Matching of dispersion function

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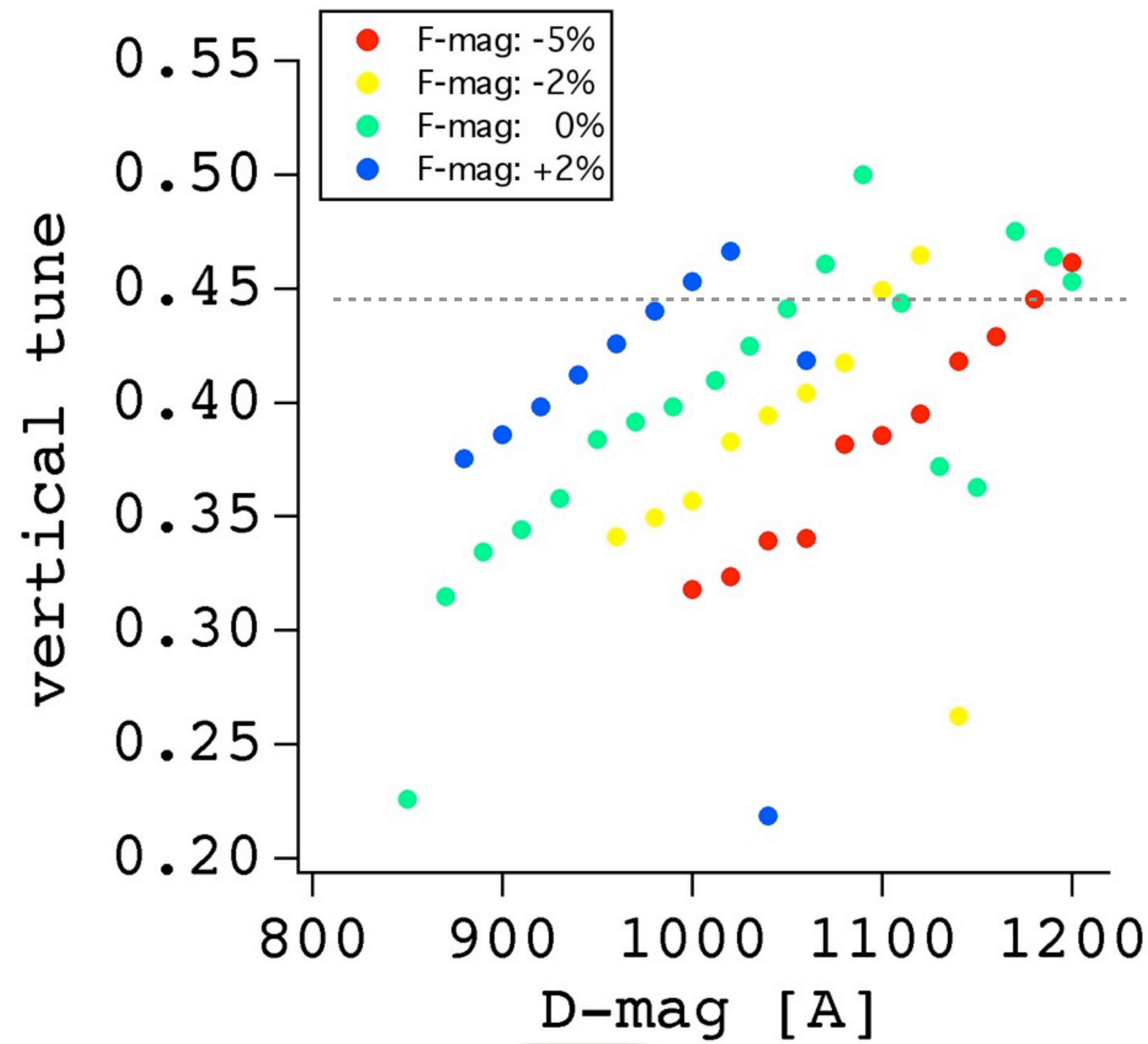
- Dispersion function of the injection line (at foil).
- (averaged) Dispersion function in the ring.

- Both are measured by “equivalent momentum” technique.

