Experimental studies of the in-vacuum-cryogenic undulator effect on beam instabilities at BESSY II

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Abstract

A new in-vacuum cryogenic permanent magnet undulator (CPMU17) has been installed in summer 2018 in the BESSY II storage ring at HZB. Such a small gap in-vacuum undulator device enhances the impedance of the storage ring and can contribute to the instabilities that adversely affect the beam quality and the device itself. To identify and explore the effects of CPMU17 on the instabilities at BESSY II, grow-damp and drive-damp experiments have been conducted using the installed bunch-by-bunch feedback system. In this paper, the first results of the mode and gap analysis of these studies with a brief overview of other impedance studies will be presented.

Measurements

the undulator gap was varied with a speed of 0.01-0.05 mm/s (10-50 µm steps), from 22 mm (opened) to 6 mm (closed), and beam oscillations were scanned for several beam current and landau-cavities power. Two feedback systems were used for this purpose: First, a transverse multi-bunch feedback which was originally developed and installed at the Diamond light source (DLS-TMBF) and recently at the BESSY II. This system has the ability to record complex amplitudes of the beam oscillation, yielding the amplitude and frequency for each mode.

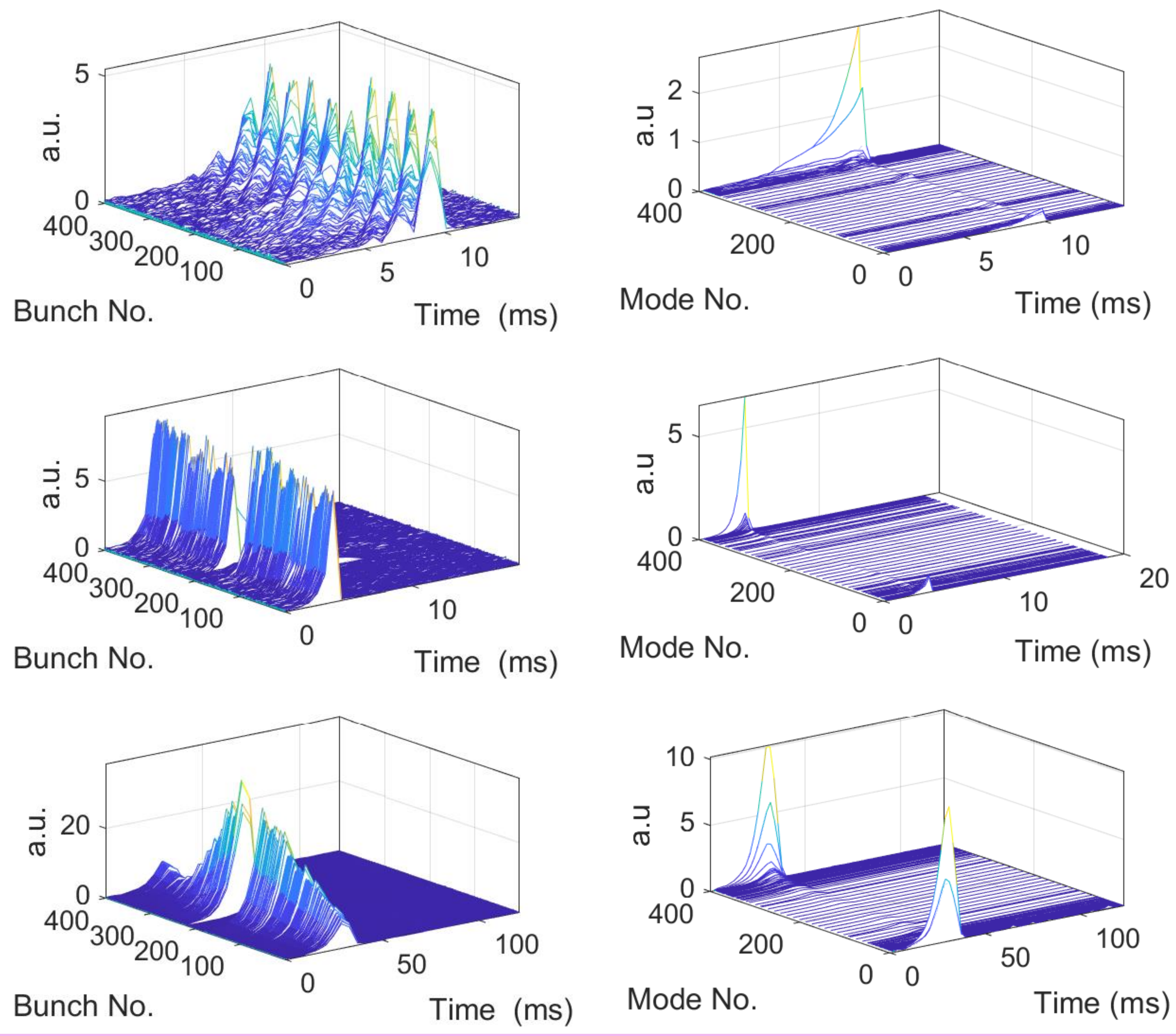
And the second was a bunch by bunch (BxB) feedback systems from Dimtel, Inc. based on iGp12 processor. Both systems use field-programmable gate arrays (FPGA), an integrated circuit for complex filter functions.

