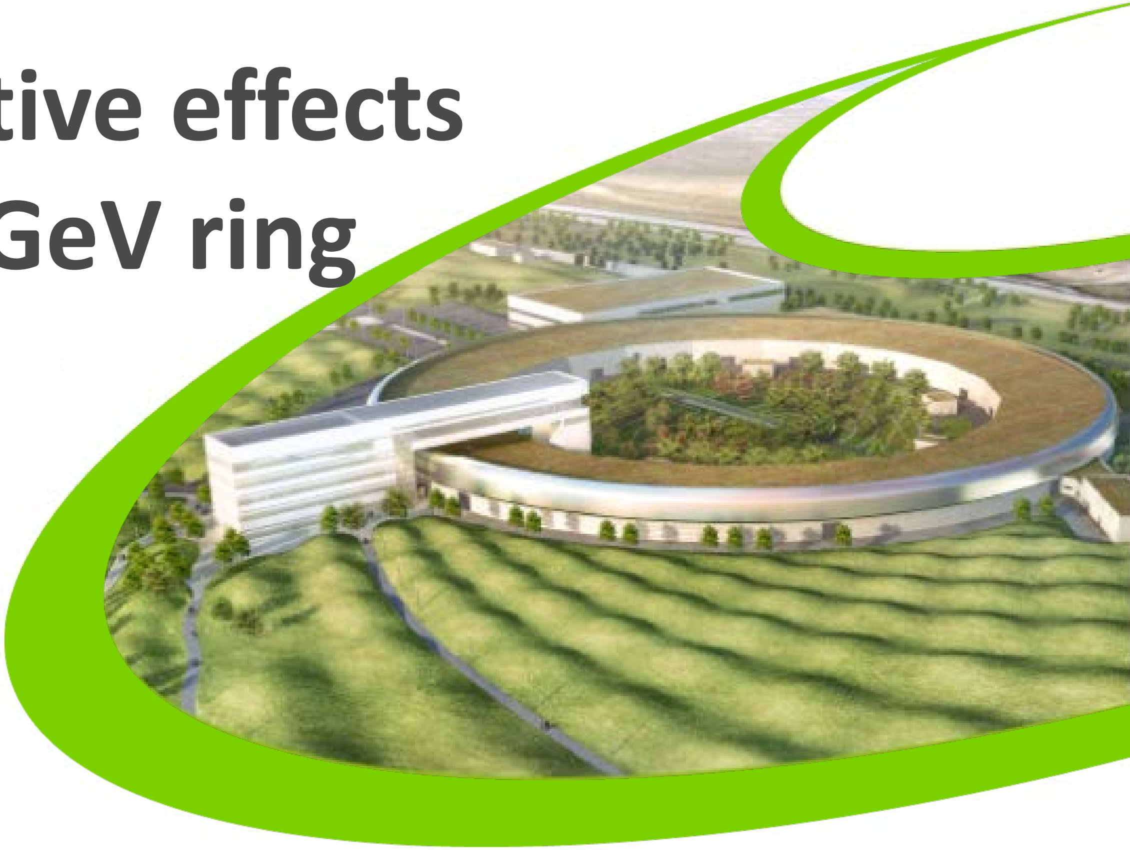
Studies of collective effects in the MAX IV 3 GeV ring



