# The Houghton College Cyclotron:

## a tool for educating undergraduates

Mark Yuly, Houghton College

20th International Conference on
Cyclotrons and their Applications
September 16 – 20, 2013

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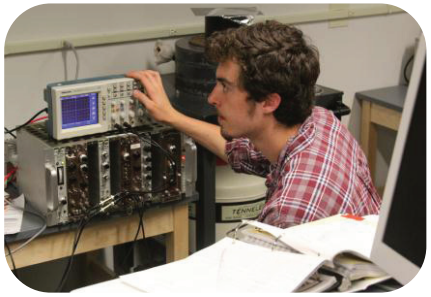
# Houghton College Physics

**Houghton College**



**Physics Department**

**Program**

**Students**

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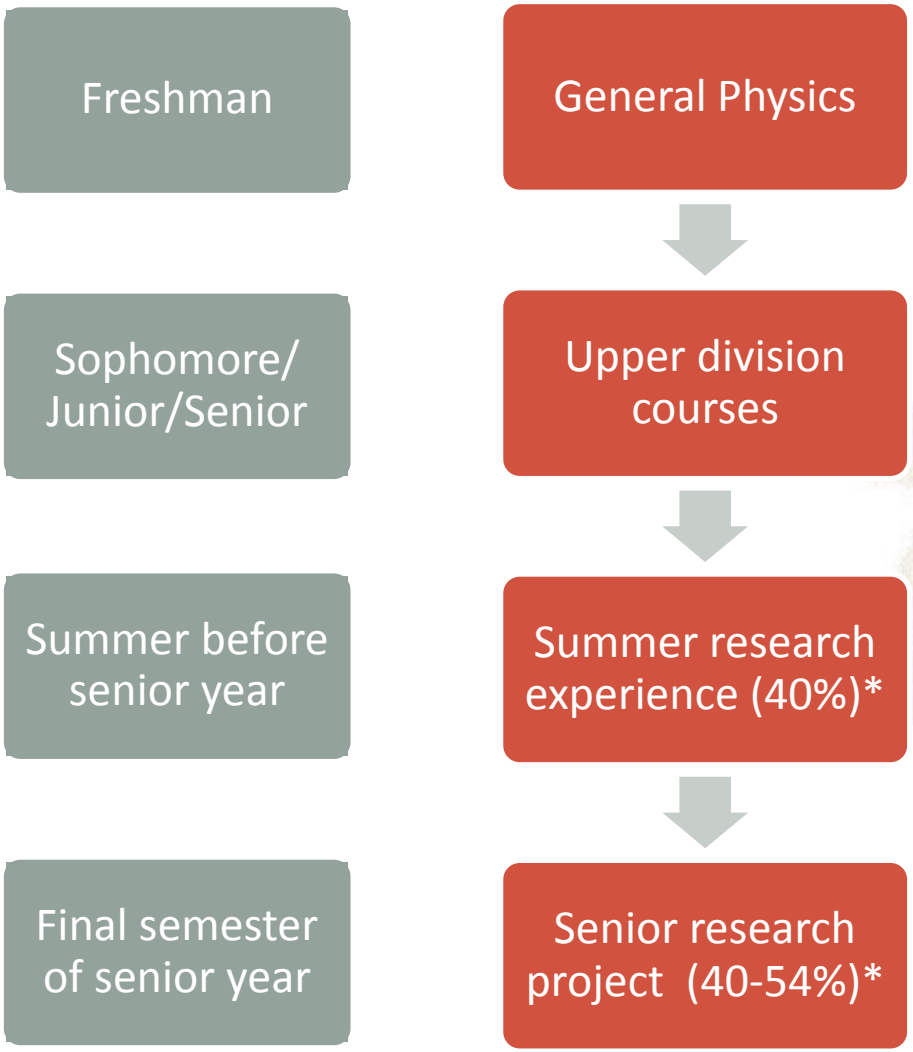
Traditional physics coursework usually focuses on the content of the discipline, but not on developing the traits needed to be a successful scientist.

# Typical Physics Major Sequence

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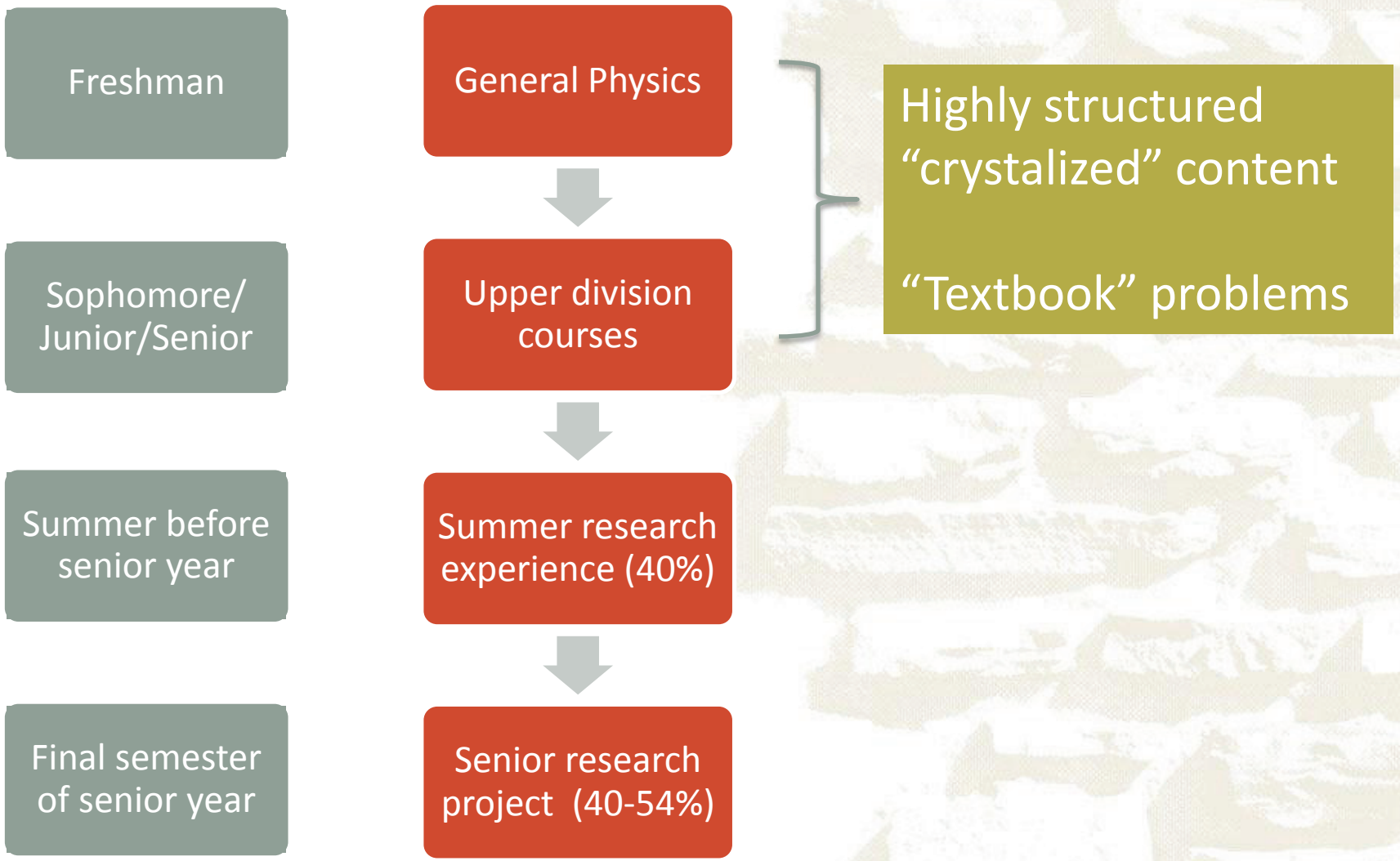
* AIP Statistical Research Center (2009)

# Houghton Physics Major Sequence

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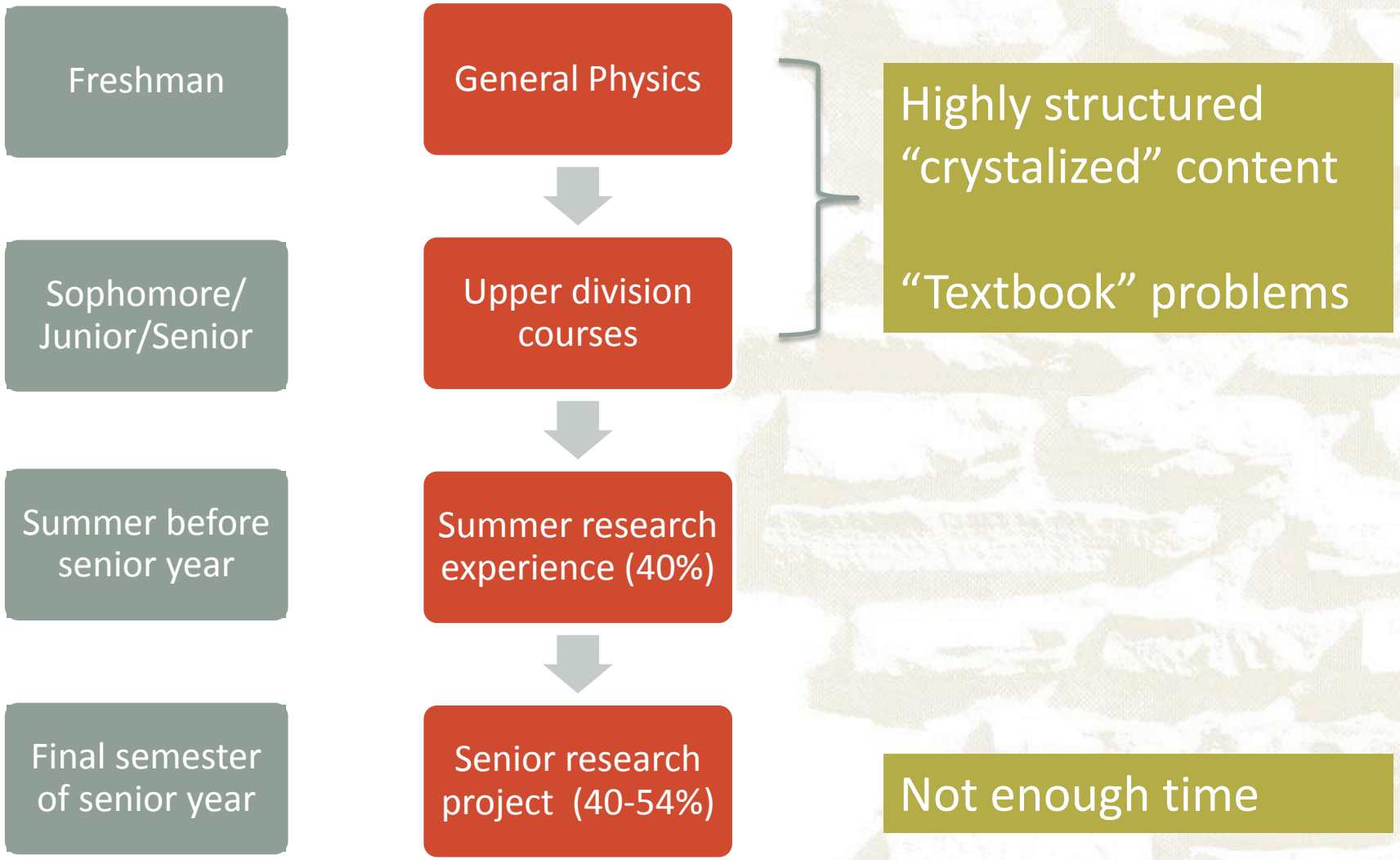
# Physics Major Sequence

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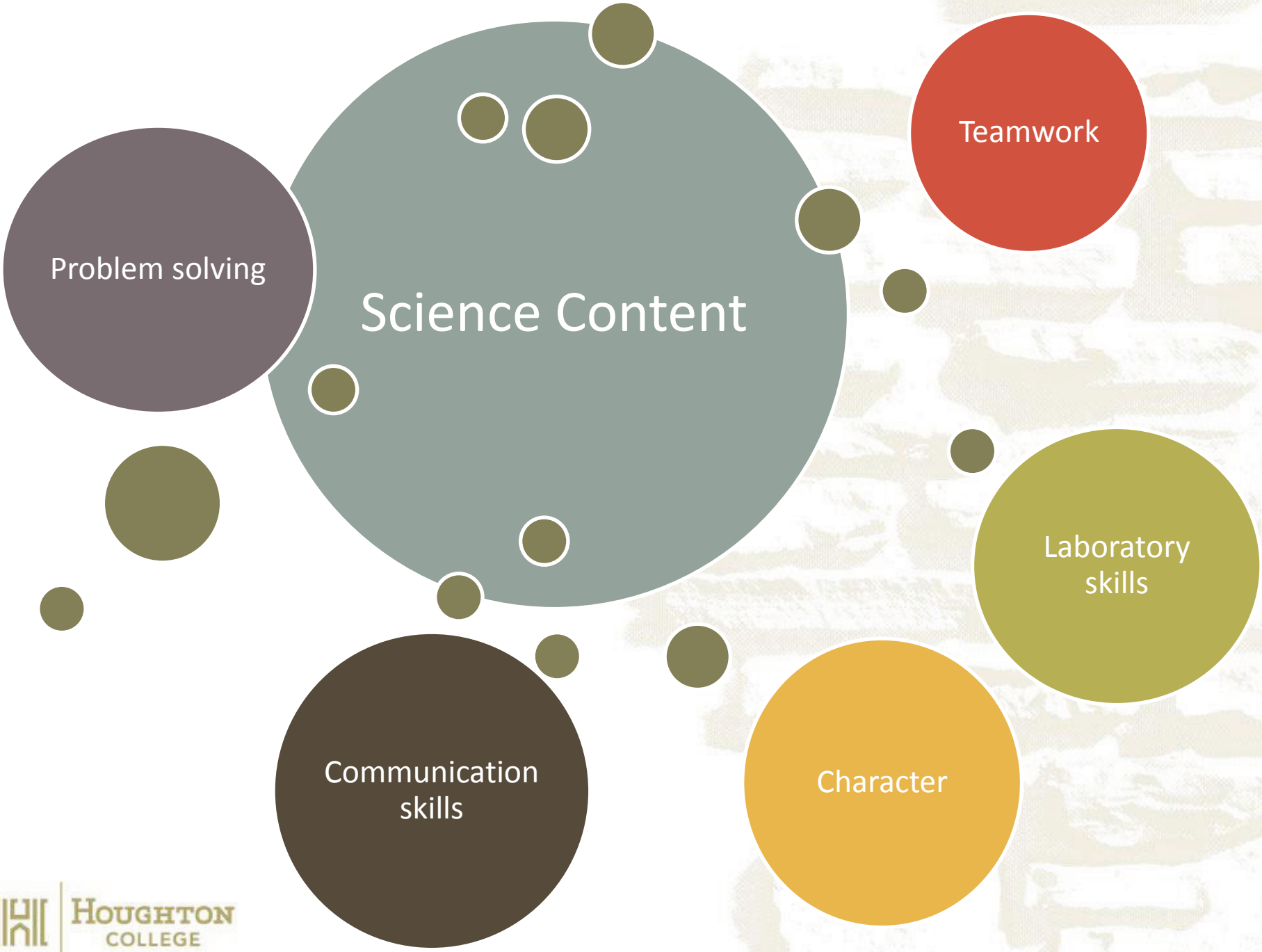


