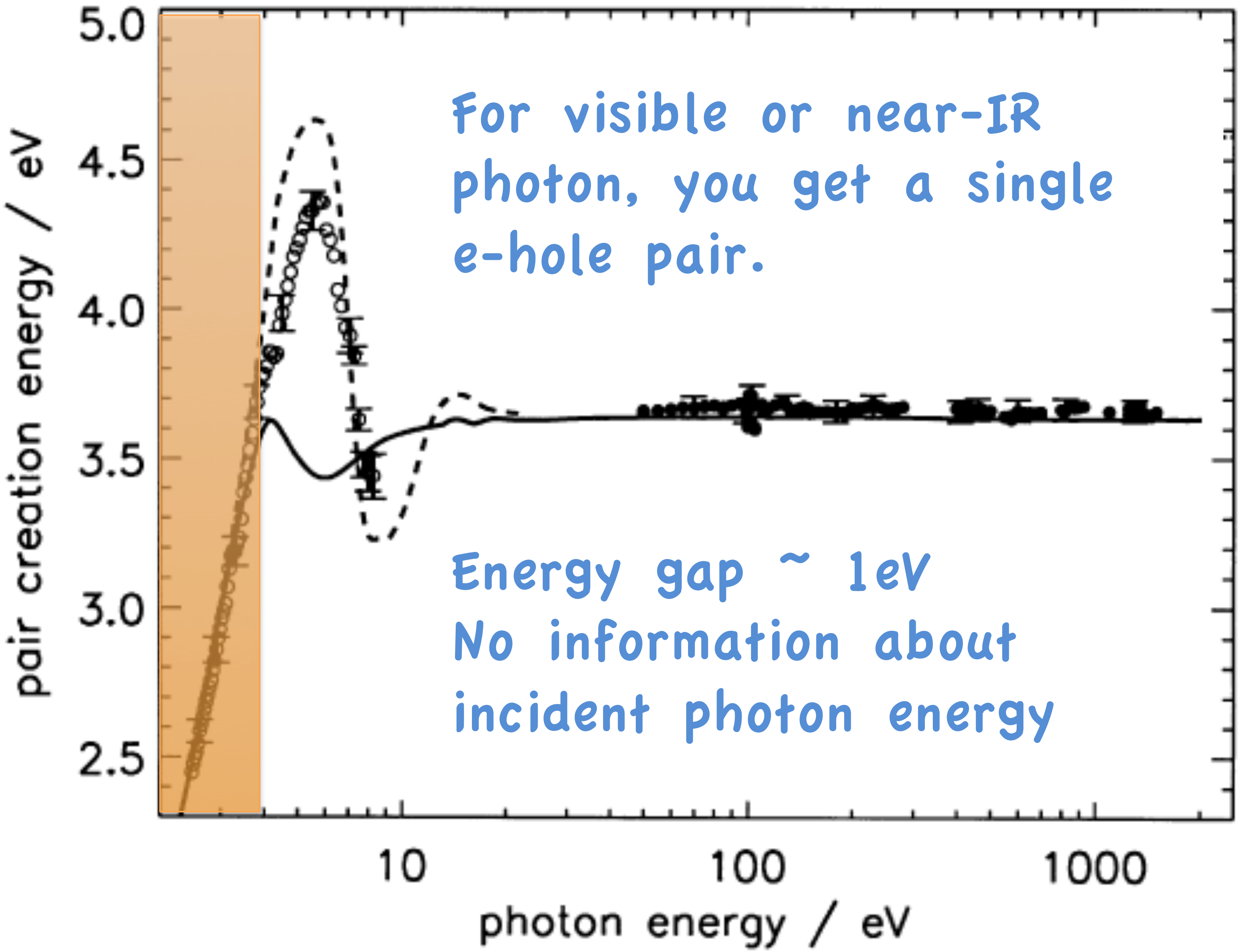
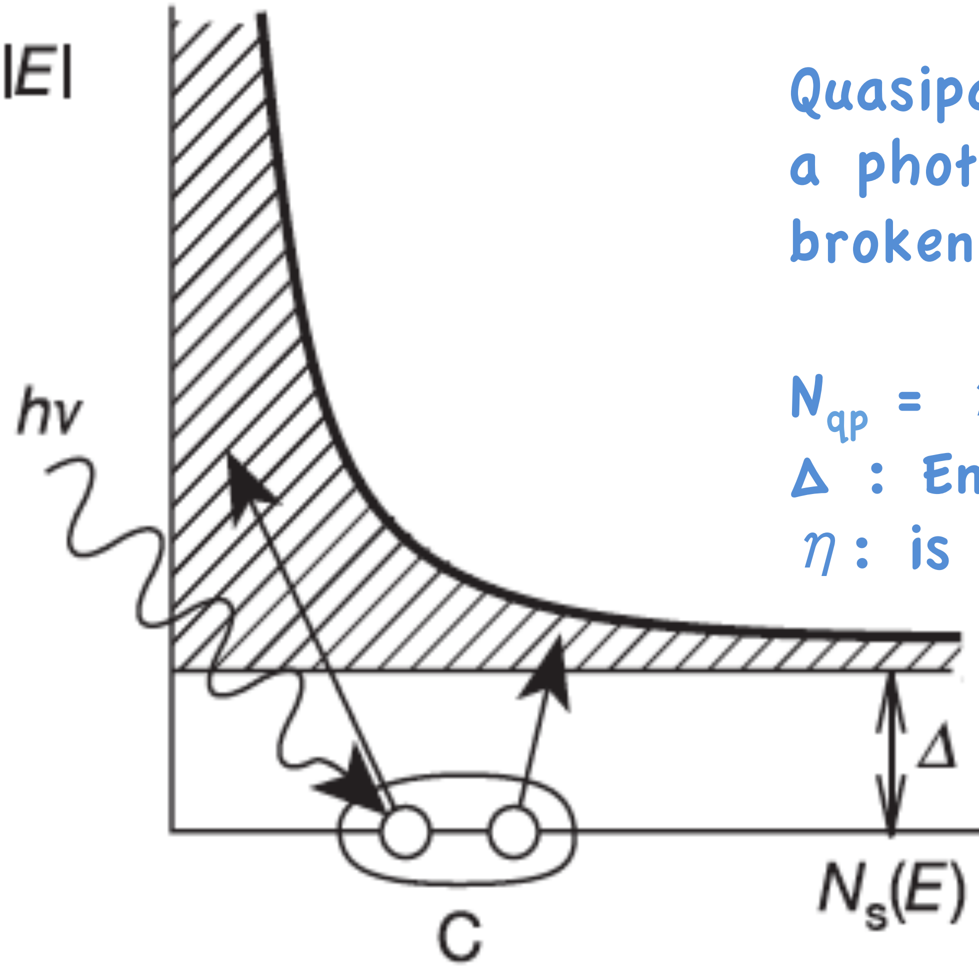
MKIDs in our lab

J.Estrada

limitation of Si semiconductor detectors...



superconductors overcome this limitation



Quasiparticles are created when a photon hits a SC (Cooper pairs broken)

$N_{qp} = \eta h\nu / \Delta$

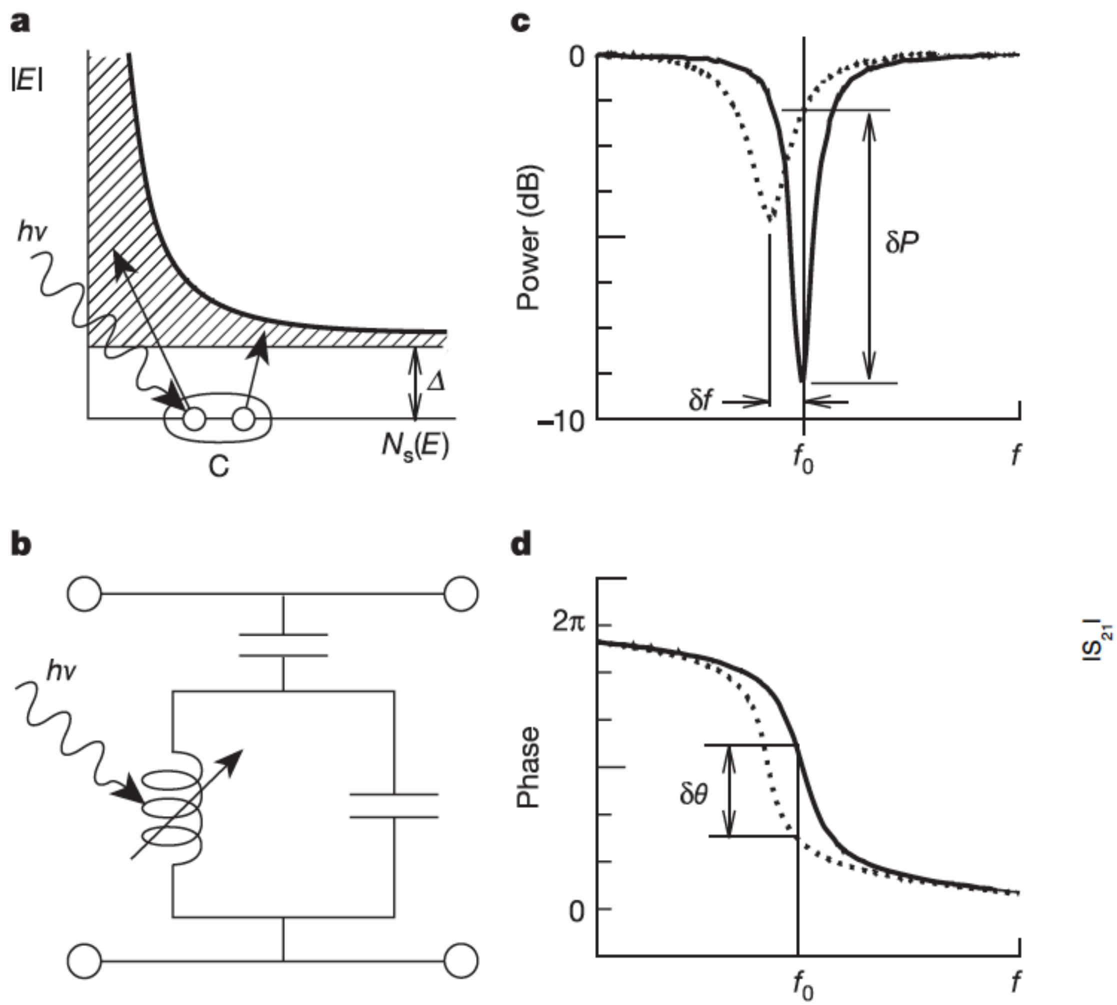
Δ : Energy gap ~ 0.001 eV

η : is an efficiency ~ 0.6

Number of quasiparticles is proportional to photon energy!

