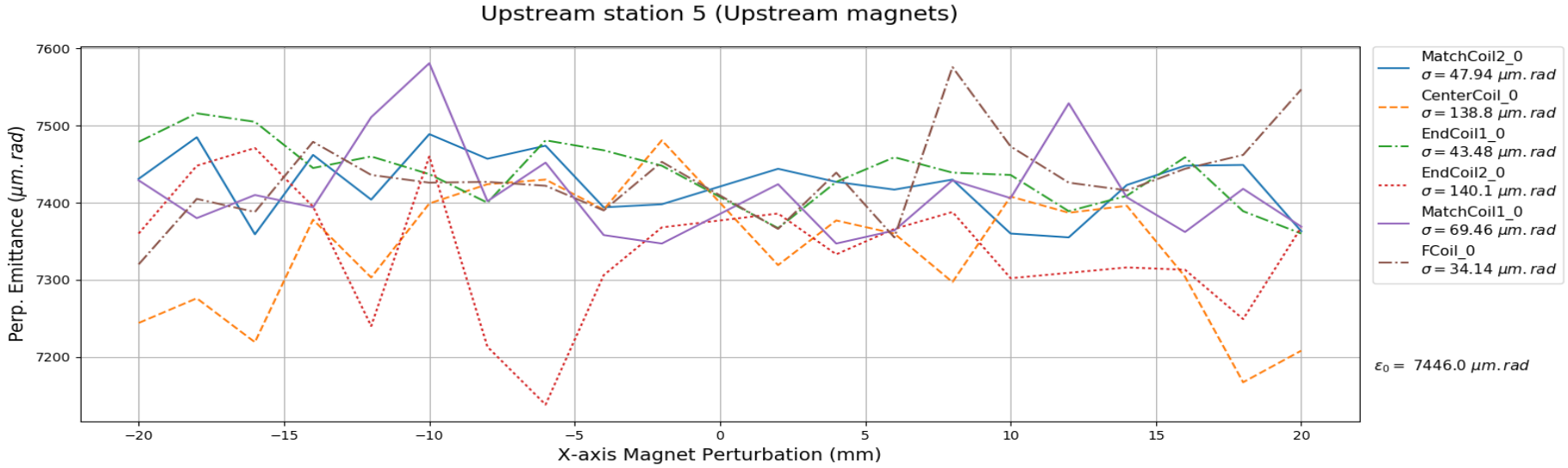
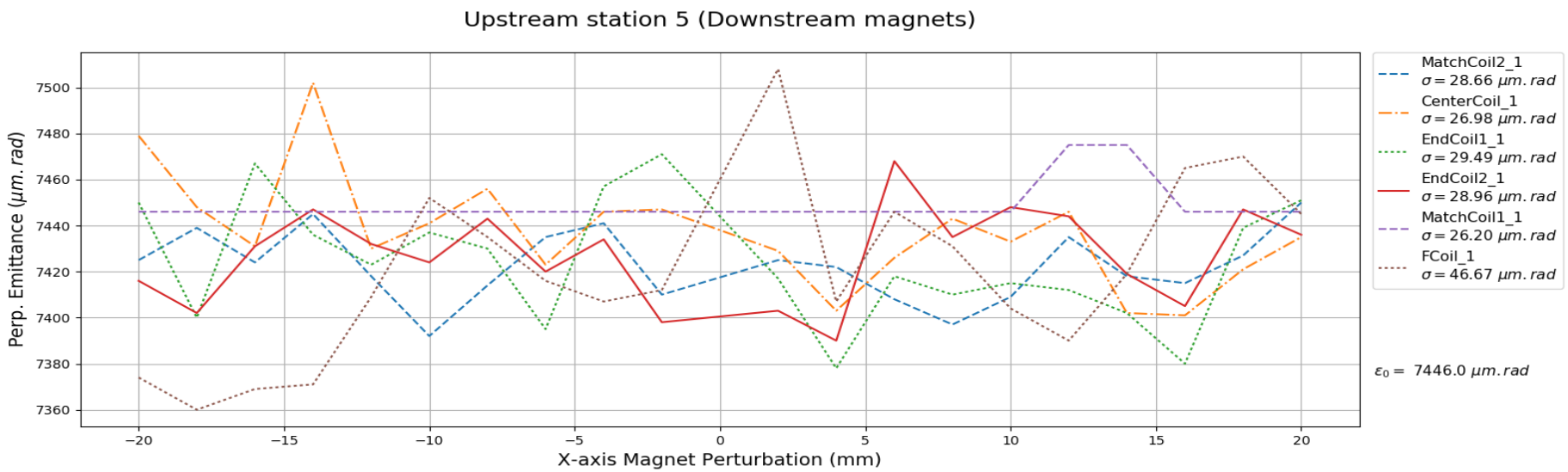
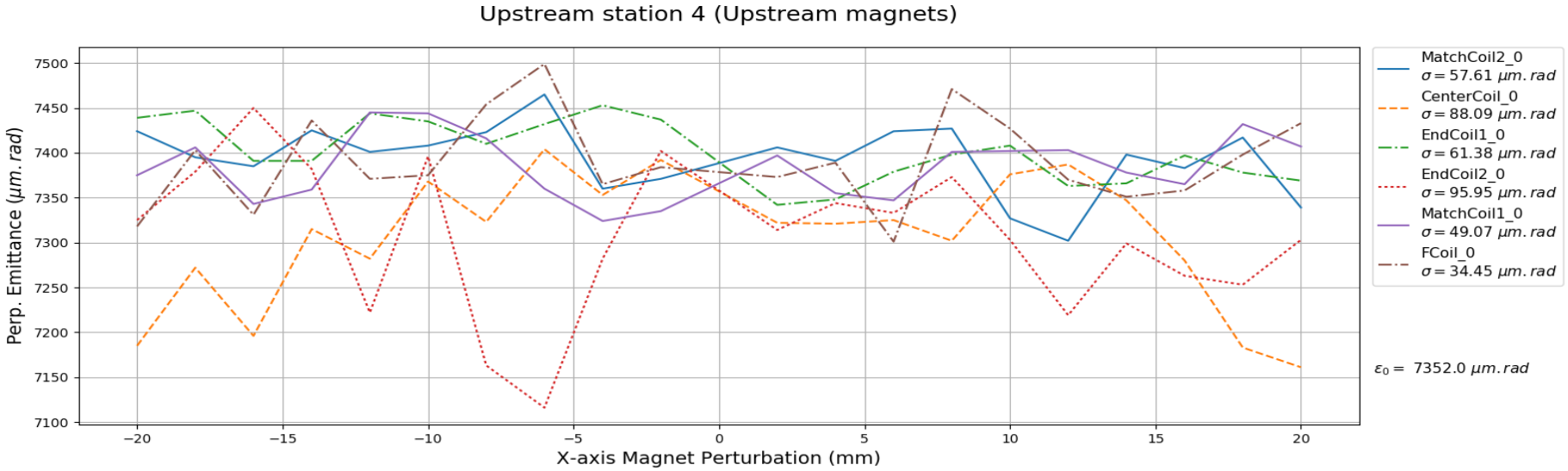
# Magnet Perturbation Error Analysis

