Insert Status

Nov 16, 2020

ADMX Collaboration Virtual Meeting

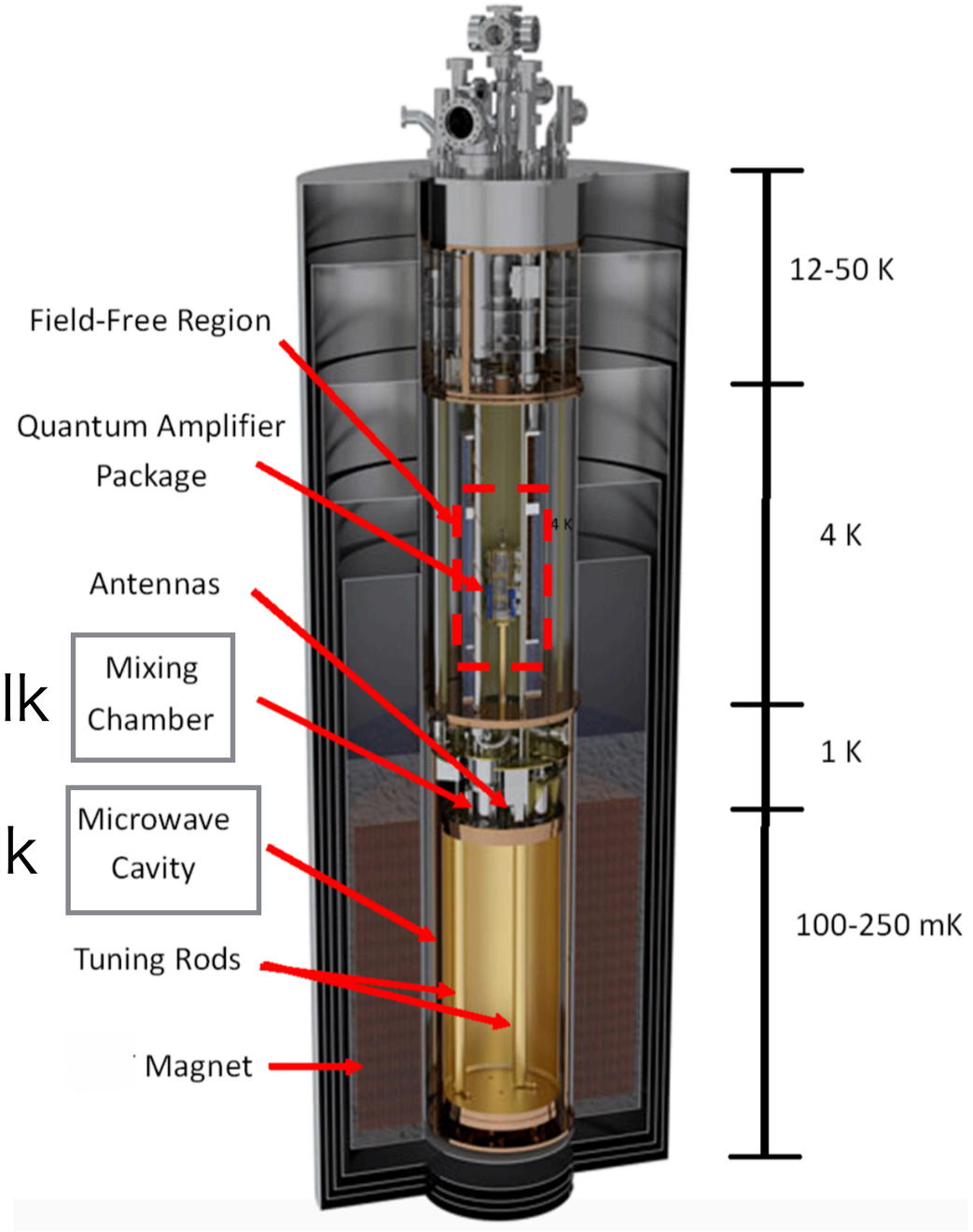
Tatsumi Nitta @ UW

Run1c Insert

Talk about
- JPA, HFET status
- antenna coupling
- operation remarks

Jihee's talk

Nick's talk



System noise measurement

$$\mathrm{SNR} = \frac{P_{\mathrm{axion}}}{k_b T_{\mathrm{sys}}}\sqrt{\frac{t}{b}}$$

How to measure T_{sys}

$P^{\mathrm{on}} = G^{\mathrm{on}} T^{\mathrm{on}}_{\mathrm{sys}} k_b b$ $X^{\mathrm{on/off}}$:

$P^{\mathrm{off}} = G^{\mathrm{off}} T^{\mathrm{off}}_{\mathrm{sys}} k_b b$ JPA on or off

$$\rightarrow \quad \frac{T^{\mathrm{off}}_{\mathrm{sys}}}{T^{\mathrm{on}}_{\mathrm{sys}}} = \frac{G^{\mathrm{on}}}{G^{\mathrm{off}}} / \frac{P^{\mathrm{on}}}{P^{\mathrm{off}}} = \mathrm{SNRI}$$

$$\rightarrow \quad T^{\mathrm{on}}_{\mathrm{sys}} = T^{\mathrm{off}}_{\mathrm{sys}} / \mathrm{SNRI}$$

SNRI measurement

$$\mathrm{SNRI} = \frac{G^{\mathrm{on}}}{G^{\mathrm{off}}} / \frac{P^{\mathrm{on}}}{P^{\mathrm{off}}}$$

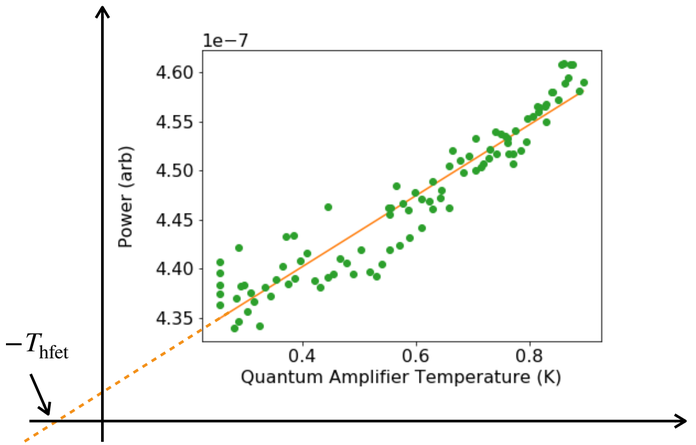
$G^{\mathrm{on/off}}$: with network analyzer

$P^{\mathrm{on/off}}$: with digitizer

Measuring every 4 digitizations

$T^{\mathrm{off}}_{\mathrm{sys}}$ measurement

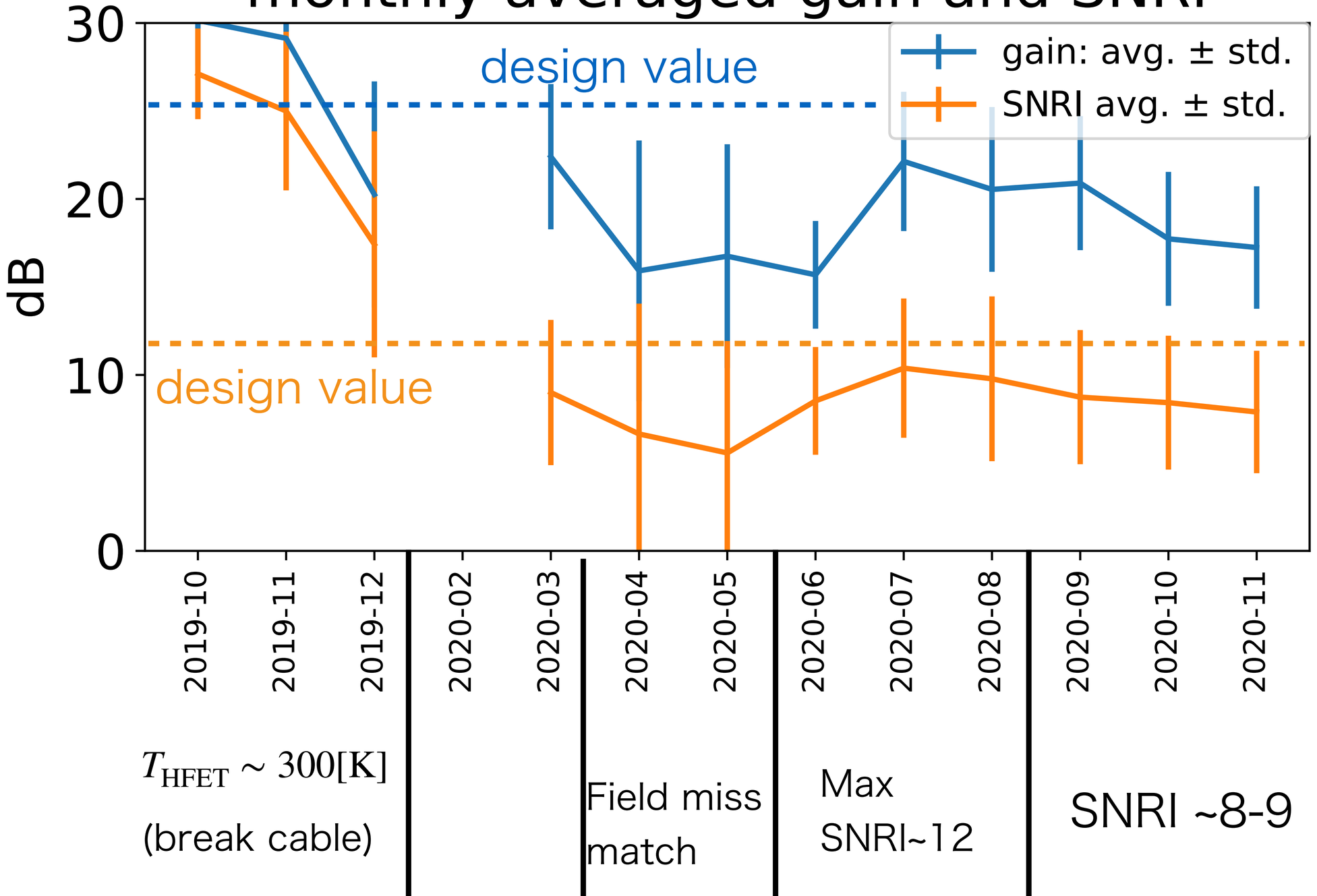
$$P = G^{\mathrm{off}}(T_{\mathrm{hot}} + T_{\mathrm{hfet}}) k_b b$$