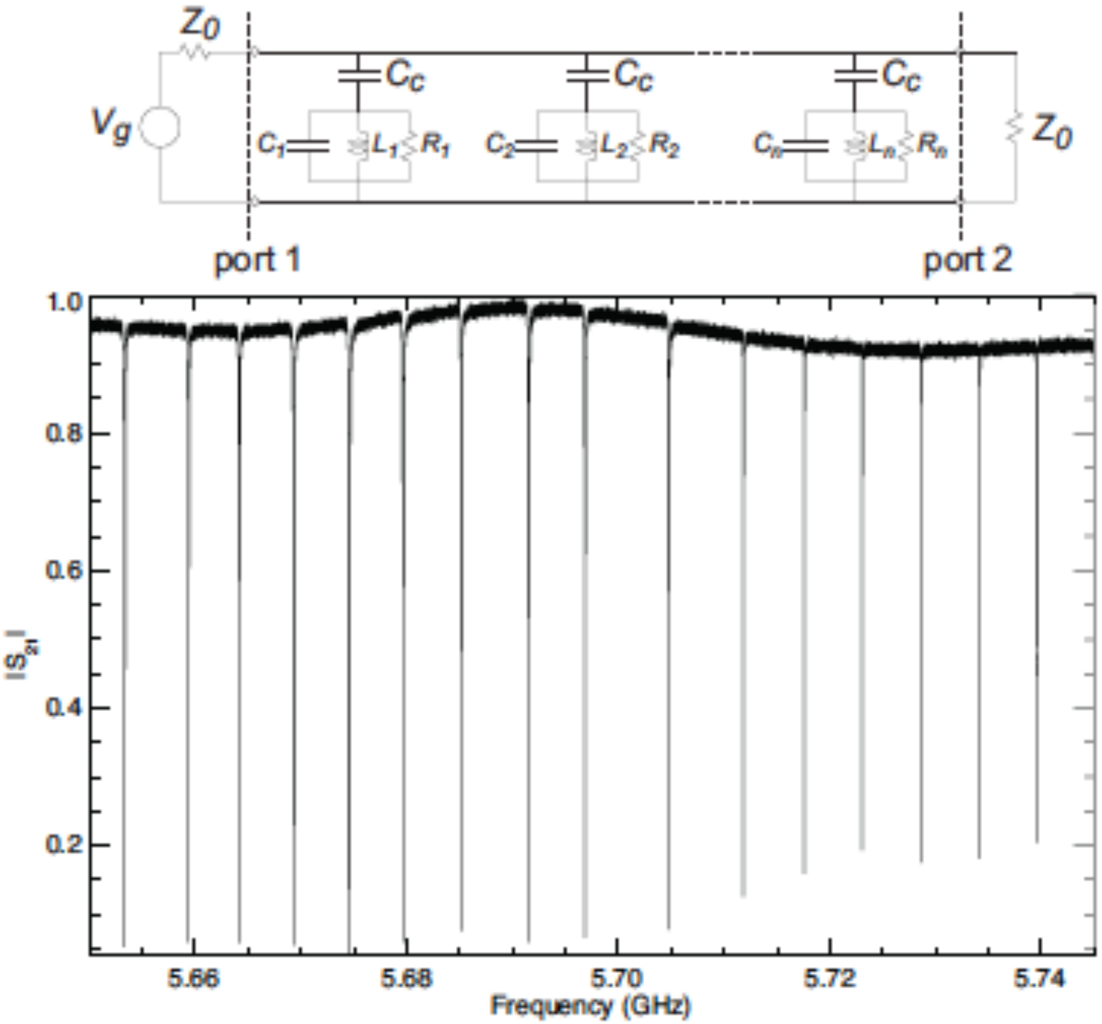
~5000 quasiparticles for a visible photon

Microwave Kinetic Inductance Detectors

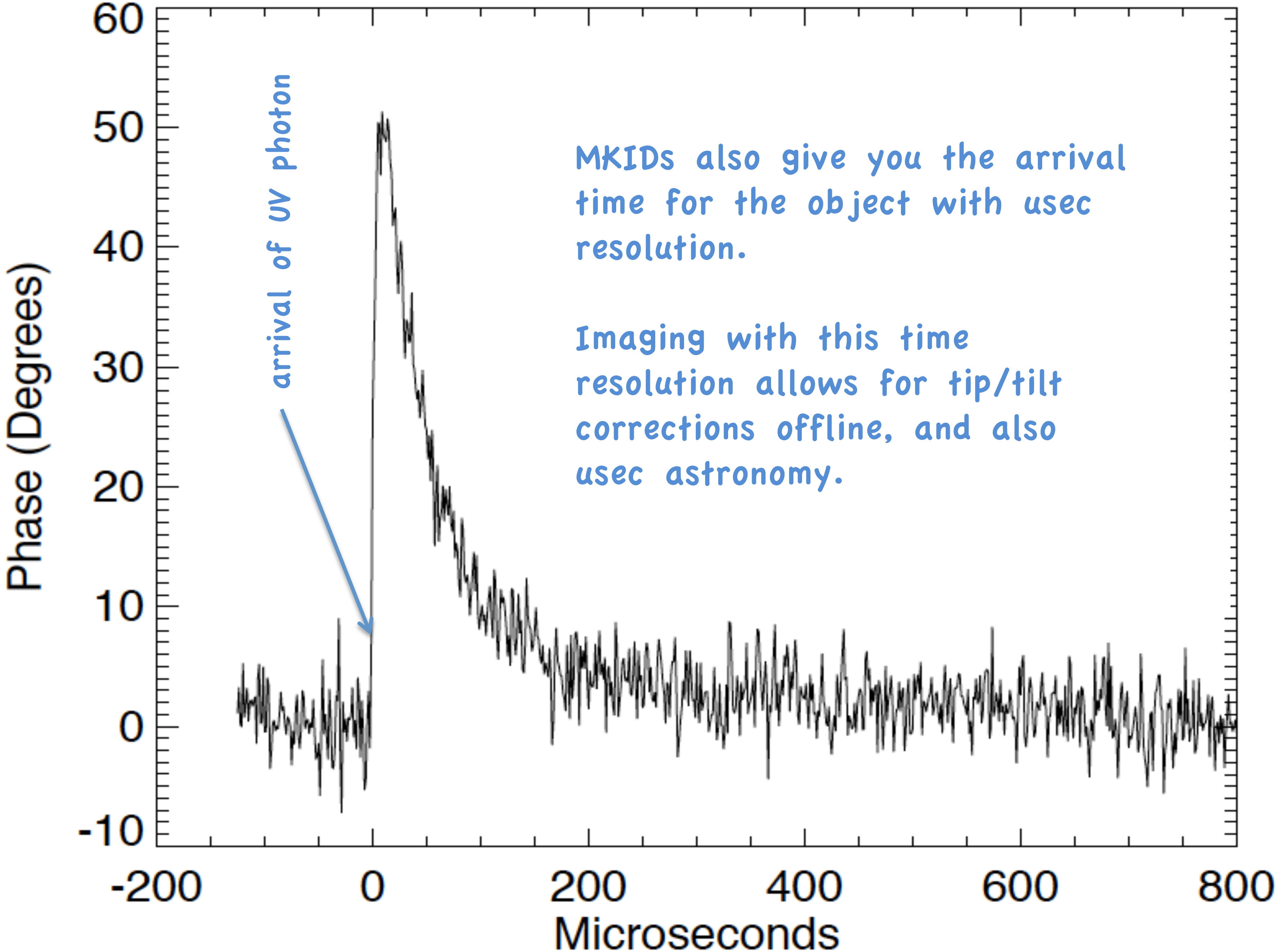


Frequency multiplexing.

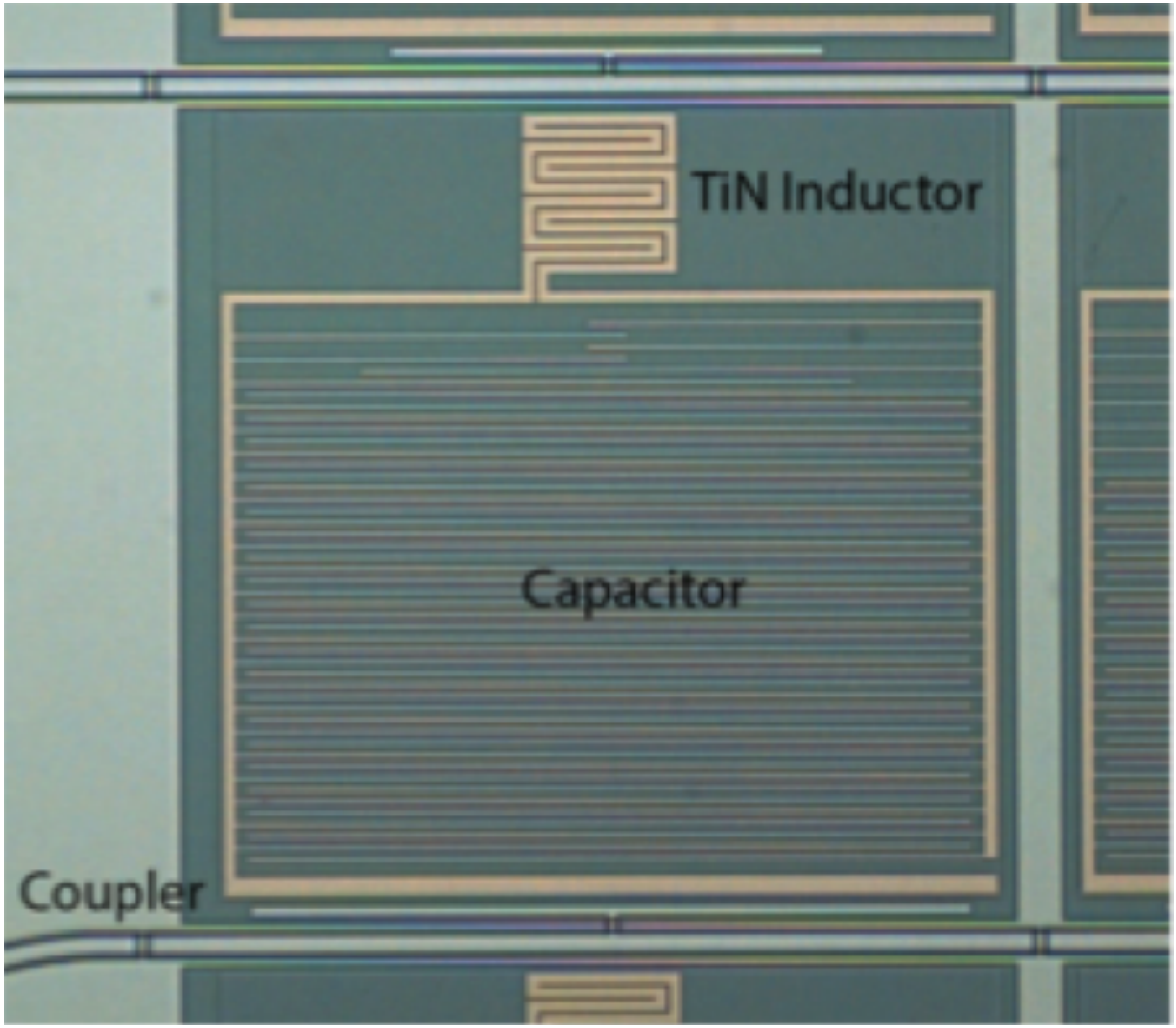
Each pixel is tuned to a different frequency. Photons each a pixel and move the resonance for that pixel. Digital FM radio.



