Extraction kicker Impedance Measurement in CSNS/RCS

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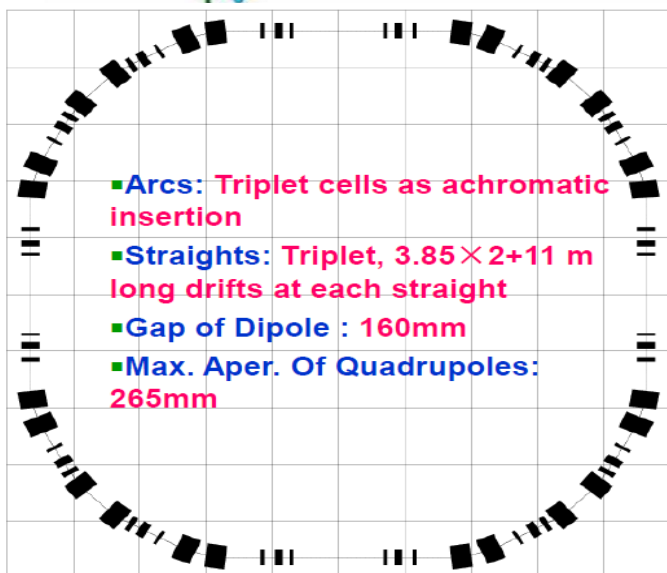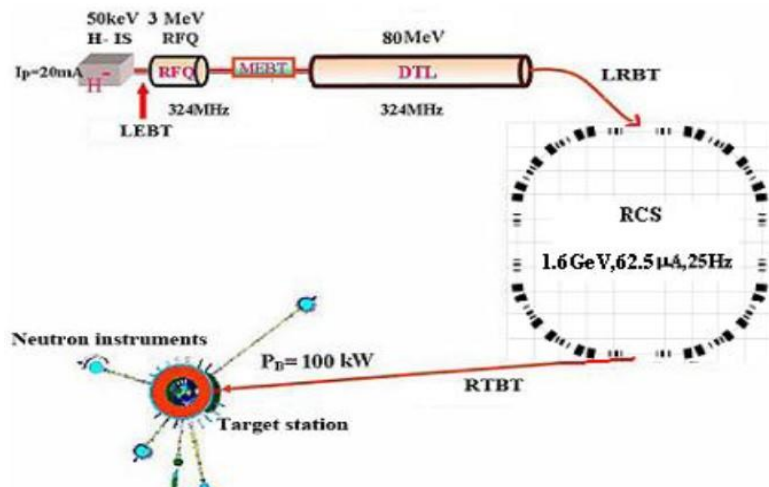
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13th. Nov. 2014

◆ **Introduction**

◆ **Impedance measurement**

  ➢ **Longitudinal measurement**

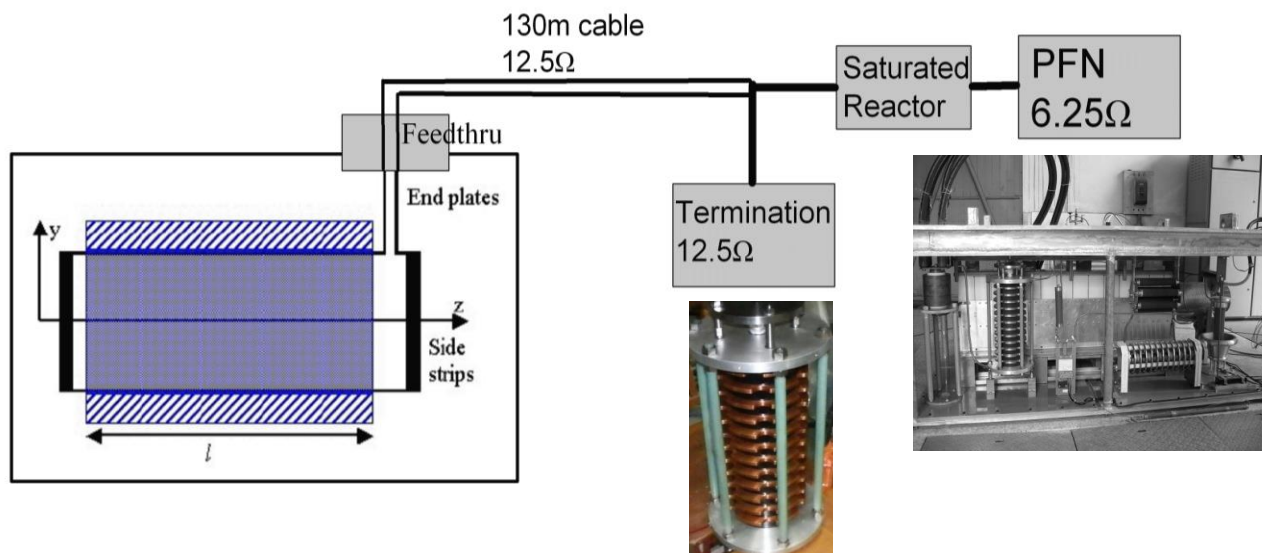 ➢ **Transverse measurement**

◆ **Summary**

Introduction：CSNS&RCS

Parameters	Values
Circumference/m	227.92
Eneregy/GeV	0.08-1.6
Repeat Rate/Hz	25
Average beta (H/V)/m	9.5/10.5
Nominal tune(H/V)	4.86/4.78
Natural chromaticity(H/V)	-4.64/-8.27
Particles per bunch/e13	0.78/3.9
Trans. acceptance /πmm.rad	540
Bunch number	2
Bunch length/ns	460/80

Extraction kick parameters

Type	Rise time	Total strength	Flat – top time	Kicker number	inductance
Lumped, twin-C	265 ns	20 mrad	600 ns	8	0.92nH

- Arcs: Triplet cells as achromatic insertion
- Straights: Triplet, 3.85×2+11 m long drifts at each straight
- Gap of Dipole : 160mm
- Max. Aper. Of Quadrupoles: 265mm

Introduction：Extraction kicker

- **No. 2 kicker is measured.**

Mag. Field	Bend angle	Effective length	Mag. Width	Mag. Gap	Field uniformity
0.0582 T	2.3675 mrad	320 mm	163 mm	220 mm	1.5 %

