UPDATE OF THE SPS KICKERS

B. Salvant and E. Métral

APC action (10/11/06): "The Committee … but it stressed the importance of evaluating the effect of the resonance peaks observed at low frequency on the longitudinal and transverse stability of the 25 ns and 75 ns LHC beams before going any further in the programme of modification of the extraction kickers"

- **Longitudinal impedance of all the SPS kickers**
- **Vertical impedance of all the SPS kickers**
- **Analysis of the effect of metallic stripes on the MKE-L10**
- **Appendix1: Vertical impedance $\Longrightarrow$ Tsutsui vs. Zotter**
- **Appendix2: Vertical impedance of each kicker in 2006**

TABLE OF THE KICKERS' APERTURES IN 2006 AFTER CROSS-CHECK WITH E. GAXIOLA (G. Arduini, 01/06/06)

KICKERS IN 2006

Length of the ferrite ~ 20% smaller

@	PARTICLE	%06s	PROTON							
@	PC	%le	26							
@	GAMMA	%le	27.72855253							
@	LENGTH	%le	6911.5038							
@	GAMMATR	%le	22.77284397							
@	Q1	%le	26.12992431							
@	Q2	%le	26.18084922							
@	DQ1	%le	0.439325966							
@	DQ2	%le	0.319623397							
@	ORIGIN	%19s	MAD-X 3.01.01 Win32							
@	DATE	%08s	13/04/06							
@	TIME	%08s	18.40.17							
*	NAME		s [m]	LENGTH [m]	BETX [m]	DX [m]	BETY [m]	FULLAPERX [mm]	FULLAPERY [mm]	
$	%s		%le		%le	%le	%le	%le	%le	
	MKQH.11653**		524.6862	0.96	64.51713859	-0.203834072	37.18877804	115	32.3	
	MKQV.11679		535.7712	1.416	33.88229322	-0.265543616	70.08046855	102	56	
	MKDV.11731	MKDVA	550.619	2.892	25.67939112	-0.422827627	88.2797746	75	56	
	MKDV.11736	MKDVB	553.81	2.892	31.20924701	-0.487568806	75.4367941	83	56	
	MKDH.11751	MKDHA	556.021	1.6	35.78005965	-0.532427078	67.27627624	96	56	
	MKDH.11754	MKDHA	557.92	1.6	40.18894924	-0.570955282	60.74970389	96	56	
	MKDH.11757	MKDHB	559.819	1.6	45.04424364	-0.609483486	54.66890535	105	60	
	MKPA.11931	MKPA	615.0954	3.423	26.32855499	-0.216015187	85.77846538	100	61	
	MKPA.11936	MKPA	618.7174	3.423	32.83404863	-0.181650065	71.5862138	100	61	
	MKPC.11952	MKPC	620.6964	1.78	37.07009874	-0.162873539	64.51516613	100	61	
	MKP.11955	MKP	624.3184	3.423	46.07038936	-0.128508417	52.82431039	140	54	
	MKE.41631	MKEL	3973.3482	2.014	91.97523046	-0.162968793	24.03938714	147.7	35	
	MKE.41634	MKEL	3975.6612	2.014	82.32729483	-0.175742387	27.57626338	147.7	35	
	MKE.41637	MKES	3977.9742	2.014	73.33678277	-0.18851598	31.77220251	135	32	
	MKE.41651	MKES	3980.2872	2.014	65.00369429	-0.201289573	36.62720455	135	32	
	MKE.41654	MKEL	3982.6002	2.014	57.32802939	-0.214063166	42.1412695	147.7	35	
	MKE.61631	MKEL	6277.1828	2.014	92.08548438	-0.148157569	24.11653436	147.7	35	
	MKE.61634	MKEL	6279.4958	2.014	82.4230454	-0.161396499	27.70271087	147.7	35	
	MKE.61637	MKES	6281.8088	2.014	73.41886037	-0.174635428	31.95216455	135	32	
	MKE.61651	MKES	6284.1218	2.014	65.07292927	-0.187874358	36.86489539	135	32	

** inner dimensions of the ceramic insert

KICKERS IN 2007

- **Discussion with L. Ducimetiere (26/04/07)**
  - **The spare kicker MKE-L10 (all ferrite cells equipped with serigraphed interleaved metallic stripes) has been put in 61631 (replacing the MKE-L8 which has been removed)**
  - **The MKE-S3 in 61637 has been removed and replaced by the MKE-S6 in 61651 (with impedance reduction on 2 cells only)**

$\Longrightarrow$ Conclusion: Only 8 MKE kickers in the SPS in 2007 (9 in 2006)

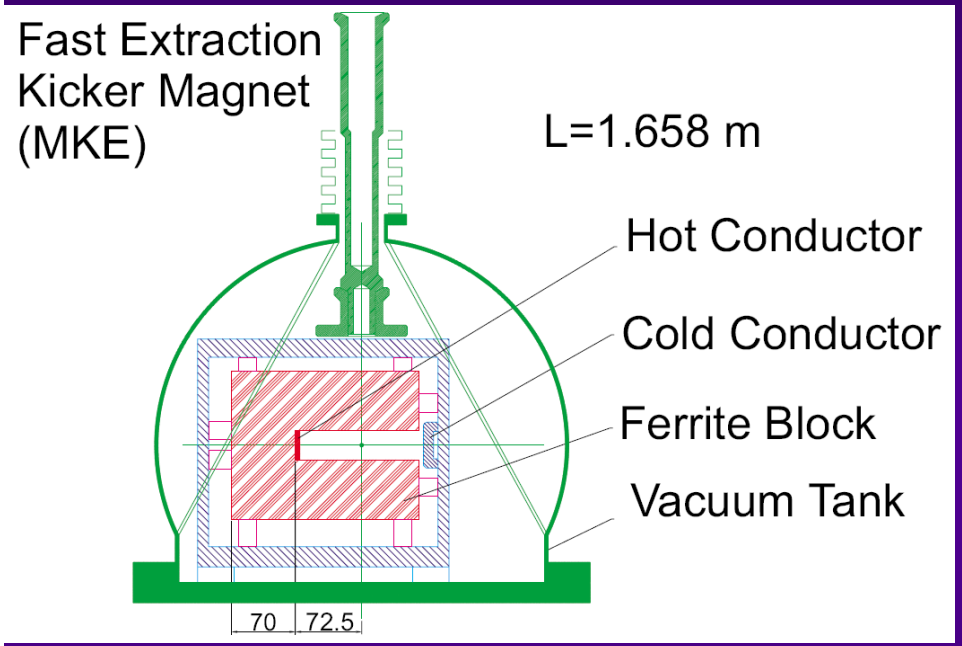
- 6 not shielded (8 in 2006)

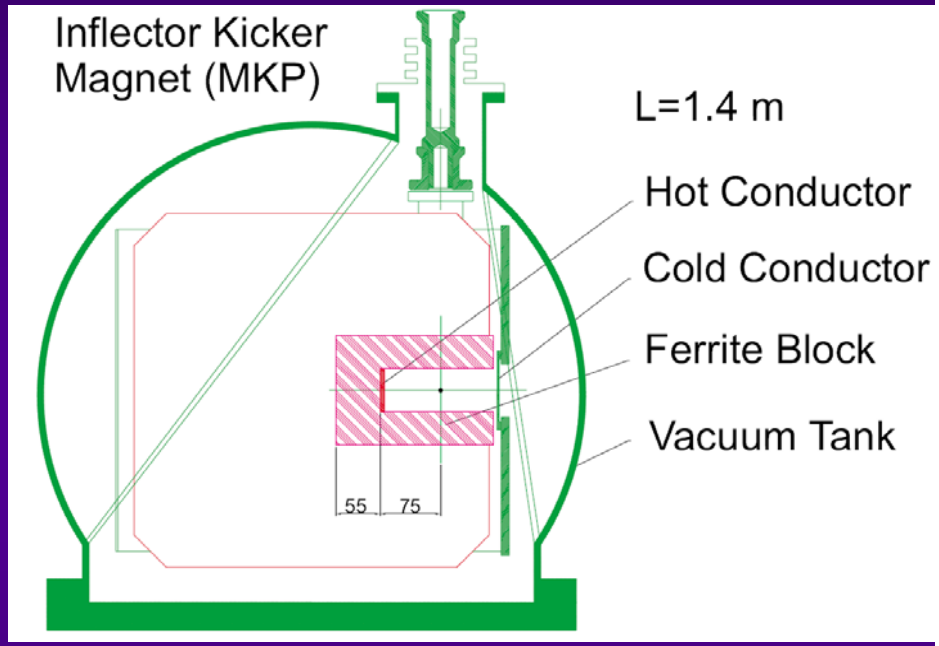
- 1 fully shielded (not present in 2006)

- 1 shielded on 2 cells only (present in 2006)

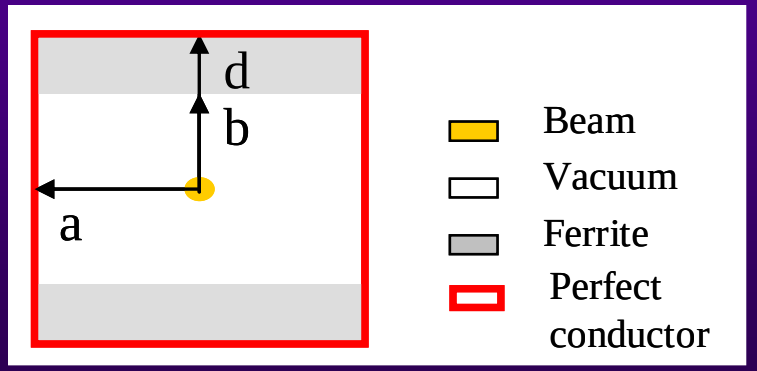
MKE AND MKP KICKERS

Example of cross sections of the SPS MKE and MKP kicker magnets (F. Caspers, Chamonix X)





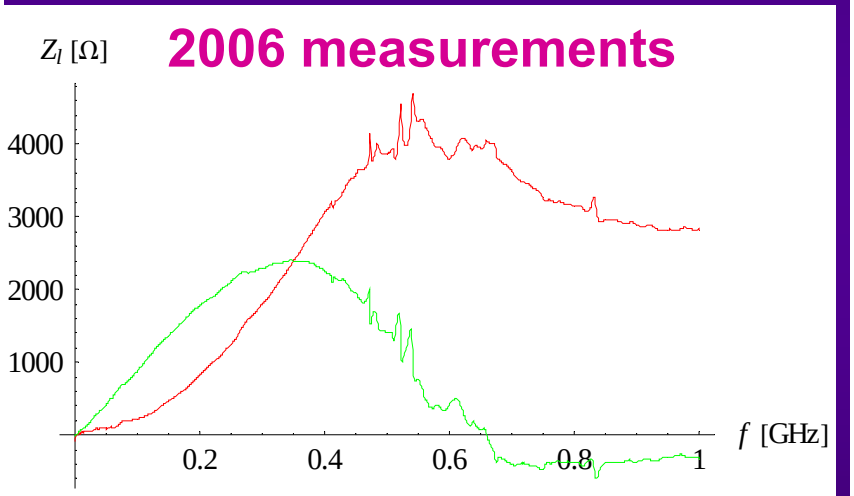
$\Longrightarrow$ From the impedance point of view, a SPS kicker can be approximated by the following sketch



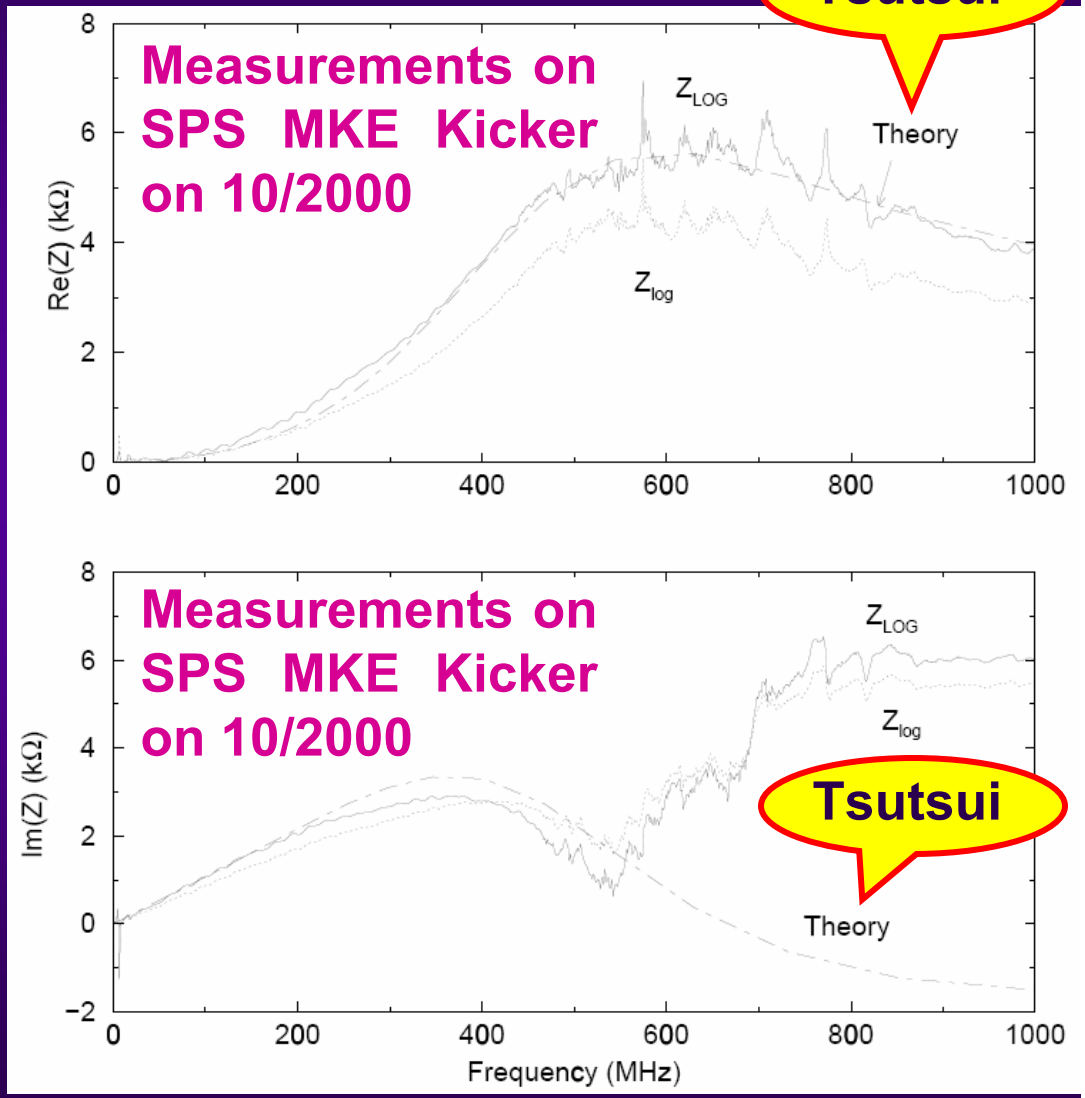
LONGITUDINAL IMPEDANCE (1/4)

