# Bunch feedback systems and luminosity

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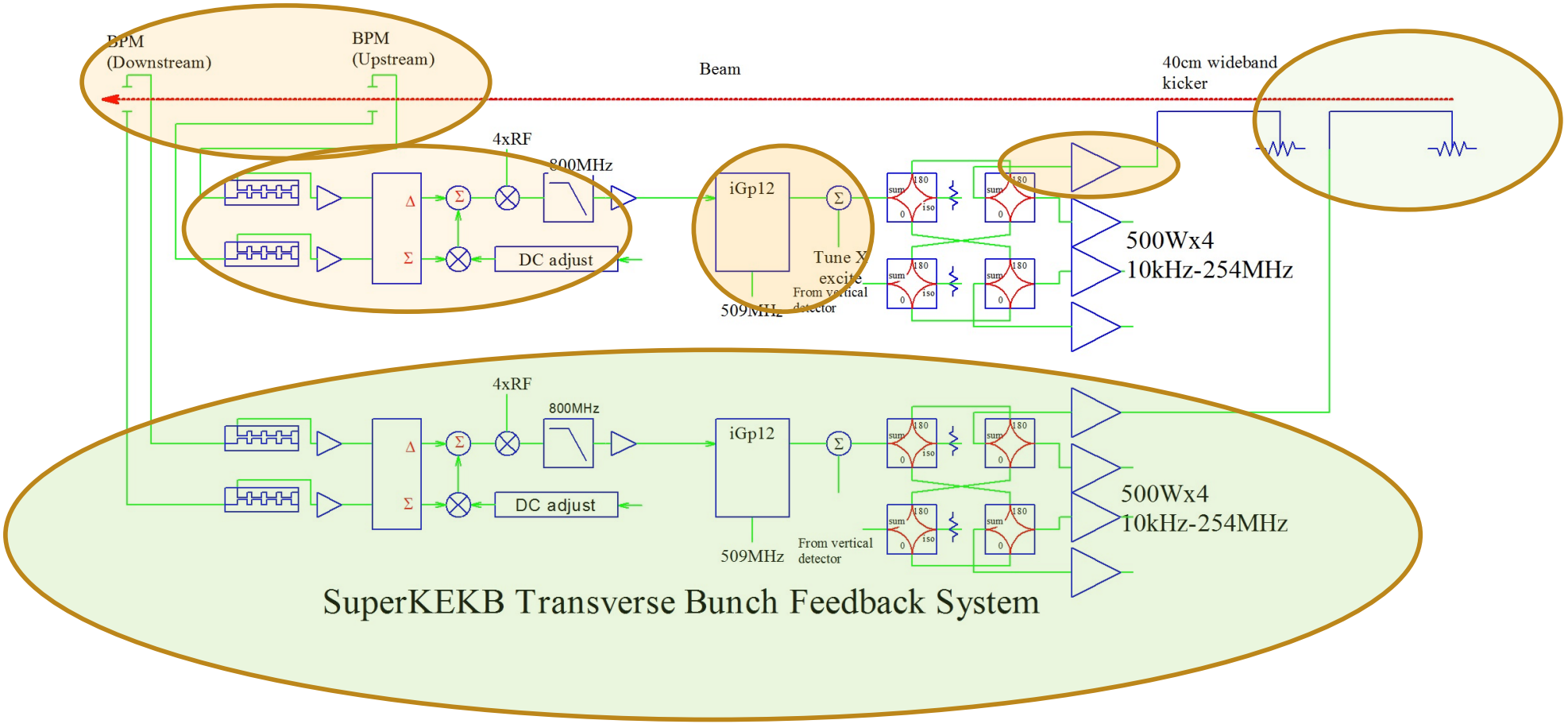
# Outlook

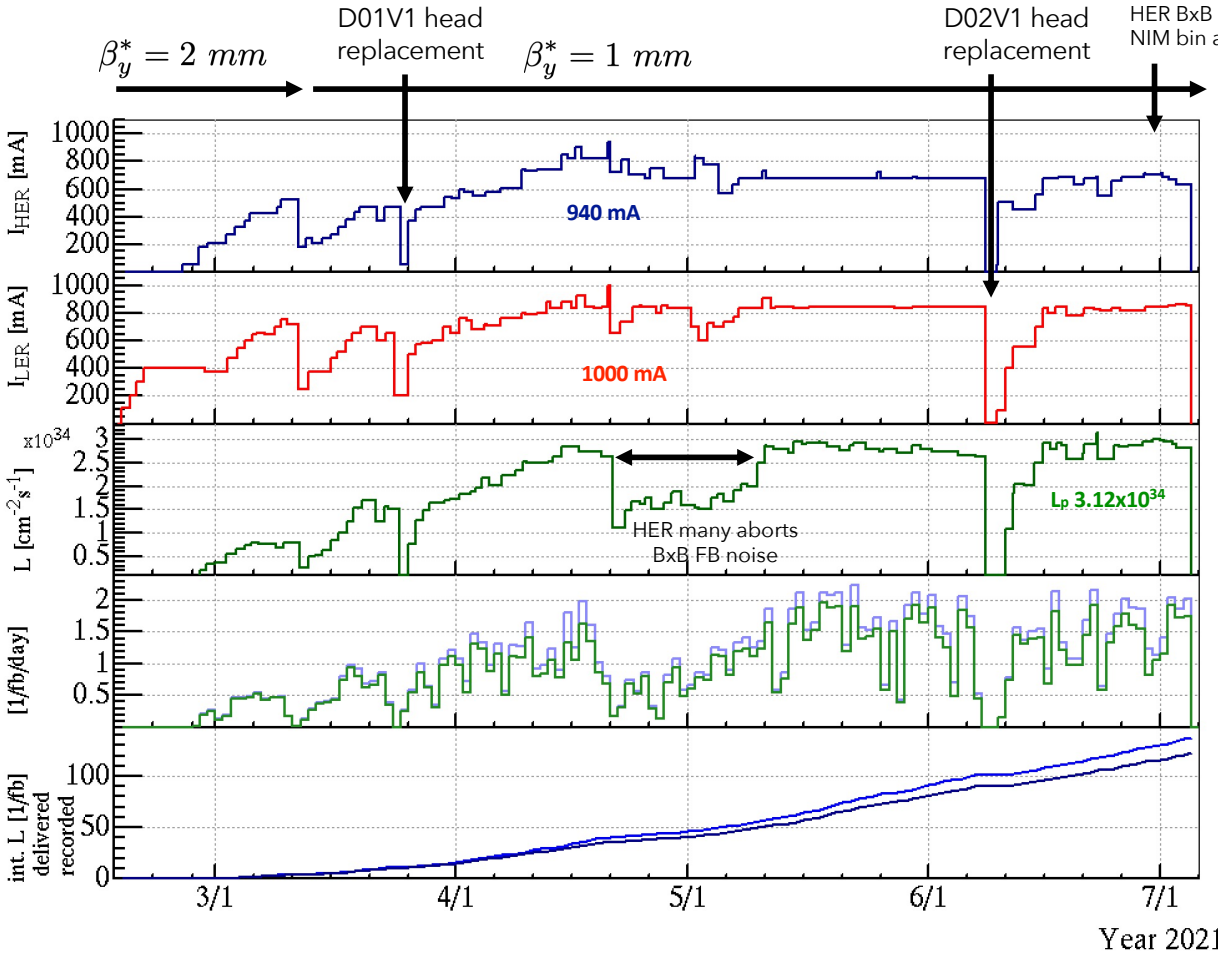
- **From around the end of Apr., the operation of the HER became difficult.**
  - Frequent beam abort due to large beam loss.
  - Luminosity drop due to large vertical beam size.
    - Suspected the large noise near HER vertical tune affect the beam. The frequency was not stable and was slowly changing with time.
- **By moving the HER vertical tune far from the noise, the operation was resumed.**
- **Also, by reducing the HER vertical feedback gain(2 shift gains, −12dB), the luminosity has been jumped up.**
  - HER beam was not stable under single beam condition due to insufficient feedback gain, though.
- **Tried to find the source of the noise injected feedback system and found the cause (broken module). By removing the module, the noise has disappeared, and it was possible to increase the vertical feedback gain (1 shift gain, 6dB) which enabled the stable operation under single beam conditions.**

# SuperKEKB Transverse FB systems



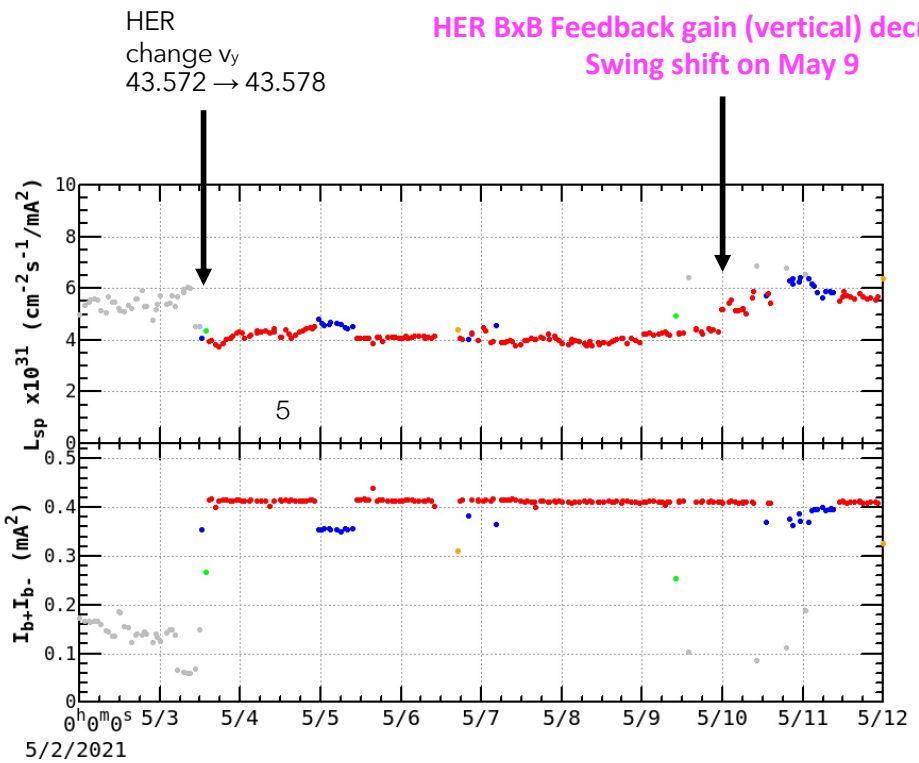

Collaborating SLAC(US-Japan) and INFN-LNF(KEK-LNF)