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Outline

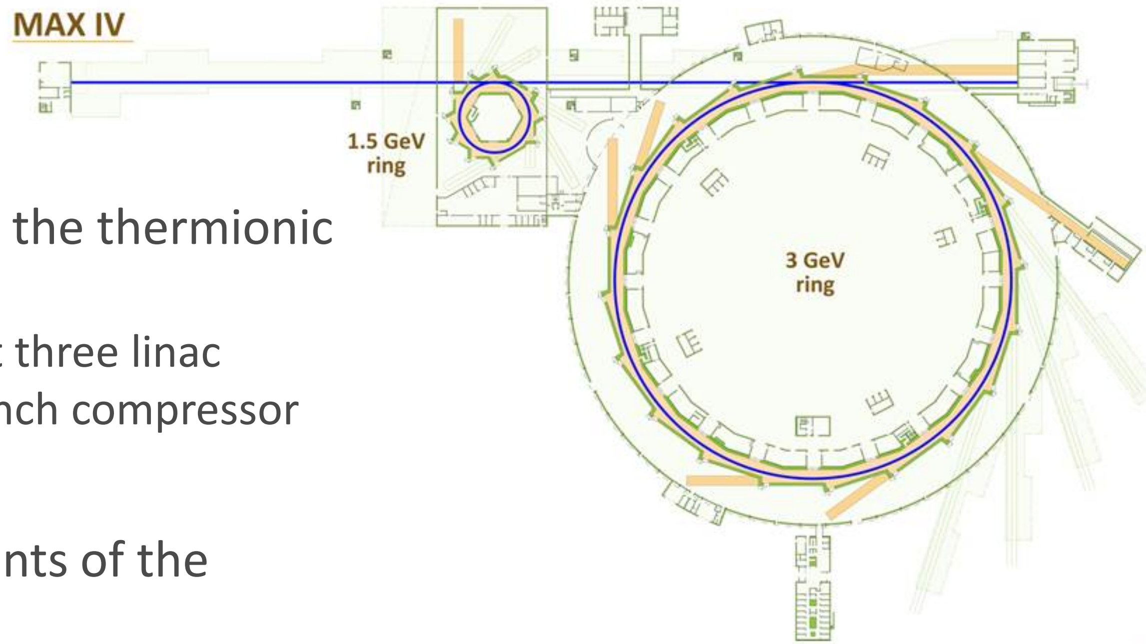
- Introduction to MAX IV 3 GeV ring
- MAX IV project status
- Scope of the project
- Latest results of studies
    - transverse single bunch
    - transverse multi bunch
    - resistive wall of low-gap ID chambers
- Thresholds overview
- Harmonic cavity and head-tail damping preliminary studies
- Outlook

MAX IV 3 GeV storage ring

Energy	E_0	3.0	GeV
Current	I	500	mA
Circumference	L	528.0	m
Harmonic number	h	176	
RMS bunch length w/o HC	σ_τ	40	ps
RMS bunch length at 500 mA	σ_τ	195	ps
Peak rf-voltage w/o IDs	V_{rf}	1.02	MV
rf-frequency	f_{rf}	99.931	MHz
Energy loss per turn w/o IDs	U_{rad}	360	keV
Higher harmonic of HC	n	3	
Quality factor of HC	Q_f	21600	
HC detuning	Δf	48.1227	kHz
Total shunt impedance HC	R_s	2.36441	MΩ

- Multibend achromat lattice
- Ultra-low hor. emittance: 0.2 - 0.4 nm rad
- Round beam pipe, small radius: 11 mm
- High beam intensity: 500 mA
- Passive harmonic cavities:
  - relax the Touschek life-time and intra-beam scattering
  - fight collective beam instabilities

MAX IV project status



- Beam commissioning with the thermionic gun has started:
  - ➢ transport through first three linac sections up to first bunch compressor
  - ➢ energy 280 MeV

- Delivery of main components of the storage ring is on track

- 3 GeV ring:
  - ➢ ongoing installation of concrete girders, cabling and cooling infrastructure
  - ➢ Installation of magnets/ chambers planned in October 2014

