# BPM and bunch feedback systems

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for SuperKEKB Beam Instrumentation Group

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  - Gated turn-by-turn monitor
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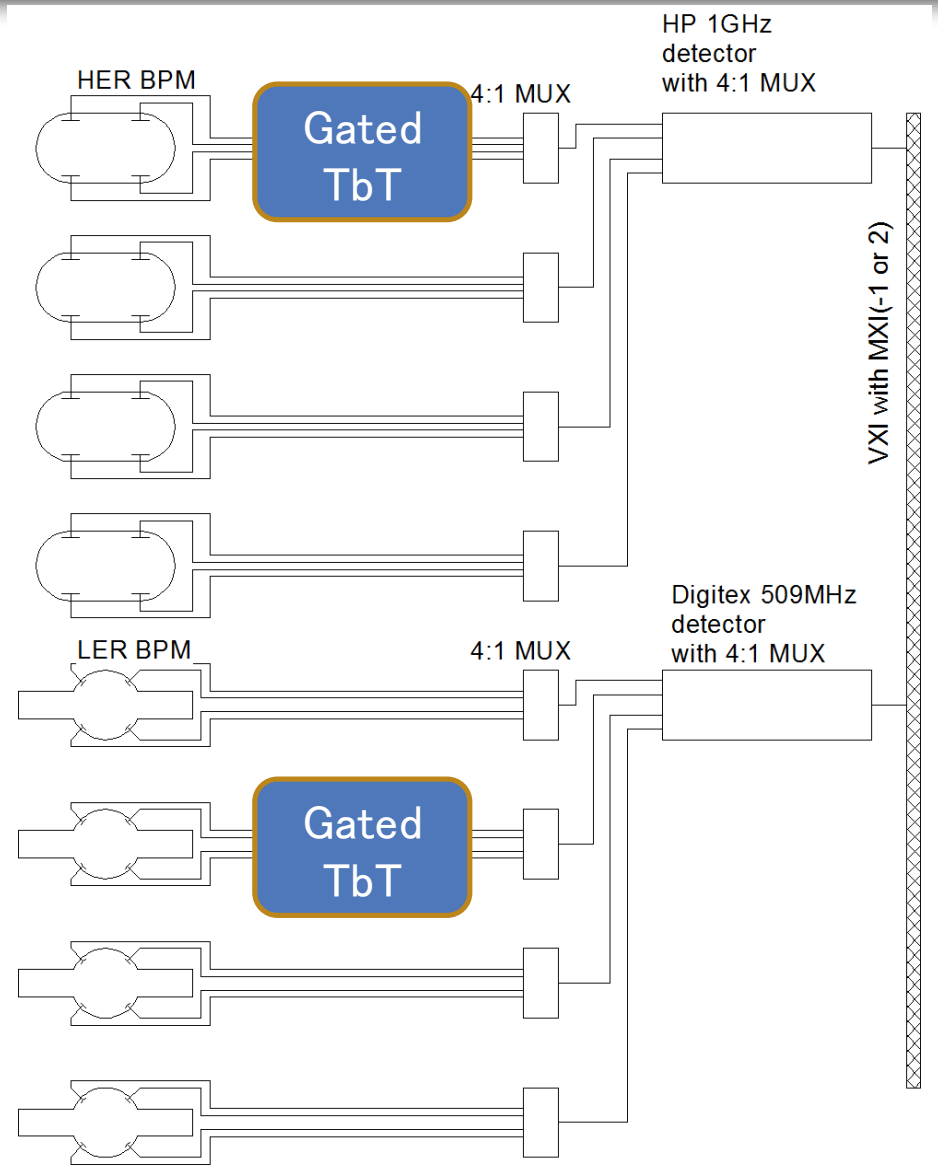
# Introduction

| System | Quantity | | |
|---|---|---|---|
| | HER | LER | DR |
| Beam position monitor (BPM) | 466 | 444 | 83 |
| Displacement sensor | 110 | 108 | 0 |
| Transverse bunch feedback system | 2 | 2 | 1 |
| Longitudinal bunch feedback system | 0(1) | 1 | 0 |
| Visible SR size monitor | 1 | 1 | 1 |
| X-ray size monitor | 1 | 1 | 0 |
| Beamstrahlung monitor | 1 | 1 | 0 |
| Betatron tune monitor | 2 | 2 | 1 |
| Beam loss monitor | 200 | | 34 |
| DCCT | 1 | 1 | 1 |
| CT | 1 | 1 | 0 |
| Bunch current monitor | 1 | 1 | 1 |

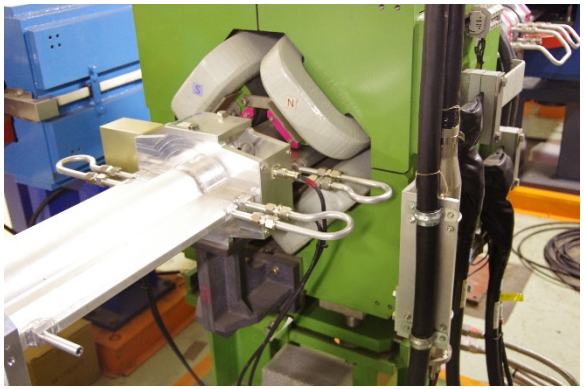
# Configuration of main BPM system




- **Separate HER and LER BPM systems.**
  - Cutoff freq. of LER chamber lower than 1GHz (989MHz).
- **Continue to use VXI system with MXI (1/2) connection.**
- **Selected 270 BPMs have gated turn-by-turn monitoring function.**
  - By Phase 1 : A total of ~110 G-TBT will be installed.

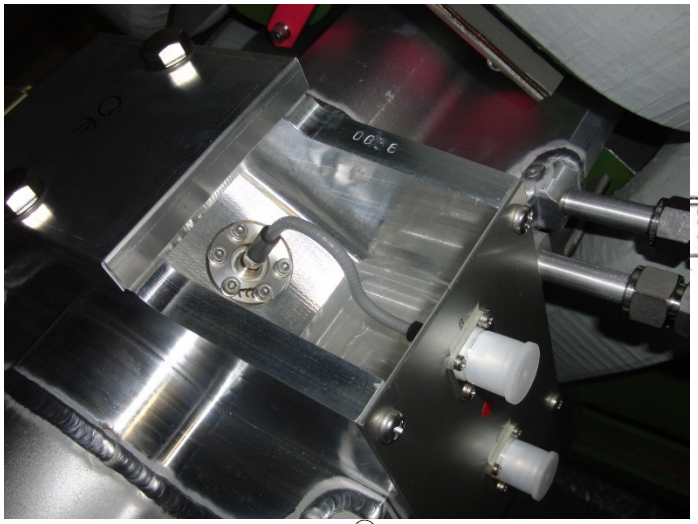
# Beam position monitors

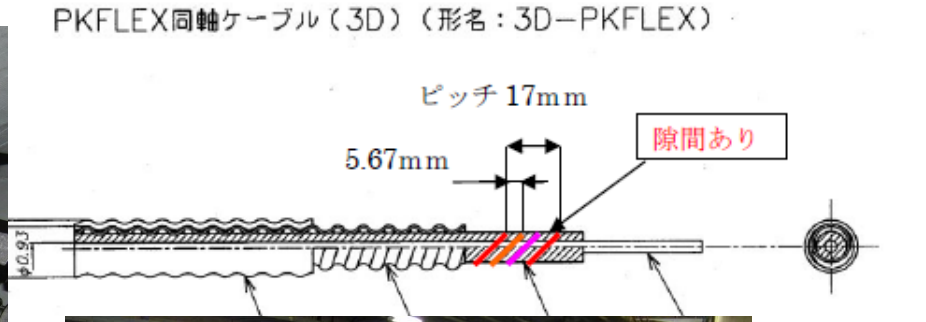
- All button electrodes have been fabricated, and most of them (except several special sections) have been installed in the tunnel.
- Cabling work and re-installation of the BPM cables are in progress and are expected to be finished by Sep/2014.
- All VXI main frames have been renewed and re-installed.

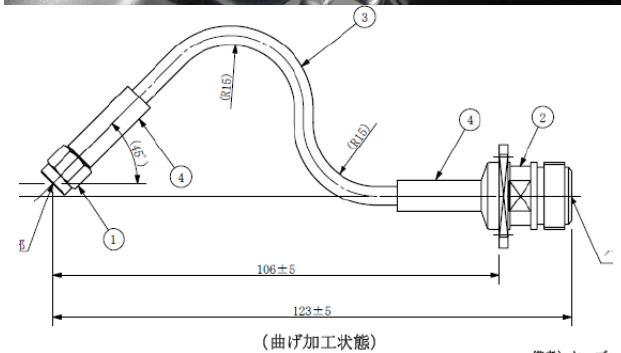


# Pigtail cable difficulties

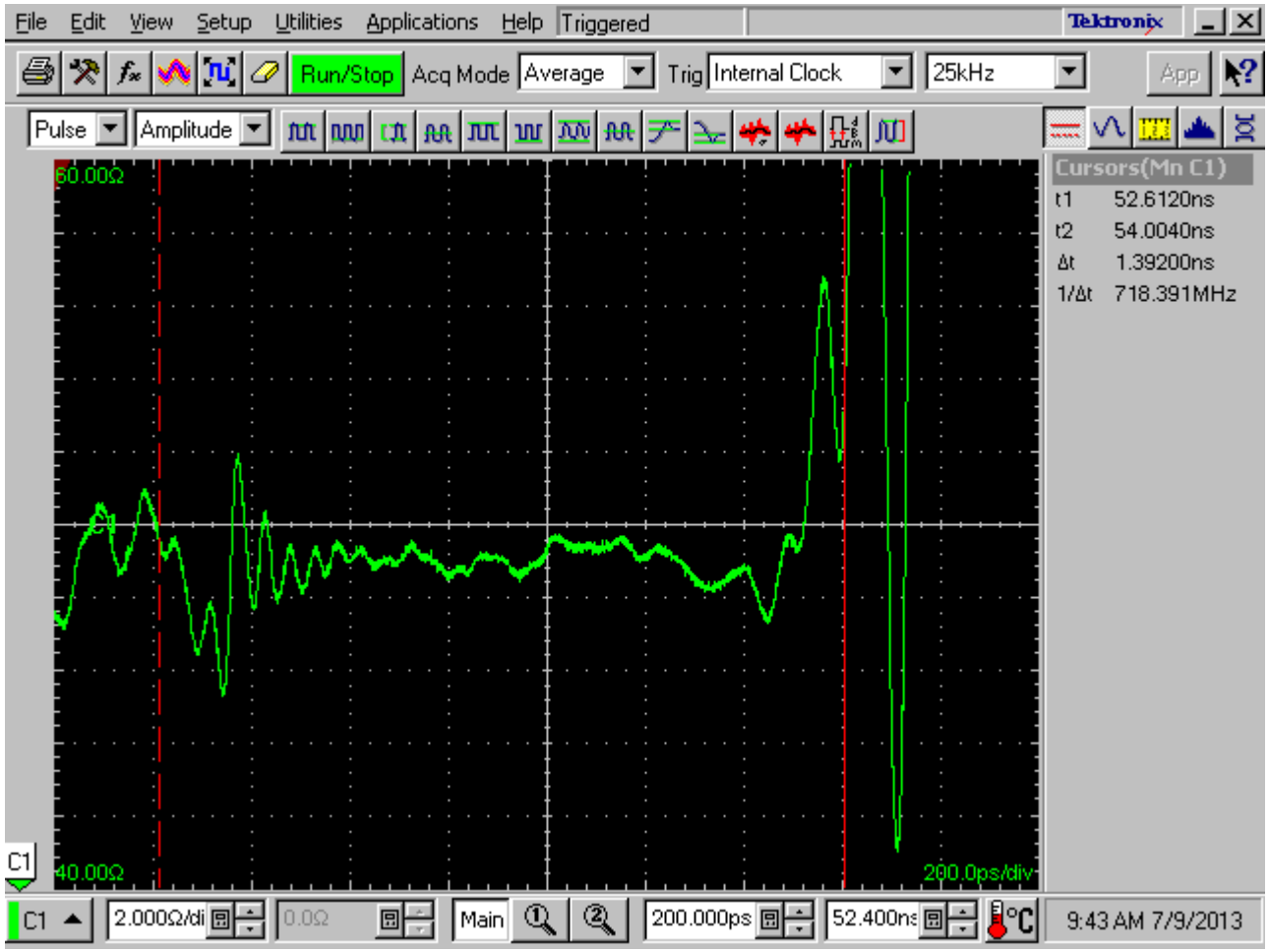
- **Many cables had failed on the insulation resistance check, one had shown short-circuit.**
  - Checked all the BPMs using TDR.





# Good (acceptable) TDR

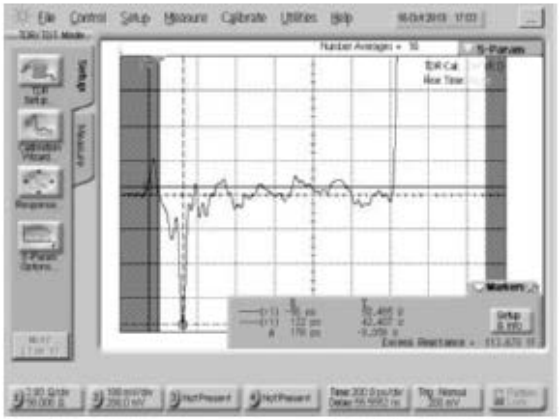


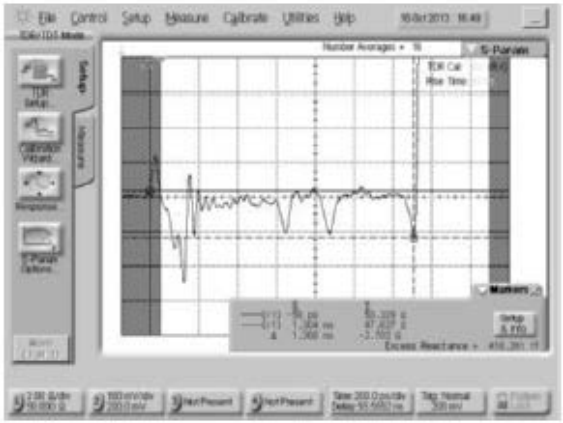
# SMA connector not in good contact

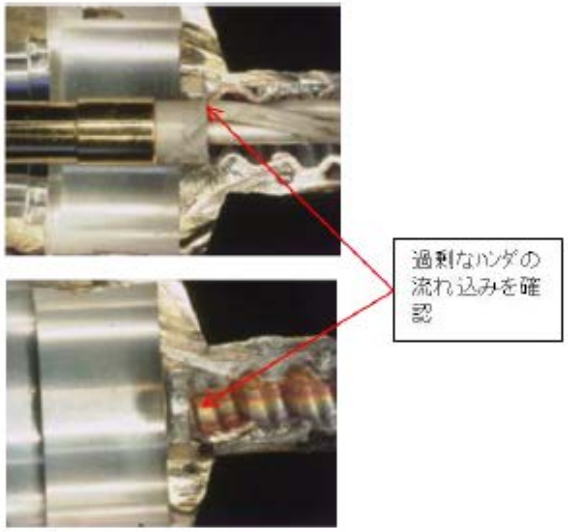
# Damaged cable

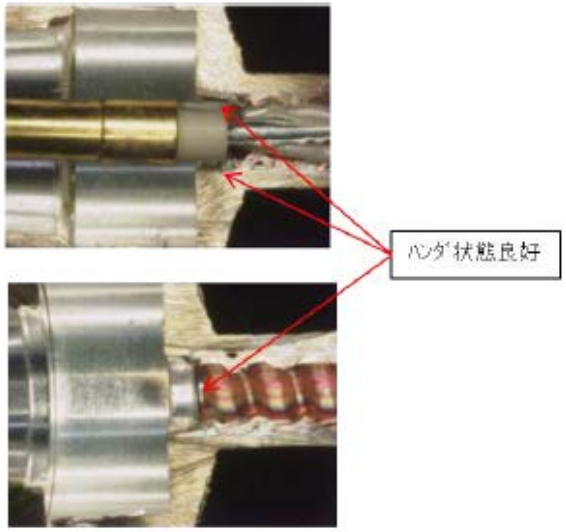
# Near SMA connector (or FT?)

