How Small is Too Small?

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The Project

Most electronics are designed to function at temperatures ranging from 280 to 300 Kelvin, so it is **essential**, as science looks to space, to know how the physical properties and functions of circuits change once subjected to cryogenic temperatures.

nasa.gov

How small of a capacitor can we measure?

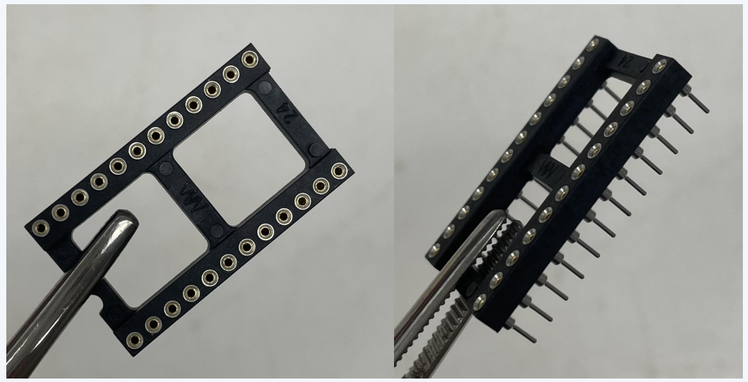
How do capacitors change in cryogenic temperatures?

Space.com

Project Outline

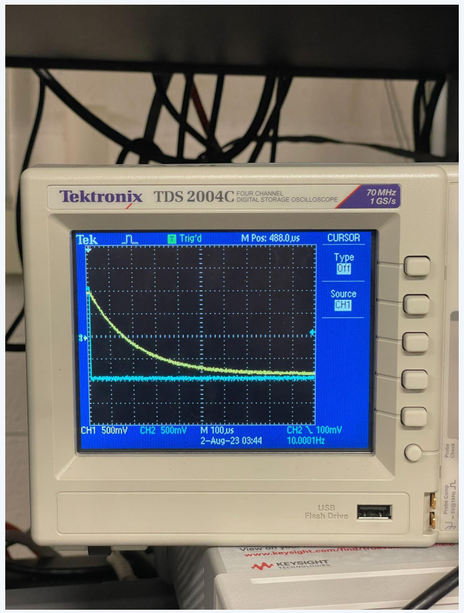
Create a chip

Not to be mistaken for a potato chip!



Take Measurements

I measured the time and frequency domain of the voltage drop of several capacitors, modeled by the oscilloscope below!



