PET experiment

BY LEVI KEAY

LAB PARTNER : MARCUS LEE

PHYS409 FALL 2021

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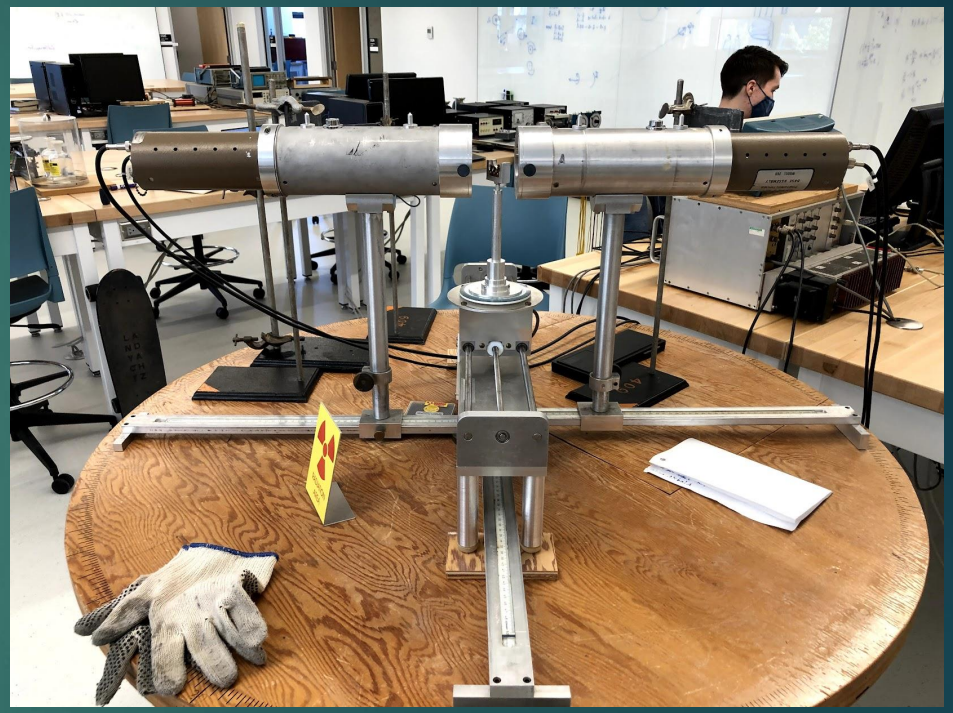
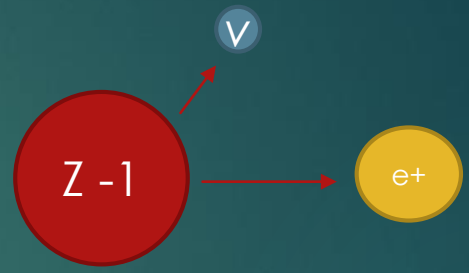


Overview Positron Emission Tomography (PET):

Physical Mechanism :

1) Beta Plus decay -> Positron emission

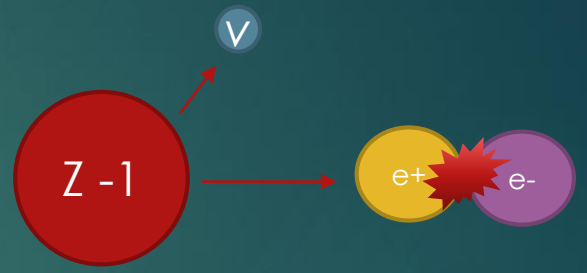


Detection :

Overview Positron Emission Tomography (PET):

Physical Mechanism :

1) Beta Positive decay -> Positron emission
2) Positron meets electron -> Annihilation

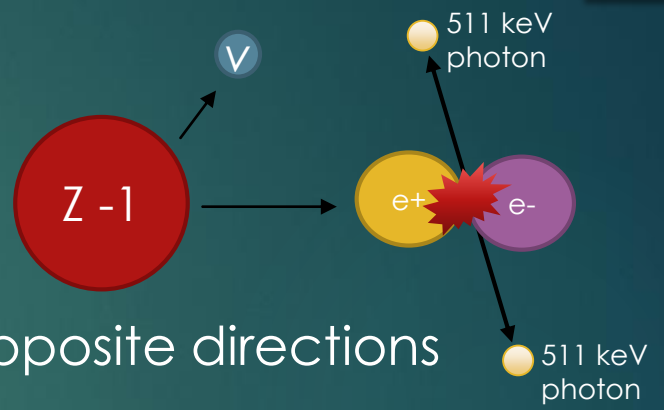


Detection :

Overview Positron Emission Tomography (PET):

Physical Mechanism :

1) Beta Positive decay -> Positron emission
2) Positron meets electron -> Annihilation
3) Two photons (511 keV) produced, travelling in opposite directions



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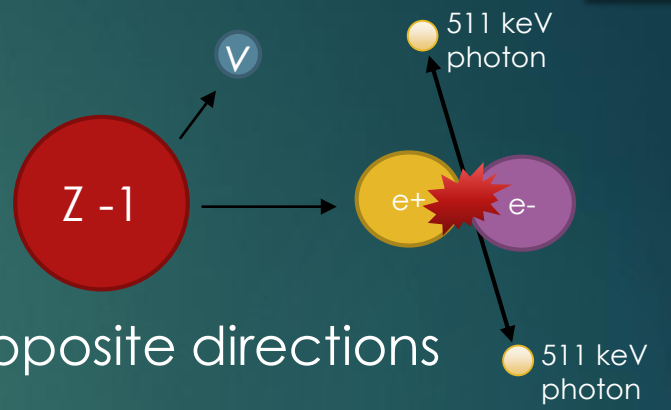
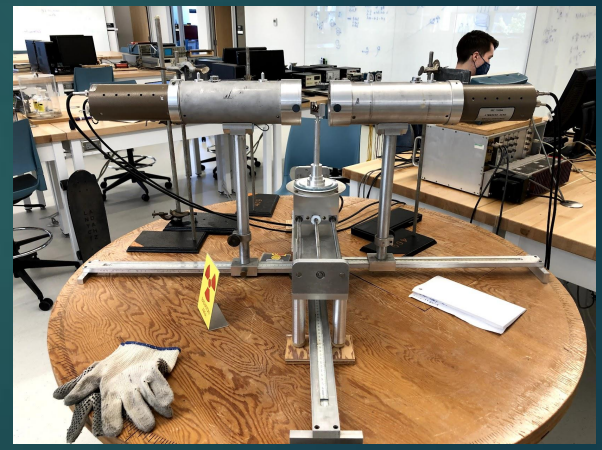


Detection :

1) Use pair of scintillators + photomultiplier tubes :

   capture gamma photons + amplify/convert to electrical signal



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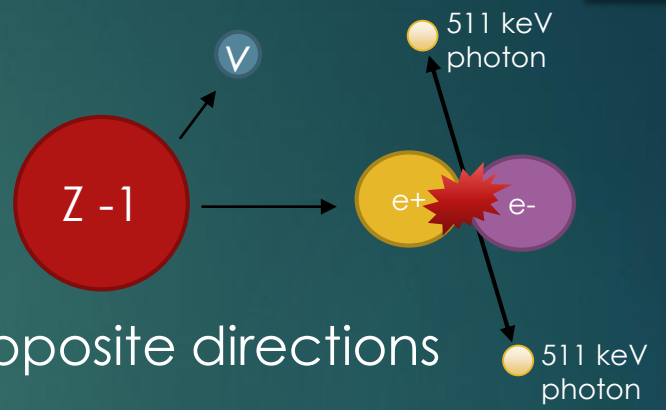
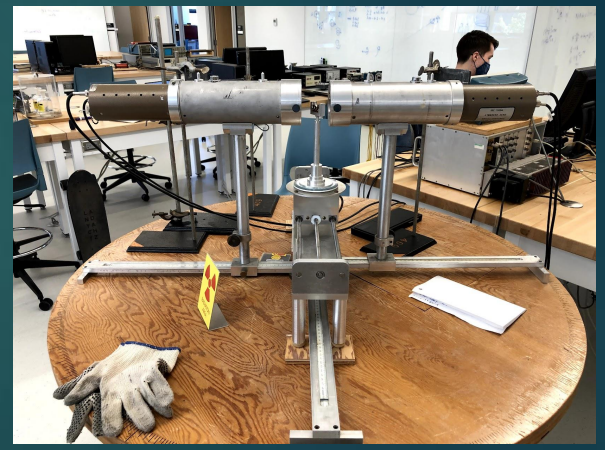


Detection :

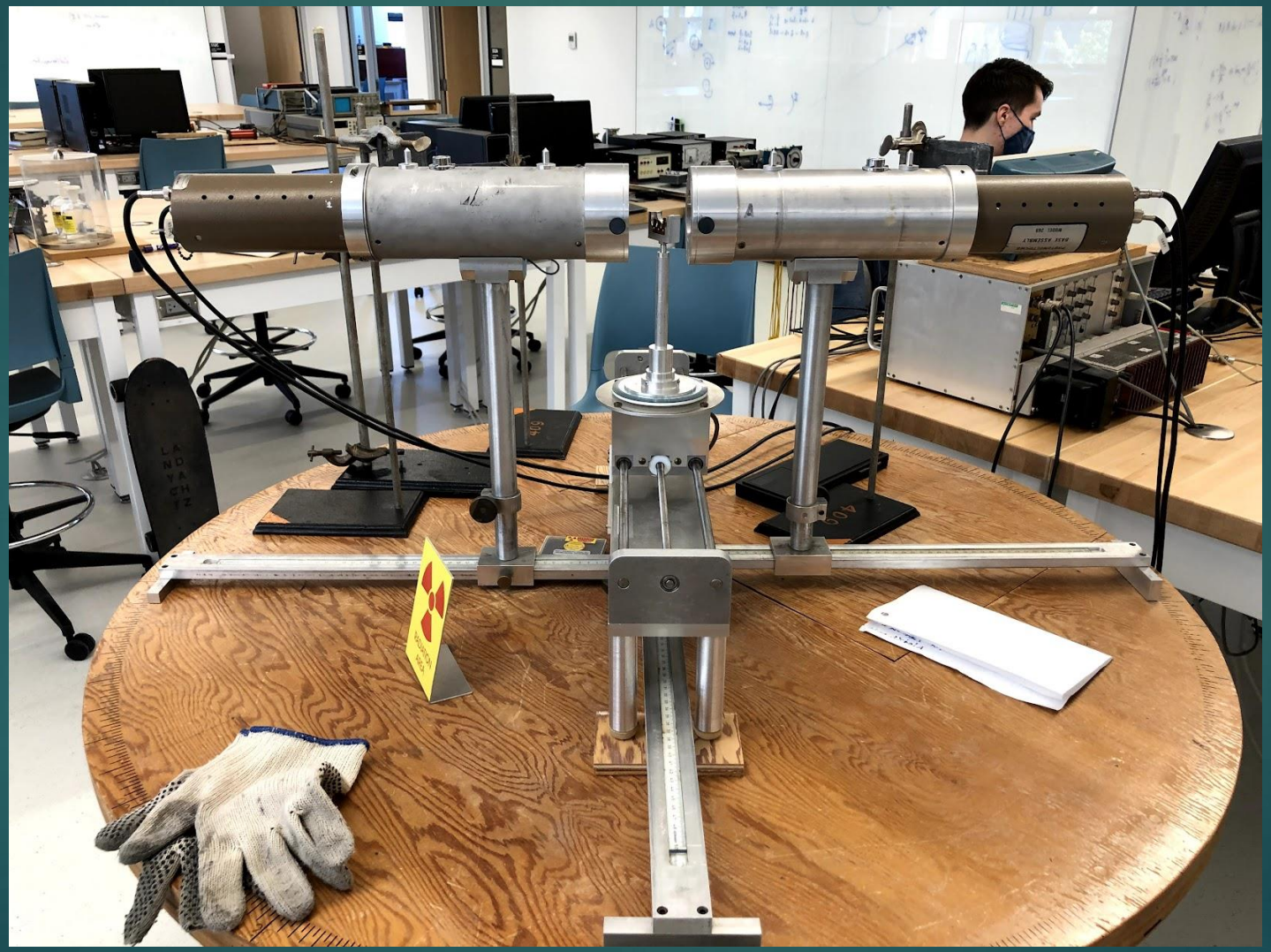
1) Use pair of scintillators + photomultiplier tubes :
   capture gamma photons + amplify/convert to electrical signal

2) Use hardware : count number of **coincident*** photon captures



*when **both scintillators activated within time window** (~ns)

Apparatus:



