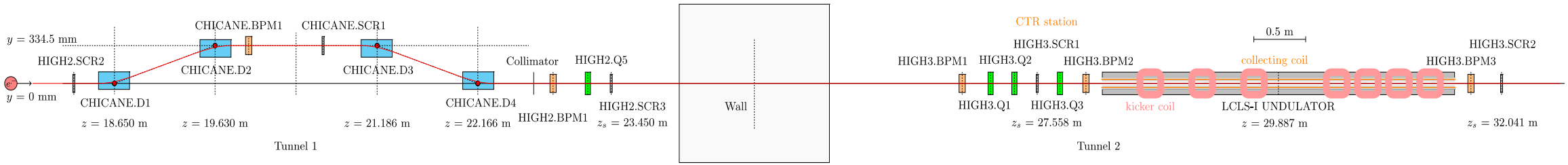
Numerical study of beam dynamics in PITZ BC for beam matching into the undulator magnet

PITZ Physics Seminar (PPS)



Ekkachai Kongmon

PITZ , 27 July 2023

HELMHOLTZ

HELMHOLTZ GEMEINSCHAFT

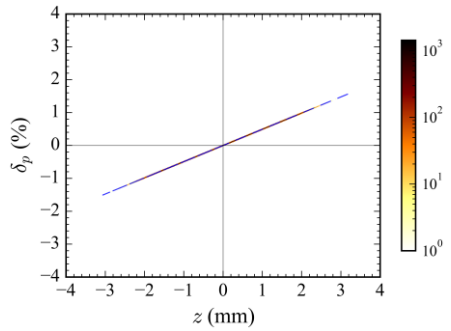
European XFEL

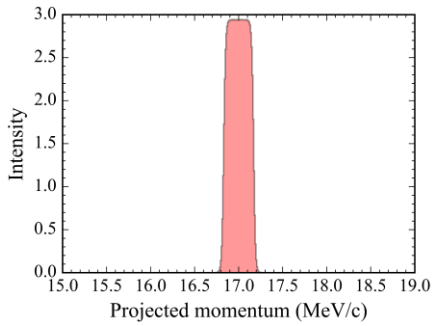
PITZ Photo Injector Test Facility Zeuthen

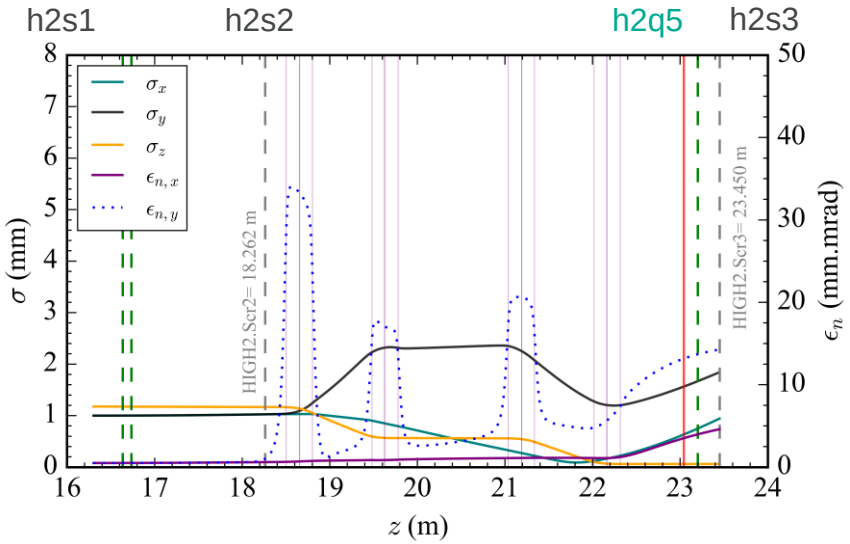
DESY.

Beam matching to BC and Undulator Magnet

Beam momentum 17 MeV/c
Beam with **chirp**
Energy spread 0.6%
Bunch length 4 ps



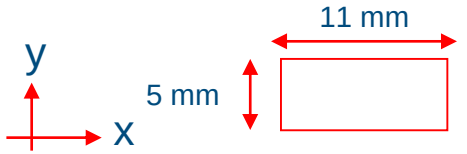




Challenges

- Only one quadrupole to focus beam after BC
- Increasing of the transverse emittance (vertical) after BC

- Match beam to small vertical pipe of an undulator magnet

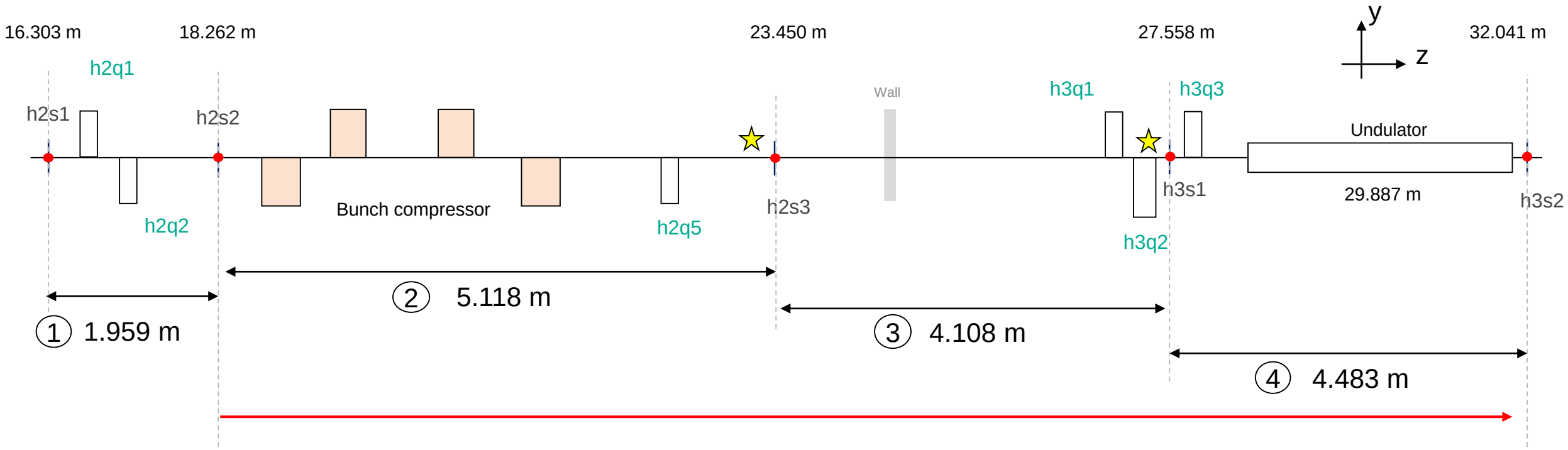


Undulator chamber cross-section

Matching parameters (transverse phase space)

- Twiss-parameters : $\beta_x,\ \beta_y, \alpha_x, \alpha_y$
- Transverse beam emittance : ϵ_x, ϵ_y