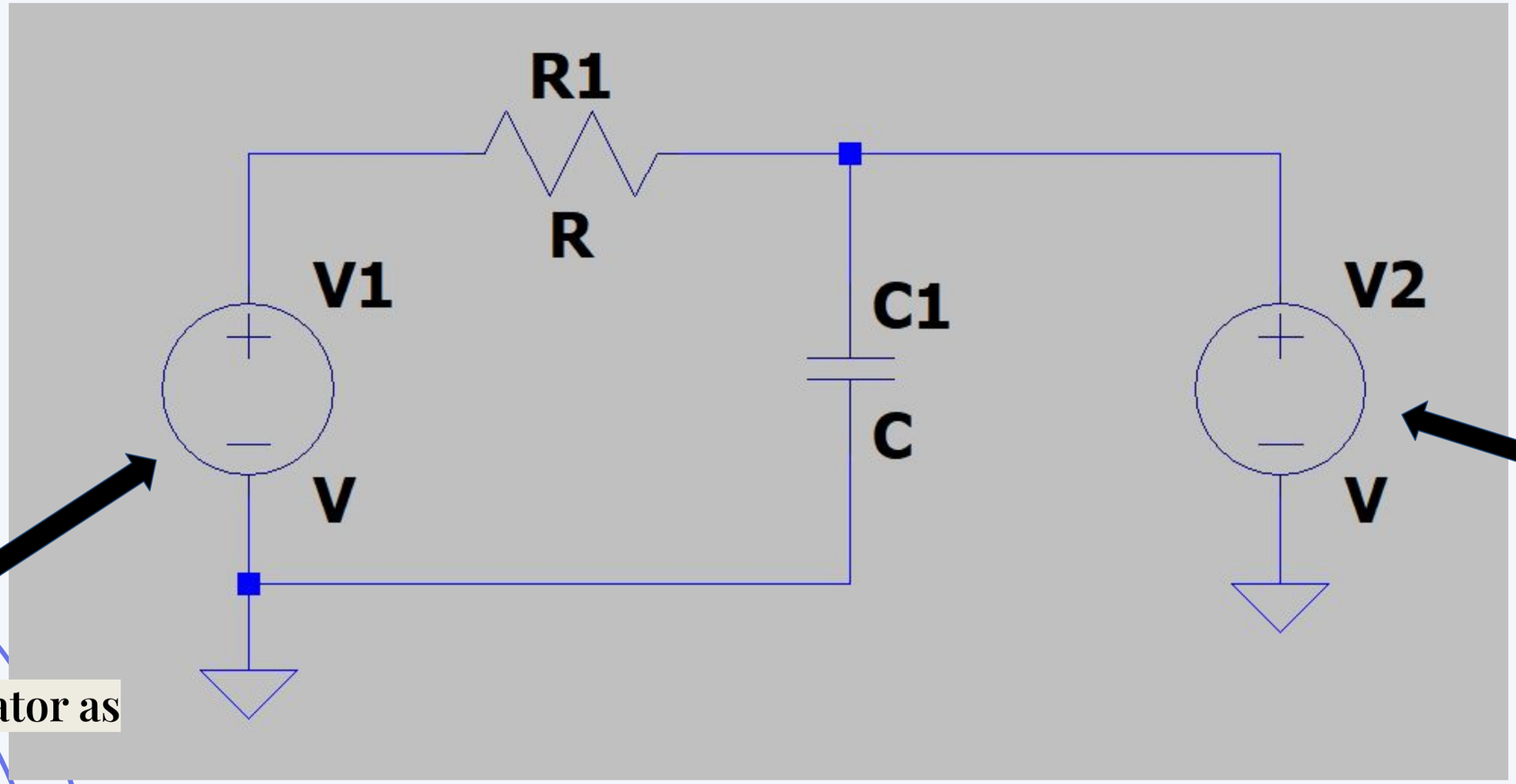
Compare Results

To be able to see changes in capacitance, I have to convert the exponential form of the capacitors voltage drop into something more linear.

$$V=(V_0)e^{-t/T}$$

$$\log(V)=(-1/RC)t + \log(V_0)$$

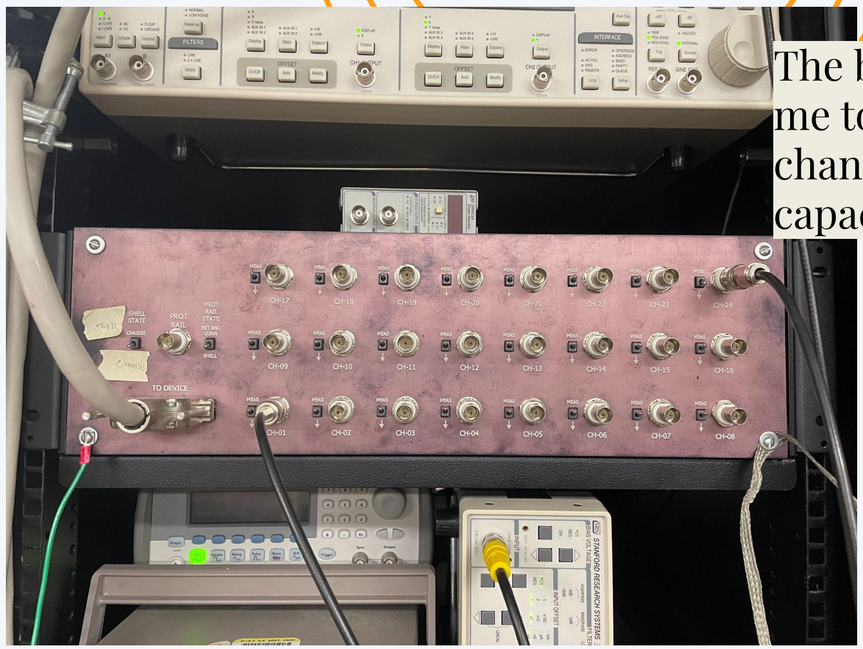
Circuit Diagram



Waveform generator as power source

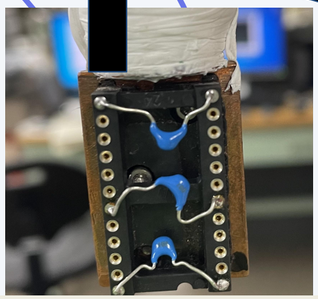
The oscilloscope used to read the voltage drop acts as a voltmeter in parallel

