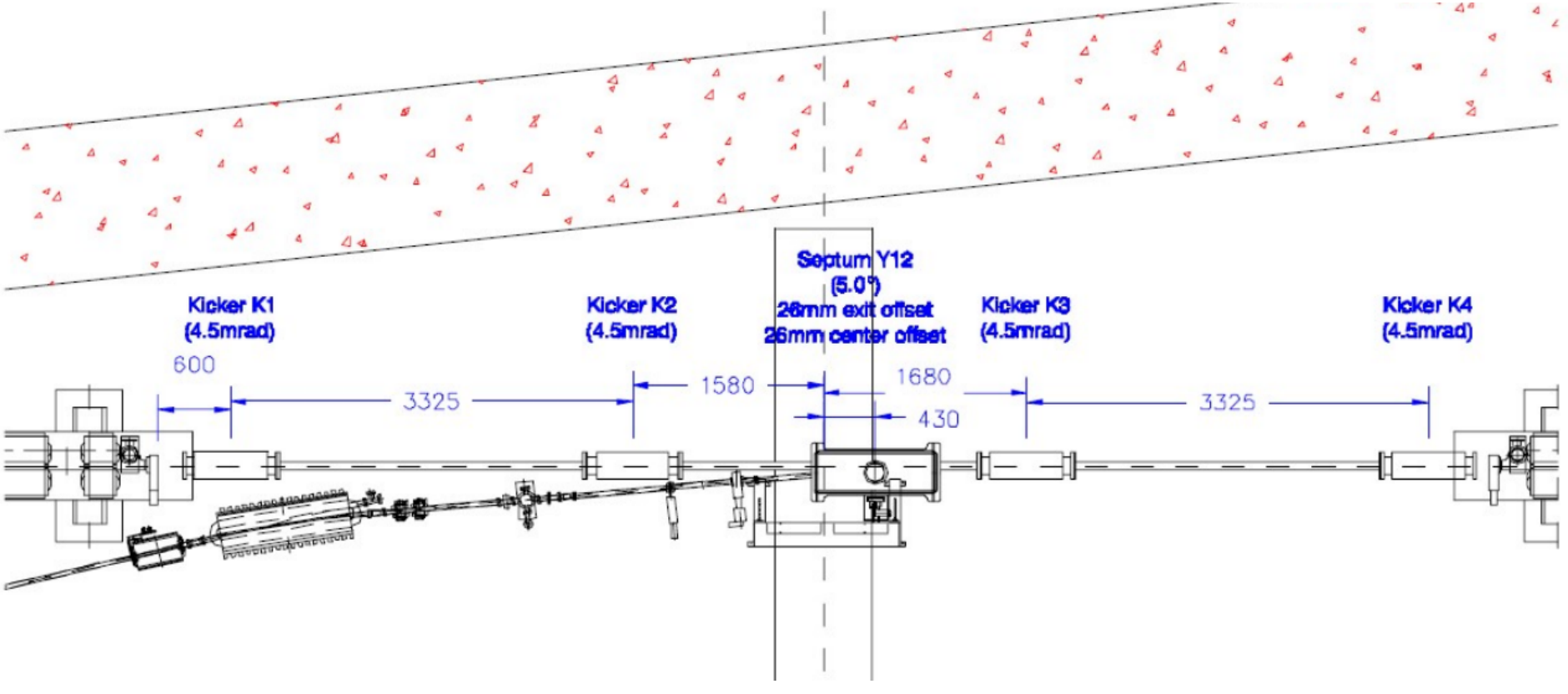
Top-up injection into the SLS using a sextupole kicker

Group members:
Linda Stoel, Salim Ogur, Samira Kasaei, Nikolaos Charitonidis, Claudio Digiulio, Daniel Barna

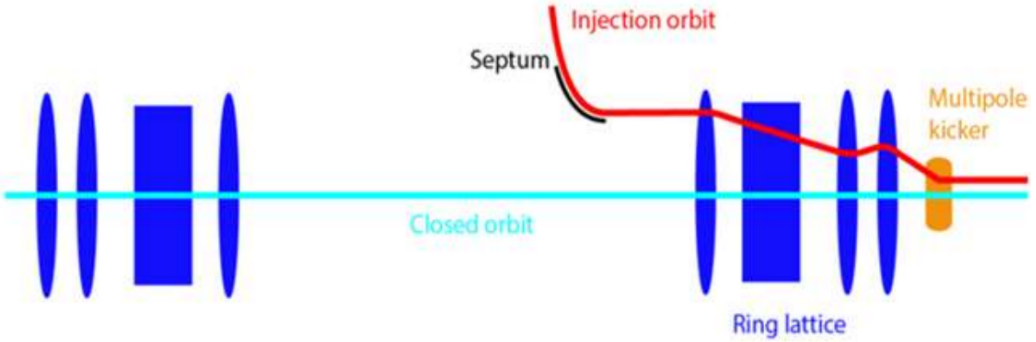


Strategy

- Too many parameters to optimize
- Not a single figure-of-merit
- Lack of time and expertise
- By coding the formulae and optimizing by computer we might loose the insight...

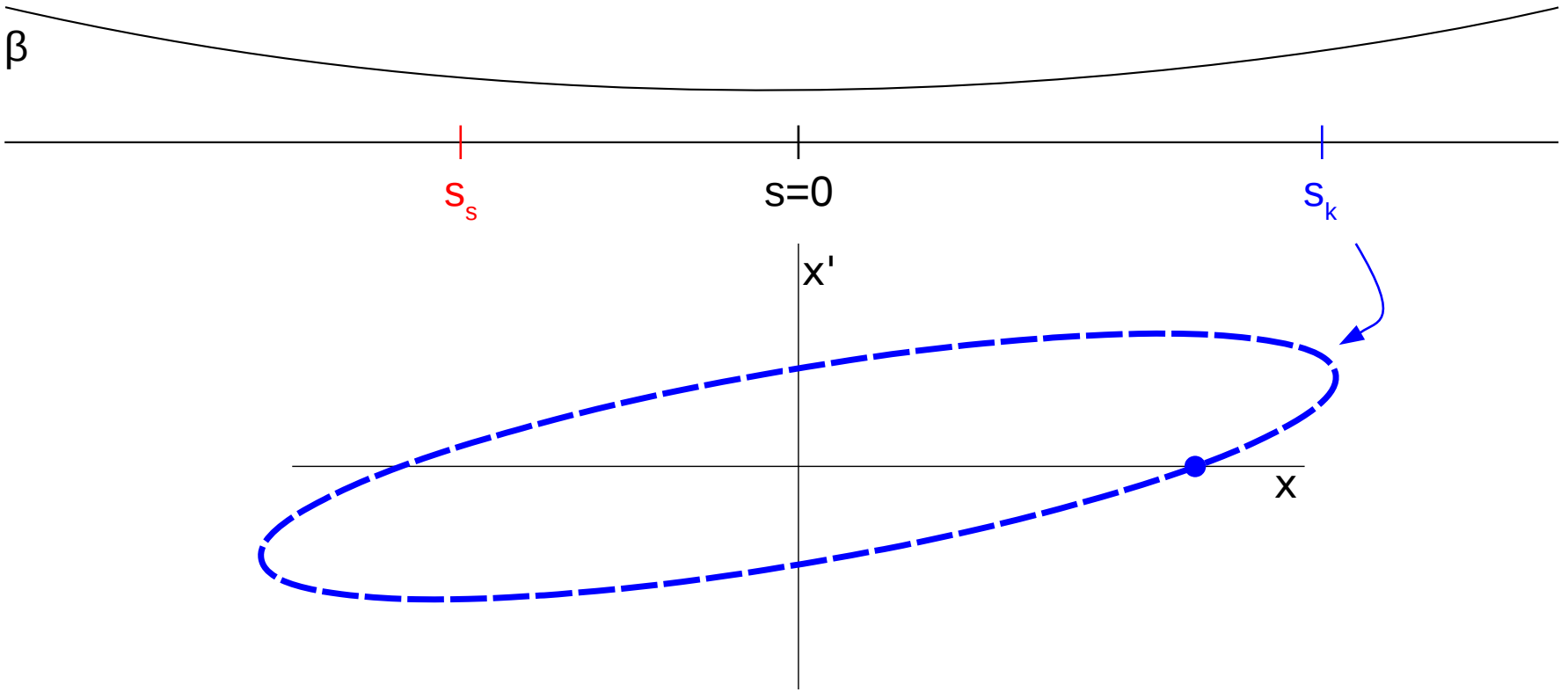
1) Find guiding principles...
2) ...to fix as many parameters as possible
3) Leave max. 2 free parameters, create catchy figures

Best (x,x')



This schematics suggests parallel injection.

Might be misleading...



