Update and preliminary data on up-conversion and excitation transfer experiments

F. Metzler, 6/7/2017

Overview

- Will present recent work on:
    1. Up-conversion experiment
    2. Excitation transfer experiment

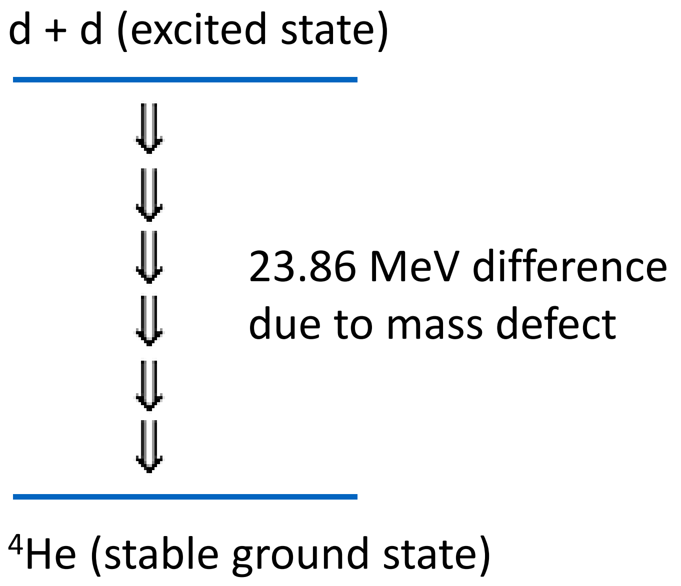
- In both experiments, the idea is to **couple phonon energy** from vibrating metal lattices (steel plates) **to nuclear states** and achieve nuclear excitation or transfer of nuclear excitation.
- The mechanical excitation is caused by **ultrasound transducers**; the expected measurable outcome is **nuclear radiation**.

Motivation

Fleischmann & Pons type experiments:

Where does the mass defect energy go?

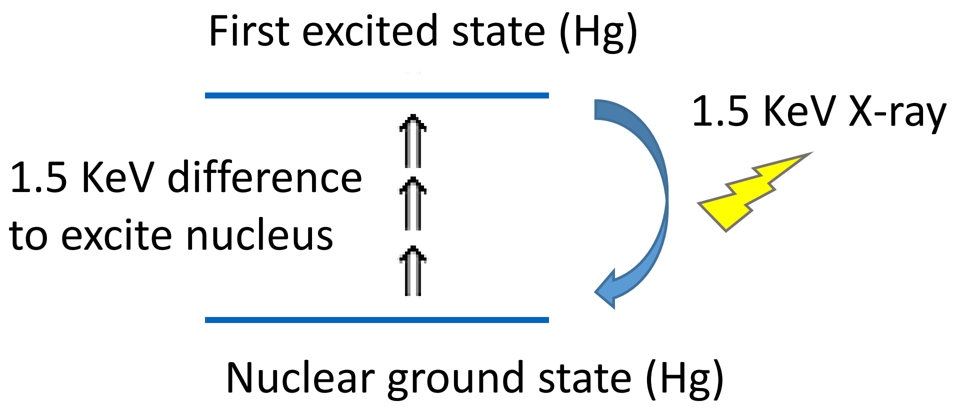
Large mass defect quantum from $d+d \rightarrow {}^{4}He$ gets down-converted into Millions of sub-eV vibrational quanta.



Karabut; Kornilova & Vysotskii experiments:

Where does the X-ray energy come from?

Thousands of sub-eV vibrational quanta pile up to 1.5 KeV and up-convert individual nuclei. Those emit 1.5 KeV X-rays as they return to ground states.



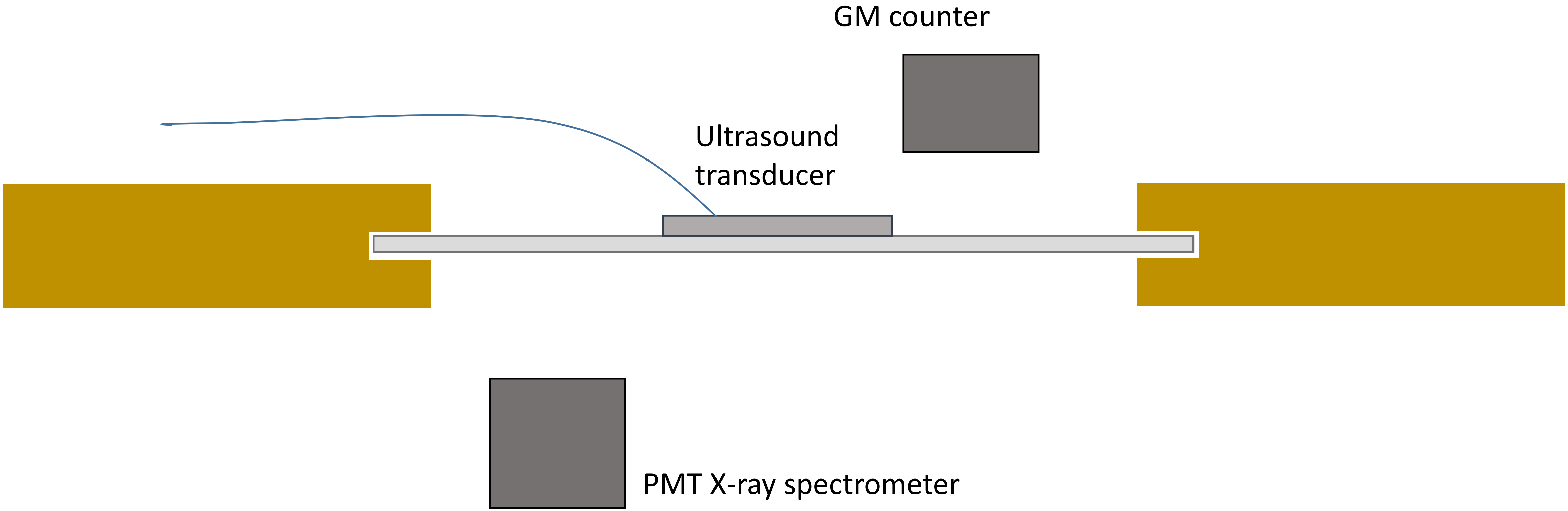
Motivation (cont'd)

- **Karabut**[1] (glow discharge exp't) - High freq. vibrations of steel correlated with 1.5 KeV collimated X-ray emission
- **Kornilova & Vysotskii**[2] (waterjet exp't) – High frequency vibrations of steel correlated with 1.5 KeV collimated X-ray emission
- **Carpinteri**[3] (hydraulic press exp't) – High-power vibrations at various freq. associated with conjectured nuclear fission of Fe to Al
- **Cardone et al.** [4] (ultrasound cleaner exp't) – High-power 20 kHz vibrations associated with neutron emission

1. Karabut, A. B. "Study of energetic and temporal characteristics of X-ray emission from solid state cathode medium of high current glow discharge." Proceedings of ICCF12, Japan. 2006.
2. Vysotskii, V. I., et al. "Observation and investigation of anomalous X-ray and thermal effects of cavitation." Current Science 108.4 (2015): 608.
3. Carpinteri, A., et al. "Piezonuclear fission reactions from earthquakes and brittle rocks failure: evidence of neutron emission and non-radioactive product elements." Experimental Mechanics 53.3 (2013): 345-365.
4. Cardone, G., et al. "Chemical changes induced by ultrasound in iron." Applied Physics A 114.4 (2014): 1233-1246.

