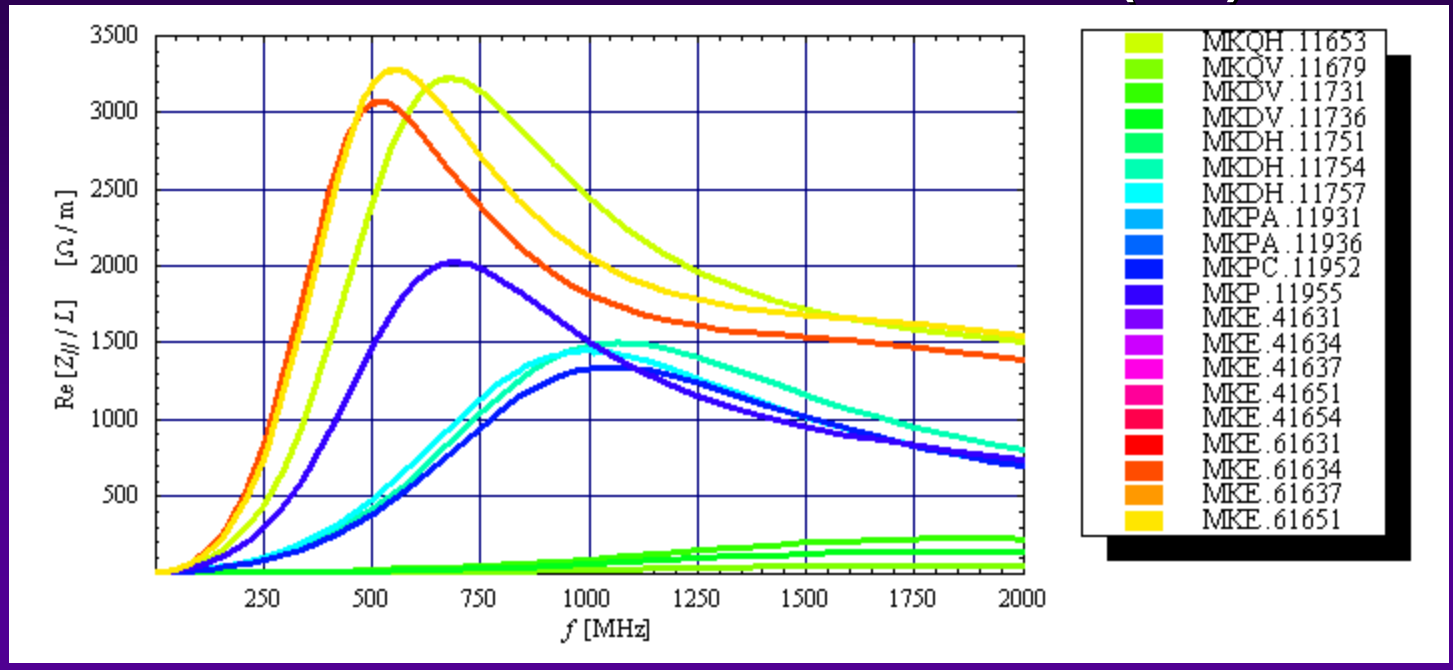
FOLLOW-UP OF THE LAST APC ON THE SPS KICKERS

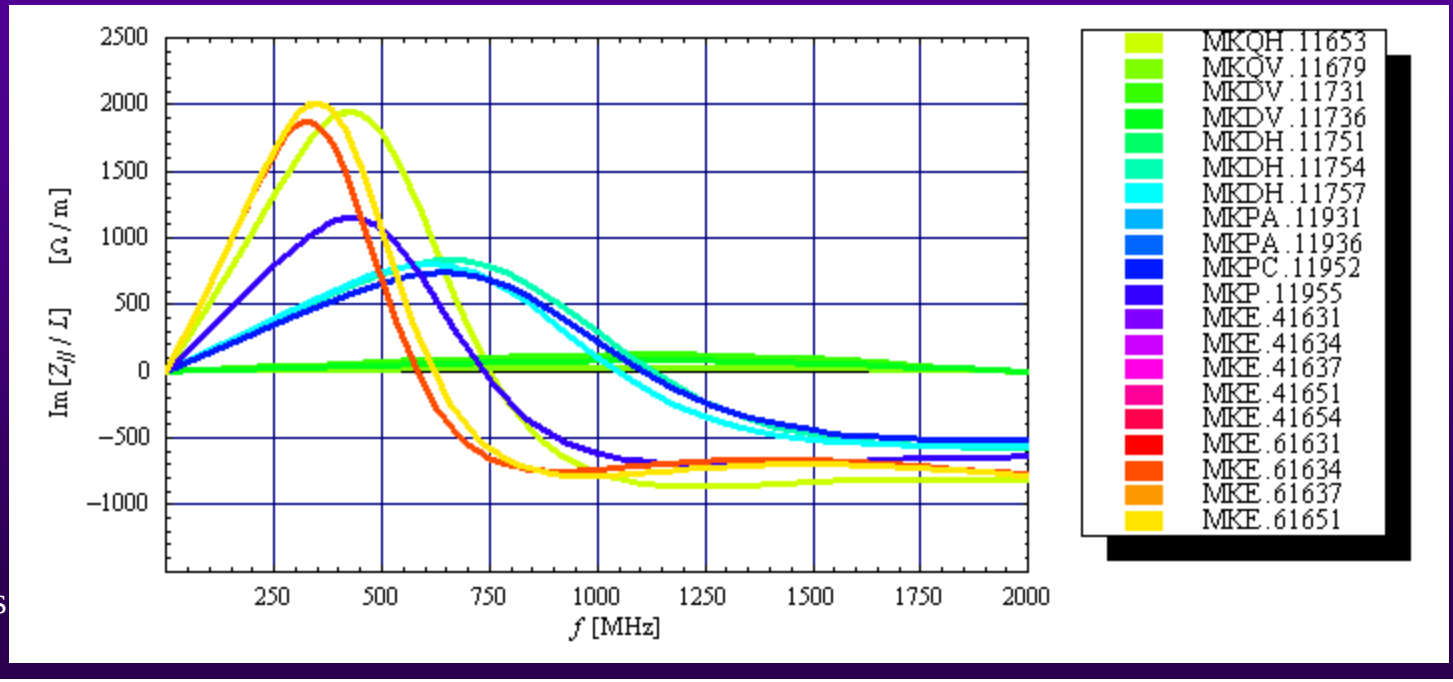
B. Salvant and E. Métral

- **Longitudinal and vertical impedances for**
  - **2001 $\Longrightarrow$ No MKE kickers (11 kickers in total)**
  - **2006 $\Longrightarrow$ + 9 MKE kickers (20 kickers in total)**
  - **2007 $\Longrightarrow$ Only 8 MKE kickers with 1 shielded (19 kickers in total)**
  - **Case with the 9 shielded MKE kickers (20 kickers in total)**
- **Comparison with measurements of the low frequency inductive part of the impedances**
- **Corresponding TMCI thresholds**
- **Conclusion**

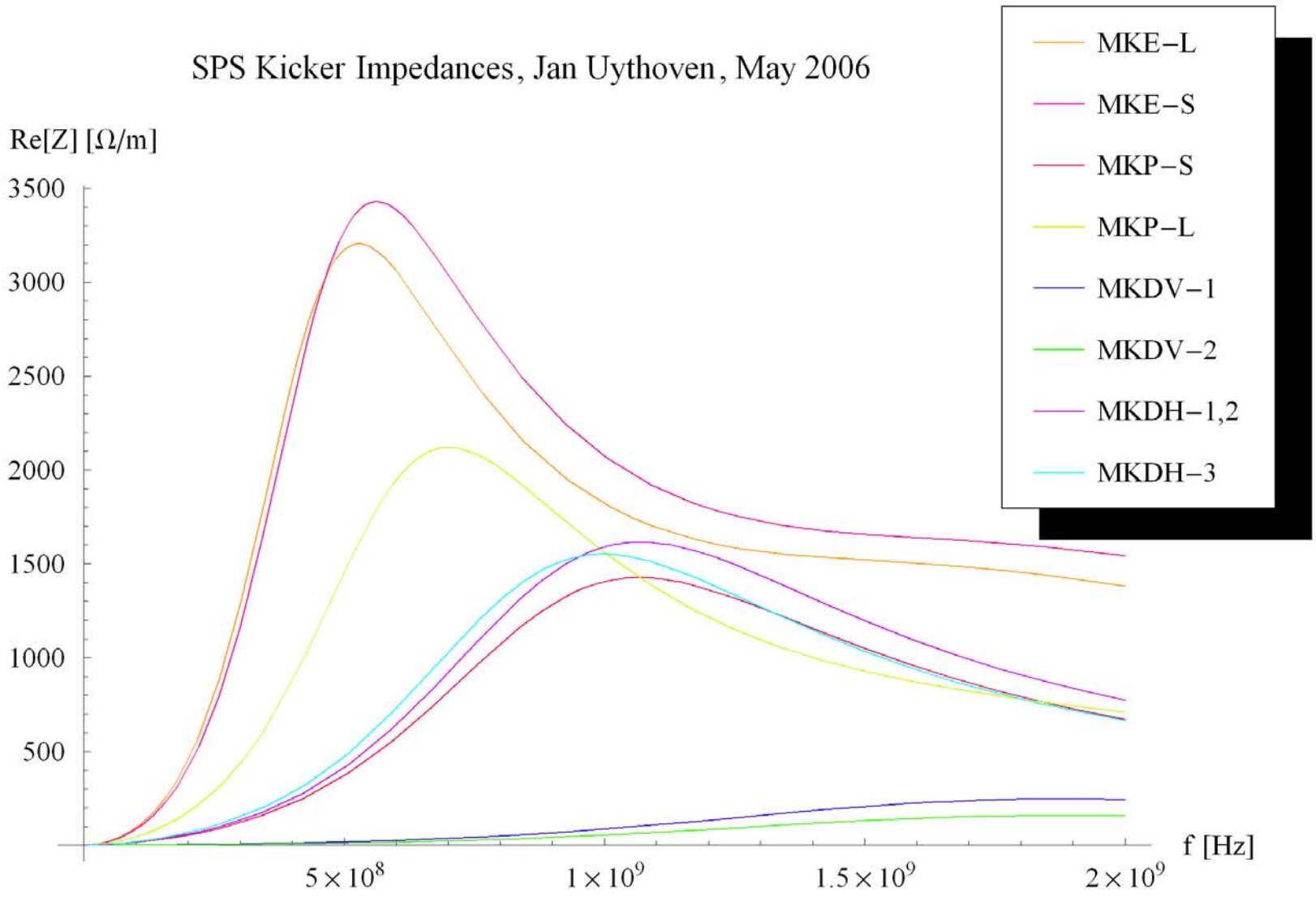
Thanks to F. Caspers and T. Kroyer!

