LHC Injectors Upgrade

Transmission Measurement of All the PSB Machine

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Facts Sheet

- PSB Damping Resistors become too hot (~400º) after LIU Upgrade
- Solution I: Double the Damping Resistor Value
- Problem I: No knowledge about the reason for those resistors!
- In 1970 those resistors were on the technical drawings then disappeared but eventually plugged into the PSB dipoles and quadrupoles in 1971.
- Problem II:
  - Michel Chanel vividly remembered a report about those resistors!
  - Reports of the SI Division Period: 1968 – 1972 not digitized.
  - Small Fraction in the PS Archive
  - All reports found either in CERN or PS Archive, the latter scanned by Frank and passed on to the CERN Archive

➔ Total of 1465 reports 655 still to be digitized.

- Solution II: Measure single dipole, quadrupoles, chain of magnets and all machine.
- Problem III: No expert to take over!
- Solution III: For the time being increase resistors but do simulations to confirm

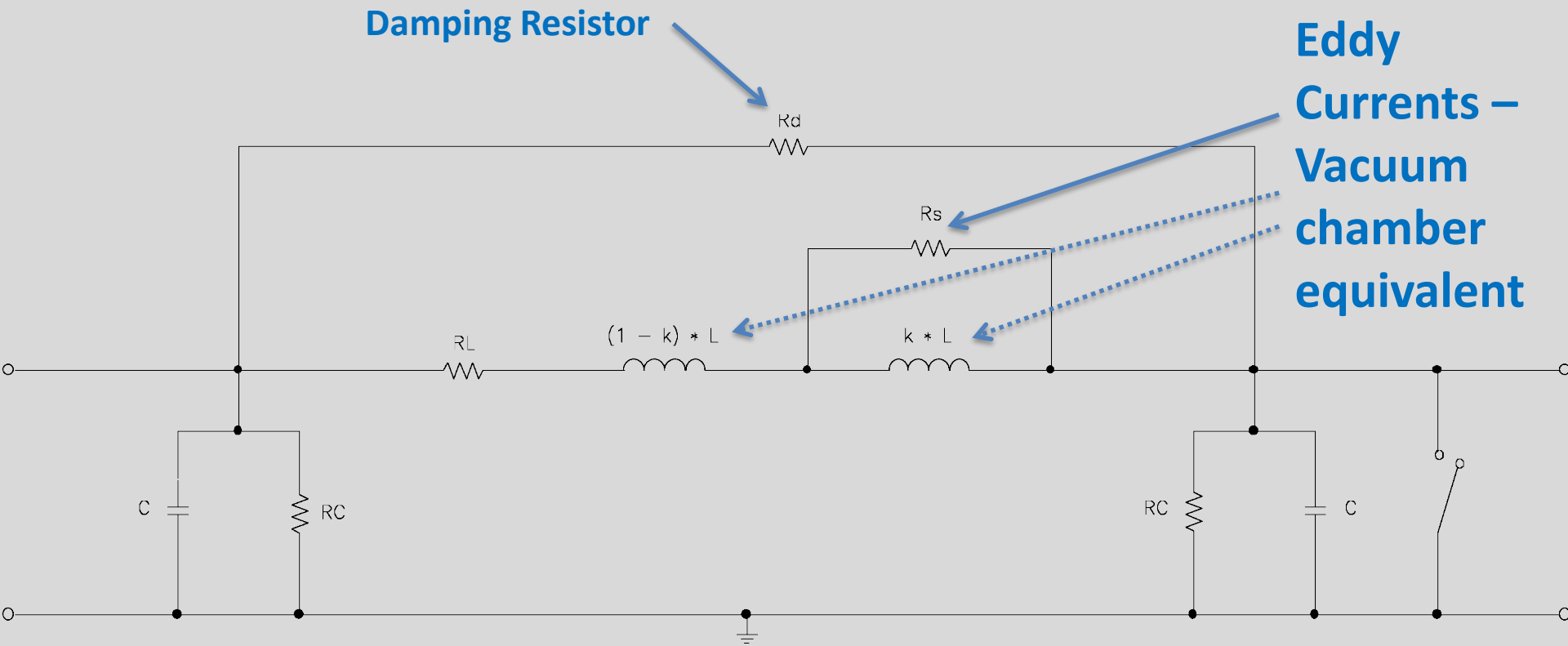
Measurements

- PSB Dipole
  - 4 in Series
  - With and without Vacuum Chamber
  - RD = { ∞, 4*(10/20/40) } [Ω]
- PSB Quad
  - QF
  - QDD
  - Vacuum Chamber
  - RD = 20, ∞ [Ω]