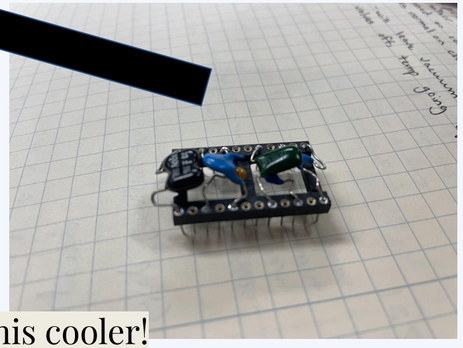
The Setup



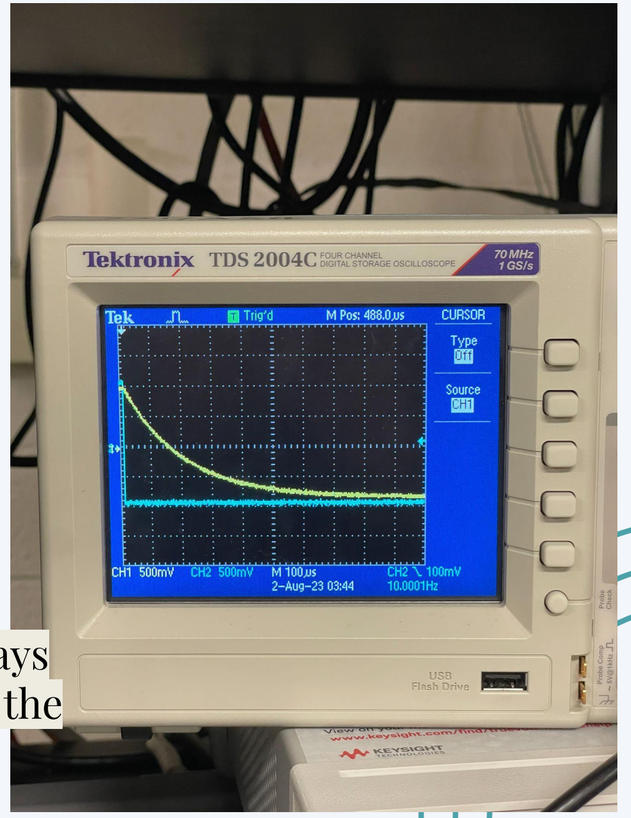
The break out box (aka BOB) allows me to move BNC cables from channel to channel to view different capacitors.

The cryostat!



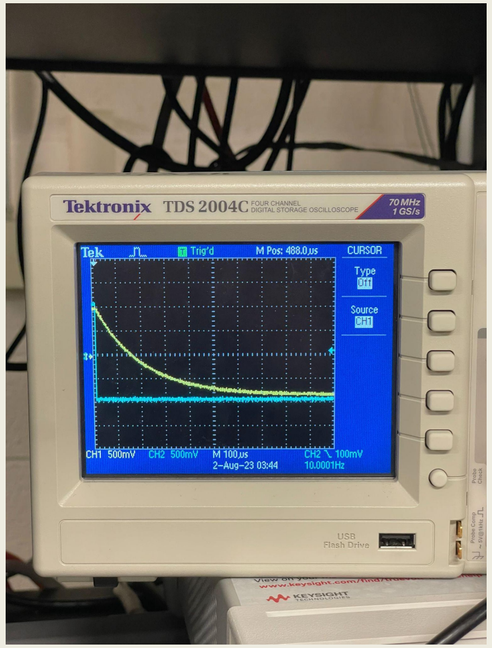


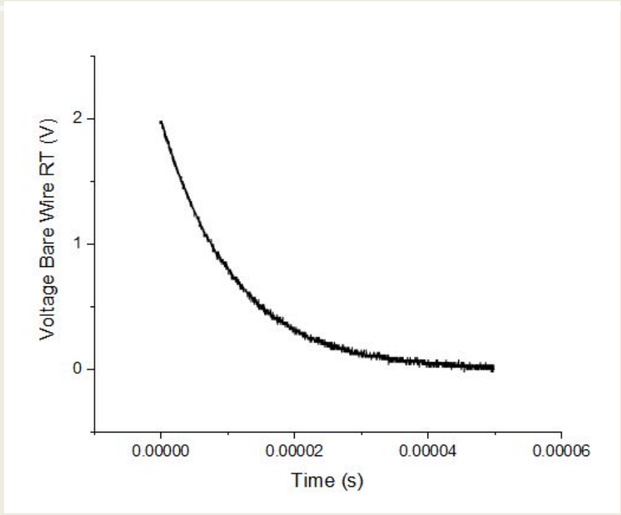
These little guys get to go at the bottom of this cooler!

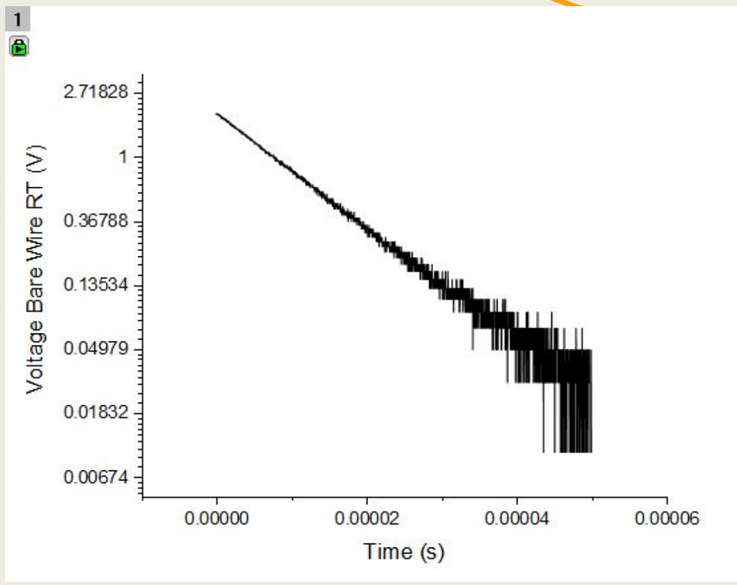


The oscilloscope displays the discharge curve of the capacitors.