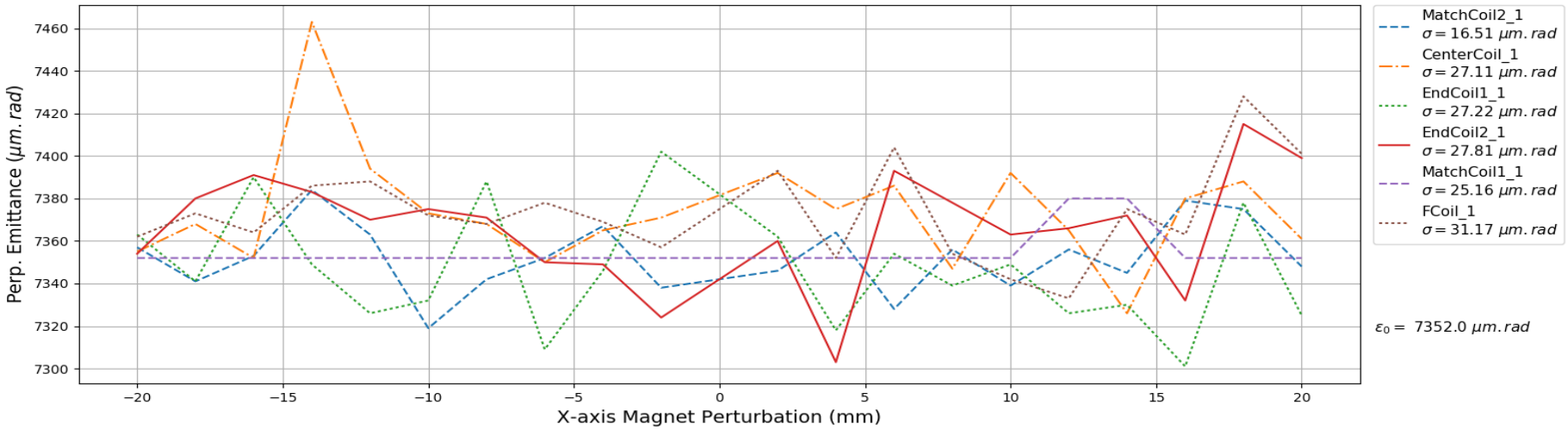
# Overview

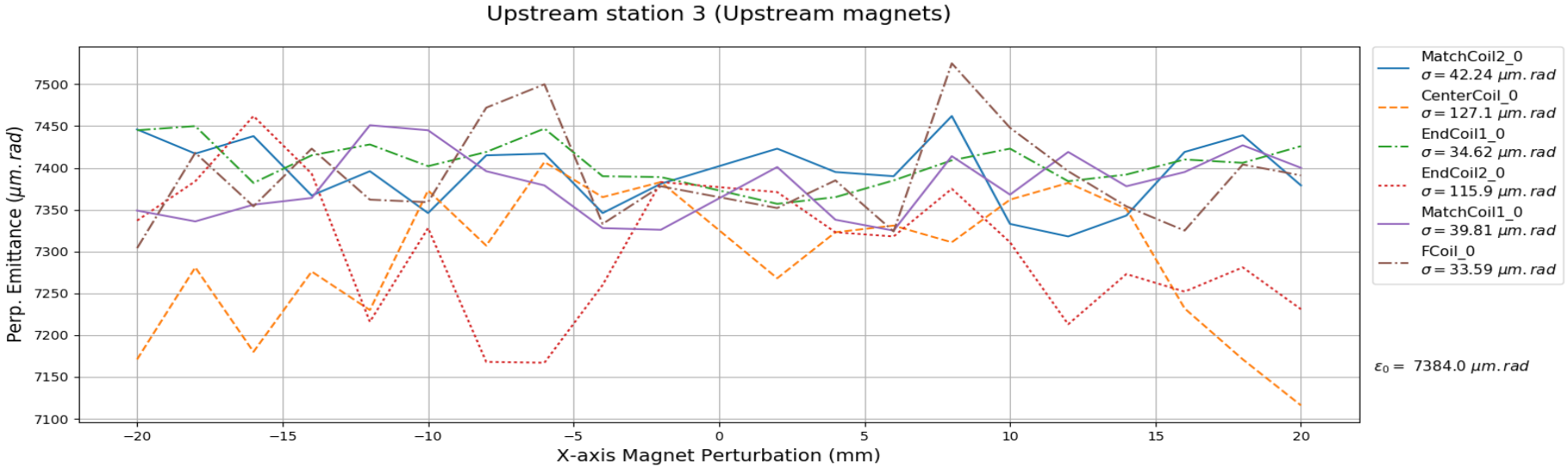
- Task
  - How do emittance values change according to CC magnet perturbations
- Method
  - Ran MC simulations on G4BL input data from MC Production page for run 9959 (**6-140 MeV LH2**)
  - Perturbed each of the 12 cooling magnets from -20 to +20 mm in the x-direction in 2mm steps. Ran simulation for each perturbation
  - Calculated transverse emittance from reconstructed simulation data using ecalc9 routine for each SciFi station.
  - Plotted emittance vs. x-perturbation

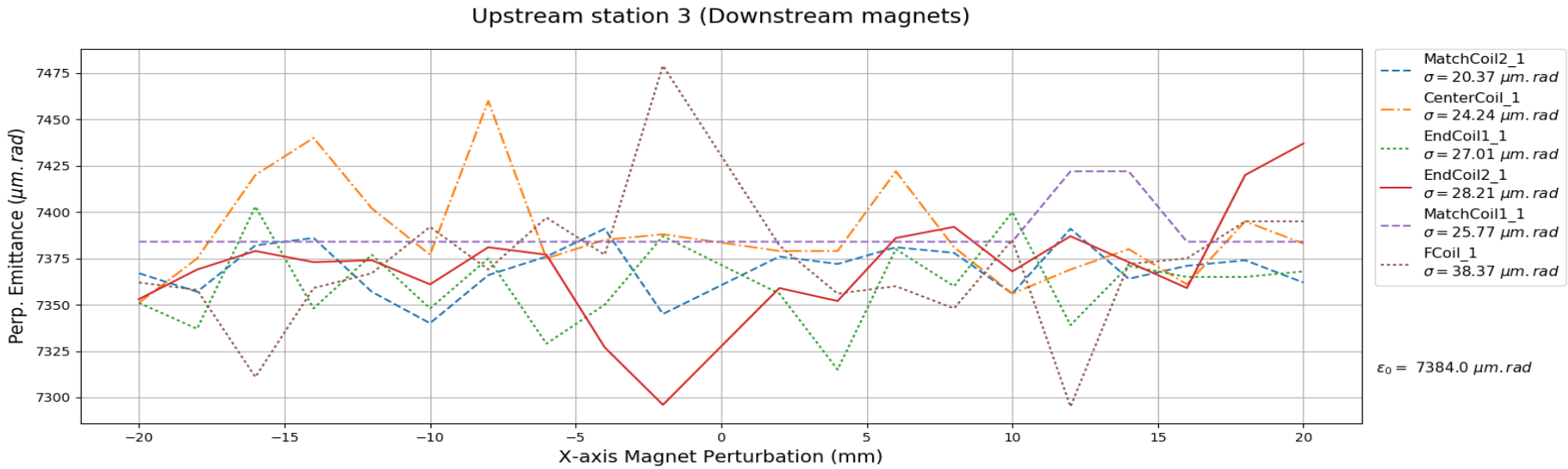

Upstream station 5 (Upstream magnets)
Perp. Emittance ($\mu m.rad$)
X-axis Magnet Perturbation (mm)
MatchCoil2_0 $\sigma = 47.94\ \mu m.rad$
CenterCoil_0 $\sigma = 138.8\ \mu m.rad$
EndCoil1_0 $\sigma = 43.48\ \mu m.rad$
EndCoil2_0 $\sigma = 140.1\ \mu m.rad$
MatchCoil1_0 $\sigma = 69.46\ \mu m.rad$
FCoil_0 $\sigma = 34.14\ \mu m.rad$
$\varepsilon_0 = 7446.0\ \mu m.rad$