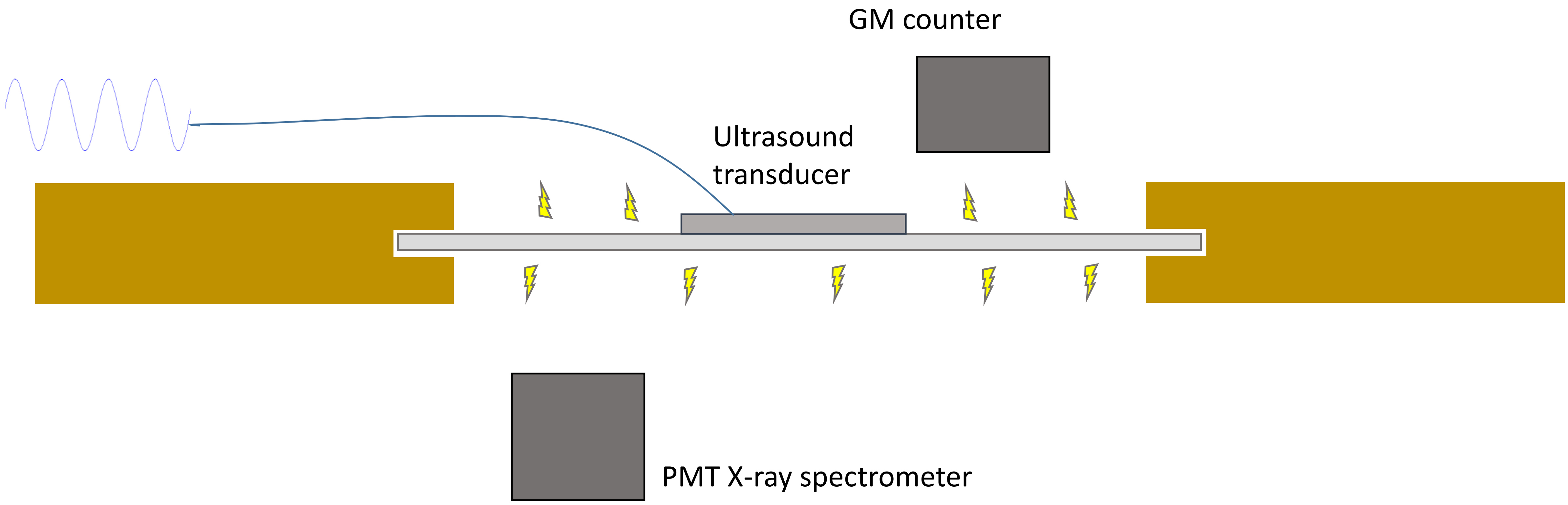
Up-conversion experiment

Vibrations OFF



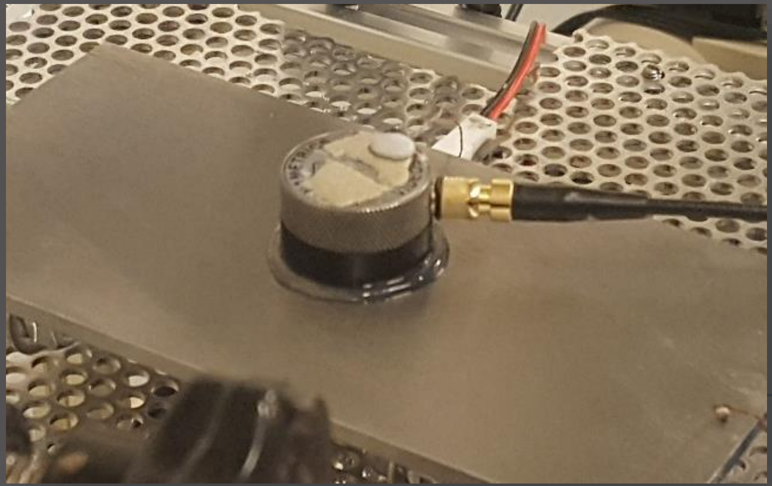
Up-conversion experiment

Vibrations ON

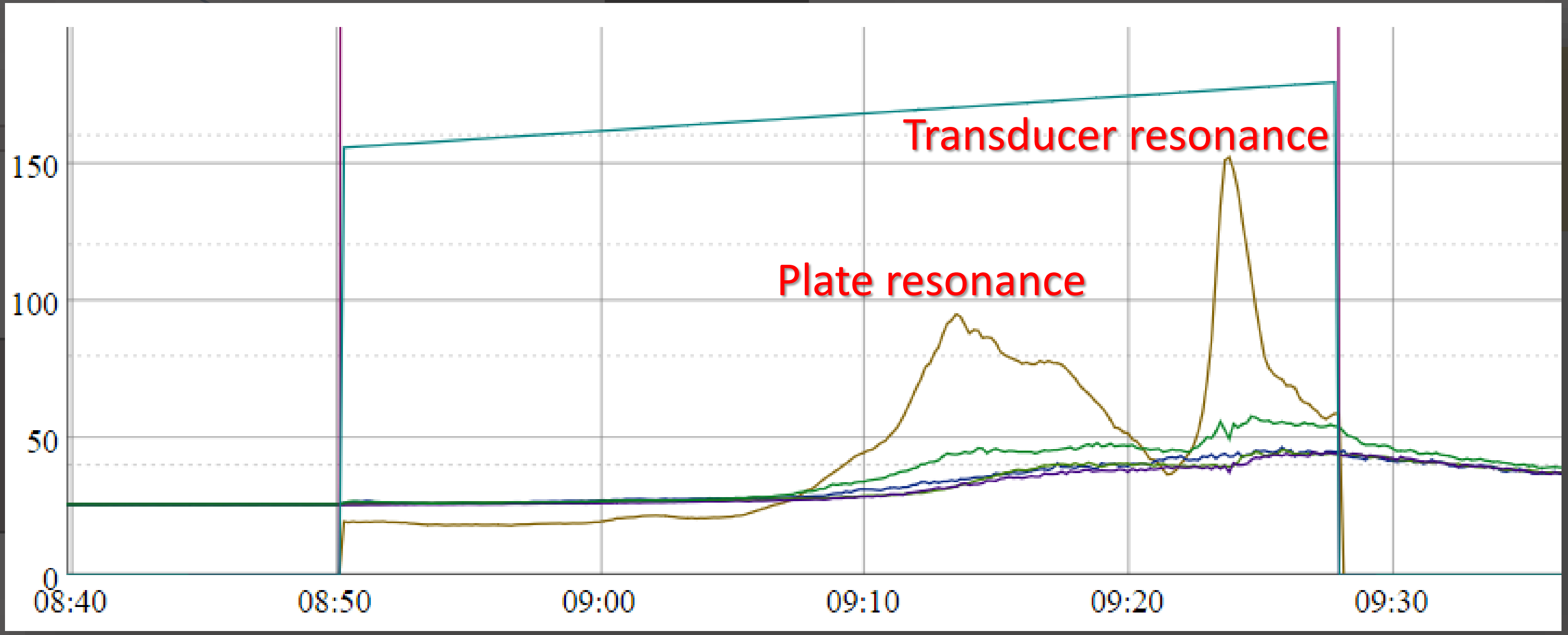


Up-conversion experiment

Dual Directional coupler for obtaining complex power and impedance spectra

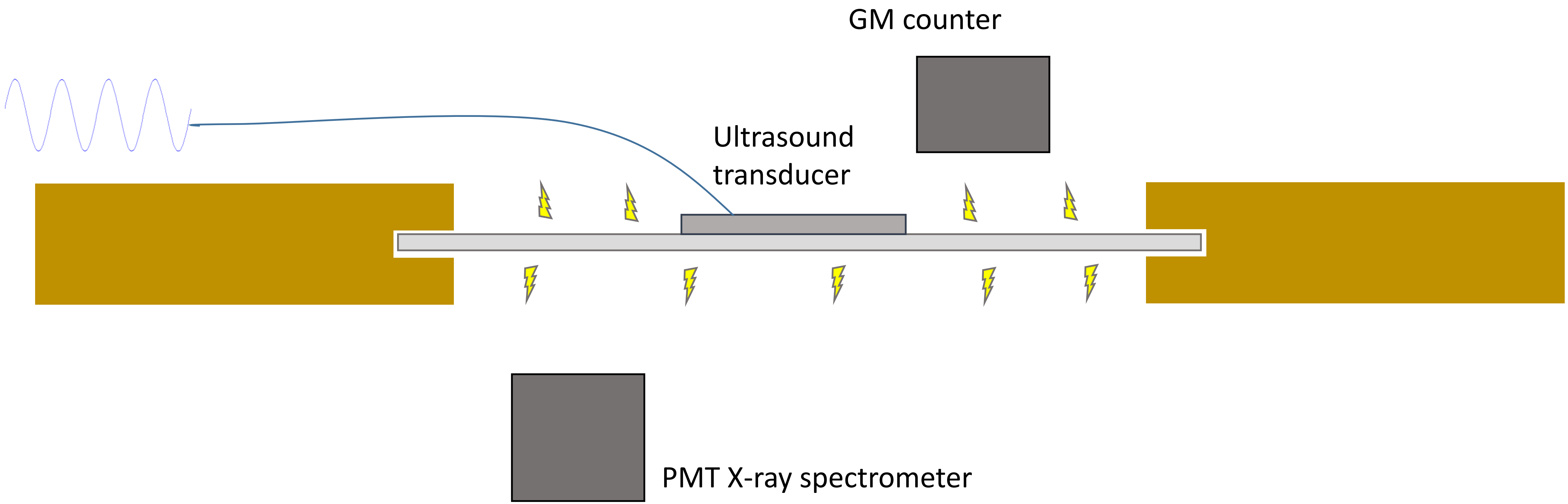


Ultrasound



Up-conversion experiment

Vibrations ON

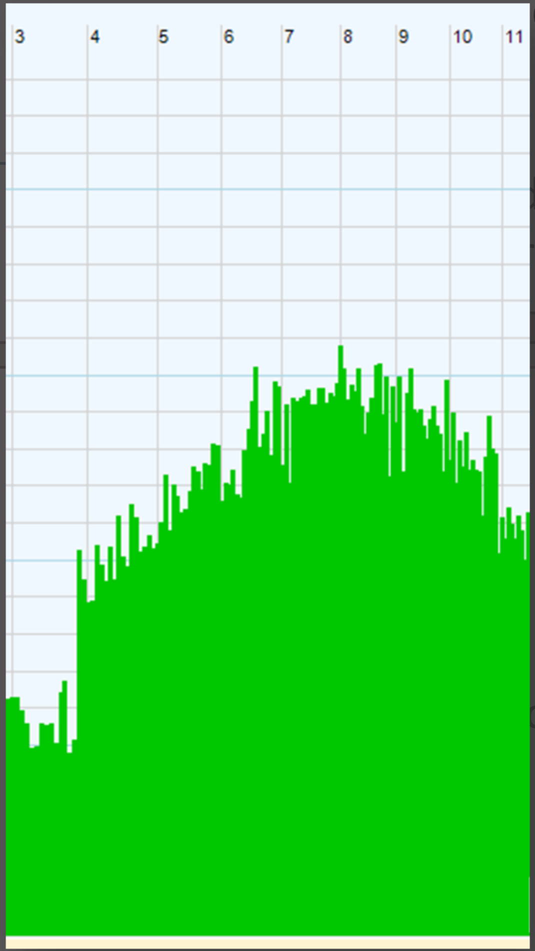


Up-conversion experiment

PMT-based X-ray spectrometer

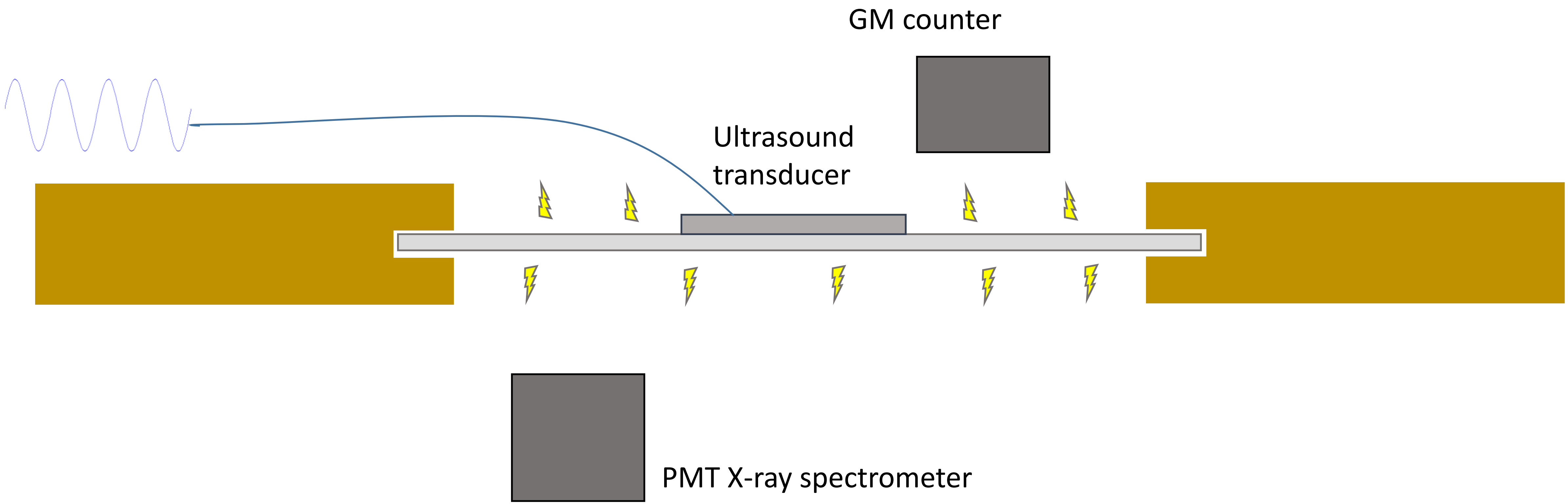
Vibrations ON

GM counter



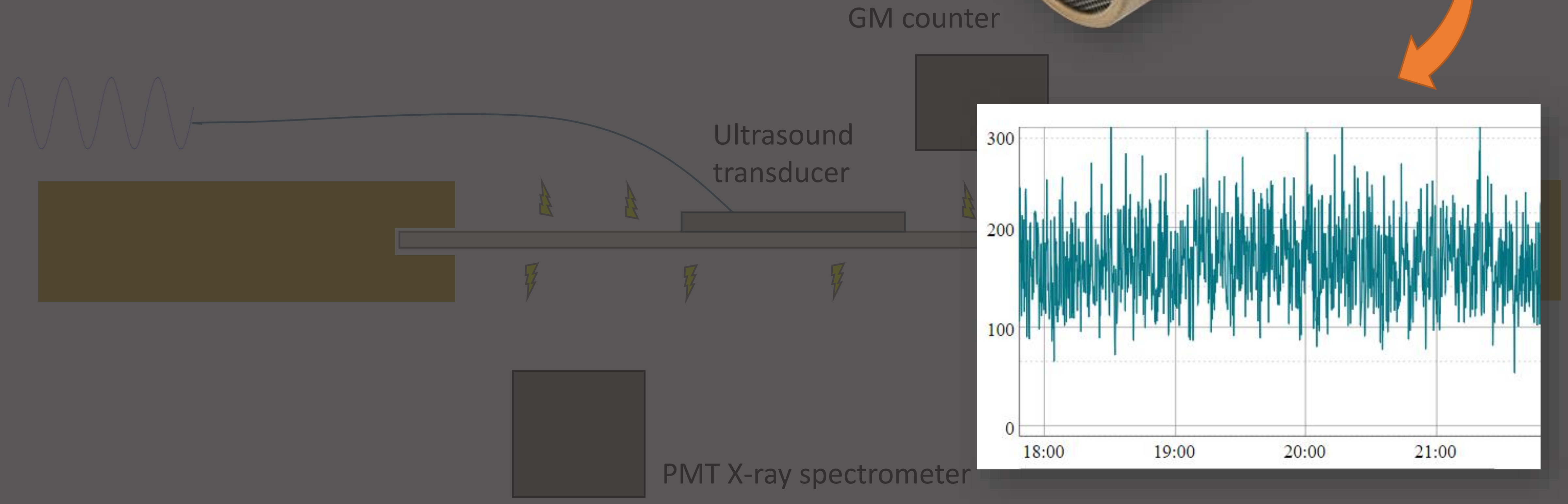
Up-conversion experiment

Vibrations ON

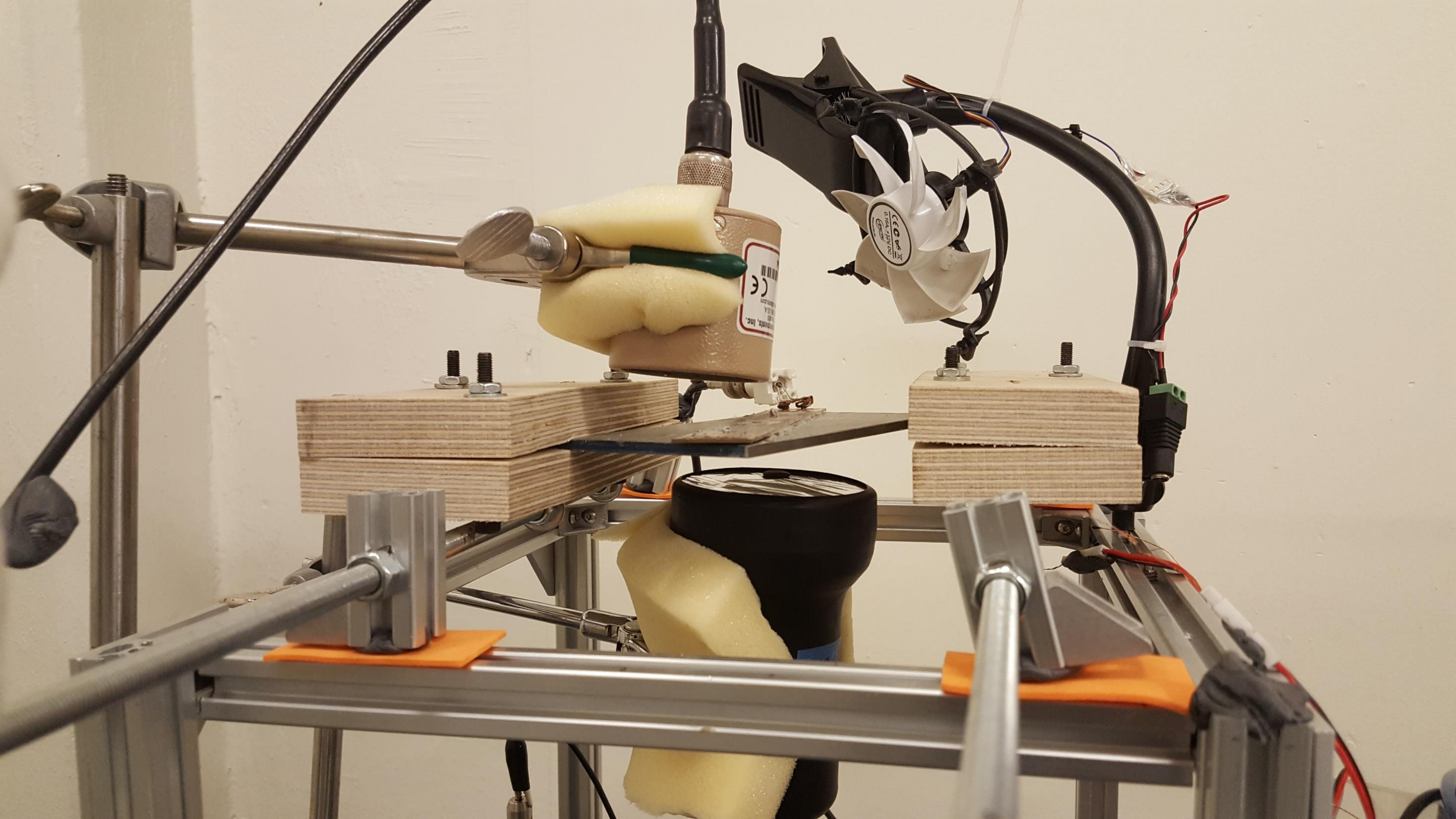


Up-conversion experiment

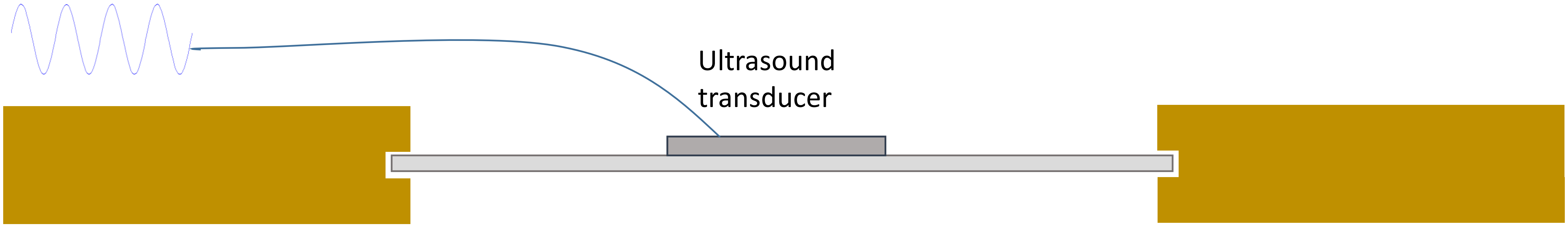
Vibrations ON



Ludlum GM counter

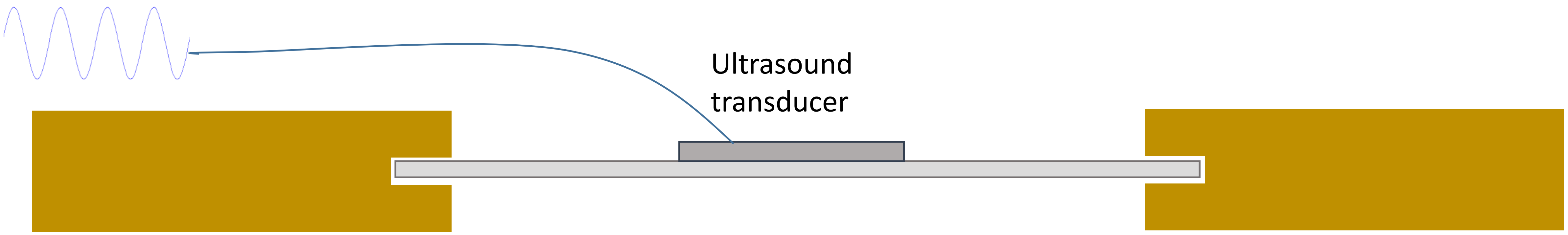


Characterizing effect of damping



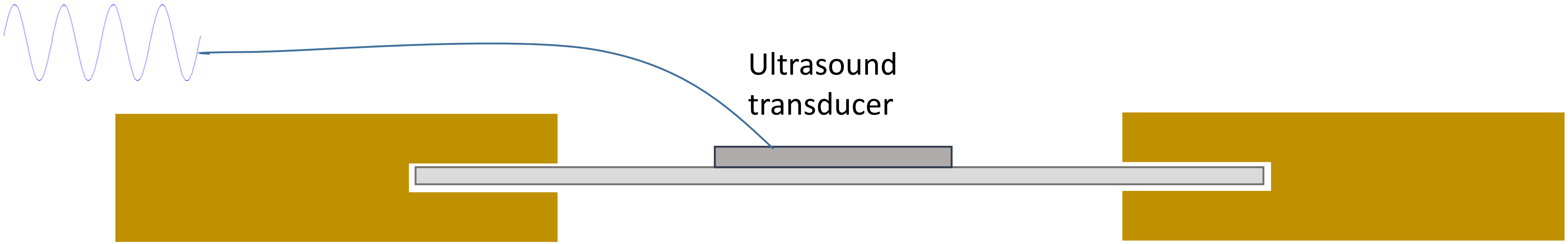
Little damping

Characterizing effect of damping

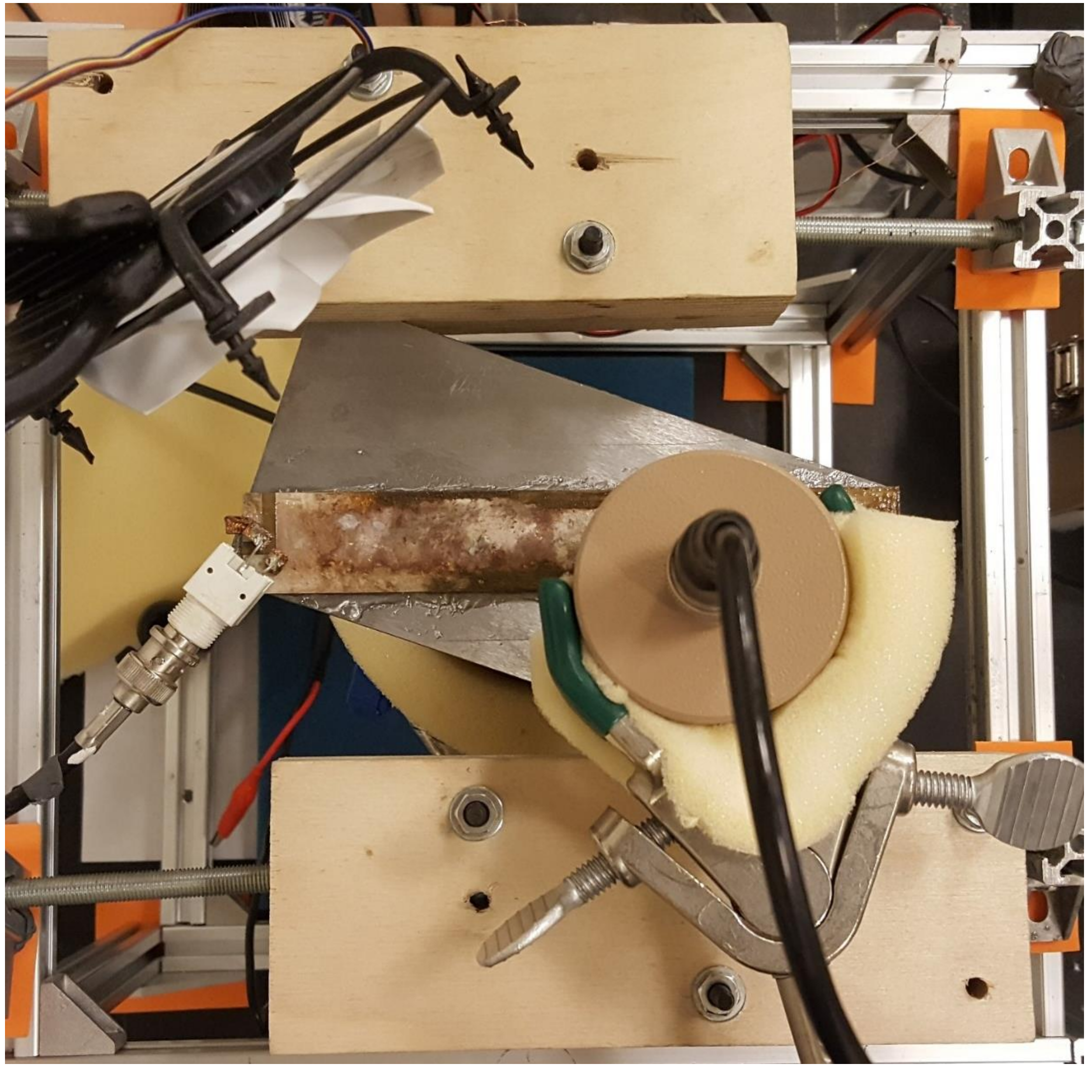


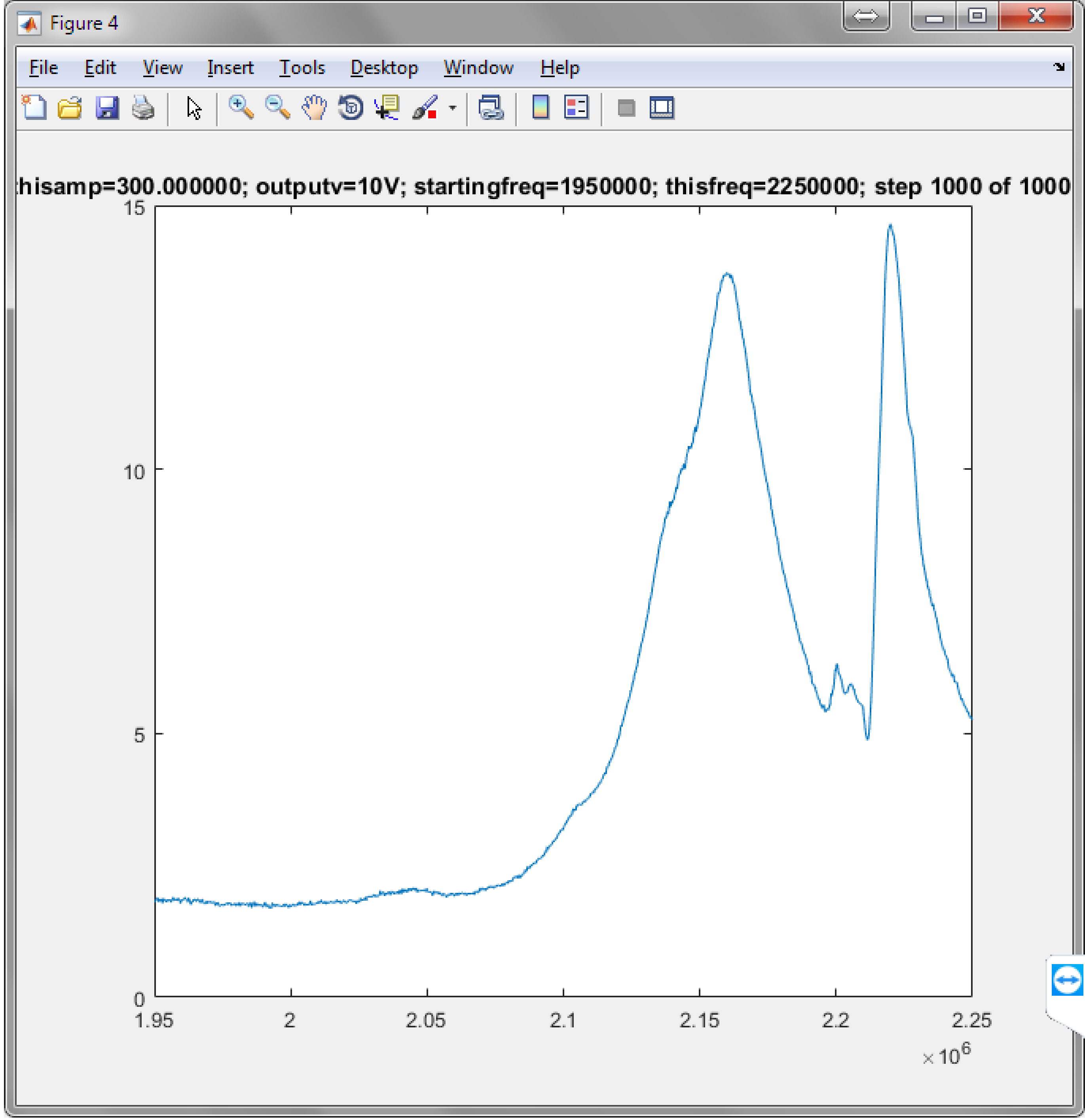
Medium damping

Characterizing effect of damping

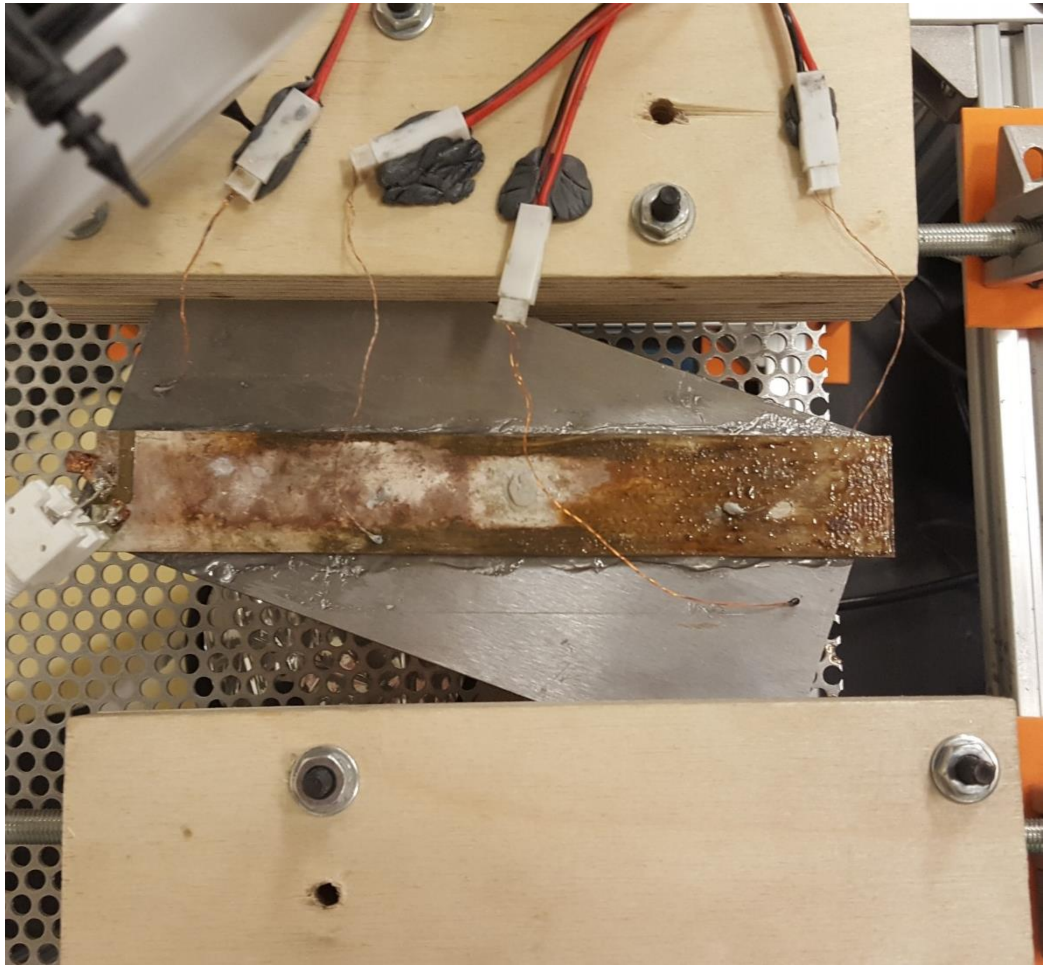


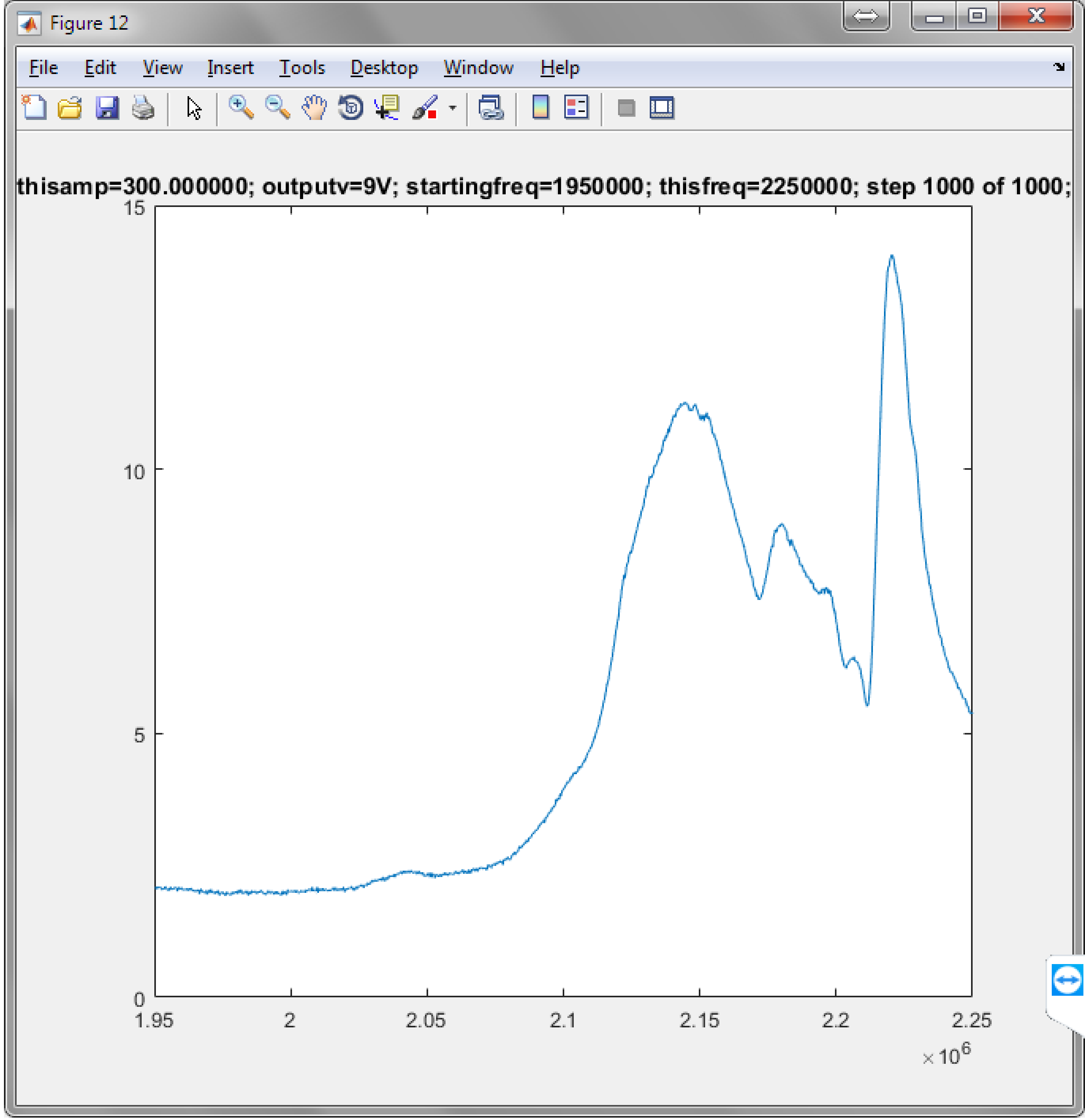
Much damping



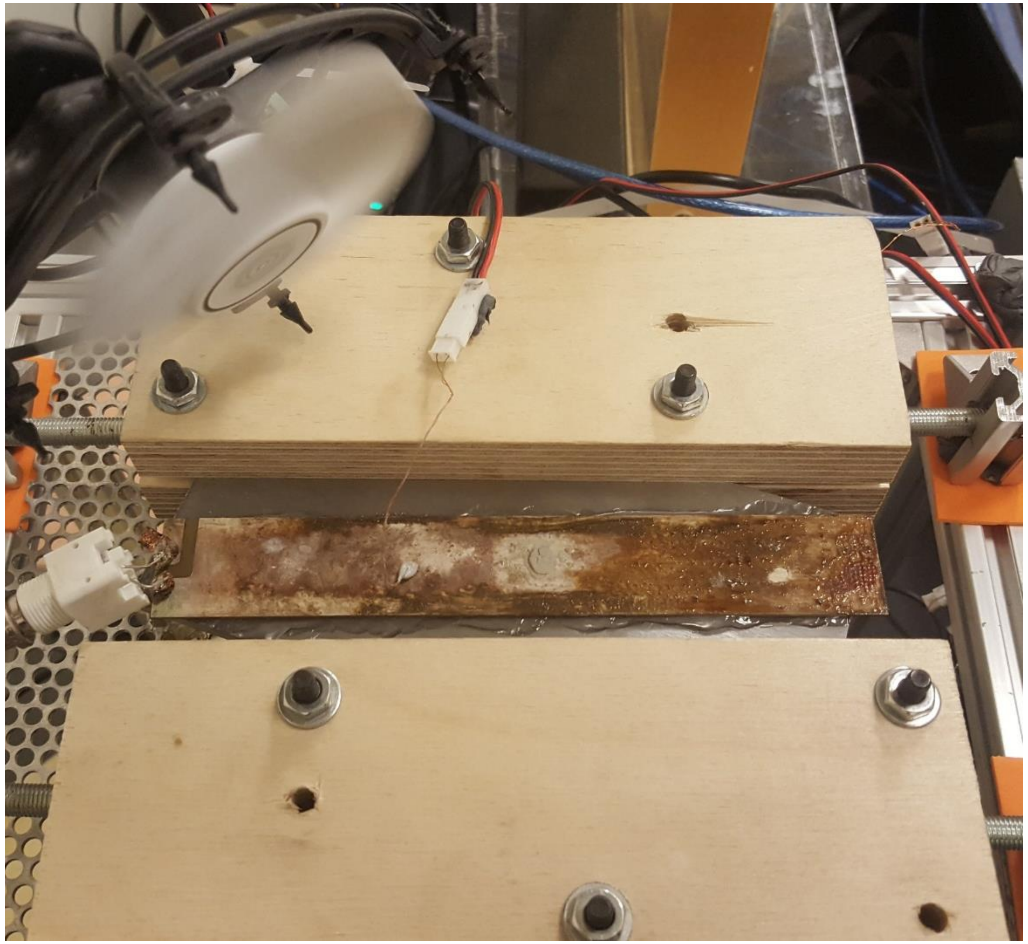


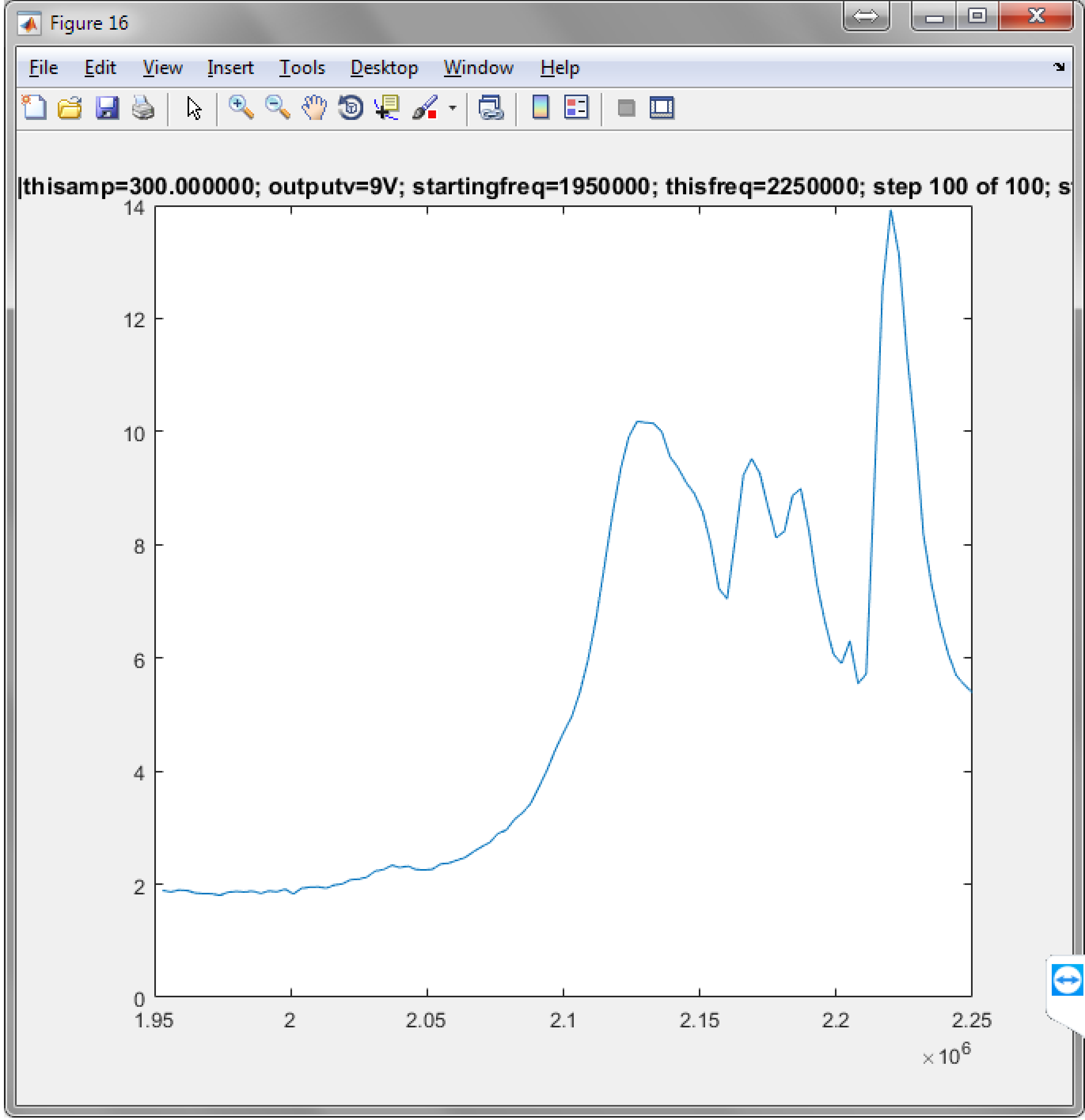
Little damping





