Giant Monopole Resonances in Unstable Nuclei

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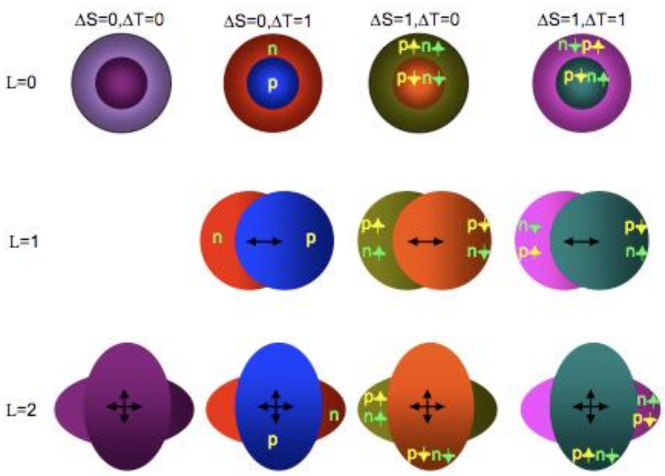
Isoscalar Giant Monopole Resonance

- Giant resonances – collective excitation of nucleus due to near-exhaustion of Energy-Weighted Sum Rule

- ISGMR is a "breathing mode," a rapid expansion and shrinking of the nucleus



http://cyclotron.tamu.edu/pics/structure_01.bmp

Compressibility of Nuclear Matter

- The compressibility of nuclear matter can be calculated from the energy of the giant monopole resonance
- $K_A = E^2 * \frac{m<r^2>}{\hbar^2}$
- This constant is important for the nuclear equation of state
- $K_{NM} = 231 \ \pm 5 \ MeV$
- Speed of sound in nuclear matter ≅ 0.15 c

Typical Method

- Collide a beam of alpha particles with a target to excite it into ISGMR
- Measure energy and angular distribution of outgoing alpha particles
- The angular distribution tells us which are from the ISGMR, and the energy of those alpha’s gives the energy of the ISGMR

Unstable Nuclei

- The problem: a target can not be made of unstable nuclei
- The solution: switch the role of beam and target
- However, alpha particles are helium, which is a gas at room temperature
- Instead, the target will be made of ^{6}Li, a solid
- Experiments with ISGMR using ^{6}Li give similar results to those involving alpha particles

