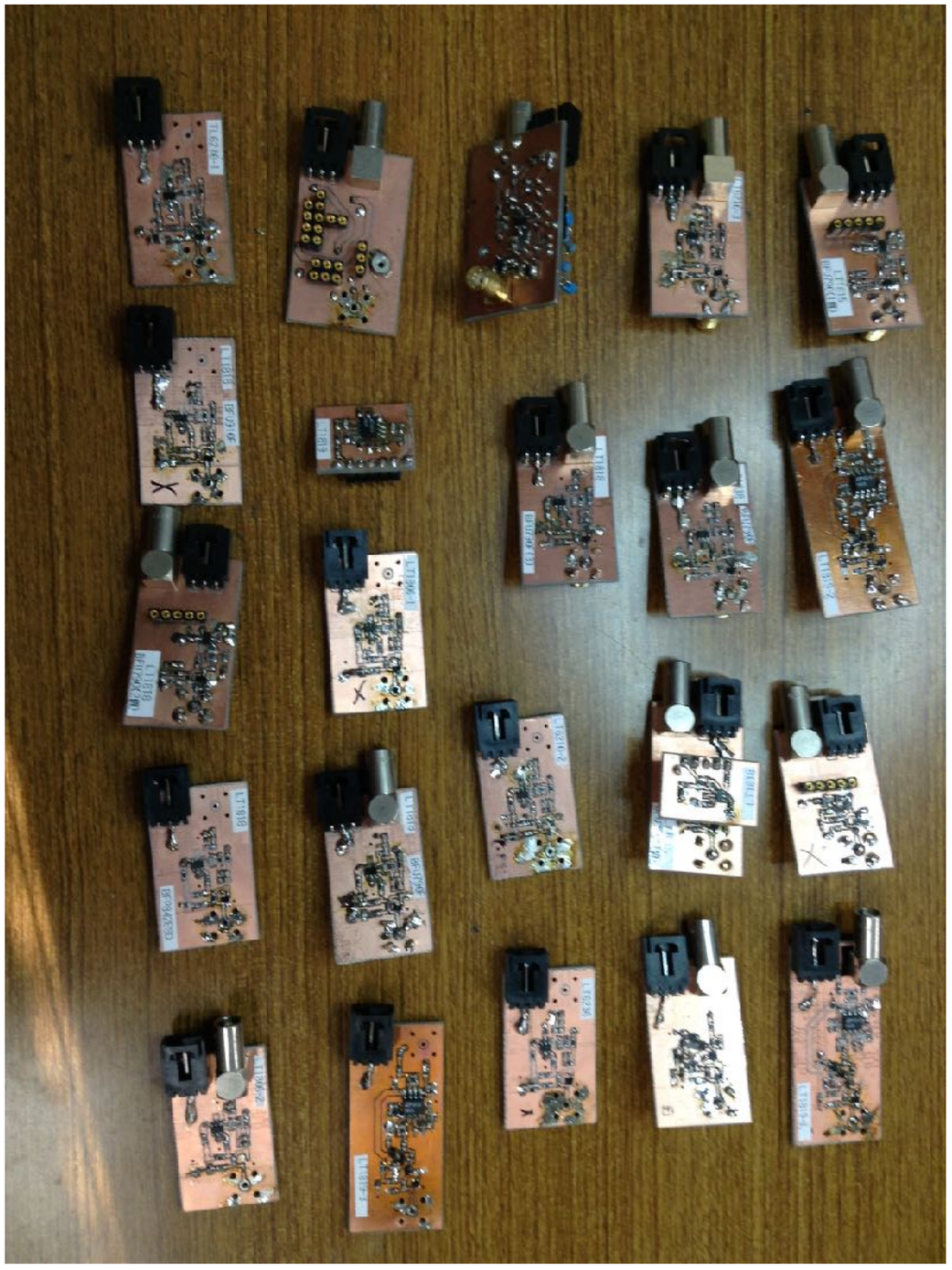

Calibration and Development of Preamplifier for 8-inch Hybrid Photo Detector

2018/11/29

5th International Workshop on New Photon-Detectors (PD18)

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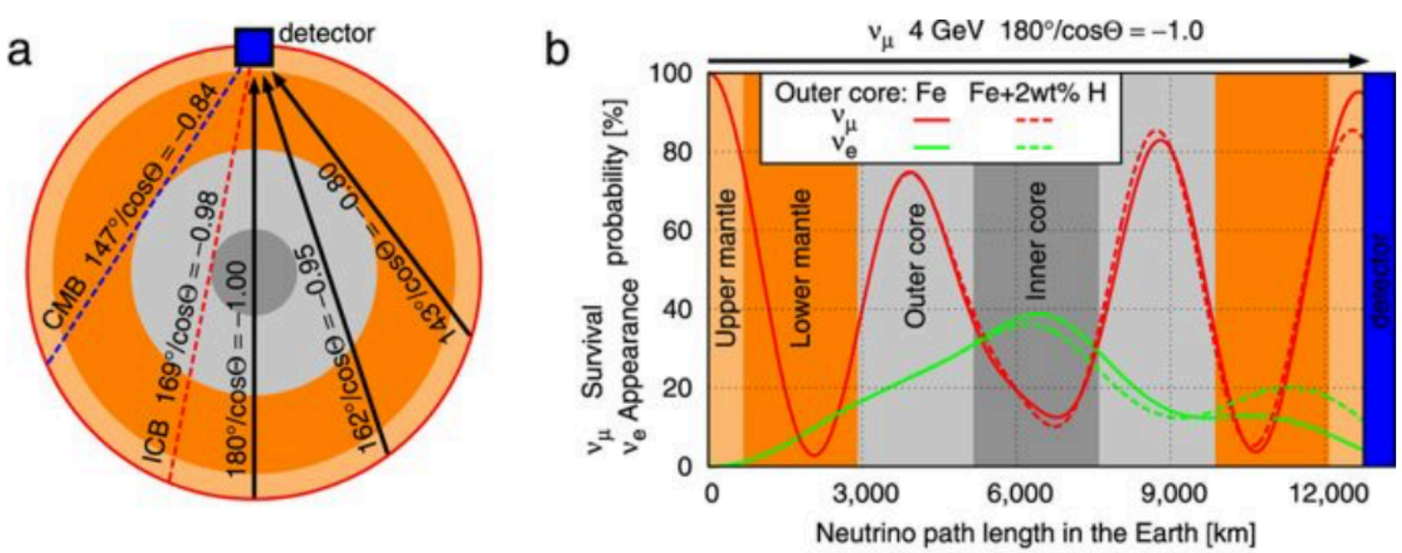
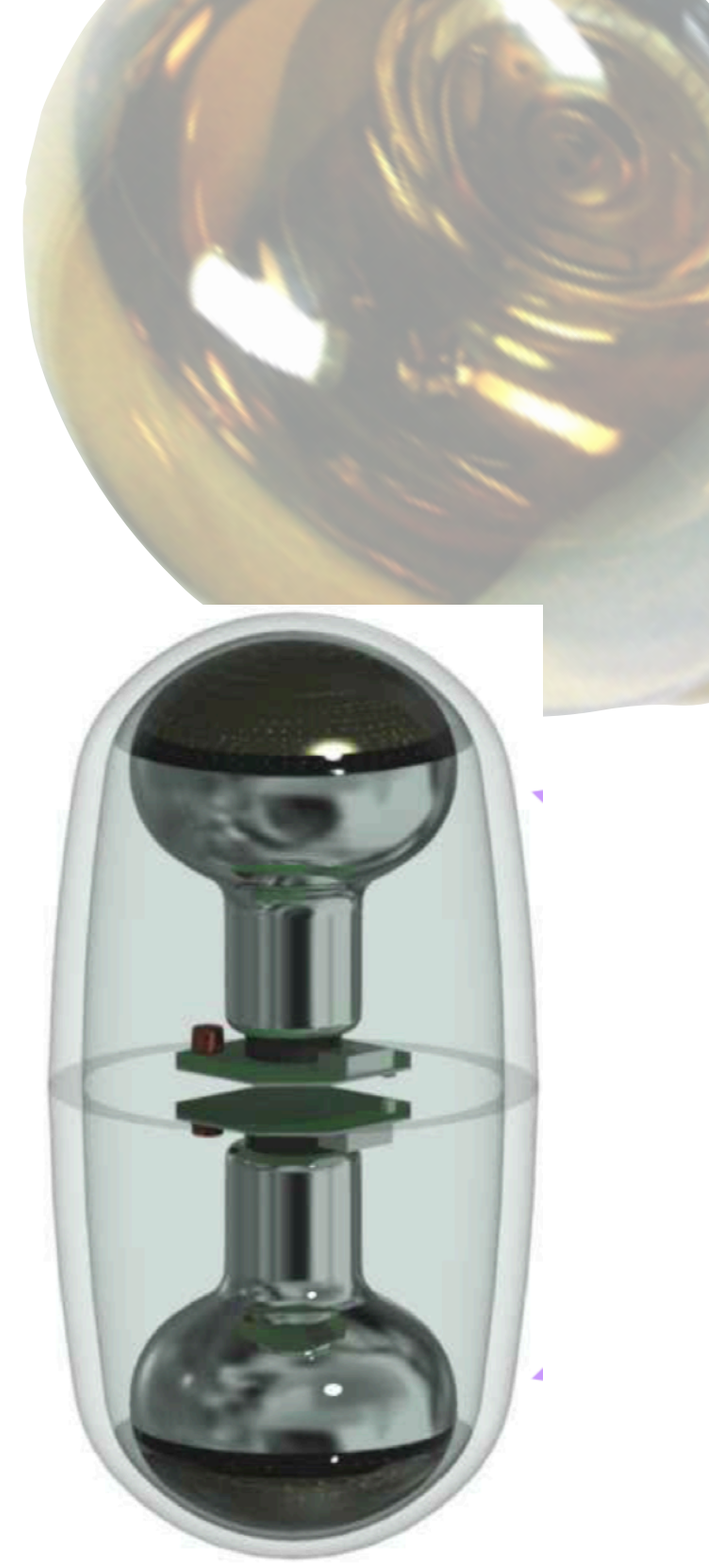
Background motivation

- A future mega-ton neutrino detectors may give limits of chemical composition of Earth's core
- The detector have to have sensitivity around GeV ~ a few ten GeV to see matter effect of oscillation
  - Reconstruction may be severe due to small number of hits
  - The detector must have good resolutions (charge, timing, etc…)



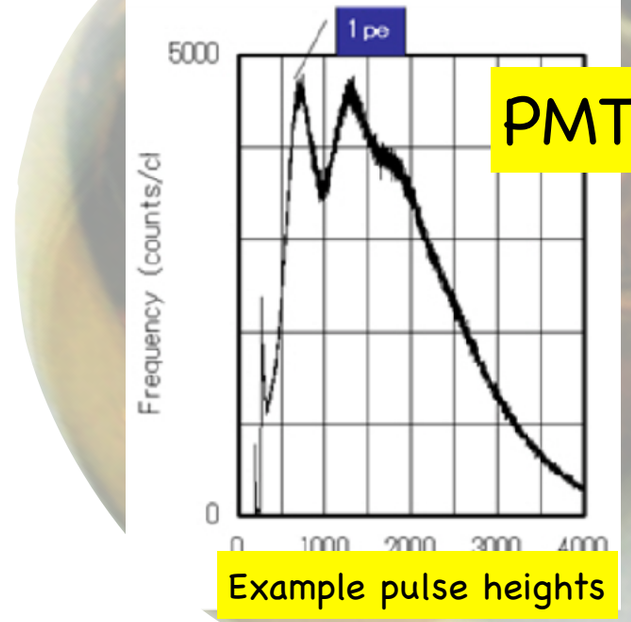
C. Rott, A. Taketa & D. Bose, Scientific Reports volume 5, Article number: 15225 (2015)

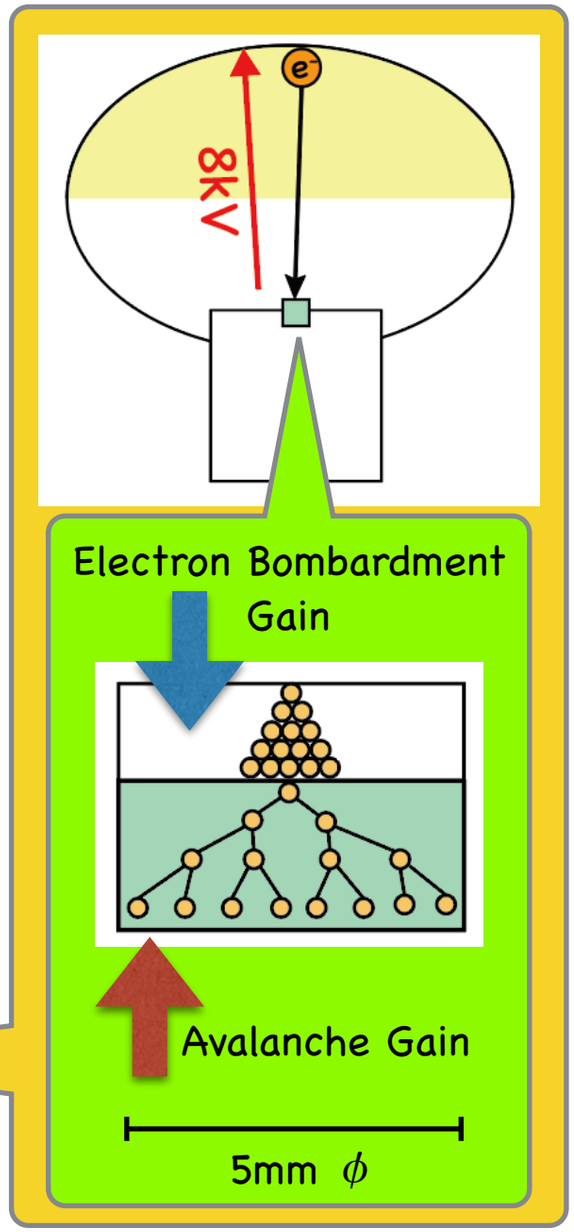


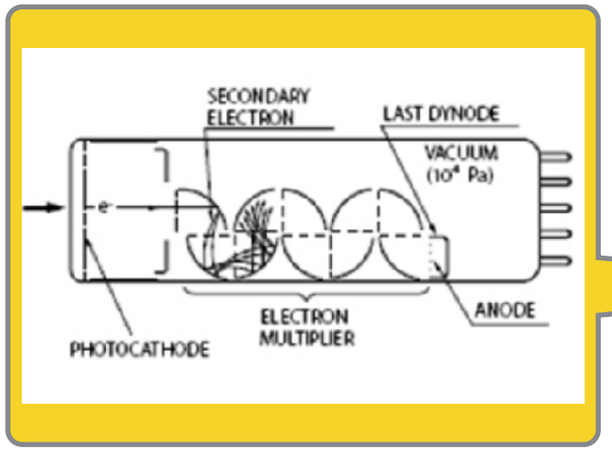
D-Egg for low energies?
(about D-Egg see Nagai-san's presentation)

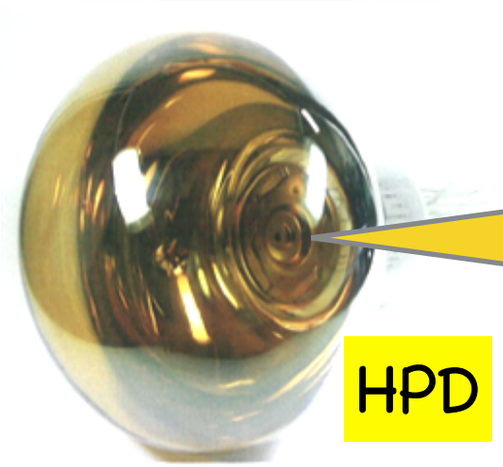
Why Hybrid Photo Detector(HPD) ?

