QuarkNet 2015 Summer Research at SMU

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$$C = \varepsilon_o A / d$$

Parallel Plate Capacitors

Goal:

- ***Empirically*** *verify Gauss' Law through analyzing parallel plate capacitors*

Instrument

Can adjust down to 10 µm

- Width of a human hair is about 15 µm

Adjustments

These effects can greatly alter capacitance:

- Body capacitance
- Edge effects
- Tilt effects

$$C = \varepsilon_o A / d$$

Body Capacitance

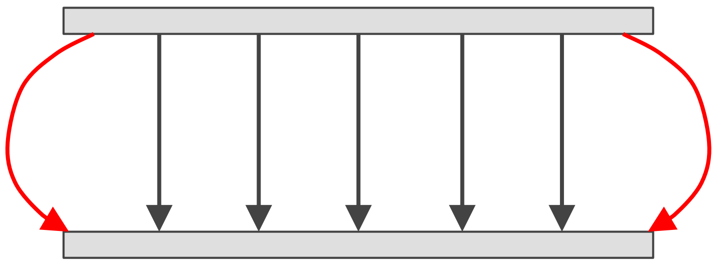
- Sources of body capacitance:
  - Probes
  - Plates
  - Frame

$$C = \varepsilon_0 A / d$$

- Accounts for a **small** error

- Found by separating the plates by a very large distance

Edge Effects



$$\alpha = 1 + 2.367b^{0.867}$$

Charge collects more around the edges

Approximated using a formula for disk capacitors

Increases capacitance by a multiplier of α

Tilt Effects

Ideal

Real

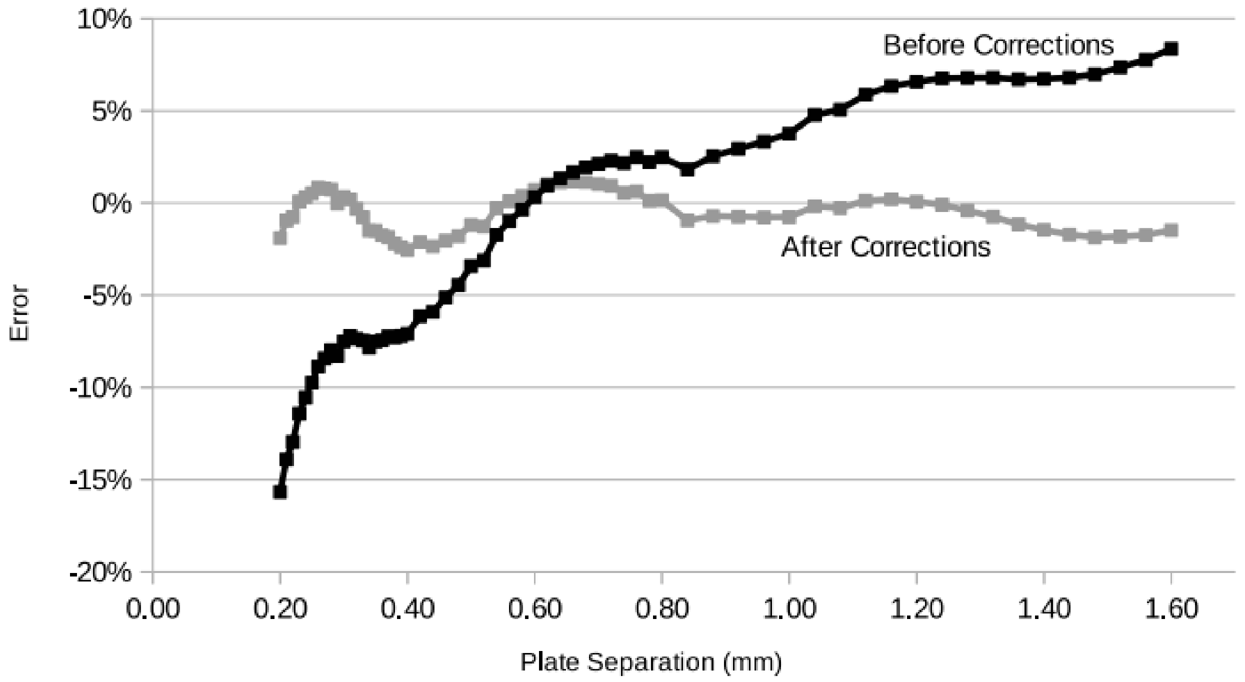
$$\Delta C=\varepsilon_0 A\Delta\left(\frac{1}{d}\right)=-\varepsilon_0 A\left(\frac{\Delta d}{d^2}\right)=-C\frac{\Delta d}{d}$$

Total Correction

$$C = C_{body} + \alpha\left(C_0 - C_0\frac{\Delta d}{d}\right) = C_{body} + \alpha\left(\varepsilon_0\frac{A}{d} - \varepsilon_0\frac{A\Delta d}{d^2}\right)$$

