All Around ATTA

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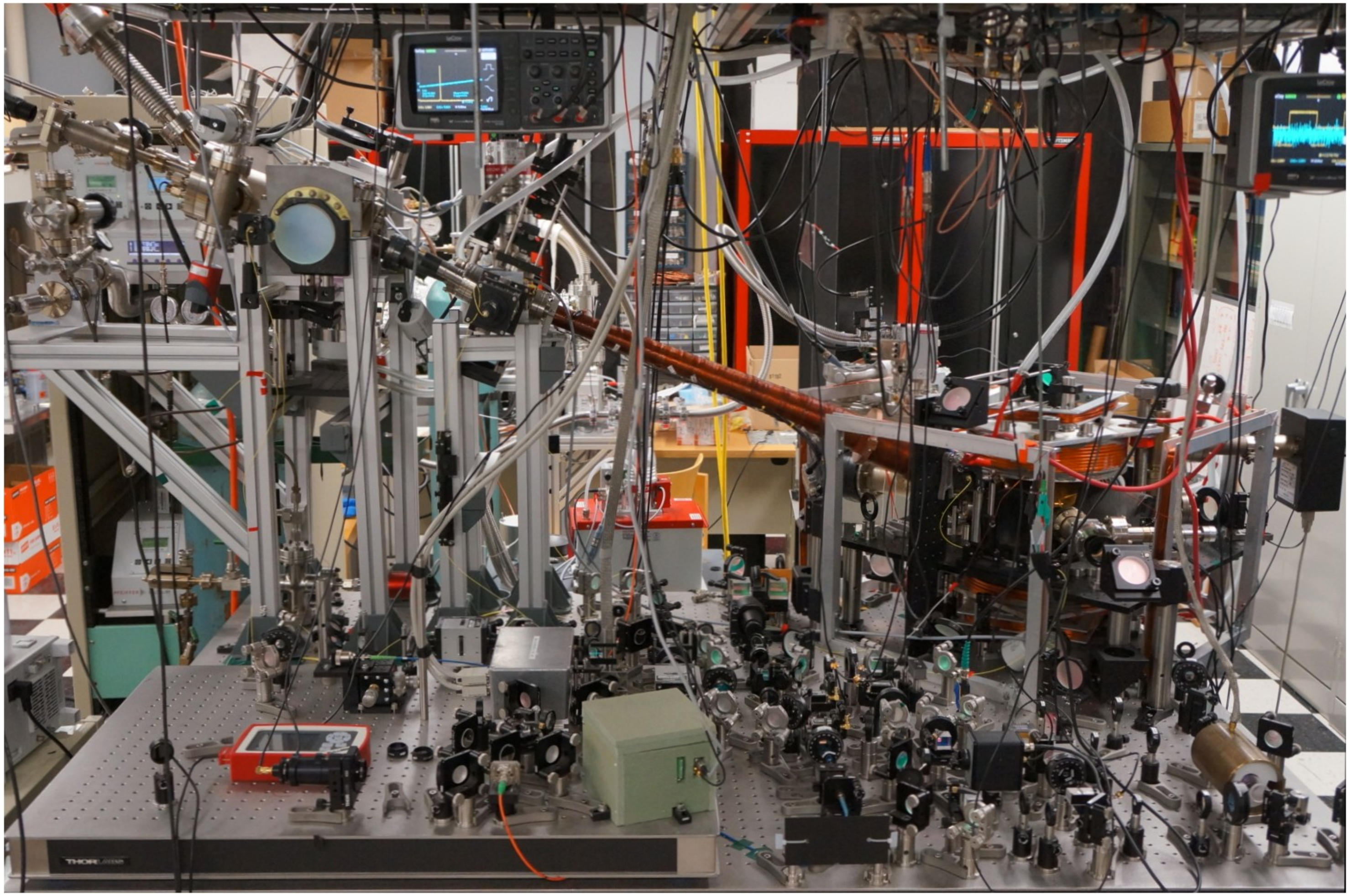
Outline

- Introduction
  - What is ATTA and why is it important?
- Experiment
  - Explanation of the system
- My Projects
  - Data Analysis
  - Pressure Valve Automation

ATTA

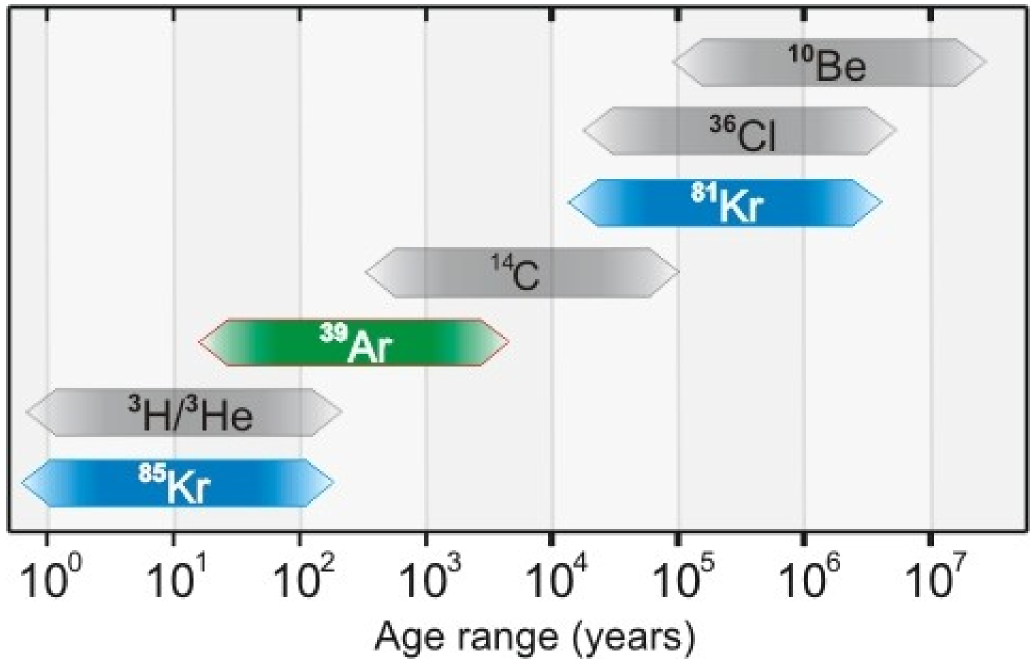


- Atom Trap Trace Analysis
- Can trap and detect single atoms of only the kind that we're interested in
- This was used because a method was needed that was selective and sensitive enough for the levels of Kr

Krypton Contamination in Xenon

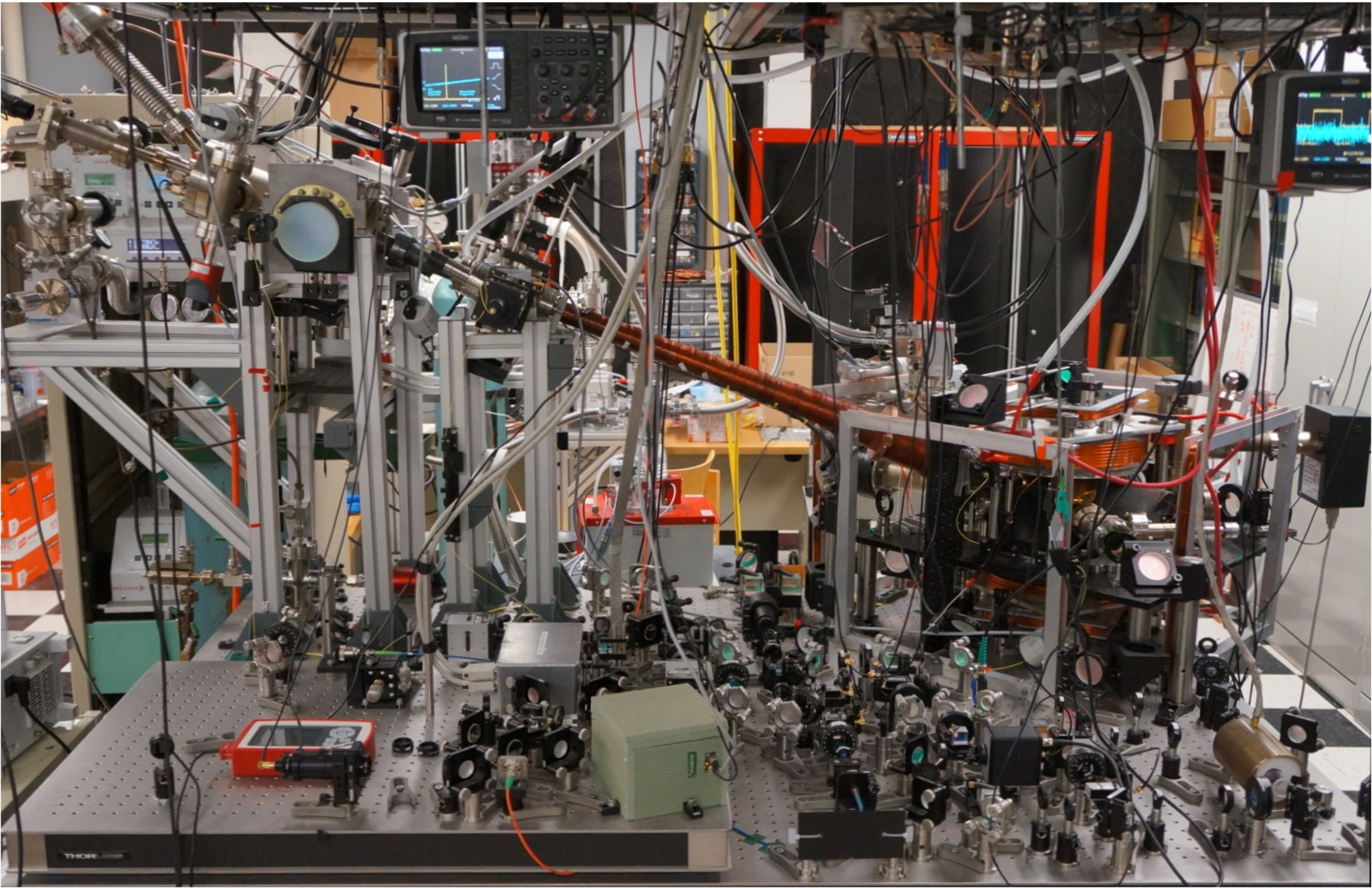
- For XENON1T, the ^{85}Kr to Xe contamination must be on the order of 1 in every 10^23
- ATTA traps ^{84}Kr since it is the most abundant isotope and we know its relation to ^{85}Kr
  - Ratio of $^{85}Kr/^{84}Kr$ is about 1.5x10^-11
  - So the ^{84}Kr level is a part per trillion

