Status of a Triple RF System for the MAX IV Rings

Åke Andersson

On behalf of

Pedro F. Tavares, Lars Malmgren, Francis Cullinan, Mikael Eriksson, Henrique Caiafa Duarte, Miriam Brosi, Aleksander Mitrovic, Robert Nilsson, Robin Svärd …

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Outline

- ❑Introduction
- ❑Implementation calculations for the MAX IV case
- ❑Time plan
- ❑Summary

Introduction

LEP/70-25

ISR-RF-TH/PB/AH/PBW/ps

12th December 1977

A higher harmonic cavity to increase the bunch length in LEP-70

P. Bramham, A. Hofmann, P.B. Wilson

2. Theory

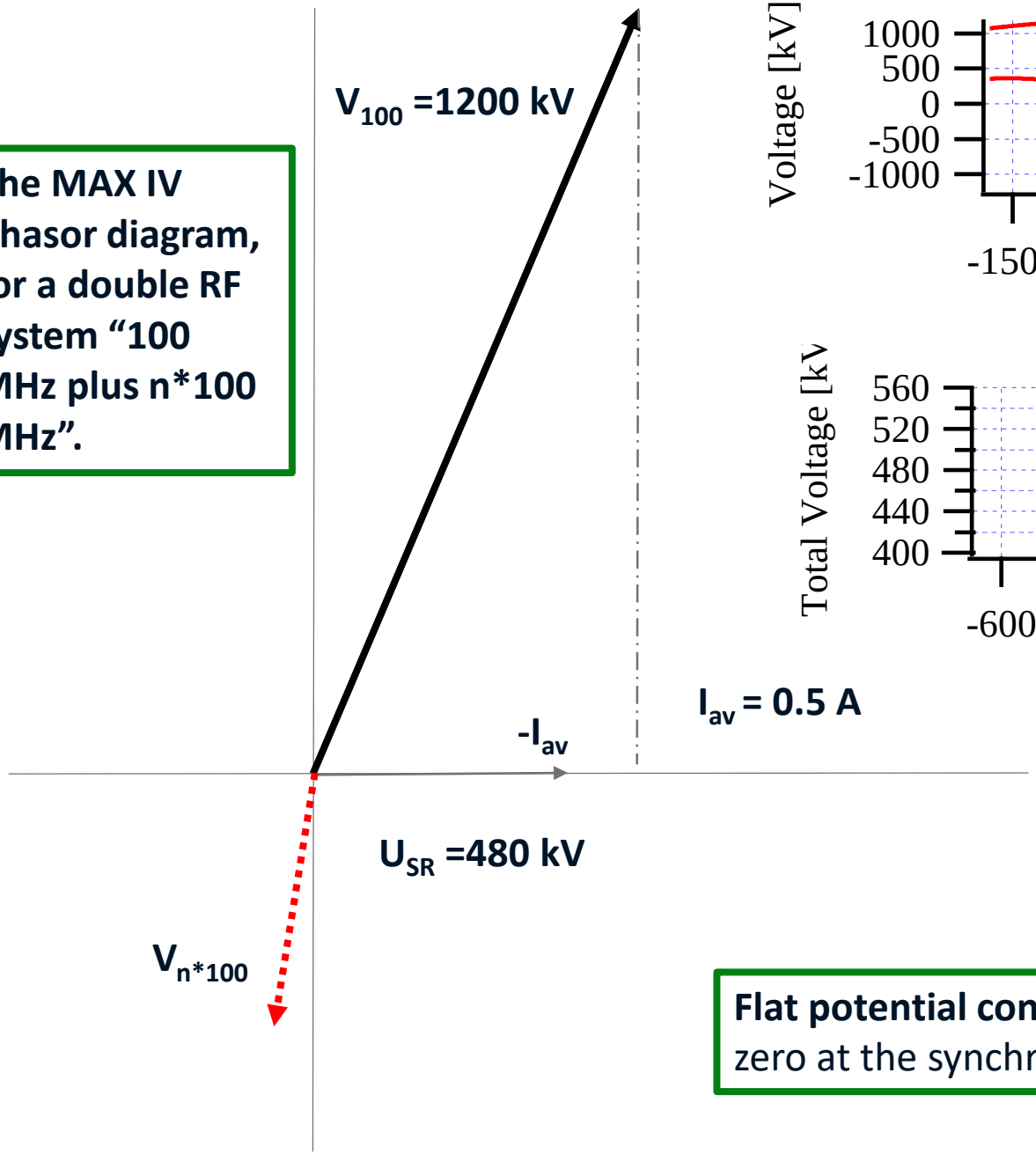
We assume a main RF system with amplitude V_o, frequency ω_{RF} and synchronous phase angle Φ_s and in addition a higher frequency system with amplitude $V_n = k\,V_o$, frequency $n\cdot\omega_{RF}$ and synchronous phase angle Φ_n (measured with respect to Φ_{RF}). The meaning of these parameters is illustrated in Fig. 1. Using Φ for the phase angle measured from the operating point

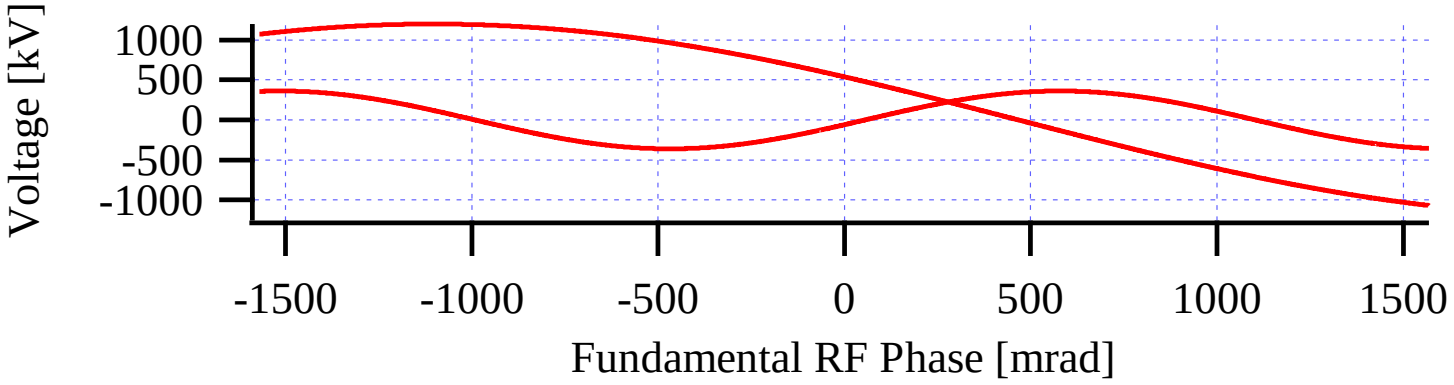
$$\Phi = \Phi_{RF} - \Phi_s = \omega_{RF} t - \Phi_s$$

