Beam Stacking at KURNS

D. Kelliher, 8/9/2022

Phase displacement

- Accelerating bucket will cause, on average, a downward shift in the energy of the coasting beam it moves through (the opposite is true in the case of a decelerating bucket).
- In the adiabatic limit, the phase area moving downwards equals the bucket area moving up. This implies the following average shift in energy.

$$\Delta E_{shift} = \frac{\omega_0 A}{2\pi}$$

- In the adiabatic limit the total energy spread for n stacked beams is then $\Delta E_{total} = n\Delta E_{shift}$.
- This implies the capture voltage grows with n^2.

Scattering

- Consider the statistical distribution of scattering of individual particles by RF modulation. First treatment by Symon & Sessler at MURA^. Further developed at the ISR*. The rms momentum spread caused by the passage of single bucket is given by#.

$$\sigma_{single} = \frac{16}{(2\pi)^{3/2}}\Gamma(\phi_s)\sqrt{\frac{eVE}{h|\eta|}}$$

- Where $\Gamma = \sin \phi_s$. Note $\sigma_{single} = \Gamma A/(2\pi \alpha(\phi_s))$. For n stacked beams the total rms momentum spread is

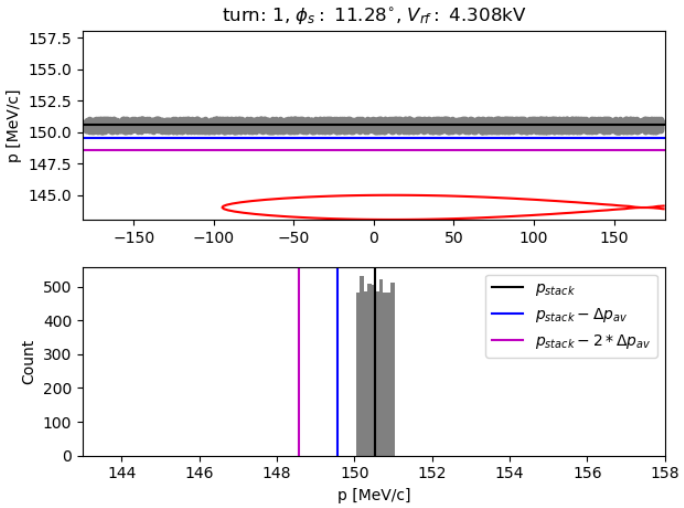
$$\Sigma_n = \left(\sigma_0^2 + n\sigma_{single}^2\right)^{0.5}$$

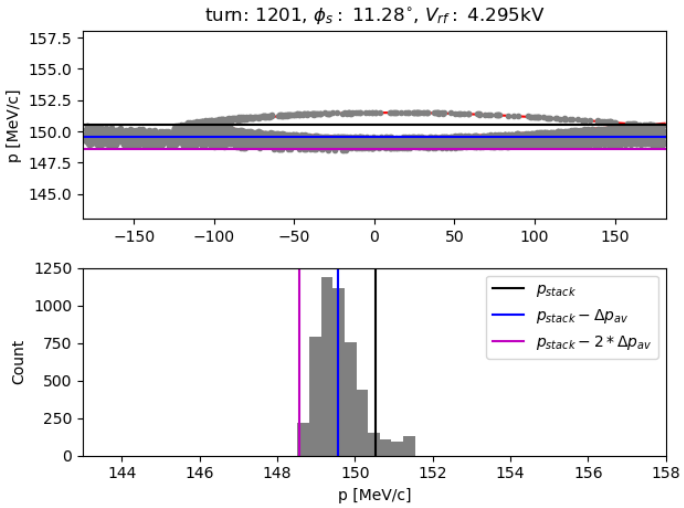
^ K. R. Symon and A. M. Sessler CERN Symposium on High-Energy Accelerators, 1956.