Beam matching to BC and Undulator Magnet

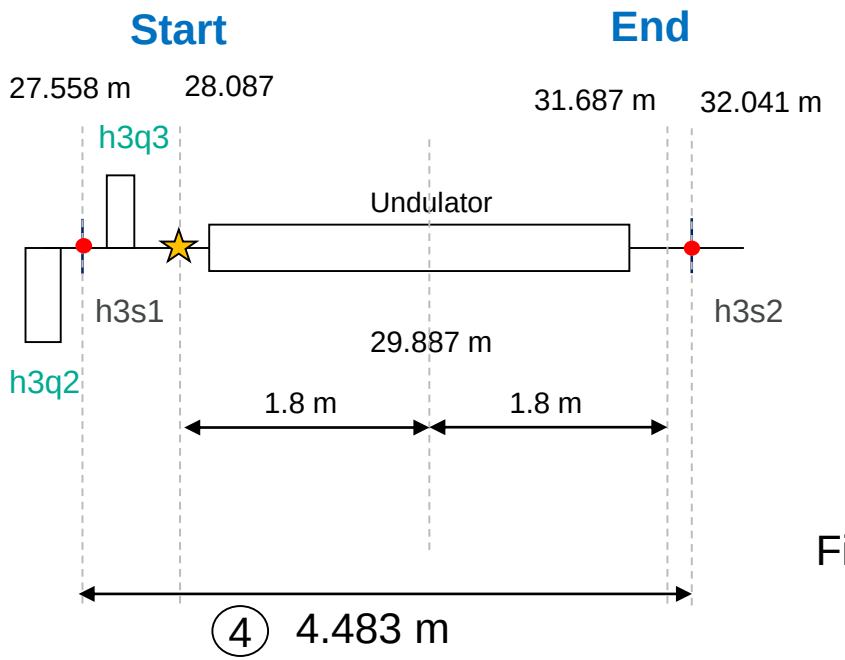


Matching parameters (transverse phase space)

- Twiss-parameters : $\beta_x,\ \beta_y, \alpha_x, \alpha_y$
- Transverse beam emittance : ϵ_x, ϵ_y

Beam matching to undulator

Forward tracking



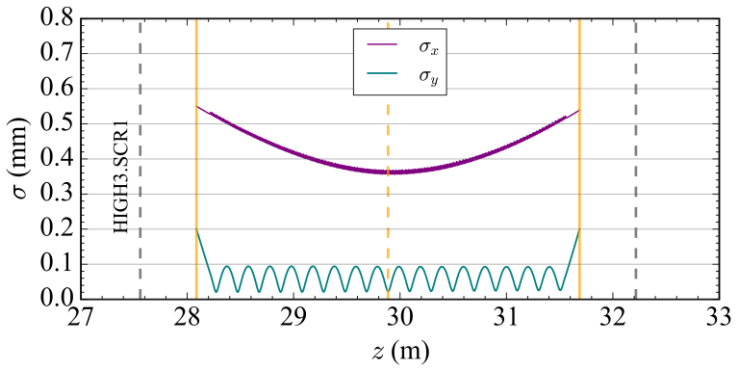
Simulation setup

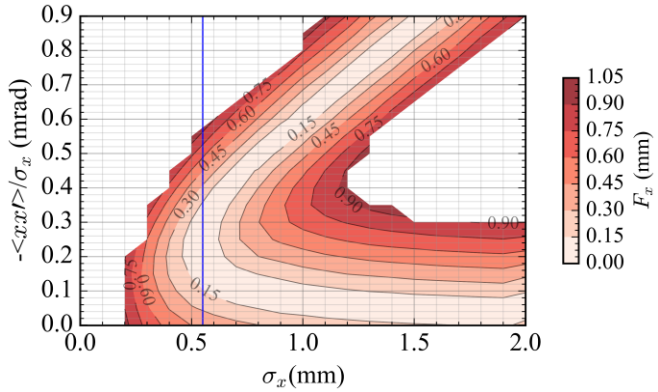
- Using ASTRA + 3D magnetic field of undulator magnet
- Optimized parameters
- Beam momentum 17 MeV/c, Bunch charge 250 pC
  - Transverse beam size $F_x = |\sigma_{xf} - \sigma_{xi}| \rightarrow 0$ $F_y = |\sigma_{yf} - \sigma_{yi}| \rightarrow 0$
  - Correlation

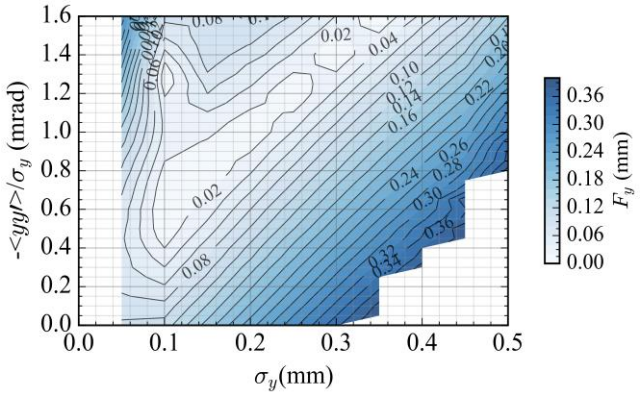
$$\sigma_x^2 = \frac{\beta_x \epsilon_{n,x}}{\beta\gamma}$$