Impedance Measurement

◆ **Assignment (Kicker No. 2)**

- **Obtain total impedance of extraction kickers, and improve design.**

- **Bunch length:460ns-80ns, spectrum:2-12.5MHz, 1-100MHz, (<100MHz)**

◆ **Longitudinal measurement**

◆ **Transverse measurement**

- **Two parts: Naked Kicker (kicker without cable (130 m length), PFN and termination) and Kicker with cable, PFN and termination.**
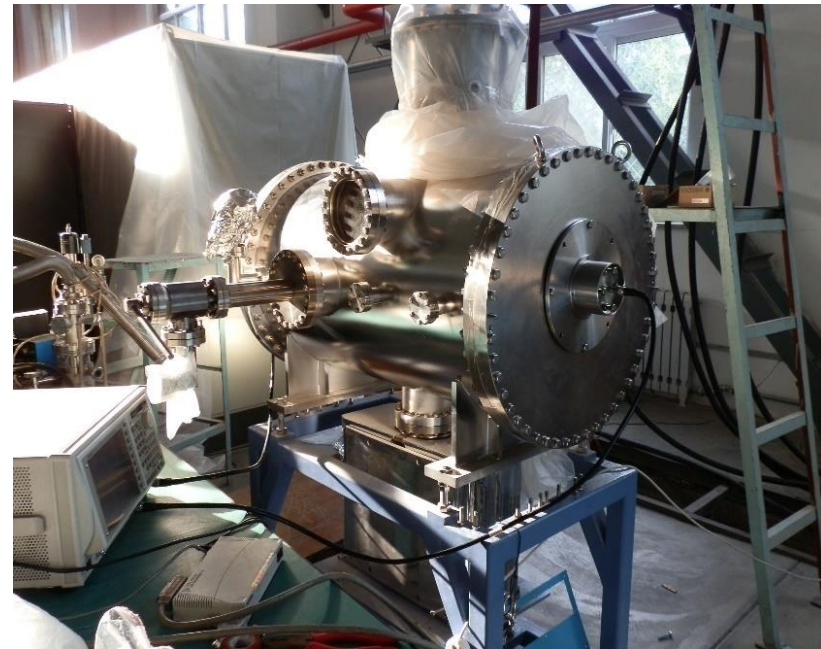
- **Longitudinal: Coaxial-line method（S_{21}）, Dual-wire method (common-mode，S_{21})**

- **Transverse: Dual-wire method (differential-mode，S_{21}), Loop method （input impedance）**

- **VNA：E5071C**

$$Z_{\parallel,Log}^{1}(\omega) = -2\,Z_c\ln\left(\frac{S_{21,DUT}}{S_{21,REF}}\right)$$

$$Z_T^2 = \frac{c}{\omega}\overline{Z}_x = \frac{cZ}{\omega(2a)^2}.$$

$$Z_T^3 = \frac{c}{w}\frac{Z^{DUT}-Z^{REF}}{N^2\Delta^2}.$$

- **wire：0.5mm diameter，space: 40mm**

- **Signal generator: hybrid (ZFSCJ-2-1-N) and splitter(ZFRSC-42-S+)**

1.L. S. Walling, D. E. McMurray, et al., *Transmission-line Impedance Measurement for an Advanced Hadron Facility*, Nucl. Instr. & Meth. A (281) 433 (1987).
2. W. K . H . Panofsky and W. A. Wenzel, Rev. Sci. Instrum. 27, 967 (1956).
3.A. Mostacci, F. Caspers, and U. Iriso, BENCH MEASUREMENTS OF LOW FREQUENCY TRANSVERSE IMPEDANCE, Proceedings of the 2003 Particle Accelerator Conference.
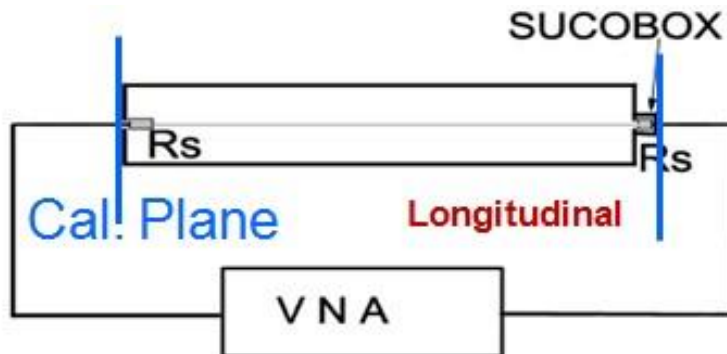
Impedance measurement—Impedance match
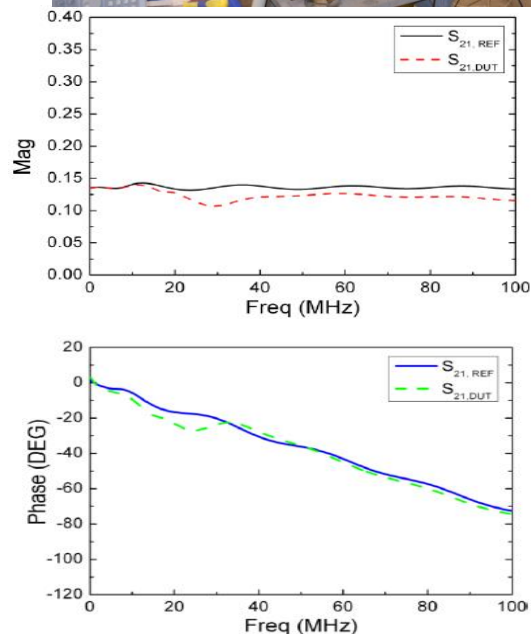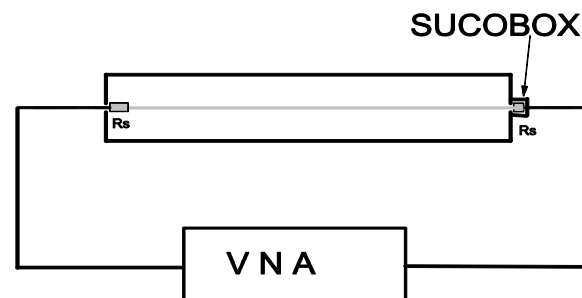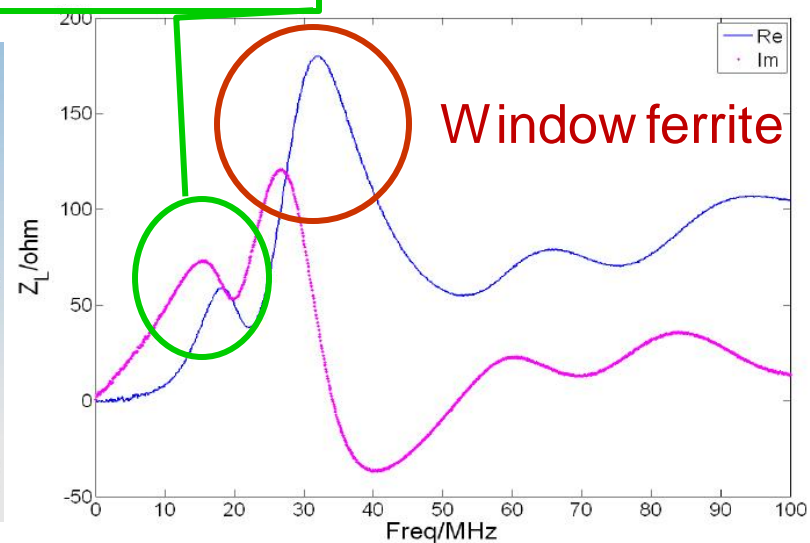
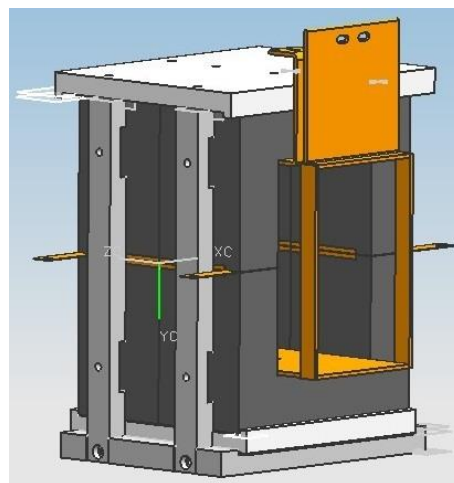- **Match section**

