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The Exciting World of Microcalorimetry

Shannon Kossmann

7 March 2019

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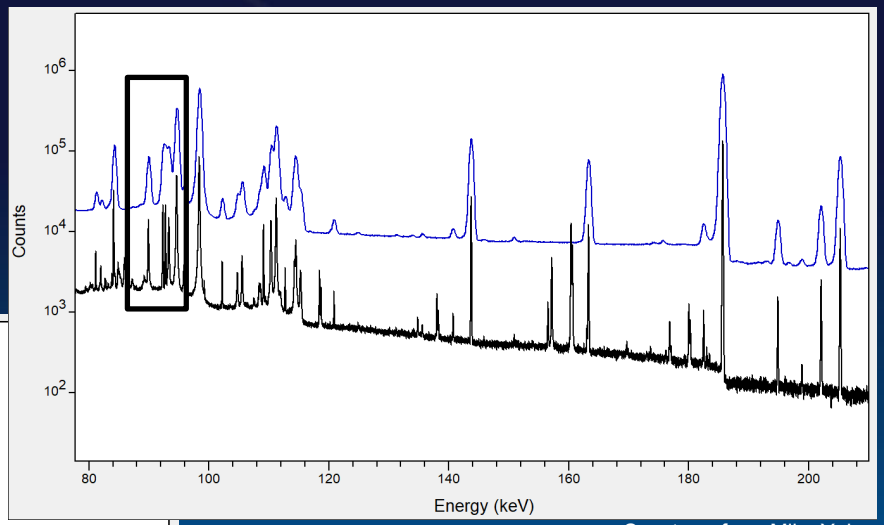
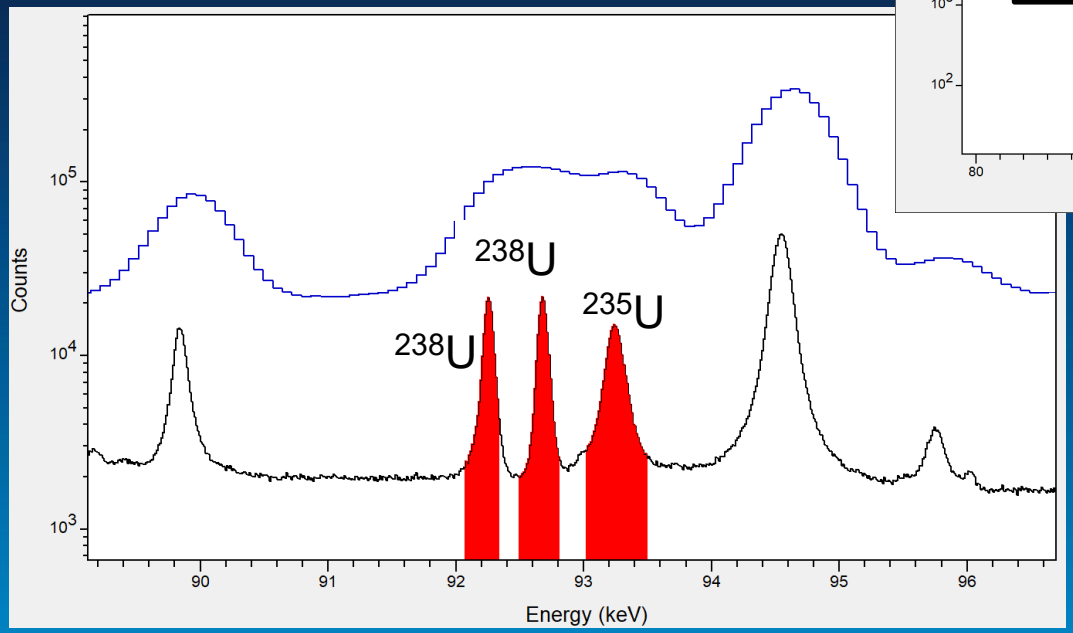
Exciting World of Microcalorimetry

Enriched Uranium, ~10%
(A1-324)



Spectrum from Mike Yoho

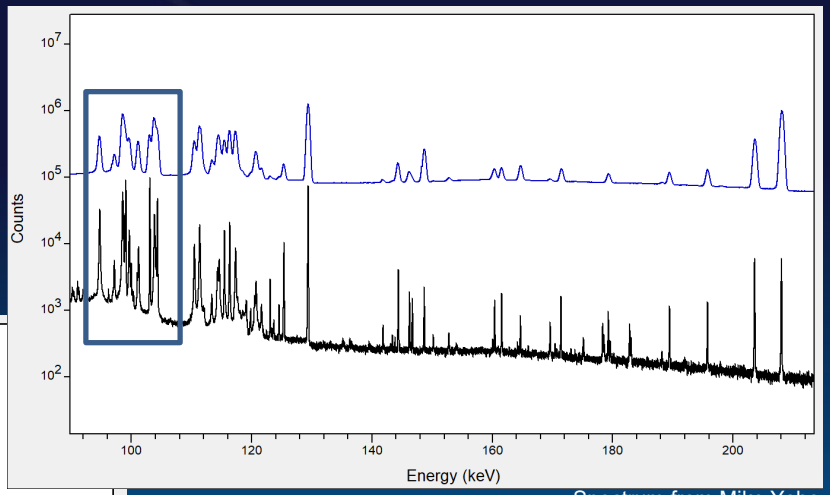


Spectrum from Mike Yoho

Microcalorimeter gamma spectroscopy allows for resolution of peaks important for isotopic analysis

Exciting World of Microcalorimetry

Low-burnup plutonium, ~6% ^{240}Pu (PIDIE 6-1)



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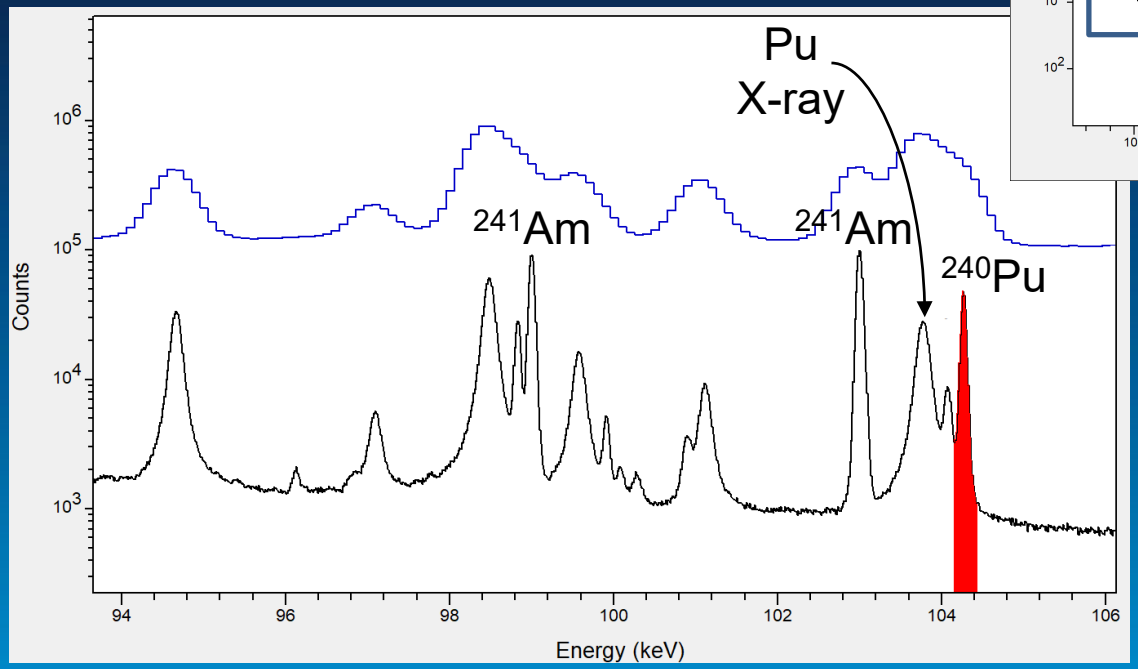


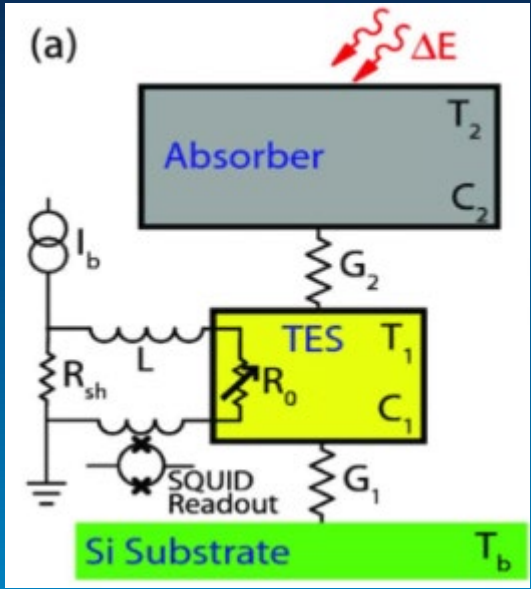
Spectrum from Mike Yoho

Microcalorimeter gamma spectroscopy allows for resolution of peaks important for isotopic analysis

Some Basics

- $\Delta E \rightarrow \Delta T \rightarrow \Delta R \rightarrow \Delta I$
- $E = C \times \Delta T$

Microcalorimeters measure changes in energy as a change in temperature



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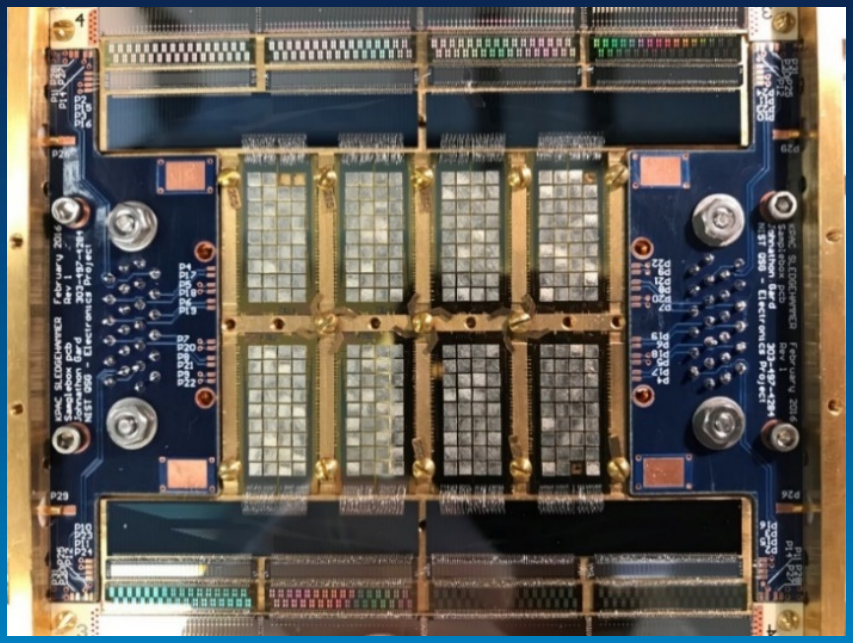
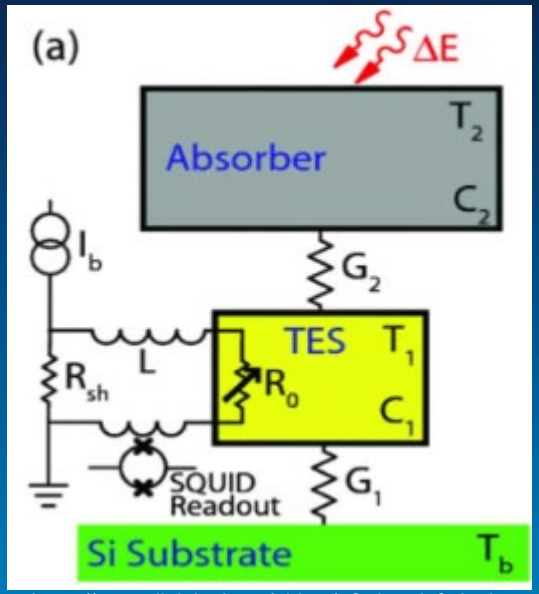


Photo credit: Mark Croce

Some Basics

- $\Delta E \rightarrow \Delta T \rightarrow \Delta R \rightarrow \Delta I$

Transition-Edge Sensors register a small change in temperature as a measureable change in resistance