Experimental Setup

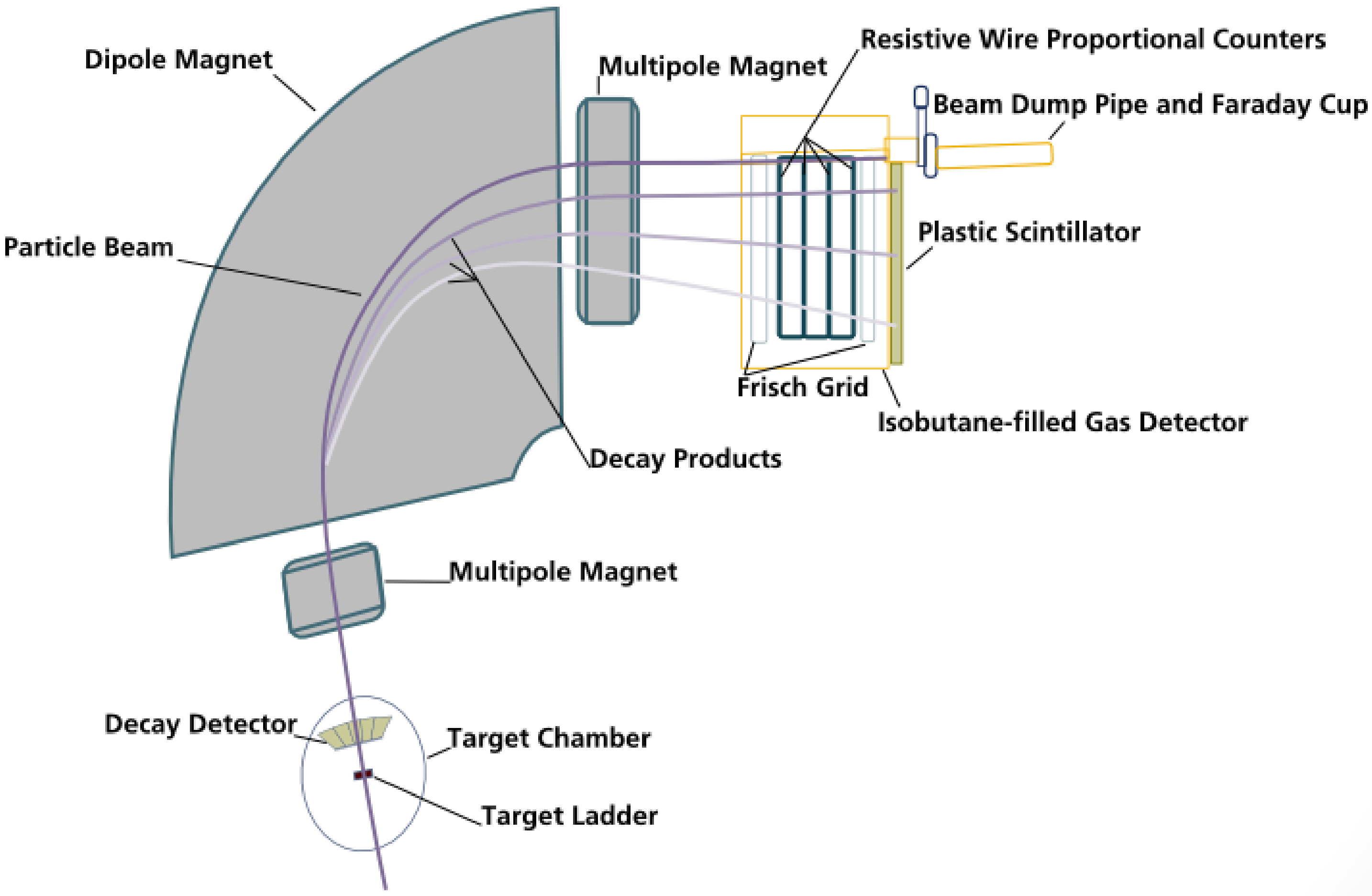


Image courtesy of J. T. Button

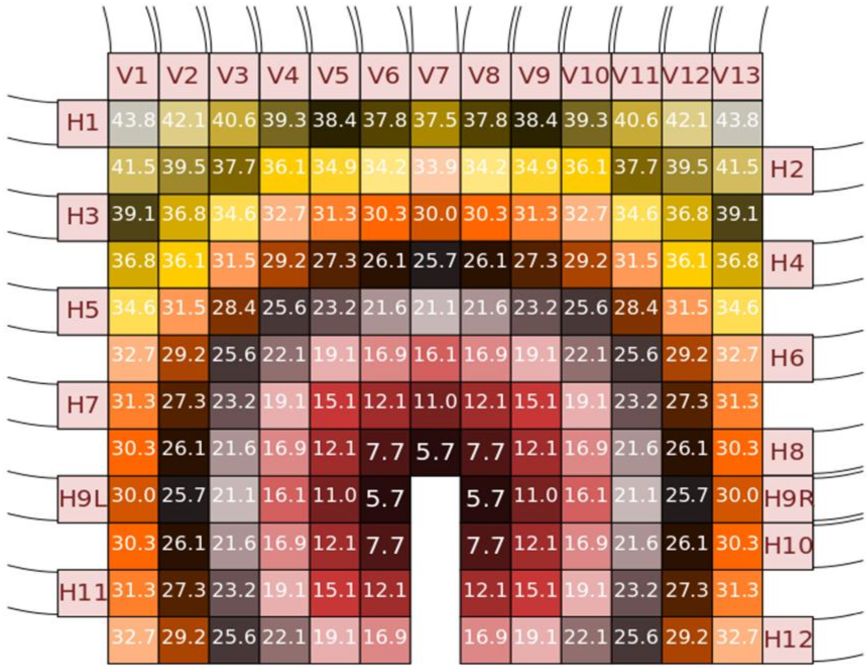
My Role

- Determine the relative gain of the individual strips in the scintillator detector
- Account for attenuation in the scintillator strips
- Design a Faraday cup to catch the beam after exiting the MDM spectrometer but before entering the wire detector
- If the beam was not stopped, it would damage the detector

Scintillator Detector

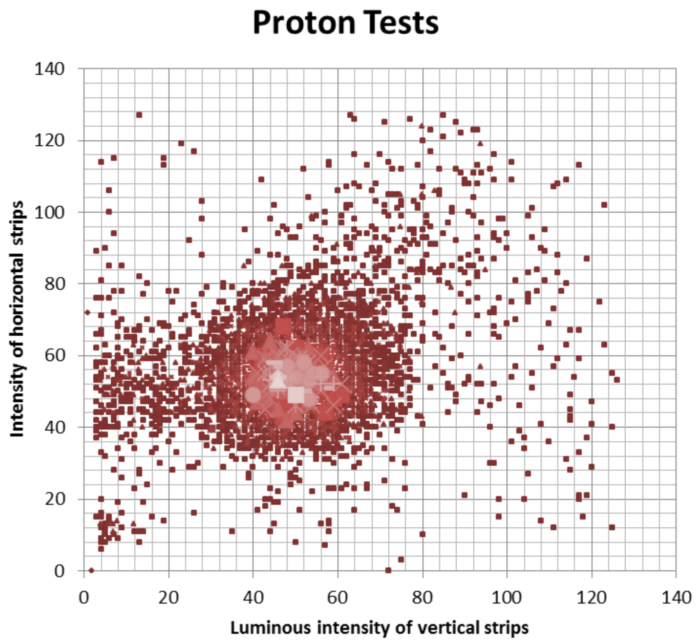
- Used to determine energy and scattering angle of small decay particles like alphas and protons
- Consists of 13 vertical strips directly in front of 12 horizontal strips
- Five vertically-oriented blocks catch all particles that pass through the first two layers
- Examining the vertical and horizontal layers in coincidence map out 152 “pixels” which give the scattering angle
- The beam and residual decay particles pass through an opening in the center of the detector