Grow Damp studies for CPMU17

A strong amplitude of mode number 390 and 399 can be seen in vertical *y* plane in all gaps, related to the ion trapping and resistive impedance, respectively.

In the longitudinal *z* plane, the dominant modes are 0 and 399; and in horizontal *x* plane the mode 399. The small peak at mode 0 and 1 in all planes (stronger in *z* plane) is a disband of the resistive mode 399.

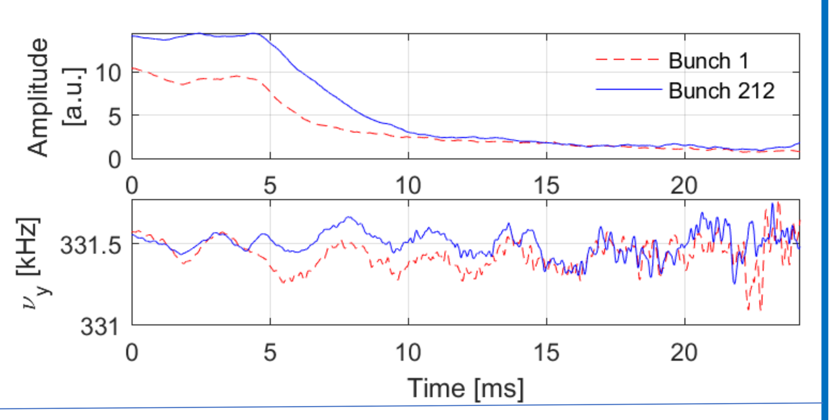
The results of first grow damp results in three planes showed no effect of ID gap variation on modes growth-rates.



