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The characteristic of thebeam position growth in CSNS/RCS

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Abstract

An instability of the beam position growth is observed in the beam commissioning of the Rapid Cycling Synchrotron of the China Spallation Neutron Source. To simplify the study, a series of measurements have been performed to characterize the instability in the DC mode with consistent energy of 80 MeV. The measurement campaign is introduced in the paper and it conforms to the characteristics of the coupled bunch instability.

INTRODUCTION

China Spallation Neutron Source (CSNS) is a high intensity proton accelerator based facility. The Rapid Cycling Synchrotron (RCS) is the core of the CSNS. The RCS accumulates and accelerate proton beam from 80 MeV to 1.6 GeV with the repetition rate of 25 Hz. The maximum voltage offered by eight cavities is 165 kV with a maximum synchronous phase of 45 degrees. The RCS beam commissioning finished in 2020. Due to the high beam intensity and high repetition rate, the beam loss must be controlled to a very low level. The impedance and instability were estimated [4]. The kicker impedance and the resistive wall impedance were studied [5,6]. A growth of the turn-by-turn (TbT) beam position of the AC mode was unfortunately [7]. To simplify the study, a series of measurements have been performed to characterize the instability in the DC mode with consistent energy of 80 MeV and it is introduced.

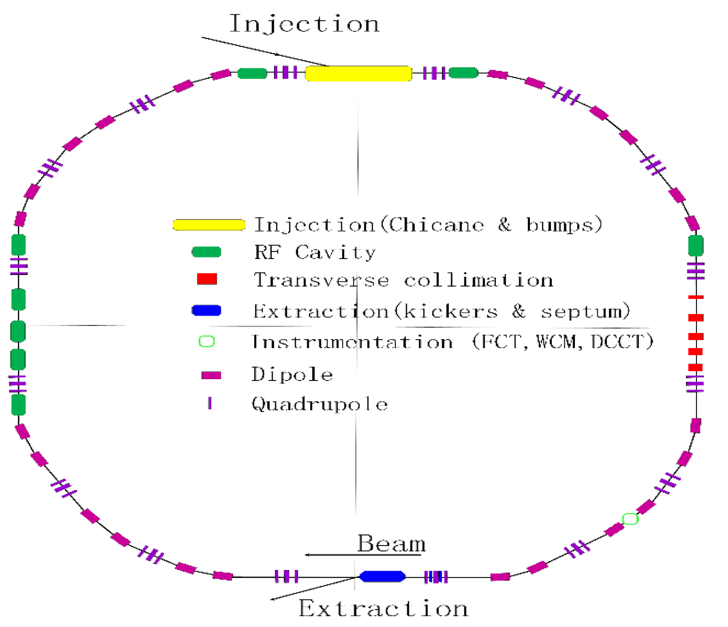

Fig 1: The RCS layout

Parameters	Values
Circumference/m	227.92
Inj/ext Energy/(MeV)	80/1600
Tunes(H/V)	4.86/4.78
Repetition rate/Hz	25
Particle Number	$1.56*10^{13}$
Bunch proton	7.8E12

Table 1: The RCS main parameters

Stainless steel：4 kΩ/m@inj, 2.5 kΩ/m@ext
Copper shield(H)：1.1 kΩ/m@inj, 0.7 kΩ/m@ext
Copper shield(V)：1.4 kΩ/m@inj, 1.0 kΩ/m@ext
TiN-ceramic（H/V）: 0.9/1.2 kΩ/m