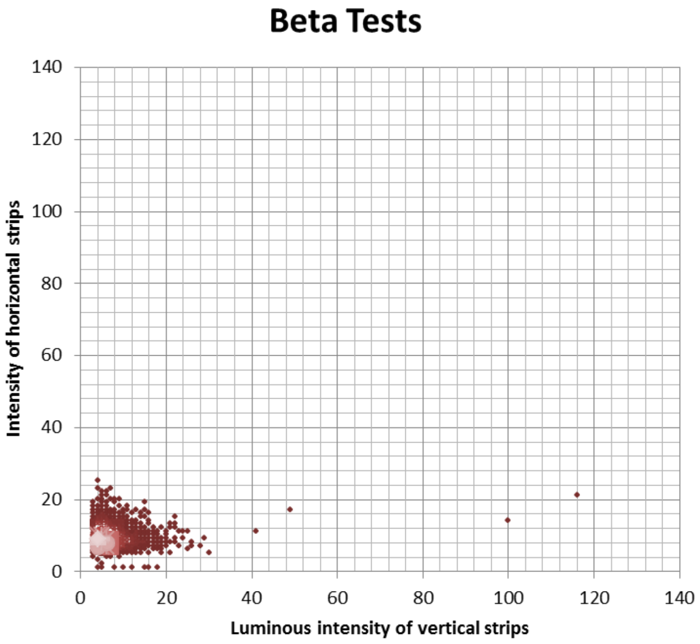
- Schematic diagram of detector
- Scattering angle indicated for each pixel
- Strip is attached to fiber-optic cable, which carries photons to photo-multiplier tubes
- One concern is attenuation



Test runs

- Test runs were performed using both protons scattering off of a ^{12}C target and a beta source

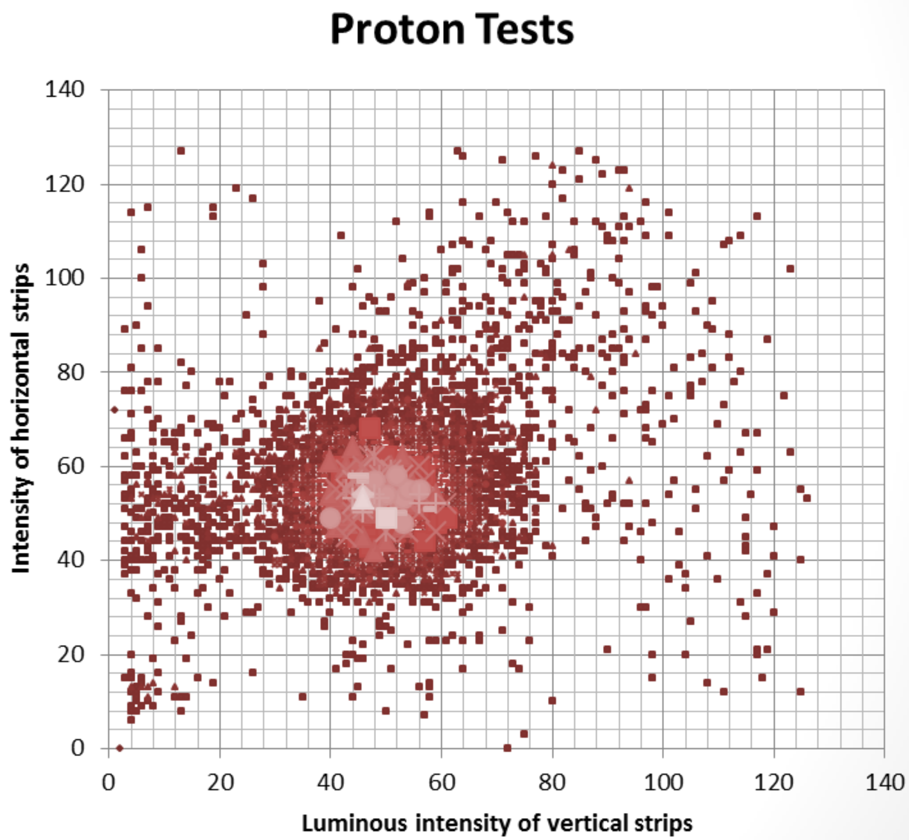




- The beta tests were ultimately disregarded for analysis due to proximity to threshold

