Update re Kicker Magnet Impedances in the SPS

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Acknowledgements:

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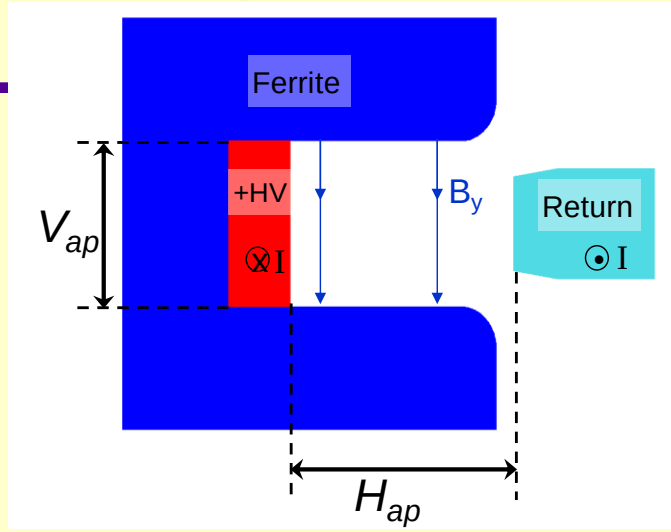
& V. Senaj

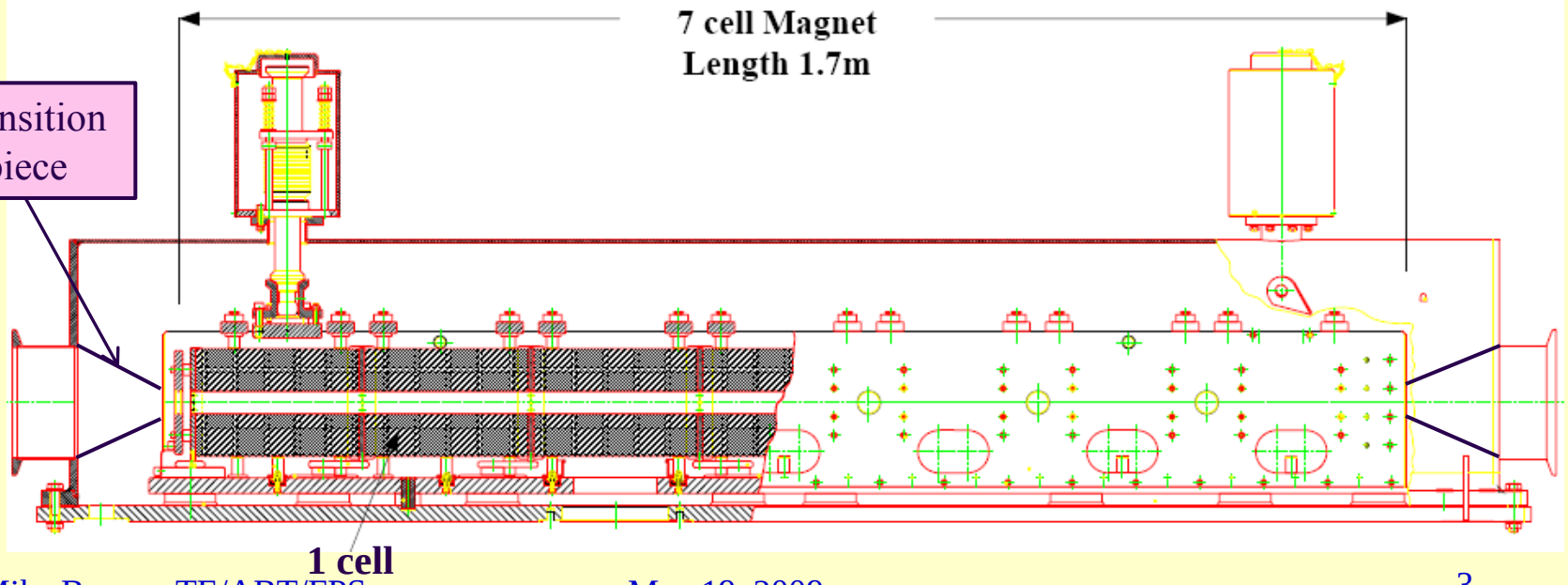
Overview of Presentation

- MKE:
  - Summary of MKE6 modifications carried out during shutdown of 2008-209;
  - MKE4 plans for the future;
  - Impedance measurements on an MKE kicker: effect of external circuit;
- MKDV: effect of transition pieces on measured impedance and application of results;
- MKDH3: Impedance measurements;
- Presence of enameled rings.

MKE4 & MKE6

- The kicker magnets installed at LSS4 & LSS6 are travelling-wave type magnets, each consisting of 7 ferrite “cells”;
- 30 year old, recuperated, equipment;
- ALL MKE kicker magnets have transition pieces between vacuum tank and magnet;
- Tank length = 2174 mm;
- Magnet length = 1700mm.

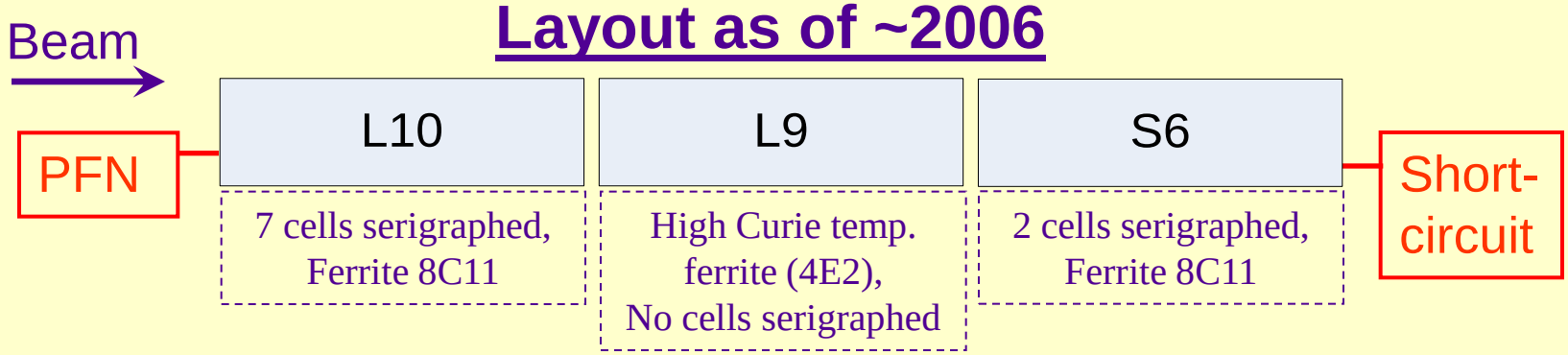




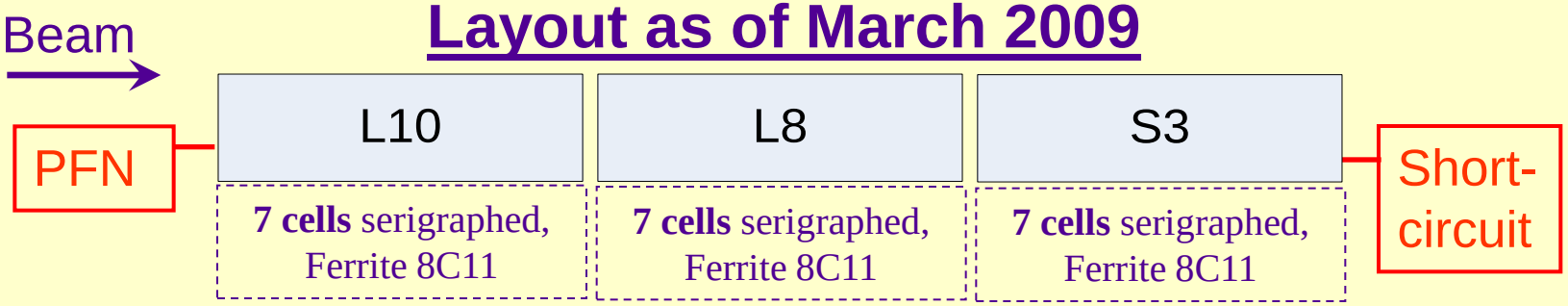
MKE6

- MKE6 is used for extraction to the clockwise LHC ring;
- Two of the magnets have “large” (L) apertures (147.7mm x 35mm);
- One magnet has “small” (S) aperture (135mm x 32mm).

