SPS IMPEDANCE BUDGET

G. Arduini, H. Medina, E. Métral, B. Salvant and B. Spataro

ZBASE

Resistive-wall formulae

MAFIA + HFSS simulations

- **Items considered until now**
  - **Kickers**
  - **BPMs**
  - **Pumping ports**

  } **Negligible (will not be discussed here)**
- **Theoretical predictions and comparison with measurements of the low frequency inductive part of the impedances**
- **TMCI threshold in the vertical plane**
- **Conclusion**

HISTORY OF KICKERS

- 2001
  - Lepton cavities removed + impedance reduction (pumping ports) done
  - No MKE kickers (11 kickers in total)
  - Impedance reduction by ~ 2.5 in the longitudinal plane (from meas.)
  - Impedance reduction by ~ 40% in the transverse one (from meas.)
- 2003
  - + 5 MKE kickers in LSS4 (16 kickers in total)
- 2006
  - + 4 MKE kickers in LSS6 (20 kickers in total) – 1 MKE kicker shielded on 2 cells
- 2007
  - - 1 MKE kicker and 1 MKE has been shielded (19 kickers in total)

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)**

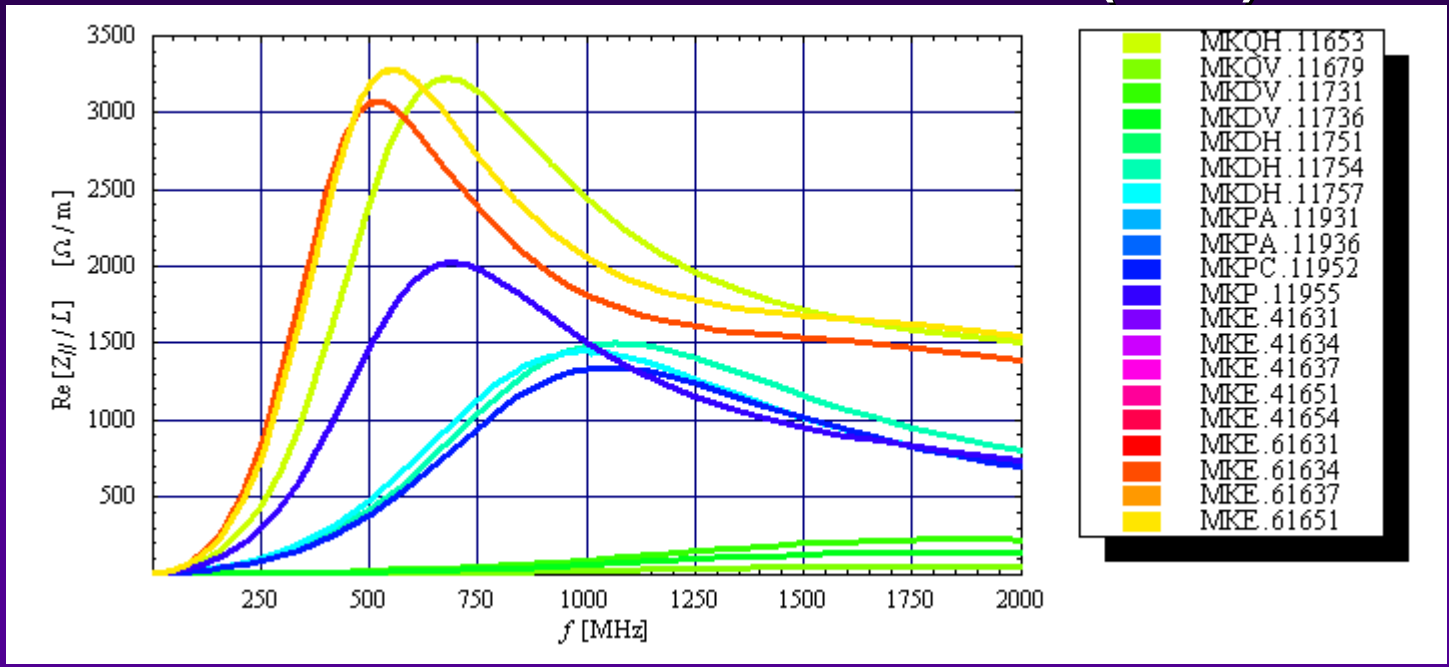
$\Longrightarrow$ Conclusion: Only 8 MKE kickers in the SPS in 2007 (9 in 2006)

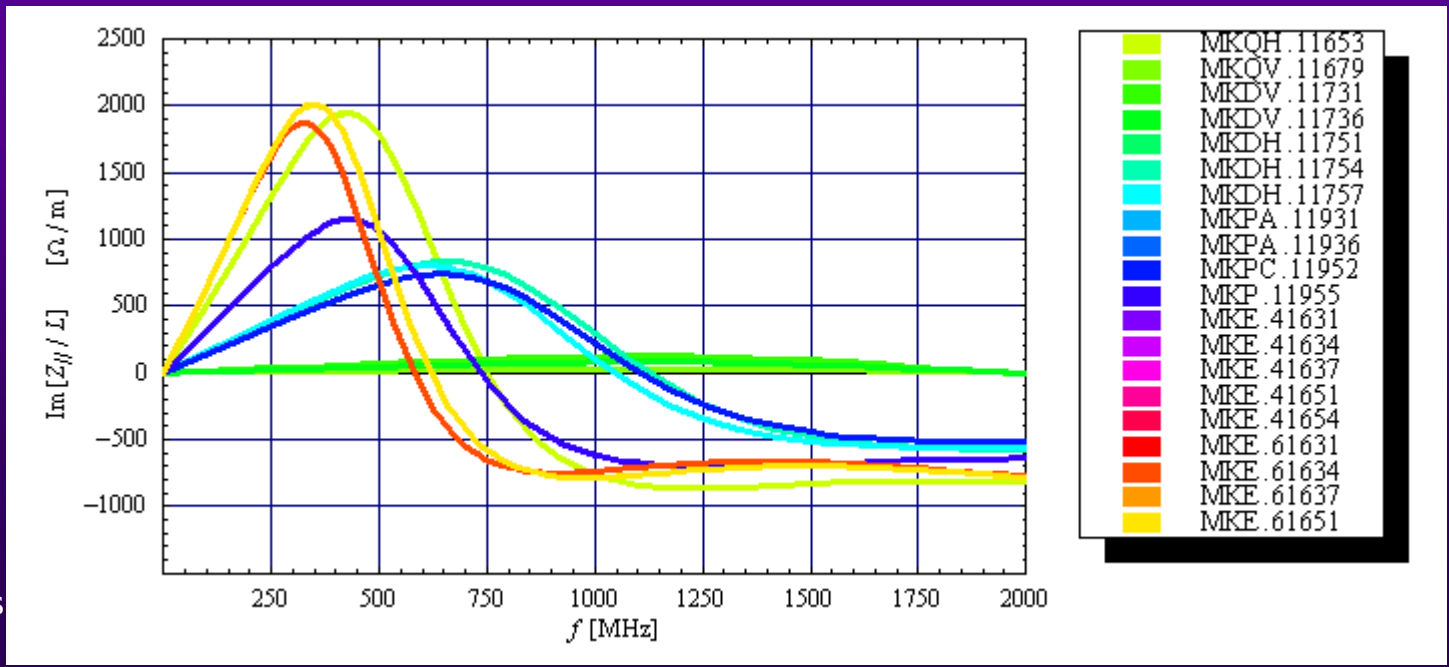
- 6 not shielded (8 in 2006)

- 1 fully shielded (not present in 2006)

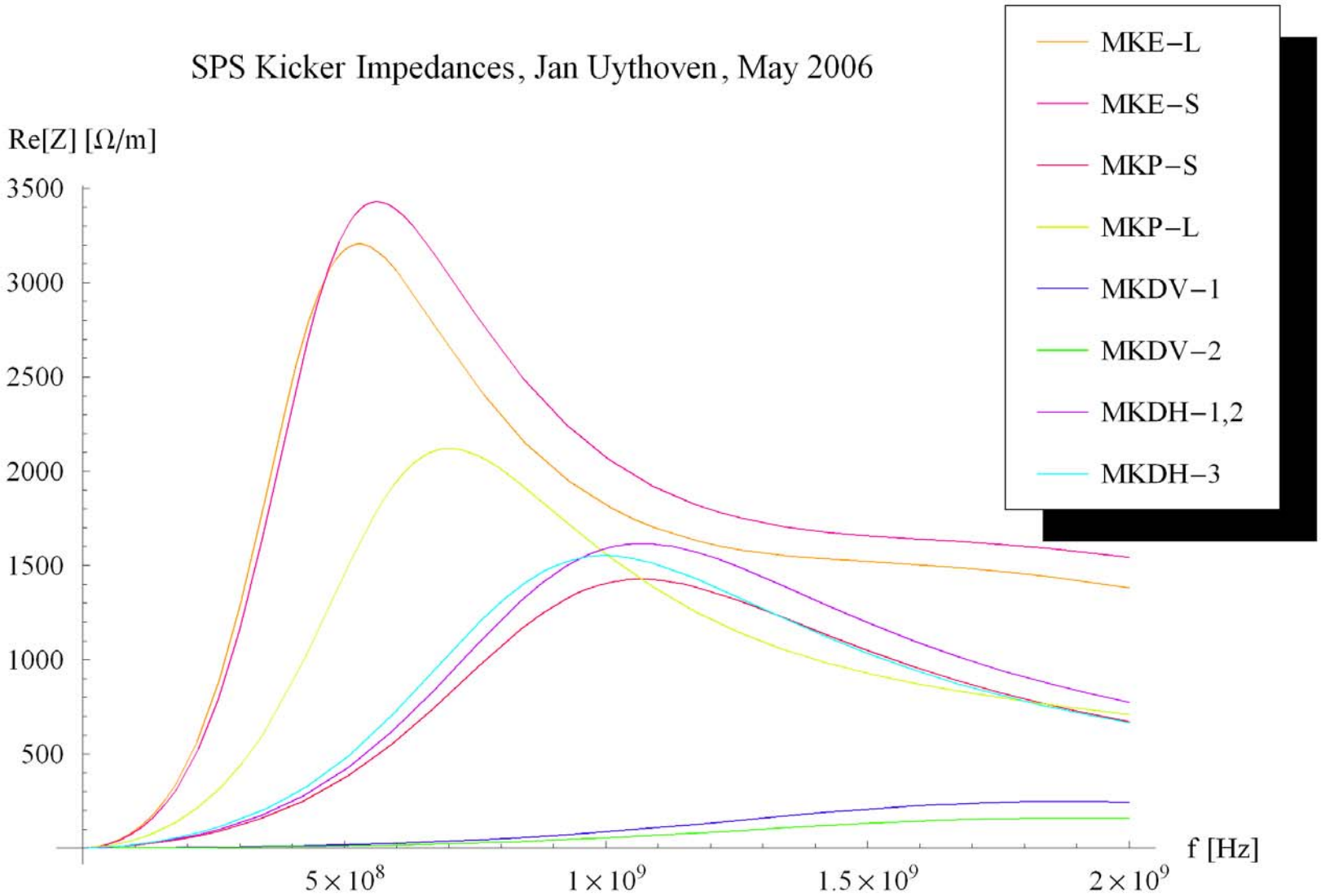
- 1 shielded on 2 cells only (present in 2006)