Hor: 6 kΩ/m@inj, 4.1 kΩ/m@ext
Ver: 6.6 kΩ/m@inj, 4.7 kΩ/m@ext

RCS impedance

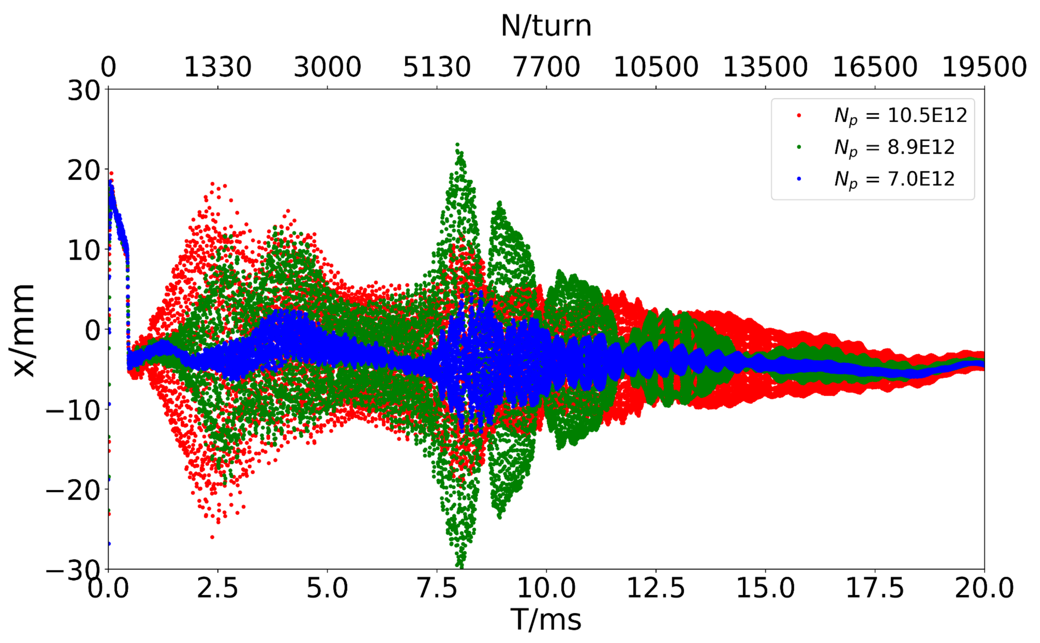

Fig 2: The growth of the beam position in the AC mode

DEPEND ON THE INTENSITY

Sets of measurements were taken for different beam intensities with the nominal tune and the natural chromaticity. double bunches and single bunch are measured. The TbT position is related to the number of the protons. The growth time with the beam power of 100 kW is about 1 ms. The growth is also observed for the single bunch. The threshold is about 7E12. With same beam power, the growth for two bunches with different bunch protons is slower than that of the same bunch intensity. Same with the position in horizontal plane, the growth in vertical plane is also observed as the beam intensity increasing.