- Commissioning is planned on July/August 2015

Scope of studies

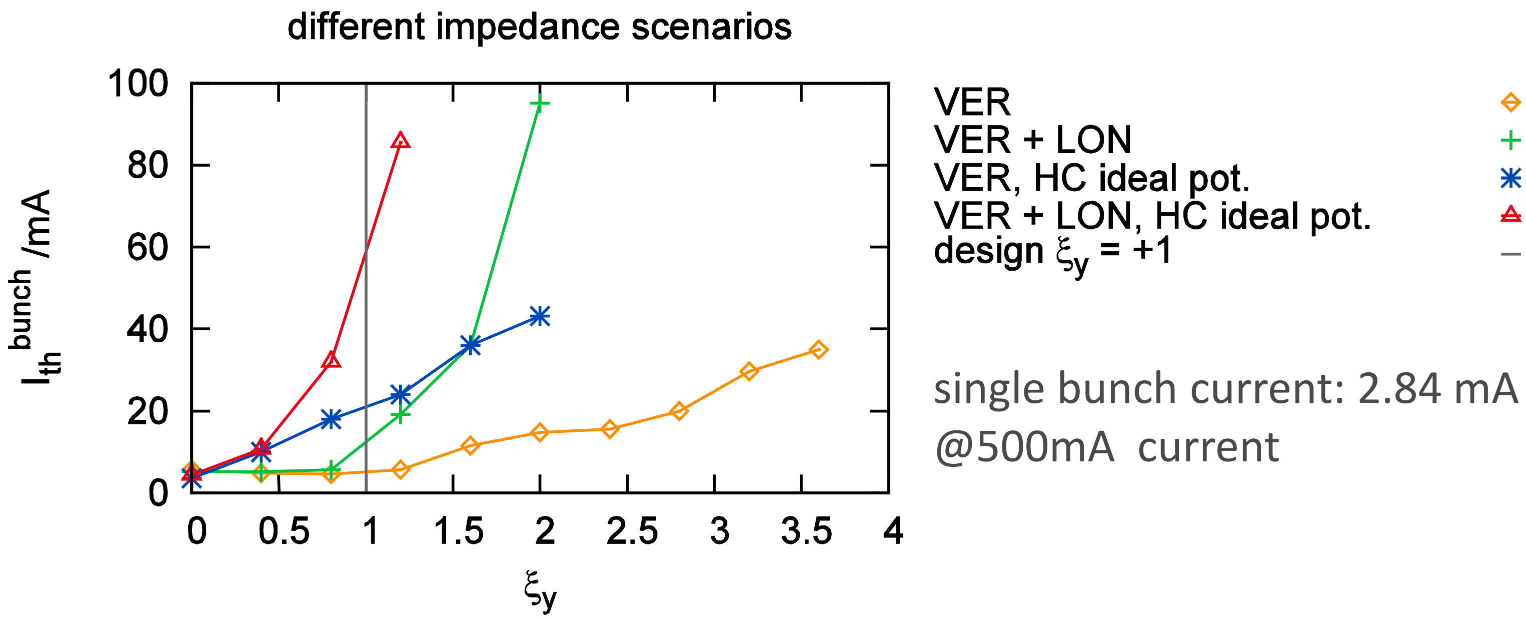
- Building the machine impedance model
    - numerical calculations using GdfidL
- Determination of single- and multi-bunch instability thresholds given the impact of
    - geometric impedance
    - resistive wall impedance
    - passive HC
- The effect of low gap insertion device(ID) chambers on the thresholds considering
    - resistive wall impedance
    - geometric impedance
- Study of harmonic cavity impact on the internal bunch motion

Particle tracking: *mbtrack*

6D macro-particle tracking code:

- Internal motion and micro-structures
- Quantum excitation and radiation damping
- Arbitrary filling pattern
- Single-(Intra-) bunch effects:
  - geometric ring impedance
  - resistive wall impedance
  - HC(passive or ideal potential)
- Multi-(Inter-) bunch effects:
  - resistive wall impedance(RW)
  - HC(passive or ideal potential)

Transverse single-bunch



single bunch current: 2.84 mA
@500mA current

HC has no effect at zero chromaticity

- Instabilities are damped by bunch lengthening and tune spread
  - Lengthening from longitudinal impedance improves the situation
  - HC enhances the effect
- Same trend in horizontal plane but more relaxed

Multi-bunch: resistive wall

For RW *mbtrack* uses the eff. radius b_{eff}

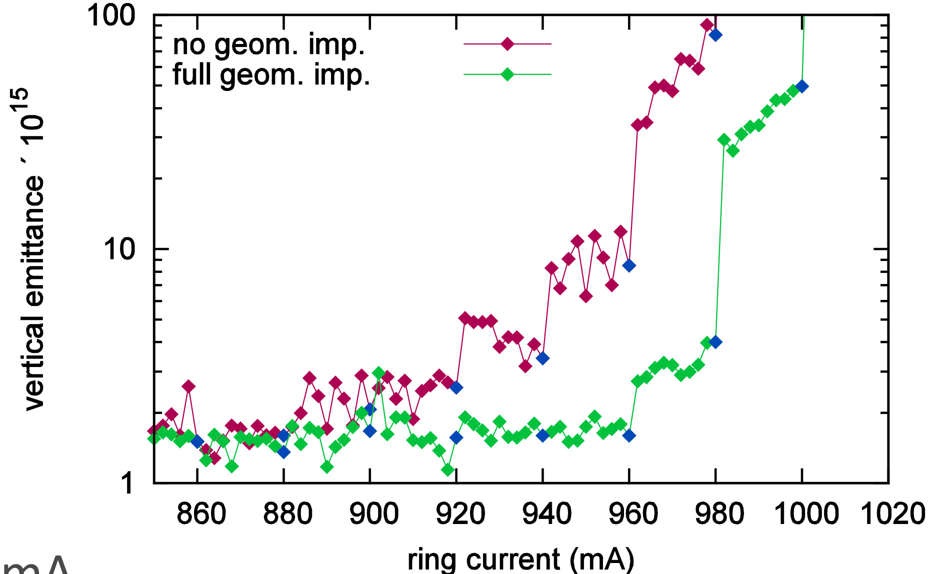
- With passive HC the threshold is at ~40 mA