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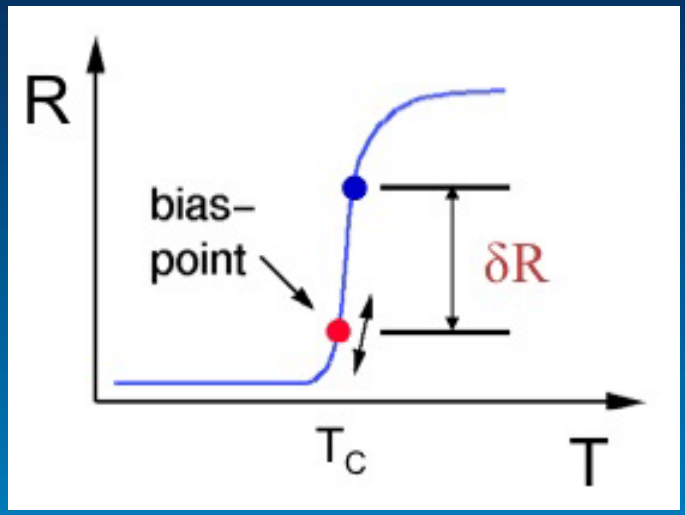
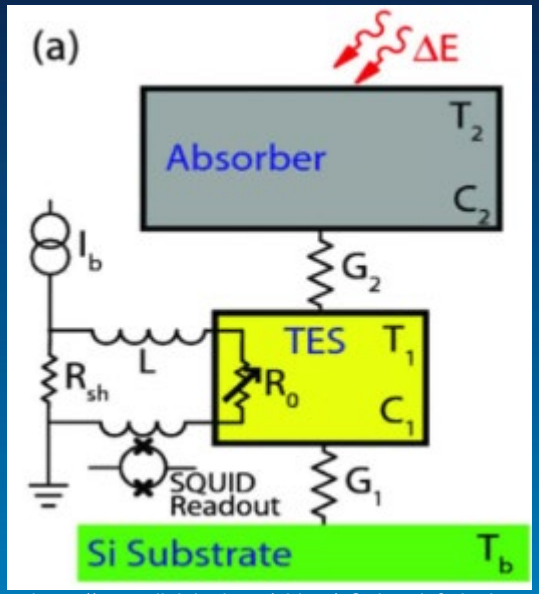


https://www.researchgate.net/figure/Illustrative-plot-of-resistance-vs-temperature-for-a-superconductor-The-transition-is_fig4_228440334

Some Basics

- $\Delta E \rightarrow \Delta T \rightarrow \Delta R \rightarrow \Delta I$



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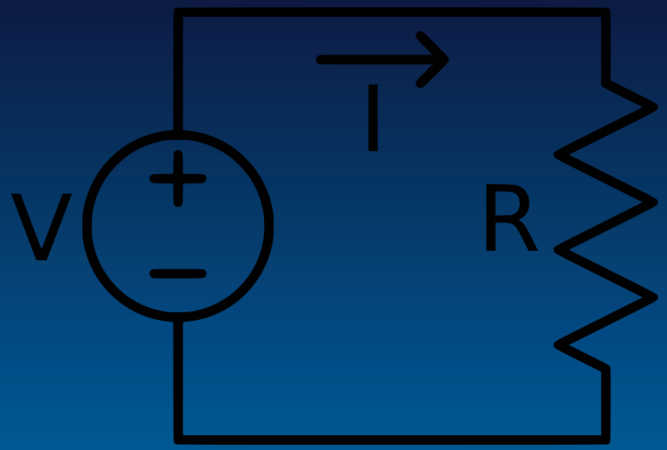
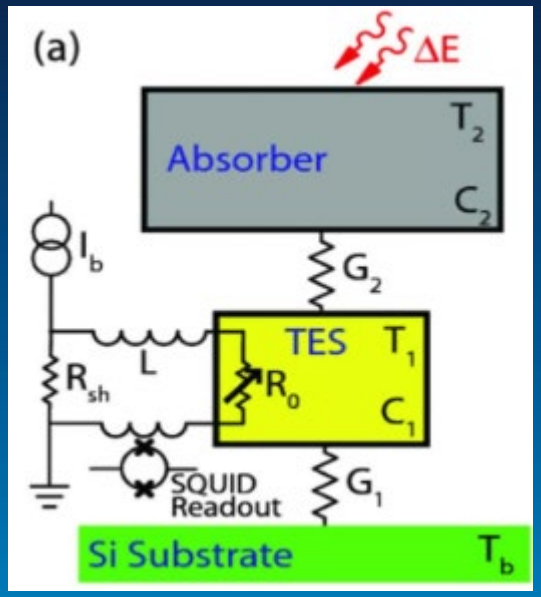


https://commons.wikimedia.org/wiki/File:Ohms_law_voltage_source.svg

By Ohm's Law with a constant voltage and a change in resistance, the current must change

Some Basics

- $\Delta E \rightarrow \Delta T \rightarrow \Delta R \rightarrow \Delta I$



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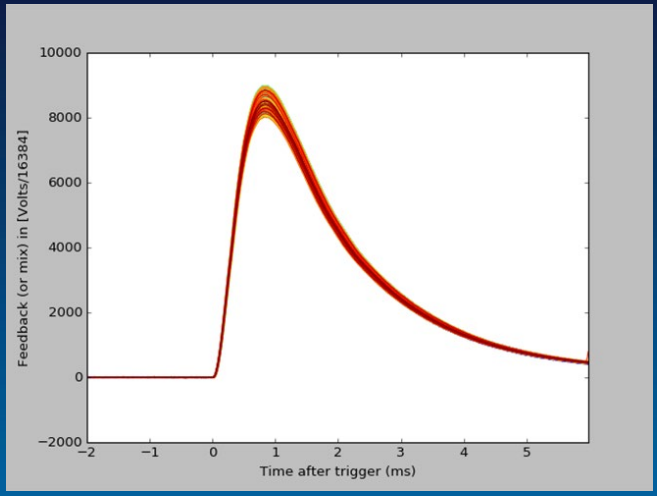
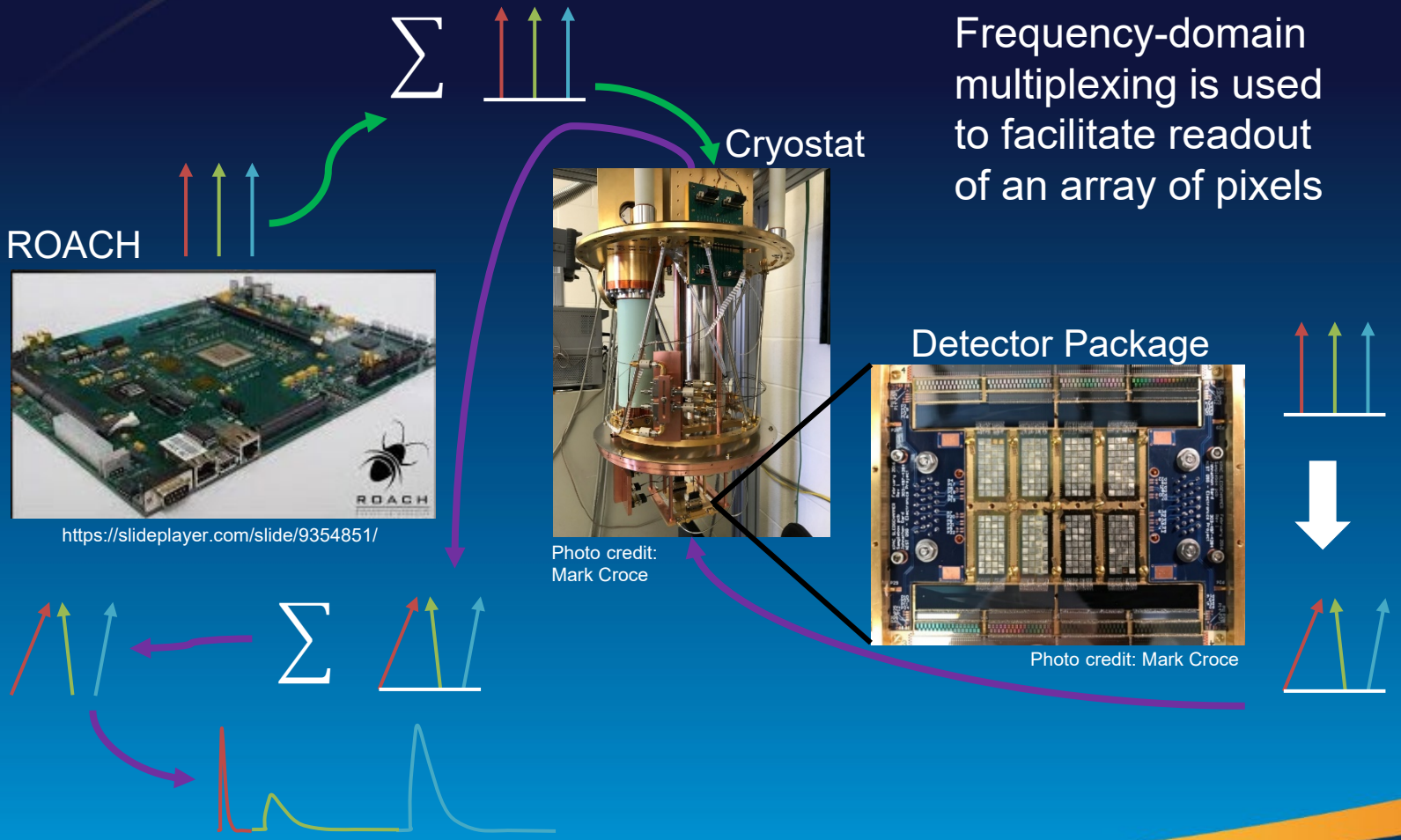


The height of each pulse is proportional to the energy of the photon

A Bit More Complicated



Frequency-domain multiplexing is used to facilitate readout of an array of pixels

The Physical Instrument

Photo credit: Mark Croce

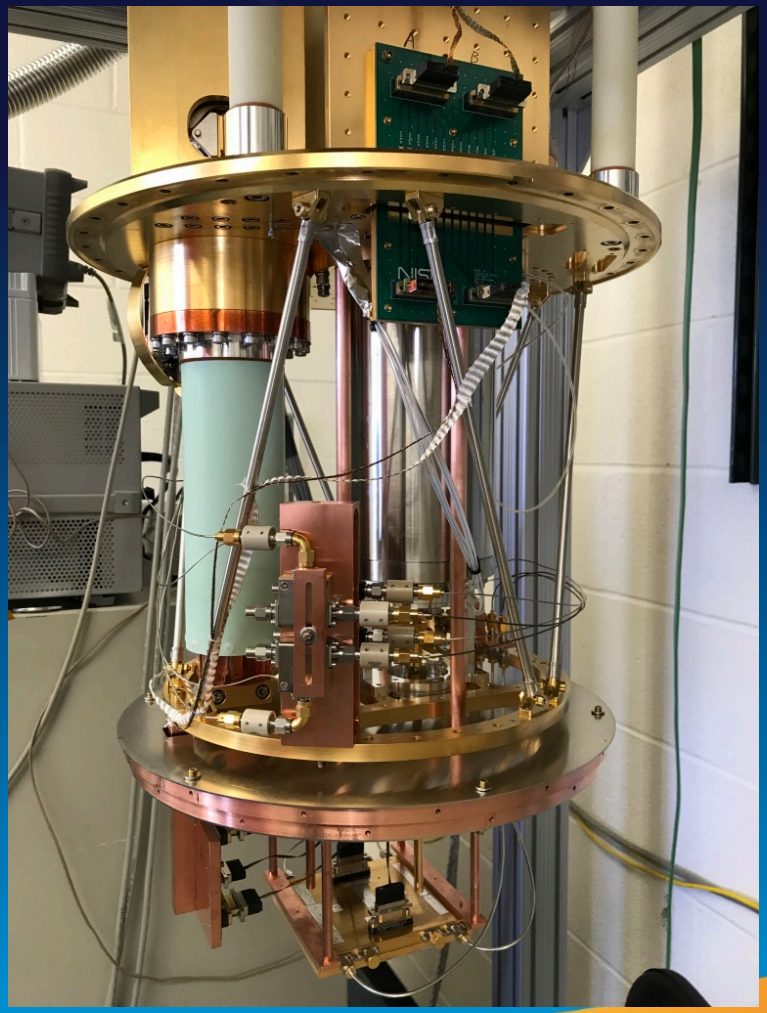


Photo credit: Mark Croce

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Microcalorimeter User Manual