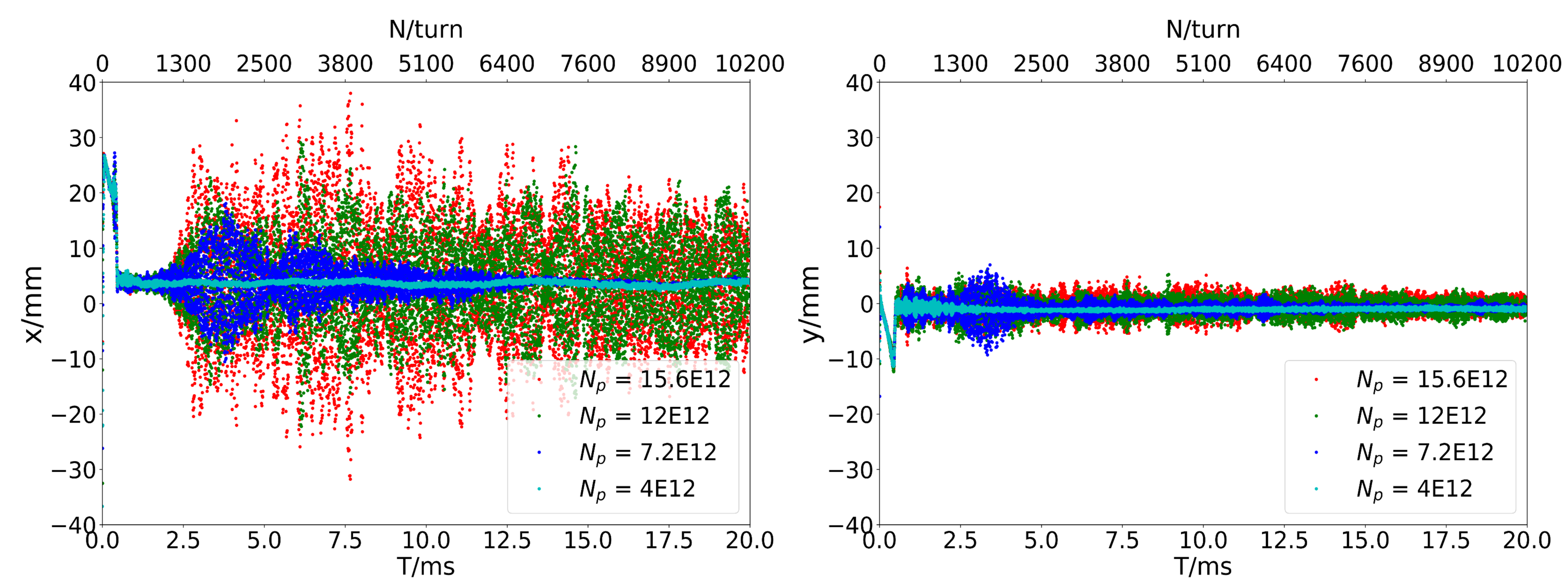

Fig 3: The TbT beam position in the RCS is a function of the beam intensity. The tune is the nominal tune with natural chromaticity and two buckets are filled.

