Dynamic aperture at APS

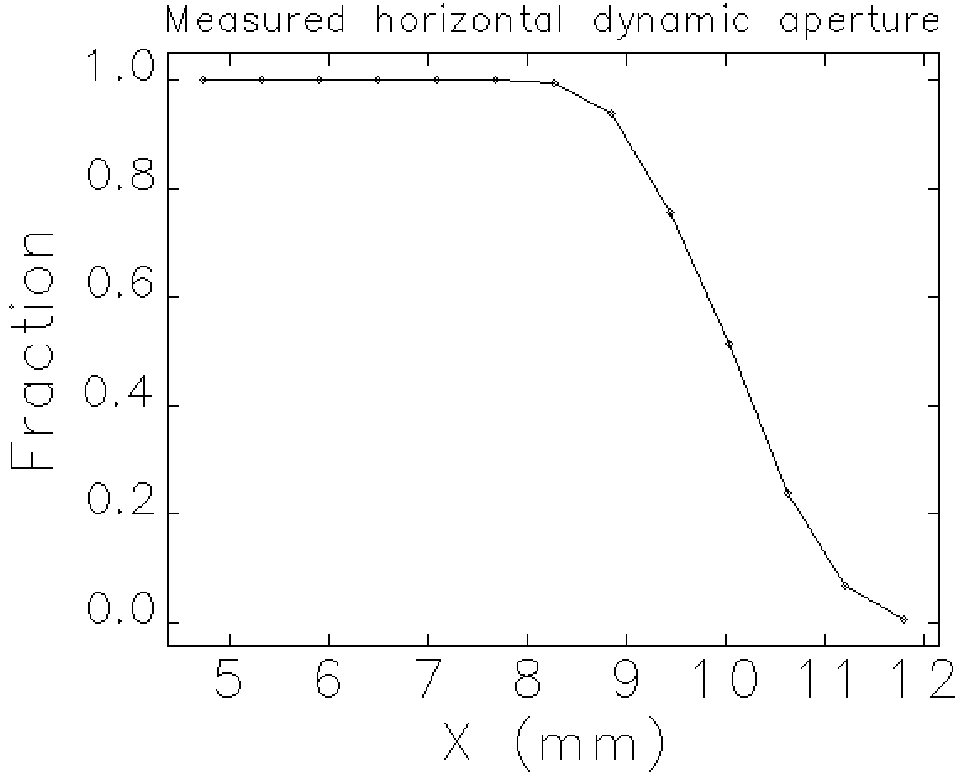
V. Sajaev, L. Emery

Measurements

- We have only horizontal kickers – we can only measure horizontal dynamic aperture
- We use current monitor to measure the current left after the kick (cannot distinguish between fast and slow losses)
- We use single-turn beam history to calibrate the amplitude of the kick

