



Project Progress Review (PPR) 8-2026

WP- 02

Présenté par: A. Fomin

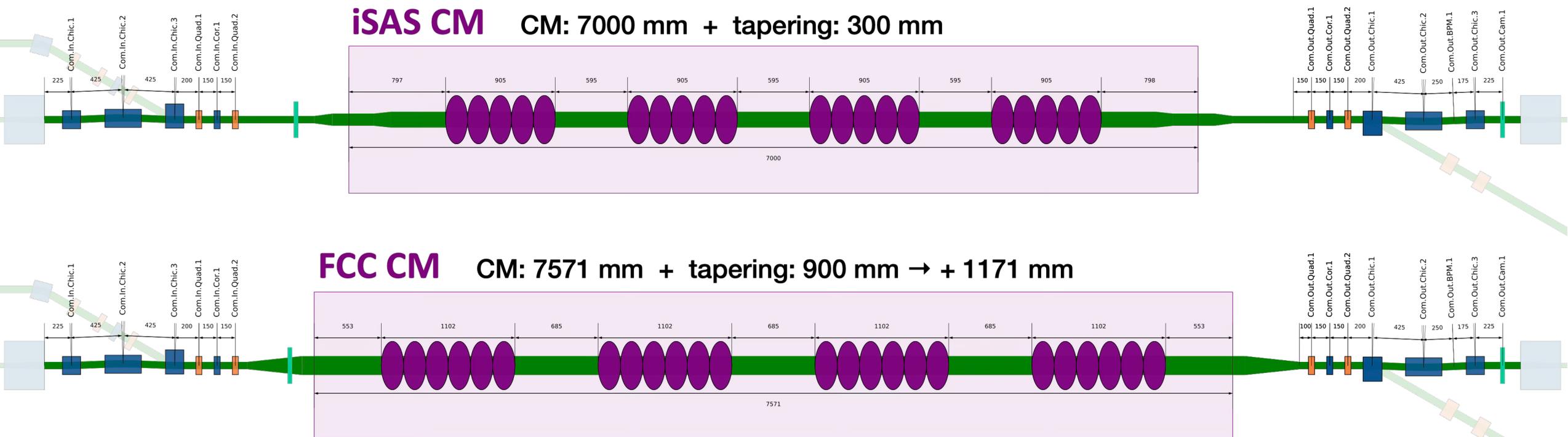
R. Abukeshek, F. Bouly, A. Cieplak, A. Fomin, J. Issa, J. Michaud, C. Monaghan, L. Perrot, S. Wallon

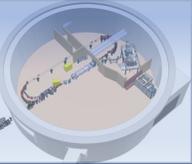
19 Mars 2026



- FCC upgrade requirements :

- Extra space for a longer cryomodule → **+571mm** of Common Section (between BComs)
- Beam pipe diameter is 157mm (iSAS 100mm) → **+600mm** of extra tapering (preliminary, **impedance studies needed**)
- ICT+BPM+Cam implemented inside tapering area → safe some space





- FCC upgrade requirements :

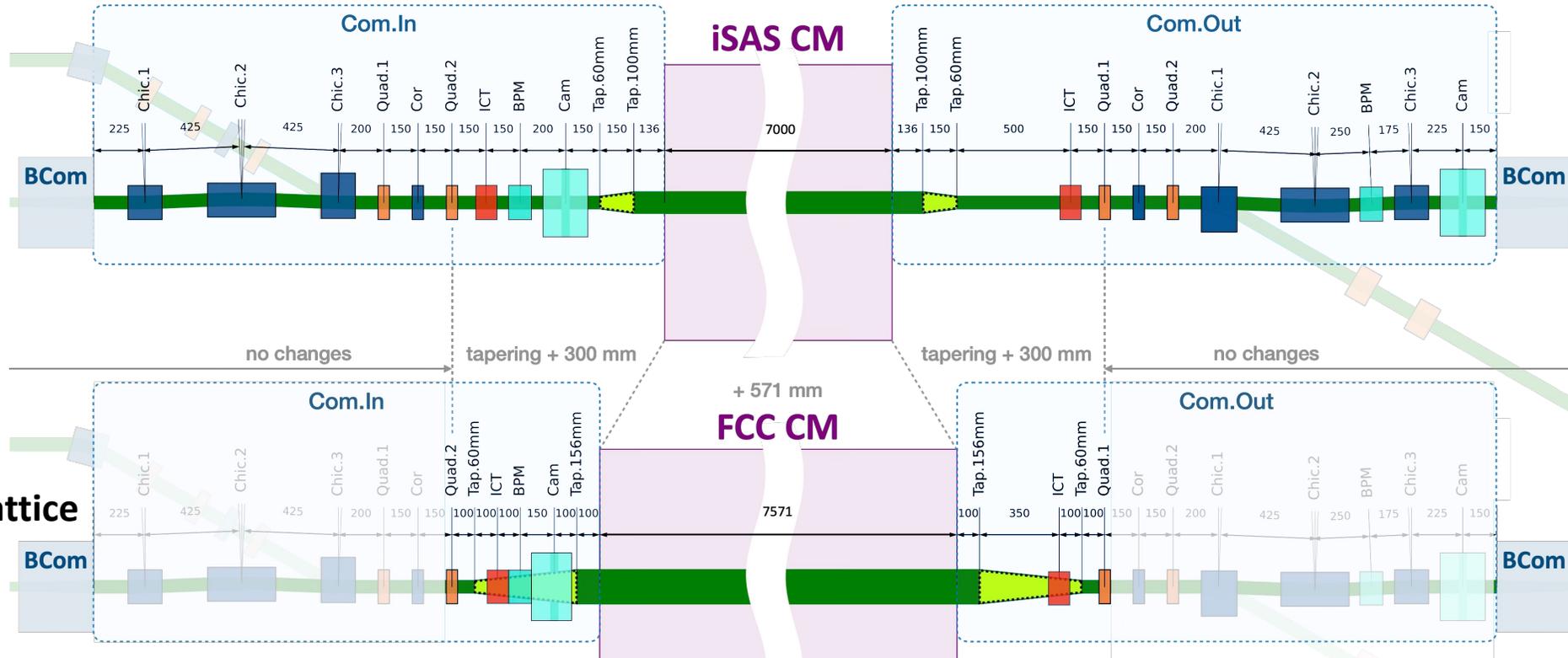
- Extra space for a longer cryomodule → +571mm of Common Section (between BComs)
- Beam pipe diameter is 157mm (iSAS 100mm) → +600mm of extra tapering (preliminary, impedance studies needed)
- **ICT+BPM+Cam implemented inside tapering area** → **-600mm**

