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Matching of vertical orbit and dispersion function

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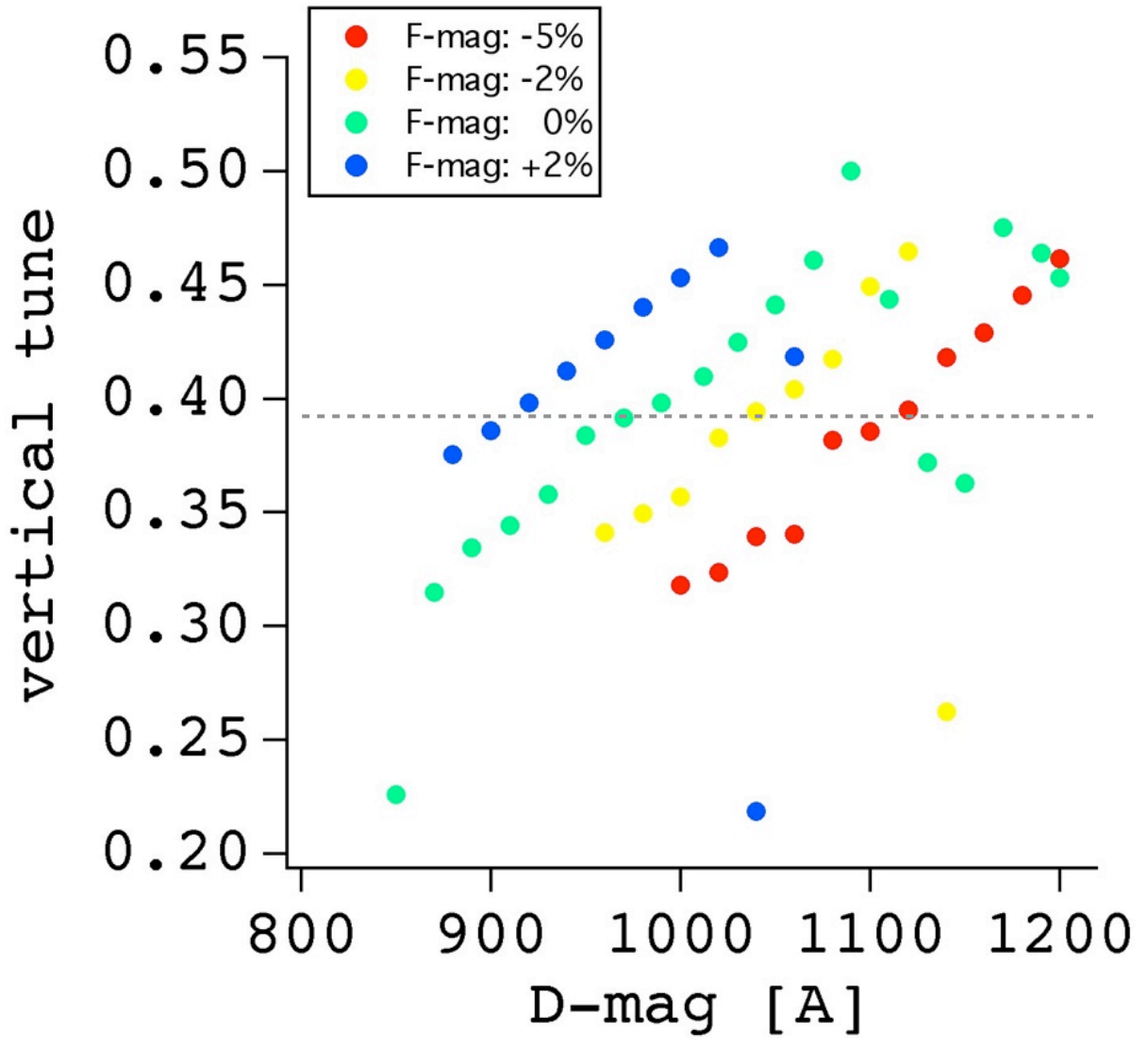
Dispersion function of line

- A way to change equivalent momentum.
  - Change F-magnet current by x%.
  - In order to keep the same F/D ratio in magnet strength, adjust D-magnet current so that the vertical tune is the same as before.
  - This does not mean the main magnet strength changes by x%, but assume that there is a linear relation between magnet current and magnet strength.
  - Change of *magnet strength* by y% creates an orbit of off-momentum particle by -y%.