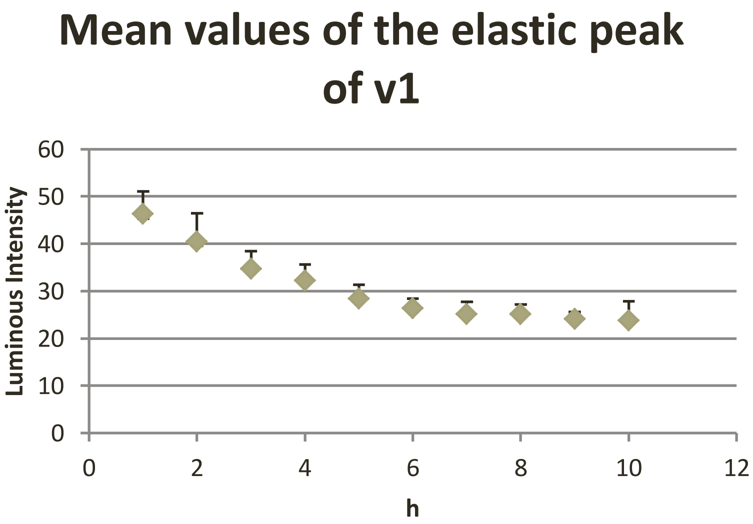
Analysis

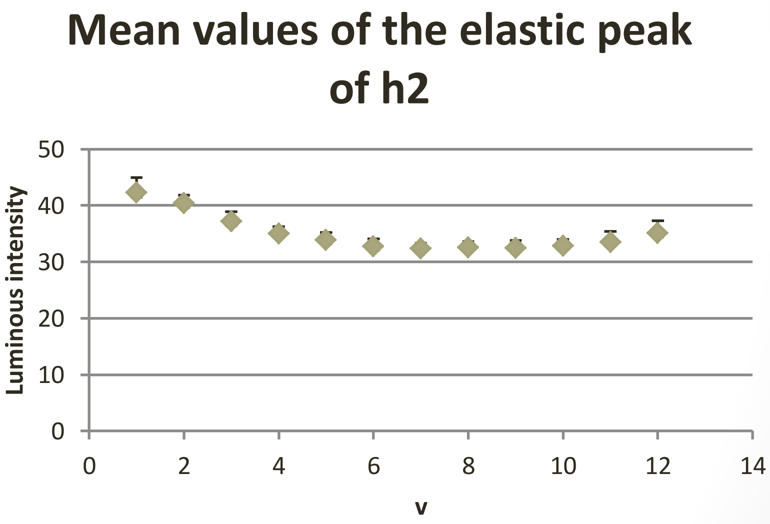
- The data were analyzed on a pixel-by-pixel basis
- The elastic peak was isolated and its mean value was determined



Dealing with attenuation

- Examination of vertical strips seemed to indicate that attenuation could be explained as an exponential with an offset

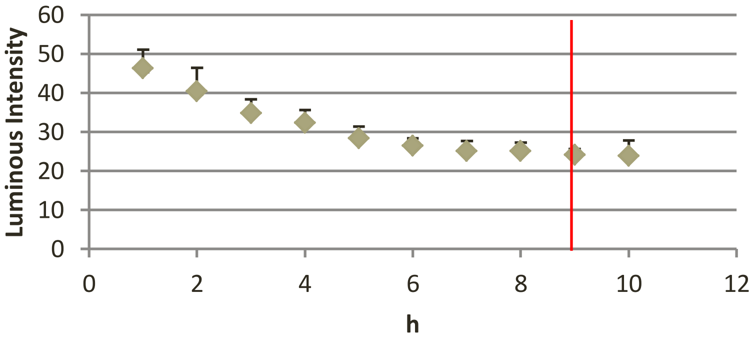




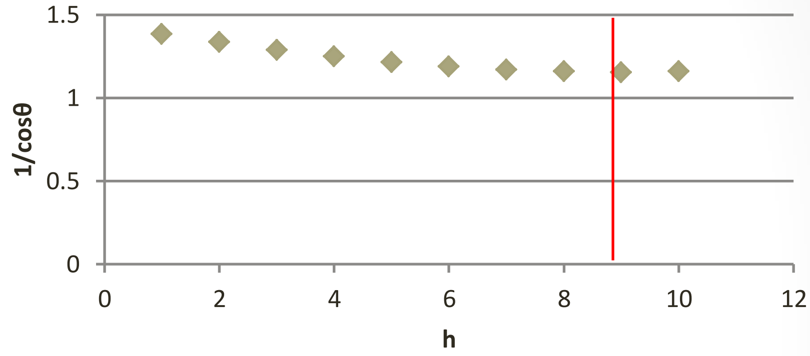
- However, examination of horizontal strips proved that the situation was more complex

