UNDERSTANDING CONFINEMENT IN QUANTUM CHROMODYNAMICS THROUGH THE GLUEX EXPERIMENT

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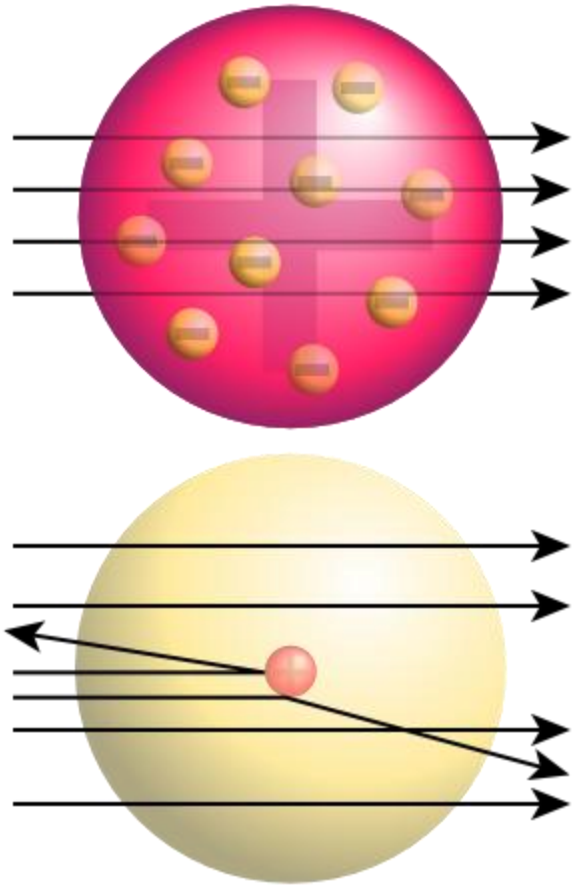
Outline

- Nuclear Physics
  - Discovery of the nucleus
  - Quarks and the Standard Model
  - Quark confinement
- GlueX Experiment
  - General overview
  - Coherent Bremsstrahlung
  - UConn contribution

Nuclear Physics

- In 1911 Rutherford discovered the nucleus
- The size of the atom is on the order of 10^{-10} m
- The nucleus is on the order of 10^{-15} m
- If the size of the nucleus is equated to 1 m then the distance driving to Penn State and back is the diameter of the atom.



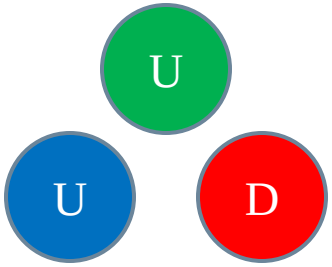
Nuclear Physics

- To probe the small structure of the nucleus experiments require very high energies, i.e. wavelength must be smaller than the size of the nucleus
- $E = h\nu = hc/\lambda$
- $E = (4.136 \times 10^{-15} eV \cdot s)(3 \times 10^{8} m/s)/(10^{-16} m)$
  $\sim 12 GeV$

Quarks

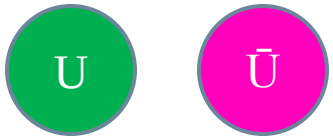
- Quarks are elementary particles that combine to form hadrons.
- Two types of hadrons: baryons and mesons