Resistors are used to match

35 mm
SUCOBOX

Transverse
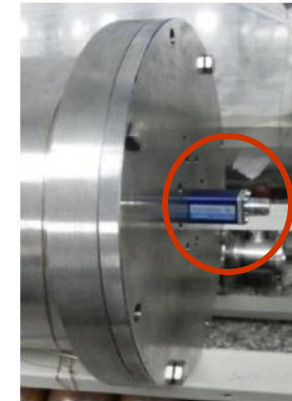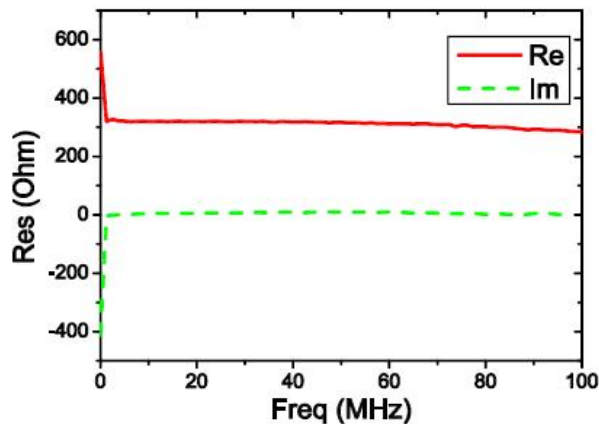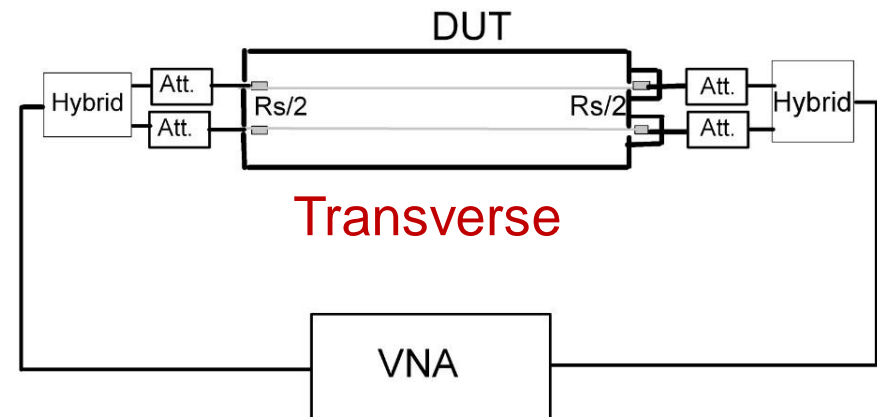
Longitudinal measurement (Naked kicker)

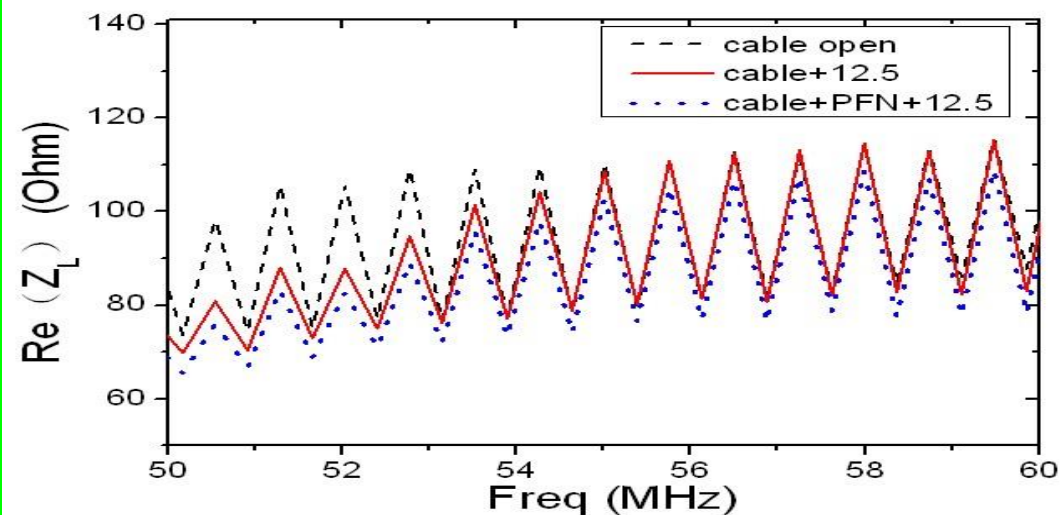SUCOBOX

Busbar gap

Window ferrite

Longitudinal measurement (Kicker with cable, PFN and termination)
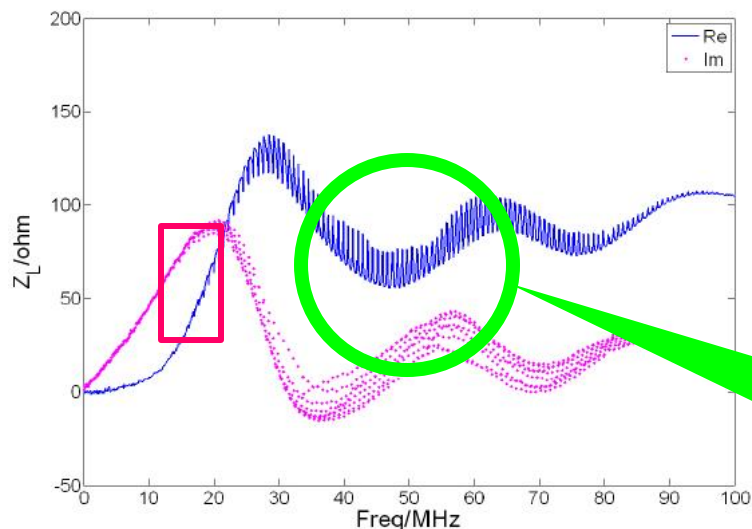
The resonance is considered the reflection of cable.