Angular effects

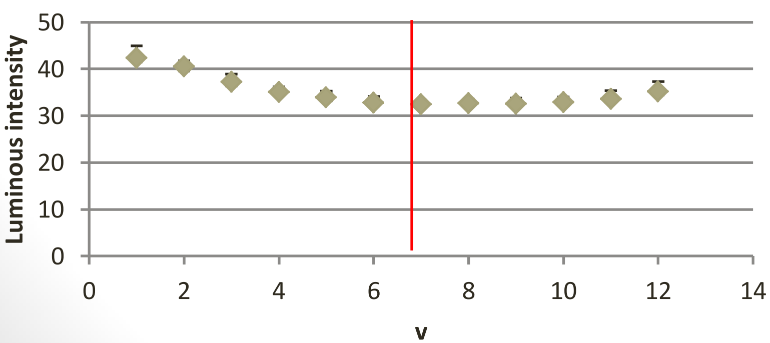
Mean values of the elastic peak of v1



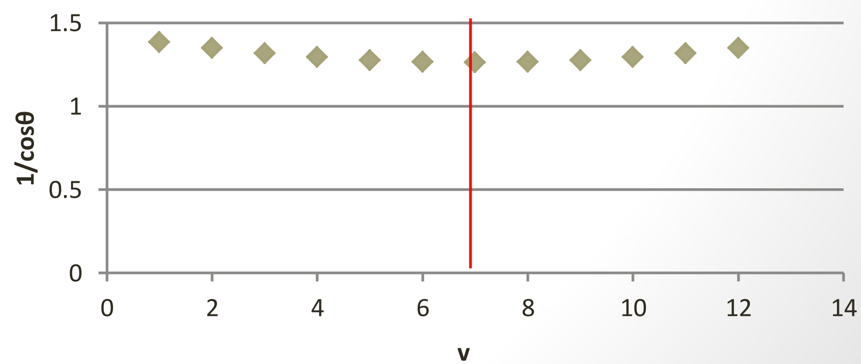
Angular effects of apparent length for v1



Mean values of the elastic peak of h2

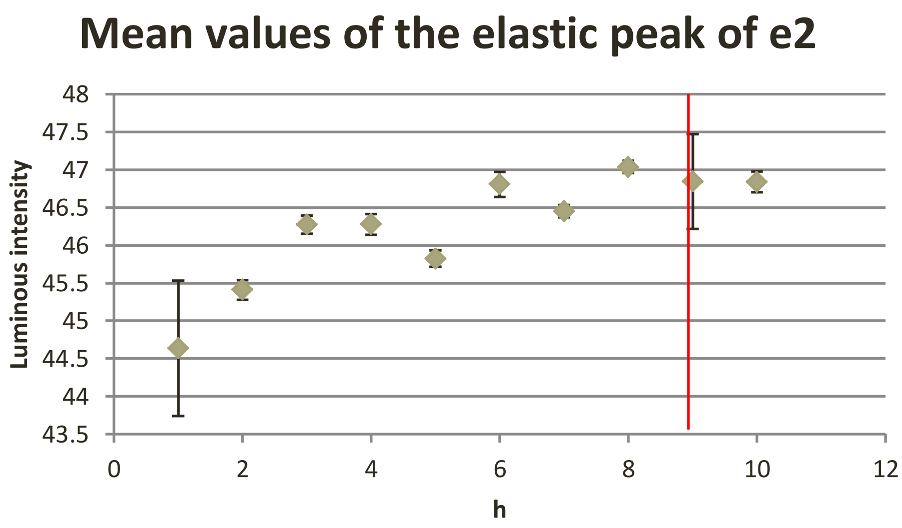


Angular effects of apparent length for h2



Energy and scattering angle

- The kinetic energy of the particles is greater near the center (h9, in this instance)
- The particles deposit more energy at extreme angles

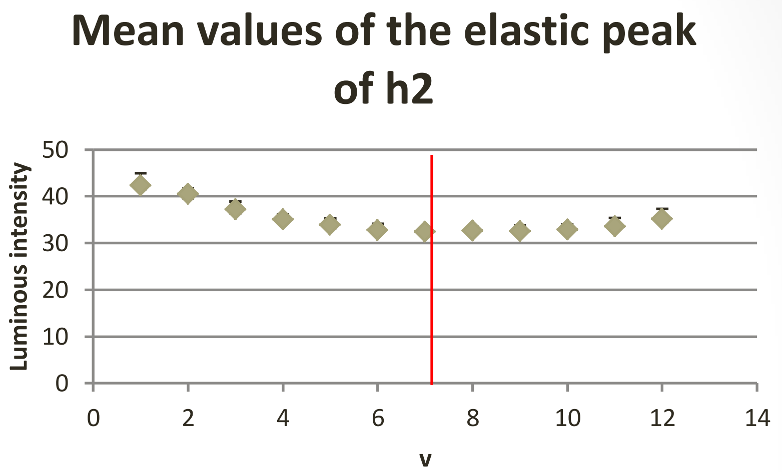


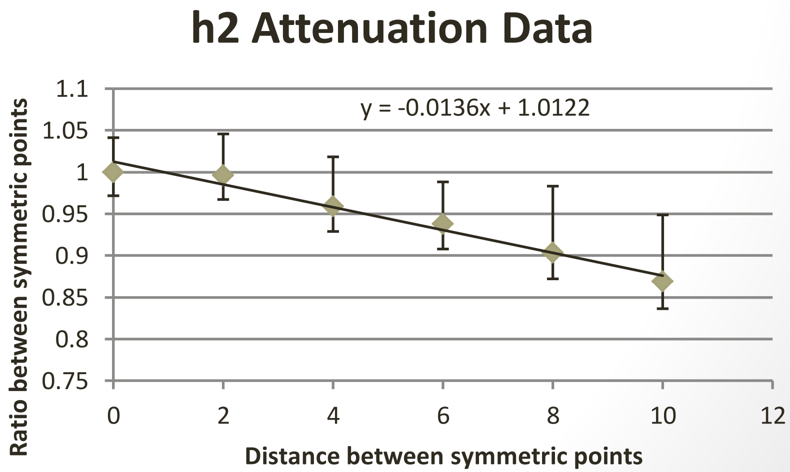
Symmetric points

- By finding the ratio of points symmetric about the center, attenuation could be determined

