**SPS IMPEDANCE BUDGET**

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

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

- **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)

<table>
<thead>
<tr>
<th>PARTICLE</th>
<th>%06s</th>
<th>PROTON</th>
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<td>%19s</td>
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<tr>
<td>DATE</td>
<td>%08s</td>
<td>13/04/06</td>
</tr>
<tr>
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<th>NAME</th>
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<th>DX [m]</th>
<th>BETY [m]</th>
<th>FULLAPERX [mm]</th>
<th>FULLAPERY [mm]</th>
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<td>524.6862</td>
<td>0.96</td>
<td>64.51713859</td>
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<td>135</td>
<td>32</td>
</tr>
</tbody>
</table>

** inner dimensions of the ceramic insert

Length of the ferrite ~ 20% smaller
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)

→ 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)
SPS Kicker Impedances, Jan Uythoven, May 2006

Re[Z] [Ω/m]

f [Hz]

Elias Métral, SPS Upgrade Study Team meeting, 21/08/07
LONGITUDINAL IMPEDANCE (3/10)

Comparison with J. Uythoven’s computation in the past
⇒ “Our” lines in black

With our slightly different parameterization for the magnetic permeability

MKQH (absent in J. Uythoven’s plot)

MKQV (absent in J. Uythoven’s plot)
LONGITUDINAL IMPEDANCE (4/10)

- Comparison between theory and measurements

Measurements on SPS MKE Kicker on 10/2000

F. Caspers et al., CERN-SL-2000-071 (AP)
Plot of the longitudinal impedance for all the SPS kickers except the 9 MKEs ➞ Case of 2001

\[ \text{Im}[Z_{\text{eff}}] = 1.2 \, \Omega \quad (\sigma_t = 0.55 \, \text{ns}) \]
LONGITUDINAL IMPEDANCE (6/10)

Plot of the longitudinal impedance for the 16 SPS kickers

Case of 2003

3.4 Ω $\Rightarrow$ + 2.2 Ω compared to 2001
LONGITUDINAL IMPEDANCE (7/10)

Plot of the longitudinal impedance for all the 20 SPS kickers

Case of 2006

5.2 Ω \Rightarrow + 1.8 Ω compared to 2003
LONGITUDINAL IMPEDANCE (8/10)

- Plot of the longitudinal impedance for all the 19 SPS kickers → 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.
Slight reduction predicted

$ImZ/n = -a \times b \times 2.5/(2fso)$

+ 4 $\Omega$ ( = 2.2 + 1.8) were expected and + 3 $\Omega$ ( = 1.8 + 1.2) were measured

+ 2.8 $\Omega$
VERTICAL IMPEDANCE (1/9)

- Comparison between measurements and theory

1 MKE kicker

Meas. by F. Caspers, T. Kroyer & E. Gaxiola

\[
Z_y \ \text{[M} \Omega \ / \ m]\]

\[
\begin{array}{c}
\text{Im} \\
\text{Re}
\end{array}
\]

\[
\begin{array}{c}
f \ [\text{GHz}]
\end{array}
\]

Elias Métral, SPS Upgrade Study Team meeting, 21/08/07
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

![Graphs showing vertical impedance plots](image)

- ~ 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) ⇔ Case of 2006

![Graphs showing vertical impedance plots](image)

~ 8.5 MΩ / m

⇒ ~ + 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) ⇒ 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)

Slight reduction predicted

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 %.

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

Elias Métral, SPS Upgrade Study Team meeting, 21/08/07
VERTICAL IMPEDANCE (8/9)

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

- $f_r = 2$ GHz
- $Q = 0.5$
- $Z_y = 1.5 \text{ M} \Omega / \text{m}$

\[ \Rightarrow N_{p}^{\text{th}} = 2.9 \times 10^{11} \text{ p/b} \]

- $f_r = 2.5$ GHz
- $Q = 0.5$
- $Z_y = 3 \text{ M} \Omega / \text{m}$

\[ \Rightarrow N_{p}^{\text{th}} = 1.4 \times 10^{11} \text{ p/b} \]

There is a “bug” in MOSES $\Rightarrow$ Does not work for $Q = 0.5$! ($\Rightarrow$ With $Q = 0.51$ it is OK)
VERTICAL IMPEDANCE (9/9)

- Real Part of $(v_q - v_q') V_s$

- Imaginary Part of $(v_q - v_q') V_s$

\[ f_r = 2 \text{ GHz} \]
\[ Q = 0.5 \]
\[ Z_y = 1.5 \text{ MΩ/m} \]

\[ f_r = 2.5 \text{ GHz} \]
\[ Q = 0.5 \]
\[ Z_y = 3 \text{ MΩ/m} \]

\[ I_{b}^{th} \approx 2 \text{ mA} \]

\[ I_{b}^{th} = 1 \text{ mA} \]

\[ N_{b}^{th} = 2.9 \times 10^{11} \text{ p} \]

\[ N_{b}^{th} = 1.4 \times 10^{11} \text{ p} \]
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 ⇒ Giovanni will upgrade HEADTAIL to be able to read a wake field from a table and study the TMCI at injection

![Vertical wake field from the 20 kickers in the SPS in 2006](image)

$W_y [\text{V/(mm*pC)}]$ vs. Time [ns]
CONCLUSION (2/2)

- Longitudinal analytical estimates and measurements of the low frequency inductive effective impedance are NOT in agreement, but
  
  ⇒ 2 uncertainties from the 2006 measurements

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

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

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