Finding the right fit







$V=(V_0)e^{-t/T}$

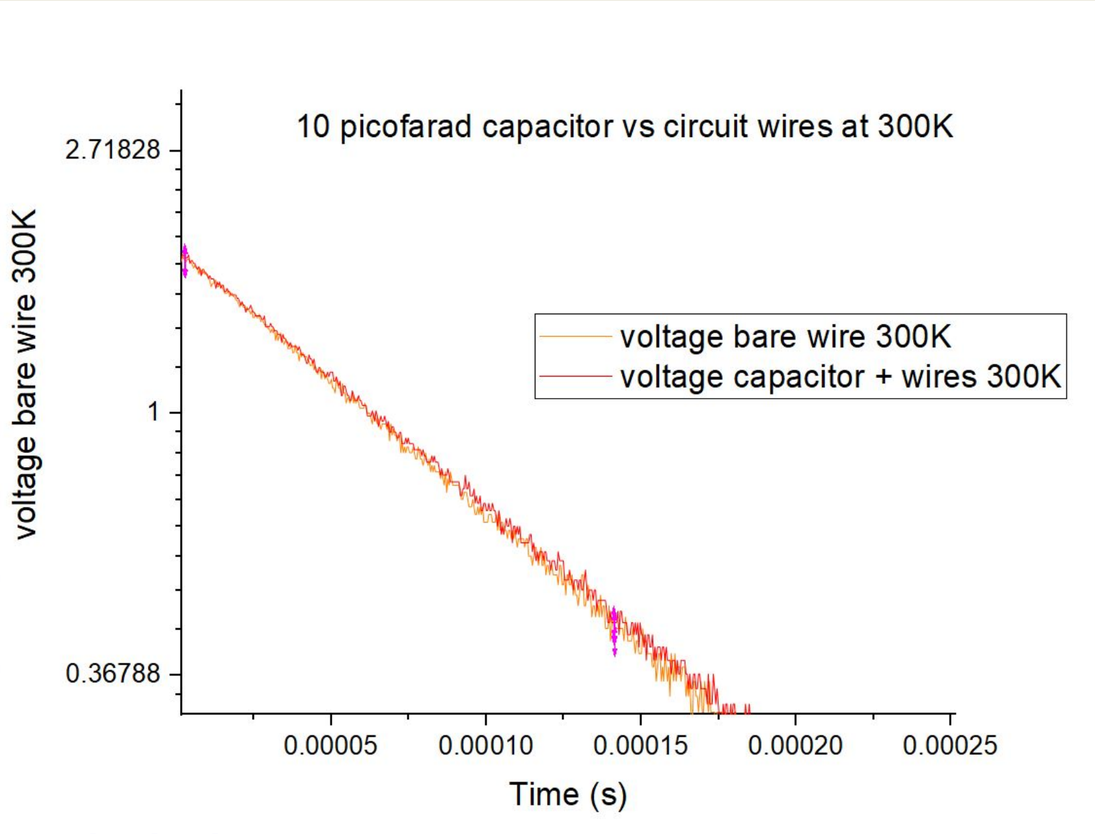
$\log(V)=(-1/RC)t + \log(V_0)$

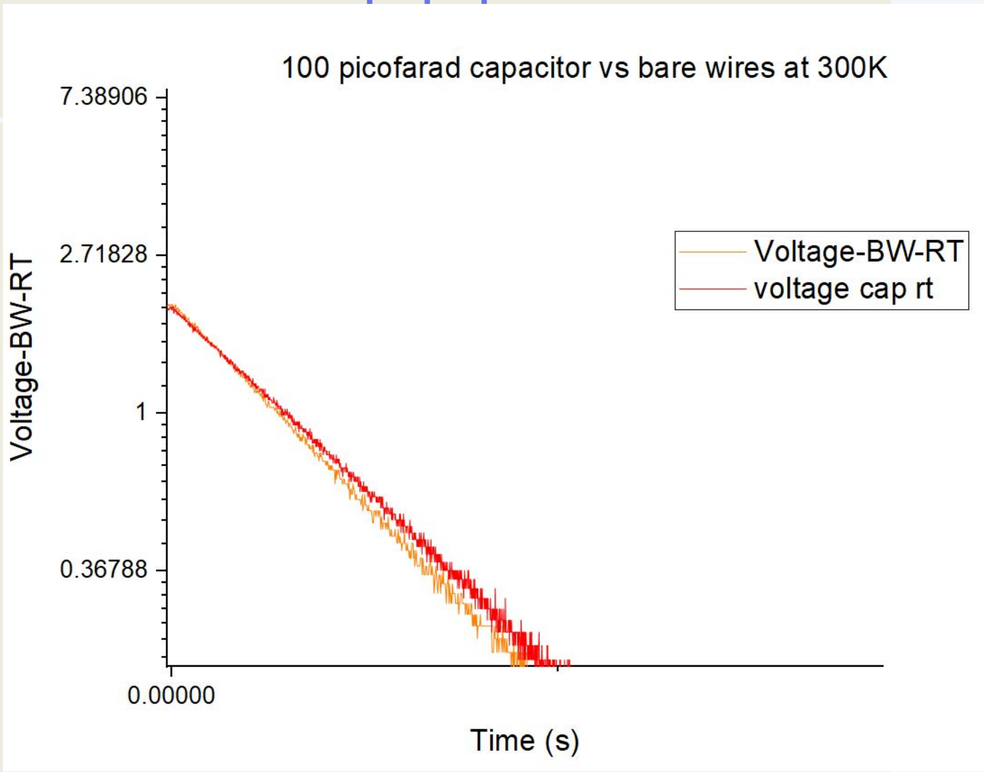
Can we see anything at room temperature?