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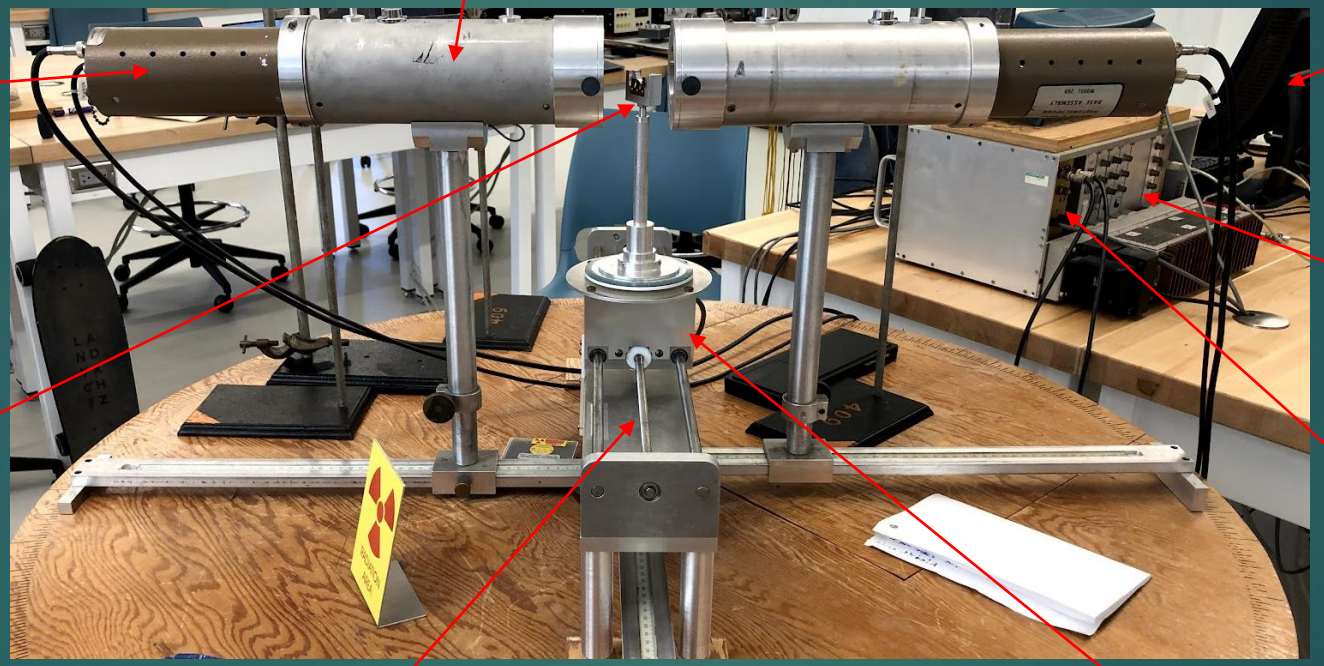
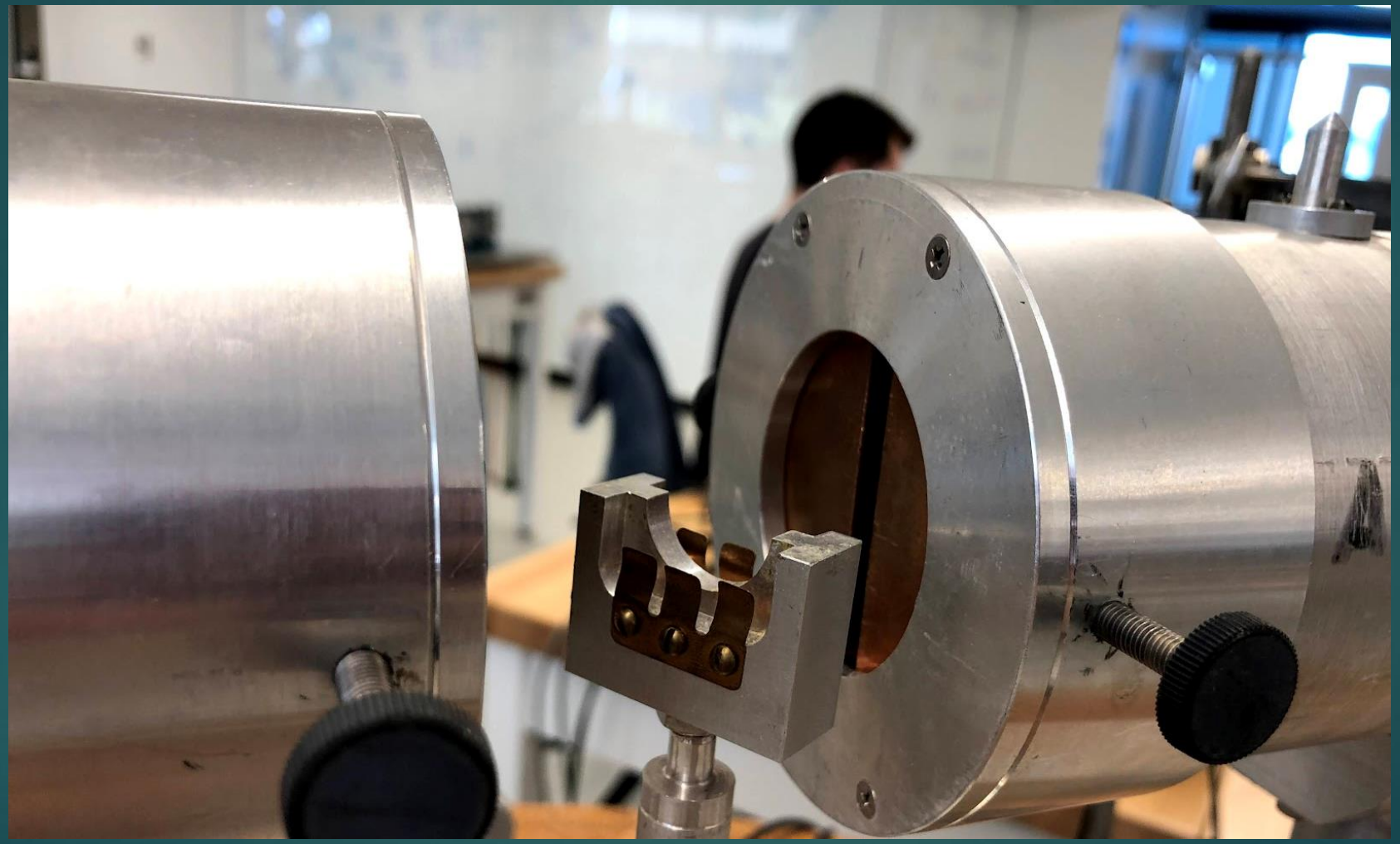

Scintillator
Photo-multiplier tube (PMT)
Source arm
Track
Computer
Hardware
High voltage power supply (for PMTs)
Step motors

Apparatus:



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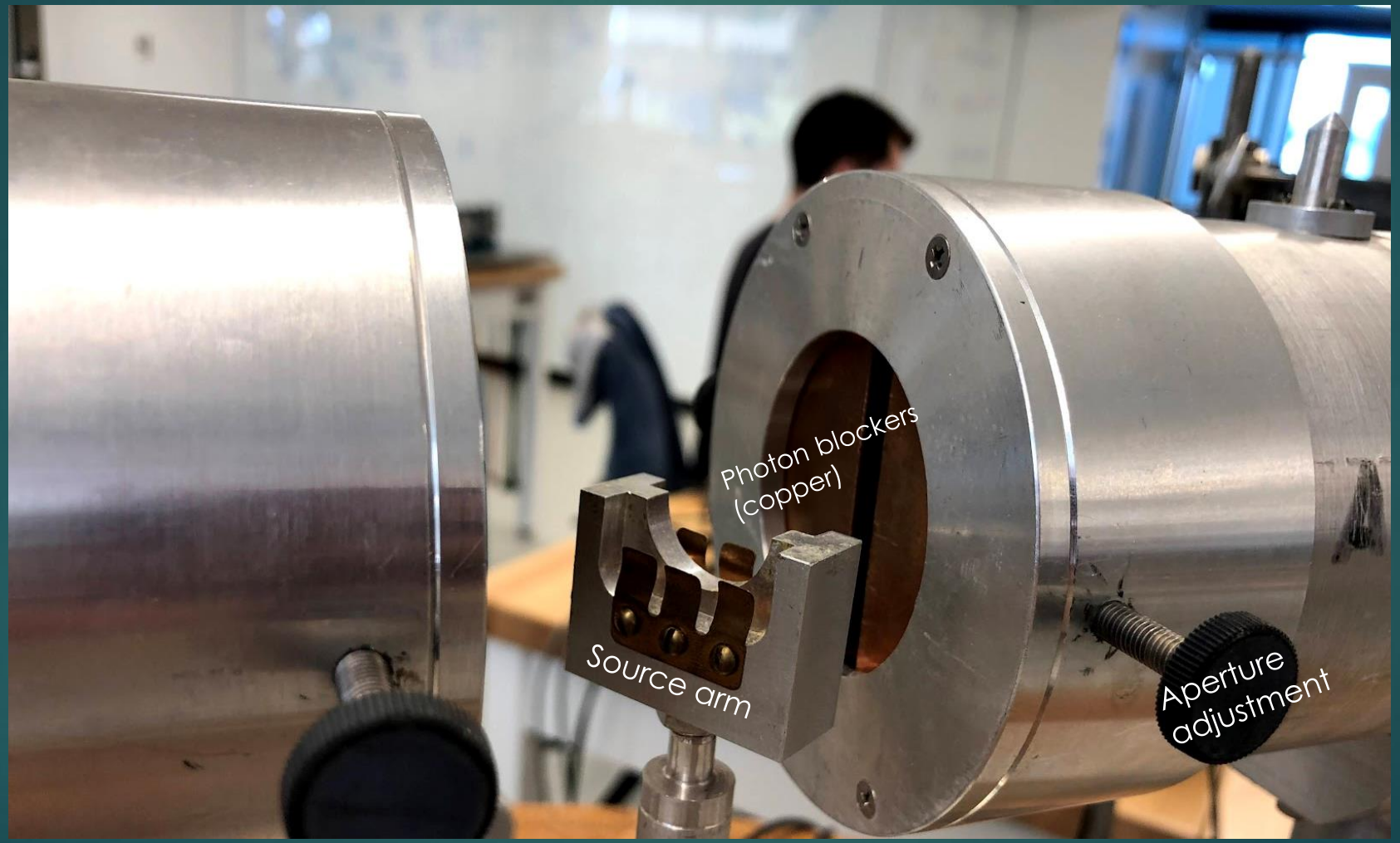
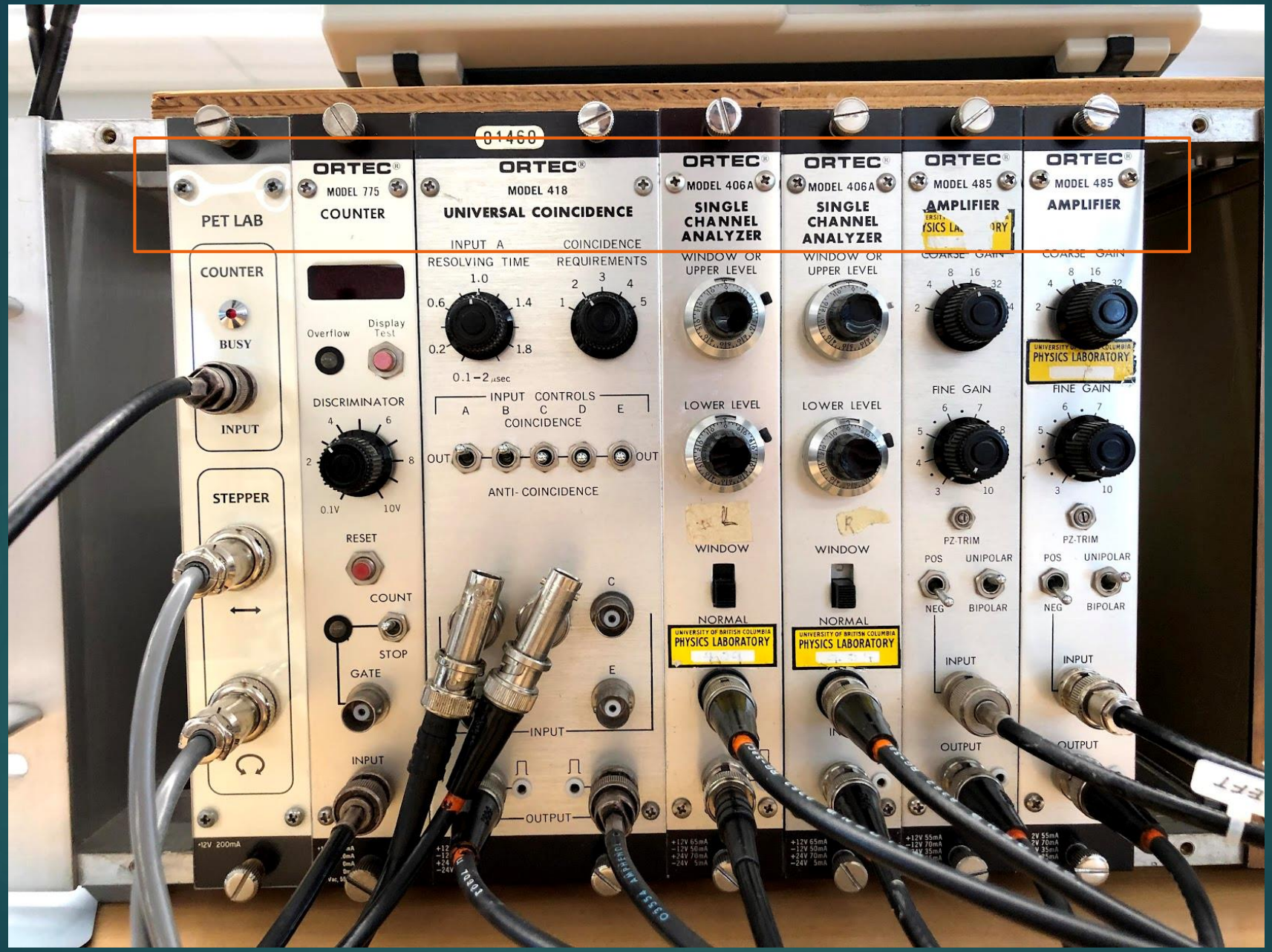
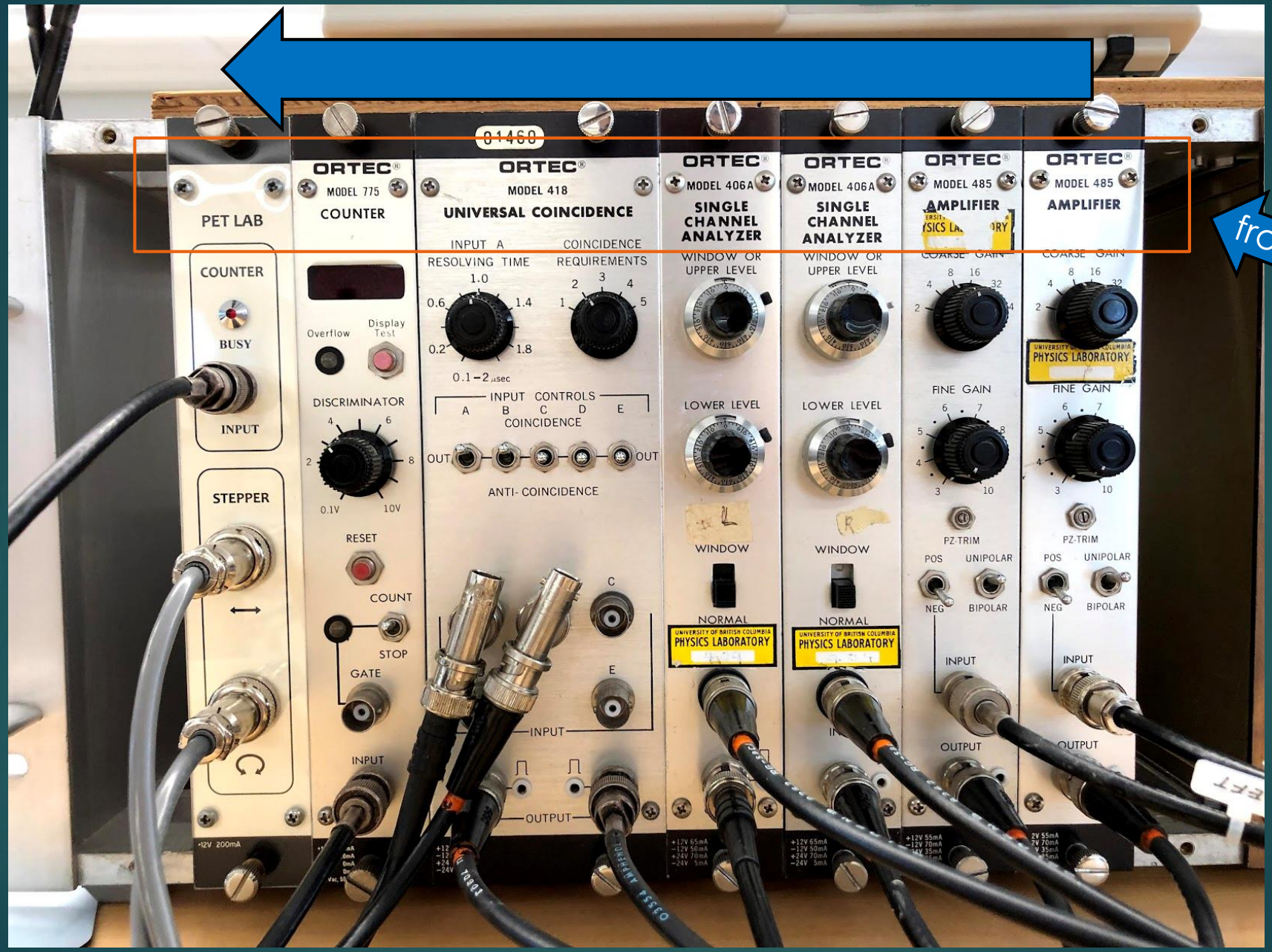


Radiation Source: Na-22

Sodium-22 is a man-made isotope with a half-life of 2.6 years.
It decays emitting a positron (β^+ decay) into stable neon-22.


