# 16-electrode Pick Up

Mini workshop (@FNAL)

Nov,2016

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- Motivation

  About J-PARC MR / Injection mismatch / The merit of 16-electrode PU

- Design

- Calibration

  Position sensitivity/Characteristic impedance/high frequency sensitivity

- Install to J-PARC MR

- Detected Signal

- Conclusion

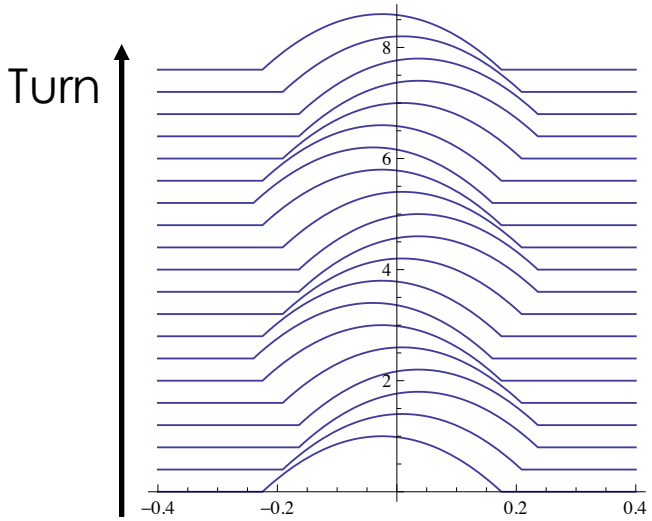
# Motivation (J-PARC MR)

- J-PARC MR is a high intensity proton synchrotron. (415kW ,12,Feb.,2016)
- Beam loss restricts beam intensity.
- Our aiming is making the beam loss smaller in MR, less than 2 kW at the collimator and 0.1% at the other part.
- Injection matching is useful for reducing beam loss.

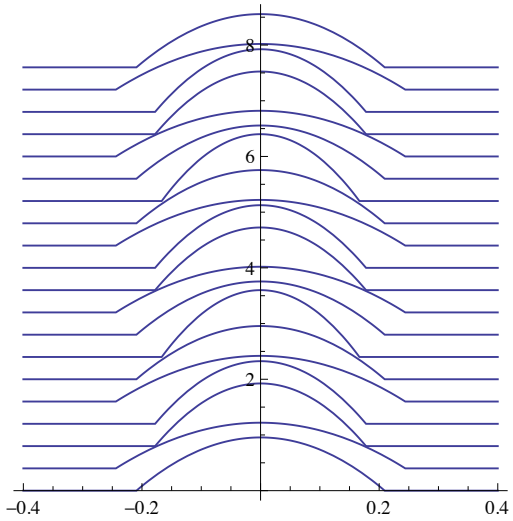
# Injection matching

- Current Status : Dipole moment matching
- For matching quadrupole moment in injection,

  16-electrode pick up is developing.
- Other way to use the pick up : measuring beam size, higher order moment




Dipole mismatch




Quadrupole mismatch

# Why 16-electrode is needed?

- **To reduce systematic error.**

  → be able to measure the true value

- **To reduce statistic error.**

Furthermore, it can measure higher order moment.

→ It has a possibility to measure higher resonance.

# Design

- Attached **16 strip-line electrodes**

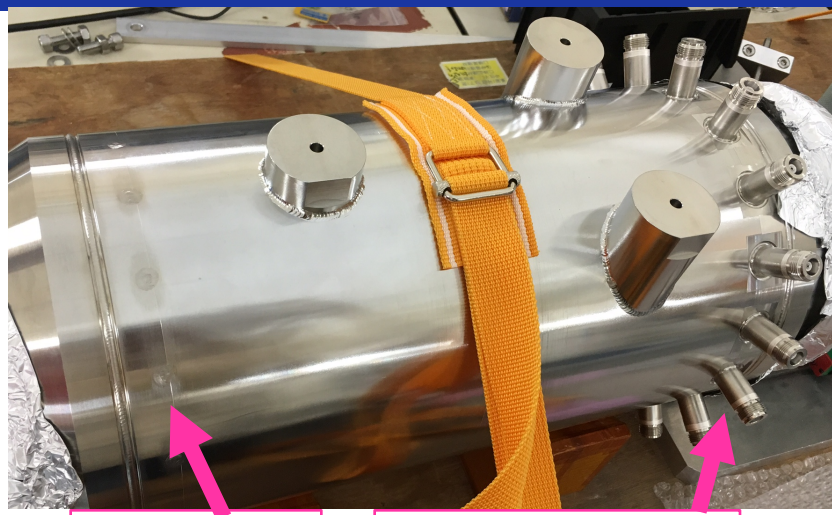
  inside the vacuum pipe.
- Each electrode arranged

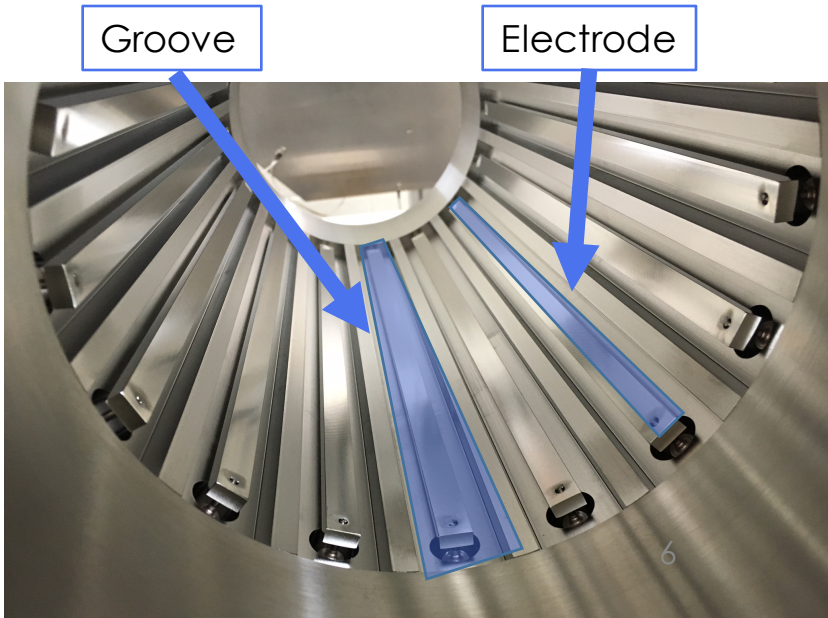
  into the groove.