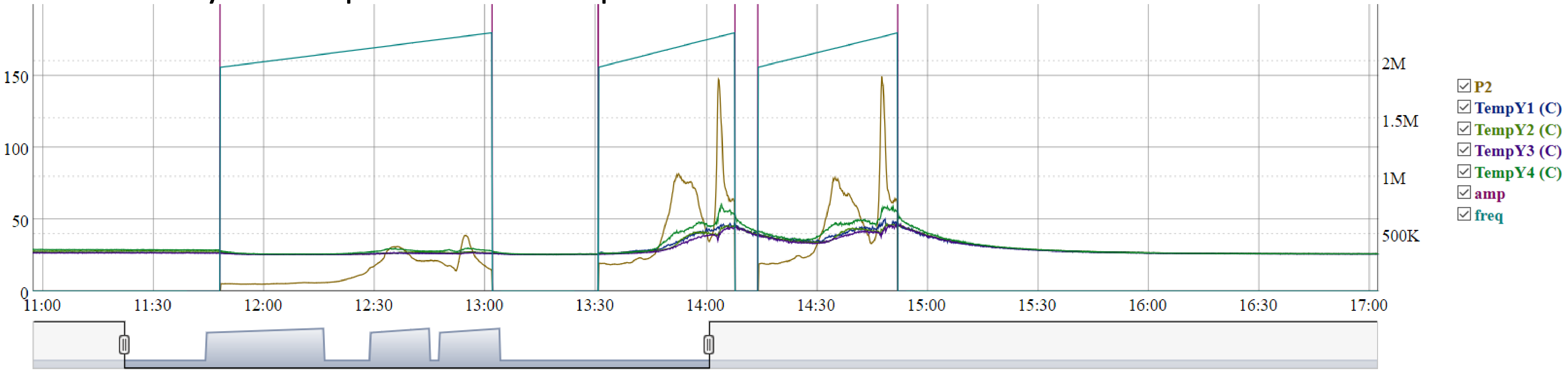
Medium damping

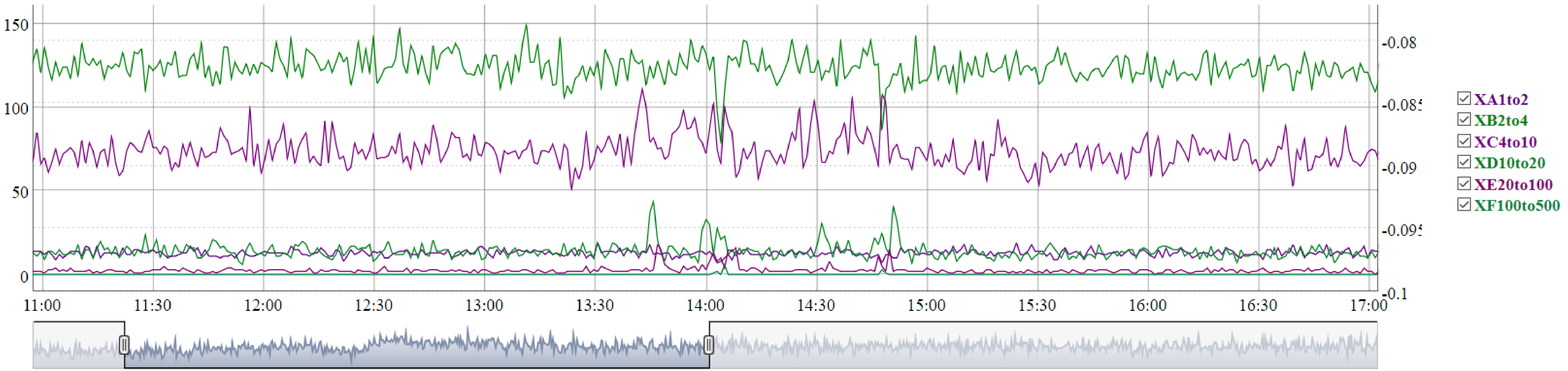




Much damping

Preliminary data: up-conversion experiment

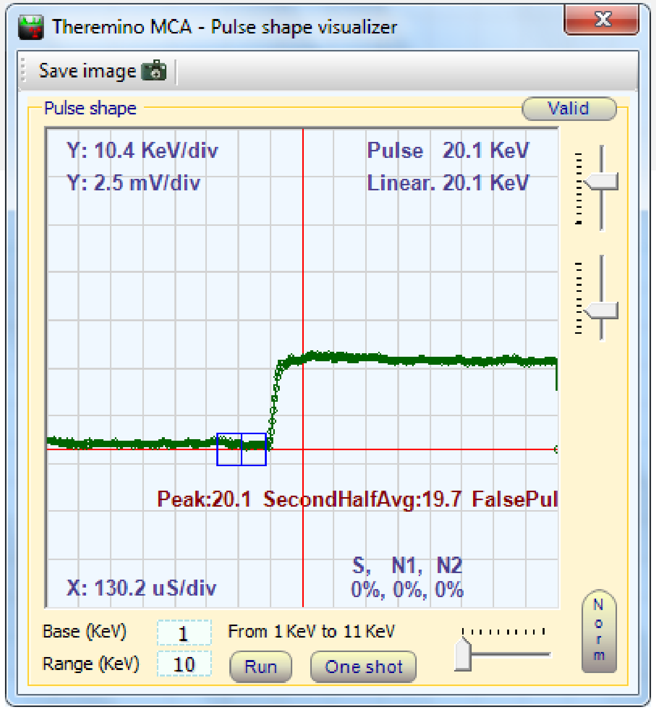




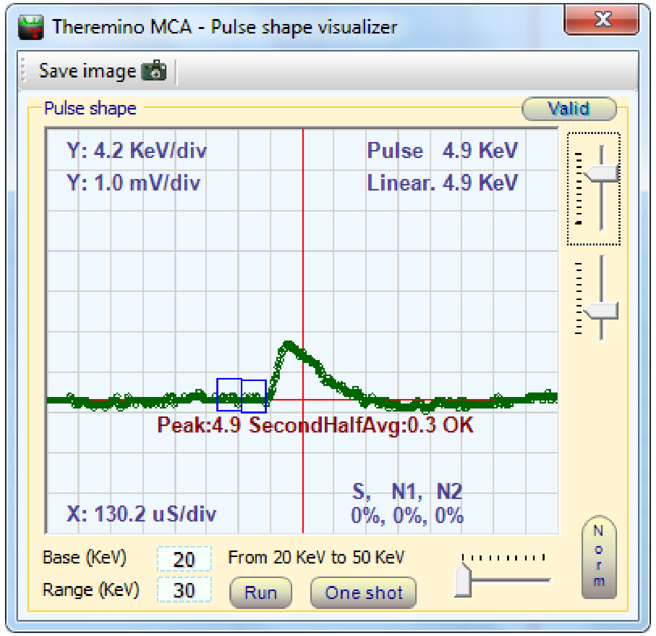
Challenges (1)

- High power ultrasound (>100 W) leads to certain "false pulses" at the PMT X-ray detector (see right)
- Possible responses:
  - Reduce mechanical transmission by damping mounting frames
  - Filter out false pulses in software
  - Operate at lower power <100 W

False pulse

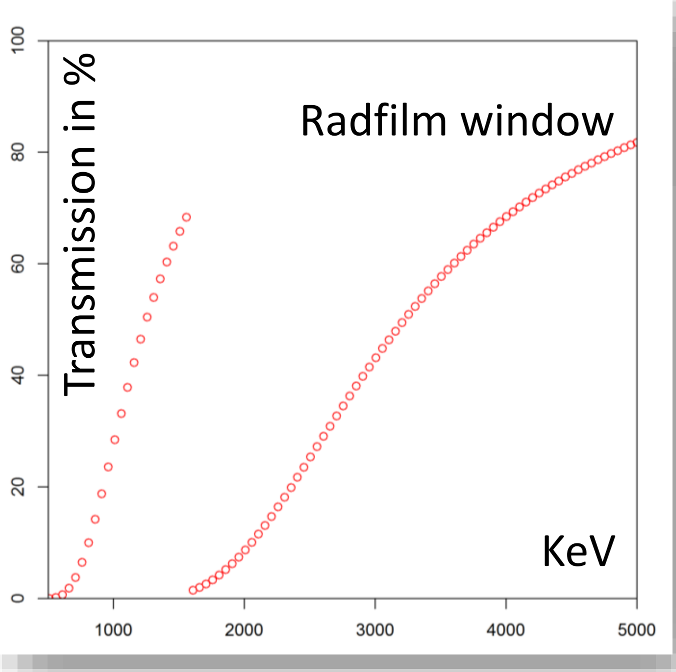


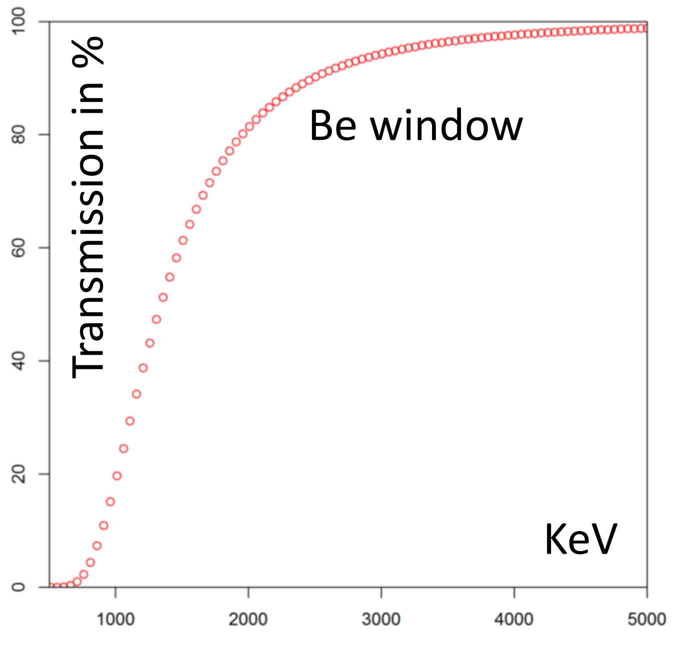
Real pulse



Challenges (2)

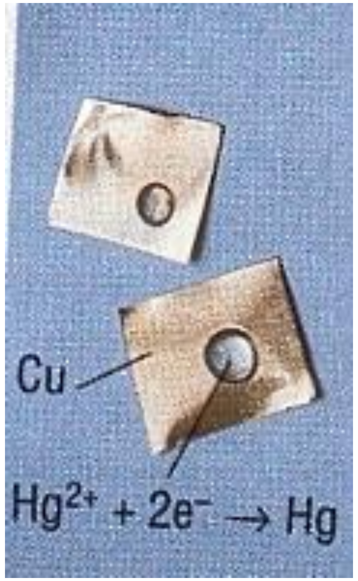
- Radfilm window of PMT X-ray detector has poor transmission around 1.5 KeV, one of the regions of interest.
- Response:
  - Work with a Be window instead that offers better transmission around 1.5 KeV

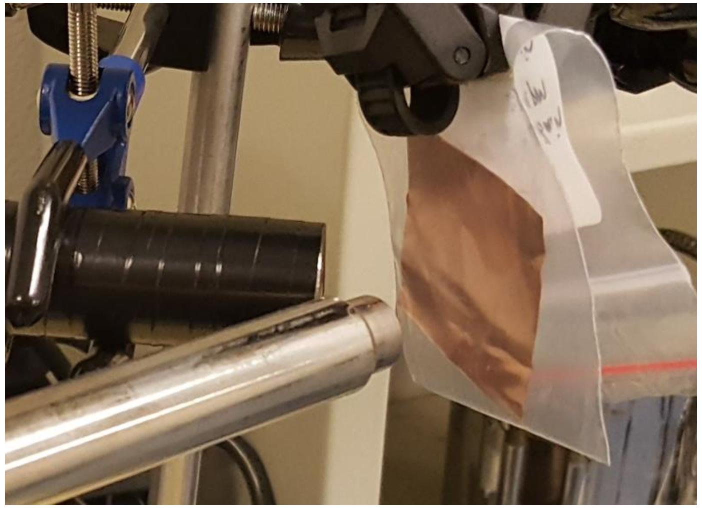




Challenges (3)

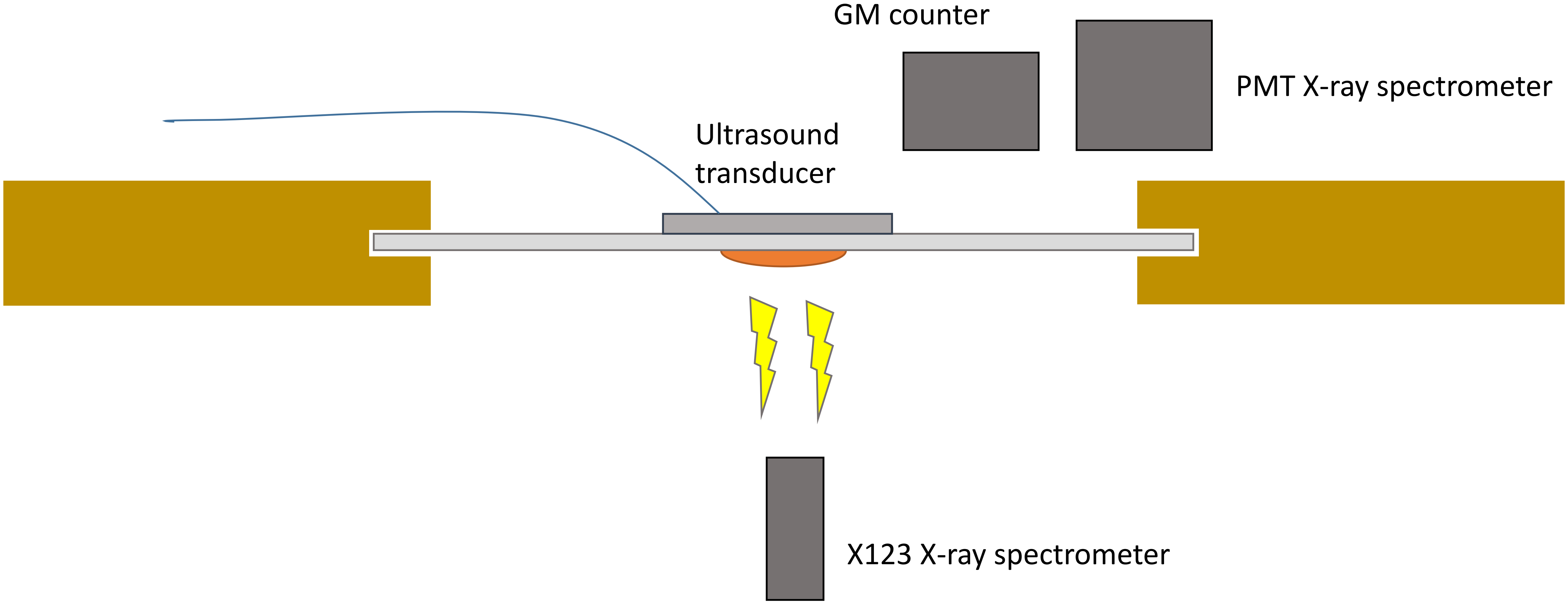
- 1.5 KeV emission due to up-conversion is assumed to be caused by small amounts of Hg contamination on the resonators.
- We do not know whether we have sufficient levels of environmental Hg contamination in our locations/on our samples.
- Response:
  - We learned how to make Hg Amalgams and add Hg to our samples in a safe way.