- Comparison between longitudinal measurements in 2000 and in 2006

F. Caspers et al., CERN-SL-2000-071 (AP)

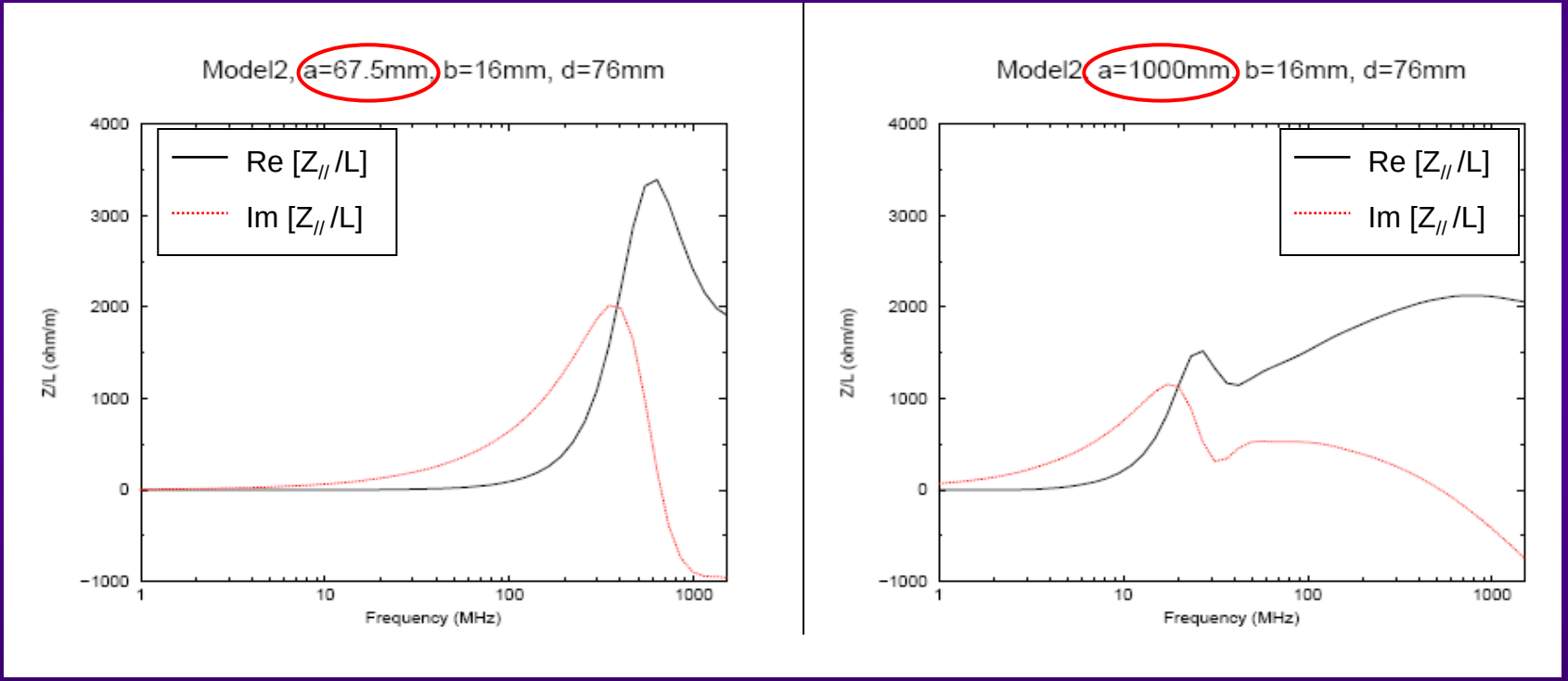


Tsutsui



LONGITUDINAL IMPEDANCE (2/4)

H. Tsutsui, CERN-SL-2000-004 (AP)



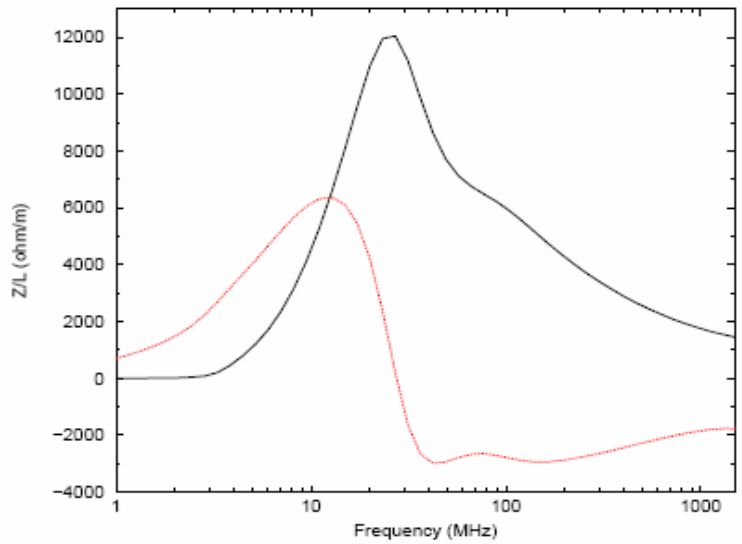
$\Longrightarrow$ **a (with the perfect conductor) is very important as found by Tsutsui, F. Caspers… and Tsutsui's formula should be used**

LONGITUDINAL IMPEDANCE (3/4)

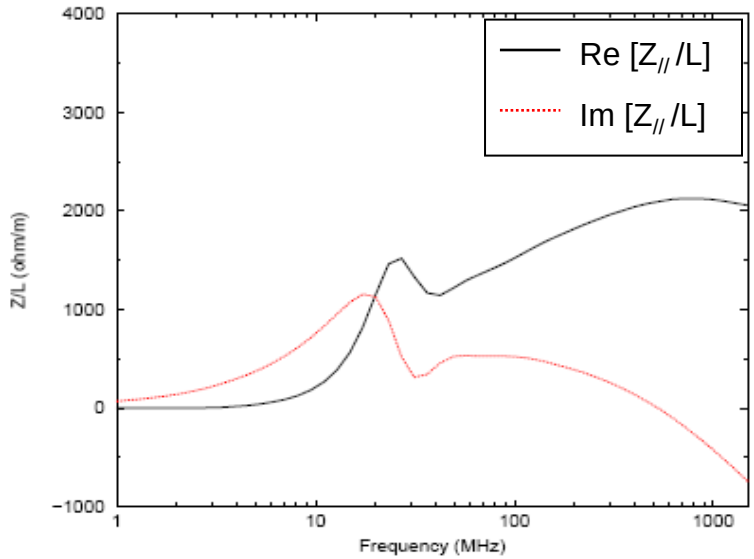
Confirmed by the new formula from Benoit (round geometry)

Should be close to the round case!

Round chamber Model 1, b=20mm, d=80mm

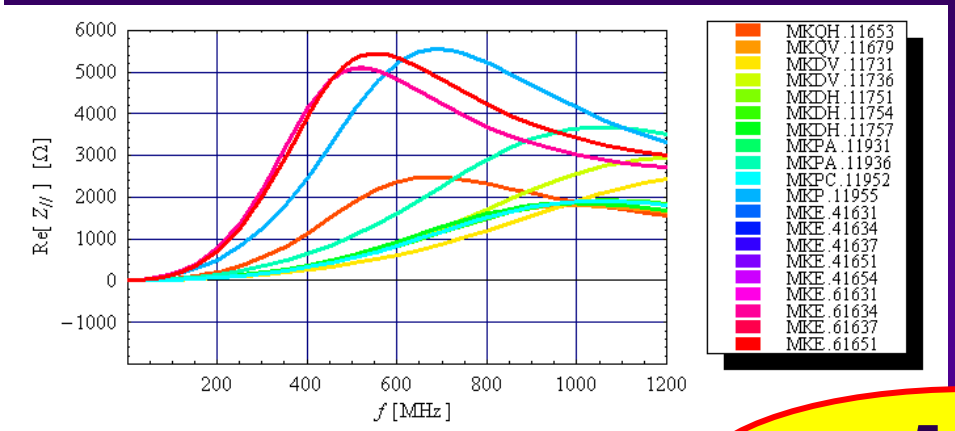


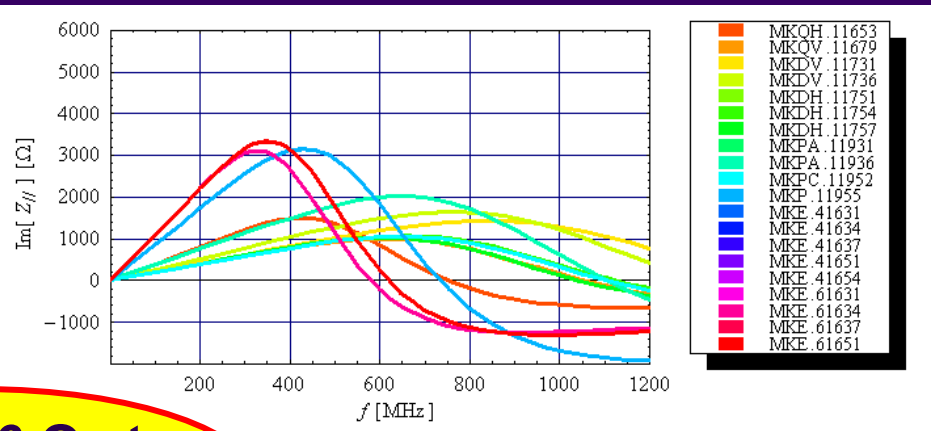
Model2 a=1000mm, b=16mm, d=76mm



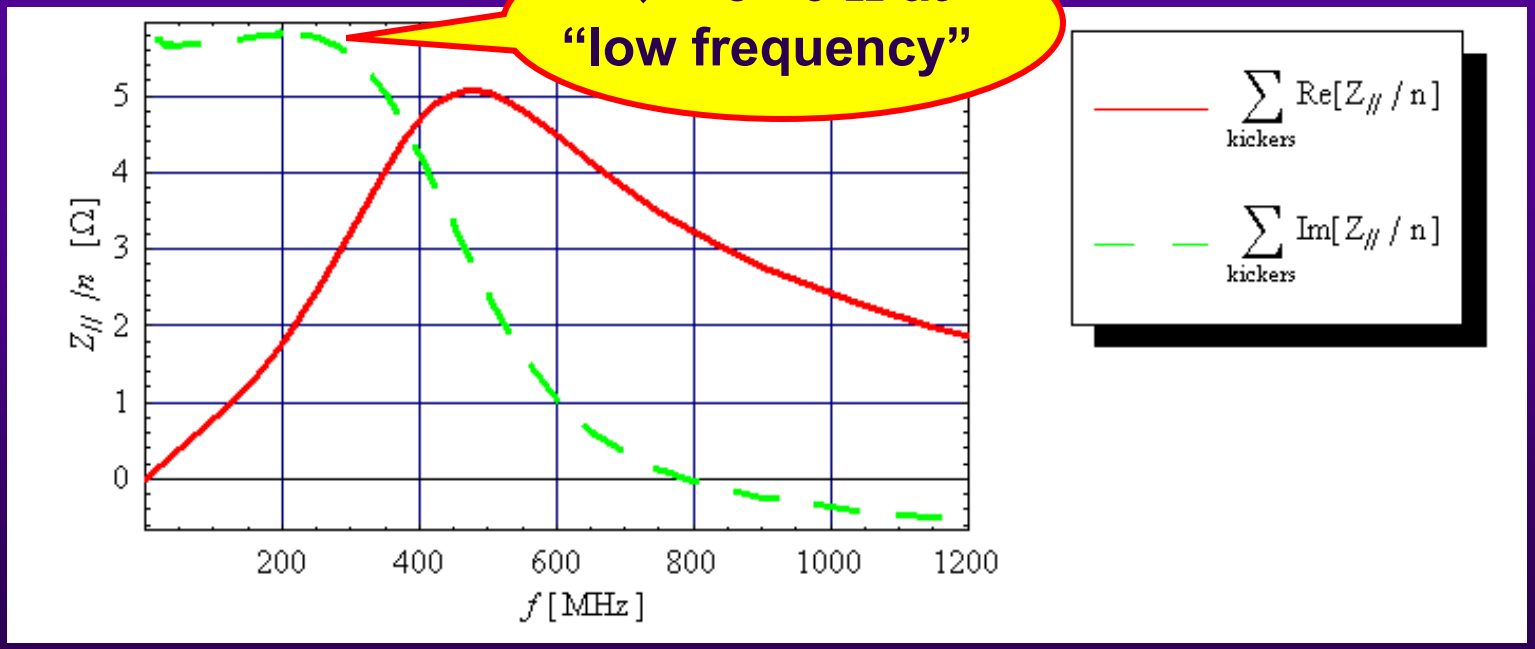
LONGITUDINAL IMPEDANCE (4/4)