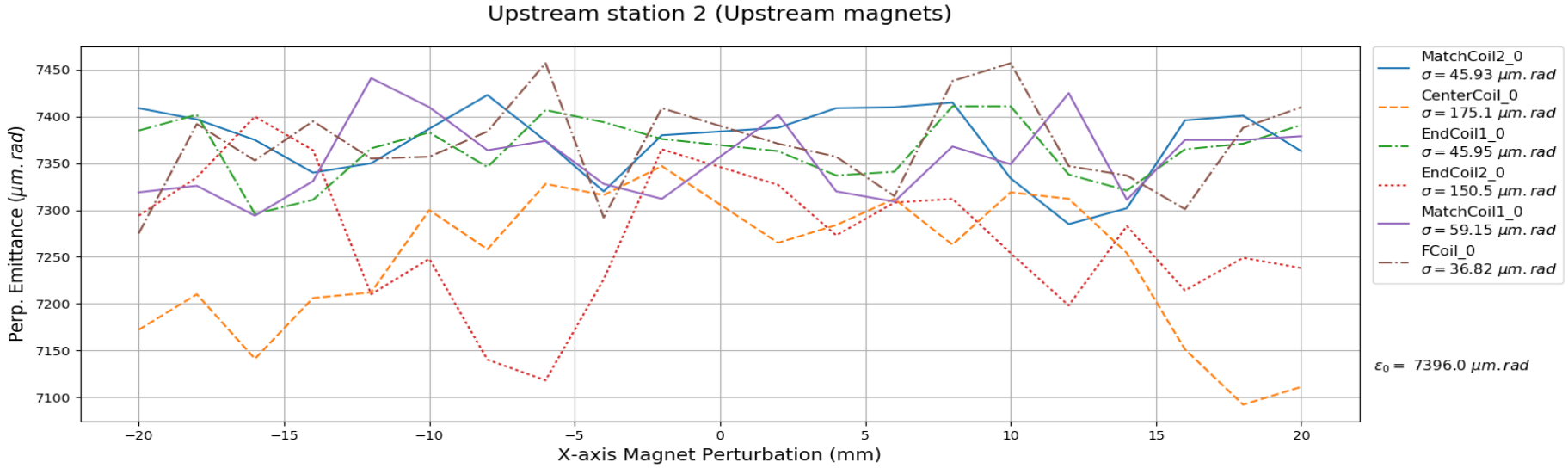

Upstream station 5 (Downstream magnets)
Perp. Emittance ($\mu m.rad$)
X-axis Magnet Perturbation (mm)
MatchCoil2_1 $\sigma = 28.66\ \mu m.rad$
CenterCoil_1 $\sigma = 26.98\ \mu m.rad$
EndCoil1_1 $\sigma = 29.49\ \mu m.rad$
EndCoil2_1 $\sigma = 28.96\ \mu m.rad$
MatchCoil1_1 $\sigma = 26.20\ \mu m.rad$
FCoil_1 $\sigma = 46.67\ \mu m.rad$
$\varepsilon_0 = 7446.0\ \mu m.rad$

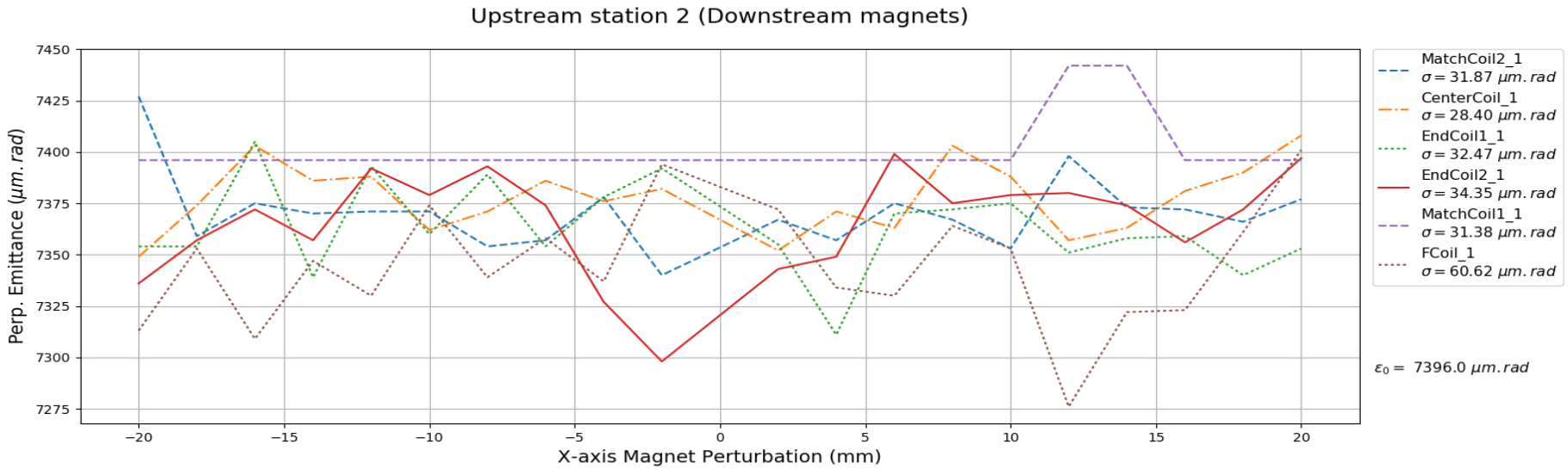

Upstream station 4 (Upstream magnets)
Perp. Emittance (μm. rad)
X-axis Magnet Perturbation (mm)
MatchCoil2_0
σ = 57.61 μm. rad
CenterCoil_0
σ = 88.09 μm. rad
EndCoil1_0
σ = 61.38 μm. rad
EndCoil2_0
σ = 95.95 μm. rad
MatchCoil1_0
σ = 49.07 μm. rad
FCoil_0
σ = 34.45 μm. rad
ε0 = 7352.0 μm. rad