Radiokrypton Dating

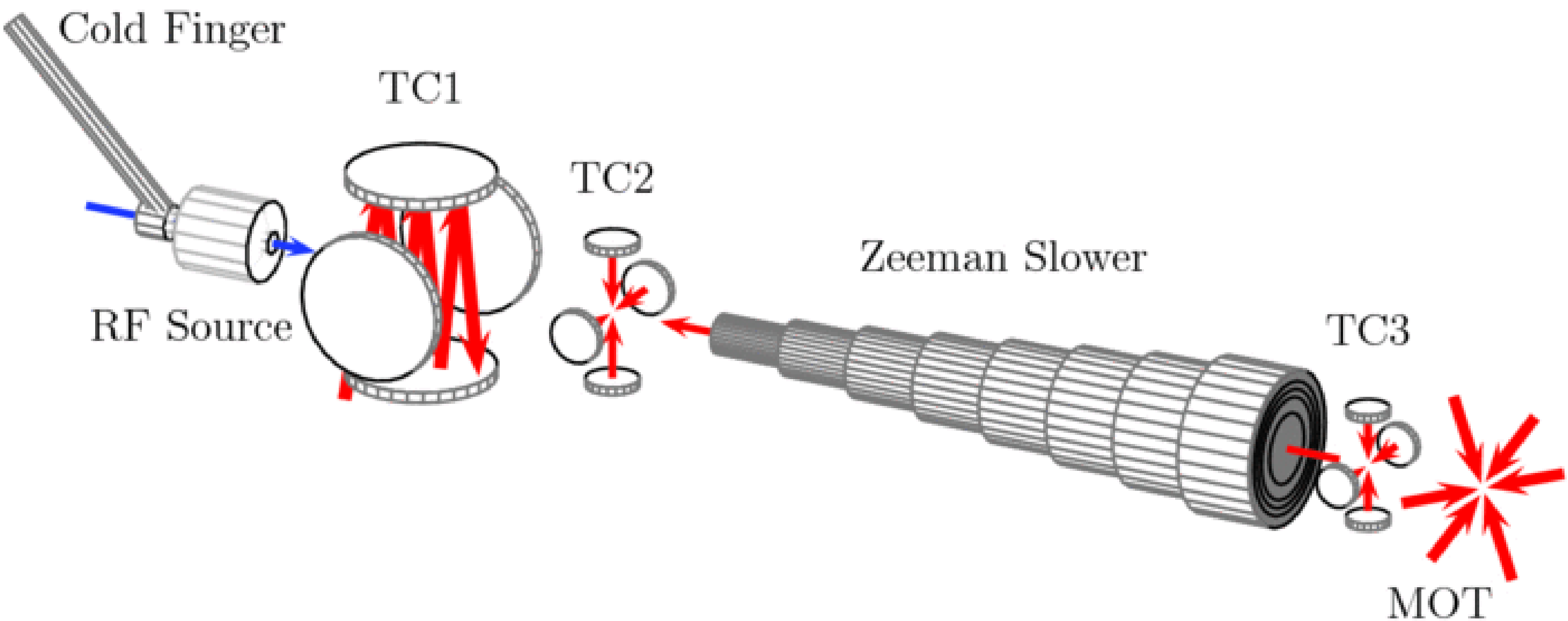


- ATTA is the only method that works for radiokrypton and radioargon that is not extremely expensive
- There are age ranges that only those radioisotopes can date
- As noble gases, the only interference is from radioactivity
- It doesn't require using a tracer in the sample

Experimental System

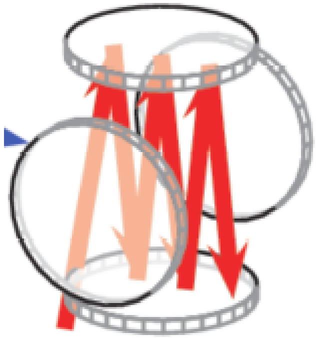


Experimental System

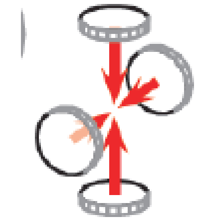


RF Discharge Source

- Xenon expands from the reservoir into the RF source
- The RF signal creates a plasma discharge
- Excites the Kr atoms to a metastable state
- This is necessary because we don’t have laser sources for slowing in the deep UV

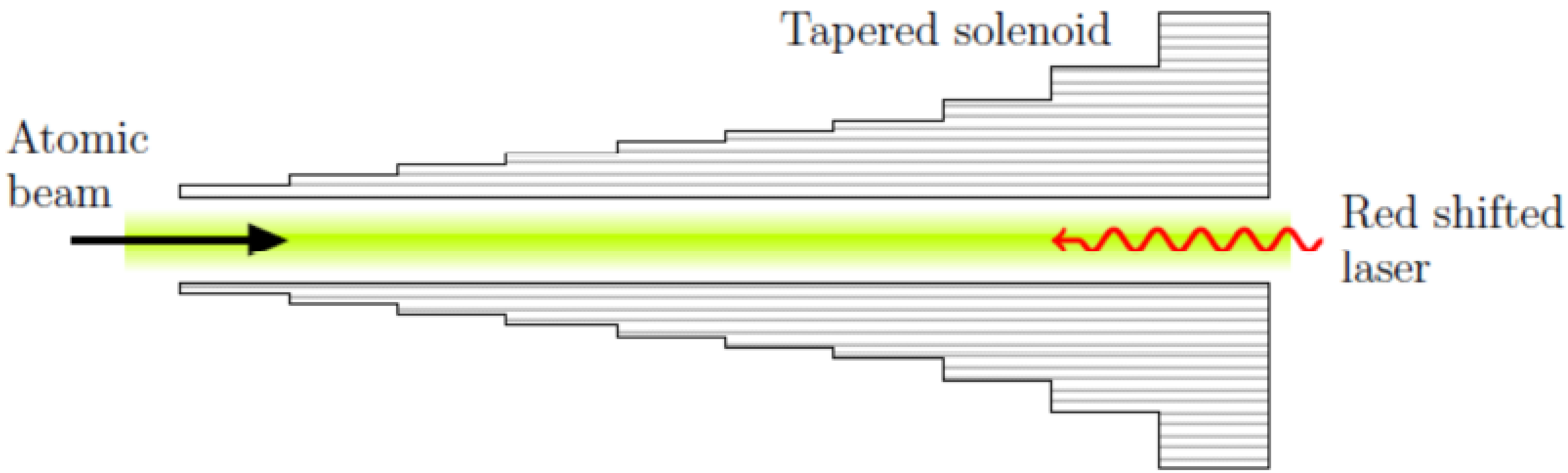


Transverse Cooling



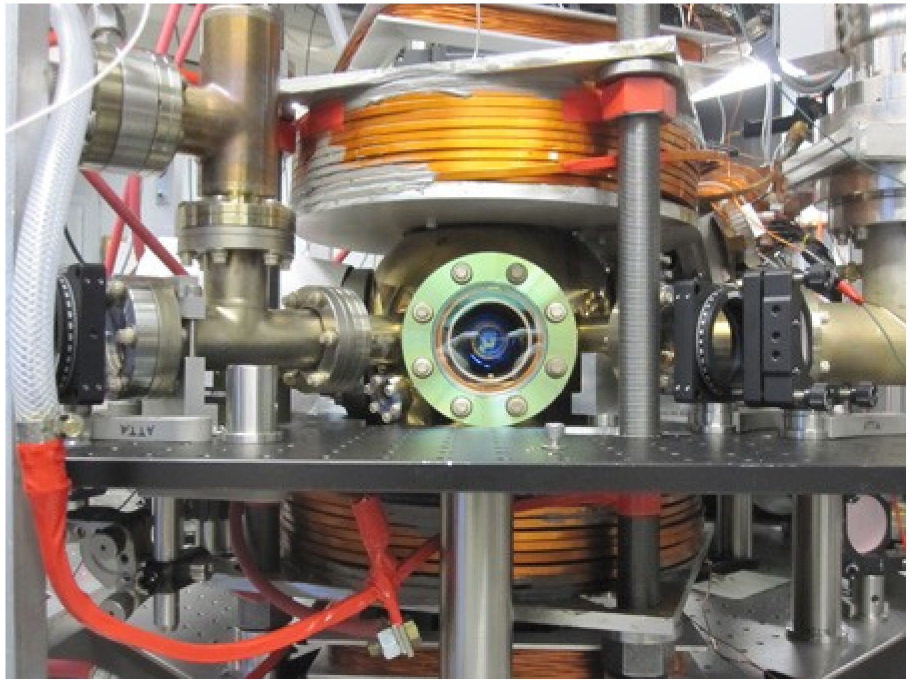
- Lasers collimate the beam of atoms and increase forward flux
- Process is also known as optical molasses
- The frequency of the lasers are tuned so that all non-forward components of movement interact with the laser and are killed off