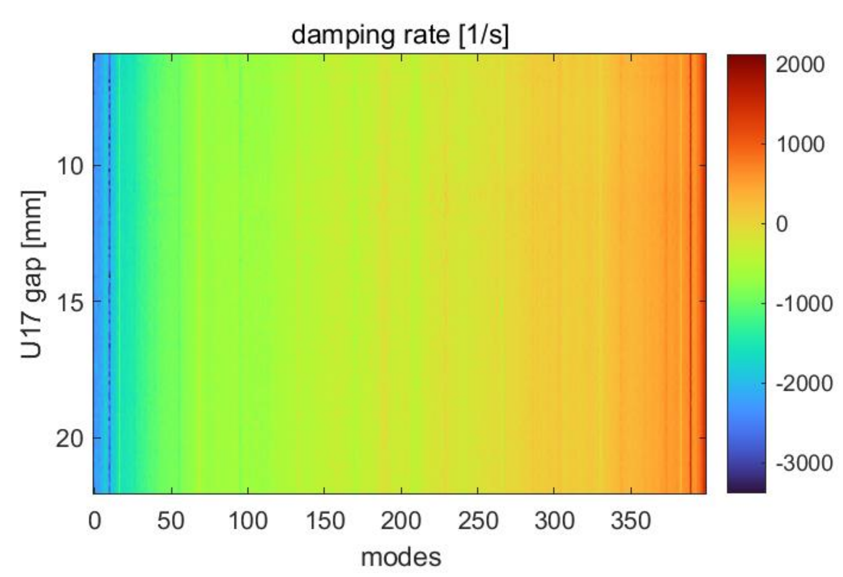
Drive-damp studies for CPMU17

- 5-15 ms, clear slope and frequency differences
- 0-5 ms range (while excitation is active) tune variation is smaller. As tune varies around center frequency ν_y= 331.5 kHz (Q_y=0.27), amplitude of the response goes up and down.
- Damping 5 ms and the modulation period is 3 ms.
- Beam responds to the drive and to tune jitter.
- Determination of damping, specially the stable modes and the modes with damping time larger than jitter time.
- Jitter caused by the ripple at 300 Hz of quadrupole power supplies.

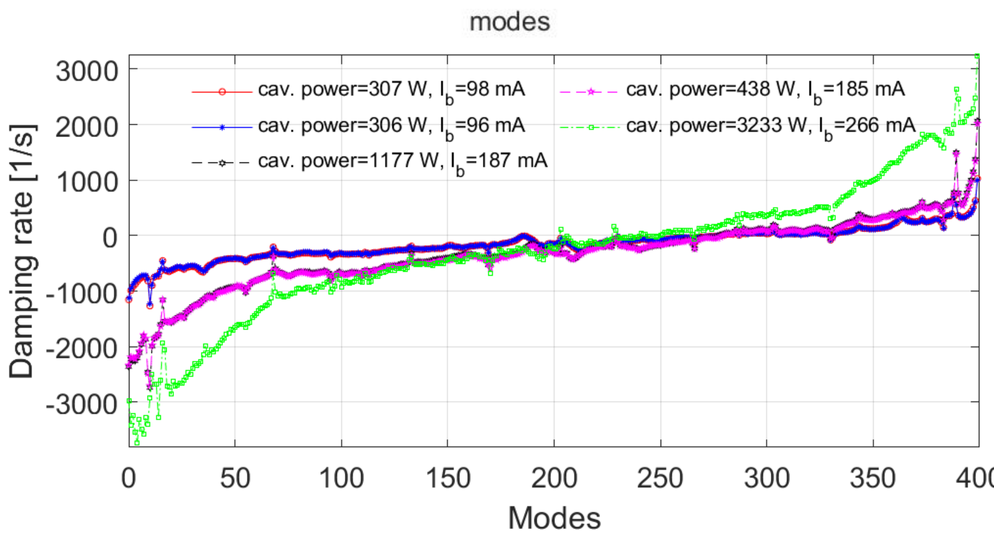
iGp12 tune tracking of mode 1 for 2 bunches with different bunch current at gap 22 mm.



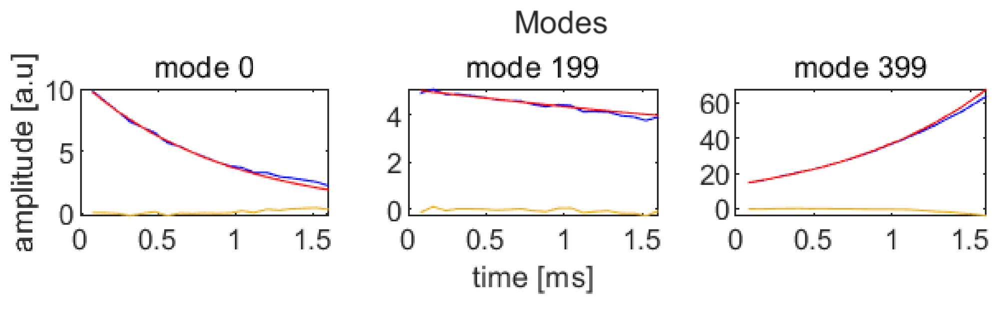
- The excitation time was reduced to 0.4 ms, much smaller than the tune jitter time.
- A fill pattern without ion clearing gap was used, and the bunch currents.
- Vertical chromatically was reduced to 0.
- Beam was excited mode-by-mode using DLS-TMBF system for 500 turns (0.4 ms), and then the passive mode-growth (open feedback loop) was observed for 2000 turns (1.6 ms). Finally, the oscillation was damped actively (closed loop) for 5000 turns (4 ms).