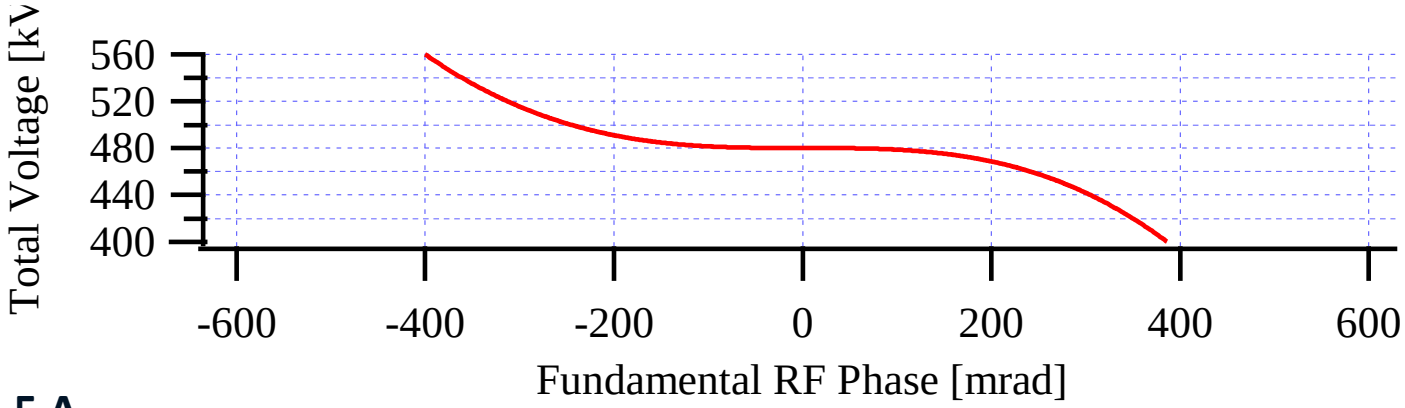
we get for the voltage $V(\Phi)$ seen by the particles in the beam

$$V(\Phi) = V_0 \left[\sin(\Phi + \Phi_s) + k \sin(n(\Phi + \Phi_n))\right] \qquad (1)$$

The MAX IV phasor diagram, for a double RF system “100 MHz plus n*100 MHz”.

