Investigation of the adiabaticity of longitudinal dynamics in the KURNS FFA

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on behalf of the International KURNS collaboration

FFA'20 Workshop, TRIUMF (Nov 30th – Dec 4th, 2020)

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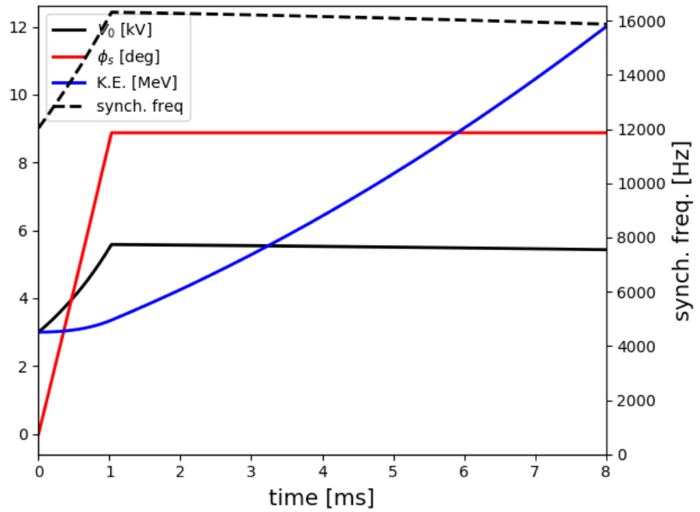
Introduction

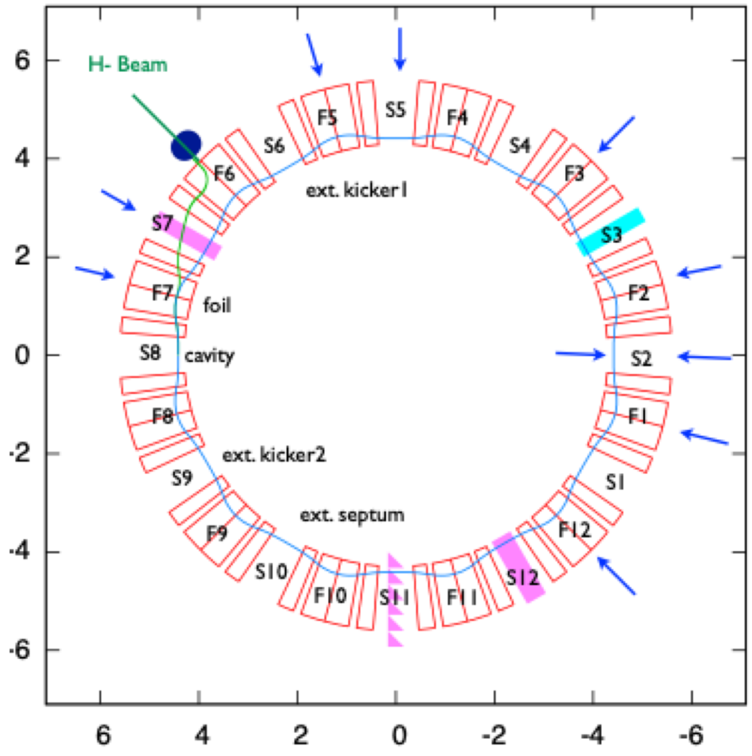
- Study the effect of varying the longitudinal parameters on the longitudinal distribution.
- We expect that if the transition is adiabatic the longitudinal emittance should be preserved.
- If the adiabaticity parameter, ε, is sufficiently low (~0.1), a distribution which is initially at equilibrium will remain in equilibrium.
- Questions to address
  - is the onset of emittance growth a threshold effect?
  - Can we establish an equation for emittance growth as a function of adiabaticity?

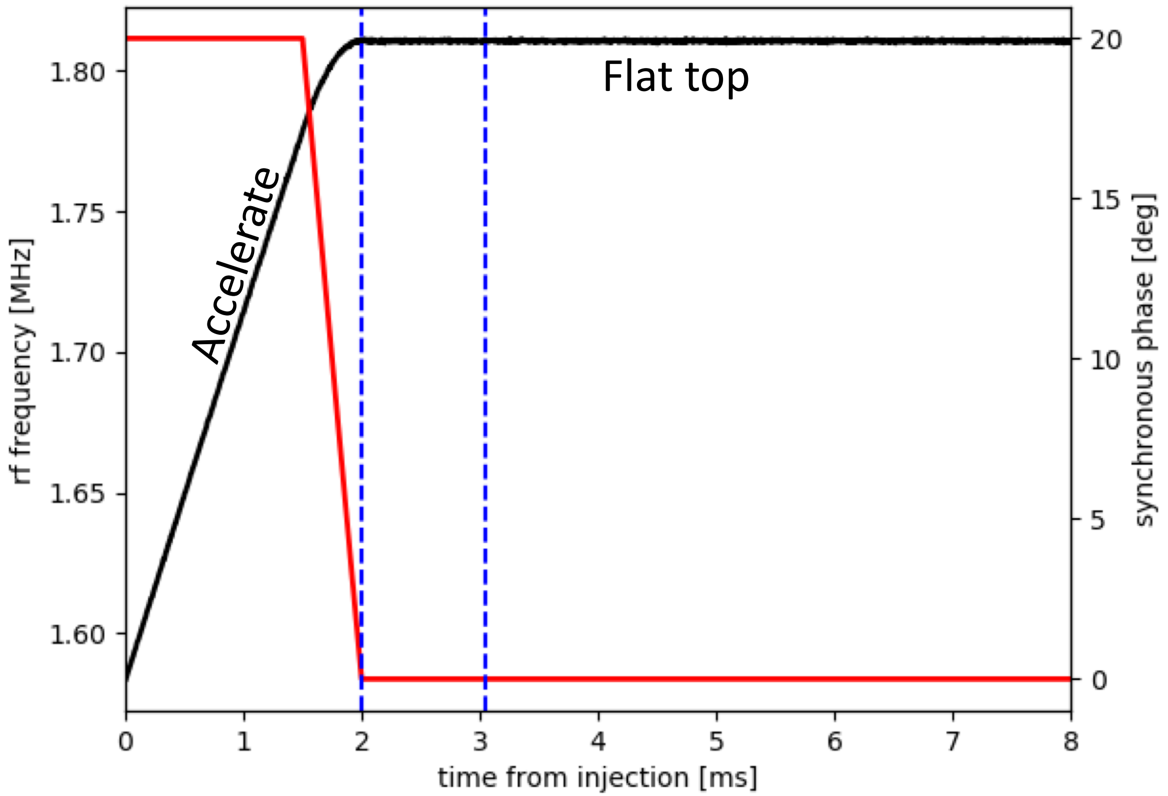
$$\epsilon = \frac{1}{\omega_s^2}\left|\frac{d\omega_s}{dt}\right|$$



FETS-FFA RF program

KURNS setup





Flexible RF – pattern generated by AWG.