Tilt effects are large at short distances, but small at long distances

Edge effects are small at short distances, but large at long distances

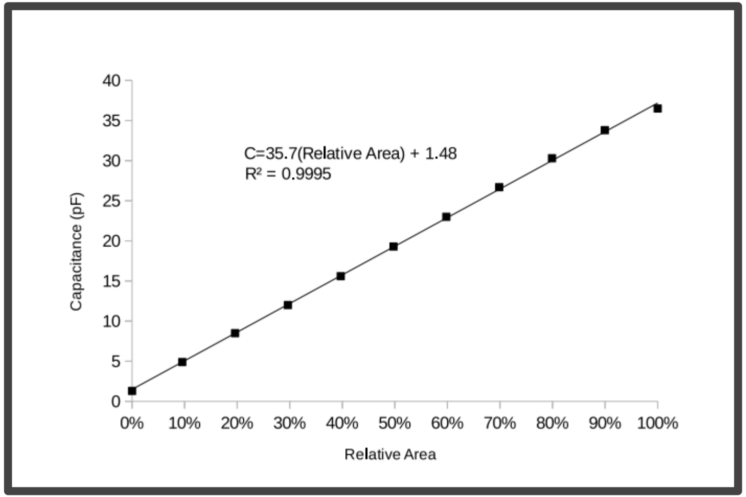


10%
5%
0%
-5%
-10%
-15%
-20%
Error
Before Corrections
After Corrections
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
Plate Separation (mm)

$C \propto A$

Goal:

- *Confirm that capacitance is directly proportional to area like in the theoretical formula*



$$C = \varepsilon_0 A / d$$

The plates were kept at a distance as to minimize edge and tilt effects

Overlapping area was adjusted

An Adjustable Parallel Plate Capacitor Instrument and Test of the Theoretical Capacitance Formula Obtained from Gauss's Law

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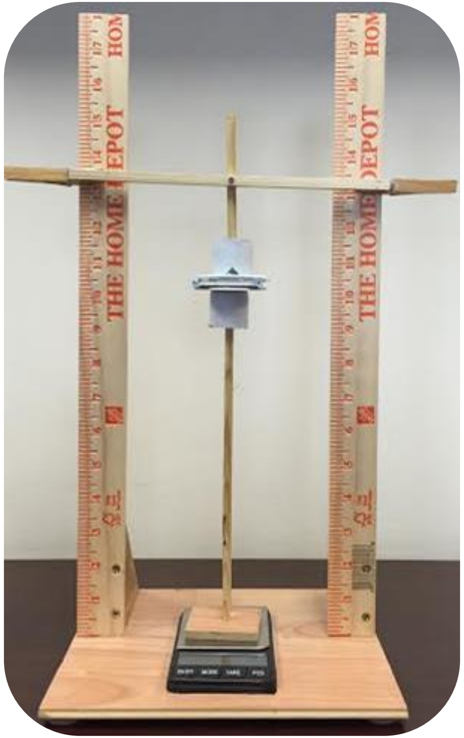
(Dated: July 30, 2015)

Abstract

We describe an adjustable parallel plate capacitor apparatus designed for use in an undergraduate laboratory which permits precise variation of plate separation distances (10 µm increments) and overlap area. Two experiments are performed with the device to test the ideal capacitor formula derived from Gauss's Law. After correcting for edge effects and minor plate tilt, the device yielded capacitance values within 3% of theoretical values.

Coulomb's Law Apparatus



Detecting Cosmic Rays

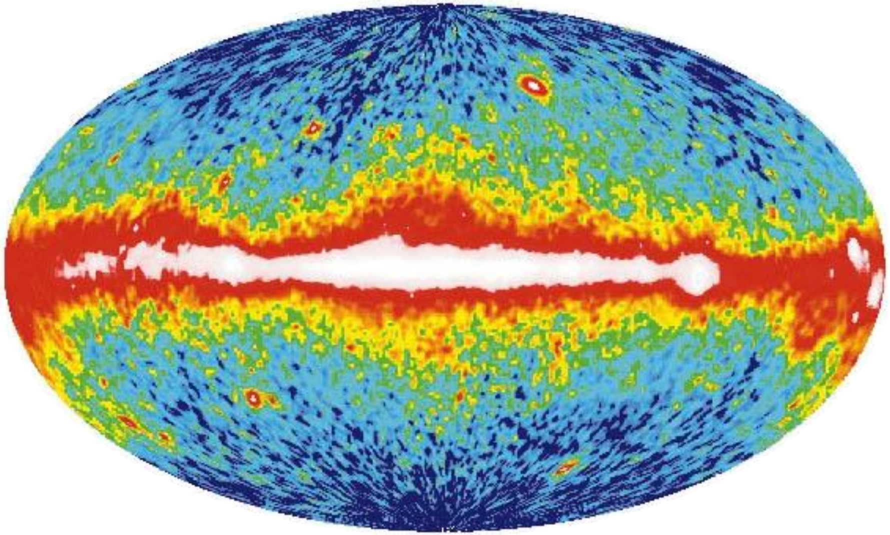
Goals:

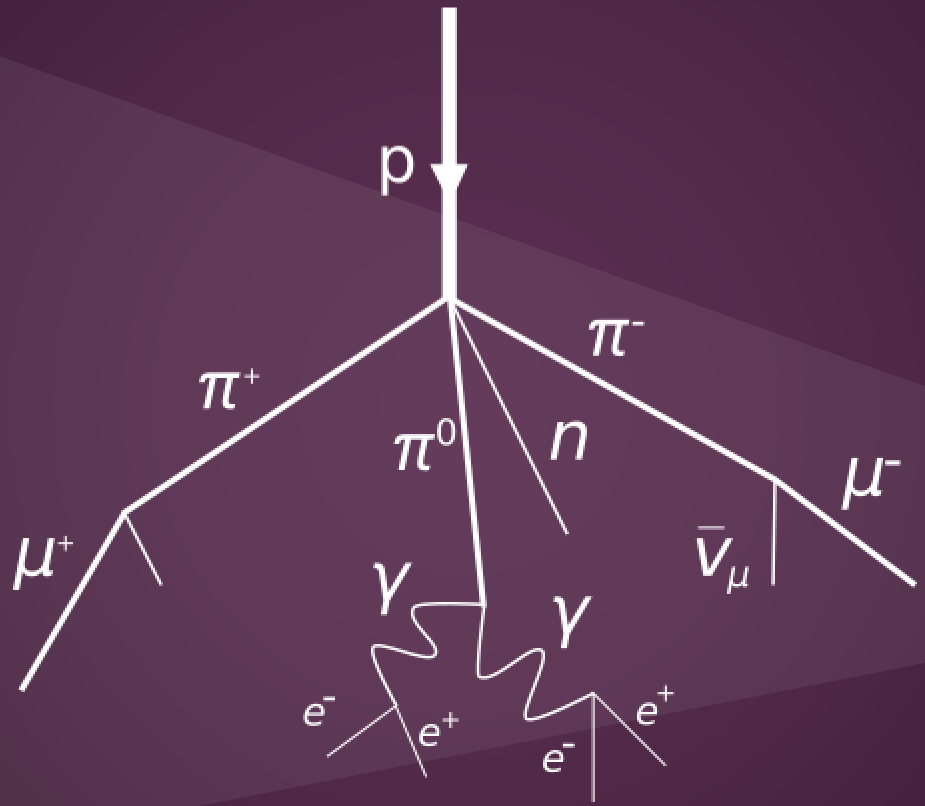
- *Get the multi-wire chamber circuit board in working condition*
- *Measure and analyze cosmic ray trajectories with angle dependency*

"We are travelers on a cosmic journey…"

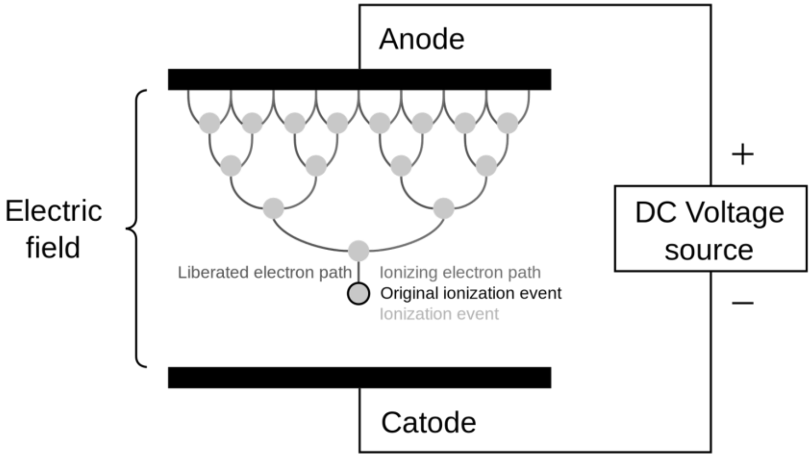
What's a Cosmic Ray?

- High energy particle (usually a proton)
- Arrives from distant galactic events
- Collisions similar to those in the LHC
- Moves at relativistic speeds




p
π⁺
π⁰
n
π⁻
μ⁺
μ⁻
$\bar{\nu}_\mu$
γ
γ
e⁻
e⁺
e⁻
e⁺

What’s Happening?