- **Real part for each kicker**
- **Im. part for each kicker**



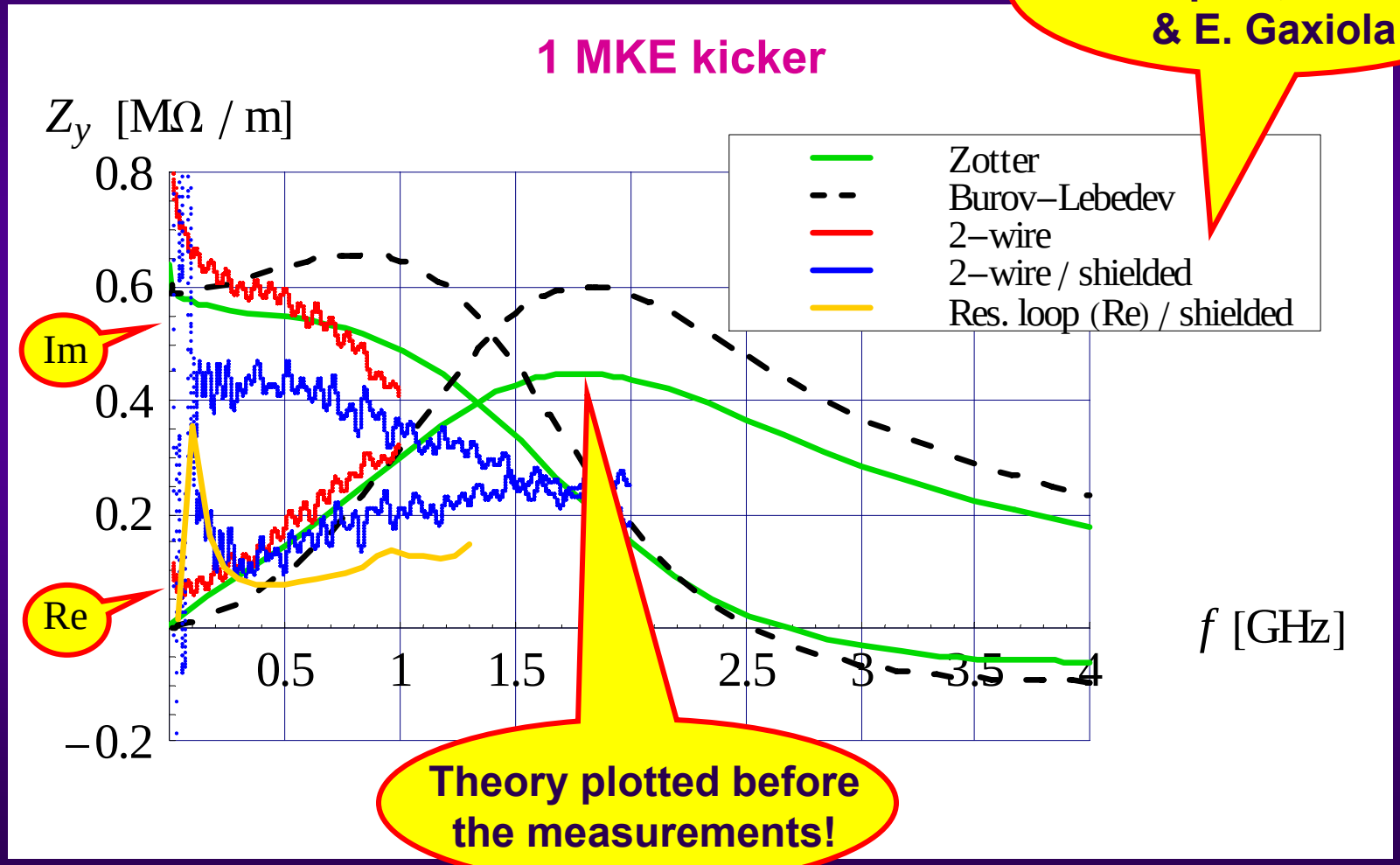


$\Longrightarrow$ **~ 5 - 6 Ω at "low frequency"**



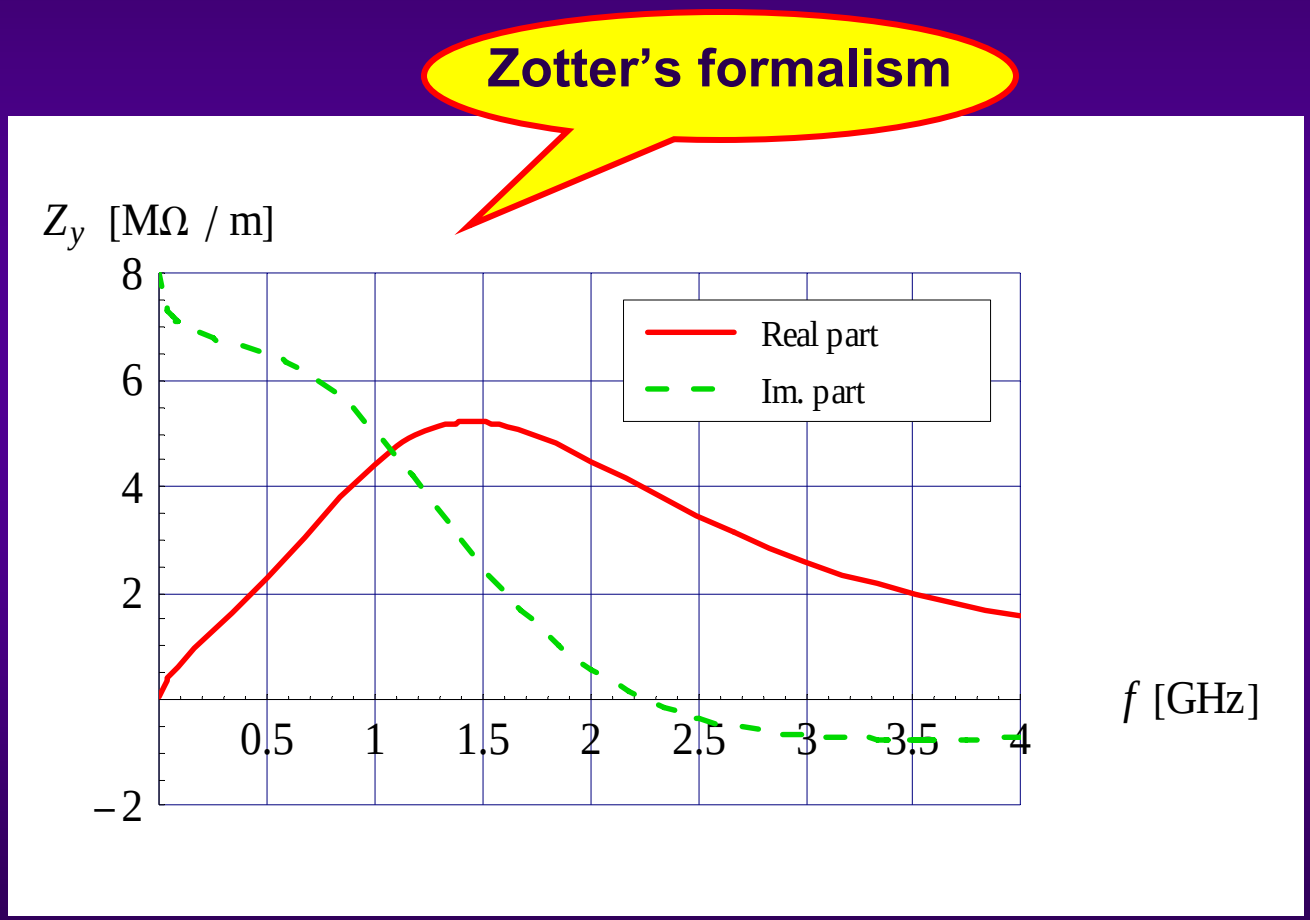
TRANSVERSE IMPEDANCE (1/3)

- **Comparison between measurements and theory**



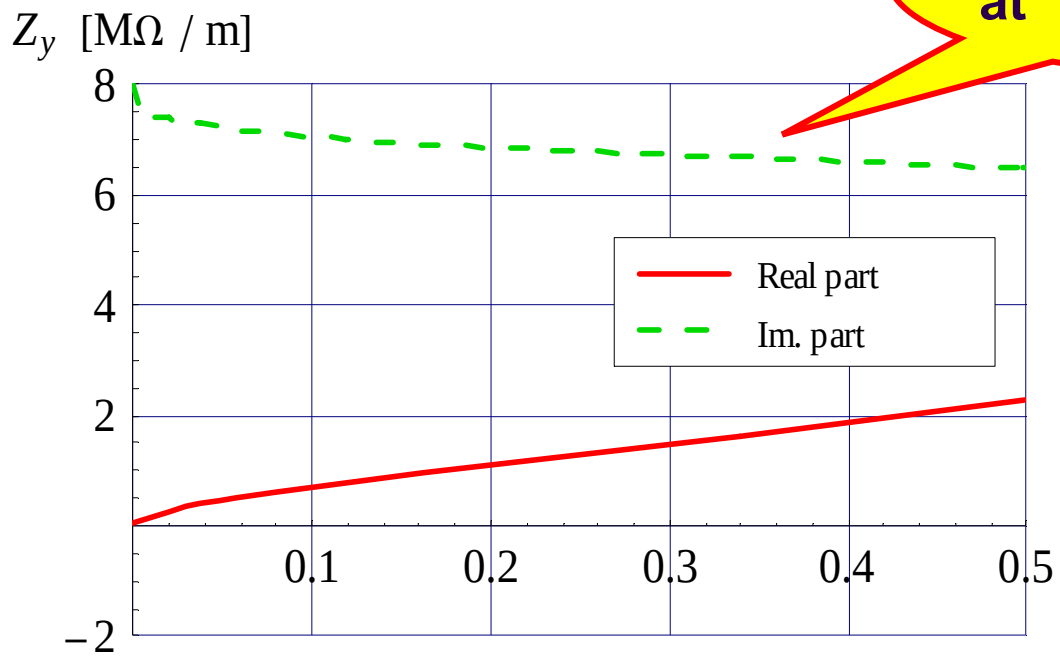
TRANSVERSE IMPEDANCE (2/3)

- **Plot of the vertical impedance for all the 20 SPS kickers in 2006 (taking into account the flat chamber + betatron function at the kicker)**



TRANSVERSE IMPEDANCE (3/3)

Zoom between 0 and 500 MHz



$\Longrightarrow$ ~ 7 MΩ / m at "low frequency"

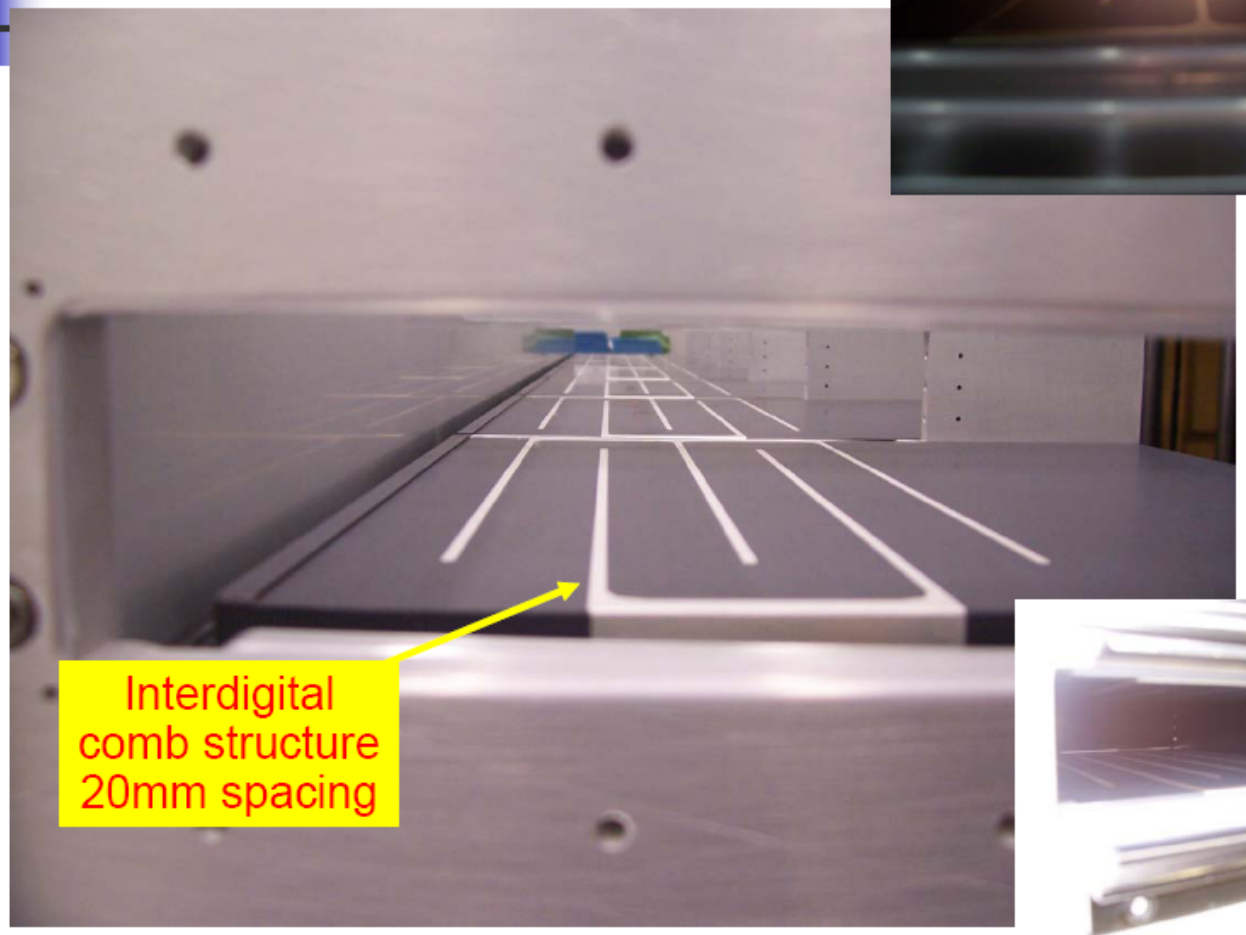
$\Longrightarrow$ ~ 7 × (3 / 2) = 10.5 MΩ / m should be measured (from kickers) when measuring the vertical coherent tune vs. intensity (dipolar + quadrupolar)

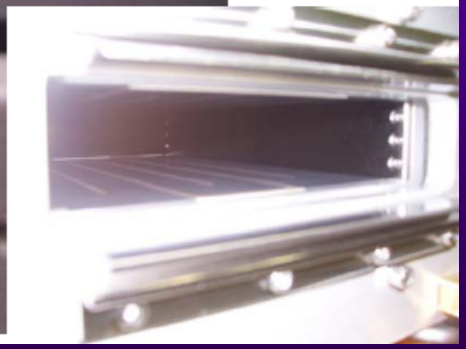
H. Burkhardt measured ~ 24 MΩ / m for the whole SPS machine (APC 10/11/06)

METALLIC STRIPES ON MKE-L10

Courtesy of E. Gaxiola (APC, 10/11/2006)

Strips Printed Directly on Ferrites



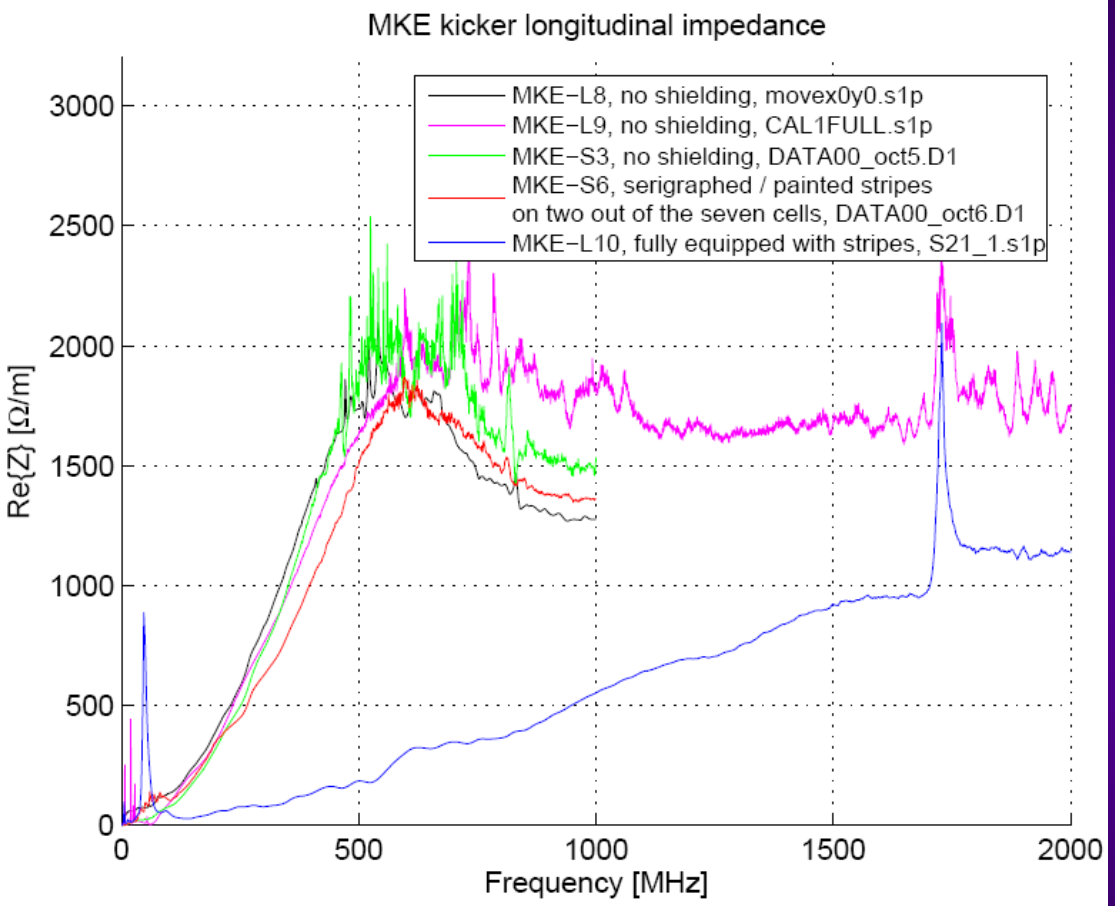


LONGITUDINAL IMPEDANCE OF MKE-L10

- In a comprehensive measurement campaign data for all types of MKE magnets was collected