Yes, we can!

- Able to measure down to 10 picofarads!

- As a reminder 1 picofarad= 1 x 10^-12 Farads

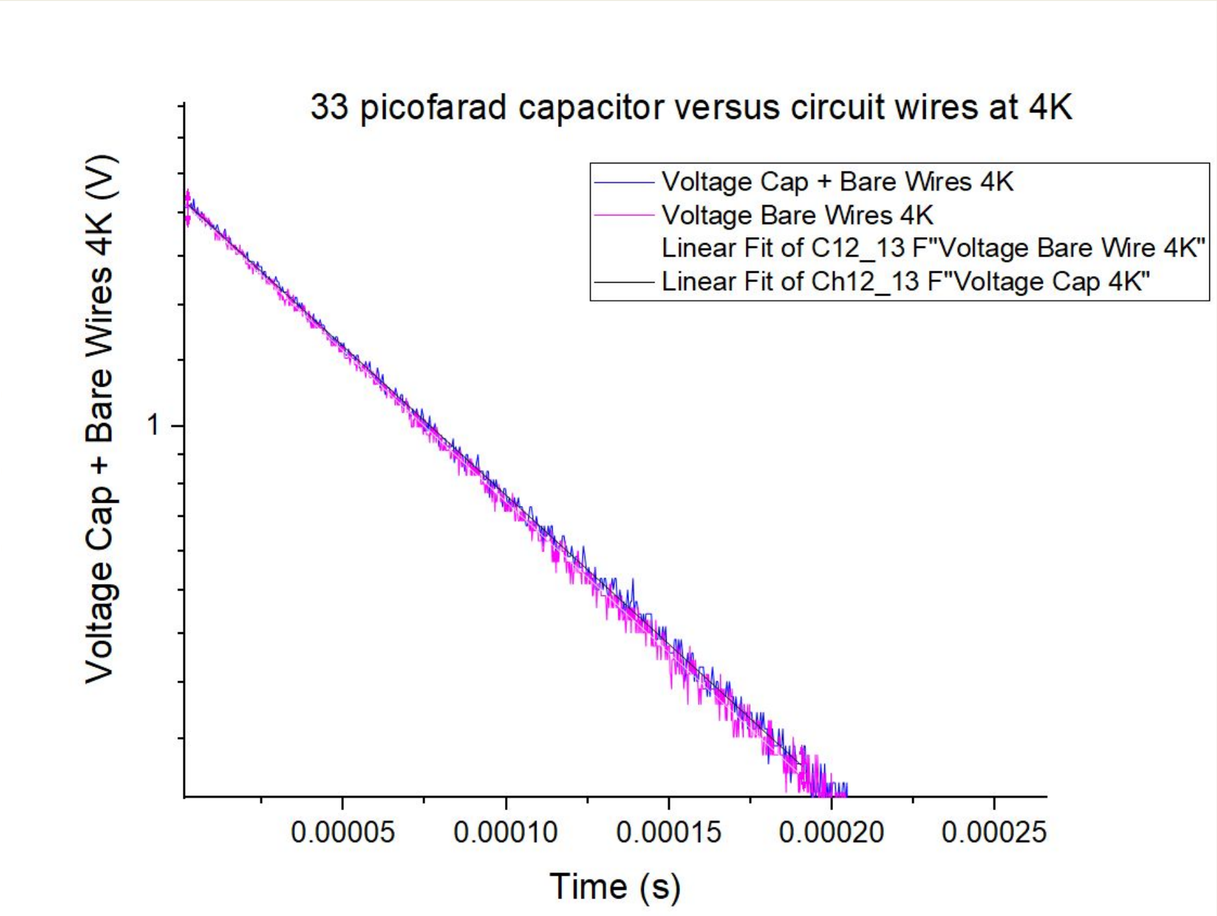


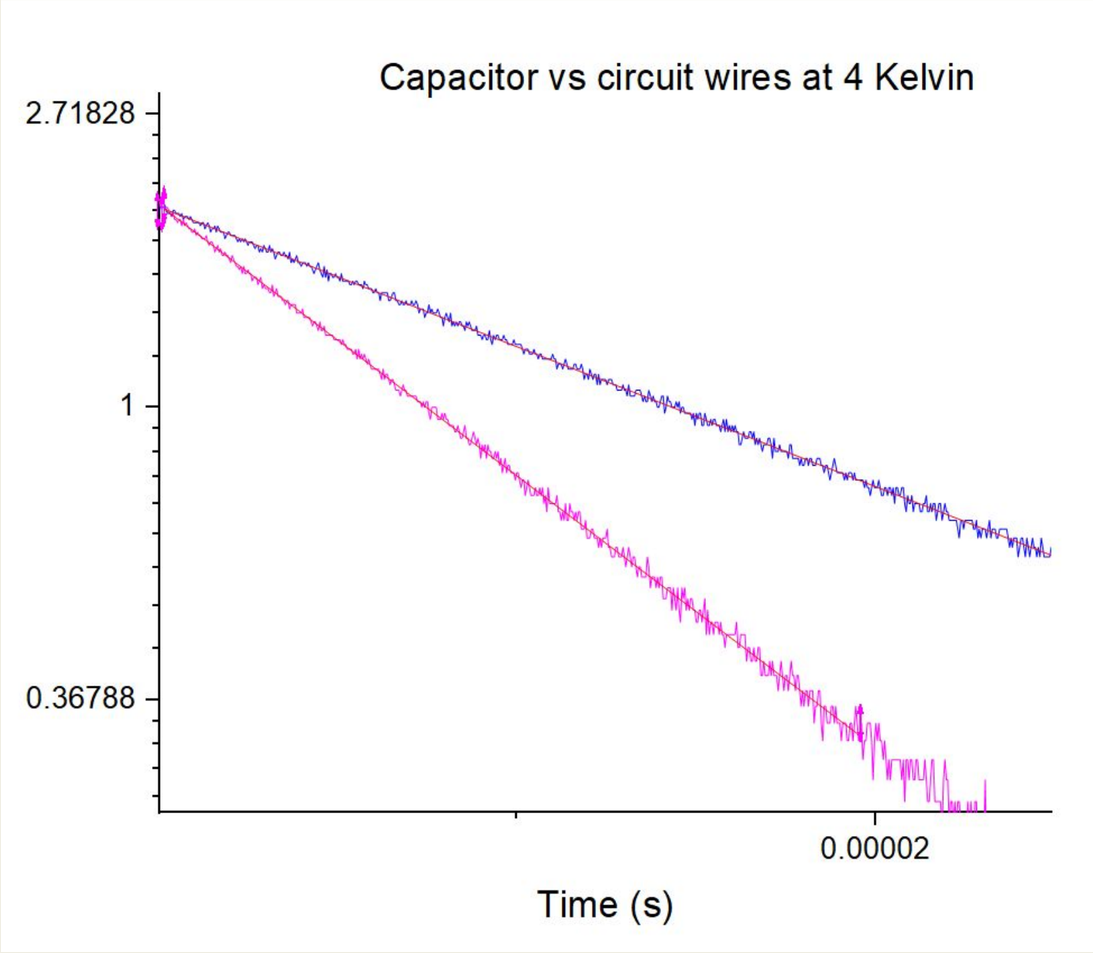


How about at 4 Kelvin?

At a temperature of 4 Kelvin (-269 degrees Celsius)...

We can see very small capacitors at 4 Kelvin as well!