- Three different regions can be distinguished by growth rate in these plots: damping (negative growth rate), nearly stable (growth rate near zero) and growing (positive growth rate).
- With increasing the current, the magnitude of the growth rates of positive and negative modes increase.

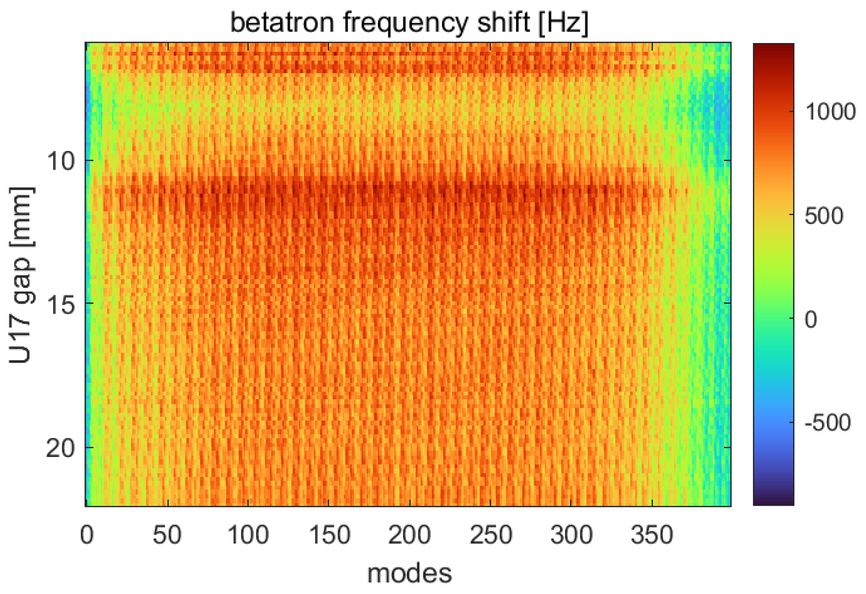


- Data-fits at each 3 damping regions:

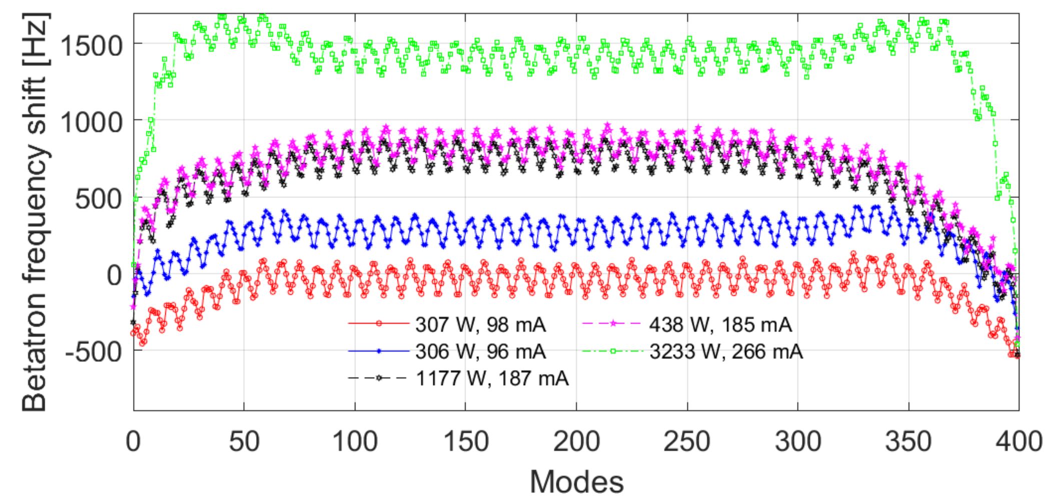


Vertical betatron oscillation tune shift

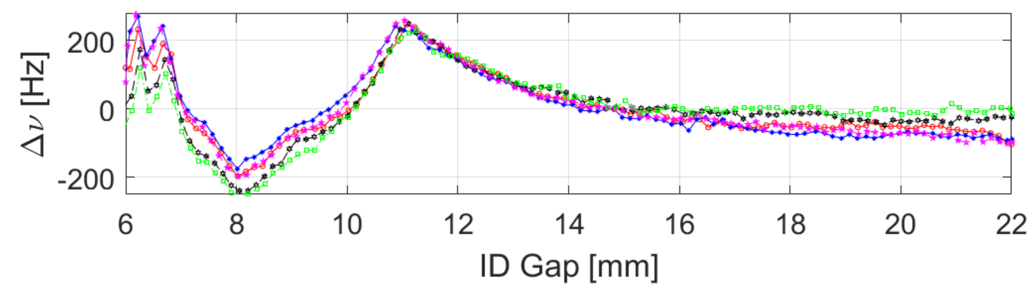
Shift of the vertical betatron oscillation of the excited beam with respect to the excitation frequency equal to the vertical betatron frequency of 900.8 kHz .



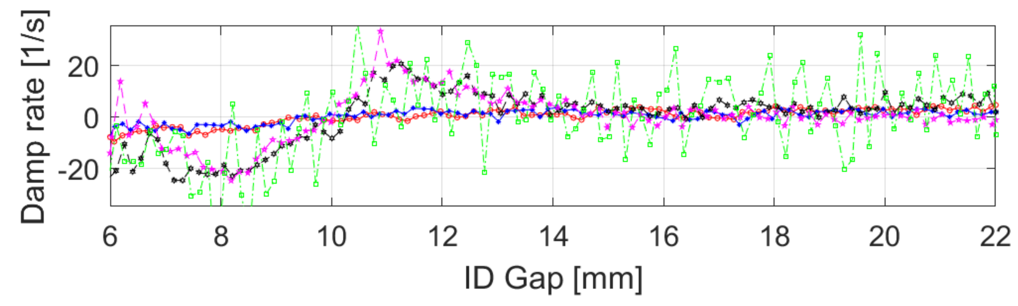
Averaged over all gaps (for different currents), regular ripples can be clearly seen in frequency shift, indicating regular changes in betatron frequency.



By subtracting the mean of frequency shift, and averaging over all modes, a gap-dependent pattern can be seen, that clearly indicates the non-perfect tune-correction tables of the ID.

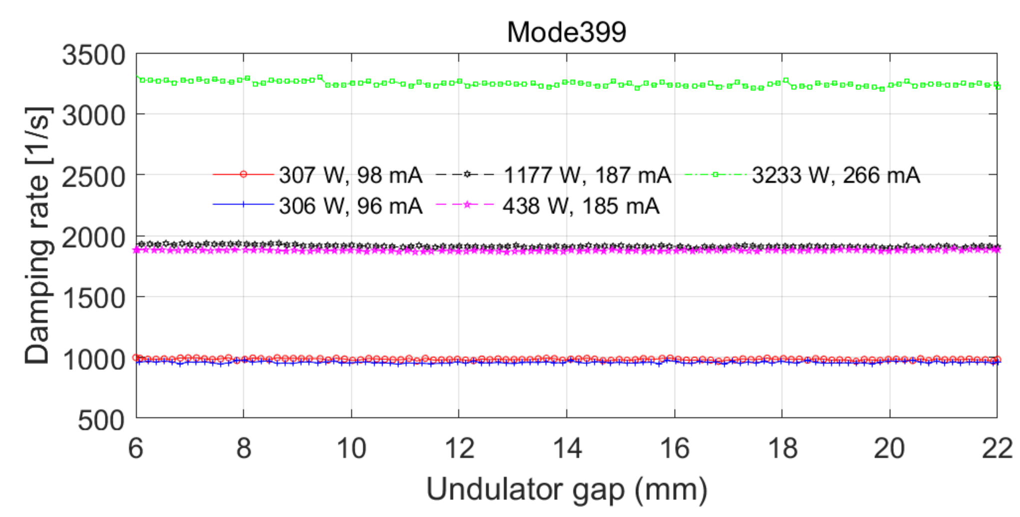


Same pattern can be seen in the damp rates, especially at high currents, but the changes are very small, in the range of ±30 [1/s].