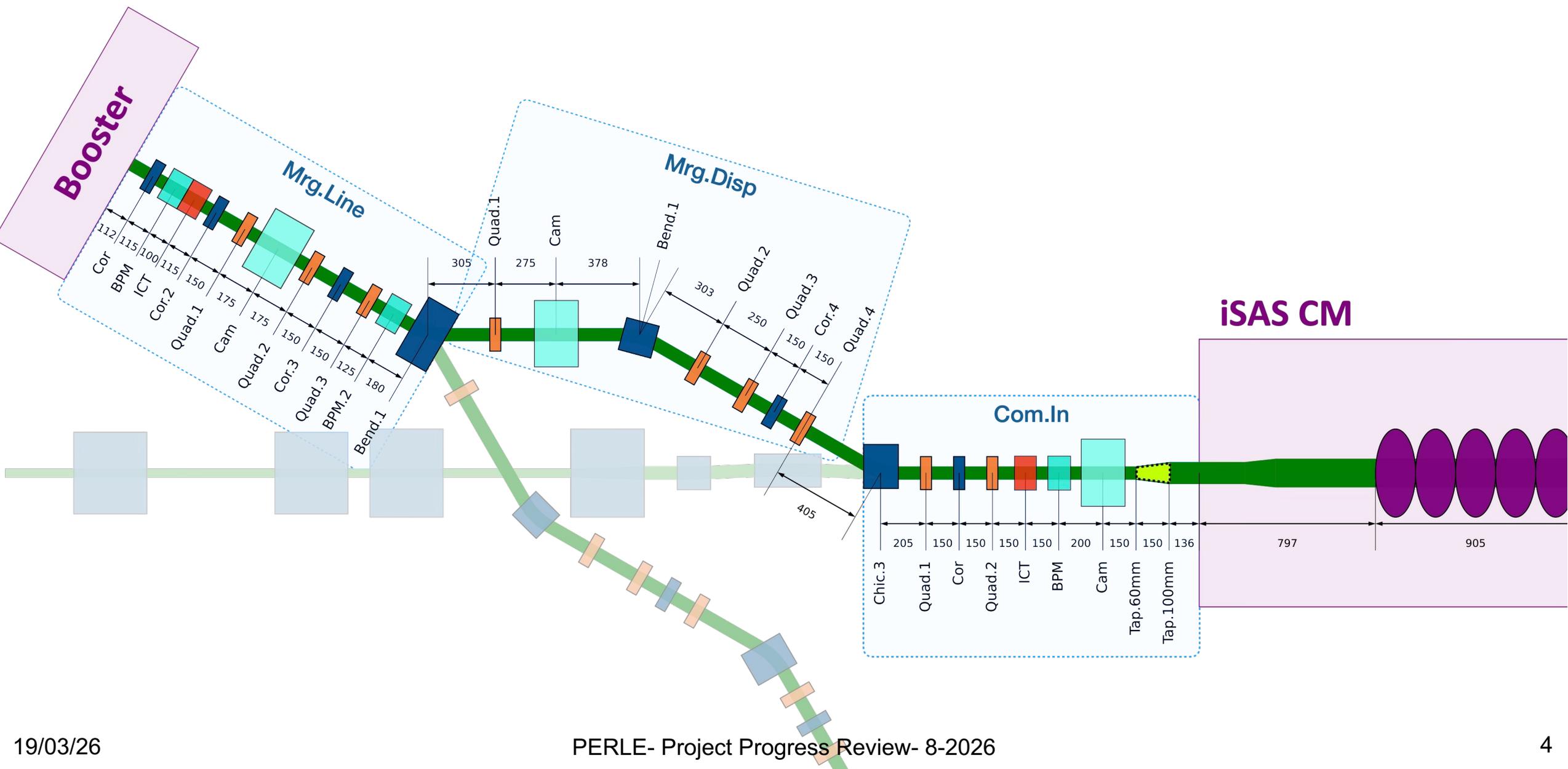
- Beam diagnostics:

- **2 ICTs** – transmission in CM
- **2 (BMP+Camera)** in front of CM and Bcom
- Q-scan simulated at 7 MeV checked at 89 MeV