LONGITUDINAL IMPEDANCE (1/9)



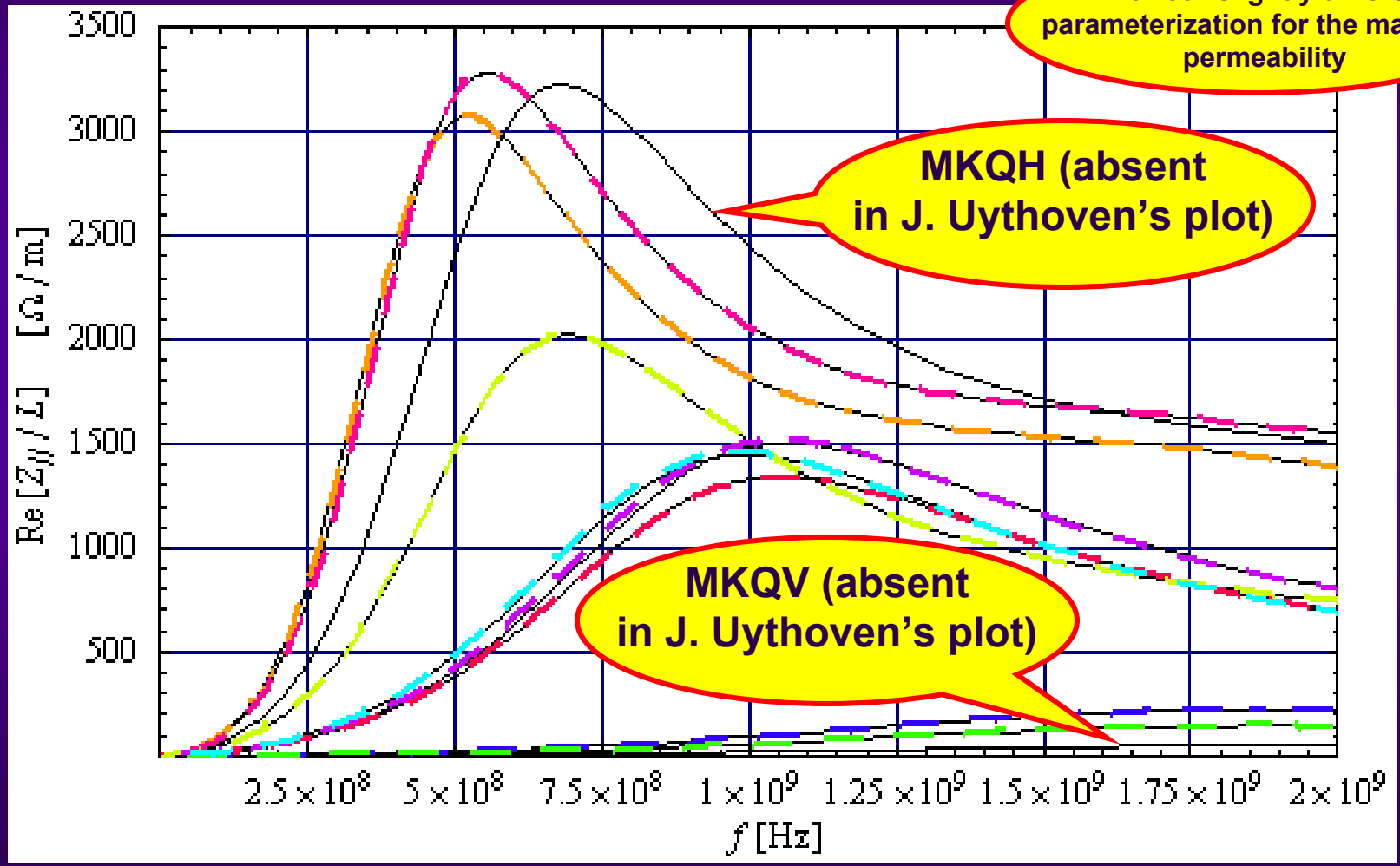


LONGITUDINAL IMPEDANCE (2/9)



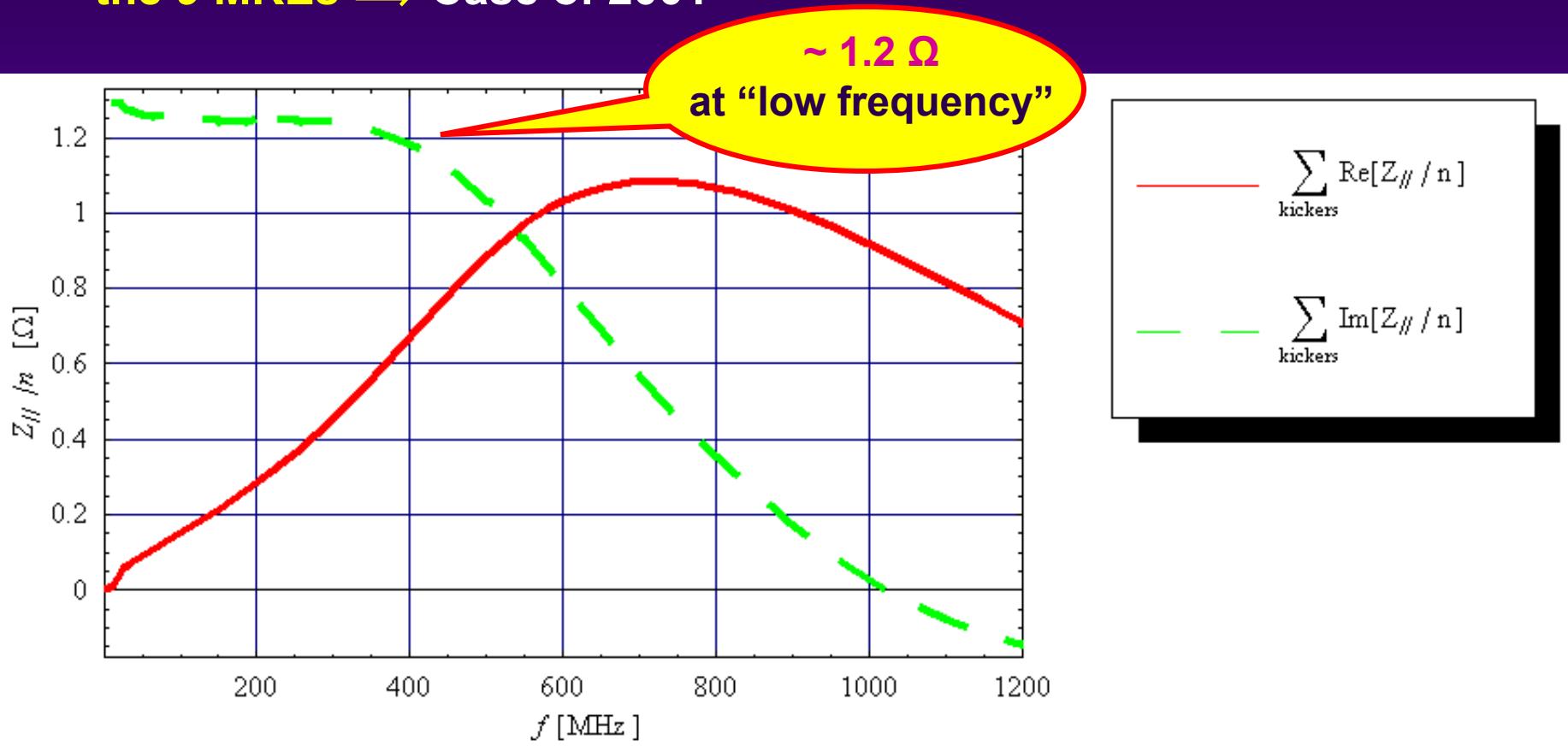
LONGITUDINAL IMPEDANCE (3/9)

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



LONGITUDINAL IMPEDANCE (4/9)