Printed strips in MKE-L10

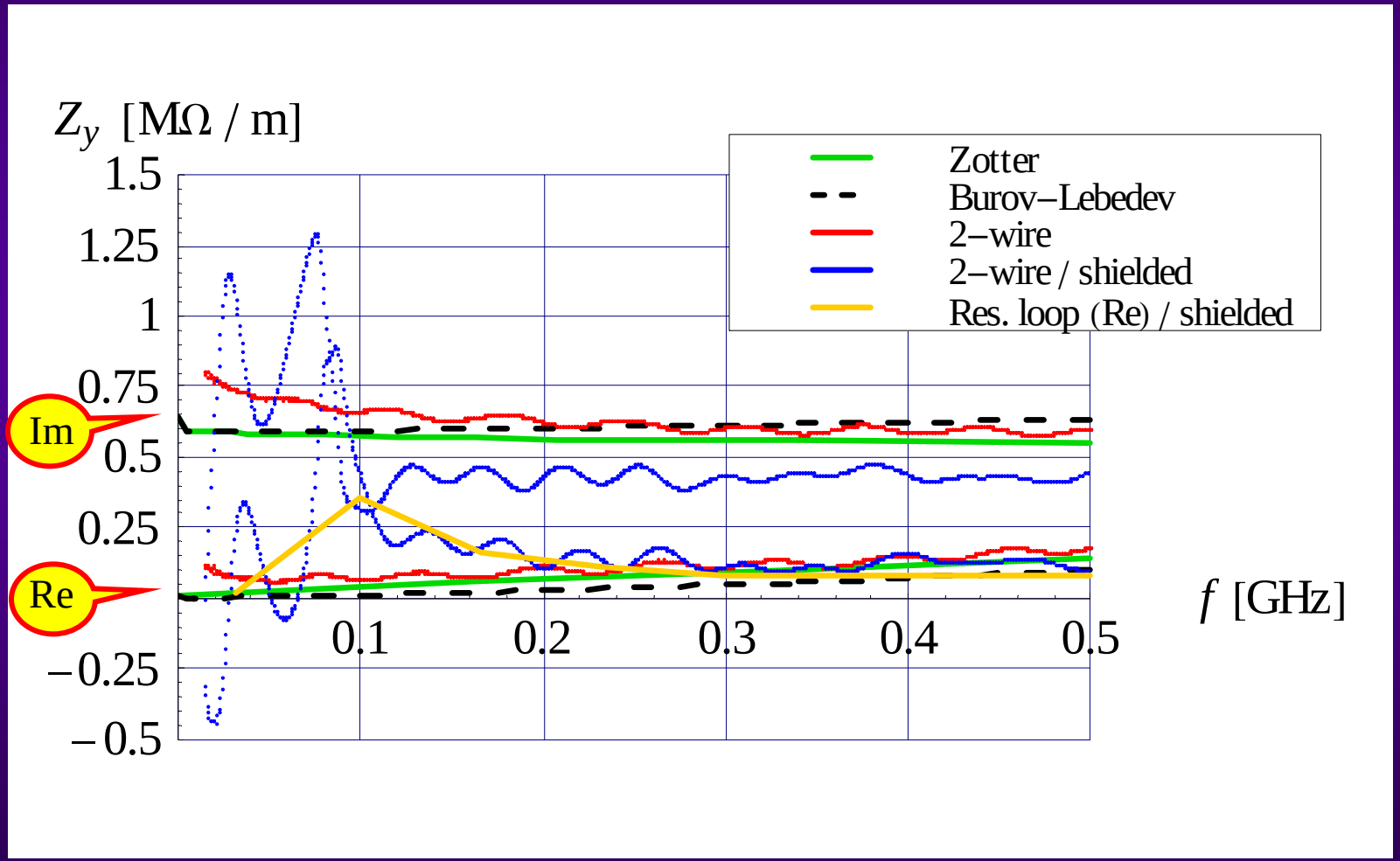
Courtesy of T. Kroyer (APC, 10/11/2006)



$\Longrightarrow$ Significant reduction of the (real part here of the) longitudinal impedance (and associated power loss)

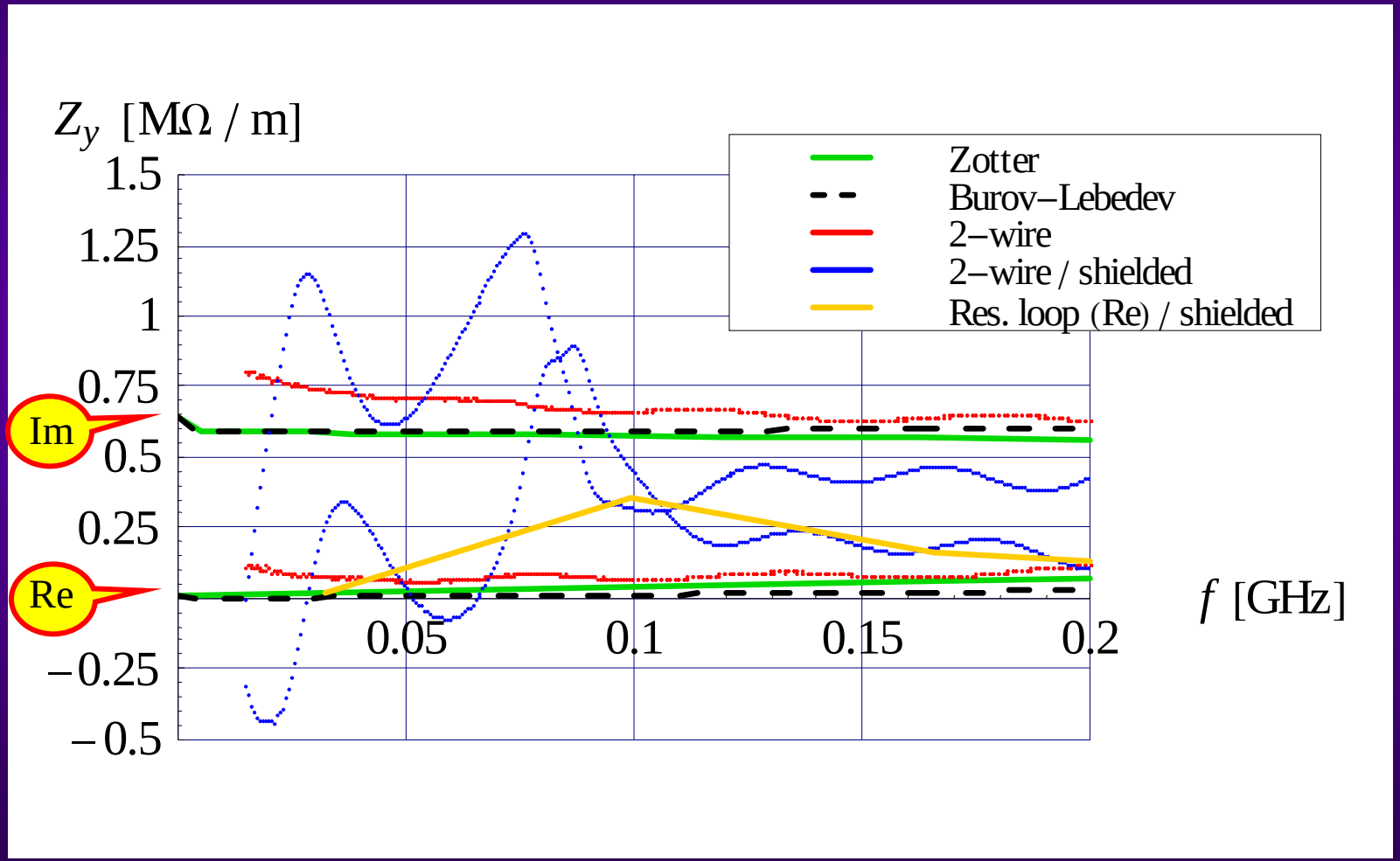
TRANSVERSE IMPEDANCE OF MKE-L10 (1/7)

Zoom between 0 and 500 MHz
(of the picture in page 9)



TRANSVERSE IMPEDANCE OF MKE-L10 (2/7)

Zoom between 0 and 200 MHz

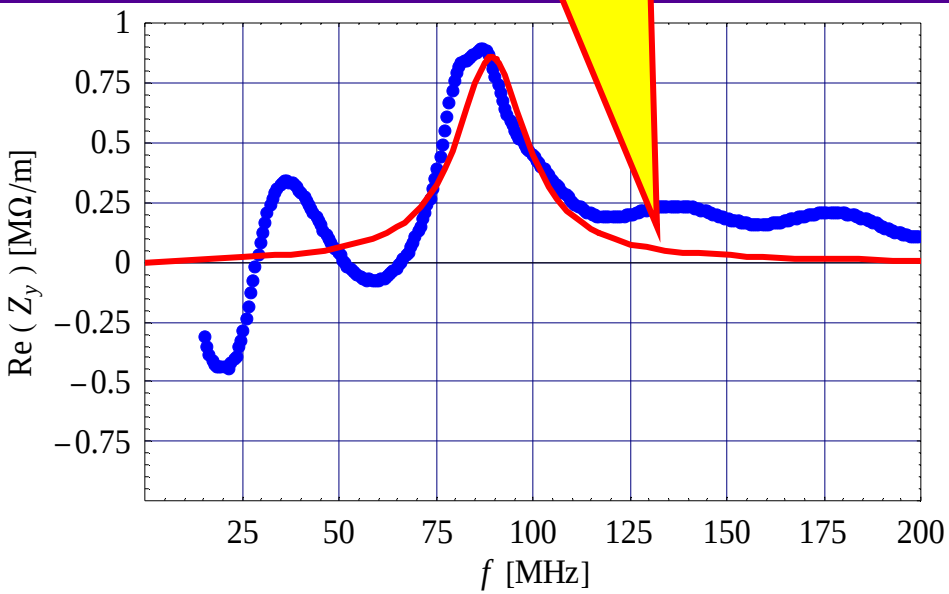


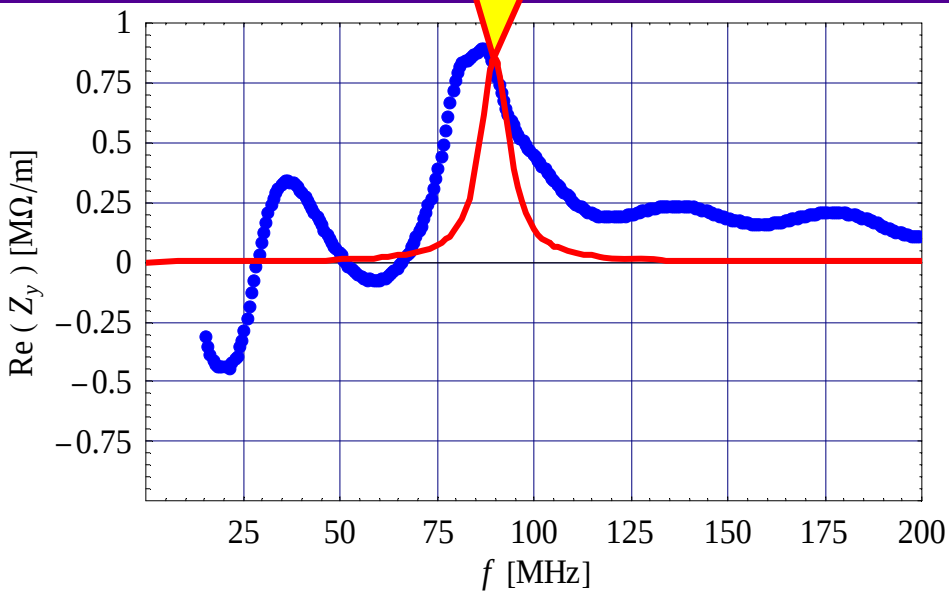
TRANSVERSE IMPEDANCE OF MKE-L10 (3/7)

"Fit" of the most critical resonance by a resonator

Resonator 1: R_y = 0.85 MΩ/m, f_r = 90 MHz, Q = 4

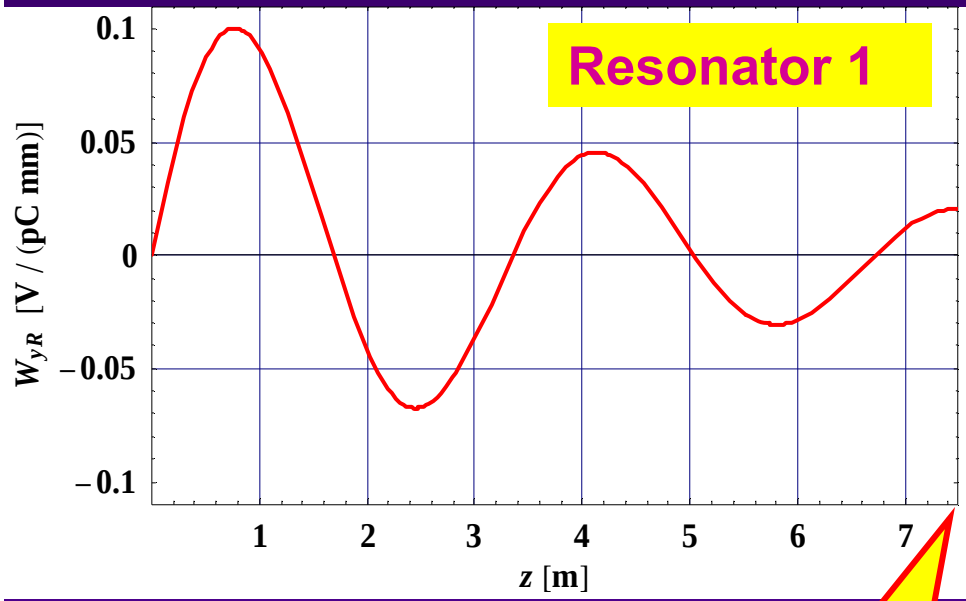
Resonator 2: R_y = 0.85 MΩ/m, f_r = 90 MHz, Q = 10 ⟹ Worst case

