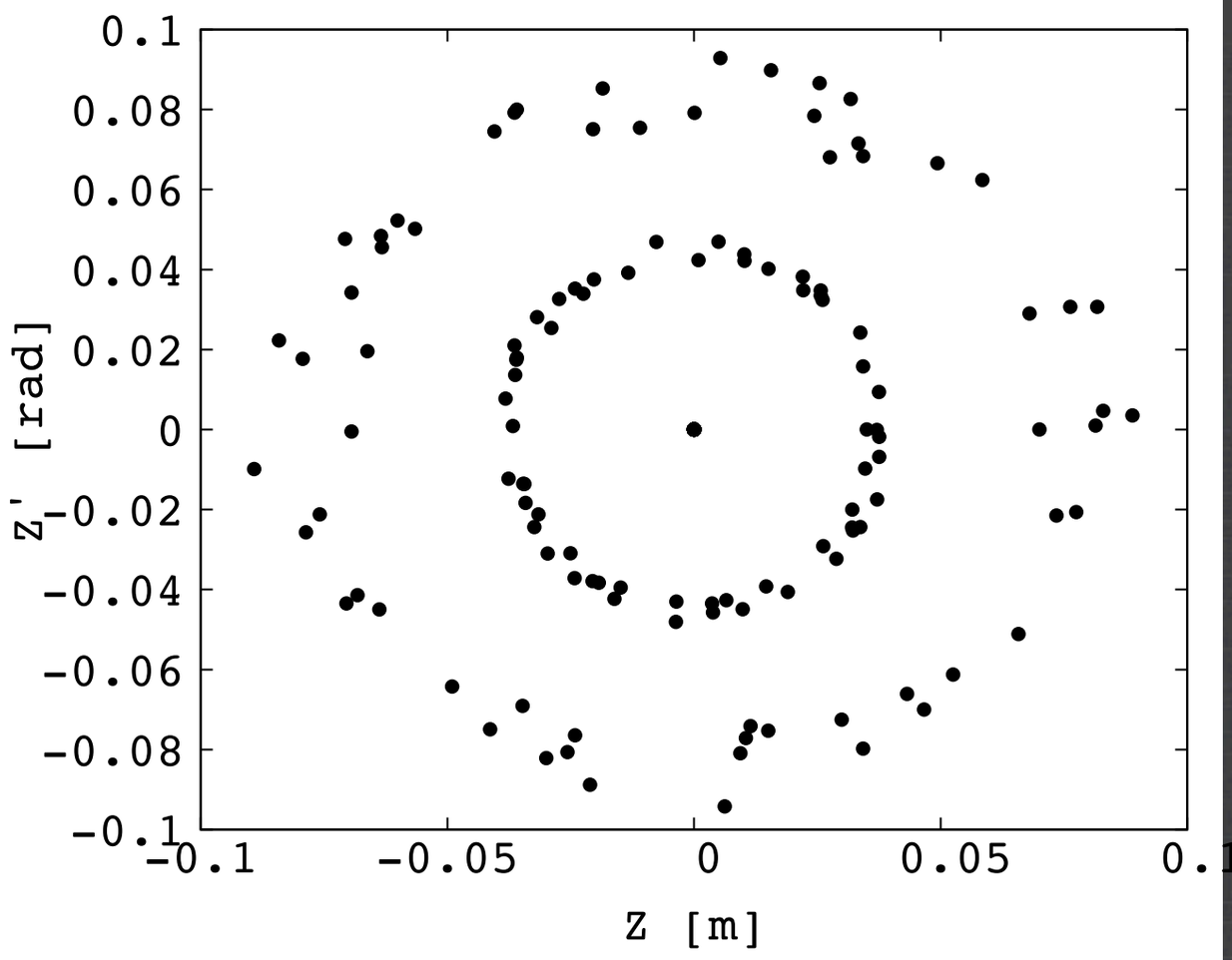
Bending cell FDF triplet	
k-value	2.55
Average radius	2.7 m
Phase advances:	
Horizontal μ_x	60 deg.
Vertical μ_z	90 deg.
Dispersion	0.8 m