Zeeman Slower



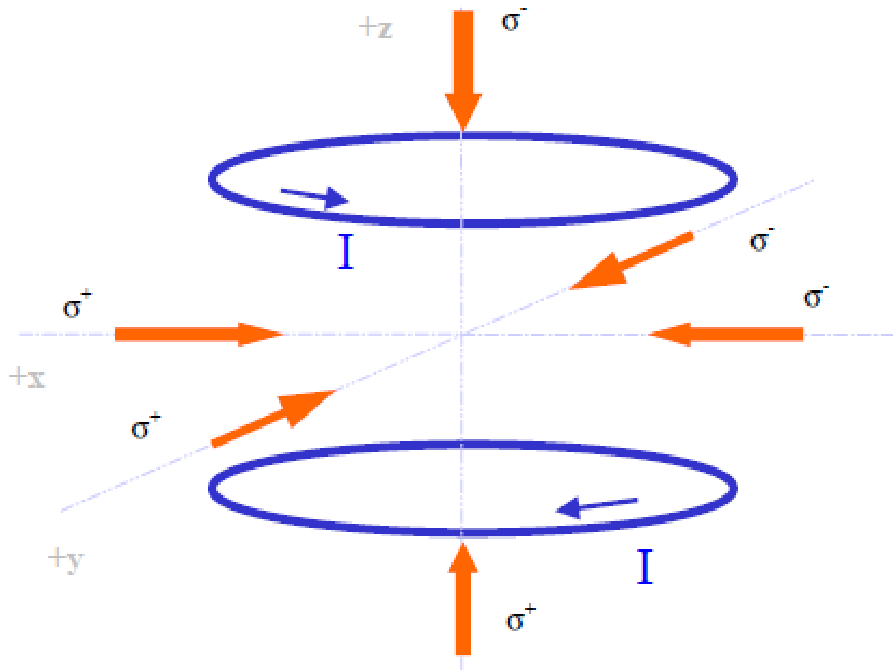
- The laser is detuned to the frequency that matches the frequency of the atomic transition of the atoms moving at 250 m/s
  - This ensures absorption
  - The atom's velocity lowers, which takes the atom out of resonance
- The magnetic field of the solenoid increases as the atoms travel
  - This displaces the energy level of the atomic transition
  - Compensates for the change in Doppler shift

Magneto-Optical Trap



- Made of three pairs of counter-propagating laser beams tuned *near* resonant frequency and a quadrupole magnetic field
  - Magnetic field is zero at the center
  - Displaces the energy levels of the atom so that when it is not in the center, it is resonant with the laser that will direct it back towards the center

Magneto-Optical Trap



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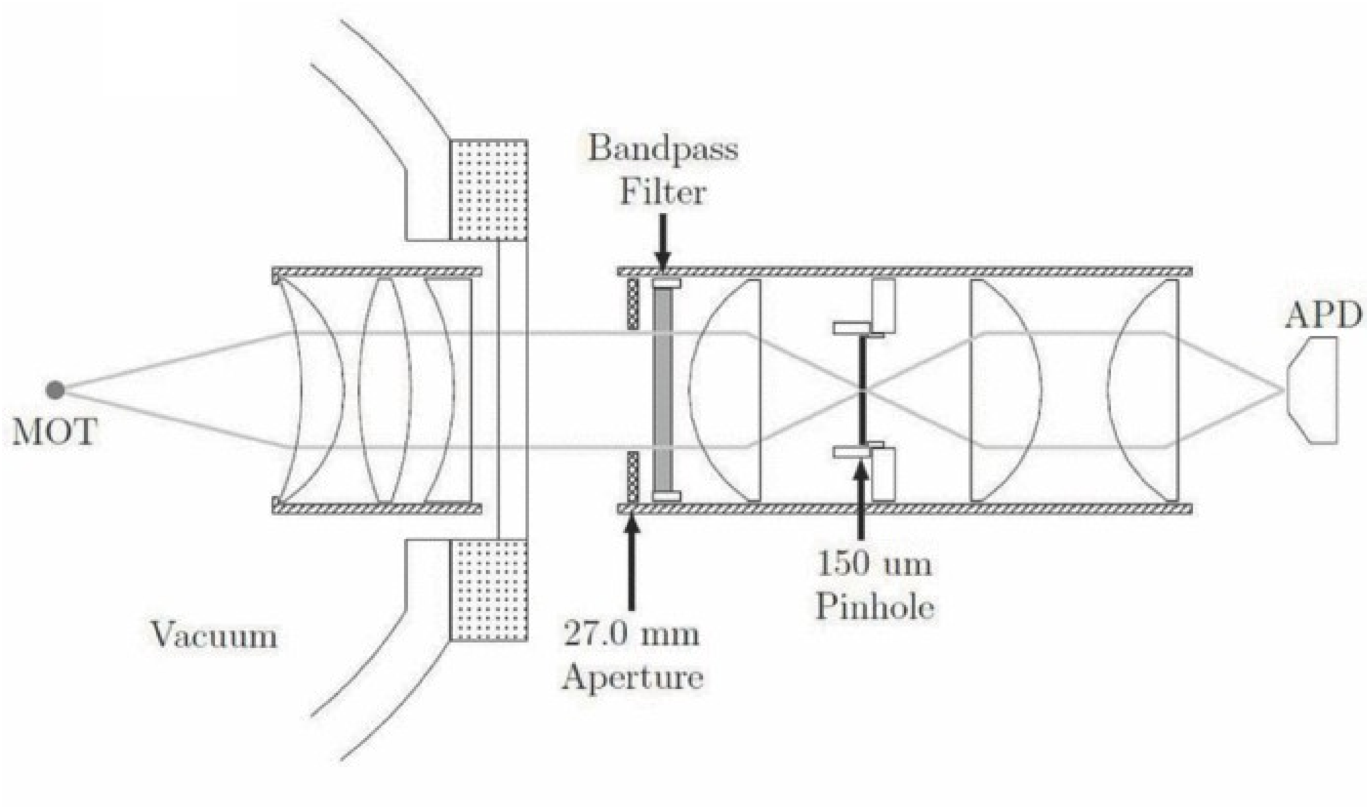
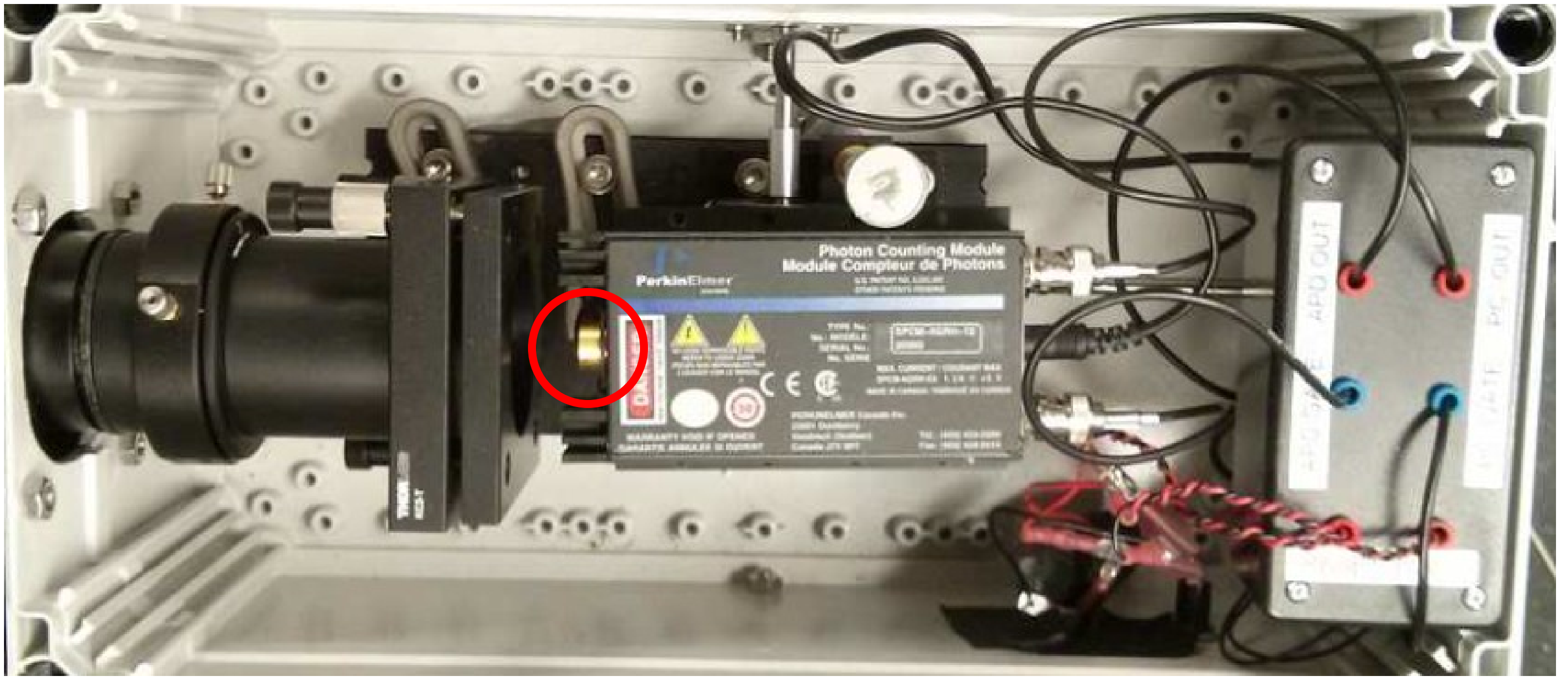
Detection Setup