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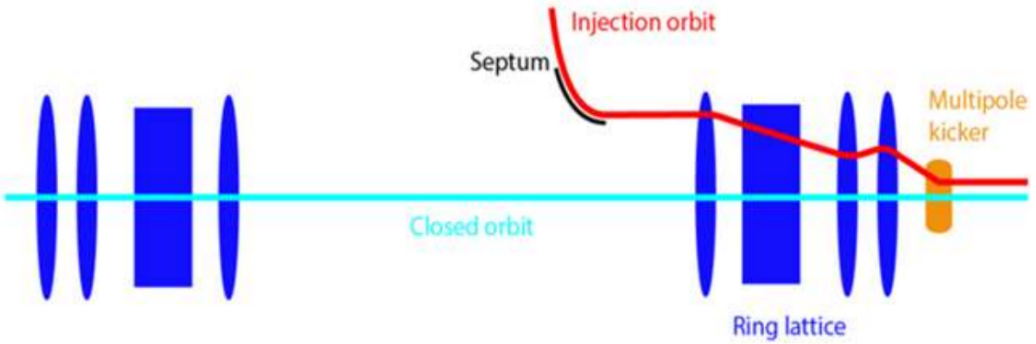

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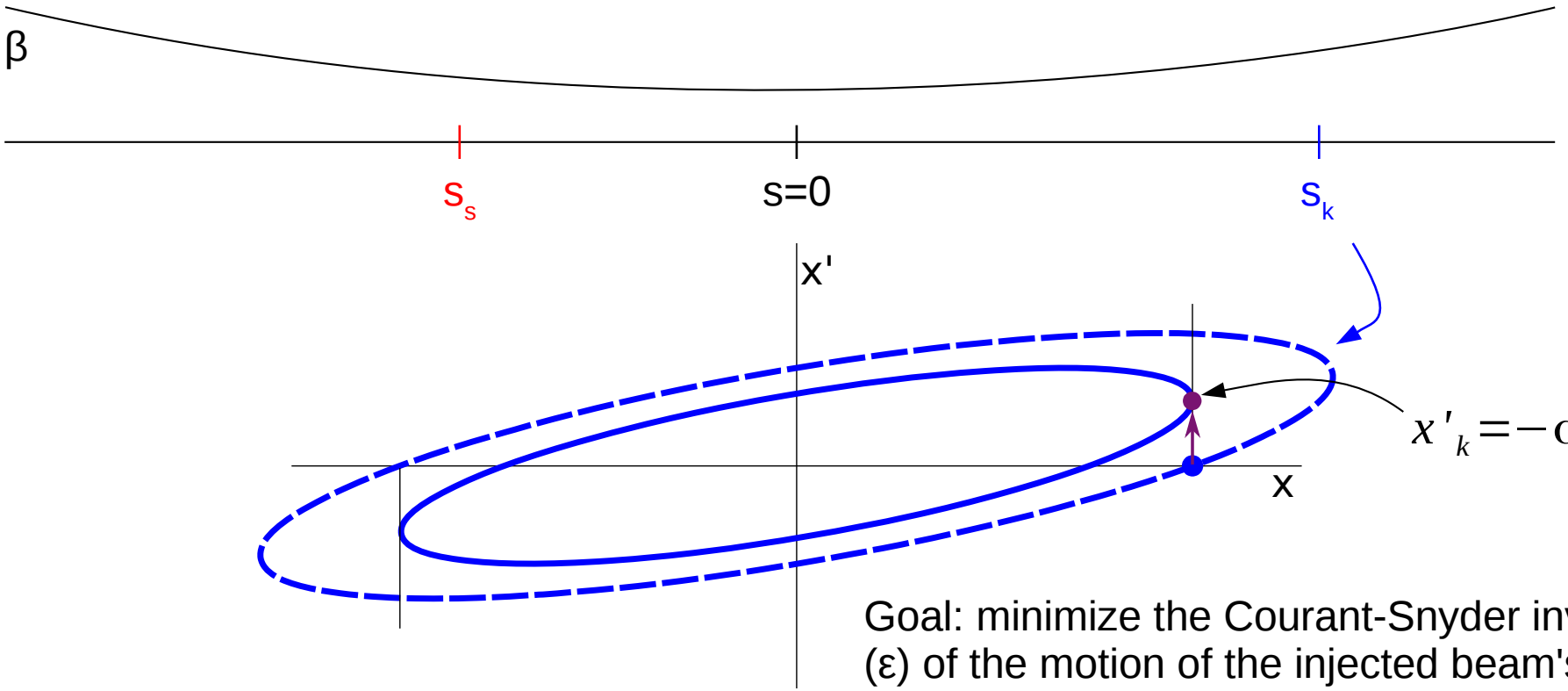
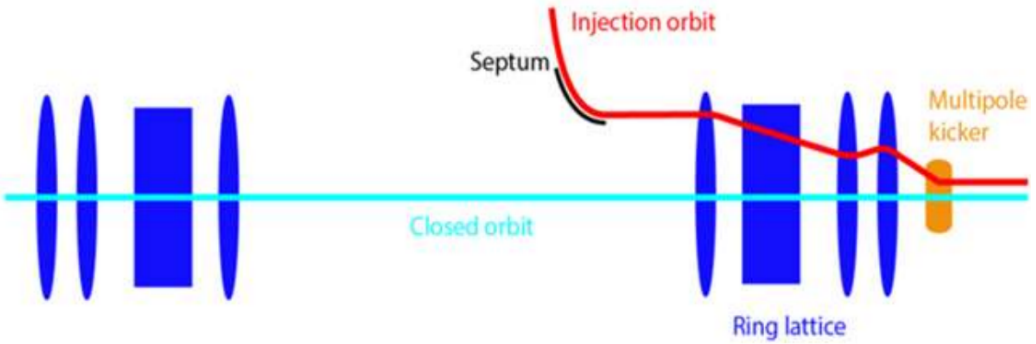


Goal: minimize the Courant-Snyder invariant (ε) of the motion of the injected beam's center

Best (x,x')



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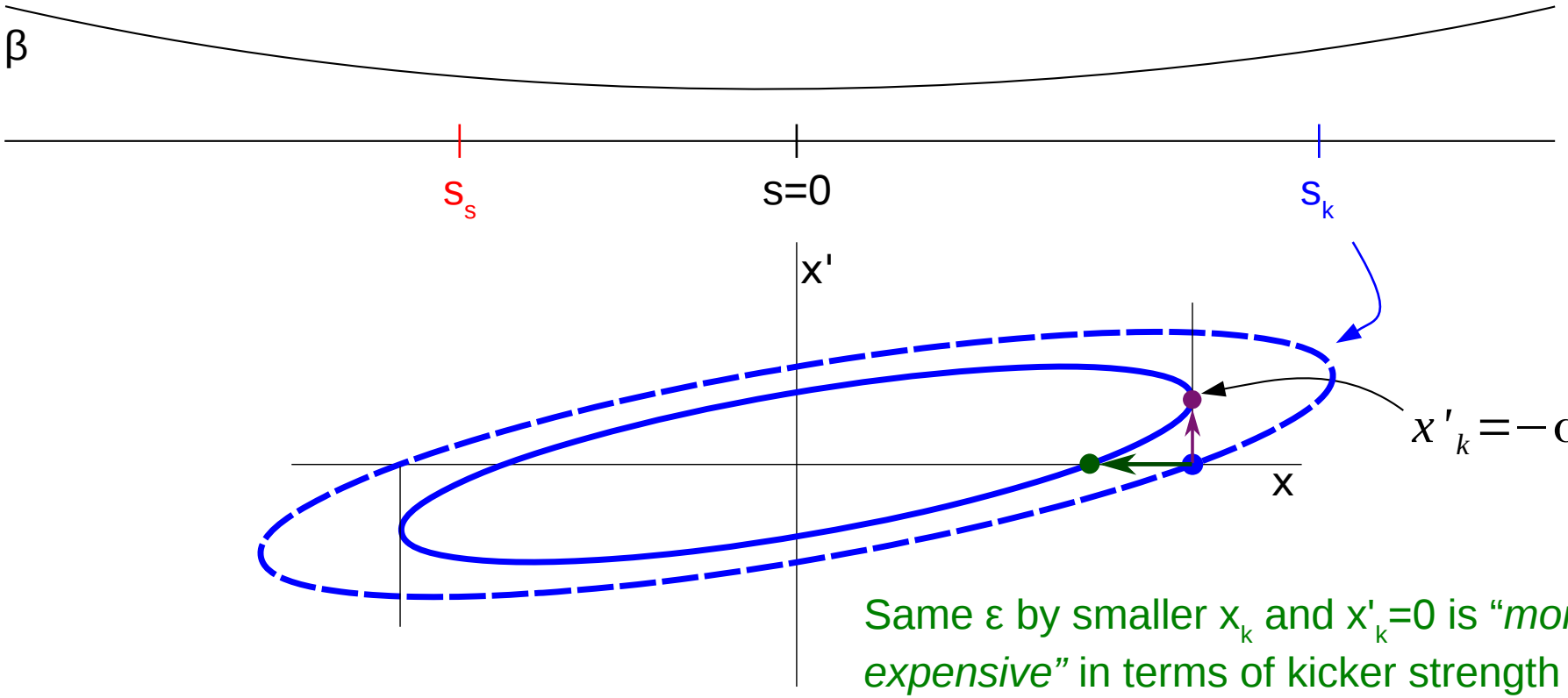

Same ε by smaller x_k and x'_k=0 is "*more expensive*" in terms of kicker strength