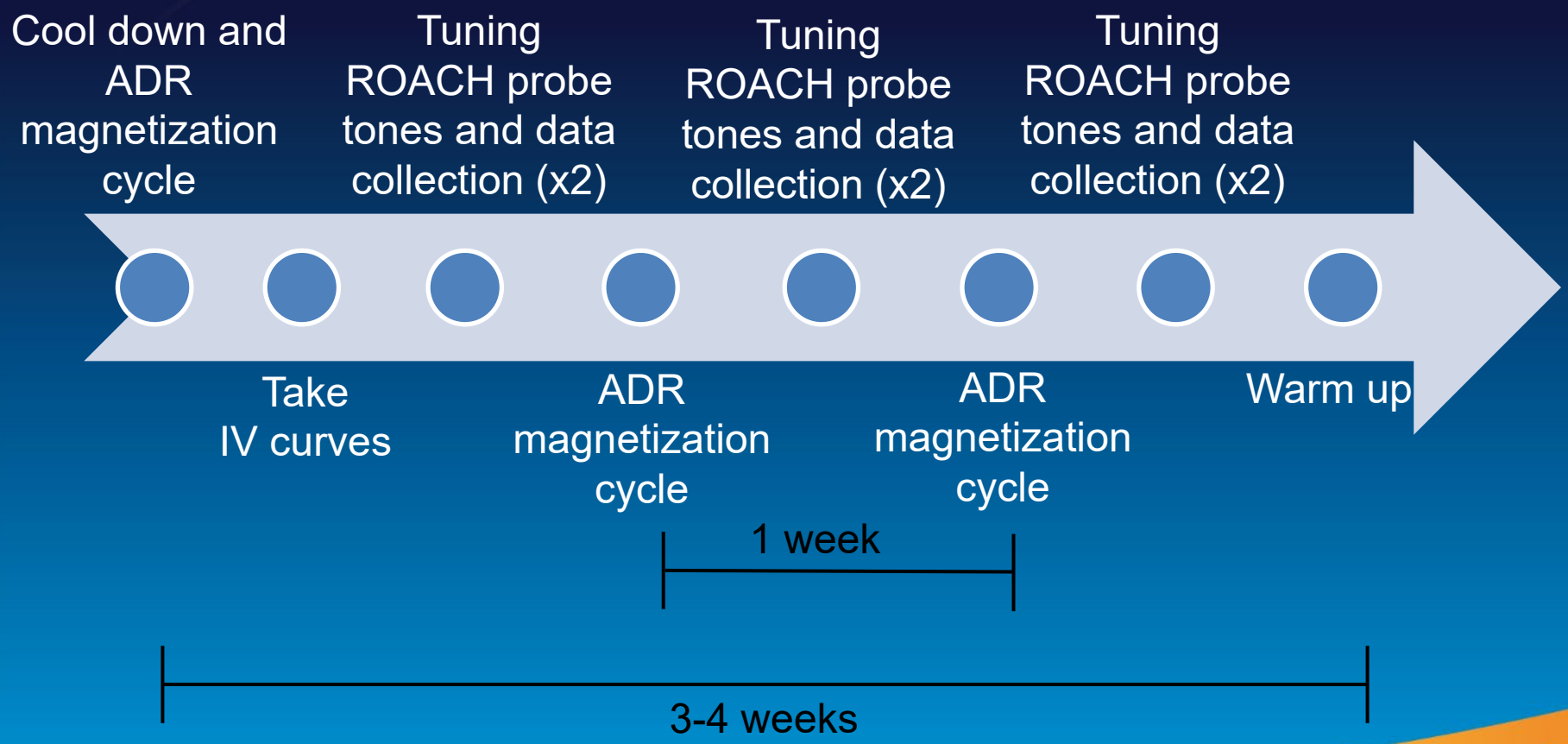
Shannon Kossmann, Katrina Koehler, and Mark Croce

March 5, 2019

Contents

1 Initial Setup 2
2 Cool Down 3
3 Taking Measurements 5
4 Turn on ROACH 7
5 Start Server 12
6 Start Matter 13
7 IQ Calibrate 14
8 IV Curves 14
9 Group Trigger 15
10 Noise Data 16

Timeline



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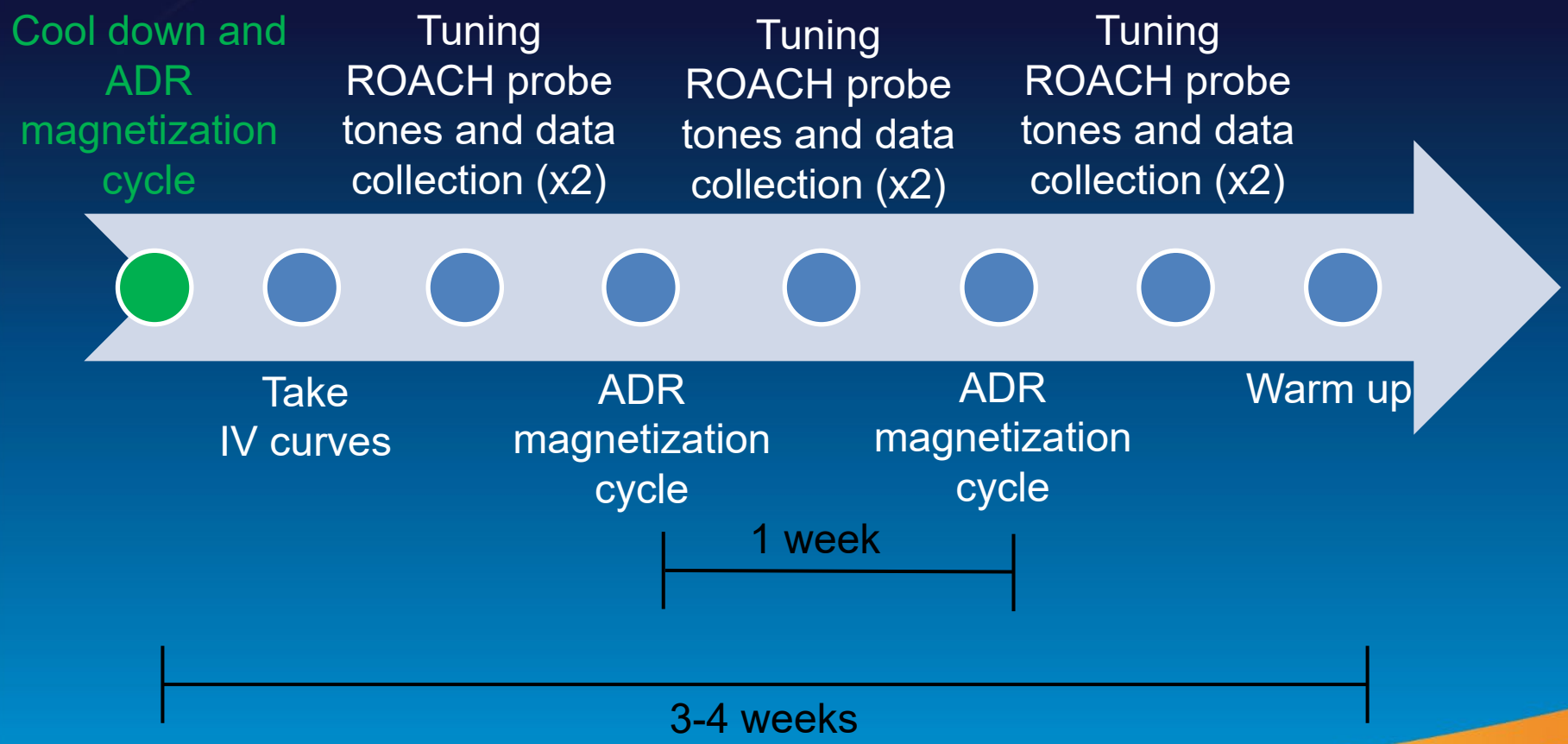
Timeline



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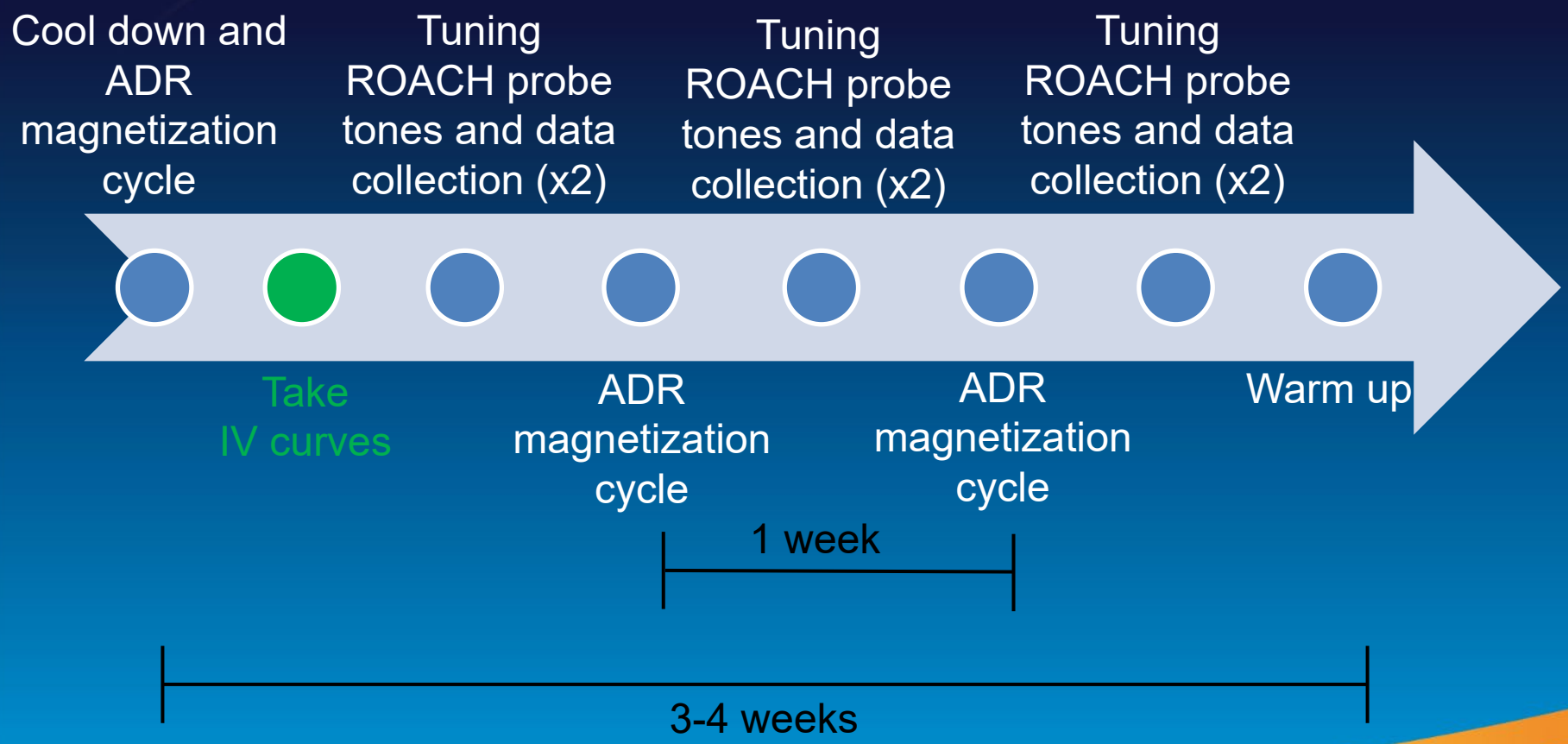
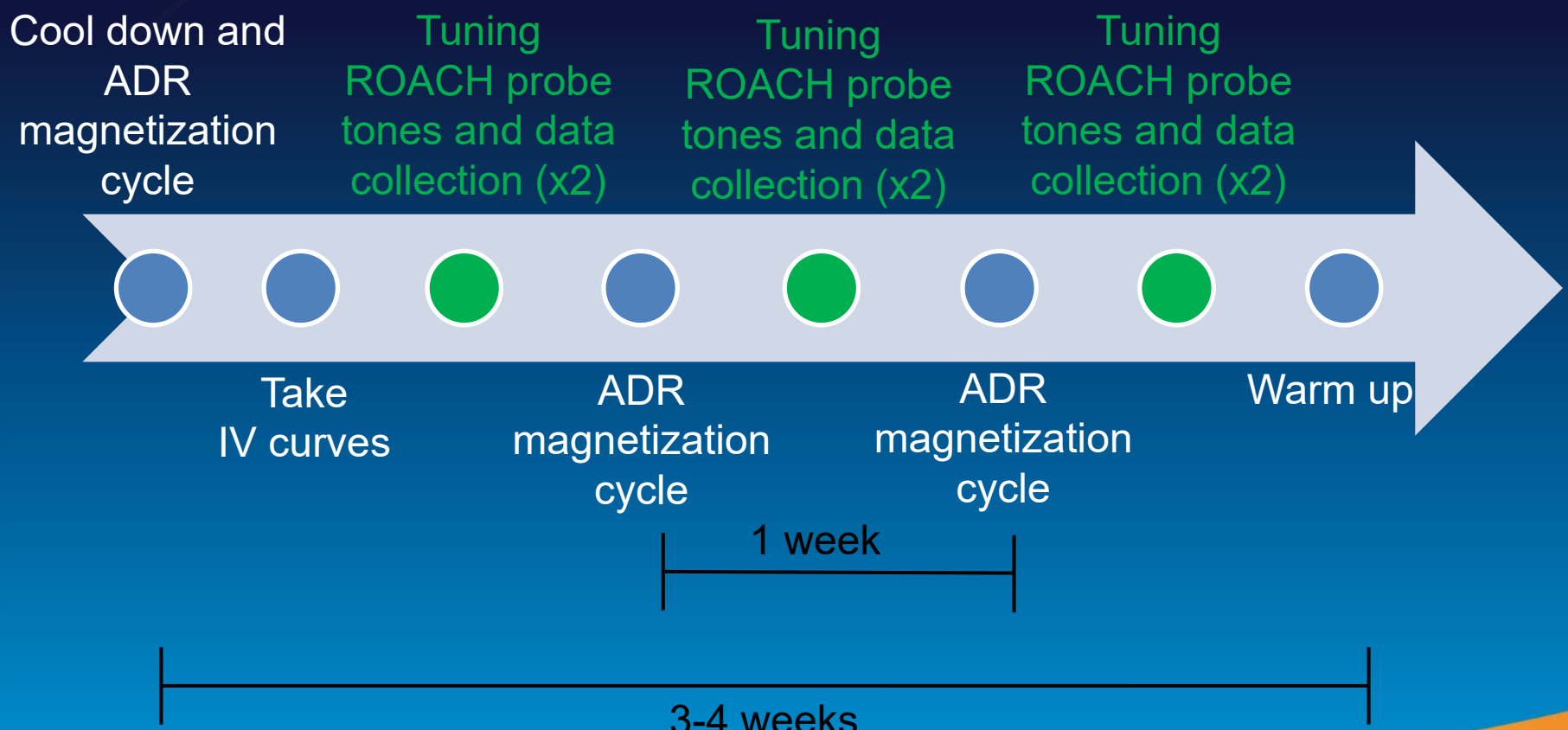
Timeline


