Improving Beam Stability in the APS Booster

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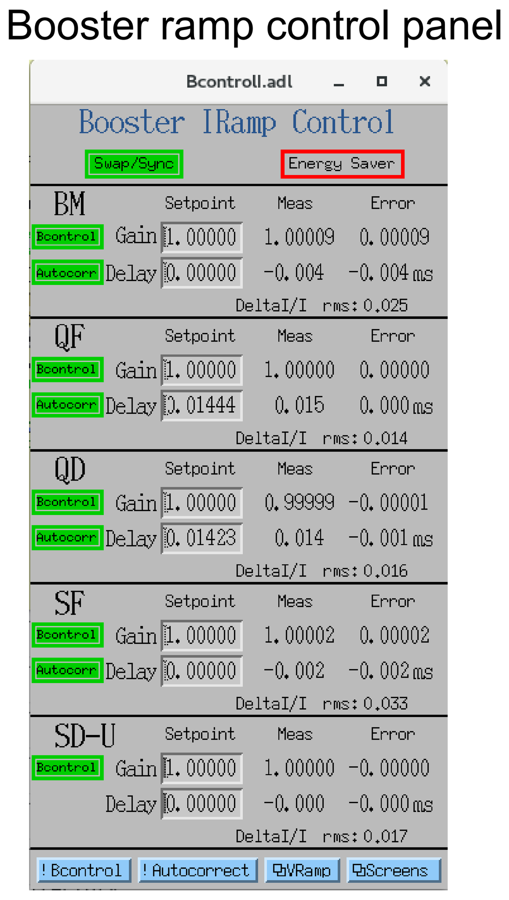
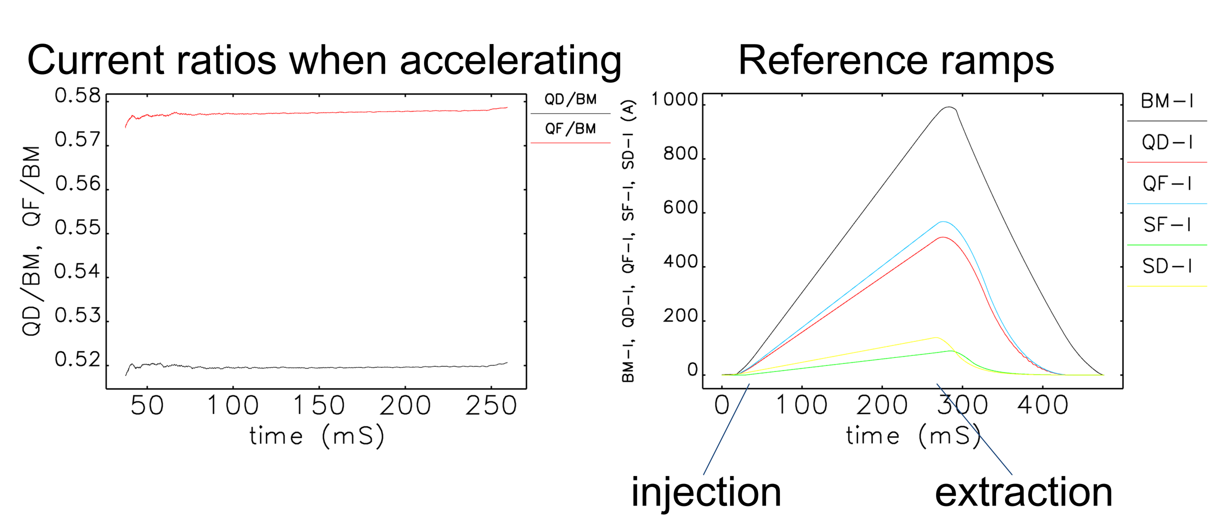
Abstract