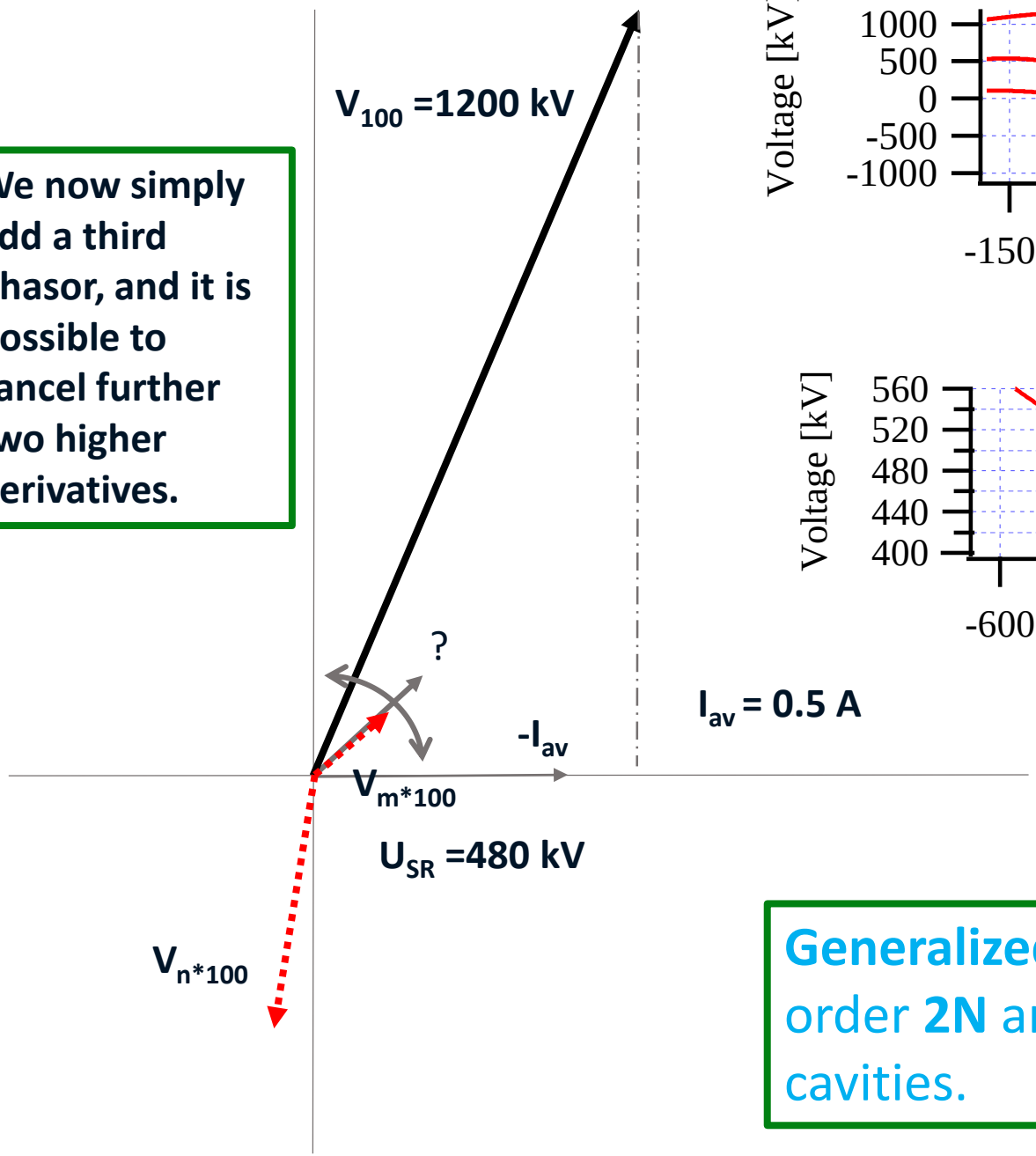


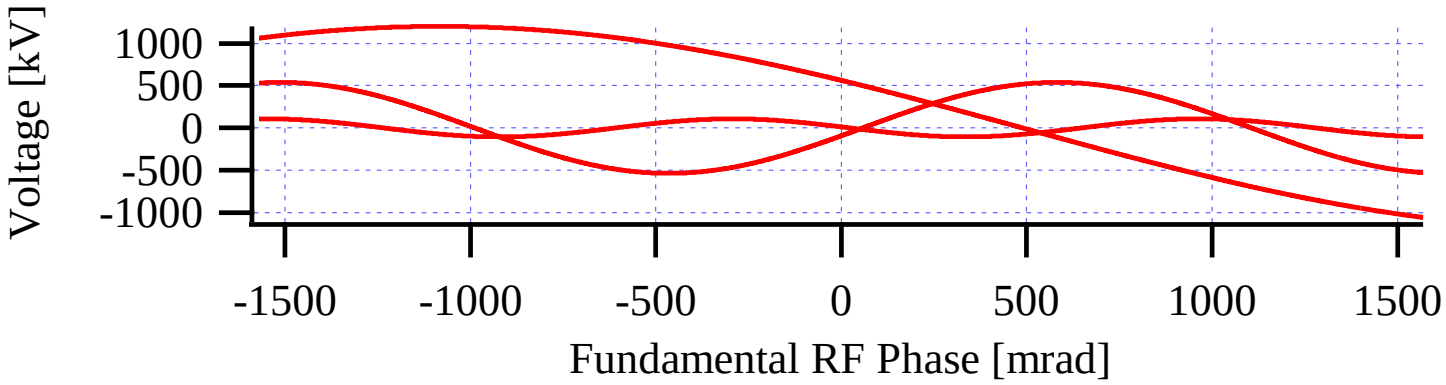


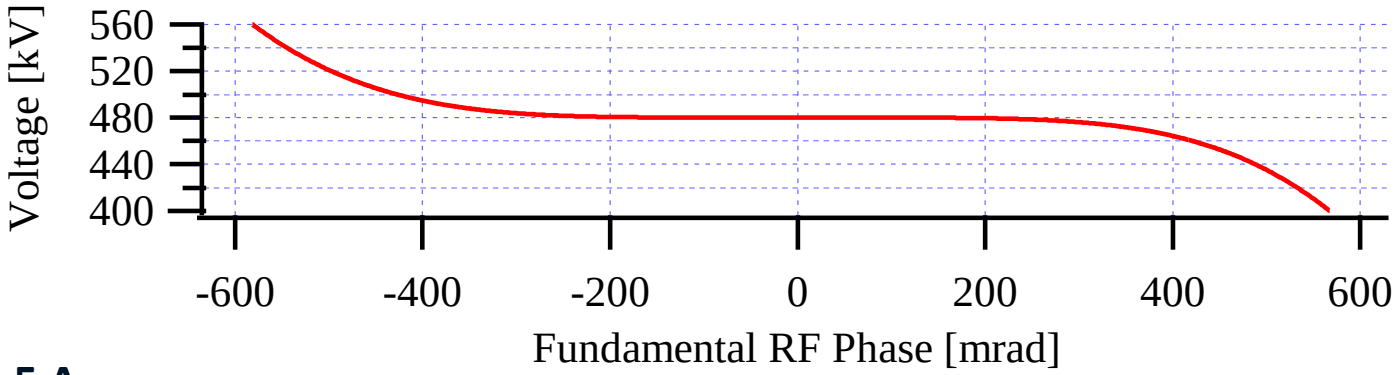


Flat potential conditions: First and second derivatives of the sum voltage, are zero at the synchronous phase. Can be achieved with **one** harmonic cavity.

We now simply add a third phasor, and it is possible to cancel further two higher derivatives.







Ultralong bunches for low emittance rings:

Generalized Flat Potential Conditions: Derivatives up to order **2N** are zero. Can be achieved with **N** harmonic cavities.

Triple RF system for reducing IBS and Touschek effects in MAX IV.

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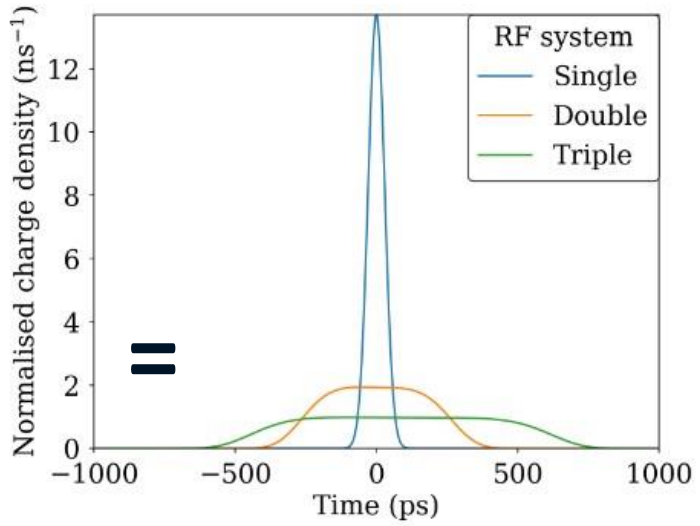
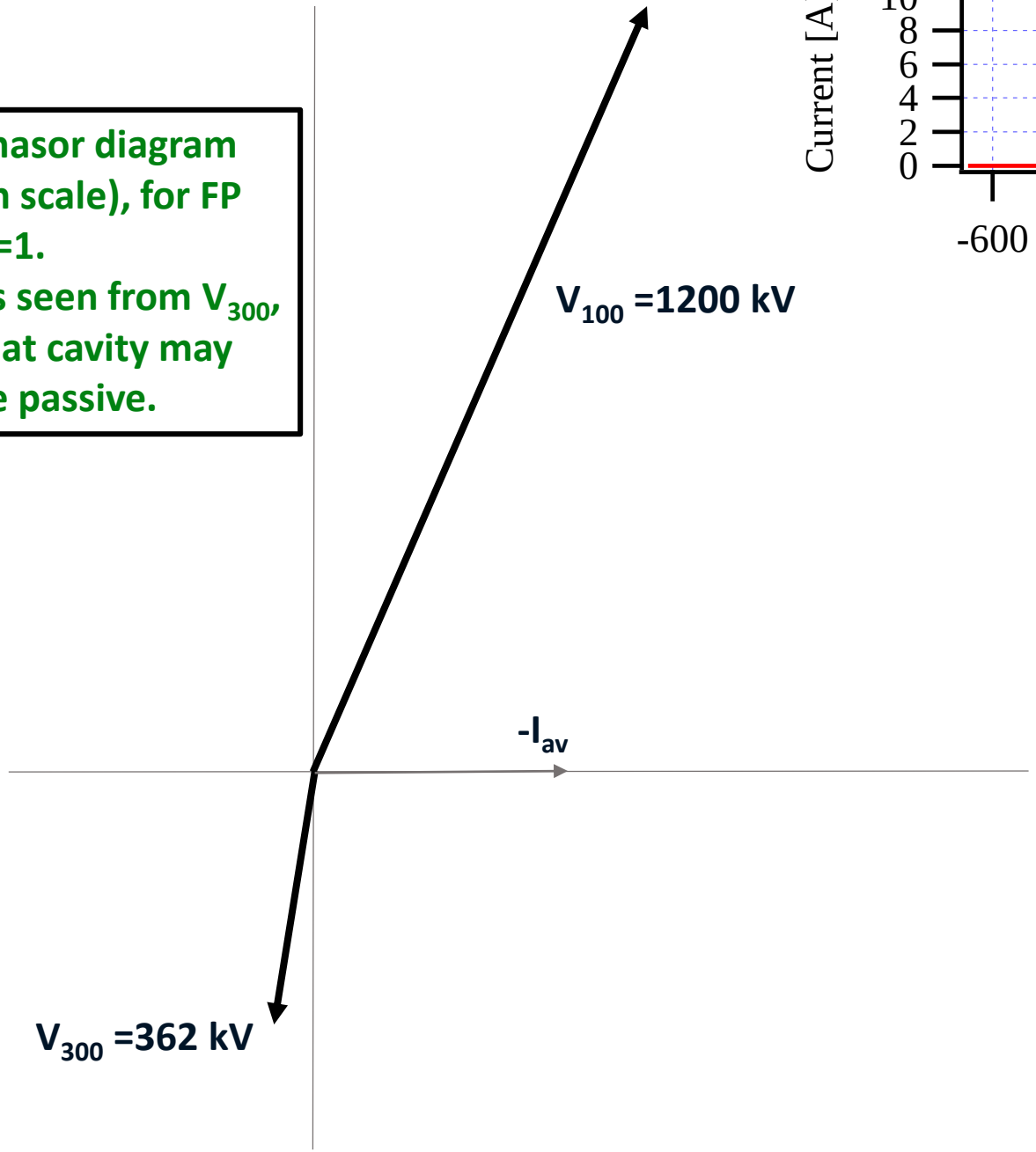
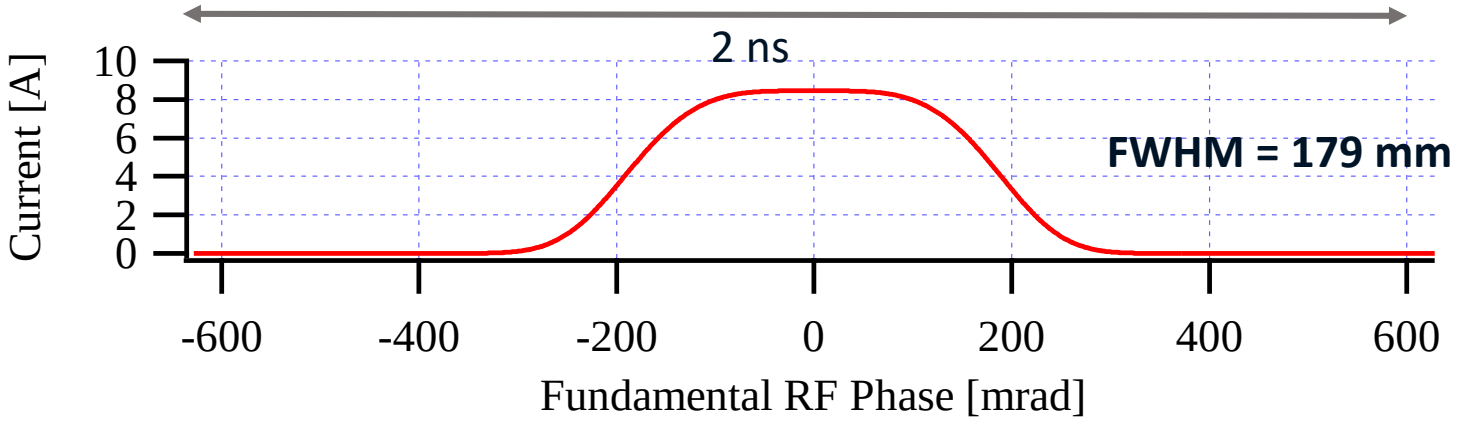
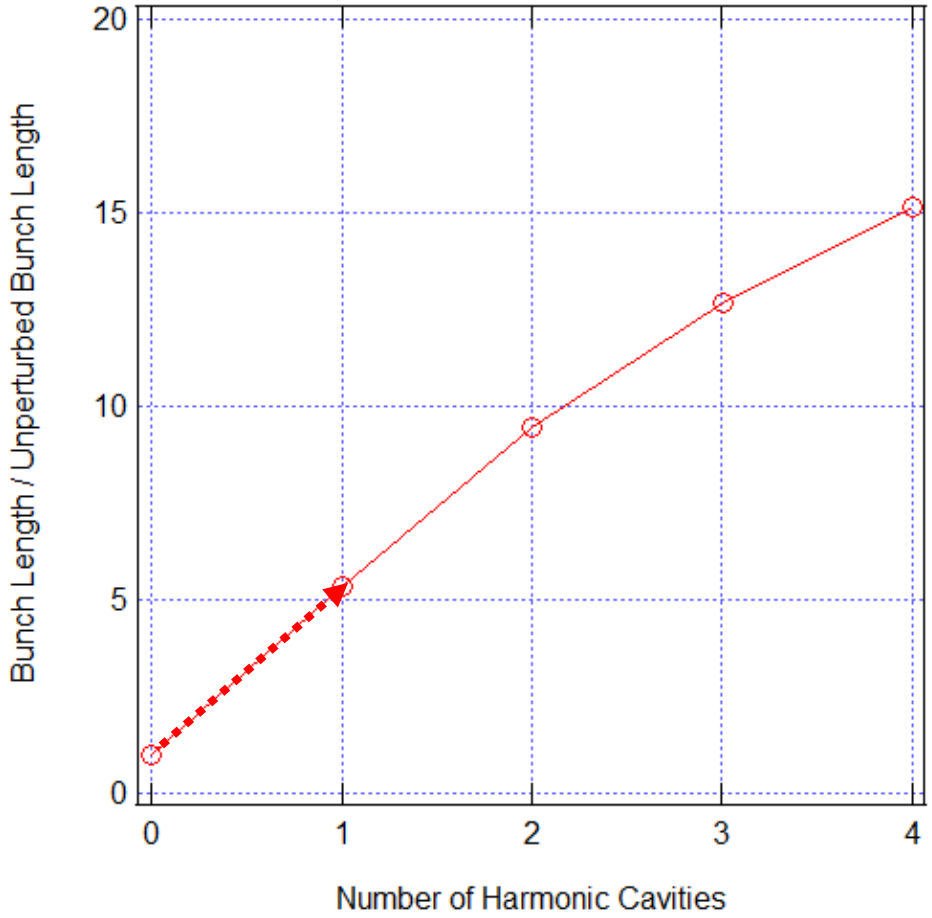