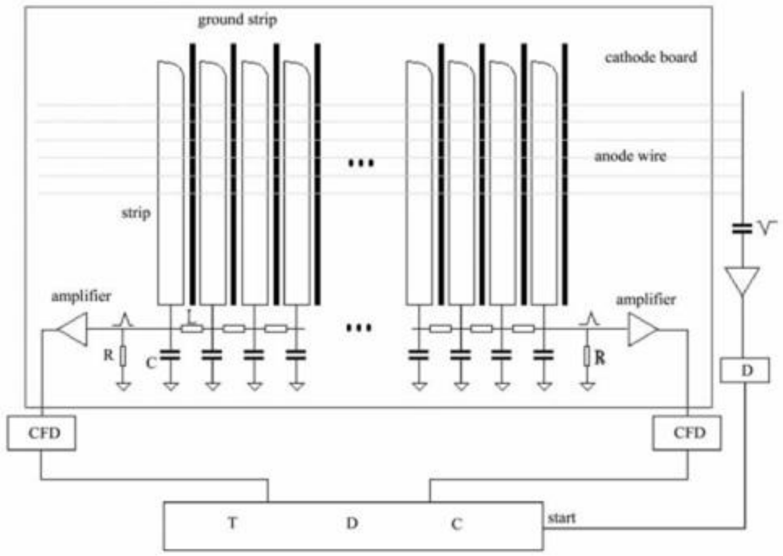
Muons ionize gaseous atoms

This ejects electrons at high energies creating…

An electron avalanche

Circuit Board

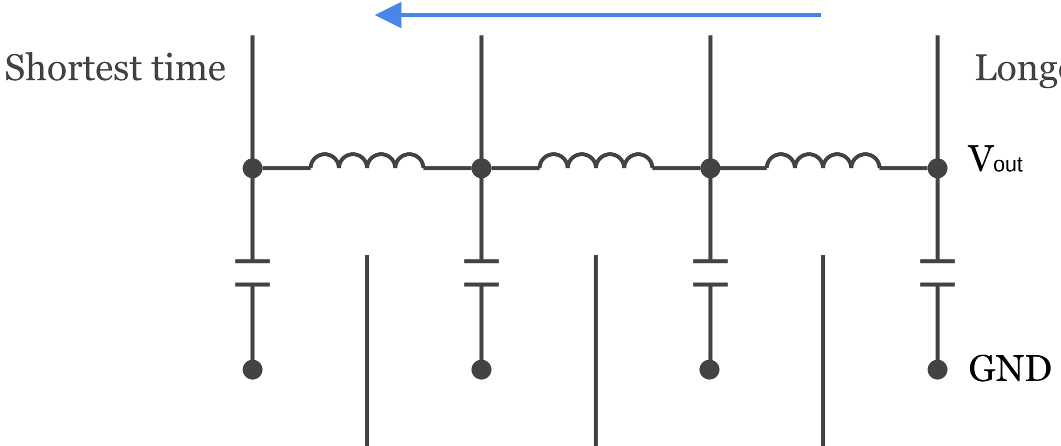
- 27 cathode strips
  - Gives x or y coordinate
- 27 anode wires
- Delay line



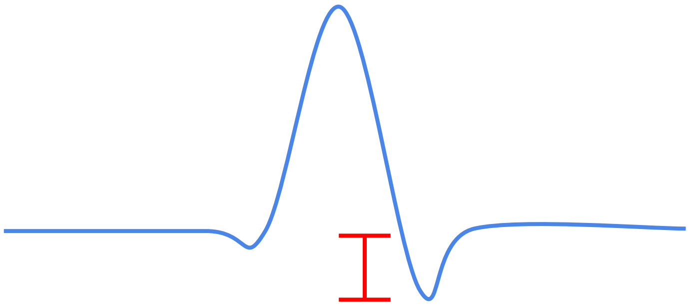
Delay Line

A sequence of inductors and capacitors

XY positions of the cosmic ray particle can be traced back knowing the time shift



Reflections



$$\varrho = V_r / V_0 = (R - Z)/(Z + R)$$

$$Z_0 \approx \sqrt{L/C}$$

$$R = -\sqrt{L/C}\,(\varrho + 1)/(\varrho - 1)$$

Problem:

Reflected voltage can alter the signals

Solution:

PCB internal resistance ≈ Resistance before amplifiers

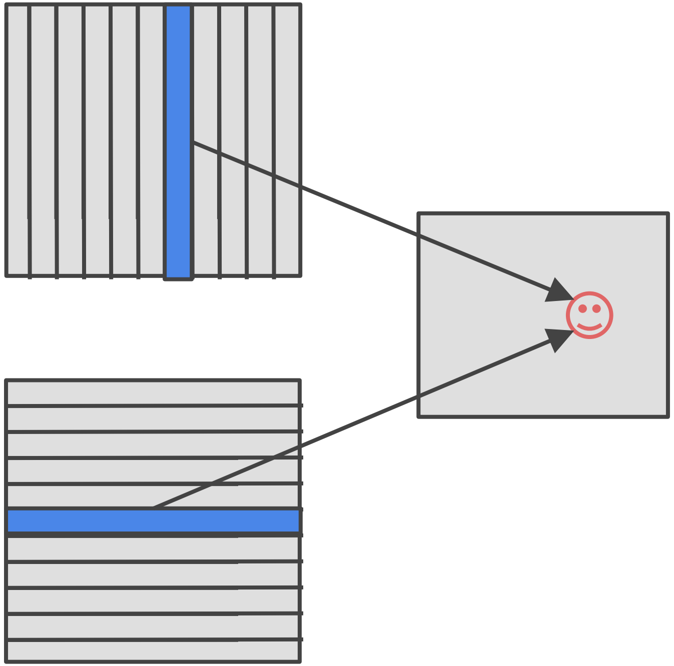
Multi-Wire Chamber

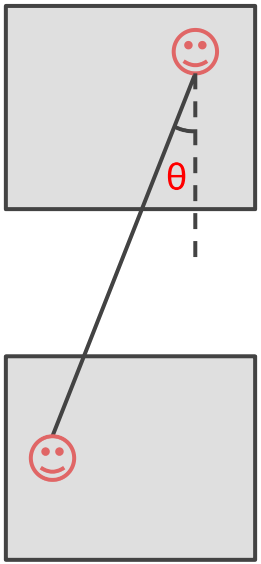
There are two multi-wire units

Each unit has two circuit boards separated by anode wires

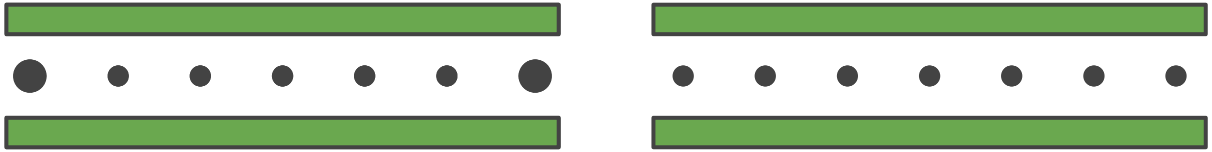
Positions from two boards gives a trajectory…