# Soldering fault in connector







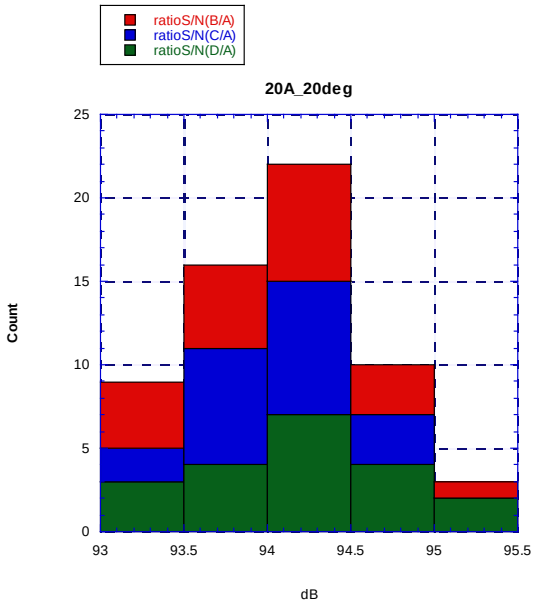



# Measure

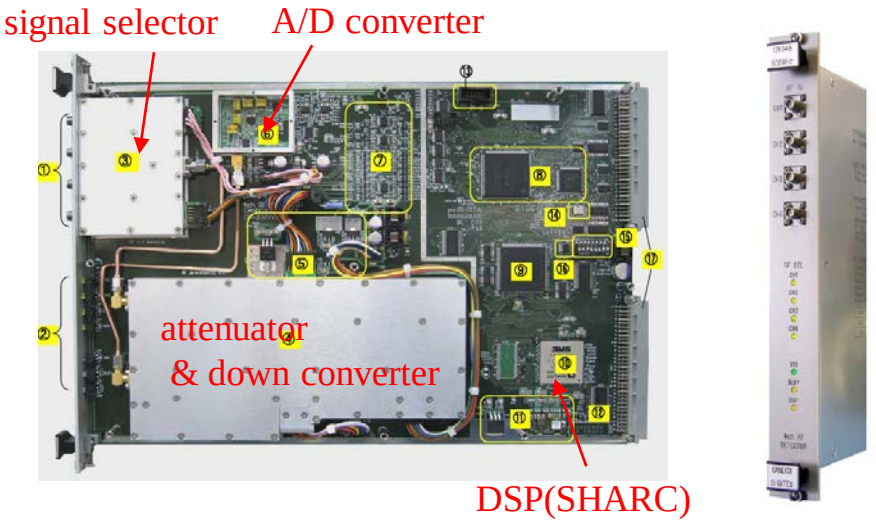
- **Take great care of handing the cable!**
- **Check all the new pigtail cables using TDR when arrived KEK.**
  - Still 6 out of 600 cables had failed recently, though.
- **Improvement of soldering control for the connectors.**
  - New insulators to protect invading the unnecessary solder to the connector.

# 509MHz narrowband detector

- 120 Narrowband(509 MHz) detectors have been arrived.
- Ratio S/N's have been confirmed to be better than 90dB.

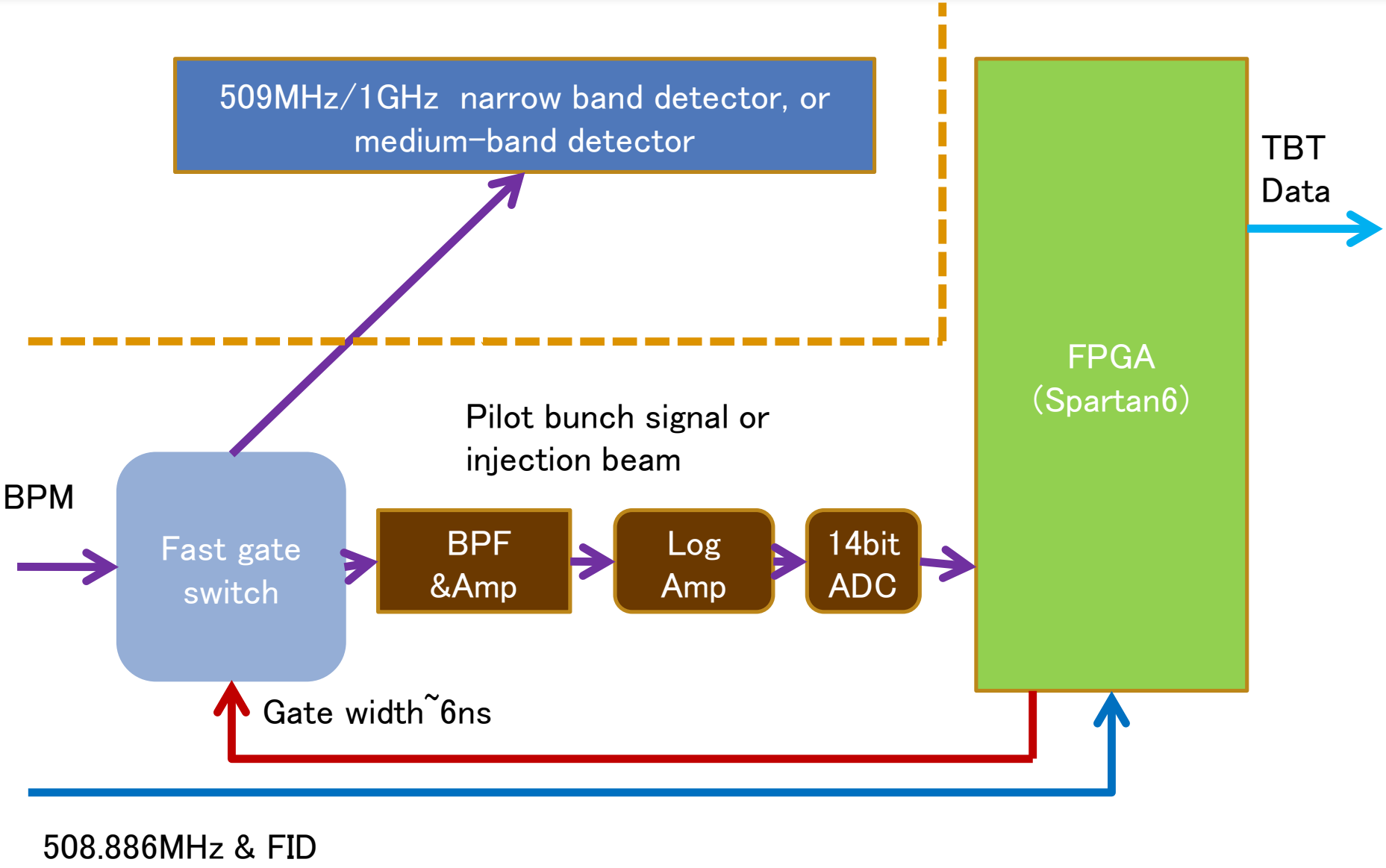



Ratio S/N of first 20 modules




A 509 MHz narrowband detector

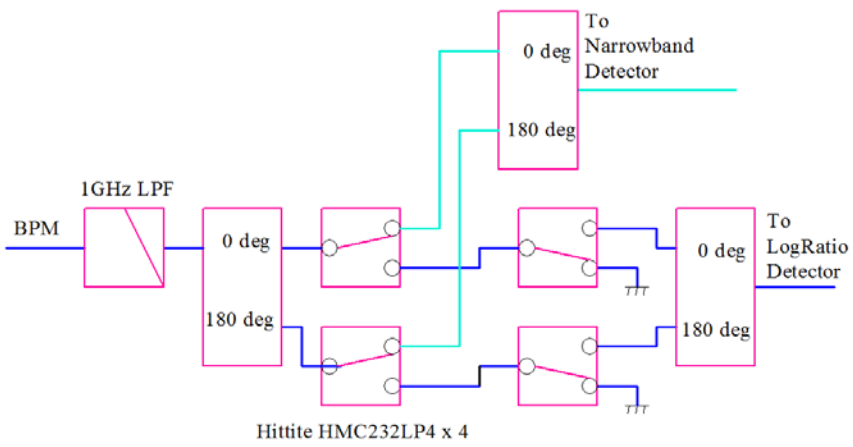
# Gated turn-by-turn monitor

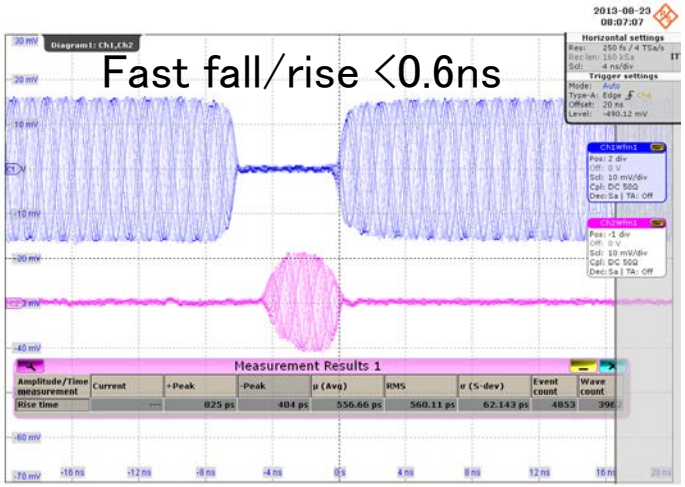


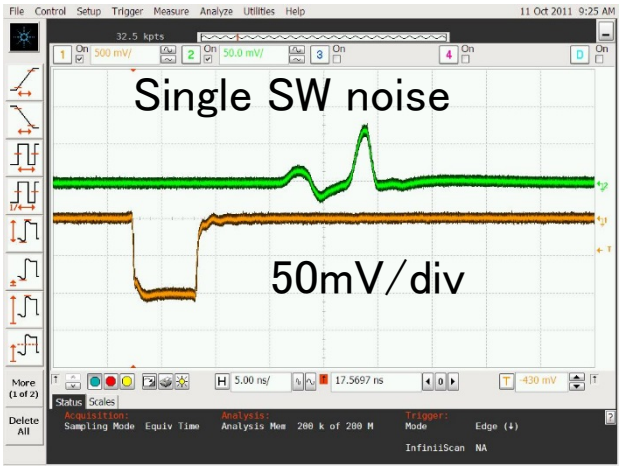
# 117 units will be ready

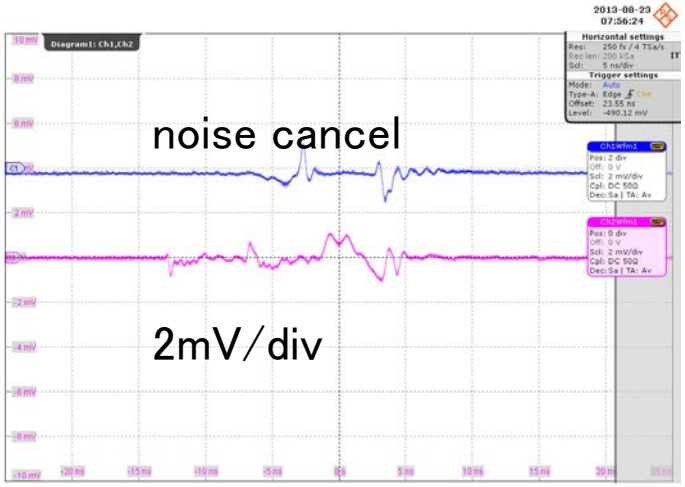

1U size
4ch Noise cancelling fast switch
GbE Ethernet connection

# Noise cancelling fast gate

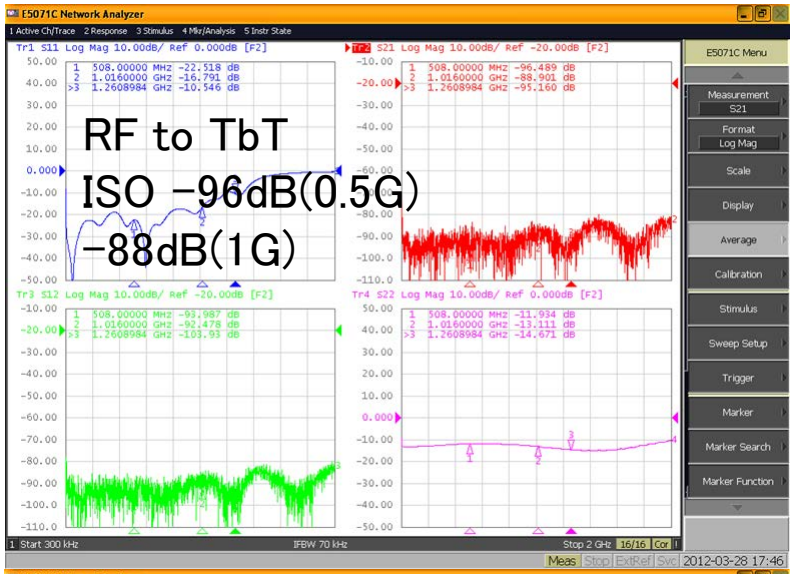


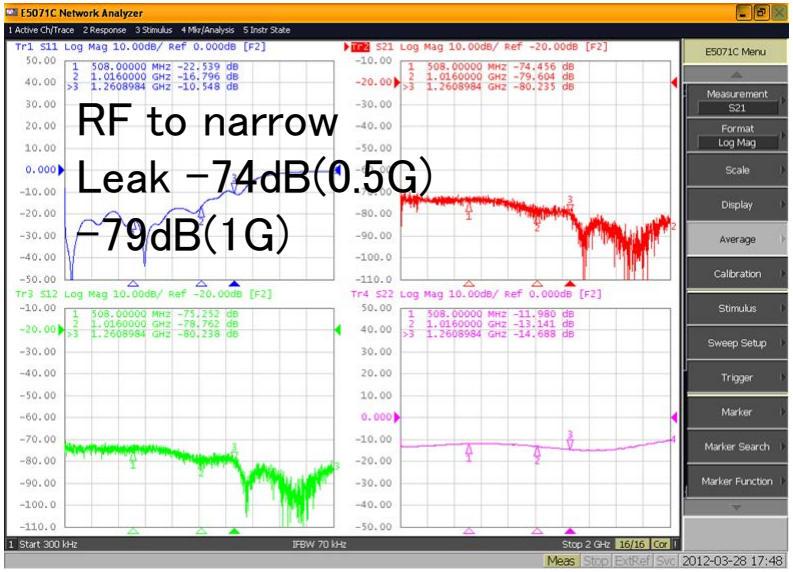



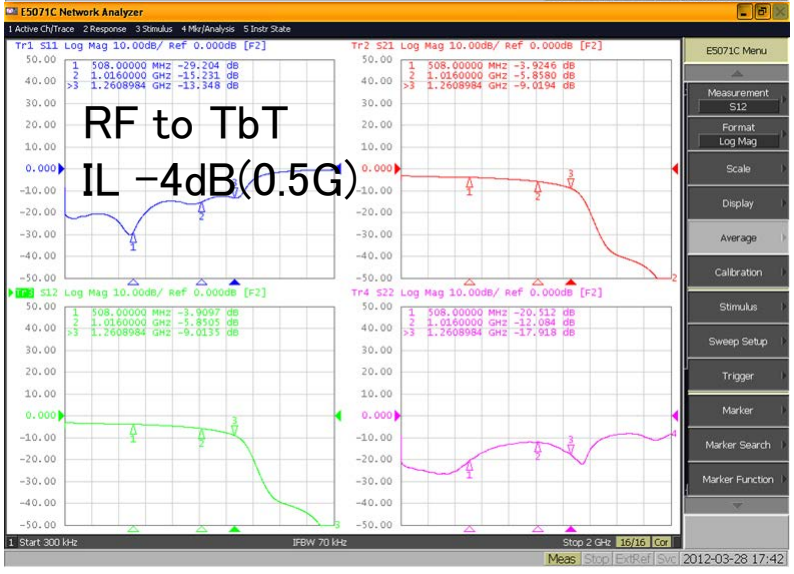



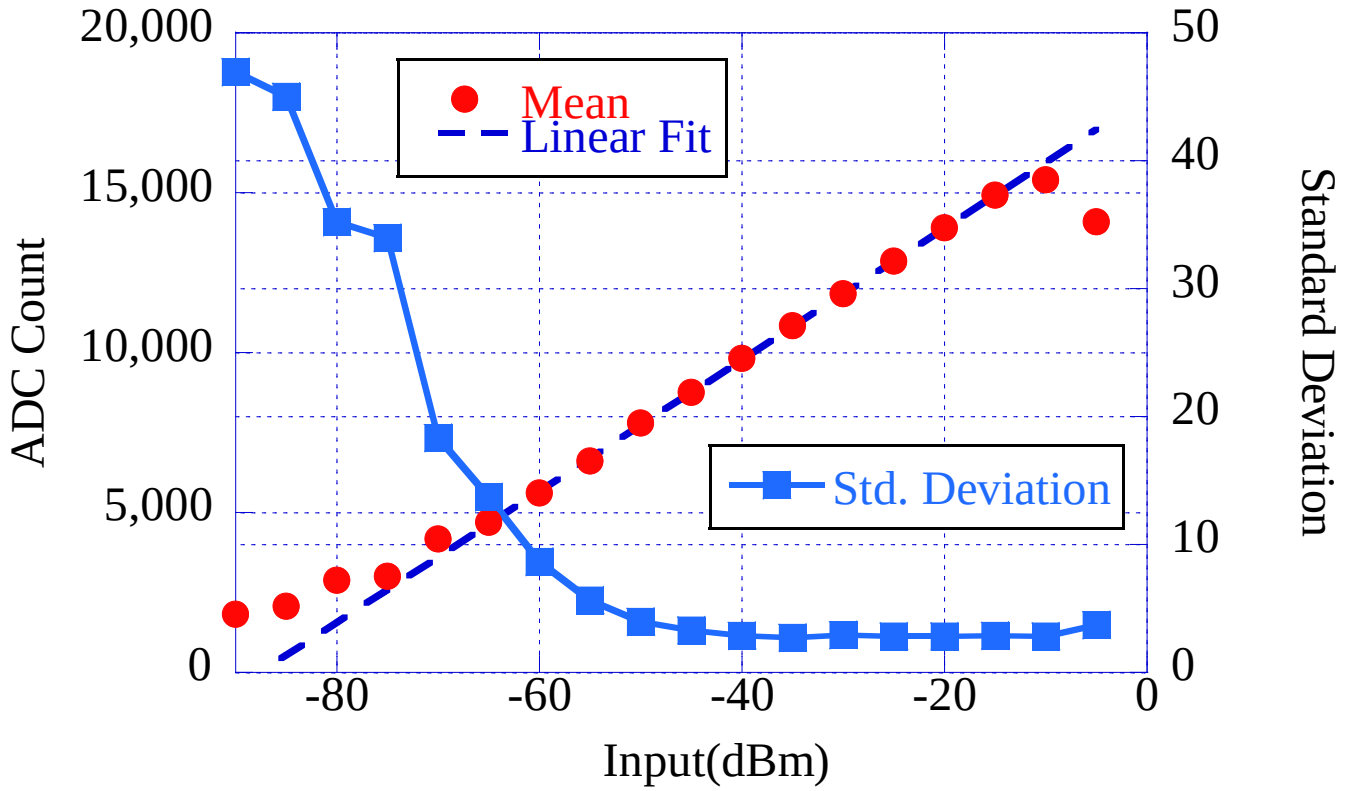
# Good isolation(>80dB)

# Position error




Standard deviation of ADC from −50dBm to −10dBm corresponds roughly 30um of position jitter.