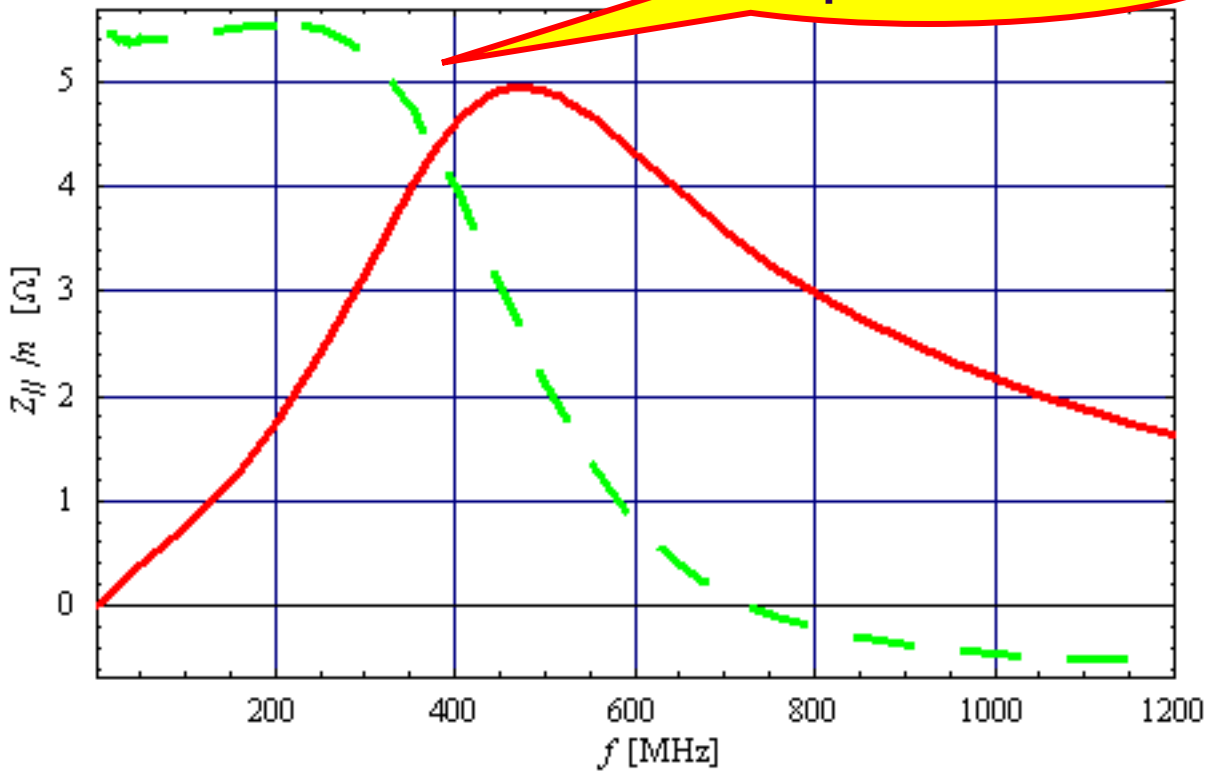
- **Plot of the longitudinal impedance for all the SPS kickers except the 9 MKEs $\Longrightarrow$ Case of 2001**

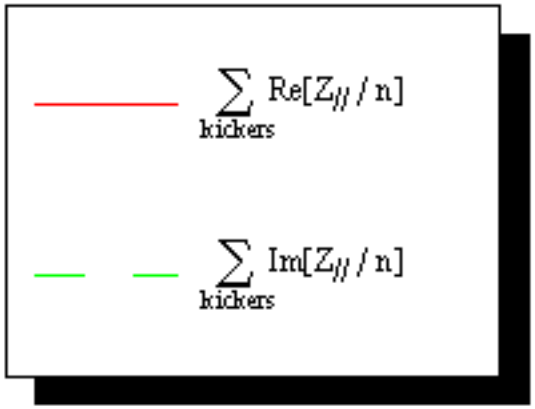


LONGITUDINAL IMPEDANCE (5/9)

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

~ 5 Ω $\Longrightarrow$ ~ + 3.8 Ω compared to 2001





LONGITUDINAL IMPEDANCE (6/9)

J. Tuckmantel (APC, 10/11/06)

b ∝ low frequency inductive impedance $\mathrm{Im}[Z_{//}/n]$

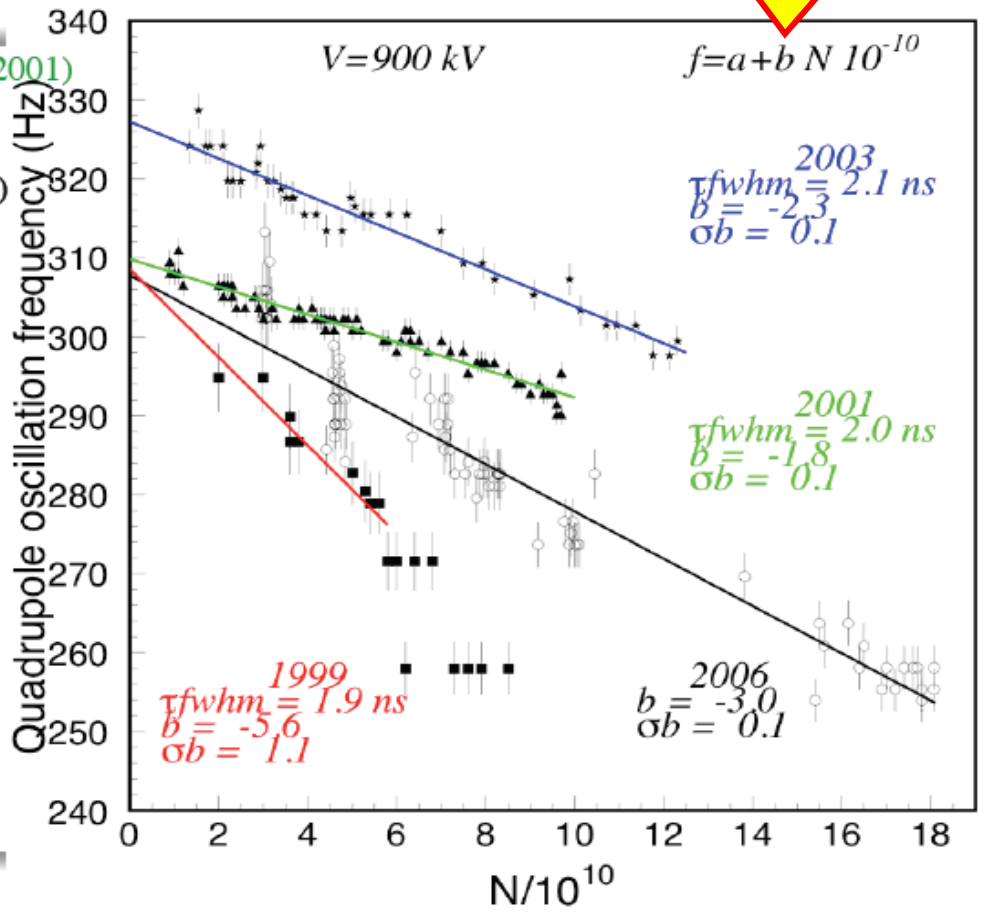
Comparison with previous measurements

1) LEP inj H/W (1999)
2) Rem. H/W, imp. red. (2001)
3) +5 MKE CNGS (2003)
4) +3+1 MKE LHC (2006)

Slopes [Hz/10^{10}]:

1) -5.6
2) -1.8
3) -2.3

4a) -3.0 (m.r.)
4b) -3.0 (scope)
4c) -3.6 (FFT)



LONGITUDINAL IMPEDANCE (7/9)

- $b_{2001} = -1.8$
- $b_{2006} = -3.0$
- Let's call K the low frequency imaginary part of the impedance Im[Z// / n] of the rest of the machine (with also the contribution from space charge, estimated at 26 GeV/c at ~ -1 Ω, see LHC Design Report, vol. III, p. 151)

$$\Rightarrow \quad \frac{K+5}{K+1.2} = \frac{3}{1.8}$$

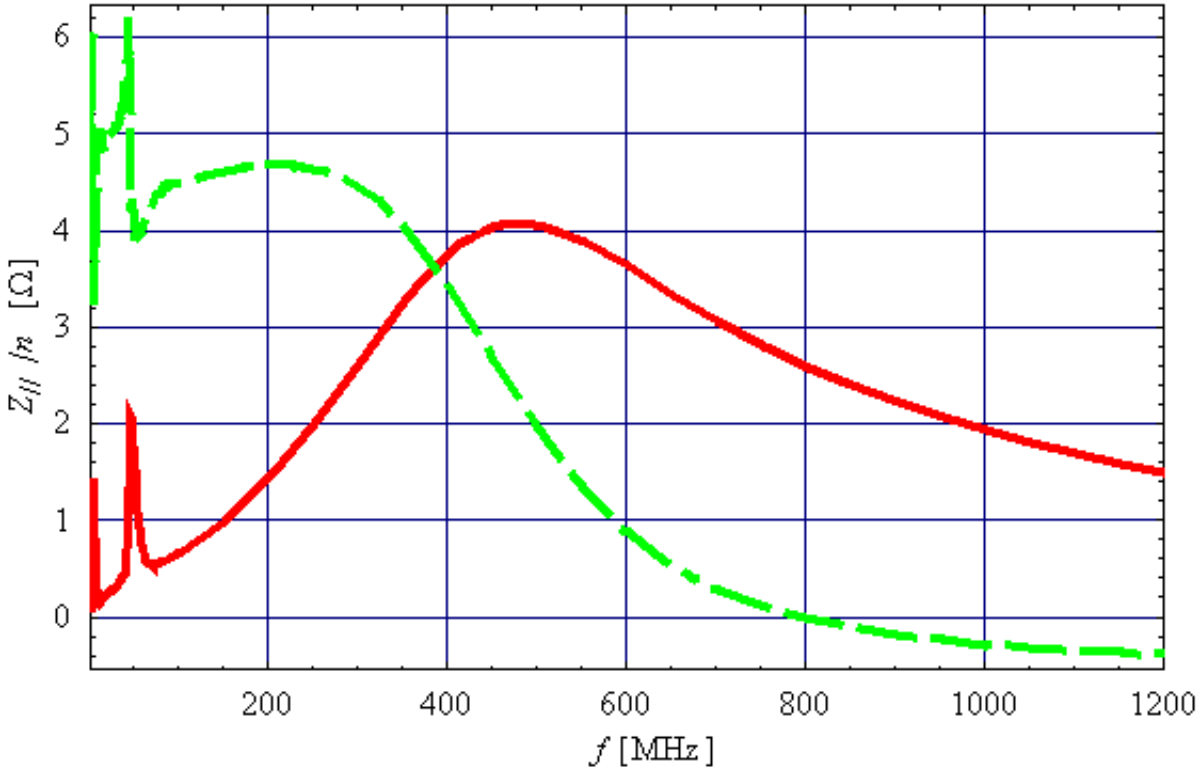
- This leads to $K = 4.5$

⟹ In good agreement with the LHC Design Report, vol. III, p. 151 (5.6 Ω)