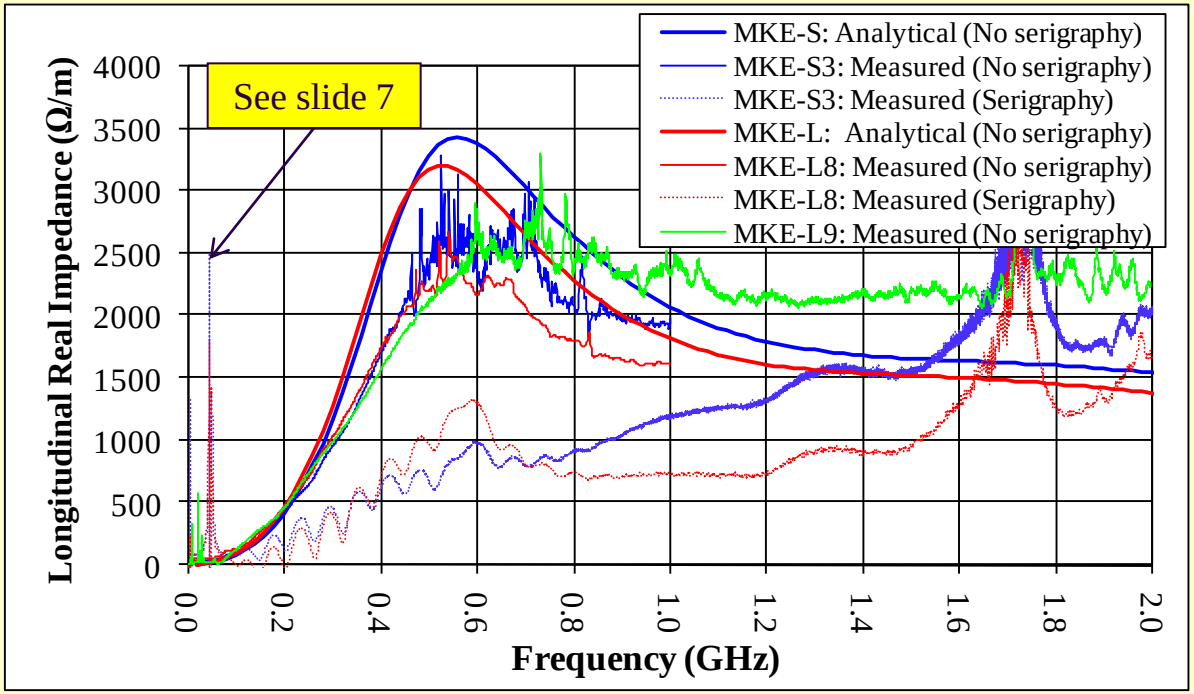
Layout as of ~2006

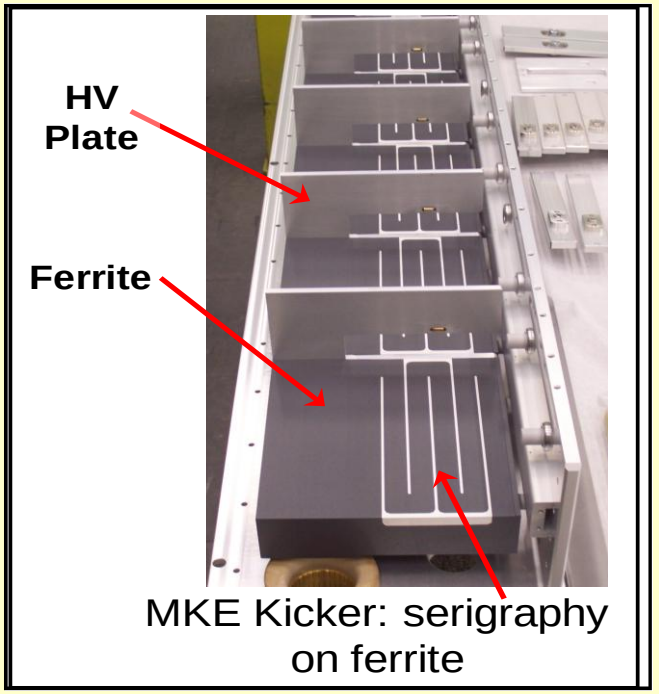


Layout as of March 2009



MKE Longitudinal Impedance (1)



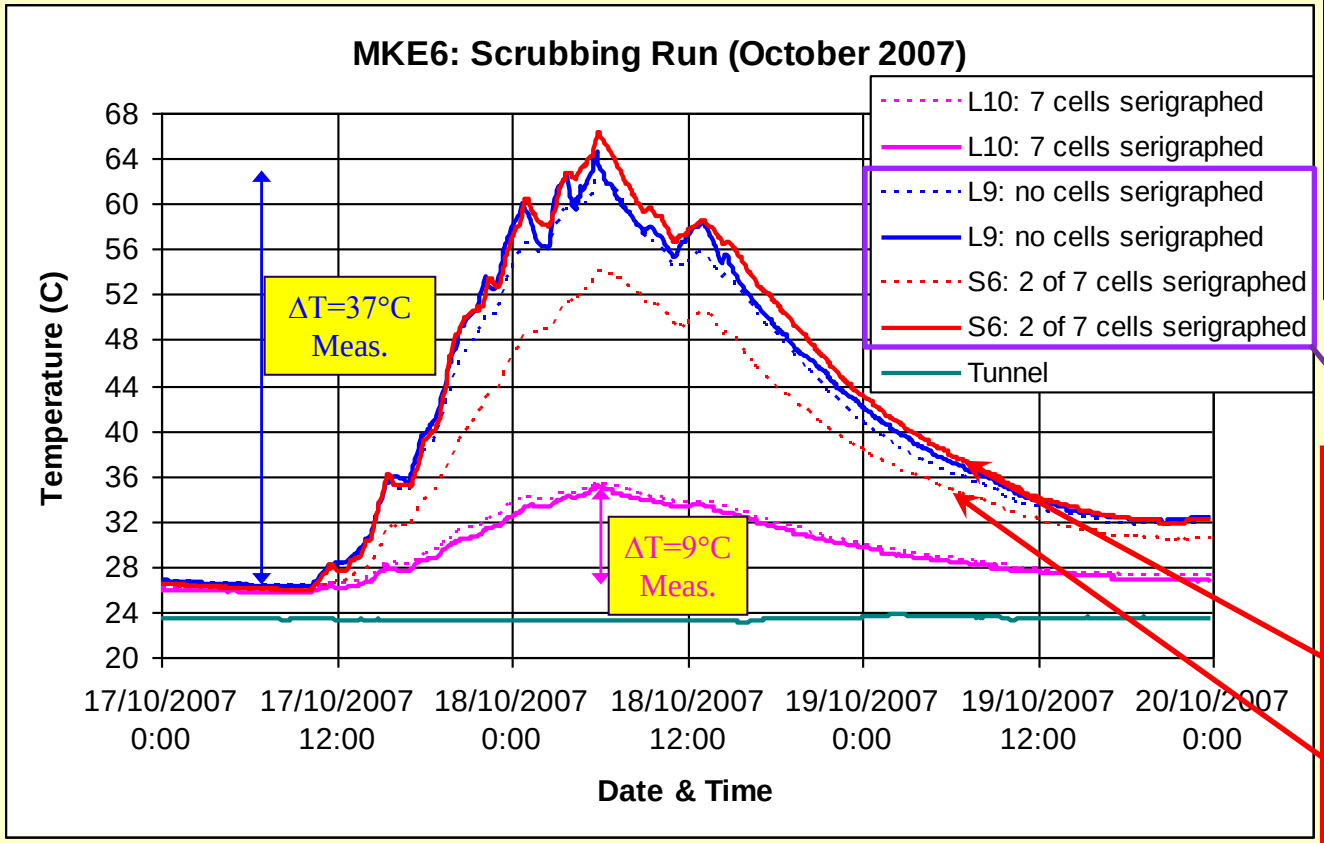


The measurement data for Real Longitudinal Coupling Impedance (RLCI) shows "spikes" starting from a frequency of ~0.45 GHz when serigraphy is NOT applied: these spikes are suppressed by the serigraphy. However the serigraphy results in a high impedance spike at ~50 MHz (see slide 7).

The cause of the measured high impedance at ~1.7 GHz is not yet understood.

MKE6: Measured Temperatures (October 2007)

- LHC type beam. MKE6.



Serigraphy on L10 results in a factor of ~4 (37/9) lower temperature rise than L9 (with LHC type beam).

