Multi-turn design for cERL
--- small footprint version ---

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Multi-turn ERL, Pros and Cons

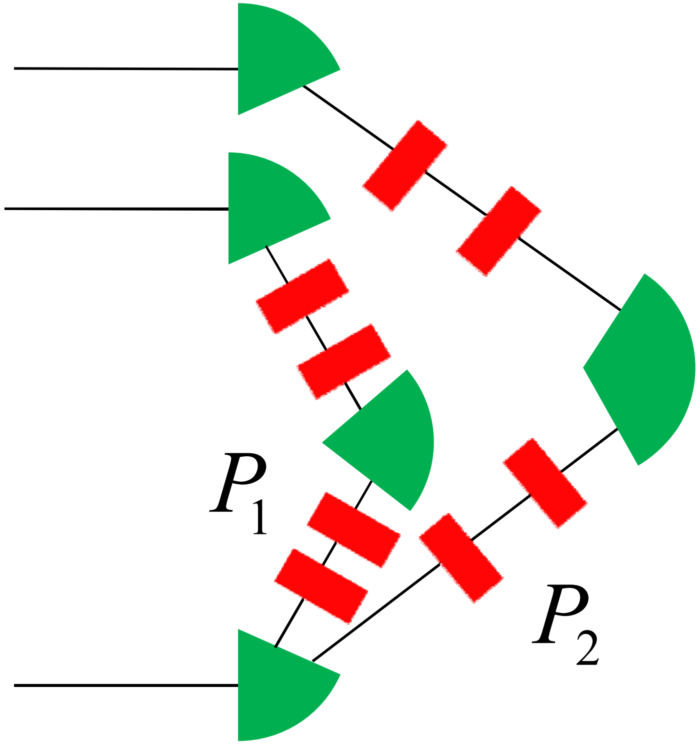
☺ Pros

- Save the cost for both construction and operation.
  - Linac → ½, refrigerator → ½ , RF → ½ …
- Smaller foot print

☹ Cons

- Complicated beam optics
- Need more attention to BBU and CSR
- Larger HOM-load in the main linac

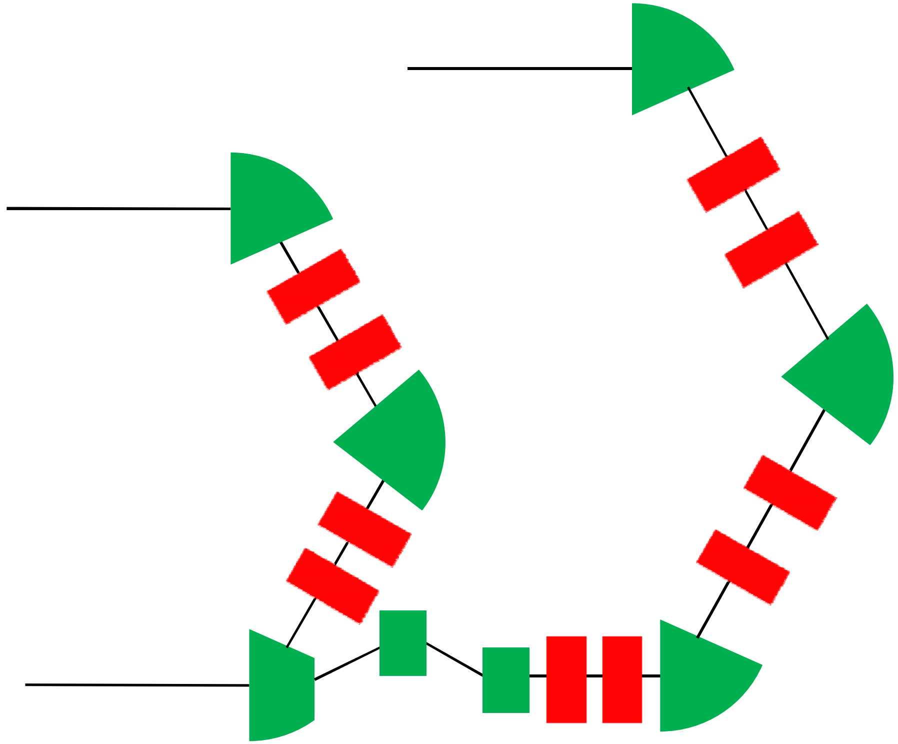
Beam splitting & merging schemes



Fixed momentum ratio

$$P_2 / P_1 = const.$$

This type is considered here.