$$cor_{px} = -\frac{\alpha_x}{\beta_x[m]}\sigma_x[mm]$$

Fixed transverse emittance ! Norm. emit_x, Norm. emit_y = 1, 1 mm.mrad



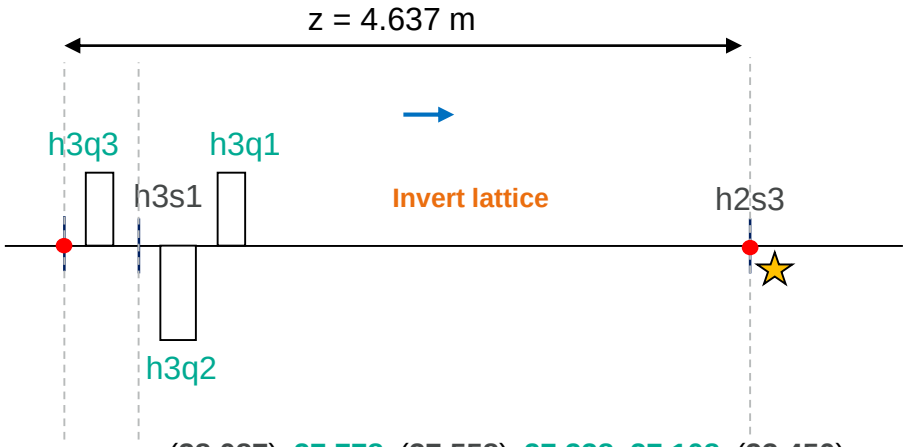




Beam matching to undulator

Backward tracking

Invert the lattice
Invert alphas

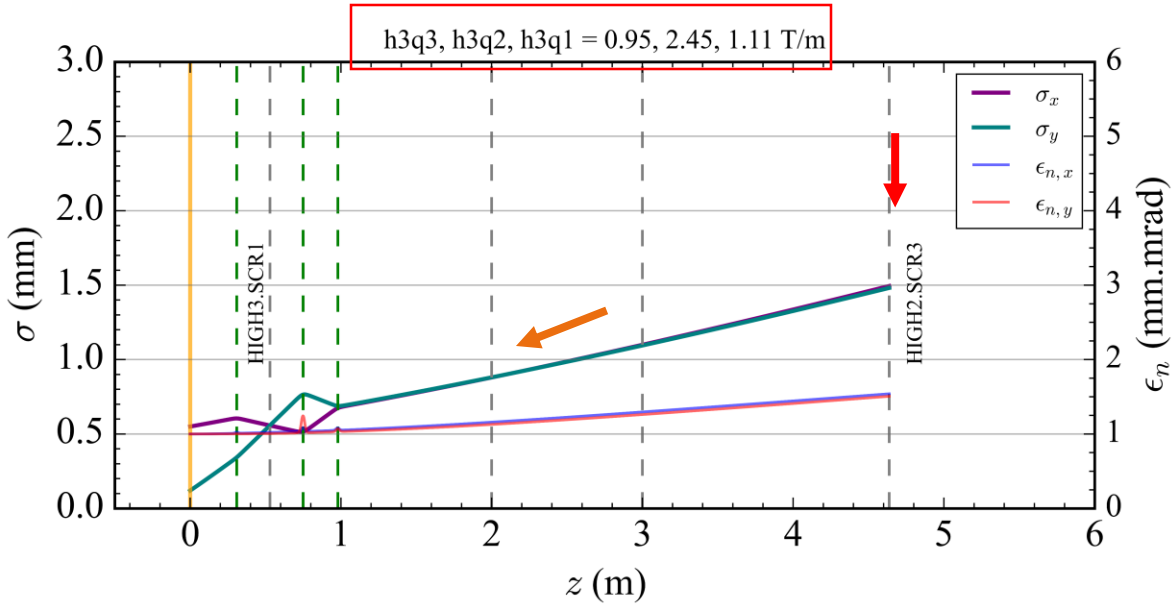


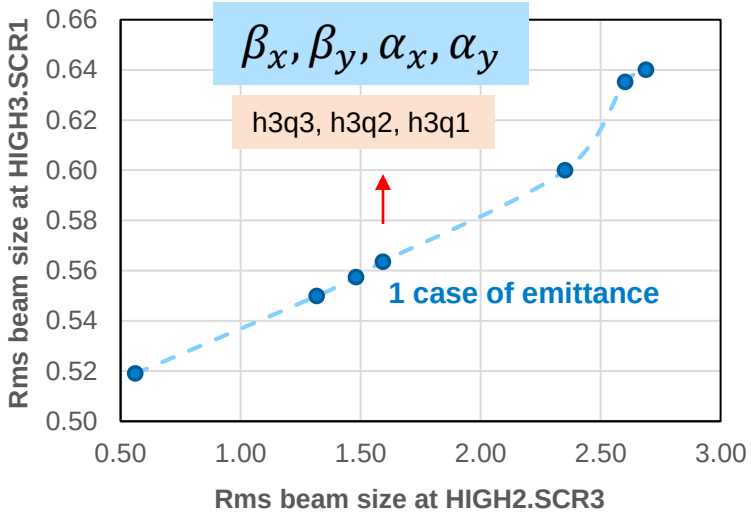
(28.087), 27.778, (27.558), 27.338, 27.108, (23.450)

Positions in beamline

(0), 0.309, (0.529), 0.749, 0.979, (4.637)