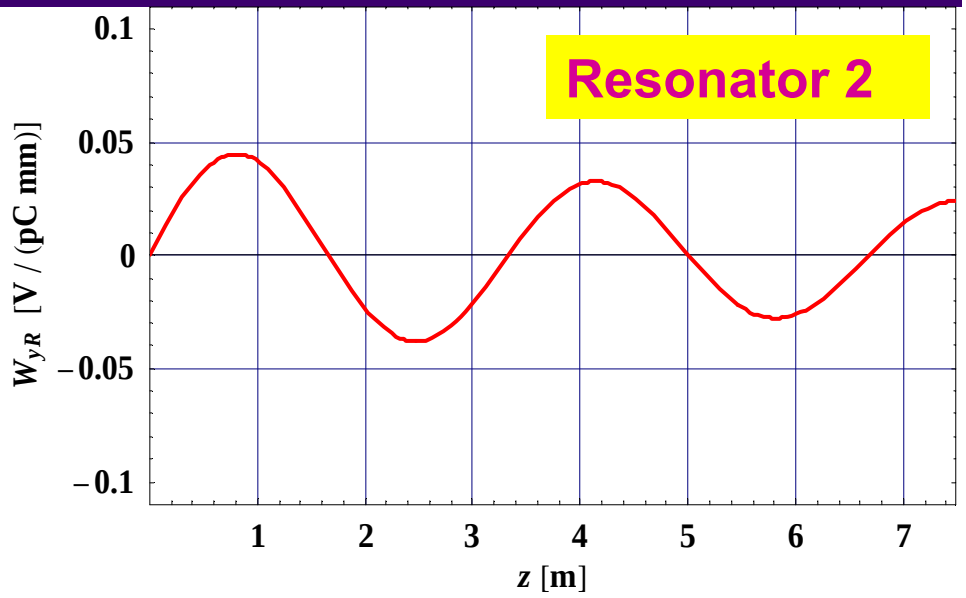




TRANSVERSE IMPEDANCE OF MKE-L10 (4/7)

Resonator wake-field and coupled-bunch instability rise-times for 1 batch of 72 bunches (1.15×10^{11}p/b) at 26 GeV/c spaced by 25 ns





$\Longrightarrow$ **Rise-time = Infinity!**

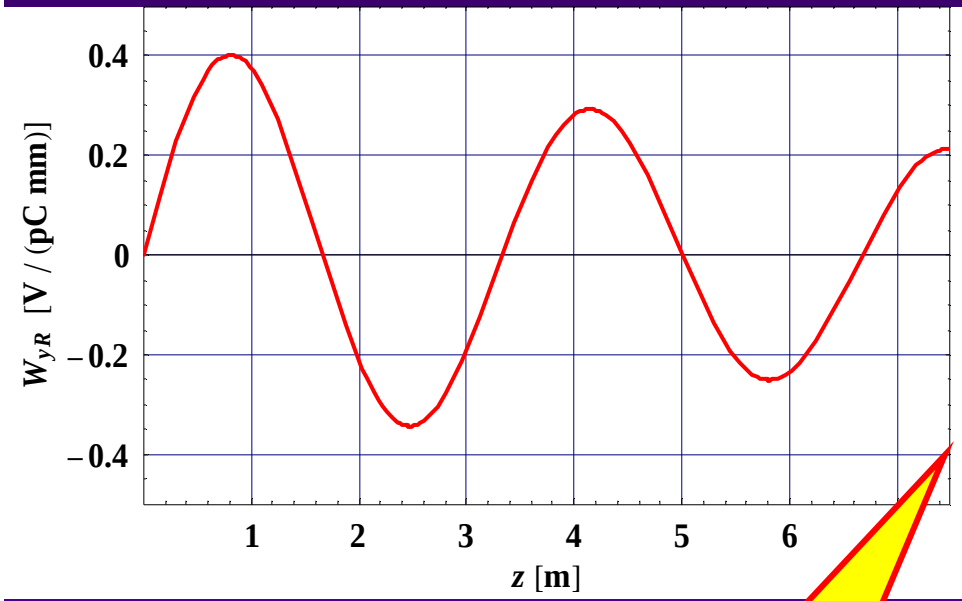
Bunch spacing = 25 ns = 7.5 m

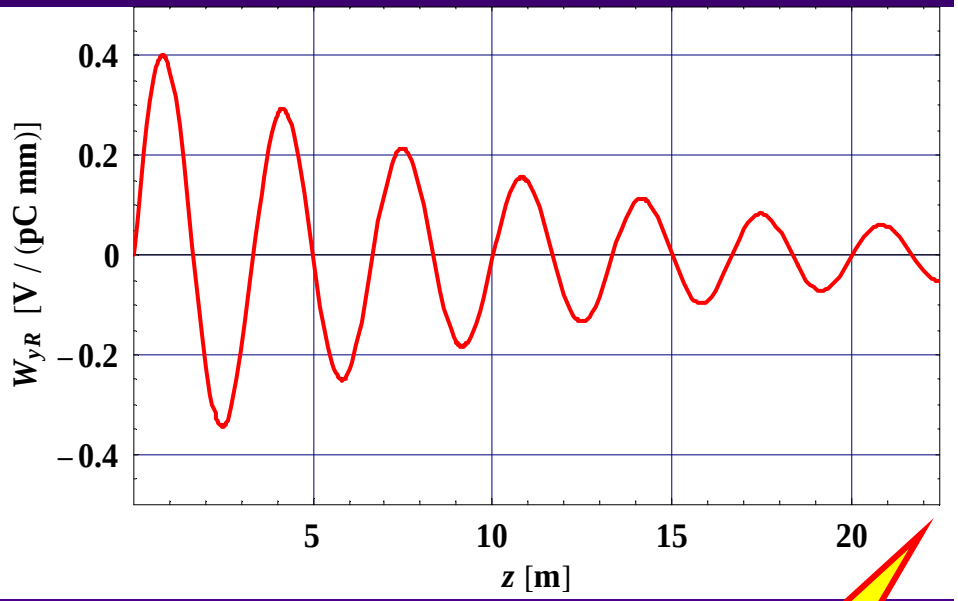
$\Longrightarrow$ **Rise-time = 11233 turns (260 ms)**

N.B.: The effect of the β-function is neglected here, but the β_s are smaller than the average one of 42 m ($\Longrightarrow$ conservative approach)

TRANSVERSE IMPEDANCE OF MKE-L10 (5/7)

For 9 shielded MKE kickers (and worst case)





$\Longrightarrow$ Rise-time = 1173 turns (27 ms)

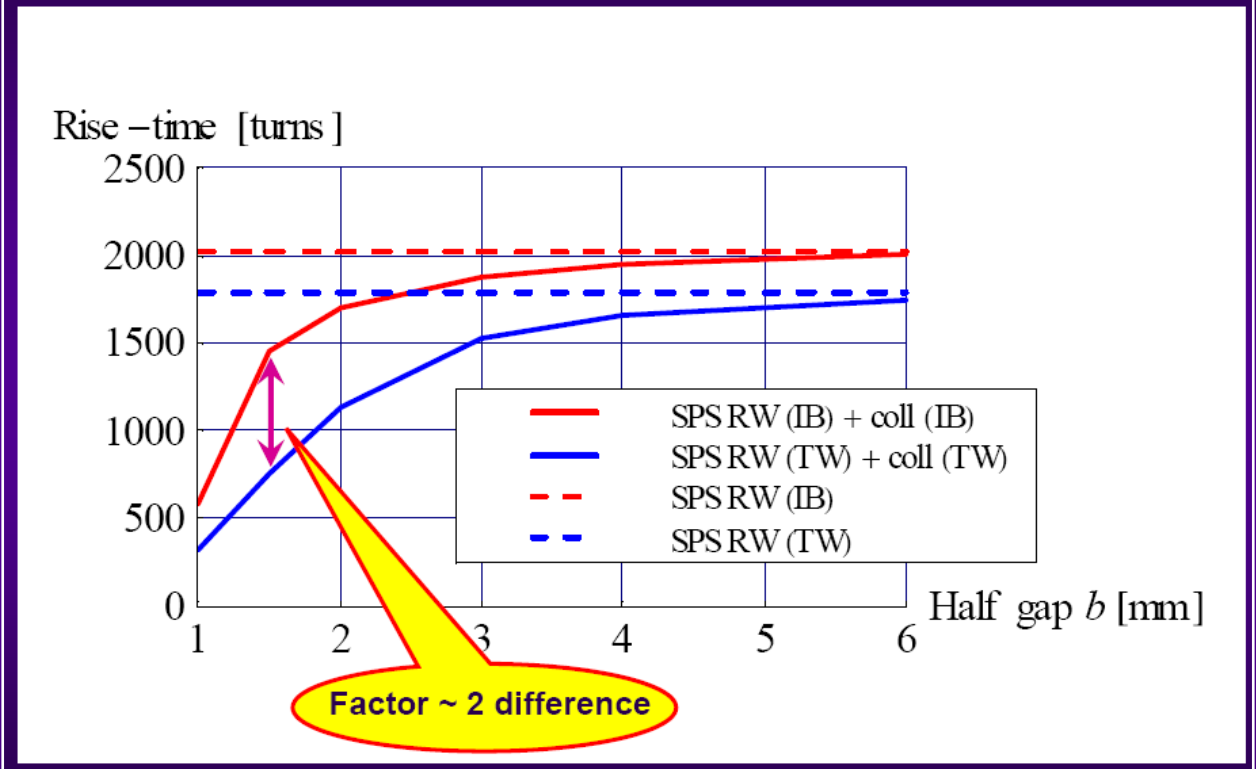
Bunch spacing = 25 ns = 7.5 m

$\Longrightarrow$ Rise-time = Infinity!

Bunch spacing = 75 ns = 22.5 m

TRANSVERSE IMPEDANCE OF MKE-L10 (6/7)

Summary of the rise-times (in SPS turns) for 1 batch of 72 bunches (1.15×10^{11} p/b) at 270 GeV/c and m = 1 (2/2)

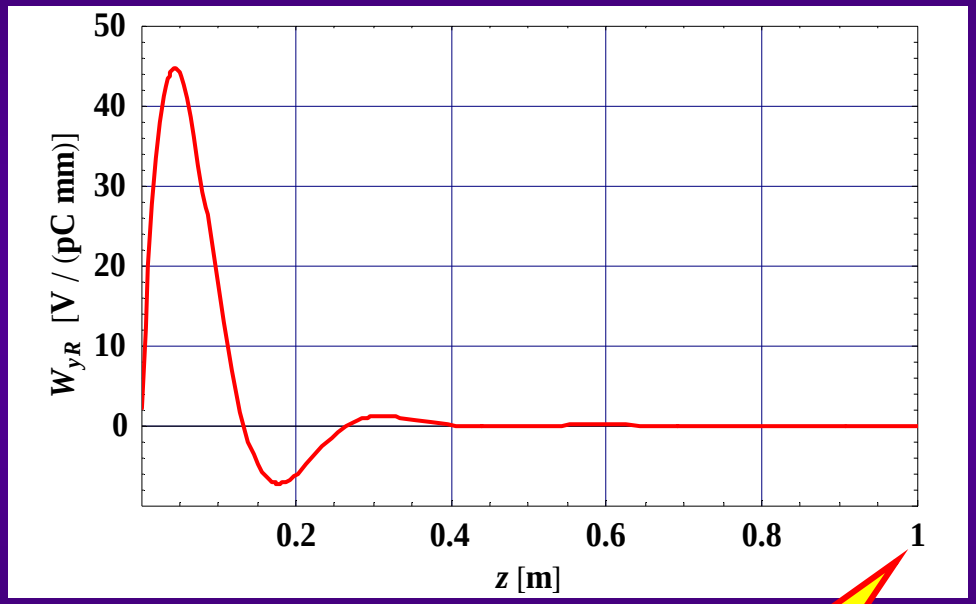


Elias Métral, APC meeting, 13/10/06 8/19

⟹ **The SPS RW coupled-bunch instability rise-time at 26 GeV/c is ~ 190 turns, i.e. much smaller than what computed previously… ⟹ Should be OK!**

TRANSVERSE IMPEDANCE OF MKE-L10 (7/7)

Example of the wake-field induced by the classical Broad-Band impedance in the SPS: R_y = 10 MΩ/m, f_r = 1.3 GHz, Q = 1



Only 1 m!

CONCLUSION (1/2)

- The longitudinal impedance of the SPS kickers seems well described using Tsutsui's formula (considering both ferrite plates on top&bottom + metallic plates on both sides)

- The vertical impedance of the SPS kickers seems well described using Zotter's formalism (considering only the ferrite plates on top&bottom)

- The serigraphed interleaved metallic stripes reduce considerably the longitudinal impedance (and associated power loss) and slightly the vertical one, introducing some resonances at low frequency, which seem not too harmful $\Longrightarrow$ Could be extended to the other kickers!