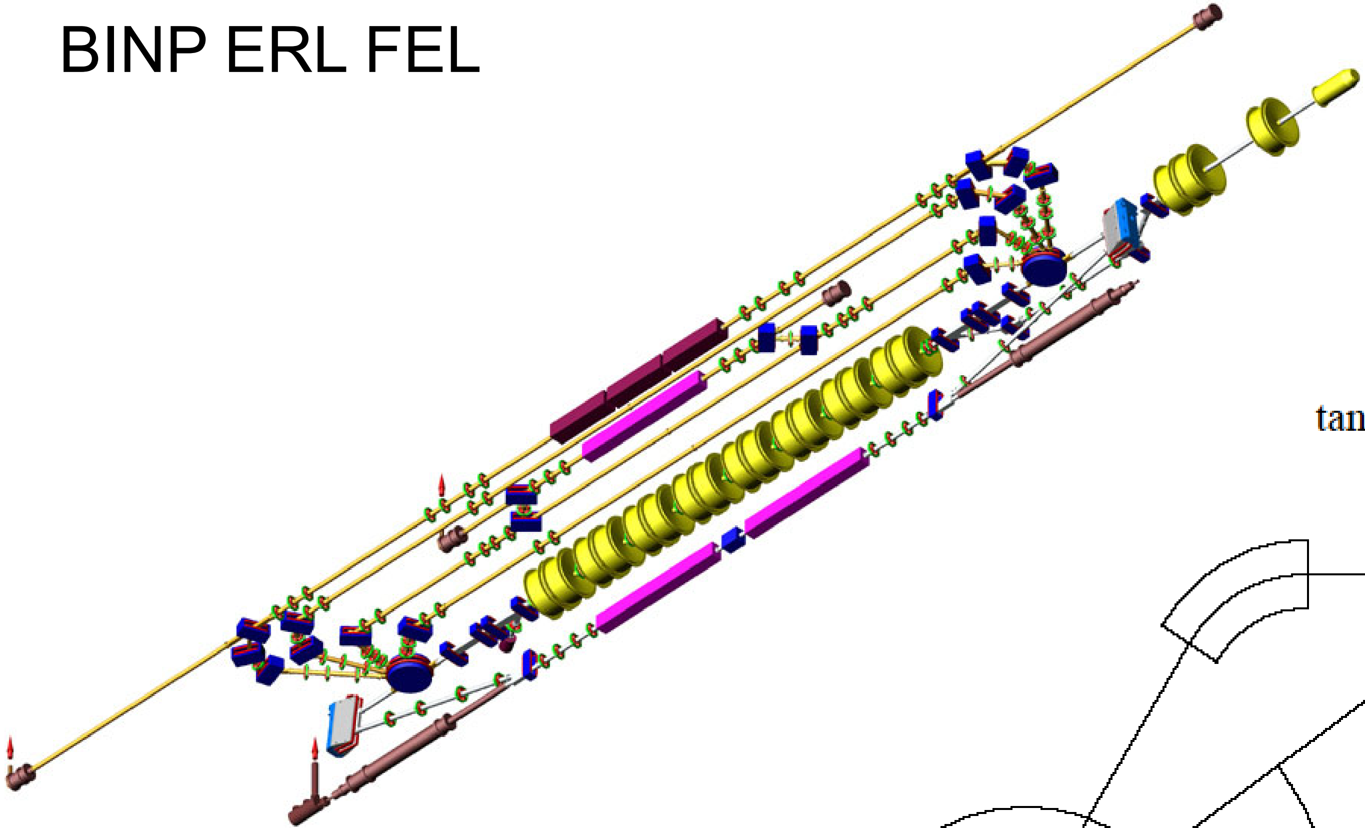


Variable momentum ratio

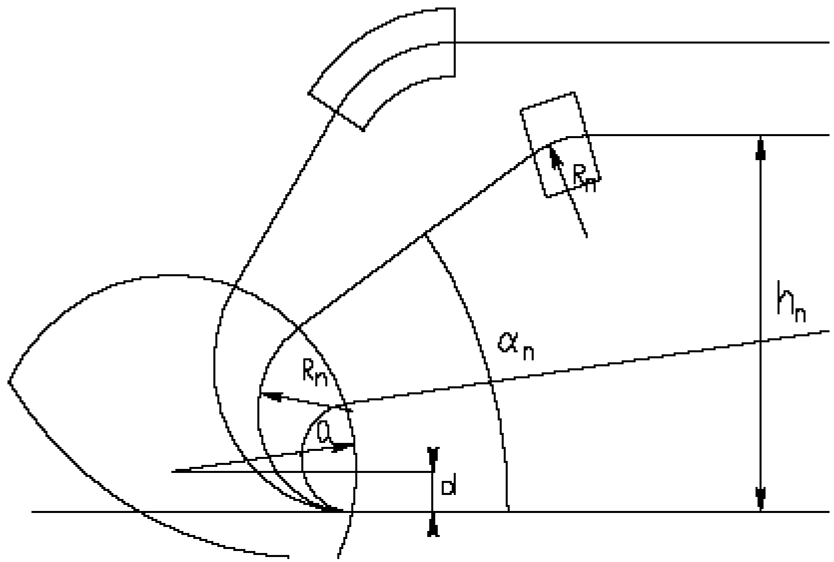
Design example was presented at the previous meetings.