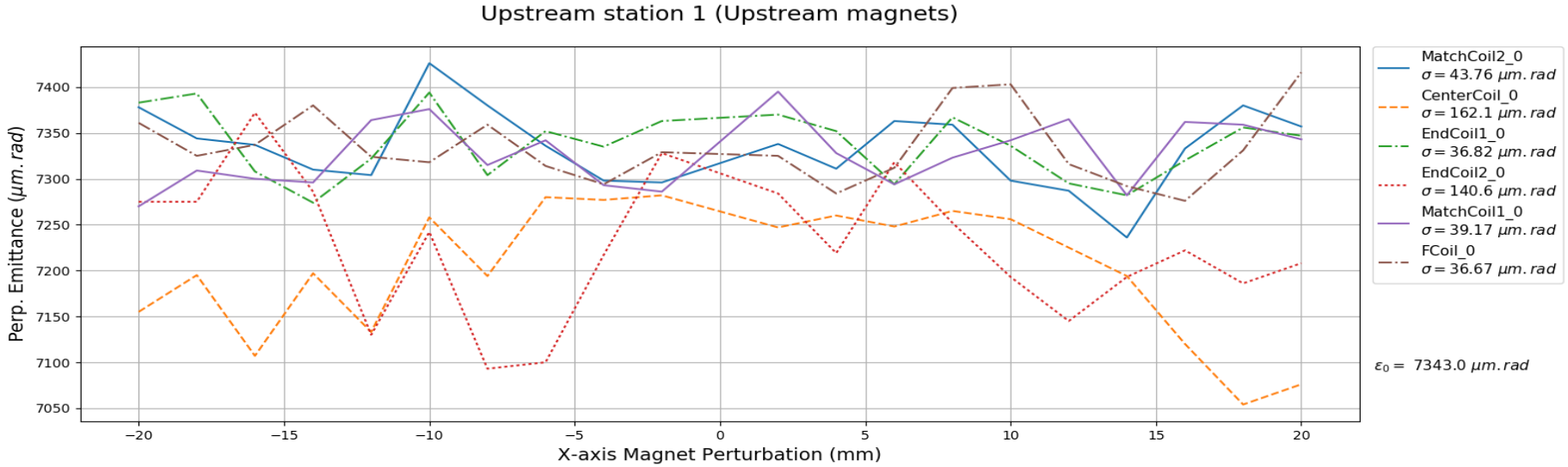

Upstream station 4 (Downstream magnets)
Perp. Emittance (μm. rad)
X-axis Magnet Perturbation (mm)
MatchCoil2_1
σ = 16.51 μm. rad
CenterCoil_1
σ = 27.11 μm. rad
EndCoil1_1
σ = 27.22 μm. rad
EndCoil2_1
σ = 27.81 μm. rad
MatchCoil1_1
σ = 25.16 μm. rad
FCoil_1
σ = 31.17 μm. rad
ε0 = 7352.0 μm. rad

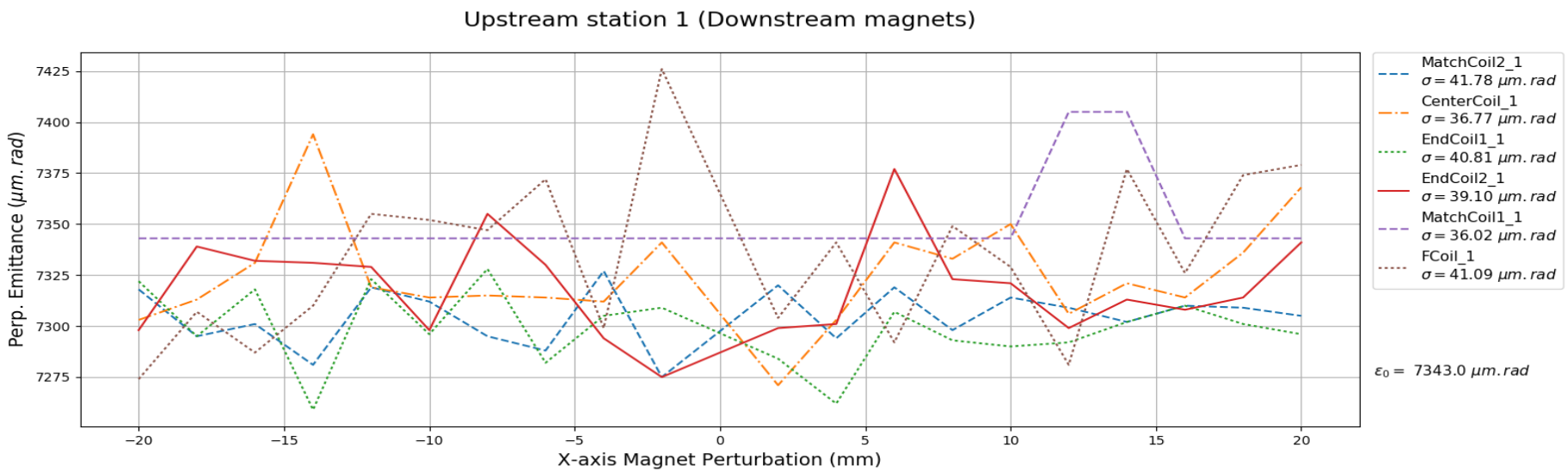

Upstream station 3 (Upstream magnets)
Perp. Emittance (μm.rad)
X-axis Magnet Perturbation (mm)
MatchCoil2_0 σ = 42.24 μm.rad
CenterCoil_0 σ = 127.1 μm.rad
EndCoil1_0 σ = 34.62 μm.rad
EndCoil2_0 σ = 115.9 μm.rad
MatchCoil1_0 σ = 39.81 μm.rad
FCoil_0 σ = 33.59 μm.rad
ε0 = 7384.0 μm.rad

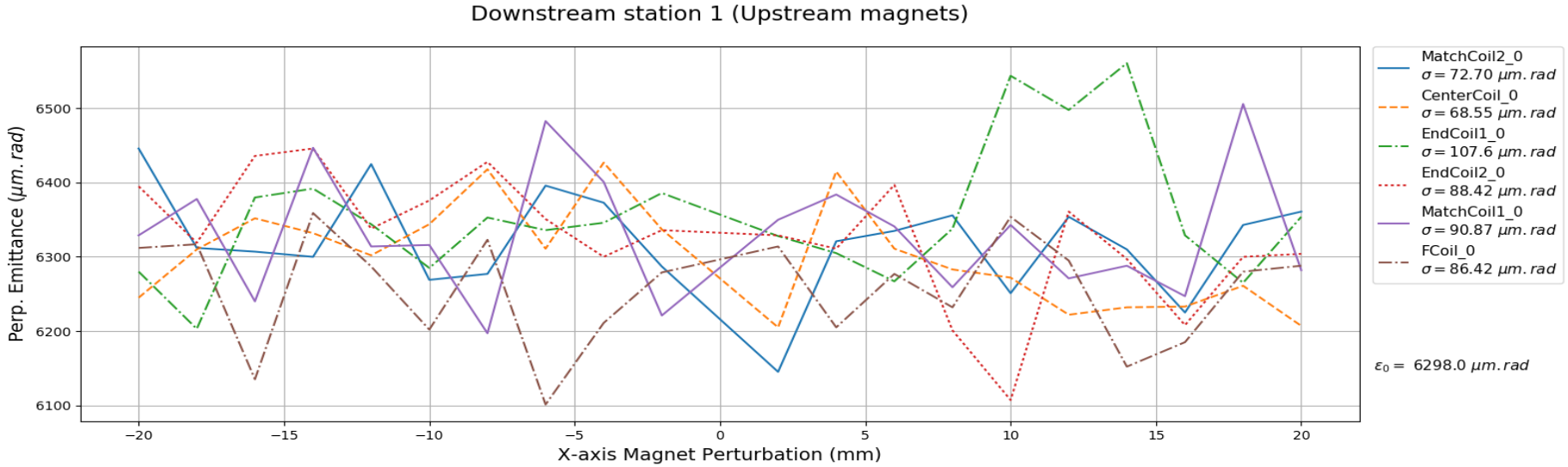

Upstream station 3 (Downstream magnets)
Perp. Emittance (μm.rad)
X-axis Magnet Perturbation (mm)
MatchCoil2_1 σ = 20.37 μm.rad
CenterCoil_1 σ = 24.24 μm.rad
EndCoil1_1 σ = 27.01 μm.rad
EndCoil2_1 σ = 28.21 μm.rad
MatchCoil1_1 σ = 25.77 μm.rad
FCoil_1 σ = 38.37 μm.rad
ε0 = 7384.0 μm.rad