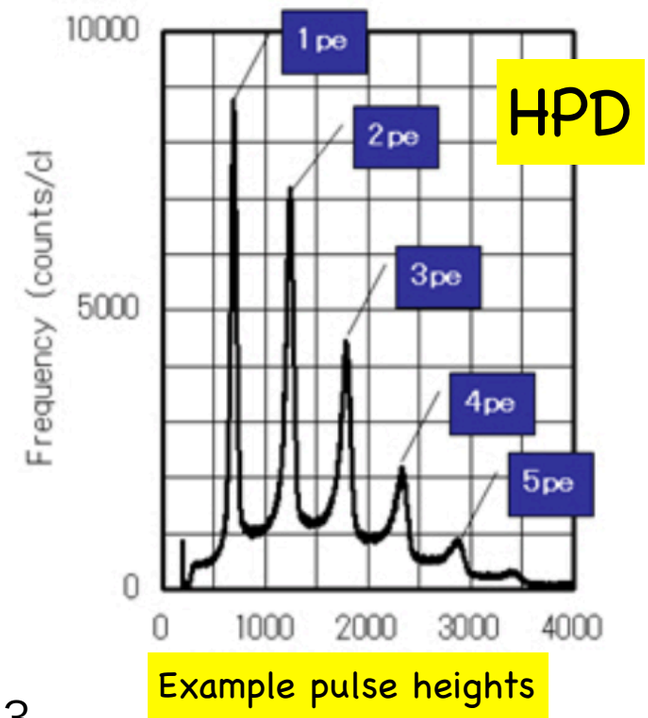
- Next generation photo detector but not too fancy
- Good charge resolution and time resolution
- Requires high voltage (8kV ~ 10kV)
- Has strong temperature dependency

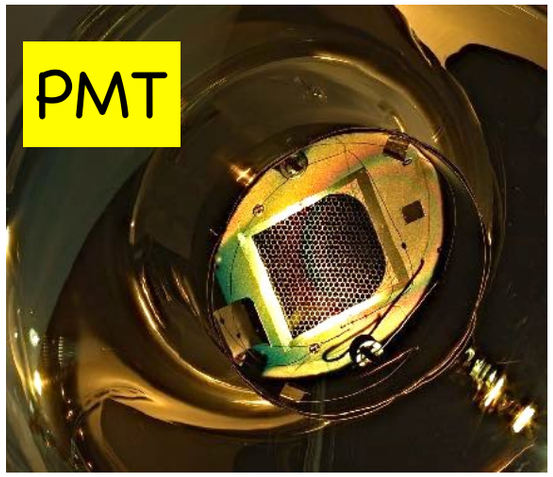












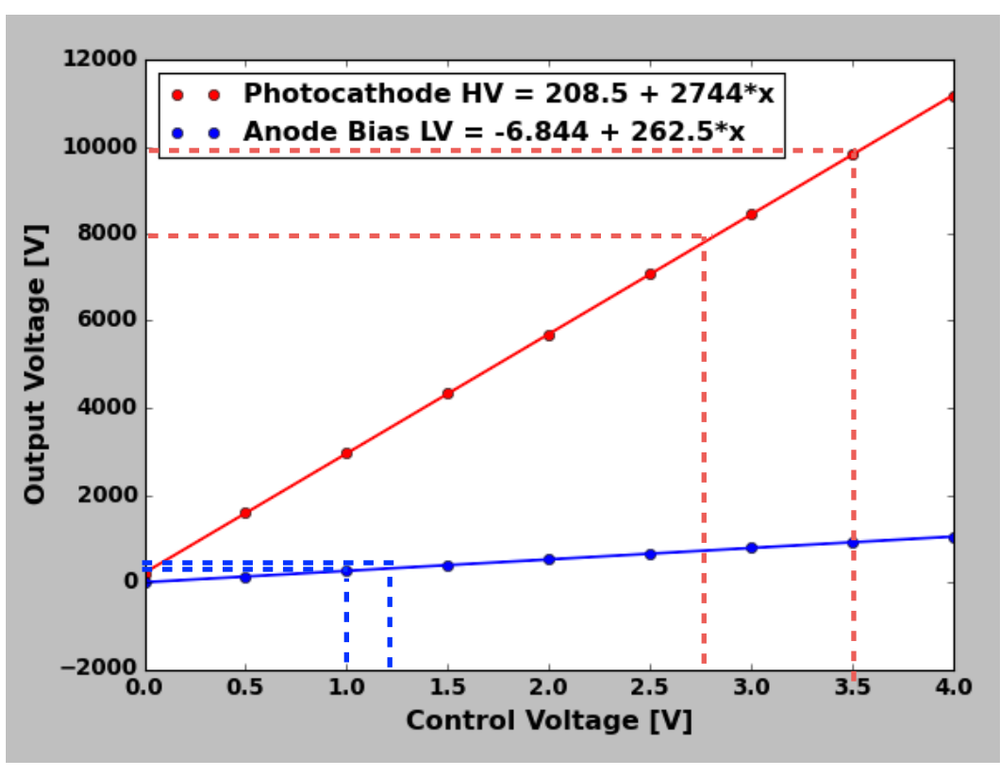
There are pros and cons.
Let's check how HPD (Hamamatsu R12112) is good!

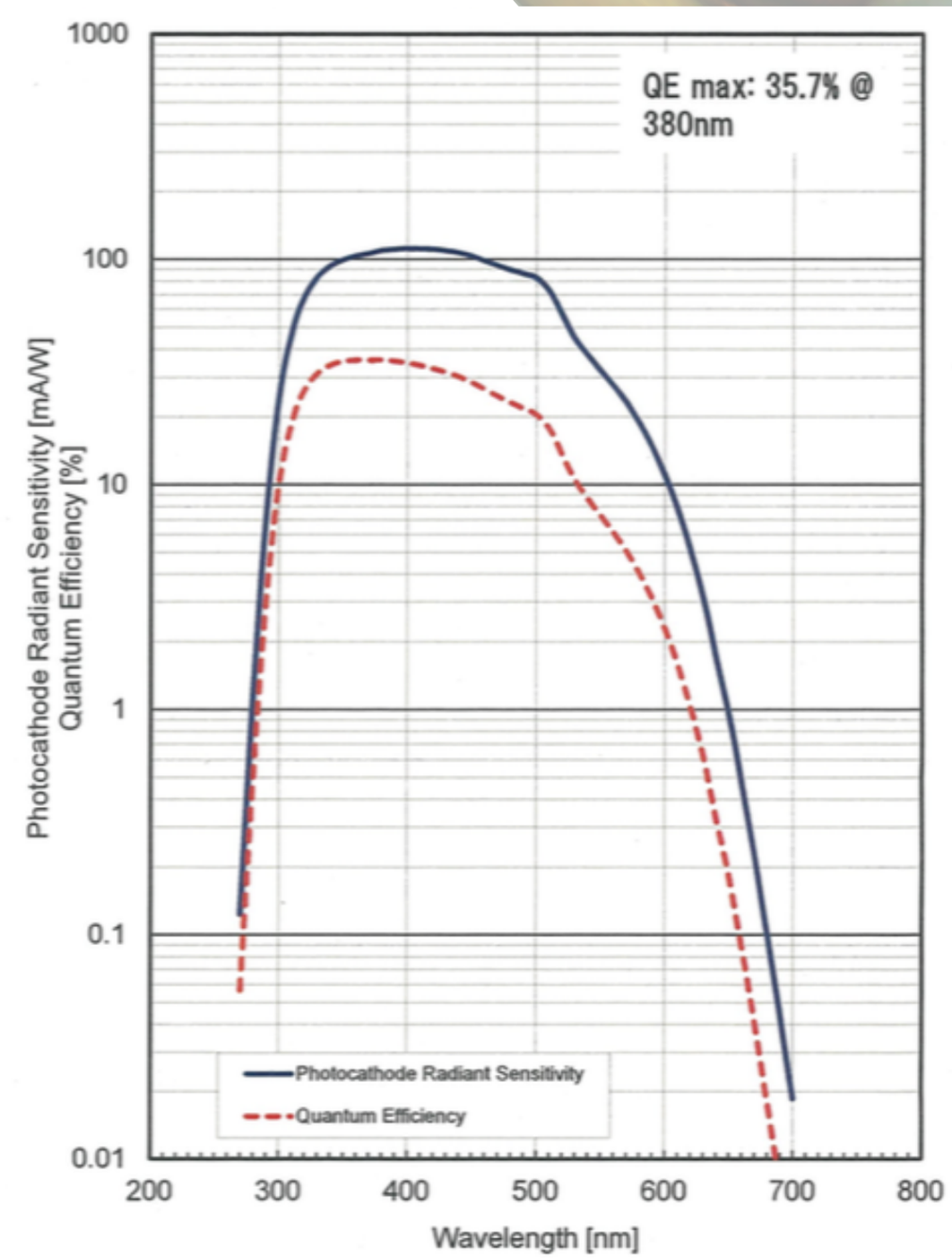
- Gain and Charge resolution
- Timing resolution
- Dynamic range
- Noise Rate
- After pulse (not yet finished, skipped today!)

All features listed above except for Noise Rate is affected by the preamplifier and main amplifier.
To get maximum performance of R12112,
we developed several preamplifiers and main amplifiers.

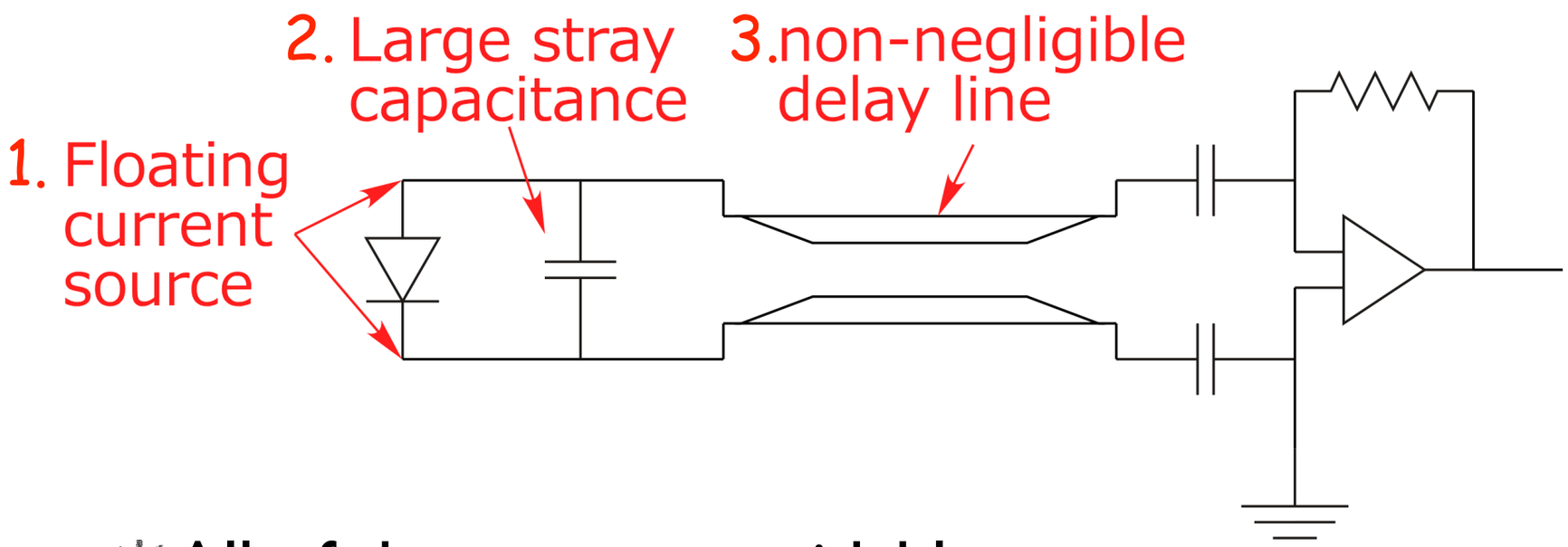
Overview of Hamamatsu 8-inch HPD (R12112)

- Operation Voltage
  - Photo Cathode to Avalanche Diode : 8kV ~ 10kV (HV Cont. Voltage 2.8V ~ 3.5V)
  - Anode Bias Voltage : 200V ~ 370V (LV Cont. Voltage 0.8V ~ 1.2V)
  - Optimum voltage range has strong dependency to operation temperature





A triple handicap of HPD circuit



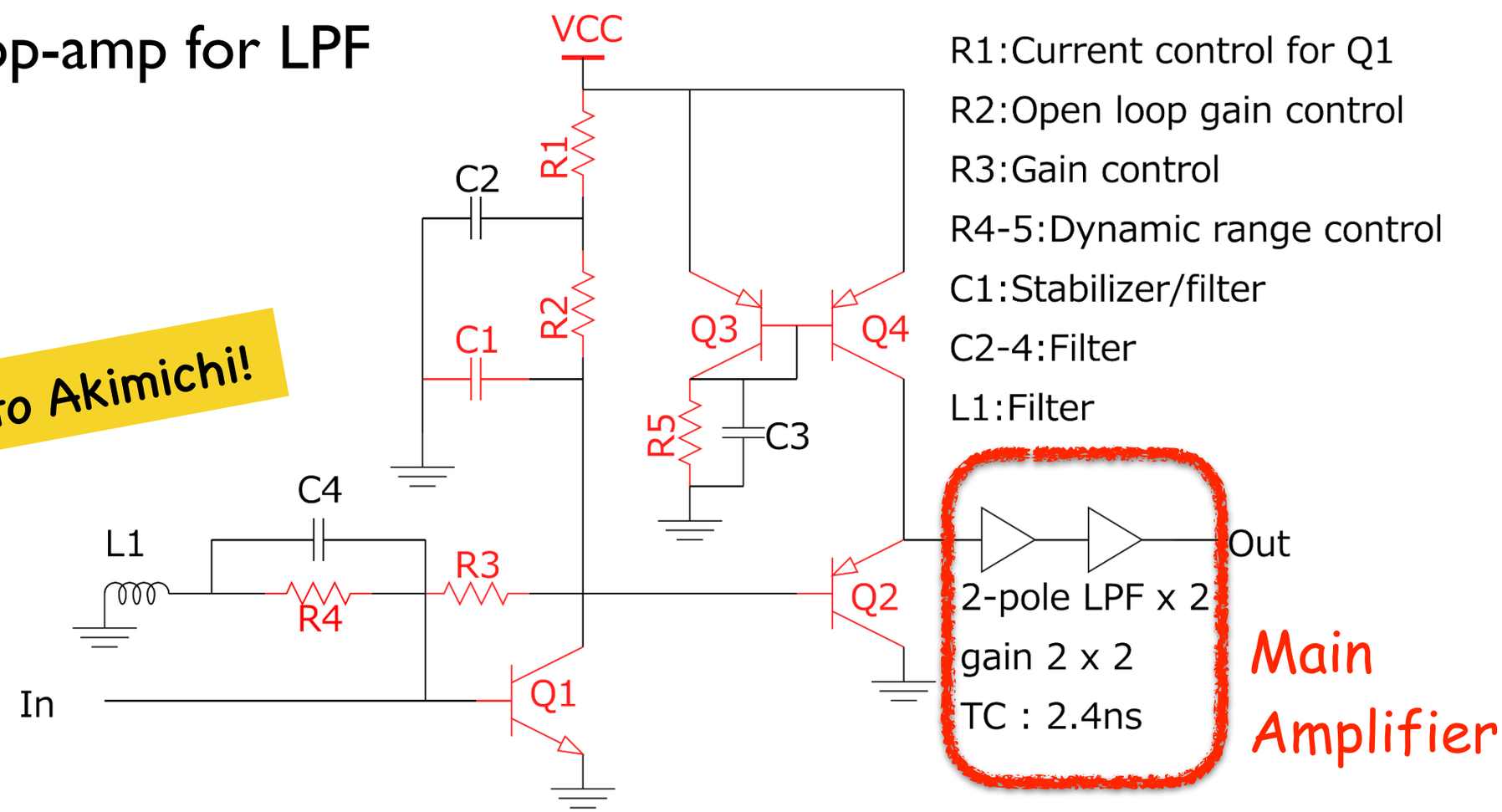
- All of them are unavoidable
  - Inside of HPD
- This circuit generates
  - Large transimpedance noise
  - Phase delay in high frequency range
- Very hard to develop fast and low noise amplifier

Ask questions to Akimichi!