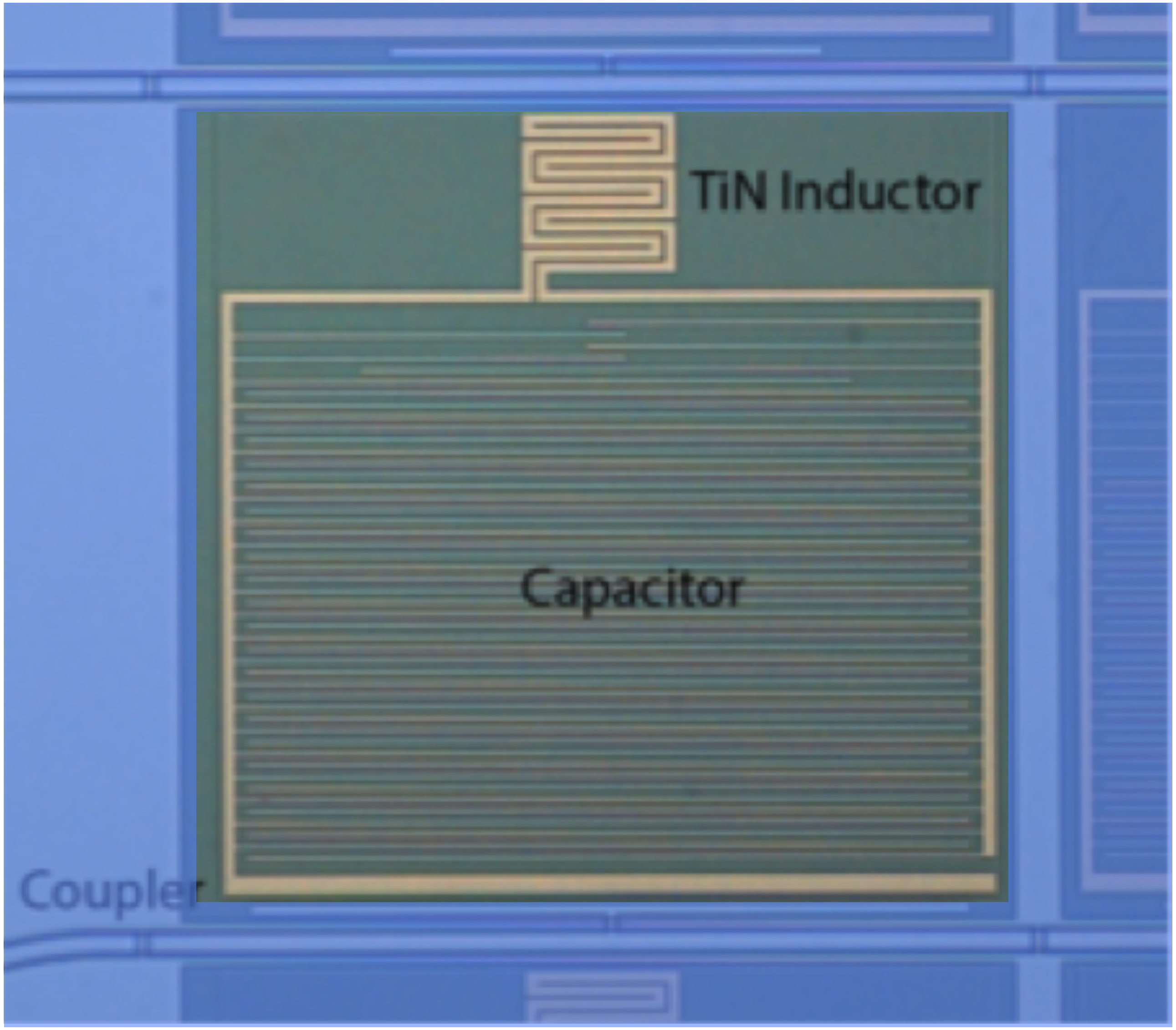
Large array of superconducting detectors are NOW possible.


MKIDs also give you the arrival time for the object with usec resolution.
Imaging with this time resolution allows for tip/tilt corrections offline, and also usec astronomy.
arrival of UV photon
Phase (Degrees)
Microseconds
60
50
40
30
20
10
0
-10
-200
0
200
400
600
800

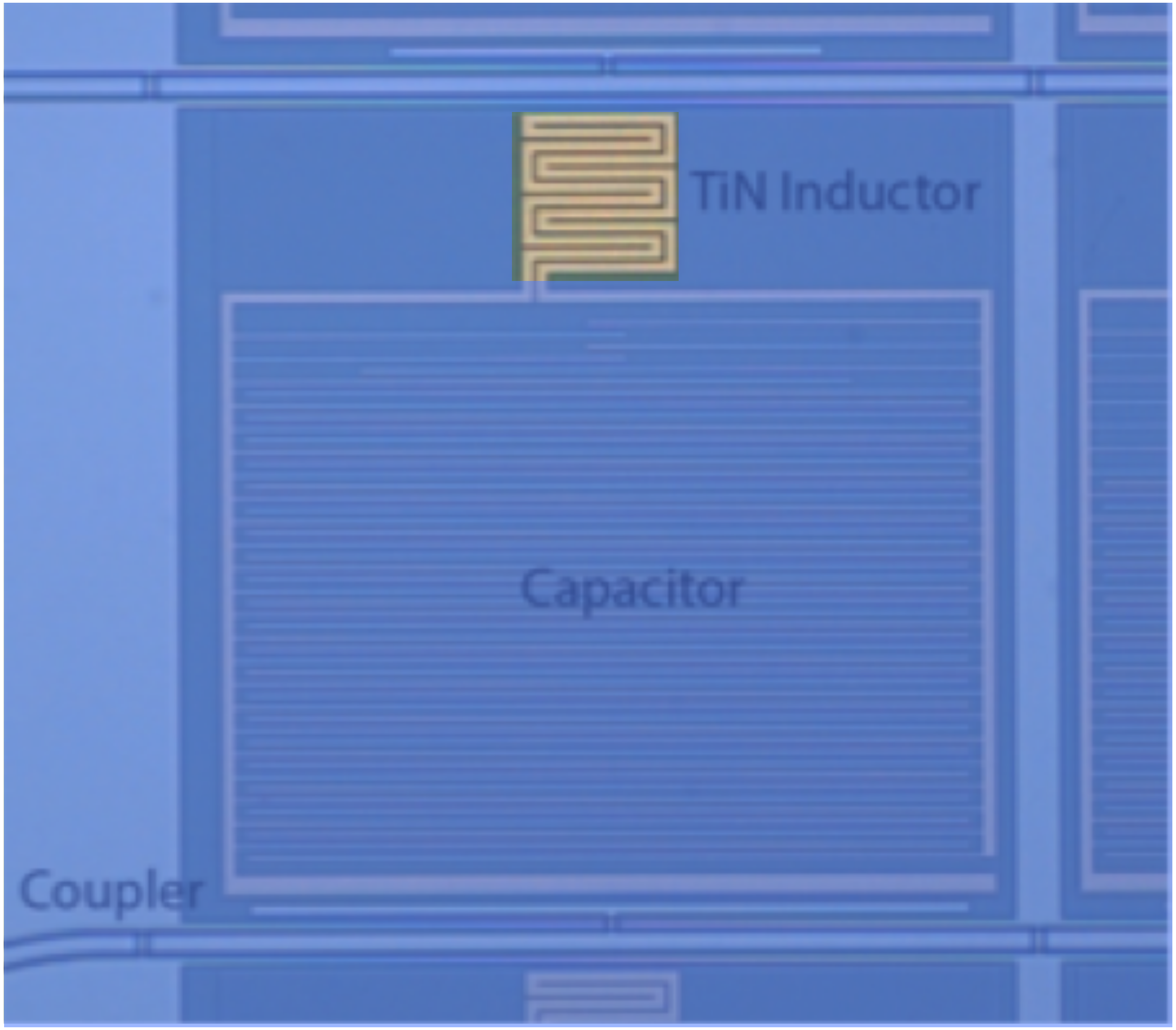
MKID pixel

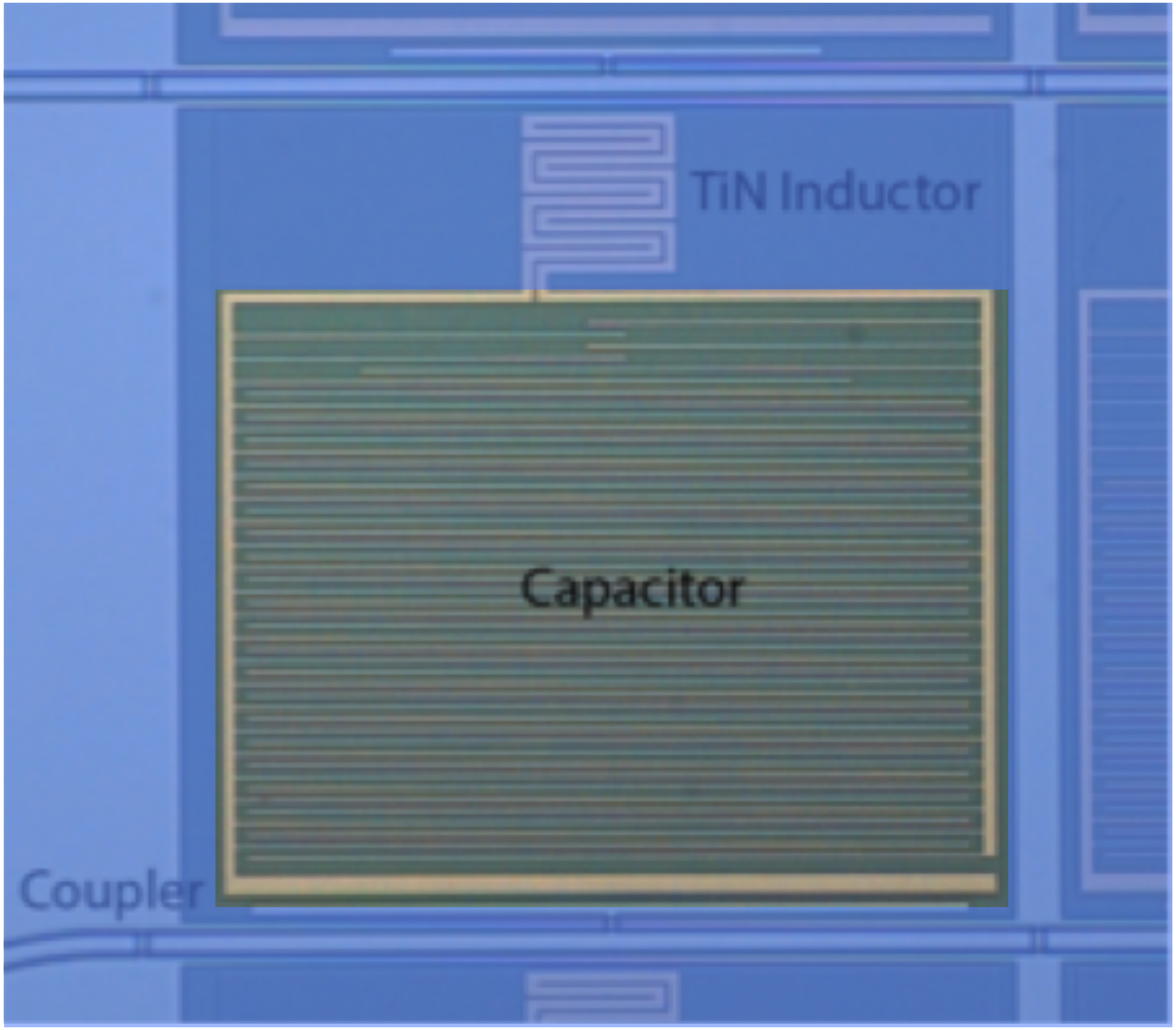


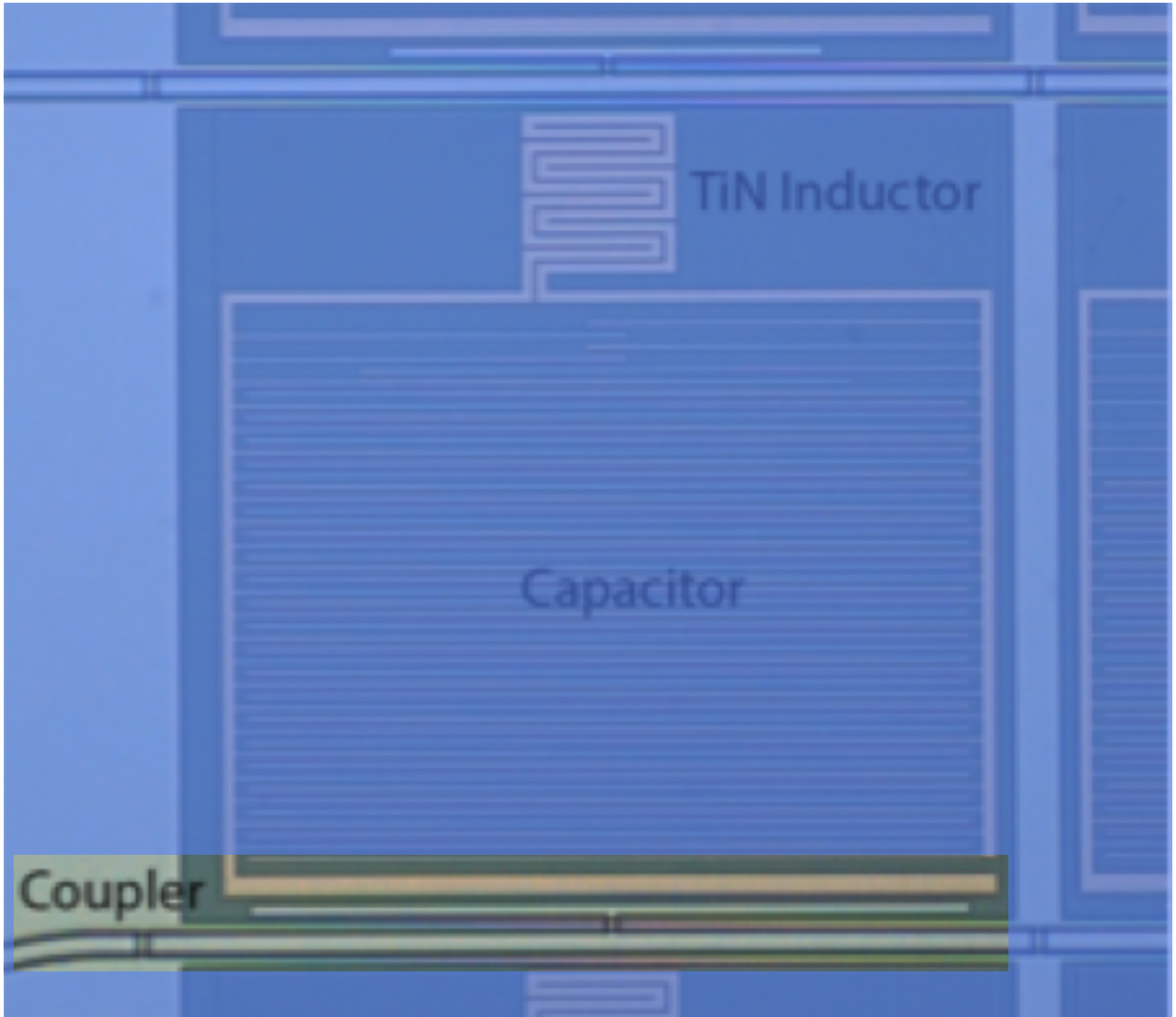
Single pixel has an inductor and a capacitor