LONGITUDINAL IMPEDANCE (1/10)



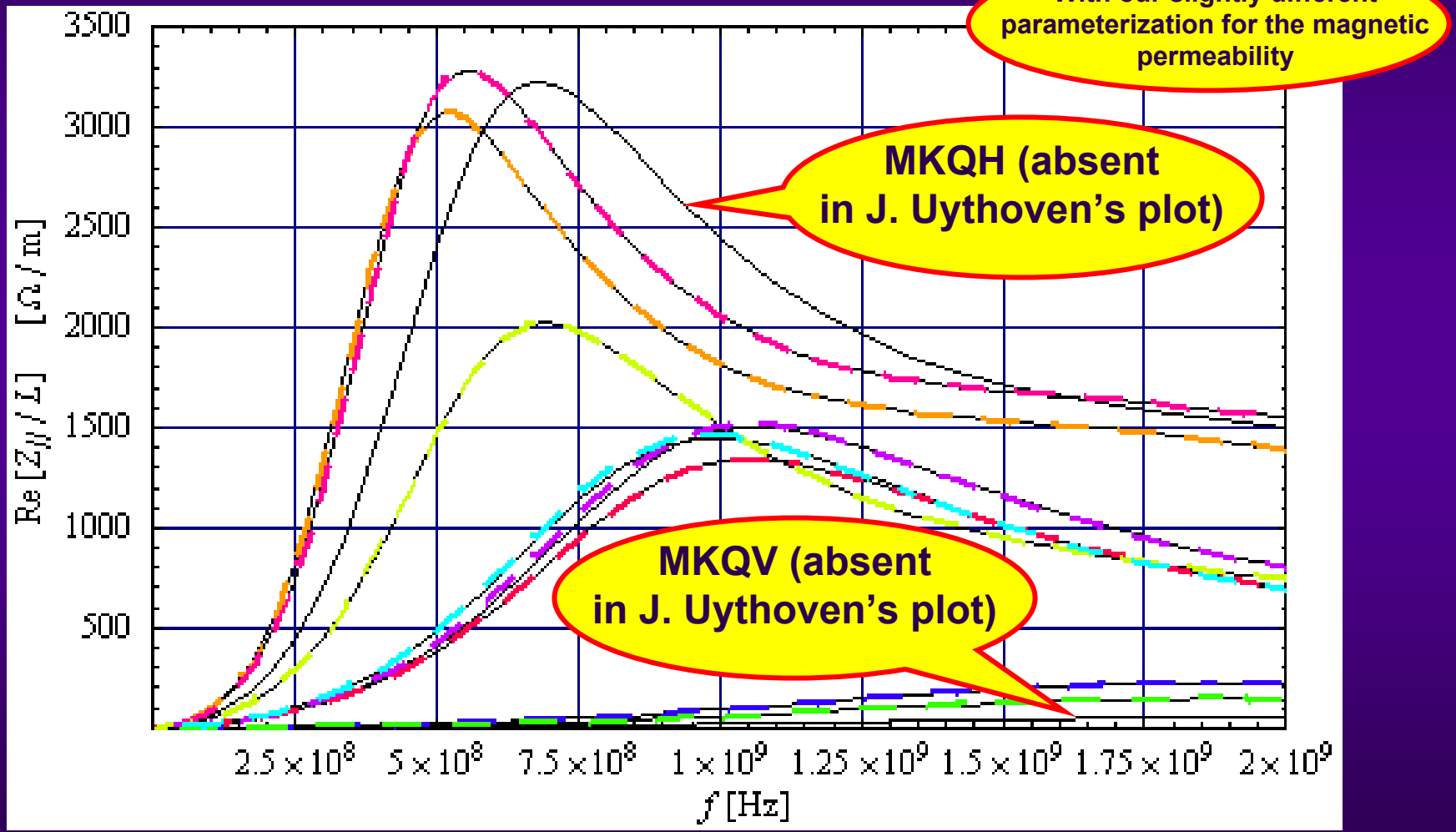


LONGITUDINAL IMPEDANCE (2/10)



LONGITUDINAL IMPEDANCE (3/10)

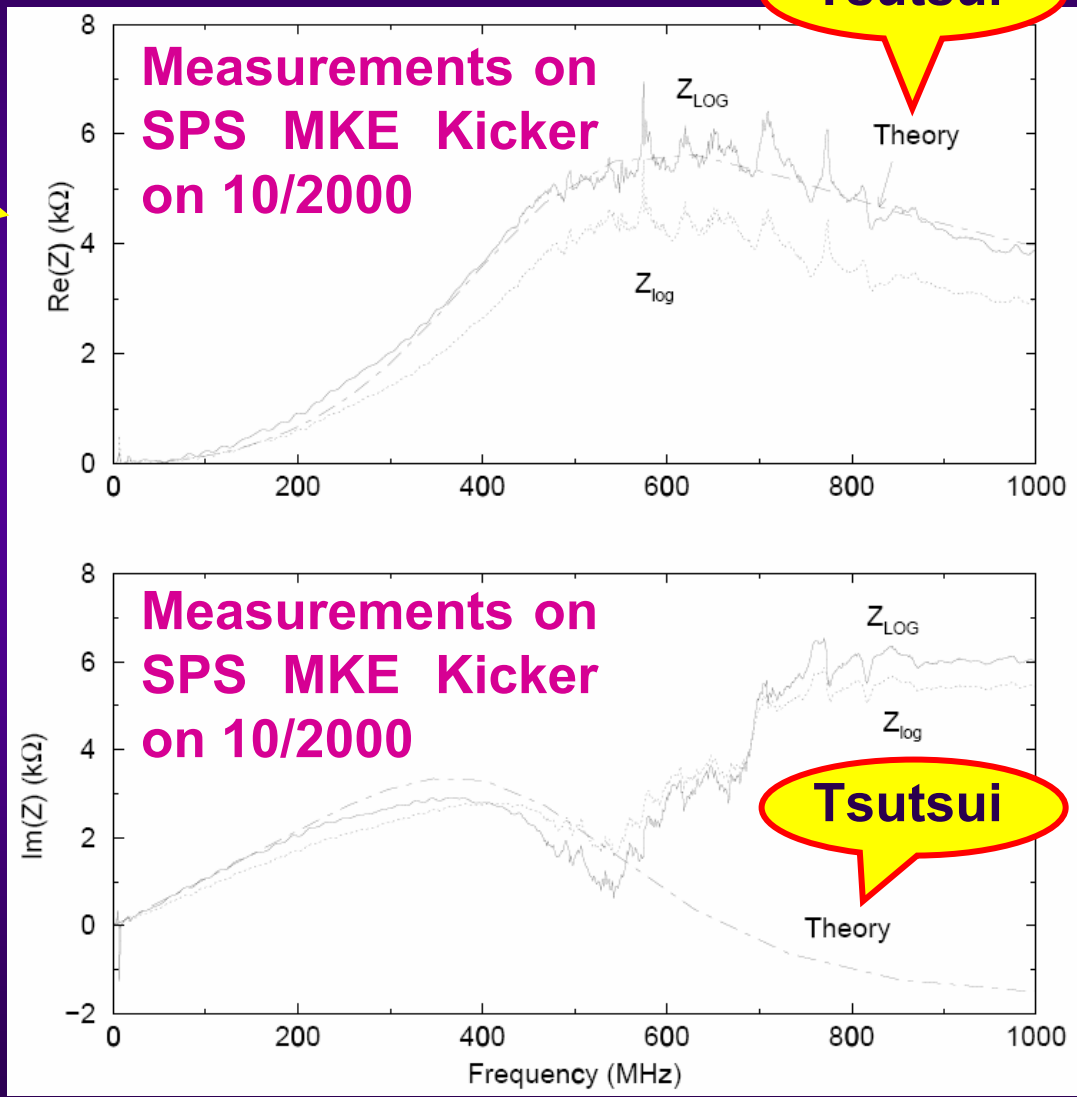
Comparison with J. Uythoven's computation in the past
$\Longrightarrow$ "Our" lines in black



LONGITUDINAL IMPEDANCE (4/10)

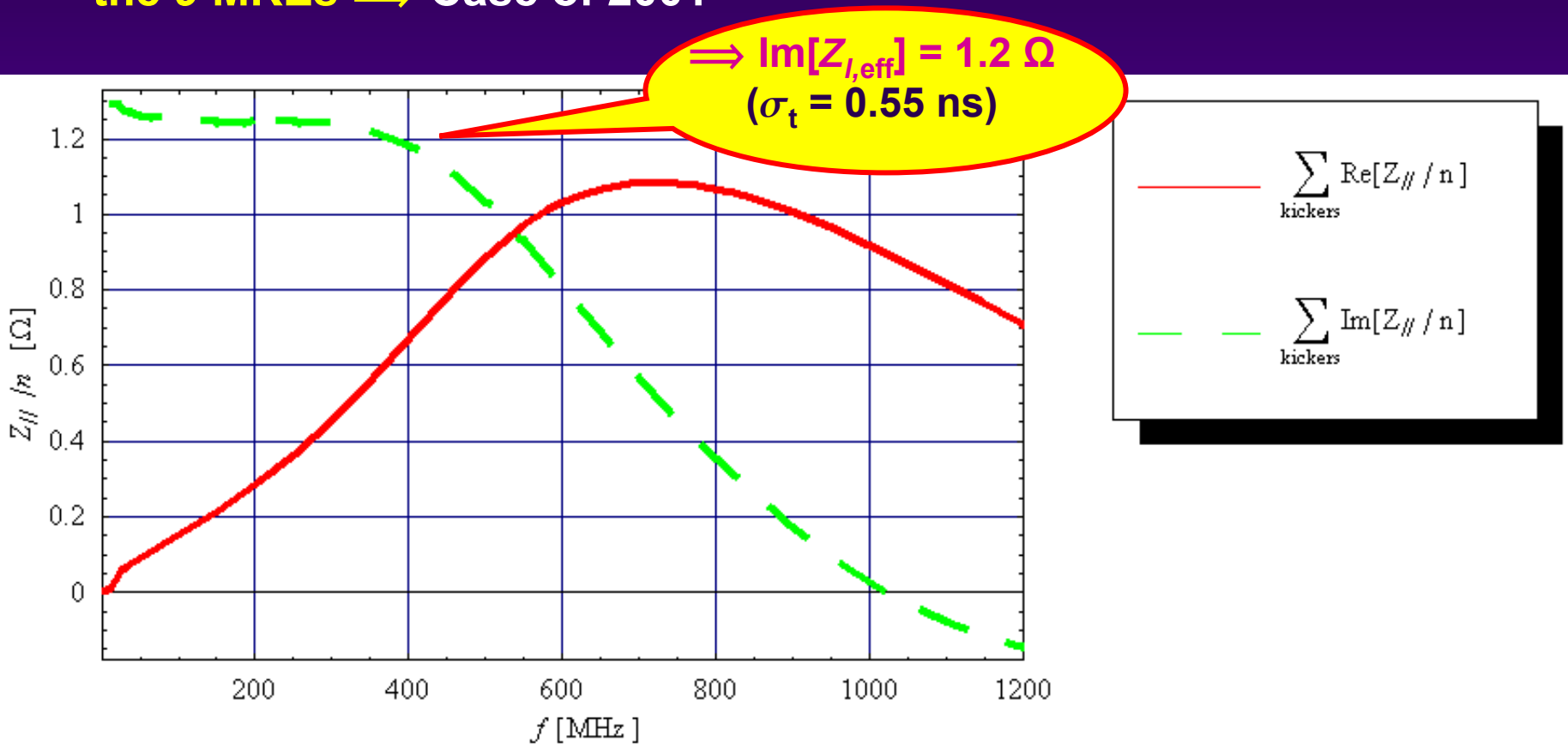
- Comparison between theory and measurements