Δf: 0.72M=3e8/(130*2*1.6)
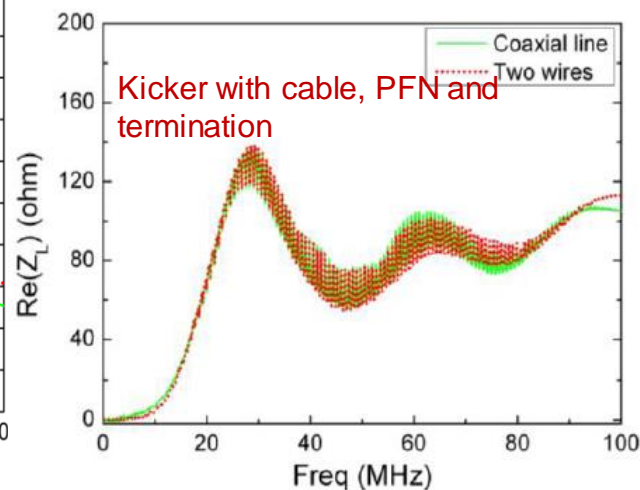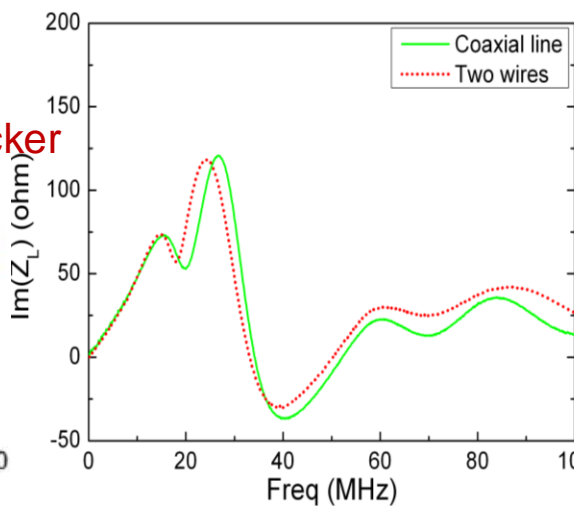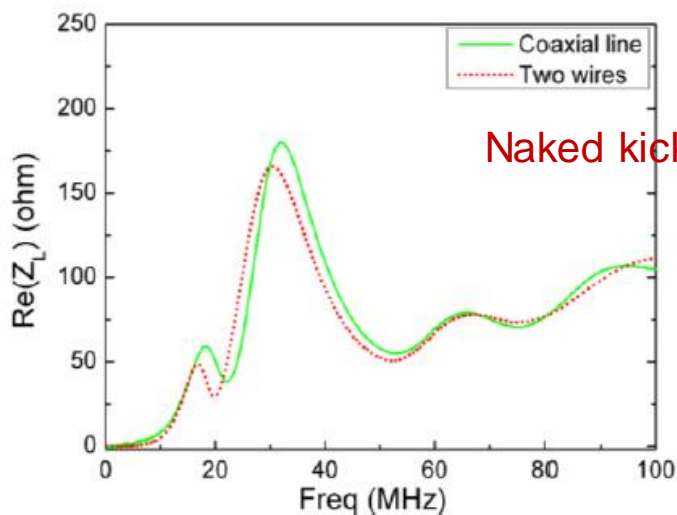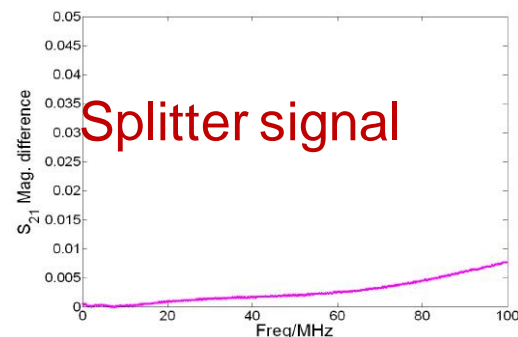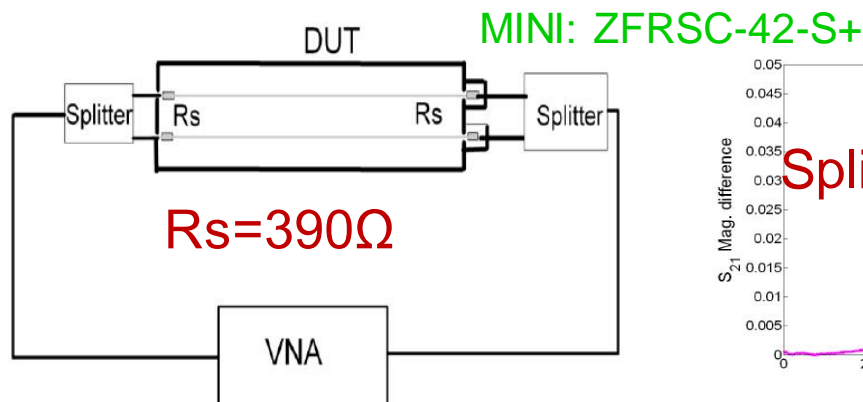
the first point of resonance frequency is not found.

Longitudinal measurement（**common-mode measurement ***）

• For dual-wire method, it is convenient to measure longitudinal and transverse impedance at the same time.
• Splitter: <20dB[#]

MINI: ZFRSC-42-S+

Rs=390Ω

Splitter signal

Naked kicker

Kicker with cable, PFN and termination

*: Takeshi Toyama, et al., COUPLING IMPEDANCE OF THE J-PARC KICKER MAGNETS, Proceedings of HB2006, Tsukuba, Japan, pp. 140.

#: L. Huang, Mode Error Analysis of Impedance Measurement using Twin Wires, Chinese Physics C.
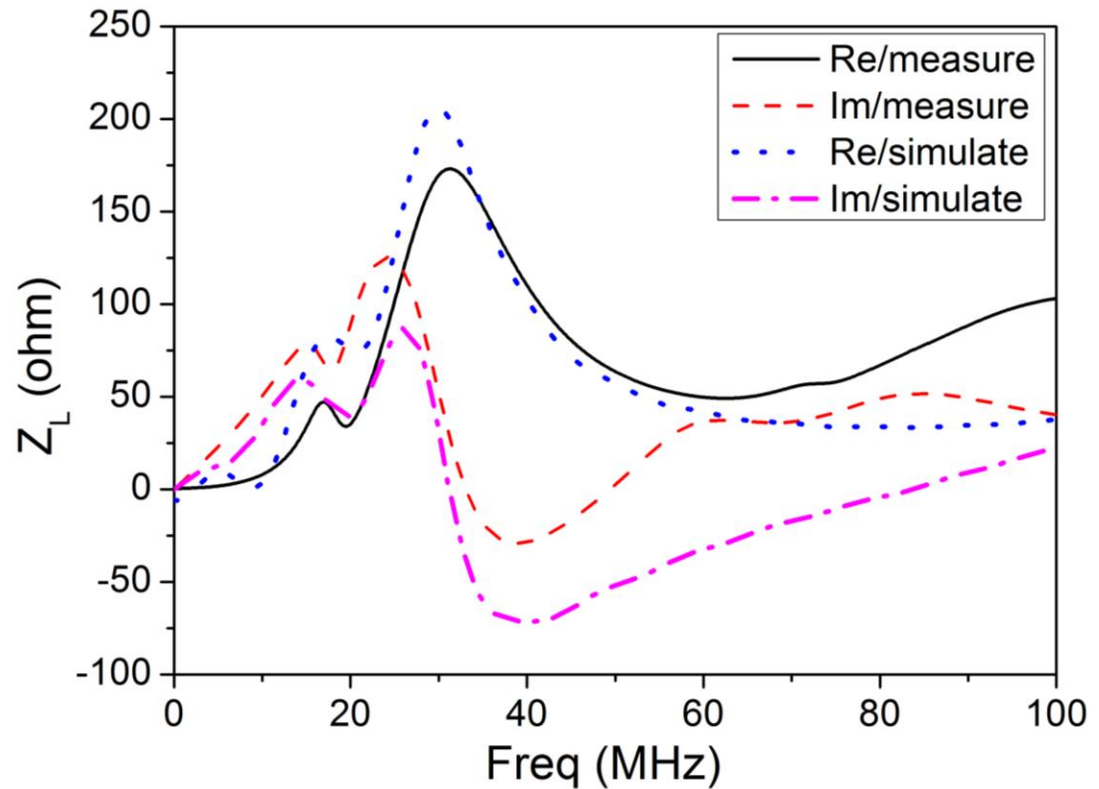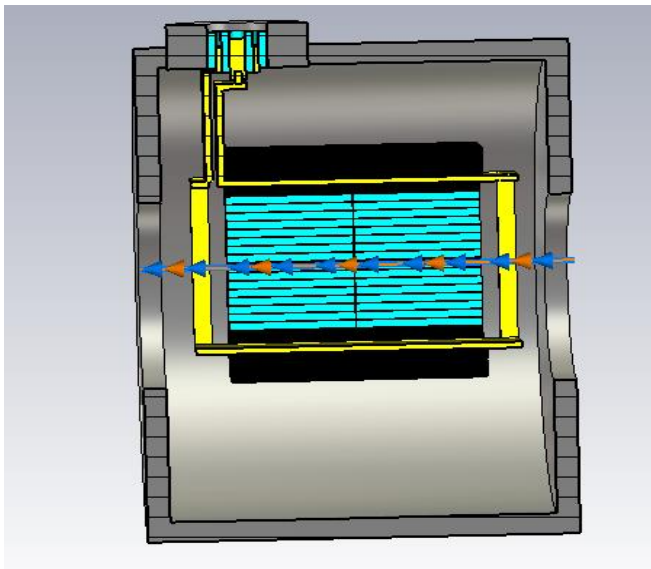
Simulation on longitudinal impedance