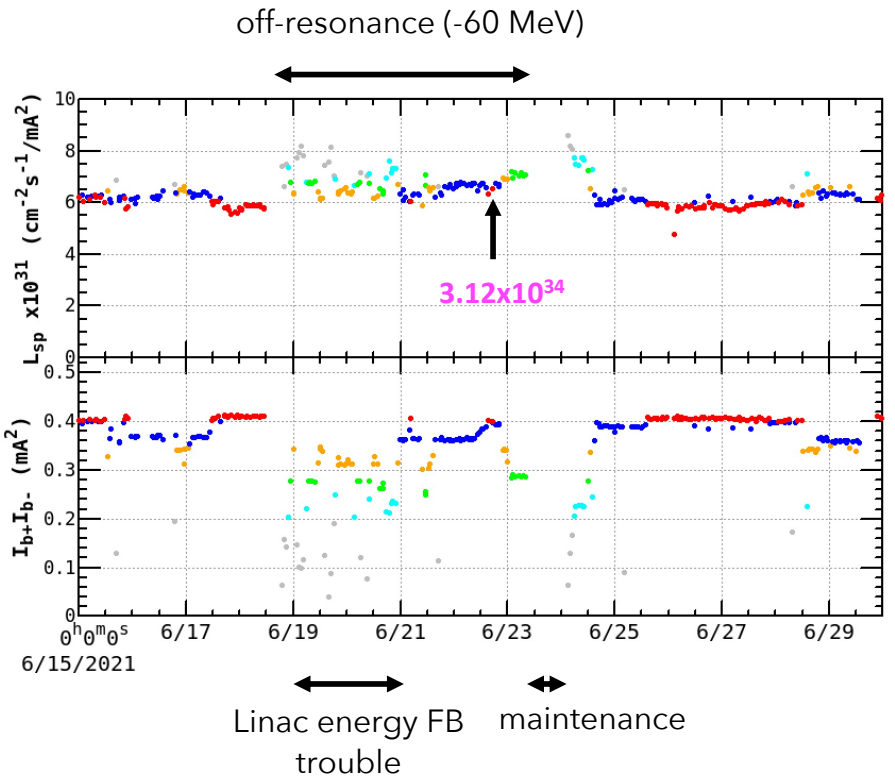
## 2021ab Operation Summary




- The 2021a run started on 16th February and operated for 140 days (4 months and half).
- The first ten days were devoted to the vacuum scrubbing.
- We operated with $\beta_y^*$ = 2 mm to check hardwares and to test high current operation safely.
- Calibrations of BPM and collimator head positions, etc. were also performed by using beams during the first two weeks.
- D01V1(HER) head was replaced. The top jaw was short for the LER collimator head (March 23).
- We squeezed $\beta_y^*$ down to 1 mm on 10th March. Beam currents increased with "baking run". 1000 mA / 940 mA w/o physics run
- HER many aborts from April 20 to May 3.
- D02V1(LER) head was replaced due damage (June 7).