Since December

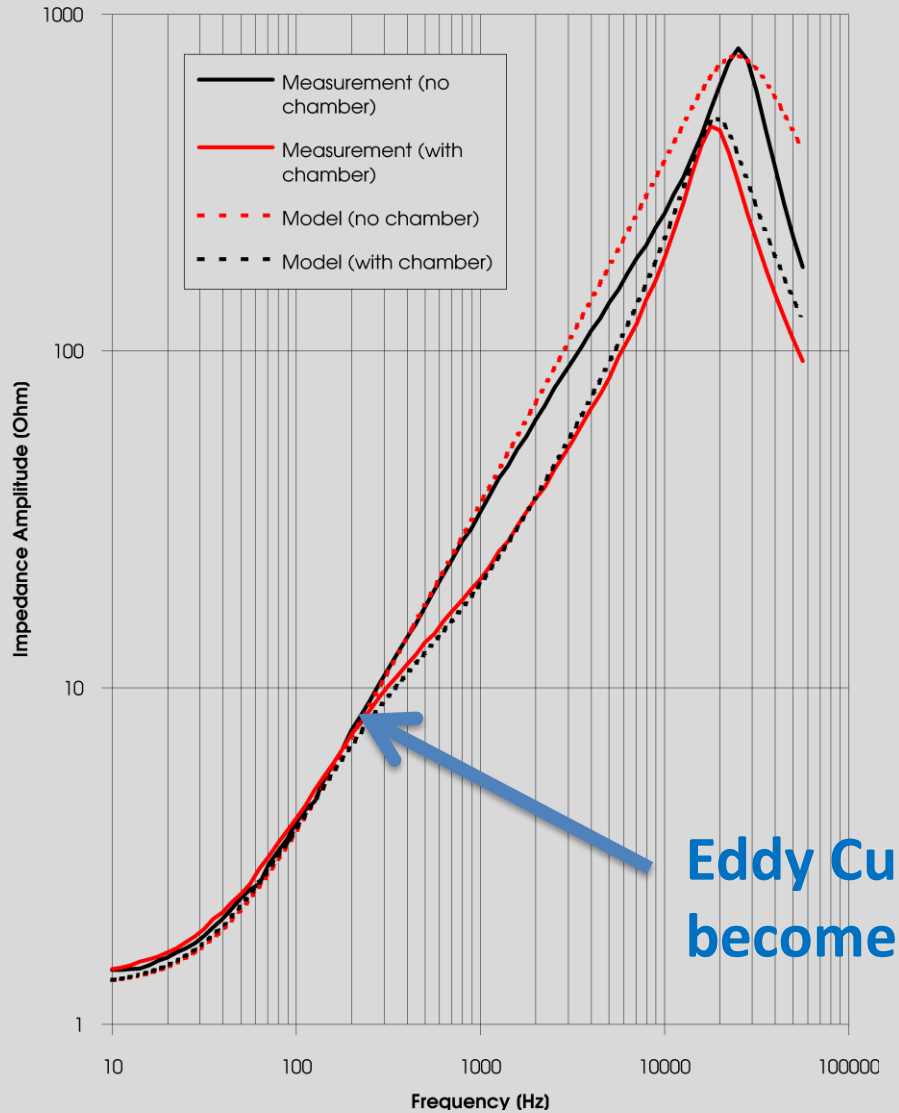
- Dipole Chain
- Quadrupole Chain
- All Machine