Beam splitter by round magnet

BINP ERL FEL

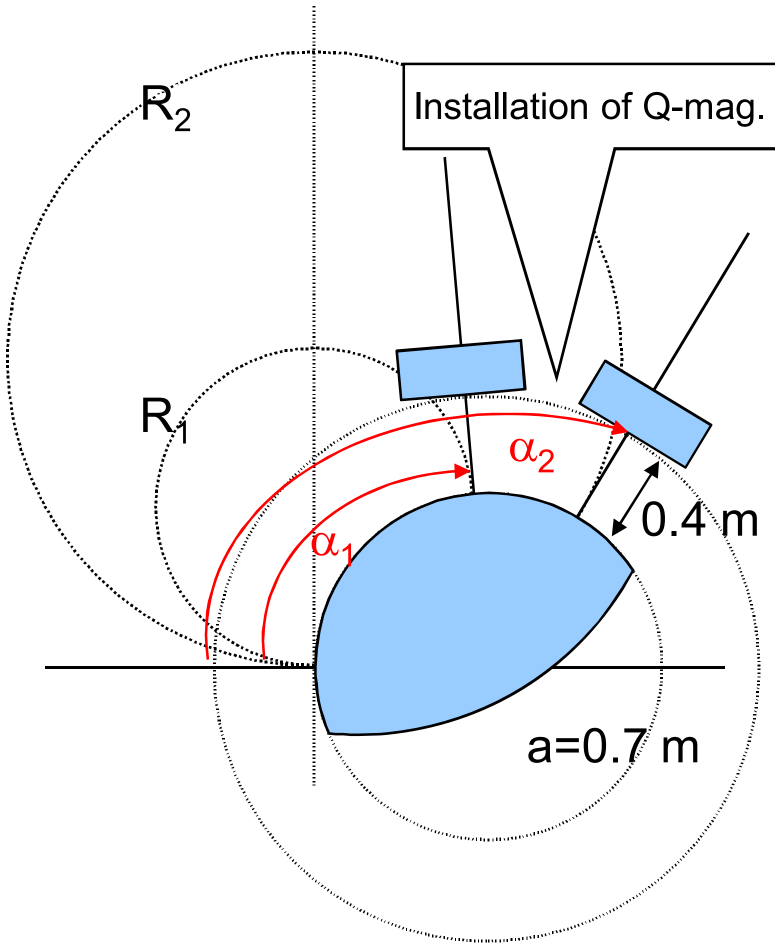


$$\tan\frac{\alpha}{2} = \frac{R-d}{\sqrt{a^2-d^2}}.$$



N.A. Vinokurov et al., RuPAC-2008.

beam splitter for cERL



we fixed the momentum ratio as $\frac{P_2}{P_1} = \frac{248}{128}$

8 + 120 + 120
5.3 + 80 + 80
…

we chose the parameters as

round magnet radius a=0.7 m
offset d=0 for the zero edge angles
α_2 = 120 deg. (bending angle = 60 deg.)

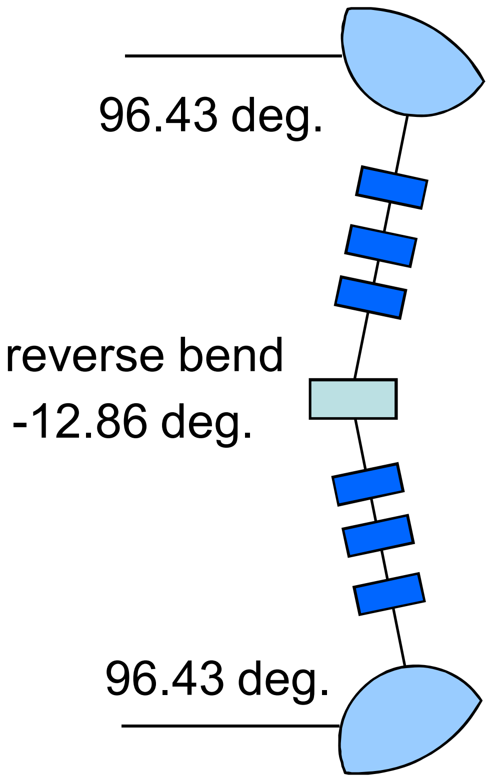
$$\tan\frac{\alpha}{2} = \frac{R-d}{\sqrt{a^2 - d^2}}.$$

$R_1 = 0.6255m \quad R_2 = 1.212m$

$\alpha_1 = 83.57\deg$ (bending angle = 96.43 deg)

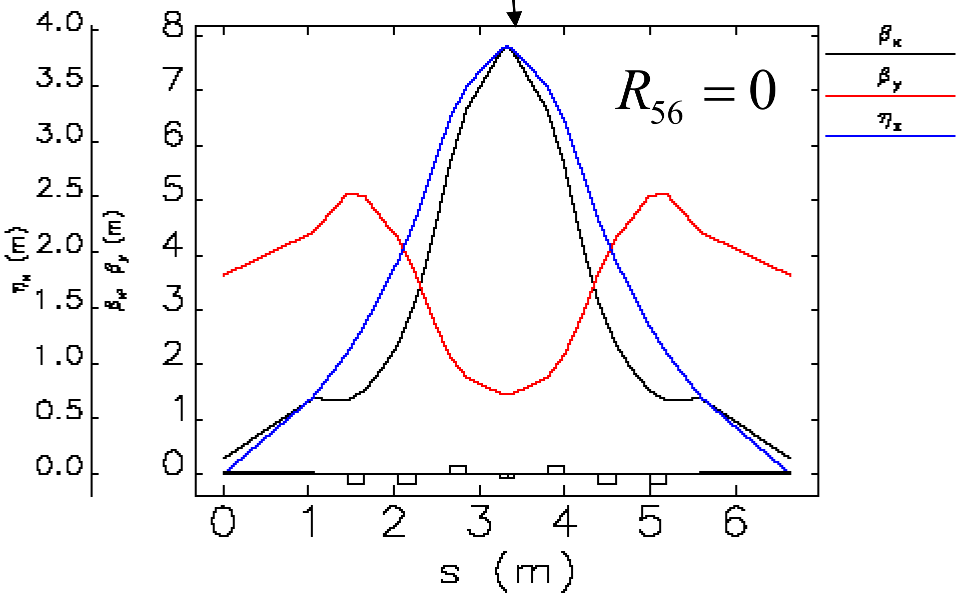
magnetic field: B=0.69 T for 248/128 MeV/c