CST Setting
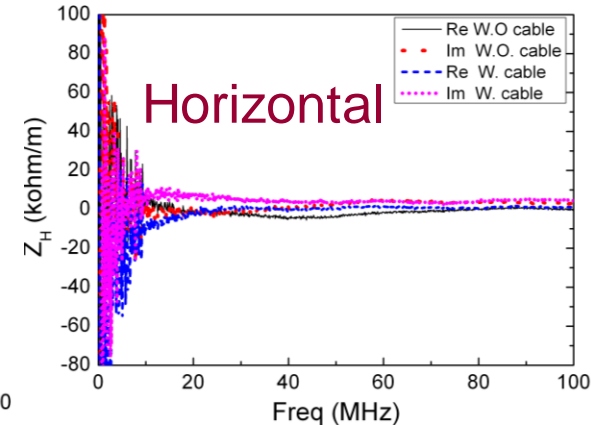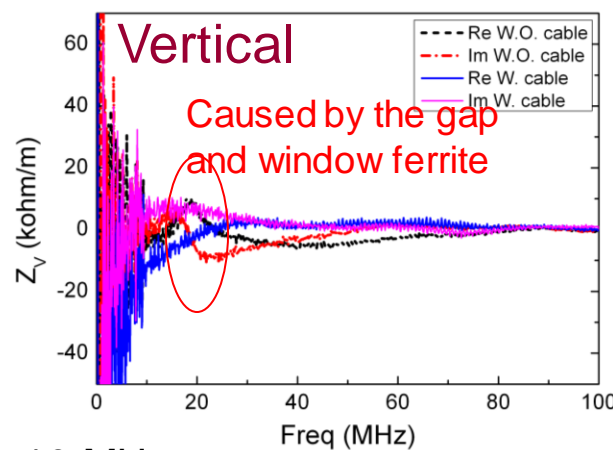
Meshcells: 2,667,168

Boundary conditions

x/y: electric

Z: open

Wakefield solver length: 40m

Transverse measurements (Dual-wire, differential-mode)

$R_s = 250\ \Omega$

Vertical
Caused by the gap and window ferrite

Horizontal
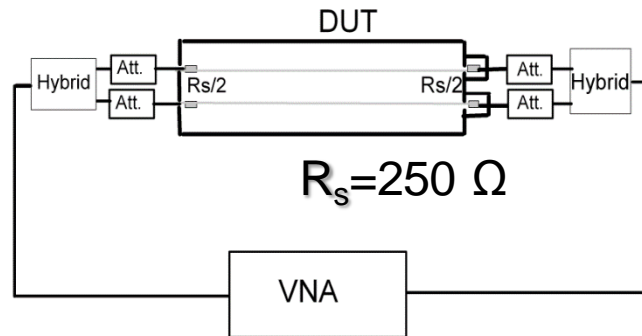
➤ The measured impedance below 10 MHz, even 20MHz is inaccuracy because of the two-wires method.

➤ Impedance peak caused by busbar gap and window ferrite is observed in transversely without connection with cable. The oscillation from the mismatch between cable and PFN appears with cable and PFN on

➤ A wire loop will substitute the dual-parallel wire to get more accuracy signal.
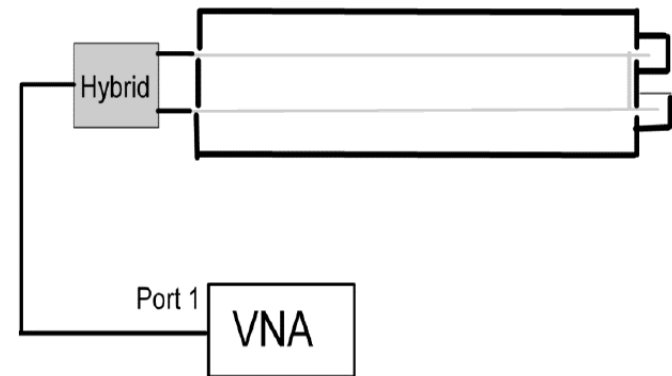
Hybrid, one loop, space: 40mm, input impedance

Transverse measurement（Loop）

- **Measured impedance is valid below 60 MHz as the inductance.**

- **Horizontal impedance is same for naked kicker and kicker with cable, PFN and termination, but vertical impedance is different.**