- Therefore $\left.\mathrm{Im}\left[\frac{Z_{//}}{n}\right]\right|_{2001}^{\mathrm{Total}} \approx 5.7\ \Omega$ $\left.\mathrm{Im}\left[\frac{Z_{//}}{n}\right]\right|_{2006}^{\mathrm{Total}} \approx 9.5\ \Omega$

LONGITUDINAL IMPEDANCE (8/9)

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

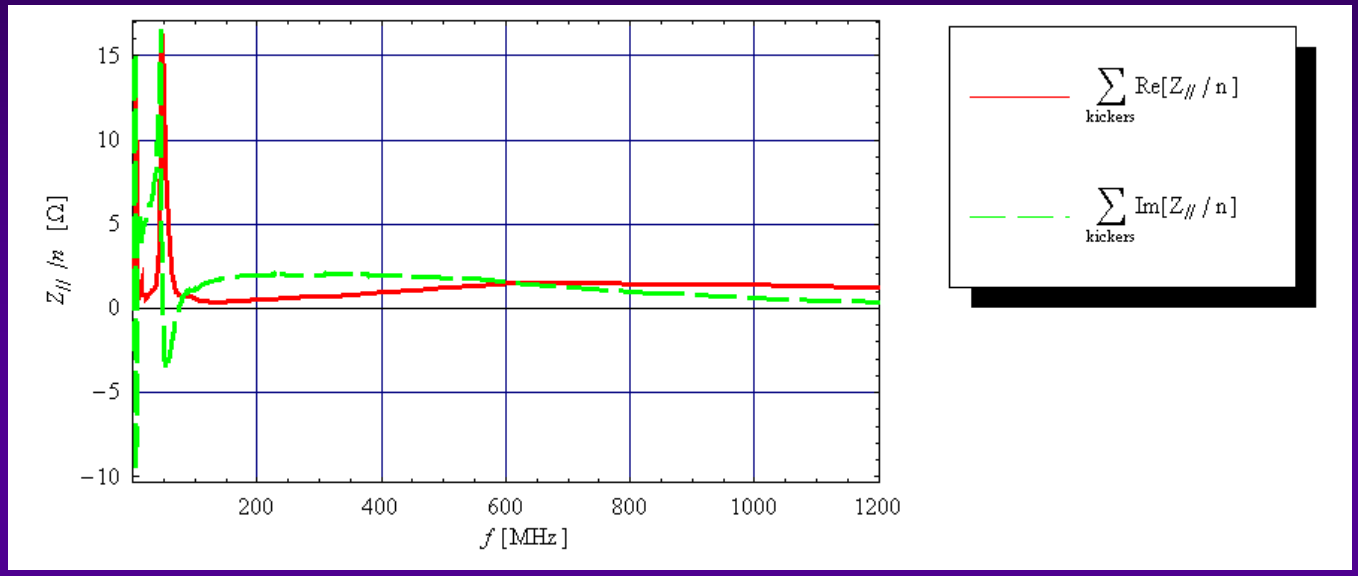


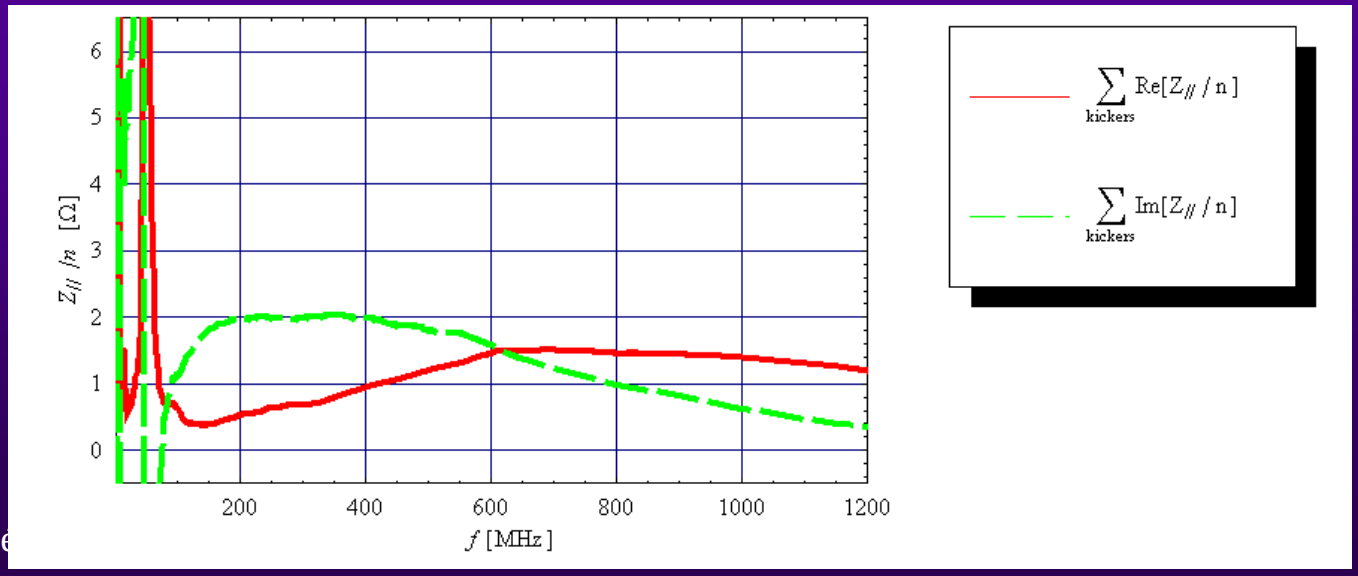
$\sum_{\text{kickers}} \text{Re}[Z_{//}/n]$

$\sum_{\text{kickers}} \text{Im}[Z_{//}/n]$

LONGITUDINAL IMPEDANCE (9/9)

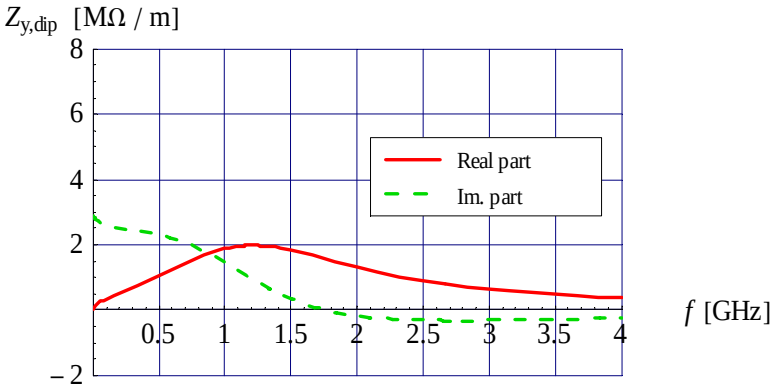
- **Plot of the longitudinal impedance for all the 20 SPS kickers with the 9 MKE kickers shielded**

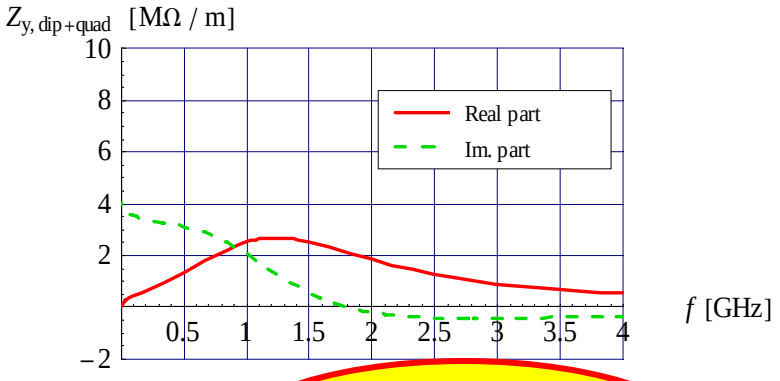




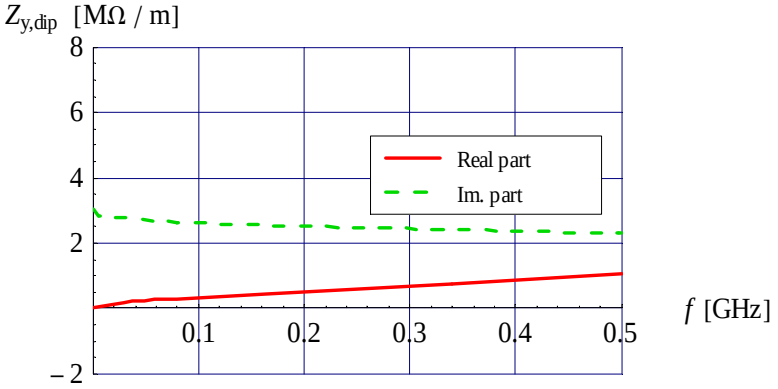
VERTICAL IMPEDANCE (1/8)