cavity tuning for optimal bunch lengthening is needed

- Further investigation with ideal cavity potential(cross check with passive HC)
  - geometric impedance improves the threshold

suggests the head-tail damping

ξ = 1.0, **Ideal potential, no IDs**



design current: 500 mA

- RW scales as $I \cdot b_{eff}^{3}$
  - I_{th} with 5 planned IDs(ξ=1): 380 mA
  - I_{th} with 5 planned IDs(ξ=1.2): >500 mA

$\xi > \xi_{design}$ allows to achieve design current

Optics design has been made to provide ξ up to +4

Threshold currents(mA) in MAX IV 3 GeV ring considering different effects

effect / plane	ξ	Z_{geom} HC off	Z_{geom} HC on	Z_{geom} + RW HC off	Z_{geom} + RW HC on	$Z_{geom} + RW_{5IDs}$ HC on
Longitudinal	-	620	970	-	-	-
Horizontal	0.0	2010	2020	120	140	-
	1.0	>2050	17100	150	3500	-
	1.2	5040	21900	-	-	-
Vertical	0.0	920	710	40	40	-
	1.0	2200	10400	-	950	380
	1.2	3170	15100	50	1250	540

*in mA

Harmonic cavity is crucial for successful operation!

Geometric impedance of low gap ID chambers

Impedance processing:

- Numerically obtained using GdfidL

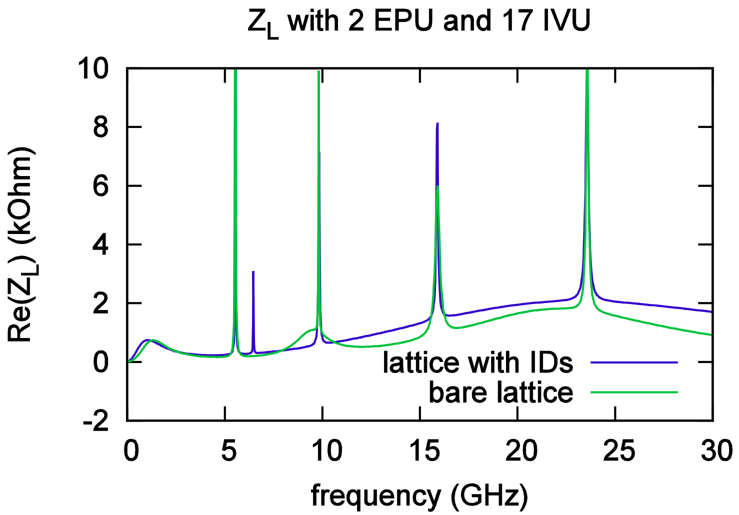
(Thomas Günzel(ALBA), David Olsson(MAX IV laboratory))

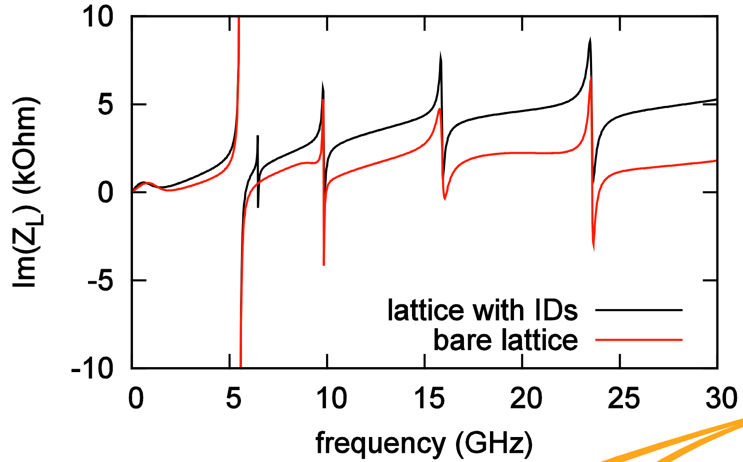
- Fitted to as series of resonators (broad- or narrow-band) with additional purely resistive and inductive components