$$T^{\mathrm{off}}_{\mathrm{sys}} = T_{\mathrm{hfet}} + T_{\mathrm{cavity}} \sim T_{\mathrm{hfet}}$$

Measuring in each nibble

monthly averaged gain and SNRI



Cable broken

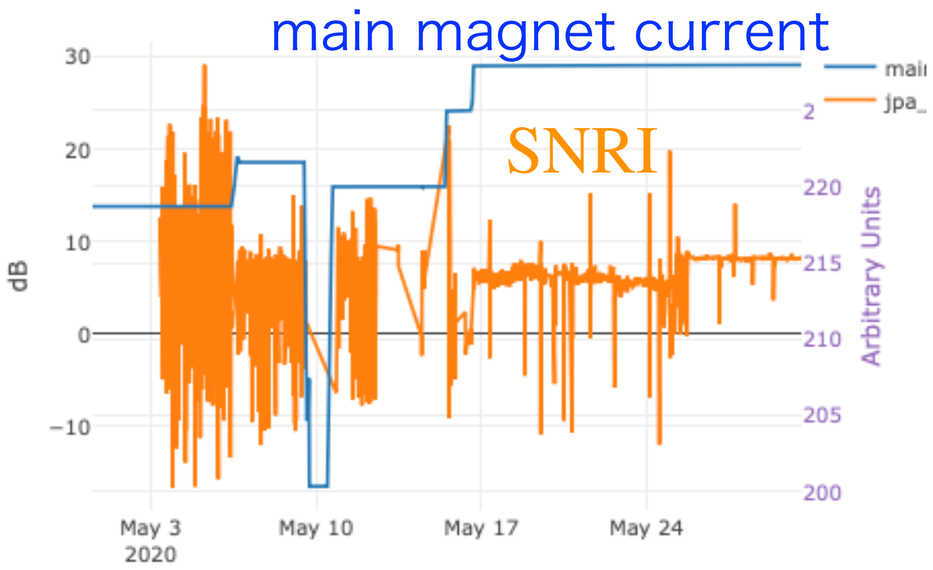
Channel 1 output cable was broken,
and it makes extra noise.

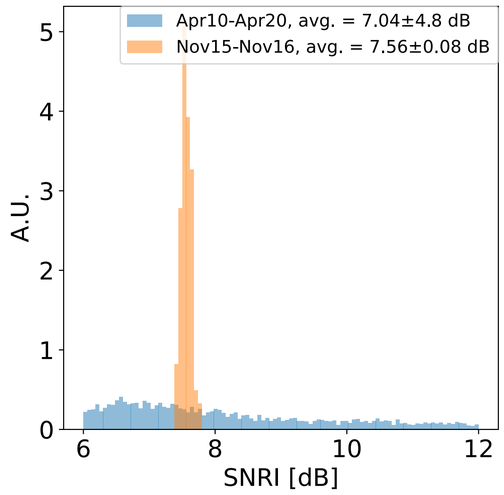
It is replaced when insert is pulled out.

T_{hfet} is drastically reduced.