Multi-Wire Chamber





Limitations



Anode wires at the ends too small

Electric Field too great at the ends

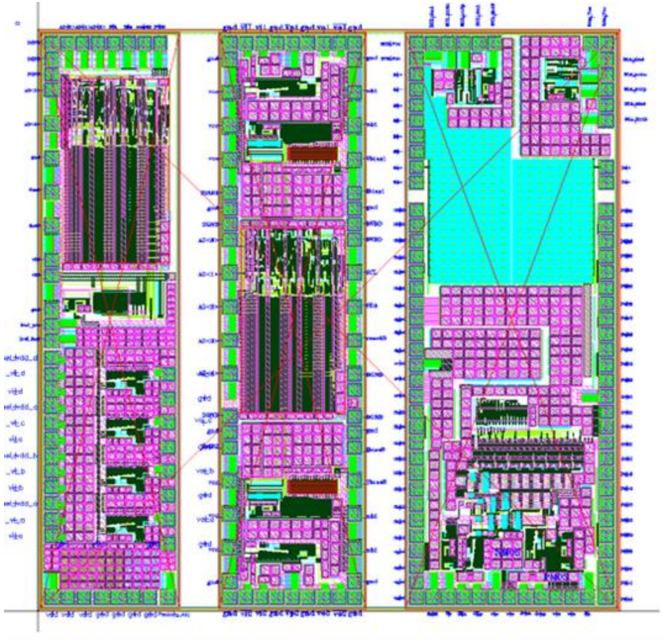
The PCB too sensitive at the ends

Data collected was not useful

Testing Transistors

Goal:

- *Analyze transistors before and after exposure to x-ray radiation*
- *Support research for the ATLAS Liquid Argon Calorimeter*



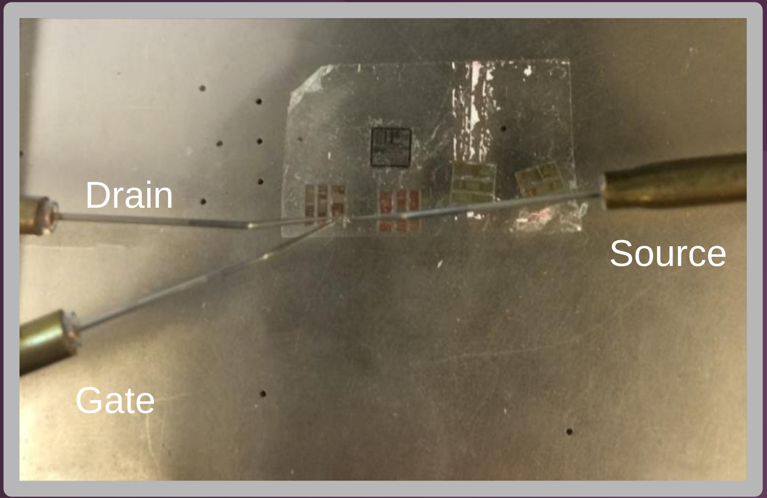
Limitations

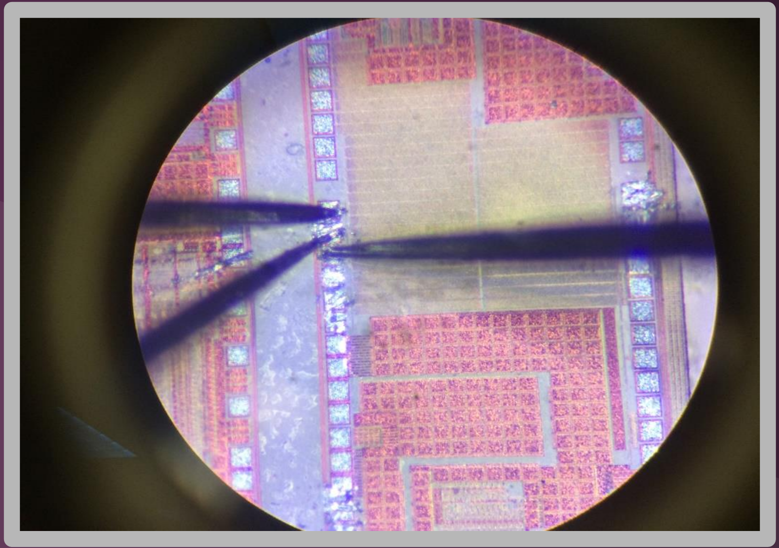
- Small size
  - 3 x 3 mm chips
  - 80 x 80 µm transistor pads