isochronous arc with a reverse bend

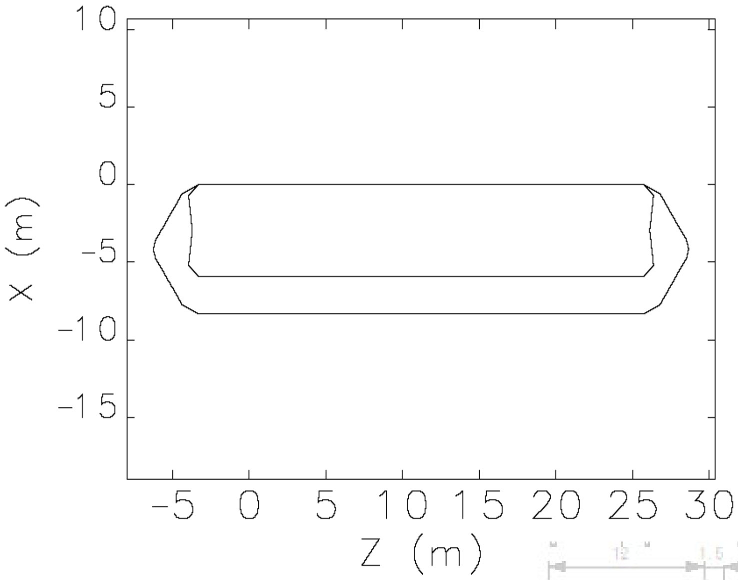


$$R_{56} = \int \frac{\eta_x}{\rho} ds$$

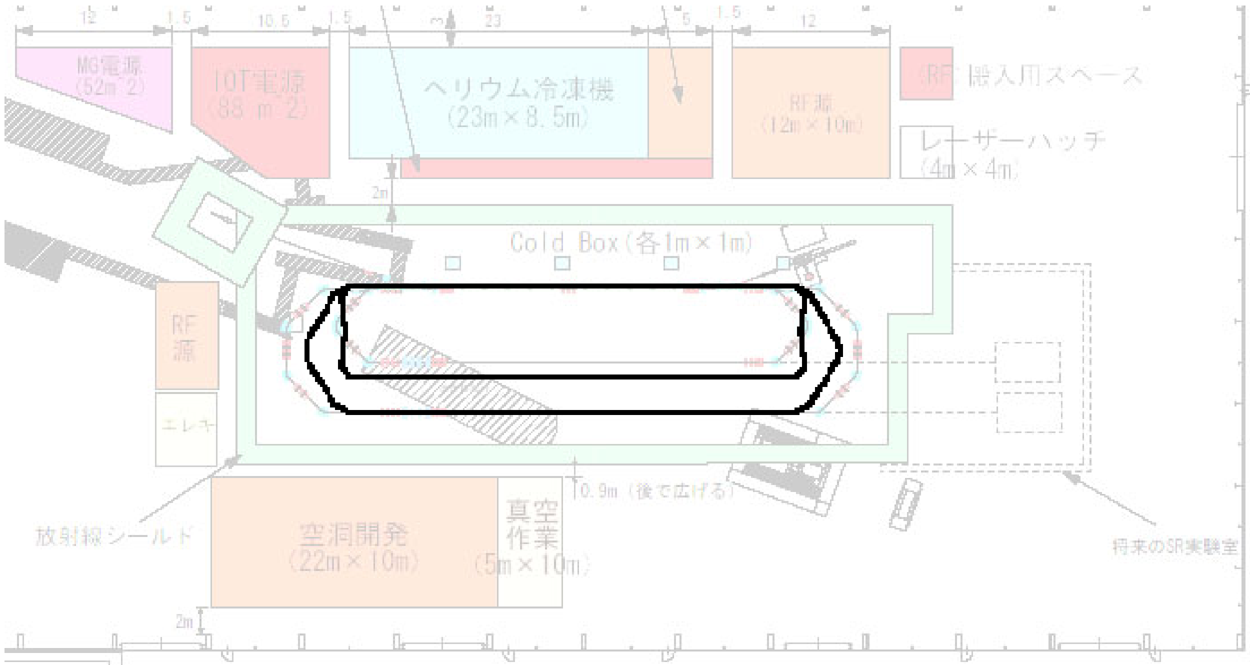
large η_x and small reverse angle ($\rho<0$)



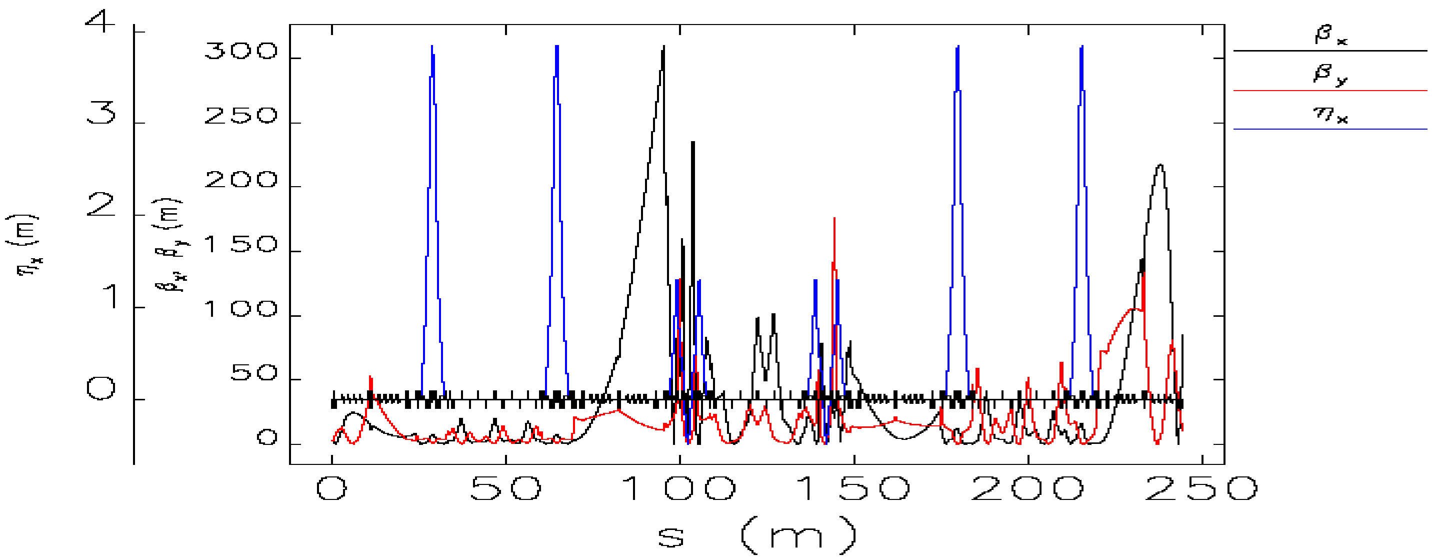
2-loop design (small foot print version)