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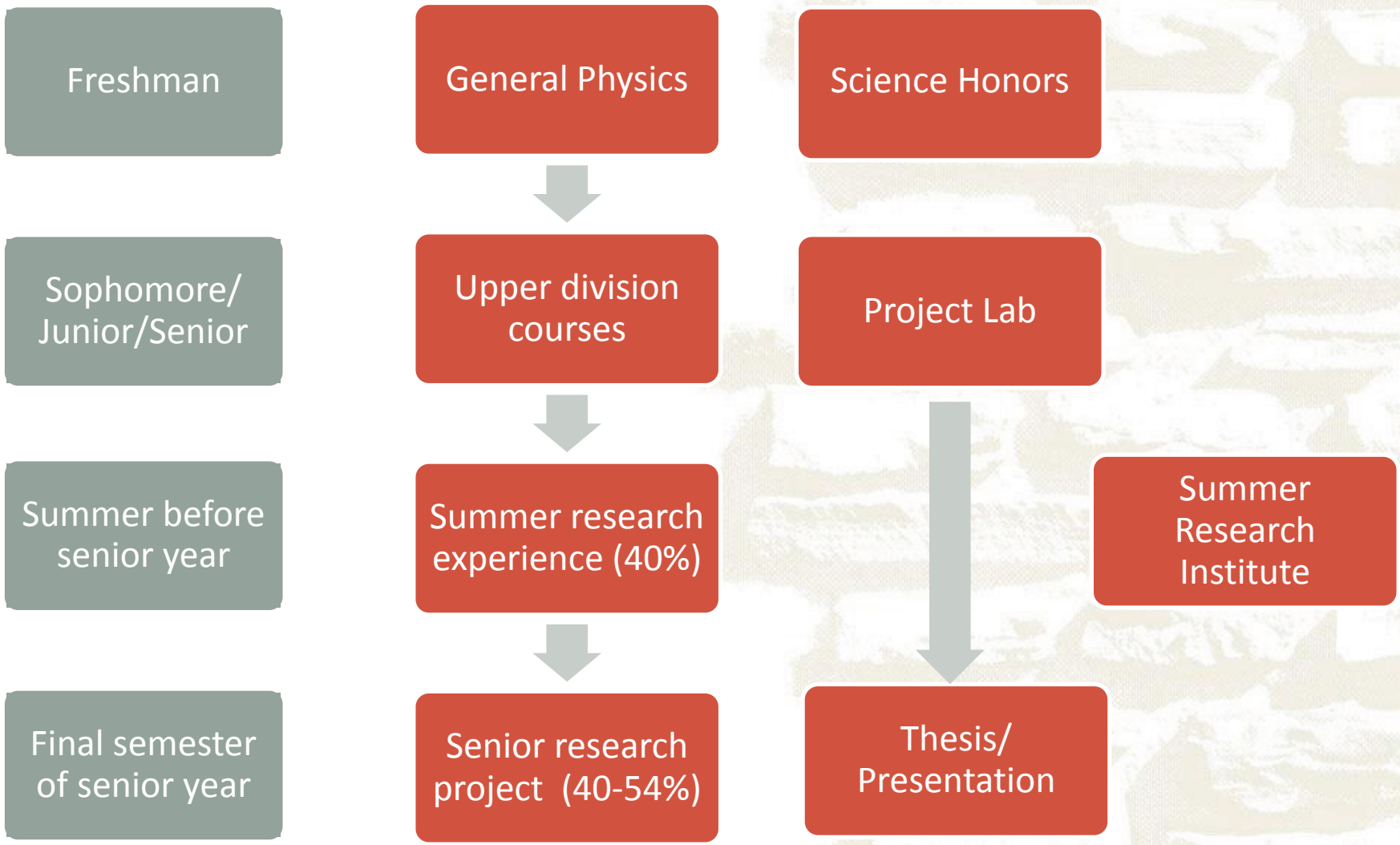
# Houghton Physics Major Sequence

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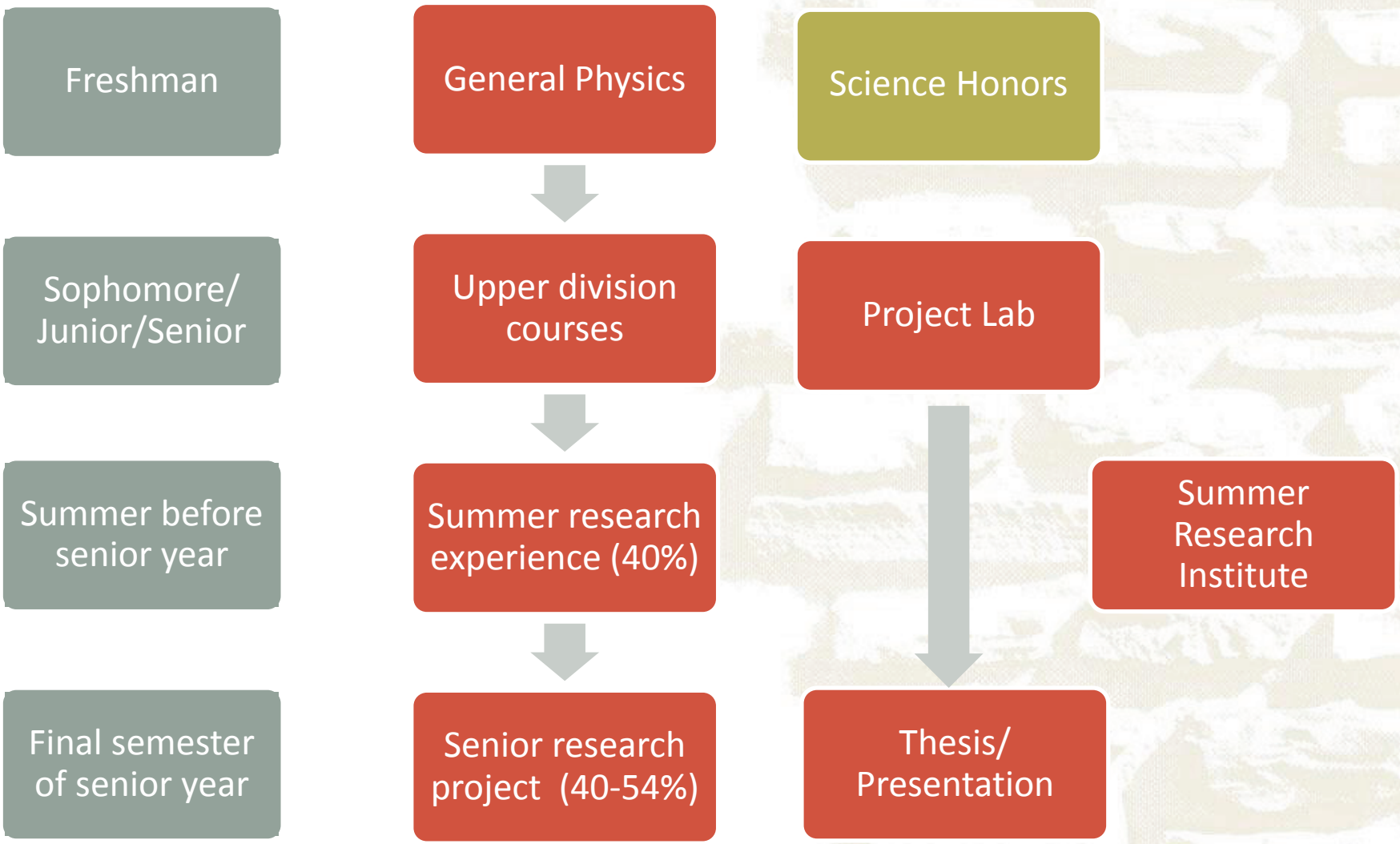
# Houghton Physics Major Sequence

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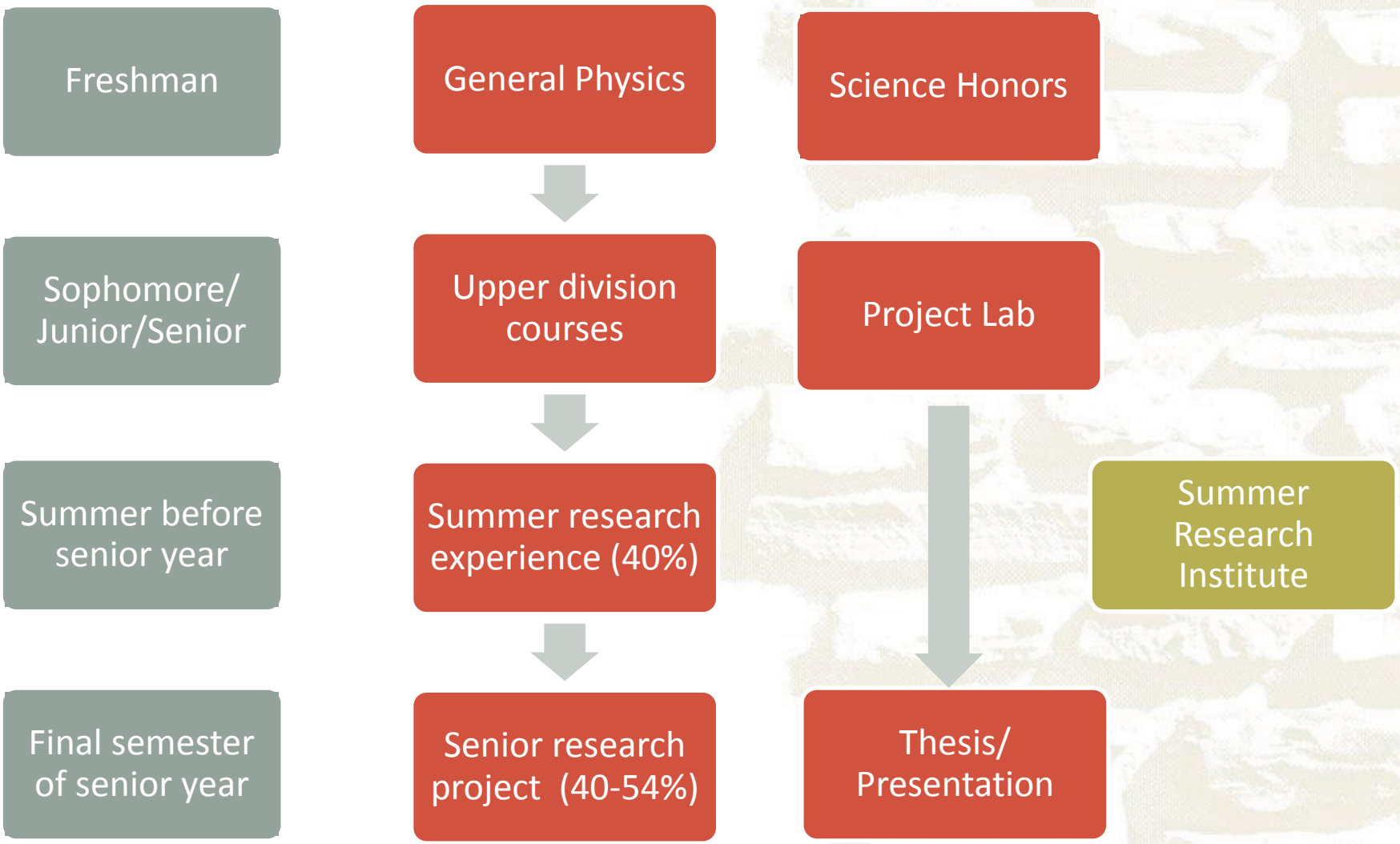
# Science Honors

# Houghton Physics Major Sequence

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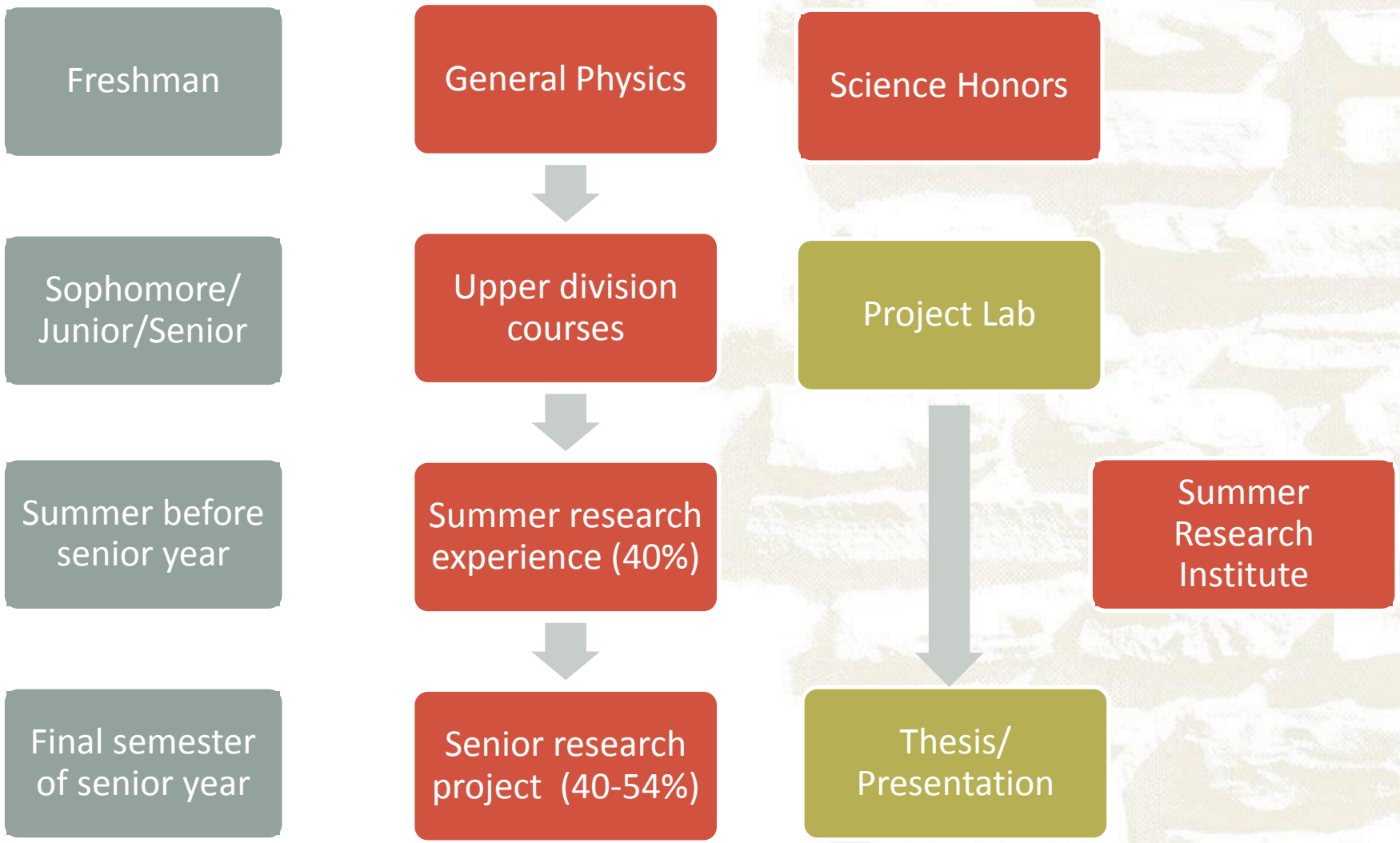
# Summer Research Institute

# Houghton Physics Major Sequence

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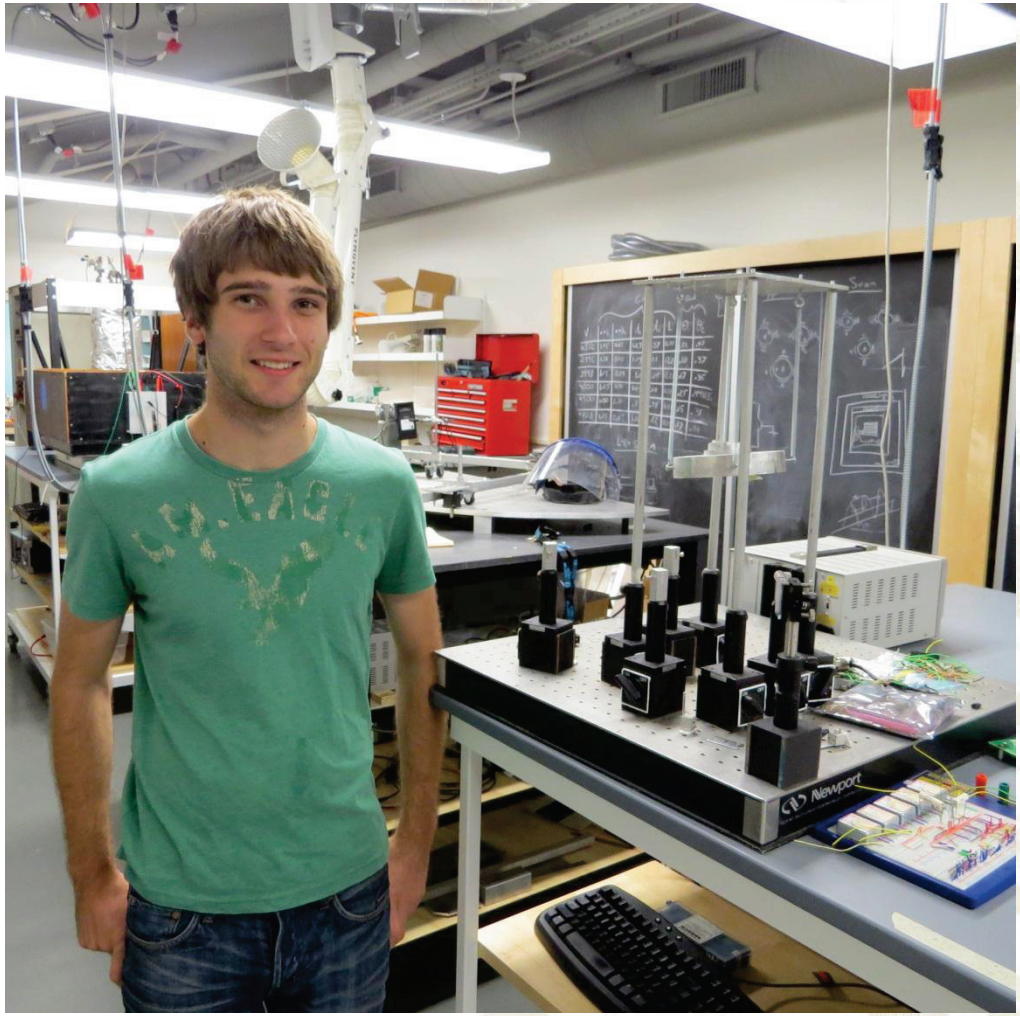
# Physics Project Lab