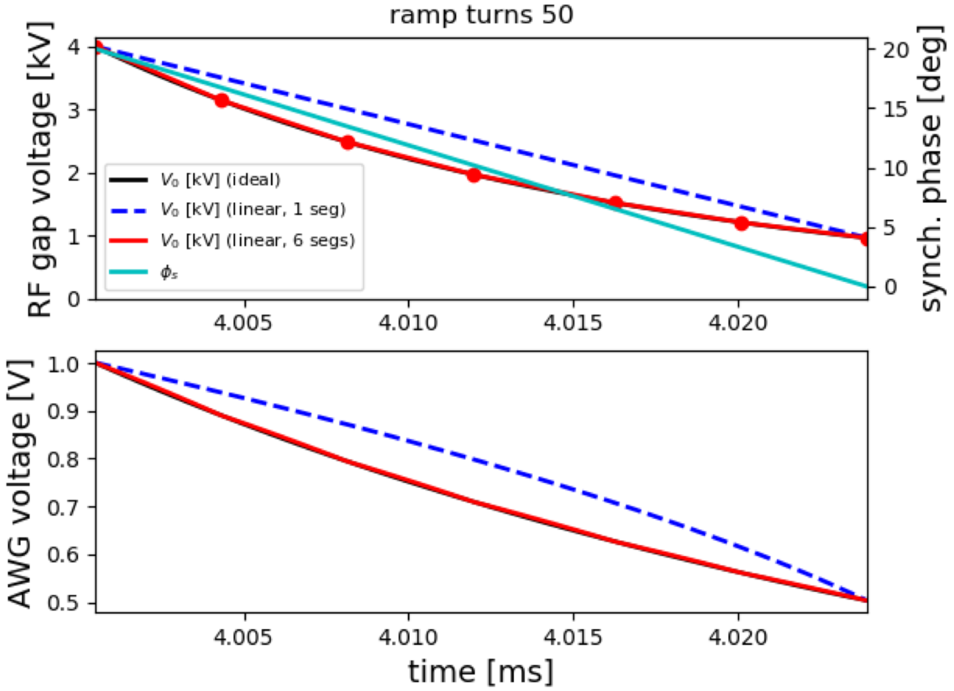
Proposed Experiment

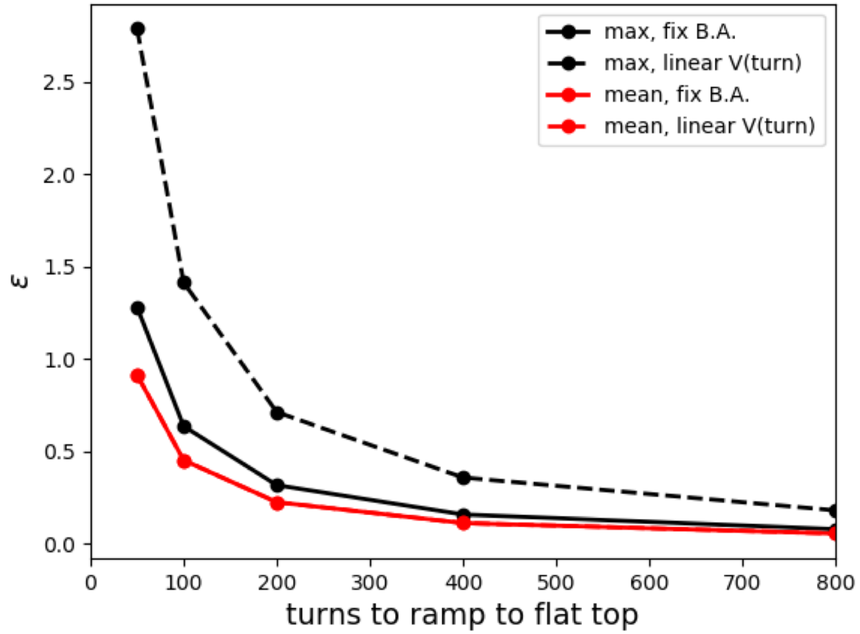
Aim: Experimentally measure the dependence of longitudinal emittance growth on the adiabatic parameter.

- Accelerate with usual settings until some point where beam has escaped foil and the emittance has reached an equilibrium.
- Ramp to zero phi_s over a range of turns. At the same time, ramp the voltage to preserve the bucket area. Note: the flat top energy varies with number of turns.
- Maintain flattop for many synchrotron oscillations.
- Use raw bunch monitor data or tomography to measure emittance blow up if any.

Specifying transition settings

- Ramp phi_s from 20 deg to 0 in varying number of turns while adjusting the voltage to keep the bucket area constant.





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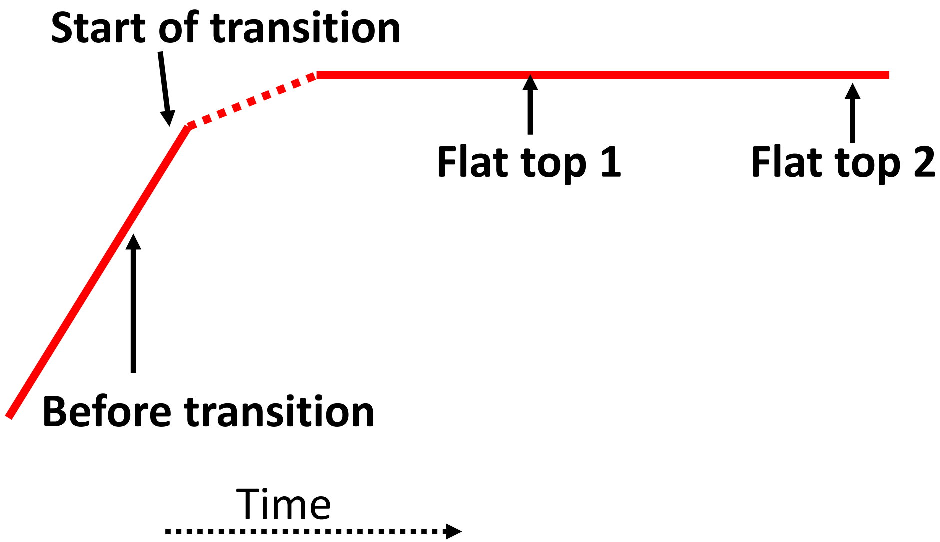
Data summary

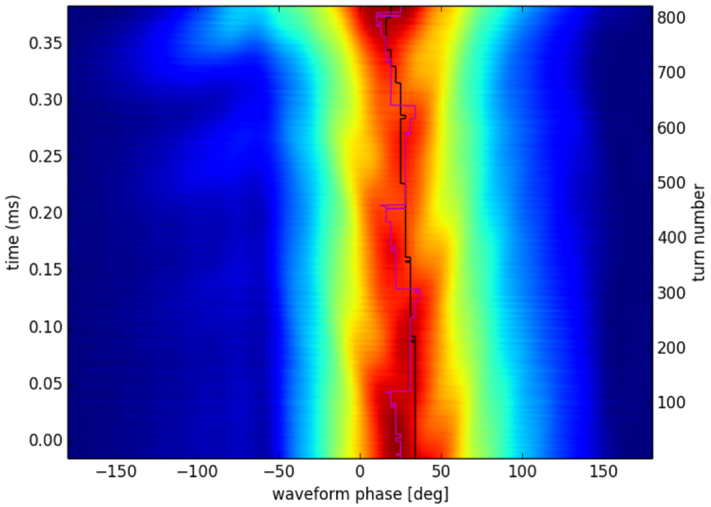
Case	Ramp turns	Peak ε	Dates
1	100	0.70	9/12, 12/12
2	200	0.35	9/12, 12/12
3	400	0.178	9/12, 12/12
4	800	0.09	9/12, 12/12
5	600	0.119	12/12
6	1100	0.066	12/12
7	1600	0.045	12/12
8	3200	0.023	12/12