PET LAB
COUNTER
BUSY
INPUT
STEPPER
ORTEC
MODEL 775
COUNTER
Overflow
Display Test
DISCRIMINATOR
0.1V
10V
RESET
COUNT
STOP
GATE
INPUT
01460
ORTEC
MODEL 418
UNIVERSAL COINCIDENCE
INPUT A
RESOLVING TIME
COINCIDENCE
REQUIREMENTS
0.1–2 μsec
INPUT CONTROLS
A B C D E
COINCIDENCE
OUT
OUT
ANTI- COINCIDENCE
C
E
INPUT
OUTPUT
ORTEC
MODEL 406A
SINGLE CHANNEL ANALYZER
WINDOW OR UPPER LEVEL
LOWER LEVEL
WINDOW
NORMAL
PHYSICS LABORATORY
ORTEC
MODEL 406A
SINGLE CHANNEL ANALYZER
WINDOW OR UPPER LEVEL
LOWER LEVEL
WINDOW
NORMAL
PHYSICS LABORATORY
ORTEC
MODEL 485
AMPLIFIER
FINE GAIN
PZ-TRIM
POS
UNIPOLAR
NEG
BIPOLAR
INPUT
OUTPUT
ORTEC
MODEL 485
AMPLIFIER
PHYSICS LABORATORY
FINE GAIN
PZ-TRIM
POS
UNIPOLAR
NEG
BIPOLAR
INPUT
OUTPUT


from PMT
PET LAB
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BUSY
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MODEL 775
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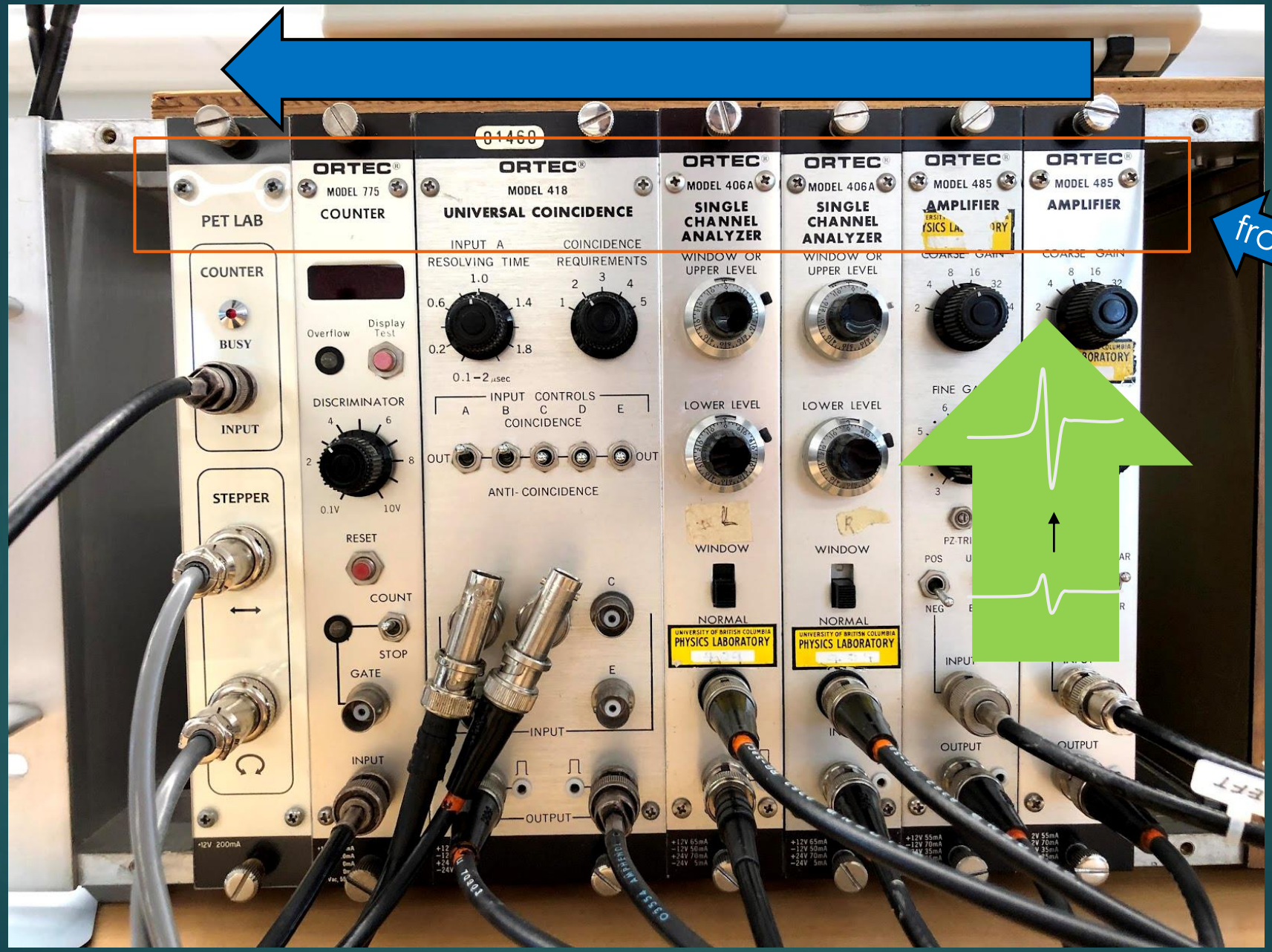
INPUT
OUTPUT


from PMT
PET LAB
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MODEL 485
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ORTEC
MODEL 485
AMPLIFIER
PHYSICS LABORATORY
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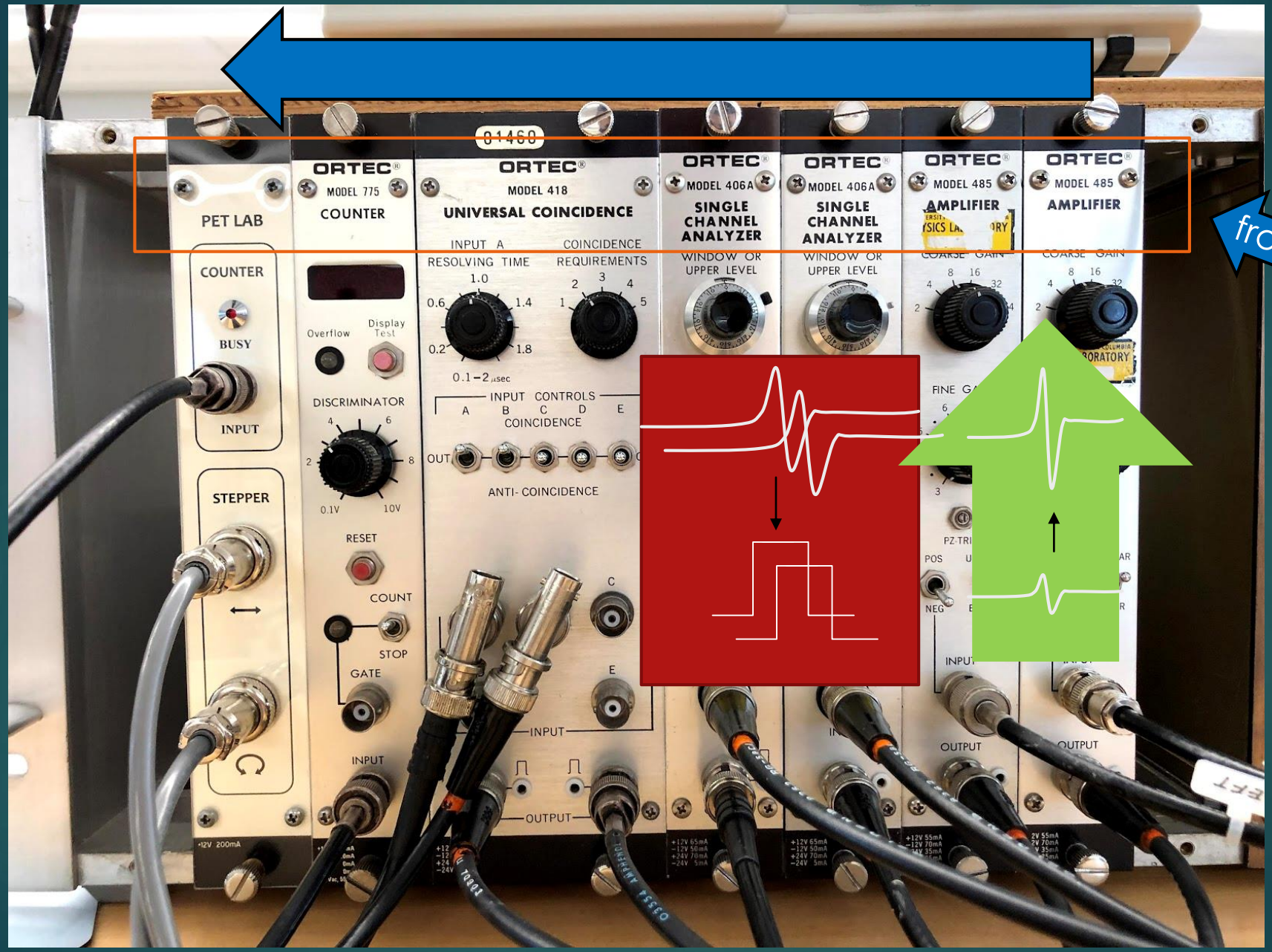
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MODEL 775
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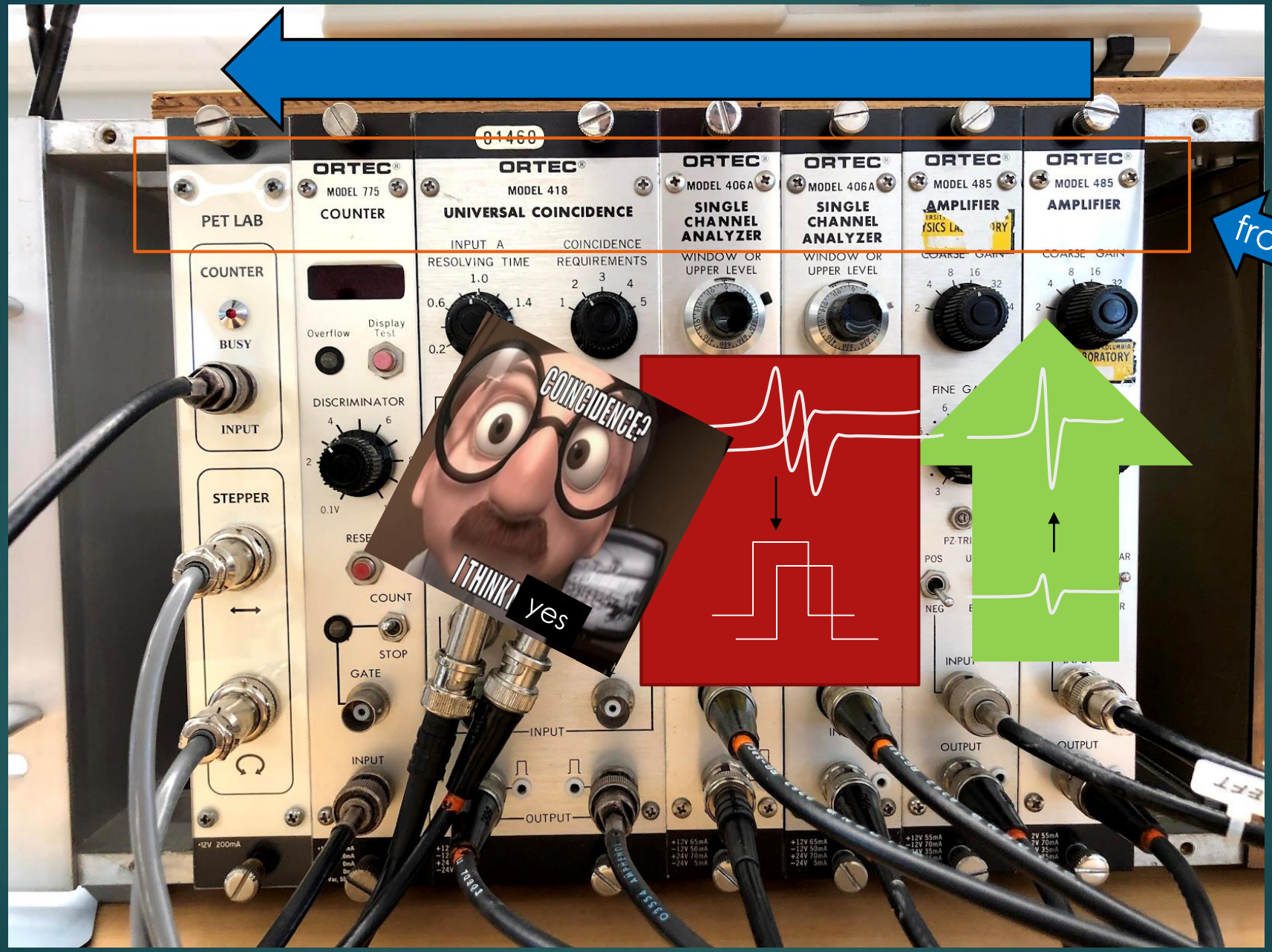
from PMT


