Science Ops

Collaboration Meeting 2020

Chelsea Bartram

ADMX
AXION DARK MATTER EXPERIMENT

Who am I?

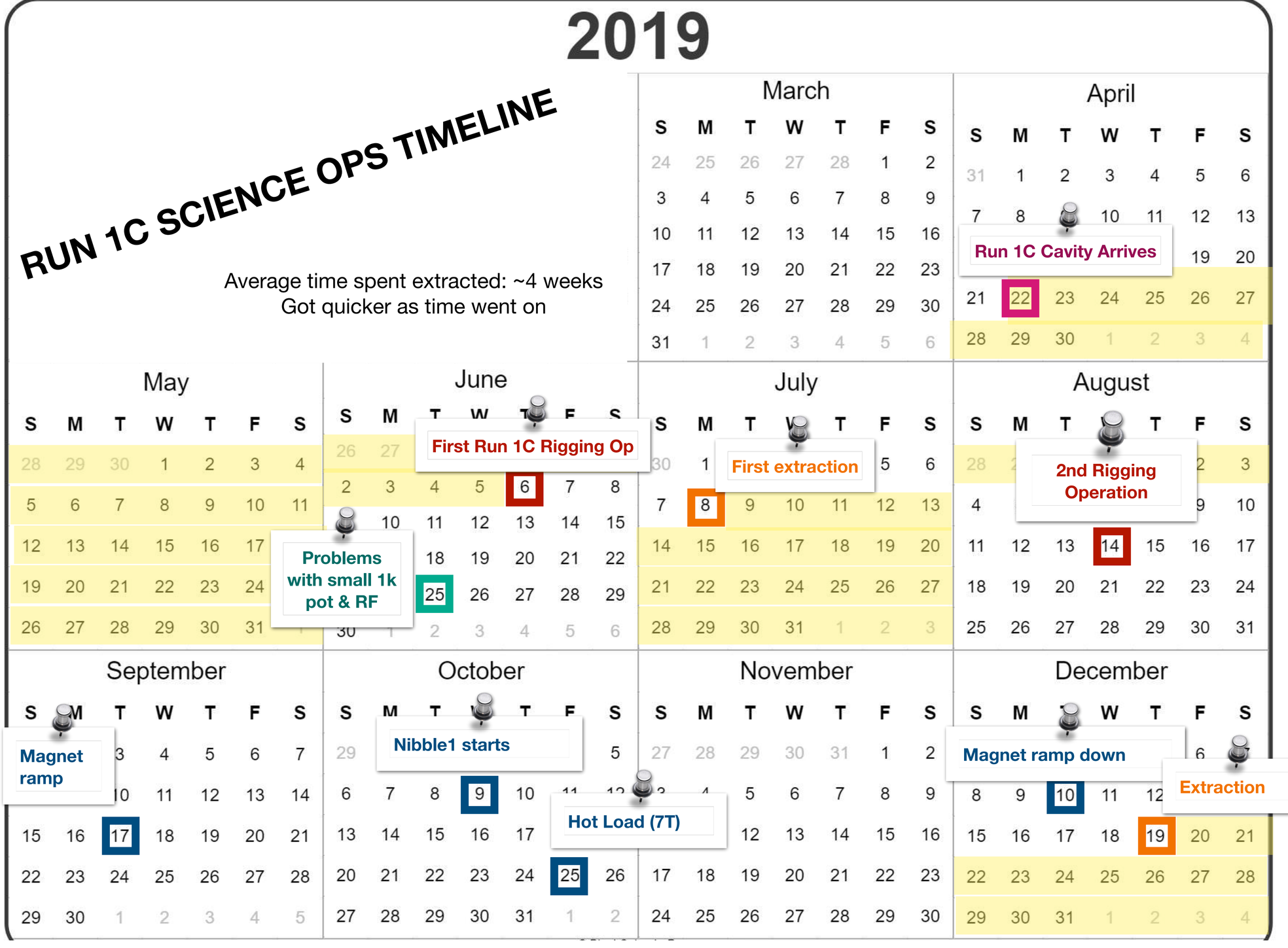
Chelsea Bartram

- ADMX Collaboration Post-doc
- Joined ADMX in March 2019 after defending at UNC Chapel Hill
- Responsible for initial Run 1C commissioning of insert, data-taking operations, and analysis, starting in March 2019. Shares duties with other on-site members.
- Have mentored ~6 undergraduate students so far on ADMX on various projects
- Am happy to mentor more students :)

RUN 1C SCIENCE OPS TIMELINE

2019

Average time spent extracted: ~4 weeks
Got quicker as time went on



2020

January

S	M	T	W	T	F	S
29	30	31	1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	1

- 3rd Rigging Operation
- Hot Load

February

S	M	T	W	T	F	S
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
1	2	3	4	5	6	7

- Extraction
- Recessed pin identified
- 4th Rigging Operation

March

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	1	2	3	4

- Magnet ramp
- LOCKDOWN STARTS

April

S	M	T	W	T	F	S
29	30	31	1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	1	2

- BC controller problem
- VERY UNSTABLE JPA

May

S	M	T	W	T	F	S
26	27	28	29	30	1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31	1	2	3	4	5	6

- JPA gain stability improves

June

S	M	T	W	T	F	S
31	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	1	2	3	4

- Start of 12 dB SNR

July

S	M	T	W	T	F	S
28	29	30	1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	1

August

S	M	T	W	T	F	S
26	27	28	29	30	31	1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31	1	2	3	4	5