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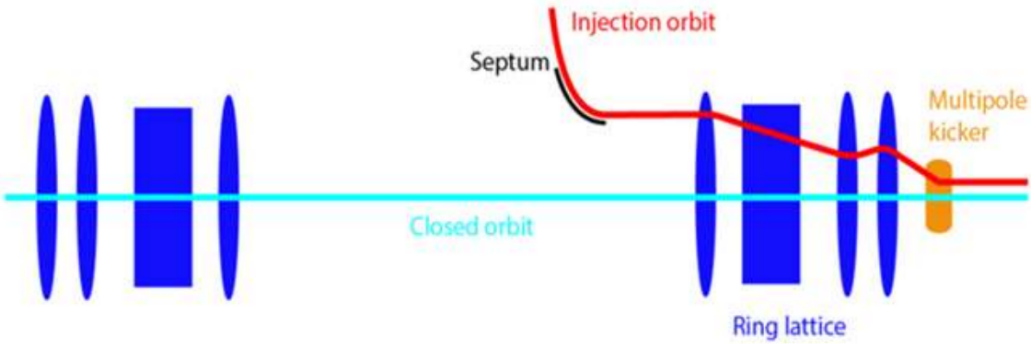

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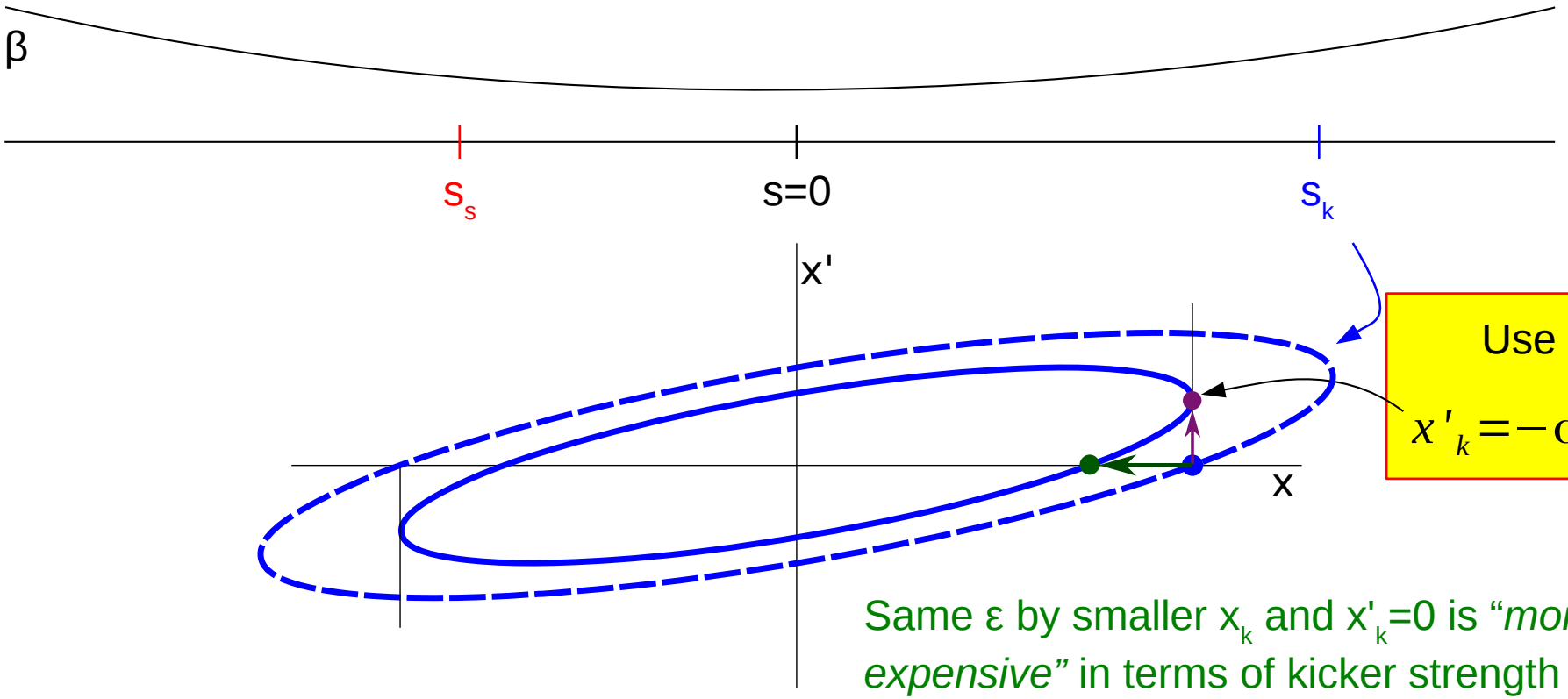
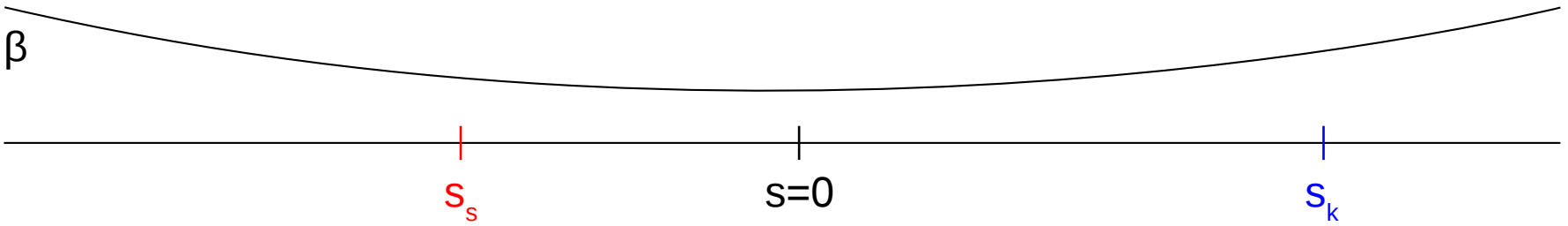


Same ε by smaller x_k and x'_k=0 is "*more expensive*" in terms of kicker strength

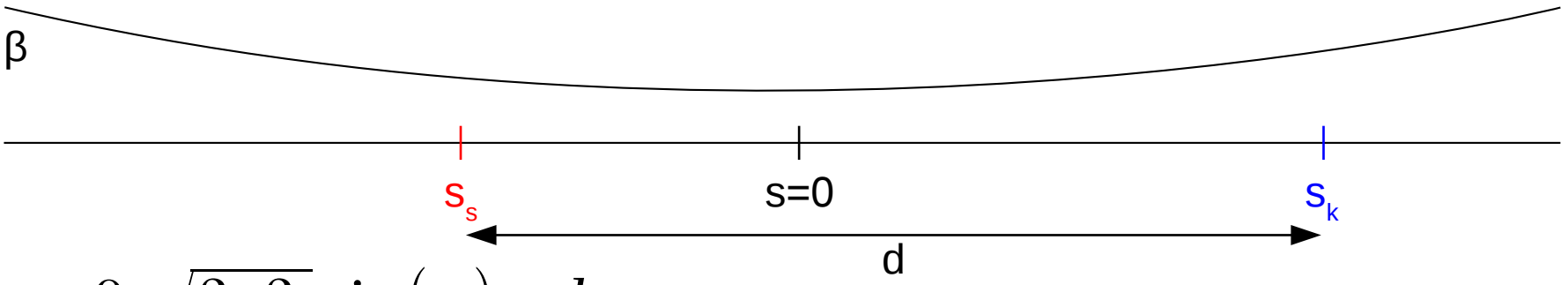
Where to put the septum and kicker?



$$x_s = \theta_k \sqrt{\beta_k \beta_s} \sin(\mu)$$

- “Put where β_k and β_s is large to have large separation at septum with small kick by kicker”... i.e. at the extremes of the the straight section.
- But wait! there is μ as well....

Where to put the septum and kicker?



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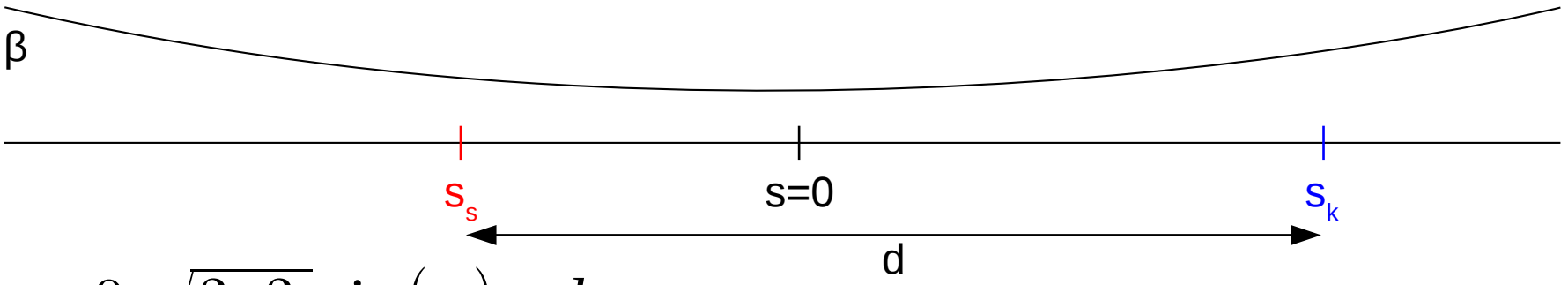