CONCLUSION (2/2)

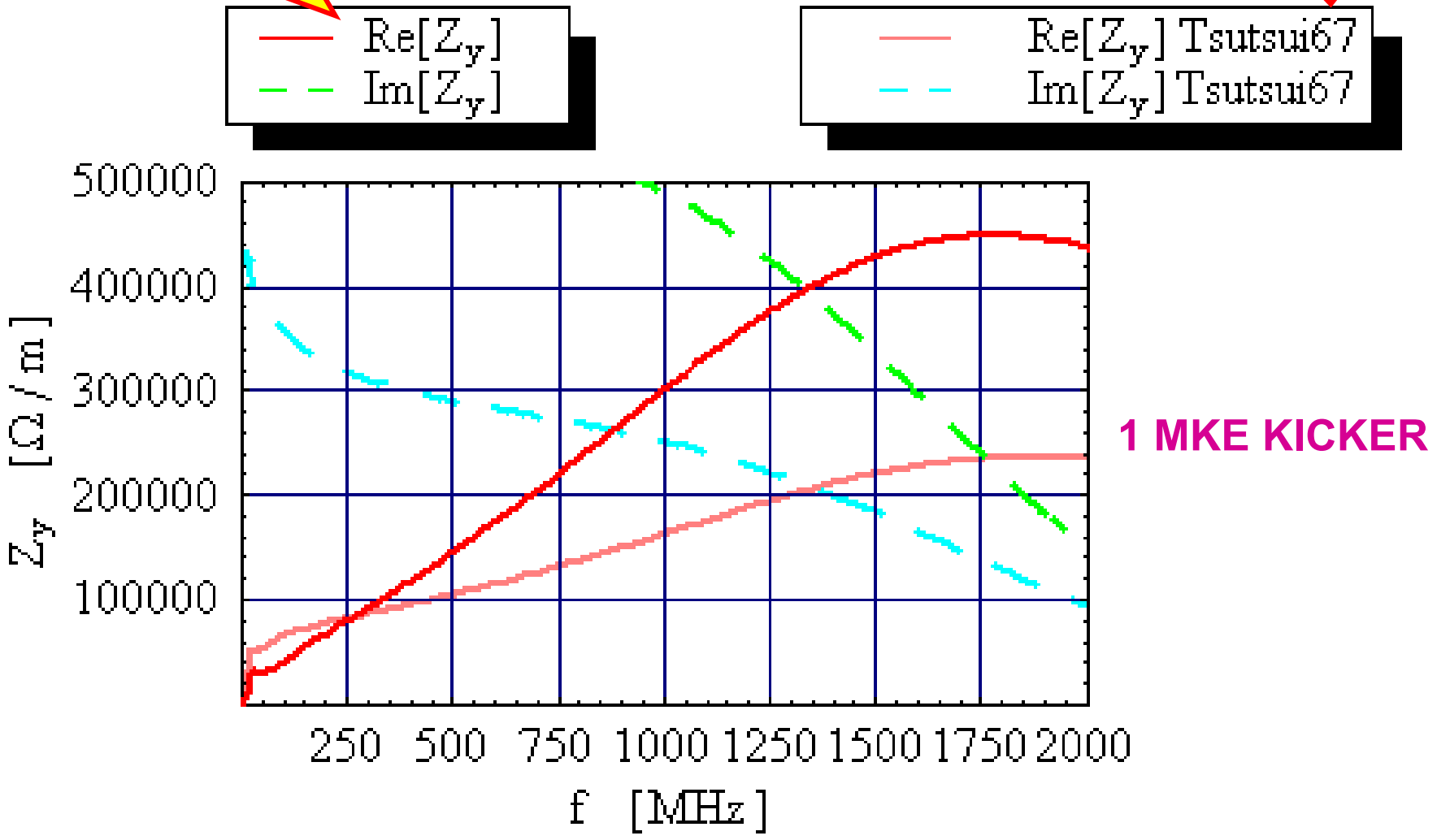
- The low-frequency imaginary longitudinal impedance $Z_{\parallel} / n$ of all the 20 kickers in 2006 is ~ 5 -6 Ω

- The low-frequency imaginary vertical (dipolar) impedance of all the 20 kickers (taking into account the flat chamber + betatron function at the kickers) is ~ 7 MΩ / m

Appendix1: Vertical impedance ⟹ Tsutsui vs. Zotter (1/4)

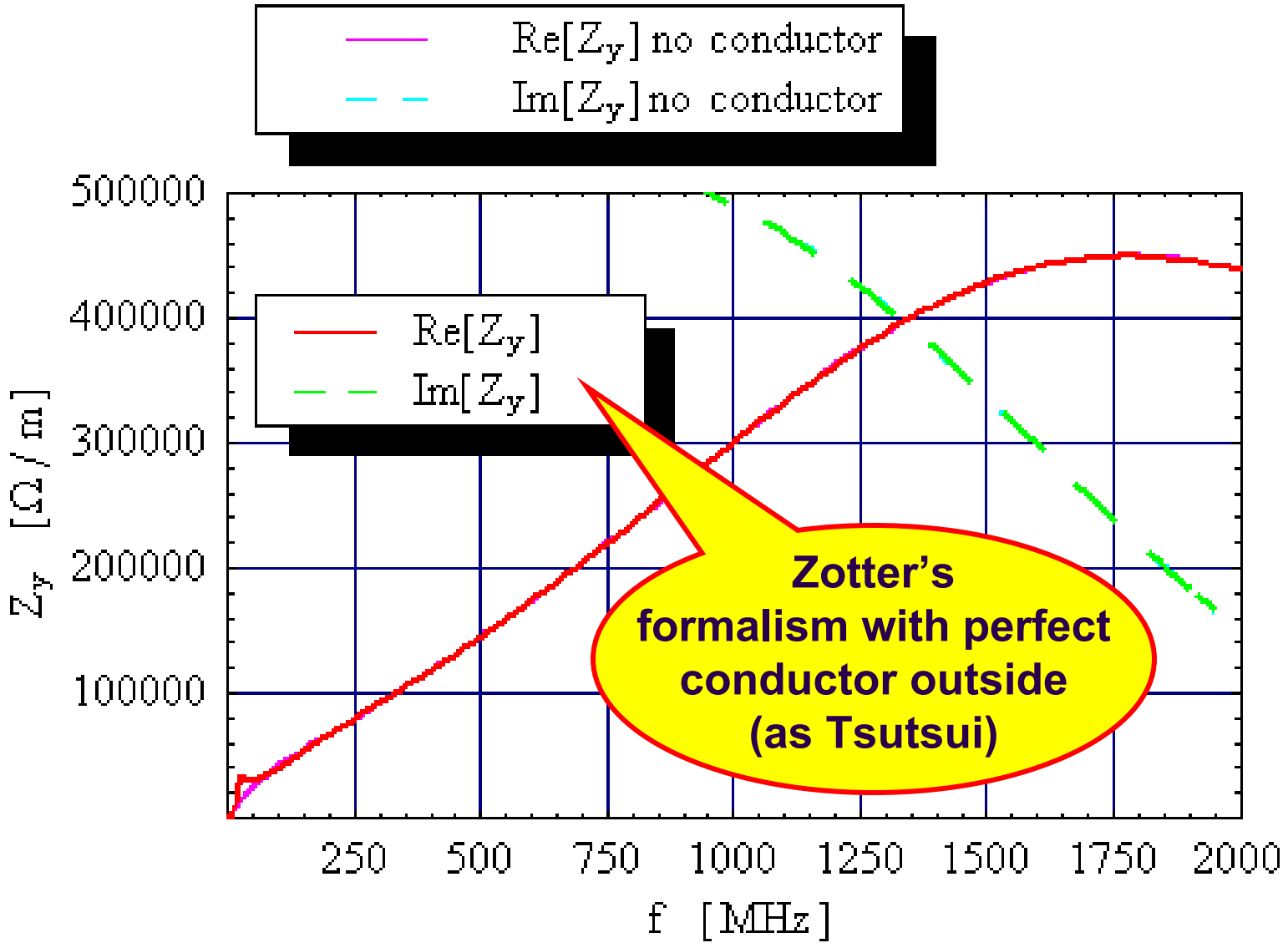
Zotter's formalism

a = 67 mm



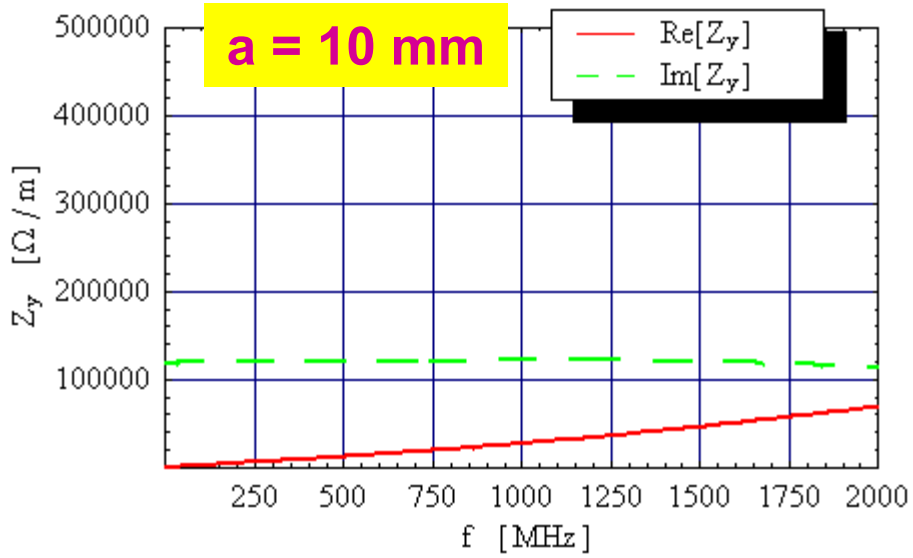
1 MKE KICKER

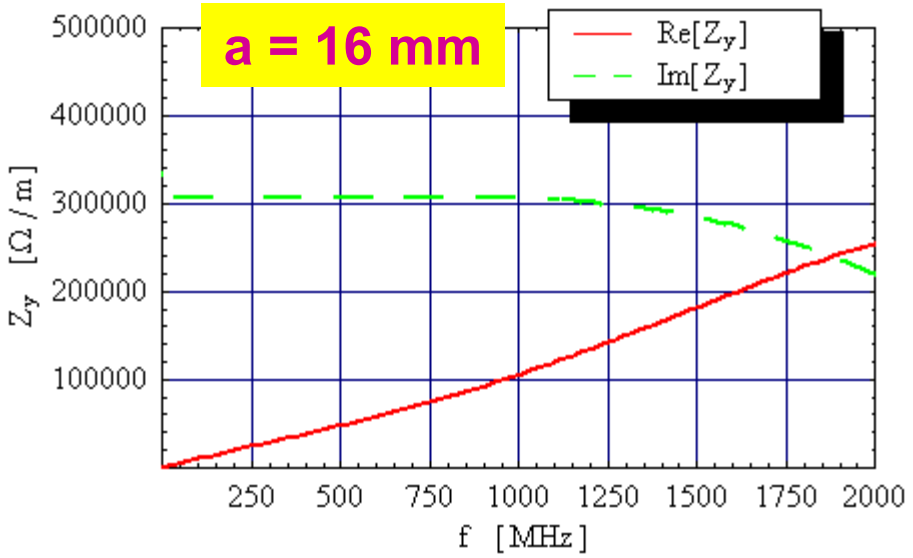
Appendix1: Vertical impedance ⟹ Tsutsui vs. Zotter (2/4)

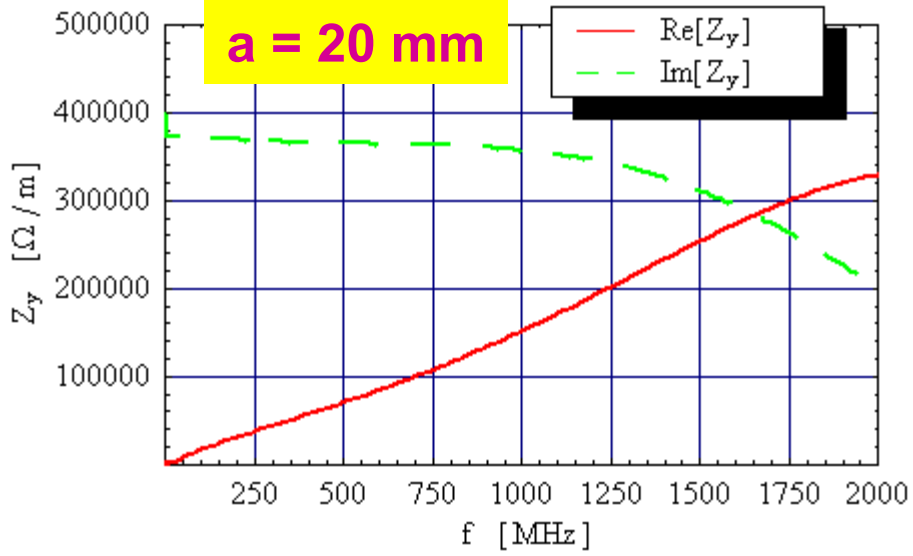


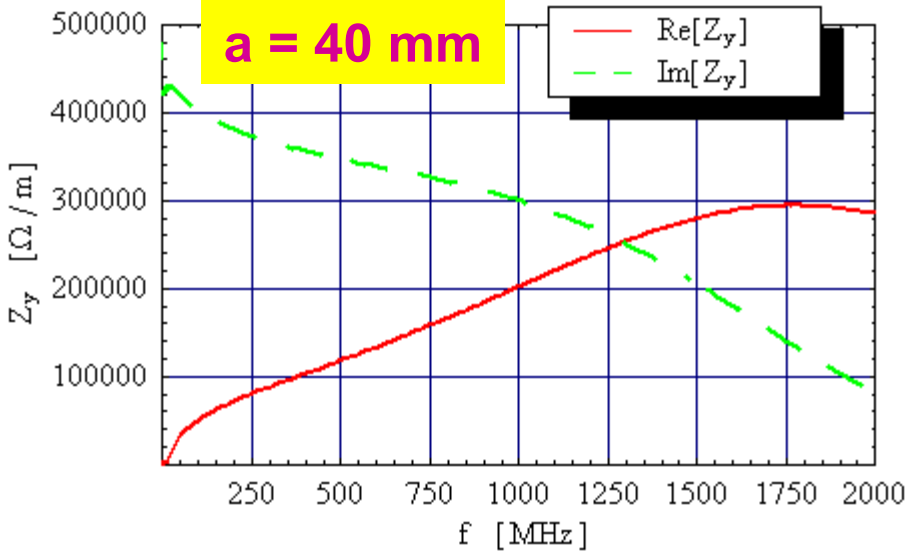
Appendix1: Vertical impedance ⟹ Tsutsui vs. Zotter (3/4)