  ←For **reducing the electric coupling**

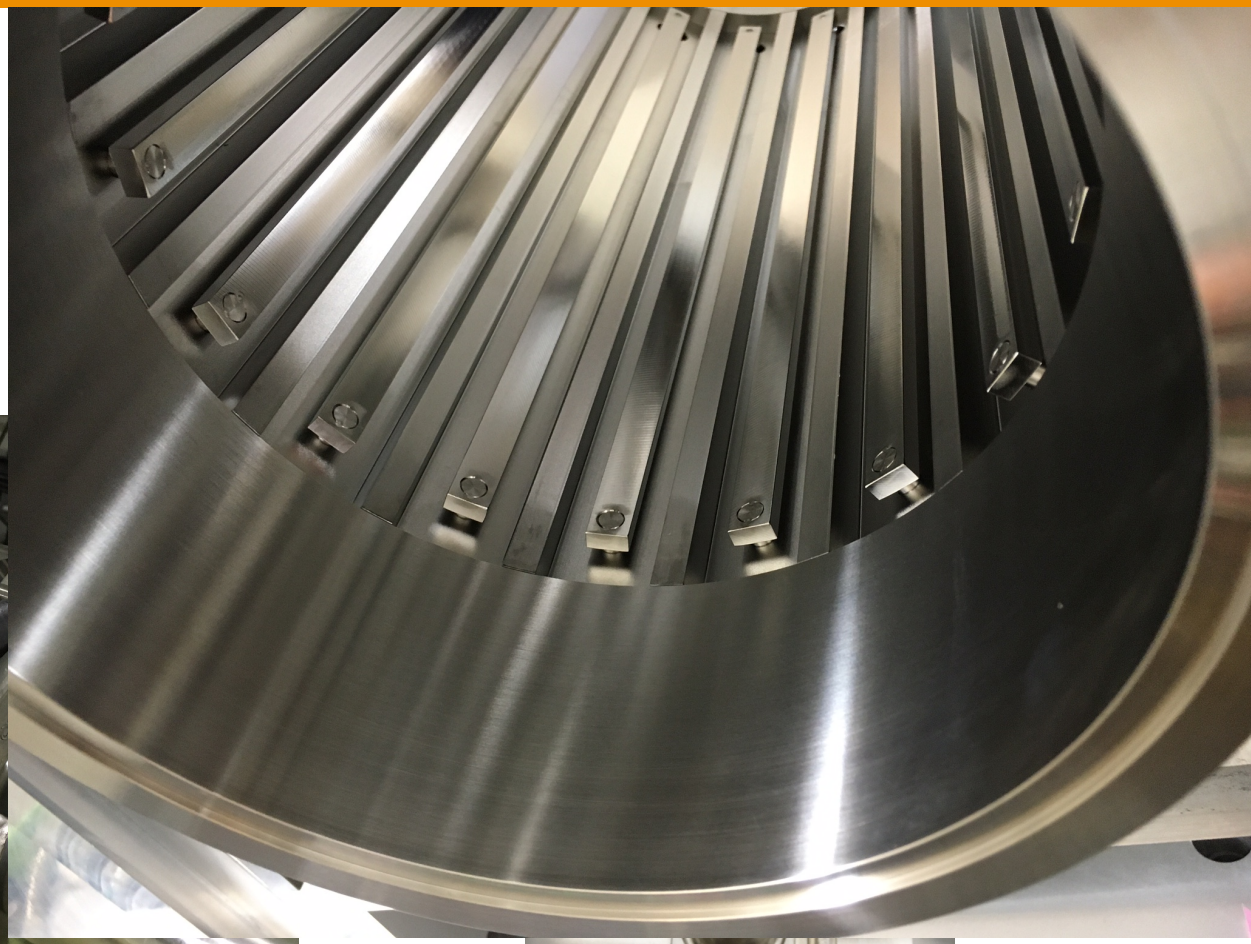
  between the two neighbor electrodes
- Characteristic impedance is 50Ω.(design)
- Size of electrode

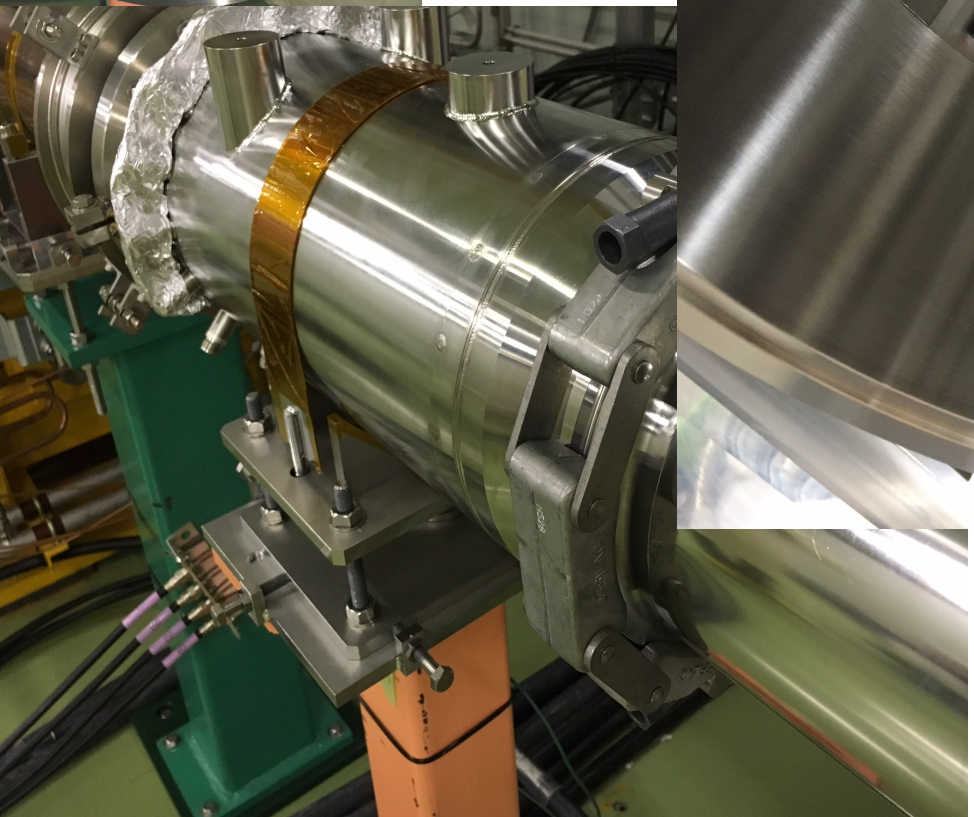
  : $9.85 \times 5.0 \times 330\ [mm](\pm 0.05[mm])$
- Size of groove : $25 \times 8\ [mm](\pm 0.05[mm])$
- Upstream : Reading out signal
- Downstream : Short circuit



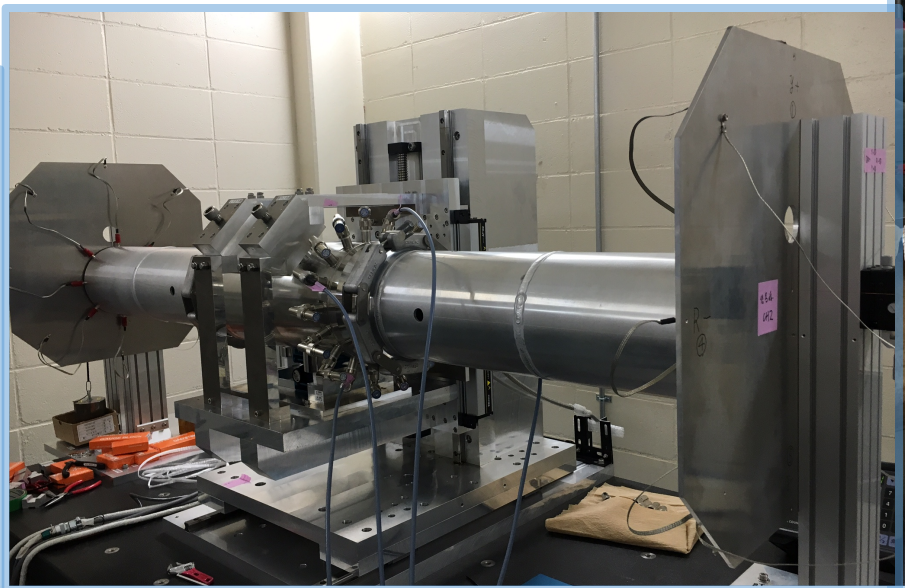
# A collection of photographs





# Calibration

- **Position sensitivity measurement (by wire)**
- **Characteristic impedance measurement (with TDR)**
- **High frequency characteristic (by taper pipe)**