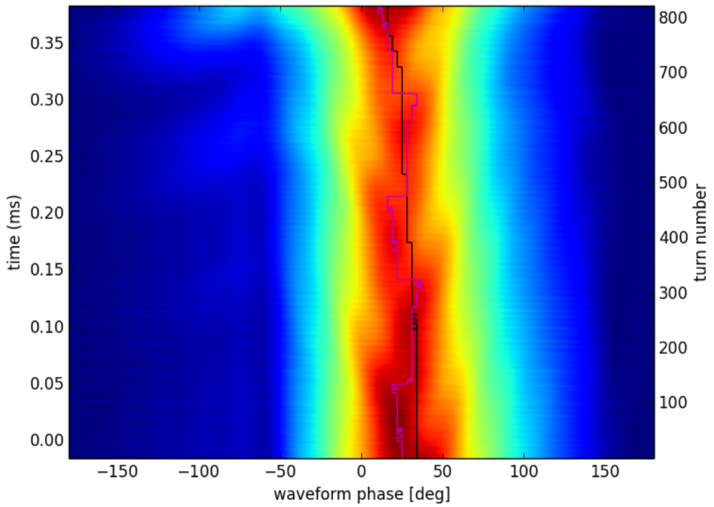
- Data taken before transition and at two later times in the flat top (about 50 and 100 synchrotron oscillations later).
- Triggers times of data acquisition: 6.162ms, 6.842ms, 9.542ms, 12.242ms
- 1 sets of data taken per condition taken on 9/12, 3 sets of 12/12.

Before transition
(filter applied, 9/12)

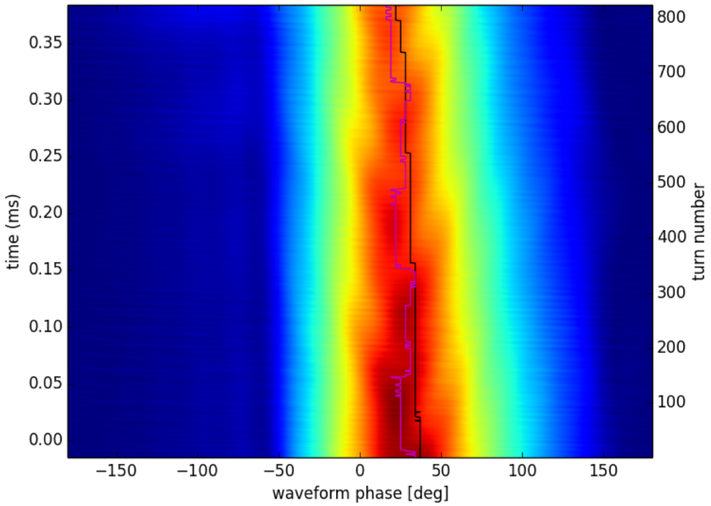
Case 1
100 turn ramp



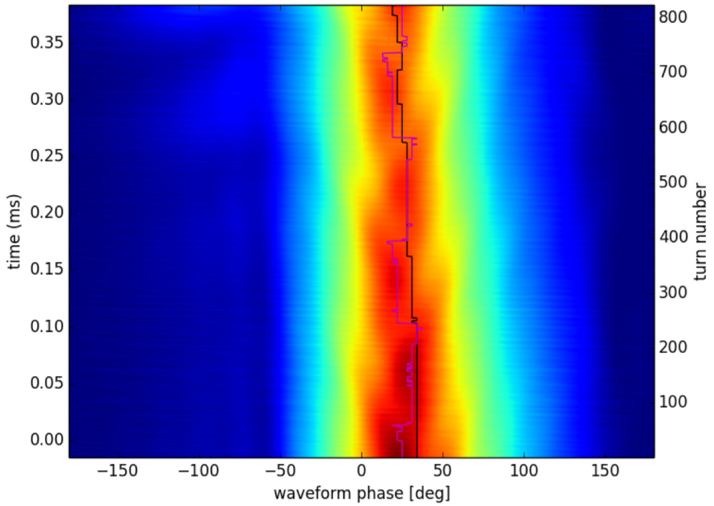
Case 2
200 turn ramps



Case 4
800 turn ramp



Case 3
400 turn ramp



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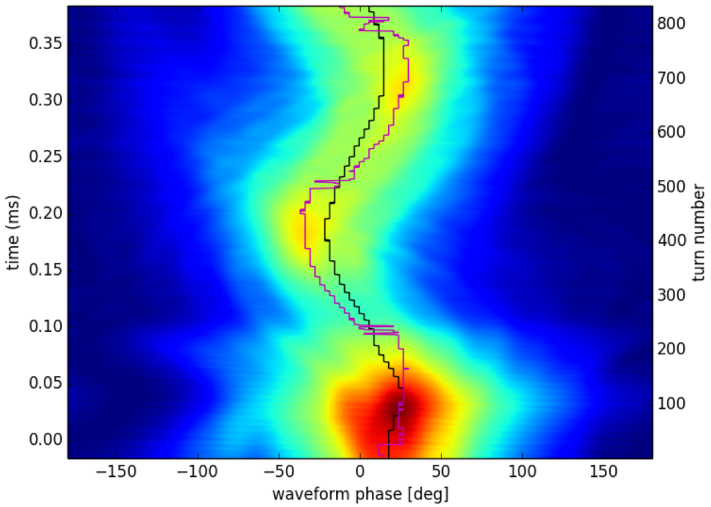
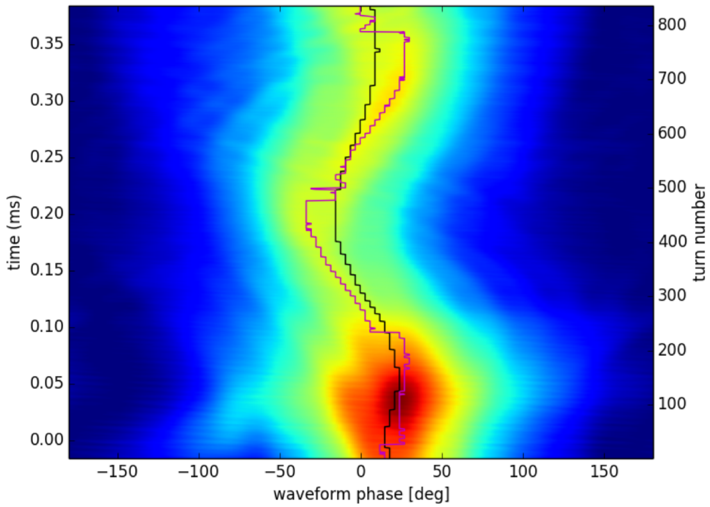
Transition

(filter applied, 9/12)

