A Parity Violation Experiment for Undergraduate Laboratories

Michael Ganger

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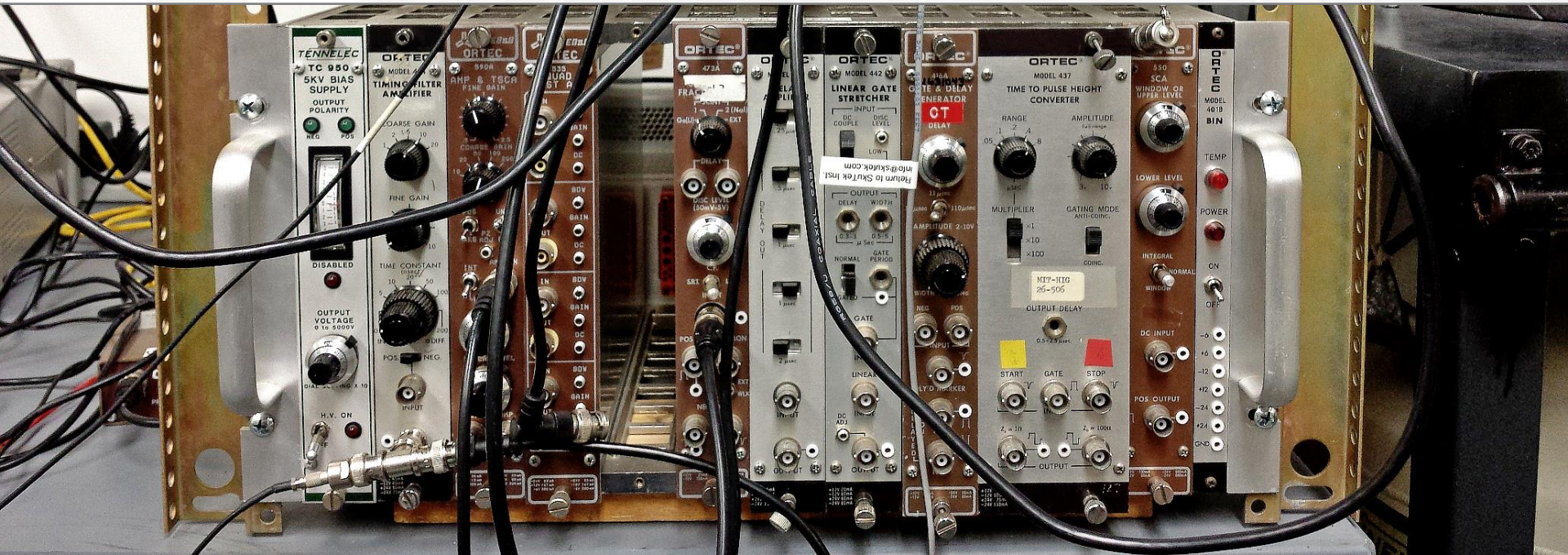
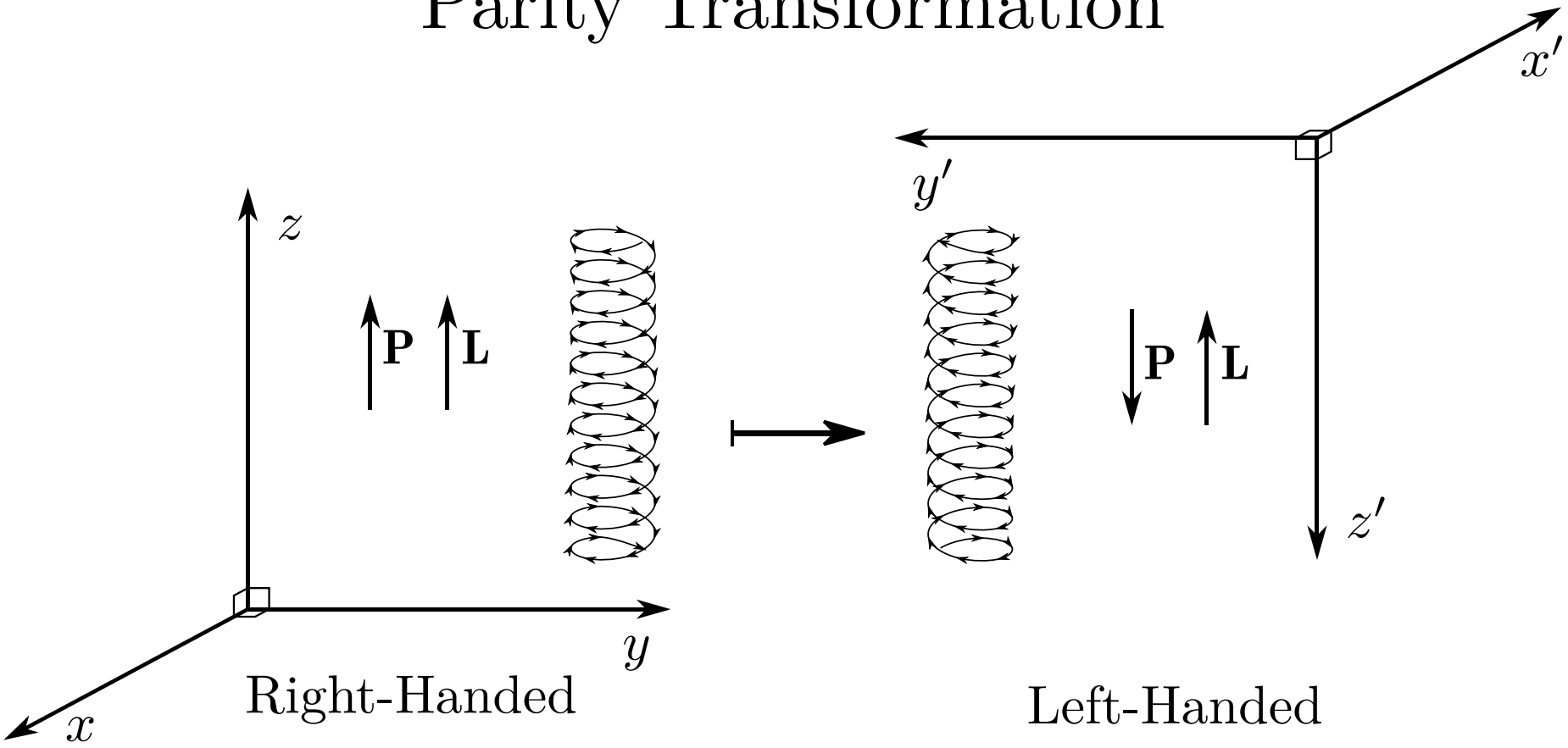
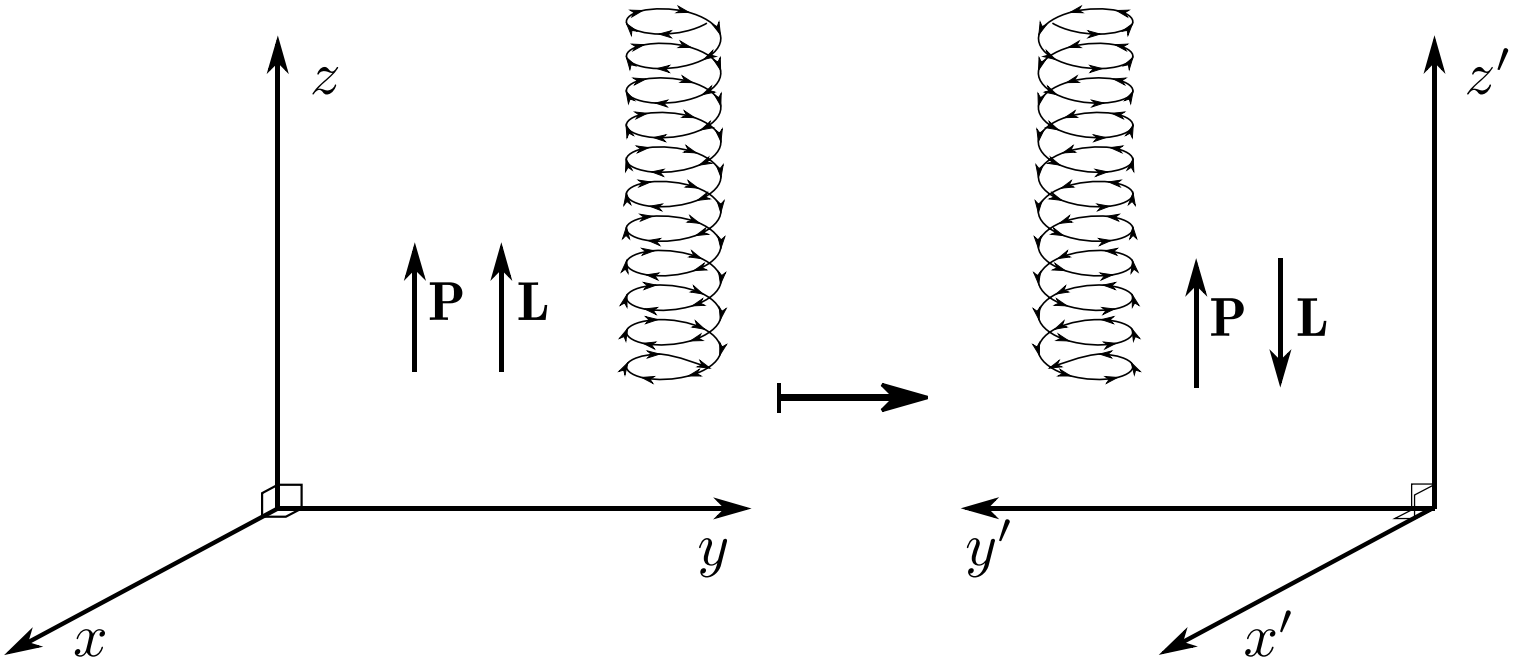