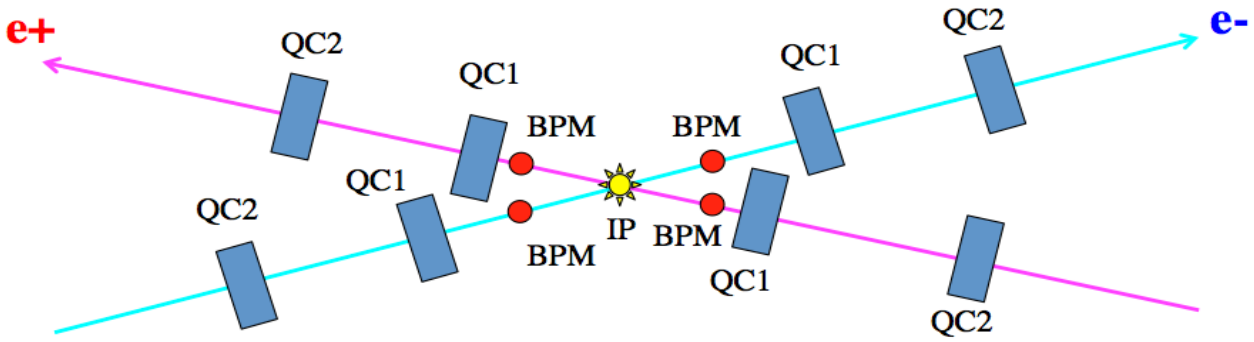
# FPGA FW and EPICS device support

- **FPGA(Spartan6 XC6LX100T-3FGG484)**
  - Gate timing : 508MHz counter delay+width(with ext. D-FF re-sync) x 4ch. Position within ±6ps, Jitter <3.3ps in sigma.
  - Data acquisition for 14bit ADC(4ch) (+ADC timing)
    - External DDR3 memory for longer data storage.
    - Simple position calculation.
  - Housekeeping measurements (temperatures, voltages, etc.)
  - Ethernet control
    - SiTCP for ultra-fast data transfer (400MB/s).
    - UART connection for debug use.
    - Online firmware update function without JTAG connection.
- **Direct TCP/IP (and UDP) connection.**
  - Semi long-term (accelerated) load test.
    - Fixed several bugs in both FPGA firmware and device support.

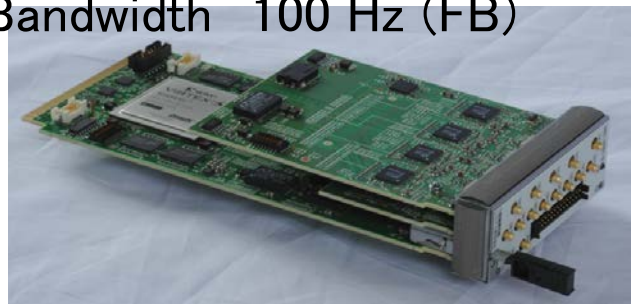
# Fabrication

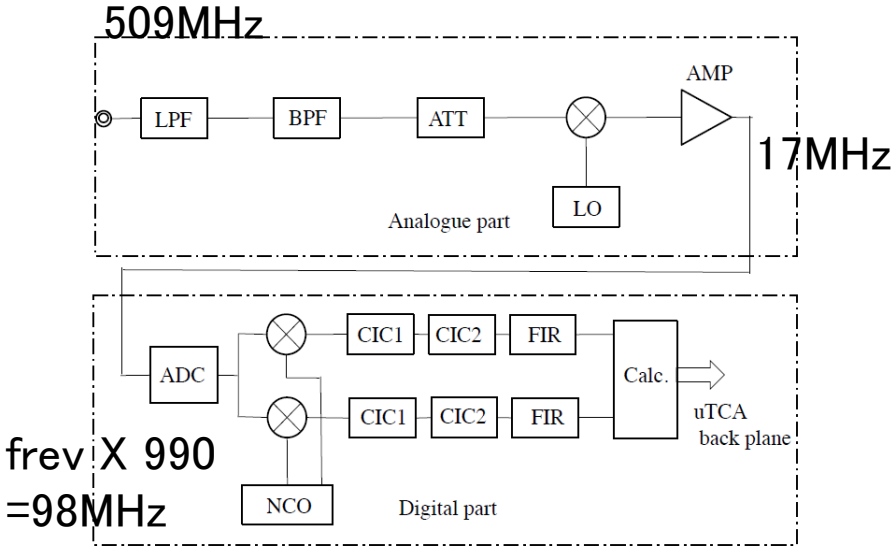
- A total of 117 units will be ready by the start of Phase 1 operation.
- Fulfillment of other ~150 units depends on the budget.

# IP orbit feedback detector

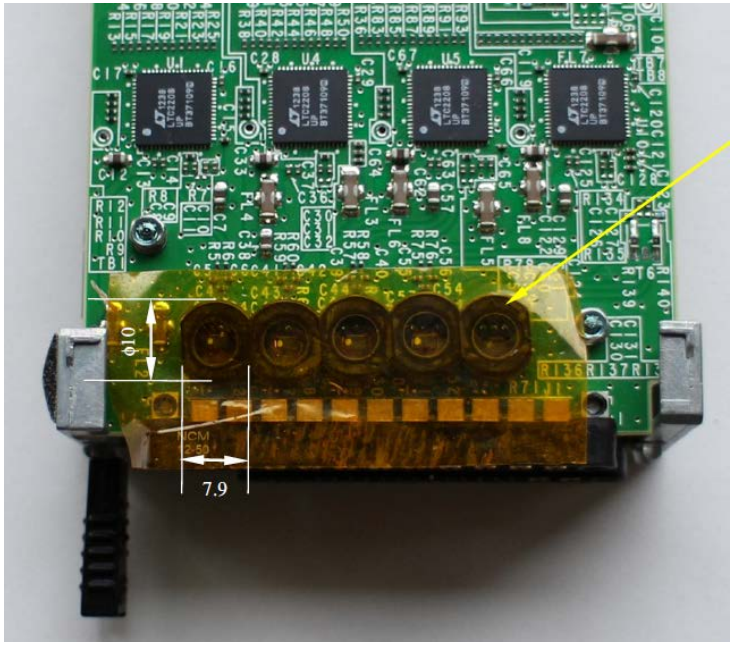



- **Tentative specification**
  - Resolution <1um
  - Repetition 5 kHz
  - Bandwidth ~100 Hz (FB)

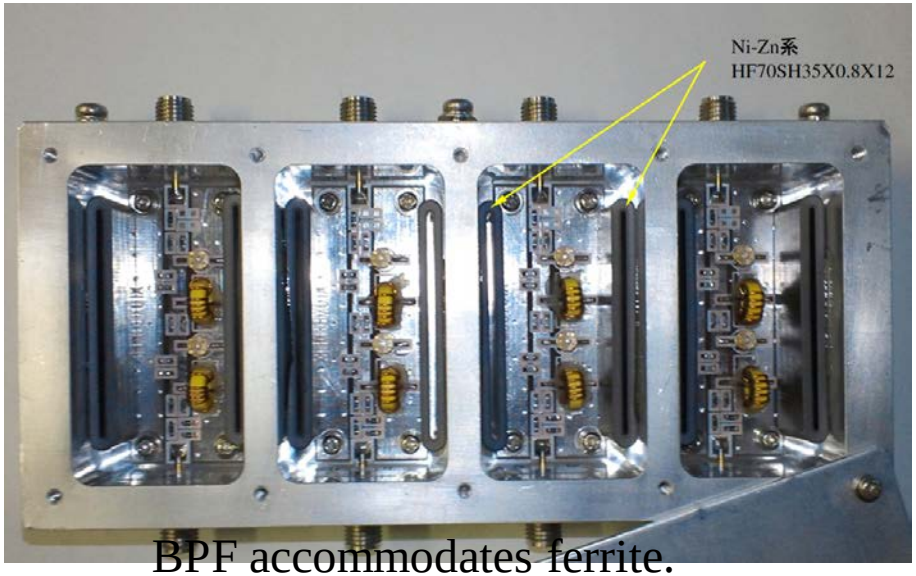




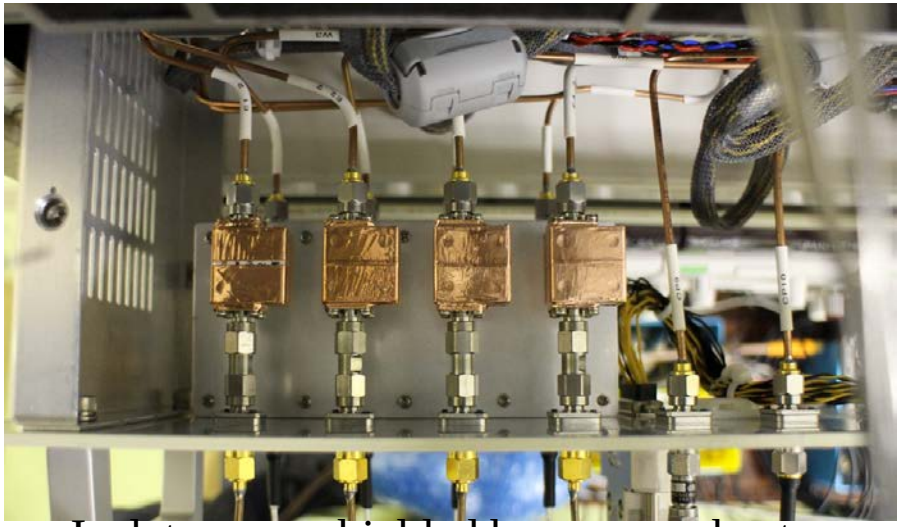
# Suppression of crosstalk




Transformers and a balun at input ports are covered by ferrite cores.

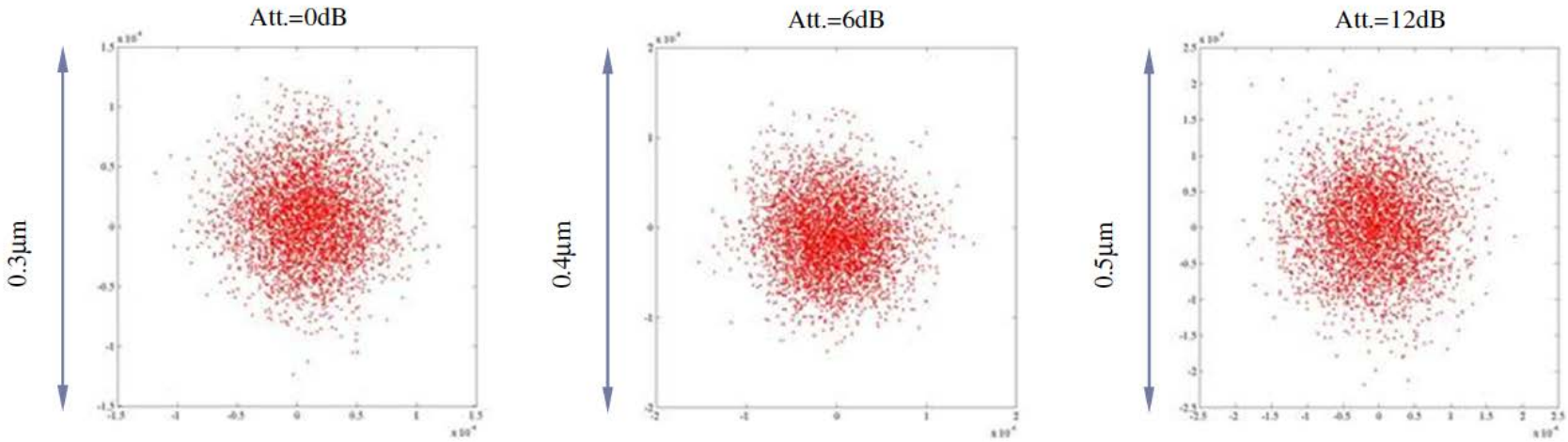



BPF accommodates ferrite.



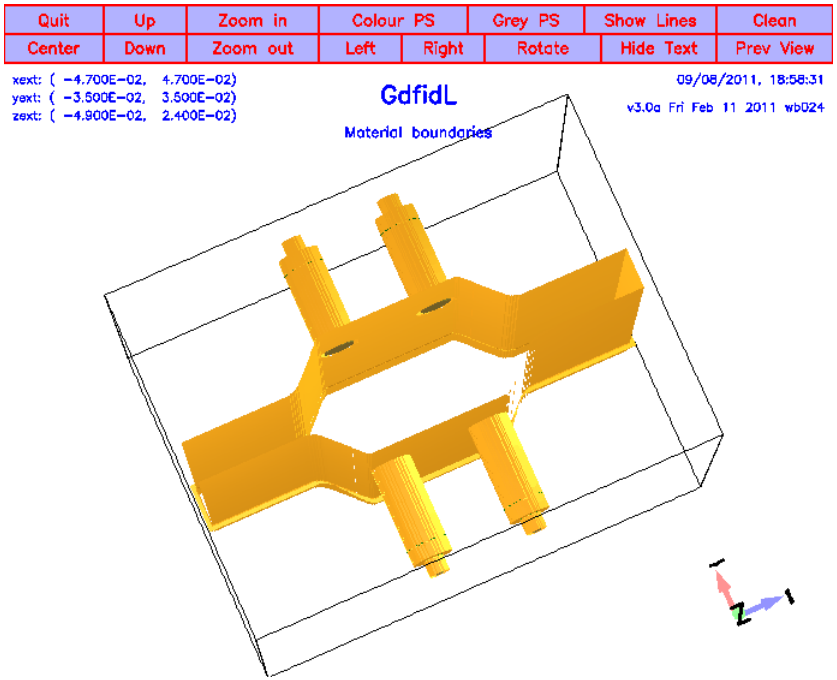
Isolators are shielded by copper sheets.

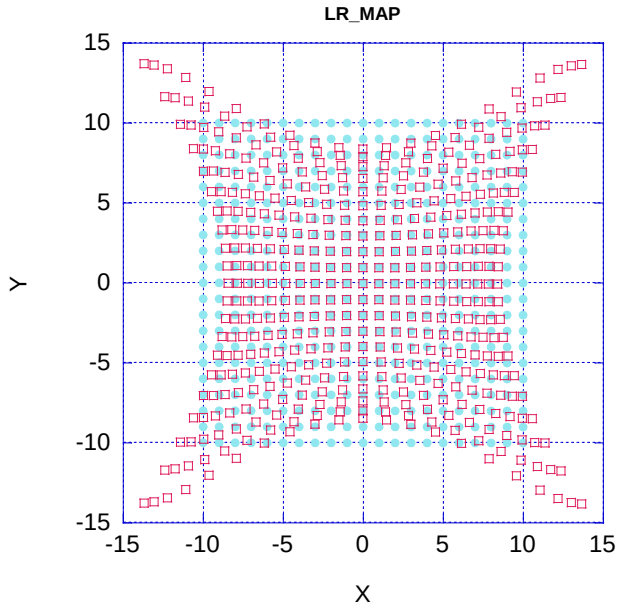
# Position resolution

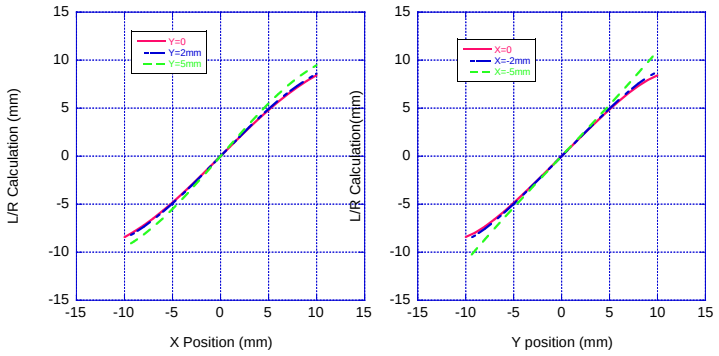



- R&D of a down-converter has completed. Ready to fabricate (scheduled on FY2015).
- Power supply controller (PS I/F) is in design stage and a prototype will be made in FY2014.