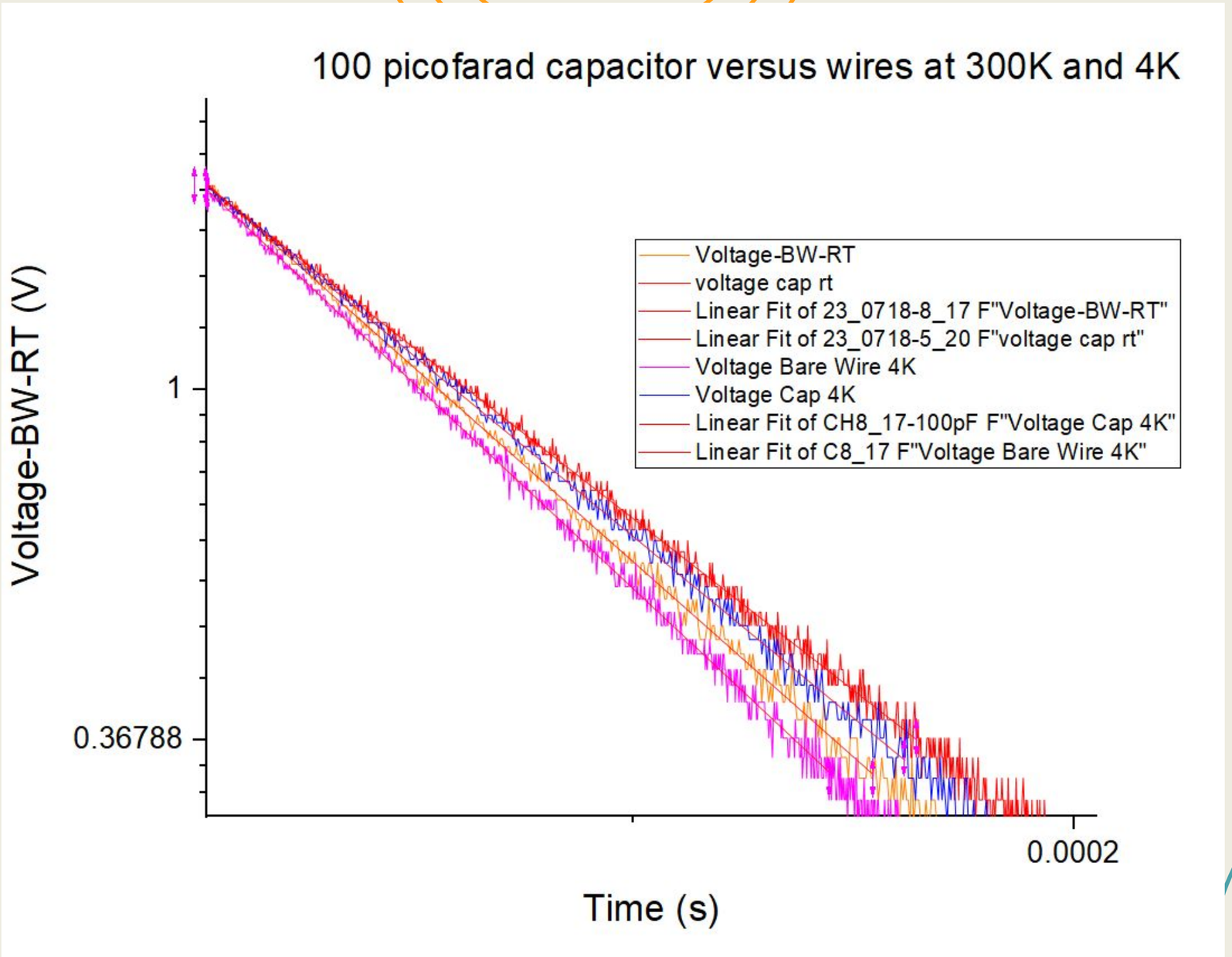




Capacitors at 300 K vs 4 K... Any differences?