- High SNR goes away

September

S	M	T	W	T	F	S
30	31	1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	1	2	3

October

S	M	T	W	T	F	S
27	28	29	30	1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

- Collaboration Meeting

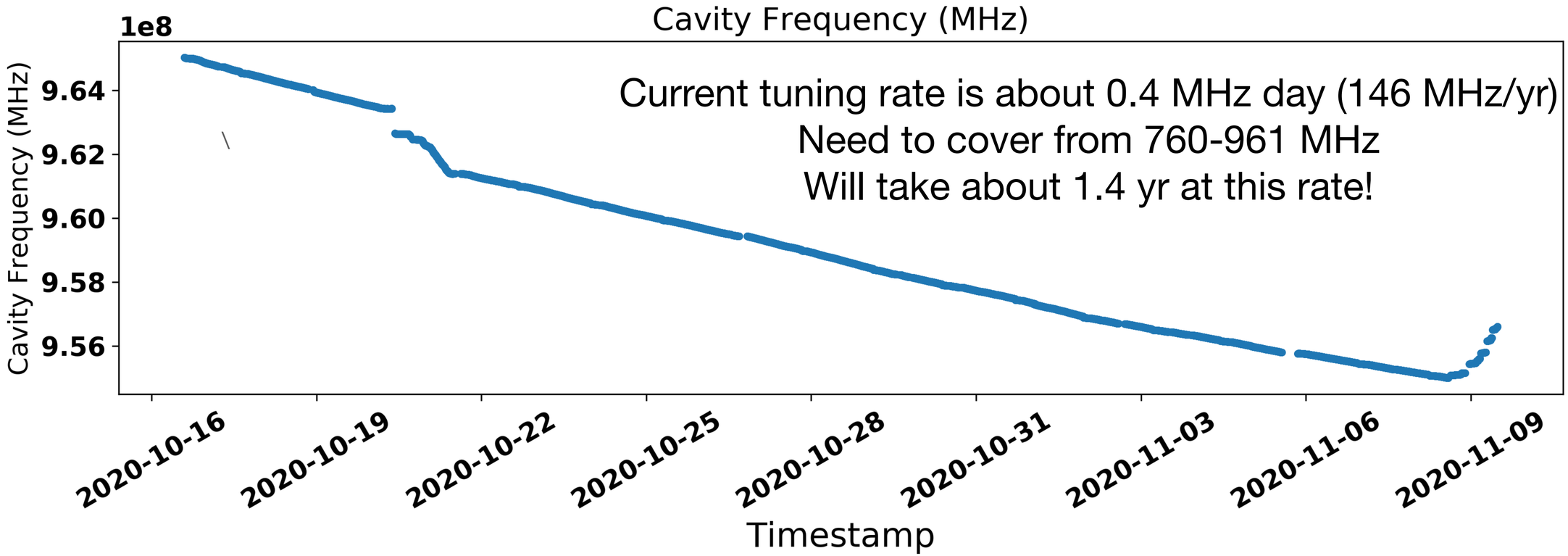
November

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	1	2	3	4	5

- End of Nibble 7

December

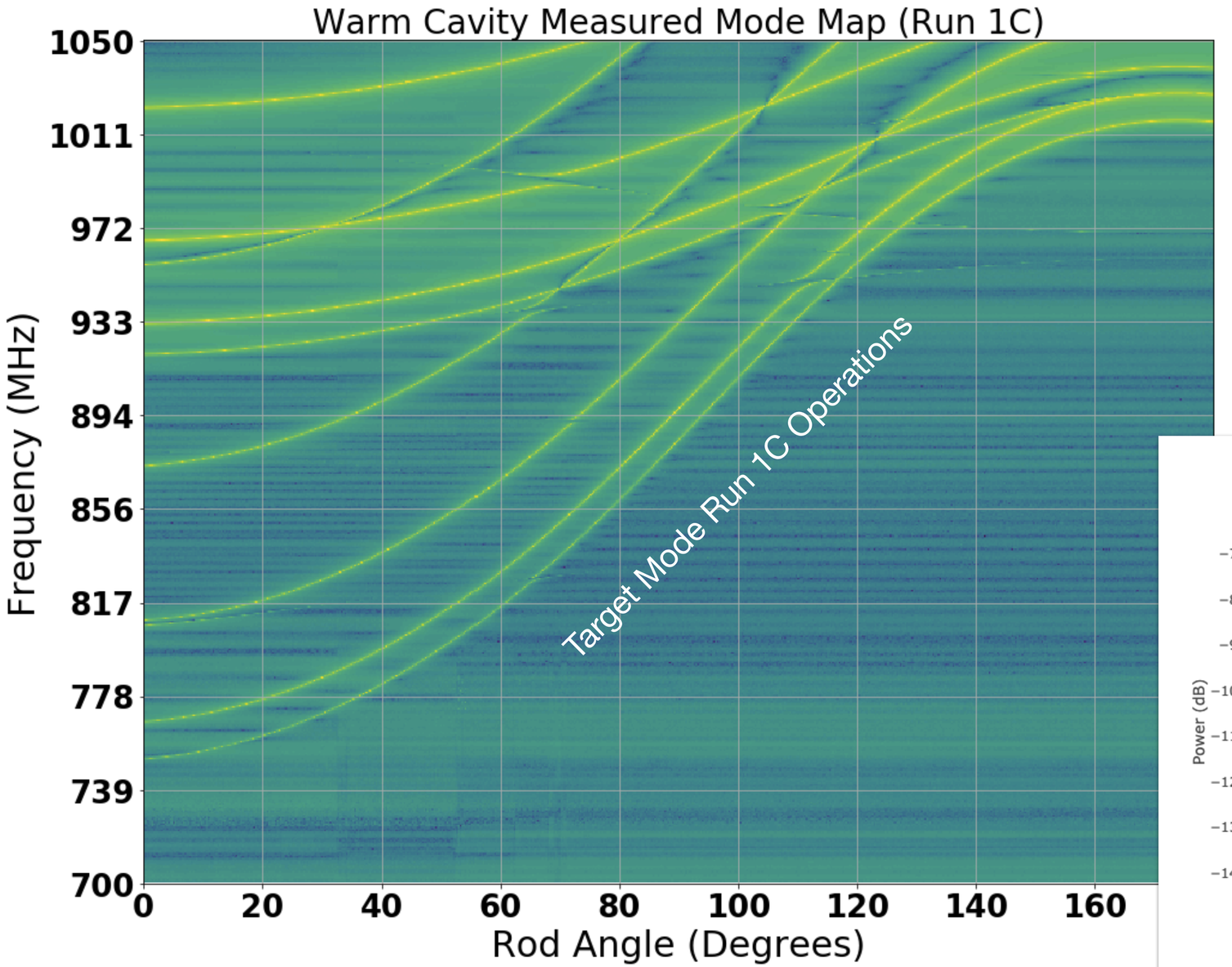
S	M	T	W	T	F	S
29	30	1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31	1	2



Scan rate equation for Run 1C (not including dead time, etc)

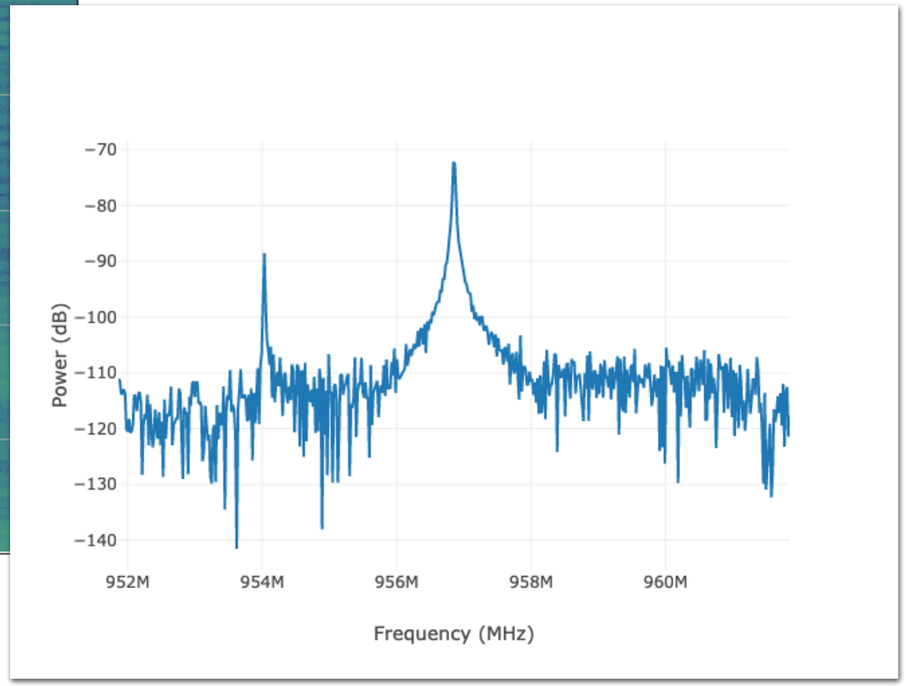
$$\frac{df}{dt} \approx 659 \ \frac{\text{MHz}}{\text{yr}} \left(\frac{g_\gamma}{0.36}\right)^4 \left(\frac{f}{890 \ \text{MHz}}\right)^2 \left(\frac{\rho}{0.45 \ \text{GeV/cm}^3}\right)^2 \left(\frac{3.5}{\text{SNR}}\right)^2 \left(\frac{B}{7.8 \ \text{T}}\right)^4 \left(\frac{V}{128 \ \ell}\right)^2 \left(\frac{Q_\text{L}}{72{,}000}\right) \left(\frac{C}{0.4}\right)^2 \left(\frac{0.2 \ \text{K}}{T_\text{sys}}\right)^2$$