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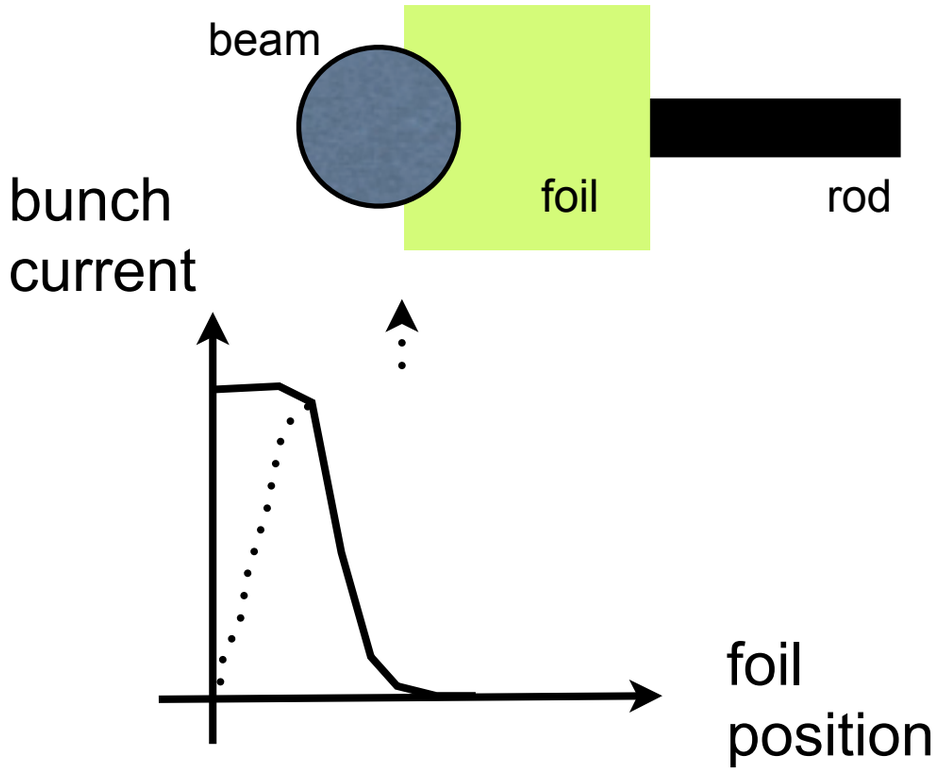
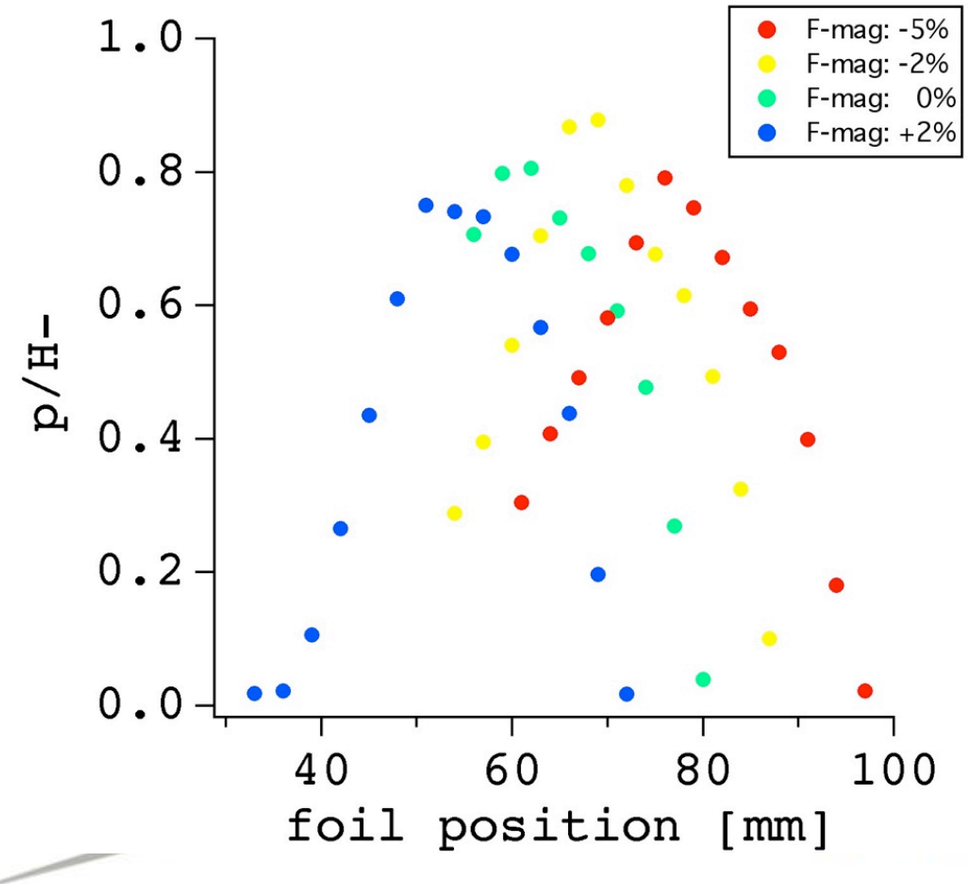
Dispersion function of line