Positions in simulation **backward tracking**

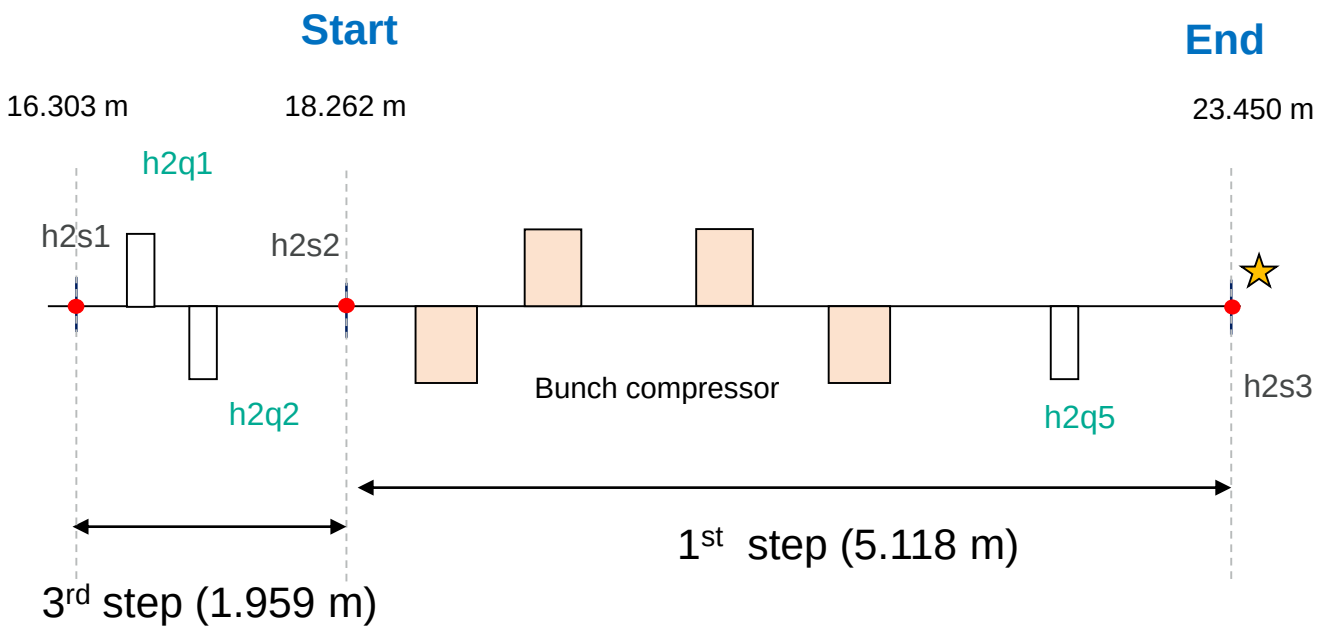




Beam parameters

1. Rms beam size (σ_x, σ_y)
2. Transverse emittance
3. Twiss parameters
   - β_x, β_y, α_x, α_y

Beam matching to BC using OCELOT



Solving these problems

1. Horizontal focusing
2. Space charge dominated
3. Effect CSR next step

Input beam properties

Meam momentum : 17 MeV/c

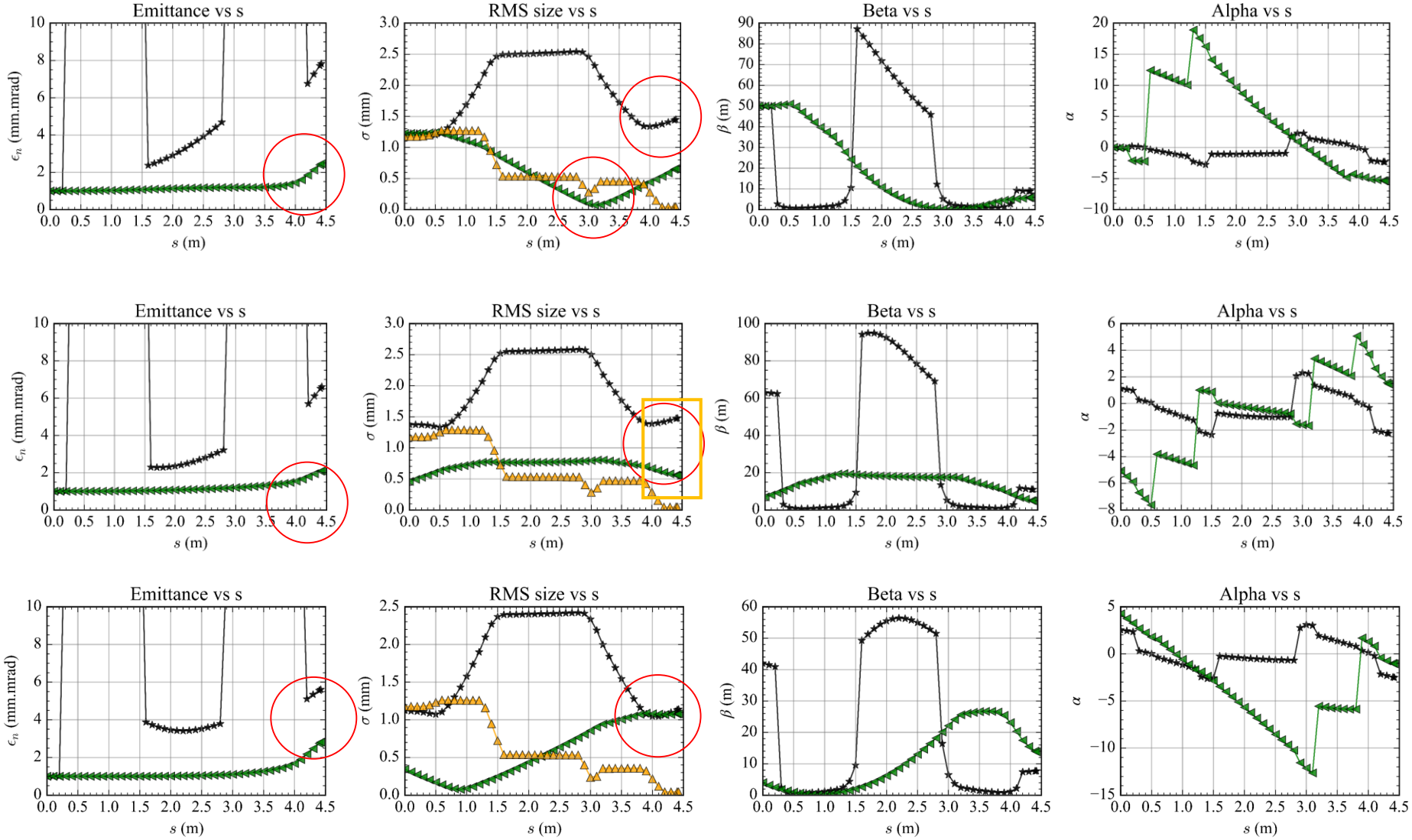
Phase : -20 deg. w.r.t. MMMG

Bunch charge : 250 pC

Norm. emittance : 1 mm.mrad

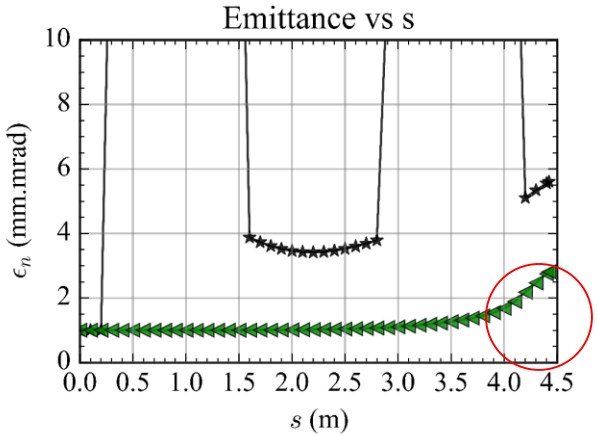
Beam matching to BC using OCELOT

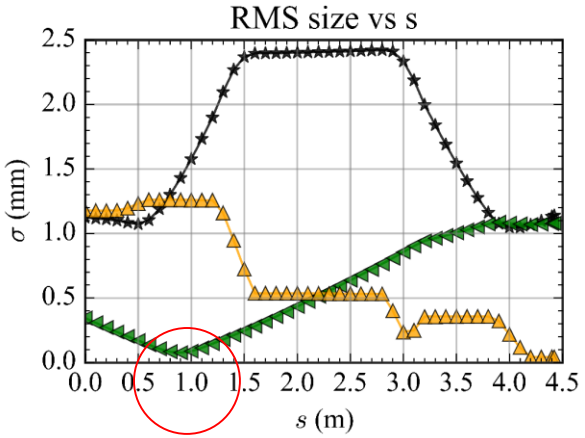
Before optimization (round beam)