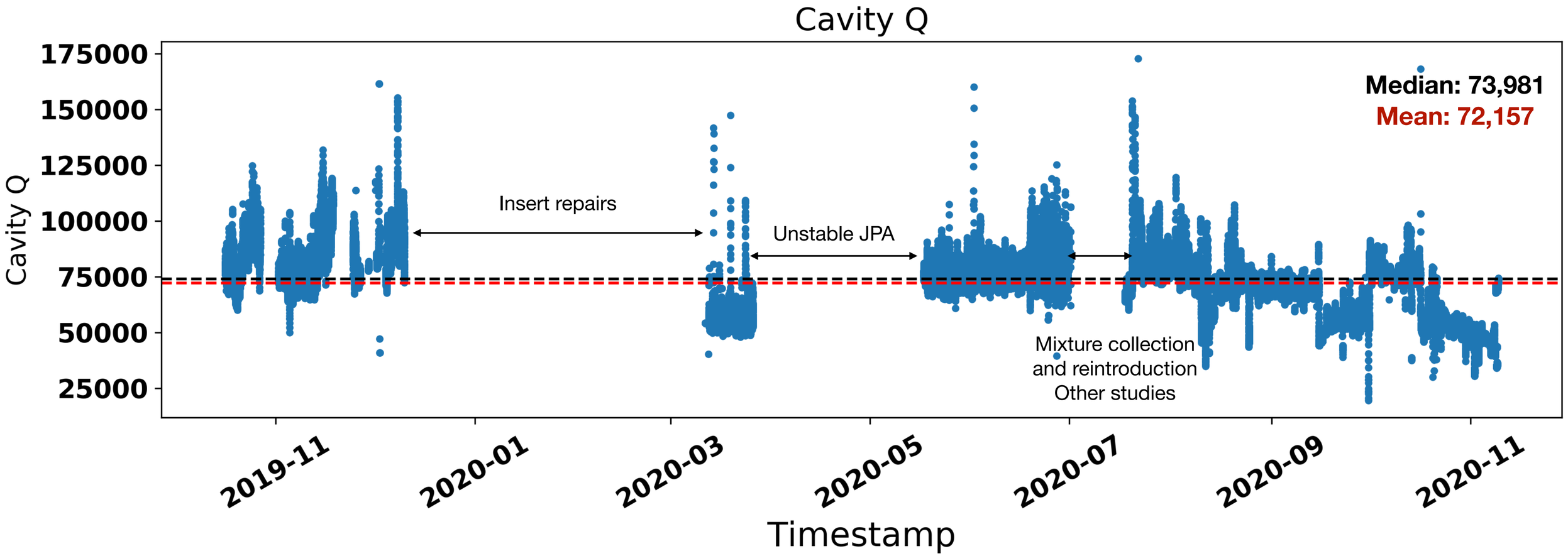
Need to adjust T_{sys} by achieving higher SNRI with the JPA



Have successfully navigated several mode-crossing so far

Widescans help navigate
Turning up resolution with widescans provides simulation input