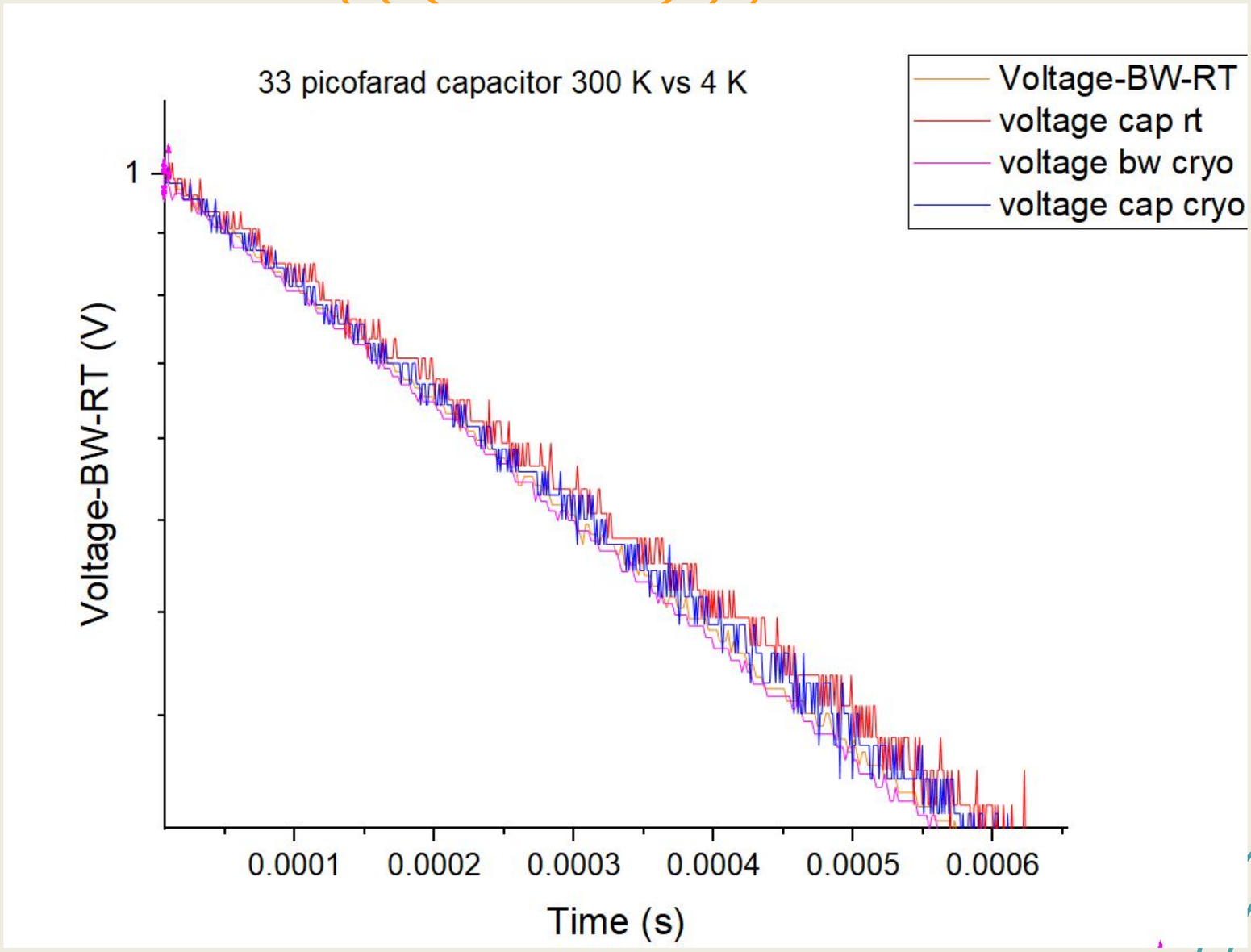
We found that capacitance decreases in cryogenic temperatures!