An example of circuit…

- Solution is not unique
- Very old topology, but latest technology
- Q1 : SiGe:C NPN (8th generation)
- Low noise op-amp for LPF

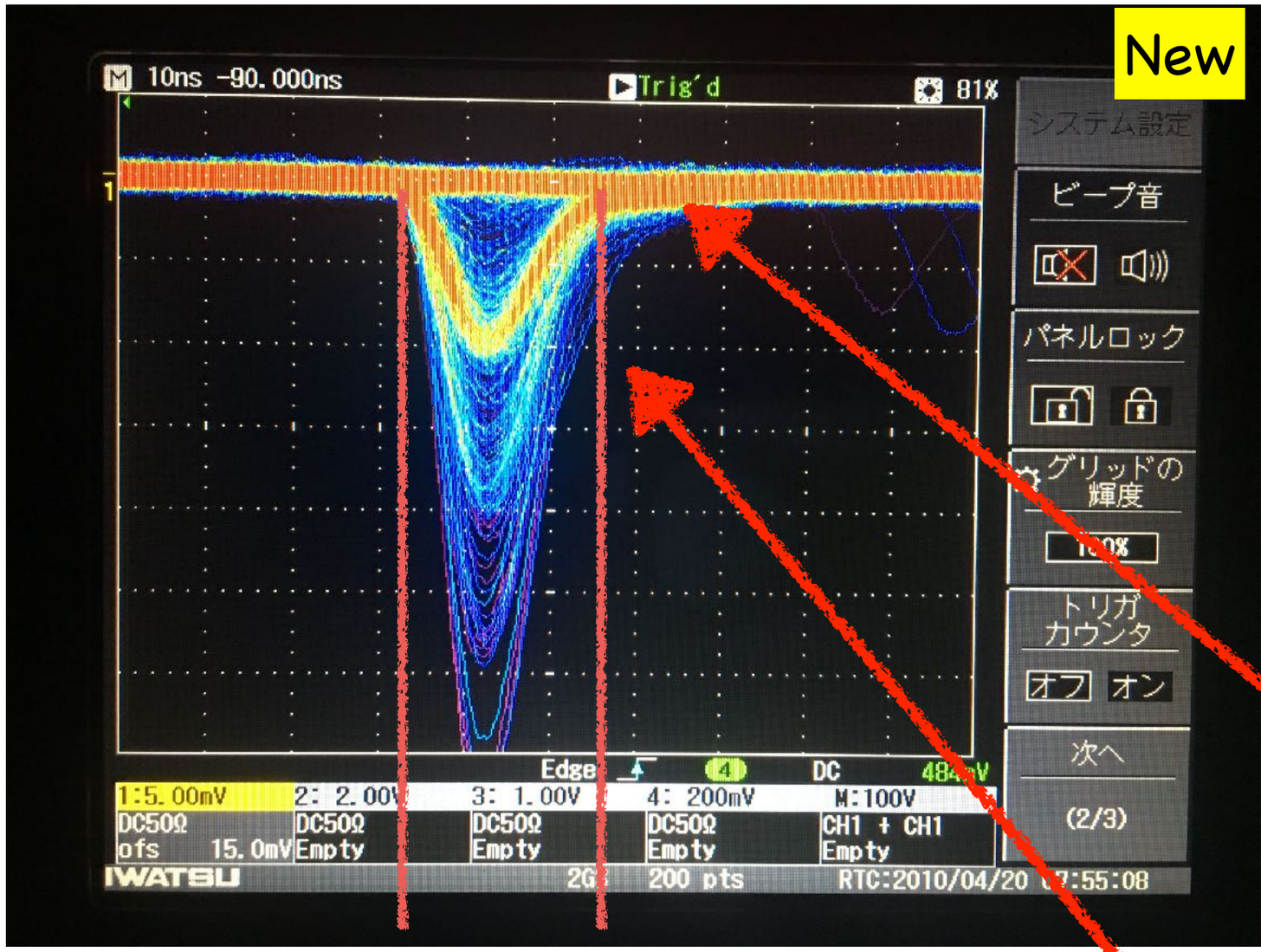
Ask questions to Akimichi!

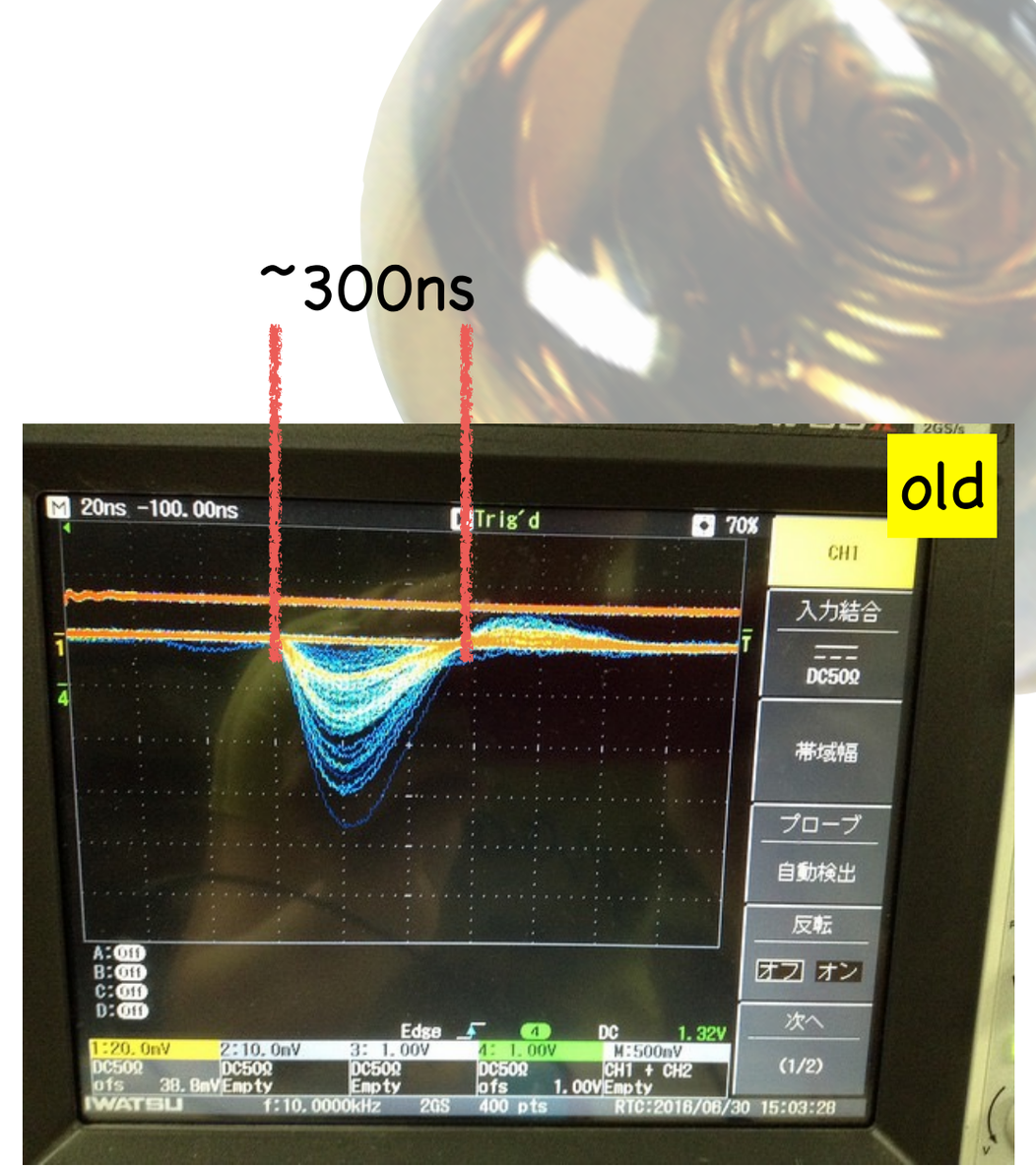


R1:Current control for Q1
R2:Open loop gain control
R3:Gain control
R4-5:Dynamic range control
C1:Stabilizer/filter
C2-4:Filter
L1:Filter

A few PEs pulse with New Amplifier

1bin 5mV, 10ns





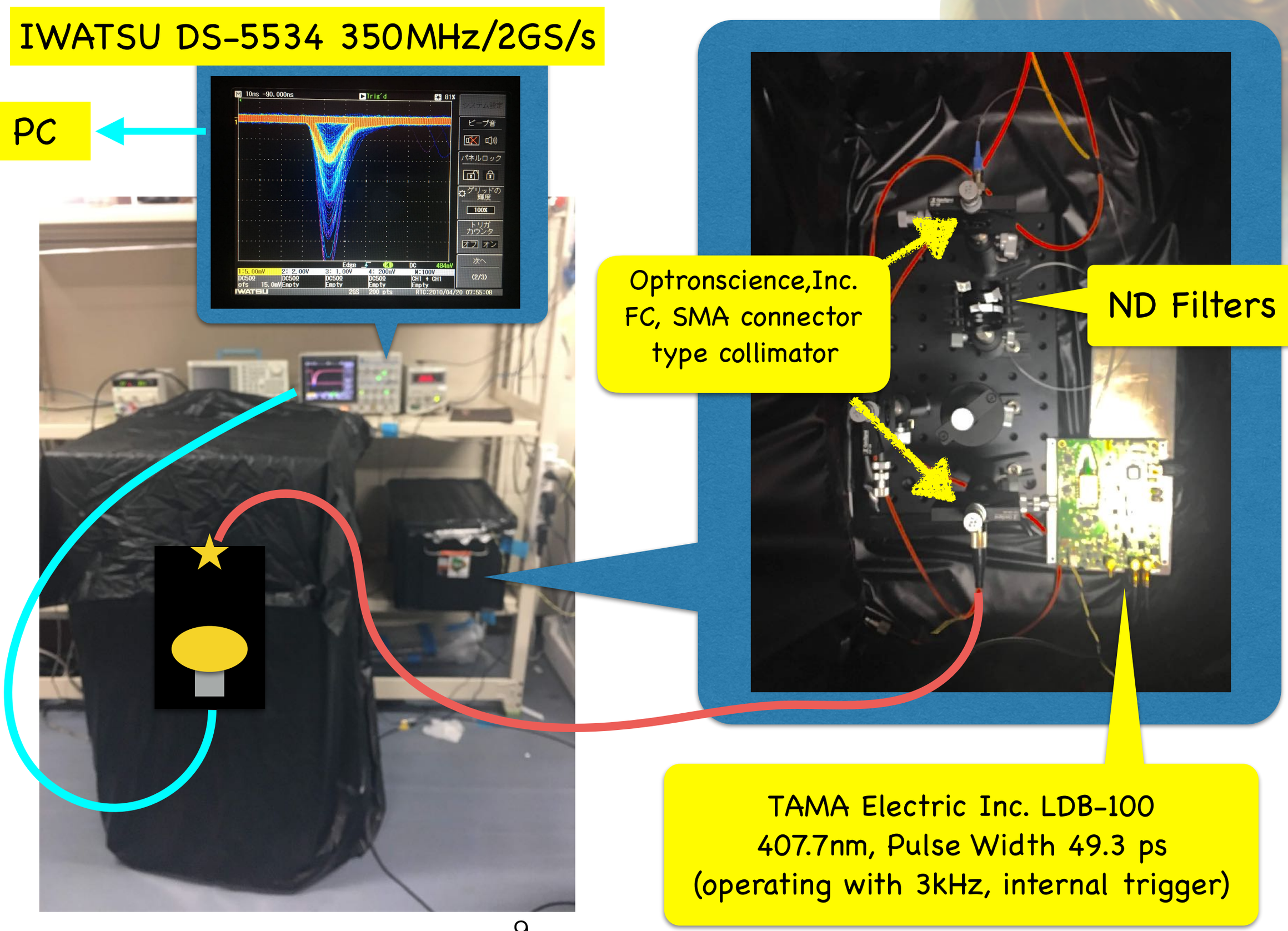
~300ns

~20ns

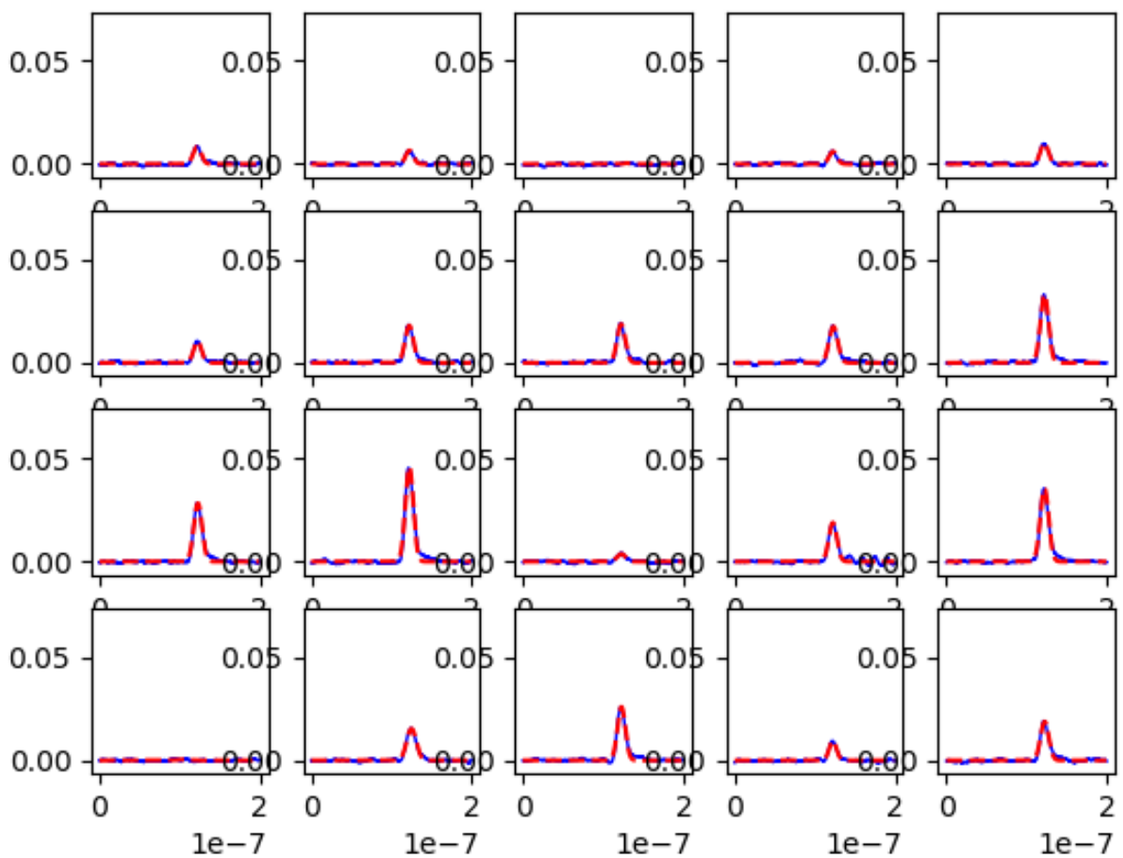
No overshoot!