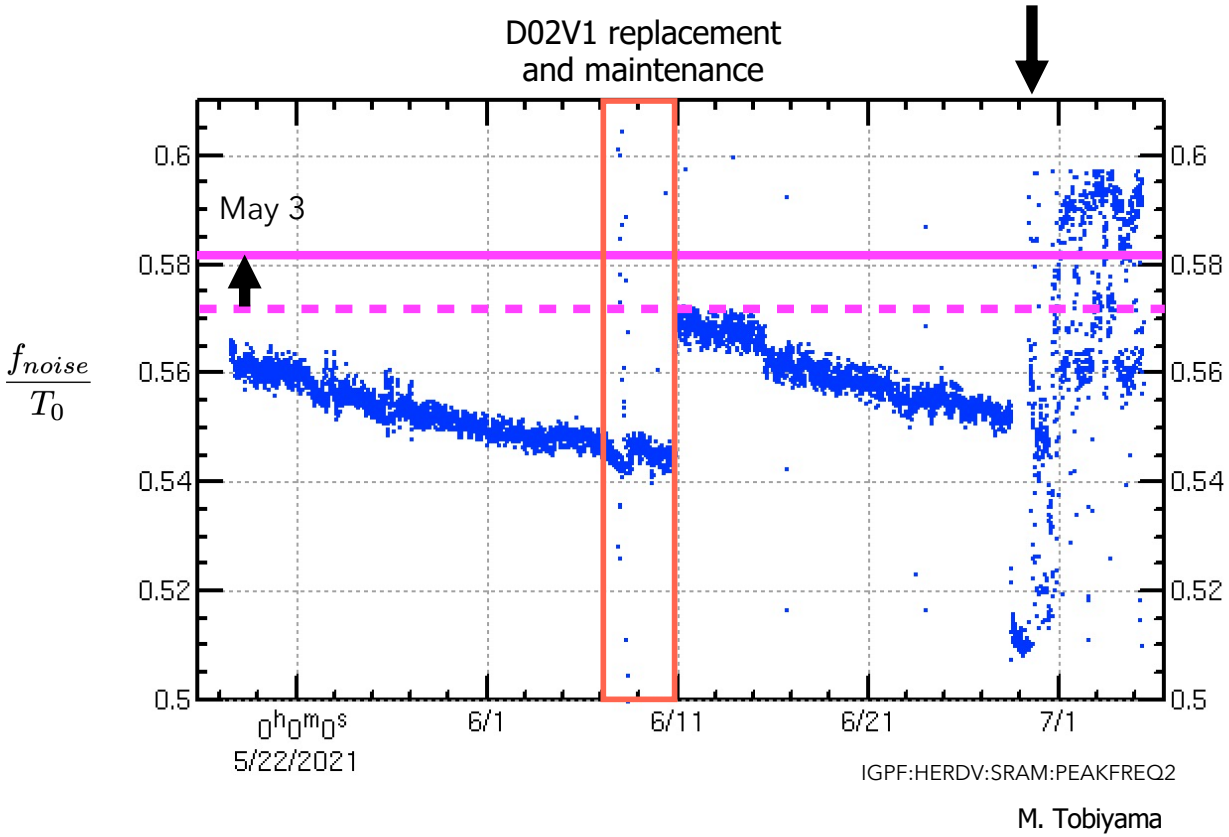
# More detail of $L_{sp}$



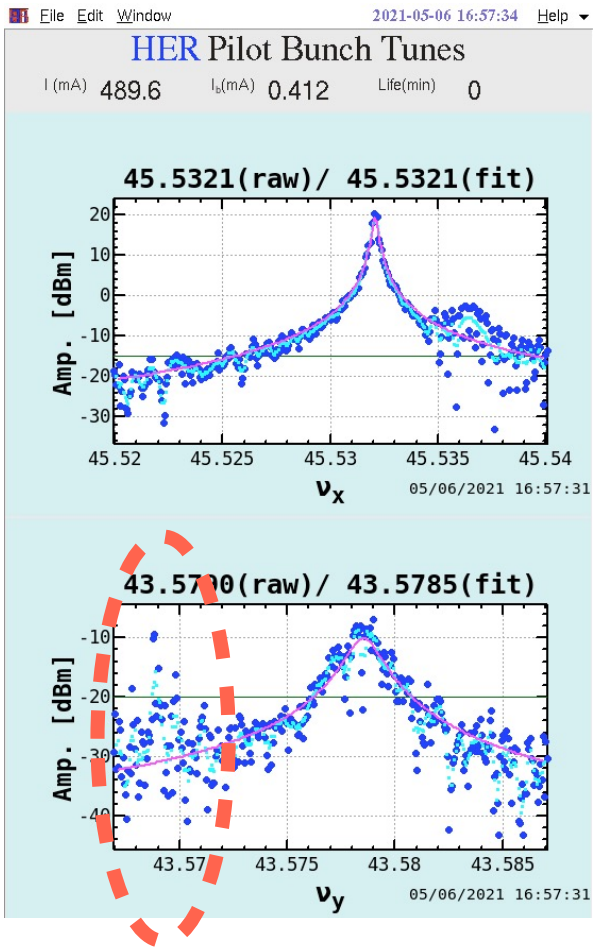
# BxB Feedback Noise in HER

HER BxB FB noise is fixed on June 29.
NIM bin and fanout replacement



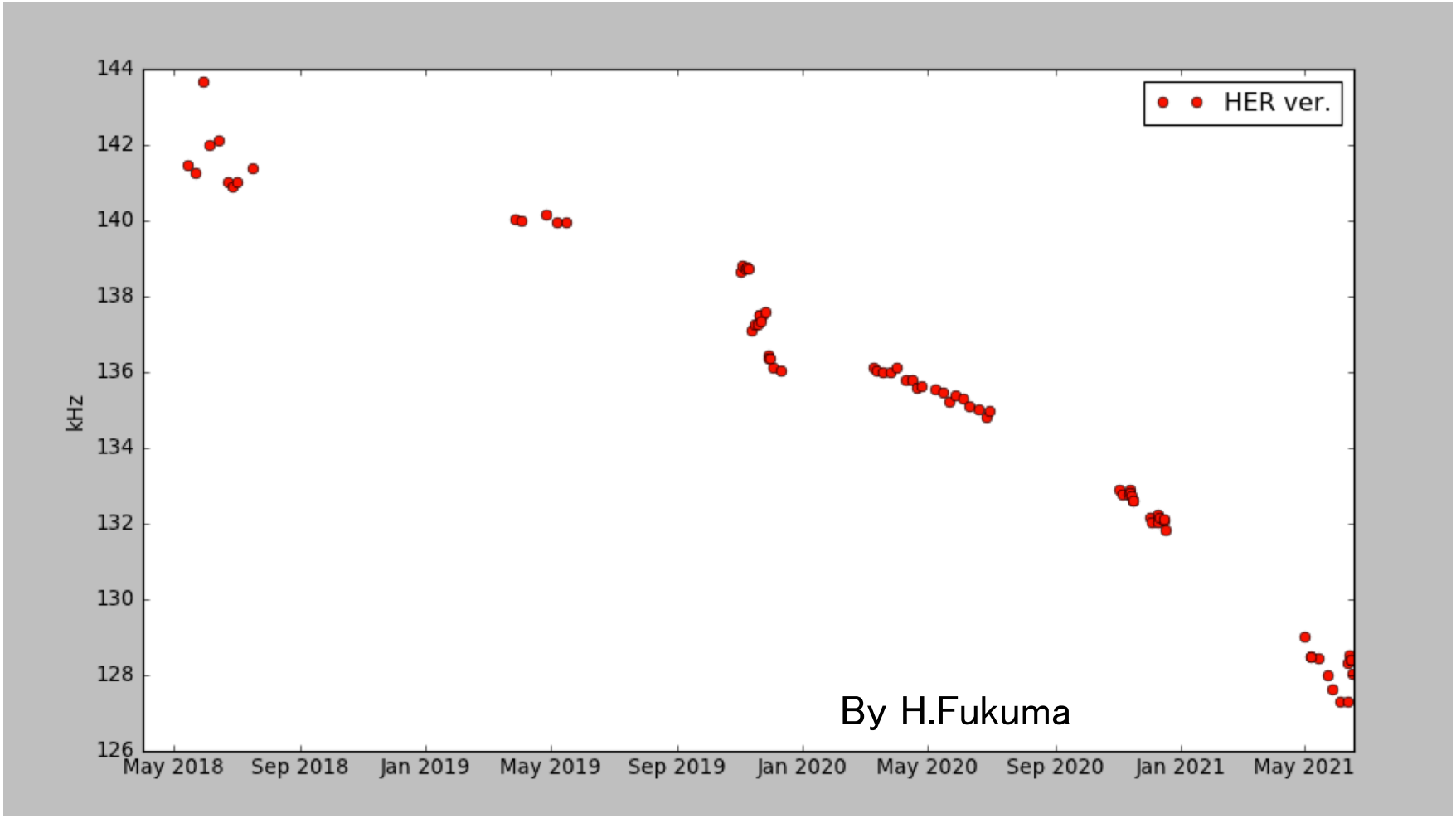

M. Tobiyama

May 6




The noise moved away from the working point on May 14.

# Found noise in the HER BxB FB



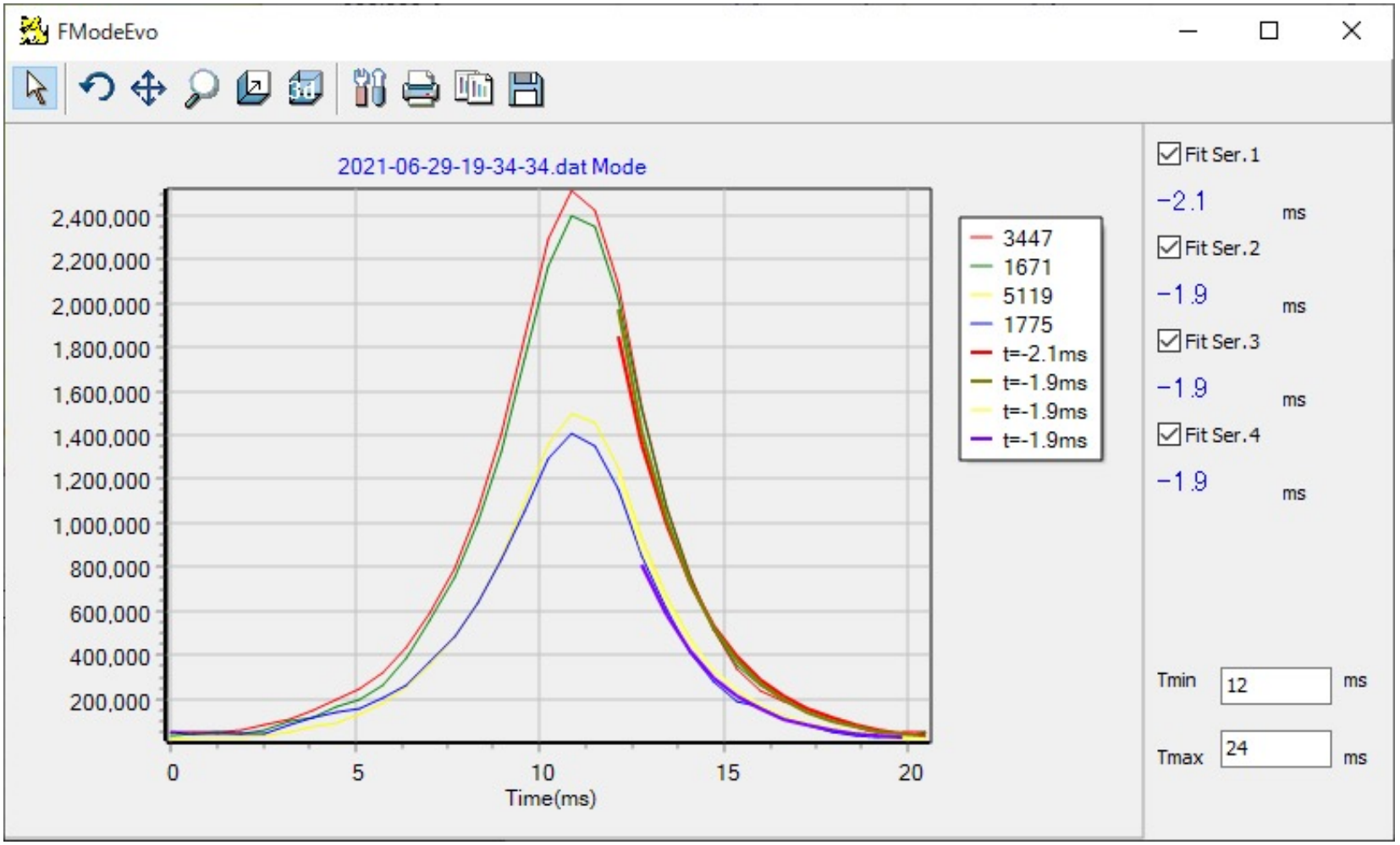

2nd harmonics of this signal (254kHz) affected the HER BxB FB

- **Found the suspicious NIM-PS for the HER timing system**
  - RF x4 multiplier
  - RF amplifiers
  - 2GHz phase shifter
  - 2-in 4-out Fanout (for fiducial distribution)
  - Huge voltage oscillation, especially -6V (Vpp~2V) with 127kHz
- **Prepared new NIM-ps, new RF x4 multiplier, switched the timing singal on 29/Jun**
- **No huge signal near vertical betatron tune**
  - Before : >20dB to baseline
  - After : almost no noise line (still tiny spurious remain)
- **Real cause:**
  - Fanout (2-in, 4-out, Houshin elec. ~10 years old) was the real cause of the PS oscillation.
  - Old technology (many large transistors, large package ECLs, etc) but not obviously damaged.

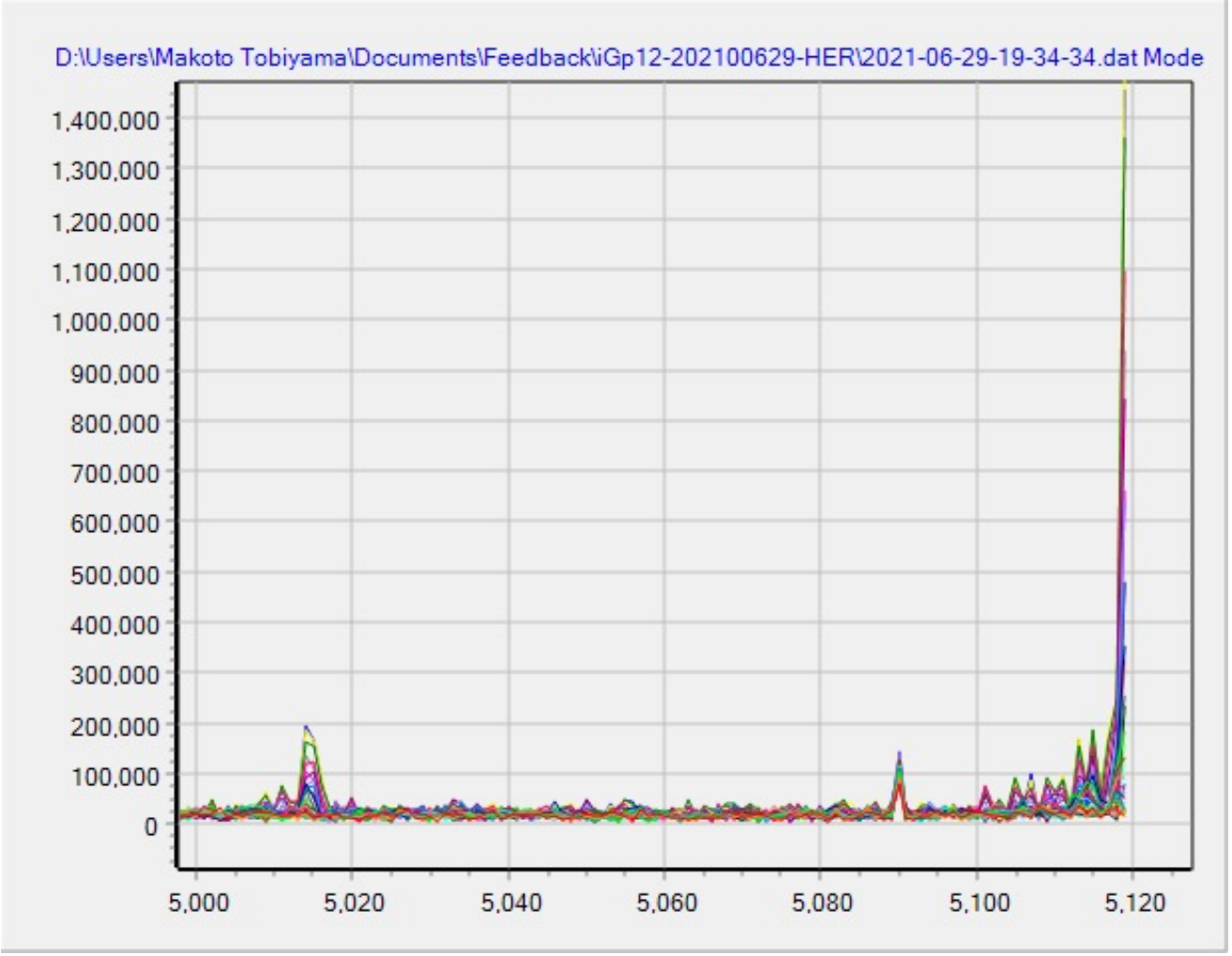
# HER vertical FB situation

- **Measurement of instability growth rate and feedback damping rate using transient domain analysis with iGp12 digital filters.**
  - turn off FB (10ms – 15ms) and turn-on again, record 12MB data
- **by*=8mm (200mA, 370mA), by*=1mm (200mA, 400mA, 600mA) with normal filling pattern of current runs.**
- **Mode -1 is the strongest mode, which is suspected to be caused by the resistive wall impedance.**
  - Unstable mode measurement at SuperKEKB Phase 1 has shown the ion-like unstable modes (and behaviors).
  - Recent measurement shows much weaker ion-like unstable modes.