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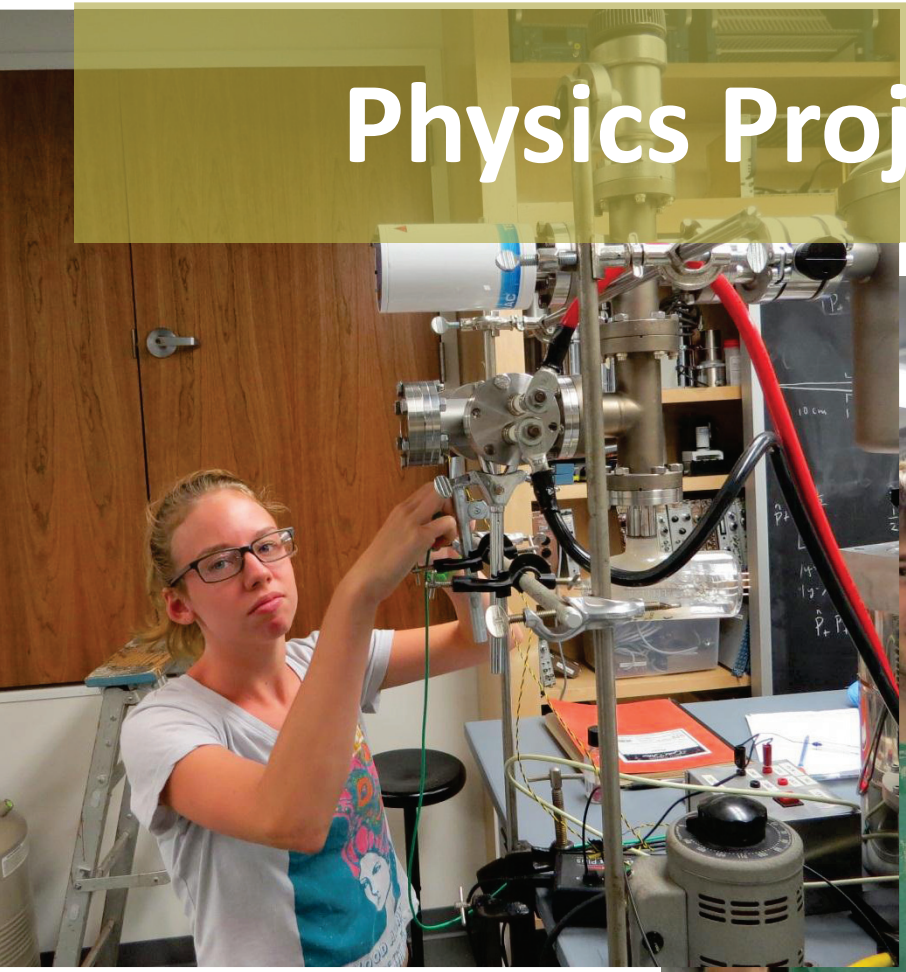

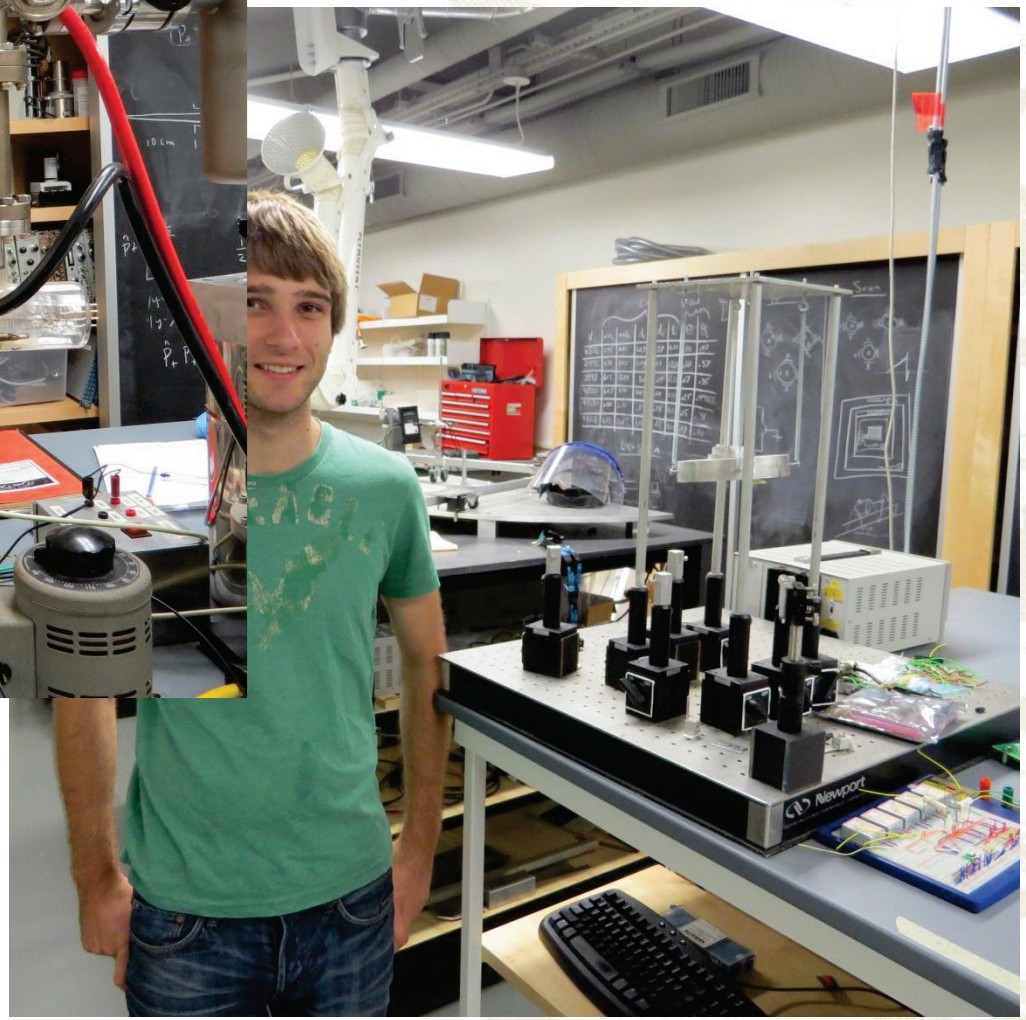


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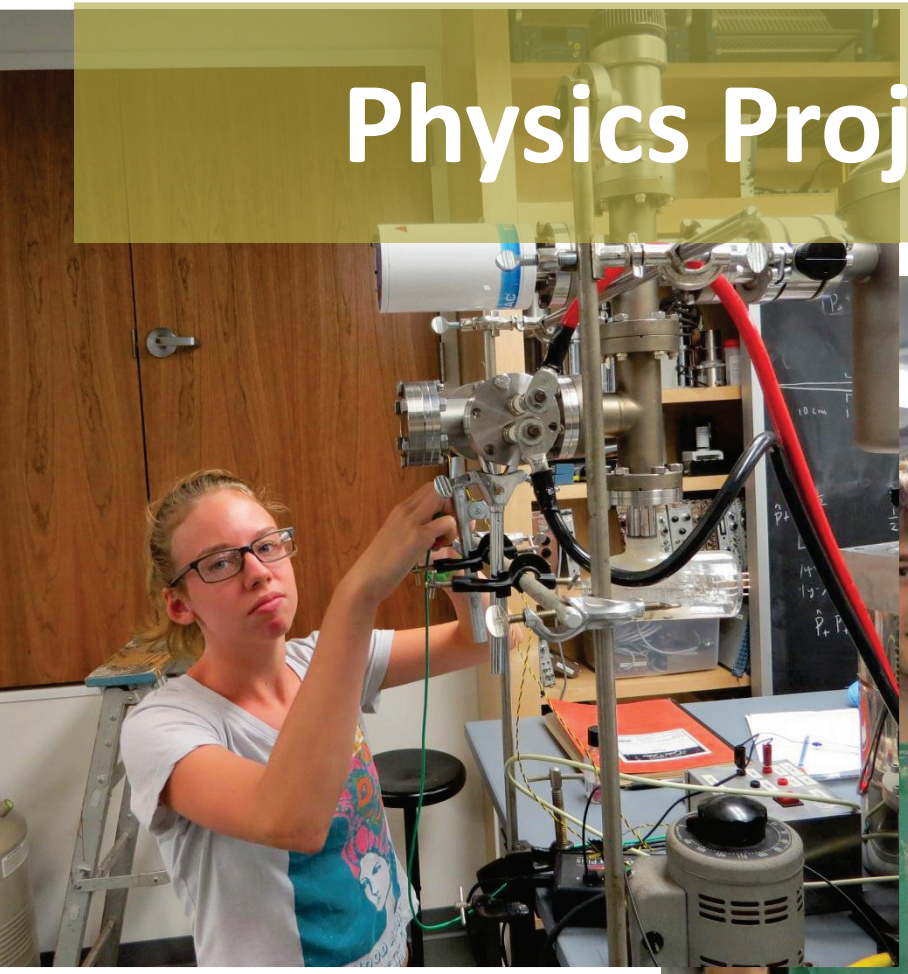

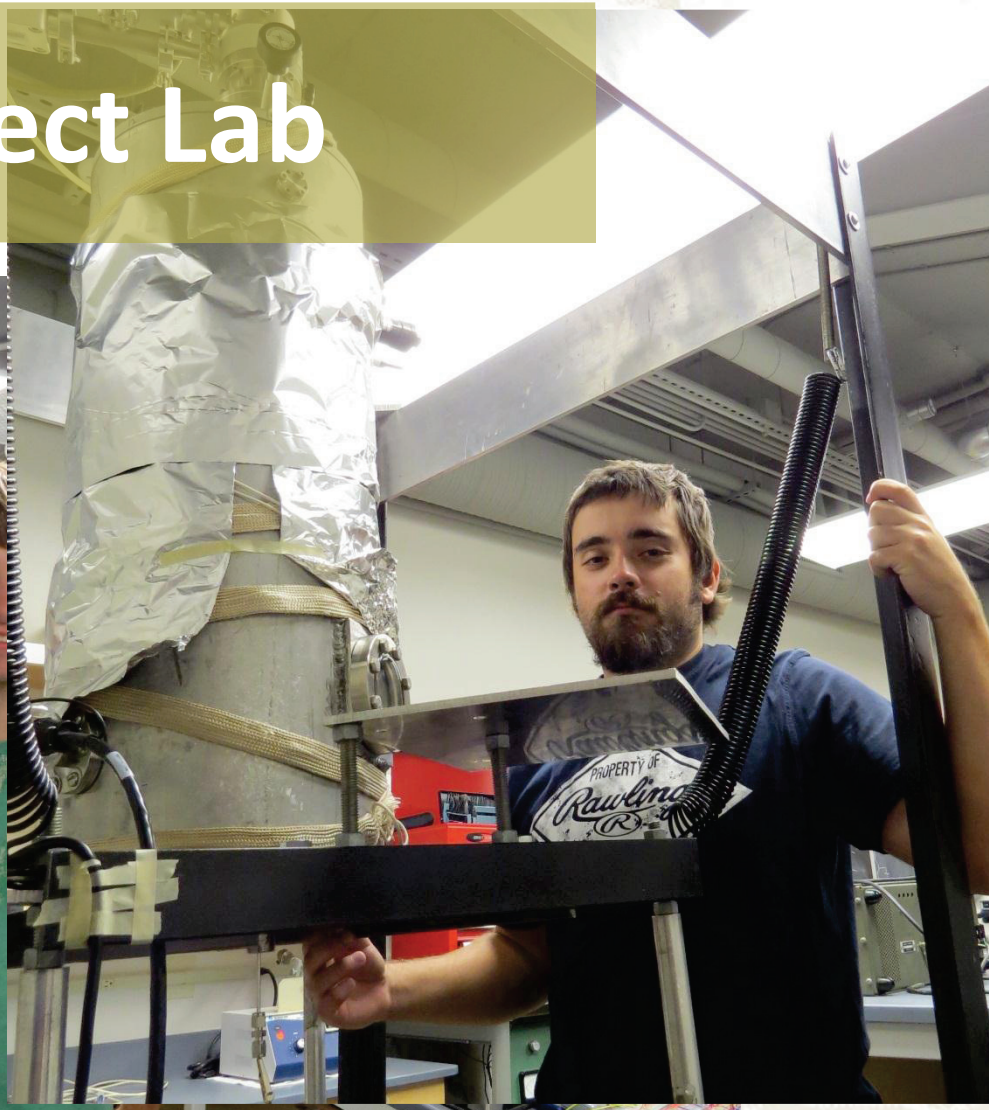

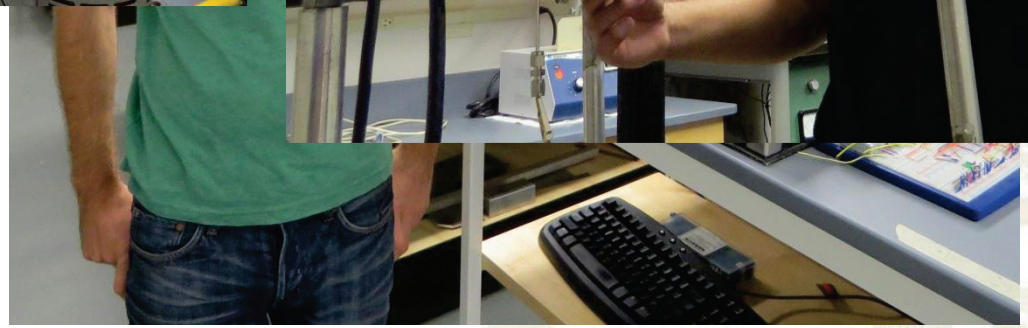

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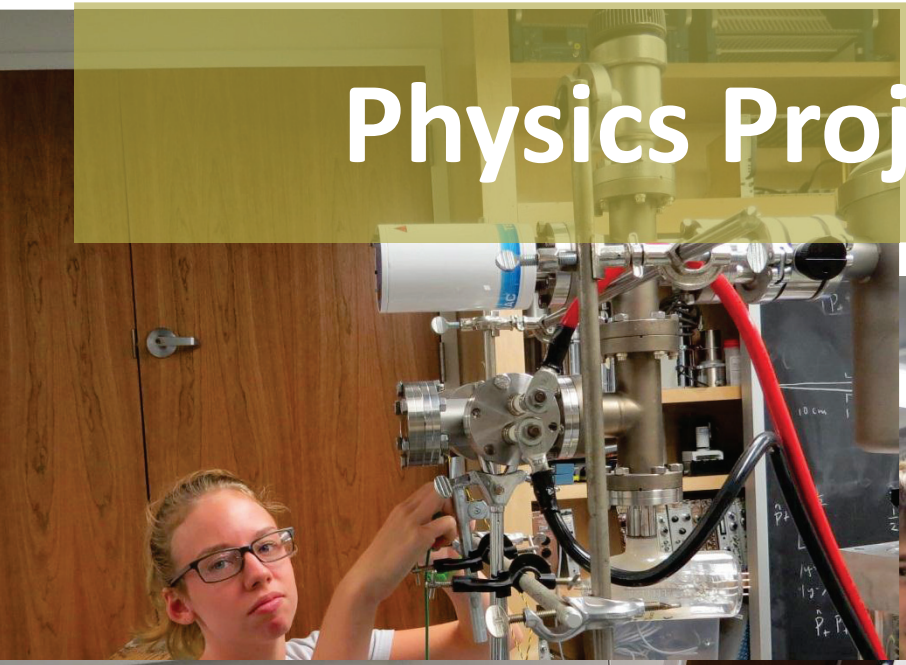