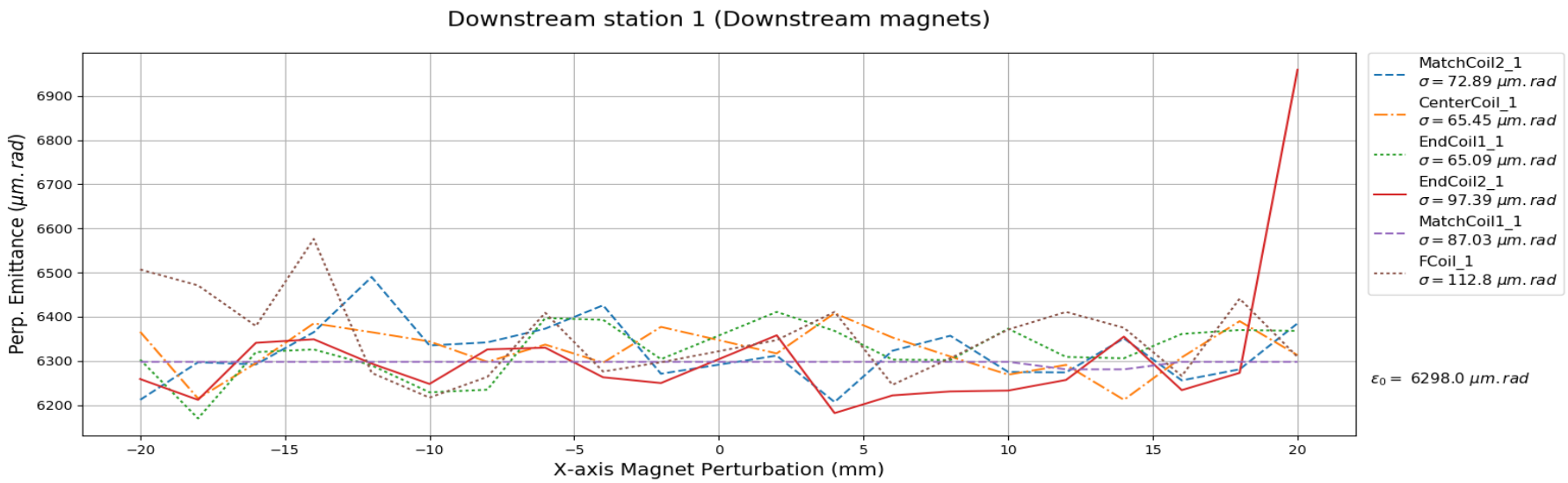

Upstream station 2 (Upstream magnets)
Perp. Emittance (μm.rad)
X-axis Magnet Perturbation (mm)
MatchCoil2_0
σ = 45.93 μm.rad
CenterCoil_0
σ = 175.1 μm.rad
EndCoil1_0
σ = 45.95 μm.rad
EndCoil2_0
σ = 150.5 μm.rad
MatchCoil1_0
σ = 59.15 μm.rad
FCoil_0
σ = 36.82 μm.rad
ε0 = 7396.0 μm.rad

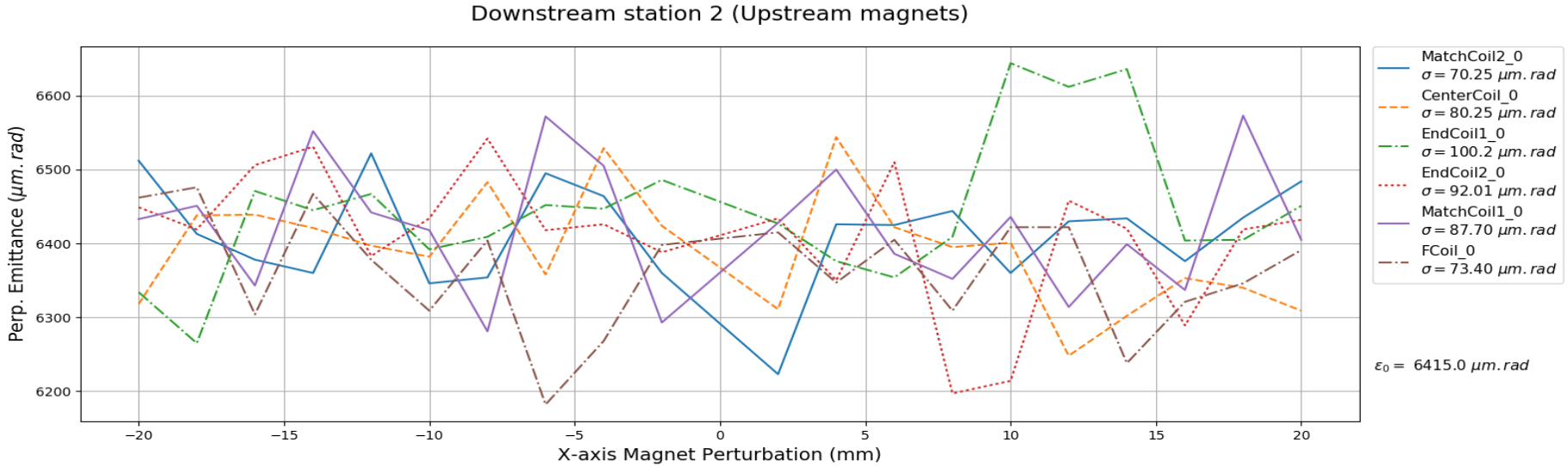

Upstream station 2 (Downstream magnets)
Perp. Emittance (μm.rad)
X-axis Magnet Perturbation (mm)
MatchCoil2_1
σ = 31.87 μm.rad
CenterCoil_1
σ = 28.40 μm.rad
EndCoil1_1
σ = 32.47 μm.rad
EndCoil2_1
σ = 34.35 μm.rad
MatchCoil1_1
σ = 31.38 μm.rad
FCoil_1
σ = 60.62 μm.rad
ε0 = 7396.0 μm.rad