Parity Transformation



Mirror Transformation



Right-Handed

Left-Handed

History

Until 1956:

Parity thought to be a symmetry of all fundamental interactions.

1956:

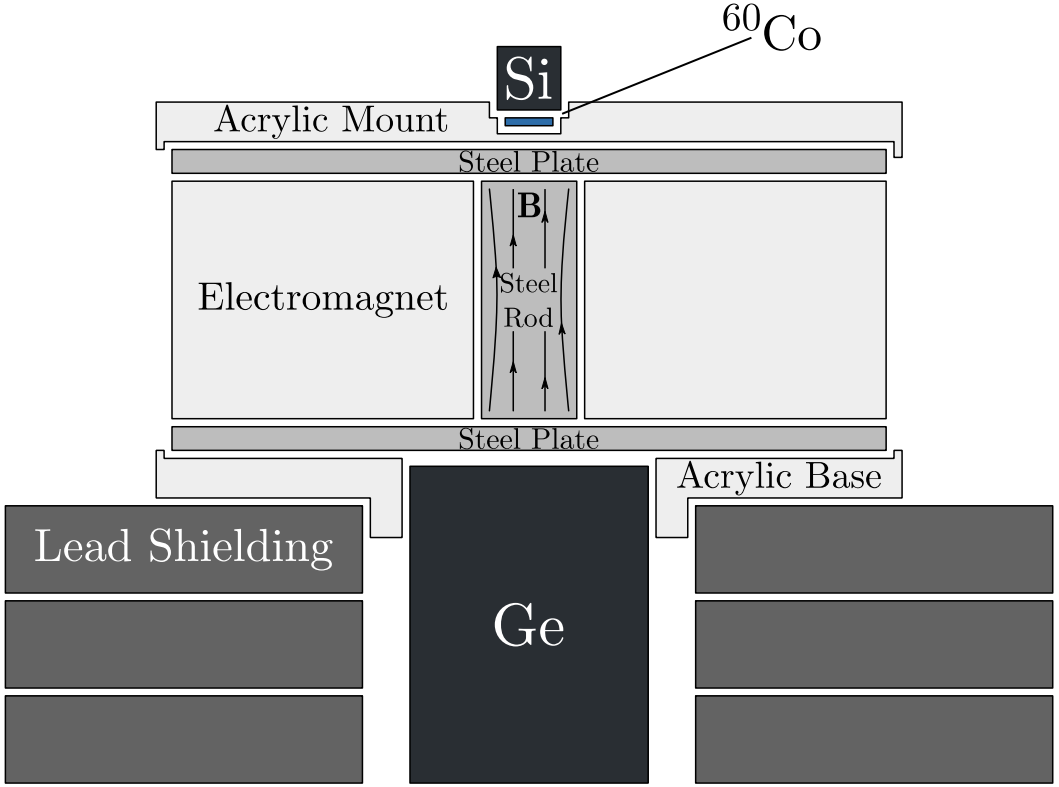
Lee and Yang propose experiments to test in the weak interaction.

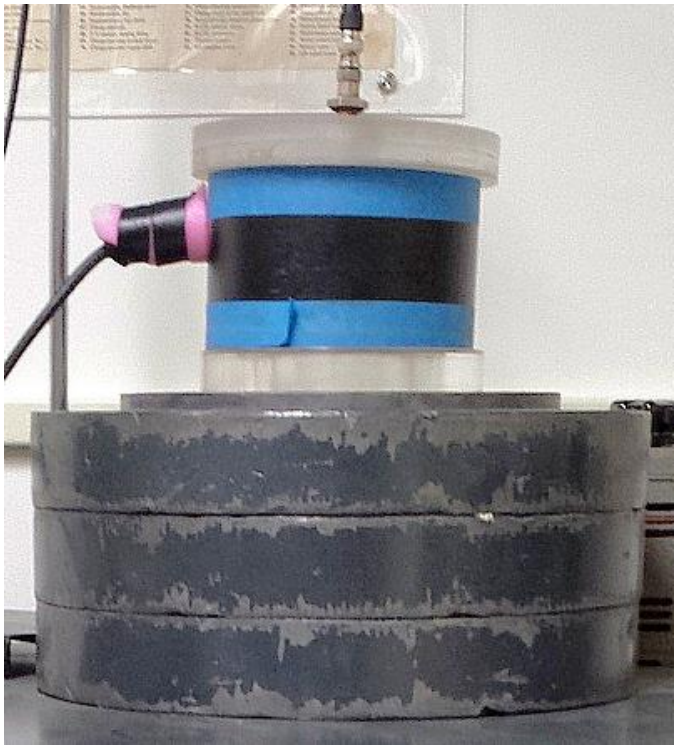
1957-1958:

Experimentally shown not to be a symmetry of weak interactions by Wu, Lundby, et al., and others.