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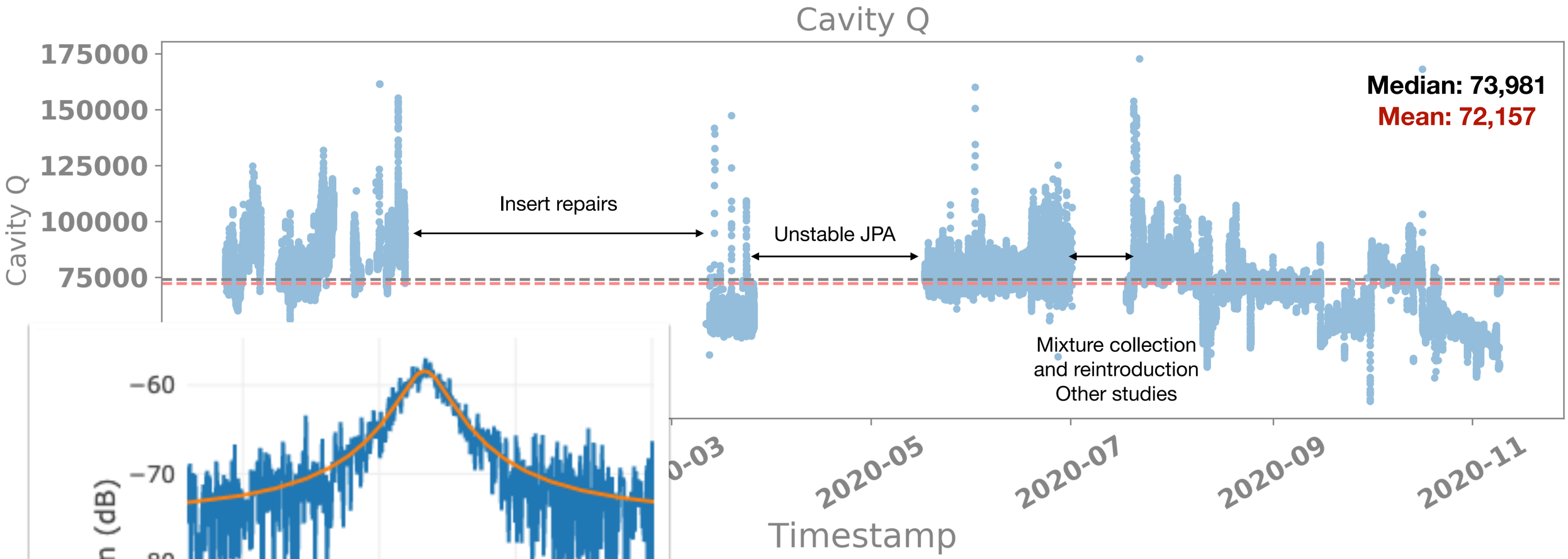
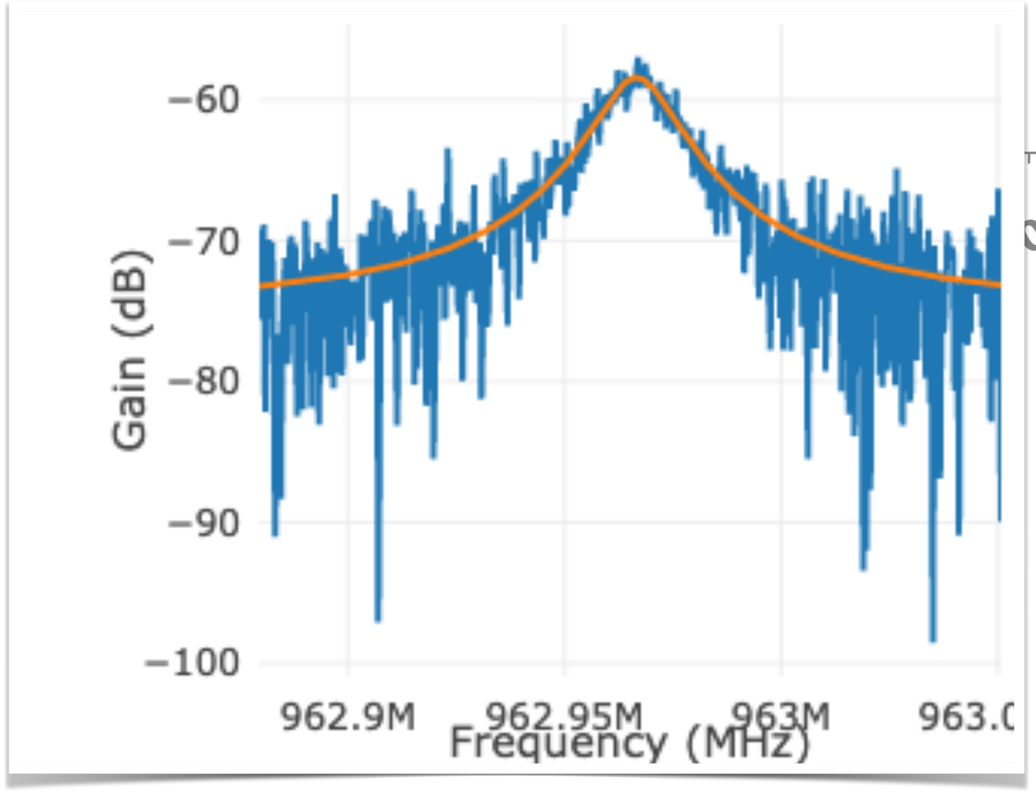
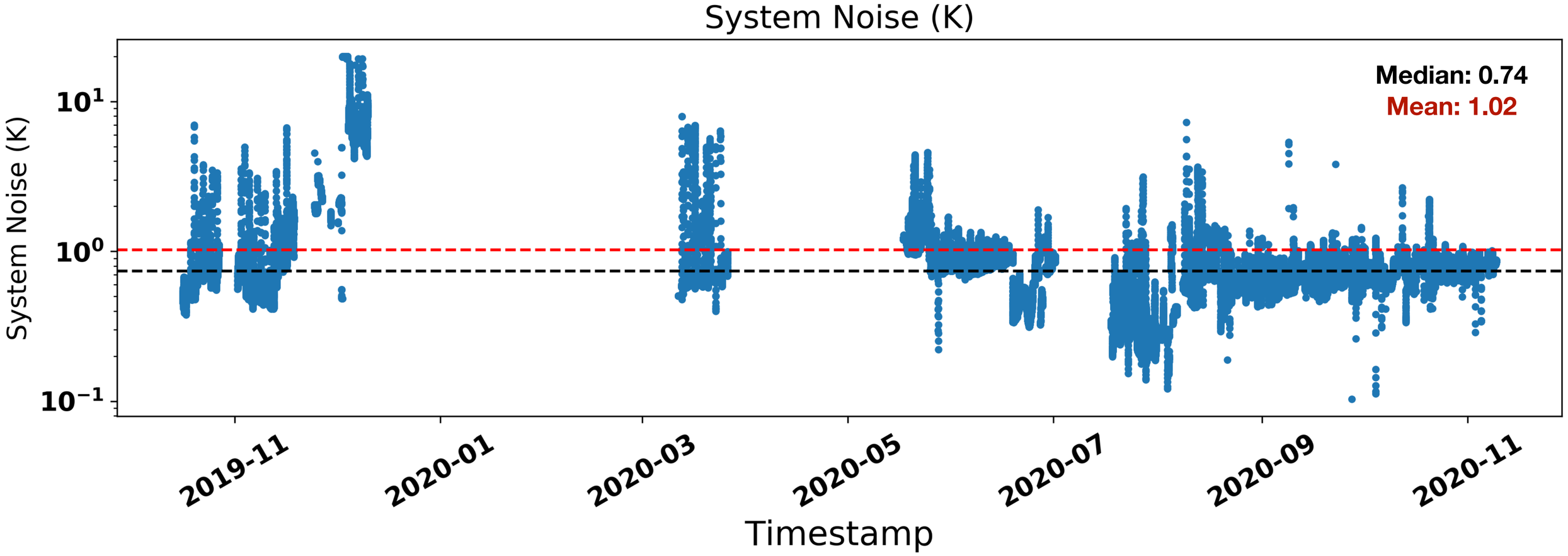
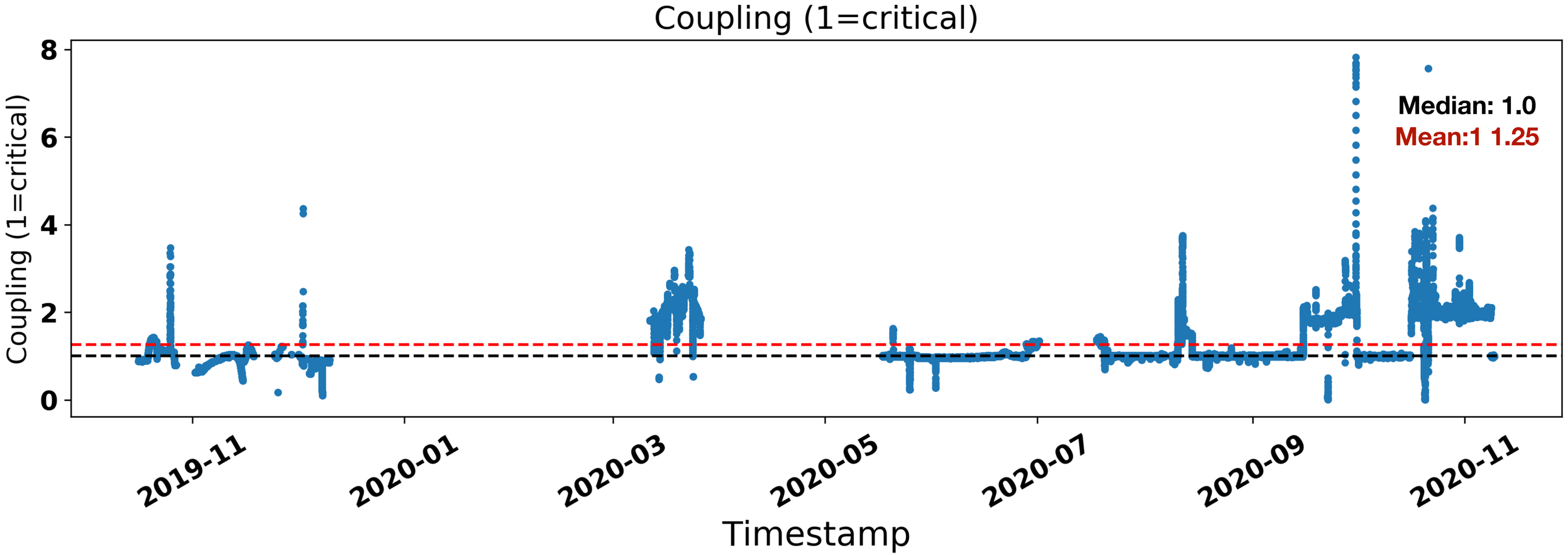