- Measure beam position at foil.
  - Move foil from inner radius position.
  - Measure proton current after one turn at S7up.
  - Define the beam position at foil when p/H- ratio becomes maximum.
  - There is no flat top in the measured p/H- ratio suggesting beam size is larger than foil.

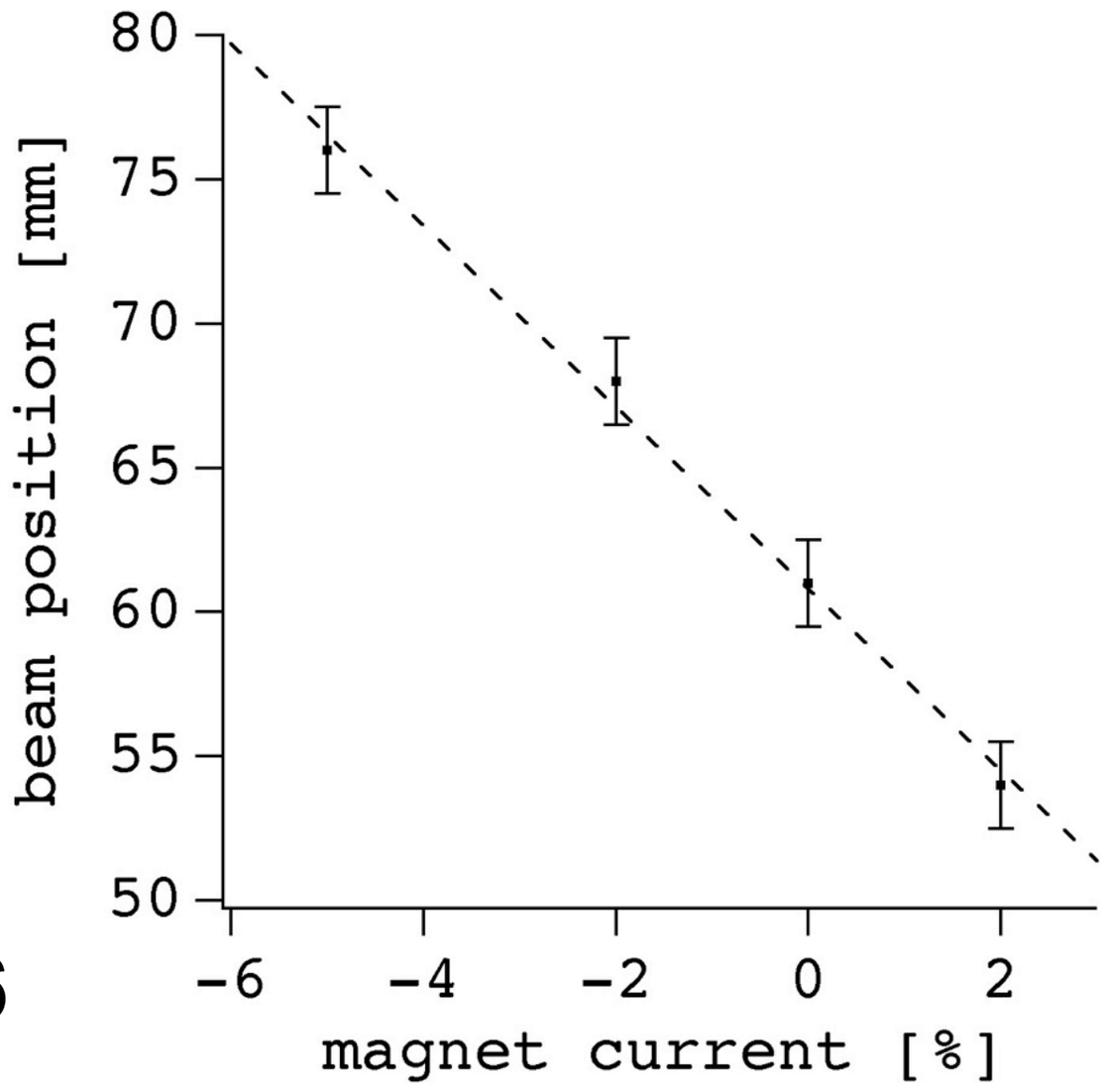




Dispersion function of line

- Results
  - Increasing magnet current (equivalently decreasing momentum) move the beam position outward.
  - Note the value of beam position increase toward the machine centre.
  - Dispersion is negative.