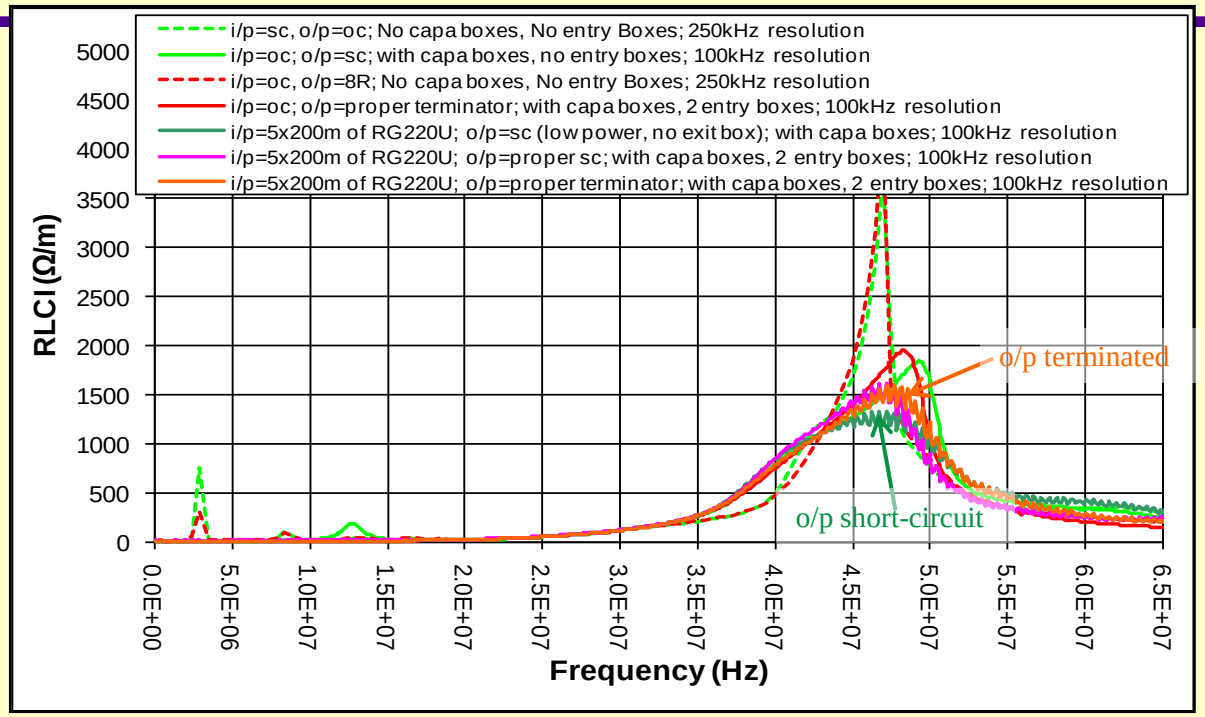
Now replaced by L8 & S3 (7 cells serigraphed)

For S6, 2 of 7 cells serigraphed (first and last cell):

- at exit, PT100 is on a "normal" cell (no serigrapy);
- at entrance, PT100 is on a serigraphed cell.

All 3 MKE6 magnets (L10, L8 & S3) are now expected to exhibit a temperature rise of ~10 C during scrubbing.

MKE Longitudinal Impedance (2)

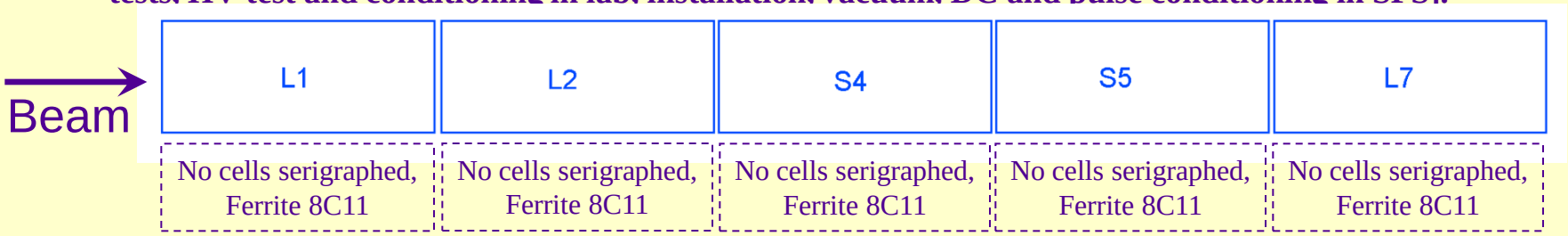


With serigraphy there is a strong resonance in the frequency range of 47MHz to 49MHz.

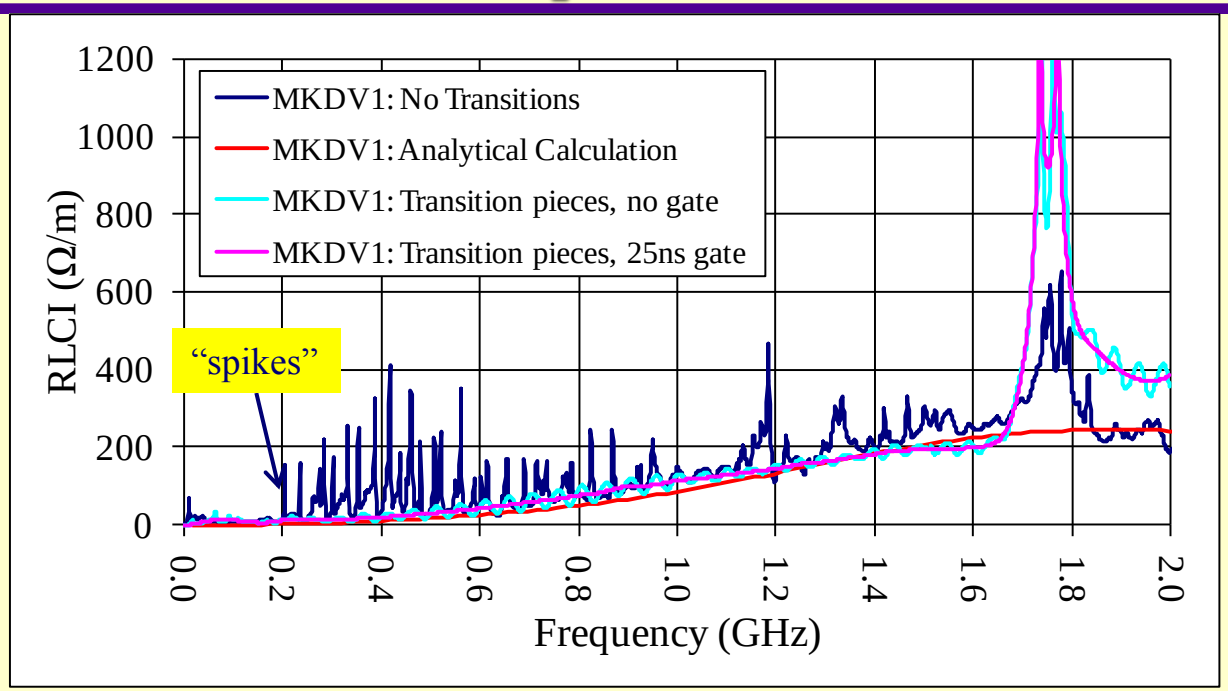
Resonances below ~70 MHz are affected by the external circuit on the output of the magnet (resistor termination or short-circuit): further measurements are needed to determine whether capacitor boxes, which are external to the MKE magnets, also affect resonances. With the correct output termination and capacitor boxes present, the presence or absence of 200 m of RG220U cable on the input of the magnet has a small, but measurable, effect.

MKE4: Future Plans

- Magnet spares: only one L-type and one S-type spare available (not serigraphed);
- One-set of serigraphed ferrite now ready for each of L-type and S-type magnets;
- Plan is to replace one S and one L magnet at each "normal" SPS shutdown (using the normal operation year to convert the 2 spare magnets for the next shutdown) -- 3 shutdowns required!!
- BUT potential problem of converting 2 spare magnets during operation: if problem is encountered with an installed magnet, there may not be an available spare;
- If faster deployment is needed;
  a) Equip 2 spare magnets with serigraphed ferrite during operation (see above) or a few weeks before shutdown;
  b) Prepare non-serigraphed ferrite, removed from spare magnets during "step a" [machining of ferrite (radii), serigraphy (by another CERN service)];
  c) Exchange non-serigraphed ferrite, in presently installed magnets, for serigraphed ferrite prepared in "step b" (a shutdown of at least 3 months is necessary [work includes: dismantling, mounting, vacuum tests, HV test and conditioning in lab, installation, vacuum, DC and pulse conditioning in SPS].