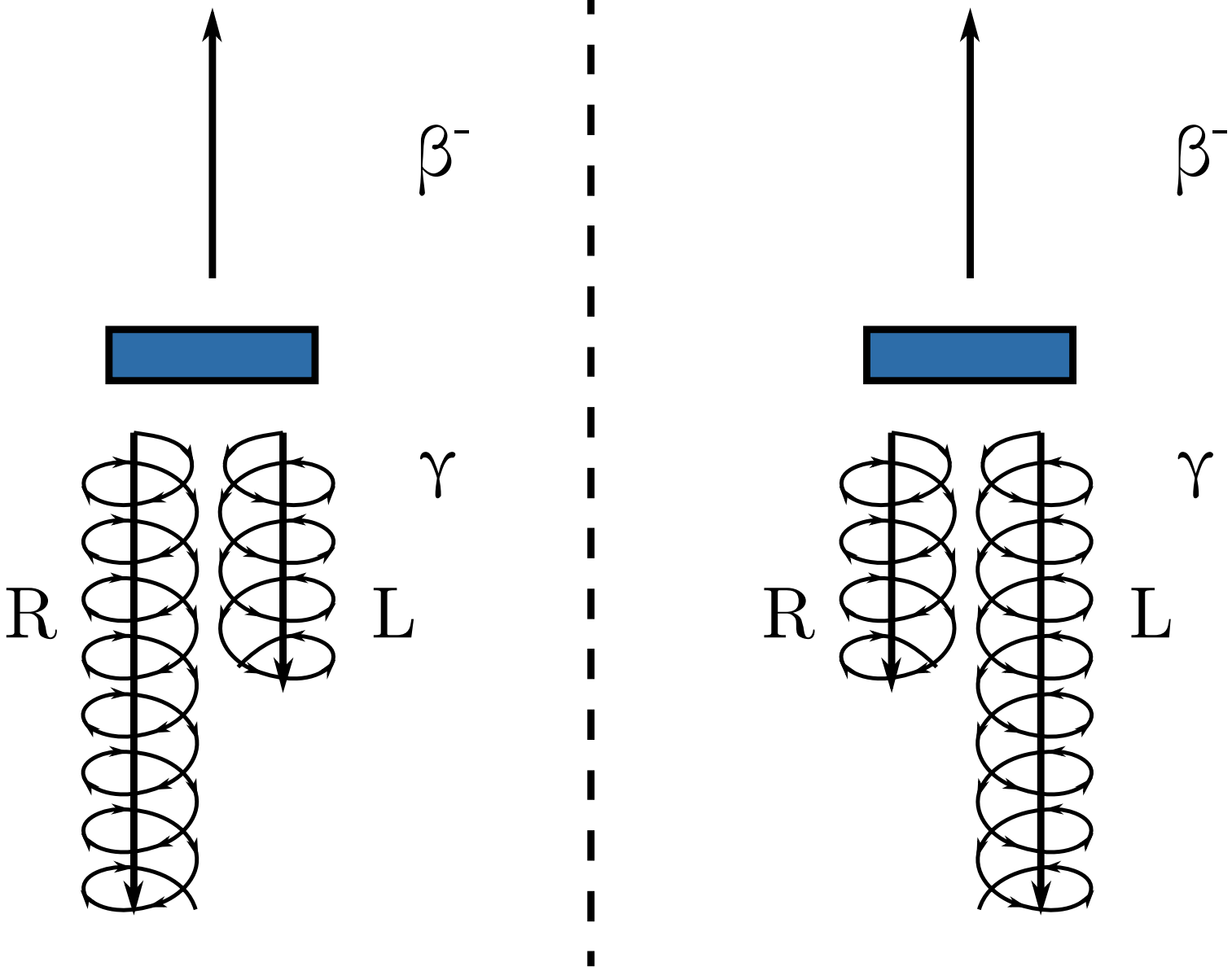
Our Experiment

- Working toward an undergraduate physics laboratory
- Goals:
  - Accessible equipment
  - Exempt radiation source
  - Automate data collection and switching the magnetic polarity

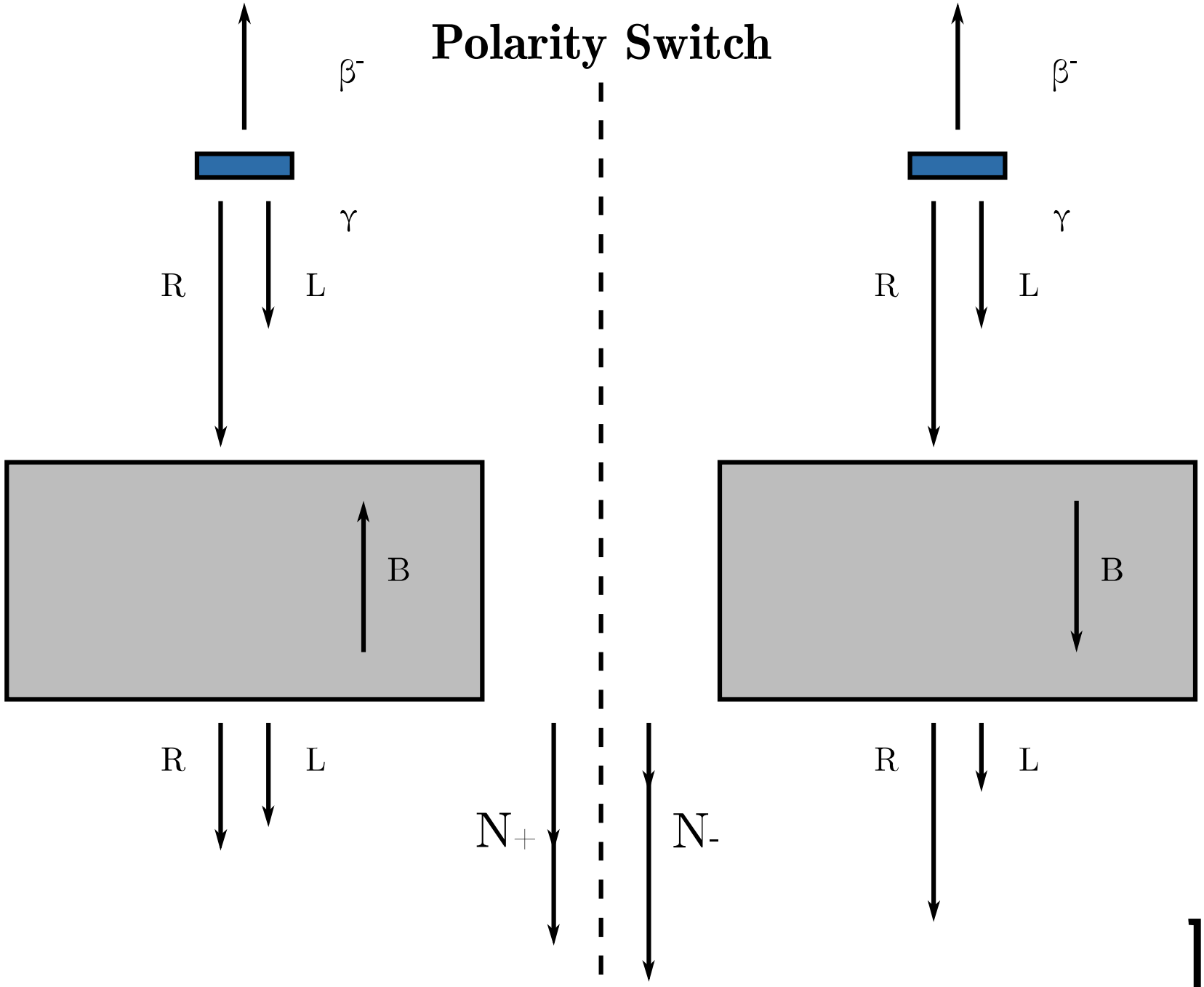

^{60}Co
Si
Acrylic Mount
Steel Plate
B
Electromagnet
Steel
Rod
Steel Plate
Acrylic Base
Lead Shielding
Ge