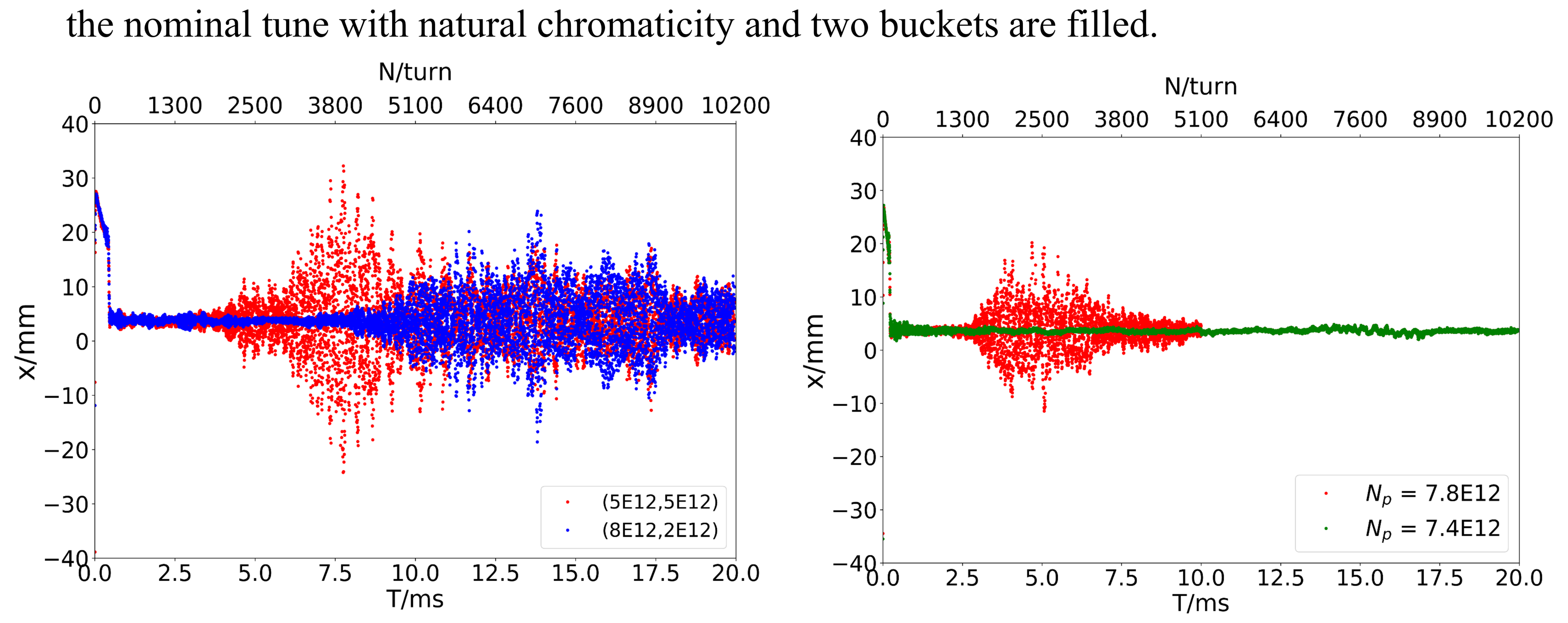

Fig 4: The left shows the beam position for the double bunches with different bunch protons for the nominal tune with the natural chromaticity of 65 kW. The right shows that the beam position is changed with the bunch protons increasing the for the single bunch.

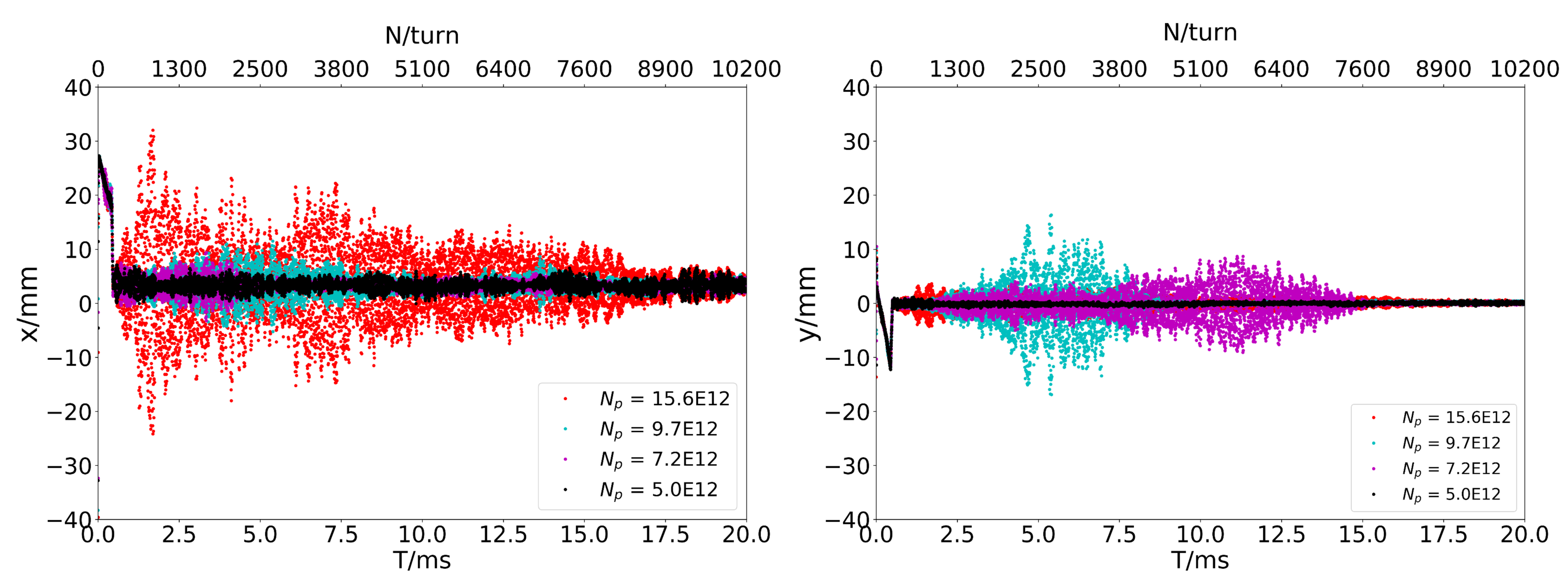

Fig 5: Measured the TbT beam position for the double bunches with different bunch protons for the tune of (4.78, 4.83) with the natural chromaticity.