Light is collected at the inductor (micro-lens needed for fill factor)

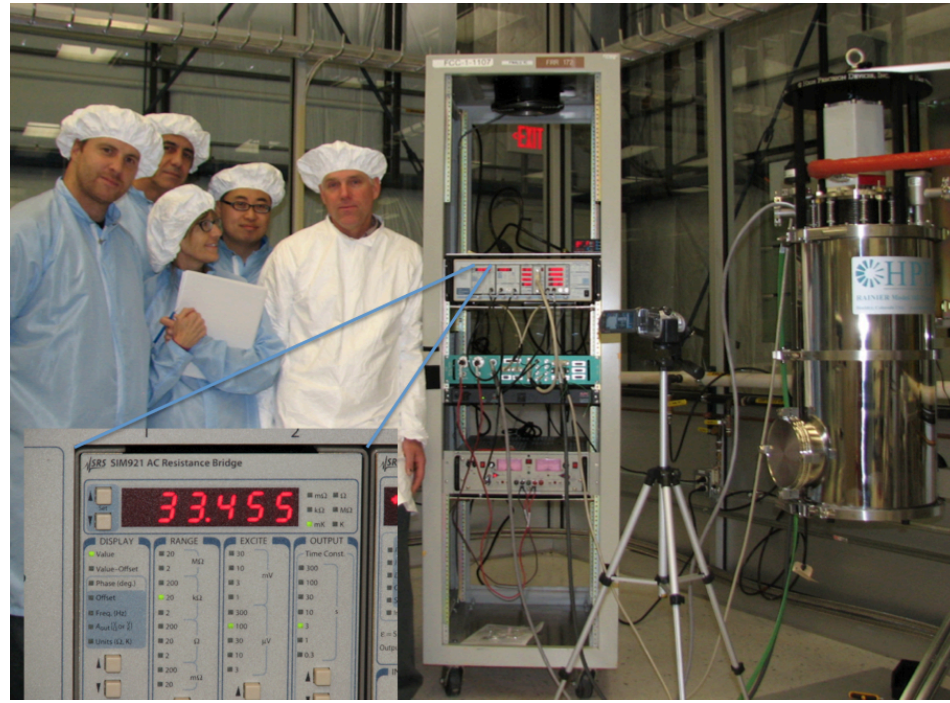


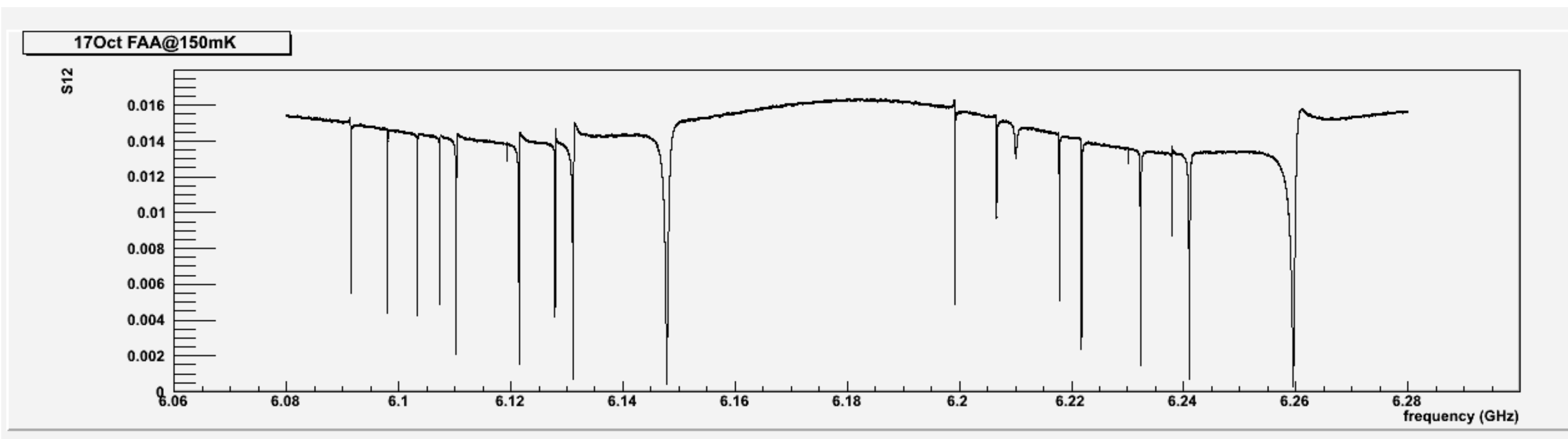

TiN Inductor
Capacitor
Coupler


TiN Inductor
Capacitor
Coupler

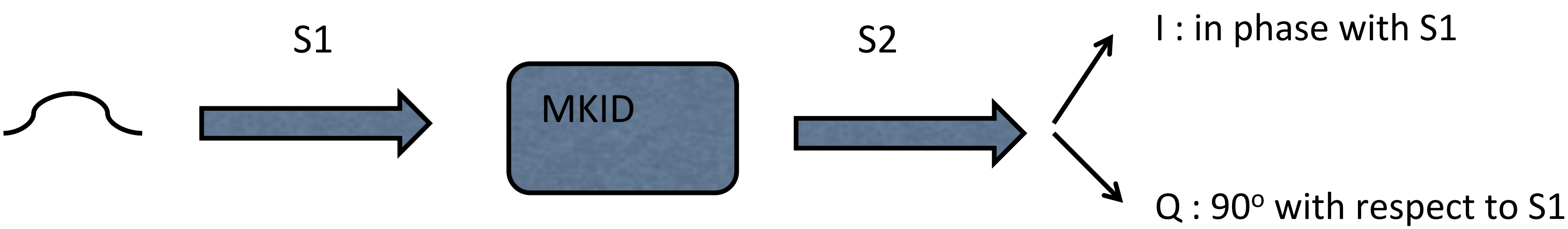
MKIDs @ Fermilab started in 2013

MKIDs work at 100mK, but now this is easy. In two days installed and commissioned an ADR to 33mK temperature.



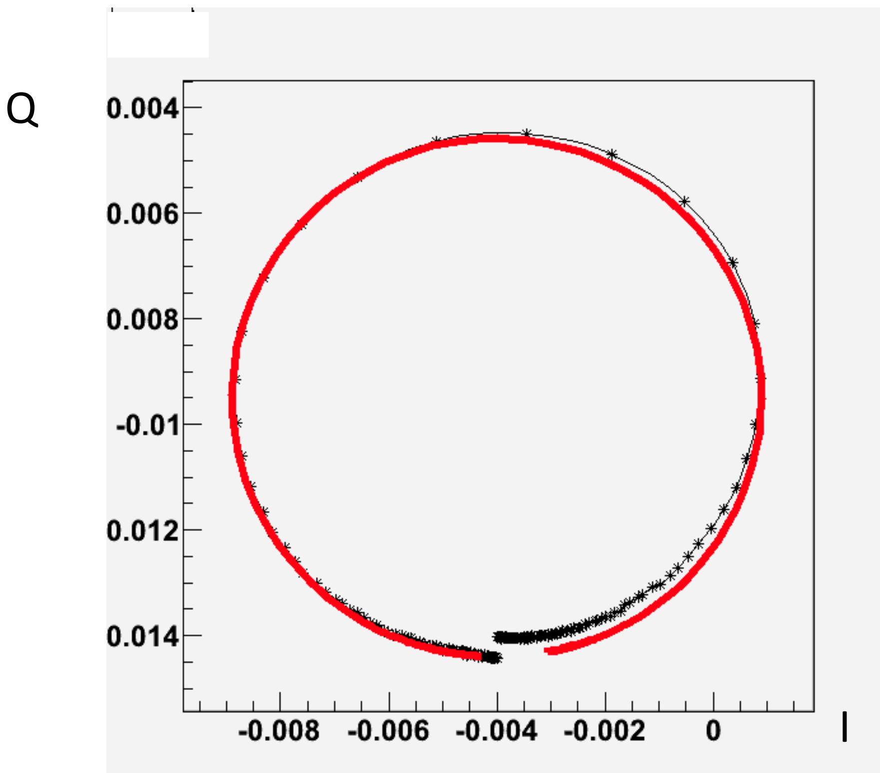


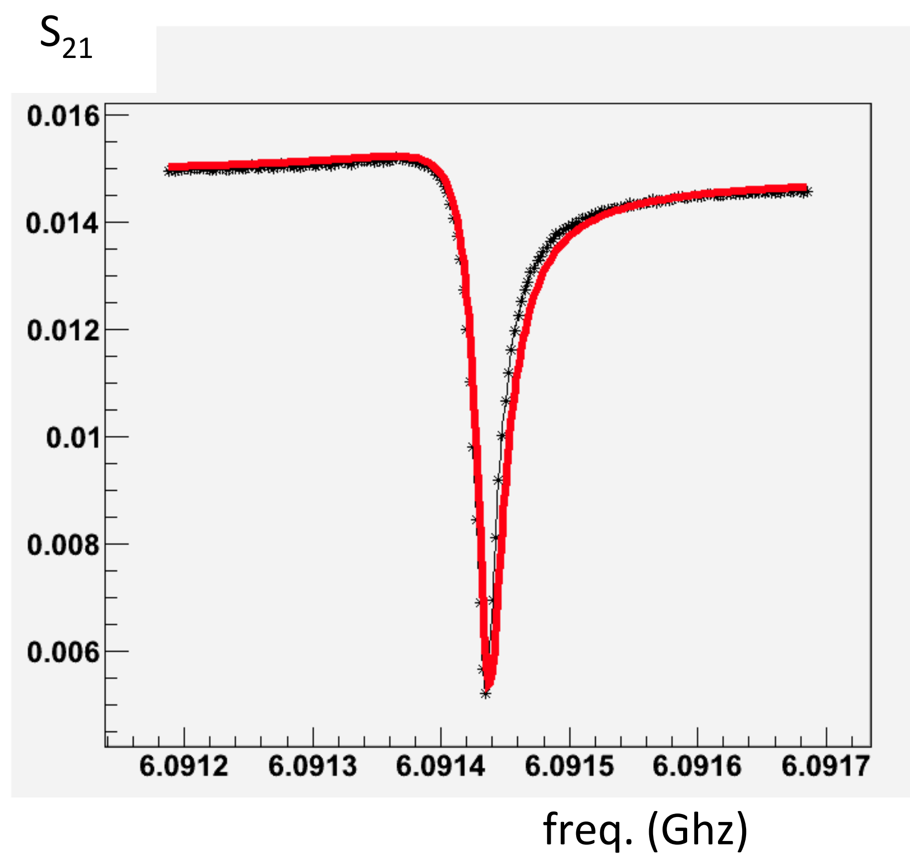
A couple of months after that, we started operating a 20 pixel MKID fabricated at Argonne National Laboratory.