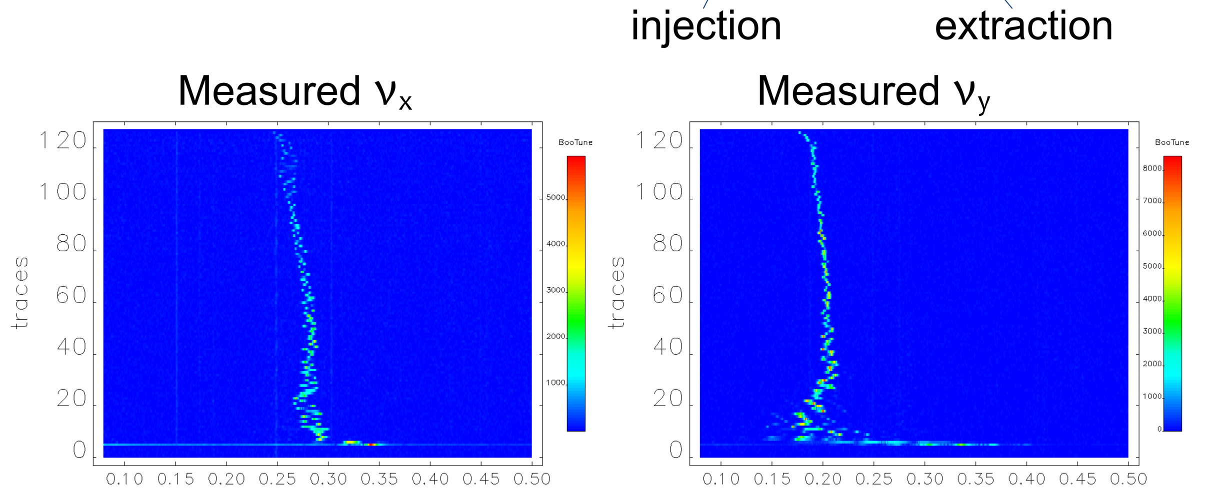
The tune instability in booster synchrotron has been a problem since the starting of the APS. The designed tune (oscillation frequency divided by revolution frequency) in x and y directions are respectively 11.75 and 9.8. The tune instability affects the emittance of the beam as well as the transport efficiency. Thus, it is critical to make the tunes as constant as possible throughout the acceleration in booster. Simulations of the beam behavior were performed, and a few experiments were done to verify the result. Several options for mitigating the tune swing were also investigated.

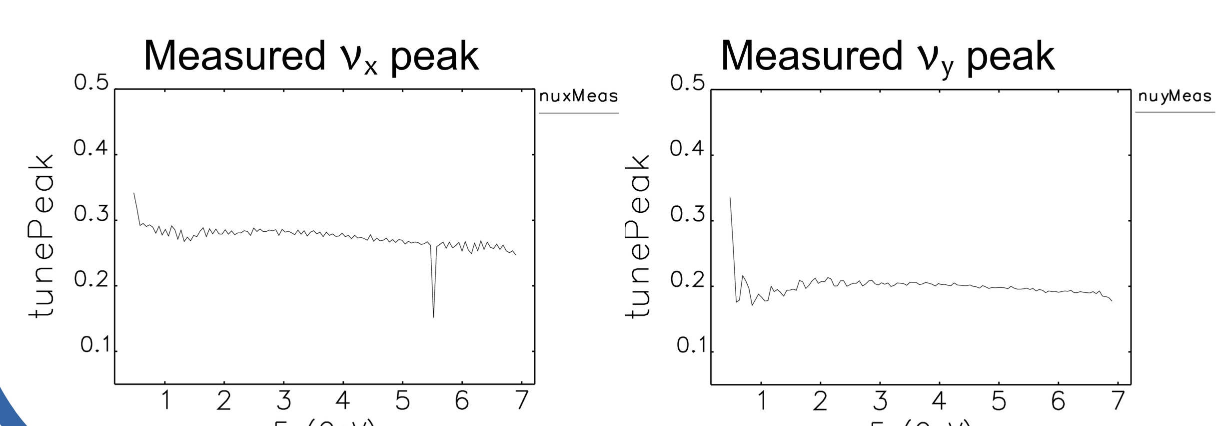
Experimental Data

The beam is transversely manipulated by dipole (BM), quadrupole (QF and QD) and sextupole (SF and SD) magnets, which are ramped as the beam is accelerated. These ramps can be controlled by "gains" and "delays" from a panel[1] in the control room. The fractional parts of the tune in the x and y directions under default conditions are shown below.