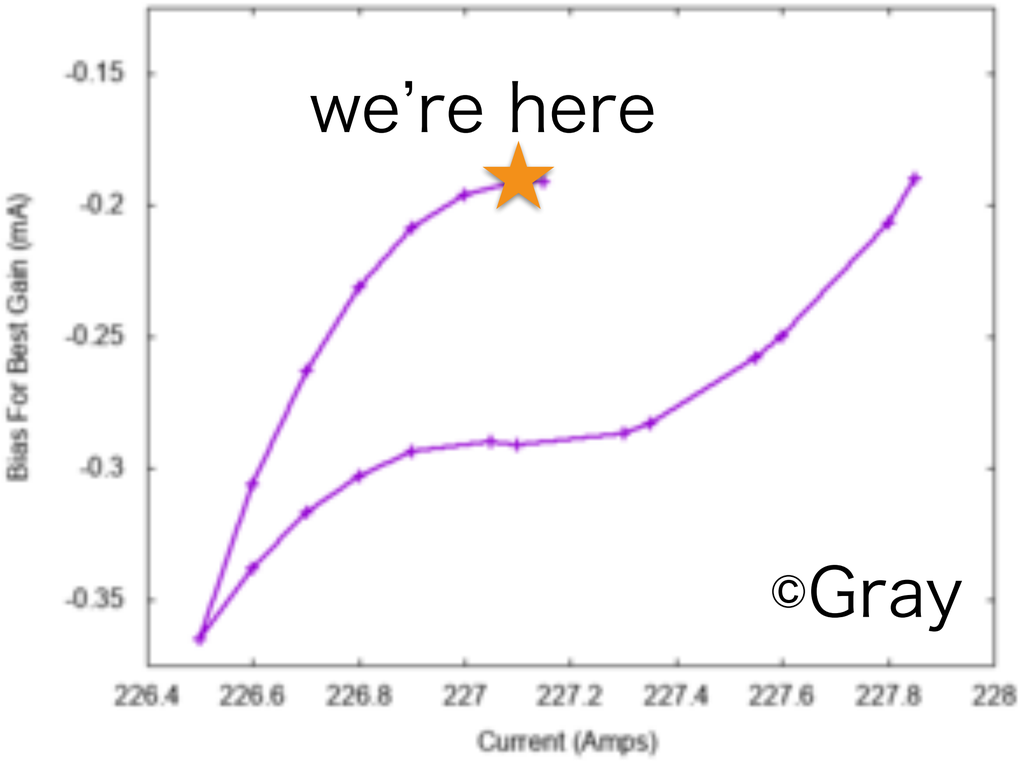
Field Mismatch

JPA very sensitive to external fields.
JPA is covered μ-metal shield, and backing coil to remove field.





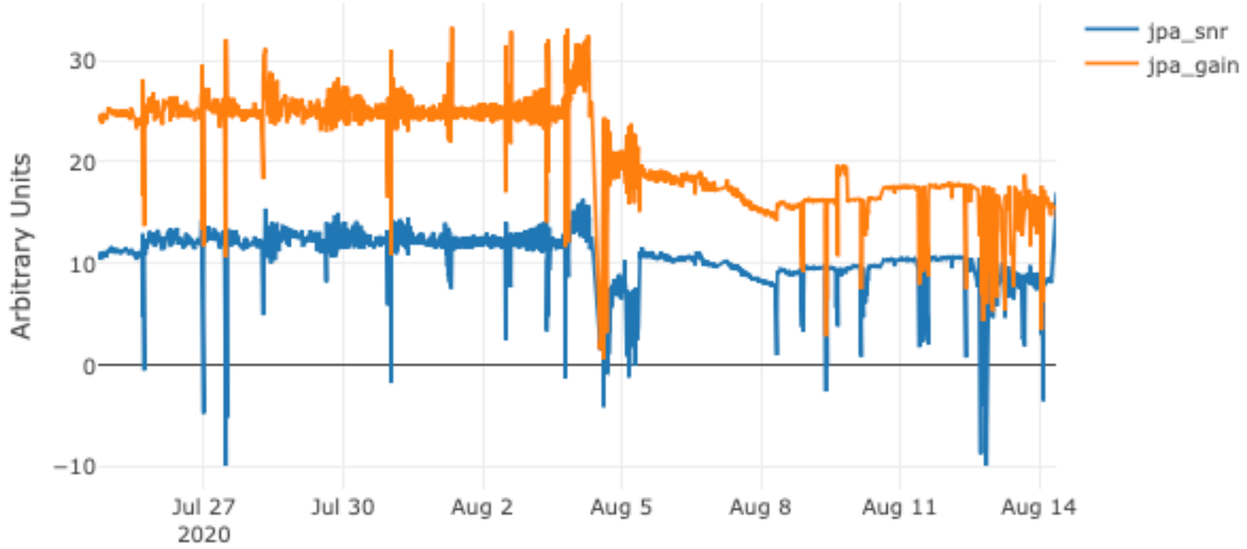
Hysteresis feature appeared.



JPA performance improves hugely after modifying Fields.

Max SNRI~12dB

We have certainly have been operating 12 dB for 2 weeks.