Dispersion function of the injection 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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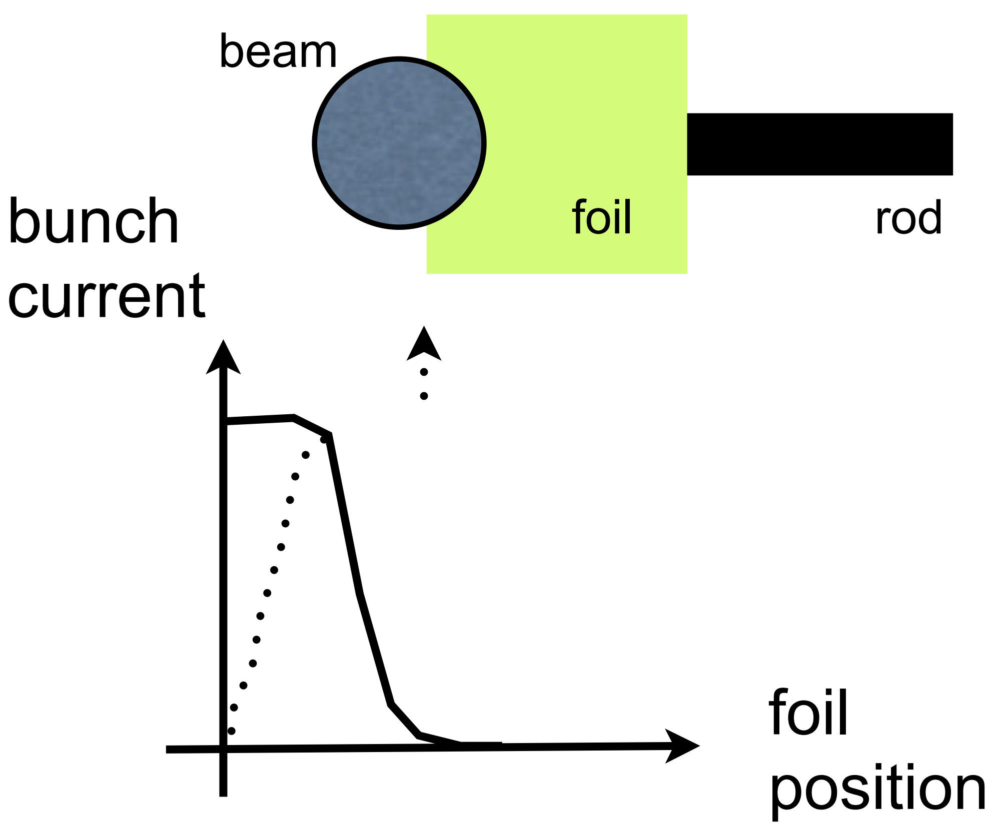
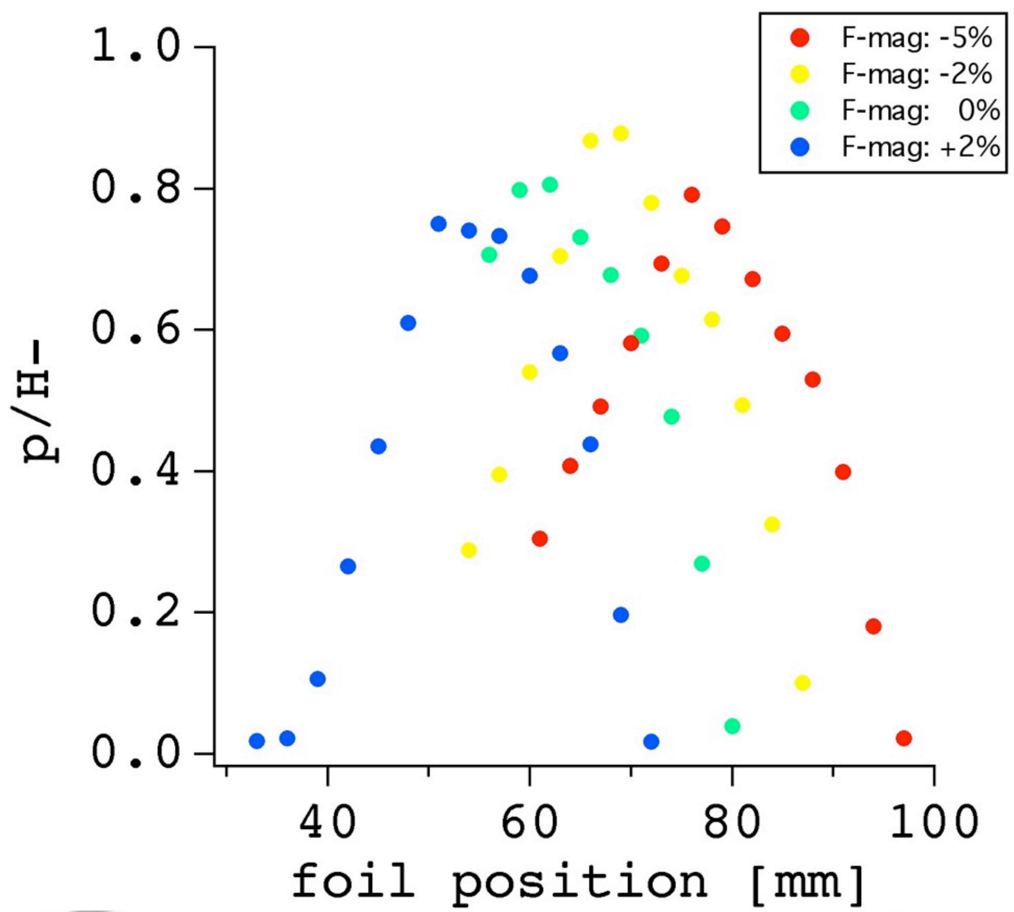
Dispersion function of the injection line