from PMT
COINCIDENCE?
I THINK
yes
PET LAB
ORTEC
MODEL 775
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UNIVERSAL COINCIDENCE
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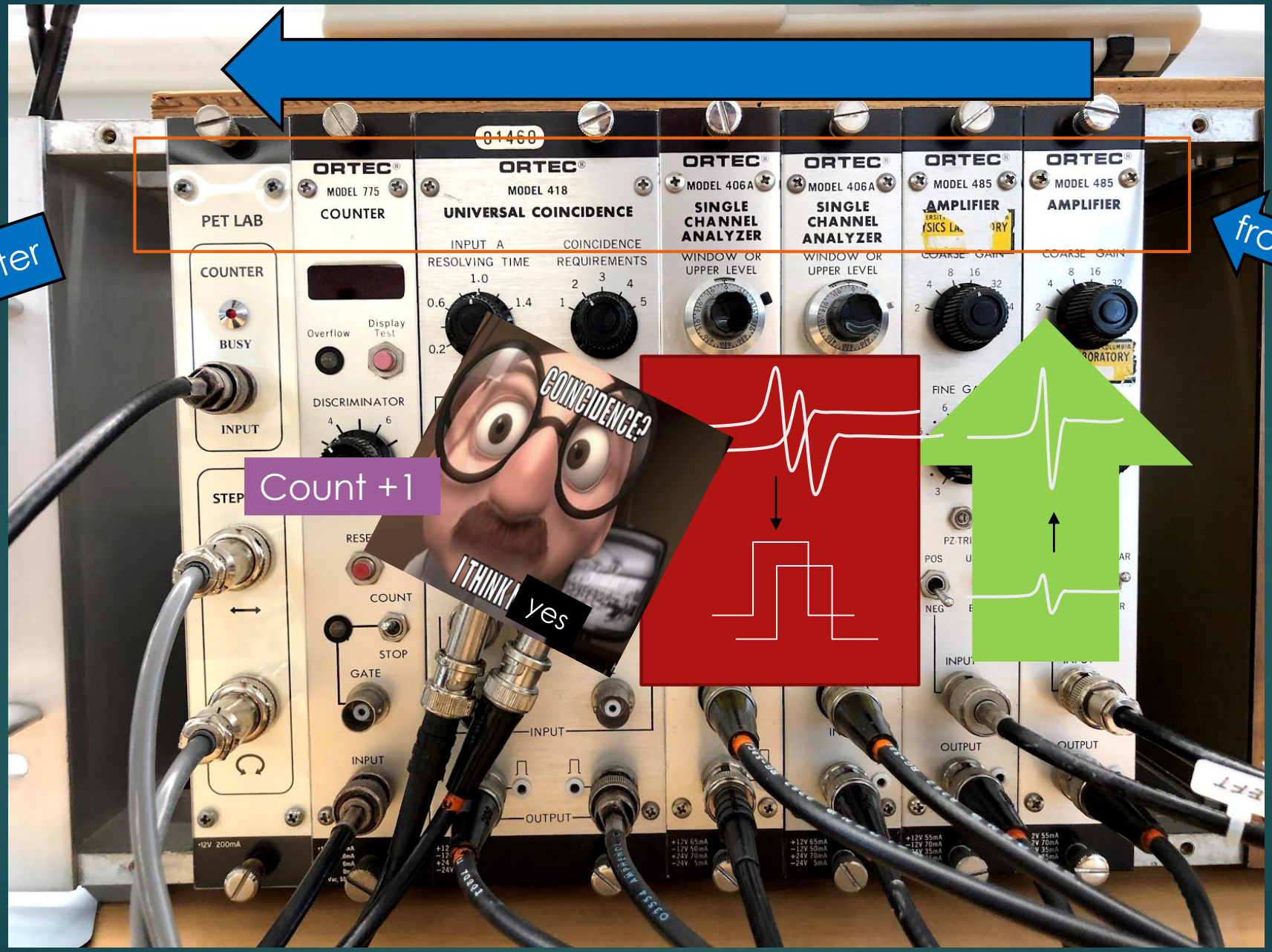
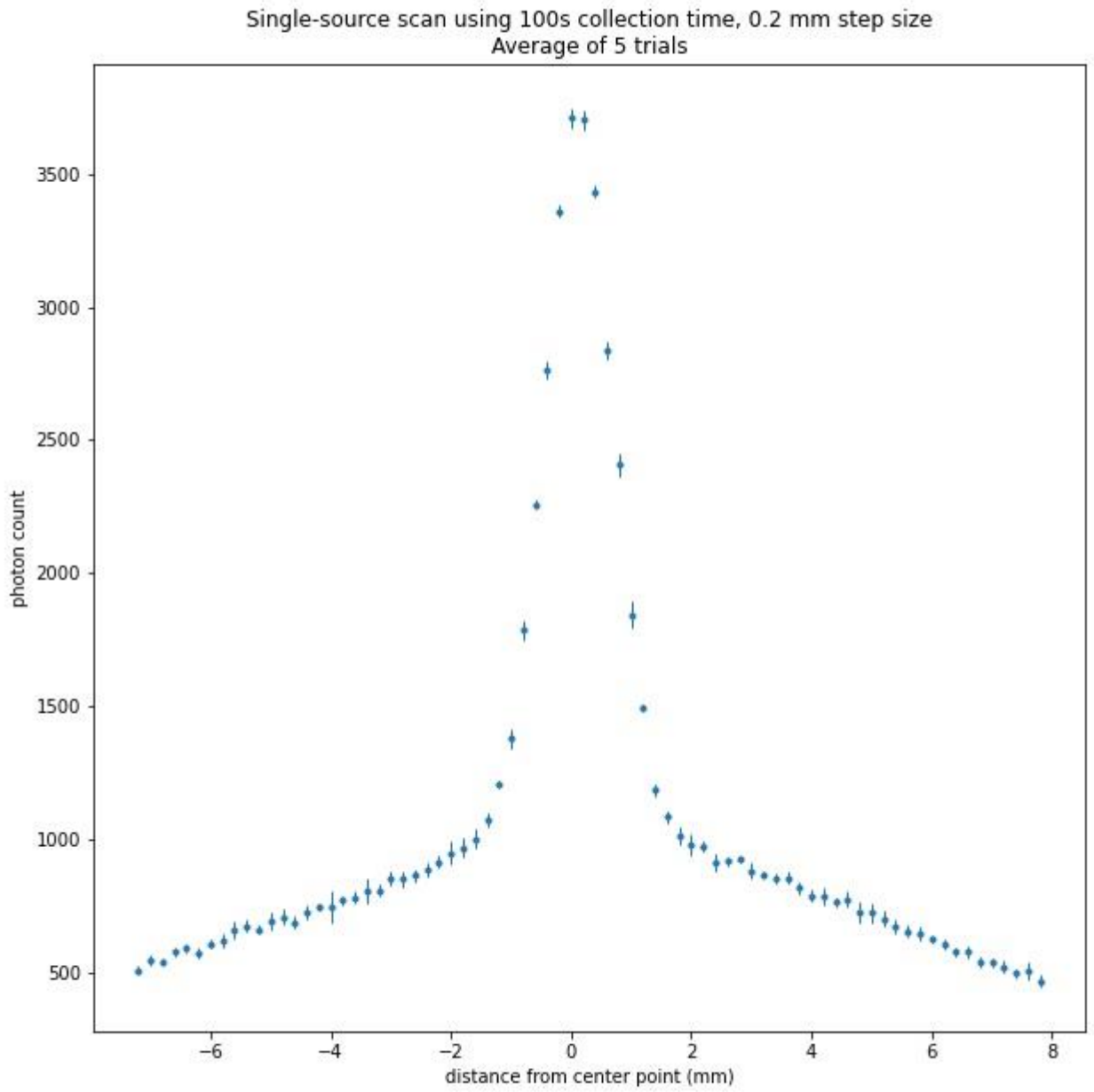

to computer
from PMT
PET LAB
ORTEC
MODEL 775
COUNTER
MODEL 418
UNIVERSAL COINCIDENCE
MODEL 406A
SINGLE CHANNEL ANALYZER
MODEL 485
AMPLIFIER
COUNTER
BUSY
INPUT
DISCRIMINATOR
Overflow
Display Test
COUNT
STOP
GATE
INPUT
OUTPUT
Count +1
COINCIDENCE?
I THINK
yes

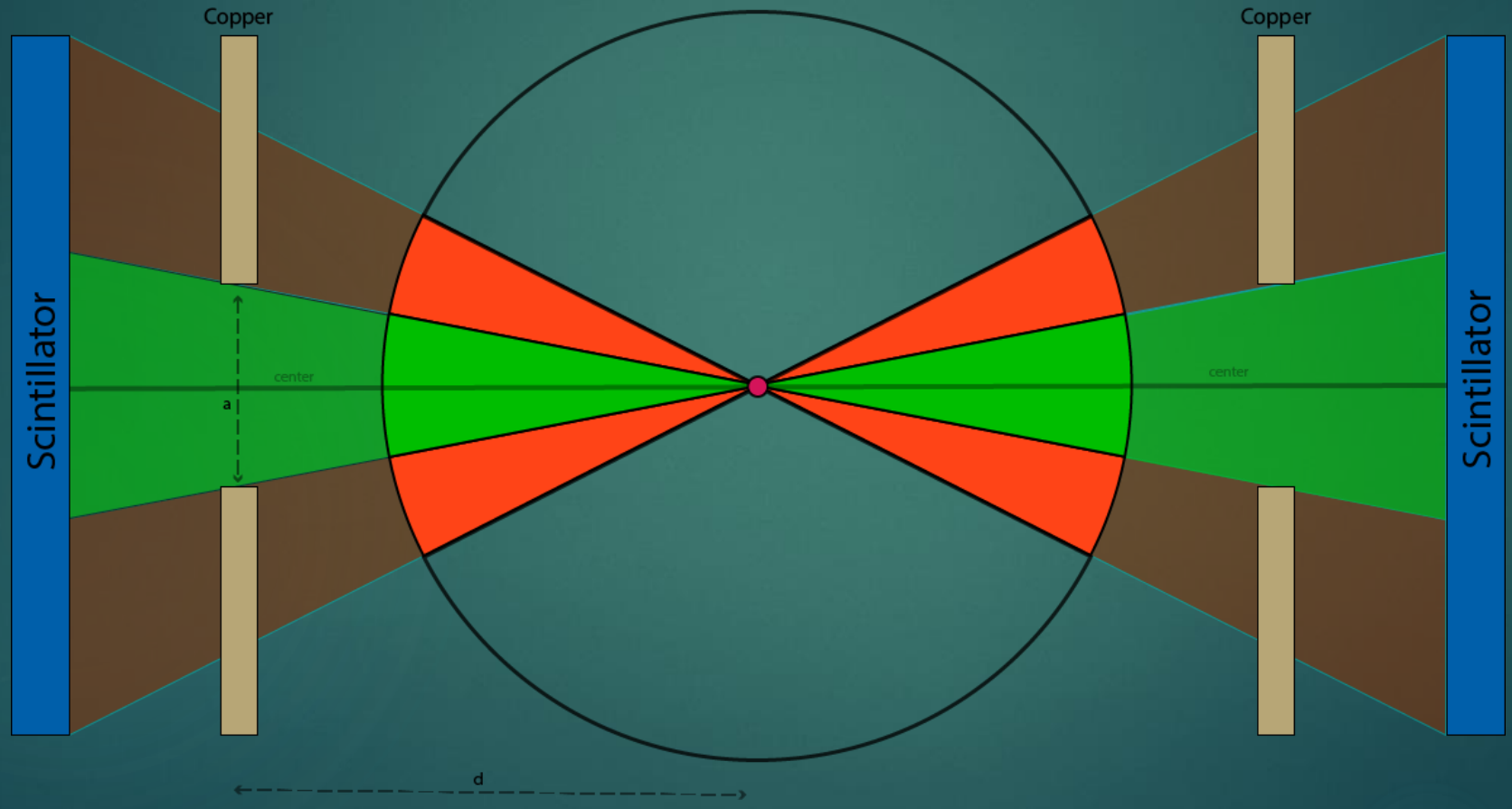
Data collected from a scan of a single radioactive source looks like this:

The aperture is set to 3mm.

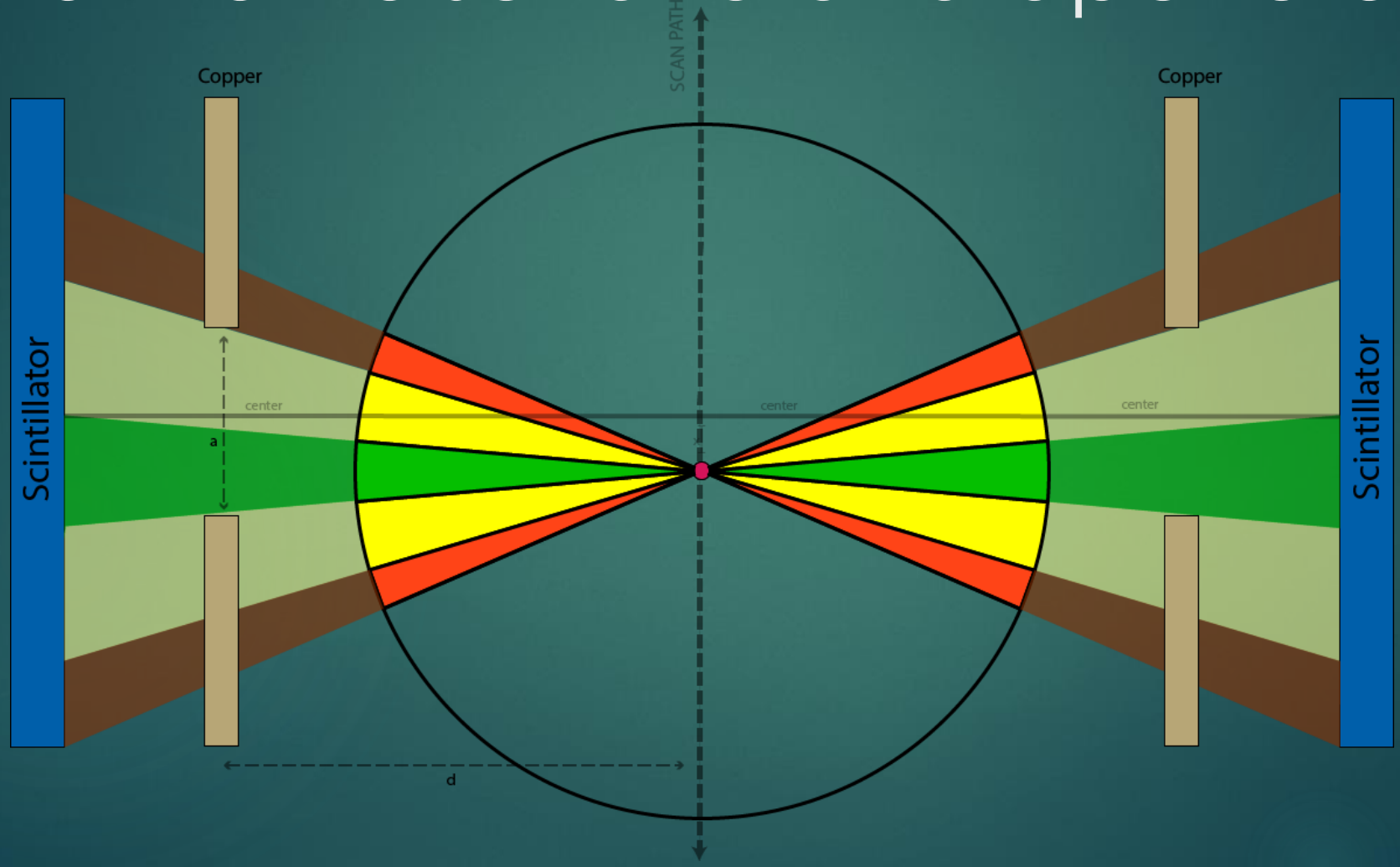
Why does it not go to zero outside of the aperture?