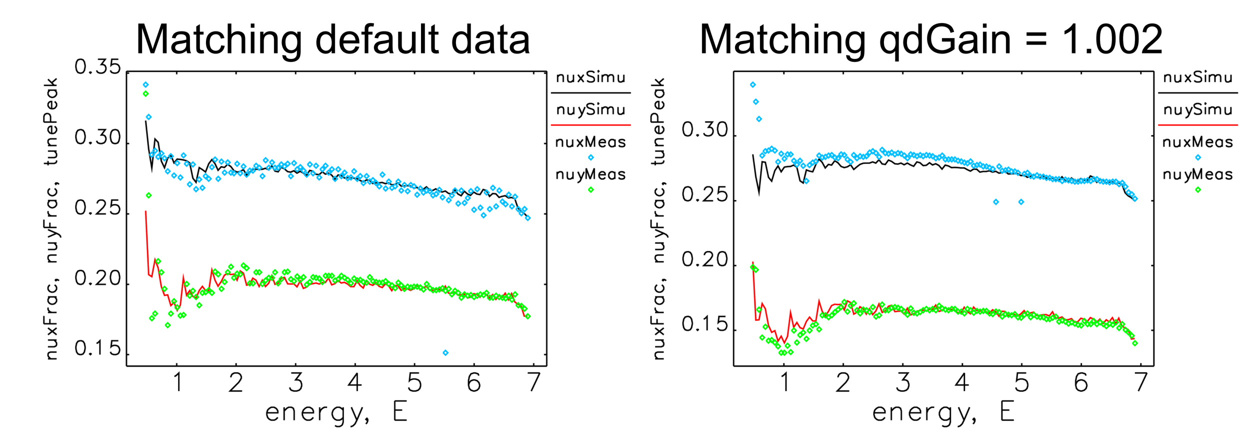


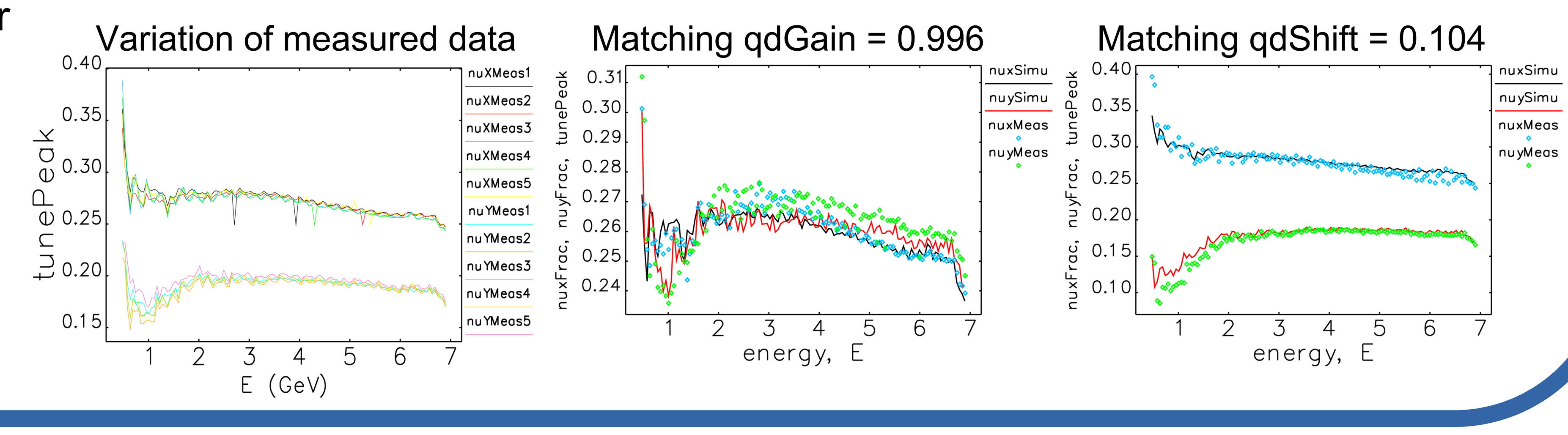
Simulation

I. Match with BM. Matching energies with dipole magnetic fields at injection time and extraction time.

II. Match with QD and QF. Find parameters for using elegant[2] for