- Measure beam position at foil.
  - Move the foil from inside.
  - 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.

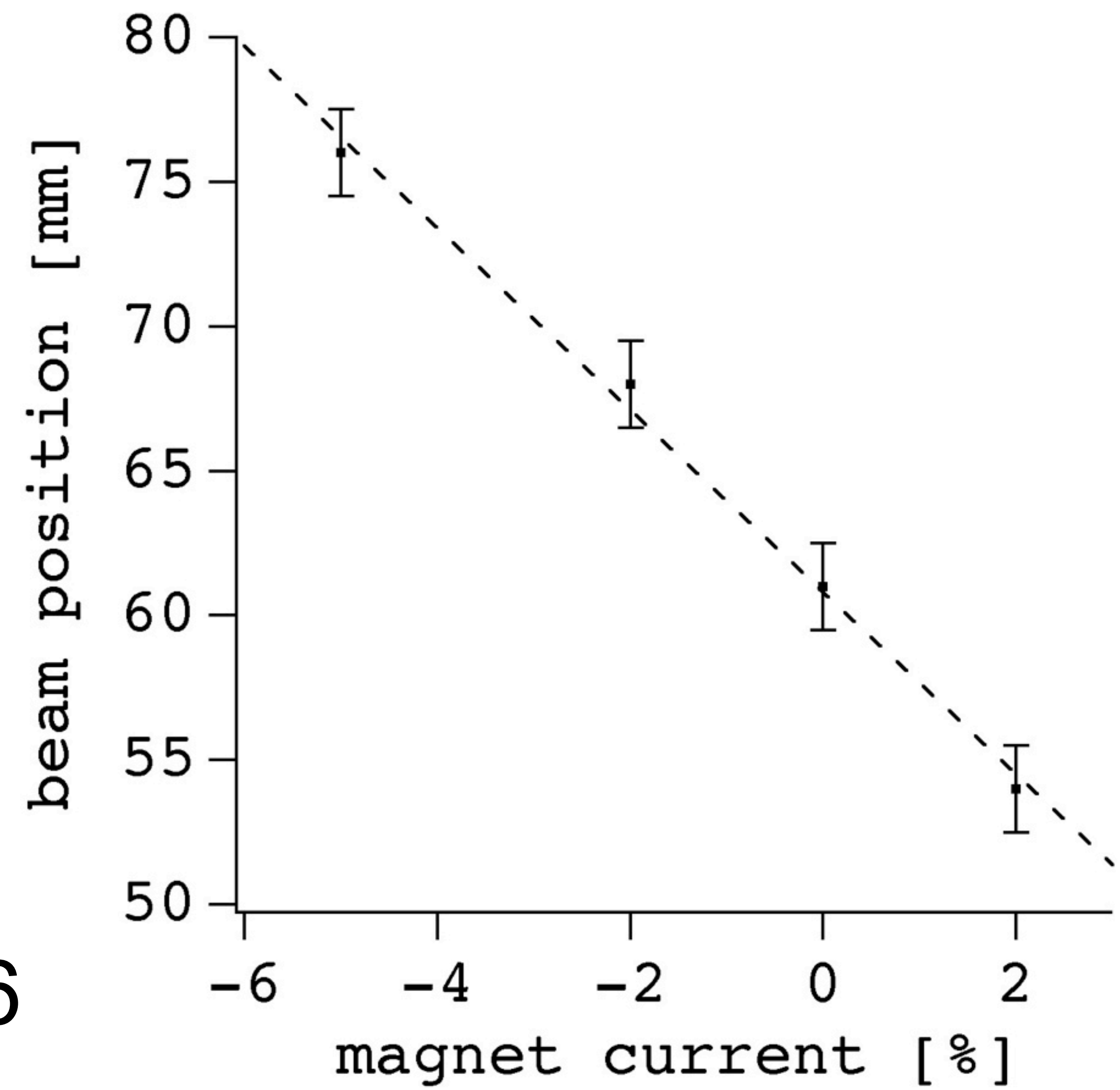




Dispersion function of the injection line

- 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



Dispersion function of the injection 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.