- Attenuation has a linear relationship with distance over the area of interest

- Oddly, max attenuation varied between 7% and 30% among the various strips





Determining relative gain

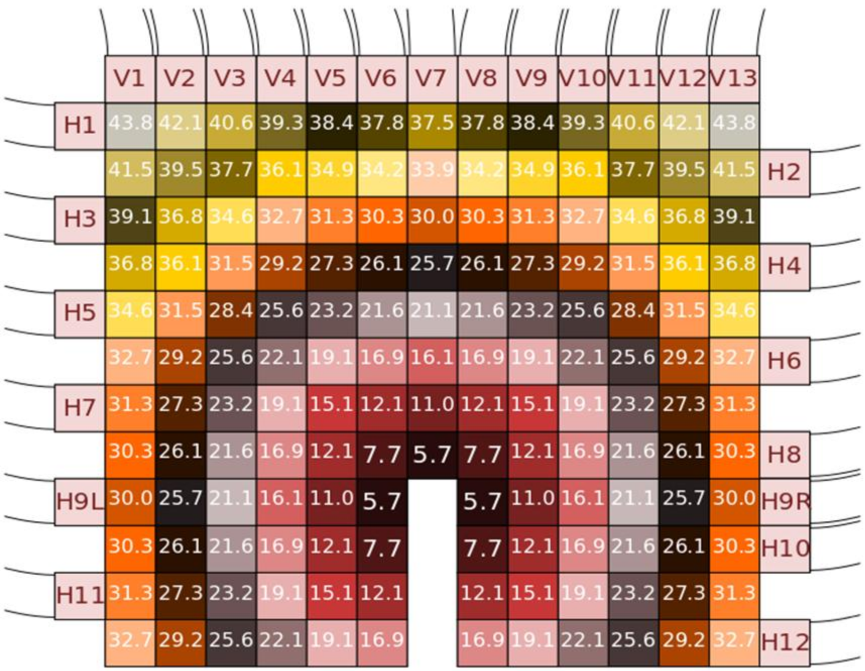


Image courtesy of J. T. Button

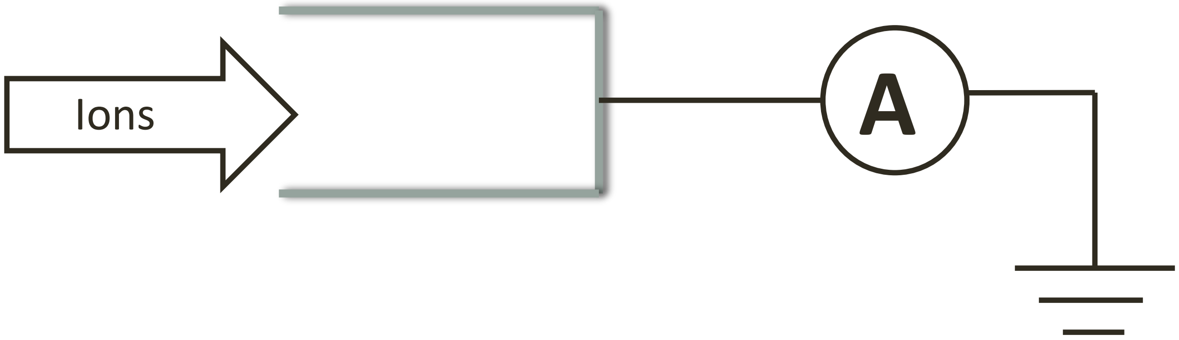
- By comparing pixels with equal scattering angles, the relative gain could be calculated

v1	0.40
v2	0.70
v3	0.62
v4	0.65
v5	1.00
v6	0.94
v7	1.11
v8	1.18
v9	0.80
v10	0.63
v11	0.74
v12	0.48