MKDV1: Longitudinal Impedance

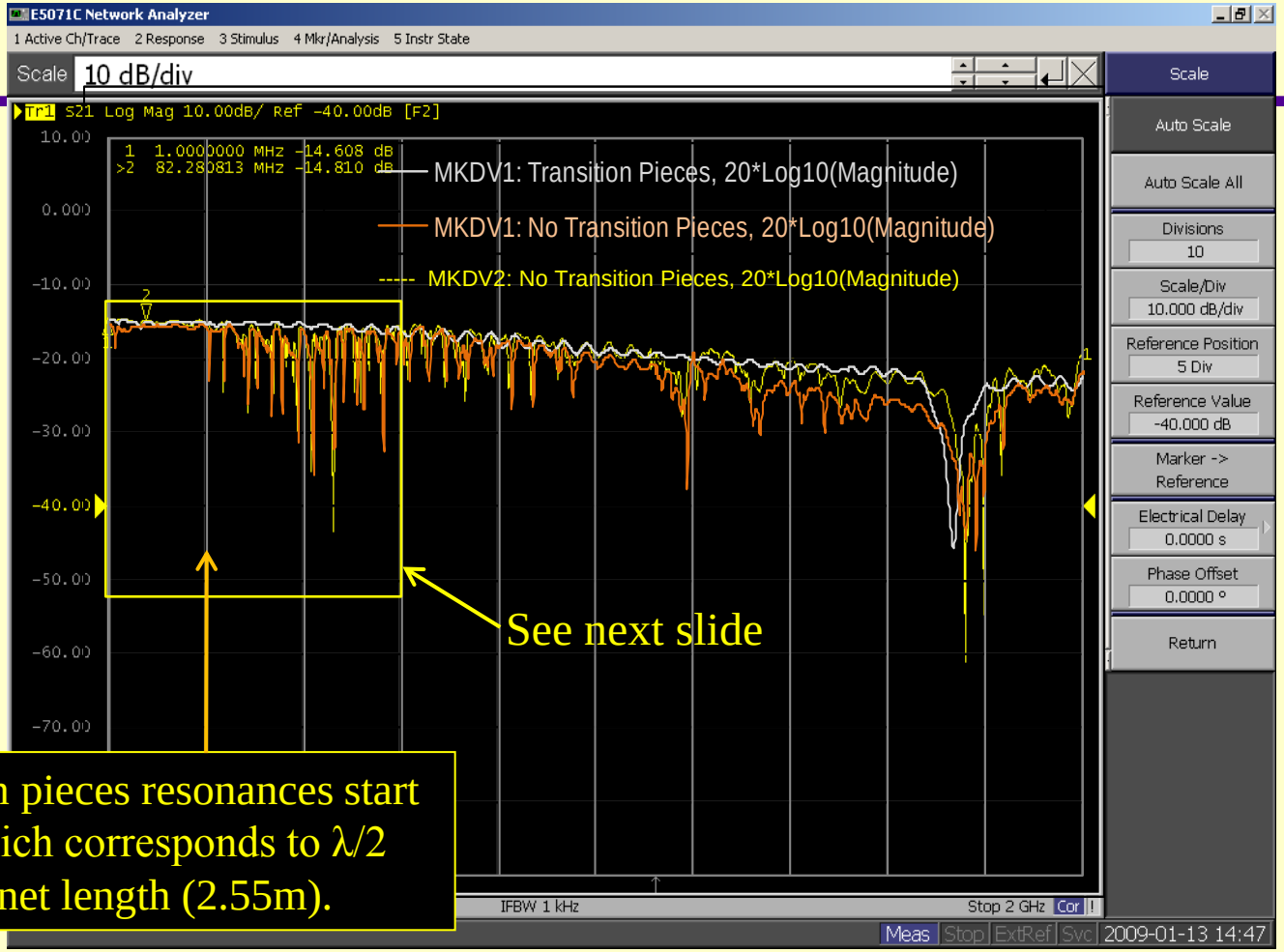


Transition pieces suppress the spikes in the RLCI, and thus may reduce heating of ferrite (measurement with matching resistors included in the SucoBoxes #1, attached to each end flange and a full 2-port calibration carried out at 50 Ω).

Note: presence of measured high impedance at ~1.7 GHz ("attenuated" without transition pieces!).

PT100 temperature probes and transition pieces only fitted to one MKDV1 magnet: installed during early 2009.