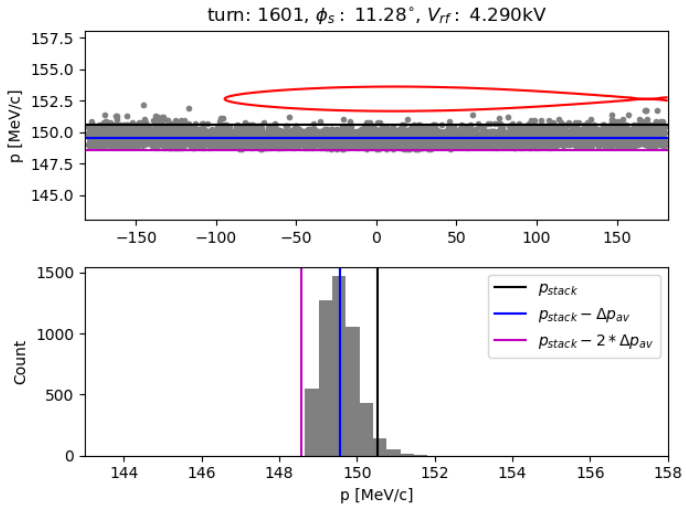
* E. W. Messerschmid, ”Scattering of particles by phase displacement acceleration in storage rings”, CERN/ISR-TH/73-31

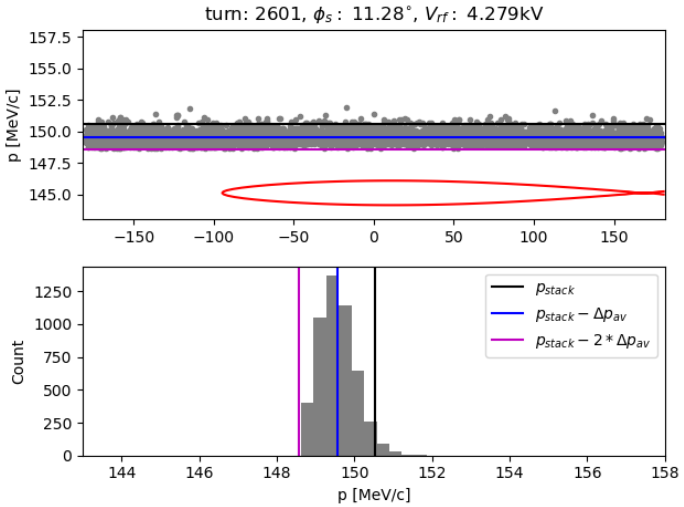
S. Watanabe et al, “Beam stacking experiments at the ion accumulation ring TARN”, NIM A271 (1988) 359-374

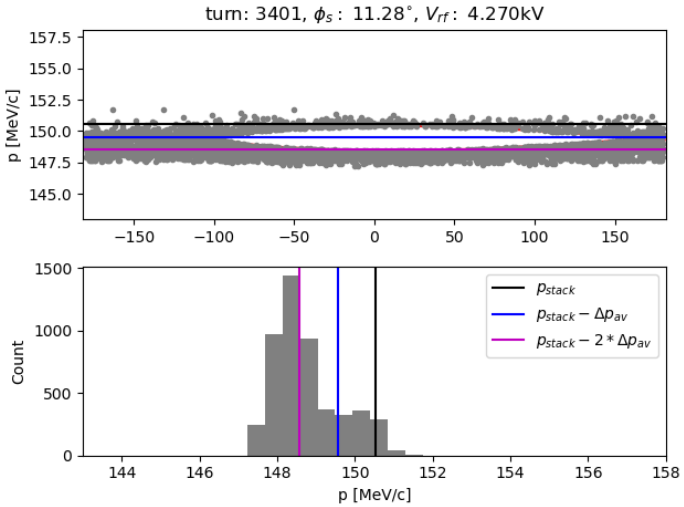
Empty buckets (accelerating)