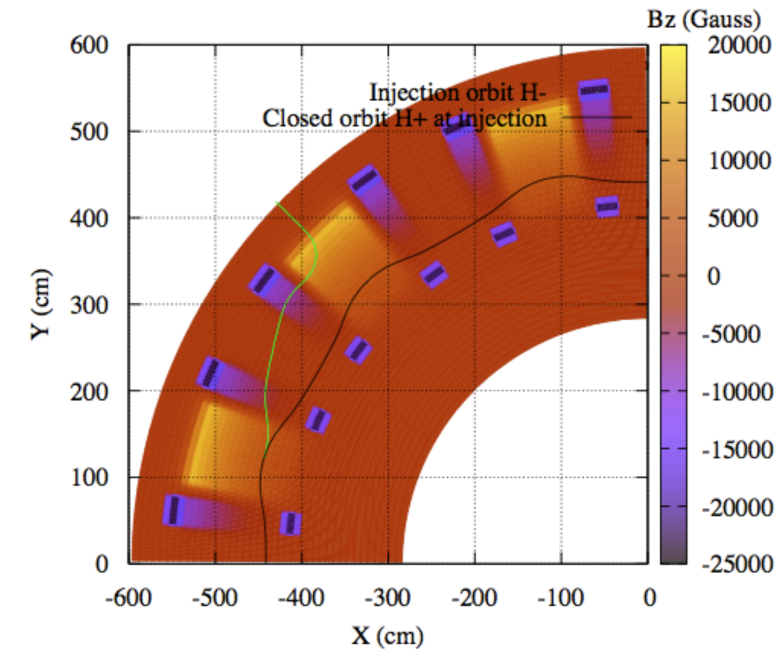
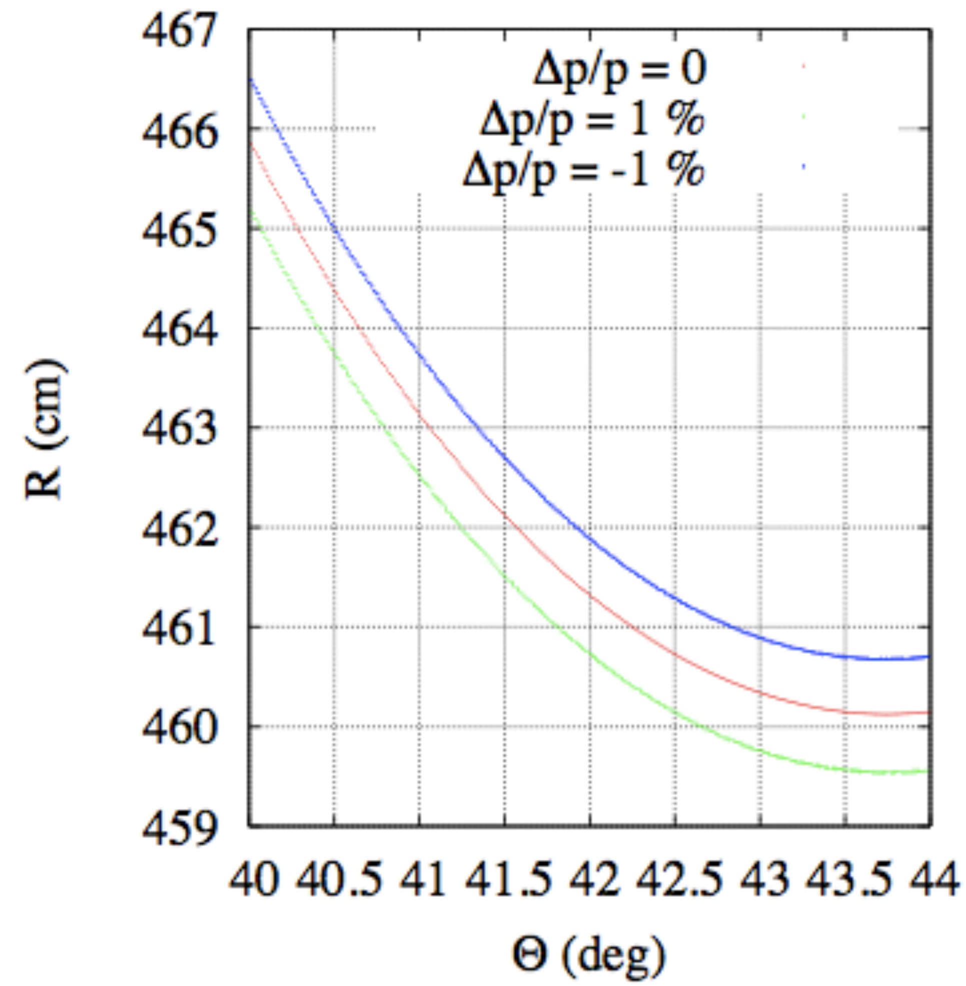