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



LONGITUDINAL IMPEDANCE (5/10)

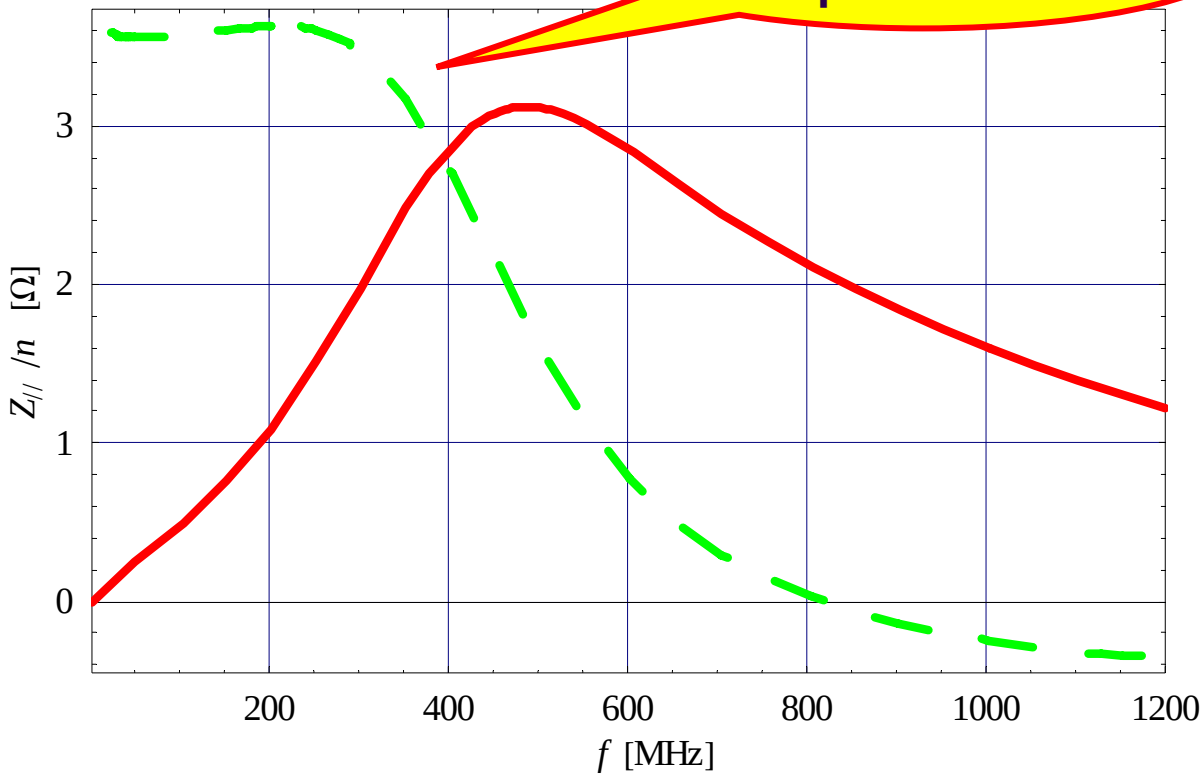
- **Plot of the longitudinal impedance for all the SPS kickers except the 9 MKEs $\Longrightarrow$ Case of 2001**

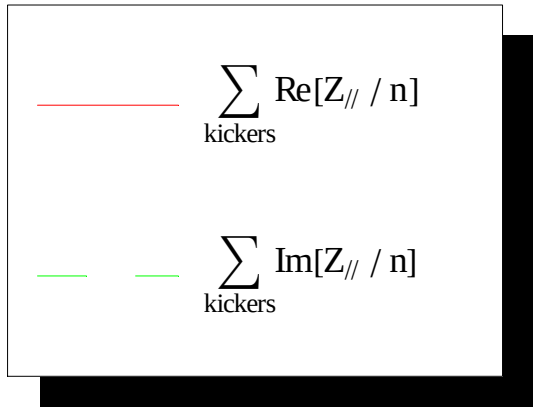


LONGITUDINAL IMPEDANCE (6/10)

- **Plot of the longitudinal impedance for the 16 SPS kickers $\Longrightarrow$ Case of 2003**

3.4 Ω $\Longrightarrow$ + 2.2 Ω compared to 2001

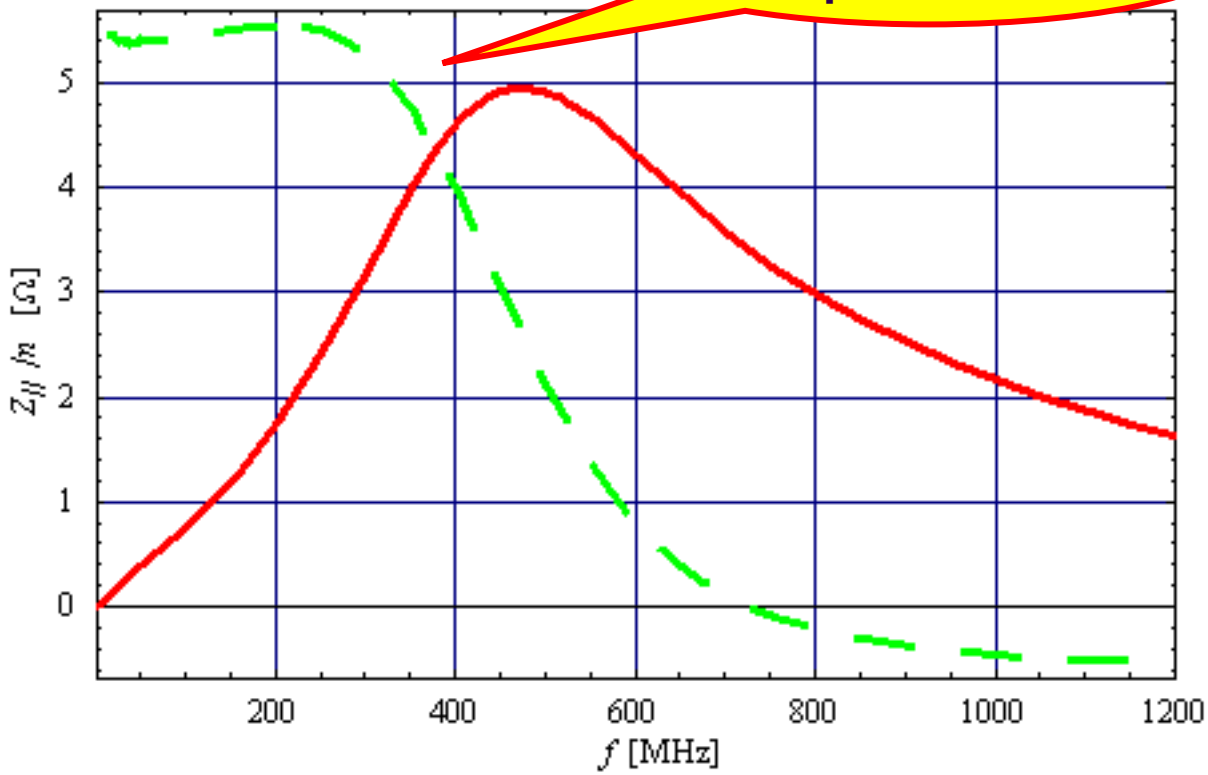


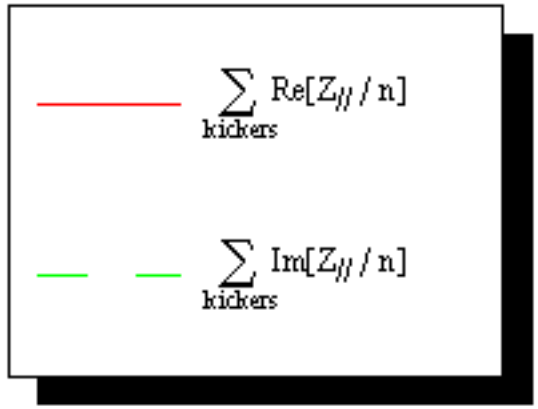


LONGITUDINAL IMPEDANCE (7/10)

- **Plot of the longitudinal impedance for all the 20 SPS kickers $\Longrightarrow$ Case of 2006**

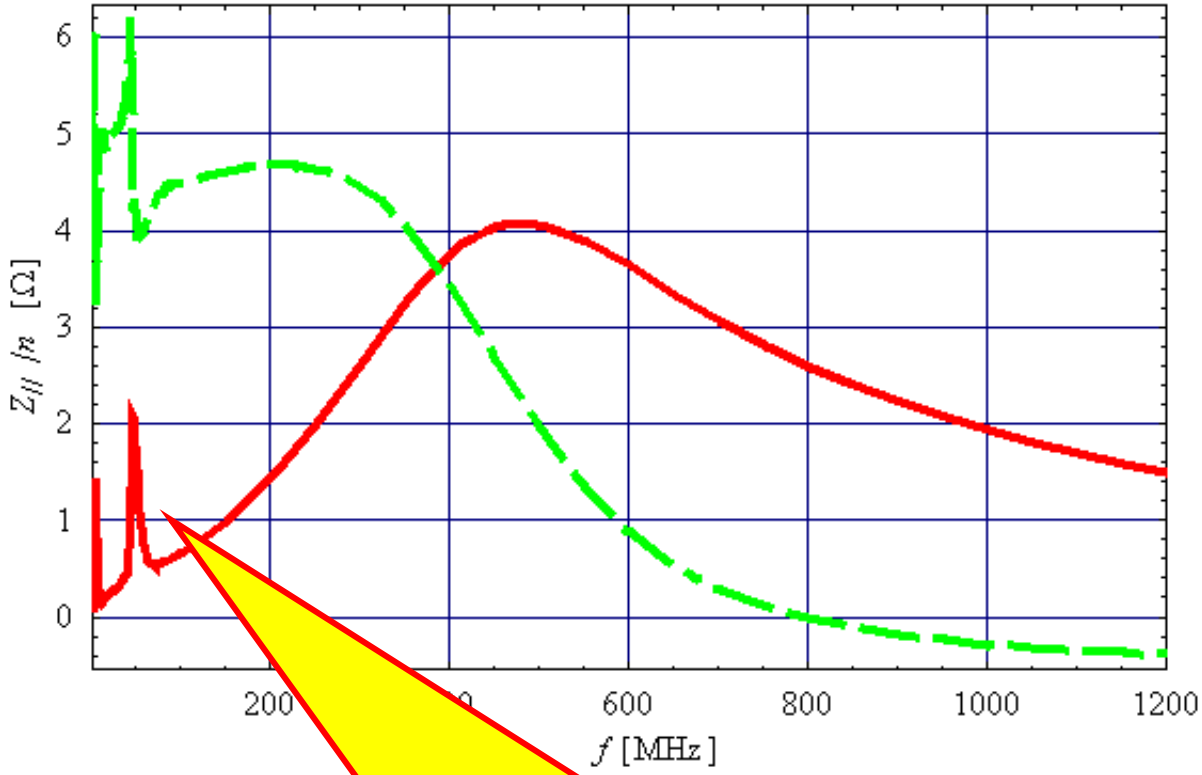
5.2 Ω $\Longrightarrow$ + 1.8 Ω compared to 2003