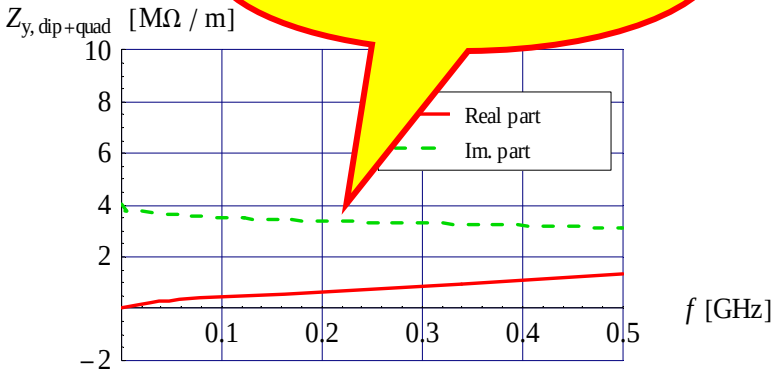
- **Plot of the vertical impedance for all the SPS kickers except the 9 MKEs (taking into account the flat chamber + betatron function at the kicker) ⟹ Case of 2001**





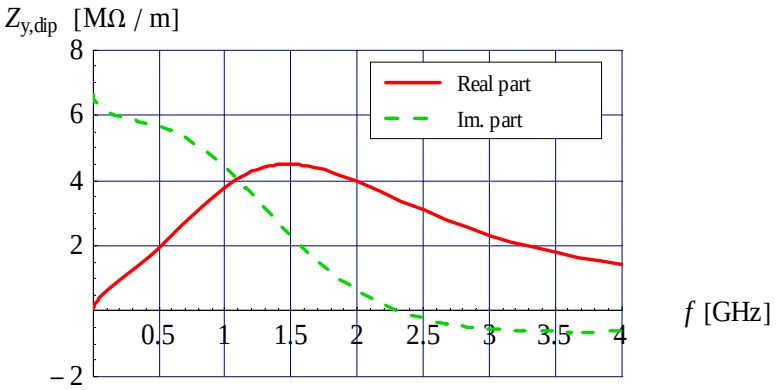
~ 3.5 MΩ / m at "low frequency"

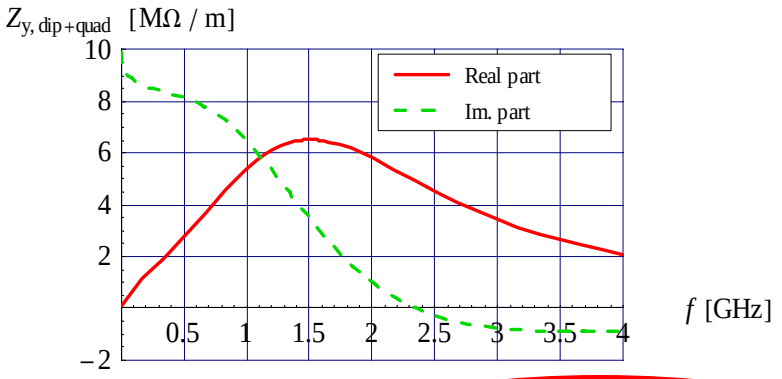




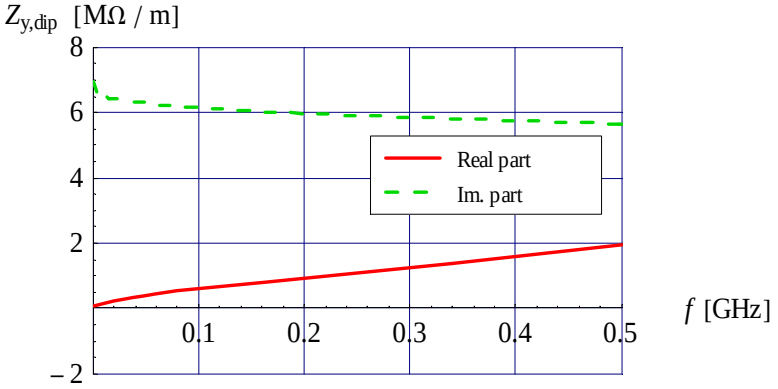
VERTICAL IMPEDANCE (2/8)

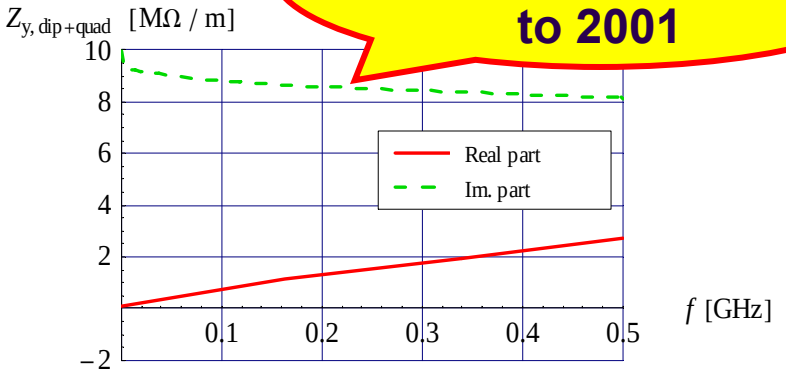
- **Plot of the vertical impedance for all the 20 SPS kickers in 2006 (taking into account the flat chamber + betatron function at the kicker) $\Longrightarrow$ Case of 2006**





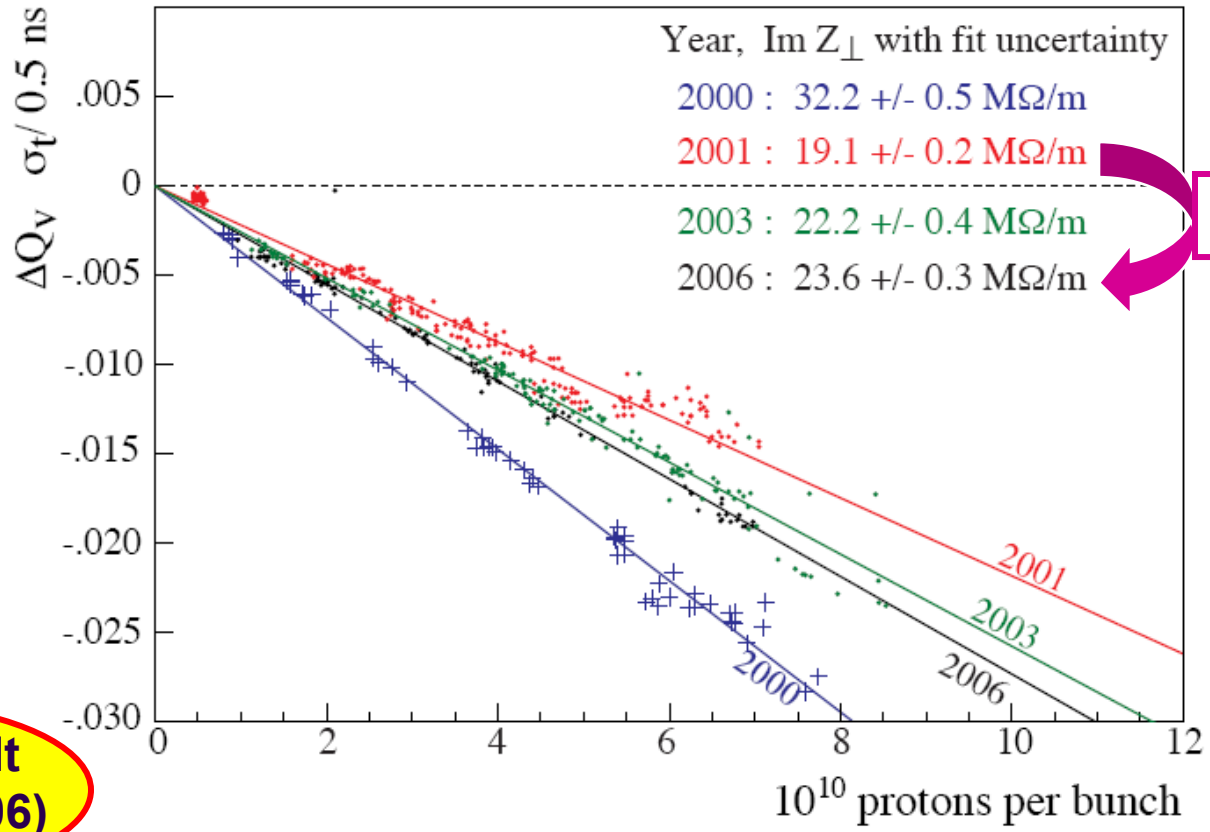
~ 8.5 MΩ / m
$\Longrightarrow$ ~ + 5 MΩ / m compared to 2001





VERTICAL IMPEDANCE (3/8)