Mirror



Polarity Switch



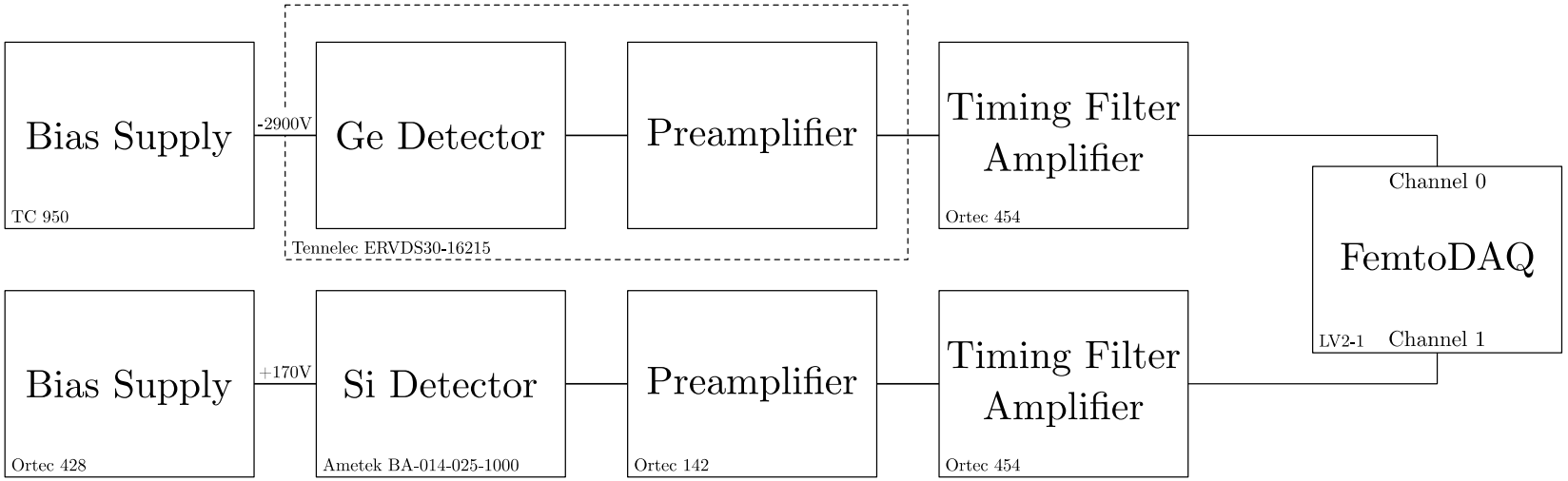
Our Experiment

Asymmetry:

$$E = \frac{N_+ - N_-}{\frac{1}{2}(N_+ + N_-)}$$

$$\delta E = 4\sqrt{\frac{N_+ N_-}{(N_+ + N_-)^3}}$$

Coincidence Circuit



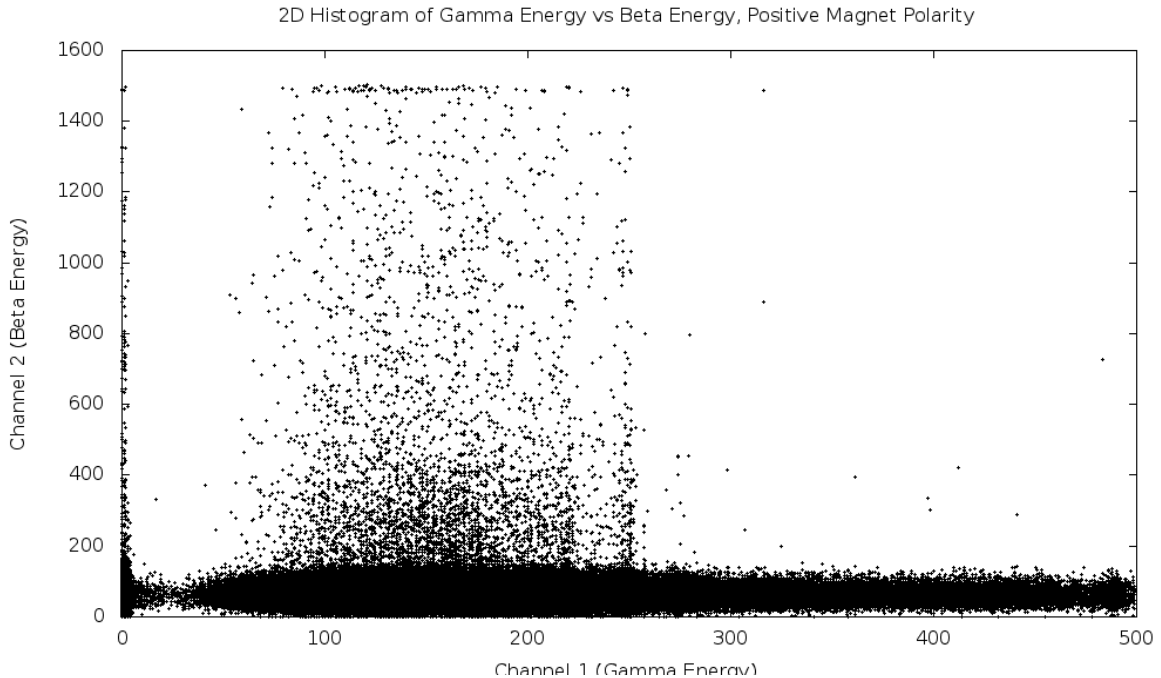
Results

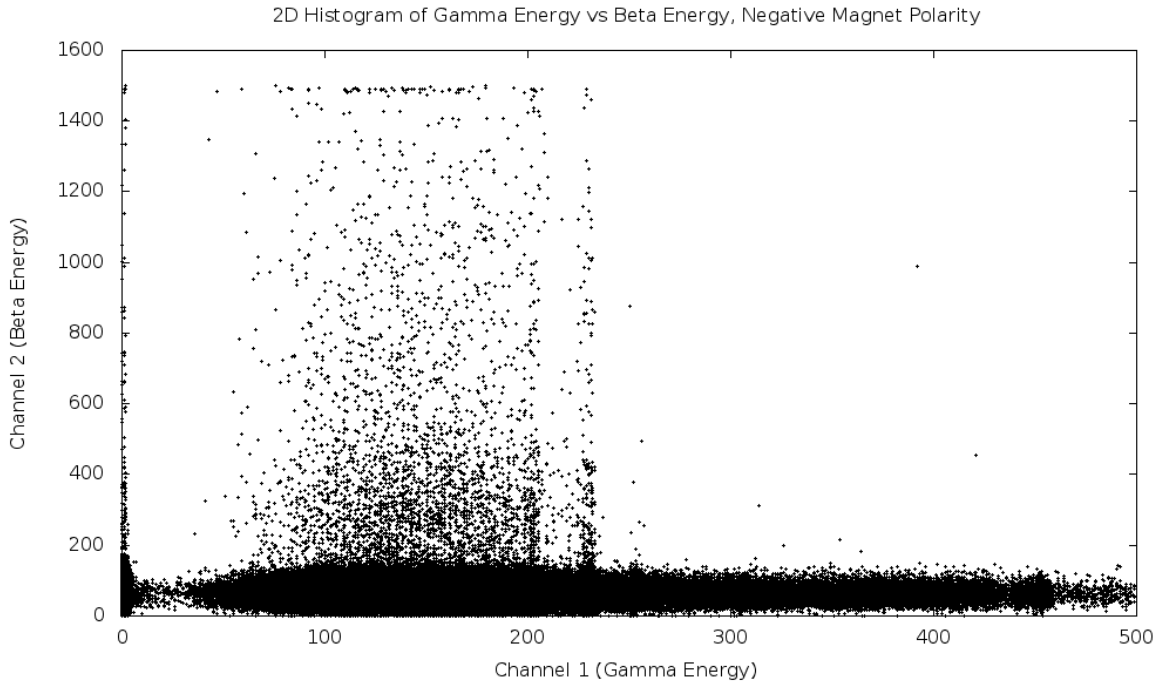
Top:

Positive Polarity

Bottom:

Negative Polarity





Results

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Positive Polarity

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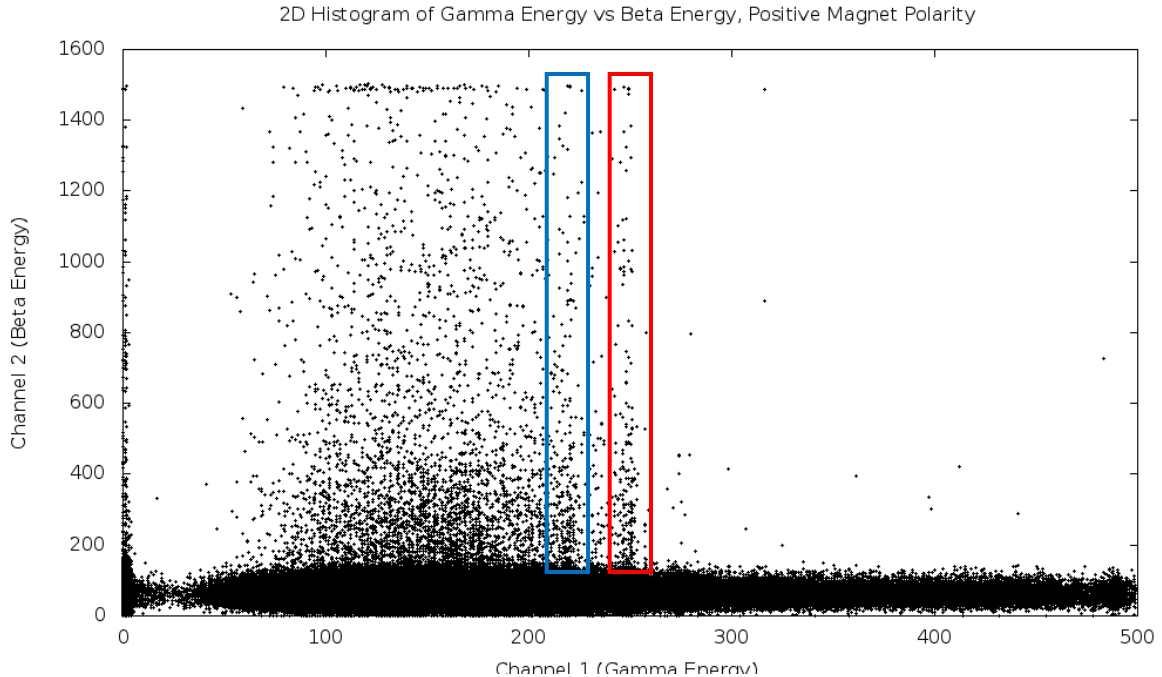
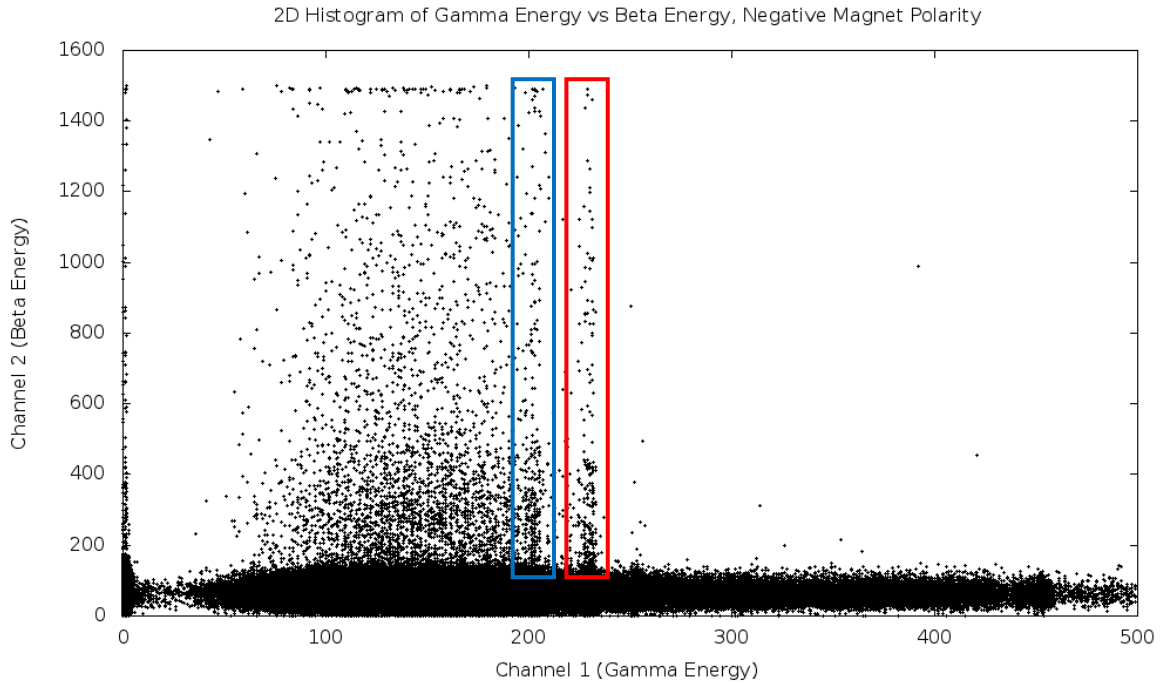
Negative Polarity





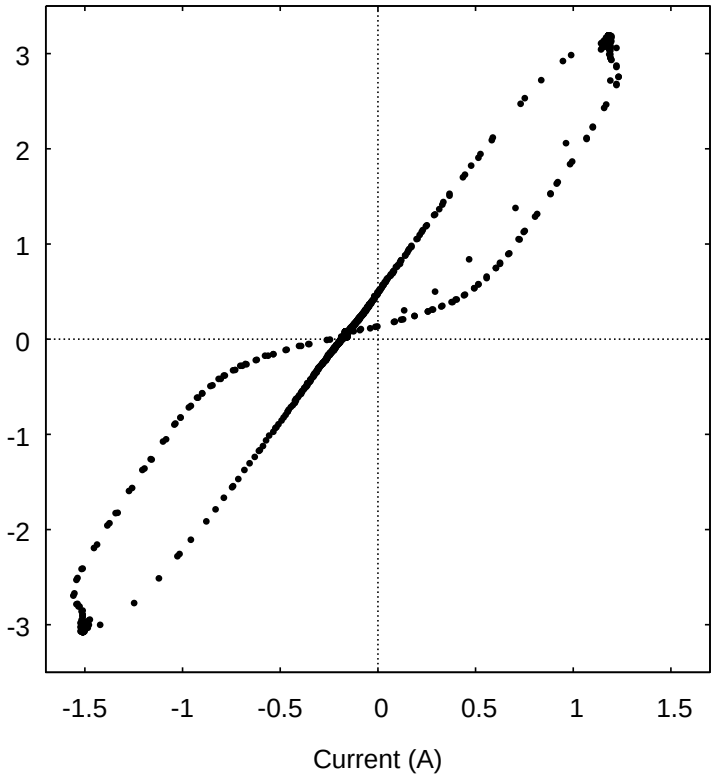
Results

$$E = \frac{N_+ - N_-}{\frac{1}{2}(N_+ + N_-)} \qquad \delta E = 4\sqrt{\frac{N_+ N_-}{(N_+ + N_-)^3}}$$