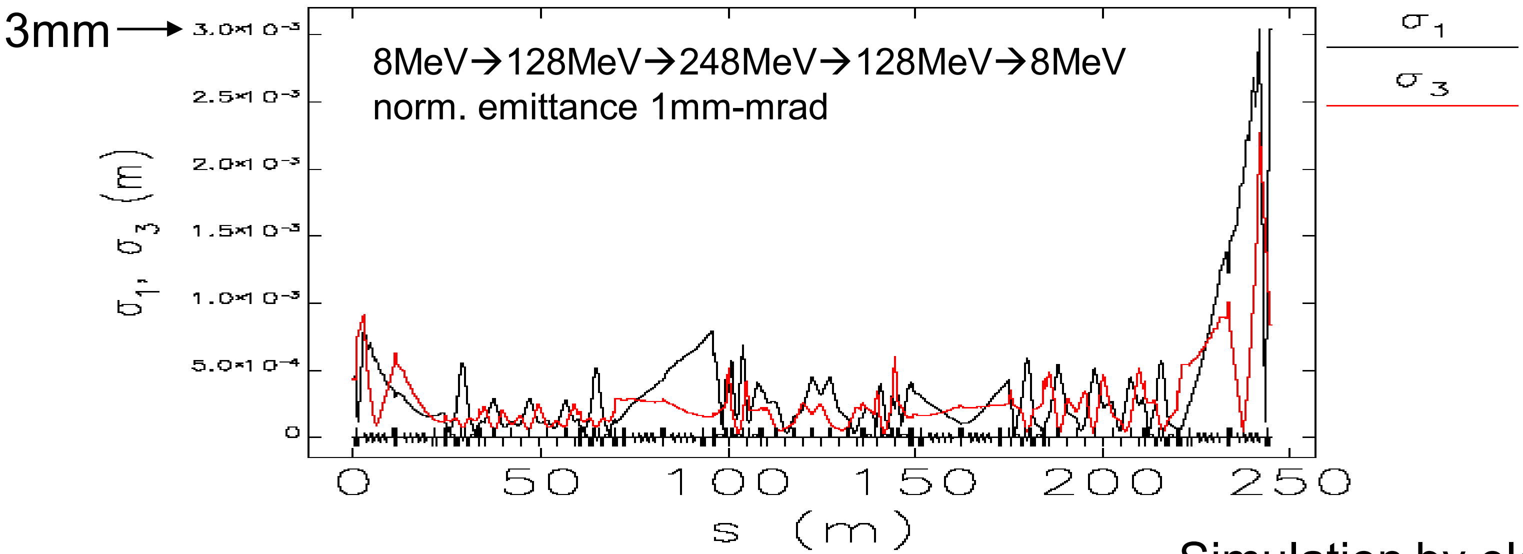


9-cell x 4 cavity x 2 module
space for each SCA module = 10.2 m (Q-to-Q)



2-loop design (small foot print version)