Cool down and ADR magnetization cycle
Tuning ROACH probe tones and data collection (x2)
Tuning ROACH probe tones and data collection (x2)
Tuning ROACH probe tones and data collection (x2)
Take IV curves
ADR magnetization cycle
ADR magnetization cycle
Warm up
1 week
3-4 weeks

Timeline



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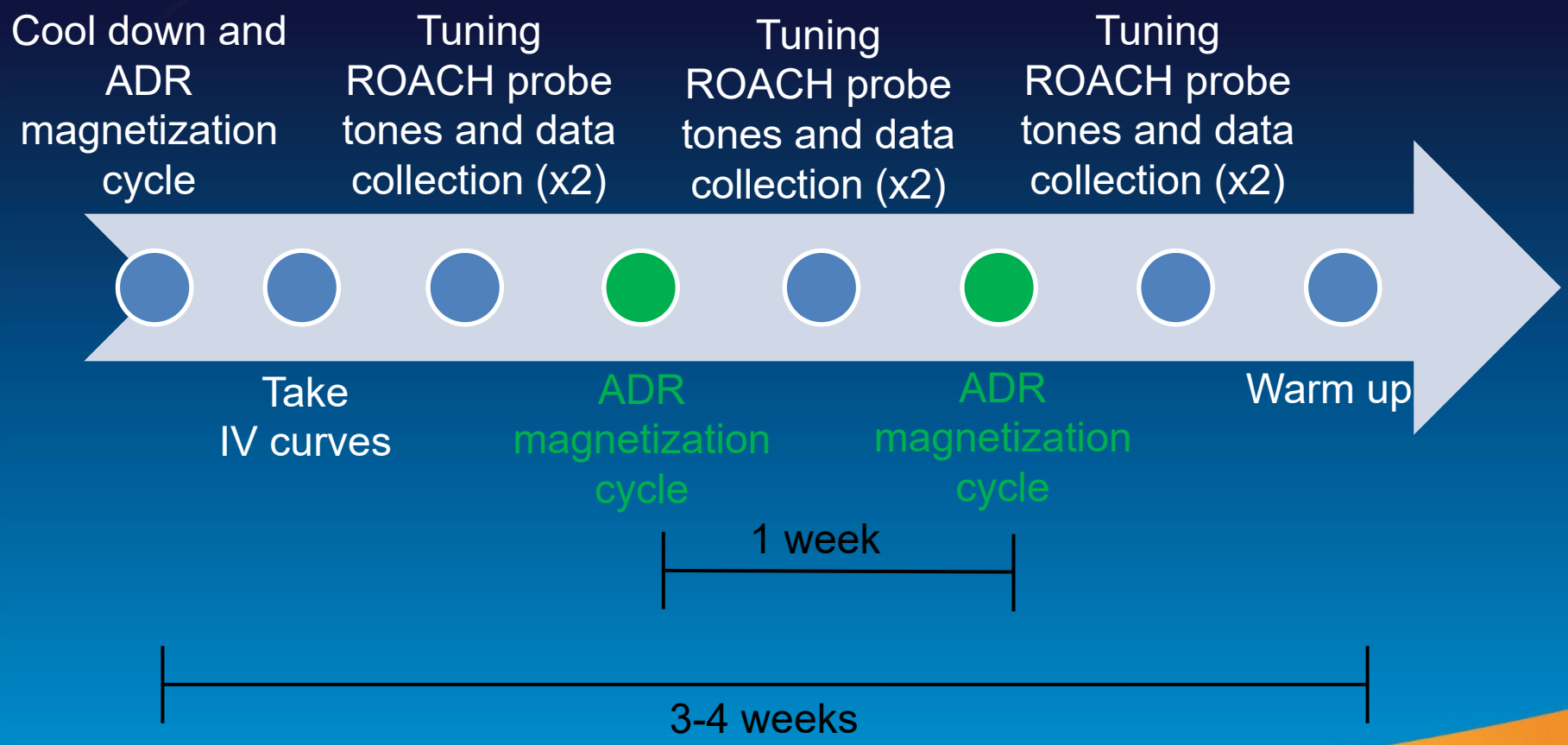
Timeline



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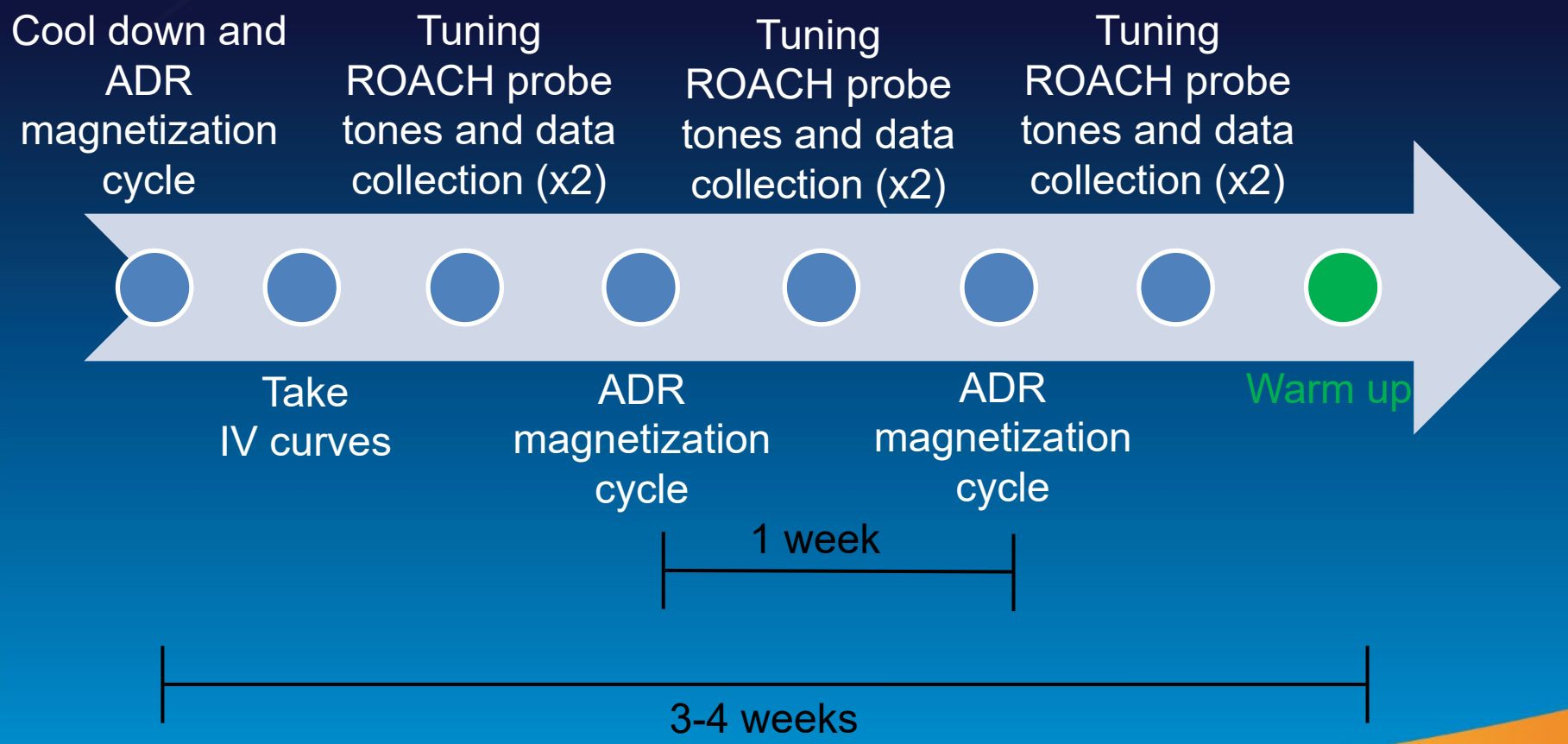
Timeline



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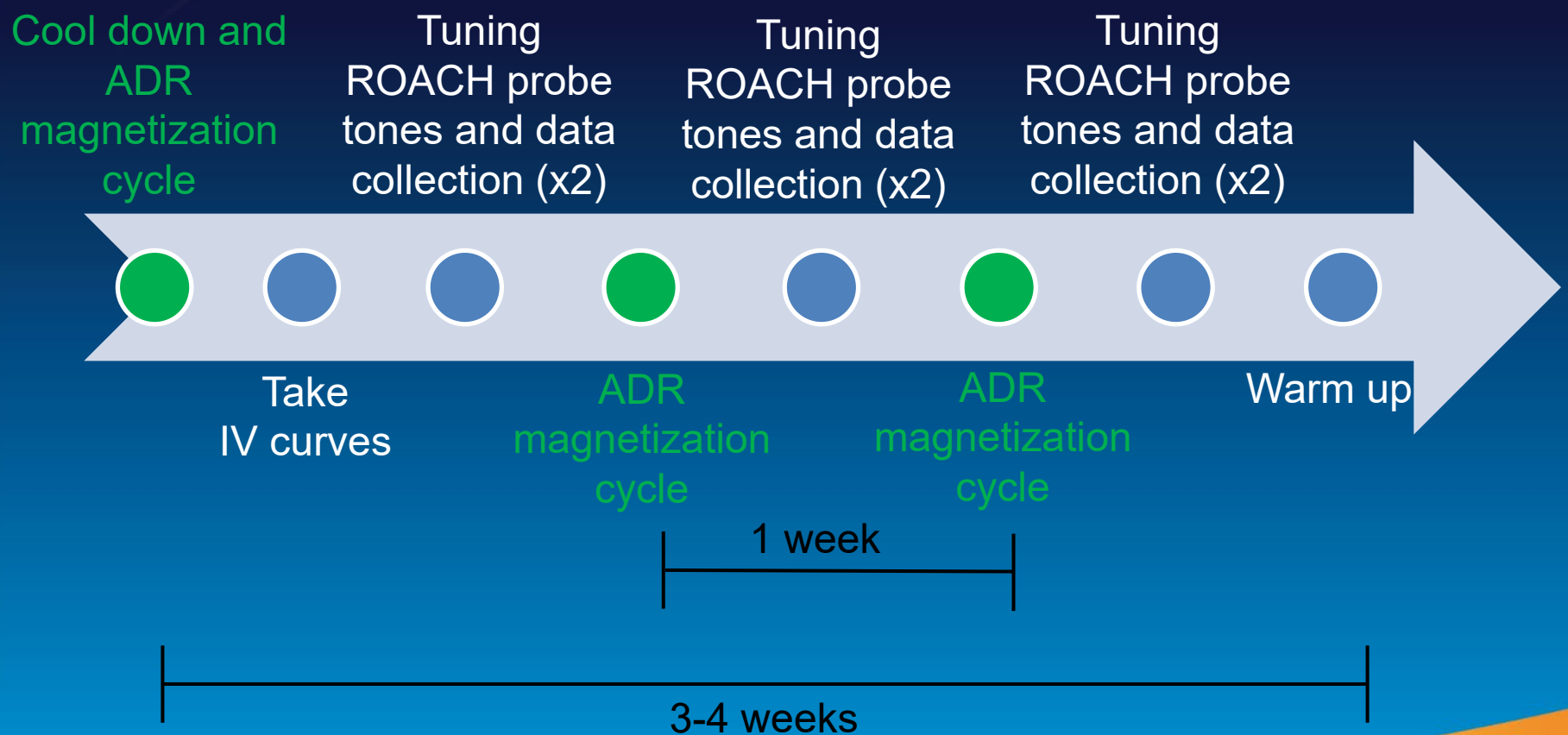
Timeline