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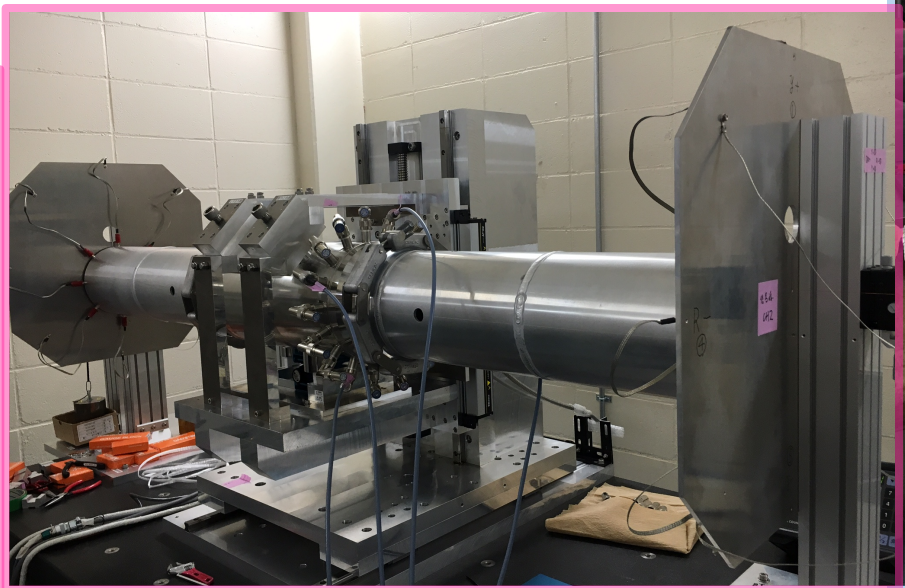
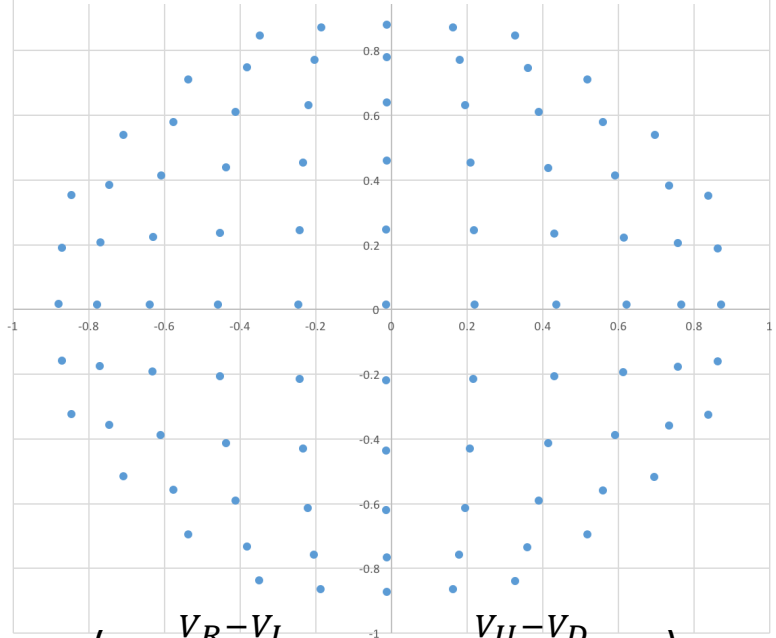


# Position sensitivity

- Range of frequency：0.85MHz~21.25MHz (step by 0.85MHz :25points)
- Range of position：R(radius)≦55mm (10mm step)

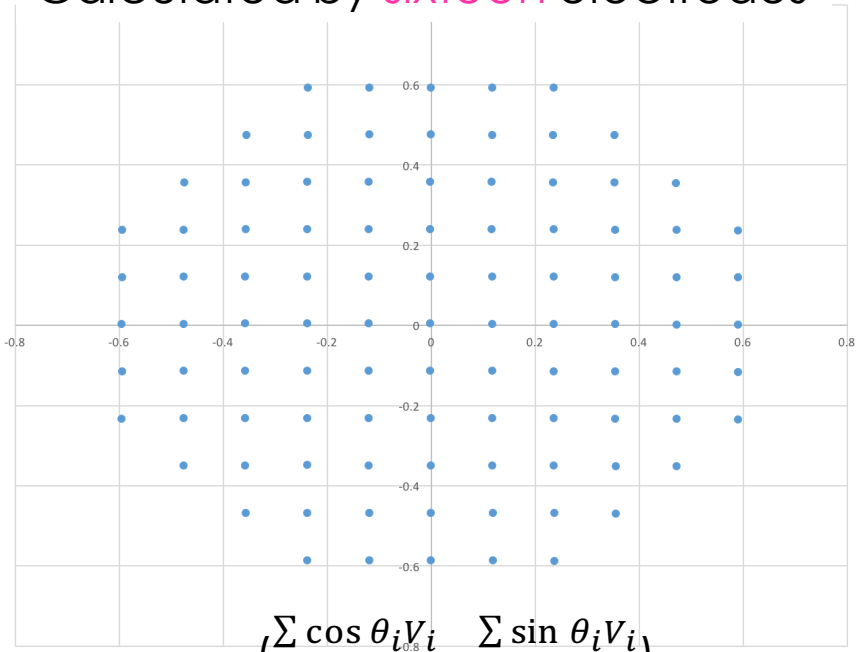
**Position of wire** @5.1MHz

Calculated by four electrodes



$$\left(\frac{V_R - V_L}{V_R + V_L + V_U + V_D}, \frac{V_U - V_D}{V_R + V_L + V_U + V_D}\right)$$

Calculated by sixteen electrodes



$$\left(\frac{\sum \cos\theta_i V_i}{\sum V_i}, \frac{\sum \sin\theta_i V_i}{\sum V_i}\right)$$

Position calculated by four electrodes is warping
<-> Position calculated by sixteen electrodes is less warping!

# Calibration

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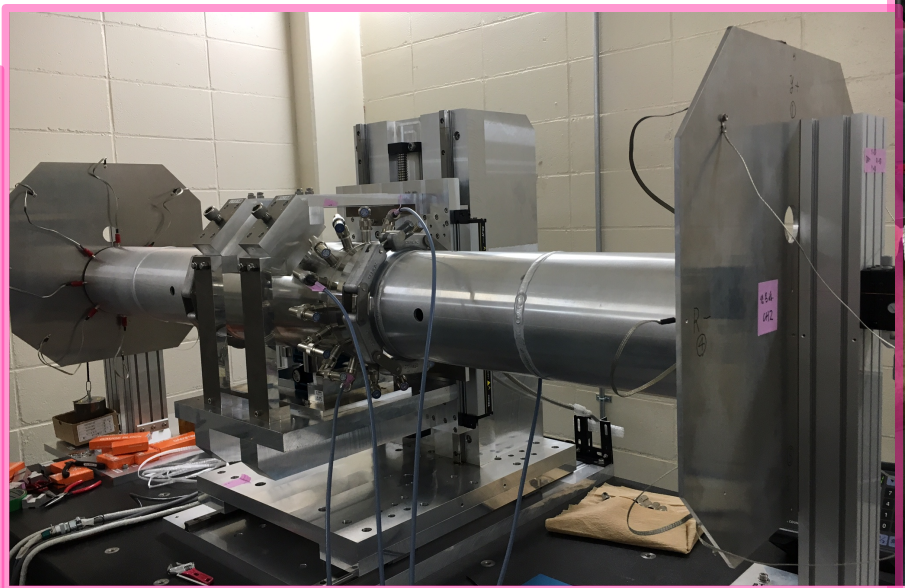
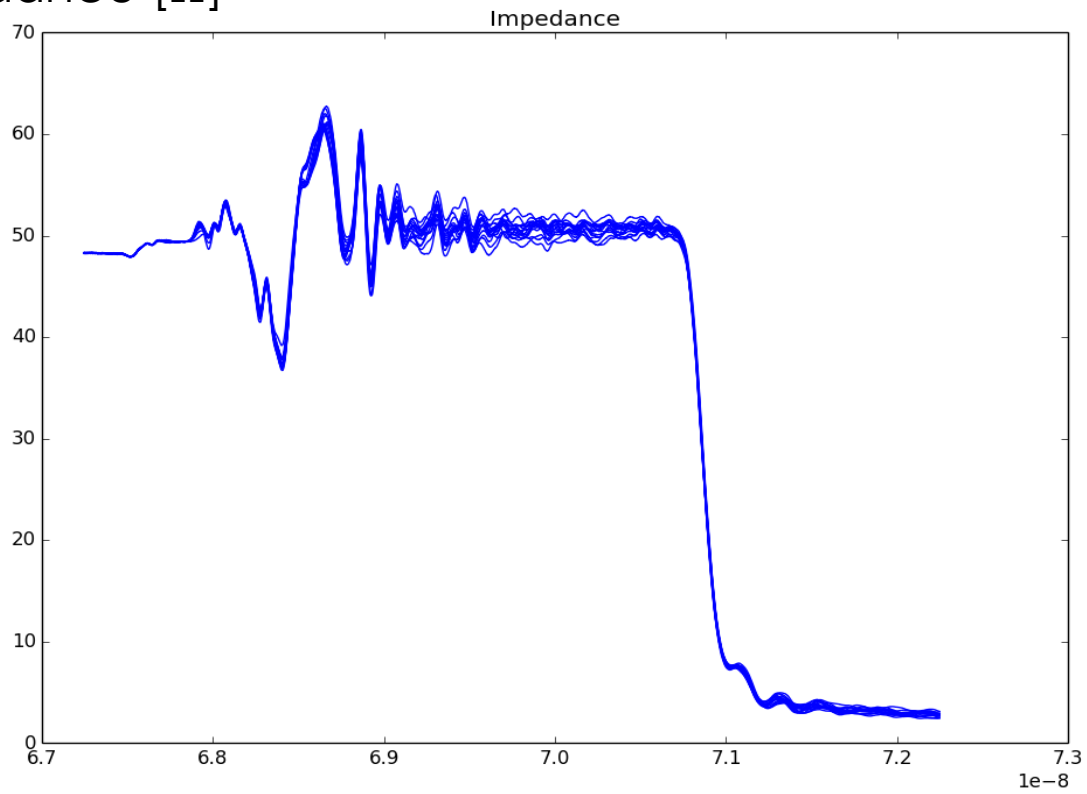