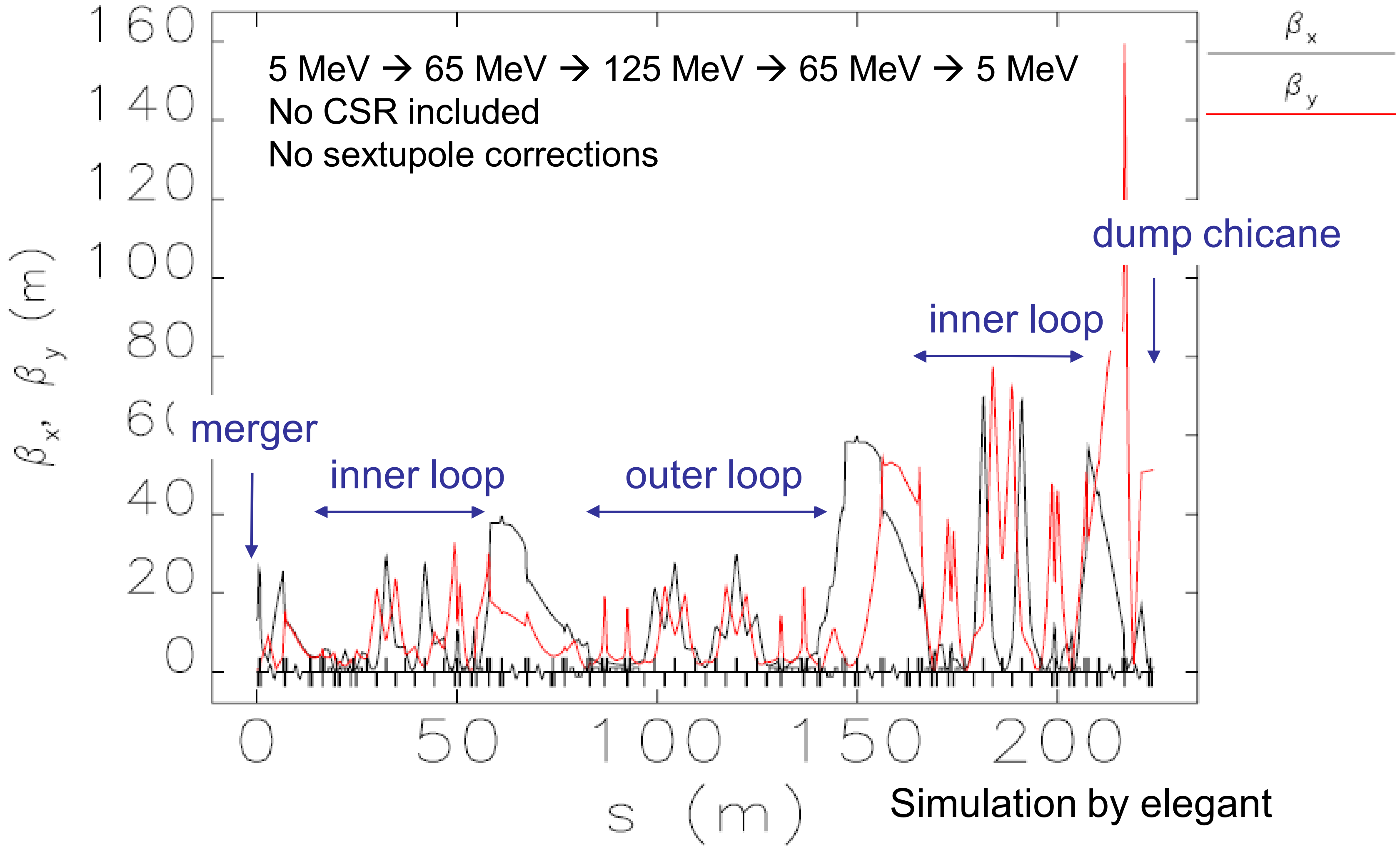




Simulation by elegant

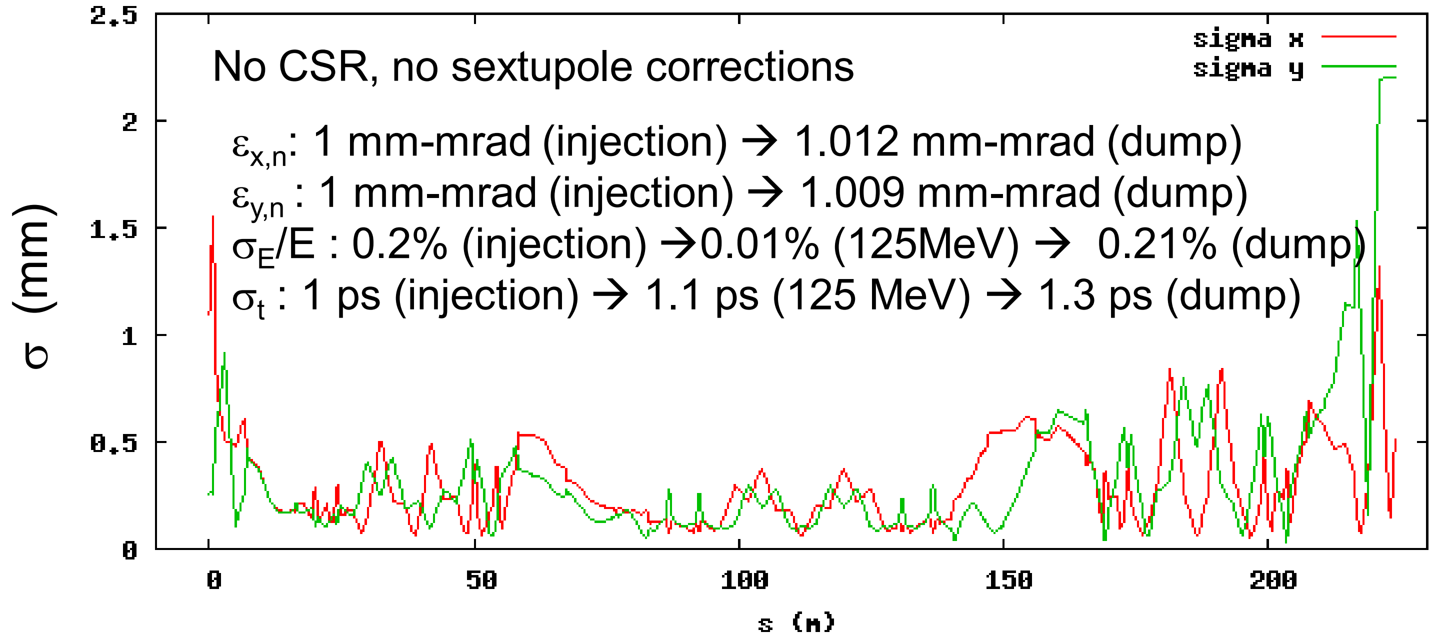
Previous design (larger footprint)