Symmetric 4-Pole Model



Eddy Currents – Vaccum Chamber

Example: SPS vacuum chamber very relevant



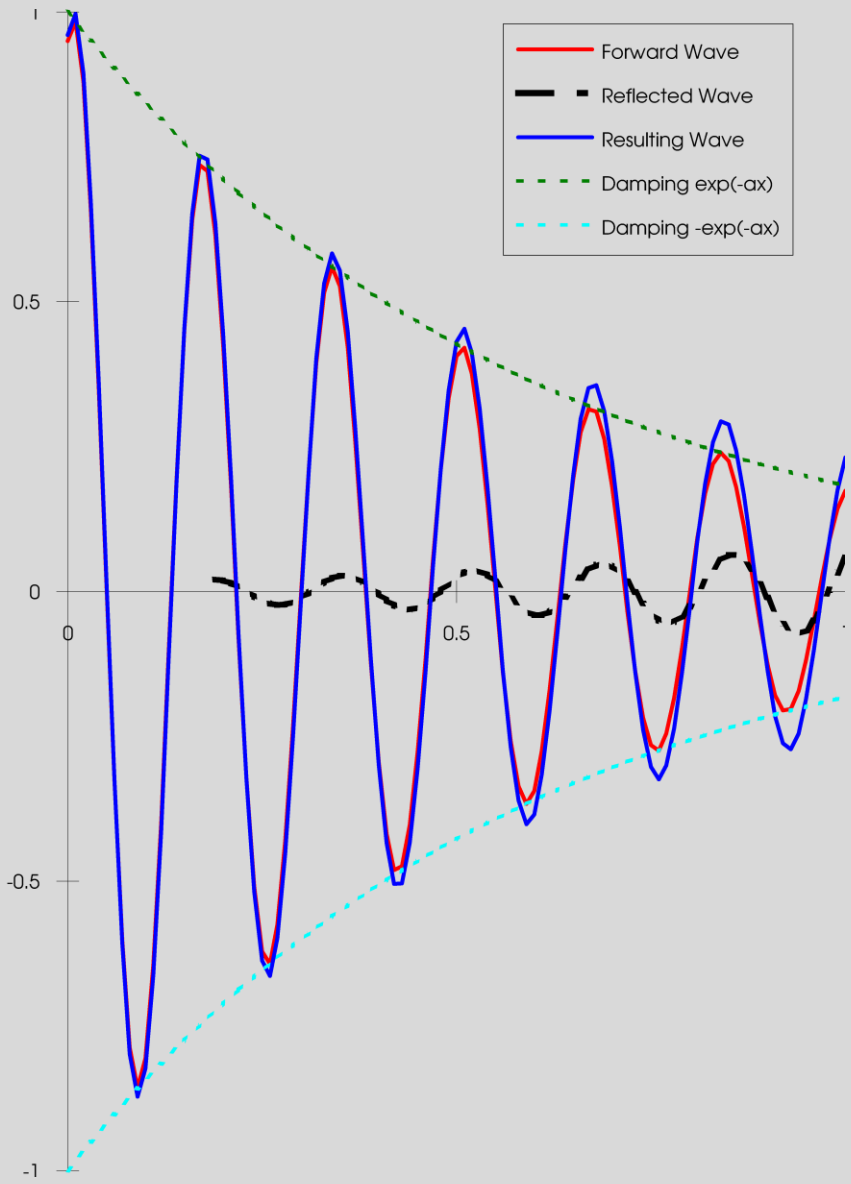
Eddy Currents become relevant

Transmission Line Model

$$U e^{i\omega t} = a_1 e^{-\alpha x} e^{i(\omega t - \beta x)} + a_2 e^{\alpha x} e^{i(\omega t + \beta x)}$$

$$I e^{i\omega t} = \frac{a_1}{Z_o} e^{-\alpha x} e^{i(\omega t - \beta x)} - \frac{a_2}{Z_o} e^{\alpha x} e^{i(\omega t + \beta x)}$$