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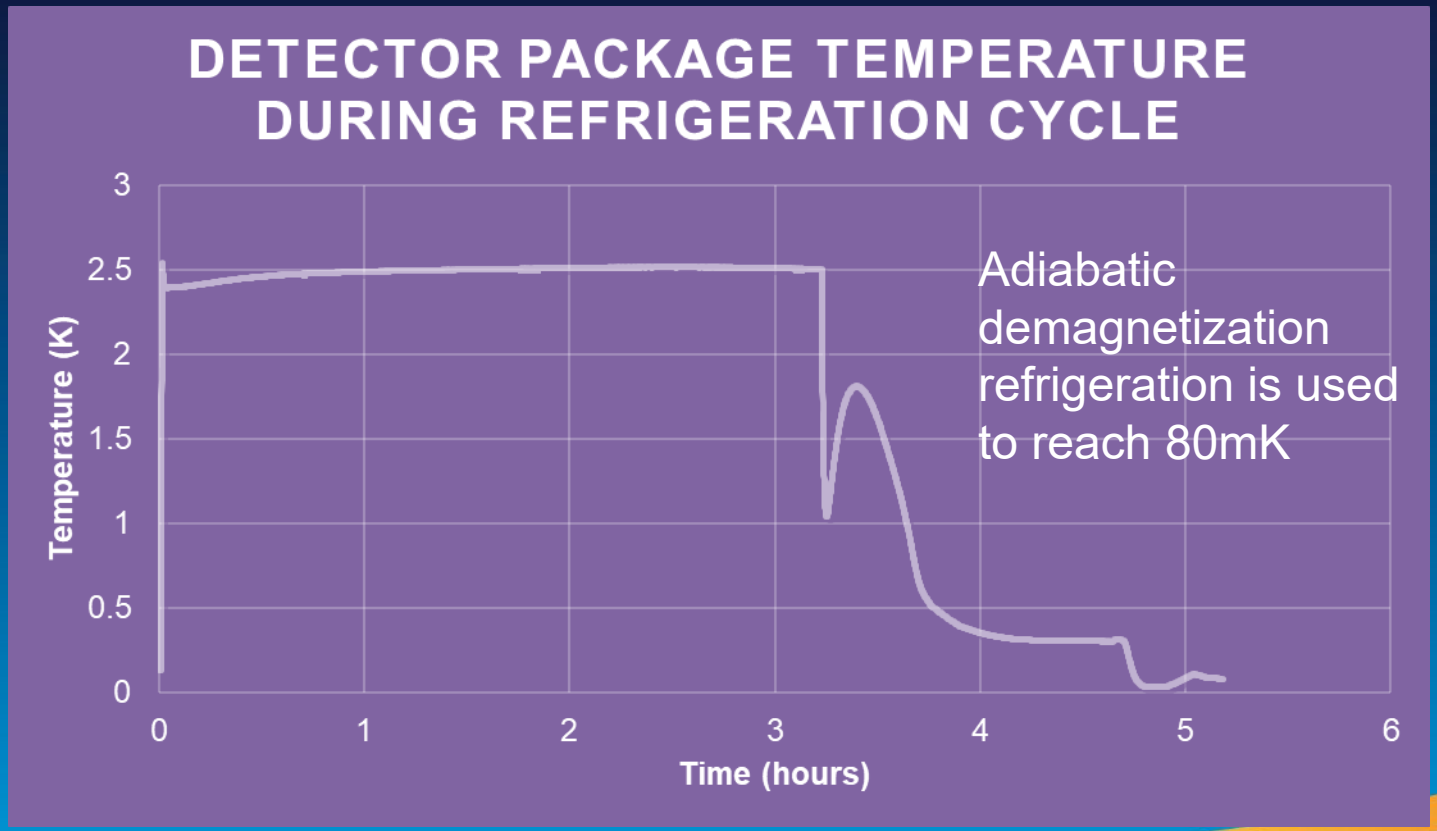
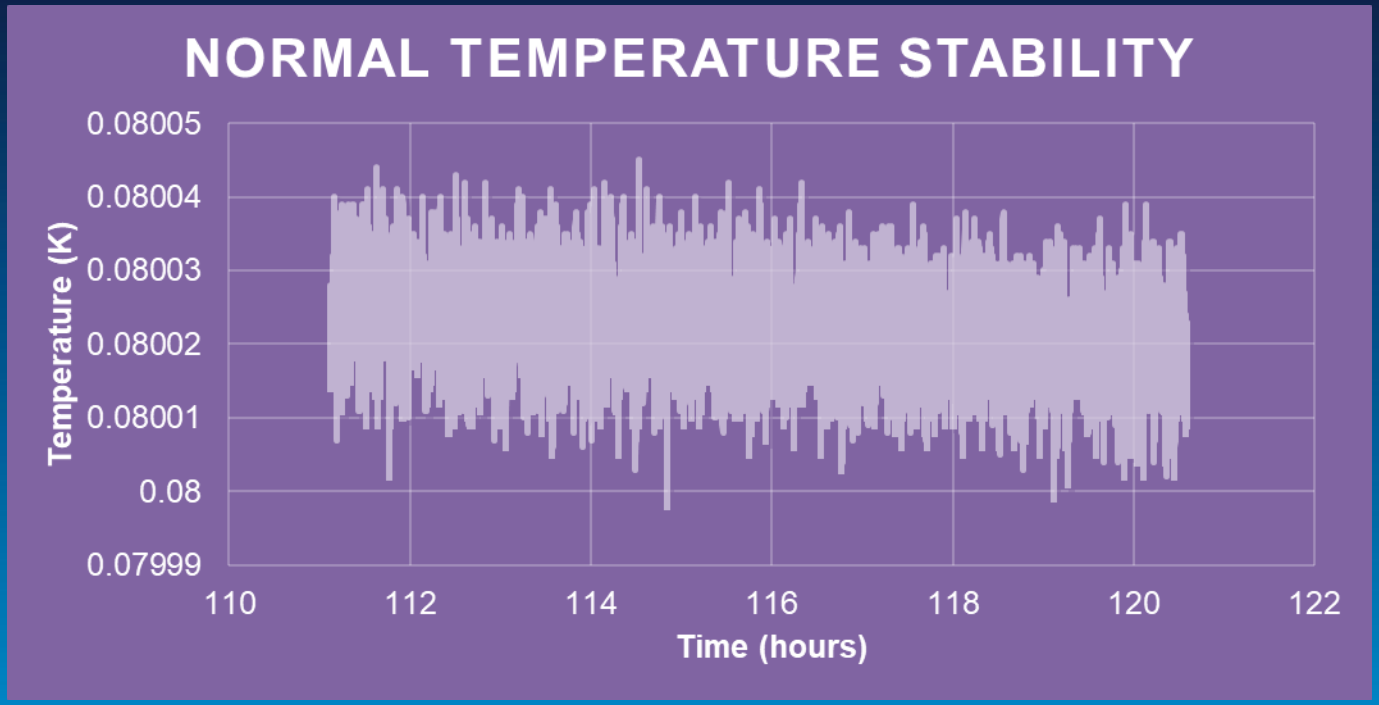
Running the Instrument

- Operating temperature (80mK)



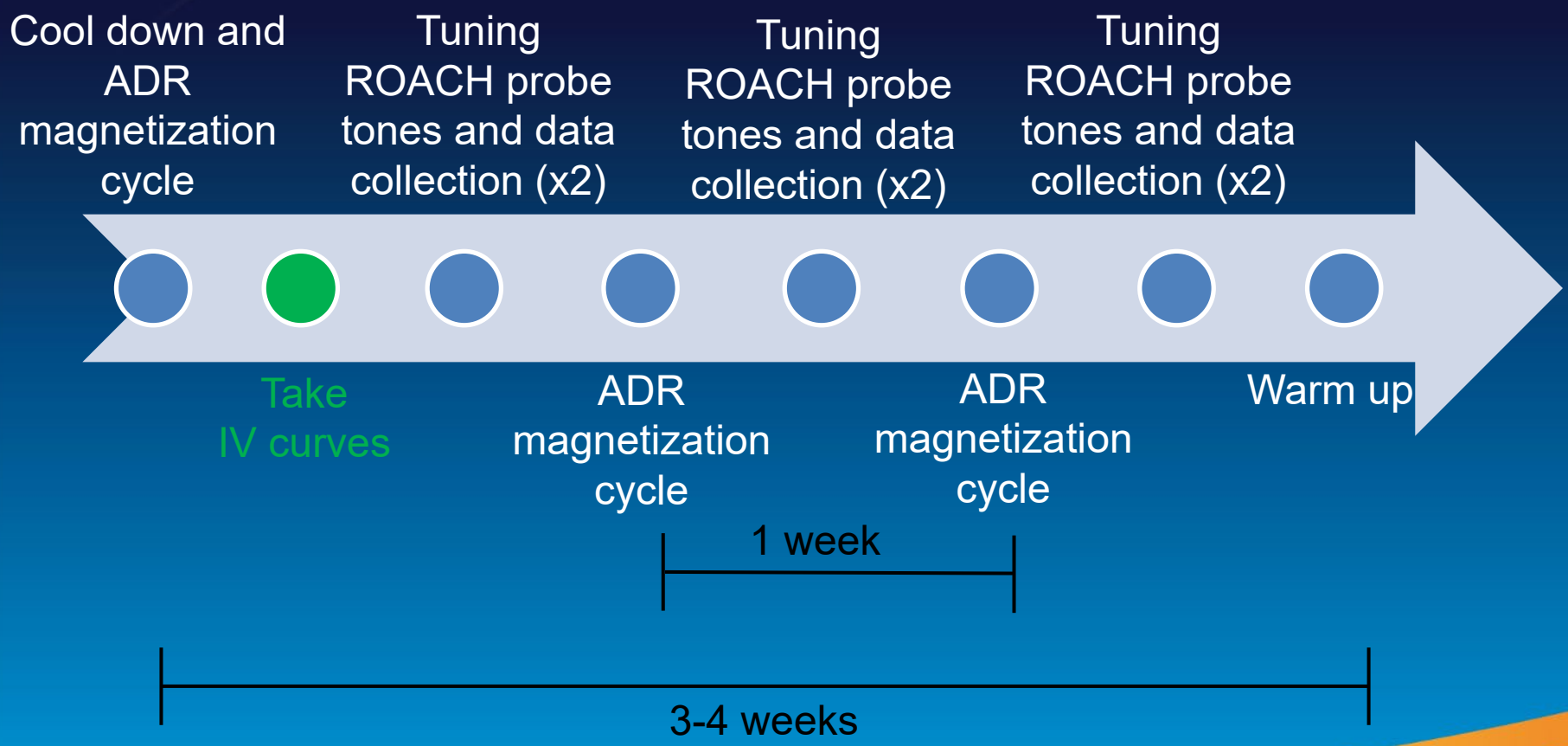
Running the Instrument

- Temperature/vibrational stability



Temperature and vibrational stability remain a challenge because of microcalorimeter sensitivity

Timeline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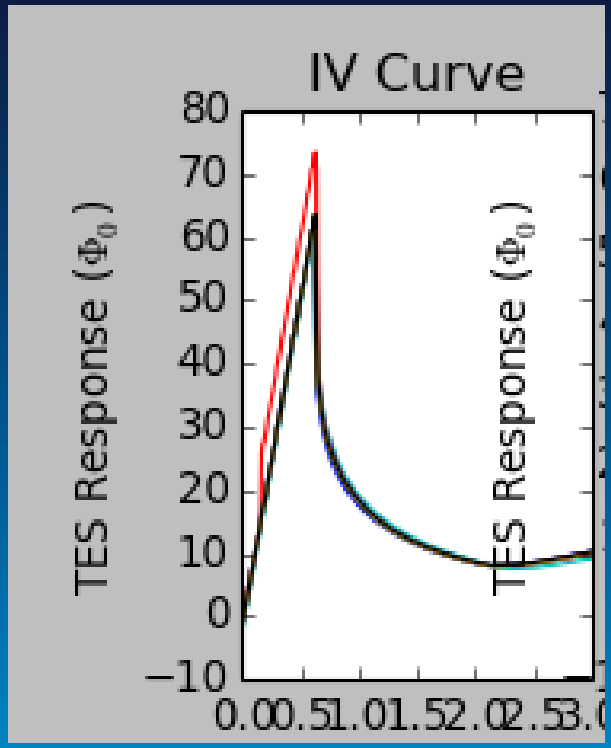
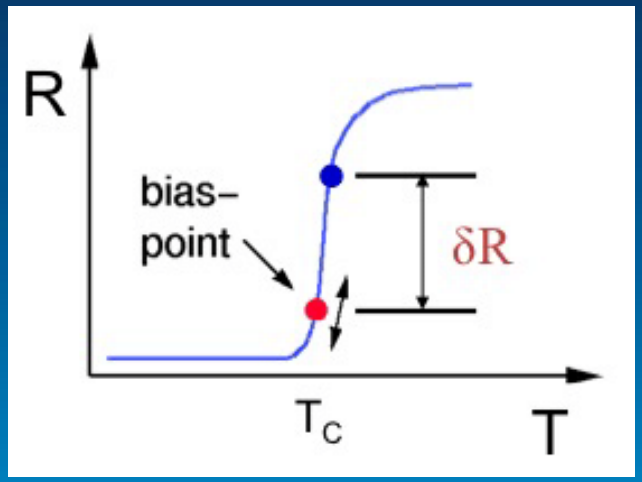
Take IV curves
ADR magnetization cycle
ADR magnetization cycle
Warm up
1 week
3-4 weeks