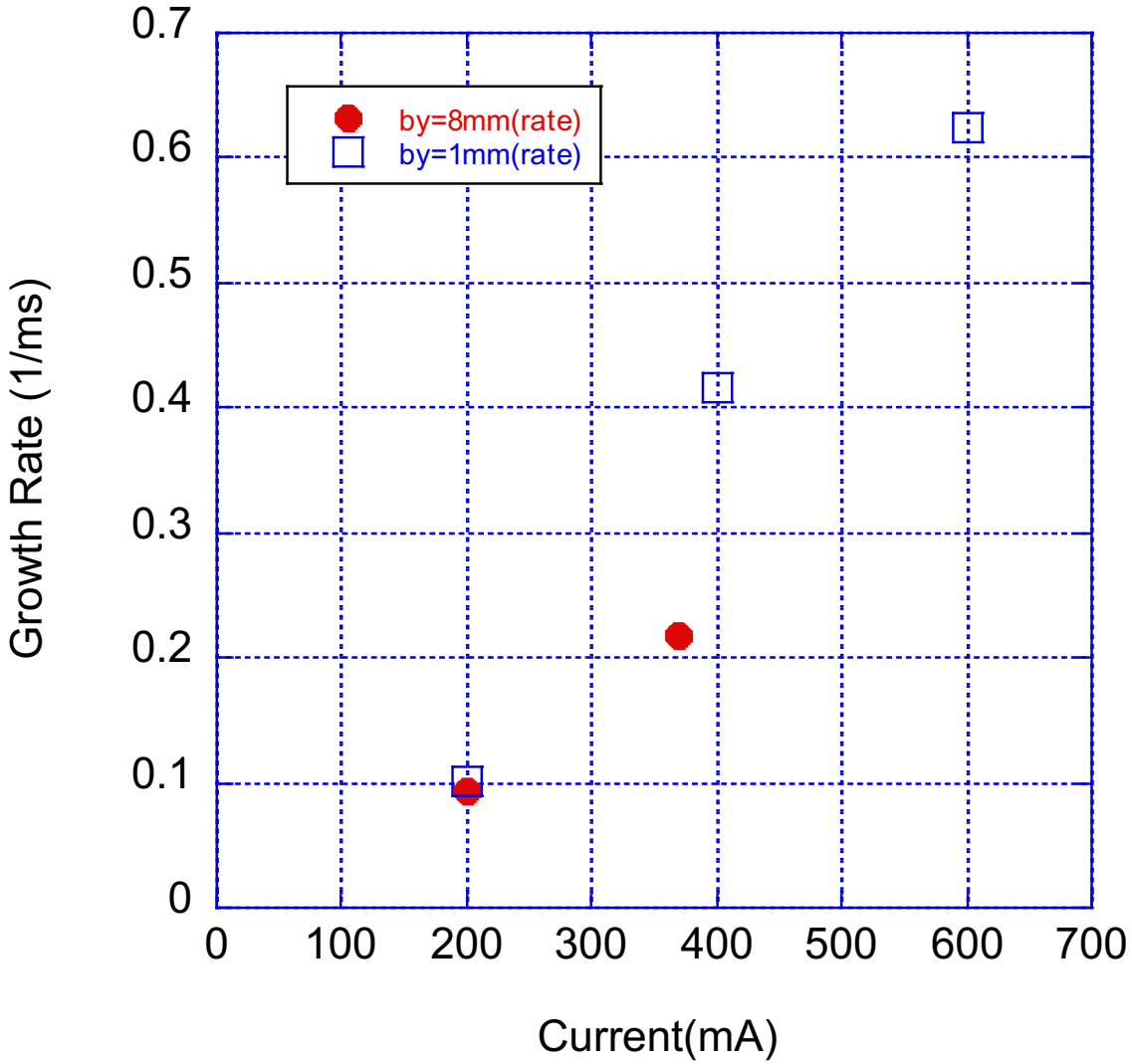
# Growth and damp of unstable modes



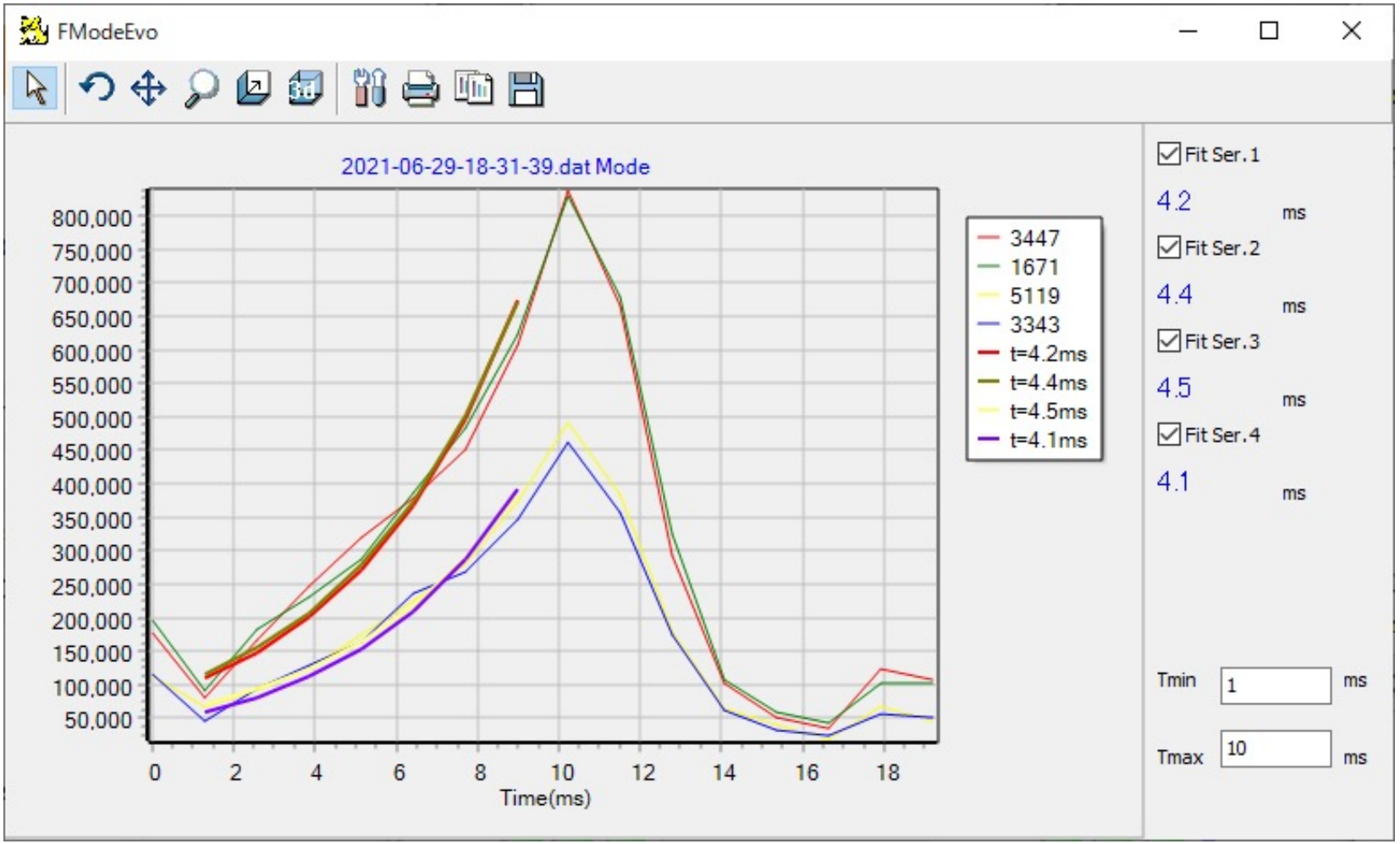
# −1 mode dominant



# Growth rate of (−1) mode



# During collision (by*=1mm, 670mA)



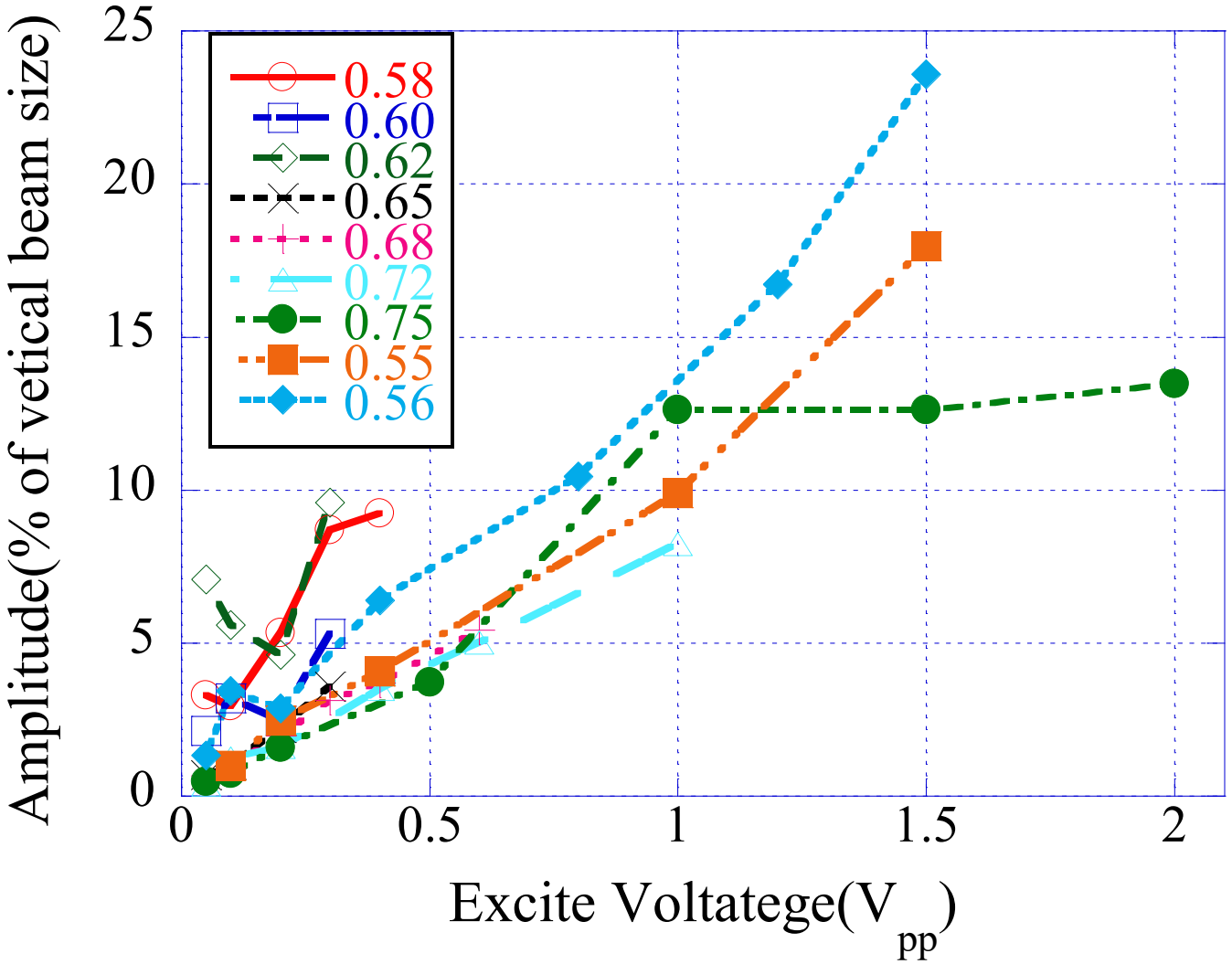
# Broadband noise in the FB system (KEKB time)

- **The effect has first observed during the KEKB operation**
  - Final amplifier in the 2GHz phase shifters (all HER and LER) were modified during long maintenance time– the output power had (significantly) increased. This caused the increase of the noise level of the FB detectors (also caused the increase of the feedback power).
  - After the maintenance, the luminosity had decreased.
  - Occasionally, one electrode of LER transverse feedback kicker had failed--- I've turned off one final power amplifier and observed the jumping up of the luminosity (to almost the original luminosity level)!
  - We've adjusted the level of the output of 2GHz phase shifter and lowered the V-FB gain.

# Noise effect study at KEKB

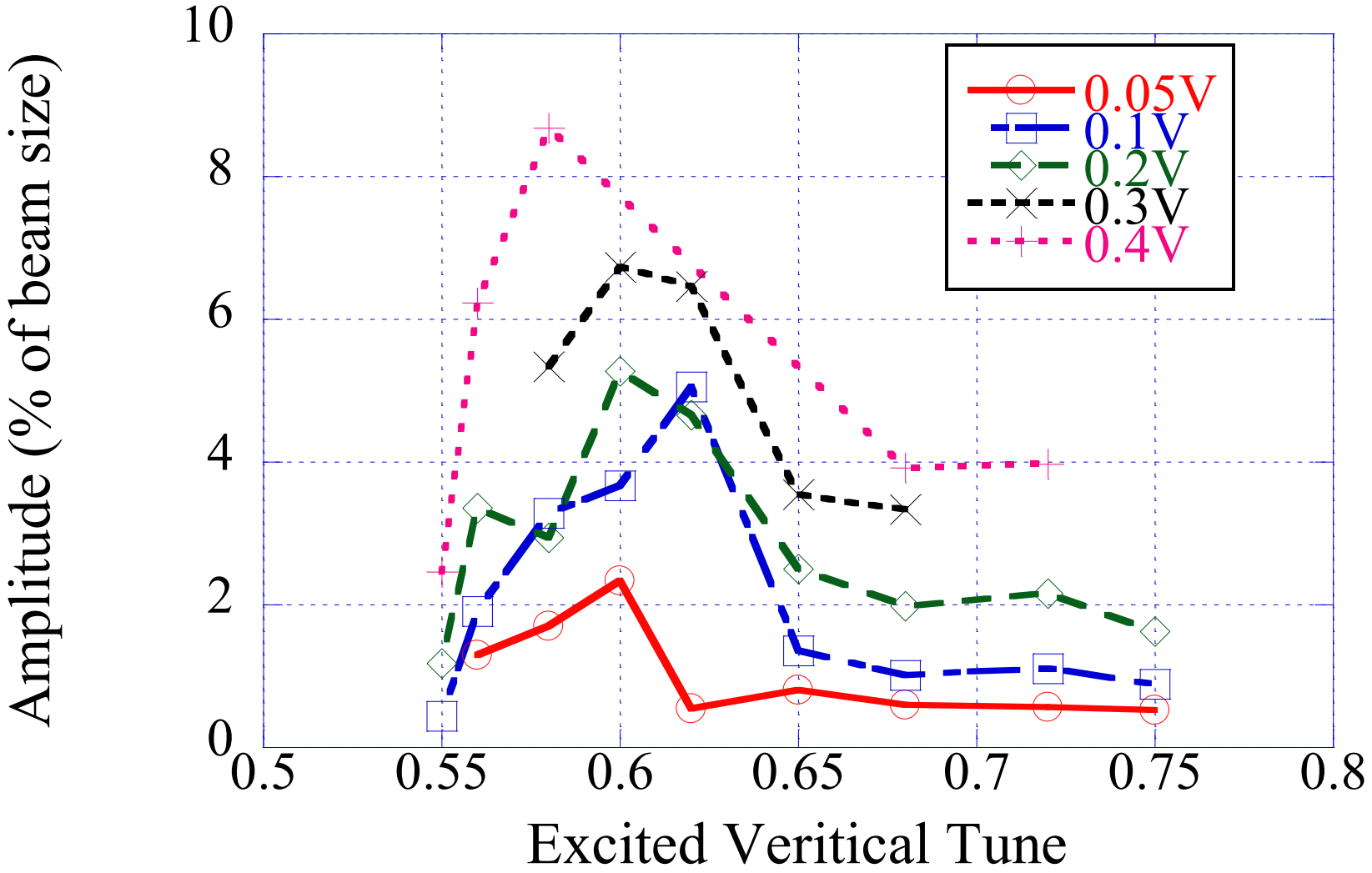