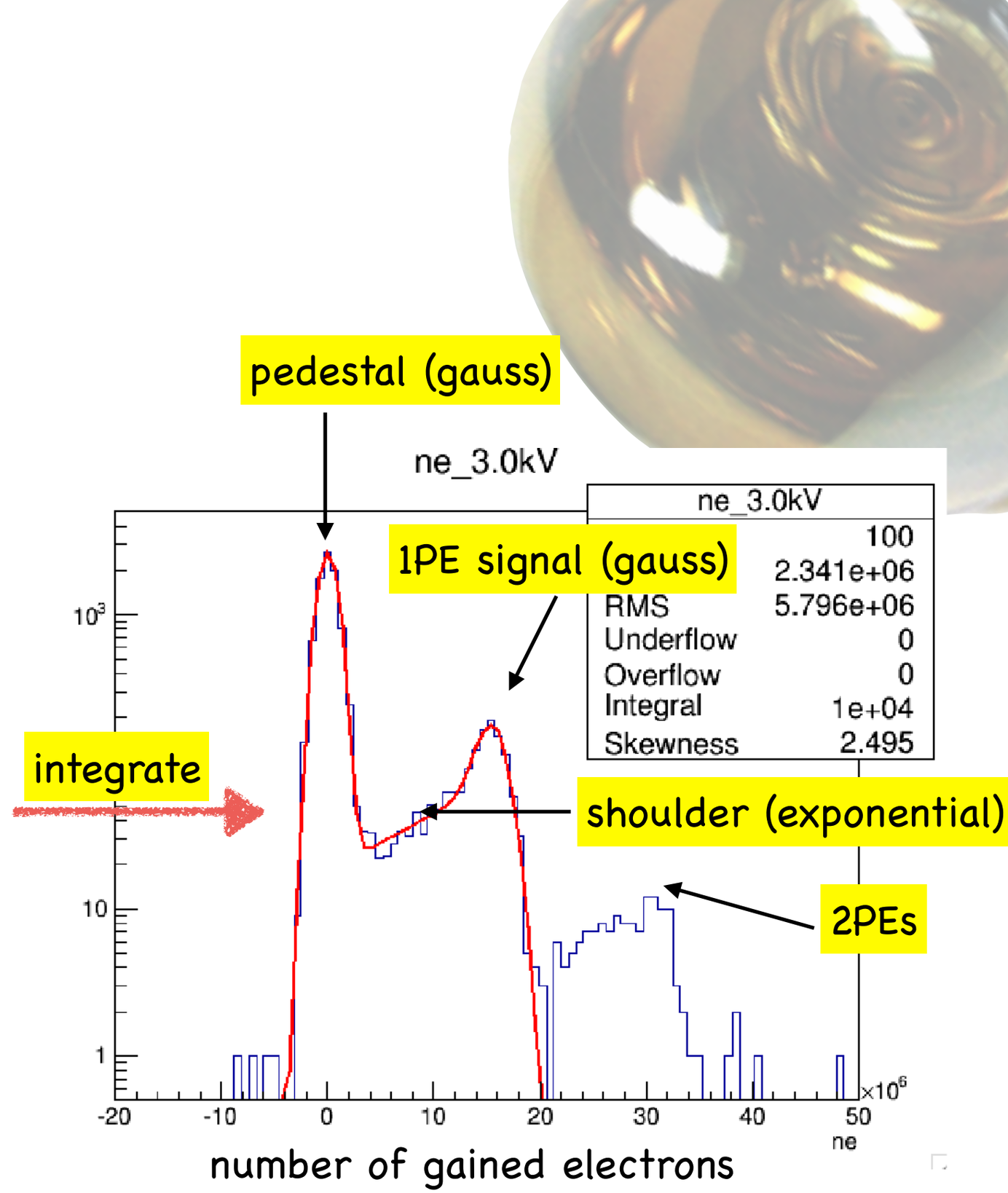
1PE ~10mV

Setup (for room temperature measurements)



Waveform Data



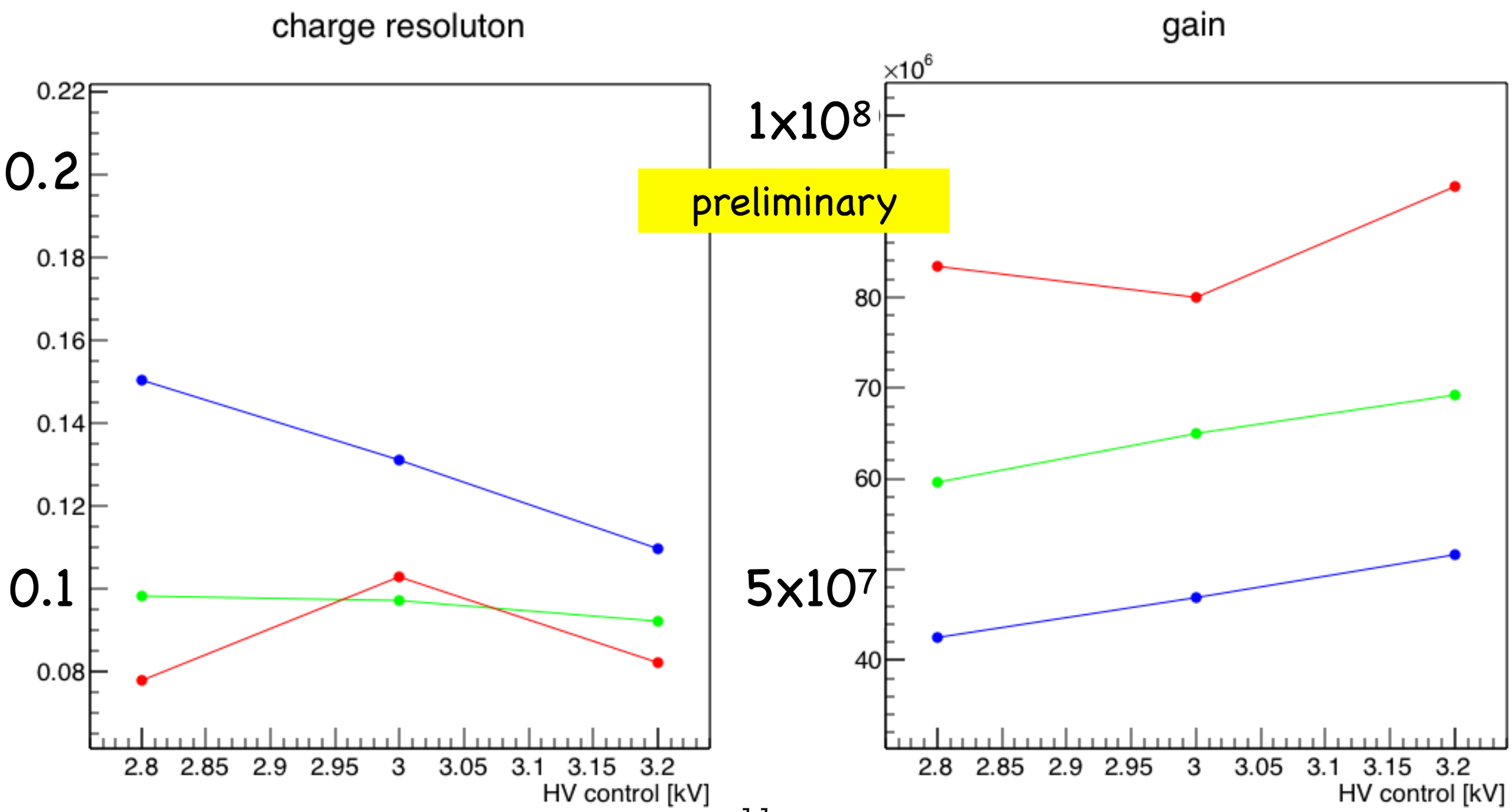


Fitting Function = pedestal_gauss + signal_gauss + shoulder_exponential

Charge Resolution and Gain

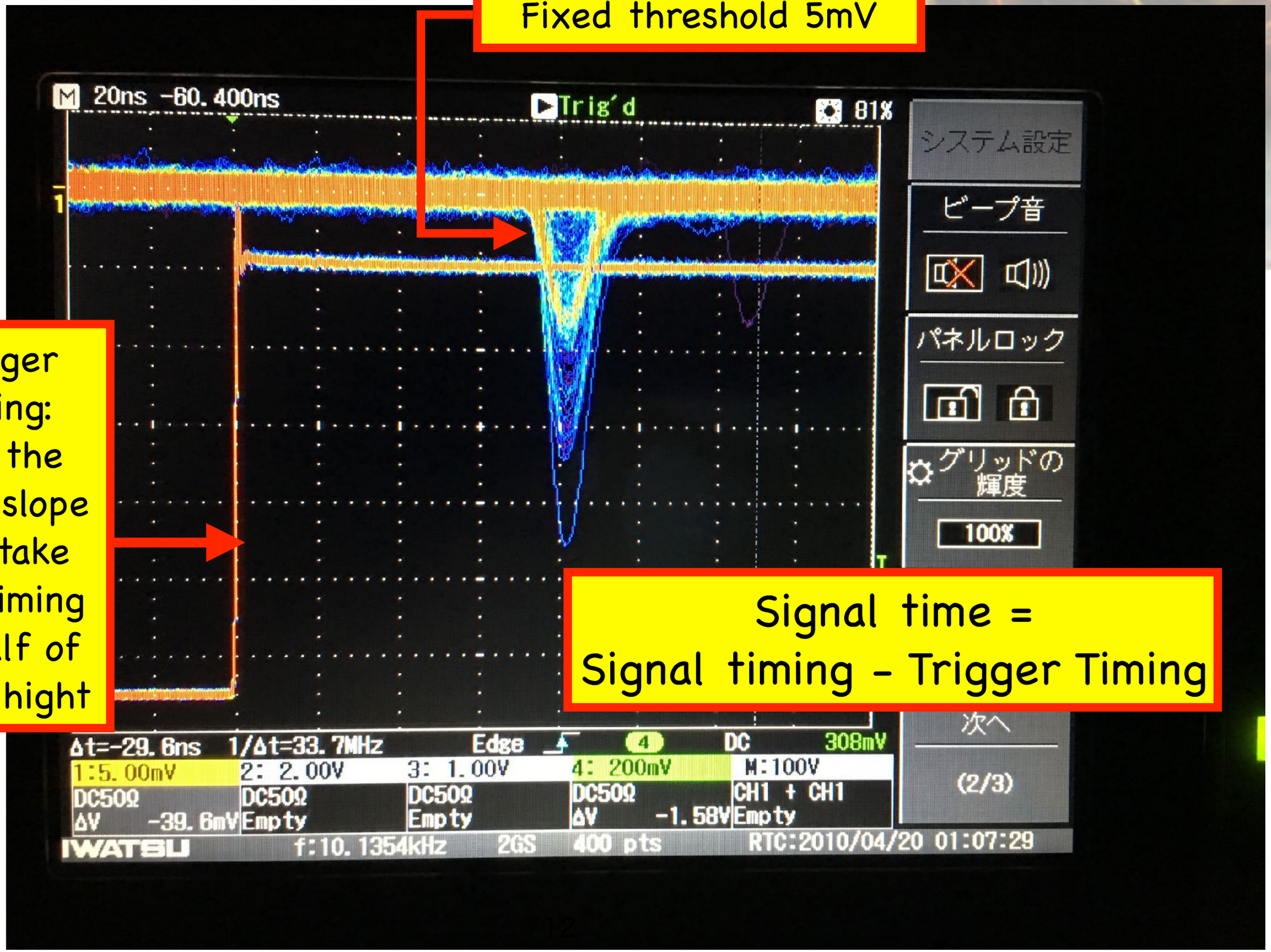
BLUE Temp. 20C, LV Cont. 1.00V
GREEN Temp. 20C, LV Cont. 1.10V
RED Temp. 20C, LV Cont. 1.20V

*With 9a-series preamp



Timing Resolution

Signal timing:
Fixed threshold 5mV



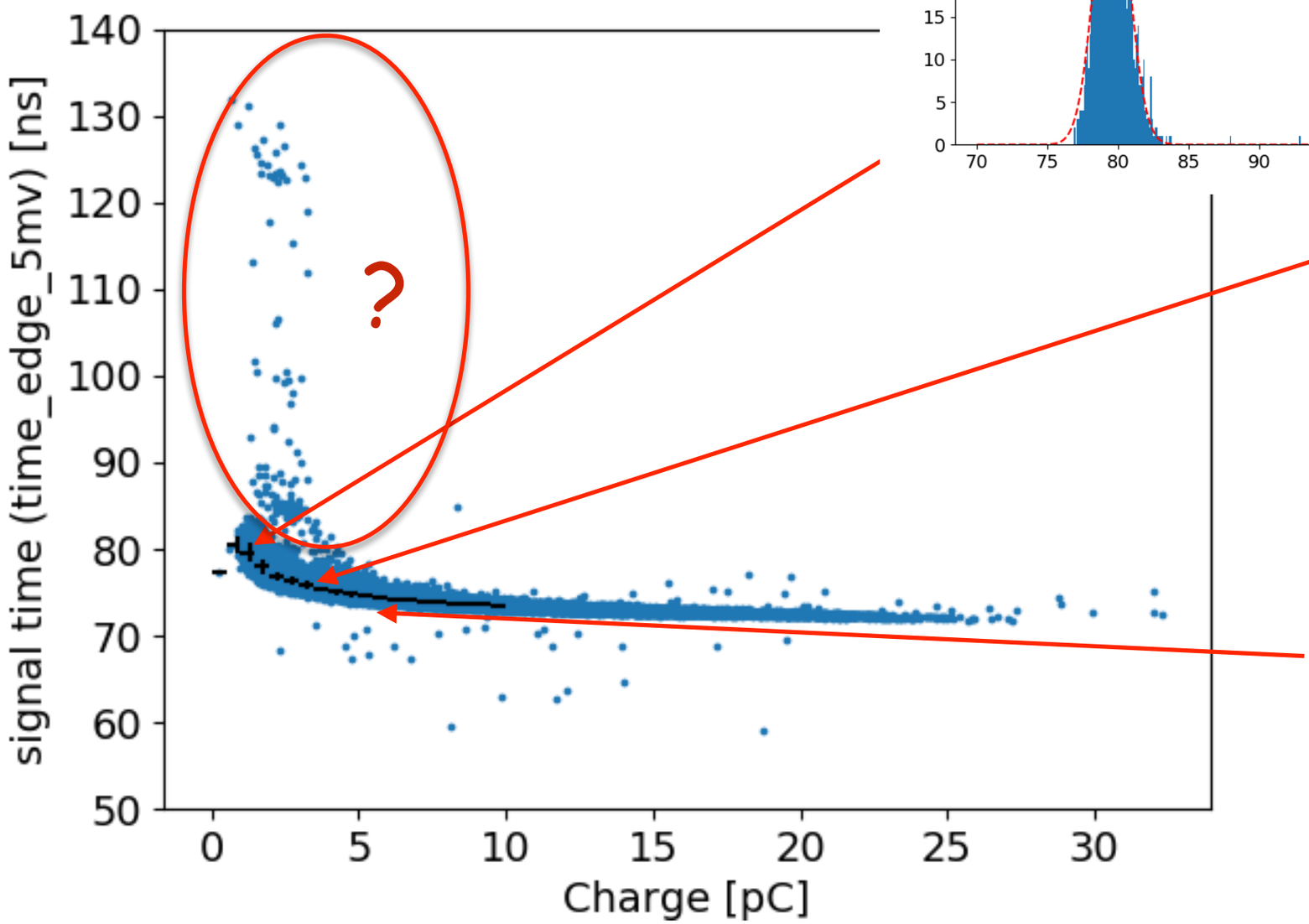
Trigger Timing:
Get the down slope and take the timing of half of pulse hight

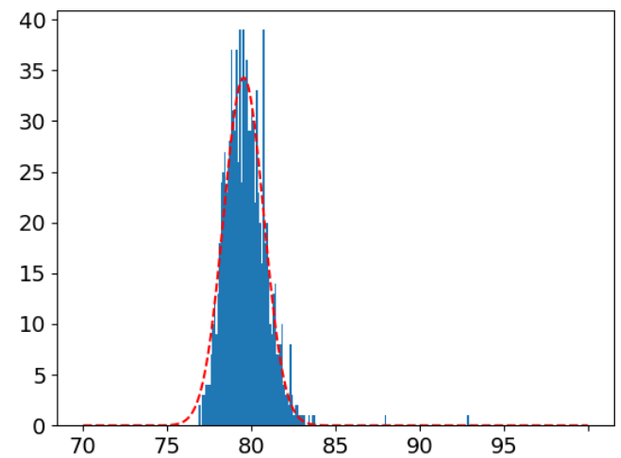
Signal time =
Signal timing - Trigger Timing