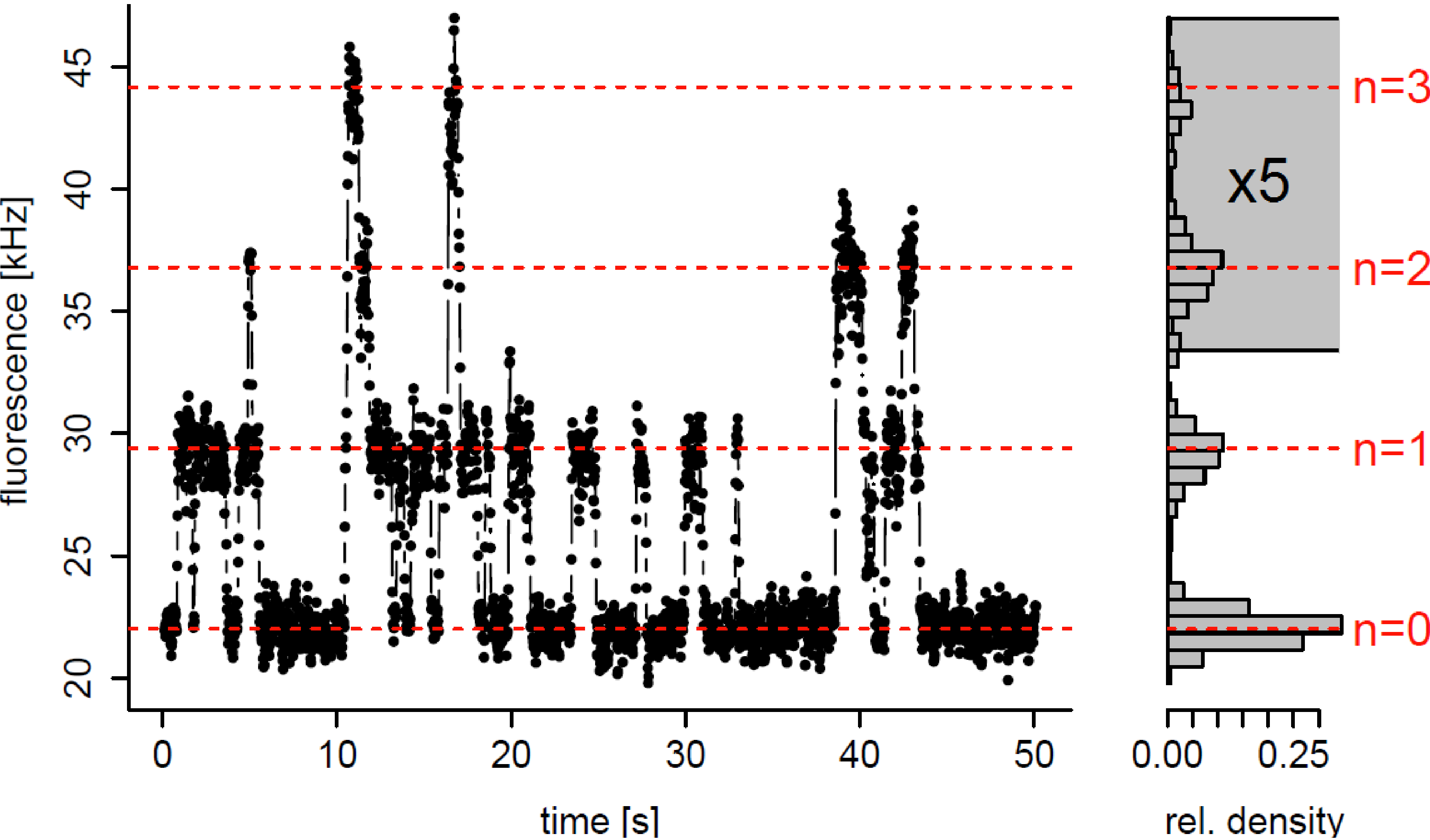
- Main concern is reducing any background fluorescence
- This setup is all enclosed and the inner walls of the vacuum tube are painted black

Avalanche Photodiode

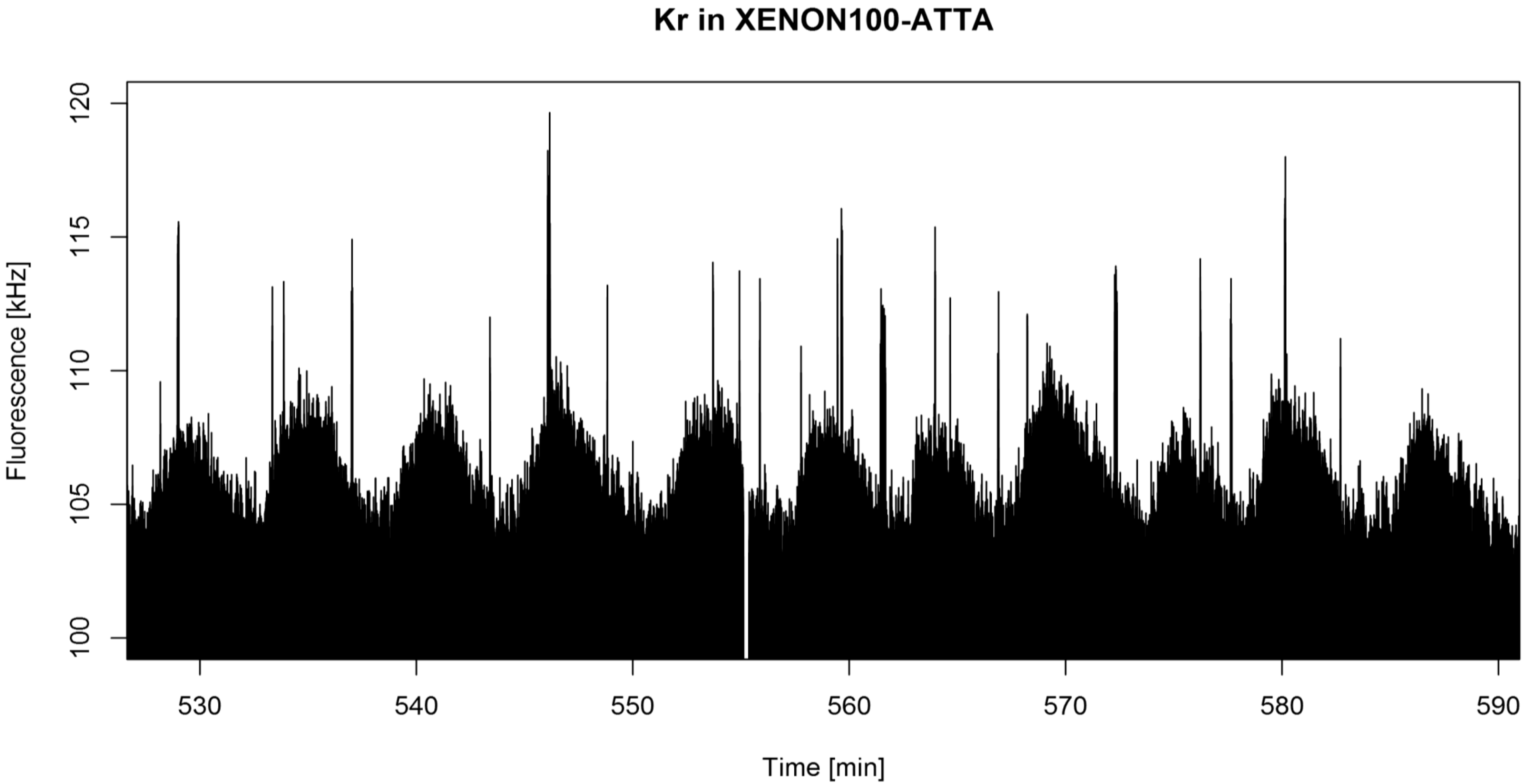


- Detects single photons
- Basically, takes the single photon and increases the electrons per photon
  - So that the signal is large enough to be read by the computer
- Signal is read by the computer program and recorded in counts per second