Impedance model of ID chambers:

- Longitudinal is obtained assuming all straight sections occupied
  - ➢ increase of inductive component

- Transverse in progress…





tracking with new impedance model is next step

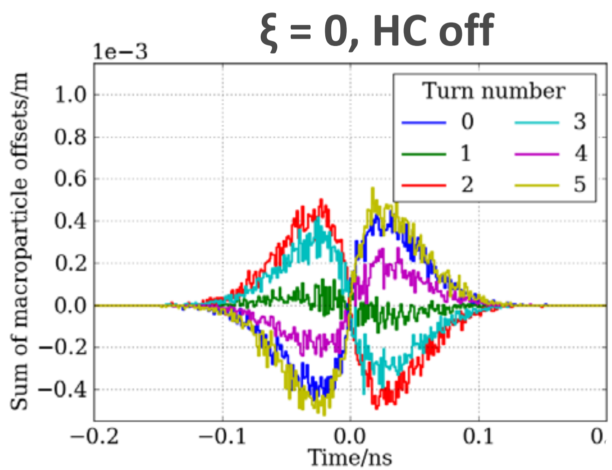
Head-tail modes influenced by HC

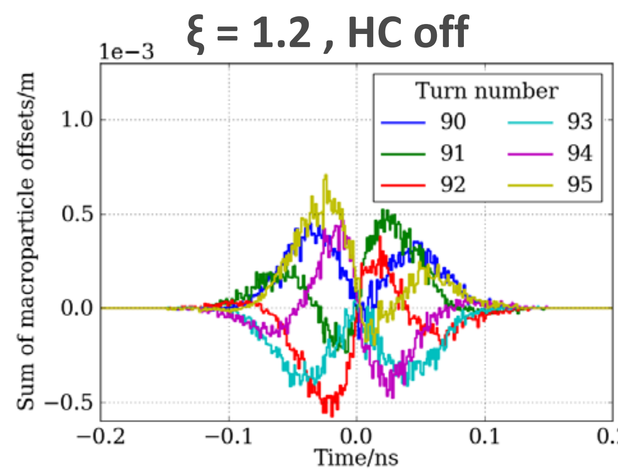
m=1 mode is excited
in initial distribution

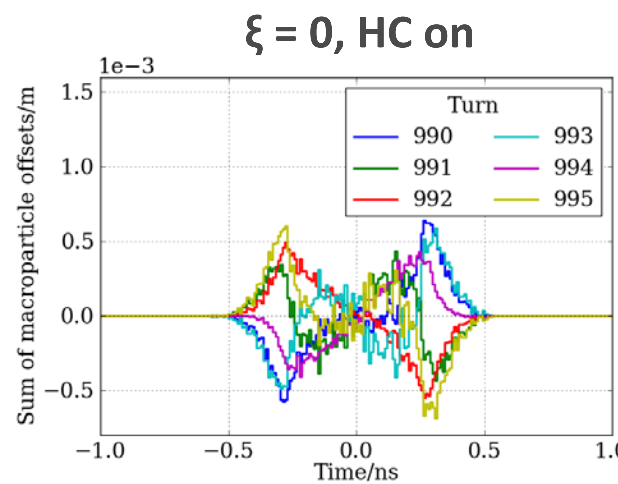
no impedance effects

- Evolution w/o HC
  - ➢ ξ = 0: pure m=1 present
  - ➢ ξ = 1.2: m=1 with CM offset