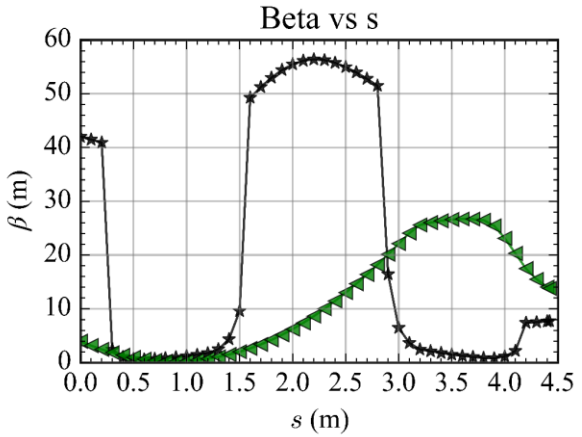


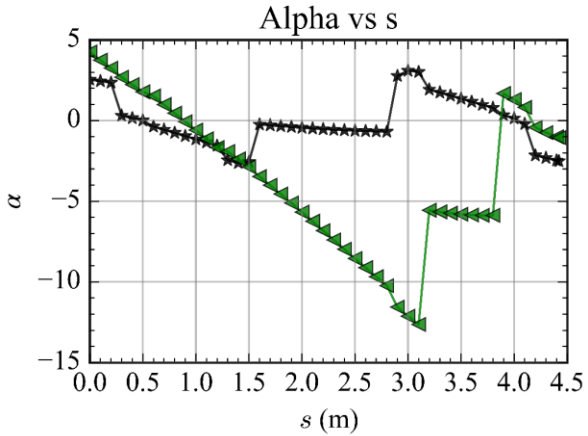
Beam matching to BC using OCELOT

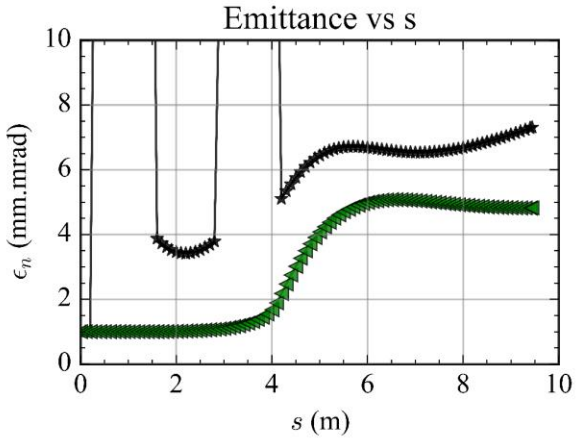
Setup BC (Chicane) → beam dynamics

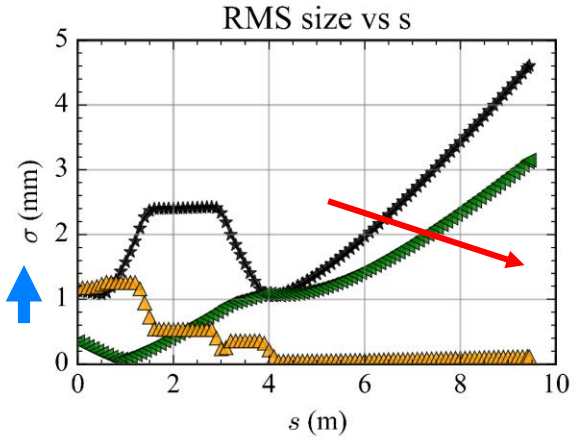


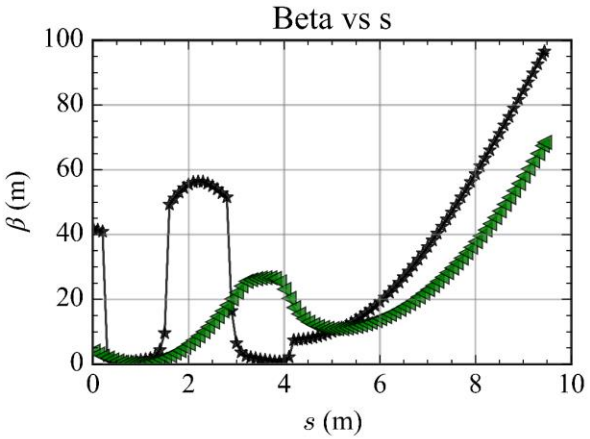


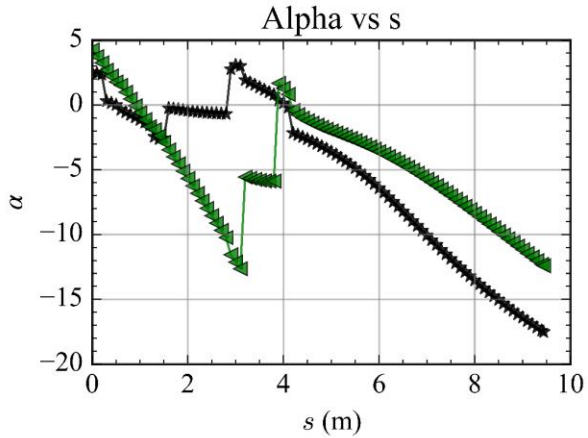






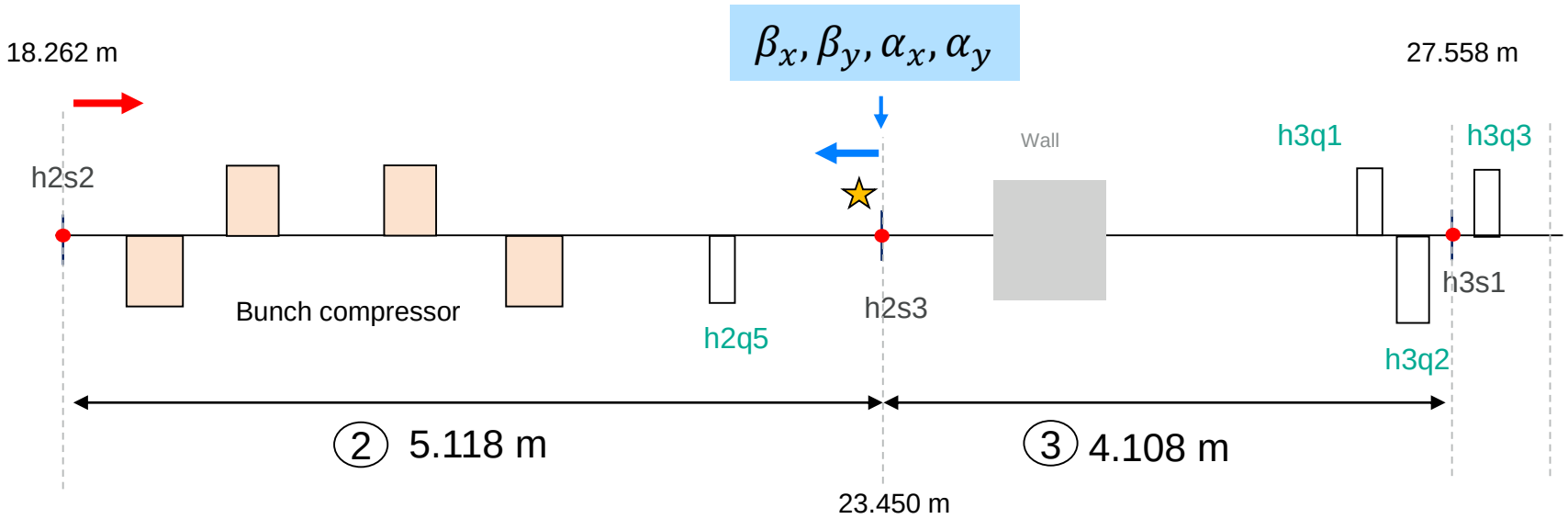




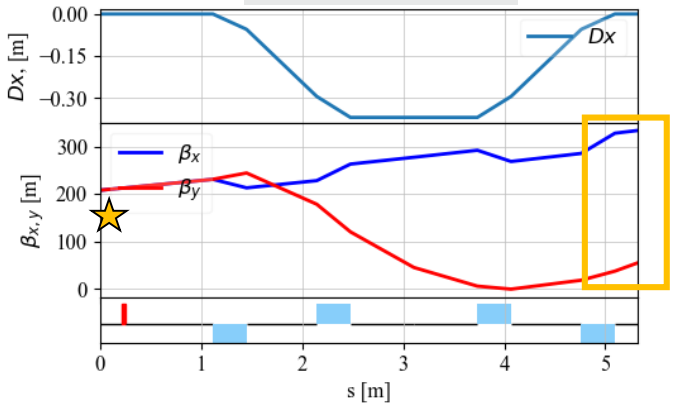


Beam matching to BC using OCELOT

Lattice for BC



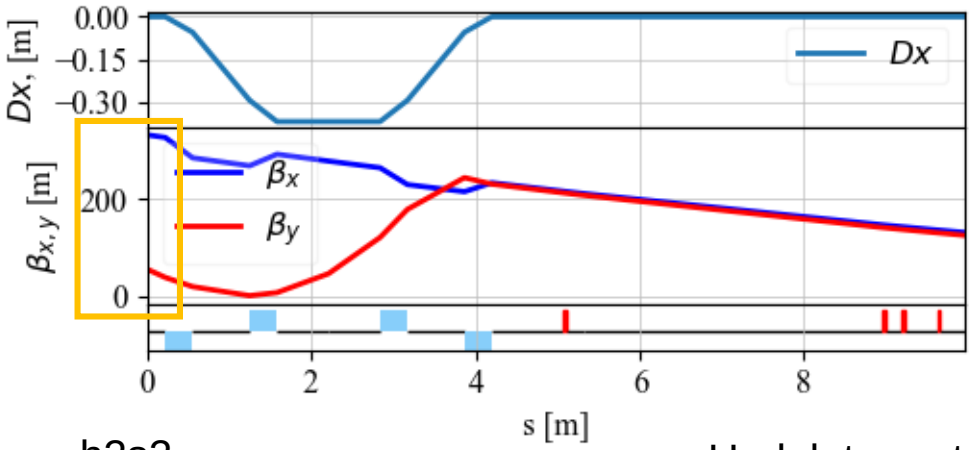
Invert the lattice



h2s3 h2s2

$\beta_x, \beta_y, \alpha_x, \alpha_y$

Invert alphas
+
Invert lattice!!