Plot: Courtesy of F. Cullinan

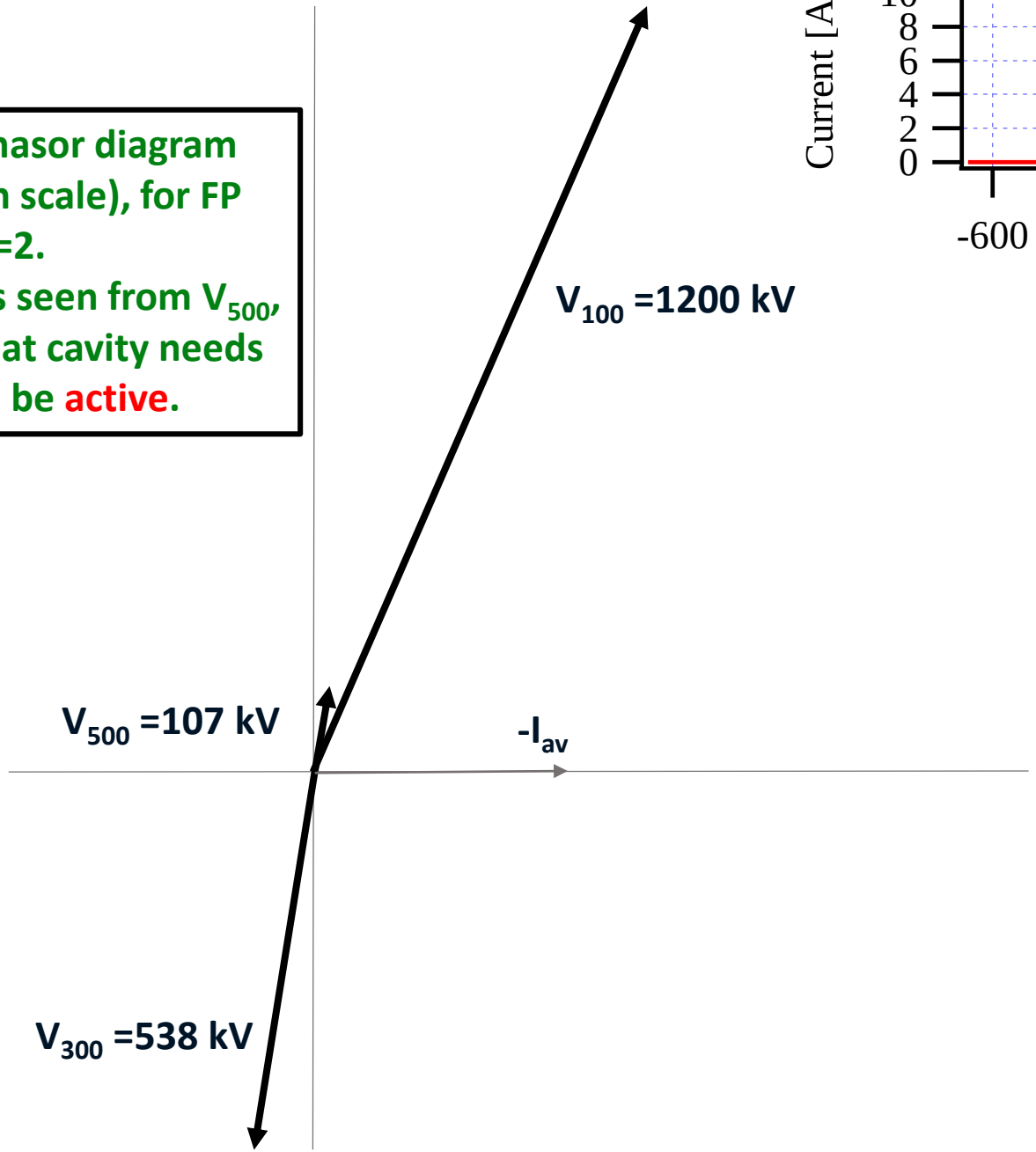
Phasor diagram (in scale), for FP N=1.
As seen from V_{300}, that cavity may be passive.