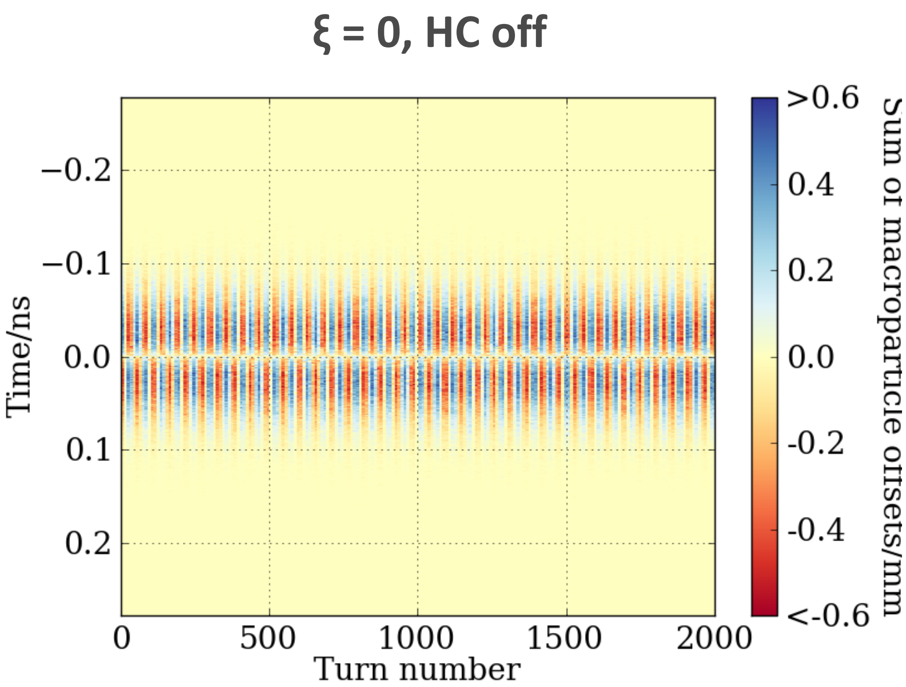
- Evolution with HC
  - ➢ ξ = 0: HC induced amplitude dependent tune shift destroys coherent motion

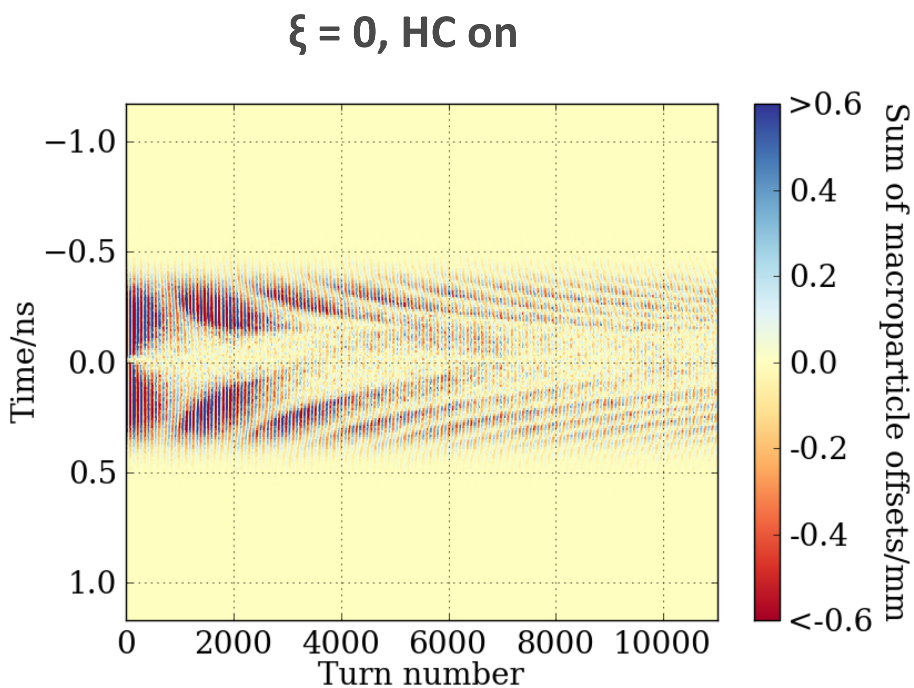






Head-tail modes influenced by HC





- Tune shift smears out the coherence
- What is the effect of the chromaticity and HC together?

To be studied further…

Conclusion and Outlook

- MAX IV instability thresholds without ID chambers determined
  - Single-bunch: at design chromaticity **ξ = 1** well above the operation current
  - Multi-bunch: instability sets in at low currents leading to the need of precise cavity tuning
  - Provided optimal lengthening from HC and **ξ = 1** threshold is above the operating current
- MAX IV instability thresholds with ID chambers RW effect
  - RW from low-gap chambers requires slight increase of chromaticity to reach the design current
- Evaluation of low-gap ID chambers impedance launched
  - tracking to follow
- Nature of instabilities and HC role is under thorough investigation

Thank you