dr/(-dI/I)=-0.315+/-0.016



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Dispersion function of line

- Results dr/(-dI/I)=-0.315+/-0.016
  - This is consistent with Malek's Zgoubi simulation which shows

    dr/(dp/p)=-0.57

  - One possible reason is (dp/p)=(dField/Field)<(dI/I). (dp/p) and (-dI/I) should be the same order and (dp/p)/(-dI/I)<1 due to B-H curve.

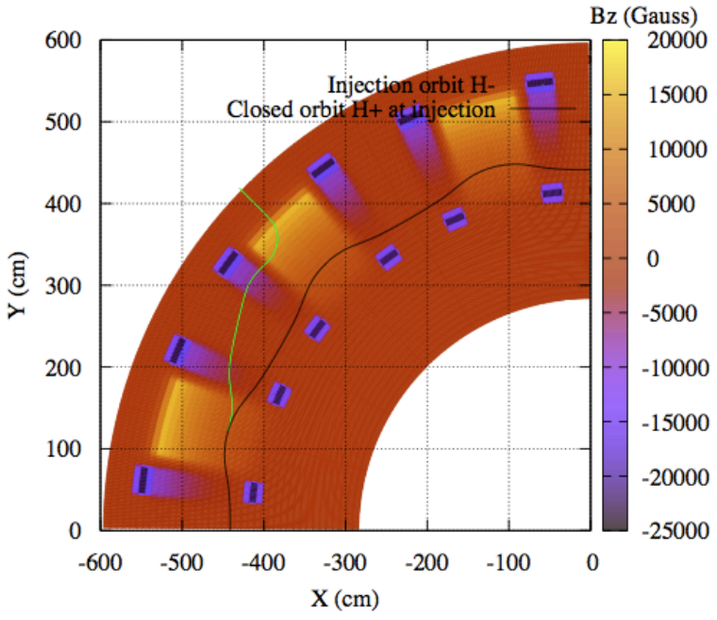

Figure 9: Injection trajectory for H- ions (shown in green).