Baryons: 3 quarks



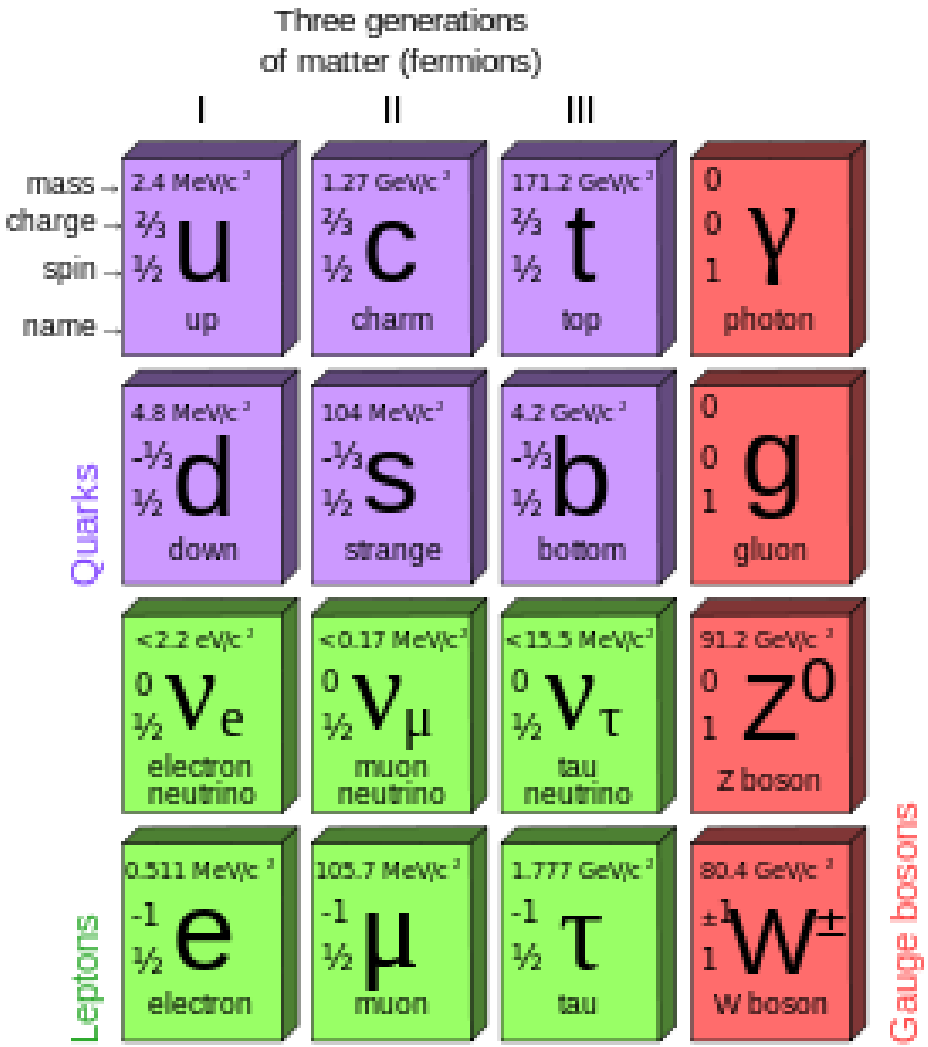
Total charge = 2/3 + 2/3 + (-1/3) = 1

Mesons: quark-antiquark pair



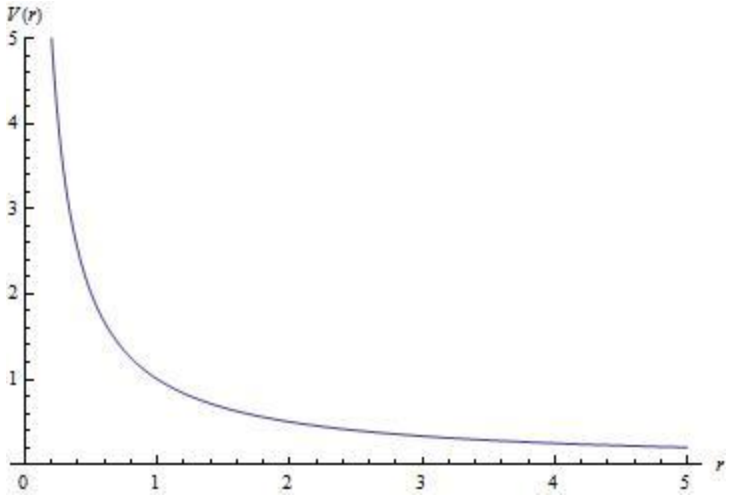
Total charge = 2/3 + (-2/3) = 0

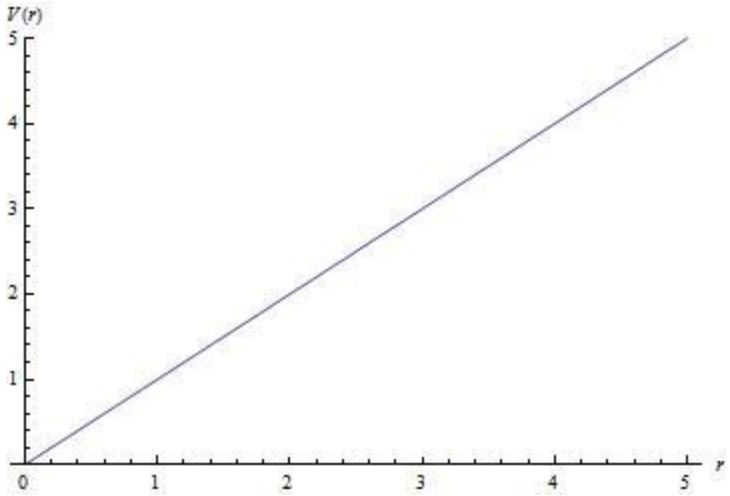
Standard Model



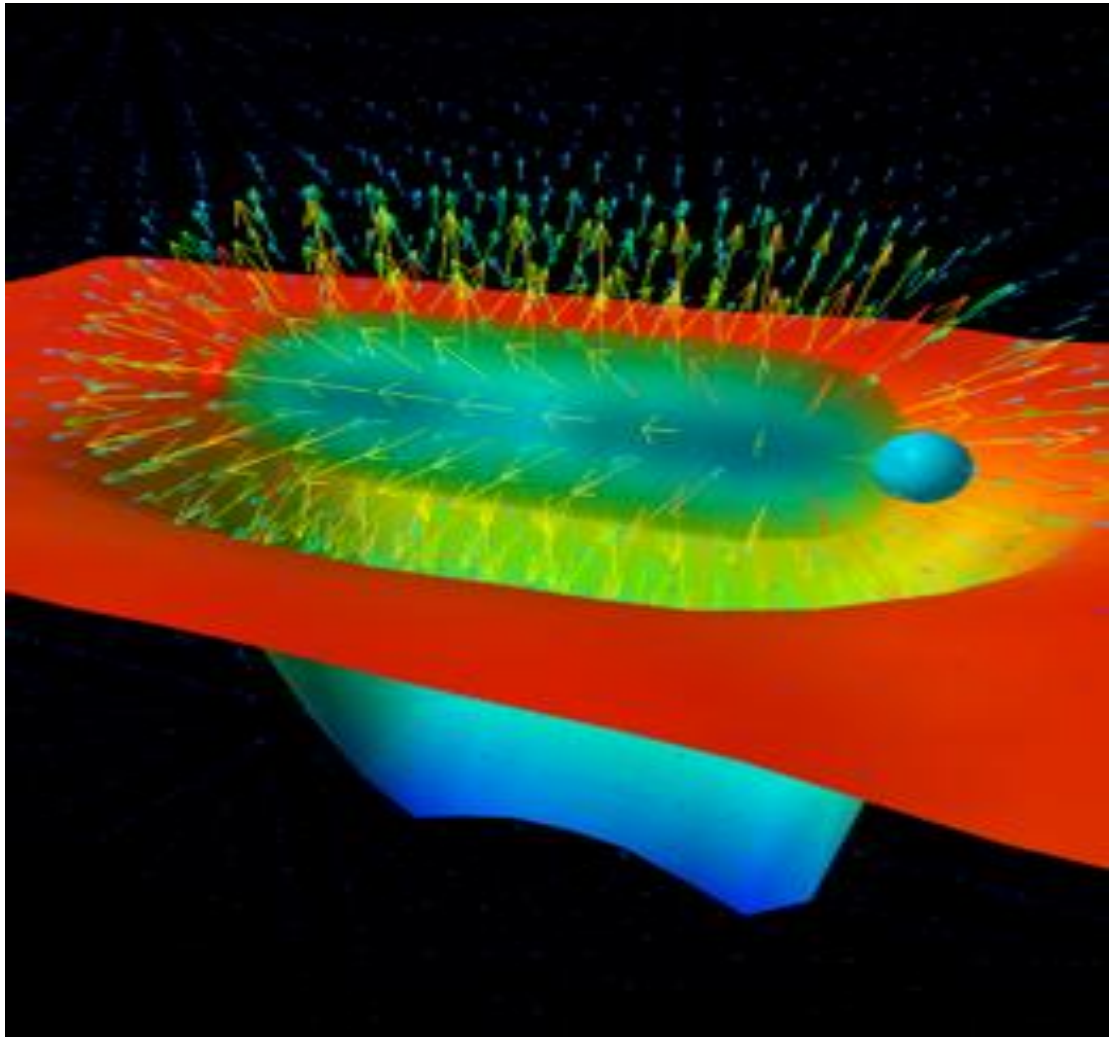
Quark Confinement

- In at atom, the electron obeys the Coulomb potential V(r) ~ 1/r
- Quarks interact via the strong force which has a potential V(r) ~ r
- Before quarks will separate, it will become more energetically favorable to form a new quark-antiquark pair