# Damping ring BPM

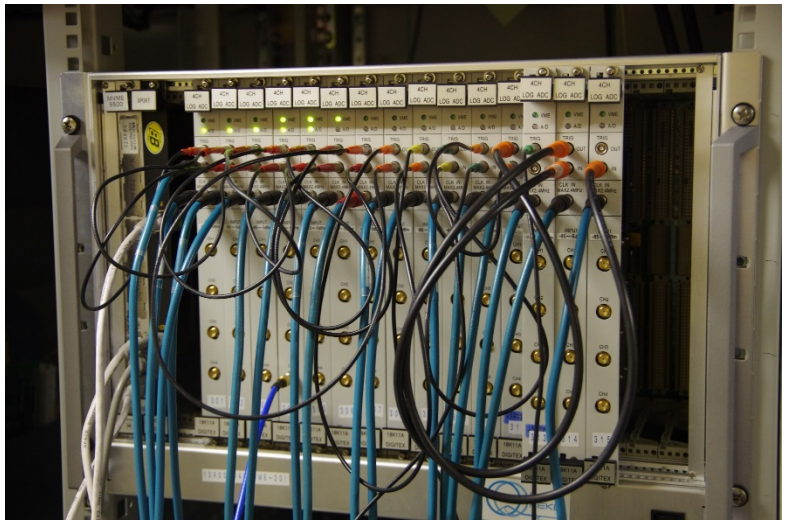


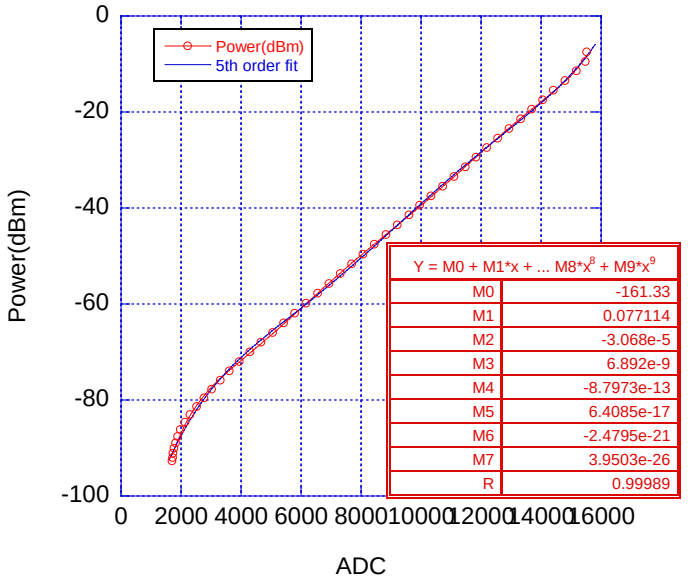



# Damping Ring BPM

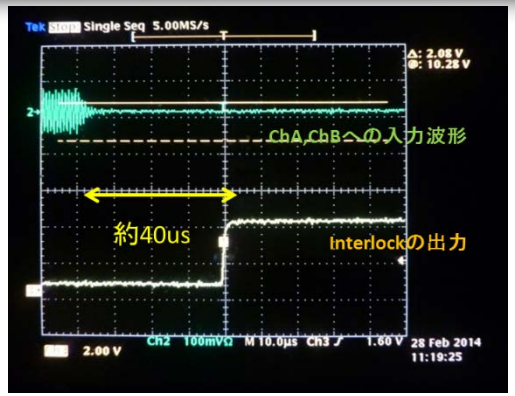
- **VME-based L/R detectors have been fabricated and calibrated.**





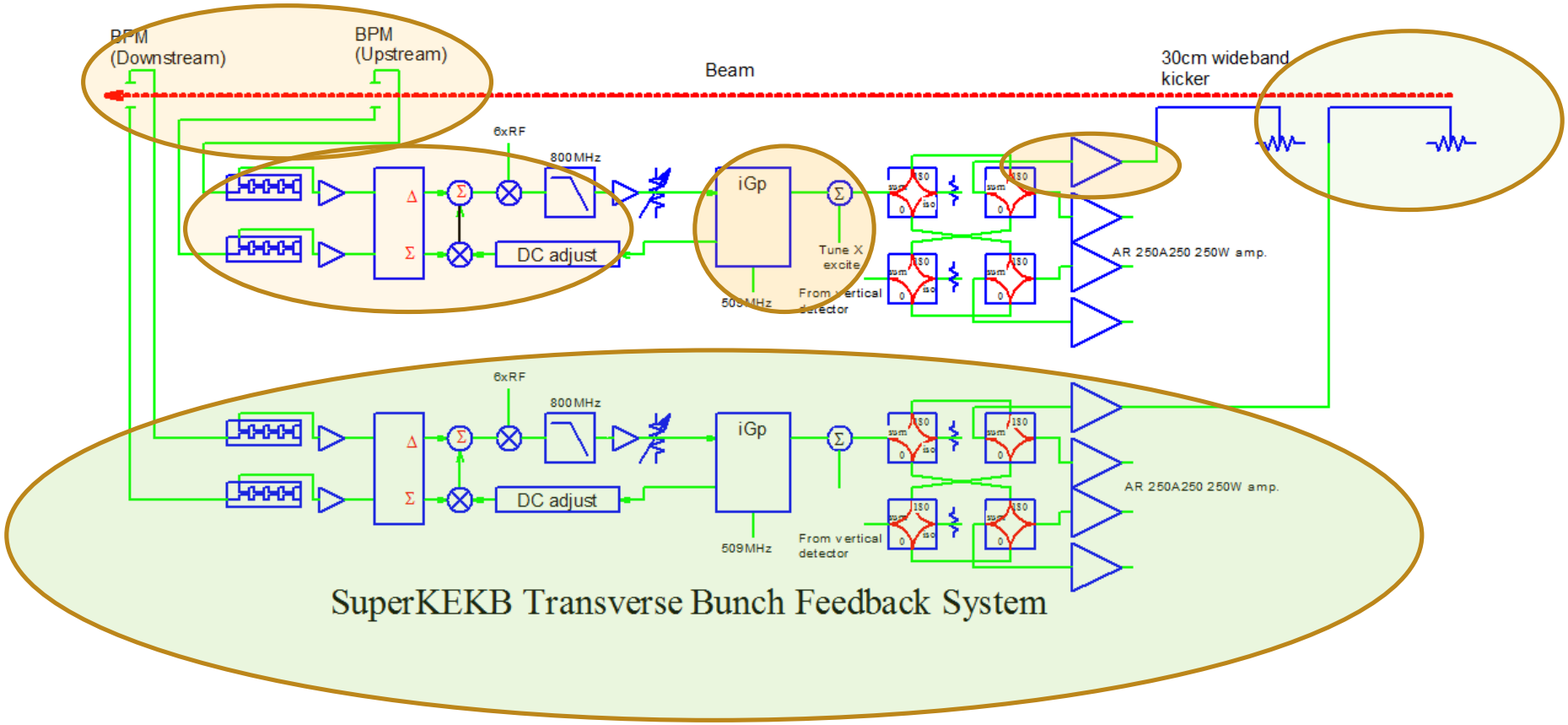

- **Need bunch timing (ADC timing) through Event system.**
  - 1 (or 2) Hz data acquisition.

# Special monitors

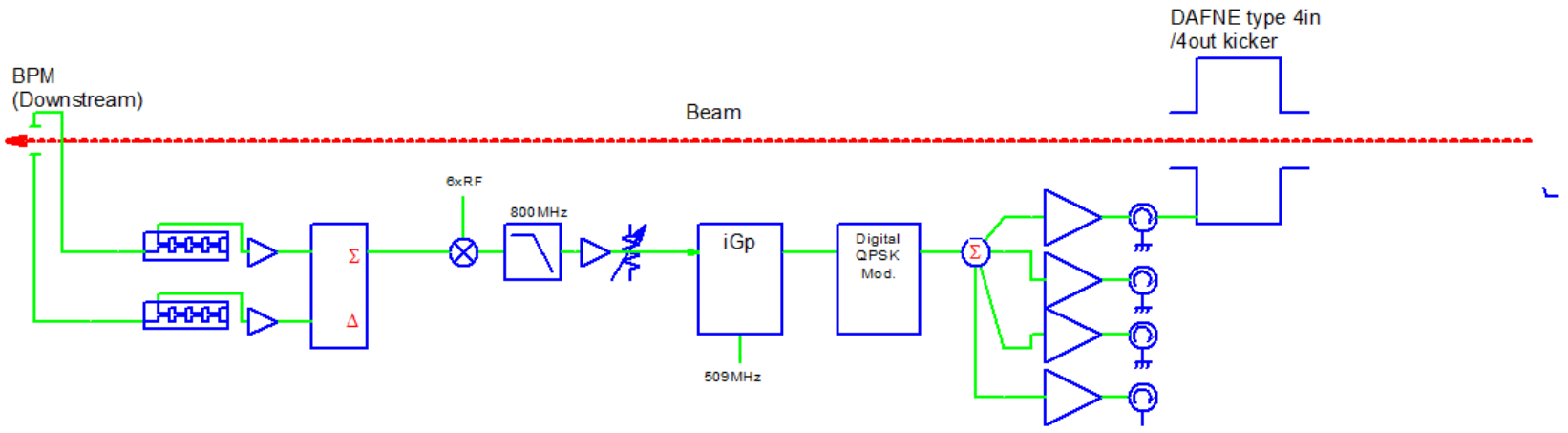



- **Orbit interlock**
  - Libera Brilliance+
    - turn-by-turn mode, latency <10 turns
    - Evaluation in progress: Latency < 4 turns
- **Medium-band detector**
  - Libera Brilliance+, FA mode (10kHz)
  - Tsukuba local chromaticity correction area
- **Synchrotron oscillation monitor**
  - Re-use 508MHz I/Q detectors.
  - Use VME-based ADC, timing.
- **DCCT**
  - Modified to cope with the increased beam current (LER).
  - Faster data acquisition using fast digitizer (SL1000 or Agilent 34410A)

# SuperKEKB Transverse FB plan



# SuperKEKB Longitudinal FB plan



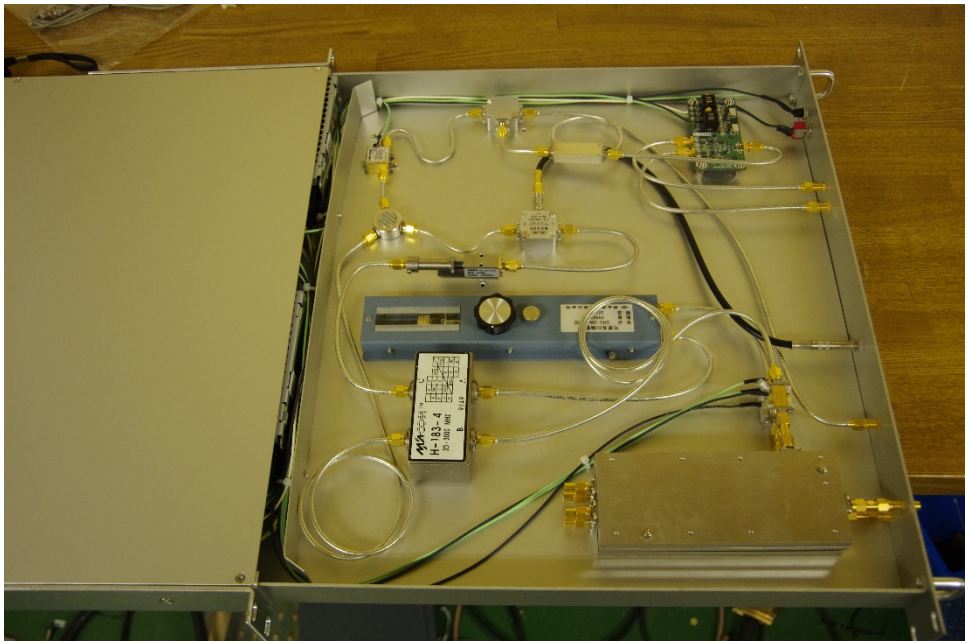

SuperKEKB Longitudinal Bunch Feedback System

Install LFB in LER only. HER is optional.
Considering to use 4 DAFNE type kickers, with 2-input, 2-output ports for larger capture range.

# New bunch detection electronics

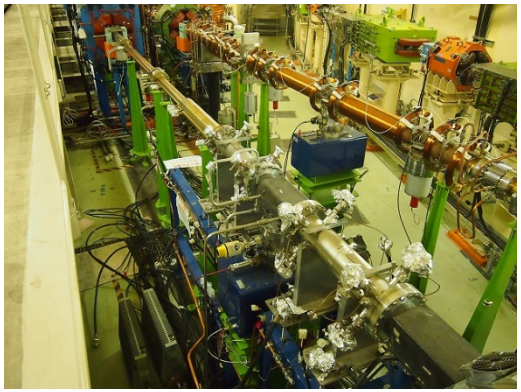
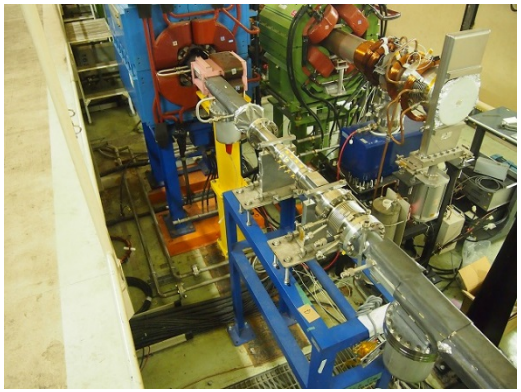

1U size detection circuit / plane
(2xH/2xV for transverse, 1 for longitudinal)

Inside of the transverse detection circuit.-->
Internal timing has already been adjusted using a SRD pulsar.
Timing difference between two inputs will be adjusted using a trombone delay inside.



# Bunch feedback systems

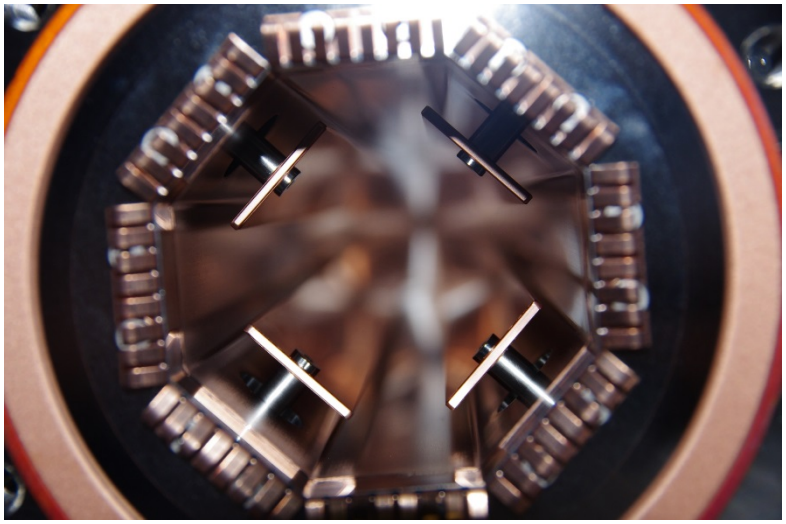
- **Most of the FB-related vacuum components have been installed.**

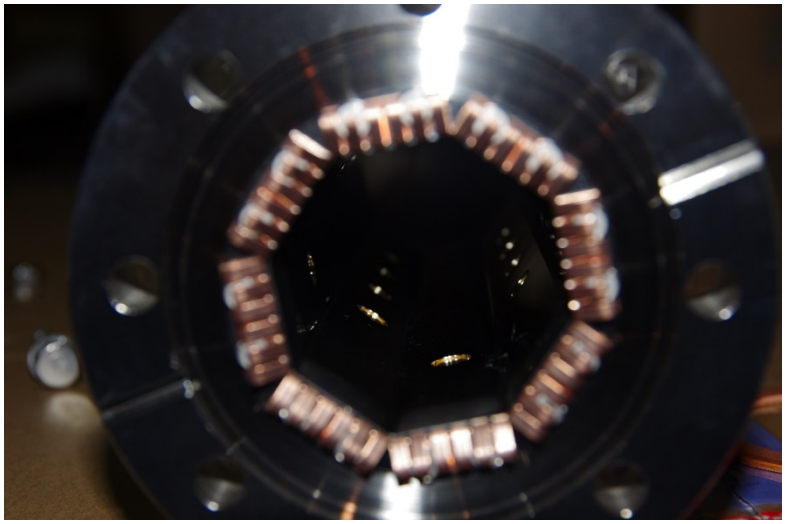




- **Remains:**
  - LER-LKicker(Aug/2014)

# DR transverse bunch feedback

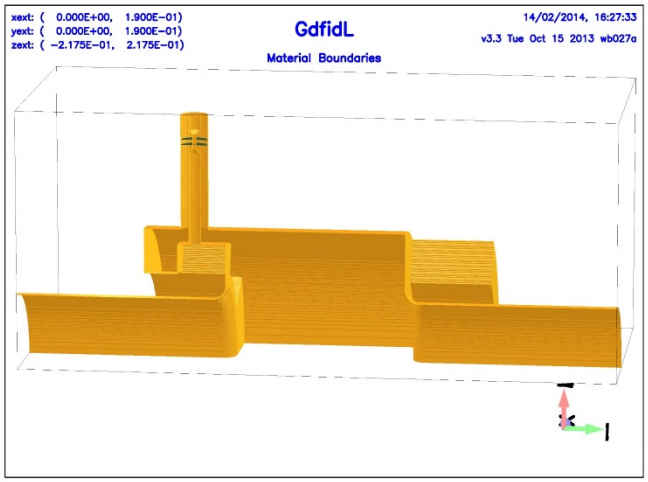
- Mainly to suppress the bunch oscillation due to injection/extraction kickers.
- Position detectors are the same as SuperKEKB.
- iGp8s and AR250A250 amplifiers will be used.