Damping

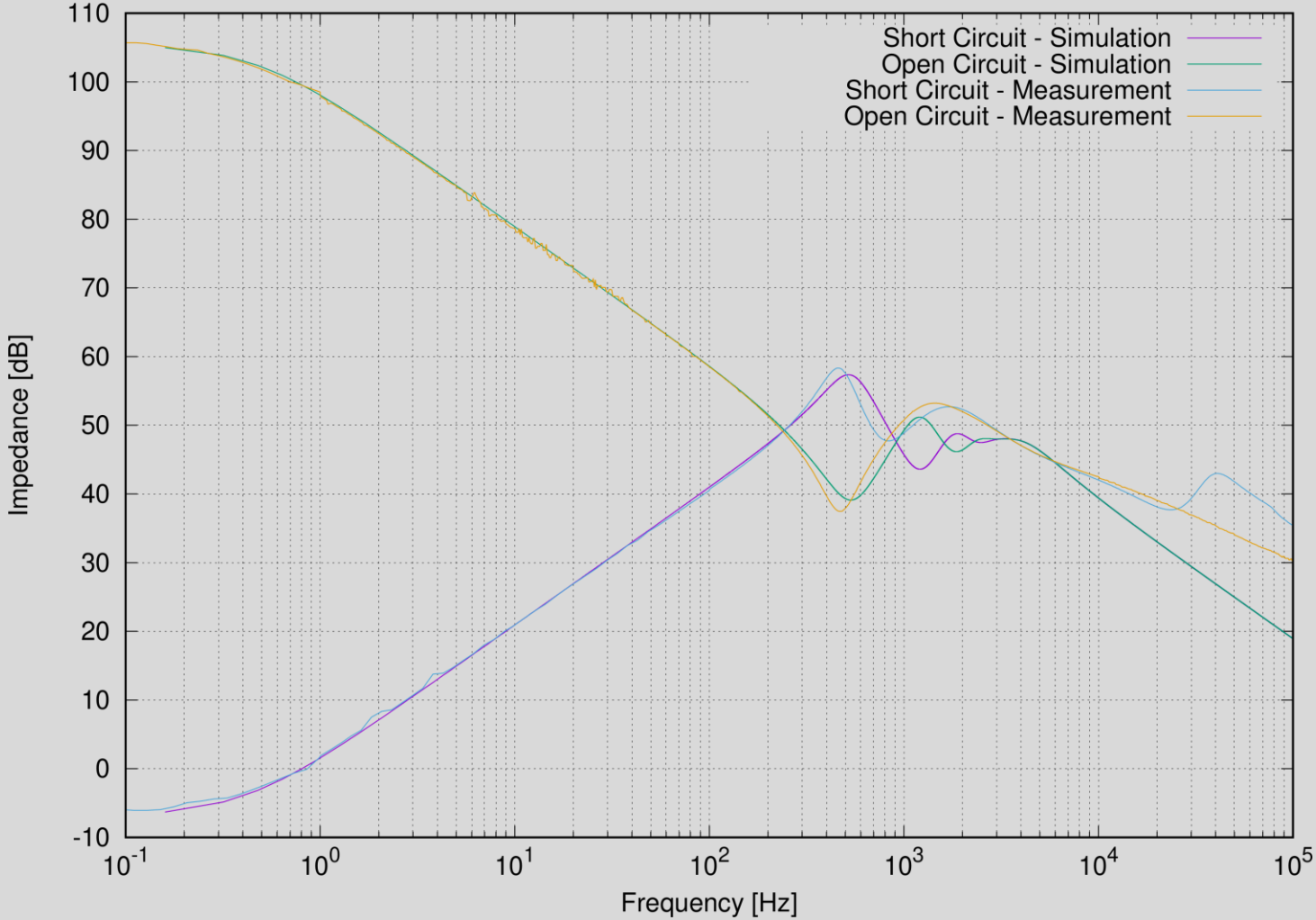

Forward Wave
Reflected Wave
Resulting Wave
Damping exp(-ax)
Damping -exp(-ax)
1
0.5
0
-0.5
-1
0
0.5