Quality Factor Comes From Transmission Measurement Fit
Efforts to retrieve ‘bad fits’ have been made by various students



$$\frac{df}{dt} \approx 659 \, \frac{\mathrm{MHz}}{\mathrm{yr}} \left(\frac{g_\gamma}{0.36}\right)^4 \left(\frac{f}{890 \ \mathrm{MHz}}\right)^2 \left(\frac{\rho}{0.45 \ \mathrm{GeV/cm^3}}\right)^2 \left(\frac{3.5}{\mathrm{SNR}}\right)^2 \left(\frac{B}{7.8 \ \mathrm{T}}\right)^4 \left(\frac{V}{128 \ \ell}\right)^2 \left(\frac{Q_\mathrm{L}}{72{,}000}\right) \left(\frac{C}{0.4}\right)^2 \left(\frac{0.2 \ \mathrm{K}}{T_\mathrm{sys}}\right)^2$$



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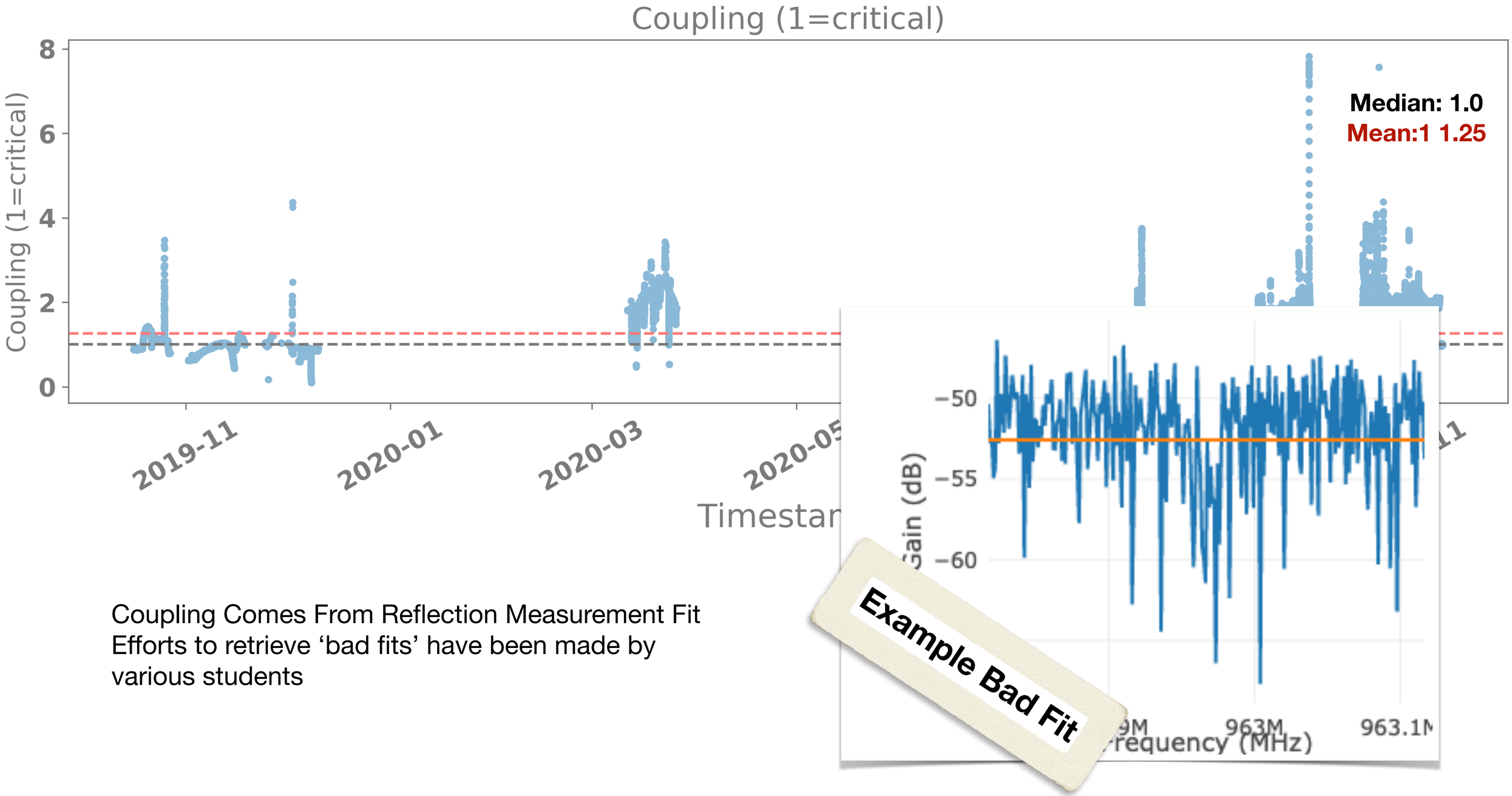
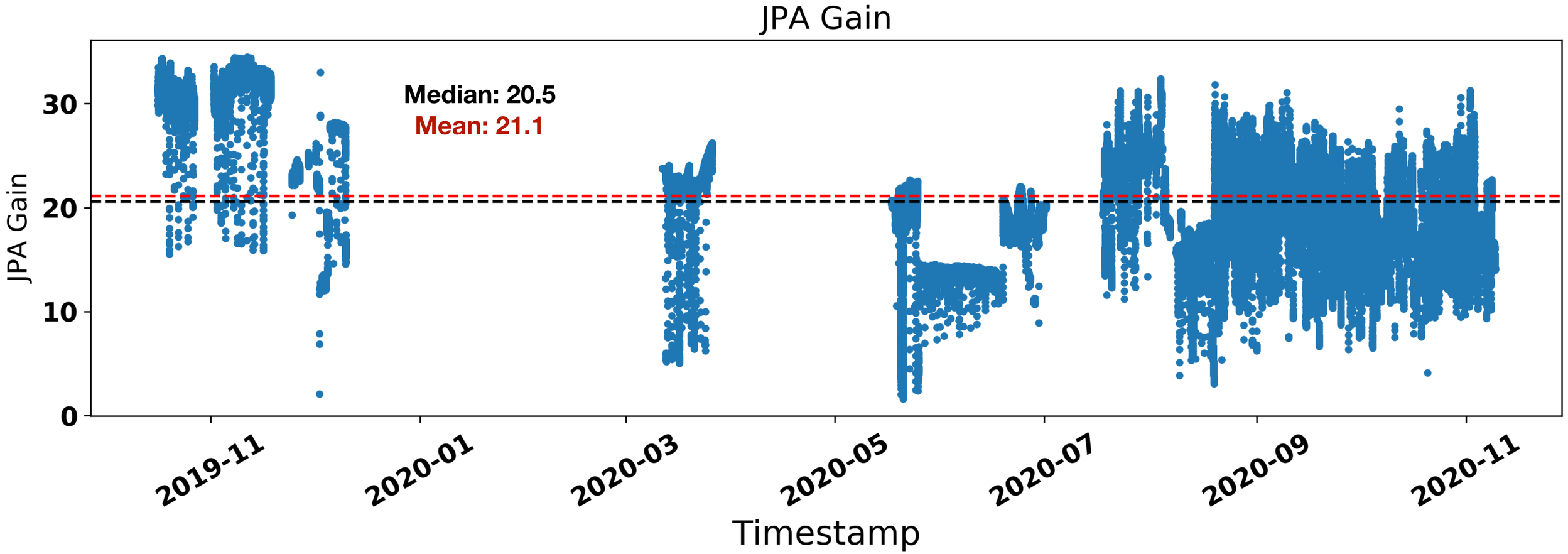


Coupling Comes From Reflection Measurement Fit
Efforts to retrieve ‘bad fits’ have been made by various students



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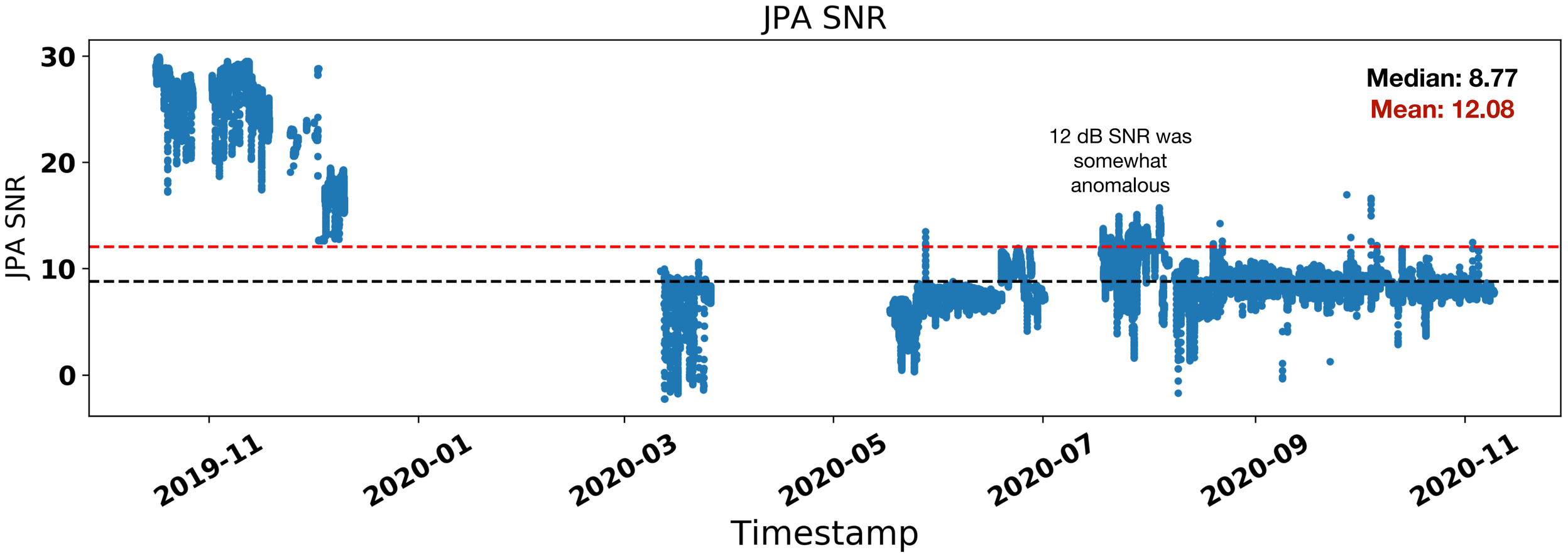