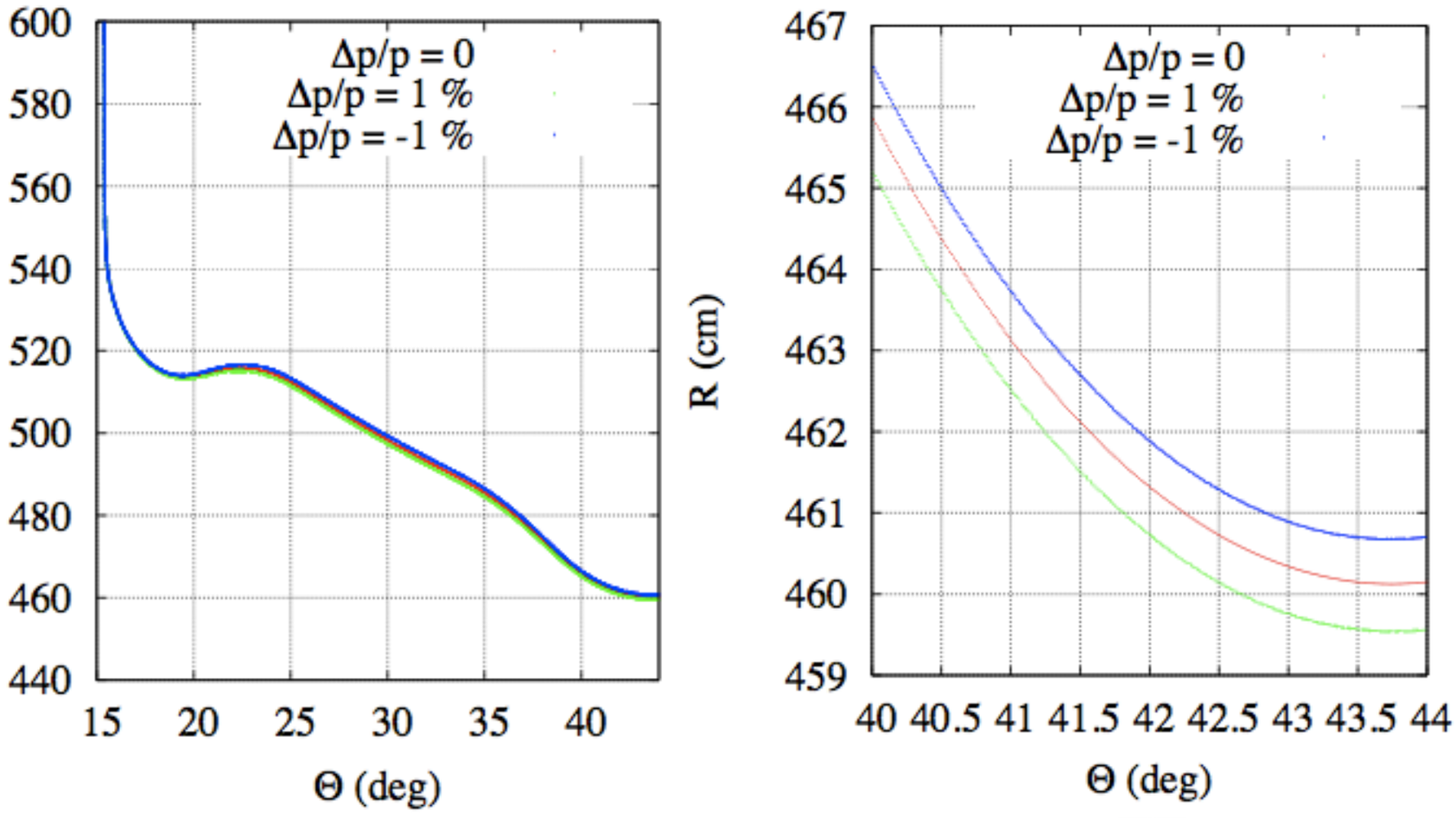

Figure 6: Injection trajectories for different set of Δp/p

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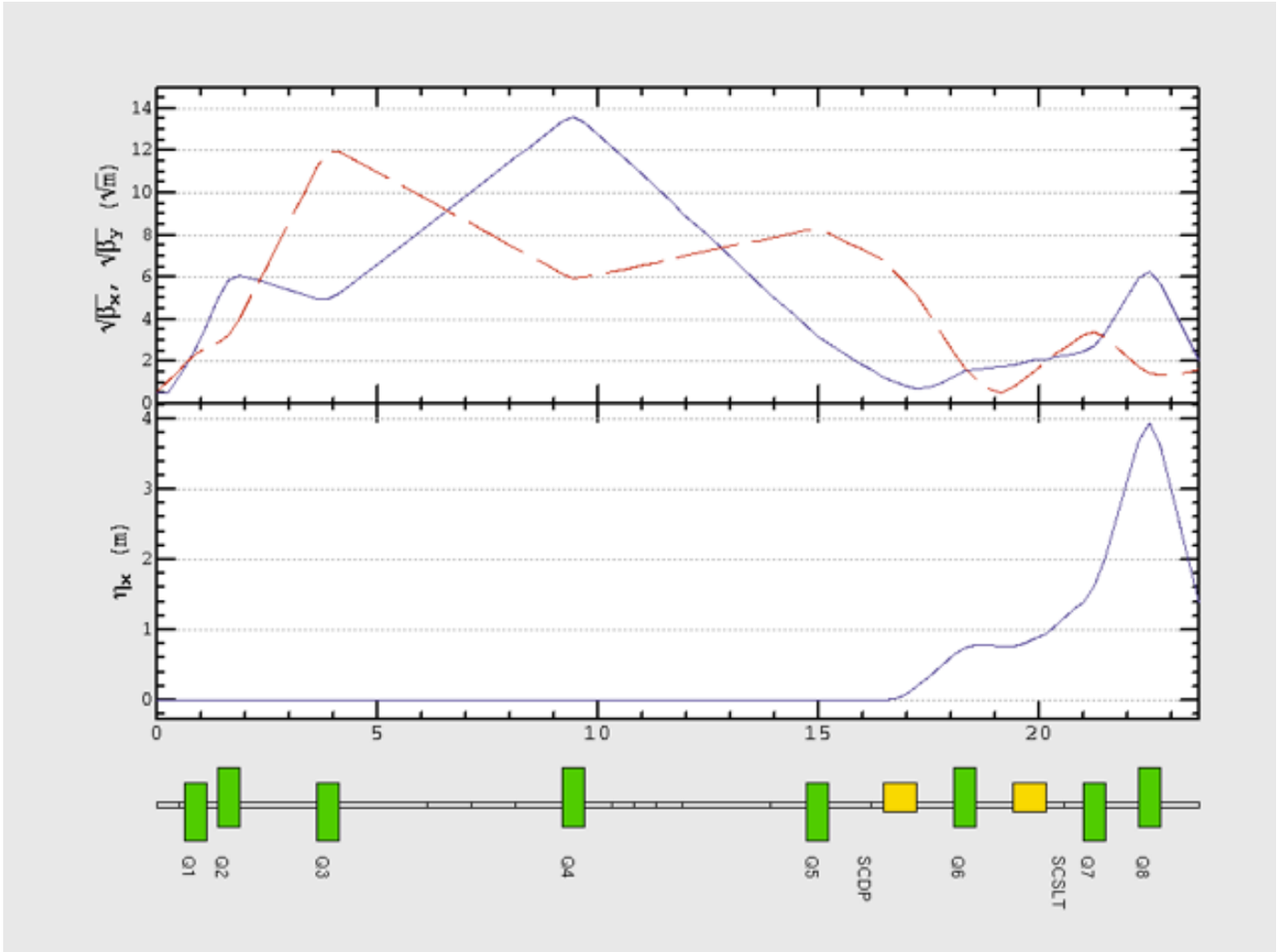
Dispersion function of line