particle tracking simulation and "greedy-like" algorithm to find a good fit for quads parameters.

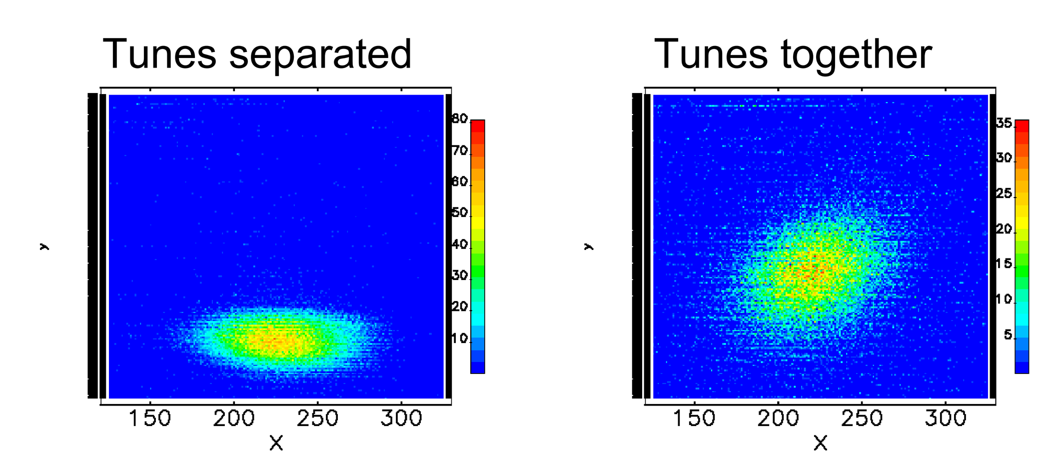
III. Verify the tunes. Change to different quads parameters and compare with experiments. Good predictions were made.