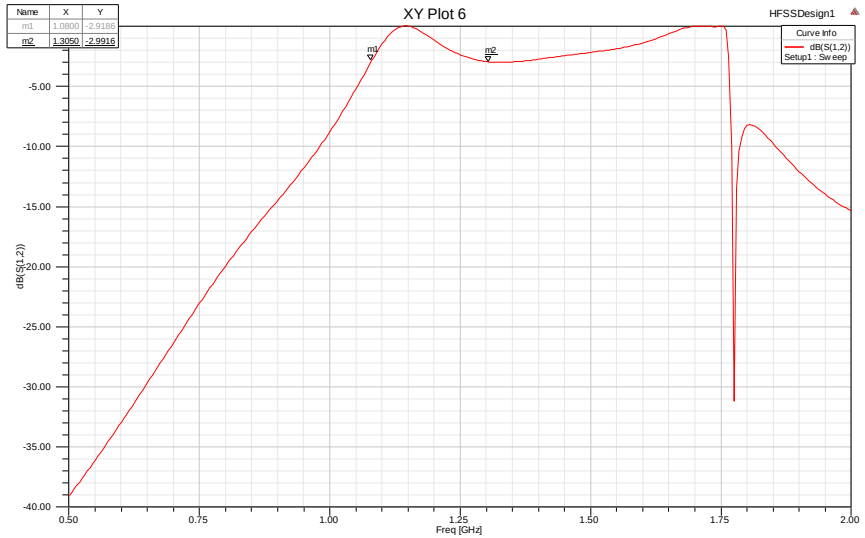




# Longitudinal kicker

- 2-input, 2-output, DAFNE type kicker.
- center frequency =2.25 x fRF (1150 MHz)
- Bandwidth ~ 250MHz
- 10 wideband UHF amplifiers (R&K and Millimega) are ready (900M-1.8GHz, Po=500W).




Q~ 5, Rsh ~ 1.6kΩ by HFSS calculation

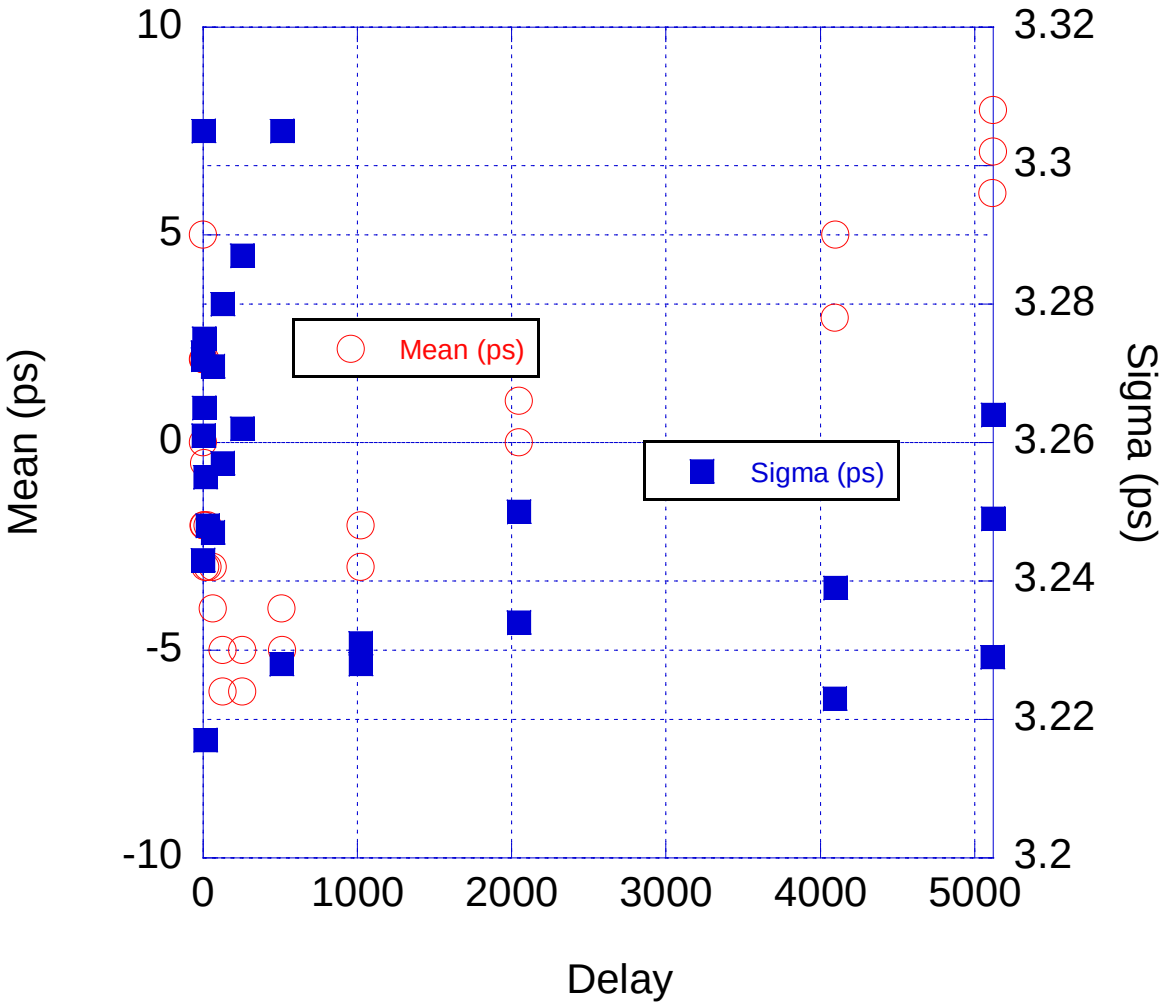
# Schedule

- **Cabling work**
  - Tunnel : Sep/2014
  - Control room : Jun/2014
- **Installation of G-TbT : Oct/2014**
- **Feedback systems**
  - Installation of vacuum components : Aug/2014
  - Cabling in the local control : Oct/2014
- **Software (EPICS device support and GUI etc.) work needed before commissioning.**

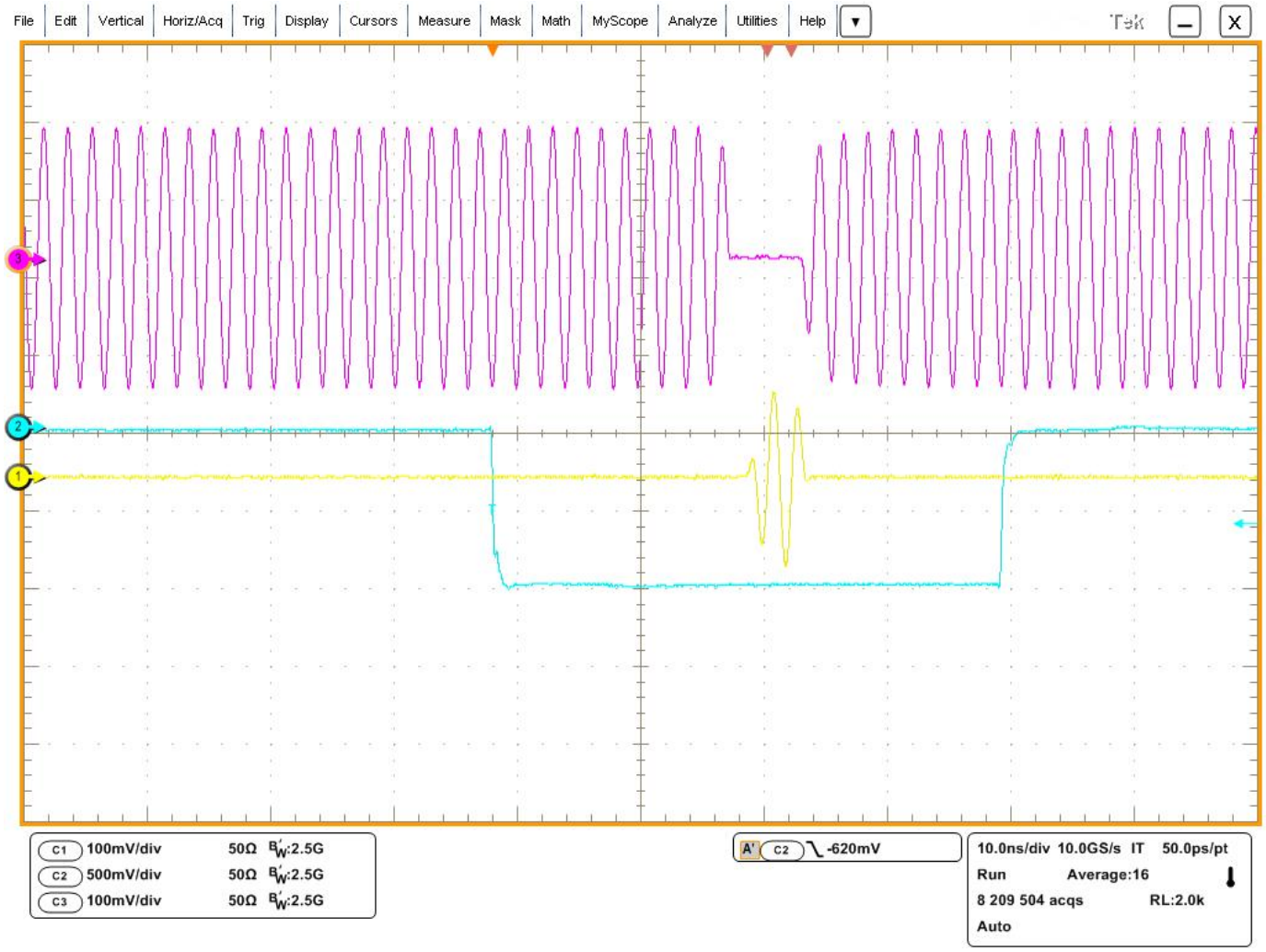
- **DR schedule strongly depends on the progress of other groups.**

# Backup

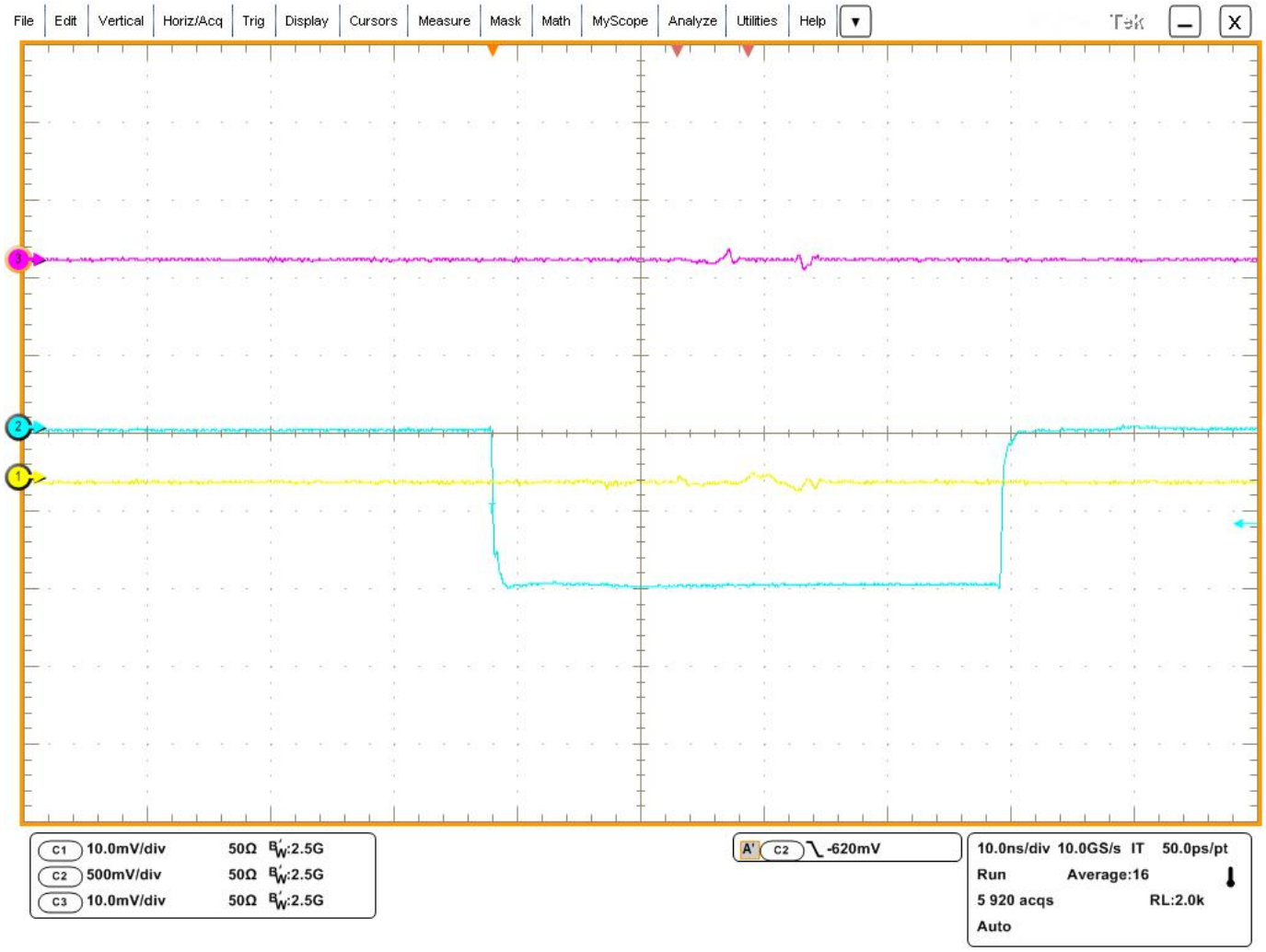
# Mean / Sigma


10
5
0
-5
-10
3.32
3.3
3.28
3.26
3.24
3.22
3.2
0
1000
2000
3000
4000
5000
Mean (ps)
Sigma (ps)
Mean (ps)
Sigma (ps)
Delay

# 4ns Gate

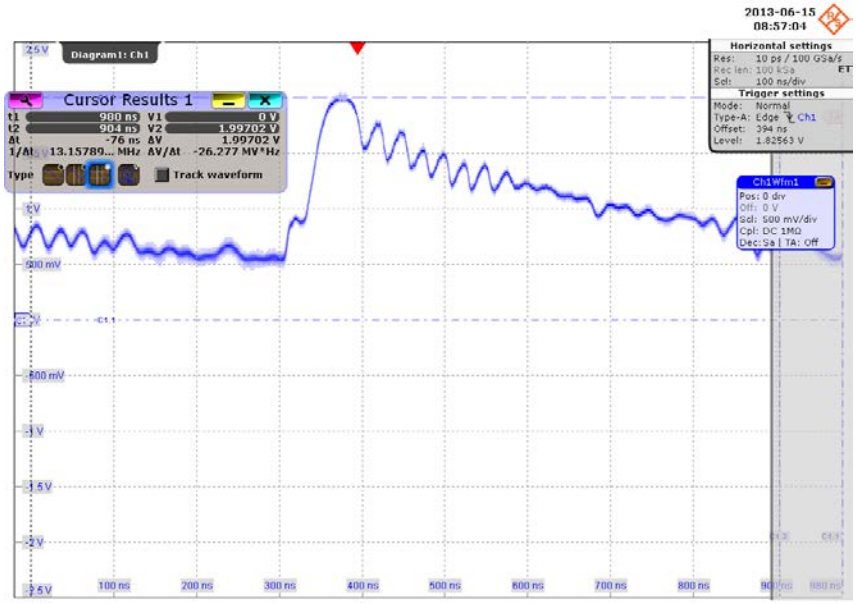

File
Edit
Vertical
Horiz/Acq
Trig
Display
Cursors
Measure
Mask
Math
MyScope
Analyze
Utilities
Help
Tek
C1 100mV/div 50Ω BW:2.5G
C2 500mV/div 50Ω BW:2.5G
C3 100mV/div 50Ω BW:2.5G
A' C2 -620mV
10.0ns/div 10.0GS/s IT 50.0ps/pt
Run Average:16
8 209 504 acqs RL:2.0k
Auto