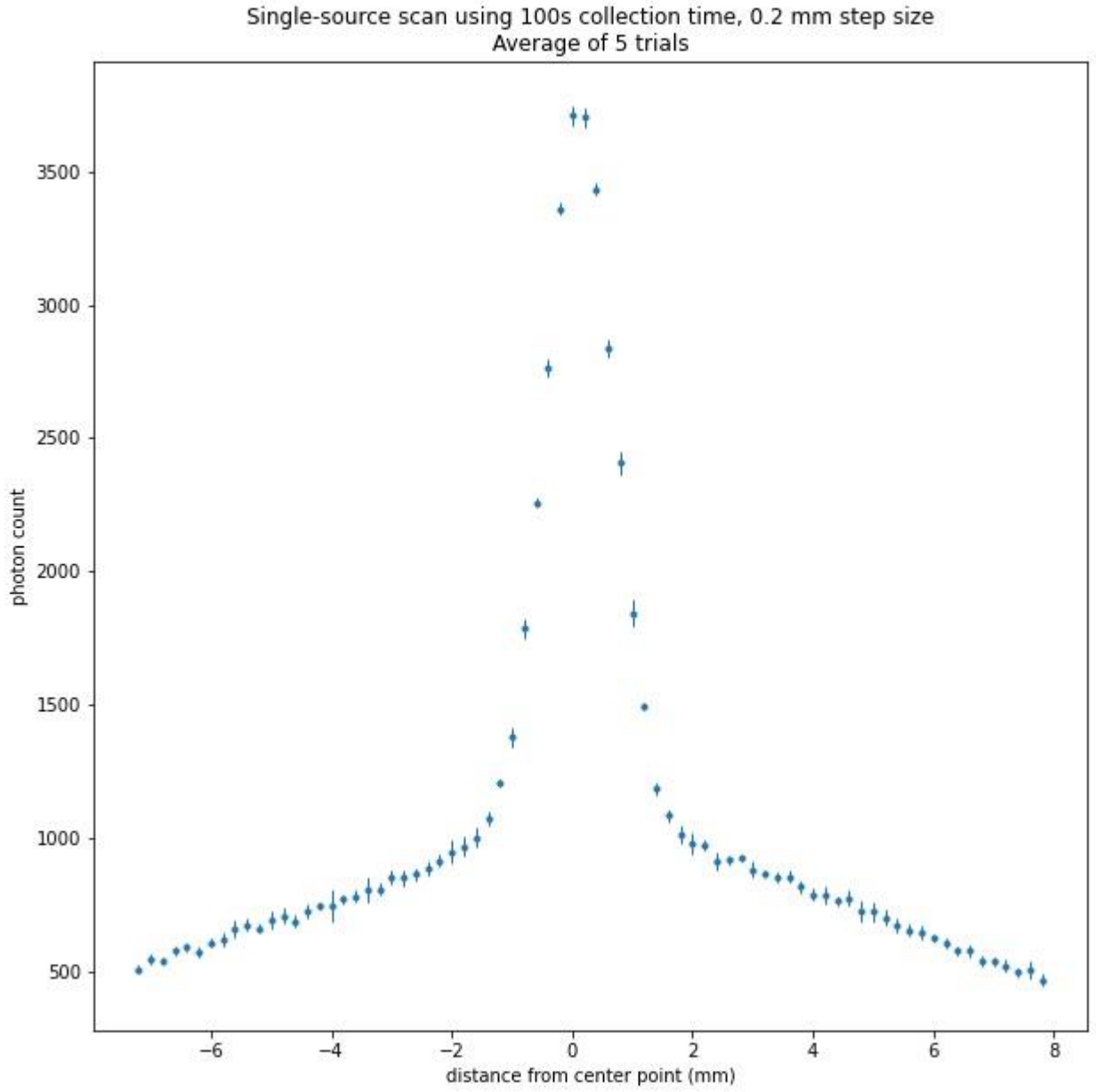
Limitations of resolution: SNR and aperture



Limitations of resolution: Signal -to-noise ratio and aperture

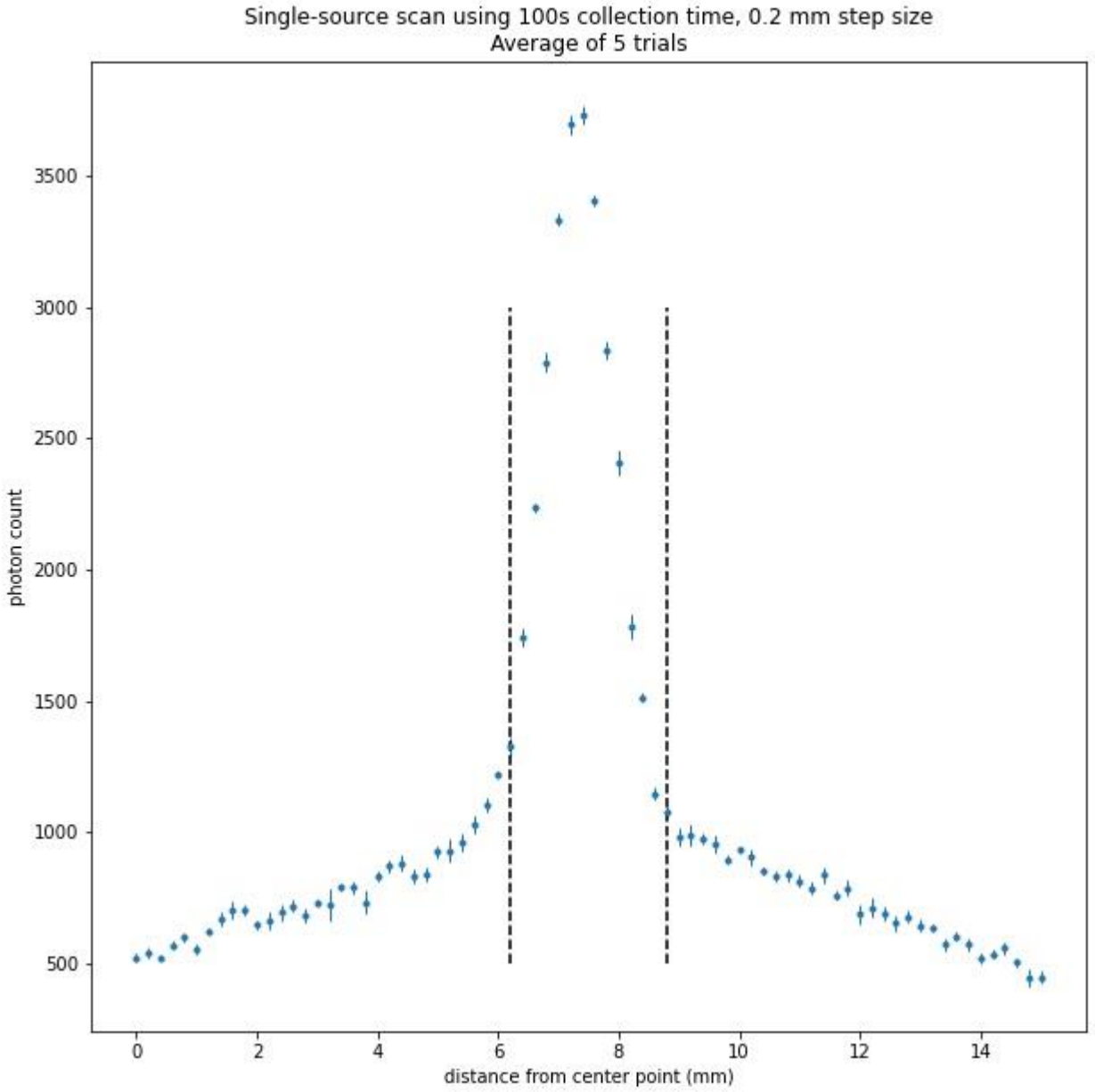


Measuring the primary signal:



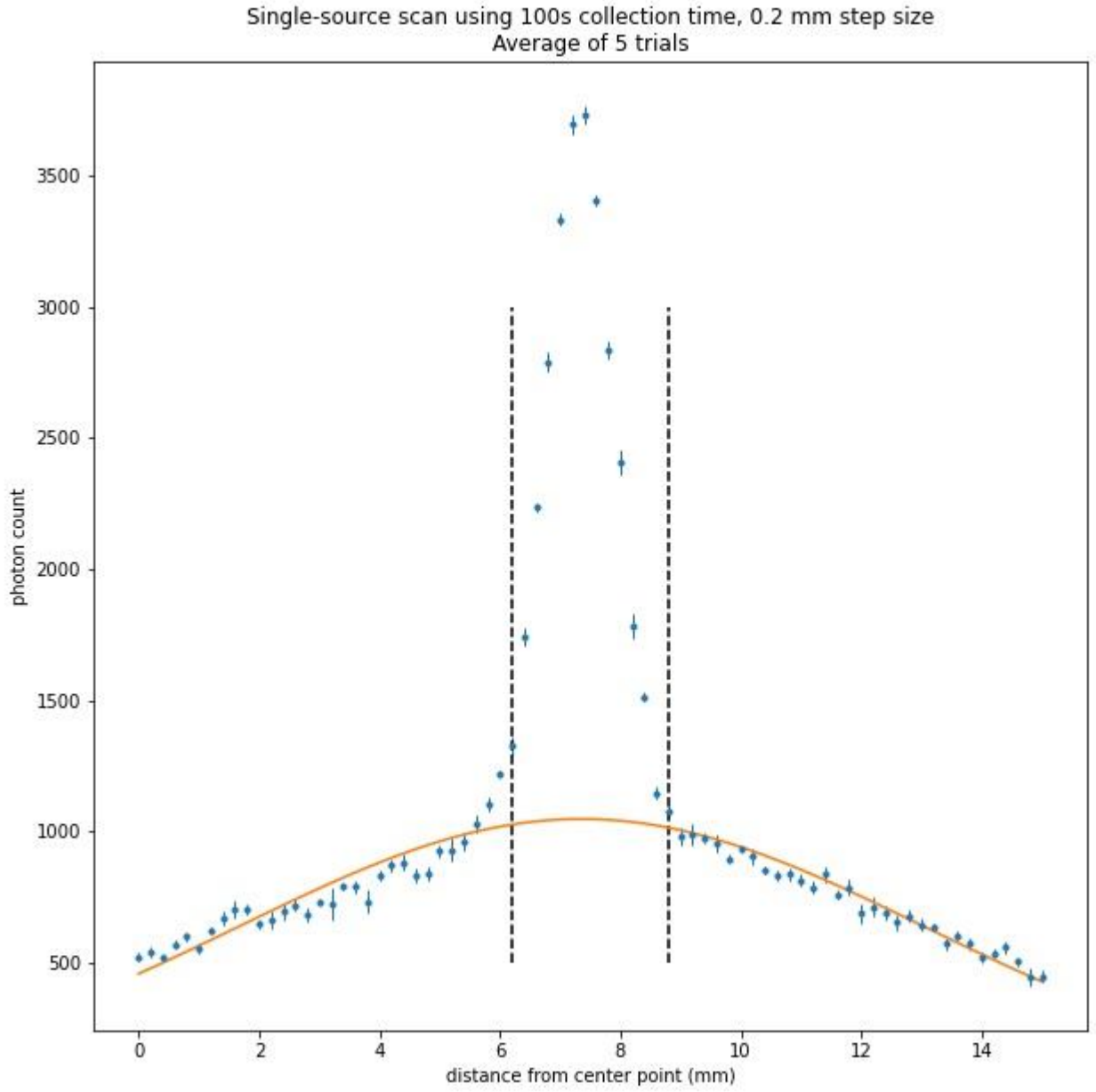
Measuring the primary signal:

1. Segment using first spatial derivative



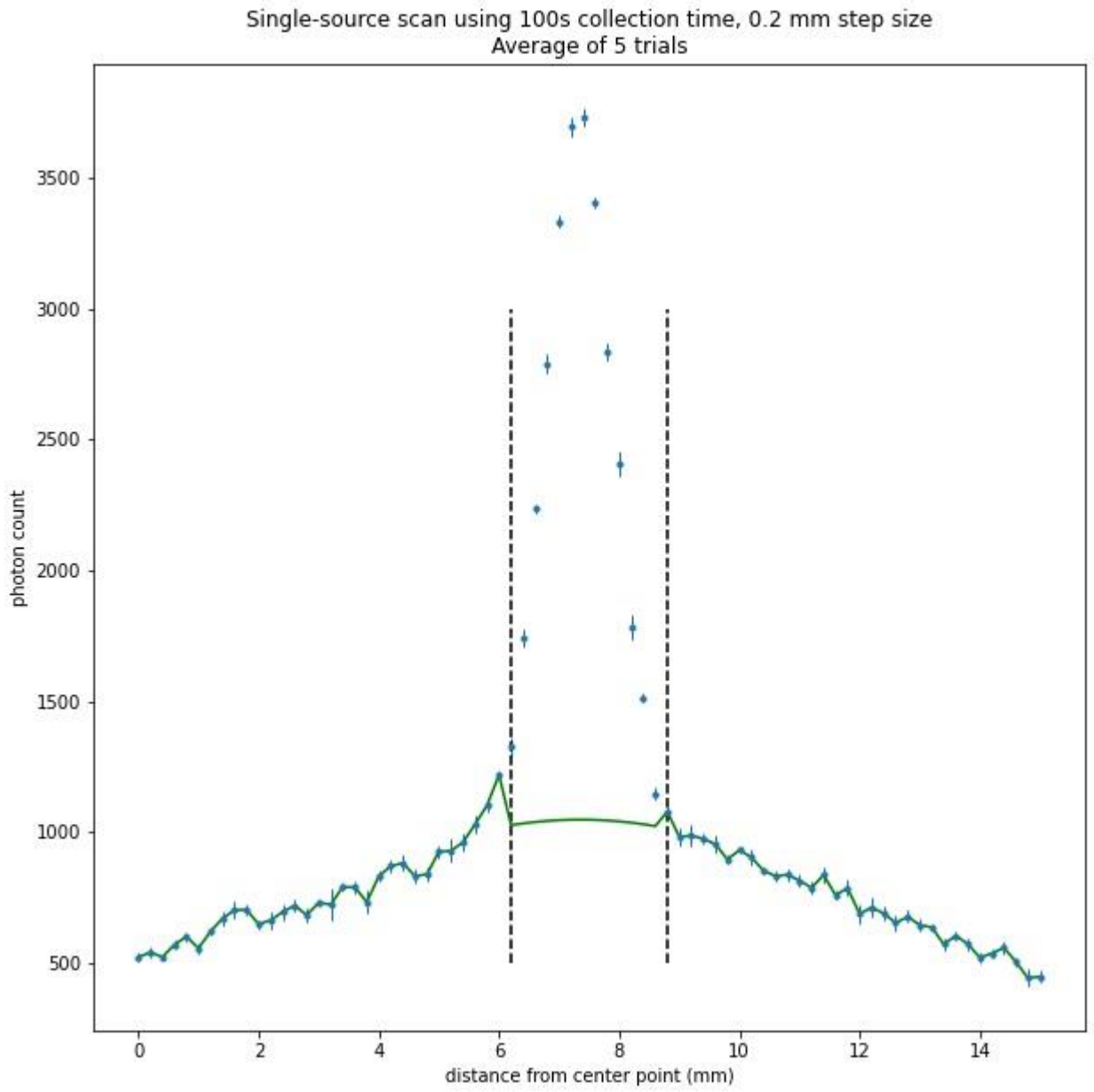
Measuring the primary signal:

1. Segment using first spatial derivative
2. Fit gaussian to the tails



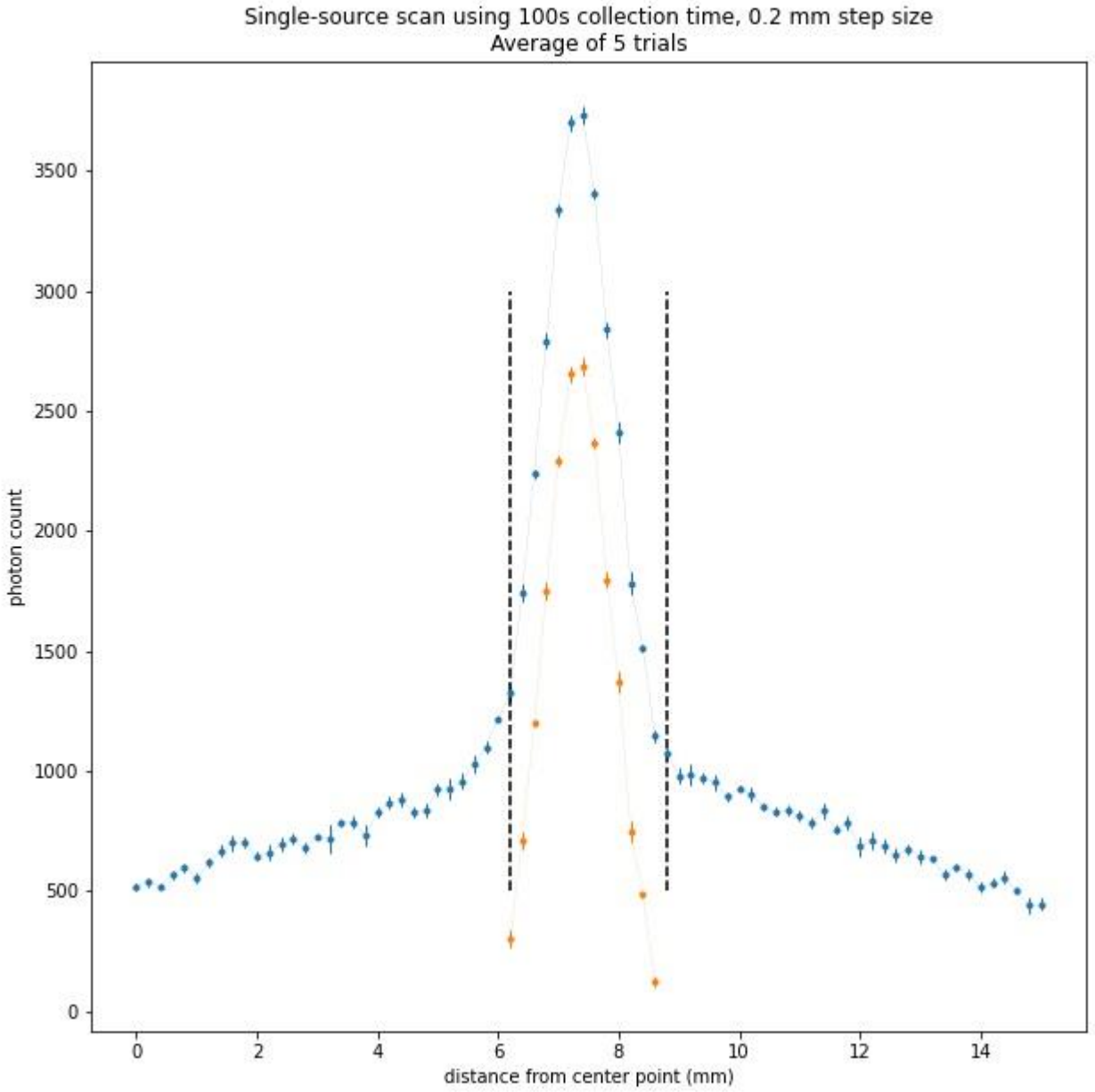
Measuring the primary signal:

1. Segment using first spatial derivative
2. Fit gaussian to the tails
3. Generate corrective signal



Measuring the primary signal:

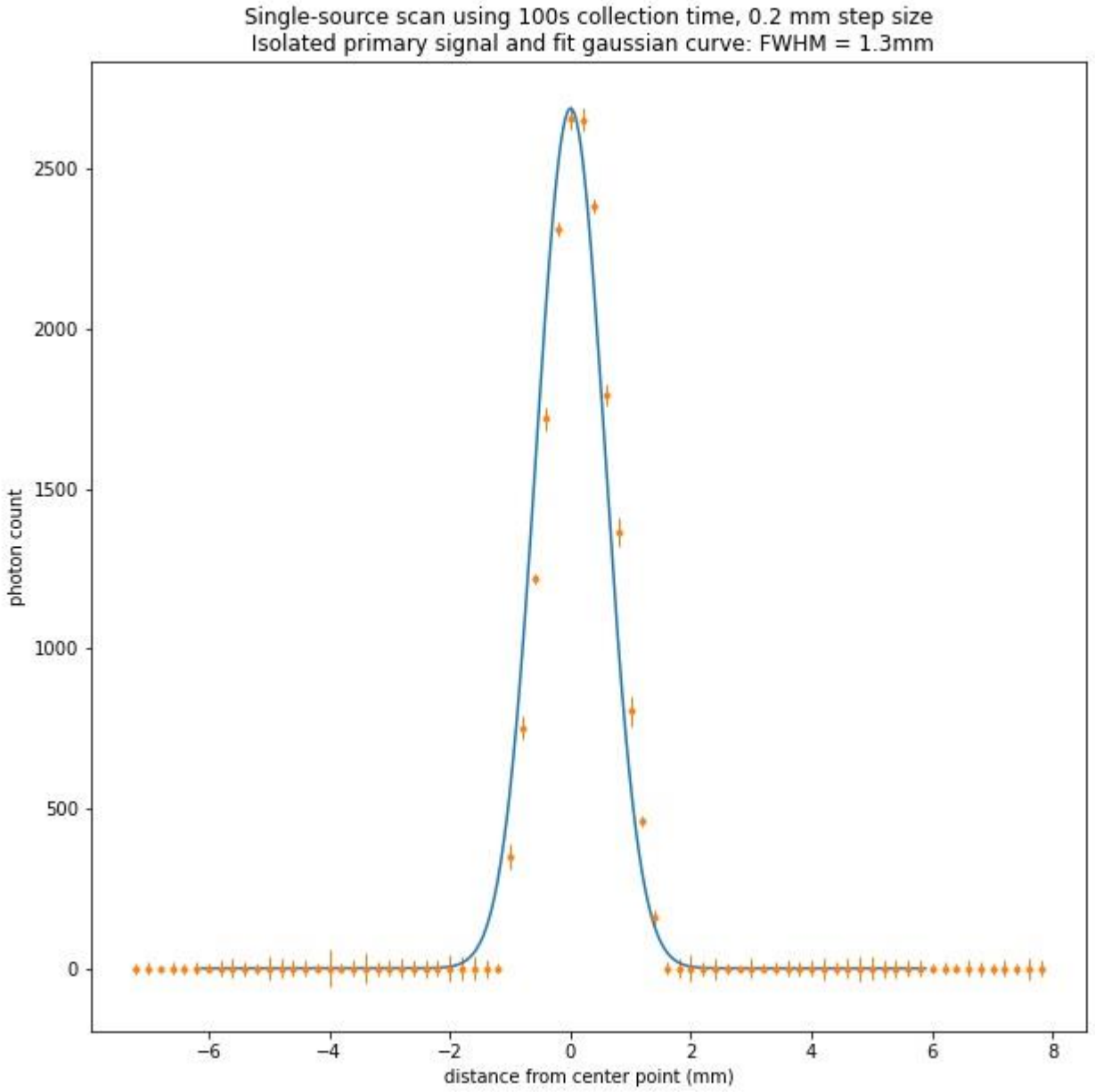
1. Segment using first spatial derivative
2. Fit gaussian to the tails
3. Generate corrective signal
4. Isolate the primary signal by subtracting the corrective signal



Measuring the primary signal:

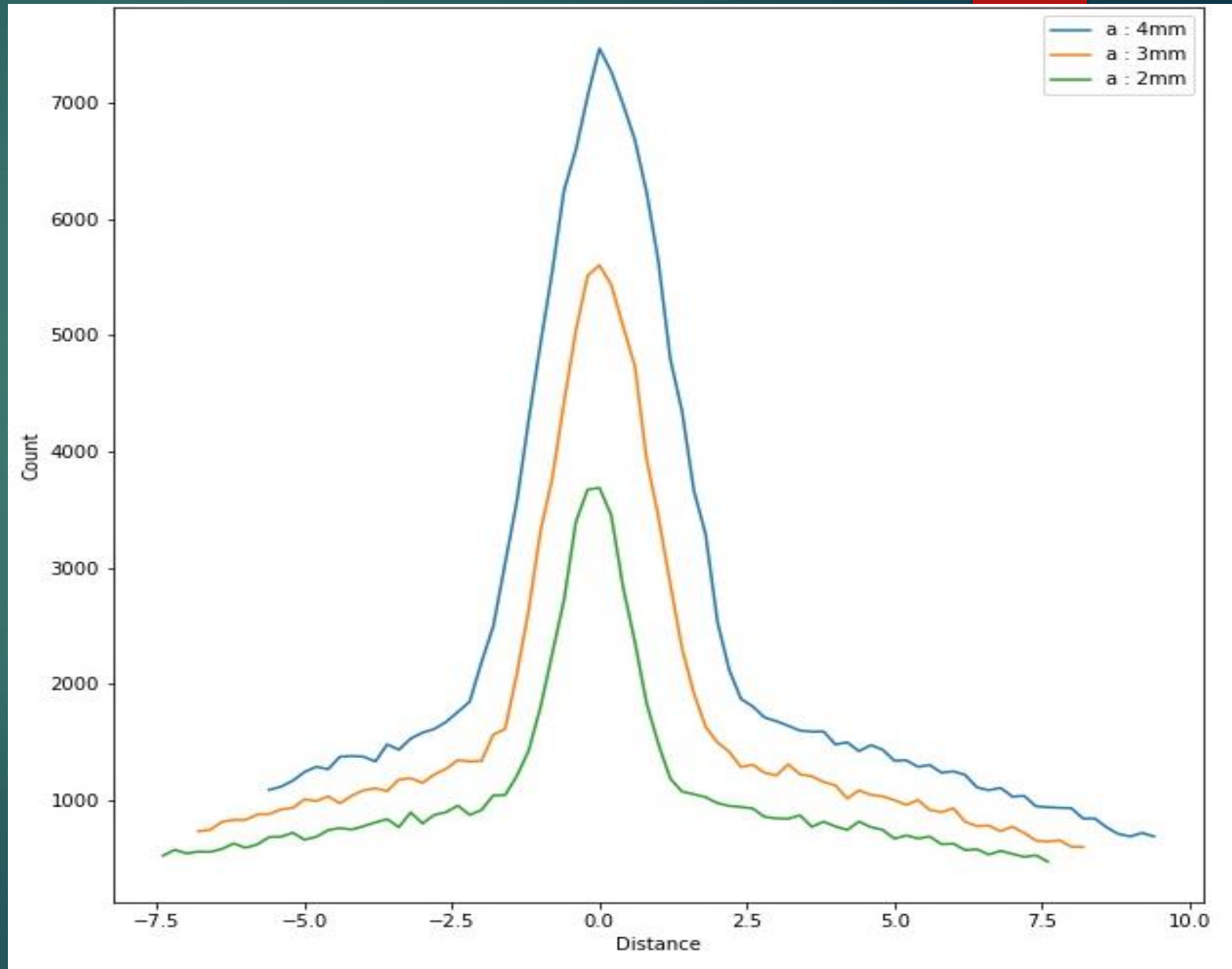
1. Segment using first spatial derivative
2. Fit gaussian to the tails
3. Generate corrective signal
4. Isolate the primary signal by subtracting the corrective signal
5. Fit gaussian to the primary signal,

   measure full width @ half maximum (FWHM)



Testing Aperture:

- By NARROWING the aperture, localization of the signal increases (GOOD)
- But, the amplitude of the signal relative to noise decreases (BAD)



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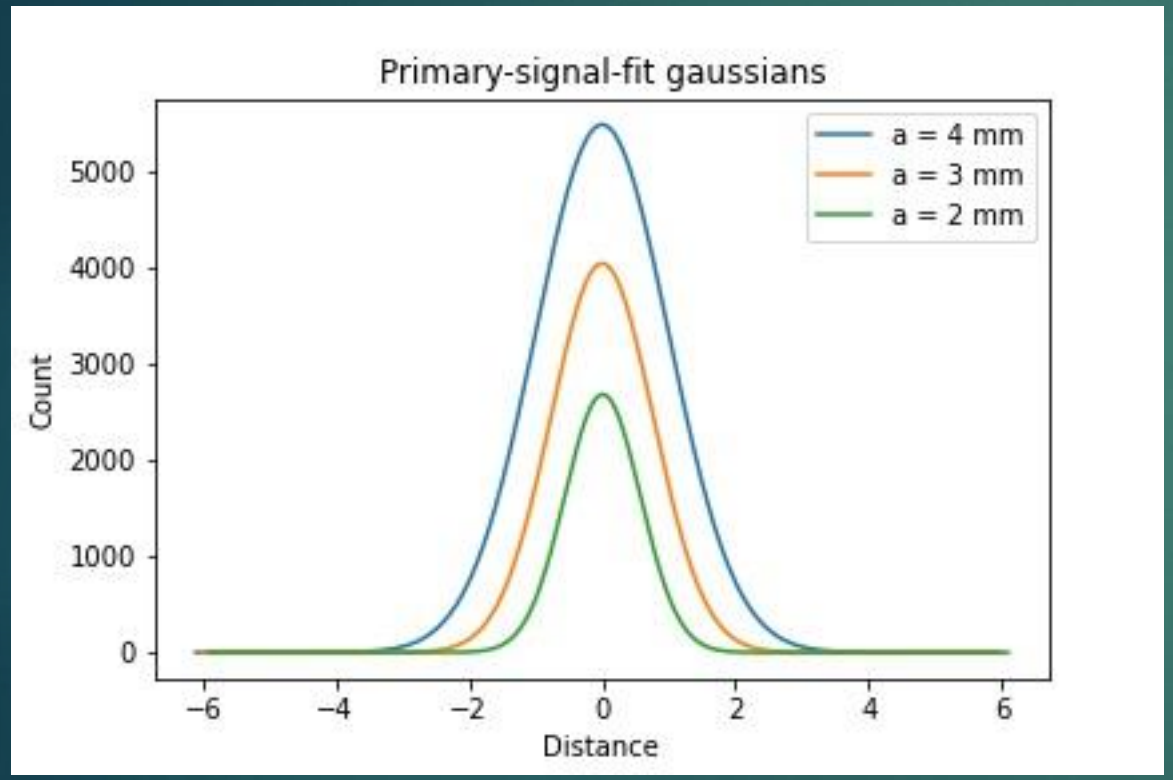

