FAST TUNE MONITORS AND FEEDBACK IN THE TEVATRON, RHIC AND LHC

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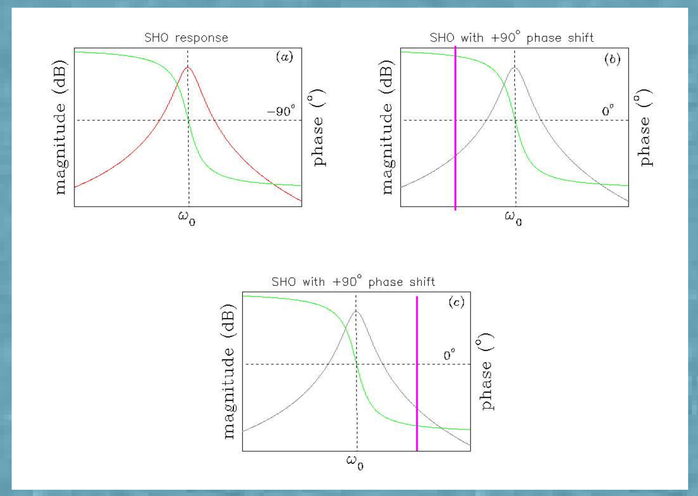
INTRODUCTION

Fast tune monitoring and feedback will be essential for the successful commission and operation of the LHC. As part of the US-LARP (LHC Accelerator Research Program) collaboration, Fermilab, Brookhaven and CERN have been actively looking into this for the past few years.

The fast tune monitoring adopted by all the collaborating laboratories is based on exciting the beam transversely and then phase locking to the null of the phase response. This monitoring technique has been successfully commissioned and used routinely both in the Tevatron and RHIC. The accuracy of this technique is better than 0.0001 and the tune measurement rate can be >100kHz but the data return rate is limited by the handshake overhead and ethernet bandwidth.

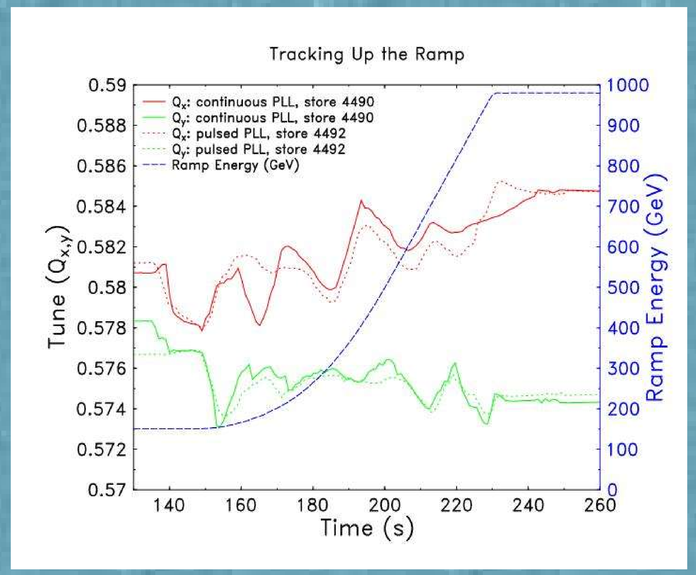
Successful tune feedback has been recently demonstrated at RHIC. Two keys to this success were the implementation of a coupling feedback loop which decoupled the beam in real time and a new tune detector called the 3D-BBQ (Direct Diode Detector Base Band Tune) invented at CERN.

TUNE TRACKING TECHNIQUE



As a demonstration of the tune tracking technique. Let us look at the frequency response of a simple harmonic oscillator (SHO) shown in (a). The peak of the resonance is when the excitation phase is -90° out of phase with the SHO. (b) shifts this phase by +90° so that at resonance, the phase difference is zero. If the excitation is too low (pink line), the phase difference is positive and so we must increase the excitation frequency. If the excitation frequency is too high, the phase difference is negative (c). Thus by measuring the phase difference and tracking zero phase, we can track the betatron tune.