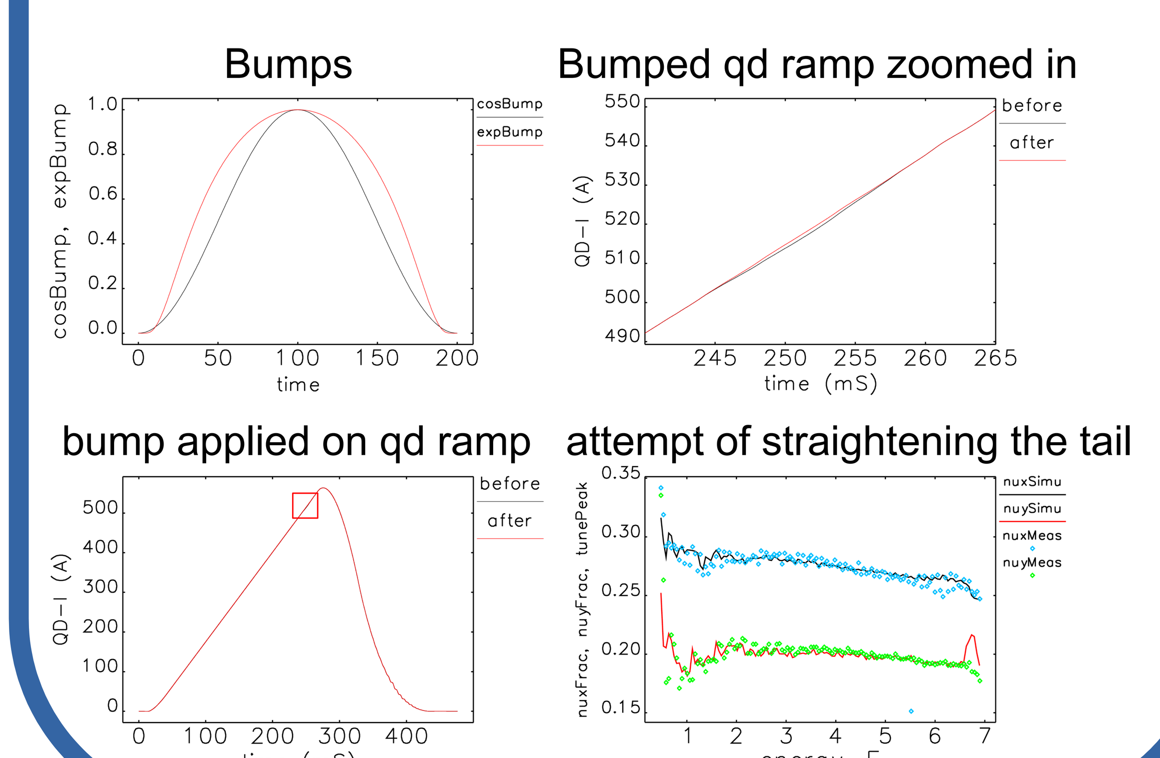
Interactions between ν_x and ν_y

When the fractional tunes are brought close together (qdGain = 0.996), the vertical emittance is blown up and the horizontal emittance is slightly reduced, which is desired for the injection of the storage ring.



Modifying Reference Ramp

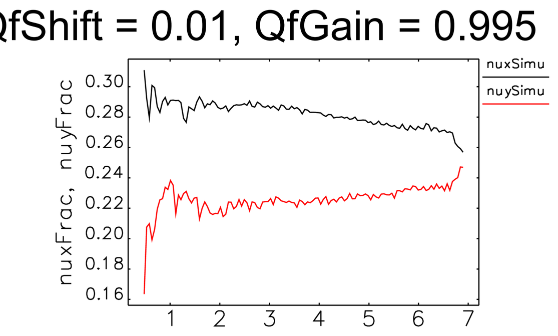
Proof of principle of fixing the tunes by manipulating the reference ramp file.



Future Work

- Using machine learning, generically find better parameters to fit the data; includes consideration of sextupole[3].
- Better calculation of field strength parameters for dipole due to eddy current effect[4].
- To examine the feasibility of moving ν_y from 9.8 to 9.2 at high-energy portion.
- To continue trying to modify quadrupole ramp to get more stable tunes.

QdShift = 0.12, QDGain = 0.964, QfShift = 0.01, QfGain = 0.995



References

[1] C. Yao, H. Shang, S. Xu, and G. Fystro. "A new ramp correction process for booster main supplies." Technical Report OAG-TN-2014-033, Accelerator Division, Advanced Photon Source, June 2014.
[2] M. Borland. "elegant: A flexible sdds-compliant code for accelerator simulation." Technical Report LS-287, Advanced Photon Source, September 2000.
[3] C. Yao and H. Shang. "Chromaticity measurement of the APS booster." In Proceedings of 2012 Beam Instrumentation Workshop, pages 225–227, 2012.
[4] N. Sereno and S. Kim. "Eddy-current-induced multipole field calculations." Technical Report LS-302, Advanced Photon Source, September 2003.