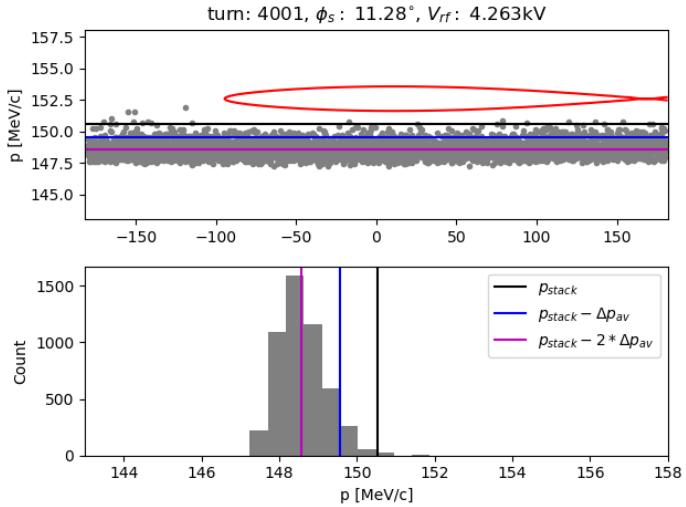




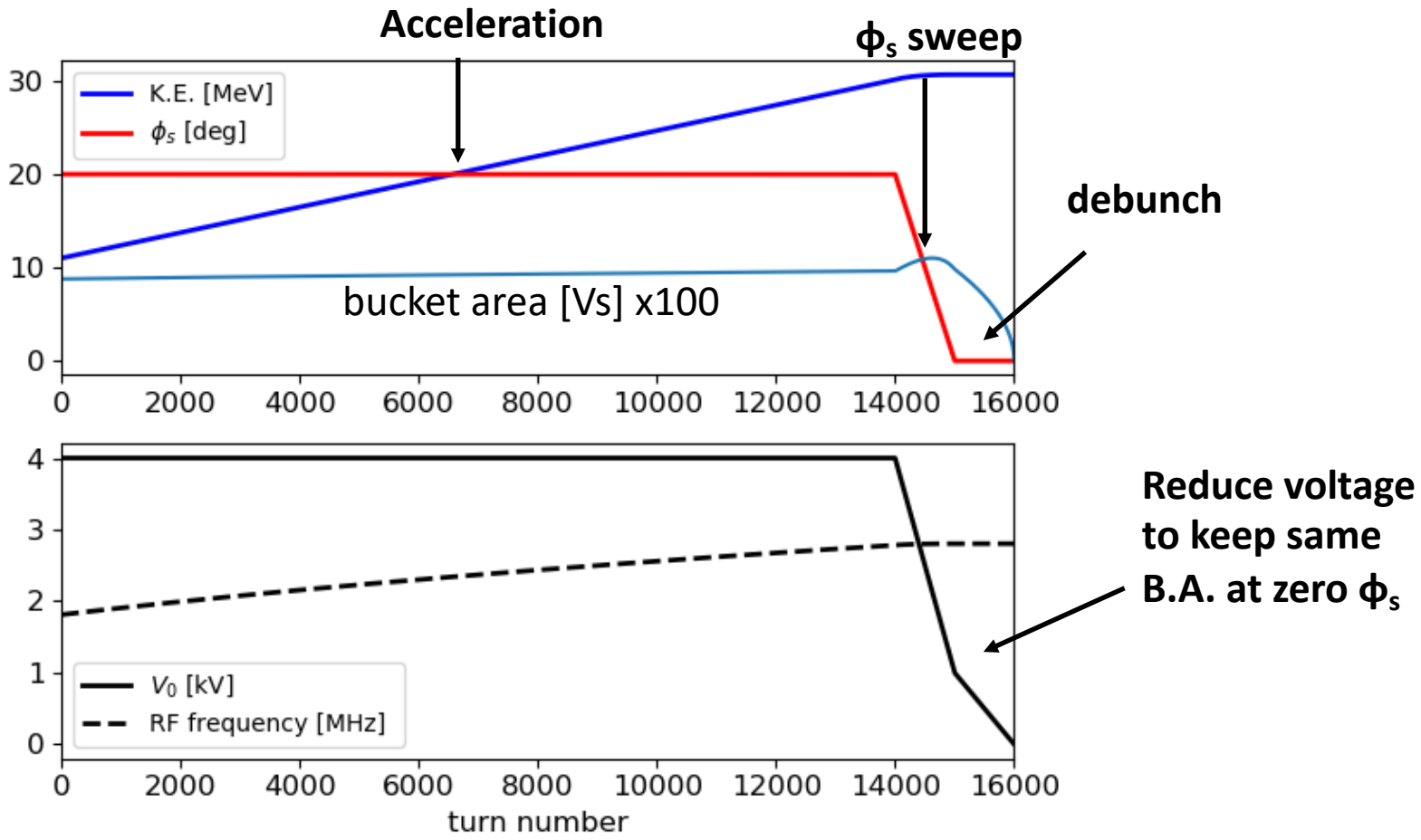








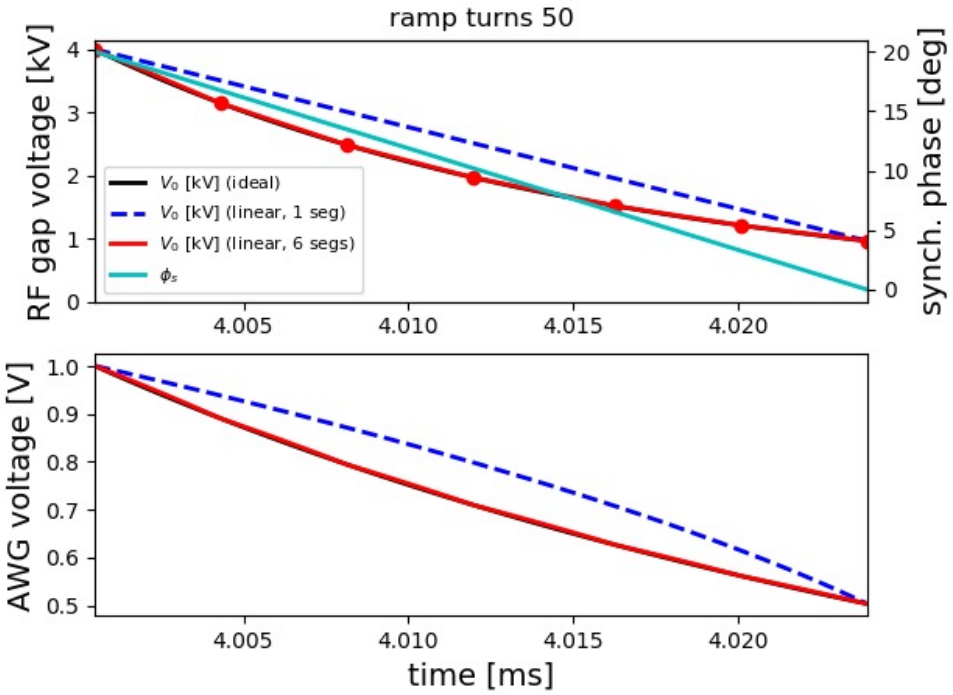
RF program to stack a beam at 30MeV