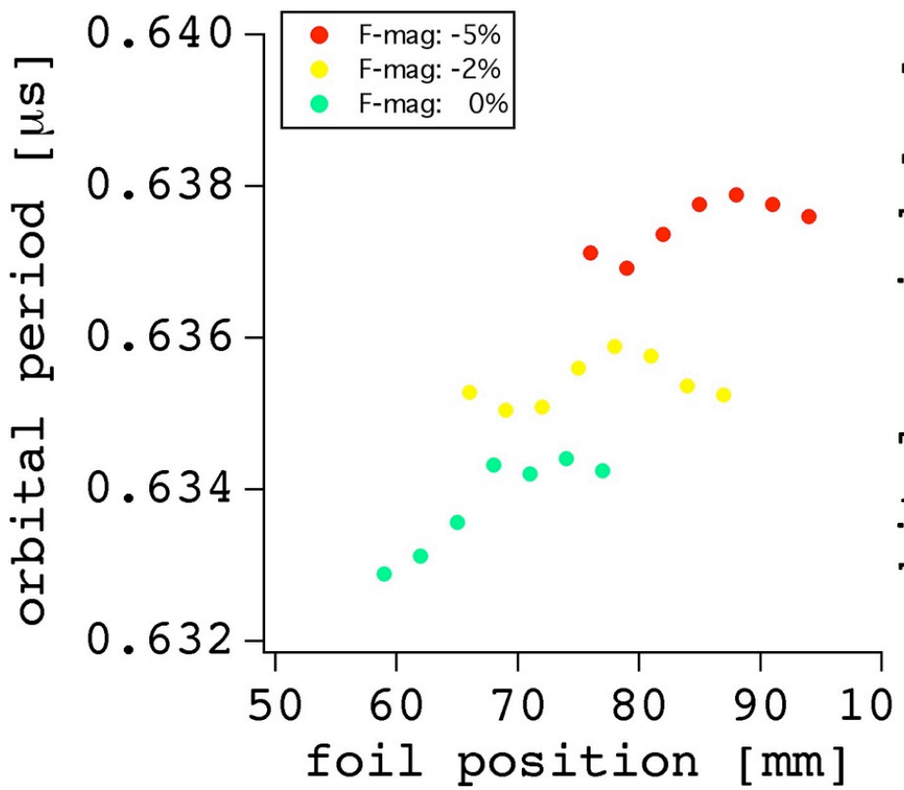
- In reality
  - Measured dispersion function is true only with the initial condition of D=D'=0 (at entrance of FFAG main magnets) that is not the case in reality.
  - In reality, there is a finite D and D', which makes the dispersion function at foil positive.
  - Measured data can be used to transfer dispersion function from the point before FFAG main magnets to the foil.