# Characteristic impedance

Impedance [Ω]




Time[s]

One electrode has fluctuation by 1ohm ~ 2ohm.
This comes from manufacturing error of groove or strip line electrode.

Error : width of electrode 400μm <-> impedance 1.2ohm (estimated by BEM)

# Calibration

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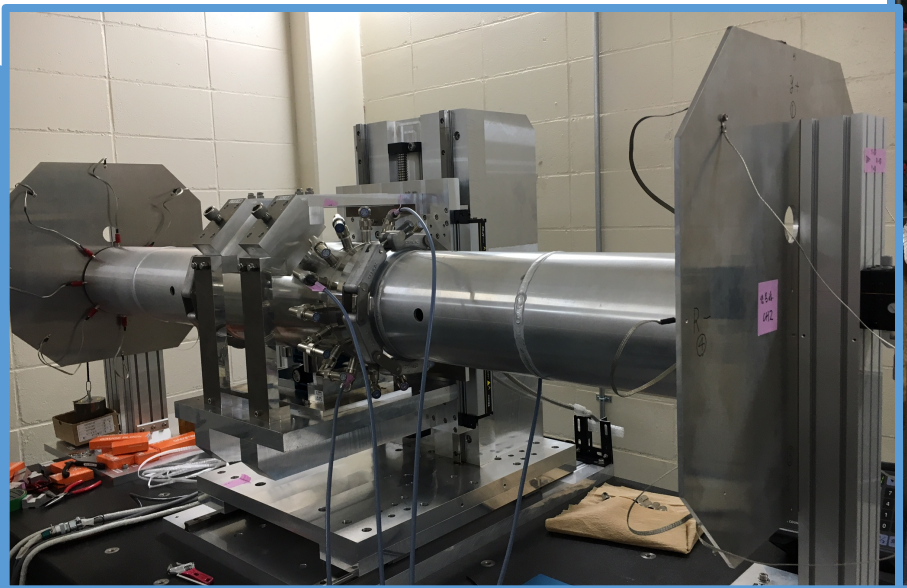


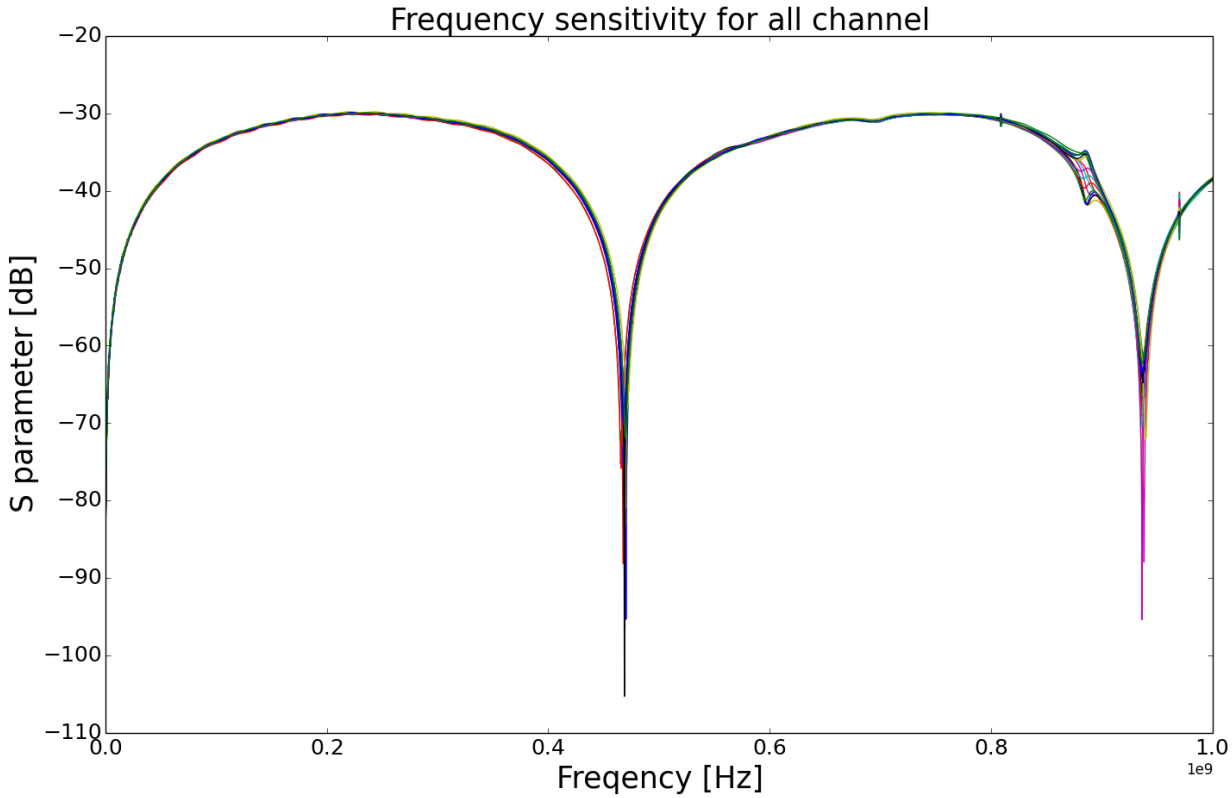
# Frequency sensitivity

**Method**

- Put a conductor into 16-PU
- Measure S-parameter (reflection) with network analyzer
  - Input: center tube, Output : upper stream end

**Conclusion**

- Almost all electrode have same sensitivity.
- Around 470(×n)MHz, the sensitivity dramatically decreases.