TUNE TRACKING IN THE TEVATRON



This plot shows the tunes being tracked for consecutive stores 4490 and 4492 using continuous and pulsed excitation. The pulsed excitation technique smooths out the phase response of the synchrotron lines in the betatron tune.

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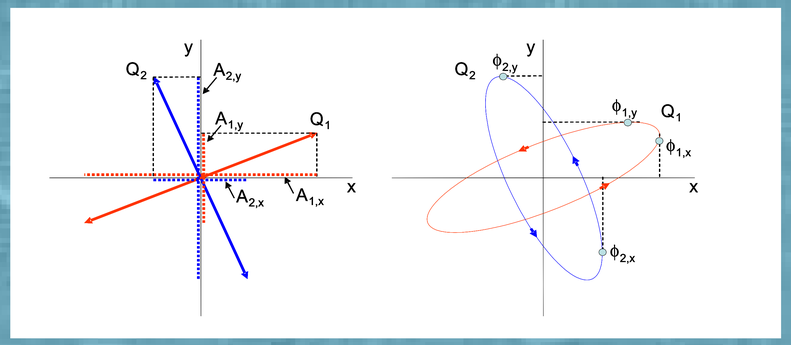
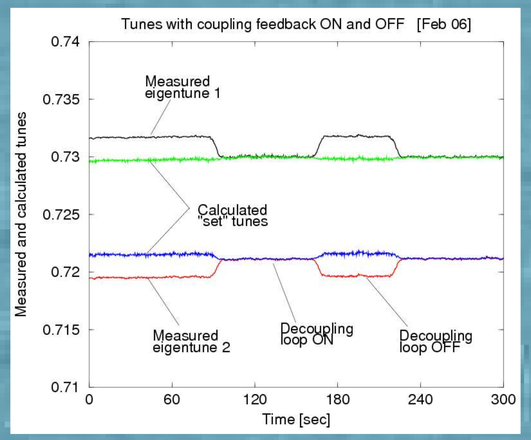
DECOUPLING IS ESSENTIAL FOR TUNE FEEDBACK

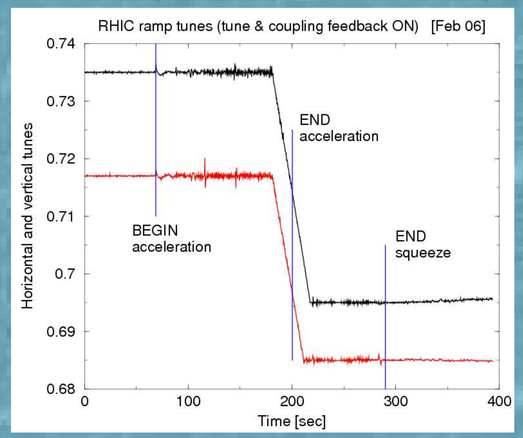


This picture shows the two eigenmodes rotated due to coupling. The figure on the left shows the projections of each mode which are in phase. The figure on the right shows the more general case when coupling introduces a phase shift.

Coupling breaks tune feedback because when the eigenmodes are rotated by more than 45° eigenmode Q_1 which was the horizontal tune becomes the vertical tune. (Similarly for Q_2). Thus the wrong set of tune quads will be used to correct the tune.

SUCCESSFUL COUPLING AND TUNE FEEDBACK AT RHIC





These pictures show the successful implementation of coupling feedback (left) and tune feedback at RHIC (right). Before coupling feedback is turned on, the measured and "set" tunes are separated because of coupling. Once the feedback loop is on, there is essentially no difference between the two. For the ramp and squeeze, with tune feedback and coupling feedback on, the tunes lie on the designed tunes.

CONCLUSION

With the demonstration of fast tune monitoring at the Tevatron and at RHIC and more importantly tune and coupling feedback at RHIC, the US-LARP collaboration has delivered essential technology that will benefit the LHC commissioning. Currently, better optimizations of the tune feedback loops are being looked into at both BNL and Fermilab. For the future, the collaboration will be looking into chromaticity monitoring and feedback using this technology.

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