Quark Confinement

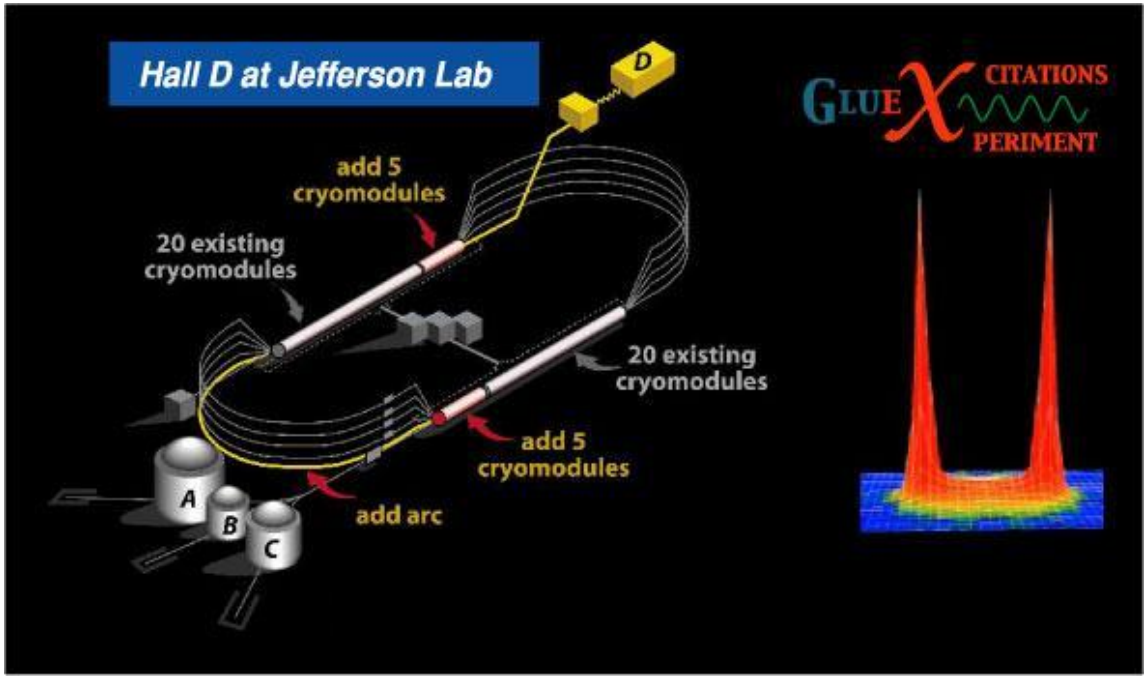


Exotic Mesons

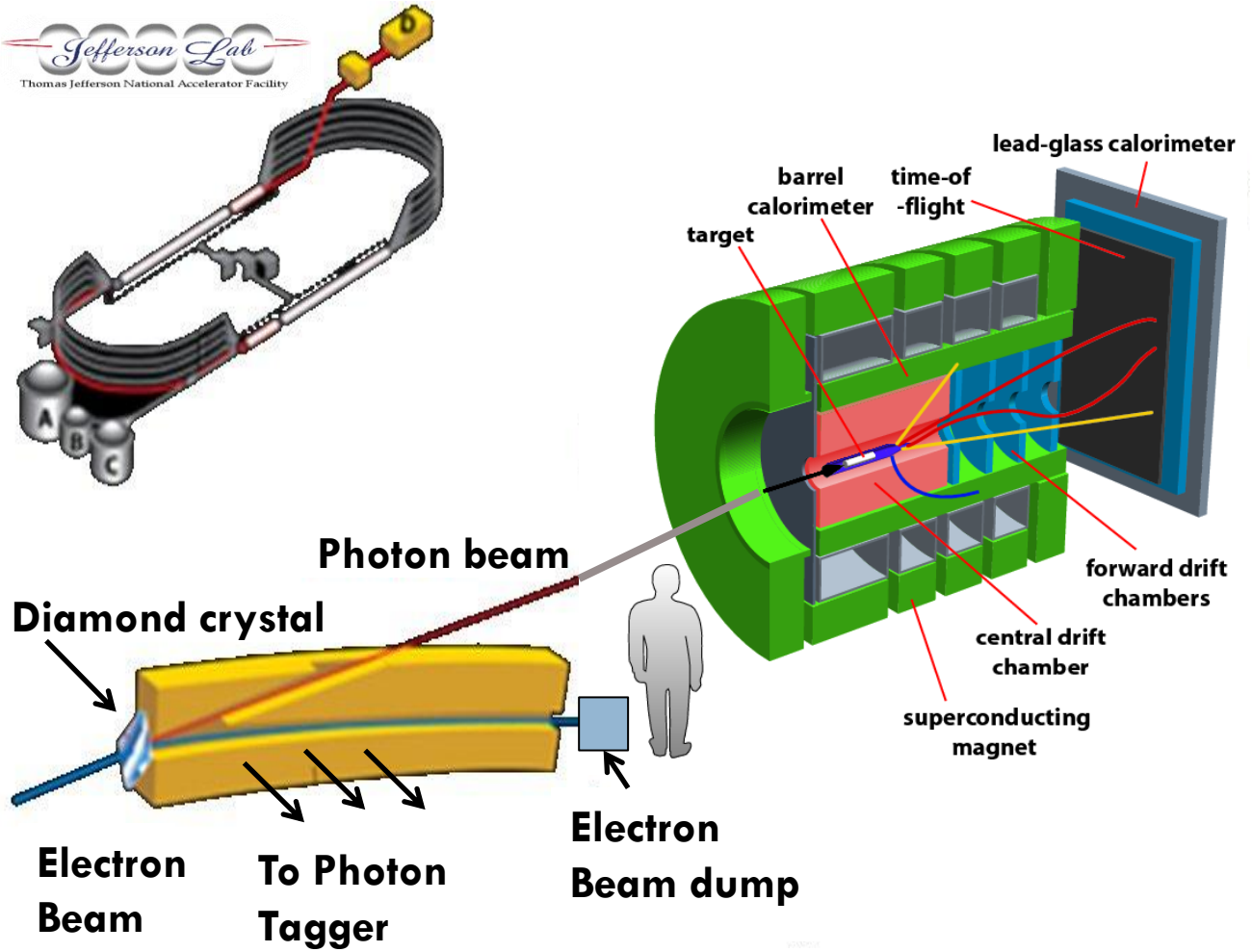
- When considering the total angular momentum, parity, and charge conjugation of the quarks, mesons have specific unallowed states
- If the gluons in the flux tube are considered as well and are excited, these unallowed states become allowed
- These mesons in ‘unallowed’ states are called ‘exotic mesons’

GlueX

- The GlueX experiment has been designed to investigate the confinement of quarks.
- The concept is to excite the glue of a meson thus making it an exotic meson and measure it's spectrum