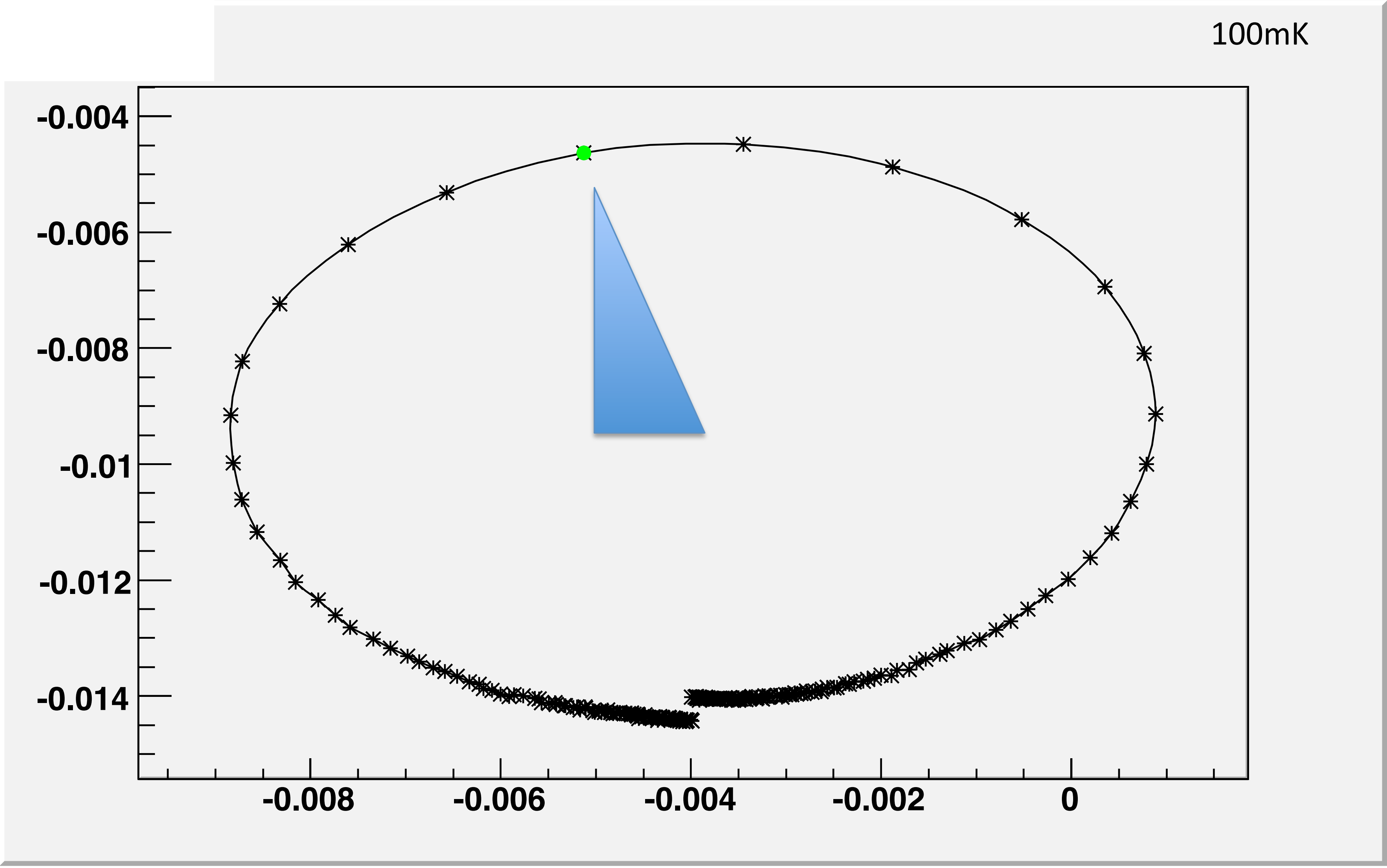
Q & I measured relative to S1

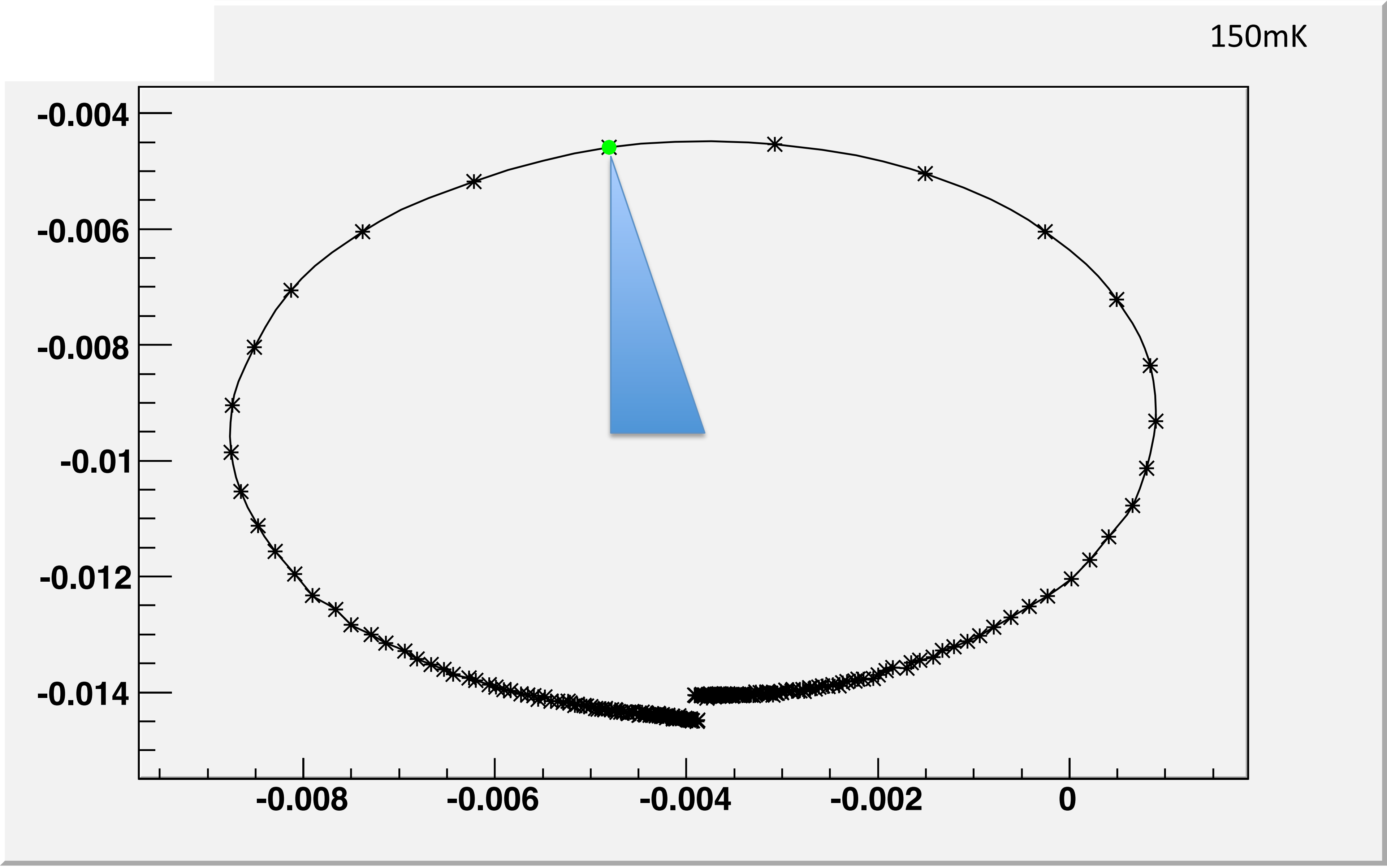
S_{21} is the sum in quadrature of Q & I





Pixel 1: Q=187k , f0=6.09143 Ghz

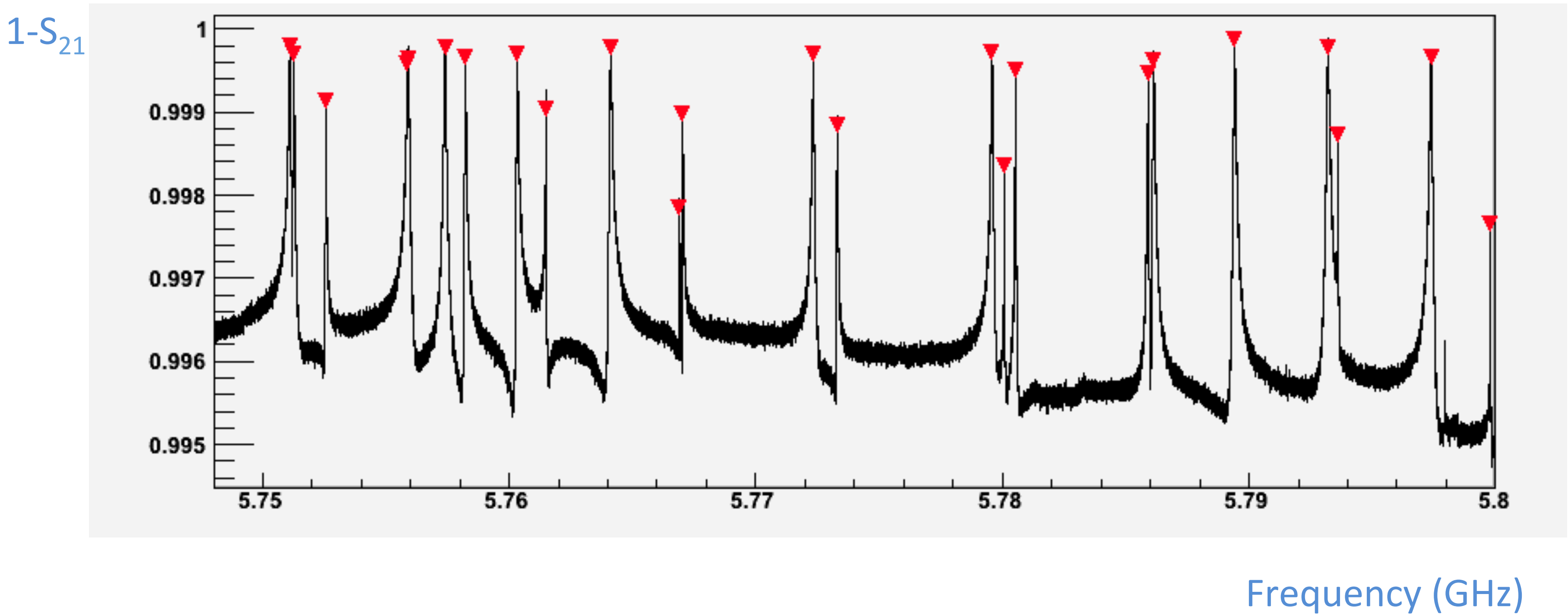

100mK
-0.004
-0.006
-0.008
-0.01
-0.012
-0.014
-0.008
-0.006
-0.004
-0.002
0



150mK
-0.004
-0.006
-0.008
-0.01
-0.012
-0.014
-0.008
-0.006
-0.004
-0.002
0

There is still a lot of work to do

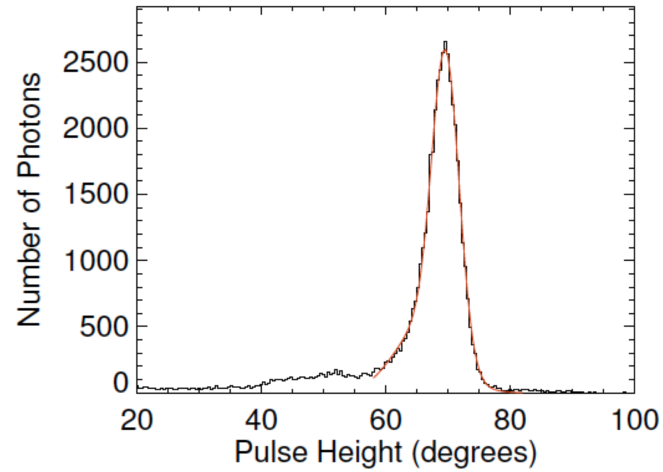
- Pixel overlap
- Pixel non-uniformity (Q)
- Pixel spacing