Qv detuning with current. Observed changes 2000 - 2006



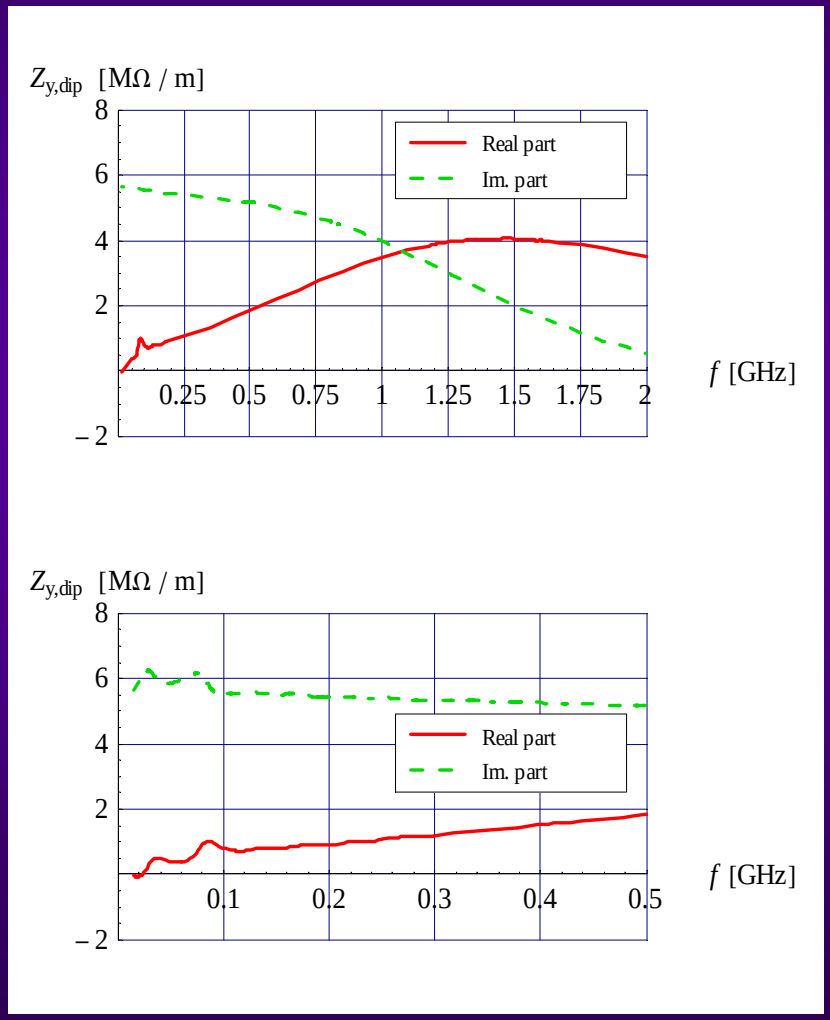
+ 4.5 MΩ / m

H. Burkhardt (APC, 10/11/06)

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 %.

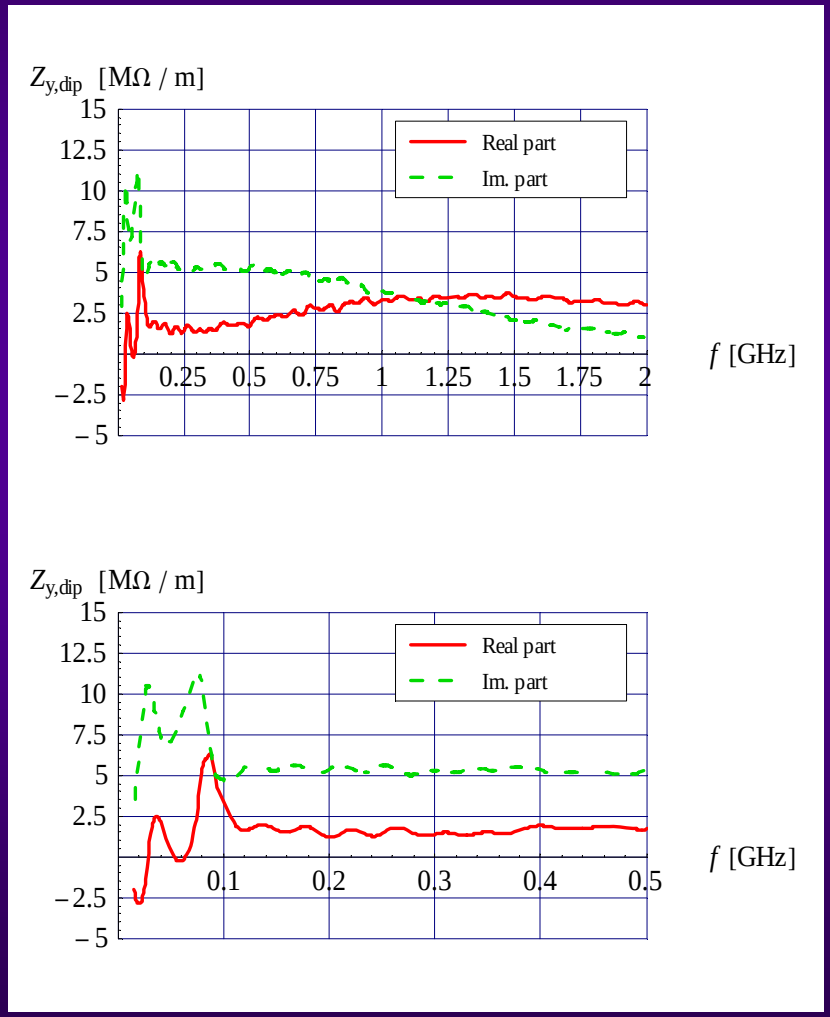
VERTICAL IMPEDANCE (4/8)

- **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**



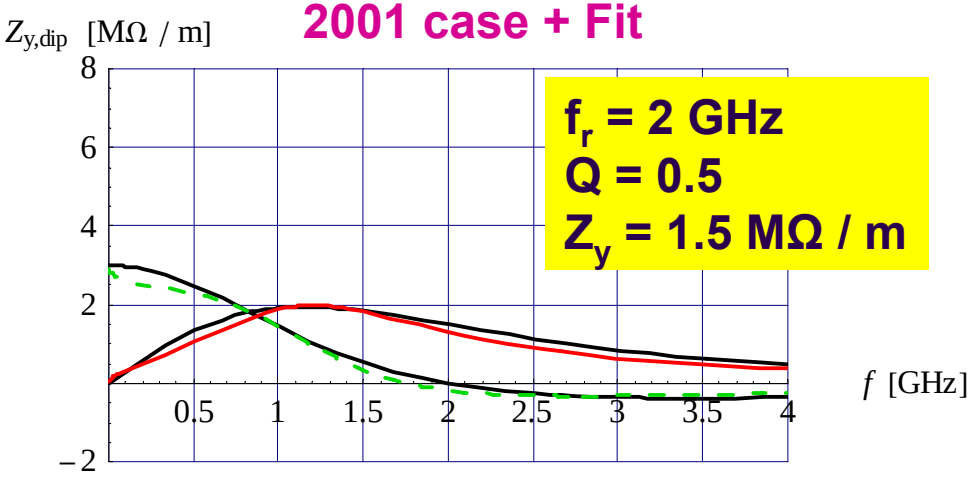
VERTICAL IMPEDANCE (5/8)

- **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)**



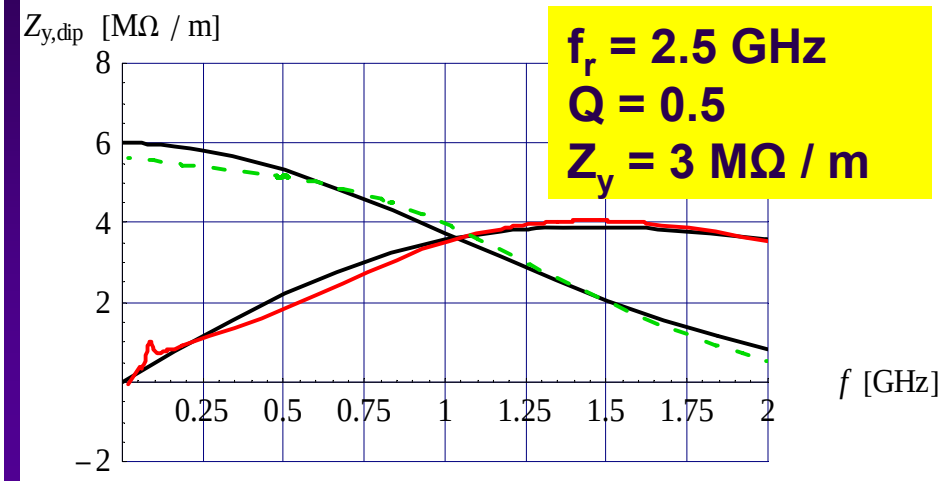
VERTICAL IMPEDANCE (6/8)