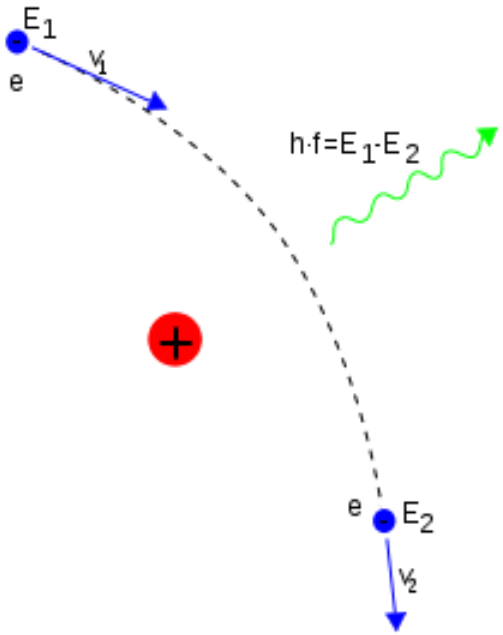


Experimental Setup



Bremsstrahlung

- Bremsstrahlung comes from German for 'braking radiation'.
- As the electron decelerates a photon is emitted corresponding to the energy lost by the electron.



Bremsstrahlung

- This process is used to tag the photon energy as it travels to the experiment.

$$(p_{e,initial} - p_{e,final})c = E_{photon}$$

- The electrons follow a curved path due to a magnet
- Any electron that has emitted a photon will be incident on a detector to record its final energy
- All non-slowed electrons travel into a beam dump and are not considered in the experiment

Detectors

- The photons collide with a liquid hydrogen target and create a particle shower
- These particles travel into various detectors which measure certain properties of the particles such as time and energy
- Exotic mesons are formed by colliding a photon with a proton and looking at the decay chain

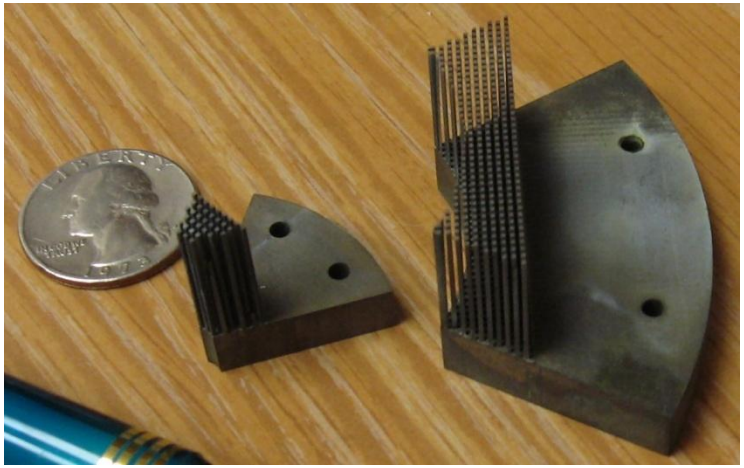
Work at UConn

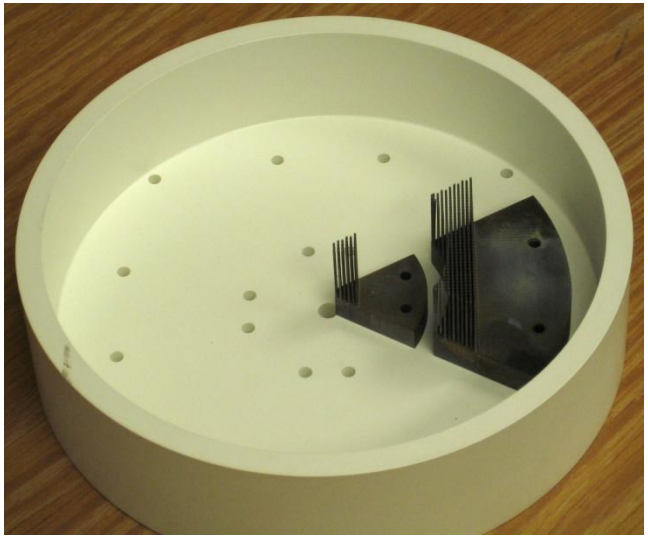
We have designed and constructed:

- The active collimator
- The diamond radiator
- The electron tagger microscope and electronics