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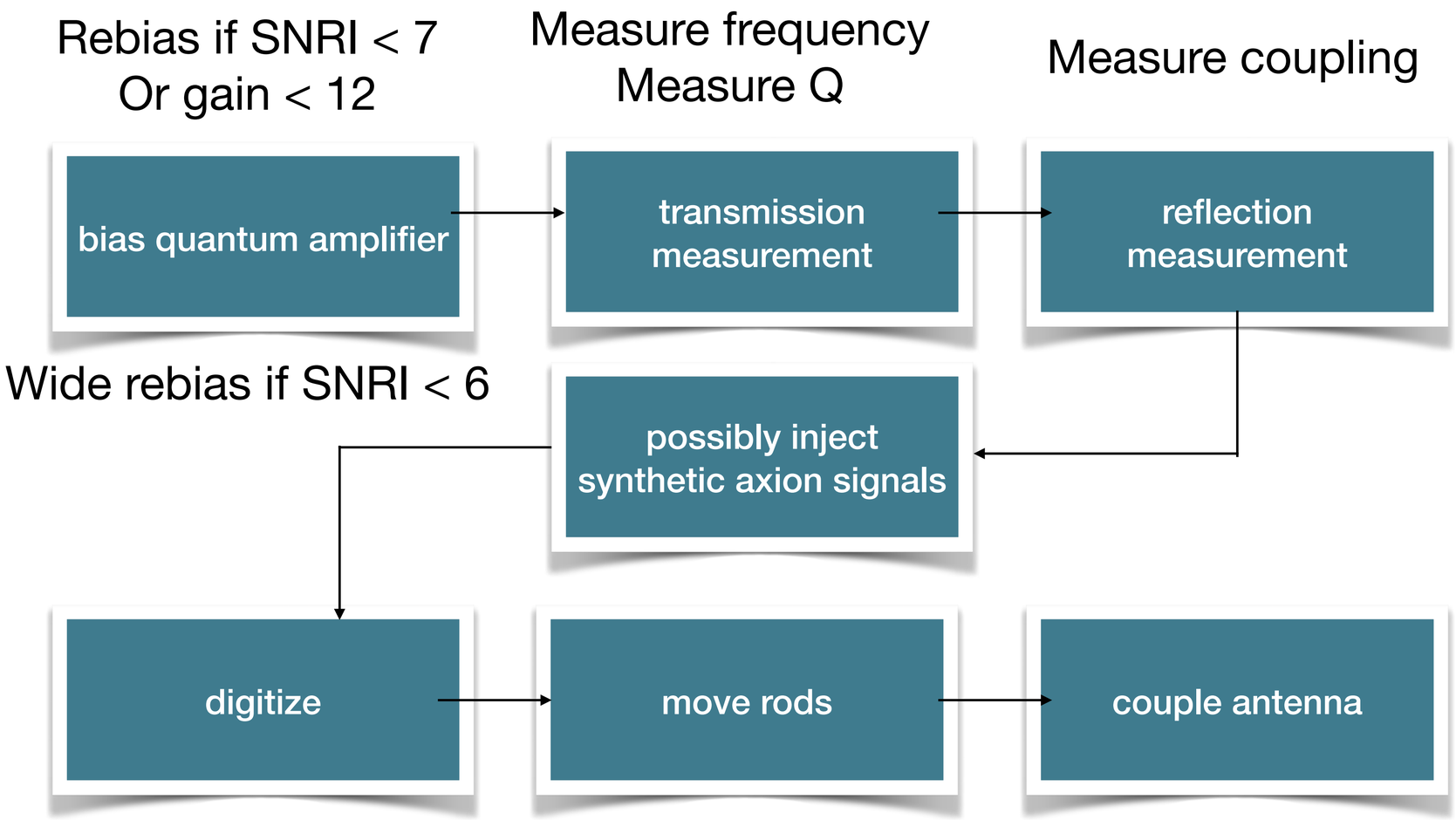
How science ops works

- Target frequency ranges in nibbles ~10 MHz.
  - Has been fairly consistent for Run 1C. First pass has been taking ~2 weeks. Rescans+eliminating all candidates ~2 weeks.
- Interrupted to acquire noise temp measurements.
- Rotate roles (Tatsumi—>Chelsea—>Gray—>Nick)
- Scan—>Rescan—>Report candidates—>Eliminate candidates (see flow chart)

Run Cadence



Data-taking operations:

- 1st pass through—determine if we rescan
- Interrupted by noise temperature measurements
- 2nd pass through to achieve necessary sensitivity, or eliminate rescan regions

Want to look at all scripts called during a single data-taking iteration?
Go to admx.npl.washington.edu under Scripts.
Then Category—>take_data
Script—>take_data_main

Rescan Procedure

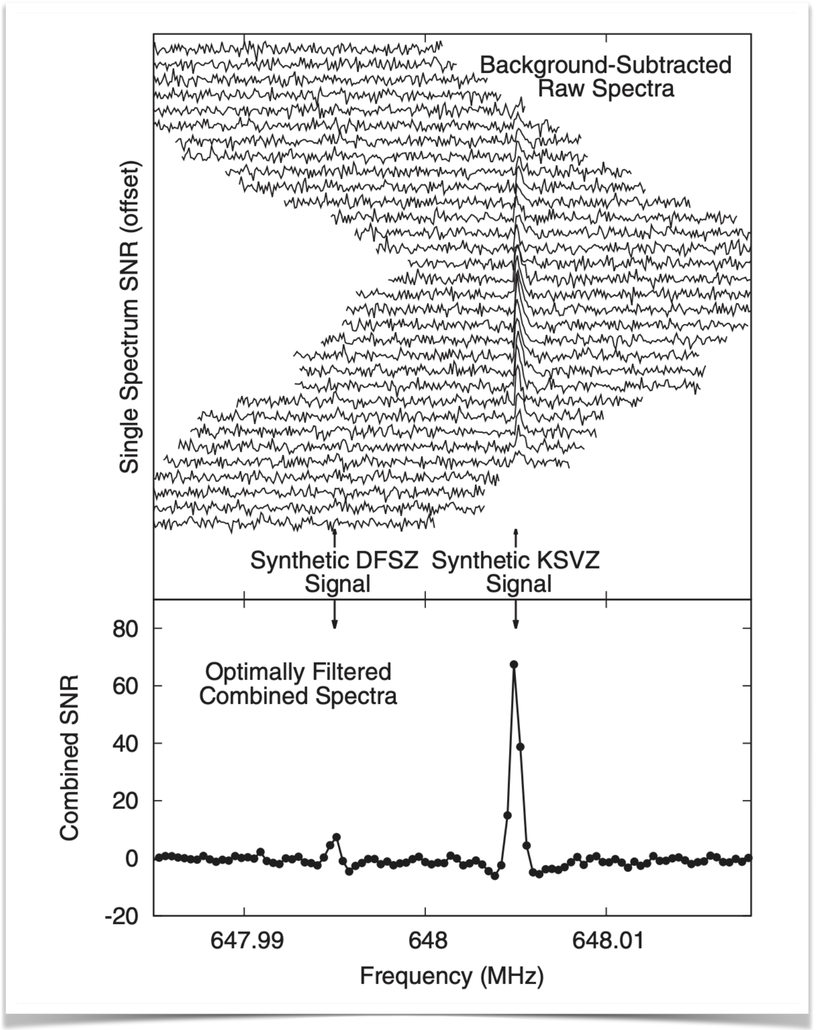
When do you decide to rescan?

3 conditions:

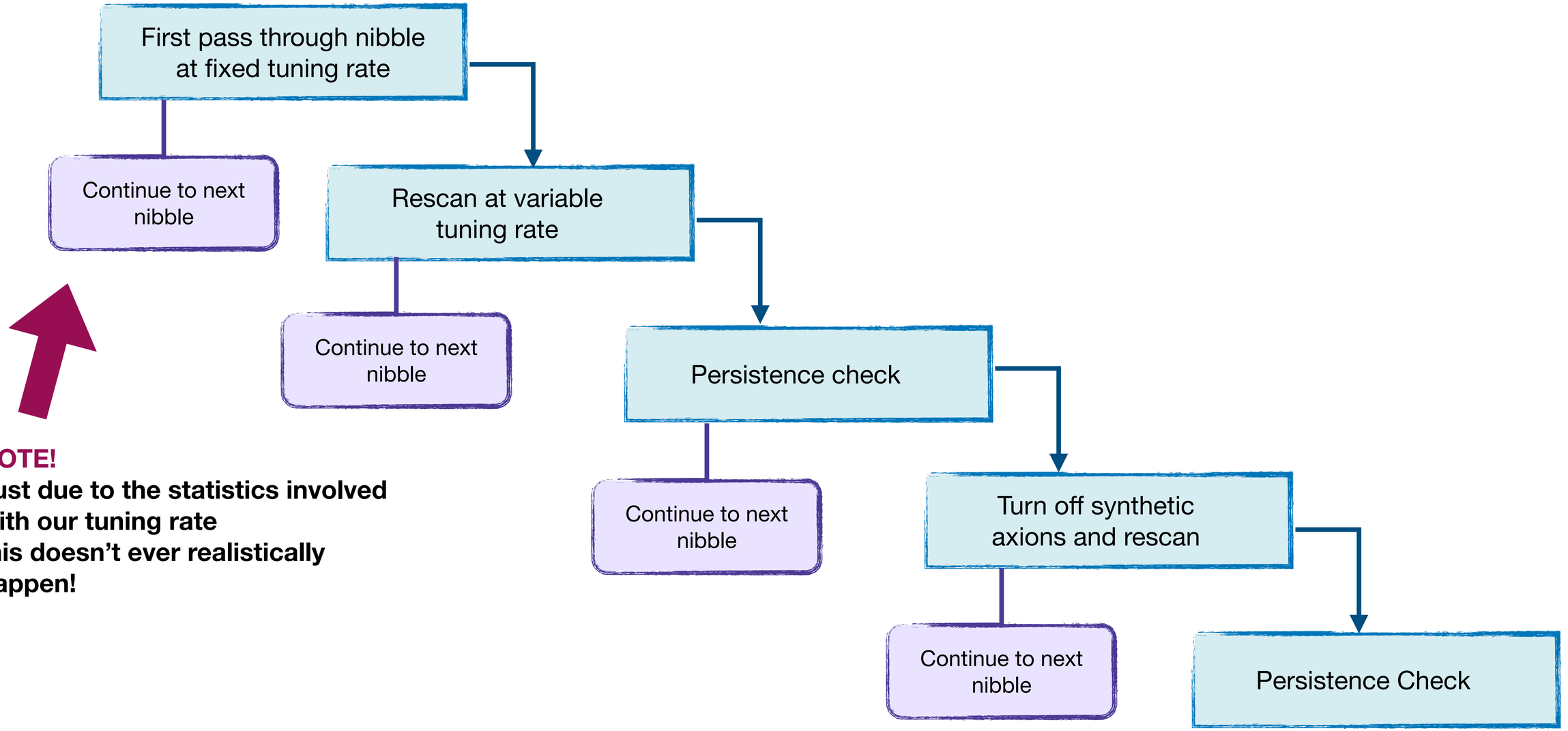
- Not enough data (low SNR): min SNR of 3
- 3.4σ excess
- Excess at DFSZ threshold or above