# Switching noise

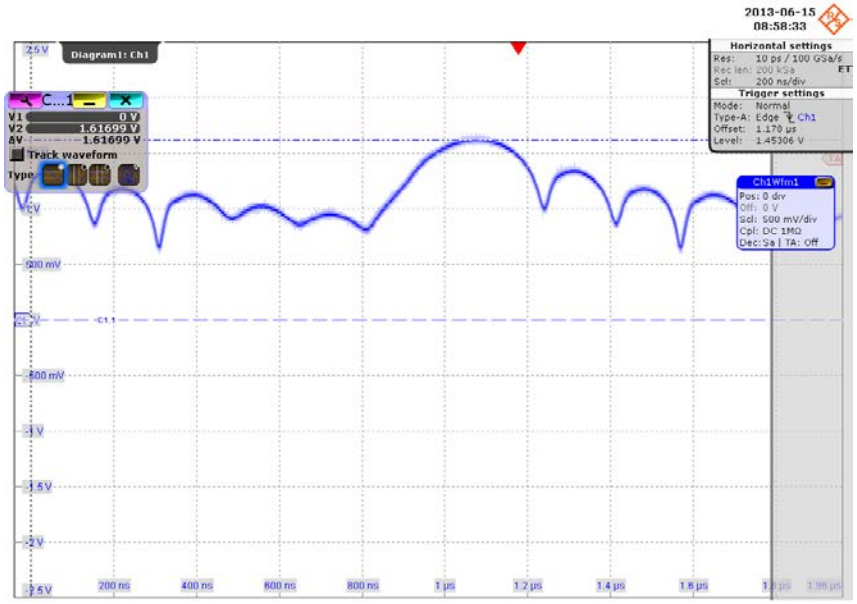


# Log amplifier output (using AR beam)

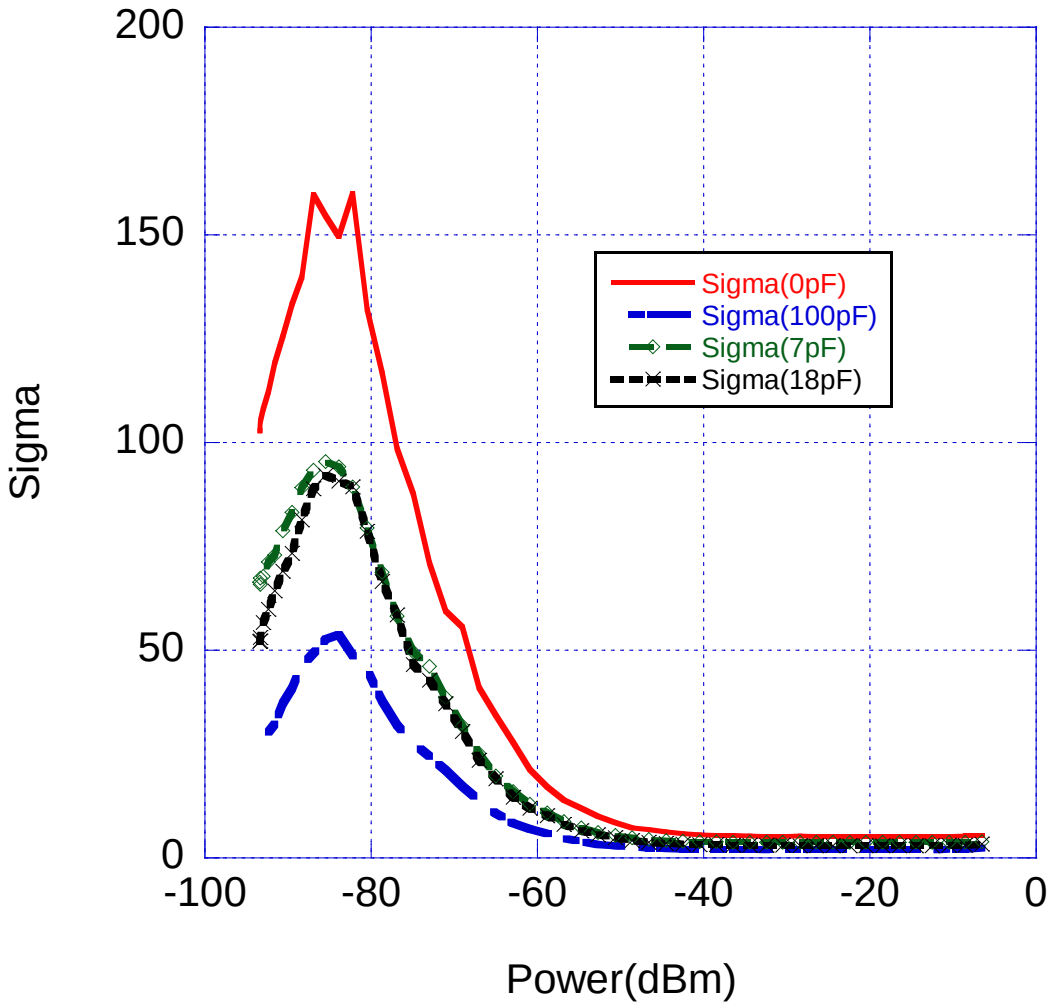
## 6dB wide




## 6dB Narrow

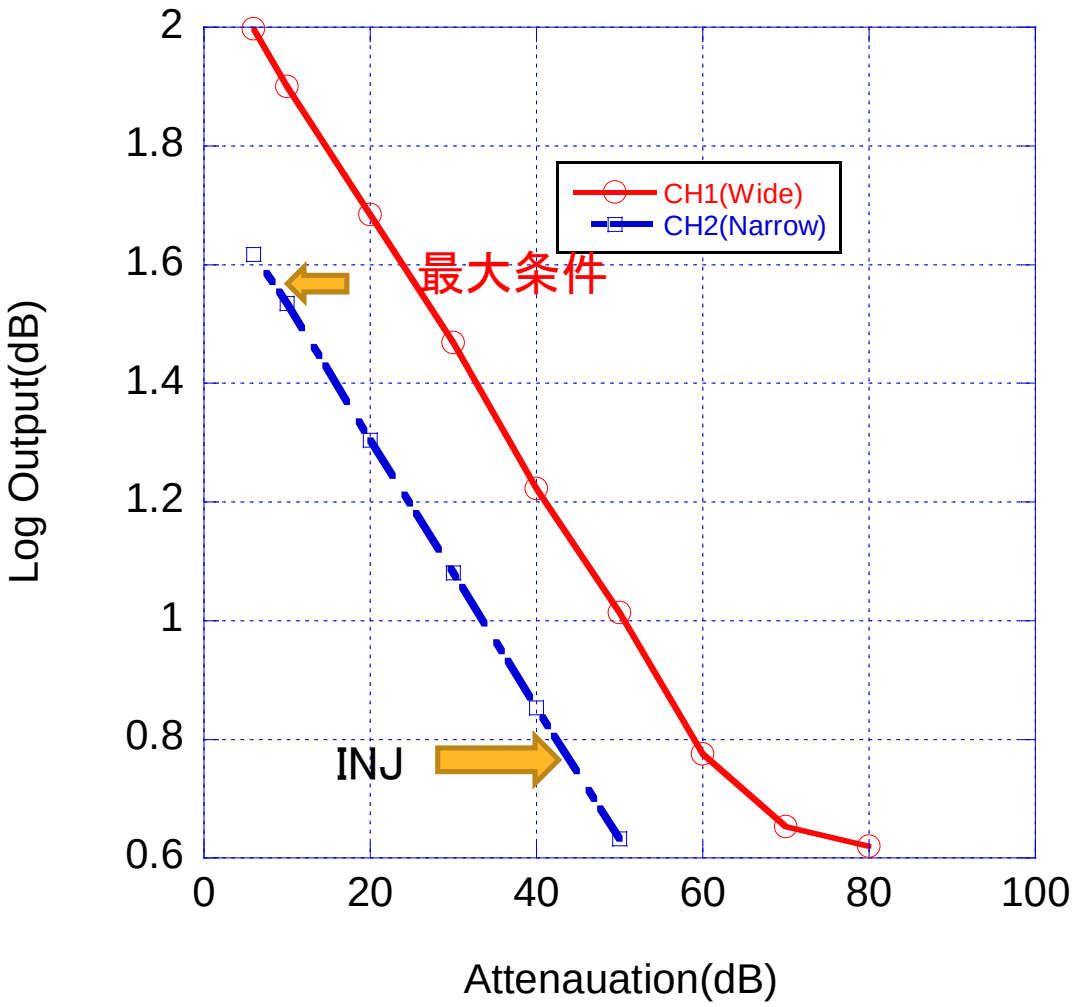


# CextとSigma

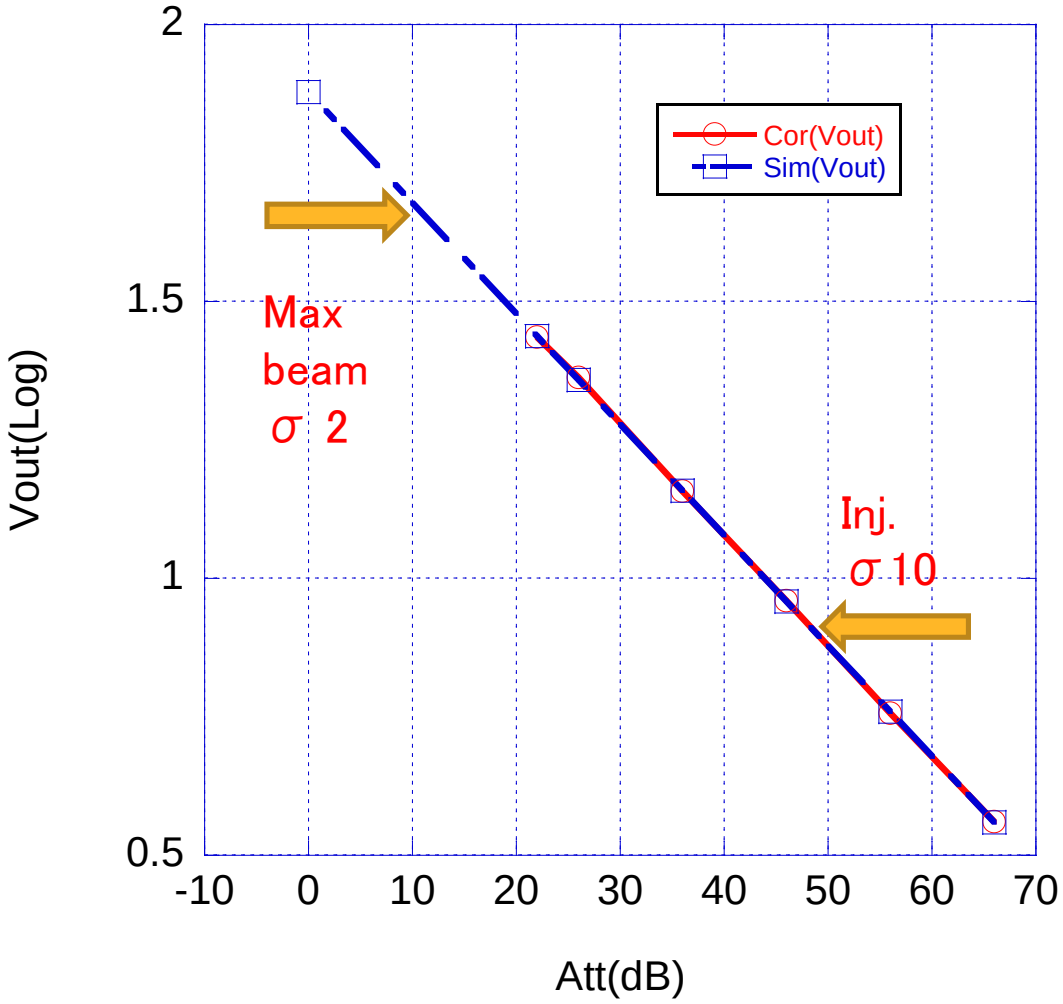



- 最低使用領域(−80dBm)ではCext(100,18,7,0)で48、89、89、150となる
- 常用域(−40dBm)では2、3.2、3.9、5.5となる
- 最大域(−15dBm)では2、3.0、3.7、5.2となる

# SuperKEKB


2
1.8
1.6
1.4
1.2
1
0.8
0.6
0
20
40
60
80
100
Log Output(dB)
Attenauation(dB)
CH1(Wide)
CH2(Narrow)
最大条件
INJ

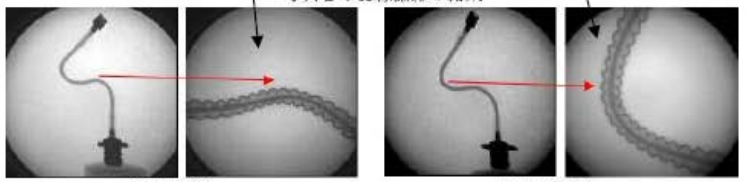
# 20dB Amp −4dB loss 100pF



絶縁の撚り線から中心導体がはみ出して接触していると考えられる

中心導体が偏芯しているように見える

写真２：X線撮影の結果



サンプル①　　サンプル②

サンプル①は、内部導体と外部導体が完全に接触している箇所が確認できました。サンプル②は、接触はしていないものの内部導体と外部導体が接近している箇所が確認できました。