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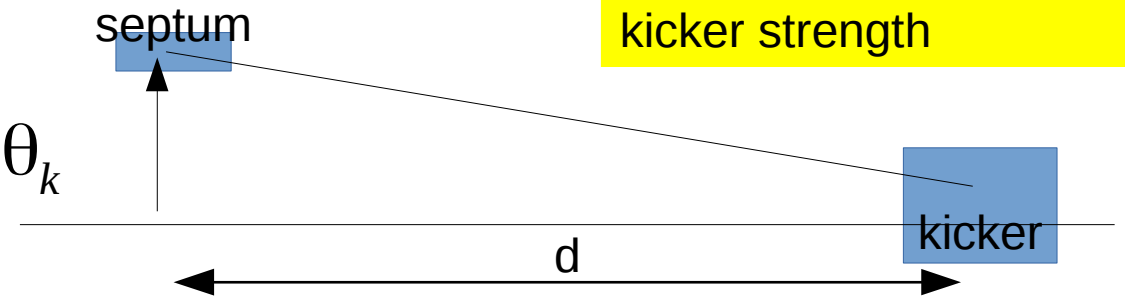
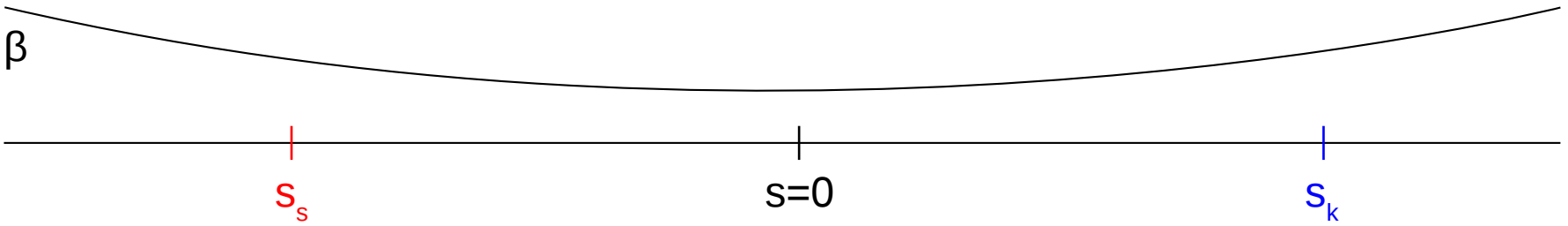
Grandma's wisdom:

$$x_s = d \cdot \theta_k$$



So put them as far apart as needed to reduce kicker strength

Where to put the septum and kicker?



Biggest distance if symmetrically at the extremes... but...

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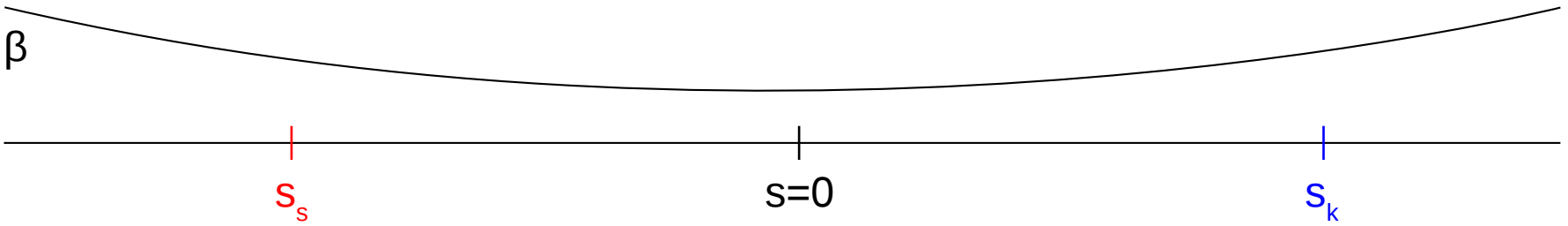
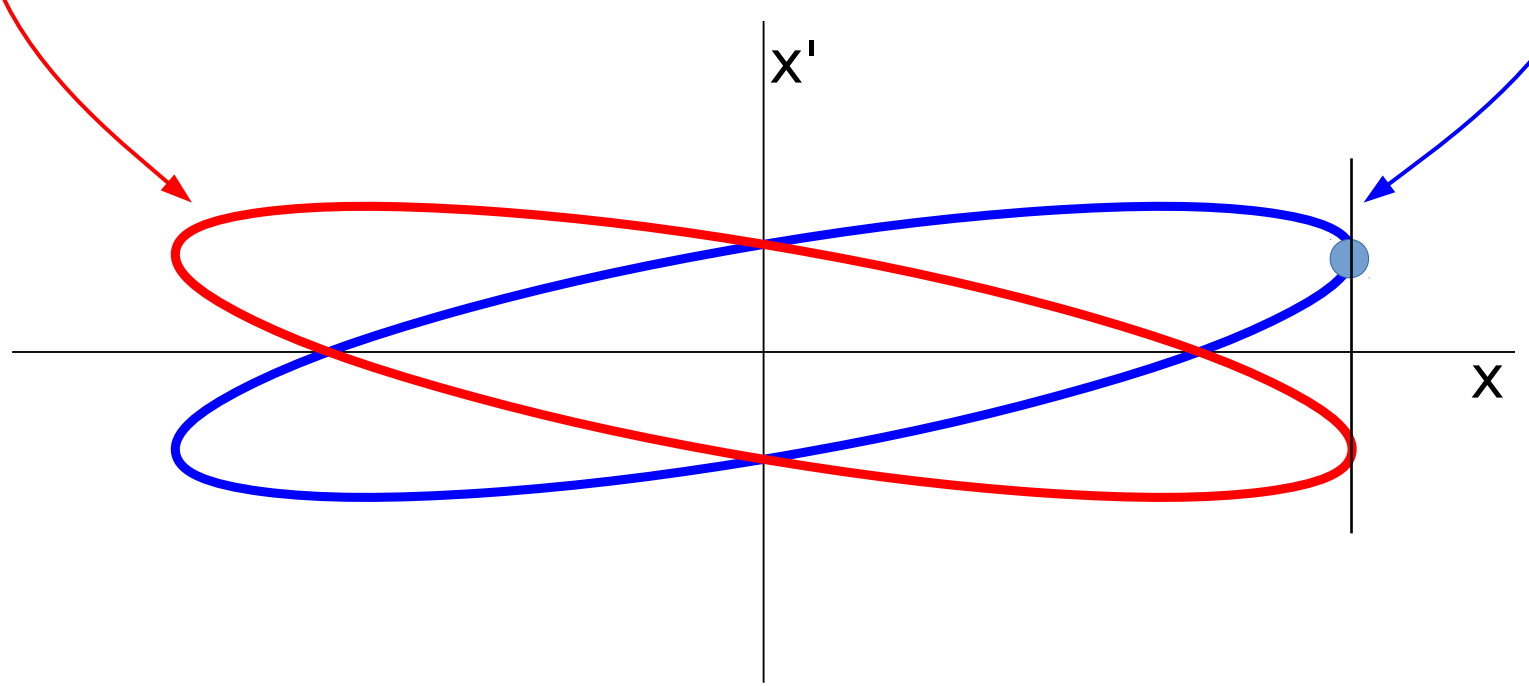
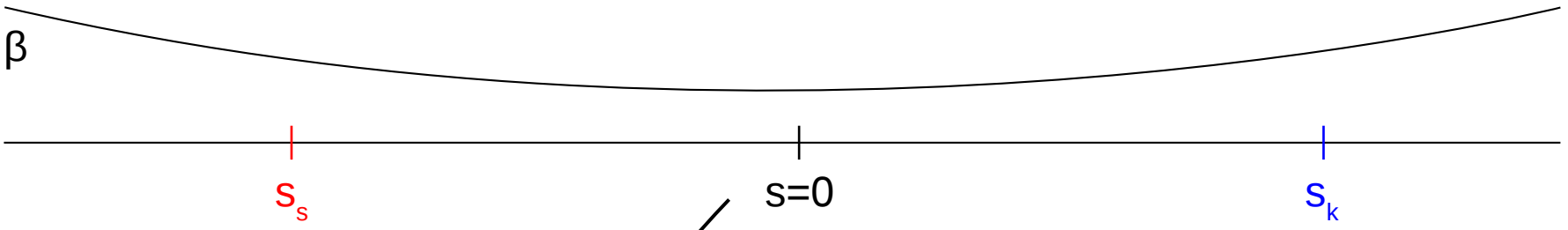


Biggest distance if symmetrically at the extremes... but...

- Ellipse is vertically flipped there...
- Oscillation amplitude at septum is the same as the injection position at kicker