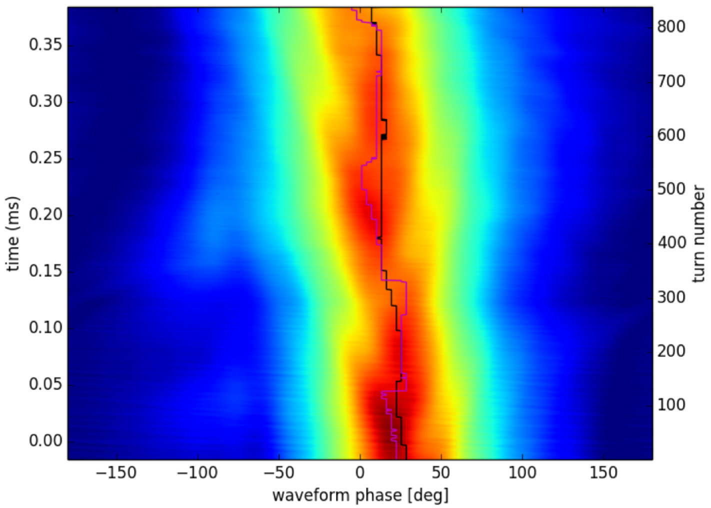
Case 1
100 turn ramp



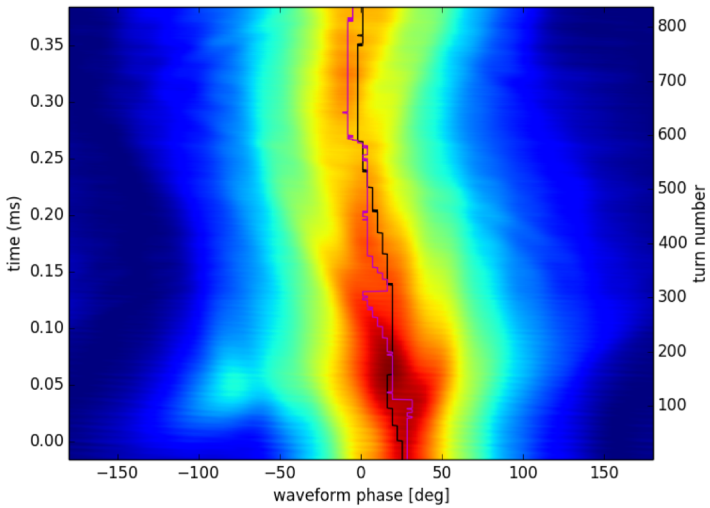
Case 2
200 turn ramp



Case 4
800 turn ramp



Case 3
400 turn ramp



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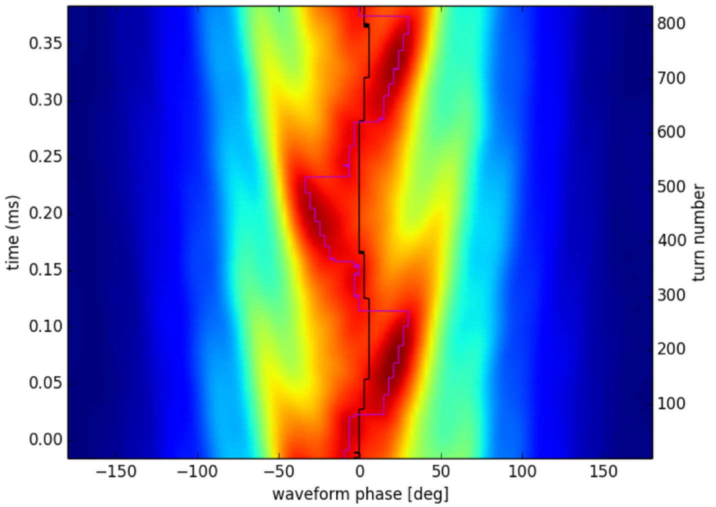
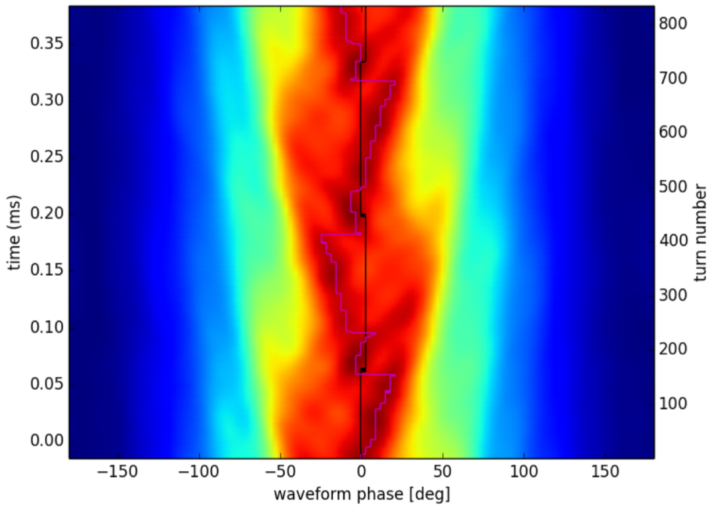
50 synchrotron oscillations later

(filter applied, 9/12)