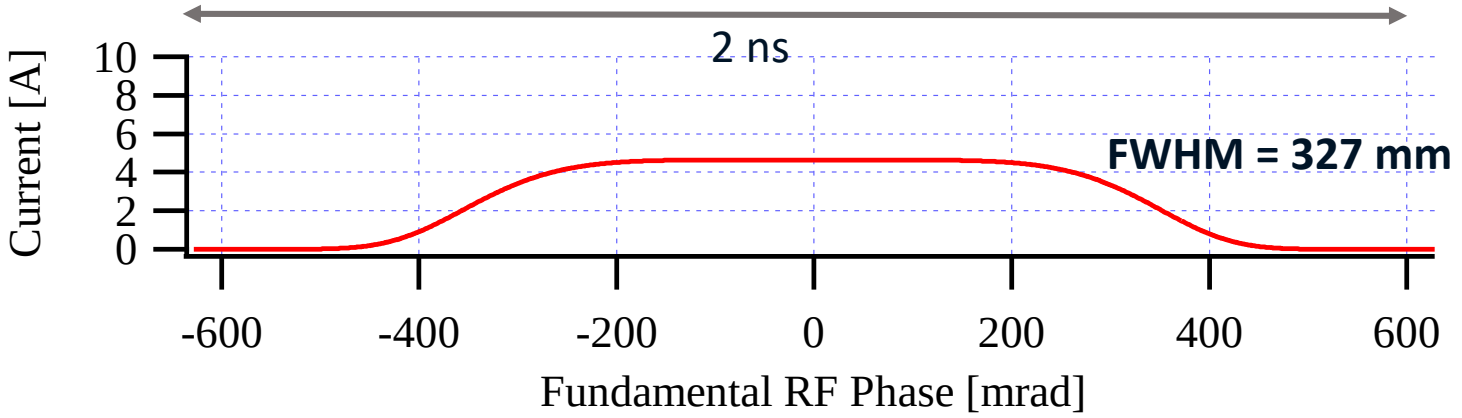


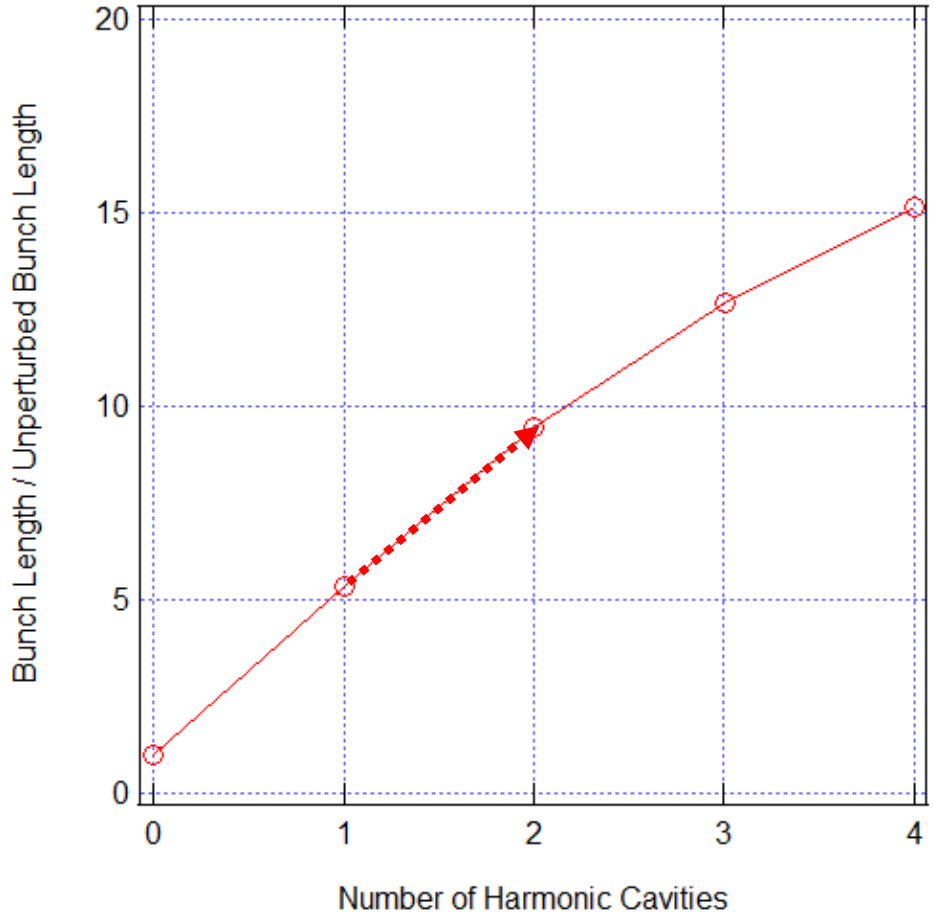




Phasor diagram (in scale), for FP N=2.
As seen from V_{500}, that cavity needs to be active.