Energy	N_+	N_-	**Asymmetry**
1.1732 MeV	302	329	-0.09 ± 0.08
1.3325 MeV	207	216	-0.04 ± 0.08
Total	509	545	-0.07 ± 0.06
Expected	-	-	0.066

Potential Sources of Uncertainty

- Magnetic hysteresis
  - ~ 0.005 Asymmetry
- Cylindrical asymmetry of apparatus
- Low timing resolution



Future Work

- Run experiment longer for smaller uncertainty

  $\frac{\delta E}{E} \propto \frac{1}{\sqrt{T}}$

- Use a shorter magnet

  $\frac{\delta E}{E} \propto e^{\frac{\lambda x}{2}}$ (large x)

- Replace the Germanium detector with a NaI detector

Acknowledgements

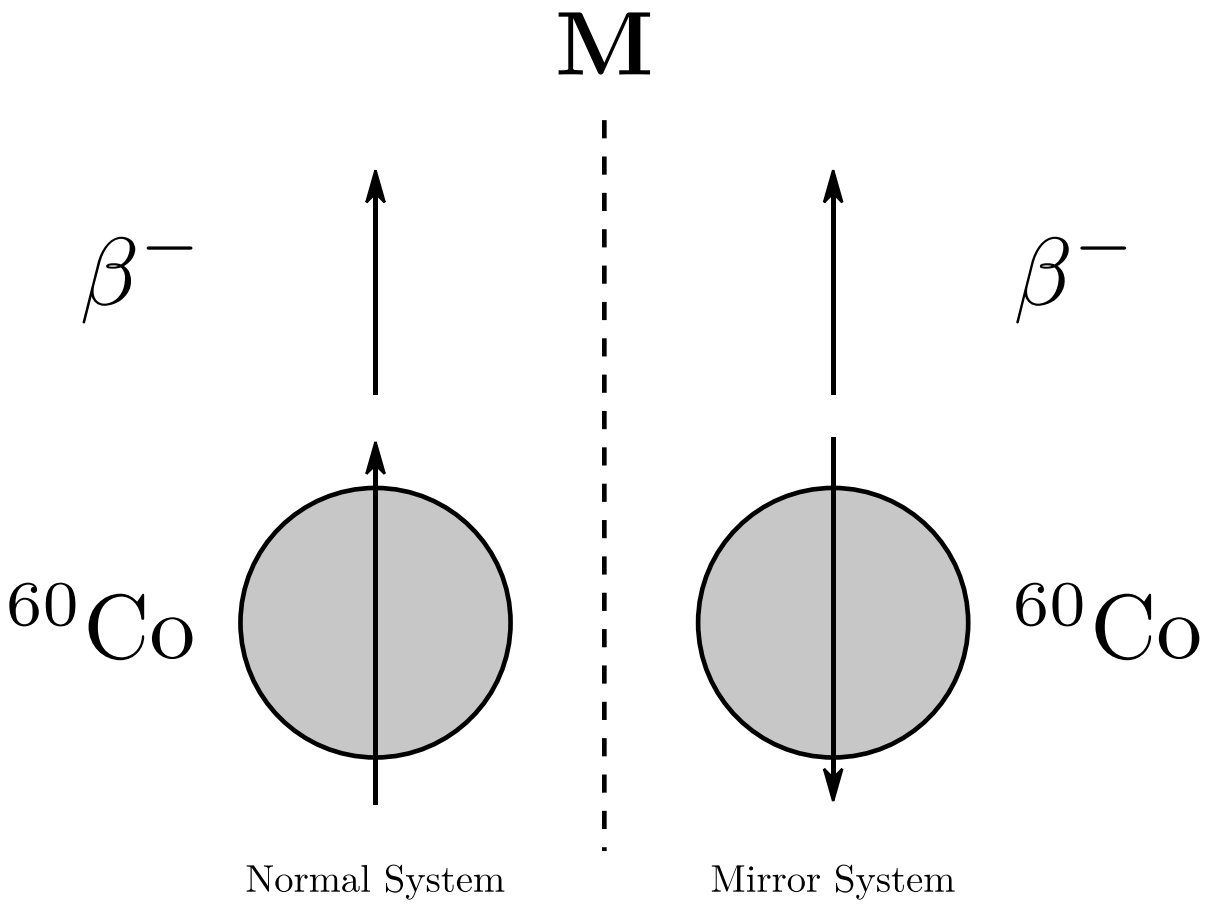
Dr. Yuly

Physics Department

Houghton College

Questions?

^{60}Co Decay in Mirror



Noether's Theorem

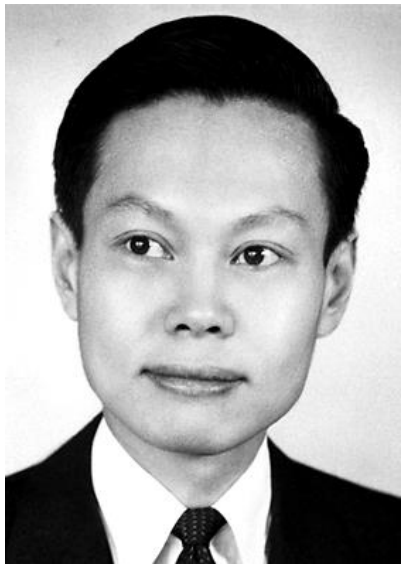
Every differentiable symmetry of the action of a physical system has a corresponding conservation law.

This implies that parity symmetry corresponds to a conserved quantity—this is known as **parity**.

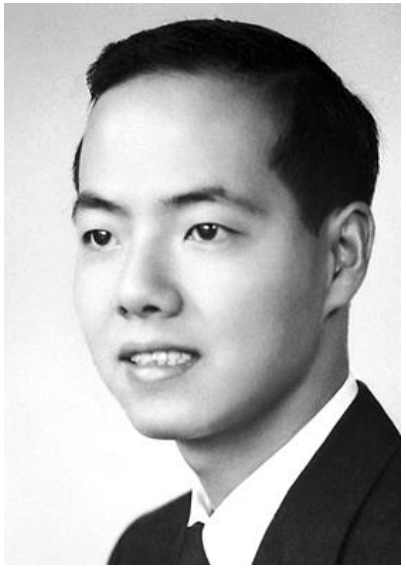
Credit: https://en.wikipedia.org/wiki/Noether%27s_theorem

Lee and Yang

- Awarded Nobel Peace Prize in Physics, 1957
- Investigated parity laws of the time
- Claimed there was no evidence for the conservation of parity in weak interactions