Measurements

- Measured dynamic aperture (an amplitude of 50% loss) is 10 mm

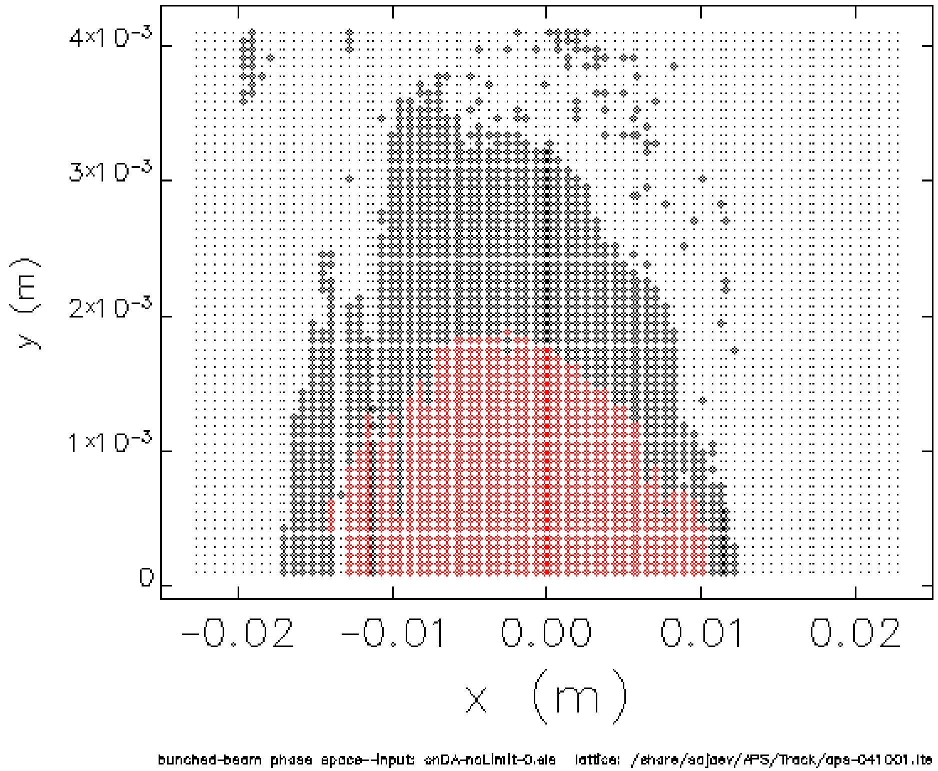


Calculations

- We use sdds-complaint `elegant`
- We use calibrated model
- We use all aperture limitations
- We use linux cluster, sdds toolkit and tcl-tk scripting. All this combined allows us to do fast and extensive calculations

Dynamic aperture calculation

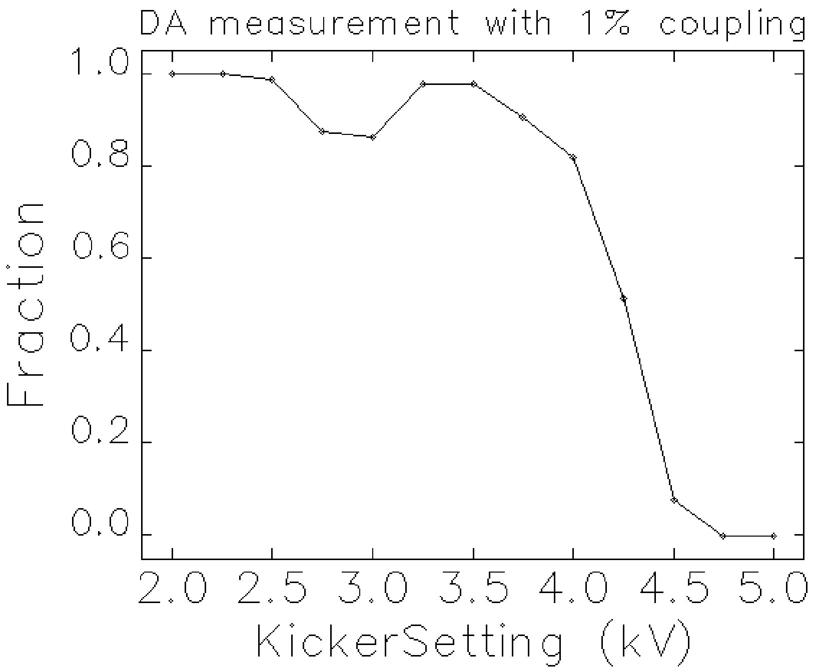
Black dots are tracked particles
Black symbols are stable particles with no aperture limitations
Red symbols are stable particles with aperture limitations