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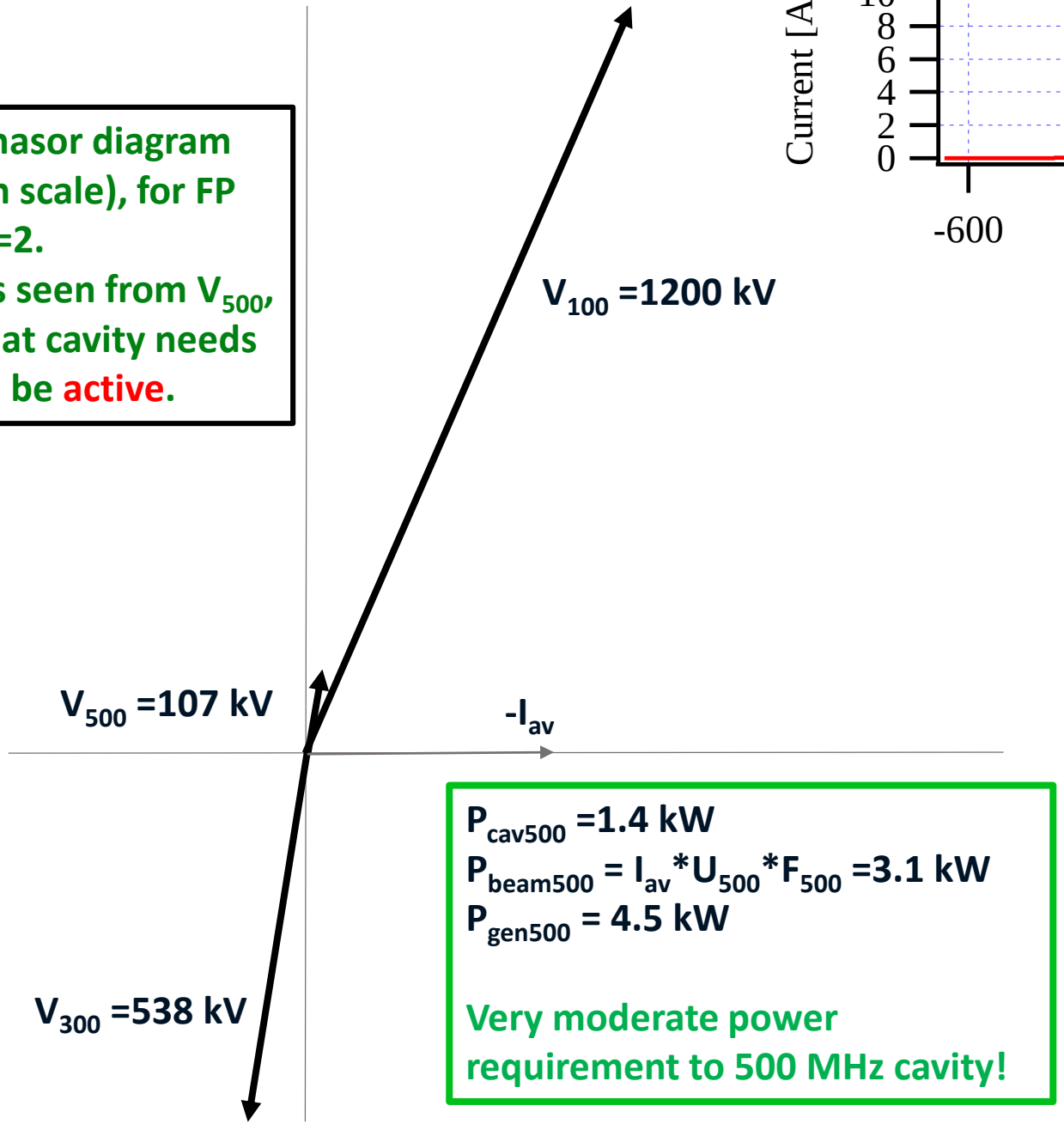
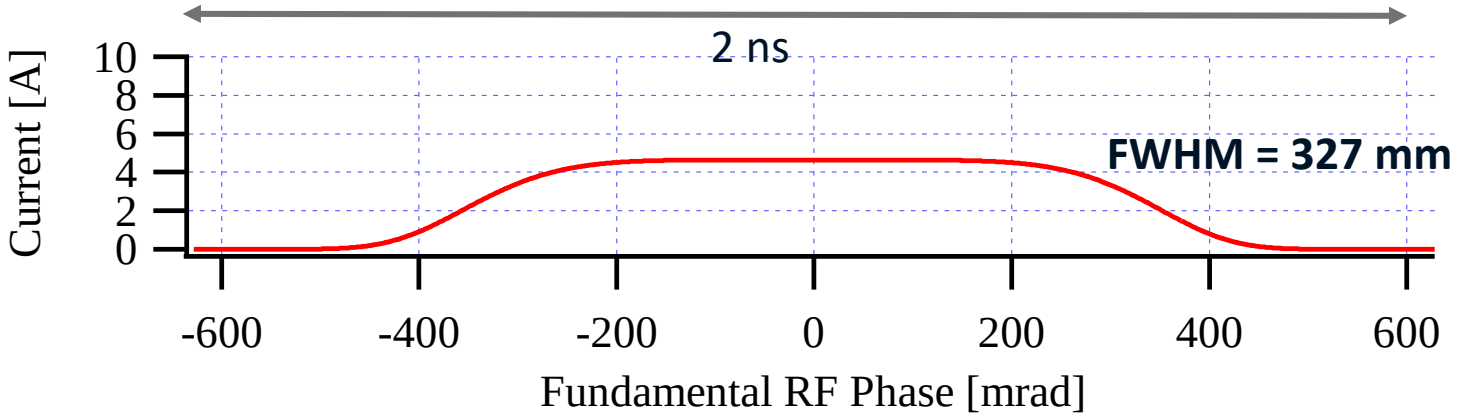
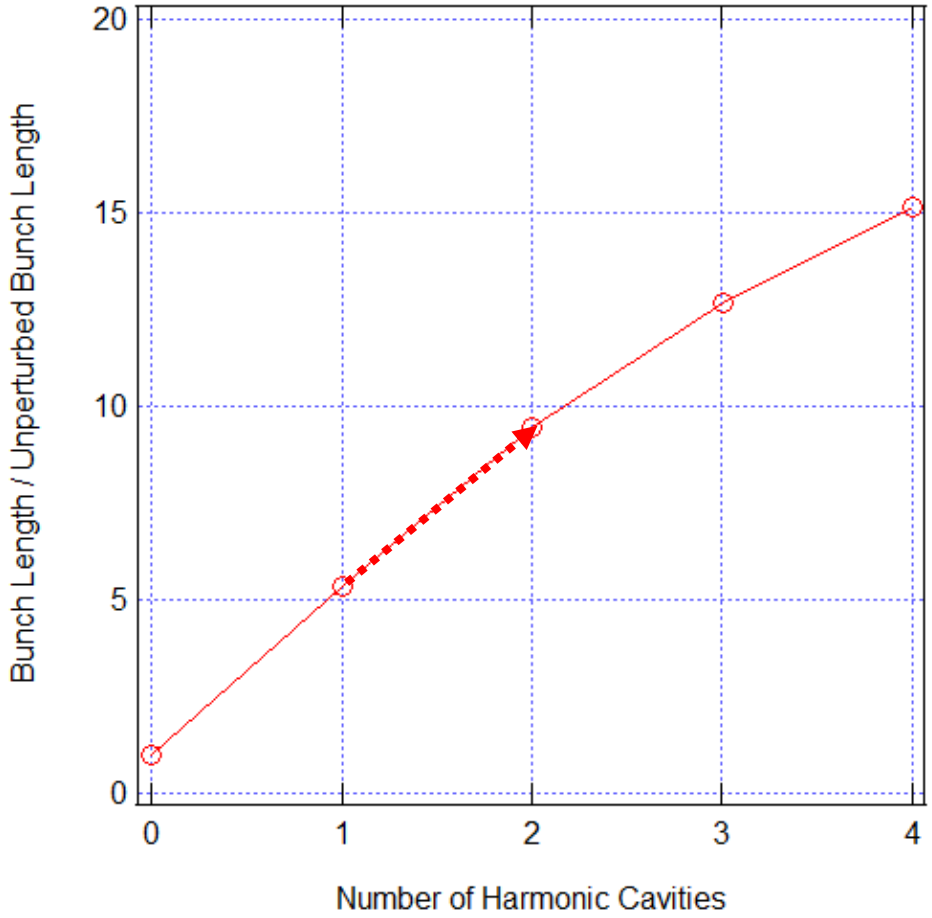
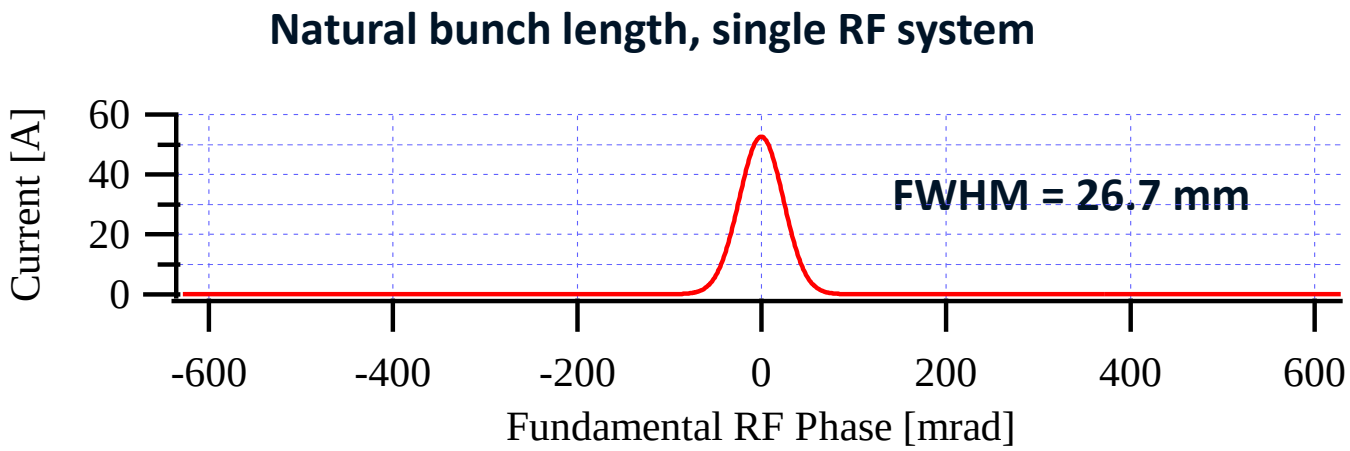


P_{cav500} =1.4 kW
$P_{beam500} = I_{av} * U_{500} * F_{500}$ =3.1 kW
P_{gen500} = 4.5 kW

Very moderate power requirement to 500 MHz cavity!