Running the Instrument

- Determining the TES bias value

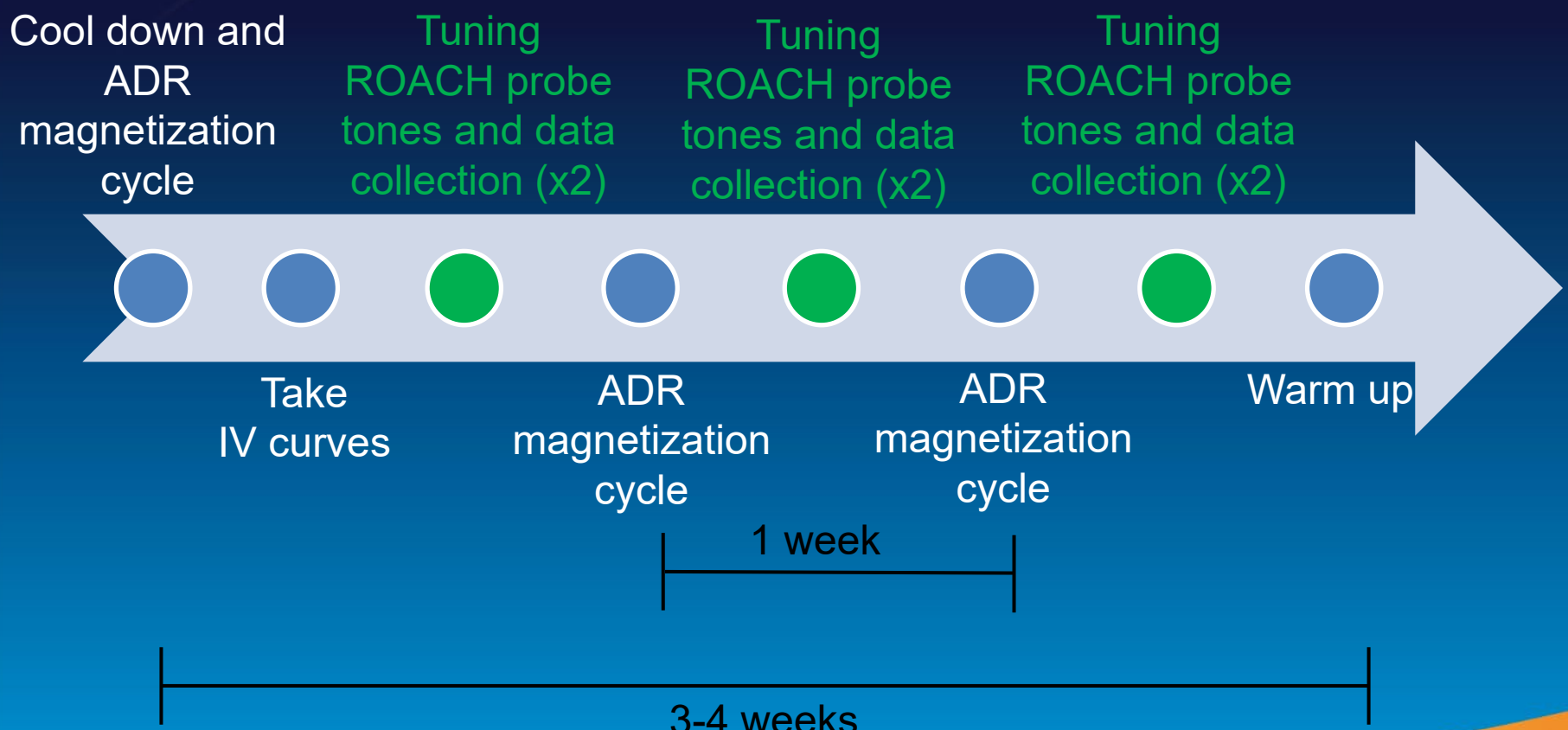




https://www.researchgate.net/figure/Illustrative-plot-of-resistance-vs-temperature-for-a-superconductor-The-transition-is_fig4_228440334

The bias point is chosen low on the superconducting-normal transition edge

Timeline



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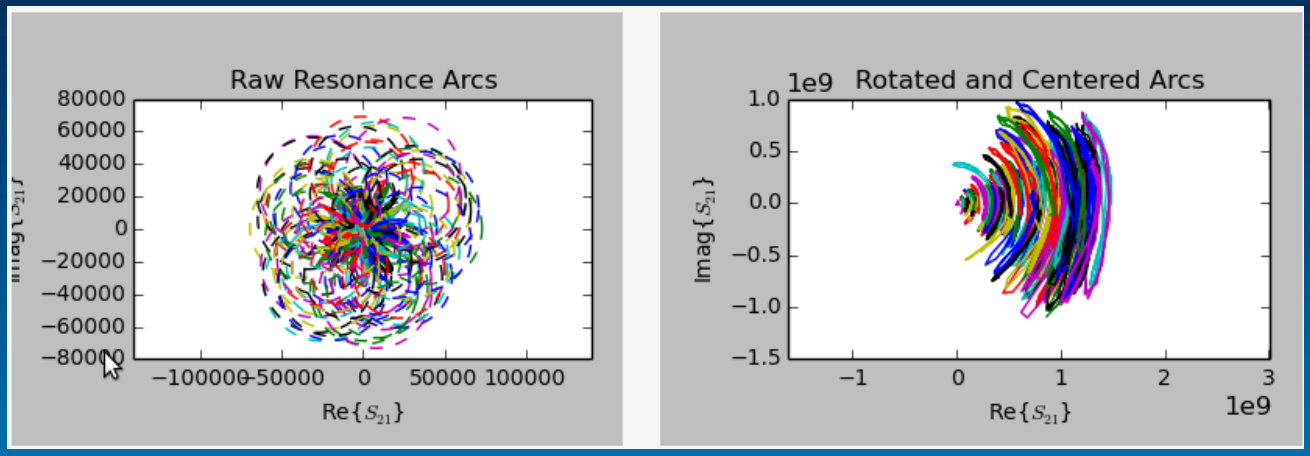
Running the Instrument