Scan in half gap a using Tsutsui's formula

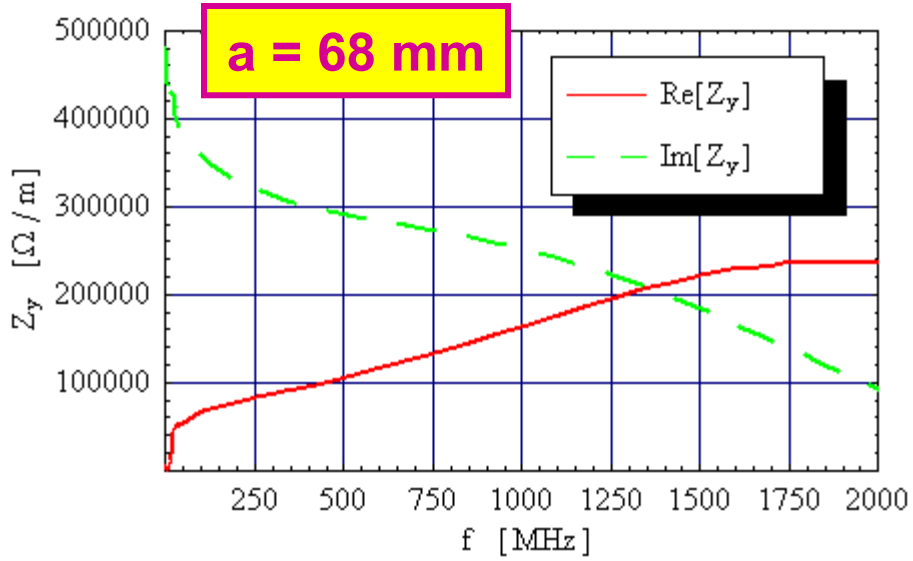


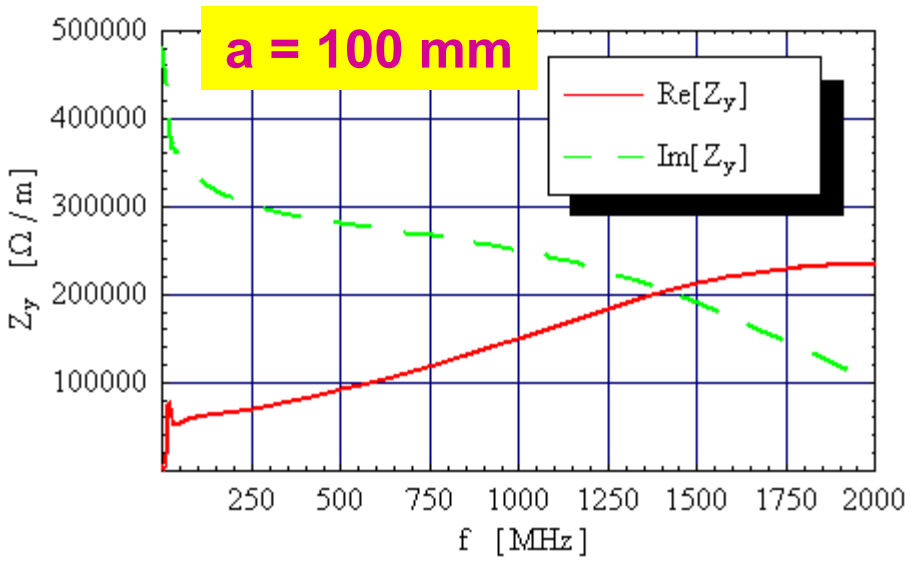


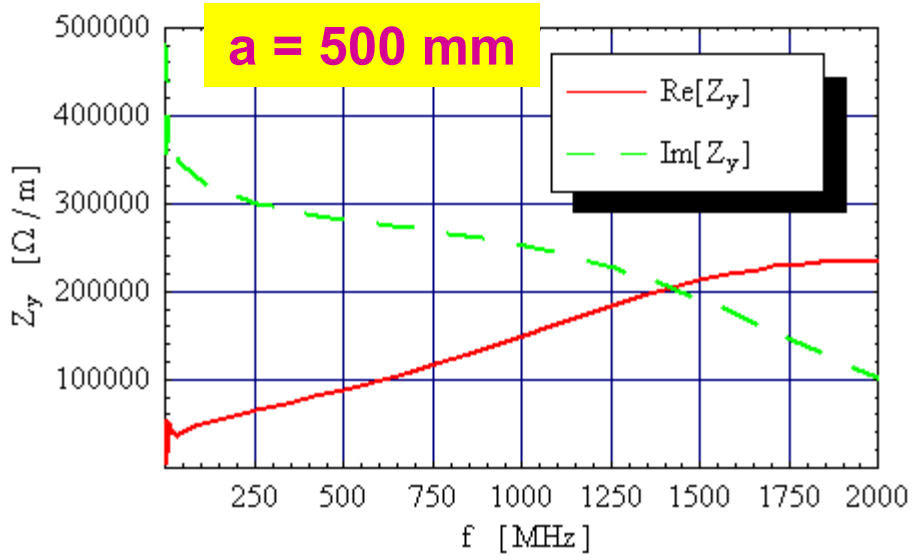


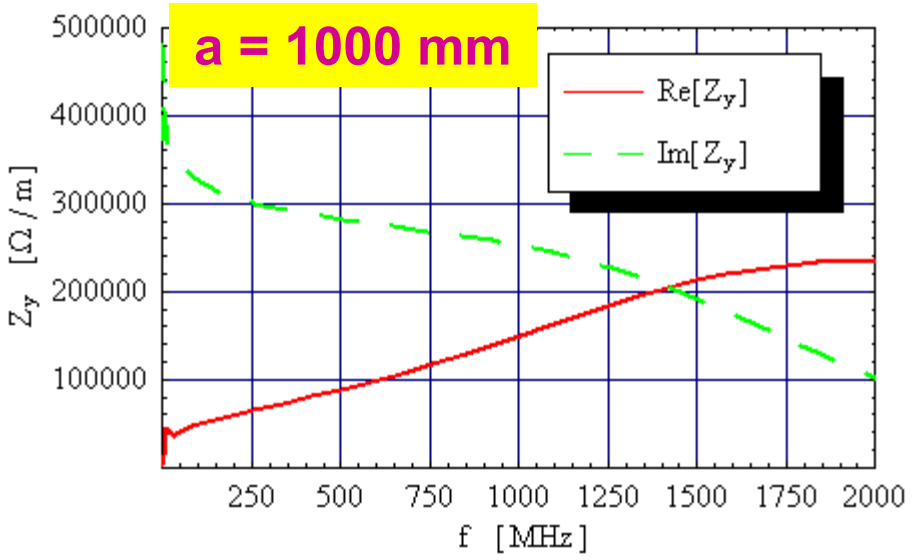


Appendix1: Vertical impedance ⟹ Tsutsui vs. Zotter (4/4)





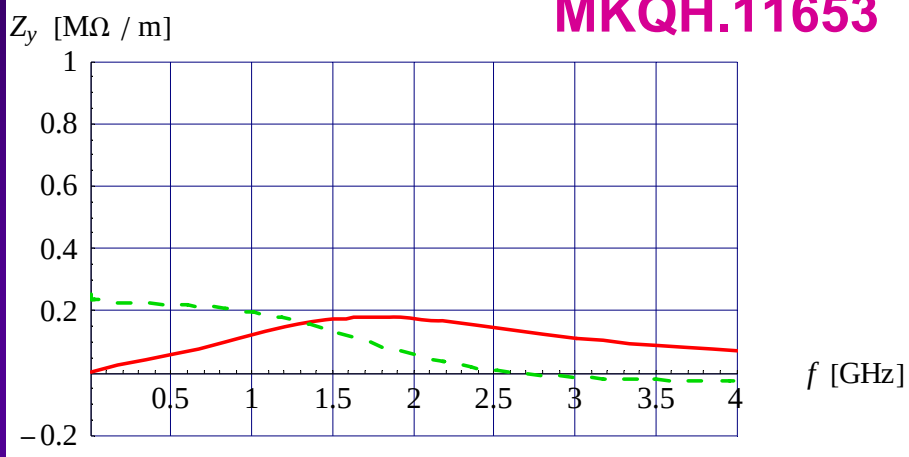




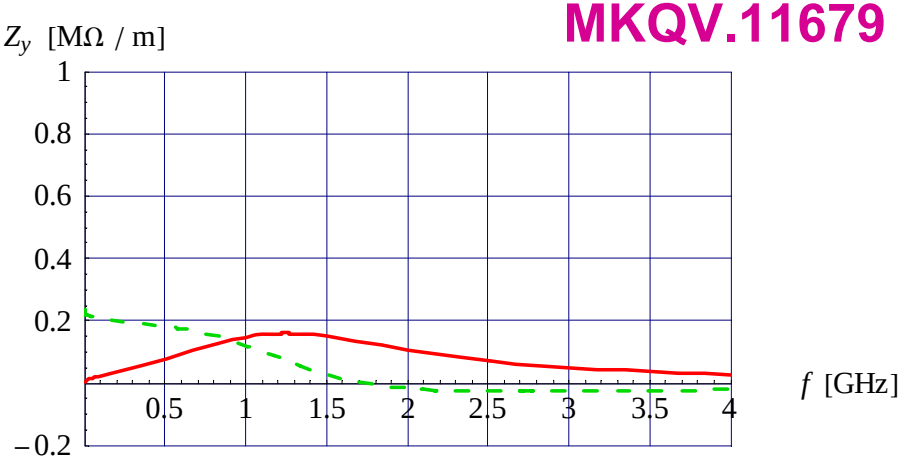
Appendix2: Vertical impedance of each kicker in 2006 (1/5)

(taking into account the flat chamber + betatron function at the kicker)