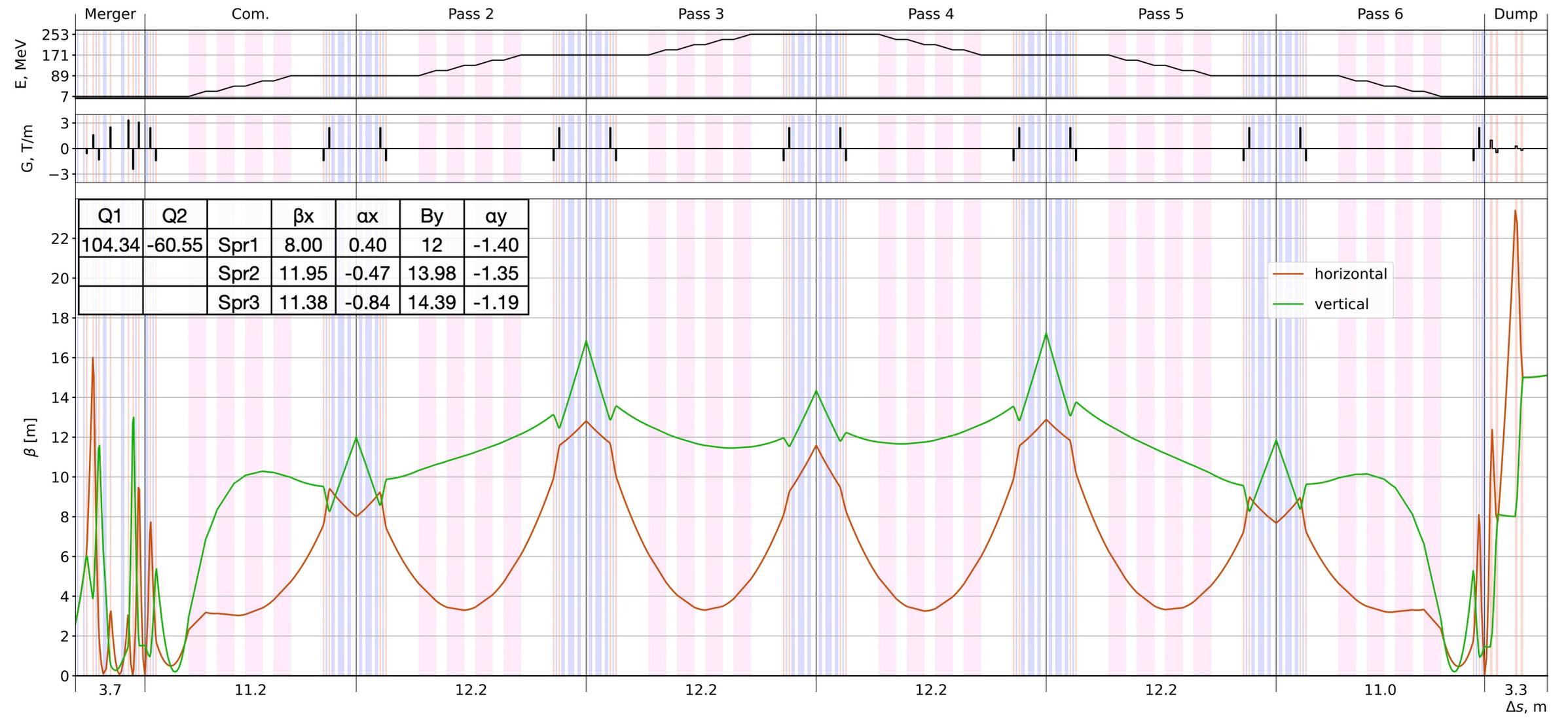
- FCC upgrade

- **No changes to the main lattice**
- Only diag next to CM

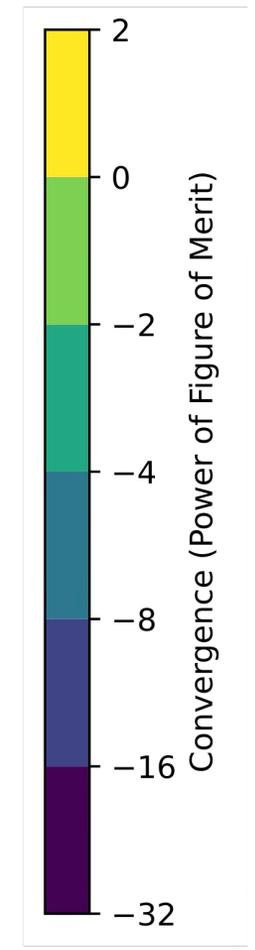
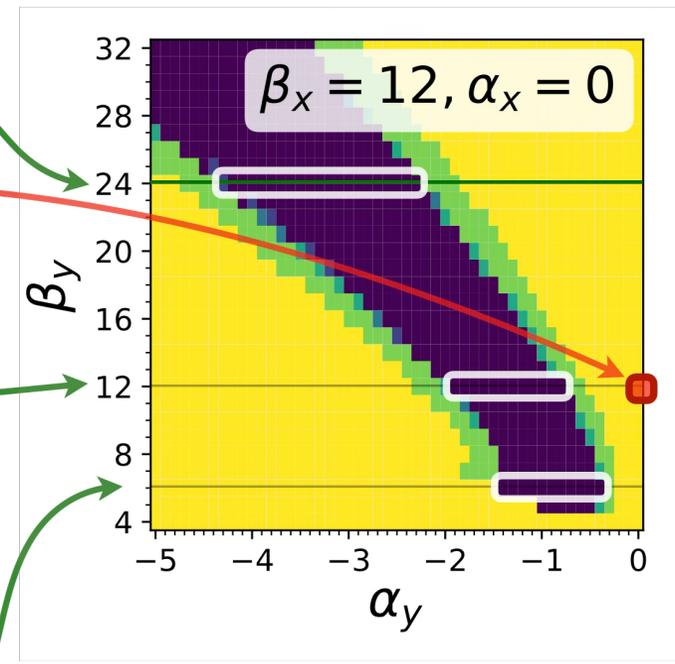
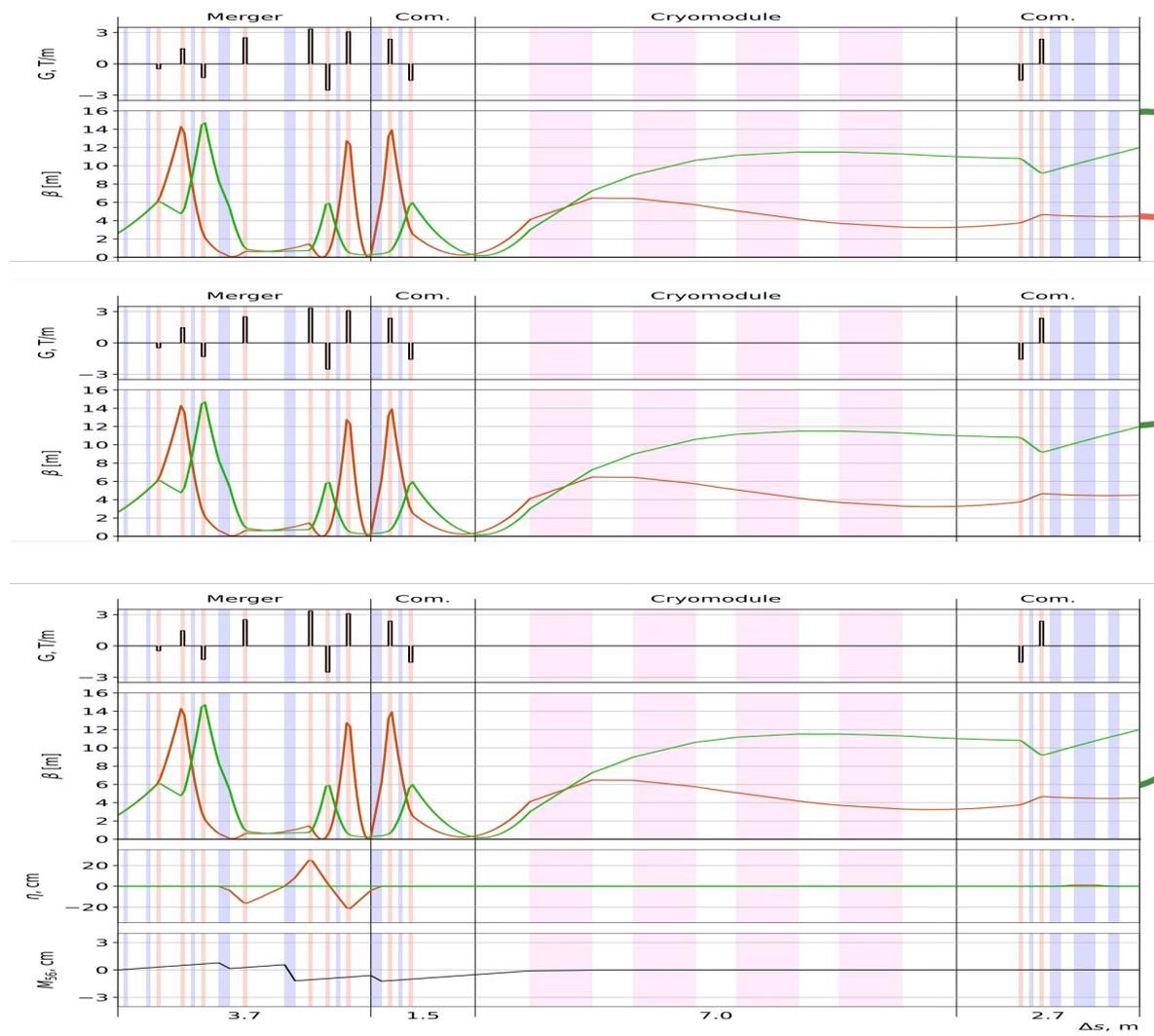