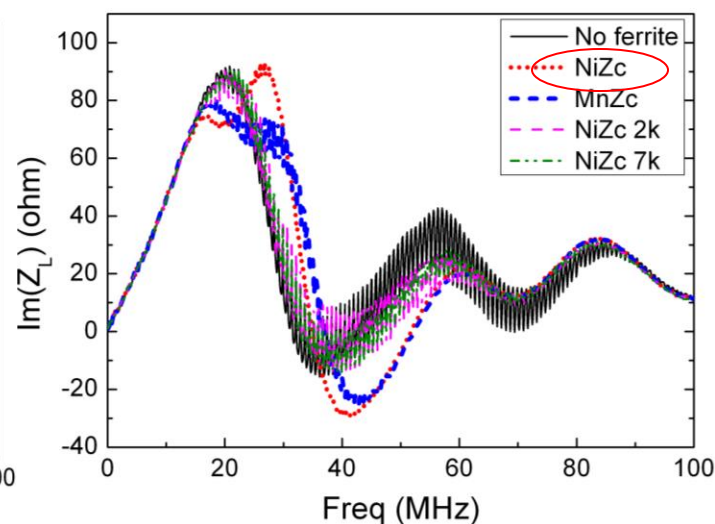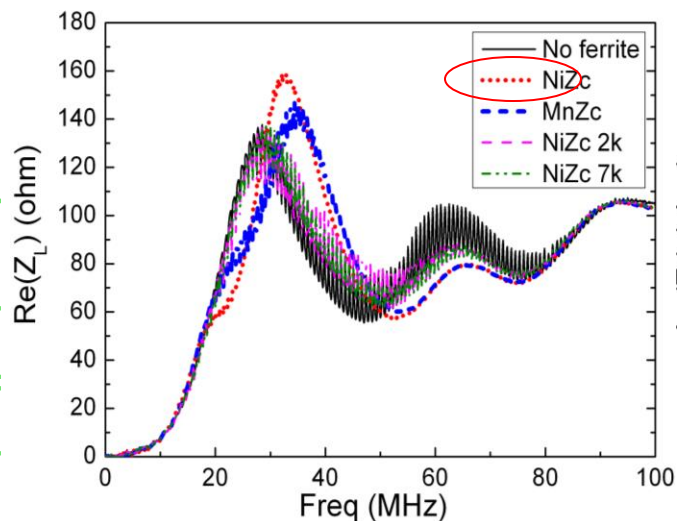- **The oscillation, start point:0.36 MHz,.space:0.72 MHz.**

Naked kicker

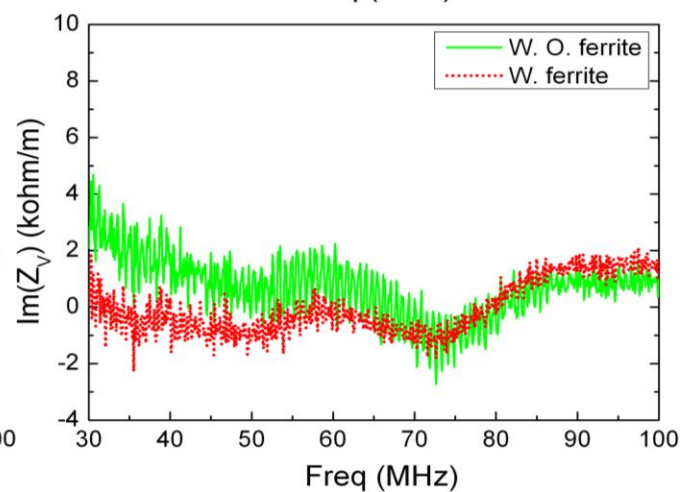Kicker with cable, PFN and termination

Cable open
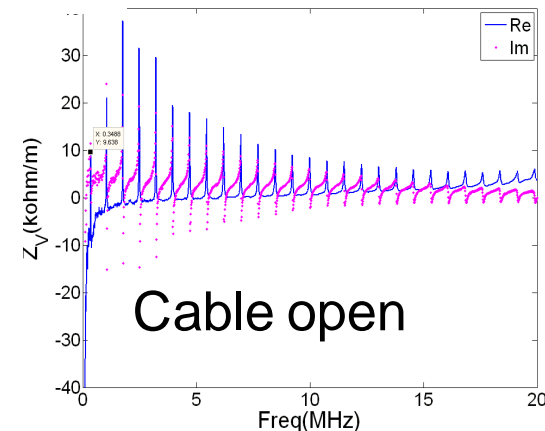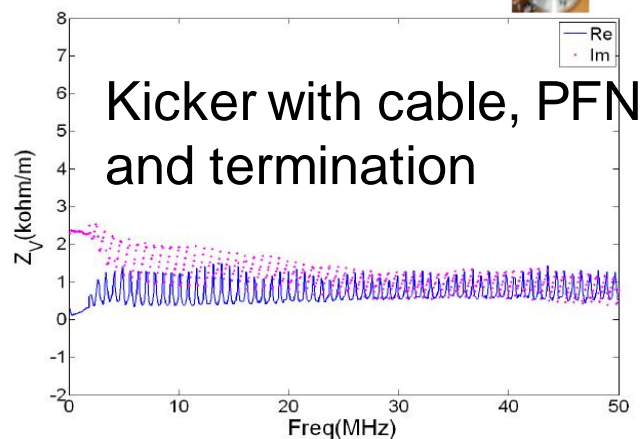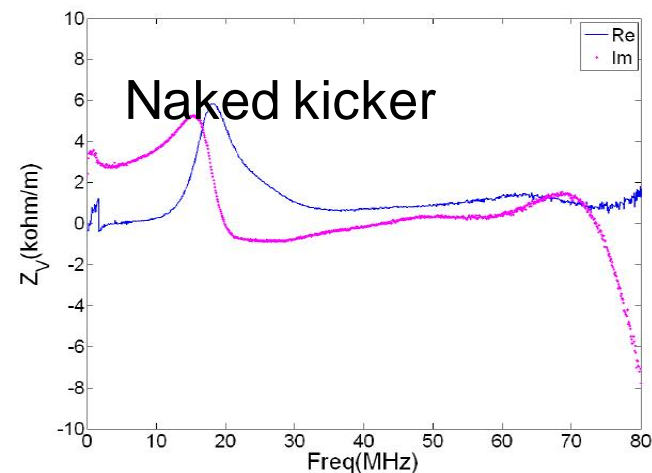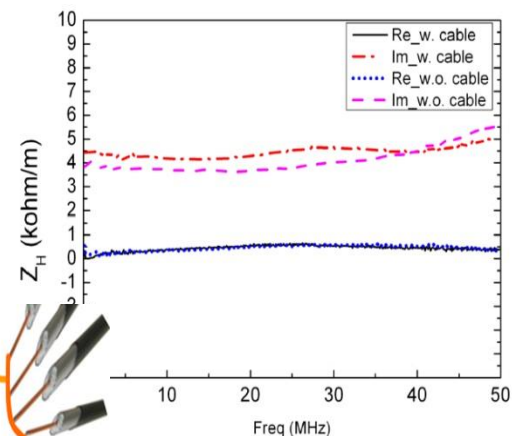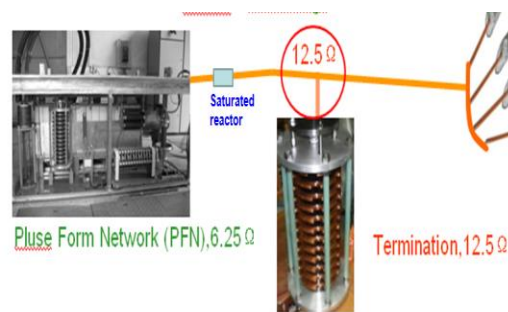
Restrict the oscillation