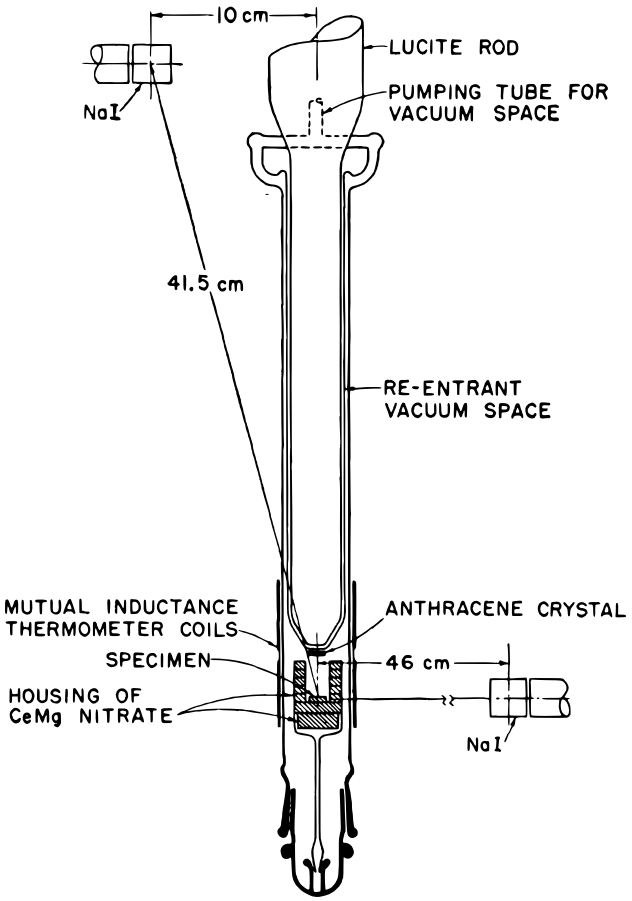
Chen Ning Yang
(1922 -)



Tsung-Dao (T.D.) Lee
(1926 -)

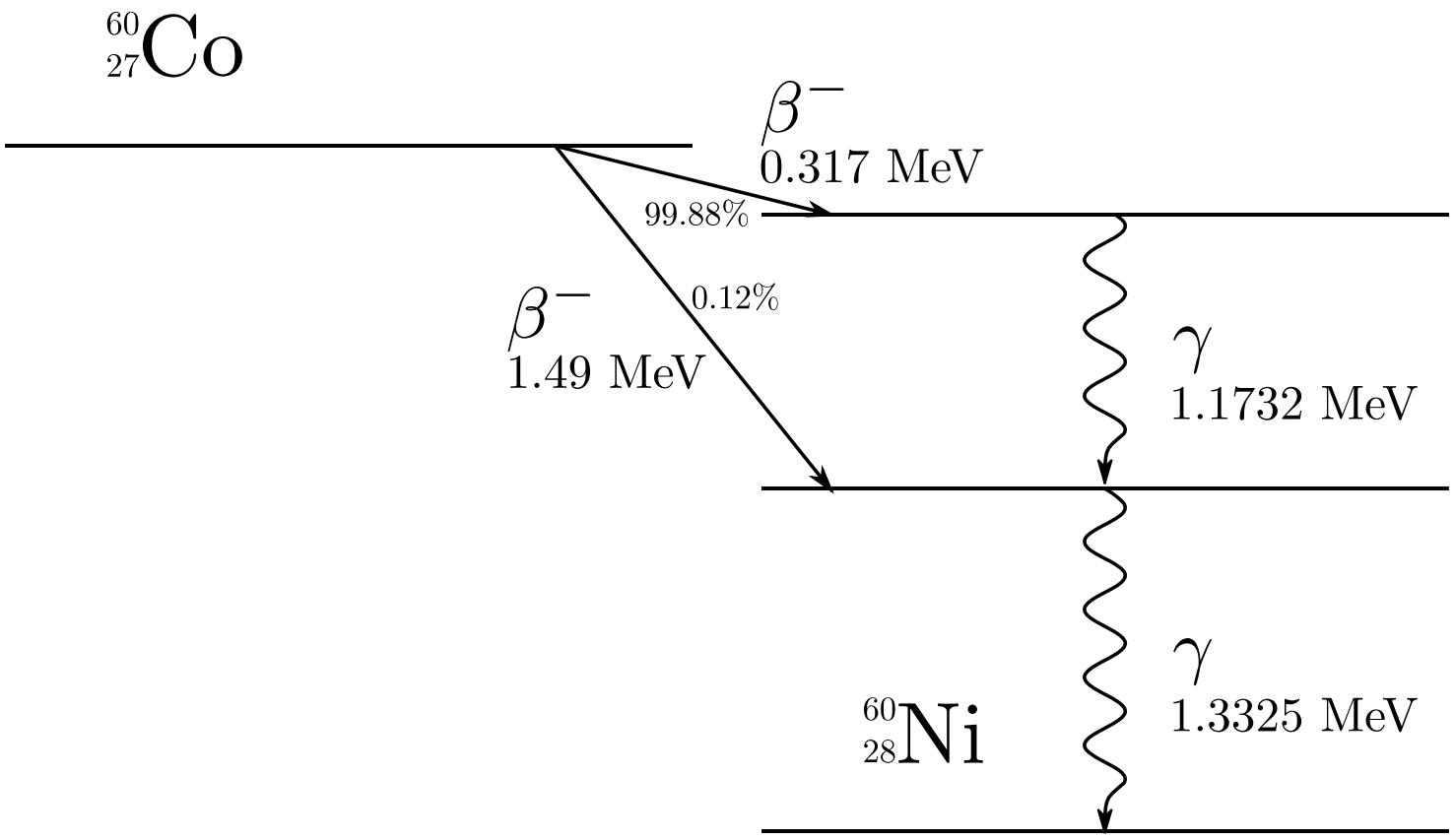
Credit: http://www.nobelprize.org/nobel_prizes/physics/laureates/1957/

Wu Experiment (1956)