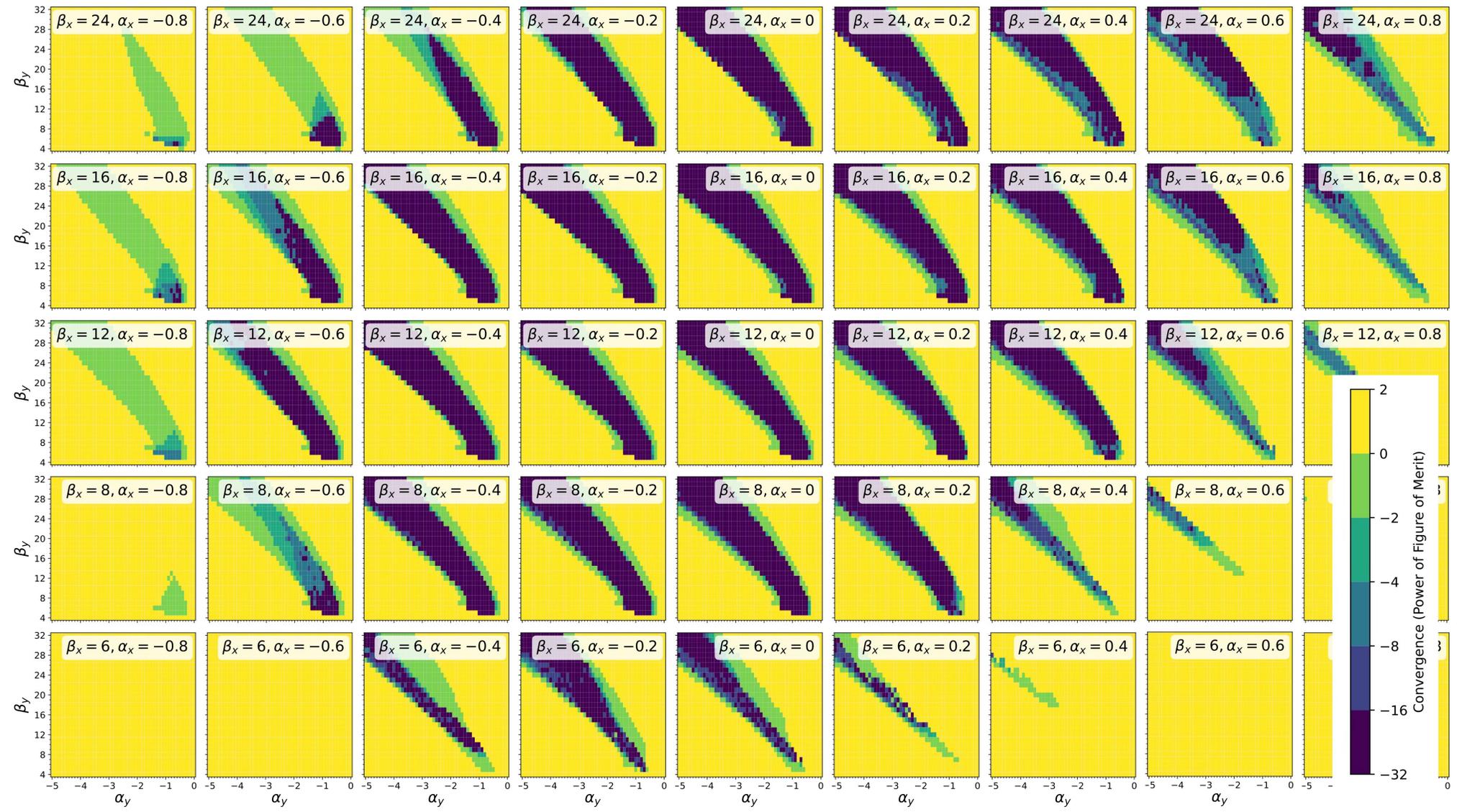
Three Turns Tuning



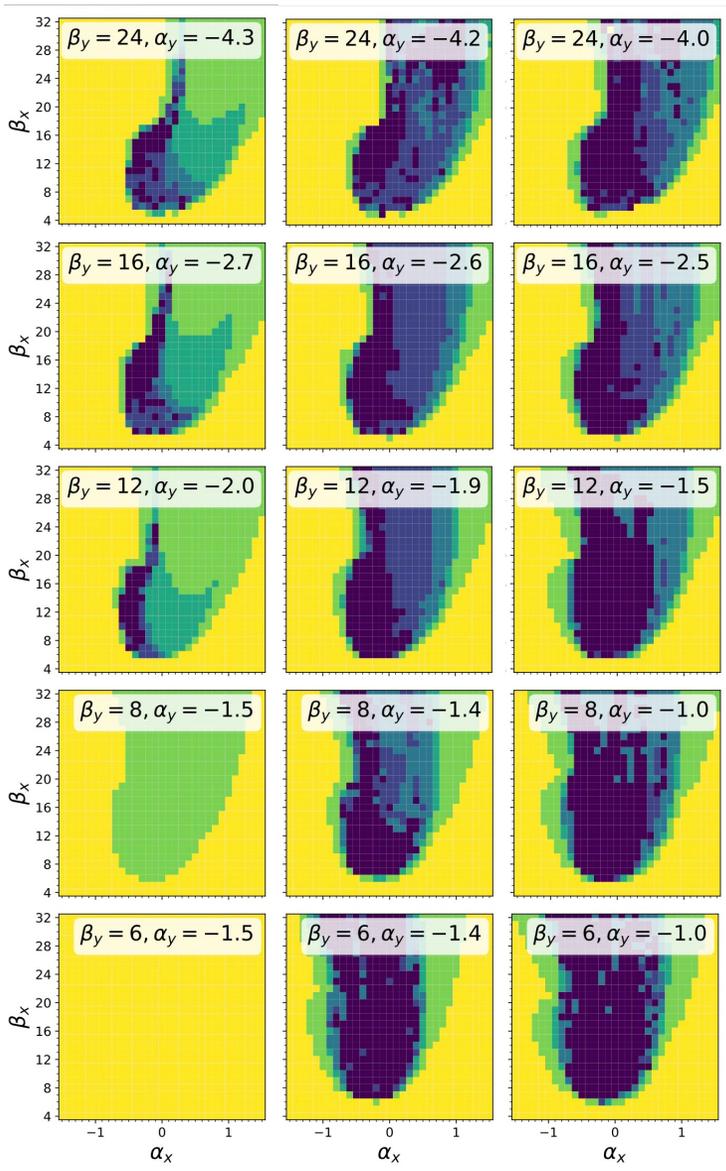
Three Turns Tuning



Three Turns Tuning



Three Turns Tuning



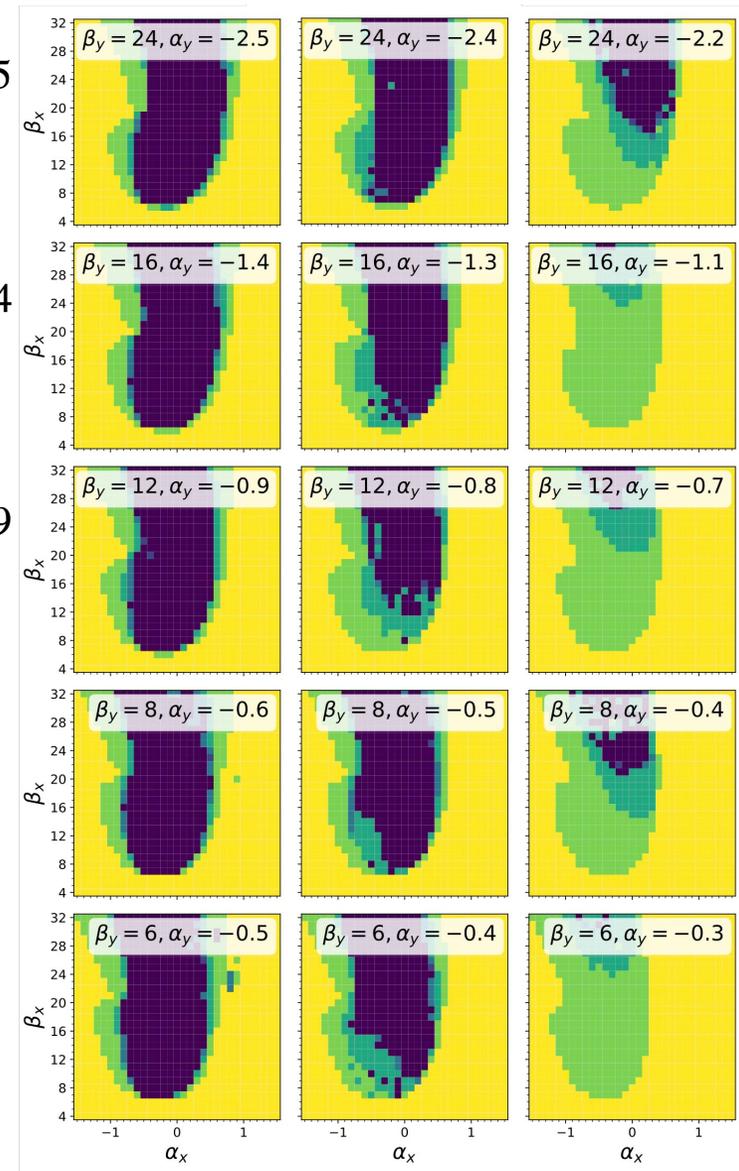
$\beta_y = 24 \text{ m} \quad -4.2 < \alpha_y < -2.5$

$\beta_y = 16 \text{ m} \quad -2.6 < \alpha_y < -1.4$

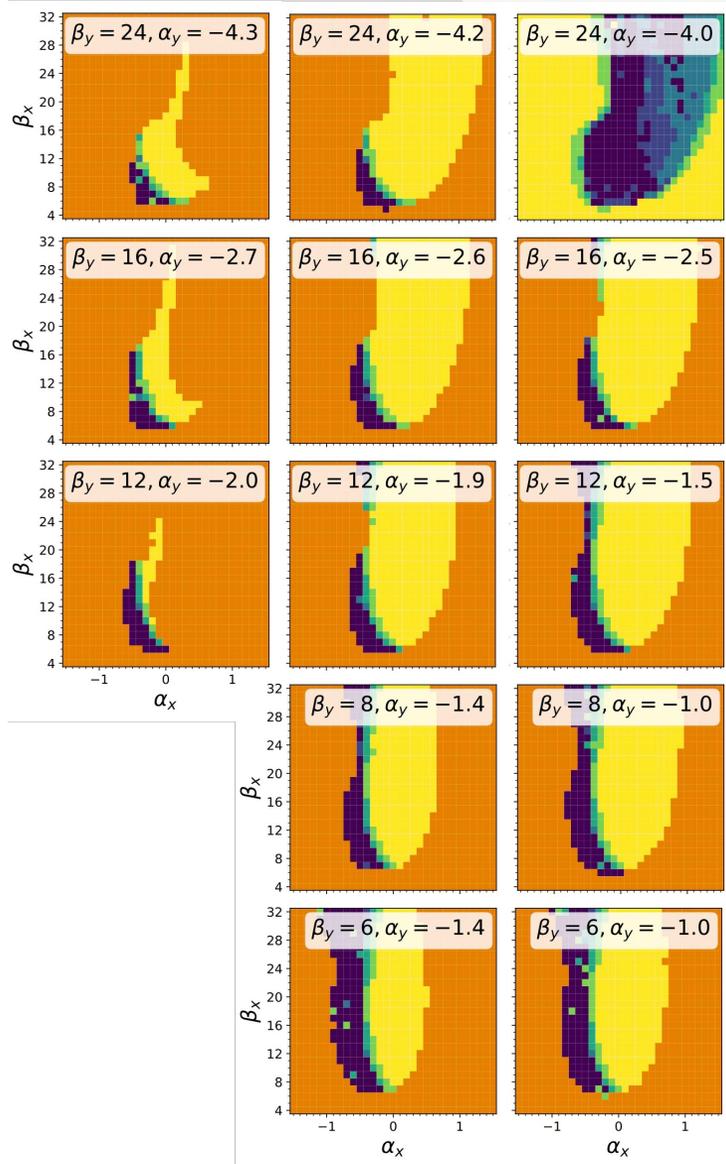
$\beta_y = 12 \text{ m} \quad -1.9 < \alpha_y < -0.9$