h2s2 Undulator entrance

Beam matching to BC using OCELOT

Beam dynamics simulation

Input beam properties

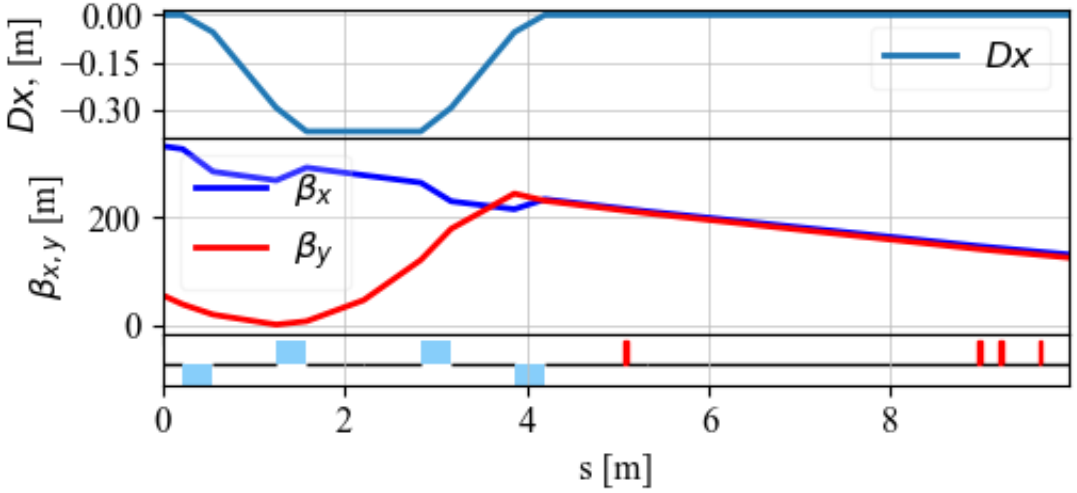
Meam momentum : 17 MeV/c

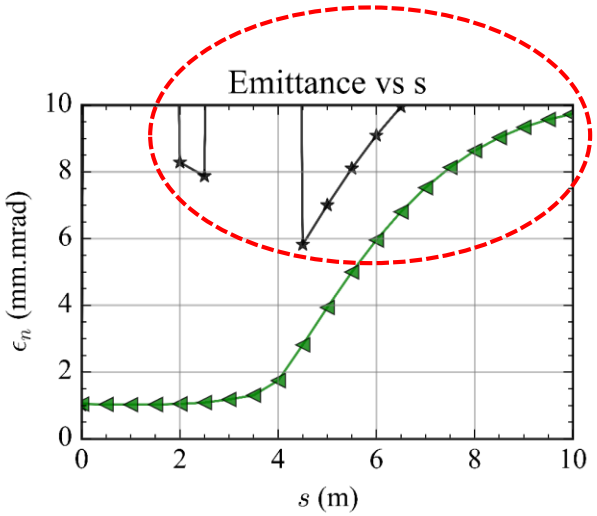
Phase : -20 deg. w.r.t. MMMG ~ 0.6%

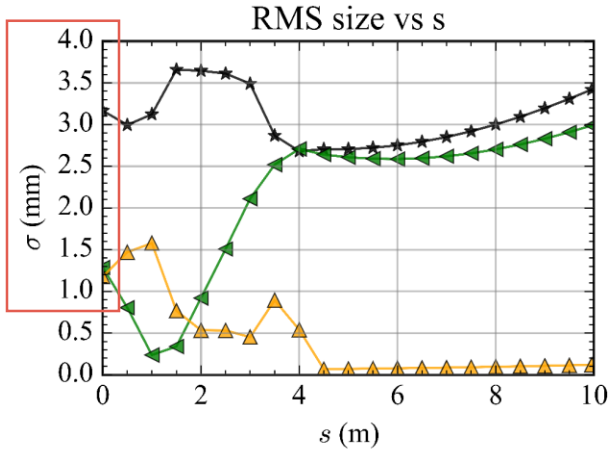
energy spread

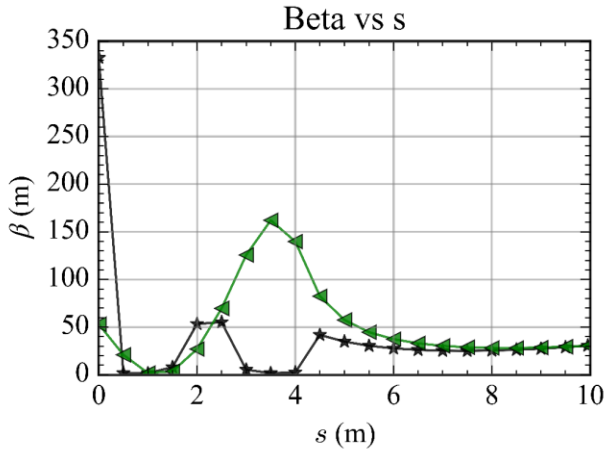
Bunch charge : 250 pC

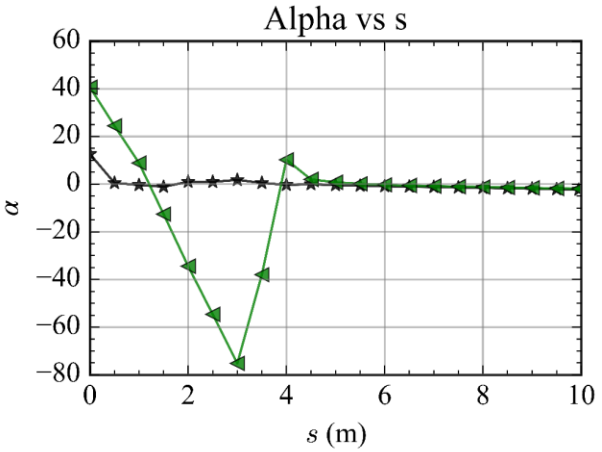
Norm. emittance : 1 mm.mrad











Beam matching to BC using OCELOT

Beam dynamics simulation

Input beam properties

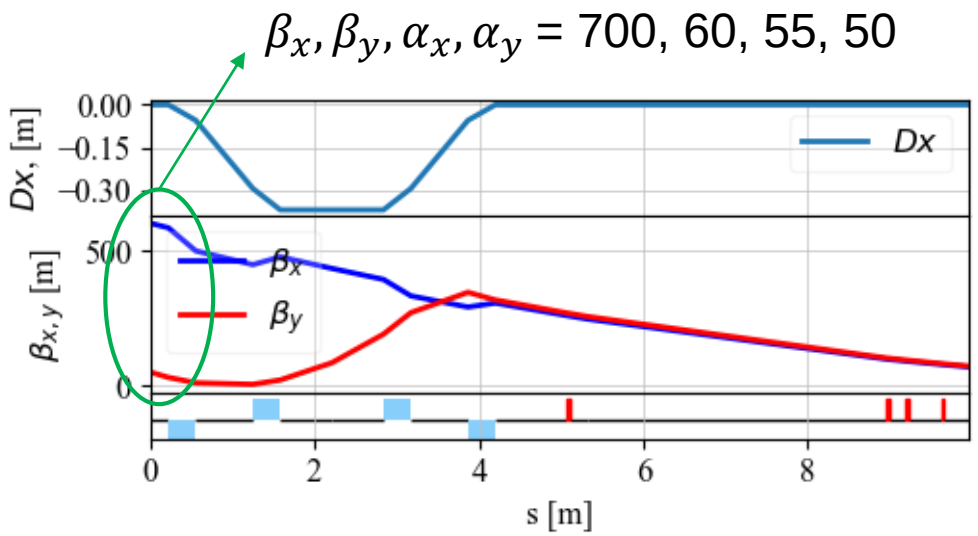
Meam momentum : 17 MeV/c