Transport Matrix

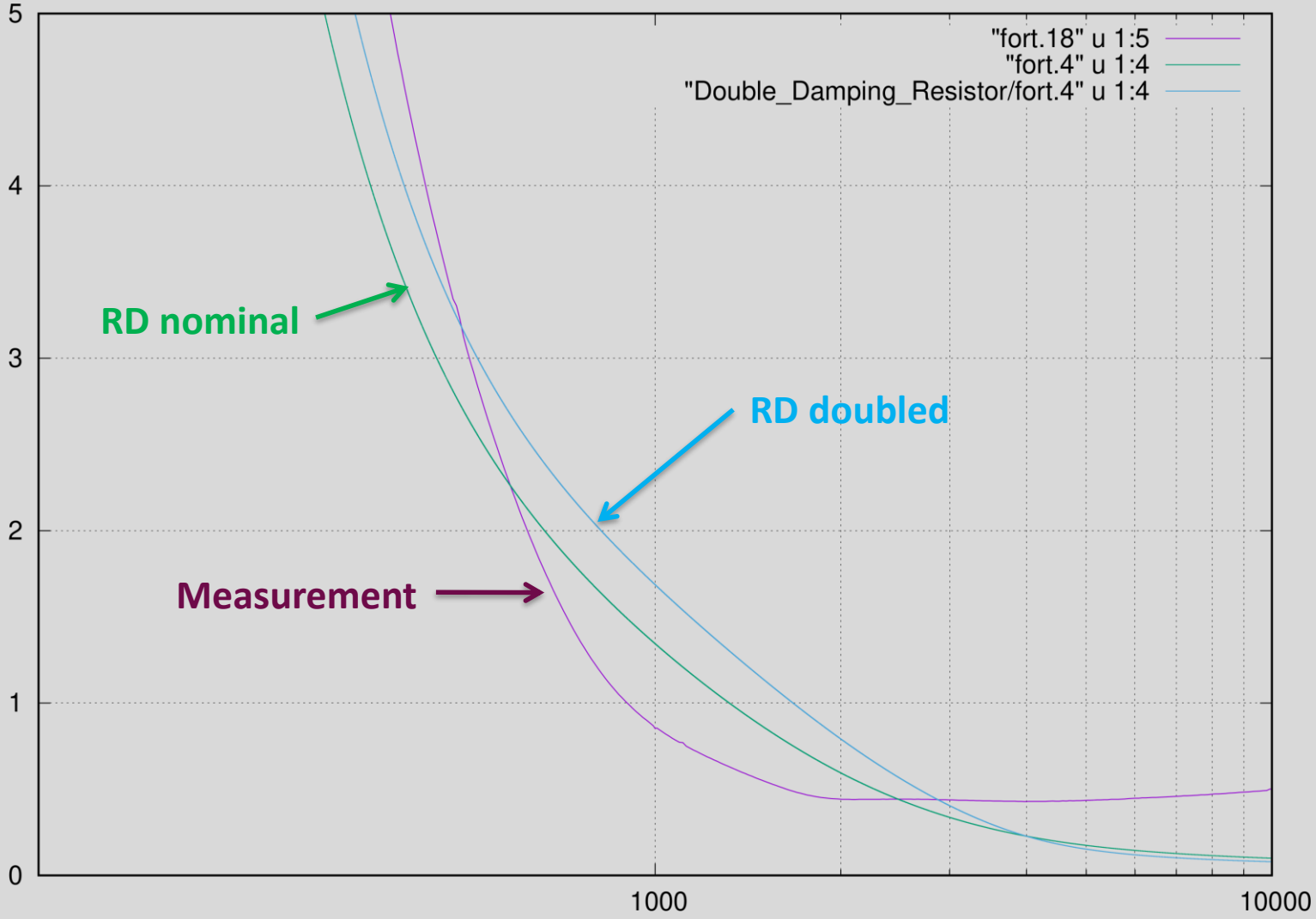
$$\gamma = \alpha + i\,\beta$$

$$\begin{pmatrix} U_1 \\ I_1 \end{pmatrix} = \begin{pmatrix} \cosh(\gamma l) & Z_o \sinh(\gamma l) \\ \frac{1}{Z_o}\sinh(\gamma l) & \cosh(\gamma l) \end{pmatrix} \times \begin{pmatrix} U_2 \\ I_2 \end{pmatrix}$$

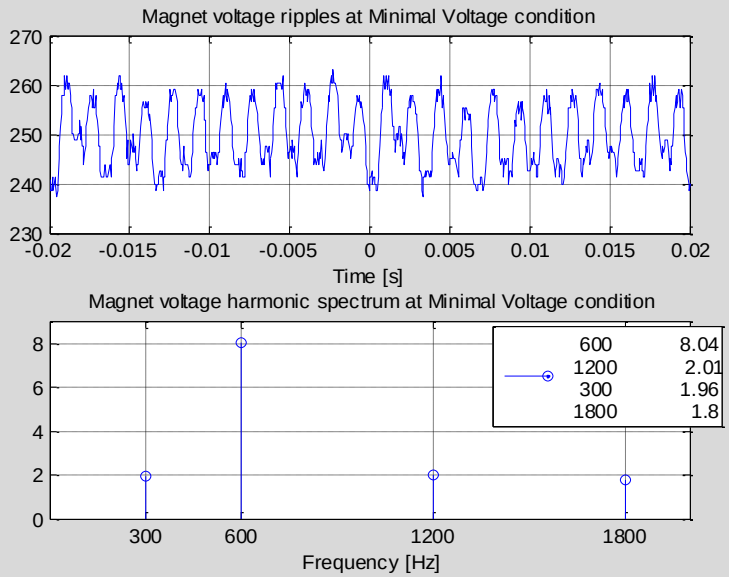
PSB – All Machine



PSB – All Machine Damping 1/α



PSB – Old PS System Harmonics



Harmonic Frequency[Hz]	Harmonic Amplitude [V]
600	8.04
1200	2.01
300	1.96
1800	1.8
$\sqrt{\sum_{\square} A_h^2}$	9.189

Table 1. MPS magnet voltage (pk value) dominant harmonics at minimal voltage condition.