$\beta_y = 8 \text{ m} \quad -1.4 < \alpha_y < -0.6$

$\beta_y = 6 \text{ m} \quad -1.4 < \alpha_y < -0.5$



Three Turns Tuning



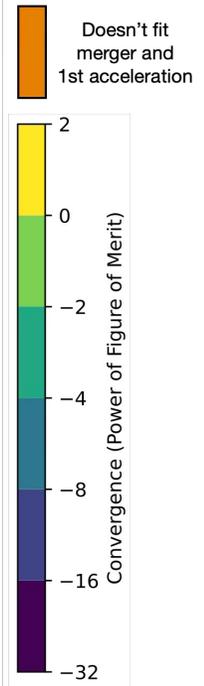
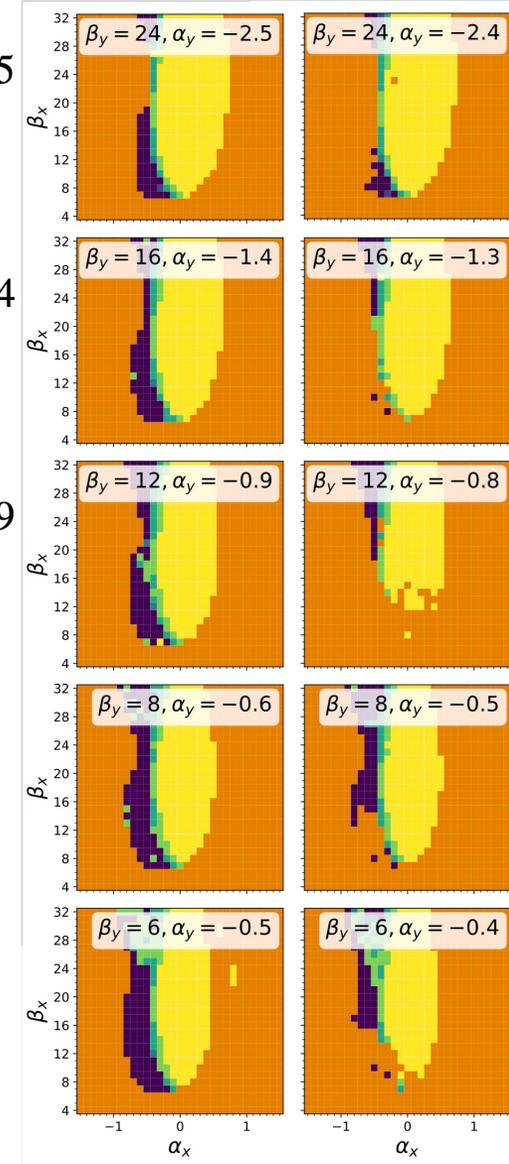
$\beta_y = 24 \text{ m} \quad -4.2 < \alpha_y < -2.5$

$\beta_y = 16 \text{ m} \quad -2.7 < \alpha_y < -1.4$

$\beta_y = 12 \text{ m} \quad -2.0 < \alpha_y < -0.9$

$\beta_y = 8 \text{ m} \quad -1.4 < \alpha_y < -0.6$

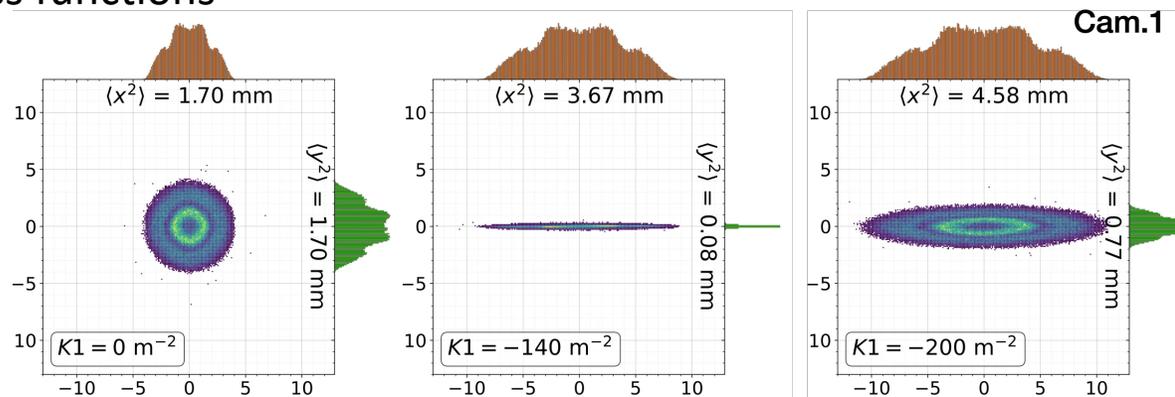
$\beta_y = 6 \text{ m} \quad -1.4 < \alpha_y < -0.5$





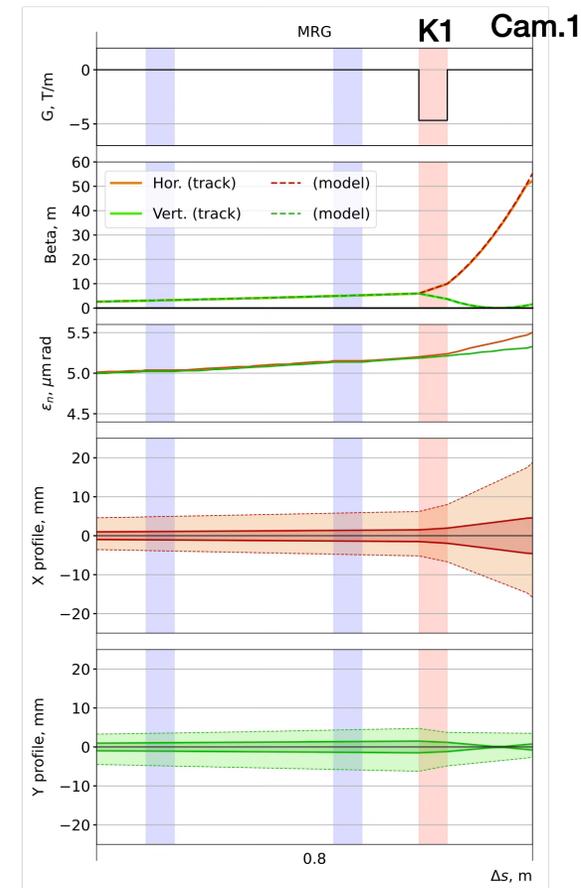
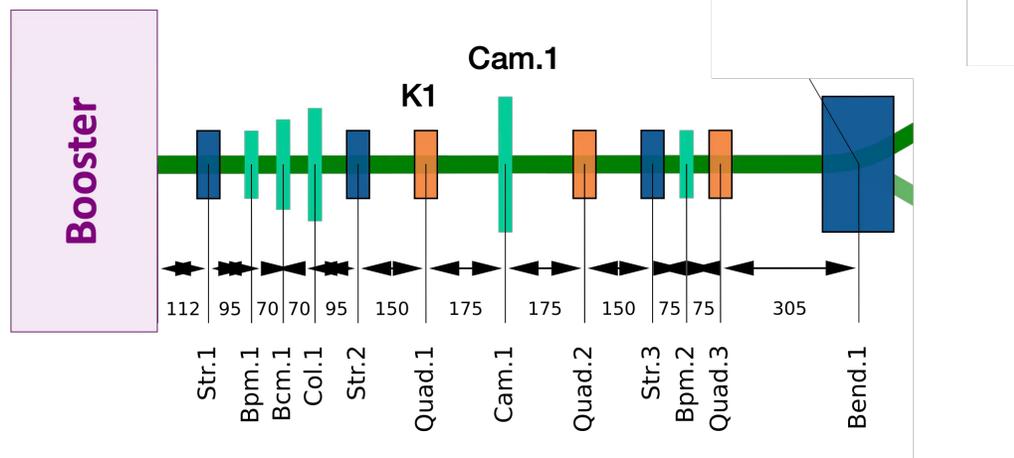
- Purpose :