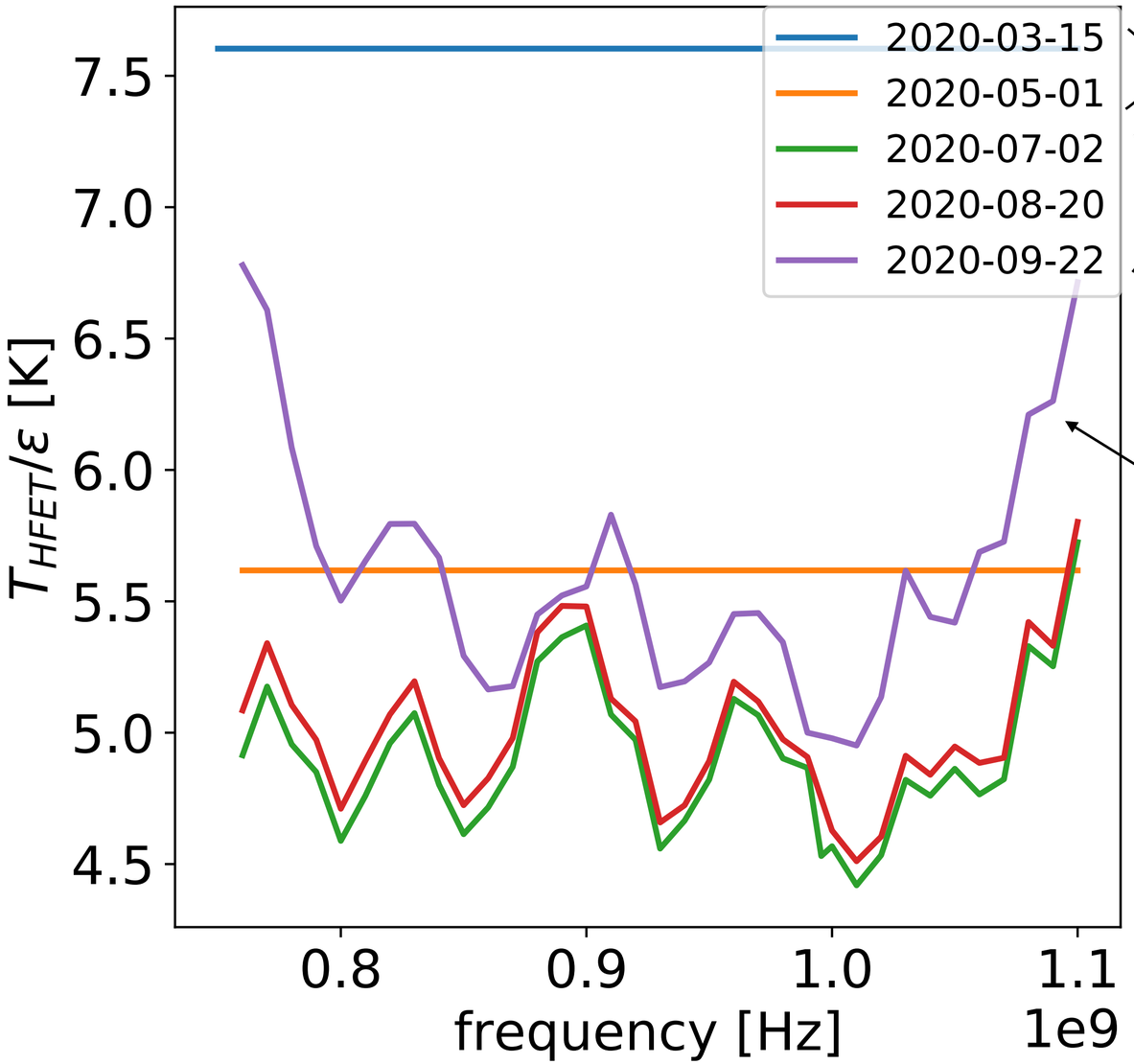


But it’s suddenly dropped.

We’re working on to know why it drops.

Check out Chelsea’s talk.

HFET



cavity as T_{hfet}

simultaneous fit

This is current baseline

Definitions of coupling β

$\frac{1}{Q_L} = \frac{1}{Q_0} + \frac{1}{Q_e}$ where Q_L, Q_0, Q_e are Loaded, Unloaded, External Q.