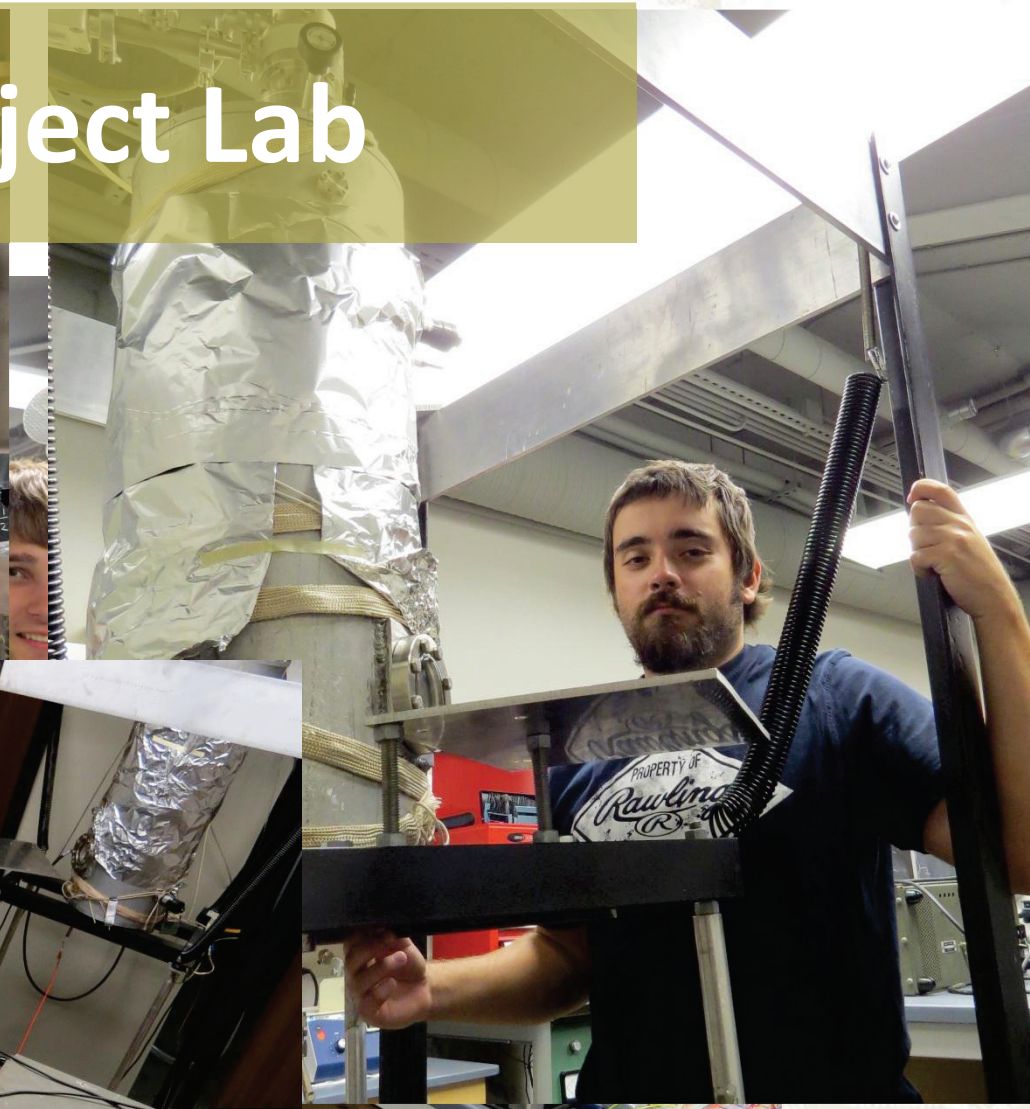

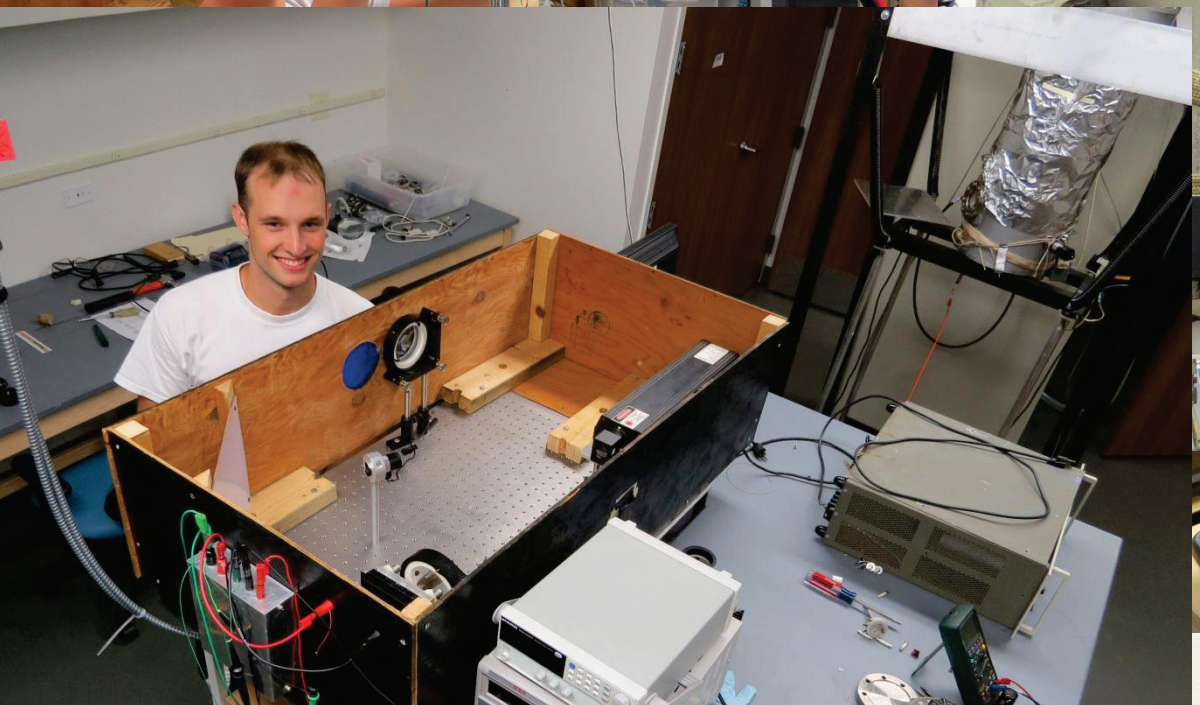

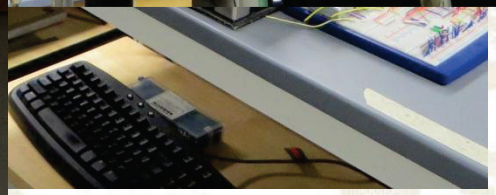

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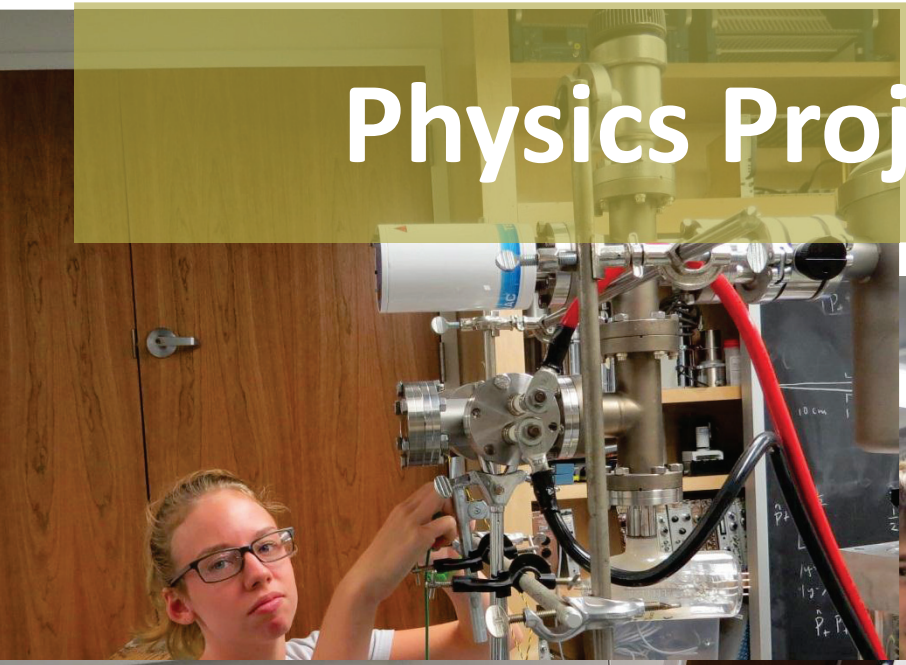

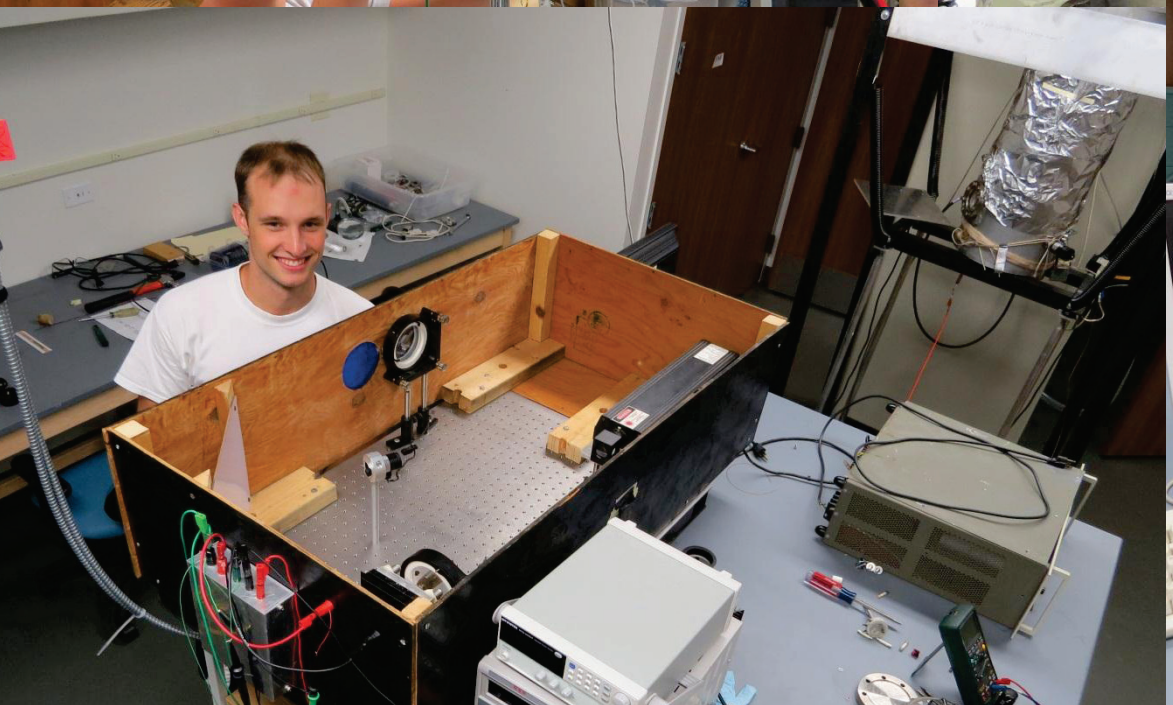

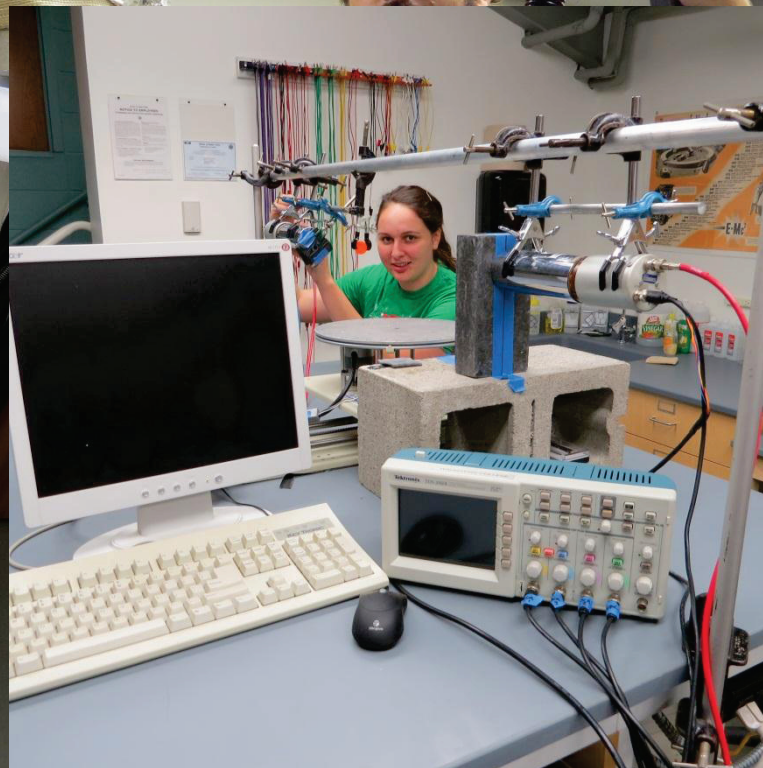

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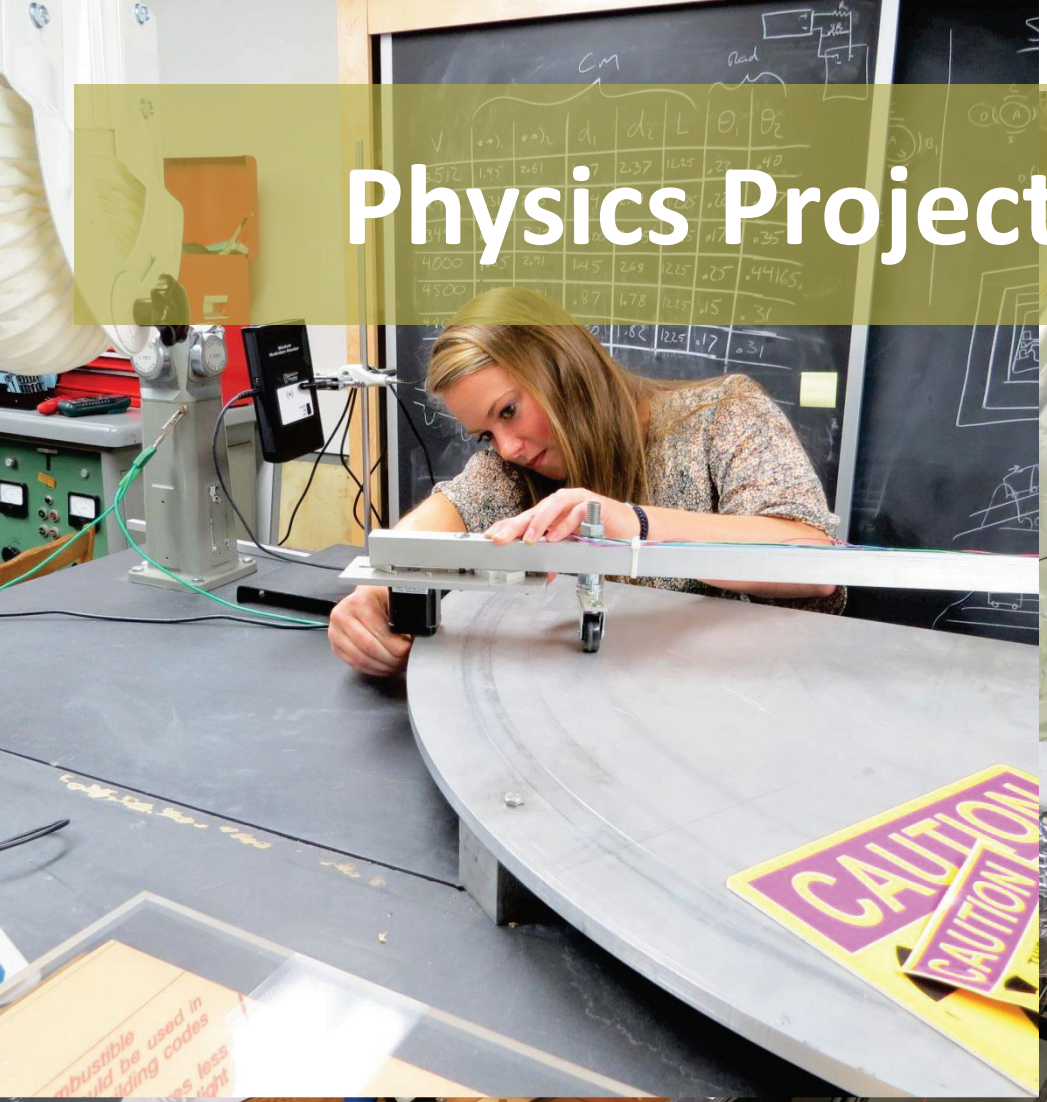