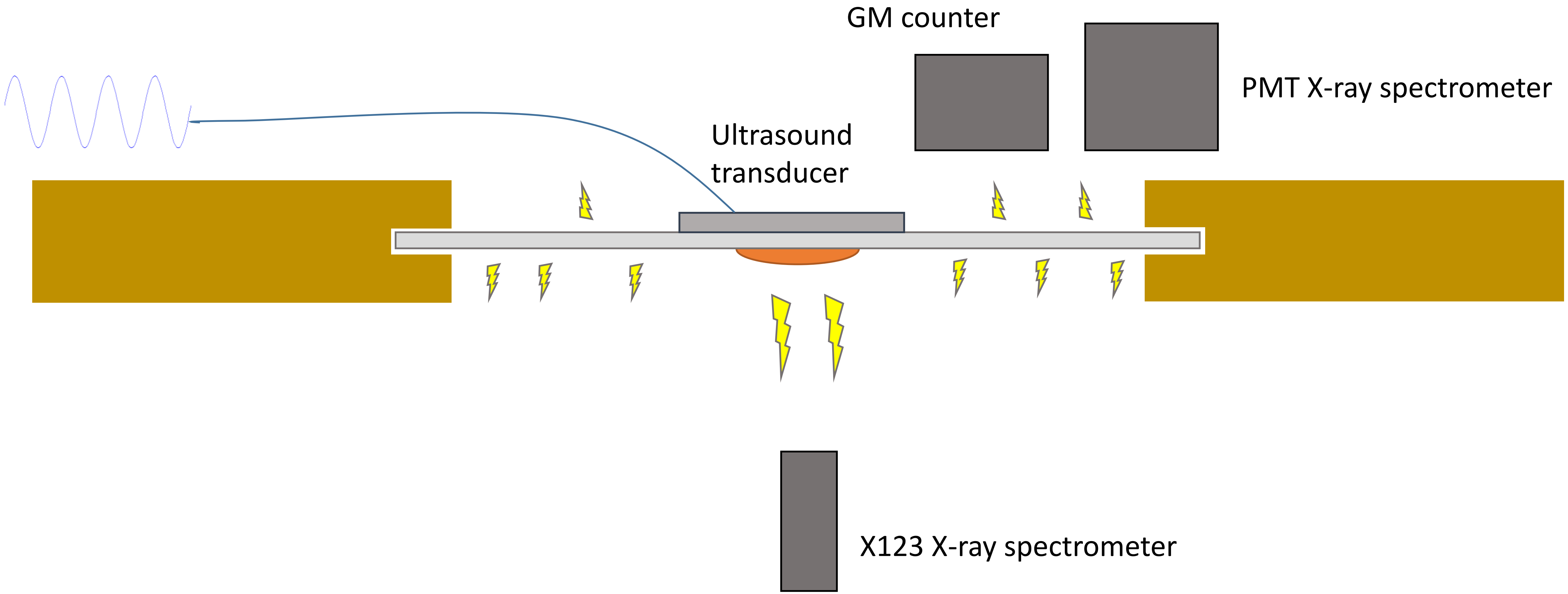
Excitation transfer experiment

Vibrations OFF



Excitation transfer experiment

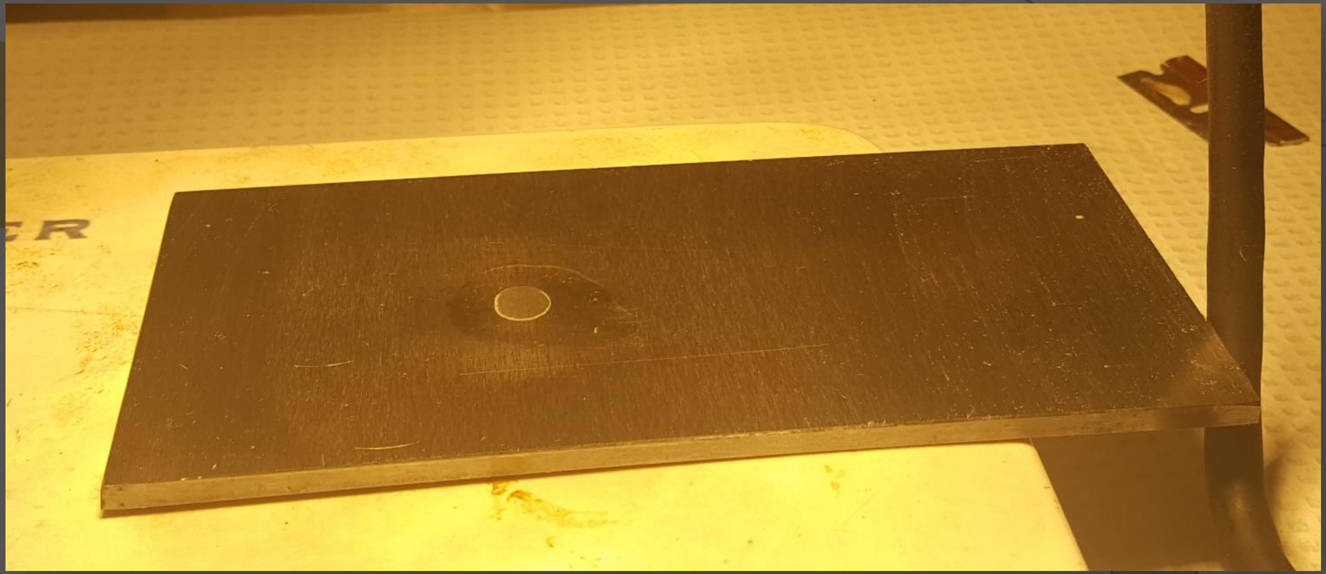
Vibrations ON



Excitation transfer experiment

Vibrations ON

200 uCi of Co-57 on steel plate



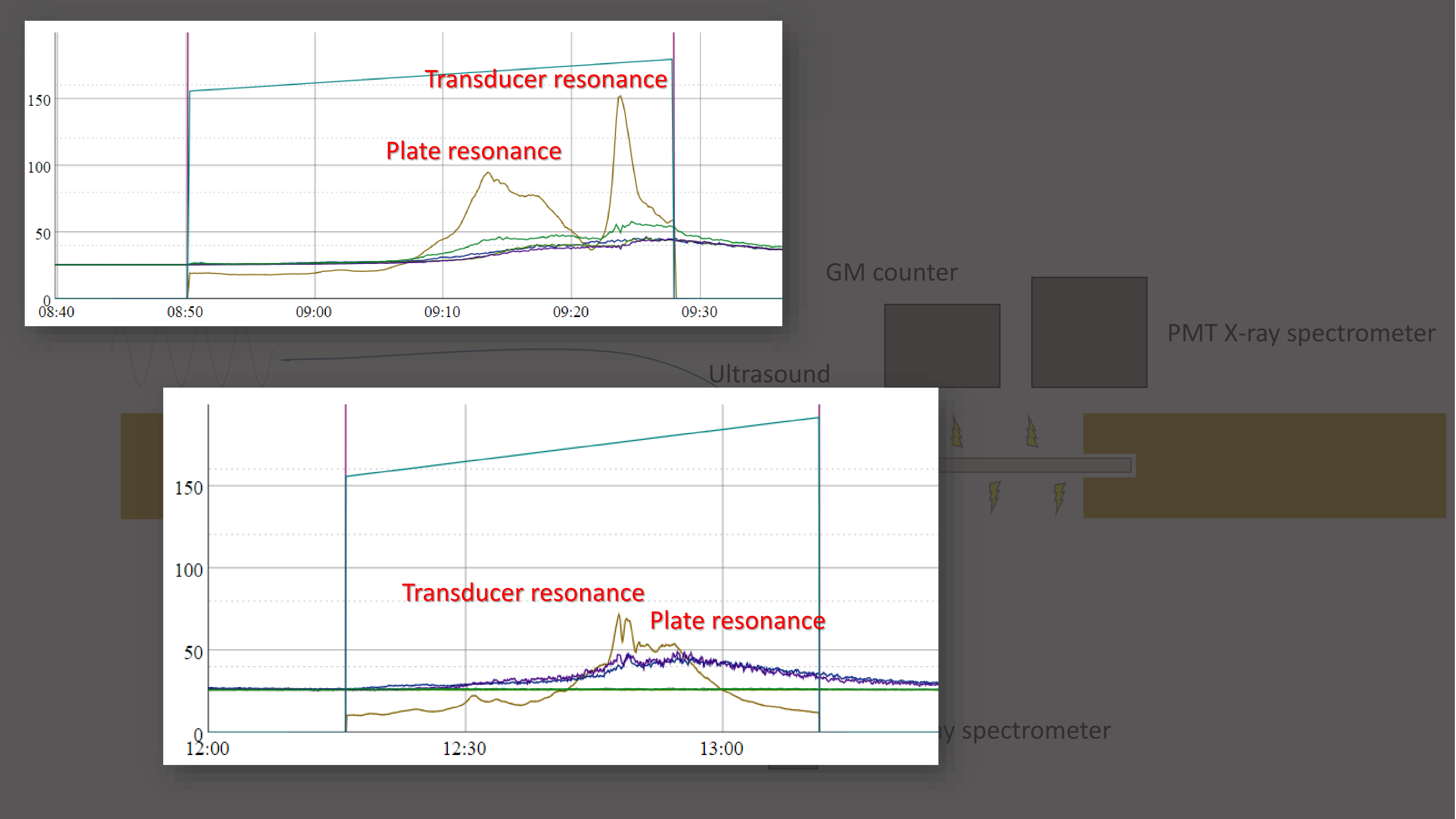
On Polaroid film after 30 min exposure

GM counter

spectrometer

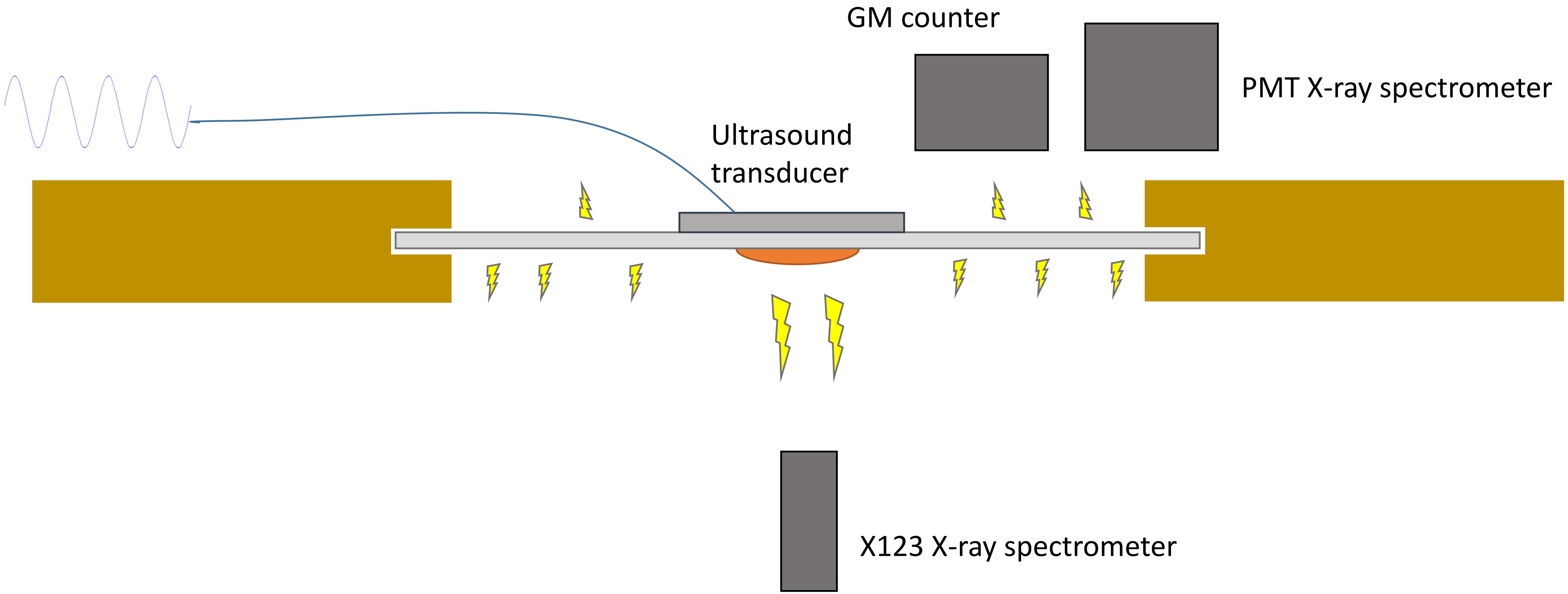
Ultrasound

X123 X-ra


Transducer resonance
Plate resonance
150
100
50
0
08:40
08:50
09:00
09:10
09:20
09:30
GM counter
PMT X-ray spectrometer
Ultrasound
Transducer resonance
Plate resonance
150
100
50
0
12:00
12:30
13:00
y spectrometer

Excitation transfer experiment

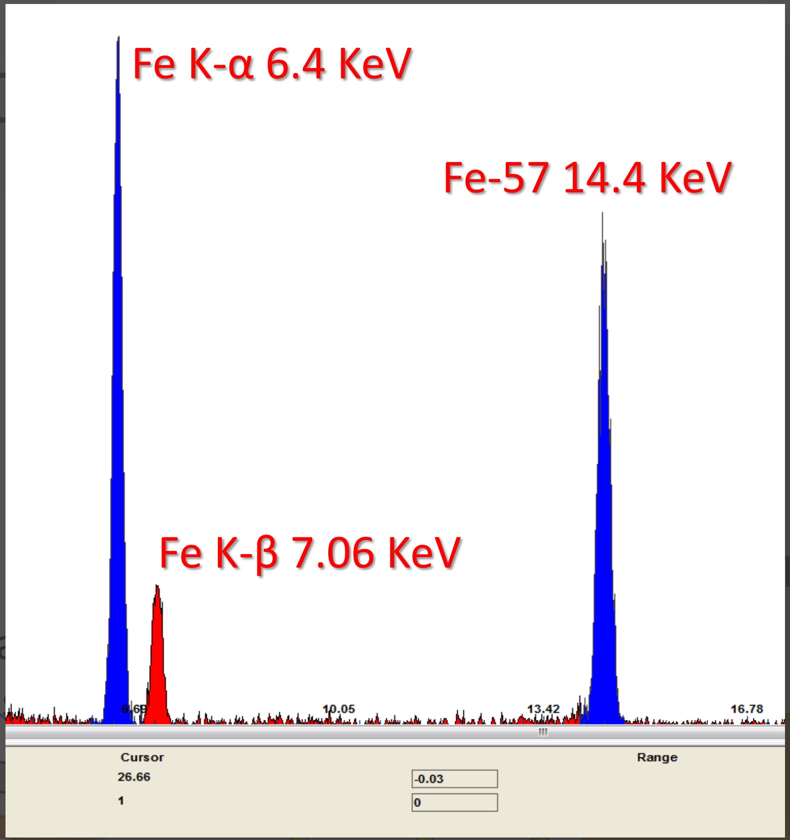
Vibrations ON

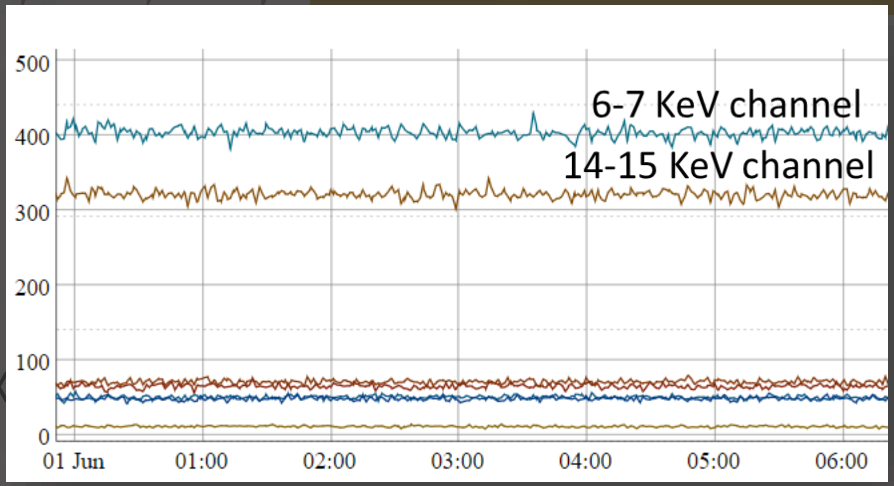


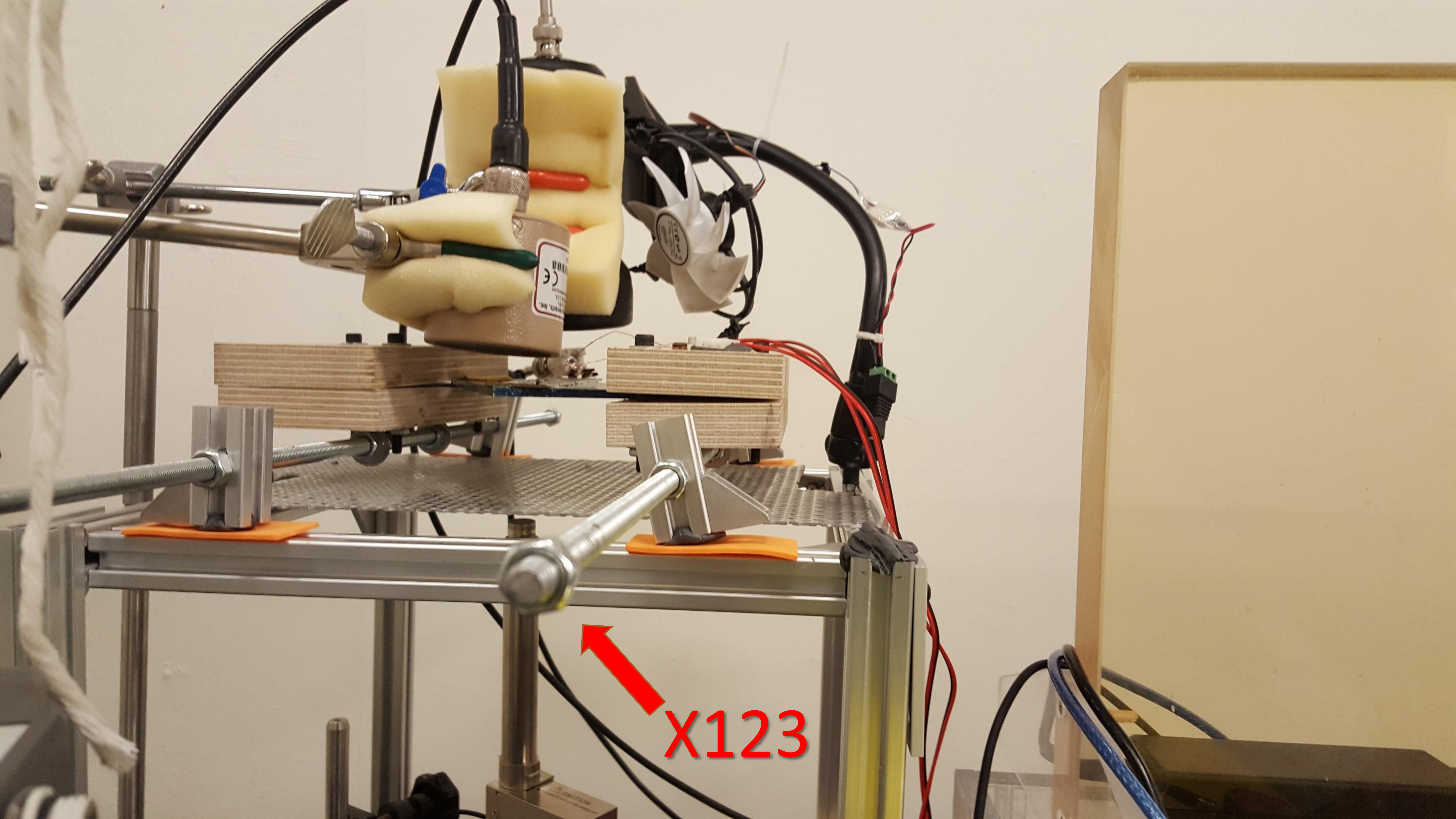
Excitation transfer experiment

X123 with 1-30 KeV range

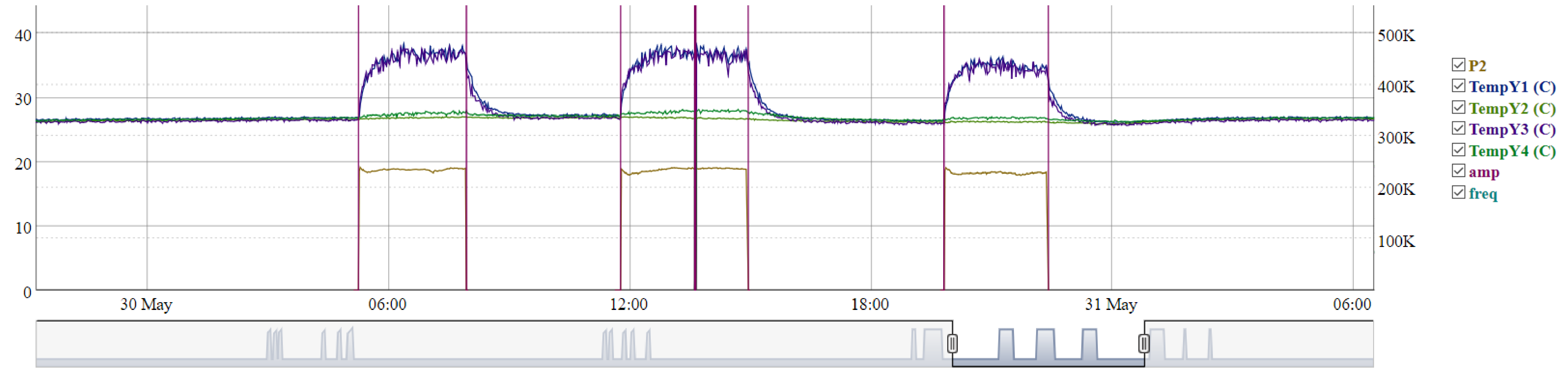
Vibrations ON

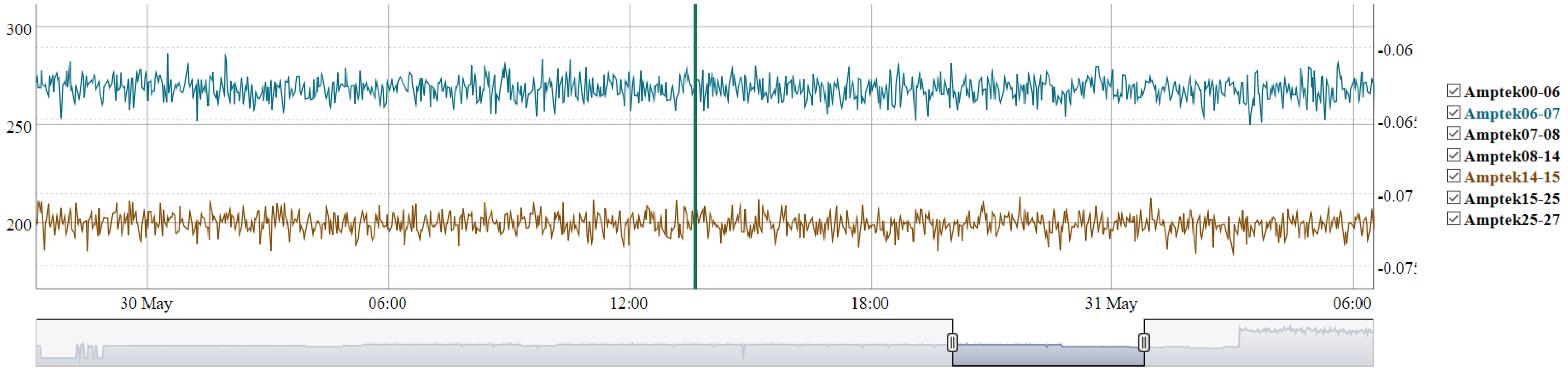




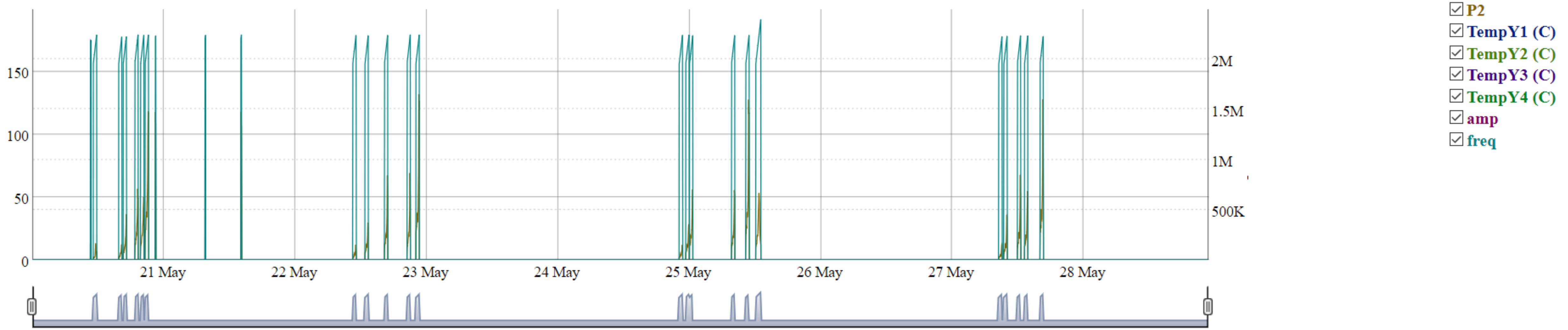

X123

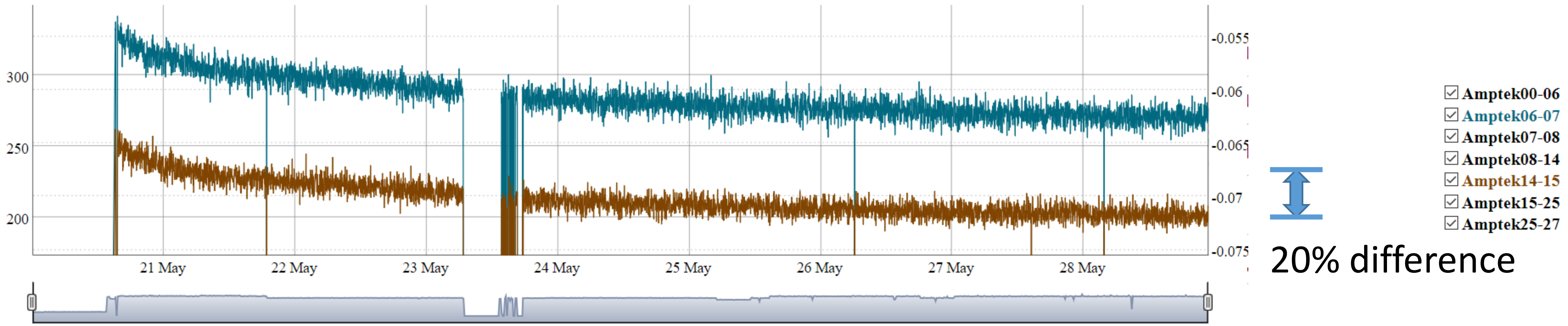
Preliminary data: excitation transfer experiment