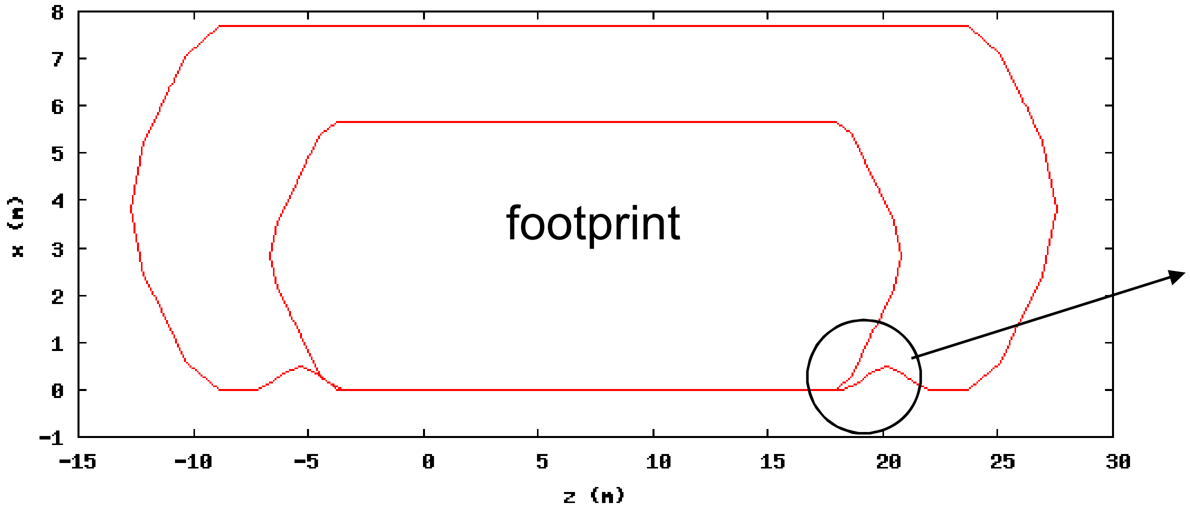
Inner loop → similar to the CDR design, R_{56}=0, FODO for the back straight
Outer loop → TBA arc, ρ=2m (ready for 400 MeV), R_{56}=0, FODO for the back straight
Linac → 9-cell (15 MeV) x 2 cavities x 2 modules



Simulation by elegant

Previous design (larger footprint)

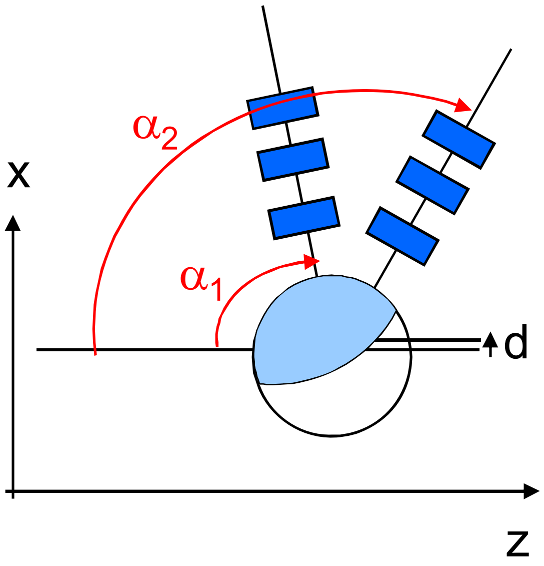




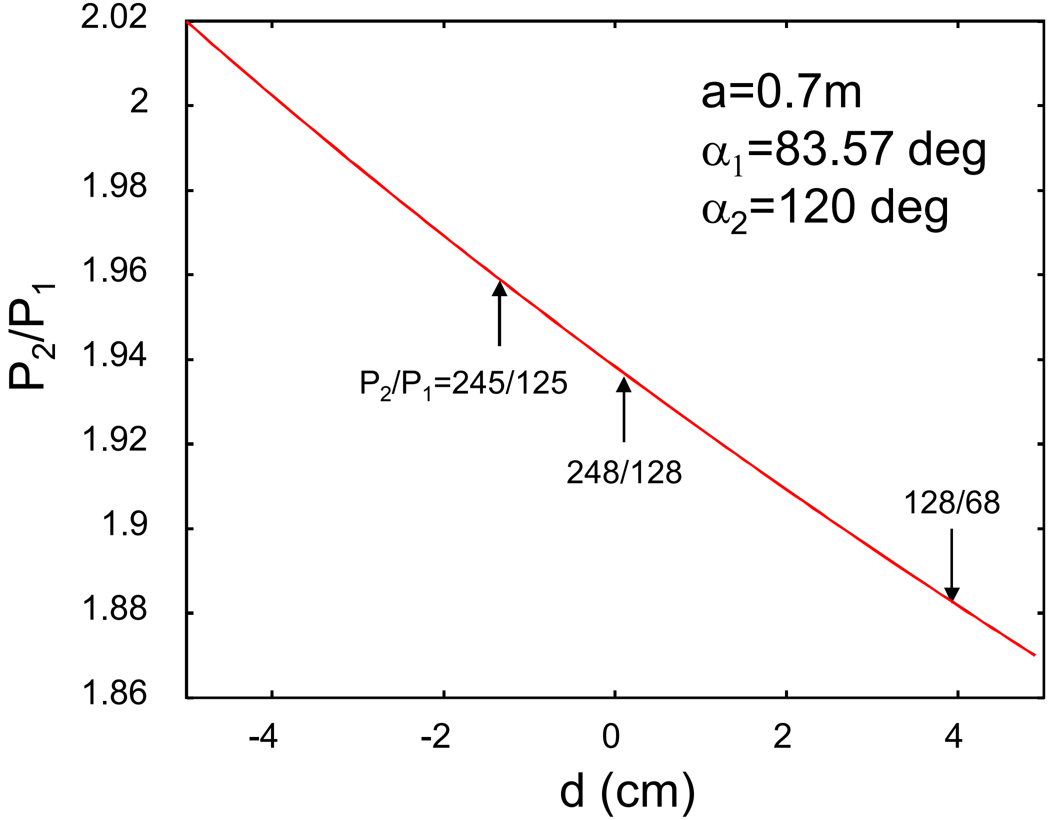
installation of magnets is difficult

Variable momentum ratio with a round magnet

Even if we fix α_1 and α_2, the momentum ratio is variable by tuning "d".