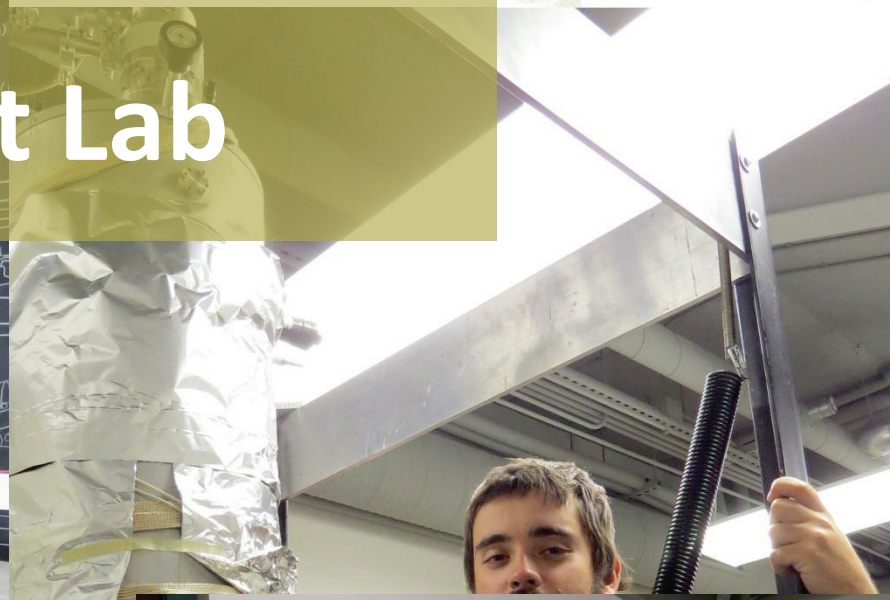

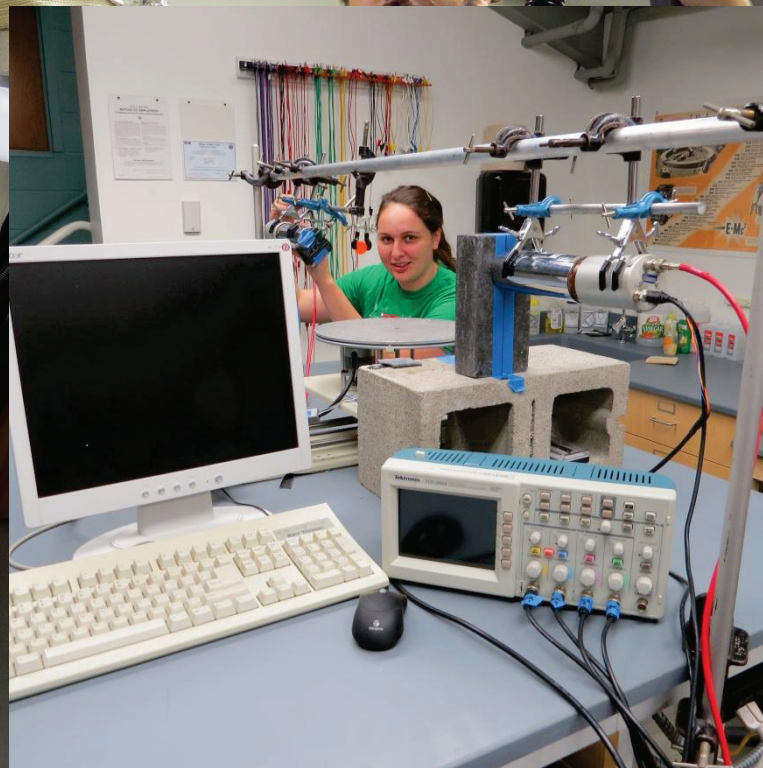

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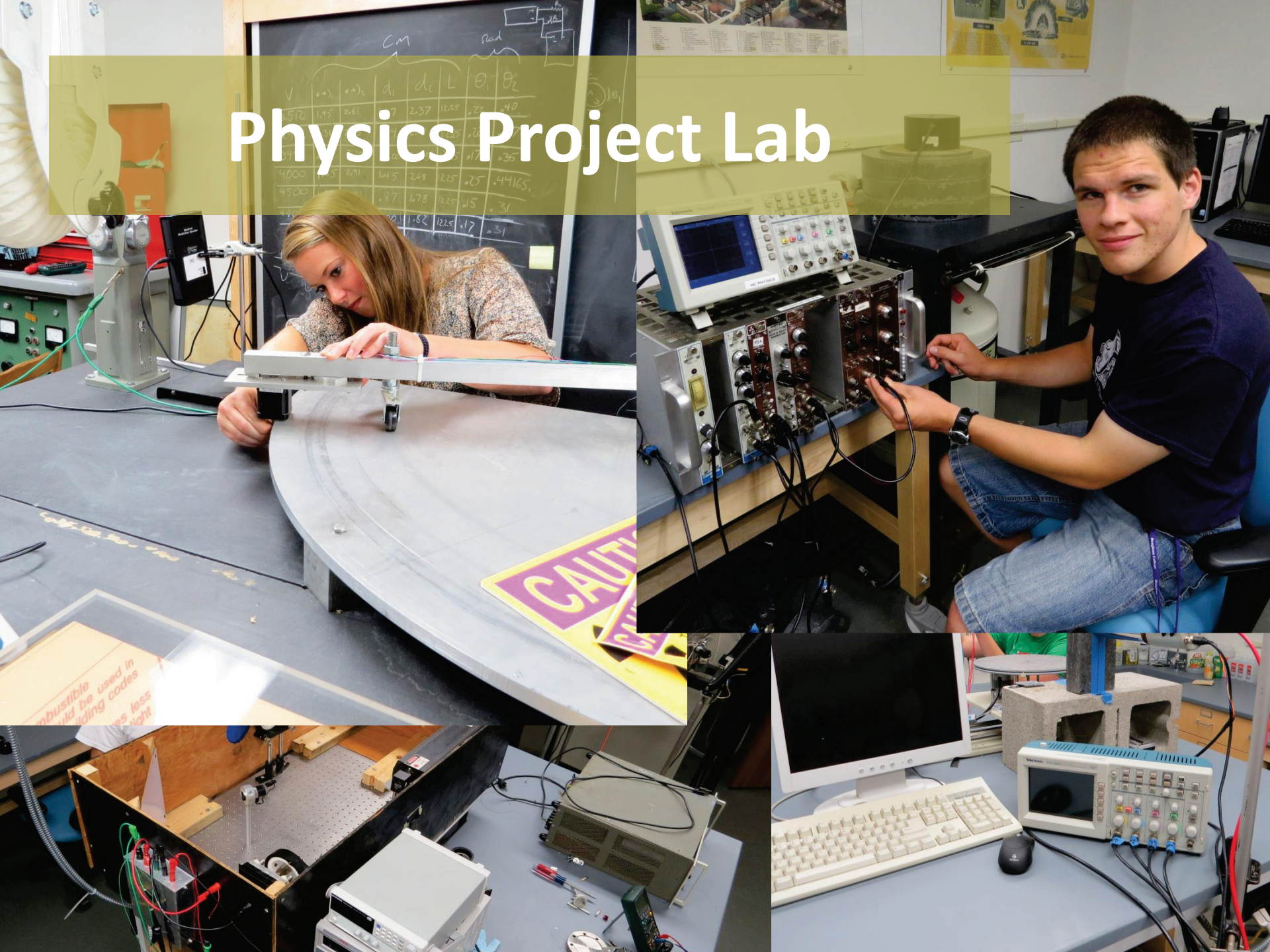

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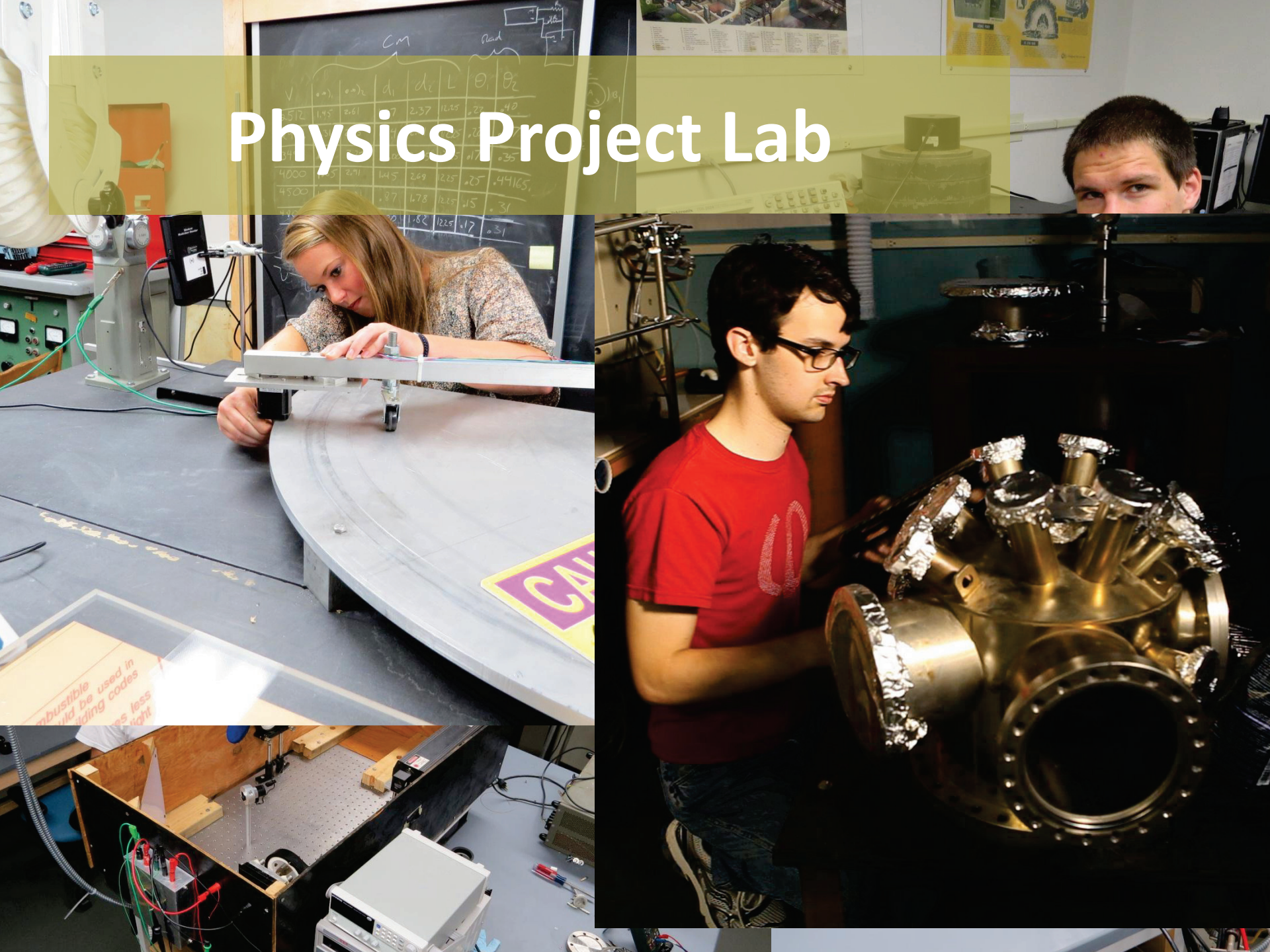

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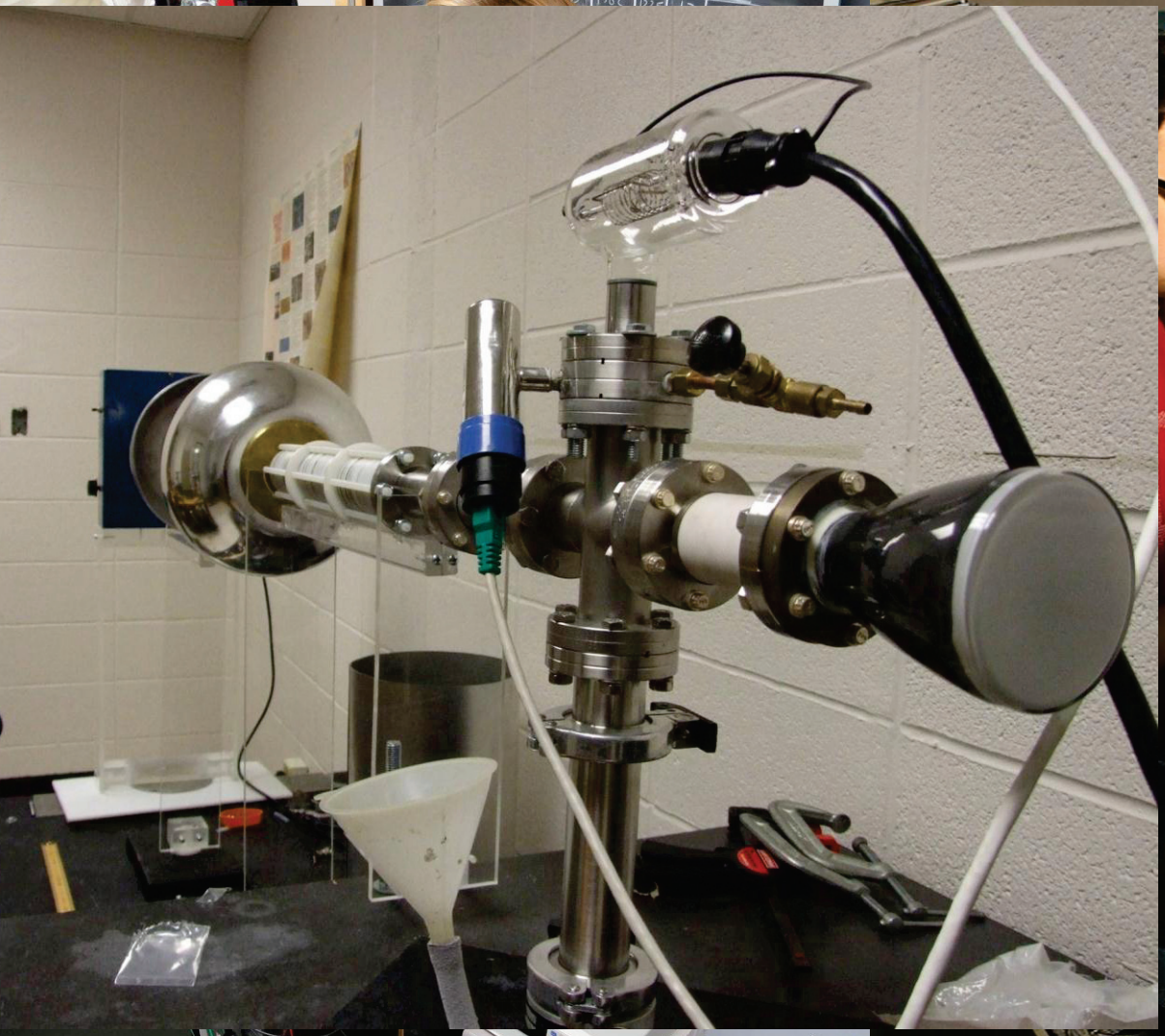