DEPEND ON THE TUNE

The growth is only observed when the horizontal tune is below the integer.

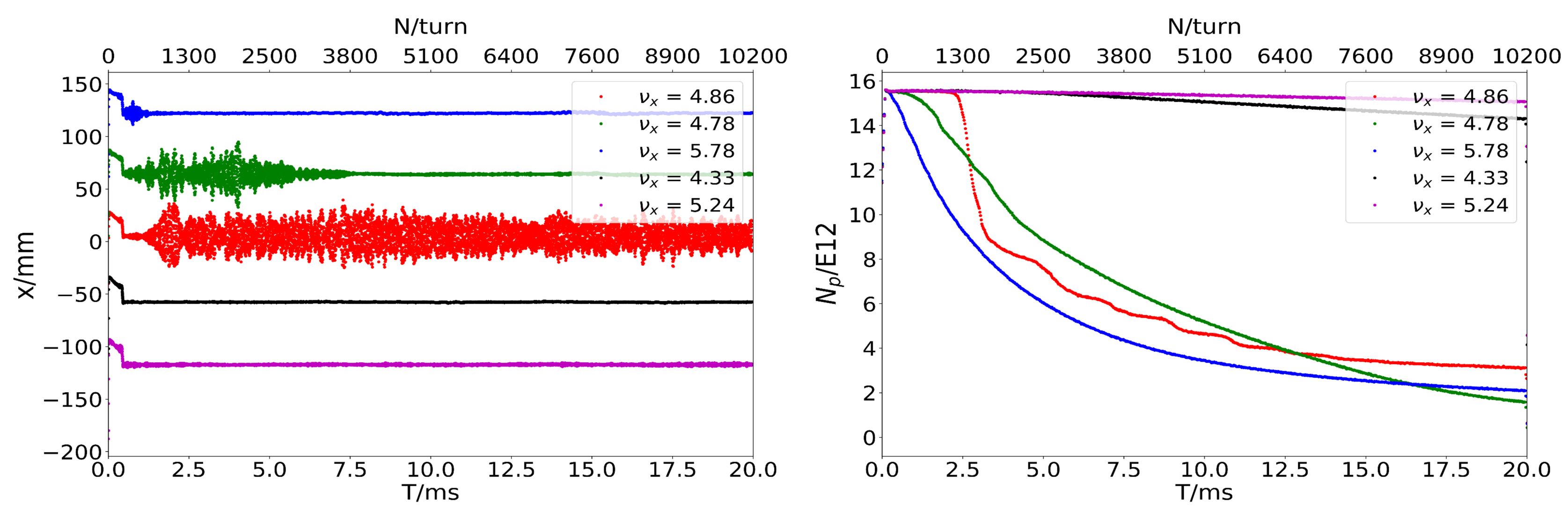

Fig 6: The position (left) and the living protons (right) for the double bunches: scan the tune with the natural chromaticity. The position in the left is shifted on the vertical axis for clarity.

DEPEND ON THE CHROMATICITY

Two buckets are perfectly filled with the equivalent power of 100 kW and sets of measurements were taken for different chromaticity for the nominal tune. The beam position in horizontal plane as a function of the chromaticity is given and the head-tail mode is observed.