- Measure emittance and twiss functions
- Beam alignment
- BPM calibration



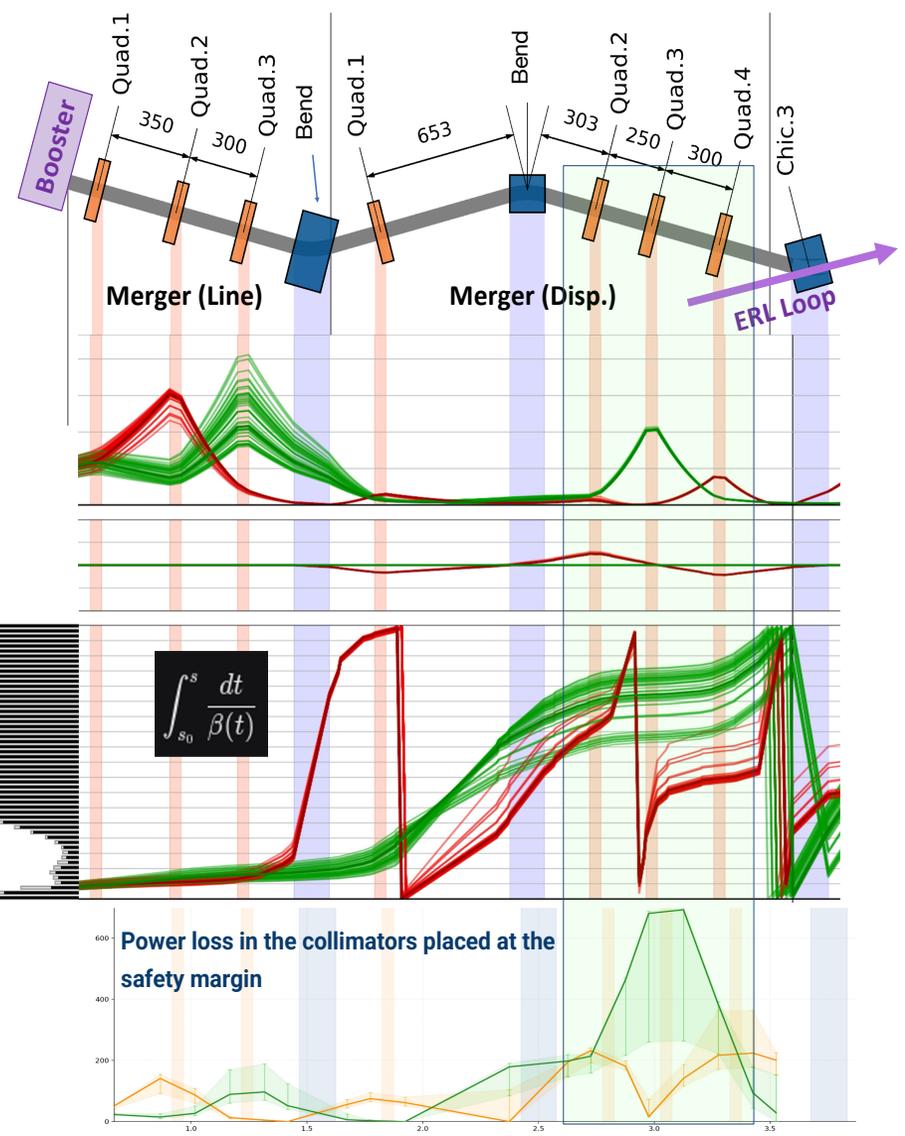
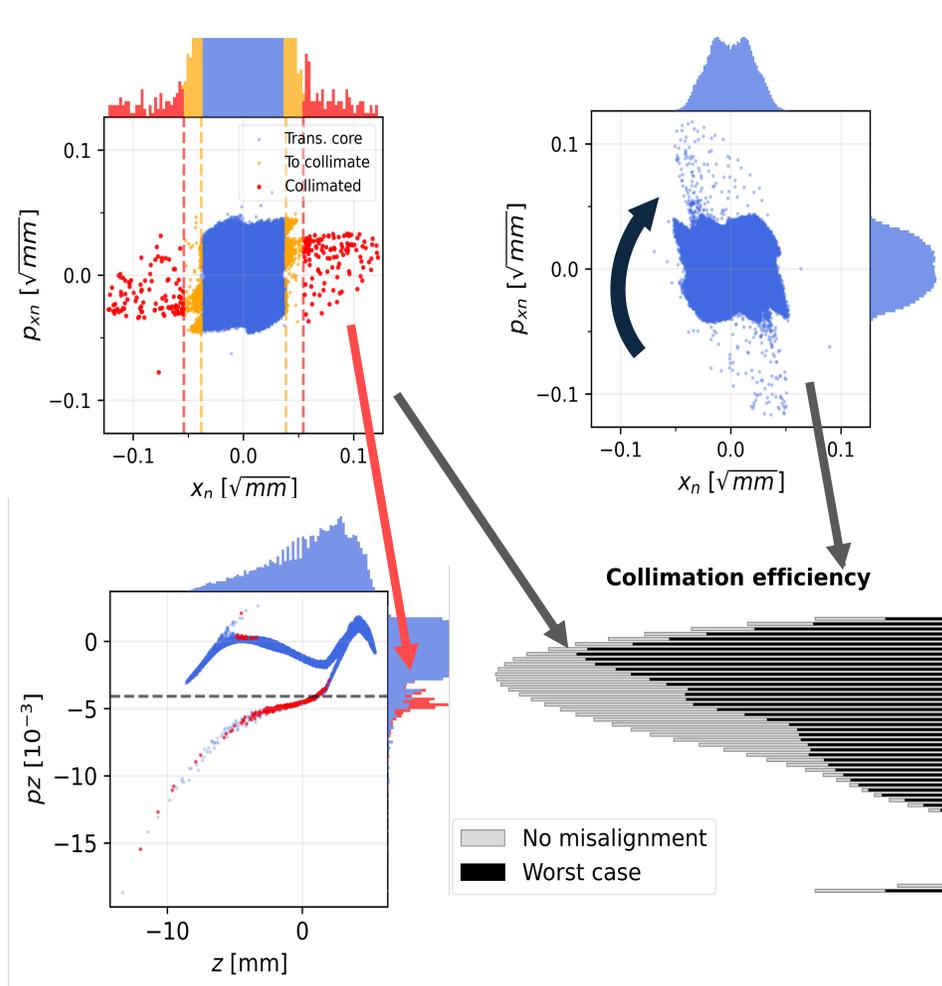
- Requirements :

- Distance from Q1 $\gtrsim 175$ mm
- Q1 gradient ~ 6 T/m
- Screen size 40mm
- Resolution ~ 50 μ m
- Checked with 50% larger β

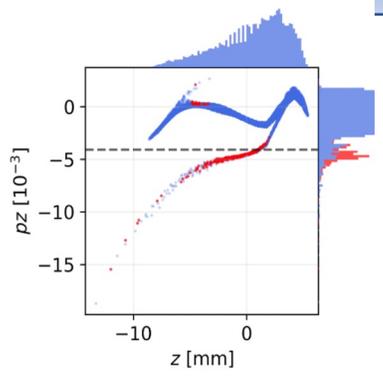




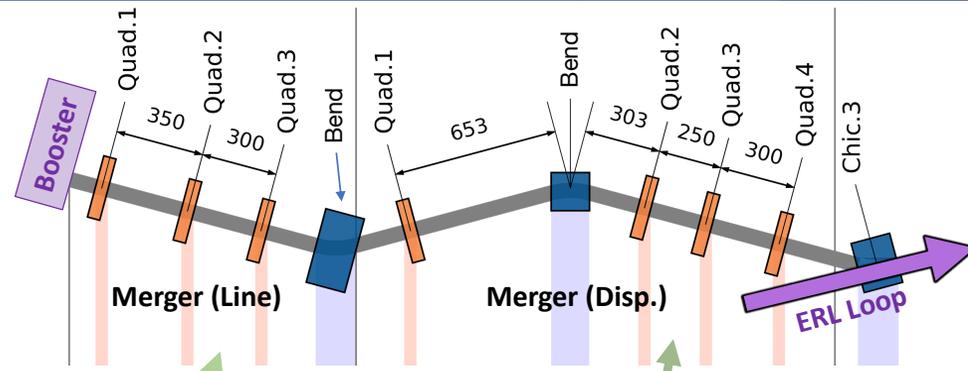
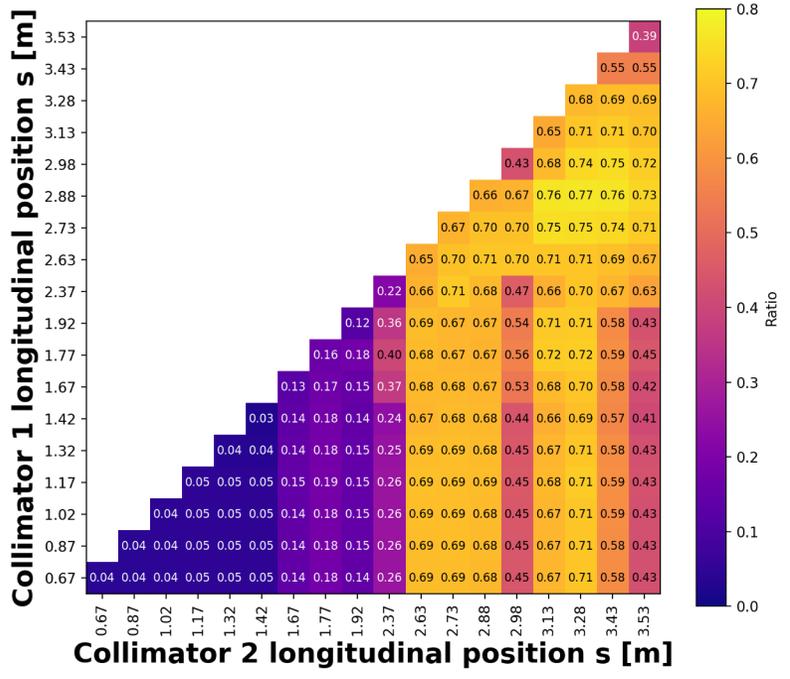
- Initial 6D distribution [OPAL] + **misalignments** in Booster
- Collimation **limit** is 1kW on each collimator (**orange**)
- Collimation with a safety **margin: 0.5mm** offset of collimator jaw (**red**)
- Collimation efficiency as a function of the **phase advance**
- Correlation between **transverse and longitudinal halo**