2001 case + Fit



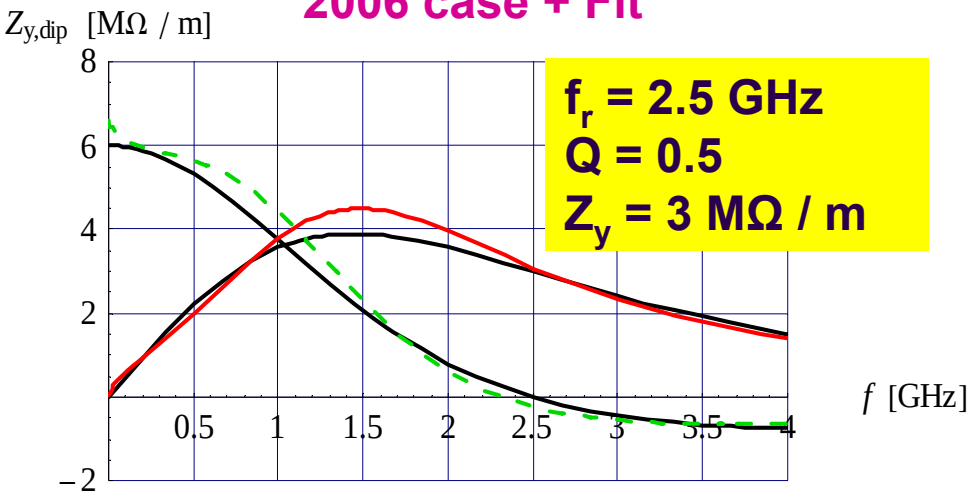
f_r = 2 GHz
Q = 0.5
Z_y = 1.5 MΩ / m

2007 case + Fit



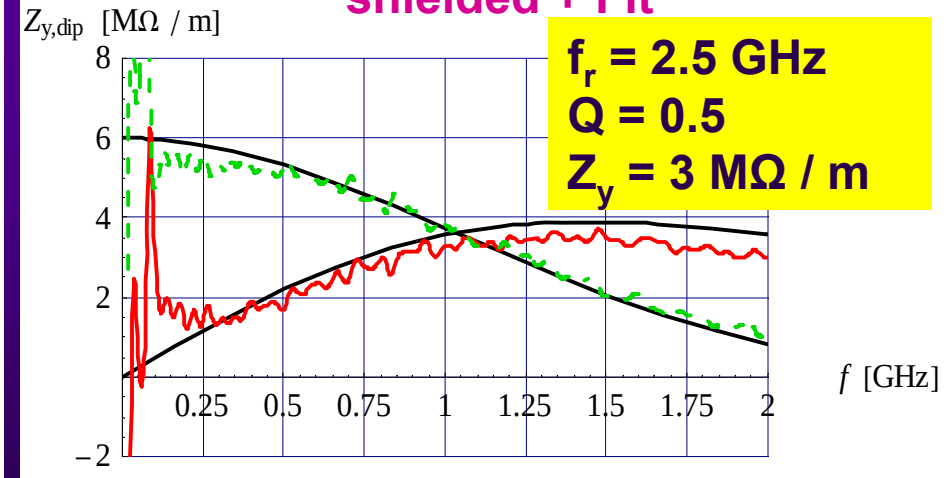
f_r = 2.5 GHz
Q = 0.5
Z_y = 3 MΩ / m

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 (7/8)

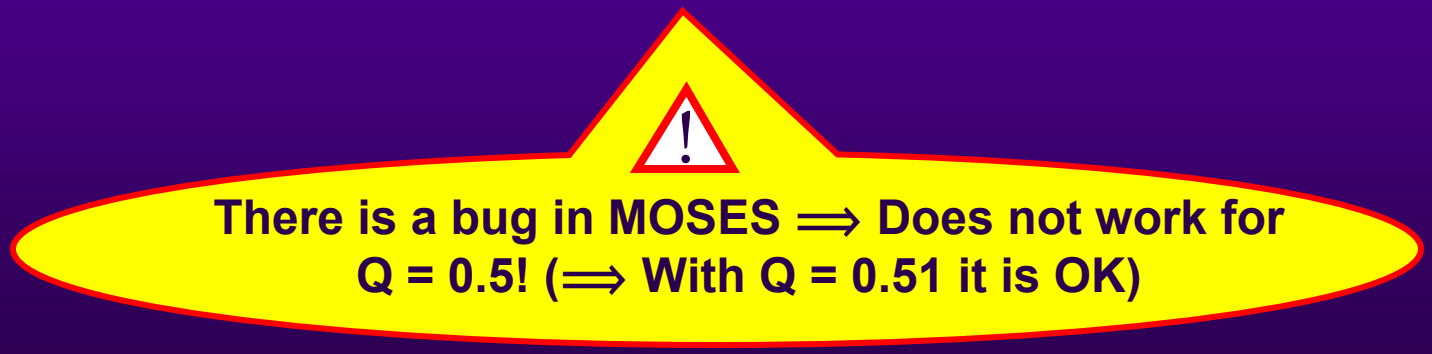
- TMCI threshold in the SPS at injection (with the usual "low emittance" beam) from MOSES

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

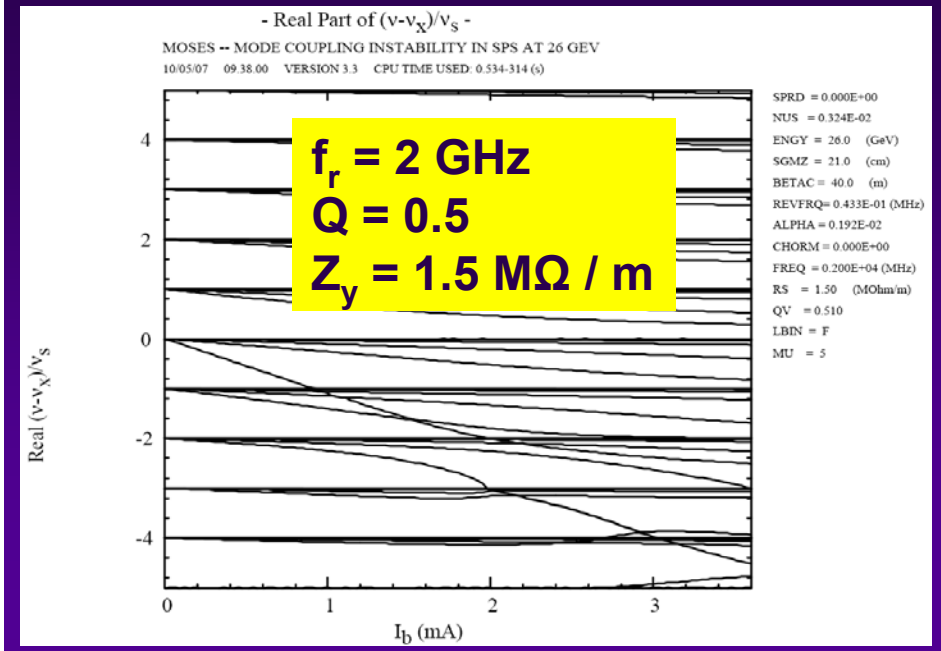
  $\Longrightarrow N_b^{th} = 2.9\ 10^{11}$ p/b

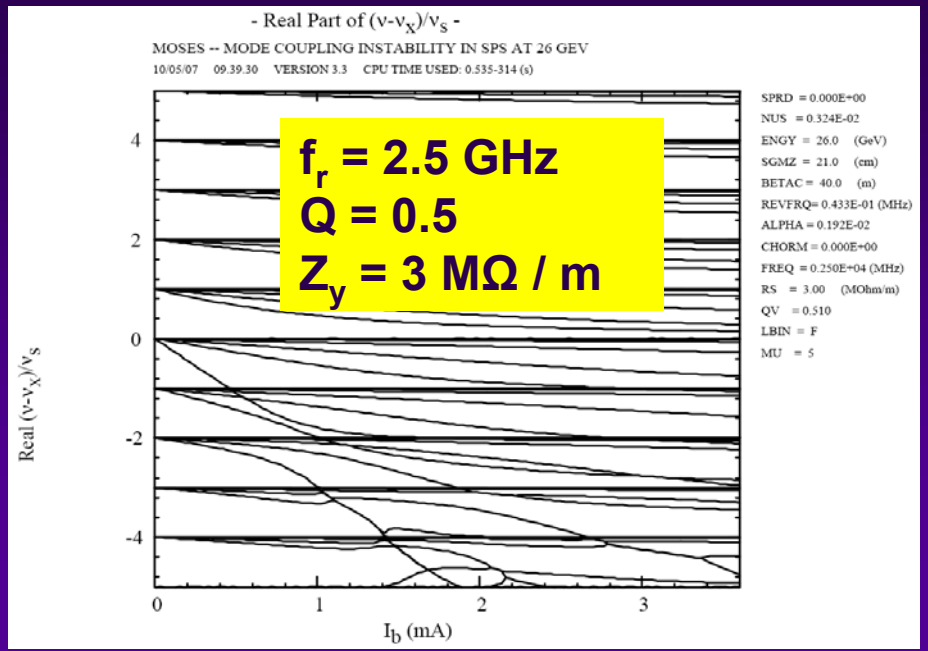
  - f_r = 2.5 GHz
  - Q = 0.5
  - Z_y = 3 MΩ / m