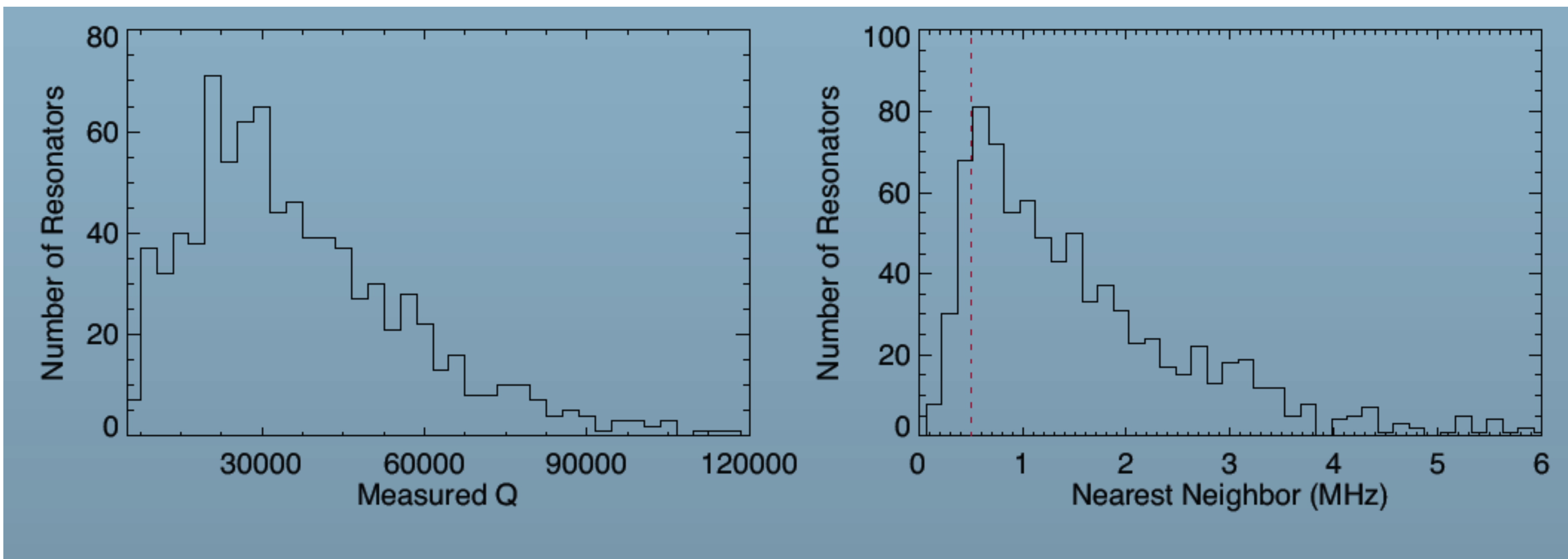


R= E/ δ E = 16 @250nm

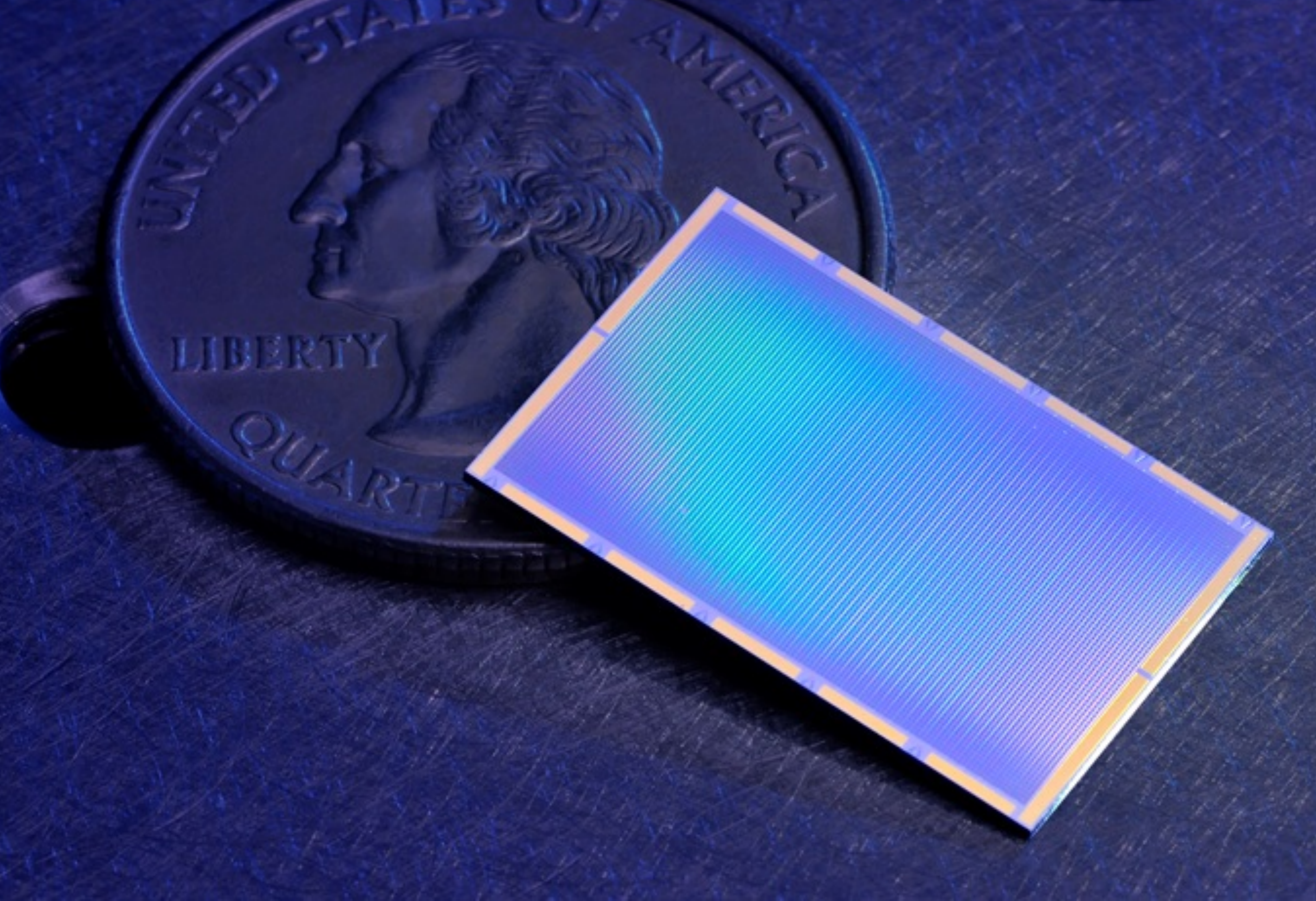
Theoretical limit for the MKIDs is R=180… there is still ways to go.

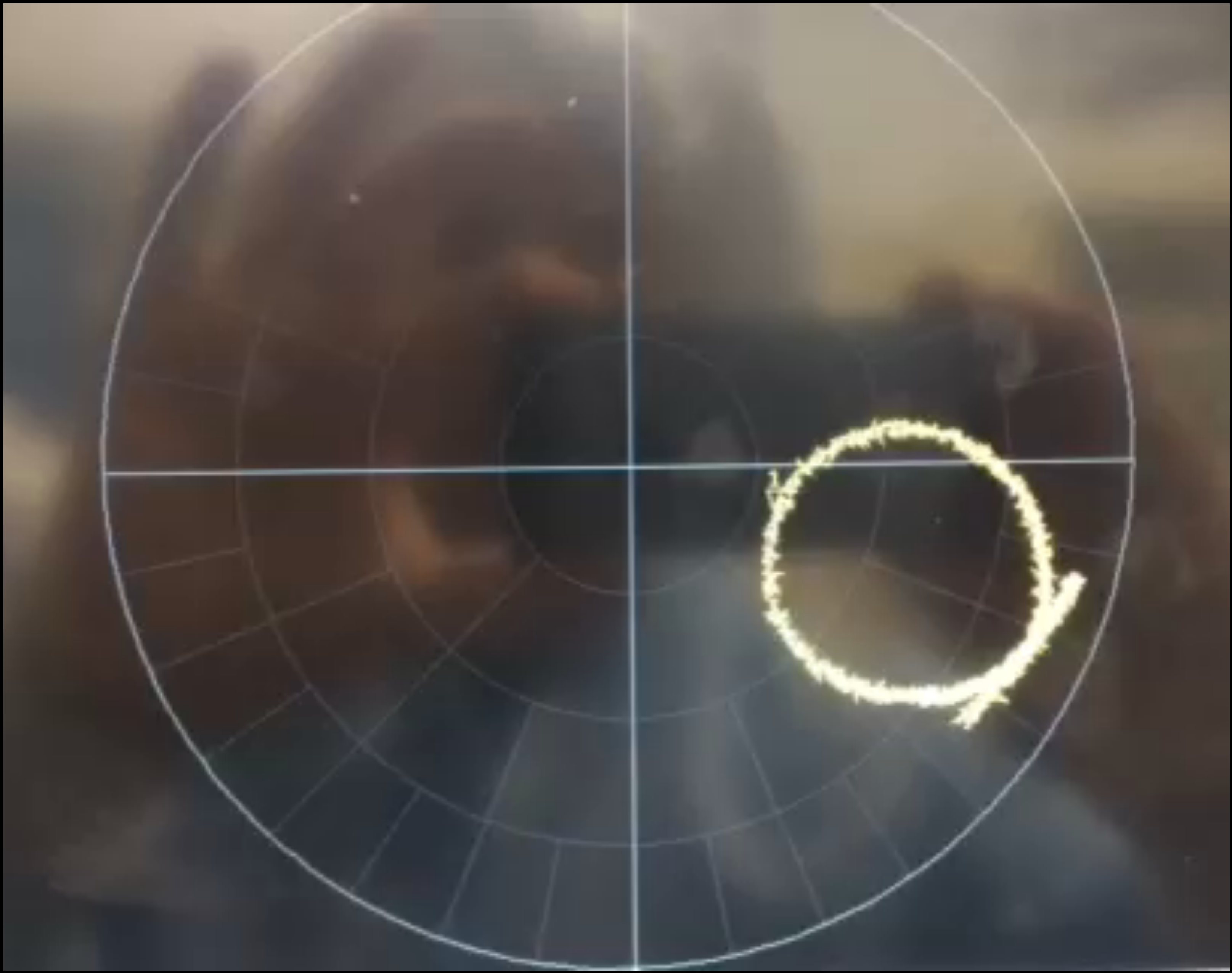
Q is not always the same.