Data Analysis

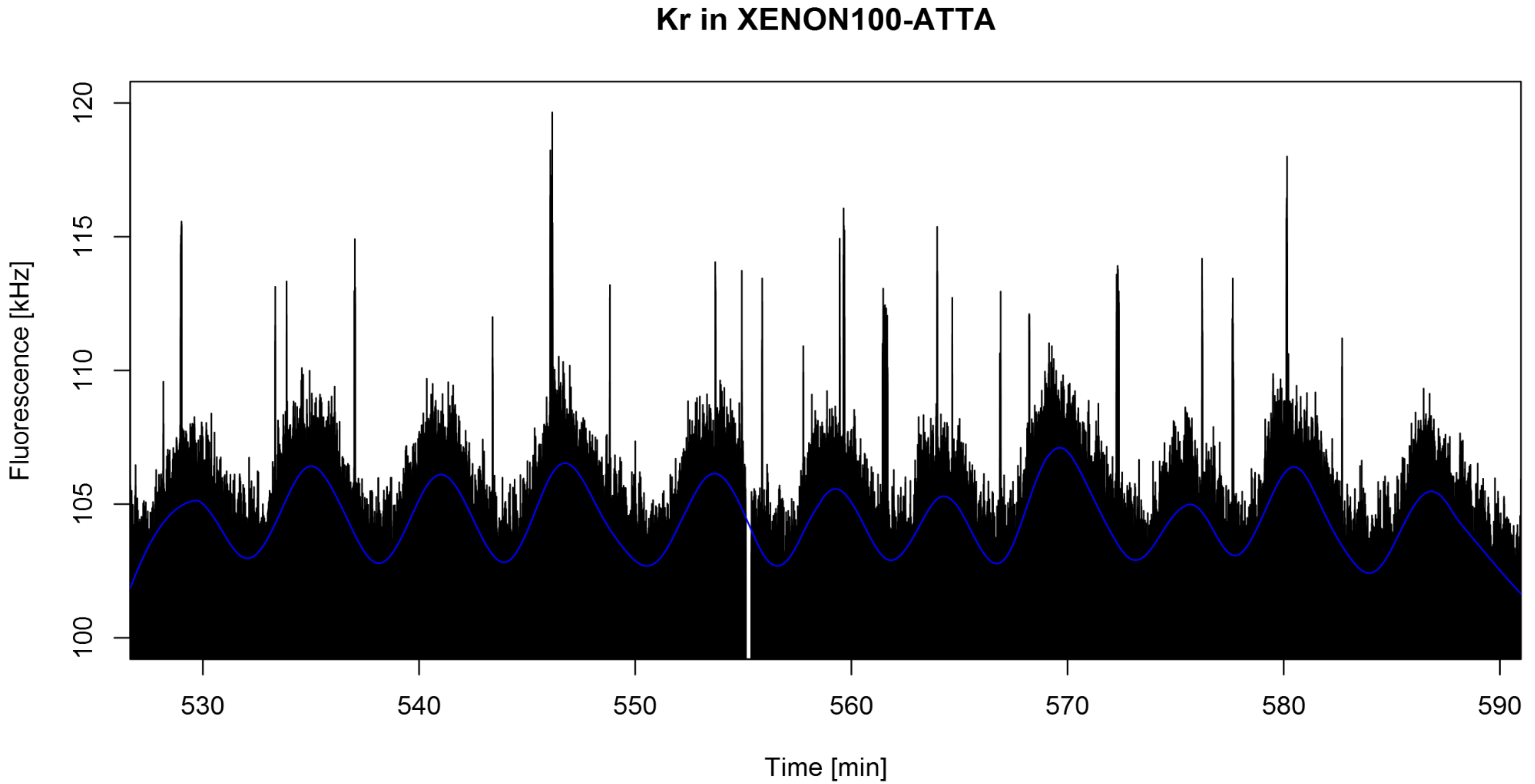


The Backgrounds

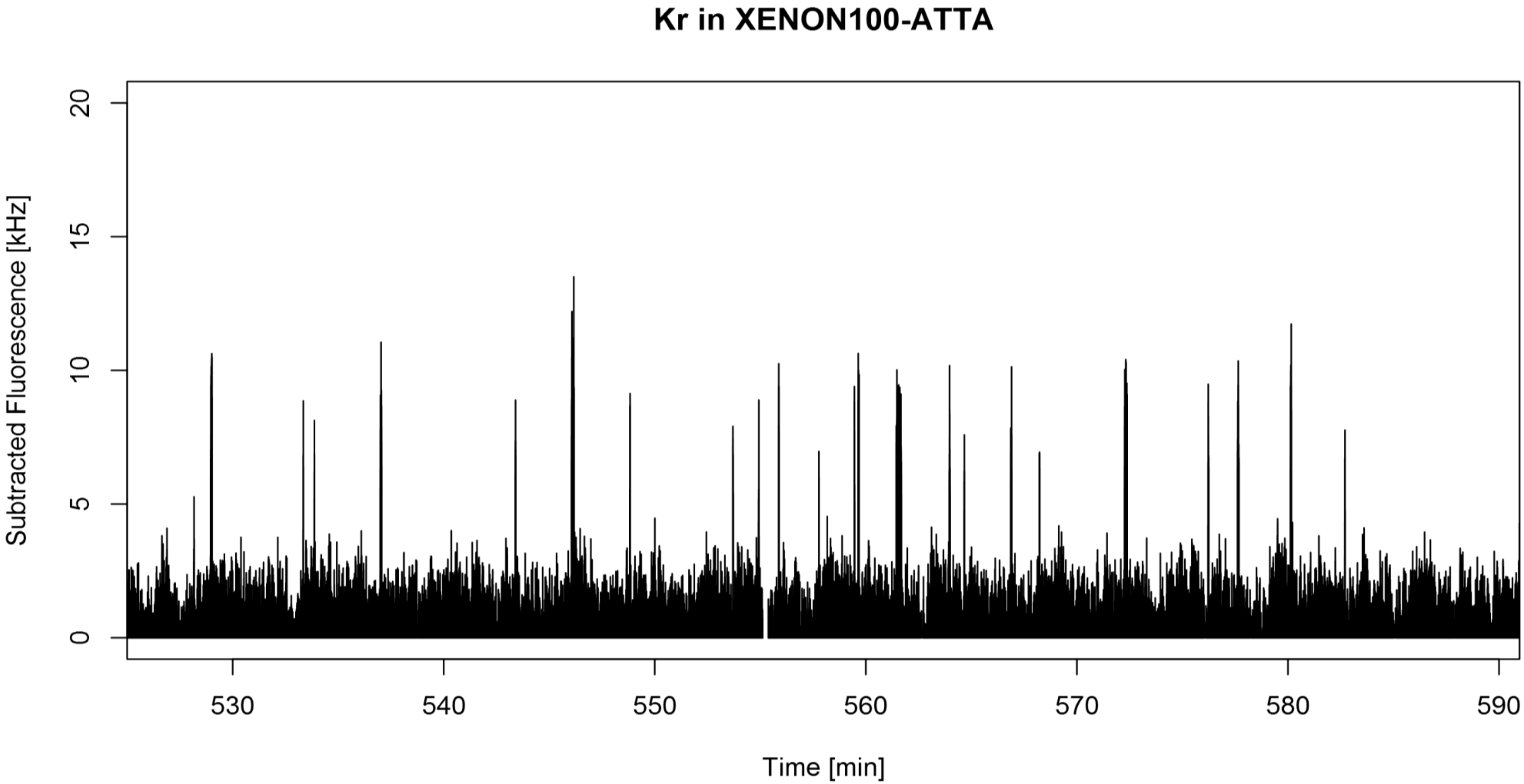


- Internal reflections
- Variations in temperature and humidity
- Laser noise

The Backgrounds

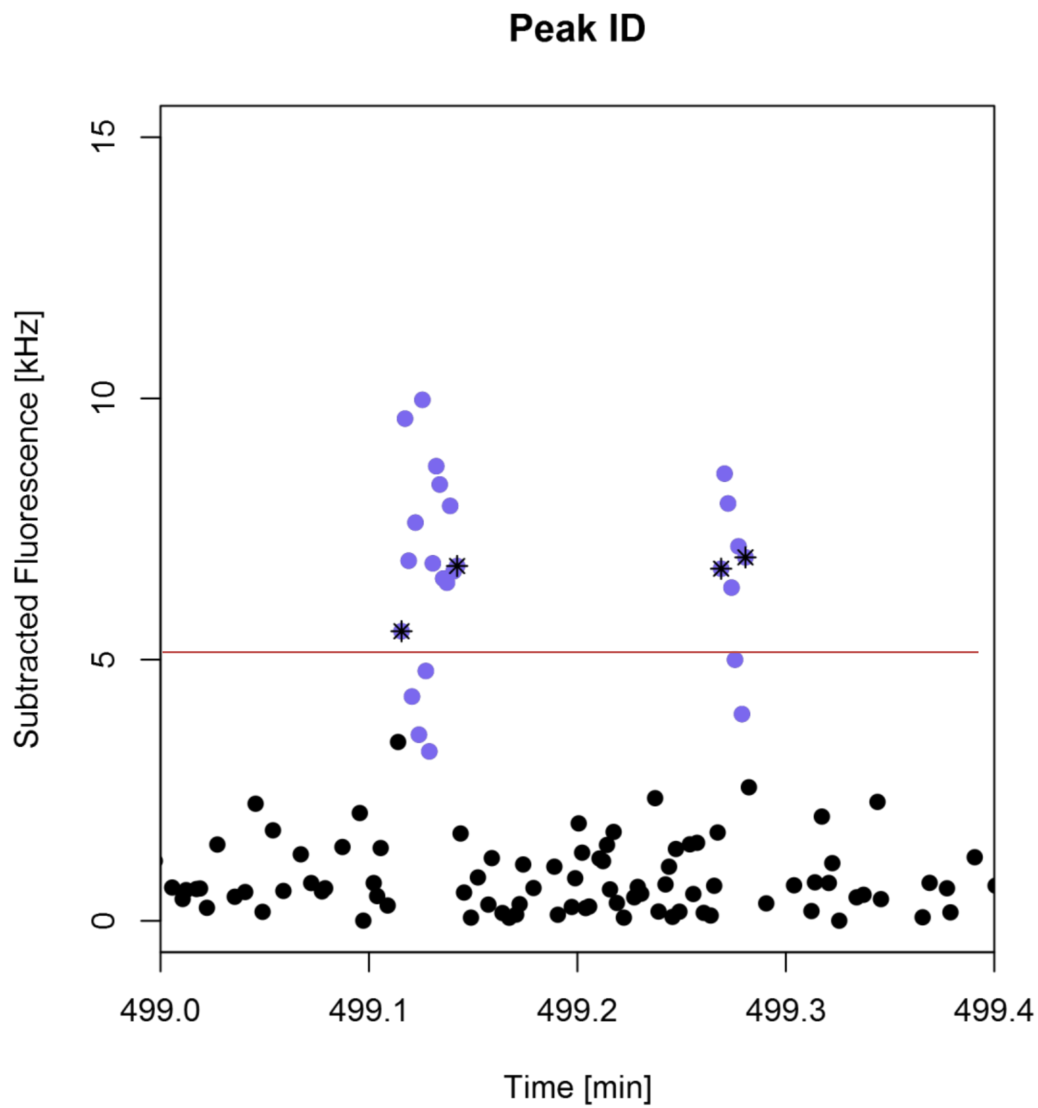


The Backgrounds

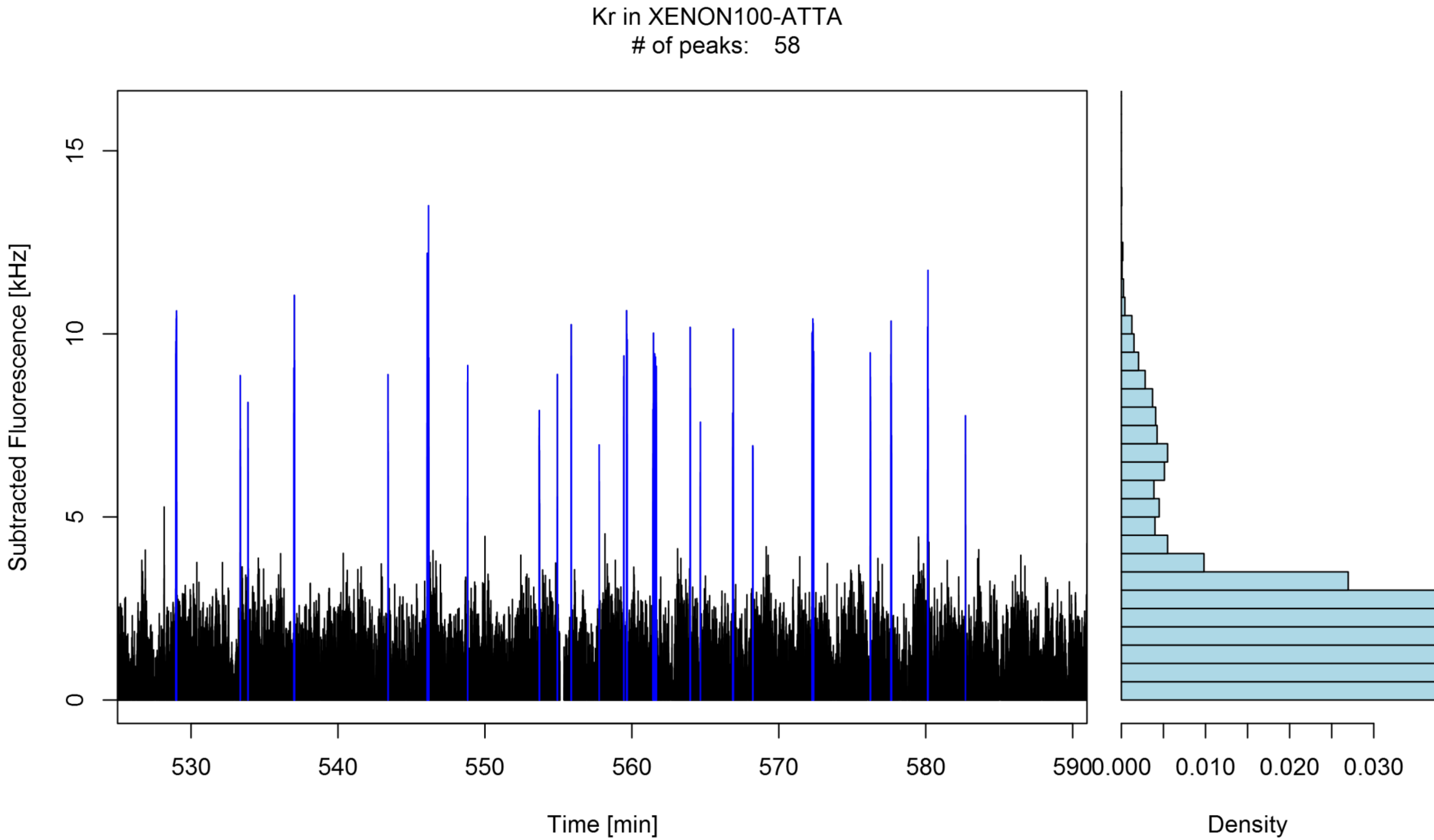


Identifying the Peaks