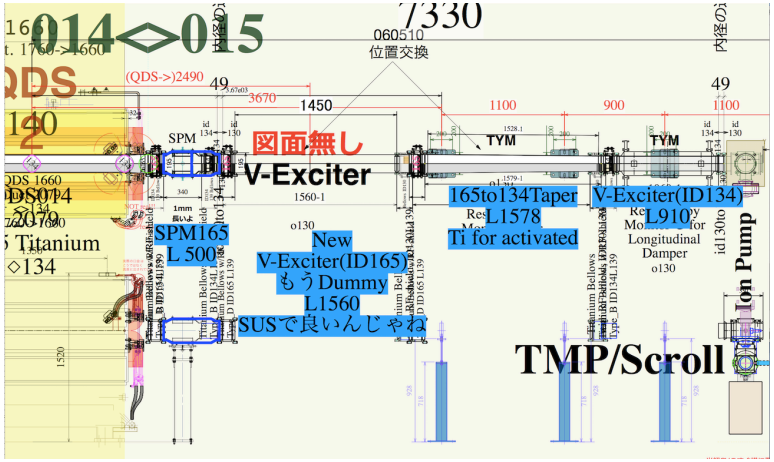


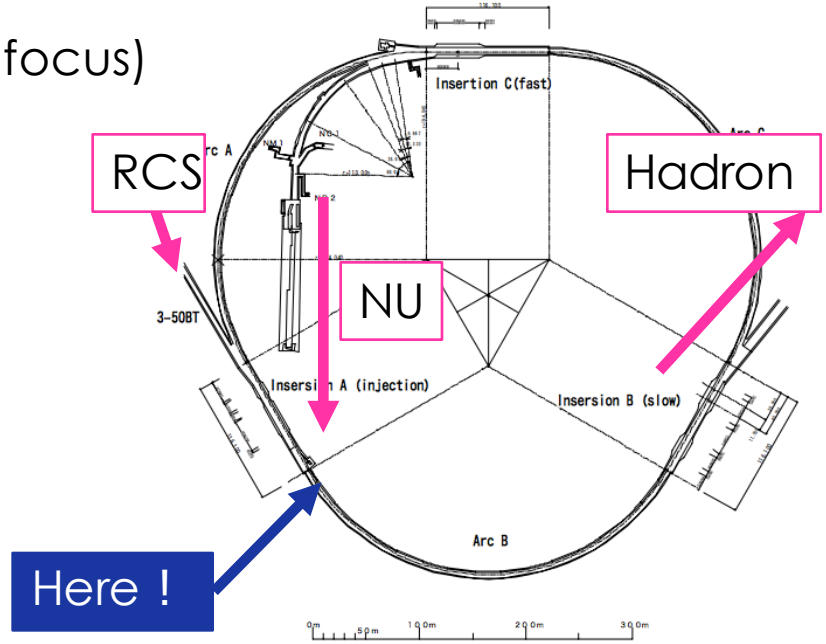
# Where the pick up is installed ?

- Place：MR #15

  the downstream from Q-magnet(defocus)

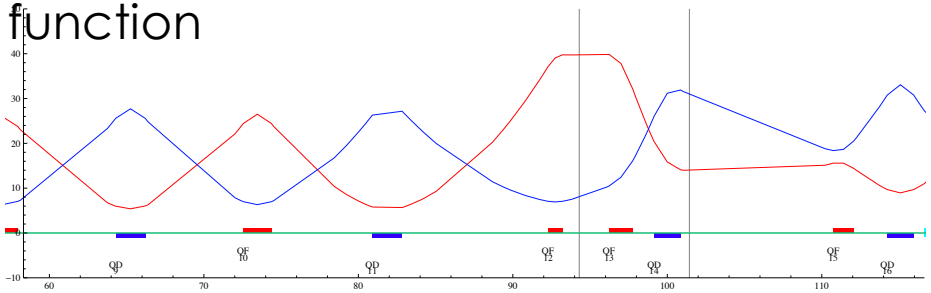
  just after tapered coupler BPM




- To measure beam just after injection
- The beta function @#15 is different from one @#13 where tapered coupler.

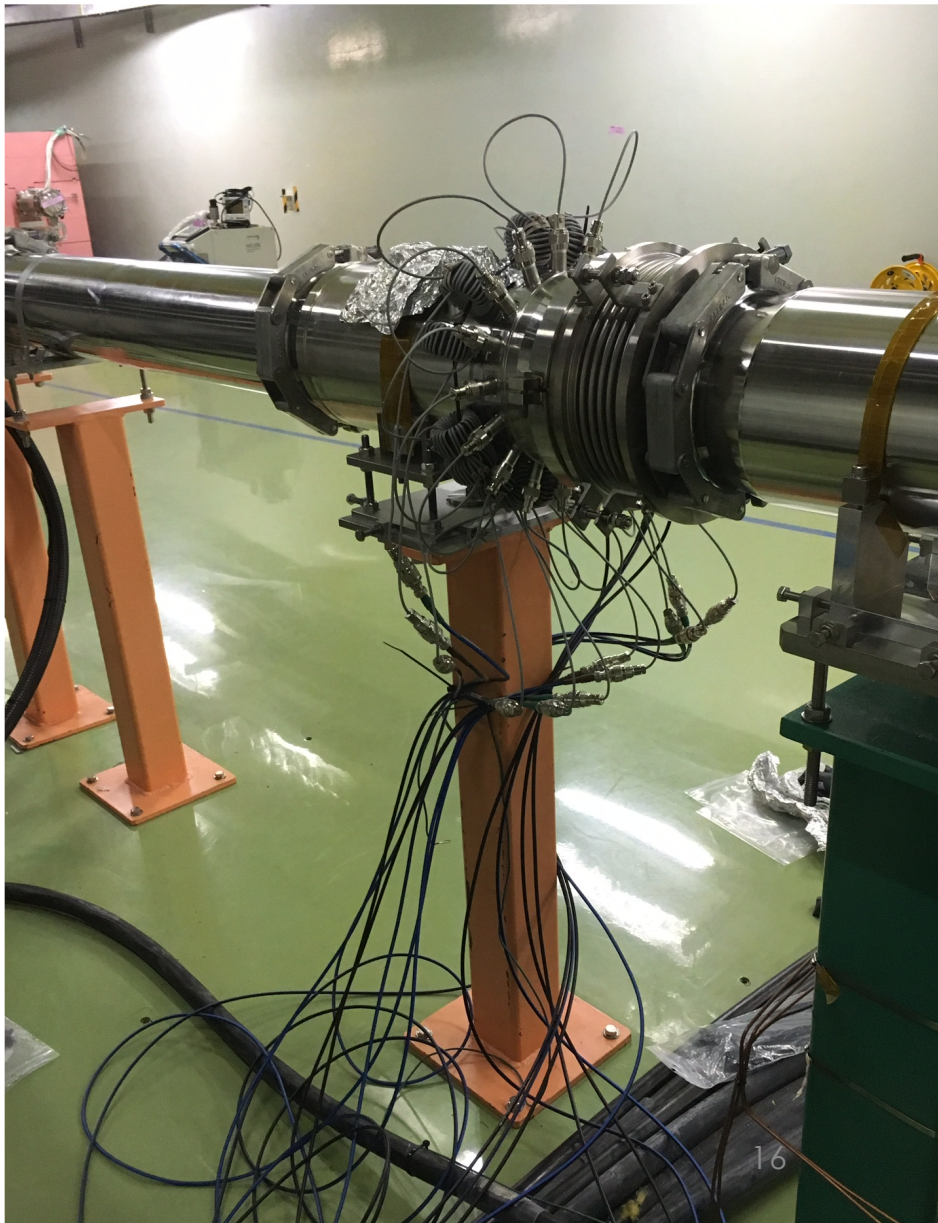
- beta function



--- : horizontal

--- : vertical

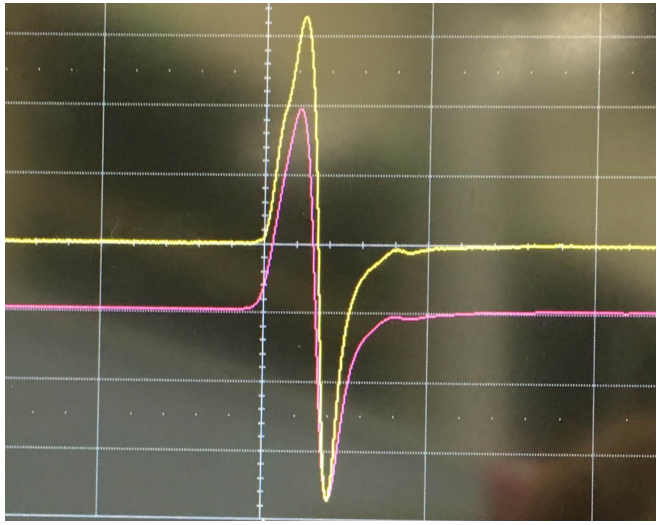
# Install to J-PARC MR(Pictures)