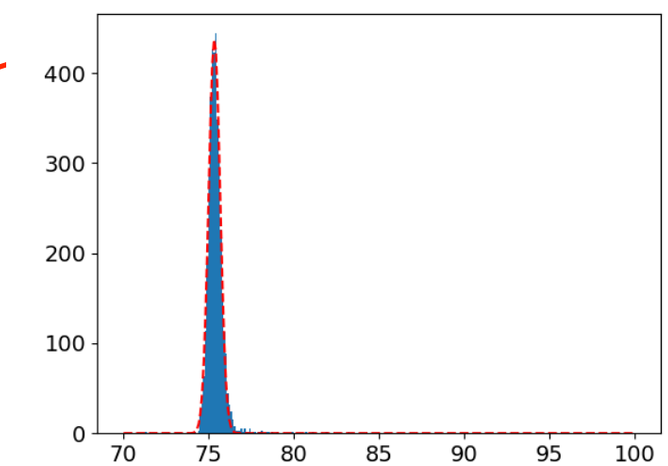
Timing Resolution

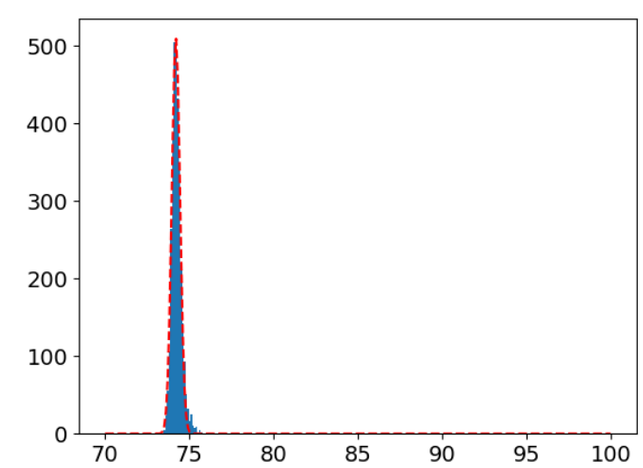
histograms of signal times
sliced in charge bins

With 12a-series preamp
@ room temperature(24C)



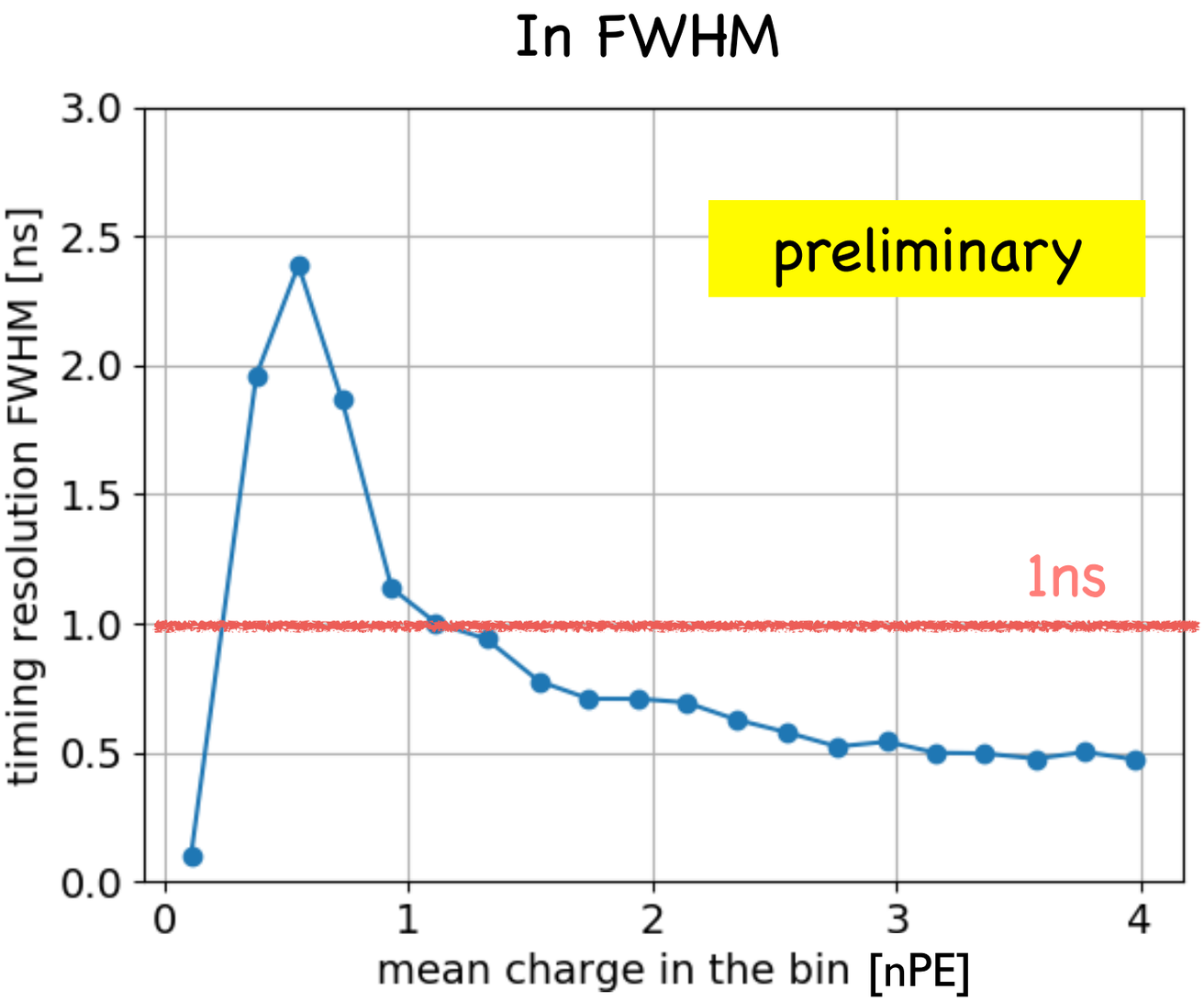


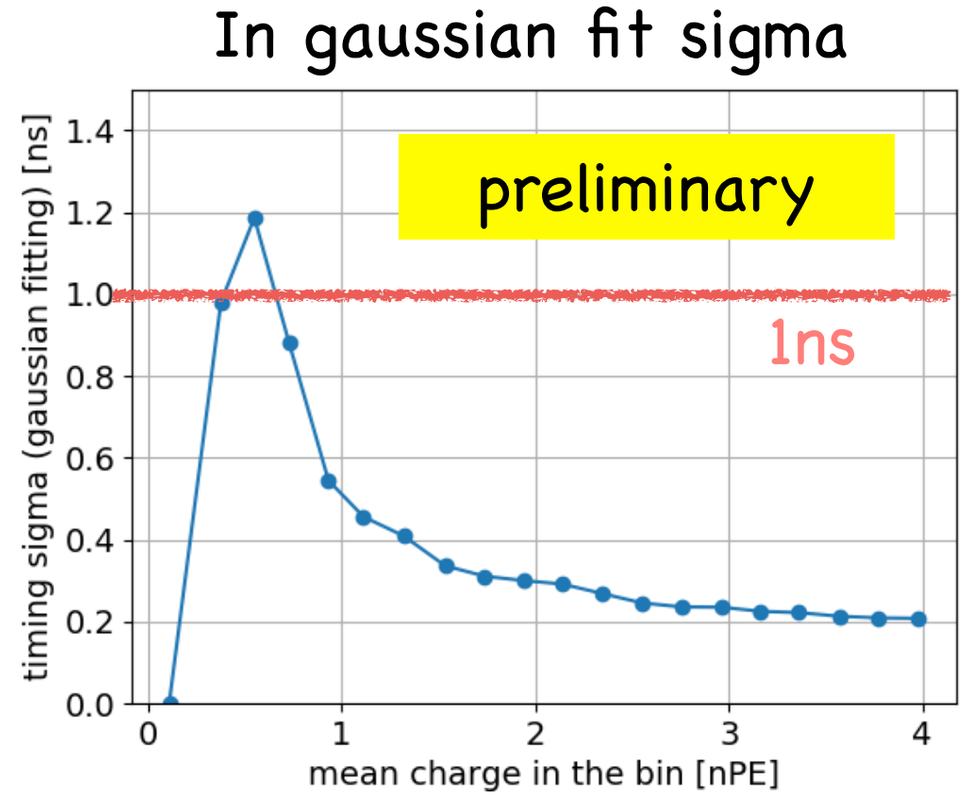




Timing Resolution

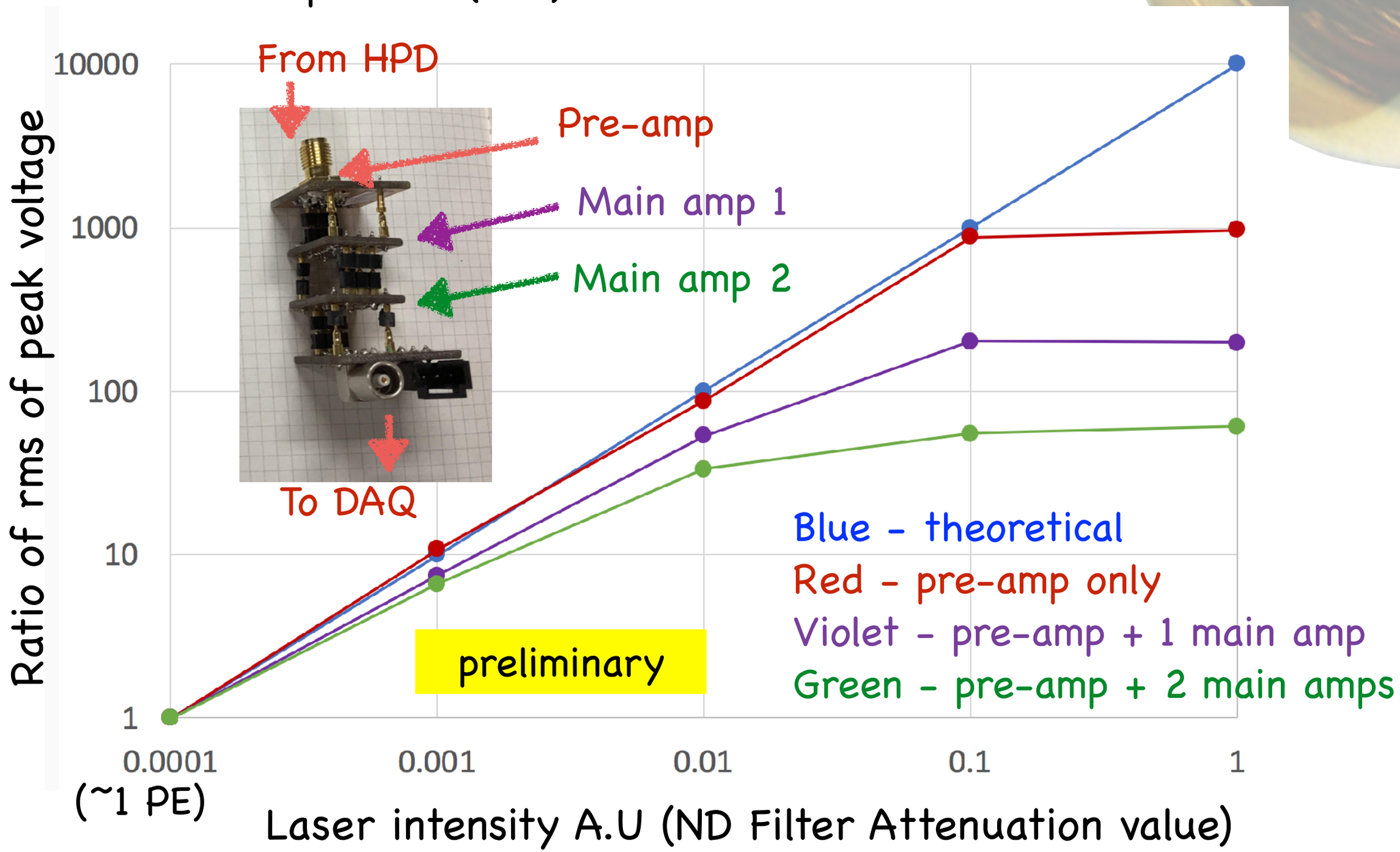
- HV cont. 3.0V, LV cont. 1.2V
- Late pulses are currently investigated





Dynamic Range (peak voltage)

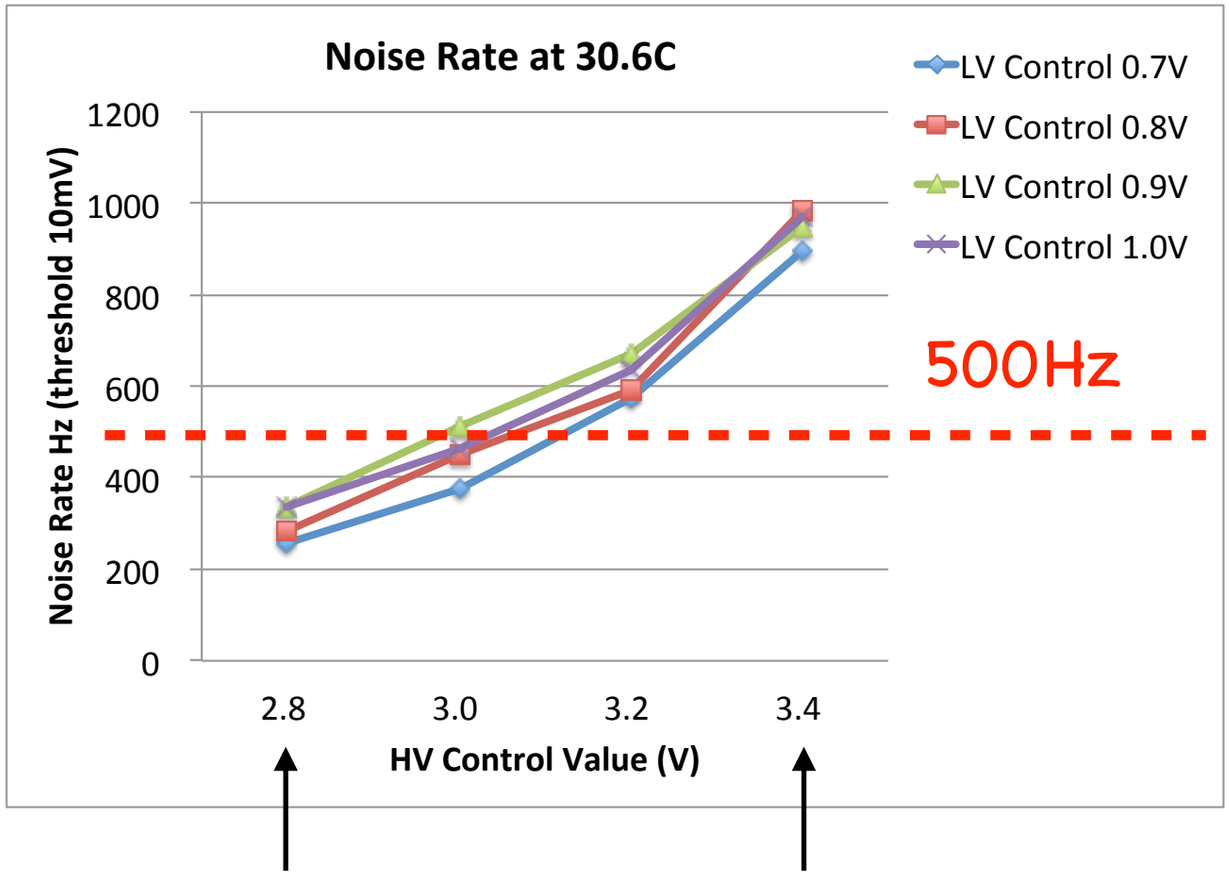
With 12a-series preamp
@ room temperature(24C)



Noise Rate (Hamamatsu Preamplifier)

- Has very strong temperature dependency
- These are scaler count measurement. Need to check correlated dark noise.