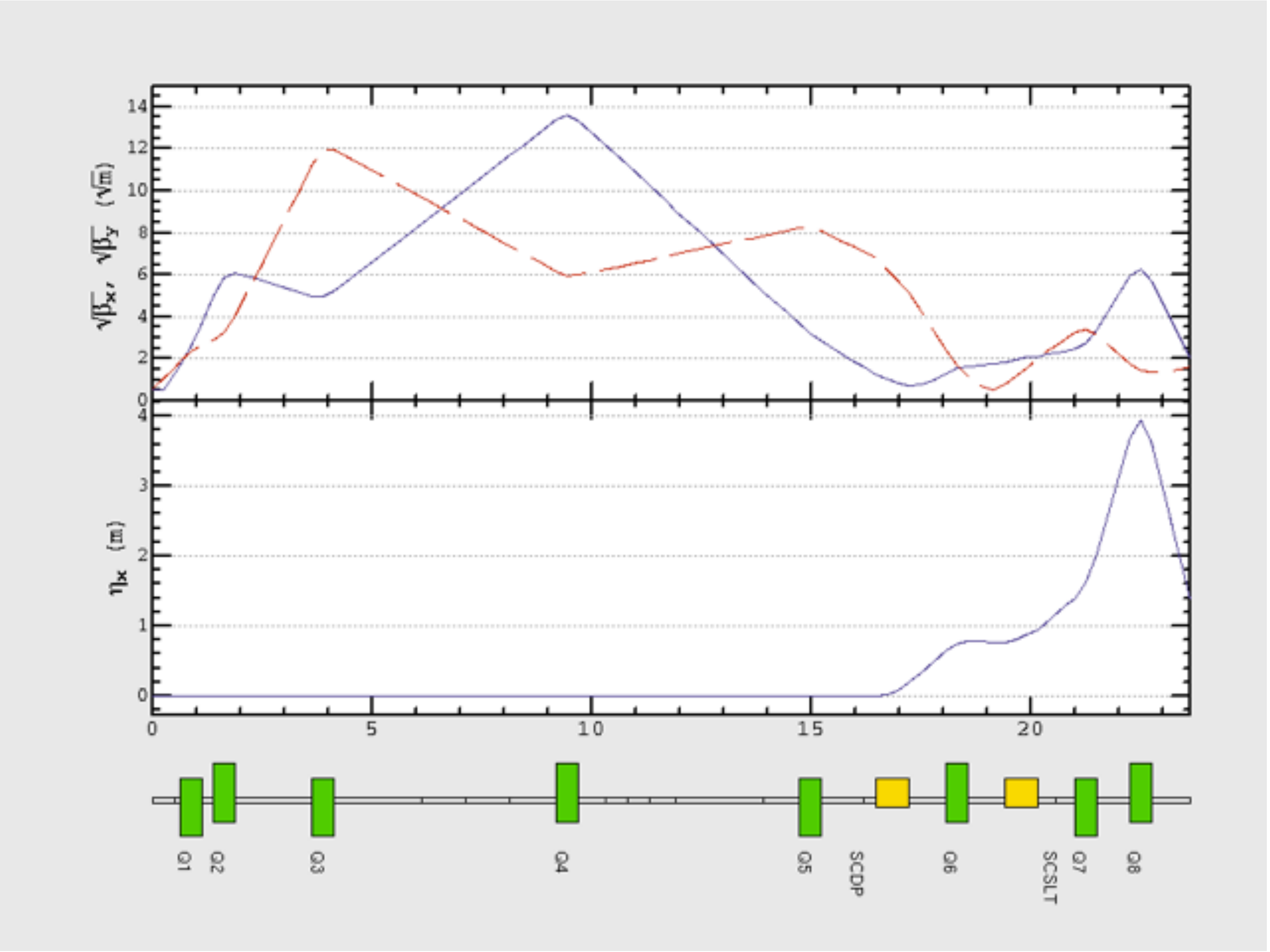