# Signal

## Detected signal

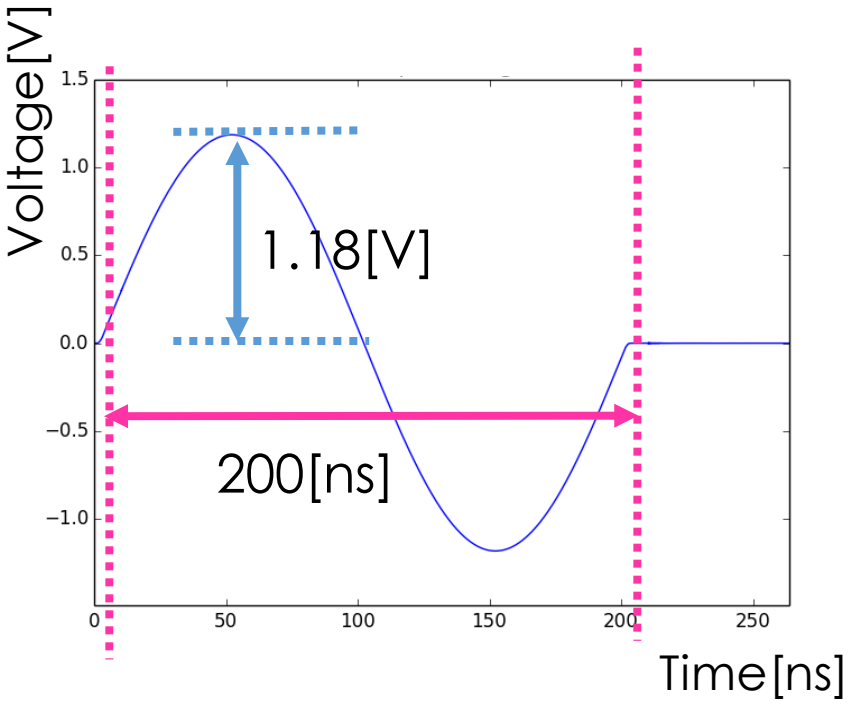
Beam intensity: ~$2\times10^{12}$proton/bunch
3.9kW



height~3V
width ~40ns

## Estimated signal by CST

Beam current height 40A,
Bunch width 200ns (~$10^{13}$proton)



# Conclusion

**Conclusion**

- 16-electrode is useful for measuring quadrupole moment.
  Reduce systematic and statistical error
- Developed the pick up and installed to J-PARC MR.
- Detected signals from the pick up.

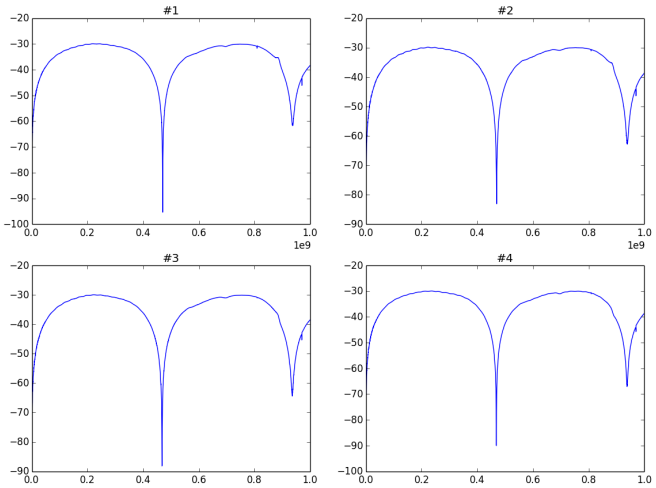
**Future Plan**

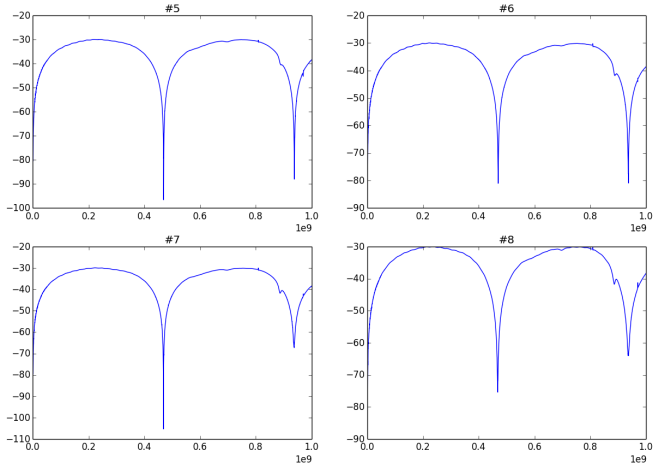
- Check the quadrupole moment using the signal by 16-PU.
- The injection mismatch will be measured by 16-PU.
- The beam size will be measured by 16-PU and 4-electrode pick up.

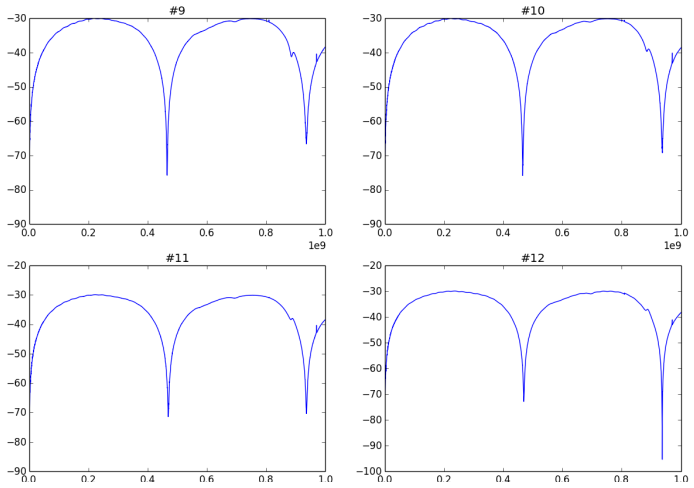
# BACK UP

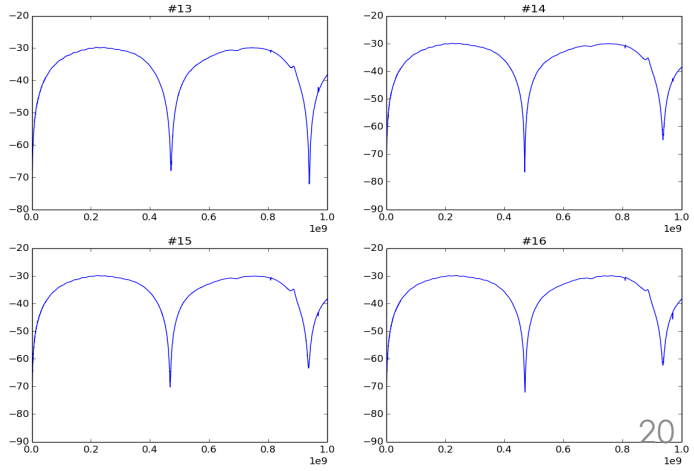
# High frequency characteristic (by taper pipe)