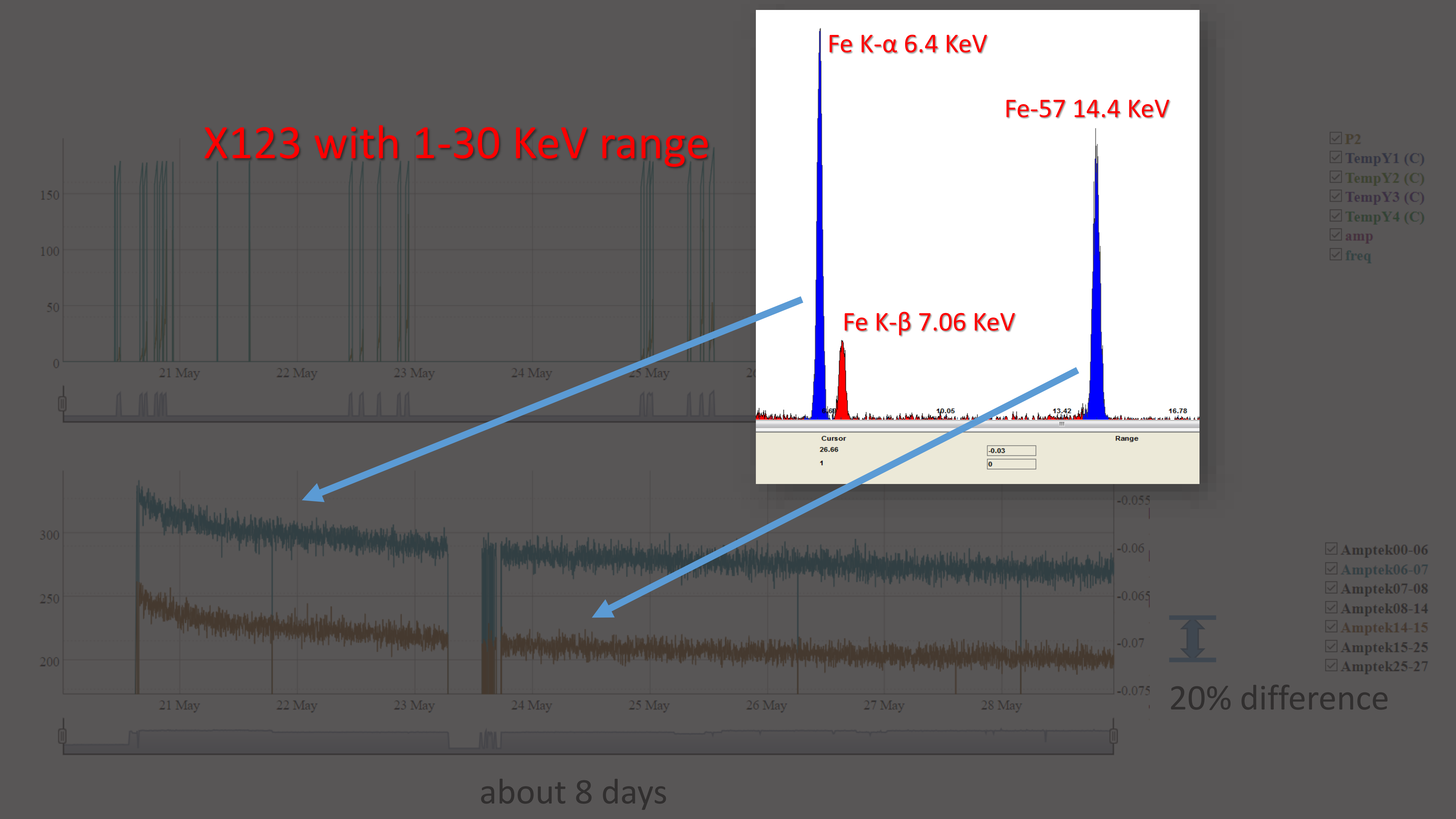


Observation of an anomaly





about 8 days

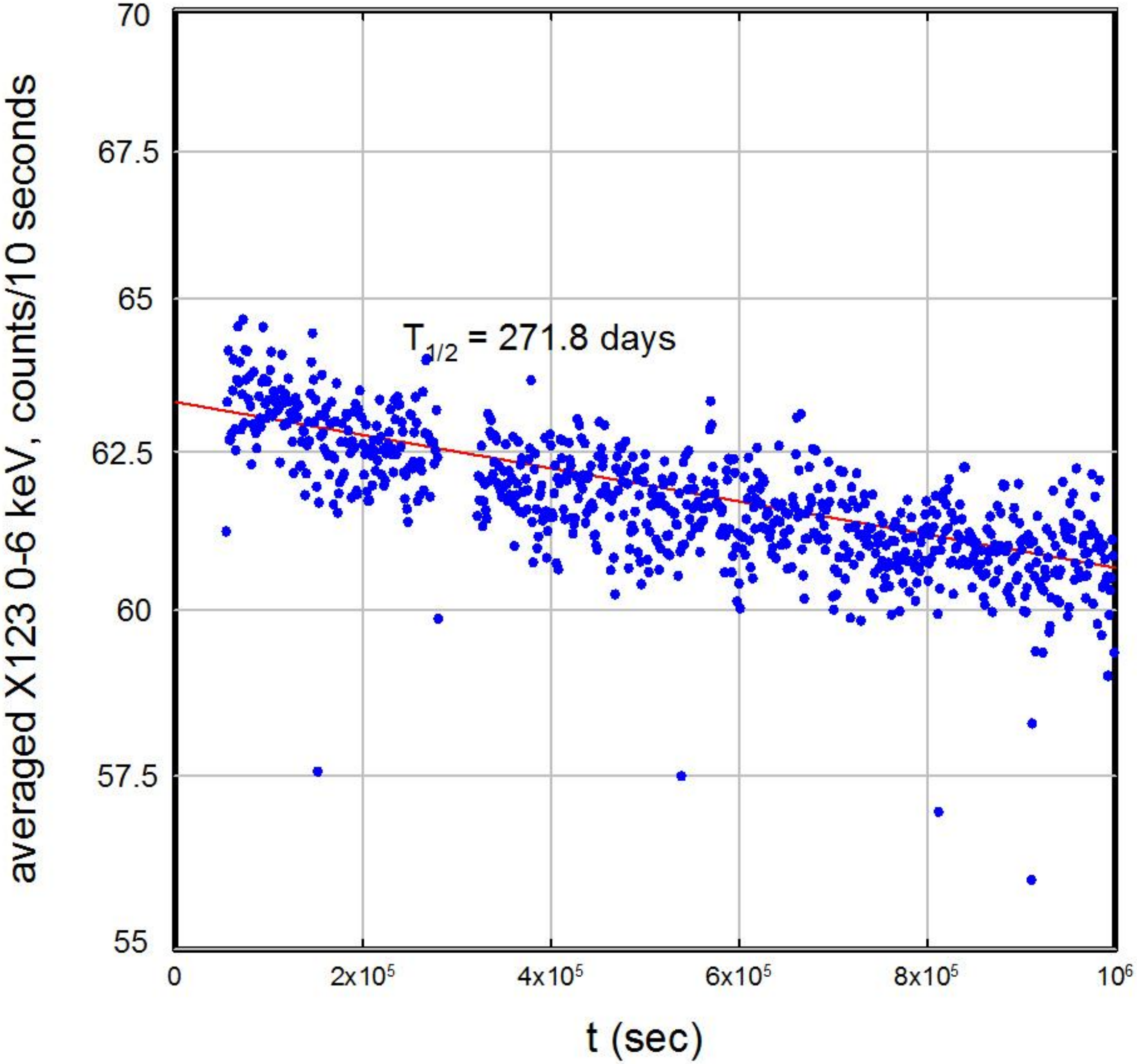


X123 with 1-30 KeV range
Fe K-α 6.4 KeV
Fe-57 14.4 KeV
Fe K-β 7.06 KeV
10.05
13.42
16.78
Cursor
26.66
1
Range
-0.03
0
150
100
50
0
21 May
22 May
23 May
24 May
25 May
P2
TempY1 (C)
TempY2 (C)
TempY3 (C)
TempY4 (C)
amp
freq
300
250
200
26 May
27 May
28 May
-0.055
-0.06
-0.065
-0.07
-0.075
Amptek00-06
Amptek06-07
Amptek07-08
Amptek08-14
Amptek14-15
Amptek15-25
Amptek25-27
20% difference
about 8 days

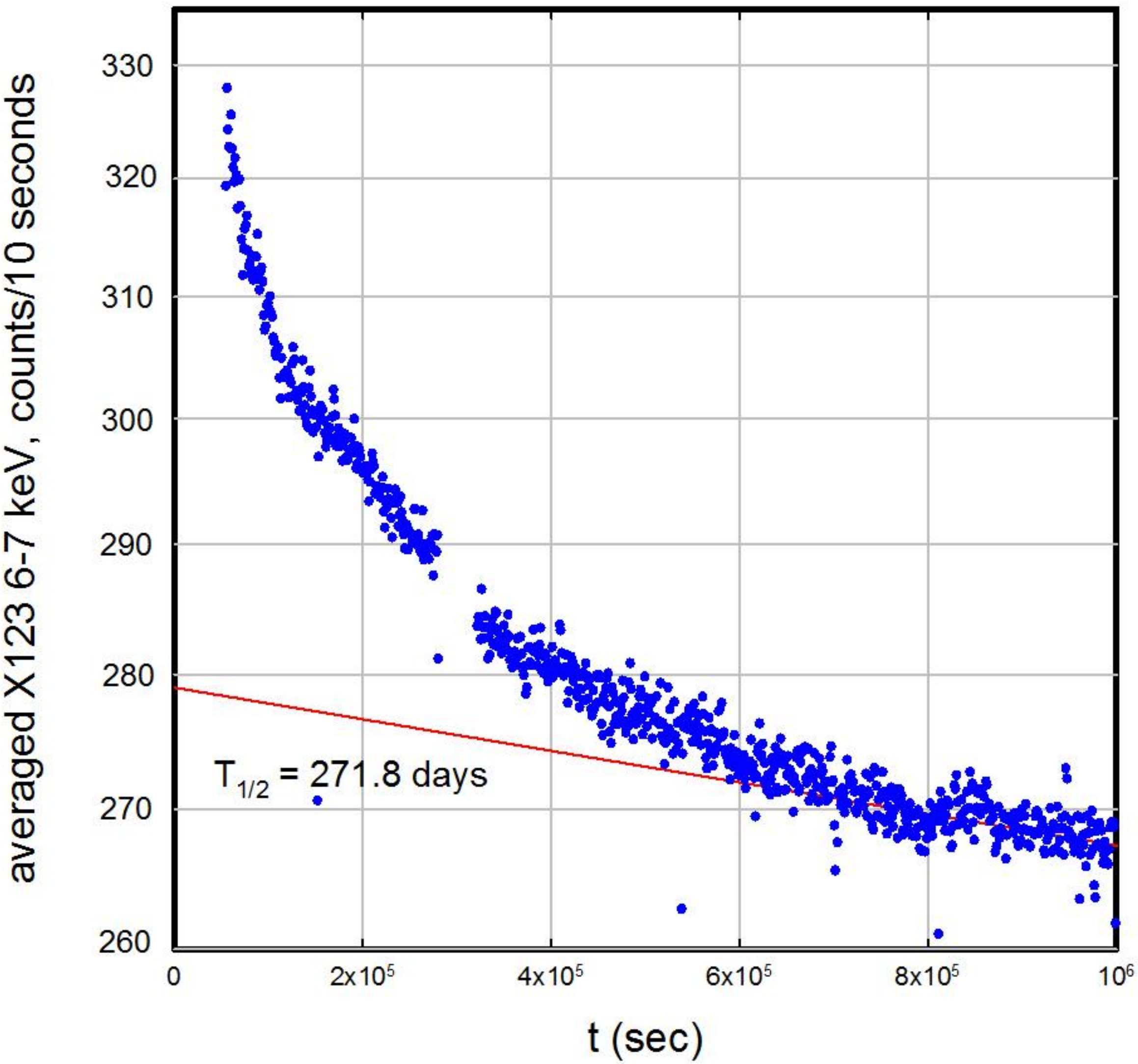
Current status

- Carried out initial excitation transfer experiments.
  - Several frequency scans to characterize plate resonance.
  - One run with low power on-off sequence.
- Based on the preliminary data, we have not observed the predicted excitation transfer effect.
- Did observe an anomalous decline of Co-57 X-ray peaks that is not understood to date.

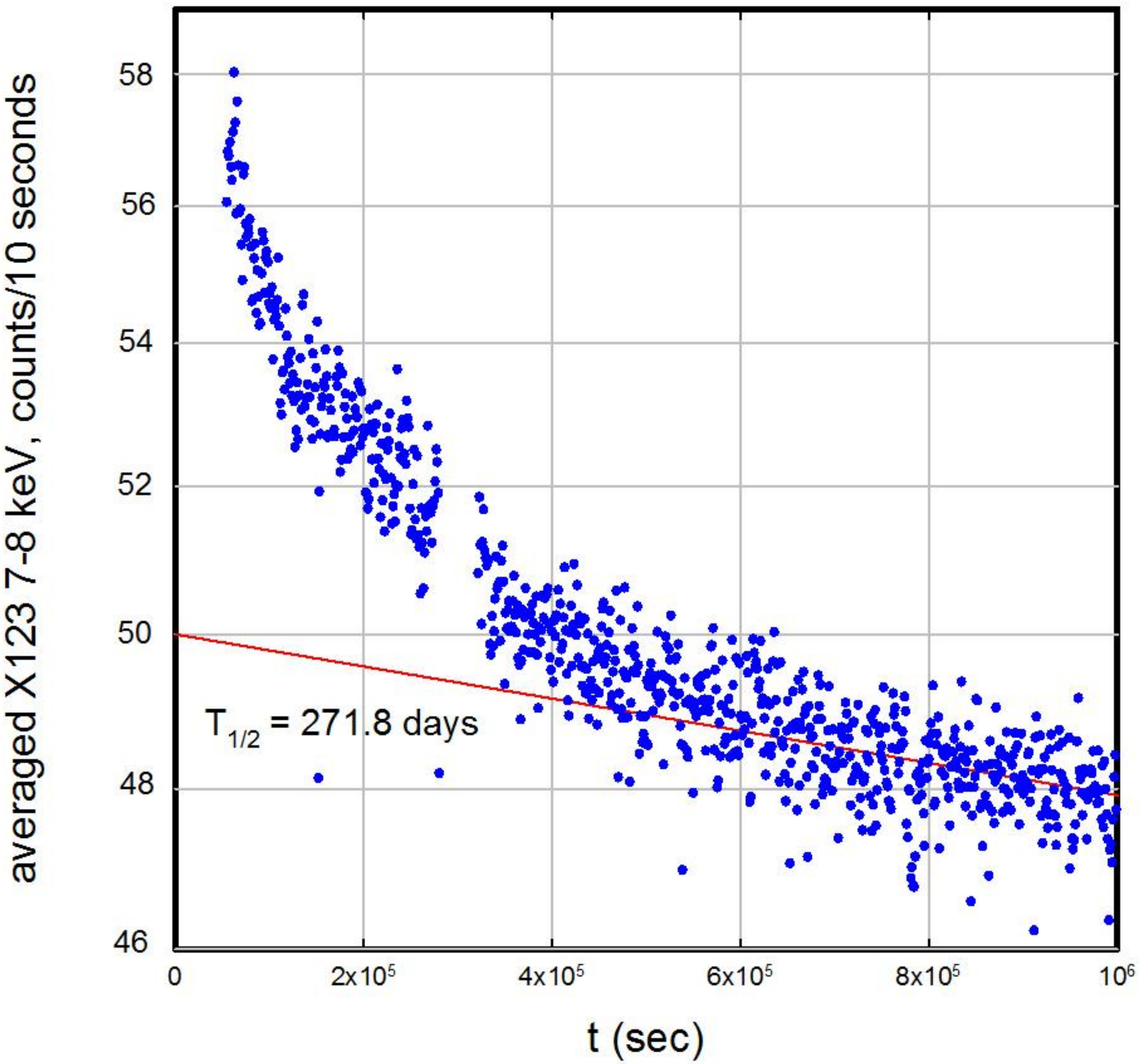
X-123 data, log-lin plots



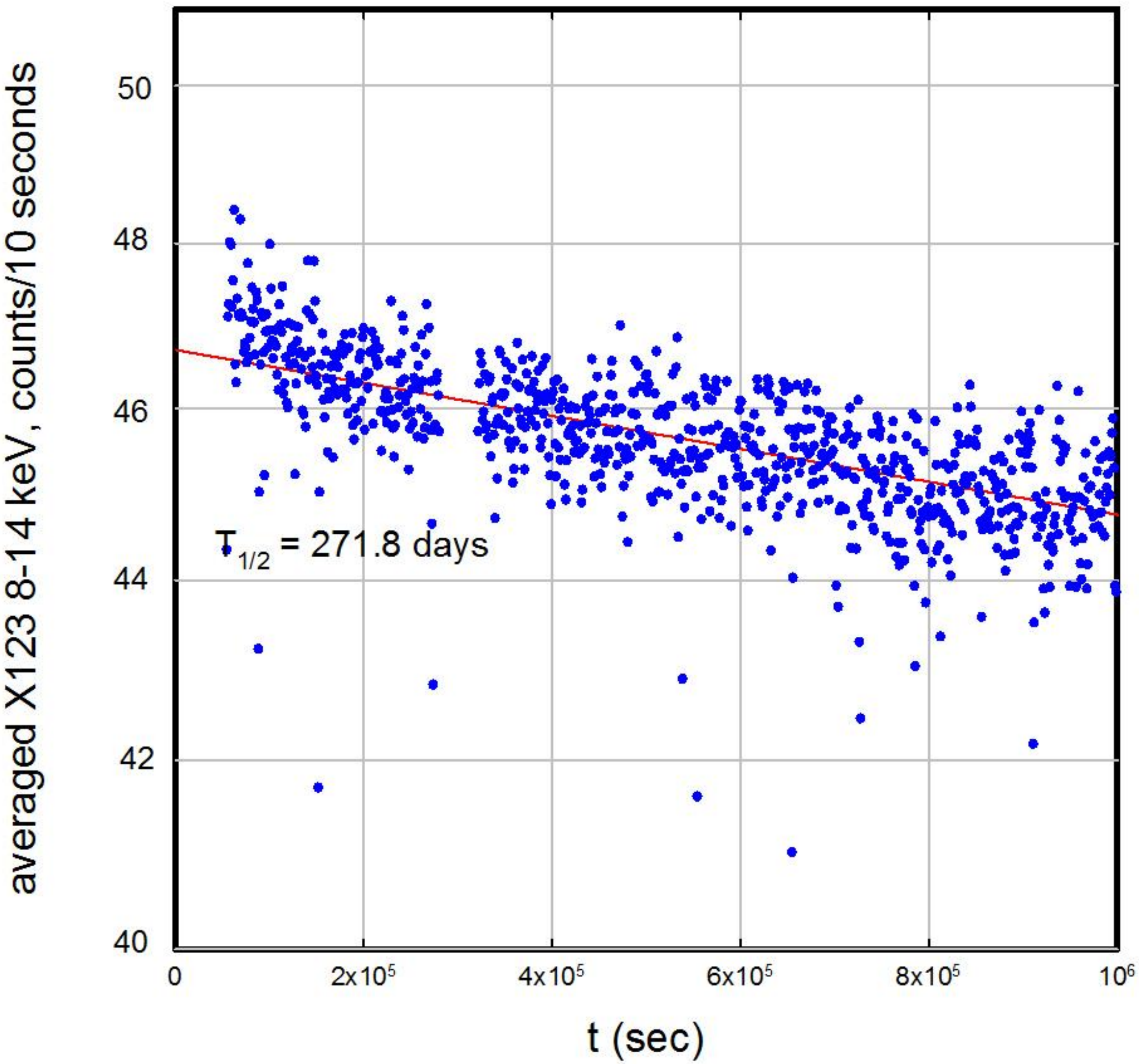
70
67.5
65
62.5
60
57.5
55
averaged X123 0-6 keV, counts/10 seconds
$T_{1/2}$ = 271.8 days
0
2x10^5
4x10^5
6x10^5
8x10^5
10^6
t (sec)



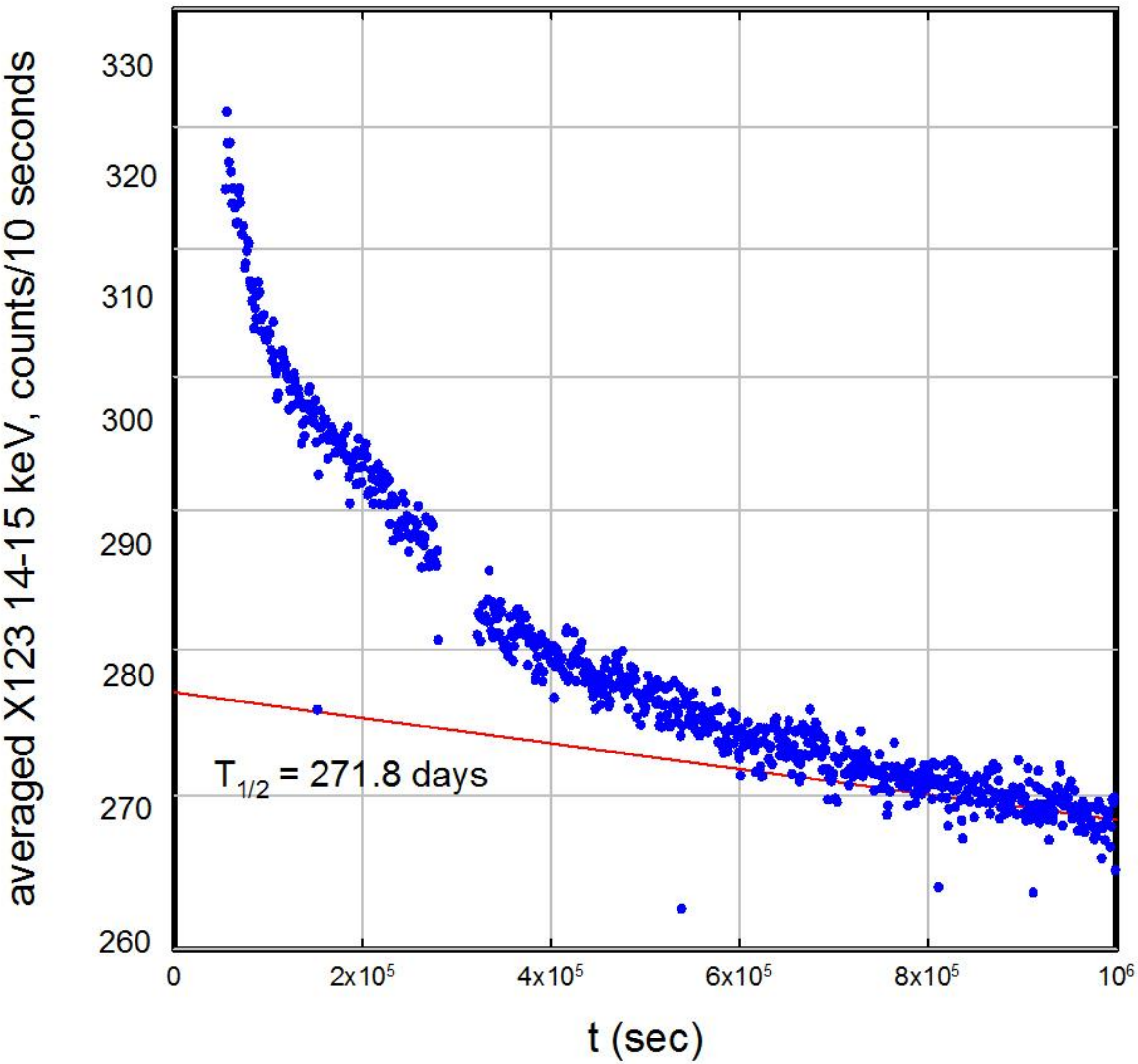
averaged X123 6-7 keV, counts/10 seconds
330
320
310
300
290
280
270
260
0
2x10^5
4x10^5
6x10^5
8x10^5
10^6
t (sec)
T1/2 = 271.8 days