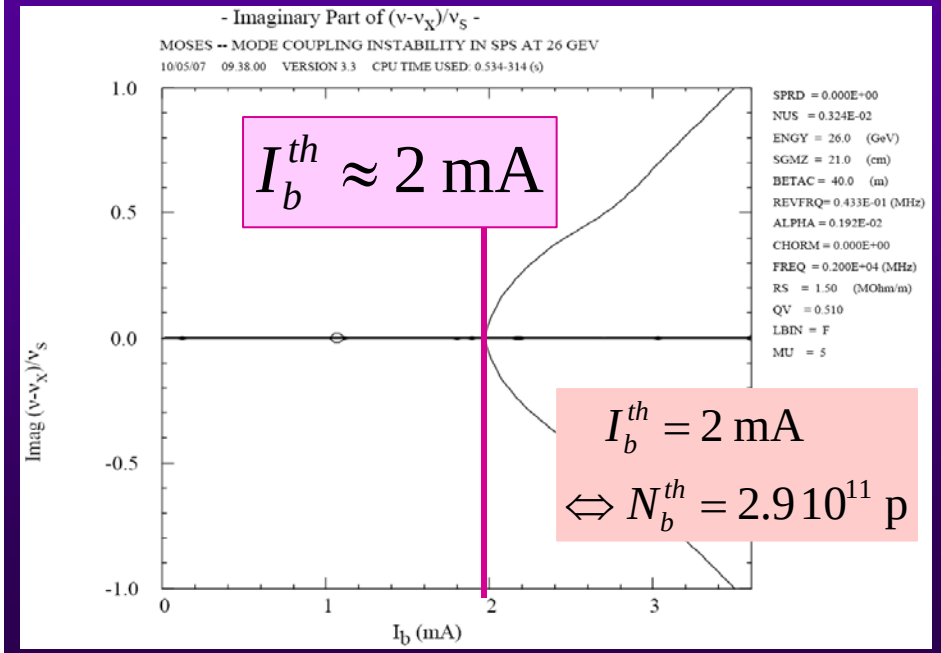
  $\Longrightarrow N_b^{th} = 1.4\ 10^{11}$ p/b

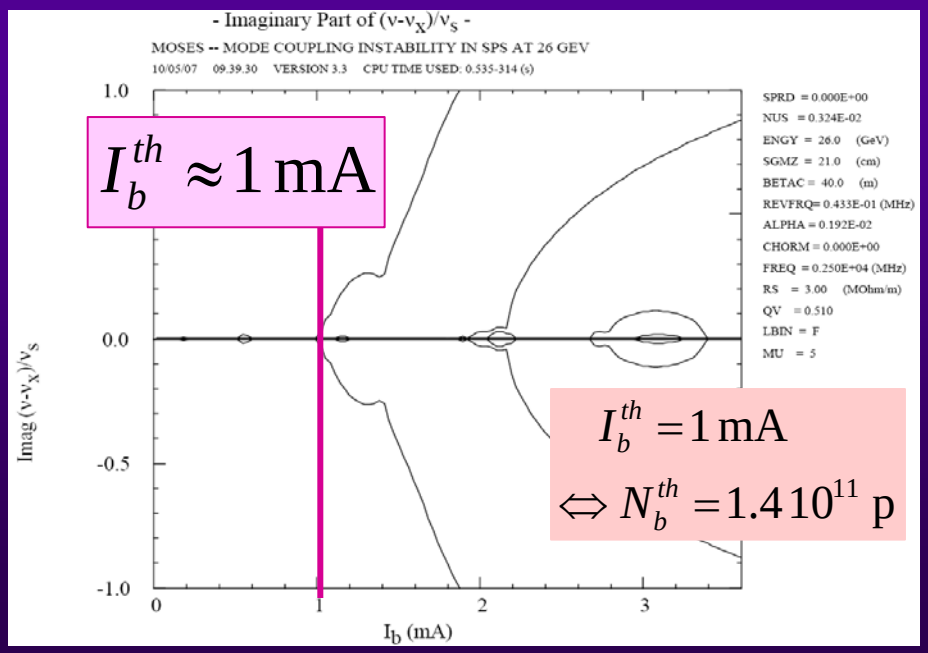


VERTICAL IMPEDANCE (8/8)





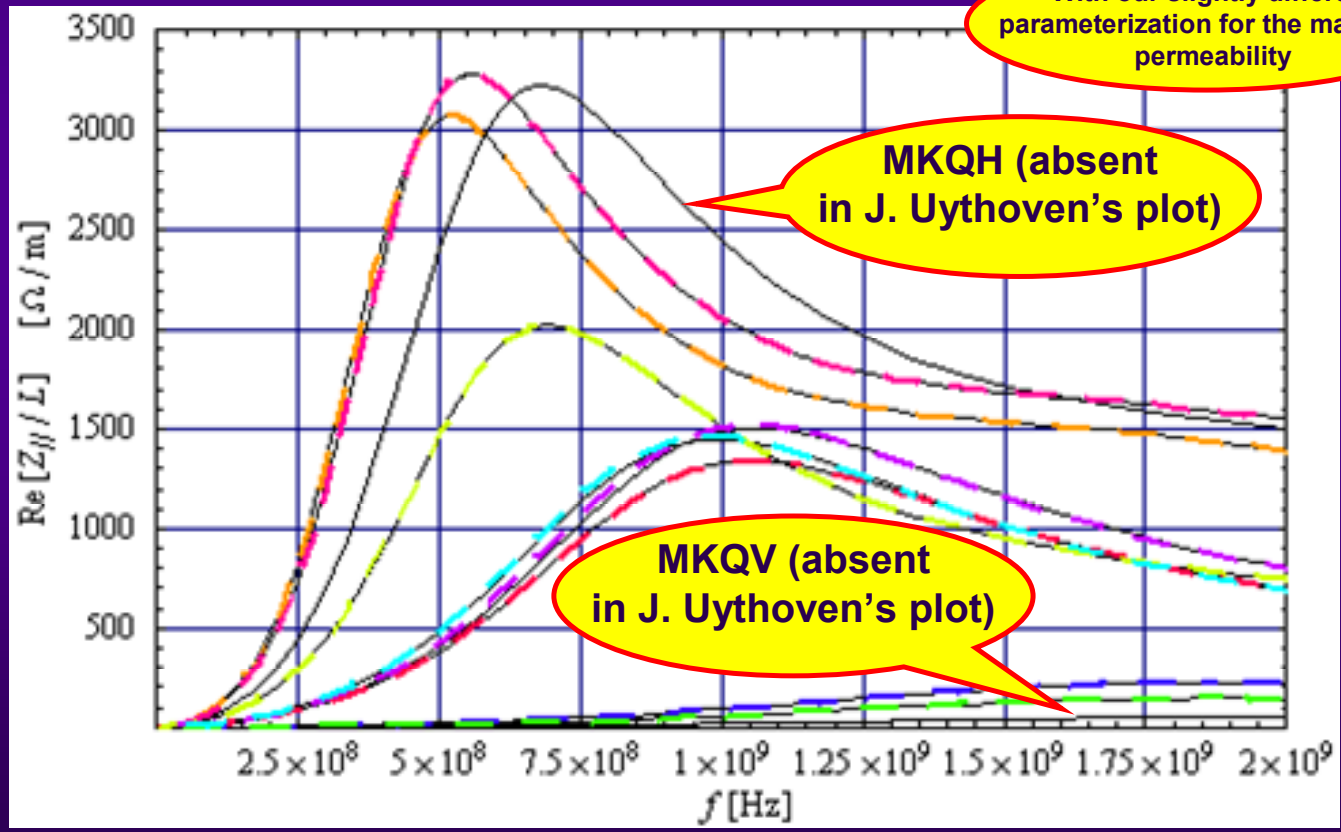




CONCLUSION (1/4)

- We checked that for the longitudinal impedance we recover the results from J. Uythoven

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



CONCLUSION (2/4)

- The transverse and longitudinal impedances have been estimated for
  - 2001 $\Longrightarrow$ No MKE kickers (11 kickers in total)
  - 2006 $\Longrightarrow$ + 9 MKE kickers (20 kickers in total)
  - 2007 $\Longrightarrow$ Only 8 MKE kickers with 1 shielded (19 kickers in total)
  - Case with the 9 shielded MKE kickers (20 kickers in total)

- The estimated longitudinal and vertical impedances of the kickers are in good agreement with measurements of the low frequency inductive part of the impedances (relative comparison between 2001 and 2006)
  - + ~ 4 Ω in longitudinal for the 9 MKE kickers
  - + ~ 5 MΩ / m in vertical for the 9 MKE kickers

CONCLUSION (3/4)

- The corresponding TMCI thresholds have been estimated using MOSES for the usual "low emittance" beam
  - The intensity threshold in 2001 (i.e. without the 9 MKE kickers) is ~ 3 10^{11} p/b
  - The intensity threshold in 2006, 2007 or in the case with the 9 shielded MKE kickers is ~ 1.5 10^{11} p/b

In 2003 (i.e. with 5 MKEs), no losses observed if intensity reduced to ~ 6 10^{10} p/b (see ICFA-HB2004) $\Longrightarrow$ ~ 40 % only of the impedance is coming from all the kickers

- L. Ducimetiere will send us at some point during the year the exact longitudinal structure of the ferrite for all the kickers $\Longrightarrow$ Final iteration then

CONCLUSION (4/4)

- Summary of the different contributions for the SPS low frequency inductive impedances

	Longitudinal [Ω]	Vertical [MΩ/m]
Kickers except MKEs (2001)	1.2	3.5
Kickers including 9 MKEs (2006)	5	8.5
9 MKEs	3.8	5
SPS meas. in 2001	5.7	19.1
SPS meas. in 2006	9.5*	23.6
% from the kickers in 2006	53 %	36 %**
% from the 9 MKEs in 2006	40 %	21 %
% from the kickers except MKEs in 2006	13 %	15 %
Kickers including 9 shielded MKEs	~ 2 (resonances)	~ 5 (resonances)
Expected SPS meas. with 9 shielded MKEs	6.5 (instead of 9.5)	20.1 (instead of 23.6)

* Deduced from the 2006 slope and the estimation for the MKEs
** Consistent with the TMCI considerations (~ 40%)