レントゲン検査
サンプル①、サンプル②

曲げ規定 R15 を越えた部分と、規定どおりの曲げ部分

サンプル①の曲げ加工状態

サンプル②の曲げ加工状態

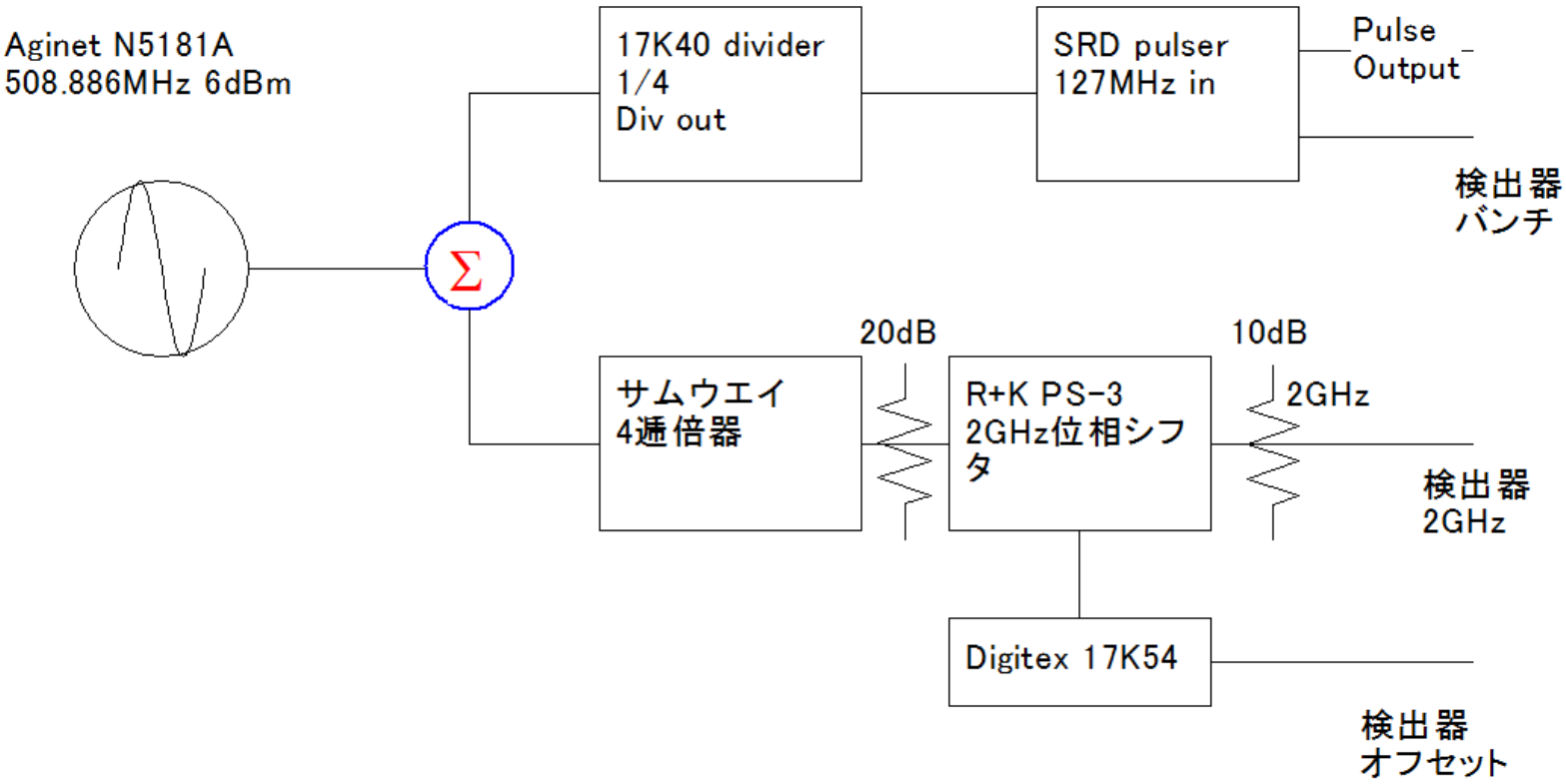
TDR で確認した結果、短絡していると推測される箇所

２つの曲げ箇所で規程曲げ半径(R15mm)以下となっている。

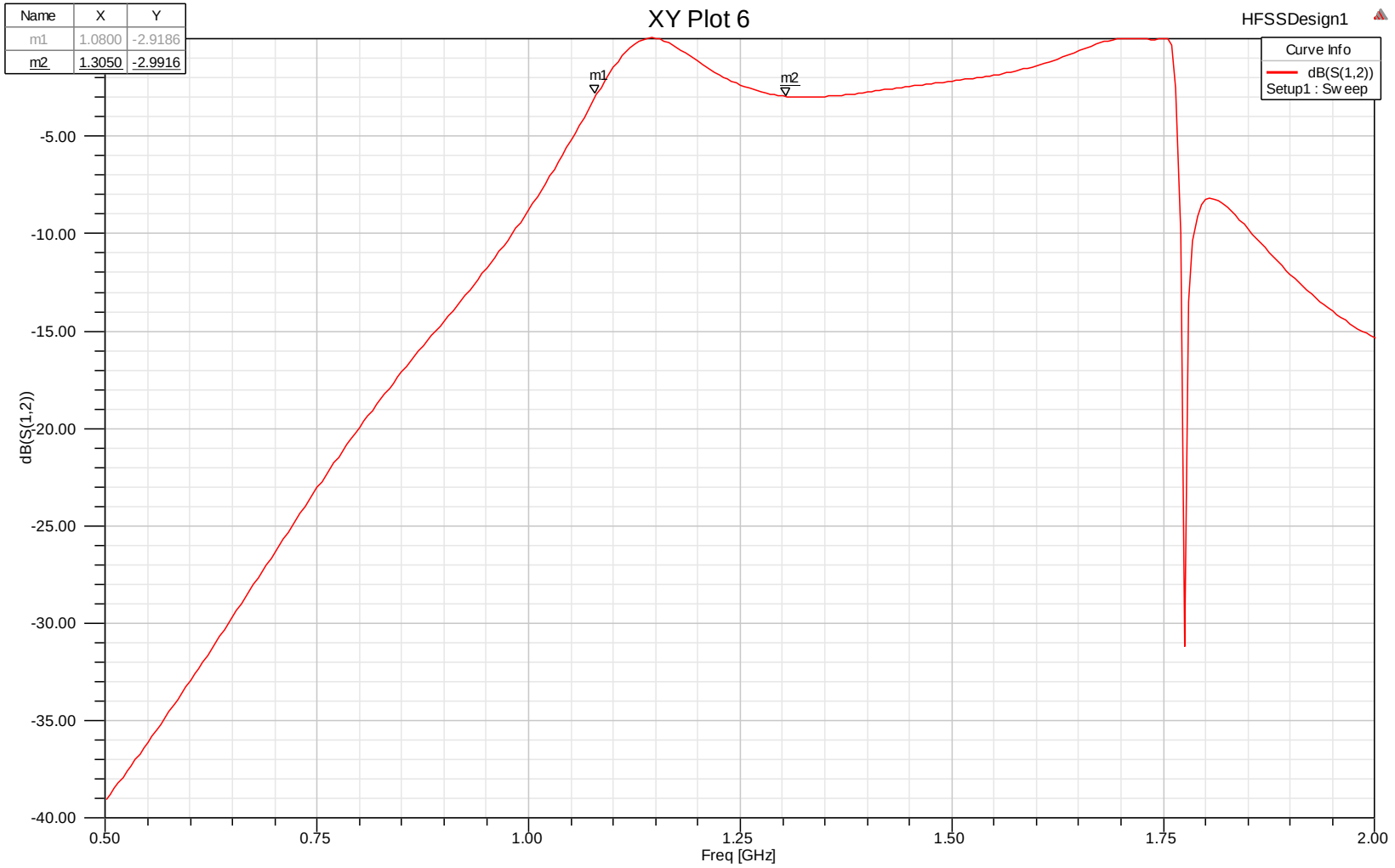
サンプル③の曲げ加工状態

SMA ｺﾈｸﾀ側の曲げ箇所で規程曲げ半径(R15mm)以下となっている。
当社で絶縁抵抗計にて確認したところ抵抗値は∞の値を示した。

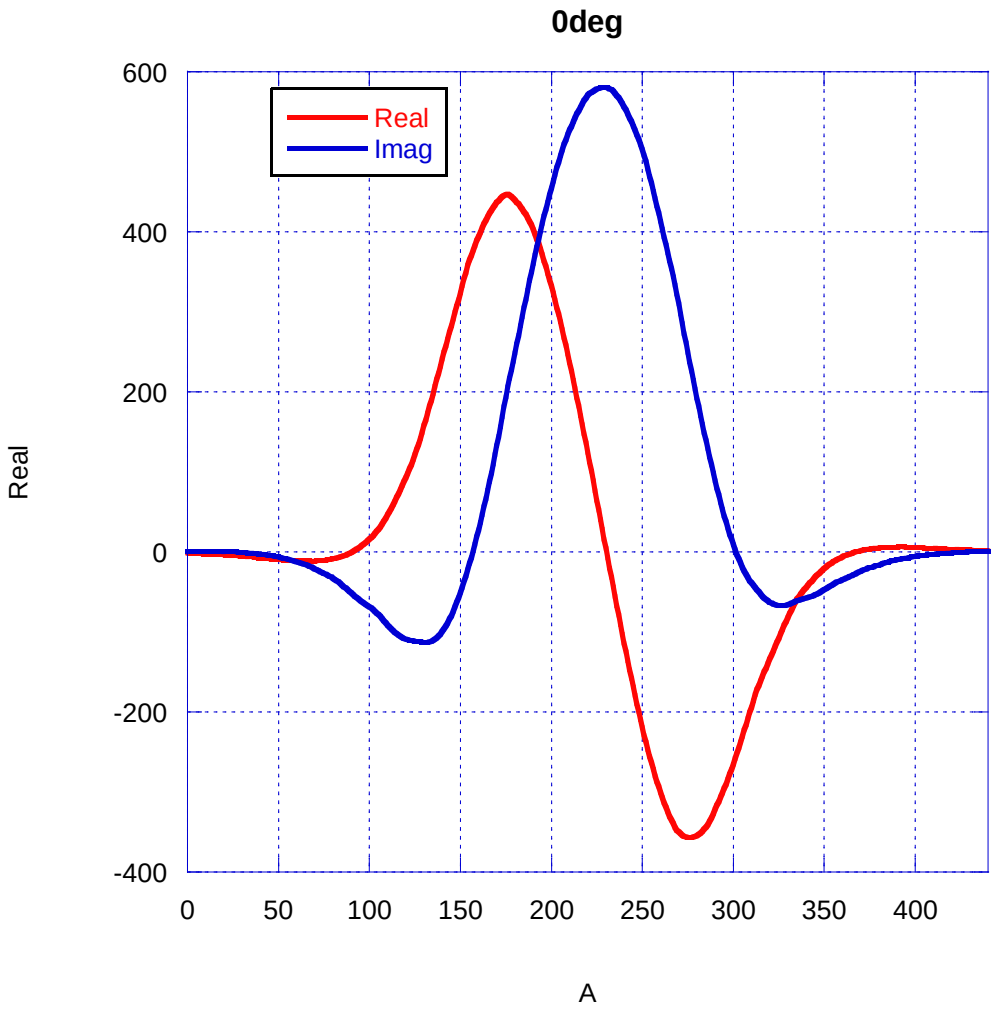
# 試験回路


Aginet N5181A
508.886MHz 6dBm
Σ
17K40 divider
1/4
Div out
SRD pulser
127MHz in
Pulse
Output
検出器
バンチ
20dB
10dB
サムウエイ
4逓倍器
R+K PS-3
2GHz位相シフタ
2GHz
検出器
2GHz
Digitex 17K54
検出器
オフセット

# Q=5.1

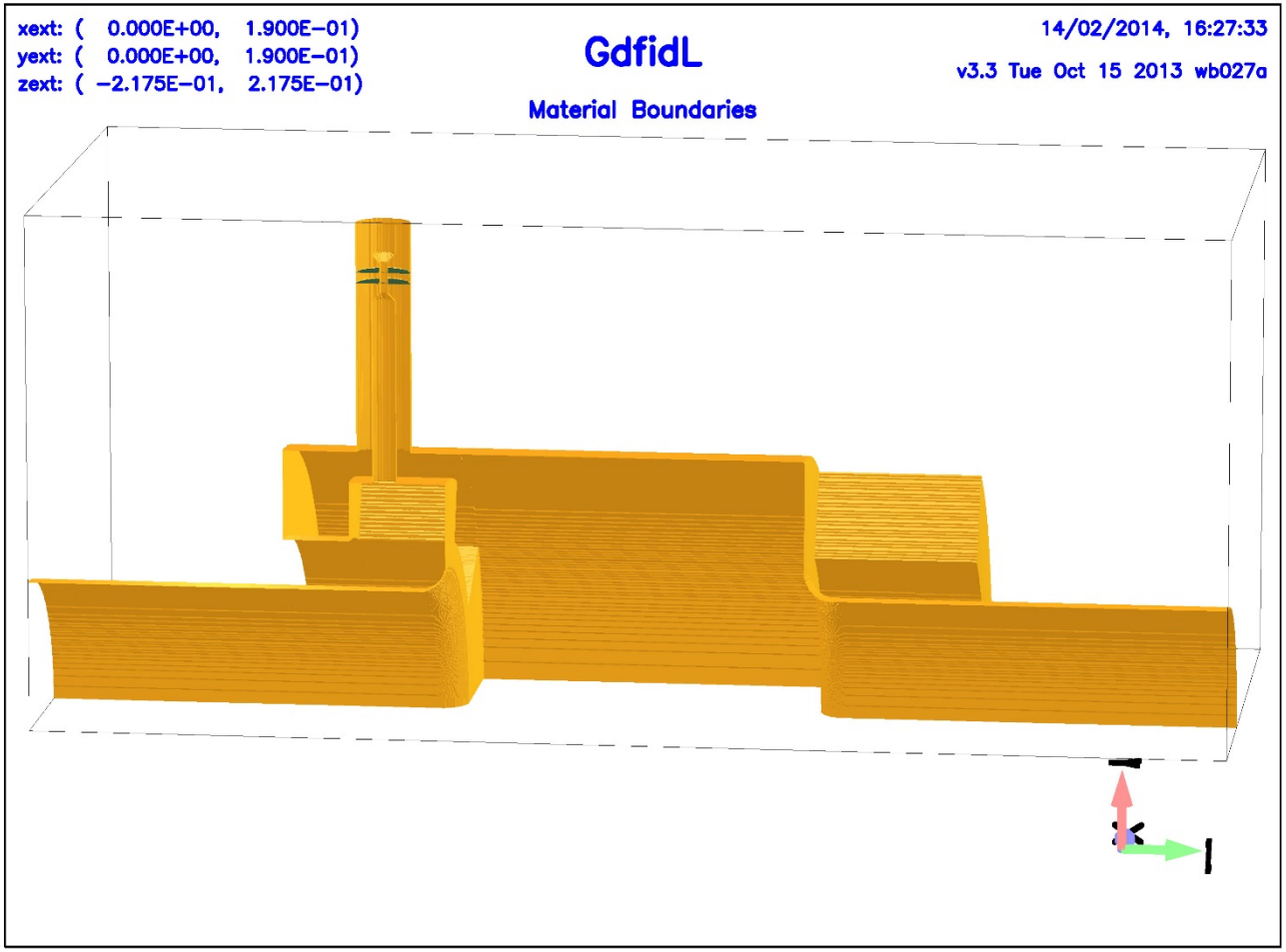

Name
X
Y
m1
1.0800
-2.9186
m2
1.3050
-2.9916
XY Plot 6
HFSSDesign1
Curve Info
dB(S(1,2))
Setup1 : Sweep
m1
m2
-5.00
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
dB(S(1,2))
0.50
0.75
1.00
1.25
1.50
1.75
2.00
Freq [GHz]