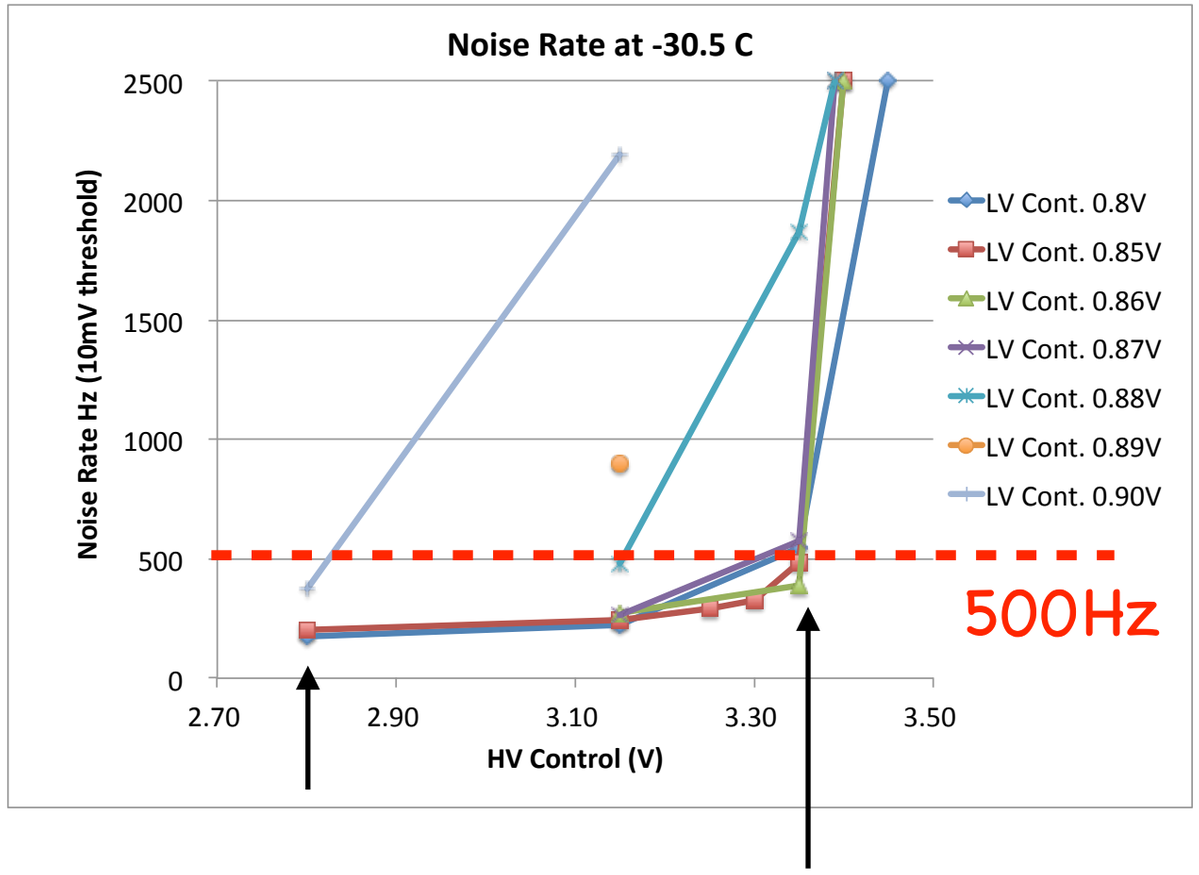
At Room Tmp (30.6C)



8kV HV

9.54kV HV

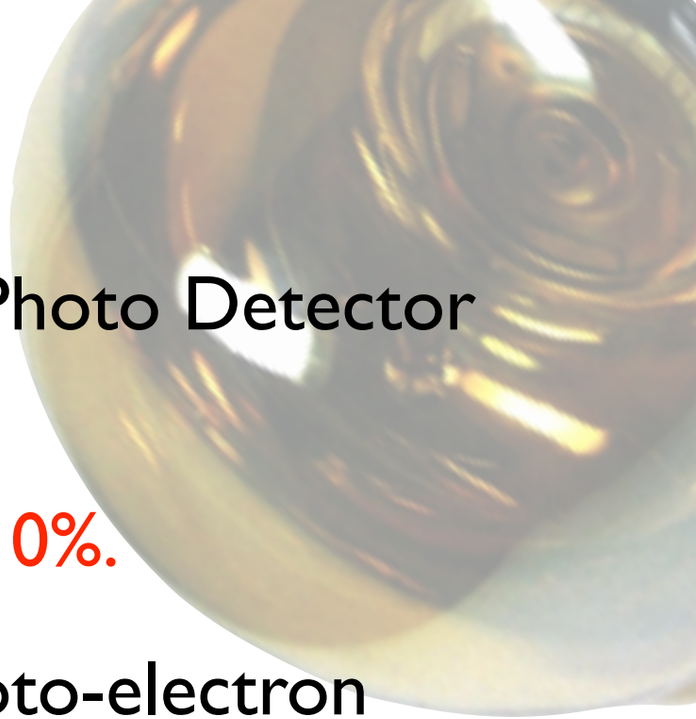
At Low Tmp (-30.5C)



2.8V (8kV HV)

3.35V (9.4kV HV)

Summary



- New preamplifiers for Hamamatsu 8-inch Hybrid Photo Detector (R12112) has been developed.
- Charge resolution at typical operation voltages is 10%.
- Timing resolution (FWHM) is 1.1 nsec for one photo-electron signal, could be better with parameter tuning.
- First result of dynamic range for pulse height measurement shows O(3) extent for pre-amplifier only. We continue optimizing main amps and repeat the measurement for charge dynamic range.
- Noise rate and optimum operation voltages strongly depend on operation temperature.
- Next plans :
  - After pulse measurement
  - Correlated noise measurement

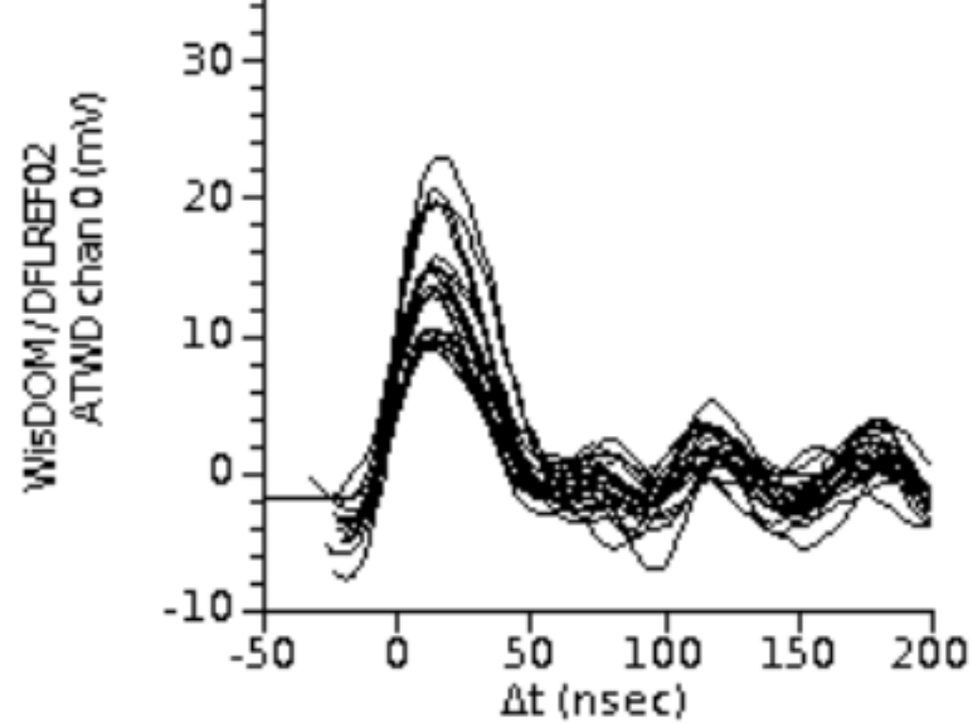
Back up

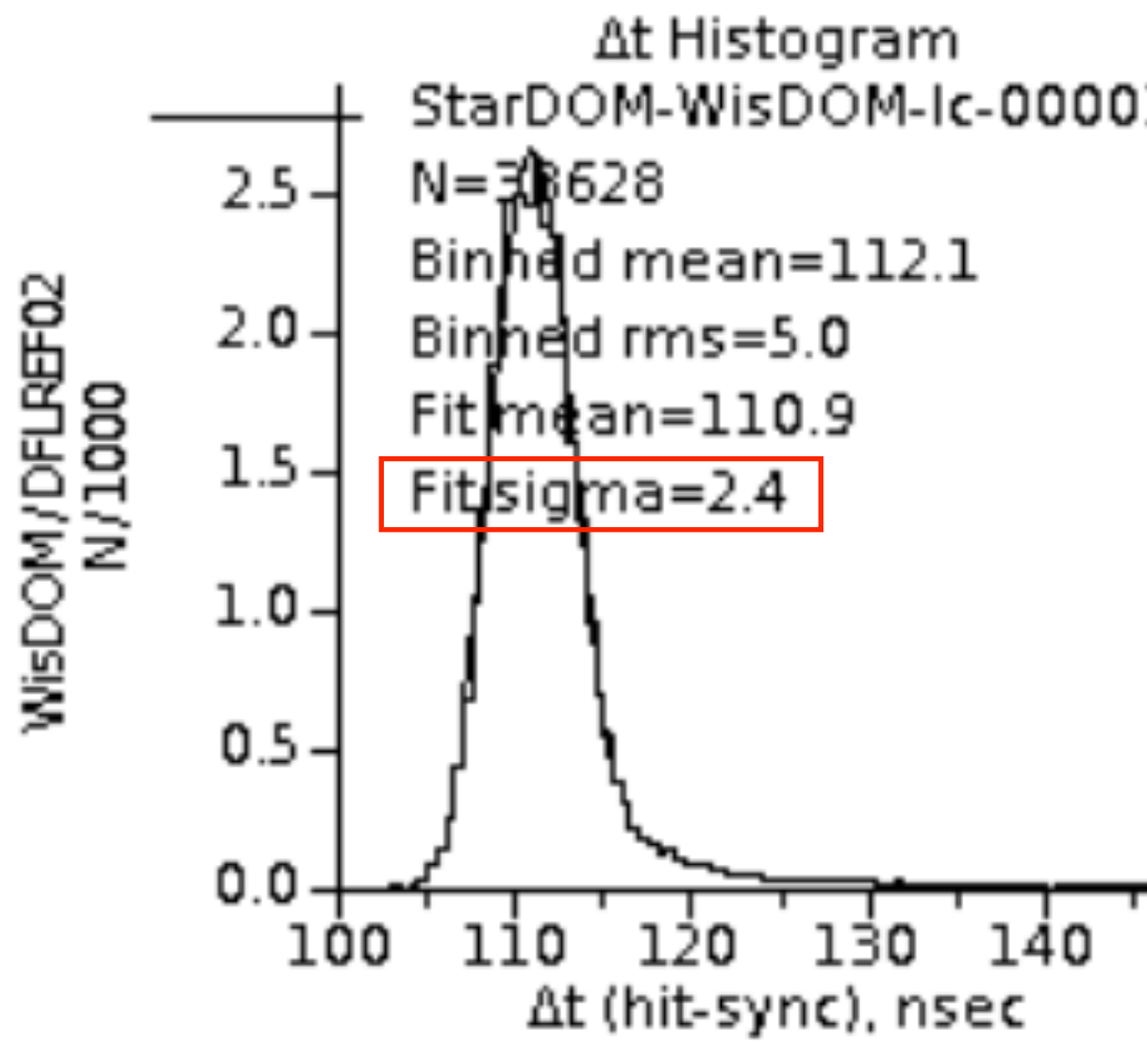
Cf: Hamamatsu Preamplifier

- Time resolution for 1PE:
  2.1ns ~ 2.4ns
  - Not too bad compared with 10 inch Hamamatsu PMT (2ns on average)
  - Could be improved by removing noise from ground line
- Very mild temperature dependence, stable at least within -25~-35 degrees

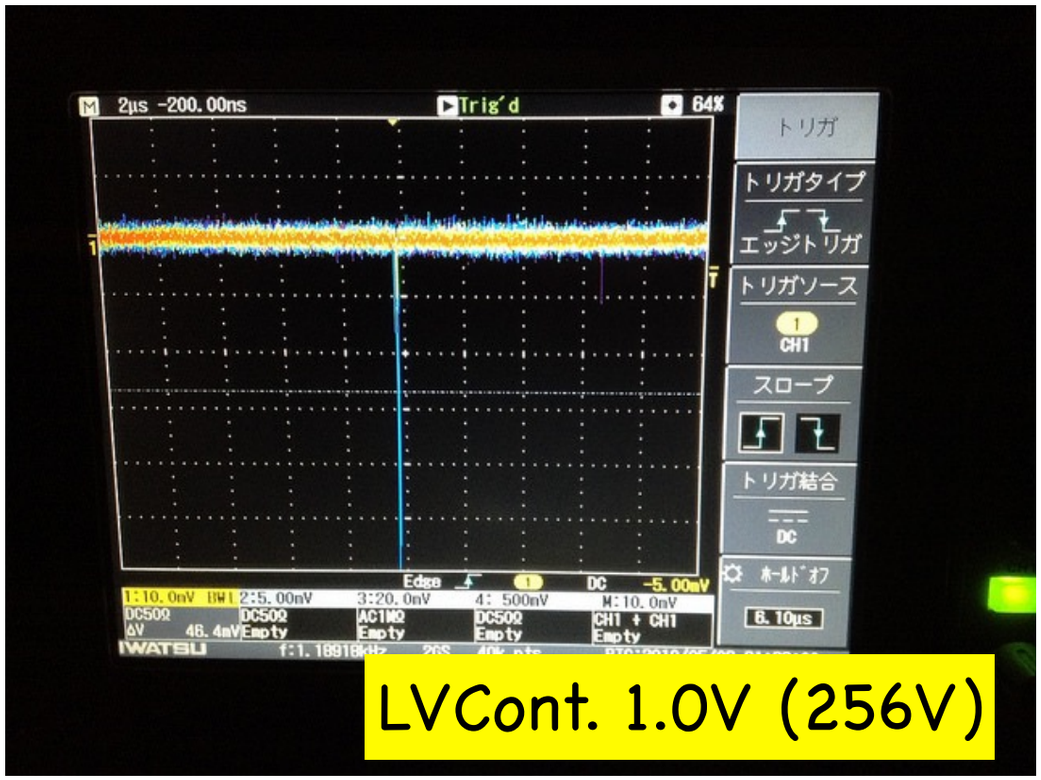
HPD (Hamamatsu R-12112) Time Resolution (nsec)				
	Temperature			
HV Cont.	-36 ℃	-32 ℃	-26 ℃	+5 ℃
2.8 V	2.1	2.4	2.2	2.7
3.0 V	2.3	2.3	2.1	2.8
3.2 V	2.1	2.1	2.1	2.6