Horizonal axis : Frequency[Hz]
Vertical axis : S-parameter



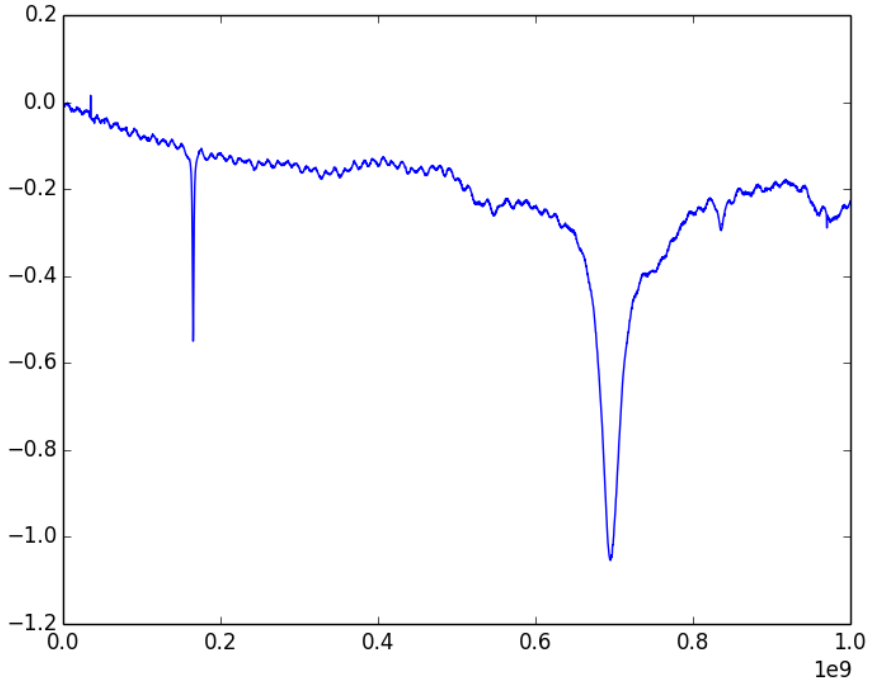



# High frequency characteristic (by taper pipe)

- S-parameter
  (Transmission rate through inner conductor tube)




Horizonal axis : Frequency[Hz]
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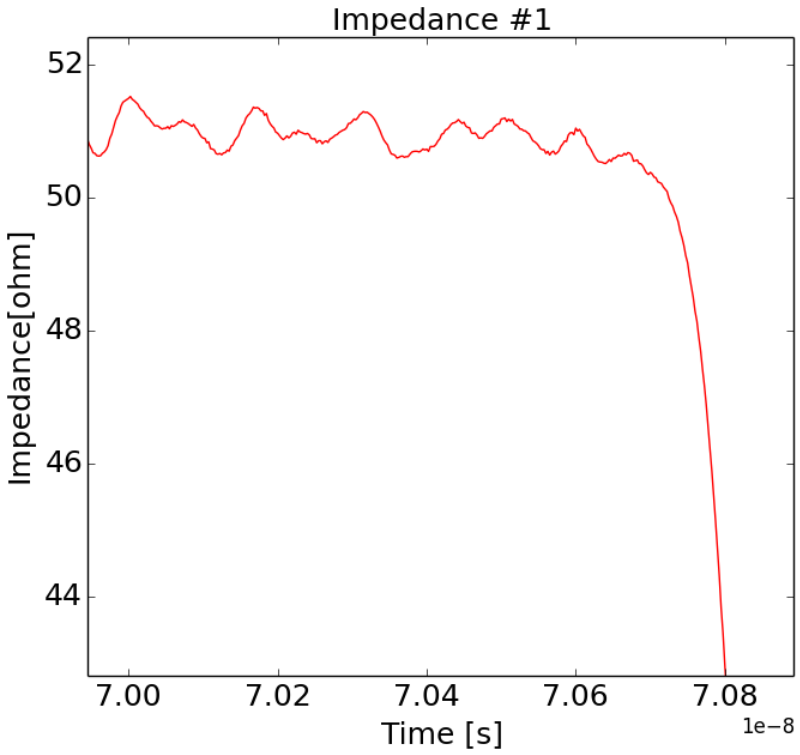
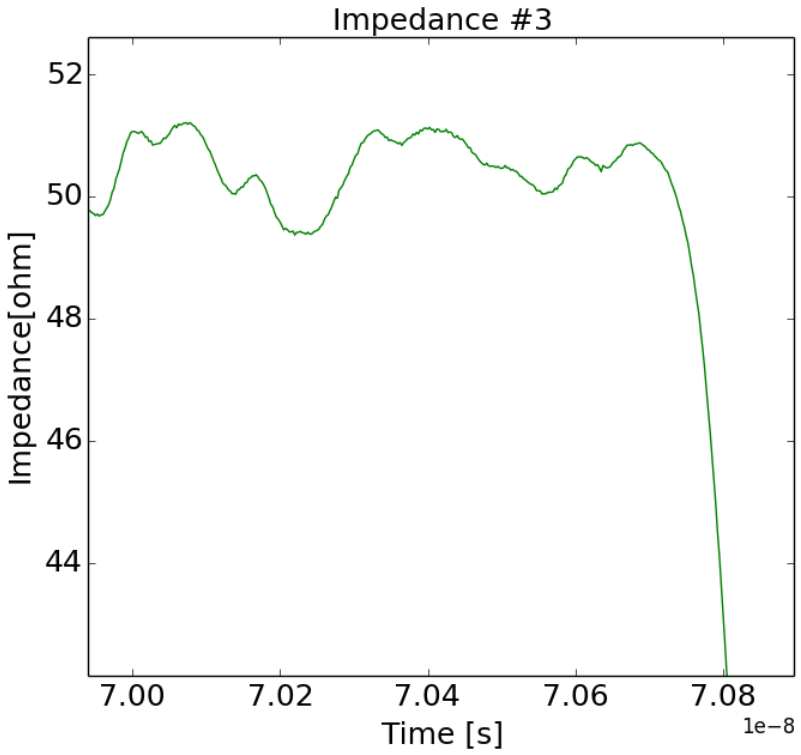
# Characteristic impedance

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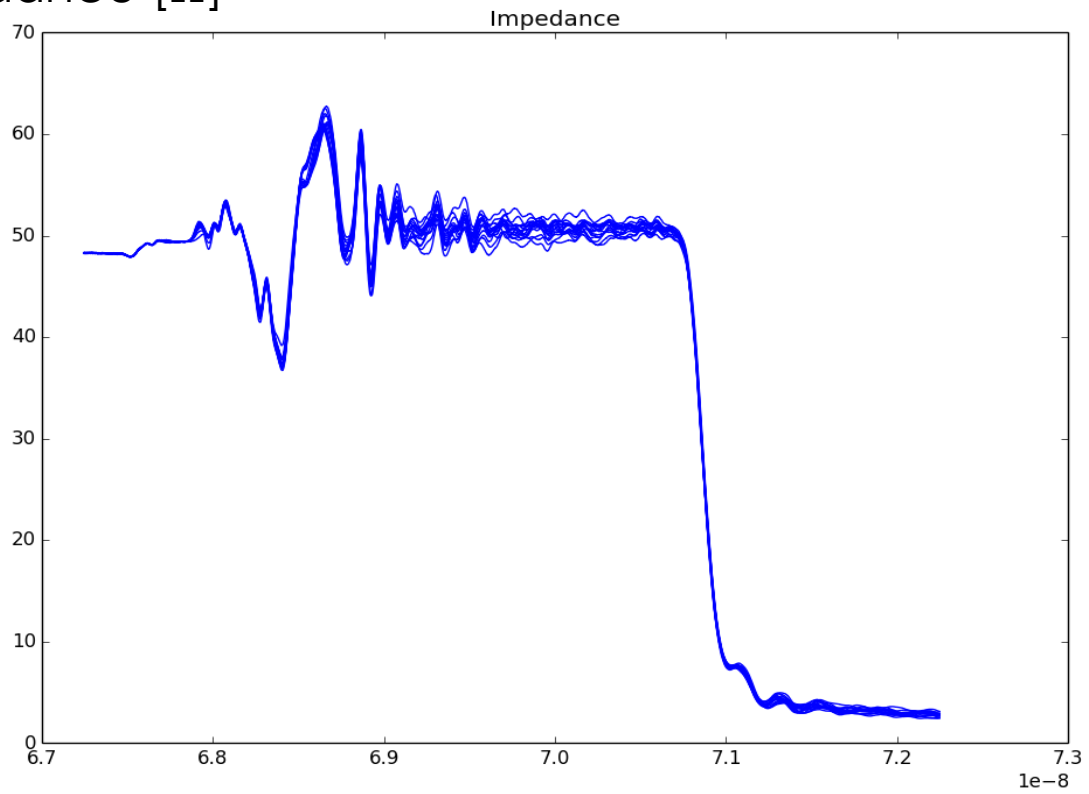
# Characteristic impedance