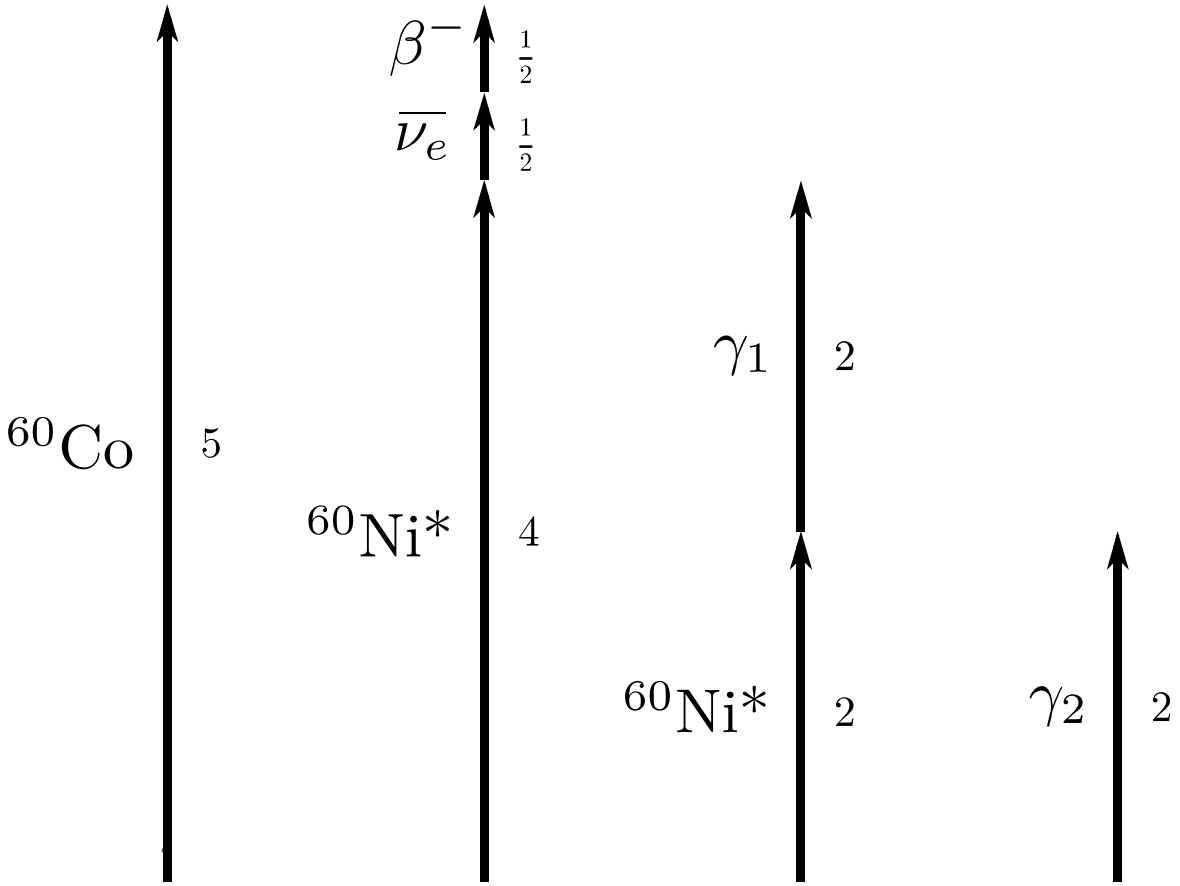


- Directly measured the asymmetry of

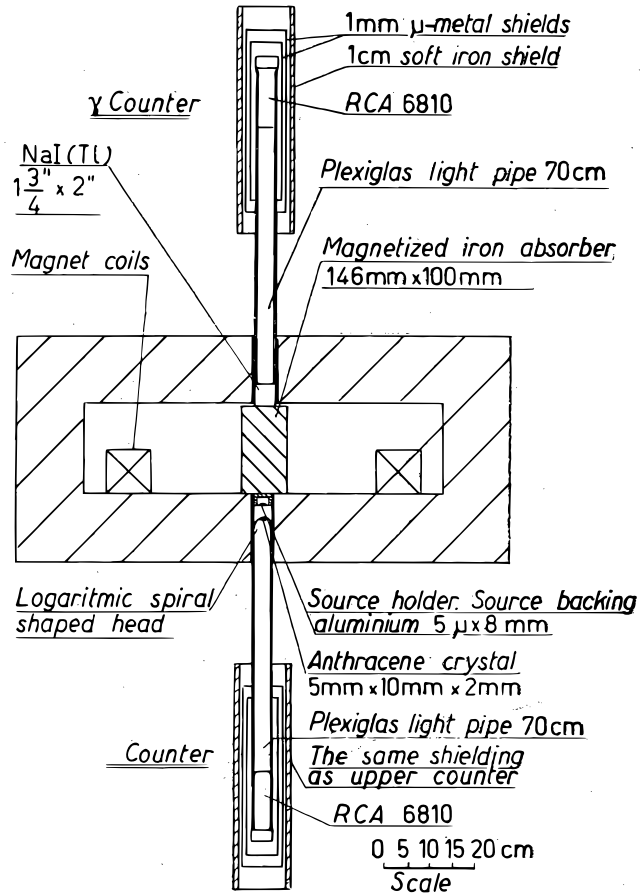
^{60}Co Decay


$^{60}_{27}$Co
β^-
0.317 MeV
99.88%
β^-
1.49 MeV
0.12%
γ
1.1732 MeV
γ
1.3325 MeV
$^{60}_{28}$Ni

^{60}Co Decay (Angular Momentum)



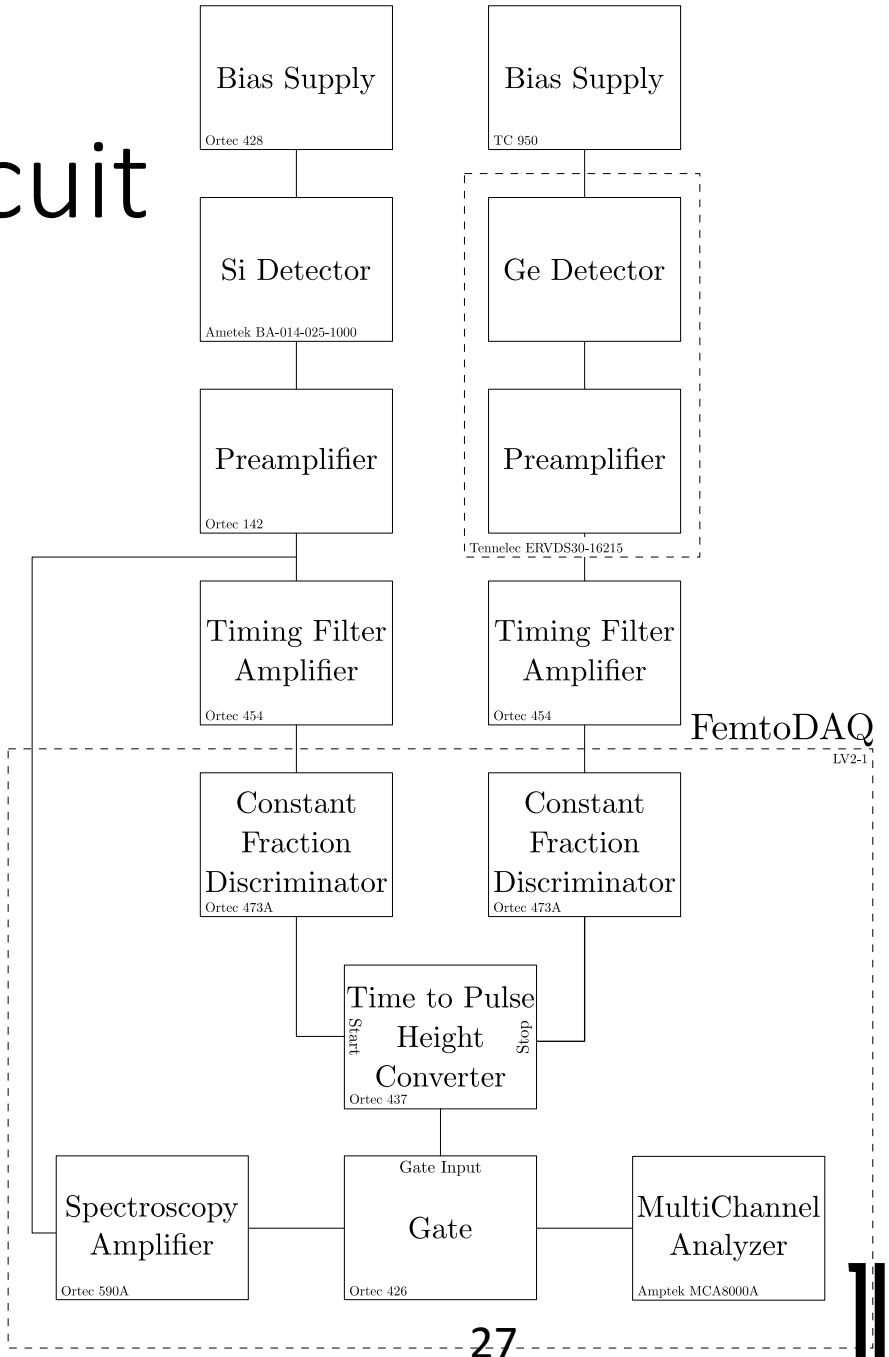
Lundby, et. al (1957)



- Measured the asymmetry of the circular polarization of the gamma rays

Coincidence Circuit

- Analog Version
- Coincidence portion moved to digital portion of circuit



Singles (Gamma Rays)