- With the systematic study of the relations between the trans-verse feedback gains and the luminosity, we have found only LER vertical feedback gain affected the luminosity and the vertical beam size; other transverse feedback gain, LER-H, HER-H and HER-V had no obvious relation to the luminosity.
- Though the vertical beam size slowly increased (~10%) with the feedback gain during single-beam condition, it jumped up more than 40% with small change of the feedback gain during collision. The resulting luminosity decreased around 10 to 20% with the blowup of the vertical beam size.
- We have injected pure sinusoidal signals or band-limited white noises from a function generator to the V-FB system. The amplitudes of the excited oscillation of the LER beam were detected with the bunch oscillation recorders (BOR).
- Reported at DIPAC2011 (MOPD73).

# Single frequency response (collision)

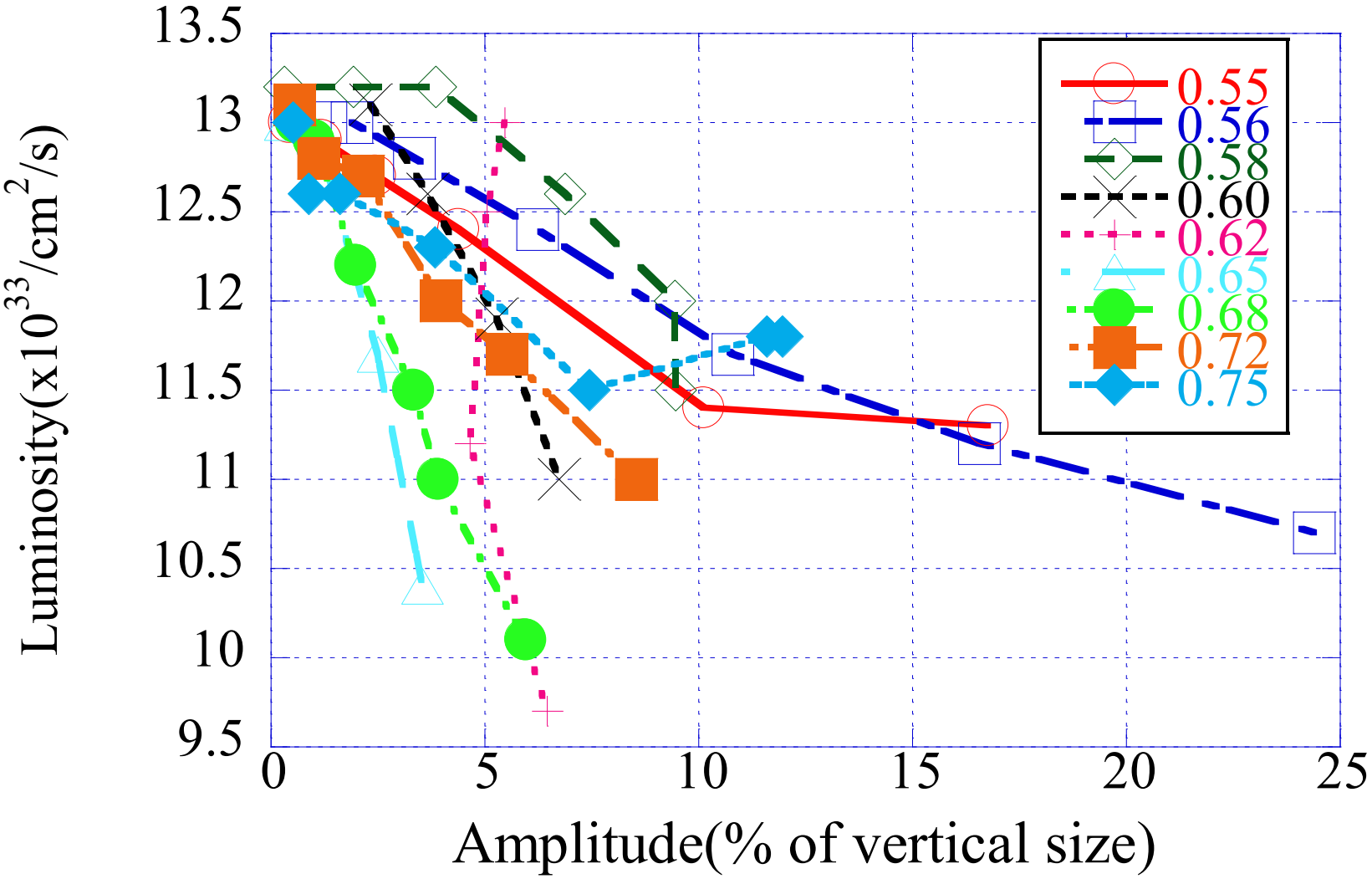



Larger response from tune (0.58) to 0.63 (tune + beam-beam tune shift)