Straight cell	
m-value	$1.3\,\mathrm{m}^{-1}$
Length	1.8 m
Phase advances:	
Horizontal μ_x	27 deg.
Vertical μ_z	94 deg.
Dispersion	0.8 m

Applications

Acceptances of race-track PRISM

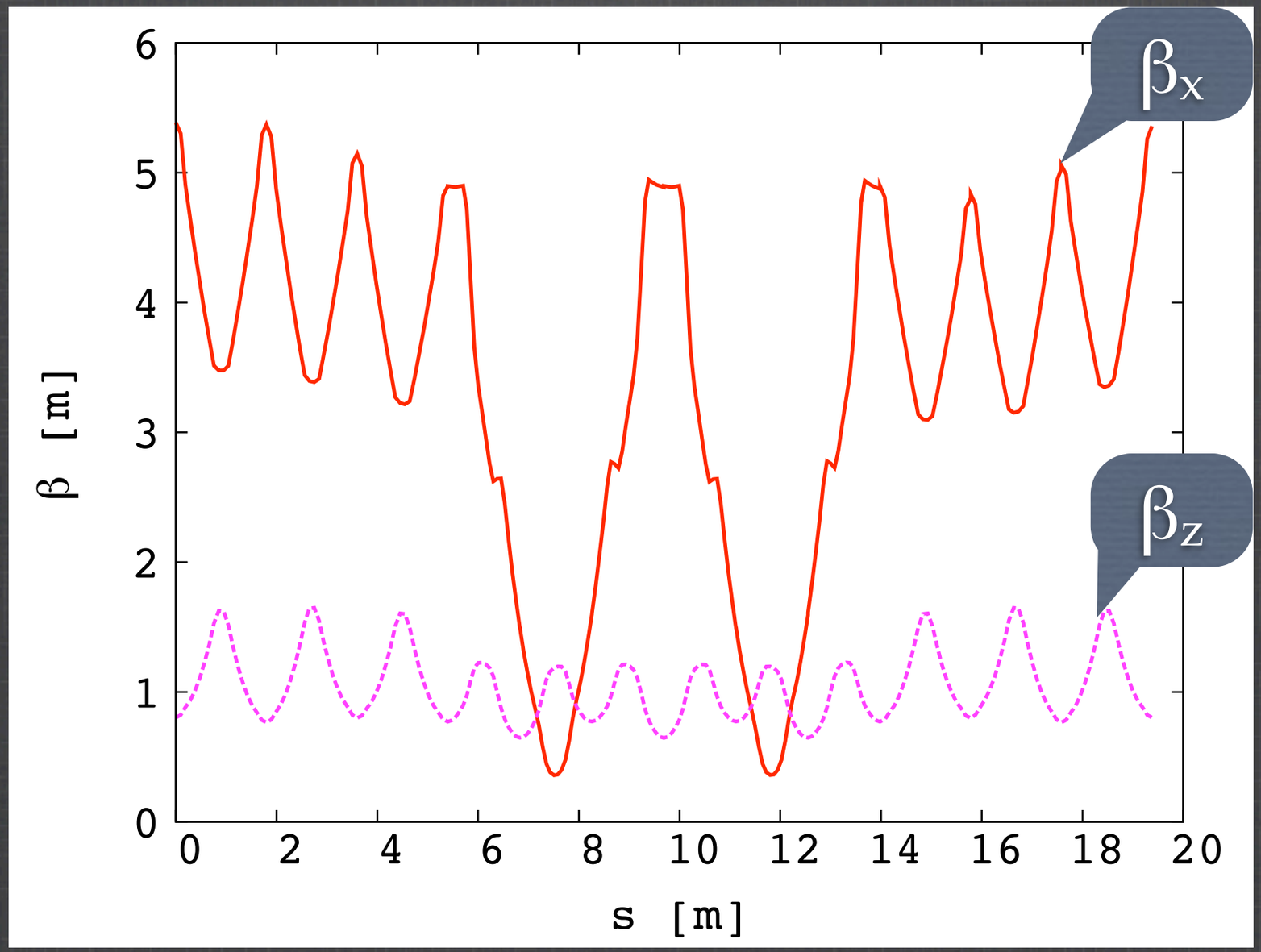




Horizontal (left) and vertical (right) acceptance of the ring over 30 turns
Far collimators identify lost particles