Lengthening ratios:

At FP	RMS-lengthening	FWHM-lengthening
1 HC frequency	5.0	6.7
2 HC frequencies	8.7	12.2

Coming back to the introduction paper:

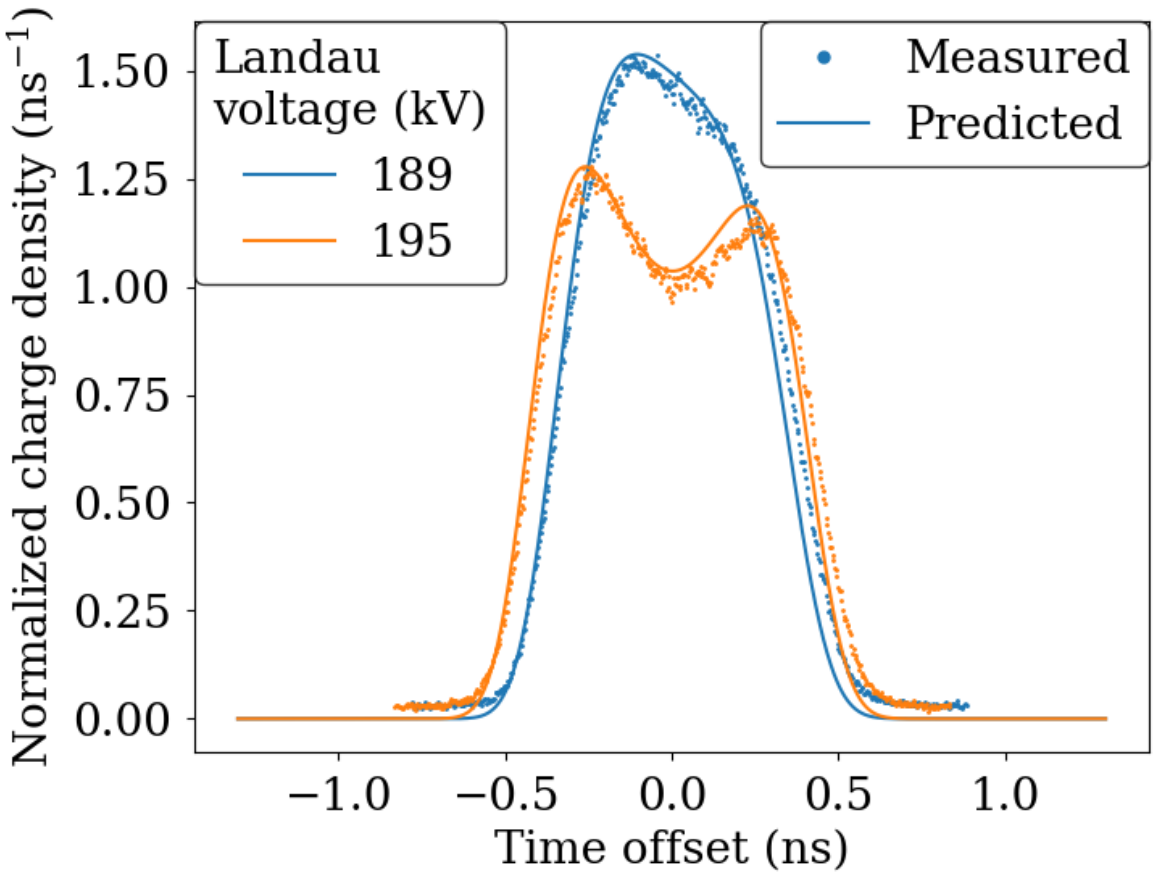
To obtain a large increase of the bunch length we make the slope of the RF wave form zero at the bunch

$$\frac{dV}{d\bar{\Phi}}(0) = V_0 \left[\cos \bar{\Phi}_s + nk \cos(n\bar{\Phi}_n)\right] = 0 \qquad (3)$$

Furthermore we would like to avoid the wave form having a maximum or minimum at the bunch. This could form a small bucket inside the normal bucket. Although this would probably do no harm regarding the operation of the cavity, it makes the analysis more complicated. To avoid this we demand

$$\frac{d^2V}{d\bar{\Phi}^2}(0) = - V_0 \left[\sin \bar{\Phi}_s + n^2 k \sin(n\bar{\Phi}_n)\right] = 0$$

At MAX IV we are indeed often operating outside the FP condition:



Plot: Courtesy of F. Cullinan

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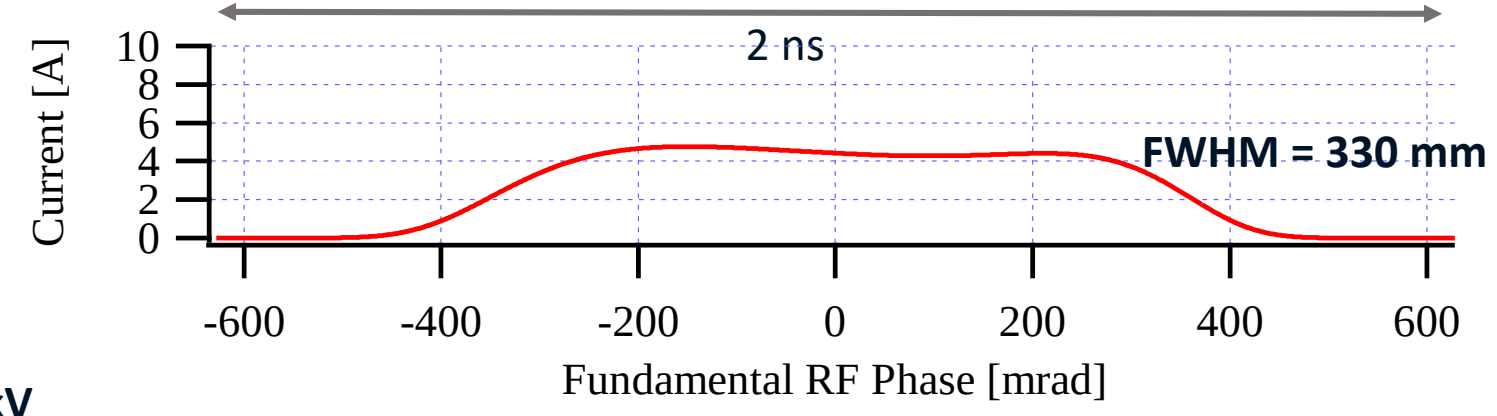
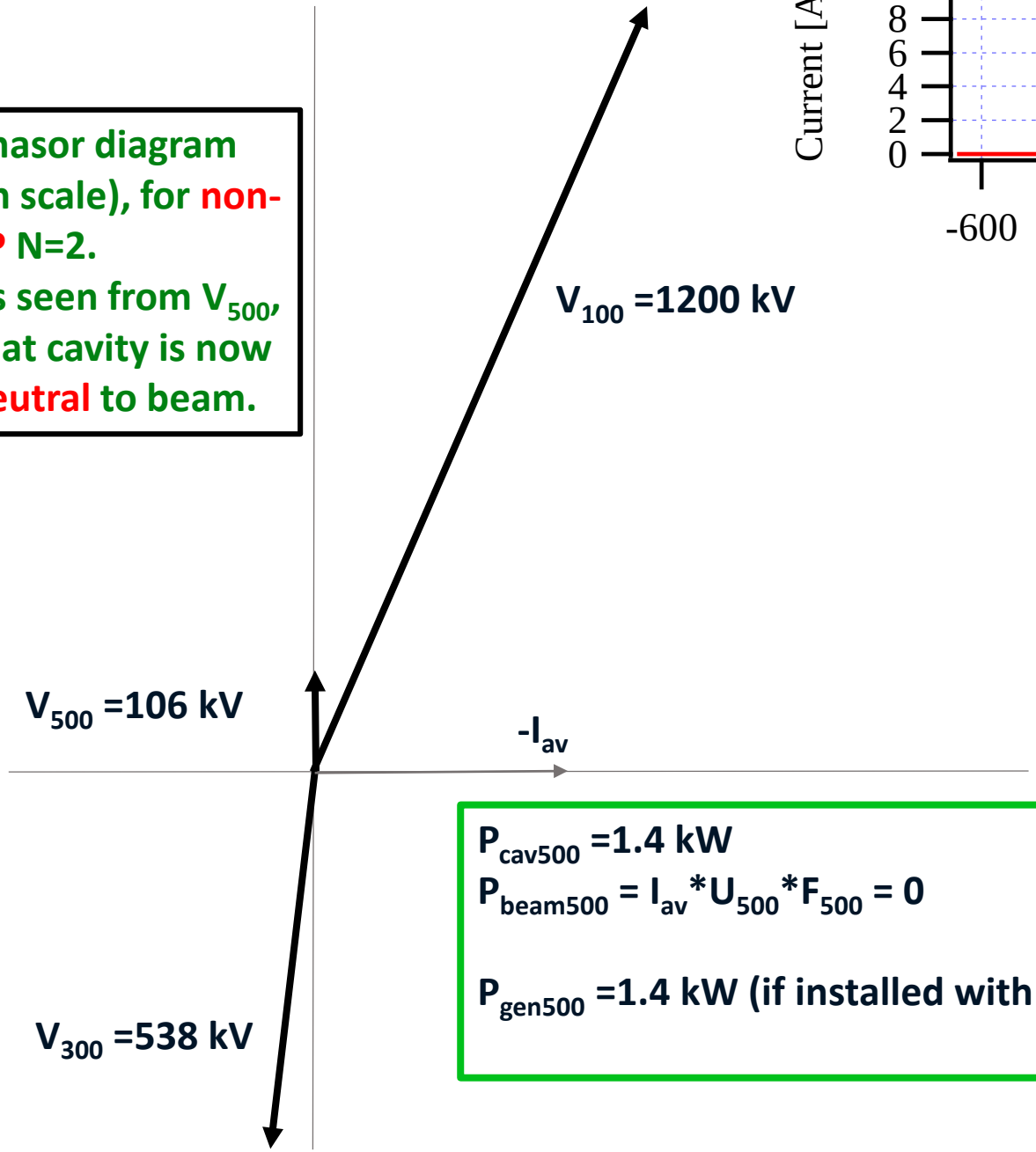
Equilibrium bunch density distribution with passive harmonic cavities in a storage ring

Pedro F. Tavares, Åke Andersson, Anders Hansson, and Jonas Breunlin
MAX IV Laboratory, Lund University, P.O. Box 118, SE-221 00 Lund, Sweden

Phasor diagram (in scale), for non-FP N=2.
As seen from V_{500}, that cavity is now neutral to beam.





P_{cav500} =1.4 kW
$P_{beam500} = I_{av} * U_{500} * F_{500} = 0$

P_{gen500} =1.4 kW (if installed with beta=1)

Time plan:

- Installation Summer 2024, with power coupler at **beta = 1**, but we will have no transmitter.
- **First goal** is to use it **passively**, extracting **~ 10 kW** from the beam, in comb. with 100 MHz cavities
- The bunch lengthening will be shorter by $3^{1/4}$ ~ 1.3, at FP
- To reach FP it may be convenient with an adjustable beta (stub matching), to reach beta < 1

Time plan:

- **Second goal**, drive it **actively** with **~ 1.4 kW** RF generator power, at **beta=1**, in the beginning of **2025**.
- Together with the passive 300 MHz cavities, we should reach near the generalized FP for a triple RF-system.
- The rms-bunch lengthening should be close to 9.

Summary

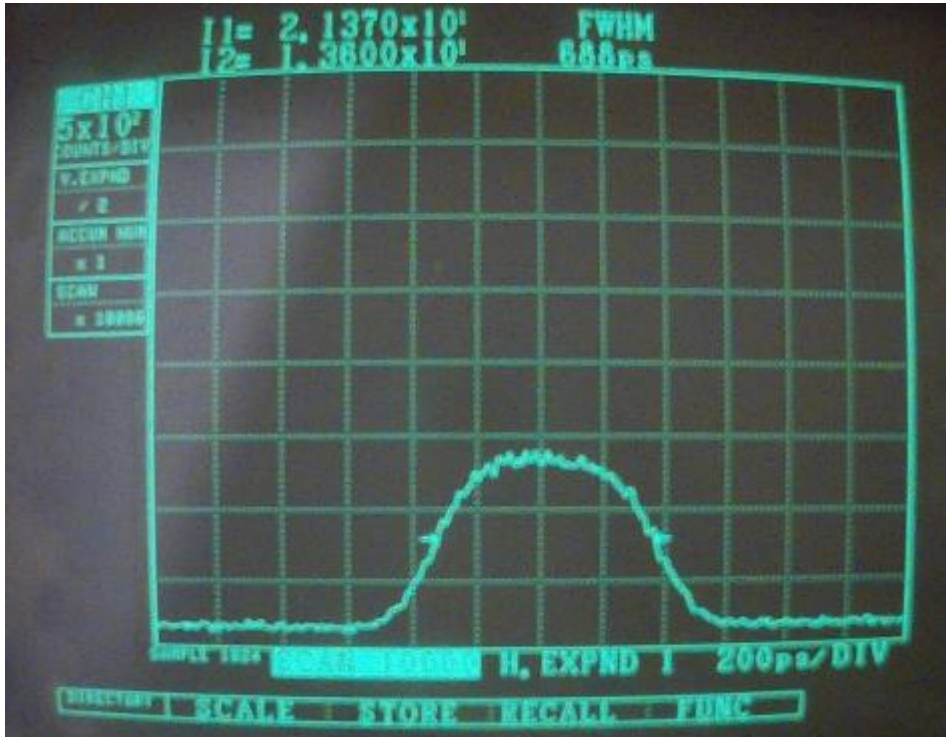
- A double-frequency harmonic cavity system is being implemented in MAX IV 3 GeV ring, by installing a 5th harmonic cavity.
- Power requirements for reaching near Flat Potential conditions are very modest.
- We anticipate IBS and Touschek scattering effects to be reduced, scaling inversely with the lengthening .

At FP	RMS-lengthening	FWHM-lengthening
1 HC frequency	5.0	6.7
2 HC frequencies	8.7	12.2

Many thanks to all people involved!!

Backup slides

Flat Potential conditions in MAX IV



Very close to **ideal Flat Potential** case, for N=1. Data at 40 mA.

Our two present passive 300 MHz cavities, have no power coupler installed.

Phasor diagram (in scale), for FP N=2.
As seen from V_{500}, that cavity needs to be active.