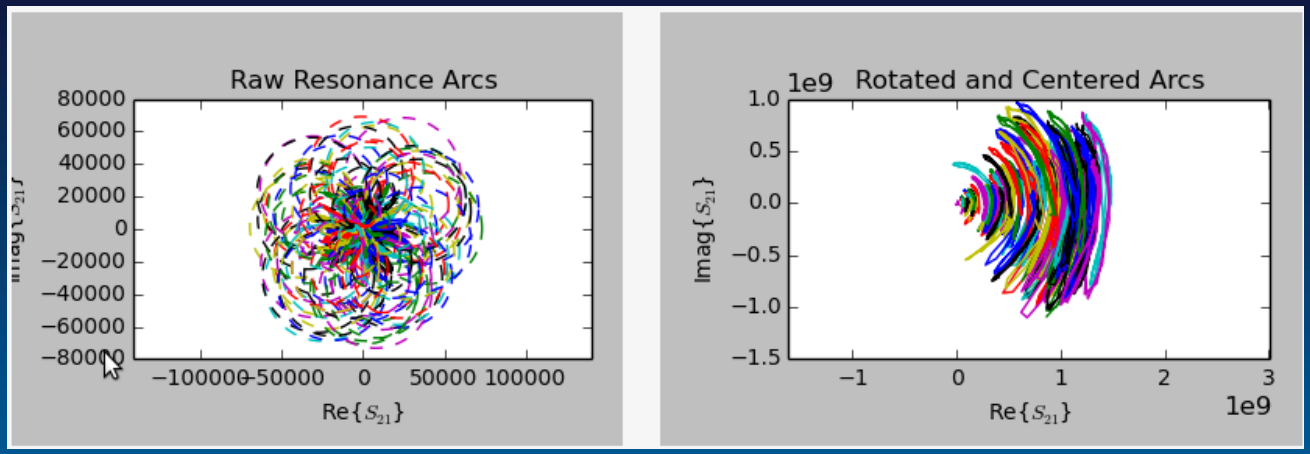
- Checking ROACH generated probe tones

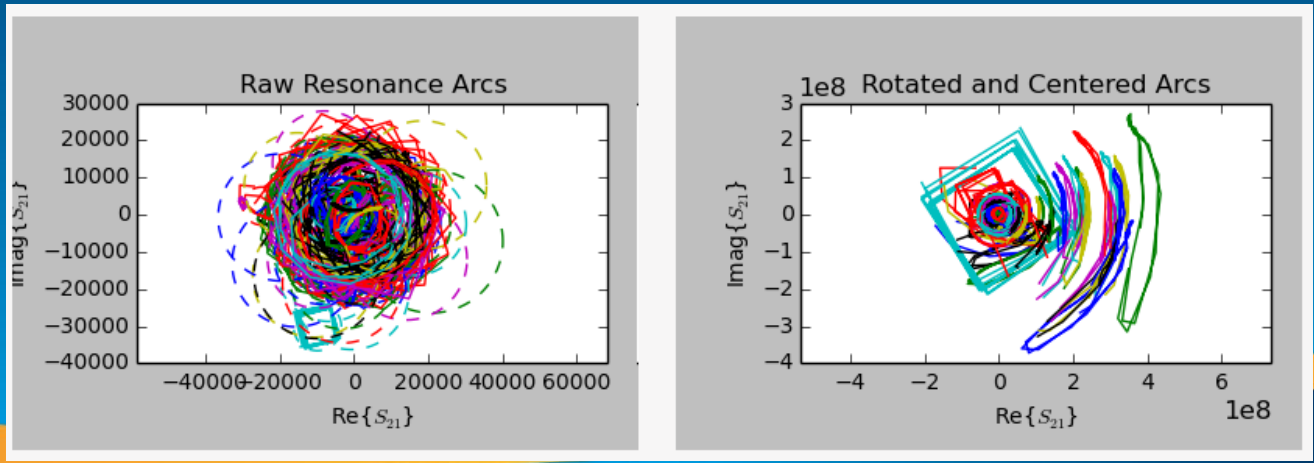


Each arc represents one pixel

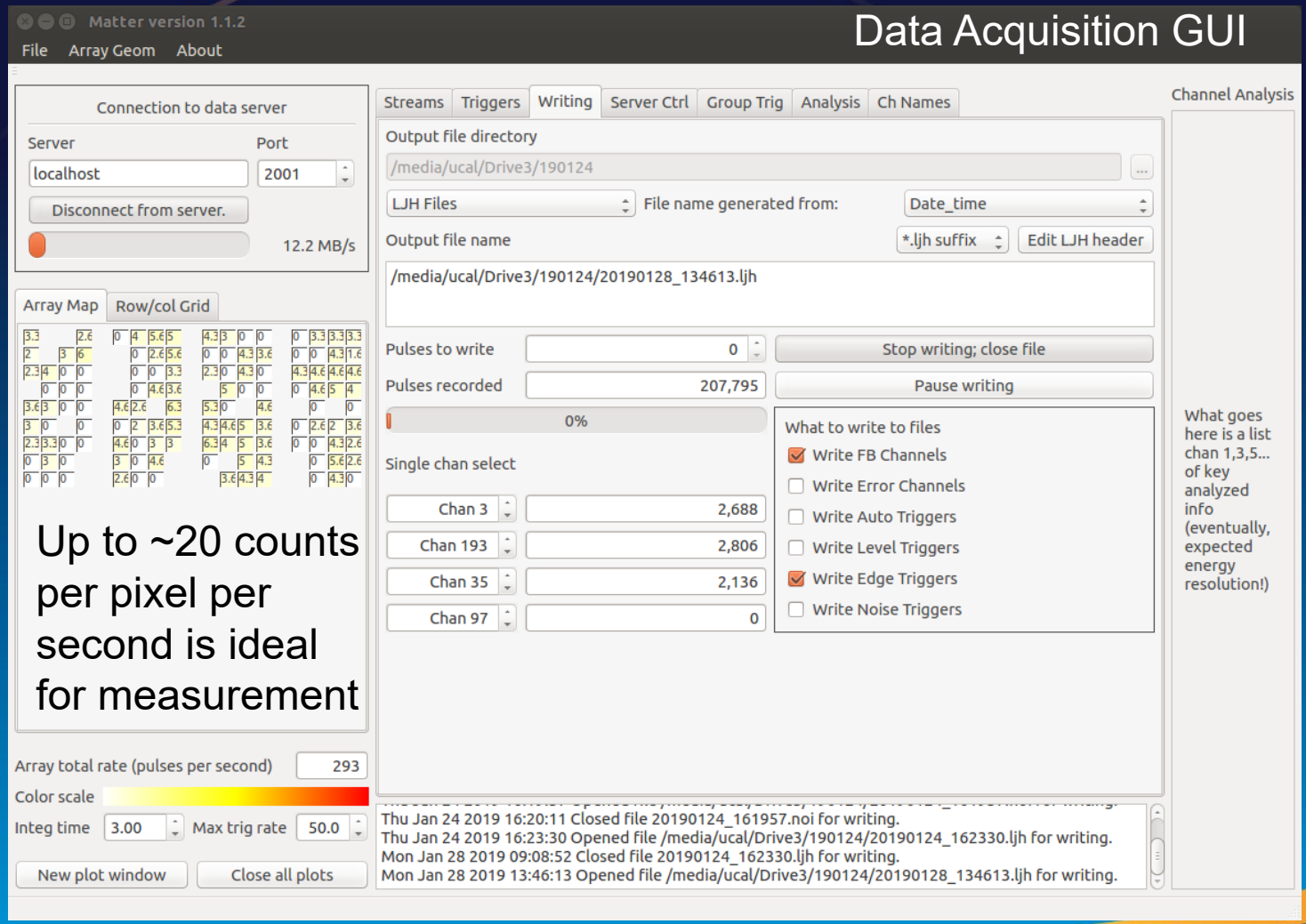
Running the Instrument

- Checking ROACH generated probe tones



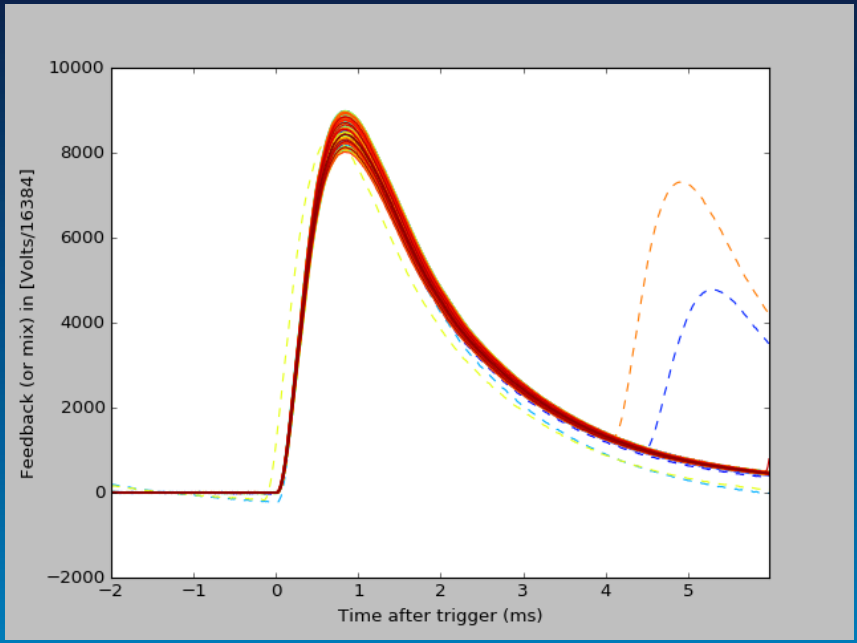


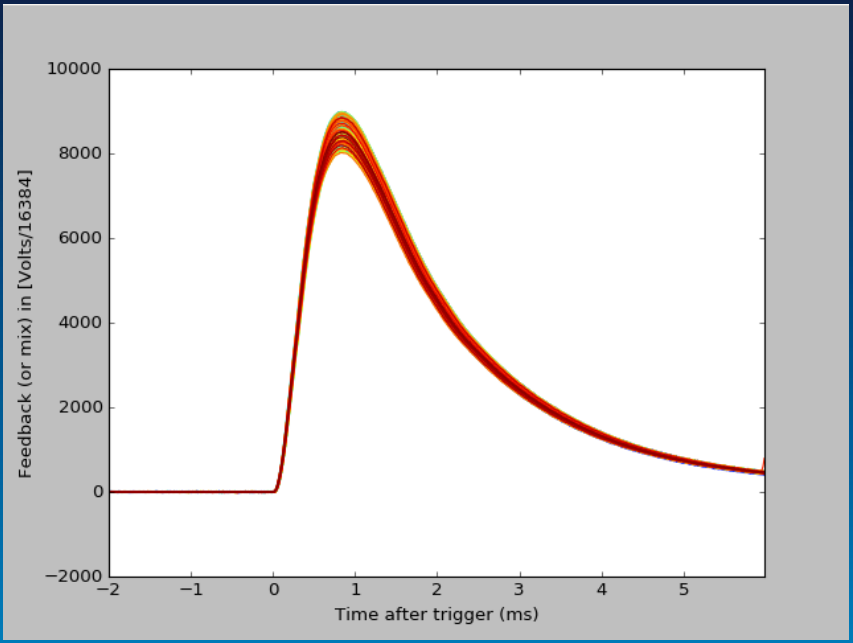
Running the Instrument



Making a Spectrum

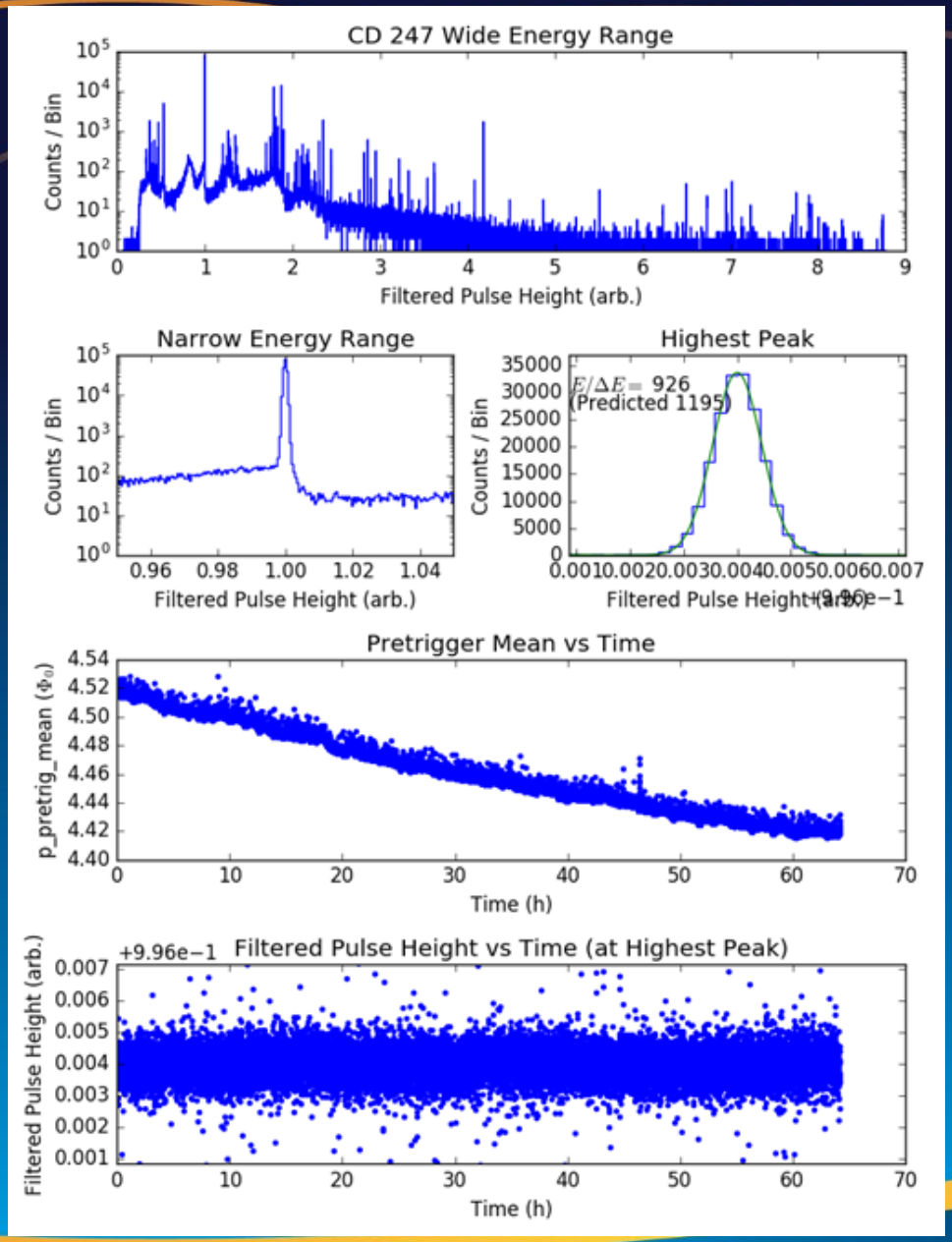
- Data saved! Now what?





Cut bad pulses and bad channels

Information is compiled for each pixel individually



Making a Spectrum

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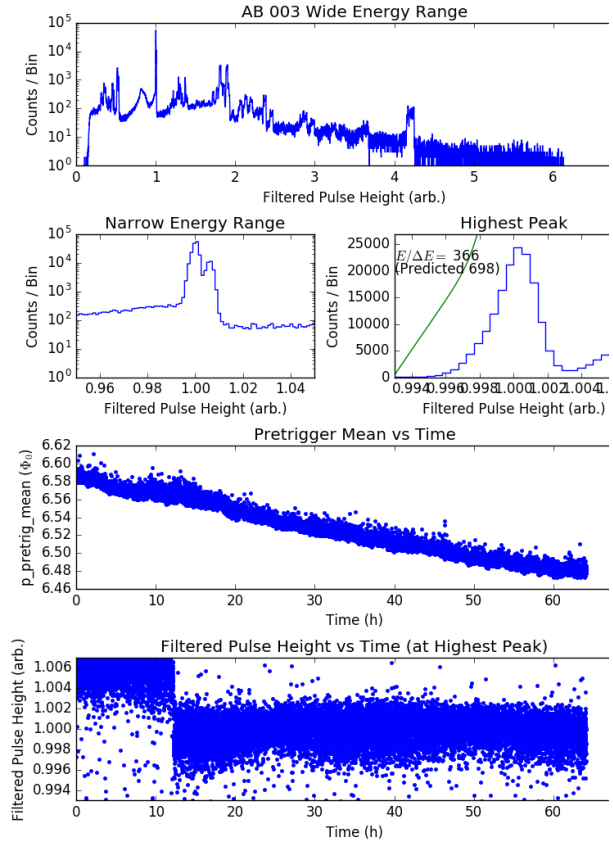
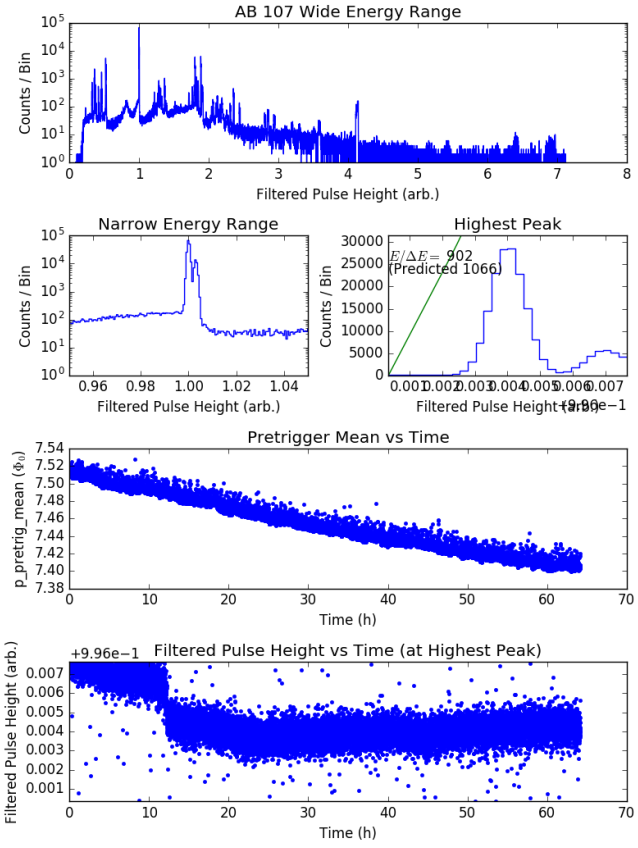
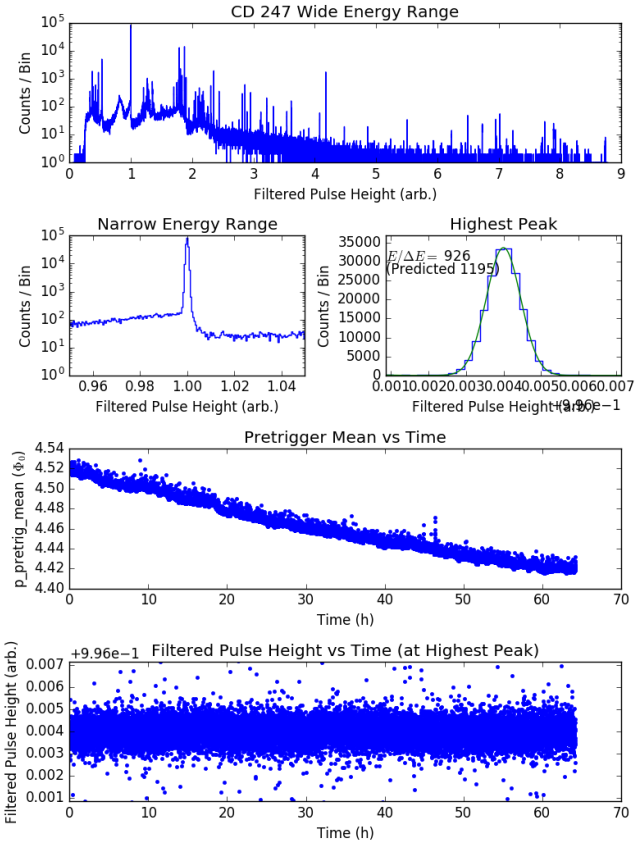
Every pixel is different