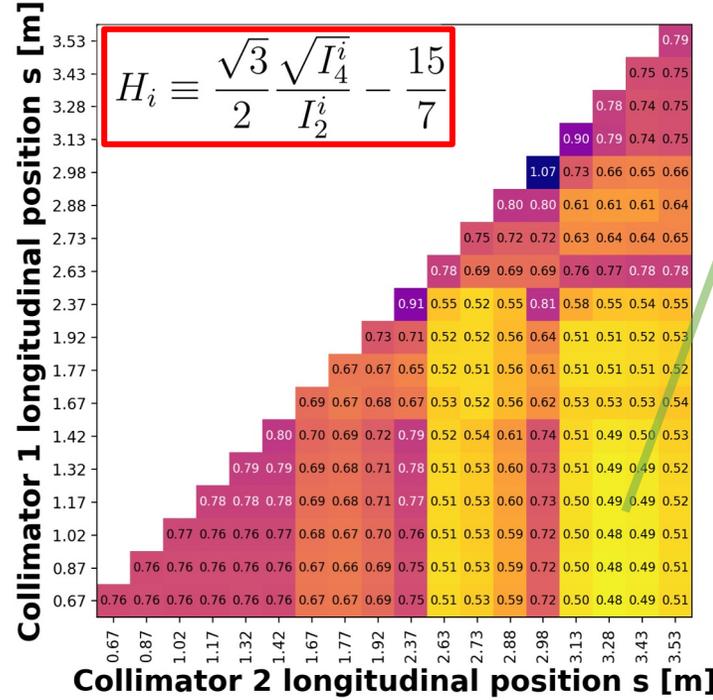
Merger. Collimation



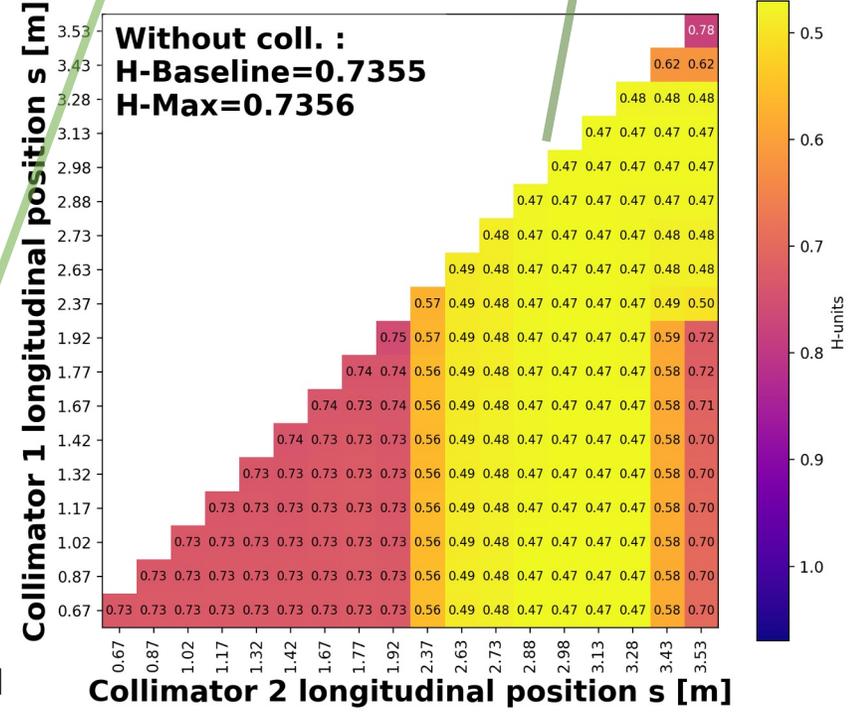
Longitudinal cleaning efficiency
Red/Blue ($p_z < p_{z_min}$)



Halo-factor (hor. plane)



Halo-factor (vert. plane)





Objective: Construct the *longitudinal response matrix* M of PERLE to RF errors, to understand how RF related perturbations propagate to some beam dynamics parameters:

- Pass 1 (P1)
- Pass 2 (P2)
- Interaction point(s)
- End of machine

$$y = \begin{bmatrix} (\Delta E/E)_{PASS1} \\ \phi_{PASS1} \\ (\Delta\sigma_z/\sigma_z)_{PASS1} \\ (\Delta\sigma_\delta/\sigma_\delta)_{PASS1} \\ \varepsilon_{x,PASS1} \\ \varepsilon_{y,PASS1} \\ \text{ParticleLosses}_{PASS1} \\ (\Delta E/E)_{PASS2} \\ \phi_{PASS2} \\ (\Delta\sigma_z/\sigma_z)_{PASS2} \\ (\Delta\sigma_\delta/\sigma_\delta)_{PASS2} \\ \text{ParticleLosses}_{PASS2} \\ (\Delta E/E)_{END} \\ (\Delta\sigma_\delta/\sigma_\delta)_{END} \\ (\Delta\sigma_z/\sigma_z)_{IP1} \\ (\Delta\sigma_\delta/\sigma_\delta)_{IP2} \end{bmatrix}$$

Beam dynamic parameters

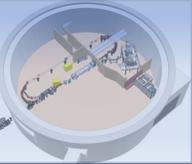
Sensitivity Matrix

$$y = M x$$

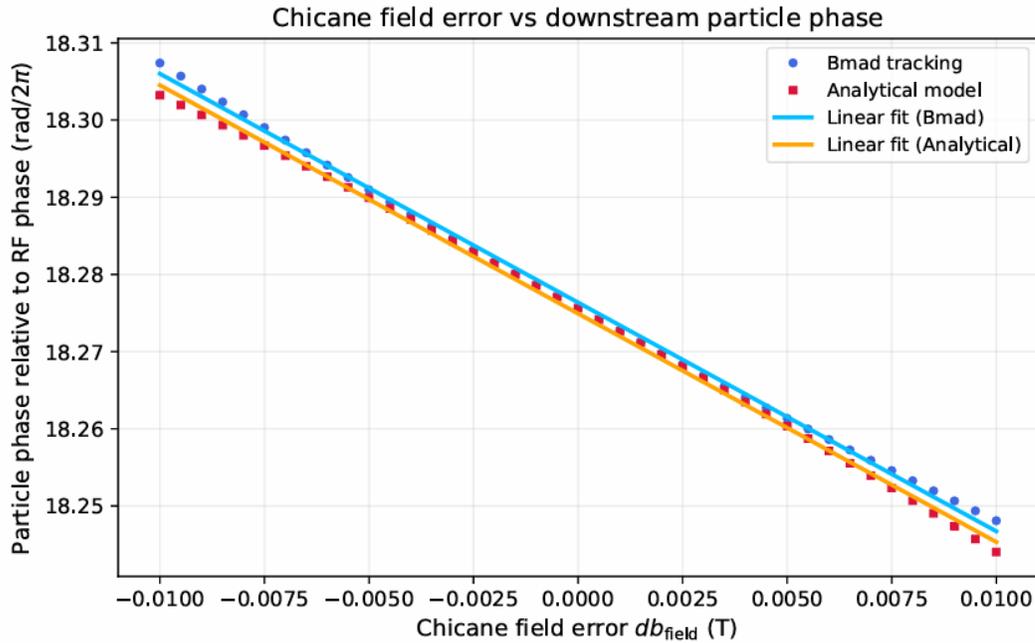
$$x = \begin{bmatrix} \phi_{Buncher} \\ \Delta V/V_{Buncher} \\ \phi_{Booster 1} \\ \Delta V/V_{Booster 1} \\ \phi_{Booster 2} \\ \Delta V/V_{Booster 2} \\ \phi_{Booster 3} \\ \Delta V/V_{Booster 3} \\ \phi_{Booster 4} \\ \Delta V/V_{Booster 4} \\ \phi_{Linac 1} \\ \Delta V/V_{Linac 1} \\ \phi_{Linac 2} \\ \Delta V/V_{Linac 2} \\ \phi_{Linac 3} \\ \Delta V/V_{Linac 3} \\ \phi_{Linac 4} \\ \Delta V/V_{Linac 4} \end{bmatrix}$$