MKDV's S21 Measurements

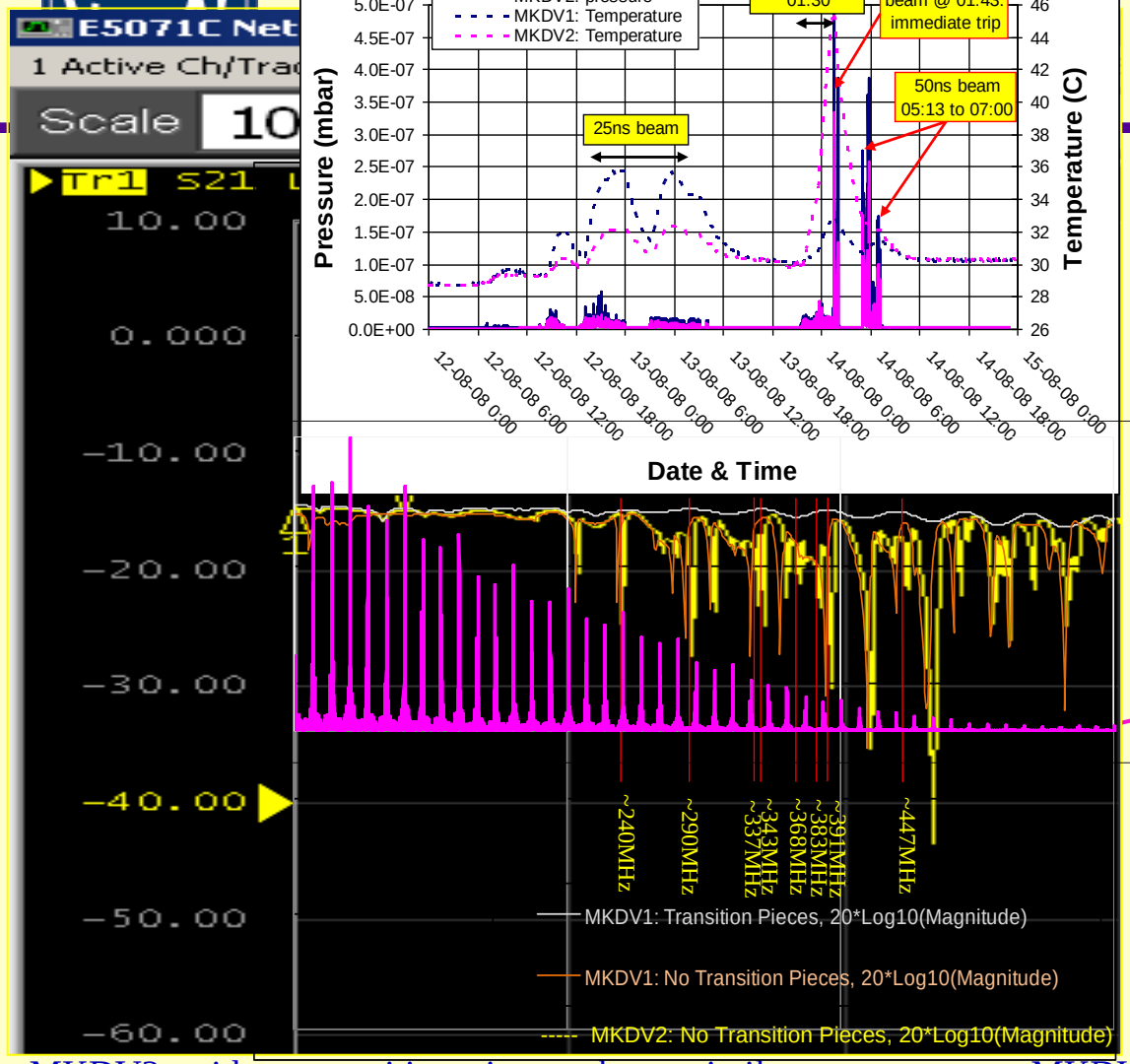


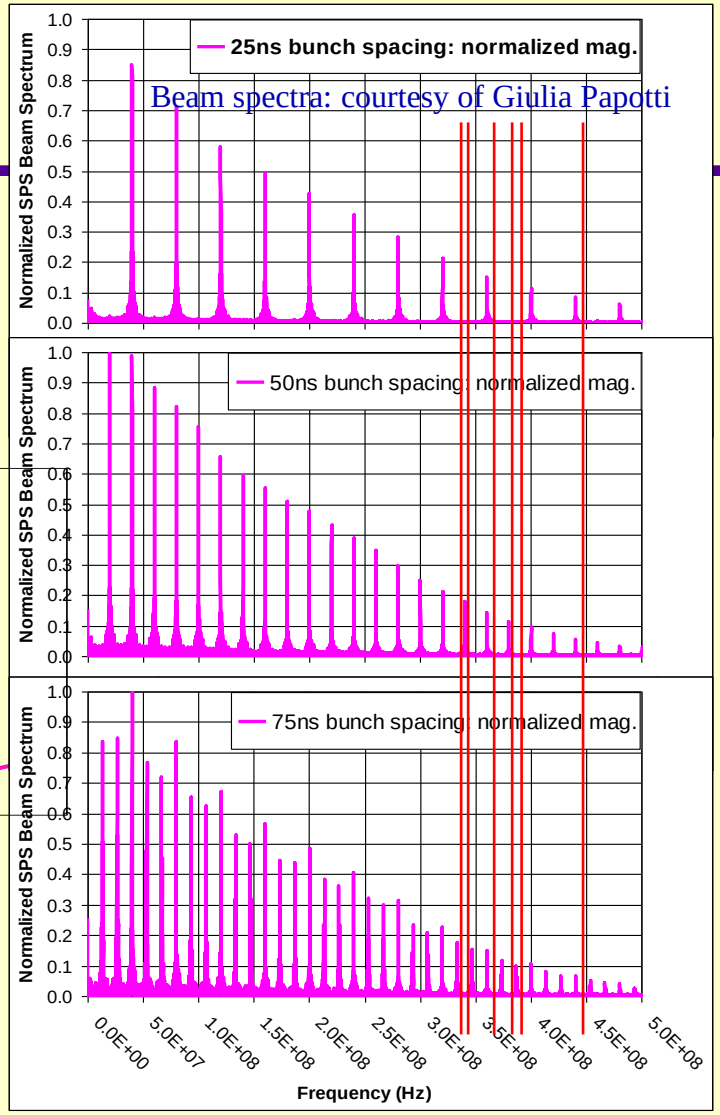
Without transition pieces resonances start at ~200 MHz, which corresponds to $\lambda/2$ based on the magnet length (2.55m).

No numerical data for MKDV2; only screen-capture.

The resonances are considerably suppressed when transition pieces are added.

MKDV: S21 Zoom to 500MHz

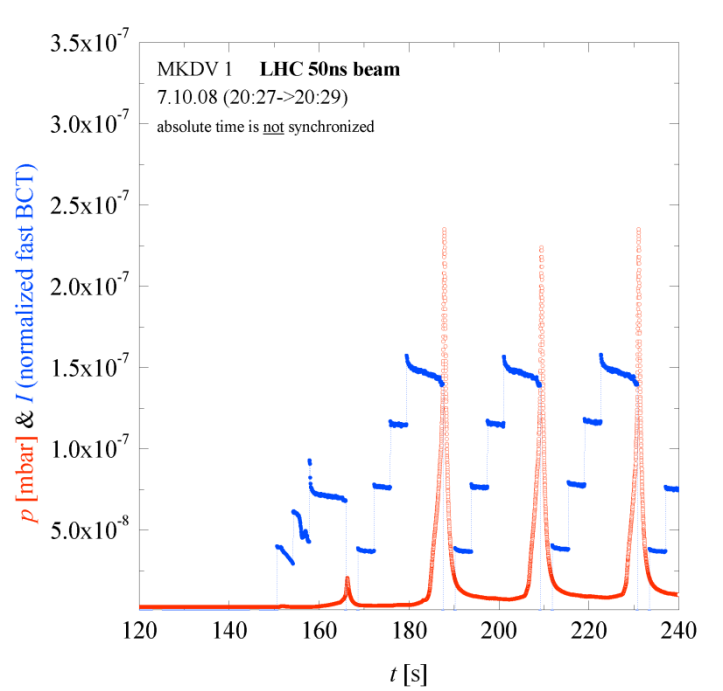


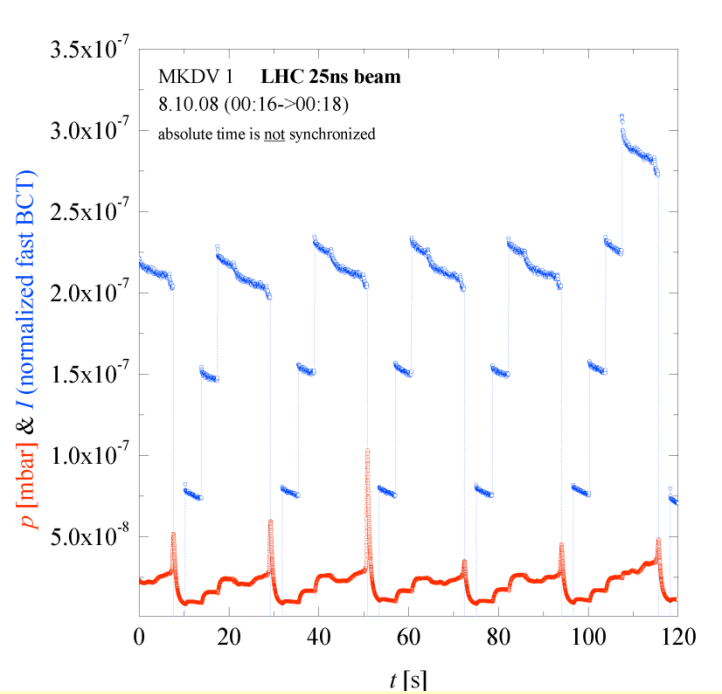


Beam spectra: courtesy of Giulia Papotti

MKDV2, without transition pieces, shows similar resonances to MKDV1 (without transition pieces), but at slightly different frequencies. Hence this probably explains the heating of MKDV2 with 75ns bunch spacing: thus adding transition pieces to MKDV2, in the future, may significantly reduce its heating with 75ns bunch spacing.

MKDV1 Out-gassing (October 2008)





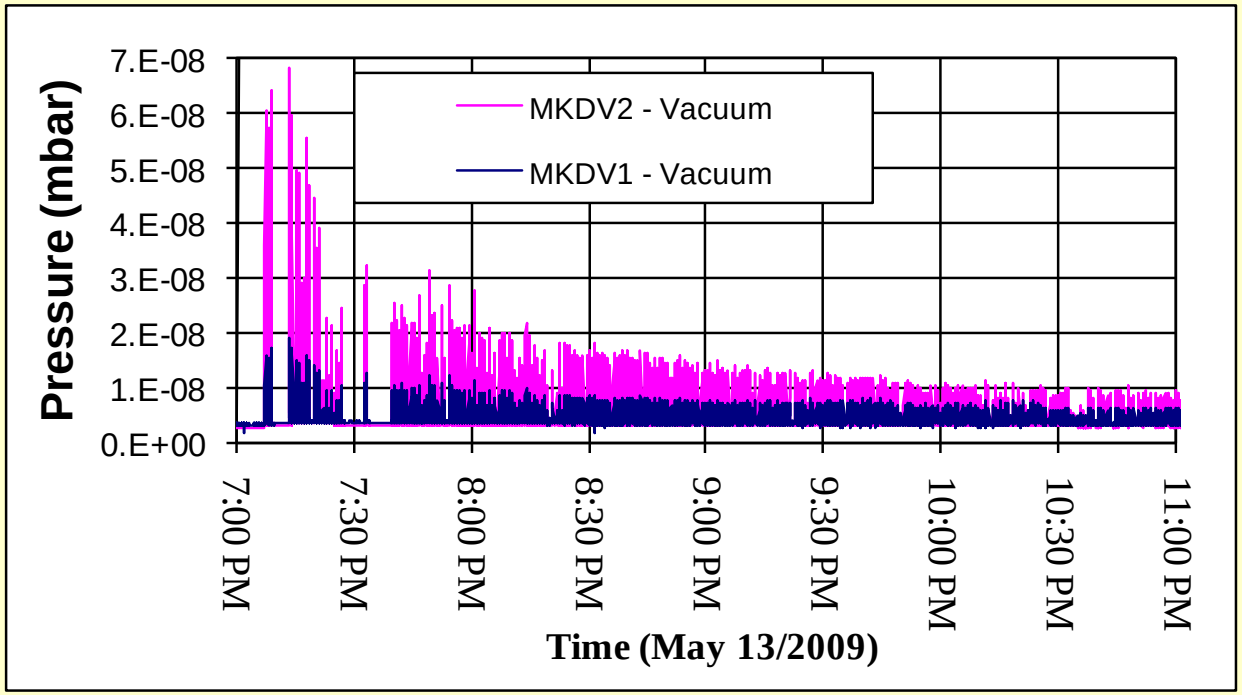
BCT data courtesy of Elena Benedetto. Vacuum data and plots courtesy of Edgar Mahner. (NOTE: peak of pressure every 24.6 s, which corresponds to the SPS super-cycle).