Our definition of beta has been turned out to be defined differently from others.

$$\beta_{\text{other}} = \frac{Q_0}{Q_e},\ P_{\text{other}} \propto \frac{\beta_{\text{other}}}{1+\beta_{\text{other}}}$$

c.f. HAYSTAC(2017) $P_S = \left(g_\gamma^2 \frac{\alpha^2}{\pi^2} \frac{\rho_a}{\Lambda^4}\right)\left(\omega_c B_0^2 V C_{mn\ell} Q_L \frac{\beta}{1+\beta}\right)$

$$\beta_{\text{our}} = \frac{2Q_L}{Q_e},\ P_{\text{our}} \propto \beta_{\text{our}}$$

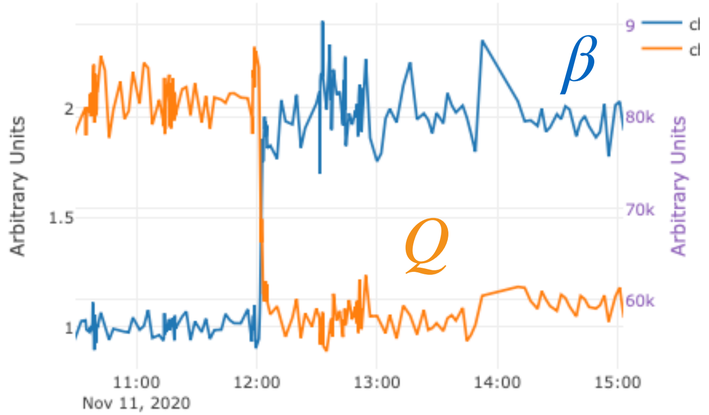
$$\rightarrow\ \beta_{\text{our}} = \frac{2\beta_{\text{other}}}{1+\beta_{\text{other}}}, P_{\text{our}} \propto 2P_{\text{other}}$$

We've using the same definition for others.

Utilize Over Coupling

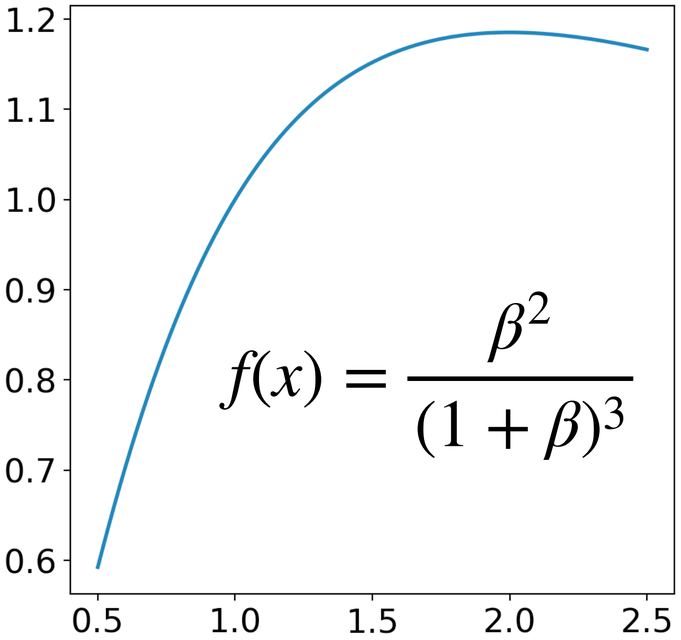
We've operated with critical coupling ($\beta = 1$).

Start to utilize since Sep.