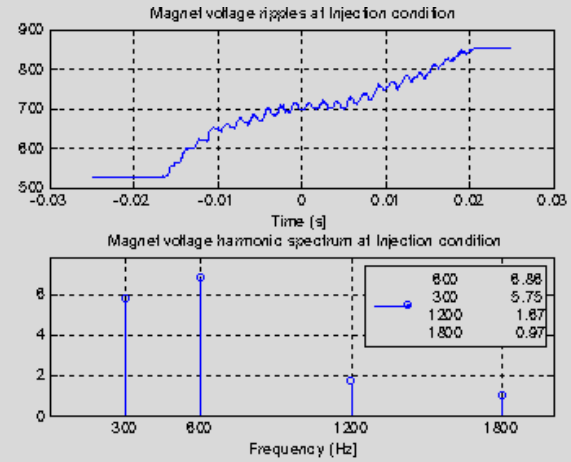
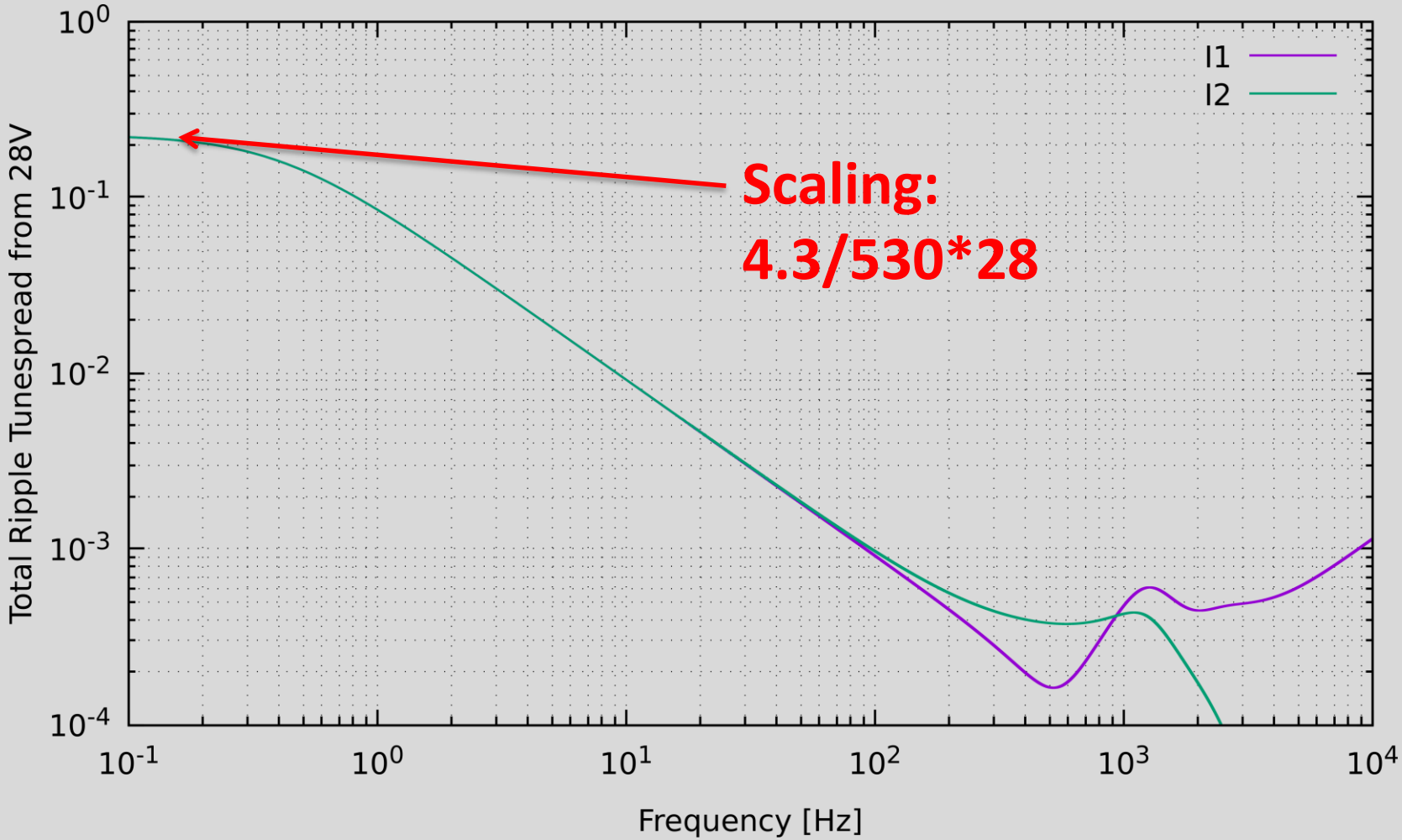


Figure 4. MPS magnet voltage at injection point

Harmonic Frequency[Hz]	Harmonic Amplitude [V]
600	6.86
1200	1.67
300	5.75
1800	0.97
$\sqrt{\sum_{\square} A_h^2}$	9.15

Table 2. MPS magnet voltage dominant harmonics at injection.