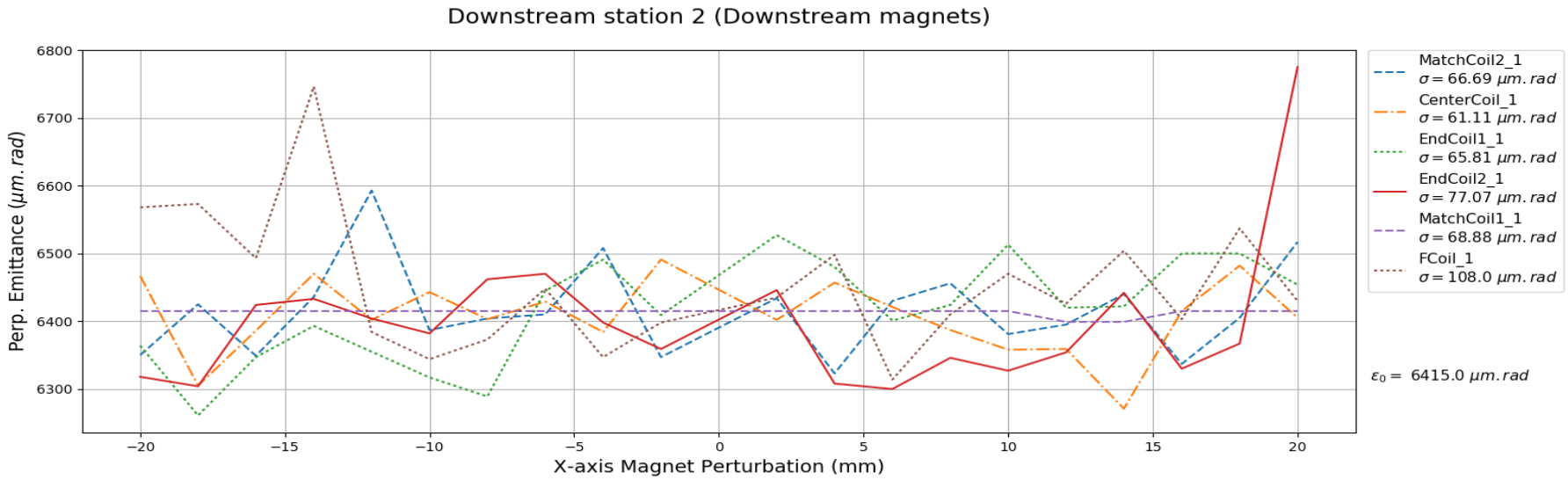

Upstream station 1 (Upstream magnets)
Perp. Emittance (μm.rad)
X-axis Magnet Perturbation (mm)
MatchCoil2_0
σ = 43.76 μm.rad
CenterCoil_0
σ = 162.1 μm.rad
EndCoil1_0
σ = 36.82 μm.rad
EndCoil2_0
σ = 140.6 μm.rad
MatchCoil1_0
σ = 39.17 μm.rad
FCoil_0
σ = 36.67 μm.rad
ε0 = 7343.0 μm.rad

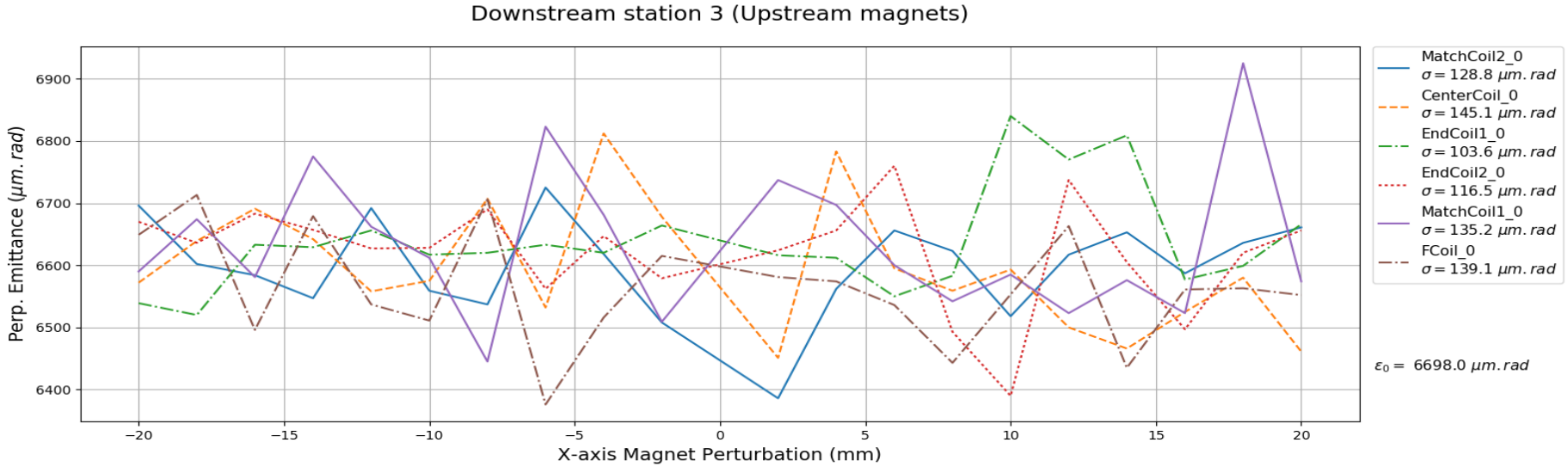

Upstream station 1 (Downstream magnets)
Perp. Emittance (μm.rad)
X-axis Magnet Perturbation (mm)
MatchCoil2_1
σ = 41.78 μm.rad
CenterCoil_1
σ = 36.77 μm.rad
EndCoil1_1
σ = 40.81 μm.rad
EndCoil2_1
σ = 39.10 μm.rad
MatchCoil1_1
σ = 36.02 μm.rad
FCoil_1
σ = 41.09 μm.rad
ε0 = 7343.0 μm.rad

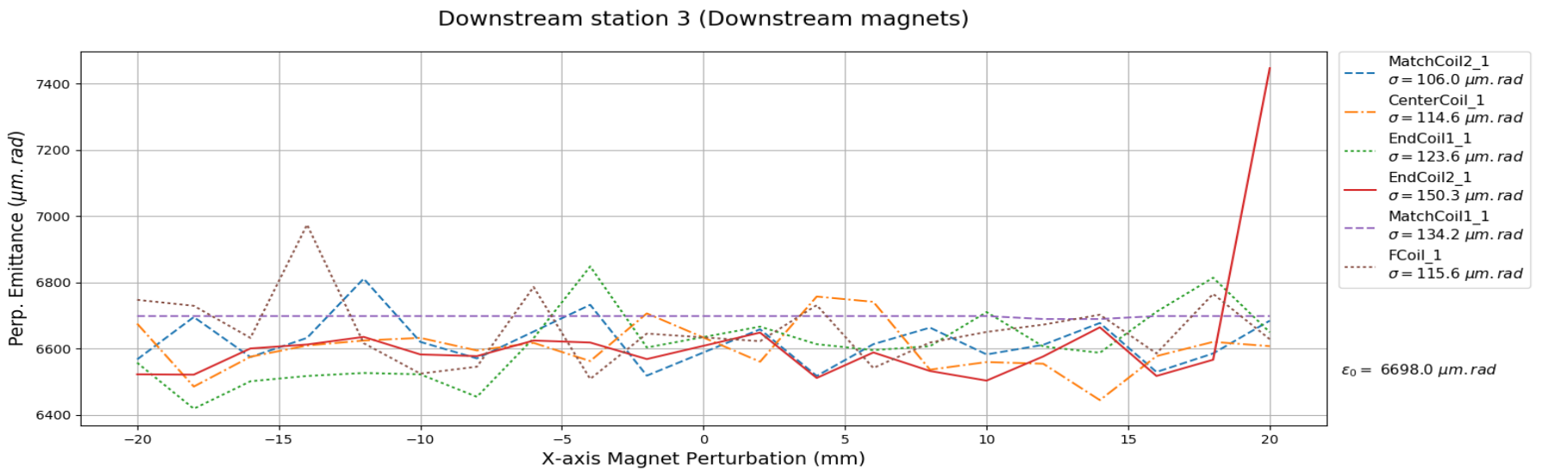

Downstream station 1 (Upstream magnets)
Perp. Emittance (μm. rad)
X-axis Magnet Perturbation (mm)
MatchCoil2_0
σ = 72.70 μm. rad
CenterCoil_0
σ = 68.55 μm. rad
EndCoil1_0
σ = 107.6 μm. rad
EndCoil2_0
σ = 88.42 μm. rad
MatchCoil1_0
σ = 90.87 μm. rad
FCoil_0
σ = 86.42 μm. rad
ε0 = 6298.0 μm. rad