As noted by Giovanni Rumolo in a talk [1], MKDV1 does show a pressure rise with 25 ns bunch spacing, during the MDs, but at a much reduced level compared with 50 ns bunch spacing.

Contrary to above measurement results, monitors and simulations both show maximum electron-cloud density with 25 ns bunch spacing.

MKDV Out-gassing, May 2009

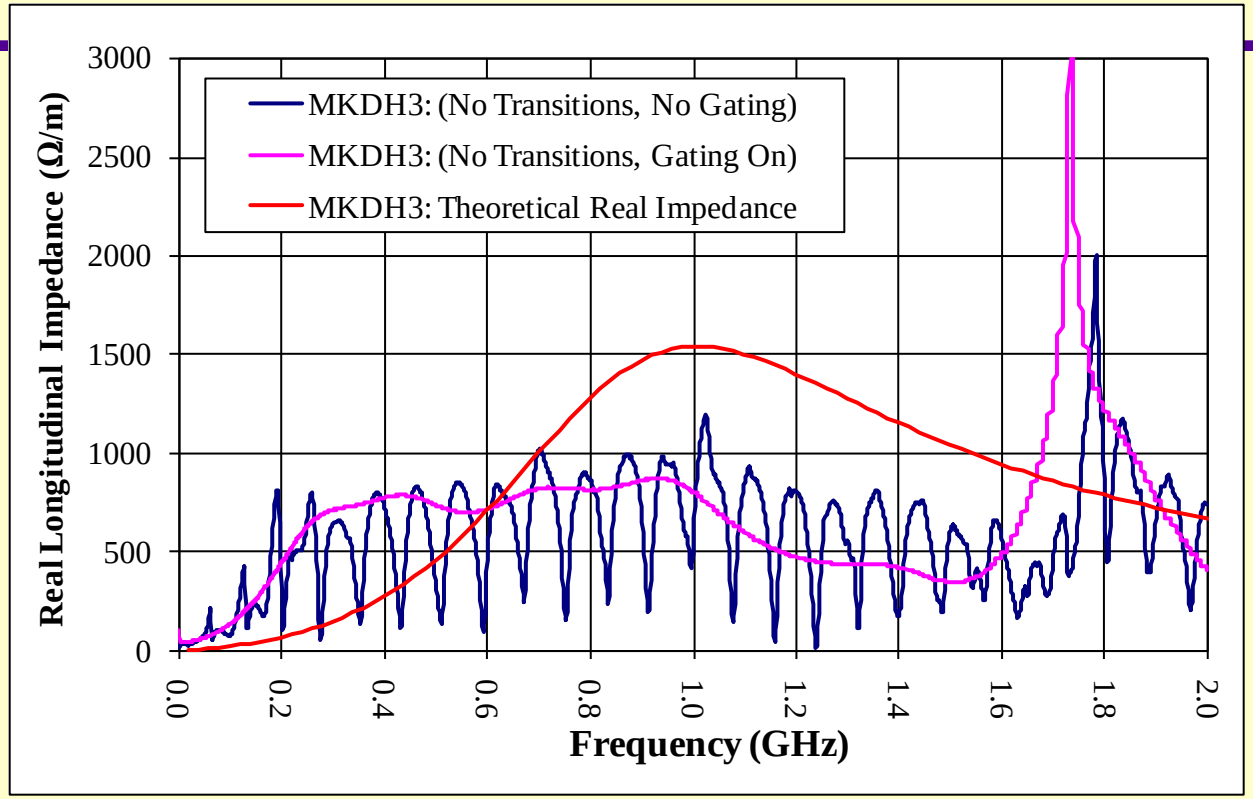
Newly installed MKDV1: ferrites baked (in air) to 1000 C, transition pieces installed, PT100.



Plot of vacuum on evening of Wed May 13th 2009 for MKDV1 & MKDV2 (Note: lower pressure in MKDV1 than MKDV2).

Hypothesis: Transition pieces in MKDV1 appear to reduce fast out-gassing…..

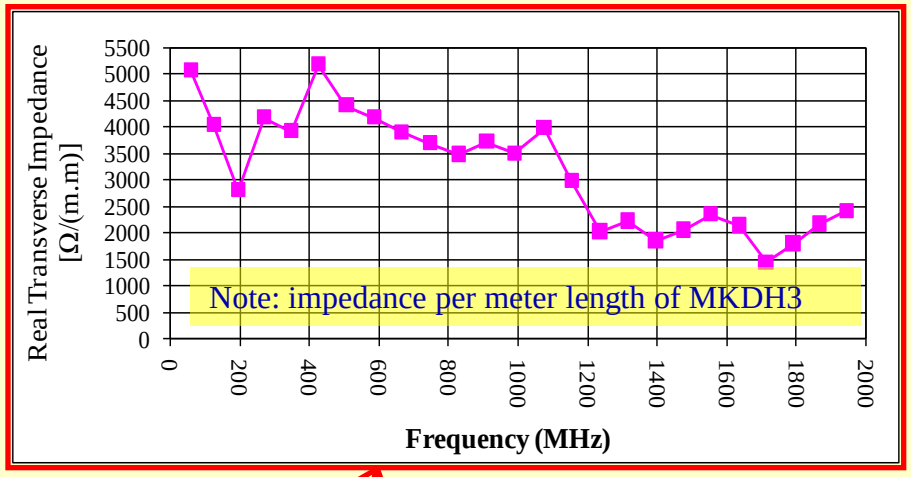
MKDH3 Longitudinal Impedance

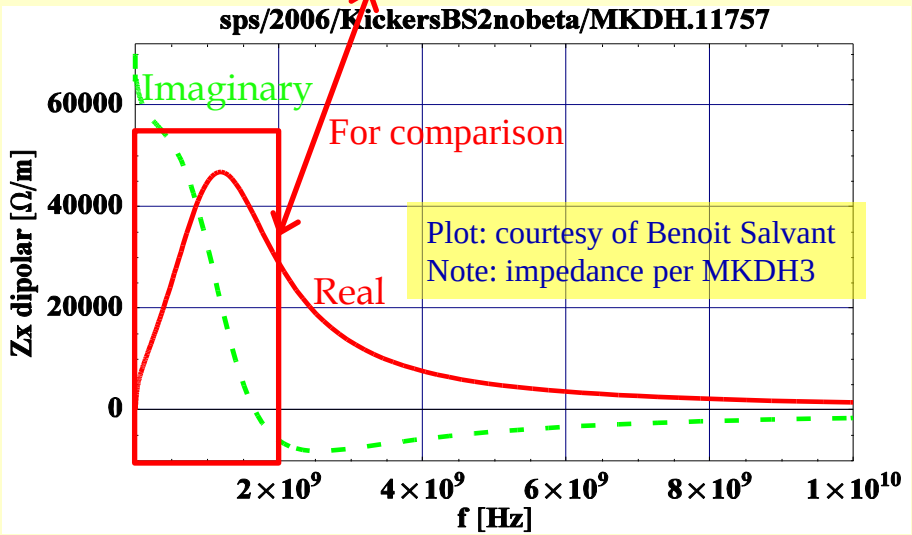


The RLCI, calculated from measurements, shows "unrealistic?" resonances. Hence the measurement was repeated with the VNA function "Time Domain Gating On" to eliminate ringing after the first zero crossing of the (real) low pass impulse response.

The permeability and permittivity of ferrite were utilized for the analytical calculation whereas the magnetic material used in the MKDH kickers is 0.35 mm thick laminated steel: the laminations probably have a significant effect upon the impedance.