- **Ferrite ring：8C12** of Ferroxcube INC.
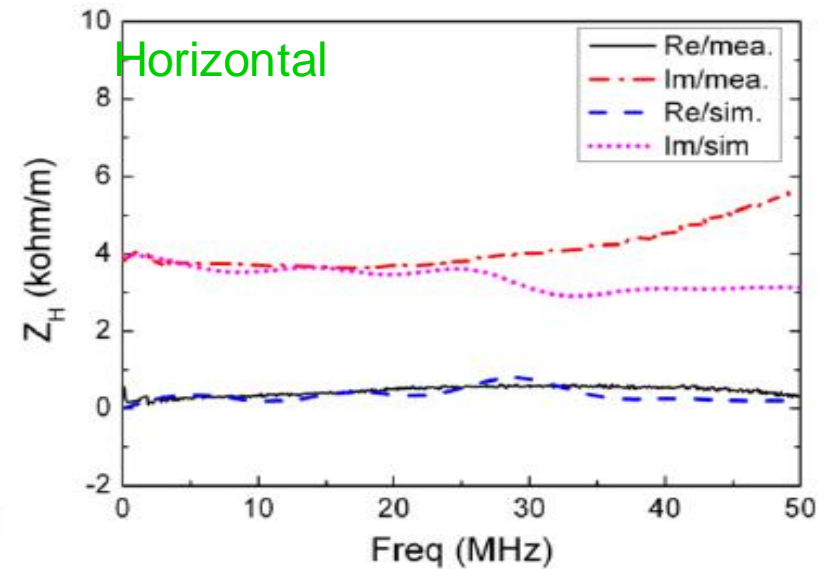
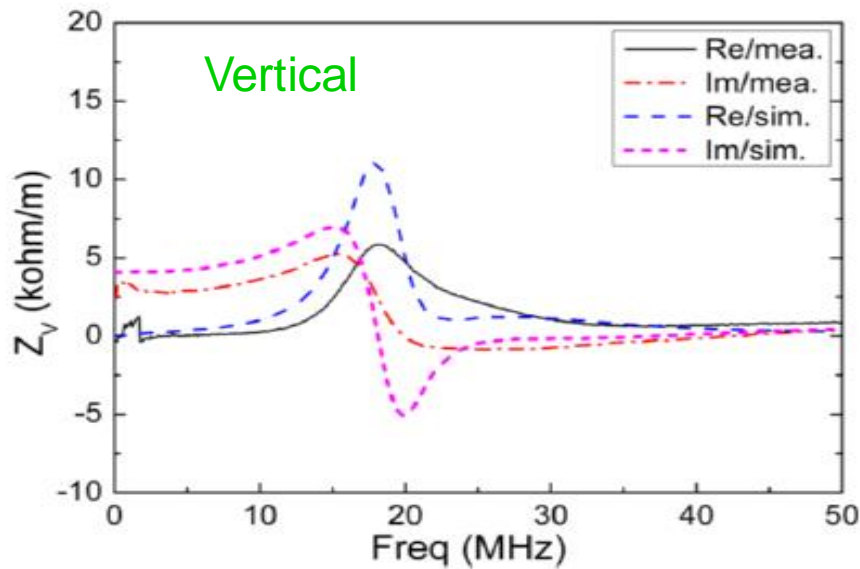Inn. dia.=20mm,
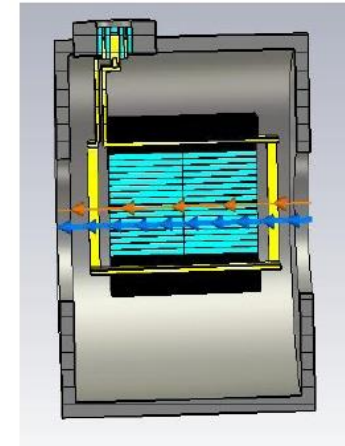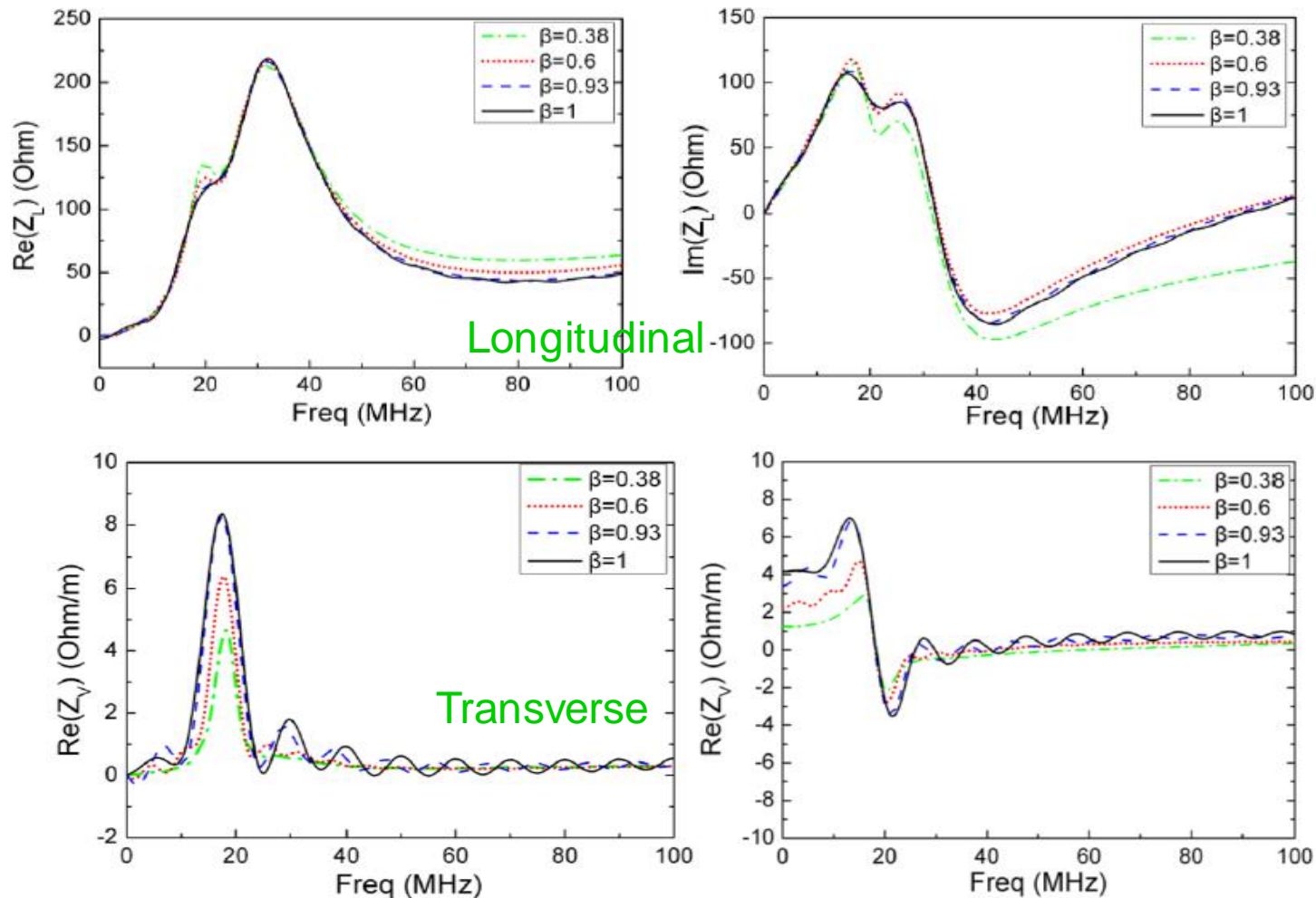Out. dia.=97mm
Length=20mm