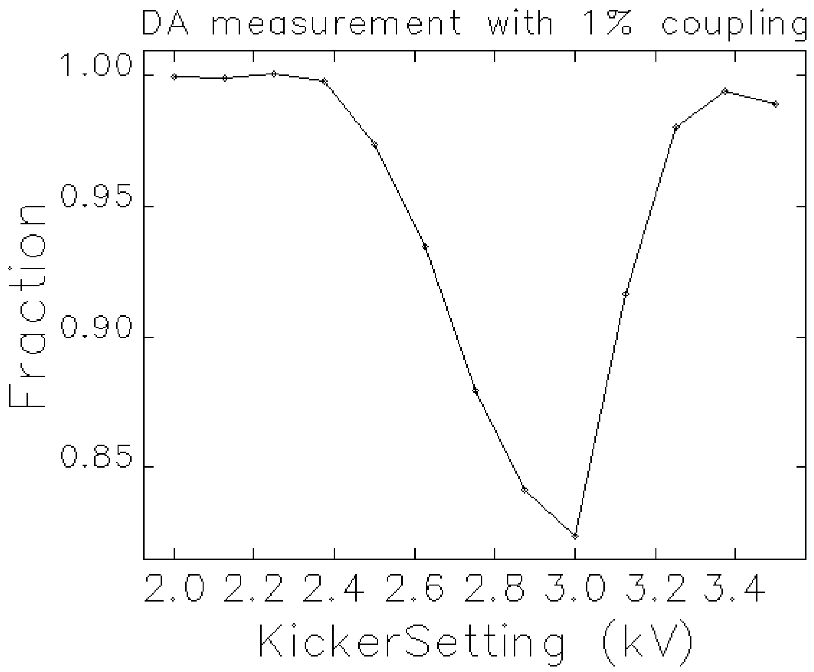


Calculated horizontal dynamic aperture is 10.5 mm

DA measurement with coupling

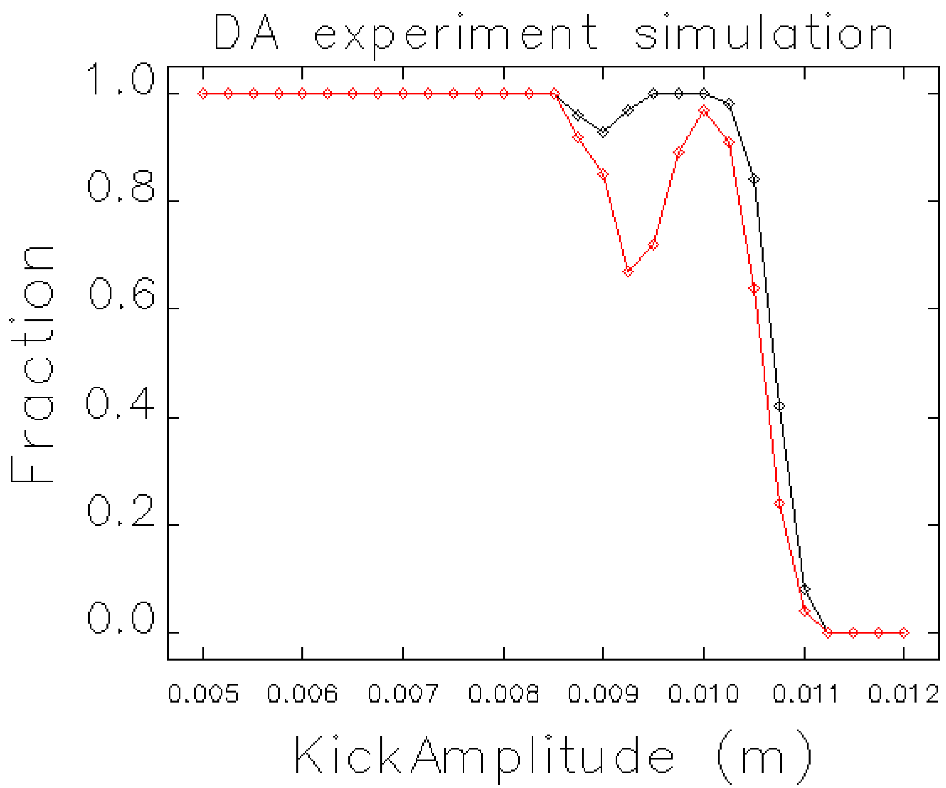
- Interesting dip observed during measurements with 1% coupling