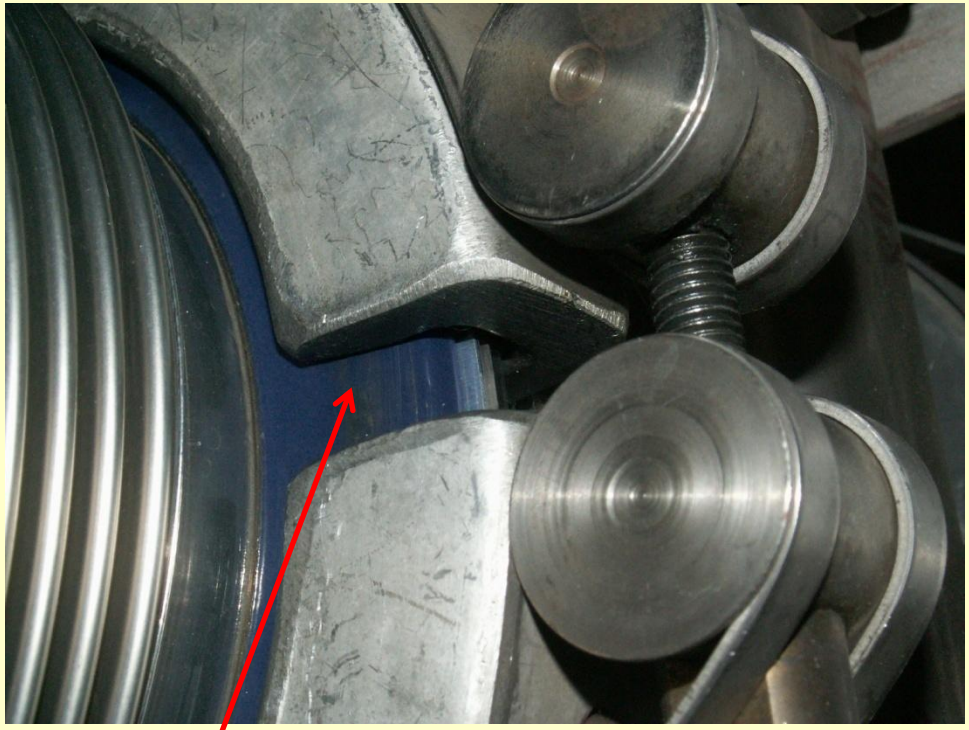
MKDH3 Transverse Impedance





The real Transverse Dipolar Horizontal Impedance (TDHI) for MKDH3, derived from measurements, is shown. The theory is very different to the measurements, but theoretical calculations are only available assuming a ferrite core, and not for a laminated steel core.

Enameled Flanges in Beam Pipe



Enameled Flange

There are several enameled flanges installed in-between bellows near some SPS kicker magnets (e.g. there is one enameled flange at MKE6 and several at MKDV/MKDH). These flanges break the (DC) electrical conductivity of the beam pipe connection between adjacent flanges.

Fritz Caspers confirmed that enameled flanges similar to these exist in the PS and, as a remedy, RF bypasses have been installed. See: https://edms.cern.ch/document/434204/1

Summary

- All three MKE6 magnets now have serigraphed 8C-11 ferrites;
- Serigraphy of the 5 MKE4 magnets will commence next "normal" (2010-2011) shutdown;
  - Plan is to replace one S and one L magnet at each SPS shutdown (using the normal operation year to convert the 2 spare magnets for the next shutdown) -- 3 shutdowns required!!
  - BUT potential problem of converting 2 spare magnets during operation: if problem is encountered with an installed magnet, there may not be an available spare.
- MKDV:
  - Transition pieces suppress the spikes in the RLCI of MKDV1 and thus are expected to reduce heating of ferrite of MKDV2 with 75 ns bunch spacing;
  - Transition pieces may also reduce fast out-gassing. MDs, especially with 50 ns bunch spacing, will prove or disprove this;
  - It is planned to install transition pieces for MKDV2 (MKDV1 installed in early 2009 has transition pieces). However we only have a spare MKDV1 (Vap=75mm, c.f. 83mm for MKDV2) – (Note: G. Arduini recommends that a spare MKDV1 is **NOT** used in place of MKDV2 [email to E. Chapochnikova, dated 17 October 2008]);
  - Radiation level for MKDV2; transition pieces could be installed during "normal" shutdown (following 1 to 2 month cool-down) – BUT available manpower would not allow this to be carried out together with more MKE4 work than just swapping 2 magnets.
- MKDH:
  - Transition pieces to be installed, but spare only for MKDH3 (largest MKDH aperture);
  - MKDH: The measured RLCI and TDHI are very different to theory: this is probably due to the theory using parameters for a ferrite core and not for a laminated (0.35mm) steel core.
- Plan re enameled flanges…..

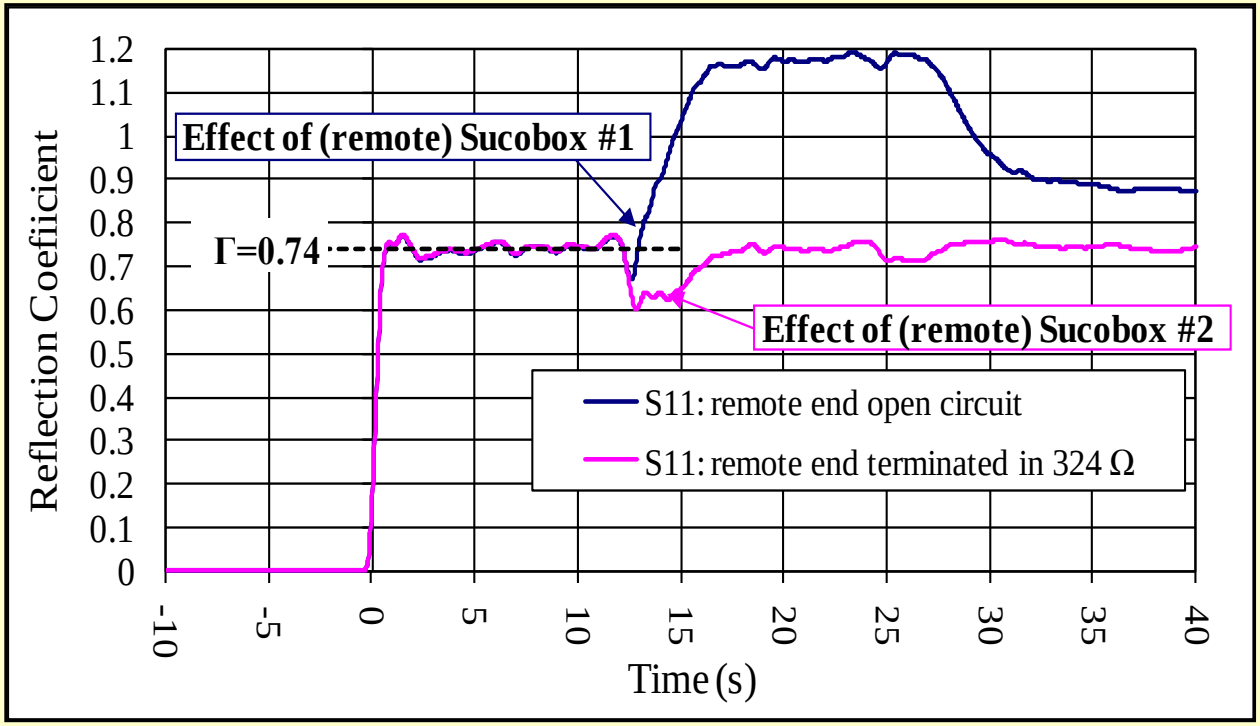
Questions and Comments

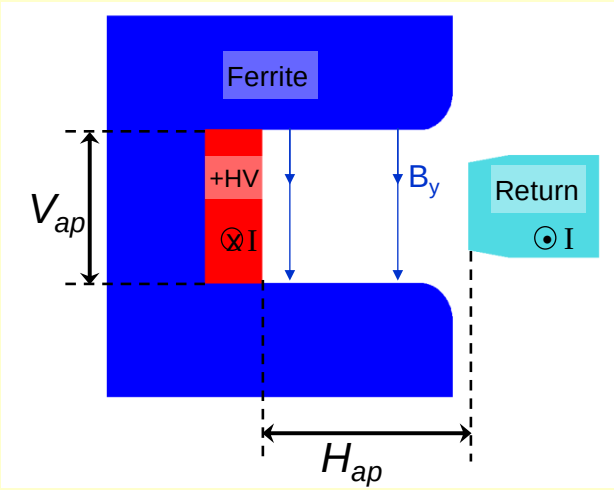
Thanks for your attention!

References & Bibliography

1. G. Rumolo, “Study of electron cloud build up in the MKDV1 in the SPS”, in the minutes of the LIS Section meeting held on 17th November 2008.
2. H. Meinke, F.W. Gundlach, Taschenbuch der Hochfrequenztechnik, Springer-Verlag, 1968, p263.
3. T. Kroyer, F. Caspers, E. Gaxiola, “Longitudinal and Transverse Wire Measurements for the Evaluation of Impedance Reduction Measures on the MKE Extraction Kickers”, CERN AB-Note-2007-028.
4. M.J. Barnes, F. Caspers, T. Kroyer, E. Métral, F. Roncarolo, B. Salvant, Measurement and Analysis of SPS Kicker Magnet Heating and Outgassing with Different Bunch Spacing”, proc. of PAC09.
5. M.J. Barnes, F. Caspers, T. Kroyer, E. Metral, F. Roncarolo, B. Salvant, “Measurement of Longitudinal and Transverse Impedance of Kicker Magnets Using the Coaxial Wire Method”, proc. of PAC09.
6. Coupling impedance measurements on the CPS RF Bypass, and configuration file (FLANGE02.STA) for the Vector Network Analyzer (VNA) type HP 8753D, https://edms.cern.ch/document/434204/1.