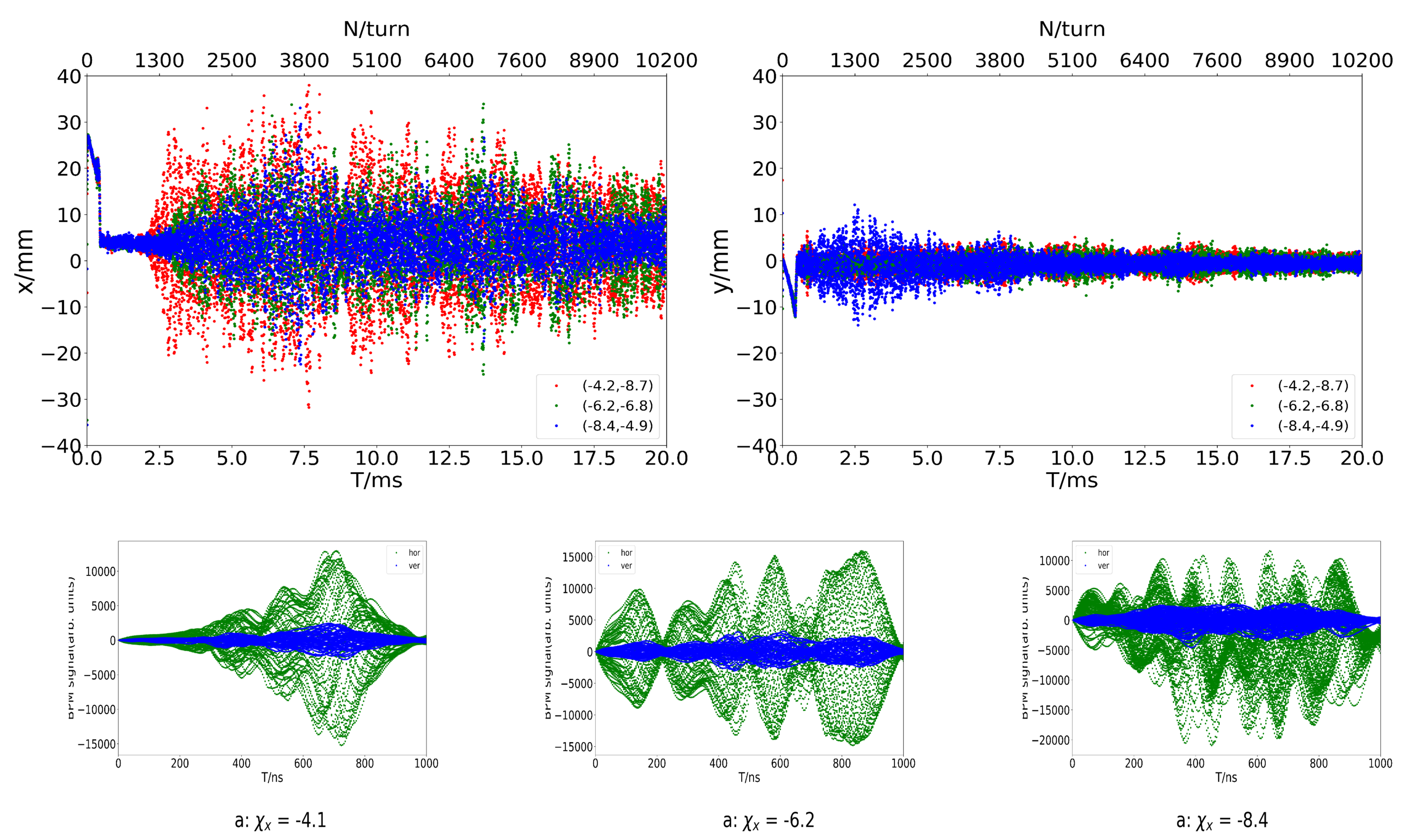

Fig 7: The position (upper) and the head-tail mode (lower) for the double bunches with nominal tune: scan the chromaticity.

SUMMARY

The growth is more and more serious with the beam power increasing. The growth is observed for the double bunches and the single bunch and the threshold is about 7E12. The growth mainly happens in horizontal plane and it may be also excited when the vertical tune is closed to the integer of 5. The head-tail mode is also observed when the beam position growth happens. It is similar with the characteristics of the coupled bunch instability. Unfortunately, the source of the instability has not found. The instability was mitigated by the tune adjusting and the chromaticity correction.

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