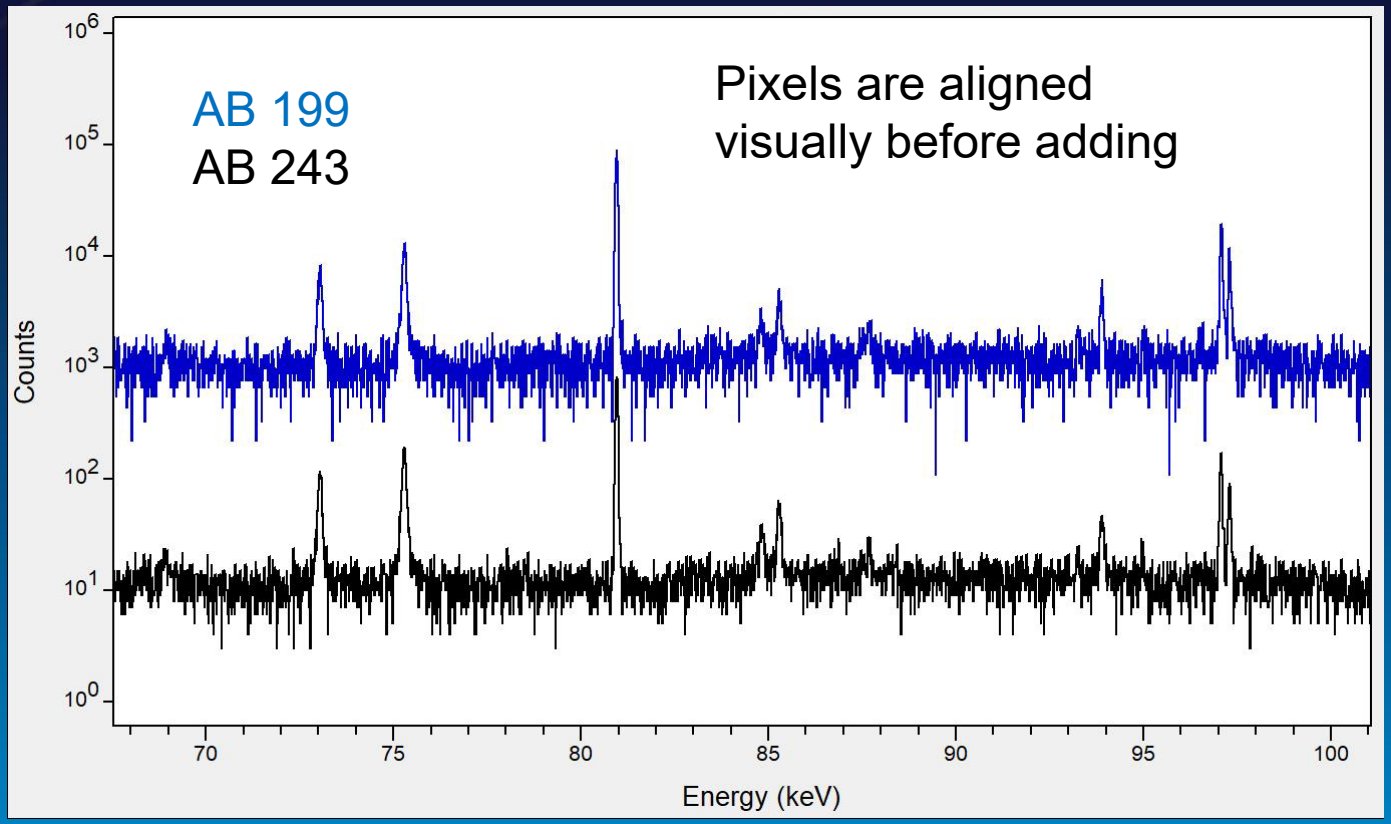






Eliminate double peaks

Making a Spectrum



Spectra from Mike Yoho

Co-57 + Ho-166m

Making a Spectrum

Low-burnup plutonium (PIDIE 6-1)

Parameter at 129.294 keV	Average	Co-added
FWHM [keV]	0.070	0.069
FWTM [keV]	0.13	0.14

High-burnup plutonium (PIDIE 6-6)

Parameter at 129.294 keV	Average	Co-added
FWHM [keV]	0.096	0.089
FWTM [keV]	0.19	0.20

Co-57 + Ho-166m

Parameter at 80.57 keV	Average	Co-added
FWHM [keV]	0.068	0.066
FWTM [keV]	0.13	0.13

Energy resolution is not degraded by adding pixels

Data provided by Mike Yoho

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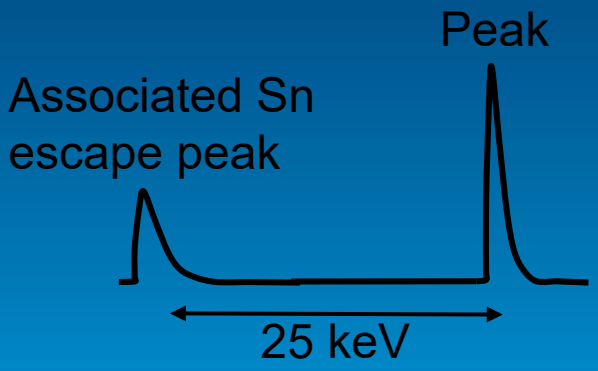
Making a Spectrum

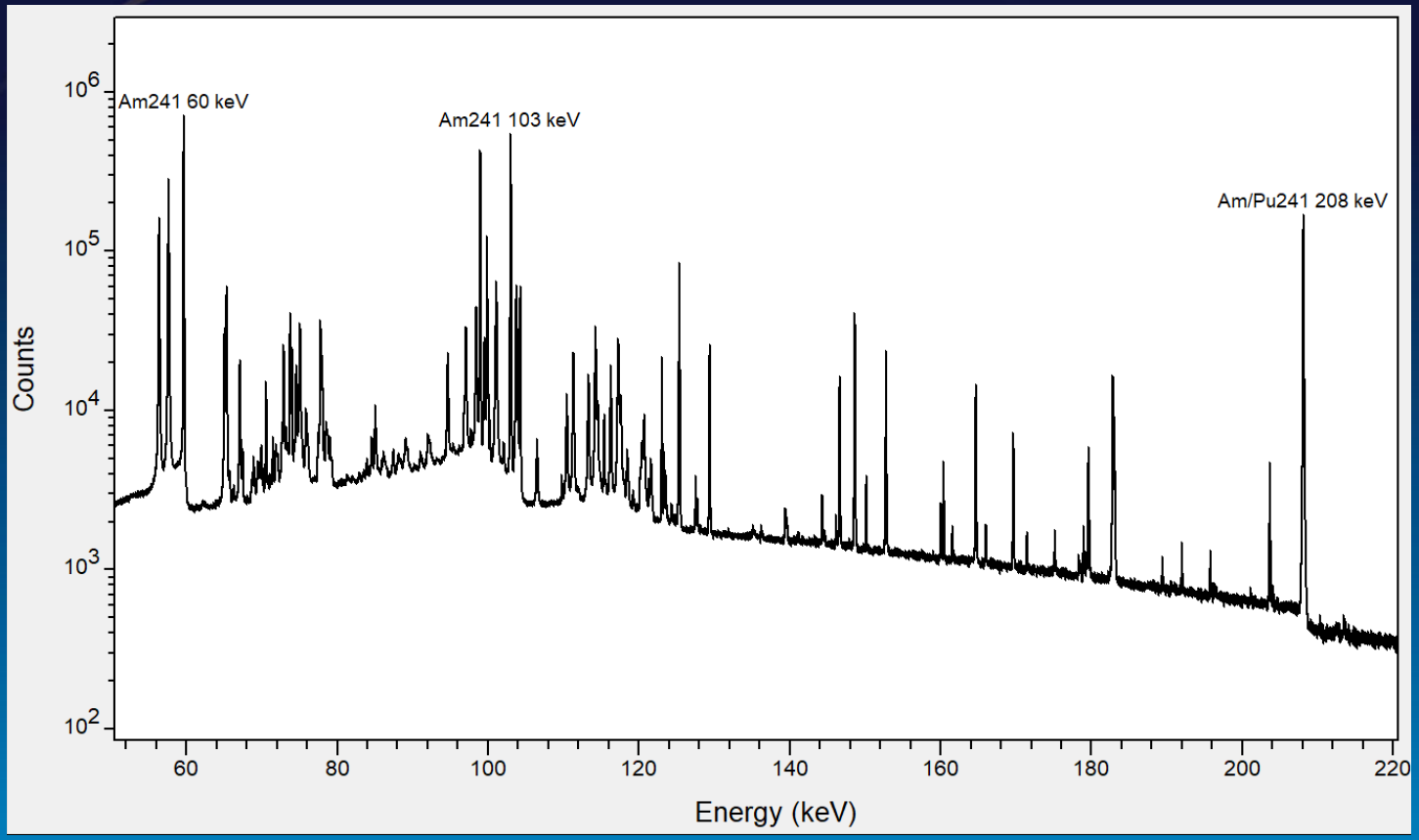
- Energy Calibration

Peaks from Ta and Sn to energy calibrate spectrum without knowing source



https://www.vectorstock.com/royalty-free-vector/periodic-table-element-tantalum-icon-vector-20585357

Making a Spectrum



Spectrum from Mike Yoho

High-burnup plutonium,
~26% ^{240}Pu (CBNM 61)

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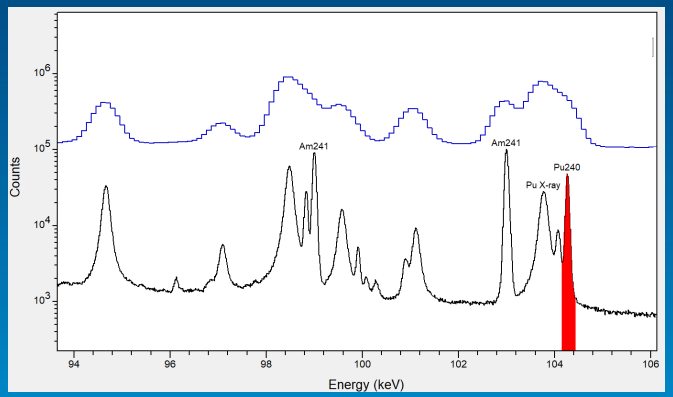
Conclusion

- Energy of absorbed particles recorded as pulses
- Frequency-domain multiplexing for readout of pixel array
- Good pulses used to create histogram
- Co-add pixels
- Energy calibrate
- Best spectra
- INL and field test



Low-burnup plutonium, ~6% ^{240}Pu (PIDIE 6-1)

Spectrum from Mike Yoho