# same excitation voltage



# Luminosity drop



- **Broadband noise in the feedback system could excite the beam, especially near V-tune (V-tune + beam-beam tune shift)**
- **Reducing the noise in the feedback system is essential.**
- **For SuperKEKB**
  - Use stripline-coupled filter to cut the lower frequency noise.
    - But cause large (>20dB) insertion loss (IL) in the system, need to amplify around 20dB to recover- main cause of the broadband noise.
  - Use low noise amplifers (LNAs) to reduce noise
    - Noise Figure (NF) at the head of the system is meaningful- good LNAs after large IL might not be important, though.

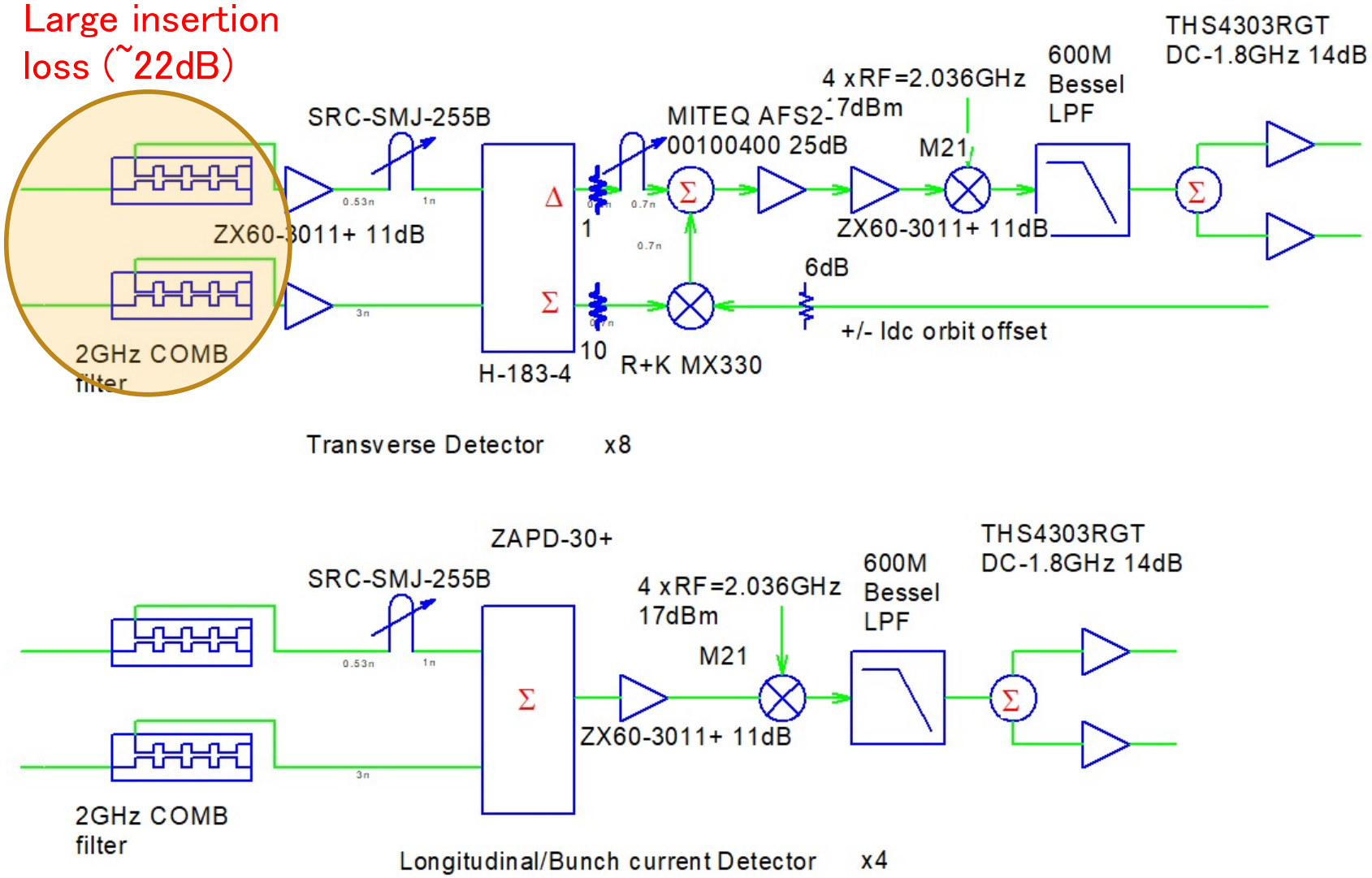
# Current situation

- **Noise level from the FB detector is around 10 counts of ADC RMS (12 bit ADC)– with internal noise level of 1.1 counts.**
- **Sensitivity of the FB detector is roughly**

  **2.0 counts/mA/um (HER upstream) to**

  **4.4 counts/mA/um (LER downstream)**
- **Resulting RMS counts with zero current is around 10 counts.**
- **FB gain effect to the luminosity seems not so large now**
  - Turning off one LER vertical loop showed small improvement of the luminosity

# SuperKEKB BxB detection system



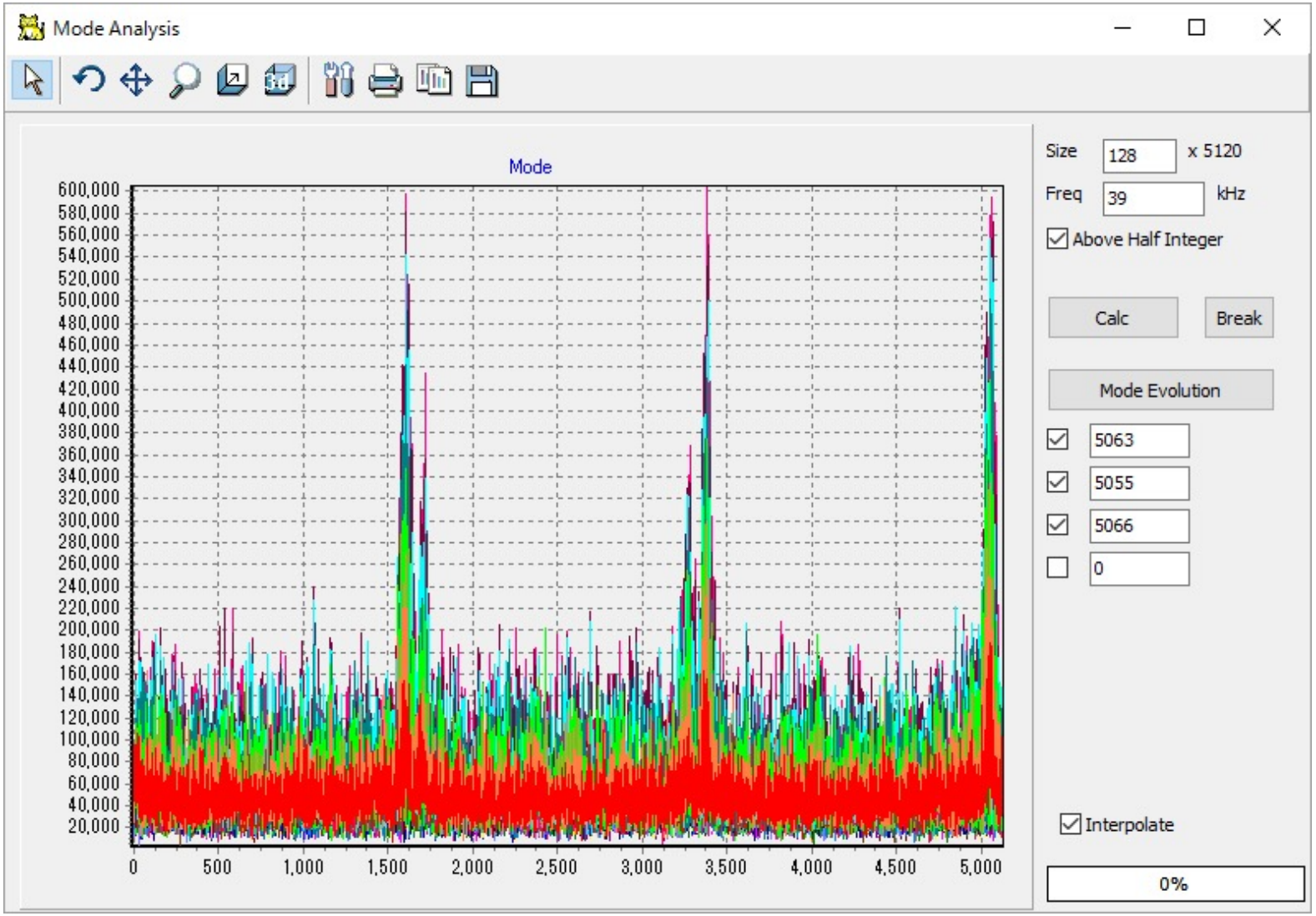
- **Replacing 2GHz stripline-coupled comb filter with cable-delay type BPF (2GHz) could improve the noise figure more than 20dB.**
  - Insertion loss (22dB) + Noise figure of Low noise amplifier (>1dB)
- **Cable-type BPF passes low frequency noise- the effect should be checked by the beam.**