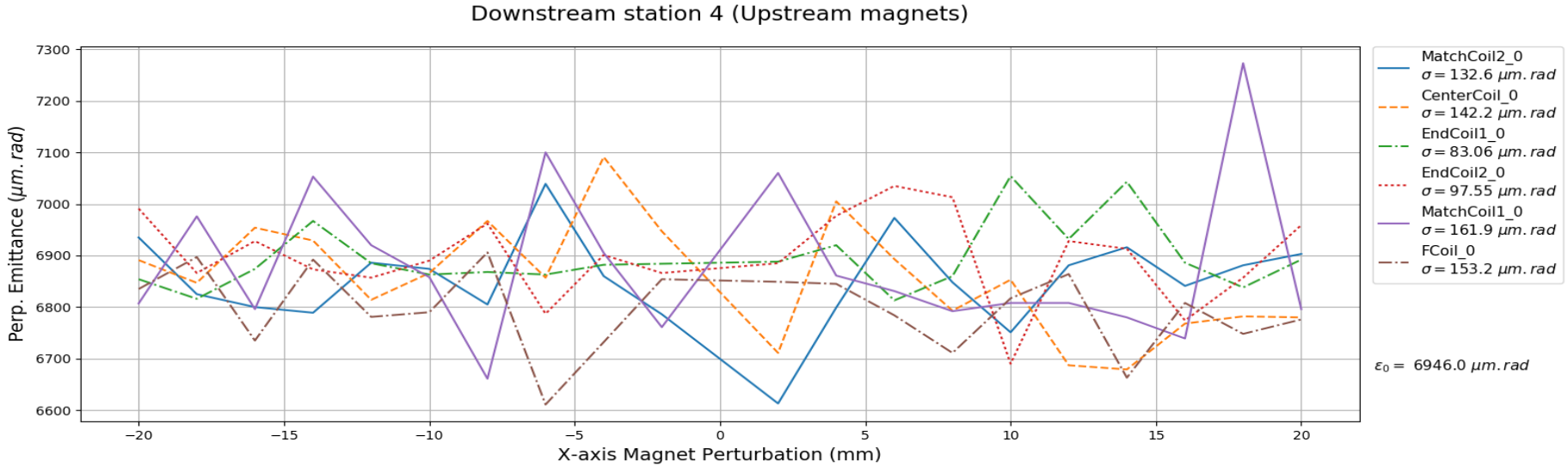

Downstream station 1 (Downstream magnets)
Perp. Emittance (μm. rad)
X-axis Magnet Perturbation (mm)
MatchCoil2_1
σ = 72.89 μm. rad
CenterCoil_1
σ = 65.45 μm. rad
EndCoil1_1
σ = 65.09 μm. rad
EndCoil2_1
σ = 97.39 μm. rad
MatchCoil1_1
σ = 87.03 μm. rad
FCoil_1
σ = 112.8 μm. rad
ε0 = 6298.0 μm. rad

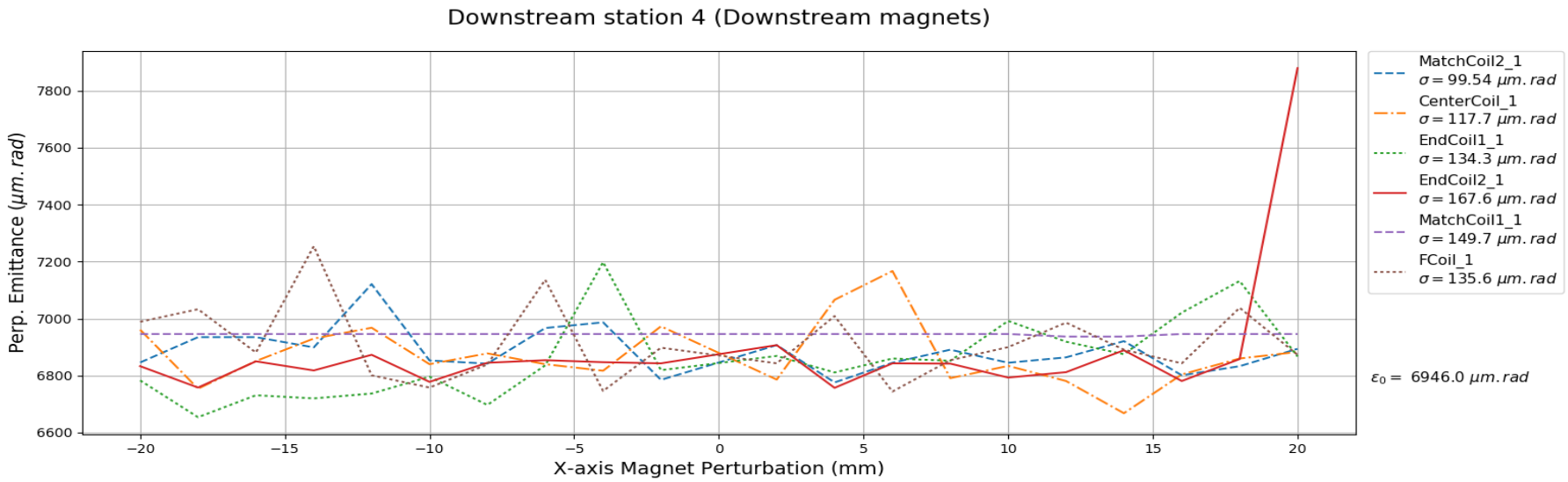

Downstream station 2 (Upstream magnets)
Perp. Emittance (μm. rad)
X-axis Magnet Perturbation (mm)
MatchCoil2_0
σ = 70.25 μm. rad
CenterCoil_0
σ = 80.25 μm. rad
EndCoil1_0
σ = 100.2 μm. rad
EndCoil2_0
σ = 92.01 μm. rad
MatchCoil1_0
σ = 87.70 μm. rad
FCoil_0
σ = 73.40 μm. rad
ε0 = 6415.0 μm. rad