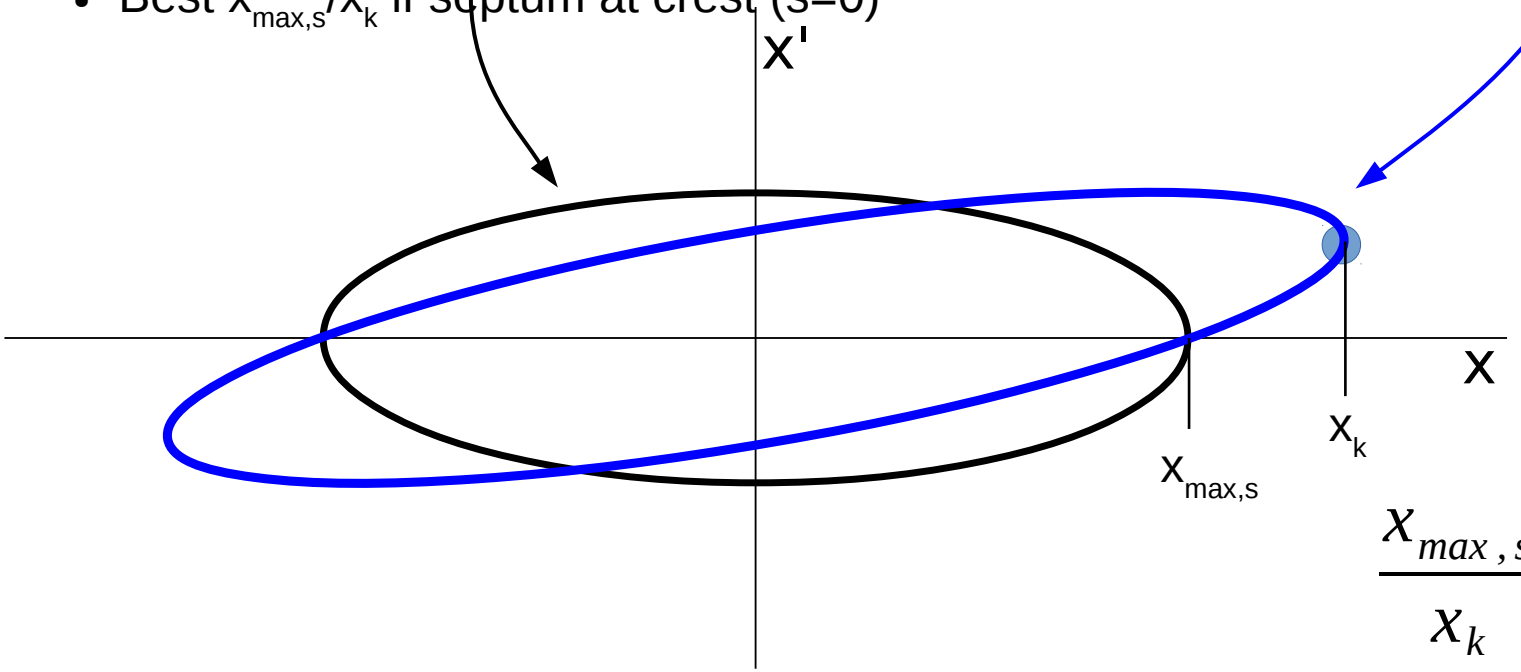


Where to put the septum and kicker?



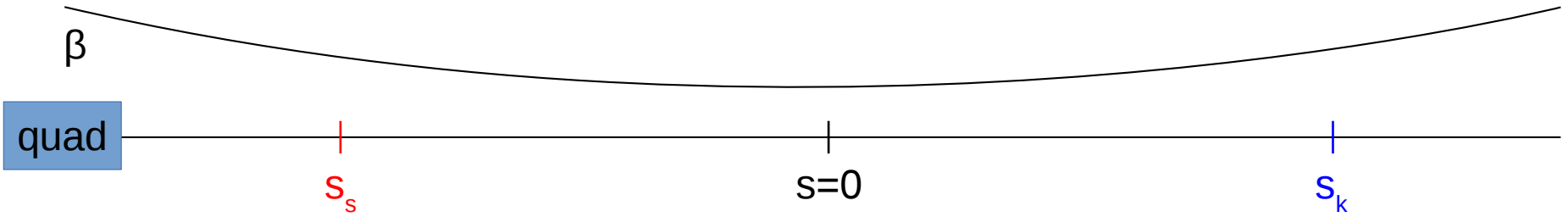
Biggest distance if symmetrically at the extremes... but...

- Ellipse is vertically flipped there...
- Oscillation amplitude at septum is the same as the injection position at kicker
- Best $x_{max,s}/x_k$ if septum at crest (s=0)



$$\frac{x_{max,s}}{x_k} = \sqrt{\beta_s/\beta_k}$$

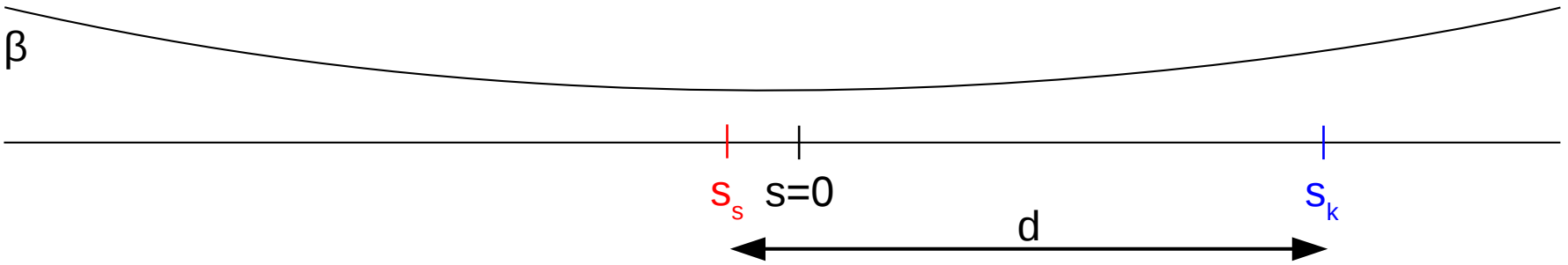
Where to put the septum and kicker?



Biggest distance if symmetrically at the extremes... but...

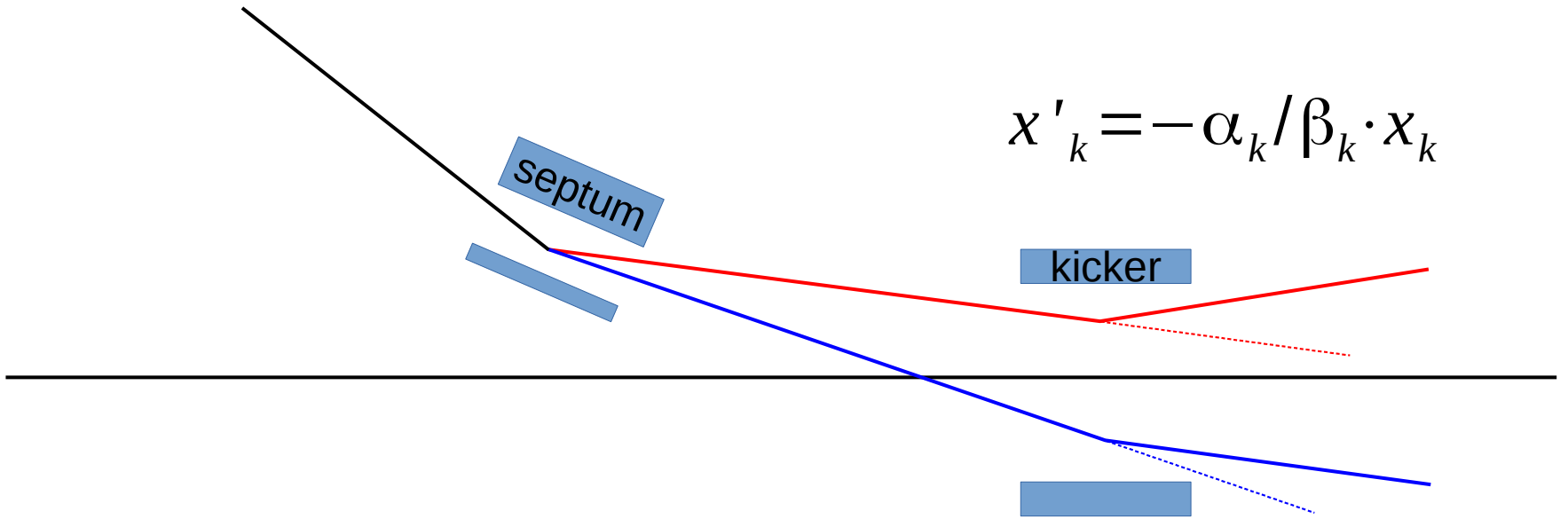
- Septum too close to upstream quad
- Must be strong to avoid the beam hitting the quad

Where to put the septum and kicker?



1) Have enough distance (d) between them to release kicker strength requirements
2) Shift both downstream
   - Septum close to s=0
   - Or as it fits conveniently

Cross the beam axis?



Which one needs a weaker kicker?

Chosen parameters

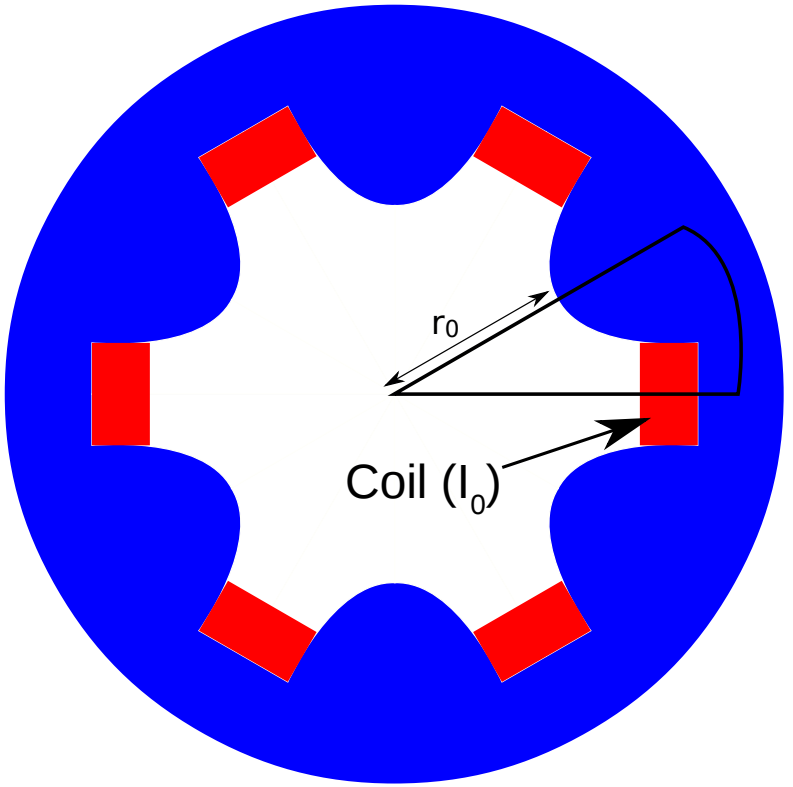
- Fixed parameters
  - $s_s = 0$ – septum at center of straight, at crest
    - It is currently there, no need to move
    - Have space to avoid hitting upstream quad
    - Minimize oscillation amplitude of injected beam here
  - $s_k = 4$ m – kicker position along beamline
    - Largest possible distance leaving some more room
  - L = 1 m – kicker length
    - easy to remember and multiply by
  - $r_0 = 15$ mm – kicker aperture radius
- Free parameters
  - x_s, x_k