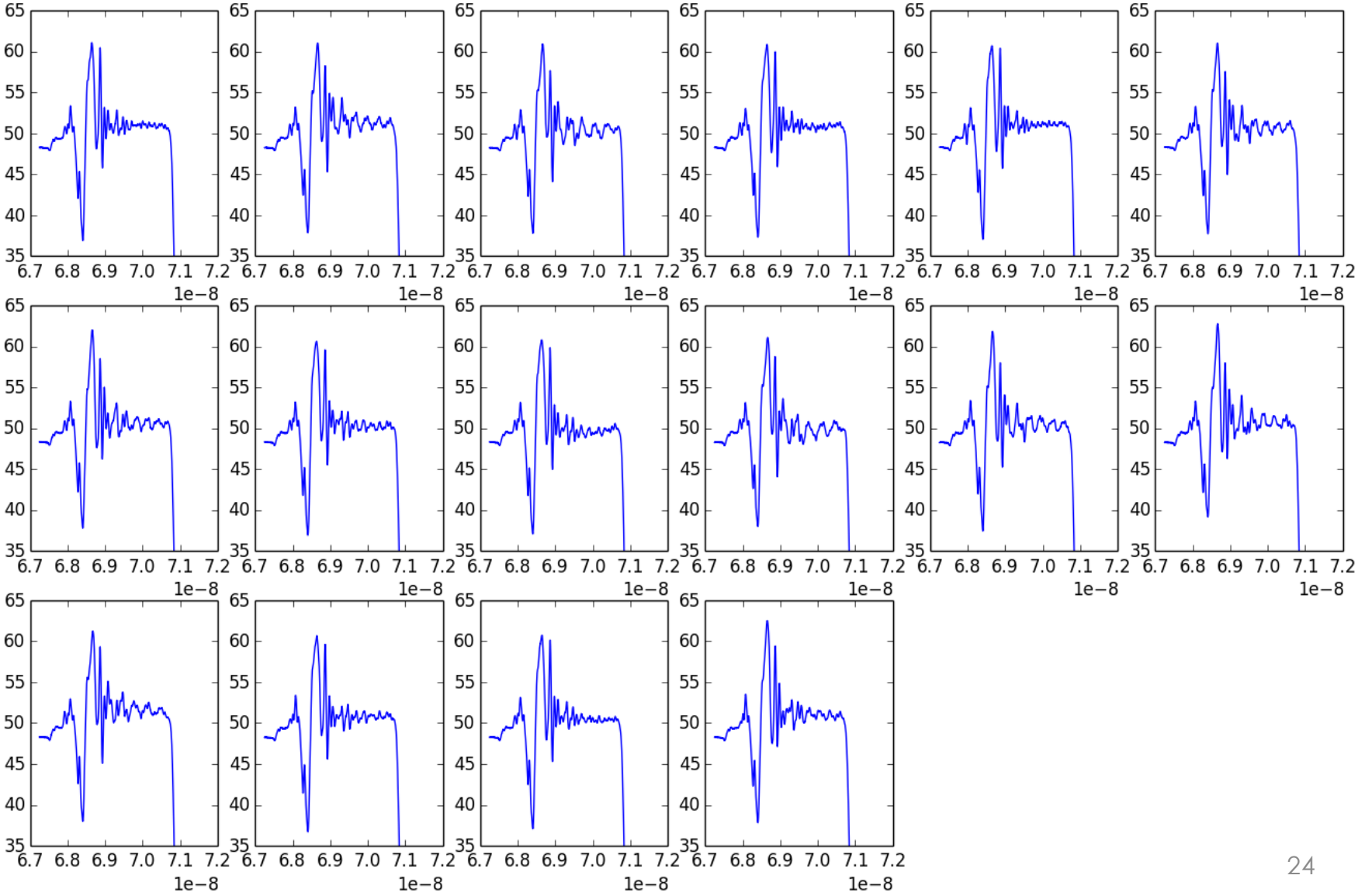
Impedance [Ω]



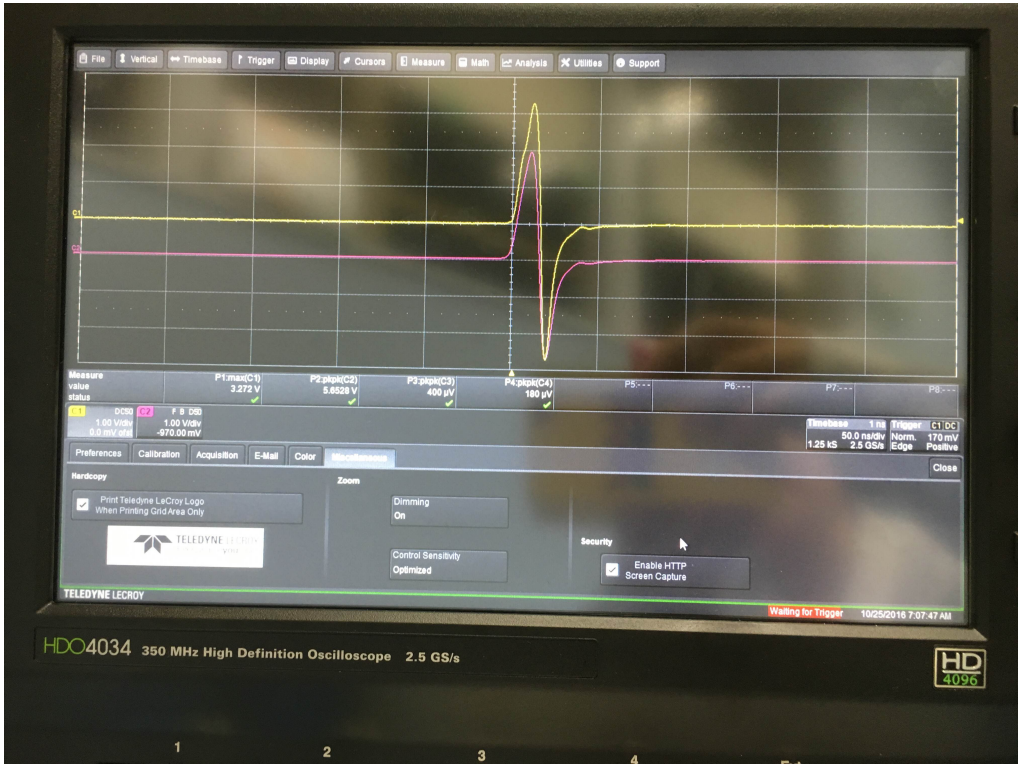

Time [s]

Impedance of one electrode fluctuates

# Characteristic impedance



# Waveform




**Shot No., Date&Time, BeamDest, N.Bunch, ChopWidth, thinning, DCCT1-P2, DCCT1-P3, MR PWR, MR Cycle, DCCT2-P2, DCCT2-P3**

Shot 374 at 10/25/2016 17:23:17.033 - Acc-Abort 1-bunch x 222 ns 8/32 Thinning 2.119e+12 2.038e+12 3.94 kW 2480 ms 2.196e+12 2.106e+12

# Calibration of quadrupole moment