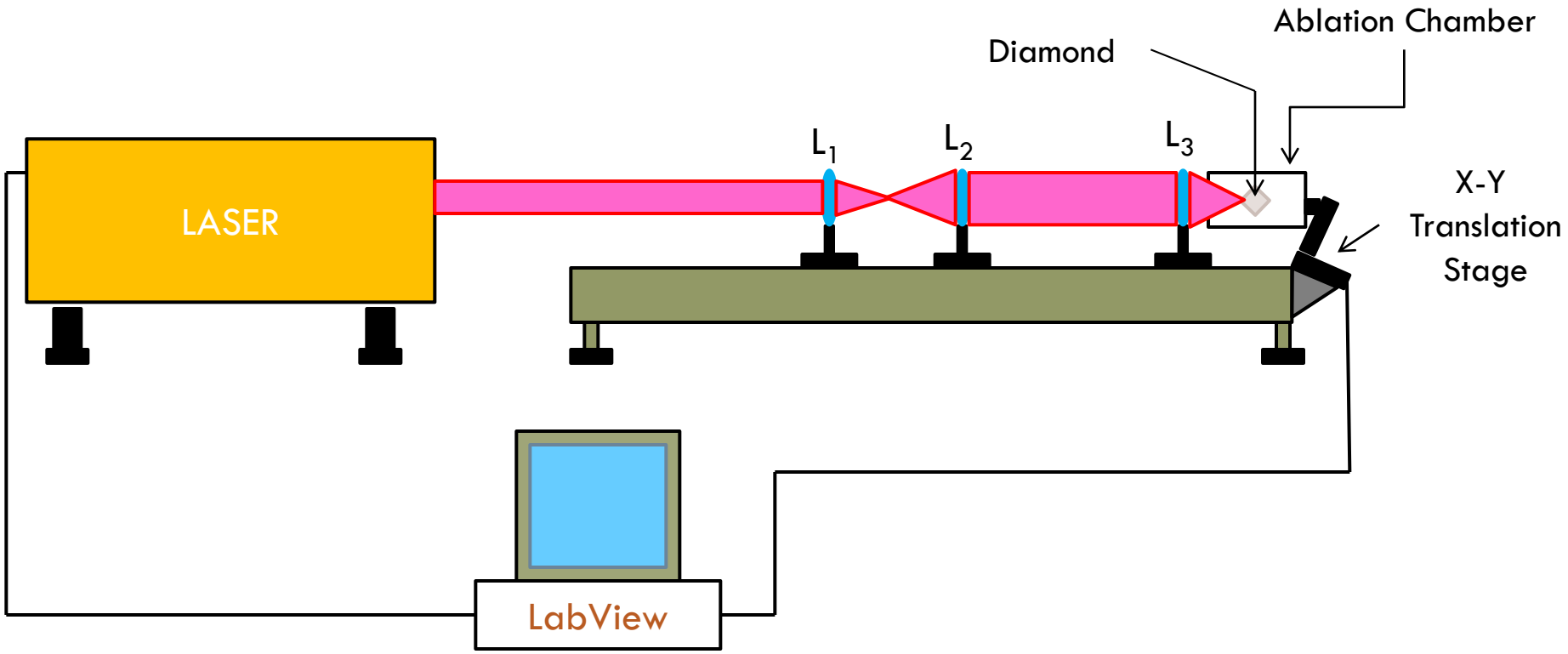
Active Collimator

- The active collimator is used to align the photon beam
- There are a total of 4 tungsten wedges
- When the photons hit a wedge a current is created
- Based on the current and the source wedge, magnets are adjusted to center the beam