RF knobs

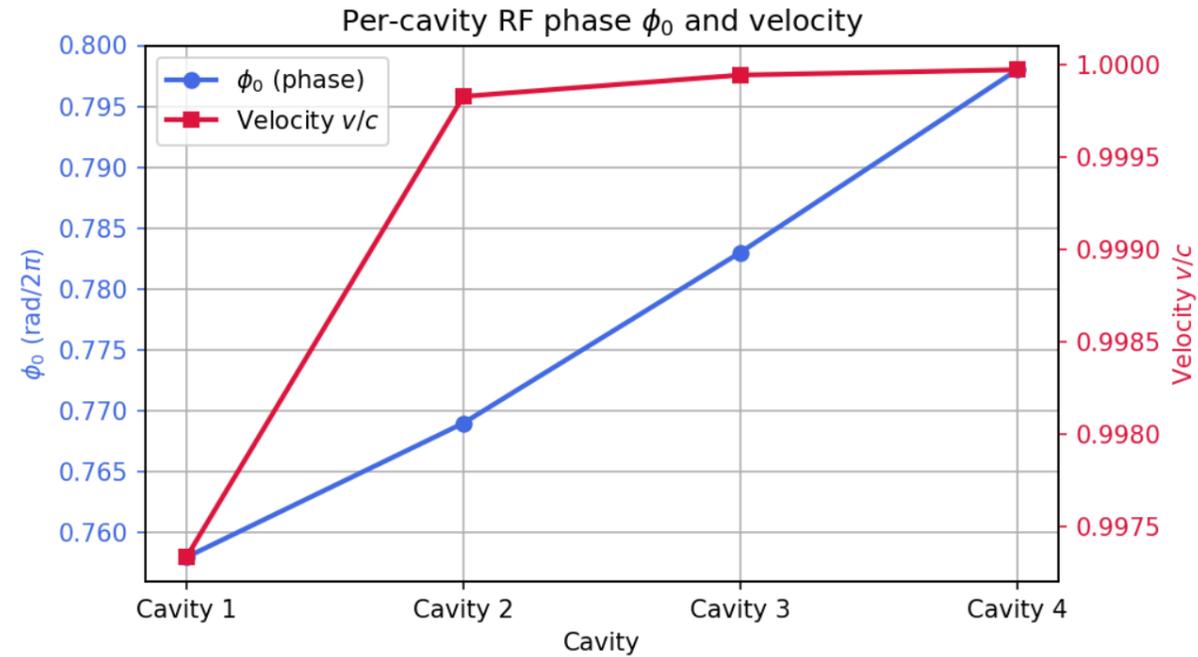
	ϕ_{Bun}	V_{Bun}					V_{B2}					V_{B4}	ϕ_{L1}	V_{L1}	ϕ_{L2}	V_{L2}	ϕ_{L3}	V_{L3}	ϕ_{L4}	V_{L4}	
E P1	0.0000	0.0000					0.0000					0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
phi P1	0.0000	0.0000					0.0000					0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
σ_z P1	0.0000	0.0000					0.0000					0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
σ_δ P1	0.0000	0.0000					0.0000					0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ε_x P1	0.0000	0.0000					0.0000					0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ε_y P1	0.0000	0.0000					0.0000					0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Loss P1	0.0000	0.0000					0.0000					0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
E P2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1225	0.2234	0.1229	0.2242	0.1229	0.2242	0.1229	0.2242	0.2242
phi P2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.2792	-0.8862	-0.3498	-1.0144	-0.3585	-1.0302	-0.3613	-1.0355	
σ_z P2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3701	1.1303	0.3015	1.0478	0.2927	1.0370	0.2898	1.0361	
σ_δ P2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-22.6457	0.4046	-22.7708	0.2632	-22.7781	0.2523	-22.7783	0.2505	
Loss P2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0200	0.0000	0.0200	0.0000	0.0200	0.0000	0.0200	
E END	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0781	-0.0821	-0.0798	-0.0843	-0.0798	-0.0844	-0.0783	-0.0830	
σ_z END	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-1.4532	-0.5409	-1.5167	-0.5868	-1.5212	-0.6171	-1.5371	-0.9292	
σ_δ END	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-10.5510	-3.9194	-10.6778	-4.2529	-10.6850	-4.2764	-10.6381	-4.1079	
σ_z IP1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.4185	0.0142	1.3477	0.0093	1.3390	0.0076	1.3362	0.0072	
σ_δ IP2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-22.6457	0.4046	-22.7708	0.2632	-22.7781	0.2523	-22.7783	0.2505	

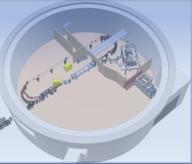


Chicane simulation
analytical model vs BMAD tracking



Optimize phases for maximum acceleration
(using absolute time tracking in BMAD)





Optimisation of longitudinal beam parameters at DESTIN (Single turn operation)

energy spread minimisation (green)

bunch length minimisation (blue)

Chirped initial distribution from the injector

+ R56 in the merger

+ Chirp in the cavities (compensated later by the chicane)

+ R56 in the arc and spreader (tuning quadrupoles)

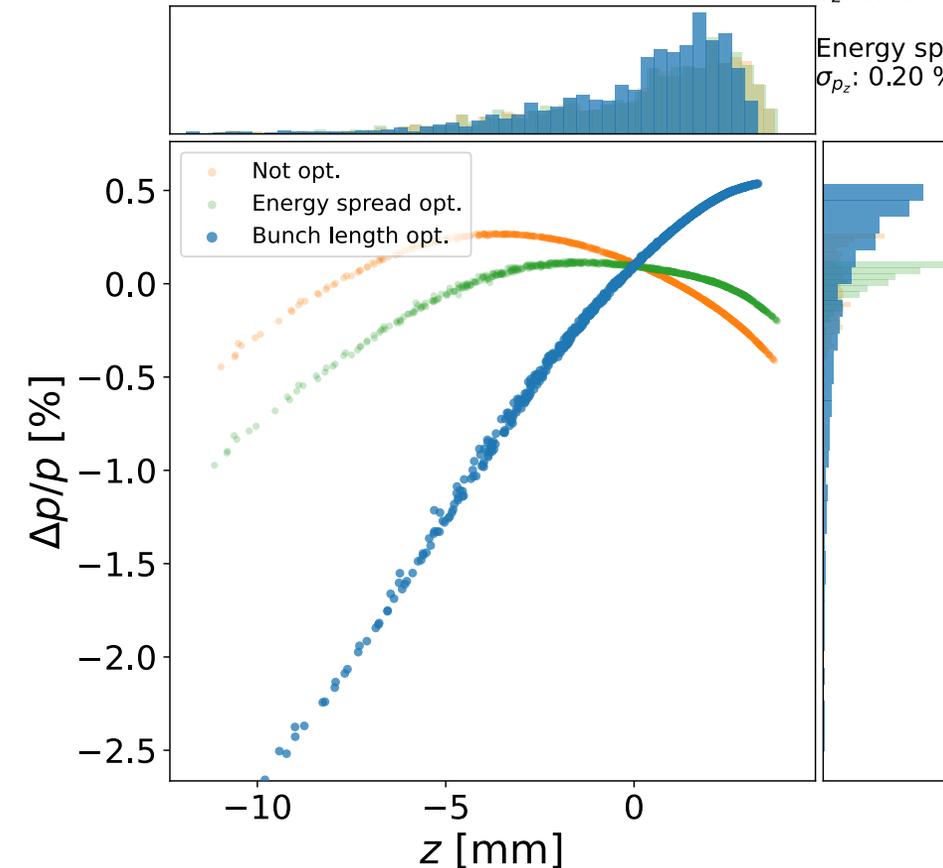
+ minimal losses,

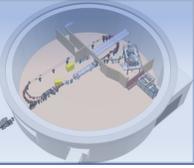
+ stable twiss parameters

Longitudinal phase space at IP2

Bunch length optimization:
 σ_z : 3.00 mm \rightarrow 2.72 mm

Energy spread optimization:
 σ_{p_z} : 0.20 % \rightarrow 0.17 %





- Review beam dynamics in September
 - List of invited reviewers
- IPAC 2026 :
 - A number of abstracts - posters
 - Talk
- Introduction cartes de champs pour simulations plus réalistes
 - RF cavities (more realistic simulation)
 - For dipoles and quadrupoles (halo studies)
- TDR : 30 pages/40
 - A compléter très bientôt avec les paramètres finaux de la machine 3-tours