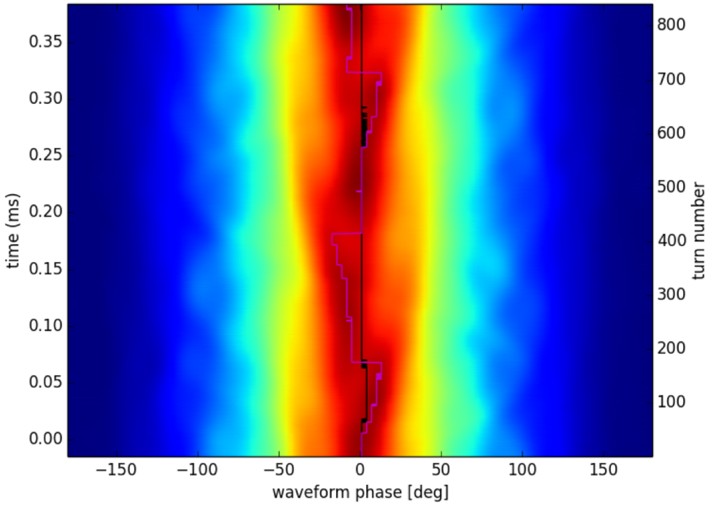
Case 1
100 turn ramp



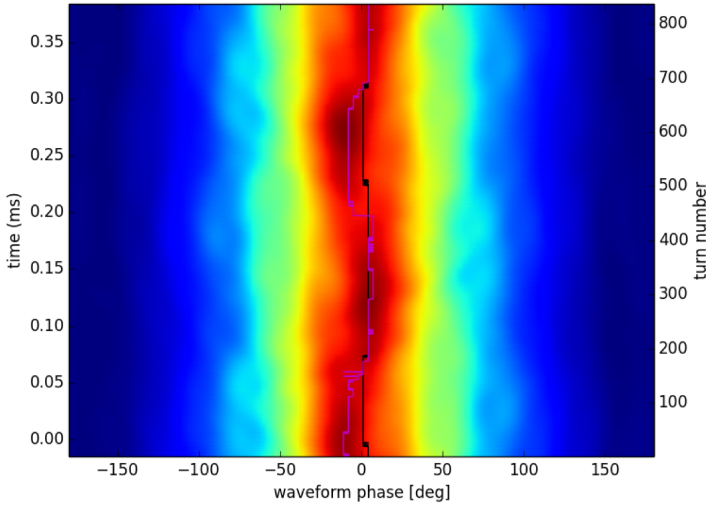
Case 2
200 turn ramps



Case 4
800 turn ramp



Case 3
400 turn ramp



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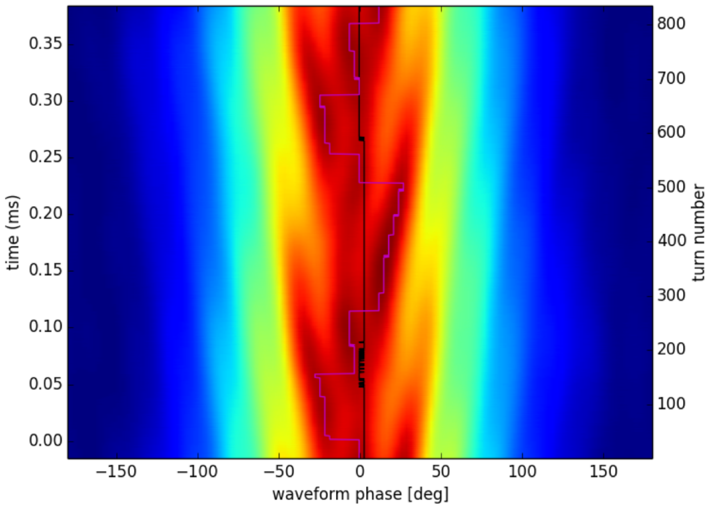
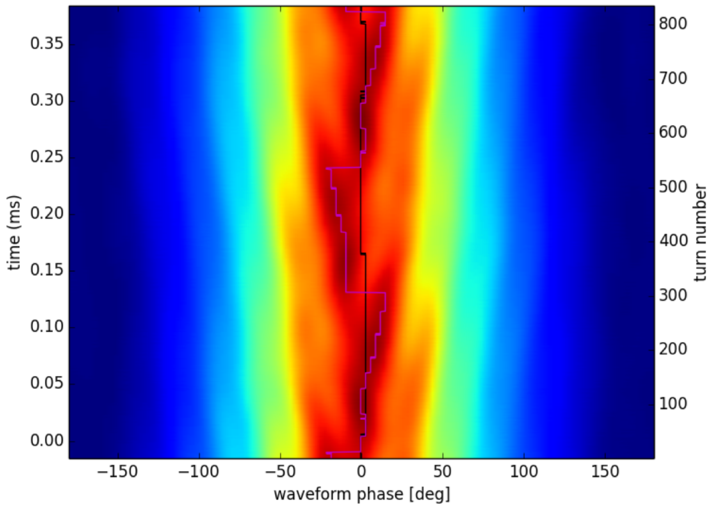
100 synchrotron oscillations later

(filter applied, 9/12)