- Probes
  - Too large
  - Scratches

- Sensitive instrument

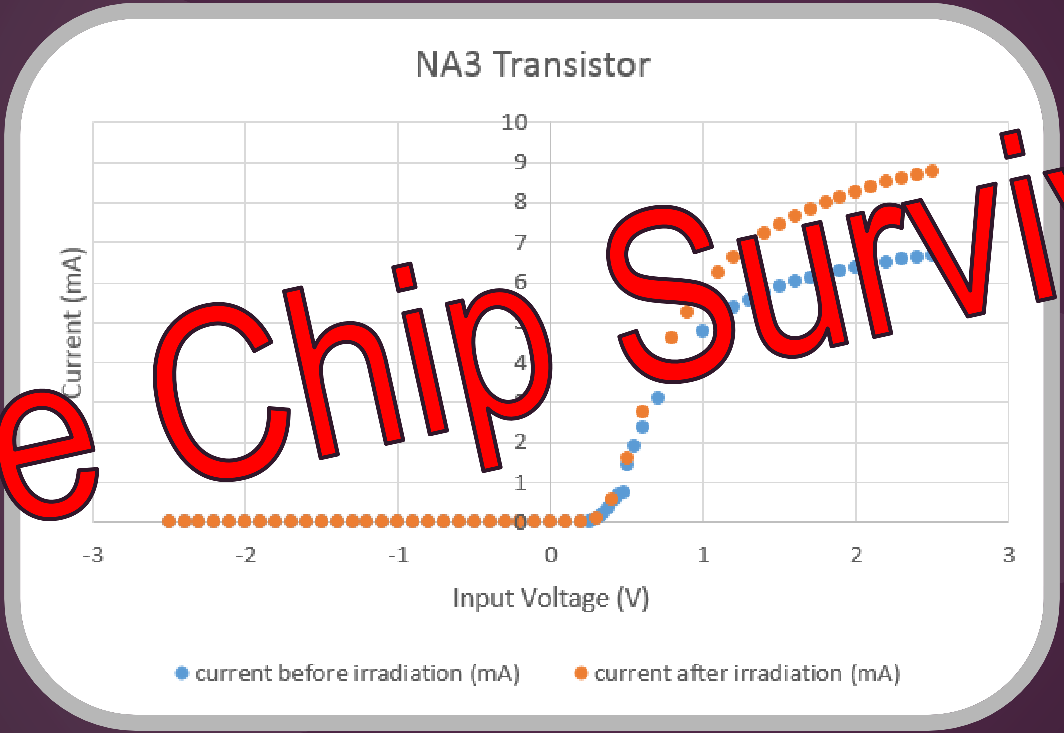
- Limited depth perception





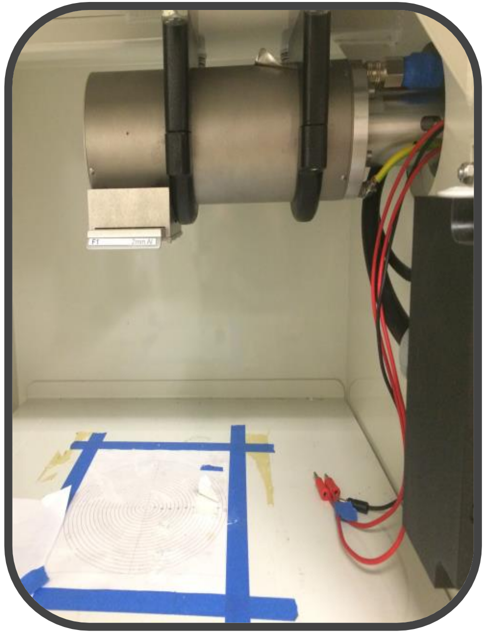
Three tungsten probes were matched to their respective drain, gate, and source pads.

Data Before/After Radiation



The Chip Survived!

Irradiating the Chips



The chips are exposed to 100 times the lethal dose of radiation at 100,000 Rads for six minutes.

Robotic Arm Project

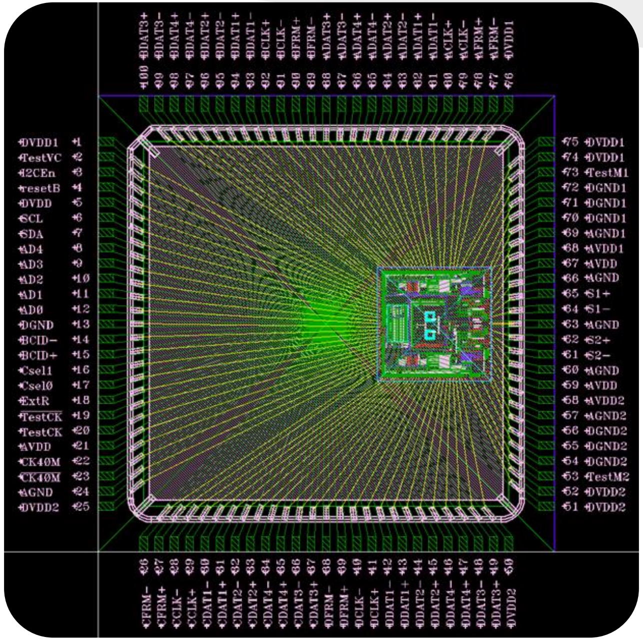
Goal:

- *Assemble a robotic arm which can test chips*
- *Create a program to autonomously run the robotic arm*