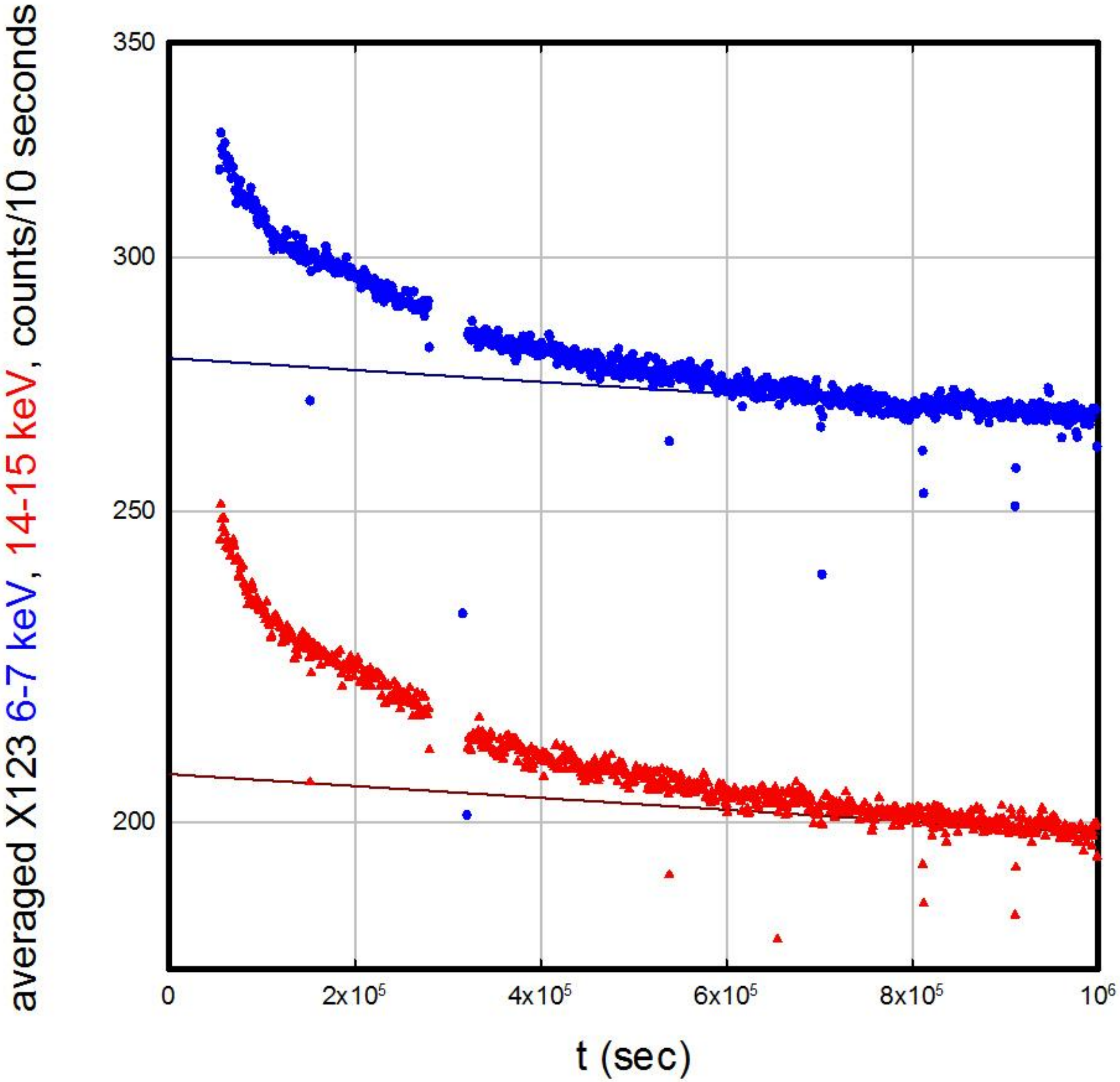
averaged X123 7-8 keV, counts/10 seconds
58
56
54
52
50
48
46
0
2x10^5
4x10^5
6x10^5
8x10^5
10^6
t (sec)
T1/2 = 271.8 days



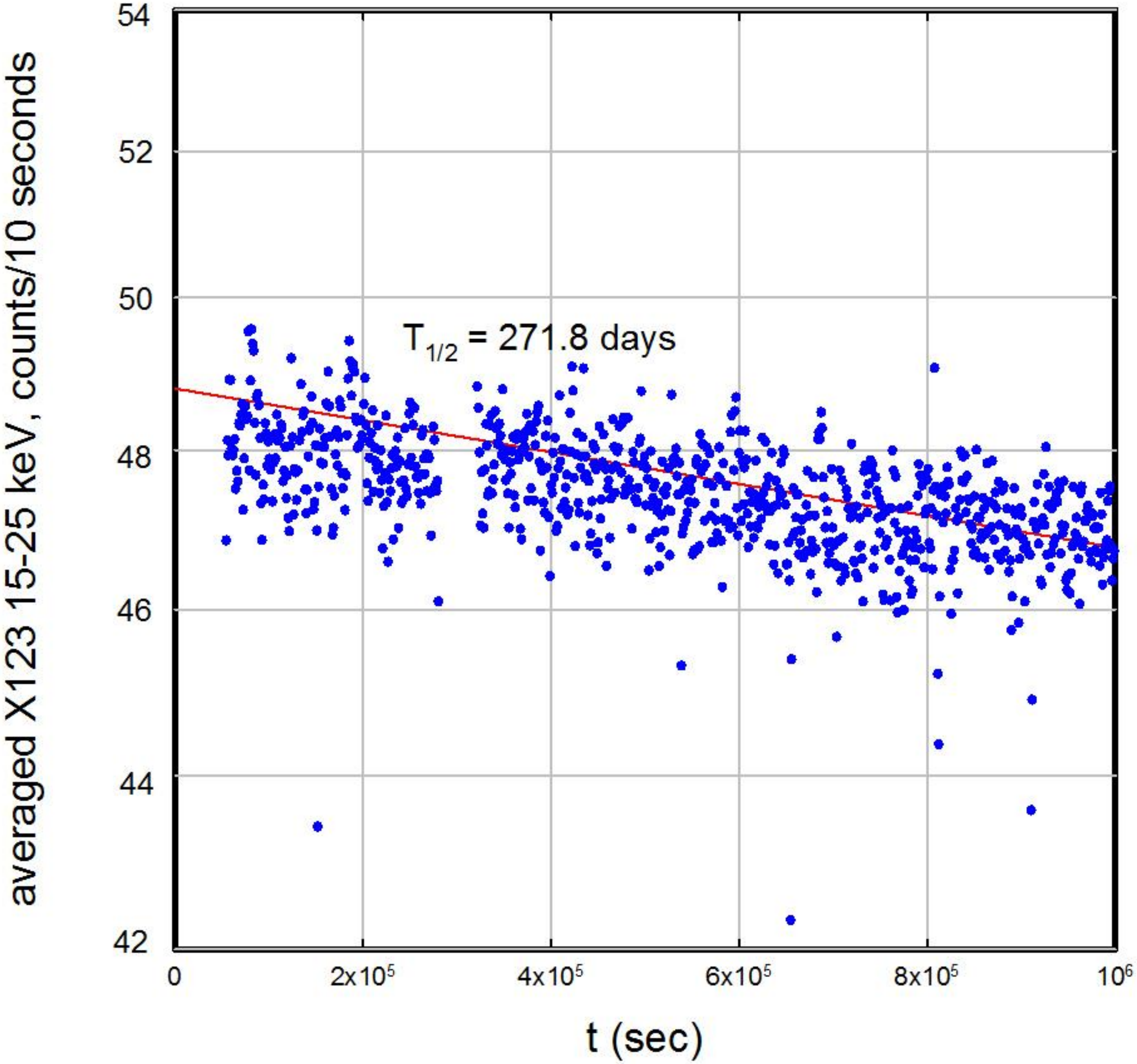
averaged X123 8-14 keV, counts/10 seconds
50
48
46
44
42
40
0
2x10^5
4x10^5
6x10^5
8x10^5
10^6
t (sec)
T1/2 = 271.8 days



averaged X123 14-15 keV, counts/10 seconds
330
320
310
300
290
280
270
260
$T_{1/2}$ = 271.8 days
0
2x10^5
4x10^5
6x10^5
8x10^5
10^6
t (sec)



averaged X123 6-7 keV, 14-15 keV, counts/10 seconds
350
300
250
200
0
2x10^5
4x10^5
6x10^5
8x10^5
10^6
t (sec)

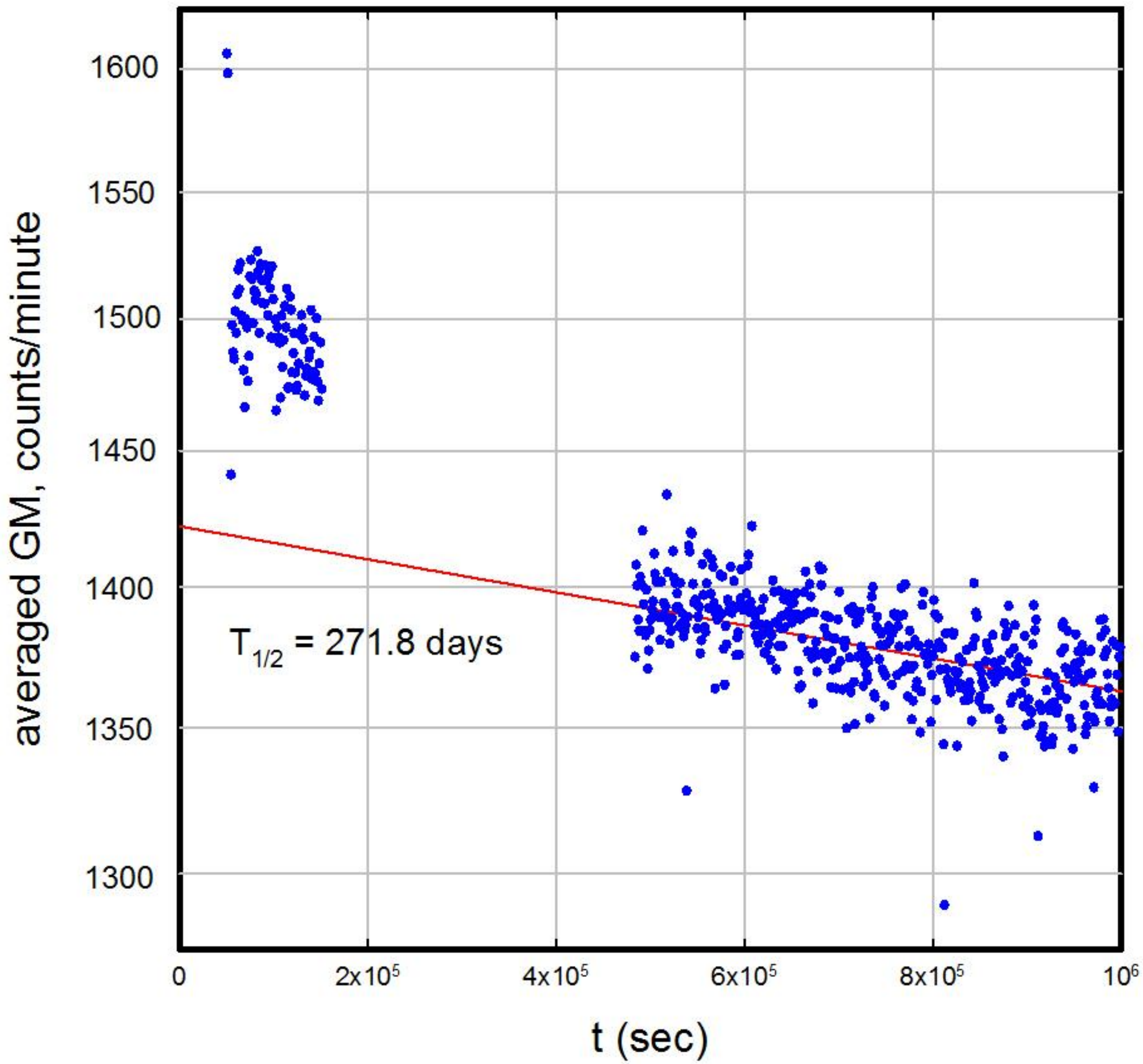


averaged X123 15-25 keV, counts/10 seconds
54
52
50
48
46
44
42
$T_{1/2}$ = 271.8 days
0
2x10^5
4x10^5
6x10^5
8x10^5
10^6
t (sec)

Thinking…

- X-123 data showing clear anomaly
- Faster than exponential decay for Fe K_α, Fe K_β and Fe-57 14.4 keV transition
- Exponential decay with expected half-life late in run
- Exponential decay with expected half-life in 0-6 and 8-14 keV channels
- Perhaps deviation from exponential decay in 15-25 keV channel
- Enhancement of Fe K_α, Fe K_β and Fe-57 14.4 keV emission at early time

Geiger counter data



averaged GM, counts/minute
1600
1550
1500
1450
1400
1350
1300
$T_{1/2}$ = 271.8 days
0
2x10^5
4x10^5
6x10^5
8x10^5
10^6
t (sec)

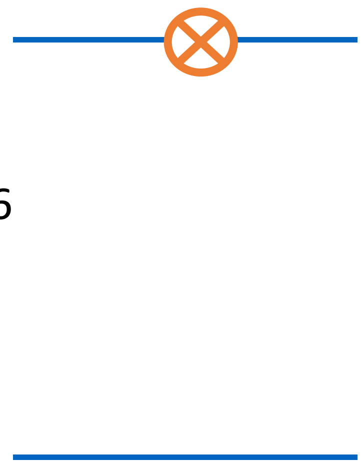
Thinking…

- Geiger counter looking at the back side
- Geiger counter showing exponential decay at late time with expected half-life for Co-57
- Elevated count rate at early time
- Qualitatively consistent with X-123 effect
- Need to re-analyze taking out constant background level near 200

Interpretation of observed anomaly

Fleischmann & Pons type experiments:

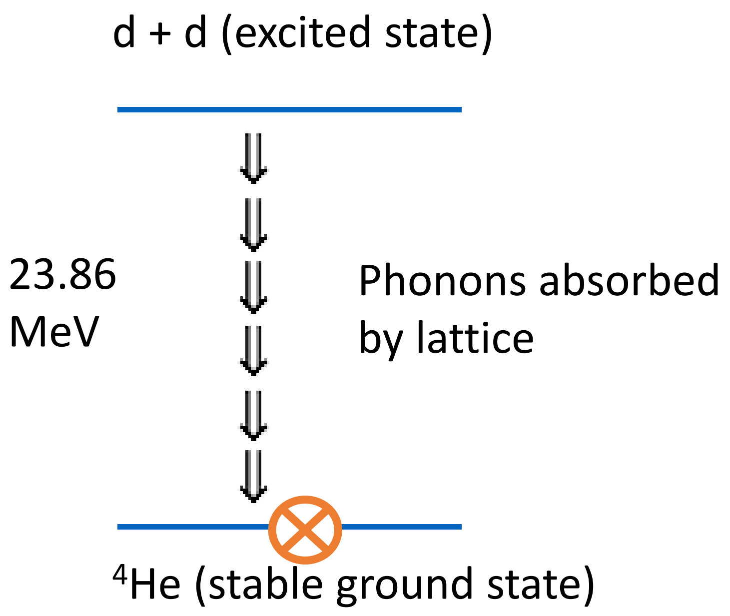
FIRST PICTURE:



Interpretation of observed anomaly

Fleischmann & Pons type experiments:

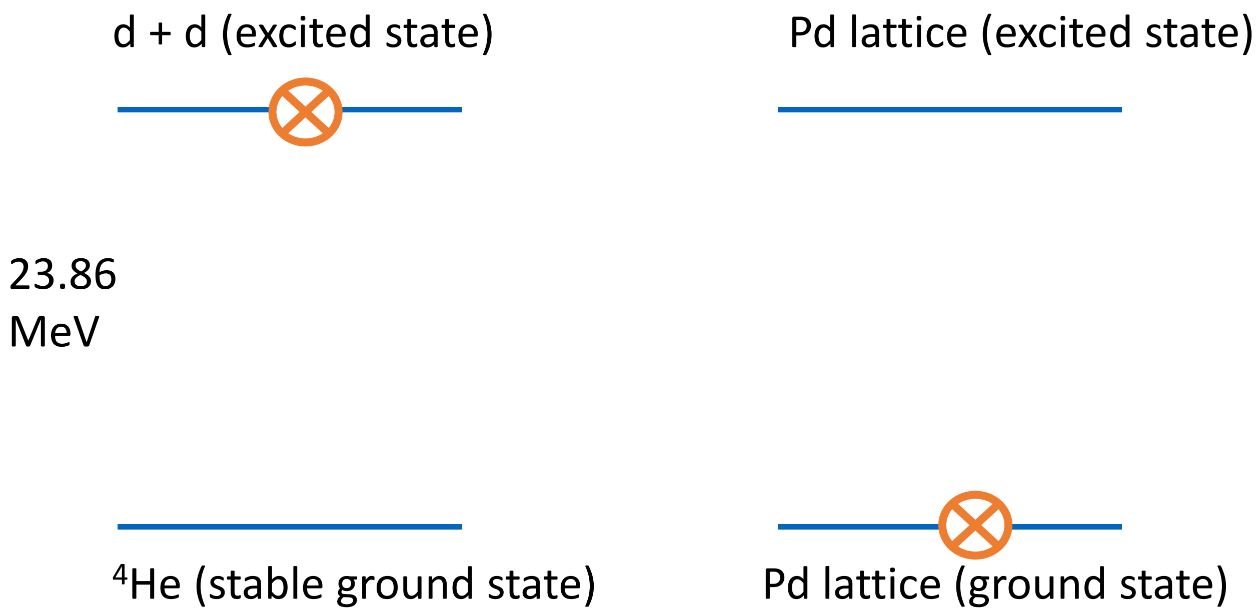
FIRST PICTURE:



Interpretation of observed anomaly

Fleischmann & Pons type experiments:

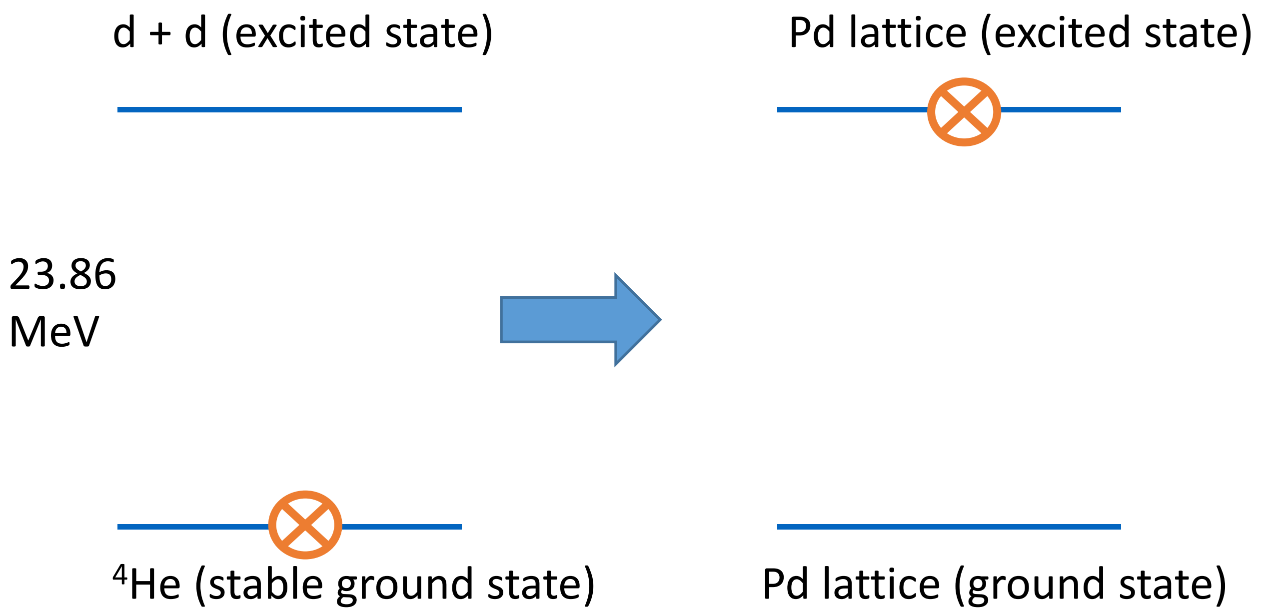
SECOND PICTURE:



Interpretation of observed anomaly

Fleischmann & Pons type experiments:

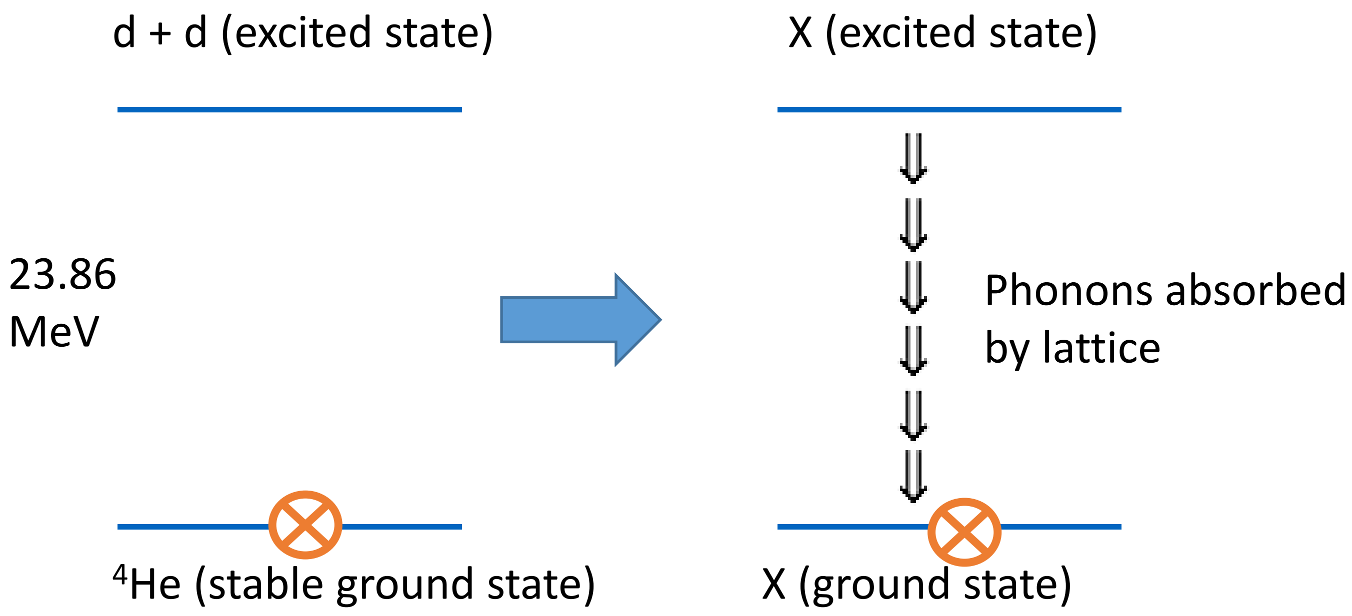
SECOND PICTURE:



Interpretation of observed anomaly

Fleischmann & Pons type experiments:

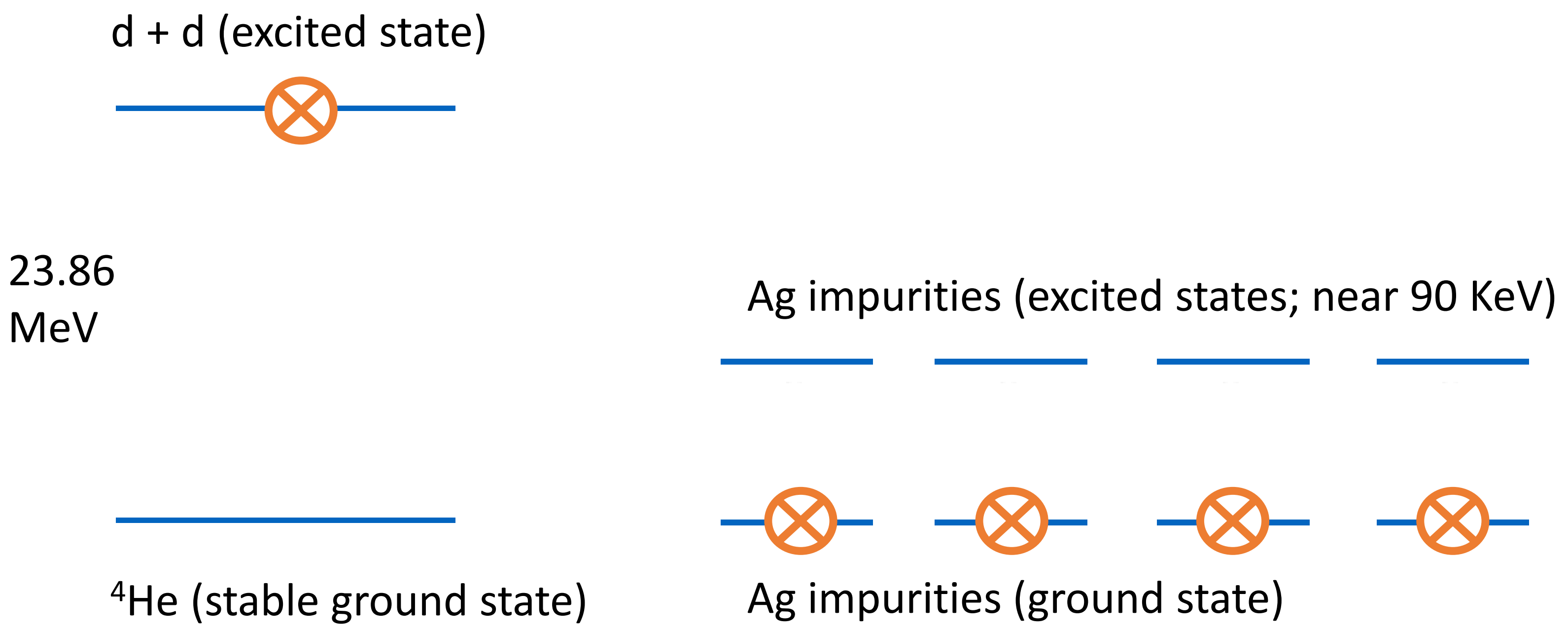
SECOND PICTURE:



Interpretation of observed anomaly

Fleischmann & Pons type experiments:

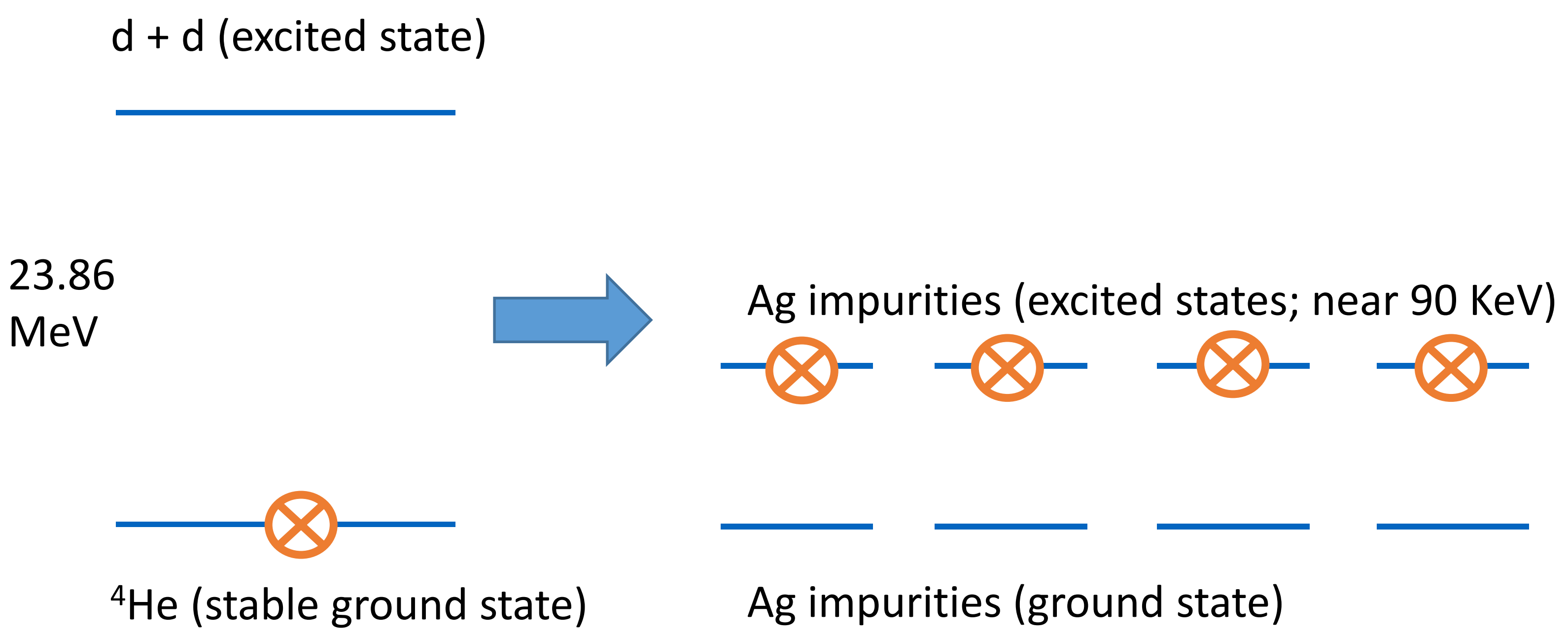
THIRD PICTURE:



Interpretation of observed anomaly

Fleischmann & Pons type experiments:

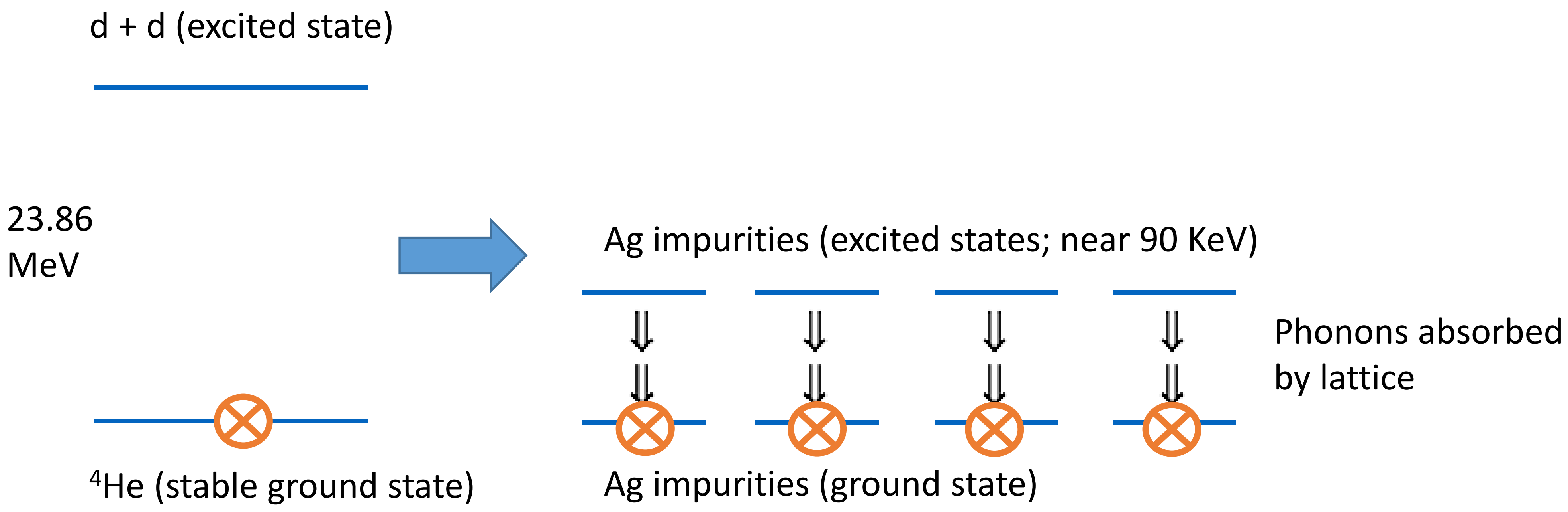
THIRD PICTURE:



Interpretation of observed anomaly

Fleischmann & Pons type experiments:

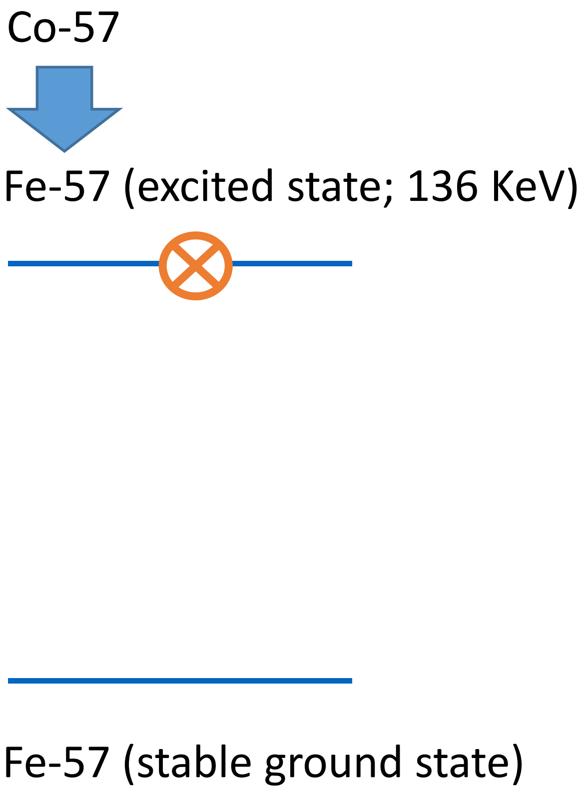
THIRD PICTURE:



Interpretation of observed anomaly

Excitation transfer experiment:

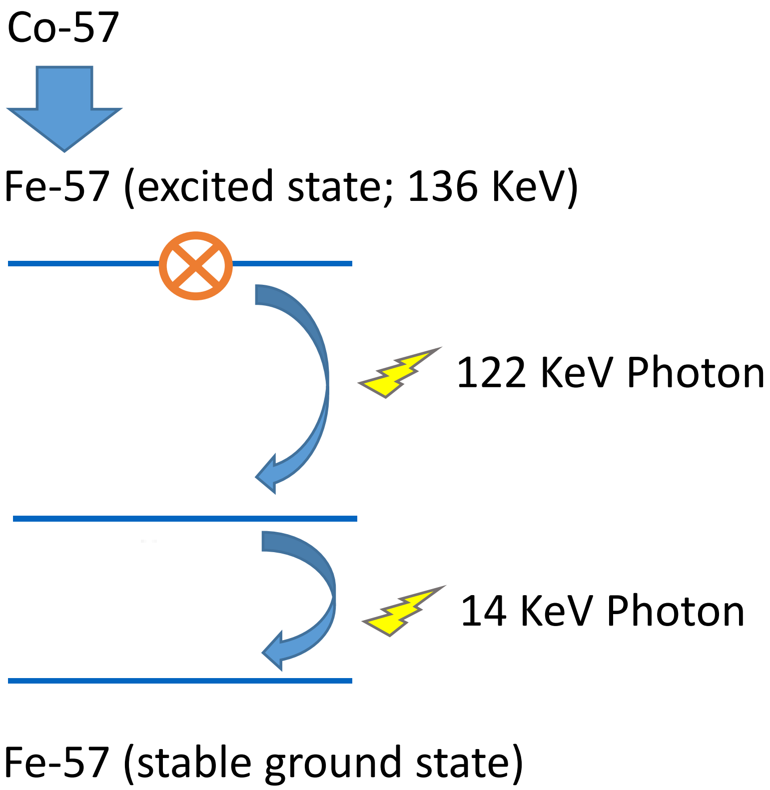
TRADITIONAL PICTURE:



Interpretation of observed anomaly

Excitation transfer experiment:

TRADITIONAL PICTURE:

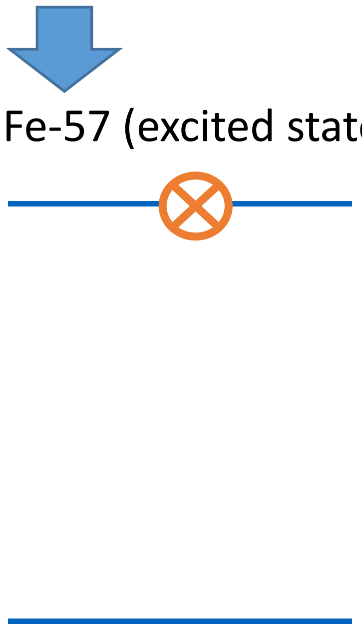


Interpretation of observed anomaly

Excitation transfer experiment:

TRADITIONAL PICTURE:

Co-57



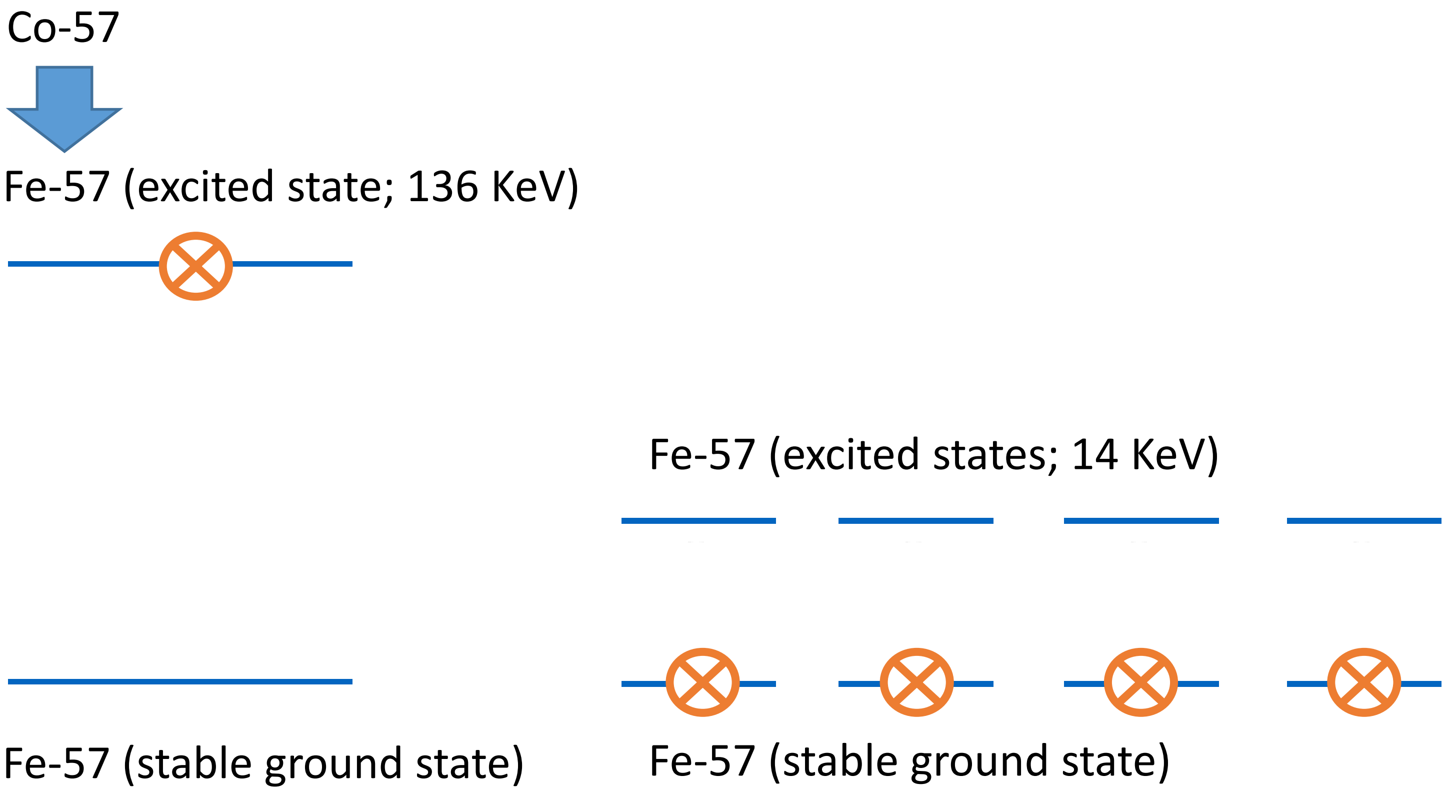
Fe-57 (excited state; 136 KeV)

Fe-57 (stable ground state)

Interpretation of observed anomaly

Excitation transfer experiment:

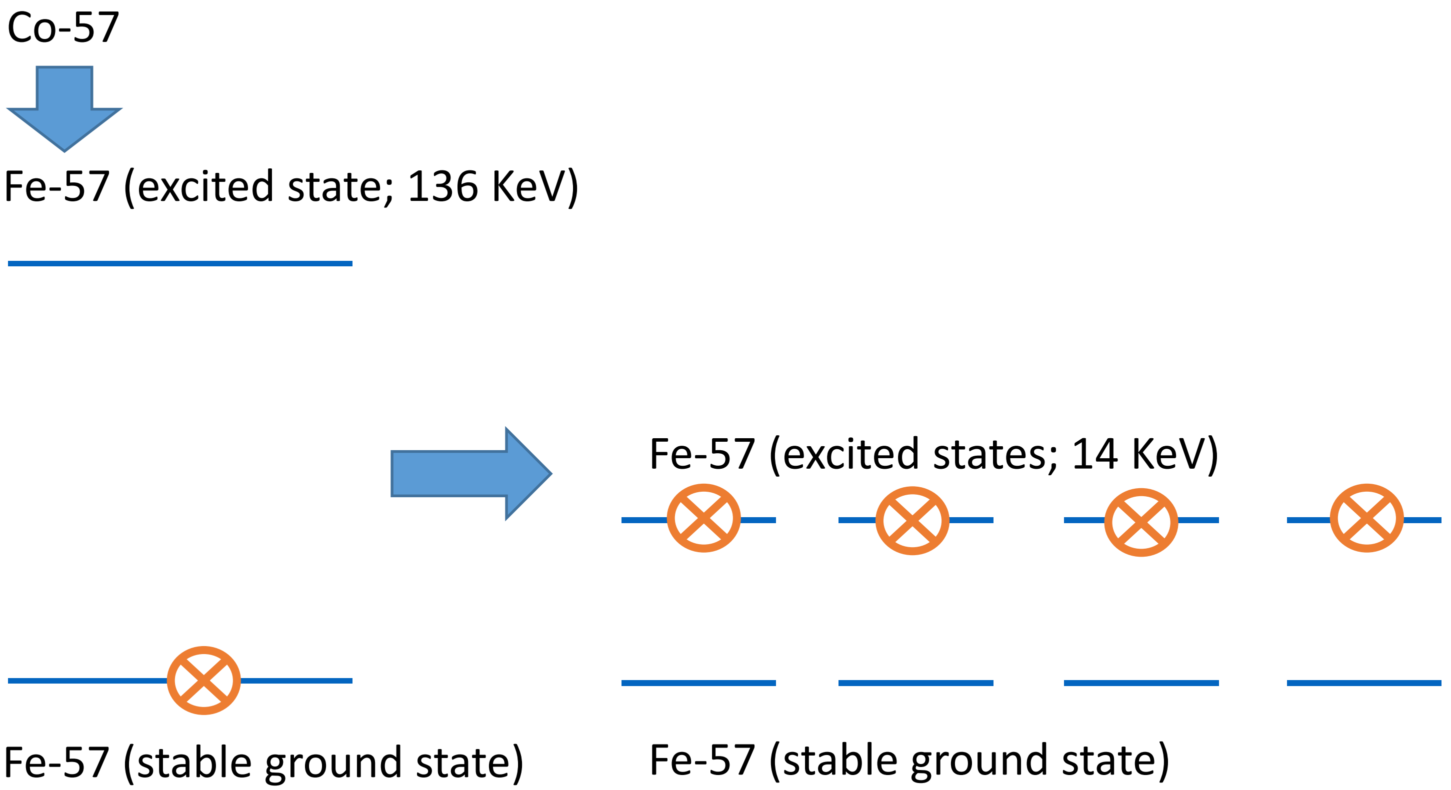
SUBDIVISION PICTURE:



Interpretation of observed anomaly

Excitation transfer experiment:

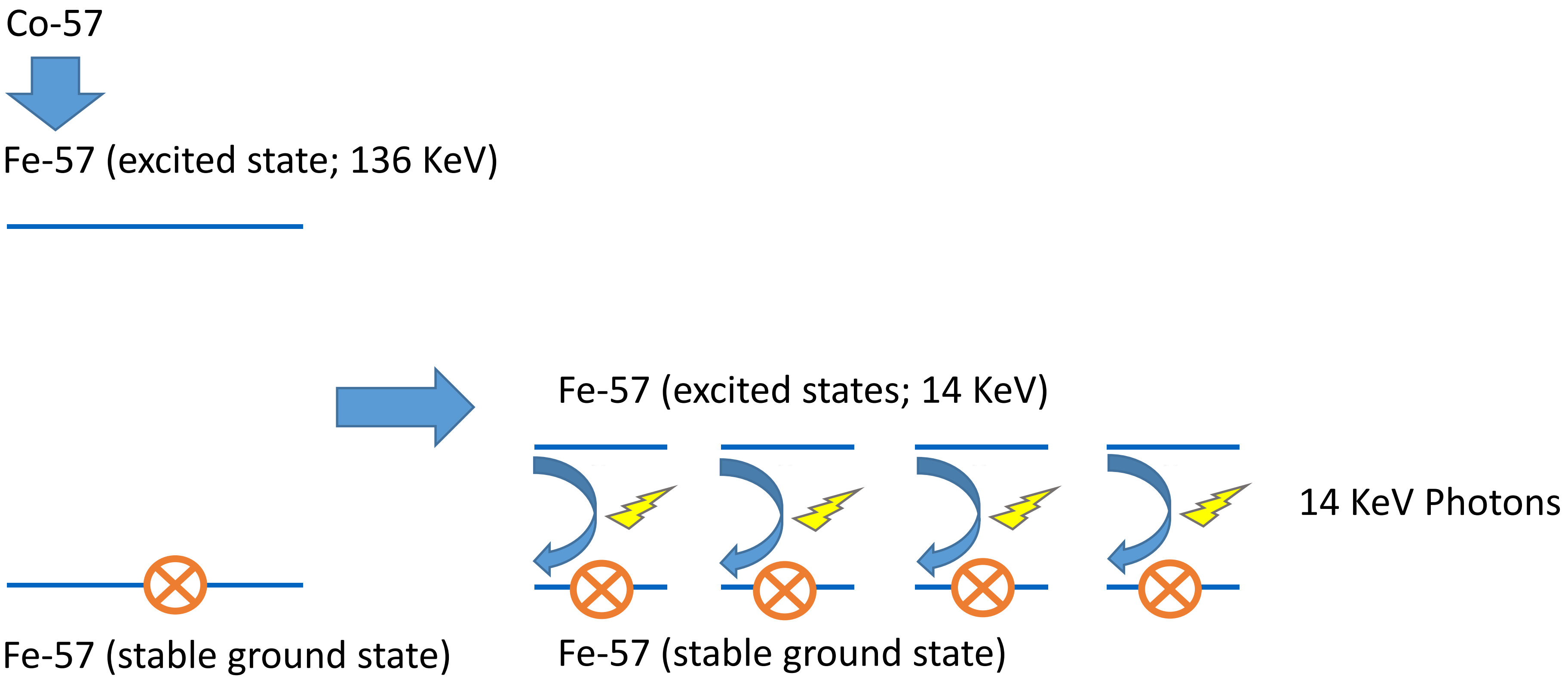
SUBDIVISION PICTURE:



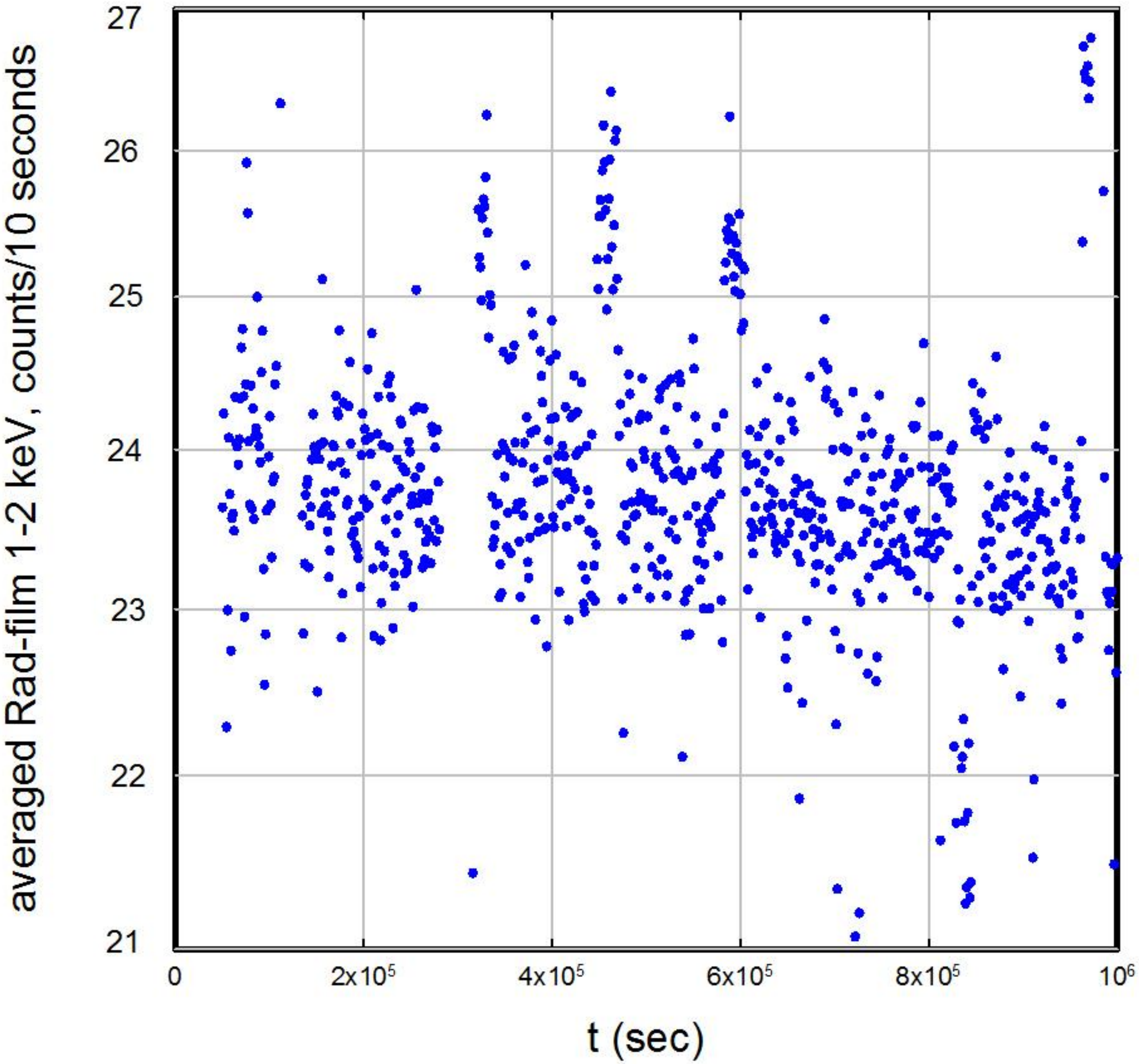
Interpretation of observed anomaly

Excitation transfer experiment:

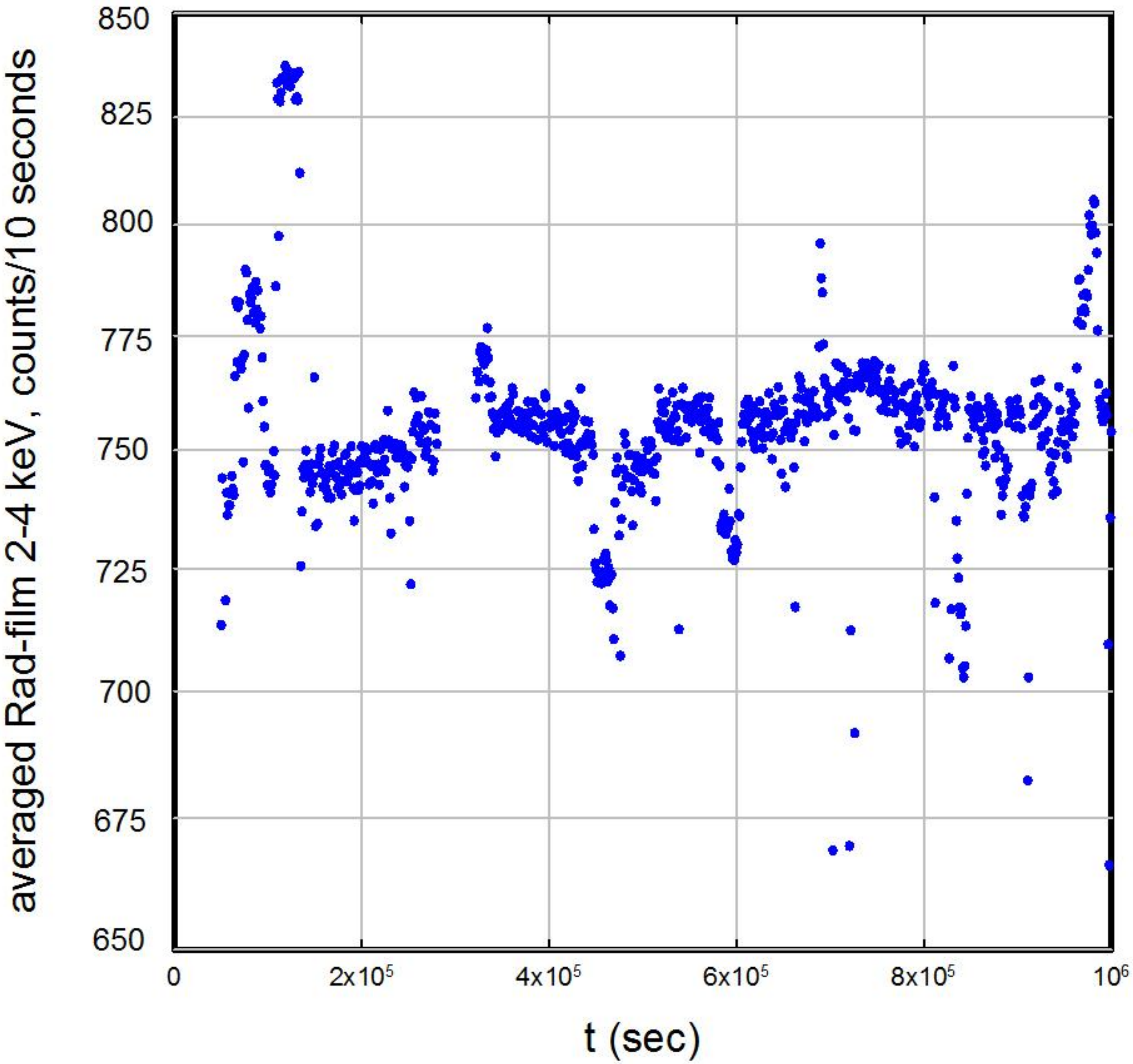
SUBDIVISION PICTURE:



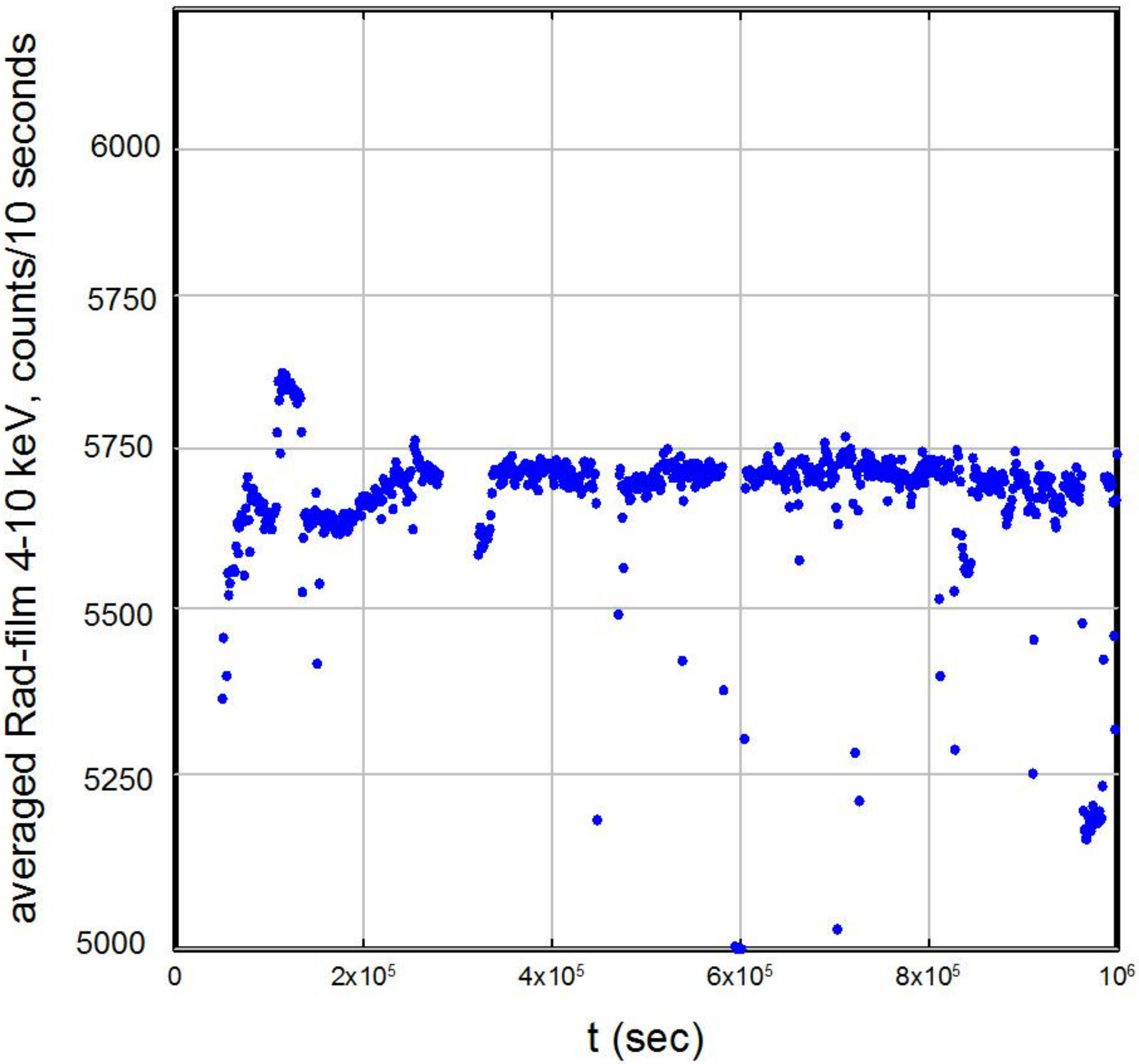
Rad-film data, log-lin plots

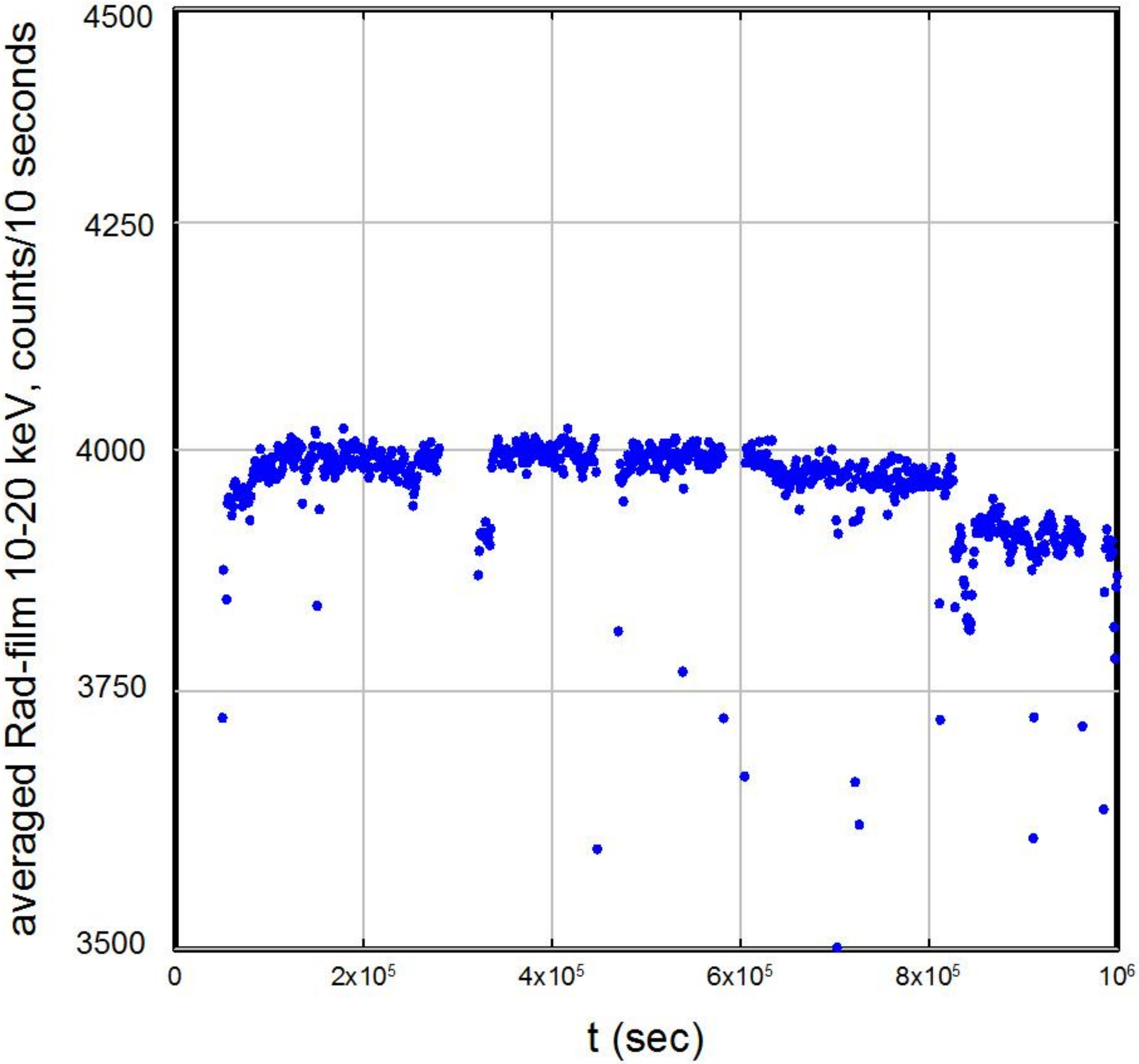


averaged Rad-film 1-2 keV, counts/10 seconds
27
26
25
24
23
22
21
0
2x10⁵
4x10⁵
6x10⁵
8x10⁵
10⁶
t (sec)

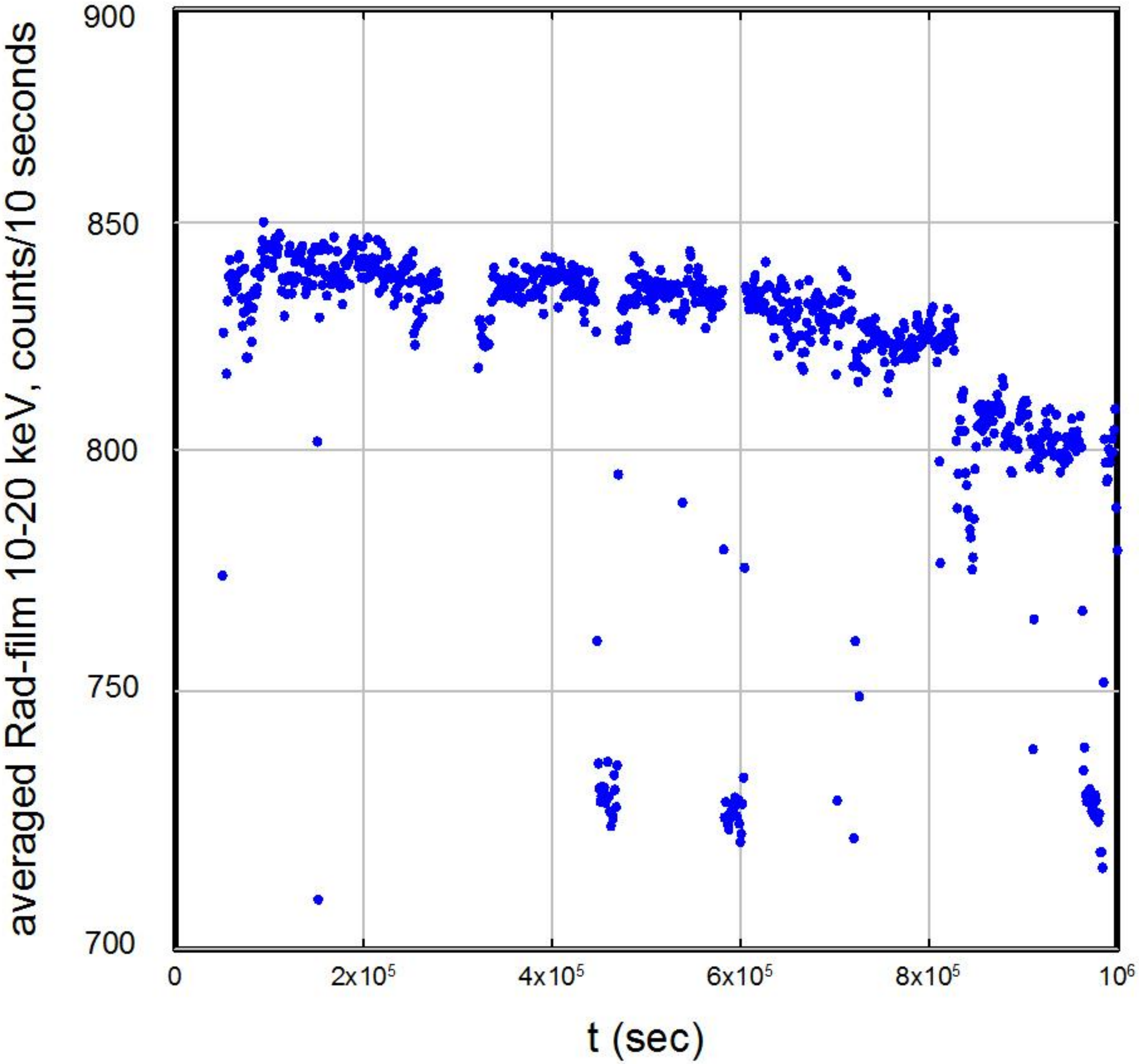


averaged Rad-film 2-4 keV, counts/10 seconds
850
825
800
775
750
725
700
675
650
0
2x10⁵
4x10⁵
6x10⁵
8x10⁵
10⁶
t (sec)


averaged Rad-film 4-10 keV, counts/10 seconds
6000
5750
5750
5500
5250
5000
0
2x10^5
4x10^5
6x10^5
8x10^5
10^6
t (sec)



averaged Rad-film 10-20 keV, counts/10 seconds
4500
4250
4000
3750
3500
0
2x10^5
4x10^5
6x10^5
8x10^5
10^6
t (sec)

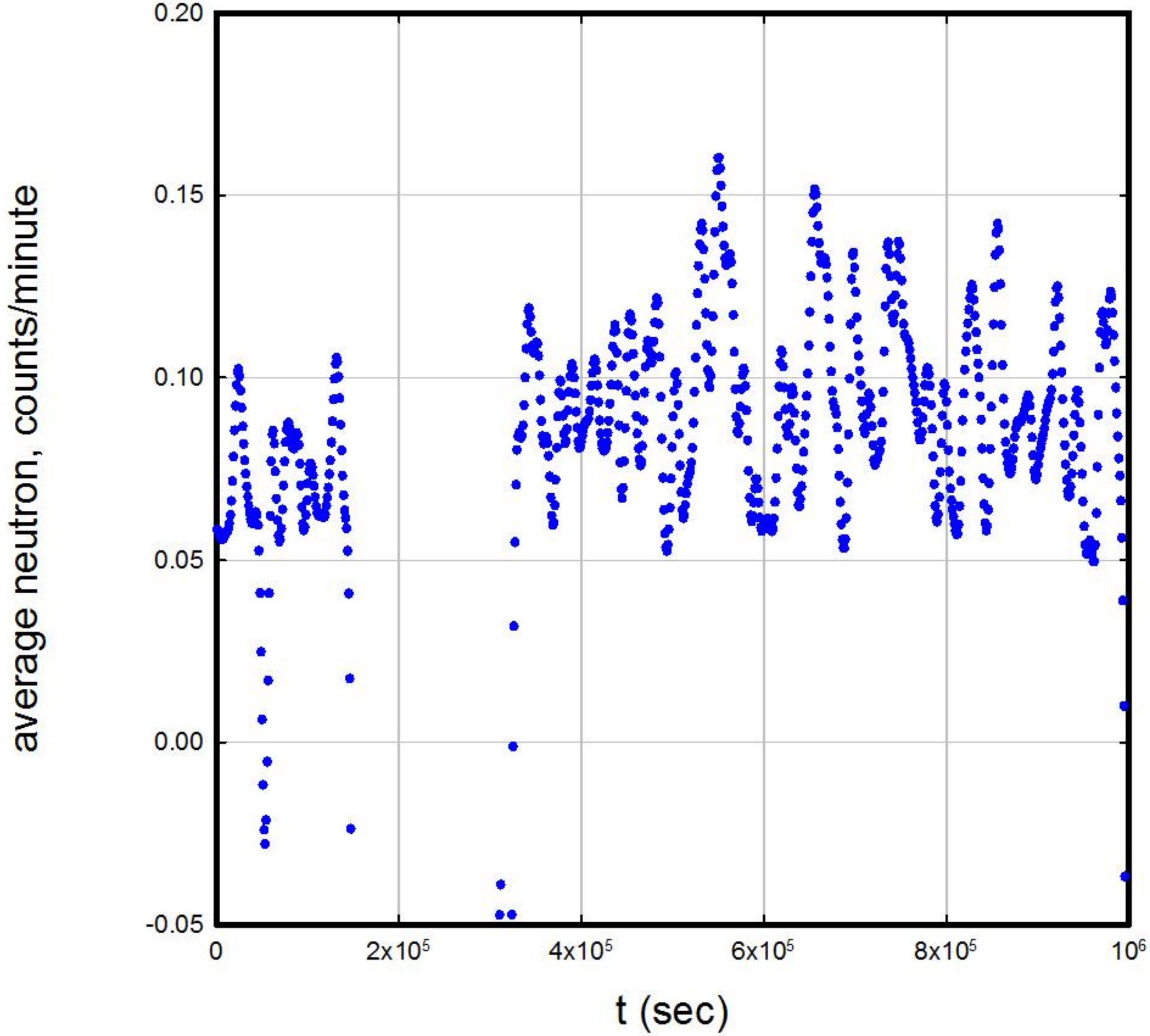


900
850
800
750
700
averaged Rad-film 10-20 keV, counts/10 seconds
0
2x10^5
4x10^5
6x10^5
8x10^5
10^6
t (sec)

Thinking…

- Rad-film detector looking at the back side
- See clear dynamics, and non-exponential decay
- Event probably not over when experiment interrupted
- Perhaps evidence for system responding after 2.25 MHz stimulation

Neutron data



0.20
0.15
0.10
0.05
0.00
-0.05
0
2x10^5
4x10^5
6x10^5
8x10^5
10^6
average neutron, counts/minute
t (sec)

Thinking…

- Count rate is low, so get significant fluctuations even with averaging
- Probably the neutron emission rate is low early, and higher later

Conclusions and Hypotheses

Conclusion for now

- Looks like we saw an anomaly
- Non-exponential decay in several channels…
- …with exponential decay with correct half-life in other channels
- GM seems to support X-123 data
- Originally thought that the rad-film detector was the odd man out…
- …now thinking that the rad-film detector was detecting anomalous emission that had not finished by the time the experiment was interrupted

Not Co-57 loss…

- Each day looking at the data set and thinking leads to new ideas and conclusions
- Last version was the possibility that we were losing Co-57
- However, the channels not looking at resonance lines are going down with $T_{1/2}$ = 271.8 days more or less
- And late time emission on strong X-123 lines goes down exponentially with half-life consistent with Co-57 decay
- This could be interpreted as no anomalous loss of Co-57
- Need to get the gamma detector looking at the experiment to monitor emission at 122 keV

More thinking…

- Excitation transfer is a candidate to account for GM signal on back side
- We were hoping for excitation transfer to reduce the front side signal, so although possible that we are seeing excitation transfer in the X-123 data I consider this at the moment not to be so likely
- Another possibility is that we are seeing up-conversion
- Also possible that we got both up-conversion and excitation transfer
- Need further experimentation to clarify
- However, since the X-123 detector sees an increase at early time, up-conversion is strongly favored for this part of the anomaly

Acoustic vs optical phonons

- Vibrational excitation is at 2.25 MHz when stimulation on
- X-123 signal not showing a strong response to 2.25 MHz stimulation
- Something else probably responsible
- Current thinking is that optical phonons, and high frequency acoustic phonons, all created during the relaxation of the stressed metal (and wood)
- Time-dependence in X-123 signal perhaps due to relaxation effect
- Optical phonons could produce up-conversion
- Consistent with effects seen by Cardone et al, who probably create damaged and stressed metal in vicinity of welding head
- Note that Karabut tightens screws in his chamber, and stresses the system when it goes under vacuum