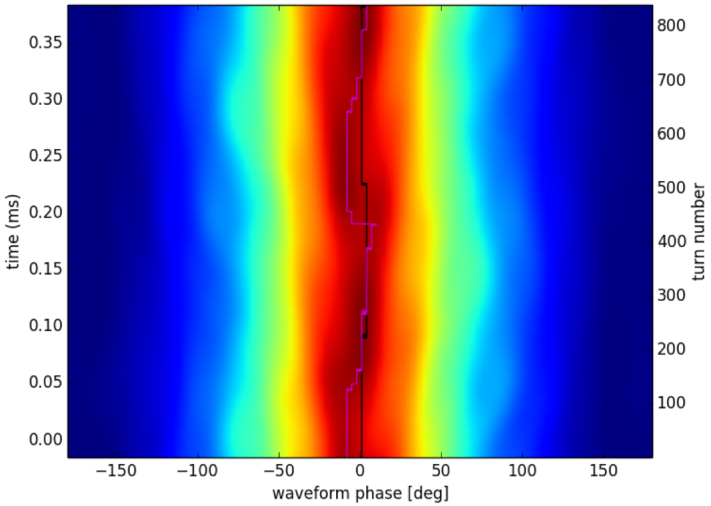
Case 1
100 turn ramp



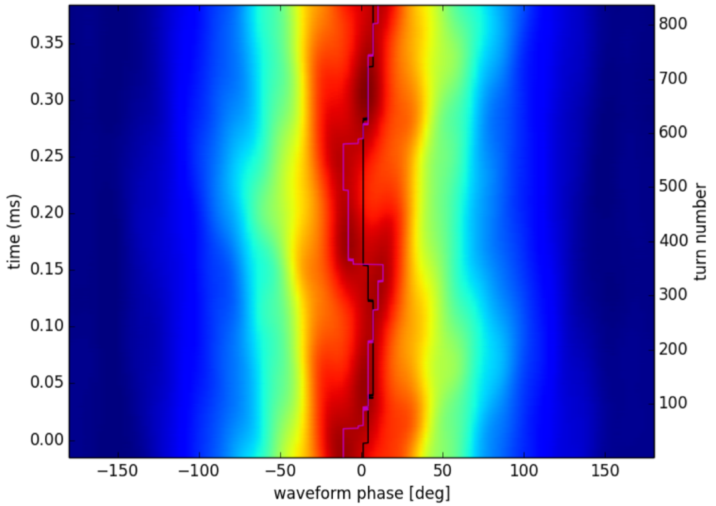
Case 2
200 turn ramps



Case 4
800 turn ramp



Case 3
400 turn ramp



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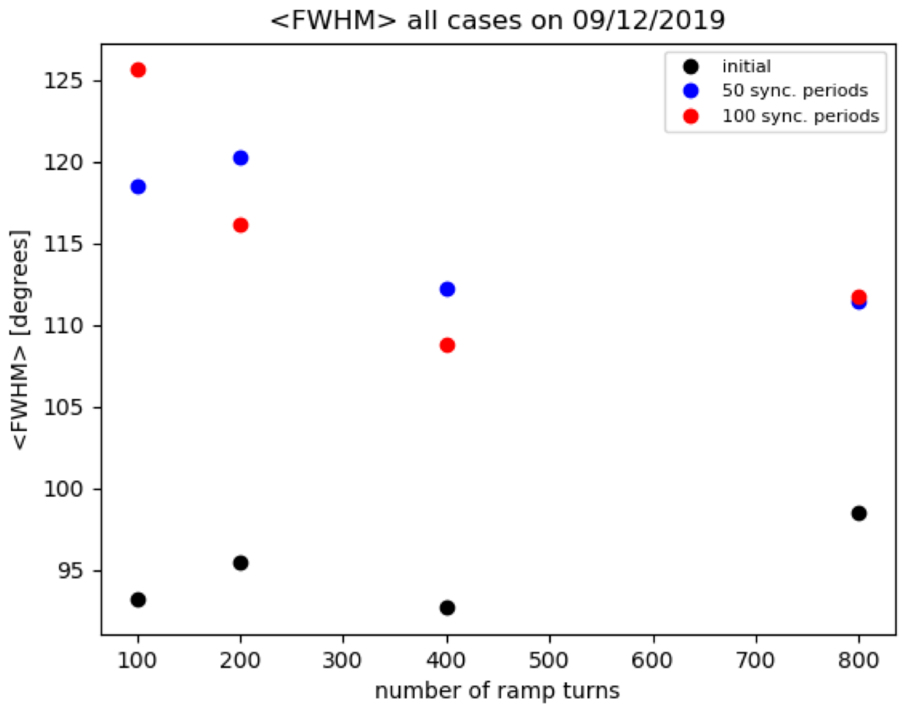
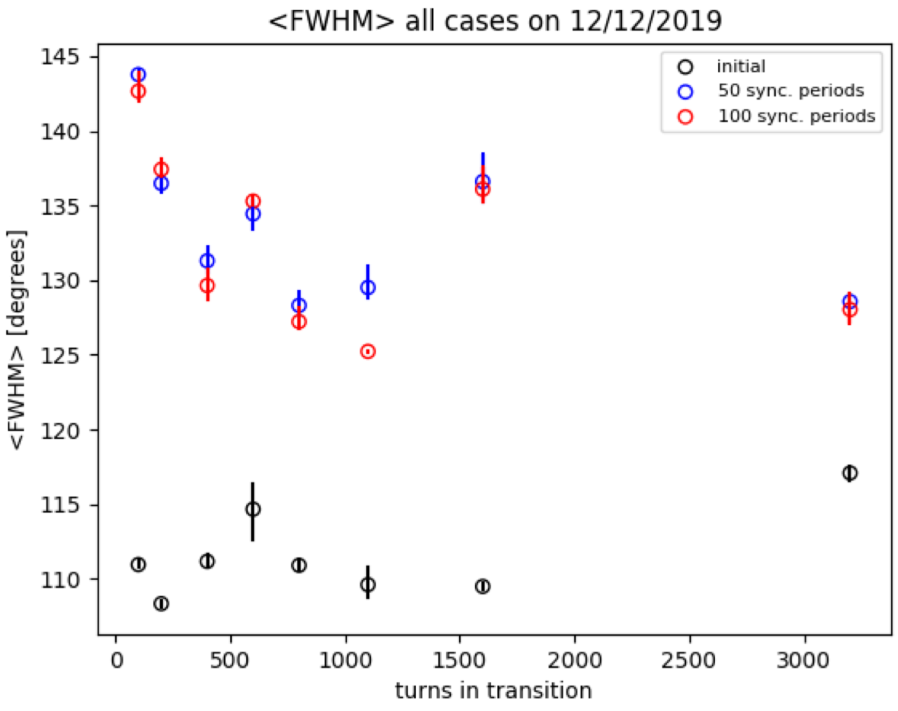
Mean FWHM of the bunch monitor signal





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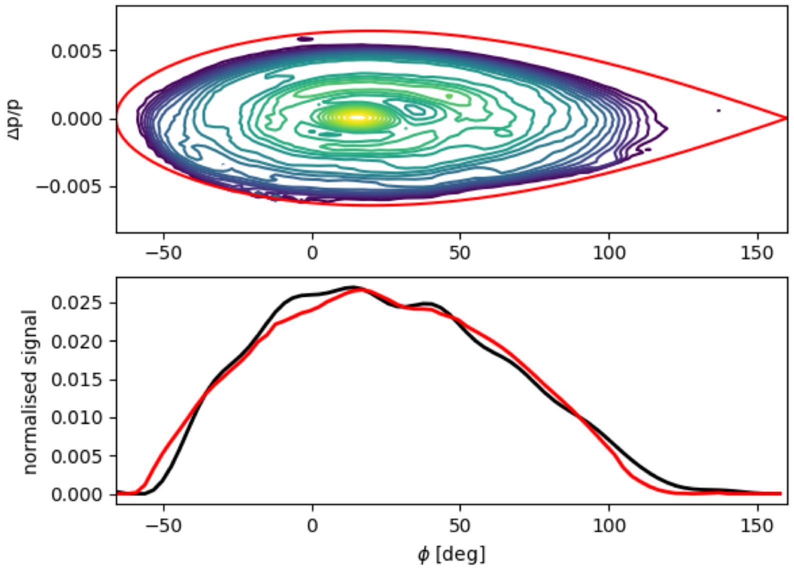
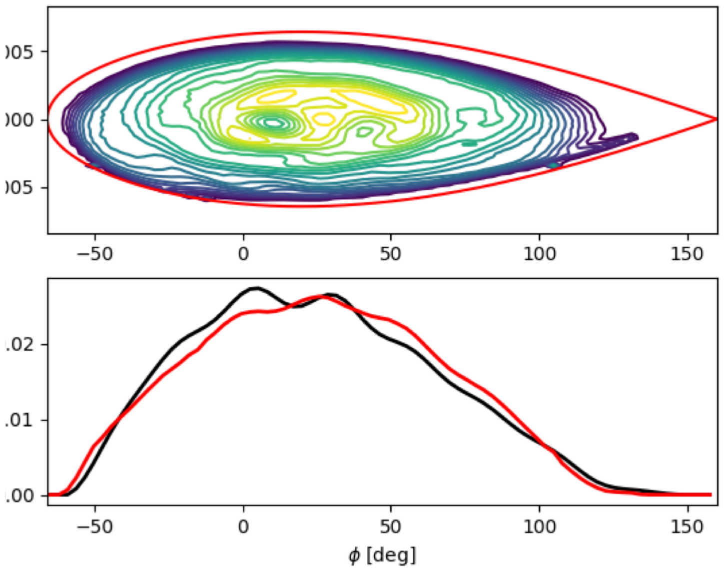
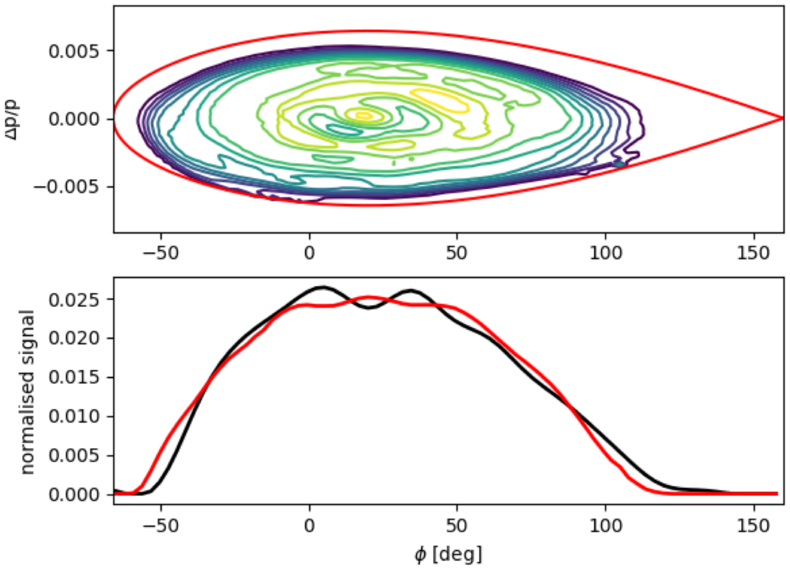
Tomography reconstruction – before transition