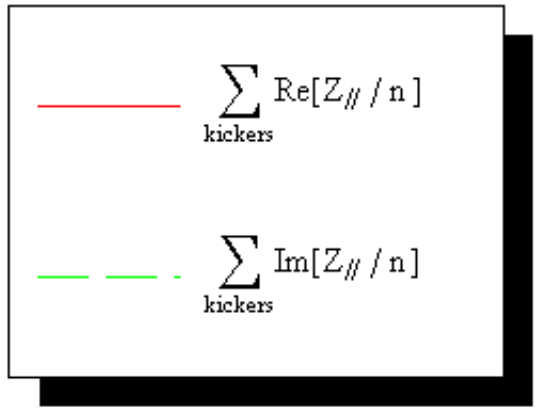




LONGITUDINAL IMPEDANCE (8/10)

- **Plot of the longitudinal impedance for all the 19 SPS kickers $\Longrightarrow$ Case of 2007**

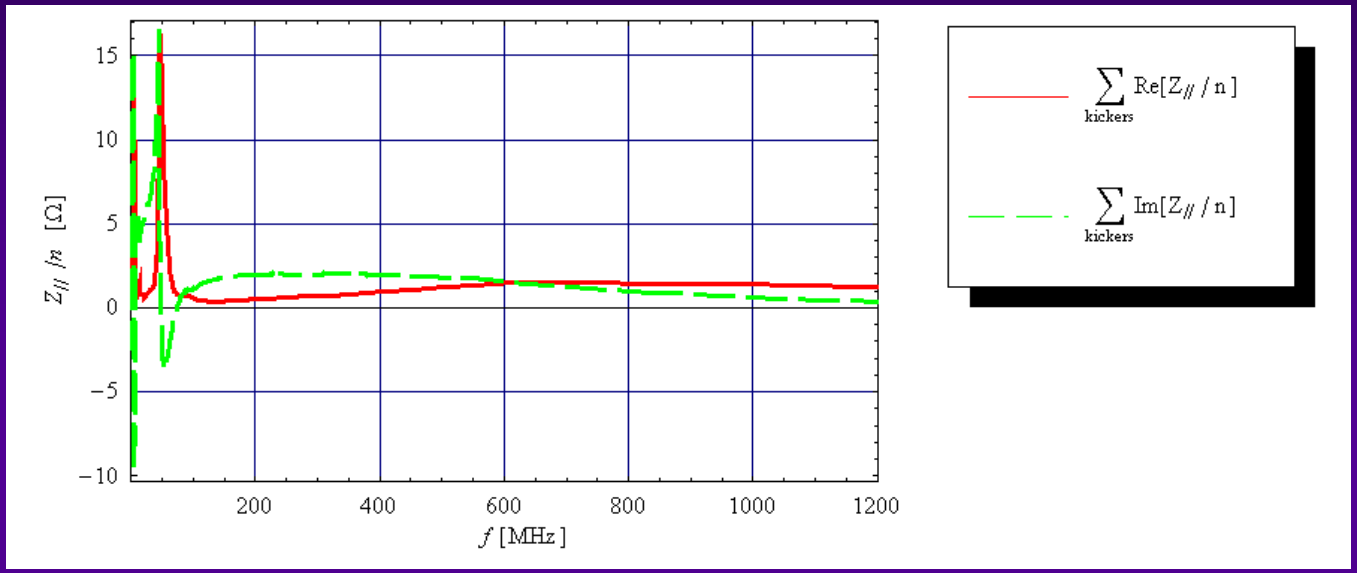


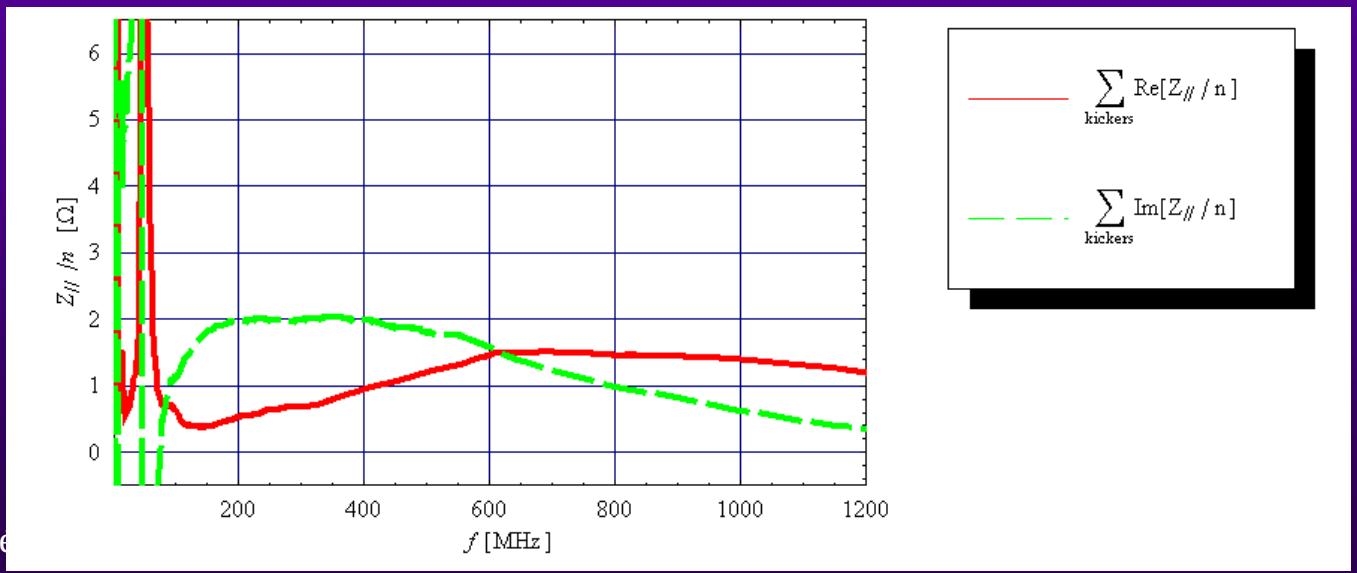


Resonance measured by T. Kroyer and F. Caspers (also at high frequencies)

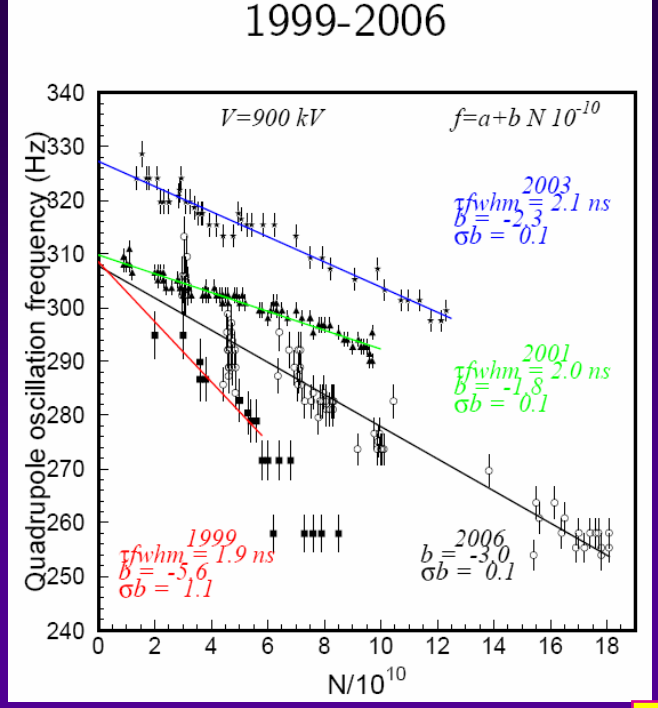
LONGITUDINAL IMPEDANCE (9/10)

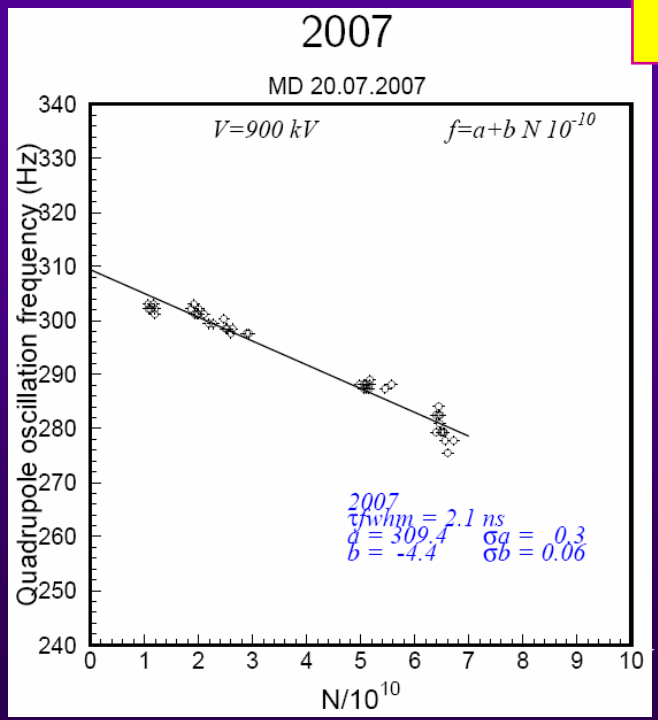
- **Plot of the longitudinal impedance for all the 20 SPS kickers with the 9 MKE kickers shielded**





LONGITUDINAL IMPEDANCE (10/10)