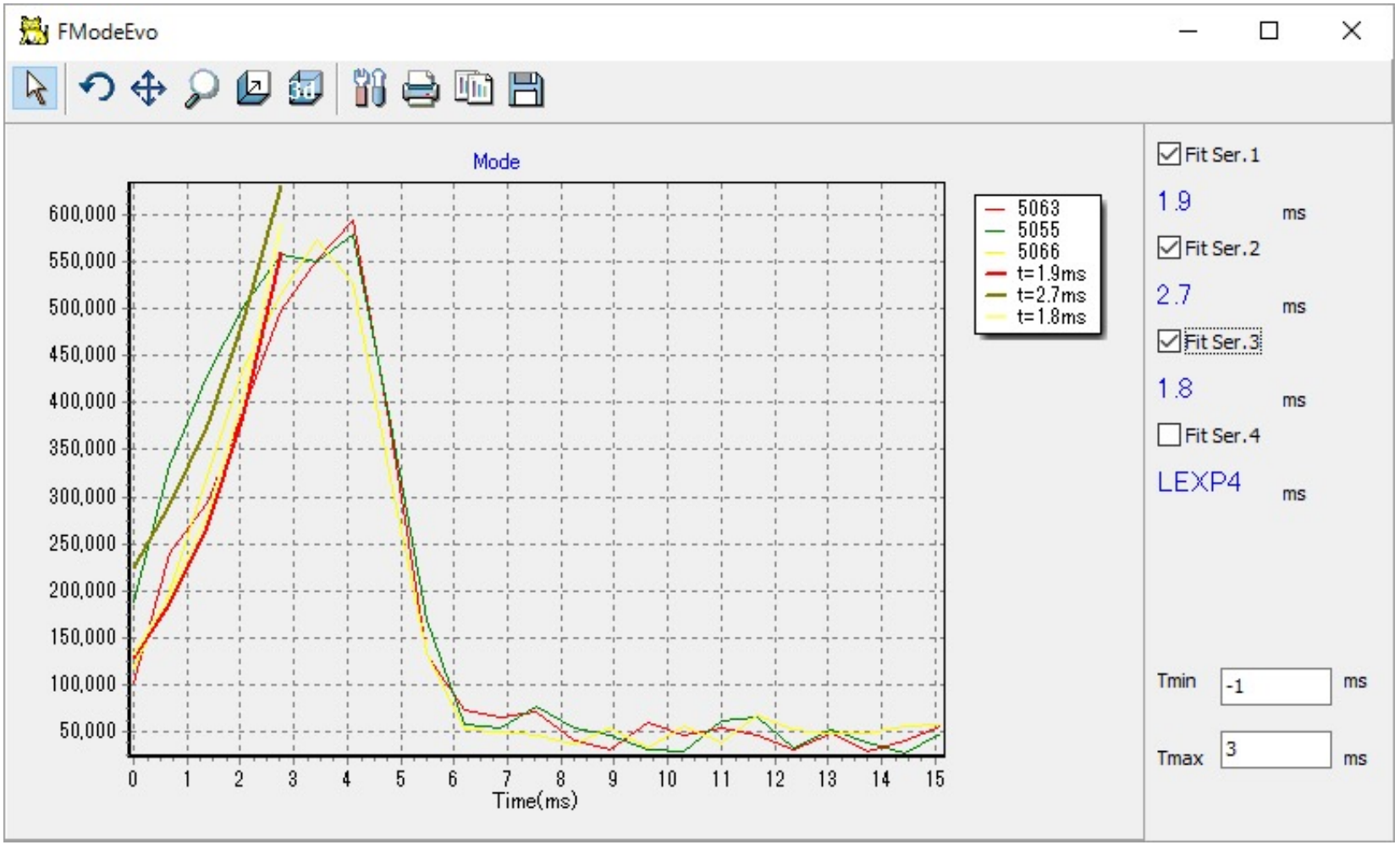
# Summary

- Noise injected to the HER BxB feedback system has caused vertical beam blowup, beam loss, and luminosity drop.
- The source of the noise has been identified and removed.
- Current HER vertical feedback gain seems to be enough to suppress the CBI (mode −1).
- For further reduction of the FB detector noise, we will replace the first 2GHz comb filter with large insertion loss to the cable-type bans pass filter, and check the result with the beam (maybe around 2022a/b runs).