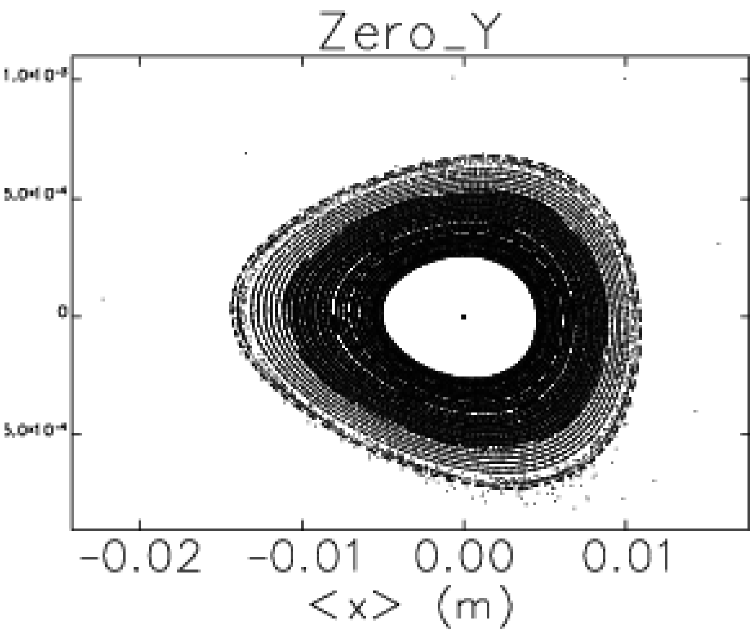
DA experiment simulation

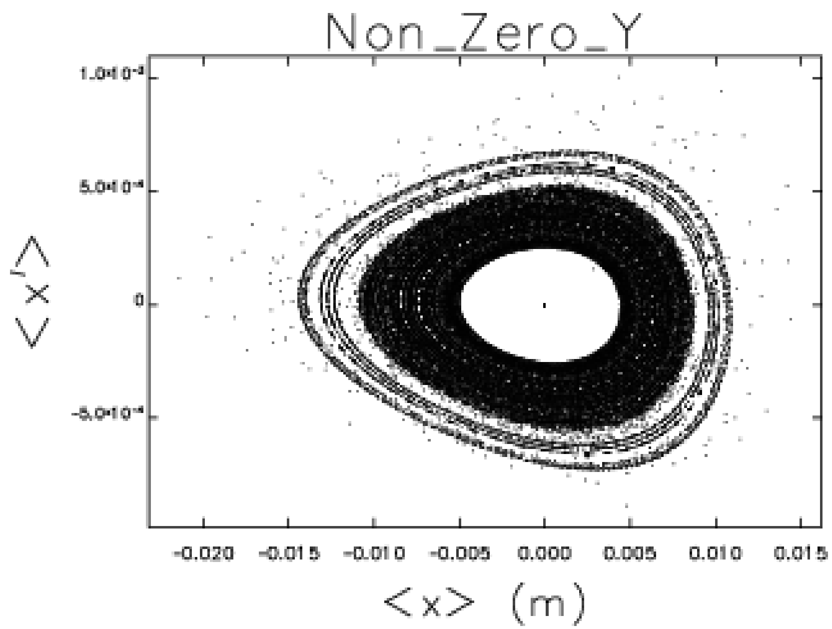
- In order to understand this effect, we simulate the kick measurement
- We use 100 particles per bunch and track for 1000 turns



Phase space

- Horizontal phase space with zero Y amplitude (left) doesn’t show anything special
- Horizontal phase space with small Y amplitude (right) shows unstable trajectories around X amplitude of 8 mm





Nonlinear detuning

- Tracking shows that vertical nonlinear detuning with horizontal amplitude causes vertical tune to cross integer resonance ν_y=19
- Due to fast decoherence, it is difficult to directly confirm this in experiment
- MIA refined measurements were used by C.-X. Wang to calculate the detuning using decoherence rate some time ago – they were in correspondence with simulations