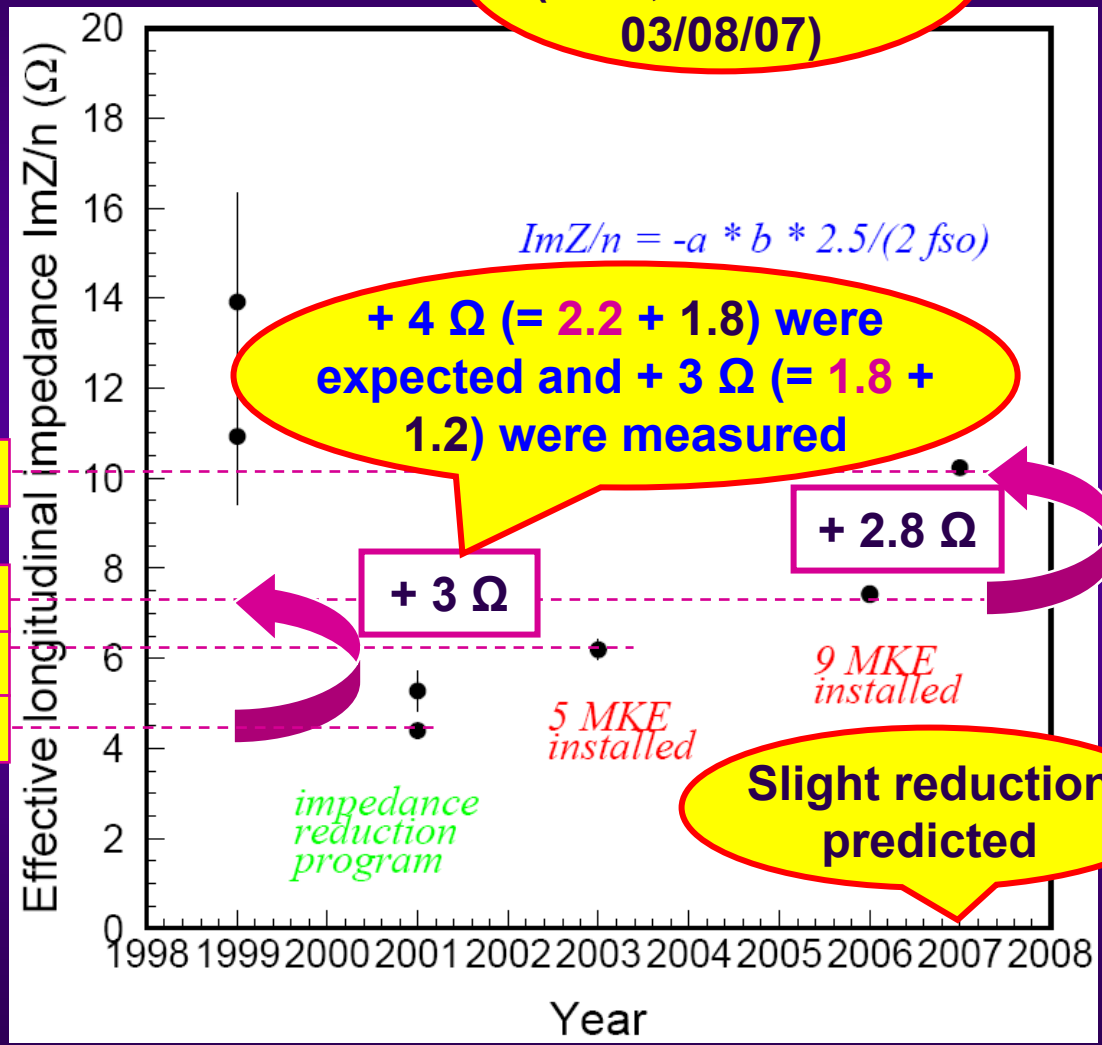
10.2

7.4

6.2

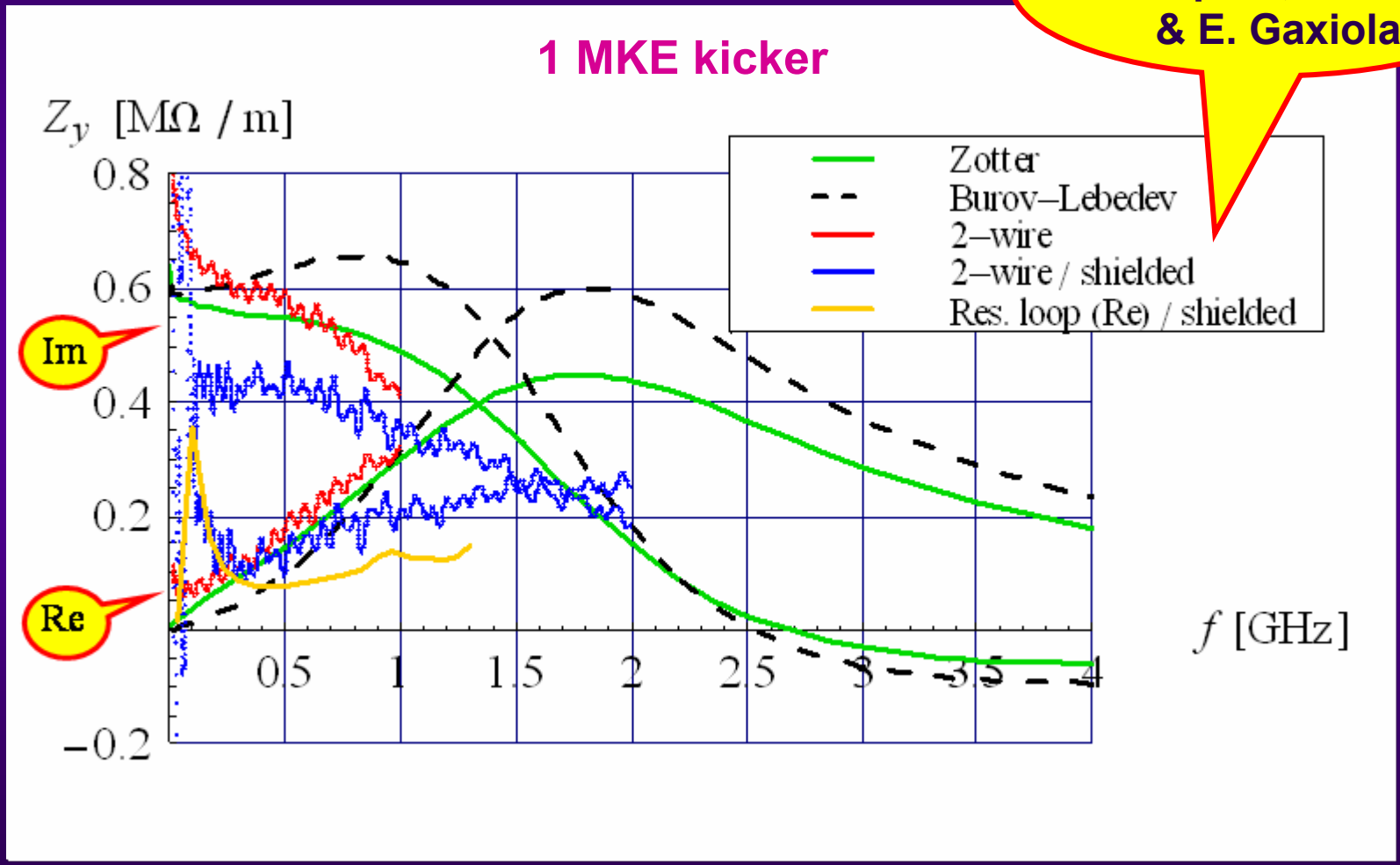
4.4

E. Chapochnikova (APC, 11/05/07 & 03/08/07)



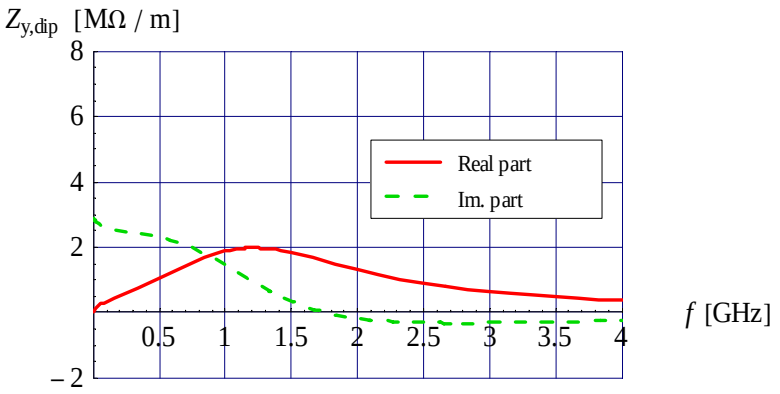
VERTICAL IMPEDANCE (1/9)

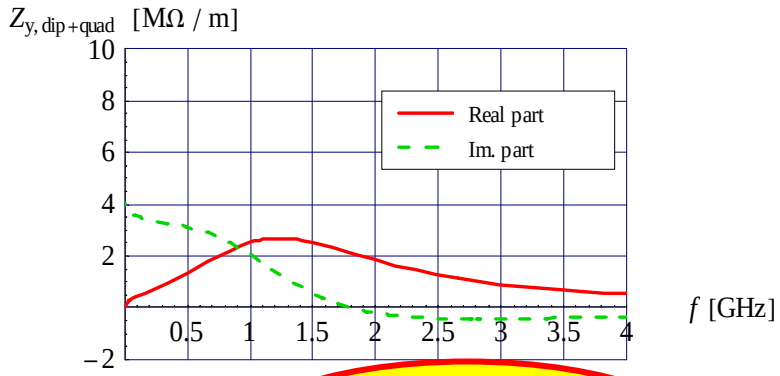
- Comparison between measurements and theory

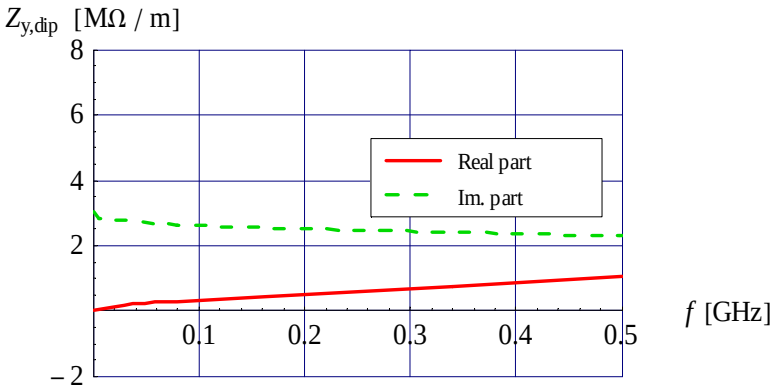


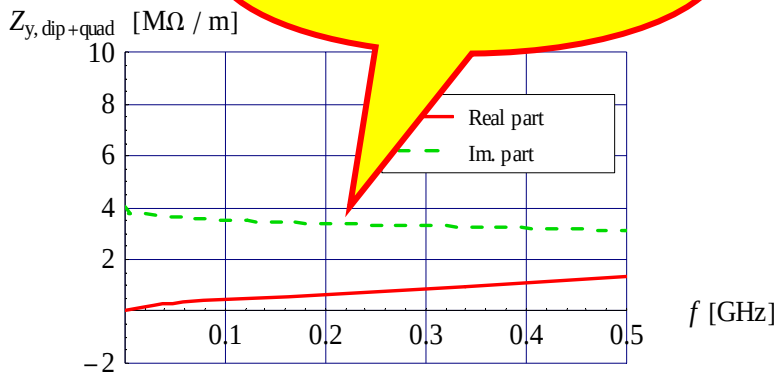
VERTICAL IMPEDANCE (2/9)

- **Plot of the vertical impedance for all the SPS kickers except the 9 MKEs (taking into account the flat chamber + betatron function at the kicker) ⟹ Case of 2001**