Figure 9: Injection trajectory for H- ions (shown in green).



Dispersion function of the injection line

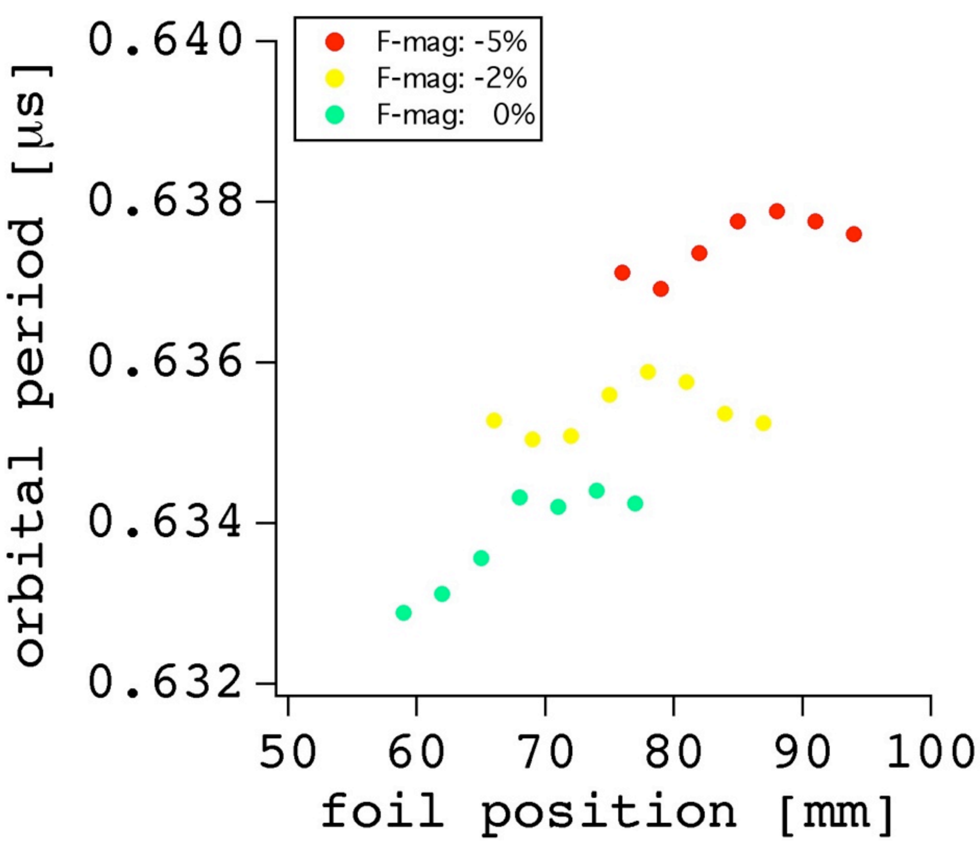
- In reality
  - Measured dispersion function is true only with the initial condition of D=D'=0 (at entrance of FFAG main magnets) that is not the case in reality.
  - In reality, there is a finite D and D', which makes the dispersion function at foil positive.
  - Measured data can be used to transfer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