Pictured to the right is the data from a 100 picofarad capacitor at 300 K and at 4 K.



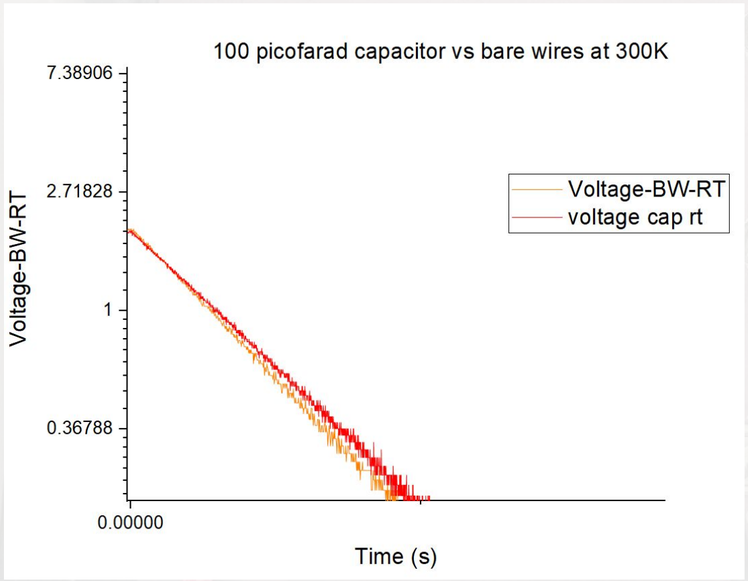
How small can we go?

Turns out I can still measure changes in capacitance with an even smaller capacitor!

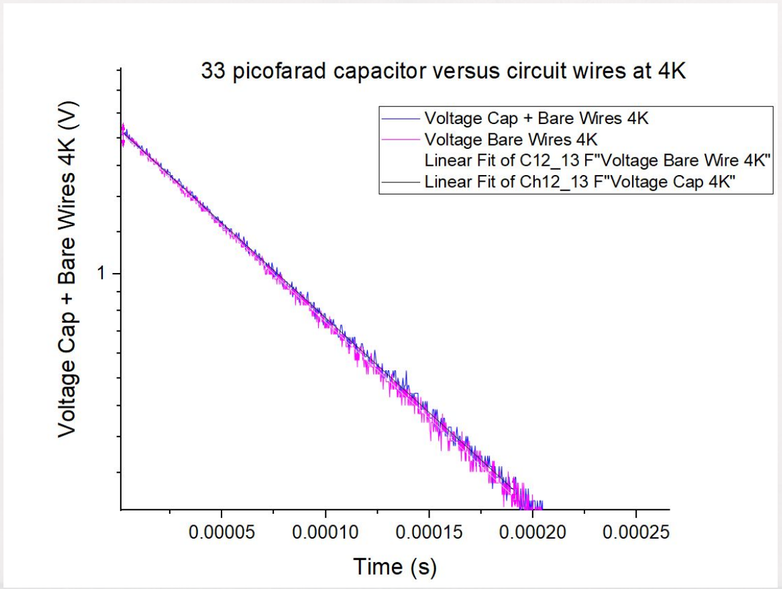


Conclusions

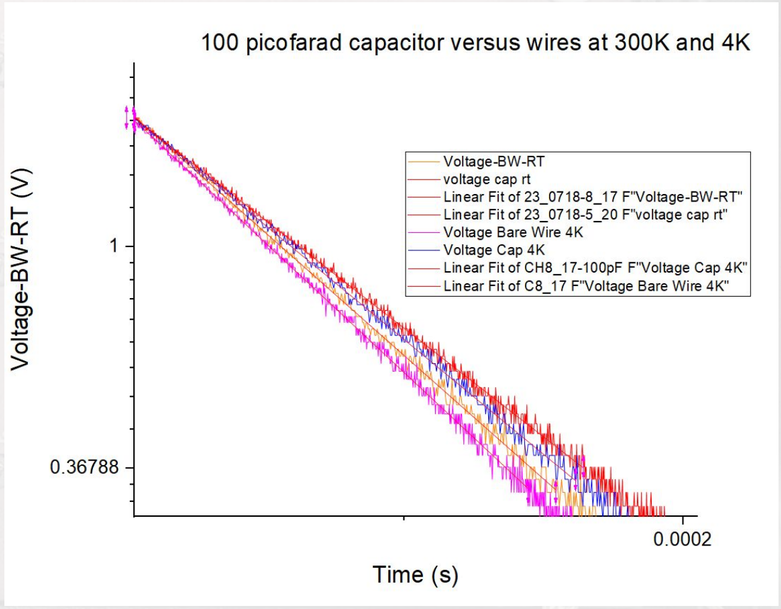
We are able to measure capacitors on a scale of picofarads!



We were able to see the same capacitors at 4 Kelvin



Capacitance decreases in cryogenic environments!



Thank You!

Acknowledgements

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