Longitudinal

Vertical
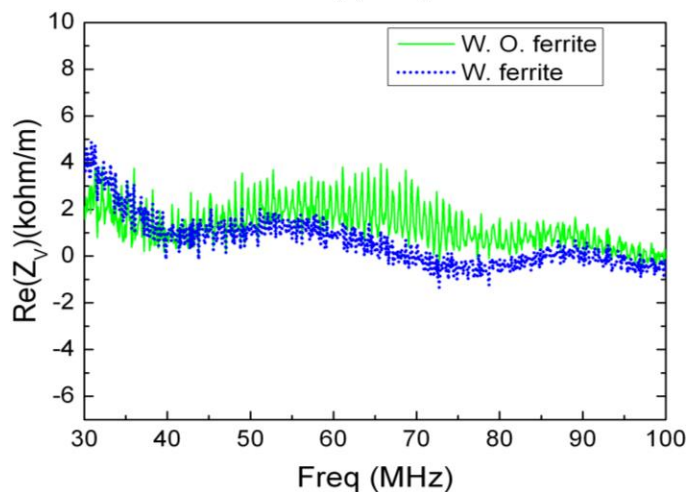
Transverse measurement—CST simulation

- **Bunch length：600mm，β=1**

- **wakefield：30m**

- **Meshcells：1.236 million**

CST simulation-different velocity

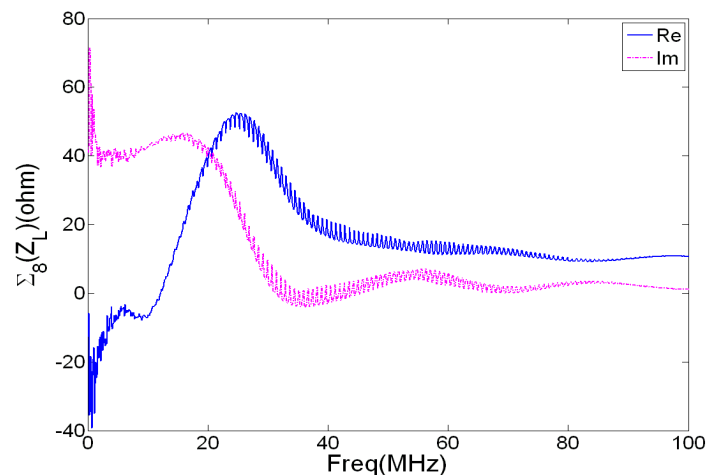- **Ultrorelativistic impedance is smaller than relativistic one.**

The total Impedance for Kicker System (8kickers)

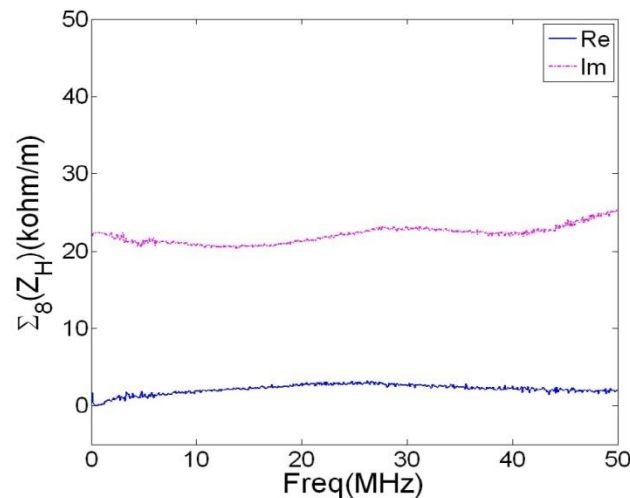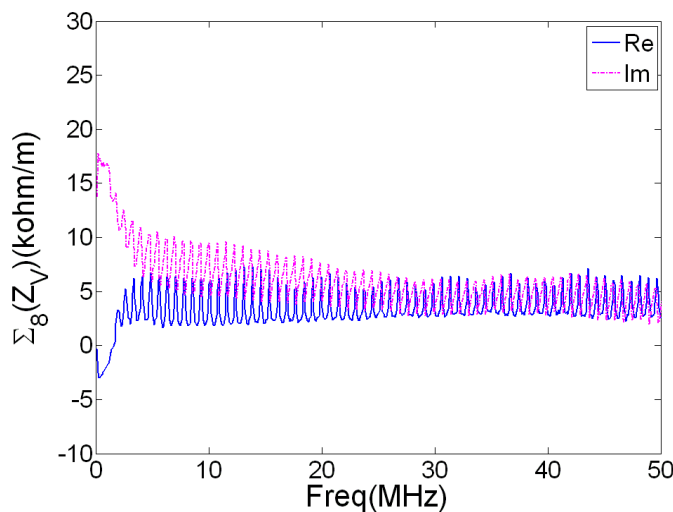$$Z_{measured\parallel} \frac{S_{measured}}{L_{measured}} = Z_{i\parallel} \frac{S_i}{L_i}$$

$$Z_{measured\perp} = \left(\frac{h_i}{h_{measured}}\right)^2 Z_{i\perp}$$

Longitudinal total average impedance: 53+j47Ω

Horizontal total impedance: 5+j10kΩ/m

Vertical: 3+j22kΩ/m.

Summary

- ✓ In impedance measurement system, a series of resistors is used as matching section which is proved to be reliable for vacuum component with big size.

- ✓ Longitudinal impedances for kicker with and without cable are measured by coaxial transmission line and dual-wire (common mode), and two methods results agree well. Measured impedance is consistent with CST simulation result.

- ✓ For transverse impedance, because of the low measurement accuracy for impedance below 20MHz with dual-wire, Loop method is used to measure transverse impedance. Measured impedance also agrees well with CST simulation result.

- ✓ The mismatch among cable, PFN and termination is a serious oscillation source in the kicker system which may become the restriction for beam stability. Ferrite ring is useful to restrict it, but more experiment should be done before the ring is applied.

- ✓ The average total impedance of kicker system (with 8 kickers) can be estimated about $Z_{//} \sim 53+j47\Omega$; $Z_H \sim 5+j10k\Omega$; $Z_V \sim 3+j22k\Omega$. The total impedance should be further study.

- ✓ The scaling law of total impedance should be more studied.

- ✓ The influence of beam for extraction kicker is estimating.

Acknowledgement

We would like to acknowledge the discussion with prof. Fritz Caspers in the measurement.

Thank you for your attention !