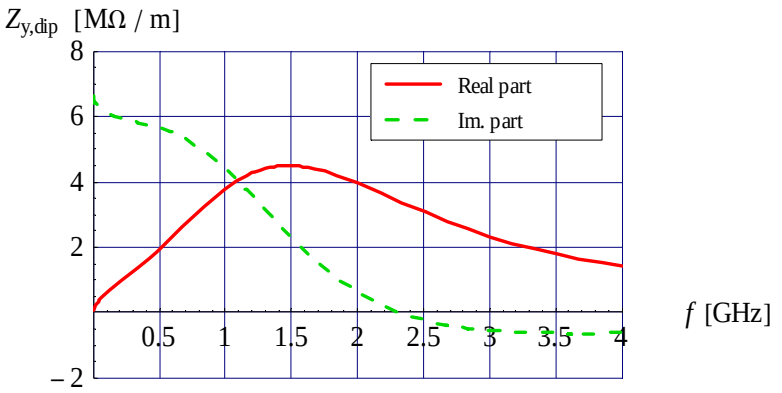


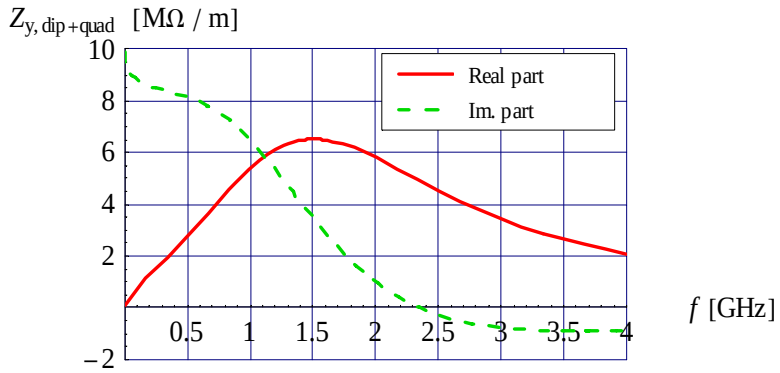


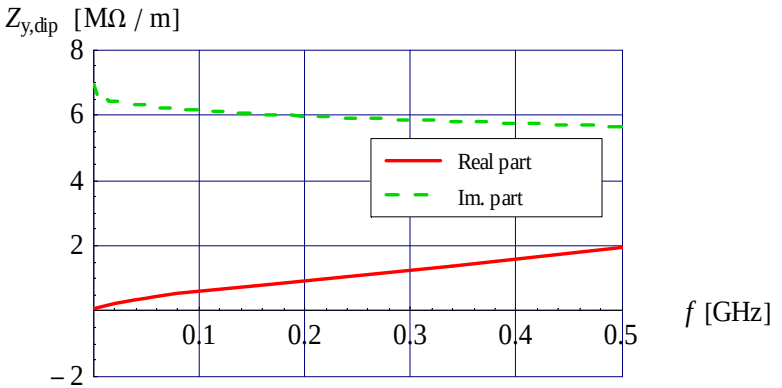
~ 3.5 MΩ / m at "low frequency"

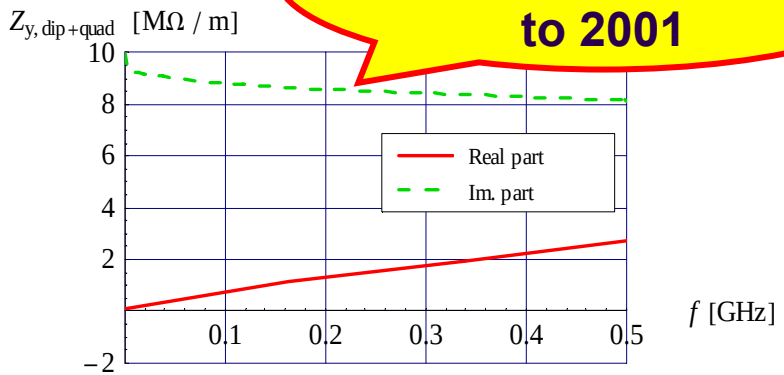
VERTICAL IMPEDANCE (3/9)

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





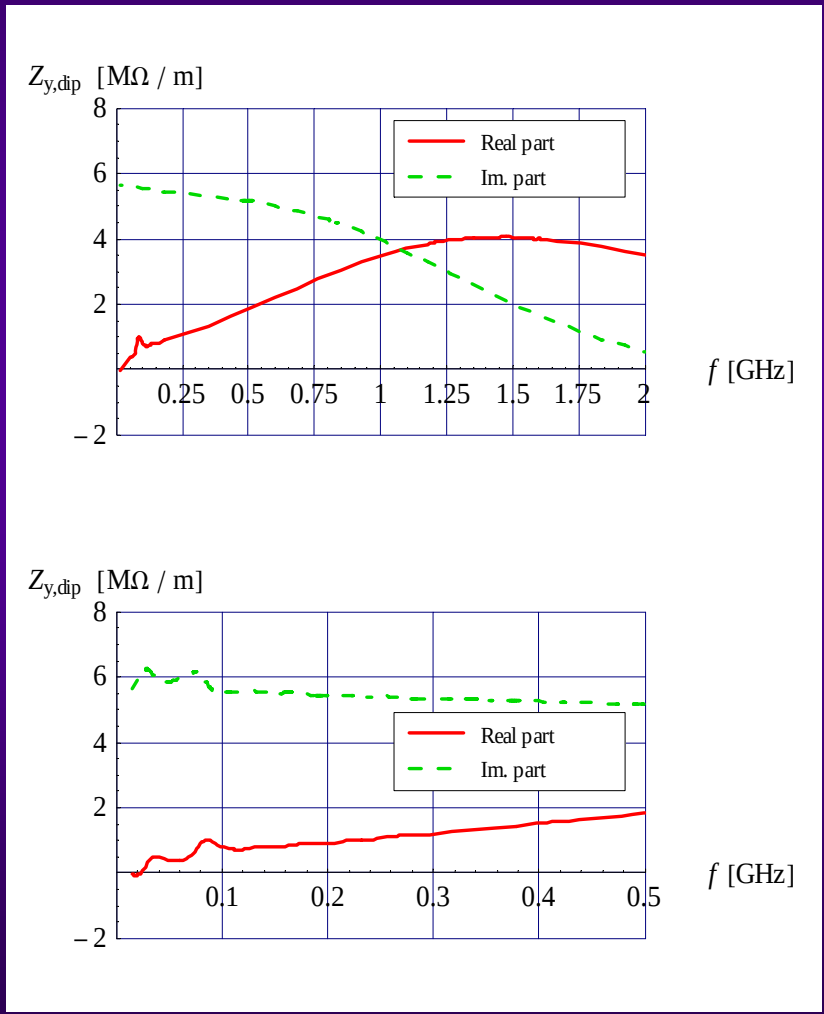




~ 8.5 MΩ / m
$\Longrightarrow$ ~ + 5 MΩ / m compared to 2001

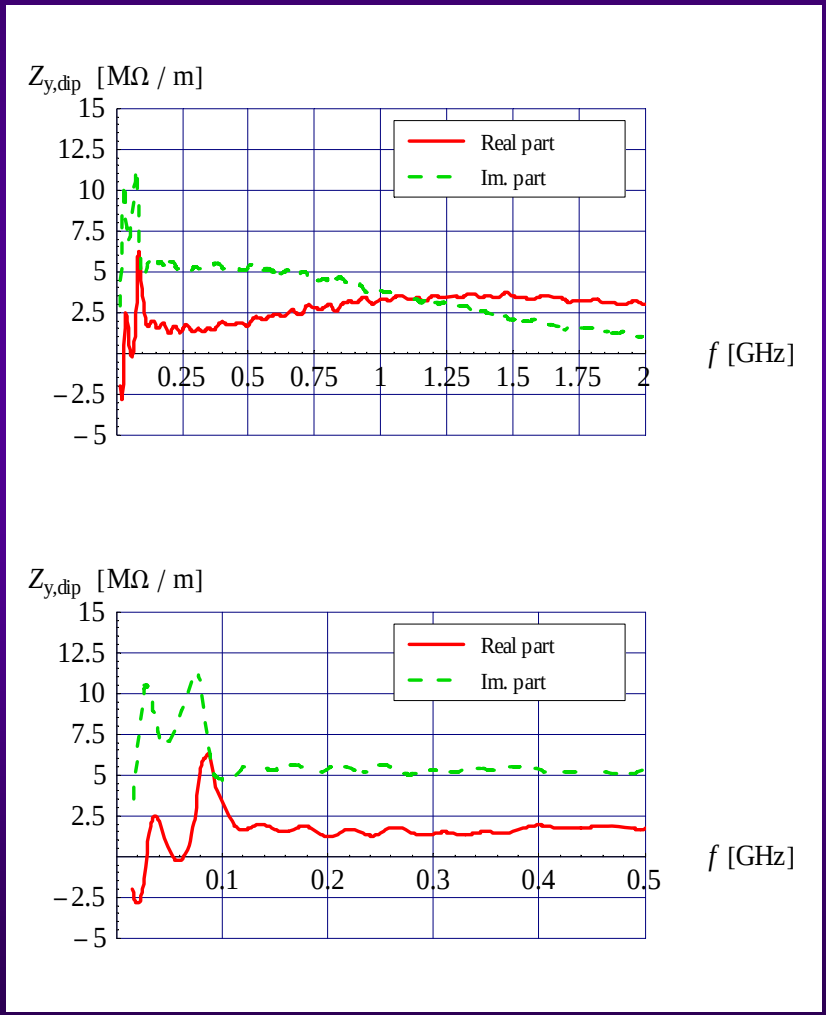
VERTICAL IMPEDANCE (4/9)

- **Plot of the vertical impedance for all the 19 SPS kickers in 2007 (taking into account the flat chamber + betatron function at the kicker) $\Longrightarrow$ Case of 2007**



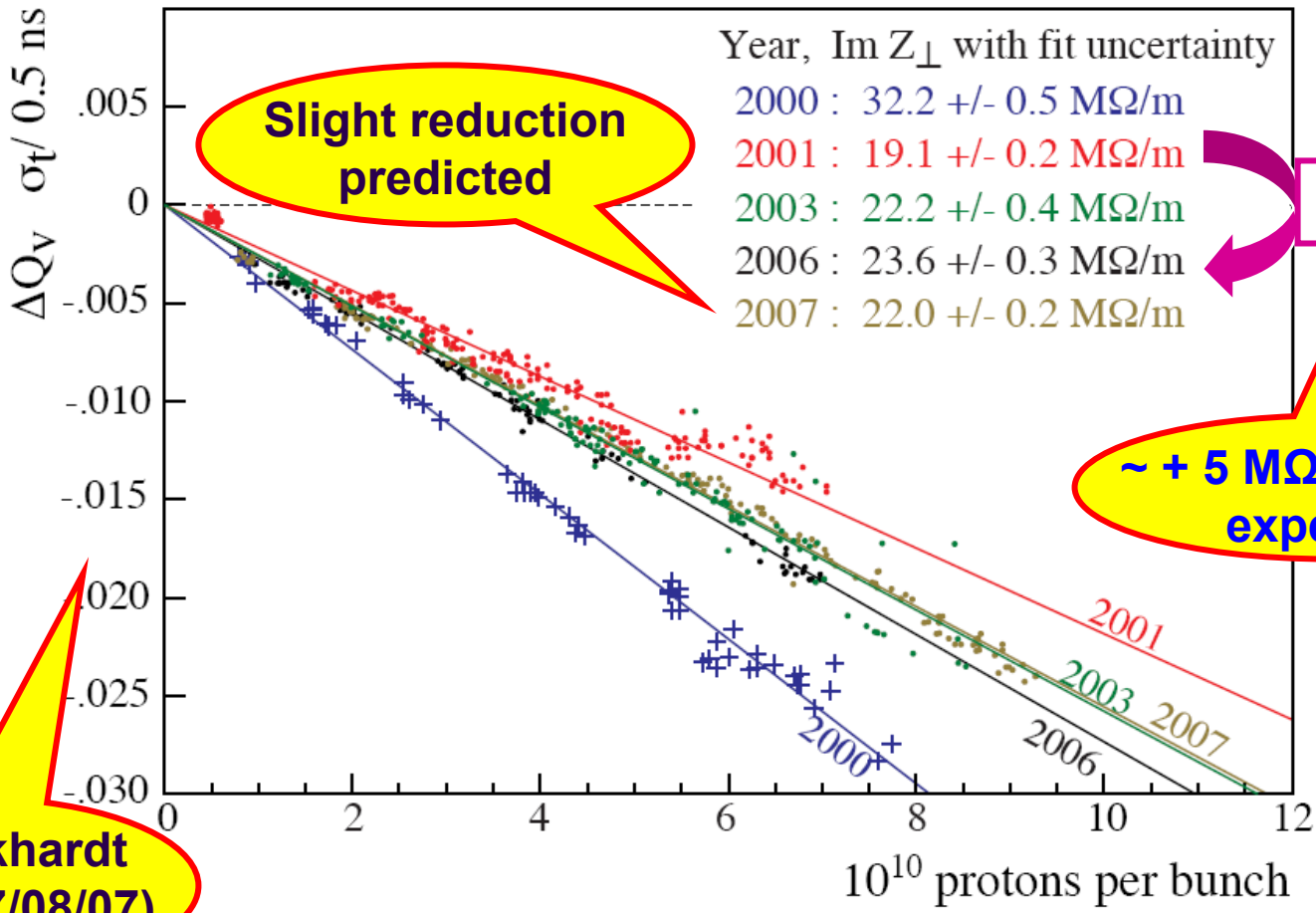
VERTICAL IMPEDANCE (5/9)