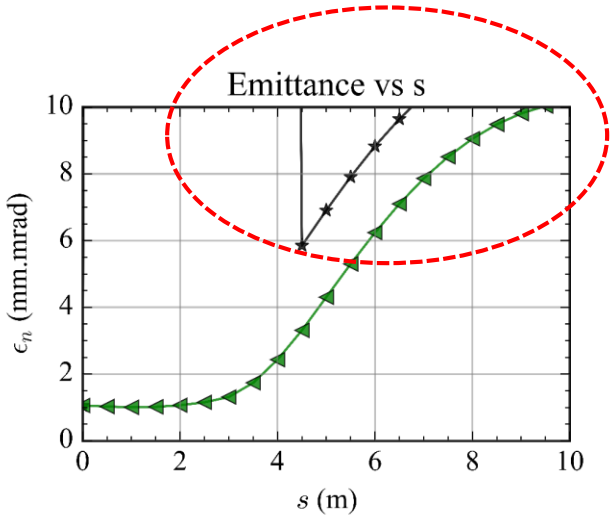
Phase : -20 deg. w.r.t. MMMG ~ 0.6%

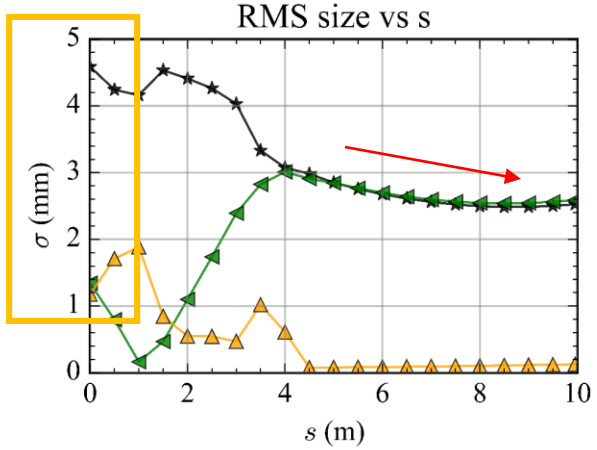
energy spread

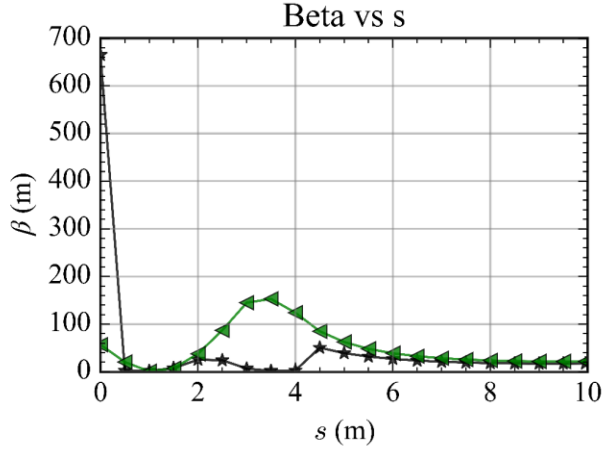
Bunch charge : 250 pC

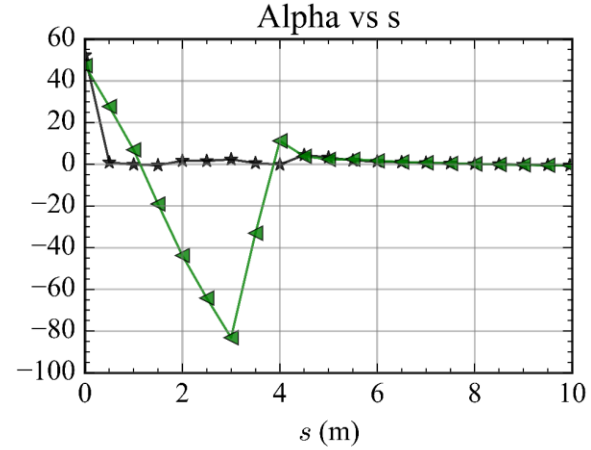
Norm. emittance : 1 mm.mrad



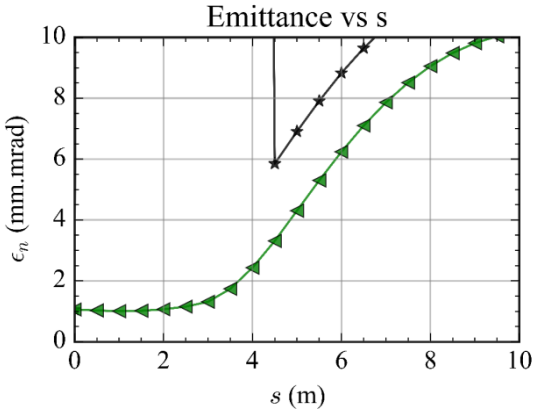


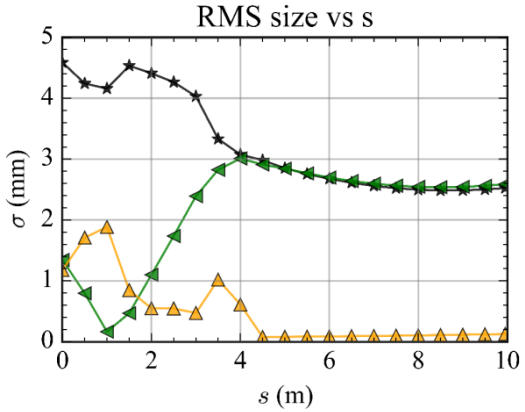


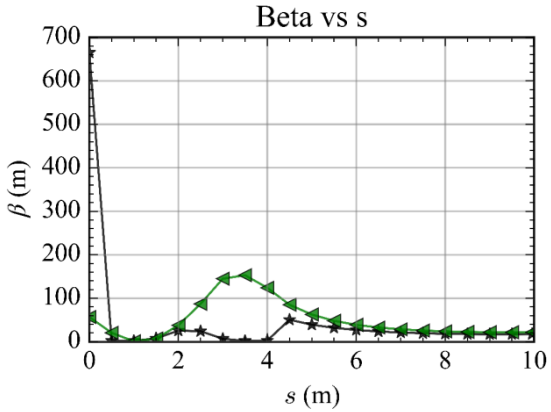


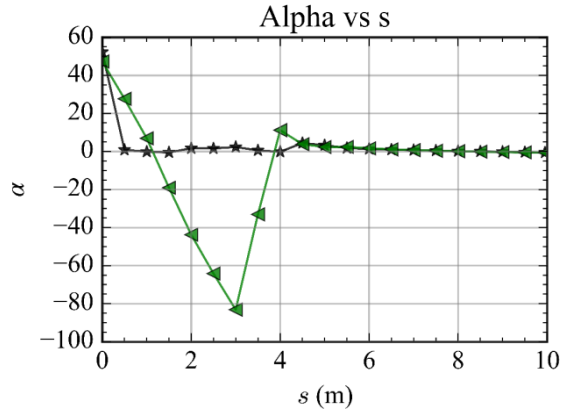


Conclusion and Outlook









Requirements beam properties (in this procedure)

- Beam must be focused from h2s3 to h3s1

Difficulty