※LV Cont. is fixed at 0.8 V

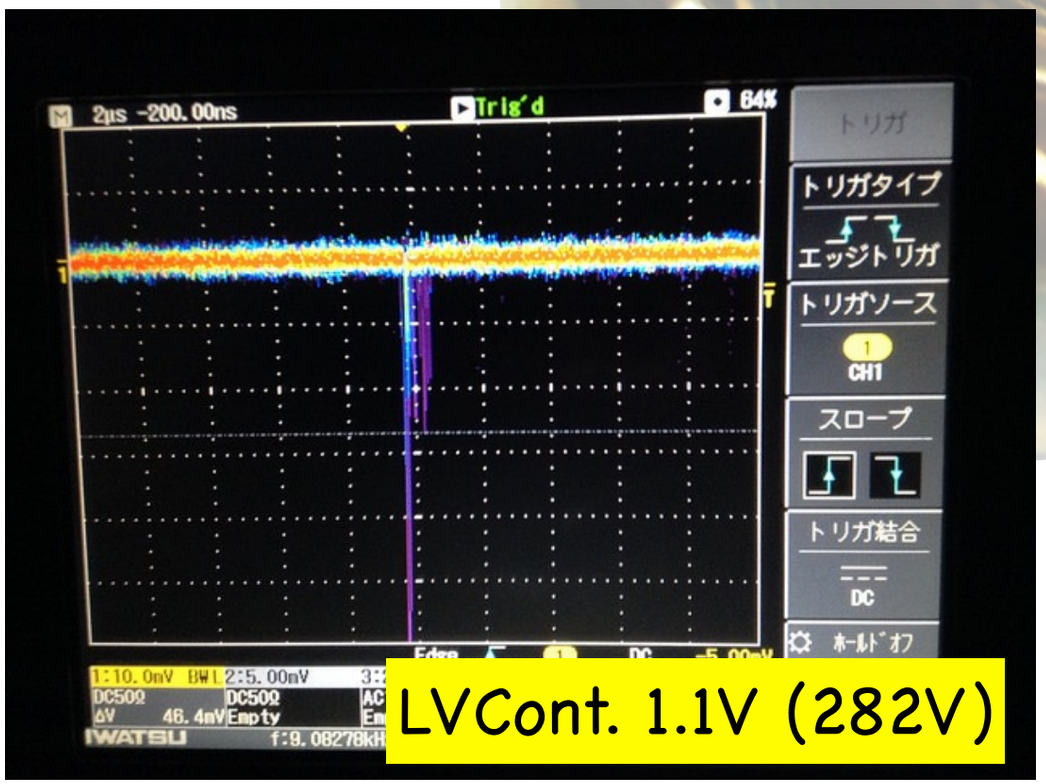




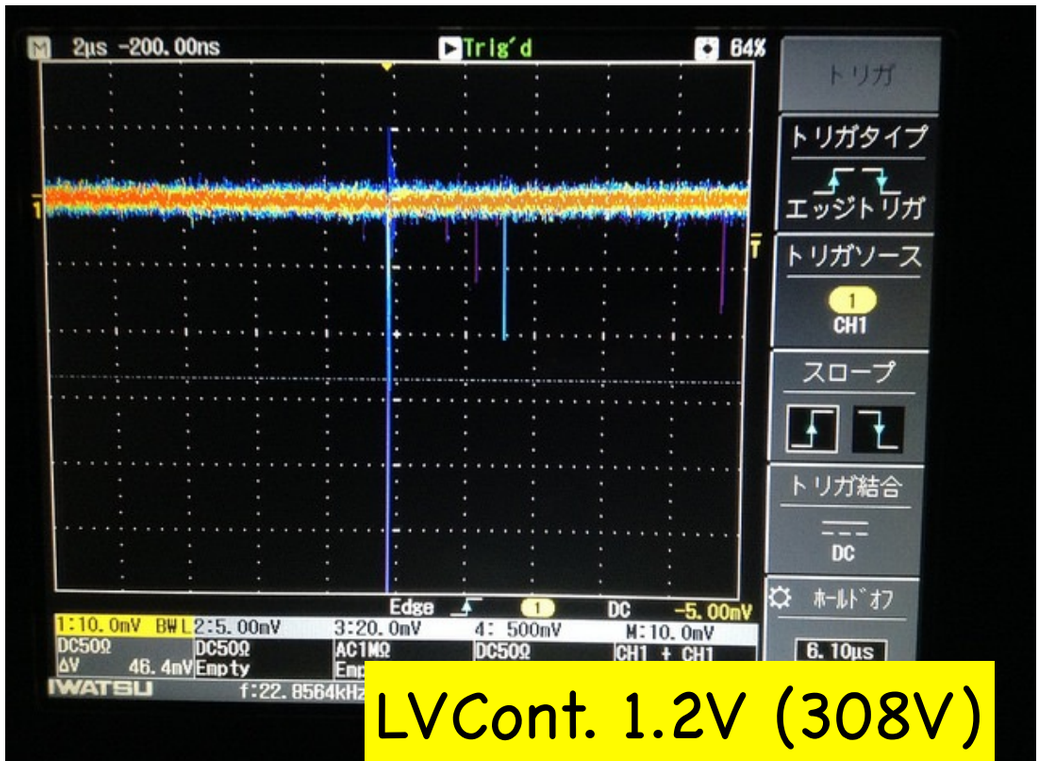
Maximum LV control value



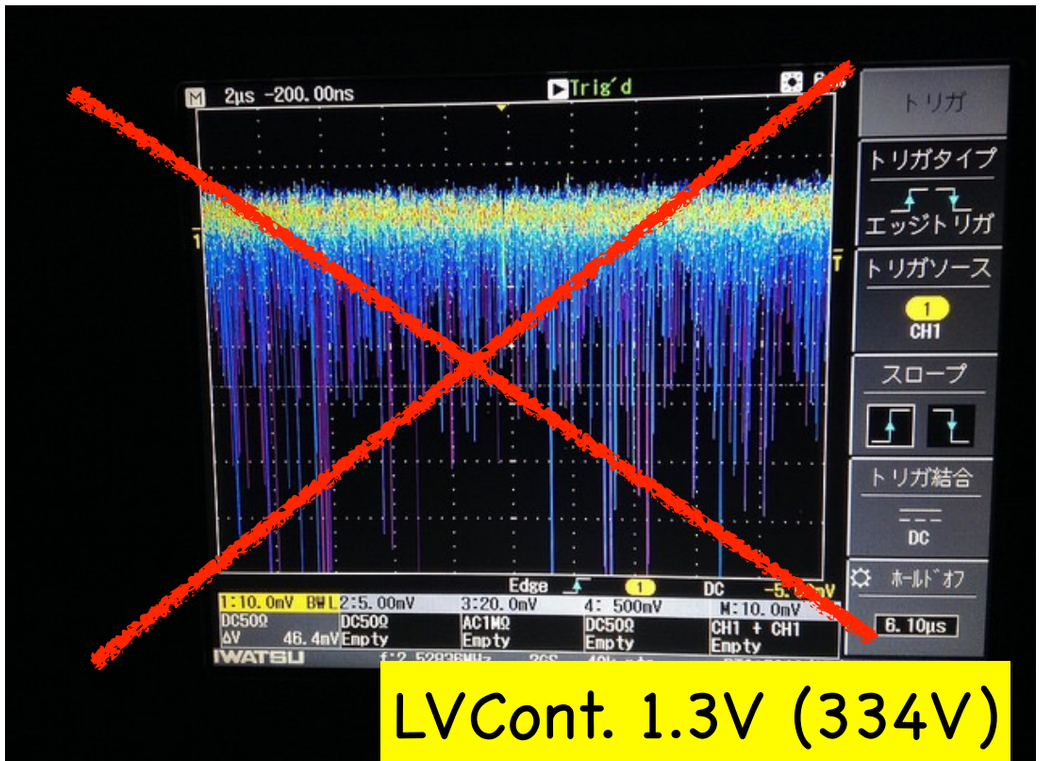
LVCont. 1.0V (256V)



LVCont. 1.1V (282V)

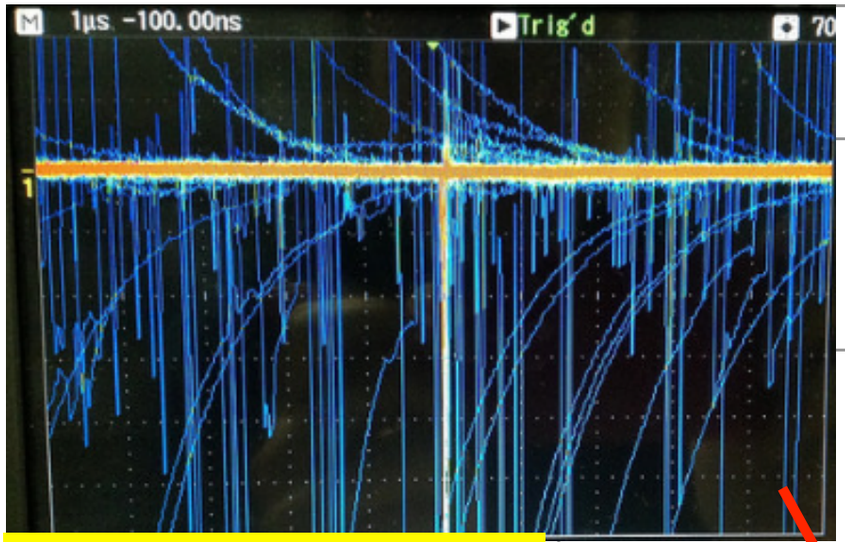


LVCont. 1.2V (308V)

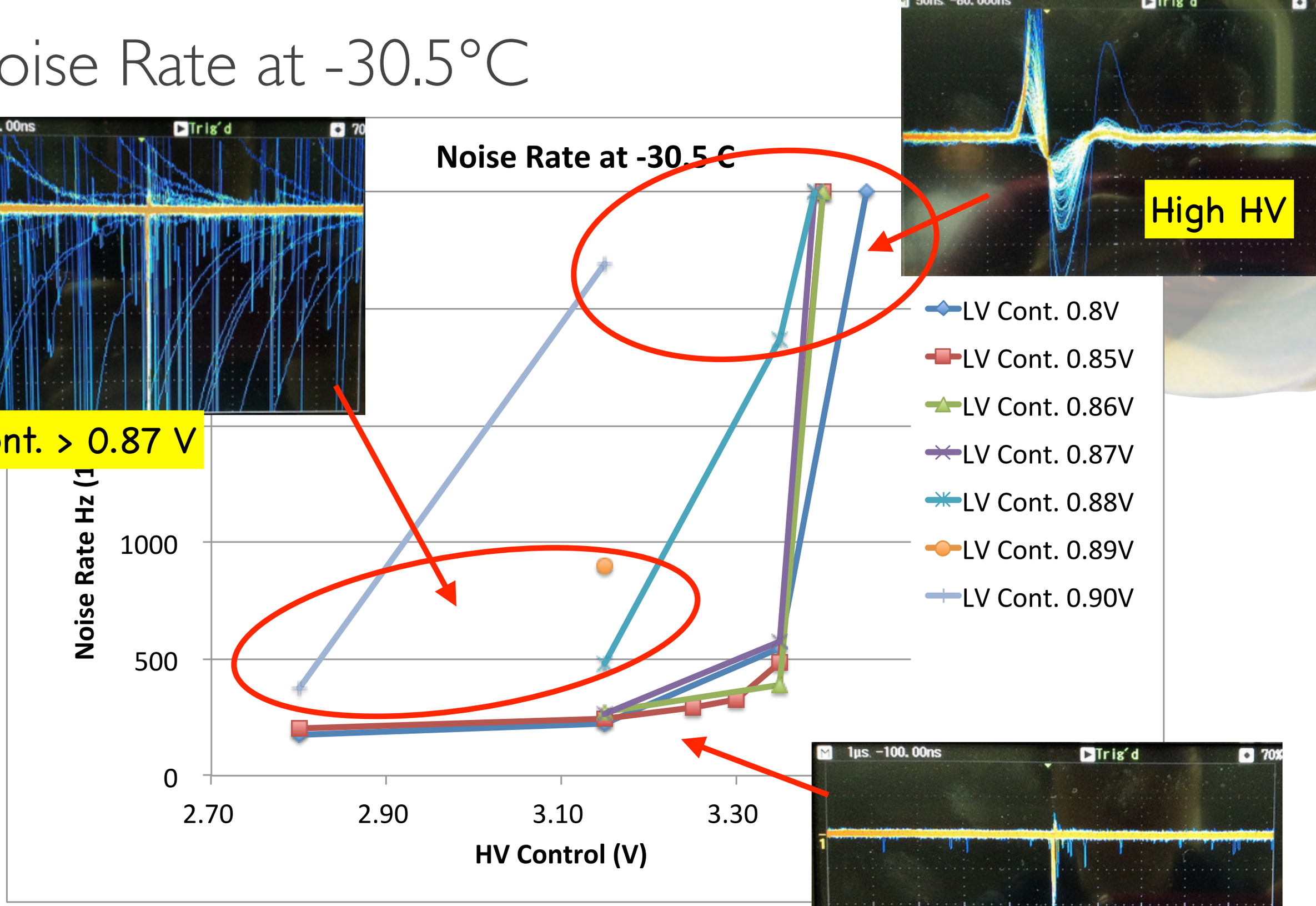


LVCont. 1.3V (334V)