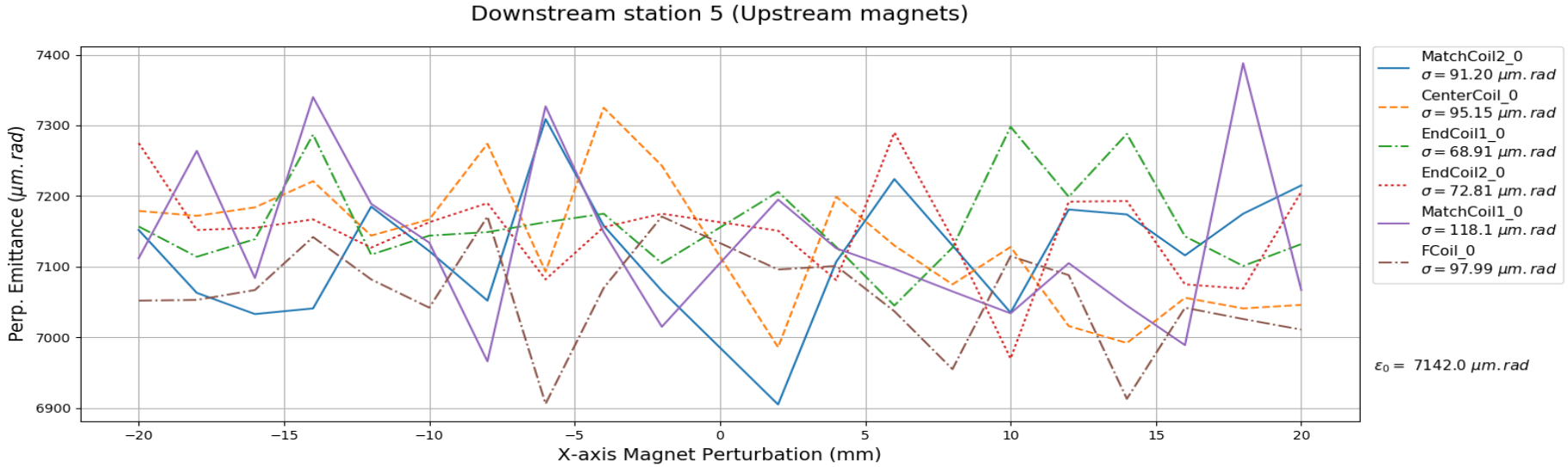

Downstream station 2 (Downstream magnets)
Perp. Emittance (μm. rad)
X-axis Magnet Perturbation (mm)
MatchCoil2_1
σ = 66.69 μm. rad
CenterCoil_1
σ = 61.11 μm. rad
EndCoil1_1
σ = 65.81 μm. rad
EndCoil2_1
σ = 77.07 μm. rad
MatchCoil1_1
σ = 68.88 μm. rad
FCoil_1
σ = 108.0 μm. rad
ε0 = 6415.0 μm. rad

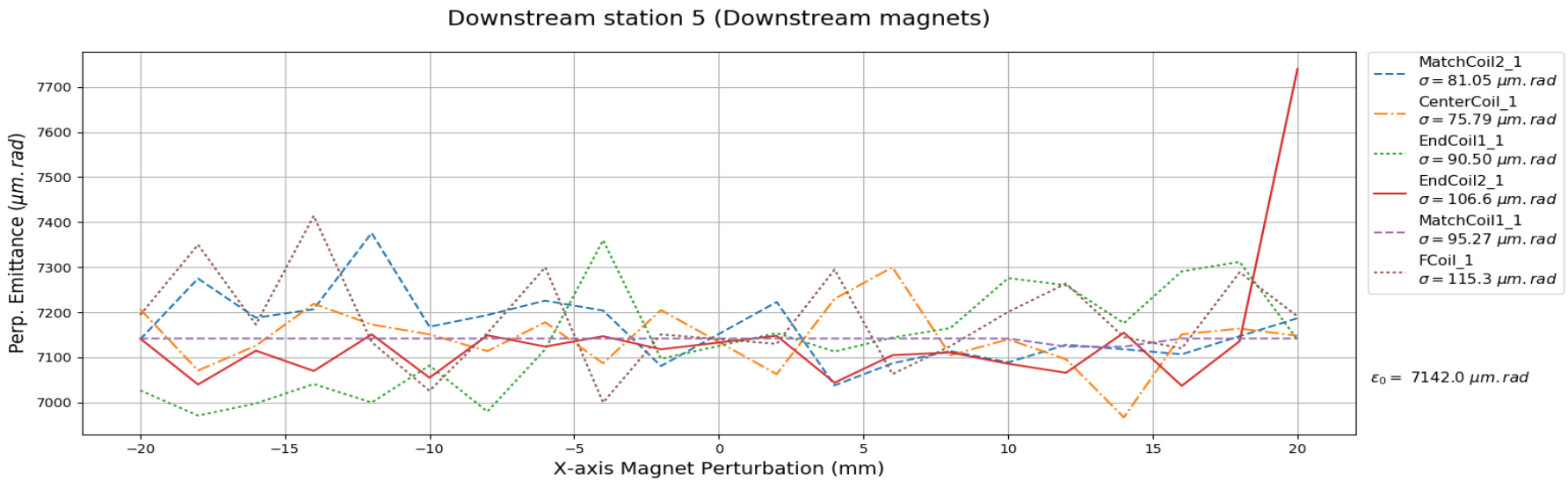

Downstream station 3 (Upstream magnets)
Perp. Emittance (μm.rad)
X-axis Magnet Perturbation (mm)
MatchCoil2_0
σ = 128.8 μm.rad
CenterCoil_0
σ = 145.1 μm.rad
EndCoil1_0
σ = 103.6 μm.rad
EndCoil2_0
σ = 116.5 μm.rad
MatchCoil1_0
σ = 135.2 μm.rad
FCoil_0
σ = 139.1 μm.rad
ε0 = 6698.0 μm.rad


Downstream station 3 (Downstream magnets)
Perp. Emittance (μm.rad)
X-axis Magnet Perturbation (mm)
MatchCoil2_1
σ = 106.0 μm.rad
CenterCoil_1
σ = 114.6 μm.rad
EndCoil1_1
σ = 123.6 μm.rad
EndCoil2_1
σ = 150.3 μm.rad
MatchCoil1_1
σ = 134.2 μm.rad
FCoil_1
σ = 115.6 μm.rad
ε0 = 6698.0 μm.rad


Downstream station 4 (Upstream magnets)
Perp. Emittance (μm.rad)
X-axis Magnet Perturbation (mm)
MatchCoil2_0
σ = 132.6 μm.rad
CenterCoil_0
σ = 142.2 μm.rad
EndCoil1_0
σ = 83.06 μm.rad
EndCoil2_0
σ = 97.55 μm.rad
MatchCoil1_0
σ = 161.9 μm.rad
FCoil_0
σ = 153.2 μm.rad
ε0 = 6946.0 μm.rad


Downstream station 4 (Downstream magnets)
Perp. Emittance (μm.rad)
X-axis Magnet Perturbation (mm)
MatchCoil2_1
σ = 99.54 μm.rad
CenterCoil_1
σ = 117.7 μm.rad
EndCoil1_1
σ = 134.3 μm.rad
EndCoil2_1
σ = 167.6 μm.rad
MatchCoil1_1
σ = 149.7 μm.rad
FCoil_1
σ = 135.6 μm.rad
ε0 = 6946.0 μm.rad


Downstream station 5 (Upstream magnets)
Perp. Emittance (μm. rad)
X-axis Magnet Perturbation (mm)
MatchCoil2_0
σ = 91.20 μm. rad
CenterCoil_0
σ = 95.15 μm. rad
EndCoil1_0
σ = 68.91 μm. rad
EndCoil2_0
σ = 72.81 μm. rad
MatchCoil1_0
σ = 118.1 μm. rad
FCoil_0
σ = 97.99 μm. rad
ε0 = 7142.0 μm. rad


Downstream station 5 (Downstream magnets)
Perp. Emittance (μm. rad)
X-axis Magnet Perturbation (mm)
MatchCoil2_1
σ = 81.05 μm. rad
CenterCoil_1
σ = 75.79 μm. rad
EndCoil1_1
σ = 90.50 μm. rad
EndCoil2_1
σ = 106.6 μm. rad
MatchCoil1_1
σ = 95.27 μm. rad
FCoil_1
σ = 115.3 μm. rad
ε0 = 7142.0 μm. rad

# Results

- Resembles oscillatory distribution
- Mean transverse emittance decreases from upstream to downstream stations

# Future Work

- Optimize curve fit
- Use random normal distribution for perturbation values, see how it affects emittance
- Perturb magnets in x and y