h1	0.57
h2	0.69
h3	1.23
h4	0.94
h5	1.15
h6	2.01
h7	1.85
h8	1.00
h9	1.25
h10	1.05

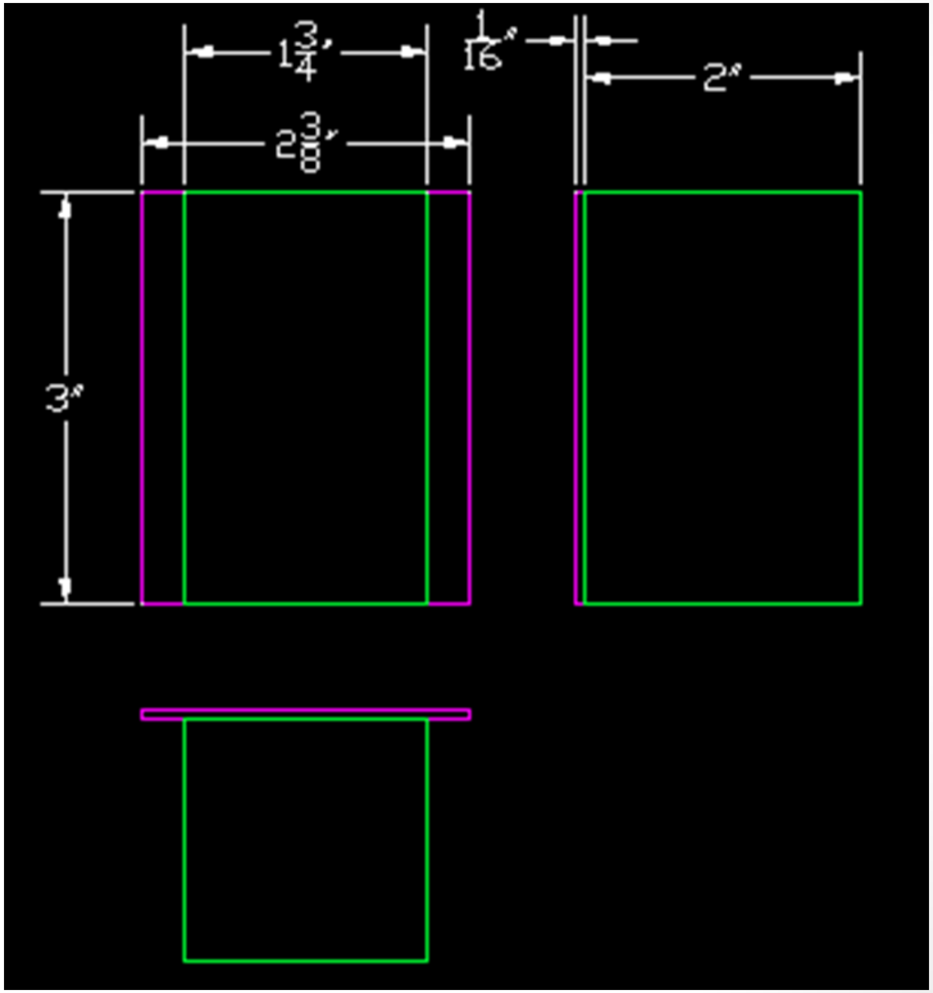
Principles of a Faraday cup

- A beam of ions impinges upon a metal surface
- The charge hits the surface and flows to ground, resulting in a measurable current