$$P_{\text{measured}} + 0.85\sigma > P_{\text{DFSZ}}$$

There will always be some of these remaining just due to statistics!

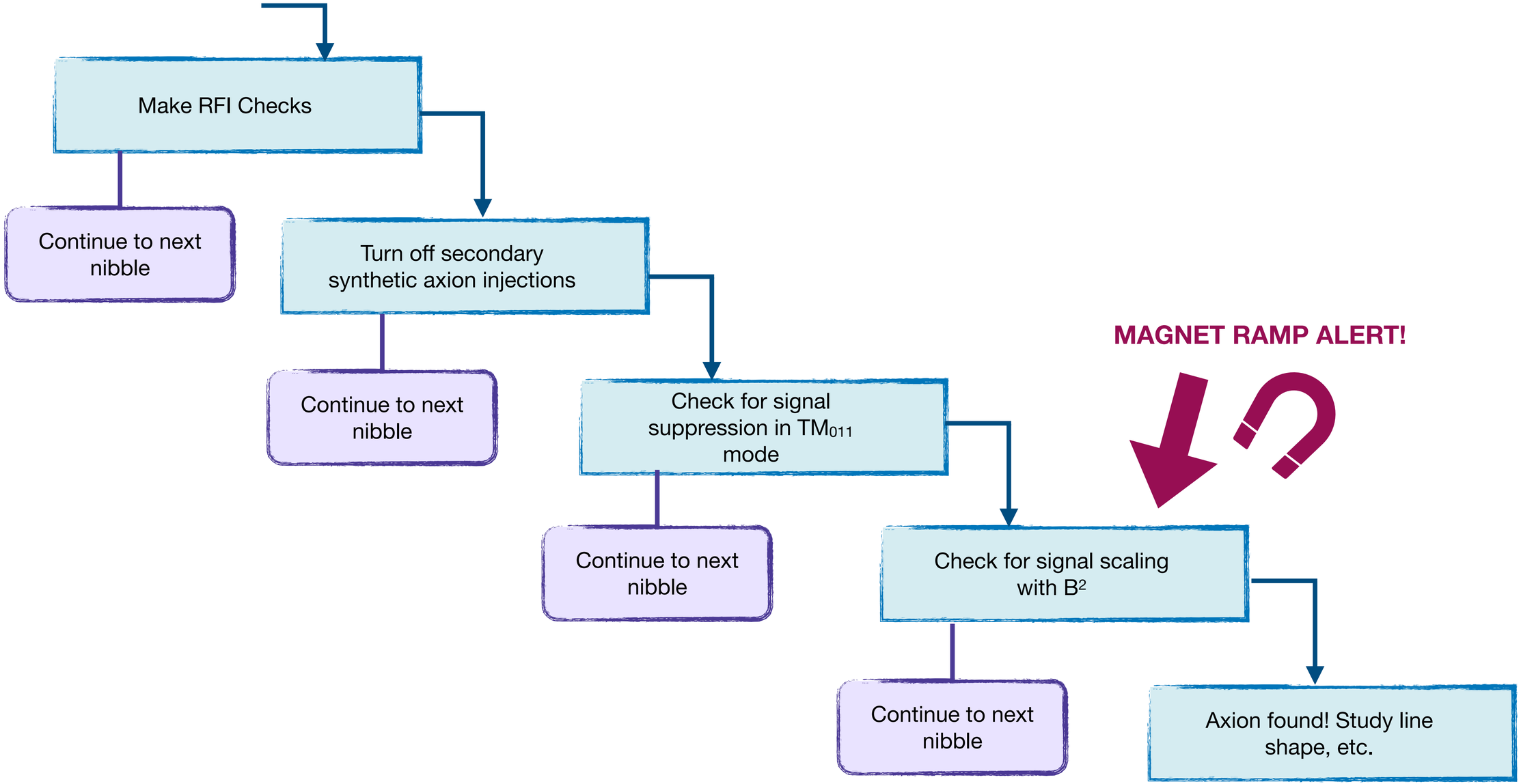


ADMX Search Decision Tree



NOTE!
Just due to the statistics involved with our tuning rate this doesn't ever realistically happen!

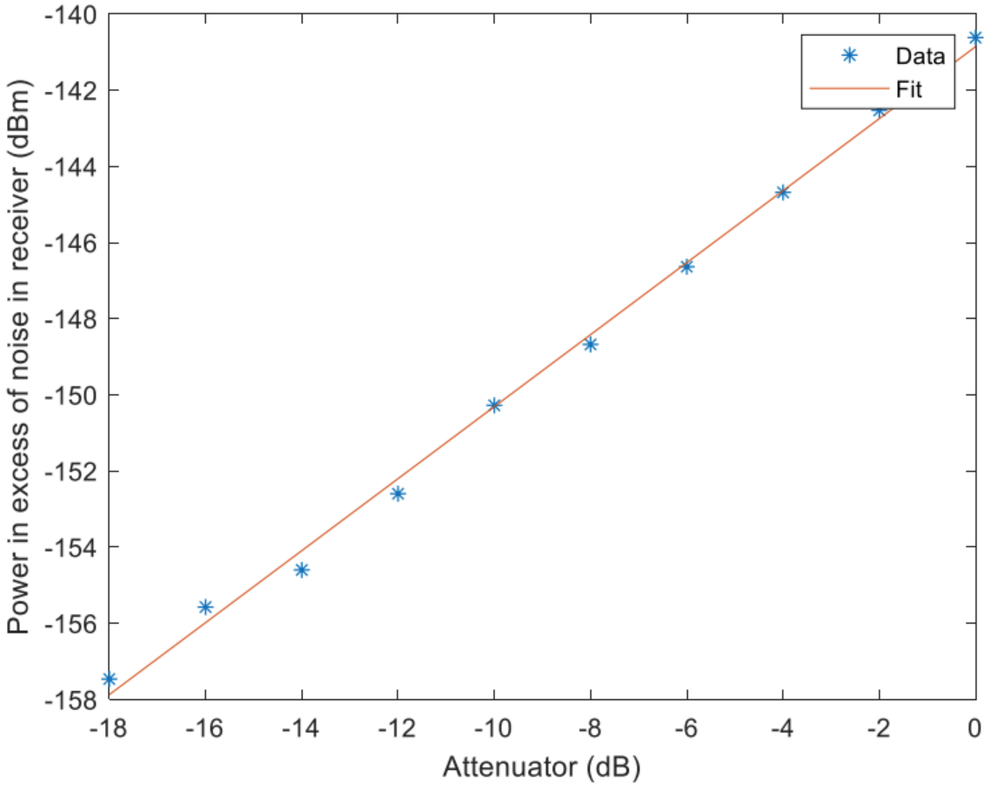
ADMX Search Decision Tree



Run 1C Synthetic Injections

SAG power calibration courtesy of Nick Du

- SAG created at cavity resonance
- JPA turned off
- SAG attenuation set to 40 dB (roughly below noise floor)
- Enable SAG injection
- Digitize for 70 seconds
- Repeat steps 3-5 while decreasing attenuation to 0 dB



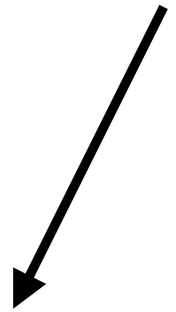
How often should we do this?