$$\tan\frac{\alpha}{2} = \frac{R-d}{\sqrt{a^2-d^2}}.$$

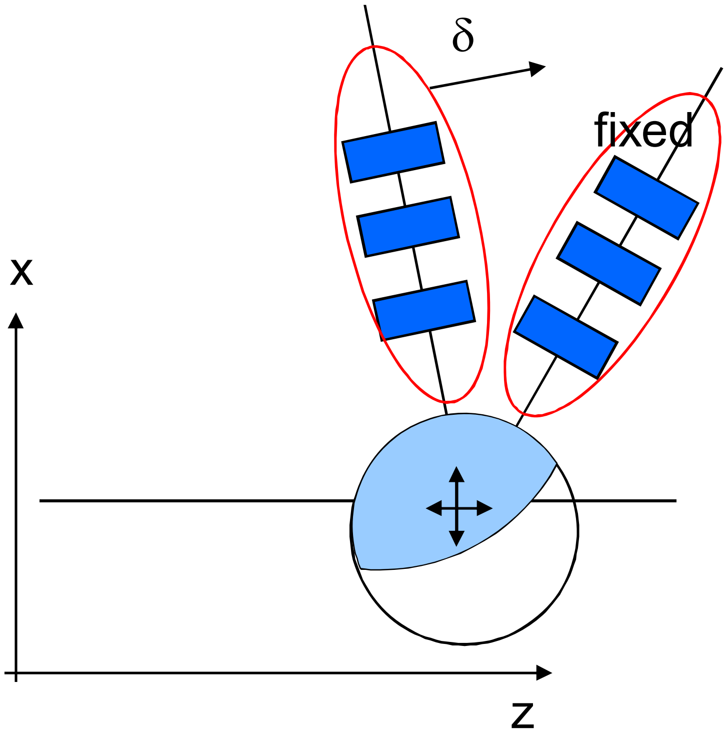


small shift in x-direction

↓

variable momentum ratio

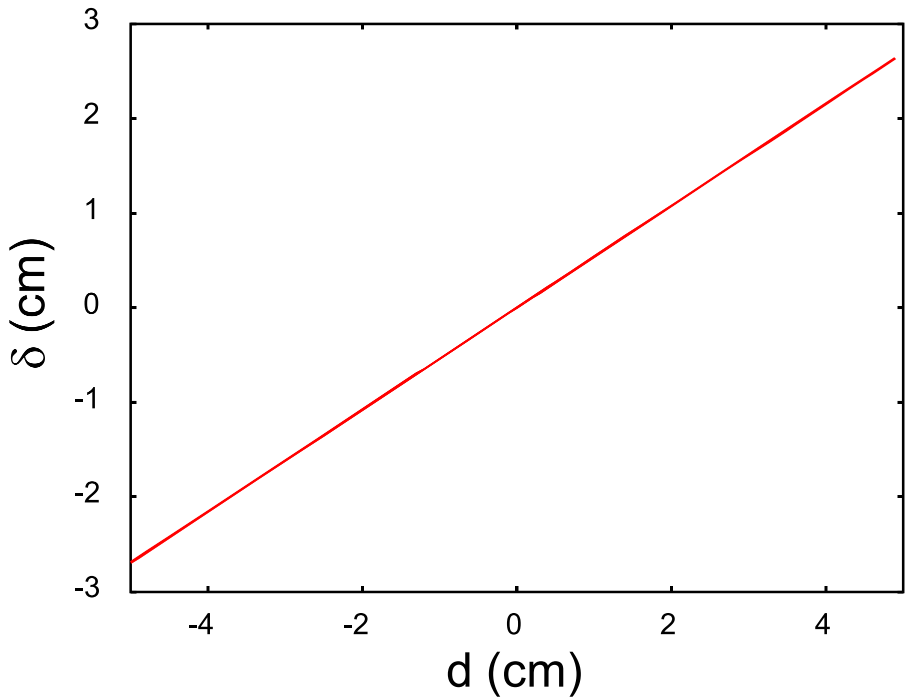
orbit correction for the variable momentum ratio



We fix the outer-loop orbit.

The momentum ratio is variable by moving the round magnet in x-direction. Shift in z-direction is also necessary to keep the outer-loop at the fixed position.

We need orbit correction for the inner loop.



possible scenario

- fabrication of all the magnets (max. ~240 MeV)
- installation of the outer loop and commissioning of a 60-MeV beam (9cell x 2 x 2) with the outer loop
- (a) SCA upgrade, and then 2-loop upgrade
  - energy upgrade (~120 MeV, 9-cell x 4 x 2) with the outer loop
  - installation of the inner loop and commissioning of a ~240-MeV beam with 2-loop ERL
- (b) 2-loop upgrade
  - installation of the inner loop and commissioning of a ~120-MeV beam