# E_z計算

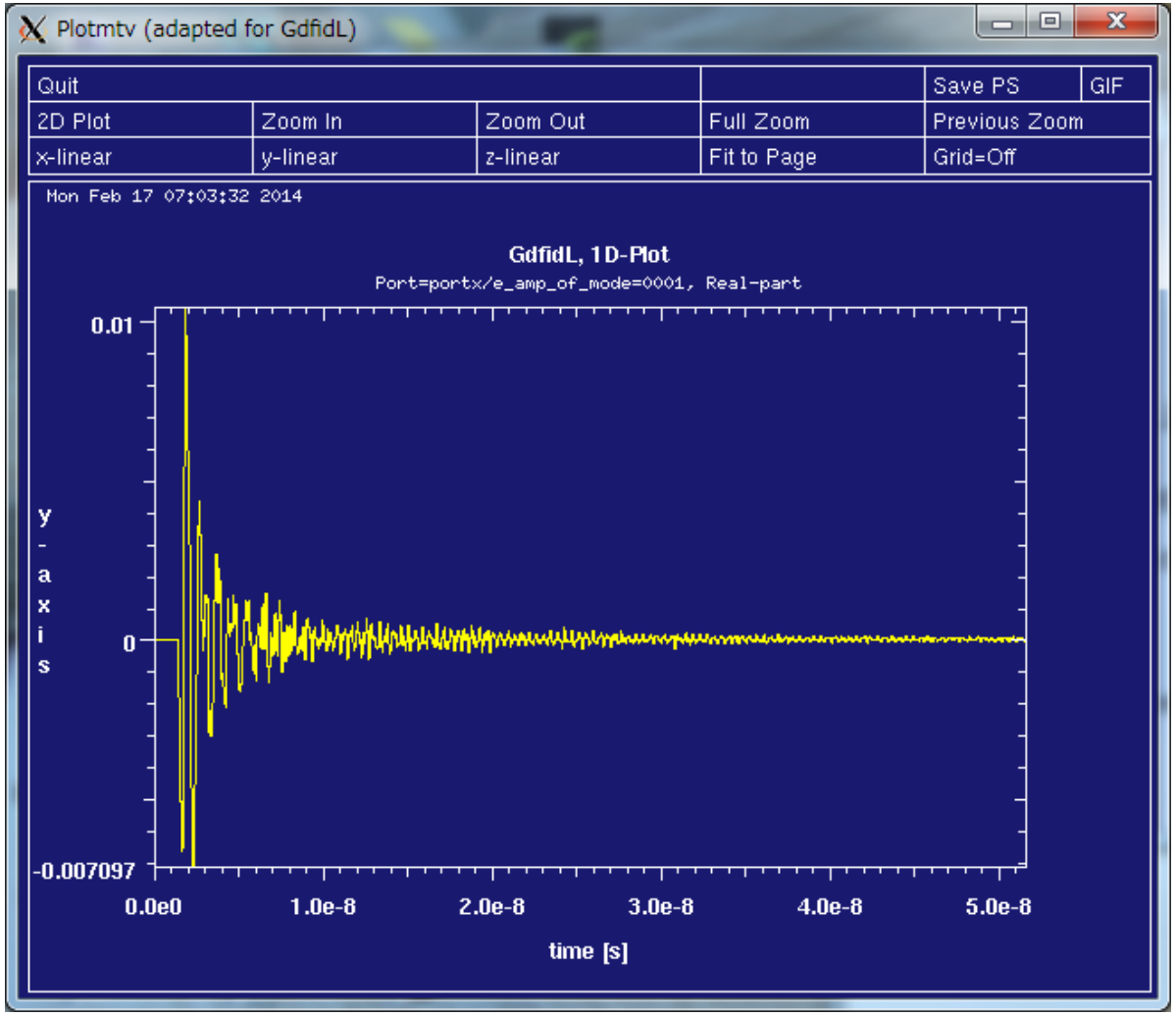


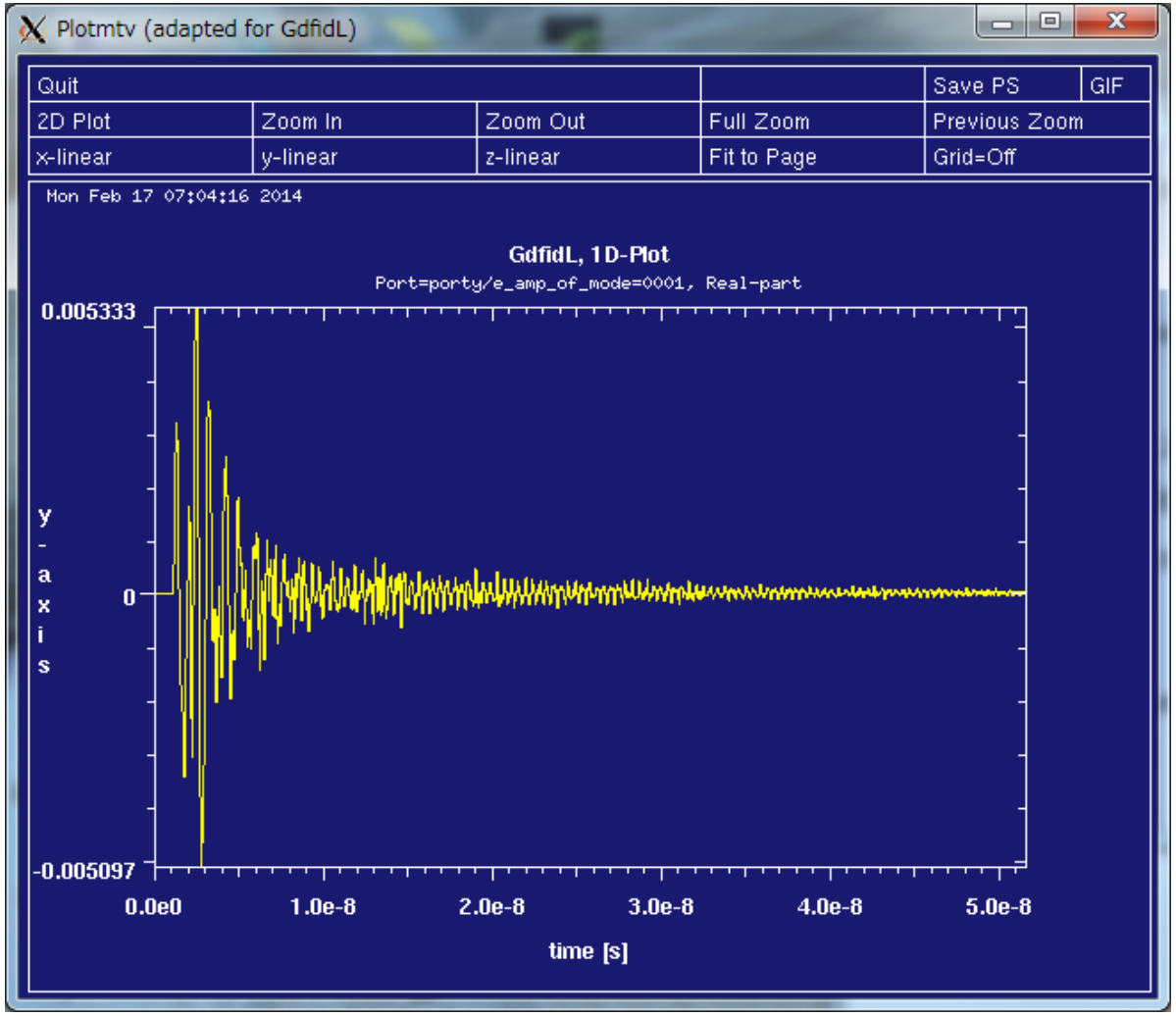

Q=5.1
Rsh=1628ohm

# GdfidLモデル

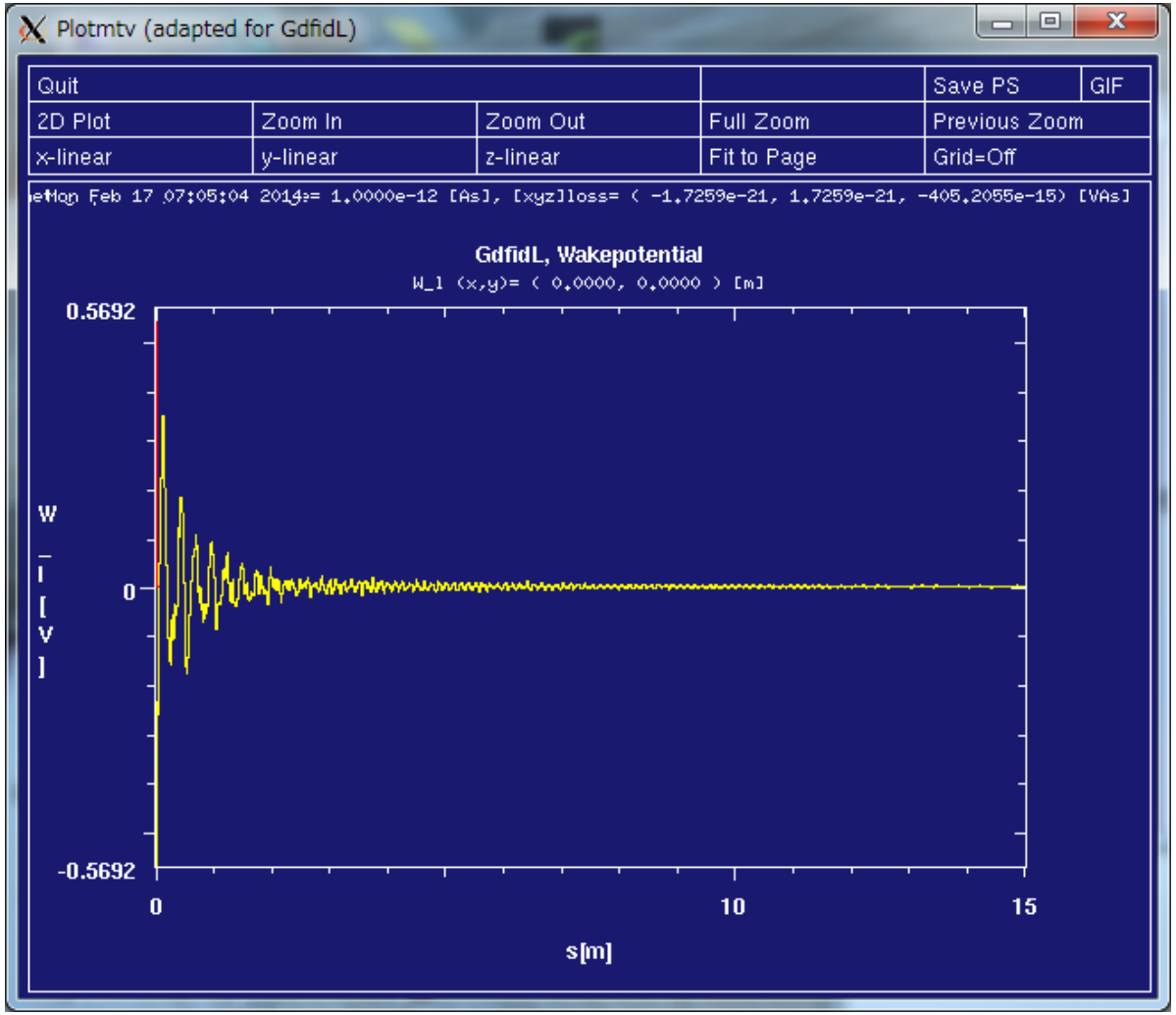

xext: ( 0.000E+00, 1.900E-01)
yext: ( 0.000E+00, 1.900E-01)
zext: ( -2.175E-01, 2.175E-01)
GdfidL
Material Boundaries
14/02/2014, 16:27:33
v3.3 Tue Oct 15 2013 wb027a

# ポート出力(1pC)


Plotmtv (adapted for GdfidL)
Quit
Save PS
GIF
2D Plot
Zoom In
Zoom Out
Full Zoom
Previous Zoom
x-linear
y-linear
z-linear
Fit to Page
Grid=Off
Mon Feb 17 07:03:32 2014
GdfidL, 1D-Plot
Port=portx/e_amp_of_mode=0001, Real-part
0.01
0
-0.007097
y-axis
0.0e0
1.0e-8
2.0e-8
3.0e-8
4.0e-8
5.0e-8
time [s]

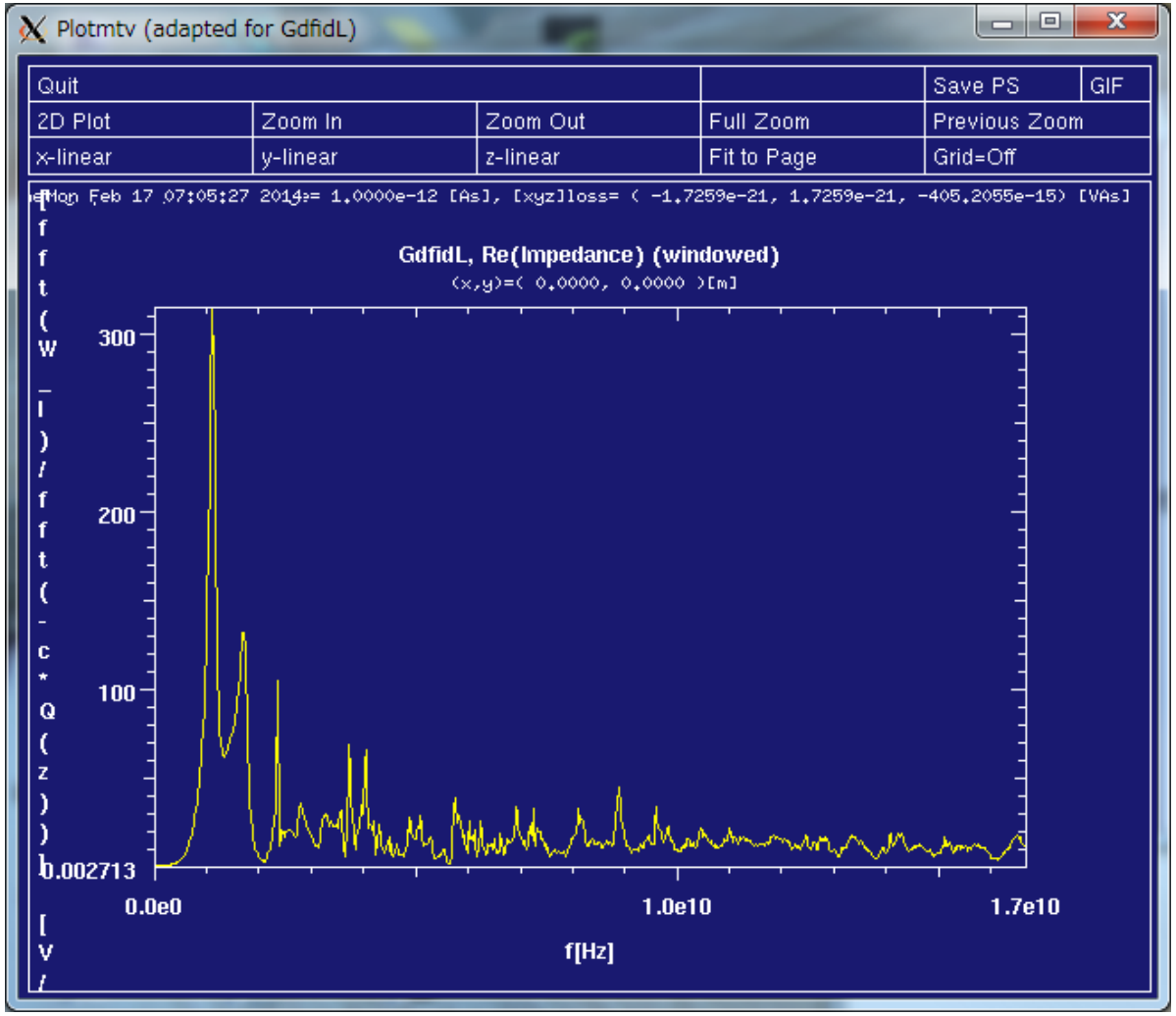

Plotmtv (adapted for GdfidL)
Quit
Save PS
GIF
2D Plot
Zoom In
Zoom Out
Full Zoom
Previous Zoom
x-linear
y-linear
z-linear
Fit to Page
Grid=Off
Mon Feb 17 07:04:16 2014
GdfidL, 1D-Plot
Port=porty/e_amp_of_mode=0001, Real-part
0.005333
0
-0.005097
y-axis
0.0e0
1.0e-8
2.0e-8
3.0e-8
4.0e-8
5.0e-8
time [s]

# longitudinal wake

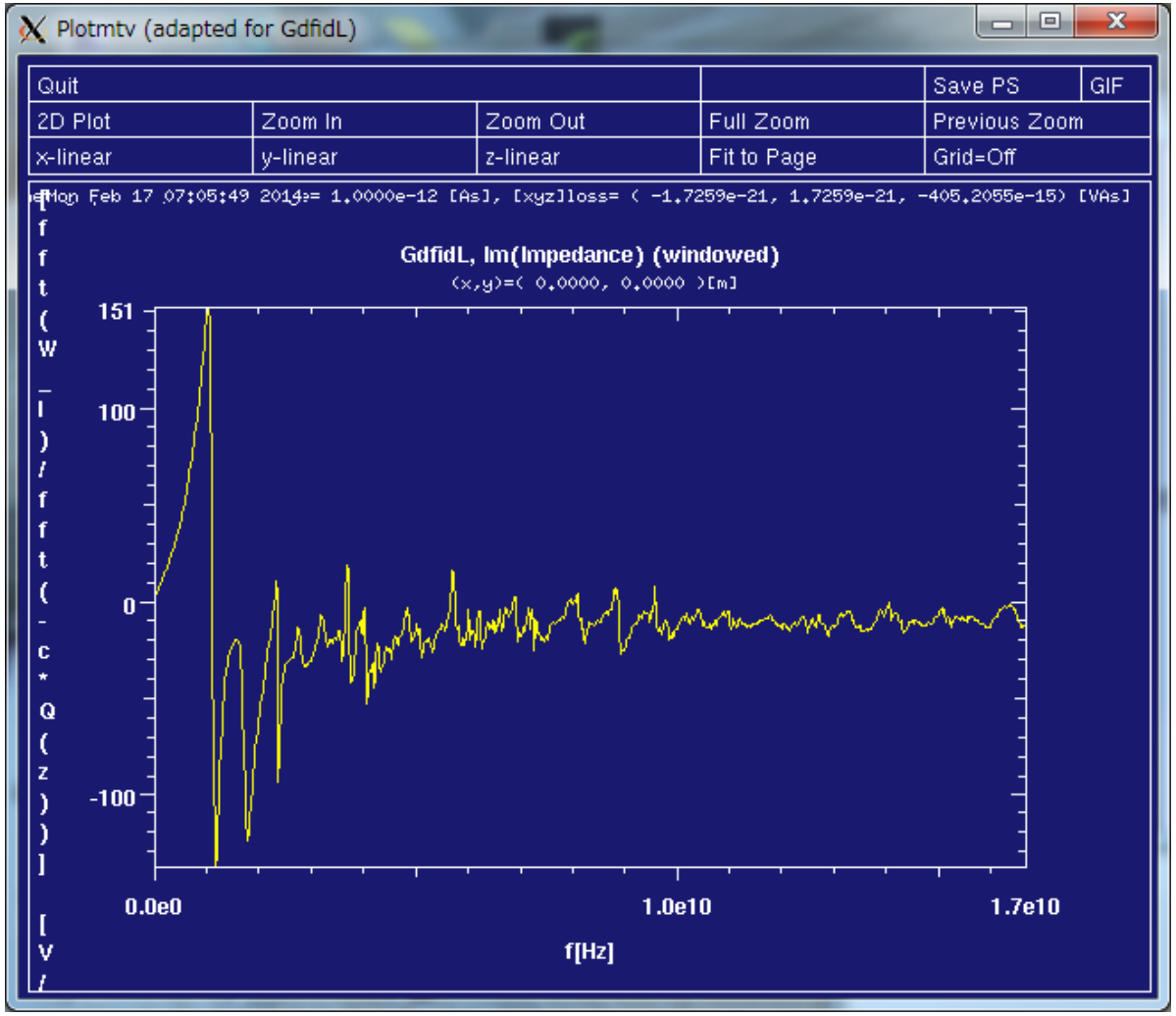



Loss factorは0.4V/pC

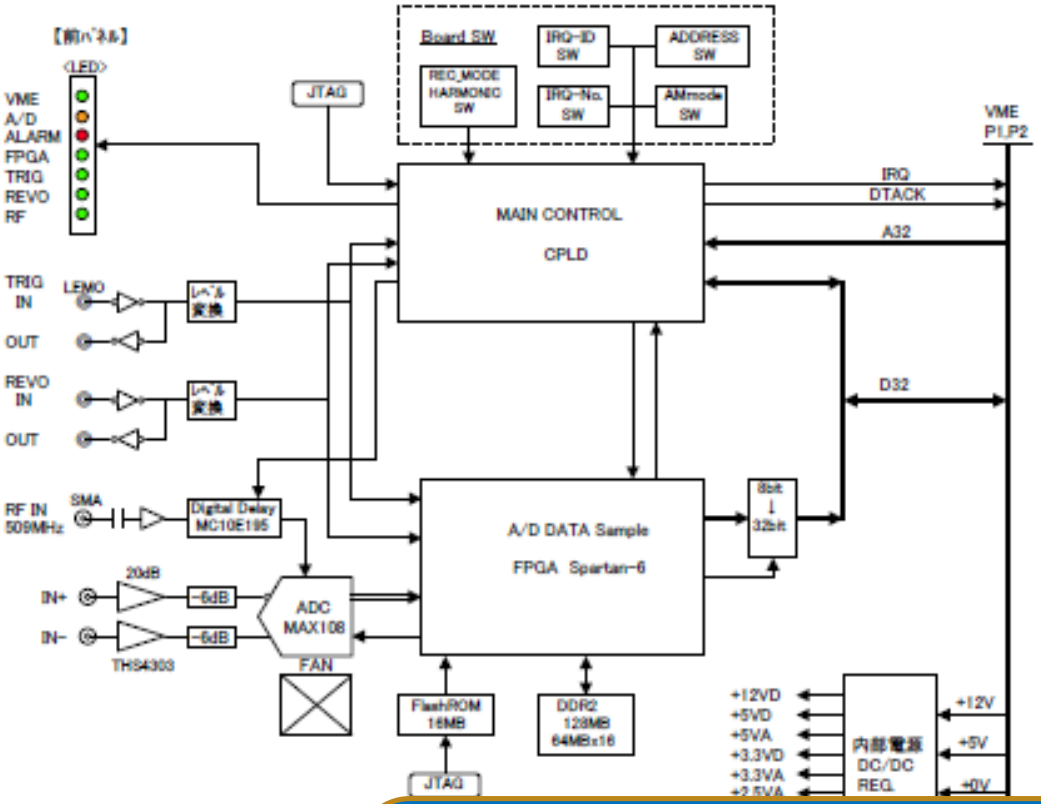
# Impedance(real)



# Impedance(imag)



# Bunch current monitor




MAX108 8bit ADC
Spartan6 FGPA
VME 2W size

Bunch current information will be sent through reflective memory (real-time) to the bucket selection system during injection period.

# Betatron Tune

- Global tune measurement for multi-bunch, small beam current
- Gated tune measurement for pilot bunch only
- PLL excitation of the pilot bunch using iGp12 or Lock-in amplifiers