- Want the process automated
- So we need to pick criteria that catches at least 90%

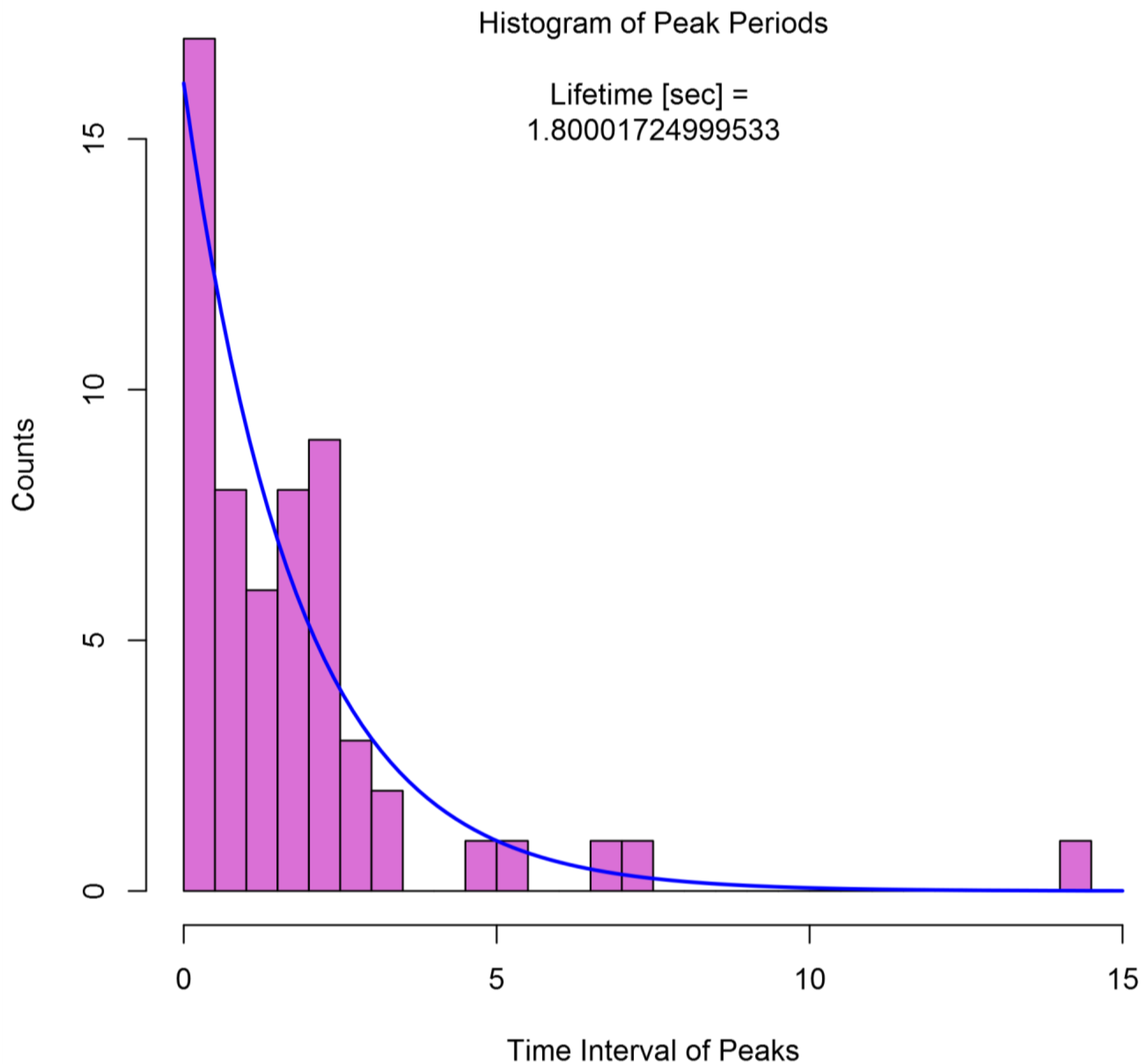


Peaks

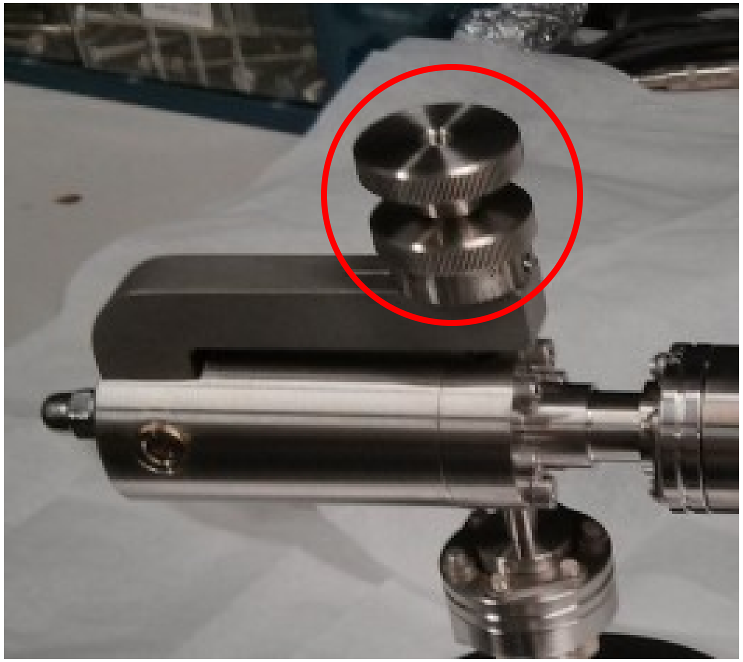


Kr in XENON100-ATTA
# of peaks: 58
Subtracted Fluorescence [kHz]
0
5
10
15
530
540
550
560
570
580
590
0.000
0.010
0.020
0.030
Time [min]
Density