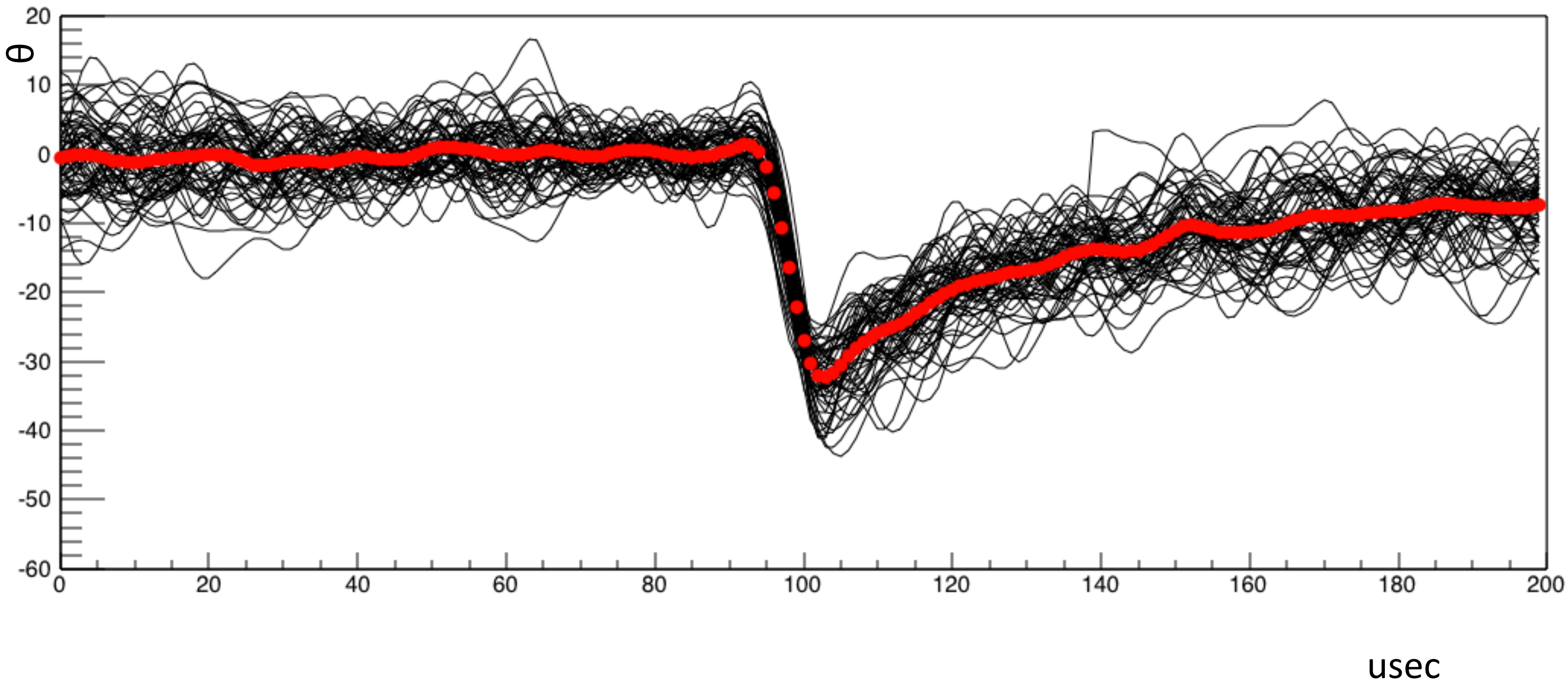


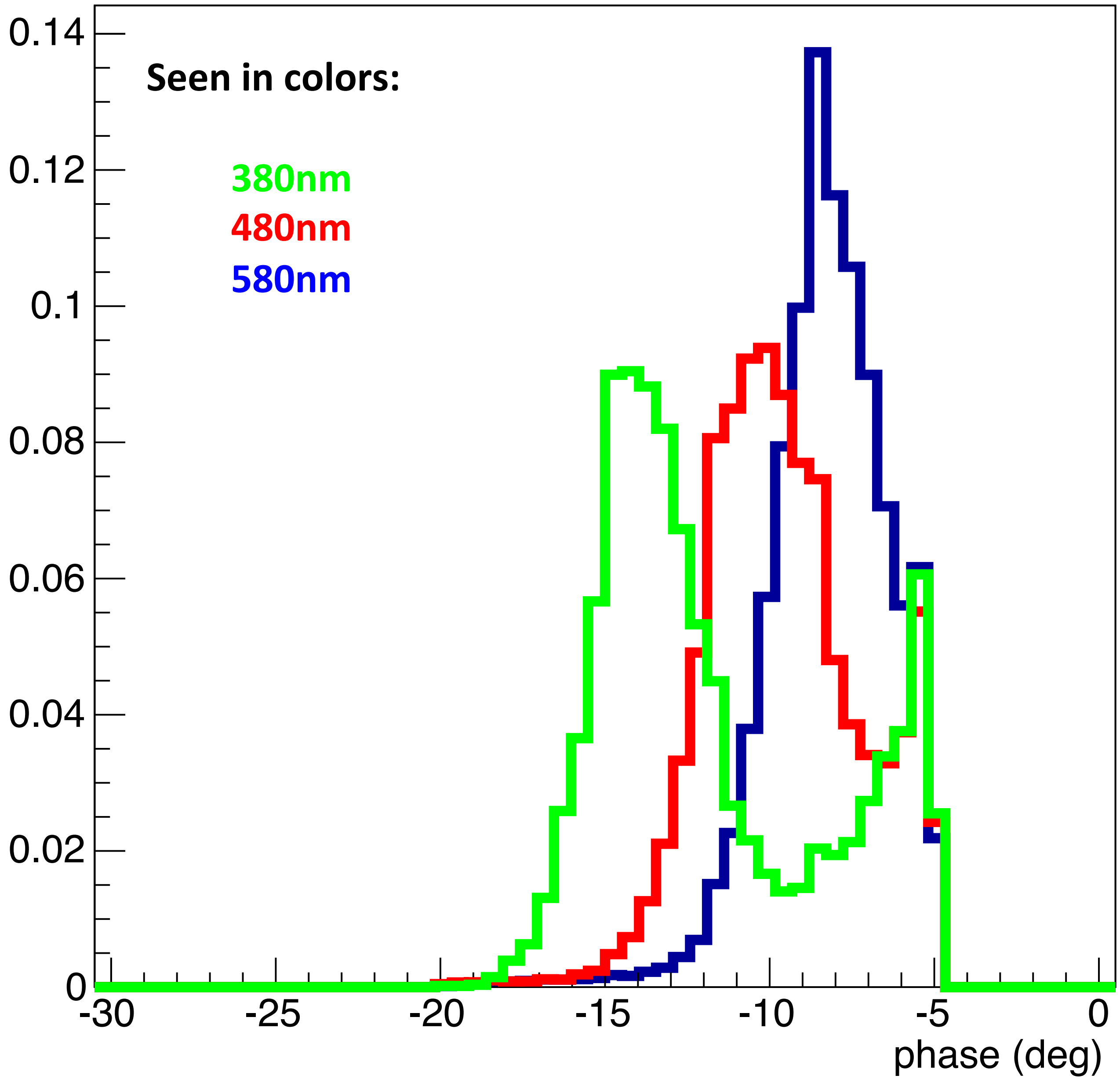
10k array exists – Design by B.Mazin (UCSB) .Not yet tested
Development funded by NSF for DarkNess, a 10kpix MKID based IFU for coronagraph (Palomar)