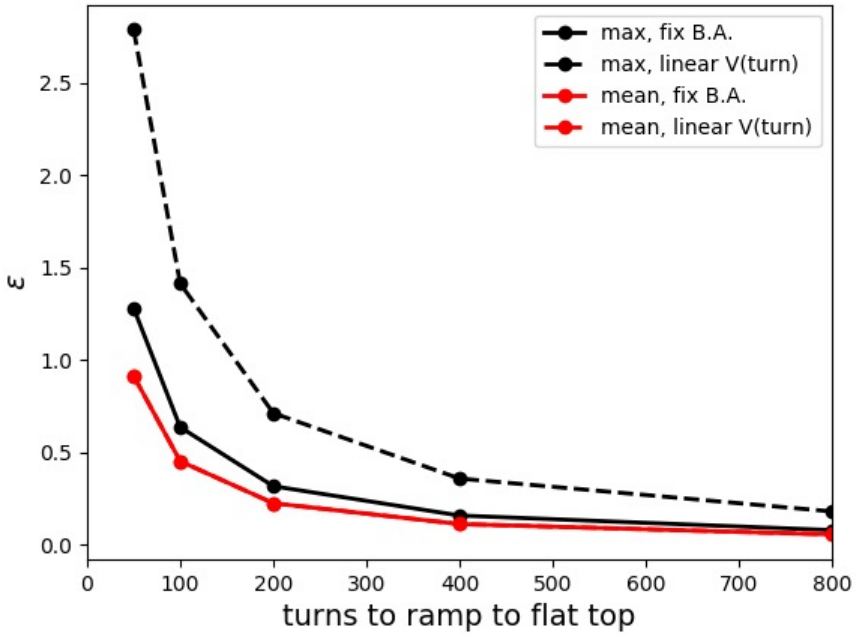


Repeat if stacking at the top. Reduce acceleration turns if stacking at bottom.
How slowly do we need to reduce synchronous phase?