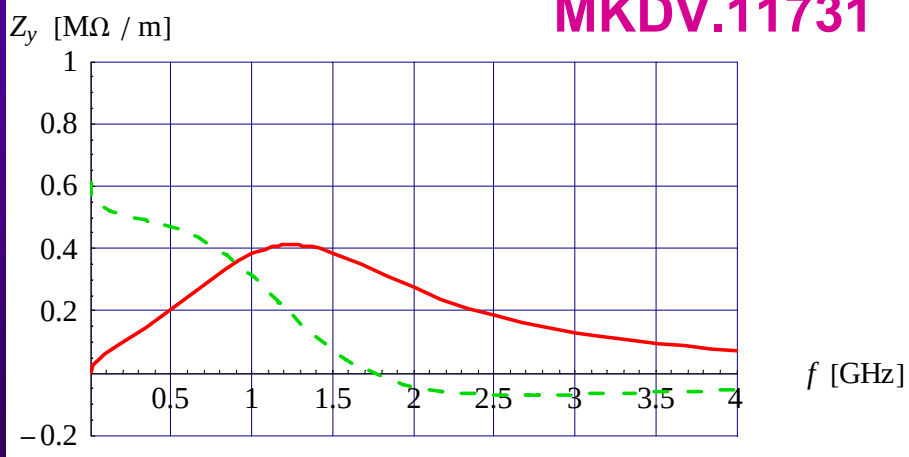
MKQH.11653



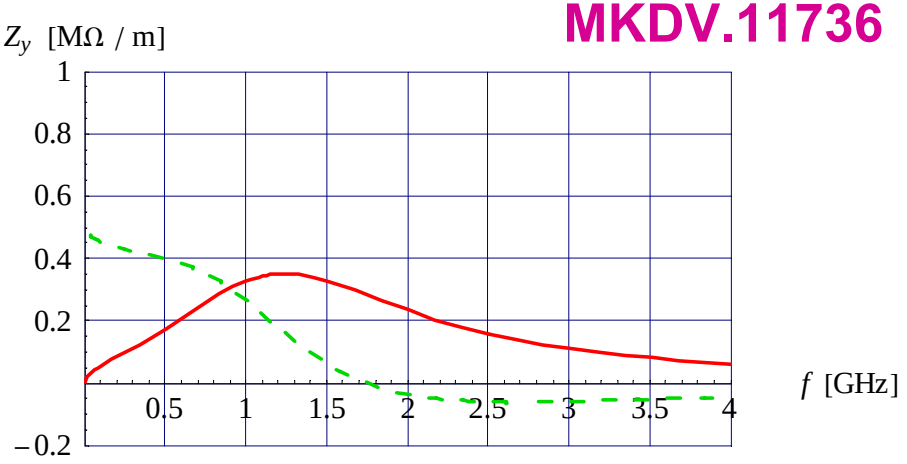
MKQV.11679



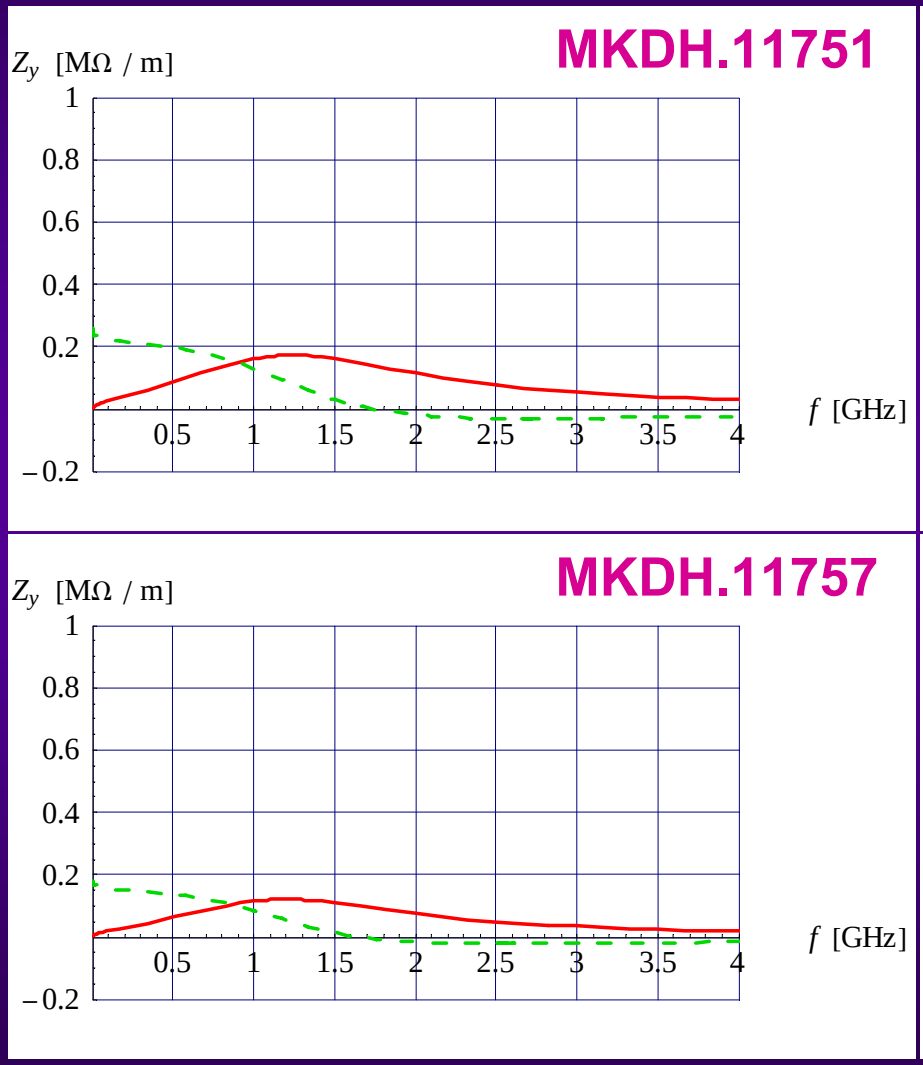
MKDV.11731

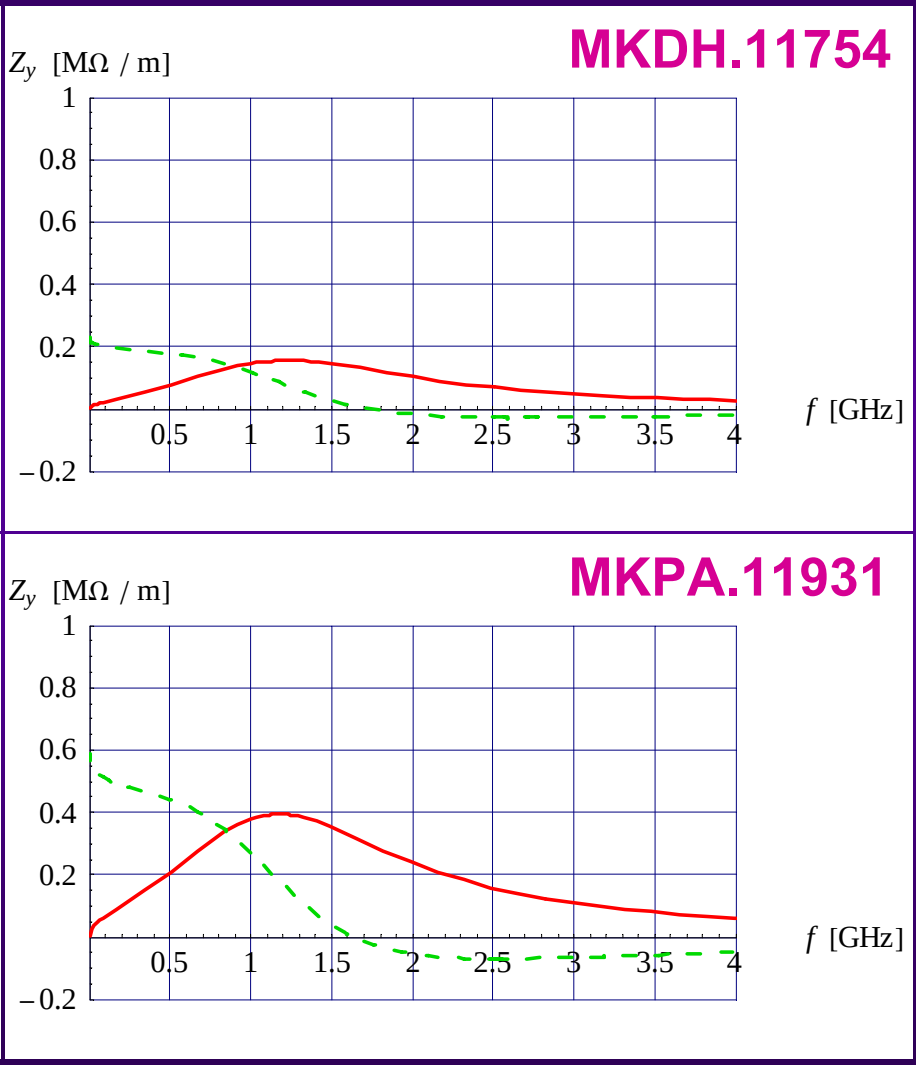


MKDV.11736

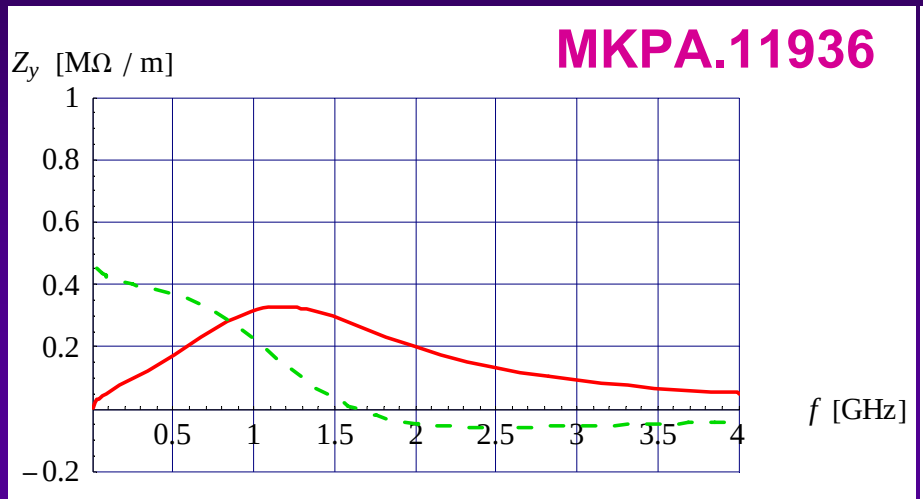


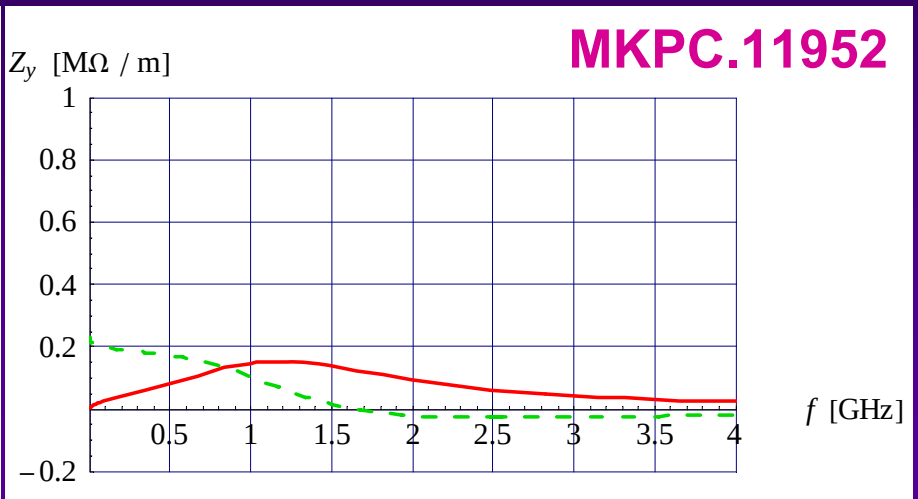
Appendix2: Vertical impedance of each kicker in 2006 (2/5)

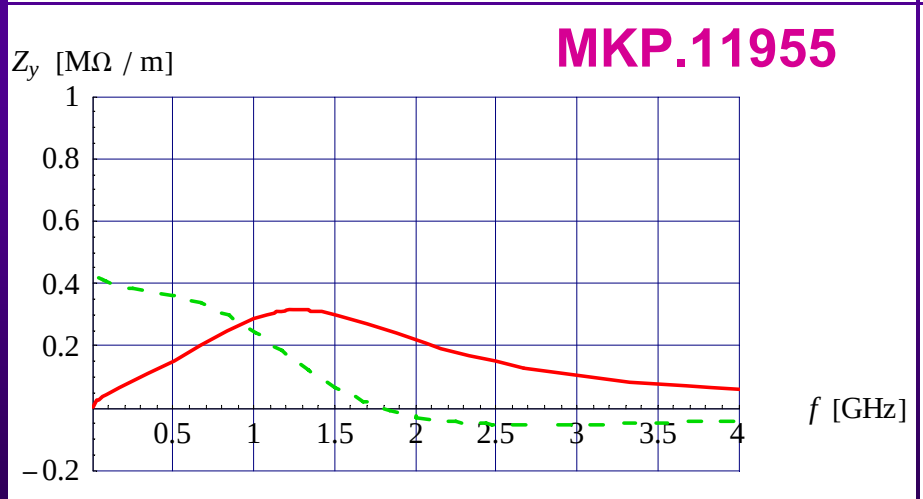


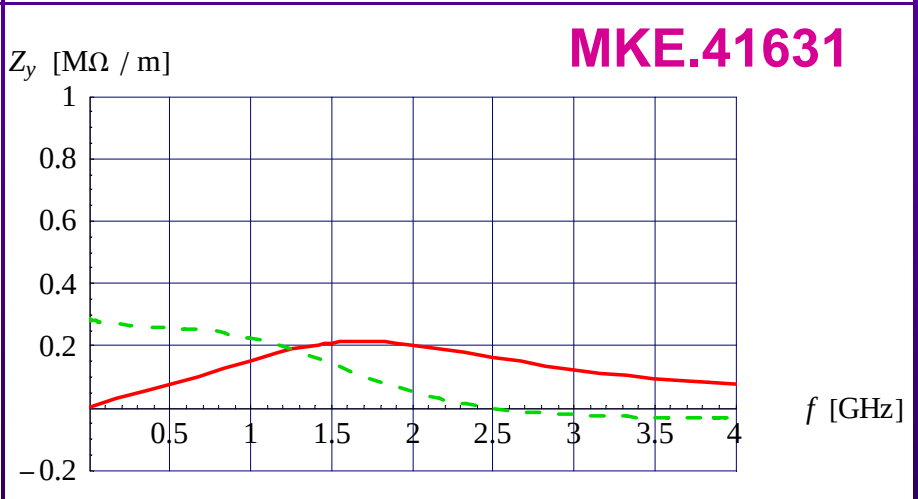


Appendix2: Vertical impedance of each kicker in 2006 (3/5)

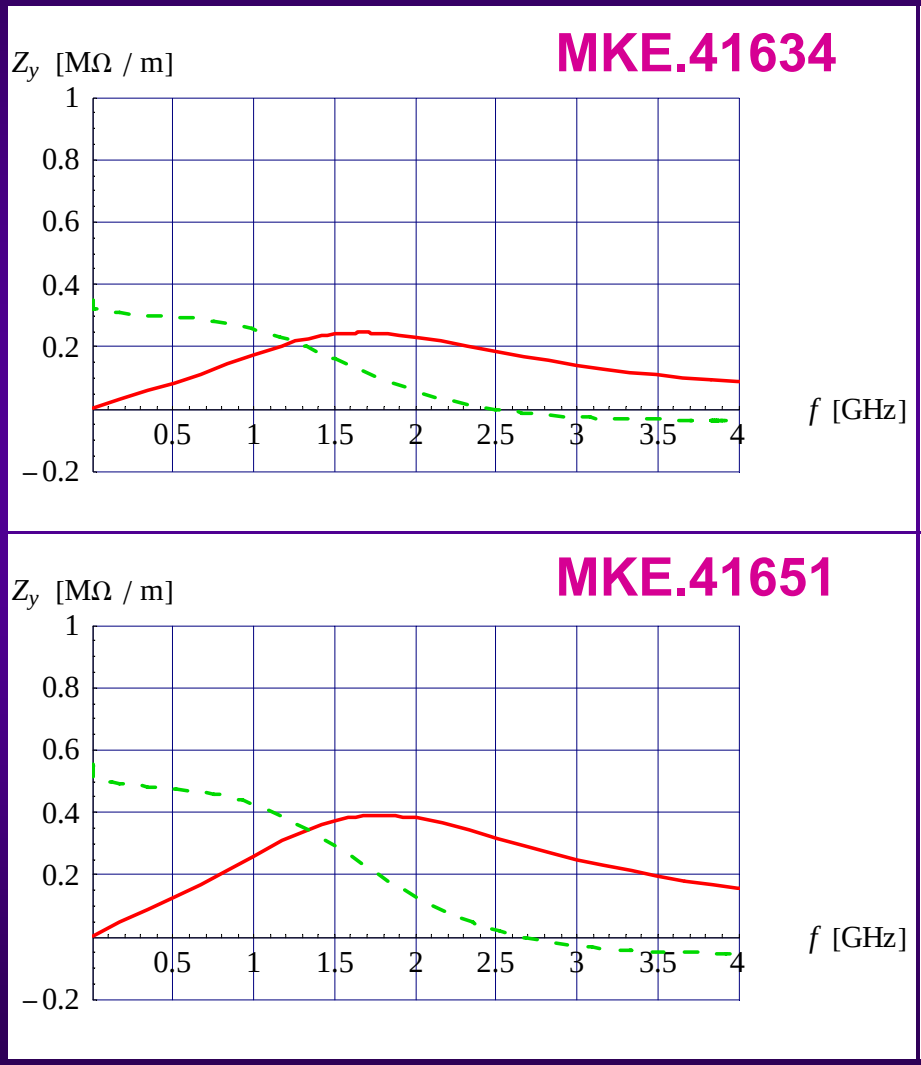


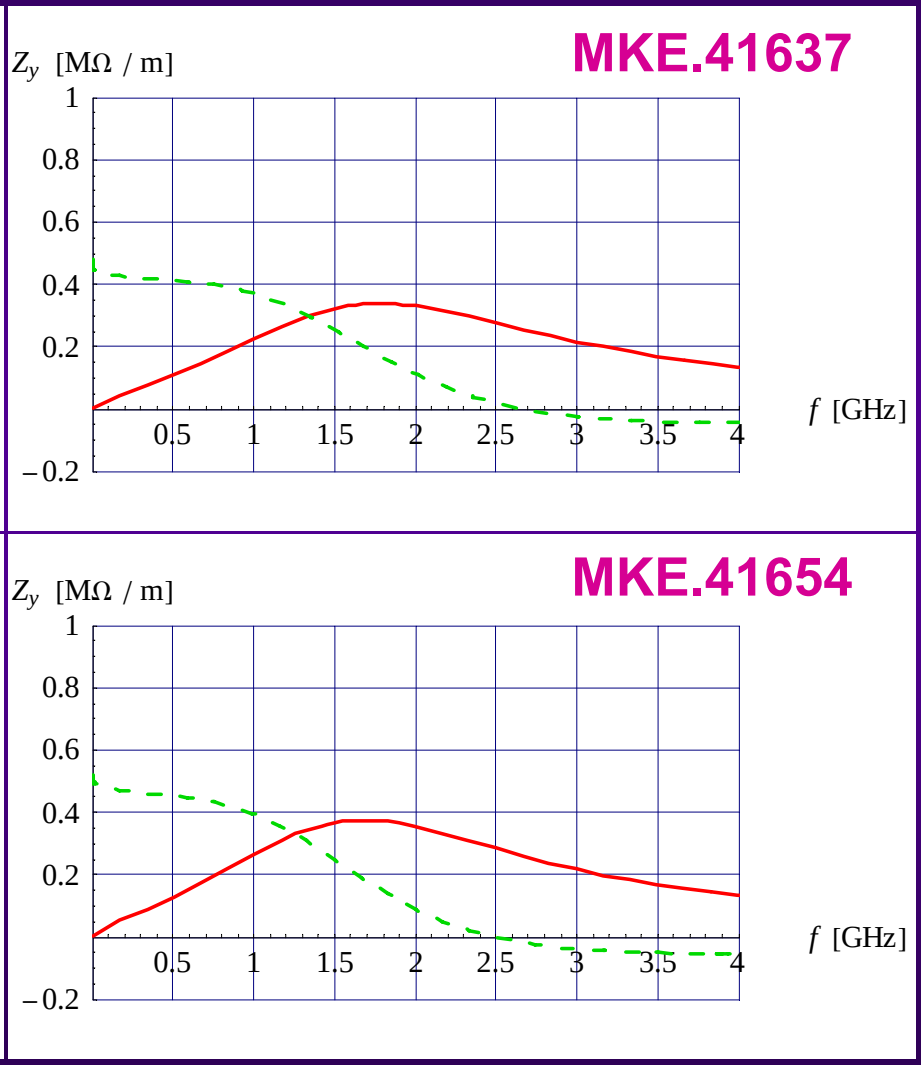






Appendix2: Vertical impedance of each kicker in 2006 (4/5)





Appendix2: Vertical impedance of each kicker in 2006 (5/5)