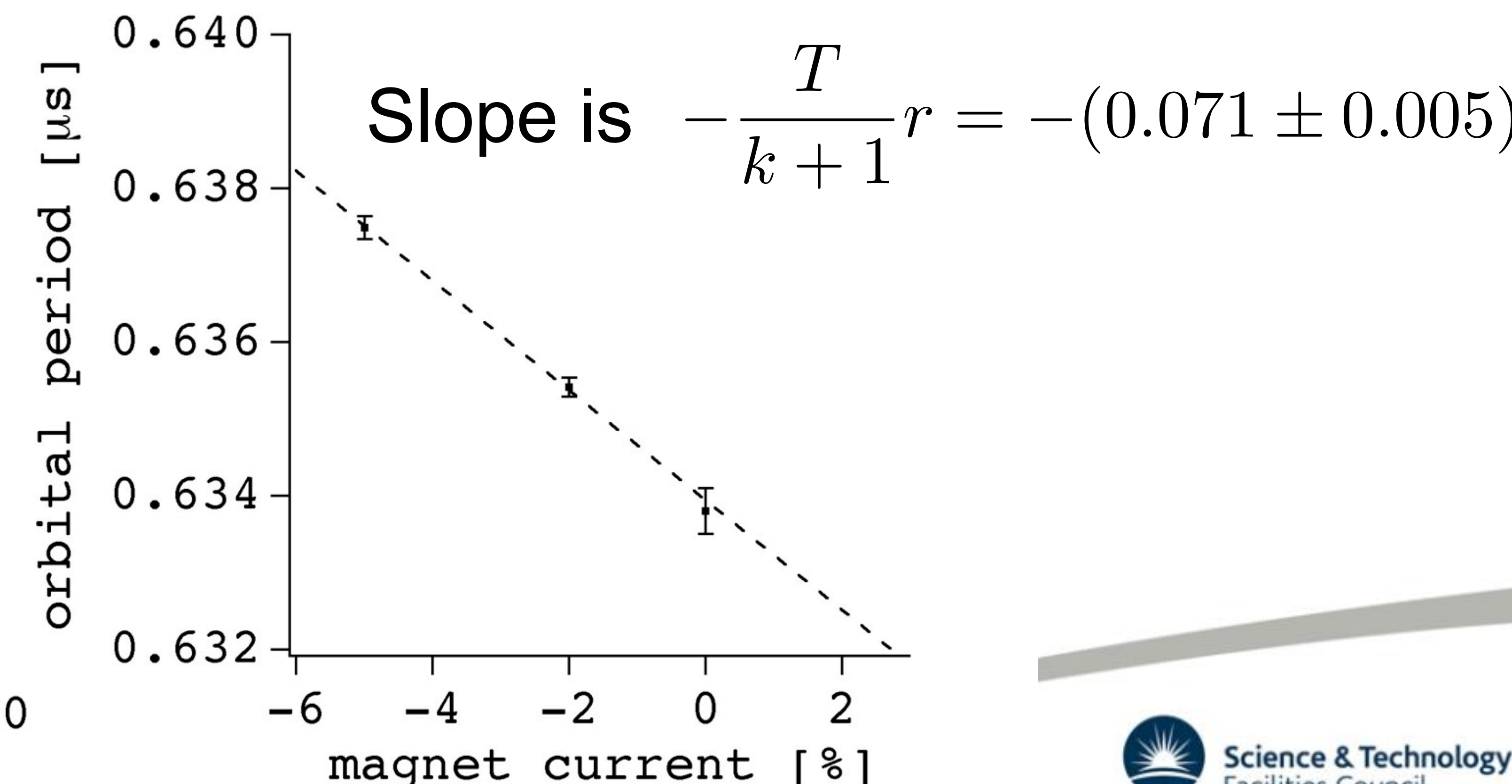


Dispersion function in the ring

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

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





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Dispersion function in the ring

- Assume r=(dp/p)/(dl/l)=1

$$k + 1 = 8.9 \pm 0.6$$

- and dispersion function is

$$D = \frac{R}{k+1} = \frac{4.6}{8.9} = 0.52 \text{ m}$$

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

- 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.