Multipole kicker

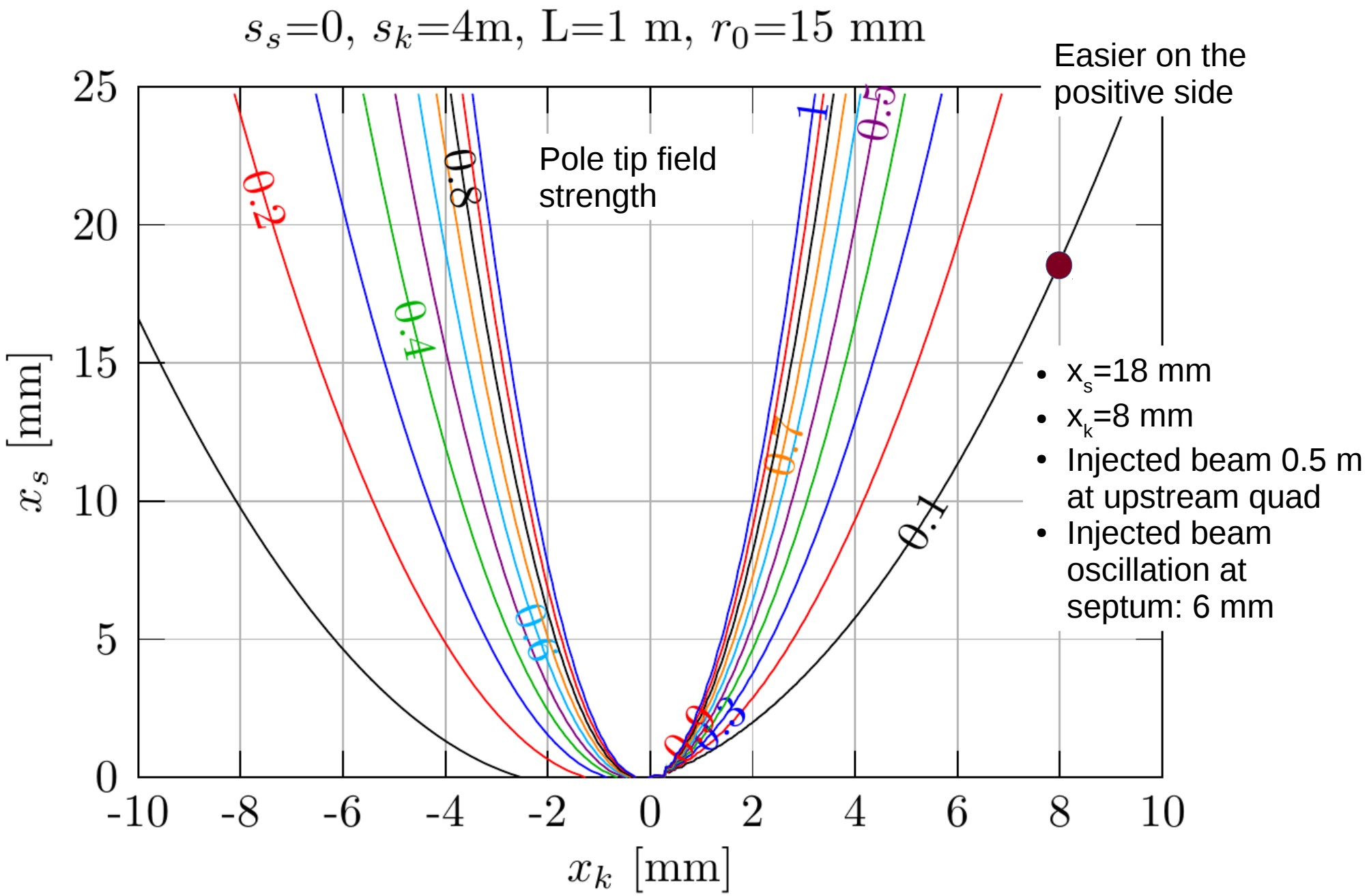
- $B_y = \frac{S}{2} x_k^2$
- $x_k' = x_s' + \frac{B(x_k) L}{B\rho} = \frac{x_k - x_s}{s_k - s_s} + \frac{LS}{2 B\rho} x_k^2 = -\alpha_k / \beta_k \cdot x_k$
- From this express sextupole strength “S”
- Pole tip field: $\frac{S}{2} r_0^2$
- Excitation coil: single-turn (minimize L for fast risetime)
- Required current:

$$\oint B\,dl = \int_0^{r_0} \frac{S}{2} r^2\,dr = \frac{S}{6} r_0^3 = \mu_0 I_0 / 2$$