Potential Total Tune Ripple

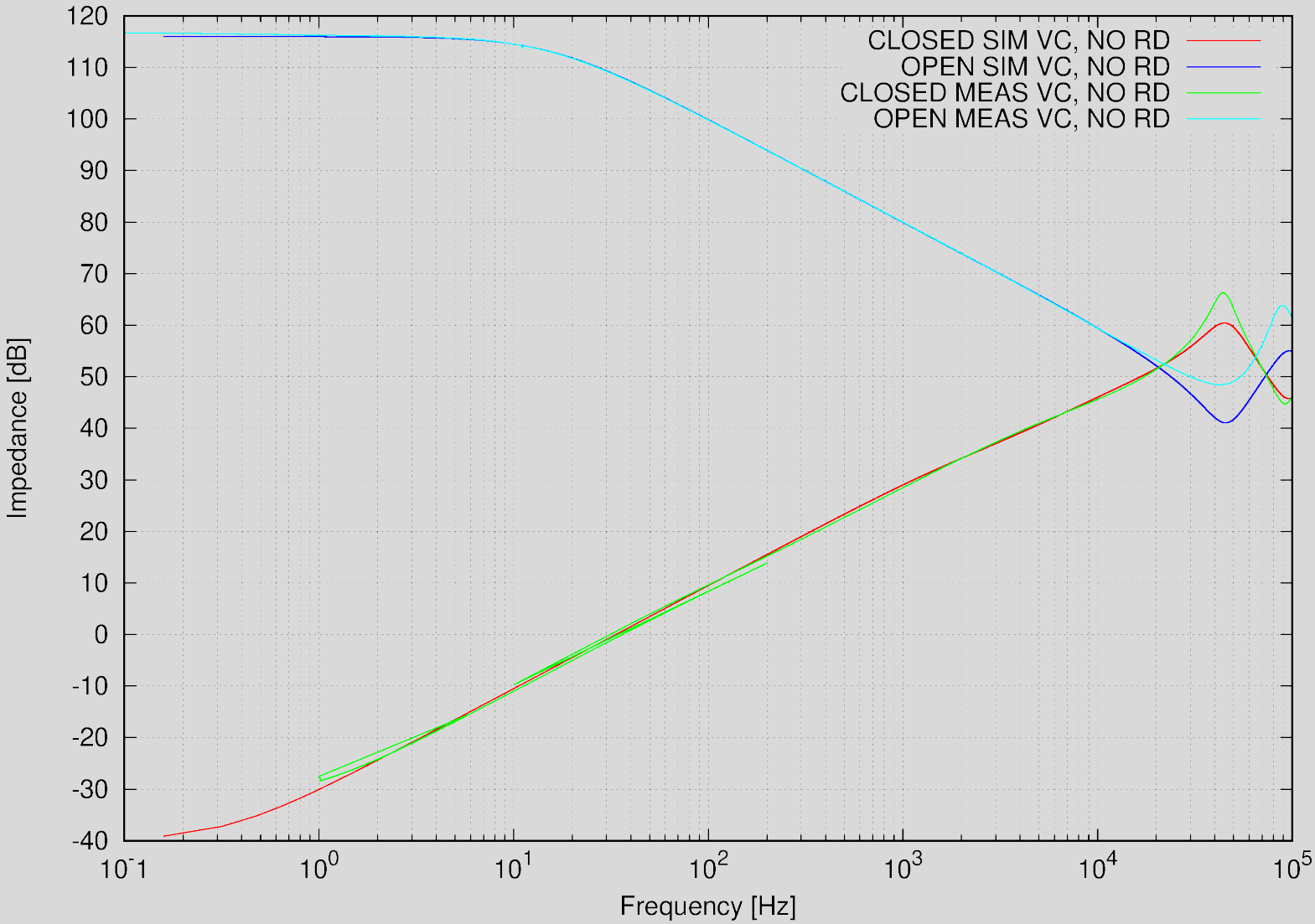


Conclusions

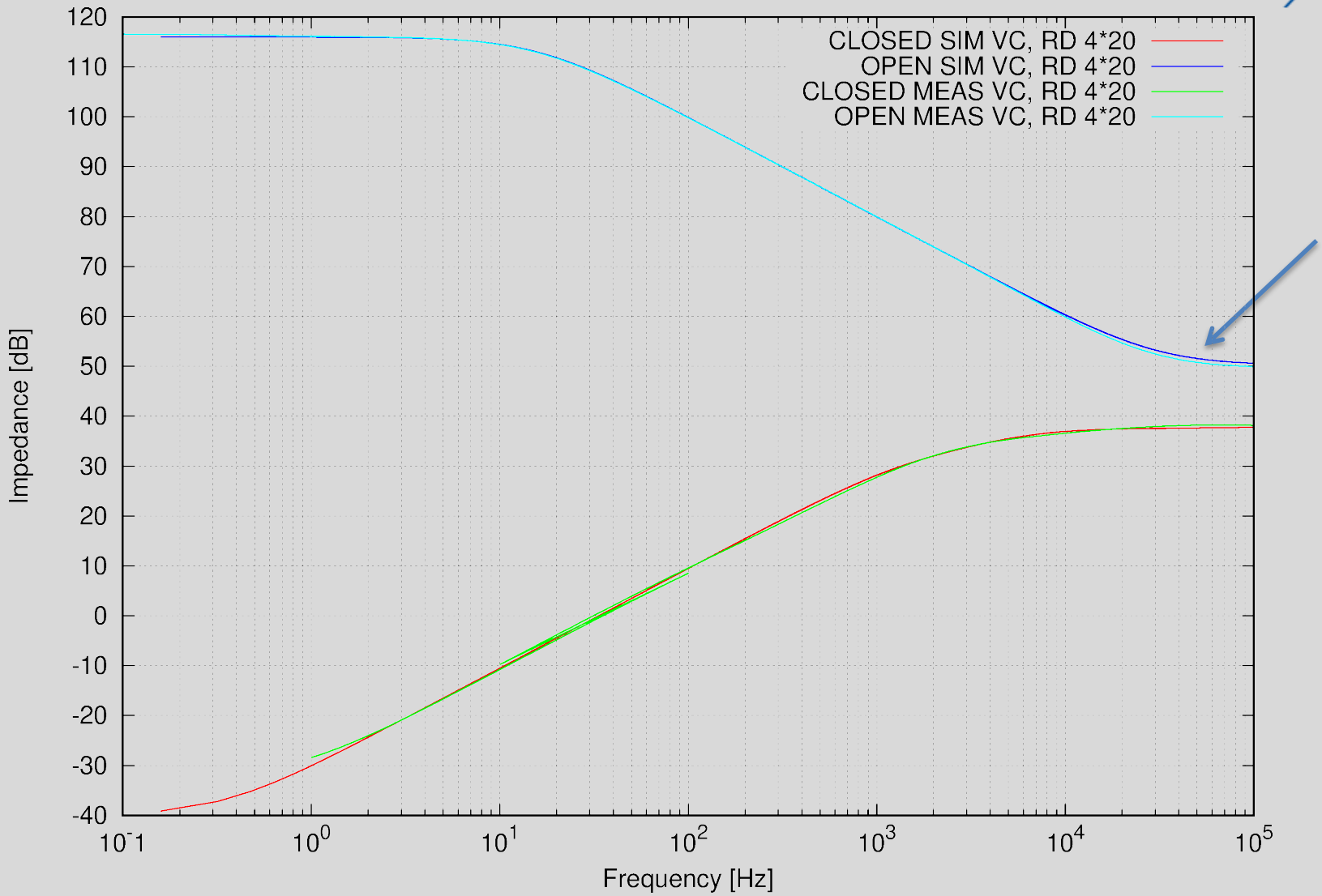
- Measurements of both dipoles and quadrupoles done
- Measurements done for single chains and the complete machine
- Signal Damping in reasonable good agreement
- High quality voltage of old PS system indicate that tune ripple might cause effect on beam stability at injection energy ➔ Simulations foreseen in spring 2019
- New PS system at injection 1 or 2 voltage ripple (333 & 2kHz) lines smaller by factor of ~3 ➔ Effect on beam stability unlikely!
- Continue with doubling of damping resistors by a factor of 2. Review!

Reserve

Dipole, VC RD = ∞


CLOSED SIM VC, NO RD
OPEN SIM VC, NO RD
CLOSED MEAS VC, NO RD
OPEN MEAS VC, NO RD
Impedance [dB]
Frequency [Hz]
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
10^-1
10^0
10^1
10^2
10^3
10^4
10^5

Dipole, VC RD = 4*20 Ω



Todo List

- Finish PSB Dipole
- Analyze PSB Quads
- Full Magnet Chains
- Measurement of Full Chain in 19th of June
- Proper Documentation missing from the early Days!