S11 Measurement for MKDH3: Single Wire





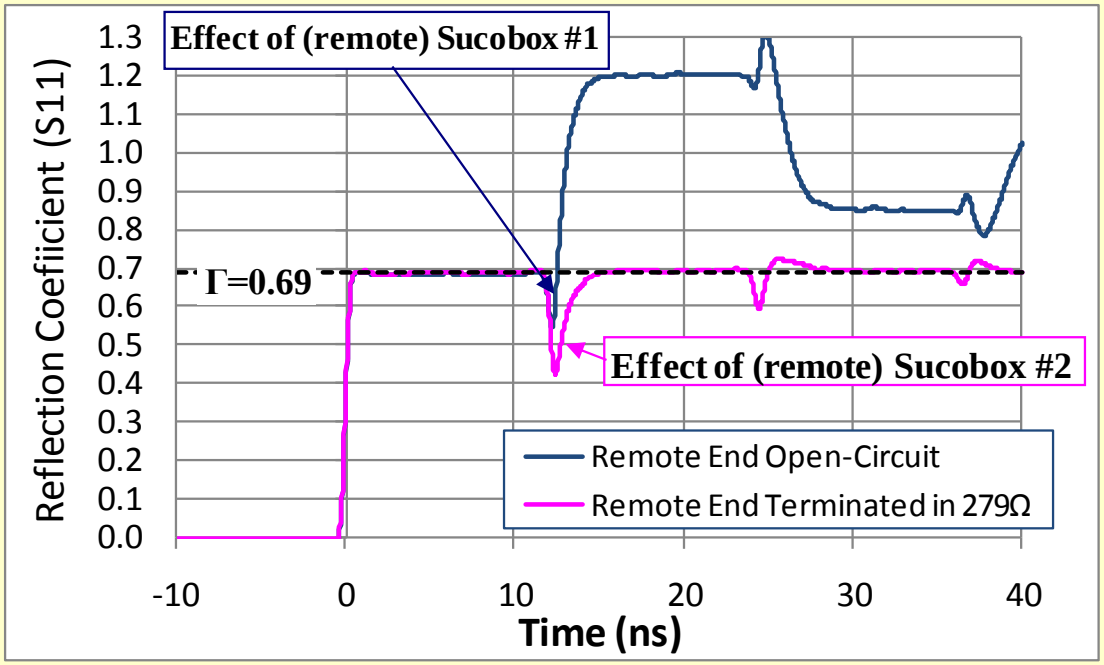
$Z_L \approx 60 \ln 1.27 H_{ap}/d$ [2], where d is the diameter of the measurement wire.

For MKDH3, Hap=105 mm → Z_L=335 Ω.

$$Z_L = Z_0\left(\frac{1+\Gamma}{1-\Gamma}\right) = 50\left(\frac{1+0.74}{1-0.74}\right) = 335\Omega$$

Thus the Z_L given by S11 is the same value as given by the equation from [1].

S11 Measurement for MKDH3: Two Wire, Horizontal Plane



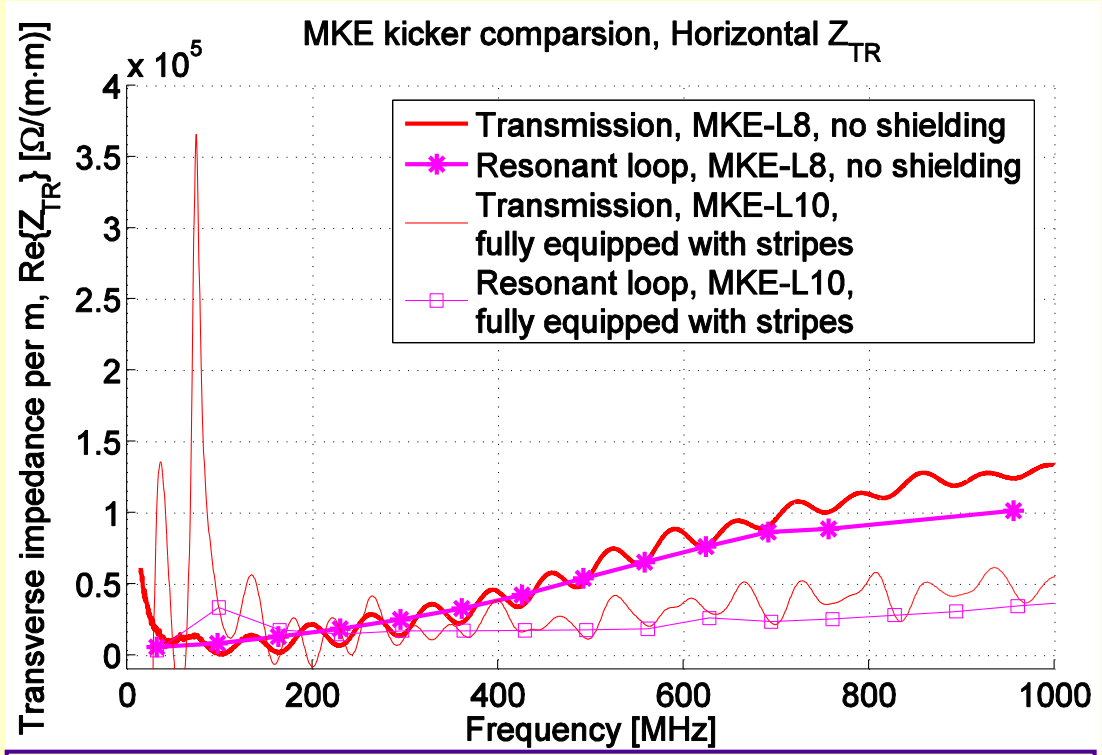
A two-wire transmission method was used to determine the TDHI of MKDH3: the two-wires were separated by 28 mm in Hap. From Eq. (2.17) in [3], the difference-mode impedance of this two-wire line in free space is 566 Ω (an S11 measurement gave Γ=0.69 which corresponds to 283 Ω to a virtual ground mid-way between the two wires i.e. 546 Ω between wires).

Thus the characteristic impedance given by S11 is the same value as given by the equation.

Transverse Impedance

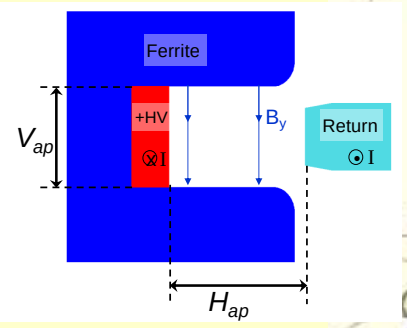
- **Information re Transverse Impedance, and measurement techniques, can be found in:**

Tom Kroyer's presentation "*Wire Measurements on the MKE Extraction Kicker Magnets*" APC meeting 10/11/2006.



Shielding may increase transverse impedance at ~100MHz, but reduces transverse impedance above ~300MHz.

SPS & LHC KICKER SYSTEMS



4 x MKQAV

4 x KKQAH

LHC

Kicker Magnet	Nb of magnets	H_{ap} (mm)	V_{ap} (mm)	Length x number of cells
MKP-S	12	100	61	26mm x 17
MKP-L	2	140	54	26mm x 22
MKQH	1	135	33.9	242mm x 2
MKQV	1	56	102	788mm x 2
MKDH1/2	2	97.1	56	1256mm x 1
MKDH3	1	106.1	60	1256mm x 1
MKDV1	1	56	75	512mm x 5
MKDV2	1	56	83	512mm x 5
MKE4-L	3	147.7	35	240mm x 7
MKE4-S	2	135	32	240mm x 7
MKE6-L	2	147.7	35	240mm x 7
MKE6-S	1	135	32	240mm x 7

30 x MKD

12 x MKBV

8 x MKBH

4 x MKI

5 x MKE4

3 x MKDH

2 x MKDV

MKQV

4 x MKP

SPS

MKQH

3 x MKE6

4 x MKI

PS Complex

Point 4

Point 5

Point 7

Point 8

Point 2

Point 1

Prévessin-Moëns

Ferney-Voltaire

Genis-Pouilly

Meyrin

CERN

TI 2

TI 8