$$I_0 = \frac{S}{3} \frac{r_0^3}{\mu_0}$$



Kicker strength vs. injection offset

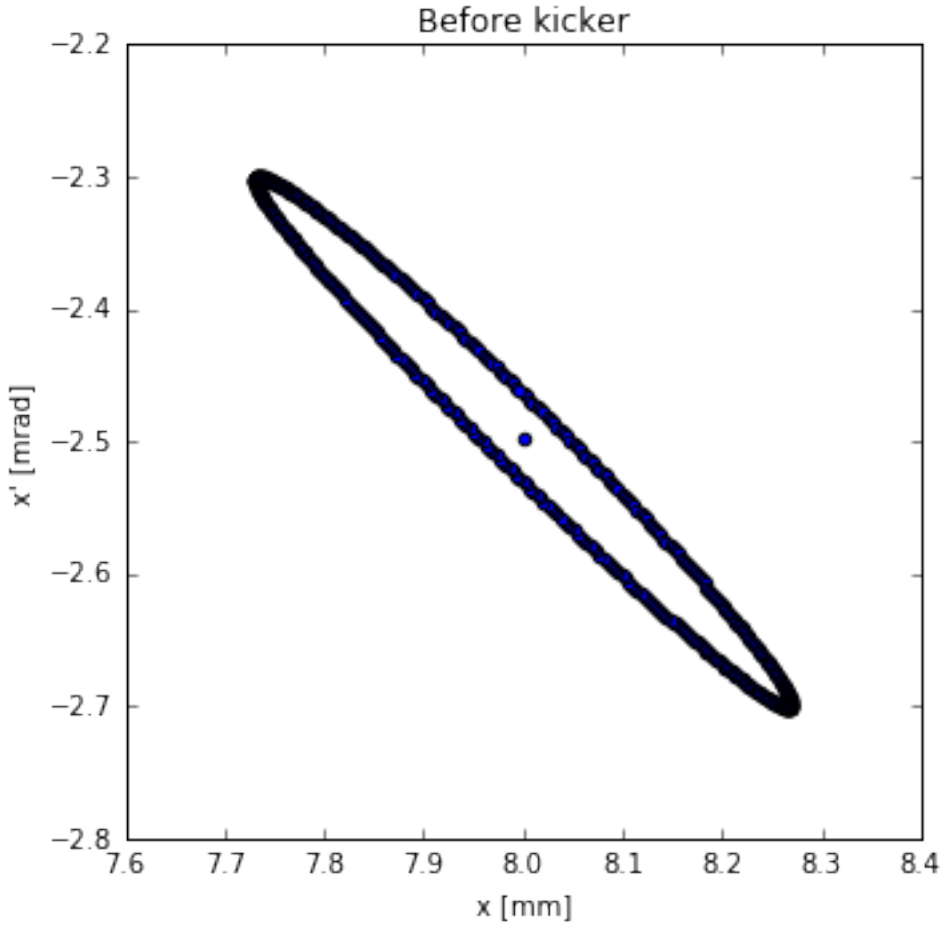


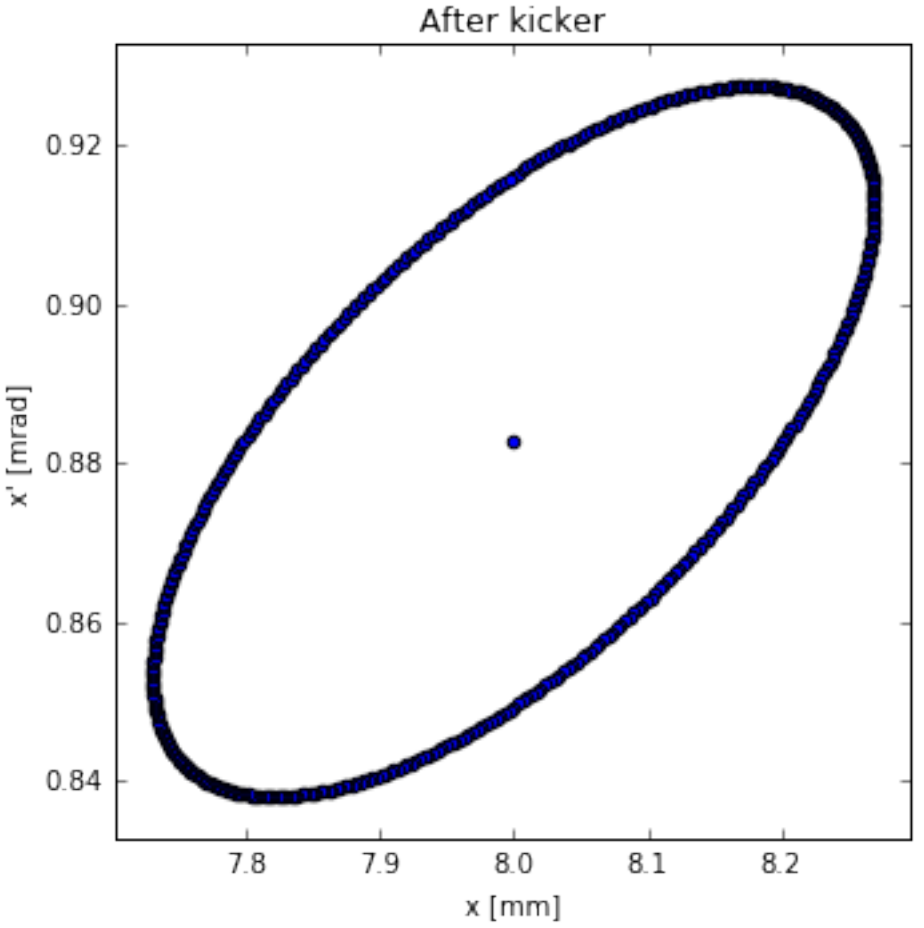
- x_s=18 mm
- x_k=8 mm
- Injected beam 0.5 m at upstream quad
- Injected beam oscillation at septum: 6 mm

The sextupole kicker defocuses.. tune incoming beam

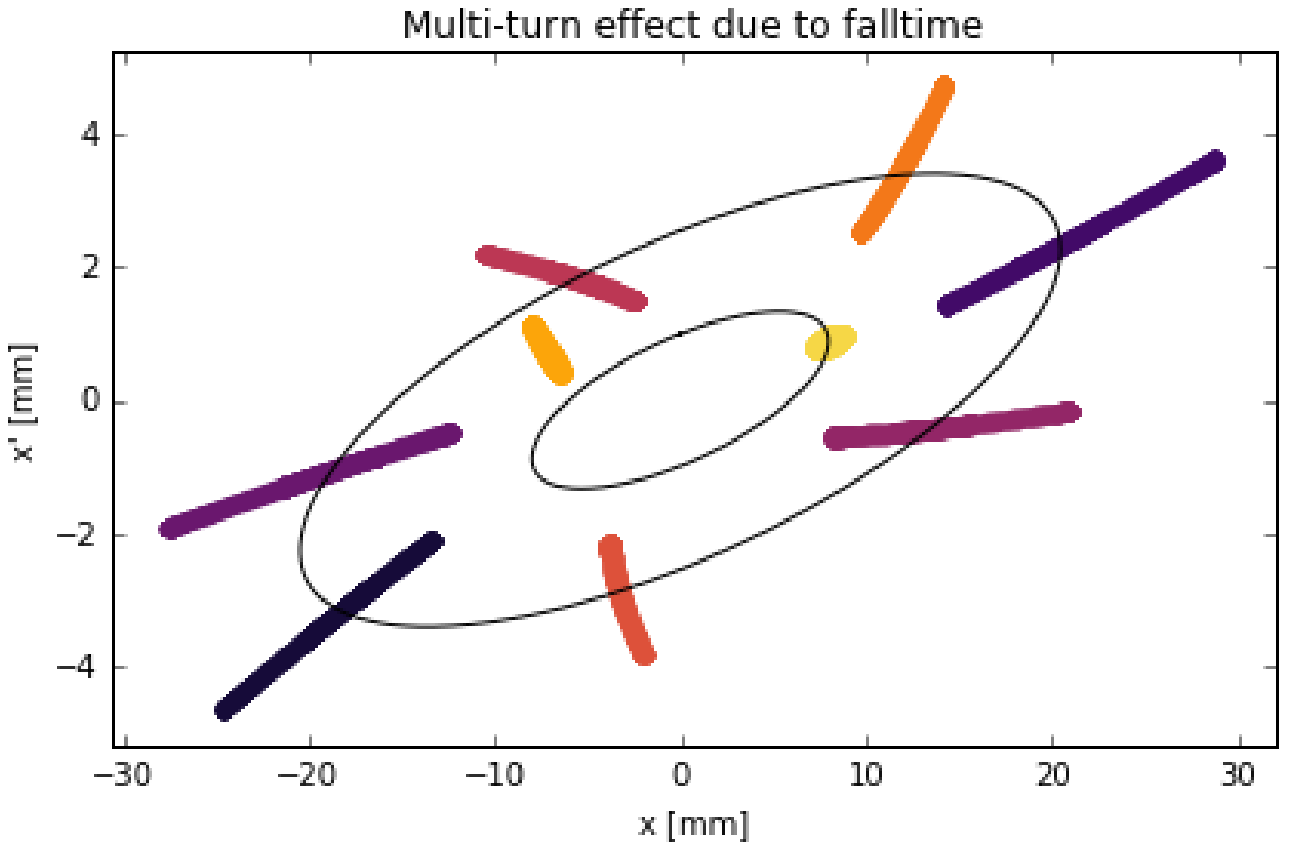
Required input – strongly focused (i.e. large beamsize upstream)

to give required ellipse after kicker





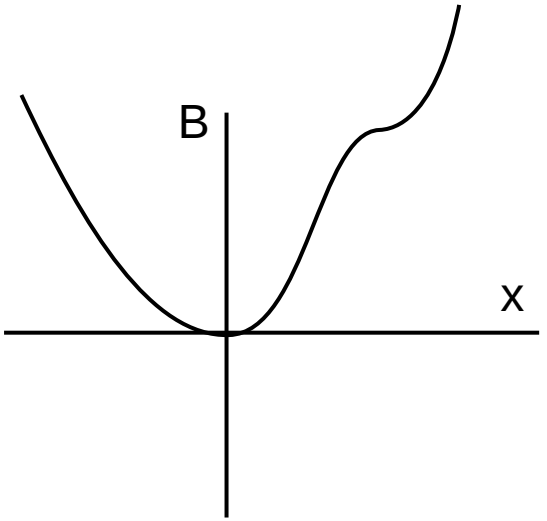
Decay of kicker field over several turns



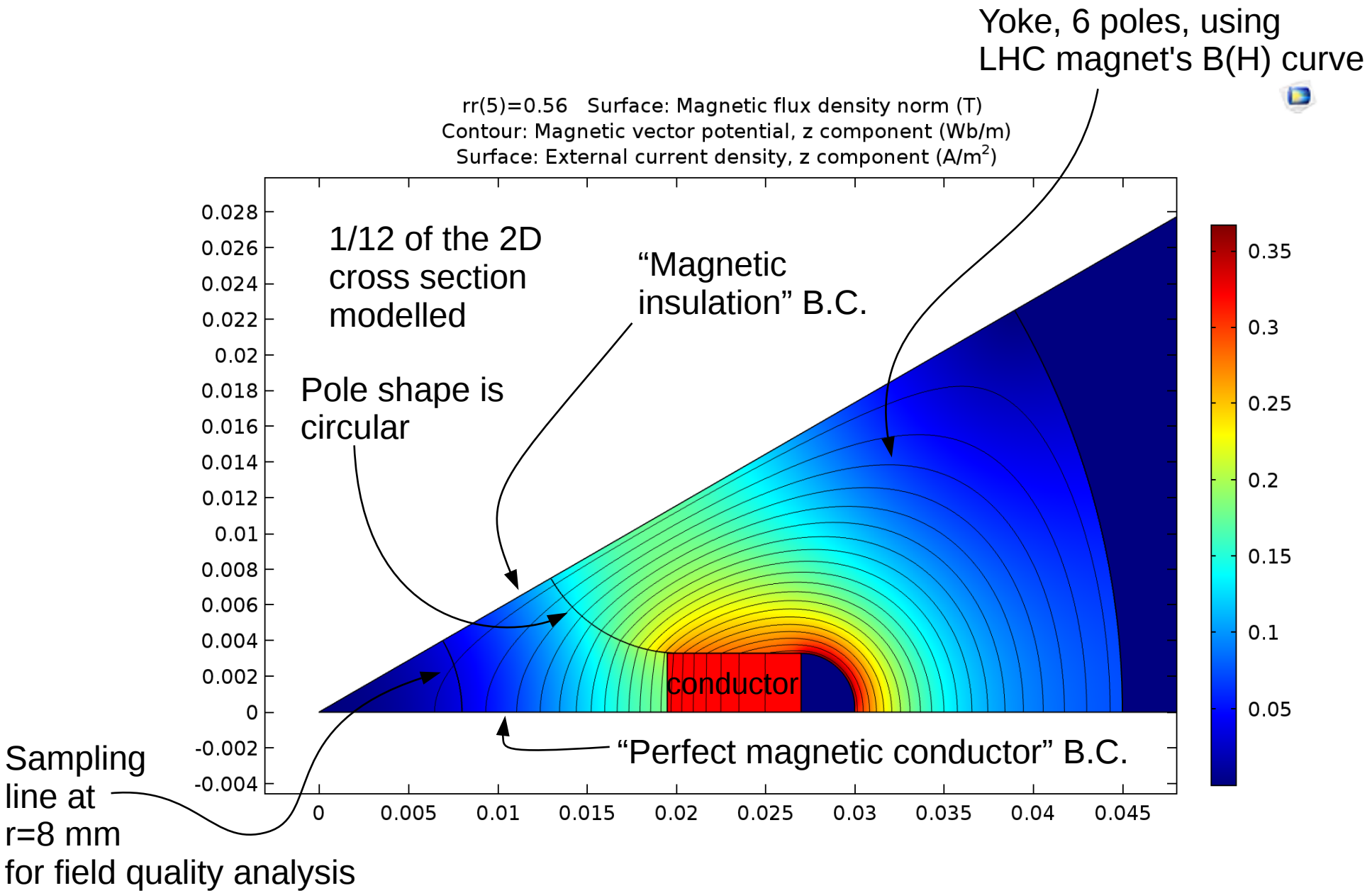
- Subsequent kicks bring beam center to larger orbits
- Strong defocusing makes beam large
- Kicker needs to have larger aperture