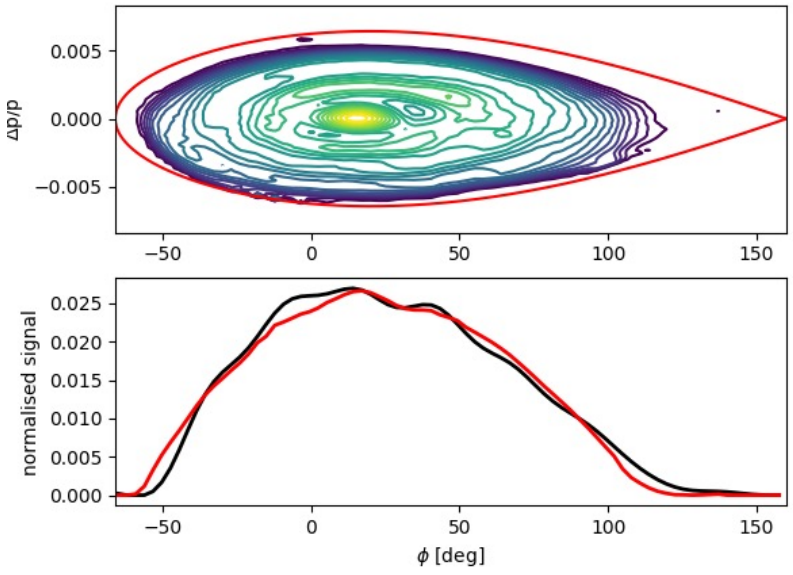
Adiabaticity experiment (2019)

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

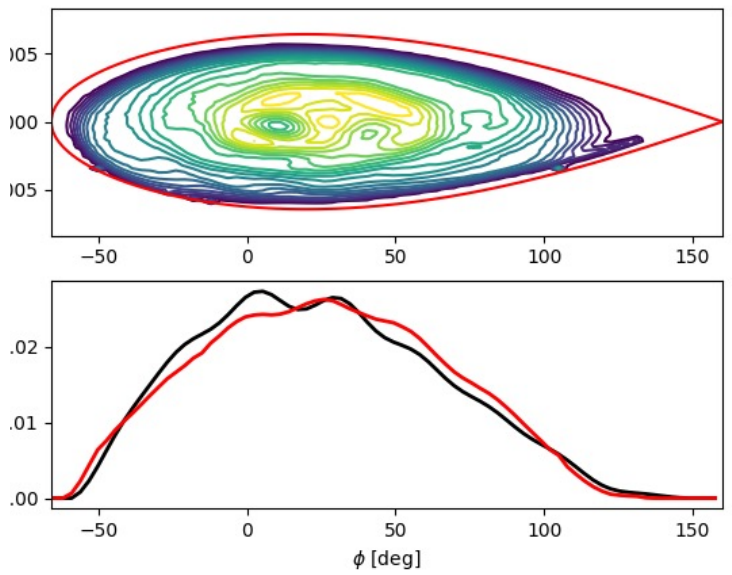




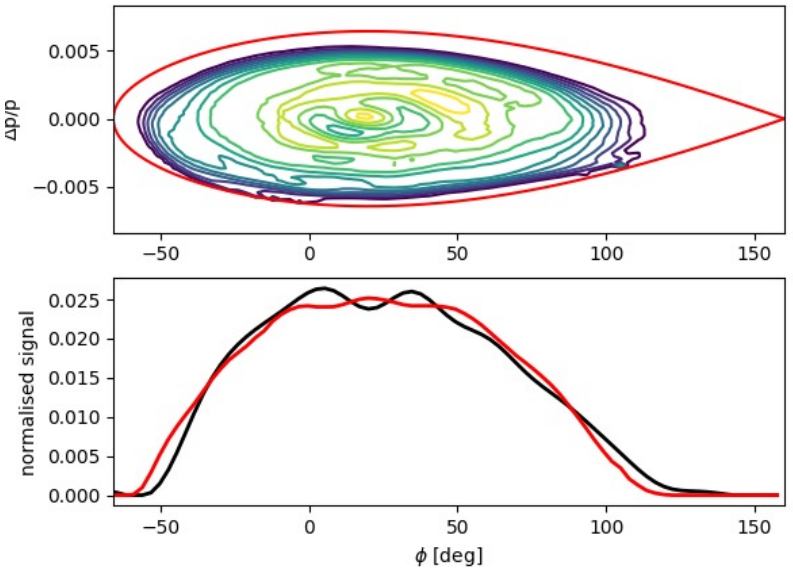
Tomography reconstruction – before transition