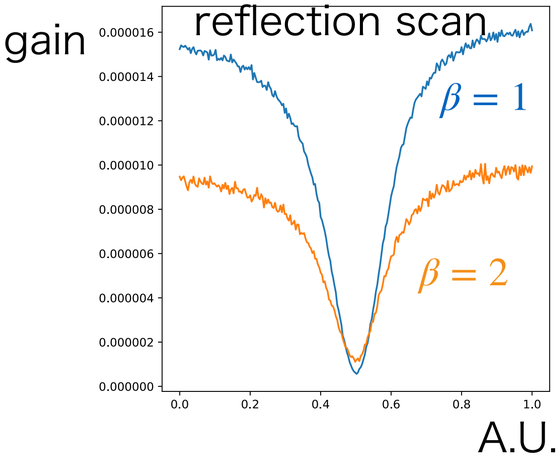
c.f. arXiv:1611.07123v2

$$\frac{df}{dt} \propto \frac{\beta^2}{(1+\beta)^3}$$



$\beta = 2$ **improves**

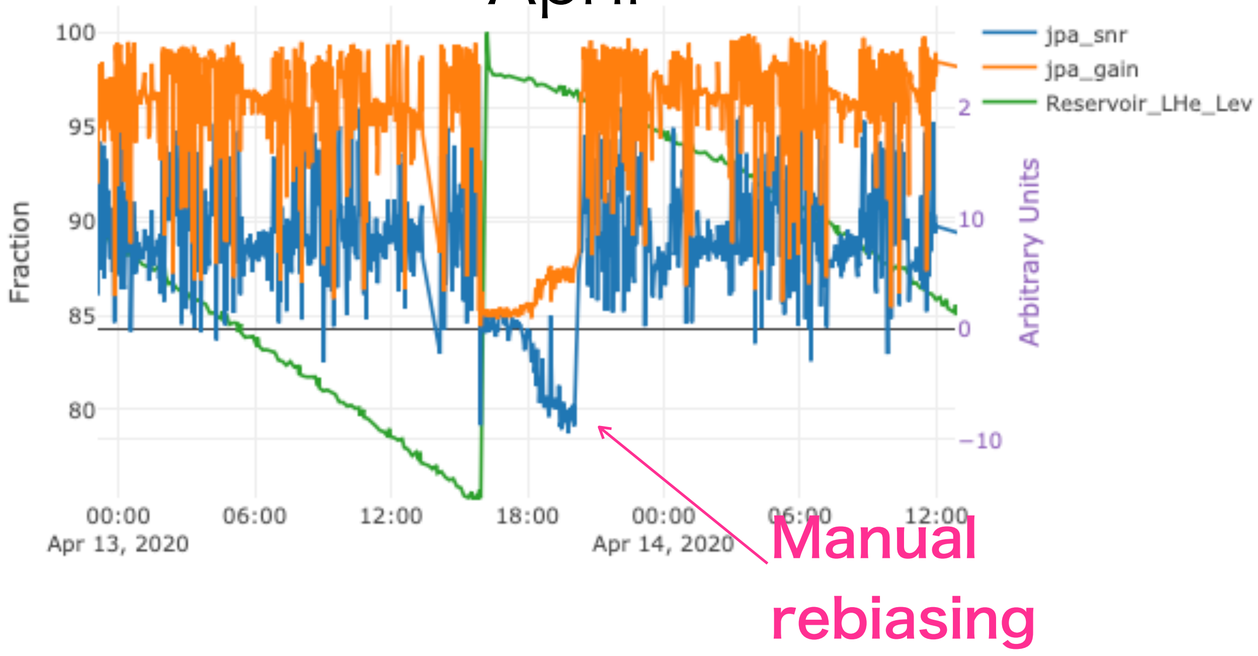
18% of scan speed.



Confirmed ~15 % speed up.

Conquer fills

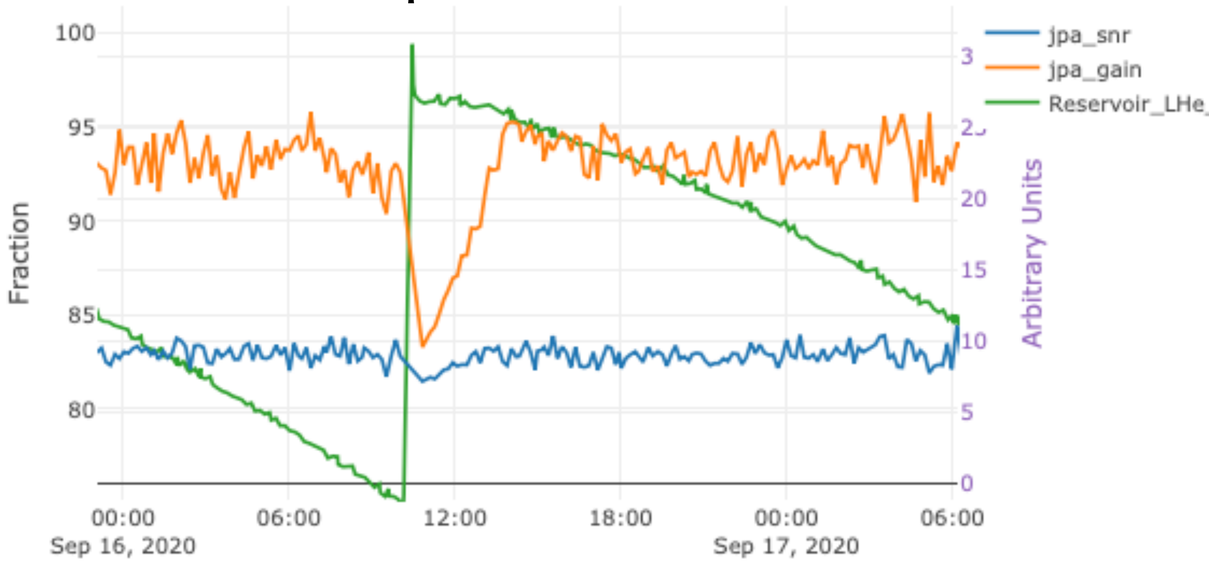
April



Vibration from a fill makes JPA unstable.

We've rebiased JPA manually.