Lifetime and topup

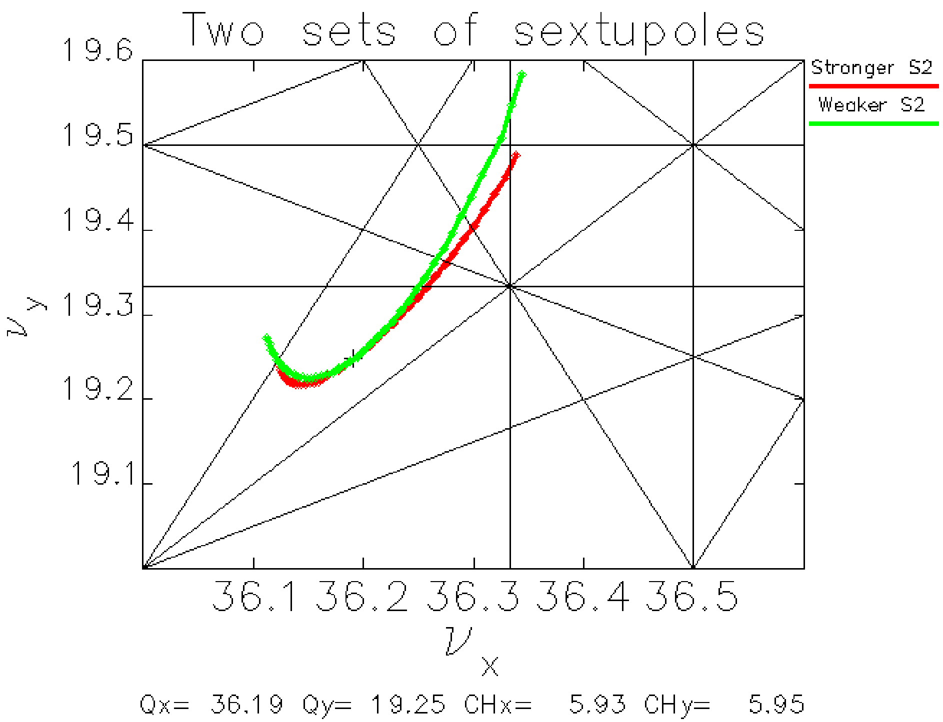
- Topup does not remove lifetime problem
- Minimum possible lifetime is defined by injection charge and topup interval
- For APS the maximum injection charge is 3 nQ and injection interval is 2 minutes – this gives the lifetime limit of about 5 hours
- To maintain lifetime of 6 hours in the low-emittance lattice at 100mA in 24 singlets, we had to run with 2.8% coupling

Rearranging sextupole families for lifetime increase

- APS has 4 families of sextupoles
- Strengths of sextupole families came from earlier high emittance lattice
- Experimental scan to increase lifetime was not successful
- Dynamic aperture optimization using tracking didn't give big benefit within limits of power supplies
- A new script to perform standardized nonlinear calculation for different lattices was written for different purpose. That script helped us to find a simple way to improve the lifetime

Lifetime increase

- We found that with our present sextupole scheme the working point hits 19.5 at dp/p=0.016
- By increasing S2 family (S3 and S4 were used to keep chromaticity) we increased that to dp/p=0.019



This change combined with small tune change and small optimization of RF voltage allowed us to lower our coupling to 1%