ramp turns = 100



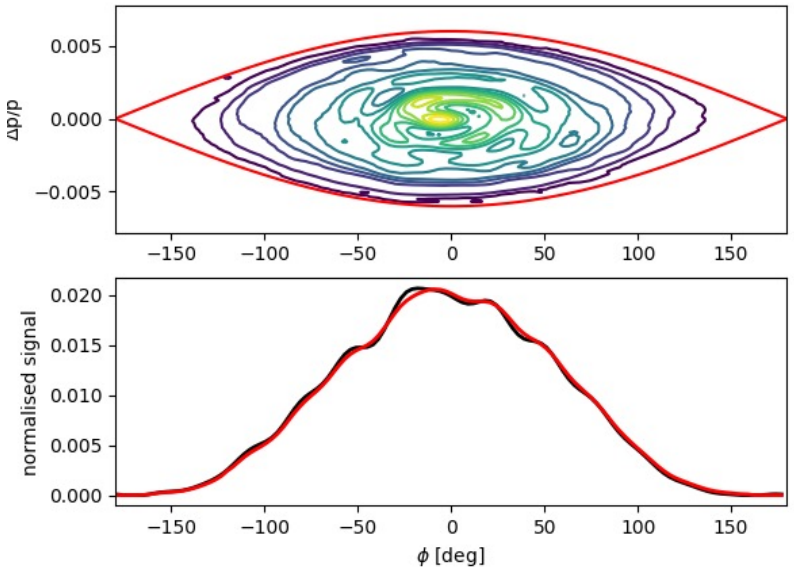
ramp turns = 800



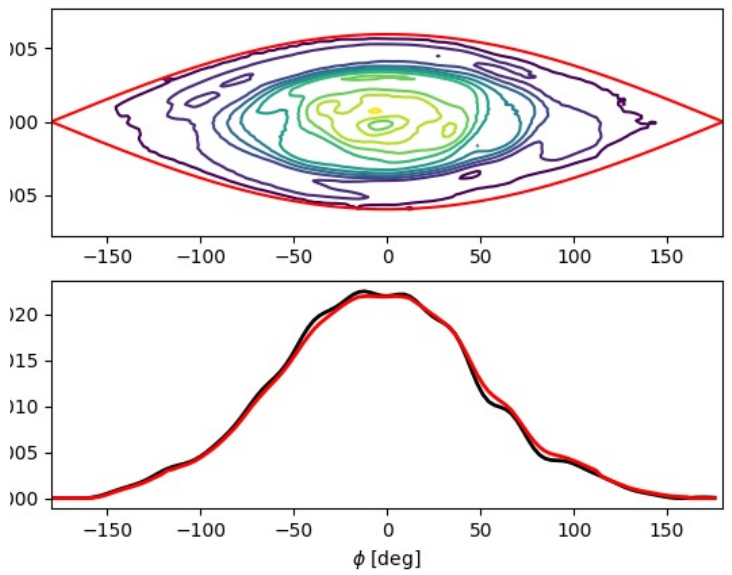
ramp turns = 3200

phi_s = 20 deg, V_rf = 4kV

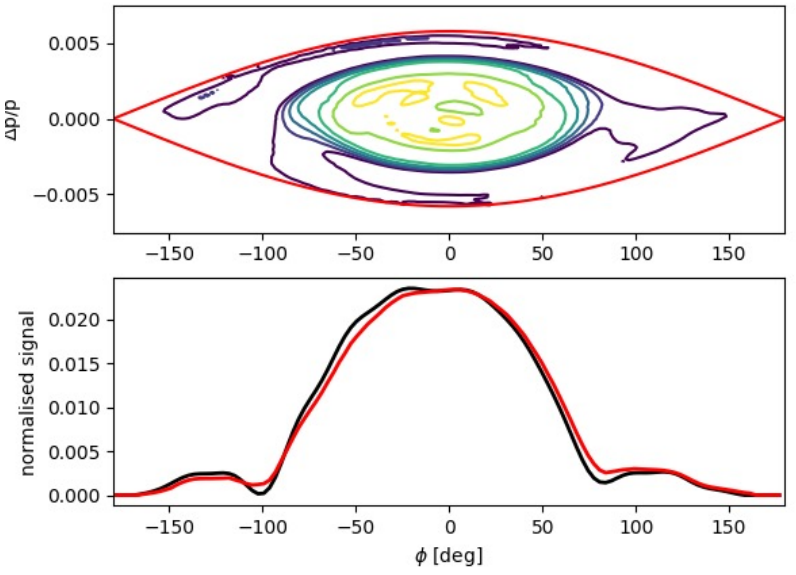
Tomography reconstruction – flat top 2



ramp turns = 100



ramp turns = 800



ramp turns = 3200

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

Tomography – rms emittance