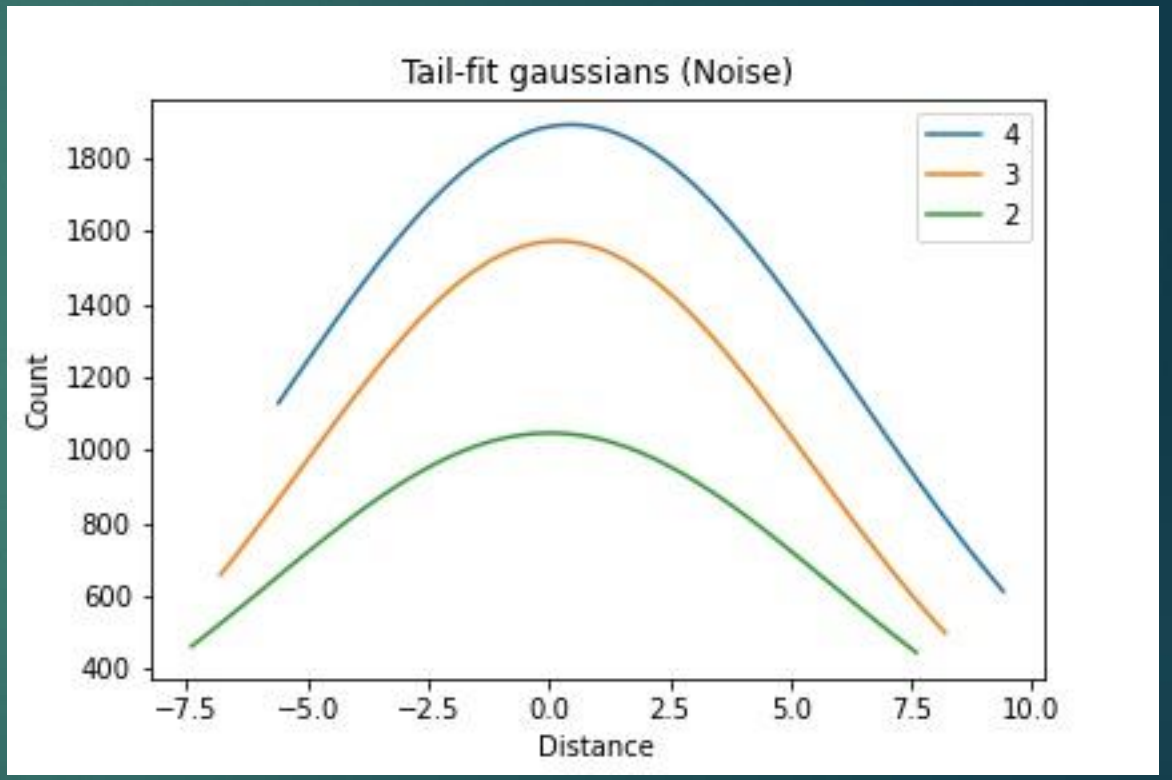

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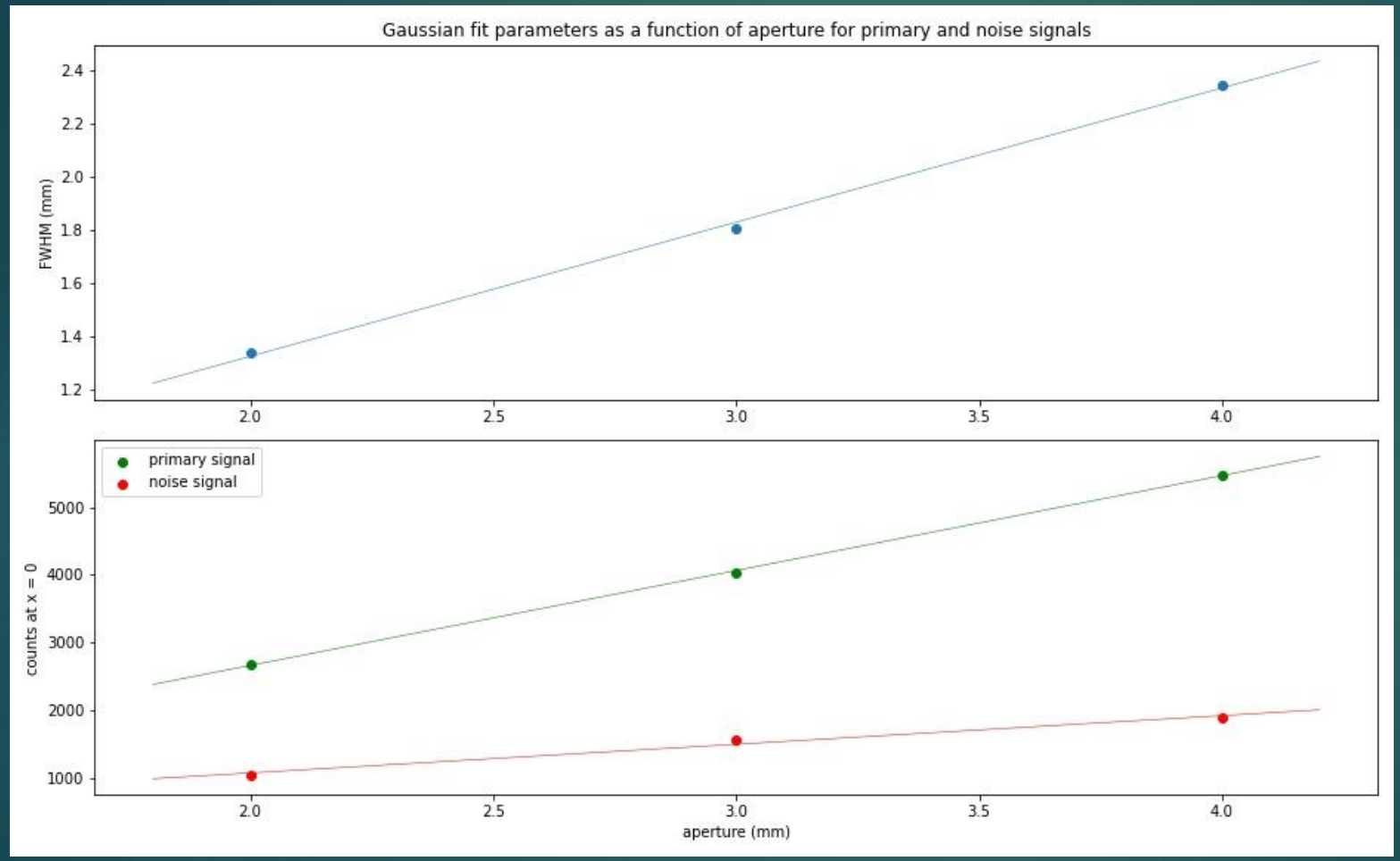

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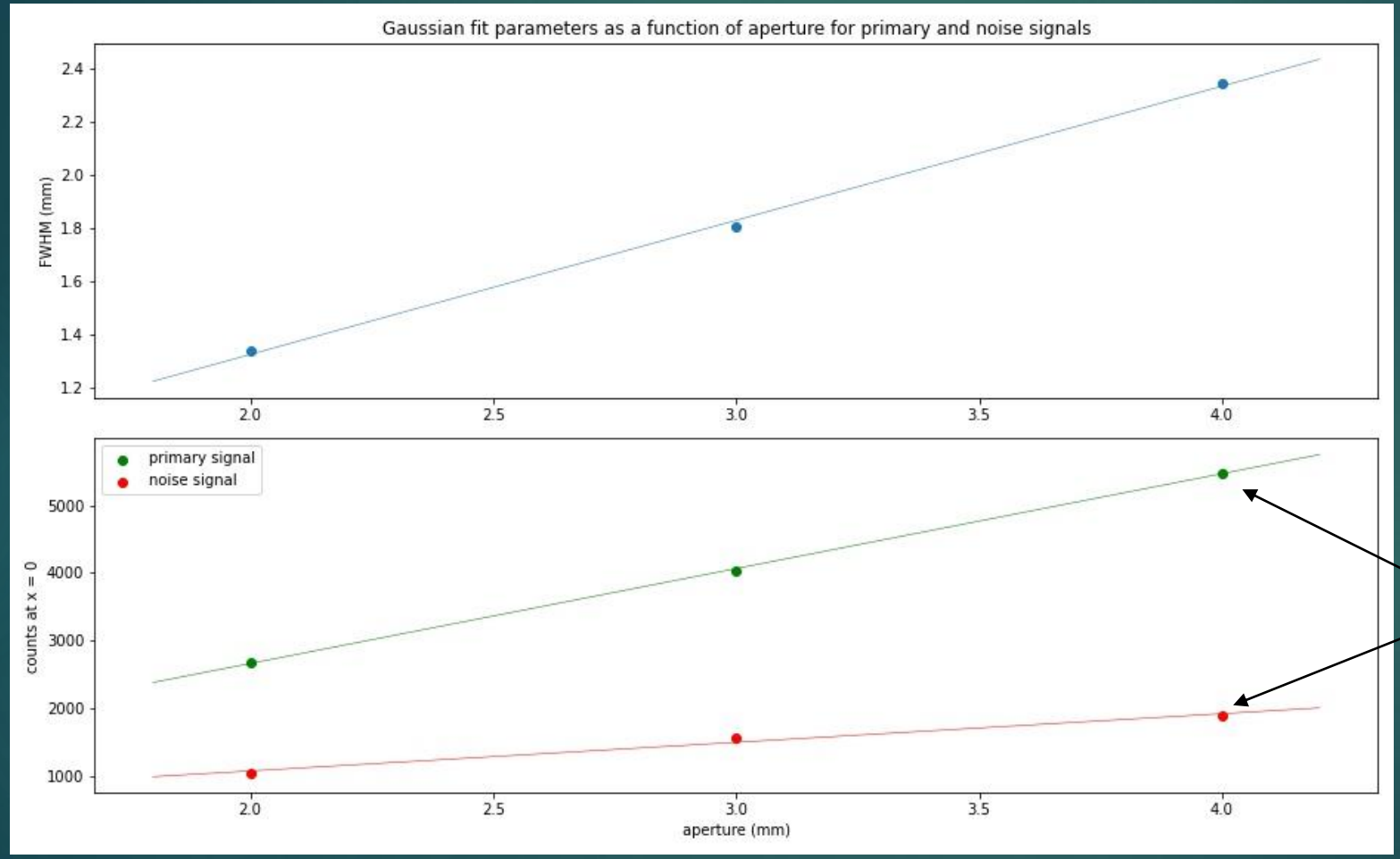


The FWHM is a measure of blurring

The ratio between the primary signal and the noise signal is the SNR

Testing Aperture:

Why is SNR, blurring important?

Testing Aperture:

Why is SNR, blurring important?

- Medical application :
  - Inject patient with radiotracer
  - Not localized
  - Smaller signal
  - Diagnosis important to get right!

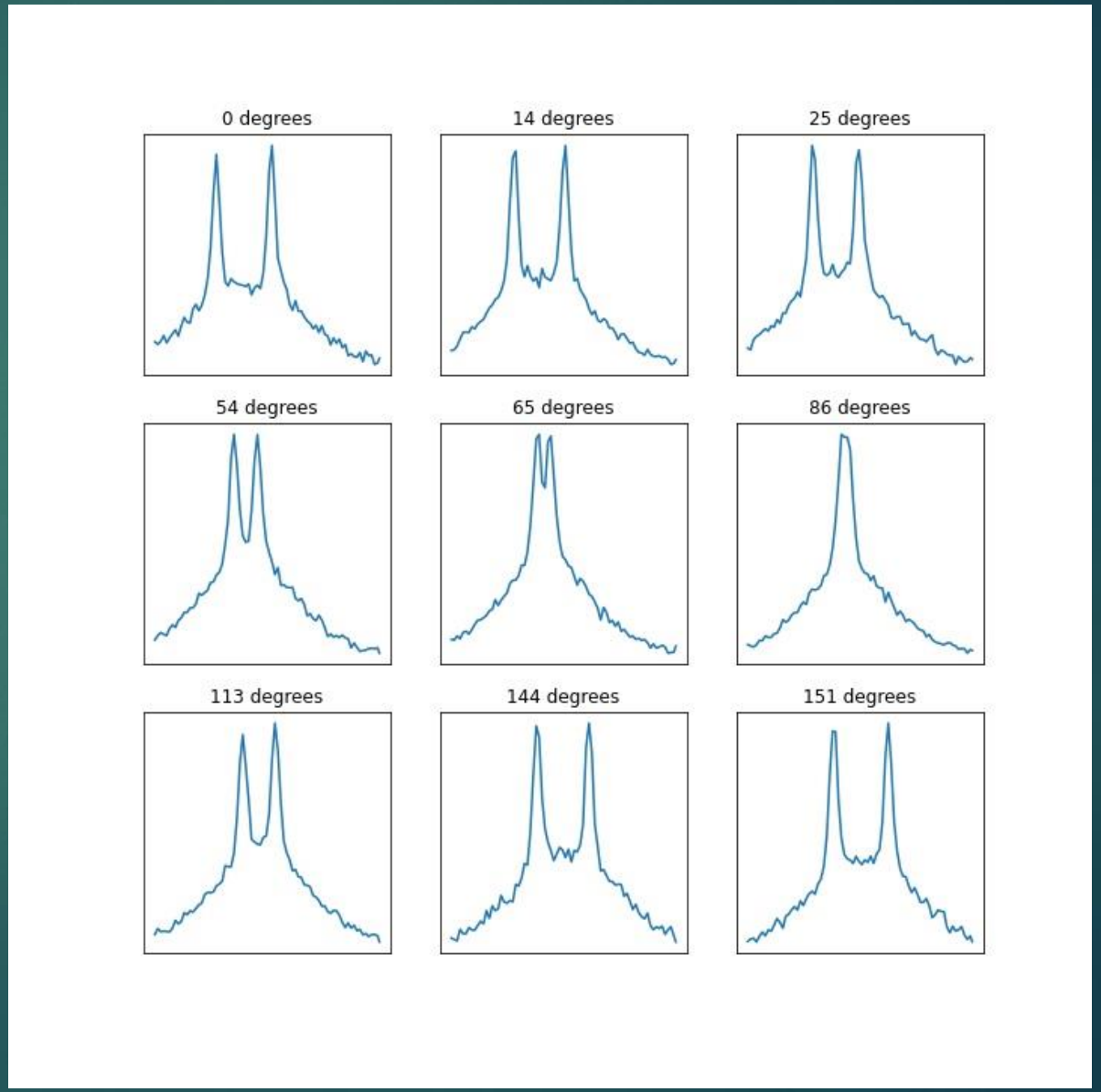
Image Reconstruction:

Make image of two sources by:

- Use the rotation of the scanner system to obtain multiple projection angles

- Use all projections to perform the **inverse radon transform** to reconstruct image

(Figure to the right : 9 angles of a total of 50 taken for this scan)



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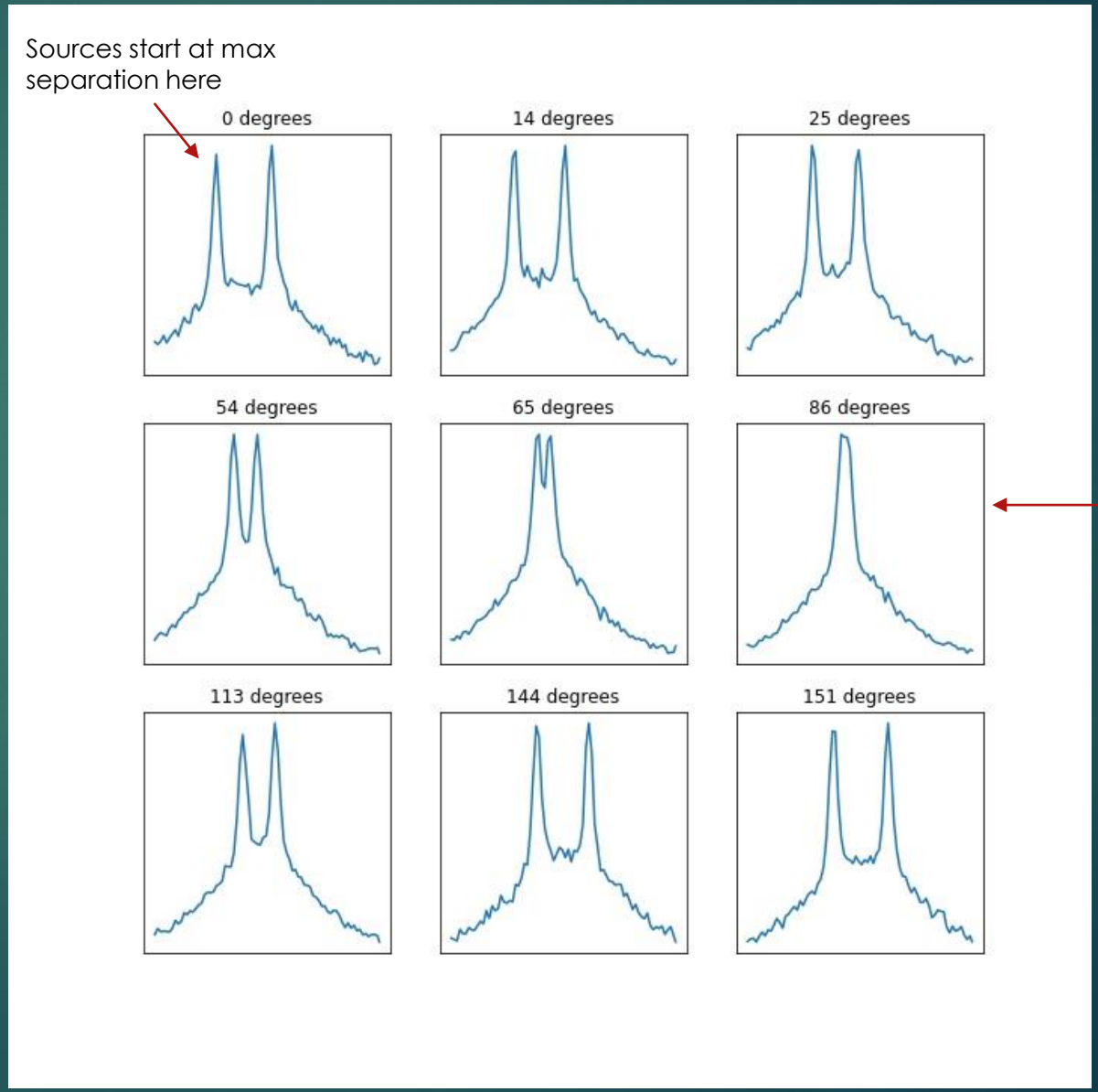