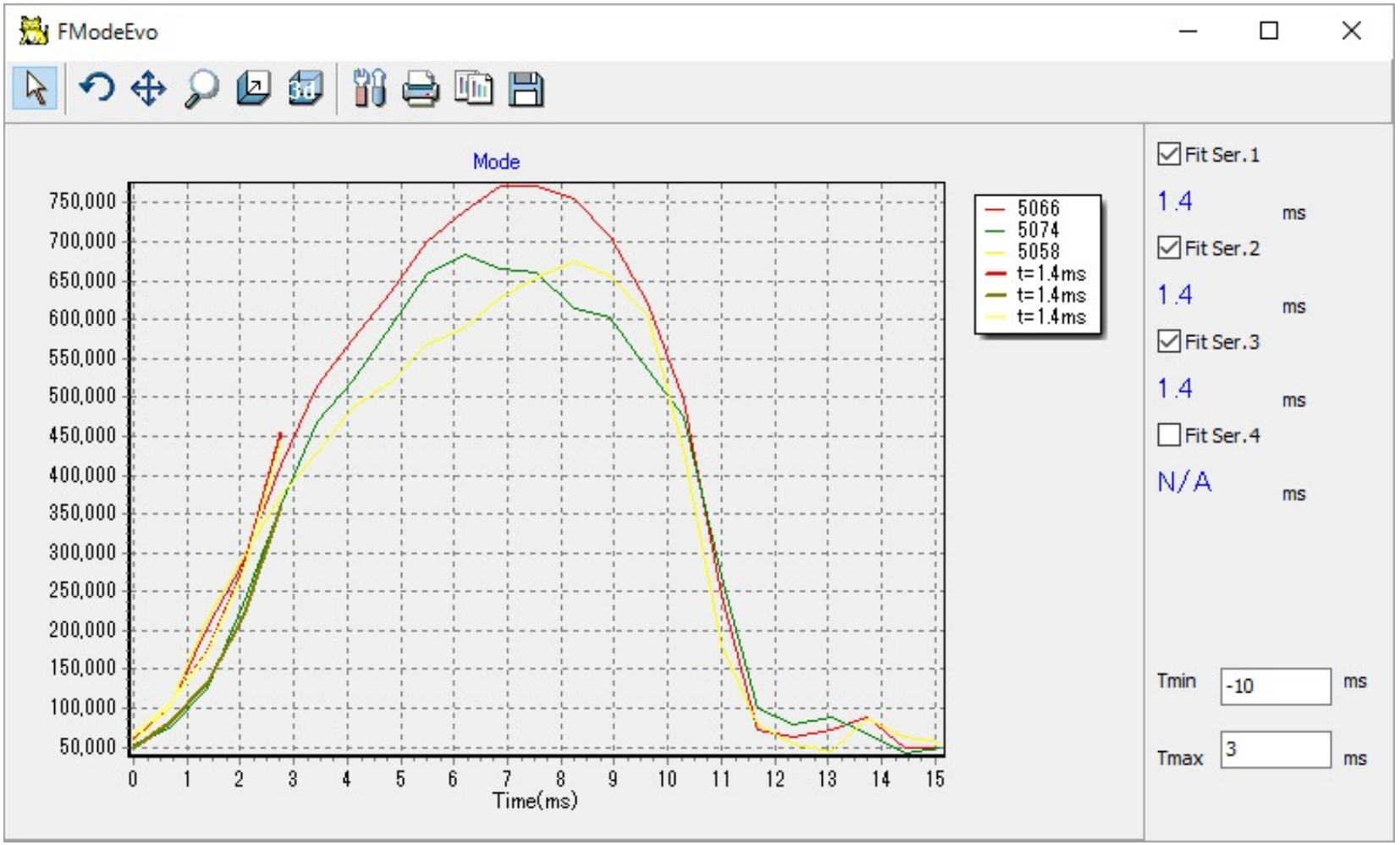
# backup

# Mode analysis at Phase 1

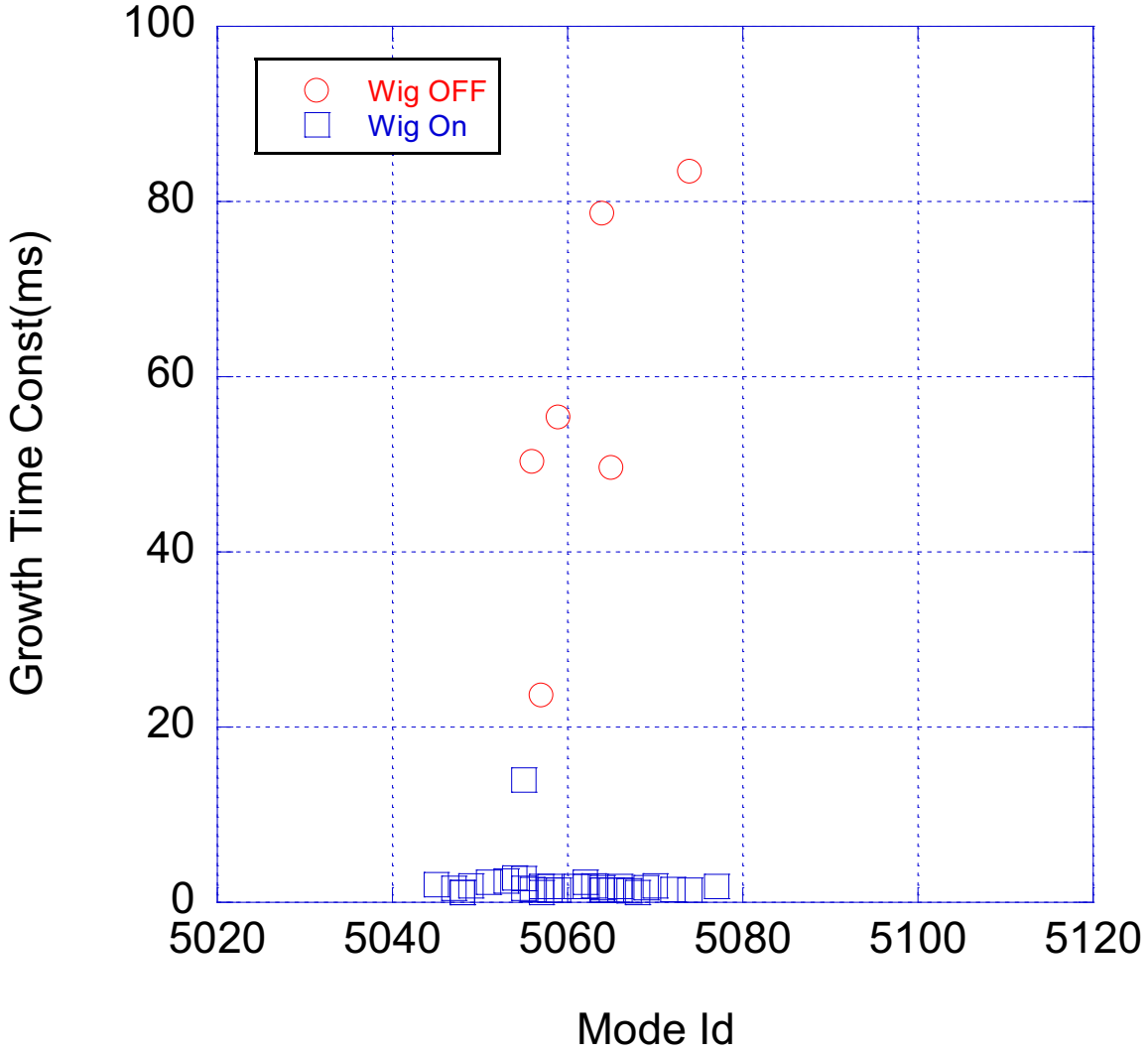


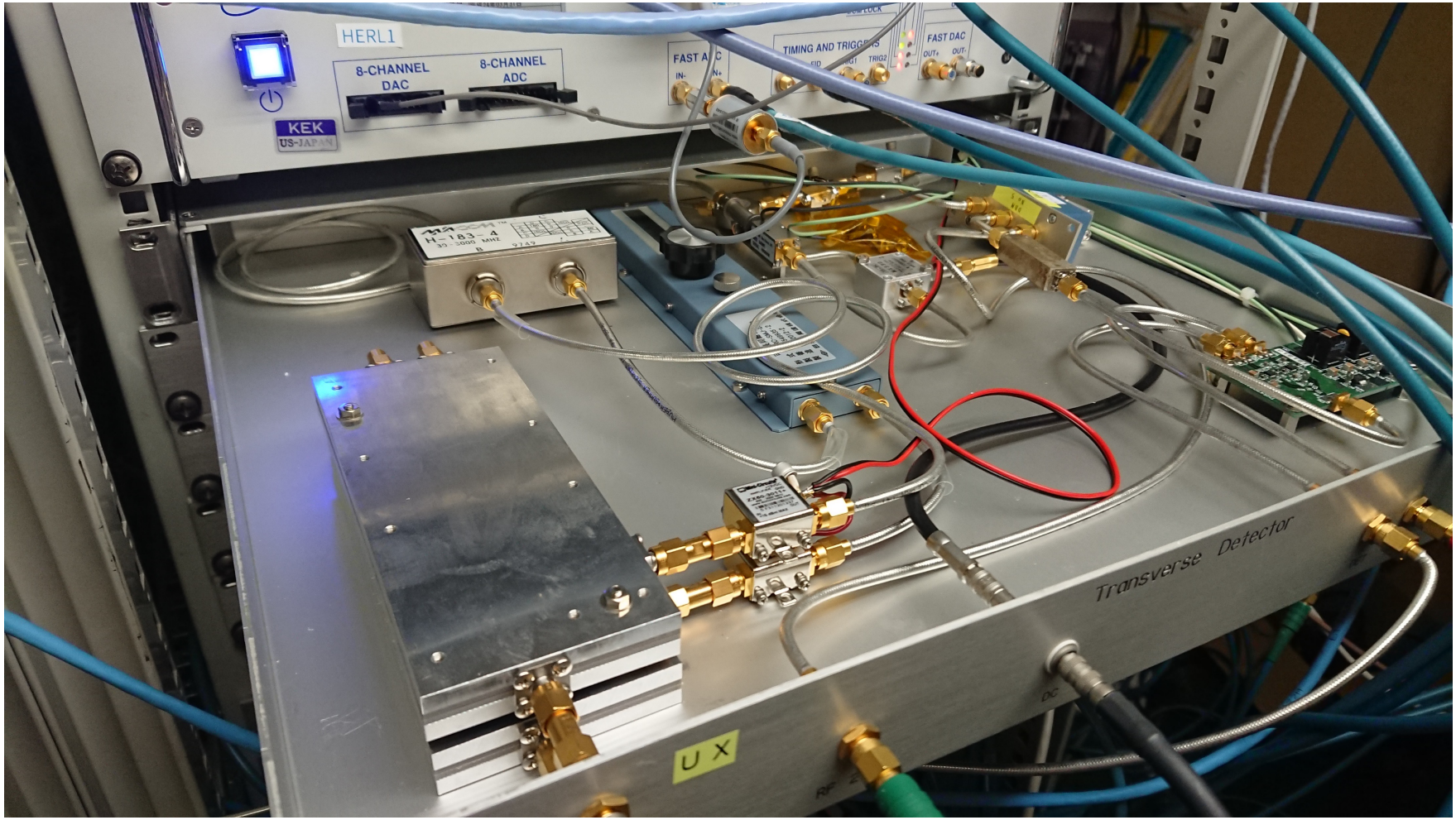

FModeEvo
Mode
600,000
550,000
500,000
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Time(ms)
5063
5055
5066
t=1.9ms
t=2.7ms
t=1.8ms
Fit Ser.1
1.9
ms
Fit Ser.2
2.7
ms
Fit Ser.3
1.8
ms
Fit Ser.4
LEXP4
ms
Tmin
-1
ms
Tmax
3
ms

# longer time after FB off

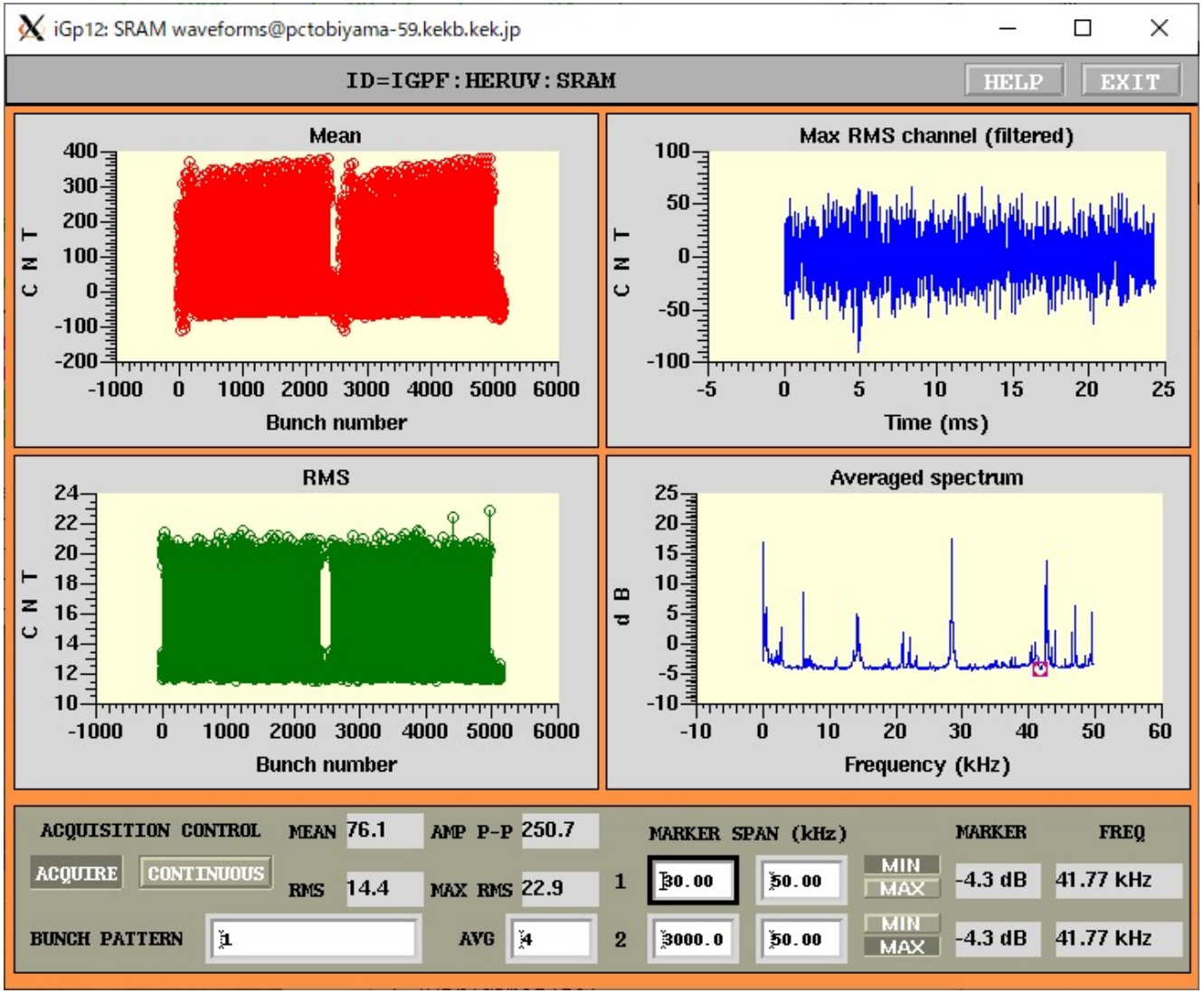


# Vertical Mode




HERL1
8-CHANNEL DAC
8-CHANNEL ADC
KEK
US-JAPAN
FAST DAC
Transverse Detector
U X

# Using iGp12 RMS



# Example

| | |
|---|---|
| iGp12 only (with offset cancel from int DAC) | 1.1 |
| Final DC amp only | 2.5 |
| | |
| With cable | 14.1 |
| Input terminate | 14.1 |
| W/O offset cancel DC | 14.1 |
| H183-4 input terminate | 7.7 |
| | |
| W/O Final DC amp | 6.0 |