ramp turns = 100



ramp turns = 800



ramp turns = 3200

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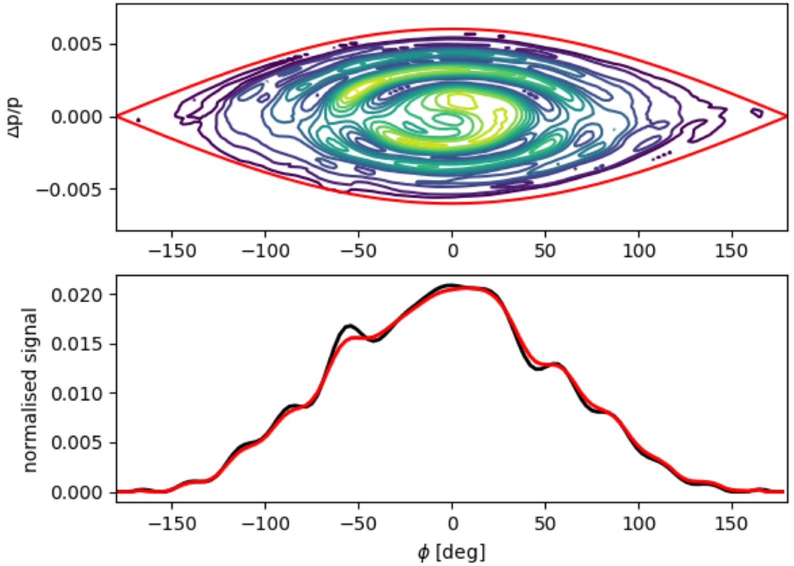
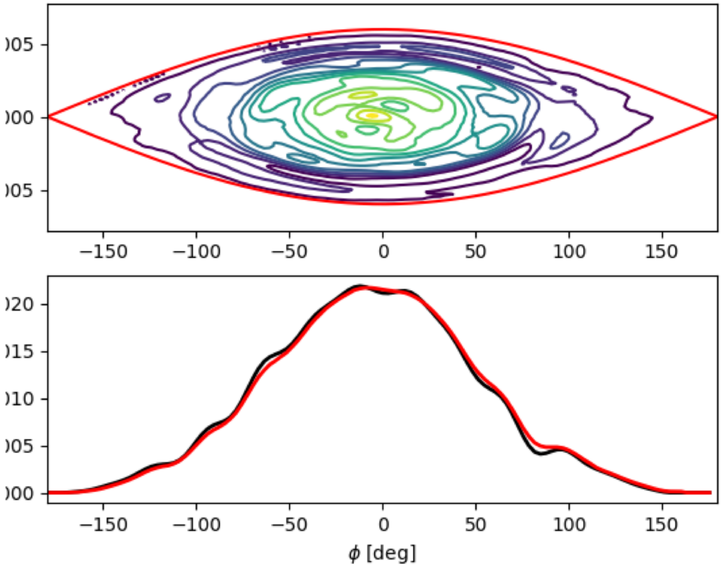
phi_s = 20 deg, V_rf = 4kV

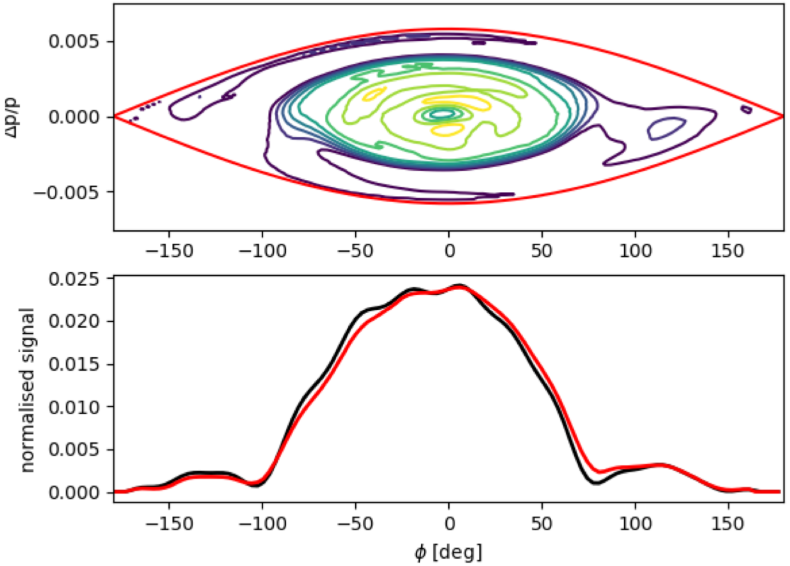
Tomography reconstruction – flat top 1



ramp turns = 100



ramp turns = 800



ramp turns = 3200

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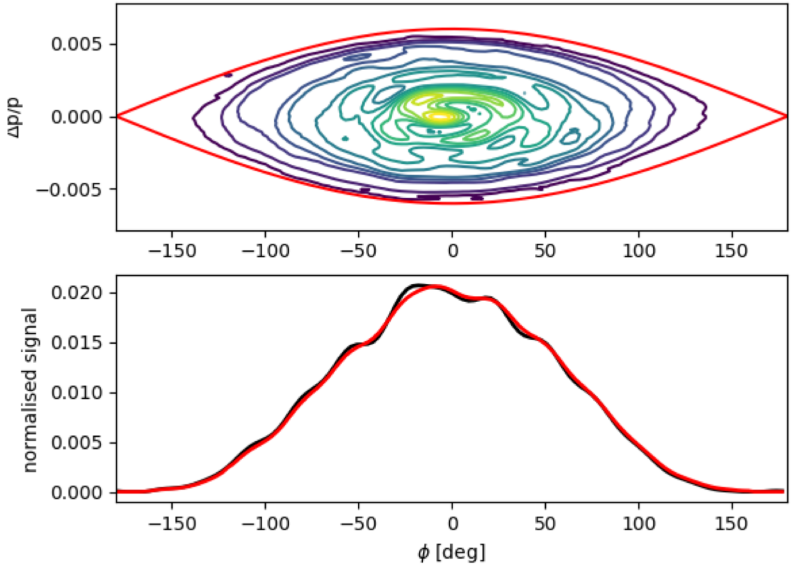
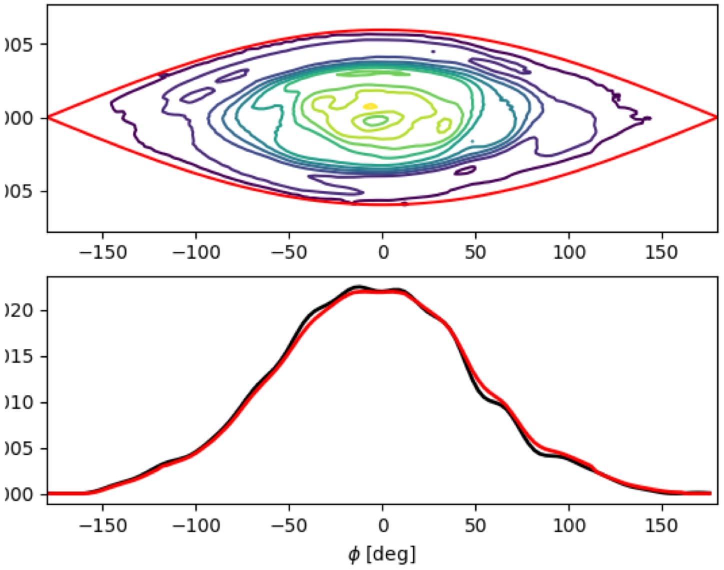
phi_s = 20 deg, V_rf = 2kV (based on gap voltage monitor)