September



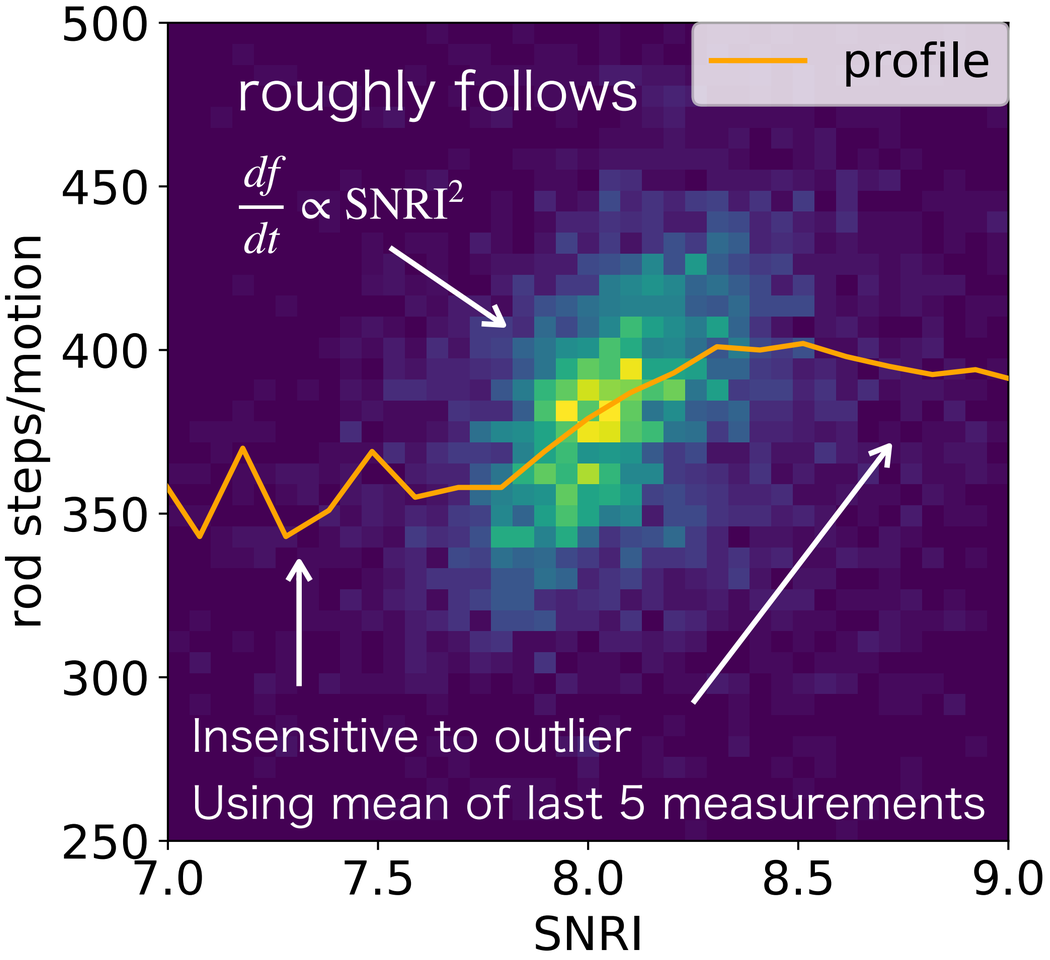
Nick's fill script stop automatic biasing before fills, and start after fills.

→ no need to rebias manually!

Automated rod speed

We've used fixed step size for rod motion.
→ Sometimes too slow or fast depends on SNRI.

Implemented "Fixed SNR mode":
Calculate SNR in each data-taking period, and modified rod motion optimally.



Summary

Operation is ongoing! Insert works fairly well.

Several improvements are implemented

- Change β definition → We're on the same page to others
- Over coupling → Achieved 15 % speed up
- Automated rod speed → Scan becomes more efficient
- Fill script → Operation becomes much stable

JPA performance is crucial, 400% slower scan speed than ideal JPA.

auto coupling script

beta=2

rod motion

Run1c History

Until Oct 2019	Run1c assembly (slides)
Oct 16 - Nov 27:	Nibble1 1005 - 1020 MHz
Nov 27 - Dec 31:	Nibble2 1000 - 1005 MHz
Jan - Mar :	Pull out Insert
Mar 3 - Apr 16:	Nibble3 995 - 1005 MHz
Apr 16 - May 17:	Field cancellation work
May 17 - Jul 7 :	Nibble4 985 - 995 MHz
Jul 18 - Aug10 :	Nibble3b, Nibble1b, Nibble4b
Aug 10 - Sep 14 :	Nibble5 975 - 985 MHz
Sep 14 - Oct 16 :	Nibble6 965 - 975 MHz
Oct 16 - :	Nibble7 955 - 965 MHz