- Emittance x and y are increasing after BC, which is the main issue of increasing the transverse beam size.

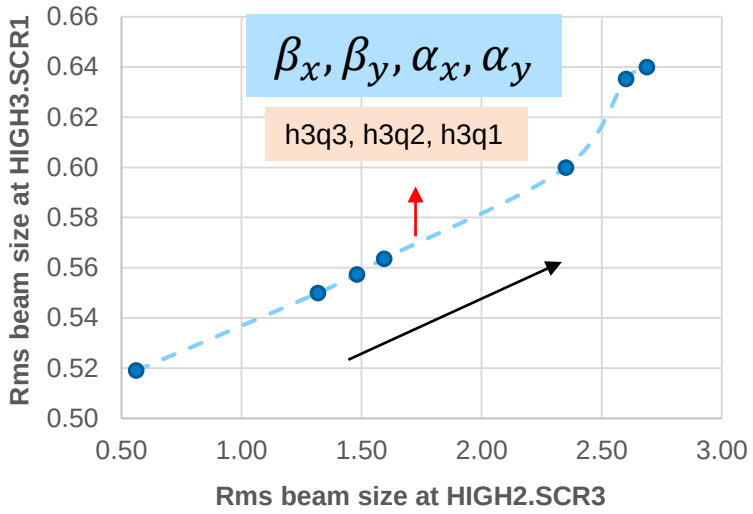
How to dealing with the problem!

- Increasing Twiss-parameters ($\beta_x, \beta_y, \alpha_x, \alpha_y$) before BC at h2s2
  - **Issue** → Can't match the beam to provide the desired beam properties at h2s2.
- Finding the new matching parameters from undulator entrance
  - Increasing transverse emittance

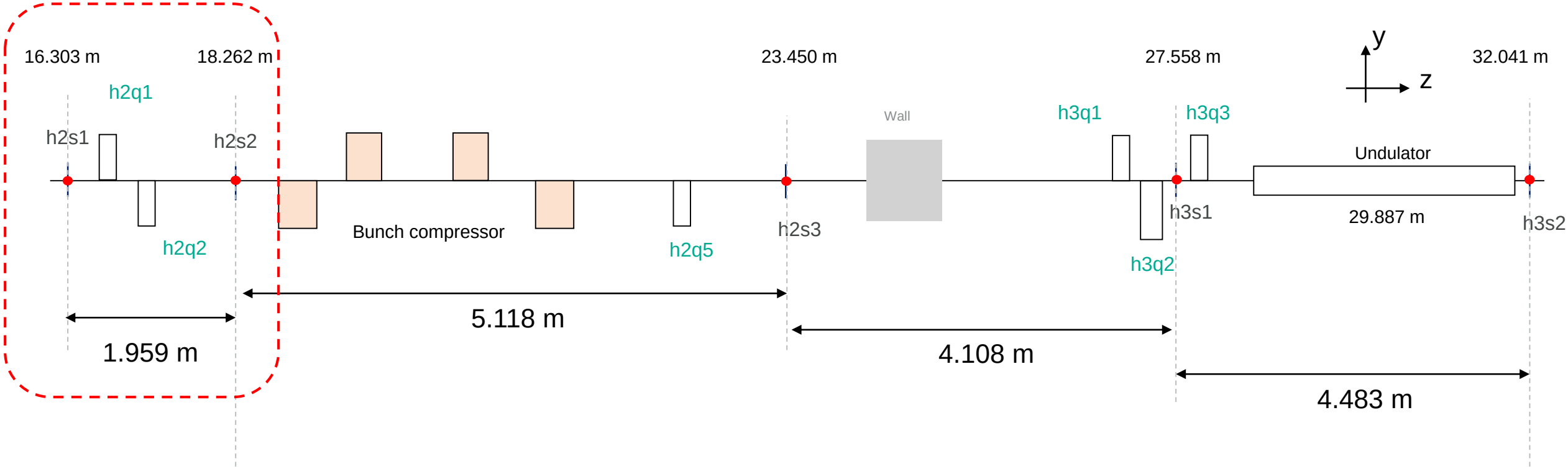
More option

- Relaxing the compression after BC

Conclusion and Outlook



← Match beam between h2s2 and h2s1



Thank you for your attention