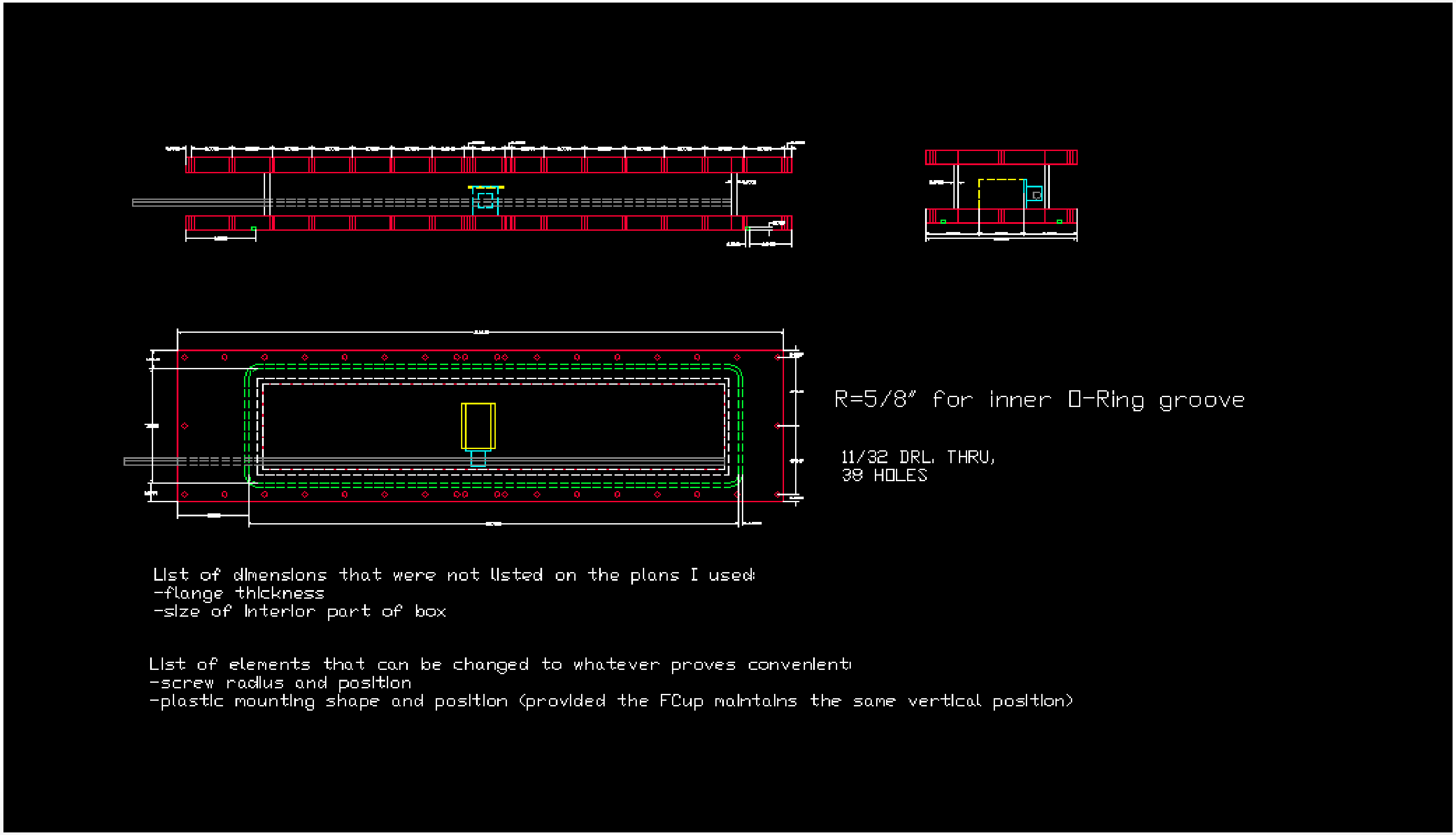


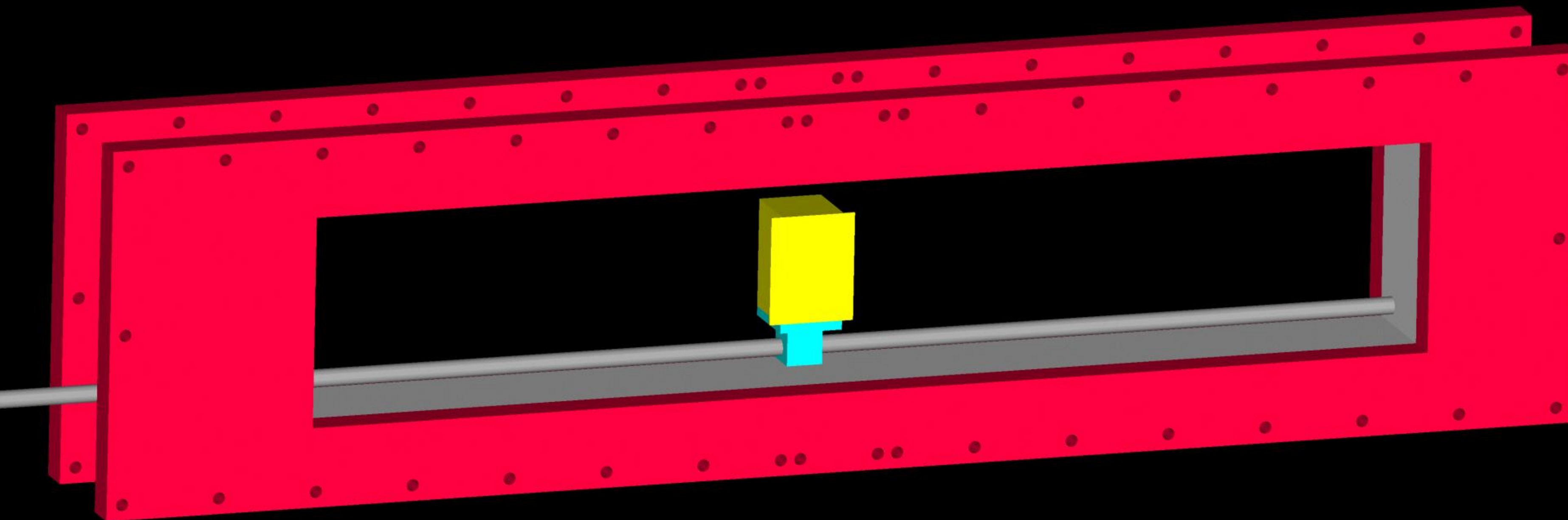
My Design

- Designed using AutoCAD 2002
- Used SRIM (Stopping Range of Ions in Matter) program
- One thin layer of aluminum to stop the beam
- A much thicker layer of tantalum to stop alpha particles produced by the beam



Entire assembly





Additional specifications

- The mounting of the cup will be made of plastic to electrically isolate it
- Electrical connection will be made using a brush sliding over a PC-board
- The screw will be powered with a motor positioned outside of the box
- A position sensor will be used inside the box

The Next Step

- The Faraday cup must be constructed
- The cyclotron must be conditioned for the higher energies that will be used in this experiment
- The experimental phase should begin next Fall, with a beam of stable ^{28}Si, to assure that the experiment is providing the expected results
- Finally, the experiment can be performed on unstable nuclei

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