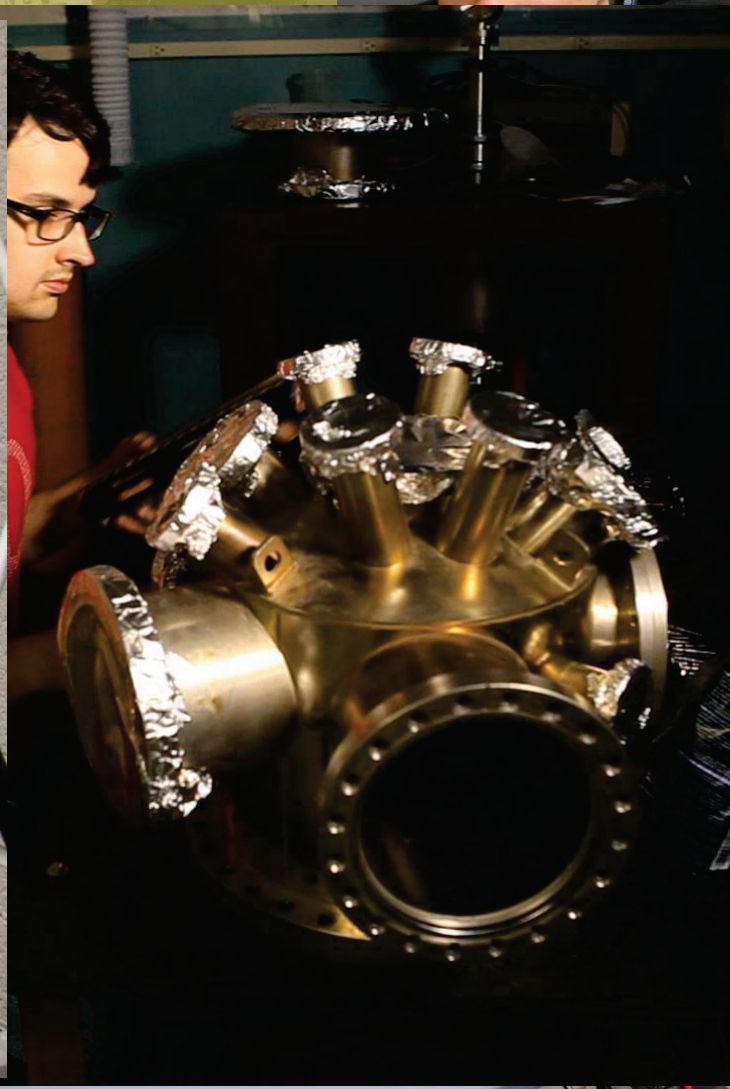

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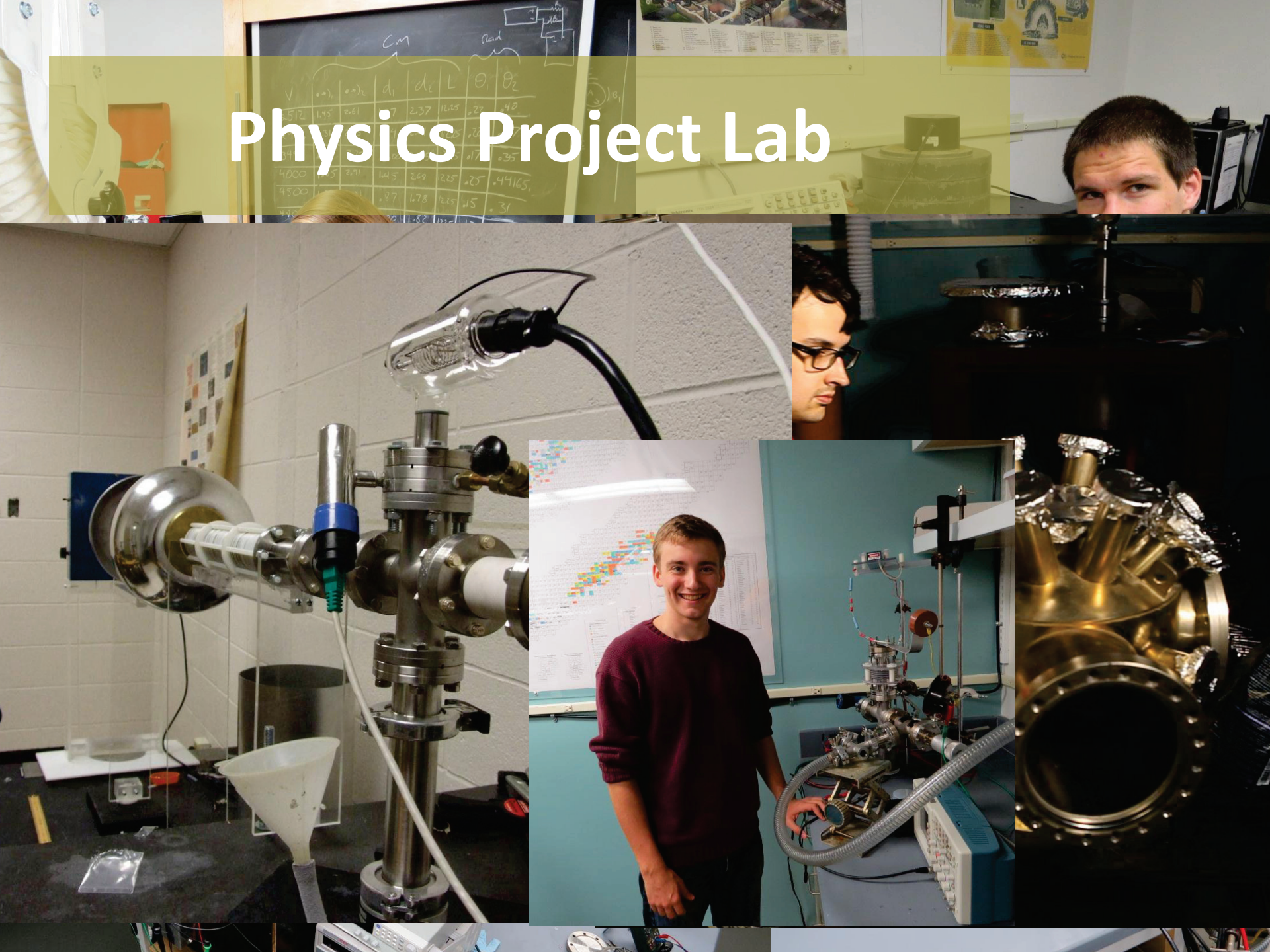
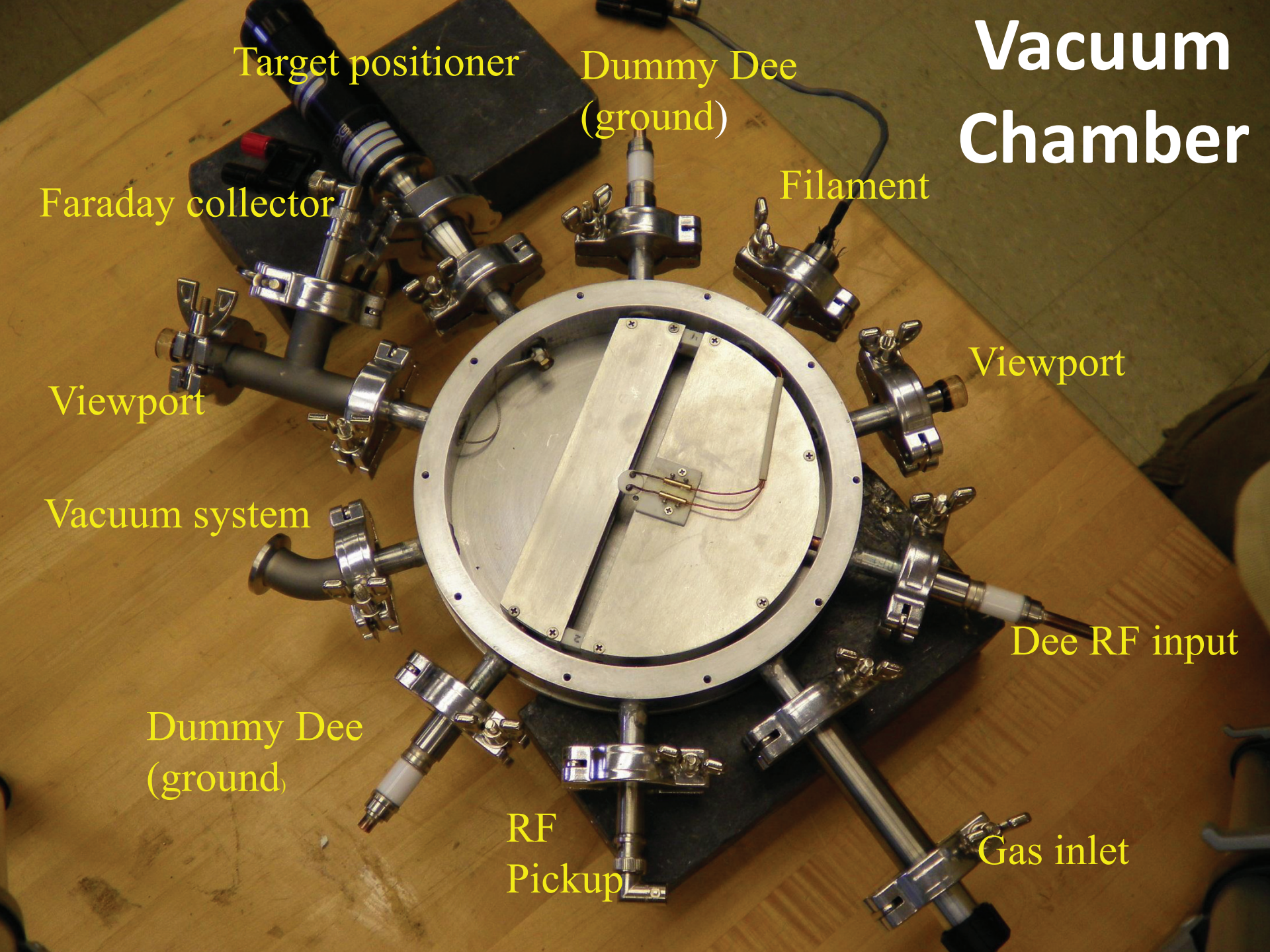
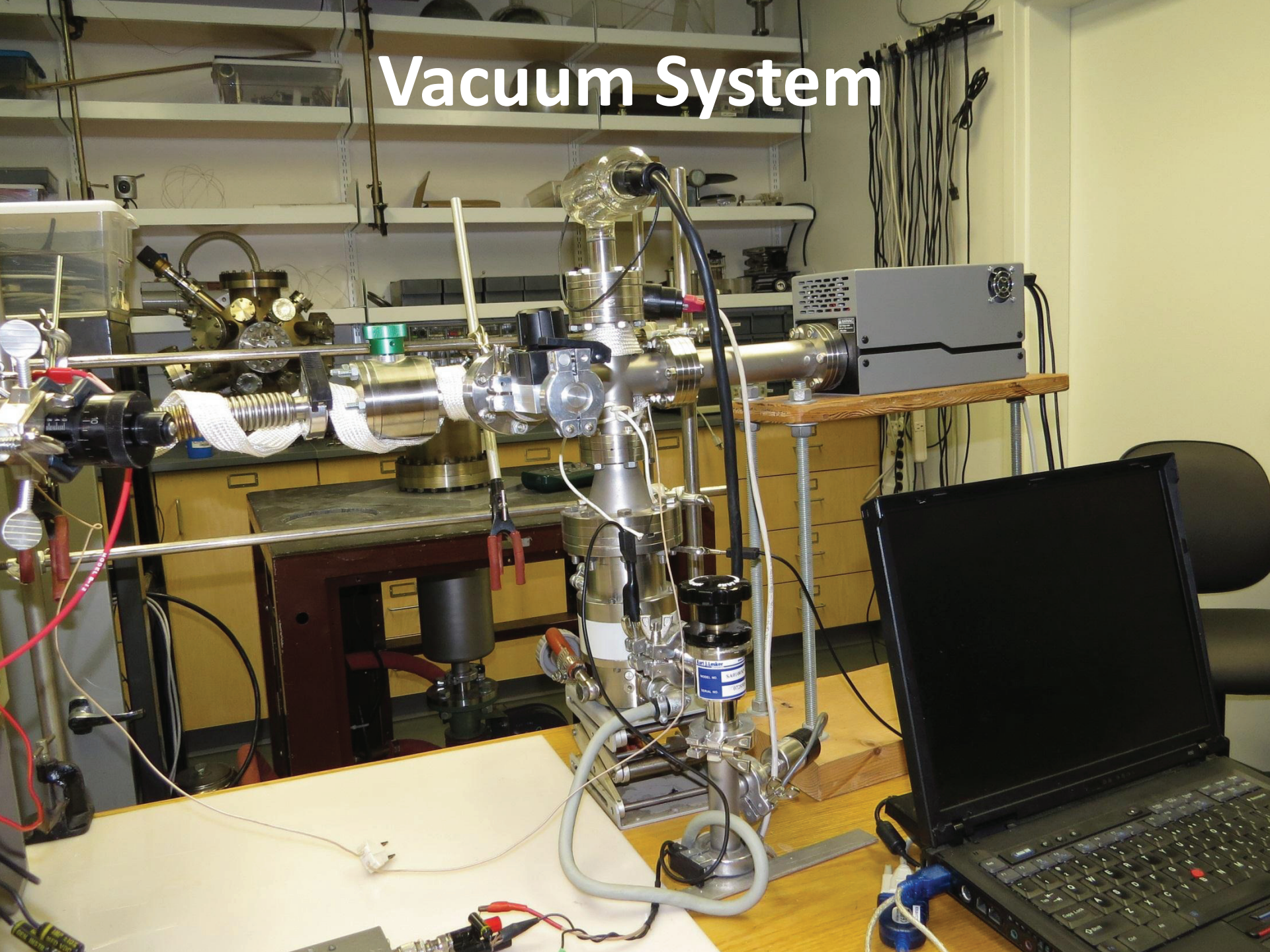
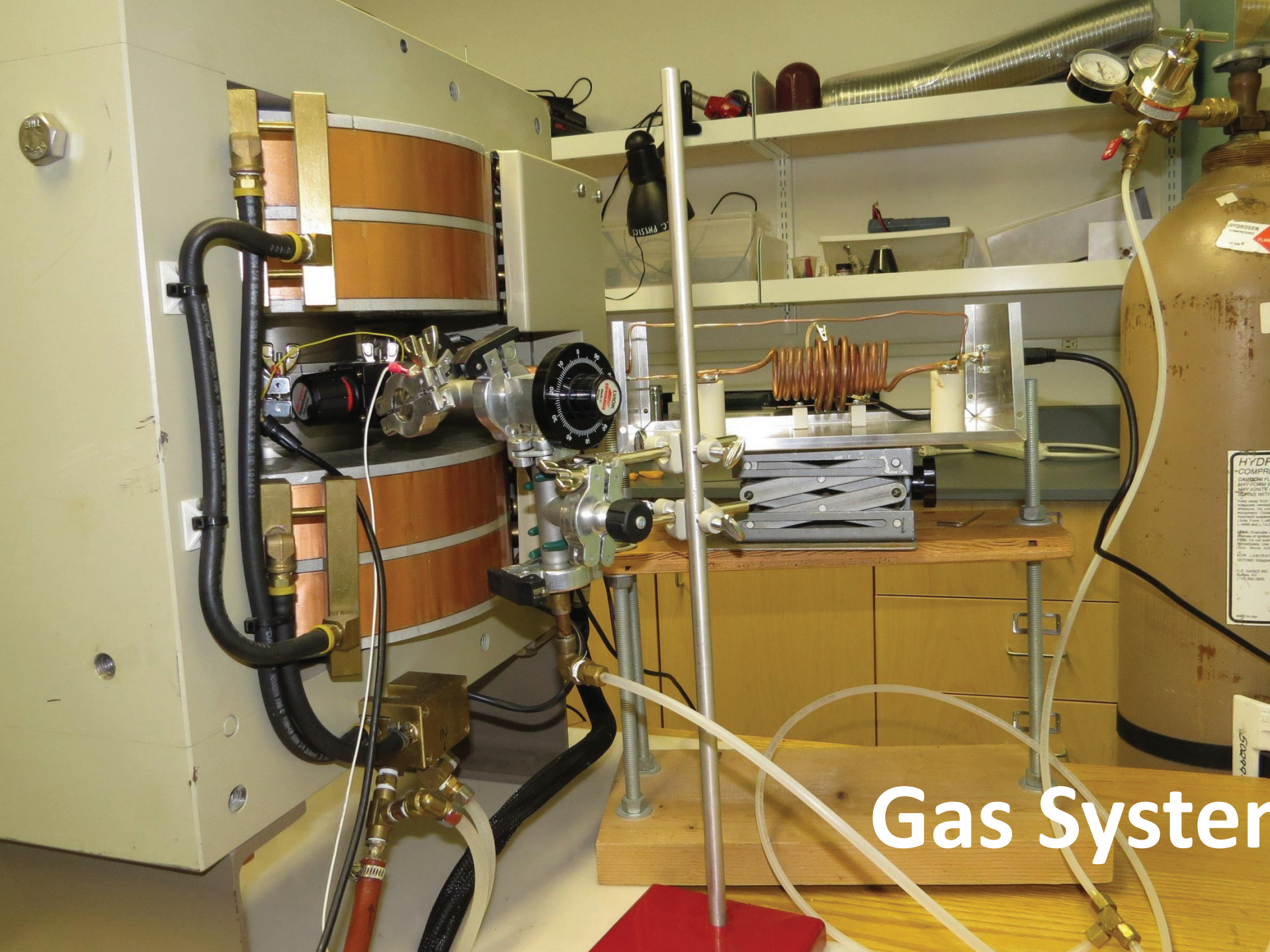