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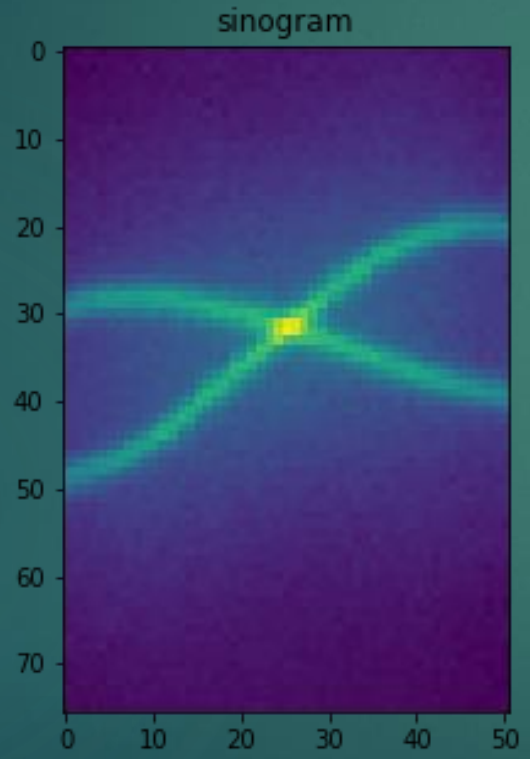
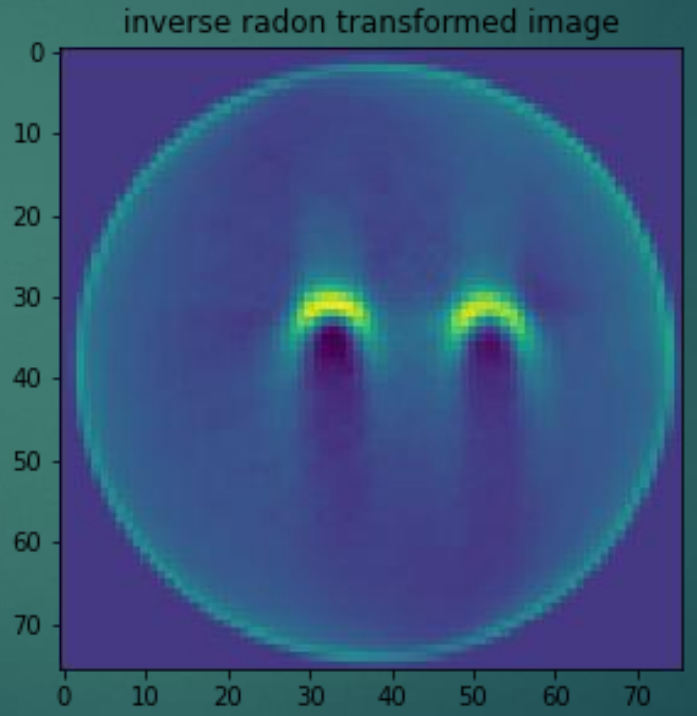
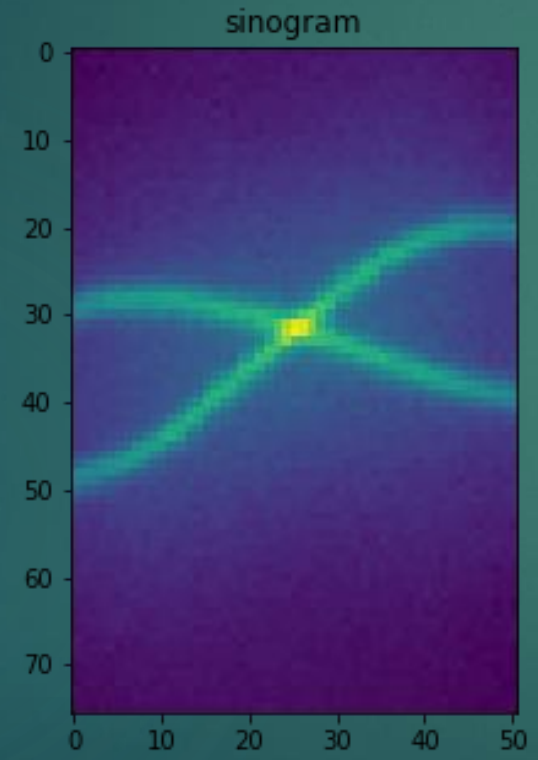
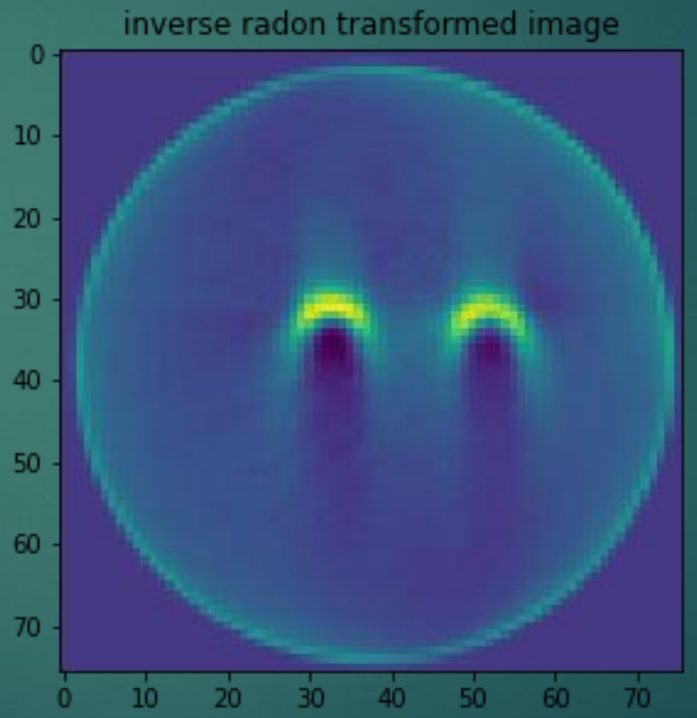




Result: reconstructed image final image

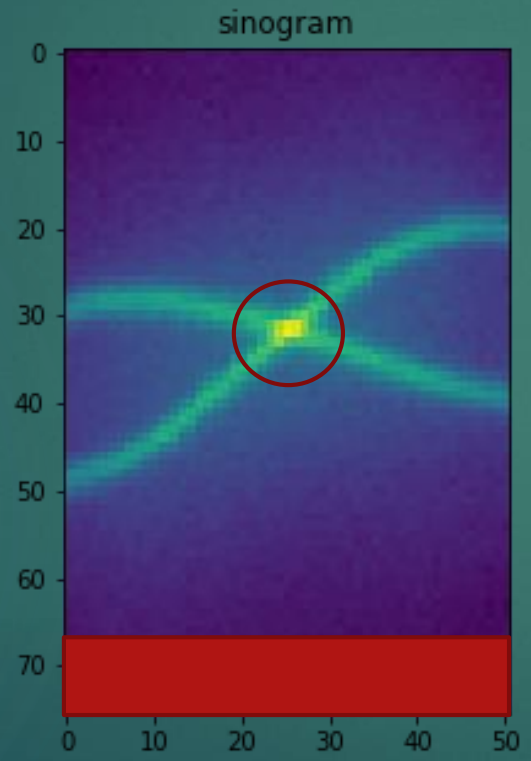


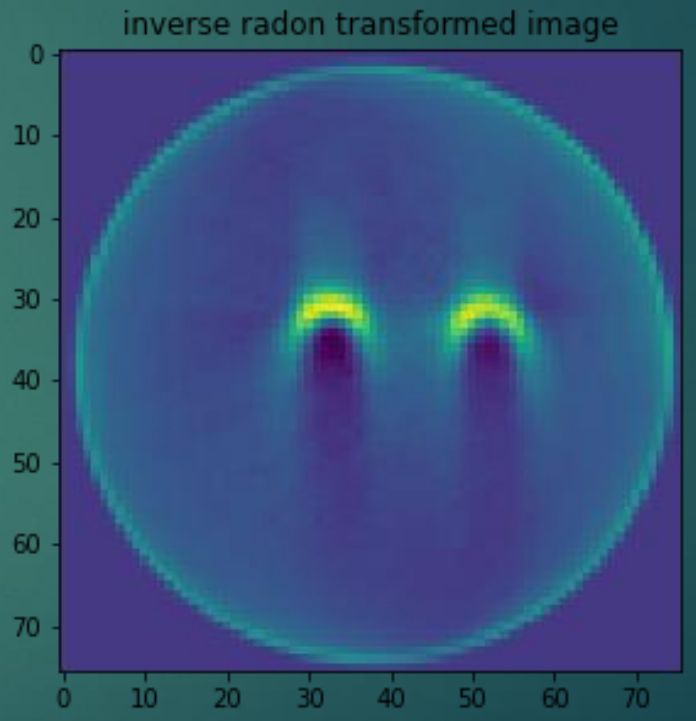


Sensitive to scanner alignment!

Result: reconstructed image final image

Attempt to center this point on the spatial (vertical) axis by removing rows at the bottom:





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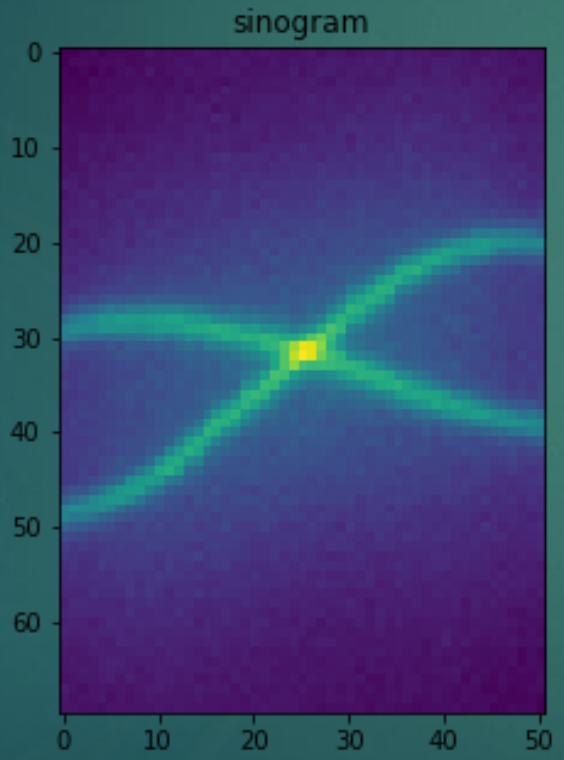
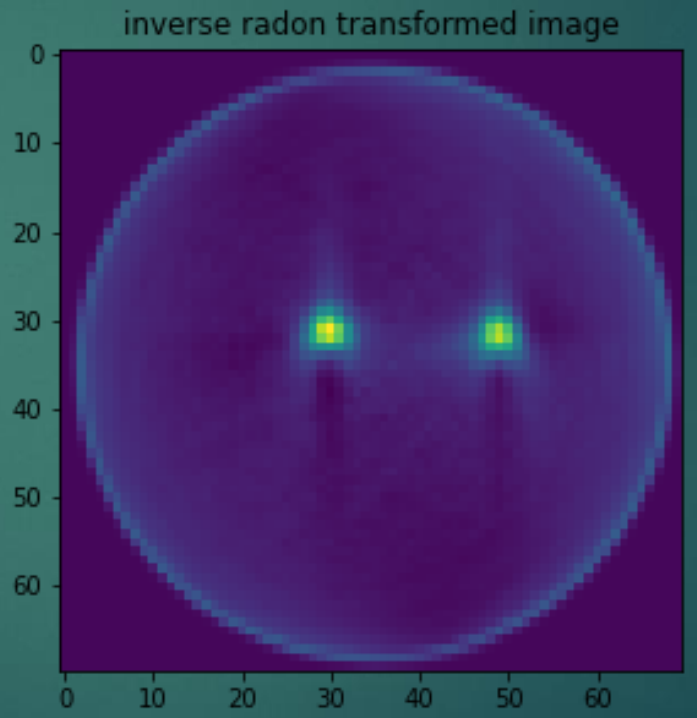
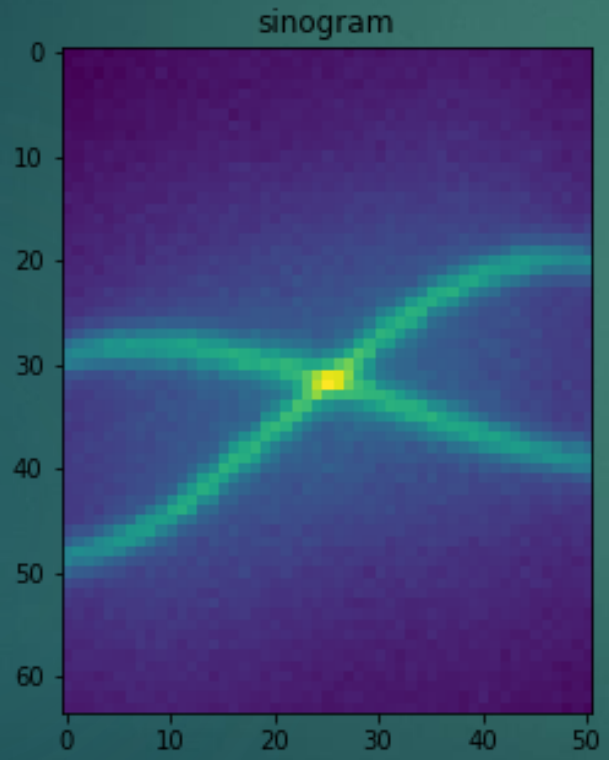




That's better!

QUESTIONS?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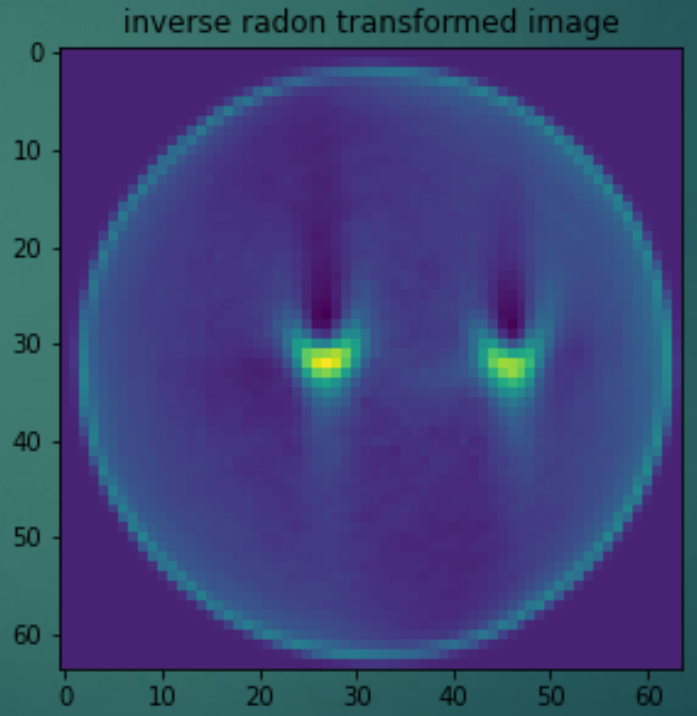
inverse radon transformed image
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