Applications

Horizontal (plain red) and vertical (dotted purple) betafunctions of half the ring in race-track PRISM



Applications

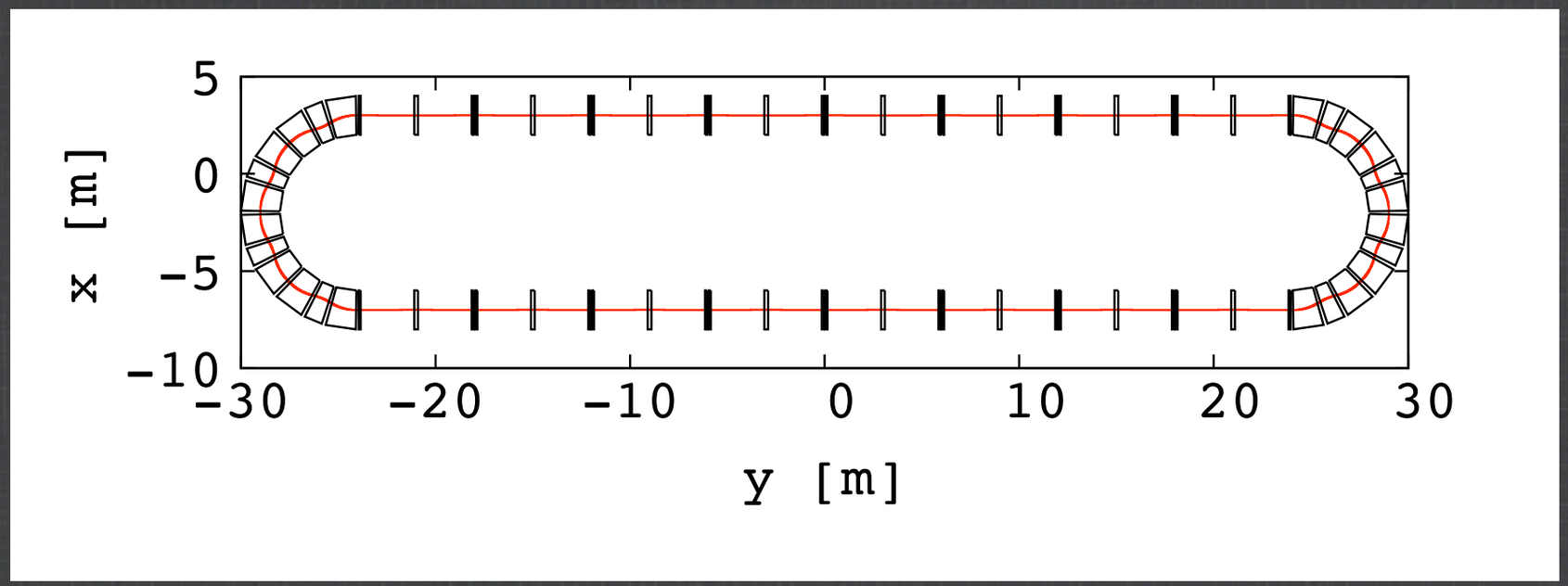
VLENF: storage ring proposal (Preliminary)

Beam momentum : 1 GeV/c (3 GeV/c)

Momentum acceptance ~± 50%

Transverse acceptance $\varepsilon_N > 30\,000\ \pi$ mm.mrad

Scallop in the straight part < 5 mrad



Bmax ~ 1.5 T

m ~ 8 m^{-1}

k ~ 2.5

r ~ 5 m

cf. T. Roberts, VLNEF July 2011: 6D acceptance > 100 times bigger

Summary

- Recently a new field law has been found to guide particles with no overall bend in scaling FFAGs
- An experiment is under construction to study this new law.
- It is very promising in various applications, to solve problems and improve accelerator performances.

Thank you for your attention