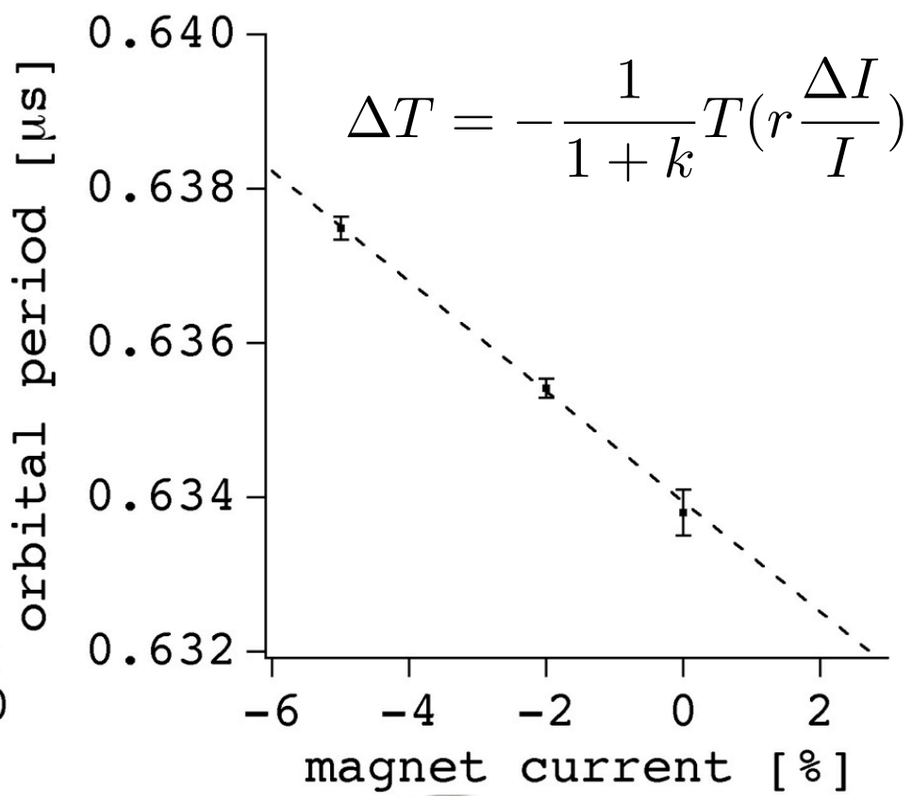


Dispersion function in ring

- Orbital period (or time of flight) measurement
  - With different equivalent momentum, orbital period changes

$$\frac{\Delta T}{T} = \frac{\Delta C}{C} = \alpha_p \frac{\Delta p}{p} = -\frac{1}{1+k} r \frac{\Delta I}{I}$$





$$\Delta T = -\frac{1}{1+k} T (r \frac{\Delta I}{I}) = -(0.071 \pm 0.005) \frac{\Delta I}{I}$$

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Dispersion function in ring

- Assume *k*=7.5

$$\Delta T = -\frac{1}{1+k} T (r \frac{\Delta I}{I}) = -(0.071 \pm 0.005) \frac{\Delta I}{I}$$

$$r = \frac{(0.071 \pm 0.005)(1+k)}{T}$$

$$= 0.95 \pm 0.07 \quad !!$$

- Either (dp/p)/(dI/I)~1 or *k* is less than 7.5.

Note on a factor r=(dp/p)/(dI/I)

- From the dispersion measurement in the ring, we could conclude (dp/p)=(dI/I) if k at injection is 7.5.
- Comparison between Malek Zgoubi simulation and the dispersion measurement of line, we could conclude (dp/o)=0.6(dI/I).
- TOSCA calculation should tell us which is correct or something more involved. For example,
  - r depends on radius.
  - Zgoubi tracking is very sensitive to field profile.

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Dispersion function

- To do
  - TOSCA modelling to determine the relation between magnet current and magnet strength and therefore (dI/I) and (dp/p).
  - Calculation of optics in the injection line from linac to the foil.
  - Evaluate dispersion matching at foil.
    - Assume optics from linac to the entrance of FFAG main magnets.
    - Use measured translation of dispersion function from the FFAG main magnet to the foil.