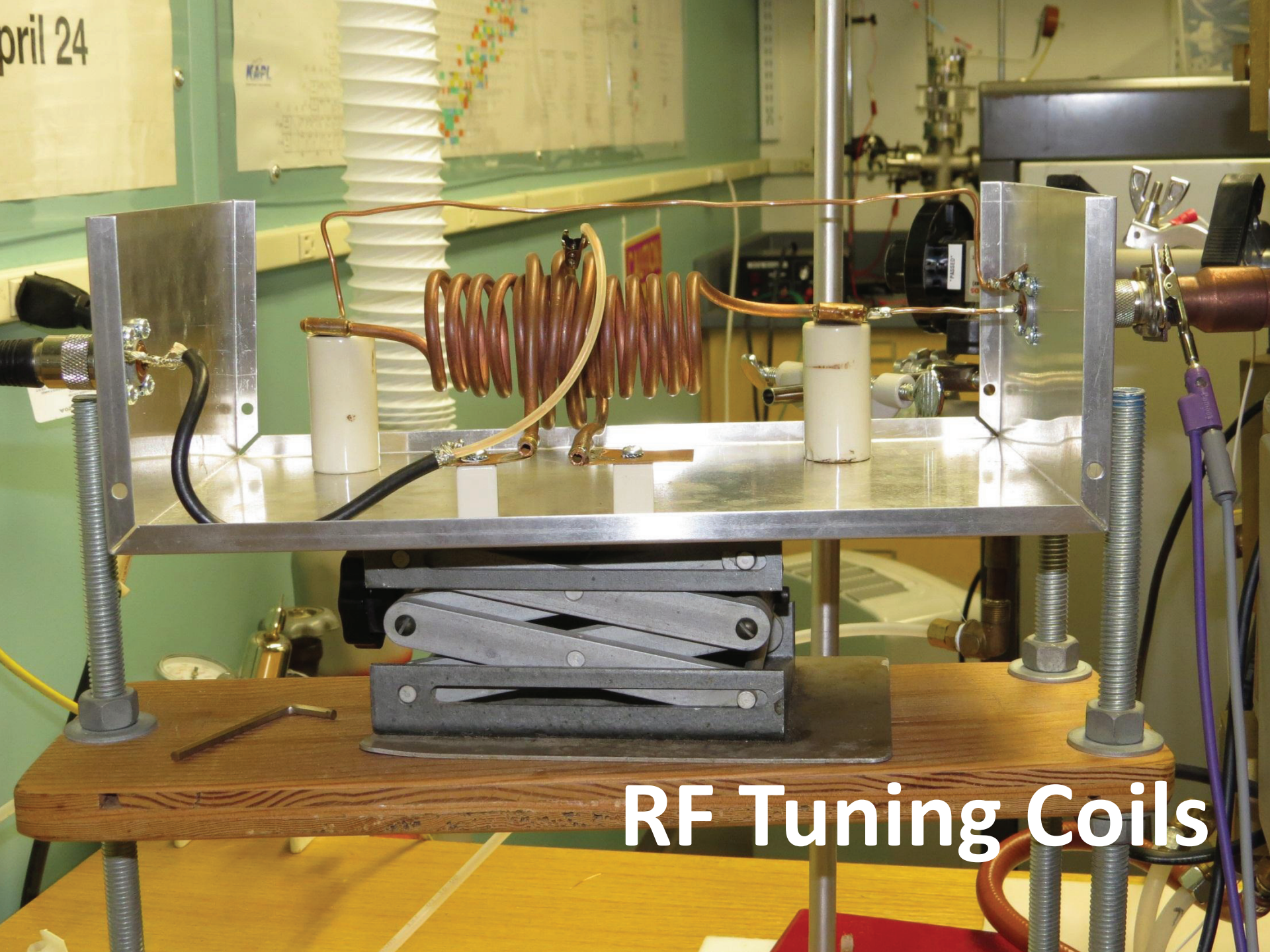

# The Houghton College Cyclotron


Vacuum Chamber
Target positioner
Dummy Dee (ground)
Filament
Faraday collector
Viewport
Viewport
Vacuum system
Dee RF input
Dummy Dee (ground)
RF Pickup
Gas inlet

# Vacuum System



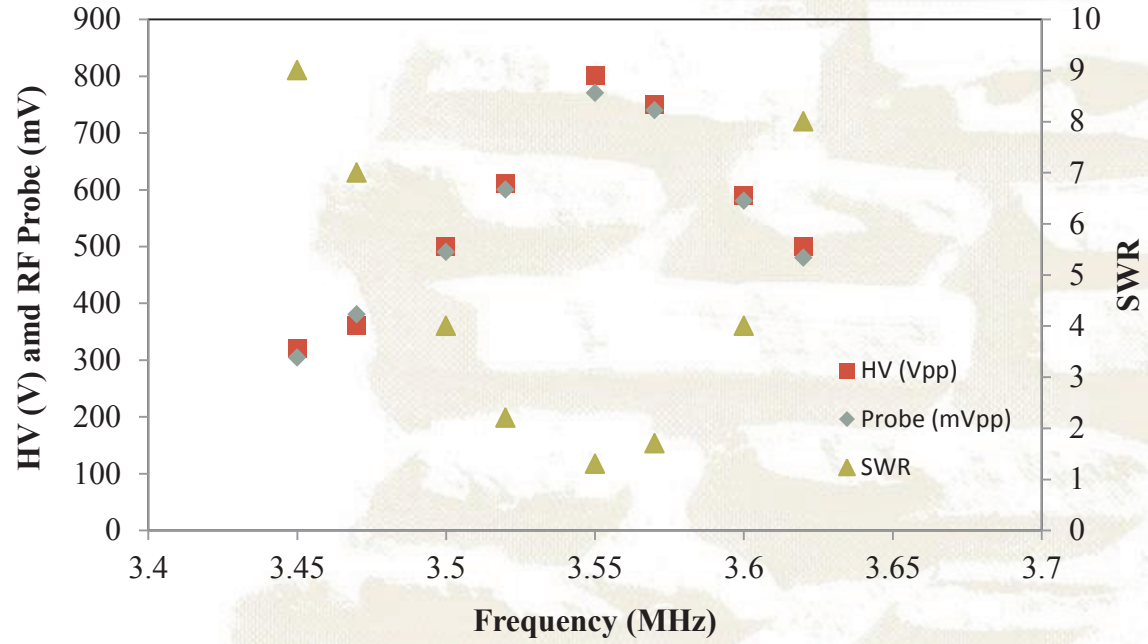

Gas Syster

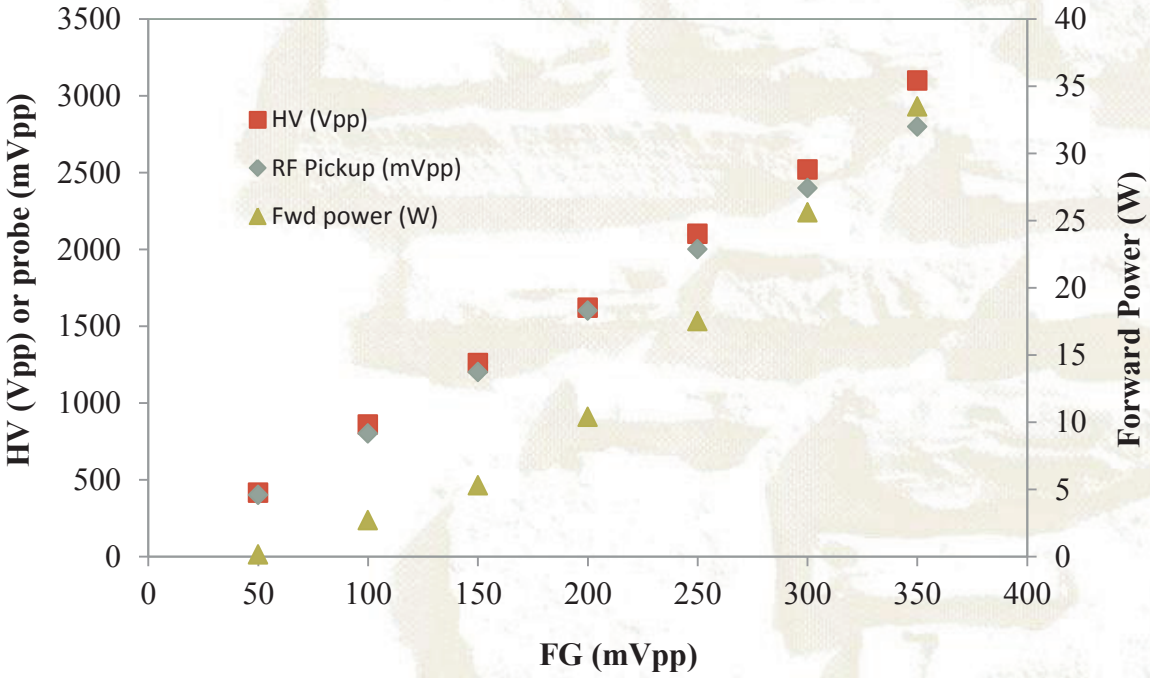

RF Tuning Coils


AT-200PC Autotuner
HEWLETT PACKARD 33120A
GW INSTEK GDS-2204
POWER AMPLIFIER
ON
OFF
PWR
TEMP
FWD
REF
DO NOT EXCEED 1 VOLT
INPUT
6ASB
15A
155LCRH

# RF System

# Tune at 3.55 MHz.

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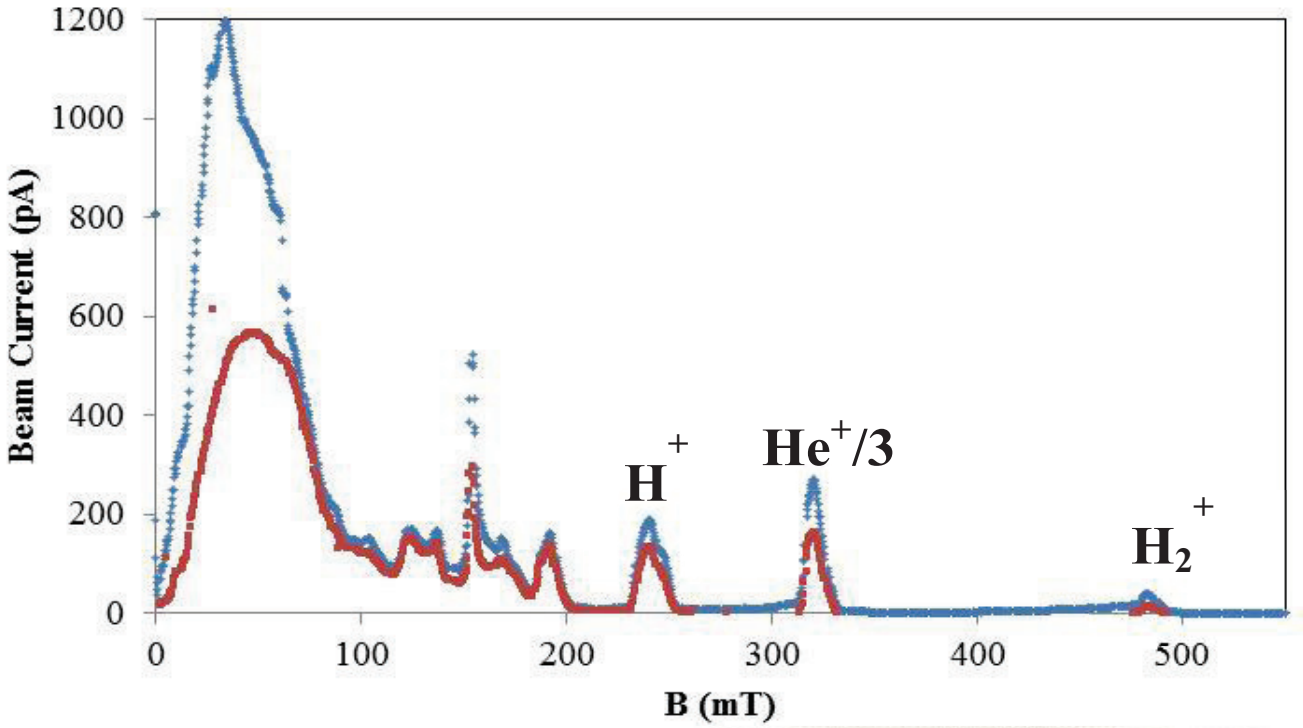
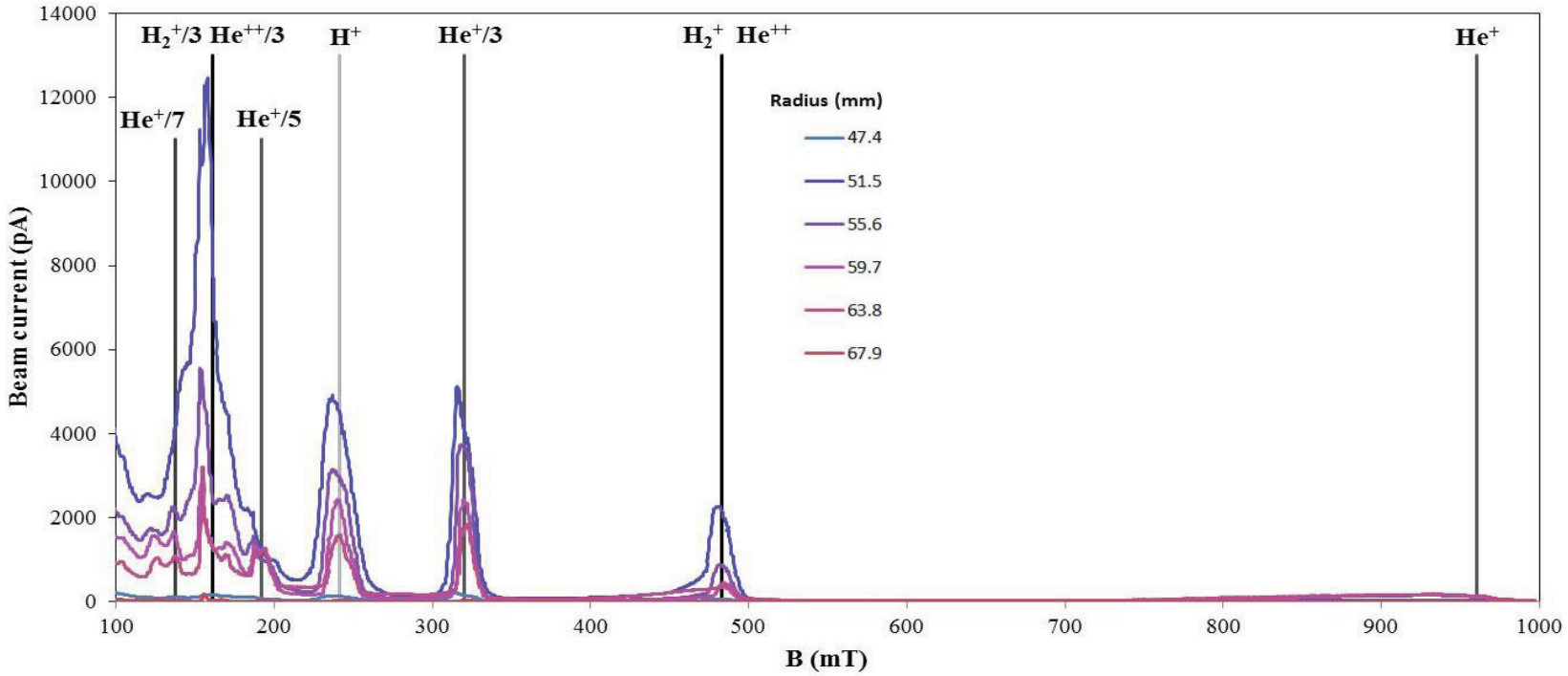
# Typical Magnet Scan



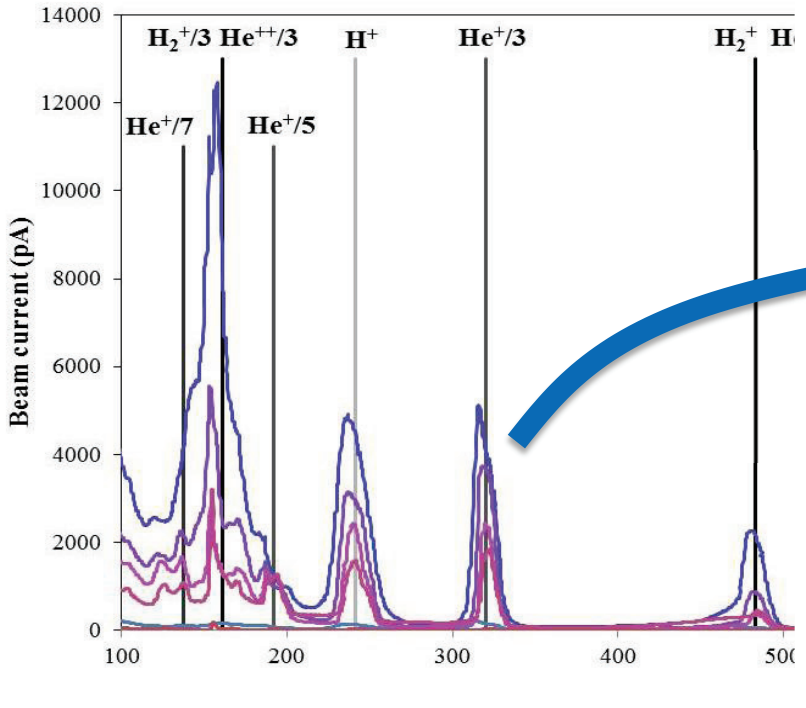

A typical spectrum for a mixture of hydrogen and helium at 3.68 MHz with the target at ground (blue) and +9 V on the target (red). The Dee voltage was approximately 2100 Vpp, the target radius was 62 mm and the chamber was filled with about $2 \times 10^{-5}$ Torr of a gas mixture of approximately equal partial pressures of hydrogen and helium.