Possible solutions:

- Change machine tune close to 0.25 or 0.75
- Make kicker decay faster
- Introduce a small 'flat' into the B(x) profile



Magnet design



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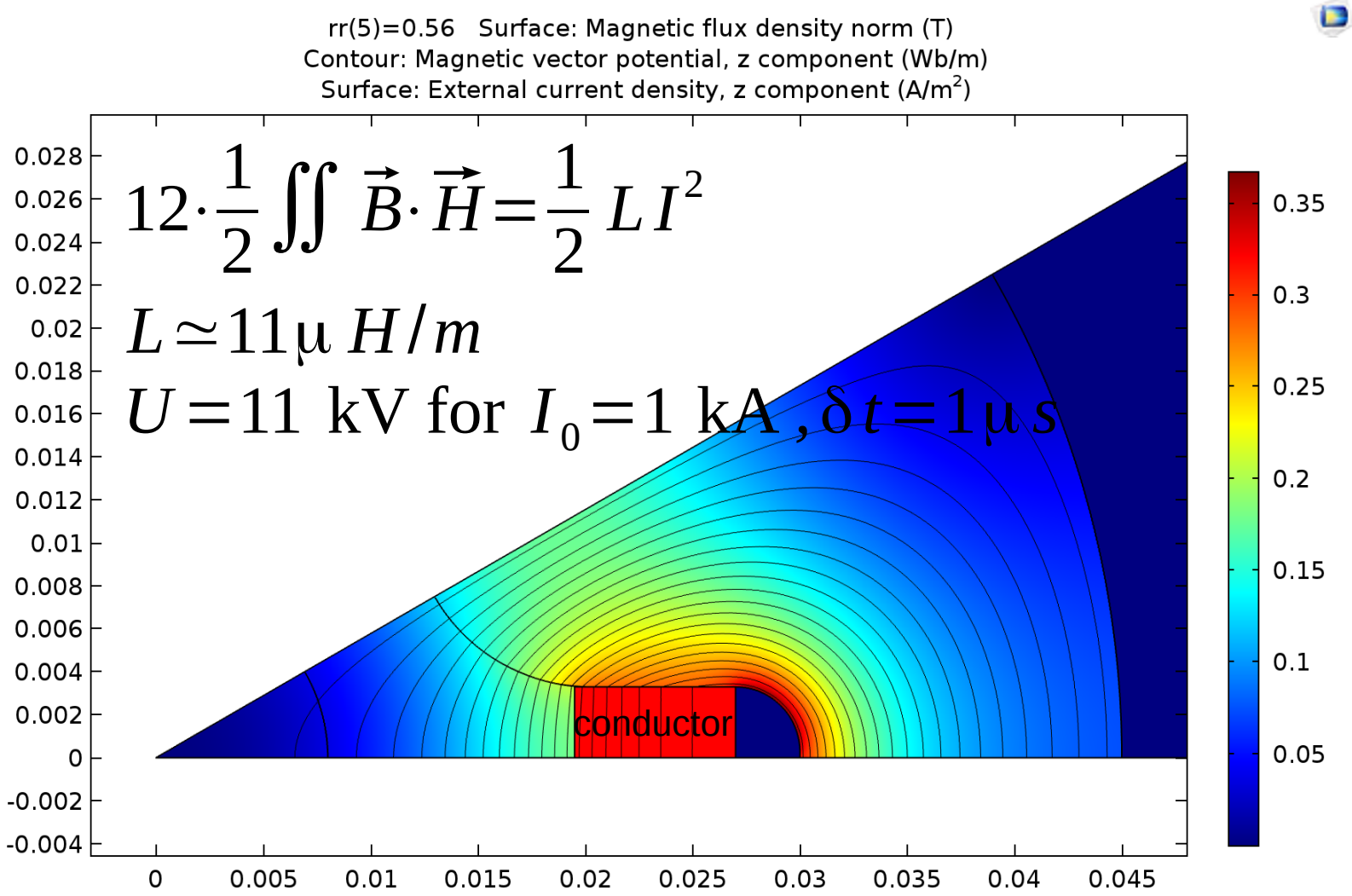
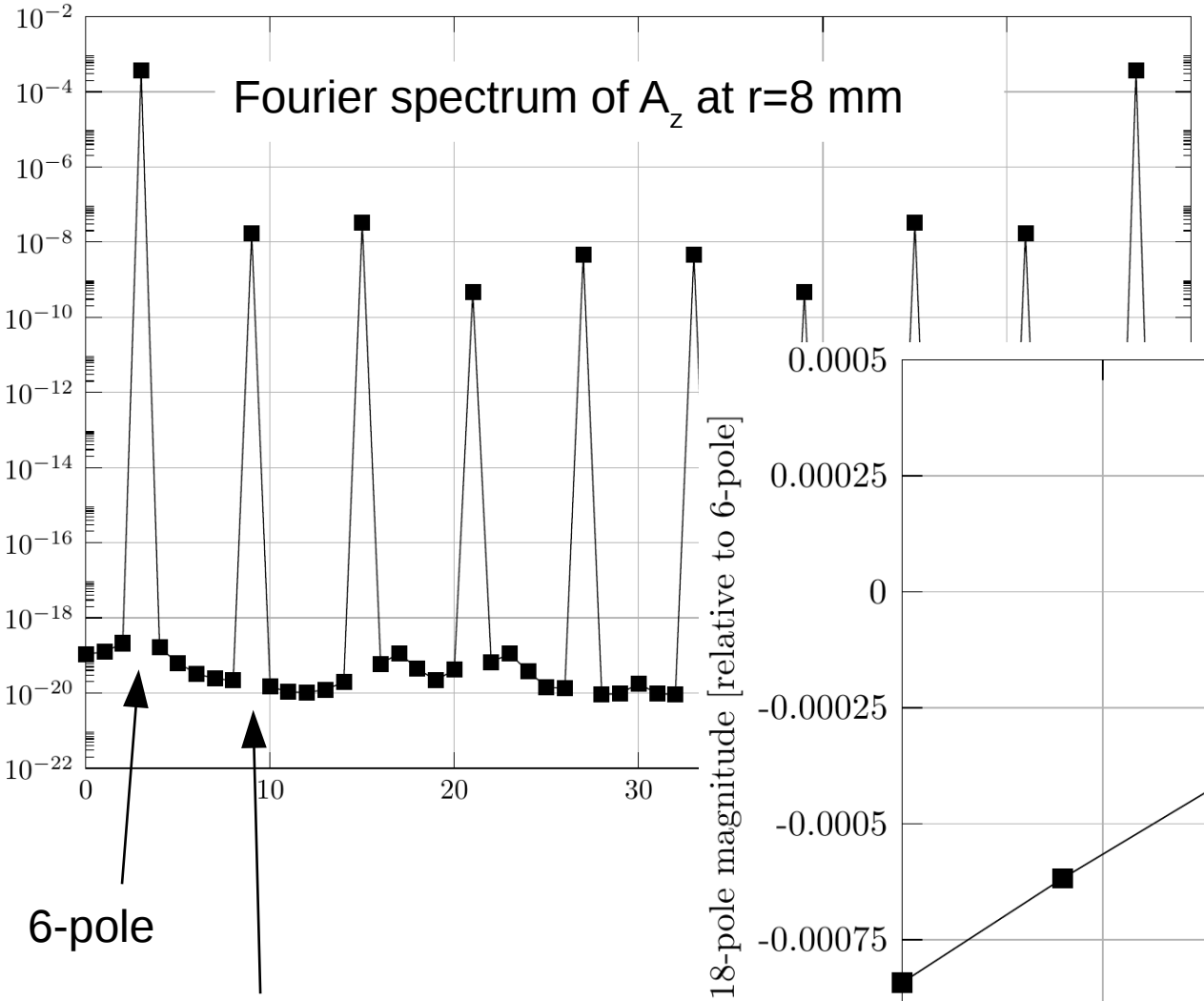


Magnet design: pole shape



(Just for fun... it probably doesn't matter at all)