Mission

- 10,000 chips need to be tested

- Error < 1 in a trillion bits



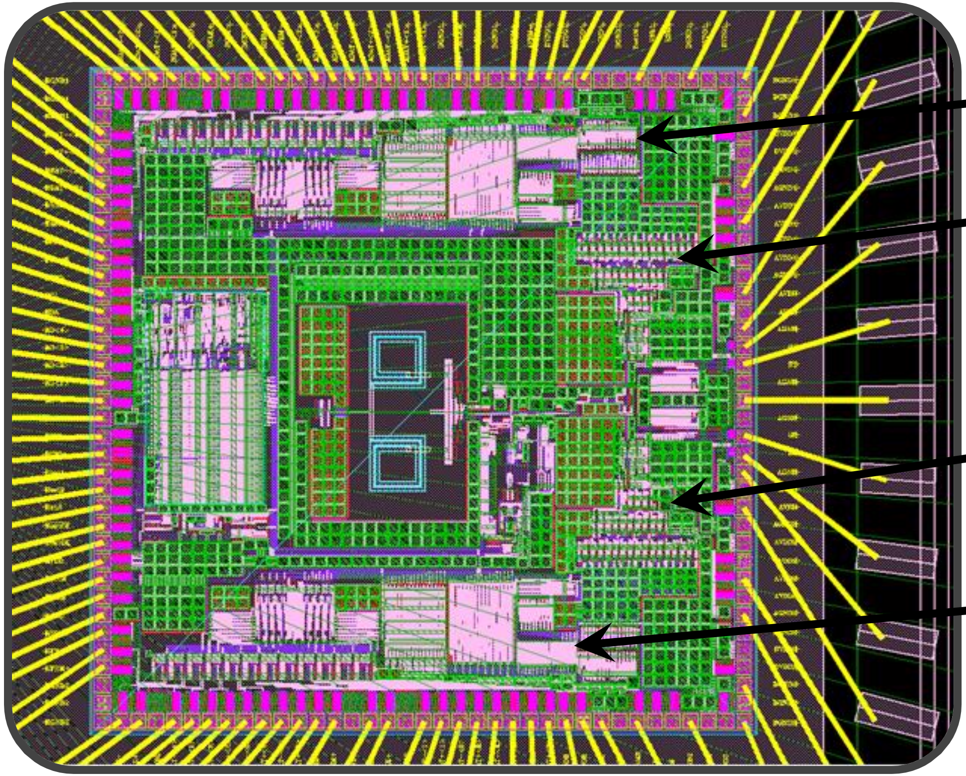
Inside of the LOCx2 chip

LOCx2 Chip

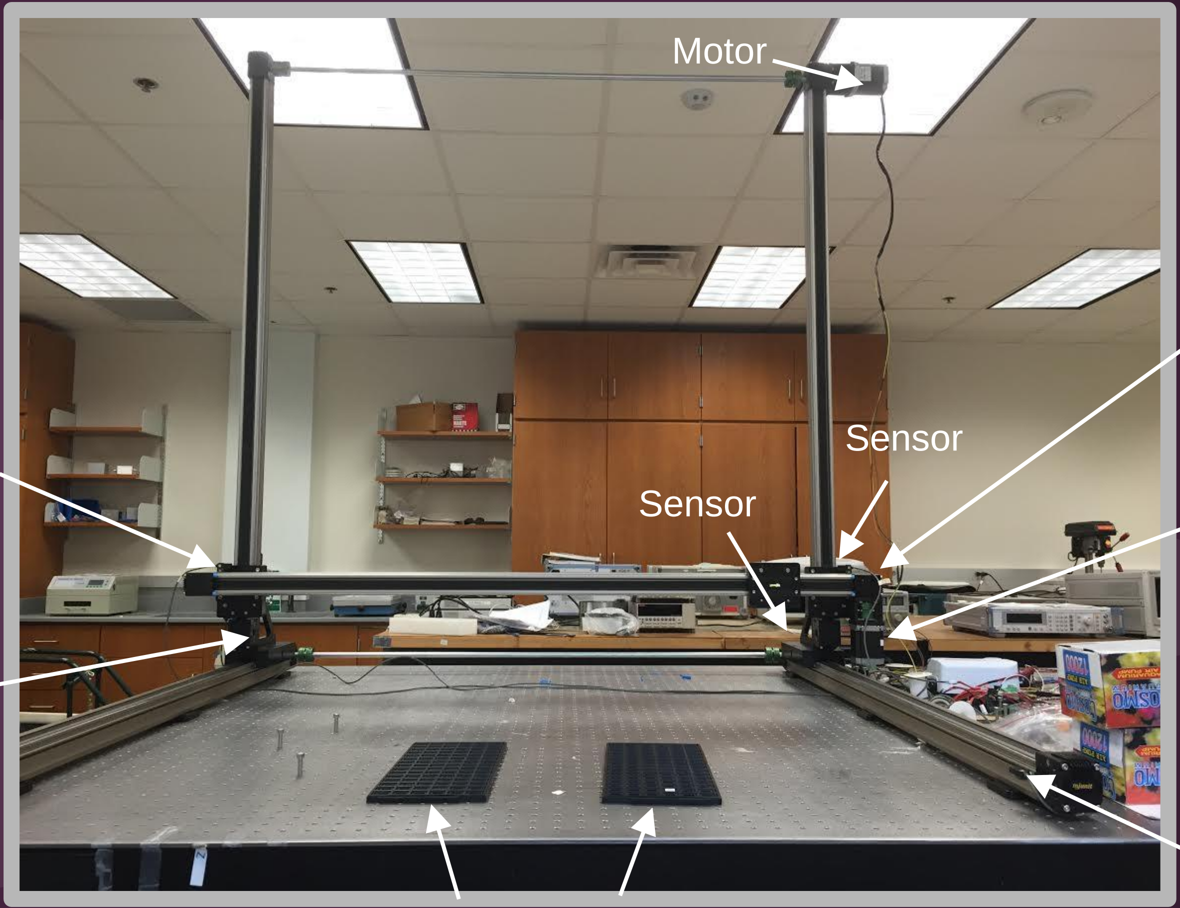
- High Luminosity-Large Hadron Collider
  - ATLAS Liquid Argon Calorimeter
  - Data transmission