- **Plot of the vertical impedance for all the SPS kickers with the 9 shielded MKE kickers (taking into account the flat chamber + betatron function at the kicker)**



VERTICAL IMPEDANCE (6/9)

Vertical coherent tune shift with intensity at 26 GeV, scaled to 0.5 ns



Slight reduction predicted

+ 4.5 MΩ / m

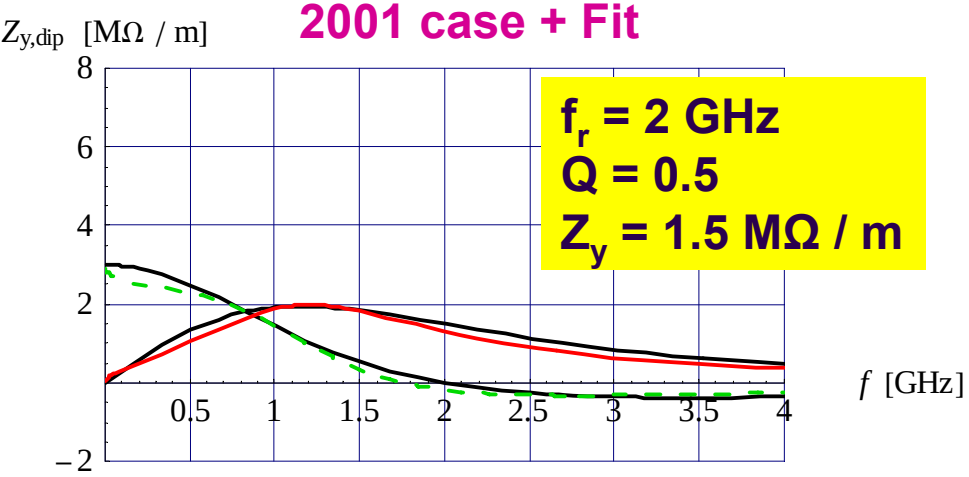
~ + 5 MΩ / m were expected

H. Burkhardt (APC, 17/08/07)

Same analysis and very similar beam parameters (~ 0.5 - 0.6 ns rms bunch length)
The measured slopes can directly be compared. Estimated uncertainty ~ 10 - 20 %.

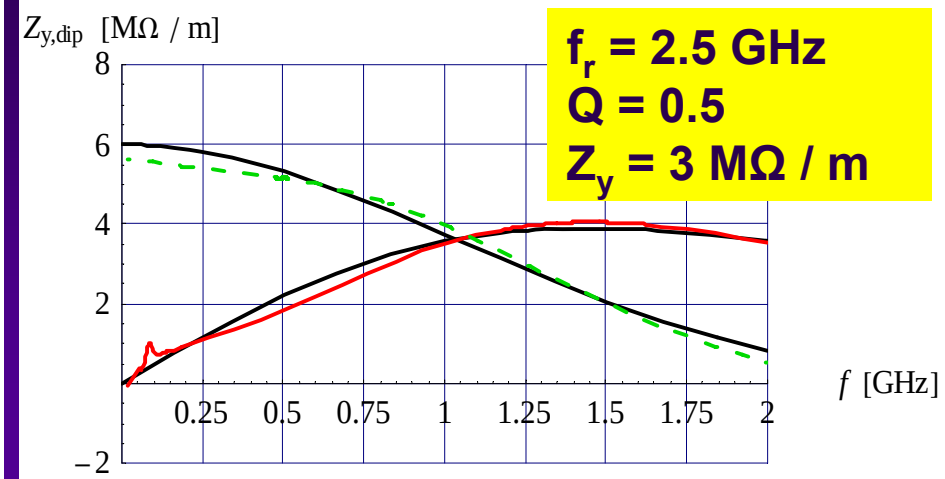
VERTICAL IMPEDANCE (7/9)

2001 case + Fit



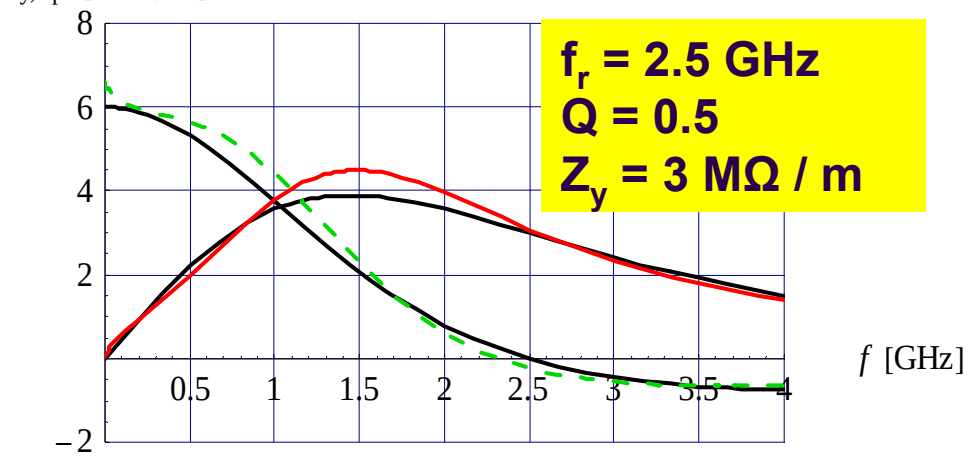
f_r = 2 GHz
Q = 0.5
Z_y = 1.5 MΩ / m

2007 case + Fit



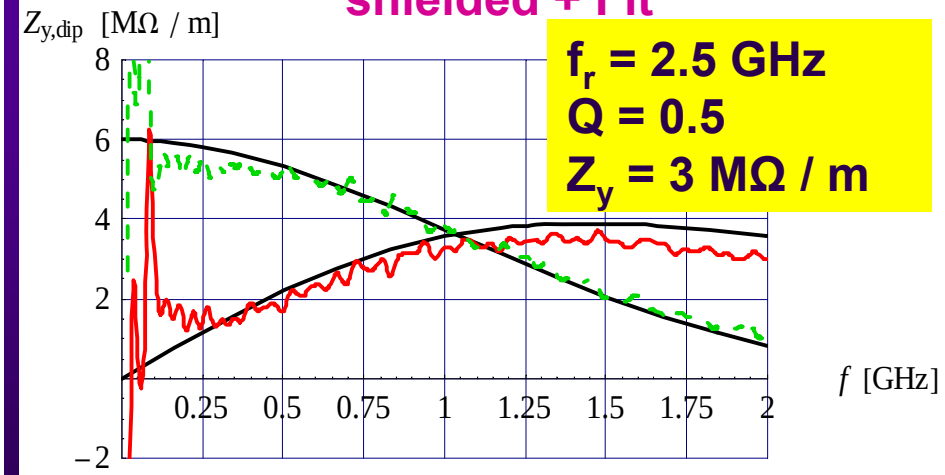
f_r = 2.5 GHz
Q = 0.5
Z_y = 3 MΩ / m

2006 case + Fit



f_r = 2.5 GHz
Q = 0.5
Z_y = 3 MΩ / m

Case will all MKEs shielded + Fit



f_r = 2.5 GHz
Q = 0.5
Z_y = 3 MΩ / m

VERTICAL IMPEDANCE (8/9)

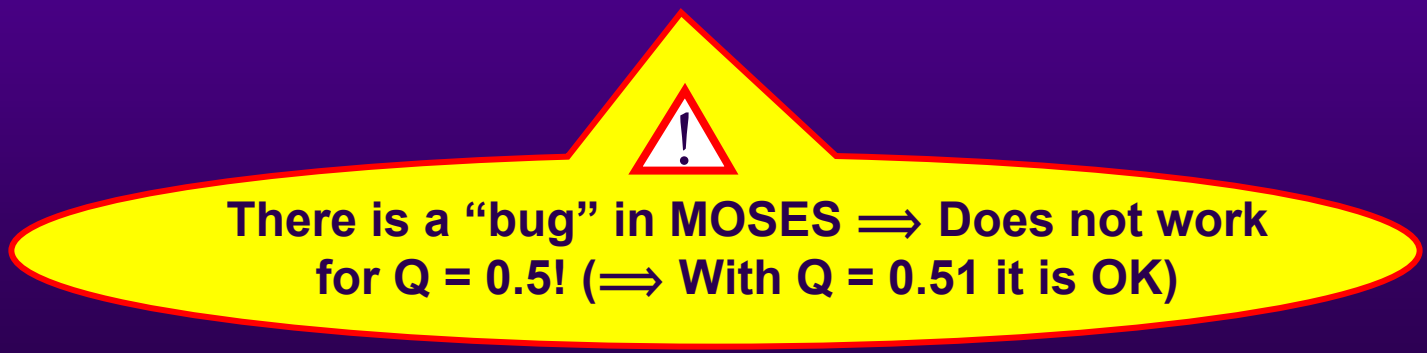
- TMCI threshold in the SPS at injection (with the usual "low emittance" beam) from MOSES

  - f_r = 2 GHz
  - Q = 0.5
  - Z_y = 1.5 MΩ / m

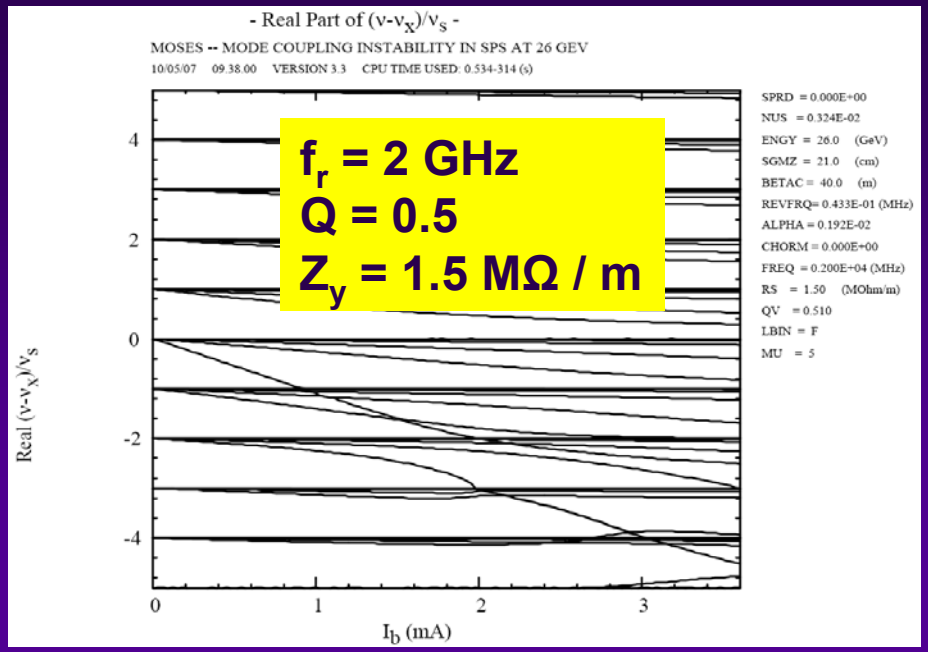
  $\Longrightarrow N_b^{th} = 2.9\ 10^{11}$ p/b