Diamond Ablation

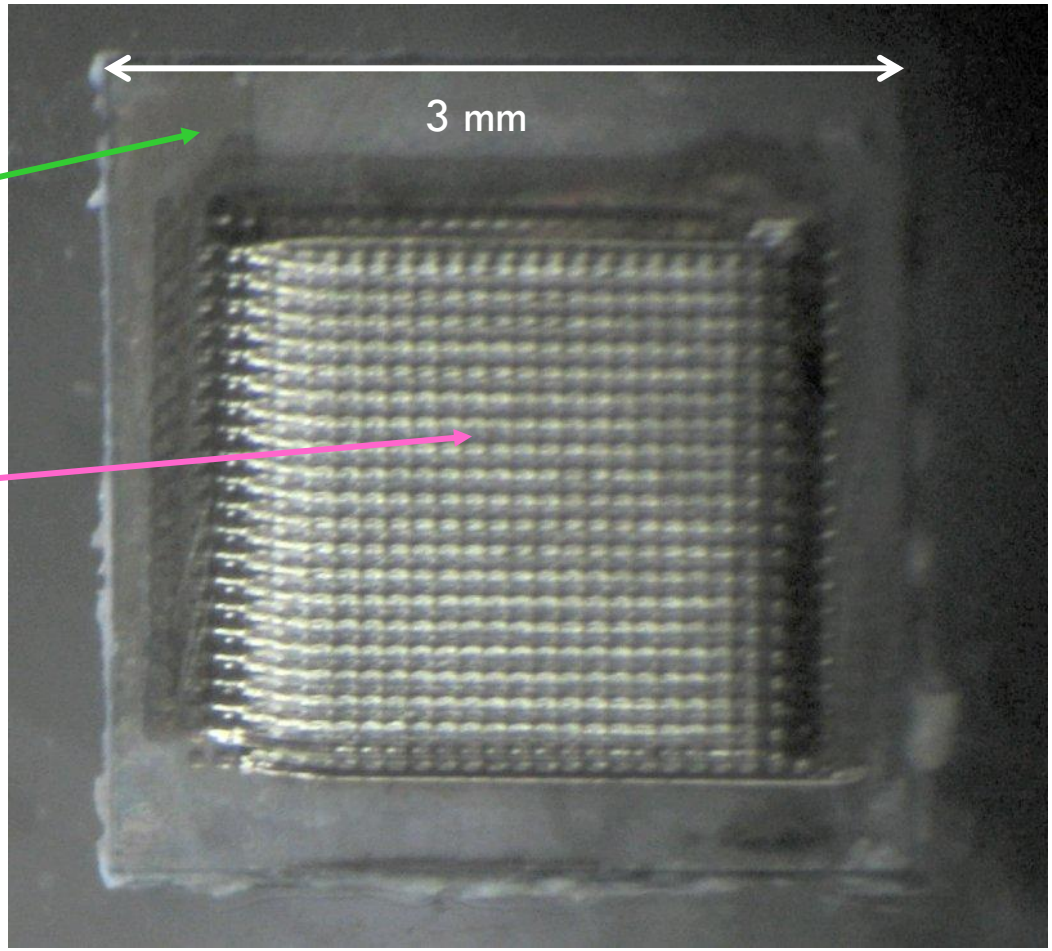


Diamond Ablation

315 micron frame around outside edge

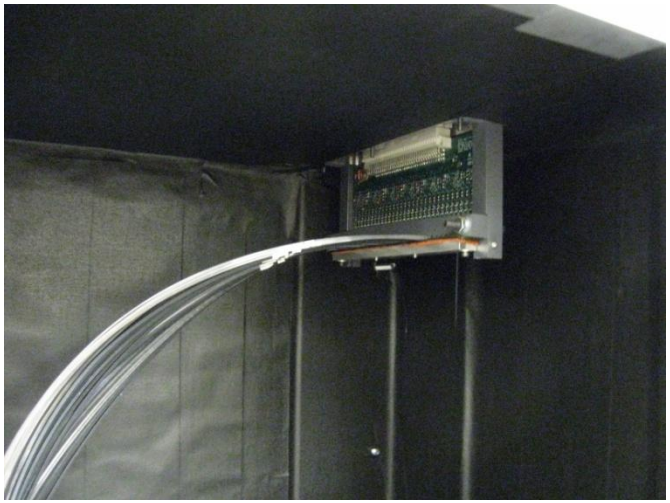
thinned inner rectangular window

residual raster pattern is from a coarse laser step size



Tagger Microscope Chamber

The tagger microscope directs electrons into scintillating fibers which lead directly to detectors on a circuit board.



The fibers are bundled as 5 rows and 6 columns where each column corresponds to a different energy and the rows are used for calibrating the electron plane.

Tagger Electronics

The tagger electronics consist of:

- Preamplifier board
  - Amplifies signal from electrons
- Digital control board
  - Regulates voltages
  - Monitors the temperature
- Backplane
  - Contains outputs
  - Joins all 3 boards together
  - Supplies voltages to the preamp

QUESTIONS?