Peaks


Histogram of Peak Periods
Lifetime [sec] =
1.80001724999533
Counts
0
5
10
15
0
5
10
15
Time Interval of Peaks

Pressure Valve Automation

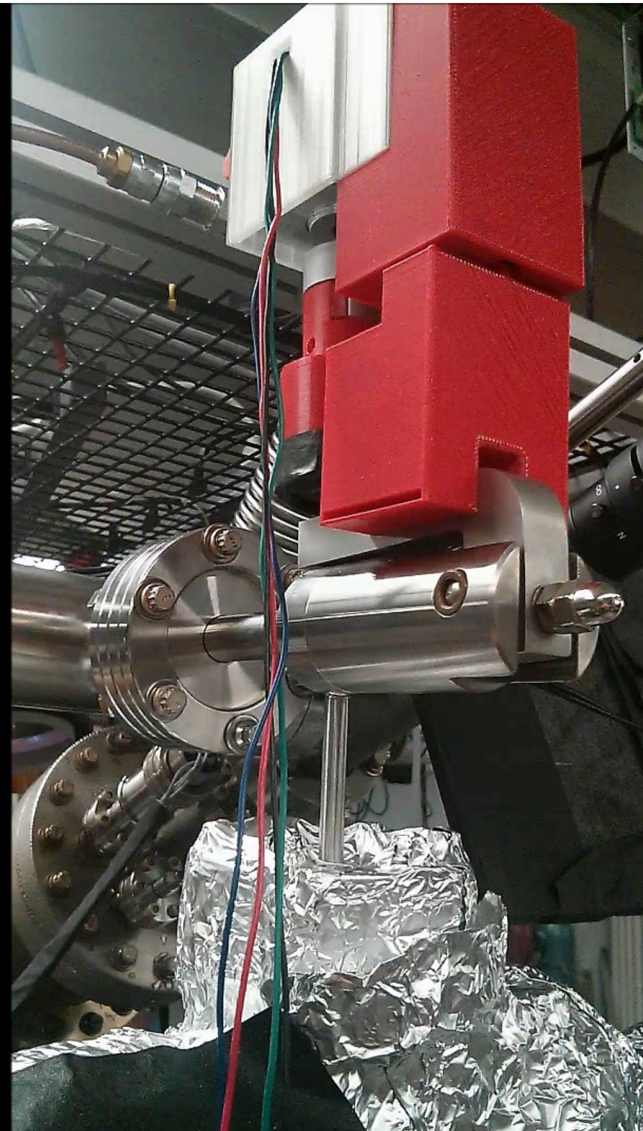


- The flow of atoms needs to stay constant so that the plasma in the RF source stays on and to keep the rate of metastable Kr produced constant to keep detection at its most efficient
- This adjustment is currently done by hand multiple times throughout the experiment

The Automation

- A stepper motor will turn the valve based on what it reads in from the pressure sensor
- Need a way to attach and hold the stepper motor to the reservoir valve and keep it steady

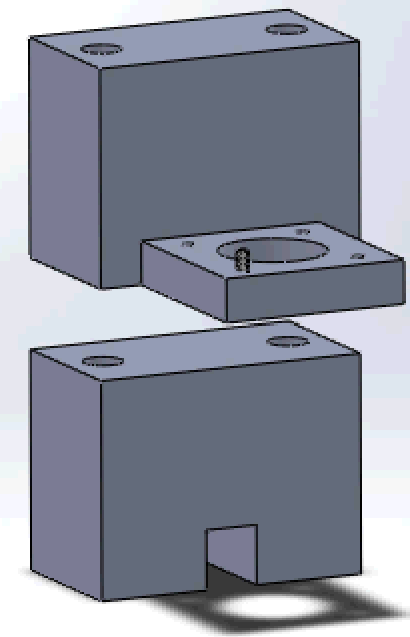
Design Process



- I analyzed the original holder

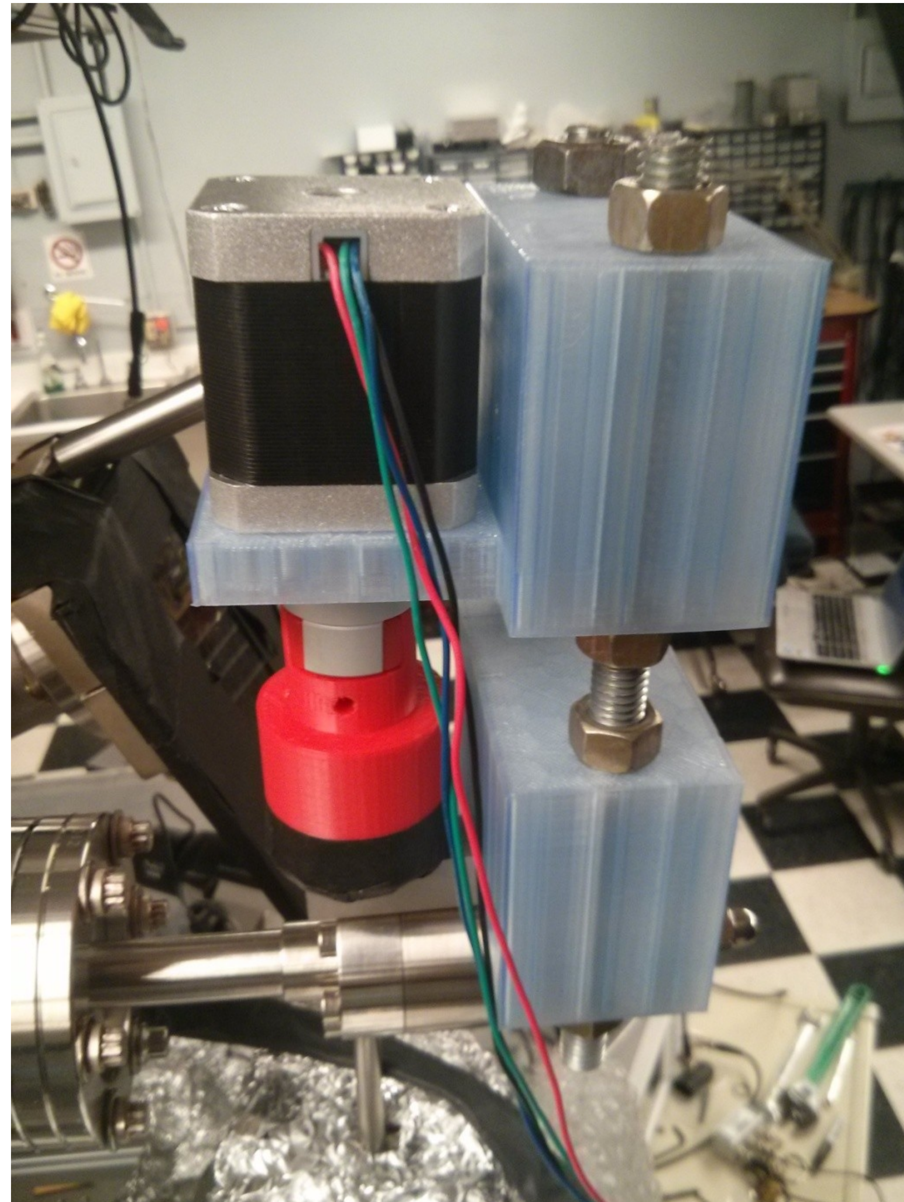
Design Process

- Used SolidWorks to create new design
- Met with the Emerging Technologies Coordinator and discussed my design