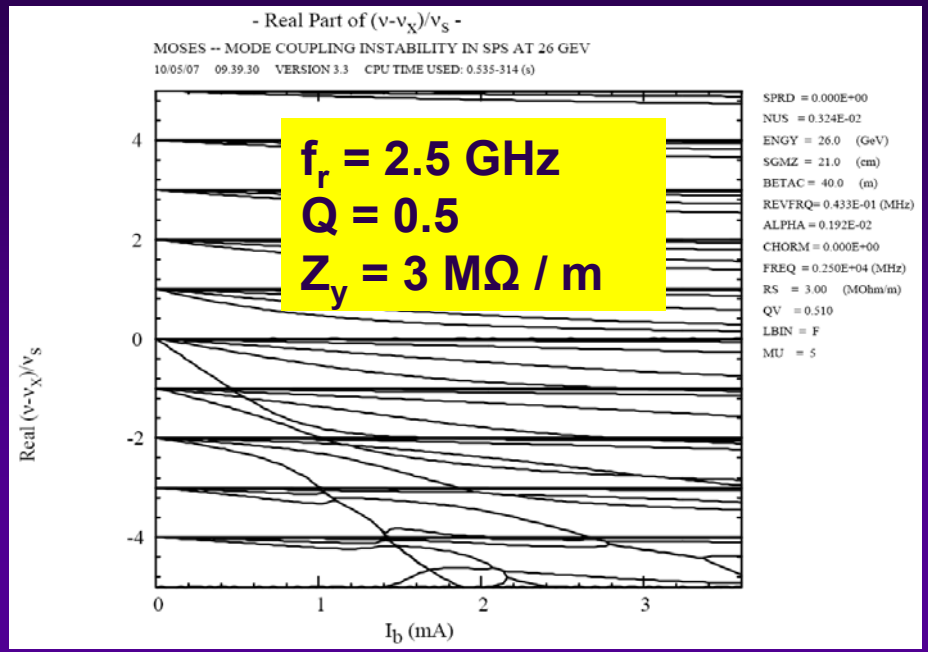
  - f_r = 2.5 GHz
  - Q = 0.5
  - Z_y = 3 MΩ / m

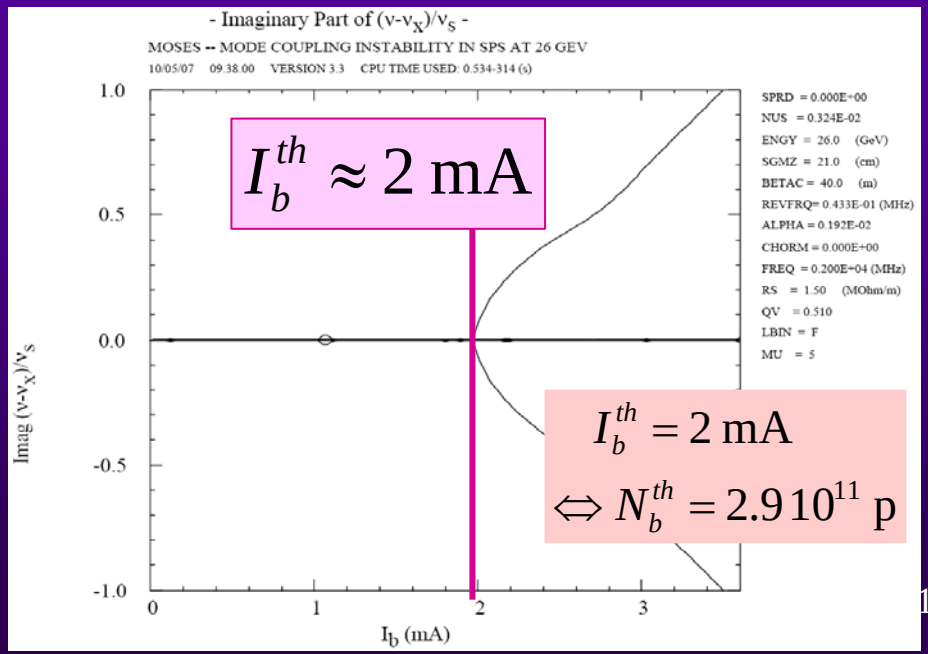
  $\Longrightarrow N_b^{th} = 1.4\ 10^{11}$ p/b

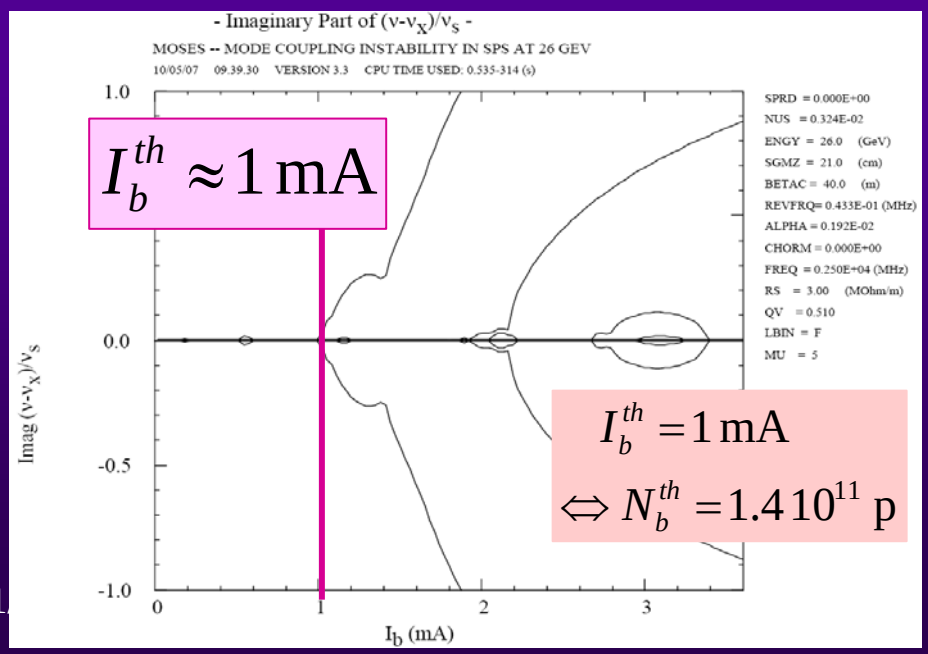


VERTICAL IMPEDANCE (9/9)



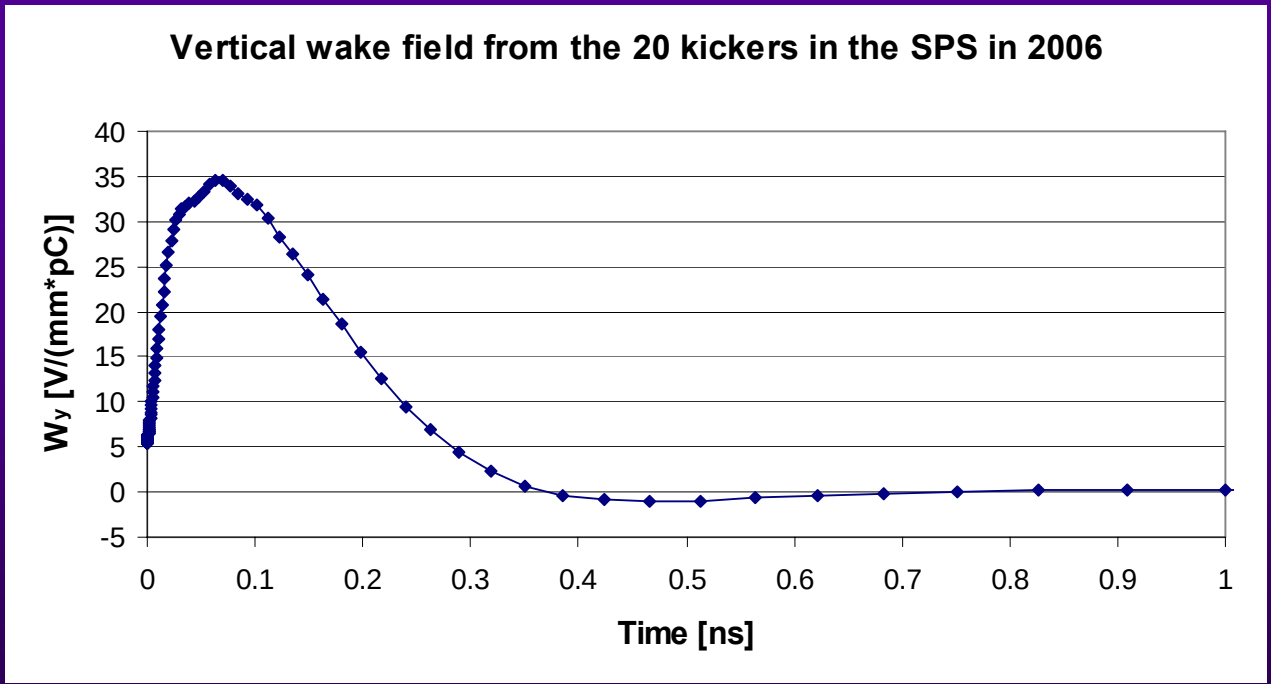






CONCLUSION (1/2)

- Transverse analytical estimates and measurements of the low frequency inductive effective impedance are in good agreement
- Waiting from detailed data analysis of the 2007 TMCI MD
- Hubert entered in ZBASE all the SPS kickers. Example below for 2006 $\Longrightarrow$ Giovanni will upgrade HEADTAIL to be able to read a wake field from a table and study the TMCI at injection



CONCLUSION (2/2)

- Longitudinal analytical estimates and measurements of the low frequency inductive effective impedance are NOT in agreement, but

  $\Longrightarrow$ 2 uncertainties from the 2006 measurements

  - The only one with very high intensity per bunch (the emittance was certainly not 0.2 eVs!!! $\Longrightarrow$ Longer bunch)
  - What would be the 2006 result considering only intensities below ~ 10^{11} p/b, as usual for the other measurements? $\Longrightarrow$ Larger impedance in 2006 as predicted from the theory?

- All the kickers can only explain ~ 50% of the longitudinal and transverse impedances $\Longrightarrow$ Continue the investigation as recommended by the APC (11/05/07)

- Future work: RF cavities to be included, IPM...