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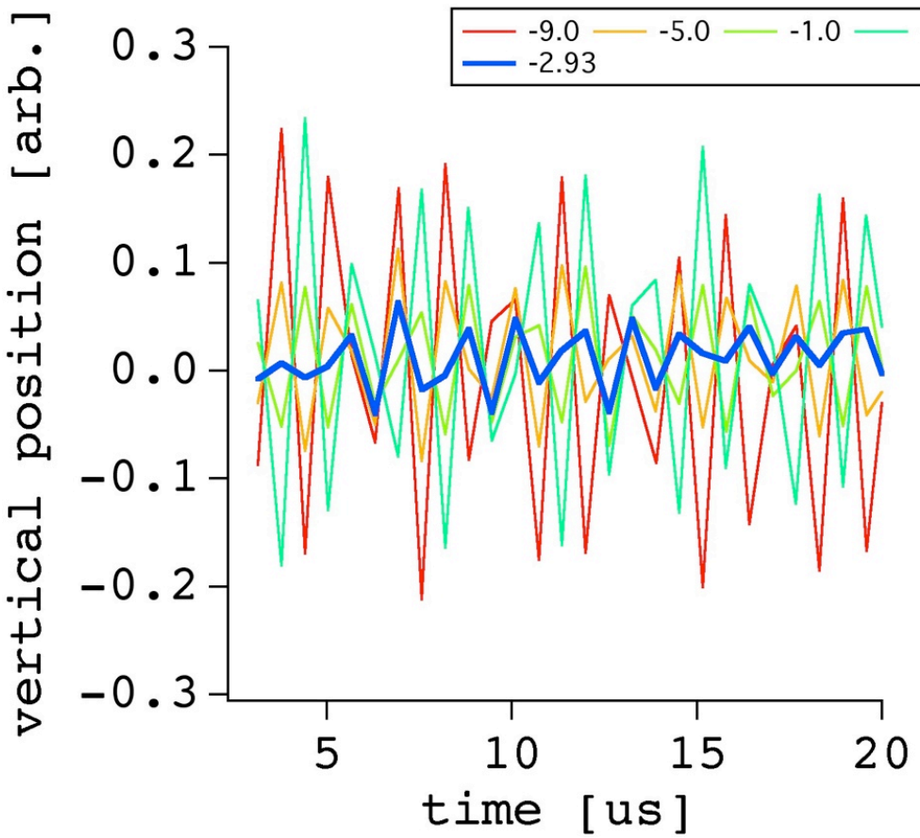
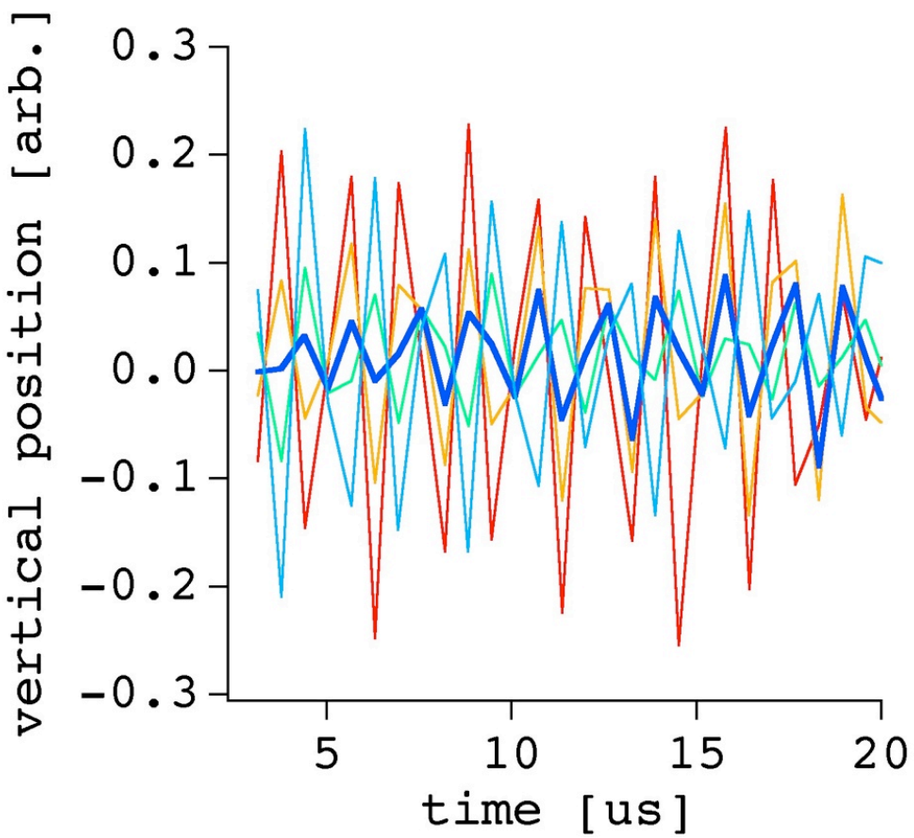
Vertical orbit matching

- For two setting of F/D ratio.





- Nominal setting of S5V=-2.93A is the best among we tried.

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Vertical orbit matching

- To do
  - Need a model of (vertical) BPM to convert (Vu-Vd)/(Vu+Vd) to position.

Requests

- Horizontal BPM monitor
  - Triangle plates could be paired. Is it possible to make it?
- Larger foil folder
  - Foil folder will be not the aperture limit.

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