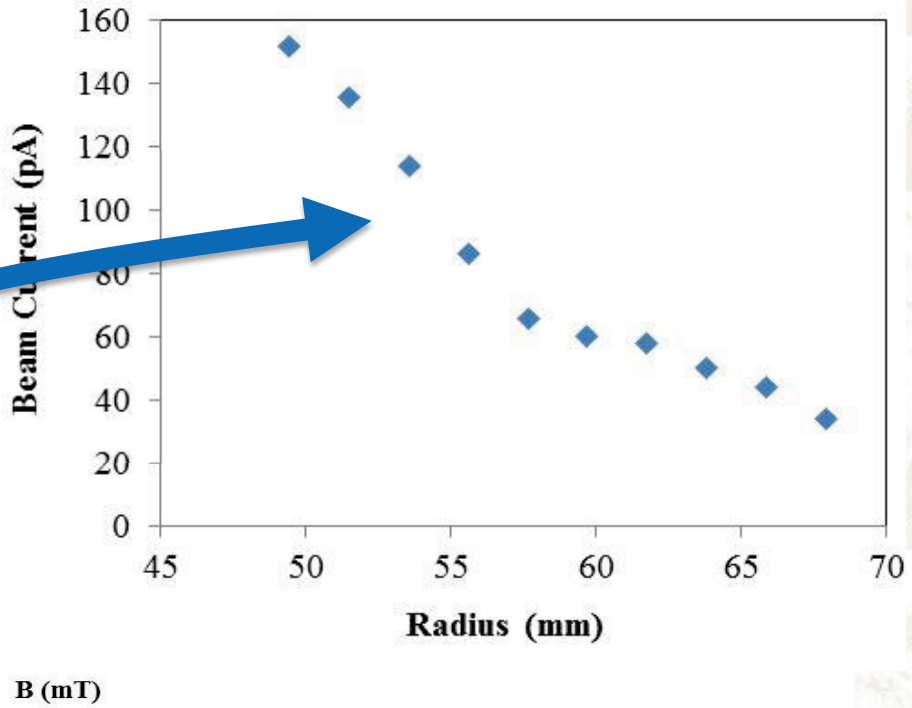
# Beam current as a function of target radius




Beam current as a function of magnetic field for various target radii at 3.68 MHz. The Dee voltage was about 2100 Vpp and the chamber was filled with about $2 \times 10^{-5}$ Torr of a gas mixture of approximately equal partial pressures of hydrogen and helium.

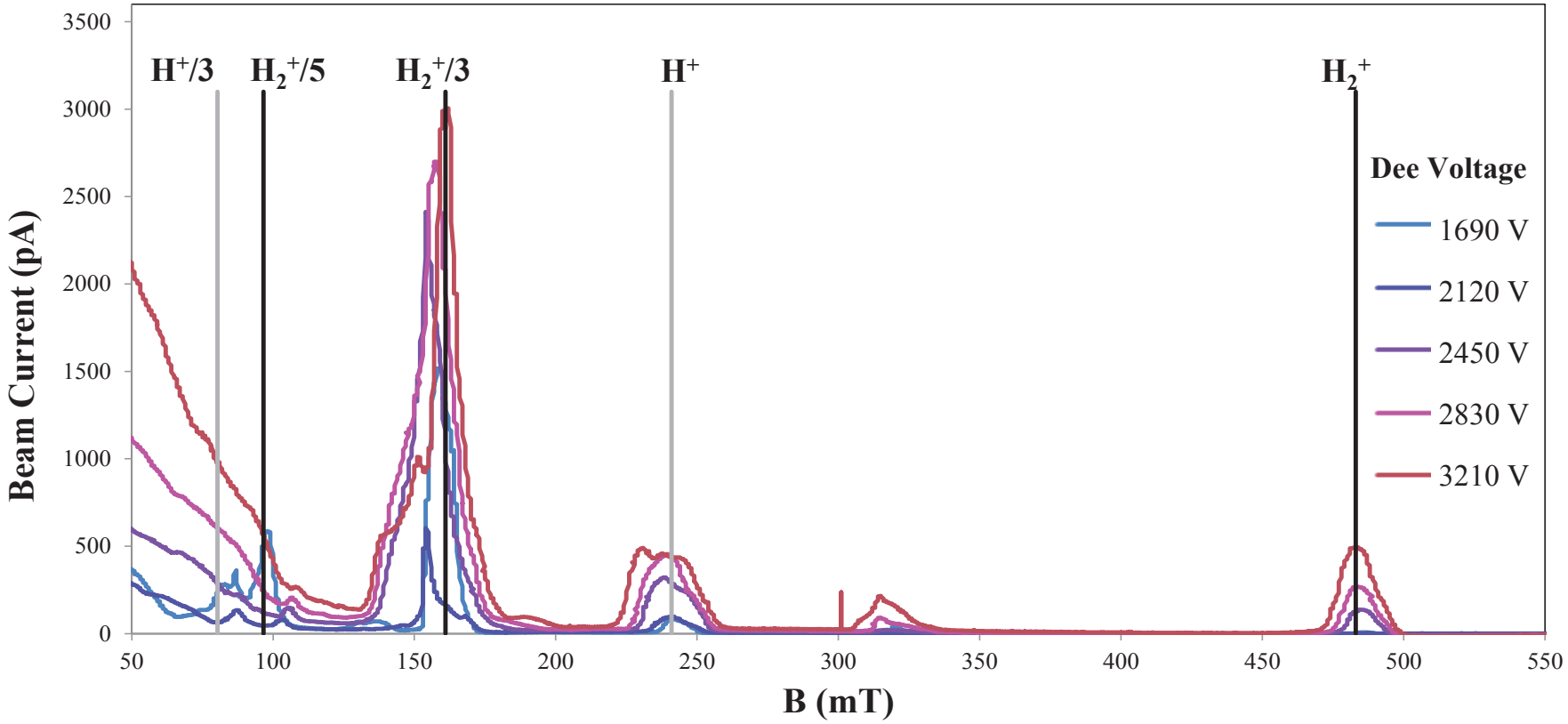
# Beam current as a function of target radius



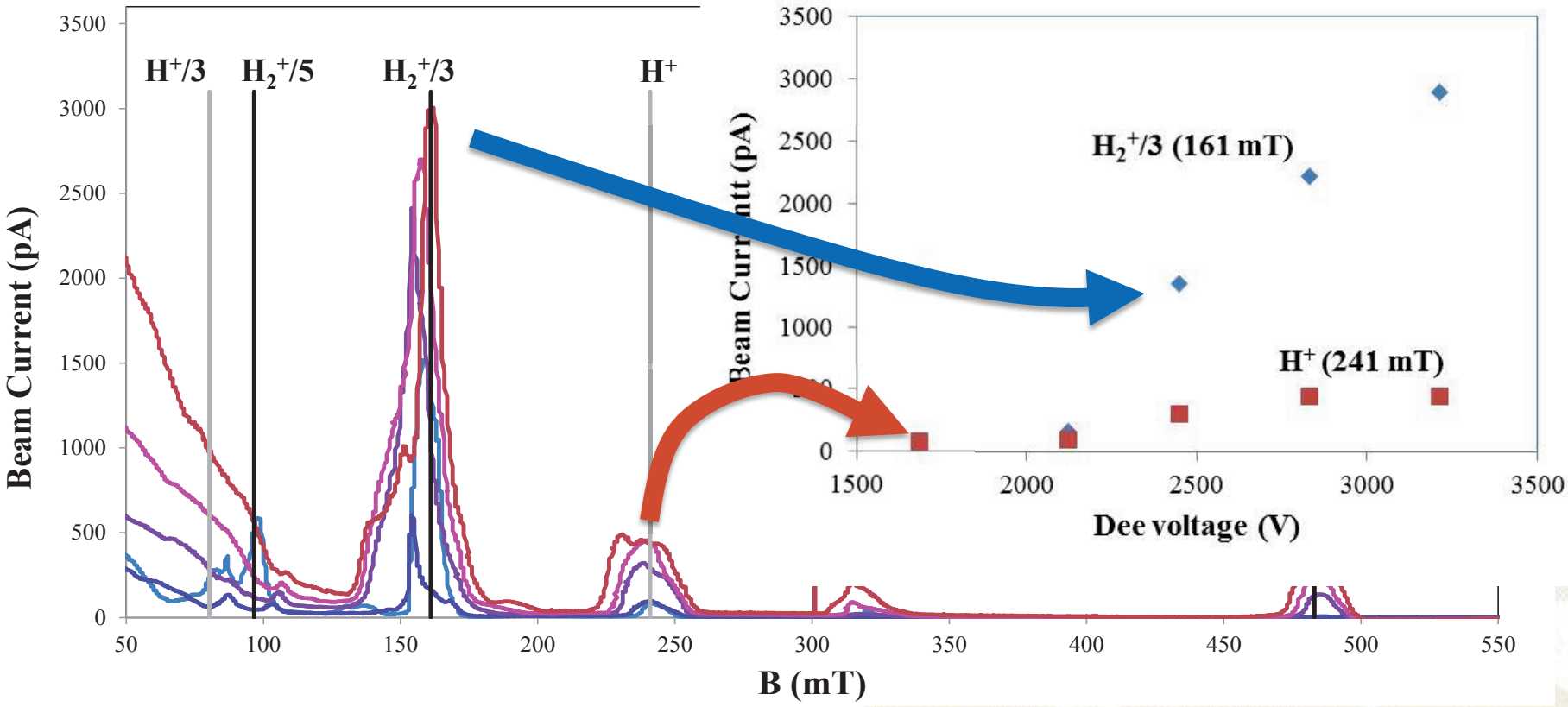

A plot of the beam current as a function of target radius for the $He^{+/}3$ peak at 320 mT.

# Beam current as a function of Dee voltage



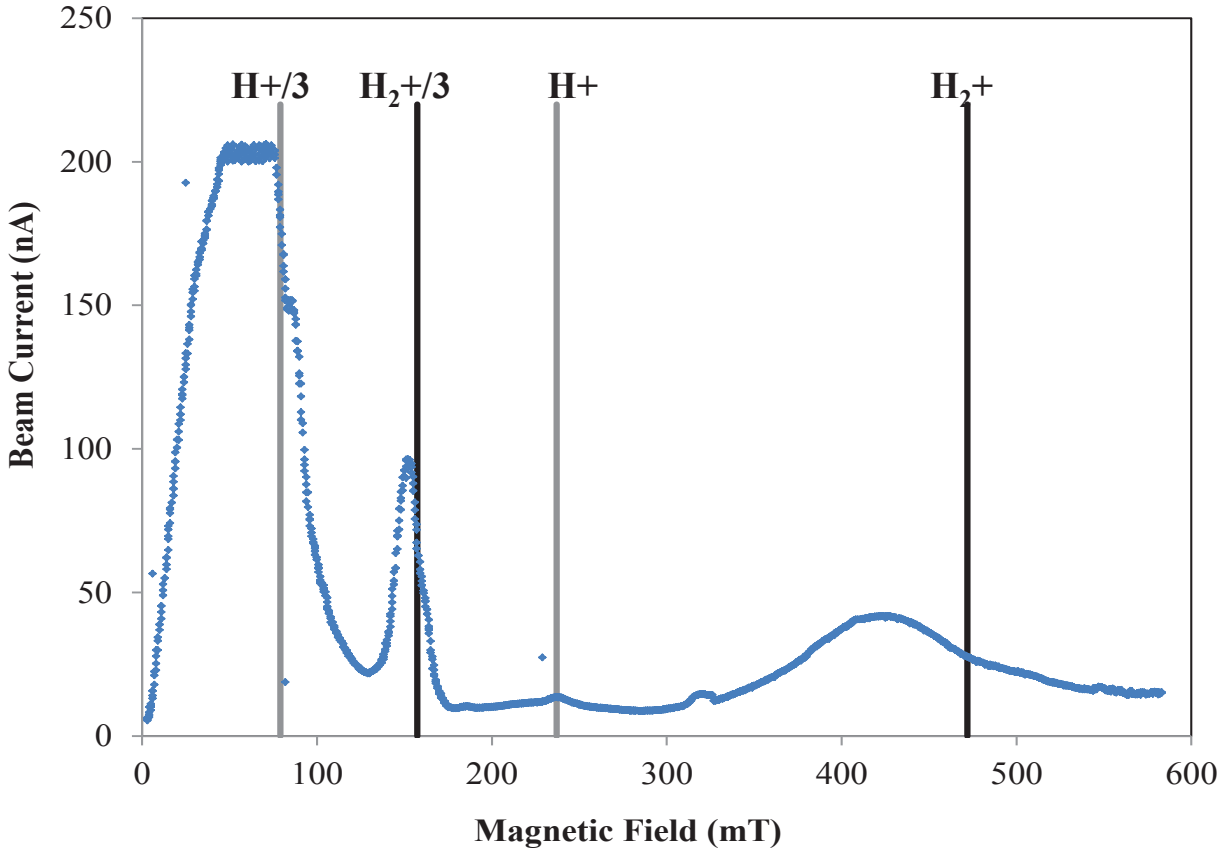

Beam current as a function of magnetic field for various Dee voltages at 3.68 MHz. The target radius was 62 mm and the chamber was filled with about $2 \times 10^{-5}$ Torr of hydrogen.

# Beam current as a function of Dee voltage




A plot of the beam current as a function of Dee voltage for the $H_2^+/3$ peak at 161 mT and the $H^+$ peak at 241 mT.

# Highest current




Highest current peak recorded, nearly 0.1 μA, at 3.62 MHz, for hydrogen at approximately $1\times10^{-4}$ Torr.

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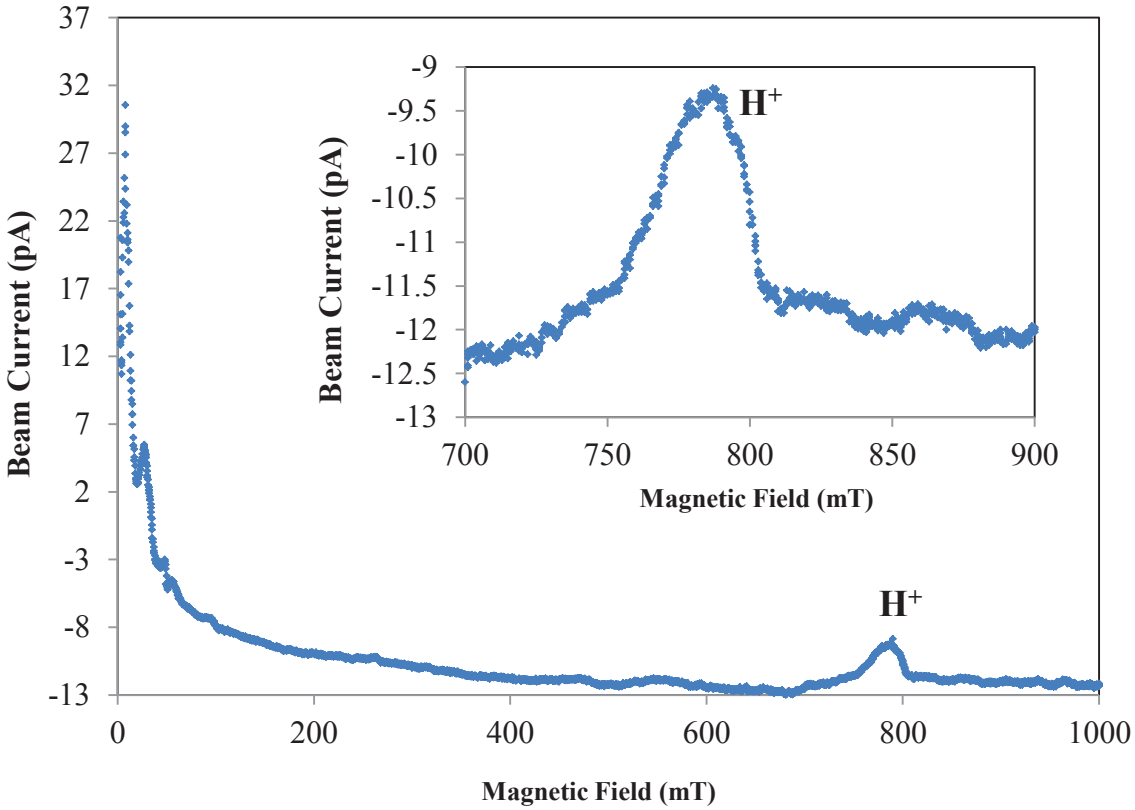
# Highest energy




Magnet scan at 12.1 MHz, with $3.5\times10^{-5}$ Torr of hydrogen in the chamber at the target at +9 V.

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# Future Plans

**Improve performance**

- Computer model -- Poisson Superfish and Simion
- Magnetic focusing – pole shaping
- To reach 400 keV
  - 70 A magnet power supply
  - RF amplifier/freq. generator

**Nuclear Physics**

- No beam extraction
- Internal target
  - Neutron or gamma
  - Port at 90° for charged particles
- Reactions below 400 keV
  - $^{2}H(d, n)\ ^{3}H$, and $^{2}H(d, p)\ ^{3}He$
  - $^{2}H(^{3}He, p)\ ^{4}He$
  - $^{19}F(p,\gamma)\ ^{16}O$, $^{31}P(p,\gamma)^{32}S$

# Conclusion

The cyclotron has been a very effective tool in teaching students to solve practical research problems and “think like a physicist”.

- knowledge from almost every area of physics
- synthesize workable, practical solutions
- innumerable quantities to measure
- unexpected behaviors to explain
- because it’s a cyclotron, it develops character qualities like patience and perseverance!