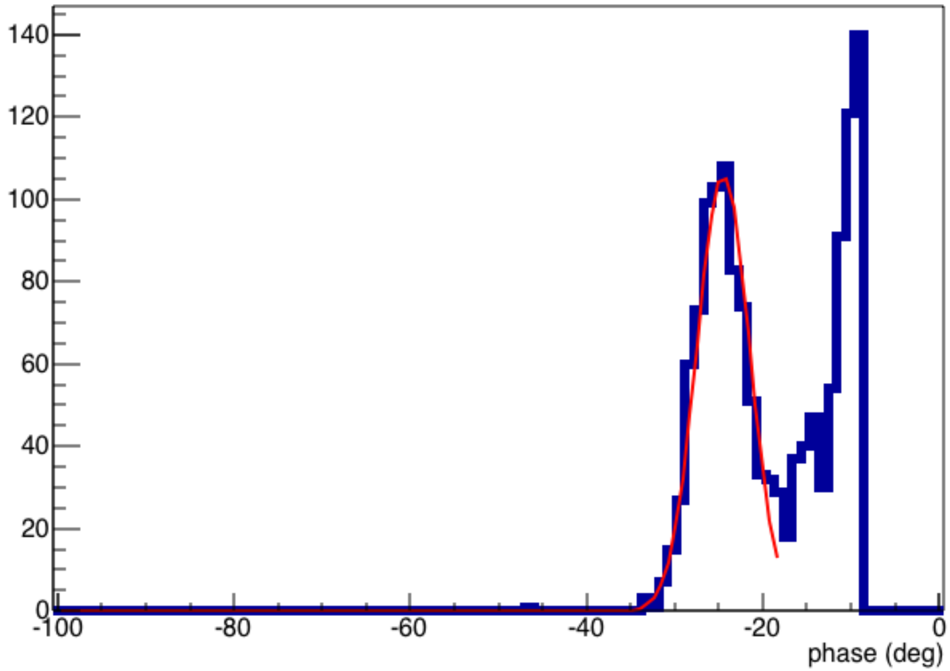


400nm pulses at FNAL with for a single pixel

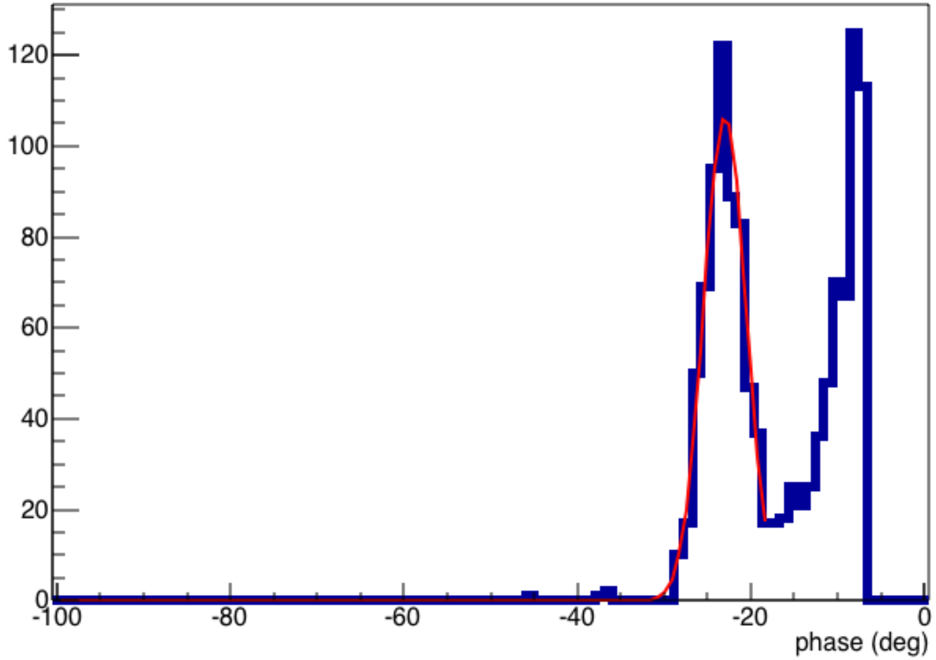




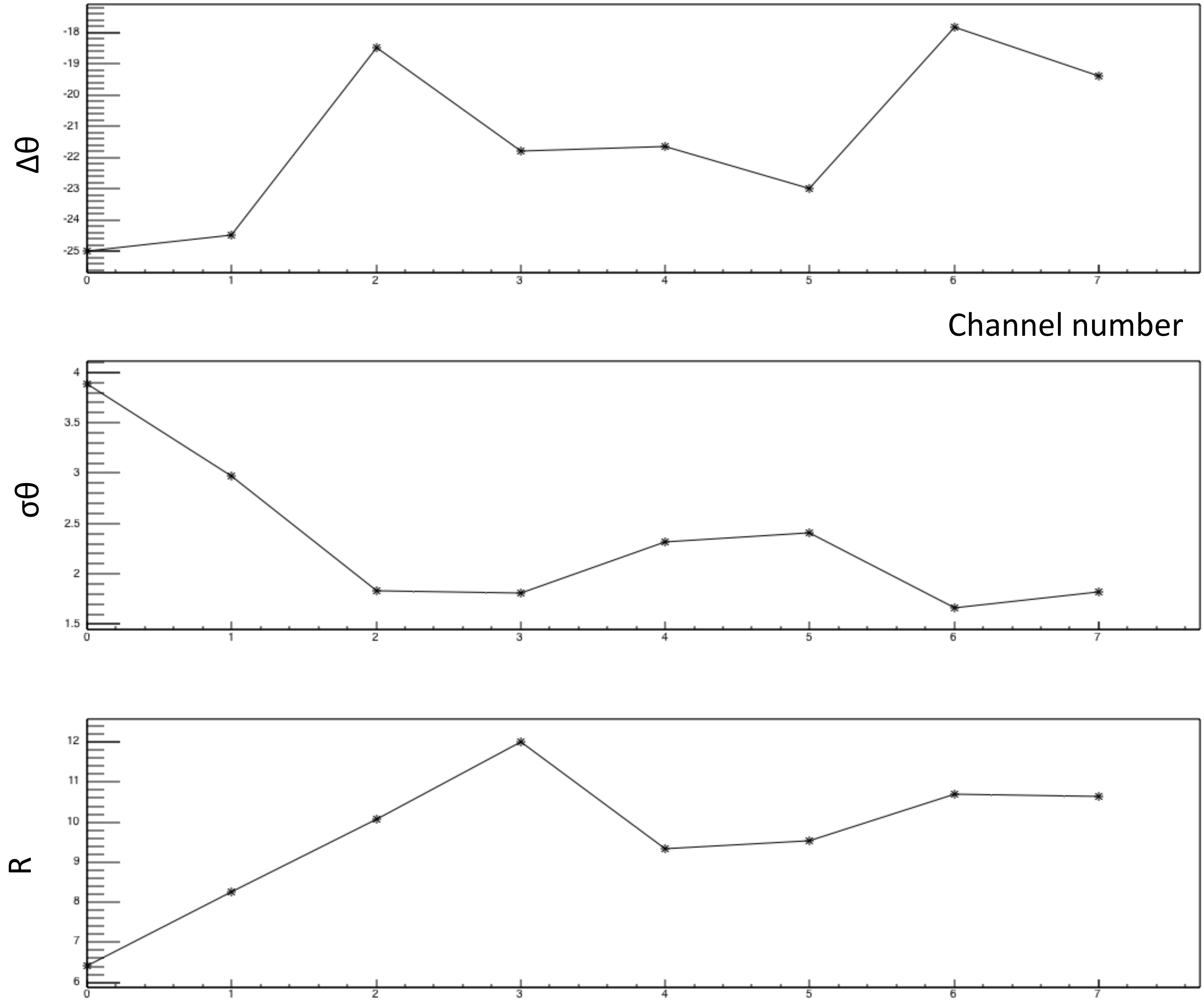
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-30
-25
-20
-15
-10
-5
0
phase (deg)
Seen in colors:
380nm
480nm
580nm



Performance achieved at FNAL with 400nm photons. We can get in a few pixels R>10.

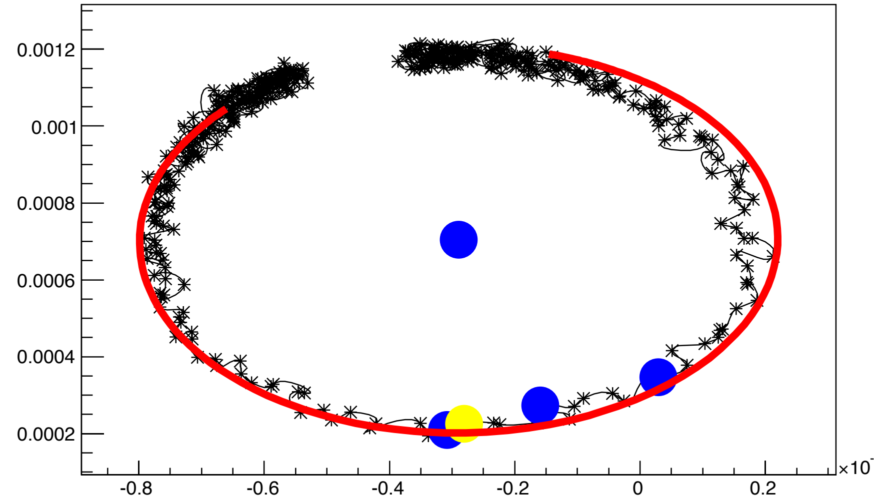


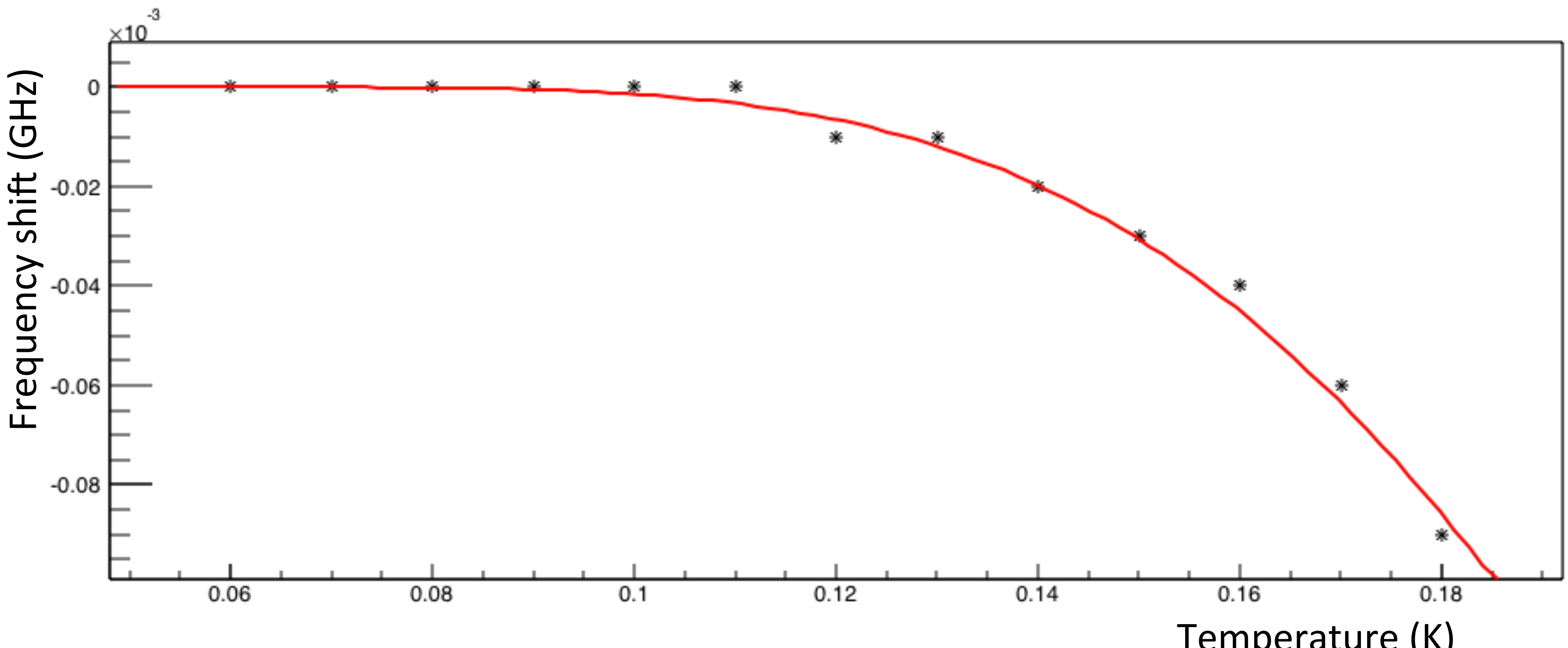
We are still trying to understand what happens when a lot more pixels are excited on the same line… we are not getting the same performance yet.

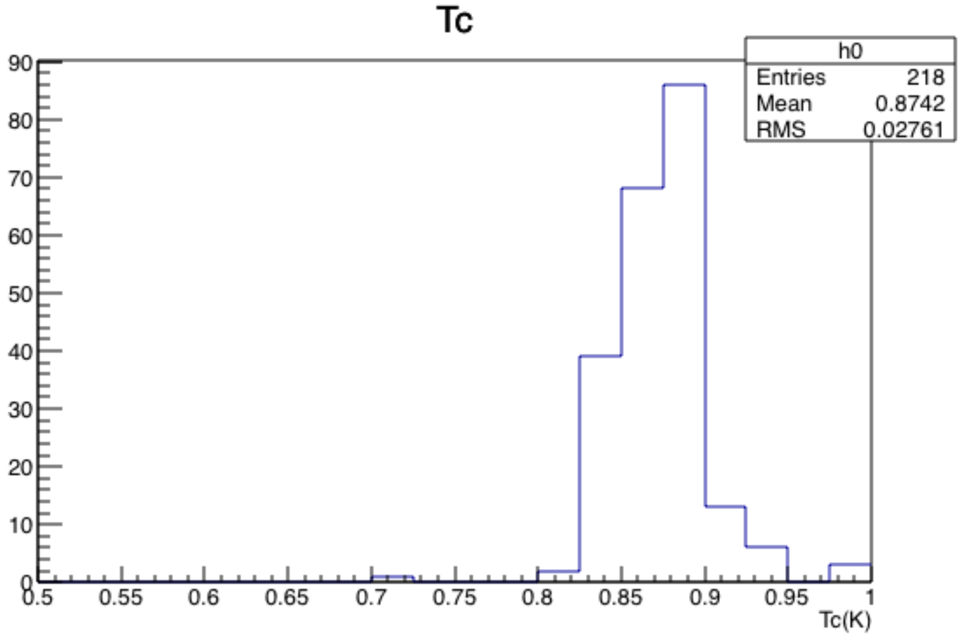

Δθ
-18
-19
-20
-21
-22
-23
-24
-25
0
1
2
3
4
5
6
7
Channel number
σθ
4
3.5
3
2.5
2
1.5
0
1
2
3
4
5
6
7
R
12
11
10
9
8
7
6
0
1
2
3
4
5
6
7

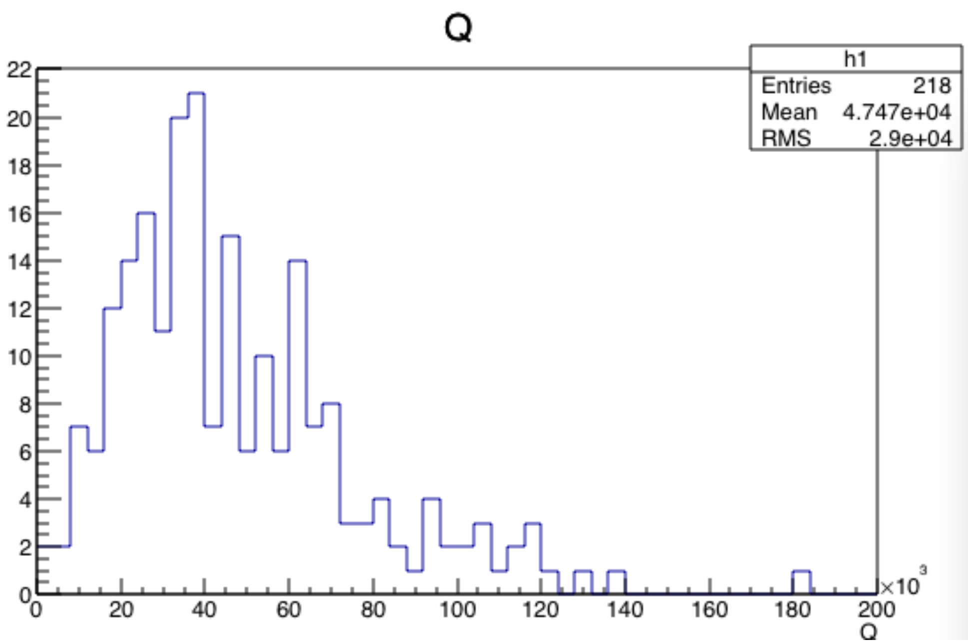
For each resonator collected data of the S21 as a function of frequency, for temperatures between 50mK and 180mK.

The results are using to fit the resonator parameters, and the frequency shift as a function of temperature.









Now we have the tools to characterize large arrays of resonators.

The performance is not uniform. We are looking for the reasons for this non-uniformity. Does not seem to be coming from changes in critical temperature.

A lot to learn, but we have the tools to make progress.