Tune Measurement at the Tevatron

C.Y. Tan

Fermi National Accelerator Laboratory, P.O. Box 500, Batavia, IL 60510, USA

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Betatron tunes in the Tevatron are measured primarily with two instruments: the 21.4 MHz and the 1.7GHz Schottky systems. Two other instruments are currently being worked on as secondary instruments: the 3D-BBQ (direct diode detection baseband tune) system which is a copy of the system to be used at the LHC, and a direct digitization technique which gives very fast bunch by bunch tunes.

1. INTRODUCTION

The Tevatron is a single beam pipe machine which contains both protons and anti-protons for HEP. This poses a challenge for measuring betatron tunes because of the possibility of contamination from the other species. In order to overcome this problem, stripline type structures are usually used because they are directional by construction or for the case of the 21.4 MHz Schottky system, a clever method is used to distinguish between the two. In the Tevatron, tunes are measured primarily with two instruments: the 21.4 MHz and the 1.7 GHz Schottky systems. Two other systems currently in development are the 3D-BBQ (direct diode detection baseband tune) system and a direct digitization technique which gives very fast bunch by bunch tunes.

2. 21.4 MHz Schottky System

The 21.4 MHz Schottky system is the workhorse for measuring betatron tunes. This detector was installed in 1989 and is the oldest of all the tune measuring devices used in the Tevatron. This detector is the default standard for measuring proton tunes despite its limitations because historically it was the only detector available. To distinguish protons from anti-protons, the signals from two resonant structures are electrically combined. See the paper by J. Marriner:


Despite this, the proton signals contaminate the anti-proton signals and so in order to see the anti-proton tunes, the anti-protons have to be excited. Furthermore, because of its high $Q$, it is not possible to gate individual bunches at the detector. However, by gating the kick instead, individual anti-proton tunes can be measured. This gated kick method cannot be used for the protons because the unkicked signal is already strong enough to produce a tune spectrum.

Other references to the 21.4 MHz Schottky system are:


3. 1.7 GHz Schottky System

This detector was installed in 2002. It was a breakthrough detector for the Tevatron because it was designed to be able to see anti-proton tunes without excitation and to measure individual bunch tunes.

1 Email address: cytan@fnal.gov
This detector is a slow wave waveguide structure which has directivity and designed with a low $Q \sim 20$ so that individual proton and anti-proton tunes can be gated and measured.

References for the 1.7GHz Schottky system are:


4. 3D-BBQ System

This system in the Tevatron is similar to the one that will be installed at the LHC. The novelty of this system lies in the electronics which at its heart is a diode detector. It uses a stripline pickup so that the proton and anti-proton signals can in principle be distinguished. Presently, it is an R&D project funded under US LARP. This system is presently not operational, but is being worked on by a student.

A reference for the 3D-BBQ System is:

5. Direct Digitization

This system is called the “Digital Tune Monitor” at Fermilab. It uses direct digitization of the transverse signal from a standard beam position monitor stripline. Unlike the other systems which in principle do not need any beam excitation, this system requires kicks to the beam transversely in order to get the signal above noise floor. The advantage of this system is its speed in getting tunes of individual bunches because it digitizes all the bunches at every turn, compare this with the gated systems which looks at one bunch for many turns and then goes on to the next bunch. Presently, it is an R&D project and is not operational.

A reference for the digital tune monitor is:

6. COMPARISON

A comparison between all the detectors is shown in the table below. A summary of all the detectors are in the talk associated with this report:
<table>
<thead>
<tr>
<th>Detector</th>
<th>Injection</th>
<th>Ramp</th>
<th>Flattop</th>
<th>Squeeze</th>
<th>Bunch by Bunch</th>
<th>Coupled Tunes</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>21.4 Mhz</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>1.00E-004</td>
</tr>
<tr>
<td>1.7 Ghz</td>
<td>Y</td>
<td>?**</td>
<td>?**</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>1e-3 to 1e-4</td>
</tr>
<tr>
<td>3D-BBQ</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>1.00E-004</td>
</tr>
<tr>
<td>Tune Monitor</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>1.00E-004</td>
</tr>
</tbody>
</table>

*For 3D-BBQ tunes at collisions S/N gets really poor

**For 1.7GHz, tunes tend to either disappear or look coherent when going up the ramp and squeeze. The accuracy of 1e-3 is for single bunch mode and 1e-4 is for average mode.

The digital tune monitor has not been demonstrated to work up the ramp and squeeze.