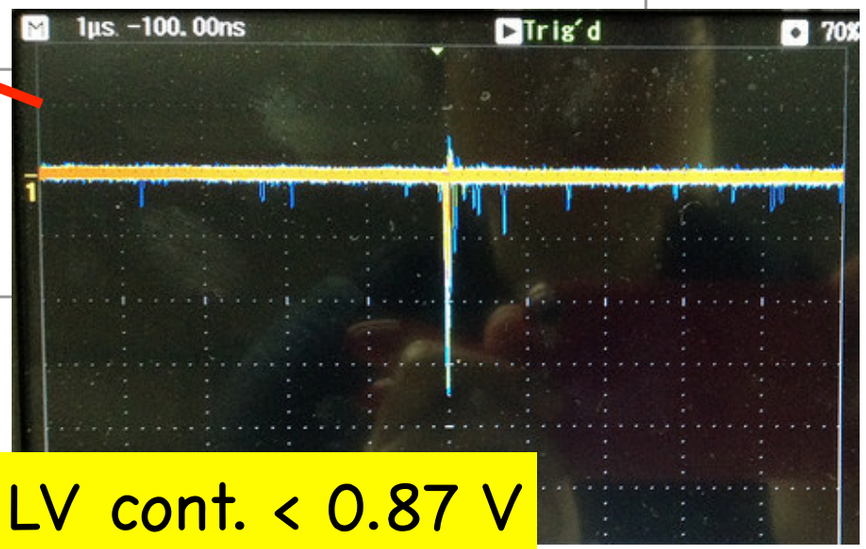
Noise Rate at -30.5°C



LV cont. > 0.87 V

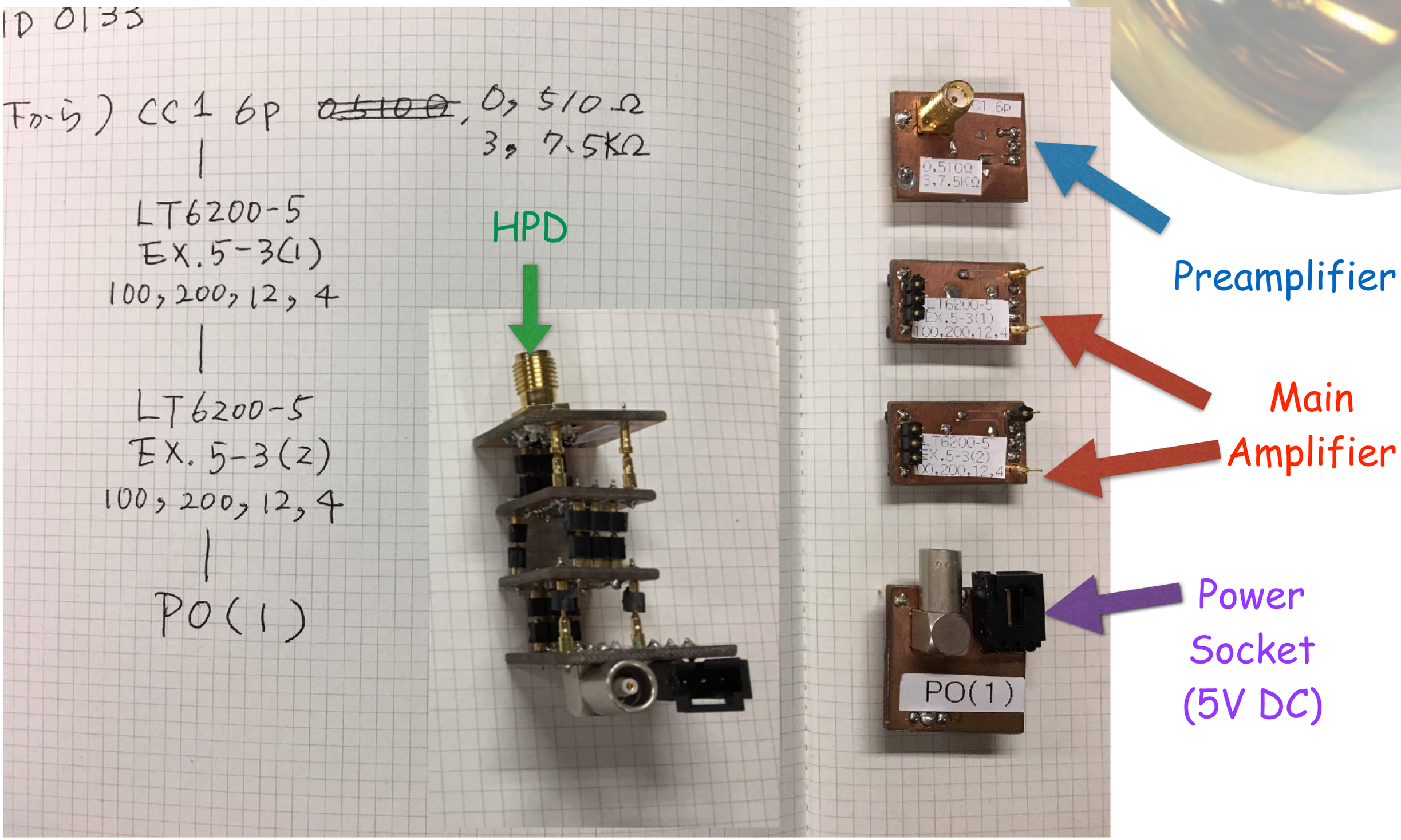


High HV

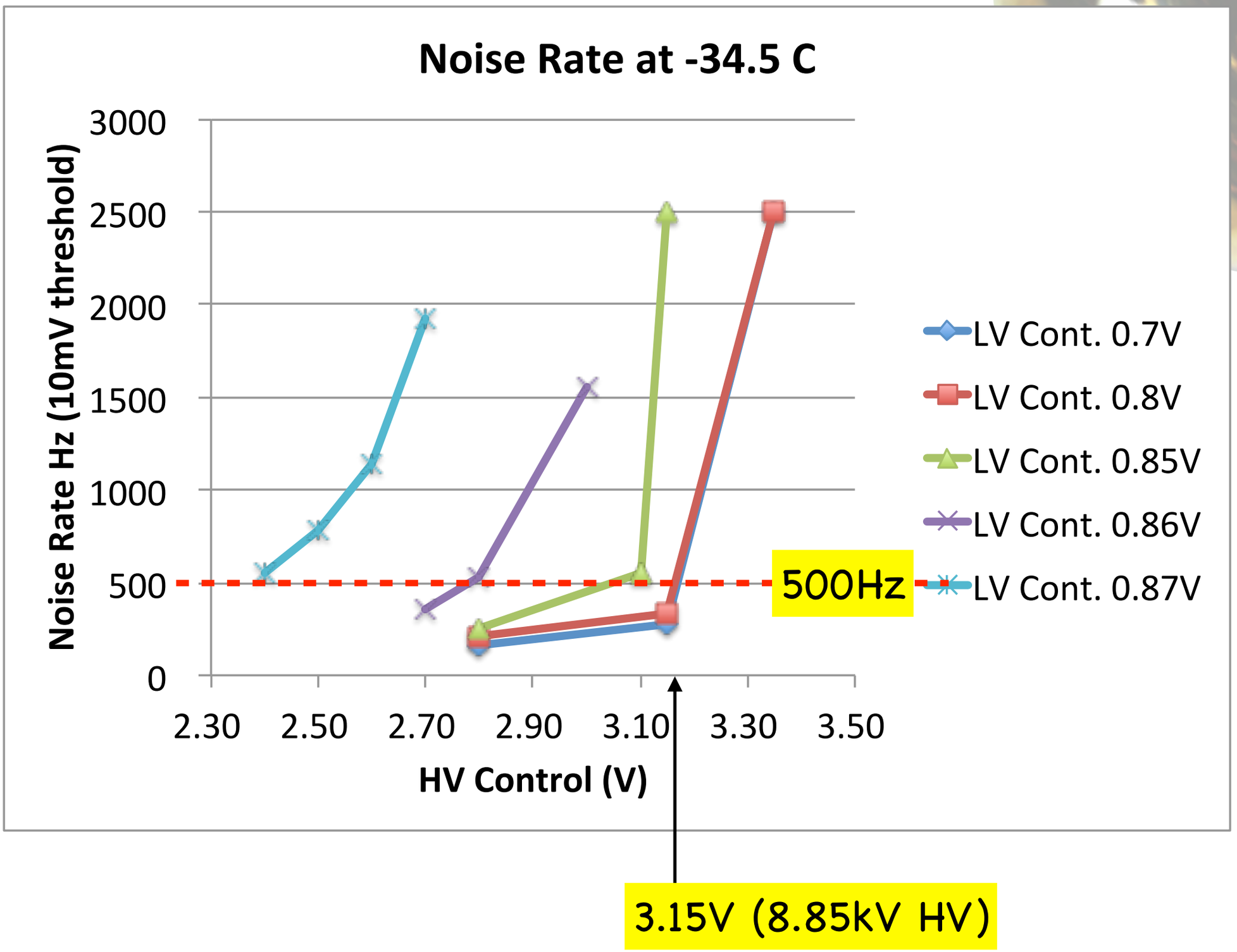


LV cont. < 0.87 V

Developing preamplifier and main amplifier

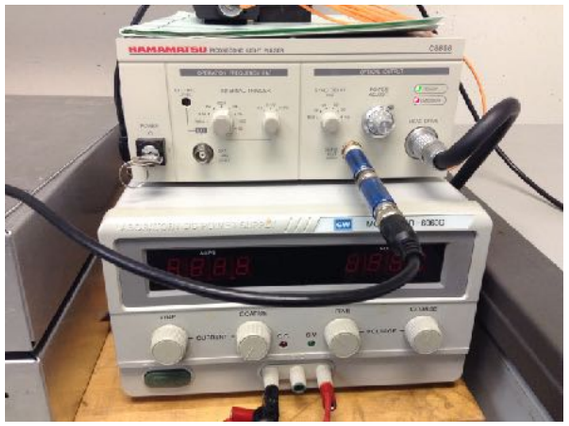


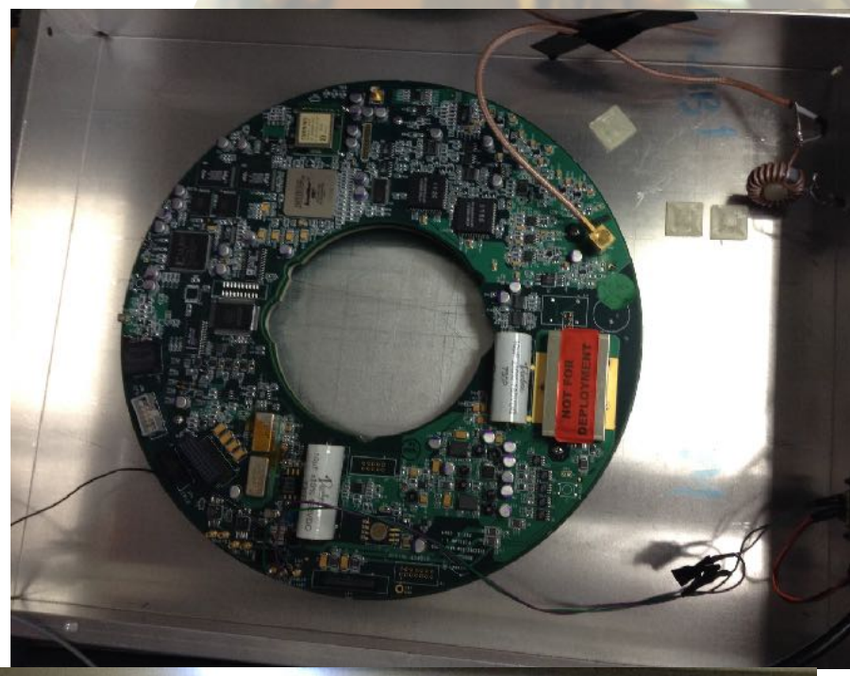
Noise Rate at -34.5°C

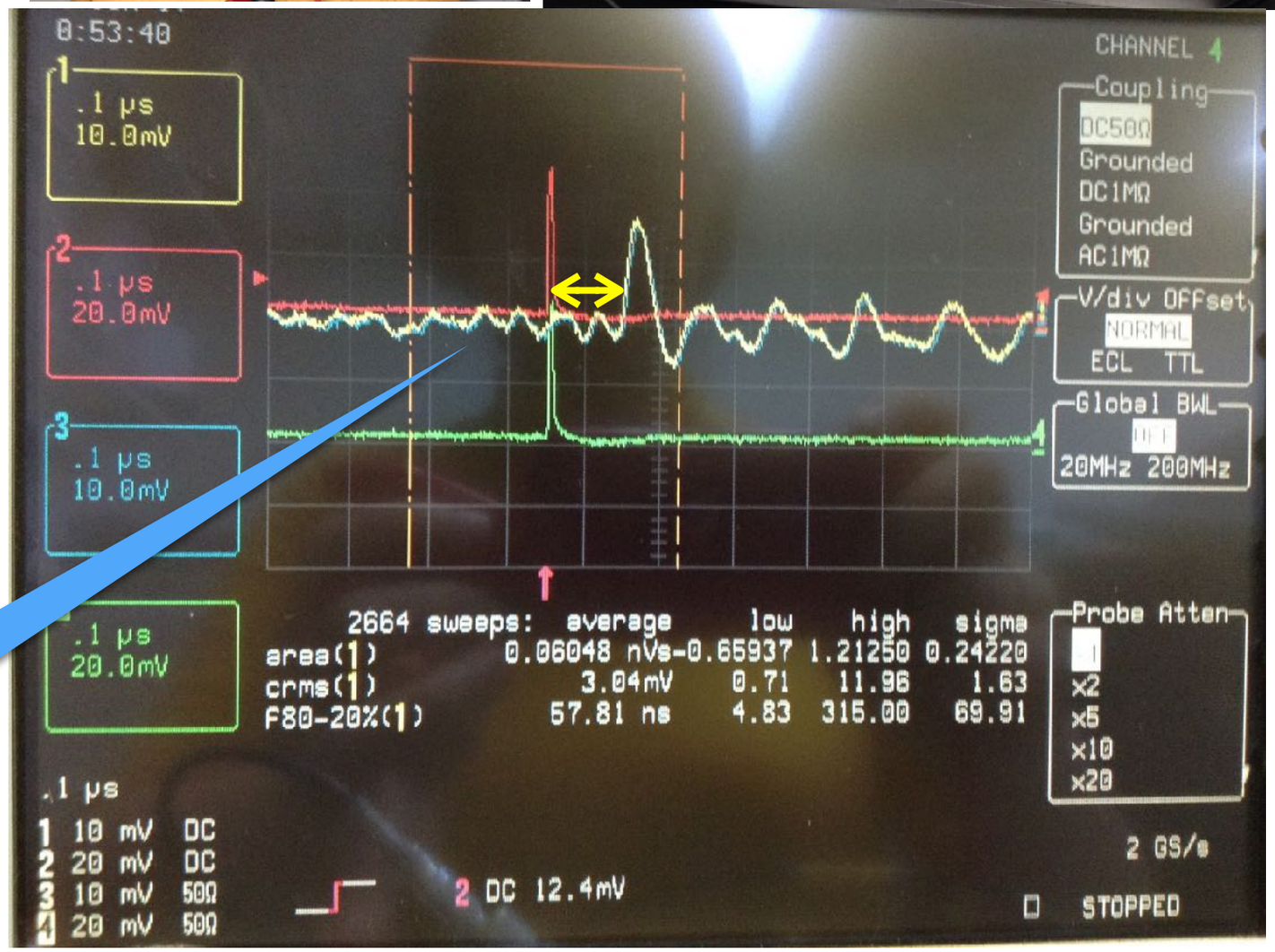


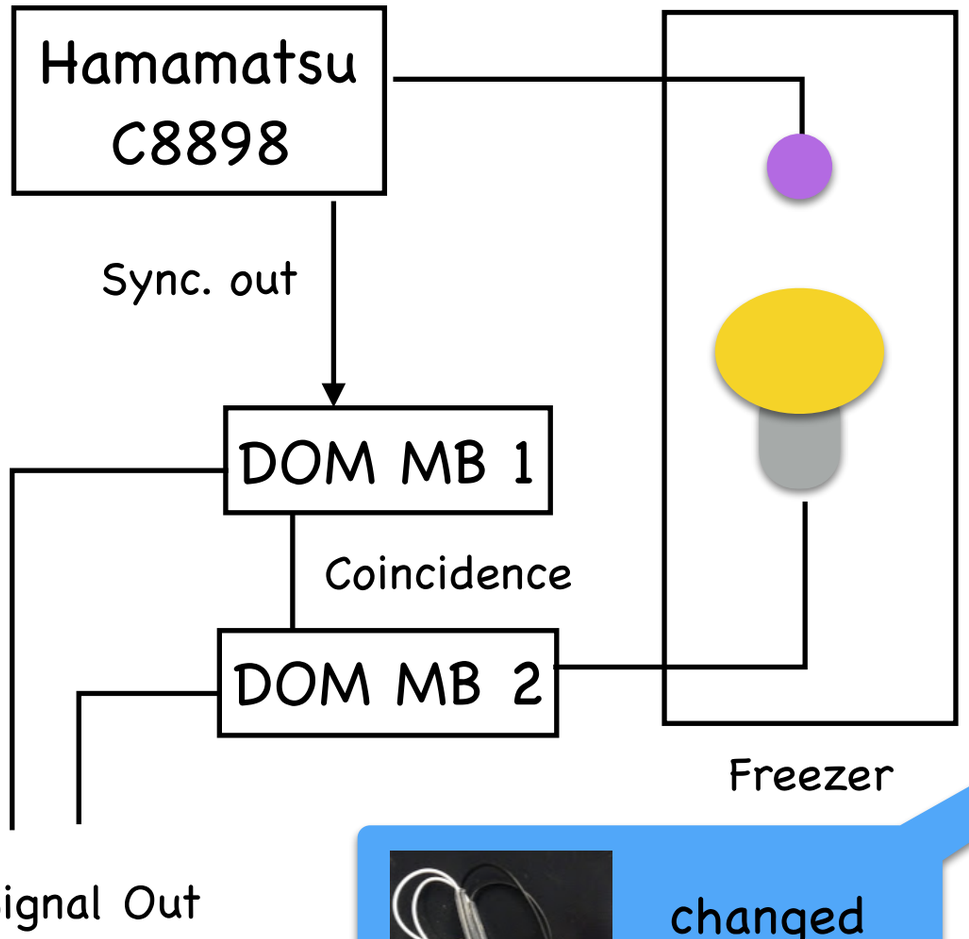
Time Resolution measurement

- Measured with two IceCube DOM main board and Hamamatsu Pico Pulser









changed negative signal to positive

The 1st trial (early 2015)

- Too much noise (~100kHz) and electric discharge!!
- Hamamatsu tried to fix it, but eventually they send us a replacement. (Because it's hard to fix it once heavy electric discharge happens? We don't know why.)