Damp rates for mode 399:

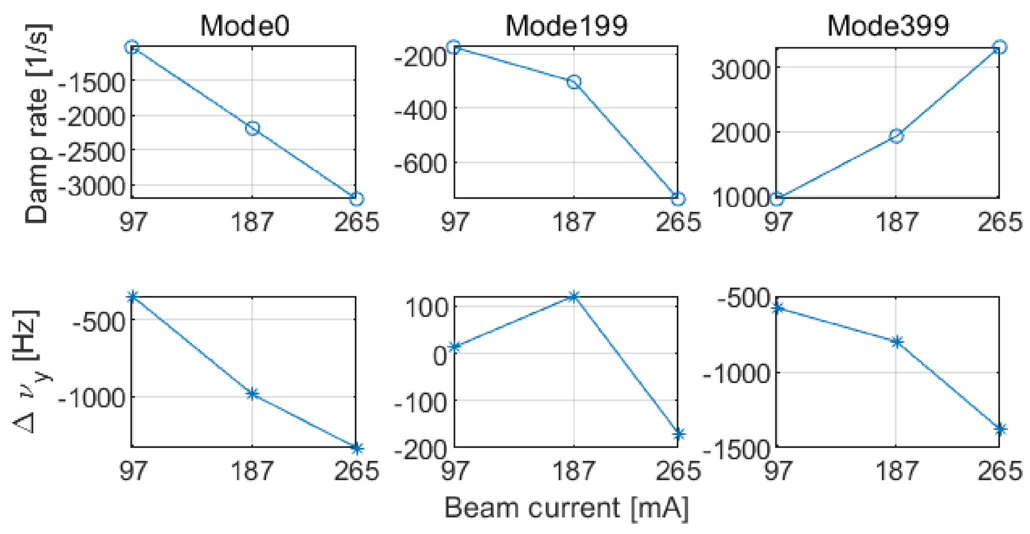
- The growth rate increases with beam current. Changing the Landau power at current
- ~ 186 mA did not change the growth rates significantly.
- Clearly there is no gap-dependency of damp rates.



Impedance estimation

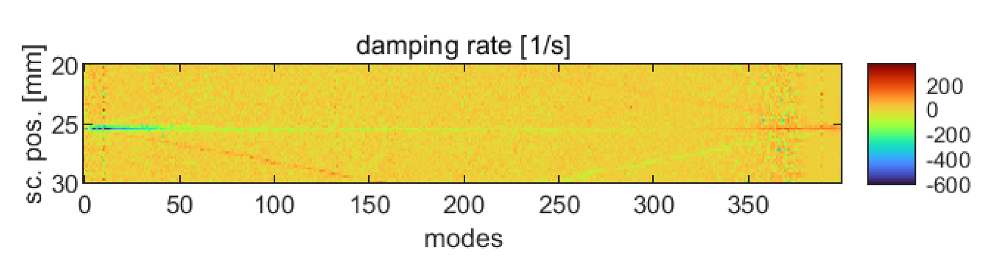
Variation of growth rates and frequencies with beam current with aim of estimating the impedance at each mode

The analysis of this data is still ongoing.



Drive-damp studies for scraper

The vertical position of the scraper was changed, and grow-damp times were extracted from drive-damp experiments. A resonance seems to cross a harmonic of fundamental (n x 500 MHz) at a position of 25.4 mm



Conclusion & Outlook

- After performing extensive grow-damp and drive-damp studies using two different feedback systems, the main conclusion is, that no changes to transverse coupled bunch damping could be observed for variation of the CPMU17 gap.
- Also, no harmful modes were found, that could be linked to a heating event in vacuum components of the transition region of the CPMU17 (last year), confirming that an upstream-dipole radiation was the main responsible for that. However, the temperature of CPMU17 varies by gap changes, clearly due to the wakefields, but this only effects the vacuum pressure, which is an issue for gas lifetime and Bremsstrahlung and is a source of gas-loss-rate (when ID is closed).
- Further related studies could be: the current-dependent mode-growth with better accuracy to deduce the impedance spectra, understanding frequency and amplitude modulation, comparison of iGp12 and DLS system, installation of RF-antennas in IVU chamber and using a spectrum analyzer as a complementary bench measurement to beam based measurements.