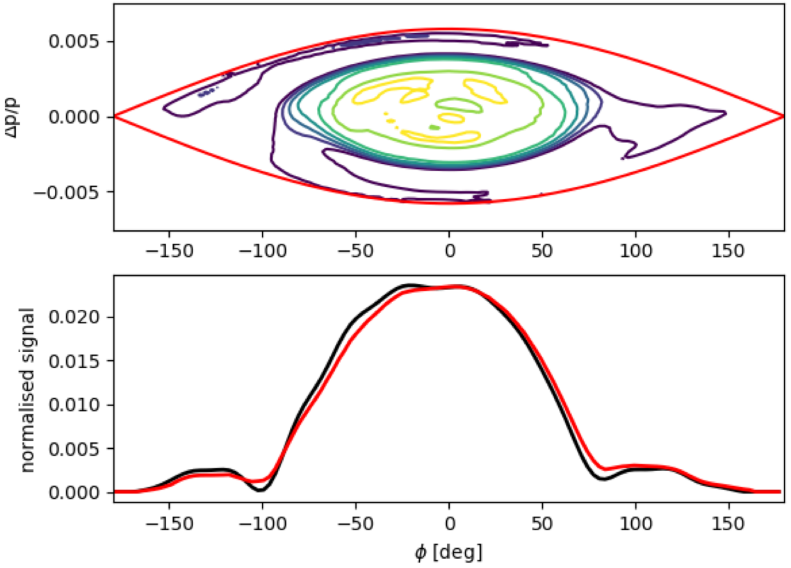
Tomography reconstruction – flat top 2



ramp turns = 100



ramp turns = 800



ramp turns = 3200

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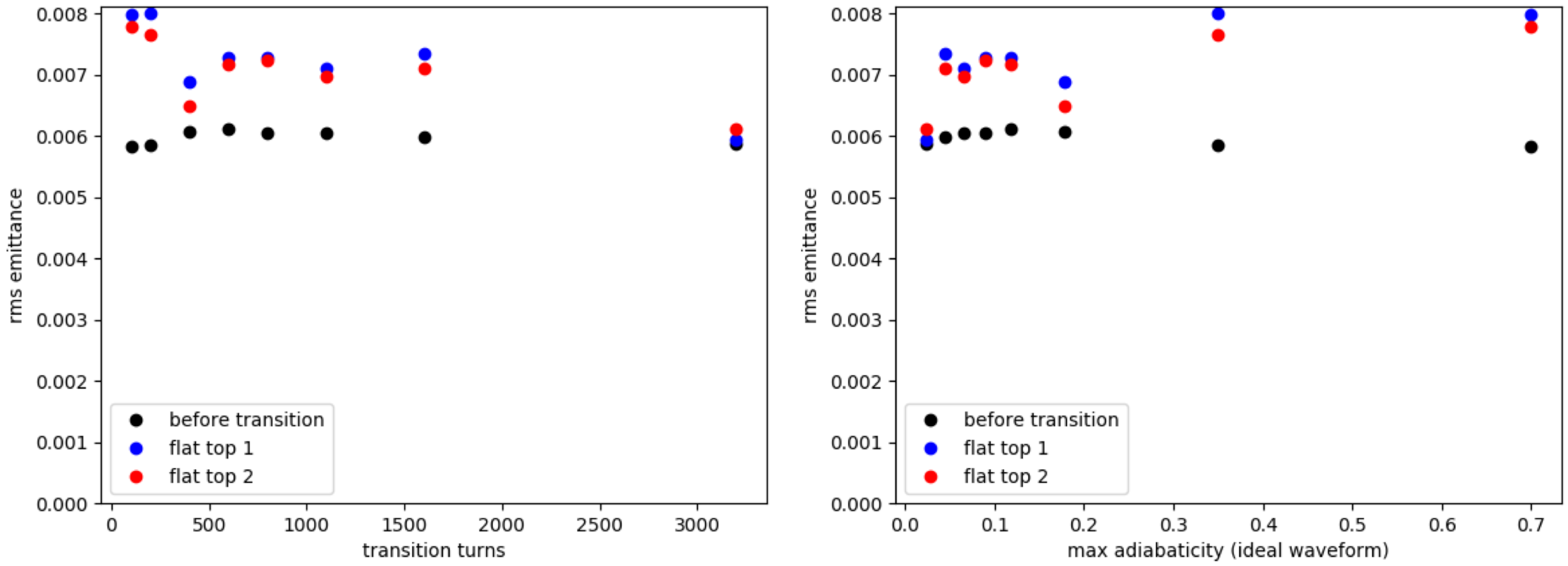
phi_s = 20 deg, V_rf = 2kV (based on gap voltage monitor)

Tomography – rms emittance



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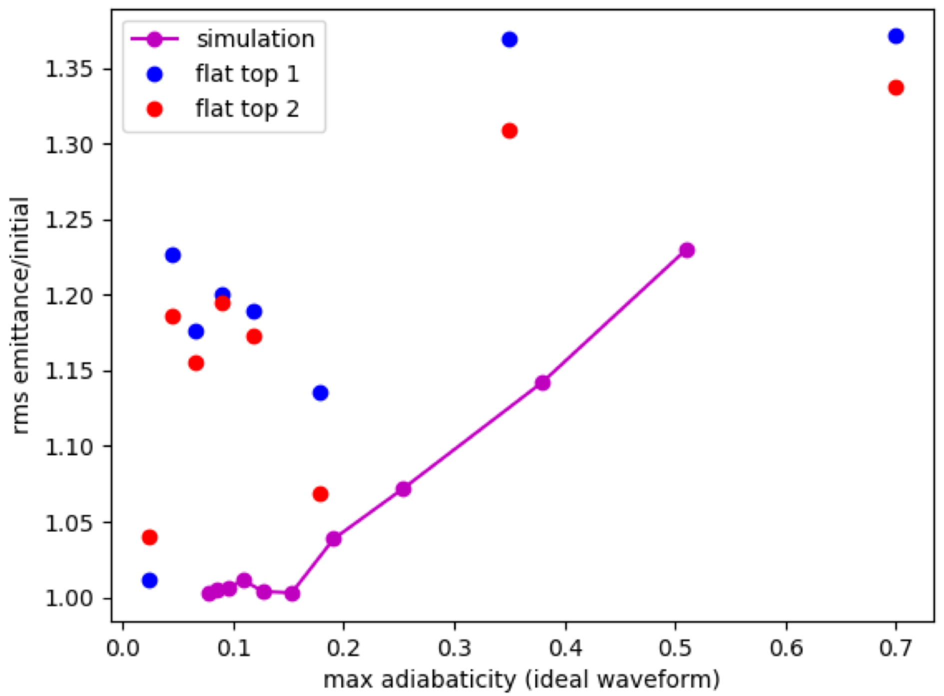
Comparison with simulation



- Simulation used PyHEADTAIL. Start with equilibrium distribution in with approximately same bunch length as measured distribution.

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Conclusions

- The flexibility of the RF waveform in FFAs make them an ideal tool to study longitudinal dynamics.
- More data and analysis needed to experimentally establish the relationship between adiabaticity and emittance growth.