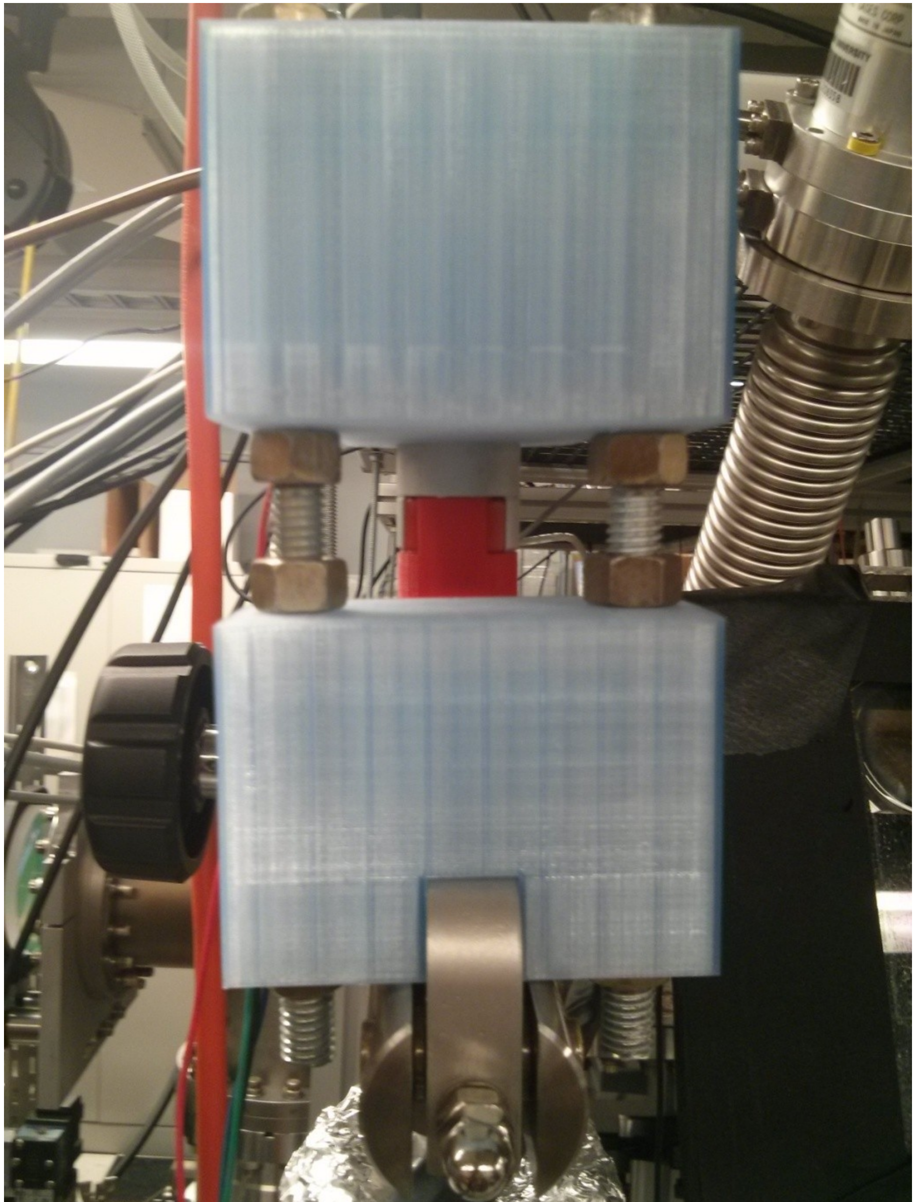


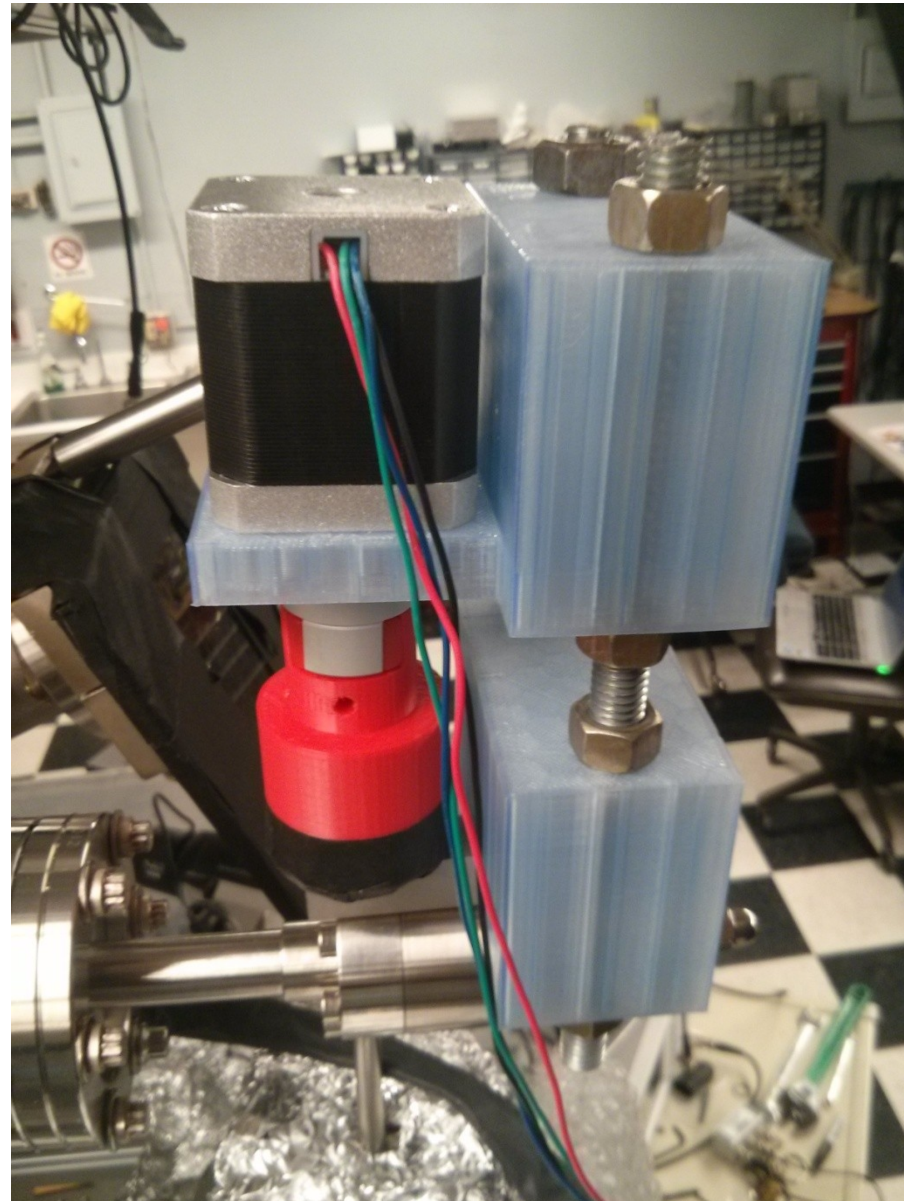
Prototype!

- Attached the stepper motor and the threaded rods to the components

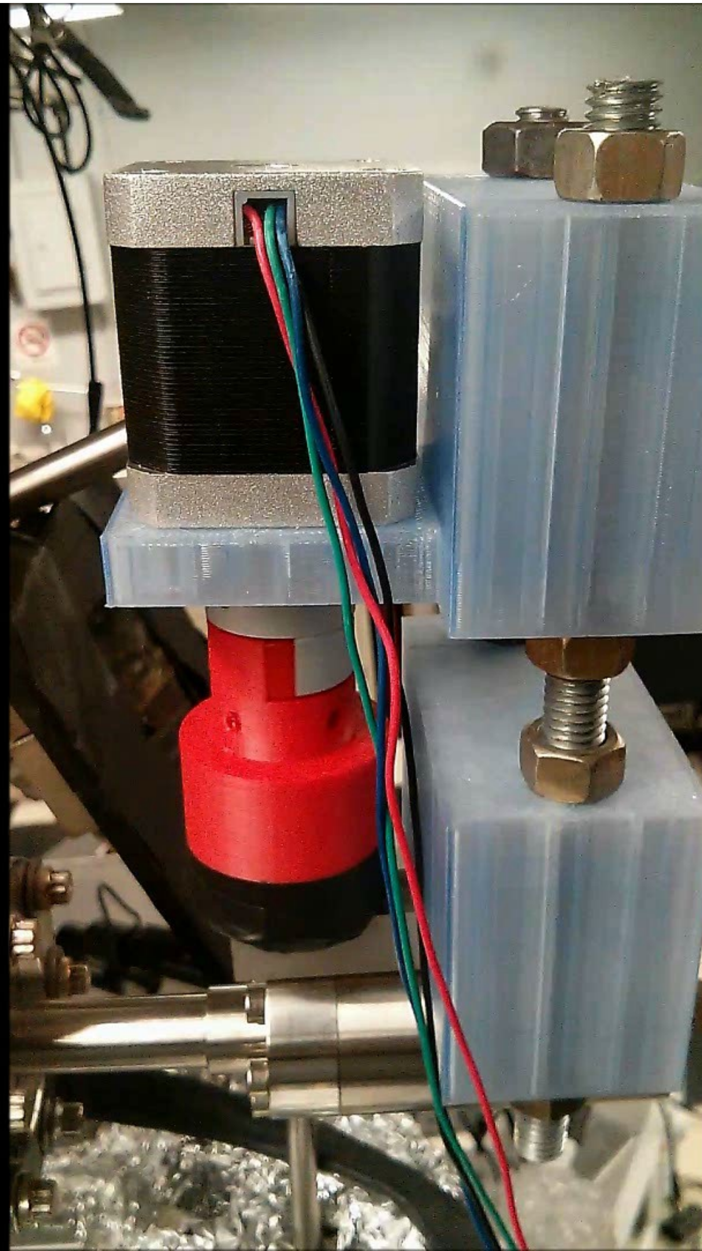


Prototype!





Prototype!



Conclusion

- I gained a lot of new skills:
  - R Programming Language
  - SolidWorks
  - 3D Printing
  - Programming stepper motors
- As well as learned a lot

Acknowledgements

- Dr. Andre Loose
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- Everyone at Nevis for being so welcoming and helpful
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