Christian

Have detected all SAGs that Noah has created so far for Run 1C

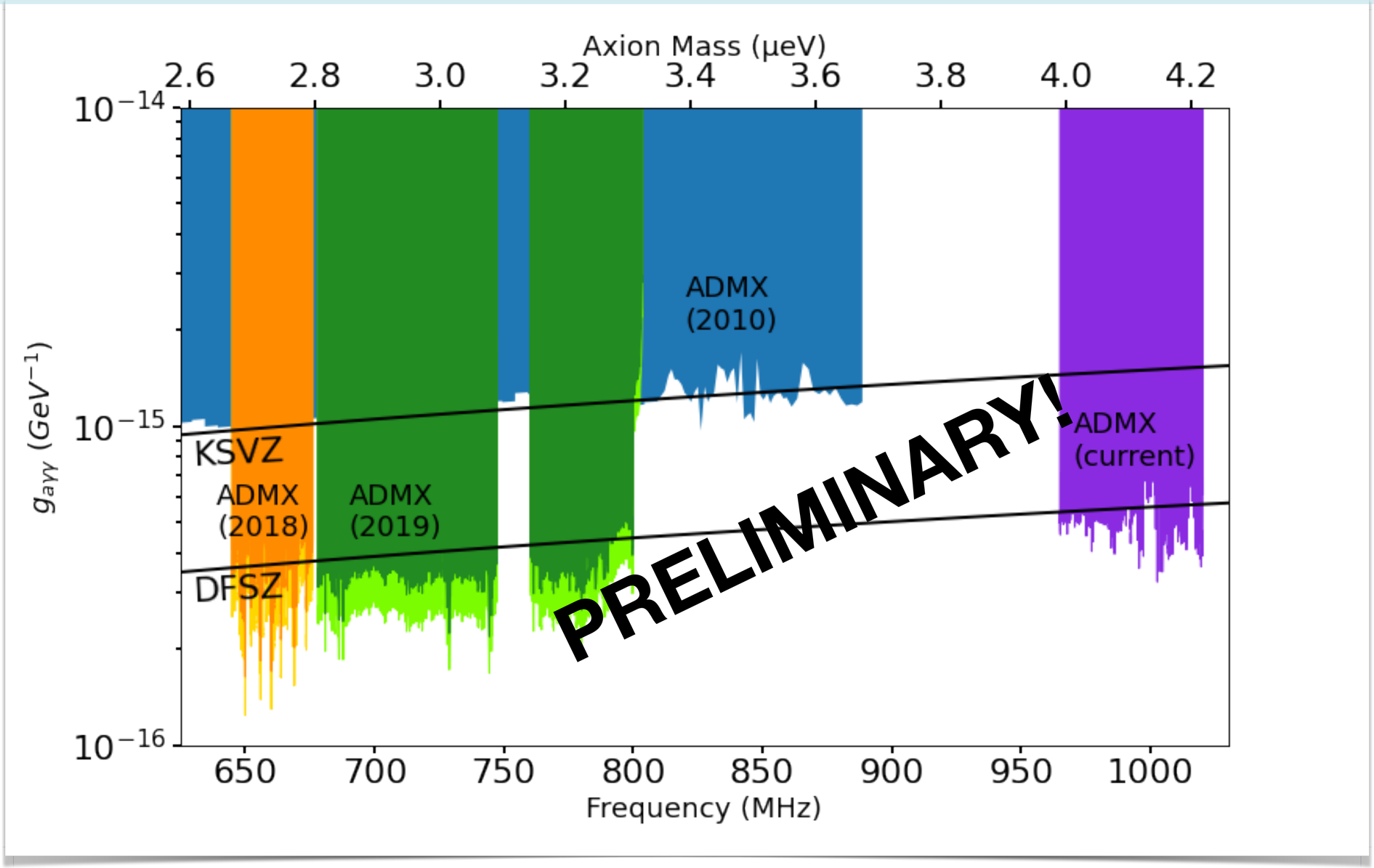
‘Online’ Analysis

- The medium resolution analysis is run on the Fermilab server (or locally on one’s laptop) and connects to the database.
- This is done by the operators, ideally every day.
- For more details, see talk by Tatsumi Nitta.
- Rescan candidates from the medium resolution analysis are fed back into ongoing data-taking operations manually
  - I have built in a means of injecting candidates into the database, which would automate the process further.
  - Rescan triggers from high-resolution analysis is not built-in yet.



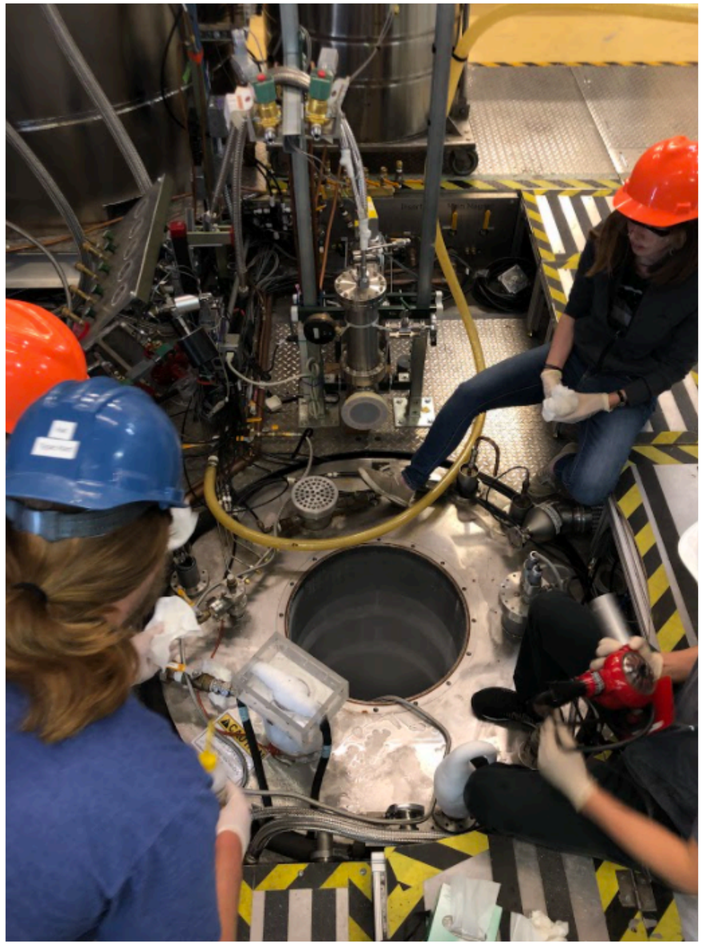
Ambitious students, please ask if you are interested in working with me on this :)

Preliminary Limit Plot



Conclusions

- Have been able to maintain steady data-taking operations from March until now.
- Making steady progress, but need to continue optimizing scan speed.
- Possibility of axion discovery at any moment.



ADMX Collaboration

- Founded in 1994 at LLNL
- One of 3 “Gen-2” Dark Matter Projects
- Now located at University of Washington

Sponsors

HEISING - SIMONS FOUNDATION

Primary Sponsor

THE UNIVERSITY OF WESTERN AUSTRALIA

Pacific Northwest NATIONAL LABORATORY

Berkeley UNIVERSITY OF CALIFORNIA

Lawrence Livermore National Laboratory

The University Of Sheffield.

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

This work was supported by the U.S. Department of Energy through Grants No DE-SC0009800, No. DE-SC0009723, No. DE-SC0010296, No. DE-SC0010280, No. DE-SC0011665, No. DEFG02-97ER41029, No. DE-FG02-96ER40956, No. DEAC52-07NA27344, No. DE-C03-76SF00098 and No. DE-SC0017987. Fermilab is a U.S. Department of Energy, Office of Science, HEP User Facility. Fermilab is managed by Fermi Research Alliance, LLC (FRA), acting under Contract No. DE-AC02-07CH11359. Additional support was provided by the Heising-Simons Foundation and by the Lawrence Livermore National Laboratory and Pacific Northwest National Laboratory LDRD offices.