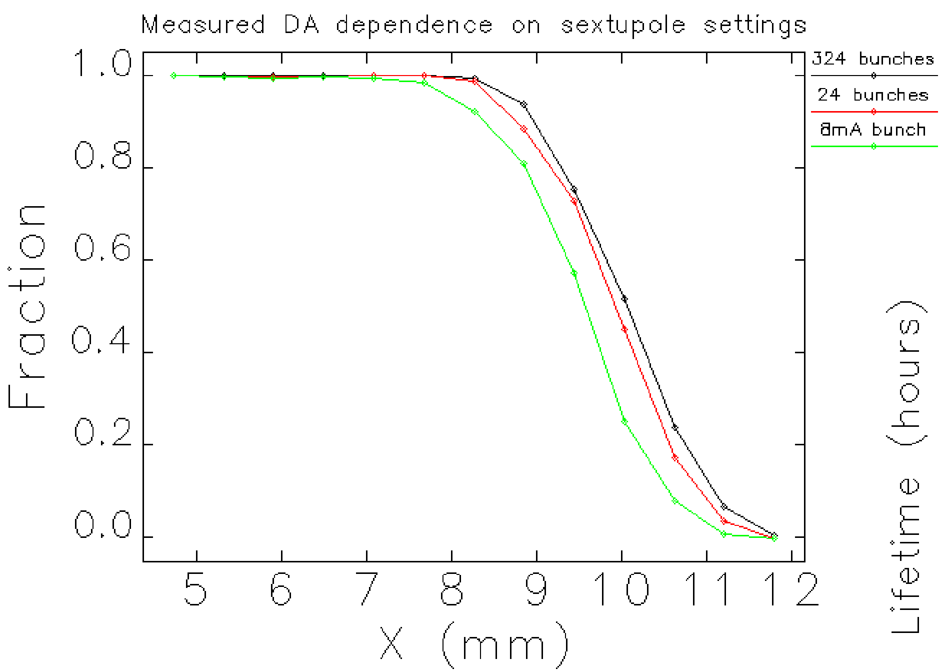
Operation modes

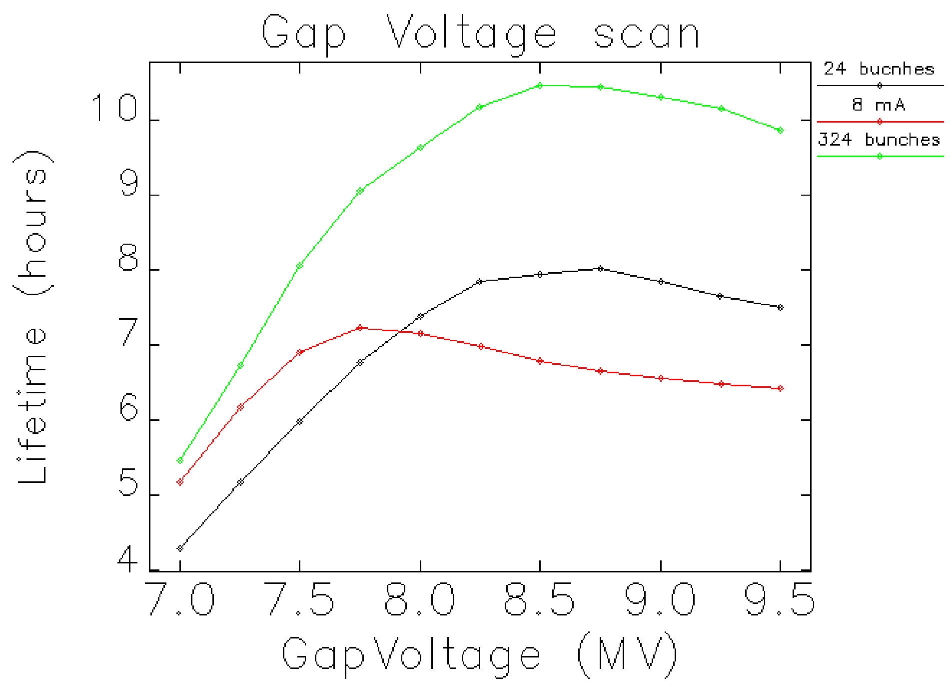
- APS now has 3 operating modes (100mA always):
- Standard operation mode – 24 singlets, topup
- Non-topup mode – 324 bunches
- Hybrid mode – 8 mA single bunch + 8x7 bunch train on the opposite side of the ring

Operation modes

	Chrom X	Chrom Y	dp/p ν_y=19.5 limit
24 singlets	6.0	6.0	0.019
324 bunches	3.0	5.0	0.022
8 mA	9.5	9.0	0.016

Dynamic aperture for different modes





Conclusions

- In general, we have a good correspondence between dynamic aperture measurements and simulations
- Tracking with calibrated model and with real aperture limitations is important
- Fast calculations are useful, they allow us to quickly test many different ideas. Fast calculations are achieved by combining parallel processing with sdds toolkit and tcl/tk scripting