- Components of the LOCx2
  - Serializer
  - Encoder

Die Schematic

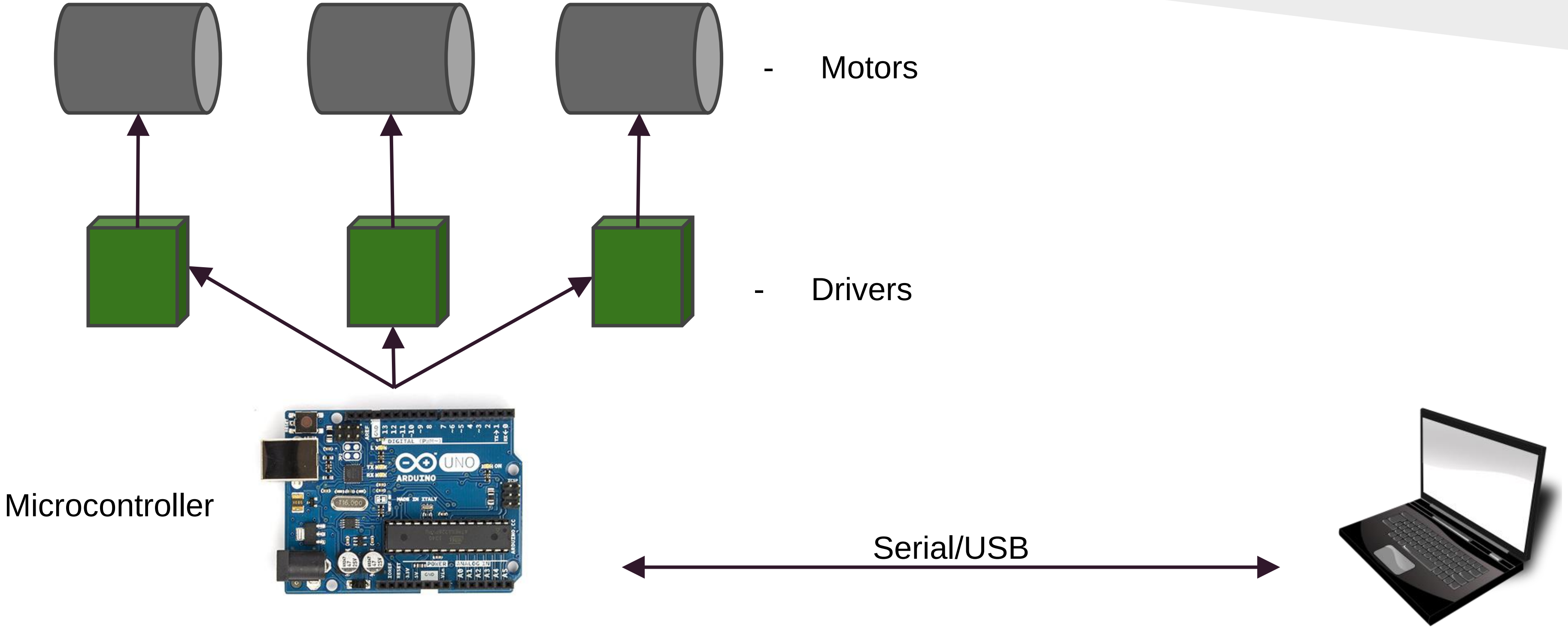


Setup



Motor
Sensor
Motor
Sensor
Sensor
Motor
Sensor
Sensor
Testing Boards

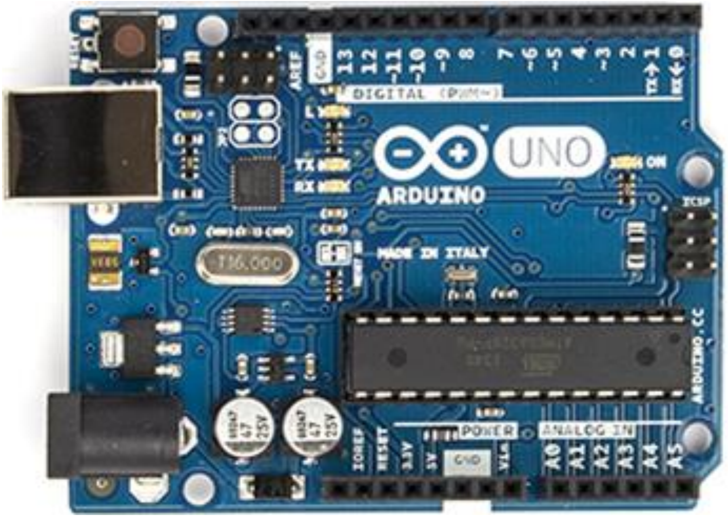
Communication Setup



Communication

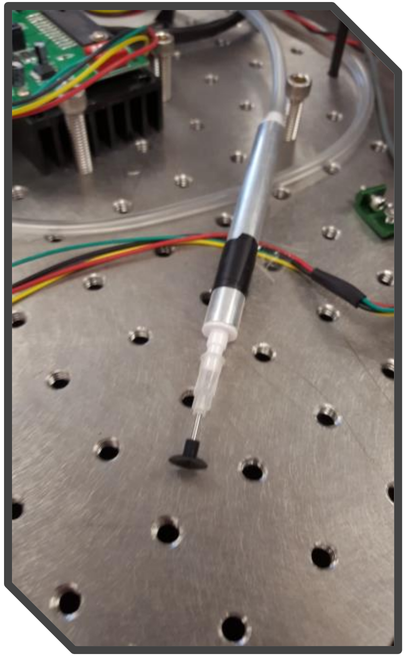
- Arduino
  - Interface between computer and arm

- LabView
  - Conducts tests on chips



Vacuum Pump

- Assembling vacuum pump
  - Relay
  - Connecting to Arduino



Challenges

- Arm too heavy to be supported by the motor
    - Counterbalance
    - Torsion Spring
    - Tape Measure Spring

Where are we now?
What's Next?

- What have we accomplished?
  - Arm movement
  - Sensors
  - Vacuum pen

- What must be done?
  - Attach the vacuum pen to the arm
  - Install spring
  - Master program